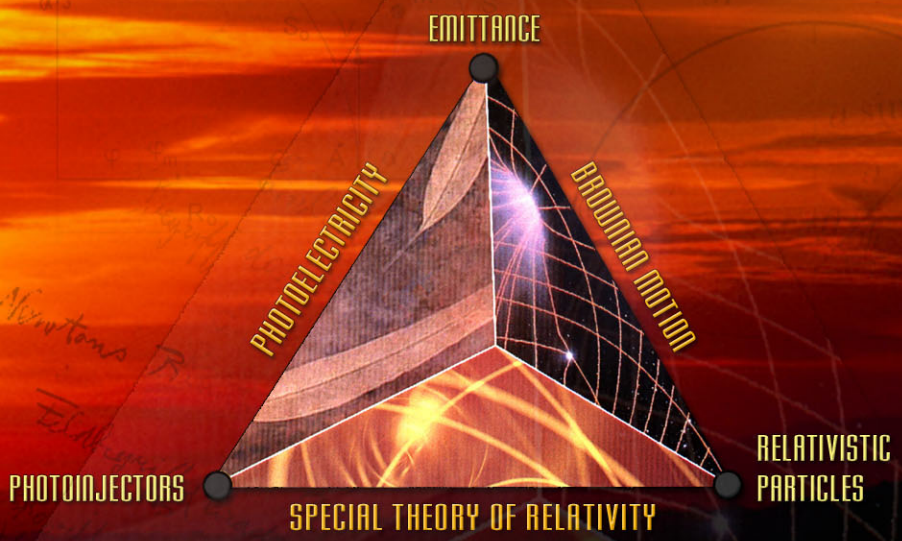
PAC05

# 2005 Particle Accelerator Conference

## Abstracts Brochure



NSF APS IEEE Oak Ridge National Laboratory Jefferson Lab SNS

05-02139/arm

# 2005 Particle Accelerator Conference

**May 16-20, 2005**

**Knoxville Convention Center**
**Knoxville, Tennessee, USA**

**www.sns.gov/pac05/**

Hosted by:
Oak Ridge National Laboratory/Spallation Neutron Source
managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725
for the U.S. Department of Energy

Thomas Jefferson National Accelerator Facility
managed by Southeastern Universities Research Association
for the U.S. Department of Energy

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# Acknowledgments

The PAC05 Organizing Committee, Scientific Program Committee, and Local Organizing Committee would like to acknowledge and thank the following for their sponsorship and support:

American Physical Society, Division of Physics of Beams
Institute of Electrical and Electronics Engineers, Nuclear and Plasma Sciences Society

National Science Foundation
U.S. Department of Energy

Oak Ridge National Laboratory
Thomas Jefferson National Accelerator Facility

Norbert Holtkamp

***Welcome*** to PAC05 on behalf of the American Physical Society (APS), the Institute of Electrical and Electronics Engineers (IEEE), with its subdivision of the Nuclear and Plasma Sciences Society (NPSS), and the organizing committees. We thank you, as part of the global community, for your suggestions that have contributed to an exciting PAC05 program.

As an official World Year of Physics (WYOP) event, PAC05 has planned several WYOP events. The Scientific Program includes a special Einstein Session, where world-renowned scientists will speak about the mysteries of cosmic acceleration, dark energy and matter, symmetries in the subatomic world, and the elusive world of neutrinos. In addition, both plenary sessions will include presentations by distinguished world leaders in science and technology, including opening remarks by Phil Bredesen, honorable Governor of Tennessee—and a one-time physicist by profession.

Swapan Chattopadhyay

We've also planned two special WYOP evening events. On Tuesday is "Science and Music." Violinist Jack Liebeck and pianist Inon Barnatan will present a concert tailored to this event and introduced by our colleague Brian Foster, a particle physicist from the University of Oxford. On Wednesday is "Einstein in the City." Open to the citizens of Knoxville, this fun event will include a variety of activities to commemorate Einstein's outstanding contributions.

In closing, thank you again for participating in this significant event and for making it a success. This is a gala celebration—let the beam-fest begin!

**Norbert Holtkamp, ORNL/SNS**
**PAC05 Conference Chair**

**Swapan Chattopadhyay, JLab**
**Scientific Program Chair**

## Organizing Committee

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Thomas Wangler, LANL
Bill Weng, BNL
Glen A. Westenskow, LLNL
Marion M. White, ANL

*Thanks to Bruce Brown for serving on the committee through January 1 of this year.

## Local Organizing Committee

Stuart Henderson, ORNL/SNS, Chair
Kathy Rosenbalm, ORNL/SNS, Conference Coordinator

Janet Bivens, ORNL/SNS, Finance
Dan Ciarlette, ORNL/SNS, Information Technology
Craig Deibele, ORNL/SNS, Industrial Exhibits
Al Ekkebus, ORNL/SNS, Tours
Kelly Hanifan, JLab, Scientific Program
Charlie Horak, ORNL/SNS, Publications & Web
Ann Jordan, ORNL/SNS, Registration
Doris Shubert, ORNL/SNS, Satellite Meetings
Loretta Simpson, ORNL/SNS, Hospitality
Sherry Thomas, JLab, Scientific Program

*Special thanks to Angie Beach, ORNL Conference Office, for her invaluable assistance.

## Scientific Program Committee

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Gerry Dugan, Cornell University, Vice-Chair
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A. Hutton, JLab
A. Jackson, ASP
G. Jackson, Hbar-Technologies, Inc.
A. Jason, LANL
C. Johnstone, Fermilab
T. Katsouleas, USC
R. Keller, LBNL
K. J. Kim, ANL
W. Kimura, STI
P. Krejcik, SLAC
N. Solyak, Fermilab
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S.Y. Lee, IUCF
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L. Merminga, JLab
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J. Murphy, BNL
W. Namkung, POSTECH
K. Nielson, LANL
W. Oren, JLab
P. O'Shea, IREAP
H. Padamsee, Cornell University
F. Pilat, BNL
M. Poole, CCLRC/DL
C. Prior, RAL
T. Raubenheimer, SLAC
D. Rice, Cornell University
L. Rivkin, PSI
D. Robin, LBNL
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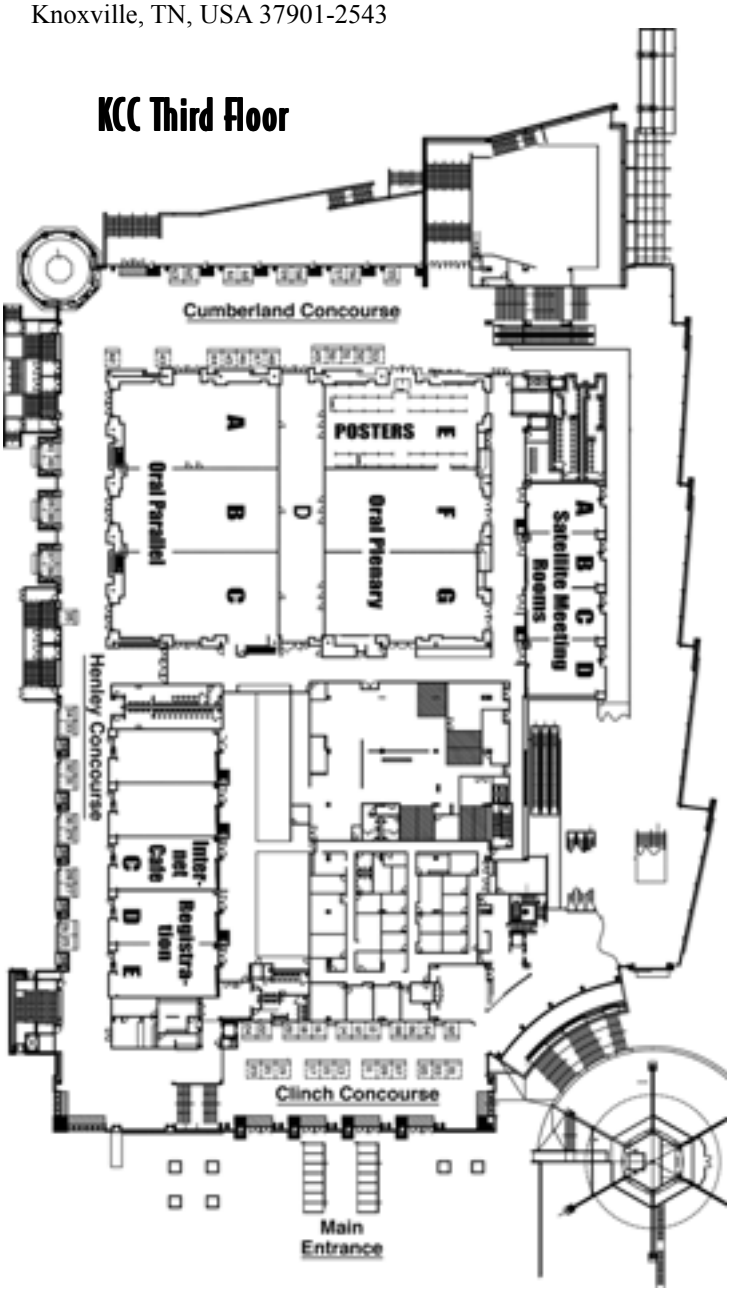
R. Webber, Fermilab
J. Wei, BNL
U. Wienands, SLAC
G. J. Wurtele,UCB
Y. Yamazaki, JAERI
A. Zhang, BNL
F. Zimmermann, CERN

# Venue

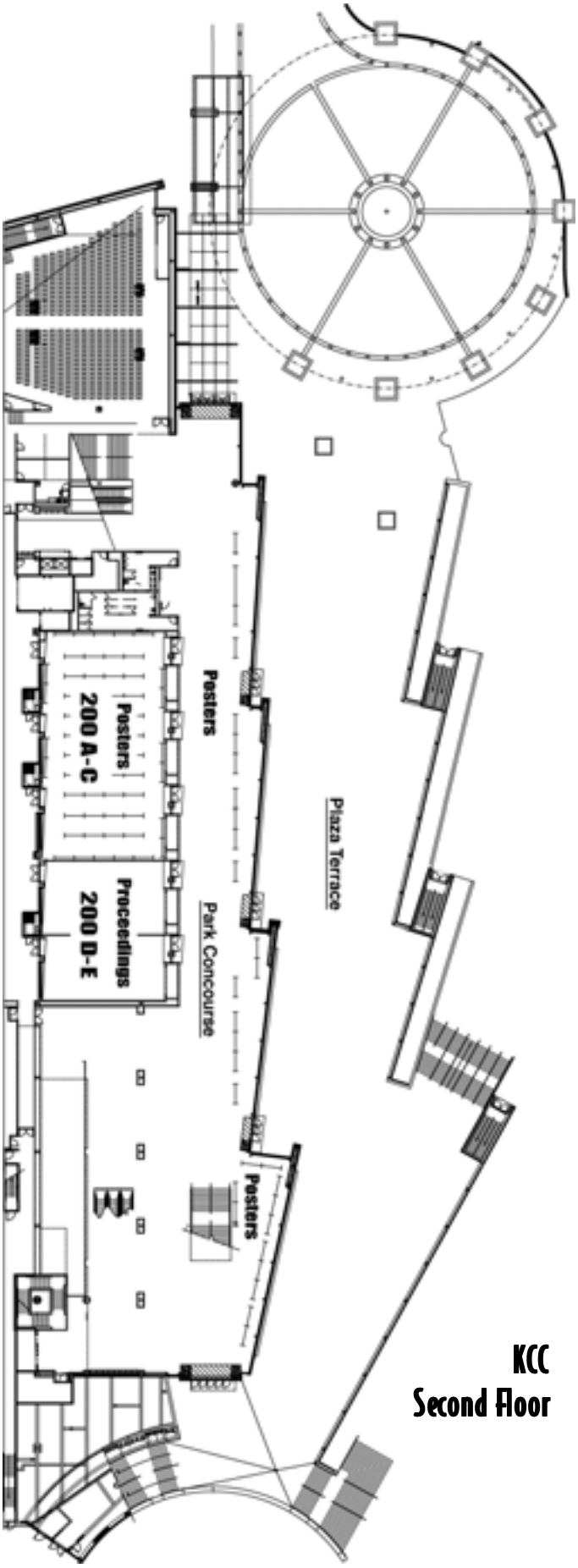
**Knoxville Convention Center (KCC)**
**www.kccsmg.com**
701 Henley Street
Knoxville, TN, USA 37902
Phone: 865-KCC-KNOX (522-5669)
Fax: 865-329-0422

**Mailing Address:**
P.O. Box 2543
Knoxville, TN, USA 37901-2543

## KCC Third Floor




## KCC Second Floor



## Transportation During the Conference

The Knoxville Trolley Service will provide *free* transportation to and from the downtown hotels, restaurants, and the KCC. A schedule is provided in your conference portfolio. More details and schedules are also available online at www.ci.knoxville.tn.us/kat/web%20pages/Trolley/Trolley_Main.asp.

In addition, public buses run in the downtown and surrounding areas. For more information, see www.ci.knoxville.tn.us/kat/web%20pages/home.asp. Limited taxi service is also available in the downtown area.

## Registration

Registration is located on the third floor in Rooms 301 D & E (off the Henley Concourse). Registration hours are

| | |
|---|---|
| Sunday | 5:00 p.m. to 9:30 p.m. |
| Mon.-Thur. | 7:30 a.m. to 5:00 p.m. |

A message board is located near the registration desk.

Your registration fee includes attendance at all technical sessions of the conference, coffee breaks, conference guidebook, abstract book (on USB memory stick), and one copy of the proceedings on CD-ROM. All receptions and the conference banquet are being sponsored by nonfederal sources. Hard copies of the proceedings may be purchased from IEEE at an estimated cost of $300.

The fee for registration after March 18 is $495 (U.S. dollars). For participants whose registration fees have not been paid in full, payment may be made at the registration desk by credit card, check, or cash. Registration fees of $125 for one day and of $70 for students and retirees are also available.

Attendees are requested to wear their conference badges at all PAC-sponsored events. If you need assistance, please ask anyone wearing a badge with a red stripe (Local Organizing Committee staff).

## Internet Café

An e-mail room is located in Room 301C, off the Henley Concourse. It contains laptops, a black & white printer, and wireless access. Hours are

| | |
|---|---|
| Sunday | 5:00-7:00 p.m. |
| Monday | 12:30-6:00 p.m. |
| Tuesday | 8:00-6:00 p.m. |
| Wednesday | 8:00-6:00 p.m. |
| Thursday | 8:00-6:00 p.m. |
| Friday | 8:00-1:00 p.m. |

This room also includes an area where speakers can preview/test their presentations. *Please note that all speakers must give their presentations with the computer systems set up in the ballrooms. Use of individual laptops cannot be accommodated.*

## Proceedings Office

The Proceedings Office is located in Rooms 200 D & E, off the Park Concourse on the second floor. The editorial staff will process papers before and during the conference.

The paper submission deadline was Wednesday, May 11. Authors are requested to come by the Proceedings Office to check on their papers via the status board that will be located in or near the Proceedings Office.

Authors are requested to bring a hard copy of their paper and a signed IEEE copyright form to the Proceedings Office as soon as possible upon arrival at the conference. *A copyright form must be turned in before a paper can be accepted for publication.* Forms are available in the Proceedings Office and at www.sns.gov/pac05/ieee_copyright.shtml.

Proceedings Office hours:

| | |
|---|---|
| Sunday | 5:00-7:00 p.m. |
| Monday | 8:00-6:00 p.m. |
| Tuesday | 8:00-6:00 p.m. |
| Wednesday | 8:00-6:00 p.m. |
| Thursday | 8:00-6:00 p.m. |
| Friday | 8:00-1:00 p.m. |

The conference proceedings will be published on CD-ROM and on the Joint Accelerator Conferences Web Site (JACoW) at accelconf.web.cern.ch/accelconf/. Hard copies will be available only from IEEE at an estimated cost of $300 per copy.

A selected set of papers, based on papers submitted to PAC05, will appear in a special edition of *Physical Review Special Topics—Accelerators and Beams* (PRST-AB), a peer-reviewed journal published by the APS.

## Industrial Exhibits

The industrial exhibits hours are

| | |
|---|---|
| Monday | 8:30-6:00 p.m. |
| Tuesday | 8:00-6:00 p.m. |
| Wednesday | 8:00-6:00 p.m. |

Exhibitors registered at press time:

Accel Instruments GmBH
AccelSoft Inc.
Acqiris
Advanced Design Consulting USA, Inc.
Advanced Energy Systems Inc.
ADVENT Research Materials Limited
AFT Inc.
American Magnetics, Inc.
American Technical Services
Amuneal Manufacturing Corporation
A&N Corporation
ATK Mission Research
Bergoz Instrumentation
Bruker Biospin SA

Burle Industries, Inc.
CAEN Technologies
Ceramic Magnetics
CeramTec North America Corp.
CML Engineering
Communications and Power Industries, Inc.
Cryofab Inc.
CST of America
Danfysik A/S
Diversified Technologies
e2v Technologies Inc.
Energen, Inc.
Everson Tesla, Inc.
The Ferrite Company
FMB Feinwerk-und Messtechnik GmbH
Framework Scientific
Gamma Vacuum, LLC
GMW Associates
Goodfellow Corporation
H. C. Starck Inc.
Heatwave Labs
IE Power Inc.
Instrumentation Technologies
Kurt J. Lesker Company
L-3 Communications Electron Devices
Linde BOC Process Plants LLC
Mega Industries, LLC
Meyer Tool & Manufacturing, Inc.
Microwave Amplifiers Ltd.
OCEM S. p. A.
Pearson Electronics
PHPK Technologies
QEI Corporation
SAES Getters USA, Inc.
Scanditronix Magnet AB
SDMS
SIGMAPHI
Simulation Technology & Applied Research
Struck Innovative Systeme GmbH
Tektronix
Thales
Titan Pulse Sciences Division
Toshiba Electron Tubes & Devices Co., Ltd
VAT Inc.
Vector Fields Inc.
Wah Chang
Wiener, Plein & Baus, Ltd.
Windels Timm Morgen
UMA Group

A complete listing of exhibitors is also on the web at www.sns.gov/pac05/exhibitor_list.shtml.

# Companion Programs

Companion tours are available during and after the conference and are being handled by Knoxville Tourism and Sports Corporation. Pickup points for the companion tours will be at the four downtown hotels (Hilton, Holiday Inn Select, Marriott, and Radisson) and the Holiday Inn at Papermill Road.

Activities during the conference:

## Monday

**"Welcome to Knoxville" Continental Breakfast**
Hilton Hotel, 8:30-9:30 a.m.

**Historic Knoxville City Tour**
9:30 a.m.-4:30 p.m.

## Tuesday

**A Step Back in Time**
8:30 a.m.-4:30 p.m.

## Wednesday

**A Day in Old Appalachia**
8:30 a.m.-3:30 p.m.

## Thursday

**A Day at Dollywood and Pigeon Forge Outlets**
8:30 a.m.-4:30 p.m.

## Friday

**Wild Mountain Tour**
8:30 a.m.-4:30 p.m.

## Saturday

**Secret City Tour**
9:00 a.m.-3:30 p.m.

More information is available on the web at www.sns.gov/pac05/tours.shtml.

# Special Events

## Sunday Welcome Reception

A welcome reception will be held outside on the KCC Plaza Terrace from 6:30 to 9:30 p.m. In case of rain, the reception will be held at the corner of the Henley and Cumberland concourses (third floor). All registrants are invited.

## Tuesday Special Events

### Meet the Editors of *Physical Review* and *Physical Review Letters*
### 2:30–4:30 p.m., Cumberland Concourse

### WYOP/Einstein Special Event: Science and Music
### 6:00–7:45 p.m., Ballrooms D, F, & G

*(Please see page 9 for more information. An invitation with the evening's program is included in your conference bag.)*

## Wednesday Special Events

The 100th anniversary of Einstein's three important contributions will be honored in several World Year of Physics conference activities.

### Live Radio Broadcast

Hallerin Hilton Hill will broadcast his morning talk show on WNOX (FM 99.1, 99.3, and AM 990) from the conference site, 6:00-10:00 a.m.

### High School Physics Teachers' Day

This all-day seminar will present an opportunity for local physics teachers to learn more about particle accelerators and Einstein's contributions to this field.

### Special Session: Accelerator Science and Technology Awards
### 1:00–3:00 p.m., Ballrooms D–G

Chaired by Nan Phinney (SLAC), this special session will include an awards ceremony, sponsored by the APS Division of Physics of Beams (DPB) and the IEEE/NPSS, to present the following awards and prizes:

- APS Robert R. Wilson Prize
- APS Award for Outstanding Doctoral Thesis Research in Beam Physics
- IEEE/NPSS Particle Accelerator Science and Technology Awards (presented by Ilan Ben-Zvi, BNL)
- U.S. Particle Accelerator School Prize (USPAS) for Achievement in Accelerator Physics and Technology (presented by Herman Winick for the USPAS)
- Announcement of newly elected APS fellows
- Student Travel Awards

Along with presentation of the prizes, the session will be devoted to talks by winners of the APS/DPB, IEEE/NPSS, and USPAS awards.

### Special Session: "Einstein and the World Year of Physics"
### 3:00–5:55 p.m., Ballrooms D–G

Jointly sponsored by PAC, EPAC, and APAC.

Chaired by Bill Madia (Battelle), former director of ORNL, this special session will feature the following presentations:

- Introduction: Einstein's Legacy in Charged Particle Acceleration, *S. Chattopadhyay (JLab)*
- Einstein and Cosmic Acceleration, *Michael Turner (NSF)*
- Symmetries and Einstein, *Makoto Kobayashi (KEK)*
- Neutrinos and Einstein, *Yoichiro Suzuki (University of Tokyo)*
- The Quest for Dark Matter, *Carlo Rubbia (CERN)*

### "Einstein in the City" Celebration
### 6:00–9:00 p.m., World's Fair Park

Sponsored by the city of Knoxville. *Conference badge required for entry.*

This event will be an opportunity for the public to celebrate and learn more about Einstein's legacy alongside the conference attendees. In addition to food and drinks from local restaurants and live entertainment, planned events include a science fair for local high school students, live demonstrations, children's activities, and a science discussion chaired by Bill Madia.

## Thursday Special Events

### Gala Dinner
### 7:00–10:00 p.m., KCC Plaza Terrace

Entertainment will be provided by the Rocky Wynder Jazz Trio.

## Saturday Special Events

### Tour of the SNS Site—Reservations Required

The Spallation Neutron Source (SNS) is a new, accelerator-based science facility that will provide neutron beams with up to ten times more intensity than any other source in the world. This motorcoach tour will depart from the KCC at 9:00 a.m. and will return to the KCC after lunch. The tour will include an overview of the SNS project, including the specific components of the front end, klystron gallery, linear accelerator, accumulator ring, and target facility. Industrial vendors will be positioned near their equipment to answer questions and provide additional information.

Cost for the tour, including transportation and lunch, is $15. You must preregister for this tour; please see registration staff for more information.

## WYOP/Einstein Special Event: Science and Music, 6:00–7:45 p.m., Ballrooms D, F, & G

**Jack Liebeck and Inon Barnatan will present an evening of violin and piano music, introduced by Brian Foster.**

**Master of Ceremonies: S. Chattopadhyay (JLab)**

**Jack Liebeck** was born in 1980 in London. He attended the Purcell School of Music and then the Royal Academy of Music. His first public appearance was at the age of 10 for BBC television. Performing in concertos and recitals since the age of 11, Jack's appearances have taken him all over the world to perform with many world-renowned orchestras and conductors. His debut disc on the new *Quartz* label was released in July 2004 to enormous critical acclaim, becoming CD of the Week in a UK national newspaper and earning him praise as "…one of the most accomplished violinists of his generation…."

Planned appearances for this season include concertos and recitals in Armenia, France, Germany, Israel, Japan, Korea, Portugal, Switzerland, the UK, and the United States.

Jack plays the "Ex-Wilhelmj" Guadagnini, dated 1785. For more details, go to www.jackliebeck.com.

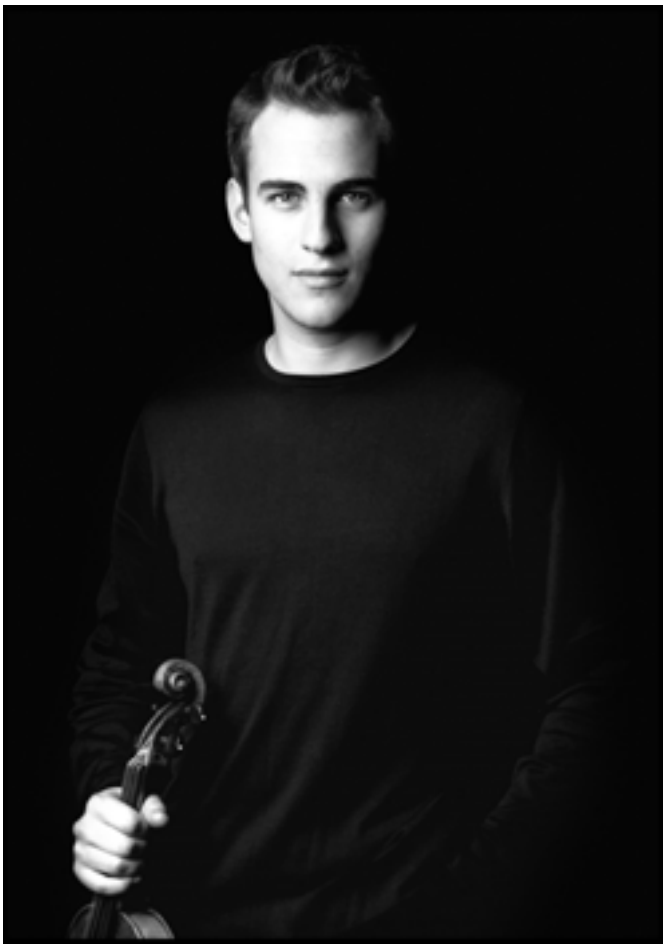


*Photo courtesy of Tim Meara*

*Photo courtesy of Rita Castle*

Israeli pianist **Inon Barnatan** started playing piano at the age of 4 and entered the Tel Aviv Conservatory a year later. He made his orchestral debut at the age of 11 and in the following years won many national prizes, playing throughout Israel. In 1997 he moved to London to study at the Royal Academy of Music. Inon has performed in concerts all over the world, and his name is attached to a lengthy list of awards and prizes. His CD, a live, all-Beethoven recital, has been named CD Discovery of the Month in the October 2002 issue of *Classica Magazine*.

In the 2003-04 season, Inon gave his debut recital at Carnegie Hall in New York, among other appearances in the United States. He will also be returning to venues throughout Europe, the United States, and Africa.

**Professor Brian Foster** is an internationally recognized particle physicist. He is a Fellow of Balliol College in the University of Oxford and heads the European Committee for Future Accelerators. Professor Foster loves music and, like Albert Einstein, is a keen amateur violinist. In celebration of the Einstein year, he has collaborated with Jack Liebeck in a performance titled "Superstrings," which explains and illustrates through lecture and the violin—Einstein's favorite instrument—the concept of superstring theory.

*Photo courtesy of Jack Liebeck*

# Accelerator Prizes

## 2005 APS Robert R. Wilson Prize

*To recognize and encourage outstanding achievement in the physics of particle accelerators—a prize of the American Physical Society sponsored by the APS Divisions of Physics of Beams and Particles and Fields and the friends of R. R. Wilson.*

Awarded to: **Keith Randolph Symon,** University of Wisconsin

"For fundamental contributions to accelerator science including the FFAG concept and the invention of the RF phase manipulation technique that was essential to the success of the ISR and all subsequent hadron colliders."

## APS Award for Outstanding Doctoral Thesis Research in Beam Physics

*To recognize doctoral thesis research of outstanding quality and achievement in beam physics and engineering. The award was established in 1990 by the Division of Physics of Beams and is supported by Brookhaven Science Associates and Universities Research Association.*

Awarded to: **Dr. Eduard Pozdeyev**, Thomas Jefferson National Accelerator Facility/ Michigan State University

"For pioneering research on space charge effects of beams in the isochronous regime, including simulations and experimental verification following the design and construction of the Small Isochronous Ring."

His thesis: *CYCO and SIR: New Tools for Numerical and Experimental Studies of Space Charge Effects in the Isochronous Regime.* Submitted to Michigan State University, Department of Physics and Astronomy, 2003. Thesis Supervisor: Dr. Felix Marti, Michigan State University.

## IEEE NPSS Particle Accelerator Science and Technology Award

Awards of the Particle Accelerator Conference given on behalf of the Nuclear and Plasma Sciences Society of the IEEE and sponsored by the NPSS. Two awards are given to recognize outstanding contributions to the development of particle accelerator technology.

Awarded to: **Ronald Davidson**, Plasma Physics Laboratory, Princeton University

"For pioneering contributions to the theory of charged particle beams with intense self fields, including fundamental studies of nonlinear dynamics and collective processes."

Awarded to: **Thomas Roser**, Brookhaven National Laboratory

"For pioneering scientific work and introduction of new technology in the acceleration, storage and collision of polarized protons in the high energy collider RHIC."

## U.S. Particle Accelerator School Prize for Achievement in Accelerator Physics and Technology

The U.S. Particle Accelerator School honors individuals by recognizing their outstanding achievements over the full range of accelerator physics and technology. The awards are made possible by donations from the Brookhaven Science Associates, Southeastern Universities Research Association, the Universities Research Association, and John Wiley and Sons Publishers.

Awarded to: **Wim Leemans**, Lawrence Berkeley National Laboratory

"For his contributions to the developments of laser wakefield accelerators, in particular the guiding of high-intensity laser beams and acceleration to high-energy of high-quality electron beams."

Awarded to: **Anton Piwinski**, Deutsches Elektronen Synchrotron

"For his fundamental contribution to the understanding of charged particle beams in circular accelerators, in particular of intra-beam scattering, beam-beam effects and synchro-betatron resonances."

## Newly Elected IEEE/NPSS Fellows Relevant to the Field of Accelerators

**Patrick G. O'Shea**, University of Maryland

"For contributions to charged particle accelerators and free-electron lasers."

**Bruce Paul Strauss**, U.S. Department of Energy

"For leadership in low temperature superconducting materials and magnet systems."

**Stanley O. Schriber**, Michigan State University

"For contributions to linear accelerator technology."

**Wu-Tsung (Bill) Weng**, Brookhaven National Laboratory

"For leadership in particle accelerator development."

## Newly Elected APS/DPB Fellows

At the November 2004 APS Council Meeting, the following list of 2005 DPB Fellows was approved:

**David H. Rice**, Cornell University

"For his key role in conception and implementation of pioneering accelerator physics innovations in electron-positron colliders and storage rings."

**Leonid Rivkin**, Paul Scherrer Institute

"For his scientific contribution and technical leadership role in the design and construction of accelerators for high energy physics and synchrotron light sources, and for furthering our understanding of beam instabilities."

**Michael James Syphers**, Fermi National Accelerator Laboratory

"For his contributions to non-linear beam dynamics and beam optics design, and to education in accelerator physics."

**Jonathan Syrkin Wurtele**, University of California-Berkeley

"For his many theoretical contributions to free electron lasers, laser-plasma acceleration, laser-plasma interactions, and muon beam manipulations."

**Victor A. Yarba**, Fermi National Accelerator Laboratory

"For his technical leadership of frontier accelerator projects in Russia and the U.S. and for fostering international collaborations."

**Li-Hua Yu**, Brookhaven National Laboratory

"For creative contributions to the theory of self-amplified spontaneous emissions and high-gain harmonic-generation, and the experimental demonstration of the high-gain harmonic-generation free-electron laser."

**Frank Zimmermann**, European Organization for Nuclear Research

"For many theoretical and experimental contributions to accelerator physics including the study of beam-ion and beam-electron cloud interactions, collective instabilities, nonlinear optics, and beam measurements."

## Student Travel Awards

The National Science Foundation, APS/DPB, and IEEE/NPSS have sponsored grants to worthy students to help defray their travel costs. These grants are being awarded in honor of two people who have made many contributions to the accelerator community. The APS/DPB grants honor Mel Month for his dedication to students and education, and the IEEE/NPSS grants honor Lou Costrell for his nurturing of the particle accelerator conferences. The awards include a complimentary one-year student membership in the sponsoring professional society. Awards were made to the following students:

Natalia Abreu, LNLS
Gerard Andonian, UCLA
Lucrezia Auditore, Messina/INFN
Gang Bai, IREAP
Christopher Barnes, SLAC
Elena Benedetto, CERN
Dmitry Berkaev, BINP
Ronak Bhatt, MIT
Alexander Brandt, DESY
Stephen Brooks, CCLRC/RAL/ASTeC
Rama Calaga, BNL
Xiangyun Chang, BNL
Gianluigi Clemente, IAP
Alan Cook, UCLA
Michel Covo, LBNL
Benjamin Cowan, SLAC
Rodion Dostovalov, BINP
Illya Drebot, NSC/KIPT
Michael Dunning, UCLA
Peder Eliasson, CERN
Umberto Emanuele, Messina/INFN
Robert England, UCLA
Christof Gabor, IAP
Yue Hao, IUCF
Dazhang Huang, ANL
Dharmaraj Indurthy, University of Texas at Austin
Chunguang Jing, ANL
Davit Kalantaryan, CANDLE
Vasily Kvardakov, BINP
Fanglei Lin, BNL
Augusta Loftsdottir, LBNL/ALS
Javier Lopez, CERN
Roark Marsh, MIT

Nathan Moody, IREAP
Boaz Nash, SLAC
Jia Ning, Fermilab
Caolionn O'Connell, SLAC
Jaroslaw Pasternak, CERN
Tatiana Pieloni, CERN
Sakhorn Rimjaem, FNRF
Guillaume Robert-Demolaize, CERN
Federico Roncarolo, CERN
Taku Saito, RISE
Nicholas Sammut, CERN
Ksenia Samokhvalova, MIT
Christopher Sears, SLAC
Lei Shao, UCLA
Garegin Simonyan, YSU
Jeffrey Smith, Cornell University
Giovanni Spiezia, CERN
Bastien Steiner, TEMF
Ralph Steinhagen, CERN
Yingmei Su, BNL
Yin-e Sun, Fermilab
Christopher Tennant, JLab
Kai Tian, IREAP
Rodion Tikhoplav, Fermilab
Jeremy Urban, Cornell University
Nikita Vasyukhin, FZJ/IKP
Fei Wang, IUCF
Haitao Wang, ANL
Stephen Weathersby, SLAC
Emma Wooldridge, CCLRC/DL/ASTeC
Qiong Wu, IUCF
Lingyun Yang, IUCF
Phil Sung Yoon, Fermilab
Davit Zakaryan, YSU
Kai Zheng, NSRL
Jing Zhou, MIT
Robert Zwaska, Fermilab

# Satellite Meetings

## Sunday, May 15

**DPB Executive Committee Meeting**, 5:00-11:00 p.m., Room 301A

## Monday, May 16

**2006 Advanced Accelerator Concepts Workshop Organizing Committee Meeting**, 1:00-5:00 p.m., Room 300C

**International Conference on RF Superconductivity Program Committee Meeting**, 6:00-7:30 p.m., Room 300B

**ICFA Beam Dynamics Panel Meeting**, 6:00-8:00 p.m., Room 301A

## Tuesday, May 17

**Code Benchmarkers Group Meeting**, 11:00 a.m.-12:00 p.m., Room 301A

**PAC05 Organizing Committee Luncheon Meeting**, 12:50-1:20 p.m., Rotunda Boardroom (invitation only)

**Meet the Editors of *Physical Review* and *Physical Review Letters***, 2:30-4:30 p.m., Cumberland Concourse

**DPB Business Meeting**, 5:30-6:30 p.m., Room 301A

## Wednesday, May 18

**High School Physics Teachers' Day**, 8:00 a.m.-4:00 p.m., Rooms 300 C&D

**BIW06 Organizing Committee Meeting**, 11:30 a.m.-1:00 p.m., Room TBD (invitation only)

**Physical Review Special Topics—Accelerators and Beams Editorial Board Meeting**, 12:30-2:30 p.m., Rotunda Boardroom (invitation only)

**Magnet Simulations for Particle Accelerators Workshop**, 1:50-6:30 p.m., Room 300A (day 1)

## Thursday, May 19

**JACoW Steering Committee Meeting**, 12:00 to 2:00 p.m., Rotunda Boardroom (invitation only)

**LINAC06 OC Meeting**, 12:30-2:30 p.m., Room 301A (invitation only)

**Magnet Simulations for Particle Accelerators Workshop**, 1:50-6:30 p.m., Room 300A (day 2)

## Friday, May 20

**PACCC Meeting**, 12:00-1:30 p.m., Rotunda Boardroom (invitation only)

# Scientific Program

The schedule included here details the scientific program with the program code, title, authors, and abstract of each paper (only publicly available information will be discussed).

## Oral Sessions

Oral sessions will be held in the third floor ballrooms. Plenary sessions will be in Ballrooms D-G. Parallel sessions will be in Ballrooms A, B, and C.

A preview/testing area is available for speakers in the Internet Café. *Please note that all speakers must give their presentations from the computer systems set up in the ballrooms. Use of individual laptops cannot be accommodated.*

## Poster Sessions

Poster sessions will be held in three areas:

Ballroom E (third floor)
Park Concourse (second floor)
Rooms 200 A-C (second floor)

Posters should be in place by the beginning of the session and should be taken down at the end of each session.

*Authors are reminded that no contributions are accepted for publication only. Any paper accepted for presentation that is not presented at the conference will be excluded from the proceedings.*

*The Scientific Program Committee reserves the right to refuse papers for publication that have not been properly presented or staffed in the poster sessions. Manuscripts of contributions to the proceedings (or enlargements of them) are not considered to be posters, and papers presented in this way will not be accepted for publication.*

## Identification of Contributions

The date, type of presentation, and location for each contribution in the program can be easily identified from the program code, which is composed as follows:

- The first letter indicates the day: M, T, W, R, F.
- The second letter indicates presentation type: O for oral, P for poster.
- The third letter indicates time of day: A for a.m., P for p.m.
- The fourth letter indicates the location:

**Oral Sessions (third floor)**
A Ballroom A
B Ballroom B
C Ballroom C
D Ballroom A, B, or C (check program schedule for exact room)
E Ballroom A, B, or C (check program schedule for exact room)

Note: All plenary and special sessions will be held in Ballrooms D-G.

**Poster Sessions (second and third floor)**
E Ballroom E (third floor)
P Park Concourse (second floor)
T Rooms 200 A-C (second floor)

### Monday, May 16

| | | |
|---|---|---|
| 8:30-12:20 | Opening Plenary | Ballrooms D-G |
| 13:50-17:20 Monday Afternoon Oral Sessions | High-Energy Hadron Accelerators and Colliders | Ballroom A |
| | Sources and Injectors | Ballroom B |
| | Multiparticle Beam Dynamics | Ballroom C |
| 13:50 17:10 Monday Afternoon Poster Sessions | Single-Particle Beam Dynamics and Optics | Ballroom E |
| | Instabilities and Feedback | Park Concourse |
| | Magnets | Rooms 200 A-C |

### Tuesday Morning, May 17

| | | |
|---|---|---|
| 8:30-12:25 Tuesday Morning Oral Sessions | Magnets | Ballroom A |
| | Light Sources and Free-Electron Lasers | Ballroom B |
| | Instabilities and Feedback | Ballroom C |
| | Instrumentation | |
| 8:30-12:20 Tuesday Morning Poster Sessions | Advanced Concepts | Ballroom E |
| | High-Energy Hadron Accelerators and Colliders | Park Concourse |
| | Multiparticle Beam Dynamics, Extreme Beams, & High-Energy Hadron Accelerators and Colliders | Rooms 200 A-C |

### Tuesday Afternoon, May 17

| | | |
|---|---|---|
| 13:50-17:35 Tuesday Afternoon Oral Sessions | Advanced Concepts | Ballroom A |
| | Light Sources and Free-Electron Lasers | Ballroom B |
| | Development in the South, East, and Mid-East/Nuclear Physics High-Energy Physics | |
| | Instrumentation | Ballroom C |
| | Linear Colliders | |
| 13:50-17:10 Tuesday Afternoon Poster Sessions | Sources and Injectors | Ballroom E |
| | Lepton Accelerators and Colliders | Park Concourse |
| | Radio-Frequency Systems | Rooms 200 A-C |

## Wednesday Morning, May 18

| | | |
|---|---|---|
| 8:30-12:25 Wednesday Morning Oral Sessions | Linear Colliders | Ballroom A |
| | Lepton Accelerators and Colliders | |
| | Development in the South, East, and Mid-East/Light Sources | Ballroom B |
| | Single-Particle Dynamics and Optics | Ballroom C |
| 8:30-12:20 Wednesday Morning Poster Sessions | Accelerator Technology | Ballroom E |
| | Sources and Injectors | Park Concourse |
| | Radio-Frequency Systems | Rooms 200 A-C |

## Wednesday Afternoon, May 18

| | | |
|---|---|---|
| Wednesday Afternoon Oral Sessions 13:00-15:00 | Special Session: Accelerator Science and Technology Awards | Ballrooms D-G |
| 15:00-17:55 | Special Session: Einstein and the World Year of Physics | Ballrooms D-G |

## Thursday Morning, May 19

| | | |
|---|---|---|
| 8:30-12:25 Thursday Morning Oral Sessions | Lepton Accelerators and Colliders | Ballroom A |
| | Accelerator Technology | |
| | Pulsed-Power and High-Intensity Beams | Ballroom B |
| | Radio-Frequency Systems | Ballroom C |
| 8:30-12:20 Thursday Morning Poster Sessions | Light Sources and Free-Electron Lasers | Ballroom E |
| | Applications of Accelerators & Instrumentation | Park Concourse |
| | Instrumentation | Rooms 200 A-C |

## Thursday Afternoon, May 19

| | | |
|---|---|---|
| 13:50-17:20 Thursday Afternoon Oral Sessions | Controls and Computing | Ballroom A |
| | Two-Stream Instabilities and Collective Processes | Ballroom B |
| | Low- and Medium-Energy Accelerators and Rings | Ballroom C |
| 13:50-17:10 Thursday Afternoon Poster Sessions | Accelerator Technology | Ballroom E |
| | Linear Colliders | Park Concourse |
| | Light Sources and Free-Electron Lasers; Development in the South, East, and Mid-East; & Secondary Beam Facilities: Neutrons, Muons, and Photons | Rooms 200 A-C |

## Friday, May 20

| | | |
|---|---|---|
| 8:30-12:25 Friday Morning Oral Sessions | Accelerator Technology | Ballroom A |
| | Application of Accelerators | Ballroom B |
| | Secondary Beam Facilities: Neutrons, Muons, and Neutrinos | Ballroom C |
| | Extreme Beams | |
| 8:30-12:20 Friday Morning Poster Sessions | Low- and Medium-Energy Accelerators and Rings | Ballroom E |
| | Two-Stream Instabilities and Collective Processes | Park Concourse |
| | Controls and Computing & Pulsed-Power and High-Intensity Beams/Induction Linacs | Rooms 200 A-C |
| 13:50-17:00 | Closing Plenary | Ballrooms D-G |

# Monday, May 16, 2005

**Session MOAA: Opening Plenary**
**Ballroom D-G, 8:30**
**Chair: S. Chattopadhyay (JLab)**

**9:00 MOAA001—Einstein, Nobel Prize, and Accelerators**
*Cecilia Jarlskog (Lund Univ.)*
We are celebrating the year of physics thanks to Einstein's monumental contributions a hundred years ago. Indeed, the current field of accelerator physics is also deeply indebted to him. Why did it take more than a decade and a half for him to be "crowned" in Stockholm by the Nobel Prize? Did he get the Prize for the "wrong" thing? Based on original material from the archives of the Swedish Academy of Sciences, I will discuss how Einstein got the Nobel Prize and will give a short summary of his everlasting impact on the field of accelerator physics.

**9:40 MOAA002—Personal Perspectives on the ITRP Recommendation and on the Next Steps Toward the International Linear Collider**
*Barry Barish (CALTECH)*
The linear collider is the consensus choice for the next major accelerator in particle physics and it is to be build as a worldwide project. The science case for such a machine has become very strong as a result of precision electroweak results that support both a low mass Higgs and an energy scale for supersymmetry or other phenomena beyond the standard model that should be accessible by a linear collider. On the technical side, an outstanding R&D program led to two viable technologies to build such a machine. Finally, a process involving an international committee, ITRP, recommended that the ILC design should be based on superconducting RF technology. I will report here on that decision from the perspective of some time and space, and I will give some personal views of how to move forward toward realizing this great machine.

Department of Energy National Science Foundation.

**10:50 MOAA003—PEP-II and KEK-B Operational Status**
*John Seeman (SLAC)*
The present two B-Factories, KEKB at Tsukuba in Japan and PEP-II at SLAC in California, operate at the Upsilon 4S and have reached parameter levels unprecedented for e+e- colliders. They have provided very large data samples for their respective particle detectors, BELLE and BaBar. Luminosities are approaching 1 x 10^34/cm^2/s and beyond. Beam currents have reached over 2.5 A with 1600 positron bunches spaced by 4 nsec. Continuous injection with the detectors taking data has added significantly to data collection rates. Bunch-by-bunch feedback systems damp strong longitudinal and transverse coupled bunch instabilities. The beam-beam interaction has allowed high tune shift levels even in the presence of parasitic crossing and crossing angle effects. Both B-Factory colliders have significant near term luminosity improvement programs.

Work supported by DOE contract DE-AC02-76SF00515.

**11:20 MOAA004—RHIC Operational Status**
*Thomas Roser (BNL)*
As the first hadron accelerator and collider consisting of two independent superconducting rings RHIC has operated with a wide range of beam energies and particle species. Machine operation and performance will be reviewed that includes high luminosity gold-on-gold and copper-on-copper collisions at design beam energy (100 GeV/u), asymmetric deuteron-on-gold collisions as well as high energy polarized proton-proton collisions (100 GeV on 100 GeV). Plans for future upgrades of RHIC will also be discussed.

Work was performed under the auspices of the U.S. Department of Energy.

**11:50 MOAA005—FNAL Tevatron Operational Status**
*David McGinnis (Fermilab)*
The Fermilab Tevatron Proton-Antiproton Collider is currently the world's highest energy hadron collider. The luminosity of the Fermilab collider has been significantly increased with the Main Injector operating at its design goals. Further increases in luminosity have been the result of combining antiprotons from the Recycler and Accumulator storage rings. Recent commissioning of proton slip-stacking in the Main Injector has noticeably increased the antiproton accumulation rate. The increased stacking rate permits the sustained operation of using antiprotons from both the Accumulator and Recycler. Further increases in peak luminosity are expected from electron cooling in the Recycler and increased antiproton flux from the Antiproton Source.

Work supported by the Universities Research Assos., Inc., under contract DE-AC02-76CH03000 with the U.S. Dept. of Energy.

**Oral Session MOPA–High-Energy Hadron Accelerators and Colliders,**
**Ballroom A @ 13:50**
**Chair: V. Shiltsev (FNAL)**

**13:50 MOPA001—Advances in the Understanding and Operations of Superconducting Colliders**
*Pierre Bauer, Giorgio Ambrosio, Gerald Annala, Joseph DiMarco, Michael A. Martens, Vladimir Shiltsev, John Tompkins, Gueorgui Velev (Fermilab), Luca Bottura (CERN)*
Chromaticity drift is a well-known and more or less understood phenomenon in superconducting colliders such as the Tevatron. Less known is the effect of tune and coupling drift, also observed in the Tevatron during injection. Recently, in the context of the Tevatron collider run II, extensive studies of chromaticity, tune and coupling drifts were conducted to improve Tevatron performance. The studies included not only beam studies but also extensive off-line magnetic measurements on spare Tevatron dipoles. Some of these measurements were conducted in collaboration with Cern. Cern's interest in multipole drifts is related to the future LHC, which will have similar issues. The following will report on the results of these studies. A new result, which will be presented here also, is related to fast drifts occurring in the first few seconds of the injection porch. These fast drifts were observed first in the Tevatron and efforts are underway to explain them. The author will also attempt to broaden the discussion to include the discussion of drift effects in the accelerating fields of superconducting linear accelerators.

**14:15 MOPA002—Performance Limitations in High-Energy Ion Colliders**
*Wolfram Fischer (BNL)*
High-energy ion colliders (hadron colliders operating with species other than protons) are premier research tools for nuclear physics. The collision energy and high luminosity are important design and operations considerations. However, the experiments also expect flexibility with frequent changes in the collision energy, lattice configuration, and ion species, including asymmetric collisions. For the creation, acceleration, and storage of bright intense ion beams, attention must be paid to space charge, charge exchange, and intra-beam scattering effects. The latter leads to luminosity lifetimes of only a few hours for heavy ions. Ultimately cooling at full energy is needed to overcome this effect. Currently, the Relativistic Heavy Ion Collider at BNL is the only operating high-energy ion collider. The Large Hadron Collider, under construction at CERN, will also run with heavy ions.

Work supported by U.S. DOE under contract No DE-AC02-98CH10886.

**14:40 MOPA003—Testing of the LHC Magnets in Cryogenic Conditions: Operation Challenges, Status, and Outlook**
*Vinod Chohan (CERN)*
For the Large Hadron Collider under construction at CERN and the testing of its 1706 lattice magnets in cryogenic conditions, considerable challenges had to be overcome since 2002 to arrive at the situation of today, with semi-routine operation of the purpose built tests facility. With the setting up of an Operation Team comprising of non-expert CERN Accelerator operation staff, few in number and a large external collaboration, it was essential to develop the methodology of working in light of external collaboration limits and base it on CERN-known techniques and experience in accelerator running-in, commissioning and routine operation. A flavour of the operation tools that were necessary or developed will be given, i.e., web-based tests follow-up management & information systems, development of precisely defined 'to do list' of tests sequences, associated methods, procedures and strict check-lists, electronic logbooks and so forth. The presentation will briefly outline the test programme and its context & constraints, give a summary of the accomplishments so far, together with the outlook for the successful completion of the whole programme within the project goals.

**14:55 MOPA004—Status of Slip Stacking at Fermilab Main Injector**
*Kiyomi Seiya, Tim Berenc, Brian Chase, Joseph Dey, Ioanis Kourbanis, James Angell Mac Lachlan, Keith G. Meisner, Ralph James Pasquinelli, John Reid, Claudio Hector Rivetta, Jim Steimel (Fermilab)*
In order to increase proton intensity on anti proton production cycle of the Main Injector we are going to use the technique of 'slip stacking' and doing machine studies. In slip stacking, one bunch train is injected at slightly lower energy and second train is at slightly higher energy. Afterwards they are aligned longitudinally and captured with one rf bucket. This longitudinal stacking process is expected to double the bunch intensity. The required intensity for anti proton production is 8E12 protons in 84 bunches. Beam studies of the slip stacking process have started and we have already established that the stacking procedure works as expected for a low beam intensity. In order to make this stacking process usable for higher intensity beam in standard mode of operation, we are working on high intensity beam and the development of the feedback and feed forward system is under way.

Operated by Universities Research Association, Inc. for the U.S. Department of Energy under contract DE-AC02-76CH03000.

**15:10 MOPA005—Protection Against Accidental Beam Losses at the LHC**
*Jorg Wenninger, Ruediger Schmidt (CERN)*
Protection of the LHC against uncontrolled beam losses is of prime importance due to the very high stored beam energy. For nominal beam intensities, each of the two 7 TeV/c proton beams has a stored energy of 350 MJ threatening to damage accelerator equipment. At injection a number of passive beam absorbers must be correctly positioned and specific procedures have been proposed to ensure safe injection of high intensity. The LHC beam dump block being the only LHC element that can safety absorb the full LHC beam, it is essential that the beams are extracted unto the dump block in case of emergency. The failure time constants extend from 100 microseconds to few seconds depending on the equipment. Failures must be detected at a sufficiently early stage and transmitted to the beam interlock system that triggers the beam dumping system. To ensure safe operation the machine protection system uses a variety of systems to detect such failures. The strategy for protection of the LHC will be illustrated, with emphasis on new developments and studies that aim for an increased redundancy of the protection system.

Oral Session MOPB–Sources and Injectors
Ballroom B @ 13:50
Chair: R. Sheffield (LANL)

**13:50 MOPB001—An 8 GeV Superconducting Injector Linac**
*G. William Foster (Fermilab)*
The Fermilab Proton Driver is an 8 GeV Superconducting H- injector linac which replaces both the Fermilab 8 GeV Booster Synchrotron and its injector linac. In addition to its primary mission of enabling 2 MW beam power at 120 GeV for the Fermilab Main Injector neutrino program, it also provides stand alone beam power of 0.5-2 MW at 8 GeV for a variety of physics goals. The main linac from 1.3-8 GeV uses 1300 MHz TESLA klystrons and cryomodules, and thus represents a ~1.5% system test of the Linear Collider. The front end linac uses a combination of 1300 MHz beta<1 eliptical cavities and 325 MHz spoke resonators. By extending the TESLA technique of driving many superconducting cavities from a single large klystron, the 8 GeV linac requires only 11 klystrons. This has required the development of fast, high power YIG-ferrite phase shifters to provide individual RF phase and amplitude control at each cavity. Using this technique, the linac up to 100 MeV is powered by a single JPARC/Toshiba 325 MHz 2.5 MW Klystron. Proton Driver project status will be discussed in light of recent program developments at Fermilab. http://protondriver.fnal.gov.

U.S. Department of Energy, Office of Science.

**14:15 MOPB002—High Intensity High Charge State ECR Ion Sources**
*Daniela Leitner (LBNL)*
The next-generation heavy ion beam accelerators such as the proposed Rare Isotope Accelerator (RIA), the Radioactive Ion Beam Factory at RIKEN, the GSI upgrade project, the LHC-upgrade, and IMP in Lanzhou require a great variety of high charge state ion beams with a magnitude higher beam intensity than currently achievable. High performance Electron Cyclotron Resonance (ECR) ion sources can provide the flexibility since they can routinely produce beams from hydrogen to uranium. Over the last three decades, ECR ion sources have continued improving the available ion beam intensities by increasing the magnetic fields and ECR heating frequencies to enhance the confinement and the plasma density. With advances in superconducting magnet technology, a new generation of high field superconducting sources is now emerging, designed to meet the requirements of these next generation accelerator projects. The talk will briefly review the field of high performance ECR ion sources and the latest developments for high intensity ion beam production. The currently most advanced next-generation superconducting source ECR ion source VENUS will be described in more detail.

This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Nuclear Physics Division of the U.S. Department of Energy under Contract DE AC03-76SF00098.

**14:40 MOPB003—Two-Charge-State Injector Prototype for the RIA Project**
*Nikolai Vinogradov, Vladislav Aseev, Peter Ostroumov, Richard Claude Pardo (ANL)*
The Rare Isotope Accelerator (RIA) facility utilizes the concept of simultaneous acceleration of two charge states from the ion source. We are building a prototype two charge-state (2Q) injector of the RIA Driver Linac, which includes an ECR ion source originally built by Berkeley Ion Equipment Corporation, a LEBT and one-segment of the prototype RFQ. The reassembly and commissioning of the ECR source has been completed. During the commissioning process we modified and replaced several major components of the BIE-100 to increase the source performance. A new diagnostic station has been designed and built for accurate measurements of the output beam emittance. The paper will discuss detailed beam dynamics studies together with extensive emittance measurements of various ion beams. The status of the design and fabrication of 100 kV high voltage platform, achromatic bending system, multi-harmonic buncher, and a full power 57.5 MHz RFQ segment will be presented.

This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. W-31-109-ENG-38.

**14:55 MOPB004—Progress on Test EBIS and the Design of an EBIS-Based RHIC Preinjector**
*James Alessi, Edward Beebe, Omar Gould, Ahovi Kponou, Robert Lockey, Alexander I. Pikin, Krsto Prelec, John Ritter, Louis Snydstrup (BNL)*
Following the successful development of the Test EBIS at BNL,* we now have a design for an EBIS-based heavy ion preinjector which would serve as an alternative to the Tandem Van de Graaffs in providing beams for RHIC and the NASA Space Radiation Laboratory. This baseline design includes an EBIS producing mA-level currents of heavy ions (ex. Au 32+) in ~ 10-20 microsecond pulses, injecting into an RFQ which accelerates the beams to 300 keV/amu, followed by an IH linac accelerating to 2 MeV/amu. Some details of this design will be presented, as well recent experimental results on the Test EBIS.
*E.N. Beebe et al., Proc. Ninth International Symposium on Electron Beam Ion Sources and Traps, Journal of Physics: Conference Series 2 (2004) 164–173.

Work supported under the auspices of the U.S. DOE.

**15:10 MOPB005—Recent Advances in the Performance and Understanding of the SNS Ion Source**
*Robert Welton, Syd Nails Murray, Martin P. Stockli (ORNL/SNS)*
The ion source developed for the Spallation Neutron Source (SNS) is a radio frequency, multi-cusp source designed to produce ~ 40 mA of H- with a normalized rms emittance of less than 0.2 pi mm mrad. To date, the source has been utilized in the commissioning of the SNS accelerator and has already demonstrated stable, satisfactory operation at beam currents of 10 - 40 mA with duty-factors of ~0.1% for operational periods of several weeks. Ultimately the SNS facility will require beam duty-factors of 6% (1 ms pulse length, 60 Hz repetition rate). To ascertain the capability of the source to deliver beams at this duty-factor over sustained time periods, ongoing experiments are being performed in which the ion source has been continuously operated on a dedicated test stand. The results of these tests are reported as well as a theory of the Cs release and transport processes which was derived from these data. The theory was then employed to develop a more effective source conditioning procedure which led to a dramatic improvement in source performance. The theory was also employed to develop a new-concept, direct-transfer Cs collar which also led to a considerable improvement in source performance.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**Oral Session MOPC–Multiparticle Beam Dynamics**
**Ballroom C @ 13:50**
**Chair: K Harkay (ANL)**

**13:50 MOPC001—Final Results from the Novel Multiturn Extraction Studies at CERN Proton Synchrotron**
*Massimo Giovannozzi, Roberto Cappi, Simone Silvano Gilardoni, Michel Martini, Elias Métral, Rende Richard Steerenberg (CERN), Anke-Susanne Müller (FZK-ISS-ANKA)*
Recently a novel approach to perform multi-turn extraction was proposed based on beam splitting in the transverse phase space by means of trapping inside stable islands. An experimental campaign was launched since the year 2002 to assess the feasibility of such an extraction scheme at the CERN Proton Synchrotron. During the year 2004 run, a high-intensity single-bunch beam was successfully split and the generated beamlets separated without any measurable losses. The latest experimental results are presented and discussed in details in this paper. These achievements represent a substantial step forward with respect to what achieved in previous years, as only a low-intensity bunch could be split without losses. Furthermore, this opens the possibility of using such a technique for routine operation with the high-intensity proton beams required for the planned CERN Neutrino to Gran Sasso Project.

**14:15 MOPC002—Benchmark of Space Charge Simulations and Comparison with Experimental Results for High Intensity Low Energy Accelerators**
*Sarah M. Cousineau (ORNL/ASD)*
Space charge effects are a major contributor to beam halo and emittance growth leading to beam loss in high intensity, low energy accelerators. As future accelerators strive towards unprecedented levels of beam intensity and beam loss control, a more comprehensive understanding of space charge effects is required. A wealth of simulation tools have been developed for modeling beams in linacs and rings, and with the growing availability of high-speed computing systems, computationally expensive problems that were inconceivable a decade ago are now being handled with relative ease. This has opened the field for realistic simulations of space charge effects, including detailed benchmarks with experimental data. A great deal of effort is being focused in this direction, and several recent benchmark studies have produced remarkably successful results. This paper reviews the achievements in space charge benchmarking in the last few years, and discusses the challenges that remain.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**14:40 MOPC003—Benchmarking of Simulation Codes Based on the Montague Resonance in the CERN-PS**
*Ingo Hofmann, Giuliano Franchetti (GSI), Massimo Giovannozzi, Elias Métral (CERN), Panagiotis Spentzouris (Fermilab), Shinji Machida (KEK), Ji Qiang (LBNL), Robert Ryne (LBNL/CBP), Sarah M. Cousineau, Jeffrey Alan Holmes (ORNL/SNS), Frederick Jones (TRIUMF)*
Experimental data on emittance exchange by the space charge driven "Montague resonance" have been obtained at the CERN Proton Synchrotron in 2002-2004 as a function of the working point. These data are used to carry out a benchmarking of simulation codes for high intensity accelerators to test their adequacy for describing nonlinear motion in connection with space charge. In this paper we first summarize the experimental findings and their theoretical interpretation with a discussion of possible sources of deviation from an idealized picture of the Montague resonance. We then compare the results from different simulation codes (MICROMAP, IMPACT, ORBIT, SIMPSON, ACCIM, SYNERGIA) for a characteristic working point and discuss the influence on code results of various degrees of complexity of modelling the real PS combined function lattice (dispersion, AG focusing, lattice nonlinearities).

**14:55 MOPC004—Dynamics of a High Density Ion-Beam with Electron Cooling in HIMAC Synchrotron**
*Tomonori Uesugi, Takashi Fujisawa, Koji Noda, Daisuke Tann, Hiroshi Uchiyama (NIRS), Shinji Shibuya (AEC), Igor Meshkov, Evgeny Syresin (JINR), Yoshinori Hashimoto (KEK), Shiro Ninomiya (RCNP)*
High density circulating-ion beam was obtained with electron-cooling and cool-stacking injection in HIMAC synchrotron. The ion density was saturated at 1.0e9/cm^2. Coherent transverse instability was observed when ion- and electron-beam density was high. The dynamics of the cooled ion-beam are described in this report.

**15:10 MOPC005—Chromaticity and Impedence Effect on the Transverse Motion of Longitudinal Bunch Slices in the Tevatron**
*Vahid Houston Ranjbar (Fermilab)*
The Transverse turn-by-turn evolution of a bunch slice are examined considering chromatic and impedence effects. A quasi-analytical approximation is developed using perturbative expansion of Hills equation with a wake field. This approximation is compared to turn-by-turn measurements taken in the Tevatron and from this linear and second order chomaticity, and Impedence are calculated as well as beam stability thresholds.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the U.S. Department of Energy.

**Oral Session MOPA (Cont.)–High-Energy Hadron Accelerators and Colliders,**
**Ballroom A @ 15:30**
**Chair: W. Barletta (LBNL)**

**15:30 MOPA006—Theory and Reality of Beam-Beam Effects at Hadron Colliders**
*Yuri Alexahin (Fermilab)*
The beam-beam phenomena in hadron colliders is just as rich as in e+e- machines: orbit and focusing perturbations, excitation of nonlinear resonances, coherent tuneshifts. Moreover, the absence of radiation damping and long duration of a store permit even high-order (and correspondingly weak) resonances to manifest themselves presenting a major challenge for both theoretical analysis and machine operation. The recent progress in understanding of and coping with the beam-beam effects at hadron colliders, primarily at the Tevatron, is discussed.

**15:55 MOPA007—Polarized Proton Collisions at RHIC**
*Mei Bai, Leif Ahrens, James Alessi, Joanne Beebe-Wang, Michael Blaskiewicz, Alexendro Bravar, Joseph Michael Brennan, Donald Bruno, Gerry Bunce, John J. Butler, Peter Cameron, Roger Connolly, Joseph DeLong, Theodore D'Ottavio, Angelika Drees, Wolfram Fischer, George Ganetis, Chris J. Gardner, Joseph Glenn, Thomas Hayes, Hsiao-Chaun*

*Hseuh, Haixin Huang, Peter Ingrassia, Ubaldo Iriso, Jonathan S. Laster, Roger C. Lee, Alfredo U. Luccio, Yun Luo, William W. MacKay, Yousef Makdisi, Gregory James Marr, Al Marusic, Gary McIntyre, Robert Michnoff, Christoph Montag, John Morris, Tony Nicoletti, Peter Oddo, Jinnouchi Osamu, Fulvia C. Pilat, Vadim Ptitsyn, Thomas Roser, Todd Satogata, Kevin Smith, Steven Tepikian, Rogelio Tomas, Dejan Trbojevic, Nicholaos Tsoupas, Joseph Tuozzolo, Kurt Vetter, Michelle Wilinski, Alex Zaltsman, Anatoli Zelenski, Keith Zeno, S.Y. Zhang (BNL), Igor Gennadievich Alekseev, Dima Svirida (ITEP)*
The Relativistic Heavy Ion Collider~(RHIC) provides not only collisions of ions but also collisions of polarized protons. In a circular accelerator, the polarization of polarized proton beam can be partially or fully lost when a spin depolarizing resonance is encountered. To preserve the beam polarization during acceleration, two full Siberian snakes were employed in RHIC to avoid depolarizing resonances. In 2003, polarized proton beams were accelerated to 100~GeV and collided in RHIC. Beams were brought into collisions with longitudinal polarization at the experiments STAR and PHENIX by using spin rotators. RHIC polarized proton run experience demonstrates that optimizing polarization transmission efficiency and improving luminosity performance are significant challenges. Currently, the luminosity lifetime in RHIC is limited by the beam-beam effect. The current state of RHIC polarized proton program, including its dedicated physics run in 2005 and efforts to optimize luminosity production in beam-beam limited conditions are reported.

The work was performed under the auspices of the U.S. Department of Energy and RIKEN Japan.

**16:20 MOPA008—On the Feasibility of a Tripler Upgrade for LHC**
*Peter M. McIntyre, Akhdiyor Sattarov (Texas A&M University)*
Recent developments in the performance of superconductors and the design of high-field superconducting dipoles have opened the possibility to extend dipole field strength to ~25 Tesla in the arc dipoles of a future hadron collider. Design issues are presented for a concept of a Tripler upgrade of LHC, in which a second dual ring would be installed over the LHC ring in the same tunnel. Proton beams from LHC would be transferred to the Tripler midway through the LHC cycle and accelerated to ~20 TeV/beam for collisions. A number of obvious issues are explored. Synchrotron radiation power would be 80 times greater, but the critical energy would come as soft X-rays rather than hard UV, and so could be absorbed locally on ~150 K photon stops following each dipole so that total refrigeration power could perhaps be no more than that for LHC. Synchrotron damping would be dramatically enhanced in the Tripler compared to LHC, with damping times of ~one hour. Alternatives for beam transfer and low-beta insertions will be discussed. Like LHC, the Tripler would access new mass scales primarily through gluon fusion. The Tripler should reach about twice the mass scale attainable with LHC.

This work is supported by the U.S. Dept. of Energy, grant #DE-FG03-95ER40924.

**16:35 MOPA009—Global Decoupling on the RHIC Ramp**
*Yun Luo, Peter Cameron, Al Dellapenna, Jonathan S. Laster, Roger C. Lee, Al Marusic, Fulvia C. Pilat, Thomas Roser, Dejan Trbojevic, Jie Wei (BNL)*
The global betatron decoupling on the ramp is an important issue for the operation of the Relativistic Heavy Ion Collider (RHIC). In the polarized proton run, the betatron tunes are required to keep almost constant on the ramp to avoid spin resonance line crossing and the beam polarization loss. Some possible correction schemes on the ramp, like three-ramp correction, the coupling amplitude modulation and the coupling phase modulaxtion, have been found. The principles of these schemes are shortly reviewed and compared. Operational results of their applications on the RHIC ramps are given.

Work supported by U.S. DOE under contract No. DE-AC02-98CH10886.

**16:50 MOPA010—Studies of the Chromaticity, Tune, and Coupling Drift in the Tevatron**
*Michael A. Martens, Jerry Annala, Pierre Bauer, Vladimir Shiltsev, Gueorgui Velev (Fermilab)*
Chromaticity drift is a well-known and more or less well-understood phenomenon in superconducting colliders such as the Tevatron. Less known is the effect of tune and coupling drift, also observed in the Tevatron during injection. These effects are caused by field drifts in the superconducting magnets. Understanding of the behavior of the tune, coupling, and chromaticity at the start of the ramp is an important part of understanding the observed 5-10% loss in beam intensity at the start of the Tevatron ramp. In addition modifications in the Tevatron shot set-up procedure are being implemented to allow for a gain in integrated luminosity. In this context we conducted several beam-studies, during the period of April to August 2004, in which we measured the drift in the Tevatron chromaticity, tune and coupling during the injection porch. In some case we also measured the snapback at the start of the ramp. We will present the results of these studies data and put them into context of the results of off-line magnetic measurements conducted in spare Tevatron dipoles at the same time. Finally we will propose optimized feed-forward algorithms that successfully compensate for the drift effects in the Tevatron.

**Oral Session MOPB (Cont.)–Sources and Injectors**
**Ballroom B @ 15:30**
**Chair: J. Alessi (BNL)**

**15:30 MOPB006—Frontiers of RF Photoinjectors**
*M. Ferrario (INFN)*
New ideas have been recently proposed to achieve ultra-high brightness electron beams, as particularly needed in SASE-FEL experiments, and to produce flat beams, as required in linear colliders. Low emittance schemes already foreseen for split normal conducting photoinjectors have been applied to the superconducting case in order to produce high peak and high average beam brightness. RF compressor techniques have been partially confirmed by experimental results and more compact RF photoinjector designs including compression scheme are under development. Research and experiments in the flat beam production from a photoinjector as a possible alternative to damping rings are in progress. An overview of recent advancements and future perspectives in photoinjector beam physics is reported in this talk.

**15:55 MOPB007—Future Directions in Electron Sources**
*J. Lewellen (ANL)*
The emittance-compensated rf photoinjector is in the process of evolving from an experiment in and of itself, to a laboratory instrument, to a workhorse component of large user facilities such as next-generation light sources. In recent years the performance achieved by the standard p-mode design has approached the levels predicted by theory and experiment. The

basic design has been scaled from X-band down to less than 1 GHz in terms of operating frequency, and superconducting designs are presently undergoing initial testing at various locations. The requirements for linac-based light sources will require at least one order of magnitude improvement in beam quality; other applications, such as electron microscopes or high-energy electron lithography, require still greater improvements. The migration towards fully superconducting accelerators provides some additional design challenges. This paper briefly presents requirements for some future applications, and presents four new approaches to extending injector performance: the diamond-emitter photocathode, the planar focusing cathode, the magnetic-mode emittance compensation technique, and the field-emission-gated cathode.

Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**16:20 MOPB008—Temporal E-Beam Shaping in an S-Band Accelerator**

*Shen Yuzhen, James Murphy, Brian Sheehy, Xijie Wang, Zilu Wu (BNL/NSLS), Luca Serafini (INFN-Milano), Massimo Ferrario, Carlo Vicario (INFN/LNF), David Dowell, Sasha Gilevich, Cecile Limborg-Deprey, Henrik Loos (SLAC)*

New short-wavelength SASE light sources will require very bright electron beams, brighter in some cases than is now possible. One method for improving brightness involves the careful shaping of the electron bunch to control the degrading effects of its space charge forces. We study this experimentally in an S-band system, by using an acousto-optical programmable dispersive filter to shape the photocathode laser pulse that drives the RF photoinjector. We report on the efficacy of shaping from the IR through the UV, and the effects of shaping on the electron beam dynamics.

This work was supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contracts DE-AC02-98CH10886 and DE-AC03-76SF00515.

**16:35 MOPB009—Review of the Production Process of TTF and PITZ Photocathodes**

*Daniele Sertore, Paolo Michelato, Laura Monaco (INFN/LASA), Siegfried Schreiber (DESY), Antonio Bonucci (SAES Getters S.p.A)*

In the present article, the production process of the photocathodes for the TESLA Test Facility (TTF) at DESY Hamburg and the Photo Injector Test Facility at DESY-Zeuthen (PITZ) is reviewed in order to highlight key elements for the final photocathode performances. Since the first photocathode production in 1998, we have continuosly collected relevant paramenters of the cathode plugs and deposition process. These data are now critically analized in view of an optimization of the photocathode performances for the next generation of high brilliance sources.

**16:50 MOPB010—Simulations of Electron Beams Pre-Modulated at the Photocathode**

*Jonathan Gary Neumann, Ralph Fiorito, Patrick G. O'Shea (IREAP), Larry Carr, Timur Shaftan, Brian Sheehy, Yuzhen Shen, Zilu Wu (BNL/NSLS), William Graves (MIT), Henrik Loos (SLAC)*

The University of Maryland and the Source Development Laboratory at Brookhaven National Laboratory have been collaborating on a project that explores the use of electron beam pre-modulation at the cathode to control the longitudinal structure of the electron beam. This technique could be applied to creating deliberate modulations which can lead to the generation of terahertz radiation, or creating a smooth profile in order to supress radiation. This paper focuses on simulations that explore some of the pre-modulated cases achieved experimentally.

Work is supported by the Office of Naval Research, the Joint Technology Office, and the Department of Energy.

**17:05 MOPB011 – Axial Power Input in Photocathode Electron Guns**

*Dietmar Janssen (FZR), Hans Bluem, Alan Murray Melville Todd (AES), Vladimir Volkov (BINP SB RAS)*

We discuss the coaxial power input in normal and superconducting RF (SRF)photoinjector cavities. Upstream coaxial power input has been previously used at the PITZ facility where the output beam tube is an intrinsic part of the coaxial transmission line into the gun. In this paper, we describe coaxial coupling from the cathode side of the gun. For normal conducting RF guns, in addition to the advantage from symmetric coupling, an emittance compensation solenoid can now be positioned close to the gun cavity to deliver optimal transverse emittance. Beam dynamics calculations demonstrate 0.8 mm-mrad at 1 nC in X-band. For an SRF gun, we present a design for coaxial input around the cathode using a superconducting coupling cell. This cell matches the external quality factor of the gun for different beam powers and there is no RF loss associated with the axial gap of the cathode. The heat input into the coaxial feed and the surface field of the coupler are discussed. For a 1.3 GHz half-cell gun cavity with stored energy of 6.6 J, a 2.5 MeV electron beam can be delivered with a peak accelerating field of 50 MV/m. At 10 mA,the external Q is 2.1 x 106 and the coaxial line power loss that must be cooled is 28 W.

## Oral Session MOPC (Cont.)–Multiparticle Beam Dynamics
## Ballroom C @ 15:30
## Chair: S. Henderson

**15:30 MOPC006—Simulations and Experiments of Beam-Beam Effects in e+e- Storage Rings**

*Yunhai Cai, John Seeman (SLAC), Witold Kozanecki (CEA/DSM/DAPNIA), Kazuhito Ohmi, Masafumi Tawada (KEK)*

Over the past decade, extensive simulations of beam-beam effects in positron-electron collliders, based on the particle-in-cell method, were developed to explain many complex experimental observations. Recently, such simulations were used to predict the future luminosity performance of e+e- colliders. Some predictions have been proven to be correct in the existing accelerators. In this paper, many effects such as dynamic beta, beam-beam limit, crossing angle, parasitic collisions, betatron spectrum, and beam-beam lifetime, will be reviewed from the viewpoints of both simulation and experiment. Whenever possible, direct comparisons between the predictions of the simulation and the corresponding experimental results will be provided.

Work partially supported by the Department of Energy under Contract No. DE-AC02-76SF00515.

**15:55 MOPC007 – Anisotropy-Driven Collective Instabilities in Intense Charged Particle Beams**

*Edward Startsev, Ronald Davidson, Hong Qin (PPPL)*

In electrically neutral plasmas with strongly anisotropic distribution functions, free energy is available to drive different collec-

tive instabilities such as the electrostatic Harris instability and the transverse electromagnetic Weibel instability. Such anisotropies develop naturally in particle accelerators and may lead to a detoriation of beam quality. We have generalized the analysis of the classical Harris and Weibel instabilities to the case of a one-component intense charged particle beam with anisotropic temperature including the important effects of finite transverse geometry and beam space-charge. For a long costing beam, the delta-f particle-in-cell code BEST and the eighenmode code bEASt have been used to determine detailed 3D stability properties over a wide range of temperature anisotropy and beam intensity. A theoretical model is developed which describes the essential features of the linear stage of these instabilities. Both, the simulations and analytical theory, clearly show that moderately intense beams are linearly unstable to short-wavelength perturbations, provided the ratio of the longitudinal temperature to the transverse temperature is smaller than some threshold value.

Research supported by the U.S. Department of Energy.

**16:20 MOPC008—Dynamic Beam-Beam Effects Measured at KEKB**

*Takao Ieiri, Yoshihiro Funakoshi, Takashi Kawamoto, Mika Masuzawa, Makoto Tobiyama (KEK)*

KEKB is a multi-bunch, high-current, electron/positron collider for B meson physics. The two beams collide at one interaction point (IP) with a finite horizontal crossing angle and with a bunch-space of 6 to 8 ns. The luminosity achieved at KEKB is the best in the world. The betatron tunes are set close to a half integer, to expect the dynamic beam-beam effects that change the beta function around the rings and the emittance as a function of the beam-beam parameter. In order to investigate such attractive beam-beam effects, the beam-beam kick and the beam-beam tune-shift were obtained by comparing the beam parameters between a colliding bunch and a non-colliding one. The horizontal beam size at the IP estimated from a beam-beam kick curve was slightly less than a calculated value without the dynamic effect. The horizontal emittance estimated from the beam-beam tune shift was somewhat larger than a calculated natural emittance. These experimental results reflect the dynamic beam-beam effects.

This work is partially supported by Grant-in-Aid Scientific Research (16540271) from Japan Society for the Promotion of Science and Technology.

**16:35 MOPC009—Experiments on LHC Long-Range Beam-Beam Compensations and Crossing Schemes at CERN SPS**

*Frank Zimmermann, Jean-Pierre Koutchouk, Federico Roncarolo, Jorg Wenninger (CERN), Yannis Papaphilippou (ESRF), Tanaji Sen, Vladimir Shiltsev (Fermilab)*

Experiments with two prototype long-range beam-beam compensators (current-carrying wires) during the 2004 CERN SPS run explored the efficiency of a proposed long-range beam-beam compensation for the LHC. In addition, the SPS compensators were also used to 'simulate' the effect of different planes of crossing at two LHC interaction points. We present the experimental results and compare them with computer simulations.

**16:50 MOPC010—Longitudinal Dynamics in the University of Maryland Electron Ring**

*John R. Harris, Renee Feldman (University of Maryland), Donald Feldman, Yijie Huo, Jonathan Gary Neumann, Patrick G. O'Shea, Bryan Quinn (IREAP), Martin Reiser (University Maryland)*

The University of Maryland Electron Ring (UMER) is a low energy electron recirculator for the study of space charge dominated beam transport. The system's pulse length (100 ns) and large number of diagnostics make it ideal for investigating the longitudinal evolution of intense beams. Pulse shape flexibility is provided by the pulser system and the gridded gun, which has the ability to produce thermionic and photoemission beams simultaneously. In this paper, we report on the generation and evolution of novel line charge distributions in UMER.

Work supported by the Department of Energy, the Office of Naval Research, the Joint Technology Office, and the Directed Energy Professional Society.

## Poster Session MPPE—Single-Particle Beam Dynamics and Optics, Ballroom E, 13:50- 17:10

**MPPE001—Study of the LNLS Wiggler Non-linear Effects Through Frequency Maps**

*Ximenes Rocha Resende, Natalia Prado Abreu, Ruy H.A. Farias, Lucia Cabral Jahnel, Lin Liu, Pedro Tavares (LNLS)*

A 2T hybrid wiggler will be the first insertion device installed at the Brazilian Synchrotron Light Source. Its high field may induce strong non-linear behavior in the beam dynamics compromising long-term stability parameters. Here we report our studies on non-linear effects of the wiggler on the dynamics of the beam. The main tools used in our analysis are Frequency Maps which are constructed from results of a numerical particle tracking code that uses simulated and measured field maps of the wiggler.

**MPPE002—Beam Propagation in Misaligned Magnetic Elements: A MatLab Based Code**

*Tiago Fiorini Silva, Mauricio Lima Lopes, Marcos Martins, Paulo Beolchi Rios (USP/LAL)*

We present a method to calculate kinematical parameters of a beam subject to a misaligned magnetic element. The procedure consists in transforming the kinematical parameters of the beam to the reference frame in which the magnetic element is aligned, propagating the beam through the element, and transforming back to the original frame. This is done using rotation matrices around the X-, Y-, and Z-axes. These matrices are not Lorentz invariant, so the rotations must be performed in a reference frame where the beam is at rest. We describe the transformation matrices, present a MatLab based code that uses this method to propagate up to 100 particles trough a misaligned quadrupole, and show some graphical outputs of the code.

Fundacao de Amparo a Pesquisa do Estado de Sao Paulo - FAPESP Conselho Nacional de Desenvolvimento Cientifico e Tecnologico - CNPq.

**MPPE003—Monte Carlo Simulations of Thin Internal Target Scattering In CELSIUS**

*Yi-Nong Rao (TRIUMF), Dag Reistad (TSL)*

In the practical operation of the storage ring CELSIUS with the hydrogen pellet target, we simetimes observe a cooling phenomenon in the longitudinal phase space, that is, the circulating beam's phase space gets shrunk instead of blown up. This phenomenon occurs independently on the electron cooling. In this paper, we aim to investigate and interpret this phenomenon as well as the beam lifetime in the presence of hydrogen pellet target with and without rf and with and without electron cooling in CELSIUS using Monte Carlo simulations.

**MPPE004—Evaluation of Nonlinear Effects in the 3GeV Rapid Cycling Synchrotron of J-PARC**
*Hideaki Hotchi, Fumiaki Noda (JAERI/J-PARC), Junichi Kishiro, Norio Tani (JAERI/LINAC), Shinji Machida, Alexander Yu. Molodojentsev (KEK)*
In order to accelerate an ultra-high intense beam with small particle losses, the 3GeV Rapid Cycling Synchrotron (RCS) of J-PARC, which is being constructed at JAERI, has a large acceptance. In this case the nonlinearity associated with the motion of particles at large amplitude and large momentum deviation plays a significant role. The sources of nonlinear magnetic fields in RCS are mainly connected with the fringe of the main dipole and quadrupole magnets and with the sextupole magnets used for the linear chromaticity correction. In this paper, we will present simulation results including such nonlinear effects. In addition, the possible correction scheme for the induced transverse resonances will be discussed.

**MPPE005—Dynamic Aperture and Resonance Correction for JPARC-RCS**
*Alexander Yu. Molodojentsev, Etienne Forest, Shinji Machida, Masashi Shirakata (KEK), Hideaki Hotchi, Fumiaki Noda, Yoshihiro Shobuda, Hiromitu Suzuki, Kazami Yamamoto (JAERI/J-PARC), Yoshihiro Ishi (Mitsubishi Electric Corp)*
Main intrinsic field nonlinearities, which are common for synchrotrons with large aperture, are the nonlinear field of the bending magnets, the fringing field of the magnets and the sextupole field nonlinearity, used for the chromaticity correction. The particle motion in the ring bending magnets has been analyzed by two methods: (1) by direct integration of the particle motion equations in the 3D magnetic field (Tosca output), based on the 4th order Runge-Kutta integrator and (2) by determination the transfer 8th order map of the bending magnet by using the Gaussian wavelet in the 3D space. The second technique allows us to use powerful tools such as the normal form analysis, to define the resonance driving terms, which can be used for the resonance correction. As the result of this study it was shown that the main limitation of the RCS dynamic aperture can be caused by the structure normal sextupole-order resonance and the normal octupole-order resonance. Other high-order resonances have smaller effects on the particles motion than the resonances mentioned above. The correction scheme to improve the dynamic aperture near the normal sextupole-order resonance has been analyzed.

**MPPE006—Particle Distribution Function Forming in Nonlinear Systems**
*Serge Andrianov, Nikolaj Edamenko (St. Petersburg State University)*
Modern ion-optical systems are used in different fields of beam physics both independent facilities as consisting of largemachines. One of these destination is to create beams with a desired distribution of beams particles. Often there is a need to ensure a homogeneous distribution for a terminal beam phase portrait in a transverse configuration space. This is one of problems of nonlinear aberrations management. It is known that nonlinearity properties inhere to any beam lines. Such these nonlinearities have unremovable character, and their influence can be remove using only special nonlinear lattice elements, which are introduced artificially into the beam line. In this paper we suggest a procedure to find necessary nonlinear correcting control elements for purposive forming of beam particle distribution functions.

**MPPE007—Problems of Conservative Integration in Beam Physics**
*Serge Andrianov, Anna Abramova (St. Petersburg State University)*
In this paper an approach to conservative integration methods development is discussed. This problem is very important for beam physics: from beam line synthesis up to long time evolution simulation. This approach is based on a Lie algebra technique. On the first step we find a special form of decomposition for a Lie map, describing the system under study. On the second step a researcher finds exact solutions for some classes of hamiltonians in symbolic forms. These steps allows forming an integration scheme, which have a desired symplectic property. The additional invariant and symmetry properties can be included using dynamical invariants conception.

**MPPE008—Synthesis of Beam Lines with Necessary Properties**
*Serge Andrianov (St. Petersburg State University)*
In this paper a new approach to the problem of synthesis of beam lines is discussed. Usually this problem can be overcome by the use of numerical simulation and optimal control theory methods. But this results in sufficiently great number of variable parameters and functions. Obviously, that this degrades quality of a modeling procedure. The suggested approach is demonstrated on a problem of a microprobe design problem. Essence of the problem is that necessary to design a high precision focusing system which satisfies some additional conditions. For solution of this problem we use an algebraic treatment based on Lie algebraic methods and computer algebra techniques. Using the symmetry ideology this approach allows rewriting beam properties to enough simple conditions for control parameters and functions. This leads a set of desired solutions and show results in some most suitable form. Moreover, this approach decreases the number of variable parameters.

**MPPE009—2003-2004 Nonlinear Optics Measurements and Modeling for the CERN SPS**
*Angeles Faus-Golfe (IFIC), Rogelio Tomas (BNL), Gianluigi Arduini, Frank Zimmermann (CERN)*
In 2003 and 2004 nonlinear chromaticity, amplitude detuning, chromatic phase advance, resonance driving terms and off-energy orbits were measured in the CERN SPS at 14 GeV/c and 26 GeV/c, respectively. From the nonlinear chromaticity, the SPS optics model has been updated, by adjusting the strength of nonlinear field errors in dipoles and quadrupoles. Furthermore, we have added to the model the effect of the displacement of all main bends and the voluntary misalignments of all the other elements of the machine. We compare the field errors with those founded in 2002, 2001 and 2000. The tune shifts with transverse amplitude, driving terms, etc., predicted by this nonlinear optics model are compared with direct measurements.

**MPPE010—LHC Beam Loss Predictions with Collimation, Halo Tracking and a Detailed Aperture Model**
*Ralph Assmann, Jean-Bernard Jeanneret, Stefano Redaelli, Guillaume Robert-Demolaize (CERN)*
The cleaning performance of the LHC collimation system is reviewed. The study is based on a detailed tracking of secondary and tertiary beam halo in the LHC, which includes the correct treatment of off-momentum particles and an aperture model of the full LHC ring. The longitudinal beam loss distributions are given both for the perfect machine optics and for a perturbed machine with imperfections, such as static and transient closed-orbit and beta-beat errors. The studies include both injection and collision optics. The optics tolerances required for commissioning the collimation system and for achieving the required LHC cleaning performance are discussed.

**MPPE011—Expected Emittance Growth and Beam Tail Repopulation from Errors at Injection into the LHC**
*Brennan Goddard, Helmut Burkhardt, Verena Kain, Thys Risselada (CERN)*
The preservation of the transverse emittance of the proton beam at injection into the LHC is crucial for luminosity performance. The population of the beam tails is also important for beam losses and collimation. The transfer and injection process is particularly critical in this respect, and several effects can contribute to the expected emittance increase and tail repopulation, like optical and geometrical mismatch, injection offsets and coupling, etc. The various effects are described, together with the tolerance limits on the parameters, and the expected contributions evaluated analytically where possible. The emittance growth and tail distributions are also simulated numerically using realistic errors. The implications for the tolerances on the matching of the transfer lines are discussed.

**MPPE012—MAD-X PTC Integration**
*Frank Schmidt (CERN)*
MAD-X is CERN's successor for MAD8, a program for accelerator design with a long history. MAD-X is a modular, better maintainable re-write of MAD8 with data structures written in C. Early on in the design of MAD-X we relied on the fact that older or doubtful modules could be replaced by new modules using the PTC code by E. Forest. Both codes remain independent entities but are linked via a converter to the MAD-X data structures. PTC is used for symplectic tracking of smaller machines and transfer line using better defined physical models of the elements and taking into account of how the elements are placed in the tunnel. The matching of the LHC will profit form the fact that the high order nonlinear parameters are provided by a PTC Normal Form analysis.

**MPPE013—High Precision Measurement of Muon Beam Emittance Reduction in MICE**
*Chris Rogers, Malcolm Ellis (Imperial College of Science and Technology)*
Muon ionization cooling, an essential ingredient of a neutrino factory, will be demonstrated for the first time by the MICE experiment. The central part of MICE consists of a short section of a neutrino factory cooling channel and the emittance reduction achieved in this experiment is quite modest, 10% to 15%. In order to extrapolate the performance of a full cooling channel from these values, it is crucial for MICE to achieve an emittance measurement accuracy of 10^-3 absolute. So far, beam emittance has never been measured with such a high level of precision and normailzed emittance in its present definition is not even conserved to 10^-3 in the absence of dissipative forces. We present an improved definition of beam emittance and the requirements and constraints on MICE beam optics and spectrometers that are necessary to achieve the 10^-3 level of accuracy.

**MPPE014—Non-Linear Beam Dynamics Studies of the Diamond Storage Ring**
*Riccardo Bartolini, Mahdia Belgroune, Ian Martin, James Henry Rowland, Beni Singh (Diamond), James Jones (CCLRC/DL/ASTeC)*
The non-linear beam dynamics have been investigated for the non-zero dispersion lattice of the Diamond storage ring. Effects in realistic lattice configurations such as the introduction of coupling errors, beta beating, closed orbit correction, quadrupole fringe field and in-vacuum and helical insertion devices have been studied in the presence of realistic physical aperture limitations. Frequency map analysis together with 6D tracking allows identification of the limiting resonances as well as the loss locations and calculation of the influence of non-linear longitudinal motion on the Touschek lifetime. The sensitivity of the lattice to some of these effects leads to the identification of a better working point for the machine.

**MPPE015—Non-Linear Ring Model Calibration with Frequency Analysis of Betatron Oscillations**
*Riccardo Bartolini (Diamond), Frank Schmidt (CERN)*
A precise model of an accelerator ring is crucial to achieve ultimate performance both in synchrotron light sources and high energy synchrotrons. Algorithms have been developed to calibrate the linear model of the ring. They have been successfully applied experimentally to determine and correct the linear optics of the machine. More recently the Frequency Map Analysis has been used to model also the non-linear optics. We propose here a technique based on the fit of non-linear spectral lines to recover the non-linear driving terms and to compensate the non-linear field errors around the ring.

**MPPE016—Hamiltonian Analysis of RF Photo Injectors**
*Chun-Xi Wang (ANL)*
We derive from first principles a general Hamiltonian that governs the beam dynamics in a rf photo injector. With proper choice of coordinates, the resulting Hamiltonian has a simple and familiar form, yet taking into account the rapid acceleration, rf focusing, magnetic focusing and space-charge forces. From the linear Hamiltonian, beam envelope evolution is readily obtained, which better illuminates the theory of emittance compensation. Preliminary result on the analysis of the third-order nonlinear Hamiltonian will be given as well.

**MPPE017—Longitudinal Acceptance in Linear Non-Scaling FFAGs**
*J. Scott Berg (BNL)*
Linear Non-Scaling FFAGs have, particularly for muon acceleration, a unique type of longitudinal motion. This longitudinal motion can be approximated by a parabolic dependence time-of-flight on energy. This motion can be described in dimensionless variables with two parameters. I describe the relationship between the parameters and the distortion of ellipses in longitudinal space. I discuss the relationship between the longitudinal acceptance and the time spent in the FFAG, the latter being especially relevant for decays in muon accelerators. I discuss what improvement one can expect to achieve by adding higher-harmonic RF systems to the accelerator.

Work supported by U.S. Department of Energy contract DE-AC02-98CH10886.

**MPPE018—Comparison of Particle Tracking Methods**
*J. Scott Berg (BNL)*
Particle tracking is done by numerically solving ordinary differential equations, generally arising from a Hamiltonian. I discuss three methods for solving these differential equations: Runge-Kutta, split-operator symplectic, and implicit midpoint. I examine 2nd and 4th order versions of these methods. I discuss which situations the different methods are appropriate for. I compare the accuracy and the number of function evaluations for these methods. I discuss methods for choosing the evaluation points: fixed and adaptive stepping, and how to do these optimally.

Work supported by U.S. Department of Energy contract DE-AC02-98CH10886.

**MPPE019—Accuracy of Hard-Edge End Field Models**
*J. Scott Berg (BNL)*
Magnets are often modeled as having a longitudinally independent field in the body of the magnet which abruptly goes away at the end of the magnet. This model is not completely accurate, howver: the fields in fact gradually go to zero at the end of the magnet. Maxwell's equations require these longitudinally varying fields cause fields of a different transverse dependence arise as a result of this. I define "hard-edge" end field models to be those that try to approximate these fields in a way that is independent of the precise form of this longitudinal variation. I describe some end field models, and compare calculations using those models with exact integration through the correct Maxwellian fields using realistic examples.

Work supported by U.S. Department of Energy contract DE-AC02-98CH10886.

**MPPE020—Self-Consistent Numerical and Analytical Modeling of Synchrotron Light Sources**
*Johan Bengtsson (BNL/NSLS)*
Given the following frameworks: "A Hamiltonian-Free Description of Single Particle Dynamics for Hopelessly Complex Periodic Systems" (Forest, 1990), "Normal Form Methods for Complicated Periodic Systems" (Forest, Berz, Irwin, 1989), "The Correct Local Description for Tracking in Rings" (Forest, 1994), "The C++ Programming Language" (Stroustrup, 1985), we have designed a compact object oriented beam dynamics class by re-using existing FORTRAN libraries for: Truncated Power Series Algebra (Berz, SSC, 1988), and Map Normal Rorm (Forest, CBP, LBNL, 1990). In other words, implemented a numerical- and analytical model for: 6-dim phase space tracking, with classical radiation, and evaluation of equilibrium emittance, driving terms, amplitude dependent tune shifts, chromaticity, momentum compaction, etc., to arbitrary order, with self-consistent treatment of magnet errors. The tool was developed for the lattice design of NSLS-II.

Under Contract with the U.S. Department of Energy Contract Number DE-AC02-98CH10886.

**MPPE021—Non-Linear Beam Transport System for the LENS 7 MeV Proton Beam**
*William Philip Jones, David Baxter, Vladimir Peter Derenchuk, Thomas Rinckel, Keith Solberg (IUCF)*
A beam transport system has been designed to carry a high-intensity low-emittance proton beam from the exit of the RFQ-DTL acceleration system of the Indiana University Low Energy Neutron System (LENS)* to the neutron production target. The goal of the design was to provide a beam of uniform density over a 3cm by 3cm area at the target. Two octupole magnets** are employed in the beam line to provide the necessary beam phase space manipulations to achieve this goal. First order calculations were done using TRANSPORT and second order calculations have been performed using TURTLE. Second order simulations have been done using both a Gaussian beam distribution and a particle set generated by calculations of beam transport through the RFQ-DTL using PARMILA. Comparison of the design characteristics with initial measurements from the LENS commissioning process will be made.
*V.P. Derenchuk et al., "The LENS 7 MeV, 10mA proton Linac," these proceedings. **E. Kashy & B. Sherrill, Nuclear Instruments and Methods in Physics Research, B26 (1987) p. 610.

This work has been supported by the National Science Foundation under grants DMR-0220560 and DMR—0320627, by the Indiana 21st Century Science and Technology Fund, and by the Department of Defense.

**MPPE022—Modifications to the Lattice of the Fermilab Debuncher Ring To Improve the Performance of the Stochastic Cooling Systems**
*Gerald Dugan (Cornell University), Bill Ashmanskas (Fermilab)*
The Fermilab Debuncher is used to collect antiprotons from the production target, reduce the momentum spread of the beam by an RF bunch rotation, and stochastically cool the transverse and longitudinal emittances of the beam prior to transfer to the Accumulator. A large value of the slip factor of the ring lattice is favored to provide a larger momentum acceptance for the bunch rotation process, while a small value of the slip factor is desirable for stochastic cooling. A dynamic change in the lattice from a large slip factor at injection to a smaller slip factor at extraction would optimize both processes and could lead to an improvement in antiproton stacking rate. This paper discusses the details of lattice modifications to the Debuncher, achievable with the existing hardware, which would result in a 60% increase in the slip factor, while maintaining the tunes and chromaticities fixed, and keeping the betatron functions within an acceptable range.

Supported by the Department of Energy and the National Science Foundation.

**MPPE023—Improvement of the Longitudinal Beam Dynamics Tuning Procedure for the MSU RIA Driver Linac**
*Marc Doleans (MSU), Dmitry Gorelov, Terry L. Grimm, Felix Marti, Xiaoyu Wu, Richard York (NSCL)*
The Rare Isotope Accelerator (RIA) driver linac will use a superconducting, cw linac with independently phased superconducting radio frequency cavities for acceleration and, for the heavier ions, utilize beams of multiple-charge-states (multi-q). Given the acceleration of multi-q beams and a stringent beam loss requirement in the RIA driver linac, a new beam envelope code capable of simulating nonlinearities of the multi-q beam envelopes in the longitudinal phase space was developed. Using optimization routines, the code is able to maximize the linearity of the longitudinal phase space motion and thereby minimizing beam loss by finding values for the amplitude and phase of the cavities for a given accelerating lattice. Relative motion of the multi-q beams is also taken into account so that superposition of the beam centroids and matching of their Twiss parameters are automatically controlled. As a result, the linac tuning procedure has been simplified and the longitudinal lattice performance has been improved. In this paper, the general architecture of the code and the results of using it to determine tuning parameters for the RIA driver linac are presented.

**MPPE024—Failure Modes Analysis for the MSU-RIA Driver Linac**
*Xiaoyu Wu, Marc Doleans, Dmitry Gorelov, Terry L. Grimm, Felix Marti, Richard York (NSCL, East )*
Previous end-to-end beam dynamics simulation studies* using experimentally-based input beams including alignment and rf errors and variation in charge-stripping foil thickness have indicated that the Rare Isotope Accelerator (RIA) driver linac proposed by MSU has adequate transverse and longitudinal acceptances to accelerate light and heavy ions to final energies of at least 400 MeV/u with beam powers of 100 to 400 kW. During linac operation, equipment loss due to, for example, cavity contamination, availability of cryogens, or failure of rf or power supply systems, will lead to at least a temporary loss of some of the cavities and focusing elements. To achieve high facility availability, each segment of the linac should be capable of adequate performance even with failed elements. Beam dynamics studies were performed to evaluate the linac performance under various scenarios of failed cavities and focusing elements with proper correction schemes, in order to prove the

flexibility and robustness of the driver linac lattice design. The result of these beam dynamics studies will be presented.
*X. Wu, "End-to-End Beam Simulations for the MSU RIA Driver Linac," Proceedings of the XXII Linac Conference, Lubeck, Germany, August 2004.

**MPPE025—Dynamical Effects Due to Fringe Field of the Magnets in Circular Accelerators**
*Yunhai Cai, Yuri Nosochkov (SLAC)*
The leading Lie generators, including the chromatic effects, due to hard edge fringe field of single multipole and solenoid are derived from the vector potentials within a Halmitonian system. These nonlinear generators are applied to the interaction region of PEP-II to analyze the linear errors due to the feed-down from the off-centered quadrupoles and solenoid. The nonlinear effects of tune shifts at large amplitude, the synchro-betatron sidebands near half integer and their impacts on the dynamic aperture are studied in the paper.

Work supported by the Department of Energy under Contract No. DE-AC02-76SF00515.

**MPPE026—Dynamic Aperture of Proposed Neutrino Factory FFAG**
*Dan Tyler Abell (Tech-X), J. Scott Berg (BNL)*
Recent years have seen increased interest in the use of fixed-field alternating-gradient (FFAG) rings for meeting—in a cost-effective manner—the demands of wide energy-acceptance and rapid acceleration required of muon beams for muon colliders and neutrino factories.* We present the results of dynamic aperture studies, performed using an updated version of Mad-9, that examine the effects of various parameters, including sextupole fringe field components and their correction.
*J.S. Berg, ICFA Beam Dynamics No.29, p.27 (2002).

DOE: DE-FG03-00ER83105.

**MPPE027—Modeling of Non-linear Effects in RF Cavities**
*Dan Tyler Abell, David L. Bruhwiler (Tech-X), Ilan Ben-Zvi (BNL)*
Emerging accelerator applications require beam radii comparable to RF cavity apertures, placing new demands on the modeling of particle motion in RF cavities using map-based techniques. A new method has been developed for computing nonlinear maps for arbitrary RF cavities.* We describe this new approach and present comparisons with more traditional approaches.
*D.T. Abell, in preparation.

DOE: DE-FG02-03ER83796.

**MPPE028—Non Linear Error Analysis from Orbit Measurements in SPS and RHIC**
*Javier Fernando Cardona, Rogelio Tomas (BNL)*
Recently, an "action and phase" analysis of SPS orbits measurements proved to be sensitive to sextupole components intentionally activated at specific locations in the ring. In this paper we attempt to determine the strenght of such sextupoles from the measured orbits and compare them with the set values. Action and phase analysis of orbit trayectories generated by RHIC models with non linearities will also be presented and compare with RHIC experiments.

U.S. Department of Energy and Colciencias.

**MPPE029—Spin Tracking in AGS with Two Partial Siberian Snakes**
*Alfredo U. Luccio, Mei Bai, William W. MacKay, Thomas Roser (BNL), Junpei Takano (RIKEN)*
The AGS is set to accelerate polarized protons using two helical Siberian snakes: a cold superconductive snake with a magnetic field of 2.5 T, and a warm snake with field of 1.5 T. Strong vertical focusing effects on the lattice due to the cold snake will be compensated by the use of new quadrupoles whose strength will vary with energy, since, during acceleration, the snake's focusing of the beam will decrease. Also spin rotation due to snakes at constant field will change with energy. To simulate in detail the AGS spin dynamics in the presence of snakes, the SPINK tracking program has been modified to accept the variation of machine and snake parameters versus energy. The new features of the code will be described, and results of the tracking, to be used as a guide to the operation of the AGS in upcoming polarized proton runs, will be presented.

U.S. Department of Energy.

**MPPE030—Comparison of Off-Line IR Bump and Action-Angle Kick Minimization**
*Yun Luo, Fulvia C. Pilat, Vadim Ptitsyn, Dejan Trbojevic, Jie Wei (BNL)*
The interaction region bump (IR bump) nonlinear correction method has been used for the sextupole and octupole field error on-line corrections in the Relativistic Heavy Ion Collider (RHIC). Some differences were found for the sextupole and octupole corrector strengths between the on-line IR bump correction and the predictions from the action-angle kick minimization. In this report we compare the corrector strengths from these two methods based on the RHIC Blue ring lattice with the IR nonlinear modeling. The comparison confirms the differences between resulting corrector strengths. And the reason for the differences is found and discussed. It is followed by a further discussion of the operational IR bump applications to the octupole, and skew sextupole and skew quadrupole field error corrections.

Work supported by U.S. DOE under contract No. DE-AC02-98CH10886.

**MPPE031—Simulation of Resonance Streaming at the eRHIC Electron Storage Ring**
*Christoph Montag (BNL)*
To estimate electron beam lifetime and detector background at the future electron-ion collider eRHIC, knowledge of the electron beam halo region is essential. Simulations have been performed to determine the deviation of the transverse beam profile from a Gaussian distribution.

Work performed under the auspices of the U.S. Department of Energy.

**MPPE032—Tracking of Particle Motion in a Proton FFAG with Adjusted Field Profile**
*Alessandro Ruggiero, Joanne Beebe-Wang (BNL)*
To compensate for the chromatic behavior of a Proton Fixed-Field Alternating-Gradient (FFAG) Accelerator, and for a compact magnet configuration of the ring lattice, an Adjusted Field Profile that varies across the width and the length of the ring magnets has been proposed* to be applied. Such a Field Profile is highly nonlinear and there is a concern that it may have a consequence on the Dynamic Aperture across the momentum range during acceleration. To resolve this concern a systematic particle tracking has been initiated to study the

particle stability over several hundreds of revolutions at different initial betatron amplitude. The paper presents the results of the numerical investigation.
*A.G. Ruggiero, "Adjusted Field Profile for the Chromaticity Cancellation in a FFAG Accelerator," Contribution to ICFA-HB2004, October 18-22, 2004, Bensheim, Germany.

Work performed under the auspices of the U.S. Department of Energy.

**MPPE033—RHIC Sextupole Beam-Based Alignment**
*Todd Satogata, Peter Cameron, Vladimir N. Litvinenko, Christoph Montag, Jennifer Niedziela, Vadim Ptitsyn (BNL)*
Each RHIC ring contains 144 sextupoles, powered in 12 families, for chromaticity control. These sextupoles create substantial tune shift, coupling changes, and nonlinear orbit feed-down during global and local orbit corrections. To improve orbit correction and optimize the orbit through these sextupoles, we use an iterative three-bump method to determine BPM offsets from sextupole centers and optimize the RHIC orbit through sextupoles and their corresponding quadrupoles. This paper presents methods, analysis, and results for this beam-based alignment effort during the RHIC 2005 run. Determination of these offsets will permit global orbit correction for the RHIC spin program at the required RMS level of <400um.

Work performed under the auspices of the U.S. Department of Energy.

**MPPE034—Symmetries and Invariants of the Envelope Equation**
*Hong Qin, Ronald Davidson (PPPL)*
Single-particle dynamics in a time-dependent focusing field is examined. The existence of the Courant-Snyder invariant* is fundamentally the result of the corresponding symmetry admitted by the oscillator equation with time-dependent frequency.** A careful analysis of the admitted symmetries reveals a deeper connection between the nonlinear envelope equation and the oscillator equation. A general theorem regarding the symmetries and invariants of the envelope equation, which includes the existence of the Courant-Snyder invariant as a special case, is demonstrated. The symmetries of the envelope equation enable a fast algorithm for finding matched solutions without using the conventional iterative shooting method.
*E.D. Courant and H.S. Snyder, Ann. Phys. 3, 1 (1958). **R.C. Davidson and H. Qin, Physics of Intense Charged Particle Beams in High Energy Accelerators (World Scientific, 2001).

Research supported by the U.S. Department of Energy.

**MPPE035—Transfers from High Power Hadron Linacs to Synchrotrons**
*Gerald Peter Jackson (Hbar Technologies)*
The Fermilab Proton Driver is an example of a high power H- linear accelerator proposed as a new source of high brightness protons for the Main Injector synchrotron. Because of the elevated radioactive activation of accelerator components associated with beam losses during injection and acceleration, extra attention must be paid to RF manipulations wherein small losses were once deemed acceptable. Especially when injecting into existing synchrotrons from upgraded injectors, instabilities and beam loading make loss free manipulations especially problematic. This paper discusses some options for reducing the losses associated with common longitudinal beam manipulations.

**MPPE036—Characterization of the Chaotic or Regular Nature of Dynamical Orbits: A New, Fast Method**
*Ioannis V. Sideris (Northern Illinois University)*
A new method of characterization of the regular or chaotic nature of dynamical orbits is introduced. It takes advantage of both morphological and dynamical properties of orbits, and can be applied to systems of all degrees of freedom. The new technique has been designed to analyze time-independent, time-dependent and N-body systems. It can provide straightforward information about the transition of orbits from regular to chaotic and vice versa, which can be found in time-dependent regimes. Equally important is the distinction it can make in time-independent regimes between sticky and wildly chaotic epochs during the evolution of chaotic orbits. Its most important advantage over the existing methods is, that it characterizes an orbit using information from a very small number of orbital periods. For these reasons the new method is extremely promising to be useful and effective in a broad spectrum of disciplines.

**MPPE038—Synchrotron Sidebands of a Linear Differential Coupling Resonance**
*Masaru Takao, Mitsuhiro Masaki, Jun Schimizu, Kouichi Soutome, Shiro Takano, Hitoshi Tanaka (JASRI/SPring-8)*
Sidebands of a linear differential coupling resonance are observed in the tune survey of the SPring-8 storage ring. The vertical beam size and the Touschek beam lifetime blow up at a distance by synchrotron tune from the linear differential resonance. The synchrotron sidebands of a linear betatron coupling resonance are excited by the vertical dispersion at sextupole magnets. Although the vertical dispersion of the SPring-8 storage ring is well reduced to be small, order of 1 mm, the linear betatron coupling resonance is further suppressed. In addition, the sextupole magnets are relatively strong as well as other third generation light source facilities. Hence at the SPring-8 storage ring we can observe the synchrotron sidebands of the coupling resonance. By means of the tracking simulation based on the ring model obtained by the response matrix measurement we confirm the existence of the synchrotron sidebands of a linear differential coupling resonance. In order to incorporate synchrotron motion in the simulation, the 6-dimensional tracking code developed at SPring-8 is used.

**MPPE039—A C++ Platform for High-Performance Tracking Studies for Storage Ring Collider**
*Andreas C. Kabel (SLAC)*
High-resolution tracking studies such as the ones presented in*,** require unprecented amounts of CPU power. Usually, flexibility of a simulation code compromises performance; we have developed a C++ framework for parallel simulation of circular accelerators which provides a high degree of flexibility and programmability (parsing of MAD beamline descriptions, manipulation of beamlines and interfaces, optimization and matching of beamlines, tracking of particles or differential-algebraic objects) while achieving raw tracking speeds comparable to and surpassing hand-coded Fortran code. We describe some of the techniques used, such as compile-time polymorphism, meta-programming, and present benchmarking results.
*A. Kabel, Y. Cai, this conference. **A. Kabel, Y. Cai, T. Sen, V. Shiltsev, this conference.

**MPPE040—Efficient Modeling of Nonlinear Beam Optics Using Parametric Model Independent Analysis**
*Bijan Sayyar-Rodsari, Eric Hartman, Carl Schweiger (Pavilion Technologies, Inc, Austin, Texas), Martin J. Lee, Yiton T. Yan (SLAC)*
Based on precision beam orbit measurements, Model Independent Analysis(MIA) has been used successfully to build a

computer model that matches the linear optics of the real accelerator. We report a parametric extension of MIA that will allow efficient modeling of the nonlinear beam optics to account for energy dispersions. A simulation study is presented where the nonlinear dependency of lattice parameters on beam energy is captured by constrained training of a universal nonlinear approximator. These parametric nonlinear models of beam optics are easy to construct, diagnose, and modify. They can be very useful for more accurate model predicted beam operation and control.

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**MPPE041—Orbit Stability at the Brazilian Synchrotron Light Source**
*Lin Liu, Natalia Prado Abreu, Ruy H.A. Farias, Lucia Cabral Jahnel, Pedro Tavares (LNLS)*
A task force has been implemented at the Brazilian Synchrotron Light Laboratory to improve the beam orbit stability in the 1.37 GeV electron storage ring. The main problems faced during this year (2004) were due to the installation of a second RF cavity in the machine. We describe the main problems and the solutions that were implemented.

**MPPE042—Beam Dynamics Simulations in FFAG Rings**
*Francois Meot (CEA/DSM/DAPNIA), Franck Lemuet (CERN)*
Efficient beam dynamics software has been developed for the simulation of FFAG accelerators, and applied to topics as 6-D full acceleration cycle tracking, design of isochronous optics, merging fringe-fields, automatic optimization of magnet and machine parameters, etc. A detailed presentation of the methods used, and examples of applications, are given.

CEA/DAPNIA and CERN.

**MPPE043—The Status of Optics Design and Beam Dynamics Study in J-PARC RCS**
*Fumiaki Noda, Hideaki Hotchi, Pranab Kumar Saha, Yoshihiro Shobuda, Kazami Yamamoto (JAERI/J-PARC), Shinji Machida (KEK)*
The 3GeV RCS at J-PARC is designed to provide proton beam of 3GeV and a goal of output beam power is 1MW. The beam commissioning starts on May 2007. At present, more qualitative studies concerning beam dynamics are in progress: core beam handlings, halo beam handlings, instabilities and so on. In this paper, the RCS optics design and the present status of beam dynamics studies are summarized.

**MPPE044—Damping Wiggler Study at KEK-ATF**
*Takashi Naito, Hitoshi Hayano, Yosuke Honda, Kiyoshi Kubo, Masao Kuriki, Shigeru Kuroda, Toshiya Muto, Nobuhiro Terunuma, Junji Urakawa (KEK), Maxim Korostelev, Frank Zimmermann (CERN), Kaori Takezawa (Kyoto University), Marc Ross (SLAC)*
The effects by damping wiggler magnets have been studied at KEK-ATF. The damping ring of the KEK-ATF is a 1.3 GeV storage ring capable of producing ultra-low emittance electron beams. It is significant issue to realize fast damping in the damping ring. The tuning method with 4 sets of wiggler was investigated for the ultra-low emittance beam. The performance on the beam quality, which is related to the transverse (x and y) and the longitudinal (z and dp/p), has been measured by the SR monitor, the laser wire, the streak camera and the energy spread monitor at the extraction line. We report on the operation condition and the measurement results.

**MPPE045—Accelerator Physics Issues at the 2.5 GeV PLS Storage Ring**
*Eun-San Kim (PAL)*
Over the past decade, PLS has served the synchrotron light source with the 2.0 GeV to 2.5 GeV electron beam. Accelerator physics issues at the present 2.5 GeV storage ring have been investigated in order to improve the performance of the light source. We present the issues of the low-beta lattice, low-emittance lattice, effects of six insertion devices on the lattice and low-alpha lattice, and show their effects on the beam dynamics in the storage ring.

**MPPE046—The Design Study for RCS Lattice of CSNS**
*Sheng Wang, Shouxian Fang, Qing Qin, Jingyu Tang (IHEP Beijing)*
China Spallation Neutron Source (CSNS) is based on Rapid Cycling Synchrotron (RCS), which can provide average beam power of 100 kW. The RCS should be with large momentum acceptance, small beam envelope and small dispersion, and the sufficient dispersion-free straights are also required for housing injection, extraction, collimation and RF system. Several lattice structures are compared and summarized in this paper for CSNS design.

**MPPE047—Optics Flexibility and Matching at LHC Injection**
*Helmut Burkhardt, Oliver Sim Brüning, Brennan Goddard, Verena Kain, Volker Mertens, Thys Risselada, Andre Verdier (CERN)*
An excellent match between the SPS, the several kilometers long transfer lines and the LHC will be required to minimise emittance blow-up at injection. Several optics changes in the SPS and the LHC injection insertions had to be accommodated in the design phase. The new 3-phase collimation system in the transfer lines results in additional phase advance constraints. It will be important to maintain some tuning range for the LHC commissioning phase and to accommodate possible further optics changes. We analyse the requirements, the constraints, the current status and options to enhance the optics flexibility.

**MPPE048—Beam Based Alignment of the LHC Transfer Line Collimators**
*Verena Kain, Brennan Goddard, Stefano Redaelli (CERN)*
At LHC injection energy the aperture available in the transfer lines and in the LHC is small and the intensities of the injected beams are an order of magnitude above the damage level. The setting of protection elements such as the transfer line collimators is therefore very critical; mechanical and optical tolerances must be taken into account to define the nominal setting. Being able to measure and control the collinearity of the collimator jaws with the beam relaxes the requirement on the settings considerably. A method to measure angular misalignment of the collimator jaws in the transfer line based on a transmission measurement is discussed. Simulations have been made and are compared with the results of an alignment test performed with beam during the 2004 commissioning of the transfer line TI 8.

**MPPE049—Sensitivity Study for Evaluating the Extracted Beam Parameters of the LLUMC Proton Therapy Synchrotron**
*George H. Gillespie, Barrey Hill (G.H. Gillespie Associates, Inc.), George Coutrakon, Jeff Hubbard, Ed Sanders (LLU/MC)*
The MINOS nonlinear constrained optimization program, working in concert with the beam optics code TRANSPORT, has been shown in recent work to provide a fast, efficient and reliable procedure for determining the parameters of the beam

extracted from the LLUMC proton therapy synchrotron. MINOS and TRANSPORT work together as Modules of the Particle Beam Optics Laboratory (PBO Lab) software. The software was used to determine the parameters of the beam extracted from the synchrotron accelerator that best fit the extensive wire scanner profile data used to monitor the LLUMC proton therapy beamlines. In this paper additional constraints and optimizer variables are utilized with the procedure, in order to evaluate the sensitivity of the best fit extracted beam parameters to various assumptions. The methods used will be described and selected results from the study presented.

**MPPE051—Phase Trombone Program Migration for the Recycler at Fermilab**
*Meiqin Xiao (Fermilab)*
In the Recycler Ring, a phase trombone is used to control tunes. 9 pairs of independently power supplied adjustable quadruples are located in RR-60 straight section. They are segmented into 5 families currently to maintain a symmetrical structure. By adjusting these circuits, a tune variation of up to ±0.5 units is attainable. These adjustments are coordinated in such a way that the Twiss parameters at the ends of the straight section keep unchanged. A new phase trombone program is written in C and is integrated into the data acquisition program in CNS. This program now gets rid of network communication, and does not need to run code MAD. In this report, a test program written in Mathematic is described, and several matching conditions for the Twiss parameters are compared. Test results for the setting and measured tune values using running program on console are presented.

**MPPE052—The Study on Coupling Issues in the Recycler at Fermilab**
*Meiqin Xiao, Yuri Alexahin, David E. Johnson, Ming-Jen Yang (Fermilab)*
We have been working and trying to answer the following questions: where are the coupling sources in the Recycler and is the existing correcting system working fine? In this paper, we report the analysis on the sources from both modeling by code MAD based on nonlinear lattice and real machine. From the first turn flesh orbit, we fit the off-plane orbits by third order polynomial, then separate 1st, 2nd and 3rd order coefficients to see different effects. On the other hand, we present the analysis from turn by turn data, which is to verify the phase of two skew quads families are more or less orthogonal, and to make sure the minimum tune split is small enough, and is consistent with the measurement.

**MPPE055—Fitting the Fully Coupled ORM for the Fermilab Booster**
*Xiaobiao Huang, Shyh-Yuan Lee (IUCF), Eric Prebys (Fermilab)*
The orbit response matrix (ORM) method* is applied to model the Fermilab Booster with parameters such as the BPM gains and rolls, and parameters in the lattice model, including the gradient errors and magnets rolls. We found that the gradients and rolls of the adjacent combined-function magnets were deeply correlated, preventing full determination of the model parameters. Suitable constraints of the parameters were introduced to guarantee an unique, equivalent solution. Simulations show that such solution preserves proper combinations of the adjacent parameters. The result shows that the gradient errors of combined-function magnets are within design limits.
*J. Safranek, Nucl. Instr and Meth. A, {\bf 388}, 27 (1997).

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**MPPE056—Studies to Increase the Anti-Proton Transmission from the Target to the Debuncher Ring**
*Ina Reichel (LBNL/CBP), Keith Gollwitzer, Steven J. Werkema (Fermilab), Michael Zisman (LBNL)*
The AP2 beamline at Fermilab transports anti-protons from the production target to the Debuncher ring. The measured admittance of the Debuncher ring and the theoretical aperture of the line are larger than the size of the transmitted beam. Extensive tracking studies were done using the Accelerator Toolbox (AT) to understand the sources of the difference. As simulations pointed to chromatic effects being a source of problems, measurements were done to study this. Several possible remedies were studied including adding sextupoles to the line to reduce the chromatic effects.

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**MPPE057—Measurement of the Vertical Emittance and Beta Function at the PEP-II Interaction Point Using the BaBar Detector**
*Joshua Thompson, Aaron Roodman (SLAC)*
We present measurements of the effective vertical emittance and IP beta function in the PEP-II Asymmetric B Factory. These beam parameters are extracted from fits to the longitudinal dependence of the luminosity and of the vertical luminous size, measured using e+ e- —> mu+ mu- events recorded in the Babar detector. The results are compared, for different sets of machine conditions, to accelerator-based measurements of the optical functions of the two beams.

U.S. Department of Energy.

**MPPE058—Virtual Accelerator for Accelerator Optics Improvement**
*Yiton T. Yan, Yunhai Cai, Franz-Josef Decker, Stanley Ecklund, John Irwin, John Seeman, Michael K. Sullivan, James Leslie Turner, Ulrich Wienands (SLAC)*
Through determination of all quadrupole strengths and sextupole feed-downs by fitting quantities derivable from precision orbit measurement, one can establish a virtual accelerator that matches the real accelerator optics. These quantities (the phase advances, the Green's functions, and the coupling eigen-plane ellipses tilt angles and axis ratios) are obtained by analyzing turn-by-turn Beam Position Monitor (BPM) data with a model-independent analysis (MIA). Instead of trying to identify magnet errors, a limited number of quadrupoles are chosen for optimized strength adjustment to improve the virtual accelerator optics and then applied to the real accelerator accordingly. These processes have been successfully applied to PEP-II rings for beta beating fixes, phase and working tune adjustments, and linear coupling reduction to improve PEP-II luminosity.

Work supported by Department of Energy contract DE-AC02-76SF00515.

**MPPE059—Precision Measurement of Coupling Ellipses Parameters in a Storage Ring**
*Yiton T. Yan, Yunhai Cai (SLAC)*
Eigen-mode coupling ellipses' tilt angles and axis ratios can be precisely measured with a Model-Independent Analysis (MIA) of the turn-by-turn BPM data from resonance excitation of the betatron motion. For each BPM location one can measure 4 parameters from the two resonance excitation, which completely describe the linear coupling of the location. Results from application to PEP-II storage rings are presented.

Work supported by Department of Energy contract DE-AC02-76SF00515.

**MPPE060—Quadrupole Beam-Based Alignment at RHIC**
*Jennifer Niedziela, Christoph Montag, Todd Satogata (BNL)*
Successful implementation of a beam-based alignment algorithm, tailored to different types of quadrupoles at RHIC, provides significant benefits to machine operations for heavy ions and polarized protons. This algorithm is used to calibrate BPM centers relative to interaction region (IR) quadrupoles to maximize aperture. It is also used to determine the optimal orbit through transition jump quadrupoles to minimize orbit changes during the transition jump for heavy ion acceleration. This paper provides background discussion and results from first application during the RHIC 2005 run.

Work performed under the auspices of the U.S. Department of Energy

**MPPE061—Measurement and Correction of Nonlinear Chromaticity in RHIC**
*Steven Tepikian, Peter Cameron, Al Dellapenna, Vadim Ptitsyn (BNL)*
To improve luminosity in RHIC by using smaller Beta,* higher order chromatic effects may need to be corrected. Measuring of higher order chromaticities is discussed and compared to a model of RHIC, showing good agreement. Assuming round beams, four families of octupoles are used to correct the second order chromaticities while keeping under control the amplitude dependent betatron tune spread in the beams. We show that the octupoles can reduce the second order chromaticity in RHIC, but they have insufficient strength for complete correction.

Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the U.S. Department of Energy.

**MPPE062—Measurement and Optimization of Local Coupling from RHIC BPM Data**
*Rogelio Tomas, Sanjee Abeytunge, Mei Bai, Rama Calaga, Wolfram Fischer (BNL), Andrea Franchi, Giovanni Rumolo (GSI)*
Global coupling in RHIC is routinely corrected by using three skew quadrupole families to minimize the tune split. In this paper we aim to re-optimize the coupling at top energy by minimizing resonance driving terms and the C-matrix in two steps: 1. Find the best configuration of the three skew quadrupole families and 2. Identify locations with coupling sources by inspection of the driving terms and the C-matrix around the ring. The measurements of resonance terms and C-matrix are presented.

U.S. Department of Energy.

**MPPE063—Optimization of Steering Elements in the RIA Driver Linac**
*Eliane Schnirman Lessner, Vladislav S. Assev, Peter Ostroumov (ANL)*
The driver linac of the projected RIA facility is a versatile accelerator, a 1.4-GV, CW superconducting linac designed to simultaneously accelerate several heavy-ion charge states, providing beams from protons at about 1 GeV to uranium at 400 MeV/u at power levels at a minimum of 100 kW and up to 400 kW for most beams. Acceleration of multiple-charge-state uranium beams places stringent requirements on the linac design. A steering algorithm was derived that fulfilled the driver's real estate requirements, such as placement of steering dipole coils on SC solenoids and of beam position monitors outside cryostats, and beam-dynamics requirements, such as coupling effects induced by the focusing solenoids.* The algorithm has been fully integrated in the tracking code TRACK** and is used to study and optimize the number and position of steering elements that minimize the multiple-beam centroid oscillations and preserve the beam emittance under misalignments of accelerating and transverse focusing elements in the driver linac.
*E.S. Lessner and P.N. Ostroumov, Proceedings of the 9-th European Particle Accelerator Conference, July 2005, pp.1476-1478. **V.N. Aseev, P.N. Ostroumov, E.S. Lessner, and B. Mustapha, these proceedings.

Work supported by the U.S. Department of Energy under contract W-31-109-ENG-38.

**MPPE064—Dynamic Aperture Study and Lifetime Improvement at the Advanced Photon Source**
*Vadim Sajaev, Louis Emery (ANL)*
Over past few years, the optics of the Advanced Photon Source storage ring was optimized to provide lower natural emittance. Presently, APS operates at 2.5 nm-rad emittance. The optimization was done at the expense of stronger sextupoles and shorter lifetime. Here we present our work on measurement and understanding the dynamic aperture of APS in low-emittance mode. We found good agreement between the dynamic aperture measurements and that of the model derived from the response matrix analysis. Based on the model, we were able to increase the lifetime significantly by optimizing sextupoles, correcting optics, moving working point, and adjusting rf voltage. The higher lifetime allowed us to decrease operating coupling from 2.5% to 1%.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**MPPE065—Fully Coupled Analysis of Orbit Response Matrices at the FNAL Tevatron**
*Vadim Sajaev (ANL), Valeri Lebedev, Vladimir Nagaslaev, Alexander Valishev (Fermilab)*
Optics measurements have played an important role in improving the performance of the FNAL Tevatron collider. Initial optics measurements were performed using a small number of differential orbits, which allowed us to carry out the first round of optics corrections. However, because of insufficient accuracy, it was decided to apply the response matrix analysis method for further optics improvements. The response matrix program developed at ANL has been expanded to include coupling – the essential feature required to describe the Tevatron optics. The results of the optics calibration are presented and compared to local beta function measurements.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38, and by the Universities Research Association, Inc., under contract DE-AC02-76CH03000 with the U.S. Dept. of Energy.

**MPPE066—Streak Camera Imaging Studies of Vertical Synchro-Betatron-Coupled Electron Beam Motion in the Advanced Photon Source Storage Ring**
*Bingxin Yang, Michael Borland, Weiming Guo, Katherine C. Harkay, Vadim Sajaev (ANL)*
We present experimental studies of synchro-betatron-coupled electron beam motion in the Advanced Photon Source storage ring. We used a vertical kicker to start the beam motion. When the vertical chromaticity is nonzero, electrons with different

initial synchrotron phases have slightly different betatron frequencies from the synchronous particle, resulting in a dramatic progression of bunch-shape distortion. Depending on the chromaticity and the time following the kick, images ranging from a simple vertical tilt in the bunch to more complicated twists and bends are seen with a visible light streak camera. Turn-by-turn beam position monitor data were taken as well. We found that the experimental observations are well described by the synchro-betatron-coupled equations of motion. We are investigating the potential of using the tilted bunch to generate picosecond x-ray pulses. Also note that the fast increase in vertical beam size after the kick is dominated by the internal synchro-betatron-coupled motion of the electron bunch. Experimentally this increase could be easily confused with decoherence of vertical motion if the bunch is only imaged head-on.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

**MPPE067—"Zero" Current Operation of the University of Maryland Electron Ring (UMER)**
*Gang Bai, Santiago Bernal, Irving Haber, Rami Alfred Kishek, Patrick G. O'Shea, Bryan Quinn, Jayakar Charles Tobin Thangaraj, Mark Walter (IREAP), Martin Reiser (University Maryland)*
The University of Maryland electron ring is completed for multi-turn operation of beams over a broad range of intensities (see general abstract on UMER). Although UMER is specially designed for space-charge dominated beam transport, "zero" current operation is important for various reasons. First, effects such as dispersion and chromaticity must be understood in the low-current, emittance-dominated, regime before their effects can be appreciated with high intensity beams. Secondly, measurement of zero-current phase advance per period is standard for machine characterization. Third, "zero" current operation is useful for beam-based alignment, a prerequisite for operation at higher currents. We review in this paper issues related to low-current operation of the ring: electron source, beam diagnostics, emittance measurements, beam matching and injection, dispersion and chromaticity effects. Some of these issues, e.g., envelope matching and steering, are compared with their counterparts in the space-charge dominated regime.

This work is funded by U.S. Dept. of Energy under grants DE-FG02-94ER40855 and DE-FG02-92ER54178.

**MPPE068—Effects on Flat-Beam Generation from Space-Charge Force and Beamline Errors**
*Yin-e Sun (University of Chicago), Kwang-Je Kim (ANL), Philippe Regis-Guy Piot (Fermilab)*
The transformation of a round, angular-momentum-dominated electron beam into a flat beam using a skew-quadrupole channel has been developed theoretically in several papers and demonstrated experimentally at the Fermilab/NICADD Photoinjector Laboratory. In this paper, we address the impacts of space-charge force and beamline errors on the round-to-flat beam transformation. We discuss the physical process of angular momentum cancellation during the beam passage through the skew-quadrupole channel, present analytical and numerical studies of the linear and nonlinear space-charge forces, and evaluate the corresponding limits on the ratio of vertical-to-horizontal emittances. We also investigate the sensitivities of flat-beam emittances on several systematic factors such as errors on quadrupole strengths and alignments.

**MPPE069—Beam Dynamics Issues of the Lattice for ALBA**
*Marc Muñoz, Dieter Einfeld (CELLS)*
ALBA will be a third generation synchrotron light source built in Spain near Barcelona. The lattice chosen for ALBA consists in an extended DBA-like structure with finite dispersion in the straight sections, providing low emittance (under 5nmrad), small beam cross sections at the source points (sigma x ~ 150 micrometers and sigma y ~ 10micrometers), and a large number of straight sections (4 times 8m, 12 times 4.2m and 8 times 2.6m). The small circumference (268 meters) and medium energy (3GeV) makes it challenging to provide the desired emittance while preserving a large enough dynamic aperture and energy acceptance. This paper reviews the main beam dynamics issues (dynamic aperture, energy acceptance, closed correction, lifetime, influence of insertion devices, and higher multipoles of magnets) and the solutions adopted.

**MPPE070—Correction of the Integer Spin Resonance for Precise Mass Measurement Experiment of Tau Lepton**
*Anton Bogomyagkov, Sergei Nikitin, Dmitry Shatilov (BINP SB RAS)*
The experiment on mass measuremnt of tau lepton is planned to be done in energy region of tau threshold 1777 MeV. The influence of spin integer resonance (nu=4, E=1762) significantly reduses life time of the beam polarization, which makes immpossible to perform an energy calibration by resonant depolarization technique. The succesfull attemt have been done to increase the life time of the polarization by vertical closed orbit correction, in other words minimizing the forth harmonic in the spin orbit coupling function.

**MPPE071—Einstein's General Relativity Effects on Beam Dynamics in a Storage Ring**
*Dong Dong, Chao Guang Huang, Zhou Zusheng (IHEP Beijing)*
In this paper we will discuss Einstein's tide force predicted by Einstein's general relativity, how the new tide force would affect the beam orbits in a storage ring, and how to pick up and recognize it from the beam signals in a storage ring. The result shows this effect can be accumulated by the charged particle beam in a storage ring, it is a very interesting result.

The work is supported by National Science Foundation of China under Grant No. 10475094.

**MPPE072—Efficient Modeling for Beam-Beam Interactions**
*Antonina N. Fedorova, Michael G. Zeitlin (RAS/IPME)*
We consider modeling for strong-strong beam-beam interactions beyond the standard perturbative methods. In our approach, based on projection methods and efficient functional space decomposition in localized bases with control of convergence for a nonlinear and/or singular integral operators (Hilbert transform etc) based models, the full possible spectrum, partly discovered before (discrete coherent and possible incoherent oscillations), appears as the result of the exact multiresolution/multiscale fast convergent decomposition in the bases of high-localized exact nonlinear modes. The constructed solutions represent the full multiscale spectrum with contributions from all internal (hidden) modes from the slow to fast oscillating eigenmodes. The underlying methods provide some sort of the algebraical control of the spectrum and the type of dynamical behaviour.*
*A. Fedorova, M. Zeitlin, Classical and Quantum Ensembles via Multiresolution. I. BBGKY Hierarchy; II. Wigner Ensembles; arXiv: quant-ph/0406009, 0406010; NIMA, 534A, 1-2, 2004, 309-313, 314-318, 2004 and papers on http://www.ipme.ru/zeitlin.html.

**MPPE073—Effects of a Passive Harmonic Cavity on Bunch Length and Beam Energy Spread with Considering Radiation Damping and RF Phase Noise**
*Lung-Hai Chang, Ming-Chyuan Lin, Chaoen Wang, Meng-Shu Yeh (NSRRC)*
In this paper, the bunch length and the energy spread are investigated from the longitudinal motion of the particles of a bunch, which is simulated by the particle tracking. In this particle motion tracking, the effects of the radiation damping, quantum excitation and the RF phase noise are considered. The accelerating voltage of the passive harmonic cavity is calculated from the motion of the bunch particles and the characteristics of the cavity. It is seen in the numerical simulation that when the passive harmonic cavity is operated in the bunch lengthen mode, the beam energy spread can be escalated with the increase in the stored beam current if RF generator has phase noise.

**MPPE074—Commissioning of a Locally Isochronous Lattice at the ALS**
*Weishi Wan, Gregory James Portmann (LBNL/ALS), Warren Byrne, Hiroshi Nishimura, David Robin, Fernando Sannibale, Alexander Zholents (LBNL)*
With the advance of ultrafast science, manipulating electron beam at the sub-micron and nanometer scale has been actively pursued. A special lattice of the ALS storage ring was conceived to studythe sub-micron longitudinal structure of the beam. It contains sections that are isochronous to the firstorder. Due to the practical constraints of the accelerator, sextupoles have to be off and the dispersion at the injection point is 60 cm, which make commissioning a highly nontrivial task. After a few months of tuning, we have been able to store at 30 mA of beam at the life time of 2 hours. After a brief introduction to the motivation of the experiment and the design of the lattice, the process and more detailed results of the commissioning will be presented. Future plan will also be discussed.

Work supported by the Director, Office of Energy Research, Office of Basic Energy Science, Material Sciences Division, U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**MPPE075—Simulation of the Effect of an In-Vacuum Undulator on the Beam Dynamics of the ALS**
*Weishi Wan (LBNL/ALS), Christoph Steier (LBNL)*
The femtosecond slicing project at the Advanced Light Source (ALS) requires that a short period (3 cm) and narrow gap (5.5 mm) in vacuum undulator to be installed. The combination of the short period and the narrow gap raised concern of the impact on the beam dynamics. A 3D field model was established based on numerical data using 8 longitudinal and 4 transverse harmonics. At first fourth-order symplectic integrator was used. It was to our surprise that the dynamic aperture decreased by a fact of 3. To understand the cause of the drastic change in the dynamic aperture, the field model was implemented in a differential algebraic code and the Taylor map of the undulator was obtained. Tracking result using the Taylor map showed little change in the dynamic aperture, which was latter corroborated by that using the symplectic integrator with 150 slices per period (as opposed to 10 before). Yet it is simply too time consuming to use the symplectic integrator with such thin slices. For this case, Taylor proves to be a much faster alternative.

Work supported by the Director, Office of Energy Research, Office of Basic Energy Science, Material Sciences Division, U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**MPPE076—Design Study on a New Separator for PEEM3**
*Weishi Wan (LBNL/ALS), Jun Feng, Howard A Padmore (LBNL)*
A new aberration-corrected Photoemission Electron Microscope, called PEEM3, is under development at the Advanced Light Source. The resolution and transmission improvement is realized by correcting the lowest order spherical and chromatic aberrations using an electron mirror. A separator is required to separate the incoming uncorrected electron beam to the mirror from the corrected outgoing electron beam to the projector column. In this paper, we present a design study of a new separator for PEEM3. The layout, the Gaussian optics, the analysis of aberrations and the tolerance on power supply stability and alignment errors are reported.

Work supported by the Director, Office of Energy Research, Office of Basic Energy Science, Material Sciences Division, U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**MPPE078—Quantum Theory of Accelerator Optics**
*Sameen Ahmed Khan (MECIT)*
A general procedure for construction of the formalism of quantum beam optics for any particle is reviewed. The quantum formalism of spin-1/2 particle beam optics is presented starting ab initio with the Dirac equation. As an example of application the case of normal magnetic quadrupole lens is discussed in detail. In the classical limit the quantum formalism leads to the well-known Lie algebraic formalism of classical particle beam optics.

**MPPE079—Motion of Particle in Plane Monochromatic Elliptic Polarized Electro Magnetic Field**
*Garegin Perch Simonyan, Davit Armenak Zakaryan (YSU)*
Lasers are used in modern accelerators very much. It is very important to know the behavior of particles in laser field. In this paper the trajectory of charged particles in plane monochromatic elliptic polarized electro magnetic field is found. Comparison with the particular solutions obtained before is done. The obtained results will be used for solution of many practical problems.

**MPPE080—Transversal Deflection of Electrons Moving in Parallel with Linearly Polarized Laser Beam and its Application**
*Davit Armenak Zakaryan (YSU), Davit Kalantar Kalantaryan (CANDLE; YSU), Edmond David Gazazyan, Karo Ispirian, Michael Karo Ispirian (YerPhI)*
The motion of electrons in linearly polarized laser beams in a finite length interaction region and after in a field free drift length is investigated. It is shown that in the interaction region the trajectory of the electrons is almost straight lines with very small oscillation weakly depending on the laser intensity. In the drift region the electrons acquire significant transversal deflection that allows to carry out the measurement of the length and longitudinal particle distribution of femtosecond bunches. The dependence of this deflection upon the electron energy, interaction region length, etc is studied. The principles of the construction of femtosecond oscilloscopes are discussed.

**MPPE081—The Comparison of a New Beam-Tracking Code to the Acceleration Test**
*Kazuo Yamamoto, Toshiyuki Hattori (RLNR), Satoru Yamada (NIRS), Masahiro Okamura (RIKEN)*
We made a new beam-tracking code using some 3D electromagnetic simulation software. Using this code, 3D-beam dynamics including non-linear and dipole effects can be easily

estimated. We have manufactured an IH-linac as a test of a new high efficiency cavity for a medical accelerator injector. An acceleration test of a proton beam was carried out in a test bench. We will report the simulation code, the results of the acceleration test and the comparison.

**MPPE082—Non-Linear Beam Dynamics in High Resolution Multi-Pass Time of Flight Mass Separator**
*Viatcheslav Anatolievitch Shchepunov (ORAU), Hermann Wollnik (JIHIR)*
A multi-pass time-of-flight (MTOF) mass separator is under development by the UNIRIB collaboration. The MTOF consists of two coaxial electrostatic mirrors, focusing lenses and auxiliary injection, extraction and separation elements. The injected ions having almost the same energy but different masses undergo hundreds or thousands of reflections between the mirrors. In the course of this periodic motion, the ions of different masses and hence velocities are spatially separated in longitudinal direction. The periodic motion in the MTOF has been investigated with a recently developed ray tracing program utilizing the canonical integration technique. Results of the performed numerical simulations are discussed. The simulations displayed nonlinear character of the ion's behavior both in transverse and longitudinal phase spaces. The ion's transverse stability and longitudinal isochronicity were the matters of primary attention. It is shown in particular that at transverse tunes of around q=0.75 the system can be adjusted to be isochronous up to at least the 3rd order of the ToF optical aberrations.

This work was supported by the UNIRIB collaboration and Oak Ridge Associated Universities.

**MPPE083—Harmonic Decomposition of Orbit Data for Multipole Analysis**
*Ming-Jen Yang (Fermilab)*
The unprecedented position resolution provided by the newly commissioned Recycer BPM system is opening up a new chapter of beam based multipole analysis at Fermilab. The closed orbit data, taken with circulating beam and averaged over many consecutive turns, has been shown to have the resolution of a few microns. The result of polynomial fit to BPM position data, as a function of dipole kick sizes, is used to separate orbit data into first, second, and third order. Combining both the in-plane and cross-plane orbit data it is possible to determine the multipole content within each half cell. This paper presents the algorithm behind the procedure, the data collected from the Fermilab Recycler Ring, and the final analysis result.

**MPPE084—Skew Coupling Analysis Using Closed Local 3-Bump Orbit Data**
*Ming-Jen Yang, Meiqin Xiao (Fermilab)*
This paper reports the result of our effort to identify sources of coupling in the Fermilab Recycler Ring. In addition to the conventional approach to coupling compensation using skew quadrupoles at strategic locations, the accuracy of the new BPM system is making it possible to identify the sources directly. By using local 3-bump orbit, to limit the contributing sources to be within one lattice cell, it is possible to identify rolled quadrupole fields, rolled trim dipoles, and rolled BPMs, based on their differing characteristics.

**MPPE085—The TBT Data from the New Recycler BPM System**
*Ming-Jen Yang (Fermilab)*
The new BPM system for the Fermilab Recycler Ring was commissioned over a year ago and its performance has been very impressive. With single turn orbit resolution around 20 micron it is providing unprecedented opportunity for many types of measurements. This write-up will focus only on the aspect of of TBT data analysis. It was also realized that, in addition to measuring the lattice function of the Recycler Ring, the TBT data can be used to obtain relative calibration between BPMs as well. Both types of analysis results will be presented here.

## Poster Session MPPP—Instabilities and Feedback
## Park Concourse, 13:50- 17:10

**MPPP001—A Vertical Multi-Bunch Feedback System for ANKA**
*Pawel Wesolowski, Ingrid Birkel, Erhard Huttel, Anke-Susanne Müller (FZK-ISS-ANKA), Francisco Pérez, Montserrat Pont (CELLS); FZK-ISS-ANKA)*
ANKA is a synchrotron light source with a top energy of 2.5 GeV. The maximum electron current at ANKA is presently limited by multi-bunch instabilities to 200 mA. In order to overcome this barrier a transverse analog multi-bunch feedback system is presently being commissioned. A BPM is used for beam detection. The vertical position signal passes a notch filter, is amplified, and subsequently fed to a vertical beam kicker. The present paper shows the layout of ANKA feedback system and discusses the first results of its operation.

**MPPP002—Stochastic Cooling Electrodes for a Wide Velocity Range in the CR**
*Fritz Nolden, Bernhard Franzke, Claudius Peschke (GSI), Fritz Caspers, Lars Thorndahl (CERN), Rolf Schuhmann (TEMF), Monika Christine Balk (TU Darmstadt)*
The CR storage ring is part of the FAIR project at GSI. It serves as a first stage of stochastic cooling for secondary rare isotopes at v/c=0.83 as well as for antiprotons at v/c=0.97. To avoid the installation of dedicated structures for each kind of beam, electrodes have been developed which are usable for both beams. They are based on slotline structures mounted perpendicular to the beam. They are shorted at the ends, and their signal is extracted by two striplines on the rear side, placed a quarter wavelength away from the open ends. The width of the structures can be adjusted to the initial betatron oscillation amplitudes. Their length is 24 mm, and the signal from many of these structures mounted in a row can be combined. The signal combination can be matched to the different beam velocities. The paper shows results from field calculations, prototype tests, and estimates of the signal combination efficiency. The beam impedance of the novel structures is compared with the superelectrodes applied in the former CERN AC and with the slow-wave structures currently installed in the FNAL Debuncher.

**MPPP003—Slow Global Orbit Feedback at the PLS**
*Heung-Sik Kang, Jinhyuk Choi, Myung-Hwan Chun, Ki Man Ha, Jung Yun Huang, Young-Chan Kim, Eun-Hee Lee, Tae-Yeon Lee, Wol Woo Lee, Jae-Hak Suh (PAL)*
A slow global orbit feedback was developed at PLS. The feedback uses the SVD (singular value decomposition) method and the MATLAB channel access to EPICS IOCs of BPMs and correctors. The orbit feedback uses 22 correctors in each plane which were improved to 20-bit capability for the vertical plane and 16-bit capability for the horizontal plane, and the feedback speed is 4 seconds. The orbit stability can be maintained below 1

mm in rms in both planes for one hour and 3 mm for a 12-hour operation. To reduce the orbit variation due to insertion device operation, a feedforward correction is incorporated for EPU (Elliptically Polarized Undulator) with the 10 Hz correction speed. It is believed that the long term orbit variation under feedback is mostly due to the false BPM readings coming from the Bergoz BPM's nonlinear intensity dependence and the vacuum chamber motion by synchrotron radiation thermal load change.

Ministry of Science and Technology, Korea.

**MPPP004—LHC Orbit Stablisation Tests at the SPS**
*Ralph Steinhagen, Jens Andersson, Lars K. Jensen, Rhodri Jones, Jorg Wenninger (CERN)*
The LHC presently build at CERN is the first proton collider that requires a continuous orbit control for safe and reliable machine operation. A realistic test of the orbit feedback system has been performed in 2004 using already present LHC instrumentation and infrastructure on a 270 GeV coasting beam in the SPS. It has been demonstrated that the chosen feedback architecture can stabilise the beam better than 10 micrometre and is essentially limited by the noise of the beam position monitor and the bandwidth of the corrector magnets. The achieved orbit stability is comparable to those found at modern light sources and gives enough operational margin with respect to the requirements of the LHC Cleaning System (70 micrometre). Estimates for the long term drifts and achievable stability will be presented based on the experimental results.

**MPPP005—A New Longitudinal Kicker for TLS**
*Wai-Keung Lau, Ping Jung Chou, Kuo-Tung Hsu (NSRRC), Cheng Wei Chen, Huan Yang Chen (NTHU), Micha Dehler (PSI)*
A new longitudinal kicker that is modified from the Swiss Light Source (SLS) design to fit into the TLS storage ring. It will be served as the actuator in the longitudinal multi-bunch feedback control loop. Beam coupling impedance has been calculated by Gdfidl with a PC cluster. Previous to the installation of this new kicker, bench measurement has been performed in the laboratory to characterize this new kicker. The experimental setups for bandwidth and coaxial wire measurement of longitudinal coupling impedance and their corresponding test results will be reported. As a cross check, bead-pull measurement has also been done to verify the beam coupling measurement by coaxial wire method at the kicker center frequency. Longitudinal field profile of the accelerating mode along the beam path has also been mapped. High order cavity modes of the kicker have also been observed and their effects on the beam are evaluated.

**MPPP006—Issues on Closed Orbit Feedback for NSLSII**
*Li-Hua Yu (BNL/NSLS)*
We discuss the preliminary calculation on the performance of closed orbit feedback system for NSLSII its relation to the requirement on BPM floor and girder stability power supply stability etc.

**MPPP007—Operating Performance of the Low Group Delay Woofer Channel in PEP-II**
*Dmitry Teytelman, John Fox, Daniel Van Winkle (SLAC)*
In PEP-II collider a dedicated low group-delay processing channel has been developed in order to provide high damping rates necessary to control the fast-growing longitudinal eigenmodes driven by the fundamental impedances of the RF cavities. A description of the digital processing channel operating at 9.81 MHz and capable of supporting finite impulse response (FIR) controllers with up to 32 taps will be presented. A prototype system has been successfully commissioned in the High-Energy Ring (HER) in May 2004. Operating experiences with the prototype and the newly determined limits on achievable longitudinal damping will be discussed and illustrated with experimental data.

Work supported by U.S. Department of Energy contract DE-AC02-76SF00515.

**MPPP008—Equilibrium Invariants of X-Y Coupled System**
*Juhao Wu, Alex Chao, Boaz Nash (SLAC)*
In accelerator systems, it is very common that the motion of the horizontal plane is coupled to that of the vertical plane. Such coupling will induce tune shifts and can cause instabilities. The damping and diffusion rates are also changed, which in turn will lead to a change in the equilibrium invariants. Following the perturbative approach which we developed for synchrobetatron coupling,* we study the x-y coupled case in this paper. Starting from the one turn map, we give explicit formulae for the tune shifts, damping and diffusion rates, and the equilibrium invariants. We focus on the cases where the system is near the integer or half integer, and sum or difference resonances where small coupling can cause a large change in the beam distribution.
*B. Nash, J. Wu, and A. Chao, work in progress.

Work is supported by the U.S. Department of Energy under contract DE-AC02-76SF00515.

**MPPP009—Linac Coherent Light Source Longitudinal Feedback Model**
*Juhao Wu, Paul Emma, Linda Hendrickson (SLAC)*
The Linac Coherent Light Source (LCLS) will be the world's first x-ray free-electron laser (FEL). To ensure the vitality of FEL lasing, it is critical to preserve the high quality of the electron beam during acceleration and compression. The peak current and final energy are very sensitive to system jitter. To minimize this sensitivity, a longitudinal feedback system on the bunch length and energy is required, together with other diagnostics and feedback systems (e.g., on transverse phase space). In this paper, we describe a simulation framework, which includes a realistic jitter model for the LCLS accelerator system, the RF acceleration, structure wakefield, and second order optics. Simulation results show that to meet the tight requirements set by the FEL, such a longitudinal feedback system is mandatory.

Work is supported by the US Department of Energy under contract DE-AC02-76SF00515.

**MPPP010—Feedback to Suppress Phase Noise at Aladdin**
*Robert Arthur Bosch, Ken Jacobs, Kevin J Kleman (UW-Madison/SRC)*
The performance of the Aladdin infrared beamline is adversely affected by a Robinson mode in which all bunches move in unison with a frequency of 3 kHz. To decrease these oscillations, feedback has been installed in the radiofrequency system to damp longitudinal motion of the bunch centroids. Simulations indicate that at frequencies around 3 kHz, the phase noise generated by Robinson modes may be reduced 20 dB by feedback with a damping time of 0.3 ms. This agrees with the measured performance of feedback circuitry. Since the feedback greatly improves operation of the infrared beamline, it is now incorporated into the standard operation of Aladdin.

**MPPP011—Fermilab Recycler Damper Requirements and Initial Design**
*Martin Hu, James L. Crisp (Fermilab)*
The design of transverse dampers for the Fermilab Recycler storage ring is described. An observed instability and analysis of subsequent measurements are used to identify the requirements. The digital approach being mplemented is presented.

**MPPP012—First-Principles Simulation and Comparison with Beam Tests for Transverse Instabilities and Damper Performance in the Fermilab Main Injector**
*Dennis Nicklaus, G. William Foster, Vladimir Kashikhin (Fermilab)*
An end-to-end performance calculation and comparison with beam tests was performed for the bunch-by-bunch digital transverse damper in the Fermilab Main Injector. Time dependent magnetic wakefields responsible for "Resistive Wall" transverse instabilities in the Main Injector were calculated with OPERA-2D using the actual beam pipe and dipole magnet lamination geometry. The leading order dipole component was parameterized and used as input to a bunch-by-bunch simulation which included the filling pattern and injection errors experienced in high-intensity operation of the Main Injector. The instability growth times, and the spreading of the disturbance due to newly mis-injected batches was compared between simulations and beam data collected by the damper system. Further simulation models the effects of the damper system on the beam.

**MPPP013—Stabilizing Low Frequency Beam Motion in the Tevatron**
*Vahid Houston Ranjbar (Fermilab)*
A feed back orbit stabilization system has been developed using a set of BPMS and existing Tevatron corrector magnets to stabilize beam motion up to 50 microns below 25 Hz. The construction of this system is described and the stability limits and magnitude of beam motion reduction is explored.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**MPPP014—A Digital Mode 1 Damper for the Fermilab Main Injector**
*Philip Adamson (Fermilab; UCL), Joseph Dey (Fermilab)*
We observe a mode1 longitudinal instability in the Fermilab Main Injector during high-intensity studies for NuMI. The wideband longitudinal damper cavities in the MI do not have enough power to damp this instability. We describe the implementation and performance of a mode 1 damper system using the existing digital damper hardware to provide a feedback signal to the main RF.

**MPPP015—Operational Performance of a Bunch by Bunch Digital Damper in the Fermilab Main Injector**
*Philip Adamson (Fermilab; UCL), Bill Ashmanskas, G. William Foster, Sten Hansen, Alberto Marchionni, Dennis Nicklaus, Alexei Semenov, David Wildman (Fermilab), Hyejoo Kang (Stanford University)*
We have implemented a transverse and longitudinal bunch by bunch digital damper system in the Fermilab Main Injector, using a single digital board for all 3 coordinates. The system has been commissioned over the last year, and is now operational in all MI cycles, damping beam bunched at both 53MHz and 2.5MHz. We describe the performance of this system both for collider operations and high-intensity running for the NuMI project.

**MPPP016—Adaptive Feed Forward Beam Loading Compensation Experience at the Spallation Neutron Source Linac**
*Kay-Uwe Kasemir, Mark Champion, Mark Crofford, Hengjie Ma (ORNL/SNS)*
When initial beam studies at the Spallation Neutron Source (SNS) indicated a need for better compensation of the effects of beam loading, a succession of rapid-prototyping and experimentation lead to the development of a simple yet successful adaptive feed forward technique within a few weeks. We describe the process and first results.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**MPPP017—User Operation and Upgrades of the Fast Orbit Feedback at the SLS**
*Michael Böge, Boris Keil, Andreas Lüdeke, Thomas Schilcher (PSI)*
A report on the performance of the fast orbit feedback (FOFB) in its 2nd year of user operation is given. Photon beam position monitors (PBPM) have been included by means of a slow feedback which changes the reference settings of the FOFB. Users are permitted to change the PBPM references within certain limits while the feedback is running. A fast synchronous readout of the PBPMs allows their integration into the FOFB loop. The FOFB has been extended by an additional BPM in order to satisfy the requirements of the upcoming FEMTO project.

**MPPP018—Correction of Insertion Device Induced Orbit Distortions at the SLS**
*Michael Böge, Jan Chrin, Boris Keil, Jurai Krempasky, Volker Schlott, Thomas Schmidt, Andreas Streun (PSI)*
Corrections of insertion device (ID) induced orbit distortions are performed by means of feed forward schemes down to the micron level at the corresponding photon beam position monitors (PBPMs). The remaining orbit fluctuations are suppressed by the PBPM feedback which is an integral part of the fast orbit feedback system. As a result, sub-micron stability at the PBMs is achieved while the ID settings are varied.

**MPPP019—Beam Orbit Diagnostics and Control in CANDLE Storage Ring**
*Gayane A. Amatuni, Yuri Lawrent Martirosyan, Vasili Mkrtich Tsakanov, Ashot Vardanyan (CANDLE)*
Stability requirements for the CANDLE light source are the consequence of a small electron beam size and a tolerable photon beam parameters. In a real machine, the components of the storage ring have static and dynamic imperfections, which cause disturbance of the electron beam and consequently photon beams parameters. In the present paper the basic approaches to the beam diagnostics, control and correction issues for the CANDLE facility are given. The algorithms, electronics and processing hardware are described.

**MPPP020—RF Phase Modulation at the LNLS Electron Storage Ring**
*Natalia Prado Abreu, Ruy H.A. Farias, Pedro Tavares (LNLS)*
In the Brazilian Electron Storage Ring, we observed that modulating the phase of accelerating fields at twice the synchrotron frequency suppressed remarkably well a longitudinal coupled-bunch mode of the beam driven by one of the RF cavities. We present results of a set of systematic measurements, in single and multi-bunch mode, aimed at characterizing the

effects of the modulation on the beam. We also compare those experiments with the results of tracking simulations.

FAPESP

**MPPP021—Evolution of the Machine Impedance following the ESRF Upgrade to Low-Gap NEG Coated Aluminium Chambers**
*Thomas Friedrich Günzel, Laurent Farvacque, Thomas Perron, Jean-Luc Revol (ESRF)*
The installation of 5 meter-long, 8 mm vertical aperture insertion device (ID) aluminum chambers coated in house with non evaporable getter material is progressing at a rate of one chamber per shutdown. The evolution of the impedance with associated consequences on instability thresholds, following the installation of a number of low aperture insertion device chambers will be reported. In particular the impedance measurement using the local bump method allowed the identification and the replacement of the chambers of highest impedance. Correlation with the evolution of the single bunch instability thresholds and the theoretical prediction will be discussed. It could be observed that change in vertical aperture has a sensible effect on the single bunch horizontal threshold.

**MPPP022—The Impedance of Selected Components of the Synchrotron Light Source Petra III**
*Rainer Wanzenberg, Klaus Balewski (DESY)*
At DESY it is planned to convert the PETRA ring into a synchrotron radiation facility, called PETRA III, in 2007. Since the impedance of the machine determines its performance with respect to coupled and single bunch instabilities it is important to know the wakefields and higher order modes (HOMs) of the different components of the vacuum system. Numerical calculations of wakefields and HOMs are presented for several components of PETRA III, including the rf-cavities, shielded bellows and tapered vacuum chamber transitions. The impedance of these components is presented in terms of the loss and kick parameters.

**MPPP023—Numerical Calculation of Coupling Impedances for Kicker Modules**
*Burkhard Doliwa, Herbert De Gersem, Thomas Weiland (TEMF)*
Maintaining the impedance budget is an important task in the planning of any new accelerator facility. While estimates from analytical computations and measurements play a central role in doing so, numerical calculations have become an important alternative today. On the basis of Finite Integration Theory, we have developed a simulation tool for the direct computation of coupling impedances in the frequency domain. After discussing the special features of our code as compared to commercial programs, we present our results for cases where coupling impedances have been obtained from another source, e.g. experiment. In particular, we consider the longitudinal and transverse impedances of the SNS extraction kicker and present investigations related to the injection/extraction system of the future heavy-ion synchrotron at GSI.

Work supported in part by DFG under contract GraKo 410 and GSI, Darmstadt.

**MPPP024—Recent Observations on a Horizontal Instability in the DAFNE Positron Ring**
*Alessandro Drago, Mikhail Zobov (INFN/LNF), Dmitry Teytelman (SLAC)*
A strong horizontal instability limits the maximum positron current storable in the DAFNE Phi-Factory. A powerful feedback system makes it possible to store and collide up to 1250 mA of positron current in 105 bunches. Nevertheless, a much higher current (> 2.4A) has been successfully stored in the twin electron ring. Measurements have been carried out to understand the positron current limit and to characterize the behavior of the horizontal instability at high current with different bunch patterns. Grow/damp turn-by-turn data obtained by turning off the horizontal feedback have been acquired and analyzed. Spectral analysis and grow rates of the instability are shown. In particular, the -1 mode has strong evidence and fast grow rate. Its grow rate behavior is analyzed at different beam currents and bunch patterns.

**MPPP025—The Impedance of the Ceramic Beam Pipe in J-PARC**
*Yoshihiro Shobuda (JAERI/J-PARC), Yong Ho Chin, Kazuhito Ohmi, Takeshi Toyama (KEK)*
The ceramic chamber is adopted at the RCS (rapid cycling synchrotron) in J-PARC. The copper stripes are on the outer surface of the chamber in order to shield the electro-magnetic field produced by the beam. The inner surface of the chamber is coated by TiN to suppress the secondary electron emission. In this paper, we calculate the strength of electro-magnetic field produced by the beam and evaluate the impedance of this ceramic chamber.

**MPPP026—Development of Longitudinal Coupling Impedance Measurement Platform for BEPCII**
*Gang Huang, Huang Wenhui, Shuxin Zheng (Tsinghua University), Jiuqing Wang, Demin Zhou (IHEP Beijing)*
A coaxial line impedance measurement platform is developed for BEPCII. A pair of gradual change impedance matching section is designed and fabricated by numerical control milling machine. The special designed RF connector is applied to strengthen the inner conductor. The algorithm of TRL calibration is applied in the system to avoid the usage of a reference pipe for each device under test. The measurement is accomplished by a VNA under the control of the software written in LabView.

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**MPPP027—Suppression of the Longitudinal Coupled-Bunch Instabilities by the RF Phase Modulation in the Pohang Light Source**
*Ilmoon Hwang, Moohyun Yoon (POSTECH), Yeung-Jin Han, Eun-San Kim, Jaeseok Yang (PAL)*
In the 2.5 GeV Pohang Light Source, we have investigated the suppression of the longitudinal coupled instabilities (CBI) caused by higher order modes (HOMs) of RF cavities. At higher beam current than 170 mA the 758 MHz or 1300 MHz HOMs occurred and the beam could be unstable. The longitudinal CBI could be suppressed by modulating the phase of an RF accelerating voltage at a frequency of 2 times the synchrotron oscillation frequency and by adjusting the water temperatures of the RF cavities. The longitudinal beam oscillations measured by streak camera in synchro-scan mode were shown. The experiment results were compared with the macro particle tracking simulation.

**MPPP028—The Code MBIM1 for the Calculation of the Multibunch Beams Coherent Oscillations Stability (in Approach of Short Bunches)**
*Natalya Mityanina (BINP SB RAS)*
The code MBIM1 for the calculation of the coherent oscillations stability for multibunch beams in storage rings is presented. The multibunch beams with arbitrary charges of bunches are considered, including counterrotating bunches (in approach of

short bunches in comparison with minimal wavelength of considered environment RF spectrum), with the account of beams coupling with the environment (i.e. RF cavities or/and smooth vacuum chamber with walls of finite conductivity). The code uses the approach of small shifts of coherent frequencies, when different multipole types of synchrotron oscillations can be treated as independent from each other.

**MPPP029—The Code MBIM2 for the Calculation of the Arbitrary Multibunch Beams Longitudinal Coherent Oscillations Stability (in the Case of Long Bunches)**
*Natalya Mityanina (BINP SB RAS)*
The presented code is an advanced version of the code MBIM1 also presented at this conference and dealing with short bunches. The code MBIM2 analyses the stability of longitudinal coherent motion for arbitrary multibunch beams in storage rings without limitations on the bunch length or RF cavities wavelength, which is especially important for higher types of multipole synchrotron oscillations. The code implies also the possibility to consider coupling between different types of multipole synchrotron oscillations and Landau damping. In considered approach, the problem reduces to the eigenvalue problem for the linear algebraic equation system. The order of this system is equal to the number of bunches times number of multipole types times approximation order wich appears to be small (a few units) in most cases.

**MPPP030—Analytic Evaluation of the Series over Azimuthal Harmonics at the Analysis of the Stability of Bunched Beams Coherent Oscillations**
*Natalya Mityanina (BINP SB RAS)*
At the analysis of the stability of coherent motion of multibunch beams including counterrotating beams) one should deal with expressions analogous to the effective impedance - the serieses over harmonics of revolution frequency of the RF structure impedance at the side frequencies to these harmonics, with certain factors depending on the harmonic number, such as the bunch line density spectrum, the phase factor and the factor describing the order of multipole synchrotron oscillations. In this paper, we present the method for analytic summation of these serieses for resonant impedance, which seems not to be made before in the common case including all mentioned factors. Comparison of obtained expressions with formulae used in previous papers shows the limits of validity of simpler approaches. The obtained expressions are used in the computer codes MBIM1 and MBIM2 presented at this conference, which calculate coherent oscillations stability for arbitrary multibunch beams.

**MPPP031—The CERN-SPS Experiment on Microwave Transmission Through the Beam Pipe**
*Tom Kroyer, Fritz Caspers (CERN)*
In the CERN SPS microwave transmission measurements through beampipe sections with a length of 30 m and 7 m meter respectively have been carried out in the frequency range 2-4 GHz since spring 2003. Here we report on new results obtained with improved measurement techniques during the 2004 run. Observation techniques include a fast real time scope, spectrum analyser IF and video output signal registration and baseband signal observation using a PC soundcard. The unexpected beam induced amplitude modulation has been confirmed on all kinds of available beams including single bunches. It was found that there is a correlation between the amount of beam induced signal attenuation and the beam losses registered by external scintillators. Potential theoretical models are discussed.

Ministry for Education, Science and Culture, Austria.

**MPPP032—Bunch Lengthening and Threshold for Turbulence**
*Albert Hofmann (CERN)*
A Bunch circulating in a storage ring in the presence of an inductive impedance undergoes some length change due to the potential well. This effect is particularly simple if the particles have an elliptic energy distribution. In this case the longitudinal shape of the bunch is not changed but only scaled in length. This is extended to include a resistive impedance at low frequencies. Here, the inductive impedance has a linear and the resistive one a quadratic increase with frequency giving induced voltages proportional to the first and second derivative of the bunch current. The resulting bunch form is no longer symmetric but can still be expressed by an analytic function containing powers and exponentials. It indicates a maximum current beyond which particles are no longer contained. This threshold for turbulence is expressed by an equation of the same form as the one obtained from the Boussard criterion. The choice of a low frequency impedance and an elliptic energy distribution makes this approach applicable to long bunches and mainly to protons. On the other hand its analytic treatment illustrates the physics relevant for turbulence.

**MPPP033—Beam Transfer Functions and Beam Stabilisation in a Double RF System**
*Elena Shaposhnikova, Thomas Bohl, Trevor Paul Linnecar (CERN)*
The high intensity proton beam for LHC accelerated in the CERN SPS is stabilised against coupled-bunch instabilities by a 4th harmonic RF system in bunch-shortening mode. Bunch-lengthening mode, which could also be useful to reduce peak line density and alleviate problems from e-cloud and kicker heating does not give desirable results for beam stability. In this paper an analysis of the limitations of these two different modes of operation is presented together with measurements of the Beam Transfer Function for the double RF system. As predicted by theory, for sufficiently long bunches with the same noise excitation, the measured amplitude of the beam response in bunch-lengthening mode is an order of magnitude higher than that for bunch-shortening mode or for a single RF system.

**MPPP034—Collective Effects in the TLS Storage Ring After the Installation of Superconducting RF Cavity**
*Ping Jung Chou, Jenny Chen, Kuo-Tung Hsu, Tzong-Shyan Ueng, Chaoen Wang, Min-Huey Wang (NSRRC)*
A superconducting rf cavity designed by Cornell University was installed in the storage ring at Taiwan Light Source in December of 2004. The purpose of rf system upgrade is to achieve a stored beam current of 400 mA without collective instabilities caused by high-order-modes of rf cavities. Beam measurements related to collective effects are performed. Results are compared with those measured prior to the rf system upgrade. Theoretical studies on collective effects after the rf upgrade are also presented.

**MPPP035—Investigation of APS PAR Vertical Beam Instability**
*Chihyuan Yao, Yong-Chul Chae, Nicholas Sereno, Bingxin Yang (ANL)*
The Advanced Photon Source (APS) particle accumulator ring (PAR) is a 325-MeV storage ring that collects and compresses linac pulse trains into a single bunch for booster injection. A vertical beam instability has been observed when only a single linac bunch is injected and the total beam charge is from 0.15 to 0.7 nC. The instability starts about 80 ms after the injection, lasts about 160 ms, and is highly reproducible. We performed spectral measurement and time-resolved imaging with both a gated-

intensified camera and a streak camera in order to characterize this instability. Initial analysis of the data indicates that the instability is due to ion trapping. A stable lattice was established as result of the investigation. This report summarizes the experimental results and gives some preliminary analysis.

This work is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**MPPP036—Collective Effects for NSLS-II**
*Alexei Blednykh, Samuel Krinsky, Boris Podobedov, James Rose, Nathan Towne, Jiunn-Ming Wang (BNL/NSLS)*
NSLS-II is a 3 GeV ultra high brightness storage ring that is planned to succeed the present NSLS rings at Brookhaven. NSLS-II will provide hard X-ray photons from ~20 mini-gap undulators that may significantly contribute to the machine impedance. This, in combination with very high beam phase space density, and low momentum compaction drives a number of coherent instabilities. This paper reviews the most important collective effects for NSLS-II and their implications on the machine design.

**MPPP037—An Impedance Study of NSLS-II Storage Ring**
*Alexei Blednykh (BNL/NSLS)*
In this paper the results of GdfidL calculations of the impedances of NSLS-II ring components such as MGU taper, BPM, absorber and bellows are presented.

**MPPP038—Harmonic Cavity Performance for NSLS-II**
*Alexei Blednykh, Samuel Krinsky, Boris Podobedov, James Rose, Nathan Towne, Jiunn-Ming Wang (BNL/NSLS)*
NSLS-II is a 3 GeV ultra-high brightness storage ring that is planned to succeed the present NSLS rings at Brookhaven. Ultra-low emittance bunch combined with a short bunch length results in the Touschek lifetime of only a few hours, which strongly advocates including harmonic RF in the baseline design of NSLS-II. This paper describes the required harmonic RF parameters, trade-offs between the possible choices and the expected system performance, including the implications on lifetime and instabilities.

**MPPP039—Impedance and Wakefield of Finite Length Resistor**
*Samuel Krinsky, Boris Podobedov (BNL/NSLS), Robert Gluckstern (University of Maryland)*
We determine the impedance of a cylindrical metal tube (resistor) of radius a and length g, attached at each end to perfect conductors of semi-infinite length. Our main interest is in the behavior of the impedance at high frequency (k>>1/a). In the equilibrium regime, ka^2<>g, we derive an analytic expression for the impedance and compute the short-range wakefield.

Department of Energy contract DE-AC02-98CH10886.

**MPPP040—Transverse Coupled Mode Instability with Landau Bunch Lengthening Cavity**
*Samuel Krinsky (BNL/NSLS)*
In the case of a low emittance storage ring, it may be beneficial to use a higher-harmonic, bunch-lengthening (Landau) cavity to increase the Touschek lifetime. Use of a Landau cavity affects the transverse coupled mode instability in two ways: (1) it lengthens the bunch thus reducing the peak current; (2) it reduces the (average) synchrotron tune. The first of these effects promotes transverse stability and the second transverse instability. Using time-domain tracking, we discuss the transverse stability of a single bunch in a ring with a Landau cavity.

Department of Energy contract DE-AC02-98CH10886.

**MPPP041—Transverse Instability of a Rectangular Bunch**
*Valeri Balbekov (Fermilab)*
Some results of theoretical investigations of transverse dipole instability of a rectangular bunch are reported in this paper. Such a form is characteristic of the bunch in a rectangular potential wall which is created by a barrier-shaped acceleration field. Similar regime is a major one for accumulating and cooling of antiproton beams in the Fermilab Recycler Ring. In this case, the known theory of transverse instability of a bunched beam is inapplicable directly both because of "unusual" form of phase trajectories and strong dependence of synchrotron frequency on energy. A series of equations, adequately describing the instability is derived in the paper. Exact analytical solution is obtained for space charge dominated impedance, and some approximate methods are proposed for arbitrary impedance. The theory is applied to the Fermilab Recycler Ring including a numerical simulation.

Work supported by the U.S. Department of Energy under contract No. DE-AC02-76CH03000.

**MPPP042—Landau Damping of the Weak Head-Tail Instability at Tevatron**
*Petr Mikhailovich Ivanov, Yuri Alexahin, Jerry Annala, Valeri Lebedev, Vladimir Shiltsev (Fermilab)*
Landau damping of the head-tail modes in Tevatron beam with the help of octupole-generated betatron tune spreads permits to reduce chromaticity from 15-20 units to zero thus significantly improving the beam lifetime. The octupole strengths have been experimentally optimized at different stages of the Tevatron operation, from proton injection to collision. Predictions of the analytical Landau damping model are compared with the experimental results.

**MPPP043—Betatron Tune Spread Generation and Differential Chromaticity Control by Octupole at Tevatron**
*Petr Mikhailovich Ivanov, Yuri Alexahin, Jerry Annala, Valeri Lebedev (Fermilab)*
Application of octupoles for Landau damping of the unstable head-tail modes requires careful consideration at their combination into separate families to insure maximum effectiveness and avoid degradation of the dynamic aperture due to the non-linear magnetic fields. Existing octupolar magnets around the machine have been arranged into four functional families with individual power supplies. Two of these families generate betatron tune spreads in the vertical and horizontal planes whereas the other two control the differential chromaticity between the proton and antiproton helices. The calculated effect on tunes and chromaticity is compared with direct measurements. Analytical formulas for betatron tune spectral density functions are presented.

**MPPP044—Impedance Calculation for Ferrite Inserts**
*Shyh-Yuan Lee, Sara Breitzmann (IUCF), King Yuen Ng (Fermilab)*
Passive ferrite inserts were used to compensate the space charge impedance in high intensity space charge dominated accelerators. We study the narrowband longitudinal impedance of these ferrite inserts. We find that the shunt impedance and the quality factor for ferrite inserts are inversely proportional to the imaginary part of the permeability of ferrite materials. We also provide a receipe for truly passive space charge impedance

compensation and, at the same time, avoiding the narrowband microwave instabilities.

NSF PHY-0244793; DOE DE-FG02-92ER40747.

**MPPP045—Two Dimensional Aspects of the Regenerative BBU**
*Eduard Pozdeyev (Jefferson Lab)*
In this paper, I present the formula, describing a threshold of the regenerative multi-pass Beam Breakup (BBU) for a single dipole higher order mode with arbitrary polarization in a two-pass accelerator with a general-form, 4x4 recirculation matrix. To illustrate specifics of the BBU in two dimensions, the formula is used to calculate the threshold for the reflecting and rotating optics of the recirculator that can lead to higher threshold currents. Then, I present a mathematical relation between transfer matrices between cavities of the accelerating structure and recirculation matrices for each cavity, which must be satisfied in order to successfully suppress the BBU by reflection or rotation in several cavities. At the end of the paper, a fast, two-dimensional BBU code developed at the Jefferson Lab is described.

Work supported by DOE Contract DE-AC05-84ER40150.

**MPPP046—Transient Resistive Wall Wake for Very Short Bunches**
*Gennady Stupakov (SLAC)*
The catch up distance for the resistive wall wake in a round pipe is approximately equal to the square of the pipe radius divided by the bunch length. The standard formulae for this wake are applicable at distances much larger than the catch up distance. For extremely short bunches, considered recently by Zholents and Fawley in application for SASE (PRL, vol. 92, p. 224801), this formation length can be tens of meters. In this paper, we calculate the resistive wall wake for such a beam at distances compared with the catch up distance assuming a constant wall conductivity. We also discuss how the derivation can be modified to include the frequency dependence of the conductivity characteristic for very short wavelength.

Work supported by U.S. Department of Energy, contract DE-AC03-76SF00515.

**MPPP047—Study of the Longitudinal Beam Instability at Duke Storage Ring**
*Ping Wang, Jingyi Li, Stepan Mikhailov, Victor Popov, Y. K. Wu (DU/FEL), Grigory Yakovlevich Kurkin (BINP SB RAS)*
The Duke storage ring is a 1Gev electron ring, which is designed for driving UV_VUV free electron lasers. It also provides energy variable high intensive gammarays by Campton back scattering. It requires one or two bunches of high electron peak current being stored to generate powerful laser source and intensive gamma rays. At Duke storage ring, the beam current is limited mainly by logitudinal and transverse beam instabilities. The longitudinal vaccum chamber impedance has been measured with stored beam. Two longitudinal feedback loops has been added into operation. A transverse coupled-bunch feedback system is under construction.

Work supported by the US department of Energy under contract No. DE-FG02-01ER41175.

**MPPP048—Improving Dynamic Aperture of the Duke Storage Ring with OK-5 FEL**
*Y. K. Wu, Jingyi Li, Stepan Mikhailov (DU/FEL)*
The Duke FEL lab operates a unique UV/VUV storage ring FEL and an FEL driven nearly monochromatic, high intensity Compton gamma-ray light source. The next generation UV/VUV FEL and gamma-ray sources will be driven by a new OK-5 FEL system to take advantage of the high performance of the electron beam in the storage ring. The OK-5 FEL consists of four four-meter long electromagnetic wigglers with variable polarizations. The impact of FEL wigglers on the beam dynamics have been studied in detail via extensive particle tracking. A large momentum dynamic aperture is critical in realizing a long beam lifetime for the FEL operation and for the high flux gamma operation in a no electron loss mode. By choosing proper operational parameters of the storage ring, significant improvements of the momentum dynamic aperture have been obtained in simulation. Using this technique, we have experimentally demonstrated improved the momentum dynamic aperture with the existing OK-4 FEL system.

This work is supported by the U.S. AFOSR MFEL grant F49620-001-0370 and by U.S. DOE grant DE-FG05-91ER40665.

**MPPP049—Observations and Measurements of Anomalous Hollow Electron Beams in a Storage Ring**
*Y. K. Wu, Jingyi Li (DU/FEL ), Juhao Wu (SLAC)*
This paper reports first observations and measurements of anomalous hollow electron beams in a storage ring. In a lattice with a negative chromaticity, hollow electron beams consisting of a solid core beam inside and a large ring beam outside have been created and studied in the Duke storage ring. We report the detailed measurements of the hollow beam phenomenon, including its distinct image pattern, spectrum signature, and its evolution with time. By capturing the post-instability bursting beam, the hollow beam is a unique model system for studying the transverse instabilities, in particular, the interplay of the wake field and the lattice nonlinearity. In addition, the hollow beam can be used as a powerful tool to study the linear and nonlinear particle dynamics in the storage ring.

This work is supported by the U.S. AFOSR MFEL grant F49620-001-0370 and by U.S. DOE grant DE-FG05-91ER40665 (YW and JL). This work is also supported by U.S. DOE contract DE-AC02-76SF00515 (JW).

**MPPP050—Longitudinal Instabilities in Duke FEL Storage Ring**
*Y. K. Wu, Jingyi Li, Stepan Mikhailov, Victor Popov, Ping Wang (DU/FEL), Grigory Yakovlevich Kurkin (BINP SB RAS)*
The Duke storage ring is a dedicated UV/VUV FEL storage ring with a wide operational energy range from 0.27 to 1.2 GeV. A linac injection is employed to inject 270 MeV electrons into the storage ring; energy ramping is then performed for user operation. Operating in symmetric two-, four-, and eight- bunch modes, the FEL can be used as a driver for a high intensity Compton gamma ray source. The performance of the FEL as well as the gamma ray source critically depends on the longitudinal performance of the electron beam. With a newly installed HOM-damped cavity, the single bunch beam is very stable longitudinally. In contrast, the two-bunch beam is very unstable at lower energies. This longitudinal coupled-bunch instability eventually limits the maximum two-bunch current. Longitudinal beam dynamics have been studied for different bunch patterns and beam energies. Longitudinal impedance has been measured using the streak camera and via the measurement of the synchronous phase. By deliberately driving the electron beam unstable longitudinally using the amplitude feedback loop of the RF cavity, we successfully improved the two- and four-bunch

current threshold. Studies of this interesting phenomenon will also be reported in this paper.

This work is supported by the U.S. AFOSR MFEL grant F49620-001-0370 and by U.S. DoE grant DE-FG05-91ER40665.

**MPPP051—Transverse Impedance of Two-Layer Tube**
*Michael Ivanyan, Andranik Vasili Tsakanian (CANDLE)*
The exact analytical expressions for the multipole longitudinaland transverse impedances of two-layer tube with finite wall thickness areobtained. The numerical examples for the impedances of the vacuum chamberwith laminated walls are given.

**MPPP052—Longitudinal Impedance Measurements of the Components for the BEPCII**
*Demin Zhou, Jiuqing Wang (IHEP Beijing)*
A longitudinal impedance measurement system was established for the BEPCII. The measurements, done in the frequency domain, are based on the coaxial wire method using HP Agilent 8720ES network analyzer. The applications of the TRL calibration technique and absorbers were investigated to find a good approach for impedance measurements. The impedance, larger than 20 Ohm and below 6 GHz, can be measured using the TRL calibration technique in the experiment. And better measurement results were got using the reference lines with the absorbers. So, this system satisfies the requirements of the BEPCII. This paper gives a review on this impedance measurements system for the BEPCII. The measurements results show that there are no serious impedance problems for BEPCII bellows and BPM, agreeing well with the numerical simulations. More improvements on this system are in progress.

Work supported by the National Natural Science Foundation of China (NSFC) under contract No.10375076.

## Poster Session MPPT–Magnets
## Meeting Room 200 A-C, 13:50- 17:10

**MPPT001—Research and Manufacture of the Prototype Magnets for BEPCII**
*Caitu Shi, Zan Cao, Wan Chen, Li Li, Ganlin Ni, XianJing Sun, Yaolin Sun, Zhaosheng Yin (IHEP Beijing)*
Beijing Electron Positron Collider (BEPC) will be upgraded to a double ring machine in the near future. A new storage ring will be added in the existing BEPC tunnel. The conventional magnets for the new ring contain dipoles, quadrupoles, sextupoles and correctors. Due to the limited space of the existing BEPC tunnel and the antechamber is adopted in BEPCII to decrease PE instability. It is trouble to design and fabricate for the conventionalnormal magnets. The trial produce of three kind magnet prototypes be described in this paper. Also given are the results of the magnetic field measurement for the prototypes.

**MPPT002—Design and Experiment of the BEPCII IR Conventional Dual Aperture Quadrupole**
*Zhaosheng Yin, Yingzhi Wu, Jiafei Zhang (IHEP Beijing)*
The quadrupole magnet Q1a is one of the final horizontal focus quadrupoles for the Beijing Electron-Positron Collider Interaction Region (BEPCII IR). The BEPCII IR lattice design specification calls for a very high field quality for the quadrupole magnet. The Q1a is a conventional dual apertures quadrupole magnet. The required integral quadrupole strengths in two apertures are the same. This magnet is a septum quadrupole with high current density and solid core. 2D pole contour optimization and pole end chamfers are used to minimize harmonic error. The design methods, experiment results and magnet performances are described in this paper.

**MPPT003—Resolutions of the Problems Occurred in SPEAR3 Magnet Production**
*Nanyang Li, Richard Merrill Boyce, Dave Ernst (SLAC), Fuhe Huang, Huamin Qu (IHEP Beijing)*
Few problems occurred during the SPEAR3 magnets production at IHEP, China. It was very hard to find resolution from existing knowledge of those problems. It was possible that similar problems might happen in building accelerator magnet in other institutes before, but they were not addressed in public papers. Those problems were discussed and solved by engineers from both SSRL and IHEP after conducting certain experiments. Traditionally, the magnet design and measurement data have been always well documented and addressed in the papers, but the production experiences have not been recorded adequately. It is the goal of this paper to record the problems and their resolutions during SPEAR3 magnet production, which will certainly benefit future magnet projects.

DOE National Institutes of Health.

**MPPT004—End Chamfer Study and Field Measurements of the BEPCII Dipoles**
*Wan Chen, Zan Cao, Caitu Shi, Zhaosheng Yin (IHEP Beijing)*
The new BEPCII double ring will be added in the existing BEPC tunnel. There are more than 40 bending magnets named 67B in the new ring. The 67B is conventional 'C'-type dipole magnet. The magnetic filed properties are dominated by the magnet end effect. The end effect have been studied and minimized by a proper end chamfer. Magnetic measurements of the prototype and productions were carried out using long coil. The developing process of the pole end chamfers and the measurement results of the 67B prototype and batch productions are described in the paper.

**MPPT005—A New Slotted-Pipe Kicker Magnet for BEPCII Storage Ring**
*Wen Kang, Yaodou Hao (IHEP Beijing)*
The requirements of BEPCII injecting kicker magnets are so severe. In the range of Äx=±20mm, the field uniformity is required to be better than ±1% in the central plane, ±2% in the y=5mm plane and ±5% in y=10mm plane, while the effective beam impedance of each kicker magnet must be lower than 0.025Ù. For the large aperture of vacuum chamber and the fast risetime of kicker magnetic field, the two schemes of low impedance kicker magnets used in other accelerator labs in the world are not adaptive to the BEPCII storage ring. A new slotted-pipe kicker magnet, which uses the ceramic bars with metal coating films as the image current conducting paths, proposed in this article solves the difficult problems of BEPCII kicker magnet design. And the successful construction of a prototype has demonstrated that the new scheme of kicker magnets is viable and the structure design of the kicker magnet is reasonable.

**MPPT006—The Extraction Kicker System of the RCS in J-PARC**
*Junichiro Kamiya, Tomohiro Takayanagi (JAERI/J-PARC), Tadamichi Kawakubo (KEK)*

The kicker magnet plays a role of extracting the proton beam which is accelerated up to 3GeV by the Rapid Cycling Synchrotron in J-PARC. The kicker system is required the fast rise time of the magnetic field because the interval between the beam bunches is only 349nsec. The kicker magnet is the distributed type. The findings in our measurements revealed that the delay time in the magnet is about 180nsec. The power supply has the pulse forming network system, which consists of co-axial cables whose characteristic impedance is 10 ohm. We accomplished the current rise time of 80 nsec quickness. Therefore we had a good prospect of the fast rise time of the magnetic field. The characteristic impedance of the kicker magnet was also measured. The value was close to 10 ohm. There will be no large mismatching between the power supply and the magnet. This pulse magnet is installed in the vacuum chamber to prevent the electric discharge. Outgas from the components has the adverse effects the vacuum in the accelerator. We have reduced the outgas rate from the ferrite core and aluminum plates which construct the magnet by backing them at appropriate temperature.

**MPPT007—Design of the Pulse Bending Magnets for the Injection System of the 3-GeV RCS in J-PARC**

*Tomohiro Takayanagi, Yoshiro Irie, Junichiro Kamiya (JAERI/J-PARC), Tadamichi Kawakubo, Izumi Sakai (KEK, Ibaraki)*

The pulse bending magnets for the injection system of the 3-GeV RCS in J-PARC has been designed using a 3D magnetic analysis code. The injection system consists of the pulse bending magnets for the injection bump orbit, which are four horizontal bending magnets (shift bump), four horizontal painting magnets (h-paint bump), and two vertical painting magnets (v-paint bump). The injection beam energy and the extraction beam power are 400 MeV and 1 MW at 25-Hz repetition rate, respectively. The beam orbit area with a full acceptance beam of the injection beam, painting beam and the circulating beam at the shift bump points is a 400 mm width and a 250 mm height.The shift bump has accomplished 1.0% good field region at 0.22 T.

**MPPT009—HTS Power Leads for the BTeV Interaction Region**

*Sandor Feher, Ruben H. Carcagno, Darryl Orris, Yuriy Pischalnikov, Roger Rabehl, C. Sylvester, Mike Tartaglia, John Tompkins (Fermilab)*

A new Interaction Region for the BTEV experiment is planned to be built soon at Fermilab. This IR will require new superconducting quadrupole magnets and many additional power circuits for their operation. The new “low beta” quadupole magnet design is based upon the Fermilab LHC quadrupole design, and will operate at 9.56 kA in 4.5 K liquid helium. The use of conventional power leads for these circuits would require substantially more helium for cooling than is available from the cryogenic plant, which is already operating close to its limit. To decrease the heat load and helium cooling demands, the use of HTS power leads is necessary. Fermilab is in the process of procuring HTS leads for this new interaction region. Several 6 kA HTS leads produced by American Superconductor Corporation have been tested at over-current conditions. Based on the test results, design requirements are being developed for procuring the HTS current leads. This paper summarizes the test results and describes the design requirements for the 9.65 kA HTS power leads.

**MPPT010—A New Correction Magnet Package for the Fermilab Booster Synchrotron**

*Vladimir Kashikhin, David J. Harding, Carson John, James Lackey, Alexander Makarov, William Pellico, Eric Prebys (Fermilab)*

Since its initial operation over 30 years ago, most correction magnets in the Fermilab Booster Synchrotron have only been able to fully correct the orbit, tunes, coupling, and chromaticity at injection (400MeV). We have designed a new correction package, including horizontal and vertical dipoles, normal and skew quadrupoles, and normal and skew sextupoles, to provide control up to the extraction energy (8GeV). In addition to tracking the 15Hz cycle of the main, combined function magnets, the quadrupoles and sextupoles must swing through their full range in 1ms during transition crossing. The magnet is made from 12 water-cooled racetrack coils and an iron core with 12 poles, dramatically reducing the effective magnet air gap and increasing the corrector efficiency. Magnetic field analyses of different combinations of multipoles are included.

Work supported by the U.S. Department of Energy under Contract No. DE-AC02-76CH03000.

**MPPT011—Wide Aperture Quadrupole for the Fermilab Main Injector Synchrotron**

*Vladimir Kashikhin, Leon Bartelson, Bruce Brown, Weiren Chou, David J. Harding, Carson John, David E. Johnson, Jean-Francois Ostiguy, William Robotham (Fermilab)*

During the design of the Fermilab Main Injector synchrotron it was recognized that the aperture was limited at the beam transfer and extraction points by the combination of the Lambertson magnets and the reused Main Ring quadrupoles located between Lambertson magnets. While adequate until now, more aperture will be required to support the additional intensity demands on the Main Injector from antiproton production for the collider program, slow spill to the meson fixed target program, and high intensity beam to the high energy neutrino program. In 2005 we plan to replace those aperture-limiting quadrupoles with newly built magnets that will have the same physical length, but a larger aperture. The great challenge is that, running on the quadrupole bus, the new magnets must have the same integrated strength and saturation characteristics as the original magnets. The steel characteristics are thus critical. We present here the design considerations, 2-D and 3-D magnetic models, and the implementation.

Work supported by the U.S. Department of Energy under Contract No. DE-AC02-76CH03000.

**MPPT012—Measurements of CMD10 Ferrite Blocks for Pulsed Magnets**

*Vladimir Kashikhin, Ruben H. Carcagno, David J. Harding, Andrzej Makulski, Darryl Orris, Yuriy Pischalnikov, William Robotham (Fermilab)*

To achieve a magnetic field of 0.28T in a pulsed magnet for the Fermilab Booster injection orbit bump, we designed a yoke of CMD10, a Ni-Zn ferrite with a high saturation flux density of more than 0.4T and excellent high frequency characteristics. We have measured the unipolar and bipolar B-H curves of a sample of the bricks at 10kHz as well as the power losses. We report here the measurement technique and results.

Work supported by the U.S. Department of Energy under Contract No. DE-AC02-76CH03000.

**MPPT013—New Pulsed Orbit Bump Magnets for the Fermilab Booster Synchrotron**

*James Lackey, David J. Harding, Carson John, Vladimir Kashikhin, Alexander Makarov, Eric Prebys (Fermilab)*

The beam from the Fermilab Linac is injected onto a bump in the closed orbit of the Booster Synchrotron where a carbon foil strips the electrons from the Linac’s negative ion hydrogen beam. Although the Booster itself runs at 15Hz, heat dissipation

in the orbit bump magnets has been one limitation to the fraction of the cycles that can be used for beam. New, 0.28T pulsed window frame dipole magnets have been constructed that will fit into the same space as the old ones, run at the full repetition rate of the Booster, and provide a larger bump to allow a cleaner injection orbit. The new magnets use a high saturation flux density Ni-Zn ferrite in the yoke rather than laminated steel. The presented magnetic design includes two and three dimensional magnetic field calculations with eddy currents and ferrite nonlinear effects.

Work supported by the U.S. Department of Energy under Contract No. DE-AC02-76CH03000.

**MPPT014—Design Concept for AGS Injection Kicker Upgrade to 2 GeV**

*Gary Dale Wait, Roberto Armenta, Michael John Barnes, Ewart W. Blackmore, Ori Hadary (TRIUMF), Leif Ahrens, Chris J. Gardner, Wu Zhang (BNL)*

The present AGS injection kickers at A5 location were designed for 1.5 GeV proton injection. Recent high intensity runs have pushed the transfer kinetic energy to 1.94 GeV, but with an imperfect matching in transverse phase space. Space charge forces result in both fast and slow beam size growth and beam loss as the size exceeds the AGS aperture. A proposed increase in the AGS injection energy to 2 GeV with adequate kick strength would greatly reduce the beam losses making it possible to increase the intensity from 70 TP (70 * 10^12 protons/s) to 100 TP. R&D studies are being undertaken by TRIUMF, in collaboration with BNL, to design two new kicker magnets for the AGS A10 location to provide an additional kick of 1.5 mrad to 2 GeV protons. TRIUMF has proposed a design for a 12.5 W transmission line kicker magnet with rise and fall times of 100 ns, 3% to 97% and field uniformity of ±3% over 90% of the aperture, powered by matched 12.5 W pulse-forming lines. This paper describes the present status of a prototype design including the results of detailed 2D and 3D electromagnetic modeling of a transmission line kicker magnet and PSpice time domain analysis of the magnetic kick strength.

Canada Foundation for Innovation, U.S. Dept of Energy.

**MPPT015—Design of Septum Magnets Based on Measurements and 3D Calculation of a Prototype Septum Magnet for 3 GeV Synchrotron of J-PARC**

*Masao Watanabe, Yoshiro Irie, Junichiro Kamiya, Hiromitu Suzuki, Tomohiro Takayanagi (JAERI/J-PARC), Taihei Shimada (JASRI/SPring-8), Hiroshi Fujimori, Susumu Igarashi, Tadamichi Kawakubo, Eiji Nakamura (KEK)*

Septum magnets used in the injection and extraction section of the 3 GeV rapid cycle synchrotron of the J-PARC require large aperture for low losses of high intensity beam, protection against the high radiation and the high durability to avoid the maintenance after the high activation. Therefore the septum magnets have been designed to work by DC for the mechanical stability. A prototype septum magnet was constructed. Magnetic fields in the gap of the core and leakage field outside of the magnetic shield were measured by a Hall device probe. The experimental results were compared with the 3D calculation by TOSCA. The measurements of the magnetic field in the gap agree well with a simple 3D model. On the other hand, leakage field of the measurements is larger than the one of the model. After we made a more detailed model, it cleared that bolt holes which fasten a return yoke make effective sectional area and permeability small at the return yoke and therefore leakage field is larger. Because the thickness of the return yoke is not sufficient, magnetic flux density approaches saturation easily. Based on the results of the analysis, we have been designing the actual septum magnets.

**MPPT016—Success of the Beam Injection for the PF-AR with a Single Pulsed Quadrupole Magnet without Dipole Kickers**

*Kentaro Harada, Yukinori Kobayashi, Tsukasa Miyajima, Shinya Nagahashi (KEK)*

We develop the injection system for PF-AR (Photon Factory Advanced Ring for Pulsed X-ray) with single pulse quadrupole (PQ) magnet without pulse local bump of the stored beam with four dipole kickers. The pulse quadrupole magnet has the length of 30cm, the field gradient of 3T/m, half-sine-form pulse width of 2.4mSec, measured inductance of 1.8mH and the peak current of about 2000A. With this magnet, the amplitude of the injected beam can be reduced to about the half of that only with septum magnets and the reduced amplitude is almost the same as the case of the usual injection with the pulse bump of the stored beam. We installed PQ-magnet at the short straight section near the south symmetric point of PF-AR in this summer of 2004 and succeeded to inject beam to the storage ring during the machine study in autumn, 2004.

**MPPT017—Design of Switching Magnet for 20-MeV Beamlines at PEFP**

*Hyung Suck Suh, Hong Sik Han, Seong-Hun Jeong, Young Gyu Jung, Heung-Sik Kang, Hong-Gi Lee, Ki-Hyeon Park, Chun-Kil Ryu (PAL)*

The PEFP(Proton Engineering Frontier Project) proton linac is designed to have two proton beam extraction lines at the 20-MeV and 100-MeV end. The 20-MeV extraction line is branched out into 5 beamlines by using the switching magnet. The magnet bends the proton beam by +20, +10, 0, -10, -20 degrees, respectively, and has an AC frequency of 5 Hz with a programmable ac power supply. It employs an H-shape, 0.45 T magnetic field, 0.5 m effective magnet length, 30x5 cm bore aperture. The pole shape is optimized for the field levels. Laminated steel of 0.5 mm is enough to suppress the eddy current effect in the yoke. This paper presents the magnet specification and primary design.

Ministry of Science and Technology.

**MPPT018—Magnets for the ISIS Second Target Station Extracted Proton Beamline**

*Stephen Jago, Dan Faircloth, Chris Thomas (CCLRC/RAL/ISIS)*

As an essential part of the ISIS Second Target Station Project it is necessary to deliver 800 MeV protons from the ISIS accelerator to the new spallation neutron target. The optical design for the beam transport line defines the requirements of several different types of magnets. These include a variety of normally conducting quadrupoles and dipoles, including a high current septum magnet and two pulsed kicker magnets. The design of these magnets involves many practical mechanical, electrical and thermal aspects. The engineering problems are discussed and the resulting parameters and designs for the magnets, along with the overall beamline layout, are presented.

**MPPT019—Magnet Design for the ISIS Second Target Station Proton Beam Line**

*Chris Thomas, Dan Faircloth, Stephen Jago (CCLRC/RAL/ISIS)*

The ISIS facility, based at the Rutherford Appleton Laboratory in the UK, is an intense source of neutrons and muons for condensed matter research. The accelerator facility delivers an 800 MeV proton beam of 2.5x1013 protons per pulse at 50 Hz to the present target station. As part of a facility upgrade, it is planned to share the source with a second, 10 Hz, target station. The beam line supplying this target will extract from the existing target station beam line. Electromagnetic Finite Element Modelling techniques have been used to design the magnets

required to meet the specified beam line optics. Kicker, septum, dipole, quadrupole, and steering magnets are covered. The magnet design process, involving 2D and 3D modelling, the calculation of ideal shims and chamfers, choice of steel, design of conducting coils, handling of heating issues and eddy current effects, is discussed.

**MPPT020—Magnetic Field Measurement on a Refined Kicker**
*Tai-Ching Fan, Ching-Shiang Hwang, Fu-Yuan Lin (NSRRC)*
To prepare for the operation of top-up mode and increase the efficiency of injection at storage ring, National Synchrotron Radiation Research Center (NSRRC) has upgraded the kicker magnets and power supply. We have built up a new magnetic field measurement system to test the kicker. This system, including a search coil and a coil loop, can map the field and take the first integral of field automatically. We also simulate the trajectory of electron beam by pulsed wire method of field measurement. We analyze the performance of the kicker system in this paper.

**MPPT021—Magnetic Measurement System for the NSLS Superconducting Undulator Vertical Test Facility**
*David Harder, George Rakowsky, John Skaritka (BNL/NSLS)*
One of the challenges of small-gap superconducting undulators is measurement of magnetic fields within the cold bore to characterize the device performance and to determine magnetic field errors for correction or shimming, as is done for room-temperature undulators. Both detailed field maps and integrated field measurements are required. This paper describes a 6-element, cryogenic Hall probe field mapper for the NSLS Superconducting Undulator Vertical Test Facility (VTF). The probe is designed to work in an aperture only 3 mm high. A pulsed-wire insert is also being developed, for visualization of the trajectory, for locating steering errors and for determining integrated multi-pole errors. The pulsed-wire insert will be interchangeable with the Hall probe mapper. The VTF and the magnetic measurement systems can accommodate undulators up to 0.4 m in length.
*J. Skaritka et al., MEDSI'04.

**MPPT022—Magnetic Field Measurement and Compensation in Recycler Electron Cooler**
*Vitali Tupikov, Grigory Kazakevich, Thomas K. Kroc, Lionel Prost, Chuck Schmidt, Alexander V. Shemyakin, Mary Sutherland, Arden Warner (Fermilab)*
Cooling of 8.9-GeV/c antiprotons in Recycler Electron Cooler requires a round 4.34-MeV electron beam with a small angular spread propagating through a 20-m long cooling section. To confine the electron beam tightly and to keep its transverse angles below 0.1 mrad the cooling section is immersed in a solenoidal field of 50-200 G. The field was measured with a dedicated compass-based sensor (transversal) and hall-probe (longitudinal) after installation of the solenoids into the Recycler tunnel. For a field strength of 105 G, the transverse field components were compensated to a level that should provide corresponding dipole beam oscillations below 0.1 mrad. The paper discusses the field measurements and compensation scheme. Also we plan to present results of dipole oscillation measurements that will be done in the spring of 2005.

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**MPPT023—A New Magnetic Field Integral Measurement System**
*Joseph Z. Xu, Isaac Vasserman (ANL)*
In order to characterize the insertion devices at the Advanced Photon Source (APS) more efficiently, a new stretched-coil magnetic field integral measurement system has been developed. The system uses the latest state-of-the-art field programmable gate array (FPGA) technology to compensate the speed variations of the coil motions. Initial results demonstrate that the system achieves the system measurement accuracy of 0.15 Gauss centimeter (G-cm) in a field integral measurement of 600 G-cm, probably the world's best accuracy of its kind.

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**MPPT024—Rotating Coil for Magnetic Measurement of BEPCII Quadrupole Magnet Prototype**
*Li Li, Wan Chen, XianJing Sun (IHEP Beijing)*
We report here an update harmonic coil measurement system for the field measurement of the BEPCII quadrupole magnets. A prototype of 266-mm-long, 105-mm aperture conventional quadrupole magnet has been designed and built by IHEP, and a total of 88 magnets is under fabrication. The multipole components, the magnetic field gradient and the transfer function of the quadrupole magnets were performed in September, using an update measurement system, which includes a rotating coil field measurement and Hall probe measurement. In this paper we describe the design of the rotating measurement coil and give the main results of the magnetic field measurement for the quadrupole magnet prototype.

**MPPT025—Field Quality and Magnetic Center Stability Achieved in a Variable Permanent Magnet Quadrupole for the ILC**
*Yoshihisa Iwashita, Takanori Mihara (Kyoto ICR ), Masayuki Kumada (NIRS), Cherrill M. Spencer (SLAC)*
The precise tolerances on the last two quadrupoles before the interaction point of the proposed, superconducting e+e- collider (ILC) have not been determined yet. These quads will be aligned with a beam-based alignment (BBA) process during which their integrated strengths will be decreased by 20%. Their magnetic centers must move by less than a few microns during the BBA else a systematic error will be introduced, yielding an increase in the beam spot size. These strong quads must be small to fit in the tight space. A compact, variable, superstrong permanent magnet quad (PMQ) has been fabricated and tested. The PMQ has inner and outer rings of NEOMAX; the outer ring is subdivided along its length and each section can rotate. By rotating different lengths one can vary the integrated strength in small steps. Because of the fixed inner ring and tight mechanical tolerances, the sensitivities of the magnetic center and pole angles to the rotation of the outer rings are largely suppressed. Measurements of the PMQ will be presented, plus how observed small center and angle shifts were further reduced by adjustments to the stopping angles of the rotating rings and by shimming these rings.

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**MPPT026—Insertion Device Upgrade Plans at the NSLS**
*Toshiya Tanabe, David Harder, George Rakowsky, John Skaritka (BNL/NSLS)*
This paper describes plans to upgrade insertion devices at the National Synchrotron Light Source (NSLS), Brookhaven National Laboratory, U.S.A. The aging wiggler (W80) at X25 is being replaced by a 1 m long in-vacuum mini-gap undulator (MGU-18) optimized for a dedicated macromolecular crystallography program. A new, 1/3 m long, in-vacuum undulator (MGU-13.5), will be installed between a pair of RF cavities at X9, and will serve a new beamline dedicated for small angle x-ray scattering (SAXS). Both MGU's will have provision for cryocooling the NdFeB hybrid arrays to 150K to raise the field and K-value and to obtain better spectral coverage. Design issues of the devices and other considerations, especially magnetic measurement methods in low temperature will be discussed.

**MPPT027—Three-Dimensional Design of a Non-Axisymmetric Periodic Permanent Magnet Focusing System**
*Chiping Chen, Ronak Bhatt, Alexey Radovinsky, Jing Zhou (MIT/PSFC)*
A three-dimensional (3D) design is presented of a non-axisymmetric periodic permanent magnet focusing system which will be used to focus a large-aspect-ratio, ellipse-shaped, space-charge-dominated electron beam. In this design, an analytic theory is used to specify the magnetic profile for beam transport. The OPERA3D code is used to compute and optimize a realizable magnet system. Results of the magnetic design are verified by two-dimensional particle-in-cell and three-dimensional trajectory simulations of beam propagation using PFB2D and OMNITRAK, respectively. Results of fabrication tolerance studies are discussed.

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**MPPT028—An Air Bearing Rotating Coil Magnetic Measurement System**
*Stephen C. Gottschalk, Kenneth Kangas, David James Taylor, William Thayer (STI), Zachary Wolf (SLAC)*
This paper describes a rotating coil magnetic measurement system supported on air bearings. The design is optimized for measurements of 0.1micron magnetic centerline changes on long, small aperture quadrupoles. Graphite impregnated epoxy resin is used for the coil holder and coil winding forms. Coil holder diameter is 11 mm with a length between supports of 750mm. A pair of coils is used to permit quadrupole bucking during centerline measurements. Coil length is 616mm, inner radius 1.65mm, outer radius 4.57mm. The key features of the mechanical system are simplicity; air bearings for accurate, repeatable measurements without needing warm up time and a vibration isolated stand that uses a steel-topped Newport optical table with air suspension. Coil rotation is achieved by a low noise servo motor controlled by a standalone Ethernet servo board running custom servo software. An object oriented, multi-tiered GUI is used to perform data collection, analysis and archiving. Coil calibration procedures that correct wire placement errors, tests for hardware/software means to mitigate mechanical resonances, and all other system checks will also be discussed.

**MPPT029—Performance of an Adjustable Strength Permanent Magnet Quadrupole**
*Stephen C. Gottschalk, Terence Ellis DeHart, Kenneth Kangas (STI), James T. Volk (Fermilab), Cherrill M. Spencer, Zachary Wolf (SLAC)*
An adjustable strength permanent magnet quadrupole suitable for use in Next Linear Collider has been built and tested. The pole length is 43cm, aperture diameter 13mm, peak pole tip strength 1.10Tesla and peak integrated gradient * length (GL) is 73Tesla. This paper describes measurements of strength, magnetic centerline and field quality made using an air bearing rotating coil system. The magnetic centerline stability during -20% strength adjustment proposed for beam based alignment was < 0.12 microns. Strength hysteresis was negligible. Thermal expansion of quadrupole and measurement parts caused a repeatable and easily compensated change in the vertical magnetic centerline. Calibration procedures as well as centerline measurements made over a wider tuning range of 100% to 20% in strength useful for a wide range of applications will be described. The impact of eddy currents in the steel poles on the magnetic field during strength adjustments will be reported.

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**MPPT030—Magnetic and Engineering Analysis of an Adjustable Strength Permanent Magnet Quadrupole**
*Stephen C. Gottschalk, David James Taylor (STI)*
Magnetic and engineering analyses used in the design of an adjustable strength permanent magnet quadrupole will be reported. The quadrupole designed has a pole length of 43cm, aperture diameter 13mm, peak pole tip strength 1.10Tesla and peak integrated gradient * length (GL) of 73Tesla. Analyses of magnetic strength, field quality, magnetic centerline, temperature compensation and dynamic eddy currents induced during field adjustments will be presented. Magnet sorting strategies, pole positioning sensitivity, component forces, and other sensitivity analyses will be presented. Engineering analyses of stress, deflection and thermal effects as well as compensation strategies will also be shown.

Department of Energy grant DE-FG03-01ER83305.

**MPPT031—Radiation Resistant Magnets for the RIA Fragment Separator**
*Al Zeller, Valetin Blideanu, Reginald Ronningen, Bradley Sherrill (NSCL), Ramesh C. Gupta (BNL)*
The high radiation fields around the production target and the beam dump in the fragment separator at the Rare Isotope Accelerator requires that radiation resistant magnets be used. Because large apertures and high gradients are required for the quadrupoles and similar demanding requirements for the dipole and sextupoles, resistive coils are difficult to justify. The radiation heating of any materials at liquid helium temperatures also requires that superconducting versions of the magnets have low cold-masses. The final optical design has taken the practical magnets limits into account and sizes and fields adjusted to what is believed to be achievable with technology that is possible with sufficient R&D. Designs with higher obtainable current densities and having good radiation tolerances that use superconducting coils are presented, as well as the radiation transport calculations that drive the material parameters.

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**MPPT032—Construction and Performance of Superconducting Magnets for Synchrotron Radiation**
*Ching-Shiang Hwang, Cheng-Hsiang Chang, Cheng-Kuo Chang, Ho-Ping Chang, Chien-Te Chen, Hui-Huang Chen, Jenny Chen, June-Rong Chen, Yuan-Chen Chien, Tai-Ching Fan, Gao-Yu Hsiung, Kuo-Tung Hsu, Shen-Nung Hsu, Ming-Hsiung Huang, Chin-Cheng Kuo, Fu-Yuan Lin (NSRRC)*
Two superconducting magnets, one wavelength shifter (SWLS) with a field of 5 T and one wiggler (SW6) with a field of 3.2 T, were constructed and routinely operated at NSRRC for generating synchrotron x-rays. In addition, three multipole wigglers (IASW) with fields of 3.1 T will be constructed and installed each in the three achromatic short straight sections. A warm beam duct of 20 mm inner gap and a 1.5 W GM type cryo-cooler were chosen for the SWLS to achieve cryogen-free operation. For the SW6, a cold beam duct of 11 mm inner gap was kept at 100 K temperature and no trim coil compensation is necessary for its operation. Meanwhile, no beam loss was observed when the SW6 was quenched. A cryogenic plant with cooling power of 450 W was constructed to supply the liquid helium for the four superconducting wigglers. The design concept, magnetic field quality, the commissioning results, and the operation performance of these magnets will be presented.

**MPPT033—Development of a Superconducting Helical Undulator for a Polarised Positron Source**
*Yury Ivanyushenkov, Frederick Stephen Carr (CCLRC/RAL/ASTeC), James Clarke, Oleg B. Malyshev, R. J. Reid, Duncan Scott, Brian Todd (CCLRC/DL/ASTeC), Elwyn Baynham, Thomas William Bradshaw, James Rochford (CCLRC/RAL), Desmond P. Barber (DESY), Gudrid Moortgat-Pick (Durham University), Peter Cooke, John Dainton, T. Greenshaw (Liverpool University)*
A method of producing a polarised positron beam from e+e- pair production in a target by circularly polarised ã-radiation is being investigated. Polarised photons are to be generated by the passage of a high energy electron beam (250 GeV as anticipated in the International Linear Collider - ILC) through a helical undulator. For production of 20 MeV photons, an undulator with a period of 14 mm, a bore of approximately 4 mm and magnetic field on axis of 0.75 T is required. First prototypes have been constructed using both superconducting and permanent magnet technologies which are capable of producing the necessary magnetic field configuration in the undulator. This paper details the design, construction techniques and field measurement results of the first superconducting prototype and compares the results with simulation.

**MPPT034—Field Modelling for the CESR-c Superconducting Wiggler Magnets**
*James Arthur Crittenden, Alexander A. Mikhailichenko, Eric Smith, Karl William Smolenski, Alexander Temnykh (Cornell University)*
Superconducting wiggler magnets for operation of the CESR electron-storage ring at energies as low as 1.5 \gev have been designed, built and installed in the years 2000 to 2004. Finite-element models of field quality have been developed, various sources of field errors investigated and compared to field measurements. Minimization algorithms providing accurate analytic representations of the wiggler fields have been established. We present quantitative descriptions of field modelling, of measured field quality and of the accuracy achieved in the analytic functions of the field.

National Science Foundation.

**MPPT035—Magnetic Field Analysis of Superconducting Undulators with Variable Field Polarization**
*Suk Hong Kim (ANL)*
An undulator with double-helix coils on a cylindrical beam tube is the classical method of producing a helical magnetic field. This type of device, however, can produce only circularly polarized radiation and has limited horizontal aperture for beam injection. A planar superconducting undulator SCU) unit of helical field, which generates horizontal and vertical fields perpendicular to the beam direction, is inserted in between the magnetic poles of a vertical-field unit. This paper analyzes the magnetic fields and a scaling law of the SCU. The angle of the coil windings for the inserted unit is analyzed to maximize the horizontal field Bx. The range of the optimum rotation angle, for the range of gap/period ratio 0.1 - 0.6, is calculated to 30 - 40 degrees.

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**MPPT036—R&D of Short-Period NbTi and Nb3Sn Superconducting Undulators for the APS**
*Suk Hong Kim, Charles Doose, Robert Kustom, Elizabeth Rahm Moog, Isaac Vasserman (ANL)*
A superconducting undulator (SCU) with a period of 14.5 mm is under development at the Advanced Photon Source (APS). The undulator is designed to achieve a peak field on the beam axis of 0.8 T with an 8 mm pole gap and an average current density of 1 kA/mm2 in the NbTi coil. A 22-period half-section of a SCU has been fabricated. The SCU half-section was charged up to near the average critical current density jc of 1.4 kA/mm2, and the stability margin was measured by imposing external heat fluxes on the coil at 4.2 K in pool boiling LHe. The magnetic fields along the midplane of the SCU were measured using a Hall-probe field-mapping unit installed in a vertical dewar. The first test of a Nb3Sn short-section SCU reached an average current density of 1.45 kA/mm2, slightly higher than the jc for the NbTi SCU.

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**MPPT037—Design Study of Superconducting Magnets for the Super-KEKB Interaction Region**
*Norihito Ohuchi, Yoshihiro Funakoshi, Haruyo Koiso, Katsunobu Oide, Kiyosumi Tsuchiya (KEK)*
The KEKB accelerator has achieved the highest luminosity of 1.39E10^34cm-2s-1 at June-03-2004. For getting the higher luminosity over 1E10^35cm-2s-1, the KEKB accelerator group continues to study the upgraded machine of the KEKB, that is the Super-KEKB. The designed machine parameters for this Super-KEKB are the vertical beta of 3 mm at the interaction point (IP), the LER and HER currents of 9.4 A and 4.1 A, and the half crossing angle of 15 mrad for the target luminosity of 1-5E10^35cm-2s-1. For achieving these beam parameters, the superconducting magnets (final focus quadrupoles and compensation solenoids) are newly required to design. The magnet-cryostats have very tight spatial constraints against the Belle particle detector and the beam pipe so that the beam and the synchrotron light do not have any interference with the beam pipe. In this design, the final focus quadrupoles generate the field gradient of 42.3 T/m and their effective magnetic lengths are 0.30m and 0.36m in each side with respect to the IP, respectively. The compensation solenoids are overlaid with the quadrupoles. We will report the design of these magnets in detail and show the difficulties for the Super-KEKB-IR.

**MPPT038—Status of BEPC-II IR Magnet Production at BNL**
*Brett Parker, Michael Anerella, John Escallier, Arup Ghosh, Animesh Kumar Jain, Andrew Marone, Joseph F. Muratore, Peter Wanderer (BNL)*
The luminosity upgrade of the Beijing Electron Positron Collider, BEPC-II, at IHEP Beijing depends upon creation of a pair of compact multi-function superconducting interaction region (IR) magnets to be placed inside the BES experimental detector solenoid. These magnets are constructed using BNL's direct wind technology, originally developed to produce IR magnets for the HERA-II upgrade at DESY,* and provide strong focusing to reduce the IR beam spot size. BEPC-II magnets have one seventh the length, similar strength but more than double the inner coil radius of their HERA-II counterparts and thus require more coil layers. Like HERA-II the BEPC-II IR magnets have dipole and skew-quadrupole correction coils but unlike HERA-II the BEPC-II magnets have an extra multi-section anti-solenoid to provide local compensation of the detector solenoid. We improved many coil production aspects with the invention of continuous Serpentine style coil winding. Our aggressive production schedule has coil winding and vertical testing of completed cold masses finished early in 2005 followed by cryostating at BNL before the magnet assemblies are sent to Beijing.
*P. Wanderer et al., "Completion of Superconducting Magnet Production by BNL for the HERA Luminosity Upgrade," 17th International Conference on Magnet Technology (MT-17), Geneva, Switzerland, September, 24-28, 2001.

**MPPT039—Eddy-Current Effect on Field Multipoles Arising in Dipole and Quadrupole Magnets with Elliptic and Rectangular Beam Pipe**
*Evgueni Perevedentsev, Alexander L. Romanov (BINP SB RAS)*
We present an analytical evaluation of the field-distortion effect from eddy currents for the changing magnetic field of dipole and quadrupole magnets with elliptic or rectangular beam pipe of finite conductivity. The pipe sizes and aspect are arbitrary except that for practical reasons we assume the pipe wall thickness small as compared to the skin depth. Handy formulas are presented for the field multipoles arising from non-round shape of the beam pipe.

**MPPT040—The LHC Magnetic Field Model**
*Nicholas Joseph Sammut, Luca Bottura (CERN), Joseph Micallef (University of Malta)*
The compensation of the dynamic field changes during the proton and ion beam injection and acceleration in the LHC requires an accurate forecast and an active control of the magnetic field in the accelerator. The LHC Magnetic Field Model is the core of this magnetic prediction system. This open loop control scheme will provide the desired field components at a given time, magnet operating current, magnet ramp-rate, magnet temperature and magnet powering history to the required precision. The model is based on the identification and physical decomposition of the effects that contribute to the total field in the magnet aperture of the LHC dipoles. By using data obtained from series measurements, these components are then quantified theoretically or empirically depending on the complexity of the physical phenomena involved. This paper presents the developments of the newly fine-tuned magnetic field model and evaluates its accuracy, reproducibility and predicting capabilities.

**MPPT041—Improvement of the Geometrical Stability of the LHC Cryodipoles when Blocking the Central Support Post**
*Fabien Seyvet, Jean-Bernard Jeanneret, Alain Poncet, Davide Tommasini (CERN)*
The LHC will be composed of 1232 horizontally curved 16 meter long super-conducting dipole magnets cooled at 1.9K, supported within their vacuum vessel by three Glass Fiber Resin Epoxy (GFRE) support posts. The two support posts at the dipole extremities were initially designed free to slide longitudinally with respect to the vacuum vessel and the central support post was designed free to slide transversally. However the magnet shape did not retain the tight geometrical tolerances, of the order of fractions of mm, imposed by machine aperture and magnetic corrector centering requirements. Thereafter a modification to the supporting system, removing the initial transversal degree of freedom of the lower flange of the central support post with respect to the vacuum vessel, was designed and implemented. This paper describes the design of the magnet/cryostat interface with and without blockage of the central support post, analyzes the additional mechanical loads related to the modification and reviews the experimental results with respect to the requirements for beam aperture and magnetic corrector centering.

**MPPT042—Field Quality and Alignment of the Series Produced Superconducting Matching Quadrupoles for the LHC Insertions**
*Nuria Catalan-Lasheras, Glyn Kirby, Ranko Ostojic, Juan Carlos Perez, Herve Prin, Walter Venturini Delsolaro (CERN)*
The production of the superconducting quadrupoles for the LHC insertions is advancing well and about half of the magnets have been produced. The coil size and field measurements performed on individual magnets both in warm and cold conditions are yielding significant results. In this paper we present the procedures and results of steering the series production at the magnet manufacturers and the assembly of cold masses at CERN. In particular, we present the analysis of warm-cold correlations and hysteresis of the main field multipoles, the correlation between coil sizes and geometrical field errors and the effect of permeability of magnet collars. The results are compared with the target errors for field multipoles and alignment.

**MPPT043—Low-Beta Quadrupole Designs for the LHC Luminosity Upgrade**
*Ranko Ostojic, Nuria Catalan-Lasheras, Glyn Kirby (CERN)*
Several candidate scenarios are considered for the upgrade of the LHC insertions in view of increasing the luminosity in excess of 10^34 cm-2s-1. In all cases, superconducting low-beta quadrupoles with apertures in the range of 90-110 mm are required in view of increased heat loads and beam crossing angles. We present possible low-beta quadrupole designs based on Nb3Sn and NbTi superconducting cables, including existing LHC-class superconductors, present scaling laws for the magnet parameters and discuss relative advantages of the underlying triplet layouts.

**MPPT044—The Construction of the Low-Beta Triplets for the LHC**
*Ranko Ostojic, Mikko Karppinen, Thomas Taylor, Walter Venturini Delsolaro (CERN), R. Bossert, Joseph DiMarco, Sandor Feher, James Kerby, Michael Joseph Lamm, Thomas H. Nicol, Alfred Nobrega, Thomas M. Page, Thomas Peterson, Roger Rabehl, Phil Schlabach, James Strait, C. Sylvester, Mike Tartaglia, Gueorgui Velev (Fermilab), Nobuhiro Kimura, Tatsushi Nakamoto, Toru Ogitsu, Norihito Ohuchi, Takakazu Shintomi, Kiyosumi Tsuchiya, Akira Yamamoto (KEK)*
The performance of the LHC depends critically on the low-beta triplets, located on either side of the four interaction points. Each triplet consists of four superconducting quadrupole magnets, which must operate reliably at up to 215 T/m, sustain extremely high heat loads and have an excellent field quality. A collabora-

tion of CERN, Fermilab and KEK was set up in 1996 to design and build the triplet systems, and after nine years of joint effort the production will be completed in 2005. We retrace the main events of the project and present the design features and performance of the low-beta quadrupoles, built by KEK and Fermilab, as well as of other vital elements of the triplet. The experience in assembly of the first triplet at CERN and plans for tunnel installation and commissioning in the LHC are also presented. Apart from the excellent technical results, the construction of the LHC low-beta triplets has been a highly enriching experience combining harmoniously the different competences and approaches to engineering in a style reminiscent of physics experiment collaborations, and rarely before achieved in accelerator building.

**MPPT045—The Assembly of the LHC Short Straight Sections (SSS) at CERN: Project Status and Lessons Learned**

*Vittorio Parma, Nicolas Bourcey, Paulo Manuel Dos Santos de Campos, Rogerio Carolino Feitor, Makcim Gandel, Peter Rohmig, Martin Schmidlkofer, Ivo Slits (CERN)*

The series production of the LHC SSS has started in the beginning of 2004 and is foreseen to last until end 2006. The production consists in the assembly of 474 cold masses housing superconducting quadrupoles and corrector magnets within their cryostats. 87 cold mass variants, resulting from various combinations of main quadrupole and corrector magnets, have to be assembled in 55 cryostat types, depending on the specific cryogenic and electrical powering schemes required by the collider topology. The assembly activity features the execution of more than 5 km of leak-tight welding on 20-bar design pressure cryogenic lines in stainless steel and aluminium, according to high qualification standards and undergoing severe QA inspections. Some 2500 leak detection tests, using He mass spectrometry, are required to check the tightness of the cryogenic circuits. Extensive electrical control work, to check the integrity of the magnet instrumentation and electrical circuits throughout the assembly of the SSS, is also carried out. This paper presents the current status of production, the assembly facilities at CERN, work organisation and Quality Assurance issues, and the acquired assembly experience after one and a half years of production.

**MPPT046—Superconducting Helical Snake Magnet for the AGS**

*Erich Willen, Michael Anerella, John Escallier, George Ganetis, Arup Ghosh, Ramesh C. Gupta, Michael Harrison, Animesh Kumar Jain, Alfredo U. Luccio, William W. MacKay, Andrew Marone, Joseph F. Muratore, Stephen Richard Plate, Thomas Roser, Nicholaos Tsoupas, Peter Wanderer (BNL), Masahiro Okamura (RIKEN)*

A superconducting helical magnet has been built for polarized proton acceleration in the Brookhaven AGS. This "partial Snake" magnet will help to reduce the loss of polarization of the beam due to machine resonances. It is a 3 T magnet some 1940 mm in magnetic length in which the dipole field rotates with a pitch of 0.2053 degrees/mm for 1154 mm in the center and a pitch of 0.3920 degrees/mm for 393 mm in each end. The coil cross-section is made of two slotted cylinders containing superconductor. In order to minimize residual offsets and deflections of the beam on its orbit through the Snake, a careful balancing of the coil parameters was necessary. In addition to the main helical coils, a solenoid winding was built on the cold bore tube inside the main coils to compensate for the axial component of the field that is experienced by the beam when it is off-axis in this helical magnet. Also, two dipole corrector magnets were placed on the same tube with the solenoid. A low heat leak cryostat was built so that the magnet can operate in the AGS cooled by several cryocoolers. The design, construction and performance of this unique magnet will be summarized.

**MPPT047—2-in-1 Large-Aperture IR Quadrupoles for the LHC Luminosity Upgrade**

*Vadim Kashikhin, Alexander V. Zlobin (Fermilab)*

After LHC operates for several years at nominal parameters, it will be necessary to upgrade it to higher luminosity. Replacement of the low-beta insertions with higher performance design based on advanced superconducting magnets is one of the most straightforward steps in this direction. An interesting option for a new IR design is a double bore inner triplet with separation dipoles placed in front of the focusing quadrupoles. This approach reduces the number of parasitic collisions by more than a factor of three with respect to the quadrupoles-first option and allows independent field error correction for each beam. Several designs of the 2-in-1 Nb3Sn quadrupole magnets suitable for the LHC IR upgrade have been studied, including magnets with "cold" and "warm" iron yokes based on symmetric or asymmetric coils. This paper will describe the magnet design concepts and compare their major performance parameters, including aperture size, field gradient, field quality, electromagnetic stresses in the coils, and discuss some technological aspects of the magnet fabrication.

This work was supported by the U.S. Department of Energy.

**MPPT048—Test Results of HTS Coil and Magnet R&D for RIA**

*Ramesh C. Gupta, Michael Anerella, Michael Harrison, William Sampson, Jesse Schmalzle (BNL), Al Zeller (NSCL)*

Brookhaven National Laboratory is developing quadrupole magnets for the proposed Rare Isotope Accelerator (RIA) based on commercially available High Temperature Superconductors (HTS). These quadrupoles will be used in the Fragment Separator region and are one of the more challenging elements in the RIA proposal. They will be subjected to several orders of magnitude more energy and radiation deposition than typical beam line and accelerator magnets receive during their entire lifetime. The proposed quadrupoles will operate in the 20-40 K temperature range for efficient heat removal. HTS coils that have been tested so far indicate that the coils meet the magnetic field requirements of the design. We will report the test results of about 10 HTS coils and of a magnetic mirror configuration that simulates the magnetic field and Lorentz force in the proposed quadrupole. In addition, the preliminary design of an HTS dipole magnet for the Fragment Separator region will also be presented.

Work supported by the U.S. Department of Energy and by the National Science Foundation.

**MPPT049—Optimization of Open Midplane Dipole Design for LHC IR Upgrade**

*Ramesh C. Gupta, Michael Anerella, Arup Ghosh, Michael Harrison, Jesse Schmalzle, Peter Wanderer (BNL), Nikolai V. Mokhov (Fermilab)*

The proposed ten-fold increase in Large Hadron Collider (LHC) luminosity requires high field (~15 T) magnets that are subjected to the high radiation power of ~9 kW/per beam directed towards each interaction region. This has a major impact in the design of first dipole in the "Dipole First" optics. The proposed design allows sufficient clear space between coils so that most of the particle showers from the interaction points (concentrated at the midplane due to strong magnetic field) can be transported outside the coil region to a warm absorber thus drastically reducing the peak power density in the coils and removing heat

at a higher (nitrogen) temperature. The concept, however, presents several new technical challenges: (a) obtaining good field quality despite a large midplane gap, (b) minimizing peak fields on coil, (c) dealing with large vertical forces with no structure between the coils, (d) minimizing heat deposition in the cold region, (e) designing a support structure. Designs with different horizontal and vertical coil spacing are presented that offer significant savings in the operating and infrastructure cost of the cryo-system, providing reliable quench-stable operation with a lifetime of the critical components of at least ten years.

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**MPPT050—Test Results for LHC Insertion Region Dipole Magnets**

*Joseph F. Muratore, Michael Anerella, John P. Cozzolino, George Ganetis, Arup Ghosh, Ramesh C. Gupta, Michael Harrison, Animesh Kumar Jain, Andrew Marone, Stephen Richard Plate, Jesse Schmalzle, Richard Thomas, Peter Wanderer, Erich Willen, Kuo-Chen Wu (BNL)*

The Superconducting Magnet Division at Brookhaven National Laboratory (BNL) has made 20 insertion region dipoles for the Large Hadron Collider (LHC) at CERN. These 9.45 m-long, 8 cm aperture magnets have the same coil design as the arc dipoles now operating in the Relativistic Heavy Ion Collider (RHIC) at BNL and are of single aperture, twin aperture, and double cold mass configurations. They produce fields up to 3.8 T for operation at 7.56 TeV. Eighteen of these magnets have been tested at 4.5 K using either forced flow supercritical helium or liquid helium. The testing was especially important for the twin aperture models, which have the most challenging design. In these, the dipole fields in both apertures point in the same direction, unlike LHC arc dipoles. This paper reports on the results of these tests, including spontaneous quench performance, verification of quench protection heater operation, and magnetic field quality. Magnetic field measurements were done at 4.5K and at room temperature, and warm-cold correlations have been determined. Some dynamic measurements to study the effect of time decay and snapback at injection were also done, using a fast rotating coil.

U.S. Department of Energy.

**MPPT051—Reshimming of Tevatron Dipoles; A Process-Quality and Lessons-Learned Perspective**

*James N. Blowers, Ray Hanft, David J. Harding, Carson John, William Robotham (Fermilab)*

Over the last two years corrections have been made for the skew quadrupole moment in 530 of the 774 installed dipoles in the Tevatron. This process of reshimming the magnets in situ has inherent risk of degrading the performance of the superconducting accelerator. In order to manage the risk, as well as to ensure the corrections were done consistently, formal quality tools were used to plan and verify the work. The quality tools used to define the process and for quality control are discussed, along with highlights of lessons learned.

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**MPPT052—Adding Sextupole to a Quadrupole to Control Chromaticity in the Fermilab AP2 Beamline**

*David J. Harding, Henry Glass, Steven J. Werkema (Fermilab)*

From the initial design stage it has been recognized that it would be beneficial to control the chromaticity in the Fermilab AP2 beam line between the p-bar production target and the Debuncher ring. The chief difficulty is that in the regions of non-zero dispersion the magnets are packed in so tightly that adding a sextupole magnet is not practical. The current attempts to improve the p bar collection efficiency have raised the issue again, prompting the question of whether the field in the appropriate quadrupoles could be distorted sufficiently to generate the needed sextupole component. Powering the left and right (top and bottom) coils unequally will generate a normal (skew) sextupole component of the field, but presents its own difficulties. Calculations and magnet measurements are presented in support of this proposal.

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**MPPT053—Restoring the Skew Quadrupole Moment in Tevatron Dipoles**

*David J. Harding, Pierre Bauer, James N. Blowers, Joseph DiMarco, Henry Glass, Ray Hanft, Carson John, William Robotham, Mike Tartaglia, John Tompkins, Gueorgui Velev (Fermilab)*

In early 2003 it was realized that mechanical changes in the Tevatron dipoles had led to a deterioration of the magnetic field quality that was hindering operation of the accelerator. After extensive study, a remediation program was started in late 2003 which will continue through 2005. The mechanical and magnetic effects are discussed. The readjustment process and experience are reported, along with other observations on aging magnets.

Work supported by the U.S. Department of Energy under Contract No. DE-AC02-76CH03000.

**MPPT054—Development of Nb3Sn Accelerator Magnets at Fermilab**

*Alexander V. Zlobin, Giorgio Ambrosio, Nicolai Andreev, Emanuela Barzi, R. Bossert, Ruben H. Carcagno, Joseph DiMarco, Luciano Elementi, Sandor Feher, Vadim Kashikhin, Vladimir Kashikhin, Robert Kephart, Michael Joseph Lamm, Igor Novitski, Darryl Orris, Yuriy Pischalnikov, Phil Schlabach, Richard Stanek, C. Sylvester, Mike Tartaglia, John Tompkins, Daniele Turrioni, Gueorgui Velev, Ryuji Yamada, Victor Yarba (Fermilab)*

High-field superconducting accelerator magnets (dipoles and quadrupoles) are being developed at Fermilab for present and future hadron colliders. These magnets are designed to operate at a nominal field of 10-12 T and a temperature of 4.5 K. In order to reach these parameters, magnets use brittle Nb3Sn superconductor, which require new design and fabrication approaches. The baseline approach being explored at Fermilab for the dipoles and quadrupoles uses shell-type coils and wind-and-react techniques. The design of dipole with 43.5 mm aperture based on this approach has been developed and five 1-m long models have been fabricated and tested. After several failures attributed to electromagnetic instabilities in the state-of-the-art high-Jc Nb3Sn strands, used in first models, the magnetic field above 10 T was reached. The designs of Nb3Sn quadrupole with 90-mm aperture for the high luminosity interaction regions were also developed and the fabrication of the first short model has been started. This paper presents the details of the Fermilab's high field accelerator magnet program, reports its status and recent results, and outlines the program next steps.

This work was supported by the U.S. Department of Energy.

**MPPT055—The LANSCE Switchyard Kicker Project**

*Mark Gulley, Henry W. Alvestad, Walter C. Barkley, David B. Barlow, Dean S. Barr, Gloria A. Bennett, Leo J. Bitteker, Eric*

*Bjorklund, Michael J. Borden, Mary J. Burns, Gary Carr, Jeffry L. Casados, Stacy Chacon, Stanley Cohen, Justo F Cordova, John A. Faucett, Louis E. Fernandez, Daniel Fitzgerald, Matthew Fresquez, Floyd R. Gallegos, Robert Garnett, J. Douglas Gilpatrick, Fermin Gonzales, Frederick W. Gorman, Michael J. Hall, David J. Hayden, David Henderson, Glen D. Johns, Debora Kerstiens, Matthew D. Lusk, Alfred J. Maestas, Henry P. Marquez, Derwin Martinez, Martin P. Martinez, John B. Merrill, Edward A. Morgan, Angela Naranjo, James Francis O'Hara, Felix R. Olivas, Michael A. Oothoudt, Tim D. Pence, Edward M. Perez, Chandra Pillai, Brandon Jason Roller, Amos M. Romero, Dolores B. Romero, Gary Sanchez, Jacob B. Sandoval, Stuart Schaller, Fred E. Shelley, Robert Shurter, Jerry L. Stockton, James Sturrock, Victor P. Vigil, Thomas Zaugg (LANL/LANSCE), Ross E. Meyer, Frank P. Romero, James R. Sims (LANL)*
Until 2003, the existing configuration of the LANSCE switchyard did not allow simultaneous delivery of the H^- beam to Lines D and X. In the late 1990's, with increased activities in Areas B and C, which serve the ultracold neutron experiments (UCN) and proton radiography (PRad), respectively, planning began to increase beam availability to all areas by installing a kicker system, dubbed the "Switchyard Kicker." The Switchyard Kicker is a system of two pulsed and two direct current magnets that enables simultaneous, uninterrupted beam delivery to Line D for the Lujan Center and the Weapons Neutron Research (WNR) Facility and, on request, a tailored H^- beam pulse to Line X for the pRad and UCN research areas. The project received funding in July 2001 for design and implementation. During the 2003 Extended Maintenance Period this upgrade was installed in the Switchyard and commissioned during the Accelerator Turn-On period in the summer of 2003. With the commissioning successful, LANSCE now routinely operates in "Kick" mode, delivering simultaneous beam to Line X and Line D, increasing beam availability to all areas and simplifying production scheduling.

**MPPT056—First Ideas Towards the Super-Conducting Magnet Design for the HESR at FAIR**

*Ralf Eichhorn, F.M. Esser, Achim Gussen (FZJ), Siegfried Martin (FZJ/IKP)*
The Forschungszentrum Juelich has taken the leadership of a consortium being responsible for the design of the HESR going to be part of the FAIR project at GSI. The HESR is a 50 Tm storage ring for antiprotons, based on a super-conducting magnet technology. On basis of the RHIC Dipole D0 (3.6 T), the magnet design for the HESR has started recently. One key issue will be a very compact layout because of the rather short magnets (been 1.82 m for the dipoles and 0.5 m for the other magnets). This paper will present first ideas of the magnetic and cryogenic layout, give a status report on the achievements so far and discuss the need and possible solutions for a bent magnet with a radius of curvature of 13.2 m.

**MPPT057—Design of a Magnet System for a Muon Cooling Ring**

*Stephen Alan Kahn, Harold G. Kirk (BNL), Frederick E. Mills (Fermilab), David Cline, Albert A. Garren (UCLA)*
A hydrogen gas filled muon cooling ring appears to be a promising approach to reducing the emittance of a muon beam for use in a neutrino factory or a muon collider. A small muon cooling ring is being studied to test the feasibility of cooling by this method. This paper describes the magnet system to circulate the muons. The magnet design is optimized to produce a large dynamic aperture to contain the muon beam with minimum losses. Muons are tracked through the field to verify the design.

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**MPPT058—Progress on the Focus Coils for the MICE Channel**

*Michael Green (LBNL), Yury Ivanyushenkov (CCLRC/RAL), Wing Lau, Rohan Senanayake, Stephanie Yang (OXFORDphysics)*
This report describes the progress on the magnet part of the absorber focus coil module for the international Muon Ionization Cooling Experiment (MICE). MICE consists of two cells of a SFOFO cooling channel that is similar to that studied in the level 2 study of a neutrino factory. The MICE absorber focus coil module consists of a pair of superconducting solenoids, mounted on an aluminum mandrel. The coil package that is in its own vacuum vessel surrounds an absorber, which does the ionization cooling of the muons. Either a liquid or solid absorber is within a separate vacuum vessel that is within the warm bore of the superconducting magnet. The superconducting focus coils may either be run in the solenoid mode (with the two coils at the same polarity) or in the flip mode (with the coil at opposite polarity causing the field direction to flip within the magnet bore). The superconducting coils will be cooled using a pair of small 4 K coolers. This report discusses the progress on the MICE focusing magnets, the magnet cooling system and the magnet current supply system.

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**MPPT059—Progress on the Coupling Coil for the MICE Channel**

*Michael Green, Derun Li, Steve Virostek, Michael Zisman (LBNL), Yury Ivanyushenkov (CCLRC/RAL), Wing Lau, Adam White, Holger Witte, Stephanie Yang (OXFORDphysics)*
This report describes the progress on the coupling coil module for the international Muon Ionization Cooling Experiment (MICE). MICE consists of two cells of a SFOFO cooling channel that is similar to that studied in the level 2 study of a neutrino factory. The MICE RF coupling coil module consists of a superconducting solenoid, mounted around four cells of conventional 201.25 MHz closed RF cavities. This report discusses the progress that has been made on the superconducting coupling coil that is around the center of the RF coupling module. This report also describes the process one would use to cool the coupling coil using a single small 4 K cooler. The coupling magnet power system and quench protections system is also described.

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**MPPT060—Comparison of Designed and Measured Characteristics of CESR's SC Wiggler**

*Alexander A. Mikhailichenko (Cornell University)*
We represent here results of measurements and their comparison with calculated field profiles for 2.1 T wigglers installed in CESR storage ring.

**MPPT061—Ideal Wiggler**

*Alexander A. Mikhailichenko (Cornell University)*
Described is the wiggler with reduced nonlinear components for usage in damping ring of Linear Collider. Zigzag field dependence on longitudinal coordinate made by profiling of poles.

**MPPT062—3D Trajectory Analyses for Positron Spectrometer**
*Alexander A. Mikhailichenko (Cornell University)*
We represent here trajectory analyses for positron spectrometer for E-166 experiment at SLAC. 3D calculations of magnetic field made with MERMAID 3D code with further numerical tracking in this 3D field.

**MPPT063—Optimized Analyzing Magnet for Measurements of Polarization of Gamma-Quants at 10 MeV**
*Alexander A. Mikhailichenko (Cornell University)*
We described here calculations and test of magnet for measurement of polarization of gammas by its helicity-dependent attenuation in magnetized iron. Magnet is a compact device which size is ~ten times smaller, than world wide analogues.

**MPPT064—Elements of Magneto-Optics Acting in One Direction**
*Alexander A. Mikhailichenko (Cornell University)*
We describe here the way to use quadrupole, octupole– lenses so they are acting in one direction only. The beam is running across the lens in contrast with usual axis running.

**MPPT065—Resistive Undulator**
*Alexander A. Mikhailichenko (Cornell University, Ithaca, New York)*
We describe here new type of helical undulator, based on interaction of beam with image fields. As magnetic field penetrates in material with finite conductivity but electrical field does not, this introduces misbalance of forces and, hence, attraction to the wall. Helical thread serves as a body of an undulator.

**MPPT066—Pulsed Undulator for Polarized Positron Production**
*Alexander A. Mikhailichenko (Cornell University)*
We represent here elements of design and results of testing for helical undulator with ~2.5-mm period, manufactured in Cornell LEPP for polarized positron production at SLAC. At 2.3 kA undulator reaches K~0.2 and operated up 30 Hz.

**MPPT067—Stray Field Reduction in Eddy Current Septum Magnets**
*Derek Shuman, Ross Schlueter, Christoph Steier, Gregory D. Stover (LBNL)*
Stray field from an eddy current septum magnet is reduced with a variety of techniques discussed here. Peak stray field magnitude is reduced by ~4x by changing the half sine drive current pulse to a full sine current pulse. The resulting stray field time history has a brief sine-like time history section and a longer, exponential decay-like time history section, and is verified by experiment. A method for tuning the second half-sine (reverse) current pulse to eliminate the exponential decay-like section is given. A method for further reducing the remaining sine-like section is also given. The effect of adding ferromagnetic shielding in conjunction with some of the above stray field reduction methods is given. Finally, a curved septum plate is shown to improve field uniformity in the magnet gap closer to the septum, possibly allowing slower drive pulses and/or more resistive septum materials.

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**MPPT068—A High Gradient, Low Inductance Pulsed Quadrupole for Intense Ion Beam Transport**
*Derek Shuman, Andy Faltens, Gary Ritchie, Peter Seidl (LBNL), Michel Kireeff Covo (LLNL)*
A design for a high gradient, low inductance pulsed quadrupole magnet, with integral position corrector magnets is described. The magnet is a circular current dominated design with a circular iron return yoke. Novel features include a five turn eddy current compensated solid conductor coil design which effectively eliminates the first four higher order multipole field components, a single layer "non-spiral" "bedstead" coil design minimizes utilization of radial space, maximizes utilization of axial space, and allows incorporation of position corrector coils within existing radial space. The coils are wound and stretched straight in a special winder, then bent in simple fixtures to form the upturned ends, simplifying fabrication and assembly. An eddy current end field shield is incorporated which minimizes core pole end saturation and reduces end pseudo-multipoles.

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**MPPT069—A High Field Pulsed Solenoid for Intense Ion Beam Transport**
*Derek Shuman, Gary Ritchie, David Vanecek, William Waldron, Simon Yu (LBNL)*
A design for a high field pulsed solenoid magnet is presented. Some simple design formulas are given that are useful for initial design scoping. Design features to simplify fabrication and improve reliability are presented. Fabrication, assembly, and test results are presented.

This work was supported by the Director, Office of Science, Office of Fusion Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**MPPT070—Construction and Power Test of the Extraction Kicker Magnet for the SNS Accumulator Ring**
*Chien Pai, Harald Hahn, Hsiao-Chaun Hseuh, Yong Yung Lee, Wuzheng Meng, Jian-Lin Mi, Deepak Raparia, Jon Sandberg, Robert J. Todd, Nicholaos Tsoupas, Joseph Tuozzolo, David S. Warburton, Jie Wei, Daniel Weiss, Wu Zhang (BNL)*
Two extraction kicker magnet assemblies that contain seven individual pulsed magnet modules each will kick the proton beam vertically out of the SNS accumulator ring into the aperture of the extraction lambertson septum magnet. The proton beam then travels to the 1.4 MW SNS target assembly. The 14 kicker magnets and major components of the kicker assembly have been fabricated in BNL. The inner surfaces of the kicker magnets were coated with TiN to reduce the secondary electron yield. All 14 PFN power supplies have been built, tested and delivered to ORNL. Before final installation, a partial assembly of the kicker system with three kicker magnets was assembled to test the functions of each critical component in the system. In this paper we report the progress of the construction of the kicker components, the TiN coating of the magnets, the installation procedure of the magnets and the full power test of the kicker with the PFN power supply.

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**MPPT071—The Lambertson Septum Magnet of the Spallation Neutron Source**
*Jim Rank, Yong Yung Lee, William J. McGahern, Gary Miglionico, Deepak Raparia, Nicholaos Tsoupas, Joseph Tuozzolo, Jie Wei (BNL)*
In the Spallation Neutron Source, at Oak Ridge National Laboratory in Tennessee, multiple-stage injections to an accumulator ring increase intensity until a final extraction delivers the full proton beam to the target via transfer line. This extraction is achieved by a series of kicker elements and a thin septum Extraction Lambertson Septum Magnet. Here we discuss the lattice geometry, beam dynamics and optics, and the vacuum, electromagnetic and electromechanical design aspects of the SNS Extraction Lambertson Septum Magnet. Relevant datums are established. Beam optics is studied. Vector calculus is solved for pitch and roll angles. Fundamental magnet sections are depicted schematically. Coil, pole and yoke design calculations and electromagnetics optimization are presented.

Work performed under contract for SNS, managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 with the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**MPPT072—3D Simulation Studies of SNS Ring Doublet Magnets**
*Jian-Guang Wang (ORNL/SNS), Nicholaos Tsoupas (BNL), Marco Venturini (LBNL)*
The accumulator ring of the Spallation Neutron Source (SNS) at ORNL employs in its straight sections closely packed quadrupole doublet magnets with large aperture of R=15.1 cm and relatively short iron-to-iron distance of 51.4 cm.* The magnetic interference among the magnets in the doublet assemblies is not avoidable due to the fringe fields. Though each magnet in the assemblies has been individually mapped to high accuracy of delta(B)/B~1x10-4, the experimental data including the magnet interference effect in the assemblies will not be available. We have performed 3D computer simulations on a quadrupole doublet model in order to assess the degree of the interference and to obtain relevant data which should be very useful for the SNS commissioning and operation. This paper reports our simulation results.
*N. Tsoupas et al. "A Large-aperture Narrow Quadrupole for the SNS Accumulator Ring," Proc. EPAC 2002, p.1106, Paris, June 3-7, 2002.

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**MPPT073—Field Distribution of Injection Chicane Dipoles in SNS Ring**
*Jian-Guang Wang (ORNL/SNS)*
3D computing simulations have been performed to study the magnetic field distribution of the injection chicane dipoles in the SNS ring.* The simulation studies have yielded the performance characteristics of the magnets and generated the magnetic field data in three dimensional grids, which can be used for detailed investigation of beam dynamics. Based on the simulation data, a 3D multipole expansion of the chicane dipole field, consisting of generalized gradients and their derivatives, has been made. The harmonic and pseudo-harmonic components in the expansion give much insight into the magnet physics. The expansion is quasi-analytical by fitting numeric data into a few interpolation functions. A 5th-order representation of the field is generated, and the effects of even higher order terms on the field representation are discussed.
*The injection chicane dipoles were designed at BNL by Y.Y. Lee, W. Meng, et al. See "Injection into the SNS Accumulator Ring: Minimizing Uncontrolled Losses and Dumping Stripped Electrons," D.T. Abell, Y.Y. Lee, W. Meng, EPAC 2000.

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**MPPT074—Design of RCS Magnets for CSNS 1.6GeV Synchrotron**
*Chang Dong Deng, Zan Cao (IHEP Beijing)*
The 1.6GeV synchrotron proposed in the Chinese Spallation Neutron Source (CSNS) project is a Rapid-Cycling Synchrotron (RCS), which accelerators a high-intensity proton beam from 70MeV to 1.6GeV at a repetition rate of 25Hz. The RCS magnet system consists of 32 dipole magnets (main dipoles), 68 quadrupole magnets (main quadrupoles), a number of sextupole magnets• Atune shift quadrupoles• Acorrector magnets, and so on. Since the magnets for the 1.6GeV synchrotron are required to have a large aperture in order to realize the large beam power 0.1 MW, one of serious issue is a large fringe field at a pole end comparing to an usual synchrotron magnets. Main dipoles and main quadrupoles are excited with 25Hz repetition frequency current and high repetition magnetic field will induce large eddy current in iron core• Aend plate and coil conductors. So, the structure and technology of the magnet core and coil are the key issue in magnet research and fabrication. In this paper the magnet design and technology considerations of the two kinds of main magnet will be described.

**MPPT075—Analysis and Design of Backing Beam for Multipole Wiggler (MPW14) at PLS**
*Hong-Gi Lee, Chin Wha Chung, Hong Sik Han, Young Gyu Jung, Dong Eon Kim, Ki-Hyeon Park, Hyung Suck Suh (PAL)*
Pohang Accelerator Laboratory (PAL) had developed and installed a Multipole Wiggler (MPW14) to utilize high energy synchrotron radiation at Pohang Light Source (PLS). The MPW14 is a hybrid type device with period of 14 cm, minimum gap of 14 mm, maximum flux density of 2.02 Tesla and total magnetic structure length of 2056 mm. The support locations and structure of an insertion device are optimized to achieve a minimum deflection due to the magnetic loads. A Finite Element Analysis (FEA) is performed to find out the amount of maximum deflection and optimal support positions on the backing beam, the support and drive structures of the MPW14 under expected magnetic load of 14 tons. To reduce the deflection effect further, two springs are designed and installed to compensate the gap dependent magnetic loads. The optimized deflection is estimated to be about 20.6 ? while the deflection before optimization is 238 ?.

**MPPT076—Conceptual Designs of Magnet System for the Taiwan Photon Source Project**
*Cheng-Hsiang Chang, Tai-Ching Fan, Ching-Shiang Hwang (NSRRC)*
The National Synchrotron Radiation Research Center (NSRRC) at Taiwan is designing a 3.0 GeV energy with ultra-low emittance storage ring for new Taiwan Photon Source (TPS) project. The storage has a circumference of 514 m with 24 periods of double-bend achromatic magnet system. The conceptual designs for each magnet family for the storage ring are optimize for operation of electron energy at 3.0- 3.3 GeV. This paper reviews the preliminary design and the key accelerator magnet issues.

**MPPT077—Radiation of Electron in the Field of Plane Light Wave**
*Andrey Yurij Zelinsky, Ilia Vladimir Drebot, Yurij Grigor'ev, Olga Zvonarjova (NSC/KIPT)*
In the work the process of electron interaction with field of oncoming light wave (Compton scattering) has been considered with methods of classical electrodynamics. As results of Lorenz equation integration the trajectories of electron motion in the wave field were derived. On the base of obtained results the expressions for electron radiation spectrum were produced.In the work dependences of spectrum shape on electron and photon beams parameters are analyzed.

**MPPT078—Present Status of Design and Development of NESTOR X-Ray Source**
*Andrey Yurij Zelinsky, Valeriy Pavel Androsov, Eugene Victor Bulyak, Ilia Vladimir Drebot, Peter Gladkikh, Vjatsheslav Grevtsev, Vadim Anatolij Ivashchenko, Ivan Karnaukhov, Vladislav Kozin, Vladimir Lapshin, Vadim Lyashchenko, Vasilij Markov, Nikolaj Mocheshnikov, Vadim Molodkin, Andrey Mytsykov, Ivan Necklyudov, Fedor Peev, Alexandr Valerij Rezaev, Alexander Shcherbakov, Vasilij Skirda, Vladislav Skomorokhov, Yurij Nikolajevich Telegin, Vladimir Trotsenko, Olga Zvonarjova (NSC/KIPT), Roman Tatchyn (SLAC), Jan Botman (TUE)*
In NSC KIPT design and development of compact X-ray source NESTOR is carrying out. The source is based on Compton backscattering. The source will provide radiation intensity up to 1012 phot/sec. The realization of the project is supporting by the NATO SfP grant #977982.In the presented work the main parameters and present status of design and development activities on Kharkov X-ray source NESTOR (New Electron STOrage Ring) are described. Status of the main complex systems (magnetic system, laser-optical system, diagnostic and power supply system, injection system and injector, construction activity) are described. It is supposed that NESTOR storage ring will take to operation in the middle of 2006 y.

**MPPT079—Measurement, Shimming and Beam Commissioning of an APPLE-II Type Undulator at Daresbury Laboratory for the SRS**
*James Clarke, Fay Elizabeth Hannon, Duncan Scott, Ben Shepherd, Naomi Wyles (CCLRC/DL/ASTeC)*
A new variable polarisation undulator of the APPLE-II type has been designed and constructed at Daresbury Laboratory. Initial magnet testing of the 56mm period device was followed by an intensive period of shimming to improve the field quality. After this was successfully completed the undulator was installed into the SRS and tests made of the effect of the device upon the electron beam. This beam commissioning was completed in a very short space of time with the beamline being given full control of the gap and phase of the magnet within a few weeks of installation. This paper summarises the measurement of the magnet and the shimming techniques employed to improve the field quality. It also describes the effect of the device upon the stored 2 GeV electron beam and the measures taken to minimise these effects during user operations.

**MPPT080—Design, Fabrication and Characterization of a Large-Aperture Quadrupole Magnet for CESR-c**
*Mark Alan Palmer, James Arthur Crittenden, Jagadisan Kandaswamy, Tim O'Connell, Alexander Temnykh (Cornell University)*
Installation of a radiative Bhabha luminosity monitor for CESR-c operation in 2004 required replacing a 40-mm aperture steel quadrupole magnet with one of aperture 75 mm, while maintaining field-quality tolerances at the level of a few parts in $10^{4}$. We present the design methodology using 2D- and 3D-finite-element field calculations, compare the calculated 3D integrals to flip-coil measurements, and discuss related mechanical tolerances.

National Science Foundation.

**MPPT081—Undulator for the LCLS Project—Changes in the Magnet Structure Design**
*Emil Trakhtenberg, Mark Erdmann, Thomas Powers (ANL)*
The design modifications of a new hybrid-type undulator with a fixed gap of 6.4 mm, a period of 30 mm and a length of 3.4 m are presented. The prior pole design included side "wings" which were used for precise positioning, and clamps to fasten poles to the magnet base. This design has been replaced by a more straightforward assembly, where the pole is attached to the magnet structure base using only two screws. Tests were performed on the vanadium permendure pole material to prove that the threaded holes are easy to fabricate and are able to successfully withstand the torque required to hold the pole in place. A fixture was also developed to ensure the precise location of the poles on the base during assembly. In addition to the pole modifications, the magnet structure base is now manufactured as one piece as opposed to three, which greatly eases assembly. Finally, a small section of the original prototype had these changes successfully implemented, and the test results are presented.

**MPPT082—The 8 cm Period Electromagnetic Wiggler Magnet with Coils Made from Sheet Copper**
*George Herman Biallas, Stephen Vincent Benson, Tommy Hiatt, George R. Neil, Michael David Snyder (Jefferson Lab)*
The electromagnetic wiggler, now lasing at the Jefferson Lab FEL, has 29 eight cm periods with K variable from 0.6 to1.1 and gap of 2.6 cm. The wiggler was made inexpensively in 11 weeks by an industrial machine shop. The conduction cooled coil design uses copper sheet material cut to forms using water jet cutting. The conductor is cut to serpentine shapes and the cooling plates are cut to ladder shape. The sheets are assembled in stacks insulated with polymer film, also cut with water jet. The coil design extends the serpentine conductor design of the Duke OK4 to more and smaller conductors. The wiggler features graded fields in the two poles at each end and trim coils on these poles to eliminate field errors caused by saturation. An added critical feature is mirror plates at the ends with integral trim coils to eliminate three dimensional end field effects and align the entrance and exit orbit with the axis of the wiggler. Details of construction, measurement methods and excellent wiggler performance are presented.

Work supported by the U.S. DOE Contract #DE-AC05-84ER40150, the Office of Naval Research, the Air Force Research Laboratory, the U.S. Army Night Vision Laboratory and the Commonwealth of Virginia.

**MPPT083—Radiation Damage to Advanced Photon Source Undulators**
*Shigemi Sasaki, Charles Doose, Elizabeth Rahm Moog, Maria Petra, Isaac Vasserman (ANL)*
Radiation-induced magnetic field strength losses are seen in undulator permanent magnets in the two sectors with small-aperture (5 mm) vacuum chambers. Initially, simple retuning of the affected undulators could restore them to full operation. As the damage has accumulated, however, it has become necessary to disassemble the magnetic arrays and either replace magnet blocks or remagnetize and reinstall magnet blocks. Some of the damaged magnet blocks have been studied, and the demagneti-

zation was found to be confined to a limited volume at the surface close to the electron beam. Models for the magnetic damage were calculated using RADIA* and were adjusted to reproduce the measurements. Results suggest that a small volume at the surface has acquired a weak magnetization in the opposite direction. Small magnet samples provided by NEOMAX and Shin-Etsu are being placed in the storage ring tunnel for irradiation exposure testing. Simulations of the radiation environment at the undulators have been performed.
*O. Chubar, P. Elleaume, J. Chavanne, J. Synchrotron Radiat. 5, 481 (1998).

Supported by the U.S. DOE Office of Science under Contract No. W-31-109-ENG-38.

**MPPT084—Dipole and Quadrupole Magnets for the Duke FEL Booster Injector**
*Stepan Mikhailov (DU/FEL, Durham, North Carolina), Nikolai Gavrilov, Denis Gurov, Oleg B. Kiselev, Alexander Ogurtsov, Egor S Rouvinsky, Konstantin Zhiliaev (BINP SB RAS)*
The full energy booster injector for the Duke FEL storage ring is presently under installation. The booster is designed to provide continuous injection into the Duke FEL storage ring in the top-off mode at the energy variable from 270 MeV to 1.2 GeV. The magnetic elements for the booster have been fabricated and magnetically measured in the Budker Institute of Nuclear Physics, Russia. The paper presents magnetic and mechanical design of the booster dipole and quadrupole magnets and results of their magnetic measurements. Results of simulation of the booster lattice taking into account residual field and non-linearity of the magnets are also presented.

This work is supported by U.S. DOE grant # DE-FG02-01ER41175 and by AFOSR MFEL grant # F49620-001-0370.

**MPPT085—Fast Magnets for the NSLS-II Injection**
*Igor Pinayev (DU/FEL, Durham, North Carolina), Timur Shaftan (BNL/NSLS)*
Third generation light sources require top-off operation in order to provide proper stability of the photon beam. In this paper we present the conceptual design of the fast pulsed magnets used for injection into the 3 GeV storage ring.

Under Contract with the U.S. Department of Energy Contract Number DE-AC02-98CH10886.

**MPPT086—Conventional Magnets Design for the Candle Storage Ring**
*Vitali Khachatryan, Artush Petrosyan (CANDLE)*
The lattice of 216m long CANDLE storage ring (16 Double Bend Achromat cells) will contain 32 gradient dipole magnets, 80 quadrupole magnets of three types and two types of sextupole magnets. Magnetic as well as mechanical design of those magnets have been performed relying on extensive world experience. Computer simulations and large volume of computations have been carried out to design magnets that conform to the requirements.

**MPPT087—Fast Magnets for Light Sources**
*Nils Hauge, Henning Bach (Danfysik A/S)*
Circular accelerators like booster synchrotrons and storage rings use fast magnets for beam injection and extraction processes. Danfysik has developed a range of simple and reliable low-cost magnets such as Kicker, Septum and Bumper Magnets. Kicker Magnet designs includes Ferrite yokes in or out of vacuum and Strip line types. Septum Magnets are all out of vacuum with active septum. Bumper Magnets are window frame magnets with thin walled beam pipes for low field attenuation. Both analytical and finite element methods (2d), including eddy current calculations, are used in the design of these magnet types. This paper describes the different magnet types built or under construction by Danfysik and their performance in different applications.

**MPPT088—Magnet Systems for Diamond Booster Synchrotron**
*Henning Bach, Nils Hauge (Danfysik A/S)*
Turn key magnet sub-systems for Synchrotron storage- and booster rings, has become a standard product,* pioneered by Danfysik A/S, for a cost effective and fast installation. Sub-systems typically concist of complete lattice sections finalized mounted with all components including vacuum system, diagnostics and infrastructure. The systems are pre-aligned and ready to connect to external supplies.
*Status of the Canadian Light Source booster synchrotron, EPAC 2002, p. 601.

**MPPT089—Magnetic Blocks Measurement and Sorting for the SOLEIL HU80 Undulator**
*Bruno Diviacco, Roberto Bracco, Cristina Knapic, Daniele Millo, Dino Zangrando (ELETTRA), Zeus Martí (LLS)*
Individual characterization of the constituent magnet blocks and their optimal sorting within the magnetic structure is a necessary step when assemblying a permanent magnet insertion device for a modern light source. A total of 750 NdFeB blocks have been purchased for the two HU80 variable polarization undulators presently under construction in the framework of an ELETTRA-SOLEIL collaboration. At ELETTRA a Helmholtz Coil system is being used for the measurement of the blocks magnetization vector. Based on these data, a sorting code has been written in order to find an optimum undulator configuration. Following a description of the algorithms used and of the quality parameters included in the optimization, the predicted field distributions and other performance indicators are shown and compared with the case of a non-sorted undulator.

**MPPT090—Design, Construction, and Field Characterization of a Variable Polarization Undulator for SOLEIL**
*Bruno Diviacco, Roberto Bracco, Cristina Knapic, Daniele Millo, Dino Zangrando (ELETTRA), Zeus Martí (LLS), Michel Massal (SOLEIL)*
Two variable polarization undulators (HU80) are being designed and constructed in the framework of an ELETTRA-SOLEIL collaboration. The four-quadrant permanent magnet structure, of the APPLE-II type, will produce various polarization modes by means of parallel or anti-parallel displacement of two diagonally opposite magnet arrays. In this paper the main aspects of the magnetic and mechanical design will be summarized. The post-assembly field quality optimization methods will be described in some detail, discussing our approach to the correction of phase, trajectory and multipole errors. Finally the magnetic measurement results on the completed device will be presented.

**MPPT091—Managing Coil Epoxy Vacuum Impregnation Systems at the Manufacturing Floor Level To Achieve Ultimate Properties in State-of-the-Art Magnet Assemblies**
*Jeffrey George Hubrig (Innovation Services, Inc), George Herman Biallas (Jefferson Lab)*
Liquid epoxy resin impregnation systems remain a state-of-the-art polymer material for vacuum and vacuum/pressure impregnation applications in the manufacture of both advanced and conventional coil winding configurations. Epoxy resins inherent

latitude in processing parameters accounts for their continued popularity in engineering applications, but also for the tendency to overlook or misinterpret the requisite processing parameters on the manufacturing floor. Resin system impregnation must be managed in detail in order to achieve device life cycle reliability. This closer look reveals how manufacturing floor level management of material acceptance, handling and storage, pre- and post- impregnation processing and cure can be built into a manufacturing plan to increase manufacturing yield, lower unit cost and ensure optimum life cycle performance of the coil.

# Tuesday, May 17, 2005

Oral Session TOAA – Magnets
Ballroom A @ 8:30
Chair: M. Harrison (BNL)

**8:30 TOAA001—Limits of Nb3Sn Magnets**
*Shlomo Caspi (LBNL/AFR), Paolo Ferracin (LBNL)*
Pushing accelerator magnets beyond 10T holds a promise of future upgrades to machines like the Tevatron at FermiLab and the LHC at CERN. Exhausting the current density limits of NbTi, superconductor, Nb3Sn is at the present time the only practical superconductor capable of generating fields beyond 10T. Several Nb3Sn pilot magnets, with fields as high as 16T, have been built and tested, paving the way for future attempts at fields approaching 20T. The combination of high current density and the required high magnetic fields has resulted in reduced conductor volume and significantly increased the accumulated Lorentz forces. Future coil and structure designs will be required to deal with stresses of several 100's of MPa and forces of 10's of MN/m. The combined engineering requirements on size and cost of accelerator magnets will require a magnet technology that diverges from the one currently used with NbTi conductor. How far can the engineering of high field magnets be pushed, what are the issues and limitations, and what tools will we need before such magnets can be used in particle accelerators. In this paper we shall address such issues and attempt to provide possible answers.

Work supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**8:55 TOAA002—U.S. Accelerator Contribution to the LHC**
*Michael Joseph Lamm (FNAL)*
In 1998, the United States entered into an agreement with CERN to help build the Large Hadron Collider (LHC), with contributions to the accelerator and to the large HEP detectors. To accomplish this, the US LHC Accelerator Project was formed, encompassing expertise from Brookhaven National Laboratory, Fermi National Accelerator Laboratory and the Lawrence Berkeley National Laboratory. Contributions from the US LHC Accelerator project included superconducting high gradient quadrupoles and beam separation dipoles for the four interaction regions and the RF section; feedboxes for cryogenic, power and instrumentation distribution; neutral and hadron beam absorbers in the high luminosity regions; design of the inner triplet cryogenic system; beam tracking studies utilizing the design IR magnet field quality and magnet alignment; particle heat deposition studies in the IR's; and short sample characterization of superconducting cables used in the arc dipoles and quadrupoles. This report is a summary of these contributions including the progress towards project completion, as well as a discussion of future plans for US participation in the LHC accelerator.

**9:20 TOAA003—Survey of Superconducting Insertion Devices for Light Sources**
*Nikolai Alexandrovich Mezentsev, Evgueni Perevedentsev (BINP)*
The first Superconducting Insertion devices were designed, fabricated and installed on electron storage rings more than 25 years ago for generation of synchrotron radiation. For these years wide experience of manufacturing and use of such superconducting insertion devices as superconducting wave length shifters, multipolar wigglers and undulators is accumulated. Review of various types of Superconducting Insertion Devices for Light Sources is given in the report. Their basic characteristics as SR sources are discussed.

**9:45 TOAA004—Field Quality Study in High-Field Nb3Sn Accelerator Magnets**
*Vadim Kashikhin, Giorgio Ambrosio, Nicolai Andreev, Emanuela Barzi, R. Bossert, Joseph DiMarco, Vladimir Kashikhin, Michael Joseph Lamm, Igor Novitski, Phil Schlabach, John Tompkins, Gueorgui Velev, Ryuji Yamada, Alexander V. Zlobin (Fermilab)*
High field accelerator magnets are being developed at Fermilab for present and next generation hadron colliders. These magnets are designed for a nominal field of 10-12 T in the magnet bore of 40-50 mm and an operating temperature of 4.5 K. To achieve these design parameters, a new, high-performance Nb3Sn superconducting strand is used. Four short Nb3Sn dipole models of the same design based on a single-bore cos-theta coil and a cold iron yoke have been fabricated and tested at Fermilab. Their field quality was measured at room temperature during magnet fabrication and at helium temperature. This paper reports the results of warm and cold magnetic measurements. The systematic geometrical harmonics and their RMS spread due to cross-section imperfections, the coil magnetization effects caused by persistent currents in superconductor and eddy current in the cable, the "snap-back" effect at injection and the iron saturation effect at high fields are presented and compared with theoretical predictions.

This work was supported by the U.S. Department of Energy.

**10:00 TOAA005—Field Quality Optimization of Superconducting Quadrupoles for the HCX Experiment**
*GianLuca Sabbi, Andy Faltens, Alan Lietzke, Sara Mattafirri, Peter Seidl (LBNL), Nicolai Martovetski (LLNL)*
The High Current Experiment (HCX) is exploring the physics of intense beams with high line-charge density. Superconducting focusing quadrupoles are being developed for future magnetic transport studies at the HCX. A baseline design was selected following the testing of several pre-series models. Optimization of the baseline design led to the development of a first prototype in 2003. This magnet achieved a conductor-limited gradient of 132 T/m in a 70 mm bore without training, with measured field errors at the 0.1% level. Based on these results, both the magnet geometry and the fabrications procedures were modified to further improve the field quality. These modifications were implemented in a second prototype. In this paper, comparisons between the design harmonics and magnetic measurements performed on the new prototype will be presented and discussed.

Supported by the Office of Energy Research, US DOE, at LBNL and LLNL under contract numbers DE-AC03-76SF00098, W-7405-Eng-48, and at MIT under contract number DE-FC02-93-ER54186.

Oral Session TOAB–Light Sources and Free-Electron Lasers
Ballroom B @ 8:30
Chair: M. Cornacchia (SLAC)

**8:30 TOAB001—VUV/Soft X-Ray FEL Projects on the Horizon**
*Rene Johan Bakker (PSI)*
Free-Electron Lasers (FELs) combine the properties of lasers and synchrotron radiation: the possibility to produce high-

power, short-pulsed, laser-like radiation in spectral regions not accessible by other light-sources. Operation of an FEL in the Vacuum Ultra Violet (VUV) to X-ray spectral region has proven challenging, however, mainly because of the increased demands set to the accelerator technology as the wavelength becomes shorter (higher peak currents and beam energy, combined with a high stability and a lower emittance and/or energy spread). Over the last decade many of these challenges have been addressed and several laboratories have demonstrated successful operation from the Infrared to the VUV. These results are very significant as they pave the way to the construction of the next-generation light-sources. Moreover, they have demonstrated the validity of the tools used to design and predict performances of such devices at these-, or ever shorter wavelengths. This presentation gives an overview of the VUV and soft X-Ray FEL activity. Emphasis goes to the proposed new user-facilities and the FEL R&D projects, which can make these- and future X-ray FEL light-sources a success.

**8:55 TOAB002—First Results from the VUV FEL at DESY**
*Bart Faatz (DESY)*
The VUV-FEL is an upgrade of the TTF1-FEL, which was taken in operation until end 2002. During this phase of the project it showed lasing in the wavelength range from 80-120 nm and it successfully provided beam for two pilot experiments. For over one year, the machine has been redesigned and upgraded, based on the experience gained during the first phase, to a user facility extending the wavelength range. Commissioning started in february 2004. In this contribution, the characterization of the VUV-FEL will be discussed, its electron beam parameters, photon beam properties and the status of the coming user experiments.

**9:20 TOAB003—First Results from the DUV-FEL Upgrade at BNL**
*Xijie Wang, James Murphy, Igor Pinayev, George Rakowsky, James Rose, Timur Shaftan, Brian Sheehy, John Skaritka, Zilu Wu, Li-Hua Yu (BNL/NSLS, Upton, Long Island, New York), Henrik Loos (SLAC)*
The DUV-FEL at BNL is the world's only facility dedicated to laser-seeded FEL R&D and its applications. Tremendous progress was made in both HGHG FEL and its applications in the last couple years.*,** In response to the requests of many users to study chemical science at the facility, the DUV-FEL linac was upgraded from 200 to 300 MeV to enable the HGHG FEL to produce 100 uJ pulses of 100 nm light. This will establish the DUV FEL as a premier user facility for ultraviolet radiation and enable state-of-the-art gas phase photochemistry research. The upgraded facility will also make possible key R&D experiments such as higher harmonic HGHG (n>5) that would lay the groundwork for future X-ray FEL based on HGHG. The upgraded HGHG FEL will operate at the 4th harmonic with the seed laser at either 800 nm or 400nm. The increase of the electron beam energy will be accomplished by installing a 5th linac cavity and two 45 MW klystrons. New HGHG modulator and dispersion sections vacuum chambers will be manufactured to accommodate new matching optics and 8th harmonic HGHG. The initial results of the DUV-FEL upgrade and other FEL and accelerator physics R&D opportunities will be discussed.
*L.H. Yu et al., Phy. Rev. Lett. 91, 074801-1 (2003). **W. Li et al., Phy. Rev. Lett. 92, 083002-1(2004).

**9:45 TOAB004—An Optimized Low-Charge Configuration of the Linac Coherent Light Source**
*Paul Emma, Zhirong Huang, Cecile Limborg-Deprey, Juhao Wu (SLAC), William M. Fawley, Max Zolotorev (LBNL), Sven Reiche (UCLA)*
The Linac Coherent Light Source (LCLS) is an x-ray free-electron laser (FEL) project based on the SLAC linac. The nominal parameter set is founded on a 1-nC bunch charge and normalized emittance of about 1 micron. The most challenging issues, such as emittance generation, wakefields, and coherent synchrotron radiation (CSR), are associated with the high bunch charge. In the LCLS in particular, with its strong linac wakefields, the bunch compression process produces sharp temporal horns at the head and tail of the bunch with degraded local emittance, effectively wasting much of the charge. The sharp horns intensify CSR in the bends and further drive a strong resistive-wall wakefield in the long FEL undulator. Although these issues are not insurmountable, they suggest a lower bunch charge may be more suitable. This study uses a 0.2-nC bunch charge and 0.85-micron emittance with only 30 A of peak current in the injector, producing the same FEL saturation length. The resulting performance is more stable, has negligible resistive-wall wakefield, greatly reduced CSR effects, and no transverse wakefield emittance dilution in the linac, with no change to the baseline engineering design.

Work supported by U.S. Department of Energy contract DE-AC02-76SF00515.

**10:00 TOAB005—4GLS and the Energy Recovery Linac Prototype Project at Daresbury Laboratory**
*Elaine Seddon, Michael W. Poole (CCLRC/DL)*
4GLS is a novel next generation proposal for a UK national light source to be sited at Daresbury Laboratory. It is based on a superconducting energy recovery linac (ERL) with capabilities for both high average current spontaneous photon sources (undulators and bending magnets) and high peak current free electron lasers. Key features of the proposal are a high gain, seeded FEL amplifier to generate XUV radiation and the prospect of advanced dynamics work arising from its unique combinations of sources and its femtosecond pulse structure. To meet the challenging accelerator technology involved, a significant R&D programme has commenced and a major part of this is a 35 MeV demonstrator, the ERL Prototype (ERLP), currently under construction. This paper summarises the 4GLS design activities, describes the ERLP in detail and explains the 4GLS project status and plans.

**Oral Session TOAC—Instabilities and Feedback**
**Ballroom C @ 8:30**
**Chair: E. Shaposhnikova (CERN)**

**8:30 TOAC001—Overview of Impedance and Single-Beam Instability Mechanisms**
*Elias Métral (CERN)*
Single-bunch and coupled-bunch instability mechanisms will be reviewed in both longitudinal and transverse planes. The resistive-wall impedance will be discussed in the particular case of the LHC collimators, which reveal a new physical regime. Stabilization by Landau damping, feedbacks, or linear coupling between the transverse planes will also be treated. Benchmarking of analytical predictions with some instability codes will be shown as well as several experimental results.

**8:55 TOAC002—Beam Loading Compensation for Super B-Factories**
*Dmitry Teytelman (SLAC)*
Super B-factory designs under consideration expect to reach luminosities in the 10^{35} - 10^{36} range. The dramatic luminosity increase relative to the existing B-factories is achieved, in part, by raising the beam currents stored in the electron and positron rings. For such machines to succeed it is necessary to consider in the RF system design not only the gap voltage and beam power, but also the beam loading effects. The main effects are the synchronous phase transients due to the uneven ring filling patterns and the longitudinal coupled-bunch instabilities driven by the fundamental impedance of the RF cavities. A systematic approach to predicting such effects and for optimizing the RF system design will be presented. Existing as well as promising new techniques for reducing the effects of heavy beam loading will be described and illustrated with examples from the existing storage rings including PEP-II, KEKB, and DAFNE.

Work supported by U.S. Department of Energy contract DE-AC02-76SF00515.

**9:20 TOAC003—Stochastic Cooling for Bunched Beams**
*Michael Blaskiewicz, Joseph Michael Brennan, Jie Wei (BNL)*
A longitudinal stochastic cooling system for RHIC is under construction and partial commissioning is planned for the upcoming run. The state of the system and future plans are discussed.

Work performed under the auspices of the U.S. DOE.

**9:45 TOAC004—Experimental Investigation of Beam Breakup in the Jefferson Laboratory 10 kW FEL Upgrade**
*Chris Tennant, David Douglas, Kevin Jordan, Lia Merminga, Eduard Pozdeyev, Haipeng Wang (Jefferson Lab), Ivan Vasilyevich Bazarov, Georg Hoffstaetter, Charles Kent Sinclair (Cornell University), Stefan Simrock (DESY), Todd Iversen Smith (Stanford University)*
In recirculating accelerators, and in particular energy recovery linacs (ERLs), the maximum current has been limited by multipass, multibunch beam breakup (BBU), which occurs when the electron beam interacts with the higher-order modes (HOMs) of an accelerating cavity on the accelerating pass and again on the energy recovered pass. This effect is of particular concern in the design of modern high average current energy recovery accelerators utilizing superconducting technology. Experimental observations of the instability at the Jefferson Laboratory 10 kW Free-Electron Laser (FEL) are presented. Measurements of the threshold current for the instability are presented and compared to the predictions of several BBU simulation codes. To further characterize the instability, beam based measurements were made to determine the orientation of the dangerous HOMs. With BBU posing a threat to high current beam operation in the FEL, several suppression schemes were developed. These include direct damping of the dangerous HOMs and appropriately modifying the electron beam optics. Preliminary results of their effectiveness in raising the threshold current for stability are presented.

This work supported by the Office of Naval Research, the Joint Technology Office, the Commonwealth of Virginia, the Air Force Research Laboratory, Cornell University and by DOE Contract DE-AC05-84ER40150.

**10:00 TOAC005—Coherent Synchrotron Radiation as a Diagnostic Tool for the LCLS Longitudinal Feedback System**
*Juhao Wu, Paul Emma, Zhirong Huang (SLAC)*
The Linac Coherent Light Source (LCLS) will be the world's first x-ray free-electron laser (FEL). To ensure the vitality of FEL lasing, a longitudinal feedback system is required together with other diagnostics. In this paper, we study the possibility of using Coherent Synchrotron Radiation (CSR) from the chicane as the diagnostic tool for bunch length feedback. Calculations show that CSR is a good candidate, even for the non-Gaussian, double-horn longitudinal charge distribution. We further check the feasibility for low and high charge options, and also the possibility for detecting the microbunching.

Work is supported by the US Department of Energy under contract DE-AC02-76SF00515.

**TOAA (Cont.)—Magnets**
**Ballroom A @ 10:40**
**Chair: J. Strait (FNAL)**

**10:40 TOAA006—Development of Superconducting Combined Function Magnets for the Proton Transport Line for the J-PARC Neutrino Experiments**
*Tatsushi Nakamoto, Yasuo Ajima, Norio Higashi, Atsuko Ichikawa, Nobuhiro Kimura, Takashi Kobayashi, Yasuhiro Makida, Toru Ogitsu, Hirokatsu Ohhata, Ken-ichi Sasaki, Minoru Takasaki, Ken-ichi Tanaka, Akio Terashima, Takayuki Tomaru, Akira Yamamoto (KEK), Michael Anerella, John Escallier, George Ganetis, Ramesh C. Gupta, Michael Harrison, Animesh Kumar Jain, Joseph F. Muratore, Brett Parker, Peter Wanderer (BNL), Tetsuhiro Obana (GUAS/AS), Yosuke Iwamoto (JAERI)*
A second generation of long-baseline neutrino oscillation experiments has been proposed as one of the main projects at J-PARC jointly built by JAERI and KEK. Superconducting combined function magnets, SCFMs, will be utilized for the 50 GeV, 750 kW proton beam line for the neutrino experiment and an R&D program is in underway at KEK. The magnet is designed to provide a combined function of a dipole field of 2.6 T with a quadrupole field of 19 T/m in a coil aperture of 173.4 mm. A series of 28 magnets in the beam line will be operated DC in supercritical helium cooling below 5 K. A design feature of the SCFM is the left-right asymmetry of the coil cross section: current distributions for superimposed dipole- and quadrupole- fields are combined in a single layer coil. Another design feature is the adoption of glass-fiber reinforced phenolic plastic spacers to replace the conventional metallic collars. To evaluate this unique design, fabrication of full-scale prototype magnets is in progress at KEK and the first prototype will be tested at cold soon. This paper will report the development of the SCFMs.

**11:05 TOAA007—SNS Injection and Extraction Devices**
*Deepak Raparia (BNL)*
The Spallation Neutron Source (SNS) is a second generation pulsed neutron source (1.5 MW) and is presently in the sixth year of a seven-year construction cycle at Oak Ridge National Laboratory. The operation of the facility will begin in 2006. The most stringent requirement for the SNS accelerator complex is to allow hands-on maintenance. Operational experiences show that the most losses occur in the injection and extraction. SNS accumulator ring injection and extraction has been design with

grate care to reduce uncontrolled losses. Injection systems consist of fast programmable kicker magnets and DC dump magnets to paint the beam in transverse phase space. Extraction systems consist of fast kicker magnets and a Lamberton magnet to extract beam in single turn. Paper will discuss design, construction and testing of these devices.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**11:30 TOAA008—Progress and Status of SNS Magnet Measurements at ORNL**
*Ted Hunter, Steve Heimsoth, Doug Lebon, Robert McBrien, Jian-Guang Wang (ORNL/SNS)*
The Spallation Neutron Source (SNS) contains more than 600 magnets. Among them, about 400 magnets for the Linac and transfer lines are being measured on site at Oak Ridge National Laboratory. These magnets include Permanent Magnet Quadrupoles, Electro-magnetic Quadrupoles, Dipoles and Correctors. The Permanent Magnet Quadrupoles are installed in the Drift Tube Linac (DTL) and are the only Permanent Magnets in the machine. These measurements are for magnets installed in the DTL, Coupled Cavity Linac (CCL), Superconducting Linac (SCL), High Energy Beam Transport (HEBT), and the Ring to Target Beam Transport (RTBT) line. All magnets have met specifications. Approximately three fourths of the magnets have so far been measured and installed. This presentation outlines the magnet measurements for SNS at ORNL and overviews the activities and accomplishments to date.

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**11:45 TOAA009—Recent Test Results of the Fast-Pulsed 4T-Dipole GSI001**
*Gebhard Moritz, Juris Kaugerts (GSI), John Escallier, George Ganetis, Animesh Kumar Jain, Andrew Marone, Joseph F. Muratore, Richard Thomas, Peter Wanderer (BNL), Martin Wilson (Oxford Instruments)*
For the FAIR-project at GSI a model dipole was built at BNL with the nominal field of 4 T and a nominal ramp rate of 1 T/s. The magnet design was similar to the RHIC dipole with some changes for loss reduction and better cooling. The magnet was already successfully tested in a vertical cryostat with good training behaviour. Cryogenic losses were measured and first results of field harmonics were published. However, for a better understanding of the cooling process quench currents at several ramp rates were investigated. Detailed measurements of the field harmonics at different ramp rates and at several cycles were performed. To separate the effects of the coil and the iron yoke the magnet was disassembled and tested as collared coil only. Recent test results will be presented.

**12:00 TOAA010—Serpentine Coil Topology for BNL Direct Wind Superconducting Magnets**
*Brett Parker, John Escallier (BNL)*
BNL direct wind technology, with the conductor pattern laid out without need for extra tooling (no collars, coil presses etc.) began with RHIC corrector production. RHIC patterns were wound flat and then wrapped on cylindrical support tubes. Later for the HERA-II IR magnets we improved conductor placement precision by winding directly on a support tube. To meet HERA-II space and field quality goals took sophisticated coil patterns, (some wound on tapered tubes). We denote such patterns, topologically equivalent to RHIC flat windings, "planar patterns." Multi-layer planar patterns run into trouble because it is hard to wind across existing turns and magnet leads get trapped at poles. So we invented a new "Serpentine" winding style, which goes around 360 degrees while the conductor winds back and forth on the tube. To avoid making solenoidal fields, we wind Serpentine layers in opposite handed pairs. With a Serpentine pattern each turn can have the same projection on the coil axis and integral field harmonics then closely follow the 2D cross section. This and other special Serpentine coils properties are discussed in this paper and applied to a variety of direct wind magnet projects.

Work supported by the U.S. Department of Energy under contract DE-AC-02-98-CH10886.

## TOAB (Cont.)—Light Sources and Free-Electron Lasers
## Ballroom B @ 10:40
## Chair: L. Rivkin (PSI)

**10:40 TOAB006—First Year of SPEAR 3 Operation**
*R. Hettel (SLAC)*
The first electrons were accumulated in the new 3-GeV SPEAR 3 storage ring in December, 2003, five days after the beginning of commissioning. By mid-January of 2004, the phase-1 current of 100 mA were stored. Ring characterization and tuning continued until early March when the first photon beam line was opened for users. By the end of the first run in July, SPEAR 3 beam properties and ring performance had been extensively measured by the accelerator and beam line groups. These included micron stability using slow orbit feedback, an emittance coupling of ~0.1% and 30-h lifetimes at 100 mA. During the present 2005 user run, turn-by-turn BPMs, fast orbit feedback, a high resolution UV synchrotron light monitor, and beam scrapers are being commissioned and 500-mA operation will be established. A modified lattice that will incorporate a double vertical waist chicane has been designed that will enable future installation of two small gap insertion devices. A study of top-off injection modes will also commence this year. The performance of SPEAR 3 during its first year of commissioning and operation, together with plans to improve performance, are described.

Work supported in part by Department of Energy Contract DE-AC03-76SF00515 and Office of Basic Energy Sciences, Division of Chemical Sciences.

**11:05 TOAB007—Femtoslicing in Storage Rings**
*S. Khan (BESSY)*
The generation of ultrashort synchrotron radiation pulses by laser-induced energy modulation of electrons and their subsequent transverse displacement, now dubbed "femtoslicing," was demonstrated at the Advanced Light Source in Berkeley. More recently, a femtoslicing user facility was commissioned at the BESSY storage ring in Berlin, and another project is in progress at the Swiss Light Source. The paper reviews the principle of femtoslicing, its merits and shortcomings, as well as the variations of its technical implementation. Various diagnostics techniques to detect successful laser-electron interaction are discussed and experimental results are presented.

Funded by the Bundesministerium fuer Bildung und Forschung and by the Land Berlin.

**11:30 TOAB008—New Storage Ring Light Sources on the Horizon**
*Boris Podobedov (BNL)*
The world's appetite for light sources keeps growing as new ones are under construction or being proposed for every continent but Antarctica. While some viable alternatives are emerging, the great majority of new light sources are based on mature electron storage ring technology. We review the design and performance of the new machines worldwide and speculate on the future directions.

Work supported by the U.S. DOE.

**11:55 TOAB009—Generation of Short X-Ray Pulses Using Crab Cavities at the Advanced Photon Source**
*Katherine C. Harkay, Michael Borland, Yong-Chul Chae, Glenn Decker, Roger J. Dejus, Louis Emery, Weiming Guo, Douglas Horan, Kwang-Je Kim, Robert Kustom, Yuelin Li, Dennis M. Mills, Stephen Milton, Elizabeth Rahm Moog, Geoffery Pile, Vadim Sajaev, Sarvjit D. Shastri, Geoff J. Waldschmidt, Marion White, Bingxin Yang (ANL), Alexander Zholents (LBNL/AFR)*
There is an increasing interest in ultra-short X-ray pulses in the synchrotron user community. Conventional third-generation light sources cannot provide short enough electron bunches. However, it was recently proposed by A. Zholents et al. to use rf orbit deflection to generate subpicosecond X-ray pulses.* In this scheme, two crab cavities are used to deliver a longitudinally dependent vertical kick to the beam, thus exciting longitudinally correlated vertical motion of the electrons. This makes it possible to spatially separate the radiation coming from different longitudinal parts of the beam. An optical slit can then be used to slice out a short part of the radiation pulse, or an asymetrically cut crystal can be used to compress the radiation in time. In this paper, we present a feasibility study of this method applied to the Advanced Photon Source. We find that the pulse length can be decreased down to a few-picosecond range using superconducting crab cavities.
*A. Zholents et al., NIM A 425, 385 (1999).

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**12:10 TOAB010—Research and Development of a Variable Polarization Superconducting Undulator at the NSLS**
*Shailendra Chouhan, George Rakowsky (BNL)*
In this work a new concept for the construction of planar variable polarization superconductive insertion device is presented. The construction of the device with 8 mm gap and magnetic period of 26 mm is described compared with permanent magnet insertion device with the same gap & period length, as well as with previously published concepts. Advantage of this design include: (1) electrical tunability for both right and left circular and elliptical, as well as linear vertical or horizontal, (2) it requires no compensation of unwanted vertical field component and (3) used only simple windings of superconductive wire in an interlaced pattern. As a first step towards the construction of full-length device we propose to build & test a short prototype that will serve as a proof of the concept for versatile variable polarization superconductor magnet.

Office Of Science.

## Oral Session TOAD—Instrumentation
## Ballroom C @ 10:40
## Chair: T. Shea (ORNL/SNS)

**10:40 TOAD001—Techniques for Pump-Probe Synchronisation of Fsec Radiation Pulses**
*Holger Schlarb (DESY)*
The increasing interest on the production of ultra-short photon pulses in future generations of Free-Electron Lasers operating in the UV, VUV or X-ray regime demands new techniques to reliably measure and control the arrival time of the FEL-pulses at the experiment. For pump-probe experiments using external optical lasers the desired synchronisation is in the order of tens of femtoseconds, the typical duration of the FEL pulse. Since, the accelerators are large scale facilities of the length of several hundred meters or even kilometers, the problem of synchronisation has to be attacked twofold. First, the RF acceleration sections upstream of the magnetic bunch compressors need to be stabilised in amplitude and phase to high precision. Second, the remain electron beam timing jitter needs to be determined with femtosecond accuracy for off-line analysis. In this talk, several techniques using the electron or the FEL beam to monitor the arrival time are presented, and the proposed layout of the synchronisation system for the European XFEL towards the 10 fsec regime.

**11:05 TOAD002—Novel Tune Diagnostics for the Tevatron**
*Cheng-Yang Tan (Fermilab)*
The Tevatron collides protons and antiprotons in the same beam pipe. This poses a challenge in the measurement of tunes for both species simultanously because of the possibility of signal contamination from the other species. On top of this, since both beams are in the same beam pipe, tunes of individual bunches are also important because tune shifts from the beam-beam effect affects each bunch differently. Three different tune diagnostics used in the Tevatron will be discussed in this paper: 1.7GHz Schottky pickups, 21.4 MHz Schottky pickups and 27 kHz baseband pickups. These pickups look at the tune spectrum at different frequency bands and provide useful physics information for each frequency regime.

**11:30 TOAD003—Development of the Beam Diagnostics System for the J-PARC Rapid-Cycling Synchrotron**
*Naoki Hayashi, Seiji Hiroki, Junichi Kishiro, Yuzou Teruyama, Ryoji Toyokawa (JAERI/J-PARC), Dai Arakawa, Seishu Lee, Takako Miura, Takeshi Toyama (KEK)*
Development of the beam diagnostics system for the J-PARC (Japan Proton Accelerator Research Complex) Rapid-Cycling Synchrotron is described. The system consists of Beam Position Monitor (BPM), Beam Loss Monitor (BLM), Current monitors (DCCT, SCT, MCT, FCT, WCM), Tune meter system, 324MHz-BPM, Profile monitor, and Halo monitor. BPM electrode is electro-static type and its electronics is designed for both COD and turn-by-turn measurements. Five current monitors have different time constants in order to cover wide frequency range. The tune meter is consisted of RFKO and the beam pick-up electrode. For the continuous injected beam monitoring, 324MHz-BPM detects Linac frequency. Two types of profile monitor are multi-wire for low intensity tuning and the residual gas monitor for non-destructive measurement.

**11:45 TOAD004—The Possibility of Noninvasive Micron High Energy Electron Beam Size Measurement Using Diffraction Radiation**
*Gennady Naumenko, A.P. Potylitsyn (Tomsk Polytechnic University), Sakae Araki, Alexander Aryshev, Hitoshi Hayano, Pavel Karataev, Toshiya Muto, Junji Urakawa (KEK), Marc Ross (SLAC), Ryosuke Hamatsu (TMU), David Cline, Yasuo Fukui (UCLA)*
During the last years a noninvasive method for beam size measurement based on the optical diffraction radiation (ODR) has been in progress (P. Karataev, et al., Physical Review Letters 93, 244802 (2004). However this technique encounters with hard sensitivity limitation for electron energies larger than several GeV. For example, for SLAC conditions the sensitivity of this method is 4 orders smaller than an appropriate one. We suggest to use a "dis-phased" slit target, where two semi-planes are turned with respect to each other at a small "dis-phased" angle. In order to ensure the interference between the diverged radiation beams we use a cylindrical lens. This method has much better sensitivity and resolution. A "dis-phased" angle 10 milliradians gives the optimal sensitivity to 5 microns transversal beam size. The theoretical model for calculating the ODR radiation from such targets (including focusing by cylindrical lens) is presented. It is shown that the sensitivity of this method does not depend on the Lorenz-factor directly. The target with the "dis-phased" angle 6.2 milliradians and the slit width 425 microns was manufactured for experimental test. Some preliminary experimental results are presented.

**12:00 TOAD005—Observation of Frequency Locked Coherent Transition Radiation**
*Roark A. Marsh, Amit S. Kesar, Richard J. Temkin (MIT/PSFC)*
Measurements of frequency locked, coherent transition radiation (CTR) were performed at the 17 GHz high-gradient accelerator facility built by Haimson Research Corporation at MIT PSFC. CTR produced from a metallic foil placed in the beam path was extracted through a window, and measured with a variety of detectors, including: diode, Helium cooled Si Bolometer, and double heterodyne receiver system. The angular energy distribution measured by the diode and bolometer are in agreement and consistent with calculations for a 15 MeV 200 mA 110 ns beam of 1 ps bunches. Heterodyne receiver measurements were able to show frequency locking, namely inter-bunch coherence at integer multiples of the accelerator RF frequency of 17.14 GHz. At the locked frequencies the power levels are enhanced by the number of bunches in a single beam pulse. The CTR was measured as a comb of locked frequencies up to 240 GHz, with a bandwidth of 50 MHz.

This work was supported by the Department of Energy, High Energy Physics, under contract DE-FG02-91ER40648.

## Poster Session TPAE—Advanced Concepts
## Ballroom E, 8:30-12:20

**TPAE001—Experiments on Wake Field Acceleration in Plasma and the Program of the Further Works in YerPhI**
*Marzik Petrosyan, Mikhaiel Akopov, Yurik Garibyan, Edouard Laziev, Robert Melikian, Yuri Nazaryan, Mesrop Oganesyan, Gevorg Petrosyan, Lyudvig Petrosyan, Vazgen Pogosyan, Gagik Tovmasyan (YerPhI)*
The use of wake field acceleration basically is aimed to obtaining of high acceleration rate in comparison with traditional methods of acceleration. Meantime in the last years in YerPhI it was offered to use wake field acceleration for acceleration of high-current electron bunches on energy about 100 MeV. Experimental installation for research of formation of high-current electron bunches of the given configuration, necessary for wake field acceleration and acceleration of these bunches in plasma is created. The installation is intended for acceleration of electron bunches with a current of few tens amperes and up to energy 1-2 MeV. For excitation of wake waves in plasma the electron accelerator of direct action with use of high-voltage pulse transformer is used. Results of researches have revealed some properties of formation of high-current bunches, especially restrictions of a electron current because of space charge effects at sub-picoseconds duration of bunches. The basic parameters of the wake field acceleration project on energy about 100 MeV are given, taking into account results of researches on experimental installation.

ISTC, Project A-405.

**TPAE002—The Project PLASMONX for Plasma Acceleration Experiments at ILIL and LNF and a Thomson X-Ray Source at SPARC**
*Luca Serafini, Franco Alessandria, Alberto Bacci, Ilario Boscolo, Simone Cialdi, Carlo De Martinis, Dario Giove, Cesare Maroli, Marco Mauri, Vittoria Petrillo, Roberto Pozzoli, Massimiliano Romé (INFN-Milano), Walter Baldeschi, Alessandro Barbini, Marco Galimberti, Antonio Giulietti, Leonida Antonio Gizzi, Petra Koester, Luca Labate, Antonella Rossi, Paolo Tommasini (CNR/IPP), Ubaldo Bottigli, Bruno Golosio, Pier Nicola Oliva, Angela Poggiu, Simone Stumbo (INFN-Cagliari), Francesco Broggi (INFN/LASA), David Alesini, Marco Bellaveglia, Sergio Bertolucci, Maria Biagini, Roberto Boni, Manuela Boscolo, Michele Castellano, Alberto Clozza, Giampiero Di Pirro, Alessandro Drago, Adolfo Esposito, Massimo Ferrario, Daniele Filippetto, Valeria Fusco, Alessandro Gallo, Andrea Ghigo, Susanna Guiducci, Maurizio Incurvati, Carlo Ligi, Fabio Marcellini, Mauro Migliorati, Andrea Mostacci, Luigi Palumbo, Luigi Pellegrino, Miro Preger, Ruggero Ricci, Claudio Sanelli, Mario Serio, Francesco Sgamma, Bruno Spataro, Alessandro Stecchi, Angelo Stella, Franco Tazzioli, Cristina Vaccarezza, Mario Vescovi, Carlo Vicario (INFN/LNF), Carlo Alberto Cecchetti, Danilo Giulietti (UNIPI), Rodolfo Bonifacio, Nicola Piovella (Universita' degli Studi di Milano)*
We present the status of the activity on the project PLASMONX, which foresees the installation of a multi-TW Ti:Sa laser system at the CNR-ILIL laboratory to conduct plasma acceleration experiments and the construction of an additional beam line at SPARC to develop a Thomson X-ray source at INFN-LNF. After pursuing self-injection experiments at ILIL, when the electron beam at SPARC will be available the SPARC laser system will be upgraded to TW power level in order to conduct either external injection plasma acceleration experiments and ultra-bright X-ray pulse generation with the Thomson source. Results of numerical simulations modeling the interaction of the SPARC electron beam and the counter-propagating laser beam are presented with detailed discussion of the monochromatic X-ray beam spectra generated by Compton backscattering: X-ray energies are tunable in the range 20 to 1000 keV, with pulse duration from 30 fs to 20 ps. Preliminary simulations of plasma acceleration with self-injection are illustrated, as well as external injection of the SPARC electron beam. The proposed time schedule for this initiative is finally shown, which is tightly correlated with the progress of the SPARC project.

**TPAE003—Numerical Study of Injection Mechanisms for Generation of Mono-Energetic Femtosecond Electron Bunch from the Plasma Cathode**
*Takeru Ohkubo, Mitsuru Uesaka (UTNL), Alexei Zhidkov (NIRS)*
Acceleration gradients of up to the order of 100GV/m and mono-energetic electron bunch up to 200MeV have recently been observed in several plasma cathode experiments. However, mechanisms of self-injection in plasma are not sufficiently clarified, presently. In this study, we carried out 2D PIC simulation to reveal the mechanisms of mono-energetic femtosecond electron bunch generation. We found two remarkable conditions for the generation: electron density gradient at vacuum-plasma interface and channel formation in plasma. Steep electron density gradient (~ plasma wave length) causes rapid injection and produces an electron bunch with rather high charge and less than 100fs duration. The channel formation guides an injected laser pulse and decreases the threshold of laser self-focusing, which leads to high electric field necessary for wave-breaking injection.

**TPAE004—Generation of Femtosecond Electron Bunches by Ultra-Intense Laser Wake-Field Acceleration in Plasma Channels**
*Alexei Zhidkov, Mitsuru Uesaka (UTNL)*
Femtosecond electron beams can be produced via wake field acceleration by short relativistically intense laser pulses and can be measured. Being fully optical, an acceleration system based on the laser wake-field acceleration allows femtosecond adjustment of a couple of electron bunches that makes femtosecond-resolved measurements practical. Investi-gation of the effects of laser and plasma parameters on the bunch duration becomes a crucial part of laser-plasma accelerators. We study numerically, through the 'moving-window' 3D particle-in-cell simulation, mechanisms of generation of tens MeV electrons in gas jet and effects of plasma and laser parameters on the bunch length. Such processes as the relativistic wave-breaking and plasma relaxation may lead to increase in the bunch duration, to picosecond range. Self-injection injection mechanisms, from the rapid wave-breaking to the relativistic self-injection, are discussed for production mono-energetic electron bunches. For generation of monoenergetic electron bunches, two different kind of plasma channels are considered: laser produce plasma channel with relatively high density, and the capillary discharge.

**TPAE005—Generation of Small Energy Spread Electron Beam from Self-Modulated Laser Wakefield Accelerator**
*Changbum Kim, In Soo Ko (POSTECH), Nasr Hafz, Guang-Hoon Kim, Hyyong Suk (KERI)*
Laser and plasma based accelerators have been studied for a next generation particle accelerator. Still, there are some problems to solve for real applications. For example, it has been observed that the accelerated electron beam from laser and plasma based accelerators has a 100% energy spread. Thus, the generation of small energy spread beam is an important issue in the laser and plasma based accelerator study. In this work, we introduce a method to control the energy spread. From a basic theory and simulation, it is found that the transverse electron distribution is changed from the Gaussian to a Maxwell-Boltzmann distribution and low energy electrons spread out more rapidly than high energy electrons as they propagate in vacuum. Thus, a small size collimator is installed to remove the small energy electrons and it is conformed that the small energy spread can be obtained from an experiment.

The authors are grateful for financial support from the Korean Ministry of Science and Technology through the Creative Research Initiatives Program.

**TPAE006—Current Status of Design of the Large-Scale Particle-in-Cell Code at KERI**
*Jincheol Benjamin Kim (POSTECH), Hyyong Suk (KERI), In Soo Ko (PAL; POSTECH)*
The current status of design of the large-scale particle-in-cell code at Center for Advanced Accelerators in the Korea Electrotechnology Research Institute is briefly introduced. The migration of the existing particle-in-cell kernel written in Fortran 90 to a new application framework in C++ is attempted. Extended class structures for the new PIC code are discussed. Advanced design concepts using design patterns are introduced and relevant patterns for large-scale scientific codes are discussed. Some design issues currently considered related to the extention of the computation scheme to generalized coordinates are considered.

This research is supported by the Creative Research Initiatives Program of Korean Ministry of Science and Technology. J. B. Kim and I. S. Ko also appreciate the financial support from CHEP at Kyoungpook National University.

**TPAE007—High-Power Positron Beams and Development Prospects for Technological Innovations**
*Vladimir Gorev (RRC Kurchatov Institute)*
The aim of this report is to discuss a project of experiments on generation of ultrastrong (gigavolts) quasi-electrostatic fields by means of powerful (about 100 MW) accelerators of positrons. The proposal to use positron beams for accumulation of the positive charge (and, consequently, for generation of the potentials) on a macroscopic body(ballistic anode), freely moving in high vacuum was discussed in Gorev.*,** This concept was been development in Gorev*** where ultrastrong quasi-electrostatic fields were proposed to be used to accelerate protons and heavy ions.As a result of a future development it was suggested that the ultrastrong potencial be created on an anode immovably suspended in electromagnetic field. The schemes essentially independent of the accelerated particle mass and consist of high current positron source, accelerator for positron and a vacuum chamber a few meters in diameter to accommodate the ballistic anode. The following issues will be under consideretion:positive charge pumping of the ballistic anode, ultrahigh current positron sources, highly unified scheme of protons, ions, negative ions and neutrals accelerators as well as macroparticle accelerator.
*V. V. Gorev., Proc. 4 Int. Conf. "Zababakhin Sc.Talks," Snezhinsk, p. 8, 1995. **V. V. Gorev and Z. Parsa. Preprint UCSB.NSF-ITP-96-159, 1996. ***V. V. Gorev. EPAC04 (in press).

**TPAE008—Analysis of Metallic Photonic Band Gap Structures for Accelerator Applications with the Boundary Integral Equation Method**
*Lyudmyla Illyashenko-Raguin, Peter Arbenz (ETH), Jean-Yves Raguin (PSI)*
Metallic photonic band gap (PBG) structures with single or multiple defects have recently been proposed for accelerator applications due their mode-selective properties. A computer code based on the method of boundary integral equations has been developed to analyse such structures. It allows fast and accurate computations of the eigenmodes and its associated modal field patterns of PBG structures with metal rods of almost arbitrary shapes. The results of some simulations are compared with those obtained with the code SUPERFISH.

**TPAE009—On the Structure of Electron and the Nature of Its Spin**
*Nikolai Maksyuta (National Taras Shevchenko University of Kyiv)*
In the given paper on the basis of euristic considerations it is confirmed for the first time that inside structures of electron and positron could be represented as left- and right-handed knotted strings. From the point of view of the knot theory these are left- and right-handed trefoils. The first argument in favour of this structure if an electron bare mass coincides with a Planck mass , is the fact that mass defect at gravitational interaction of two particles with the same masses at Planck distance coincides with. The second argument in favour of the considered structure of electron is the magnitude of knotted motion quantity. Spin of such electron (selectron) equals to zero, since according to the author's supposition it could be only in a crystal-like vacuum of "dark matter" where there is an isotropy of its inside motion. Just at selectron transition into a surrounding space crystal-like vacuum it occurs simultaneously both vacuum polarization and anisotropy of its inside motion. So selectron excites vacuum with the spin (this quasi-particle is called electron neutrino), transforming at this into the electron with the spin. In other words, electron spin is a moment of crystal vacuum response or inertia moment.

**TPAE010—Resonant Excitation of Selected Modes by a Train of Electron Bunches in a Rectangular Dielectric Wakefield Accelerator**
*Ivan N. Onishchenko, Nikolay Onishchenko, Gennadiy Sotnikov (NSC/KIPT), Thomas C. Marshall (Yale University)*
The dielectric wake field accelerator is based on particle acceleration by wake fields excited in a dielectric waveguide by a regular sequence of electron bunches. Enhancement of the accelerating field can be achieved using two phenomena: coherent excitation by many bunches (multibunch effect) and constructive interference of many excited eigenmodes (multimode effect). It was believed that the latter is possible only for planar slab geometry in which the excited modes are equally spaced in frequency. By analysis and simulation, in this presentation the effect of wake field superposition to high amplitude is demonstrated for arbitrary rectangular geometry that is more realizable in experiment. We find this result using simultaneous multibunch and multimode operation providing the repetition frequency of the bunch sequence is equal to the frequency difference between selected modes, whereupon resonant oscillation takes place. Moreover, it is shown that for an appropriate choice of selected modes and bunch repetition frequency a "quasimonopolar" peaked wake field can be excited.

This work was partly supported by CRDF award #UP2-2569-KH-04

**TPAE011—Fast Sweeping Device for Laser Bunch**
*Alexander A. Mikhailichenko (Cornell University)*
Electro-optical laser sweeping device deflects the head and tail of laser bunch into different frontal directions, so at some distance, the laser bunch becomes tilted with respect to forward direction. For sweeping of laser bunch having 300 ps duration up to 10 mrad, the voltage drop along the laser bunch must be ~10kV. Repetition rate desirable for this type of device used in laser acceleration or generation of secondary back-scattered electrons is up to 1 MHz. Details of the scheme described here.

**TPAE012—Rectangular Diamond-Lined Accelerator Structure**
*Changbiao Wang, Vyacheslav P. Yakovlev (Omega-P, Inc.), Jay L. Hirshfield (Omega-P, Inc.; Yale University)*
For high frequency accelerators with normal-conducting structures studied by the NLC/GLC collaboration and the CLIC group, rf breakdown is the main gradient limitation. In this paper, a Ka-band rectangular dielectric-lined structure is described as an attempt to increase accelerating gradient beyond the limits suitable for metallic structures. The structure is based on amorphous dielectrics that are known to exhibit high breakdown limits (~ GV/m). An example is artificial diamond that has already been successfully used on an industrial basis for large-diameter output windows of high power gyrotrons, and is produced industrially in increasing quantities. Artificial diamond has low loss tangent, moderate dielectric constant and high breakdown limit of ~2 GV/m. In the proposed structure diamond-slabs are employed to support high-gradient acceleration fields. Interposition of vacuum gaps between the dielectric slabs and the side walls is shown to reduce Ohmic losses substantially, leading to an increase in shunt impedance and reduced susceptibility to rf breakdown and fatigue on metal surfaces.

Work supported by U.S. DOE.

**TPAE013—Rectangular Dielectric-Lined Two-Beam Accelerator Structure**
*Changbiao Wang, Vyacheslav P. Yakovlev (Omega-P, Inc.), Thomas C. Marshall (Columbia University), Jay L. Hirshfield (Omega-P, Inc.; Yale University)*
A novel dielectric structure is described for a two-beam wake field accelerator (WFA), which consists of three or four rectangular dielectric slabs positioned within a rectangular conducting pipe. This structure can be thought of as equivalent to two symmetric dielectric-lined three-zone rectangular waveguides, joined side-by-side. The design mode in the two-beam structure is the LSM-31 mode, a combination of two symmetric LSM-11 modes of the two three-zone waveguides. This two-channel mode can be employed to decelerate drive particles in one channel and accelerate test particles in the other. It is possible to find structure parameters that give a high ratio of acceleration gradient for the test beam, to deceleration gradient for the drive beam, of the order of 100.

Work supported by U.S. DOE.

**TPAE014—Optical Phase Locking of Modelocked Lasers for Particle Accelerators**
*Tomas Plettner, Supriyo Sinha, Jeffrey Wisdom (Stanford University), Eric R. Colby (SLAC)*
Particle accelerators require precise phase control of the electric field through the entire accelerator structure. Thus a future laser driven particle accelerator will require optical synchronism between the high-peak power laser sources that power the accelerator. The precise laser architecture for a laser driven particle accelerator is not determined yet, however it is clear that the ability to phase-lock independent modelocked oscillators will be of crucial importance. We report the present status on our work to demonstrate long term phaselocking between two modelocked lasers to within one dregee of optical phase and describe the optical synchronization techniques that we employ.

Department of Energy DE-FG03-97ER41043, DARPA DAAD19-02-1-0184.

**TPAE015—Laser and Particle Guiding Micro-Elements for Particle Accelerators**
*Tomas Plettner, Romain Maxime Gaume, Jeffrey Wisdom (Stanford University), James Spencer (SLAC)*
Laser driven particle accelerators based on the current generation of lasers will require sub-micron control of the laser field as

well as precise beam guiding. Hence the fabrication techniques that allow integrating both elements into an accelerator-on-chip format become critical for the success of such particle accelerators. Micromachining technology for silicon has been shown to be one such feasible technology in PAC2003 but with a variety of complications on the laser side. Fortunately, in recent years the fabrication of transparent ceramics has become an interesting technology that could be applied for laser-particle accelerators in several ways. We discuss this area, its advantages such as the range of materials it provides and various ways to implement it followed by some different test examples that have been considered. One important goal of this approach is an integrated system that could avoid the necessity of having to inject either laser or particle pulses into these structures.

Department of Energy contract DE-AC02-76SF00515, DARPA contract DAAD19-02-1-0184.

**TPAE016—The Argonne Wakefield Accelerator Facility: Status and Recent Activities**

*Manoel Conde, Sergey P. Antipov, Wei Gai, Chunguang Jing, Richard Konecny, Wanming Liu, John Gorham Power, Haitao Wang, Zikri Yusof (ANL)*

The Argonne Wakefield Accelerator Facility (AWA) is dedicated to the study of electron beam physics and the development of accelerating structures based on electron beam driven wakefields. In order to carry out these studies, the facility employs a photocathode RF gun capable of generating electron beams with high bunch charges (up to 100 nC) and short bunch lengths. This high intensity beam is used to excite wakefields in the structures under investigation. The wakefield structures presently under development are dielectric loaded cylindrical waveguides with operating frequencies of 7.8 or 15.6 GHz. The facility is also used to investigate the generation and propagation of high brightness electron beams. Presently under investigation, is the use of photons with energies lower than the work function of the cathode surface (Schottky-enabled photoemission), aimed at generating electron beams with low thermal emittance. Novel electron beam diagnostics are also developed and tested at the facility. The AWA electron beam is also used in laboratory-based astrophysics experiments; namely, measurements of microwave Cherenkov radiation and fluorescence of air. We report on the current status of the facility and present recent results.

This work is supported by the U.S. Department of Energy, under contract No. W-31-109-ENG-38.

**TPAE017—Progress on High Power Tests of Dielectric-Loaded Accelerating Structures**

*Chunguang Jing, Wei Gai, Richard Konecny, Wanming Liu, John Gorham Power (ANL), Steven H. Gold (NRL)*

This paper presents a progress report on a series of high-power rf experiments that were carried out to evaluate the potential of the Dielectric-Loaded Accelerating (DLA) structure for high-gradient accelerator operation. Since the last PAC meeting in 2003, we have tested DLA structures loaded with two different ceramic materials: Alumina (Al2O3) and MCT (MgxCa1-xTiO3). The alumina-based DLA experiments have concentrated on the effects of multipactor in the structures under high-power operation, and its suppression using TiN coatings, while the MCT experiments have investigated the dielectric joint breakdown observed in the structures due to local field enhancement. In both cases, physical models have been set up, and the potential engineering solutions are being investigated.

This work was supported by the U.S. Dept of Energy, High Energy Physics Division and Office of Naval Research.

**TPAE018—34.272 GHz Multilayered Dielectric-Loaded Accelerating Structure**

*Chunguang Jing, Wei Gai, Wanming Liu, John Gorham Power (ANL), Alex Kanareykin (Euclid Concepts, LLC)*

A scheme of multilayered structure design of 34.272 GHz with alternating dielectric of 38 and 9.7 is presented. The multilayer structure employs the Bragg Fiber concepts where the dielectric layers are used to create multiple reflections in order to confine the accelerating fields, thus greatly reducing the power loss of from external metal wall. The structure will operate at TM03 mode instead of normal TM01 mode. Numerical examples for the 2- and 4-layers 34.272 GHz multilayered structures are presented with detailed analysis of TM (acceleration) modes and HEM (parasitic) modes. We found that the power attenuation of the proposed structure can be lowered from ~ 20 dB/m for a single layer structure to ~ 6 dB/m for 2 -4 layered structure in at 34.272 GHz. We will also present a coupler design for the multilayered dielectric-loaded accelerating structure, which has capability of mode selection and high efficient RF transmission.

**TPAE019—Experimental Progress on a 1 GeV Laser Accelerator at LBNL**

*Wim Leemans, Eric Esarey, Cameron Guy Robinson Geddes, Csaba Toth, Jeroen Van Tilborg (LBNL), Pierre Michel, Bob Nagler, Kei Nakamura, Carl Bernhardt Schroeder (LBNL/CBP), Anthony J. Gonsalves, Simon Hooker, D Spence (OXFORDphysics), Thomas Cowan, Catalin Filip, Estelle Michel (University of Nevada)*

Experimental progress towards the realization of a 1 GeV laser-driven plasma-based accelerator at the L'OASIS facility of LBNL will be discussed. The design of the 1 GeV accelerator module consists of two components: (1) an all-optical electron injector and (2) a plasma channel for laser guiding and electron acceleration to high energy via the laser wakefield acceleration (LWFA) mechanism. Experimental results on the injector development include the demonstration of laser guiding at relativistic intensities in preformed plasmas and production of quasi-monochromatic electron beams with energy around 100 MeV. Recently guiding experiments using the 100 TW-class laser upgrade of the L'OASIS facility have been started with capillary discharges. The capillary system provides multi-cm scale plasma channels in hydrogen gas at densities on the order of 10^18 cm^-3. Such densities are required to have sufficiently high phase velocity of the plasma wave to result in GeV electron beams.

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**TPAE020—Electron Injection into Laser Plasma Wakefields via Two-Beam Colliding Pulse Scheme**

*Kei Nakamura, Eric Esarey, Gwenael Fubiani, Cameron Guy Robinson Geddes, Wim Leemans, Pierre Michel, Carl Bernhardt Schroeder, Csaba Toth, Jeroen Van Tilborg (LBNL), Catalin Filip (University of Nevada)*

Laser driven plasma-based accelerators have succeeded in producing high quality electron beams containing considerable amount of charge (>100 pC) at energies in excess of 100 MeV. For application, positive control of the electron injection phase of the plasma wave is desirable to provide energy-tunable monoenergetic electron beam in a reproducible manner. The Laser triggered electron injection into wakefields with the colliding pulse scheme* allows us to perform such an accelerator. We report on the progress of the experiments employing two laser, the wakefield drive beam and the colliding injection beam. The experiments use the multi-beam, multi-terawatt Ti:Al2O3

laser at the l'OASIS facility of LBNL. Two counter propagating beams 19 degree angle are focused onto a high density (10^19/cm^3) gas jet. Preliminary results indicate that electron beam properties are affected by the colliding beam. Details of the experiments will be shown.
*G. Fubiani, et., al, Phys. Rev. E 70, 016402 (2004).

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**TPAE021—Laser Guiding of a 100 TW Laser Beam in a Capillary Discharge Waveguide**
*Bob Nagler (LBNL/CBP), Eric Esarey, Catalin Filip, Cameron Guy Robinson Geddes, Wim Leemans, Csaba Toth (LBNL), Anthony J. Gonsalves, Simon Hooker, D. Spence (OXFORDphysics), Thomas Cowan (University of Nevada)*
Experiments are underway at LBNL on guiding high peak power (up to 100 TW), ultra-short (<50 fs) laser pulses using a pre-formed plasma channel created by an electrical discharge in a capillary. The laser beam is produced by the multi-beam l'OASIS Ti:sapphire laser system and is focused onto the entrance of the capillary using a 2 meter focal length off-axis parabola. The capillary has been developed at Oxford University and creates a fully ionized plasma channel with a radial density profile that is suitable for guiding over a length ranging from 30 to 70 mm. The laser beam is monitored using a CCD camera based mode profile diagnostic, an optical spectrometer and a pulse length diagnostic. Experimental results will be presented on the plasma channel characteristics and on laser guiding and its dependenceo n laser and channel parameters.

This work is sponsored by the Department of Energy - High Energy Physics under contract DE-AC03 76SF0098.

**TPAE022—Analytical and Numerical Calculations of Two-Dimensional Dielectric Photonic Band Gap Structures and Cavities for Laser Acceleration**
*Ksenia R. Samokhvalova, Chiping Chen (MIT/PSFC), Bao Liang Qian (National University of Defense Technology)*
Dielectric photonic band gap (PBG) structures have many promising applications in laser acceleration. For these applications, accurate determination of fundamental and high order band gaps is critical. We present the results of our recent work on analytical calculations of two-dimensional (2D) PBG structures in rectangular geometry. We compare the analytical results with computer simulation results from the MIT Photonic Band Gap Structure Simulator (PBGSS) code, and discuss the convergence of the computer simulation results to the analytical results. Using the accurate analytical results, we design a mode-selective 2D dielectric cylindrical PBG cavity with the first global band gap in the frequency range of 8.8812 THz to 9.2654 THz. In this frequency range, the TM01-like mode is shown to be well confined.

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**TPAE023—3D Metallic Lattices for Accelerator Applications**
*Michael A. Shapiro, Jagadishwar R. Sirigiri, Richard J. Temkin (MIT/PSFC), Gennady Shvets (The University of Texas at Austin)*
We present the results of research on 3D metallic lattices operating at microwave frequencies for application in (1) accelerator structures with higher order mode suppression, (2) Smith-Purcell radiation beam diagnostics, and (3) polaritonic materials for laser acceleration. Electromagnetic waves in a 3D simple cubic lattice formed by metal wires are calculated using HFSS. The bulk modes in the lattice are determined using single cell calculations with different phase advances in all three directions. The Brillouin diagram for the bulk modes is presented and indicates the absence of band gaps in simple lattices except the band below the cutoff. Lattices with thin wires as well as with thick wires have been analyzed. The Brillouin diagram also indicates the presence of low frequency 3D plasmon mode as well as the two degenerate photon modes analogous to those in a 2D lattice. Surface modes for a semi-infinite cubic lattice are modeled as a stack of cells with different phase advances in the two directions along the surface. The surface modes are found for both the thin and thick wire lattices in the band below the cutoff. They demonstrate that the lattice acts as a negative dielectric constant material.

DOE-HEP

**TPAE024—Determination of Phase Space in SLAC Main Accelerator Beams and Application to Plasma Accelerator Studies**
*Christopher Barnes, Franz-Josef Decker, Paul Emma, Mark Hogan, Rasmus Ischebeck, Richard Iverson, Patrick Krejcik, Caolionn O'Connell, Robert Siemann, Dieter Walz (SLAC), Chris Clayton, Chengkun Huang, Devon K. Johnson, Chan Joshi, Wei Lu, Kenneth Marsh, Warren Mori, Miaomiao Zhou (UCLA), Suzhi Deng, Tom Katsouleas, Patric Muggli, Erdem Oz (USCa)*
In the E164 Experiment at that Stanford Linear Accelerator Center (SLAC), we seek to drive plasma wakes for electron acceleration using 28.5 GeV bunches from the main accelerator. These bunches can now be made with an RMS length of less than 20 microns, and direct measurement is not feasible. Instead, we use an indirect technique, measuring the energy spectrum at the end of the linac and comparing with detailed simulations of the entire machine. We simulate with LiTrack, a 2D code developed at SLAC which includes wakefields, synchrotron radiation and all second order optical aberrations. Understanding the longitudinal profile allows a better understanding of acceleration in the plasma wake, as well as investigation of possible destructive transverse effects. We present results from the July 2004 experimental run and show how this technique aids in data analysis. We also discuss accuracy and validation of phase space determinations.

**TPAE025—Field Ionization of a Neutral Lithium Vapor Using a 28.5 GeV Electron Beam**
*Caolionn O'Connell, Christopher Barnes, Franz-Josef Decker, Mark Hogan, Richard Iverson, Patrick Krejcik, Robert Siemann, Dieter Walz (SLAC), Chris Clayton, Chengkun Huang, Devon K. Johnson, Chan Joshi, Wei Lu, Kenneth Marsh, Warren Mori, Miaomiao Zhou (UCLA), Suzhi Deng, Tom Katsouleas, Patric Muggli, Erdem Oz (USC)*
The E164/E164X plasma wakefield experiment studies beam-plasma interactions at the Stanford Linear Acceleration Center (SLAC). Due to SLAC recent ability to variably compress bunches longitudinally from 650 microns down to 20 microns, the incoming beam is sufficiently dense to field ionize the neutral Lithium vapor. The field ionization effects are characterized by the beam's energy loss through the Lithium vapor column. Experimental results are presented.

**TPAE026—Wakefields in a Dielectric Tube with Frequency Dependent Dielectric Constant**
*Robert Siemann, Alex Chao (SLAC)*
Dielectric laser driven accelerators could operate at a fundamental mode frequency where consideration must be given to the frequency dependence of the dielectric constant when calculating wakefields. Wakefields are calculated for a frequency dependence that arises from a single atomic resonance. Causality is considered, and the effect on the short range wakefield is calculated.

U.S. Department of Energy.

**TPAE027—Calculations for Tera-Hertz (THz) Radiation Sources**
*James Spencer, Yasser Hussein (SLAC), Samir El-Ghazaly (University of Tennessee)*
We explore possibilities for THz sources from 0.3 - 30 THz. While still inaccessible, this broad gap is even wider for advanced acceleration schemes extending from X or, at most, W band RF at the low end up to CO2 lasers. While the physical implementations of these two approaches are quite different, both are proving difficult to develop so that even lower frequency, superconducting RF seems to be the currently preferred means. Similarly, the validity of modelling techniques varies greatly over this range of frequencies but generally mandates coupling Maxwell's equations to the appropriate device transport physics for which there are many options. Here we calculate radiation from shaped transmission lines using finite-difference, time-domain (FDTD) simulations of Maxwell's equations coupled to Monte-Carlo techniques for both the production and transport physics of short electron pulses. Examples of THz sources that demonstrate coherent interference effects will be discussed with the goal of optimizing on-chip THz radiators for different applications - ultimately including improved electron sources and accelerators.

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**TPAE028—Beam Dynamics Studies for a Laser Acceleration Experiment**
*James Spencer, Eric R. Colby, Robert Noble, Dennis Thomas Palmer, Robert Siemann (SLAC)*
The NLC Test Accelerator at SLAC was built to address various beam dynamics issues for the Next Linear Collider. An S-Band RF gun, originally proposed for the NLCTA, is being installed together with a large-angle extraction line at 60 MeV. This is followed by a matching section, final focus and buncher for the laser acceleration experiment, E163. The laser-electron interaction area is followed by a broad range, high resolution spectrometer (HES) for electron bunch analysis. The RF gun is discussed in another paper. We discuss only the beam dynamics and high resolution analysis system at 6 MeV based on using Parmela and high-order Transport for bunch charges from 50 pC to 1 nC. Beyond the diagnostics, this system uses the emittance compensating solenoids and a low energy, high resolution spectrometer (LES) to help tune for best operating point and match to the linac. Optical symmetries in the design of the 25.5° extraction line provide 1:1 phase space transfer without linear dispersion or use of sextupoles for a large, 6D phase space volume and range of input conditions. Tolerances and tuning sensitivities (knobs) for certain parts of the system are discussed.

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**TPAE029—High Order Resonance IFEL Interaction at 800 nm**
*Chris M.S. Sears, Eric R. Colby, Benjamin Cowan, Robert Siemann, James Spencer (SLAC), Tomas Plettner (Stanford University)*
The inverse Free Electron Laser (IFEL) interaction has recently been proposed and used as a short wavelength modulator for micro bunching of beams for laser acceleration experiments*,**. These experiments utilized the fundamental of the interaction between the laser field and electron bunch. In the current experiment, we explore the higher order resonances of the IFEL interaction from a 3 period, 1.8 centimeter wavelength undulator with a picosecond, 0.25 mJ/pulse laser at 800 nm. The resonances are observed by adjusting the gap of the undulator while keeping the beam energy constant. We will also discuss diagnostics for obtaining beam overlap and statistical techniques used to account for machine drifts and analyze the data.
*W. D. Kimura, et. al., Phys. Rev. S.T. Acc. & Beams 4 101301 (2001). **P. Musumeci, et. al., AAC 2004 Proceedings. Pg 170.

This work supported by Department of Energy contracts DE-AC03-76SF00515 (SLAC) and DE-FG03-97ER41043-II (Stanford).

**TPAE030—Distributed Bragg Coupler for Optical All-Dielectric Electron Accelerator**
*Zhiyu Zhang, Ronald Ruth, Sami G. Tantawi (SLAC)*
A Bragg waveguide consisting of multiple dielectric layers with alternating index of refraction becomes an excellent option to form electron accelerating structure powered by high power laser sources. It provides confinement of a synchronous speed-of-light mode with extremely low loss. However, laser field can not be coupled into the structure collinearly with the electron beam. There are three requirements in designing input coupler for a Bragg electron accelerator: side-coupling, selective mode excitation, and high coupling efficiency. We present a side coupling scheme using Bragg grating assisted input coupler to inject the laser field into the waveguide. Side coupling is achieved by a second order Bragg grating with period on the order of optical wavelength. The phase matching condition results in resonance coupling thus providing selective mode excitation capability. The coupling efficiency is limited by profile matching between the outgoing beam and the incoming beam which is normally a Gaussian profile. We demonstrate a non-uniform distributed grating structure generating outgoing beam with Gaussian profile and therefore increasing the coupling efficiency.

Department of Energy.

**TPAE031—Simulations of Laser Pulse Coupling and Transmission Efficiency in Plasma Channels**
*Rodolfo Giacone, David L. Bruhwiler, Dimitre Dimitrov, Peter Messmer (Tech-X), John R. Cary (CIPS; Tech-X), Eric Esarey, Cameron Guy Robinson Geddes, Wim Leemans (LBNL)*
Optical guiding of the laser pulse in a laser wakefield accelerator (LWFA) via plasma channels can greatly increase the interaction length and, hence, the maximun energy of trapped electrons.* Energy efficient coupling of laser pulses from vacuum into plasma channels is very important for optimal LWFA performance. We present 2D particle-in-cell simulations of this problem using the VORPAL code.** Some of the mechanisms considered are enhanced leakage of laser energy transversely through the channel walls, enhanced refraction due to tunneling ionization of neutral gas on the periphery of the gas jet, ionization of neutral gas by transverse wings of the laser pulse and effect of the pulse being off axis of the channel. Using power spectral diagnostics,*** we are able to differentiate between

pump depletion and leakage from the channel. The results from our simulations show that for short (\approx"_{p}) plasma ramp, very little leakage and pump depletion is seen. For narrow channel walls and long ramps, leakage increases significantly. *C. G. R. Gedes et al., Nature 431 (2004), p. 538. **C. Nieter and J. R. Cary, J. Comp. Phys. 196 (2004), p. 448. ***D. A. Dimitrov et al., Proc. Advanced Accel. Concepts Workshop (2004).

Work supported by U.S. DOE under contracts DE-FG03-02ER83557, DE-FC02-01ER41178, DE-AC03-76SF00098, DE-FG03-95ER40926 and use of NERC supercomputer facilities.

**TPAE032—Particle-in-Cell Simulations of Lower-Density CM-Scale Capillary Channels**

*Peter Messmer, David L. Bruhwiler (Tech-X), Eric Esarey, Cameron Guy Robinson Geddes, Wim Leemans, Brad Shadwick (LBNL), Carl Bernhardt Schroeder (LBNL/CBP)*

Capillary channels of cm-length and at plasma density low compared to gas jets are promising setups for low noise laser wakefield acceleration. Computationally, however, the large discrepancy of the length scales of the plasma and the laser are a big challenge. Methods are therefore sought that relax the need to concurrently resolve both length scales. Moving windows allow to reduce the size of the computational box to a few plasma wave-lengths, which can already be a big gain compared to the full length of the capillary. On the other hand, average methods allow to relax the constraint to resolve the laser wavelength. These methods split the laser induced current into a fast varying part and a slowly varying envelope. The average over the fast timescales is performed in a semi analytic way, leaving the evolution of the envelope to be modeled. Such an envelope model is currently being incorporated into the VORPAL code.* Preliminary results show considerable time savings compared to fully resolved simulations. The status of this ongoing work will be presented.

*C. Nieter and J. R. Cary, J. Comp. Phys. 196 (2004), p. 448.

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**TPAE033—Experimental and Numerical Studies of Particle Acceleration by an Active Microwave Medium**

*Paul Schoessow (Tech-X), Alex Kanareykin (Euclid Concepts, LLC)*

There has been considerable theoretical work on the so-called PASER concept, in which a particle beam is accelerated directly by absorbing energy from an active medium, analogous to the amplification of an optical signal in a laser. Use of an active microwave (maser) medium would have the advantage of requiring relaxed beam quality (mm vs. nm characteristic beam dimensions). Recent work using electron paramagnetic resonance (EPR) techniques has demonstrated activity in the microwave regime (i.e. negative imaginary part of the magnetic susceptibility) for a class of organic compounds. A solution of fullerene (C60) in a liquid crystal solvent has been reported in the literature to possess a maser transition in the X-band region. An external DC magnetic field is required to obtain the effect; the frequency of the maser transition is adjustable by varying the magnetic field strength. We will report on the development of numerical and laboratory tools to evaluate the use of this material for accelerator applications, and evaluate the feasibility of an accelerating structure based on an active microwave medium.

**TPAE034—Hose Instability of Intense Electron Beam in a Self-Ionized Gas**

*Suzhi Deng, Tom Katsouleas, Patric Muggli, Erdem Oz (USC), Christopher Barnes, Franz-Josef Decker, Richard Iverson, Caolionn O'Connell (SLAC), Chris Clayton, Ricardo A. Fonseca, Chengkun Huang, Devon K. Johnson, Chan Joshi, Wei Lu, Warren Mori, Miaomiao Zhou (UCLA)*

The propagation of an intense relativistic electron beam through a gas that is self-consistently ionized by the beam space charge and wake fields is examined. A new instability mechanism associated with the gas ionization is found and studied analytically and with 3-D PIC simulations. The growth rate of the ionization hosing is generally smaller than that of the electron hose instability in pre-formed plasmas. When the self-fields of the beam are right above the tunnel-ionization threshold, both ionization hose and traditional electron hose get suppressed. This suggests a possible regime for hose stable plasma wakefield accelerators.

DOE: DE-FG02-92ER40745, DOE-SCIDAC: DE-FC02-01ER41192.

**TPAE035—Halo Formation and Emittance Growth of Positron Beams in Long, Dense Plasmas**

*Patric Muggli, Tom Katsouleas, Seung lee (USC), Ralph Assmann (CERN), Pantaleo Raimondi (INFN/LNF), Franz-Josef Decker, Mark Hogan, Richard Iverson, Robert Siemann, Dieter Walz (SLAC, Menlo Park, California), Brent Blue, Chris Clayton, Evan Dodd, Chan Joshi, Kenneth Marsh, Warren Mori, Shouquin Wang (UCLA)*

The propagation of a 28.5 GeV positron beam in a 1.4 m-long, <5e14/cc density, pre-ionized plasma is studied experimentally and numerically. The positron bunch propagating in a neutral plasma attracts the plasma electrons toward and through the bunch, which is in turn focused. However, the focusing force varies non-linearely, both along and across the bunch therefore also resulting in halo formation and emittance growth. These effects are observed experimentally by recording the transverse beam image downstream from the plasma, and are well described by numerical simulations. Simulation results show that the final emittance is dominated by growth in the first and last longitudinal slices of the bunch. Bunches entering the plasma with an emittance ratio of 5 in the transverse planes exit the plasma with approximately equal emittances. Emittance growth also modifies the characteristics of the focusing force along the plasma column. Understanding and controlling emittance growth by positron beams in long, dense plasmas is critical for future high energy plasma accelerator for electron/positron collider.

Work supported by U.S. DOE.

**TPAE036—First Results of the CRFQ Proof of Principle**

*Alessandro Ruggiero, James Alessi, Vincent Lo Destro (BNL), Maria Rosaria Masullo (INFN-Napoli), Luigi Campajola, Vittorio Giorgio Vaccaro (Naples University Federico II), Daniele Davino (Universita'degli Studi del Sannio)*

The Circular Radio-Frequency Quadrupole (CRFQ) is a new concept of a storage and accelerator ring for intense beams of light and heavy ions, protons and electrons. It is basically a Linear Radio-Frequency Quadrupole completely bent on a circle. The advantages, that are expected to be the same performance features of a linear RFQ, would be smaller overall dimension with respect to accelerators with comparable beam intensity and emittance. A collaboration between BNL and INFN, University of Naples and University of Sannio was setup at the end of 2002 with the aim of the proof of the bending principle. The prototype design is based on a 4-rods scheme and has a linear sector followed by a 45-degree curved sector. The

1mA proton beam produced by a reconditioned RF source goes through a beam gap diameter of 10mm with circular 10mm diameters rods. Each sector is 700 mm long and is placed in 150 mm diameter pipe. The RF power at 202.56 MHz is fed by a CERN "Frank James" 50 kW amplifier. In this paper the first power and beam tests of the linear and curved sectors are presented.

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**TPAE037—Numerical Simulations of the Laser Acceleration Experiment at the Femilab/NICADD Photoinjector Laboratory**

*Philippe Regis-Guy Piot (Fermilab), Adrian C. Melissinos, Rodion Tikhoplav (Rochester University)*

The possibility of using a laser to accelerate electrons in a waveguide structure with dimension much larger than the laser wavelength was first proposed by Pantell [NIM A 393 pg 1-5 (1997)] and investigated analytically by M. Xie [reports LBNL-40558 (1997) and LBNL-42055 (1998) available from LBNL Berkeley]. In the present paper we present the status of our experimental plan to demonstrate the laser interaction on an electron beam with initial momentum of 40-50 MeV/c. A laser (lambda=1.06 micron) operating on the TM*01 mode has been developed. The large wavenumber (k~6x10^6 m^-1) together with the initial low electron momentum poses a serious problem for efficient acceleration. In the present paper, we present start-to-end simulations of the laser acceleration experiment as foreseen to be installed in the upgraded Femilab/NICADD photoinjector laboratory.

**TPAE038—Particle-in-Cell Simulation of LWFA Using 50 fs Pulses in Guided and Unguided Plasmas**

*Frank Shih Yu Tsung, Ricardo Fenseca, Chan Joshi, Wei Lu, Warren Mori, Luis O Silva, Michail Tzoufras (UCLA)*

In 2004, we reported on 3D simulation results that using a modest laser, it was possible to generate a ~250 MeV monoenergetic beam with .5 nC of charge and to generate a few .8GeV electrons (Tsung et al, Phys. Rev. Lett., 93, 185002). We found that the self-injected electrons originated only after the laser distorted from a combination of photon deceleration and longitudinal group velocity dispersion and these electrons originated from the edge of the laser. We also observed that the mono-energetic nature arose due to phase space rotation and beam loading. In the September, 30, 2004 issue of Nature, many experimental groups have reported the observation of mono-energetic beams of electrons in the range of 100 MeV. These experiments have been performed for a range of plasma parameters. We have begun to systematically study (in 2 and 3D) the acceleration mechanisms for plasma conditions under which these experiments operated to verify that what we observed in our simulations is universal. Our 3D simulation of the experiment by Mangles et al produced excellent agreement in electron energy spectrum and we have begun to look at the other two experiments reported in Nature.

Work supported by DOE and NSF.

**TPAE039—The Effects of Ion Motion in Very Intense Beam-Driven Plasma Wakefield Accelerators**

*James Rosenzweig, Alan Cook, Matthew Colin Thompson, Rodney Yoder (UCLA)*

Recent proposals for using plasma wakefield accelerators in the blowout regime as a component of a linear collider have included very intense driver and accelerating beams, which have densities many times in excess of the ambient plasma density. The electric fields of these beams are widely known to be large enough to completely expel plasma electrons from the beam path; the expelled electrons often attain relativistic velocities in the process. We examine here another aspect of this high-beam density scenario: the motion of ions. In the lowest order analysis, for both cylindrically symmetric and "flat" beams, it is seen that for the recently discussed "after-burner" scenario the ions completely collapse inside of the electron beam. In this case the ion density is significantly increased, with a large increase in the beam emittance expected as a result. Particle-in-cell simulations of ion-collapse in the nonlinear regime are discussed.

This work is supported by U.S. Dept. of Energy grant DE-FG03-92ER40693.

**TPAE040—Nonlinear Theory in the Blowout Regime for Both Particle Beam and Laser Drivers**

*Wei Lu, Ricardo Fenseca, Chengkun Huang, Warren Mori, Luis O Silva, Frank Shih Yu Tsung, Michail Tzoufras, Miaomiao Zhou (UCLA), Tom Katsouleas (USC)*

Recent progress in both PWFA and LWFA has confirmed the promising characteristics of the blowout regime. So it is worthwhile to understand the wake excitation process and other relevant issues (e.g. self trapping mechanism, laser self guiding, scaling laws) in this regime. Because the plasma electrons always cross each other in the blowout regime, it is not possible to use a fluid model. Instead, we use a particle picture. Based on the analysis of the innermost particle trajectory, we have developed a self-consistent theory for this regime. For particle beam drivers, we explained why linear theory can be a good approximation in the weakly nonlinear blowout regime and also obtained formulas to predict the wake amplitude. In the strongly nonlinear blowout regime (relativistic or ultra-relativistic), the theory can predict the wake structures and amplitudes in terms of the particle beam or laser pulse intensity. The theory also provides a basis for a beam loading theory in the blowout regime as well a basis for finding optimum driver profile. We will also give some results on the energy gain and total charge scalings based on this theory.

DOE and NSF.

**TPAE041—Modeling TeV Class Plasma Afterburners**

*Chengkun Huang, Chris Clayton, Johnson Devon, Chan Joshi, Wei Lu, Warren Mori, Miaomiao Zhou (UCLA), Christopher Barnes, Franz-Josef Decker, Mark Hogan, Richard Iverson, Caolionn O'Connell (SLAC), Suzhi Deng, Tom Katsouleas, Patric Muggli, Erdem Oz (USC)*

Plasma wakefield acceleration can sustain acceleration gradients three orders of magnitude larger than conventional RF accelerator. In the recent E164X experiment, substantial energy gain of about 3Gev has been observed. Thus, a plasma afterburner, which has been proposed to double the incoming beam energy for a future linear collider, is now of great interest. In an afterburner, a particle beam drives a plasma wave and generates a strong wakefield which has a phase velocity equal to the velocity of the beam. This wakefield can then be used to accelerate part of the drive beam or a trailing beam. Several issues such as the efficient transfer of energy and the stable propagation of both the drive and trailing beams in the plasma are critical to the afterburner concept. We investigate the nonlinear beam-plasma interaction in such scenario using the 3D computer modeling code QuickPIC. We will report the latest simulation results of both 50 GeV and 1 TeV plasma afterburner stages for electrons including the beam-loading of a trailing

beam. Analytic analysis of hosing instability in this regime will be presented.

Work supported by DOE and NSF.

**TPAE042—Beam Matching to a Plasma Wake Field Accelerator Using a Ramped Density Profile at the Plasma Boundary**

*Kenneth Marsh, Chris Clayton, Chengkun Huang, Devon K. Johnson, Chan Joshi, Wei Lu, Warren Mori, Miaomiao Zhou (UCLA), Christopher Barnes, Franz-Josef Decker, Mark Hogan, Richard Iverson, Patrick Krejcik, Caolionn O'Connell, Robert Siemann, Dieter Walz (SLAC), Suzhi Deng, Tom Katsouleas, Patric Muggli, Erdem Oz (USC)*

An important aspect of plasma wake field accelerators (PWFA) is stable propagation of the drive beam. In the under dense regime, the drive beam creates an ion channel which acts on the beam as a strong thick focusing lens. The ion channel causes the beam to undergo multiple betatron oscillations along the length of the plasma. There are several advantages if the beam size can be matched to a constant radius. First, simulations have shown that instabilities such as hosing are reduced when the beam is matched. Second, synchrotron radiation losses are minimized when the beam is matched. Third, an initially matched beam will propagate with no significant change in beam size in spite of large energy loss or gain. Coupling to the plasma with a matched radius can be difficult in some cases. This paper shows how an appropriate density ramp at the plasma entrance can be useful for achieving a matched beam. Additionally, the density ramp is helpful in bringing a misaligned trailing beam onto the drive beam axis. A plasma source with boundary profiles useful for matching has been created for the PWFA experiments at SLAC.

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**TPAE043—Production of Terahertz Seed Radiation for FEL/IFEL Microbunchers for Second Generation Plasma Beatwave Experiments in Neptune**

*Joseph Ralph, Chan Joshi, James Rosenzweig, Chieh Sung, Sergei Tochitsky (UCLA)*

To achieve phase locked injection of short electron bunches in a plasma beatwave accelerator, the Neptune Laboratory will utilize microbunching in an FEL or IFEL system. These systems require terahertz (THz) seed radiation on the order of 10 kW for the FEL and 10 MW for the IFEL bunchers. We report results of experiments on THz generation using nonlinear frequency mixing of CO2 laser lines in GaAs. A two-wavelength laser beam was split and sent onto a 2.5 cm long GaAs crystal cut for noncollinear phase matching. Low power measurements achieved ~1 W of 340 m andμm radiation using 200 ns CO2 pump pulses with wavelengths 10.3μ m. We also demonstrated tunability of difference frequency radiation,μ10.6 m by mixing two different CO2 laser lines. By going toproducing 240 shorter laser pulses and higher intensities, we were able to increase the conversion efficiency while decreasing the surface damage threshold. Using m radiation. Future studies in thisμ200ps pulses we produced ~2 MW of 340  area will focus on developing large diameter Quasi-Phase matched structures for production of high power THz radiation.

This work was supported by the DOE Contract No. DE-FG03-92ER40727.

**TPAE044—Terahertz IFEL/FEL Microbunching for Plasma Beatwave Accelerators**

*Chieh Sung, Chan Joshi, Pietro Musumeci, Claudio Pellegrini, Sven Reiche, James Rosenzweig, Sergei Tochitsky (UCLA)*

In order to obtain monoenergetic acceleration of electrons, phase-locked injection using electron microbunches shorter than the accelerating structure is necessary. For a laser-driven plasma beatwave accelerator experiment, we propose to microbunch the electrons by interaction with terahertz (THz) radiation in an undulator via two mechanisms– free electron laser (FEL) and inverse free electron laser (IFEL). Since the high power FIR radiation will be generated via difference frequency mixing in GaAs by the same CO2 beatwave used to drive the plasma wave, electrons could be phase-locked and pre-bunched into a series of microbunches separated with the same periodicity. Here we examine the criteria for undulator design and present simulation results for both IFEL and FEL approaches. Using different CO2 laser lines, electrons can be microbunched with different periodicity 300 – 100 mm suitable for injection into plasma densities in the range 1016 – 1017 cm-3, respectively. The requirement on the THz radiation power and the electron beam qualities are also discussed.

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**TPAE045—Is it Possible To Generate nC, Mono-Energetic Electron Beams at 1GeV and Beyond Using Existing or Near Term Lasers via LWFA?**

*Michail Tzoufras, Ricardo A. Fonseca, Wei Lu, Warren Mori, Luis O Silva, Frank Shih Yu Tsung (UCLA)*

Recently, several groups around the world observed mono-energetic beams between 80 MeV and 170 MeV using ~15 TW lasers. We have begun a comprehensive study of the acceleration of electrons by the interaction of ultra-intense short and ultra-short laser pulses with underdense plasma. We concentrate our parameter space to existing and near term laser parameters, i.e., laser parameters between 30 and 100 TW. We use 3D particle in cell simulations using the code OSIRIS. The goal is to show that the generation of mono-energetic beams with energy beyond 1GeV with current and near future laser systems is possible without the need for any external injection. In this ultra-relativistic regime the laser blows out all the electrons forming an almost spherical cavity. Some electrons are self-injected in the blowout region and accelerated by the laser wakefield to ultrahigh energy. In order to maximize the energy gain, the beam charge and quality, we need an improved understanding of the wakefield generation as well as of processes such as self-injection and beam loading. We will provide theoretical estimates and verify their validity with 3D simulations. We will address possible limitations of particle acceleration in this regime.

Tsung et al., Phys. Rev. Lett., 93, 185002. S.P.D. Mangles et al. Nature 431, 535 (2004). C.G.R. Geddes et al. Nature 431, 538 (2004). J. Faure et al. Nature 431, 541 (2004). A. Pukhov and J. Meyer-ter-vehn, Appl.Phys.B, 74, 355 (2002).

Work supported by DOE and NSF.

**TPAE046—Modeling Self-Ionized Plasma Wakefield Acceleration for Afterburner Parameters Using QuickPIC**

*Miaomiao Zhou, Chris Clayton, Viktor K. Decyk, Johnson Devon, Chengkun Huang, Chan Joshi, Wei Lu, Warren Mori, Frank Shih Yu Tsung (UCLA), Christopher Barnes, Franz-Josef Decker, Richard Iverson, Caolionn O'Connell, Dieter Walz (SLAC), Suzhi Deng, Tom Katsouleas, Patric Muggli, Erdem Oz (USC)*

A plasma wakefield accelerator (PWFA) has been proposed as a way to double the energy of a future linear collider. This afterburner concept will require meter long uniform plasmas. For the parameters envisaged in possible afterburner stages, the self-fields of the particle beam are intense enough to tunnel

ionize some neutral gases such as lithium. Tunnel ionization has been investigated as a way for the beam itself to create the plasma.* Furthermore, tunnel ionization in a neutral or partially pre-ionized gas may create new plasma electrons and alter the plasma wake.*,** Unfortunately, it is not possible to model a PWFA with afterburner parameters using the models described in Bruhwiler et al. and Deng et al. Here we describe the addition of a tunnel ionization package using the ADK model into QuickPIC, a highly efficient quasi-static particle in cell (PIC) code which can model a PWFA with afterburner parameters. There is excellent agreement between QuickPIC and OSIRIS(a full PIC code) for pre-ionized plasmas. Effects of self-ionization on hosing instability—one of the most critical issues to overcome to make an afterburner a reality—for a bunch propagating in a plasma hundreds of betatron oscillations long will be discussed.
*D. L. Bruhwiler et al., Phys. Plasmas 10 (2003), p. 2022. **S. Deng et al., Phys. Rev. E, 68, 047401 (2003).

DOE

**TPAE047—Parameters Optimization for a Novel Vacuum Laser Acceleration Test at BNL-ATF**
*Lei Shao, David Cline, Feng Zhou (UCLA)*
This paper presents a new VLA theory model which has revealed that the injection electrons with low energy and small incident angle relative to the laser beam are captured and significantly accelerated in a strong laser field. For the further step for verifying the novel-VLA mechanics, we propose to use the BNL-ATF Terawatt CO2 laser and a high-brightness electron beam to carry out a proof-of-principle beam experiment. Experiment setup including the laser injection optics and electron extraction system and beam diagnostics is presented. Extensive optimized simulation results with ATF practical parameters are also presented, which shows that even when the laser intensity is not very high, the net energy gain still can be seen obviously. This could be prospect for a new revolution of vacuum laser acceleration.

U.S. DOE.

**TPAE048—The UCLA/FNPL Time Resolved Underdense Plasma Lens Experiment**
*Matthew Colin Thompson, James Rosenzweig, Gil Travish (UCLA), Helen Edwards, Philippe Regis-Guy Piot, James Santucci (Fermilab), Rodion Tikhoplav (Rochester University)*
An underdense plasma lens experiment is planned as a collaboration between UCLA and the Fermilab NICADD Photoinjector Laboratory (FNPL). The experiment will focus on measuring the variation of the plasma focusing along the longitudinal beam axis and comparing these results with theory and simulation. The experiment will utilize a thin gaussian underdense plasma lens with peak density 6 x 10^12 cm^-3 and a FWHM length of 1.6 cm. This plasma lens will have a focusing strength equivalent to a quadrupole magnet with a 180 T/m field gradient. A 15 MeV, 8nC electron beam with nominal dimensions ór = 400 μm and óz = 2.1 mm will be focused by this plasma lens onto an OTR screen approximately 2 cm downstream of the lens. The light from the OTR screen will be imaged into a streak camera in order to directly measure the correlation between z and ór within the beam. Status and progress on the experiment are reported.

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**TPAE049—The UCLA/SLAC Ultra-High Gradient Cerenkov Wakefield Accelerator Experiment**
*Matthew Colin Thompson, Hristo Badakov, James Rosenzweig, Gil Travish, Rodney Yoder (UCLA), Mark Hogan, Rasmus Ischebeck, Robert Siemann, Dieter Walz (SLAC), Patric Muggli (USC)*
An experiment is planned to study the performance of dielectric Cerenkov wakefield accelerating structures at extremely high gradients in the GV/m range. This new UCLA/SLAC collaboration will take advantage of the unique SLAC FFTB electron beam and its demonstrated ultra-short pulse lengths and high currents (e.g., óz = 20 μm at Q = 3 nC). The electron beam will be focused down and sent through varying lengths of fused silica capillary tubing with two different sizes: ID = 200 μm / OD = 325 μm and ID = 100 μm / OD = 325 μm. The pulse length of the electron beam will be varied in order to alter the accelerating gradient and probe the breakdown threshold of the dielectric structures. In addition to breakdown studies, we plan to collect and measure coherent Cerenkov radiation emitted from the capillary tube to gain information about the strength of the accelerating fields. Status and progress on the experiment are reported.

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**TPAE050—Optical Injection Through Oblique Collisions**
*John R. Cary (CIPS), Eric Esarey, Wim Leemans (LBNL), David L. Bruhwiler, Rodolfo Giacone, Chet Nieter (Tech-X)*
The accelerating gradient of laser generated wake fields can be orders of magnitude greater than the gradients obtainable in traditional, rf structures. However, one must now develop methods for reliable, stable injection into these wake fields in order to obtain high-energy beams with narrow energy spread. Pulses colliding in a number of different configurations have been proposed. In this talk we examine the obliquely colliding pulses using the versatile plasma simulation application code, VORPAL.* Through such simulations we have been able to predict the variation of the beam with both timing and aiming errors. In addition, we have considered the damping induced by propagation in plasma channels. We consider a series of simulations with varying pulse length and width, but with overall power constant. For each simulation we match the width to the channel radius for optimum guiding, and we match the length to the plasma frequency at the bottom of the channel. We show that below a certain prolateness, optical injection produces multiple beams. Above that prolateness, single, clean beams emerge.
*C. Nieter and J.R. Cary, J. Comp. Phys. 196 (2004), p. 448.

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**TPAE051—Designing Photonic Crystal Devices for Accelerators**
*Gregory Werner (CIPS), John R. Cary (CIPS; Tech-X, Boulder)*
Photonic crystals (periodic dielectric structures with a lattice constant on the order of the wavelength of light) can have a wide range of properties. For instance, photonic crystals can be designed to be completely reflective within a certain bandwidth, thereby becoming a replacement for metal in accelerator structures such as waveguides and cavities. To see whether photonic crystals might find application in accelerators, and to design potential accelerator structures, we will need reliable computer simulations to predict fields and frequencies and other properties of photonic crystal structures. We propose to build photonic crystal structures in the microwave regime and test the

validity of computer simulation against experiment. We can then explore more complex issues such as coupling to photonic crystal structures, higher-order mode rejection, and tunable photonic crystals.

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**TPAE053—Near-GeV Electron Beams from the Laser Wakefield Accelerator in the "Bubble" Regime**
*Nasr Hafz, Guang-Hoon Kim, Hyyong Suk (KERI), Il Woo Choi, Do-Kyeong Ko, Jongmin Lee (APRI-GIST)*
This Communication describes a 2D-PIC simulation of a laser wakefield accelerator in which an ultrashort, petawatt-class laser is focused and propagated through an underdense preformed plasma. We are looking at the phase-spaces of a large number of background plasma electrons that are accelerated to very high energies by the laser-induced plasma bubble. The result shows the possibility of generating a GeV-level electron beam in a few millimeters plasma size. As a future work, we will use a 500 TW laser system, that is under construction at APRI-GIST in Korea, for laser-plasma based accelerator researches to which the current simulation is relevant.

This research was funded by the Korean Ministry Science and Technology through the Creative Research Initiative (CRI) Program.

**TPAE054—Ultraintense and Ultrashort Laser Pulses from Raman Amplification in Plasma for Laser-Plasma Accelerators**
*Min Sup Hur, Nasr Hafz, Guang-Hoon Kim, Victor V. Kulagin, Ki-Hong Pae, Hyyong Suk (KERI), Changbum Kim (POSTECH)*
We present analysis and simulations of kinetic effects in the Raman pulse amplification in plasma. An ultraintense and ultrashort laser pulse is a very essential part in an advanced acceleration scheme using laser and plasma. To make strong pulses, a noble scheme of using Raman backscatter in plasma was proposed and has been studied intensively.* The Raman amplification in plasma does not have a restriction in material damage threshold. However, for the new amplifier to be a promising alternative of the CPA technique, more extensive studies on various issues are required. One of the fundamental issues is the electron kinetic effect such as particle trapping or wavebreaking. We present a theoretical analysis of the kinetic effect; a new kinetic term is derived to be added to the fluid model and the effect of the new term is verified by averaged-PIC (aPIC)** simulations. Various one dimensional and semi-two dimensional aPIC simulations of pulse amplification are presented. We discuss the future application of the Raman scheme to upgrading the laser pulse of the Center of Advanced Accelerator in KERI, which are currently 2 TW and 700 fs, into a few more TW and less than 100 fs.
*V. M. Malkin, G. Shvets, and N. J. Fisch, Phys. Rev. Lett. vol. 82, 4448 (1999). **M. S. Hur, G. Penn, J. S. Wurtele, and R. Lindberg, Phys. Plasmas vol. 11, 5204 (2004).

Korea Electrotechnology Research Institute, Korea; Creative Research Initiatives, Korea.

**TPAE055—Laser-Based Electron Acceleration Experiment in KERI/APRI-GIST**
*Guang-Hoon Kim, Nasr Hafz, Hyyong Suk (KERI), Il Woo Choi, Do-Kyeong Ko, Jongmin Lee, T. J. Yu (APRI-GIST)*
Laser-based acceleration of charged particles has been of interest since laser wakefield produces very strong longitudinal electrical field to accelerate electrons upto relativistic energy. Recently, 20TW Ti:sapphire laser system, with pulse width of 30 fs and energy pf 600 mJ, was installed in APRI-GIST. The laser pulse is focused onto a gas jet to produce plasma and accelerate electrons in the scheme of self-modulated laser wakefield acceleration. Details of laser system and diagnostic results of electron beam will be discussed

**TPAE056—Acceleration of Charged Particles by High Intensity Few-Cycle Laser Pulses**
*Ulrich Schramm, Florian Gruener, Dietrich Habs, Jörg Schreiber (LMU), Michael Geissler, Ferenc Krausz, Juergen Stein, George Tsakiris, Laszlo Veisz, Klaus Witte (MPQ)*
Only recently a breakthrough in laser plasma acceleration has been achieved with the observation of intense (nC) mono-energetic (10% relative width) electron beams in the 100MeV energy range.* Above the wave-breaking threshold the electrons are trapped and accelerated in a single wake of the laser pulse, called bubble, according to PIC simulations.** However, pulse energis varied from shot-to-shot in the experiments. At the MPQ Garching we prepare the stable acceleration of electrons by this bubble regime by the use of 10TW few-cycle laser pulse. As the pulse lenght of 5-10fs remains below the plasma period also at higher plama densities, we expect the scheme to be more stable and efficient. The status of the experiment will be reported. Further, we exploit a colliding beam setup existing at the Jena multi TW laser system for the investigation of the positron generation in the electron-electron collision or in the collision of hard X-rays resulting from Thomson backscattering. The presentation of results on heavy ion acceleration from laser-irradiated thin foils will round up this summary of the Munich activities.
*See 'dream beams' in Nature 431 (2004). **A. Pukhov, J. Meyer-ter-Vehn, Appl. Phys. B 74, 355 (2002).

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**TPAE057—A Multibunch Plasma Wakefield Accelerator**
*Efthymios Kallos, Tom Katsouleas, Patric Muggli (USC), Ilan Ben-Zvi, Igor Pogorelsky, Vitaly Yakimenko (BNL), Wayne D. Kimura (STI)*
We investigate a plasma wakefield acceleration scheme where a train of bunches is fed into a high density plasma tuned to the separation of the bunches. Simulations use the beam line parameters of Brookhaven's Accelerator Test Facility operating in the configuration of the STELLA IFEL experiment: The 60MeV electron beam is modulated by a 10.6um CO2 1.5ps rise laser via an Inverse Free Electron Laser interaction with a magnetic wiggler, producing a train of 150 bunches separated at the laser's wavelength. When the bunch train enters a plasma that has a wavelength equal to the bunch separation distance, a strong wakefield is resonantly driven to an amplitude that is at least one order of magnitude higher than that from an unbunched beam. Preliminary simulation results suggest that self-modulation of the beam occurs increasing the wake beyond what would be expected from linear theory and also indicate a relativistic detuning effect similar to that seen in laser beat wave accelerators. The design of an upcoming experiment at Brookhaven will be presented.

**TPAE058—Plasma Dark Current in Plasma Wake Field Accelerators (PWFA)**
*Erdem Oz, Suzhi Deng, Tom Katsouleas, Patric Muggli (USC), Franz-Josef Decker, Mark Hogan, Richard Iverson, Patrick Krejcik, Caolionn O'Connell, Dieter Walz (SLAC), Chris Clayton, Chengkun Huang, Devon K. Johnson, Chan Joshi, Wei Lu, Kenneth Marsh, Miaomiao Zhou (UCLA)*
Particle trapping is investigated with experiment, theory and simulations for conditions relevant to beam driven Plasma Wake

Field Accelerators. Such trapping produces plasma dark current when the wakefield aplitude is above a threshold values and may place a limit on the maximum acceleration gradient in a PWFA. Trapping and dark current are enhanced when in an ionizing plasma, that is self-ionized by the beam as well as in gradual density gradients. In the E164X conducted at the Stanford Linear Accelerator Center by a collaboration of USC, UCLA and SLAC, evidence of trapping has been observed. Here we present experimental results and a simplified analytical model of the particle trapping threshold which is compared to simulations done with an object oriented fully parallel 3-D PIC code OSIRIS.

**TPAE059—Towards Ultra-Bright Electron Bunches Using Pancakes, Waterbags, and Cold Atoms**
*Jom Luiten (TUE)*
We propose a comprehensive, 3-step strategy addressing nonlinear space-charge forces and thermal emittance, thus enabling orders of magnitude improvement in electron beam brightness. First, using ultra-short pancake bunches in the initial part of the acceleration trajectory enables much higher peak currents without aggravating space-charge induced emittance growth.* Second, by shaping the radial intensity distribution of the required femtosecond photoexcitation laser pulse into a half-circle profile, the pancake bunch will automatically evolve into a uniformly charged, 3-D ellipsoidal bunch, i.e. the ideal waterbag bunch with pefectly linear space charge forces, and thus zero emittance growth.** Third, the thermal emittance may be reduced by at least an order of magnitude if the radially shaped pancake bunch is extracted from an ultra-cold plasma, which can be fashioned from a cloud of laser-cooled atoms by photo-ionization just above threshold. The latter method in addition features efficient velocity bunching, leading automatically to femtosecond bunch lengths without magnetic compression. *O. J. Luiten, in "The Physics and Applications of High Brightness Electron Beams", edited by J. Rosenzweig, G. Travish and L. Serafini (World Scientific, Singapore, 2003), p. 108. **O. J. Luiten et al., Phys. Rev. Lett. 93, 094802 (2004).

Netherlands Foundation for Fundamental Research on Matter (FOM).

**TPAE060—Planned Enhanced Wakefield Transformer Ratio Experiment at Argonne Wakefield Accelerator**
*Alex Kanareykin (Euclid Concepts, LLC), Wei Gai, Richard Konecny, John Gorham Power, Haitao Wang (ANL)*
In this paper, we present a preliminary experimental study of a wakefield accelerating scheme that uses a carefully spaced and current ramped electron pulse train to produce wakefields that increases the transformer ratio much higher than 2. A dielectric structure was designed and fabricated to operate at 13.625 GHz with dielectric constant of 15.7. The structure will be initially excited by two beams with first and second beam charge ratio of 1:3. The expected transformer ratio is 3 and the setup can be easily extend to 4 pulses which leads to a transformer ratio of more than 6. The dielectric structure cold test results show the tube is within the specification. A set of laser splitters was also tested to produce ramped bunch train of 2 - 4 pulses. Overall design of the experiment and initial results will be presented.

U.S. Department of Energy.

**TPAE061—Experimental Investigation of an X-Band Tunable Dielectric Accelerating Structure**
*Alex Kanareykin, Pavel Avrakhov, Sergei Fedorovich Karmanenko (Euclid Concepts, LLC), Wei Gai, John Gorham Power (ANL)*
Experimental study of a new scheme to tune the resonant frequency for dielectric based accelerating structure (driven either by the wakefield of a beam or an external rf source) is underway. The structure consists of a single layer of conventional dielectric surrounded by a very thin layer of ferroelectric material situated on the outside. Carefully designed electrodes are attached to a thin layer of ferroelectric material. A DC bias can be applied to the electrodes to change the permittivity of the ferroelectric layer and therefore, the dielectric overall resonant frequency can be tuned. In this paper, we present the test results for an 11.424 GHz rectangular DLA prototype structure that the ferroelectric material's dielectric constant of 500 and show that a frequency tuning range of 2% can be achieved. If successful, this scheme would compensate for structure errors caused by ceramic waveguide machining tolerances and dielectric constant heterogeneity.

U.S. Department of Energy.

**TPAE062—Simulation of the Collective Acceleration of 100 Picosecond Ion Pulses with the Ionization Front Accelerator**
*Dale Welch, David Rose (ATK-MR), Craig Olson (Sandia National Laboratories)*
Heavy ion beams have the potential to drive matter to conditions suitable for high energy density physics experiments. One scheme under consideration is the Ionization Front Accelerator (IFA) which uses the collective fields of an electron beam to accelerate a dense bunch of ions. Here, the position of the space charge of an intense 30-kA, 1-MeV 1-cm radius electron beam is controlled by laser ionization of a working gas. The desired ion species is seeded near the entrance of the electron beam. New simulations with the LSP particle-in-cell code confirm earlier theoretical and experimental results [see C. L. Olson, et al, Phys. Rev. Lett. 56, 2260 (1986)]. These simulations predict the creation of a >20-MeV, 100-ps, He++ ion beam in a 30 cm length. Scaling of the ion current, energy, pulse length, radius and stability to electron beam and plasma conditions is presented. Application of this device to the study of high energy density physics with ion beams is discussed.

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**TPAE063—Observation of Superposition of Wake Fields Generated by Electron Bunches in a Dielectric-Lined Waveguide**
*Sergey V. Shchelkunov, Thomas C. Marshall (Columbia University), Marcus Babzien (BNL), Jay L. Hirshfield (Omega-P, Inc.; Yale University), Michael A. LaPointe (Yale University)*
We report results from an experiment, done at the Accelerator Test Facility, Brookhaven National Laboratory, which demonstrates the successful superposition of wake fields excited by 50MeV bunches which travel ~50cm along the axis of a cylindrical waveguide which is lined with alumina. Wake fields from two short (5-6psec) 0.15-0.35nC bunches are superimposed and the energy losses of each bunch are measured as the separation between the bunches is varied so as to encompass approximately one wake field period (~21cm). A spectrum of 40 TM0m eigenmodes is excited by the bunch. A substantial retarding wake field (2.65MV/m×nC for just the first bunch) is developed because of the short bunches and the narrow vacuum channel diameter (3mm) through which they move. The energy loss of the second bunch exhibits a narrow resonance with a 4mm (13.5psec) footprint. This experiment may be compared with a related experiment reported by a group at the Argonne National Laboratory where a much weaker wake field (~0.1MV/m×nC for the first bunch) having ~10 eigenmodes was excited by a

train of much longer bunches,* and the bunch spacing was not varied.
*J. G. Power, M. E. Conde, W. Gai, R. Konecny, and P. Schoessow, Phys. Rev. ST Accel. Beams 3, 101302 (2000).

Research supported by the Department of Energy, Division of High Energy Physics.

**TPAE064—Externally Controlled Injection of Electrons by a Laser Pulse in a Laser Wakefield Electron Accelerator**
*Szu-Yuan Chen, Chun-Ling Louis Chang, Wei-Ting Chen, Ting-Yei Chien, Chau-Hwang Lee, Jiunn-Yuan Lin, Jyhpyng Wang (IAMS)*
Spatially and temporally localized injection of electrons is a key element for development of plasma-wave electron accelerator. Here we report the demonstration of two different schemes for electron injection in a self-modulated laser wakefield accelerator (SM-LWFA) by using a laser pulse. In the first scheme, by implementing a copropagating laser prepulse with proper timing, we are able to control the growth of Raman forward scattering and the production of accelerated electrons. We found that the stimulated Raman backward scattering of the prepulse plays the essential role of injecting hot electrons into the fast plasma wave driven by the pump pulse. In the second scheme, by using a transient density ramp we achieve self-injection of electrons in a SM-LWFA with spatial localization. The transient density ramp is produced by a prepulse propagating transversely to drill a density depression channel via ionization and expansion. The same mechanism of injection with comparable efficiency is also demonstrated with a transverse plasma waveguide driven by Coulomb explosion.

National Science Council, Taiwan.

**TPAE065—Development of a 20-MeV Dielectric-Loaded Accelerator Test Facility**
*Steven H. Gold (NRL), Wei Gai, Chunguang Jing, Richard Konecny, John Gorham Power (ANL), Allen Kinkead (LET), Christopher Dennis Nantista, Sami G. Tantawi (SLAC), Huaibi Chen, Yuan Hu, Y. Lin, C. Tang (TUB)*
This paper will describe a joint project by the Naval Research Laboratory (NRL) and Argonne National Laboratory (ANL), in collaboration with the Stanford Linear Accelerator Center (SLAC), to develop a dielectric-loaded accelerator (DLA) test facility powered by the high-power 11.424-GHz magnicon that was developed by NRL and Omega-P, Inc. The magnicon can presently produce 25 MW of output power in a 250-ns pulse at 10 Hz, and efforts are in progress to increase this to 50 MW.* The facility will include a 5-MeV electron injector being developed by the Accelerator Laboratory of Tsinghua University in Beijing, China. The DLA test structures are being developed by ANL, and some have undergone testing at NRL at gradients up to ~8 MV/m.** SLAC is developing a means to combine the two magnicon output arms, and to drive an injector and accelerator with separate control of the power ratio and relative phase. The installation and testing of the first dielectric-loaded test accelerator, including injector, DLA structure, and spectrometer, should take place within the next year. The initial goal is to produce a compact 20-MeV dielectric-loaded test accelerator.
*O. A. Nezhevenko et al., Proc. PAC 2003, p. 1128. **S. H. Gold et al., AIP Conf. Proc. 691, p. 282.

Work supported by DOE and ONR.

**TPAE066—Robust Autoresonant Excitation in the Plasma Beat-Wave Accelerator: A Theoretical Study**
*Andrew Emile Charman, Ryan Roger Lindberg (UCB), Jonathan Wurtele (LBNL/CBP), Lazar Friedland (The Hebrew University of Jerusalem)*
A modified version of the Plasma Beat-Wave Accelerator scheme is introduced and analyzed, which is based on autoresonant phase-locking of the nonlinear Langmuir wave to the slowly chirped beat frequency of the driving lasers via adiabatic passage through resonance. This new scheme is designed to overcome some of the limitations of previous approaches, namely relativistic detuning and nonlinear modulations in the driven Langmuir wave amplitude, and sensitivity to frequency mismatch from density fluctuations. As in previous schemes, instabilities of the ionic background ultimately limit the useful interaction time, but nevertheless peak electric fields approaching the wave-breaking limit seem readily attainable. Compared to traditional approaches, the autoresonant scheme achieves larger accelerating electric fields for given laser intensity; the plasma wave excitation is more robust to variations in plasma density; it is largely insensitive to the choice of chirp rate, provided that chirping is sufficiently slow; and the quality and uniformity of the resulting plasma wave and its suitability for accelerator applications may be superior.

Division of High Energy Physics, U.S. Department of Energy, DARPA, U.S. Department of Defense.

## Poster Session TPAP—High-Energy Hadron Accelerators and Colliders, Park Concourse, 8:30-12:20

**TPAP001—Crystal Bending of LHC Beam for In-Situ Calibration of CMS/ATLAS Calorimeters**
*Valery M. Biryukov, Yuri Chesnokov (IHEP Protvino), Stefano Bellucci (INFN/LNF)*
We consider physical possibilities for bending the LHC protons and ions a huge angle of 1-20 degrees in the energy range of 0.45-8 TeV by means of a bent channeling crystal of Si or Ge. Such an application was earlier proposed for calibration of CMS (or ATLAS) calorimeters in situ. We show by computations that such an application would be feasible at the LHC, and report the experience of IHEP Protvino in bending 70 GeV protons by 9 degrees (150 mrad) over 10 years in 1994-2004 experiments.

**TPAP002—Summary of Recent Studies of Cryosorbers for LHC Long Straight Sections**
*Rodion Dostovalov, Vadim Anashin, Alexandre Krasnov (BINP SB RAS)*
The vacuum chamber inside some cryogenic elements in the LHC long straight sections will have cold bore (CB) at 4.5K and a beam screen (BS) at temperature between 5 and 20K. The gas molecules desorbed due to photons and electrons will pass through the slots on the BS to the shadowed part between the CB and BS. All desorbed gases except H2 could be adsorbed on the CB and BS but a cryosorber is required to pump H2. The new types of anodized aluminum, porous copper and charcoal-based materials were developed and studied to cryopump H2 at temperatures between 10 and 20K. The advantages and disadvantages of cryosorbers and technological problems of development of new similar cryosorbers were defined. The vacuum parameters of LHC vacuum chamber prototypes with charcoal and two types of carbon fiber cryosorbers were measured. The dynamic pressure behavior at BS temperature oscillations was studied for BS with woven carbon fiber to predict the dynamic pressure at nonstandard or transient regimes of the LHC operation. A main result is that woven carbon fiber cryosorber

meets the LHC requirements and can be proposed as cryosorber for LHC. The summary results of these studies are presented.

This work was supported by CERN AT Division vacuum group.

**TPAP003—Exploring a Nonlinear Collimation System for the LHC**
*Javier Resta, Angeles Faus-Golfe (IFIC), Ralph Assmann, Stefano Redaelli, Guillaume Robert-Demolaize, Daniel Schulte, Frank Zimmermann (CERN)*
We explore the adaptation of a nonlinear collimation system, as previously considered for linear colliders, to LHC betatron cleaning. A possible nonlinear system for LHC consists of a horizontal and vertical primary collimator located in between a pair of skew sextupoles. We discuss the modified LHC optics, the need for and optimum placement of secondary absorbers, and the simulated cleaning efficiency.

**TPAP004—Mechanical Design for Robustness of the LHC Collimators**
*Alessandro Bertarelli, Oliver Aberle, Ralph Assmann, Sergio Calatroni, Alessandro Dallocchio, Tadeusz Kurtyka, Manfred Mayer, Roger Perret, Stefano Redaelli, Guillaume Robert-Demolaize (CERN)*
The functional specification of the LHC Collimators requires, for the start-up of the machine and the initial luminosity runs (Phase 1), a collimation system with maximum robustness against abnormal beam operating conditions. The most severe cases to be considered in the mechanical design are the asynchronous beam dump at 7 TeV and the 450 GeV injection error. To ensure that the collimator jaws survive such accident scenarios, low-Z materials were chosen, driving the design towards Graphite or Carbon/Carbon composites. Furthermore, in-depth thermo-mechanical simulations, both static and dynamic, were necessary.This paper presents the results of the numerical analyses performed for the 450 GeV accident case, along with the experimental results of the tests conducted on a collimator prototype in Cern TT40 transfer line, impacted by a 450 GeV beam of 3.1e13 protons, with impact parameters from 1 to 5 mm.

**TPAP005—Calculation of Residual Dose Rates and Intervention Scenarios for the LHC Beam Cleaning Insertions—Constraints and Optimization**
*Markus Brugger, Oliver Aberle, Ralph Assmann, Doris Forkel-Wirth, Stefan Roesler, Helmut Vincke (CERN)*
Radiation protection of the personnel who will perform interventions in the LHC Beam Cleaning Insertions is mandatory and includes the design of equipment and the establishment of work procedures. Residual dose rates due to activated equipment are expected to reach significant values such that any maintenance has to be planned and optimized in advance. Three-dimensional maps of dose equivalent rates at different cooling times after operation of the LHC have been calculated with FLUKA. The simulations are based on an explicit calculation of induced radioactivity and of the transport of the radiation from the radioactive decay. The paper summarizes the results for the Beam Cleaning Insertions and discusses the estimation of individual and collective doses received by personnel during critical interventions, such as the exchange of a collimator or the installation of Phase 2. The given examples outline the potential and the need to optimize, in an iterative way, the design of components as well as the layout of the beam cleaning insertions. Furthermore, results of measurements and simulations of residual dose rates for a collimator test recently performed at the SPS are presented.

**TPAP006—Detecting Impacts of Proton Beams on the LHC Collimators With Vibration Measurements**
*Stefano Redaelli, Oliver Aberle, Ralph Assmann, Alessandro Masi (CERN), Giovanni Spiezia (Naples University Federico II)*
The 350 MJ stored energy of the 7 TeV LHC beams can seriously damage the beam line elements in case of accidental beam losses. Notably, the LHC collimators, which sit at 6 to 7 sigmas from the beam centre (1.2-1.4 mm), might be hit and possibly damaged in case of failures, with a consequent degradation of their cleaning performance. The experience from operating machines shows that an a-posteriori identification of the damaged collimators from the observed performance degradation is extremely challenging. Collimator tests with beam at the SPS have proven that the impact of 450 GeV proton beams at intensities from 10^10 to 3x10^13 can be detected by measuring the collimator vibrations. This was achieved by using high-resolution, radiation hard accelerometers and a microphone to record mechanical and sound vibrations of a LHC-like prototype collimator with impacting beams at different intensities and depth. A similar system could be also used in the LHC to detect collimators damaged by the beam.

**TPAP007—LHC Collimation: Design and Results from Prototyping and Beam Tests**
*Ralph Assmann, Oliver Aberle, Gianluigi Arduini, Alessandro Bertarelli, Markus Brugger, Helmut Burkhardt, Sergio Calatroni, Fritz Caspers, Enrico Chiaveri, Bernd Dehning, Alfredo Ferrari, Eva Barbara Holzer, Jean-Bernard Jeanneret, José Miguel Jimenez, Alessandro Masi, Manfred Mayer, Elias Métral, Roger Perret, Christian Rathjen, Stefano Redaelli, Guillaume Robert-Demolaize, Stefan Roesler, Daniel Schulte, Peter Sievers, Vasilis Vlachoudis, Jorg Wenninger (CERN), Igor Baishev (IHEP Protvino), Giovanni Spiezia (Naples University Federico II)*
The problem of collimation and beam cleaning concerns one of the most challenging aspects of the LHC project. A collimation system must be designed, built, installed and commissioned with parameters that extend the present state-of-the-art by 2-3 orders of magnitude. Problems include robustness, cleaning efficiency, impedance and operational aspects. A strong design effort has been performed at CERN over the last two years. The system design has now been finalized for the two cleaning insertions. The adopted phased approach is described and the expected collimation performance is discussed. In parallel robust and precisely controllable collimators have been designed. Several LHC prototype collimators have been built and tested with the highest beam intensities that are presently available at CERN. The successful beam tests are presented, including beam-based setup procedures, a 2 MJ robustness test and measurements of the collimator-induced impedance. Finally, an outlook is presented on the challenges that are ahead in the coming years.

**TPAP008—Measurements of the LHC Collimator Impedance with Beam in the SPS**
*Helmut Burkhardt, Gianluigi Arduini, Ralph Assmann, Fritz Caspers, Marek Gasior, Rhodri Jones, Tom Kroyer, Elias Métral, Stefano Redaelli, Guillaume Robert-Demolaize, Federico Roncarolo, Daniel Schulte, Ralph Steinhagen, Jorg Wenninger, Frank Zimmermann (CERN)*
The transverse impedance of the LHC collimators will likely dominate the overall transverse impedance in the LHC at high energies and potentially limit the maximum intensity. A prototype collimator was recently tested in the SPS. Small, but significant tune shifts depending on the collimator position have been observed using different independent high resolution tune measurement methods. In addition trapped modes predicted from numerical simulation at the ends of the collimator jaws have been identified by bench measurement techniques as well

as with the beam. We present a description of the measurements and an analysis of the results.

**TPAP009—Collimation in the Transfer Lines to the LHC**
*Helmut Burkhardt, Brennan Goddard, Yacine Kadi, Verena Kain, Thys Risselada, Wim Weterings (CERN)*
Injection intensities for the LHC are over an order of magnitude above damage level. The TI 2 and TI 8 transfer lines between the SPS and LHC are each about 2.5 km long and comprise many active elements running in pulsed mode. The collimation system in the transfer lines is designed to dilute the beam energy sufficiently in case of accidental beam loss or mis-steered beam. A system using three collimator families spaced by 60 degrees in phase advance, both in the horizontal and the vertical plane has been chosen. We discuss the reasons for this choice, the layout and, the expected performance of the system in terms of maximum amplitudes and energy deposition.

**TPAP010—Reliability Analysis of the LHC Beam Dumping System**
*Roberto Filippini, Etienne Carlier, Brennan Goddard, Jan Uythoven (CERN)*
The design of the LHC Beam Dumping System is aimed at ensuring a safe beam extraction and deposition under all circumstances. The system adopts redundancy and continuous surveillance for most of its parts. Extensive diagnostics after each beam dumping action will be performed to reduce the risk of a faulty operation at the subsequent dump trigger. Calculations of the system's safety and availability are presented, considering the detailed design of the trigger generation system and the power converters of the beam dumping kickers and septa magnets.

**TPAP011—Reliability Assessment of the LHC Machine Protection Systems**
*Roberto Filippini, Bernd Dehning, Gianluca Guaglio, Felix Rodriguez-Mateos, Ruediger Schmidt, Benjamin Todd, Jan Uythoven, Antonio Vergara-Fernández, Markus Zerlauth (CERN)*
A large number of complex systems will be involved in ensuring a safe LHC operation, such as beam dumping and collimation, beam loss and position detection, quench protection, power interlock controller and beam interlock system. The latter will monitor the status of all other systems and trigger the beam abort if necessary. While the overall system is expected to provide an extremely high level of protection, none of the involved components should unduly impede machine operation by creating physically unfounded dump requests or beam inhibit signals. This paper investigates the resulting trade-off between safety and availability and provides quantitative results for the most critical protection elements.

**TPAP012—Heavy-Ion Luminosity Limit from Bound-Free Pair Production in the LHC**
*John M. Jowett, Roderik Bruce, Simone Silvano Gilardoni (CERN)*
The luminosity of the LHC as a lead-ion collider is known to be limited by the large cross-sections for electromagnetic processes in ultra-peripheral collisions. In particular, the process of bound-free e-e+ pair production creates secondary beams of Pb81+ ions emerging from the collision points and impinging on the vacuum envelope inside superconducting magnets. New Monte-Carlo simulations, exploiting recent implementations of the physics of ion interactions with matter, are helping us to quantify the relationships among luminosity, energy deposition in the magnet coils and signals on beam loss monitors with a view to predicting and alleviating the quench limit on luminosity.

**TPAP013—The Performance of the New TCDQ System in the LHC Beam Dumping Region**
*Andrew Presland, Brennan Goddard, Wim Weterings (CERN)*
The superconducting quadrupole magnet Q4 in IR6 and other downstream LHC machine elements risk destruction in the event of a beam dump that is not synchronised with the abort gap. In order to protect these elements, a single sided mobile graphite diluter block TCDQ, in combination with a two-sided secondary collimator TCS and an iron shield TCDQM, will be installed in front of Q4. This protection system should also intercept spurious particles in the beam abort gap to prevent quenches from occurring during regular beam aborts, and must also intercept the particles from the secondary halo during low beam lifetime without provoking quenches. The conceptual design of the TCDQ system is briefly presented, with the load conditions and performance criteria. The FLUKA energy deposition simulations are described, and the results discussed in the context of the expected performance levels for LHC operation.

**TPAP014—Energy Deposition Studies for the Betatron Cleaning Insertion**
*Vasilis Vlachoudis, Ralph Assmann, Alfredo Ferrari, Matteo Magistris, Mario Santana-Leitner, Ekaterini Tsoulou (CERN)*
Two insertions (IR3, IR7) of the Large Hadron Collider (LHC) are dedicated to beam cleaning with the design goals of absorbing part of the primary beam halo and of the secondary radiation. The tertiary halo which escapes the collimation system in IR7 may heat the cold magnets at unacceptable levels, if no additional absorber is used. In order to assess the energy deposition in sensitive components, extensive simulations were run with the Monte Carlo cascade code FLUKA. The straight section and the dispersion suppressors of IR7 were fully implemented. A modular approach in the geometry definition and an extensive use of user-written programs allowed the implementation of all magnets and collimators with high precision, including flanges, steel supports and magnetic field. This paper provides the number and location of additional absorbers needed to keep the energy deposition in the coils of the magnets below the quenching limit.

**TPAP015—Commissioning of the LHC Beam Transfer Line TI 8**
*Jan Uythoven, Gianluigi Arduini, Brennan Goddard, Delphine Jacquet, Verena Kain, Mike Lamont, Volker Mertens, Alan Spinks, Jorg Wenninger (CERN), Yu-Chiu Chao (Jefferson Lab)*
The first of the two LHC transfer lines was commissioned in autumn 2004. Beam reached an absorber block located some 2.5 km downstream of the SPS extraction point at the first shot, without the need of any threading. The hardware preparation and commissioning phase will be summarised, followed by a description of the beam tests and their results regarding optics and other line parameters, including the experience gained with beam instrumentation, the control system and the machine protection equipment.

**TPAP016—Energy Calibration of the SPS with Proton and Lead Ion Beams**
*Jorg Wenninger, Gianluigi Arduini, Claudio Arimatea, Thomas Bohl, Paul Collier, Karel Cornelis (CERN)*
The momentum of the 450 GeV/c proton beam of the CERN Super Proton Synchrotron was determined by a high precision measurement of the revolution frequencies of proton and lead ion beams. To minimize systematic errors the magnetic cycle of

the SPS had to be rigorously identical for both beams, and corrections due to Earth tides had to be taken into account. This paper presents how the beam momentum was determined from the RF frequency for which the beams are centred in the machine sextupoles. The measured beam momentum is 449.16 +- 0.14 GeV/c for a nominal momentum of 450 GeV/c, and the accuracy is limited by systematic errors.

**TPAP017—Beam Stability of the LHC Beam Transfer Line TI8**

*Jorg Wenninger, Brennan Goddard, Verena Kain, Jan Uythoven (CERN)*

Injection of beam into the LHC at 450 GeV/c proceeds over two 2.7 km long transfer lines from the SPS. The small aperture of the LHC at injection imposes tight constraints on the stability of the beam transfer. The first transfer line TI8 was commissioned in the fall of 2004 with low intensity beam. Since the beam position monitor signal fluctuations were dominated by noise with low intensity beam, the beam stability could not be obtained from a simple comparison of consecutive trajectories. Instead model independent analysis (MIA) techniques as well as scraping on collimators were used to estimate the intrinsic stability of the transfer line. This paper presents the analysis methods and the resulting stability estimates.

**TPAP018—Optics Studies of the LHC Beam Transfer Line TI8**

*Jorg Wenninger, Gianluigi Arduini, Brennan Goddard, Delphine Jacquet, Verena Kain, Mike Lamont, Volker Mertens, Jan Uythoven (CERN), Yu-Chiu Chao (Jefferson Lab)*

The optics of the newly commissioned LHC beam transfer line TI 8 was studied with beam trajectories, dispersion and profile measurements. Steering magnet response measurements were used to analyze the quality of the steering magnets and of the beam position monitors. A simultaneous fit of the quadrupole strengths was used to search for setting or calibration errors. Residual coupling between the planes was evaluated using high statistics samples of trajectories. Initial conditions for the optics at the entrance of the transfer line were reconstructed from beam profile measurements with Optical Transition Radiation monitors. The paper presents the various analysis methods and their errors. The expected emittance growth arising from optical mismatch into the LHC is evaluated.

**TPAP019—Aperture Studies of the SPS to LHC Transfer Lines**

*Brennan Goddard, Verena Kain, Riccardo Schmid (on leave), Jorg Wenninger (CERN)*

The SPS to LHC transfer lines TI 2 and TI 8 are each several km in length and use magnets with small apertures. An aperture model for the lines has been developed in MAD-X format, with a full description of all installed vacuum elements and the possibility to interpolate at any length interval. This model has been used with tolerances and errors to simulate the expected line aperture available for the beam. The model features and simulation results are presented, with derived aperture limits. The results from aperture measurements made during the TI 8 line beam commissioning in 2004 are presented and compared to the expectations.

**TPAP020—Beam Test of a Roman Pot Prototype for the TOTEM Experiment**

*Mario Deile, Fritz Caspers, Karsten Eggert, Friedrich Haug, Pierre Jarron, Daniela Macina, Hubert Niewiadomski, Elias Philippe Noschis, Marco Oriunno, Anne-Laure Perrot, Gennaro Ruggiero, Walter Snoeys, Andre Verdier (CERN), Cinzia Da Vià, Jasmine Hasi, Angela Kok, Stephen Watts (Brunel University), Vojtech Kundrát, Milos Vaclav Lokajicek (FZU), Valentina Avati, Erik Goussev, Matti Järvinen, Juha Kalliopuska, Kari Kurvinen, Rauno Lauhakangas, Fredrik Oljemark, Risto Orava, Kenneth Österberg, Vittorio Palmieri, Heimo Saarikko, Stefan Tapprogge, Arto Mika Toppinen (Helsinki University), Ralf Herzog, Rainer Rudischer, Eberhard Wobst (ILK Dresden), Vittorio Boccone, Marco Bozzo, Alberto Buzzo, Stefano Cuneo, Fabrizio Ferro, Mario Macri, Saverio Minutoli, Aldo Morelli, Paolo Musico, Marco Negri, Alberto Santroni, Giuseppe Sette, Andrei Sobol (INFN Genova), Vincenzo Berardi, Maria Gabriella Catanesi, Emilio Radicioni (INFN-Bari)*

The TOTEM collaboration has developed and tested the first prototype of its Roman Pots to be operated in the LHC.* TOTEM Roman Pots contain stacks of 10 silicon detectors with strips oriented in two orthogonal directions. To measure proton scattering angles of a few microradians, the detectors will approach the beam centre to a distance of 10 sigma + 0.5 mm (= 1.3 mm). Dead space near the detector edge is minimised by using two novel “edgeless” detector technologies. The silicon detectors are used both for precise track reconstruction and for triggering. The first full-sized prototypes of both detector technologies as well as their read-out electronics have been developed, built and operated. The tests took place first in a fixed-target muon beam at CERN’s SPS, and then in the proton beam-line of the SPS accelerator ring. We present the test beam results demonstrating the successful functionality of the system despite slight technical shortcomings to be improved in the near future.

TOTEM, Technical Design Report, CERN-LHCC-2004-002.

**TPAP021—Schemes for Producing High Intensity Low-Longitudinal Emittance Proton Bunches for the pp and ppbar Colliders**

*Chandra Bhat (Fermilab)*

I describe here very promising schemes for producing high intensity low longitudinal emittance proton bunches for pp and ppbar high energy colliders. These methods are based on the use of wide-band barrier rf systems in the up-stream circular accelerators. The beam dynamics simulations clearly suggest that these schemes allow a wide range of bunch intensities and longitudinal emittances. In this paper I present the principle of these methods and results of multi-particle beam dynamics simulations applied to the Fermilab Tevatron. The feasibility of these methods to LHC pp collider will also be discussed. I also review a few other schemes which have been adopted and investigated at collider facilities.

Work supported by the Universities Research Association, Inc., under contract DE-AC02-76CH03000 with the U.S. Department of Energy.

**TPAP022—2.5 MHz pbar Bunch Transfer from Accumulator and Recycler to the Fermilab Main Injector and pbars to the Tevatron ppbar Collider**

*Chandra Bhat, David Capista, Brian Chase, Joseph Dey, Ioanis Kourbanis, Kiyomi Seiya, Vincent Wu (Fermilab)*

Recently, we have adopted a scheme called “Mixed pbar Source Operation” to transfer 2.5 MHz pbar bunches from the Recycler and the Accumulator to the Fermilab Main Injector (MI). In this scheme, 2.5MHz pbar bunches are captured adiabatically in 53 MHz buckets at 8 GeV in the MI and accelerated to 150 GeV before bunch coalescing and transfer to the Tevatron collider stores. A special magnet ramp was needed in the MI to allow for pbar beam of slightly different 8 GeV energies from the Recycler and the Accumulator. Here we present the details of the

scheme and its advantage over the method used for past several years.

Work supported by the Universities Research Association, Inc., under contract DE-AC02-76CH03000 with the U.S. Department of Energy.

**TPAP023—High Intensity Beam Studies in the Recycler: Simulations and Beam Measurements**
*Chandra Bhat (Fermilab)*
Recycler is an 8 GeV anti-proton storage ring at Tevatron p-pbar !010 pbars.×collider facility and is designed to store in access of 600 The beam is cooled using stochastic cooling and planned to cool further using electron cooling to <54 eVs longitudinally and <-mm-mrπ7 transversly. It is important to study beam stability issues in advance which can be done using proton beam. Recently, we have developed an efficient beam transfer scheme to the Recycler which involves bucket to bucket beam transfer using barrier bucket rf system and able to store in !010 proton with longitudinal emittance of about 40 eVs.×access of 300 Here we report on the method and some results of multi-particle beam dynamics simulations carried out using ESME.* *Special thanks to J. MacLachlan.

Work supported by the Universities Research Association, Inc., under contract DE-AC02-76CH03000 with the U.S. Department of Energy.

**TPAP024—Decoupling Schemes for the Tevatron in the Presence of Skew Quad Fields**
*Carol Johnstone, Pavel Snopok (Fermilab), Martin Berz (MSU)*
With increasing demands for luminosity, optimal performance must be extracted from the existing Tevatron optics. We have, therefore, initiated a high-order dynamical study of the Tevatron to assess the performance, functionality and potential of the baseline lattice. This work describes the nonlinear or high-order performance of the Tevatron lattice with emphasis on the coupled and increased nonlinear behavior introduced by the significant skew quadrupole error in combination with conventional sextupole correction, a behavior still clearly evident after optimal tuning of available skew quadrupole circuits. An optimization study is then performed using different skew quadrupole families, and, importantly, local and global correction of the linear skew terms in maps generated by the code, COSY. A correction scheme, with two families locally correcting each arc and eight independent correctors outside the arc for global correction is shown to be optimal and dramatically improve the linear performance of the baseline Tevatron lattice.

Work is supported by the U.S. Department of Energy under contract no DE-AC02-76CH03000.

**TPAP025—Energy Deposition Constraints on LHC IR Design at the Upgraded Luminosity**
*Nikolai V. Mokhov, Tanaji Sen, James Strait (Fermilab)*
A ten-fold luminosity upgrade of the LHC planned by the middle of the next decade is very challenging. With a power of 9-kW from pp-collision products directed towards both sides of the interaction region (IR), energy deposition limitations become the principle technical challenges of the IR design. Here we present results of the analysis of several IR options. Based on detailed modeling with the MARS15 code results are presented in all major areas considered: local peak power density related to the superconducting magnet quench stability, dynamic heat loads on the cryogenic system, radiation damage of critical components and their lifetime, radioactivation and hands-on maintenance, luminosity and machine-related backgrounds in the collider detectors. We consider various methods of mitigating these problems including an optimal choice of superconducting material, higher critical current margin, improved cooling and heat transfer, active front absorber, larger magnet aperture and additional collimators. Interference of the beam dynamics requirements with some of the above choices is analyzed.

Work supported by the Universities Research Association, Inc., under contract DE-AC02-76CH03000 with the U.S. Department of Energy.

**TPAP026—Improving the Tevatron Collision Helix**
*Ronald Moore, Yuri Alexahin, John Johnstone, Tanaji Sen (Fermilab)*
In the Tevatron, protons and pbars circulate in a single beam pipe, so electrostatic separators are used to create helical orbits that separate the two beams except at the two interaction points (IP). Increasing the separation outside of the IPs is desirable in order to decrease long range beam-beam effects during high energy physics (HEP) stores. We can increase separation by running the separators at higher gradients or by installing additional separators. We are pursuing both strategies in parallel. Here, we describe Tevatron operation with higher separator gradients and with new separators installed during a recent shutdown. We also describe possible future improvements.

**TPAP027—Deterioration of the Skew Quadrupole Moment in Tevatron Dipoles Over Time**
*Michael James Syphers, David J. Harding (Fermilab)*
During the 20 years since it was first commissioned, the Fermilab Tevatron has developed strong coupling between the two transverse degrees of freedom. A circuit of skew quadrupole magnets is used to correct for coupling and, though capable, its required strength has increased since 1983 by more than an order of magnitude. In more recent years changes to the Tevatron for colliding beams operation have altered the skew quadrupole corrector distribution and strong local coupling become evident, often encumbering routine operation during the present physics run. Detailed magnet measurements were performed on each individual magnet during construction, and in early 2003 it was realized that measurements could be performed on the magnets in situ which could determine coil movements within the iron yoke since the early 1980's. It was discovered that the superconducting coils had become vertically displaced relative to their yokes since their construction. The ensuing systematic skew quadrupole field introduced by this displacement accounts for the required corrector settings and observed beam behavior. An historical account of the events leading to this discovery and progress toward its remedy are presented.

U.S. Department of Energy under Contract No. DE-AC02-76CH03000.

**TPAP028—Observations of Strong Transverse Coupling in the Tevatron**
*Michael James Syphers, Gerald Annala, Donald Edwards, Norman Gelfand, John Johnstone, Michael A. Martens, Tanaji Sen (Fermilab)*
During the beginning of Run II of the Tevatron Collider it became apparent that a large skew quadrupole source, or sources, had developed in the superconducting synchrotron. Efforts to locate the current source of coupling were undertaken, with the eventual discovery that the main magnets had developed a systematic skew quadrupole moment over their lifetime. Over the past year, the magnets have been altered in place in an attempt to restore the systematic skew quadrupole moment to

zero. Beam observations and their interpretations are presented, and remedial measures are discussed.

U.S. Department of Energy under Contract No. DE-AC02-76CH03000.

**TPAP029—Measurements of Field Decay and Snapback Effect on Tevatron Dipole and Quadrupole Magnets**
*Gueorgui Velev, Giorgio Ambrosio, Jerry Annala, Pierre Bauer, Ruben H. Carcagno, Joseph DiMarco, Robert Kephart, Michael Joseph Lamm, Michael A. Martens, Phil Schlabach, Mike Tartaglia, John Tompkins (Fermilab)*
Since the beginning of 2002 an intensive measurement program has been performed at the Fermilab Magnet Test Facility to understand dynamic effects in the Tevatron magnets. Based on the results of this program a new correction algorithm was proposed to compensate for the decay of the sextupole field during the dwell at injection and for the subsequent field "snapback" during the first few seconds of the energy ramp. Beam studies showed that the new correction algorithm works better than the original one, and improves the Tevatron efficiency by at least 3%. The beam studies also indicated insufficient correction during the first 20 s of the injection plateau where an unexpected discrepancy of 0.15 sextupole units of extra drift was observed. This paper reports on the most recent measurements of the Tevatron dipoles field at the beginning of the injection plateau. Results on the field decay and snapback in the Tevatron quadrupoles are also presented.

**TPAP030—Tevatron Alignment Issues 2003-2004**
*James T. Volk, Jerry Annala, Luciano Elementi, Norman Gelfand, Keith Gollwitzer, John A. Greenwood, Michael A. Martens, Craig Damon Moore, Alfred Nobrega, Allison Russell, Terry Sager, Vladimir Shiltsev, Raymond Stefanski, Michael James Syphers, George Wojcik (Fermilab)*
It was observed during the early part of Run II that dipole corrector currents in the Tevatron were changing over time. Measurement of the roll for dipoles and quadrupoles confirmed that there was a slow and systematic movement of the magnets from their ideal position. A simple system using a digital protractor and laptop computer was developed to allow roll measurements of all dipoles and quadrupoles. These measurements showed that many magnets in the Tevatron had rolled more than 1 milli-radian. To aid in magnet alignment a new survey network was built in the Tevatron tunnel. This network is based on the use of free centering laser tracker. During the measurement of the network coordinates for all dipole, quadrupole and corrector magnets were obtained. This paper discusses roll measurement techniques and data, the old and new Tevatron alignment network.

U.S. Department of Energy under contract No. DE-AC02-76CH03000.

**TPAP031—Simulations of an Acceleration Scheme for Producing High Intensity and Low Emittance Antiproton Beam for Fermilab Collider Operation**
*Vincent Wu, Chandra Bhat, James Angell Mac Lachlan (Fermilab)*
During Fermilab collider operation, the Main Injector (MI) provides high intensity and low emittance proton and antiproton beams for the Tevatron collider. The present coalescing scheme for antiproton acceleration and rf manipulations in the Main Injector yields about a factor of two increase in the longitudinal emittance and a factor of 5% to 25% decrease in intensity before injection to the Tevatron. In order to maximize the integrated luminosity delivered to the collider experiments, it is important to minimize the emittance growth and maximize the intensity of the MI beam. To this end, a new scheme* using a combination of 2.5 MHz and 53 MHz accelerations has been developed and tested. This paper describes the full simulation of the new scheme, taking account of space charge, 2.5 MHz and 53 MHz beam loading, and the effect of residual 53 MHz rf voltage during 2.5 MHz acceleration and rf manipulations. The simulations show the longitudinal emittance growth at the 10% level with no beam loss. The experimental test of the new scheme is reported in another PAC05 paper.
*G.P. Jackson, The Fermilab Recycler Ring Technical Design Report, FERMILAB-TM-1991, November 1996.

Operated by Universities Research Association, Inc. for the U.S. Department of Energy under contract DE-AC02-76CH03000.

**TPAP032—The Experiments and Operation of the 1st Tevatron Electron Lens**
*Xiaolong Zhang, Vladimir Shiltsev (Fermilab, Batavia, Illinois), Kip Bishofberger (UCLA)*
In this report, we will show the daily operation TEL1 as the irreplaceableTevatron DC beam cleaner and the upgrades made to improve its stability. We will also describe the beam-beam compensation attempts. Some other use of the TEL1 will also be discussed.

Work supported by the Universities Research Assos., Inc., under contract DE-AC02-76CH03000 with the U.S. Dept. of Energy.

**TPAP033—Tevatron Acceptance Measurement**
*Xiaolong Zhang, Vladimir Shiltsev, Cheng-Yang Tan (Fermilab)*
We measured the Tevatron Beam Acceptance by the method of exciting the beam emittance growth with the beam tickling system with noise. The noise power was about 3Watt with 100Hz bandwidth and centered either in horizontal betatron frequency or vertical betatron frequency. We were able to blow the beam emittance fast while under control. From the point the beam emittance stop growing, we measured the beam acceptance of the Tevatron.

Work supported by the Universities Research Assos., Inc., under contract DE-AC02-76CH03000 with the U.S. Dept. of Energy.

**TPAP034—Analysis of Tevatron Beam Loss Scenario and Mitigation for TEVB Pixel Detector**
*Xiaolong Zhang, Michael Church, Vladimir Shiltsev (Fermilab)*
In this report, we analyzed the Tevatron beam loss scenarios based on the Tevatron RunII experience. Based on these analyses, we will try to devise the operation considerations for future TEVB operation. As well some possibilities of future upgrades will be discussed.

Work supported by the Universities Research Assos., Inc., under contract DE-AC02-76CH03000 with the U.S. Dept. of Energy.

**TPAP035—Energy Deposition Issues at 8 GeV H- Beam Collimation and Injection to the Fermilab Main Injector**
*Alexandr I. Drozhdin, Mikhail A. Kostin, Nikolai V. Mokhov (Fermilab)*
The energy deposition and radiation issues at 8 GeV H- beam collimation in the beam transfer line and at stripping injection to the Fermilab Main Injector are analyzed. Detailed calculations with the STRUCT and MARS15 codes are performed on heating of collimators, stripping foils and other critical components, as well as on beam line and accelerator element radioactivation both at normal operation and accidental beam loss. Extraction of

the unstripped part of the beam to the external beam dump and loss of the excited-state Ho atoms in the Main Injector are also studied.

**TPAP036—Fitting the Luminosity Decay in the Tevatron**
*Elliott McCrory, Anna Jean Slaughter, Aimin Xiao (Fermilab)*
This paper explores the various ways in which the decay of the luminosity in the Tevatron have been fit. The standard assumptions of a fixed-lifetime exponential decay are only appropriate for very short time intervals. A "1/time" funcional form fits rather well, and is supported by analytical derivations. A more complex form, assuming a time-varying lifetime, produces excellent results. Changes in the luminosity can be factored into two phenomena: The luminosity burn-off rate, and the burn-off rate from non-luminosity effects. The luminous and the non-luminous burn rate are shown for stores in the Tevatron.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**TPAP037—Monte Carlo of Tevatron Operations, Including the Recycler**
*Elliott McCrory (Fermilab)*
A Monte Carlo model, which was originally developed for "Run I" of the Tevatron Collider, has been enhanced in many ways, most notably, to incorporate the effect of the Recycler Ring. This model takes into account reasonable random fluctuations in the performance of the Collider, and normal interruptions in operation of each accelerator due to downtime. Optimization of the integrated luminosity delivered to the experiments is based on when to end the store and how to deal with the anitprotons. Preliminary results show that a 20% gain in integrated luminosity in the Collider results from using the Recycler for one-third of the anitprotons in each store. As electron cooling becomes operative in the Recycler, Collider performance improves by as much as a factor of two.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**TPAP038—Characterizing Luminosity Evolution in the Tevatron**
*Elliott McCrory, Vladimir Shiltsev, Anna Jean Slaughter, Aimin Xiao (Fermilab)*
We derive an approximate form of a luminosity evolution in a high intensity hadron collider taking into account the most important phenomena of intrabeam scattering (IBS), beam burn-up due to luminosity and beam-beam effects. It is well known that an exponential decay does not describe luminosity evolution very well unless the lifetime is allowed to vary with time. However, a "1/time" evolution, which this derivation shows is a good approximation, fits data from the Tevatron well.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**TPAP040—Feasibility Study of Beam-Beam Compensation in the Tevatron with Wires**
*Tanaji Sen (Fermilab), Béla Erdélyi (Northern Illinois University)*
At large distances the field profile of a current carrying wire matches the profile of the field of a round beam. We consider the practical applicability of this principle in compensating long-range beam-beam effects in the Tevatron. Changes in the helix and beam separation from injection energy to collision energy require that different wire configurations at these different energies. Due to the seventy or more long-range interactions, each set of wires must compensate several interactions. We first develop the principles of non-local compensation with a small set of wires. Next we use these principles in detailed simulation studies with beam-beam interactions and wire fields to determine the feasibility of the compensation in the Tevatron.

Dept. of Energy.

**TPAP041—Simulations of Beam-Beam Phenomena in the Tevatron with BBSIM**
*Tanaji Sen, Vinay Boocha (Fermilab)*
BBSIM is a parallelized weak-strong beam-beam simulation program developed at Fermilab over the last two years. The motivation was to understand the dynamics due to long-range beam-beam interactions. These interactions have a strong influence on beam lifetime at all stages of the Tevatron's cycle. We describe some of the key features of the code including the algorithm for fast evaluations of long-range beam-beam kicks and the important accelerator physics issues included in the model. We report on simulations done to benchmark the code against observations including for example bunch by bunch dependence of anti-proton emittance growth and lifetimes. We also report on predictions for anti-proton beam behaviour under different machine conditions such as different chromaticities and different cogging schemes at injection energy.

Dept. of Energy.

**TPAP042—Luminosity Limits Due to Intra-Beam and Background**
*Yaroslav Derbenev, Andrei Afanasev, Yuhong Zhang (Jefferson Lab)*
We discuss high energy electron cooling (EC) in the context of reaching higher luminosity at the existing and future colliders with hadron beams. The presented concepts of high luminosity involve the energy recovering linac and circulator ring based EC, strong high frequency bunching field in superconducting resonators and crab-crossing colliding beams. These techniques deliver the low emittance, short hadron beam bunches and allow one to design the interaction regions in electron-hadron and hadron-hadron colliders with very low beta-star at a very high bunch collision rate while eliminating the parasitic beam-beam interaction. We present our results on calculations of the achievable luminosity level and lifetime due to intra-beam scattering, multiple and single (Touschek scattering). We also evaluate limitations on the beam lifetime due to low-angle scattering in the interaction regions. For the case of electron-ion collider, the effect of background scattering is dominated by Mott scattering, while for the proton and ion colliders, we considered the Coulomb scattering mechanism complemented by Regge-pole exchanges, including their quantum interference.

Work supported by DOE Contract DE-AC05-84ER40150.

**TPAP043—Electron Cooling of RHIC**
*Ilan Ben-Zvi, Donald Barton, Dana Beavis, Michael Blaskiewicz, Joseph Michael Brennan, Andrew Burrill, Rama Calaga, Peter Cameron, Xiangyun Chang, Roger Connolly, Yury Isaakovich Eidelman, Alexei V. Fedotov, Wolfram Fischer, David Mark Gassner, Harald Hahn, Michael Harrison, Ady Hershcovitch, Hsiao-Chaun Hseuh, Animesh Kumar Jain, Peter Johnson, Dmitry Kayran, Jorg Kewisch, Robert Lambiase, Vladimir N. Litvinenko, William W. MacKay, George Mahler,*

*Nikolay Malitsky, Gary McIntyre, Wuzheng Meng, Kerry Mirabella, Christoph Montag, Thomas Nehring, Tony Nicoletti, Brian Oerter, George Parzen, David Pate, Jim Rank, Triveni Rao, Thomas Roser, Thomas Russo, Joseph Scaduto, Kevin Smith, Dejan Trbojevic, Jie Wei, Neville Willaims, Kuo-Chen Wu, Vitaly Yakimenko, Alex Zaltsman, Yongxiang Zhao (BNL), Al Burger, Anthony Favale, Douglas Holmes (AES), Hans Bluem, Michael Cole, John Rathke, Tom Schultheiss, Alan Murray Melville Todd (AES), Ivan Koop, Vasily Parkhomchuk, Yuri Shatunov, Alexander Skrinsky (BINP SB RAS), Jacek Sekutowicz (DESY), Alexey Burov, Sergei Nagaitsev (Fermilab), Igor Meshkov, Anatoly Olegovich Sidorin, Alexander Smirnov, Grigory Troubnikov (JINR), Jean Roger Delayen, Yaroslav Derbenev, Warren Funk, Peter Kneisel, Lia Merminga, Larry Phillips, Joseph P. Preble (Jefferson Lab), Dan Tyler Abell, David L. Bruhwiler (Tech-X)*
We report progress on the R&D program for electron-cooling of the Relativistic Heavy Ion Collider (RHIC). This electron cooler is designed to cool 100 GeV/nucleon at storage energy using 54 MeV electrons. The electron source will be a superconducting RF photocathode gun. The accelerator will be a superconducting energy recovery linac. The frequency of the accelerator is set at 703.75 MHz. The maximum electron bunch frequency is 9.38 MHz, with bunch charge of 20 nC. The R&D program has the following components: The photoinjector and its photocathode, the superconducting linac cavity, start-to-end beam dynamics with magnetized electrons, electron cooling calculations including benchmarking experiments and development of a large superconducting solenoid. The photoinjector and linac cavity are being incorporated into an energy recovery linac aimed at demonstrating ampere class current at about 20 MeV. A Zeroth Order Design Report is in an advanced draft state, and can be found on the web at http://www.agsrhichome.bnl.gov/eCool/.

Under contract with the U.S. Department of Energy, Contract Number DE-AC02-98CH10886.

**TPAP044—Observations of Snake Resonance in RHIC**

*Mei Bai, Haixin Huang, William Mac Kay, Vadim Ptitsyn, Thomas Roser, Steven Tepikian (BNL), Georg Hoffstaetter (Cornell University), Shyh-Yuan Lee, Fanglei Lin (IUCF)*
Siberian snakes now become essential in the polarized proton acceleration. With proper configuration of Siberian snakes, the spin precession tune of the beam becomes $\frac{1}{2}$ which avoids all the spin depolarizing resonance. However, the enhancement of the perturbations on the spin motion can still occur when the betatron tune is near some low order fractional numbers, called snake resonances, and the beam can be depolarized when passing through the resonance. The snake resonances have been confirmed in the spin tracking calculations, and observed in RHIC with polarized proton beam. Equipped with two full Siberian snakes in each ring, RHIC provides us a perfect facility for snake resonance studies. This paper presents latest experimental results. New insights are also discussed.

The work was performed under the auspices of the U.S. Department of Energy.

**TPAP045—Localizing Sources of Horizontal Orbit Oscillations at RHIC**

*Rama Calaga, Christoph Montag, Thomas Roser, Todd Satogata (BNL)*
Vibrations of low-beta triplet quadrupoles at RHIC create horizontal oscillations of the closed orbit at frequencies around 10Hz. These oscillations lead to beam offsets at the collision point, and could result in emittance growth and reduced luminosity. An approach to localize the sources of these vibrations using Singular Value decomposition (SVD) of RHIC orbit data is presented. Data from the 2005 Cu-Cu and pp runs is evaluated to spatially resolve the location of the vibration sources and identify their corresponding frequencies.

This work was performed under the auspices of the U.S. Department of Energy.

**TPAP046—Measurements of the Total Cu-Cu Cross Section at RHIC**

*Angelika Drees (BNL)*
Using the Vernier Scan or Van der Meer Scan technique, where one beam is swept stepwise across the other while measuring the collision rate as a function of beam displacement, the transverse beam profiles, the instantaneous luminosity and the cross section can be measured. The cross section is an important ingredient when the total delivered luminosity is determined and when the instantaneous luminosity is monitored. The experimental detectors need the cross section to normalize their measurements. Though it can be calculated to some level of accuracy it has never been measured so far. This report presents the measurements and the results from the FY2005 Cu-Cu run.

Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the U.S. Department of Energy.

**TPAP047—Longitudinal and Transverse Vertex Distributions at RHIC**

*Angelika Drees, Roger Connolly, Roger C. Lee, Seth Nemesure (BNL)*
The experimental detectors at RHIC have different longitudinal acceptances. However, in all cases the acceptance is smaller than the bunch length or the width of the vertex distribution provided by the accelerating cavities and is for some even smaller than the length provided by the storage cavities. A vertex area outside the experimental acceptance does not contribute to the integrated luminosity. In addition, the experiments are sensitive to a shift of the mean of the vertex distribution in the order of a few 10^-2 m. Therefore it is important to measure, monitor and control the vertex distribution. Since the FY2005 run online measurements of the longitudinal vertex distributions of most experiments are available and can be compared to longitudinal profiles from the RHIC Wall Current Monitor. Additionally, some experiments provide transverse vertex distributions which are compared to profile measurements from the Ionization Profile Monitor and from Vernier Scans. This report summarizes the measurements and presents the available data from the RHIC FY2005 run.

Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the U.S. Department of Energy.

**TPAP048—Optimization of the Phase Advance Between RHIC Interaction Points**

*Rogelio Tomas, Wolfram Fischer (BNL)*
We consider the scenario of having two identical Interaction Points (IPs) in the Relativistic Heavy Ion Collider (RHIC). The strengths of beam-beam resonances strongly depend on the phase advance between these two IPs and therefore certain phase advances could improve beam lifetime and luminosity. We compute the dynamic aperture as function of the phase advance between these IPs to find the optimum settings. The beam-beam interaction is treated in the weak-strong approximation and a complete non-linear model of the lattice is used. For the current RHIC proton working point (0.69,0.685) the design lattice is found to have the optimum phase advance. However this is not the case for other working points.

U.S. department of Energy.

**TPAP049—Beam Pipe Desorption Rate in RHIC**
*Haixin Huang, Wolfram Fischer, Ping He, Hsiao-Chaun Hseuh, Ubaldo Iriso, Vadim Ptitsyn, Dejan Trbojevic, Jie Wei, S.Y. Zhang (BNL)*
Increase of beam intensity in RHIC has caused several decades of pressure rises in the warm sections during recent operations. This has been one of major limiting factors to RHIC luminosity. About 60 meters NEG coated beam pipes have been installed last year in many warm sections to fight this problem. Beam ion induced desorption is one possible cause of pressure rises. A series beam studies in RHIC have been dedicated to estimate the desorption rate of various beam pipes (regular and NEG coated) at various warm sections. Local correctors were used to generate local beam loss and consequently local pressure rises. The experiment results are presented and analyzed in this paper.

Work performed under the auspices of the US Department of Energy.

**TPAP050—RHIC Luminosity with Larger Tune Advance in FODO Cells**
*Vladimir N. Litvinenko, Mei Bai, Joanne Beebe-Wang, Peter Cameron, Roger Connolly, Angelika Drees, Alexei V. Fedotov, Wolfram Fischer, George Ganetis, Haixin Huang, Dmitry Kayran, Jorg Kewisch, Yun Luo, William W. MacKay, Nikolay Malitsky, Christoph Montag, George Parzen, Fulvia C. Pilat, Vadim Ptitsyn, Thomas Roser, Alessandro Ruggiero, Todd Satogata, Steven Tepikian, Dejan Trbojevic, Kurt Vetter, Jie Wei (BNL)*
Present level of average luminosity in ion-ion collision at RHIC is affected by intra-beam scattering (IBS), both the transverse and the longitudinal. The present arc lattice in RHIC is based on FODO lattice with 82-degrees phase advance. Our studies showed that increase phase advance in FODO lattice can provide for 2-to-3 fold reduction of the transverse IBS rate. Additional improvement in longitudinal direction comes from the increase of the energy acceptance of the RF separatrix and corresponding reduction of the ions de-bunching. Overall, this scheme promises increase of the integrated luminosity up to a factor of two. In this paper we present the evaluation of scheme including the limitations imposed by the RHIC magnets, power supplies and super-conducting leads, and compare available options including reduction of beta-star value. We present the results of theoretical studies and experimental test of RHIC lattice with 92-degrees phase advance.

Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the U.S. Department of Energy.

**TPAP051—Principle of Global Decoupling with Coupling Phase Modulation**
*Yun Luo, Fulvia C. Pilat, Thomas Roser, Dejan Trbojevic (BNL)*
The global betatron decoupling on the ramp is an important issue for the operation of the Relativistic Heavy Ion Collider (RHIC). A new scheme coupling phase modulation is found. It introduces a rotating extra coupling into the coupled machine to detect the residual coupling. The eigentune responses are measured with a high resolution phase lock loop (PLL) system. From the minimum and maximum tune splits, the correction strengths are given. The time period occupied by one coupling phase modulation is less than 10 seconds. So it is a very promising solution for the global decoupling on the ramp. In this article the principle of the coupling phase modulation is given. The simulation with the smooth accelerator model is also done. The practical issues concerning its applications are discussed.

Work supported by U.S. DOE under contract No. DE-AC02-98CH10886.

**TPAP052—Phase Loop for Global Betatron Decoupling**
*Yun Luo, Peter Cameron, Al Dellapenna, Al Marusic, Steve Peggs, Dejan Trbojevic (BNL)*
Besides two eigentunes Q_1 and Q_2 , two amplitude ratios r_1 and r_2 and two phase differences • •_{1} and • •_{2} are introduced for the global coupling observation. Simulations are carried out to check their behaviors in the process of the skew quadrupole strength scans. Some attractive features of the phase differences • •_{1,2} have been found, which are possibly useful for the global decoupling phase loop, or future global decoupling feedback. Analytical descriptions to these 6 quantities are described in the Twiss parameters through the linear coupling's action-angle parameterization, or in coupling coefficient through the linear coupling's Hamiltonian perturbation theory. Dedicated beam experiments are carried out at the Relativistic Heavy Ion Collider (RHIC) to check the global coupling observables from the phase lock loop (PLL) system. The six observables are measured under PLL driving oscillations during the 1-D and 2-D skew quadrupole scans. The experimental results are reported and discussions are given.

Work supported by U.S. DOE under contract No. DE-AC02-98CH10886.

**TPAP053—RHIC IP Optics Measurements**
*Yun Luo, Mei Bai, Fulvia C. Pilat, Todd Satogata, Dejan Trbojevic (BNL)*
The interaction region (IP) optics are measured with the two DX/BPMs close to the IPs at the Relativistic Heavy Ion Collider (RHIC). The beta functions at IP are measured with the two eigenmodes' phase advances between the two BPMs. And the beta waists are also determined through the beta functions at the two BPMs. The coupling parameters at the IPs are also given through the linear coupling's action-angle parameterization. All the experimental data are taken during the driving oscillations with the AC dipole. The methods to do these measurements are discussed. And the measurement results during the beta^{*} squeezings are also presented.

Work supported by U.S. DOE under contract No. DE-AC02-98CH10886.

**TPAP054—Helium Flow Induced Orbit Jitter at RHIC**
*Christoph Montag, Tony Nicoletti, Todd Satogata (BNL)*
Horizontal beam orbit jitter at frequencies around 10 Hz has been observed at RHIC for several years. The distinct frequencies of this jitter have been found at superconducting low-beta qudrupole triplets around the ring, where they coincide with mechanical modes of the cold masses. Recently, we have identified liquid helium flow as the driving force of these oscillations.

Work performed under the auspices of the US Department of Energy.

**TPAP055—Fast IR orbit feedback at RHIC**
*Christoph Montag, Al Marusic, Robert Michnoff, Thomas Roser, Carl Schultheiss (BNL)*
Mechanical low-beta triplet vibrations lead to horizontal jitter of RHIC beams at frequencies around 10 Hz. The resulting beam offsets at the interaction points are considered detrimental to RHIC luminosity performance. To stabilize beam orbits at the interaction points, installation of a fast orbit feedback is foreseen. A prototype of this system is being developed and tested. Recent results are presented.

Work performed under the auspices of the U.S. Department of Energy.

**TPAP056—Electron Beam Stability Requirements for Linac-Ring Electron-Ion Colliders**
*Christoph Montag (BNL)*
In recent years, linac-ring electron-ion colliders have been proposed at a number of laboratories around the world. While the linac-ring approach overcomes the beam-beam tuneshift limitation on the electron beam, it also introduces noise into the ion beam, via the beam-beam interaction with electron bunches of slightly fluctuating intensity and transverse size. The effect of these fluctuations is studied using a linearized model of the beam-beam interaction. Upper limits for the rms jitter amplitudes of electron beam parameters for various linac-ring electron-ion colliders are presented.

Work performed under the auspices of the U.S. Department of Energy.

**TPAP057—Beam-Beam Simulations for the eRHIC Electron Ring**
*Christoph Montag (BNL)*
To study collisions between polarized electrons and heavy ions or polarized protons at high energy, adding a 10 GeV electron storage ring to the existing RHIC facility is currently under consideration. To achieve high luminosities, vertical beam-beam tuneshift parameters of 0.08 are required for the electron beam. Simulation studies are being performed to study the feasibility of these high tuneshift parameters and to explore the potential for even higher tuneshifts. Recent results of these studies are presented.

Work performed under the auspices of the U.S. Department of Energy.

**TPAP058—Beam-Beam Simulations for Double-Gaussian Beams**
*Christoph Montag, Ilan Ben-Zvi, Vladimir N. Litvinenko, Nikolay Malitsky (BNL)*
Electron cooling together with intra-beam scattering results in a transverse distribution that can best be described by a sum of two Gaussians, one for the high-density core and one for the tails of the distribution. Simulation studies are being performed to understand the beam-beam interaction of these double-Gaussian beams. Here we report the effect of low-frequency random tune modulations on diffusion in double-Gaussian beams and compare the effects to those in beam-beam interactions with regular Gaussian beams and identical tuneshift parameters.

Work performed under the auspices of the U.S. Department of Energy.

**TPAP059—Progress in Polarized Protons Above 100 GeV Energy in RHIC**
*Vadim Ptitsyn, Mei Bai, Haixin Huang, William W. MacKay, Thomas Roser (BNL)*
In previous RHIC runs polarized proton beams were accelerated to 100 GeV energy with a pair of Siberian snakes installed in both RHIC rings to prevent beam depolarization. The maximum energy to which proton beams can be accelerated in RHIC is 250 GeV. Spin resonance strengths increase considerably as the beam energy grows, complicating the task of the polarization preservation. Based on the experience of previous RHIC runs factors influencing the beam polarization such as the betatron tune working point and tolerances on the beam closed orbit distortion are evaluated. Results of first tests of RHIC polarized proton beam acceleration beyond 100 Gev energy are also presented and discussed.

**TPAP060—Survey of RHIC Misalignments**
*Vadim Ptitsyn, F. M. Hemmer, Francis Karl, Charles Spataro, Dejan Trbojevic (BNL)*
As a part of its operation RHIC uses polarized proton beams. The beam polarization is affected by vertical orbit excursion which results from magnet misalignments. Thus the misalignments are a crucial factor for the polarization preservation. In the paper the analysis of RHIC magnet misalignment data is presented. The misalignment data is a result of several misalignment measurements in RHIC over a period of 10 years. The analysis shows the evolution of RHIC misalignments with the time in different locations in the RHIC tunnel revealing considerable ground sinking in interaction regions. Criteria for local realignments done in several ring locations are described.

Work performed under the auspices of the United States Department of Energy.

## Poster Session TPAT—Multiparticle Beam Dynamics, Extreme Beams, & High-Energy Hadron Accelerators and Colliders
## Meeting Room 200 A-C, 8:30-12:20

**TPAT001—A Source for Non-Relativistic Electrons Approaching the Brightness Quantum Limit**
*Max Zolotorev, Peter Denes, Zahid Hussain, Gennadi Lebedev, Steven M. Lidia, David Robin, Fernando Sannibale, Robert W. Schoenlein, Robert Vogel (LBNL), Eugene Commins (UCB)*
We describe a novel scheme for an electron source in the 10 - 100 eV range with the capability of approaching the brightness quantum-limit and of lowering the effective temperature of the electrons orders of magnitude with respect to existing sources. Such a device can open the way for a wide range of novel applications that utilize angstrom-scale spatial eV-scale energy resolution. Possible examples include resolution and electron microscopy, electron holography, and investigations of dynamics on a picosecond time scale using pump-probe techniques. In this paper we describe the concepts for such a source including a complete and consistent set of parameters for the construction of a real device based on the presented scheme.

Work supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**TPAT002—Three-Dimensional Simulation of Large-Aspect-Ratio Ellipse-Shaped Charged-Particle Beam Propagation**
*Ronak Bhatt, Chiping Chen, Jing Zhou (MIT/PSFC)*
The three-dimensional trajectory code, OMNITRAK, is used to simulate a space-charge-dominated beam of large-aspect-ratio elliptic cross-section propagating in a non-axisymmetric periodic permanent magnet focusing field. The simulation results confirm theoretical predictions in the paraxial limit. A realistic magnetic field profile is applied, and the beam sensitivity to magnet nonlinearities and misalignments is studied. The image-charge effect of conductor walls is examined for a variety of beam tunnel sizes and geometries.

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**TPAT003—Cold-Fluid Equilibrium of a Large-Aspect-Ratio Ellipse-Shaped Charged-Particle Beam in a Non-Axisymmetric Periodic Permanent Magnet Focusing Field**
*Jing Zhou, Ronak Bhatt, Chiping Chen (MIT/PSFC)*
A new class of equilibrium is discovered for a large-aspect-ratio ellipse-shaped charged-particle beam in a non-axisymmetric periodic permanent magnet focusing field. A paraxial cold-fluid model is employed to derive the equilibrium flow properties and generalized envelope equations with negligibly small emittance. A periodic beam equilibrium solution is obtained numerically from the generalized envelope equations. It is shown that the beam edges are well confined in both transverse directions, and that the equilibrium beam exhibits a small-angle periodic wobble as it propagates. A two-dimensional particle-in-cell (PIC) code, PFB2D, is used to verify the theoretical predictions in the paraxial limit, and to establish validity under non-paraxial situations and the influence of the conductor walls of the beam tunnel.

U.S. DOE, Grant: No. DE-FG02-95ER40919,Grant No. DE-FG02-01ER54662, Air Force Office of Scientific Research, Grant No. F49620-03-1-0230, and the MIT Deshpande Center for Technological Innovation.

**TPAT004—Strongly Asymmetric Beams at the University of Maryland Electron Ring (UMER)**
*Santiago Bernal, Gang Bai, Rami Alfred Kishek, Hui Li, Patrick G. O'Shea, Bryan Quinn, Mark Walter (IREAP), Martin Reiser (University Maryland)*
The standard operation of the University of Maryland electron ring employs symmetric strong focusing with magnetic quadrupoles, i.e., a FODO scheme whereby the zero-current betatron phase advances per period in the two transverse planes are equal or nearly so. Asymmetric focusing, on the other hand, employs quadrupoles with different strengths in a FODO cell. Typically, a small focusing asymmetry is implemented in most accelerators to set the operating point (horizontal and vertical zero-current tunes) in order to avoid resonances and/or compensate for edge focusing of bend magnets. Extreme asymmetry, however, is rarely, if at all, used. We review the motivation and theory of beam transport with general focusing asymmetry. We also present results of preliminary experiments and simulations with highly asymmetric focusing of a space-charge dominated electron beam in UMER.

This work is funded by U.S. Dept. of Energy under grants DE-FG02-94ER40855 and DE-FG02-92ER54178.

**TPAT005—Start to End Error Study for the SPIRAL2 Linac**
*Romuald Duperrier, Didier Uriot (CEA/DSM/DAPNIA)*
The possibility of a high intensity accelerator at GANIL, producing secondary beams of unprecedented intensity, is considered. The proposed driver for the SPIRAL2 project aims to accelerate a 5 mA deuteron beam up to 20 A.MeV and a 1 mA ion beam for q/A = 1/3 up to 14.5 A.MeV. It is a continuous wave regime linac, designed for a maximum efficiency in the transmission of intense beams and a tunable energy. This paper presents the error sensitivity study which has been performed for this linac in order to define the tolerances for the construction. The correction scheme and the expected losses are described.

**TPAT006—Optics, Geometry and CSR-Related Emittance Growth in Bunch Compressor Chicanes**
*Torsten Limberg, Martin Dohlus (DESY)*
The dependence of emittance growth due to Coherent Synchrotron radiation (CSR) in bunch compression chicanes on optics and chicane geometry has been noticed and empirically studied in the past. We revisit the subject in a more systematic approach, suggesting and testing the validity of different models to explain emittance growth with full 3D CSR beam dynamics calculations.

**TPAT007—RF Defocusing in Super-Conducting Structure with Constant Geometry**
*Yurij Senichev, Rudolf Maier, Nikita Vasyukhin (FZJ/IKP)*
Due to higher accelerating gradient in the super-conducting linac the RF defocusing factor plays significant role in the beam dynamics. Together with the space charge it is a main reason for the stability loss. Usually it is estimated in frame of the travelling wave formalism with synchronous motion. However, the super-conducting cavity is desirable to have the constant geometry, when synchronous motion is absent. In this case the quasi-synchronous phase velocity is adjusted by RF phasing. In this paper we investigate RF defocusing factor in absent of synchronism between the beam and the accelerating structure.

**TPAT008—Numerical Dispersion Error Reduction in EM Calculations for Accelerators**
*Thomas Lau, Erion Gjonaj, Thomas Weiland, Igor Zagorodnov (TEMF, Darmstadt)*
In this contribution novel numerical algorithms with no dispersion along the beam axis are investigated. This property is of interest for the long-time calculation of electromagnetic fields in accelerators. Instead of increasing the spatial stencil of the Yee scheme the compared methods modify the time-stepping algorithm.The results are compared on several test examples. As a practical application the electromagnetic field of a very short bunch inside a cavity is calculated.

Deutsches Elektronen-Synchrotron DESY.

**TPAT009—Physics in Induction Acceleration**
*Yoshito Shimosaki, Ken Takayama (KEK, Ibaraki), Kota Torikai (Kyushu University, Fukuoka)*
Proof-of-principle experiments of the induction synchrotron concept using the KEK 12-GeV PS make progress, in which RF bunches and a super-bunch will be accelerated by a long step-voltage generated in the induction accelerating gaps. Beam dynamics of super-bunch including space-charge fields and a wake potential will be discussed.

**TPAT010—Practical Definitions of Beam Lifetimes in an Electron Storage Ring**
*Tae-Yeon Lee (PAL, Pohang)*
Derived are simple definitions of beam lifetimes in an electron storage ring. They are defined in terms of measured beam lifetime and its time derivative. They are practical rather than theoretical. The only condition required is suppression or saturation of the radiative polarization.

**TPAT011—Impedance Analysis of Longitudinal Bunch Shape Measurements at PLS**
*Ilmoon Hwang, Moohyun Yoon (POSTECH), Yeung-Jin Han, Eun-San Kim (PAL)*
We measured the longitudinal bunch shape by streak camera at 2.5 GeV Pohang Light Source. The impedances estimated by a series R+L model indicate a resistance R= 820 ohm, an inductance L= 61 nH and a longitudinal impedance Z/n= 0.4 ohm. The scaling law for the bunch lengthenig is expressed as I^0.22. The effects of insertion device in the ring on the ring impedance, particularly the vertical height of in-vacuum undulator are also presented.

**TPAT012—Space-Charge Effects Influence on Ion Beam**

**Dynamics in Undulator Linear Accelerator**
*Eduard Sergeevich Masunov, Sergey Markovich Polozov (MEPhI)*
RF undulator accelerator (UNDULAC-RF) is suggested as an initial part of high intensity ion linac. Such accelerator can be realized in axi-symmetric periodical IH structure where a field has no spatial harmonics in synchronism with the beam.* An accelerating force is to be driven by a combination of two non-synchronous harmonics. Its value is proportional to the particle sign squared. Acceleration gradient and transmission coefficient for low velocity ions with the identical sign of charge are the same as in RFQ. But the limit beam current can be substantially increased in UNDULAC by using space charge compensation of positive and negative charged ions. In UNDULAC positive and negative ions can be accelerated simultaneously within the same bunch.** The process of acceleration and focusing of oppositely charged ions with the identical charge-to-mass ratio in the single bunch is discussed in this paper.
*E.S. Masunov, Technical Physics, V. 46, 11, 2001, pp. 1433-1436. **E.S. Masunov, Autor's certificate USSR #1600007, Bull. "Discovered and Inventions", 1990, 38.

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**TPAT013—Effects of Localization in Models of Fusion/ Energy Confinement in Plasma/Beam Physics in BBGKY Framework**
*Michael G. Zeitlin, Antonina N. Fedorova (RAS/IPME)*
An efficient analytical approach is proposed for analysis of models of energy confinement/fusion in plasma physics based on the full hierarchy of kinetic equations (BBGKY-like systems of equations) describing the complex collective dynamics of non-equilibrium ensembles. Our calculations are based on variational and multiresolution approaches in the basis of polynomial tensor algebras of various localized bases. We construct the representation for hierarchy of distribution functions and dynamical variables via the exact multiscale decomposition in high-localized nonlinear eigenmodes. The corresponding cut-off of infinite hierarchy, reductions to finite dimensional subsets and accuracy of calculations are based on the new multiscale metric structure of the whole Fock-like space of all distribution functions. We demonstrate the possibility of the existence of energy confinement/fusion in the small regions of the whole phase space (waveleton configurations).*
*A. Fedorova, M. Zeitlin, Classical and Quantum Ensembles via Multiresolution. I. BBGKY Hierarchy; II. Wigner Ensembles; arXiv: quant-ph/0406009, 0406010; NIMA, 534A, 1-2, 2004, 309-313, 314-318, 2004 and papers on http://www.ipme.ru/zeitlin.html.

**TPAT014—A Novel Technique for Multiturn Injection in a Circular Accelerator Using Stable Islands in Transverse Phase Space**
*Massimo Giovannozzi, Julien Morel (CERN)*
By applying a time-reversal to the multiturn extraction recently proposed a novel approach to perform multiturn injection is proposed. It is based on the use of stable islands of the horizontal phase space generated by means of sextupoles and octupoles. A particle beam can be injected into stable islands of phase space, and then a slow tune variation allows merging the beam trapped inside the islands. The results of numerical simulations will be presented and discussed in details, showing how to use the proposed approach to generate hollow bunches.

**TPAT015—Simulations of Error-Induced Beam Degradation in Fermilab's Booster Synchrotron**
*Phil Sung Yoon (Rochester University), Weiren Chou (Fermilab), Courtlandt L. Bohn (Northern Illinois University; Fermilab)*
Individual particle orbits in a beam will respond to both external focusing and accelerating forces as well as internal space-charge forces. The external forces will reflect unavoidable systematic and random machine errors, or imperfections, such as jitter in magnet and radio-frequency power supplies, as well as magnet translation and rotation alignment errors. The beam responds in a self-consistent fashion to these errors; they continually do work on the beam and thereby act as a constant source of energy input. Consequently, halo formation and emittnace growth can be induced, resulting in beam degradation and loss. We have upgraded the ORBIT-FNAL package and used it to compute effects of machine errors on emittance degradation and halo formation in the existing FNAL-Booster synchrotron. This package can be applied to study other synchrotrons and storage rings, as well.

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**TPAT017—Impedance of Elliptical Tapered Vacuum Chambers**
*Boris Podobedov (BNL/NSLS)*
The geometric impedance of small-gap undulator chambers is of paramount importance for modern light sources because it may drive transverse single bunch instabilities. Analytical expressions are derived for the transverse impedance assuming a slowly tapered vacuum chamber with a confocal elliptical cross-section. The analytical results are confirmed by numerical simulations with the GdfidL Electromagnetic Field simulator and they yield the correct asymptotic limits for both round and flat chambers.

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**TPAT018—Stability of Barrier Buckets with Short Rf-Barrier Separations**
*King Yuen Ng (Fermilab)*
A barrier bucket with small separation between the rf barriers (relative to the barrier widths) or even zero separation has its synchrotron tune decreasing rather slowly towards the boundary of the bucket. As a result, large area at the bucket edges can become unstable under the modulation of rf voltage and rf phase. Application is made to those barrier buckets used in the process of momentum mining on the issues of bunch-distribution distortion and particle loss.

**TPAT019—Discussions on the Cancellation Effect on a Curved Orbit**
*Rui Li, Yaroslav Derbenev (Jefferson Lab)*
The canonical formulation and the cancellation effect for bunch dynamics under collective interaction on a curved orbit were presented in Ref. [*]. Some possible controversial representations of the cancellation effect were later addressed by Geloni et al.** In this study, we discuss all the points raised in Ref. [**] based on our canonical treatment, and show how these points can be perceived from the view point of the cancellation picture.
*R. Li and Ya. S. Derbenev, Jefferson Laboratory Report No. LJAB-TN-02-054, 2003. **G. Geloni et al., DESY Report No. DESY 03-165, 2003.

Work supported by DOE Contract DE-AC05-84ER40150.

**TPAT020—CSR Interaction at the Cross-Over of the Full Compression Point in a Magnetic Chicane**
*Rui Li (Jefferson Lab)*
In this work, we study the CSR interaction for a bunch being transported through a magnetic chicane under design optics. In particular, the R56 of the chicane and the initial bunch energy chirping are arranged such that the bunch goes over the full compression point slightly before the end of the chicane. Our analysis shows an interesting behavior in the magnitude of the effective longitudinal force right after the full compression point. Further study is needed to check if this analytical result is related to some of the interesting experimental observations of the energy spread at the cross-over of the full compression point.

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**TPAT021—Analysis of the Effective CSR Forces for an Energy-Chirped Bunch on a Circular Orbit**
*Rui Li (Jefferson Lab)*
For an energy-chirped electron bunch moving in a magnetic bend, the effective curvature-induced longitudinal collective force depends on the horizontal-longitudinal correlation (or tilting) of the bunch charge distribution in the bending plane, as revealed earlier by simulations.* As one step toward understanding the coherent synchrotron radiation (CSR) effect during a bunch compression process, in this study, we analyze the curvature-induced (free-space) effective longitudinal and transverse collective forces as functions of bunch tilting, assuming the relativistic energy-chirped bunch is transported on a circular orbit under design optics. Here our main focus is on mild compression, i.e., before the bunch crosses over the full compression point. The analytical results are presented both for a line bunch and for a bunch with intrinsic transverse emittance and energy spread, with Landau damping included in the latter case.
*M. Dohlus, CSR workshop, Berlin (2002).

Work supported by DOE Contract DE-AC05-84ER40150.

**TPAT022—Future Plans for the Small Isochronous Ring**
*Eduard Pozdeyev (Jefferson Lab), Felix Marti, Jose Alberto Rodriguez, Richard York (NSCL)*
The Small Isochronous Ring has been operational at Michigan State University since December 2003. It is used for experimental studies of the beam dynamics in high-intensity isochronous cyclotrons and synchrotrons at the transition energy. The operational experience with SIR has proven that the ring can be successfully used to study space charge effects in accelerators. The low velocity of beam particles in the ring allowed us to achieve a high accuracy of longitudinal profile measurements that is difficult to achieve in full-size accelerators. The experimental data obtained in the ring was used for validation of multi-particle, space-charge codes CYCO and WARP3D. Inspired by the solid performance of SIR in the isochronous regime, we consider options for expanding the scope of the beam physics studied in the ring. In this paper, we outline possible future experiments and discuss required modifications of the ring optics and hardware.

Work supported by NSF Grant #PHY-0110253 and DOE Contract DE-AC05-84ER40150.

**TPAT023—Tests of a 3D Self Magnetic Field Solver in the Finite Element Gun Code MICHELLE**
*Eric Michael Nelson (LANL), John Petillo (SAIC)*
We have recently implemented a prototype 3d self magnetic field solver in the finite-element gun code MICHELLE. The new solver computes the magnetic vector potential on unstructured grids. The solver employs edge basis functions in the curl-curl formulation of the finite-element method. A novel current accumulation algorithm takes advantage of the unstructured grid particle tracker to produce a compatible source vector, for which the singular matrix equation is easily solved by the conjugate gradient method. We will present some test cases demonstrating the capabilities of the prototype 3d self magnetic field solver. One test case is self magnetic field in a square drift tube. Another is a relativistic axisymmetric beam freely expanding in a round pipe.

Work supported by ONR.

**TPAT024—Drift-Compression Simulations for Heavy-Ion Fusion**
*William M. Sharp, John J. Barnard, David Grote (LLNL), C. M. Celata (LBNL)*
Beams for heavy-ion fusion (HIF) must be compressed lengthwise by a factor of more than ten between an induction accelerator and the final-focus magnets. The compression scenario favored by the US HIF program is to impose a head-to-tail velocity increase or "tilt," so the beam tail approaches the head in a "drift-compression" section. The beam current and velocity must be accurately tailored before drift-compression so that the longitudinal space-charge field removes the velocity tilt just as the beam traverses the final-focus lattice. The principle physics questions posed by this section are how much the total emittance grows, whether a beam halo develops, and how these processes scale with beam and lattice parameters. This paper presents theoretical work to model the final longitudinal compression of HIF beams. Pulse-shaping fields are calculated using a fluid/envelope dynamics model and then used in the three-dimensional electrostatic particle-in-cell (PIC) code WARP3d to study beam transport during pulse-shaping and drift-compression. Possible low-energy, near-term experiments are discussed, and for these, we examine how emittance growth and sensitivity to errors scale with the beam and lattice parameters.

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**TPAT025—RIA Post Accelerator Beam Dynamics Issues**
*Stan Owen Schriber (NSCL), Robert Garnett, Thomas Wangler (LANL/LANSCE), Kenneth Crandall (TechSource)*
Details of beam dynamics calculations for the post accelerator of the RIA project are provided. These calculations are mainly for the low energy portion of the accelerator in order to show design tradeoffs and parameter choices that have significant impacts on performance.

**TPAT026—Synergia: An Advanced Object-Oriented Framework for Beam Dynamics Simultation**
*Douglas Ricker Dechow, Peter Stoltz (Tech-X), James Frederick Amundson, Panagiotis Spentzouris (Fermilab)*
Synergia is a 3-D, parallel, particle-in-cell beam dynamics simulation toolkit. At heart of the software development effort is the integration of two extant object-oriented accelerator modeling frameworks—Impact written in Fortran 90 and mxyptlk

written in C++—so that they may be steered by a third, a more flexible human interface framework, written in Python. Recent efforts are focused on the refactoring of the Impact-Fortran 90 codes in order to expose more loosely-coupled interfaces to the Python interface framework.

**TPAT027—Measurement of Transverse Echoes in RHIC**
*Wolfram Fischer, Todd Satogata, Rogelio Tomas (BNL)*
Beam echoes are a very sensitive method to measure diffusion, and longitudinal echo measurements were performed in a number of machines. In RHIC, for the first time, a transverse beam echo was observed after applying a dipole kick followed by a quadrupole kick. After application of the dipole kick, the dipole moment decohered completely due to lattice nonlinearities. When a quadrupole kick is applied at time T after the dipole kick, the beam re-cohered at time 2T thus showing an echo response. We describe the experimental setup and measurement results. In the measurements the dipole and quadrupole kick amplitudes, amplitude dependent tune shift, and the time between dipole and quadrupole kick were varied. In addition, measurements were taken with gold bunches of different intensities. These should exhibit different transverse diffusion rates due to intra-beam scattering.

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**TPAT028—TRACK: The New Beam Dynamics Code**
*Brahim Mustapha, Vladislav Aseev, Eliane Schnirman Lessner, Peter Ostroumov (ANL)*
The new ray-tracing code TRACK was developed* to fulfill the special requirements of the RIA accelerator systems. The RIA lattice includes an ECR ion source, a LEBT containing a MHB and a RFQ followed by three SC linac sections separated by two stripping stations with appropriate magnetic transport systems. No available beam dynamics code meet all the necessary requirements for an end-to-end simulation of the RIA driver linac. The latest version of TRACK was used for end-to-end simulations of the RIA driver including errors and beam loss analysis.** In addition to the standard capabilities, the code includes the following new features: i) multiple charge states ii) realistic stripper model; ii) static and dynamic errors iii) automatic steering to correct for misalignments iv) detailed beam-loss analysis; v) parallel computing to perform large scale simulations. Although primarily developed for simulations of the RIA machine, TRACK is a general beam dynamics code. Currently it is being used for the design and simulation of future proton and heavy-ion linacs at TRIUMF, Fermilab, JLAB and LBL.
*P.N. Ostroumov and K.W. Shepard. Phys. Rev. ST. Accel. Beams 11, 030101 (2001). **P.N. Ostroumov, V. N. Aseev, B. Mustapha. Phys. Rev. ST. Accel. Beams, Volume 7, 090101 (2004).

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**TPAT029—RIA Beam Dynamics: Comparing TRACK to IMPACT**
*Brahim Mustapha, Vladislav Aseev, Peter Ostroumov (ANL), Ji Qiang, Robert Ryne (LBNL/CBP)*
In order to benchmark the newly developed beam dynamics code TRACK we have performed comparisons with well established existing codes. During code development, codes like TRANSPORT, COSY, GIOS and RAYTRACE were used to check TRACK's implementation of the different beam line elements. To benchmark the end-to-end simulation of the RIA driver linac, the simulation of the low-energy part (from the ion source to the entrance of the SC linac) was compared with PARMTEQ and found to agree well. For the simulation of the SC linac the code IMPACT is used. Prior to these simulations, the code IMPACT had to be updated to meet the special requirements of the RIA driver linac. Features such as multiple charge state acceleration, stripper simulation and beam collimation were added to the code. IMPACT was also modified to support new types of rf cavities and to include fringe fields for all the elements. This paper will present a comparison of the beam dynamics simulation in the RIA driver linac between the codes TRACK and IMPACT. A very good agreement was obtained which represents another validation of both codes.

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**TPAT030—Transverse Beam Matching Application for SNS**
*Chungming Chu, Viatcheslav V. Danilov, Dong-o Jeon, Michael Plum (ORNL/SNS)*
An automated transverse beam matching application has been developed for the Spallation Neutron Source (SNS) beam transport lines. The application is written within the XAL Java framework and the matching algorithm is based on the simplex optimization method. Other functionalities, such as emittance calculated from profile monitor measurements (adopted from a LANL Fortran code), profile monitor display, and XAL on-line model calculation, are also provided by the application. Test results obtained during the SNS warm linac commissioning will be reported. A comparison between the emittances obtained from this application and an independent Trace-3D routine will also be shown.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**TPAT031—Painting Self-Consistent Beam Distributions in Rings**
*Jeffrey Alan Holmes, Sarah M. Cousineau, Viatcheslav V. Danilov (ORNL/SNS )*
We define self-consistent beam distributions to have the following properties: 1) time-independence or periodicity, 2) linear space charge forces, and 3) maintainance of their defining shape and density under all linear transformations. The periodic condition guarantees zero space-charge-induced halo growth and beam loss during injection. Some self-consistent distributions can be manipulated into flat, or even point-like, beams, which makes them interesting to colliders and to heavy-ion fusion. This paper presents methods for painting 2D and 3D self-consistent distributions and for their manipulation to produce flat and point-like beams.

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**TPAT032—Transverse Stability Studies of the SNS Ring**
*Jeffrey Alan Holmes, Viatcheslav V. Danilov (ORNL/SNS), Lalit Kumar Jain (UW/Physics)*
Detailed studies of the transverse stability of the SNS ring have been carried out for realistic injection scenarios. For coasting beam models and single harmonic impedances, analytic and

computational results including phase slip, chromaticity, and space charge are in excellent agreement. For the dominant extraction kicker impedance and bunched beams resulting from injection, computationally determined stability thresholds are significantly higher than for coasting beams. At this time, we have no analytic model to treat the bunched beam case, but we present a formulation that provides an approach to this problem.

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**TPAT033—Experimental Characteristics of Transverse 4-D Beam's Phase Spaces at Bunch Compression**

*Feng Zhou, David Cline, James Rosenzweig (UCLA), Vitaly Yakimenko (BNL)*

Coherent synchrotron radiation can significantly distort beam phase spaces in longitudinal direction and bending plane through a bunch compressor. A tomography technique is used to reconstruct transverse phase space of electron beam. Transverse 4-D phase spaces are systematically measured at UCLA/ATF compressor and their characteristics with different bunch compression conditions are analyzed.

Work supported by U.S. DOE.

**TPAT034—Manipulations of Double Beams in One RF Period for STELLA SM-LWFA Experiment**

*Feng Zhou, David Cline (UCLA), Marcus Babzien, Vitaly Yakimenko (BNL), Wayne D. Kimura (STI)*

Although seeded SM-LWFA only requires one electron beam to initiate the laser wakefield, it would be highly desirable to have a second electron beam traveling after the first one to probe the accelerated electrons. To create and preserve significant amount of wakefield in the STELLA SM-LWFA experiment, the first e-beam needs to be tiny (<40 microns FWHM) in size and short in length within the plasma. To probe the wakefield which is damped within 10 ps for certain plasma density, the separation between the first and second beams needs to be within one RF period and the second e-beam must have smaller energy spread and smaller size. Design of double beams in one RF period to meet the strict requirements and the preliminary beam study at BNL-ATF facility are presented. The scheme of double beams with ATF bunch compressor is also discussed.

Work supported by U.S. DOE.

**TPAT035—Coherent Synchrotron Radiation from an Electron Beam in a Curved Waveguide**

*David Gillingham, Tom Antonsen, Patrick G. O'Shea (IREAP)*

The radiation emitted by a pulsed electron beam as it travels on a circular trajectory inside a waveguide is calculated using a 3D simulation. Forward-propagating wave equations for the fields in the waveguide are calculated by a perturbation of the Maxwell equations where the radius of curvature is large compared to the dimensions of the waveguide. These are integrated self-consistently with the distribution of charge in the beam to provide the complete fields (electric and magnetic) for all times during the passage of the beam through the waveguide and therefore are applicable to sections of any length or combinations thereof. The distribution of electrons and their momentum are also modified self-consistently so that the results may be used to estimate the effect of the radiation on the beam quality (emittance and energy spread).

Research supported by the office of Naval Research and the Joint Technology Office.

**TPAT036—Ferroelectric Plasma Source for Heavy Ion Beam Charge Neutralization**

*Philip Efthimion, Ronald Davidson, Erik P. Gilson, Larry Grisham (PPPL), B. Grant Logan, William Waldron, Simon Yu (LBNL)*

Plasmas are employed as a medium for charge neutralizing heavy ion beams to allow them to focus to a small spot size. Calculations suggest that plasma at a density of 1-100 times the ion beam density and at a length ~ 0.1-1 m would be suitable. To produce 1 meter plasma, large-volume plasma sources based upon ferroelectric ceramics are being considered. These sources have the advantage of being able to increase the length of the plasma and operate at low neutral pressures. The source will utilize the ferroelectric ceramic BaTiO3 to form metal plasma. The drift tube inner surface of the Neutralized Drift Compression Experiment (NDCX) will be covered with ceramic. High voltage (~ 1-5 kV) is applied between the drift tube and the front surface of the ceramic by placing a wire grid on the front surface. A prototype ferroelectric source 20 cm long produced plasma densities ~ 5x1011 cm-3. The source was integrated into the experiment and successfully charge neutralized the K ion beam. Presently, the 1 meter source is being fabricated. It will be characterized and integrated into NDCX for charge neutralization experiments. Experimental results will be presented.

Research supported by the U.S. Department of Energy.

**TPAT037—Simulating the Long-Distance Propagation of Intense Beams in the Paul Trap Simulator Experiment**

*Erik P. Gilson, Moses Chung, Ronald Davidson, Philip Efthimion, Richard Majeski, Edward Startsev (PPPL)*

The Paul Trap Simulator Experiment (PTSX) makes use of a compact Paul trap configuration with quadrupolar oscillating wall voltages to simulate the propagation of intense charged particle beams over distances of many kilometers through magnetic alternating-gradient transport systems. The simulation is possible because of the similarity between the transverse dynamics of particles in the two systems. One-component pure cesium ion plasmas have been trapped that correspond to normalized intensity parameters $s < 0.8$, where s is the ratio of the square of the plasma frequency to twice the square of the average transverse focusing frequency. The PTSX device confines the plasma for hundreds of milliseconds, which is equivalent to beam propagation over tens of kilometers. Results are presented for experiments in which the amplitude of the oscillating confining voltage waveform has been modified as a function of time. A comparison is made between abrupt changes in amplitude and adiabatic changes in amplitude. The effects of varying the frequency are also discussed. A barium ion source and a laser system have been installed and initial measurements made with this system are presented.

Research supported by the U.S. Department of Energy.

**TPAT038—Chaos in Time-Dependent Space-Charge Potentials**

*Gregory Thomas Betzel, Courtlandt L. Bohn, Ioannis V. Sideris (Northern Illinois University)*

We consider a spherically symmetric, homologously breathing, space-charge-dominated beam bunch in the spirit of the particle-core model. The question we ask is: How does the time dependence influence the population of chaotic orbits? The static beam has zero chaotic orbits; the equation of particle motion is integrable up to quadrature. This is generally not true once the bunch is set into oscillation. We quantify the population of chaotic orbits as a function of space charge and oscillation amplitude (mismatch). We also apply a newly developed measure of chaos, one that distinguishes between regular, sticky,

and wildly chaotic orbits, to characterize the phase space in detail. We then introduce colored noise into the system and show how its presence modifies the dynamics. One finding is that, despite the presence of a sizeable population of chaotic orbits, halo formation in the homologously breathing beam is much less prevalent than in an envelope-matched counterpart wherein an internal collective mode is excited.

**TPAT039—Wavelet-Based Poisson Solver for Use in Particle-in-Cell Simulations**
*Balsa Terzic, Daniel Mihalcea (Northern Illinois University), Ilya V Pogorelov (LBNL)*
We present a new, wavelet-based Poisson-solver for use in particle-in-cell simulations. It harnesses advantages afforded by the wavelet formulation, such as sparsity of operators, removing numerical noise in particle distribution through compression and effective preconditioning of the Laplacian operator. We incorporate the above Poisson solver into the IMPACT3D N-body code and present a comparative study, both versus the conventional IMPACT3D and laboratory measurements.

**TPAT040—On the Study of Actual Stationary State for Plasma Lens**
*Vladimir Fotievich Zadorozhny (NASU/IOC), Zohreh Parsa (BNL), Alexey Goncharov (NSC/KIPT)*
The electrostatic plasma lens (PL) provides an attractive and unique tool for manipulating high-current heavy ion beams. The fundamental concept of the PL is based on the use of magnetically insulated electrons and equipotentialization of magnetic field lines. Rigorous application of PL is, however, limited. The reason is the estimation behaviour of electrons for complicated magnetic fields runs into severe difficults.We show that there are specific conditions that admit steady-state of a longitudinal motion, and consider a question of it stability. These results are needed to develop an optimized PL with minimal spherical aberation, in party by optimization of the magnetic field conficuration in the low-magnetic-field range.

**TPAT041—On the Vlasov-Maxwell Equation**
*Vladimir Fotievich Zadorozhny (NASU/IOC), Zohreh Parsa (BNL), Alexey Goncharov (NSC/KIPT)*
There are many interesting physical question which based on of the solution Vlasov-Maxwell Equation (VME). However, the procedure of solve is very difficult and hard. But it is often preferable, on physical grounds, to a common point of view. Such point of view maybe a structure of some solution. We define and discuss the notaion of structure for the distribution function and prove, the structure of the Lorentz force represent the structure of the one. At the time of the discovery of the integrable systems the question of VME integrability had been considered. Moreover, as example, we consider, by means of this approach, the relation integrability and dispersion with a spectra of Vlasov's operat.

**TPAT042—Coherent Synchrotron Radiation from Arbitrary Planar Orbits: A Vlasov Approach**
*Gabriele Bassi, James A. Ellison (UNM), Robert Warnock (SLAC)*
We study the influence of coherent synchrotron radiation (CSR) on particle bunches traveling on arbitrary planar orbits between parallel conducting plates (shielding). The time evolution of the phase space distribution is determined by solving the Vlasov-Maxwell equations in the time domain. This provides lower numerical noise than the macroparticle method, and allows the study of emittance degradation and microbunching in bunch compressors. We calculate the fields excited by the bunch in the lab frame using a formula simpler than that based on retarded potentials.* We have developed an algorithm for solving the Vlasov equation in the beam frame using arc length as the independent variable and our method of local characteristics (discretized Perron-Frobenius operator).We integrate in the interaction picture in the hope that we can adopt a fixed grid. The distribution function will be represented by B-splines, in a scheme preserving positivity and normalization of the distribution. The transformation between lab and beam frame is carefully treated. Here we report on our implementation of the algorithm for a chicane bunch compressor with linear energy chirp and take steps to treat the nonlinear case.
*"Vlasov Treatment of Coherent Synchrotron Radiation from Arbitrary Planar Orbits" to be published in the Proceedings of ICAP04, St. Petersburg, R. Warnock, G. Bassi and J. A. Ellison.

Support from DOE grants DE-AC02-76SF00515 and DE-FG02-99ER1104 is gratefully acknowledged.

**TPAT043—The MICHELLE 2D/3D ES PIC Code: Advances and Applications**
*John Petillo, Norman John Dionne, Kenneth Eppley, Dimitrios Panagos, Xiaoling Zhai (SAIC), Eric Michael Nelson (LANL), Baruch Levush (NRL), Liya Chernyakova, John F. DeFord, Ben Held (STAR, Inc.)*
MICHELLE is a new 2D/3D steady-state and time-domain particle-in-cell (PIC) code* that employs electrostatic and now magnetostatic finite-element field solvers. The code has been used to design and analyze a wide variety of devices that includes multistage depressed collectors, gridded guns, multibeam guns, annular-beam guns, sheet-beam guns, beam-transport sections, and ion thrusters. Latest additions to the MICHELLE/Voyager tool are as follows: 1) a prototype 3D self magnetic field solver using the curl-curl finite-element formulation for the magnetic vector potential, employing edge basis functions and accumulating current with MICHELLE's new unstructured grid particle tracker, 2) the electrostatic field solver now accommodates dielectric media, 3) periodic boundary conditions are now functional on all grids, not just structured grids, 4) the addition of a global optimization module to the user interface where both electrical parameters (such as electrode voltages)can be optimized, and 5) adaptive mesh refinement improvements. Applications illustrating these latest additions will be presented, including a relativistic sheet beam gun, a relativistic MIG gun, and a depressed collector optimization example.
*John Petillo, et al., IEEE Trans. Plasma Sci., vol. 30, no. 3, June 2002, pp. 1238-1264.

Office of Naval Research, Naval Research Laboratory.

**TPAT044—Reduced Models of Backstreaming Ion Behavior in Radiogaphic Accelerators**
*James F. McCarrick (LLNL)*
Radiographic accelerators produce high-current (~2 kA) electron beams that are focused to small spot sizes (~1 mm) on bremsstrahlung converter targets. The rapid heating of the target material releases contaminants from the surface, which are ionized by the incoming electrons and rapidly "backstream" in the electric field produced by the beam at the grounded target. Even a small quanitity of ions is enough to disturb the balance between the beam's self magnetic and electric fields, causing the beam's focusing characteristics to change with time. Much numerical and experimental work has been done to study this phenomenon. In this paper we present some analytic work on highly reduced ion models that yield various quantities of interest, such as the spot disruption rate and asymptotic neutralization, with minimal computational effort.

This work performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

**TPAT045—Equilibrium and Stability in the Transport of Intense Off-Axis Beams in Periodic Focusing Systems**
*Renato Pakter, Jorge da Silva Moraes, Felipe Rizzato (IF-UFRGS)*
A general equation for the centroid motion of free, continuous, intense beams propagating off-axis in solenoidal periodic focusing fields is derived.* The centroid equation is found to be independent of the specific beam distribution and may exhibit unstable solutions. A new Vlasov equilibrium for off-axis beam propagation is also obtained. Properties of the equilibrium and the relevance of centroid motion to beam confinement are discussed. The effects of a conducting pipe encapsulating the beam are also investigated.** It is shown that the charge induced at the pipe may generate chaotic orbits which can be detrimental to the beam transport.
*J.S. Moraes, R. Pakter, F.B. Rizzato, Phys. Rev. Lett., accepted for publication (2004). **J.S. Moraes, R. Pakter, F.B. Rizzato, Phys. Plasmas, accepted for publication (2004).

Work supported by Brazilian agencies CNPq, CAPES, and FAPERGS.

**TPAT046—Nonlinear Stability of Intense Mismatched Beams in a Uniform Focusing Field**
*Renato Pakter, Felipe Rizzato, Wilson Simeoni (IF-UFRGS)*
We investigate the nonlinear coupling between axisymmetric and elliptic oscillations in the dynamics of intense beams propagating in a uniform magnetic focusing field. It is shown that finite amplitude mismatched oscillations of an initially round beam may destabilize elliptic oscillations, heavily affecting stability and the shape of the beam. This is a potential mechanics for beam particle loss in such systems. Self consistent simulations are performed to verify the findings.

Work supported by Brazilian agencies CNPq, CAPES, and FAPERGS.

**TPAT047—Space Charge Compensation Studies of Low Energy Hydrogen Ion Beams**
*Ahmed BenIsmail, Romuald Duperrier, Didier Uriot (CEA/DSM/DAPNIA), Nicolas Pichoff (CEA/DAM)*
High-power accelerators are being studied for several projects including accelerator driven neutron or neutrino sources. The low energy part of these facilities has to be carefully optimized to match the beam requirements of the higher energy parts. The complexity of high intensity beam dynamics in the low energy line is essentially due to the non-linear space charge effects. The PIC code CARTAGO* has been developed in order to simulate the beam transport at low energy including the temporal evolution effects of the space charge compensation. This paper relates the structure and the numerical methods of a 2D (r,z) new version of the code. The effects of the longitudinal space charge, the image charge and external 2D (r,z) magnetic field were included. The results of H+ and H- beam transports using solenoid lenses are discussed. Space charge compensation degrees are given for each studied cases.
*A. Ben Ismail et al., in Space Charge Compensation in Low Energy Proton Beams, proceeding of the International Linear Accelerator Conference, Lübeck, 2004.

Work supported by the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).

**TPAT048—The Transverse Nonlinear Tune Shift as Stabilising Factor in Halo Creation in Space Charge Dominated Beam**
*Nikita Vasyukhin, Yurij Senichev, Raimund Tölle (FZJ/IKP)*
One of the most important problems for space charge dominated beam in the low energy part of superconducting linac is halo creation. Many authors show one of the key effects in halo creatiation is parametric resonance due to the mismatched beta-function oscillation (between core and particle). To estimate parametric resonance conditions the nonlinear tune shift for binomial distributed beam is described theoretically in this article. Simultaneously the beam dynamics simulation 3D PIC code was developed. The transverse oscillation frequencies compared with parametric resonance criteria. As a result the recommendation for space charge shift is concluded to minimize halo creation.

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" program (CARE, contract number RII3-CT-2003-506395).

**TPAT049—Comparison of Beam Dynamic in Different Superconducting Options of Low Energy High Intense Linac**
*Nikita Vasyukhin, Yurij Senichev, Raimund Tölle (FZJ/IKP)*
At present the superconducting proton linacs have obvious applications in energy range ~100-1000 MeV. For the lower energy the comprehensive investigations are required. In this article the various variants of superconducting options from 3MeV up to 100MeV are discussed. The considered variants include both the conventional combination of half-wave and spoke cavity with quadrupoles and new schemes. In conclusion the table of major parameters for different structures is given.

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" program (CARE, contract number RII3-CT-2003-506395).

**TPAT050—Beam Dynamics Design of the L3BT for J-PARC**
*Tomohiro Ohkawa (JAERI, Ibaraki-ken), Masanori Ikegami (KEK)*
L3BT is beam transportation line from the linac to the 3-GeV RCS which is the part of the accelerators for the High-Intensity Proton Accelerator Facility Project, J-PARC.In this paper, especially results of the beam simulation of the injection section of the L3BT are presented. And the matching of rms envelopes and dispersion function for space charge dominated beams are also discussed.

**TPAT051—Asymmetrical Spectrum Observed at the KEKB High Energy Electron Ring**
*Takao Ieiri, Yukiyoshi Ohnishi, Makoto Tobiyama (KEK)*
KEKB is a multi-bunch, high-current, electron/positron collider for B meson physics. The two beams collide at one interaction point (IP) with a finite horizontal crossing angle. The luminosity achieved at KEKB is the best in the world. In order to keep up the performance, the tune of a non-colliding bunch, placed just after a colliding bunch-train, is continuously monitored. It was observed that an electron bunch showed an asymmetrical distribution biased to a higher tune in the vertical tune-spectrum. We found that the asymmetrical spectrum was reinforced by the beam-beam interaction, though the electron bunch did not

collide. The asymmetry was reinforced moreover, as the electron bunch approached a bunch-train further. These observations suggest that the asymmetry in the spectrum is not related to trapped-ions or fast-ions observed in an electron single beam, but related to ions produced by the beam-beam interaction, which makes the particles scattered and they might yield new ions due to the collision with residual gas. We can imagine that the ions are accumulated along a bunch-train and some ions survive after colliding bunches passed through in the electron ring. A quantitative analysis remains for future study.

**TPAT052—High Current Beam Dynamics in Lebedev Physical Institute Racetrack Microtron**
*Vyacheslav Kurakin, Alexander Vladimirovich Koltsov (LPI)*
Maximum electron beam current achieved so far in Lebedev Physical Institute Racetrack microtron is limited by intensity auto modulation. This instability arises from the specific interaction mechanism that takes place in the beam – accelerating structure system. This mechanism in turn depends strongly on electron injection conditions. To relax microtron parameters tolerances and suppress instability as well computer simulation had been performed and new accelerator parameters had been found. Racetrack configuration had been changed according these calculations. We also have replaced racetrack monitoring and control system with new computer based one. All this comprise the first step of our program of the accelerator upgrade. The details of the main racetrack features as well as the results of the accelerator parameters adjustment at high beam intensity comprise the content of the paper. The possibilities of the microtron energy increase up to value as high as 50 MeV are discussed as well.

**TPAT053—Zoo of Patterns in Collective Vlasov-Maxwell Dynamics**
*Antonina N. Fedorova, Michael G. Zeitlin (RAS/IPME)*
An exact variational/projection approach is proposed for modeling the complex collective behaviour and the propagation of the intense charged particle beams described by different forms of Vlasov-Maxwell equations. We give representations for distribution functions and fields via the multiscale/multiresolution decomposition corresponding to exact expansions into the slow and fast nonlinear high-localized eigenmodes providing the full information about (stochastic) dynamical process. Numerical modeling shows the creation of different internal structures from localized modes, which are related to stable/unstable type of behaviour and the corresponding patterns (waveletons) formation. Reduced algebraical structure provides the pure algebraical control of (meta)stability/unstability scenario: different patterns (chaotic or localized) are controlled in space of parameters.*
*A. Fedorova, M. Zeitlin, Classical and Quantum Ensembles via Multiresolution. I. BBGKY Hierarchy; II. Wigner Ensembles; arXiv: quant-ph/0406009, 0406010; NIMA, 534A, 1-2, 2004, 309-313, 314-318, 2004 and papers on http://www.ipme.ru/zeitlin.html.

**TPAT054—Dispersion Matching of a Space Charge Dominated Beam at Injection into the CERN PS Booster**
*Klaus Hanke, Jorge Sanchez-Conejo, Richard Scrivens (CERN)*
In order to match the dispersion at injection into the CERN PS Booster, the optics of the injection line was simulated using two different codes (MAD and TRACE). The simulations were benchmarked versus experimental results. The model of the line was then used to re-match the dispersion. Experimental results are presented for different optics of the line. Measurements with varying beam current show the independence of the measured quantity of space-charge effects.

**TPAT055—On Start to End Simulation and Modeling Issues of the Megawatt Proton Beam Facility at PSI**
*Andreas Adelmann, Stefan Adam, Hansruedi Fitze, Roman Geus, Martin Humbel, Lukas Stingelin (PSI)*
At the Paul Scherrer Institut (PSI) we routinely extract a one megawatt (CW) proton beam out of our 590 MeV Ring Cyclotron. In the frame of the ongoing upgrade program, large scale simulations have been undertaken in order to provide a sound basis to assess the behaviour of very intense beams in cyclotrons. The challenges and attempts towards massive parallel three dimensional start-to- end simulations will be discussed. The used state of the art numerical tools (mapping techniques, time integration, parallel FFT and finite element based multigrid Poisson solver) and their parallel implementation will be discussed. Results will be presented in the area of: space charge dominated beam transport including neighbouring turns, eigenmode analysis to obtain accurate electromagnetic fields in large the rf cavities and higher order mode interaction between the electromagnetic fields and the particle beam. For the problems investigated so far a good agreement between theory i.e. calculations and measurements is obtained.

**TPAT056—Dynamics of High-Current Ion Beams in the Accelerator Combining APF and RFQD**
*Vasilij Bomko, Zinaida Ptukhina, Sergej Tishkin (NSC/KIPT)*
The results of investigations of the high-current beam dynamics are presented. Acceleration rate and radial and phase stability are provided by combination of RF focusing of two types – alternating phase focusing (APF) and focusing with the RF quadrupole doublets (RFQD). This structure of the accelerating and focusing channel, from one hand, allows us to increase the limiting current of the beams being accelerated, and from other hand – to achieve a high acceleration rate. The investigation of the beam dynamics at different stage of acceleration was performed for the focusing period where the synchronous phase changes from a region of negative values to a region of positive phases which are small in absolute value. With that, the main focusing effect is by way of RFQD. The optimization of the accelerating and focusing channel with the sequence of cells having À/q=4 with APF and RFQD in the energy region of 30-1000 keV/n has been performed. The efficiency of the RFQD for accelerating high-current proton beams is also investigated in the energy range of 3 – 40 Mev.

**TPAT057—Observations of UHF Oscillations in the IPNS RCS Proton Bunch**
*Jeffrey Craig Dooling, Gerald McMichael, Shaoheng Wang (ANL)*
The Intense Pulsed Neutron Source (IPNS) Rapid Cycling Synchrotron (RCS) accelerates 3.2x10E12 protons from 50 MeV to 450 MeV in a single bunch (h=1) at 30 Hz. The rf frequency varies from 2.21 MHz to 5.14 MHz during the 14.2 ms acceleration interval. To maintain stability of the bunch, phase modulation is introduced to the rf at approximately twice the synchrotron frequency (synchrotron tune is 0.0014). This phase modulation causes a parametric quadrupole oscillation to develop in the bunch, and as this occurs, the bunch spectrum shows a significant increase in high frequency content. Without phase modulation, the beam experiences an instability which results in the loss of a large fraction of the charge 2-4 ms prior to extraction. It is unclear if the stability imparted to the beam by phase modulation comes from the quadrupole oscillation or from the high frequency excitation. A longitudinal tracking code is presently being modified to include amplitude and phase modulation of the bunch. The numerical analysis will be used to compare growth rates with those observed in the machine. The results of this analysis will be important as we introduce second harmonic rf with a new third cavity in the RCS later in 2005.

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**TPAT058—Calculation of Electron Beam Potential Energy from RF Photocathode Gun**
*Wanming Liu, Wei Gai, John Gorham Power, Haitao Wang (ANL)*
In this paper, we consider the contribution of potential energy to beam dynamics as simulated by PARMELA at low energies (10 - 30MeV). We have developed a routine to calculate the potential energy of the relativistic electron beam using the static coulomb potential in the rest frame (first order approximation as in PARMELA). We found that the potential energy contribution to the beam dynamics could be very significant, particularly with high charge beams generated by an RF photocathode gun. Our results show that when the potential energy is counted correctly and added to the kinetic energy from PARMELA, the total energy is conserved. Simulation results of potential and kinetic energies for short beams (~1 mm) at various charges (1 - 100 nC) generated by a high current RF photocathode gun are presented.

U.S. Department of Energy.

**TPAT059—Space Charge Experiments and Simulation in the Fermilab Booster**
*James Frederick Amundson, Panagiotis Spentzouris (Fermilab)*
We have studied space charge effects in the Fermilab Booster. Our studies include investigation of coherent and incoherent tune shifts and halo formation. We compare experimental results with simulations using the 3-D space charge package Synergia.

Scientific Discovery through Advanced Computing project, "Advanced Computing for 21st Century Accelerator Science and Technology," U.S. DOE/SC Office of High Energy Physics and the Office of Advanced Scientific Computing Research.

**TPAT060—Overview of the Synergia 3-D Multi-Particle Dynamics Modeling Framework, Including Benchmarks and Applications**
*Panagiotis Spentzouris, James Frederick Amundson (Fermilab), Douglas Ricker Dechow (Tech-X)*
High precision modeling of space-charge effects is essential for designing future accelerators as well as optimizing the performance of existing machines. Synergia is a high-fidelity parallel beam dynamics simulation package with fully three dimensional space-charge capabilities and a higher-order optics implementation. We describe the Synergia framework and model benchmarks we obtained by comparing to semi-analytic results and other codes. We also present Synergia simulations of the Fermilab Booster accelerator and comparisons with experiment.

Scientific Discovery through Advanced Computing project, "Advanced Computing for 21st Century Accelerator Science and Technology," U.S. DOE/SC Office of High Energy Physics and the Office of Advanced Scientific Computing Research.

**TPAT061—Accurate Iterative Analysis of K-V Equations for a Matched Beam**
*Oscar A. Anderson (LBNL)*
Previous solutions of the K-V equations have either yielded poor accuracy or have been complex and difficult to follow. We describe a new approach, simple in concept, easy to use, with accuracy substantially improved over previous treatments. The results are given in the same form as the smooth approximation but include a few correction terms obtained from the field gradient integrated along the axis of a quadrupole cell. The input quantities—quadrupole field, beam current, and emittance—yield the average beam radius, the maximum envelope excursion, and the depressed and undepressed tunes. For all values of the input parameters, the results are much closer to the exact values from simulations than are results from the smooth approximation. For example, with the parameters adjusted for an exact phase advance of 83.4 degrees and 50% tune depression, both tunes are in error by less than 0.5%—over 22 times better than the smooth approximation. The error in maximum radius is 0.04%, improved by a factor of 80. The new method and its application to a wide range of cases will be presented.

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**TPAT062—Uncorrelated Energy Spread and Longitudinal Emittance for a Photoinjector Beam**
*Zhirong Huang, Paul Emma, Cecile Limborg-Deprey, Gennady Stupakov, Juhao Wu (SLAC)*
Longitudinal phase space distribution of a photoinjector beam is important in many areas of high-brightness applications such as bunch compression, transverse-to-longitudinal emittance exchange, and high-gain free-electron lasers. In this paper, we discuss both the rf and the space charge effects on the uncorrelated energy spread as well as the longitudinal beam emittance generated from a photocathode rf gun. Analytical estimations of these longitudinal phase space parameters are compared with numerical simulations and with experimental results from the Gun Test Facility at SLAC.

**TPAT063—Analysis of Longitudinal Space Charge Effects with Radial Dependence**
*Juhao Wu, Paul Emma, Zhirong Huang (SLAC)*
Longitudinal space charge (LSC) force can be a main effect driving the microbunching instability in the linac for an x-ray free-electron laser (FEL). In this paper, the LSC-induced beam modulation is studied using an integral equation approach that takes into account the transverse (radial) variation of LSC field. Changes of beam energy and the transverse beam size can be also incorporated. We discuss the validity of this approach and compare it with other analyses as well as numerical simulations. We apply this approach to study the LSC effect in the LCLS accelerator.

Work is supported by the U.S. Department of Energy under contract DE-AC02-76SF00515.

**TPAT064—Measurement of Head-Tail Instability Parameters with a Fast Strip-Line Pickup in the Tevatron**
*Vahid Houston Ranjbar, Petr Mikhailovich Ivanov (Fermilab)*
Since recent efforts to reduce the impedance in the Tevatron have improved the stability thresholds a complete measurement of the instability parameters has yet to be undertaken. Using a fast digital oscilloscope connected to a strip-line we have recently measured the growth rate and coherent tune shifts for the unstable mode with monopole longitudinal configuration at negative chromaticities. These measurements were carried out during the injection of high intensity proton beam into the Tevatron.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the U.S. Department of Energy.

**TPAT065—Damping Transverse Instabilities in the Tevatron Using AC Chromaticity**
*Vahid Houston Ranjbar (Fermilab)*
Several papers*,** have suggested possibility of using varying chromaticity to damp the head-tail instability. We test this by cycling the chromaticity sextupole magnets in the Tevatron near the synchrotron frequency to see if the head-tail stability threshold is increased. Further we compare the turn-by-turn evolution of a bunch slice in the presence of varying chromaticity to a model previously developed.
*W.-H. Cheng, A. M. Sessler, and J. S. Wurtele, Phys. Rev. Lett. 78, 4565 (1997). **T. Nakamura in Proceedings of the 1995 IEEE Particle Accelerator Conference (IEEE, Dallas, 1995), Vol. 5, p. 3100.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the U.S. Department of Energy.

**TPAT066—Theory and Simulations for UMER Commissioning**
*Rami Alfred Kishek, Gang Bai, Santiago Bernal, Terry Godlove, Irving Haber, Bryan Quinn, Mark Walter (IREAP), Patrick G. O'Shea (IREAP; University Maryland), Martin Reiser (University Maryland)*
The University of Maryland Electron Ring (UMER)* is a small scaled ring designed to probe the little-known regions of high beam intensity using low-energy electrons. As such, design, commissioning and operation of UMER presents many challenges, some quite novel. For example the UMER beam energy of 10 keV makes the beam very sensitive to the Earth magnetic field, which we can fortunately use to assist in bending the beam. Another complication is the injection and extraction which have to be accomplished on a rapid timescale in a crowded lattice using dual-function magnets, thus coupling steering and focusing. In addition, the well-diagnosed machine affords us to experiment with different correction schemes, whether for centroid errors or for more exotic aberrations, such as skew quadrupole effects. Theory from first principles as well as simulations using centroid, envelope, and the particle-in-cell code WARP are used to better understand and learn to control these issues.
*"Commissioning of the University of Maryland Electron Ring (UMER)," P.G. O'Shea, et al., this conference.

This work is funded by U.S. Dept. of Energy grant numbers DE-FG02-94ER40855 and DE-FG02-92ER54178.

**TPAT067—Study of Longitudinal Space-Charge Wave Dynamics in Space-Charge Dominated Beams**
*Kai Tian, Yupeng Cui, Irving Haber, Yijie Huo, Rami Alfred Kishek, Patrick G. O'Shea, Yun Zou (IREAP), Martin Reiser (University Maryland)*
Understanding the dynamics of longitudinal space charge waves is very important for advanced accelerator research. Although analytical solutions of space charge wave equations based on the cold fluid model exist in one dimension, there are few results for two-dimension wave evolution. From one-dimensional theory, there are two eigen solutions, given an initial perturbation. One is called the fast wave, which moves toward the beam head in the beam frame and the other is termed the slow wave, which moves backward in the beam frame. If the initial current and velocity perturbation strengths are chosen properly, only fast or slow waves could be selectively generated. In this paper, a two-dimension PIC code, WARP, was used to study the behavior of longitudinal waves in space-charge dominated beams. We also report experimental results of space charge wave studies conducted on a 2-meter long linear beam line at the University of Maryland. In this experiment, an energy analyzer is used to directly measure the energy of space-charge waves at the end of the transport line. The experimental results are compared with the WARP simulations and show good agreement.

Work supported by the U.S. Department of Energy, Office of Science.

**TPAT068—LSP Numerical Simulations of the Neutralized Drift Compression Experiment**
*Adam Sefkow, Ronald Davidson (PPPL), Dale Welch (ATK-MR), Simon Yu (LBNL)*
Heavy ion drivers for high energy density physics applications and inertial fusion energy use space-charge-dominated beams which require longitudinal bunch compression in order to achieve high beam current. The Neutralized Drift Compression Experiment (NDCX) at Lawrence Berkeley National Laboratory will investigate the issues which determine the effective limits of drift compression. The LSP simulation code is used to model the longitudinal and transverse compression of an intense ion beam, achieved by imposing an initial velocity tilt on the drifting beam and by neutralizing the beam space charge by background plasma, respectively. Measuring the longitudinal and transverse beam compression and current density with high resolution is critical for NDCX, and an understanding of the accessible parameter space is possible with LSP simulations. Knowledge of the current density of the compressed heavy ion beam is important for determining the amount of power that can be delivered to the target. Designs for two ion beam probes will be presented, one for measuring the total current at focus (compression) and the other for measuring the current density as a function of space and time.

Research supported by the U.S. Department of Energy.

**TPAT069—Darwin Model for Intense Charged Particle Beams**
*Edward Startsev, Ronald Davidson, Wei-li Lee (PPPL)*
A numerical scheme for the electromagnetic particle simulation of high-intensity charged-particle beams has been developed which is a modification of the Darwin model. The Darwin model neglects the transverse induction current in Ampere's law and therefore eliminates light waves from the simulations. The model has been incorporated into the Beam Equilibrium Stability and Transport(BEST) code. As a benchmark, we have applied the model to simulate the transverse electromagnetic Weibel-type instability in a single-species charged-particle beam with large temperature anisotropy. Results are compared with previous theoretical and numerical studies using the eighenmode code bEASt.

Research supported by the U.S. Department of Energy.

**TPAT070—Intensity and Bunch-Shape Dependent Beam Loss Simulation for the SIS100**
*Giuliano Franchetti, Ingo Hofmann, Peter J. Spiller (GSI)*
We have studied the combined influence of magnet nonlinearities, space charge and bunch shape on the long-term loss in the planned SIS100 synchrotron of the FAIR project. During the injection flat-bottom the high-intensity bunches from the booster SIS18 are held for up to 1 s to transfer four batches. The simulation is a 3D tracking with "frozen-in" space charge calculation employing the MICROMAP code. In previous exploratory studies with initial 3D Gaussian bunches we have found that beam loss over this period may be as high as 10%, which is unacceptable. The loss is interpreted as a combined result of the dynamic aperture and resonance trapping by

synchrotron motion and space charge. In this paper we study an optimization of the losses by initial transverse tail shaping, various longitudinal bunch profiles in different RF scenarios and proper choice of the working point.

**TPAT071—Induced Voltage from Coherent Synchrotron Radiation (CSR) in a Toroidal Chamber**
*Robert Warnock (SLAC), Marco Venturini (LBNL)*
Longitudinal beam dynamics in the presence of CSR, suppressed at long wavelengths by the vacuum chamber, was investigated with the chamber modeled by infinite parallel plates. Here we consider instead a circular toroidal chamber with rectangular cross section, with infinite conductivity. Although this model has a closer geometric resemblance to a real vacuum chamber, it might give a less realistic picture of beam dynamics since it supports whispering gallery modes (resonances of the entire structure) that may be impossible to excite in a real machine. We find a rigorous expression for the induced voltage from CSR, with account of bunch deformation, which is quite different from the usual convolution of a wake potential with the present form of the charge density. It consists of a term that is simply proportional to the present value of the charge density in the beam frame, plus time integrals over past values of the Fourier-transformed charge density.

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**TPAT072—Lifetime Studies for the Tevatron at Collision Energy**
*Andreas C. Kabel, Yunhai Cai (SLAC), Tanaji Sen, Vladimir Shiltsev (Fermilab)*
The weak-strong beam-beam effect is expected substantially to contribute to the degradation of beam lifetimes in the Tevatron at collision energy. We have expanded an existing multi-processor code (which previously was applied to the Tevatron at injection energy* to include chromatic and non-linear lattice effects as well as a fully-coupled treatment of the lattice in different approximations.** We obtain lifetime predictions by doing temporal statistics on the tracking results of a weighted macroparticle distribution and fitting it to a class of solutions for the diffusion equation. We present typical results of parameter scans.
*A. Kabel, Y. Cai, B. Erdelyi, T. Sen, M. Xiao; Proceedings of PAC03. **A. Kabel, this Conference.

**TPAT074—PIC Simulation of the Strong-Strong Beam-Beam Interaction Including Parasitic Crossings**
*Andreas C. Kabel, Yunhai Cai (SLAC)*
We have developed and benchmarked a code* simulating the dynamics of charged-particle beams in storage ring colliders subject to strong-strong beam-beam forces. It is optimized for running on a high number (several hundreds) of processors with high longitudinal resolution, as necessitated by a pronounced hourglass effect, and with a high number of parasitic crossings, as they occur in machines such as the Tevatron or LHC. We apply the code to the Tevatron in the collision case and PEP-II and present typical results, scanning parameters such as fractional tunes and chromaticities.
*A. Kabel, Y. Cai, Proceedings of EPAC04.

**TPAT075—The Design of IH-Linac Including Dipole Effect**
*Taku Ito, Toshiyuki Hattori, Noriyosu Hayashizaki, Kazuo Yamamoto (RLNR), Masahiro Okamura (RIKEN)*
We designed an IH-linac by 3D beam dynamics simulation code. This code is able to calculate beam dynamics including dipole effect. We chose an APF as a focusing method. This focusing method is strongly influenced by the electric field in the acceleration gap. Accordingly, the cavity design was carried out by 3D electro-magnetic simulation software. The beam dynamics was calculated by Runge-Kutta method using this field. We will report the results of the beam dynamics simulation.

**TPAT076—Measurement of the Luminous-Region Profile at the PEP-II IP, and Application to e+/- Bunch-Length Determination**
*Benoit Francis Viaud (Montreal University), Witold Kozanecki (CEA/DSM/DAPNIA), Chris O'Grady, Amedeo Perazzo (SLAC)*
The three-dimensional luminosity distribution at the interaction point (IP) of the SLAC B-Factory is measured continuously, using e+e- —> e+e- and e+e —> mu+mu- events reconstructed online in the silicon tracker of the BaBar detector. The centroid of the transverse luminosity profile provides a very precise and reliable monitor of medium- and long-term orbit drifts at the IP. The longitudinal centroid is sensitive to variations in the relative RF phase of the colliding beams, both over time and differentially along the bunch train. The measured horizontal r.m.s. width of the distribution is consistent with a sizeable dynamic-beta effect; it is also useful as a benchmark of strong-strong beam-beam simulations. The longitudinal luminosity distribution depends on the e+/- bunch lengths and vertical IP beta-functions, which can be different in the high- and low-energy rings. Using independent estimates of the beta-functions, we analyze the longitudinal shape of the luminosity distribution in the presence of controlled variations in accelerating RF voltage and/or beam current, to extract separate measurements of the e+ and e- bunch lengths.

**TPAT077—Beam-Beam Study on the Upgrade of Beijing Electron Positron Collider**
*Sheng Wang (IHEP Beijing)*
It is an important issue to study the beam-beam interaction in the design and performance of such a high luminosity collider as BEPCII, the upgrade of Beijing Electron Positron Collider. The weak-strong simulation is generally used during the design of a collider. For performance a large scale tune scan, the weak-strong simulation studies on beam-beam interaction were done, and the geometry effects were taken into account The strong-strong simulation study were done for investigating the coherent phenomena of beam-beam interaction, and the goal of the luminosity.

**TPAT078—Coherent Beam-Beam Modes in the LHC for Multiple Bunches, Different Collisions Schemes and Machine Symmetries**
*Werner Herr, Tatiana Pieloni (CERN)*
In the LHC almost 3000 bunches in each beam will collide near several experimental regions and experience head-on as well as long range beam-beam interactions. In addition to single bunch phenomena, coherent bunch oscillations can be excited. Due to the irregular filling pattern and the unsymmetric collision scheme, a large number of possible modes must be expected, with possible consequences for beam measurements. To study these effects, a simulation program was developped which allows to evaluate the interaction of many bunches. It is flexible enough to easily implement any possible bunch configuration and collision schedule and also to study the effect of machine imperfections such as optical asymmetries. First results will be presented and future developments are discussed.

**TPAT079—Multipole Compensation of Long-Range Beam-Beam Interactions In Tevatron**
*Jack Shi, Ben Anhalt (KU)*
In Tevatron, serious long-range beam-beam effects are due to many parasitic collisions that are distributed around the ring. Because of this non-localized nature of long-range beam-beam interactions, the multipole compensation with one-turn or sectional maps aims a global compensation of long-range beam-beam interactions. Since nonlinear beam dynamics in a storage ring can usually be described by a one-turn map that contains all global information of system nonlinearities, by minimizing nonlinear terms of the maps order-by-order with a few groups of multipole correctors, one could reduce the nonlinearity globally. Since a large beam separation is typical at parasitic points, in the phase-space region that is relevant to the beam, long-range beam-beam interactions can be expanded into a Taylor series around the beam separation and be included into the one-turn map for the global compensation. To examine the effect of this multipole compensation scheme, the emittance growth of both p and pbar beam in Tevatron were studied with a beam-beam simulation. The result showed that the multipole compensation can significantly reduces the emittance growth of the pbar beam due to long-range beam-beam interactions.

The U.S. Department of Energy under Grant No. DE-FG02-04ER41288.

**TPAT080—Diffusion Due to Beam-Beam Resonances in Hadron Colliders**
*Yuri Alexahin (Fermilab)*
Beam-beam tune spread in hadron colliders usually is small enough to avoid most dangerous low-order betatron resonances. However, even weak high-order resonances can be detrimental due to cooperative effect of the external noise. Mechanisms of such cooperation are considered, simple analytical estimates of the diffusion rate being verified with numerical simulations. The developed theory is used to evaluate the beam-beam resonance contribution to the emittance growth and beam lifetime in the Tevatron.

**TPAT081—Beam Loss and Profile Evolution Under Intra-Beam Scattering in RHIC: Theory and Experiments**
*Jie Wei, Alexei V. Fedotov, Wolfram Fischer, Nikolay Malitsky (BNL), Ji Qiang (LBNL)*
Intra-beam scattering is one of the leading mechanisms limiting the luminosity in the Relativistic Heavy Ion Collider (RHIC). The multiple Coulomb scattering among the charged particles causes transverse mittance growth, longitudinal beam de-bunching, and beam loss, compromising machine performance during collision. Theoretically, the original theories developed by A. Piwinski, J. Bjorken, and S. Mtingwa are inadequate in predicting the beam loss and luminosity degradation. Equations based on the Fokker-Planck approach are developed to describe the longitudinal beam profile evolution and beam loss. During the 2004 RHIC heavy-ion operation, dedicated IBS experiments are performed to bench-mark the rms beam size growth, beam loss, and beam profile evolution both for a Gaussian-like beam and a longitudinal hallow beam. This paper summarizes the experimental bench-marking results.

Work performed under the auspices of the U.S. Department of Energy.

**TPAT082—Phonon Modes and the Maintenance Condition of a Crystalline Beam**
*Jie Wei (BNL), Hayato Enokizono, Hiromi Okamoto, Yosuke Yuri (HU/AdSM), Andrew Sessler (LBNL), Xiao-Ping Li (Skyworks Solutions, Inc.)*
Previously it has been shown that the maintenance condition for a crystalline beam requires that there not be a resonance between the crystal phonon frequencies and the frequency associated with a beam moving through a lattice of N periods. This resonance can be avoided provided the phonon frequencies are all below half of the lattice frequency. Here we make a detailed study of the phonon modes of a crystalline beam. Analytic results obtained in a "smooth approximation" using the ground-state crystalline beam structure is compared with numerical evaluation employing Fourier transform of Molecular Dynamic (MD) modes. The MD also determines when a crystalline beam is stable. The maintenance condition, when combined with either the simple analytic theory or the numerical evaluation of phonon modes, is shown to be in excellent agreement with the MD calculations of crystal stability.
*X-P. Li, A. M. Sessler, J. Wei, EPAC (1994) p. 1379 - 1381. 'Necessary Conditions for Attaining a Crystalline Beam"} **J. Wei, H. Okamoto, A.M. Sessler, Phys. Rev. Lett., Vol. 80, p. 2606-2609 (1998).

Work performed under the auspices of the U.S. Department of Energy.

**TPAT083—Computational Study of the Beam-Beam Effect in Tevatron Using the LIFETRAC Code**
*Alexander Valishev, Yuri Alexahin, Valeri Lebedev (Fermilab), Dmitry Shatilov (BINP SB RAS)*
Results of a comprehensive numerical study of the beam-beam effect in the Tevatron are presented including the dependence of the luminosity lifetime on the tunes, chromaticity and optics errors. These results help to understand the antiproton emittance blow-up routinely observed in the Tevatron after the beams are brought into collision. To predict a long term luminosity evolution, the diffusion rates are increased to represent long operation time (~day) by using a small number of simulated turns. To justify this approach, a special simulation study of interplay between nonlinear beam-beam resonances and diffusion has been conducted. A number of ways to mitigate the beam-beam effects are discussed, such as increasing bunch spacing, separation between the beams and beam-beam compensation with electron lenses.

Work supported by the Universities Research Assos., Inc., under contract DE-AC02-76CH03000 with the U.S. Dept. of Energy.

**TPAT084—LIFETRAC Code for the Weak-Strong Simulation of the Beam-Beam Effect in Tevatron**
*Alexander Valishev, Yuri Alexahin, Valeri Lebedev (Fermilab), Dmitry Shatilov (BINP SB RAS)*
A package of programs for weak-strong simulation of beam-beam effects in hadron colliders is described. Accelerator optics parameters relevant to the simulation are derived from beam measurements and calculations are made using OptiM optics code. The key part of the package is the upgraded version of the LIFETRAC code which now includes 2D coupled optics, chromatic modulation of beta-functions, non-Gaussian shape of the strong bunches and non-linear elements for beam-beam compensation. Parallel computations are used and in the case of the Tevatron (2 main IPs + 70 parasitic IPs) the code has a productivity of ~1E10 particles*turns/day on a 32-node cluster of Pentium IV 1.8 GHz processors.

Work supported by the Universities Research Assos., Inc., under contract DE-AC02-76CH03000 with the U.S. Dept. of Energy.

**TPAT085—Development of a Beam-Beam Simulation Code for the e+e- Collider**
*Yuan Zhang (IHEP Beijing), Kazuhito Ohmi (KEK)*
BEPC will be upgraded into BEPCII, and the luminosity will be about 100 times higher. We developed a new 3D strong-strong simulation code to study the beam-beam effects in BEPCII. The code is parallelized with Message Passing Interface(MPI). The finite bunch length effect is included by cutting the beam into several slices along longitudinal direction. Since the synchrotron tune is very small, we assume that the particles in one slice will not jump into not-adjacent ones the next turn. Then it is natural for us to store the data of macro-particles in one slice into one computer node. When one bunch is cut into n slices, 2*n computer nodes will be used in the simulation. With this scheme, the computation time vary linearly with the number of slices. The beam-beam effects in BEPCII is studied by simulation using the code. The results will be contributed to the design and even for the operation of BEPCII.

**TPAT086—Enhanced Optical Cooling of Particle Beams in Storage Rings**
*Evgueni Grigorievich Bessonov (LPI)*
In this scheme undulators are installed in straight sections of a storage ring at distances determined by a phase advance 2p–+– between first and second undulators and 2– between next undulators, where p=1,2,3.. . UR emitted in the first undulator pass through an optical system with movable screens 1,2 in the image plane of the particle beam. If screens let pass the UR then the past UR is amplified and pass through the second and next undulators together with the particle. Every particle loses its energy in the overlapped fields of the amplified UR and these undulators. Motion of screens in the optical system leads to particle energy losses in second and following undulators similar to losses in moving targets T1,2 in the schemes of enhanced ion cooling.* Energy losses are accompanied by a decrease of both energy spread and amplitudes of betatron oscillations that is enhanced cooling if, at first, the moving screen 2 will produce conditions of the energy loss for higher energy particles. When the screen 2 will open image of all particles the system must be closed and then the cooling process can be repeated.*
*physics/0404142.

**TPAT087—The Effect of Magnetic Field Errors on Dynamical Friction in Electron Coolers**
*David L. Bruhwiler, Dan Tyler Abell, Richard Busby (Tech-X), Ilan Ben-Zvi, Alexei V. Fedotov, Animesh Kumar Jain, Vladimir N. Litvinenko (BNL), John R. Cary (CIPS; Tech-X), Alexey Burov (Fermilab)*
A proposed luminosity upgrade to the Relativistic Heavy Ion Collider (RHIC) includes a novel electron cooling section,* which would use ~55 MeV electrons to cool fully-ionized 100 GeV/nucleon gold ions. A strong (1-5 T) solenoidal field will be used to magnetize the electrons and thus enhance the dynamical friction force on the ions. The physics of magnetized friction is being simulated for RHIC parameters, using the VORPAL code.** Most theoretical treatments for magnetized dynamical friction do not consider the effect of magnetic field errors, except in a parametric fashion.*** However, field errors can in some cases dramatically reduce the velocity drag and corresponding cooling rate. We present a simple analytical model for the magnetic field errors, which must be Lorentz transformed into the beam frame for use in our simulations. The simulated dynamical friction for the case of a perfect solenoidal field will be compared with results from this new model, for parameters relevant to RHIC.
*Fedotov et al., Proc. 33rd ICFA Adv. Beam Dynamics Workshop (2004). **Nieter & Cary, J. Comp. Phys. 196 (2004). ***Parkhomchuk, Nucl. Instr. Meth. Phys. Res. A 441 (2000).

Work supported by US DOE grants DE-FG03-01ER83313 and DE-FG03-95ER40926.

**TPAT088—Consideration of Relativistic Dynamics in High-Energy Electron Coolers**
*David L. Bruhwiler, George I. Bell (Tech-X)*
A proposed electron cooler for RHIC would use ~55 MeV electrons to cool fully-ionized 100 GeV/nucleon gold ions.* At two locations in the collider ring, the electrons and ions will co-propagate for ~13 m, with velocities close to c and gamma>100. To lowest-order, one can Lorentz transform all physical quantities into the beam frame and calculate the dynamical friction forces assuming a nonrelativisitc, electrostatic plasma. However, we show that nonlinear space charge forces of the bunched electron beam on the ions must be calculated relativistically, because an electrostatic beam-frame calculation is not valid for such short interaction times. The validity of nonrelativistic friction force calculations must also be considered. Further, the transverse thermal velocities of the high-charge (~20 nC) electron bunch are large enough that some electrons have marginally relativistic velocities, even in the beam frame. Hence, we consider relativistic binary collisions — treating the model problem of two charged particles on a line, comparing nonrelativistic dynamics, marginally relativistic (in the Darwin approximation) and fully relativistic, with retarded potentials.
*A.V. Fedotov et al., Proc. 33rd ICFA Advanced Beam Dynamics Workshop (2004), in press.

Work supported by U.S. DOE grant DE-FG02-04ER84094.

**TPAT089—Cooling Dynamics Studies and Scenarios for the RHIC Cooler**
*Alexei V. Fedotov, Ilan Ben-Zvi, Vladimir N. Litvinenko (BNL)*
In this paper, we discuss various cooling dynamics studies for RHIC, such as an equilibrium process between intra-beam scattering within ion bunch and electron cooling, critical number of electrons needed, magnetized cooling logarithm and resulting requirements on parameters of electron beam, effects of solenoid errors, etc. We also present simulations of various possibilities of using electron cooling at RHIC, which includes cooling at the top energy, pre-cooling at low energy, aspects of transverse and longitudinal cooling and their impact on the luminosity. Electron cooling at various collision energies both for heavy ions and protons is also discussed.

Work supported by the U.S. Department of Energy under contract No. DE-AC02-98CH10886

**TPAT090—Simulations of High-Energy Electron Cooling**
*Alexei V. Fedotov, Ilan Ben-Zvi, Yury Isaakovich Eidelman, Vladimir N. Litvinenko, Nikolay Malitsky (BNL), Igor Meshkov, Anatoly Olegovich Sidorin, Alexander Smirnov, Grigory Troubnikov (JINR), David L. Bruhwiler (Tech-X)*
High-energy electron cooling of RHIC presents many unique features and challenges. An accurate estimate of the cooling times requires a detailed calculation of the cooling process, which takes place simultaneously with various diffusive mechanisms in RHIC. In addition, many unexplored effects of high-energy cooling in a collider complicate the task of getting very accurate estimates of cooling times. To address these high-energy cooling issues, a detailed study of cooling dynamics

based on computer codes is underway at Brookhaven National Laboratory. In this paper, we present an update on code development and its application to the high-energy cooling dynamics studies for RHIC.

Work supported by the U.S. Department of Energy under contract No. DE-AC02-98CH10886.

**TPAT091—IBS for Ion Distribution Under Electron Cooling**
*Alexei V. Fedotov, Ilan Ben-Zvi, Yury Isaakovich Eidelman, Vladimir N. Litvinenko, George Parzen (BNL)*
Standard models of the intra-beam scattering (IBS) are based on the growth of the rms beam parameters for a Gaussian beam distribution. As a result of electron cooling, the core of beam distribution is cooled much faster than the tails, producing a denser core. Formation of such a core is an important feature since it plays dominant role in the luminosity increase. A simple use of standard rms-based IBS approach may significantly underestimate IBS for the beam core. A detailed treatment of IBS, which depends on individual particle amplitudes, was recently proposed by Burov,* with an analytic formulation done for a Gaussian distribution. However, during the cooling process the beam distribution quickly deviates from a Gaussian profile. To understand the extent of the dense core formation in the ion distribution, the "core-tail" model for IBS, based on the diffusion coefficients for bi-Gaussian distributions, was employed in cooling studies for RHIC. In addition, the standard IBS theory was recently reformulated for rms parameters growth of a bi-Gaussian distribution by Parzen.** In this paper, we compare various approaches to IBS treatment for such distribution. Its impact on the luminosity is also discussed.
*A. Burov, FERMILAB-TM-2213 (2003). **G. Parzen, Tech Note C-AD/AP/150 (2004).

Work supported by the U.S. Department of Energy under contract No. DE-AC02-98CH10886.

**TPAT092—Numerical Studies of the Friction Force for the RHIC Electron Cooler**
*Alexei V. Fedotov (BNL), David L. Bruhwiler (Tech-X)*
Accurate calculation of electron cooling times requires an accurate description of the dynamical friction force. The proposed RHIC cooler will require ~55 MeV electrons, which must be obtained from an RF linac, leading to very high transverse electron temperatures. A strong solenoid will be used to magnetize the electrons and suppress the transverse temperature, but the achievable magnetized cooling logarithm will not be large. Available formulas for magnetized dynamical friction are derived in the logarithmic approximation, which is questionable in this regime. In this paper, we explore the magnetized friction force for parameters of the RHIC cooler, using the VORPAL code.* VORPAL can simulate dynamical friction and diffusion coefficients directly from first principles.** Various aspects of the friction force, such as dependence on magnetic field, scaling with ion charge number and others, are addressed for the problem of high-energy electron cooling in the RHIC regime.
*C. Nieter & J.R. Cary, J. Comp. Phys. 196 (2004), p. 448.
**D.L. Bruhwiler et al., Proc. 33rd ICFA Advanced Beam Dynamics Workshop (2004).

Work performed under the auspices of the U.S. Department of Energy.

**TPAT093—Operations and Performance of RHIC as a Cu-Cu Collider**
*Fulvia C. Pilat, Leif Ahrens, James Alessi, Mei Bai, Donald Barton, Joanne Beebe-Wang, Michael Blaskiewicz, Joseph Michael Brennan, Donald Bruno, John J. Butler, Peter Cameron, Roger Connolly, Joseph DeLong, Theodore D'Ottavio, Angelika Drees, Wolfram Fischer, George Ganetis, Chris J. Gardner, Joseph Glenn, Thomas Hayes, Hsiao-Chaun Hseuh, Haixin Huang, Peter Ingrassia, Ubaldo Iriso, Vladimir N. Litvinenko, Yun Luo, William W. MacKay, Gregory James Marr, Al Marusic, Robert Michnoff, Christoph Montag, John Morris, Tony Nicoletti, Brian Oerter, Vadim Ptitsyn, Thomas Roser, Thomas Russo, Jon Sandberg, Todd Satogata, Carl Schultheiss, Loralie Smart, Dannie Steski, Steven Tepikian, Rogelio Tomas, Dejan Trbojevic, Nicholaos Tsoupas, Joseph Tuozzolo, Kurt Vetter, Alex Zaltsman, Keith Zeno, S.Y. Zhang, Wu Zhang (BNL)*
The 5th year of RHIC operations, started in November 2004 and expected to last till June 2005, consists of a physics run with Cu-Cu collisions at 100 GeV/u followed by one with polarized protons at 100 GeV. We will address here overall performance of the RHIC complex used for the first time as a Cu-Cu collider, and compare it with previous operational experience with Au, PP and asymmetric d-Au collisions. We will also * squeeze to 85cm in the highβdiscuss operational improvements, such as a luminosity interaction regions from the design value of 1m, system improvements and machine performance limitations, such as vacuum pressure rise, intra-beam scattering, and beam beam interaction.

Work performed under the auspices of the U.S. Department of Energy.

**TPAT094—Optical Signals from the Polarized Proton Jet Target in RHIC Used To Measure the Beam Profile and Impurities in Jet**
*Dejan Trbojevic, Roger Connolly, Nicholas P. Luciano, Yousef Makdisi, Anatoli Zelenski (BNL)*
This is the second polarized proton run in Relativistic Heavy Ion Collider (RHIC) with a new polarized proton jet target used to provide accurate polarization measurements. The interactions between the stored polarized protons with the polarized jet target will produce, in addition to polarization, optical signals due to exited states of Hydrogen or other molecules, ions, or atoms. Additional lenses, optical window, optical analyzer, and the CCD camera are added to the system to allow transfer and detection of optical signals from the interaction chamber. Oxygen or other elements (impurities) could be mixed within the jet target and affect the accuracy of the polarization measurements. It is important to have continuous information of the jet content without affecting the polarization measurements. The optical signals coming from the exited states of molecules, ions, and atoms from the polarized proton beam interaction with the jet will provide that. In addition, the beam profile might be obtained.

Work performed under Contract Number DE-AC02-98CH10886 with the auspicies of the US Deparment of Energy.

**TPAT095—Beam Induced Pressure Rise at RHIC**
*S.Y. Zhang, James Alessi, Mei Bai, Michael Blaskiewicz, Peter Cameron, Angelika Drees, Wolfram Fischer, Justin Gullotta, Ping He, Hsiao-Chaun Hseuh, Haixin Huang, Ubaldo Iriso, Roger C. Lee, Vladimir N. Litvinenko, William W. MacKay, Tony Nicoletti, Brian Oerter, Steve Peggs, Fulvia C. Pilat, Vadim Ptitsyn, Thomas Roser, Todd Satogata, Loralie Smart, Louis Snydstrup, Peter Thieberger, Dejan Trbojevic, Lanfa Wang, Jie Wei, Keith Zeno (BNL)*
Beam induced pressure rise in RHIC warm sections is currently one of the machine intensity and luminosity limits. This pressure rise is mainly due to electron cloud effects. The RHIC warm section electron cloud is associated with longer bunch spacings

compared with other machines, and is distributed non-uniformly around the ring. In addition to the countermeasures for normal electron cloud, such as the NEG coated pipe, solenoids, beam scrubbing, bunch gaps, and larger bunch spacing, other studies and beam tests toward the understanding and counteracting RHIC warm electron cloud are of interest. These include the ion desorption studies and the test of anti-grazing ridges. For high bunch intensities and the shortest bunch spacings, pressure rises at certain locations in the cryogenic region have been observed during the past two runs. Beam studies are planned for the current 2005 run and the results will be reported.

Work performed under the auspices of the U.S. Department of Energy.

**TPAT096—Focusing-Free Transition Crossing in RHIC Using Induction Acceleration**

*Ken Takayama, Yoshito Shimosaki, Kota Torikai (KEK), Jie Wei (BNL)*

Focusing-free transition crossing (FFTC) in RHIC is proposed. The original idea of FFTC proposed by J.Griffin was tried in the FNAL 500GeV main ring, where a gradient in the acceleration voltage was smoothed flat by introducing multi higher-harmonic RF. If the longitudinal focusing disappears during a limited time period near TC, various undesired features, such as bunch shortening and elongation in the momentum space, should be mitigated. In present RHIC operation, the slow ramping across transition leads into complications of nonlinear chromatic effects, vacuum pressure rise, instability, and transition-jump related lattice distortions. Recently, induction acceleration of a single RF bunch has been successfully demonstrated in KEK-PS,* where a proton bunch is trapped by the existing RF and accelerated with an induction step-voltage to 8 GeV. The utilized acceleration device is capable of generating a step voltage of 2 kV/cell at most at an arbitrary repetition rate up to 1 MHz. We here propose focusing-free TC in RHIC, introducing similar devices. In this scheme, the RF voltage is tuned off during an optimized time-period of several tens of ms, and the required acceleration voltage is provided as an induction flat-voltage. *K.Takayama et al., submitted to Phys. Rev. Lett., http://www.arxiv.org/pdf/physics/0412006.

**TPAT097—CLIC Drive Beam and LHC Based FEL-Nucleus Collider**

*Omer Yavas (Ankara University), Hans-Heinrich Braun, Roberto Corsini (CERN), Saleh Sultansoy (Gazi University)*

Main parameters of CLIC-LHC based FEL-Nucleus collider are determined. The matching of beam structures for maximum luminosity is studied. The advantages of the collider with respect to the traditional Nuclear Resonance Fluorescence (NRF) methods are presented considering (/Gamma-/Gamma^(prime)) reactions. Determination of unknown decay width, spin and parity of excited levels is discussed for Pb nucleus.

Ankara University, Ankara, Turkey.

**TPAT098—A Review of TeV Scale Lepton-Hadron and Photon-Hadron Colliders**

*Saleh Sultansoy (Gazi University)*

The investigation of lepton-hadron and photon-hadron collisions at TeV scale is crucial both to clarify the strong interaction dynamics from nuclei to quark-parton level and for adequate interpretation of experimental data from future hadron colliders (LHC and VLHC). In this presentation different TeV scale lepton-hadron and photon-hadron collider proposals (such as THERA, "LEP"-LHC, QCD Explorer etc) are discussed. The advantages of linac-ring type colliders has been shown comparatively.

Gazi University, Ankara, Turkey.

**TPAT099—Main Parameters of ILC-Tevatron Based Lepton-Hadron and Photon-Hadron Colliders**

*Saleh Sultansoy (Gazi University), Omer Yavas (Ankara University, Orhan Cakir, Abbas Kenan Ciftci, Erdal Recepoglu (Ankara University)*

The construction of the ILC tangential to Tevatron ring will give opportunity to investigate electron-proton, positron-proton, electron-antiproton, positron-antiproton interactions at 1 TeV center of mass energy. The analysis of the lepton-hadron collisions in these energy region is very important both for understanding of strong interaction dynamics and for adequate interpretation of future LHC and VLHC data. In addition, ILC-Tevatron collider will provide a possibility to realize photon-hadron collisions in the same energy region using Compton backscattered laser photon of ILC electron beam. Main parameters of these colliders are estimated and their physics search potential is briefly discussed.

Ankara University.

**TPAT100—On the Feasibility of a 20 Tesla Wiggler to Damp Phase Space in LHC**

*Peter M. McIntyre, Akhdiyor Sattarov (Texas A&M University)*

Recent developments in the performance of superconductors and the design of high-field superconducting dipoles have opened the possibility to extend dipole field strength as high as ~25 Tesla. One interesting potential application of such technology would be a wiggler system to damp the phase space of the beams in LHC. For this purpose a dual dipole design has been developed that would provide 20 Tesla bend field with the same aperture and beam tube separation as in the LHC arcs. A 50 m string of such dipoles, each ~5 m long and alternating in polarity, could be installed in straight sections in the LHC lattice. Integration into the LHC lattice and optimization of focal length through the wiggler are being investigated. The possibility of including a gradient index in the wiggler dipoles is being investigated. If the damping time can be reduced sufficiently that it competes favorably with emittance growth from beam-beam interactions, it might be used to achieve luminosity leveling through the duration of a store.

This work is funded by the U.S. Dept. of Energy, grant #DE-FG03-95ER40924.

Oral Session TOPA–Advanced Concepts
Ballroom A @ 13:50
Chair: C. Pellegrini (UCLA)

**13:50 TOPA001—Mono Energetic Beams from Laser Plasma Interactions**
*Cameron Guy Robinson Geddes, Eric Esarey, Wim Leemans, Carl Bernhardt Schroeder, Csaba Toth, Jeroen Van Tilborg (LBNL), John R. Cary (CIPS; Tech-X), David L. Bruhwiler, Chet Nieter (Tech-X)*
A laser driven wakefield accelerator has been tuned to produce high energy electron bunches with low emittance and energy spread by extending the interaction length using a plasma channel. Wakefield accelerators support gradients thousands of times those achievable in RF accelerators, but short acceleration distance, limited by diffraction, has resulted in low energy beams with 100% electron energy spread. In the present experiments on the L'OASIS laser,* the relativistically intense drive pulse was guided over 10 diffraction ranges by a plasma channel. At a drive pulse power of 9 TW, electrons were trapped from the plasma and beams of percent energy spread containing >200pC charge above 80 MeV and with normalized emittance estimated at < 2 pi -mm-mrad were produced.** Data and simulations (VORPAL***) show the high quality bunch was formed when beam loading turned off injection after initial trapping, and when the particles were extracted as they dephased from the wake. Up to 4TW was guided without trapping, potentially providing a platform for controlled injection. The plasma channel technique forms the basis of a new class of accelerators, with high gradients and high beam quality.
*W.P. Leemans et al., Phys. Plasmas 5, 1615-23 (1998). **C.G.R. Geddes et al., Nature 431, 538-41 (2004). ***C. Nieter et al., J. Comp. Phys. 196, 448-73 (2004).

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**14:15 TOPA002—Review of Beam-Driven Plasma Wakefield Experiments at SLAC**
*Mark Hogan, Christopher Barnes, Franz-Josef Decker, Paul Emma, Richard Iverson, Patrick Krejcik, Caolionn O'Connell, Robert Siemann, Dieter Walz (SLAC), Chris Clayton, Chengkun Huang, Devon K. Johnson, Chan Joshi, Wei Lu, Kenneth Marsh, Warren Mori (UCLA), Suzhi Deng, Tom Katsouleas, Patric Muggli, Erdem Oz (USC)*
In the plasma wakefield accelerator, a short relativistic-electron bunch drives a large amplitude plasma wave or wake. In experiment E-164X, we use the 28.5 GeV, ultra-short (?80 femtosecond), high peak-current (?30 kiloamperes) bunch now available at the Stanford Linear Accelerator Center Final Focus Test Beam facility. The head of this bunch fieldionizes a lithium vapor and excites the wake, and the tail samples the accelerating field. The latter is accomplished by setting the plasma density to match the plasma wavelength to the bunch length. After the plasma, the bunch is dispersed in energy by an imaging magnetic-spectrometer. Preliminary analysis shows that gradients in excess of 15 GeV/m are excited over a plasma length of approximately 10 cm, leading to energy gain on the order of of 1.5 GeV, or about an order of magnitude larger than energy gains reported to date. This gradient is also three orders of magnitude larger than that in the three-kilometer long Stanford linear accelerator that produces the incoming beam. These results are obtained in a new regime for beam-driven plasma accelerators in which the electron bunch creates its own plasma. The current status of the experiment as well as future plans will be discussed.

Department of Energy contracts DE-AC02-76SF00515 (SLAC), DE-FG03-92ER40745, DE-FG03-98DP00211, DE-FG03-92ER40727, DE-AC-0376SF0098, and National Science Foundation grants No. ECS-9632735, DMS-9722121 and PHY-0078715.

**14:40 TOPA003—Optical Injection into Laser Wake Field Accelerators**
*John R. Cary (CIPS; Tech-X), Eric Esarey, Cameron Guy Robinson Geddes, Wim Leemans (LBNL), David L. Bruhwiler, Rodolfo Giacone, Chet Nieter (Tech-X)*
The accelerating gradient of laser-generated wake fields in plasmas can be orders of magnitude greater than the gradients obtainable in traditional, rf structures. One of the hurdles to overcome on the road to practical utilization of said plasma wake fields for production of high energy particles is the creation of quality beams having significant charge, low emittance, and narrow energy spread. To generate appropriate beams, various injection methods have been proposed. Injection by conventional means of beam prepartion using conventional technology is very difficult, as the accelerating buckets are only tens of microns long. Therefore, the field has turned to all-optical injection schemes, which include injection by colliding pulses, plasma ramps, wave breaking, and self-trapping through pulse evolution. This talk will review the various concepts proposed for injection, including plasma ramps, colliding pulses, and self trapping. The results of simulations and experiments will be discussed along with proposed mechanisms for improving the generated beams. Parameter studies to find optimal beam generation scenarios will be presented.

This work supported by the U.S. Department of Energy grants DE-FG02-04ER41317, DE-FG02-01ER41178, aand DE-FG02-03ER83857, and NSF grant 0113907.

**15:05 TOPA004—First Demonstration of a Staged Optical Injection and Laser Wakefield Acceleration**
*Dmitri Kaganovich (NRL; LET ), Daniel Gordon, Richard Hubbard, Theodore Jones, Phillip Sprangle, Antonio Ting (NRL)*
A two stage experiment on optically injected Laser Wakefield Acceleration (LWFA) was performed at the Naval Research Laboratory. Two temporally and spatially synchronized laser beams at 2 TW and 10 TW respectively are each focused collinearly into two adjacent gas jets. Electrons at <0.5 MeV generated from the 2 TW laser beam are injected into the wakefields generated by the 10 TW laser beam. Accelerated electrons >20 MeV are observed, implying an acceleration gradient of 20 GeV/m for the \sim1 mm acceleration distance. Apparent peaks and structures are observed in the energy spectrum. This is a clear demonstration of substantial laser wakefield acceleration of externally and optically produced injection electrons. Details of the experiment will be presented.

The U.S. Department of Energy and the Office of Naval Research.

**15:20 TOPA005 – Left-Handed Metamaterials Studies and Their Application to Accelerator Physics**
*Sergey P. Antipov, Wanming Liu, John Gorham Power (ANL), Linda Klamp Spentzouris (Illinois Institute of Technology)*
Recently, there has been a growing interest in applying artificial materials, known as Left-Handed Metamaterials (LHM), to

accelerator physics. These materials have both negative permittivity and permeability and therefore possess several unusual properties: the index of refraction is negative and the direction of the group velocity is antiparallel to the direction of the phase velocity (along k). These properties lead to a reverse Cherenkov effect, which has potential beam diagnostic applications, in addition to accelerator applications. Several LHM devices with different configurations are being experimentally and theoretically studied at Argonne. In this paper, we describe permittivity and permeability retrieval techniques that we have developed and applied to these devices. We have also investigated the possibility of building a Cherenkov detector based on LHM and propose an experiment to observe the reverse radiation generated by an electron beam passing through a LHM. The potential advantage of a LHM detector is that the radiation in this case is emitted in the direction reversed to the direction of the beam, so it could be easier to get a clean measurement.

DOE grant NSF grant.

## Oral Session TOPB—Light Sources and Free-Electron Lasers
## Ballroom B @ 13:50
## Chair: L. Merminga (JLab)

**13:50 TOPB001—Methods of Attosecond X-Ray Pulse Generation**
*Alexander Zholents (LBNL)*
Our attitude towards attosecond x-ray pulses has changed dramatically over the past several years. Not long ago x-ray pulses with a duration of a few hundred attoseconds were just science fiction for most of us, but they are already a tool for some researchers in present days. Breakthrough progress in the generation of solitary soft x-ray pulses of attosecond duration has been made by the laser community. Following this lead, people in the free electron laser community have begun to develop new ideas on how to generate attosecond x-ray pulses in the hard x-ray energy range. In this report I will review some of these ideas.

This work was supported by the Director, Office of Science of the U. S. Department of Energy under Contract No. DE-AC03-76SF00098.

**14:15 TOPB002—Sub-Picosecond Pulse Source: Recent Results**
*Jerome Hastings (SLAC)*
The Sub-Picosecond Pulse Source (SPPS)at SLAC is a unique photon source produced from 80 femtosecond electron bunches with 3 nC of charge. At 28 GeV they produce spontaneous synchrotron radiaiton with unprecedented peak brightness. This source provides a window into the science and technology of ultra-fast x-ray studies that x-ray free electron lasers will permit. Recent results from the SPPS in both x-ray science and technology will be discussed, in particular the methods and results for pump-probe studies of laser-solid interactions.

**14:40 TOPB003—Progress in Large Scale Femtosecond Timing Distribution and RF-Synchronization**
*Franz Xaver Kaertner, Fatih Oemer Ilday, Jung-Won Kim (MIT), Axel Winter (Uni HH)*
For future advances in accelerator physics in general and seeding of free electron lasers (FELs) in particular, precise synchronization between low-level RF-system, photo-injector laser, seed radiation as well as potential probe lasers at the FEL output is required. We propose a modular system based on optical pulse trains from mode-locked lasers for timing distribution and timing information transfer in the optical domain to avoid detrimental effects due to amplitude to phase conversion in photo detectors. Synchronization of various RF- and optical sub-systems with femtosecond precision over distances of several hundred meters can be achieved. First experimental results and limitations of the proposed scheme for timing distribution are discussed.

**15:05 TOPB004—Overview of Energy Recovery Linacs**
*Ivan Vasilyevich Bazarov (Cornell Univ.)*
Existing Energy Recovery Linacs (ERLs) are successfully operated as kW-class average power infrared Free Electron Lasers (FELs). Various groups worldwide actively pursue ERLs as a technology of choice for a number of new applications. These include high brilliance light sources in a wide range of photon energies utilizing both spontaneous and FEL radiation production techniques, electron cooling of ion beams, and ERL-based electron-ion collider. All of these projects seek in various ways to extend performance parameters possible in ERLs beyond what has been achieved in existing relatively small scale demonstration facilities. The demand is for much higher average currents, significantly larger recirculated beam energies and powers and substantially improved electron sources. An overview of the ongoing ERL projects will be presented along with the summary of the progress that is being made in addressing the outstanding issues in this type of accelerators.

Supported by the NSF.

## Oral Session TOPC—Instrumentation
## Ballroom C @ 13:50
## Chair: R. Webber (FNAL)

**13:50 TOPC001—Visualizing Electron Beam Dynamics and Instabilities with Synchrotron Radiation at the Advanced Photon Source**
*Bingxin Yang, Alex Lumpkin (ANL)*
The Advanced Photon Source (APS) is a third generation hard x-ray source serving a large user community. In order to characterize the high-brilliance beams, the APS diagnostics beamlines have been developed into a full photon diagnostics suite. We will describe the design and capabilities of the APS visible light imaging line, the bend magnet x-ray pinhole camera, and a unique diagnostics undulator beamline. Their primary functions are to support the APS user operations by providing information on beam sizes (20 - 100 micrometers), divergence (3 – 25 microradians), and bunch length (20 – 50 ps). Through the use of examples, we will show how these complementary imaging tools are used to visualize the electron dynamics and investigate beam instabilities. Special emphasis will be put on the use of undulator radiation, which is uniquely suitable for time-resolved imaging of electron beam with high spatial resolution, and for measurements of longitudinal beam properties such as beam energy spread and momentum compaction.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

**14:15 TOPC002—Residual-Gas-Ionization Beam Profile Monitors in RHIC**
*Roger Connolly, Robert Michnoff, Steven Tepikian (BNL)*
Four ionization profile monitors (IPMs) are in RHIC to measure vertical and horizontal beam profiles in the two rings. These work by measuring the distribution of electrons produced by beam ionization of residual gas. During the last two years both the collection accuracy and signal/noise ratio have been improved. An electron source is mounted across the beam pipe from the collector to monitor microchannel plate (MCP) aging and the signal electrons are gated to reduce MCP aging and to allow charge replenishment between single-turn measurements. Software changes permit simultaneous measurements of any number of individual bunches in the ring. This has been used to measure emittance growth rates on six bunches of varying intensities in a single store. Also the software supports FFT analysis of turn-by-turn profiles of a single bunch at injection to detect dipole and quadrupole oscillations.

Work performed under Contract #DE-AC02-98CH10886 under the auspices of the U.S. Department of Energy.

**14:40 TOPC003—Beam Measurements and Upgrade at BL 7.2, the Second Diagnostics Beamline of the Advanced Light Source**
*Fernando Sannibale, Alan Biocca, Nicholas Kelez, Michael C. Martin, Toshiro Nishimura, Tom Scarvie, Eric Williams (LBNL), Gregory James Portmann (LBNL/ALS)*
Beamline BL 7.2 of the Advanced Light Source (ALS) at the Lawrence Berkeley National Laboratory is a beam diagnostics system that uses the synchrotron radiation (SR) emitted by a dipole magnet. It consists of two branches, in the first one the x-ray portion of the SR is used in a pinhole camera system for measuring the transverse profile of the beam. The second branch is equipped with a x-ray BPM system and with a multipurpose port where the visible and the infrared part of the SR can be used for various applications such as bunch length measurements and IR coherent synchrotron radiation experiments. The pinhole system has been commissioned at the end of 2003 and since then is in successful operation. The installation of the second branch has been completed recently and the results of its commissioning are presented in this paper together with examples of beam measurements performed at BL 7.2.

Work supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**14:55 TOPC004—Tevatron Beam Position Monitor Upgrade**
*Stephen Wolbers, Michael A. Martens, Jim Steimel, Robert C. Webber (FNAL)*
The Tevatron Beam Position Monitor (BPM) readout electronics and software have been upgraded to improve measurement precision, functionality and reliability. The original system, designed and built in the early 1980s, became inadequate for current and future operations of the Tevatron. The upgraded system consists of 960 channels of new electronics to process analog signals from 240 BPMs, new front-end software, new online and controls software, and modified applications to take advantage of the improved measurements and support the new functionality. The new system reads signals from both ends of the existing directional stripline pickups to provide simultaneous proton and antiproton position measurements. Measurements using the new system are presented that demonstrate its improved resolution and overall performance.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the U.S. Department of Energy.

**15:10 TOPC005—Transverse Emittance Blow-Up Due to the Operation of Wire Scanners, Analytical Predictions and Measurements**
*Federico Roncarolo, Bernd Dehning (CERN)*
Wire Scanner monitors are used in the CERN accelerators to measure the transverse beam size. In the SPS and the LHC they will serve as calibration devices for other emittance monitors. The PSB, PS and SPS are equipped with scanners which move through the beam a 30 um wire, with a speed that can vary between 0.4 to 20 m/s. During each scan, the beam suffers an emittance blow up, due to multiple Coulomb scattering of the beam protons on the lattice nuclei of the wire material. The effect depends on the particles' energy, the betatron function at the monitor location and on the wire characteristics (material, diameter and speed). In this paper we will present a comparison of the analytically predicted emittance increase caused by the instruments and a number of experimental measurements. For the small LHC beams the relative emittance blow-up can exceed a few 10e-2.

**Oral Session TOPA (Cont.)–Advanced Concepts**
**Ballroom A @ 15:35**
**Chair: W. Leemans (LBNL)**

**15:35 TOPA006—High Energy Gain IFEL at Neptune/UCLA**
*Pietro Musumeci, Chris Clayton, Adnan Doyuran, Robert Joel England, Chan Joshi, Claudio Pellegrini, Joseph Ralph, James Rosenzweig, Chieh Sung, Sergei Tochitsky, Gil Travish, Rodney Yoder (UCLA), Sergey Tolmachev, Alexander Varfolomeev (RRC Kurchatov Institute)*
We report the observation of energy gain in excess of 20 MeV at the Inverse Free Electron Laser Accelerator experiment at the Neptune Laboratory at UCLA. A 14.5 MeV electron beam is injected in an undulator strongly tapered in period and field amplitude. The IFEL driver is a CO2 10.6 mkm laser with power larger than 400 GW. The Rayleigh range of the laser, ~ 1.8 cm, is much shorter than the undulator length so that the interaction is diffraction dominated. A few per cent of the injected particles are trapped in a stable accelerating bucket. Electrons with energies up to 35 MeV are measured by a magnetic spectrometer. Simulations, in good agreement with the experimental data, show that most of the energy gain occurs in the first half of the undulator at a gradient of 70 MeV/m and that the structure in the measured energy spectrum arises because of higher harmonic IFEL interaction in the second half of the undulator.

**16:00 TOPA007—Proton Acceleration and High-Energy Density Physics from Laser Foil Interactions**
*Peter Andrew Norreys (CCLRC/RAL), Karl Krushelnick (Imperial College of Science and Technology), Matthew Zepf (Queen's University of Belfast)*
Intense laser plasma interactions have long been shown to be a source of very energetic ions - from the first experiments in the 1970's. However, there has been a recent revival of interest in the production of protons and ions from the such plasmas - primarily from the observation of collimated beams of protons and heavier ions which were observed at the rear thin foil targets irradiated by ultra-high intensity laser pulses (such that I > 1018 W/cm2). These ion beams have unique properties which may make them suitable for a variety of applications such as for probing high density plasmas, for fast ignition in inertial confinement fusion, as an ion source for subsequent acceleration stages in a particle accelerator or potentially for medical

applications. Recent experimental results will be reviewed and the potential for such future applications will be highlighted.

**16:25 TOPA008—First Observation of Laser-Driven Particle Acceleration in a Semi-Infinite Vacuum Space**
*Tomas Plettner, Robert L. Byer, Todd Iversen Smith (Stanford University), Eric R. Colby, Benjamin Cowan, Chris M.S. Sears, Robert Siemann, James Spencer (SLAC)*
We have observed acceleration of relativistic electrons in vacuum driven by a linearly polarized laser beam incident on a thin gold-coated reflective boundary. The observed energy modulation effect follows all the characteristics expected for linear acceleration caused by a longitudinal electric field. As predicted by the Lawson-Woodward theorem the laser driven modulation only appears in the presence of the boundary. It shows a linear dependence with the strength of the electric field of the laser beam and also it is critically dependent on the laser polarization. Finally, it appears to follow the expected angular dependence of the inverse transition radiation process.

Department of Energy DE-FG03-97ER41043.

**16:50 TOPA009—Photonic Band Gap Accelerator Demonstration at Ku-Band**
*Evgenya I. Smirnova, Amit S. Kesar, Ivan Mastovsky, Michael A. Shapiro, Richard J. Temkin (MIT/PSFC), Lawrence M. Earley, Randall L. Edwards (LANL)*
We report progress on the design and cold test of a metal Ku-band PBG accelerator structure. The 17.140 GHz 6-cell PBG accelerator structure with reduced long-range wakefields was designed for the experiment. The copper structure was electroformed and cold-tested. Tuning was performed through chemical etching of the rods. Final cold test measurements were found to be in very good agreement with the design. The structure will be installed on the beam line at the accelerator laboratory at Massachusetts Institute of Technology and will be powered with 3 MW of peak power from the Haimson 17.14 GHz klystron. Results of the design, fabrication, cold test and hot test on the Haimson accelerator will be presented.

The research is supported by DOE High Energy Physics, Contract No. DE-FG02-91ER40648.

**17:05 TOPA010—Photonic Crystal Laser-Driven Accelerator Structures**
*Benjamin Cowan (SLAC)*
We discuss simulated photonic crystal structure designs, including two- and three-dimensional planar structures and fibers. The discussion of 2D structures demonstrates guiding of a speed-of-light accelerating mode by a defect in a photonic crystal lattice and reveals design considerations and trade-offs. With a three-dimensional lattice, we introduce a candidate geometry and discuss beam dynamics, coupling, and manufacturing techniques for that structure. In addition we discuss W-band scale tests of photonic crystal structures. The computational methods are also discussed.

Work supported by Department of Energy contract DE-AC03-76SF00515 (SLAC).

**17:20 TOPA011—Self-Consistent Scheme for Obtaining Electron-Positron Collisions with Multi-TeV Energy**
*Alexander A. Mikhailichenko (Cornell Univ.)*
We describe here a self-consistent scheme for arrangement of multi-TeV collisions of electrons and positrons by using laser burst swept along microstructures with stable rate of acceleration ~10GeV/m. Shown that all component of the scheme are within present day technology. For energy ~1TeV luminosity could reach 10^35 /cm^2/s with wall-plug power of few tens of kW only.

## Oral Session TOPD – Development in the South, East, and Mid-East/Nuclear Physics High-Energy Physics
## Ballroom B @ 15:30, Chair: P. Schmor (TRIUMF)

**15:30 TOPD001—SC Cyclotron and RIB Facilities in Kolkata**
*Bikash Sinha, Rakesh Kumar Bhandari (DAE/VECC)*
The superconducting cyclotron under construction at this Centre has bending limit (K-bend) of 520 and focusing limit (K-foc) of 160. It is being constructed, primarily, for nuclear physics experiments with heavy ion beams at intermediate energies. The 100-ton main magnet is currently in the commissioning phase with the main coil already at 4.2K temperature. Magnetic field measurements will be carried out over the next several months. All other systems of the cyclotron are in an advanced stage of fabrication or development. We plan to start assembly of the complete cyclotron around the end of 2005. In the phase-I of the project one beam line has been provided. Construction of three more beam lines and various experimental facilities for nuclear physics as well as irradiation experiments has also been funded and the work is well on its way. An ISOL type Radioactive Ion Beam (RIB) facility is being built with the existing K=130 room temperature cyclotron, VEC, as the primary beam source. In-beam RIB production as well as release measurements have been initiated using the VEC beam. The two-ion-source charge breeder consists of a surface ion source and a 6.4 GHz ECR source. The latter has been commissioned. A low beta RFQ to accelerate RIBs to 86 keV/u energy is being fabricated and the cold model tests completed. Design of first three linac tanks, for acceleration up to 400 keV/u, has been finalized and cold model for the first tank has been fabricated. In this talk status of both the projects will be presented.

**15:55 TOPD002—The Second Phase Construction of the Beijing Electron-Positron Collider**
*Chuang Zhang, Guoxi Pei (IHEP Beijing)*
The Beijing Electron-Positron Collider (BEPC) was constructed for both high energy physics and synchrotron radiation researches. The peak luminosity of the BEPC has reached its design goal of 5*10^30 cm^-2s^-1 at J/sai energy of 1.55 GeV and 1*10^31 cm^-2s^-1 at 2 GeV respectively. As the second phase construction of the BEPC, the BEPCII has been approved with total budget of 640 million RMB. The construction was started in the beginning of 2004 and is scheduled to be completed by the end of 2007. The BEPCII is a double ring machine with its luminosity goal of 1*10^33 cm^-2s^-1 at 1.89 GeV, two orders of magnitude higher than present BEPC. The upgrading of the collider should also provide an improved SR performance with higher beam energy and intensity. The beam currents will be increased to 250 mA at E=2.5 GeV for the dedicated synchrotron radiation operation of the BEPCII. Some key technologies, such as superconducting RF system, low impedance vacuum devices, superconducting micro-beta quadrupoles and etc., are being developed in order to achieve the target of the BEPCII.*
*Submitted on behalf of the BEPCII Team.

**16:20 TOPD003—Cooler Storage Ring at China Institute of Modern Physics**
*Jia Wen Xia (IMP)*
CSR, a new ion cooler-storage-ring project in China IMP, is a double ring system, and consists of a main ring (CSRm) and an experimental ring (CSRe). The two existing cyclotrons SFC (K=69) and SSC (K=450) of the Heavy Ion Research Facility in Lanzhou (HIRFL) will be used as its injector system. The heavy ion beams with the energy range of 7—30 MeV/nucleus from the HIRFL will be accumulated, cooled and accelerated to the higher energy range of 100—500 MeV/ nucleus in CSRm, and then extracted fast to produce radioactive ion beams or highly charged heavy ions. Those secondary beams will be accepted and stored or decelerated by CSRe for many internal-target experiments or high precision spectroscopy with beam cooling. On the other hand, the beams with the energy range of 100—1000MeV/ nucleus will also be extracted from CSRm by using slow extraction or fast extraction for many external-target experiments. CSR project was started in the end of 1999 and will be finished in 2006. In this paper the outline and the activities of the project will be described.

**16:45 TOPD004—RIB Facility at VECC Kolkata–A Status Report**
*Alok Chakrabarti (DAE/VECC)*
The status of the Radioactive Ion Beam (RIB) facility being built at VECC, Kolkata will be presented. The facility is being built around the existing K=130 cyclotron and will be installed in one of the existing experimental caves. The scheme is to use proton and alpha particles from the cyclotron on a thick production target placed inside an integrated surface ion-source. Radioactive ions with charge state q=1+ extracted from the target-ion-source are to be injected into an on-line ECRIS "charge breeder" for further ionization to q=n+. The 1keV/u, q/A=1/16, RIB of interest will be selected in an isotope separator downstream of the ECRIS and accelerated initially to about 86 keV/u in a Radio Frequency Quadrupole (RFQ) linac and subsequently to about 400 keV/u in three IH-Linac tanks. Since RIB development is R&D intensive, it has been decided to build at first all the basic building blocks and to carry out simultaneously thick target R&D and release measurements using the existing He-jet ISOL facility. Future expansion for further upgradation of energy has been planned. The design of the facility and some recent results will be presented.

**Oral Session TOPE–Linear Colliders**
**Ballroom C @ 15:30**
**Chair: M. Tigner (Cornell Univ.)**

**15:30 TOPE001—Experience with the TTF-2**
*Lutz Lilje (DESY)*
The TESLA Test Facility in its second phase (TTF-2) serves two main purposes: It is a testbed for the superconducting RF technology for the International Linear Collider as well as a user facility providing a VUV-FEL beam for experiments using synchrotron light. The presentation will review the progress on the superconducting RF technology. This includes tests on individual cavities as well as full accelerating modules. First experiences with the setup of TTF-2 will be presented. Among others, the measurements of higher order modes in the superconducting cavities are presented. Measurements of the beam properties will be shown.

**15:55 TOPE002—Advances in Normal Conducting Accelerator Technology from the X-Band Linear Collider Program**
*Chris Adolphsen (SLAC)*
In the early 1990's, groups at SLAC and KEK began dedicated development of X-band (11.4 GHz) rf technology for a next generation, TeV-scale linear collider. The choice of a relatively high frequency, four times that of the SLAC 50 GeV Linac, was motivated by the cost benefits of having lower rf energy per pulse (hence fewer rf components) and reasonable efficiencies at high gradients (hence shorter linacs). However, to realize such savings requires operation at gradients and peak powers much higher than that hitherto achieved. During the past 15 years, these challenges were met through innovations on several fronts, and resulted in a viable rf system design for a linear collider. This paper reviews these achievements, which include developments in the generation and transport of high power rf, and new insights into high gradient limitations.

**16:20 TOPE003—Results from DR and Instrumentation Test Facilities**
*Junji Urakawa (KEK)*
The KEK Accelerator Test Facility (ATF) is a 1.3GeV storage ring capable of producing ultra-low emittance electron beams and has a beam extraction line for ILC R&D. The ATF has proven to be an ideal place for researches with small, stable beams. 2x1010 single bunch and low current 20 bunch-train with 2.8nsec bunch spacing have been extracted to develop Nano-Cavity BPM's, FONT, Nano Beam Orbit handling (FEATHER), Optical Diffraction Radiation (ODR) monitor, a precision multi-bunch laser-based beam profile monitor and polarized positron beam generation via backward-Compton scattering by the international collaboration. A set of three cavity BPM's is installed in the ATF extraction line on a set of extremely stiff supports. The KEK group installed another set of three BPM's, with their own support mechanism. The full set of 6 will prove extremely useful. In the DR (Damping Ring), we are researching the fast ion instability, micro-wave instability with four sets of damping wiggler and developing pulsed laser wire monitor, X-ray SR monitor, very fast kicker with about 1nsec rise/fall time to make ILC beam. I will report the recent results on above R&D's.

**16:45 TOPE004—CLIC Progress Towards Multi-TeV Linear Colliders**
*Jean-Pierre Delahaye, Hans-Heinrich Braun (CERN)*
Novel parameters of an e+/e- Linear Collider based on CLIC technology with a broad colliding energy range from 0.5 to 5 TeV are presented for an optimised luminosity of 8x1034 cm-2s-1 at the nominal energy of 3 TeV. They are derived in part from the very successful tests and experience accumulated in the CLIC Test facility, CTF2. A new and ambitious test facility, CTF3, presently under construction at CERN within an international collaboration of laboratories and institutes, and aimed at demonstrating the key feasibility issues of the CLIC scheme, is described.

**Poster Session TPPE–Sources and Injectors**
**Ballroom E, 13:50-17:10**

**TPPE001—The HERA RF-Volume Source**
*Jens Peters (DESY)*
The HERA RF-Volume Source is the only source that delivers routinely a H – current of 40 mA without Cs. It has been running for years without interruption for maintenance. The production mechanism for H – ions in this type of source is still under discussion. Laser photodetachment measurements have been done at DESY in order to measure the H – distribution in the source. The measurements were done also under extraction conditions at high voltage. The dependency of the quality of the Hminus beam on the frequency was investigated. A frequency range of 1.65 – 9 Mhz was scanned and the emittance was measured for several Hminus currents up to 40 mA. The results of our investigations make further source improvements possible. Recently currents of 60 mA were reached.

The support of EEC (Contract HPRI-CT-2001-50021) is gratefully acknowledged.

**TPPE002—Development of an Ion Source Via Laser Ablation Plasma**
*Fabio Belloni, Domenico Doria, Antonella Lorusso, Vincenzo Nassisi (INFN-Lecce)*
Experimental results on the development of a laser ion source (LIS) are reported. LISs can be particularly useful in ion accelerators, ion implanters and devices for electromagnetic isotope separation. A focused UV laser beam (0.1 – 1 GW/cm^2 power density) was used to produce a plasma plume from a Cu target. Several aspects have been investigated: ion angular distribution, energy distribution, ion extraction and charge loss due to ion recombination. Particular attention was devoted to avoid arcs during the extraction phase; it was accomplished by allowing the proper plasma expansion in a suitable chamber before the extraction gap. Diagnostics on free expanding plasma and extracted ions was carried out mainly by time-of-flight measurements, performed by means of Faraday cups and electrostatic spectrometers. At 18 kV acceleration voltage, the ion beam current, measured along a drift tube at 147 cm from the target, resulted modulated on ion mass-to-charge ratio and its maximum value was 220 uA. The Cu+1 ion bunch charge was estimated to be 4.2 nC. Ion implantation tests have been successfully performed at 40 kV acceleration voltage, by using a simple experimental arrangement.

Work supported by INFN and Department of Physics, Lecce - I.

**TPPE003—Analysis of Multigrid Extraction Plasma Meniscus Formation**
*Marco Cavenago (INFN/LNL), Vanni Antoni, Fabio Sattin (CNR/RFX, Arturo Tanga (MPI/IPP)*
Effects of plasma meniscus on the emittance in negative ion source proposed for spallation sources or neutral beam injectors (NBI) for tokamaks are particularly interesting to study with fluid models because: 1) at least three different charged fluid can be recognised: the thermalized and fully magnetized electrons; the slightly magnetized and roughly thermalized positive ions; the negative ions, typically formed within few cm from meniscus; 2) different implementation of the magnetic filter system need to be compared; 3) optimization of electron dump and outlet electrode strongly depends on plasma meniscus contact point. With reasonable assumption on system geometry, 2D and 3D charged fluid quation for the selfconsistent electrostatic field can be written and effect of grid aperture is investigated. Moreover, these equations are easily implemented into a multiphysics general purpose program. Preliminary results are described, and compared to existing codes.

INFN-LNL, CNR-RFX.

**TPPE004—Charge Exchange Efficiency Measurements for 6Li+ /7Li+ Beams Using a Cs Vapour Cell**
*Maurizio Re, Francesco Chines, Giacomo Cuttone, Mariano Menna, Esteban Messina (INFN/LNS), Jean-Christophe Bilheux, Dan Stracener (ORNL)*
These measurements were carried out at the Oak Ridge National Laboratory in collaboration between research groups from LNS (EXCYT facility) and ORNL (Holifield Radioactive Ion Beam Facility) in August 2004. The Cesium Charge Exchange Cell (CEC) consists of a vacuum chamber containing Cs vapours at a variable temperature, T, in which positive ions, accelerated from an ion source, are transformed into negative ions via collisions with the Cs atoms. The goal of this test was to measure the efficiency for producing 7Li(-) ions at different operating conditions, such as Li beam energy (5 keV to 55 keV) and Cs temperature (190°C to 300°C). Moreover, the efficiency measurements performed with a 6Li beam give indications about the isotopic shift effects, as foreseen by Massey's adiabatic criterion. These results are useful to estimate the charge exchange efficiency related to 8Li and 9Li beams which are the first radioactive beams to be produced at the EXCYT facility. The measurements show that the charge exchange efficiency at the EXCYT extraction energy of 20-25 keV is around 1%.

**TPPE005—50keV, 50mA Pulsed Proton Injector for PEFP**
*In-Seok Hong, Yong-Sub Cho, Sang-Hyo Han (KAERI)*
Duoplasmatron type ion source with 50keV proton beam has been constructed and stably operated as the injector for Proton Engineering Frontier Project(PEFP). In DC operation, the beam current of 50mA with 50kV extraction voltage is routinely obtained. However, the pulsed operation mode of the ion source also has been considered to reduce beam induced damage at the entrance of RFQ. A high voltage pulse switch is connected between accelerating electrode and ground electrode for this purpose. The detailed scheme on the focusing of the pulsed proton beam with space charge compensation is in progress. Beam profile and current in front of RFQ will be measured by DCCT and optical measuring tools.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**TPPE006—Radioactive Beams from 252CF Fission Using a Gas Catcher and an ECR Charge Breeder at ATLAS**
*Richard Claude Pardo, Samuel I. Baker, Adam Hecht, Eugene Frank Moore, Guy Savard (ANL)*
An upgrade to the radioactive beam capability of the ATLAS facility has been proposed using 252Cf fission fragments thermalized and collected into a low-energy particle beam using a helium gas catcher. In order to reaccelerate these beams an existing ATLAS ECR ion source will be reconfigured as a charge breeder source. A 1Ci 252Cf source is expected to provide sufficient yield to deliver beams of up to ~106 far from stability ions per second on target. A facility description, the expected performance and the expected performance will be presented in this paper. This work is supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract W-31-109-ENG-38.

Department of Energy Office of Nuclear Science.

**TPPE007—Energy Correction for High Power Proton/H Minus Linac Injectors**
*Deepak Raparia, Yong Yung Lee, Jie Wei (BNL)*
High-energy proton/H minus (> GeV) linear accelerators suffer from energy jitter due to RF amplitude and phase stability. For high-power operations, such energy jitter often results in beam losses at more than 1 W/m level required for hands-on maintenance. Depending upon the requirements for next accelerator in the chain, this energy jitter may or may not require correction. This paper discusses the sources of energy jitter and correction feasibility with specific examples of the Spallation Neutron Source linac and a higher-energy H minus linac.

**TPPE009—Considerations for High Current Density Ion Injectors for HEDP**
*Joe W. Kwan (LBNL), Glen Westenskow (LLNL)*
For our planned high energy density physics (HEDP) experiments using 20 MeV Ne+ ions, the required beam charge is about 1 micro-Coulomb. Lighter ions would take lower beam energy and more beam charge. For the desired pulse length on target of a few nanoseconds, and with a reasonable time compression factor, the pulse length at the ion source should not be more than a few 100 ns. Thus the beam current at the injector will be on the order of 10 A. To focus the beam onto a small spot requires low transverse emittance, therefore the ion source must be simultaneously both very high current and very high current density. This is typically a difficult beam transport problem at low beam energy. Drawing from our experience in developing injectors for heavy ion fusion (HIF), we will examine the various possible options that can be employed to design injector systems for HEDP drivers and identify our favorite approach.

This work is supported by the Office of Fusion Energy Science, U.S. DOE under contract No. DE-AC03-76SF00098 (LBNL) and W-7405-ENG-48 (LLNL).

**TPPE010—A Parallel 3D Model for the Multi-Species Low Energy Beam Transport System of the RIA Prototype ECR Ion Source VENUS**
*Ji Qiang, Daniela Leitner, Damon Todd (LBNL)*
The driver linac of the proposed Rare Isotope Accelerator (RIA) requires a great variety of high intensity, high charge state ion beams. In order to design and optimize the low energy beam line optics of the RIA front end, we have developed a new parallel three-dimensional model to simulate the low energy, multi-species beam transport from the ECR ion source extraction region to the focal plane of the analyzing magnet. A multi-section overlapped computational domain has been used to break the original transport system into a number of independent subsystems. Within each subsystem, macro-particle tracking is used to obtain the charge density distribution in this subdomain. The three-dimensional Poisson equation is solved within the subdomain and particle tracking is repeated until the solution converges. Two new Poisson solvers based on a combination of the spectral method and the multigrid method have been developed to solve the Poisson equation in cylindrical coordinates for the beam extraction region and in the Frenet-Serret coordinates for the bending magnet region. Some test examples and initial applications will also be presented.

This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Nuclear Physics Division of the U.S. DOE under Contract DE AC03-76SF00098.

**TPPE011—A Compact High-Brightness Heavy-Ion Injector**
*Glen Westenskow, David Grote, Erni Halaxa (LLNL), Frank Bieniosek, Joe W. Kwan (LBNL)*
To provide compact high-brightness heavy-ion beams for Heavy Ion Fusion (HIF) accelerators, we have been experimenting with merging multi-beamlets in an injector which uses an RF plasma source. In an 80-kV 20-microsecond experiment, the RF plasma source has produced up to 5 mA of Ar+ in a single beamlet. An extraction current density of 100 mA/cm2 was achieved, and the thermal temperature of the ions was below 1 eV. More than 90% of the ions were in the Ar+ state, and the energy spread from charge exchange was found to be small. We have tested at full voltage gradient the first 4 gaps of a 61-beamlet injector design. Einzel lens were used to focus the beamlets while reducing the beamlet to beamlet space charge interaction. We will report on a converging 119 multi-beamlet source. Although the source has the same optics as a full 1.6 MV injector system, the test will be carried out at 400 kV due to the test stand HV limit. We will measure the beam's emittance after the beamlets are merged and have been transported through an electrostatic quadrupole. Our goal is to confirm the emittance growth and to demonstrate the technical feasibility of building a driver-scale HIF injector.

This work has been performed under the auspices of the U.S. DOE by UC-LBNL under contract DE-AC03-76SF00098 and by UC-LLNL under contract W-7405-ENG-48, for the Heavy Ion Fusion Virtual National Laboratory.

**TPPE012—Using the Orbit Tracking Code Z3CYCLONE To Predict the Beam Produced by a Cold Cathode PIG Ion Source for Cyclotrons Under DC Extraction**
*Edward Forringer (NSCL)*
Experimental measurements of the emittance and luminosity of beams produced by a cold-cathode Phillips Ionization Guage (PIG) ion source for cyclotrons under dc extraction are reviewed. (The source being studied is of the same style as ones that will be used in a series of 250 MeV proton cyclotrons being constructed for cancer therapy by ACCEL Inst, Gmbh, of Bergisch Gladbach, Germany.) The concepts of 'plasma boundary' and 'plasma temperature' are presented as a useful set of parameters for describing the initial conditions used in computational orbit tracking. Experimental results for r-pr and z-pz emittance are compared to predictions from the MSU orbit tracking code Z3CYCLONE with results indicating that the code is able to predict the beam produced by these ion sources with adequate accuracy such that construction of actual cyclotrons can proceed with reasonably prudent confidence that the cyclotron will perform as predicted.

**TPPE013—Simulations of Solenoid and Electrostatic Quadrupole Focusing of High Intensity Beams from an ECR Ion Source at NSCL**
*Qiang Zhao, Anatoly Balabin, Felix Marti, Jeffry W. Stetson, Xiaoyu Wu (NSCL)*
Solenoidal focusing has been widely used to focus beams at various injectors for its axisymmetric focusing with reasonable effectiveness. Experiments and simulations have shown that space charge effects can significantly deteriorate the beam quality when solenoidal focusing is used in a multi-component beam. This is due to the magnetic focusing strength dependence on the beam charge-to-mass ratio. Electrostatic quadrupole focusing has been explored as an alternate option at NSCL for the injection line of the superconducting cyclotron. We present in this paper the results of simulations for both systems. The electrostatic quadrupoles have been optimized to reduce the radial dependent aberrations and to increase the transmission efficiency.

**TPPE014—Extraction of Space-Charge-Dominated Ion Beams from the 6 GHz Flat-Field ECR Ion Source: Simulations and Experiments**
*Hassina Zaim Bilheux, Gerald Alton, Yoko Kawai, Yuan Liu (ORNL)*
Extraction of space-charge-dominated ion beams from plasma sources requires finding an optimal plasma emission surface or meniscus that acts to first converge, then diverge the beam. The position and shape of the meniscus depend on the extraction voltage, extraction gap, plasma density and shape of the extraction electrodes. A preferred method to effect changes in the extraction field is to mount the extraction electrode on a remotely movable carriage so that the extraction gap can be varied at fixed extraction voltage. This enables control of the meniscus over a wide range of plasma densities and charge compositions without changing the beam energy. A movable extraction electrode system has been designed for the 6 GHz flat-field ECR ion source at the HRIBF of ORNL. In this presentation, the experimentally observed optimized extraction gap and measured beam emittances for the 6 GHz ECR ion source will be compared with the corresponding values derived from simulation studies.

Research at ORNL is supported by the U.S. DOE under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

**TPPE015—The Effusive Flow Properties of Target/Vapor-Transport Systems for Radioactive Ion Beam Applications**
*Yoko Kawai, Gerald Alton, Yuan Liu (ORNL)*
Radioactive atoms produced by the ISOL technique must diffuse from a target, effusively flow to an ion source, be ionized, be extracted, and be accelerated to research energies in a time commensurate with the lifetime of the species of interest. We have developed a fast valve system (closing time ~100 us) that can be used to accurately measure the effusion times of chemically active or inactive species through arbitrary geometry and size vapor transport systems with and without target material in the reservoir. The effusive flow times are characteristic of the system and thus serve as figures of merit for assessing the quality of a given vapor transport system as well as for assessing the permeability properties of a given target design. This article presents effusive flow data for noble gases flowing through a target reservoir and ion source system routinely used to generate radioactive species at the HRIBF with and without disks of 6 times and 10 times compressed Reticulated Vitreous Carbon Foam (RVCF) with the objective of determining the added delay time associated with each of these target matrices.

Research at ORNL is supported by the U.S. DOE under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

**TPPE016—ISOL Targets Prepared with a New Infiltration Paint Coating Method**
*Yoko Kawai, Gerald Alton, Jean-Christophe Bilheux, Ralph Barton Dinwiddie, J. O. Kiggans, W. D. Porter, Dan Stracener (ORNL)*
A new infiltration paint coating method has been developed for fabricating ISOL targets for radioactive ion beam applications. The technique has been shown to be inexpensive, fast, and almost universal for the uniform deposition of many refractory target materials onto the interior surfaces of complex geometry matrices, such as Reticulated-Vitreous-Carbon-Foam (RVCF). The process yields robust, highly permeable targets with fast diffusion and release properties. We demonstrate the viability of the technique for coating forms of RVCF compressed by factors of 6 and 10 with materials to form targets for use at high energy facilities such as RIA. The use of compressed RVCF, coated with an optimum thickness of target material, reduces target lengths to practical values, while preserving high permeability. We calculate thermal conductivities and diffusion for various targets on 6xRVCF and 10xRVCF.

Research at ORNL is supported by the U.S. DOE under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

**TPPE017—A New Method for Enhancing the Performance of Conventional B-Field Configuration ECR Ion Sources**
*Yoko Kawai, Gerald Alton, Hassina Zaim Bilheux, Yuan Liu (ORNLe)*
The multiple discrete frequency technique has been used to improve the performance of conventional B-field configuration ECR ion sources. However, the practical application of this technique is very costly, requiring multiple independent single-frequency rf power supplies and complicated rf injection systems. Broadband sources of rf power offer a low-cost and more effective method for increasing the physical size of the ECR zone within these ion sources. An Additive White Gaussian Noise Generator (AWGNG) system for injecting broadband rf power into these ion sources has been developed in conjunction with a commercial firm. The noise generator, in combination with an external oscillator and a traveling wave tube amplifier, can be used to generate broadband rf power without modifying the injection system. The AWGNG and its use for enhancing the performance of conventional B-field configuration ECR ion sources will be described.

Research at ORNL is supported by the U.S. DOE under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

**TPPE018—Characterization of Hot-Cavity Surface Ionization Sources**
*Yuan Liu, Hassina Zaim Bilheux, Yoko Kawai (ORNL)*
Elements with low ionization potentials can be efficiently ionized by positive surface ionization. It has been experimentally observed and theoretically shown that the ionization efficiency in a hot-cavity can be significantly higher than expected for the surface ionization mechanism. This is explained by the existence of a thermal plasma inside the cavity consisting of surface ionized ions and thermionic electrons in a quasi-neutral state and in thermal equilibrium with the cavity wall. We have investigated the suggested ionization mechanisms in tubular hot-cavity surface ionization sources where the area of the exit aperture is small compared with the tube inner surface. Thermal analyses of the tubular cavity and calculated mean number of wall collisions of a neutral particle in the cavity before escaping through the exit aperture are presented. Measured emittance and ionization efficiencies of various elements as a function of the cavity temperature for different cavity materials are discussed.

Managed by UT-Battelle, LLC, for the U.S. DOE under contract DE-AC05-00OR22725.

**TPPE019—Laser Ion Source Development for ISOL Systems at RIA**
*Yuan Liu, Cyrus Baktash, James R. Beene, Hassina Zaim Bilheux, Charles Havener, Herbert F. Krause, David Robert Schultz, Dan Stracener, C. Randy Vane (ORNL), Kim Brueck, Christopher Geppert, Thomas Kessler, Klaus Wendt (Johannes Gutenberg University Mainz)*
The isobaric purity of radioactive ion beams (RIBs) is of crucial importance to many experiments. Laser ion sources based on resonant photoionization have already proved to be of great value at existing ISOL RIB facilities. In these ion sources, ions of a selected isotope are produced by laser radiation via stepwise

atomic resonant excitations followed by ionization in the last transition. Because each element has its own unique atomic energy levels, the resonant photoionization process can provide elemental selectivity of nearly 100%. We have initiated a research effort to develop a prototype laser ion source with the potential to achieve the high selectivity and high efficiency required for research with ISOL-generated RIBs at the Rare Isotope Accelerator (RIA). A pilot experiment has been conducted to demonstrate resonant photoionization of three atomic species using all-solid-state tunable Ti:Sapphire lasers. Three Ti:Sapphire lasers were provided by the University of Mainz and used in the experiment for three-photon resonant ionization of the elements. Laser generated Sn, Ni, and Ge ions have been successfully obtained in a hot-cavity laser ion source with overall efficiencies of 22%, 2.7%, and 3.3%, respectively.

Managed by UT-Battelle, LLC, for the U.S. DOE under contract DE-AC05-00OR22725.

**TPPE020—Radioactive Ion Beam Development at the Holifield Radioactive Ion Beam Facility**

*Dan Stracener, Gerald Alton, James R. Beene, Hassina Zaim Bilheux, Jean-Christophe Bilheux, Jeff C. Blackmon, Darryl Dowling, Raymond Juras, Yoko Kawai, Yuan Liu, Martha Meigs, Paul Mueller, A. Tatum (ORNL), Ken Carter, Andreas Kronenberg, Eugene Henry Spejewski (Center of Excellence for RIB Studies for Stewardship Science)*

Radioactive beams are produced at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory using the Isotope Separator On-Line (ISOL) technique. Radioactive nuclei are produced in a thick target via irradiation with energetic light ions (protons, deuterons, helium isotopes) and then post-accelerated to a few MeV/nucleon for use in nuclear physics experiments. An overview of radioactive beam development at the HRIBF will be presented, including ion source development, improvements in the ISOL production targets, and a description of techniques to improve the quality (intensity and purity) of the beams. Facilities for radioactive ion beam development include two ion source test facilities, a target/ion source preparation and quality assurance facility, and an in-beam test facility where low intensity production beams are used. A new test facility, the High Power Target Laboratory, will be available later this year. At this facility, high intensity production beams will be available to measure the power-handling capabilities of ISOL production targets. This information will be used to optimize target materials and geometries for high power densities.

Managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725.

**TPPE021—Simulation Studies of Diffusion-Release and Effusive-Flow of Short-Lived Radioactive Isotopes**

*Yan Zhang, Gerald Alton (ORNL)*

Delay times associated with diffusion release from targets and effusive-flow transport of radioactive isotopes to ion sources are principal intensity limiters at ISOL-based radioactive ion beam facilities, and simulation studies with computer models are cost effective methods for designing targets and vapor transport systems with minimum delay times to avoid excessive decay losses of short lived ion species. A finite difference code, Diffuse II, was recently developed at the Oak Ridge National Laboratory to study diffusion-release of short-lived species from three principal target geometries. Simulation results are in close agreement with analytical solutions to Fick's second equation. Complementary to the development of Diffuse II, the Monte-Carlo code, Effusion, was developed to address issues related to the design of fast vapor transport systems. Results, derived by using Effusion, are also found to closely agree with experimental measurements. In this presentation, the codes will be used in concert to make realistic estimations of intensities of a number of short-lived isotopes that are candidates for use in future nuclear physics and nuclear astrophysics experiments at the HRIBF.

Research supported by the U.S. DOE under contract DE-AC05-00OR22725 with UT-Battelle, LLC.

**TPPE022—First Results on the Path Towards a Microwave-Assisted H- Ion Source**

*Roderich Keller (LBNL/AFR), Peter A. Luft, Marco T. Monroy, Alessandro Ratti, Mark J. Regis, Donald L. Syversrud, Joseph G. Wallig (LBNL), David E. Anderson, Robert Welton (ORNL/SNS)*

A novel concept for creating intense beams of negative hydrogen ion beams is presented. In this approach, an ECR ion source operating at 2.45 GHz frequency is utilized as a primary plasma generator and coupled to an SNS-type multi-cusp H- ion source. The secondary source is driven by chopped dc power avoiding the use of filaments or of an internal rf antenna. The development of the new ion source is aimed at the future beam-power goal of 3 MW for the Spallation Neutron Source (SNS) that will be pursued after the start of SNS operations, but application to other proton driver accelerators that include an accumulator ring is feasible as well. The first two phases of this development effort have been successfully completed: assembly of a test stand and verification of the performance of an rf-driven SNS ion-source prototype; and extraction of electrons with more than 350 mA current from a 2.45-GHz ECR ion source obtained on loan from Argonne National Laboratory. The next goal is the demonstration of actual H- ion production by this novel, hybrid ion source. This paper describes the source principle and design in detail and reports on the current status of the development work.

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**TPPE023—Development and Performance of a Proton and Deuteron ECR Ion Source**

*Kai Dunkel, Florian Kremer, Christian Piel (ACCEL)*

A 5mA proton and deuteron rf source is under development at ACCEL. This source will provide the front end of our superconducting proton/deuteron linear accelerator. The design of the source is based on the proven AECL design of a 100 mA proton source. The paper will describe the design of the source and the layout of the test bench currently set up at ACCEL to characterize the source. Results of the beam dynamic simulations performed to optimize the source geometry based on KOBRA 3D will be presented and compared with first measurement results.

**TPPE024—Manufacturing and Testing of 2.45 GHz and 4.90 GHz Biperiodic Accelerating Structures for MAMI C**

*Kai Dunkel, Christian Piel, Hanspeter Vogel, Peter vom Stein (ACCEL), Hans Euteneuer, Andreas Jankowiak (IKP)*

At the Institut für Kernphysik (IKPH) of Mainz University the fourth stage of the Mainz Microtron (MAMI), a 855 MeV to 1500 MeV Harmonic Double Sided Microtron,* is under construction. For this project ACCEL Instruments GmbH manufactures biperiodic, on axis coupled, standing wave accelerating structures at frequencies of 2.45 GHz and 4.90 GHz. Prototypes of both types as well as first series structures were manufactured, low power characterized and after delivery tested at the high power test stand of IKPH. This paper describes the production and characterization of these structures, presents

results of the high power tests, and will compare this with data gained by IKPH with own built prototypes for the present upgrade project and structures built in the 1980´s.
A. Jankowiak et al., "Design and Status of the 1.5 GeV-Harmonic Double Sided Microtron for MAMI," Proceedings EPAC2002, Paris, p. 1085.

**TPPE025—Separating the Penning and Analysing Fields in the ISIS H- Ion Source**
*Dan Faircloth, Reg Sidlow, Mark Whitehead, Trevor Wood (CCLRC/RAL/ISIS)*
The development of H- ion sources with performances exceeding those achieved today is a key requirement for the next generation of high power proton accelerators. The Penning surface plasma source development program at ISIS is now well established. To allow different ion source designs to be fully tested, the ability to vary the Penning field is required. Until now the Penning field has been generated by the same magnetic circuit that creates the analyzing field, giving no practical way of altering the Penning field alone. This paper describes the infrastructure changes required to allow the Penning field to be independently varied. The effect the Penning field has on beam current, emittance and discharge stability are discussed.

This work was supported by the European Union High Performance Negative Ion Source (HP-NIS) network, contract number HPRI-CT-2001-50021.

**TPPE026—Commissioning and First Measurement Results at the LEG 100 keV Test Stand**
*Simon Christian Leemann, Romain Ganter, Volker Schlott, Andreas Streun, Detlef Vermeulen, Albin Wrulich (PSI)*
In the scope of the Low Emittance Gun Project (LEG) at PSI a field emitter array (FEA) cathode is being considered as an electron source. In order to study the emission of electrons from such a cathode and to study space charge compensation techniques as well as to develop diagnostic procedures to characterize the beam resulting from an FEA cathode it has been decided to build a 100 keV gun test stand. The test stand gun and diagnostics have been modeled with the codes MAFIA and GPT. From extensive parameter studies a design has been derived and construction of the gun and diagnostics has just recently been completed. We present first measurement results acquired during the commissioning of the test stand and report on the initial operation experience.

**TPPE027—Properties of Laser-Produced Highly Charged Heavy Ions for Direct Injection Scheme**
*Kazuhiko Sakakibara, Toshiyuki Hattori, Noriyosu Hayashizaki, Taku Ito (RLNR), Hirotsugu Kashiwagi (JAERI/ARTC), Masahiro Okamura (RIKEN)*
To accelerate highly charged intense ion beam, we have developed the Direct Plasma Injection Scheme (DPIS) with laser ion source. In this scheme an ion beam from a laser ion source is injected directly to a RFQ linac without a low energy beam transport (LEBT) and the beam loss in the LEBT can be avoided. We achieved high current acceleration of carbon ions (60mA) by DPIS with the high current optimized RFQ. As the next setp we will use heavier elements like Ag, Pb, Al and Cu as target in LIS (using CO2, Nd-YAG or other laser) for DPIS and will examine properties of laser-produced plasma (the relationship of between charge state and laser power density, the current dependence of the distance from the target, etc).

**TPPE028—In-Situ Electron Cyclotron Resonance (ECR) Plasma Potential Determination Using an Emissive Probe**
*Fred Wolfgang Meyer, Yuan Liu (ORNL), Hyun Jong You (Hanyang University)*
In this paper, real-time, in-situ, plasma potential measurements are reported for an ECR ion source and correlated with extracted beam characteristics. The local real-time plasma potential of the ORNL CAPRICE ECR ion source was measured using an emissive probe, which was inserted perpendicularly from the plasma chamber wall at the mid-plane of the ECR zone between one of the six radial loss cones of the magnetic field structure, where perturbation of the main ECR plasma is expected to be small. Slots machined through the plasma- and puller-electrodes at the plasma chamber wall radius permitted insertion of the probe from the extraction side of the ECR source without perturbation of the coaxial microwave injection. The emissive probe technique permits plasma potential determination independent of plasma conditions and avoids problems related to probe geometry. The probe loop tip was pointed toward the chamber center in a radial plane and was located about 5 mm outside of the ECR zone. Details of the measurements, and a comparison with an external-beam-deceleration-based plasma potential determination will be presented.

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**TPPE029—Measurements of Selective Ion Containment on the RF Charge Breeder Device BRIC**
*Vincenzo Variale (INFN-Bari), Petr Alekseevich Bak, Gennady Ivanovich Kuznetsov, Boris Skarbo, Michael A. Tiunov (BINP SB RAS), Tarcisio Clauser, Antonio Rainò (Bari University; INFN-Bari)*
The "charge state breeder" BRIC (BReeding Ion Charge) is based on an EBIS source and it is designed to accept Radioactive Ion Beam (RIB) with charge +1, in a slow injection mode, to increase their charge state up to +n. BRIC has been developed at the INFN section of Bari (Italy) during these last 3 years with very limited funds. Now, it has been assembled at the LNL (Italy) where are in progress the first tests as stand alone source. The new feature of BRIC, with respect to the classical EBIS, is given by the insertion, in the ion drift chamber, of a Radio Frequency (RF) Quadrupole aiming to filtering the unwanted elements and then making a more efficient containment of the wanted ions. In this contribution, the measurements of the selective effect on the ion charge state containement of the RF quadrupole field, applied on the ion chamber, will be reported and discussed. The ion charge state analisys of the ions trapped in BRIC seem confirm, as foreseen by simulation results carried out previously, that the selective containment can be obtained. A modification of the collector part to improve the ion extraction of BRIC will be also presented and shortly discussed.

Istituto Nazionale Fisica Nucleare.

**TPPE030—A Method to Polarize Stored Antiprotons to a High Degree**
*Paolo Lenisa (INFN-Ferrara), Frank Rathmann (FZJ)*
The PAX collaboration proposes a method to produce intense beams of polarized antiprotons. Polarized antiprotons can be produced in a storage ring by spin-dependent interaction in a purely hydrogen gas target. The polarizing process is based on spin transfer from the polarized electrons of the target atoms to the orbiting antiprotons. After spin filtering for about two beam lifetimes at energies of about 50-100 MeV using a dedicated large acceptance ring, the antiproton polarization would reach

P=0.2-0.4. In the presentation, beside a description of the polarization technique and its potentiality, a description of the ideal characterstics of the antiproton polarizer will be given.

hep-ph/0411046

**TPPE031—60 mA Carbon Beam Acceleration with DPIS**
*Masahiro Okamura (RIKEN), Robert Jameson, Alwin Schempp (IAP), Hirotsugu Kashiwagi (JAERI/ARTC), Toshiyuki Hattori, Noriyosu Hayashizaki (RLNR)*
We have studied "direct plasma injection scheme (DPIS)" since 2000. This new scheme is for producing very intense heavy ions using a combination of an RFQ and a laser ion source. An induced laser plasma goes directly into the RFQ without an extraction electrode nor any focusing devices. Obtained maximum peak current of Carbon 4+ beam reached 60 mA with this extremely simple configuration. The details of the experimental result will be presented.

**TPPE032—Particle-in-Cell Simulations of the VENUS Ion Beam Transport System**
*Damon Todd, Daniela Leitner, Claude Lyneis, Ji Qiang (LBNL), David Grote (LLNL)*
The next-generation superconducting ECR ion source VENUS serves as the prototype injector ion source for the linac driver of the proposed Rare Isotope Accelerator (RIA). The high-intensity heavy ion beams required by the RIA driver linac present significant challenges for the design and simulation of an ECR extraction and low energy ion beam transport system. Extraction and beam formation take place in a strong (up to 3T) axial magnetic field, which leads to significantly different focusing properties for the different ion masses and charge states of the extracted beam. Typically, beam simulations must take into account the contributions of up to 30 different charge states and ion masses. Two three-dimensional, particle-in-cell codes developed for other purposes, IMPACT and WARP, have been adapted in order to model intense, multi-species DC beams. A discussion of the differences of these codes and the advantages of each in the simulation of the low energy beam transport system of an ECR ion source is given. Direct comparisons of results from these two codes as well as with experimental results from VENUS are presented.

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**TPPE033—Experimental Comparison of Electrostatic and Magnetic Solenoid Focusing of Low Energy Heavy Ion Beams at the NSCL/MSU**
*Jeffry W. Stetson, Guillaume Machicoane, Felix Marti, Mathias Steiner, Peter Andras Zavodszky (NSCL), Nikolay Kazarinov (JINR)*
Experience at the NSCL has shown that the first focusing element after the ECR ion source, before the beam is analyzed by a magnetic dipole, is critical to subsequent beam transport and matching into the cyclotron. Until 2004, both ion sources at the NSCL used a solenoid as this first focusing element. Observation of hollow beam formation led to further analysis and the decision to replace the solenoid with an electrostatic quadrupole triplet on a test basis. Substantial increases in net cyclotron output were achieved, leading us to adopt electrostatic quadrupole focusing as the permanent configuration. Motivations for this change and results of operating experience are discussed.

This work has been supported by National Science Foundation under grant PHY-0110253.

**TPPE034—Possible Scheme of the Analyzing Part of a Cyclotron Injection Beamline with Higher Energy**
*Nikolay Kazarinov (JINR), Peter Andras Zavodszky (NSCL)*
The ion beam produced with an ECR ion source (ECRIS) with an extraction voltage of 30 kV may be additionally accelerated using a negative voltage of -30 kV applied to the last electrode of the extraction system, connected to the beamline biased to the same -30 kV potential. In this way the kinetic energy of the beam is increased to 60 keV/q, decreasing to half the space charge effect on the beam emittance. Using a large gap analyzing magnet placed right after the ECRIS and no focusing element, the transmission is still close to 100%. The voltage on the beamline must be kept constant from the ECRIS till the image focal plane of the analyzing magnet where the full separation of the beam charge states is achieved. An insulator break separates the biased beamline from the downstream section, which is at zero potential. Passing through this section of the beamline, the ion beam is decelerated to 30 keV/q, the energy necessary for the injection in the cyclotron. In order to prevent the increase of the beam divergence, a focusing solenoid is installed behind the break point. This work will present the results of a simulation of the transport of an argon beam in the proposed beamline.

This work was supported in part by the National Science Foundation under grant PHY-0110253.

**TPPE035—Efficiency of the Fermilab Electron Cooler's Collector**
*Lionel Prost, Alexander V. Shemyakin (Fermilab)*
The newly installed high-energy Recycler Electron Cooling system (REC) at Fermilab will work at an electron energy of 4.34 MeV and a DC beam current of 0.5 A in an energy recovery scheme. For reliable operation of the system, the relative beam current loss must be maintained to levels < 3.e-5. Experiments have shown that the loss is determined by the performance of the electron beam collector, which must retain secondary electrons generated by the primary beam hitting its walls. As a part of the Electron cooling project, the efficiency of the collector for the REC was optimized, both with dedicated test bench experiments and on two versions of the cooler prototype. We find that to achieve the required relative current loss, an axially-symmetric collector must be immersed in a transverse magnetic field with certain strength and gradient prescriptions. Collector efficiencies in various magnetic field configurations, including without a transverse field on the collector, are presented and discussed

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**TPPE036—Progress of BEPCII Linac Upgrade**
*Guoxi Pei (IHEP Beijing)*
BEPCII-an upgrade project of the BEPC is a factory type of e+e- collider. It requires its injector linac to have a higher beam energy (1.89 GeV) for on-energy injection and a higher beam current (40 mA e+ beam) for a higher injection rate (=50 mA/min.). The low beam emittance (1.6ðmm-mrad for e+ beam, and 0.2ðmm-mrad for 300 mA e- beam) and low beam energy spread (±0.5%) are also required to meet the storage ring acceptance. Hence we need a new electron gun system, a new positron source, a much higher power and more stable RF system with its phasing loops, and a new beam tuning system with orbit correction. Up to date, all system design and fabrication work have been completed. And in five months from May 1st of 2004, the positron production system—from the electron gun to the positron source, has been installed into the tunnel. In this paper, we will introduce major upgrades of each system, and present the recent beam commissioning.

**TPPE037—Relative Contributions of Volume and Surface-Plasma Generation of Negative Ions in Gas Discharges**
*Vadim Dudnikov (BTG)*
The relative contribution of volume and surface-plasma generation of extracted Í- ions in gas discharge sources will be analyzed. At the present time, it is well known that surface-plasma generation of extracted Í- ion is dominate above volume processes in discharges with admixture of cesium or other catalysts with low ionization potential. We will attract attention to evidences, that surface-plasma generation can be enhanced in high density discharges without cesium after electrode activation by high temperature conditioning in discharge. A diffusion of impurity with a low ionization potential can be a reason of observed enhancement of H- emission. For the effective generation of Í- ion beams in discharge without cesium, it is necessary to optimize surface-plasma generation of extracted Í- ion. Such optimization allows considerable improvement of Í-/D- sources characteristics.

**TPPE038—Thermal Hydraulic Design of PWT Accelerating Structures**
*David Yu, A. Baxter, Ping Chen, Martin Lundquist, Yan Luo (DULY Research Inc.)*
Microwave power losses on the surfaces of accelerating structures will transform to heat which will deform the structures if it is not removed in time. Thermal hydraulic design of the disk and cooling rods of a Plane Wave Transformer (PWT) structure is presented. Experiments to measure the hydraulic (pressure vs flow rate) and cooling (heat removed vs flow rate) properties of the PWT disk are performed, and results compared with simulations using Mathcad models and the COSMOSM code. Both experimental and simulation results showed that the heat deposited on the structure could be removed effectively using specially designed water-cooling circuits and the temperature of the structure could be controlled within the range required.

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**TPPE039—Development of Advanced Models for 3D Photocathode PIC Simulations**
*Dimitre Dimitrov, David L. Bruhwiler, John R. Cary, Peter Messmer, Peter Stoltz (Tech-X), Donald Feldman, Patrick G. O'Shea (IREAP), Kevin Jensen (NRL)*
Codes for simulating photocathode electron guns invariably assume the emission of an idealized electron distribution from the cathode, regardless of the particular particle emission model that is implemented. The output of such simulations, a relatively clean and smooth distribution with very little variation as a function of the azimuthal angle, is inconsistent with the highly irregular and asymmetric electron bunches seen in experimental diagnostics. To address this problem, we have implemented a recently proposed theoretical model* that takes into account detailed solid-state physics of photocathode materials in the VORPAL particle-in-cell code.** Initial results from 3D simulations with this model and future research directions will be presented and discussed.
*K.L. Jensen, D.W. Feldman, M. Virgo, and P.G. O'Shea, Phys. Rev. ST Accel. Beams, 6:083501, 2003. **C. Nieter and J.R. Cary, J. Comp. Phys. 196 (2004), p. 448.

This work is supported by the U.S. DOE, use of NERSC supercomputer facilities, and the Joint Technology office (JTO).

**TPPE040—RF and Magnetic Measurements on the SPARC Photoinjector and Solenoid at UCLA**
*James Rosenzweig, Alan Cook, Michael P. Dunning, Pedro Frigola, Gil Travish (UCLA), Dennis Thomas Palmer (SLAC)*
The rf photocathode gun and the solenoid for the SPARC project at INFN-LNF (Frascati) have been fabricated and undergone initial testing at UCLA. The advanced aspects of the design of these devices are detailed. Final diagnosis of the tuning of the RF gun performance, including operating mode frequency and field balance, is described. The emittance compensating solenoid magnet, which is designed to be tuned in longitudinal position by differential excitation of the coils, has been measured using Hall probe scans for field profiling, and pulsed wire methods to determine the field center.

This work is supported by U.S. Dept. of Energy grant DE-FG03-92ER40693.

**TPPE041—Multi-Alkali Photocathode Development at Brookhaven National Lab**
*Andrew Burrill, Ilan Ben-Zvi, David Pate, Triveni Rao, Zvi Segalov (BNL), David Dowell (SLAC)*
In this paper we will report our progress on the development of cesium potassium antimonide photocathodes and their application in superconducting photoinjectors. Quantum efficiencies of 2-3 % at 545 nm, and 10% at 365 nm have been routinely obtained in the test stand, and electron emission uniformity, quantum efficiency at a variety of wavelengths, and lifetime under different vacuum conditions has been well characterized. The extraction of high charge per laser pulse will also be addressed in addition to the comparison of results from two different deposition techniques.

**TPPE042—Study of Secondary Emission Enhanced Photoinjector**
*Xiangyun Chang (BNL)*
The secondary emission enhanced photoinjector (SEEP) is a very promising new approach to the generation of high-current, high-brightness electron beams. Primary electrons with a few thousand electron-volts of energy strike a specially prepared diamond window. The large Secondary Electron Yield (SEY) provides a multiplication of the number of electrons by about two orders of magnitude. The secondary electrons drift through the diamond under an electric field and emerge into the accelerating proper of the "gun" through a Negative Electron Affinity (NEA) surface of the diamond (Hydrogen terminated). We present the calculation of heating power sources and the temperature distribution in details. Some properties of the secondary electron beam related to beam dynamics are also reported. The results show feasibility of this kind of cathode.

**TPPE043—Electron Beam Generation and Transport for the RHIC Electron Cooler**
*Jorg Kewisch, Ilan Ben-Zvi, Xiangyun Chang, Dmitry Kayran, Vladimir N. Litvinenko (BNL)*
An electron cooler, based on an Energy Recovery Linac (ERL) is under development for the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. This will be the first electron cooler operating at high energy with bunched beams. A better understanding of the cooling process and more accurate measurements of Intra Beam Scattering in RHIC have imposed increased requirements on the electron accelerator: Besides a doubling of the bunch charge to 20 nC, the strength of the cooling solenoid was increased five-fold to 5 Tesla. The magnetic field on the cathode should be increased to 500 Gauss to match the magnetization required in the cooling solenoid. This paper reports the measures taken to minimize the electron

beam emittance in the cooling section. The front-to-end simulation using different tracking codes is presented.

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**TPPE044—Upgrade of the Fermilab/NICADD Photoinjector Laboratory**
*Philippe Regis-Guy Piot, Helen Edwards, Markus Huening (Fermilab), Timothy Koeth (Rutgers University)*
The Femilab/NICADD photoinjector laboratory (FNPL) is a 16 MeV electron accelerator dedicated to beam dynamics and advanced accelerator studies. FNPL will soon be capable of operating at 50 MeV, after the installation of a high gradient TESLA cavity. In this paper we present the foreseen design for the upgraded facility along with its performance. We discuss the possible application of 50 MeV beam including the possible use of FNPL as an injector for the superconducting module and test facility (SM&TF).

This work was supported by Universities Research Association Inc. under contract DE-AC02-76CH00300 with the U.S. DOE, and by NICADD.

**TPPE045—Normal-Conducting High Current RF Photoinjector for High Power CW FEL**
*Sergey Kurennoy, Dale L. Schrage (LANL/*LANSCE*), Vincent Christina (AES), John Rathke, Tom Schultheiss (AES), Dinh Cong Nguyen, Richard L. Wood (LANL), Lloyd Martin Young (TechSource)*
An RF photoinjector capable of producing high average current with low emittance and energy spread is a key enabling technology for high power CW FEL. The design of a 2.5-cell, pi-mode, 700-MHz normal-conducting RF photoinjector cavity with magnetic emittance compensation is completed. With average gradients of 7, 7, and 5 MV/m in its three accelerating cells, the photoinjector will produce a 2.5-MeV electron beam with 3-nC charge per bunch and transverse rms emittance below 7 mm-mrad. Electromagnetic modeling has been used extensively to optimize ridge-loaded tapered waveguides and RF couplers, and led to a new, improved coupler iris design. The results, combined with a thermal and stress analysis, show that the challenging problem of cavity cooling can be successfully solved. Fabrication of a demo 100-mA (at 35 MHz bunch repetition rate) photoinjector is underway. The design is scalable to higher average currents by increasing the electron bunch repetition rate, and provides a path to a MW-class FEL. This paper presents the cavity design and details of RF coupler modeling.

**TPPE046—Computer Simulation of the UMER Gridded Gun**
*Irving Haber, Santiago Bernal, Rami Alfred Kishek, Patrick G. O'Shea, Yun Zou (IREAP), Jean-Luc Vay (LBNL), Alex Friedman, David Grote (LLNL), Martin Reiser (University Maryland)*
The electron source in the University of Maryland Electron Ring (UMER) injector employs a grid 0.15 mm from the cathode to control the current waveform. Under nominal operating conditions, the grid voltage during the current pulse is sufficiently positive relative to the cathode potential to form a virtual cathode downstream of the grid. Three-dimensional computer simulations have been performed that use the mesh refinement capability of the WARP particle-in-cell code to examine a small region near the beam center in order to illustrate some of the complexity that can result from such a gridded structure. These simulations have been found to reproduce the hollowed velocity space that is observed experimentally. The simulations also predict a complicated time-dependent response to the waveform applied to the grid during the current turn-on. This complex temporal behavior appears to result directly from the dynamics of the virtual cathode formation and may therefore be representative of the expected behavior in other sources, such as some photoinjectors, that are characterized by a rapid turn-on of the beam current.

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**TPPE047—Fabrication and Measurement of Low Work Function Cesiated Dispenser Photocathodes**
*Nathan A. Moody, Donald Feldman, Patrick G. O'Shea (IREAP), Kevin Jensen (NRL)*
Photoinjector performance is a limiting factor in the continued development of high powered FELs and electron beam-based accelerators. Presently available photocathodes are plagued with limited efficiency and short lifetime in an RF-gun environment, due to contamination or evaporation of a photosensitive surface layer. An ideal photocathode should have high efficiency at long wavelengths, long lifetime in practical vacuum environments, and prompt emission. Cathodes with high efficiency typically have limited lifetime, and vice versa, and the needs of the photocathode are generally at odds with those of the drive laser. A potential solution is the low work function dispenser cathode, where lifetime issues are overcome by periodic in situ regeneration that restores the photosensitive surface layer, analogous to those used in the microwave power tube industry. This work reports on the fabrication techniques and performance of cesiated metal photocathodes and cesiated dispenser cathodes, with a focus on understanding and improving quantum efficiency and lifetime, and analyzing issues of emission uniformity. The efficiency versus coverage behavior of cesiated metals is discussed and closely matches that predicted by recent theory.* *K. L. Jensen, et al., "Photoemission from Low Work Function Coated Metal Surfaces: A Comparison of Theory to Experiment" (this conference).

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**TPPE048—The Injection System of SAGA Light Source**
*Yoshitaka Iwasaki, Shigeru Koda, Toshihiro Okajima, Hiroyuki Setoyama, Yuichi Takabayashi, Takio Tomimasu, Katuhide Yoshida (Saga Synchrotron Light Source), Hideaki Ohgaki (Kyoto IAE)*
Saga light Source is a 1.4-GeV electron storage ring with a circumference of 75.6m. The injector is a 250-MeV linac producing 1 ms macro-pulse with a peak current of 12mA and repetition rate of 1Hz. The output beam from the linac is transported though a transport line, and injected into the ring though a septum magnet with a bending angle of 20-degree. The transport line consists of two bending magnets, two quadrupole doublelets, and a quadrupole singlet. The bump orbit is formed by four kicker magnets, two of which are installed at both sides of septum magnet, and other two are positioned apart by one magnet cell of the ring. They are excited by sinusoidal electric currents with a half width of 0.5 ms. The beam optics for the injection trajectory is computed and shown at control room, the parameters for which are provided directly from the power supply control server PC. The operator is able to see real-time result of the beam trajectory calculation. This tool is quite effective to optimize the magnets parameter setting. The commissioning of the light source was started in August 2004, and 250-MeV electrons ware stored first time on November 2004.

**TPPE049—Synchronizaiton Between Laser and Electron Beam at Photocathode RF Gun**
*Akira Sakumi (RIKEN/RARF/BPEL), Yusa Muroya, Mitsuru Uesaka (UTNL)*
The chemical reactions of hot, room temperature and critical water in a time-range of picosecond and sub-picosecond have been carried out by the 18 MeV S-band linac and a Mg photocathode RF gun with the irradiation of third harmonic Ti: Sapphire laser, at Nuclear Engineering Research Laboratory (NERL), the University of Tokyo. Although this short bunch and 100 fs laser light are enough to perform the experiment of radiation chemistry in the time-range of sub-picosecond, the total time-resolution become worse by the instability of synchronization between laser and radio frequency of linac. We found that the fluctuation of room temperature causes the instability, particularly the cycle of turning on/off of the air-conditioner. It is shown that 0.3 ºC (peak-to-peak) fluctuation of the laser-room temperature have approximately corresponded to the instability of 6 ps. We are trying to decrease the fluctuation of the room temperature, together with the local temperature stability of the Ti: Sapphire crystal, the pumping laser. Furthermore, we will develop the feed back system for reducing the instability of the synchronization.

**TPPE050—Beam Injection in Recirculator SALO**
*Ivan Guk, Anatoly Nikolayevich Dovbnya, Stanislav Kononenko, Fedor Peev, Alexander Tarasenko (NSC/KIPT), Jan Botman, Marnix Van der Wiel (TUE)*
Possible antetypes of injectors for electron recirculator SALO,* intended for nuclear-physical research, are analyzed. The plan injection of beams in recirculator is offered. Expected parameters of beams are designed.
*I.S. Guk, A.N. Dovbnya, S.G. Kononenko, A.S. Tarasenko, M. van der Wiel, J.I.M. Botman, NSC KIPT accelerator on nuclear and high energy physics, Proceedings of EPAC 2004, Lucerne, Switzerland, p. 761-764.

**TPPE051—The Optimization of the Electrons Injector Resonance System Based on the Evanescent Oscillations**
*Sergey Perezhogin, Mykola Ivanovich Ayzatskiy, Kateryna Kramarenko, Volodymyr Kushnir, Viktor Mytrochenko, Valentin Zhiglo (NSC/KIPT)*
The report presents the results of the bunching system optimization and electrons motion simulation in the compact S – band injector. The injector consists of the low-voltage diode electron gun and optimized bunching system based on the resonant system with the evanescent oscillations. The amplitude of RF electrical field is increased along the axis of the bunching system. The resonance system optimization allows to obtain electron bunches with the phase length less than 10° (for 70 % particles) at the injector exit.

**TPPE052—Characteristics of Electron Beam Produced by Magnetron Diode with a Secondary-Emission Cathode**
*Nikolay Reshetnyak, Anatoly Nikolayevich Dovbnya, Natalya Dovbnya, Viktor Mytrochenko, Valeriy Zakutin (NSC/KIPT)*
The beam parameters were investigated using an azimuth-sectionalized 8-channel Faraday cup and a 12-channel computer-aided measuring system. The magnetron diode had a cathode (40 mm in diameter) and a 15 mm anode-cathode gap. At a cathode voltage amplitude of 50 kV and a cathode magnetic field of ~1200 Oe, the diode generates a tubular electron beam with an outer diameter of 50 mm, an inner diameter of 44 mm, a beam current of ~50 A. The short time instability of the total beam current, and of the current from each of eight segments of the Faraday cup was estimated to be ~2 ... 3%, and long time instability (3 hours) was 5…7 %. Azimuthal distribution of beam current was investigated versus the amplitude, distribution and direction of the magnetic field. At a cathode magnetic field of 1200 Oe, that falls off inhomogeneity in the vicinity of the Faraday cup down to ~800 Oe, the azimuthal beam current distribution has a ± (3 ... 5)%. As the magnetic field strength increases up to ~1700 Oe in the region of beam emergence from the gun and the Faraday cup, the azimuthal inhomogeneity of the beam current increases up to ± (100 ... 150)%.

**TPPE053—Design Issues for the ILC Positron Source**
*Vinod Bharadwaj, Yuri Batygin, Rainer Pitthan, David Schultz, John Sheppard, Heinz Vincke (SLAC), Jeff Gronberg, Werner Stein, Aaron Matthew Tremaine (LLNL)*
A positron source for the ILC can be designed using either a multi-GeV electron beam or a multi-MeV photon beam impinging on a metal target. The major issues are: the drive beam, choice of target material, the design of the target station, the capture section, the target vault, and beam transport to the damping ring. In this paper, positron source parameters for the various schemes are outlined and the advantages and disadvantages of each scheme are discussed.

Work supported by Department of Energy contract DE-AC02-76SF00515.

**TPPE054—Status of the Injection System for the Australian Synchrotron Project (Including Combined Function Magnets)**
*Jesper Kristensen, Henning Bach (Danfysik A/S)*
DANFYSIK A/S designs and builds the complete injection system for the Australian Synchrotron Project. The full-energy booster will accelerate the beam from the injection energy of 100 MeV. to a maximum of 3.0 GeV. The booster is using combined function magnets. The status of the project is presented.

**TPPE055—Low Emittance Beam Generated by DC-SC Photo-Injector of Peking University**
*Rong Xiang (FZR; PKU/IHIP), Xiangyang Lu, Shengwen Quan, Baocheng Zhang, Kui Zhao (PKU/IHIP)*
High average power Free Electron Lasers require the high quality electron beams with the low emittance and the sub-picosecond bunches. The design of DC-SC photoinjector, directly combining a DC photoinjector with an SRF cavity, can produce high average current beam with moderate bunch charge and high duty factor. Because of the DC gun, the emittance increases quickly at the beginning, so a carefully design is needed to control that. In this paper, the simulation of an upgraded design has been done to lower the normalized emittance below 1.5mm•mrad. The photoinjector consists of a DC gap and a 2+1/2-cell SRF cavity, and it is designed to produce 4.2 MeV electron beams at 100pC bunch charge and 81.25MHz repetition rate (8 mA average current).

**TPPE056—Status of Upgrade RF Gun System at SPring-8**
*Akihiko Mizuno (JASRI/SPring-8)*
A single cell pill box type RFgun has been developing at the SPring-8 since 1999. The minimun record of the normalized emittance is 2.3 pi mmmrad with charge of 0.1 nC/bunch which was measured by double silts scanning method. Last year, we replaced the experimental room, and installed one accererator sturucture to investigate emittance behavior of the whole injector system including the accelerator structure. On the other hand, we also has been studying laser profile shaping both spatially and temporally in order to reduce emitttance. In this paper, we will report present status of our upgrade RFgun

system, several results on measuring emittance including the accelerator structure, and effects on emittance quality with carefully shaping the laser profile.

**TPPE057—An Experimental Study of the Quantum Efficiency and Topology of Single Crystal Copper Cu100 Photocathode Due to Plasma Cleaning and Etching**
*Robert Kirby, Dennis Thomas Palmer (SLAC)*
We have developed an experimental research program to the study of the photoemission properties of single crystal copper Cu100 photocathodes as a function of various plasma cleaning/etching parameters. The quantum efficiency, QE, and topology, Ra and Rpp, of Single Crystal Copper Photocathodes, Cu100, will be monitored while undergoing plasma cleaning/etching process. We will monitor the QE as a function of time for the various test coupons while we optimize the various plasma processing parameters. In addition, surface topology, will be studied to determine the suitability of the cleaning/etching process to produce an acceptable photoemitter. We propose to use two metrics in the evaluation of the plasma cleaning process as an acceptable cleaning method for metallic photocathodes, Quantum Efficiency versus Wavelength and Surface roughness: Ra and Rpp represent the Average Roughness and Peak to Peak Roughness parameters, respectively.

**TPPE058—Dual Feed RF Gun Design for the LCLS**
*Liling Xiao, Richard Boyce, David Dowell, Zenghai Li, Cecile Limborg-Deprey, John Schmerge (SLAC)*
In order to remove the dipole field introduced by the coupler in existing S-band BNL/SLAC/UCLA 1.6 cell rf gun, a dual feed design for the LCLS RF gun is proposed together with several significant changes. The improvements include adopting Z-coupling instead of è-coupling for easier machining and reducing heating, increasing the 0-and -mode separation from 3.4 to 15 MHz to reduce the amplitude of the 0π mode, incorporating race-track cavity shape to minimize the quadruple fields, increased cooling for operation at 120Hz and other small changes to improve performance and diagnostic capabilities. The new design has been modeled with the parallel finite element eigenmode solver Omega3P to provide the desired RF parameters and to generate the gun cavity dimensions needed for fabrication.

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**TPPE059—New Electron Gun System for BEPCII**
*Bo Liu, Yun Long Chi, Mengping Gu, Chuang Zhang (IHEP Beijing)*
The new electron gun system for BEPCII has been put into operation since Nov. 2004. The article describes the design, experiment and operation of this new system. The design current of the gun is 10 A for the pulse lengths of 1 ns, 2.5 ns and 1 ìs with repetition rate of 50 Hz. The gun is operated with a pulsed high voltage power supply which can provide up to 200 kV high voltage. Computer simulations have been carried out in the design stage, including simulation of the gun geometry and beam transportation. Some important relation curves are obtained during the experiment. Two-bunch operation is available and some elementary tests have been performed. New scheme of the gun control system based on EPICS is also presented. The real operation shows that the design and manufacturing is basically successful.

**TPPE060—Simulation Study of a Thermionic RF Gun for High Brightness and Short Pulse Beam**
*Takumi Tanaka, Hiroyuki Hama, Fujio Hinode, Masayuki Kawai, Atsushi Miyamoto, Katsuhiro Shinto (LNS)*
Characteristics of thermionic RF guns are not understood completely. In particular, measured intense beam emittances extracted from thermionic RF guns do not agree well with simulated values so far. Most of simulation codes solve the equation of electron motion in an intrinsic mode of the RF field calculated by a separated code. The way of such simulation codes is not self-consistent completely. That is probably a major reason for the discrepancy between the experiments and the simulations. One of the other way for a self-consistent simulation codes is to use an FDTD (Finite Difference Time Domain) method. Since the FDTD method can take into account the microwave propagation including the space charge effect and the beam loading self-consistently, we have developed an FDTD code as 3-D Maxwell's equation solver and applied for a study of beam dynamics in a thermionic RF gun. The main purpose of simulaiton study is to obtain overall properties of the beam dynamics at the time. The goal of this simulation study of the thermionic RF gun is to understand correct characteristics of the thermionic RF gun for producing high brightness and short pulse beam.

**TPPE061—RF Design and Operating Performance of the BNL/AES 1.3 GHz Single Cell Superconducting RF Photocathode Electron Gun**
*Michael Cole (AES), Ilan Ben-Zvi, Andrew Burrill, Harald Hahn, Triveni Rao, Yongxiang Zhao (BNL), Peter Kneisel (Jefferson Lab)*
Over the past several years Advanced Energy Systems and BNL have been collaborating on the development and testing of a fully superconducting photocathode electron gun. Over the past year we have begun to realize significant results which have been published elsewhere.* This paper will review the RF design of the gun under test and present results of its performance under various operating conditions. Results for cavity quality factor will be presented for various operating temperatures and cavity field gradients. We will discuss various methods of determining the cavity fields and the extent of agreement between them. We will also discuss future plans for testing using this gun.
*Photoemission studies on BNL/AES all niobium, Superconducting RF injector, T. Rao, these proceedings.

**TPPE062—Photoemission from Low Work Function Coated Metal Surfaces: A Comparison of Theory to Experiment**
*Kevin Jensen (NRL), Donald Feldman, Nathan A. Moody, Patrick G. O'Shea (IREAP)*
The development of rugged and/or self rejuvenating photocathodes with high quantum efficiency (QE) using the longest wavelength drive laser is of paramount importance for RF photo-injectors for high power FELs and accelerators. We report on our program to develop advanced photocathodes and to develop and validate models of photoemission from coated metals to analyze experimental data,* provide emission models usable by beam simulation codes,** and project performance. The model accounts for the effects of laser heating, thermal evolution, surface conditions, laser parameters, and material characteristics, and predicts current distribution and QE. The photoemission and QE from metals and dispenser photocathodes is evaluated: the later introduces complications such as coverage non-uniformity and field enhancement. The performance of the models is compared to our experimental results for dispenser photocathodes and cesiated surfaces (e.g., tungsten, silver, etc.) in which the time-dependent models are shown to agree very well with experimental findings, but also to results in the

literature. Extrapolations to performance regimes of interest shall be given.
*N. Moody et al., "Fabrication and Measurement of Low Workfunction Cesiated Dispenser Photocathodes" (this conference). **D.A. Dimitrov et al., "Development of Advanced Models for 3D Photocathode PIC Simulations" (this conference).

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**TPPE063—Improved Electron Yield and Spin-Polarization from III-V Photocathodes Via Bias Enhanced Carrier Drift**
*Gregory A. Mulhollan, John Bierman (Saxet), Axel Brachmann, James E. Clendenin, Edward Garwin, Robert Kirby, Dah-An Luh, Takashi Maruyama (SLAC), Richard Prepost (UW-Madison/PD)*
Spin-polarized electrons are commonly used in high energy physics. Future work will benefit from greater polarization. Polarizations approaching 90% have been achieved at the expense of yield. The primary paths to higher polarization are material design and electron transport. Our work addresses the latter. Photoexcited electrons may be preferentially emitted or suppressed by an electric field applied across the active region. We are tuning this forward bias for maximum polarization and yield, together with other parameters, e.g., doping profile Preliminary measurements have been carried out on bulk GaAs. As expected, the yield change far from the bandgap is quite large. The bias is applied to the bottom (non-activated) side of the cathode so that the accelerating potential as measured with respect to the ground potential chamber walls is unchanged for different front-to-back cathode bias values. For a bias which enhances emission, the yield nearly doubles. For a bias which diminishes emission, the yield is approximately one half of the zero bias case. The size of the bias to cause an appreciable effect is rather small reflecting the low drift kinetic energy in the zero bias case.

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**TPPE064—Study of Electron Bunch Distribution in RF Guns**
*Vladimir Gorgadze (UCB), Jonathan Wurtele, Alexander Zholents (LBNL)*
RF photocathode guns are excellent sources of high brightness electron bunches. In the limit of high-current short bunches the electron are complicated space-charge fields. To mitigate space charge effect downstream of the gun it is often desirable to produce electorn bunches with uniform distribution. Our goal is to understand to what extent the non-uniformity of the laser pulse intensity is responsible for a non-uniform electron distribution and to what extent this is due to the electron beam dynamics near to the cathode. We investigate these effects with particle-in-cell simulations and simple theory. These studies are focused on the regime where the peak current as well as the temporal current profile are influenced by the self-fields of the bunch. The simulation code XOOPIC has been employed. The critical current limitation for virtual cathode formation and current density profile at the exit of the injector have been found.

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**TPPE065—Calculating of Coupling Factor of Microwave Electron Gun**
*Xiaohao Bian, Huaibi Chen, Shuxin Zheng (TUB), Derun Li (LBNL)*
To design the coupler of a designing microwave electron gun, we use the "energy method" proposed by Derun Li, et al. The intrinsic Q of the electron gun cavity is very high: about 20000. The method calculates the intrinsic and external Q values of a cavity coupled to a waveguide using MAFIA code in time domain. The comparisons between simulation and experimental results are given for a set of different coupling iris apertures and height. The result shows that "energy method" works efficiently for high Q cavities.

**TPPE066—Geometry Optimization of DC/RF Gun**
*Ping Chen, Alexei Smirnov, David Yu (DULY Research Inc.)*
Pre-acceleration of photoelectrons in a pulsed, high voltage, short, dc gap and its subsequent injection into an rf gun is a promising method to improve electron beam emittance in rf accelerators. Simulation work has been performed in order to optimize the geometric shapes of a dc/rf gun and improve electron beam properties. Variations were made on cathode and anode shapes, dc gap distance, and inlet shape of the rf cavity. Simulations showed that significant improvement on the normalized emittance (< 1 mm-mrad), compared to a dc gun with flat cathode, could be obtained after the geometric shapes of the gun were optimized.

Work supported by DOE SBIR Grant No. DE-FG02-03ER83878.

## Poster Session TPPP—Lepton Accelerators and Colliders
## Park Concourse, 13:50-17:10

**TPPP001—Design of Damping Ring for SuperKEKB**
*Mitsuo Kikuchi (KEK)*
In the SuperKEKB, a plan upgrading the KEKB to higher luminosity of (2.5-5) x10^35 cm^2/sec, the beam currents are 9.4 A for the LER (3.5 GeV-electrons) and 4.1 A for the HER (8 GeV-positrons). In order to supply the HER with the positron beam, which is currently injected to the LER, the field gradient of the injector linac has to be increased. To meet this requirement, the S-band accelerating structures placed at the beam energy greater than 1 GeV, after the positron target, are replaced with C-band structures. A damping ring (DR) is indispensable since the aperture of the C-band structure is much smaller than the beam emittance. In this paper, we describe on the design of DR. We adopt a new cell structure for DR; FODO cell with alternating bends, where one of two bends in a cell is reversed. One of advantages of the proposed ring is that very small, even negative, momentum compaction factor is easily achieved by properly choosing the bend-angle ratio of the reverse bend to the main bend. Tracking simulation for the proposed DR has shown that it has very large dynamic aperture in both transverse and longitudinal phase space, for very wide tune space.

**TPPP002—Global-Beta Measurement and Correction at the KEKB Rings**
*Akio Morita, Haruyo Koiso, Yukiyoshi Ohnishi, Katsunobu Oide (KEK)*

The global-beta correction is a part of the optics corrections which are performed to regularize the ring optics for the

luminosity tunings. The global-beta measurement is performed by the reconstruction of the beta function from the set of the single kick orbits generated by the 6 kinds of the steering magnets. The distortion of the beta fucntion and the phase advance are corrected by the global beta correction using the fudge factors of power supplies of quadrupole magnets. These correction scheme are successfully working. In the typical case, the r.m.s. of the beta function beat and the betatron tune difference are corrected within 5% and 0.0005, respectively. In the luminosity run, we can operate the low energy ring(LER) with the horizontal betatron tune very close to half-integer(45.5050). In this paper, we will report in detail the global-beta measurement and correction techniques and its performance in the KEKB operation.

**TPPP003—Lattice Upgrade Plan for Crab Crossing at the KEKB Rings**
*Akio Morita, Kazumi Egawa, Haruyo Koiso, Mika Masuzawa, Katsunobu Oide, Ryuhei Sugahara, Masato Yoshida (KEK)*
We plan to install two superconducting crab cavities into the rings at Janyary, 2006. In our plan, we will install one crab cavity per one ring into the NIKKO straight section where the cryogenic infrastructure is already operated for the superconducting accelerating cavities. In order to obtain the correct crabbing angle at the interaction point(IP), we have to enlarge the horizontal beta function(200m for HER) and have to adjust the horizontal phase advance between the IP and the cavity installation point. In this paper, we will report the lattice modified for the crab crossing and the study results about the single beam dynamics.

**TPPP004—Study of the Beam-Beam Effect for Crab Crossing**
*Kazuhito Ohmi, Yoshihiro Funakoshi, Masafumi Tawada (KEK)*
Luminosity upgrade using crab cavities is planned at KEK-B factory (KEKB)in 2006. The crab crossing is expected to increase the beam-beam parameter >0.1, which is twice of present value, for KEKB. We discuss torelances of crab cavities and lattice to get the high beam-beam parameter.

**TPPP005—Optics and Orbit Measurements Using Turn-By-Turn BPMs**
*Yukiyoshi Ohnishi, Shigenori Hiramatsu, Hitoshi Ishii, Kenji Mori, Masaki Tejima (KEK)*
We have measured the optics and orbits using turn-by-turn BPMs at KEKB. When a single pulsed kick is excited by a kicker, the horizontal or vertical betatron oscillations can be measured by a turn-by-turn BPM in the laboratory coordinate system. A harmonic analysis has been performed to extract betatron phases and tunes obtained from the detected betatron oscillations.

**TPPP006—Beam-Beam Simulation Study with Parasitic Crossing Effect at KEKB**
*Masafumi Tawada, Yoshihiro Funakoshi, Kazuhito Ohmi (KEK)*
KEKB is an asymmetric-energy, two-ring, electron-positron collider for B physics. Two beams collide at one interaction point with a finite crossing angle of 22 mrad. The bunch spacing has chosen to be 4 buckets (8 nsec) in most physics run of KEKB. While the shorter bunch spacing is necessary for a higher luminosity, the degradation of the specific luminosity by unknown reason is observed in 4 or 6 nsec spacing. In order to investigate whether parasitic crossing effect degrades a beam-beam performance, we have performed strong-strong beam-beam simulation with parasitic long-range beam-beam force. In this paper we present and discuss our simulation results.

**TPPP007—Recent Progress at KEKB**
*Yoshihiro Funakoshi, Kazunori Akai, Kiyokazu Ebihara, Kazumi Egawa, Atsushi Enomoto, John Walter Flanagan, Hitoshi Fukuma, Kazuro Furukawa, Takaaki Furuya, Junji Haba, Shigenori Hiramatsu, Takao Ieiri, Naoko Iida, Hitomi Ikeda, Tatsuya Kageyama, Susumu Kamada, Takuya Kamitani, Shigeki Kato, Mitsuo Kikuchi, Eiji Kikutani, Haruyo Koiso, Mika Masuzawa, Toshihiro Mimashi, Akio Morita, Tatsuro Nakamura, Hisayoshi Nakayama, Yujiro Ogawa, Kazuhito Ohmi, Yukiyoshi Ohnishi, Norihito Ohuchi, Katsunobu Oide, Miho Shimada, Samo Stanic, Masaaki Suetake, Yusuke Suetsugu, Takashi Sugimura, Tsuyoshi Suwada, Masafumi Tawada, Masaki Tejima, Makoto Tobiyama, Sadaharu Uehara, Shoji Uno, Su Su Win, Noboru Yamamoto, Yasuchika Yamamoto, Yoshiharu Yano, Kazue Yokoyama, Masato Yoshida, Mitsuhiro Yoshida, Shin-ichi Yoshimoto (KEK), Frank Zimmermann (CERN)*
We summarize the machine operation of KEKB during past one year. Progress for this period, causes of present performance limitations and future prospects are described.

**TPPP008—Beam-Beam Effects Observed at KEKB**
*Yoshihiro Funakoshi, Mika Masuzawa, Kazuhito Ohmi, Masafumi Tawada (KEK)*
Like other colliding machines, the beam-beam effects impose a strict restriction on the luminosity also at KEKB. Beam-beam effects observed at KEKB are summarized in this report. A comparision between the experimental data and beam-beam simulations is also shown.

**TPPP009—Precise Energy Measurements in Experiments on VEPP-4M Collider**
*Anton Bogomyagkov, Vladimir Blinov, Vladimir Petrovich Cherepanov, Vladimir Kiselev, Evgeny Levichev, Svyatoslav Mishnev, Nickolai Muchnoi, Sergei Nikitin, Ivan Nikolaev, Dimitry Nikolenko, Andrey Shamov, Evgeny Shubin, Alexander Skrinsky, Dimitry Toporkov, German Tumaikin (BINP SB RAS)*
The series of experiments on mass measurements of J/Psi, Psi', X and D mesons have been done on VEPP4-M collider. The accuracy of obtained masses values for psi mesons exceeded world value more than 3 times. Preparation for mass measuremnt of tau lepton is in progress. All these experiments require absolute energy calibration of the beams. Resonant depolarization technique has been used for most accurate energy measurement with relative accuracy of 1 ppm (10^-6). Compton backscattering effect is used in developing facility for fast energy measurements. Also Moller effect of beam scattering on polarized gas jet target has been used for energy calibrations.

**TPPP010—Photon-Nucleon Collider Based on LHC and CLIC**
*Husnu Aksakal, Abbas Kenan Ciftci (Ankara University, Tandogan/Ankara), Daniel Schulte, Frank Zimmermann (CERN)*
We describe the scheme of a photon-nucleon collider where high-energy photons generated by Compton back-scattering off a CLIC electron beam, at either 75 GeV or 1.5 TeV, are collided with protons or ions stored in the LHC. Different design constraints for such a collider are discussed and the achievable luminosity performance is estimated.

**TPPP011—Investigations of Injection Orbits at CESR Based on Turn-By-Turn BPM Measurements**
*Michael Billing, James Arthur Crittenden, John Dobbins, Mark Alan Palmer, Charles Ralph Strohman (Cornell University)*
Development of a data acquisition permitting turn-by-turn orbit measurements has been employed at CESR to study the optics of the injected electron beam. An optimization algorithm uses these

measurements to determine the effective lattice functions describing the behavior of the injected electrons. We present comparisons of these measurements to tracking calculations of injection acceptance envelopes which account for the parasitic beam-beam interactions with the stored positron beam.

National Science Foundation.

**TPPP012—A Study of the Effects of Beam-Beam Interactions on CESR Optics**

*Michael Billing, James Arthur Crittenden, David Rubin (Cornell University)*

The CESR storage ring facility has begun operation in an energy region which allows high-statistics investigation of charm-quark bound states. Experience during the first year has shown that the effects of parasitic crossings in the pretzel orbits present an important factor in injection efficiency, in the beam lifetime and stored current limits. We compare the results of beam dynamics and tracking calculations which quantify the effects of these parasitic crossings on optics and dynamic aperture for the injected and stored trajectories to observations of beam behavior.

National Science Foundation.

**TPPP013—Simulations of Parametric Resonance Ionization Cooling of Muon Beams**

*Kevin Beard, S. Alex Bogacz, Yaroslav Derbenev (Jefferson Lab), Katsuya Yonehara (Illinois Institute of Technology), Rolland Johnson, Kevin Paul, Thomas Roberts (Muons, Inc)*

The technique of using a parametric resonance to allow better ionization cooling is being developed to create small beams so that high collider luminosity can be achieved with fewer muons. In the linear channel that is studied in this effort, a half integer resonance is induced such that the normal elliptical motion of particles in x-x' phase space becomes hyperbolic, with particles moving to smaller x and larger x' as they pass down the channel. Thin absorbers placed at the focal points of the channel then cool the angular divergence of the beam by the usual ionization cooling mechanism where each absorber is followed by RF cavities. Thus the phase space of the beam is compressed in transverse position by the dynamics of the resonance and its angular divergence is compressed by the ionization cooling mechanism. We report the first results of simulations of this process, including comparisons to theoretical cooling rates and studies of sensitivity to variations in absorber thickness and initial beam conditions.

This work was supported in part by DOE SBIR grants DE-FG02-03ER83722, and 04ER84016.

**TPPP014—Ionization Cooling Using a Parametric Resonance**

*Yaroslav Derbenev (Jefferson Lab), Rolland Johnson (Muons, Inc)*

Muon collider luminosity depends on the number of muons in the storage ring and on the transverse size of the beams in collision. Ionization cooling as it is presently envisioned will not cool the beam sizes sufficiently well to provide adequate luminosity without large muon intensities. A new idea to combine ionization cooling with parametric resonances has been developed that will lead to beams with much smaller sizes so that high luminosity in a muon collider can be achieved with fewer muons. In the linear channel described here, a half integer resonance is induced such that the normal elliptical motion of particles in x-x' phase space becomes hyperbolic, with particles moving to smaller x and larger x' as they pass down the channel. Thin absorbers placed at the focal points of the channel then cool the angular divergence of the beam by the usual ionization cooling mechanism where each absorber is followed by RF cavities. We discuss the theory of Parametric-resonance Ionization Cooling, including the sensitivity to aberrations and the need to start with a beam that has already been cooled adequately.

This work was supported in part by DOE SBIR grant DE-FG02-04ER84016.

**TPPP015—ELIC at CEBAF**

*Yaroslav Derbenev, Andrei Afanasev, S. Alex Bogacz, Joseph Michael Grames, Andrew Hutton, Geoffrey Arthur Krafft, Rui Li, Lia Merminga, Matt Poelker, Byung Chel Yunn, Yuhong Zhang (Jefferson Lab)*

We report on the progress of the conceptual development of the energy recovering linac (ERL)-based Electron-Light Ion Collider (ELIC) at CEBAF that is envisioned to reach luminosity level of 1033-1035 /cm2s with both beams polarized to perform a new class of experiments in fundamental nuclear physics. Four interaction points with all light ion species longitudinally or transversally polarized and fast flipping of the spin for all beams are planned. The unusually high luminosity concept is based on the use of the ERL and circulator ring-based electron cooling and crab crossing colliding beams. Our recent studies concentrate on the design of low beta interaction points with crab-crossing colliding beams, the exploration on raising the polarized electron injector current to the level of 3-30 mA with the use of electron circulator-collider ring, forming a concept of stacking and cooling of the ion beams, specifications of the electron cooling facility, and studies of beam-beam interaction and intra-beam scattering.

Work supported by DOE Contract DE-AC05-84ER40150.

**TPPP016—Beam Physics for the 12 GeV CEBAF Upgrade Project**

*Lia Merminga, Jay Benesch, S. Alex Bogacz, Yu-Chiu Chao, Joseph Michael Grames, Leigh Harwood, Geoffrey Arthur Krafft, Michael Tiefenback, Byung Chel Yunn, Yuhong Zhang (Jefferson Lab)*

Beam physics aspects of the 12 GeV Upgrade of CEBAF are presented. The CEBAF Upgrade to 12 GeV is achieved via 5.5 recirculations through the linacs, and the installation of 10 new high-gradient cryomodules. A new experimental hall, Hall D, is envisioned at the end of North Linac. Simulation results for straight-through and recirculated injectors are summarized and compared. Beam transport designs are discussed and evaluated with respect to matching and beam breakup (BBU) optimization. Effects of synchrotron radiation excitation on the beam properties are calculated. BBU simulations and derived specifications for the damping of higher order modes of the new 7-cell cavities are presented. The energies that provide longitudinal polarization in multiple experimental halls simultaneously are calculated. Finally, a detailed optics design for the Hall D transport line has been obtained.

Work supported by DOE Contract DE-AC05-84ER40150.

**TPPP017—Study of Beam-Beam Effects in eRHIC with Self-Consistent Beam-Beam Simulation**

*Jack Shi, Lihui Jin (KU), Dong Wang, Fuhua Wang (MIT)*

The eRHIC is a proposed electron ring at the RHIC that will provide collisions between a polarized 5-10 GeV electron beam and an ion beam from one of the RHIC rings. In order to achieve proposed high luminosity, large bunch current and small beta-

functions at the IP has to be employed. Such measures result in large beam-beam parameters, 0.029 and 0.08 for the electron beam and 0.0065 and 0.0033 for the proton beam in the horizontal and vertical plane, respectively, in the current ZDR design. The beam-beam effect especially the coherent beam-beam effect is therefore one of important issues to the eRHIC. Moreover, the proposed configuration of unequal circumferences of the electron and proton rings could further enhance the coherent beam-beam effect. The beam-beam effect of eRHIC has therefore been studied with a self-consistent beam-beam simulation by using the particle-in-cell method. Beam-beam limits of the electron and proton beam were examined as thresholds of the onset of coherent beam-beam instability. For the proposed luminosity, the electron and proton bunch currents optimized with the consideration of the beam-beam effect will be discussed.

The U.S. Department of Energy under Grant No. DE-FG02-04ER41288.

**TPPP018—Progress on the Cryogenic System for a Liquid Absorber in the MICE Cooling Channel**
*Michael Green (LBNL), Elwyn Baynham, Thomas William Bradshaw, Yury Ivanyushenkov (CCLRC/RAL), Mary Anne Clare Cummings (Fermilab), Shigeru Ishimoto (KEK), Wing Lau, Stephanie Yang (OXFORDphysics)*
This report describes the progress made on the design of the liquid hydrogen absorber for the international Muon Ionization Cooling Experiment (MICE). The absorber consists of a 21-liter vessel that contains liquid hydrogen (1.5 kg) or liquid helium (2.63 kg). The cryogen vessel is within the warm bore of the superconducting focusing magnet for the MICE. The purpose of the magnet is to provide a low beam beta region within the absorber. For safety reasons, the vacuum vessel for the hydrogen absorber is separated from the vacuum vessel for the superconducting magnet and the vacuum that surrounds the RF cavities or the detector. The absorber has two 300 mm-diameter thin aluminum windows. The vacuum vessel around the absorber has a pair of thin aluminum windows that separate the absorber vacuum space from adjacent vacuum spaces. Because the muon beam in MICE is of low intensity, there is no beam heating in the absorber. As a result, the absorber can be cooled using a single 4 K cooler. This report describes progress on the MICE liquid absorber and its cryogenic cooling system.

This work was supported by the Office of Science, U.S. Department of Energy under DOE contract number DE-AC03-76SF00098.

**TPPP019—Beam Lifetime in the Lepton Ring of eRHIC**
*Dong Wang (MIT)*
The eRHIC is a new generation lepton-hadron collider undergoing design studies by a collaboration of BNL, MIT, DESY and BINP. The collider complex will consist of a hadron machine that is mainly the existing RHIC with necessary upgrades, and a new lepton machine that can provide intense, highly polarized electron and positron beams at energy of 5-10 GeV. The ring-ring option of eRHIC is to build a 5-10 GeV electron ring with a injector chain. In this paper the beam lifetime of lepton beams is calculated.

Department of Energy.

**TPPP020—Design of a Multi-Cell S-Band Superconducting RF Cavity**
*Dong Wang (MIT)*
Design studies of a multi-cell 2856MHz superconducting RF cavity is carried out. The purpose of this cavity is to provide a high acceleration voltage up to 1.0-1.5 MV for the electron storage ring at Bates Laoratory, MIT. This would greatly help produce the ultra short(sub-ps) and stable electron bunches for many applications, e.g., Terahertz coherent radiations, etc. The cell shape and number of cells are optimized through simulations. The considerations on cryogenic system are also discussed.

Department of Energy, USA.

**TPPP021—A Multi-Cell Deflecting Superconducting RF Cavity for X-Ray FEL**
*Dong Wang (MIT)*
Deflecting RF cavities are used to manipulate the beam for different purposes. We have designed a set of multi-cell deflecting RF cavities to transversely kick or rotate the electron bunches. This kind of cavity can also find applications in other accelerator machines for beam manipulations and diagnostics.

U.S. Department of Energy.

**TPPP022—The eRHIC Ring-Ring Collider Design**
*Fuhua Wang, Manouchehr Farkhondeh, Wilbur Franklin, William Graves, Richard Milner, Chris Tschalaer, Jan Van der Laan, Dong Wang, Abbasali Zolfaghari, Townsend Zwart (MIT), Joanne Beebe-Wang, Vladimir N. Litvinenko, William W. MacKay, Christoph Montag, Satoshi Ozaki, Brett Parker, Steve Peggs, Vadim Ptitsyn, Thomas Roser, Steven Tepikian, Dejan Trbojevic (BNL), Desmond P. Barber (DESY), Jack Shi (KU), Abhay Deshpande (Stony)*
The eRHIC ring-ring collider is the main design option of the future lepton-ion collider at Brookhaven National Laboratory. We report the revisions of the ring-ring collider design features to the baseline design presented in the eRHIC Zeroth Design Report (ZDR). These revisions have been made during the past year. They include changes of the interaction region which are required from the modifications in the design of the main detector. They also include changes in the lepton storage ring for high current operations as a result of better understandings of beam-beam interaction effects. The updated collider luminosity and beam parameters also take into account a more accurate picture of current and future operational aspects of RHIC.

**TPPP023—Predicting PEP-II Accelerator-Induced Backgrounds Using TURTLE**
*Roger John Barlow, William Dunwoodie, Theodore (Ted) Fieguth, Jaroslav Va'vra (SLAC), Witold Kozanecki (CEA/DSM/DAPNIA), Patrick Roudeau, Achille Stocchi (LAL), Stephanie Majewski (Stanford University)*
We present studies of accelerator-induced backgrounds in the BaBar detector at the SLAC B-Factory, carried out using a modified version ofthe DECAY TURTLE simulation package. Lost-particle backgrounds in PEP-II are dominated by a combination of beam-gas bremstrahlung, beam-gas Coulomb scattering, radiative-Bhabha events and beam-beam blow-up. The radiation damage and detector occupancy caused by the associated electromagnetic shower debris can limit the usable luminosity. In order to understand and mitigate such backgrounds, we have performed a full programme of beam-gas and luminosity-background simulations, that include the effects of the detector solenoidal field, detailed modelling of limiting apertures in both collider rings, and optimization of the betatron collimation scheme in the presence of large transverse tails.

**TPPP024—Experimental Study of Crossing-Angle and Parasitic-Crossing Effects at the PEP-II e+e- Collider**
*Witold Kozanecki (CEA/DSM/DAPNIA), Ilya V. Narsky (CALTECH), Yunhai Cai, John Seeman, Michael K. Sullivan (SLAC)*
In a series of dedicated accelerator experiments, we have measured the dependence of the PEP-II luminosity performance on small horizontal crossing angles and on the horizontal separation at the first parasitic crossing. The experiment was carried out by varying the IP angle of one of the beams in two different bunch patterns, one with and one without parasitic crossings. The experimental measurements show satisfactory agreement with three-dimensional beam-beam simulations.

**TPPP025—Modeling Lost-Particle Accelerator Backgrounds in PEP-II Using LPTURTLE**
*Theodore (Ted) Fieguth, Roger John Barlow (SLAC), Witold Kozanecki (CEA/DSM/DAPNIA)*
Background studies during the design, construction, commissioning, operation and improvement of BaBar and PEP-II have been greatly influenced by results from a program referred to as LPTURTLE (Lost Particle TURTLE a modified version of Decay TURTLE) which was originally conceived for the purpose of studying gas background for SLC. This venerable program is still in use today. We describe its use, capabilities and improvements and refer to current results now being applied to BaBar.

Department of Energy Contract DE-AC02-76SF00515.

**TPPP026—Bunch-Length Measurements in PEP-II**
*Alan Stephen Fisher, Robert Holtzapple, Alexander Novokhatski, James Leslie Turner, Ulrich Wienands, Gerald Steven Yocky (SLAC)*
We measured the lengths of colliding e+e- bunches in the PEP-II B Factory at SLAC using various techniques. First, at several RF voltages and with both single-bunch and multibunch beams, a synchroscan streak camera measured synchrotron emission through a narrow blue filter. With 3.8 MV of RF, the length of a single positron bunch was 12 mm at low current, rising to 13 mm at 1.5 mA and 14.8 mm at 3 mA. The electrons measured 12.2 mm with little current dependence. Both are longer than the expected low-current value of 10 mm (e+) and 11 mm (e-), derived from the energy spread and the measured synchrotron tune. We also determined the length from measurements between 2 and 13 GHz of the bunch spectrum on a BPM button. After correcting for the frequency dependence of cable attenuation, we then fit the measured spectrum to that of a Gaussian bunch. With 3.8 MV, the positrons measurement gave 13.2 mm at 1.5 mA/bunch in a full ring, in agreement with the streak camera, but we found 11.4 mm for the electrons at 16.7 MV and 1 mA/bunch, lower than the streak measurement.

Supported by U.S. Department of Energy contract DE-AC03-76SF00515.

**TPPP027—Single Bunch Tune and Beam Size Measurements Along Mini-Trains in PEP-II**
*Robert Holtzapple, Denis Dujmic, Alan Stephen Fisher (SLAC)*
By scanning a gated camera and a gated tune monitor across the bunch pattern during normal colliding-bunch operation of PEP-II, the single-bunch tunes and beam sizes were measured simultaneously in the high and low energy storage rings of PEP-II. The measurements were made with 1561 colliding bunches in PEP-II, arranged in trains of 66 bunches, with each bunch in the train separated by 4.2 ns. The tune and beam size measurements were correlated with the current, luminosity, and specific luminosity of the bunch. The results show a vertical tune shift at the start and end of the mini-trains, a luminosity droop along the mini-train, and specific luminosity drop in the first and last bunches of the train, since they experience a different parasitic crossing on either side of the IP.

**TPPP028—Simulation of HOM Leakage in the PEP-II Bellows**
*Cho-Kuen Ng, Nathan T. Folwell, Jay Langton, Lie-Quan Lee, Alexander Novokhatski (SLAC)*
An important factor that limits the PEP-II from operating at higher currents is higher-order-mode (HOM) heating of the bellows. One source of HOM heating is the formation of trapped modes at the bellows as a result of geometry variation in the vacuum chamber, for example, the masking near the central vertex chamber. Another source comes from HOMs generated upstream that leak through the gaps between the bellows fingers. Modeling the fine details of the bellows and the surrounding geometry requires the resolution and accuracy only possible with a large number of mesh points on an unstructured grid. We use the parallel finite element eigensolver Omega3P for trapped mode calculations, and the S-matrix solver S3P for transmission analysis. The damping of the HOMs by the use of absorbers inside the bellows will be investigated.

Work supported by U.S. DOE contract, DE-AC02-76SF00515.

**TPPP029—A Preliminary Interaction Region Design for a Super B-Factory**
*Michael K. Sullivan, Martin Donald, Stanley Ecklund, Alexander Novokhatski, John Seeman, Ulrich Wienands (SLAC), Maria Biagini (INFN/LNF)*
The success of the two B-Factories (PEP-II and KEKB) has encouraged us to look at design parameters for a B-Factory with a 30-50 times increase in the luminosity of the present machines (L~1e36). In order to achieve this high luminosity, the beta y* values are reduced to 3-2 mm, the bunch spacing is minimized (0.6-0.3 m) and the bunch currents are increased. Total beam currents range from 5-25 A. The interaction region (IR) of these "SuperB" designs presents special challenges. Synchrotron radiation fans from local bending in shared magnets and from upstream sources pose difficulties due to the high power levels in these fans. High-order-mode(HOM)heating, effects that have been seen in the present B-factories, will become much more pronounced with the very short bunches and high beam currents. Masking the detector beam pipe from synchrotron radiation must take into account effects of HOM power generation. Backgrounds that are a function of the luminosity will become very important. We present an initial design of an IR with a crossing angle of +/- 14 mrad and include a discussion of the constraints, requirements and concerns that go into designing an IR for these very high luminosity e+e- machines.

Work supported by the Department of Energy under contract number DE-AC03-76SF00515.

**TPPP030—Damping Higher Order Modes in the PEP-II B-Factory Vertex Bellows**
*Stephen Weathersby, Jay Langton, Alexander Novokhatski, John Seeman (SLAC)*
Higher stored currents and shorter bunch lengths are requirements for increasing luminosity in colliding storage rings. As a result, more HOM power is generated in the IP region. This HOM power propagates to sensitive components causing undesirable heating, thus becoming a limiting issue for the PEP-II B-factory. HOM field penetration through RF shielding fingers has been shown to cause heating in bellows structures.

To overcome these limitations, a proposal to incorporate ceramic absorbers within the bellows cavity to damp these modes is presented. Results show that the majority of modes of interest are damped, the effectiveness depending on geometrical considerations. An optimal configuration is presented for the PEP-II B-factory IR bellows component utilizing commercial grade ceramics with consideration for heat transfer requirements.

Work supported by the U.S. Department of Energy under contract number DE-AC03-76SF00515.

**TPPP031—A Proposal for a New HOM Absorber in a Straight Section of the PEP-II Low Energy Ring**
*Stephen Weathersby, Michael Kosovsky, Nadine Kurita, Alexander Novokhatski, John Seeman (SLAC)*
Attainment of high luminosity in storage ring colliders necessitates increasing stored currents and reducing bunch lengths. Consequently, intense beam fields will scatter more power into higher order modes from beam line sources such as collimators, masks and tapers. This power penetrates into sensitive components such as a bellows, causing undesirable heating and limits machine performance. To overcome this limitation we propose incorporating ceramic absorbers in the vicinity of the bellows to damp beam induced modes while preserving a matched impedance to the beam. This is accomplished with an absorber configuration which damps TE dipole and quadrupole traveling waves while preserving TM monopole propagation. A scattering parameter analysis is presented utilizing properties of commercial grade ceramics and indicates a feasible solution.

Work supported by the U.S. Department of Energy under contract number DE-AC03-76SF00515.

**TPPP032—Proposal for a Multi-Use Test Beam Area in the SLAC B-Line**
*Paul Emma, Lynn Bentson, Roger Erickson, Theodore (Ted) Fieguth, John Seeman, Andrei Seryi (SLAC)*
With the impending construction of the Linac Coherent Light Source (LCLS) at SLAC, displacing the well-used Final Focus Test Beam (FFTB) area, there is growing interest in developing a new test beam facility, available during LCLS operations and located in the old B-Line tunnel at the end of the linac. The success of the Sub-Picosecond Pulse Source (SPPS) and the desire to preserve this capacity suggests a new beamline with similar or improved electron beam quality, including bunch length compression to 10 microns. Beam availability during LCLS operations requires a new 1.2-km bypass line connecting the 2/3-point of the linac with the B-Line. A second operating mode, with LCLS not in use, involves a trajectory directly from the end of the linac to the B-line. This feature provides the highest beam quality at 30 GeV, and also allows a possible third operational mode by deflecting a few of the very high-brightness 120-Hz, 14-GeV LCLS bunches at low rate (1-10 Hz) into the B-line. Finally, linear collider research can be carried out in a short final focus system at the end of the B-Line, capable of producing a 70-nm rms beam size. We describe a possible design for these systems.

Work supported by U.S. Department of Energy contract DE-AC02-76SF00515.

**TPPP033—Cavity Alignment Using Beam Induced Higher Order Modes Signals in the TTF Linac**
*Marc Ross, Josef Frisch, Kirsten Elaine Hacker, Roger Michael Jones, Douglas McCormick, Caolionn O'Connell, Tonee Smith (SLAC), Olivier Napoly (CEA/DSM/DAPNIA), Nicoleta Baboi, Manfred Wendt (DESY), Rita Paparella (INFN-Milano)*
Each nine cell superconducting accelerator cavity in the TESLA Test Facility (TTF) at DESY* has two higher order mode (HOM) couplers that efficiently remove the HOM power.** They can also provide useful diagnostic signals. The most interesting modes are in the first 2 cavity dipole passbands. They are easy to identify and their amplitude depends linearly on the beam offset from the cavity axis making them excellent beam position monitors (BPM). By steering the beam through an eight-cavity cryomodule, we can use the HOM signals to estimate internal residual alignment errors and minimize wakefield related beam emittance growth. We built and commissioned a four channel heterodyne receiver and time-domain based waveform recorder system that captures information from each mode in these two bands on each beam pulse. In this paper we present an experimental study of the single-bunch generated HOM signals at the TTF linac including estimates of cavity alignment precision and HOM BPM resolution.
*P. Piot, DESY-TESLA-FEL-2002-08. **R. Brinkmann et al. (eds.), DESY-2001-011.

DE-AC02-76SF00515.

**TPPP034—Parameters of a Super-B-Factory Design**
*John Seeman, Michael K. Sullivan, Ulrich Wienands (SLAC)*
Submitted for the High Luminosity Study Group: Parameters are being studied for a high luminosity e+e- collider operating at the Upsilon 4S that would deliver a luminosity in the range of 7 to 10 x 10^35/cm^2/s. Particle physics studies dictate that a much higher luminosity collider is needed to answer new key physics questions. A Super-B-Factory with 20 to 100 times the performance of the present PEP-II accelerator would incorporate a higher frequency RF system, lower impedance vacuum chambers, higher power synchrotron radiation absorbers, and stronger bunch-by-bunch feedback systems. Parameter optimizations are discussed.

Work supported by DOE contract DE-AC02-76SF00515.

**TPPP035—Performance of the PEP-II e+e- Collider at SLAC**
*John Seeman, Stanley Ecklund, Michael K. Sullivan, Ulrich Wienands (SLAC)*
For the PEP-II Operation Staff: PEP-II is an asymmetric e+e- collider operating at the Upsilon 4S and has recently set several performance records. The luminosity has reached 9.2 x 10^33/cm^2/s. PEP-II has delivered an integrated luminosity of 710/pb in one day. It operates in continuous injection mode for both beams boosting the integrated luminosity. The peak positron current has reached 2.55 A in 1588 bunches. The total integrated luminosity since turn on in 1999 has reached 256/fb. This paper reviews the present performance issues of PEP-II and also the planned increase of luminosity in the near future to over 2 x 10^34/cm^2/s. Upgrade details and plans are discussed.

Work supported by DOE contract DE-AC02-76SF00515.

**TPPP036—A Study of PEP-II Lattice Fixes**
*Gerald Steven Yocky (SLAC)*
In order to determine the efficacy of particular optics fixes implemented into the PEP-II rings, a study of the evolution of measurable parameters and their relation to said fixes is of paramount importance. Phase advance data, orbit response matrix (ORM) data, beam-beam scans, and dispersion measurements are compared to known operator-induced fixes, model

independent analysis (MIA) fixes, IP Beta changes, and steering for PEP-II run 4.

Work supported by Department of Energy contract DE-AC03-76SF00515.

**TPPP037—Beam-Based Aligment in PEP-II LER**
*Gerald Steven Yocky, Janice Nelson, Tonee Smith, James Leslie Turner, Mark Woodley (SLAC)*
Surplus SPEAR-II switchable shunting resistors have been installed on the PEP-II quadrupole strings that lack individual control. Eight fixed shunts are installed in the LER IP region, and another twenty in the LER arcs have a modular installation design to facilitate their re-positioning in several different locations nearby. These shunts provide approximately a two percent decrease in excitation current in the main quadrupole winding and are used in a coupled-beam analysis to determine the beam offset relative to the quadrupole center. A comparison of model calculations and phase-advance data is performed to validate the beam-based alignment (BBA) results. Tune versus quadrupole field data taken during the BBA procedure offer additional parameters for comparison to model calculations and offer a measurement that infers local beta functions.

Work supported by Department of Energy contract DE-AC03-76SF00515.

**TPPP038—Optimizing the Injection System for PEP-II**
*Franz-Josef Decker, Ron Akre, Axel Brachmann, Roger Erickson, Artem Kulikov, Michael Stanek, James Leslie Turner (SLAC)*
The injection system for PEP-II uses many components of the SLAC Linac. The rate is typically 30 Hz to save energy compared to the 60 Hz design number. Since the energy costs have increased since Jan 2005, we are trying to optimize the system with the new changed parameters. There are different goals which are pushing in opposite directions: The operation of PEP-II demands faster fills and more current to fill pushing for a higher rate (60 Hz, two-bunch injection, and/or higher charge per bunch). But this infrequent injection from cratch of 5-10 times a day doesn't justify the higher cost of an injection system at 60 Hz and even lowering it to 15 Hz, which is enough for trickle injection, is under discussion to save about $2000.- per day. So two-bunch injection and quickly increasing the charge per bunch seem to be worth further investigations.

Work supported by U.S. Department of Energy contract DE-AC03-76SF00515.

**TPPP039—Simulating Six Dimensional Cooling of a Muon Beam in a Ring Cooler**
*Amit Klier, Gail G. Hanson (UCR)*
The reduction of the phase-space volume of the beam (cooling) is essential for both muon colliders and neutrino factories. In a muon collider, in particular, the six-dimensional (6D) emittance must be reduced by six orders of magnitude. Cooling the beam in all phase space dimensions can be done through emittance exchange, where the beam loses energy passing through wedge-shaped absorbers in a dispersive magnetic field, designed in a way that fast muons go through more absorber material than slow ones and lose more energy. The longitudinal momentum is then regained using RF cavities. We simulate ring coolers, in which the beam undergoes 6-dimensional cooling through emittance exchange while rotating several times in the ring. The simulation software is a Geant3-based package, specially designed this purpose, with changing electric fields in RF cavities treated correctly. Magnetic fields are read from external maps. Some ring cooler designs and cooling simulation results are presented.

**TPPP040—Front-End Design Studies for a Muon Collider**
*Richard Fernow, Juan Carlos Gallardo (BNL)*
Using muons instead of electrons is a promising approach to designing a lepton-lepton collider with energies beyond that available at the proposed ILC. At this time a self-consistent design of a high-luminosity muon collider has not been completed. However, a lot of progress has been made in simulating cooling and parts of other systems that could play a role in an eventual collider design. In this paper we look at front-end system designs that begin with a single pion bunch produced from a high power mercury target. We present ICOOL simulation results for phase rotation, charge separation, and pre-cooling of the muon beams. A design is presented for a single-frequency phase rotation system that can transmit 0.47 muons per incident proton on the target. A bent solenoid can be used for high-efficiency separation of the positive and negative muon beams.

Work supported by U.S. Department of Energy.

**TPPP041—Recent Developments on the Muon-Facility Design Code ICOOL**
*Richard Fernow (BNL)*
Current ideas for designing neutrino factories and muon colliders require unique configurations of fields and materials to prepare the muon beam for acceleration. We have continued the development of the 3D tracking code ICOOL for examining possible system configurations. Development of the ICOOL code began in 1996 in order to simulate the process of ionization cooling. This required tracking in magnetic focusing lattices, together with interactions in shaped materials that must be placed in the beam path.* The most important particle interactions that had to be simulated were energy loss and straggling. Since the optimum way of designing a cooling channel was not known, the code had to have a flexible procedure for specifying field and material geometries. Eventually the early linear cooling channels evolved into cooling rings. In addition the designs require many other novel beam manipulations besides ionization cooling, such as pion collection in a high field solenoid, rf phase rotation, and acceleration in FFAG rings. We describe new features that have been incorporated in ICOOL for handling these new requirements. A suite of auxilliary codes have also been developed for pre-processing, post-processing, and optimization.
*R.C. Fernow, ICOOL: a simulation code for ionization cooling of muon beams, Proc. 1999 Part. Accel. Conf., New York, p. 3020.

Work supported by U.S. Department of Energy.

**TPPP042—Synchrotron Radiation in eRHIC Interaction Region**
*Joanne Beebe-Wang, Christoph Montag (BNL), Daniel James Rondeau (Binghamton University), Bernd Surrow (MIT), Abhay Deshpande (Stony Brook University)*
The eRHIC currently under study at BNL consists of an electron storage ring added to the existing RHIC complex. The interaction region of this facility has to provide the required low-beta focusing while accommodating the synchrotron radiation generated by beam separation close to the interaction point. In the current design, the synchrotron radiation caused by 10GeV electrons bent by low-beta triplet magnets will be guided through the interaction region and dumped 5m downstream.

However, it is unavoidable to stop a fraction of the photons at the septum where the electron and ion vacuum system are separated. In order to protect the septum and minimize the backward scattering of the synchrotron radiation, an absorber and collimation system will be employed. In this paper, we first present the overview of the current design of the eRHIC interaction region with special emphasis on the synchrotron radiation. Then the initial design of the absorber and collimation system, including their geometrical and physical properties, will be described. Finally, our initial investigation of synchrotron radiation in the eRHIC interaction region, especially a simulation of the backward scattering from the absorber, will be presented.

Work performed under the auspices of the US DOE.

**TPPP043—ERL Based Electron-Ion Collider eRHIC**
*Vladimir N. Litvinenko, Leif Ahrens, Mei Bai, Joanne Beebe-Wang, Ilan Ben-Zvi, Michael Blaskiewicz, Joseph Michael Brennan, Rama Calaga, Xiangyun Chang, Alexei V. Fedotov, Wolfram Fischer, Dmitry Kayran, Jorg Kewisch, William W. MacKay, Christoph Montag, Brett Parker, Steve Peggs, Vadim Ptitsyn, Thomas Roser, Alessandro Ruggiero, Todd Satogata, Bernd Surrow, Steven Tepikian, Dejan Trbojevic, Vitaly Yakimenko, S.Y. Zhang (BNL), Manouchehr Farkhondeh (MIT), Abhay Deshpande (Stony Brook University)*
We present the designs of a future polarized electron-hadron collider, eRHIC* based on a high current super-conducting energy-recovery linac (ERL) with energy of electrons up to 20 GeV. We plan to operate eRHIC in both dedicated (electron-hadrons only) and parallel(with the main hadron-hadron collisions) modes. The eRHIC has very large tunability range of c.m. energies while maintaining very high luminosity up to 1034 cm-2 s-1 per nucleon. Two of the most attractive features of this scheme are full spin transparency of the ERL at all operational energies and the capability to support up to four interaction points. We present two main layouts of the eRHIC, the expected beam and luminosity parameter, and discuss the potential limitation of its performance.
*http://www.agsrhichome.bnl.gov/eRHIC/, Appendix A: Linac-Ring Option.

Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the US Department of Energy.

**TPPP044—Interaction Region Design for the Electron-Light Ion Collider ELIC**
*Christoph Montag (BNL), S. Alex Bogacz, Yaroslav Derbenev, Lia Merminga (Jefferson Lab)*
The Electron-Light Ion Collider ELIC proposed by Jefferson Lab aims at very high luminosities for collisions of 150 GeV protons on 7 GeV electrons. To achieve these high luminosities, very strong low-beta focusing of low-emittance beams is required. Taking advantage of the unequal design proton beam emittances in the two transverse planes, an interaction region design based on superconducting quadrupole doublets has been deveoped. Compared with the original design, this scheme provides larger beam apertures at lower magnetic fields, while potentially doubling the luminosity.

Work performed under the auspices of the U.S. Department of Energy.

**TPPP045—Interaction Region Design for the Electron-Ion Collider eRHIC**
*Christoph Montag, Brett Parker, Steven Tepikian (BNL), Dong Wang (MIT)*
To facilitate the study of collisions between 10 GeV polarized electrons and 100 GeV/u heavy ions or 250 GeV polarized protons at high luminosities, adding a 10 GeV electron storage ring to the existing RHIC complex has been proposed. The interaction region of this electron-ion collider eRHIC has to provide the required low-beta focusing, while simultaneously accomodating the synchrotron radiation fan generated by beam separation close to the interaction point, which is particularly challenging. The latest design status of the eRHIC interaction region is presented.

Work performed under the auspices of the U.S. Department of Energy.

**TPPP046—Improvent of the Muon Collider Momentum Acceptance**
*Dejan Trbojevic (BNL), Carol Johnstone (Fermilab)*
The muon collider facility last component is the storage ring where the muon beams will collide. To reach very high luminosities a zero momentum compaction isochronous ring had previously been designed.* The very narrow buckets in time require large momentum acceptance. A new estimate of the muon cooling and accelerating components, in the future collider facility, shows that the momentum width of the beam will require larger then previously assumed storage ring acceptance. This is an attempt to raise the collider acceptance by reduction of the dispersion function.
*D. Trbojevic, K.Y. Ng, E.D. Courant, S.Y. Lee, C. Johnstone, J. Gallardo, R. Palmer, and S. Tepikian, "Design of the Muon Collider Isochronous Storage Ring Lattice", AIP Conf. Proc. 367, Micro Bunches Workshop, Upton, NY, Sep. 1995, pg.269-279.

Work performed under Contract Number DE-AC02-98CH10886 with the auspicies of the U.S. Deparment of Energy.

**TPPP047—New and Efficient Neutrino Factory Front-End Design**
*Juan Carlos Gallardo, J. Scott Berg, Richard Fernow, Harold G. Kirk, Robert Palmer (BNL), David Neuffer (Fermilab), Kevin Paul (Muons, Inc)*
As part of the APS Joint Study on the Future of Neutrino Physics* we have carried out detailed studies of the Neutrino Factory front-end. A major goal of the new study was to achieve equal performance to our earlier feasibility studies** at reduced cost. The optimal channel design is described in this paper. New innovations included an adiabatic buncher for phase rotation and a simplified cooling channel with LiH absorbers. The linear channel is 295 m long and produces 0.17 muons per proton on target into the assumed accelerator transverse acceptance of 30 mm and longitudinal acceptance of 150 mm.
*APS Multi-Divisional Study of the Physics of Neutrinos, http://www.aps.org/neutrino/. **S.Ozaki, R.B.Palmer, M.Zisman and J.C.Gallardo, edts., Tech. Rep., BNL-52623 (2001), http://www.cap.bnl.gov/mumu/studyii/FS2-report.html.

Work supported by U.S. Department of Energy.

**TPPP048—A Compact Ring for the 6D Cooling of a Muon Beam**
*Harold G. Kirk, Stephen Alan Kahn (BNL), Frederick E. Mills (Fermilab), Don Summers (Mississippi University), David Cline, Yasuo Fukui, Albert A. Garren (UCLA), Romulus Godang (UMiss)*
We discuss a conceptual design for a compact muon cooling system based on a weak-focusing ring loaded with high-pressure Hydrogen gas. We demonstrate that such a ring will be capable

of cooling a circulating muon beam in each of the three spatial dimensions so that 6d cooling of the muon beam phase space is achieved.

U.S. Department of Energy.

**TPPP049—eRHIC Detector Design Studies—Implications and Constraints on the ep(A) Interaction-Region Design**
*Bernd Surrow (BNL)*
An electron-proton/ion collider facility (eRHIC) is under consideration at Brookhaven National Laboratory. This high energy, high intensity polarized electron/positron beam facility to collide with the existing RHIC heavy ion and polarized proton beam would significantly enhance the exploration of fundamental aspects of Quantum Chromodynamics (QCD), the underlying quantum field theory of strong interactions. The design of a new optimized detector is closely coupled to the design of the interaction region and thus to the machine development work in general. A GEANT-based detector simulation framework has been developed to study various processes at eRHIC taking into consideration the impact of machine elements inside the detector volume and the synchrotron radiation fan generated by the electron/positron beam. The GEANT-based detector simulation framework called ELECTRA will be presented followed by a discussion of constraints and implications on the interaction region design.

**TPPP050—Novel Muon Cooling Channels Using Hydrogen Refrigeration and High Temperature Superconductor**
*Emanuela Barzi, Daniele Turrioni (Fermilab), Rolland Johnson, Moyses Kuchnir (Muons, Inc)*
Ionization cooling, a method for shrinking the size of a muon beam, requires a low Z energy absorber, high-field magnets, and high gradient RF. It is proposed to use one gaseous hydrogen system to provide ionization energy loss for muon beam cooling, breakdown suppression for pressurized high-gradient RF cavities, and refrigeration for superconducting magnets and cold RF cavities. We report progress on the design of a cryostat and refrigeration system that circulates hydrogen through magnetic coils, RF cavities, and the absorber volume to achieve a safe, robust means to enable exceptionally bright muon beams. We find that the design can be greatly simplified if a high temperature superconductor can be used that has the capability to carry adequate current in fields above 10 T at a temperature above 33 K, the critical temperature of hydrogen.

This work was supported in part by DOE STTR grant DE-FG02-04ER86191.

**TPPP051—A Muon Cooling Ring with Curved Lithium Lenses**
*Yasuo Fukui, David Cline, Albert A. Garren (UCLA), Harold G. Kirk (BNL)*
We design a muon cooling ring with curved Lithium lenses for the 6 dimensional muon phase space cooling. The cooling ring can be the final muon phase space cooling ring for a Higgs Factory, a low energy muon collider.Tracking simulation shows promising muon cooling with simplified magneti element models.

**TPPP052—Simulations of a Gas-Filled Helical Muon Beam Cooling Channel**
*Katsuya Yonehara, Daniel Kaplan (Illinois Institute of Technology), Kevin Beard, S. Alex Bogacz, Yaroslav Derbenev (Jefferson Lab), Rolland Johnson, Kevin Paul, Thomas Roberts (Muons, Inc)*
A helical cooling channel (HCC) has been proposed to quickly reduce the six-dimensional phase space of muon beams for muon colliders, neutrino factories, and intense muon sources. The HCC is composed of a series of RF cavities filled with dense hydrogen gas that acts as the energy absorber for ionization cooling and suppresses RF breakdown in the cavities. Magnetic solenoidal, helical dipole, and helical quadrupole coils outside of the RF cavities provide the focusing and dispersion needed for the emittance exchange for the beam as it follows a helical equilibrium orbit down the HCC. In the work presented here, two Monte Carlo programs have been developed to simulate a HCC to compare with the analytic predictions and to begin the process of optimizing practical designs that could be built in the near future. We discuss the programs, the comparisons with the analytical theory, and the prospects for a HCC design with the capability to reduce the six-dimensional phase space emittance of a muon beam by a factor of over five orders of magnitude in a linear channel less than 100 meters long.

This work was supported in part by DOE STTR/SBIR grants DE-FG02-02ER86145 and 03ER83722.

**TPPP053—Beryllium RF Windows for Gaseous Cavities for Muon Acceleration**
*Mohammad Alsharo'a (Muons, Inc) Ivan Gonin, Alfred Moretti, Gennady Romanov (Fermilab)*
RF cavities for muon ionization cooling channels can have RF windows over their ends to create better internal voltage profiles and to make them independent of each other. To be effective, the conducting window material must be sufficiently transparent to the muons to not affect the beam cooling, which means low mass and low Z. In the case of pressurized RF cavities, as to opposed to those that operate in vacuum, the RF window design is simplified because the heat deposited in the windows from the RF and the beam is carried off by the hydrogen gas. In this report we analyze the thermal, mechanical, and electrical properties of a simple beryllium grid structure to improve the performance of pressurized RF cavities that are to be used for muon beam cooling.

This work was supported in part by DOE STTR grant DE-FG02-02ER86145.

**TPPP054—Studies of RF Breakdown of Metals in Dense Gases**
*Pierrick M. Hanlet, Mohammad Alsharo'a, Rolland Johnson, Moyses Kuchnir (Muons, Inc), Charles Ankenbrandt, Alfred Moretti, Milorad Popovic (Fermilab), Daniel Kaplan, Katsuya Yonehara (Illinois Institute of Technology)*
A study of RF breakdown of metals in gases has begun as part of a program to develop RF cavities filled with dense hydrogen gas to be used for muon ionization cooling. A pressurized 800 MHz test cell has been used at Fermilab to compare the conditioning and breakdown behavior of copper, molybdenum, chromium, and beryllium electrodes as functions of hydrogen and helium gas density. These results are compared to the predicted or known RF breakdown behavior of these metals in vacuum.

This work was supported in part by DOE STTR grant DE-FG02-02ER86145.

**TPPP055—Simultaneous Bunching and Precooling Muon Beams with Gas-Filled RF Cavities**
*Kevin Paul (Muons, Inc), David Neuffer (Fermilab), Yaroslav Derbenev (Jefferson Lab)*
High-gradient, pressurized RF cavities are investigated as a means to improve the capture efficiency, to effect phase rotation

to reduce momentum spread, and to reduce the angular divergence of a muon beam. Starting close to the pion production target to take advantage of the short incident proton bunch, a series of pressurized RF cavities imbedded in a strong solenoidal field is used to capture, cool, and bunch the muon beam. We discuss the anticipated improvements from this approach to the first stage of a muon cooling channel as well as the requirements of the RF cavities needed to provide high gradients while operating in intense magnetic and radiation fields.

This work was supported in part by DOE SBIR grant DE-FG02-03ER83722.

**TPPP056—A Muon Cooling Demonstration Experiment Using Gaseous Hydrogen**
*Thomas Roberts, Mohammad Alsharo'a, Pierrick M. Hanlet, Rolland Johnson, Moyses Kuchnir, Kevin Paul (Muons, Inc), Charles Ankenbrandt, Alfred Moretti, Milorad Popovic, Victor Yarba (Fermilab), Daniel Kaplan, Katsuya Yonehara (Illinois Institute of Technology)*
Most ionization cooling schemes now under consideration are based on using many large flasks of liquid hydrogen energy-absorber. One important example is the proposed Muon Ionization Cooling Experiment (MICE). In the work reported here, potential muon cooling demonstration experiments based on a gaseous energy absorber are discussed. For transverse cooling, the gaseous absorber leads to a conceptually simpler design than with liquid flasks and has better cooling and several engineering advantages, including the potential of higher accelerating gradients. We report on the development of the concept of an ionization-cooling channel based on a gaseous absorber with high-gradient RF cavities and the design of a channel section suitable for testing in a muon beam. We also discuss the possibility of a six-dimensional cooling demonstration experiment based on a cooling channel using solenoidal and helical dipole magnetic fields.

This work was supported in part by DOE SBIR grant DE-FG02-04ER84015.

## Poster Session TPPT—Radio-Frequency Systems
## Meeting Room 200 A-C, 13:50-17:10

**TPPT001—Computer Simulations of High Beta TRIUMF Quarter Wave Resonators**
*Vladimir Zviagintsev, Robert Edward Laxdal (TRIUMF)*
The second superconductive stage of ISAC-II linac at TRIUMF will comprise high beta quarter wave resonators for bo~0.1. Two variants at 106 and 141 MHz are considered. Computer simulations of the cavities are done with HFSS and ANSYS codes to model rf, mechanical and thermal characteristics. Modifications for compatibility with a cryomodule design separating beam and insulating vacuum are considered.

TRIUMF receives funding via a contribution agreement through the National Research Council of Canada.

**TPPT003—Development of Normal Conducting CH-DTL**
*Gianluigi Clemente, Holger Podlech, Ulrich Ratzinger, Rudolf Tiede (IAP)*
The normal conducting "Crossbar H-Type" (CH) accelerating structure is a good candidate for pulsed, high intensity linac application, covering the energy range from 3 to 100 MeV. H Mode cavities are outstanding in the low-beta range with respect to shunt impedance, high acceleration fields, and compact design, That's why we propose to base the 70 ma, 70 MeV, 352 MHz proton linan for GSI FAIR project on that structure. The actual design consists of 11 CH-DTL's for a total length of around 25 m. Latest results from beam dynamics optimisation will be discussed. Moreover, this paper describes the CH-DTL cavity design with enphasis on the optimisation with MacroWave Studio (single cell cross section, as well as multi cell cavity simulation), and on the achieved progress in the development of mechanical design concepts. A stainless steel multicell model cavity is presently fabricated by our institute in collaboration with GSI, in order to investigate manufacturing and assembly details. Based on this experience, the design of a CH prototipe power cavity will be optimised.

GSI, EU (CARE, contract number RII3-CT-2003-506395).

**TPPT004—A 175 MHz RFQ Design for IFMIF Project**
*Sunao Maebara, Masayoshi Sugimoto (JAERI), Mikio Saigusa, Yuichi Saitou (Ibaraki University), Shinichi Moriyama (JAERI/NAKA)*
International Fusion Materials Irradiation Facility (IFMIF) is an accelerator-based neutron irradiation facility employing the D-Li stripping reaction, to produce the neutron field similar to the D-T Fusion reactor (2MW/m2,20 dpa/year for Fe). The required beam current of 250 mA is realized by two beam lines of 125mA, and the output energies at injector,RFQ and DTL were designed to be 0.1, 5 and 40 MeV,respectively. The operation frequency of 175MHz was selected to accelerate the large current of 125mA. After an intensive beam simulation, the RFQ with a total length of 12m was designed to keep the minimum emittance growth with the RF injection power of 2.3MW CW. For such a 175MHz RFQ, a design for RF input coupler with loop antenna and co-axial window, supplying RF power shared by 3 x 4 ports, was conducted by using the 3-D electromagnetic code of MW-Studio. In order to withstand the voltage exceeding 200kW CW per one loop antenna, the co-axial line of 4 1/16" diameter is necessary, and it is found that the electric field distortion factor less than 1% can be achieved in beam bore only by employing the 4-loop antenna configuration providing the same power for each quadrants.

**TPPT005—Dual Harmonic Operation with Broadband MA Cavities in J-PARC RCS**
*Masanobu Yamamoto (JAERI), Masahiro Nomura, Alexander Schnase, Fumihiko Tamura (JAERI/J-PARC), Shozo Anami, Eizi Ezura, Keigo Hara, Yoshinori Hashimoto, Chihiro Ohmori, Akira Takagi, Masahito Yoshii (KEK)*
In the J-PARC RCS RF system, the fundamental rf acceleration voltage and the 2nd higher harmonic one are applied to each cavity. This is possible, because the magnetic alloy loaded cavities have a broadband characteristic and require no resonant frequency tuning. The tube amplifier provides both rf components. We calculate the operation of the tube under the condition of the dual harmonic, the non-pure resistive load and the class AB push-pull mode.

**TPPT006—Development of RF Input Coupler with a Coaxial Line TiN-Coated Against Multipactoring**
*Tetsuo Abe, Tatsuya Kageyama, Hiroshi Sakai, Yasunao Takeuchi (KEK)*
In one of the normal-conducting RF cavities used in the KEKB operation, we observed unexpected rises of the vacuum pressure at certain input-power levels with and without a beam current. From the simulation study, we identify the pressure rises as an effect of the multipactoring discharge in the coaxial line of the input coupler. According to the simulation results, we have

decided to develop an input coupler with TiN coating on the inner surface of the outer conductor to suppress the multipactoring. The status of the development is shown including the recent results of the high-power tests.

**TPPT007—Application of Highly Pure Copper Lining to RF Cavities for an Electron-Positron Super B Factory**
*Tetsuo Abe, Tatsuya Kageyama (KEK), Tomaru Nakamura, Katsuya Tsujimoto (Asahi Kinzoku Co., Ltd.), Keisuke Tajiri (Churyo Engineering Co., Ltd.), Zenzaburo Kabeya, Toshihiro Kawasumi (MHI)*
We have applied a new copper lining with a high purity and a high electric conductivity to normal-conducting RF cavities for an electron-positron super B factory, in which four-times more beam current is required to be stored than in the present KEK B factory (KEKB). The lining is produced first by electroplating in an acid copper sulfate bath without brightener nor other organic additives, where the current is periodically reversed (PR process). Its electric conductivity is so high as to be comparable to that of the highest-class oxygen-free copper. Then the copper surface is electropolished to make it smoother with no mechanical polishing beforehand. A major difference from the early application to accelerator components is the lining thickness; our target of about 120um is much thinner than the early one. The results of the quantitative estimations of the quality factor and the outgassing rate on the electroplated pillbox test cavities are shown together with investigations of the copper surface.

**TPPT008—New Design of Crab Cavity for SuperKEKB**
*Kazunori Akai, Yoshiyuki Morita (KEK)*
Crab-crossing scheme has been adopted as a baseline design for SuperKEKB, which is planned as an upgrade of KEKB. For the design of crab cavities for SuperKEKB, a very high beam current of 10A with a short bunch length of 3mm must be taken into account. Much heavier damping of any parasitic mode as well as smaller loss factor are required, compared with those of KEKB crab cavities. We propose new design of crab cavities for SuperKEKB. It has a high kick voltage, sufficiently low coupling impedance to any parasitic modes including the fundamental mode, and a considerably low loss factor. The new crab cavity meets the requirements for SuperKEKB.

**TPPT009—High Gradient Study at KEK on X-Band Accelerator Structure for Linear Collider**
*Toshiyasu Higo, Atsushi Enomoto, Shigeki Fukuda, Hitoshi Hayano, Takayuki Saeki, Nobuhiro Terunuma, Ken Watanabe (KEK), Taikan Suehara (University of Tokyo)*
We have fabricated accelerator structures for linear collider of the warm X-band design. These were composed of high-precision-machined parts for reliable wake-field suppression and possible cheap mass production. The structure design is mostly based on GLC/NLC design in collaboration with SLAC but the fabrication and the high-power test are being performed at KEK to conclude the feasibility, though the application to the present linear collider project was terminated. In this paper are presented the high gradient performance of these structures, such as the initial conditioning characteristics, the stability under high-field operation and various characteristics at high-gradient operation. We conclude that the stability requirement for the linear collider of the warm X-band design is barely satisfied but the preservation of the stability over very long period of more than several years is to be further studied.

**TPPT010—HOM Damping of ARES Cavity System for SuperKEKB**
*Tatsuya Kageyama (KEK)*
The ARES cavity scheme is a decisive edge for KEKB to stably accelerate high-current electron and positron beams. The RF structure is a coupled-cavity system where a HOM-damped accelerating cavity is coupled with a large cylindrical energy storage cavity via a coupling cavity between. The HOM-damped structure is designed to be smoothly embedded into the whole coupled-cavity scheme without any structural or electromagnetic incompatibility. Currently, the total HOM power dissipated in the RF absorbers per cavity is about 5 kW according to calorimetric measurements in the KEKB LER with a beam current of 1.6 A. On the other hand, for SuperKEKB aiming at luminosity frontiers over 10^35 cm^-2 s^-1, the total HOM power per cavity is estimated about 100 kW for the LER with the design beam current of 9.4 A. In this article, a new HOM-damped structure of the ARES cavity system designed for the SuperKEKB LER is reported together with the recent activities and future plans for upgrading the HOM absorbers.

**TPPT011—R and D Status of C-Band Accelerating Section for SuperKEKB**
*Takuya Kamitani, Mitsuo Ikeda, Kazuhisa Kakihara, Satoshi Ohsawa, Takashi Sugimura, Kazue Yokoyama (KEK)*
For future energy upgrade of the KEKB injector linac, C-band accelerating section has been developed. First prototype 1-m long section has been installed in the linac and has achieved the accelerating field gradient of 42 MV/m. Developments of second prototype which has thicker coupler iris and third prototype which has smooth surface of the iris are in progress for less frequent breakdown. This paper reports on the recent R and D status of these C-band accelerating sections.

**TPPT012—High Power Testing of Input Couplers for SuperKEKB**
*Hiroshi Sakai (KEK)*
In KEKB, 32 ARES cavities have been successfully operated to stably accelerate high-current electron and positron beams. Currently, each ARES cavity is fed with RF power (frequency = 509 MHz) of about 300 kW through an input coupler, which has a ceramic disk window at the coaxial line section following the doorknob transformer section with a capacitive iris at the rectangular waveguide entrance. For SuperKEKB, which is a challenging project to boost the luminosity frontier beyond 10^35 cm^-2 s^-1, the power capability of the input coupler needs to be upgraded to more than 900 kW, while the design power capability for KEKB is 400 kW. Recently, we have constructed a new test stand in order to simulate the actual operating condition for the input coupler to drive the ARES cavity with the maximum beam loading of 9.4 A expected for the SuperKEKB LER. In this article, the key features of the new test stand are described together with the recent results of high-power tests.

**TPPT013—The Affect of HOM Couplers on the Accelerating Mode in the Damped Cavity at the Photon Factory Storage Ring**
*Takeshi Takahashi, Masaaki Izawa, Shogo Sakanaka, Kensei Umemori (KEK), Tadashi Koseki (RIKEN/RARF/CC)*
Four damped cavities have been working very stably in the Photon Factory storage ring since 1997. The damped cavity has several trapped higher order modes (HOMs) with high Q values. Each frequency of these HOMs is detuned so as not to induce coupled-bunch instabilities. However, the frequency detuning method becomes less effective for a ring with a lower revolution frequency. Therefore, we have developed a HOM coupler that

can reduce Q values of these trapped HOMs. The HOM coupler is a rod antenna type and located in the cylindrical wall of the cavity. Two or Three HOM couplers will be used for the cavity. The affect of these HOM couplers on the accelerating mode is investigated using MAFIA and the result is presented in this paper.

**TPPT014—Induction Acceleration Cavity**
*Kota Torikai, Yoshio Arakida, Tadaaki Kono, Eiji Nakamura, Yoshito Shimosaki, Ken Takayama, Takeshi Toyama, Masayoshi Wake (KEKi), Junichi Kishiro (JAERI/LINAC)*
An induction cavity capable of operating at a repetition rate of 1MHz with a 50% duty has been built and employed for the first induction acceleration of a proton bunch from 500MeV to 8GeV in the KEK-PS.* In this experiment, an acceleration voltage of 4.7kV and an repetition frequency of 667kHz-882kHz were required. The installed induction device consists of three induction cells, each of which can generate a bipolar induction voltage of a maximum output voltage of 2 kV with a flat-top of 300ns and a 25ns rising/falling time. Electrical characteristics of the cavity itself, such as inductance, capacitance, and resistance, have been evaluated in three independent ways: (1) excitation due to a small signal from a network analyzer, (2) excitation by a proton beam as a primary driver, (3) excitation with a actual pulse modulator in an entire system. This paper will compare these results as well as theoretical design values. A general design procedure for an induction acceleration cavity will be given.
*K.Takayama et al., submitted to Phys. Rev. Lett. http://www.arxiv.org/pdf/physics/0412006.

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**TPPT015—Coupler Matching Techniques for C-Band Accelerating Section**
*Kazue Yokoyama, Takuya Kamitani, Satoshi Ohsawa, Takashi Sugimura (KEK)*
Research and development of the c-band accelerating section has proceeded since 2002. This paper reports the development of the second prototype accelerating section. The coupler iris with a 4 mm thick is thicker than the first prototype because of preventing the rf breakdown at the iris edge. The coupler has a single port and the coupler cell is the same length as the waveguide(WR-187). The coupler cavity diameter and the coupling iris were optimized by using the iteration of the rf measurement which is the nordal shift method.

**TPPT016—Development of Co-Based Amorphous Core for Untuned Broadband RF Cavity**
*Toshiyuki Misu (NIRS)*
We have developed a co-based amorphous core as a new magnetic-alloy (MA) core for the loaded RF cavity. Because of its permeability found to be approximately twice as high as that of FINEMET, this MA core is an excellent candidate for constructing a compact broadband RF cavity with less power consumption. In this report, we present our recent studies of the co-based amorphous core's physical properties, performance, and development.

**TPPT017—Fabrication and Test of the Drift Tubes for PEFP 20 MeV DTL**
*Yong-Hwan Kim, Yong-Sub Cho, Hyeok-Jung Kwon (KAERI)*
Drift tubes of PEFP (Proton Engineering Frontier Project) 20MeV DTL contain electro-quadrupole magnet composed of commercial enamel wire cooled with water coolant. Those were fabricated through the process of brazing, assembling, electron-beam welding, and post-machining. During the e-beam welding, temperature increase was kept under 50 degree to protect the EQM wire from thermal damage. We performed several tests such as vacuum leak test, hydraulic test, and electrical test. EQM properties such as effective length, magnetic saturation, and offset between magnetic center and geometric center of DT were measured and recorded also.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**TPPT018—Tuning of PEFP 20 MeV DTL**
*Mi-Young Park, Yong-Sub Cho, Hyeok-Jung Kwon, Kyung Tae Seol, Young-Gi Song (KAERI)*
The PEFP (Proton Engineering Frontier Project) 20 MeV DTL have been constructing in KAERI site. The tuning goals for PEFP DTL are achieving the tank frequency as +- 5 kHz of designed resonant frequency and 1% of field profile through a tank. To tune the tank frequency 8 low power slug tuners per tank are fabricated and the tuning range is +-125 kHz per a tuner. Post couplers with tap to stabilize the field against the perturbation also are fabricated and will be installed every 3rd (1st tank) and 2nd (2,3,4th tank) drift tubes. We set up the bead perturbation measurement equipment as measuring the phase shift of a tank using network analyzer and LabView program. We are finalizing the tuning procedures and also the data calculation program. In this presentation we will show the overall features of the PEFP DTL tuning and discuss the measurement results.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**TPPT019—Numerical Study of Coupling Slot Effects on Beam Dynamics in ILU-12 Industrial Accelerator**
*Vladimir V. Tarnetsky, Vadim Auslender, Ivan Makarov, Michael A. Tiunov (BINP SB RAS)*
At Budker INP, the work is in progress on development of high-efficiency, high-power electron accelerator named ILU-12. The accelerator has a modular structure and consists of a chain of accelerating cavities connected by on-axis coupling cavities with coupling slots in the common walls (the coupling constant is about 0.08). Main parameters of the accelerator are: operating frequency of 176 MHz, electron energy of up to 5 MeV, average beam power of 300 kW. The paper presents results of 3D electromagnetic field numerical simulations for ILU-12 accelerating structure with recovery of quadrupole filed disturbance because of large coupling holes. The results show that accelerating cell geometry chosen eliminates coupling slot influence on the beam dynamics.

The work is supported by ISTC grant #2550.

**TPPT020—30 GHz Power Production in CTF3**
*Walter Wuensch, Claude Achard, Hans-Heinrich Braun, Georges Carron, Roberto Corsini, Alexej Grudiev, Samuli Tapio Heikkinen, Daniel Schulte, Jonathan Sladen, Igor Syratchev, Frank Tecker, Ian Wilson (CERN)*
One of the major objectives of CTF3 (CLIC Test Facility) is the production of 30 GHz power for the high-gradient testing of CLIC accelerating structures. To this end a dedicated beam line, power generating structure and power transfer line have been designed, installed and commissioned. 52 MW of 30 GHz power with a pulse length of 74 ns and a repetition rate of 16 Hz were delivered to the high-gradient test area. This will allow operation of test accelerating structures in the coming run of CTF3 up to

the nominal CLIC accelerating gradient of 150 MV/m and beyond the nominal pulse length. The system is described and the performances of the CTF3 linac, beam line and the rf components are reviewed.

**TPPT021—Tuning and Characterization of the SSRL Microwave Gun Cavity**
*Wai-Keung Lau (NSRRC), Cheng Wei Chen, Huan Yang Chen (NTHU)*
The SSRL rf gun cavity is electromagnetic structure with a half-cell at the cathode end and a full cell at the other end. Instead of coupling through beam pipe to produce the desired pi-mode for beam acceleration, these two cells are coupled through a frequency tunable side-coupled cell. Therefore, the strucuture is actually 3-cell cavity and the pi/2-mode will be used. This paper reports the characterization of these resonant modes at various side-coupled cell tuning conditions. And the behavior of this cavity will also be analytically examined.

**TPPT022—The Structure of the High Frequency Focusing Cells in Linear Ion Accelerators**
*Vasilij Bomko, Olexander Dyachenko, Anatolij Kobets, Elena Dmitrievna Marynina, Zinaida Ptukhina, Sergej Tishkin, Borys Zajtsev (NSC/KIPT)*
The versions of the high frequency quadrupole doublets (RFQD) for proton and heavy ion linear accelerators are discussed. Advantages of focusing of this type over magnetic quadrupoles lie in the simplicity of the structure and high efficiency and reliability of focusing. In the multi-gap structures, focusing periods contain a sequence of focusing and accelerating cells. The elaborated technique of the local cell adjustment provides the high acceleration rate. Various RFQD versions for the specific peculiarities of accelerating structures are discussed. Application of the RF-quadrupole doublets in the spoke cavity, CCDTL and Crossbar structures will allow the application of superconductive cavities for proton acceleration in the range of intermediate energies of 5-100 MeV. In the interdigital H-structures, the application of RFQDs will allow to increase the efficiency of ion beam focusing and to expand the energy range of the ions being accelerated over 10 MeV/u.

**TPPT023—Numerical Calculation of Fields in the Structures**
*Vasilij Bomko, Zinaida Ptukhina, Sergej Tishkin (NSC/KIPT)*
A variant of the integral equation method – the method of auxiliary charges – is used for calculating quasi-electrostatic fields in an RF quadrupole. According to the method, a potential of the electrostatic field is presented as a superposition of point charge fields, the point charges being located outside a region studied at a certain distance from the region. Magnitudes of charges N was determined from the boundary conditions in N points. Specifying the point charges is equivalent to use of a certain charge density on electrode surfaces. The given algorithm is realized in the QFLD code

**TPPT024—Optimization of Symmetrical RF Couplers for S-Band Accelerating Structures**
*Alireza Nassiri, Geoff J. Waldschmidt (ANL)*
A conventional S-band accelerating structure uses only a single coupling iris to transmit rf power from a rectangular waveguide to the accelerating structure. This geometry causes phase and amplitude asymmetries in the input coupler field distribution with which the beam interacts. To minimize the undesired rf transverse fields on the beam, many compensation schemes have been suggested that correct for amplitude asymmetry but do not compensate the phase asymmetry. A more effective way is to introduce a symmetrical double-input coupler. We plan to revisit the double-input coupler S-band accelerating structure to optimize the coupling cells geometry and rf parameters to effectively reduce or eliminate rf transverse deflection fields.

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**TPPT025—Breakdown in RF Cavities**
*Jim Norem, Ahmed Hassanein, Zeke Insepov, Isak Konkashbaev (ANL)*
We present a simple model of breakdown in rf cavities. For most events this involves tensile stress and tensile strength, however other effects can also contribute. We discuss the effects of different materials, fatigue, high pressure gas, primary and secondary emission sites, local field enhancements, dark currents, secondary emission, work functions, magnetic fields, macro and microscopic fracture mechanisms high current densities, surface and subsurface defects, and astronomical power densities. While primarily devoted to normal conductors, this work also has consequences for superconducting rf surfaces.

DOE

**TPPT026—Energy Upgrade of the DUVFEL Linac**
*James Rose (BNL), Joseph Greco, Thomas Seda, Pooran Singh, John Skaritka, Xijie Wang (BNL/NSLS)*
The DUVFEL linac has been upgraded from 200 to 300MeV in order to extend the FEL wavelength down to 100 microns. To achieve this higher beam energy two new klystron/modulators have been installed in addition to a new accelerating tank. A Progammable Logic Controller (PLC) provides the control and interlock functions to the high power systems. The low level rf has been updated and will be described along with the interface to the EPICS control system. The system has been commissioned and initial operating experience will be described.

This work was supported by U.S. Department of Energy.

**TPPT027—53 MHz Beam Loading Compensation for Slip Stacking in the Fermilab Main Injector**
*Joseph Dey, Ioanis Kourbanis (Fermilab)*
Recently In-Phase and Quadrature (I&Q) was added to both the 53 MHz Feedback and Feedforward Beam Loading Compensation for Slip Stacking in the Fermilab Main Injector. With 53 MHz Feedback, we can now turn the 18 Radio Frequency (RF) Stations off down to below 100 V. In using I&Q on Feedforward, beam loading compensation to the beam on both the upper and lower frequencies of Slip Stacking can be applied as we slip the beam. I&Q theory will be discussed.

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**TPPT028—Design of a New Main Injector Cavity for the Fermilab Proton Driver Era**
*Vincent Wu, Zubao Qian, David Wildman (Fermilab)*
In the design report of the Fermilab Proton Driver,* the Main Injector (MI) needs to be upgraded to a 2 MW machine. For the Main Injector radiofrequency (rf) upgrade, R&D efforts are launched to design and build a new rf system. This paper presents the new cavity design study for the rf system. The cavity is simulated with the design code Mafia.**
**Proton Driver Study II, FERMILAB-TM-2169, May 2002, edited by G.W. Foster, W. Chou and E. Malamud. **Computer Simulation Technology, MAFIA 4, December 1996.

Operated by Universities Research Association, Inc. for the U.S. Department of Energy under contract DE-AC02-76CH03000.

**TPPT029—Fabrication of the Prototype 201.25 MHz Cavity for a Muon Ionization Cooling Experiment**

*Robert Rimmer, Stephen Manning, Robert Manus, Larry Phillips, Mircea Stirbet, Genfa Wu (Jefferson Lab), Derun Li, Robert MacGill, John William Staples, Steve Virostek, Michael Zisman (LBNL), Robert Hafley, Richard Martin, Karen Taminger (NASA Langley), Michael Reep, Don Summers (UMiss)*

We describe the fabrication and assembly of the first prototype 201.25 MHz copper cavity for the muon ionization cooling experiment (MICE). This cavity was developed by the US MUCOOL collaboration and will be tested in the new Muon Test Area at Fermilab. We outline the component and subassembly fabrication steps and the various metal forming and joining methods used to produce the final cavity shape. These include spinning, brazing, TIG welding, electron beam welding, electron beam annealing and deep drawing. Assembly of the loop power coupler will also be described. Final acceptance test results are included. Some of the methods developed for this cavity are novel and offer significant cost savings compared to conventional construction methods.

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**TPPT030—RF, Thermal and Structural Analysis of the 201.25 MHz Muon Ionization Cooling Cavity**

*Steve Virostek, Derun Li (LBNL)*

A finite element analysis has been carried out to characterize the RF, thermal and structural behavior of the prototype 201.25 MHz cavity for a muon ionization cooling channel. A single ANSYS model has been developed to perform all of the calculations in a multi-step process. The high-gradient closed-cell cavity is being designed and fabricated for the MUCOOL and MICE (international Muon Ionization Cooling Experiment) experiments. The 1200 mm diameter cavity is constructed of 6 mm thick copper sheet and incorporates a rounded pillbox-like profile with an open beam iris terminated by 420 mm diameter, 0.38 mm thick curved beryllium foils. Tuning is accomplished through elastic deformation of the cavity, and cooling is provided by external water passages. Details of the analysis methodology will be presented including a description of the ANSYS macro that computes the heat loads from the RF solution and applies them directly to the thermal model. The process and results of a calculation to determine the resulting frequency shift due to thermal and structural distortion of the cavity will be presented as well.

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**TPPT031—Coupler Design for the LCLS Injector S-Band Structures**

*Zenghai Li, Lynn Bentson, David Dowell, Cecile Limborg-Deprey, John Schmerge, Liling Xiao (SLAC)*

The LCLS injector is required to provide a 1-nC, 10-ps bunch with a normalized rms transverse projected emittance of less than 1.0-μm. The LCLS beam is generated and accelerated in a 1.6-cell S-band RF gun to 6-MeV followed by two SLAC 3-m S-band accelerator structures to further accelerate the beam to 135 MeV to move it out of the space-charge dominated regime. In the SLAC S-band structures, the RF power feed is through a single coupling-hole (single-feed coupler) which results in a field asymmetry. The time dependent multipole fields in the coupler induce a transverse kick along the bunch and cause the emittance to increase above the LCLS specification. To meet the stringent emittance requirements for the injector, the single-feed couplers will be replaced by a dual-feed racetrack design to minimize the multipole field effects. We will present detailed studies of the multipole fields in the S-band coupler and the improvements with the dual-feed racktrack design using the parallel finite element eigenmode solver Omega3P.

Work supported by the U.S. DOE Contract No. DE-AC03-76SF00515.

**TPPT032—Modifications on RF Components in the LCLS Injector**

*Cecile Limborg-Deprey, David Dowell, Zenghai Li, John Schmerge, Liling Xiao (SLAC)*

Design of the first generation LCLS injector has now been completed. Components are currently under fabrication and their installation is planned for 2006. We discuss the last modifications made on both the 1.6 cell S-Band RF gun and the SLAC S-Band accelerating structures to minimize the beam emittance. We present results from PARMELA computations which justify those modifications, in particular the suppression of the time dependent dipole and quadrupole kicks. Geometry changes to increase the mode separation between the 0 and PI modes are also presented. For the initial geometry with a mode separation of 3.5MHz, the emittance can increase if the appropriate injection time along the klystron pulse is not chosen. For a mode separation of 15MHz, this problem is minimized and the beam dynamics are improved leading to a substantial reduction of total projected emittance.

This work was supported by U.S. Department of Energy, contract No. DE-AC03-76SF00515A06.

**TPPT033—Three-Dimensional Simulations Using the VORPAL Code of Power Absorbtion and Other Electron Effects in X-Band Waveguides**

*Peter Stoltz, Peter Messmer, Chet Nieter (Tech-X), John R. Cary (CIPS; Tech-X)*

We present results of three-dimensional simulations using the VORPAL code of power absorbtion by stray electrons in X-band waveguides. These simulations include field emission from the waveguide surfaces, impact ionization of background gas, and secondary emission from the walls. We discuss the algorithms used for each of these electron effects. We show the power abosrbed as a function of background gas density. Finally, we present scaling results for running these simulations on Linux Clusters.

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**TPPT034—Performance of the RFI Linac Prototype**

*Donald A. Swenson (Linac Systems), W. Joel Starling (Linac Systems)*

A prototype of the Rf Focused Interdigital (RFI) linac structure has been constructed at Linac Systems. The RFI linac structure is basically an interdigital (or Wideröe) linac structure with rf quadrupole focusing incorporated into each drift tube. This prototype, comprising a short, 200-MHz RFQ linac section followed by a short 200-MHz RFI linac section, accelerates protons from an injection energy of 25 keV to an output energy of 2.50 MeV in a total linac structure length of 1.44 meters.

Whereas the linac structures are designed for continuous (cw) operation, the rf power system is limited to a 33% duty factor. The peak structure power of 66 kW and peak beam power of 50 kW is supplied by a 144-kW, 33% duty factor, rf power system. A 20-mA proton beam is supplied by a microwave ECR ion source. The beam is steered and focused into the RFQ aperture by an articulated Einzel lens. The mechanical design of the linac structures will be presented. The operational history and performance of this prototype will be presented.

Supported by the U.S. Department of Energy.

**TPPT035—High-Power RF Testing of a 352-MHz Fast-Ferrite RF Cavity Tuner at the Advanced Photon Source**
*Douglas Horan, Ernest E. Cherbak (ANL)*
A 352-MHz fast-ferrite rf cavity tuner, manufactured by Advanced Ferrite Technology, was high-power tested on a single-cell copper rf cavity at the Advanced Photon Source. These tests measured the fast-ferrite tuner performance in terms of power handling capability, tuning bandwidth, tuning speed, stability, and rf losses. The test system comprises a single-cell copper rf cavity fitted with two identical coupling loops, one for input rf power and the other for coupling the fast-ferrite tuner to the cavity fields. The fast-ferrite tuner rf circuit consists of a cavity coupling loop, a 6-1/8" EIA coaxial line system with directional couplers, and an adjustable 360º mechanical phase shifter in series with the fast-ferrite tuner. A bipolar DC bias supply, controlled by a low-level rf cavity tuning loop consisting of an rf phase detector and a PID amplifier, is used to provide a variable bias current to the tuner ferrite material to maintain the test cavity at resonance. Losses in the fast-ferrite tuner are calculated from cooling water calorimetry. Test data will be presented.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under contract No. W-31-109-ENG-38.

**TPPT036—Higher-Order-Mode Damper Testing and Installation in the Advanced Photon Source 352-MHz Single-Cell RF Cavities**
*Geoff J. Waldschmidt, Douglas Horan, Leonard H. Morrison, Geoffery Pile (ANL)*
Higher-order-mode dampers were recently installed in the storage ring rf cavities at the Advanced Photon Source to eliminate longitudinal coupled-bunch instability. It was discovered that the 540-MHz cavity dipole mode created beam instability at beam currents in excess of 85 mA causing horizontal emittance blowup. Methods of compensating for the instability by detuning the cavities and adjusting the cavity water temperature were becoming more difficult at higher beam currents as tests were performed to prepare for eventual 300-mA beam current operation. Electric field passive dampers located on the median plane of each cavity were determined to be the most promising solution. Simulation models were created and verified with low-power testing of the dampers. High-power testing of the dampers as well as conditioning of the damper ceramic load were also performed at the APS 352-MHz rf test stand and compared with simulation results. Preliminary test results will be discussed.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**TPPT037—A Coaxial Subharmonic Cavity Design for Direct Injection at the Advanced Photon Source**
*Geoff J. Waldschmidt, Alireza Nassiri (ANL)*
Coaxial subharmonic cavity designs are being investigated at the Advanced Photon Source to improve injector reliability by injecting beam directly from the linac to the booster in storage ring top-up mode. The subharmonic system must operate jointly with the present 352-MHz booster to accelerate the beam to 7 GeV with minimal beam degradation. Design considerations must be made to ensure that bunch purity is maintained and that a large percentage of the linac macropulse is captured. An analysis of rf cavity designs using electromagnetic simulation software has been conducted at 58 MHz and 117 MHz. The final design evaluates the total power loss, field uniformity, and peak surface fields to achieve the required gap voltage.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**TPPT038—Development of C-Band Accelerator Structure with Smooth Shape Couplers**
*Takashi Sugimura, Mitsuo Ikeda, Kazuhisa Kakihara, Takuya Kamitani, Satoshi Ohsawa, Kazue Yokoyama (KEK)*
The first C-band accelerator structure for the SuperKEKB injector linac has been operated in the beam line of e+/e- injector linac for KEKB/PF/PF-AR since September, 2003. A new accelerator structure will locate upstream of the first structure. The upstream structure is exposed to higher RF field than that of downstream structure. For the case of first structure, most of an RF breakdown occurs in an input coupler. In order to reduce a frequency of the breakdown, improvement of a coupler is required. In order to suppress a thermionic emission around the coupler iris, thick and smooth iris is adopted for the upstream structure. The development status of this type of upstream structure is described.

**TPPT039—Installation and Testing for Commissioning of Normal Conducting RF Linac Segment in the SNS**
*Yoon W. Kang, Alexander V. Aleksandrov, David E. Anderson, Marianne M. Champion, Mark Champion, Mark Crofford, Craig Deibele, George W. Dodson, Ray E. Fuja, Paul Gibson, Gary Johnson, Peter Ladd, Hengjie Ma, Michael P. McCarthy, Maurice Piller, Johnny Y. Tang, Alexandre Vasilievich Vassioutchenko, Derrick Williams (ORNL/SNS), Daniel Rees, James Stovall, Lloyd Martin Young (LANL), James Billen, William Roybal, Karen Ann Young (LANL/LANSCE), Pamela Gurd, Thomas Hardek (ORNL/ASD)*
The Spallation Neutron Source (SNS) linac employs both normal conducting and superconducting linac cavities that will inject a 1.0 GeV proton beam into its accumulator ring. The normal conducting segment of this linac accelerates the beam to 185 MeV and employs one RFQ and six DTL cavities powered by seven 2.5 MW, 402.5 MHz klystrons and four CCL modules powered by four 5.0 MW, 805 MHz klystrons. Installation and RF conditioning of the RF equipment for normal conducting linac segment have been completed at ORNL with the support of LANL experts. After conditioning the accelerating structures, the linac has been successfully commissioned with beam. This paper reviews the experience in installation, RF conditioning, and commissioning of the normal conducting linac accelerating structures and RF subsystems. Checkout and operation of the RF systems and structures including conditioning procedure establishment and test results compared to the RF design specifications will be discussed.

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**TPPT040—X-Band Dipole Mode Deflecting Cavity for the UCLA Neptune Beamline**
*Robert Joel England, Brendan O'Shea, James Rosenzweig, Gil Travish (UCLA, Los Angeles, California), David Alesini (INFN/LNF, Frascati)*
We report progress on the design and construction of a nine-cell dipole (TM 110 mode) cavity for use as a temporal diagnostic of the 14 MeV 300 pC electron bunches generated at the UCLA Neptune Laboratory linear accelerator, with an anticipated temporal resolution of 150 fs at a peak input power of 50 kW. The cavity is a center-fed standing-wave pi-mode structure, operating at 9.6 GHz, and incorporating a knife-edge and gasket assembly which minimizes the need for brazing or welding. Results of initial RF tests are discussed and compared with simulation results obtained using the commercial code HFSS.

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**TPPT041—RF Tuning and Fabrication Status of the First Module for J-PARC ACS**
*Hiroyuki Ao, Takatoshi Moirshita, Akira Ueno (JAERI/LINAC), Kazuo Hasegawa (JAERI), Yoshishige Yamazaki (JAERI/J-PARC), Masanori Ikegami (KEK), Valentin Paramonov (RAS/INR)*
J-PARC Linac starts with 180-MeV SDTL temporary, and it is upgraded to 400-MeV with 21 ACS (Annular Coupled Structure) modules and two ACS bunchers and two debunchers. First buncher module is under fabrication, and second buncher and a few accelerating modules are also planed until FY2006. The first ACS module consists of two 5-cells ACS tanks and a 5-cells bridge cavity for the buncher module. Three RF tuners are installed to the bridge cavity for fine RF tuning. An operating frequency should be tuned to 972 MHz within the fine-tuning range before a brazing process in a factory. The tuning procedure has been studied with RF simulation analysis and cold-model measurements for ACS and bridge cells. This paper describes RF tuning results, fabrication status and related development items.

**TPPT042—The Simulation Calculations and Dielectric Characteristics Investigation of a Hybrid Dielectric-Iris-Loaded Travelling Accelerating Structure**
*Cong-Feng Wu, Sai Dong, Lin Wang (USTC/NSRL)*
Mafia code has been used to calculate the RF properties versus the geometric parameters and dielectric permittivity for the X-band (f=9.37GHz) hybrid dielectric-iris-loaded traveling accelerating structure. The simulation results show that when the range of the permittivity is about 5-9, the new structure may have lower ratio (about 1) of peak surface electric field at the iris to axial accelerating electric field by optimizing the geometric parameters, while r, Q, r/Q of the new structure being comparable to iris-loaded accelerating structure. The experimental investigations of the permittivity of the ceramics have been made at the X-band by using the cavity perturbation technique. The measured results are in good agreement with the simulation results of Microwave Studio. Furthermore, the stability of the ceramics is examined. A number of experimental results show that the certain ceramic with permittivity of 5.78 is applied to the design of the new accelerating structure.

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**TPPT043—The Studies of Hybrid Dielectric-Iris-Loaded Accelerating Structure**
*Cong-Feng Wu, Hui Lin, Dong Sai (USTC/NSRL)*
The dispersion property and the propagation characteristics of the accelerating mode (TM01 mode) and higher-order-modes about a new hybrid dielectric-iris-loaded accelerating structure have been analysed and discussed by the field matching method. Mafia code has been used to calculate the RF properties versus the geometric parameters and dielectric permittivity for the X-band (f=9.37GHz) hybrid dielectric-iris-loaded traveling accelerating structure. Some model cavities have been developed, and experimental investigations have been carried on. The above results will provided some beneficial datum for the design and manufacture of X-band hybrid dielectric-iris-loaded traveling-wave accelerating structure.

This work is supported by the National Natural Science Foundation of China(No.10375060,10205014) and the Project of Knowledge Innovation Program of the Chinese Academy of Sciences.

**TPPT044—Beam Position Resolution and Centering Accuracy Achieved Using HOM Signals from Damped and Detuned X-Band Accelerator Structures**
*Steffen Doebert, Chris Adolphsen, Roger Michael Jones, James R. Lewandowski, Mauro Torino Francesco Pivi, Juwen W. Wang (SLAC)*
The Next Linear Collider (NLC) and Global Linear Collider (GLC) designs require precision beam-to-accelerator-structure alignment to reduce the effect of short range wakefields. For this purpose, the HOM signals from the structure dipole mode damping ports would be used to determine the beam position in the structure, and then the structures would be moved remotely to center them about the beam (a 5 micron rms alignment is required). In 2000, a test of a 1.8 m prototype structure in the ASSET facility at SLAC achieved 11 micron rms centering accuracy, which was limited by systematic effects caused by beam jitter. This year, such measurements were repeated for a pair of shorter structures (60 cm) that were developed to improve high gradient performance. In addition, the beam position resolution was determined by measuring simultaneously three signal frequencies (14.3, 15, 15.7 GHz) corresponding to modes localized at the beginning, the middle and the end of the structures. In this paper, we present results from the beam centering and position resolution measurements.

Work Supported by DOE Contract DE-AC02-76F00515.

**TPPT045—Accelerator Structure Transverse Dipole Mode Measurement with a Stretched Wire Technique**
*James R. Lewandowski, Gordon B. Bowden, Roger Michael Jones, Juwen W. Wang (SLAC), Nicoleta Baboi (DESY)*
During the 1990s and up until the present day, SLAC and KEK have designed and fabricated X-band traveling wave accelerating structures for a linear collider as part of the NLC and JLC linear collider initiatives. As part of this program, the breakdown and wakefield properties of both traveling wave and standing wave structures were investigated. The long-range wakefield may be decomposed into individual modal components and their properties measured. The ASSET experimental facility has been successfully used for this purpose.* Here we report on a bench-top measurement, the stretched wire technique, in which the transverse modes are measured by recording the transmission characteristics as a function of transverse wire offset. In effect, the wire takes the place of the charged particle beam and readily enables the structure alignment and characteristic kick factors of the modes to be determined. We report on current measurements on X-band structures. The potential for future measurements of

accelerator structures as part of the latest linear collider initiative is also delineated.
*C. Adolphsen et al, SLAC-PUB-7519, 1997.

Work supported by U.S. Department of Energy, Contract DE-AC02-76SF00515.

**TPPT046—Wakefield Measurements of a Pair of Dipole Frequency Interleaved, High Gradient, X-Band Accelerator Structures**
*Chris Adolphsen, Gordon B. Bowden, Steffen Doebert, Valery Dolgashev, Roger Michael Jones, James R. Lewandowski, Zenghai Li, Roger Heering Miller, Mauro Torino Francesco Pivi, Juwen W. Wang (SLAC), Yasuo Higashi, Toshiyasu Higo (KEK)*
In the late 1990's, SLAC and KEK developed methods to suppress the long-range wakefield in 1.8-m-long X-band accelerator structure prototypes for the Next Linear Collider (NLC) and Japanese Linear Collider (JLC) initiatives. Although wakefield suppression was successfully demonstrated, the structures did not operate reliably at the high gradient required (65 MV/m) in these proposals. Since then, shorter (60 cm), lower group velocity structures have been developed that meet the high gradient performance requirements and include the dipole mode damping and detuning features for wakefield suppression. This paper describes the design of a pair of such structures whose dipole mode spectra have a hyperbolic secant-like profile and are interleaved to further reduce the net wakefield of the pair (i.e., the mode frequencies in one structure are effectively are filled-in by the modes from the other structure). Also presented are the wakefields measured for this pair of structures in the ASSET facility at SLAC.

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**TPPT047—Function Investigation of the Dipole Stabilizer Rods in an RFQ**
*Shinian Fu, Huafu Ouyang, Taoguang Xu (IHEP Beijing)*
Dipole field in an RFQ accelerator exerts beam a bending force and thus results in beam losses on the machine. Measures must be taken to diminish the influence of the dipole field. In our recent measurements on a cold model RFQ, we observed some new phenomena associated with the function of dipole stabilizer rods. In this paper we report our results and give an analysis on these results. A new idea of imbalance insertion of the dipole stabilizer rods is proposed for both shifting dipole mode and reducing the dipole components in an RFQ.

**TPPT049—Design and Cold Model Test of 500MHz Damped Cavity for ASP Storage Ring RF System**
*Junko Watanabe, Koichi Nakayama, Kiyokazu Sato, Hidenori Suzuki (TOSHIBA), Alan Jackson, Gregory Scott LeBlanc (ASP), Norio Nakamura, Hiroshi Sakai, Hiroyuki Takaki (ISSP/SRL), Masaaki Izawa (KEK), Tadashi Koseki (RIKEN/RARF/CC)*
TOSHIBA is constructing the storage ring RF system for the Australian Synchrotron Project(ASP). Two pairs of the 500MHz Higher Order Mode(HOM) damped cavities will be applied for this system. The cavities are modified KEK-PF type with silicon-carbide(SiC) microwave absorber and added three HOM anttenas for damping the longitudinal HOM impedance less than 20kOhm/GHz to meet requirement of ASP specification. The shunt impedance has been improved more than 5% in comparison with the original design by reducing the beam bore diameter without degrading HOM damping capability. The design of the cavity and the test results of an Al cold model are described.

**TPPT050—Multi-Beam Rod-Loaded Klystron Cavities**
*Alexei Smirnov, David Yu (DULY Research Inc.)*
Performance of PBG-like structures was studied for multi-defect and single-defect metal cavities. Conceptual designs of a 6-beam, X-band, multi-beam klystron (MBK) demonstrate feasibility of high power generation with efficiency ~63% in a compact structure. Sheet-beam and annular-beam rod-loaded configurations were also investigated.

Work supported by DOE SBIR Grant No. DE-FG02-03ER83845.

**TPPT051—RF Input Power Double Window Coupler for TESLA**
*Quan-Sheng Shu, Guangfeng Cheng, Joseph T. Susta (AMAC)*
More and more accelerators are built with superconducting cavities operating at cryogenic temperatures, and the probability of a ceramic window failure presents increasing problems because of the resulting contamination of the cavities surfaces and the resulting accelerating electric field degradation. A cost effective design and fabrication method for the TESLA cavities has been developed in the framework of a DOE STTR grant. This new design replaces the present TESLA cylindrical ceramic windows with two planar disc windows separated by a vacuum space and is optimized for RF input power, vacuum characteristics, and thermal properties. This novel coupler will reduce the costs of fabrication and improve the RF performance of the coupler, the vacuum between the two windows, and the cleaning procedure. Two couplers with this design have been fabricated and are presently being conditioned for testing at DESY, Germany, and LAL, France, on the RF high power testing stand and on a test cryomodule.

U.S. Department of Energy Grant No. DE-FG02-00ER86102.

**TPPT052—Cryogenic, Magnetic and RF Performance of the ISAC-II Medium Beta Cryomodule at TRIUMF**
*Robert Edward Laxdal, Ken Fong, Amiya Kumar Mitra, Thomas Ries, Igor Sekachev, Guy Stanford, Vladimir Zviagintsev (TRIUMF)*
The medium beta section of the ISAC-II Heavy Ion Accelerator consists of five cryomodules each containing four quarter wave resonators and one superconducting solenoid. The first cryomodule has been designed, assembled and cold tested at TRIUMF. The cryomodule vacuum space shares the cavity vacuum and contains a mu-metal shield, an LN2 cooled, copper thermal shield, plus the cold mass and support system. The bulk niobium cavities are fitted with an LN2 cooled coupling loop fed in series from the side thermal shield and a tuner plate coupled to an out-of-vacuum linear servo motor. All cavities have been locked at the ISAC-II frequency and gradient for extended periods. This paper will report the cryogenic and rf test results from the three cold tests. Of note are measurements of the magnetic field in the cryomodule and estimations of changes in the magnetic field during the test due to trapped flux in the solenoid and magnetization of the environment.

**TPPT053—Low-Beta SC Quarter-Wave Resonator and Cryomodule for SPIRAL 2**
*Stéphane Chel, Pierre-Emmanuel Bernaudin, Pierre Bosland, Guillaume Devanz, Philippe Hardy, Frédéric Michel (CEA/DSM/DAPNIA)*
In the framework of the SPIRAL 2 project to be built in GANIL, we studied a complete cryomodule for the low beta (0.07) superconducting linac. The 88 MHz quarter wave resonators were optimised for RF, mechanical and thermal considerations. A prototype resonator, which differs from the final resonator by

the Helium tank and the removable end-plate geometry and material, has been built. We present the equipments developped for the preparation of this prototype as well as the results of the RF tests. We also detail the mechanical calculation and measurements of the tuning system, and the main aspects of the cryomodule designed to save longitudinal space.

**TPPT054—CW Operation of the TTF-III Input Coupler**
*Jens Knobloch, Wolfgang Anders (BESSY GmbH), Stefan Bauer, Michael Pekeler (ACCEL), Sergey Belomestnykh (Cornell University), Denis Kostin, Wolf-Dietrich Möller (DESY), Andree Buechner, Hartmut Buettig, Frank Gabriel (FZR)*
Many newly proposed light sources, operating in the CW regime, are based on superconducting TESLA technology. Since this was originally developed for pulsed, 1-% duty-factor operation, it is important to determine the limitations of the TESLA cryomodule and its components when operated CW. Among the critical components is the RF input coupler. Two tests have been performed to determine the average power limit of the TTF-III system. First, room temperature tests up to 4 kW were performed at the Forschungszentrum Rossendorf. These permitted the calibration of computer codes developed to calculate the temperature distribution in the coupler. The programs then were used to make predictions for the (normal) cold operation of the coupler. At BESSY, the coupler test stand was assembled inside the HoBiCaT horizontal cryostat test facility to operate the coupler in an environment close to that of a real accelerator. The results of the two tests are presented here.

**TPPT055—Surface Preparation by Electro-Polishing of High Gradient Cavities at DESY**
*Axel Matheisen, Lutz Lilje, Herbert Morales Zimmermann, Bernd Petersen, Manuela Schmoekel, Nicolai Steinhau-Kuehl (DESY)*
Improvement of acceleration gradients in super conducting accelerator structures was reached by applying electro polishing of the niobium surfaces. This technology is actually foreseen to serve as major surface preparation step for projects like the XFEL at DESY and the proposed ILC linear accelerator. At DESY an electro polishing apparatus was build up in 2003. After commissioning the apparatus operates regular for cavity surface treatment. We report on experiences with the electro-polishing set up, polishing parameters and results on the preparation of S.C. resonators for a high gradient module to be tested in the TTF2 accelerator at DESY.

**TPPT056—Design of a Low Loss SRF Cavity for the ILC**
*Jacek Sekutowicz (DESY), Ivan Gonin, Timergali N. Khabibouline, Nikolay Solyak (Fermilab), Peter Kneisel (Jefferson Lab), Yuichi Morozumi, Kenji Saito (KEK), Kwok Ko, Lie-Quan Lee, Zenghai Li, Cho-Kuen Ng, Liling Xiao (SLAC)*
An international team comprising DESY, KEK, JLAB, FNAL and SLAC is collaborating on the design, fabrication and test of a low loss, 1.3 GHz 9-cell SRF structure as a potential improvement for the ILC main linac. The advantages of this structure over the TTF structure include lower cryogenic loss, shorter rise time, and less stored energy. Among the issues to be addressed in this design are HOM damping, Lorentz force detuning and multipacting. We will report on HOM damping calculations using the parallel finite element eigenmode solver Omega3P and the progress made towards an optimized design. Studies on multipacting and estimates of the Lorentz force detuning will also be presented.

**TPPT057—Quality Control of the Electro Polishing Process at DESY**
*Nicolai Steinhau-Kuehl, Axel Matheisen, Bernd Petersen, Manuela Schmoekel (DESY)*
The technology of electro-polishing of super-conducting resonators made from Niobium is foreseen as basic surface preparation technology for the Xfel accelerator project at DESY. Here about 1000 resonators will be build and installed into the accelerator section. For an industrial application of this technique a quality control has to be developed and established.A method to control the acid quality and improve the life time of the acid is under development. We report on the test setup and measurements done on samples and the implementation of this quality control to the DESY electro polishing process.

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**TPPT058—Test of the Superconducting CH-Structure**
*Holger Podlech, Horst Deitinghoff, Horst Klein, Holger Liebermann, Ulrich Ratzinger, Andreas Christoph Sauer (IAP)*
The Crossbar-H-type CH-structure is a new H-mode drift tube-structure operating in the H11-mode. Due to its mechanical rigidity room temperature as well as superconducting cavities can be realized. The superconducting CH-structure has been developed at the IAP in Frankfurt, Germany. To prove the promising results obtained by simulations a 19-cell, 352 MHz (beta=0.1) prototype cavity has been designed and built. This is the first superconducting low energy multi-cell cavity. We present the first cold tests of the cavity which have been performed in the cryogenic laboratory in Frankfurt.

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**TPPT059—Improvement of the Blade Tuner Design for Superconducting RF Cavities**
*Carlo Pagani, Angelo Bosotti, Nicola Panzeri, Rocco Paparella, Paolo Pierini (INFN/LASA)*
As of today, no complete technological solution exists for a cold tuning system fulfilling the requirements envisaged for the International Linear Collider, based on the superconducting RF technology. We present here the design improvements for the blade tuner, a coaxial device, which can provide both the slow structure tuning and the fast tuning capabilities needed for Lorentz Force Detuning (LFD) compensation and microphonics stabilitization (by means of the integration with a piezoelectric system). The system has been originally built by INFN and installed and tested at DESY on the superstructures, since it is located around the cavity helium vessel and does not require longitudinal clearance. Its design here is parametrically reviewed in terms of the requirements for higher accelerating fields and of the mechanical integration with a piezoelectric based system for the LFD and microphonics compensation.

This work is partially supported by the European Community-Research Infrastructure Activity under the FP6 “Structuring the European Research Area” programme (CARE, contract number RII3-CT-2003-506395).

**TPPT060—Design of a Multi-Cell, HOM Damped Superconducting Cavity for the Strong RF Focusing Experiment at DAFNE**
*Alessandro Gallo, David Alesini, Roberto Boni, Fabio Marcellini (INFN/LNF), Carlo Pagani (INFN/LASA; DESY)*
A strong RF focusing experiment to be performed at the DAFNE Phi-factory has been proposed to create and observe a bunch

length modulation along the ring. The very large RF gradient required to reach the strong focusing regime can only be obtained by using a multi-cell superconducting cavity. Moreover, in order to demonstrate the feasibility of a high luminosity collider based on this principle, a total multibunch current of the order of 1A has to be stored under stable conditions in this regime. A 1.3 GHz 7-cells cavity has been designed for this purpose, based on the TESLA geometry with small modifications of the basic cell to comply with the DAFNE revolution frequency. The number of cells has been changed from 9 to 7 to reduce the number of the cavity HOMs, while the beam tubes have been enlarged to let most of the HOMs propagate and be damped by room-temperature ferrite rings. The modes of the first longitudinal band, which include the accelerating TM010_pi, do not propagate in the beam tubes and have been studied with special care to prevent the overlap with the bunch revolution harmonics and/or the synchrotron tune sidebands.

**TPPT061—Prototyping of a 352 MHz, beta=0.17 Superconducting Coaxial Half Wave Resonator**
*Alberto Facco, Fabio Scarpa, Davide Zenere (INFN/LNL), Vladimir Zviagintsev (TRIUMF)*
We have designed a 352 MHz superconducting coaxial half wave resonator with beta=0.17. The cavity has a mechanical design similar to the LNL beta=0.31 one developed in 2004. It is very compact (232 mm real-estate length) and it is equipped with a side tuner not exposed to liquid helium, to make it insensitive to pressure fluctuations. Operation is foreseen at 4.2 K. The beta=0.17 cavity fills the gap from 5 to ~25 MeV between the LNL proton RFQ, under construction, and and the existing beta=0.31 half wave resonator. This allows a 5¸100 MeV proton linac working at 352 MHz with 2 types of coaxial HWR cavities with large velocity acceptance, thus able to accelerate also other ion species (e.g. deuterons). A similar scheme was previously proposed for Spoke resonators; the aim of the HWR choice is compactness and cost reduction. The beta=0.17 cavity is presently under construction in the SPES R&D program at LNL; first test results are expected by the end of 2005.

**TPPT062—High Power Tests of the Prototype Cryomodule for ADS Superconducting Linac**
*Eiji Kako, Shuichi Noguchi, Norihito Ohuchi, Toshio Shishido, Kiyosumi Tsuchiya (KEK), Etsuji Chishiro (JAERI), Nobuo Ouchi (JAERI/LINAC)*
A prototype cryomodule containing two 9-cell superconducting cavities of beta=0.725 and fo=972MHz had been constructed under the collaboration of Japan Atomic Energy Research Institute (JAERI) and High Energy Accelerator Research Organization (KEK) on the development of superconducting LINAC for Accelerator Driven System (ADS). Cool-down tests to 2.0K of the cryomodule and high power tests with a 972MHz pulsed klystron have been successfully carried out. Rf power of 350kW in a pulsed operation of 3msec and 25Hz was transferred to the nine-cell cavity through an input coupler. Accelerating gradients of about 14MV/m higher than the specification (10MV/m) were achieved in both cavities. Design and performance of the prototype cryomodule and the test results with high rf power will be reported.

**TPPT063—Higher-Order-Mode Damping of L-Band Superconducting Cavity Using a Radial Transmission Line**
*Kensei Umemori, Masaaki Izawa, Kenji Saito, Shogo Sakanaka (KEK)*
For energy-recovery-linac(ERL)-based future light souces, excellent damping of higher-order-modes (HOM) is required for preventing beam breakup. As a promising method for this purpose, we propose damping of higher-order-modes using a radial transmission line with a choke structure. Investigation of the HOM performance is underway using a copper model cavity of the TESLA type. Our concept of HOM damping and some results of low-power measurements are presented.

**TPPT064—Design of a Prototype Superconducting Third Harmonic RF Sytem at PLS**
*Eun-San Kim, Myung-Hwan Chun, Hyung-Gyun Kim, Kyungryul Kim, In-Soo Park, Young-Uk Sohn (PAL)*
The beam lifetime in the low-emittance ring of 2.5 GeV PLS is mainly determined by the Touschek lifetime. In the emittance of 10 nm and beam current of 250 mA, the beam life time is estimated to be around 6 hours. A superconducting third harmonic RF system at PLS can increase the beam lifetime by a factor of 2.5. This paper presents the results of detailed design for the prototype superconducting third harmonic RF system at PLS. The cavity is also designed in a way to almost eliminate the higher order modes.

**TPPT065—Cryogenic-Related Performance of a SRF Cavity Module in NSRRC**
*Ming-Chyuan Lin, Lung-Hai Chang, Shu-Shen Chang, Fu-Tsai Chung, Jen-Chieh Lin, Gwo-Huei Luo, Chaoen Wang, Tz-Te Yang, Meng-Shu Yeh (NSRRC)*
A supreconducting 500-MHz cavity module has been installed into the storage ring of NSRRC. This SRF module is tested both on the RF and cryogenic performances, before and after installaion. Calibration and measurements on its cryogenic losses at different operation helium bath pressures are descibed and concluded. Also the results of Qo tests are reported. Meanwhile the excellent stability of helium bath pressure, thanks to the adjustments of valve controller parameters, helps a lots on all the measurements.

**TPPT066—Operational Experience of the Superconducting Radio Frequency Cavity at NSRRC**
*Chaoen Wang, Lung-Hai Chang, Shu-Shen Chang, Chien-Te Chen, Fu-Tsai Chung, Feng-Zone Hsiao, Gao-Yu Hsiung, Kuo-Tung Hsu, Chin-Cheng Kuo, Ming-Chyuan Lin, Ren-Jie Lin, Yao-Kwang Lin, Gwo-Huei Luo, Ming-Hsum Tsai, Jia-Ying Yang, Tz-Te Yang, Meng-Shu Yeh (NSRRC)*
A superconducting radio frequency (SRF) cavity of CESR-III design was installed sucessfully in the electron storage ring at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. The project goals are to double the photon flux by raising the electron beam current and to increase the beam stability by taking advantage of the well-damped high-order modes of SRF cavity. Nowadays, SRF cavity has become the key technology for new synchrotron light sources under construction or planning worldwide. The first operational experience of the SRF cavity at the NSRRC will be presented.

**TPPT067—High Power Coupler Test Results for the ERLP**
*James Henry Paul Rogers, Carl David Beard (CCLRC/DL/ASTeC)*
Two superconducting RF modules of the ELBE type have been ordered from Accel Instruments GmbH for use on the Energy Recovery Linac Prototype (ERLP) being built at Daresbury Laboratory. One structure is to be used as a booster module, with an energy gain of 8 MeV, and the other to act as an energy recovery linac operating at an electron beam energy of up to 35 MeV. High power couplers capable of handling up to 10 kW CW are required to provide successful operation of the ERLP. The conditioning begins with the waveguide windows. The windows are initially exposed to pulses of low RF power, as the

conditioning progresses the RF power is incremented until the windows are exposed to full power. Throughout this procedure the standing wave is used. The forward and reflected power, arcing, temperature and vacuum are all monitored and form control system interlocks. Subsequently the power couplers are conditioned and tested using a purpose built test stand. Once again the standing wave is utilised to provide the high electric field. Four devices including RF windows have been conditioned and tested, this report describes the test equipment and procedure summarising the results obtained.

ASTeC, CCLRC Daresbury Laboratory.

**TPPT068—Optimized Shape of Cavity Cells for Apertures Smaller than in TESLA**

*Valery D. Shemelin (Cornell University)*

The accelerating rate (Eacc) of TESLA cavities can be increased for the same iris aperture if 1) some increase of Epk/Eacc is permitted so that the value of Hpk/Eacc can be lowered in comparison with the original cells (Epk and Hpk are maximal surface electric and magnetic fields); 2) shape of the cells is described by two elliptic arcs; 3) the reentrant cells obtained as a result of consecutive optimization with this geometry are treated as a possible version of cells in spite of some complications for fabrication. Not only the value of Hpk/Eacc can be improved but also values of cell-to-cell coupling and the geometry constants R/Q and G grow with the transition to the reentrant shapes. And these are not all benefits of this shape. The increased coupling prompts that the aperture of the original cell is big enough to be decreased without loss of field flatness in comparison with the original design. This decrease will lead to further increase of the Eacc for the same Hpk also as to improvement of others important parameters. Here, results of calculations for the original and for smaller apertures are presented and proposals for a better choice of TESLA cavity cells are derived.

Cornell University

**TPPT069—Design Considerations for the Mechanical Tuner of the RHIC Electron Cooler RF Cavity**

*Jim Rank, Ilan Ben-Zvi, Harald Hahn, Gary McIntyre (BNL), Edward Daly, Warren Funk, Joseph P. Preble (Jefferson Lab)*

The ECX Project, Brookhaven Lab's predecessor to the RHIC e-Cooler, includes a prototype RF tuner mechanism capable of both coarse and fine tuning of the superconducting RF cavity. This tuner is adapted originally from a DESY design concept but with a longer stroke and significantly higher loads due to our very stiff cavity shape. Structural design, kinematics, controls, thermal and RF issues are discussed and certain improvements are proposed.

Work is supported by the DOD Joint Technology Office and by the U.S. Department of Energy.

**TPPT070—Development of the Superconducting 3.9 GHz Accelerating Cavity at Fermilab**

*Nikolay Solyak, Tug Tacku Arkan, Pierre Bauer, Leo Bellantoni, Cristian Boffo, Evgueni Borissov, Harry Carter, Helen Edwards, Mike H. Foley, Ivan Gonin, Timergali N. Khabibouline, Shekhar Mishra, Donald Mitchell, Allan Rowe, Iouri Terechkine (Fermilab)*

A superconducting third harmonic accelerating cavity (3.9 GHz) was proposed to mprove beam quality in the TTF-like photoinjector. Fermilab has developed, built and tested several prototypes, including two copper 9-cell cavities, and niobium 3-cell and 9-cell cavities. The helium vessel and frequency tuner for the 9-cell cavity was built and tested as well. In cold tests, we achieved a peak surface magnetic field of ~120mT, well above the 70mT specification. The accelerating gradient was limited by thermal breakdown. Studies of the higher order modes in the cavity revealed that the existing cavity design with two HOM couplers will provide sufficient damping of these modes. In this paper we discuss the cavity design, results of the studies and plans for further development.

U.S. Department of Energy.

**TPPT071—Preliminary Results on the Simultaneous Excitation of the TM010 and TE011 Modes in a Single Cell Niobium Cavity**

*Gianluigi Ciovati, Peter Kneisel (Jefferson Lab)*

Simultaneous excitation of both TM010 and TE011 modes has been proposed recently for superconducting photoinjector applications to take advantage of the accelerating field of the TM mode, combined with the focusing magnetic field of the TE mode. Simultaneous excitation of both modes has been carried out on a CEBAF single cell cavity. The cavity has two beam pipe side-ports for each mode for input and pick-up couplers. Coupling to the TE011 mode is done by magnetic loop couplers while for the TM010 mode coaxial antennas are used. The TE011 mode has the property of having zero surface electric field, surface magnetic field orthogonal to the one in the TM010 mode and concentrated in the iris/wall regions of the cavity. The presence of both modes in the cavity at the same time can also be used to investigate the so-called high field Q-drop in the TM010 mode. This paper will present some preliminary result on the test of the single cell cavity at 2K.

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**TPPT072—Effects of Electric and Magnetic Fields on the Performance of a Superconducting Cavity**

*Gianluigi Ciovati, Peter Kneisel (Jefferson Lab), Jacek Sekutowicz, Waldemar Singer (DESY)*

A special two-cell cavity was designed to obtain surface field distributions suitable for investigation of electric and magnetic field effects on cavity performance. The cavity design and preliminary results were presented in a previous contribution. The bulk niobium cavity was heat-treated in a vacuum furnace at 1250C to improve the thermal conductivity. Three seamless hydroformed NbCu cavities of the same design were fabricated to investigate the role of the electron beam welds located in high field areas.

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**TPPT073—Testing of the New Tuner Design for the CEBAF 12 GeV Upgrade SRF Cavities**

*Edward Daly, Kirk Davis, Robby Hicks (Jefferson Lab)*

The new tuner design for the 12 GeV Upgrade SRF cavities consists of a coarse mechanical tuner and a fine piezoelectric tuner. The mechanism provides a 30:1 mechanical advantage, is pre-loaded at room temperature and tunes the cavities in tension only. All of the components are located in the insulating vacuum space and attached to the helium vessel, including the motor, harmonic drive and piezoelectric actuators. The requirements and detailed design are presented. Measurements of range and resolution of the coarse tuner are presented and discussed.

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**TPPT074—Simulation Study of Electronic Damping of Microphonic Vibrations in Superconducting Cavities**
*Alicia Hofler, Jean Roger Delayen (Jefferson Lab)*
Electronic damping of microphonic vibrations in superconducting rf cavities involves an active modulation of the cavity field amplitude in order to induce ponderomotive forces that counteract the effect of ambient vibrations on the cavity frequency. In lightly beam loaded cavities, a reduction of the microphonics-induced frequency excursions leads directly to a reduction of the rf power required for phase and amplitude stabilization. Jefferson Lab is investigating such an electronic damping scheme that could be applied to the JLab 12 GeV upgrade, the RIA driver, and possibly to energy-recovering superconducting linacs. This paper discusses a model and presents simulation results for electronic damping of microphonic vibrations.

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**TPPT075—Influence of Ta Content in High Purity Niobium on Cavity Performance**
*Peter Kneisel, Ganapati Myneni (Jefferson Lab), Dieter Proch, Waldemar Singer, Xenia Singer (DESY), Tadeu Carneiro (Reference Metals)*
In a previous paper* we have reported about initial tests of single cell 1500 MHz cavities made from high purity niobium with three different Ta contents of 160 ppm, ~600 ppm and ~1400 ppm. These cavities had been treated by buffered chemical polishing several times and 100 mm, 200 mm and 300 mm of material had been removed from the surfaces. This contribution reports about subsequent tests following post purification heat treatments with Ti and "in situ" baking. As a result, all cavities exhibited increased quench fields due to the improved thermal conductivity after the heat treatment. After the "in situ" baking at 120C for ~40 hrs the always present Q-drop at high fields disappeared and further improvements in accelerating gradient could be realized. Gradients as high as Eacc = 35 MV/m were achieved and there were no clear indications that the cavity performance was influenced by the Ta content in the material. A multi-cell cavity from the high Ta content material is being fabricated and results will be presented at this conference.
*P. Kneisel et al., Linac 2004.

Work supported by the U.S. DOE Contract No DE-AC05-84ER40150.

**TPPT076—Preliminary Results from Single Crystal and Very Large Crystal Niobium Cavities**
*Peter Kneisel, Gianluigi Ciovati, Ganapati Myneni (Jefferson Lab), Jacek Sekutowicz (DESY), Tadeu Carneiro (Reference Metals)*
We have fabricated and tested several single cell cavities using material from very large grain niobium ingots. In one case the central grain exceeded 7" in diameter and this was used for a 2 GHz cavity. This activity had a dual purpose: to investigate the influence of grain boundaries on the often observed Q-drop at gradients Eacc > 20 MV/m in the absence of field emission, and to study the possibility of using ingot material for cavity fabrication without going through the expensive process of sheet fabrication. The sheets for these cavities were cut from the ingot by wire electro-discharge machining (EDM) and subsequently formed into half–cells by deep drawing. The following fabrication steps were standard: machining of weld recesses, electron beam welding of beam pipes onto the half cells and final equator weld to join both half cell/beam pipe subunits.The cavities showed heavy Q–disease caused by the EDM; after hydrogen degassing at 800C for 3 hrs in UHV the cavities showed promising results, however, a Q-drop above Eacc ~ 20 MV/m was still present. Testing of the cavities is still ongoing – so far accelerating gradients of 30 MV/m have been achieved.

Work supported by the U.S. DOE Contract No DE-AC05-84ER40150.

**TPPT077—Testing of HOM Coupler Designs on a Single Cell Niobium Cavity**
*Peter Kneisel, Gianluigi Ciovati, Genfa Wu (Jefferson Lab), Jacek Sekutowicz (DESY)*
Coaxial higher order mode (HOM) couplers were developed initially for PETRA cavitiesand subsequently for TESLA cavities. They were adopted later for SNS and Jlab upgrade cavities. The principle of operation is the rejection of the fundamental mode by the tunable filter configuration of the coupler and the transmission of the HOMs. It has been recognized recently that, in high average power applications, the pick-up probe of the HOM coupler must be superconducting in order to avoid substantial heat dissipation by the fundamental mode fields and deterioration of the cavity Q. In addition, the thermal conduction of existing rf feedthrough designs is only marginally sufficient to keep even the niobium probe tip superconducting in cw operation. We have equipped a single-cell niobium cavity with different HOM coupler configurations and tested the different designs by measuring Q vs Eacc behavior at 2 K for different feedthroughs and probe tipmaterials.

Work supported by the U.S. DOE Contract No DE-AC05-84ER40150.

**TPPT078—Performance of Single-Cell SC Cavities for the JLab FEL 100mA Injector Upgrade Cryomodule**
*Joseph Paul Ozelis, John Mammosser, Jeffrey Saunders, Haipeng Wang (Jefferson Lab), Michael Cole, John Rathke, Alan Murray Melville Todd (AES)*
Jefferson Lab and Advanced Energy Systems, Inc. are collaborating on the design, fabrication, and testing of a superconducting cryomodule that will be used as a high-current injector for the JLab FEL 100kW upgrade, capable of accelerating electrons at beam currents up to 100mA. The accelerating gradients will be provided by three single-cell superconducting cavities operating at 748.5MHz, a sub-harmonic of the FEL operating frequency of 1497MHz. The cavities, based upon the SNS beta=0.8 cavity shape, and designed to provide peak accelerating surface fields of over 30 MV/m, were fabricated by AES and processed and tested at JLab. The details of cavity processing and performance test results, including Qo vs E measurements, HOM filter performance, and tuner sensitivity, are presented and compared with expected values.

**TPPT079—Performance Overview of the Production Superconducting RF Cavities for the Spallation Neutron Source Linac**
*Joseph Paul Ozelis, Jean Roger Delayen, John Mammosser (Jefferson Lab)*
As part of its efforts for the SNS construction project, Jefferson Lab has produced 23 cryomodules for the superconducting linac. These modules contained 81 industrially produced multicell Nb accelerating cavities. Each of these cavities was individually tested before assembly into a cryomodule to verify that they achieved the required performance. This ensemble of cavities represents the 3rd largest set of production superconducting cavities fabricated and tested to date. The timely qualification testing of such a collection of cavities offers both challenges and opportunities. Their performance can be characterized by achieved gradient at the required Qo, achieved peak surface field, onset of field emission, and observations of multipacting.

Possible correlations between cavity performance and process parameters, only really meaningful in the framework of a large scale production effort, will also be presented. In light of the potential adoption of these cavities for projects such as the Rare Isotope Accelerator or Fermilab Proton Driver, such an analysis is crucial to their success.

Work supported by U.S. Department of Energy under contract DE-AC05-84ER40150.

**TPPT080—Commissioning and Operational Experience With an Intermediate Upgrade Cryomodule for the CEBAF 12 GeV Upgrade**

*Tom Powers, Kirk Davis, Michael Allen Drury, Christiana Grenoble, Larry King, Tomasz Plawski, Joseph P. Preble (Jefferson Lab)*

Two cryomodules have been designed and built as intermediate prototypes for the CEBAF 12 GeV upgrade. This paper will discuss the commissioning and operational experience with the second of these cryomodules, which was installed and commissioned in the Jefferson Lab 10 kW Free Electron Laser Facility. Within the cryomodule are eight, 7-cell, 1497 MHz cavities. It was designed to accelerate 1 mA of beam in excess of 70 MV and to have the same foot print as a standard CEBAF cryomodule. The cryomodule was installed in parallel to the FEL beam line in the spring of 2004 and characterized simultaneous with beam delivery. It was installed in the beam line in the early summer of 2004 and has since been operated as part of an energy recovered linac with 5 mA of beam current and 75 MV accelerating gradient for extended periods of time. Additionally, it has been operated at 1 mA of beam current and 80 MV of accelerating gradient for several hours without a trip. In the latter operating mode the beam current was limited by the injector setup. The design has proven to be both robust and reliable with several months of trouble free operation.

Supported by U.S. DOE Contracts Nos. DE-AC05-84ER40150.

**TPPT081—Fabrication and Testing of the SRF Cavities for the CEBAF 12 GeV Upgrade Prototype Cryomodule Renascence**

*Charles E. Reece, Edward Daly, Stephen Manning, Robert Manus, Samuel Morgan, Joseph Paul Ozelis, Larry Turlington (Jefferson Lab)*

Twelve seven-cell niobium cavities for the CEBAF 12 GeV upgrade prototype cryomodule Renascence have been fabricated at JLab and tested individually. This set includes four of the "Low Loss" (LL) design and eight of the "High Gradient" (HG) design. The fabrication strategy was an efficient mix of batch job-shop component machining and in-house EBW, chemistry, and final-step machining to meet mechanical tolerances. Process highlights will be presented. The cavities have been tested at 2.07 K, the intended CEBAF operating temperature. Performance exceeded the tentative design requirement of 19.2 MV/m cw with less than 31 W dynamic heat dissipation. These results, as well as the HOM damping performance will be presented.

This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

**TPPT082—High Thermal Conductivity Cryogenic RF Feedthroughs for Higher Order Mode Couplers**

*Charles E. Reece, Edward Daly, Thomas Elliott, Joseph Paul Ozelis, Larry Phillips, Timothy Moore Rothgeb, Katherine Wilson, Genfa Wu (Jefferson Lab)*

The use of higher-order-mode (HOM) pickup probes in the presence of significant fundamental rf fields can present a thermal challenge for cw or high average power SRF cavity applications. The electric field probes on the HOM-damping couplers on the JLab "High Gradient" and "Low Loss" seven-cell cavities for the CEBAF upgrade are exposed to approximately 10% of the peak magnetic field in the cavity. To avoid significant dissipative losses, these probes must remain superconducting during operation. Typical cryogenic rf feedthroughs provide a poor thermal conduction path for the probes, and provide inadequate stabilization. We have developed solutions that meet the requirements, providing a direct thermal path from the niobium probe, thorough single-crystal sapphire, to bulk copper which can be thermally stationed (or heat sunk). Designs, electromagnetic and thermal analyses, and performance data will be presented.

This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

**TPPT083—RF Conditioning and Testing of Fundamental Power Couplers for SNS Superconducting Cavity Production**

*Mircea Stirbet, Kirk Davis, Michael Allen Drury, Christiana Grenoble, James Henry, Ganapati Myneni, Tom Powers, Katherine Wilson, Mark Wiseman (Jefferson Lab), Isidoro Enrico Campisi, Yoon W. Kang, Daniel Stout (ORNL/SNS)*

The Spallation Neutron Source (SNS) makes use of 33 medium beta (0.61) and 48 high beta (0.81) superconducting cavities. Each cavity is equipped with a fundamental power coupler, which should withstand the full klystron power of 550 kW in full reflection for the duration of an RF pulse of 1.3 msec at 60 Hz repetition rate. Before assembly to a superconducting cavity, the vacuum components of the coupler are submitted to acceptance procedures consisting of preliminary quality assessments, cleaning and clean room assembly, vacuum leak checks and baking under vacuum, followed by conditioning and RF high power testing. Similar acceptance procedures (except clean room assembly and baking) were applied for the airside components of the coupler. All 81 fundamental power couplers for SNS superconducting cavity production have been RF power tested at JLAB Newport News and, beginning in April 2004 at SNS Oak Ridge. This paper gives details of coupler processing and RF high power-assessed performances.

This work was supported by U.S. DOE contract DE-AC0500R22725.

**TPPT084—Surface Study of Nb/Cu Films for Cavity Deposition by ECR Plasma**

*Andy Ting Wu, Robert Clifton Ike, Larry Phillips, Anne-Marie Valente, Haipeng Wang, Genfa Wu (Jefferson Lab)*

Deposition of thin niobium (Nb) films on copper (Cu) cavities, using an electron cyclotron resonance (ECR) plasma appears to be an attractive alternative technique for fabricating superconducting radio frequency cavities to be used in particle accelerators. The performance of these Nb/Cu cavities is expected to depend on the surface characteristics of the Nb films. In this paper, we report on an investigation of the influence of deposition energy on surface morphology, microstructure, and chemical composition of Nb films deposited on small Cu disks employing a metallographic optical microscope, a 3-D profilometer, a scanning electron microscope, and a dynamic secondary ion mass spectrometer. The results will be compared with those obtained on Nb surfaces treated by buffered chemical polishing, electropolishing, and buffered electropolishing.

Possible implications from this study for Nb deposition on real Cu cavities will be discussed.

This manuscript has been authorized by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

**TPPT085—Niobium Thin Film Coating on a 500-MHz Copper Cavity by Plasma Deposition**
*Haipeng Wang, Larry Phillips, Robert Rimmer, Anne-Marie Valente, Andy Ting Wu, Genfa Wu (Jefferson Lab)*
A system for the deposition, using an ECR plasma source, of a thin film of niobium inside a copper cavity for superconducting accelerator applications has been designed and is being constructed. The system uses a 500-MHz copper cavity as the substrate and the vacuum chamber. The ECR plasma will be created to produce direct niobium ion deposition. The central cylindrical grid is biased to realize the energy controlled deposition. This report describes the design of several subcomponents including the vacuum chamber, RF supply, biasing grid and magnet coils. Operational parameters are compared between a working small-sample deposition system and this system. Initial plasma simulation also suggested that plasma ignition in this cavity system is feasible.

This work was supported by DOE contract DE-AC05-84ER40150 Modification No. M175, under which the Southeastern Universities Research Association (SURA) operates the Thomas Jefferson National Accelerator Facility.

**TPPT086—Elliptical Cavity Shape Optimization for Acceleration and High Order Modes Damping**
*Haipeng Wang, Robert Rimmer, Genfa Wu (Jefferson Lab)*
A normal design process for a superconducting cavity shape is to maximize the R/Q (shunt impedance/intrinsic quality factor) and geometry factor G for a given RF field limit of Bpeak/Eacc or Epeak/Eacc. For the application of an Ampere-class, high current energy recovery linac or storage ring, heavy HOM damping is required. This paper reports on a survey of single cell shapes developed for multi-cell cavities for different projects. Using a set of normalized parameters, we compare the designs for different frequencies and â structures for the fundamental mode. Using dispersion curve (frequency verse phase advance) calculated by MAFIA for a single cell, we explore further how to optimize the cavity shape to avoid a light cone line crossing at the dangerous resonance frequencies determined by the beam bunch structure or the dangerous (trapped or high R/Q) modes with a low group velocity. We expect such a formulation to inform our development of a 5-cell, optimized cavity shape, with good real estate accelerating gradient and strong HOM damping waveguide structure for the JLab 1MW ERL-FEL project.

Supported by the Office of Naval Research, the Joint Technology Office, the Commonwealth of Virginia, the Air Force Research Laboratory, and by DOE Contract DE-AC05-84ER40150.

**TPPT087—Superconducting Cavity-To-Cavity Coupling Measurement for SNS Cryomodule**
*Haipeng Wang (Jefferson Lab), An Sun (ORNL/SNS)*
The specification of cavity-to-cavity coupling coefficient on the SNS cryomodule is <0.0016%. There is about -90dB power isolation from one cavity's Fundamental Power Coupler (FPC) to adjacent cavity's FPC. It is difficult to use a low power measurement method to measure this coupling. Using an equivalent circuit model, the analytical formulas of cavity-to-cavity coupling are derived and based on measurable parameters in our high power cryomodule test. The reflected, transmitted and emitted power waveforms responding to the pulsed forward power at both tuned and detuned conditions agrees with our measurement data. The test results satisfied this coupling isolation specification.

Work supported by the U.S. Department of Energy, under the contract of DE-AC05-00OR22725.

**TPPT088—Power Dependence of the RF Surface Resistance of MgB2 Superconductor**
*Tsuyoshi Tajima, Alp Findikoglue, Frank L. Krawczyk, Jian-Fei Liu, Fred Mueller, Alan Shapiro (LANL), Hasan Padamsee, Alexander Sergeevich Romanenko (Cornell University), Brian Moeckly (STI)*
MgB2 is a superconducting material that has a transition temperature (Tc) of ~40 K. Recently, it has been shown at 4 K, liquid helium temperature, that the surface RF resistance can be lower than Nb that has the Tc of 9.2 K and has been used for most superconducting RF cavities in the past decades. One of the problems with other high-Tc materials such as YBCO was its rapid increase in RF surface resistance with higher surface magnetic fields. Recently, we have shown that MgB2 shows little increase up to about 120 Oe, equivalent of an accelerating field of about 3 MV/m. The highest field tested was limited by available power. This result is encouraging and has made us consider fabricating a cavity coated with MgB2 and test it. Also, there might be a potential that this material has a higher critical magnetic field that enables the cavity to run at a higher gradient than Nb cavities.

**TPPT089—Commissioning and Operations Results of the Industry-Produced CESR-Type SRF Cryomodules**
*Sergey Belomestnykh, Roger Kaplan, Hasan Padamsee, Peter Quigley, John Reilly, James Sears, Vadim Veshcherevich (Cornell University), Stefan Bauer, Bernd Griep, Michael Knaak, Michael Pekeler, Hanspeter Vogel (ACCEL), Mark Sybe de Jong, Elder Matias, Jonathan Stampe (CLS), Chaoen Wang (NSRRC)*
Upon signing a technology transfer agreement with Cornell University, ACCEL began producing turn-key 500 MHz superconducting cavity systems. Four such cryomodules have been delivered, commissioned and installed in accelerators for operation to date. Two more cryomodules are scheduled for testing in early 2005. One of them will be put in operation at Canadian Light Source (CLS); the other will serve as a spare at Taiwan Light Source (TLS). The commissioning results and operational experience with the cryomodules in CESR, CLS and TLS are presented.

Work is partially supported by the National Science Foundation.

**TPPT090—Progress of Injector Cavity Prototyping for Cornell ERL**
*Rong-Li Geng, Phil Barnes, Matthias Liepe, Valeri Medjidzade, Hasan Padamsee, Andrew Seaman, James Sears, Valery D. Shemelin, Karl William Smolenski (Cornell University)*
Five 1300 MHz superconducting niobium cavities are to be used for the injector of Cornell ERL. The beam power requirement (100 kW each cavity) and the need to minimize emittance dilution due to the cavity structure have important impacts to the design and fabrication of these cavities. We plan to use Conflat stainless-steel flanges brazed to niobium tubes of niobium cavities. The first copper prototy cavity has been built and measured. Most parts for the first niobium cavity have been

manufactured also. In this report, we will present the progress of the prototyping copper as well as niobium cavities.

**TPPT091—Half-Cell Technology for Superconducting Niobium Cavity Fabrication**
*Rong-Li Geng, Hasan Padamsee, James Sears (Cornell University)*
Stamped niobium cups are post-purified in a furnace. Major chemical etching/polishing is performed at the half-cell stage. A procedure has been developed to produce a smooth under-bead at the equator weld and minimum contamination to the pre-polished cavity inner surface. Performance of initial trial cavities will be reported. The half-cell technology can be economically rewarding for large-scale installation of niobium cavities (such as ILC) due to a reduced fabrication cost.

Work supported by NSF.

**TPPT092—Observation of Niobium Surface Damage at a 100 MV/m RF Electric Field**
*Rong-Li Geng, Andrew Seaman (Cornell University)*
We describe a surface damage phenonmenon in the high electric field region of a superconducting niobium cavity. The damage occured during a recent test of the 1300 MHz Cornell reentrant cavity subjected to a peak surface electric field of ~ 100 MV/m. It is characterized by randomly distributed, as well as clustered, craters of diameters up to 500 microns on the iris surfaces. The implication of this type of damage is discussed in the context of high-gradient operation of superconducting cavities. Suggestions for avoiding such damage will be given.

Work supported by NSF.

**TPPT093—RF Studies on Copper Models of the Injector Cavity for the Cornell ERL Prototype**
*Matthias Liepe, Christopher Cooper, Nabil Iqbal (Cornell University)*
The ERL injector cavity-module will accelerate bunches from a 100 mA, ultra-low emittance source to several MeV. Emittance preservation is crucial, and puts high demands on the RF system. Strong Higher-Order-Mode damping, small transverse fields from beam line asymmetries, and good cavity alignment are mandatory. The injector 2-cell cavity has been designed to fulfill these demands. For a first verification, several copper models of the 2-cell cavity have been built, and extensive RF measurements have been done, including input coupler measurements, HOM studies, and cavity electric axis measurements.

This work is supported by Cornell University.

**TPPT094—Design of the CW Cornell ERL Injector Cryomodule**
*Matthias Liepe, Sergey Belomestnykh, Rong-Li Geng, Valeri Medjidzade, Hasan Padamsee, Valery D. Shemelin, Vadim Veshcherevich (Cornell University)*
The Cornell ERL Prototype injector will accelerate bunches from an electron source to an energy of several MeV, while preserving the ultra-low emittance of the beam. The injector linac will be based on superconducting RF technology with five 2-cell RF cavities operated in cw mode. The beam tubes on one side of the cavities have been enlarged to propagate Higher-Order-Mode power from the cavities to broadband RF ring-absorbers located at 80 K between the cavities. The axial symmetry of these ferrite based absorbers, together with two symmetrically placed input couplers per cavity, avoids transverse on-axis fields, which would cause emittance growth. Each cavity is surrounded by a LHe vessel and equipped with a frequency tuner. The cryomodule provides the support and alignment for the cavity string, the LN cooling of the ferrite loads, and the 2K LHe cryogenic system for the high cw heat load of the cavities. In this paper we give an overview of the ERL injector cryomodule design.

This work is supported by Cornell University.

**TPPT095—Reactive Tuners for SRF Cavities**
*Townsend Zwart (MIT)*
The design of a reactive tuner for lightly loaded SRF cavities is presented. These ferrite tuners (phase shifters) can optimally couple RFpower into an SRF cavity even in the presence of significant microphonic pertubations. A further enhancement of the Rf power source is accomplished with the addition of a resonant ring strucure in the RF power distribution system.

DOE

**TPPT096—Cryomodule Design for a Superconducting Linac with Quarter-Wave, Half-Wave, and Focusing Elements**
*Matthew John Johnson, John Bierwagen, Steve Bricker, Chris Compton, Patrick Glennon, Terry L. Grimm, Walter Hartung, Dionna Harvell, Adam Moblo, John Popielarski, Laura Saxton, Richard York, Al Zeller (NSCL)*
The low-energy section of the driver linac for the proposed Rare Isotope Accelerator (RIA) incorporates the following superconducting elements: quarter-wave resonators, half-wave resonators, and 9 T solenoids. A prototype cryomodule has been designed to house all of these elements. A 31 T/m superferric quadrupole is also included as an alternative focusing element, since its stray magnetic field is more easily shielded. The cryomodule design is based on the RIA v/c=0.47 prototype cryomodule that was successfully tested in 2004.* The design uses a titanium rail structure to support the beam line elements. The beam line assembly is done in a class 100 clean room to maintain resonator cleanliness for optimal high-field performance. The cavities will be equipped with RF input couplers, tuners, and magnetic shields. High Tc current leads are used for both magnets. The cryomodule design takes into account static heat leak requirements and alignment tolerances for the beam line elements. A heat exchanger and J-T throttle valve will be used to provide a continuous supply of liquid helium for 2 K operation.
*T.L. Grimm et al., "Experimental Study of an 805 MHz Cryomodule for the Rare Isotope Accelerator", in Proceedings of the XXII International Linear Accelerator Conference, Lubeck, Germany (2004).

**TPPT097—Warm Data Gives Cold Fields**
*Stan Owen Schriber (NSCL)*
Measuring relative cell fields in superconducting cavities operating at cold temperatures in an accelerator-based facility is a difficult task, but such information can give confidence to the operators that fields are within acceptable bounds within each cavity. A method for determining these relative fields is given. The method is based on relative fields of the cavity modes measured at room temperature, along with their dispersion relationship. Knowing the mode frequencies at cold temperatures allows one to determine the relative fields for the operating mode.

**TPPT098—VORPAL as a Tool for Three-Dimensional Simulations of Multipacting in Superconducting RF Cavities**
*Chet Nieter, Peter Stoltz (Tech-X), Gregory Werner (CIPS), John R. Cary (CIPS; Tech-X)*
Considerable resources are required to run three dimensional simulations of multipacting in superconducting rf cavities. Three dimensional simulations are needed to understand the possible roles of non-axisymmetric features such as the power couplers. Such simulations require the ability to run in parallel. We consider the versatile plasma simulation code VORPAL* as a possible platform to study such effects. VORPAL has a general 3D domain decomposition and can run in any physical dimension. VORPAL uses the CMEE library** to model the secondary emission of electrons from metal surfaces. We will present a three dimensional simulation of a simple pillbox rf cavity to demonstrate the potential of VORPAL to be a major simulation tool for superconducting rf cavities.
*C. Nieter and J.R. Cary, J. Comp. Phys. 196 (2004), p. 448.
**P.H. Stoltz, ICFA electron cloud work shop, Napa, CA (2004).

**TPPT099—Prototype Superconducting Triple-Spoke Cavity for Beta = 0.62**
*Kenneth Shepard, Zachary Alan Conway, Fuerst, Mark Kedzie, Michael Kelly (ANL)*
This paper reports the development status of a 345 MHz, three-spoke-loaded, TEM-class superconducting cavity with a transit-time factor peaked at beta = v/c = 0.62. The cavity has a 4 cm diameter beam aperture, a transverse diameter of 45.8 cm, and an effective (interior) length of 85 cm. The cavity is the second of two three-spoke loaded cavities being developed for the RIA driver linac and other high-intensity ion linac applications. Construction of a prototype niobium cavity has been completed and the cavity has been chemically processed. Results of initial cold tests will be discussed.

This work was supported by the U.S. Department of Energy under contract no. W-31_109_ENG_38.

**TPPT100—Superconducting Triple-Spoke Cavity for Beta = 0.5 Ions**
*Kenneth Shepard, Zachary Alan Conway, Fuerst, Mark Kedzie, Michael Kelly (ANL)*
This paper reports results of cold tests of a 345 MHz, three-spoke-loaded TEM-class superconducting niobium cavity being developed for the RIA driver linac and for other high-intensity ion linac applications. The cavity has a beam aperture of 4 cm diameter, an interior length of 67 cm, and the transit-time factor peaks at beta = v/c = 0.5. In tests at 4.2 K, the cavity could be operated cw above the nominal design accelerating gradient of 9.3 MV/m, which corresponds to peak surface fields of 27.5 MV/m electric and 826 gauss magnetic. At this gradient the cavity provides more than 6 MV of accelerating potential. The cavity Q at 9.3 MV/m exceeded the nominal performance goal of 7.3E8. Operation at the design gradient at 4.2 K causes substantial boiling and two-phase flow in the liquid helium coolant, with the potential for microphonic-induced fluctuations of the rf frequency. Total microphonic eigenfrequency fluctuations were measured to be less than 1 Hz RMS in cw operation at 9.7 MV/m at 4.2 K.

This work was supported by the U.S. Department of Energy under contract no. W-31-109-ENG-38.

# Wednesday, May 18, 2005

Oral Session WOAA–Linear Colliders
Ballroom A @ 8:30
Chair: G. Dugan (Cornell Univ.)

**8:30 WOAA001—The International Linear Collider (ILC) Organization and Plans**
*Maury Tigner (Cornell Univ.)*
A discussion of the current organization and Central Team functions will be given. A plan for evolution of the organization towards governance by the funding agencies will be presented. The work plan for the first year will be described and today's ideas of a possible timeline laid out.

**8:55 WOAA002—Progress and Plans for R&D and the Conceptual Design of the ILC Main Linacs**
*Hitoshi Hayano (KEK)*
The International Linear Collider Main Linacs are based on superconducting accelerator structures operating at 1.3 GHz. The basis for this design has been developed and tested at DESY and R&D is progressing at many laboratories around the world including DESY, Orsay, KEK, FNAL, SLAC, Cornell, and JLAB. The status of the TESLA-style cavities and rf system will be reviewed and parameters for the ILC linac will be described. The role of the different linac test facilities will discussed and the critical items and R&D program to support a Conceptual Design and Technical Design will be outlined.

**9:15 WOAA003—Progress and Plans for R&D and the Conceptual Design of the ILC Injector Systems**
*Susanna Guiducci (INFN)*
The International Linear Collider Injector is a complex of different subsystems that are strictly correlated: positron source, polarized electron source, damping rings, bunch compressor and spin rotator. The choice of parameters of each subsystem has a strong influence on the others. A description of the critical items requiring further R&D in order to finalize the choice of the parameters needed for the Conceptual Design is given. The status and plans of the R&D in progress on these items at a global level are reported.

**9:35 WOAA004—The ILC Beam Delivery System—Conceptual Design and R&D Plans**
*Andrei Seryi (SLAC)*
The Beam Delivery System of the ILC has many stringent and sometimes conflicting requirements. To produce luminosity, the beams must be focused to nanometer size. To provide acceptable detector backgrounds, particles far from the beam core must be collimated. Unique beam diagnostics and instrumentation are required to monitor parameters of the colliding beams such as the energy spectrum and polarization. The detector and beamline components must be protected against errant beams. After collision, the beams must also be transported to the beam dumps safely and with acceptable losses. An international team is actively working on the design of the ILC Beam Delivery System in close collaboration. Details of the design, recent progress and remaining challenges will be summarized in this talk.

**9:55 WOAA005—Progress and Plans for R&D and the Conceptual Design of the ILC High Gradient Structures**
*Hasan Padamsee (Cornell Univ.)*
Gradients and Q's in the dominant ILC candidate structure have shown steady improvement, reaching 35–40 MV/m in the last year by using the best techniques of electropolishing, high pressure rinsing and 120 C baking for 48 hours. Progress and plans for t his structure will be reviewed. Above 40 MV/m, the surface magnetic field encroaches the rf critical magnetic field, believed to fall between 1750 and 2000 Oe, depending on the theory. One way to circumvent the limit is to modify the cavity shape to reduc e the ratio of peak magnetic to accelerating field. Two candidate shapes are evolving, the Re-entrant shape and the Low-Loss shape. Although field emission is aggravated by higher electric fields, it does not present a brick wall limit because high pressu re rinsing at 100 bar eliminates microparticles which cause field emission. Fundamental and higher mode properties of these new shapes will be compared with the dominant ILC candidate. Results of single and multicell cavities will be presented. The record field in a single cell re-entrant cavity is now 46 MV/m corresponding to a surface magnetic field of 1750 Oe and a surface electric field of 101 MV/m.N

Oral Session WOAB–Development in the South, East, and Mid-East/Light Sources, Ballroom B @ 8:30
Chair: M. Poole (CCLRC/DL)

**8:30 WOAB001—The Australian Synchrotron**
*Alan Jackson (ASP)*
The Australian Synchrotron – a synchrotron light facility based on a 3-GeV electron storage ring – is under construction at a site in the Metropolitan District of Melbourne. Building preparation started on a "green-field" site in September 2003 and staff moved in to their new offices in February 2005. Installation of the technical equipment started in April 2005 with all accelerator contracts expected to be completed before April 2006. Storage Ring commissioning with beam will start in June 2006, and project completion is scheduled for March 2007. In this paper we present an overview of the facility and discuss progress to date in meeting this very aggressive schedule.

**8:55 WOAB002—Status of the Shanghai Synchrotron Radiation Facility Project**
*Zhentang Zhao, Hongjie Xu (SINAP)*
The Shanghai Synchrotron Radiation Facility (SSRF) made its ground breaking at Zhang-Jiang High Tech Park on Dec.25, 2004 and moved into its construction phase with the plan of commencing user's operation from April 2009. The SSRF complex is based on a 3.5GeV storage ring optimized to operate with top-up injection, mini-gap undulators and superconducting RF system, the 432m circumference storage ring provides 18 ID straight sections (4X12.0m and 16X6.5m), and four of them will be used for the first SSRF beam lines. The SSRF project was proposed in 1995, and since then it has experienced the conceptual design stage, the R&D program and the design optimization phase. This paper presents the updated design specifications and the construction status of the SSRF project.

**9:20 WOAB003—The Brazilian Light Source**
*Pedro Tavares (LNLS)*
The Brazilian Synchrotron Radiation Laboratory has been operating the only light source in the southern hemisphere since July 1997. Over this 7 year period, approximately 22000 hours of beam time were delivered to users from all over Brazil as well as from 10 other countries. In this article, we report on the

present configuration of the 1.37 GeV electron storage ring and associated instrumentation, describe recent improvements to the light source and analyze future prespectives including the installation of insertion devices and additional beamlines.

**9:45 WOAB004—Applying Frequency Map Analysis on the Australian Synchrotron Storage Ring**
*Yaw-Ren Eugene Tan, Mark James Boland, Alan Jackson, Gregory Scott LeBlanc (ASP)*
The technique of frequency map analysis has been applied to study the dynamics of the Australian Synchrotron Storage Ring. The transverse and momentum maps have been used to determine a new working point and optics in order to maximise the dynamic aperture. Studies on the effect of misalignments and coupling will also be presented.

**10:00 WOAB005—The Status of Turkic Accelerator Complex Proposal**
*Saleh Sultansoy, Metin Yilmaz (Gazi University), Omer Yavas, Orhan Cakir, Abbas Kenan Ciftci, Erdal Recepoglu (Ankara University*)
Recently, the Turkic Accelerator Complex (TAC) is proposed as a regional facility for accelerator based fundamental and applied research. The complex will include linac on ring type electron-positron collider as a phi, charm and tau factory, linac based free electron laser (FEL), ring based third generation syncrothron radiation (SR) source and a few GeV proton accelerator. Preliminary estimations show that hundred inverse femto barn integral luminosity per year can be achieved for factory options. The FEL facility is planned to obtain laser beam between IR and soft X-ray region. In addition, SR facility will produce photon beams in UV and X-ray region. The proton accelerator will give opportunity to produce muon and neutron beams for applied research. The current status of the conceptual study of the complex is presented.

## Oral Session WOAC–Single-Particle Dynamics and Optics
## Ballroom C @ 8:30
## Chair: V. Lebedev (FNAL)

**8:30 WOAC001—Aberration Correction in Electron Microscopy**
*Harald Hermann Rose (LBNL)*
The resolution of conventional electron microscopes is limited by spherical and chromatic aberrations. Both defects are unavoidable in the case of static rotationally symmetric electromagnetic fields (Scherzer theorem). Multipole correctors and electron mirrros have been designed and built, which compensate for these aberrations. The principles of correction will be demonstrated for the tetrode mirror, the quadrupole-octopole corrector and the hexapole corrector. Electron mirrors require a magnetic beam separator free of second-order aberrations. The multipole correctors are highly symmetric telescopic systems compensating for the defects of the objective lens. The hexapole corrector has the most simple structure yet eliminates only the spherical aberration, whereas the mirror and the quadrupole-octopole corrector are able to correct for both aberrations. Chromatic correction is achieved in the latter corrector by cossed electric and magnetic quadrupoles acting as first-order Wien filters. Micrographs obtained with aberration-corrected electron microscopes will be shown demonstrating the improvement in resolution to better than 1 Angstroem.

**8:55 WOAC002—Chromatically Corrected Imaging Systems for Charged-Particle Radiography**
*Barbara Blind (LANL)*
In proton radiography, imaging with systems consisting of quadrupole magnets is an established technique for viewing the material distribution and composition of objects, either statically or during fast events such as explosions. With the most favorable magnet configuration, the –I lens, chromatic aberrations generally dominate the image blur. Image resolution can be improved, and largely decoupled from the input-beam parameters, by using a second-order achromatic bend with some additional higher-order aberration correction. The aberration-correction approach is discussed. For a given resolution, such a bend allows use of much lower-energy imaging particles than a –I lens. Each bend design represents a set of equivalent systems; an 800-MeV proton design and its equivalent 40-MeV electron system are presented. The electron system is useful for imaging small objects. Magnet errors in the achromatic bends must be tightly controlled to preserve image quality, but not beyond feasibility of present technology. System performance is verified by particle tracking. Configurations alternative to the canonical achromatic bend are also discussed.

**9:20 WOAC003—Effects of Fringe Fields and Insertion Devices Revealed Through Experimental Frequency Map Analysis**
*Peter Kuske (BESSY)*
Following the pioneering work at the ALS* frequency map analysis was performed at the light source BESSY. With altogether 7 families of sextupole magnets available in the storage ring, amplitude dependent tune shifts can be made rather small. Therefore, the impact of fringe fields of dipole and quadrupole magnets as well as systematic octupole and decapole field components of the quadrupole and sextupole magnets used in addition as horizontal, vertical and skew gradient correctors are clearly visible in the measured maps. Insertion devices with their known systematic and usually unknown random non-linear field components impact the appearance of the frequency maps even more strongly. In the talk the current status of the experiments as well as the results of the theoretical modeling will be presented.
*"Global Dynamics of the Advanced Light Source Revealed through Experimental Frequency Map Analysis," D. Robin, et al., Phys. Rev. Lett. 85, 558 (2000).

This work was supported by the Bundesministerium für Bildung und Forschung and by the Land Berlin.

**9:45 WOAC004—Tune Compensation and Lattice Tuning with Long FEL Wigglers in the Duke Storage Ring**
*Y. K. Wu, Steven M. Hartman, Jingyi Li, Stepan Mikhailov (DU/FEL)*
The Duke FEL lab is upgrading its storage ring based FEL system from the existing OK-4 FEL to the next generation OK-5 FEL. The OK-4 FEL consists of two 3.4 meter long planar wigglers while the OK-5 FEL is comprised of four 4-meter wigglers with variable polarizations. Both FEL systems are hosted in a dedicated 34 meter long straight section. To allow a smooth upgrade, two different straight section lattices have been designed with the first one to host a mixture of OK-4 and OK-5 wigglers and the second to host all four OK-5 wigglers. Wide operational ranges of the wiggler field and electron beam energy require sophisticated wiggler compensations to allow transparent operation of the storage ring with FEL wigglers. In this paper, we report our recent development of wiggler compensation schemes for both lattices. In addition, we report the development of the betatron tune knobs implemented in the same straight section. The performance of the wiggler compensation and

lattice tuning with the OK-4 FEL have been experimentally measured and will also be reported.

This work is supported by the U.S. AFOSR MFEL grant F49620-001-0370 and by U.S. DoE grant DE-FG05-91ER40665.

**10:00 WOAC005—Application of Independent Component Analysis for Beam Diagnosis**
*Xiaobiao Huang, Shyh-Yuan Lee (IUCF), Eric Prebys, Raymond E. Tomlin (Fermilab)*
The independent component analysis (ICA)* is applied to analyze simultaneous multiple turn-by-turn beam position monitor (BPM) data of synchrotrons. The sampled data are decomposed to physically independent source signals, such as betatron motion, synchrotron motion and other perturbation sources. The decomposition is based on simultaneous diagonalization of several unequal time covariance matrices, unlike the model independent analysis (MIA),** which uses equal-time covariance matrix only. Consequently the new method has advantage over MIA in isolating the independent modes and is more robust under the influence of contaminating signals of bad BPMs. The spatial pattern and temporal pattern of each resulting component (mode) can be used to identify and analyze the associated physical cause. Beam optics can be studied on the basis of the betatron modes. The method has been successfully applied to the Booster Synchrotron at Fermilab.
*A. Belouchrani et al., IEEE Trans. on Signal Processing, {\bf 45}, 434-444, (1997). **J. Irwin, et al., Phys. Rev. Lett. {\bf 82}, 1684 (1999); Chun-xi Wang, et al., Phys. Rev. ST Accel. Beams} {\bf 6}, 104001 (2003).

This work is supported in part by grants from DE-AC02-76CH03000, DOE DE-FG02-92ER40747 and NSF PHY-0244793.

**Oral Session WOAB (Cont.)–Development in the South, East, and Mid-East / Light Sources, Ballroom B @ 10:40**
**Chair: H. Winick (SLAC)**

**10:40 WOAB006—Report on Synchrotron Radiation Source Indus-2**
*Vinod Chandra Sahni (CAT)*
The 2.5 GeV electron SRS, Indus-2 being built at CAT, Indore (India) is now at the final installation and integration stage. The storage ring with a circumference of 172.47m, has eight super periods and eight 4.5m long straight sections of which five are meant for insertion devices. Major sub-systems like, magnets, vacuum chambers, SIP/TSP pumps, RF power system, magnet power supplies, beam diagnostics devices etc. have been fabricated indigenously and qualified. Most of the systems are now located in the ring and their final alignment is on. Barring unforeseen problems cropping up, commissioning of the system will start with Transferline-3 and then the trial beam injection into the ring will commence in mid 2005.

**11:05 WOAB007—SESAME in Jordan**
*Gaetano Vignola, Adel Amro, Maher Attal, Firas Makahleh, Maher Mustafa Shehab, Seadat Varnasseri (SESAME)*
An overview of the status of SESAME is presented. SESAME (Synchrotron-light for Experimental Science and Application in the Middle East) is an Independent Intergovernmental Organization developed and officially established under the auspices of UNESCO. It involves at the present the following Member States: Bahrain, Egypt, Islamic Republic of Iran, Israel, Jordan, Pakistan, Palestinian Authority, Turkey and United Arab Emirates. Moreover the following States are Observer of SESAME Council: France, Germany, Greece, Italy, Kuwait, Russian Federation, Sweden, UK and United States of America. SESAME will become a major international research center in the Middle East, located in Allan, Jordan. The machine design is based on a 2.5 GeV 3rd generation Light Source with an emittance of 26 nm.rad and 11 straights for insertion devices. The conceptual design of the accelerator complex has been frozen and the engineering design is started. The Phase I scientific program for SESAME has also been finalized and it foresees 6 beamlines. The construction of SESAME building is in progress and the beneficial occupancy is expected by the first half of 2006. The completion of the accelerators complex construction is scheduled for the end of 2009.

**11:30 WOAB008—CANDLE Project Overview**
*Vasili Mkrtich Tsakanov (CANDLE)*
CANDLE is a 3 GeV energy synchrotron light facility project in the Republic of Armenia. The main design features of the new facility are given. The results of the beam physics study in the future facility are overviewed including the machine impedance, ion trapping, single and multi-bunch instabilities, beam lifetime etc. The main requirements to the magnetic, RF and vacuum systems are discussed. The report includes the status of the project and the nearest R&D plans.

**11:55 WOAB009—Design, Development, Construction and Installation of a Ceramic Chamber for a Pulsed Kicker at the LNLS Storage Ring**
*Marcelo Juni Ferreira, Osmar Roberto Bagnato, Reginaldo de Oliveira Ferraz, Fernanda Regina Francisco, Angelo Luiz Gobbi, Rafael Molena Seraphim, Milton Batista Silva (LNLS)*
Following the upgrade of the LNLS injector system with the addition of a 500 MeV booster synchrotron,the storage ring in-vacuum ferrite injection kicker magnets started to show overheating due the interaction with high frequency electromagnetic fields induced by the electron beam. In this paper, we describe the design of a new ceramic chamber for the kickers which minimize this effect by decreasing the coupling impedance of the kickers and their interaction with the electron beam.

MCT - ABTLuS/LNLS.

**12:10 WOAB010—Bunch Tracing System by Bunch by Bunch Measurement in HLS**
*Kai Zheng, Jian Hong Liu, Zuping Liu, Jun Hua Wang, Yong Liang Yang (USTC/NSRL)*
In this paper, we introduce the bunch tracing system which is based on the bunch-by-bunch system in Hefei Light Source (HLS), and present the analysis of the experiment results. Using an in-phase gating signal and a double balance mixer to control the external trigger of ADC, we could tracing all numbered bunches in a prefabricate time slot or in manual burst mode. We can record all bunches' data during the injection, ramping, wiggler, and operation, and provide a facility for machine study.

Supported by National Key Project on Science-Phase II of NSRL.

Oral Session WOAC (Cont.)–Single-Particle Dynamics and Optics, Ballroom C @ 10:40
Chair: A. Chao (SLAC)

**10:40 WOAC006—Design of Large Momentum Acceptance Transport Systems**
*David Douglas (JLab)*
The use of energy recovery to enable high power linac operation often gives rise to an attendant challenge – the transport of high power beams subtending large phase space volumes. In particular applications – such as FEL driver accelerators – this manifests itself as a requirement for beam transport systems with large momentum acceptance. We will discuss the design, implementation, and operation of such systems. Though at times counterintuitive in behavior (perturbative descriptions may, for example, be misleading), large acceptance systems have been successfully utilized for generations as spectrometers and accelerator recirculators.* Such systems are in fact often readily designed using appropriate geometric descriptions of beam behavior; insight provided using such a perspective may in addition reveal inherent symmetries that simplify construction and improve operability. Our discussion will focus on two examples: the Bates-clone recirculator used in the Jefferson Lab 10 kW IR Upgrade FEL (which has an observed acceptance of 10% or more) and a compaction-managed mirror-bend achromat concept with potentially very large acceptance.
*J.B. Flanz and C.P. Sargent, "Operation of an Isochronous Beam Recirculation System," Nucl. Instrum. and Methods A 241 (1985) 325–333.

This work supported by The Office of Naval Research the Joint Technology Office, NAVSEA PMS-405, the Air Force Research Laboratory, U.S. Army Night Vision Lab, the Commonwealth of Virginia, and by DOE Contract DE-AC05-84ER40150.

**11:05 WOAC007—Beam-Based Nonlinear Optics Corrections in Colliders**
*Fulvi C. Pilat (BNL)*
A method has been developed to measure and correct operationally the non-linear effects of the final focusing magnets in colliders, which gives access to the effects of multi-pole errors by applying closed orbit bumps, and analyzing the resulting tune and orbit shifts. This technique has been tested and used during 3 years of RHIC (the Relativistic Heavy Ion Collider at BNL) operations. I will discuss here the theoretical basis of the method, the experimental set-up, the correction results, the present understanding of the machine model, the potential and limitations of the method itself as compared with other non linear correction techniques.

Work performed under the auspices of the US Department of Energy

**11:30 WOAC008—Measuring and Understanding the Momentum Aperture in a Storage Ring**
*Christoph Steier (LBNL/AFR), Winfried Decking (DESY), Y. K. Wu (DU/FEL), Jacques Laskar (IMCCE), David Robin (LBNL/ALS), Laurent Stanislas Nadolski (SOLEIL)*
The momentum aperture of a storage ring is a very important parameter that strongly influences the performance, especially the beam lifetime. For the special case of synchrotron light sources with small emittance like the Advanced Light Source (ALS), the momentum aperture depends strongly on the transverse dynamics. It is very sensitive to machine conditions such as the tunes, chromaticities, lattice symmetry, and spurious coupling, since depending on those conditions the Touschek scattered particles explore different resonance regions in the phase space. In light sources, the momentum aperture usually also depends strongly on the vertical physical aperture. Applying frequency analysis techniques in simulations and for turn-by-turn orbit measurement data provides a very powerful tool to measure and understand limitations of the dynamic momentum aperture. The techniques presented are applicable to other light sources, as well as damping rings and many types of colliders.

This work was supported by the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**11:55 WOAC009—Techniques for Measurement and Correction of the SNS Accumulator Ring Optics**
*Stuart Henderson, Sarah M. Cousineau, Viatcheslav V. Danilov, John Galambos, Jeffrey Alan Holmes, Michael Plum (ORNL/SNS)*
The Spallation Neutron Source (SNS) Accumulator Ring will reach peak intensities of 1.5x10^14 protons/pulse through multi-turn charge-exchange injection. Accumulation of these unprecedented beam intensities must be accomplished while maintaining extremely low losses (less than 1 W/m). It is anticipated that the control of the ring optics will be important for achieving these low loss rates. We describe our plans for measuring and correcting the optical functions of the accumulator ring lattice.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge.

**12:10 WOAC010—Measurement of Linear Lattice Functions in the ESRF Storage Ring Using Turn-by-Turn Data**
*Yannis Papaphilippou, Laurent Farvacque (ESRF), Stephanie-Louise Bailey (The College of William and Mary)*
A model-independent method to measure linear optics functions has been tested in turn-by-turn data from the ESRF storage ring. This method does not necessitate neither the knowledge of the model nor magnetic element manipulation. It uses only the positions measured in consecutive BPMs of betatron oscillations issued by small transverse kicks. The phase advances and tunes necessary to construct the transfer matrices are issued by refined Fourier analysis. The method's precision is compared with classical methods such as response matrix analysis and beam matrix construction.

Oral Session WOAD–Lepton Accelerators and Colliders
Ballroom A @ 10:40
Chair: A. Hutton (JLab)

**10:40 WOAD001—Super-B Factories**
*Haruyo Koiso (KEK)*
Energy-asymmetric electron-positron B factories, KEKB and PEP-II, have been operated at the luminosity frontiers and have delivered the integrated luminosities of a few hundreds of /fb to experiments. For further progress in particle physics, a luminosity of higher than 100/nb/s is strongly required, which means higher beam currents, smaller beta functions at the interaction point, larger beam-beam parameters, shorter bunch lengths, etc. This paper will review major upgrade plans of both machines toward SuperKEKB and Super PEP-II.

**11:05 WOAD002—Lepton Collider Operation with Constant Currents**
*Ulrich Wienands (SLAC)*
Traditionally, electron-positron colliders have been operating in a top-off-and-coast fashion with a cycle time depending on the beam life time, typically on the order of an hour. Each top-off involves ramping detector systems in addition to the actual filling time. The loss in accumulated luminosity is typically 20-50%. During the last year, both B-Factories have commissioned a continuous-injection mode of operation in which beam is injected without ramping the detector, thus raising luminosity integration by constant operation at peak luminosity. Constant beam currents reduce thermal drift and trips caused by change in beam loading. To achieve this level of operation, special efforts were made to reduce the injection losses and also to implement special gating procedures in the detectors, minimizing dead time. Bunch-injection control decides which bunch to inject into next while maintaining small charge variation between bunches. Beam collimation can reduce injection noise but also cause an increase in background rates. A challenge can be determining beam lifetime, important to maintain tuning of the beams. The paper will discuss the special features of continuous injection in both KEKB and PEP-II.

Work supported by US DOE under contract DE-AC03-76SF00515

**11:30 WOAD004 – JLab 12-GeV Upgrade**
*Allison Lung (JLab)*
Jefferson Lab is preparing to upgrade its 6 GeV Continuous Electron Beam Accelerator Facility (CEBAF) to 12 GeV reach in energy. The energy doubling will significantly extend the scientific reach in the three existing experimental Halls A, B and C, and the upgrade will add the capability of a newly constructed hall, Hall D, to study the 'confinement of quarks'. The energy upgrade will be achieved by the addition of ten high performance high gradient SRF cryomodules into existing space in the north and south recirculating linacs that will enhance the energy per pass to the level of 2 GeV. The SRF modules will be constructed at JLab with achieved gradients in excess of 20 MV/m and associated power RF and controls. The cryogenics will be upgraded by 50%, the transport magnets enhanced to deal with the increased beam energy, and a special radiator placed in the path of the electron beam to produce up to 9 GeV photons for Hall D physics. The present status of the 12 GeV Upgrade project will be described along with a hint of the science to be achieved.

**11:55 WOAD004—A High Luminosity Electron-Ion Collider To Study the Fundamental Structure of Matter**
*Richard Milner (MIT-Bates)*
Physicists seeking to understand the fundamental structure of matter in terms of Quantum Chromodynamics have identified a high luminosity (~1033 nucleon cm-2 s-1) electron-ion collider (EIC) with a center-of-mass energy range of approximately 10 to 100 GeV as the most promising next-generation accelerator configuration. The talk will briefly summarize the scientific motivation for EIC and describe a number of accelerator design configurations under consideration. Important areas requiring R&D for EIC realization will be identified.

**12:10 WOAD005—BEPCII Interaction Region Design and Construction Status**
*Yingzhi Wu (IHEP)*
BEPC (Beijing Electron Positron Collider) is now upgrading to a double-ring collider with a new and compact interaction region. The multi-purpose superconducting magnets and conventional dual aperture quadrupole magnets are used as final focusing quadrupole in the interaction region .The two beams collide at the interaction point with a cross angle of ±11 mrad and further beams separation is enhanced with the help of a septum bending magnet which locates just beyond the vertically focusing quadrupole and acts on the outgoing beam lines only. This paper will describe the IR design and its construction status.

## Poster Session WPAE—Accelerator Technology
## Ballroom E, 8:30-12:20

**WPAE001—Helium Distribution for the Superconducting Devices in NSRRC**
*Feng-Zone Hsiao, Sheng-Hsiung Chang, Wen-Song Chiou, Hsing-Chieh Li (NSRRC)*
In NSRRC up to five superconducting magnets and one superconducting cavity will be installed in the storage ring. At current stage two superconducting magnets and one superconducting cavity are kept in cold condition by one 450W helium cryogenic system. The crucial stable cryogenic condition required from the superconducting cavity is hard to achieve due to the join of superconducting magnets. A second cryogenic system dedicated for the superconducting magnets is planned in the next stage. A switch valve box serves the function for the backup of two cryogenic systems for each other and a 100 meter nitrogen-shielding helium transfer line dedicated for the five superconducting magnets are installed at end of the year 2004. This paper presents the helium distribution design of the two cryogenic systems and the commission result of the recent work.

**WPAE002—Safety Management for the Cryogenic System of Superconducting RF System**
*Sheau-Ping Kao, Fu-Dong Chang, Chien-Rong Chen, Feng-Zone Hsiao, Joseph Liu, Rong-Jiun Sheu, Jau-Ping Wang (NSRRC)*
The installation of the helium cryogenic system for the superconducting RF cavity and magnet were finished in the National Synchrotron Radiation Research Center •iNSRRC•j at the end of October 2002. The first phase of this program will be commissioned at the end of 2004. This was the first large scale cryogenic system in Taiwan. The major hazards to personnel are cryogenic burn and oxygen deficient. To avoid the injury of the operators and meet the requirements of local laws and regulations, some safety measures must be adopted. This paper will illustrate the methods of risk evaluation and the safety control programs taken at NSRRC to avoid and reduce the hazards from the cryogenic system of the superconducting RF cavity and magnet system.

**WPAE003—The Cryogenic Supervision System in NSRRC**
*Hsing-Chieh Li, Sheng-Hsiung Chang, Wen-Song Chiou, Feng-Zone Hsiao, Zong-Da Tsai (NSRRC)*
The helium cryogenic system in NSRRC is a fully automatic PLC system using the Siemens SIMATIC 300 controller. Modularization in both hardware and software makes it easy in the program reading, the system modification and the problem debug. Based on the Laview program we had developed a supervision system taking advantage of the Internet technology to get system's real-time information in any place. The functions of this supervision system include the real-time data accessing with more than 300 digital/analog signals, the data restore, the history trend display, and the human machine interface. The data is accessed via a Profibus line connecting the PLC system and the supervision system with a maximum baud rate 1.5 Mbit/s.

Due to this supervision system, it is easy to master the status of the cryogenic system within a short time and diagnose the problem.

**WPAE004—Energy Recovery Linac Prototype–Cryogenic System**
*Robert Smith (CCLRC/DL/ASTeC)*
Daresbury Laboratory is proposing a Fourth Generation Light Source (4GLS) to be constructed within the near future at its Cheshire location. The 4GLS accelerator will be built upon superconducting accelerator technology, requiring a 2K helium cryogenic refrigerator. This will require significant leaps in technology and expertise within the UK. Therefore it is currently undertaking the construction of a £14m Energy Recovery Linac Prototype (ERLP) technology demonstrator. This paper discusses the cryogenic design for the ERLP using innovative techniques to lower the capital cost. It is based around a Linde bespoke system with a cooling capacity in excess of 150W. The paper also examines the implications and design issues in scaling required for the 4GLS machine.

ASTeC Department, CCLRC Daresbury Laboratory.

**WPAE005—Status of the Cryogenic System Commissioning at SNS**
*Fabio Casagrande, Daniel Hatfield, Matthew Howell, William Strong (ORNL/SNS), Dana Arenius, Jonathan Creel, Kelly Dixon, Venkatarao Ganni, Peter Knudsen (Jefferson Lab), Pamela Gurd (ORNL/ASD)*
The Spallation Neutron Source (SNS) is under construction at Oak Ridge National Laboratory. The cold section of the Linac consists of 81 superconducting radio frequencies cavities cooled to 2.1 K by a 2400 Watts cryogenic refrigeration system. The major cryogenic system components include liquid nitrogen storage, gaseous helium storage, warm helium compressors with associated oil removal, gas management, helium purification and gas impurity monitoring system, 4.5 K cold box, Liquid Helium Dewar, 2.1 K cold box consisting of 4 stages of cold compressors and the cryogenic distribution transfer line system. The overall system commissioning strategy and the results will be presented.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a collaboration of six U.S. National Laboratories: Argonne, Brookhaven, Thomas Jefferson, Los Alamos, Lawrence Berkeley, and Oak Ridge.

**WPAE006—Local Shielded PETRACE Medical Cyclotron**
*Ashok Matkar, B. Karkera, S. Ojha, Kavindra Pathak (BARC)*
PETRACE Medical Cyclotron (PMC) employs two shielding versions as standard. 'Unshielded PMC,' needing up to 2 meter thick concrete walls all around and 'Self Shielded PMC,' which is fully surrounded by boronated water tanks. Both versions are bulky, heavy and costly, due to limitations imposed by shield location and underutilization of available shields. To overcome these factors, a third shielding version 'Local Shielded PMC' has been developed, which accounts for self-shielding phenomenon, skew angle of incident radiation, strategic placement of sliding shields, and application of sandwiched shields. This has resulted in an efficient shielding design, which is conservative on space criteria, shielding inventory, and structural requirements. It can be configured and adopted by other nuclear installations too. A 'Local Shielded PMC' has been recently commissioned at 'Radiation Medicine Centre' BARC, Mumbai, India. This paper describes in detail, shielding methodology of 'Local Shielded PETRACE Medical Cyclotron.'

International Atomic Energy Agency, Vienna, Austria Bhabha Atomic Research Centre, Mumbai, India.

**WPAE007—Commissioning of the LNLS 2 T Hybrid Wiggler**
*Ruy H.A. Farias, James Francisco Citadini, Marcelo Juni Ferreira, Ana Flávia Aparecida Gouveia, Lucia Cabral Jahnel, Lin Liu, Regis Neuenschwander, Ximenes Rocha Resende, Pedro Tavares, Giancarlo Tosin (LNLS), Natalia Prado Abreu (LNLS; UNICAMP)*
We present the results of the commissioning of a 28-pole 2 T Hybrid Wiggler at the 1.37 GeV electron storage ring of the Brazilian Synchrotron Light Source. The wiggler will be used mainly for protein crystallography and was optimized for the production of 12 keV photons. The very high field and relatively large gap (22 mm) of this insertion device led to a magnetic design that includes large main and side magnets and heavily saturated poles. We present the results of the commissioning with beam, with special attention to the correction of the large linear tune-shift perturbations produced by the wiggler as well as on the reduction of beam lifetime at full energy. Since the injection at the LNLS storage ring is performed at 500 MeV we also focus on the effects of non-linearities and their impact on injection efficiency.

MCT-CNPq, FAPESP.

**WPAE008—Redesign of a Low Energy Probe Head**
*Yi-Nong Rao, George H. Mackenzie, Thomas Ries (TRIUMF)*
The present situation of the low energy probe LE2 in TRIUMF cyctron is that the thickness of finger 5 is uniform in the radial direction and its weight which amounts to ~447 g is affecting its re-circulating ball mechanism and causing it to fall below the median plane over its range of movement (13.890 to 161.515 inch). We first made simulations to determine the optimum thickness of the probe head vs the radial length so as to reduce its weight. And then, we compared the simulation results with experimental measurements made. Finally, we calculated the temperature rise caused by the beam power dumped on the probe, and figured out the maximum beam current that can be dumped on the finger.

**WPAE009—Morphological and Structural Characterizations of Silicon Bent Crystals for Extraction/Collimation of Relativistic Ion Beams**
*Vincenzo Guidi, Giuliano Martinelli (UNIFE, Ferrara), Walter Scandale (CERN), Valery M. Biryukov, Yuri Chesnokov (IHEP Protvino), Alberto Vomiero (INFN/LNL), Yuri M. Ivanov (PNPI)*
Channeling of relativistic particles in bent crystals has been applied since many years for extraction/collimation of high-energy beams. Several methods exist to produce a bent crystal and different configurations have been tested for the purpose. Independently of the crystal design, great importance is to be paid to the state of the surfaces, whose atoms are the first being encountered by the beam. Indeed, mechanical operations to manufacture a crystal would induce considerable lattice imperfections, and the physical surface of a crystal has a disorder degree (mosaicity) that may exceed the critical angle for channeling. The application of a planar etching to the surfaces exposed to the beam has been demonstrated to lead to record performance for channeling. We investigated the morphology and structure of the surface of the crystals that have been used in accelerators with high efficiency. Low-energy channeling of 2-MeV alpha particles or protons was used as a probe. The presence of a superficial damaged layer in the samples just after mechanical treatment was unveiled, in contrast to chemical etching, which leaves a surface with high crystalline perfection.

We acknowledge support from INTAS-CERN 03-52-6155 and INFN NTA_HCCC projects.

**WPAE010—Neutron Flux and Activation Calculations for a High Current Deuteron Accelerator**
*Sandro Sandri, Angela Coniglio, Mario Pillon (ENEA C.R. Frascati), Marco D'Arienzo (CNR/RFX)*
Neutron analysis of the first Neutral Beam (NB) for the International Thermonuclear Experimental Reactor (ITER) was performed to provide the basis for the study of the following main aspects: personnel safety during normal operation and maintenance, radiation shielding design, transportability of the NB components in the European countries. The first ITER NB is a medium energy light particle accelerator. In the scenario considered for the calculation the accelerated particles are negative deuterium ions with maximum energy of 1 MeV. The average beam current is 13.3 A. To assess neutron transport in the ITER NB structure a mathematical model of the components geometry was implemented into MCNP computer code (MCNP version 4c2. "Monte Carlo N-Particle Transport Code System." RSICC Computer Code Collection. June 2001). The neutron source definition was outlined considering both D-D and D-T neutron production. FISPACT code (R.A. Forrest, FISPACT-2003. EURATOM/UKAEA Fusion, December 2002) was used to assess neutron activation in the material of the system components. Radioactive inventory and contact dose rate were assessed considering the potential operative scenarios.

**WPAE011—Electrostatic Deflectors: New Design for High Intensity Beam Extraction**
*Maurizio Re, Fortunato Caruso, Giacomo Cuttone, Giovanni De Luca, Giuseppe Gallo, Antonio Grmek, Giovanni Manno, Fortunato Musarra, Santi Passarello, Emilio ZappalÃ  (INFN/LNS)*
During the last years lots of study was devoted to increase the electrostatic deflectors' reliability; this provided a better comprehension of the most significant effects concerning their working conditions. Deflectors were checked during the normal operation of the K800 Superconducting Cyclotron (CS) at LNS, at a operating pressure of 1E-6 mbar and a magnetic field of 3.5 T, the maximum cathodes voltage was –60kV (120 kV/cm). The maximum extracted beam power was, up to now, 100 W; it is foreseen to extract up to 500 W. In this contribution we present the study, the tests and the design of a new water cooled electrostatic deflector. Particular effort was dedicated to optimise the beam extraction efficiency, the thermal dissipation, and the mechanical stability. In particularly we implemented new insulators, new anodised aluminium cathodes, new Ta septum, new voltage and water feedthroughs and a more efficient cooling system. All these improvements were performed to increase the mean time between failure and the beam current stability.

INFN-LNS Catania

**WPAE012—Gamma-Ray Irradiation Experiments of Collimator Key Components for the 3GeV-RCS of J-PARC**
*Michikazu Kinsho, Fumihiro Masukawa, Norio Ogiwara, Osamu Takeda, Kazami Yamamoto (JAERI/J-PARC), Joichi Kusano (Japan Atomic Energy Institute)*
The turbo molecular pump and the stepping motor which can be operated exposed to high radiation has been under development at JAERI for use in the 3GeV-RCS of the J-PARC. In order to determine the extent of radiation damage to those instruments, gamma-ray irradiation testing was performed at JAERI. It was succeed that the turbo molecular pump and stepping motor could operate properly when given an absorption dose more than 15 MGy in a gamma-ray irradiation environment.

**WPAE013—Development of the Collimator System for the 3GEV Rapid Cycling Synchrotron**
*Kazami Yamamoto (JAERI/J-PARC)*
In order to localize the beam loss in the restricted area, the beam collimation system is prepared in the 3GeV Rapid Cycling Synchrotron (RCS) of The Japan Proton Accelerator Complex (J-PARC) Project. The amount of the localized beam loss on the one collimator is estimated about 1.2kW, and that loss generates a large quantity of the secondary radiation. So the beam collimator was designed to be covered with enough shielding and to use the components with reliability and long lifetime at the high radiation area. We investigate and deverope such rad-hard collimator system.

**WPAE014—Conceptual Design of a Longitudinal Halo Collimator for J-PARC Linac**
*Masanori Ikegami (KEK), Tomohiro Ohkawa (JAERI)*
In a high-intensity proton accelerator, avoidance of excess beam loss is essentially important to enable hands-on maintenance. To reduce the uncontrolled beam loss in the following ring, we plan to install a longitudinal halo collimator system in a beam transport line after the injector linac. The collimator system is supposed to have two main roles: One is the elimination of longitudinal tail or halo particles destined to be lost in the following ring, and the other is the removal of anomalous beams which can be resulted from, for example, RF discharge of an accelerating cavity. We plan to adopt a "periodic collimation scheme" in the collimator system taking advantage of the three-fold symmetry of the arc section. The momentum aperture of the collimator system is expected to be reduced by the factor of two adopting periodic collimation. In this paper, conceptual design of the collimator system is presented together with the results of particle simulations.

**WPAE015—High Heat-Load Slits for the PLS Multipole Wiggler**
*Kyehwan Gil, Chin Wha Chung, Hyoyun Kim, Young-Chan Kim, Heung-Soo Lee (PAL)*
The HFMX (High Flux Macromolecular X-ray crystallography) beamline under commissioning at Pohang Accelerator Laboratory uses beam from a multipole wiggler for MAD experiment. Two horizontal and vertical slits relevant to high heat load are installed at its front-end. In order to treat high heat load and to reduce beam scattering, the horizontal slit has two glidcop blocks with 10° of vertical inclination and its tungsten blades defining beam size are bolted on backsides of both blocks. The blocks of the slit are adjusted on fixed slides by two actuating bars, respectively. Water through channels machined along the actuating bars cool down the heat load of both blocks. The vertical slit has the same structure as the horizontal slit except its installation direction and angle of vertical inclination. The installed slits show stable operation performance and no alignment for the blocks is required by virtue of a pair of blocks translating on slides. The cooling performance of two slits is also shown to be acceptable. In this article, the details of the design and manufacture of the two slits are presented and its operation performance is reported.

**WPAE016—Development of a Precision Amplifier for the Detector**
*Ki-Hyeon Park, Chin Wha Chung, Suk-Mo Hong, Seong-Hun Jeong, Young Gyu Jung, Dong Eon Kim, Hee-Seock Lee, Wol Woo Lee (PAL), Bong-Koo Kang (POSTECH)*
A high gain trans-resistance amplfier has been developed for measuring the intensity of synchrotron radiation at Pohang Light Source(PLS). This amplifier built with discrete elements and operational amplifiers.It had the capability of measuring range

from 1pA to 1 uA with good linearity. A microprocessor was also installed to interface the amplifier with the computer, and controlled the other sub-circuits. The various characteristics of amplifier such as linearity, sensitivity,stability, etc. have been investigated, and its experimental results carried out at the beam line are presented in this paper.

**WPAE017—Installation of the LHC Long Straight Sections (LSS)**
*Sonia Bartolome-Jimenez, Gilbert Trinquart (CERN)*
The LHC long straight sections (LSS) serve as experimental or utility insertions. There are two high luminosity experimental insertions located at points 1 and 5 and two more experimental insertions at points 2 and 8 which also contain the injection systems. The beams only cross at these four locations and are focused by superconducting low-beta triplets. Insertions 3 and 7 each contain two collimation systems. Insertion 4 contains two RF systems. Insertion 6 contains the beam dumping system. The installation of the LSS is a challenge due to the compact layout that characterises these areas and the difficulties related to the underground work mainly in zones of restricted access. Specific devices are required for handling and installing various heavy and voluminous elements. This paper reviews the installation scenarios, describes the sequences presently planned and highlights the potential problem areas. The particular case of sector 7-8 where the LSS elements will be installed in parallel with the cryogenic distribution line (QRL) is used as an example of a 'rapid' installation scheme to illustrate how resources are used. The consequences of possible shortcuts are also mentioned.

**WPAE018—Performance Tests of Survey Instruments Used in Radiation Fields Around High-Energy Accelerators**
*Sabine Mayer, Doris Forkel-Wirth, Markus Fuerstner, Christian Theis, Helmut Vincke (CERN)*
Measurements of ambient dose equivalent in stray radiation fields behind the shielding of high-energy accelerators are a challenging task. Several radiation components (photons, neutrons, charged particles), spanning a wide range of energies, contribute to the total dose equivalent. In routine-measurements, the total dose equivalent is obtained by the combination of several radiation detectors. Ionisation chambers, which are sensitive to all radiation components, are employed together with so-called REM counters, which are responding mainly to neutrons. The total dose equivalent is correctly assessed provided that the response is interpreted carefully by using appropriate corrections and calibration factors. For this reason measurements were carried out in a high-energy reference field at CERN, which allows one to study the response of the different detectors in a mixed radiation field under controlled conditions. In addition, the field was simulated by Monte Carlo simulations. The outcome of these studies serves on one hand as a basis for quality assurance and improves on the other hand the knowledge of the instrument's response for future applications at the LHC.

**WPAE019—How to Fill a Narrow 27 km Long Tube with a Huge Number of Accelerator Components?**
*Yvon Muttoni, Jean-Pierre Corso, Roger Valbuena (CERN)*
As in large scale industrial projects, research projects, such as giant and complex particle accelerators, require intensive spatial integration studies using 3D CAD models, from the design to the installation phases. The future management of the LHC machine configuration during its operation will rely on the quality of the information, produced during these studies.This paper presents the powerful data-processing tools used in the project to ensure the spatial integration of several thousand different components in the limited space available.It describes how the documentation and information generated have been made available to a great number of users through a dedicated Web site and how installation nonconformities were handled.

**WPAE020—A Large Diameter Entrance Window for the LHC Beam Dump Line**
*Andrew Presland, Brennan Goddard, José Miguel Jimenez, Raymond Veness (CERN)*
The graphite LHC beam dump block TDE has to absorb the full LHC beam intensity at 7 TeV. The TDE vessel will be filled with inert gas at atmospheric pressure, and requires a large diameter entrance window for vacuum separation from the beam dumping transfer line. The swept LHC beam must traverse this window without damage for regular operation of the beam dump dilution system. For dilution failures, the entrance window must survive most of the accident cases, and must not fail catastrophically in the event of damage. The conceptual design of the entrance window is presented, together with the load conditions and performance criteria. The FLUKA energy deposition simulations and ANSYS stress calculations are described, and the results discussed.

**WPAE021—The LHC Matching Sections Short Straight Sections (MS SSS): A Design Extension of the Arc Cryostats To Fulfill Specific Machine Functionalities**
*Vittorio Parma, Herve Prin (CERN), Franck Lutton (IPN)*
The LHC insertions require 50 specific superconducting quadrupoles, operating in boiling helium at 4.5 K and housed in individual cryostats to form the MS Short Straight Sections (MS SSS). The quadrupoles and corrector magnets are assembled in 8 families of cold masses, with lengths ranging from 5 to 11 m and weights ranging from 60 to 140 kN. The MS SSS need to fulfil specific requirements related to the collider topology, its cryogenic layout and the powering scheme. Most MS SSS are standalone cryogenic and super-conducting units, i.e. they are not in the continuous arc cryostat, and therefore need dedicated cryogenic and electrical feeding. Specially designed cryostat end-caps are required to close the vacuum vessels at each end, which include low heat in-leak Cold-to-Warm transitions (CWT) for the beam tubes and 6 kA local electrical feedthrough for powering the quadrupoles. This paper presents the design of the MS SSS cryostats as an extension of the arc cryostat's design to achieve a standard and consequently cost-effective solution, and the design solutions chosen to satisfy their specific functionalities.

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**WPAE022—Progress on the Liquid Hydrogen Absorber for the MICE Cooling Channel**
*Mary Anne Cummings (Fermilab)*
This report describes the progress made on the design of the liquid hydrogen absorber for the international Muon Ionization Cooling Experiment (MICE). The absorber consists of a 21-liter vessel that contains liquid hydrogen (1.5 kg) or liquid helium (2.63 kg). The cryogen vessel is within the warm bore of the superconducting focusing magnet for the MICE. The purpose of the magnet is to provide a low beam beta region within the absorber. For safety reasons, the vacuum vessel for the hydrogen absorber is separated from the vacuum vessel for the superconducting magnet and the vacuum that surrounds the RF cavities or the detector. The absorber has two 300 mm-diameter thin aluminum windows. The vacuum vessel around the absorber has a pair of thin aluminum windows that separate the absorber vacuum space from adjacent vacuum spaces. The absorber will be cooled down using a heat exchanger that is built into the

absorber walls. Liquid nitrogen is used to cool the absorber to 80 K. Liquid helium completes the absorber cool down and condenses hydrogen in the absorber. The absorber may also be filled with liquid helium to measure muon cooling in helium.

**WPAE023—Progress on the Absorber Focus Coil Module for the MICE Channel**
*Mary Anne Cummings (Fermilab)*
This report describes the progress on the absorber focus coil module for the international Muon Ionization Cooling Experiment (MICE). The MICE absorber focus coil module consists of a pair of superconducting solenoids, mounted on an aluminum mandrel. The coil package that is in its own vacuum vessel surrounds an absorber, which does the ionization cooling of the muons. The absorber is within a separate vacuum vessel that is within the warm bore of the superconducting magnet may be either a liquid or solid absorber. The liquid absorber will be filled with either liquid hydrogen or liquid helium. The solid absorbers used in MICE will be made from a low z material such as lithium, lithium hydride, beryllium, or a plastic (CNH2N+2). The superconducting focus coils may either be run in the solenoid mode (with the two coils at the same polarity) or in the flip mode (with the coil at opposite polarity causing the field direction to flip within the magnet bore). The superconducting coils will be cooled using a pair of small 4 K coolers. Because the intensity of the muon beam in MICE is low, the liquid absorber will be cooled using a single small 4 K cooler. The solid absorbers will be radiation cooled.

**WPAE024—Lasertron Effect in Electrostatic Separator**
*Alexander A. Mikhailichenko (Cornell University)*
New type of instability introduced by photoelectrons, irradiating the wall of electrostatic separator or other high voltage device described here. As appearance of secondary electrons synchronized with bunch passing through separator, resonance condition might occur here. So the length of feeding cables and dimensions of separator might be critical for this type of instability.

**WPAE025—Design for a 1.3 MW, 13 MeV Beam Dump for an Energy Recovery Linac**
*Charles Kent Sinclair, Yun He, Colin Healey Smith (Cornell University)*
The electron beam exiting an Energy Recovery Linac (ERL) is dumped close to the injection energy. This energy is chosen as low as possible while allowing the beam quality specifications to be met. As ERLs are designed for high average beam current, beam dumps are required to handle high beam power at low energy. Low energy electrons have a short range in practical dump materials, requiring the beam size at the dump face be enlarged to give acceptable power densities and heat fluxes. Cornell University is developing a 100 mA average current ERL as a synchrotron radiation source. The 13 MeV optimum injection energy requires a 1.3 MW beam dump. We present a mature design for this dump, using an array of water-cooled extruded copper tubes. This array is mounted in the accelerator vacuum normal to the beam. Fatigue failure resulting from abrupt thermal cycles associated with beam trips is a potential failure mechanism. We report on designs for a 75 kW, 750 keV tube-cooled beryllium plate dump for electron gun testing, and a 500 kW, 5 to 15 MeV copper tube dump for use with the prototype injector under development. We expect to test the beryllium dump within a year, and the higher power copper dump within 2-1/2 years.

Work supported by Cornell University.

**WPAE026—A 1000 T/m Lithium Lens for Fermilab's Anti-Proton Source**
*Patrick Hurh, James Morgan, Ryan Schultz, Salman Tariq (Fermilab)*
The original design of Fermilab's Anti-Proton Source called for a 1 cm radius lithium lens with a magnetic gradient of 1000 T/m. In practice this design goal was never realized due to limited lifetimes of collection lenses operated at that high gradient. An extensive effort was undertaken 4 years ago to understand problems with the original design and fabrication process and design a new collection lens and lens fabrication process that would result in meeting the original design goal with a lifetime of 10 million pulses. Current results of that effort are described here including successful operation of an 8 mm radius prototype, fatigue studies on diffusion bonded joints, most probable failure causes of lithium lenses, and status of the full-scale high gradient lens.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**WPAE027—Magnetic Shielding of an Electron Beamline in a Hadron Accelerator Enclosure**
*Thomas K. Kroc, Chuck Schmidt, Alexander V. Shemyakin (Fermilab)*
The Fermilab Electron Cooling Project requires the operation of a 4.35 MeV electron beam in the same enclosure that houses the 120 – 150 GeV Main Injector. Effective shielding of the magnetic fields from the ramped electrical buses and local static fields is necessary to maintain the high beam quality and recirculation efficiency required by the electron cooling system. This paper discusses the operational tolerances and the design of the beamline shielding, bus design, and bus shielding as well as experimental results from the prototype and final installation.

*Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**WPAE028—Radiation Issues for Fermilab Booster Magnets**
*Eric Prebys (Fermilab)*
The demands of the Fermilab neutrino program will require the 30 year old Fermilab 8 GeV Booster to deliver higher intensities than it ever has. Total proton throughput is limited by radiation damage and activation due to beam loss in the Booster tunnel. Of particular concern is the insulation in the 96 combined function lattice magnets. This poster describes a study of the potential radiation damage to these magnets from extended running at the planned intensities.

Department of Energy.

**WPAE029—The Development of the 2nd Tevatron Electron Lens**
*Xiaolong Zhang, James L. Crisp, James A. Fitzgerald, Gennady Kuznetsov, Marvin Olson, Howard Pfeffer, Greg Saewert, Vladimir Shiltsev (Fermilab), Michael A. Tiunov (BINP SB RAS), Sergey Kozub, Veniamin Sytnik, Leonid Tkachenko (IHEP Protvino), Kip Bishofberger (UCLA)*
The 2nd Tevatron electron lens (TEL2) is under the final phase of development and prepare for the installation in the Tevatron. In this report, we will describe the system and the main upgrades from the TEL1. We will also show the magnetic field measurement results, beam testing and plan for installation. The special operation consideration of the TEL2 under high radiation dose will also be discussed.

Work supported by the Universities Research Assos., Inc., under contract DE-AC02-76CH03000 with the U.S. Dept. of Energy.

**WPAE030—Thermal Analysis of the Al Window for a New CESR-c Luminosity Monitor**

*Yun He, Yulin Li, Mark Alan Palmer, David Rice (Cornell University)*

A luminosity monitor using photons from radiative bhabha events at the CLEO interaction point (IP) has been installed in the Cornell Electron Storage Ring (CESR). A key vacuum and detector component is the photon window/converter whose uniformity and thickness are critical for determining the resolution of the total energy deposited in the segmented luminosity monitor. The window design must accommodate the operational requirements of the new monitor at CLEO-c beam energies of 1.5-2.5 GeV and also provide sufficient safety margin for operation at 5.3 GeV beam energies for Cornell High Energy Synchrotron Source (CHESS) running. During 5.3 GeV operation, intense stripes of synchrotron radiation from the interaction region superconducting quadrupole magnets as well as nearby bending magnets strike the window. During the course of window development, several materials and designs were evaluated. Thermal stresses were calculated using the finite element code ANSYS for various beam conditions to guide the cooling design. A window using aluminum alloy (6061-T6) was ultimately chosen to provide optimal performance for both CLEO-c and CHESS running conditions. The window has been in successful operation since September 2004.

Work supported by the U.S. National Science Foundation.

**WPAE031—Mechanical Design of a Heavy Ion Beam Dump for the RIA Fragmentation Line**

*Werner Stein, Larry Ahle, Martin D. Roeben (LLNL)*

The RIA fragmentation line requires a beam stop for the primary beam downstream of the first dipole magnet. The beam may consist of U, Ca, Sn, Kr, or O ions. with a variety of power densities. The configuration with highest power density is for the U beam, with a spot size of 3 cm x 3 cm and a total power of up to 300 kW. The mechanical design of the dump that meets these criteria consists of a 50 cm diameter aluminum wheel with water coolant channels. A hollow drive shaft supplies the coolant water and connects the wheel to an electrical motor located in an air space in the floor above the dump. The beam strikes the wheel along the outer perimeter and passes through a thin window of aluminum where 10% of its power is absorbed and the remainder of the beam is absorbed in flowing water behind the window. Rotation of the wheel at 400 RPM results in maximum aluminum temperatures below 100 C and acceptably low thermal stresses of 5 ksi. Rotating the wheel also results in low radiation damage levels by spreading the damage out over the whole perimeter of the wheel. For some of the other beams, a stationary dump consisting of a thin aluminum window with water acting as a coolant and absorber appears to be feasible.

**WPAE032—Gamma Experiment Study System (GESS) Code**

*Jean-Christophe Bilheux (ORNL)*

Typical experiments based on the detection of gamma rays are used to measure the production rate and yield of radioactive species produced out of a target material irradiated by a primary beam. Using the number of gamma rays detected, one can deduce the number of radioactive species of interest produced in the target. To do so, a large number of parameters must be taken into account. Data analysis can be relatively fast; sometimes, it can take several weeks. The Gamma Experiment Study System (GESS) code that uses the Excel environment has been written to facilitate the process of analyzing data and avoid any systematic errors that can occur during the analysis. Once the data have been loaded into the program, it is possible to calculate the yield of the species of interest with or without taking into account the feeding from radioactive decay of the parent nuclei. A spreadsheet that summarizes the results of the various calculations is generated.

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**WPAE033—Beam-Induced Neutron Fluence in the PEP-II Interaction Region**

*Gary Bower, Jaroslav Va'vra, Dennis Wright (SLAC), William Stephen Lockman (SCIPP)*

As part of the PEP-II B-Factory luminosity upgrade, it is proposed to increase the bending power of the IP magnetic-separation dipoles using Neodynium-Iron-Boron permanent-magnet slices. To estimate the long-term radiation damage in this material, we use Geant4 simulations to compute the neutron flux produced by energy-degraded e+- from radiative-Bhabha events, that impinge onto beam-line components near the interaction point. These simulations are calibrated by comparing predicted and measured counting rates in several neutron detectors installed in the Babar interaction region.

**WPAE034—Fast Neutron Damage Studies on NdFeB Materials**

*James Spencer, James Allan, Scott Anderson, Zachary Wolf (SLAC), James T. Volk (Fermilab), David Pellet (UCD), Moe Boussoufi (UCD/MNRC)*

Many materials and electronics need to be tested for the radiation environment expected at linear colliders (LC) where the accelerator and detectors will be subjected to large fluences of hadrons, leptons and gammas over the life of the facility. Although the linacs will be superconducting, there are still many potential uses for NdFeB in the damping rings, injection and extraction lines and final focus. Our understanding of the radiation damage situation for rare earth permanent magnet materials was presented at PAC2003 and our first measurements of fast neutron, stepped doses at the UC Davis McClellan Nuclear Reactor Center (UCD MNRC) were presented at EPAC2004 where the damage appeared proportional to the distances between the effective operating points and Hc. Here we have extended those doses and included more commercial samples together with the induced radioactivities associated with their respective dopants. Hall probe data for the external induction distributions are compared with vector magnetization measurements for the different materials.

Support of this work was under U.S. Dept. of Energy contracts DE-AC02-76SF00515, DE-AC02-76CH03000 and LCRD contract DE-FG02-03ER41280.

**WPAE035—SNS Ring Injection Stripped Electron Collection: Design Analysis and Technical Issues**

*Yong Yung Lee, George Mahler, Wuzheng Meng, Deepak Raparia, Lanfa Wang, Jie Wei (BNL)*

This paper describes the simulation studies on the motions of stripped electrons generated in the injection section of the Spallation Neutron Source (SNS) accumulator ring and the effective collection mechanism. Such studies are important for high intensity machines, in order to reduce beam loss and protect other components in the vicinity. The magnetic field is applied to guide electrons to a collector, which is located at the bottom of the beam chamber. Part of the study results with and without

considering the interactions between electrons and materials are presented and discussed. The final engineering design of the electron collector (catcher) is also presented and described.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**WPAE036—Harmonic Analysis of Linac Alignment**
*Rodney C. McCrady (LANL/LANSCE)*
We have analyzed the requirements on alignment of the focusing elements (quadrupole doublets) in the Los Alamos Neutron Science Center (LANSCE) side coupled linac. The analysis is performed in terms of harmonics of the quardrupole spacing. This allows us to determine the effect of intentional deviations from a straight line, such as following the curvature of the Earth, and of unintentional deviations introduced by measurement and alignment errors. Results are compared to measured positions of the doublets.

Work conducted at Los Alamos National Laboratory, which is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

**WPAE037—Deformation Monitoring of the Spallation Neutron Source (SNS) Tunnels**
*Joseph Error, Douglas Bruce, Julius Fazekas, Scott Helus, James Maines (ORNL/SNS)*
The SNS Project is a 1.4 MW accelerator-based neutron source located at Oak Ridge National Laboratory in Oak Ridge, Tennessee. For shielding purposes, a 17 foot berm of native soil has been constructed on top of the accelerator tunnel system. This backfill has caused ongoing settlement of the tunnels. The settlement has been monitored by the SNS Survey and Alignment Group at regular intervals, in order to discover the patterns of deformation, and to determine when the tunnels will be stable enough for precise alignment of beam line components. The latest monitoring results indicate that the settlement rate has significantly decreased. This paper discusses the techniques and instrumentation of the monitoring surveys, and provides an analysis of the results.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**WPAE038—Resonance Control Cooling System Performance and Developments**
*Paul Gibson, Alexander V. Aleksandrov, Marianne M. Champion, James Phillip Schubert, Johnny Y. Tang (ORNL/SNS)*
The Spallation Neutron Source (SNS) is an accelerator-based neutron source being built at Oak Ridge National Laboratory. The warm linac portion, designed by Los Alamos, has been installed and commissioned. The warm linac is comprised of six Drift Tube Linac (DTL) tanks and four Coupled Cavity Linac (CCL) modules. For commissioning purposes the accelerating systems have been operated at less than the design 6% duty factor. During lower power operation there is less RF cavity heating. This decrease in heat load causes operational stability issues for the associated Resonance Control Cooling Systems (RCCSs) which were designed for full duty factor operation. To understand this effect operational results have been analyzed and tests have been performed. External system factors have been explored and the resulting impacts defined. Dynamic modeling of the systems has been done via a collaboration with the Institute for Nuclear Research (INR), Moscow, Russia. New RCCS operation code has been implemented. Increases in system performance achieved and solutions employed will be presented.

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**WPAE039—Optical Tooling and its Uses at the Spallation Neutron Source (SNS)**
*Scott Helus, Douglas Bruce, Joseph Error, Julius Fazekas, James Maines (ORNL/SNS)*
Optical tooling has been a mainstay of the accelerator alignment community for decades. Even now in the age of electronic survey equipment, optical tooling remains a viable alternative, and at times the only alternative. At SNS, we combine traditional optical tooling alignment methods, instrumentation, and techniques, with the more modern electronic techniques. This paper deals with the integration of optical tooling into the electronic survey world.

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**WPAE040—Comparison of Techniques for Longitudinal Tuning of the SNS Drift Tube Linac**
*Dong-o Jeon (ORNL/SNS)*
It is important to bring the cavity field amplitude and phase to the design values for a high intensity linac such as the Spallation Neutron Source (SNS)linac. A few techniques are available, such as the longitudinal acceptance scan and phase scan. During SNS linac commissioning, tuning of cavities was conducted using the acceptance scan and phase scan technique based on multiparticle simulations. The two techniques are compared.

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**WPAE041—Development of a New Beam Diagnostics Platform**
*Ronald Thomas Roseberry, Saeed Assadi, Graeme R. Murdoch (ORNL/SNS)*
The Spallation Neutron Source Project (SNS) is an accelerator-based neutron source currently under construction at Oak Ridge National Laboratory (ORNL). The availability of space along completed portions of the accelerator for the addition of beam diagnostic is limited. A new platform for mounting a variety of instruments has been created by replacing part of the Medium Energy Beam Transport (MEBT) section of the accelerator developed by Lawrence Berkeley National Laboratory. The design and current capabilities of this instrument platform will be presented along with plans for future enhancements.

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**WPAE042—Beam Loss and Residual Activation Trending**
*George W. Dodson, Mario Giannella, Ariel Tamika Ruffin, Theodore L. Williams (ORNL/SNS)*
The SNS Front End, Drift Tube Linac and most of the Coupled Cavity Linac have been operated during commissioning. Beam loss data were taken with differential Beam Current Monitors,

and Beam loss Monitors during commissioning. Residual activation data were taken at various times during and after the run. An analysis of beam loss trending, beam loss monitor data and residual activation will be shown.

This work was supported by SNS through UT-Batelle, LLC, under contract DE-AC05-00OR22725 for the U.S. DOE. The SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**WPAE043—Mechanical Alignment of the Booster Injector for the Duke FEL Storage Ring**

*Mark Emamian, Matthew D. Busch, Stepan Mikhailov, Gary Swift (DU/FEL), Nikolai Gavrilov (BINP SB RAS)*

This paper presents the methodology and initial results for mechanical alignment of the booster synchrotron for the Duke FEL storage ring. The booster is a compact design and requires special considerations for alignment. The magnetic and vacuum elements of the arcs have been designed for alignment by a laser tracker system. A parametric 3D design package has been used to determine target coordinates. These target coordinates evolve from design goals to physically verified dimensions by modifying the parametric model to match mechanical measurement data after fabrication. By utilizing the functionality of the laser tracker system and a parametric 3D modeler, a direct and efficient measurement and alignment technique has been developed for a complex geometry.

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**WPAE044—An Alignment of J-PARC Linac**

*Takatoshi Moirshita, Hiroyuki Ao, Takashi Ito, Akira Ueno (JAERI/LINAC), Kazuo Hasegawa (JAERI), Masanori Ikegami, Chikashi Kubota, Fujio Naito, Eiichi Takasaki, Hirokazu Tanaka, Kazuo Yoshino (KEK)*

J-PARC linear accelerator components are now being installed in the accelerator tunnel, whose total length is more than 400 m including the beam transport line to RCS (Rapid Cycling Synchrotron). A precise alignment of accelerator components is essential for a high quality beam acceleration. In this paper, planned alignment schemes for the installation of linac components, the fine alignment before beam acceleration, and watching the long term motion of the building are described. Guide points are placed on the floor, which acts as a reference for the initial alignment at the installation and also as a relay point for the long surveying network linking at the fine alignment. For a straight line alignment, the wire position sensor is placed on the offset position with respect to the beam center by a target holder, then a single wire can cover the accelerator cavities and the focusing magnets at the DTL-SDTL section (120m). The hydrostatic levering system (HLS) is used for watching the floor elevation (changes) over the long period.

**WPAE045—Progress on RF Coupling Coil Module Design for the MICE Channel**

*Derun Li (LBNL/AFR), Michael Green, Steve Virostek, Michael Zisman (LBNL), Wing Lau, Adam White, Stephanie Yang (OXFORDphysics)*

We describe the progress on the design of the RF coupling coil (RFCC) module for the international Muon Ionization Cooling Experiment (MICE) at Rutherford Appleton Laboratory (RAL) in the UK. The MICE cooling channel design consists of two SFOFO cells that is similar to that of the US Study-II of a neutrino factory. The MICE RFCC module comprises a superconducting solenoid, mounted around four normal conducting 201.25-MHz RF cavities. Each cavity has a pair of thin curved beryllium windows to close the conventional open beam irises, so thatnecessitating separate power feeds for each of the four cavities has to be separately powered. The coil package that surrounds the RF cavities sits is mounted on a vacuum vessel. The RF vacuum is shared between the cavities and the vacuum vessel around the cavities such that. Therefore there is no differential pressure on the thin beryllium windows. This paper discusses the design progress of the RFCC module, the fabrication progress of a prototype 201.25-MHz cavity, and the superconducting coupling coil that will be cooled using a single, small 4 K cooler.

This research work is supported by the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**WPAE046—Diffusion Brazing and Welding of the Accelerating Structure**

*Vardan Avagyan (CANDLE)*

This work presents technologies of copper accelarating structure diffusion joints. The formation conditions of copper diffusion joint with minimal residual plastic strain are determined experimentally.

This work has been performed in Yerevan Physics Institute and the Institute of Electrowelding E.O. Paton, the Ukraine.

**WPAE050—First Calibrations of Alanine and Radio-Photo-Luminescence Dosimeters to a Hadronic Radiation Environment**

*Helmut Vincke, Isabel Brunner, Idelette Floret, Doris Forkel-Wirth, Markus Fuerstner, Sabine Mayer (CERN)*

Alanine and Radio-Photo-Luminescence (RPL) dosimeters are used to monitor radiation doses occurring inside the tunnels of all CERN accelerators including the Large Hadron Collider (LHC). They are placed close to radiation sensitive machine components like cables or insulation of magnet coils to predict their remaining lifetime. The dosimeters are exposed to mixed high-energy radiation fields. However, up to now both dosimeter types are calibrated to 60Co-photons only. In order to study the response of RPL and alanine dosimeters to mixed particle fields like those occurring at CERN's accelerators, an irradiation campaign at the CERN-EC High-Energy Reference field Facility (CERF-field) was performed. Moreover, the dosimeters were first time calibrated to a proton radiation field of a constant momentum of 24 GeV/c. In addition to the experiment FLUKA Monte Carlo simulations were carried out, which provide information concerning the energy deposition and the radiation field at the dosimeter locations.

**WPAE051—Commissioning Study of the In-Vacuum Wiggler on BEPC**

*Xinhao Wang, Jiuqing Wang, Xuemei Wen, Jun Xing (IHEP Beijing)*

In the end of 2002 an in-vacumm wiggler with 2.0 T at minimum gap of 12 mm, was installed in the storage ring of BEPC. During the first period of commission in Nov. 2002, the beam life dropped sharply when the gap of magnet is reduced to 25 mm. In 2003, series of commission study, such as tuning the orbit, working point, coupling and so on, the beam life was improved stably to about 8 hours at 130 mA with about 100 bunches when the gap is 20mm. This has met the requirement for routine operation. Further improvement for smaller gap operation is under way.

**WPAE053—Neutronics Assessments for RIA Fragmentation Beam Dump**
*Jason Boles (LLNL)*
In support of pre-conceptual research and development of high-power beam dumps for the fragmentation line of the Rare Isotope Accelerator (RIA), calculations of the radiation environment in the vicinity of the beam dump are in progress. With RIA's design goal of accepting 400 kW of beam power of any element up to uranium, modeling emphasis is on 400 MeV/u uranium beams. Using the high-energy heavy-ion Monte Carlo transport code PHITS, a preliminary design of a motor-driven rotating wheel beam dump and adjacent downstream multipole have been modeled. Results of the modeling will be presented, including the energy spectra of the proton and neutron fluxes, energy deposition, absorbed dose, displacements per atom, and activation. Component lifetimes driven by the radiation environment and potential shielding configurations will be addressed.

Work performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

**WPAE054—Irradiation Effects on RIA Fragmentation Cu Beam Dump**
*Susana Reyes, Larry Ahle, Jason Boles, Werner Stein (LLNL), Brian Wirth (UCB)*
Within the scope of conceptual R&D activities in support of the Rare-Isotope Accelerator (RIA) facility, high priority is given to the development of high-power fragmentation beam dumps. A pre-study was made of a static water-cooled Cu beam dump that can meet requirements for a 400 MeV/u uranium beam. The issue of beam sputtering was addressed and found to be not a significant issue. Preliminary radiation transport simulations show significant damage (dpa) in the vicinity of the Bragg peak of uranium ions. Experimental data show that defects in Cu following neutron or high-energy particle irradiation tend to saturate at doses between 1 and 5 dpa, and this saturation in defect density also results in saturation of mechanical property degradation. However, effects of swift heavy ion irradiation and the production of gaseous and solid transmutant elements still need to be addressed. Initial calculations indicate that He concentrations on the order of 100 appm are produced in the beam dump after several weeks of continuous operation and He embrittlement should be a concern. Recommendations are made for further investigation of Cu irradiation effects RIA-relevant conditions.

U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

**WPAE056—Geant4-Based Simulation Study of PEP-II Beam Backgrounds in the BaBar Detector at the SLAC B-Factory**
*William Stephen Lockman (SCIPP), Witold Kozanecki (CEA/DSM/DAPNIA), Ben Campbell, Steven Hugh Robertson (CHEP), Mario Bondioli (INFN-Pisa), G. Wormser (IPN), Nick Barlow, Christina Louise Edgar (Manchester University), David Aston, Gary Bower, Markus Cristinziani, Dennis Wright (SLAC), Brian Aagaard Petersen (Stanford University), Giovanni Calderini (UNIPI), Nicholas Louis Blount, David Strom (University of Oregon)*
To improve the understanding of accelerator-induced backgrounds at the SLAC B-Factory and validate the proposed PEP-II luminosity upgrade, we simulate lost-particle backgrounds in the BaBar detector originating from beam-gas interactions and radiative-Bhabha scatters. To perform this study, we have extended the GEANT4-based BaBar detector simulation to include PEP-II beam-line components and magnetic fields up to 10m away from the interaction point. We first describe the simulation model and then compare predicted background levels with measurements from dedicated single-and colliding-beam experiments. Finally, we compare the simulated background levels in the current and the proposed luminosity-upgrade configurations.

**WPAE057—Net Shape Manufacturing of Accelerator Components by High Pressure Combustion Driven Powder Compaction**
*Karthik Nagarathnam (UTRON Inc)*
We present an overview of the net shape and cost-effective manufacturing aspects of high density accelerator (normal and superconducting) components (e.g., NLC Copper disks) and materials behavior of copper, stainless steel, refractory materials (W, Mo and TZM), niobium and SiC by innovative high pressure Combustion Driven Compaction (CDC) technology. Some of the unique process advantages include high densities, net-shaping, improved surface finish/quality, suitability for simple/complex geometries, synthesis of single as well as multilayered materials, milliseconds of compaction process time, little or no post-machining, and process flexibility. Some of the key results of CDC fabricated sample geometries, process optimization, sintering responses and structure/property characteristics such as physical properties, surface roughness/quality, electrical conductivity, select microstructures and mechanical properties will be presented. Anticipated applications of CDC compaction include advanced x-ray targets, vacuum seals, accelerator/RF microwave components, high temperature nozzle liner parts/heat sinks, and advanced high density magnets.

Funding Agency: Department of Energy (DOE) Under SBIR Contracts#DE-FG02-02ER83567 and DE-FG02-03ER83816.

**WPAE058—High Voltage Measurements on Nine PFNs for the LHC Injection Kicker Systems**
*Michael John Barnes, Gary Dale Wait (TRIUMF), Laurent Ducimetière (CERN)*
Each of the two LHC injection kicker magnet systems must produce a kick of 1.3 T.m with a flattop duration variable up to 7.86 microseconds, and rise and fall times of less than 900 ns and 3 microseconds, respectively. A kicker magnet system consists of four 5 Ohm transmission line magnets with matching terminating resistors, four 5 Ohm Pulse Forming Networks (PFN) and two Resonant Charging Power Supplies (RCPS). Nine PFNs, together with associated switch tanks, and dump switch terminating resistors have been built at TRIUMF and all have been tested at high voltage (54 kV) to ensure that the performance is within specification. This paper describes the HV measurements, compares these results with low voltage measurements and analyses the pulse performance of the PFNs. The measurements are compared with results from PSpice simulations and small discrepancies between the predictions and measurements are explained.

National Research Council of Canada

**WPAE059—The Dynamic Response of the Parallel Resonant Circuit with the Different Power Excitation**
*Xin Qi, Zhongxiong Xu, jing Zhang (IHEP Beijing)*
In order to avoid drawing a large reactive power from the a.c. lines, the "White Circuit" type resonant network was adopted widely as the structure of the magnet power supply system of the rapid cycle synchrotron. Reducing the higher harmonics of the magnet current in the parallel resonant network is the key technique for the magnet current tracking accuracy. Based on the

dynamic response analysis of a single mesh parallel resonant circuit in this paper, it shows that the continuous power excitation is of great benefit to reducing the magnet current harmonics. This paper also gives a description of our experimental studies on the dynamic response with the pulse and continuous power excitation in a parallel resonant network model.

**WPAE060—Programmable Power Supply for AC Switching Magnet of Proton Accelerator**
*Seong-Hun Jeong, Hong Sik Han, Young Gyu Jung, Heung-Sik Kang, Hong-Gi Lee, Ki-Hyeon Park, Chun-Kil Ryu, Hyung Suck Suh (PAL)*
The 100-MeV PEFP proton linac has two proton beam extraction lines for user' experiment. Each extraction line has 5 beamlines and has 5 Hz operating frequency. An AC switching magnet is used to distribute the proton beam to the 5 beamlines, An AC switching magnet is powered by PWM-controlled bipolar switching-mode converters. This converter is designed to operate at ±350A, 5 Hz programmable step output. The power supply is employed IGBT module and has controlled by a DSP (Digital Signal Process). This paper describes the design and test results of the power supply.

Ministry of Science and Technology.

**WPAE061—LC Filter for High Accuracy and Stability Digital MPS at PLS**
*Sung-Chul Kim, Jinhyuk Choi, Ki Man Ha, Jung Yun Huang (PAL)*
High accuracy and stability digital power supply for magnet is developed at PLS. This power supply has three sections. The first section is digital controller including DSP&FPGA and precision ADC, the second consists of IGBT driver and four quad IGBT switch, and the third is LC output section. AC input voltage of power supply is 3-phase 21V, output current is 0 ~ 150 A dc. Switching frequency of IGBT is 25 kHz. The output current of power supply has very high accuracy of 100 mA step resolution at full range and the stability of +/- 1.5 ppm for short term and +/- 5 ppm for long term. This paper describes characteristics of filter and output current performance improvement after LC output filter at four quad digital power supplies.

Work supported by the Ministry of Science and Technology, Korea.

**WPAE062—AC Power Supply for Wobbler Magnet of the MC-50 Cyclotron**
*Yu-Seok Kim, Jong-Seo Chai (KIRAMS), Dong Eon Kim, Wol Woo Lee, Ki-Hyeon Park (PAL), Bong-Koo Kang (POSTECH)*
The MC-50 cyclotron (k=50) produces the ion beam for nuclear physics, chemistry, and applied researches in Korea. It has a small beam diameter with Gaussian beam shape, whereas many users want a beam irradiation on a large target. A wobbler magnet and an AC power supply were designed and constructed to meet the users' requirement. The power supply has two independently operating channels for the vertical and horizontal coils of the wobbler magnet. The frequency of the AC power supply for both coils is programmable from 1 to 20 Hz in a step of 1 Hz, and the maximum rms output current is 12 A. Various properties of the power supply and experimental results are given in the paper.

**WPAE063—CERN-PS Main Power Converter Renovation: How To Provide and Control the Large Flow of Energy for a Rapid Cycling Machine?**
*Frederick Bordry, Jean-Paul Burnet, Friedrich Voelker (CERN)*
The PS (Proton-Synchrotron) at CERN, which is part of the LHC injector chain, is composed of 101 main magnets connected in series. During a cycle (about 1 second), the active power at the magnet terminals varies from plus to minus 40 MW. Forty years ago, the solution was to insert a motor-generator (M-G) set between the AC supply network and the load. The M-G set acts as a fly-wheel with a stored kinetic energy of 233 MJ. The power converter is composed of two 12-pulse rectifiers connected in series. A renovation or replacement of the installation is planned in the near future as part of the consolidation of the LHC injectors. This paper presents a first comparison of technical solutions: - a direct connection to the 400 kV mains; - a kinetic energy storage system either by the existing or by a new "state of the art" M-G set; - a new local inductive or capacitive energy storage system. All these solutions need new power electronics equipment, which should be based on proven industrial topologies, techniques and components. The related studies will address the challenge of controlling by a modern power converter with local energy storage the positive and negative flow of energy to a rapid cycling accelerator load.

**WPAE064—"Fast-Slow" Beam Chopping for Next Generation High Power Proton Drivers**
*Michael A. Clarke-Gayther (CCLRC/RAL/ASTeC)*
A description is given of two "state of the art" high voltage pulse generator systems, designed to address the requirements of a fast beam chopping scheme for next generation high power proton drivers.* Measurements of output waveform and timing stability, for fast transition short duration, and slower transition long duration pulse generators, are presented.
*M. A. Clarke-Gayther, "A Fast Beam Chopper for Next Generation High Power Proton Drivers," Proc. of the ninth European Particle Accelerator Conference (EPAC), Lucerne, Switzerland, 5-9 July, 2004, p. 1449-145.

Work supported by CCLRC/RAL/ASTeC and by the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).

**WPAE065—Jefferson Lab's Trim Card II**
*Trent Allison, Roger Flood, Scott Higgins, Ed Martin, William Merz (Jefferson Lab)*
Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF) uses 1 to 12 Amp series pass regulator trim cards to power approximately 1,900 dipoles, quadrupoles, and other high order correction magnets. These trim cards have had a long and industrious service record. However, some of the employed technology is now obsolete, making it difficult to maintain the system and retain adequate spares. The Trim Card II is being developed to act as a transparent replacement for the aging trim cards. A modular approach has been taken in its development to facilitate the substitution of sections if improvements are required or parts become unavailable. The resulting design has been divided into a motherboard and four daughter cards which has also allowed for parallel development. The Trim Card II utilizes modern technologies such as a field programmable gate array and a microprocessor to embed trim card controls and diagnostics. These reprogrammable devices also provide versatility for incorporating additional features.

This work was supported by DOE contract DE-AC05-84ER40150 Modification No. M175, under which the Southeastern Universities Research Association (SURA) operates the Thomas Jefferson National Accelerator Facility.

**WPAE066—PEP-II Large Power Supplies Rebuild Program at SLAC**
*Antonio Carlos de Lira, Paul Bellomo, James J. Lipari, Fernando da Silva Rafael (SLAC)*
Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF) uses 1 to 12 Amp series pass regulator trim cards to power approximately 1,900 dipoles, quadrupoles, and other high order correction magnets. These trim cards have had a long and industrious service record. However, some of the employed technology is now obsolete, making it difficult to maintain the system and retain adequate spares. The Trim Card II is being developed to act as a transparent replacement for the aging trim cards. A modular approach has been taken in its development to facilitate the substitution of sections if improvements are required or parts become unavailable. The resulting design has been divided into a motherboard and four daughter cards which has also allowed for parallel development. The Trim Card II utilizes modern technologies such as a field programmable gate array and a microprocessor to embed trim card controls and diagnostics. These reprogrammable devices also provide versatility for incorporating additional features.

This work was supported by DOE contract DE-AC05-84ER40150 Modification No. M175, under which the Southeastern Universities Research Association (SURA) operates the Thomas Jefferson National Accelerator Facility.

**WPAE067—Testing of Custom Power Supplies at Vendor Facilities**
*Robert Lambiase, Jon Sandberg (BNL), Kenneth R. Rust (ORNL/SNS)*
Brookhaven National Laboratory has specified, purchased, and tested a variety of custom power supplies for the accumulator ring and transfer lines of the Spallation Neutron Source (SNS) that will be located in Oak Ridge, Tennessee. As with all custom power supplies, there is the normal challenge of predicting performance with test loads and limited power resources for the largest of units. But, beyond this, extra care was needed to make sure the control interface was fully tested, as the units were purchased by one laboratory to be installed at another laboratory. The cooperative effort of the equipment vendors and the DOE laboratories during the entire process of specification, design review, and testing resulted in sucessful delivery and installation of equipment.

Work performed under DOE contract DE-AC02-98C10886.

**WPAE068—Upgrade of the AGS MMPS to 2.5 up to 5.0 Hz, Storing Additional Energy in Inductors or Capacitors**
*Ioannis Marneris, Sorin Viorel Badea, Rodger Bonati, Marvin Meth, Thomas Roser, Alessandro Ruggiero, Jon Sandberg, Nicholaos Tsoupas, Wu-Tsung Weng (BNL)*
The Brookhaven AGS is a strong focusing accelerator, which is used to accelerate protons and various heavy ion species to an equivalent maximum proton energy of 29 GeV. Future programs in high-energy and neutron physics may require an upgrade of the AGS accelerator from 0.1 MW to an average beam power of around 1 MW, with proton beams at the energy of 28 GeV. The beam intensity will be increased to 1 x 1014 protons per AGS cycle. This paper describes the AGS additional power supply and energy requirements to allow cycling at 2.5 up to 5 beam pulses per second. The energy will be stored in inductors or capacitors driven by power converters fed from the same input ac line, as the additional silicon controlled rectifiers needed to power the AGS magnets. Theoretical calculations will be presented, explaining the power flow from the magnets to the storing inductors or capacitors while the average input power from the ac line, remains constant. Power flow from the ac line into the AGS MMPS and inductors or capacitors are inverted images of each other. The existing motor/generator will also be used.

Work performed under the auspices of the U.S. Department of Energy.

**WPAE069—The APS Septum Magnet Power Supplies Upgrade**
*Boris Deriy, AL Hillman, Gary Sprau, Ju Wang (ANL)*
The higher requirements for beam injection stability at the APS storage ring demand improvement of pulsed power supplies for the septum magnets. The upgrade will be performed in two stages. In the first stage we will implement a new power supply circuit with a new regulation timing sequence that will provide better voltage regulation performance. A common design was made for all of the septum magnet power supplies at the APS. The new regulation module has already been tested on both thin and thick septum magnet power supplies. This test showed that the new target for the current regulation stability, 1/2000 with less than 10-ns jitter, is achievable with this approach. In the second stage we will implement an embedded microprocessor system that will provide digitally controlled shot-to-shot current regulation of the power supply. The system comprises modules for communication with EPICS, data acquisition, and precise timing. A prototype has already been built and will also be discussed.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**WPAE070—Injector Power Supplies Reliability Improvements at the Advanced Photon Source**
*AL Hillman, Stanley Joseph Pasky, Nicholas Sereno, Robert Soliday, Ju Wang (ANL)*
Operational goals for the APS facility include 97% availability and a mean time between unscheduled beam losses (faults) of 70 hours, with more than 5000 user hours of scheduled beam per year. To meet this objective, our focus has changed to maximizing the mean time between faults (MTBF). We have made various hardware and software improvements to better operate and monitor the injector power supply systems. These improvements have been challenging to design and implement in light of the facility operating requirements but are critical to maintaining maximum reliability and availability of beam for user operations. This paper presents actions taken as well as future plans to continue improving injector power supply hardware and software to meet APS user operation goals.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**WPAE071—Power Supply for Magnet of Compact Proton and/or Heavy Ion Synchrotron for Radiotherapy**
*Shinji Yamanaka, Kazumi Egawa, Kuninori Endo, Zhigao Fang (KEK)*
A resonant type pulse power supply, for an application to a compact proton and/or heavy ion synchrotron with a several Hz repetition rate, is attractive from the view point of attaining an average beam current that is enough for the radiation therapy. Maximum ampere-turn of the dipole magnet is as large as 200 kAT to make the bending radius as small as possible. Pulse current is generated by discharging the stored energy in a capacitor bank through a pulse transformer. Moreover, the auxiliary power supply for the dipole magnets which adds the flat magnetic field (10-20is) for the multi-turn beam-injection is being developed. The power supply for the quadrupole magnets

is the high switching frequency (20 kHz × 5) switching-mode Power Supply for the adjusting tune and the tracking between the quadrupole and the dipole fields. Detailed analyses on these pulse power supplies will be presented.

**WPAE072—Installation and Testing of SNS Magnet Power Supplies**

*Kenneth R. Rust, William E. Barnett, Roy I. Cutler, Joey T. Weaver (ORNL/SNS), Robert Lambiase, Jon Sandberg (BNL), Jiaqi Zeng (Digital Predictive Systems Inc.), Shashi Dewan, Robert Holmes, Sam Wong (IE Power Inc.)*

This paper describes the types and quantities of magnet power supplies required for the SNS Linear Accelerator, High-Energy Beam Transport (HEBT), Ring and the Ring-Target Beam Transport (RTBT). There are over 600 magnets and more than 550 magnet power supplies. These magnet power supplies range in size from the bipolar-corrector supplies rated at 35 volts, 20 amps to the main-ring dipole supply that is rated at 440 volts, 6000 amps. The Linac power supplies have a ripple/stability specification of 1000 parts per million while the ring supplies have a specification of 100 parts per million. There are also pulsed power supplies for beam injection and beam extraction. The paper will show acceptance test results from the manufacturers as well as test results performed by the SNS magnet power supply group.

This work was supported by SNS through UT-Batelle, LLC, under contract DE-AC05-00OR22725 for the U.S. DOE. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**WPAE073—3 kA Power Supplies for the Duke OK-5 FEL Wigglers**

*Victor Popov, Steven M. Hartman, Stepan Mikhailov, Owen Oakeley, Patrick Walter Wallace, Y. K. Wu (DU/FEL)*

The next generation electromagnetic OK-5/Duke storage ring FEL wigglers require three 3kA/70V power supplies with current stability about 20 ppm and current ripples less than 20ppm in their full operating range. Duke FEL Laboratory acquired three out-of-service thyristor controllable power supplies (Transrex, 5kA/100V) which was built almost 30 years ago. The existing archaic firing circuit, lack of any output voltage filtering and outdated DCCT, would not be able to meet the above requirements.To deliver the desirable high performance with very limited funds, all three T-Rex power supplies have been completely rebuilt in house at DFELL. Modern high stability electronic components and a Danfysik DCCT with a high current stability have been used. New symmetrical firing circuit, efficient passive LC filter and reliable transformer-coupled active filter are used to reduce output current ripples to an appropriate level. At the present time, the first refurbished power supply in operation since August, 2004 with good overall performance. The power supply testing results of this unit will also be presented in this paper.

U.S. AFOSR MFEL grant F49620-001-0370.

**WPAE074—Trim Power Supplies for the Duke Booster and Storage Ring**

*Victor Popov, Steven M. Hartman, Stepan Mikhailov, Owen Oakeley, Patrick Walter Wallace, Y. K. Wu (DU/FEL)*

The on-going Duke storage ring upgrades and the development of a new booster synchrotron injection require more than 100 units of high performance unipolar and bipolar trim power supplies in the current range of -15A to +15A. However, most of the trim power supplies on the market do not deliver two critical performance features simultaneously: a high current stability and a low current noise.An in-house trim power supply development program is then put in force to design, fabricate, and test low cost linear power supplies with current stability about 100 ppm and current ripples less than 100 ppm in a broad band. A set of unipolar power supplies (0-12A) have been designed, fabricated and successfully tested. Since August, 2004 they have been used in storage ring operation with excellent performance. The prototype of bipolar power supplies (+/- 15 A) has been designed and tested as well. The main design principles and their performance results of both unipolar and bipolar supplies will be presented in this paper.

U.S. AFOSR MFEL grant F49620-001-0370 and HIGS Upgrade DOE grant number is DE-FG02-01ER41175.

**WPAE075—Compact Digital High Voltage Charger**

*Ge Li, Yingui Zhou (USTC/NSRL)*

The operation of classical resonant circuit developed for the pulse energizing is investigated. The HV pulse or generator is very compact by a soft switching circuit made up of IGBT working at over 30 kHZ. The frequencies of macro pulses and micro pulses can be arbitrarily tuned below resonant frequency to digitalize the HV pulse power. The micro pulses can also be connected by filter circuit to get the HVDC power. The circuit topology is given and its novel control logic is analyzed by flowchart. The circuit is part of a system consisting of a AC or DC LV power supply, a pulse transformer, the pulse generator implemented by LV capacitor and leakage inductance of the transformer, a HV DC or pulse power supply and the charged HV capacitor of the modulators.

**WPAE077—Booster Ring Power Converters for Filling Up Synchrotron Light Source Storage Rings**

*Alexander Elkjaer, Lars Kruse (Danfysik A/S)*

Optimizing booster ring power converters for synchrotron light sources requires special attention concerning: over all cost, energy requirements and flexibility in use. For this following highlight must be considered: - High stability even at low injection currents. - Able to control the magnet hysteresis through 2½ quadrant operation. (Reduced four quadrant operations.) - Reuse of the stored magnet energy. - Minimizing line flicker. (Uniform power demand.) - Programmable arbitrary ramp profile with high accurate tracking and trigger skew compensation. (Timing compensation) - One shot application for "Top up mode" filling. - High efficiency through 3rd generation IGBT switch mode technology. - Modular construction for high MTBF and low MTBR. (Same modules for both Dipole and Quadrupole magnets). - Cost optimization for smaller as well as for larger synchrotron light sources. The paper describes the power converter topology and construction to guarantee the above mentioned highlights. The topology has been well proven for the ANKA (Germany), CLS (Canadian) light source and will soon be in service for the ASP project (Australia). This power converter topology also can be used for "White Circuit" applications.

**WPAE078—The Current State of the ISIS Main Magnet Power Supply Upgrade**

*Andrew Kimber, James Gray, Adrian Morris, Steve West (CCLRC/RAL/ISIS)*

The ISIS facility, based at the Rutherford Appleton Laboratory in the UK, provides intense pulsed neutron and muon beams for condensed matter studies. This paper discusses the current state of the upgrade to the main magnet power supply (MMPS) and will focus primarily on the replacement of the 1MJ storage choke which forms part of the White circuit. The 120 tonne choke will be substituted with ten smaller units and several one

fifth scale models are in the process of being manufactured. Preliminary results from the testing of these models will be included. The replacement of the existing motor-generator set, which provides a steady 50Hz AC supply for the MMPS, with a UPS system will also be discussed.

**WPAE079—Dual Power Supplies for PEP-II Injection Kickers**
*Franz-Josef Decker, Artem Kulikov, Chris Pappas (SLAC)*
Originally the PEP-II injection kickers where powered by one power supply. Since the kicker magnets where not perfectly matched, the stored beam got excited by about 7% of the maximum kicker amplitude. This led to luminosity losses which were especially obvious for trickle injection when the detector is on for data taking. Therefore two independant power supplies with thyratrons in the tunnel next to the kicker magnet were installed. This also reduces the necessary power by about a factor of five since there are no long cables that have to be charged. The kickers are now independantly adjustable to eliminate any non-closure of the kicker system and therefore excitation of the stored beam. Setup, commissioning and fine tuning of this system are discussed.

Work supported by Department of Energy contract DE-AC03-76SF00515.

**WPAE080—Development of the Pulsed Source Prototype for BEPCII New Type Kicker**
*Jinhui Chen, Qian Han, Wen Kang, Xianzu Wei (on leave) (IHEP)*
Since BEPCII is a high beam current machine, a new type slotted pipe kicker with advantage of low beam coupling impedance is adopted and a bipolar pulsed source is needed. In order to avoid difficulties caused by the floating-thyratron scheme, a balun is introduced into the LC series resonance circuit with a grounded thyratron. An overhigh inverse voltage applying at the thyratron anode immediately upon the cessation of forward current, which is intrinsic in resonance circuit, might lead to an arc-back phenomena, in which an appreciable reverse current cannot only shorten the thyratron's lift-time but also disturb the cyclic beams in storage ring. A saturable inductor and a damping resistor in series can overcome this problem efficiently. To ensure that the pulse source can produce a half-sine current pulse with 2.1 kA of amplitude and 600 ns of bottom width at less 30 kV of operating voltage, it's necessary to reduce total stray inductance of the pulse discharging loop. So all of components excluding balun are designed as coaxial structure. The test results of the prototype are described.

**WPAE081—1.12 MVA Tracking Design of Two Pulse Switch Mode Power Supplies for the SNS Injection Bump Magnets**
*Shashi Dewan, Robert Holmes, Sam Wong (IE Power Inc.), Wahfun Eng, Robert Lambiase, Jon Sandberg (BNL), Jiaqi Zeng (Digital Predictive Systems Inc.), Kenneth R. Rust (ORNL/SNS)*
This paper establishes the design considerations for tracking for SNS injection bump magnet power supplies. For each bump magnet (13mW, 160mH), the prototype power supply can supply controlled pulses at 60 Hz repetition rate. The pulse current rises from zero to maximum in less than 1 millisecond, flattop of up to 2 milliseconds, and falls to less than 1.4A within 500 ms. In addition to the normal tracking between the load current and the input current reference, these power supplies must track (within 10.5%) between pair of units with up to 110% difference in load inductance. To achieve this objective, a simulation program was realized that could predict accurately the experimental results. Several hundred simulations were carried out to establish the sensitivity of the parameters of the power and control circuits with both identical and different loads. In this paper, the simulation results have been employed to establish the design considerations to achieve tracking performance between one and two units. In addition, if system delay is matched, a single parameter (gain in the current loop) has been identified that can compensate for 110% variation of the magnet inductance.

**WPAE082—Design of a Precision Positioning System for the Undulators of the Linac Coherent Light Source**
*E. Trakhtenberg (ANL)*
A precision positioning system has been designed for the Linac Coherent Light Source (LCLS) and a prototype system is being fabricated. The LCLS will use a beam based alignment technique to precisely align all of the segments of the 130-m long undulator line. The requirement for overlap between the electron beam and the x-ray beam, in order to develop and maintain lasing, demands that each of the quadrupoles be aligned within a tolerance of ± 2 ìm and that the undulator axis be positioned within ± 10 ìm vertically and horizontally. Five cam movers, each with an eccentricity of 1.5 mm, will allow adjustment of a cradle supporting the undulator, its vacuum chamber, a quadrupole, and a beam position monitor. An additional motion transverse to the beam axis allows removal of individual undulators from the beam path. Positioning feedback will be provided by a wire position monitor system and a hydrostatic leveling system.

## Poster Session WPAP—Sources and Injectors
## Park Concourse, 8:30-12:20

**WPAP001—HELIOS, the Linac Injector of SOLEIL: nstallation and First Results**
*Bruno Pottin, Roger Chaput, Jean-Pierre Pollina, Marie-Agnès Tordeux (SOLEIL), Dominique Jousse, Jean-Luc Pastre, Andrew Setty (THALES)*
HELIOS is the Hundred MeV Electron Linac Injector Of SOLEIL the new French SR facility. The Linac is constructed by THALES as a "turn key" equipment on the basis of SOLEIL's APD design. The Linac injector is composed of a triode gun (90 kV, 500 mA), a prebuncher (10 kV, 200 W), a buncher (SW, 15 MeV, 5 MW) focalised by a solenoid and two accelerating sections (TW, 2pi/3, 45 MeV, 12 MW) feeded by 2 klystrons (35 MW). The major Linac components have been previously tested at THALES factory and the installation on the site has begun from October 2004. After a brief description of the building construction, the tests of the Linac components and operating modes will be detailed. The commissioning with beam is planned on March; the results on beam qualities will be presented: energy spread, emittance, and beam dynamics along the Linac.

SOLEIL

**WPAP003—Emission Mechanisms in a Photocathode RF Gun**
*Jang Hui Han, Juergen W. Baehr, Hans-Juergen Grabosch, Mikhail Krasilnikov, Velizar Miltchev, Anne Oppelt, Bagrat Petrosyan, Lazar Staykov, Frank Stephan (DESY Zeuthen), Michael Hartrott (BESSY GmbH), Klaus Floettmann (DESY)*
In photocathode rf guns, emission mechanisms at the photocathode play a crucial role in the overall beam dynamics. A low bunch charge as well as a short Gaussian bunch profile allow us

to study the beam dynamics depending on emission phase without space charge force. This paper presents experimental and simulation studies toward detailed understanding of the photo emission and secondary emission processes at the cathode.

**WPAP004—Dark Current and Multipacting in the Photocathode RF Guns at PITZ**
*Jang Hui Han, Juergen W. Baehr, Hans-Juergen Grabosch, Mikhail Krasilnikov, Velizar Miltchev, Anne Oppelt, Bagrat Petrosyan, Lazar Staykov, Frank Stephan (DESY Zeuthen), Michael Hartrott (BESSY GmbH), Klaus Floettmann (DESY)*
For photocathode rf guns, the amount of dark current depends on the cavity surface and the photocathodes. Smooth conditioning reduces the amount of dark current. Mechanical damages of the cathodes induce high dark current and chemical pollution changes emission properties of the cathode. Multipacting in the gun cavity changes the surface status of the cathodes and sometimes makes the gun operation impossible due to vacuum interlocks. In this paper, dark current and multipacting features of the rf gun are presented including experimental and simulation studies.

**WPAP005—Beam-Based Procedures for RF Guns**
*Mikhail Krasilnikov, Juergen W. Baehr, Hans-Juergen Grabosch, Jang Hui Han, Velizar Miltchev, Anne Oppelt, Bagrat Petrosyan, Lazar Staykov, Frank Stephan (DESY Zeuthen), Michael Hartrott (BESSY GmbH)*
A wide range of rf photo injector parameters has to be optimized in order to achieve an electron source performance as required for linac based high gain FELs. Some of the machine parameters can not be precisely controlled by direct measurements, whereas the tolerance on them is extremely tight. Therefore, this should be met with beam-based techniques. Procedures for beam-based alignment (BBA) of the laser on the photo cathode as well as solenoid alignment have been developed. They were applied at the Photo Injector Test facility at DESY Zeuthen (PITZ) and at the photo injector of the VUV-FEL at DESY Hamburg. A field balance of the accelerating mode in the 1 ½ cell gun cavity is one of the key beam dynamics issues of the rf gun. Since no direct field measurement in the half and full cell of the cavity is available for the PITZ gun, a beam-based technique to determine the field balance has been proposed. A beam-based rf phase monitoring procedure has been developed as well.

**WPAP006—Recent Developments at PITZ**
*Mikhail Krasilnikov, Juergen W. Baehr, Ulrich Gensch, Hans-Juergen Grabosch, Jang Hui Han, Sergiy Khodyachykh, Shengguang Liu, Velizar Miltchev, Anne Oppelt, Bagrat Petrosyan, Sabine Riemann, Juliane Roensch, Lazar Staykov, Frank Stephan (DESY Zeuthen), Michael Hartrott, Eberhard Jaeschke, Dieter Krämer, Dirk Lipka, Dieter Richter (BESSY GmbH), Karen Abrahamyan (on leave) (DESY Zeuthen; YerPhI), Jean-Paul Carneiro, Klaus Floettmann, Siegfried Schreiber (DESY), Galina Asova, Gancho Dimitrov (on leave), Gancho Dimitrov (DESY; INRNE), Paolo Michelato, Laura Monaco, Carlo Pagani, Daniele Sertore (INFN/LASA), Ivan Tsakov (INRNE), Wolfgang Sandner, Ingo Will (MBI), Wolfgang Ackermann, Wolfgang F.O. Müller, Sascha Schnepp, Thomas Weiland (TEMF), Jörg Rossbach (Uni HH)*
The ability to produce high brightness electron beams as required for modern Free Electron Lasers (FELs) has been demonstrated during the first stage of the Photo Injector Test Facility at DESY Zeuthen (PITZ1). The electron source optimization at PITZ1 was successfully completed, resulting in the installation of the PITZ rf gun at the VUV-FEL (DESY, Hamburg). One of the main goals of the second stage of PITZ (PITZ2) is to apply higher gradients in the rf gun cavity in order to obtain smaller beam emittance by faster acceleration of the space charge dominated beams. In order to reach the required gradients a 10 MW klystron has to be installed and the gun cavity has to be conditioned for higher peak power. Another important goal of PITZ2 is a detailed study of the emittance conservation principle by using proper electron beam acceleration with a booster. Further photo injector optimization, including update of the photocathode laser and diagnostic tools, is foreseen as well. Recent progress on the PITZ developments will be reported.

**WPAP007—Status of the 3½ Cell Superconducting RF Gun Project in Rossendorf**
*Rong Xiang, Hartmut Buettig, Pavel Evtushenko, Dietmar Janssen, W.-D. Lehmann, Ulf Lehnert, Peter Michel, Karsten Moeller, Christof Schneider, Rico Schurig, Juergen Stephan, Jochen Teichert (FZR), Thorsten Kamps (BESSY GmbH), Vladimir Volkov (BINP SB RAS), Dirk Lipka (DESY), Ingo Will (MBI)*
In the paper, we report on the status and progress of the superconducting rf gun project in Rossendorf. The gun is designed for cw operation mode with 1mA current and 10 MeV electron energy. The gun will be installed at the ELBE superconducting electron linear accelerator. It will have a 3½ cell niobium cavity operating at 1.3 GHz. The cavity consists of three cells with TESLA geometry and a specially designed half-cell in which the photocathode will be placed. Two Nb cavities, with RRR 300 and 40 respectively, will be finished at the beginning of 2005. After delivery, the rf tests will be performed and the treatment of the cavities will be started. At the same time, the design of the cryostat is finished and the fabrication of its components is under way. Further activities are the design of the diagnostic beam line, the assembling of the new photocathode preparation system, and the upgrade of the 262 nm driver laser system.

**WPAP008—Simulation for a New Polarized Electron Injector (SPIN) for the S-DALINAC**
*Bastian Steiner, Wolfgang F.O. Müller, Thomas Weiland (TEMF), Joachim Enders, Hans-Dieter Gräf, Achim Richter, Markus Roth (TU Darmstadt)*
The Superconducting DArmstädter LINear ACcelerator (S-DALINAC) is a 130 MeV recirculating electron accelerator serving several nuclear and radiation physics experiments. For future tasks, the 250 keV thermal electron source should be completed by a 100 keV polarized electron source. Therefore a new low energy injection concept for the S-DALINAC has to be designed. The main components of the injector are a polarized electron source, an alpha magnet, a Wien filter spin-rotator and a Mott polarimeter. In this paper we report over the first simulation and design results. For our simulations we used the TS2 and TS3 modules of the CST MAFIA (TM) programme which are PIC codes for two and three dimensions and the CST PARTICLE STUDIO (TM).
Work supported in part by DFG under contract SFB 634 and DESY, Hamburg.

**WPAP009—Optimization of RF Compressor in the SPARX Injector**
*Concetta Ronsivalle (ENEA C.R. Frascati), Luca Serafini (INFN-Milano), Manuela Boscolo, Massimo Ferrario, Bruno Spataro (INFN/LNF)*
The SPARX photoinjector consists in a rf gun injecting into three SLAC accelerating sections, the first one operating in the RF compressor configuration in order to achieve higher peak current. A systematic study based on PARMELA simulations has been done in order to optimize the parameters that influence the

compression also in view of the application of this system as injector of the so called SPARXINO 3-5 nm FEL test facility. The results of computations show that peak currents at the injector exit up to kA level are achievable with a good control of the transverse and longitudinal emittance by means of a short SW section operating at 11424 MHz placed before the first accelerating section. Some working points in different compression regimes suitable for FEL experiments have been selected. The stability of these points and the sensitivity to various types of random errors are discussed.

**WPAP010—Intense Electron Beams from a Non-Equilibrium Plasma Generated by a UV Laser Beam**
*Vincenzo Nassisi, Fabio Belloni, Domenico Doria, Lucia Marra, Luigi Martina (INFN-Lecce)*
The extraction of intense electron bunches from a plasma generated by a laser beam of 248 nm, 20 ns, at relatively low energy density is reported. The plasma was the ablation product by the laser interaction to a pure Ge target. The electron bunch was detected recording the output signal provided by a Faraday cup having a positive polarization and placed in front of an expansion chamber. To accelerate the charged particles, the target with the expansion chamber were biased negatively up to 20 kV. The electron beam signal behaviour was similar to the ion one at low laser power density and/or at low cup bias values. At moderate laser density and/or cup bias values the electron current resulted strongly modulated. The modulation effect modified the output current owing to the superposition of narrow peaks. The peak rate was approximately coincident to the plasma oscillating frequency inside the expansion chamber and it strongly decreased at the pulse tail as the plasma density decreased. Applying an accelerating voltage the modulation frequency and the signal intensity increased vs the accelerating electric field. The maximum charge extracted was about 25 ìC with 100 mJ laser energy. The distance between the peaks was 1 ìs.

Work supported by INFN and Department of Physics Lecce-I.

**WPAP011—SPARC Working Point Optimization for a Bunch with Gaussian Temporal Profile**
*Manuela Boscolo, Massimo Ferrario, Valeria Fusco (INFN/LNF), Concetta Ronsivalle (ENEA C.R. Frascati), Mauro Migliorati (Rome University La Sapienza), Sven Reiche (UCLA)*
We present the optimization of the working point for the SPARC photoinjector with a Gaussian temporal profile. The implications of a Gaussian temporal profile are discussed here for the standard working conditions and for the RF compressor case in comparison with the nominal working point performances of a 10ps flat top pulse with rise time of 1ps. Comparisons with the upgraded version of the HOMDYN code including arbitrary bunch temporal profiles are also reported. Advantages and drawbacks of the Gaussian and flat top pulse shapes are discussed. For the standard working point, it is shown that the two cases provide the same saturation length and average power, but the higher current in the beam core of the Gaussian pulse gives a higher peak radiation power. As the laser pulse shape could be Gaussian at the first stage of the SPARC operation, it is clear the importance of these simulation results.

**WPAP012—Dynamics of Photo-Generated Electron Beams in the SPARC Accelerator**
*Manuela Boscolo, Massimo Ferrario (INFN/LNF), Fabrizio Castelli, Simone Cialdi, Alessandro Federico Flacco (INFN-Milano), Mauro Migliorati (Rome University La Sapienza)*
In a photoinjector system the role played by the laser pulse shaping in achieving high quality electron beam is crucial, as it determines the distribution dependent space charge effects in the early stages of the acceleration. A dedicated code to simulate pulse shaping in a laser system and able to generate the corresponding initial electron beam distribution has been developed. Realistic deviations from the ideal flat top pulse give for example a ramp or multi-peaks shape with a raletive rise time, plateau deformation and ripples. The beam dynamics of electron beams with different initial temporal pulse characteristics along the SPARC photoinjector has also been studied with the code PARMELA. More exotic pulse shaping are also discussed. The study presented here gives some indications on the tolerances of the laser beam characteristics for the electron beam quality preservation.

**WPAP013—Magnesium Film Photocathodes for High Brilliance Electron Injectors**
*Franco Tazzioli, Carlo Vicario (INFN/LNF), Ilario Boscolo, Simone Cialdi (INFN-Milano), Luca Cultrera, Alessio Perrone (Lecce University), Marco Rossi (Rome University La Sapienza), Silvia Orlanducci, Maria Letizia terranova (Università di Roma II Tor Vergata)*
Advanced high brilliance electron injectors require photocathodes having low thermal emittance, high quantum efficiency (QE) and prompt response. They should be easy to handle and capable of working in the very high electric fileds of a RF gun. Magnesium films deposited by laser ablation and sputtering techniques are discussed and QE measurements are presented.

**WPAP014—Development of Electron Gun of Carbon Nanotube Cathode**
*Yasufumi Hozumi (GUAS/AS), Mitsuo Ikeda, Satoshi Ohsawa, Takashi Sugimura (KEK)*
We are developing high brightness electron guns utilizing carbon nanotube (CNT) cathodes. Recently, we succeeded to achieved field emission currents to 0.2 A (3 A/cm2) from a triode type CNT cathode of 3 mm diameter. The emission tests were performed at DC100kV acceleration voltage in pulse operations of 50 Hz using 6 nsec pulses. The emission currents were very stable for long term periods of 3 weeks. Photo emission tests from CNT cathode by 266nm laser pulses is also due to be reported simultaneously.

**WPAP015—Simulation Study of KEKB Positron Source for SuperKEKB**
*Takuya Kamitani, Yukiyoshi Ohnishi, Kazue Yokoyama (KEK)*
For the future SuperKEKB project, an intensity upgrade of the positron beam from the injector linac is necessary. This paper reports on a simulation study of the positron source concerning the yield improvement by replacing the present focusing pulse coil and a S-band capture section by a flux concentrator type of focusing device and a L-band capture section.

**WPAP016—High Brightness Electron Gun for X-Ray Source**
*Satoshi Ohsawa, Mitsuo Ikeda, Takashi Sugimura, Masafumi Tawada (KEK), Yasufumi Hozumi (GUAS/AS)*
A new electron-gun system is under development in order to increase X-ray from a rotating target. In commercial X-ray sources electron beams usually hit targets at the outer part. Owing to deformation by centrifugal force, there has been a limit on electron beam intensities. In order to overcome this difficulty, we adopted a new injection system which strikes inside of a ring-shape projection on a rotating target. It has an advantage in that heated-up points have supports back side against centrifugal force. This merit allows us to raise electron beam to give stronger X-rays.

**WPAP017—Experimental Observation of a 100fs Single Electron Bunch in Photocathode Linac with Longitudinal Emittance Compensation Technique**
*Jinfeng Yang (RCNP), Takafumi Kondoh, Takahiro Kozawa, Seiichi Tagawa, Yoichi Yoshida (ISIR)*
The realization of a 100fs electron pulse is important for the studies of ultrafast physical/chemical phenoena with a pump-probe method. We have developed a photocathode linear accelerator (linac) to generate such electron pulse with a magnetic pulse compressor. The nonlinear effect of the magnetic fields in the pulse compression was compensated carefully by optimizing the magnetic fields and the booster linac RF phase. A 105fs(rms) electron bunch with electron charge of 0.1nC was observed experimentally by using a femtosecond streak camera. The beam energy was 35MeV, and the normalized teraservers emittance was lower than 3mm-mrad. The dependences of the pulse length and the emittance on the electron charge were also measured and compared with the theoretical calculations.

**WPAP018—Generation of Double-Decker Femtosecond Electron Beams in a Photoinjector**
*Jinfeng Yang (SHI), Takafumi Kondoh, Takahiro Kozawa, Seiichi Tagawa, Yoichi Yoshida (ISIR)*
The femtosecond electron beam is a practical source in the pump-probe experiment for studies of ultrafast physical/chemical reactions in materials, in which a mode-locked ultrashort laser light is used as a probe source. The synchronized time jitter between the electron beam and the laser light limits the time resolution in the experiment. In order to reduce the time jitter, a new concept of synchronized double-decker electron beam generation in a photoinjector was proposed. The double electron beams were observed in an S-band photocathode RF gun by injecting two laser beams which produced with a picosecond laser. The double electron beams were compressed into 400fs(rms) with a phase-space rotation technique in magnetic fields. The beams, which one is used as a pump source and another is used as a probe source, are expected for ultrafast reaction studies in femtosecond resolution.

**WPAP019—X-Band Thermionic Cathode RF Gun at UTNL**
*Atsushi Fukasawa, Futaro Ebina, Tatsuo Kaneyasu, Haruyuki Ogino, Fumito Sakamoto, Mitsuru Uesaka, Tomohiko Yamamoto (UTNL), Mitsuo Akemoto, Hitoshi Hayano, Toshiyasu Higo, Junji Urakawa (KEK), Katsuhiro Dobashi (NIRS)*
The X-band (11.424 GHz) linac for compact Compton scattering hard X-ray source are under construction at Nuclear Engineering Research Laboratory, University of Tokyo. This linac designed to accelerate up to 35 MeV, and this electron beam will be used to produce hard X-ray by colliding with laser. It consists of a thermionic cathode RF gun, an alpha magnet, and a traveling wave tube. The gun has 3.5 cells (unloaded Q is 8250) and will be operated at pi-mode. A dispenser cathode is introduced. Since the energy spread of the beam from the gun is predicted to be broad due to the continuous emission from the thermionic cathode, a slit is placed in the alpha magnet to eliminate low energy electrons. The simulation on the injector shows the beam energy 2.9 MeV, the charge 23 pC/bunch, and the emittance less than 10 mm.mrad. The experiment on the gun is planed in the beginning of 2005, and the details will be discussed on the spot.

**WPAP020—The Study of Electron Beam Dynamics in Photocathode RF Gun with Variable Length of the Half Cell**
*Xiao Jin (CAEP/IAE)*
The study of electron beam dynamics in RF Gun is based on K. J. Kim's theory. The longitudinal motion of electron beam is analyzed with the variable length of the half cell of photocathode RF Gun. The relations between the half cell length and electron beam initial injection RF phase is given. The transverse motion of electron beam is also analyzed with the variable length of the half cell of photocathode RF Gun. The analytical result shows that by increasing the length of the half cell and decreasing initial injection phase, the longitudinal compressibility is increased, the emittance growth is reduced.

**WPAP021—Status of PPI (Pohang Photo-Injector) for PAL XFEL**
*Sung-Ju Park, In Soo Ko, Jong-Seok Oh, Yong Woon Parc, Chong-Do Park, Jangho Park (PAL), Xijie Wang (BNL/NSLS)*
A X-Ray Free Electron Laser (XFEL) project based on the Self-Amplified Spontaneous Emission (SASE) is under progress at the Pohang Accelerator Laboratory (PAL). One of the critical R&D for the PAL XFEL* is to develop the Pohang Photo-Injector (PPI) which is required to deliver electron beams with normalized emittance < 1.5 mm-mrad. In order to achieve the required beam quality with high stability and reliability, we will use photocathode with quantum efficiency > 0.1 % and long lifetime. This will greatly lessen the laser energy requirement for producing flat-top UV pulses, and open the possibility of using only regenerative amplifiers (RGAs) to drive the photocathode RF gun. The RGAs can produce mJs output with much better stability than multi-pass amplifiers. Both the Cs2Te and Mg are under consideration for the possible photo-cathode. To demonstrate the suitability of the Mg and Cs2Te for the future 4th generation light source application, an improved BNL-type S-band RF gun with a high-performance load-lock system will be developed for the PPI. In this article, we present the design concept of the PPI, the expected performance, and report on its development status.
*J.S. Oh, S.J. Park et al., "0.3-nm SASE-FEL at PAL," NIM A528, 582 (2004); S.J. Park, J.S. Oh et al., "Design Study of Low-Emittance Injector for SASE XFEL at Pohang Accelerator Laboratory," FEL2004, Italy, 2004.

Supported by the POSCO and the MOST, Korea.

**WPAP022—Measurements of Transverse Emittance for RF Photocathode Gun at the PAL**
*Jangho Park, In Soo Ko, Jong-Seok Oh, Yong Woon Parc, Sung-Ju Park (PAL), Xijie Wang (BNL/NSLS), Dao Xiang (TUB)*
A BNL GUN-IV type RF photo-cathode gun is under fabrication for use in the FIR (Far Infra-Red) facility being built at the Pohang Accelerator Laboratory (PAL). Performance test of the gun will include the measurement of transverse emittance profile along the longitudinal direction. Successful measurement of the emittance profile will provide powerful tool for the commissioning of the 4GLS (4th generation light source) injectors based on the emittance compensation principle. We are going to achieve this withthe use of pepper-pot based emittance meters that can be moved along the longitudinal direction. In this article, we present design considerations on the emittance meter with the resolution of 1 mm mrad.

Supported by the POSCO and the MOST, Korea.

**WPAP023—200 keV Compact Source of Electron Beam with Average Power of 2 kW**
*Ivan Kazarezov, Vadim Auslender, Alex Bryazgin, Alexandre Bulatov, Ivan Glazkov, Evgeny Kokin, Gennady Ivanovich Kuznetsov, Andrey Molokoedov, Vladimir Balakin, Gennady Krainov (BINP SB RAS)*
The paper describes a compact electron beam source with average electron energy of 200 keV. The source operates with pulse power up to 2 MW under average power not higher than 2 kW, pulsed beam current up to 10 A, pulse duration up to 2 mks,

and repetition rate up to 5 kHz. The electron beam is extracted through aluminium-beryllium alloy foil. The pulse duration and repetition rate can be changed from control desk. High-voltage generator for the source with output voltage up to 220 kV is realized using the voltage-doubling circuit which consists of 30 sections. The insulation type - gas, SF6 under pressure of 8 atm. The cooling of the foil supporting tubes is provided by a water–alcohol mixture from an independent source. The beam output window dimensions are 180õ75 mm, the energy spread in the beam +10/-30%, the source weight is 80 kg.

**WPAP024—On the Theory of Photocathode RF Guns**
*Jie Gao (IHEP Beijing)*
In this paper we give a set of analytical formulae to describe the characteristics pf photocathode RF guns at any operation frequencies, such as energy, energy spread, bunch length, outgoing current, and emittance etc. as functions of laser injection phase, which are useful in designs and practical operations of RF guns.

This work has been done at KEK when the author visited KEK from LAL/Orsay.

**WPAP027—RF Electron Gun with Driven Plasma Cathode**
*Igor Khodak, Volodymyr Kushnir (NSC/KIPT)*
It's known that RF guns with plasma cathodes based on solid-state dielectrics are able to generate an intense electron beam. In this paper we describe results of experimental investigation of the single cavity S-band RF gun with driven plasma cathode. The experimental sample of the cathode based on ferroelectric ceramics has been designed. Special design of the cathode permits to separate spatially processes of plasma development and electron acceleration. It has been obtained at RF gun output electron beam with particle energy ~500 keV, pulse current of 4 A and pulse duration of 80 ns. Results of experimental study of beam parameters are referred in. The gun is purposed to be applied as the intense electron beam source for electron linacs.

**WPAP028—Modes of Electron Beam Generation in a Magnetron Diode with a Secondary-Emission Cathode**
*Valeriy Zakutin, Anatoly Nikolayevich Dovbnya, Nikolay Reshetnyak (NSC/KIPT)*
Experiments have shown that the electron current direction can be varied along the diode axis or perpendicular to the axis, depending on the longitudinal magnetic field amplitude and distribution. The diode had a copper cathode diameter 40 mm and 15 mm anode-cathode gap. Several modes of electron beam generation are realized, namely, open, closed, and intermediate. In the first case, at a cathode magnetic field of ~ 1200 Oe, that falls off approaching the diode output down, and at a cathode voltage of 50 kV, the diode generates a tubular electron beam of a current 50 A and the anode current was about 1 % of the beam current. In the second case, the electron current was going to the anode, the secondary-emission multiplication of electrons being retained. At a cathode voltage of ~ 45 kV, the anode current was ~ 5 A, and the beam current was practically absent. This was attained by decreasing the magnetic field to ~ 1.1…1.2 of the Hell field value and by increasing the magnetic field towards the diode output. In the intermediate mode with a cathode voltage of ~ 45 kV the direct beam current measured was ~ 5 A, and the anode current was ~ 7 A.

**WPAP029—The ERLP Photo-Injector**
*Douglas M. Dykes (CCLRC/DL/ASTeC)*
The technology required for the Fourth Generation Light Source (4GLS) proposal for Daresbury Laboratory requires considerable development in order to fulfil the requirements. To bridge this skill gap, an Energy Recovery Prototype (ERLP) is being constructed, utilising a photo-injector, based on a DC photocathode electron gun. This paper summarises the required criteria and parameters, and issues relating to the design of the photo-injector chosen. Initial commissioning results and experience are discussed and a recommendation given of the choice of injector for the 4GLS machine.

**WPAP031—Use of Multiobjective Evolutionary Algorithms in High Brightness Electron Source Design**
*Ivan Vasilyevich Bazarov, Igor Senderovich, Charles Kent Sinclair (Cornell University)*
We describe the use of multiobjective evolutionary algorithms (MOEAs) for the design and optimization of a high average current, high brightness electron injector for an Energy Recovery Linac (ERL). By combining MOEAs with particle tracking, including space charge effects, and by employing parallel computing resources, we explored a multidimensional parameter space with 22 independent variables for a DC gun based injector which is being constructed at Cornell University. The simulated performance of the optimized injector is found to be excellent, with normalized rms emittances as low as 0.1 mm-mrad for a 77 pC bunch, and 0.7 mm-mrad for a 1 nC bunch. We detail the advantages and flexibility of MOEAs as a powerful tool well suited for wide application in solving various problems in the accelerator field.

Supported by Cornell University.

**WPAP032—Emittances Studies at the Fermilab/NICADD Photoinjector Laboratory**
*Rodion Tikhoplav, Adrian C. Melissinos (Rochester University), Jianliang Li, Philippe Regis-Guy Piot (Fermilab)*
The Fermilab/NICADD photoinjector incorporates an L-band rf-gun capable of generating 1-10 nC bunches. The bunches are then accelerated to 16 MeV with a TESLA superconducting cavity. In the present paper we present parametric studies of transverse emittances and energy spread for a various operating points of the electron source (RF-gun E-field, laser length and spot size, and solenoid settings). We especially study the impact, on transverse emittance, of Gaussian and Plateau temporal distribution of the photocathode drive-laser.

This work was supported by the Universities Research Association Inc. under contract DE-AC02-76CH00300 with the U.S. DOE, and by NICADD.

**WPAP033—State-of-the-Art Electron Guns and Injector Designs for Energy Recovery Linacs (ERL)**
*Alan Murray Melville Todd, Hans Bluem, Michael Cole, John Rathke, Tom Schultheiss, Vincent Christina (AES), John Wesley Lewellen (ANL), Ilan Ben-Zvi, Andrew Burrill, Rama Calaga, Xiangyun Chang, Dmitry Kayran, Vladimir N. Litvinenko, Triveni Rao (BNL), Jacek Sekutowicz (DESY), Dietmar Janssen (FZR), Edward Daly, David Douglas, Carlos Hernandez-Garcia, Peter Kneisel, George R. Neil, Larry Phillips, Joseph P. Preble, Robert Rimmer, Claus Rode, Tim Siggins, Timothy Whitlach, Mark Wiseman (Jefferson Lab), Patrick Colestock, John Patrick Kelley, Sergey Kurennoy, Dinh Cong Nguyen, Steven Russell, Richard L. Wood (LANL), Dale L. Schrage (LANL/LANSCE), Isidoro Enrico Campisi (ORNL/SNS), Lloyd Martin Young (TechSource)*
A key technology issue of ERL devices for high-power free-electron laser (FEL) and 4th generation light sources is the demonstration of reliable, high-brightness, high-power injector operation. Ongoing programs that target up to 1 Ampere injector

performance at emittance values consistent with the requirements of these applications are described. We consider that there are three possible approaches that could deliver the required performance. The first is a DC photocathode gun and superconducting RF (SRF) booster cryomodule. Such a 750 MHz device is being integrated and will be tested up to 100 mA at the Thomas Jefferson National Accelerator Facility beginning in 2007. The second approach is a high-current normal-conducting RF photoinjector. A 700 MHz gun will undergo thermal test in 2006 at the Los Alamos National Laboratory, which, if successful, when equipped with a suitable cathode, would be capable of 1 Ampere operation. The last option is an SRF gun. A half-cell 703 MHz SRF gun capable of delivering 1.0 Ampere will be tested to 0.5 Ampere at the Brookhaven National Laboratory in 2006. The fabrication status, schedule and projected performance for each of these state-of-the-art injector programs will be presented.

This work is supported by NAVSEA, NSWC Crane, the Office of Naval Research, the DOD Joint Technology Office and by the U.S. DOE.

**WPAP034—Studies of Possible ILC Positron Source Commissioning Using Target Scattered Electron Beam**

*Haitao Wang, Wei Gai, Wanming Liu (ANL)*

It is apparent that the gamma-ray based positron source components including positron linac and damping rings for ILC can not be easily commissioned until the electron beam is fully conditioned at high energies (> 150 GeV). In this paper, we discuss a scheme that could use a short and energetic electron beam scattered through a set of carefully selected targets to simulate certain behaviors of the positron beam, such as beam emittance and energy spread. The basic idea is to make the phase space distribution of the scattered electron beam to reflect certain aspects of the positron beam distributions. Subsequently, the positron source elements such as capture optics, linacs and even damping ring could be effectively commissioned before ILC colliding electron beam is ready. The simulation results using EGS4 for beam scattering and PARMELA for beam dynamics are presented.

U.S. DOE.

**WPAP035—Emittance Compensation in Flat Beam Production in an RF Gun Linac**

*Shaoheng Wang (ANL)*

Ya. Derbenev Proposed a flat beam production method in RF gun Linac, which passes the electron beam through a matched skew quadrupole channel and transform the initially transversely round beam into a flat beam. Fermilab/NICADD Photoinjector Laboratory has performed a lot of experiments, a ratio of 50 of the transverse emittances in x and y plane has been achieved and the ratio of 100 and higher is underway of research. In this paper, the S-shaped flat beam, found both in experiments and simulations, is investigated. The nonlinear transverse force from the RF field when the beam passes the superconducting cavity is found to be one of the sources which produce the transverse S-shape distribution and increase the emittance. An extra solenoid located before the superconducting cavity is proposed to be added to adjust the beam transverse size when the beam passes through the cavity. The resulted transverse nonlinear space-charge force is used to counter-act against the nonlinear transverse force from the RF field. PARMELA simulations have shown that, with proper setup of the extra solenoid, the emittance ratio can be enhanced by a factor of 2 and the S-shaped transverse distribution can also be eliminated.

This research is supported by the U.S. Department of Energy under contract DE-FG02-92ER40747 and the National Science Foundation under contract NSF PHY-0244793.

**WPAP036—Determination of the Field Enhancement Factor on Photocathode Surface Via the Schottky Effect**

*Zikri Yusof, Manoel Conde, Wei Gai (ANL)*

Using photons with energy that is less than the work function, we employ the Schottky effect to determine the field enhancement factor on the surface of a Mg photocathode. The Schottky effect is manifested via a shift in the threshold for photoemission as the amplitude of the RF in the photoinjector gun is varied. From the threshold condition, we can directly determine the field enhancement factor on the cathode surface. This is a viable technique to obtain the field enhancement factor of surfaces of other materials such as Nb and Cu.

U.S. Department of Energy.

**WPAP037—Novel Method of Emittance Preservation in ERL Merging System in Presence of Strong Space Charge Forces**

*Dmitry Kayran, Vladimir N. Litvinenko (BNL)*

Energy recovery linacs (ERLs) are potential candidates for the high power and high brightness electron beams sources. The main advantages of ERL are that electron beam is generated at relatively low energy, injected and accelerated to the operational energy in a ERL loop with a common linac, then is decelerated in the same loop down to injection energy and dumped. The intrinsic part of any ERL is a merging system for the low-energy beam with a high-energy beam passing around the ERL loop. One of the challenges for generating high charge high brightness e-beam in ERL is development of merging system, which provides achromatic condition for space charge dominated beam and which is compatible with the emittance compensation scheme. In this paper we present principles of operation of such merging system. We also describe an example of such system, which we call Zigzag or Z-system. We use a specific implementation for R&D ERL at Brookhaven for illustration.

Work performed under Contract DE-AC02-98CH10886 with the auspices of the U.S. DOE.

**WPAP038—Photoemission Studies on BNL/AES/JLab all Niobium, Superconducting RF Injector**

*Triveni Rao, Ilan Ben-Zvi, Andrew Burrill, Harald Hahn, Dmitry Kayran, Yongxiang Zhao (BNL), Michael Cole (AES), Peter Kneisel (Jefferson Lab)*

Photoemission from all niobium superconducting injector is of considerable interest for the development of higher average current electron sources. In the past year, we have generated photocurrent from such an injector by irradiating the back wall of the 1/2 cell cavity with 248 nm and 266 nm laser beams. In this paper, we present the results of these measurements including the quantum efficiency, and its dependence on the field and wavelength. Issues related to the quenching of the cavity by the laser radiation will also be addressed.

Under contract with the U.S. DOE, Contract No. DE-AC02-98CH10886.

**WPAP039—Progress on Lead Photocathodes for Superconducting Injectors**

*John Smedley, Triveni Rao (BNL), Jacek Sekutowicz (DESY), Peter Kneisel (Jefferson Lab), Richard Lefferts, Andrzej Lipski (SBUNSL)*

We present the results of our investigation of bulk, electroplated and vacuum deposited lead as suitable photocathode materials for superconducting RF injectors. The quantum efficiency of each sample is presented as a function of the wavelength of the incident light, from 310 nm to 190 nm. Quantum efficiencies of 0.3% have been obtained. Production of a niobium cavity with a lead-plated cathode is underway.

This work was supported by DOE contracts DE-AC02-98CH10886, DE-AC03-76SF00515 and DE-FG02-97ER82336.

**WPAP040—High-Brightness R&D Facility at the PAL**
*Xijie Wang (BNL/NSLS), Hyotcherl Ihee (KAIST), Sung-Ju Park, Yong Woon Park (PAL), In Soo Ko, Jangho Park (PAL; POSTECH), Dao Xiang (TUB)*
A photo-cathode RF gun for use in the FIR radiation facility is being built at the Pohang Accelerator Laboratory (PAL). The gun system will be also utilized for the critical R&Ds for the proposed PAL XFEL, high-brightness beam physics R&D and femto-second electron diffraction. The facility will be equipped with 6-D electron beam instrumentation, such as transverse beam profile monitors (BPM) and RF kicker cavity for longitudinal phase space characterization. The proposed high-brightness R&D program will not only addresses some of the fundamental issues in high-brightness electron source R&D, such as thermal emittance from photoemission process and emittance optimization; but also future challenges in SRF gun operation, such as emittacne compensation with solenoid magnets far from the SRF cavity. One of the unique feature of the propose facility is that, both solenoid magnet and BPM can be continuously positioned along the beam line so it can used for emittance optimization. The design of the high-brightness facility, including various beam diagnostic device and the initial simulation of the beam dynamics will be presented in this report.

**WPAP041—Time Dependent Quantum Efficiency and Dark Current Measurements in an RF Photo-Injector with a High Quantum Efficiency Photocathode**
*Raymond Patrick Fliller, Helen Edwards (Fermilab), Walter Hartung (NSCL)*
A system was developed at INFN Milano for preparing cesium telluride photo-cathodes and transferring them into an RF gun under ultra-high vacuum. This system has been in use at the Fermilab NICADD Photo-Injector Laboratory (FNPL) since 1997. A similar load-lock system is used at the TeSLA Test Facility at DESY-Hamburg. Two 1.625-cell high duty cycle RF guns have been fabricated for the project. Studies of the photo-emission and field emission ("dark current") behavior of both RF guns have been carried out. Unexpected phenomena were observed in one of the RF guns. In situ changes in the cathode's quantum efficiency and dark current with time were seen during operation of the photo-injector. These changes were correlated with the magnetostatic field at the cathode.* In addition, multipacting is observed in the RF guns under certain conditions. Recent measurements indicate a correlation between multipacting, anomalous photo-emission behavior, and anomalous field emission behavior. Results will be presented.
*W. Hartung, J.-P. Carneiro, H. Edwards, M. Fitch, M. Kuchnir, P. Michelato, D. Sertore, in Proceedings of the 2001 Particle Accelerator Conference, p. 2239-2241.

This work was supported by Universities Research Association Inc. under contract DE-AC02-76CH00300 with the U.S. DOE and by NICADD.

**WPAP042—Progress on Using NEA Cathodes in an RF Gun**
*Raymond Patrick Fliller, Helen Edwards (Fermilab), Hans Bluem, John Rathke (AES), Charles Kent Sinclair (Cornell University), Markus Huening (DESY)*
RF guns have proven useful in multiple accelerator applications, and are an attractive electron source for the ILC. Using a NEA GaAs photocathode in such a gun allows for the production of polarized electron beams. However the lifetime of a NEA cathode in this environment is reduced by ion and electron bombardment and residual gas oxidation. We report progress made with studies to produce a RF gun using a NEA GaAs photocathode to produce polarized electron beams. Attempts to reduce the residual gas pressure in the gun are discussed. Initial measurements of ion flux through the cathode port are compared with simulations of ion bombardment. Future directions are also discussed.

This work was supported by Universities Research Association Inc. under contract DE-AC02-76CH00300 with the U.S. DOE and by NICADD. AES personnel were supported under DOE SBIR contract #DE-FG02-04ER838.

**WPAP043—Production of Transverse Controllable Laser Density Distribution in Fermilab/NICADD Photoinjector**
*Jianliang Li, Philippe Regis-Guy Piot (Fermilab), Adrian C. Melissinos, Rodion Tikhoplav (Rochester University)*
The Fermilab/NICADD photoinjector laboratory consist of a photoemission electron source based on an L band rf-gun. The CsTe photocathode is illuminated by an ultrashort UV laser. The transport line from the laser to the photocathode was recently upgraded to allow imaging of an object plane located ~20 m from the photocathode. This upgrade allows the generation of transverse laser distributions with controlled nonuniformity, yielding the production of an electron beam with various transverse densities patterns. Measuring the evolution of the artificial pattern on the electron bunch provides information that can be used to benchmark numerical simulations and investigate the impact of space charge. Preliminary data on these investigations are presented in the present paper.

**WPAP044—Advanced Electromagnetic Analysis for Electron Source Geometries**
*Mark Hess (IUCF)*
One of the challenging issues for analytically modeling electron sources, such as rf photoinjectors, is how to incorporate fully electromagnetic effects which are generated by the electron beam. The main difficulties that arise in finding an analytical solution of the electromagnetic fields are due to the complex shape of the conductor boundary, as well as the complicated structure of the beam density and current. Both of these problems can be handled self-consistently by using an electromagnetic Green's function method. In this paper, we present a solution to the exact electromagnetic fields, which were derived from the Green's function, for a simplified electron source conductor geometry, namely a semi-infinite circular pipe with an endcap. We assume that the beam currents are in the axial direction and satisfy the continuity equation in conjunction with the beam charge density, but may have arbitrary spatial and time dependency. We discuss how these analytical methods may be extended to include in the effect of one or multiple irises, which are found in rf photoinjector systems.

**WPAP045—Ion Back-Bombardment of GaAs Photocathodes Inside DC High Voltage Electron Guns**
*Joseph Michael Grames, Phillip Adderley, Joshua Brittian, Daniel Charles, Jim Clark, John Hansknecht, Matthew Poelker, Marcy Lynn Stutzman, Kenneth Eric Surles-Law (Jefferson Lab)*
The primary limitation for sustained high quantum efficiency operation of GaAs photocathodes inside DC high voltage

electron guns is ion back-bombardment of the photocathode. This process results from ionization of residual gas within the cathode/anode gap by the extracted electron beam, which is subsequently accelerated backwards to the photocathode. The damage mechanism is believed to be either destruction of the negative electron affinity condition at the surface of the photocathode or damage to the crystal structure by implantation of the bombarding ions. This work characterizes ion formation within the anode/cathode gap for gas species typical of UHV vacuum chambers (i.e., hydrogen, carbon monoxide and methane). Calculations and simulations are performed to determine the ion trajectories and stopping distance within the photocathode material. The results of the simulations are compared with test results obtained using a 100 keV DC high voltage GaAs photoemission gun and beamline at currents up to 10 mA DC.

This work was supported by U.S. DOE Contract No. DE-ACO5-84-ER40150.

**WPAP046—Injection Options for 12 GeV CEBAF Upgrade**
*Reza Kazimi, Jay Benesch, Joseph Michael Grames, Geoffrey Arthur Krafft, Michael Tiefenback, Byung Chel Yunn, Yuhong Zhang (Jefferson Lab)*
Jefferson Lab is planning to upgrade the CEBAF accelerator from 6 to 12 GeV. In order to achieve this, the beam energy at injection into the main accelerator needs to increase from 67 MeV to either 123 or 134 MeV depending on the location of the new experimental hall relative to the accelerator. The present 100 keV electron source and beam formation to 5 MeV will remain unchanged; however, the present accelerating cryomodules in the injector cannot reach the higher injection energies. Consequently, two options for attaining these energies are considered: (1) replacing the present injector cryomodules with new, higher gradient cryomodules, or (2) re-circulating the beam through the existing cryomodules to achieve the necessary energy gain in two passes. In this paper we present simulation results and list the advantages and disadvantages of these two options.

Work supported by DOE Contract DE-AC05-84ER40150.

**WPAP047—Preliminary Results from a Superconducting Photocathode Sample Cavity**
*Peter Kneisel (Jefferson Lab), Jacek Sekutowicz (DESY), Andrzej Lipski (SBUNSL)*
Pure niobium has been proposed as a photocathode material and recently a successful test has been conducted with a niobium single cell cavity to extract photo-currents from the surface of this cavity. However, the quantum efficiency of niobium is ~2·10-4, whereas electrodeposited lead has a ~15 times higher quantum efficiency. We have designed and tested a photo-injector niobium cavity, which can be used to insert photocathodes made of different materials in the high electric field region of the cavity. Experiments have been conducted with niobium and lead, which show that neither the Q- values of the cavity nor the obtainable surface fields are significantly lowered. This paper reports about the results from these tests.

Work supported by the U.S. DOE Contract No DE-AC05-84ER40150.

**WPAP048—Meeting Extremely Demanding Beam Specifications for Parity Violation Experiments**
*Matt Poelker, Phillip Adderley, Joshua Brittian, Daniel Charles, Jim Clark, Joseph Michael Grames, John Hansknecht, Marcy Lynn Stutzman, Kenneth Eric Surles-Law (Jefferson Lab)*
The past year has seen successful completion of scheduled portions of parity violation experiments G0 Forward Angle and HAPPEx-II at the Continuous Electron Beam Accelerator Facility (CEBAF) at Jefferson Lab. These experiments were demanding from a polarized source perspective, requiring new lasers, new laser-table optical devices, new pockels cell alignment procedures, new injector beamline settings and new software tools to map and set the beam envelope through the machine. Rigorous monitoring of beam properties was required throughout each experiment to maintain consistent and reliable results. For both experiments, the run-averaged helicity-correlated beam asymmetries were maintained within acceptably small limits. The g0 and HAPPEx collaborations will continue their experiments in 2005 and 2006. Other collaborations have taken note of recent success and as a result, it is likely even more demanding parity violation experiments will receive approval for beam time at CEBAF, for example Qweak and Lead Parity. This presentation describes photogun and laser table challenges imposed by parity violation experiments that continue to set new limits on achievable beam quality.

This work was supported by U.S. DOE Contract No. DE-ACO5-84-ER40150.

**WPAP049—A High-Gradient CW RF Photo-Cathode Electron Gun for High Current Injectors**
*Robert Rimmer (Jefferson Lab)*
The paper describes the analysis and preliminary design of a high-gradient photo-cathode RF gun optimized for high current CW operation. The gun cell shape is optimized to provide maximum acceleration for the newly emitted beam while minimizing wall losses in the structure. The design is intended for use in future high-current high-power CW FELs but the shape optimization for low wall losses may be advantageous for other applications such as XFELs or Linear Colliders using high peak power low duty factor guns where pulse heating is a limitation. The concept allows for DC bias on the photocathode in order to repel ions and improve cathode lifetime.

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**WPAP050—High Average Current DC GaAs Photocathode Gun for ERLs and FELs**
*Carlos Hernandez-Garcia, Stephen Vincent Benson, Don Bullard, Fred H. Dylla, Kevin Jordan, George R. Neil, Michelle Diane Shinn, Tim Siggins, Richard Lee Walker (Jefferson Lab)*
The Jefferson Lab 10 kW IR FEL Upgrade DC GaAs photocathode gun is presently the highest average current electron source operational in the U.S., delivering a record 9.1 mA CW, 350 kV electron beam with 122 pC/bunch at 75 MHz rep rate. Pulsed operation has also been demonstrated with 8 mA per pulse (110 pC/bunch) in 16 ms-long pulses at 2 Hz rep rate. Routinely the gun delivers 5 mA CW and pulse current at 135 pC/bunch for FEL operations. The Upgrade DC photocathode gun is a direct evolution of the DC photocathode gun used in the previous 1 kW IR FEL Demo*. Improvements in the vacuum conditions and the incorporation of two UHV motion mechanisms (a retractable cathode and a photocathode shield door) have extended the GaAs photocathode lifetime to over 200 Coulombs delivered between recesiations (quantum efficiency replenishment). With each photocathode activation quantum efficiencies above 6% are routinely achieved. The photocathode activation and performance will be described in detail.
*T. Siggins et al., "Performance of a GaAs DC photocathode gun for the Jefferson Lab FEL," Nucl. Inst. Meth. A 475 (2001) 549-553.

This work supported by The Office of Naval Research under contract to the Dept. of Energy, the Air Force Research Lab, and the Commonwealth of Virginia.

**WPAP051—Field Emission Measurements from Cesiated Titanium and Stainless Steel Electrodes**

*Kenneth Eric Surles-Law, Phillip Adderley, Joshua Brittian, Daniel Charles, Jim Clark, Joseph Michael Grames, John Hansknecht, Matthew Poelker, Marcy Lynn Stutzman (Jefferson Lab)*

Literature suggests titanium electrodes produce less field emission compared to stainless steel. With this in mind, titanium electrodes were manufactured for use inside DC high voltage photoemission guns at the Continuous Electron Beam Accelerator Facility (CEBAF). The GaAs photocathodes inside these guns were activated with cesium and nitrogen trifloride to obtain a negative electron affinity condition. During activation of the photocathode surface, cesium is inadvertently applied to some portion of the cathode electrode surface. Experience revealed that excessive field emission was produced within photoguns after approximately four photocathode activations when titanium electrodes were used. Titanium electrodes were replaced with stainless steel electrodes and excessive field emission has not been observed following eight photocathode reactivations over the course of two years. For this papaer, field emission properties of titanium and stainless steel electrodes were studied as a function of cesium application, using a separate test stand in a manner consistent with typical photocathode activation.

U.S. DOE Contract No. DE-ACO5-84-ER40150.

**WPAP052—Monte Carlo Transverse Emittance Study on Cs2Te**

*Francesco Banfi, Gabriele Ferrini, Gianluca Piero Galimberti, Claudio Giannetti, Stefania Pagliara, Fulvio Parmigiani, Emanuele Pedersoli (Università Cattolica-Brescia), Barbara Ressel (ELETTRA), John Corlett, Steven M Lidia (LBNL)*

A Monte Carlo study of electron transport in Cs2Te films is performed to investigate the transverse emittance epsilon at the cathode surface. We find the photoemitted electron angular distribution and explain the physical mechanism involved in the process, a mechanism hindered by the statistical nature of the Monte Carlo method. The effects of electron-phonon scattering are discussed. The transverse emittance is calculated for different radiation wavelengths and a laser spot size of 1.5*10^{-3} m. For a laser radiation at 265 nm we find epsilon = 0.56 mm-mrad. The dependence of epsilon and the quantum yield on the electron affinity Ea is also investigated. The data shows the importance of aging/contamination on the material.

U.S. DOE, Office of Science, under Contract No. DE-AC03-76SF00098.

**WPAP053—Quantum Efficiency Measurements of Femtosecond Vectorial Photoemission on Cu Photocathodes**

*Francesco Banfi, Gabriele Ferrini, Gianluca Piero Galimberti, Claudio Giannetti, Stefania Pagliara, Fulvio Parmigiani, Emanuele Pedersoli (Università Cattolica-Brescia), Barbara Ressel (ELETTRA), John Corlett, Steven M Lidia (LBNL)*

Quantum Efficiency (QE) measurements of single photon photoemission from a Cu(111) single crystal and a Cu polycrystal photocathodes, irradiated by 150~fs-6.28~eV laser pulses, are reported over a broad range of incidence angle in both s and p polarizations. The maximum value of QE for the Cu polycrystal sample is Y~4*10^(-4), obtained with p polarization at an angle of incidence theta=65^{Ê}. Our data confirm the vectorial photoemission model. Issues concerning surface roughness and symmetry considerations are addressed. An explanation in terms of non local conductivity tensor is proposed. Advantages of a 6.28~eV photon as compared to the standard 4.71~eV photon in use with Cu photocathodes are discussed.

U.S Department of Energy, Office of Science under Contract No. DE-AC03-76SF00098.

**WPAP054—Tailored Laser Pulses for High Brightness Electron Beam Production**

*Steven M. Lidia (LBNL)*

A high-brightness electron source must be carefully optimized to minimize and preserve the electron beam emittance, particularly against the deleterious effects of space-charge. Space charge forces have their largest effect at low energies, after the electrons are pulled off the photocathode and before they reach significant kinetic energies (approximately 75-100 MeV). To produce a low-emittance beam requires optimization of the illuminating laser pulse temporal and spatial profiles. We report on simulations of optical pulse transport through elements designed to tailor the laser pulse distribution, and the effect on electron beam brightness during and after photoemission. We discuss sources of optical noise and their mitigation, and the effect of scattered light on halo production in photoinjectors.

This work was supported by the U.S. DOE, Office of Science under Contract No. DE-AC03-76SF00098.

**WPAP055—A 3D Parallel Beam Dynamics Code for Modeling High Brightness Beams in Photoinjectors**

*Ji Qiang, Steven M Lidia (LBNL), Robert Ryne (LBNL/CBP), Cecile Limborg-Deprey (SLAC)*

In this paper we report on IMPACT-T, a 3D beam dynamics code for modeling high brightness beams in photoinjectors and rf linacs. IMPACT-T is one of the few codes used in the photoinjector community that has a parallel implementation, making it very useful for high statistics simulations of beam halos and beam diagnostics. It has a comprehensive set of beamline elements, and furthermore allows arbitrary overlap of their fields. It is unique in its use of space-charge solvers based on an integrated Green function to efficiently and accurately treat beams with large aspect ratio, and a shifted Green function to efficiently treat image charge effects of a cathode. It is also unique in its inclusion of energy binning in the space-charge calculation to model beams with large energy spread. Together, all these features make IMPACT-T a powerful and versatile tool for modeling beams in photoinjectors and other systems. In this paper we describe the code features and present results of IMPACT-T simulations of the LCLS and LUX photoinjectors. We also include a comparison of IMPACT-T and PARMELA results, and a comparison of IMPACT-T and ASTRA results.

This work was supported by a SciDAC project in accelerator physics which is supported by the U.S. DOE/SC Office of High Energy Physics and the Office of Advanced Scientific Computing Research.

**WPAP056—Beam Study at Different Energy of CAMD Injector**

*Yanshan Wang, Mikhail Fedurin, Victor Paul Suller (LSU/CAMD)*

The injection study is conducted in order to increase the CAMD storage current from current status.* The impedance of the storage ring is measured, the dynamic aperture is studied, and the beam load compensation and Robinson instability is considered at different injection energy. In the paper, the theoretical

and experimental will be presented and the status of the injector will be menetioned.
*V. Suller et al., Proc EPAC2004, pp 2421-2423.

Supported by the State of Louisiana.

**WPAP057—Three-Dimensional Theory and Simulation of an Ellipse-Shaped Charged-Particle Beam Gun**
*Ronak Bhatt, Chiping Chen (MIT/PSFC)*
A three-dimensional (3D) theory of non-relativistic, laminar, space-charge-limited, ellipse-shaped, charged-particle beam formation has been developed recently (Bhatt and Chen, PR:ST-AB, submitted Dec. 2004), whereby charged particles (electrons or ions) are accelerated across a diode by a static voltage differential and focused transversely by Pierce-type external electrodes placed along analytically specified surfaces. The treatment is extended to consider the perturbative effects of anode hole lensing, thermal isolation of the emitter, finiteness and nonuniformities of beam-forming electrodes, and an initial thermal spread. Analytic and semi-analytic results are presented along with 3D simulations utilizing the 3D trajectory code, OMNITRAK. Considerations with regard to beam matching into a periodic magnetic focusing lattice are discussed.

U.S. DOE: Grant No. DE-FG02-95ER40919, Grant No. DE-FG02-01ER54662, Air Force Office of Scientific Research: Grant No. F49620-03-1-0230, and the MIT Deshpande Center for Technological Innovation.

**WPAP058—The ILC Polarized Electron Source**
*Axel Brachmann, James E. Clendenin, Edward Garwin, Robert Kirby, Dah-An Luh, Takashi Maruyama, David Schultz, John Sheppard (SLAC), Richard Prepost (UW-Madison/PD)*
The SLC polarized electron source (PES) can meet the expected requirements of the International Linear Collider (ILC) for polarization, charge and lifetime. However, experience with newer and successful PES designs at JLAB, Mainz and elsewhere can be incorporated into a first-generation ILC source that will emphasize reliability and stability without compromising the photocathode performance. The long pulse train for the ILC may introduce new challenges for the PES, and in addition more reliable and stable operation of the PES may be achievable if appropriate R&D is carried out for higher voltage operation and for a simpler load-lock system. The outline of the R&D program currently taking shape at SLAC and elsewhere is discussed. The principal components of the proposed ILC PES, including the laser system necessary for operational tests, are described.

This work is supported by U.S. DOE contracts DE-AC02-76SF00515 (SLAC) and DE-AC02-76ER00881 (UW).

**WPAP059—The Orion Photoinjector**
*Dennis Thomas Palmer, Eric R. Colby, Robert Noble, Robert Siemann, James Spencer, Dieter Walz (SLAC), James Rosenzweig (UCLA)*
The Photoinjector will replace the themonic DC gun presently used as the electron source at the SLAC Test Accelerator. The Photoinjector is comprised of following subsystems: RF Gun, Compensation Magnet, UV Drive Laser, High and Low Power RF systems and Diagnostics. The initial use is to support a demonstration experiment of laser acceleration at 800 nm with 5 pC of bunch charge. The RF gun is an S-Band 1.6 cell standing wave structure. A solid state diode pumped laser system, is used to generate 2.3 mJ of IR energy at a reparation rate of 10 Hz. The photocathode is illuminated with 266 nm generated by a harmonic tripler plate. The high power waveguide subsystem is centered on a -3dB coupler. This coupler is used to protect the 5045 klystron from reflected RF energy from the standing wave 1.6 cell RF gun and is also used as a diagnostics port for in situ low power RF gun tuning. The diagnostics subsystem is centered between the emittance compensation magnet and a 0.9 m X-Band acceleration section. Energy, emittance, spot size and charge are measured at a 10Hz repetition rate. In this paper we will report on the status and experimental results of each subsystem.

**WPAP060—Asymmetric Transverse Phase Space Measurements from an S-Band Photocathode RF Gun**
*John Schmerge, John Castro, James E. Clendenin, David Dowell, Stephen Gierman (SLAC), Steven M. Lidia (LBNL/AFR)*
Measurements of the x and y beam size at different longitudinal positions as a function of solenoid focal length at the exit of an S-Band photocathode rf gun are presented. The data is measured at low charge and is used to determine an upper limit on the thermal emittance from the cathode. The horizontal beam size vs solenoid focal length is slightly shifted with respect to the vertical beam size indicating the presence of a small quadrupole component in either the gun rf fields or the solenoid magnetic field. Measurements at different solenoid and gun field strengths will be shown to determine the source of the quadrupole field. Comparison with previously reported measurements at other laboratories will also be presented.

Work supported by U.S. DOE contract DE–AC02–76SF00515.

## Poster Session WPAT—Radio-Frequency Systems
## Meeting Room 200 A-C, 8:30-12:20

**WPAT001—HFSS Simulation of Vacuum Tube RF Power Amplifiers**
*Vladimir Zviagintsev, Iouri Bylinskii (TRIUMF)*
Upgrade and development of rf power amplifiers requires some calculations to predict and optimize parameters of the system before the manufacturing and test. ANSOFT HFSS code suggests a lot of possibilities for 3D EM simulation of the amplifier like a resonator which comprises a vacuum tube like a passive component. Two examples of these simulations applied for upgrade of TRIUMF Cyclotron rf system are considered in this paper.

TRIUMF receives funding via a contribution agreement through the National Research Council of Canada.

**WPAT002—High Power (35 kW and 190 kW) Solid State Amplifiers for the SOLEIL Synchrotron**
*Patrick Marchand, Massamba Diop, Robert Lopes, Jean Polian, Fernand Ribeiro, Ti Ruan (SOLEIL)*
In the SOLEIL Storage Ring, two cryomodules, each containing a pair of superconducting cavities will provide the maximum power of 600 kW, required at the nominal energy of 2.75 GeV with the full beam current of 500 mA and all the insertion devices. Each of the four cavities will be powered with a 190 kW solid state amplifier consisting in a combination of 315 W elementary modules (about 750 modules per amplifier). The amplifier modules, based on a technology developed in house, with MOSFET transistor, integrated circulator and individual power supply, are fabricated in the industry. In the booster, a 35 kW solid state amplifier (147 modules) will power a 5-cell copper cavity of the LEP type. The first operational results and the status of the RF power plants are reported in this paper. Although quite innovative for the required power range, the

solid state technology proved to be very attractive with significant advantages as compared to vacuum tubes.

**WPAT003—Glycol-Substitute for High Power RF Water Loads**
*Michael Ebert, Frank-Reinhard Ullrich (DESY)*
In water loads for high power rf applications, power is dissipated directly into the coolant. Loads for frequencies below approx. 1GHz are ordinarily using an ethylene glycol-water mixture as coolant. The rf systems at DESY utilize about 100 glycol water loads with powers ranging up to 600kW. Due to the increased ecological awareness, the use of glycol is now considered to be problematic. In EU it is forbidden to discharge glycol into the waste water system. In case of cooling system leakages one has to make sure that no glycol is lost. Since it is nearly impossible to avoid any glycol loss in large rf systems, a glycol-substitute was searched for and found. The found sodium-molybdate based substitute is actually a additive for corrosion protection in water systems. Sodium-molybdate is ecologically harmless; for instance, it is also used as fertilizer in agriculture. A homoeopathic dose of 0.4% mixed into deionised water gives better rf absorption characteristics than a 30% glycol mixture. The rf coolant features of this substitute were investigated and tested. The glycol coolant of all rf systems at DESY was substituted. The results of the investigations and tests are presented.

**WPAT004—Coupling Methods for Room Temperature and Superconducting CH-Cavities**
*Holger Liebermann, Holger Podlech, Ulrich Ratzinger, Andreas Christoph Sauer (IAP)*
The cross-bar H-type (CH) cavity is a multi-gap drift tube structure based on the H-210 mode currently under development at IAP Frankfurt and in collaboration with GSI. Numerical simulations and rf model measurements showed that the CH-type cavity is an excellent candidate to realize Room Temperature and Superconducting multi-cell structures with a frequency range from about 150 MHz up to 800 MHz. For coupling into such a complex structure, we compare two coupling methods, one with capacitive and the other with inductive couplers. This paper will present detailed MicroWave Studio simulations and measurements for these different coupling methods for Room Temperature and Superconducting CH-Cavities. For coupling into a Superconducting CH-Cavity we prefer a capacitive coupler. We will also present an optimized Superconducting CH-Cavity for capacitive couplers.

GSI, BMBF contr. No. 06F134I, EU.

**WPAT005—System Mode Sounding (SMS) Tuning: A Non-Invasive Field Optimization Technique**
*Vittorio Giorgio Vaccaro (Naples University Federico II), Tarcisio Clauser, Antonio Rainò, Vincenzo Variale (INFN-Bari), Carlo De Martinis, Dario Giove (INFN-Milano), Maria Rosaria Masullo (INFN-Napoli), Marco Mauri (INFN/LASA), Alessandro D'Elia (Naples University Federico II and INFN)*
In order to have efficient particle acceleration it is fundamental that the particles experience, in the accelerating gap, field amplitudes as uniform and as high as possible from gap to gap. Because of the unavoidable fabrication errors, an accelerating structure, when assembled, exhibits field values lower than the nominal ones and/or not uniform. All the usual procedures developed in order to adjust the parameter deviations responsible of the malfunction of these structures, are based on field amplitude measurements, by using the bead pull technique, which is a very invasive technique. In this paper the philosophy is reversed: it is assumed that all the information can be got by Sounding the Modes of the whole System (SMS) and correct the deviation of each frequency mode from its nominal value by means of an appropriate tuning of the cavities: resorting to a perturbative technique applied to a circuit model representing this kind of structures, it is possible to calculate the amount of tuning to give to the cavities. It will be shown that a very good equalization and maximization of the fields in the cavities can be achieved by using this technique.

**WPAT006—The SPARC RF Synchronization System**
*Alessandro Gallo, David Alesini, Marco Bellaveglia, Roberto Boni, Giampiero Di Pirro, Franco Tazzioli (INFN/LNF)*
The SPARC project consists in a 150 MeV Linac aimed at driving an ondulator for the production of 530 nm SASE FEL radiation. A bunch transverse emittance as low as 1mm mrad and a bunch peak current of about 100 A are required for this task. The RF voltages in the RF gun and in the 3 S-band accelerating sections have to be kept phase locked within 3 ps to the arrival time of the laser pulse on the photocathode to guarantee the required performances. This specification will be reduced to 0.5 ps in the phase-2 of the project when the rectilinear RF compression of the bunch will be tested. The general architecture of the SPARC RF control system together with some bench qualification measurements of the basic components is presented in this paper. First experimental measurements of the temporal jitter of the SPARC laser pulse are also reported.

**WPAT007—Control Loops for the J-PARC RCS Digital Low-Level RF Control**
*Alexander Schnase, Masahiro Nomura, Fumihiko Tamura, Masanobu Yamamoto (JAERI/J-PARC), Shozo Anami, Eizi Ezura, Keigo Hara, Chihiro Ohmori, Akira Takagi, Masahito Yoshii (KEK)*
The low-level radiofrequency control for the Rapic Cycling Syncrotron of J-PARC is based on digital signal processing. This system controls the acceleration voltages of 12 magnetic alloy loaded cavities. To achive a short overall delay, mandatory for stable loop operation, the data-processing is based on distributed arithmetics in FPGA. Due to the broadband characteristic of the acceleration cavities, no tuning loop is needed. To handle the large beam current, the RF system operates simultaneously with dual harmonics (h=2) and (h=4). The stability of the amplitude loops is limited by the delay of the FIR filters used after downconversion. The phase loop offers several operation modes to define the phase relation of (h=2) and (h=4) between the longitudinal beam signal and the vector-sum of the cavity voltages. Besides the FIR filters, we provide cascaded CIC filters with smoothly varying coefficients. Such a filter tracks the revolution frequency and has a substantially shorter delay, thereby increasing the stable operating region of the phase loops. The adaptive radial loop accumulates the orbit variation over several machine cycles to reduce the effects of measurement errors on the effective acceleration frequency program.

**WPAT008—Recent Status of RF Source in J-PARC Linac**
*Etsuji Chishiro, Toshihiko Hori, Hiroyuki Suzuki, Masayoshi Yamazaki (JAERI), Shozo Anami, Shigeki Fukuda, Yuji Fukui, Masato Kawamura, Seiya Yamaguchi, Mitsuhiro Yoshida (KEK)*
The construction of the J-PARC (Japan Proton Accelerator Research Complex) linac is under going. RF sources for the low beta linac section use 324-MHz klystrons and after the evaluation of seven prototype tubes, mass production of 20 tubes are conducted. These will be installed in the linac building from April 2005. Performances of the 324-MHz klystrons are described in this paper. The prototype klystron of 972-MHz klystron, which is planed to be installed in high beta linac section, oscillated strongly without any drive rf power, and it

had been investigated to solve it. Though it was doubted to be a diode oscillation at first, recent experiment showed the drift-tube oscillation and we succeeded in stopping oscillation by deforming the integrated cavity and detuning. After this experiment, we built a new tube and started to test it. This experiment is written in this paper. Other status of construction related to the rf sources is also shown in this paper.

**WPAT009—Status of the RF System for the 6.5-GeV Synchrotron Light Source PF-AR**
*Shogo Sakanaka, Kiyokazu Ebihara, Shigeru Isagawa, Masaaki Izawa, Tatsuya Kageyama, Toshio Kasuga, Hiroshi Nakanishi, Masaaki Ono, Hiroshi Sakai, Takeshi Takahashi, Kensei Umemori (KEK)*
The Photon Factory Advanced Ring (PF-AR) is a 6.5-GeV synchrotron light source at KEK. An rf system comprises two 1.2-MW klystrons, six alternating-periodic-structure (APS) cavities, and other components. It supplies an rf voltage of about 15 MV with a beam current of 60 mA. The system has been working well, except for a trouble (frequent trips with beams) in one of the cavities. We found that the trips were triggered by an irradiation of synchrotron radiation to the cavity wall. In the summer of 2004, we reorganized the rf system, which allows us to install two insertion devices in a part of the rf sections. We replaced the troubled cavity at a time. We report both the operation status and the modification of the rf system.

**WPAT010—RF Dielectric Properties of SiC Ceramics and their Application to Design of HOM Absorbers**
*Yasunao Takeuchi, Tetsuo Abe, Tatsuya Kageyama, Hiroshi Sakai (KEK)*
The KEKB ARES cavity is equipped with two types of HOM absorbers, which are made of different commercial products of the alpha-type SiC ceramics. Their dielectric responses to the RF frequency show the dielectric relaxation properties. Those properties can be clearly explained by the polycrystal structure model with electrically conductive grains and non-conductive grain boundaries. In this article, the RF dielectric properties of the SiC ceramics are discussed together with the application to HOM absorbers.

**WPAT011—Application of TRL Calibration in Longitudinal Coupling Impedance Measurement Platform for BEPCII**
*Gang Huang, Huang Wenhui, Shuxin Zheng (Tsinghua University), Jiuqing Wang, Demin Zhou (IHEP Beijing)*
TRL calibration is one of the standard calibration methods for RF measurement. Applying the TRL calibration method into the longitudinal coupling impedance platform makes it possible to eliminate the error matrix of the matching section and the RF connector. By using TRL calibration in the platform, the reference pipe of each device under test no longer required. The formula of the calibration is discussed in this paper and the software based on it is introduced.

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**WPAT012—Status and Test Results of HPRF System for PEFP**
*Kyung Tae Seol, Yong-Sub Cho, Han-Sung Kim, Hyeok-Jung Kwon, Mi-Young Park, Young-Gi Song (KAERI)*
The PEFP 20MeV proton accelerator is composed of 3MeV RFQ and 20MeV DTL and two sets of 1MW, 350MHz RF system are required for each accelerating structure. The high power RF system for 3MeV RFQ was already installed and operated to drive the RFQ. The klystron was tested up to 600kW itself and operated in pulse routinely. The HPRF system for 20MeV DTL which consists of 4 tanks was installed, and the RF test for 4 tanks has been carried out. The ridge-loaded power coupler was designed and installed to drive RFQ and DTL. In this paper, the status and test results of the RF system for 20MeV proton accelerator are discussed.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**WPAT013—Operation and Performance of CW Klystron Amplifier for the PLS Storage Ring**
*Myung-Hwan Chun, Yeung-Jin Han, Jung Yun Huang, Maeng Hyo Jeong, Sang-Hoon Nam, Hong-Jip Park, Jaeseok Yang, In-Ha Yu (PAL)*
The CW klystron amplifiers for the Pohang Light Source (PLS) storage ring have been operated at total maximum RF power of 240kW since 1994. According to the addition of insertion devices and the future plan of increasing the stored current up to 250mA at 2.5GeV, more RF power source is required. Therefore, the RF power has been gradually increased to 300kW by replacing 60kW klystrons with 75kW klystrons. Finally the fifth 75kW klystron amplifier was installed for increasing total RF power up to 375kW. This paper describes the operation experiences and performance about the 500MHz CW klystron amplifiers.

Ministry of Science and Technology(MOST), Korea.

**WPAT014—Sequence Control System of 1-MW CW Klystron for the PEFP**
*Byoung Ryul Park, Jinhyuk Choi, Myung-Hwan Chun, Yeung-Jin Han, Maeng Hyo Jeong, Sung-Chul Kim, Jaeseok Yang, In-Ha Yu (PAL)*
Sequence control system of 1-MW CW klystron for the PEFP (Proton Engineering Frontier Project) has been developed in order to drive the 1-MW klystron amplifier. The system is able to control several power supplies and many environment conditions. The hardware of sequence control and the interlock system are based on the Allen-Bradley's SLC500 Program Logic Controller (PLC). Also the system can be controlled by a touch screen at local mode or Ethernet network with high level HMI at remote mode.

Work support by the PEFP(Proton Engineering Frontier Project), Korea.

**WPAT015—The Digital Feedback RF Control System of the RFQ and DTL1 for 100 MeV Proton Linac of PEFP**
*In-Ha Yu, Yeung-Jin Han, Heung-Sik Kang, Do Tae Kim, Sung-Chul Kim, In-Soo Park, Jong Chel Yoon (PAL), Yong-Sub Cho, Hyeok-Jung Kwon, Kyung Tae Seol (KAERI)*
The 100 MeV Proton linear accelerator (Linac) for the PEFP (Proton Engineering Frontier Project) will include 1 RFQ and 1 DTL1 at 350 MHz as well as 7 DTL2 cavities at 700 MHz. The low level RF system with the digital feedback RF control provides the field control to accelerate a 20mA proton beam from 50 keV to 20 MeV with a RFQ and a DTL1 at 350M Hz. The FPGA-based digital feedback RF control system has been built and is used to control cavity field amplitude within ± 1% and relative phase within ± 1º. The fast digital processing is networked to the EPICS-based control system with an embedded processor (Blackfin). In this paper, the detailed description of the digital feedback RF control system will be described with the performance test results.

Work supported by the PEFP (Proton Engineering Frontier Project), Korea

**WPAT016—Stable Low Noise RF Source for Main Ring**
*Grigory Yakovlevich Kurkin (BINP SB RAS), Ping Wang (DU/FEL)*
The Duke Storage ring is a 1 Gev electron ring, which is designed for driving UV-VUV FEL. It also provides variable energy high intensive gamma rays by Compton back scattering. It requires an RF master oscillator with very low phase noise. We built a Surface Acoustic Wave (SAW) Oscillator. However, the long-term stability does not meet requirements for FEL ring. Previously we used a commercial signal generator HP 4400B as the master oscillator. It has excellent long-term stability, but the phase noise is not acceptable. A phase feedback loop has been added between the SAW oscillator and the HP source, which provides us an excellent RF source. The design details and the test results are presented in this paper.

**WPAT017—Commissioning of the New RF System with the HOM Damped RF Cavity**
*Grigory Yakovlevich Kurkin, Vladimir Sergeevich Arbuzov, Eduard Gorniker, Ermek Kenjebulatov, Alexey Anatolyevich Kondakov, Sergey Alexandrovich Krutikhin, Igor Kuptsov, Sergey Viktorovich Motygin, Vadim Nikolaevich Osipov, Victor Petrov, Andrey Pilan, Alexey Mikhailovich Popov, Evgeniy Rotov, Igor Sedlyarov, Alexey G. Tribendis, Vladimir Volkov (BINP SB RAS), Stepan Mikhailov, Patrick Walter Wallace, Ping Wang, Y. K. Wu (DU/FEL)*
A new 178 MHz RF system has been commissioned at Duke Storage Ring. It consists of a 140 kW tetrode transmitter, a high order modes (HOM) damped RF cavity and the necessary frequency and voltage control electronics. The cavity walls are made of copper-on-stainless steel bimetal (8 mm Cu, 7 mm SS). The cavity has a larger beam pipe opening (700 mm in diameter) in the down-stream side, which allows the HOM propagating out of the cavity and being absorbed by the ceramic loads. The design details and the commissioning results are presented in this paper.

**WPAT018—The LEIR RF System**
*Mauro M. Paoluzzi, Roland Garoby, Matthias Haase, Pierre Maesen, Carlo Rossi (CERN), Chihiro Ohmori (KEK)*
The lead-lead physics program of LHC relies on major changes of the CERN ion injector chain. In this framework, the conversion of LEAR (low energy antiproton ring) into the Low Energy Ion Ring (LEIR) is central and implies a new accelerating system covering a wide frequency range (0.35 - 5 MHz,) with a moderate voltage (4 kV). For this purpose two new wide-bandwidth cavities, loaded with Finemet® magnetic alloy cores, have been built in collaboration with KEK. Two 60 kW RF power amplifiers have also been built and the RF systems are now installed in the LEIR ring. They individually cover the whole frequency range without tuning and allow multi-harmonic operation. The design has been guided by need of safety margins, reliability and ease of maintenance. Some design aspects are presented as well as the performance achieved.

**WPAT019—Beam Tests of a New Digital Beam Control System for the CERN LEIR Accelerator**
*Maria-Elena Angoletta, Joao Bento, Alfred Blas, Alan Findlay, Pawel Matuszkiewicz, Flemming Pedersen, Angela Salom.Sarasqueta (CERN), Joseph DeLong (BNL)*
We are developing a digital beam control and cavity servo system for controlling the RF acceleration in CERN's Low Energy Ion Ring (LEIR), a major component in the LHC lead ion injector chain. As the LEIR ring will only start during summer 2005, we have tested a simplified prototype of the system with low intensity beams on the CERN PS Booster (PSB). The hardware and software have been developed within the framework of a CERN-BNL collaboration. This fully digital beam control system is contained in VME mother boards which can accommodate several daughter boards. The fast signal processing is implemented in Field Programmable Gate Arrays (FPGAs), while the slower signal processing and communication with the software layer above is implemented in programmable Digital Signal Processors (DSPs). The objectives of the tests with beam in the PSB are to verify the multiple DSP and FPGA architecture, the sampling rates and data flows and the feedback loop dynamics. An additional goal is to integrate a number of highly complex intelligent VME modules with many sub-functions in the CERN controls environment to provide adequate signal acquisition, control and diagnostics to operate the system.

**WPAT020—Electronics System for Superconducting RF Module at the NSRRC**
*Meng-Shu Yeh (NSRRC)*
The electron storage ring at National Synchrotron Radiation Research Center, as one of the third generation light sources, is routinely operated with a maximum beam current of 200 mA with two DOIRS cavities. One major machine performance upgrade is undertaken at NSRRC by replacing the existing Doris cavities with a single superconducting module of CESR-III design. Operation at a maximum beam current up to 400 mA in a high-order-mode well damped condition is expected, for significantly enhancing the spectral brightness and improving the beam stability. Commissioning is schedule for the winter of 2004. Two SRF modules including associated electronics for protection of window arcing as well as cavity quench, and cryogenic control of cryostat conditions will be delivered from ACCEL, according to Cornell design. On the other hand, the existing low level RF system from SLAC is being modified for functional integration with the SRF operation. The efforts and strategy of electronic integration for the SRF operation are reported.

**WPAT021—RF Supply Systems for Technological Accelerators**
*Yuriy D. Tur, Vladimir Beloglazov, Anatoly Nikolayevich Dovbnya, Leonid Dovbush, Anatoliy Khudyakov, Alexander Kosoy, Tatyana Nikitina, Sergey Shkirida (NSC/KIPT)*
In accordance with the program of design and manufacture of industrial electron linacs with high average beam power, in particular for medical radioisotopes production, we have carried on research and development on RF-systems, which is aimed at RF supply of an accelerating system and electron bunch forming elements of the injector. Powerful S-band RF-stations have to provide a pulse power not less then 10-12 MW with a pulse length of 4-5 us and repetition rate of 300-400 pps at the entrance of each accelerating section. Six versions of the RF power supply system were designed, constructed and installed; their parameters were measured and optimized. In particular the testing results of high power supply stations have shown, that the long, reliable operation is observed for levels of pulse output power not less than 12 MW, average output power not less than 18 kW (400 pps) and 13.5 kW (300 pps), full efficiency of the modulators not less than 70 % and full efficiency of high-frequency stations not less than 22 %.

**WPAT022—Low Level RF System for the Energy Recovery Linac Prototype**
*Andrew Moss (CCLRC/DL/ASTeC)*
The Low Level RF system is described for the Energy Recovery Linac Prototype (ERLP) being constructed at Daresbury Laboratory. An analogue based feedback system, built around low cost proprietary components, has been designed to control

the 1.3GHz RF system for this project. The system is scaleable, has digital control and can be easily upgraded as greater understanding of the accelerator becomes known. The design of the system is based around the central core of a very low phase noise master oscillator, which can provide, multiple outputs and timing pulses at all the required frequencies for the RF, laser and accelerator sub-systems.

ASTeC Department, CCLRC Daresbury Laboratory.

**WPAT023—Combining Cavity for RF Power Sources: Higher Power Testing and Further Simulation**
*Emma Wooldridge, Peter Andrew Corlett, James Henry Paul Rogers (CCLRC/DL/ASTeC)*
A combining cavity for RF power sources has been investigated previously reported in EPAC'04 using computer simulations in CSTs' Microwave Studio© and by building a low power model out of aluminium. The model has now been tested at higher power in a number different configurations and compared with earlier results. This paper discusses the results of the higher power test and options for a combiner that can be used at the high power required for particle accelerators. It reports the mechanical design of such a cavity including suitable cooling mechanisms and computer simulations.

ASTeC, CCLRC Daresbury Laboratory.

**WPAT024—First Results from the Use of Dual Harmonic Acceleration on the ISIS Synchrotron**
*Dean Adams, Ian Gardner, Christopher M. Warsop (CCLRC/RAL/ASTeC), Derek Bayley, Robin Bendall, Mike Glover, Adrian Morris, Andrew Seville, John Thomason (CCLRC/RAL/ISIS)*
The ISIS facility at the Rutherford Appleton Laboratory in the UK is currently the most intense pulsed, spallation, neutron source. The accelerator consists of a 70 MeV H- Linac and an 800 MeV, 50 Hz, rapid cycling, proton Synchrotron. The synchrotron beam intensity is 2.5x1013 protons per pulse, corresponding to a mean current of 200 μA. The synchrotron beam is accelerated using six, ferrite loaded, RF cavities with harmonic number 2. Four additional, harmonic number 4, cavities have been installed to increase the beam bunching factor with the potential of raising the operating current to 300 μA. This paper reports on the hardware commissioning and the first beam tests.

**WPAT025—First Results of the IOT Based 300 kW 500 MHz Amplifier for the Diamond Light Source**
*Morten Jensen, Matt Maddock, Simon Rains, Alun Vaughan Watkins (Diamond), Juergen Alex, Marc Mueller (Thales Broadcast & Multimedia AG)*
We present the first RF measurements of the IOT based 300 kW 500 MHz amplifier for the Diamond Light Source. Four 80 kW IOTs are combined using a waveguide combiner to achieve the RF requirement of up to 300 kW for each of three superconducting cavities for the main storage ring. The IOTs are protected by a full power circulator and a 300 kW ferrite RF load. This is the first time IOTs will be used for a synchrotron light source. This paper gives an overview of the design of the Thales amplifiers and IOTs with commissioning results including measurements of key components and overall RF performance following factory tests and the installation of the first unit

**WPAT026—Status of 34 GHZ, 45 MW Pulsed Magnicon**
*Oleg A. Nezhevenko, Vyacheslav P. Yakovlev (Omega-P, Inc.), Evgueni Kozyrev (BINP SB RAS), Sergey V. Shchelkunov (Columbia University), Jay L. Hirshfield (Omega-P, Inc.; Yale University), Michael A. LaPointe (Yale University)*
A high efficiency, high power magnicon at 34.272 GHz has been designed and built as a microwave source to develop RF technology for a future multi-TeV electron-positron linear collider. To develop this technology, this new RF source is being perfected for necessary tests of accelerating structures, RF pulse compressors, RF components, and to determine limits of breakdown and metal fatigue. After preliminary RF conditioning the magnicon produced an output power of 10.5 MW in 0.25 microsecond pulses, with a gain of 54 dB. The new results of the experimental tests after the tube conditioning was resumed are presented in the paper.

Research supported by the Department of Energy, Division of High Energy Physics.

**WPAT027—Recent Results from the X-Band Pulsed Magnicon Amplifier**
*Oleg A. Nezhevenko, Vyacheslav P. Yakovlev (Omega-P, Inc.), Evgueni Kozyrev (BINP SB RAS), Allen Kinkead (LET ), Arnold Fliflet, Steven H. Gold (NRL), Jay L. Hirshfield (Omega-P, Inc.; Yale University), Michael A. LaPointe (Yale University)*
A frequency-doubling magnicon amplifier at 11.4 GHz has been designed and built as the prototype of an alternative microwave source for the Next Linear Collider project, and to test high power RF components and accelerating structures. The tube is designed to produce ~60 MW, ~1.2 microsecond pulses at 58% efficiency and 59 dB gain, using a 470 kV, 220 A, 2 mm-diameter beam. In the first tests the output power was limited to a level of 26 MW in a 200 nsec pulse. This limitation was caused by the oscillations in the tube collector. Experimental results of the magnicon tests with the new collector are presented in this paper.

Research supported by the Department of Energy, Office of High Energy Physics, and the Office of Naval Research.

**WPAT028—High Power Ferrolelectric Switches at Centimeter and Millimeter Wavelengths**
*Vyacheslav P. Yakovlev, Oleg A. Nezhevenko (Omega-P, Inc.), Jay L. Hirshfield (Omega-P, Inc.; Yale University)*
High-power ultra-fast, electrically-controlled switches based on ferroelectric elements for accelerator applications in the centimeter and millimeter wavelength ranges are discussed. Examples of fast switches and phase shifters for pulse compression and power distribution systems at X– and Ka- band are presented. It is shown that such proposed switch designs based on modern ferroelectric materials allow the generation of pulsed power of hundreds of MW's in both the centimeter and millimeter wave ranges.

Research supported by the Department of Energy, Division of High Energy Physics.

**WPAT029—The RF Experimental Program in the Fermilab Muon Test Area**
*Jim Norem (ANL), Rikard Sandstrom (CUI), Alfred Moretti (Fermilab), Yagmur Torun (IIT), Robert Rimmer (Jefferson Lab), Derun Li, Michael Zisman (LBNL), Rolland Johnson (Muons, Inc)*
The rf R&D program for high gradient, low frequency cavities to be used in muon cooling systems is underway in the Fermilab Muon Test Area. Cavities at 805 and 201 MHz are used for tests of conditioning techniques, surface modification and breakdown studies. This work has the Muon Ionization Cooling Experiment (MICE) as its immediate goal and efficient muon cooling systems for neutrino sources and muon colliders as the long term

goal. We study breakdown, and dark current productions under a variety of conditions.

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**WPAT030—Upgrade of the ATLAS Positive Ion Injector Bunching System**

*Sergey I. Sharamentov, John Bogaty, Benn Clifft, Richard Claude Pardo (ANL)*

Over the last few years, significant efforts were concentrated on improving the ATLAS Positive Ion Injector (PII) RF bunching system, consisting of a four-harmonic pre-buncher, Traveling Wave Chopper (TWC) and a single-frequency sinusoidal re-buncher. The primary goal was to improve RF field stability with a redesigned RF system and to improve buncher performance for higher current beams resulting in better bunch stability and time structure at the first PII superconducting resonator. The major parts of the system were redesigned and rebuilt, including the RF 12 – 48 MHz amplifiers for the harmonic pre-buncher and re-buncher, RF driver rack for the TWC, and the RF control chassis for both the pre-buncher and re-buncher. The four-harmonic resonant structure of the harmonic buncher itself was modified, too, mainly for better mechanical stability and better RF matching. These improvements will be described and the performance of the new system presented.

**WPAT031—Design and Operation of a High Power L-Band Multiple Beam Klystron**

*Adam Balkcum, Heinz Peter Bohlen, Mark Cattelino, Lydia Cox, Mike Cusick, Scott Forrest, Fred Friedlander, Armand Staprans, Edward Wright, Lou Zitelli (CPI), Kenneth Eppley (SAIC)*

A 1.3 GHz, 10 MW, higher-order-mode multiple beam klystron (MBK) has been developed for the TESLA program. The relative advantages of such a device are many-fold. Multiple beams generate higher beam currents and thereby require much lower operating voltages which allows for the use of smaller, less expensive modulators. A lower perveance per cathode can also be used which leads to higher operating efficiencies. Higher-order-mode cavities allow for the use of much larger cathodes which leads to lower cathode current density loadings and subsequently longer cathode lifetimes. This requires that the cathodes be located far off the geometric axis of the device. The compromise is an increase in the complexity of the magnetic focusing circuit required to transport the off-axis electron beams. Such a device has been successfully built and tested. Excellent beam transmission has been achieved (99.5% DC and 98% at RF saturation). A peak power of 10 MW with 150 kW of average power and 60% efficiency, 49 dB gain have also been measured. The achieved low cathode loading of 2.1 A/cm2 corresponds to an expected cathode life of over 140,000 operational hours.

**WPAT032—Large Scale Production of 805-MHz Pulsed Klystrons for SNS**

*Stephan Lenci, Edward Lawrence Eisen (CPI)*

The Spallation Neutron Source (SNS) is an accelerator-based neutron source being built in Oak Ridge, Tennessee, by the U.S. Department of Energy. CPI is supporting the effort by providing 81 pulsed klystrons for the super-conducting portion of the accelerator. The primary output power requirements are 550 kW peak, 49.5 kW average at 805 MHz, with an electron beam-to-rf conversion efficiency of 65% and an rf gain of 50 dB. Through December 2004, 77 units have been factory-tested. Performance specifications, computer model predictions, operating results, and production statistics will be presented.

**WPAT033—Design & Tests of a High Powered YIG Coaxial Phase Shifter**

*G. William Foster, Emanuela Barzi, Ivan Gonin, Steven Hays, Vladimir Kashikhin, Timergali N. Khabibouline, Nikolay Solyak, Ding Sun, Iouri Terechkine, David Wildman (Fermilab), Douglas Horan (ANL)*

Design considerations and test results for a high-powered electrically adjustable microwave phase shifter based on YIG ferrite are presented. A pair of the devices are to be used in conjunction with a hybrid and isolator to provide independent phase and amplitude control to individual superconducting cavites, when multiple cavities are driven from a single klystron. A coaxial design is one of several possible tuner geometries, and has advantages of a relativly simple geometry and a solenoidal bias magnet. Electomagnetic simulations have been used to verify a useful effective model for the magnetically biased YIG material. Various devices have been tested at power levels up to 600kW (pulsed) and at frequencies between 325 MHz and 1300 MHz.

U.S. Department of Energy.

**WPAT034—The CEBAF Separator Cavity Resonance Control System**

*Mark J. Wissmann, Al Andres Guerra, Curt Hovater, Tomasz Plawski (Jefferson Lab)*

The CEBAF energy upgrade from 6 GeV to 12GeV will increase the range of beam energies available to the experimental halls. RF deflection cavities (separators) are used to direct the electron beam to the three experimental halls. Consequently with the increase in RF separator cavity gradient needed for the higher energies, RF power will also increase requiring the cavities to have active resonance control. At the 6 GeV energy, the cavities are tuned mechanically and then stabilized with Low Conductivity Water (LCW), which is maintained at constant temperature of 95o Fahrenheit. This is no longer feasible and an active resonance control system, that controls both water temperature and flow has been built. The system uses a commercial PLC with embedded PID controls to control water temperature and flow to the cavities. The system allows the operator to remotely adjust temperature/flow and consequently cavity resonance for the full range of beam energies. Ultimately closed loop control will be maintained by monitoring the cavities reflected power. This paper describes this system.

This work supported by the U.S. Department of Energy under contract DE-AC05-84ER40150.

**WPAT035—The LANSCE 805 MHZ RF System History and Status**

*Michael Lynch, Paul J. Tallerico (LANL), Gerry Bolme (LANL/LANSCE)*

The Los Alamos Neutron Science Center (LANSCE) linear accelerator runs at 201.25 MHz for acceleration to 100 MeV. The remainder of the acceleration to 800 MeV is at 805 MHz. This is done with 44 accelerator cavity stages driven by 805 MHz klystrons. Each klystron has a peak power capability of 1.25 MeV. Originally, 97 klystrons were purchased, which was 70 from Varian/CPI and 27 from Litton. The 44 RF systems are laid out in sectors with either 6 or 7 klystrons per sector. The klystrons in each sector are powered from a common HV sytem. The current arrangement uses the Varian/CPI klystrons in 6 of the 7 sectors and Litton klystrons in the remaining sector. With that arrangement there are 38 CPI klystrons installed and 1 spare klystron per sector and 6 Litton klystrons installed in the final sector with 2 spares. The current average life of all of the operating and spare klystrons (52 total) is >112,000 filament hours and >93,000 HV hours. That is three times the typical

klystron lifetime today for other similar klystrons. This paper summarizes the details of the LANSCE klystron history and status and a summary of the predicted failure rate.

**WPAT036—A 700 MHZ, 1 MW CW RF System for a FEL 100mA RF Photoinjector**
*William Reass, Michael Lynch, Dinh Cong Nguyen, Daniel Rees, Paul J. Tallerico (LANL), William Roybal (LANL/LANSCE)*
This paper describes a 700 MHz, 1 Megawatt CW, high efficiency klystron RF system utilized for a Free Electron Laser (FEL) high-brightness electron photoinjector (PI). The E2V klystron is mod-anode tube that operates with a beam voltage of 95 kV. This tube, operating with a 65% efficiency, requires ~96 watts of input power to produce in excess of 1 MW of output power. This output drives the 3rd cell of a 2½-cell, ð-mode PI cavity through a pair of planar waveguide windows. Coupling is via a ridge-loaded tapered waveguide section and "dog-bone" iris. This paper will present the design of the RF, RF transport, coupling, and monitoring/protection systems that are required to support CW operations of the 100 mA cesiated, semi-porous SiC photoinjector.

U.S. Department of Energy.

**WPAT037—LANSCE RF System Refurbishment**
*Daniel Rees, Joseph Bradley, Michael Lynch, William Reass, Paul J. Tallerico (LANL), Gerry Bolme, Sung-il Kwon, John T.M. Lyles, Mark Prokop (LANL/LANSCE)*
The Los Alamos Neutron Science Center (LANSCE) is in the planning phase of a refurbishment project that will sustain reliable facility operations well into the next decade. The LANSCE accelerator was constructed in the late 1960s and early 1970s and is a national user facility that provides pulsed protons and spallation neutrons for defense and civilian research and applications. We will be replacing all the 201 MHz RF systems and a substantial fraction of the 805 MHz RF systems and high voltage systems. The current 44 LANSCE 805 MHz, 1.25 MW klystrons have an average in-service time in excess of 110,000 hours. All 44 must be in service to operate the accelerator. There are only 9 spares left. The klystrons receive their DC power from the power system originally installed in 1960. Although this power system has been extremely reliable, gas analysis of the insulating oil is indicating age related degradation that will need attention in the next few years. This paper will provide the design details of the new RF and high voltage systems.

**WPAT038—Instability of the RF Control Loop in the Presence of a High-Q Passive Superconducting Cavity**
*Sergey Belomestnykh, Roger Kaplan, John Reilly, Vadim Veshcherevich (Cornell University)*
An instability of the active RF cavity field control loop was observed during experiments with beam-driven (passive) superconducting cavities in CESR when the cavity external Q factor was raised to a value above 1x10^7. A computer model was developed and further experiments have been performed to study this instability and find a way to cure it. The results of simulations are presented alongside the experimental results.
Work is supported by the National Science Foundation.

**WPAT039—Experience with the New Digital RF Control System at the CESR Storage Ring**
*Matthias Liepe, Sergey Belomestnykh, John Dobbins, Roger Kaplan, Charles Ralph Strohman, Benjamin Kojm Stuhl (Cornell University)*
A new digital control system has been developed, providing great flexibility, high computational power and low latency for a wide range of control and data acquisition applications. This system is now installed in the CESR storage ring and stabilizes the vector sum field of two of the superconducting CESR 500 MHz cavities and the output power from the driving klystron. The installed control system includes in-house developed digital and RF hardware, very fast feedback and feedforward control, a state machine for automatic start-up and trip recovery, cw and pulsed mode operation, fast quench detection, and cavity frequency control. Several months of continuous operation have proven high reliability of the system. The achieved field stability surpasses requirements.

This work is supported by NSF.

**WPAT040—Pushing the Limits: RF Field Control at High Loaded Q**
*Matthias Liepe, Sergey Belomestnykh, John Dobbins, Roger Kaplan, Charles Ralph Strohman, Benjamin Kojm Stuhl (Cornell University), Curt Hovater, Tomasz Plawski (Jefferson Lab)*
The superconducting cavities in an Energy-Recovery-Linac will be operated with a high loaded Q of several 1E7, possible up to 1E8. Not only has no prior control system ever stabilized the RF field in a linac cavity with such high loaded Q, but also highest field stability in amplitude and phase is required at this high loaded Q. Because of a resulting bandwidth of the cavity of only a few Hz, this presents a significant challenge: the field in the cavity extremely sensitive to any perturbation of the cavity resonance frequency due to microphonics and Lorentz force detuning. To prove that the RF field in a high loaded Q cavity can be stabilized, and that Cornell's newly developed digital control system is able to achieve this, the system was connected to a high loaded Q cavity at the JLab IR-FEL. Excellent cw field stability – about 2E-4 rms in relative amplitude and 0.03 deg rms in phase - was achieved at a loaded Q of 2.1E7 and 1.4E8, setting a new record in high loaded Q operation of a linac cavity. Piezo tuner based cavity frequency control proved to be very effective in keeping the cavity on resonance and allowed reliable to ramp up to high gradients in less than 1 second.

This work is supported by Cornell University.

**WPAT041—Klystron Linearizer for Use with 1 MW 476 MHz Klystrons in PEP-II RF Systems**
*John Fox, Themis Mastorides, Dmitry Teytelman, Daniel Van Winkle, Yubo Zhou (SLAC)*
The direct and comb loop feedback around the RF cavities in PEP-II is critical in reducing longitudinal instabilities driven by the cavity impedance, and the non-linear 1 MW klystron is in the signal path for these feedback loops. As a result, the effective small-signal gain of the klystron at 85% saturation reduces the impedance control by factors of 5 to 20 as compared to a linear power amplifier. A klystron linearizer circuit has been developed which operates in series with the power amplifier and acts to equalize the small and large signal gains through the combination. The technique must implement a 1 MHz linear control bandwidth over roughly 15 dB of RF signal level variation. The dynamics of this system is operating point dependent, and the channel must have dynamic gain compensation to keep the linearity compensation loop stable over changes in operating point. The design of this non-linear signal processing channel (incorporating RF and DSP techniques) and measured results from full-power klystron testing are presented.

Work supported by U.S. Department of Energy contract DE-AC02-76SF00515.

**WPAT042—Parallel Adaptive Mesh Refinement for Improving Quality Factor Determination**
*Lixin Ge, Kwok Ko, Lie-Quan Lee, Zenghai Li, Cho-Kuen Ng (SLAC)*
This paper presents the improvement in wall loss determination for accelerating cavities of complex shapes by using adaptive mesh refinement (AMR) methods with the parallel finite element eigensolver Omega3P. The new capability is under development through a US DOE supported SciDAC collaboration. For a given accuracy the approach shows a significant reduction in the number of degrees of freedom (DOFs) required as well as a faster rate of convergence when compared with uniform mesh refinement. Application to test cases that previously had posed difficulties to numerical calculations and comparison of quality factor results from Omega3P/AMR with measured data will be presented.

Work supported by the U.S. DOE Contract No. DE-AC03-76SF00515.

**WPAT043—RF Systems for LCLS**
*Peter McIntosh, Ron Akre, Richard Boyce, Paul Emma, Alan Hill, Carl Rago (SLAC)*
The Linac Coherent Light Source (LCLS) at SLAC, when it becomes operational in 2009, will provide its user community with an X-ray source many orders of magnitude brighter than anything available in the world at that time. The electron beam acceleration will be provided by existing and new RF systems capable of maintaining the amplitude and phase stability of each bunch to extremely tight tolerances. RF feedback control of the various RF systems will be fundamental in ensuring the beam arrives at the LCLS undulator at precisely the required energy and phase. This paper details the requirements for RF stability for the various LCLS RF systems and also highlights proposals for how these injector and Linac RF systems can meet these constraints.

Work supported by Department of Energy contract DE-AC03-76SF00515.

**WPAT044—An X-Band RF System for LCLS**
*Peter McIntosh, Ron Akre, William Brooks, Paul Emma, Carl Rago (SLAC)*
A single X-band (11.424 GHz) accelerating structure is to be incorporated in the LCLS Linac design to linearize the energy-time correlation (or gradient) across each bunch, features which originate in the preceding accelerating structures (L0 and L1). This harmonic RF system will operate near the negative RF crest to decelerate the beam, reducing these non-linear components of the correlation, providing a more efficient compression in the downstream bunch compressor chicanes (BC1 and BC2). These non-linear correlation components, if allowed to grow, would lead to Coherent Synchrotron Radiation (CSR) instabilities in the chicanes, effectively destroying the coherence of the photon radiation in the main LCLS undulator. The many years devoted at SLAC in the development of X-band RF components for the NLC/JLC linear collider project, has enabled the technical and financial realization of such an RF system for LCLS. This paper details the requirements for the X-band system and the proposed scheme planned for achieving those requirements.

Work supported by Department of Energy contract DE-AC03-76SF00515.

**WPAT045—A Non-Invasive Technique for Configuring Low Level RF Feedback Loops in PEP-II**
*Dmitry Teytelman (SLAC)*
The RF system of the PEP-II collider uses two fast feedback loops around each klystron and set of cavities. These loops reduce the impedance of the fundamental mode of the accelerating cavities seen by the beam, and are necessary to reduce the growth rates of longitudinal modes within the RF system bandwidth. Operation of the accelerator at high beam currents is very sensitive to the configuration of the low-level RF feedback loops. There are 7 loop control parameters that strongly influence the stability of the feedback loops and the achieved level of longitudinal impedance reduction. Diagnostic techniques for the analysis of the RF feedback via closed-loop system transfer function measurements will be presented. The model is fit to the measured closed-loop transfer function data and the extracted parameters are then used to calculate optimal tuning and corrections to the loop control elements in the physical channel. These techniques allow fine-tuning of RF feedback with stored beam as well as diagnosis of mis-configured or malfunctioning elements of the system. Results from PEP-II operation will be presented to illustrate the techniques and their applications.

Work supported by U.S. Department of Energy contract DE-AC02-76SF00515.

**WPAT046—RF Systems for SPEAR3 and Booster at SSRL**
*Sanghyun Park (SLAC)*
The Spear3 operation is into its second year of delivering user beam. While Spear3 RF system is modeled after the PEP-2, there has been no major upgrade at the Booster including the RF except that the 100 MeV linac beam is boosted to the at-energy of 3.0 GeV: There is no need for the Spear to ramp up the beam energy. The two RF systems run on different frequency derived from a single master oscillator. Since the commissioning the stored beam current was limited to 100 mA due to the radiation shielding requirements. When this issue is resolved in the near future, up to 500 mA will be stored as designed. The klystron can provide sufficient power with a substantial margin of safety. Also planned is the top-off mode where frequent injection to the storage ring maintains practically constant current stored. In this paper we will describe the operational aspect of the system and the plan for the future.

Work supported by U.S. DoE under contract DE-AC03-76SF00515.

**WPAT047—Solid-State Two Megawatt Klystron Power Control System**
*Michael Kempkes, Jeffrey Casey, Marcel Gaudreau, Timothy Hawkey, J. Michael Mulvaney, Ian Roth (Diversified Technologies, Inc.)*
Under an SBIR effort for the DOE, Diversified Technologies, Inc. designed, built, and installed a solid state power control system for the Advanced Light Source klystrons at Argonne National Laboratory (ANL). This system consists of two major elements – a 100 kV, 20 A CW solid state series switch, and a solid state voltage regulator for the mod-anode of the klystron. The series switch replaces the existing mercury ignitron crowbar, eliminating these environmentally hazardous components while providing enhanced arc protection and faster return to transmit. The mod-anode voltage regulator uses series IGBTs, operating in the linear regime, to provide highly rapid and accurate control of the mod-anode voltage, and therefore the output power from the klystron. Results from the installation and testing of this system at ANL will be presented.

**WPAT048—Solid State Modulators for the International Linear Collider (ILC)**
*Michael Kempkes, Jeffrey Casey, Marcel Gaudreau, Timothy Hawkey, J. Michael Mulvaney, Ian Roth (Diversified Technologies, Inc.)*
Diversified Technologies, Inc. is developing two solid state modulator designs for the ILC under SBIR funding from the DOE. The first design consists of a 150 kV hard switch. The key development in this design is the energy storage system, which must provide 25 kJ per pulse, at very tight voltage regulation over the 1.5 millisecond pulse. DTI's design uses a quasi-resonant bouncer (with a small auxiliary power supply and switch) to maintain the voltage flattop, eliminating the need for massive capacitor banks. The second design uses a solid state Marx bank, with ~10 kV stages, to drive the ILC klystron. In this design, staggered turn-on of the Marx stages provides voltage regulation without the need for large capacitor banks. This paper will discuss design tradeoffs, power supply and control considerations, and energy storage requirements and alternatives for both designs.

**WPAT049—The Penetrability of a Thin Metallic Film Inside the RF Field**
*Yongxiang Zhao, Ilan Ben-Zvi, Rolf Beuttenmuller, Xiangyun Chang, Wei Chen, Robert Di Nardo, Triveni Rao (BNL)*
Thin metallic film was widely applied in varies area. Especially, recently we are planning to apply it in a "Secondary emission enhanced photo-injector," of which a diamond cathode is coated with a golden film or so on its back to serve as a current path. The thickness of the film is originally considered to be in the order of 10 nm, which is much less than the skin depth, say 1/200. Since it is so thin, that intuitively the RF filed is penetrable. However, we found it is not true. The film will block most of the field. This paper addresses theoretic analysis as well as the experimental results. All demonstrated that the penetrability of a thin film is very poor. Consequently, most of the RF current will flow on the thin film causing a serous heating problem.

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**WPAT050—High Power Phase Shifter**
*Iouri Terechkine, G. William Foster, Ivan Gonin, Timergali N. Khabibouline, Alexander Makarov, Nikolay Solyak, David Wildman (Fermilab)*
One of the approaches to power distribution scheme of a superconducting proton linac under discussion at FNAL requires development of a fast-action, megawatt-range phase shifter. Using this kind of a device in an IQ modulator that controls phase and amplitude of RF power at the input of a superconducting accelerating section can result in significant reduction in number of klystrons and modulators required for the accelerator. A version of a shifter that uses Yttrium-Iron Garnet (YIG) blocks installed in a WR650 waveguide (1300 MHz) was developed and tested. This report presents the design concept of the device, and the main results of simulation and proof-of-principle tests.

**WPAT051—Development of Toshiba L-Band Multi-Beam Klystron for DESY X-FEL Project**
*Yong Ho Chin (KEK), Stefan Choroba (DESY), Yano Atsunori, Setsuo Miyake (TOSHIBA)*
A 10MW L-band multi-beam klystron (MBK)is under develpment at Toshiba, Japan for DESY X-FEL and a future linear collider projects. The design goals are to have 10MW peak power with 65% efficiency at 1.5 ms pulse length at 10Hz repetition rates. The Toshiba MBK has six low-perveance beams operated at low voltage of 115kV (for 10MW) to enable a higher efficiency than a single-beam klystron for a similar power. The prototype-0 has been built and is now under testing. At the first step, it was tested without RF and operates stably at the cathode voltage of 115KV at 1.7ms pulse length at 10Hz repetition rate with beam transmission of better than 99%. No spurious oscillation was observed. The testing is now progressed with RF on. Up to date of November 10, 2004, The output power of 10.3MW has been demonstrated at the beam voltage of 115kV with efficinecy of 68.4% at the RF pulse length of 1ms at 10Hz. The testing is under way to increase the RF pulse length to the goal value of 1.5ms. This paper summarizes the design and the testing results.

**WPAT052—Present Status of RF System for Medical Proton Synchrotron**
*Zhigao Fang, Kazumi Egawa, Kuninori Endo, Shinji Yamanaka (KEK), Yuichi Cho, Tetsuo Fusato, Teruhisa Hirashima (DKK)*
The 200MeV proton synchrotron of circumference of 9.54m is being developed for medical radiotherapy. The rf system has been carried out with a wide bandwidth of frequency sweeping from 2.0MHz to 17.8MHz. The rf cavity is designed of a compact dimension and a high acceleration gradient. The high power test of the rf system has been successfully performed and maximal acceleration gradient of 60kV/m has been achieved. The experiments with feedback control system are being studied by using a dummy beam signal. In this paper, the recent progress of the rf system and test results will be presented in detail.

**WPAT053—Dip Test, the Quick Measurement of Cathode Activity of the High Power Klystron in KEKB Injector Linac**
*Katsumi Nakao, Shigeki Fukuda, Hiroaki Katagiri, Toshihiro Matsumoto, Shinichiro Michizono, Tateru Takenaka, Yoshiharu Yano, Mitsuhiro Yoshida (KEK)*
Dip test, which is the measurement of a klystron heater activity, is recently adopted as the standard measurement to maintain the klystron operation in the KEK electron-positron linac. In 2003, we began to use a dip test as the quick way to measure the emission characteristics from the klystron cathode. After the successful results, we made the dedicated measuring systems and measured the dips of the cathode emission of 60 operating klystrons in KEK electron-positron linac. These data are important to estimate the klystron cathode life and used to select the candidate klystrons of replacement in the summer maintenance period.

**WPAT054—5 MW 805 MHz SNS RF System Experience**
*Karen Ann Young, Thomas Hardek, William Roybal (LANL/LANSCE), Joseph Bradley, Michael Lynch, Daniel Rees, Paul J. Tallerico (LANL)*
The RF system for the 805 MHz normal conducting linac of the Spallation Nuetron Source (SNS) accelerator was designed, procured and tested at Los Alamos National Laboratory(LANL) and then installed and commissioned at Oak Ridge National Laboratory (ORNL). The RF power for this room temperature coupled cavity linac (CCL) of SNS accelerator is generated by four pulsed 5 MW peak power klystrons operating with a pulse width of 1.25 mSec and a 60 Hz repetition frequency. The RF power from each klystron is divided and delivered to the CCL through two separate RF windows. The 5 MW RF system advanced the state of the art for simultaneous peak and average power. This paper summarizes the problems encountered, lessons learned and results of the high power testing at LANL of the 5 MW klystrons, 5 MW circulators, 5 MW loads, and 2.5 MW windows.*
*Tom Hardek is now at ORNL.

Work supported by the U.S. DOE.

**WPAT055—Enhancements for the 1 MW High Voltage Converter Modulator Systems at the SNS**
*David E. Anderson, Jim Hicks, Eddie Tapp, Mark Wezensky (ORNL/SNS), David Baca, William Reass (LANL), Donald Hurst (ORNL), Vladimir V. Peplov (RAS/INR)*
The first-generation high frequency switching megawatt-class high voltage converter modulators (HVCM) developed by Los Alamos National Laboratory for the Spallation Neutron Source at Oak Ridge National Laboratory have been installed and are now operational. Each unit is capable of delivering pulses up to 11 MW peak, 1 MW average power at voltages up to 140 kV to drive klystron(s) rated up to 5 MW. To date, three variations of the basic design have been installed, each optimized to deliver power to a specific klystron load configuration. Design improvements, with the primary intention of improving system reliability and availability, have been under development since the initial installation of the HVCM units. This paper will examine HVCM reliability studies, reliability operational data, and modifications and improvements performed to increase the overall system availability. We will also discuss system enhancements aimed at improving the ease of operation and providing for additional equipment protection features.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**WPAT056—60 Hz Operation of the 1 MW of the High Voltage Converter Modulator at the SNS**
*David E. Anderson, Jim Hicks, Eddie Tapp, Mark Wezensky (ORNL/SNS), David Baca, Robin F. Gribble, William Reass (LANL), Vladimir V. Peplov (RAS/INR)*
The first-generation high frequency switching megawatt-class high voltage converter modulators (HVCM) developed by Los Alamos National Laboratory for the Spallation Neutron Source at Oak Ridge National Laboratory have been installed and are now operational. The superconducting linac variation is capable of delivering pulses up to 11 MW peak, 1 MW average power at voltages up to 75 kV to drive klystron 12-packs rated up to 550 kW. Early attempts to operate this HVCM configuration at 60 Hz, 1350 us pulsewidth, were unsuccessful. Design modifications to attempt to reduce the IGBT commutation current, minimize the IGBT body diode forward current, and minimize the switching time were implemented to enable full duty cycle operation of these units. This paper will examine the history of these developments, details of design modifications that were implemented to improve performance, and the final system configuration to achieve successful operation. Additional areas of improvement for future upgrades will also be discussed.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**WPAT057—Overview of the Spallation Neutron Source Linac Low-Level RF Control System**
*Mark Champion, Mark Crofford, Kay-Uwe Kasemir, Hengjie Ma, Maurice Piller (ORNL/SNS), Lawrence Doolittle, Alessandro Ratti (LBNL)*
The design and production of the Spallation Neutron Source Linac Low-Level RF control system is complete, and installation will be finished in Spring 2005. The warm linac beam commissioning run in Fall 2004 was the most extensive test to date of the LLRF control system, with fourteen (of an eventual 96) systems operating simultaneously. In this paper we present an overview of the LLRF control system, the experience in designing, building and installing the system, and operational results.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**WPAT058—Operational Experience with the Spallation Neutron Source High Power Protection Module**
*Mark Crofford, Mark Champion, Kay-Uwe Kasemir, Hengjie Ma, Maurice Piller (ORNL/SNS)*
The Spallation Neutron Source (SNS) High Power Protection Module provides protection for the High Power RF Klystron and Distribution System and interfaces with the Low-Level Radio-Frequency (LLRF) Field Control Module (FCM). The fault detection logic is implemented in a single FPGA allowing modifications and upgrades to the logic as we gain operational experience with the LINAC RF systems. This paper describes the integration and upgrade issues we have encountered during the initial operations of the SNS systems.

**WPAT059—High Power RF Test Facility at the SNS**
*Yoon W. Kang, David E. Anderson, Isidoro Enrico Campisi, Mark Champion, Mark Crofford, Ray E. Fuja, Michael P. McCarthy, Daniel Stout, Alexandre Vasilievich Vassioutchenko, Mark Wezensky (ORNL/SNS), S.M. Shajedul Hasan (University of Tennessee)*
RF Test Facility has been completed in the SNS project at ORNL to support test and conditioning operation of RF subsystems and components. The system consists of two transmitters for two klystrons powered by a common high voltage pulsed converter modulator that can provide power to two independent RF systems. The waveguides are configured with WR2100 and WR1150 sizes for presently used frequencies: 402.5 MHz and 805 MHz. Both 402.5 MHz and 805 MHz systems have circulator protected klystrons that can be powered by the modulator capable of delivering 11 MW peak and 1 MW average power. The facility has been equipped with computer control for various RF processing and complete dual frequency operation. More than forty 805 MHz fundamental power couplers for the SNS superconducting linac (SCL) cavitites have been RF conditioned in this facility. The facility provides more than 1000 ft2 floor area for various test setups. The facility also has a shielded cave area that can support high power tests of normal conducting and superconducting accelerating cavities and components.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**WPAT060—SNS Low-level RF Control System: Design and Performance**
*Hengjie Ma, Mark Champion, Mark Crofford, Kay-Uwe Kasemir, Maurice Piller (ORNL/SNS), Lawrence Doolittle, Alessandro Ratti (LBNL)*
The LINAC RF of Spallation Neutron Source is controlled with a digital field control module (FCM). Its design is a textbook example of a modern digital implementation of the classic control theory. The digital hardware for all the control and DSP functionalities is implemented on a single high-density FPGA, and a VHDL and a Verilog model for the digital hardware have been developed. The VHDL version has being used for supporting the testing and commissioning the LINAC to the date. Both models use a similar control configuration. With a proper tuning, this configuration can produce a zero-pole cancellation which expands the control bandwidth beyond the cavity bandwidth to the limit set primarily by the loop delay . This effect has been demonstrated on some of the commissioned cavities.

ORNL is managed by UT-Battelle for the U.S. DOE.

**WPAT061—Spallation Neutron Source High Power RF Installation and Conditioning Progress**
*Michael P. McCarthy, David E. Anderson, Ray E. Fuja, Yoon W. Kang (ORNL/SNS), Joseph Bradley, Daniel Rees (LANL), William Roybal, Karen Ann Young (LANL/LANSCE), Pamela Gurd, Thomas Hardek (ORNL/ASD)*
The Spallation Neutron Source (SNS) linac will provide a 1 GeV proton beam for injection into the accumulator ring. The normal conducting (NC) section of this linac is powered by seven 2.5 MW, 402.5 MHz klystrons and four 5.0 MW, 805 MHz klystrons. Eighty-one 550 kW, 805 MHz klystrons each drive a single cavity in the superconducting section of the linac. The high power radio frequency (HPRF) equipment was specified and procured by LANL and tested before delivery to ensure a smooth transition from installation to commissioning. Installation of RF equipment to support klystron operation in the 350 meter long klystron gallery started in June 2002. The final klystron was set in place in September 2004. This paper reviews the progression of the installation and the RF conditioning of the HPRF Systems.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**WPAT062—The Spallation Neutron Source RF Reference System**
*Maurice Piller, Mark Champion, Mark Crofford, Hengjie Ma (ORNL/SNS), Lawrence Doolittle (LBNL)*
The Spallation Neutron Source (SNS) RF Reference System provides RF reference signals to the Low-Level RF (LLRF) Control Systems distributed throughout the SNS linear accelerator buildings. The RF reference signals are used by the LLRF Control Systems to accurately measure and control the phase and amplitude of the RF fields in the SNS linear accelerator RF cavities. The SNS RF Reference System requirements, implementation details, and performance are discussed.

**WPAT063—Design and Status of the BPM RF Reference Distribution in the SNS**
*James Pogge, Craig Deibele, Anthony Webster (ORNL/SNS)*
The Spallation Neutron Source (SNS) is an accelerator-based neutron source being built at Oak Ridge National Laboratory. The BPMs (Beam Position Monitors) requires RF reference signals to measure the phase of the beam with respect to the RF. In the MEBT (Medium Energy Beam Transport) Line and in the DTLs (Drift Tube Linac Cavities) are cavities that accelerate and bunch the beam at 402.5 MHz. In the CCLs (Coupled Cavity Linac) and SCLs (Superconducting Linac) accelerate the beam at 805 MHz. To mitigate effects of RF leakage into the BPM electrodes it is required to measure the phase in the MEBT and DTLs at 805 MHz and in the CCL and SCL at 402.5 MHz. We are directly connected to the RF group MO (master oscillator) and send these signals along the entire linac using fiber optic technology. Schematics, measurements, and installation update are discussed.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**WPAT064—Low Level RF Control System of J-PARC Synchrotrons**
*Fumihiko Tamura (JAERI/LINAC), Masanobu Yamamoto (JAERI), Masahiro Nomura, Alexander Schnase (JAERI, Shozo Anami, Eizi Ezura, Keigo Hara, Chihiro Ohmori, Akira Takagi, Masahito Yoshii (KEK)*
We present the concept and the design of the low level RF (LLRF) control system of the J-PARC synchrotrons. The J-PARC synchrotrons are the rapid cycling 3-GeV synchrotron (RCS) and the 50-GeV main ring (MR) which require very precise and stable LLRF control systems to accelerate the ultra-high proton beam current. The LLRF system of the synchrotron is a full-digital system based on the direct digital synthesis (DDS). The functions of the system are (1) the multi-harmonic RF generation for the acceleration and the longitudinal bunch shaping, (2) the feedbacks for stabilizing the beam, (3) the feedforward for compensating the heavy beam loading, and (4) other miscellaneous functions such as the synchronization and chopper timing. The LLRF system of the RCS is now under construction. We present the details of the system. Also, we show preliminary results of performance tests of the control modules.

**WPAT065—HLS RF System Improvement in NSRL Phase II Project**
*Kai Jin, Yibin An, Lanlin Feng, Liu Gongfa, Guirong Huang, Guicheng Wang, Xiang Zeng (USTC/NSRL)*
Hefei Light Source (HLS) is mainly composed of an 800 MeV electron storage ring and a 200 MeV Linac functioning as its injector. The RF system has been improved successfully for HLS storage-ring in NSRL Phase II Project. In this paper, the improvement of generator and power transmission system, the development of a new RF cavity and the perfection of RF controls are described in detail. The results and some analyses are presented.

**WPAT066—ALS Booster Ring RF System Upgrade for Top-Off Mode of Operation**
*Slawomir Kwiatkowski, Kenneth Michael Baptiste (LBNL/ALS)*
ALS is one of the first third generation synchrotron light sources which has been operating since 1992 at Berkeley Lab. In the present ALS operation scenario 1.5GeV electron beam is injected from the booster into the storage ring every 8 hours where is accelerated to the final energy of 1.9GeV. The beam decays between fills from 400mA to 200mA with the time average current of 250mA. In order to increase the beam brighthess ALS team plans to increase the beam current to 500mA and maintain it constant during machine operation ("Top-Off" mode of operation). This operation scenario will require full energy injection from the booster ring into the storage ring and constant operation of the injector (10 bunches with the total charge of 1nC every 30 to 35 seconds). In this paper we will present the results of the ALS injector RF system analysis fo Top-Off mode of operation and describe the way we intent to implement the necessary modifications to the booster RF system.

Supported by the U.S. Department of Energy under Contract No.DE-AC03-76SF00098.

**WPAT067—High Power Disk Loaded Guide Load**
*Zoltan David Farkas (SLAC)*
A method to design a matching section from a smooth guide to a disk loaded guide, using a variation of broadband matching* is described. Using this method, we show how to design high power loads, filters and attenuators. The load consists of a disk loaded coaxial guide, operating in the TE01 mode. This mode has no electric field terminating on a conductor, has no axial currents. Therefore, it is expected that it will carry the 600 MW peak output power of the pulse compression network. We use coaxial geometry and stainless steel material to increase the attenuation per cell.

*S. B. Cohn, Optimum Design of Stepped Transmission Line Transformers. IRE Trans., Vol. MTT-3 pp16-21, April, 1995.

Department of Energy, contract DE-AC03-76SF00515.

**WPAT068—Development of Low Level RF Control Systems and their Integration in Booster Synchrotrons and Superconducting Linear Accelerators**

*Bachtior Aminov, Sergej Kolesov, Helmut Piel, Dorothea Wehler (CRE), Michael Pekeler, Christian Piel, Hanspeter Vogel (ACCEL)*

Since 2001 ACCEL Instruments is supplying low level RF control systems together with turn key cavity systems. The early LLRF systems used the well established technology based on discrete analogue amplitude and phase detectors and modulators. Today analogue LLRF systems can make use of advanced vector demodulators and modulators combined with a fast computer controlled analogue feed back loop. Feed forward control is implemented to operate the RF cavity in an open loop mode or to compensate for predictable perturbations. The paper will introduce the general design philosophy and show how it can be adapted to different tasks as controlling a synchrotron booster nc RF system at 500 MHz, or superconducting storage ring RF cavities, as well as a linear accelerator at 176 MHz formed by a chain of individually driven and controlled superconducting lambda/2 cavities.

**WPAT069—Development of a Solid State RF Amplifier in the kW Regime for Application with Low Beta Superconducting RF Cavities**

*Christian Piel, Kai Dunkel, Hanspeter Vogel (ACCEL), Bachtior Aminov, Sergej Kolesov, Helmut Piel, Nico Pupeter (CRE)*

Projects based on the use of low beta superconducting cavities for ions are under operation or development at several labs worldwide. Often these cavities are individually driven by RF power sources in the kW regime. For an ongoing project a modular 2 kW, 176 MHz unconditionally stable RF amplifier for CW and pulsed operation was designed, built, and tested. Extended thermal analysis was used to develop a water cooling system in order to optimize the performance of the power transistors and other thermally loaded components. The paper will outline the design concept of the amplifier and present first results on the test of the amplifier with a superconducting cavity.

**WPAT070—500 MHz Coaxial Transition Between the ELETTRA Input Coupler and the Transmission Waveguide**

*Cristina Pasotti, Alessandro Fabris, Michele Svandrlik (ELETTRA)*

The investigations have shown that the 500 MHz ELETTRA input power coupler can safely sustain more than 150 KW. The critical component limiting the increase of the trasmitted RF power is the connection element between the input power coupler and the transmission line. An optimized design has been studied to overcome this limit. During the optimization process, the entire RF chain (input power coupler, connection element and transition to the standard waveguide WR1800) has been verified. The analysis has been carried out to check the performances of the whole lay-out in terms of efficiency of transmitted power and sensitivity to any signal coming from the cavity ( HOMs included). A prototype with an improved cooling system has been realized and tested.

**WPAT071—R&D Status of the 700 MHz, 1MW Klystron for PEFP**

*Sang-Ho Kim, Bo-hyun Chung, Kie-hyung Chung, Jin-Suk Hong, SeungKook Ko, Kangok Lee, S.J. Noh (KAPRA)*

KAPRA (Korea Accelerator and Plasma Research Association) are undertaking the first phase R&D for the 1 MW, CW 700 MHz klystron, which is targeting the future stage of the PEFP (Proton Engineering Frontier Project) accelerator at KAERI (Korea Atomic Energy Research Institute). The objectives of the first phase R&D are 1) setting up all infra structures/procedures for the design and fabrication, 2) developing a prototype klystron for proofs of principles, and 3) making a performance test of the prototype at a reduced duty. The second phase R&D is supposed to cover full power, CW operation and reliability issues. In this paper, a summary of R&D Status during the first phase for PEFP 1 MW, 700 MHz klystron is reported.

This study is supported by Proton Engineering Frontier Project at Korea Atomic Energy Research Institute.

**WPAT072—A 1.3GHz Inductive Output Tube for Particle Accelerators**

*Edward Sobieradzki, Alan Wheelhouse (e2v technologies)*

There is an increasing requirement for RF power sources in the L-band frequency range for operation in particle accelerators. The paper describes the development and presents test results of a new inductive output tube (IOT) for use at 1.3GHz. A target specificationof 16kW cw output power at an efficiency of 60% was set. The paper discusses progress to date having used an electron gun geometry that minimizes transit time effects in the cathode to grid gap.

**WPAT073—The LCLS LLRF Control System**

*Karen Dayle Kotturi, Ron Akre (SLAC)*

The LINAC Coherent Light Source requires an RF stability of 0.1% rms in amplitude, 100 fs in phases for a 850 ns fill time for the S-band structure, 125 fs in phase for a 100 ns fill time for the X-band structure and 30 ns rise times for the RF gun pulse shaper. This paper describes the design of a new VME/EPICS-based control system for the LCLS low level RF system that will monitor and control the RF phase and amplitude so that these requirements can be met with the use of beam based feedback. The challenges with measurement of RF phase as seen by the beam are also discussed.

U.S. DOE.

**WPAT074—In Depth Diagnostics for RF System Operation in the PEP-II B Factory**

*Daniel Van Winkle, John Fox, Dmitry Teytelman (SLAC)*

The PEP-II RF systems incorporate numerous feedback loops in the low-level processing for impedance control and operating point regulation. The interaction of the multiple loops with the beam is complicated, and the systems incorporate online diagnostic tools to configure the feedback loops as well as to record fault files in the case of an RF abort. Rapid and consistent analysis of the RF-related beam aborts and other failures is critical to the reliable operation of the B-Factory, especially at the recently achieved high beam currents. Procedures and algorithms used to extract diagnostic information from time domain fault files are presented and illustrated via example interpretations of PEP-II fault file data. Example faults presented will highlight the subtle interpretation required to determine to root cause. Some such examples are: abort kicker firing asynchronously, klystron and cavity arcs, beam loss leading to longitudinal instability, tuner read back jumps and poorly configured low-level RF feedback loop.

Work supported by U.S. Department of Energy contract DE-AC02-76SF00515.

**WPAT075—Design and Calibration of a Phase and Amplitude Detector**
*Zheqiao Geng, Pengda Gu, Mi Hou, Guoxi Pei (IHEP Beijing)*
The phase and amplitude detector (PAD) is a key unit of the phasing system for BEPCII linac. One of the main functions of the PAD is to measure the phase of each klystron accurately from such large noises. To meet the need of the phasing system, a new PAD is constructed based on I/Q demodulator and industrial computer. But the I/Q demodulator suffers form phase and amplitude mismatch, which can draw big error on phase measurement. In order to compensate the mismatch of the I/Q demodulator, we develop a calibration program using an adaptive method, LMS method. Almost all the mismatches of the I/Q demodulator are compensated after calibration.

**WPAT076—Resonant Coupling for RF Sources**
*Michel Langlois (Thales Broadcast & Multimedia AG)*
Particle accelerators need radio frequency sources. Above 300 MHz, the amplifiers mostly used high power klystrons developed for this sole purpose. As for military equipment, users are drawn to buy "off the shelf" components rather than dedicated devices. IOTs have replaced most klystrons in TV transmitters and find their way in particle accelerators. They are less bulky, easier to replace, more efficient at reduced power. They are also far less powerful. What is the benefit of very compact sources if huge 3 dB couplers are needed to combine the power? To alleviate this drawback, we investigated a resonant combiner, operating in TM010 mode, able to combine 3 to 5 IOTs. Our IOTs being able to deliver 80 kW C.W. apiece, combined power would reach 400 kW minus the minor insertion loss. Values for matching and insertion loss are given. The behavior of the system in case of IOT failure is analyzed.

**WPAT077—Finite-Element 2D & 3D PIC Modeling of RF Devices with Applications to Multipacting**
*John F. DeFord (LLNL), Eric Michael Nelson (LANL), John Petillo (SAIC)*
Multipacting currently limits the performance of many high power radio-frequency (RF) devices, particularly couplers and windows. Models have helped researchers understand and mitigate this problem in 2D structures, but useful multipacting models for complicated 3D structures are still a challenge. A combination of three recent technologies that have been developed in the Analyst and MICHELLE codes begin to address this challenge: high-order adaptive finite-element RF field calculations, advanced particle tracking on unstructured grids, and comprehensive secondary emission models. Analyst employs high-order adaptive finite-element methods to accurately compute driven RF fields and eigenmodes in complex geometries, particularly near edges, corners, and curved surfaces. To perform a multipacting analysis, we use the mesh and fields from Analyst in a modified version of the self-consistent, finite-element gun code MICHELLE. MICHELLE has both a fast, accurate, and reliable particle tracker for unstructured grids and a comprehensive secondary emission model. We will demonstrate this capability on an RF coupler.

**WPAT078—High Frequency Resonant Power Converters for High Power RF Systems**
*Michael John Bland, Jon Clare, Pat Wheeler, Pericle Zanchetta (University of Nottingham)*
Accelerators used for experiments in high-energy physics require very high power radio frequency sources to provide the energy needed to accelerate the particles. The RF power needs to be stable and predictable such that any variation in the supplied RF power has a limited and acceptable impact on the accelerated beam quality. The output load specifications for high voltage DC power systems are becoming increasingly more demanding. In addition, the impact of such systems on the electricity source is becoming more tightly regulated through power quality directives. These regulations set limits, for example, on the allowable individual harmonic current amplitudes and on "flicker" caused by transient load demands - the latter is particularly important for "long-pulse" modulators. The requirements above have to be met while still providing higher reliability to a higher specification at lower cost. A situation has now been reached where modulators based on existing approaches cannot meet these specifications and stay within acceptable cost and size limits. This demands that new approaches be taken to provide the power supplies needed for such applications. The research proposed here addresses this need.

Particle Physics and Astronomy Research Council (PPARC).

**WPAT079—Design and Control of a Direct Power Converter for High Power, RF Applications**
*David Cook, Maurizio Catucci, Jon Clare, Pat Wheeler (University of Nottingham)*
This paper is concerned with a new type of power supply for high power RF applications for CW operation. The converter is a direct topology operating with a high frequency (resonant) link. Switching losses are minimised by switching at zero current. High operating frequency allows for minimised transformer and filter size. Advantages of this topology over conventional approaches are discussed, along with the potential problems and proposed solutions. Recently, considerable interest has been shown in direct converter topologies as an alternative topology in motor drive applications. This approach offers advantages such as reduced energy storage and higher energy density compared to conventional topologies. The work presented in this paper capitalises on these advantages in other fields, namely power conversion for RF supplies. The RF power needs to be stable and predictable such that any variation has a limited impact on the accelerated beam quality. In order to meet the required output voltage specification such designs require output filters with consequent energy storage. Management of this energy in the event of a fault is necessary if destruction of the tube is to be avoided.

Particle Physics and Astronomy Research Council.

**WPAT080—Calculation of Beam-Loaded Q in High-Power Klystrons**
*John F. DeFord (STAR, Inc.), Valentin Ivanov, Kwok Ko (SLAC)*
Instabilities in the gun region of a high-power klystron can occur when there is positive feedback between a mode and an induced current on the quasi-steady state beam emitted by the gun cathode.* This instability is dependent on the gun voltage, is predicted on the basis of a negative beam-loaded Q. The established method for computing the beam-loaded Q of a cavity involves using a time-dependent electromagnetic particle-in-cell (PIC) code to track beam particles through the quasi-static gun fields perturbed by the electromagnetic fields of a cavity eigenmode.** The energy imparted to the beam by the mode is obtained by integrating the Lorentz force along the particle tracks, and this quantity is simply related to the beam-loaded Q. We have developed an alternative approach that yields comparable accuracy but is computationally much simpler. The new method is based on a much simpler time-independent electrostatic PIC calculation, resulting in much faster solutions without loss of accuracy. We will present the theory and implementation of the new method, as well as benchmarks and results from analysis of the XP-4 klystron that show a potential instability near 3 GHz.

*B. Krietenstein, et al., "Spurious oscillations in high-power klystrons," PAC95, 1995. **U. Becker, et al., "Simulation of oscillations in high-power klystrons," EPAC, 1996.

Work supported by DOE SBIR Grant DE-FG02-03ER83776.

**WPAT081—Ceramic Power Extractor Design at a Radio Frequency of 15.6 GHz**

*Alexei Smirnov, Yan Luo, Rong Yi, David Yu (DULY Research Inc.)*

Power extractor and coupler designs developed for an experiment planned at the 12th beam harmonic of the upgraded Advanced Wakefield Accelerator (AWA) facility is described. New features are an upstream HOM dielectric damper with additional tapering, and a single-port coupler considered in two variants. Performance analysis includes coupler geometric tolerances, overvoltage, dipole mode wake and BBU; and wakefield losses induced in the damper.

Work supported by DOE SBIR Grant No. DE-FG03-01ER83232.

**WPAT082—An Improved Pneumatic Frequency Control for Superconducting Cavities**

*Gary Zinkann, Sergey I. Sharamentov (ANL)*

The ATLAS (Argonne Tandem Linear Accelerator System) superconducting cavities use a pneumatic system to maintain the cavity eigenfrequency at the master oscillator frequency. The present pneumatic slow tuner control has a limitation in the tuning slew rates. In some cases, the frequency slew rate is as low as 30 Hz/sec. The total tuning range for ATLAS cavities varies from 60 KHz to as high as 450 KHz depending on the cavity type. With the present system, if a cavity is at the extreme end of its tuning range, it may take an unacceptable length of time to reach the master oscillator frequency. We have designed a new slow tuner control system that increases the frequency slew rates by at least a factor of ten to a factor of three hundred in the more extreme cases. This improved system is directly applicable for use on the RIA (Rare Isotope Accelerator) cavities. This paper discusses the design of the system and the results of a prototype test.

U.S. Department of Energy.

**WPAT083—Steering and Focusing Effects in TESLA Cavity Due to High Order Mode and Input Couplers**

*Philippe Regis-Guy Piot (Fermilab), Martin Dohlus, Klaus Floettmann, Susan Wipf (DESY)*

Many state-of-art electron accelerator proposals incorporate TESLA-type superconducting standing wave cavities. These cavities include input coupler (to feed the RF power into the cavity) and a pairs of high order mode couplers (HOM) to absorb the energy associated to HOM field excited as the bunch passes through the cavity. In the present paper we investigate, using numerical simulations, the impact of the input and HOM couplers on the beam dynamics. We show the overall effects are: a dipole kick (zeroth order) and normal and skew quadrupole-type focusing (first order). We present parametric studies of the strength of these effect for various operating gradients and incoming beam energies. We finally study the impact of this non-asymmetric field on the beam dynamics, taking as an example the low energy section of the European X-FEL injector.

This work was supported by Universities Research Association Inc. under contract DE-AC02-76CH00300 with the U.S. Department of Energy, and by NICADD.

**WPAT084—A Ceramic Material for Input Coupler of Superconducting Cavity**

*Hiroshi Matsumoto, F. Furuta, Kenji Saito (KEK), K. Hayashi (TOSHIBA)*

A typical problem of input coupler is breakdown occur on a surface and or inside the ceramic window. One of the main reason of breakdown caused by the not enough quality of ceramic material, such as micro voids and large rf lossy materials (MgO and SiO). These defects will trigger the micro discharge at the beginning of main breakdown in the coupler. This paper will report the mechanism of breakdown and the improvement of ceramic material.

Toshiba Electron Tube & Devices Co. Ltd., Tochigi, Otawa, Japan.

**WPAT085—Test Results of an SNS Medium Beta Cryomodule at 4.2 K**

*Isidoro Enrico Campisi, Fabio Casagrande, Mark Champion, Mark Crofford, Daniel Hatfield, Matthew Howell, Yoon W. Kang, Hengjie Ma, Daniel Stout, William Strong (ORNL/SNS), Pamela Gurd (ORNL/ASD)*

The Spallation Neutron Source being built at the Oak Ridge National Laboratory employs eighty one 805 MHz superconducting cavities operated at 2.1 K for the H- beam to gain energy in the main linac from 187 MeV to about 1 GeV. The superconducting cavities and cryomodules with two different values of beta .61 and .81 have been designed and constructed at Jefferson Lab for operation at 2.1 K with unloaded Q's in excess of 5x109. To gain experience in testing cryomodules in the SNS tunnel before the final commissioning of the 2.1 K Central Helium Liquefier, integration tests were conducted on a medium beta (.61) cryomodule at 4.2 K. This is the first time that a superconducting cavity system specifically designed for 2.1 K operation has been extensively tested at 4.2 K without superfluid helium. Even at 4.2 K it was possible to test all of the functional properties of the cryomodule and of the cavities. In particular, at a nominal BCS Qo˜7x108, simultaneous pulse operation of all three cavities in the cryomodule was achieved at accelerating gradients in excess of 12 MV/m. These conditions were maintained for several hours at a repetition rate of 30 pps. Details of the tests will be presented and discussed.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge.

**WPAT086—Superconducting RF Cavity Frequency and Field Flatness Sensitivity Simulation Due to Axial Force**

*An Sun (ORNL/SNS)*

Frequency's and field flatness' sensitivity of the superconducting radio frequency (SRF) cavity due to the axial squeeze or stretch is very important to SRF cavity tuner design. Normally, the frequency sensitivity was measured by pressing model cavity. In this paper, a simulation method is introduced by combining the ANSYS and SUPERFISH code. The simulation results of frequency and field flatness sensitivity agree with the test results.

Under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**WPAT087—Design of 150 kW CW Power Coupler for 700 MHz Superconducting Protons Cavities**
*Mohammed Fouaidy, Sébastien Bousson, Francois Galet, Herve Saugnac, Mehdi Souli (IPN), Guillaume Devanz, Bernard Visentin (CEA/DSM/DAPNIA)*
IPN Orsay and CEA Saclay institutes set a R&D program for developing Superconducting RF cavities with their ancillaries (Cold Tuning System, Power Coupler (PC),…) for high intensity proton linacs. We designed a 700 MHz, coaxial Power Coupler for the high energy part of these linacs. The coupler, scaled from KEK and SNS components, should transfer 150 kW CW RF power to the beam. The RF design of the coaxial window was performed using HFSS and 2 prototypes were fabricated in the industry. The thermal behaviour of the cavity with the PC was studied and a cold heat exchanger for efficient cooling of its outer conductor was designed. The cooling circuit shape and size were optimized for removing 92 W thermal power (SW mode), while minimizing the heat load to 2 K with minimum pressure drop and maximum heat transfer coefficient. The inner conductor is water-cooled (256 W heat removal in SW mode) for keeping the temperature around 300 K hence reducing thermal radiation to the cavity. Finally, the effect of the thermal anchoring of the outer conductor cold end, and the contact thermal resistance at the coupling port were studied. The first experimental data and numerical results will be presented and discussed.

CNRS-IN2P3, CEA, EU

**WPAT088—Performance of TESLA Cavities in Vertical and Horizontal Tests after Fabrication and Preparation in Industry**
*Michael Pekeler, Stefan Bauer, Peter vom Stein (ACCEL), Wolfgang Anders, Jens Knobloch (BESSY GmbH), Wolf-Dietrich Möller (DESY)*
In order to demonstrate cw operation of TESLA cavities in linear accelerators driving FEL applications, two TESLA cavities were manufactured and prepared by ACCEL for BESSY. After production, both cavities were prepared for vertical test at ACCEL's premises using state of the art chemical polishing and high pressure water rinsing techniques. The cavities were tested in DESY's vertical RF test installation. Accelerating gradients close to 25 MV/m were reached. One cavity was completed with a helium vessel modified for cw operation and prepared with chemical polishing, high pressure water rinsing, and assembled with the required High Power Coupler at ACCEL. The fully dressed cavity was then shipped under vacuum to BESSY and tested in the horizontal cryostat HoBiCaT. Horizontal RF test results will be presented and compared with the vertical test results.

**WPAT089—Test Bed for Superconducting Materials**
*Christopher Dennis Nantista, Valery Dolgashev, Robert Siemann, Sami G. Tantawi, John Weisend (SLAC), Isidoro Enrico Campisi (ORNL/SNS)*
Superconducting rf cavities are increasingly used in accelerators. Gradient is a parameter of particular importance for the ILC. Much progress in gradient has been made over the past decade, overcoming problems of multipacting, field emission, and breakdown triggered by surface impurities. However, the quenching limit of the surface magnetic field for niobium remains a hard limitation on cavity fields sustainable with this technology. Further exploration of materials and preparation may offer a path to surpassing the current limit. For this purpose, we have designed a resonant test cavity. One wall of the cavity is formed by a flat sample of superconducting material; the rest of the cavity is copper or niobium. The H field on the sample wall is 74% higher than on any other surface. Multipacting is avoided by use of a mode with no surface electric field. The cavity will be resonated through a coupling iris with high-power rf at superconducting temperature until the sample wall quenches, as detected by a change in the quality factor. This experiment will allow us to measure critical magnetic fields up to well above that of niobium with minimal cost and effort.

Work supported by the U.S. Department of Energy under contract DE-AC03-76SF00515.

**WPAT091—Fabrication and Final Field Tuning of Copper Cavity Models for a High-Current SRF ERL at 703.75 MHz**
*Michael Cole, Al Burger, Michael Falletta, Douglas Holmes, Ed Peterson, Robert Wong (AES), Ilan Ben-Zvi (BNL)*
Advanced Energy Systems is currently under contract to BNL to fabricate a five cell superconducting cavity and cryomodule for the RHIC eCooler SRF Energy Recovery Linac (ERL) program.* The cavity is designed and optimized for ampere class SRF ERL service. As part of this program, we have fabricated two low power copper models of the RF cavities. During the fabrication process a series of frequency measurements were made and compared to the frequency expected at that point in the fabrication process. Where possible, the cavity was modified either before or during, the next fabrication step to tune the cavity frequency toward the target frequency. Following completion of the cavities they were tuned for field flatness and frequency. This paper will review the measurements made, frequency tuning performed, and discuss discrepancies between the expected and measured results. We will also review the as fabricated field profiles and the results of the tuning steps. Further, the cost and benefits of extensive in process tuning will be discussed from an industrial perspective.
*Electron cooling of RHIC, Ilan Ben-Zvi, these proceedings.

**WPAT092—Fabrication Tuning of Four 748.5 MHz Single Cell SRF Booster Cavities for a 100 mA SRF FEL Injector**
*Michael Cole, Ed Peterson, John Rathke (AES)*
Advanced Energy Systems has recently completed the fabrication of four 748.5 MHz single cell superconducting cavities which are to be used in the JLAB FEL SRF Injector Test Stand. During the fabrication process a series of frequency measurements were made and compared to the frequency expected at that point in the fabrication process. Where possible, the cavity was modified either before or during, the next fabrication step to tune the cavity frequency toward the target frequency. The target frequency is calculated making a series of assumptions about the frequency effects of subsequent fabrication and processing steps.

This work is supported by NAVSEA, NSWC Crane, the Office of Naval Research, and the DOD Joint Technology Office.

**WPAT093—A Three-Cell Superconducting Deflecting Cavity Design for the ALS at LBNL**
*Jiaru Shi, Huaibi Chen, Shuxin Zheng (TUB), Derun Li (LBNL)*
Deflecting RF cavities can be used to generate sub-pico-second x-rays by creating correlations between longitudinal and transverse phase space of electron bunches in radiation devices. Up to 2-MV defecting voltage at 1.5-GHz is required for 1.9-GeV electron beam at the Advanced Light Source (ALS) at LBNL. We present a conceptual design for a 1.5-GHz three-cell superconducting RF cavity and its coupler. The cavity geometry and deflecting shunt impedance are optimized using MAFIA code. The cavity impedance from lower and higher order modes (LOM and HOM) are computed. Possible schemes for damping most harmful LOM and HOM modes are discussed and simulated.

**WPAT094—Traveling Wave Accelerating Structure for a Superconducting Accelerator**

*Alex Kanareykin, Pavel Avrakhov (Euclid Concepts, LLC), Nikolay Solyak (Fermilab)*

We are presenting a superconducting traveling wave accelerating structure (STWA) concept, which may prove to be of crucial importance to the International Linear Collider. Compared to the existing design of a TESLA cavity, the traveling wave structure can provide ~20-40% higher accelerating gradient for the same aperture and the same peak surface magnetic RF field. The recently achieved SC structure gradient of 35 MV/m can be increased up to ~50 MV/m with the new STWA structure design. The STWA structure is supposed to be installed into the superconducting resonance ring and is fed by the two couplers with appropriate phase advance to excite a traveling wave inside the structure. The system requires two independent tuners to be able to adjust the cavity and feedback waveguide frequencies and hence to reduce the unwanted backward wave. In this presentation we discuss the structure design, optimization of the parameters, tuning requirements and plans for further development.

**WPAT095—Low-Loss Ferroelectrics for Accelerator Application**

*Alex Kanareykin, Sergei Fedorovich Karmanenko, Elisaveta Nenasheva (Euclid Concepts, LLC)*

Ferroelectric ceramics have an electric field-dependent dielectric permittivity that can be altered by applying a bias voltage. Ferroelectrics have unique intrinsic properties that makes them attractive for high-energy accelerator applications: very small response time of ~10-11 sec, considerably high breakdown limit of more than 100 kV/cm, good vacuum properties. Because of these features, bulk ferroelectrics may be used as active elements of tunable accelerator structures,* or in fast, electrically - controlled switches and phase shifters in pulse compressors or power distribution circuits of future linear colliders.** One of the most critical requirements for ferroelectric ceramic in these applications is the dielectric loss factor. In this paper, the new bulk ferroelectric ceramic is presented. The new composition shows a loss tangent of 4×10-3 at 35 GHz. The ceramics have high tunability factor: the bias voltage of 50 kV/cm was enough to reduce the permittivity from 500 to 400. The material chemical compound, features of the technology process, and mechanical and electrical properties are discussed. The ways of BST ferrolectric parameters further improvement are discussed as well.

*A. Kanareykin, W. Gai, J. Power, E. Sheinman, and A. Altmark, AIP Conf. Proc. 647, Melville, N.Y., 2002, p. 565.
**V.P. Yakovlev, O.A. Nezhevenko, J.L. Hirshfield, and A.D. Kanareykin, AIP Conf. Proc. 691, Melville, N.Y., 2003, p.187.

U.S. Department of Energy.

**Oral Session WOPA–Special Session: Accelerator Science and Technology Awards, Ballrooms D-G @ 13:00**
**Chair: N. Phinney (SLAC)**

**13:00 WOPA001—Wilson Prize Talk**
*Keith R. Symon (Univ. of Wisconsin–Madison)*
The formula for the center-of-mass energy as a function of the energy of the incident particle in a collision with a stationary target shows that the required beam energy is greatly reduced if we collide incident and target particles with equal and opposite momenta. Unfortunately the cross sections for collisions of interest are so small that until the middle 1900's it was not possible to achieve colliding beams of sufficient intensities to reach needed collision rates. In 1954 fixed field alternating gradient (FFAG) accelerators were invented. With a fixed magnetic guide field, it was possible to consider stacking successively injected beams to achieve very high intensity circulating beams. Calculations using Liouville's theorem showed that colliding beam experiments were now practical. Circulating electron beams over 10 amperes were achieved in a model accelerator built by the Midwestern Universities Research Association (MURA). With the invention of storage rings, a much cheaper accelerator configuration than FFAG, and utilizing beam stacking, colliding beams are now utilized to study high energy interactions.

**13:20 WOPA002—Ph.D. Dissertation Talk: Experimental Results from the Small Isochronous Ring**
*Eduard Pozdeyev (JLab/MSU) Felix Marti, Jose Alberto Rodriguez, Richard York (NSCL)*
The Small Isochronous Ring (SIR) is a compact, low-energy storage ring designed to investigate the beam dynamics of high-intensity isochronous cyclotrons and synchrotrons at the transition energy. The ring was developed at Michigan State University and has been operational since December 2003. It stores 20 keV hydrogen beams with a peak current of 10-20 microamps for up to 200 turns. The transverse and longitudinal profiles of extracted bunches are measured with an accuracy of approximately 1 mm. The high accuracy of the measurements makes the experimental data attractive for validation of multi-particle space charge codes. The results obtained in the ring show a fast growth of the energy spread induced by the space charge forces. The energy spread growth is accompanied by a breakup of the beam bunches into separated clusters that are involved in the vortex motion specific to the isochronous regime. The experimental results presented in the paper show a remarkable agreement with simulations performed with the code CYCO. In this paper, we discuss specifics of space charge effects in the isochronous regime, present results of experiments in SIR, and conduct a detailed comparison of the experimental data with results of simulations.

Work supported by NSF Grant # PHY-0110253 and DOE Contract DE-AC05-84ER40150.

**13:40 IEEE NPSS Particle Accelerator Science and Technology Award: Comments by Award Winner**
*Ronald Davidson (Plasma Physics Laboratory, Princeton University)*

**13:55 IEEE NPSS Particle Accelerator Science and Technology Award: Comments by Award Winner**
*Thomas Roser (BNL)*

**14:10 U.S. Particle Accelerator School Prize for Achievement in Accelerator Physics and Technology: Comments by Award Winner**
*Wim Leemans (LBNL)*

**14:25 U.S. Particle Accelerator School Prize for Achievement in Accelerator Physics and Technology: Comments by Award Winner**
*Anton Piwinski (DESY)*

**14:40 Newly Elected Fellows of the APS/DPB**

**14:55 Student Travel Awards**

**Oral Session WOPB–Special Session: Einstein and the World Year of Physics, Ballrooms D-G @ 15:00**
**Chair: W. Madia (Battelle)**

**15:00 Introduction: Einstein's Legacy in Charged Particle Acceleration**
*S. Chattopadhyay (JLab)*

**15:15 WOPB001—Einstein and Cosmic Acceleration**
*Michael Turner (NSF)*

**15:55 WOPB002—Symmetries and Einstein**
*Makoto Kobayashi (KEK)*
After brief survey of influence of Einstein on current particle physics, fundamental symmetry between particles and antipaticles will be discussed. Existence of antiparticles is an important outcome of special relativity and quantum mechanics and disappearance of antiparticles from the present universe is one of the mysteries in Big Bang cosmology based on the Einstein equation. Remarkable progress has been made recently in the studies on the violation of symmetry between particles and antiparticles with the use of a new type of accelerator. Some of their achievements will be reported.

**16:35 WOPB003—Neutrinos and Einstein**
*Yoichiro Suzuki (Univ. of Tokyo)*
A tiny neutrino mass is a clue to the physics beyond the standard model of elementary particle physics. The primary cosmic rays, mostly protons, are created and accelerated to the relativistic energy in supernova remnants. They traverse the universe and reach the earth. The incoming primary cosmic rays interact with the earth's atmosphere to produce secondary particles, which subsequently decay into neutrinos, called atmospheric neutrinos. The atmospheric neutrinos have shown the evidence of the finite neutrino masses through the phenomena called neutrino oscillations. Neutrinos are detected by large detectors underground like, for example, Super-Kamiokande, SNO and KamLAND. Those detectors use large photomultiplier tubes, which make use of the photo-electric effect to convert photons created by the interaction of neutrinos to electrons to form electric pulses.

Neutrinos are therefore created and detected by "Einstein" and have step forward beyond the current physics. Neutrinos may also carry a hit to the origin of the dark energy, the Einstein's Cosmological Constant.

**17:15 WOPB004—The Quest for Dark Matter**

*Carlo Rubbia (CERN)*

Recent experiments have brought for the first time under a strong experimental basis that the total density of the Universe is $\Omega_0 = 1.02 \pm 0.02$. We have for the first time a cosmic agreement, namely matter density $\Omega_M = 0.27 \pm 0.04$ and dark energy density $\Omega_E = 0.73 \pm 0.04$ add up precisely to $\Omega_0 \approx \Omega_M + \Omega_E$. On the other hand ordinary hadronic matter (quarks and leptons) determined by the Big Bang Nucleo-synthesis (BBN) is also firmly set to $\Omega_{BBN} = 0.044 \pm 0.004$. About 100 years after Einstein's birth we know *experimentally* the identity of less than 5% of what the Universe is made of, the remaining > 95% escaping to us completely. An enormous effort is being made at LHC in order to discover SUSY particles. SUSY is an "almost necessity" of elementary particle physics. The fact that such particles may also account for the observed non baryonic dark matter is either a big coincidence or a big hint. If such SUSY particles indeed exist, they must have been produced abundantly at the time of the Big Bang and should be detectable underground as some form of Cold Dark Matter (CDM). Indeed one of the main hopes of SUSY is to become the key to the CDM problem: this cannot be achieved unless some kind of relic neutral particles exists (WIMP). Therefore the a priori chance of detecting SUSY underground at the LNGS first should not be underestimated. We should also remark that SUSY is only one of the many candidates for WIMP: other kinds of massive relic particles may exist, which may have weak-like interaction properties and therefore detectable underground.

# Thursday, May 19, 2005

Oral Session ROAA–Lepton Accelerators and Colliders
Ballroom A @ 8:30
Chair: K. Oide (KEK)

**8:30 ROAA001—DAFNE Operation and Plans for DAFNE2**
*Mikhail Zobov, David Alesini, Gabriele Benedetti, Maria Biagini, Caterina Biscari, Roberto Boni, Manuela Boscolo, Alberto Clozza, Giovanni Delle Monache, Giampiero Di Pirro, Alessandro Drago, Alessandro Gallo, Andrea Ghigo, Susanna Guiducci, Maurizio Incurvati, Carlo Ligi, Fabio Marcellini, Giovanni Mazzitelli, Catia Milardi, Luigi Pellegrino, Miro Preger, Pantaleo Raimondi, Ruggero Ricci, Claudio Sanelli, Mario Serio, Francesco Sgamma, Bruno Spataro, Alessandro Stecchi, Angelo Stella, Cristina Vaccarezza, Mario Vescovi (INFN/LNF)*
The e+e- collider DAFNE, a 1.02 Gev c.m. Phi-factory, has exceeded 1.2 1032 cm-2s-1 peak luminosity with 7.5 pb-1 maximum daily integrated luminosity. At the present performance the physics program of the three main experiments DEAR, FINUDA and KLOE will be completed by mid 2007. In this paper we describe the steps which have led to the luminosity improvement and present proposals for the upgrade of the collider towards higher energy and/or luminosity. The main accelerator issues on which we are planning to rely for this purpose, such as lattices with negative momentum compaction, strong RF focusing, design of high field magnets and Linac upgrade, are discussed in detail.

**8:55 ROAA002—CESR-c: Performance of a Wiggler-Dominated Storage Ring**
*Alexander Temnykh (Cornell Univ.)*
CESR-c operates now as a Wiggler-Dominated Storage Ring extending the lowest operating energy to 1.5GeV/beam. To improve beam stability at low energy, 12 super-ferric wiggler magnets with total length of 15m and 2.1T maximum field were installed in the ring. They cause ~90% of total beam radiation lost and increase radiation damping rate by factor 10 from ~3 to 40 Hz. However, the field of the wiggler magnets not only initiates the radiation, but potentially affects beam dynamics. The latter was an issue of a great concern from the planning the CESR-c project. In this paper we describe general performance of CESR-c and report the results of an experimental study on some aspects of beam dynamics. Comparisons are made between the experimental data and the model prediction. We find that all parameters, which are critically dependent on wigglers, such as beam properties and ring nonlinearity, are in good agreement with those calculated from the model. This validates the ring and wiggler models and justifies our design and production technique of the magnets. The experience we obtained will be extremely useful in future work on linear collider damping rings.

Work supported by the U.S. National Science Foundation.

**9:20 ROAA003—Proposal for an Experiment on Bunch Length Modulation in DAFNE**
*Caterina Biscari, David Alesini, Gabriele Benedetti, Maria Biagini, Roberto Boni, Manuela Boscolo, Alberto Clozza, Giovanni Delle Monache, Giampiero Di Pirro, Alessandro Drago, Alessandro Gallo, Andrea Ghigo, Susanna Guiducci, Maurizio Incurvati, Carlo Ligi, Fabio Marcellini, Giovanni Mazzitelli, Catia Milardi, Luigi Pellegrino, Miro Preger, Pantaleo Raimondi, Ruggero Ricci, Claudio Sanelli, Mario Serio, Francesco Sgamma, Bruno Spataro, Alessandro Stecchi, Angelo Stella, Cristina Vaccarezza, Mario Vescovi, Mikhail Zobov (INFN/LNF)*
Obtaining very short bunches is a challenge for colliders and Coherent Synchrotron Radiation sources as well. The modulation of the bunch length in a strong RF focusing regime has been proposed, corresponding to a large value of the synchrotron tune. A ring structure where the dependence of the longitudinal position of a particle on its energy (R56) along the ring oscillates between large positive and negative values can produce a bunch length modulation. The synchrotron frequency can be tuned both by means of the rf voltage and by the integral of R56, down to the limit of zero value corresponding to the isochronicity condition. We present here the proposal of bunch length modulation along the DAFNE rings. Its lattice can be tuned to positive or negative momentum compaction, or to structures in which the two arcs are alternately set to positive/negative integrals of R56. With the proposed installation of an extra RF system at 1.3 GHz, experiments on bunch length modulation both in the high and low synchrotron tune regimes can be realized.

**9:35 ROAA004—MICE: The International Muon Ionisation Cooling Experiment**
*Paul Drumm (CCLRC/RAL), Malcolm Ellis (Imperial College of Science and Technology)*
Muon storage rings have been proposed for use as sources of intense high-energy neutrino beams and as the basis for multi-TeV lepton-antilepton colliding beam facilities. To optimise the performance of such facilities is likely to require the phase-space compression (cooling) of the muon beam prior to acceleration and storage. The short muon-lifetime makes it impossible to employ traditional techniques to cool the beam while maintaining the muon-beam intensity. Ionisation cooling, a process in which the muon beam is passed through a series of liquid hydrogen absorbers followed by accelerating RF-cavities, is the technique proposed to cool the muon beam. The international Muon Ionisation Cooling Experiment (MICE) collaboration has been formed to carry out a muon-cooling demonstration experiment, and its proposal to Rutherford Appleton Laboratory has been approved. The MICE cooling channel, the instrumentation and the implementation at the Rutherford Appleton Laboratory is described together with the predicted performance of the channel and the measurements that will be made.

**9:50 ROAA005—Recent Innovations in Muon Beam Cooling and Prospects for Muon Colliders**
*Rolland Johnson, Mohammad Alsharo'a, Pierrick M. Hanlet, Robert Hartline, Moyses Kuchnir, Kevin Paul, Thomas Roberts (Muons, Inc), Charles Ankenbrandt, Emanuela Barzi, Ivan Gonin, Alfred Moretti, David Neuffer, Milorad Popovic, Gennady Romanov, Daniele Turrioni, Victor Yarba (Fermilab), Daniel Kaplan, Katsuya Yonehara (Illinois Institute of Technology), Kevin Beard, S. Alex Bogacz, Yaroslav Derbenev (Jefferson Lab)*
A six-dimensional(6D)cooling channel based on helical magnets surrounding RF cavities filled with dense hydrogen gas* is used to achieve the small transverse emittances demanded by a high-luminosity muon collider. This helical cooling channel**(HCC) has solenoidal, helical dipole, and helical quadrupole magnetic fields to generate emittance exchange. Simulations verify the analytic predictions and have shown a 6D emittance reduction of over 3 orders of magnitude in a 100 m HCC segment. Using three such sequential HCC segments, where the RF frequencies are increased and transverse dimensions reduced as the beams become cooler, implies a 6D emittance reduction of almost six orders of magnitude. After this, two new post-cooling ideas can be employed to reduce transverse emittances to one or two mm-

mr, which allows high luminosity with fewer muons than previously imagined. In this report we discuss the status of and the plans for the HCC simulation and engineering efforts. We also describe the new post-cooling ideas and comment on the prospects for a Higgs factory or energy frontier muon collider using existing laboratory infrastructure.
*R. P. Johnson et al. LINAC2004, www.muonsinc.com/TU203.pdf. **Y. Derbenev and R.P. Johnson, Submitted to PRSTAB, http://www-mucool.fnal.gov/mcnotes/public/pdf/muc0284/muc0284.pdf.

This work was supported in part by DOE SBIR/STTR grants DE-FG02-02ER86145, 03ER83722, 04ER84015, 04ER86191, and 04ER84016.

## Oral Session ROAB—Pulsed-Power and High-Intensity Beams
Ballroom B @ 8:30
Chair: E. Hartouni (LLNL)

**8:30 ROAB001—DARHT-II Long-Pulse Beam-Dynamics Experiments**
*Carl Ekdahl (LANL)*
When completed, the DARHT-II linear induction accelerator (LIA) will produce a 2-kA, 18-MeV electron beam with more than 1500-ns current/energy "flat-top." In initial tests DARHT-II has already accelerated beams with current pulse lengths from 500-ns to 1200-ns full-width at half maximum (FWHM) with more than1.2-kA, 12.5-MeV peak current and energy. Experiments are now underway with a ~2000-ns pulse length, but reduced current and energy. These pulse lengths are all significantly longer than any other multi-MeV LIA, and they define a novel regime for high-current beam dynamics, especially with regard to beam stability. Although the initial tests demonstrated absence of BBU, the pulse lengths were too short to test the predicted protection against ion-hose instability. The present experiments are designed to resolve these and other beam-dynamics issues with a ~2000-ns pulse length beam.

This work was supported by the U.S. National Nuclear Security Agency and the U.S. Department of Energy under contract W-7405-ENG-36.

**8:55 ROAB002—Advances of Transmission Line Kicker Magnets**
*Laurent Ducimetière (CERN)*
Fast pulsed magnets or kickers are widely used in circular accelerators for injection, fast extraction and beam excitation. As from the early 60's transmission line type kicker magnets have been employed to produce rectangular field pulses with good rise time. Over some 40 years this technology has evolved with the rising requirements. Whilst the necessary kick strength has increased with the particle beam energies the strive for efficiency has pushed developments towards lower impedance systems and/or short circuited magnets. The flat top ripple is constrained by the maximally tolerable beam oscillation. The beam intensity can impose a screening of the magnet yoke. The most advanced features implemented in recent transmission line kicker magnets are reviewed and illustrated with examples from different laboratories. Ongoing and potential future developments are briefly discussed.

**9:20 ROAB003—Highly Compressed Ion Beams for High Energy Density Science**
*Alex Friedman, John J. Barnard, Debra Callahan, George Caporaso, David Grote, Richard Lee, Scott D. Nelson, Max Tabak (LLNL), David Rose, Carsten Hilmar Thoma, Dale Welch (ATK-MR), C. M. Celata, Andy Faltens, Enrique Henestroza, Edward Lee, Matthaeus Leitner, B. Grant Logan, Lou Reginato, Andrew Sessler, John William Staples, William Waldron, Jonathan Wurtele, Simon Yu (LBNL), Ronald Davidson, Larry Grisham, Igor Kaganovich (PPPL), Richard J. Briggs (SAIC), Craig Olson, Tim Renk (Sandia National Laboratories)*
The Heavy Ion Fusion Virtual National Laboratory (HIF-VNL) is developing the intense ion beams needed to drive matter to the High Energy Density (HED) regimes required for Inertial Fusion Energy (IFE) and other applications. An interim goal is a facility for Warm Dense Matter (WDM) studies, wherein a target is heated volumetrically without being shocked, so that well-defined states of matter at 1 to 10 eV are generated within a diagnosable region. In the approach we are pursuing, low to medium mass ions with energies just above the Bragg peak are directed onto thin target "foils," which may in fact be foams or "steel wool" with mean densities 1% to 100% of solid. This approach complements that being pursued at GSI, wherein high-energy ion beams deposit a small fraction of their energy in a cylindrical target. We present the requirements for warm dense matter experiments, and describe suitable accelerator concepts, including novel broadband traveling wave pulse-line, drift-tube linac, RF, and single-gap approaches. We show how neutralized drift compression and final focus optics tolerant of large velocity spread can generate the necessarily compact focal spots in space and time.

Work performed under auspices of USDOE by U. of CA LLNL & LBNL, PPPL, and SNL, under Contract Nos. W-7405-Eng-48, DE-AC03-76SF00098, DE-AC02-76CH03073, and DE-AC04-94AL85000, and by MRC and SAIC.

**9:45 ROAB004—Ion Effects in the DARHT-II Downstream Transport**
*Kwok-Chi Dominic Chan, Harold Davis, Carl Ekdahl (LANL), Thomas C. Genoni, Thomas P. Hughes (ATK-MR), Martin E. Schulze (GA)*
The DARHT-II accelerator produces an 18-MeV, 2-kA, 2-ìs electron beam pulse. After the accelerator, the pulse is delivered to the final focus on an x-ray producing target via a beam transport section called the Downstream Transport. Ions produced due to beam ionization of residual gases in the Downstream Transport can affect the beam dynamics. Ions generated by the head of the pulse will cause modification of space-charge forces at the tail of the pulse so that the beam head and tail will have different beam envelopes. They may also induce ion-hose instability at the tail of the pulse. If these effects are significant, the focusing requirements of beam head and tail at the final focus will become very different. The focusing of the complete beam pulse will be time dependent and difficult to achieve, leading to less efficient x-ray production. In this paper, we will describe the results of our calculations of these ion effects at different residual-gas pressure levels. Our goal is to determine the maximum residual-gas pressure allowable in DARHT-II Downstream Transport such that the required final beam focus is achievable over the entire beam pulse under these deleterious ion effects.

Work supported by US NNSA/DOE.

**10:00 ROAB005—Helical Pulseline Structures for Ion Acceleration**
*Richard J. Briggs (SAIC), Lou Reginato, William Waldron (LBNL)*
The basic concept of the "Pulseline Ion Accelerator" involves launching a ramped high voltage pulse on a broad band traveling wave (slow-wave) structure. An applied voltage pulse at the input end with a segment rising linearly in time becomes a linear voltage ramp in space that propagates down the line, corresponding to a (moving) region of constant axial accelerating electric field. The ions can "surf" on this traveling wave, experiencing a total energy gain that can greatly exceed the peak of the applied voltage. The applied voltage waveform can also be shaped to longitudinally confine the beam against its own space charge forces, and (in the final stage) to impart an inward compression to the beam for neutralized drift compression in heavy ion HEDP applications. In the first stages of a heavy ion accelerator, the pulseline velocity needs to be the order of 1% of the speed of light and the line must be sufficiently non-dispersive for the broad band voltage pulse propagating down the line to have minimal distortion. Experimental characterization of the dispersion and pulse propagation at low voltage on several helix models will be presented, and compared with theoretical predictions.*
*Caporaso, et al, "Dispersion Analysis of the Pulseline Accelerator," this conference.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Berkeley National Laboratory, Contract DE-AC03-76SF00098.

## Oral Session ROAC—Radio-Frequency Systems
## Ballroom C @ 8:30
## Chair: S. Tantawi (SLAC)

**8:30 ROAC001—Testing of the SNS Superconducting Cavities and Cryomodules**
*Isidoro Enrico Campisi (ORNL/SNS)*
The superconducting linac for the Spallation Neutron Source is in the process of being commissioned. Eighty-one cavities resonating at 805 MHz are installed in the SNS tunnel in 11 medium beta (.61) cryomodules each containing 3 cavities and 12 high beta (.81) cryomodules each with 4 cavities. The niobium cavities and cryomodules were designed and assembled at Jefferson Lab and installed in the SNS tunnel at Oak Ridge and are operating at 2.1 K. A preliminary test of one medium beta cryomodule was performed at 4.2 K in September 2004. All functional parameters of the cryomodule were proven to meet specifications at that temperature. The Central Helium Liquefier is being commissioned for 2.1 K operation and all cavities will be tested by late Spring 2005. The testing will include all of the functional parameters necessary for beam operation, to be carried out in summer 2005. The focus of the testing is to characterize the cavities' maximum gradients and that sustained simultaneous operation can be achieved for all the cavities in preparation of beam commissioning. The results of cryomodule and cavity testing in the superconducting linac will be presented.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge

**8:55 ROAC002—Overview of LLRF Systems**
*Matthias Liepe (Cornell Univ.)*
In the past two decades accelerator controls and feedback systems have changed dramatically. While in the past relative simple analog systems where used, present systems are highly complex, and all accelerators in planning or under construction heavily relay on advanced feedback and feedforward control schemes. The Low-Level-Radio-Frequency (LLRF) system not only stabilizes the field in the RF cavities, but also has to provide among other things frequency control, exception handling, extensive diagnostic, and performance and machine availability maximization. As manifold as the tasks are for the LLRF system, so are the challenges. Linac driven light sources require highest field stability, while pulsed machines or low beta linacs bring their own challenges for the LLRF system. This presentation reviews the challenges and demands on present and future LLRF systems, gives an overview of state-of-the-art solutions, and an introduction into a very active and exciting field of accelerator physics.

**9:20 ROAC003—Superconducting RF for Low-Velocity and Intermediate-Velocity Beams**
*Terry L. Grimm, Walter Hartung (NSCL)*
Existing superconducting radio frequency (SRF) linacs are used to accelerate ions (protons through uranium) with velocities less than about 15% the speed of light, or electrons with velocities approximately equal to the speed of light. In the last ten years, prototype SRF cavities have completely covered the remaining range of velocities. They have demonstrated that SRF linacs will be capable of accelerating electrons from rest up to the speed of light, and ions from less than 1% up to the speed of light. When the Spallation Neutron Source is operational, SRF ion linacs will have covered the full range of velocities except for $v/c \sim 0.15$ to $v/c \sim 0.5$. A number of proposed projects (RIA, EURISOL) would span the latter range of velocities. Future SRF developments will have to address the trade-offs associated with a number of issues, including high gradient operation, longitudinal and transverse acceptance, microphonics, Lorentz detuning, operating temperature, cryogenic load, number of gaps or cells per cavity, proximity of magnetostatic focussing elements, and higher-order-mode damping. An overview of recent developments and future areas of interest will be presented.

**9:45 ROAC004—High Gradient Performance of Prototype NLC/GLC X-Band Accelerator Structures**
*Chris Adolphsen, Gordon B. Bowden, David Burke, Jose Chan, John Cornuelle, Steffen Doebert, Valery Dolgashev, Josef Frisch, R. Keith Jobe, Roger Michael Jones, Robert Kirby, Frederic Le Pimpec, James R. Lewandowski, Zenghai Li, Roger Heering Miller, Christopher Dennis Nantista, Janice Nelson, Marc Ross, Ronald Ruth, David Schultz, Tonee Smith, Sami G. Tantawi, Juwen W. Wang (SLAC), Tug Tacku Arkan, Cristian Boffo, Harry Carter, David Finley, Ivan Gonin, Timergali N. Khabibouline, Shekhar Mishra, Gennady Romanov, Nikolay Solyak (Fermilab), Yasuo Higashi, Toshiyasu Higo, Nobu Toge (KEK)*
During the past five years, there has been an concerted effort at FNAL, KEK and SLAC to develop accelerator structures that meet the high gradient performance requirements for the Next Linear Collider (NLC) and Global Linear Collider (GLC) initiatives. The structure that resulted is a 60-cm-long, traveling-wave design with low group velocity (< 4% c) and a 150 degree phase advance per cell. It has an average iris size that produces an acceptable short-range wakefield in the linacs, and dipole mode damping and detuning that adequately suppresses the long-range wakefield. More than eight such structures have operated over 1000 hours at a 60 Hz pulse rate at the design gradient (65 MV/m) and pulse length (400 ns), and have reached

breakdown rate levels below the limit for the linear collider. Moreover, the structures are robust in that the breakdown rates continue to decrease over time, and if the structures are briefly exposed to air, the rates recover to their low values within a few days. This paper presents a final summary of the results from this program, which effectively ended last August with the selection of 'cold' technology for a next generation linear collider.

Work Supported by DOE Contract DE-AC02-76F00515.

**10:00 ROAC005—Present Status of J-PARC Ring RF Systems**
*Masahito Yoshii, Shozo Anami, Eizi Ezura, Keigo Hara, Yoshinori Hashimoto, Chihiro Ohmori, Akira Takagi, Makoto Toda (KEK), Masahiro Nomura, Alexander Schnase, Fumihiko Tamura, Masanobu Yamamoto (JAERI)*
The accelerator of the J-PARC complex consists of the 400 MeV (initially 181 MeV) linac, the rapid cycling 3 GeV Synchrotron and the 50 GeV main Synchrotron. To accelerate an ultra-high intense proton beam, the synchrotrons require a high field gradient rf system (~25kV/m). Alleviating space charge effects is a key issue for minimizing beam losses during a cycle. Longitudinal bunch manipulation is also considered as well as acceleration. Magnetic alloy loaded cavities are the most practical choice for the J-PARC. Such system provides high field gradient, and broadband behavior. It is a stable passive system without tuning control. Multi-tone signals can be fed into the same cavity for acceleration and bunch manipulation. However, the harmonics of circulating beam current within the cavity bandwidth must be taken into account. A feed-forward scheme is used for compensating the beam induced voltages. The low level rf system is fully digital to provide precise control. The specification is based on high reliability and reproductivity. The design consideration of the whole rf system will be described and the current status presented.

**Oral Session ROAB (Cont.)—Pulsed-Power and High-Intensity Beams, Ballroom B @ 10:40**
**Chair: K.-C. Chan (LANL)**

**10:40 ROAB006—Pulsed Power Drivers and Diodes for X-Ray Radiography**
*Kenneth John Thomas (AWE)*
Flash radiography has been used as a diagnostic for explosively driven hydrodynamics experiments for several decades following the pioneering work of J C Martin and his group at AWE. Relatively simple pulsed power drivers operating between 1 and 10 MV coupled to experimentally optimised electron beam diodes have achieved great success in a number of different classes of these experiments. The next generation of radiographic facilities will aim to improve even further the radiographic performance achievable by developing both the electron beam diodes used and the accelerators that drive them. The application of the rod-pinch diode to an Inductive Voltage Adder at 2 MV in the US has already advanced the quality of radiography available for relatively thin objects. For the thickest objects accelerators operating at up to 15 MV and diodes capable of focusing electron beams to intensities of ~ 1 MA/cm2 for tens of nanoseconds will be required in the future. Since the various candidate diode configurations operate in both high and low impedance regimes there is a further challenge to design and engineer an accelerator capable of driving whichever one, or more, are eventually used.

**11:05 ROAB007—Pulsed Power Applications in High Intensity Proton Rings**
*Wu Zhang, Jon Sandberg (BNL), Tony Fowler (CERN), Tadamichi Kawakubo (KEK), Roy I. Cutler (ORNL/SNS)*
The pulsed power technology has been applied in particle accelerators and storage rings for over four decades. It is most commonly used in injection, extraction, beam manipulation, source, and focusing systems. These systems belong to the class of repetitive pulsed power. In this presentation, we review and discuss the history, present status, and future challenge of pulsed power applications in high intensity proton accelerators and storage rings.

Work performed under the auspices of the U.S. Department of Energy.

**11:30 ROAB008—Solid-State Modulators for RF and Fast Kickers**
*Edward Cook, Guy L. Akana, EDWARD J. Gower, Steven Hawkins, Bradley C. Hickman (LLNL), Craig A. Brooksby (Bechtel Nevada), Richard Cassel, Jeffrey E. De Lamare, Minh N. Nguyen, Chris Pappas (SLAC)*
As the capabilities of solid-state devices increase, these devices are being incorporated into modulator designs for high voltage accelerator applications. Solid-state modulators based on inductive adder circuit topology have demonstrated great versatility with regard to pulse width and pulse repetition rate while maintaining fast pulse rise and fall times. Additionally, these modulators are capable of being scaled to higher output voltage and power levels. An explanation of the basic circuit operation will be presented as well as test data of several different hardware systems.

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

**11:55 ROAB009—NuMI Proton Kicker Extraction System**
*Chris C. Jensen,George E. Krafczyk (FNAL)*
This system extracts up to 9.6 us of 120 GeV beam every 1.87 seconds for the NuMI beamline neutrino experiments. A pulse forming network consisting of two continuous wound coils and 68 capacitors was designed and built to drive three kicker magnets. The field stability requirement is better than +/- 1% with a field rise time of 1.6 us. New kicker magnets were built based on the successful traveling wave magnets built for the Main Injector. Two of these magnets, which have a propagation time of 550 ns, are in series making the risetime of the pulser a serious constraint. A forced cooling system using Fluorinert® was designed for the magnet termination resistors to maintain the field flatness and amplitude stability. The system has been commissioned and early results will be presented.

Fermilab is operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the U.S. Department of Energy.

**12:10 ROAB010—Development of a Compact Radiography Accelerator Using Dielectric Wall Accelerator Technology**
*Stephen Sampayan, George Caporaso, Yu-Jiuan Chen, Steven Hawkins, Clifford Holmes, James F. McCarrick, Scott D. Nelson, William Nunnally, Mark Rhodes, David Sanders, James Sullivan, James Watson (LLNL)*
We are developing of a compact accelerator system primarily intended for pulsed radiography. Design characteristics are an 8 MeV endpoint energy, 2 kA beam current and a cell gradient of

approximately 3 MV/m. Overall length of the device is below 3 m. Such compact designs have been made possible with the development of high specific energy dielectrics (> 10 J/cc), specialized transmission line designs and multi-gap laser-triggered low jitter (<1 ns) gas switches. In this geometry, the pulse forming lines, switches and insulator/beam pipe are fully integrated within each cell to form a compact stand-alone stackable unit. We detail our research and modeling to date, recent high voltage test results, and the integration concept of the cells into a radiographic system.

This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

## Oral Session ROAC (Cont.)—Radio-Frequency Systems
## Ballroom C @ 10:40
## Chair: M. Lynch (LANL)

**10:40 ROAC006—W-Band Source Development at Los Alamos**
*Bruce Carlsten, Lawrence M. Earley, Patrick Ferguson, Frank L. Krawczyk, James Potter, Steven Russell, Zhi-Fu Wang (LANL), Stanley Humphries (Field Precision)*
A high-power mm-wave source architecture is being developed at Los Alamos, based on the interaction of a sheet-electron beam with a ridged waveguide slow-wave structure. This type of traveling-wave source is capable of producing peak output rf powers up to 500 kW at 100 GHz. We will describe the source concept, present interaction simulations, and review rf structure design and cold test results and sheet beam propagation experiments.

This work was supported by funds from the Laboratory-Directed Research and Development program at Los Alamos National Laboratory, operated by the University of California for the U.S. Department of Energy.

**11:05 ROAC007—RF Breakdown in Normal Conducting Single-Cell Structures**
*Valery Dolgashev, Christopher Dennis Nantista, Sami G. Tantawi (SLAC), Yasuo Higashi, Toshiyasu Higo (KEK)*
Operating accelerating gradient in normal conducting accelerating structures is often limited by rf breakdown. The limit depends on multiple parameters, including input rf power, rf circuit, cavity shape and material. Experimental and theoretical study of the effects of these parameters on the breakdown limit in full scale structures is difficult and costly. We use 11.4 GHz single-cell traveling wave and standing wave accelerating structures for experiments and modeling of rf breakdown behavior. These test structures are designed so that the electromagnetic fields in one cell mimic the fields in prototype multicell structures for the X-band linear collider. Fields elsewhere in the test structures are significantly lower than that of the single cell. The setup uses matched mode converters that launch the circular TM01 mode into short test structures. The test structures are connected to the mode launchers with vacuum rf flanges. This setup allows economic testing of different cell geometries, cell materials and preparation techniques with short turn-around time. Simple 2D geometry of the test structures simplifies modeling of the breakdown currents and their thermal effects.

Work supported by the U.S. Department of Energy contract DE-AC02-76SF00515.

**11:30 ROAC008—Atom Probe Tomography Studies of RF Materials**
*Jim Norem (ANL), Pierre Bauer (Fermilab), Jason Sebastian, David N. Seidman (NU)*
We are constructing a facility which combines an atom probe field ion microscope with a multi-element, in-situ deposition and surface modification capability. This system is dedicated to rf studies and the initial goal will be to understand the properties of evaporative coatings: field emission, bonding interdiffusion etc, to suppress breakdown and dark currents in normal cavities. We also hope to use this system to look more generally at interactions of surface structure and high rf fields. We will present preliminary data on structures relevant to normal and superconducting rf systems.

DOE

**11:45 ROAC009—World Record Accelerating Gradient Achieved in a Superconducting Niobium RF Cavity**
*Rong-Li Geng, Hasan Padamsee, Andrew Seaman, Valery D. Shemelin (Cornell University)*
On November 16, 2004, an accelerating gradient of 46 MV/m was achieved (CW) in a superconducting niobium cavity with an unloaded quality factor (Q0) over 1E10 at a temperature of 1.9 K. This represents a world record gradient in a niobium RF resonator. At a reduced temperature of 1.5-1.6 K, an enhanced Q0 was measured, ranging from 7E10 at 5 MV/m to 2E10 at 45 MV/m. The 1.3 GHz single-cell cavity has a reduced ratio of Hpk/Eacc, ensured by a reentrant geometry. The maximum peak surface electric and magnetic field exceeded 100 MV/m and 1750 Oe respectively. A soft multipacting barrier (predicted by calculations) was observed near 25 MV/m gradient and was easily processed through. Field emission in the cavity was negligibly small, and the highest field was limited by thermal breakdown. The cavity was built, processed, and tested with LEPP facilities at Cornell University. New techniques included half-cell heat treatment with yttrium for post-purification to RRR = 500, and vertical electropolishing the finished cavity.

Work supported by NSF.

**12:00 ROAC010—Development of an Ultrafast Silicon Switch for an Active X-Band High Power RF Compression System**
*Jiquan Guo, Sami G. Tantawi (SLAC)*
In this paper, we present the recent results of our research on the high power ultra-fast silicon RF switches. This switch is composed of a group of PIN diodes on a high purity SOI (silicon on oxide) wafer. The wafer is inserted into a cylindrical waveguide under TE01 mode, performing switching by injecting carriers into the bulk silicon. Our current design is using a CMOS compatible process and the fabrication is accomplished at SNF (Stanford Nanofabrication Facility). This design is able to achieve sub-100ns switching time, while the switching speed can be improved further with 3-D device structure and faster circuit. Power handling capacity of the switch is at the level of 10MW. The switch was designed for active X-band RF pulse compression systems - especially for NLC, but it is also possible to be modified for other applications and other frequencies such as L-band.

DOE

Oral Session ROAD–Accelerator Technology
Ballroom A @ 10:40
Chair: M. Peiniger (ACCEL)

**10:40 ROAD001—Recent Progress in Power Refrigeration Below 2 K for Superconducting Accelerators**
*Serge Claudet (CERN)*
As a result of technico-economical optimization and quest for increased performance, 2 K cryogenics is now present in large accelerator projects using superconducting magnets or acceleration cavities. Consequently, large cryogenic systems producing refrigeration capacity below 2 K in the kW range and with high efficiency over a large dynamic range are needed. After CEBAF and SNS, this is now the case for the Large Hadron Collider (LHC) project at CERN for which eight 2.4 kW @ 1.8 K refrigeration units are needed to cool each a 3.3 km long sector of high-field magnets. Combining cold hydrodynamic compressors in series with warm volumetric compressors, complete preseries units as well as sets of series cold compressors have been intensively tested and validated from two different industrial suppliers. After recalling the possible 2 K refrigeration cycles and their comparative merits, this paper describes the specific features of the LHC system and presents the achieved performance with emphasis on the progress in terms of efficiency, operational compliance, reliability and maintenance. Perspectives of application to a future International Linear Collider based on cold RF technology are then briefly evoked.

**11:05 ROAD002—Remote Handling in High-Power Proton Facilities**
*Graeme R. Murdoch (ORNL/SNS)*
Design for remote handling of highly activated accelerator components is becoming more prevalent as proton facilities are designed and constructed to provide ever-increasing beam powers. During operation of these facilities it is expected that many components will become activated, consequently mechanical engineering design work must address this issue if components are to be maintained by traditional hands-on methods. These design issues are not new and operating proton facilities around the world have gone through the same process to varying degrees. In this paper we discuss the design and design philosophy of remote handling of active accelerator components, using as examples designs which have been proven at operating facilities, as well as new approaches which are being incorporated into accelerator facilities under construction, such as the Spallation Neutron Source and J-PARC.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**11:30 ROAD003—Post-Irradiation Properties of Candidate Materials for High-Power Targets**
*Harold G. Kirk, Leonard Mausner, Nikolaos Simos, Peter Thieberger (BNL), Yoshinari Hayato, Koji Yoshimura (KEK), Kirk T. McDonald (PU), John Sheppard (SLAC)*
The long term survivability of materials which can be used either for high-intensity targets or for the environment surrounding the target can be greatly influenced by how the physical properties of the material are altered by radiation damage. We have irradiated several candidate materials and report here on physical properties before and after irradiation.

U.S. DOE.

**11:45 ROAD004—TBD**

**12:00 ROAD005—Status of NEG Coating at ESRF**
*Michael Hahn, Daniela Schmied (ESRF), Roberto Kersevan [on leave], Roberto Kersevan (ESRF; ORNL/SNS)*
The ESRF non-evaporable getter (NEG) coating facility is in operation since two years now. A large part of the insertion device straight sections of the electron storage ring has been equipped with in-house coated 5m long aluminum vacuum chambers with an inner vertical aperture of 8 mm. Operational experience with different coating parameters leading to different film thicknesses will be given and compared to bremsstrahlung data. The paper deals also with improvements of the coating production and chamber preparation, and describes some aspects of NEG coating data acquisition, visualization, and remote control. The R&D program leading to a more powerful DC solenoidal coating tool to further improve the NEG coating production throughput and quality aspects is also discussed.

Poster Session RPAE–Light Sources and Free-Electron Lasers
Ballroom E, 8:30-12:20

**RPAE001—On the Issue of Phasing of Undulators at the Advanced Photon Source**
*Roger J. Dejus (ANL)*
Placing two collinear undulators in the 5.6-m-long straight sections at the Advanced Photon Source (APS) can answer the demand for increased brilliance. Whether longitudinal phasing needs to be taken into account for optimum spectral performance has been investigated. A comprehensive computer simulation study was completed to study the effect of the electron beam emittance, the magnetic field quality of the undulators, and the magnetic field strength (K value) on the spectral performance. For a zero-emittance beam, the radiation spectra exhibit strong interference that depends sensitively on the phase between the undulators. For a realistic APS-emittance beam and beam energy spread, the strong and phase-sensitive interference is substantially smoothed. A summary of the key findings including intensity losses due to unphased undulators is reported in this paper.

Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**RPAE002—Coupling Correction of a Circularly Polarizing Undulator**
Louis Emery (ANL)
The electromagnetic Circularly Polarizing Undulator (CPU) installed at the Advanced Photon Source (APS) storage ring produces skew quadrupole field errors, which were initially corrected by a small skew quadrupole magnet at one end of the device. Because the storage ring is operated at 1% coupling or less, a correction not located at the source inside the CPU is insufficient, as we have confirmed in simulation. Adding a skew coil at the other end of the CPU allows us to make a complete correction of the coupling source in the undulator. Correction setpoints are determined by APS's general optimizing software with the vertical beam size of a x-ray pinhole image as a readback.

This work is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**RPAE003—Optimization and Modeling Studies for Obtaining High Injection Efficiency at the Advanced Photon Source**
*Louis Emery (ANL)*
In recent years, the optics of the Advanced Photon Source storage ring has changed to lower equilibrium emittance (2.5 nm-rad) but at the cost of stronger sextupoles and stronger nonlinearities, which have reduced the injection efficiency from 100% in the high emittance mode. Over the years we have developed a series of optimization, measurement and modeling studies of the injection process, which allows us to obtain or maintain low injection losses. For example, the trajectory in the storage ring is optimized with trajectory knobs for maximum injection efficiency. This can be followed by collecting first-turn trajectory data, from which we can fit the initial phase-space coordinates. The model of the "optimized" trajectory would show whether the beam comes too close to a physical aperture in the injection magnets. Another modeling step is the fit and correction of the transfer line optics, which has a significant impact on phase-space matching.

This work is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**RPAE004—Parametric Mechanical Design of New Insertion Devices at the APS**
*John H. Grimmer, Ronald Kmak (ANL)*
Three permanent-magnet, planar, hybrid ID designs have recently been completed at the APS. The periods of the devices are 2.7 cm, 3.0 cm and 3.5 cm with nominal lengths of 2.4 m. Several design studies were performed for the initial 2.7 cm period device to investigate the utility of various design features. Then a parametric solid model for the initial device was developed and value engineered to minimize manufacturing, assembly and tuning costs. The model allowed the very rapid design of subsequent devices of similar periods and allowed commonality of several components of the IDs. This design family incorporates a low-cost method of pole retention and registration. Poles are secured by screws in two holes tapped into each pole. Pole location is registered by means of two small dowel pins for each pole in mating holes reamed into each pole and a base plate common to the poles and magnets. This base plate is flexible in bending along its length so shimming behind it can be used to accurately change the height of a pair of poles for tuning. Another feature of the design is modular construction to allow each device to be used full-length or shortened to a nominal 2.1 m length for use in APS "canted undulator" sectors.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

**RPAE005—The possibility for a Cryogenic Short-Period Staggered Undulator**
*Shigemi Sasaki (ANL)*
Much work is underway to develop superconducting undulators in order to generate brilliant hard x-ray radiation at many synchrotron radiation facilities. However, in spite of many R&D efforts, it might take several years to reach this goal. On the other hand, the possibilities of cryogenic permanent magnet undulators are being investigated in order to provide an interim solution for hard x-ray users' needs at Spring-8 and other facilities. However, although the in-vacuum undulator technology is well established, the in-vacuum gap-motion mechanism at a low temperature might cause major concerns regarding reliability and cost effectiveness. In this paper, the possibility for a cryogenic short-period staggered undulator was investigated. A simple model calculation by RADIA* shows that the effective undulator field is 0.825 T for a 15-mm-period staggered undulator at 6 mm gap with 1.36 T solenoid field. The pole material was assumed to be dysprosium, which has a saturation magnetization of 3.3 T at 77 K. The achievable maximum field of this simply structured device is close to that of a cryogenic permanent magnet undulator. We present calculated performances of cryogenic staggered undulators at various periods and gaps.
*O. Chubar, P. Elleaume, J. Chavanne, J. Synchrotron Radiat. 5, 481 (1998).

Work supported by the U.S. Dept. of Energy under Contract No. W-31-109-ENG-38.

**RPAE006—Feasibility Study on Introducing a Superconducting Wiggler to Saga Light Source**
*Shigeru Koda, Yositaka Iwasaki, Toshihiro Okajima, Hiroyuki Setoyama, Yuichi Takabayashi, Takio Tomimasu, Katuhide Yoshida (Saga Synchrotron Light Source), Hideaki Ohgaki (Kyoto IAE), Masami Torikoshi (NIRS)*
Saga light source (SAGA-LS) is the synchrotron radiation facility, which consists of 250 MeV electron linac and 1.4 GeV storage ring. We have a plan to introduce an existing superconducting wiggler, which has been developed for other project by National Institute of Radiological Sciences. The superconducting wiggler consists of a main pole of 7T and two side poles of 4T. Each pole is composed of a racetrack-shaped coil and an iron core. We have examined the effects of the wiggler on the beam optics when it is introduced into SAGA-LS. The distribution of multipole components in the planes perpendicular to the electron orbit, which is deformed by the wiggler fields, have been calculated using magnetic field calculation code RADIA. Then the lattice function and the dynamic aperture of the ring have been calculated by the lattice calculation code SAD. The results show that the tune shift due to the quadrupole component of the wiggler field is as large as to make horizontal beam orbit unstable. The dynamic aperture after the tune correction becomes small by about 20%. These effects due to multipole field are considered to be tolerable for the SAGA-LS.

**RPAE007—In-Vacuum and Quasi-Periodic Undulators at Danfysik A/S**
*Franz Bødker, Henning Bach, Erik Busk Christensen, Erik Juul, Michael Pedersen, Torben Leif Svendsen (Danfysik A/S)*
Danfysik A/S* has recently designed and produced the first in-vacuum insertion device. The device is a 19 mm period hybrid undulator with a minimum gap of 5 mm made for the Swiss Light Source. The device is made with ARMCO steel poles and Samarium Cobalt magnets. A 20 mm period hybrid undulator with a minimum gap of 5.5 mm has been designed for Soleil. This undulator is optimized for high peak field using Vanadium Permendur poles and relative larger magnets blocks. For the assembly and testing of these in-vacuum devices a new temperature stabilized clean facility has been build at Danfysik. A quasi-periodic undulator has been build for FEL applications at the FELIX facility, FOM-Institute for Plasma Physics. The device is based on a standard 60 mm pure permanent undulator design with a minimum gap of 23.5 mm but converted into a quasi-periodic device.** The magnetic performance of the device is very close to theoretic calculations with high suppression of the 3. and 5. harmonics. The undulator is split into two half sections with separately adjustable gap such that a step taper can be produced.
*http://www.danfysik.com/. **Development of quasiperiodic undulators at the ESRF, J. Chavanne et al., EPAC (1998) 2213.

**RPAE008—Study of Magnetic Field Errors Induced by Typical Manufacturing Errors in Superconducting Miniundulators**
*Caozheng Diao, Herbert Oskar Moser (SSLS)*
Superconducting miniundulators (supraminis) are being developed for their potential to produce either higher photon energy beams at given electron energy facilities or to save electron energy for given photon energy beams. In order to estimate the influence of mechanical errors on the quality of the field and to specify acceptable tolerances, the influence of the different potential mechanical errors is evaluated. Based on a wire model, analytical formulae are derived to describe the spatial distribution of the magnetic field as determined by the parameters of the undulator and the mechanical errors. Then, magnetic field integrals, field zeros, field uniformity, and the phase errors are calculated.

Work partly supported by NUS C-380-003-003-001, A*STAR/ MOE RP 3979908M, and A*STAR 012 105 0038 grants.

**RPAE009—Design Considerations for the Stability Improvement of Klystron-Modulator for PAL XFEL**
*Jong-Seok Oh, Yeung-Jin Han, In Soo Ko, Won Namkung, Soung Soo Park (PAL)*
The PAL linac is planed to be converted to a SASE-XFEL facility (PAL XFEL) that supplies coherent X-rays down to 0.3-nm wavelength. PAL XEL requires a 3-GeV driver linac and a 60-m long in-vacuum undulator to realize an X-ray SASE-FEL. The linac should supply highly bright beams with emittance of 1.2 mm-mrad, a peak current of 3.5 kA, and a low energy spread of 0.03%. The RF stability of 0.06% rms is required for both RF phase and amplitude for reasonably stable SASE output. This stability is mainly determined by a klystron-modulator. Therefore present stability level of the modulator has to be improved 10 times better to get the pulse stability of 0.05%. The regulation methods such as traditional de-Q'ing and precision inverter charging technology are reviewed. Design considerations for the stability improvement of klystron-modulator for PAL XFEL are presented.

Supported by the POSCO and the MOST, Korea.

**RPAE010—Simulation of the Synchrotron Kinetics in Compton X-Ray Sources**
*Eugene Victor Bulyak, Peter Gladkikh, Vladislav Skomorokhov (NSC/KIPT)*
Compton x-ray sources have small value of the momentum compaction factor provided small longitudinal bunch size and sufficiently large energy acceptance. The quadratic term in dependence of the orbit length upon the energy of circulating particles comes into play. Results of simulations of the synchrotron kinetics in Compton storage rings will be presented. The steady state longitudinal bunch size and energy spread is under study as well as quantum lifetime as functions of parameters of the laser system and magnitude of the second order term in the momentum compaction factor. As it is shown, without of the synchrotron, the energy spread within the bunch is determined by the energy of electrons and laser photons only. Response of bunches upon the combined actions of synchrotron damping and Compton scattering is in agreement with theoretical predictions based on statistical independence of these processes. The stationary spread of energy and the average longitudinal bunch size are independent on number of Compton interactions per both the revolution and synchrotron period as well. Quantum lifetime is found in qualitative agreement with predictions of a theory describing quantum loses in Compton rings.

**RPAE011—Design and Construction of NESTOR X-Ray Source Injection System**
*Andrey Yurij Zelinsky, Mykola Ivanovich Ayzatskiy, Anatoly Nikolayevich Dovbnya, Ivan Karnaukhov, Volodymyr Kushnir, Andrey Mytsykov, Alexander Shcherbakov (NSC/KIPT)*
In the presented work the conception of an injection system of the Kharkov X-ray radiation source based on Compton scattering is considered. As an injector of a complex storage ring a linear accelerator with electron beam energy up to 60 MeV will be used. In the work the properties of transportation channel are described, results of computer simulation of injection procedure taking into account misalignment of magnetic elements of the ring are presented. Two sections of pulse electromagnetic inflector of the injection system will provide injection angle equal to 30 for electron beam energy 60 MeV. The third addition section of the inflector will provide injection angle equal to 50.

**RPAE012—Shielding Design Study for X-Ray Generator NESTOR**
*Andrey Yurij Zelinsky, Anatoly Nikolayevich Dovbnya, Ivan Karnaukhov, Alexander Mazilov, Fedor Peev, Georgij Pugachev, Andrey Razsukovaniy, Alexander Shcherbakov (NSC/KIPT)*
The shielding design study for the X-ray generator based on Compton backscattering NESTOR is carried out. The complex includes a linear accelerator injector with electron beam energy up to 60 MeV, beam transport system, and an electron storage ring with beam operation energy range 40-225 MeV.

**RPAE013—Laser System for Photoelectron and X-Ray Production in the PLEIADES Compton Light Source**
*David Jeremy Gibson, C. Barty, S. Betts, John Crane, Igor Jovanovic (LLNL)*
The PLEIADES (Picosecond Laser-Electron Interaction for the Dynamic Evaluation of Structures) facility provides tunable short x-ray pulses with energies of 30-140 keV and pulse durations of 0.3 – 5 ps by scattering an intense, ultrashort laser pulse off a 35-75 MeV electron beam. Synchronization of the laser and electron beam is obtained by using a photoinjector gun, and using the same laser system to generate the electrons and the scattering laser. The Ti:Sapphire, chirped pulse amplification based 500 mJ, 50 fs, 810 nm scattering laser and the similar 300 μJ, 5 ps, 266 nm photoinjector laser systems are detailed. Additionally, an optical parametric chirped pulse amplification (OPCPA) system is studied as a replacement for part of the scattering laser front end. Such a change would significantly simplify the set-up the laser system by removing the need for active switching optics, as well as increase the prepulse contrast ratio which will be important when part of the scattering laser is used as a pump beam in pump-probe diffraction experiments using the ultrashort tunable x-rays generated as the probe.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

**RPAE014—High-Energy Compton Scattering Light Sources**
*Fred V. Hartemann, Scott Anderson, C. Barty, John Crane, David Jeremy Gibson, Aaron Matthew Tremaine, E. P. Hartouni (LLNL)*
No monochromatic, high-brightness, tunable light sources currently exist above 100 keV. Important applications that would benefit from such new hard x-ray sources include: nuclear resonance fluorescence spectroscopy, time-resolved positron annihilation spectroscopy, and MeV flash radiography. The peak brightness of Compton scattering light sources is derived for head-on collisions and found to scale with the electron beam

brightness and the drive laser pulse energy. This gamma^2-scaling shows that for low emittance electron beams (1 nC, 1 mm.mrad, < 1 ps, > 100 MeV), and tabletop laser systems (1-10 J, 5 ps) the x-ray peak brightness can exceed 10^23 photons / mm^2 x mrad^2 x s x 0.1% bandwidth near 1 MeV; this is confirmed by 3D codes that have been benchmarked against Compton scattering experiments performed at LLNL. Important nonlinear effects, including spectral broadening, are also taken into account in our analysis; they show that there is an optimum laser pulse duration in this geometry, of the order of a few picoseconds, in sharp contrast with the initial approach to laser-driven Compton scattering sources where femtosecond laser systems were thought to be mandatory.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

**RPAE015—High Energy, High Brightness X-Rays Produced by Compton Back Scattering at the Livermore PLEIADES facility**

*Aaron Matthew Tremaine, Scott Anderson, S. Betts, John Crane, David Jeremy Gibson, Fred V. Hartemann, Jeremy Scott Jacob (LLNL), Pedro Frigola, Jae Lim, James Rosenzweig, Gil Travish (UCLA)*

PLEIADES (Picosecond Laser Electron Interaction for the Dynamic Evaluation of Structures) produces tunable 30-140 keV x-rays with 0.3-5 ps pulse lengths and 10^7 photons/pulse by colliding a high brightness electron beam with a high power laser. The electron beam is created by an rf photo-injector system, accelerated by a 120 MeV linac, and focused to 20 mm with novel permanent magnet quadrupoles. To produce Compton back scattered x-rays, the electron bunch is overlapped with a Ti:Sapphire laser that delivers 500 mJ, 80 fs, pulses to the interaction point. K-edge radiography at 115 keV on Uranium has verified the angle correlated energy spectrum inherent in Compton scattering and high-energy tunability of the Livermore source. Current upgrades to the facility will allow laser pumping of targets synchronized to the x-ray source enabling dynamic diffraction and time-resolved studies of high Z materials. Near future plans include extending the radiation energies to >400 keV, allowing for nuclear fluorescence studies of materials.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract no. W-7405-Eng-48.

**RPAE016—Smith-Purcell Radiation from a Charge Moving Above a Finite-Length Grating**

*Amit S. Kesar, Stephen Korbly, Richard J. Temkin (MIT/PSFC,), Mark Hess (IUCF, Bloomington)*

Smith-Purcell radiation (SPR), emitted when a bunch is passing above a periodic structure, is characterized by a broadband radiation spectrum in which the wavelength depends on the observation angle. While various theoretical models agree on this dependence, a significant difference is introduced for the calculated radiated energy by the different approaches. We present two theoretical calculations of the SPR from a 2D bunch of relativistic electrons passing above a finite length grating. The first one uses the finite-difference time-domain approach and the second one uses an electric-field integral equation (EFIE) method. Good agreement is obtained between these two calculations. The results of these calculations are then compared with a formalism based on an infinite length grating in which a periodic boundary condition is rigorously applied. For gratings with less than approximately 50 periods, a significant error in the strength of the radiated field is introduced by the infinite grating approximation. This error disappears asymptotically as the number of periods increases. We are currently working on extending the EFIE model to the case of a three dimensional bunch moving above a finite-length grating.

This work was supported by the Department of Energy, High Energy Physics, under contract DE-FG02-91ER40648.

**RPAE017—Radially Polarized Ion Channel Laser**

*Robert Arthur Bosch (UW-Madison/SRC)*

Radially polarized radiation is amplified by a free electron laser (FEL) in which the undulator is an ion channel with uniform density. For long betatron wavelengths and low gain per pass, the gain at a given distance from the axis is three-eighths the gain of a periodic ion channel laser with the same wiggler parameter. For amplification of short wavelengths by an ultrarelativistic electron beam, a uniform-density ion channel requires a much higher ion density than a periodic ion channel laser.

**RPAE018—Calculation of Reflection Matrix Elements of a Grating for Growing Evanescent Waves**

*Vinit Kumar, Kwang-Je Kim (ANL)*

Reflection matrix elements of a grating play an important role in the study of Smith-Purcell (SP) free-electron lasers (FELs). Especially, the matrix element e_00, which couples the incident co-propagating evanescent wave to the outgoing co-propagating evanescent wave, is important for the evaluation of the gain of an SP FEL system.* We use the modal expansion method as well as the integral method and extend them to the case of growing evanescent waves. We present the results of numerical calculations for rectangular and sinusoidal gratings. We study the singularity of e_00 and find that it is possible to get a simple formula for the location of singularity for the case of rectangular grating if we chose the eigenmodes of the groove as the basis set as done by Andrews et. al.**

*K.-J. Kim and S. B. Song, Nucl. Instrum. Methods Phys. Res. A 475, 158 (2001). **H. L. Andrews and C. A. Brau, Phys. Rev. ST Accel. Beams 7, 07070 (2004).

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**RPAE019—Positron Source from Betatron X-Rays Radiated in a Plasma Wiggler**

*Devon K. Johnson, Chris Clayton, Chengkun Huang, Chan Joshi, Wei Lu, Kenneth Marsh, Warren Mori, Miaomiao Zhou (UCLA), Christopher Barnes, Franz-Josef Decker, Mark Hogan, Richard Iverson, Patrick Krejcik, Caolionn O'Connell, Robert Siemann, Dieter Walz (SLAC), Suzhi Deng, Tom Katsouleas, Patric Muggli, Erdem Oz (USC)*

In the E-164(X) plasma wakefield experiments at SLAC, an ultra-short, 28.5 GeV electron beam field ionizes a neutral Lithium vapor. In the underdense regime, all plasma electrons are expelled creating an ion column. The beam electrons undergo multiple betatron oscillations leading to a large flux of broadband synchrotron radiation. With a plasma density of 3e17 cm-3, the effective focusing gradient is near 9 MT/m with critical photon energies exceeding 50 MeV. A positron source is the initial application being explored for these X-rays, as photo-production of positrons eliminates the thermal stress and shock wave issues associated with traditional Bremsstrahlung sources. The X-rays travel 40m downstream of the plasma, colliding with a tungsten target of varying thickness from 0.65mm-1.8mm. The pairs are imaged with a magnetic spectrometer and detected by two means: silicon surface barrier detectors and by imaging a phosphor with an intensified camera. Photo-production of positrons has been understood for decades; however, the

brightness of plasma X-ray sources provides a unique approach. Preliminary experimental results are presented, and future upgrades are proposed.

**RPAE020—Production of High Harmonic X-Ray Radiation from Nonlinear Inverse Compton Scattering at LLNL PLEIADES**
*Jae Lim, James Rosenzweig (UCLA), Scott Anderson, Shawn Betts, John Crane, David Jeremy Gibson, Fred V. Hartemann, Aaron Matthew Tremaine (LLNL)*
We describe an experiment for production of high harmonic x-ray radiation from inverse Compton scattering (ICS) of an ultra-short high power density laser by a relativistic electron beam at the PLEIADES facility at LLNL. In this scenario, electrons execute a "figure-eight" motion under the influence of the high-intensity laser field, where the constant characterizing the field strength is expected to exceed above a unity, a_L=(e*E_L)/(m*c*omega_L) > 1. With large a_L this motion produces high harmonic x-ray radiation featuring and significant broadening of the spectral peaks. This paper is intended to give a layout of the PLEIADES experiment, along with progress towards experimental goals.

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**RPAE021—Feasibility Study of a Laser Beat-Wave Seeded THz FEL at the Neptune Laboratory**
*Sven Reiche, Chan Joshi, Claudio Pellegrini, James Rosenzweig, Sergei Tochitsky (UCLA), Gennady Shvets (The University of Texas at Austin)*
Free-Electron Laser in the THz range can be used to generate high output power radiation or to modulate the electron beam longitudinally on the radiation wavelength scale. Microbunching on the scale of 1-5 THz is of particular importance for potential phase-locking of a modulated electron beam to a laser-driven plasma accelerating structure. However the lack of a seeding source for the FEL at this spectral range limits operation to a SASE FEL only, which denies a subpicosecond synchronization of the current modulation or radiation with an external laser source. One possibility to overcome this problem is to seed the FEL with two external laser beams, which difference (beat-wave) frequency is matched to the resonant FEL frequency in the THz range. In this presentation we study feasibility of an experiment on laser beat-wave injection in the THz FEL considered at the UCLA Neptune Laboratory, where both a high brightness photoinjector and a two-wavelength, TW-class CO2 laser system exist. By incorporating the energy modulation of the electron beam by the ponderomotive force of the beat-wave in a modified version of the time-dependent FEL code Genesis 1.3, the performance of a FEL at Neptune is simulated and analyzed.

The work was supported by the DOE Contract No. DE-FG03-92ER40727.

**RPAE022—Improved Long Radius of Curvature Measurement System for FEL Mirrors**
*Jingyi Li, Changchun Sun, Y. K. Wu (DU/FEL)*
The 53.73 meter long Duke free electron laser (FEL) cavity consists of two concave mirrors with radius of curvature longer than 27 meters. A proper radius of curvature is designed to achieve an optimal and stable operation of the FEL. This requires accurate measurements of the cavity mirror's radius of curvature before its initial installation. Subsequent radius of curvature measurements are performed to ensure no significant deformation of the mirror occurs after a period of extensive use. A direct measurement based upon the geometric optics principles has been used at DFELL for years. Recently, we have significantly upgraded this measurement apparatus by utilizing a HeNe laser as the light source and a straight wire with a proper size as the object. In this paper we describe the details of the measurement setup and report the benefits of the recent upgrades. In addition, we report the improved data analysis technique and results of recent long radius of curvature measurements.

This work is supported by the U.S. AFOSR MFEL grant F49620-001-0370.

**RPAE023—Development of a Low-Cost Beam Profile Monitor System at Duke FEL Storage Ring**
*Jingyi Li, Y. K. Wu (DU/FEL)*
This paper reports the development of a low-cost transverse beam profile monitor system using the visible spectrum of the dipole radiation. This system consists of a lens, an aperture, mirrors, a set of neutral density and color filters, and a CCD camera. The optical system is carefully calibrated and optimized with a bench setup. While iffraction limited for measuring vertical beam sizes with a small coupled emittance at a low current, this low-cost system nevertheless provides adequate resolution for measuring horizontal beam profiles in many practical operation conditions. To take advantage of its large field of view, an upgrade to a UV CCD image system is under consideration. Some beam dynamics studies based upon this system are also reported in this paper.

This work is supported by the U.S. AFOSR MFEL grant F49620-001-0370.

**RPAE027—Linear Optics Measurements in the ESRF Booster**
*Yannis Papaphilippou, Laurent Farvacque, Annalisa Patriarca, Eric Plouviez (ESRF)*
A series of experiments has been conducted in the ESRF booster in order to measure its linear optics. A steerer response matrix was developed and used to optimise the orbit correction at injection by developing a refined model. This matrix was also used to measure the beta functions along the accelerating cycle and the steerer calibration. Dispersion was also measured with classical RF scans and compared to theory. Finally, chromaticity measurements were performed for different sextupole settings enabling their calibration and optimisation.

**RPAE028—Lattice Upgrade Options for the ESRF Storage Ring**
*Yannis Papaphilippou, Pascal Elleaume, Laurent Farvacque, Annick Ropert (ESRF)*
Several scenarios of lattice upgrade for the ESRF storage ring are under study. In order to minimise the cost, their design is based on the length constraints of the existing tunnel with the ID beamlines kept in place. The goal is to shrink the emittance in order to increase the undulator brilliance. The two main options are a double bend achromat structure with non-uniform field dipoles and a triple bend achromat lattice. The two scenarios are detailed and compared with respect to their linear optics solutions, correction of chromatic effects and non-linear dynamics. An attempt to reveal the horizontal effective emittance dependence on important design parameters, such as optics functions maxima, chromaticity and dynamic aperture, is also undertaken. Technological challenges concerning magnet design with small physical aperture in a reduced space are also addressed.

**RPAE029—Analytical Considerations for the Reduction of the Effective Emittance with Variable Dipole Field Strengths**
*Yannis Papaphilippou, Pascal Elleaume (ESRF)*
The basic optics design scope in lepton rings is to match the sections in either side of the bending magnets in order to minimise the equilibrium emittance. A further important emittance reduction can be achieved by incorporating dipoles for which the deflecting field varies along the electron beam path in the magnet. The figure of merit for such lattices when used in a synchrotron light source is the minimization of the so-called effective emittance. The effective emittance is computed in the middle of the undulator straight section as the product of the rms size and divergence and therefore includes contributions from the betatron emittance and from the electron energy spread. In this paper, analytical formulas are obtained for the minimum betatron and effective emittance in arbitrary dipole fields and the associated optics function at the dipole entrance. Examples are given for specific dipole field functions and their properties with respect to the effective emittance minimisation. Finally, the effective emittance is parameterised with respect to standard cell optics properties, such as the phase advance, the maximum beta and dispersion functions and the focusing element strengths.

**RPAE030—Commissioning of the SOLEIL Booster**
*Alexandre Loulergue (SOLEIL)*
SOLEIL is a 2.75 GeV third generation synchrotron radiation facility under construction near Paris. The injection system is composed of a 100 MeV electron Linac pre-accelerator followed by a full energy (2.75 GeV) booster synchrotron. The booster lattice is based on a FODO structure with missing magnet. With a circumference of 157 m and low field magnets (0.74 T), the emittance is of 150 nm.rad at 2.75 GeV. A flexible and economic ramping switched mode procedure for the main supply cycled up to 3 Hz and a 35 kW-352 MHz solid state amplifier powering the RF system are used. At present time, all the magnets, supports and vacuum have been received and tested. Half of the ring is already assembled and installation is the tunnel will begin in January 05. The pulsed elements and their pulser will be received and tested from January to April. The four main magnet power supplies will be received in February and tested in Marsh. We plan the booster commissioning with beam in May 2005.

SOLEIL.

**RPAE031—SOLEIL Status Report**
*Jean-Marc Filhol, Jean Claude Besson, Pascale Brunelle, Roger Chaput, Antoine Dael, Jean-Claude Denard, Jean-Marie Godefroy, Christian Herbeaux, Alain Lestrade, Marie-Paule Level, Alexandre Loulergue, Patrick Marchand, Jean-Louis Marlats, Amor Nadji, Laurent Stanislas Nadolski, Ryutaro Nagaoka, Marie-Agnès Tordeux (SOLEIL)*
This paper reports the progress achieved in the construction of the accelerators of SOLEIL. Started in January 2002, the construction comes near to its end and the installation of the equipment on the site has begun from September 2004 and shall be completed within one year. The progress on the LINAC and Booster are reported separately, therefore this paper will focus more particularly on the Storage Ring: Dedicated measuring benches have been built to perform the magnetic measurements on all the magnets and the results of measurements have been analysed in term of particle dynamics behaviour in order to prepare the operating point for the commissioning. The status of innovative developments engaged from the beginning as superconducting RF cavities, NEG coated vacuum chambers and BPMs digital electronics will be described. The construction of the first 6 insertion devices is also well advanced and will be reported. Finally, the machine impedance budget was further evaluated with consequently, still some modifications to the design of some components.

SOLEIL

**RPAE032—Femtosecond Laser-Electron Interaction in a Storage Ring Studied by Terahertz Radiation**
*Karsten Holldack, Shaukat Khan, Rolf Mitzner, Torsten Quast (BESSY GmbH)*
The laser-induced energy modulation of relativistic electrons in the BESSY II storage ring was studied by temporal and spectral characterization of femtosecond far infrared (THz) pulses being emitted due to the fact that dispersive elements convert the energy modulation into a longitudinal density modulation. Bunch shapes down to 3 ps and phase noise effects as well as the length of the femtosecond density modulation and its temporal decay were measured. The THz diagnostics is crucial for the operation of the recently commissioned undulator based "femtosecond slicing" source at BESSY.

This work was supported by the german Bundesministerium für Bildung und Forschung (BMBF).

**RPAE033—Commissioning Results from the BESSY II Femtoslicing X-Ray Source**
*Shaukat Khan, Karsten Holldack, Torsten Kachel, Torsten Quast (BESSY GmbH), Rolf Mitzner (Universitaet Muenster)*
At the BESSY II storage ring, a source of sub-100 fs x-ray pulses with tunable polarization and excellent signal-to-background ratio has been constructed in 2004. This source is based on laser-induced energy modulation ("femtoslicing") and subsequent angular separation of the short-pulse x-rays emitted by an elliptical undulator. The paper reviews the layout of the source and reports on new insights and experimental results obtained while commissioning the source for user operation.
Funded by the Bundesministerium fuer Bildung und Forschung and by the Land Berlin.

**RPAE034—Storage Ring Fill Patterns for Femtoslicing Applications**
*Shaukat Khan (BESSY GmbH)*
The generation of laser-induced ultrashort synchrotron radiation pulses ("femtoslicing") during user operation at the BESSY II storage ring requires to add several bunches with enhanced charge to the routinely used multibunch fill. The paper addresses these specialized fill patterns in view of beam stability against multibunch oscillations and ion effects, beam lifetime, and the effect of beam loading on the synchronous phase angles.

Funded by the Bundesministerium fuer Bildung und Forschung and by the Land Berlin.

**RPAE035—Orbit Stability at BESSY**
*Roland Müller, Joerg Feikes, Karsten Holldack, Peter Kuske (BESSY GmbH)*
Traditionally intrinsic component stability as well as perturbation source identification and suppression (like set-up modifications or feed-forward compensations) have been the preferred methods used to guarantee beam orbit stability for user operation at BESSY. Second focus of activity is the reliability of slow drift control and the high degree of beam position reproducibility maintained under frequently changed operation conditions. Along these lines an overview of the measures taken, the available diagnostic means as well as the achievements and shortcomings of the existing slow orbit feedback is given. Diagnostic capabilities of a fast BPM read-out and data distribu-

tion system give insight into the demands on a fast orbit feedback that could provide better operation flexibility and improved performance.

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**RPAE036—Damping Wigglers for the PETRA III Light Source**

*Markus Tischer, Klaus Balewski, Winfried Decking, Mike Seidel, Li Yongjun (DESY), Victor Kuzminykh, Evgeny Levichev, Pavel Vobly, Konstantin Zolotariov (BINP SB RAS)*

Within the reconstruction of the PETRA booster ring at DESY towards a third generation light source after 2007, damping wigglers will be installed to reduce the emittance to a value of 1 nmrad. Two damping sections in the long straights of PETRA have been assigned to accommodate 20 wigglers in total. The wigglers will be permanent magnet devices with a fixed gap which are surrounded by an iron enclosure to reduce the leakage flux. Each wiggler will provide a damping integral of 4 T2m per segment and generate a synchrotron radiation power of 42 kW. A short one period long prototype has recently been built to prove the magnetic design and study the correction scheme for tuning the pole strength. The wiggler segments will be followed by an SR absorber shading the downstream quadrupole and successive wiggler segment, the accumulated on-axis power of about 200 kW will be taken up by the final absorber at the damping section end.

**RPAE037—Operation of ANKA with Low Emittance Optics**

*Erhard Huttel, Asem Ben Kalefa, Ingrid Birkel, Anke-Susanne Müller, Pawel Wesolowski (FZK-ISS-ANKA), Francisco Pérez, Montserrat Pont (CELLS), Massimo Giovannozzi (CERN)*

ANKA is a synchrotron light source operating in an energy range from 0.5 to 2.5 GeV. The electron storage ring at ANKA is designed as a variation of an eightfold Double Bend Achromat structure. Since its commissioning the facility has been operated with zero dispersion in the long straight sections resulting in an emittance of about 100 nmrad. Since mid 2004 ANKA is operated with dispersion distributed over the complete ring thus reducing the emittance to 40 nmrad. In the course of the redesign of the storage ring optics a compensation of higher order field components leads to a visibly increased momentum acceptance. Optics calculations and measurements as well as operational experience will be discussed.

**RPAE038—Far Infrared Coherent Synchrotron Edge Radiation at ANKA**

*Anke-Susanne Müller, Ingrid Birkel, Biliana Gasharova, Erhard Huttel, Richard Kubat, Yves-Laurent Mathis, Wolfgang Mexner, David A. Moss, Robert Rossmanith, Pawel Wesolowski, Michael Wuensch (FZK-ISS-ANKA), Francisco Pérez, Montserrat Pont (FZK-ISS-ANKA; CELLS), Carol J. Hirschmugl (UWM)*

A synchrotron radiation source emits coherent infrared (IR) radiation when the electron bunch length is comparable to the wavelength of the emitted radiation. To generate coherent radiation in the far IR (THz) region, a "low alpha mode" has been devised at the ANKA storage ring operating at 1.3 GeV. The corresponding lattice has a significantly reduced momentum compaction factor. The spectral dependence of the emitted radiation is recorded at the ANKA-IR beamline, where the synchrotron light is produced in the fringe field of a bending magnet. This edge radiation has the advantage of being more collimated than constant field radiation. This allows the observation of frequencies down to 1 cm-1 through a modest vertical aperture, which would not be possible with classical constant field emission due to the increasing beam divergence with decreasing frequency. The onset of coherent emission is found at a synchrotron frequency of about 10 kHz. At 5 kHz, an intensity enhancement of up to 5 orders of magnitude, with respect to the incoherent emission, is observed in the spectral range between 1 and 65 cm-1.

**RPAE039—Operation of the ANKA Synchrotron Light Source with Superconductive Undulators**

*Robert Rossmanith, Axel Bernhard, Michael Hagelstein, Barbara Kostka, Anke-Susanne Müller, Matthias Weisser (FZK-ISS-ANKA), Erhard Steffens (Erlangen University), Tilo Baumbach, Theo Schneider (FZ Karlsruhe)*

The synchrotron light source ANKA (2.5 GeV, 200 mA) is a versatile multi-purpose storage ring with beam lines for coherent IR and THz radiation (IR-laser), LIGA applications and high brilliance X-rays. It is now plannned to install in addition several superconductive undulators for a wide range of applications: fast tunable X-rays for material research, imaging applications and an undulator with variable polarization direction for a dichroism beamline. This development of ANKA is the result of successful research on superconductive undulators which surpass the performance of permanent undulators by far (collaboration between ANKA, the University of Karlsruhe and the University of Erlangen-Nürnberg). The basic layout of the undulators and the required changes to a storage ring to accommodate the superconductive undulators is described in this paper.

**RPAE040—COD Correction at the PF and PF-AR by New Orbit Feedback Scheme**

*Kentaro Harada (KEK), Norio Nakamura, Hiroshi Sakai, Hiroyuki Takaki (ISSP/SRL)*

The eigen-vector method with a constraint condition is a new COD correction method that enables us to combine the local orbit correction at the insertion devices with the global COD correction by integrating the local one into the global one as the constraint condition using the Lagrange's undetermined multiplier method. In order to achieve this method, we only use the new contrived response matrix for the global COD correction where the local correction is involved and done simultaneously. We have tested this correction scheme at the PF ring and the PF-AR. In the machine studies, the new orbit correction method is successfully demonstrated. The RMS COD of the constraint BPMs are sufficiently suppressed and, on the other hand, there is almost no large difference in the RMS COD of all the other BPMs between the new and ordinary methods.

**RPAE041—Reconstruction of Photon Factory Storage Ring for the Straight-Sections Upgrade Project**

*Tohru Honda, Seiji Asaoka, Kaiichi Haga, Kentaro Harada, Yoichiro Hori, Masaaki Izawa, Toshio Kasuga, Yukinori Kobayashi, Hideki Maezawa, Atsushi Mishina, Toshiyuki Mitsuhashi, Tsukasa Miyajima, Hiroshi Miyauchi, Shinya Nagahashi, Takashi Nogami, Takashi Obina, Cheol-on Pak, Shogo Sakanaka, Yoshihiro Sato, Tatsuro Shioya, Mikito Tadano, Takeshi Takahashi, Yasunori Tanimoto, Kimichika Tsuchiya, Takashi Uchiyama, Akira Ueda, Kensei Umemori, Shigeru Yamamoto (KEK)*

The Photon Factory (PF) storage ring is a 2.5-GeV synchrotron light source at KEK. In 1997, we have accomplished a large reconstruction of the ring in order to reduce the beam emittance from 130 nm rad to 36 nm rad. After the reconstruction, the PF ring has continued a stable operation over 5000 hours a year. Now we are proceeding with another upgrade project to create four new straight sections and to largely lengthen the existing 10 straight sections. The shutdown for the upgrade project is scheduled for the period March-September 2005. The lattice configuration around the straight sections will be modified by

replacing quadrupole magnets with new shorter ones and by placing them closer to the near-by bending magnets. Simultaneously the beam duct in two thirds of the storage ring will be replaced. Due to this modification of the lattice, the practical emittance will be reduced to 27 nm rad. The new straight sections will have low beta functions and suitable for housing short-period narrow-gap undulators. The in-vacuum undulators, which have a sufficiently high brilliance within a spectral range from 8 to 16 keV, are being developed now.

**RPAE042—Optimization of Kicker Pulse Bump by Using a SR Monitor at the Photon Factory**
*Toshiyuki Mitsuhashi, Akira Ueda (KEK)*
We plan to operate the Photon Factory storage ring by top-up injection mode from 2006. To realize this operation mode, remaining coherent oscillation of the stored beam due to error in the injection pulse bump is one of most serious problem. To reducing the error in the injection pulse bump, we calibrated kicking angles of the injection kicker magnets by means of the term by term instantaneous observation of beam profile. We have a SR monitor inside of injection pulse bump. By measureing the tern by tern beam position after the excitation of kicker magnet, we can calibrate the kick angle of the kicker magnet. By using this calibration, we optimized injection pulse bump. As a result, we reduced amplitude of of the beam σremaining coherent oscillation less than 1/4 of the 1 size.

**RPAE043—Beam Position Monitor for Undulator by Using SR Monitor Technique**
*Toshiyuki Mitsuhashi, Mikio Tadano (KEK)*
A beam position monitor for the undulator by using the optical SR monitor technique has been tested in the Photon Factory. A visible SR in far tail of the undurater spectrum is extracted by a water-cooled beryllium mirror. The extraction mirror has a hole in the center for passing through the central peak of the undulator radiation which has an opening angle of 1/gamma. Extracted visible light in large opening angle has exactly same optical axis of the undulator radiation, because of it's a far tail of the spectrum of same radiation. We applied focusing system to observe the beam position in the undulator through the optical image of beam. The results show us this method is applicable to monitor a position of beam in the undulator, and gap change of undulator has no effect of beam position monitoring. We can easily measure the angle of visible ray, this method is applicable not only beam position monitor but also monitoring the angular deviation of undulator radiation.

**RPAE044—Operation and Recent Developments of Photon Factory Advanced Ring**
*Tsukasa Miyajima (KEK)*
The Photon Factory Advanced Ring (PF-AR) is a synchrotron light source dedicated to X-ray research. The PF-AR is usually operated at a beam energy of 6.5 GeV, but a 5.0 GeV mode is also available for medical application. In 6.5 GeV mode the typical lifetime of 15 hrs and the beam current of 60 mA with a single-bunch have been archived. Almost full-time single-bunch operation for pulse X-ray characterize the PF-AR. However, single-bunch high-current caused several problems to be solved, including the temperature rise of the some of the vacuum component, a pressure increase in the ring, and a sudden drop in lifetime. In order to avoid these issues the developments of new methods have been continued. In this paper, the status and the recent developments of the PF-AR will be presented. It concerns: the successful operation with two-bunch high-current in 5.0 GeV mode; varying the vertical beam size for the medical application; modulating the RF acceleration phase in order to elongate the length of bunch; stabilizing temperature in the ring tunnel; the study for medium emittance operation with 160 nmrad; moving the RF cavities in order to install a new insertion device; an innovative injection scheme using a pulsed quadrupole magnet.

**RPAE045—Production of Short Electron Bunches by Adiabatic Excitation of Bunch Shape Oscillations**
*Shogo Sakanaka, Toshiyuki Mitsuhashi, Takashi Obina, Kensei Umemori (KEK)*
In the Brookhaven Alternating Gradient Synchrotron (AGS), adiabatic excitation of longitudinal bunch-shape oscillations has been successfully used for extracting shortened proton bunches.* We applied this technique to the electron storage ring. In case of electron machines, growth time of bunch-shape oscillations should be shorter than the radiation damping time for preventing radiation excitation. We demonstrated in the 2.5-GeV Photon Factory storage ring that electron bunches could be shortened by a factor of about two from its natural length using this technique. We show that non-adiabatic excitation of oscillations is also very useful for obtaining shorter bunches.
*M. Bai et al., Phys. Rev. ST Accel. Beams 3, 064001 (2000).

**RPAE046—Operational Status at the PLS: Recent Improvements and Changes**
*Eung Soo Park, Jinhyuk Choi, Heung-Sik Kang, Mungyung Kim, Eun-Hee Lee, Tae-Yeon Lee (PAL)*
PLS has been operated 10 years since 1994. A few improvements has been made to stabilize the reference orbit drifts caused by insertion devices and other sources: The control system has been upgraded to 20 bit capability from 12 bit. The slow global orbit feedback is employed routinely in the user run times. These improvements and the operational status changes will be presented in this report.

**RPAE047—Lattice Study for the Taiwan Photon Source**
*Chin-Cheng Kuo, Ho-Ping Chang, Chien-Te Chen, Gwo-Huei Luo, Hung-Jen Tsai, Min-Huey Wang (NSRRC)*
The feasibility study for the new 3.0~3.3 GeV Taiwan synchrotron light source, dubbed Taiwan Photon Source, was initiated in July, 2004. The goal is to construct a high performance light source with extremely bright X-ray in complementary to the existing 1.5 GeV light source in Taiwan. The ring circumference is 518.4 m and a 24-cell DBA lattice structure is chosen. The natural emittance with distributed dispersion is less than 2 nm-rad. A large booster ring of 499.2 m sharing the storage ring tunnel will be adopted.

**RPAE048—Design Consideration of a Booster for Taiwan Photon Source**
*Gwo-Huei Luo, Ho-Ping Chang, Chin-Cheng Kuo, Ke-Kang Lin, Hung-Jen Tsai (NSRRC)*
After more than 10 years' operation and expansion, the Taiwan Light Source (TLS) of National Synchrotron Radiation Research Center (NSRRC) reaches very stable operation condition. The storage ring has better than 96% of beam availability annually with 6 Insertion Devices (ID) in a six-folds symmetry overcrowded machine. Two superconducting IDs and one superconducting RF cavity were installed in recent year, which intend to push the photon energy to hard x-ray regime and double the photon flux with better beam quality. Beamlines and experimental stations occupied all over the experimental area. The uproar for more beamlines in higher photon energy with higher brightness was frequently transpired from users' community. The Board of Trustee of NSRRC gave a green light to a new design and construction of median-energy light source, Taiwan Photon Source (TPS) in the coming decade. This paper will

present two draft designs of booster and the consideration of the design criteria for new booster to work with a top-up injected and very low-emittance storage ring.

**RPAE049—Revision of Booster to Storage Ring Transport Line Design for Top-Up Operation at NSRRC**
*Min-Huey Wang, Ho-Ping Chang, Jenny Chen, June-Rong Chen, Kuo-Tung Hsu, Chin-Cheng Kuo, Gwo-Huei Luo (NSRRC)*
In order to smoothly run the Top-Up operation of storage ring, we make every effort to improve the injection efficiency, which includes the upgrade of the booster, reconstruction of injection kicker pulser and revision of the booster to storage ring (BTS) transport line design etc. In this report we present the revisions of BTS transprot line design. The revision includes the adjustment of the optics design and the improvment of the diagnostic sheme and components. The achievement from this revision is also reported.

**RPAE050—Status of the CAMD Light Source**
*Victor Paul Suller (CCLRC/DL/ASTeC), Evan Anzalone, Mikhail Fedurin, Paul Jines, Daren Launey, Toby Miller, Yanshan Wang (LSU/CAMD)*
With the increasing diversity of its research program, the CAMD Light Source has improved its beam brightness and quality. Using a well calibrated model of the lattice, the ring optic has been refined to generate a lower beam emittance of 150 nm.rad and this has been confirmed by measuring the beta values with the modulated quadrupole shunt system. The beam sizes have also been measured with an X-ray pinhole camera and compared to the calculated emittance. The beam orbit is corrected to a standard position referenced to the quadrupole centers to a precision better than 0.5 mm, using a suite of well localized bumps which can also flexibly steer the user photon beams to their requirements. Beam reliability has been improved by bringing into use a VME control system for the energy ramp.

**RPAE051—Multipole Design for CAMD Storage Ring**
*Victor Paul Suller (CCLRC/DL/ASTeC), Mikhail Fedurin, Paul Jines, Toby Miller (LSU/CAMD)*
The CAMD storage ring has been in operation more than 12 years with only sextupole elements in the lattice for correction of nonlinear beam dynamics. To compensate for coupling arising from the integrated effect of skewed elements around the ring, and to improve beam lifetime, a multipole element is required which can be operated in active mode. The design of a magnetic multipole is presented as well as power and control systems designs. The strength and effect and of this element are calculated.

**RPAE052—Accelerator Physics Studies and Commissioning Plans for the Diamond Light Source**
*Riccardo Bartolini, Mahdia Belgroune, Chris Christou, Vince Kempson, Ian Martin, James Henry Rowland, Beni Singh, Richard Walker (Diamond), David James Holder, James Jones, Susan Louise Smith, Jennifer Anne Varley, Naomi Wyles (CCLRC/DL/ASTeC)*
DIAMOND is a 3 GeV synchrotron light source under construction at Rutherford Appleton Laboratory in Oxfordshire (UK). The accelerators complex consists of a 100 MeV LINAC, a full energy booster and a 3GeV storage ring with 22 straight sections available for IDs. Installation of all three accelerators has begun, and LINAC commissioning is due to start in Spring 2005. This paper will give an overview of the accelerator physics activity to produce final layouts and prepare for the commissioning of the accelerator complex. The DIAMOND facility is expected to be operational for users in 2007.

**RPAE053—Transient Generation of Short Pulses in the APS Storage Ring**
*Glenn Decker, Nicholas Sereno (ANL)*
A method for obtaining very short pulses using modulation of the accelerating voltage gradient is described and simulation results given. The idea is to operate the two rf stations with a phase separation adjusted so that the synchronous particle resides on the crest of one of the sources. Phase modulation of the on-crest system at twice the synchrotron frequency induces a longitudinal bunch shape oscillation with significantly reduced bunch length occurring twice each synchrotron period. Pulsed and steady-state operation will be discussed using various accelerator parameters.

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**RPAE054—Beam Stability at the Advanced Photon Source**
*Glenn Decker, Om Singh (ANL)*
The Advanced Photon Source has been in operation since 1996. Since that time, extensive incremental improvements to orbit stabilization systems have been made. This includes the addition of 80 channels of narrowband rf beam position monitors (bpm's), 40 channels of bending magnet photon bpm's, and most recently the inclusion of 36 insertion device photon bpm's into the orbit correction response matrix. In addition, considerable improvements have been made in the area of power supply regulation, both for the main multipole magnets and the steering corrector magnets. The present status of overall performance will be discussed, including long term pointing stability, reproducibility, and AC beam motion.

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**RPAE055—Results of Preliminary Tests of PAR Bunch Cleaning**
*Chihyuan Yao, Michael Borland, Arthur Grelick, Alex Lumpkin, Nicholas Sereno (ANL)*
A particle accumulator ring (PAR) is used at the Advanced Photon Source (APS) to collect multiple linac bunches and compress them into a 0.3-ns (rms) single bunch for booster injection. A 9.77-MHz fundamental rf system and a 117.3-MHz harmonic rf system are employed for initial beam capture and bunch length compression. Satellite bunches with very low charge form due to rf phase drifts or beam loading change. These satellites, when injected into the booster and then into the storage ring (SR), cause bunch impurity at three buckets from the target bucket. Storage ring and booster bunch cleaning was tried but proved to be difficult due to the top-up mode of operation in the storage ring and tune drift in the booster synchrotron. Recently we implemented a PAR bunch-cleaning system with tune-modulated harmonic rf knockout. Preliminary tests gave a measured SR bunch purity of better than 10^-6, which shows that the cleaning method is feasible and could achieve a bunch purity goal of 10^-8. This report describes the system configuration, test results, and system performance.

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**RPAE056—NSLS II: The Future of the NSLS**
*James Murphy (BNL), Johan Bengtsson, Richard Biscardi, Alexei Blednykh, Larry Carr, William Casey, Shailendra Chouhan, Steven Dierker, Edwin Haas, Richard Heese, Steve Hulbert, Erik David Johnson, Chi-Chang Kao, Stephen L. Kramer, Samuel Krinsky, Igor Pinayev, Slobodan Pjerov, Boris Podobedov, George Rakowsky, James Rose, Timur Shaftan, Brian Sheehy, John Skaritka, Nathan Towne, Jiunn-Ming Wang, Xijie Wang, Li-Hua Yu (BNL/NSLS)*
The National Synchrotron Light Source at BNL was the first dedicated light source facility and it has now operated for more than 20 years. During this time the user community has grown to more than 2400 users annually. To insure that this vibrant user community has access to the highest quality photon beams, the NSLS is pursuing the design of a new ultra-high brightness (~10E21) electron storage ring, tailored to the 0.3-20 KeV photon energy range. We present our preliminary design and review the critical accelerator physics design issues.

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**RPAE057—Dynamic Aperture Optimization for Low Emittance Light Sources**
*Stephen L. Kramer, Johan Bengtsson (BNL/NSLS)*
State of the art low emittance light source lattices, require small bend angle dipole magnets and strong quadrupoles. This in turn creates large chromaticity and small value of dispersion in the lattice. To counter the high chromaticity strong sextupoles are required which limit the dynamic aperture. Traditional methods for expanding the dynamic aperture use harmonic sextupoles to counter the tune shift with amplitude. This has been successful up to now, but is non-deterministic and limited as the sextupole strength increases, driving higher order nonlinearities. We have taken a different approach that makes use of the tune flexibility of a TBA lattice to minimize the lowest order nonlinearities, freeing the harmonic sextupoles to counter the higher order nonlinearities. This procedure is being used to improve the nonlinear dynamics of the NSLS-II lattice.

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**RPAE058—NSLS-II Injection Concept**
*Timur Shaftan, Johan Bengtsson, Alexei Blednykh, Shailendra Chouhan, Erik David Johnson, Stephen L. Kramer, Samuel Krinsky, James Murphy, Igor Pinayev, Slobodan Pjerov, Boris Podobedov, George Rakowsky, James Rose, Toshiya Tanabe, Jiunn-Ming Wang, Xijie Wang, Li-Hua Yu (BNL/NSLS)*
Currently the facility upgrade project is under progress at the NSLS (Brookhaven National Laboratory). The goal of NSLS-II is a 3 GeV ultra-low emittance storage ring that will provide three orders of magnitude increase in brightness over the present NSLS X-ray beamlines. The low emittance of the high brightness ring lattice results in quite short lifetimes, which makes operation in top-off injection mode a necessity. The NSLS-II injection system must be able to provide an electron beam at the high repetition rate and with good injection efficiency. In this paper we present a concept of the NSLS-II injection system and discuss conditions and constraints for the injector design. Various injection system parameters are estimated from the point of view of SR user demand.

**RPAE059—Design of 3 GeV Booster for NSLS-II**
*Timur Shaftan, Erik David Johnson, James Murphy, Igor Pinayev, James Rose, Xijie Wang (BNL/NSLS)*
We present preliminary design of full energy booster for NSLS-II. In the paper we analyze single- and multi-bunch modes of the booster operations. The booster lattice consists of 24 TME cells with two dispersion suppressors. Initial design of the magnets, power supply specifications, Eddy current contribution to the booster chromaticity are discussed.

**RPAE060—Simulation and Automation of the EEBI Test at ALS**
*Hiroshi Nishimura, Warren Byrne (LBNL)*
The Errant Electron Beam Interlock (EEBI) is a system that protects the vacuum chamber of the Advanced Light Source (ALS) from synchrotron light damage should the orbit, through a superconducting bend magnet (superbend), become distorted. The EEBI system monitors the vertical beam position on two BPMs, one upstream and the other downstream, of the superbend and dumps the stored beam if the orbit exceeds preset limits in either offset or angle. Discussed are the modeling studies carried out to determine how to create a large vertical bump, both for performing the test and implementing the automated test software.

Work supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**RPAE061—Beam Loss Simulation Studies for ALS Top-Off Operation**
*Hiroshi Nishimura, David Robin, Christoph Steier (LBNL)*
The ALS is planning to operate with top-off injection at higher beam currents and smaller vertical beam size. As part of a radiation safety study for top-off, we carried out two kinds of tracking studies: (1) to confirm that the injected beam cannot go into users' photon beam lines, and (2) to control the location of beam dump when the storage ring RF is tripped. (1) is done by tracking electrons from a photon beam line to the injection sector inversely by including the magnetic field profiles, varying the field strength with geometric aperture limits to conclude that it is impossible. (2) is done by tracking an electron with radiation in the 6-dim space for different combinations of vertical scrapers for the realistic lattice with errors.

Work supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**RPAE062—Estimation of the Effective Magnet Misalignments of the ALS Storage Ring**
*Hiroshi Nishimura, Tom Scarvie (LBNL)*
New storage ring lattices have traditionally been commissioned using a trial-and-error approach, where the number of turns circulated is slowly built up until enough beam is stored to correct the orbit. We have found that by combining the calculated response matrix of magnet misalignments from a linear model of a new lattice with the measured steering magnet response matrix used during normal operations, it is possible to make an educated guess for the steering magnet settings that will immediately allow beam circulation in the new lattice. "Effective" magnet misalignments are simply those that are sufficiently close to the real misalignments to make the first guess good enough to circulate beam; the relationship between effective and real magnet misalignments is also discussed in the paper. This predictive steering method makes the process of establishing enough circulating beam for SVD-based orbit correction in a new lattice very efficient.

Work supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098

**RPAE063—Status and Plans for the ALS Top-Off Upgrade**
*David Robin, Barry Bailey, Kenneth Michael Baptiste, Walter Barry, Alan Biocca, Warren Byrne, Richard Donahue, Robert M. Duarte, Michael Fahmie, William Gath, James Julian, Jin-Young Jung, Slawomir Kwiatkowski, Robert Mueller, Hiroshi Nishimura, Jim Oneill, Soren Prestemon, Steven Rossi, Fernando Sannibale, Ross Schlueter, Derek Shuman, Christoph Steier, Gregory D. Stover, Chris Timossi, Tony Warwick (LBNL)*
The brightness and thermal stability of the Advanced Light Source (ALS) is lifetime limited. Brightness improvements such as narrower gap insertion devices, smaller emittance coupling, and higher currents all result in short lifetimes. In addition current changes over a fill impact the thermal stability of both the storage ring and beamlines. In order to mitigate these limitations there is a plan to upgrade the injector of the ALS to full energy injection and to operate in a quasi-continuous filling (Top-Off) injection operation. With Top-Off, the ALS will increase its time-averaged current by two, reduce the vertical emittance, and operate with smaller gap insertion devices. In this paper we describe our upgrade plan.

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**RPAE064—Radiation Safety Studies for Top-Off Operation of the Advanced Light Source**
*David Robin, Richard Donahue, Robert Mueller, Hiroshi Nishimura, Christoph Steier (LBNL)*
The Advanced Light Source (ALS) is planning to upgrade the facility to enable continuous injection operation in the next two years. In this mode of operation, named Top-Off operation, the beam current is maintained at ~ 500 mA through frequent injections approximately every 30 seconds while the shutters are open and the photon beams are delivered to the users. The issues relevant to top-off operation, which give rise to potential radiological considerations, are accident situations which result from loss of injected particles down a photon beamline and the increased loss rate due to Touschek scattering and beam trips. In this paper we present our plan to address these issues.

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**RPAE065—Generation of Picosecond X-Ray Pulses in the ALS Using RF Orbit Deflection**
*David Robin, John Byrd, Slawomir Kwiatkowski, Derun Li, Fernando Sannibale, Christoph Steier, Weishi Wan, Alexander Zholents (LBNL)*
A scheme is studied for producing ps length pulses of x-ray radiation from the Advanced Light Source (ALS) using two RF deflecting cavities. The cavities create vertical displacements of electrons correlated with their longitudinal position in the bunch. The two cavities separated by 180 degrees of vertical phase advance. This allows the vertical kick from one cavity to be compensated by the vertical kick of the other. The location of the cavities corresponds to the end of one straight section and the beginning of the following straight section. Halfway between the cavities a bending magnet source is located. The radiation from the bend can be compressed to ~1 ps in duration.

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**RPAE066—Terahertz Coherent Synchrotron Radiation from Femtosecond Laser Modulation of the Electron Beam at the Advanced Light Source**
*John Byrd, Zhao Hao, Michael C. Martin, David Robin, Fernando Sannibale, Robert W. Schoenlein, Alexander Zholents, Max Zolotorev (LBNL)*
At the Advanced Light Source (ALS), the "femtoslicing" beamline is in operation since 1999 for the production of x-ray synchrotron radiation pulses with femtosecond duration. The mechanism used for generating the short x-ray pulses induces at the same time temporary structures in the electron bunch longitudinal distribution with very short characteristic length. Such structures emit intense coherent synchrotron radiation (CSR) in the terahertz frequency range. This CSR, whose measured intensity is routinely used as a diagnostics for the tune-up of the femtoslicing experiments, represents a potential source of terahertz radiation with very interesting features. Several measurements have been performed for its characterization and in this paper an updated description of the experimental results and of their interpretation is presented.

Work supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**RPAE067—Investigations, Experiments, and Implications for Using Existing Pulse Magnets for "Topoff" Operation at the Advanced Light Source**
*Gregory D. Stover, Kenneth Michael Baptiste, Walter Barry, William Gath, James Julian, Slawomir Kwiatkowski, Soren Prestemon, Ross Schlueter, Derek Shuman, Christoph Steier (LBNL)*
ALS top-off mode of operation will require injection of the electron beam from the Booster Ring into the Storage Ring at the full ALS energy level of 1.9GeV. Currently the Booster delivers a beam at 1.5GeV to the Storage Ring where it is then ramped to the full energy and stored for the user operation. The higher Booster beam energy will require the pulse magnets in the Booster and Storage Rings to operate at proportionally higher magnetic gap fields. Our group studied and tested the possible design and installation modifications required to operate the magnets and drivers at "top-off" levels. Our results and experiments show that with minor electrical modifications all the existing pulse magnet systems can be used at the higher energy levels, and the increased operational stresses should have a negligible impact on magnet reliability. Furthermore, simple electrical modifications to the storage ring thick septum will greatly reduce the present level of septum stray leakage fields into the storage ring beam.

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**RPAE068—The Ultra-Short Bunches in MIT SHR Storage Ring with Very Small Momentum Compactions**
*Dong Wang (MIT)*
The study of ultra-short bunches in MIT SHR storage ring with very small momentum compactions is carried out. The ultra-short bunches are to greatly enhence the coherent radiation by many orders of magnitude. The ring lattice is resigned to reach very small momentum compaction factor down to 1E-5 levels. The measurement is performed with the streak camera. The various associated issues are discussed.

U.S. Department of Energy.

**RPAE069—Terahertz Coherent Synchrotron Radiation in the MIT-Bates South Hall Ring**
*Fuhua Wang, Dan Cheever, Manouchehr Farkhondeh, Wilbur Franklin, William Graves, Ernie Ihloff, Richard Milner, Chris Tschalaer, Jan Van der Laan, Defa Wang, Dong Wang, Townsend Zwart (MIT), Larry Carr, Boris Podobedov (BNL/NSLS), Fernando Sannibale (LBNL)*
We investigate the terahertz coherent synchrotron radiation (CSR) potential of the South Hall Ring (SHR) at MIT-Bates Linear Accelerator Center. The SHR is equipped with a unique single cavity, 2.856 GHz RF system. The high RF frequency is advantageous for producing short bunch length and for having higher bunch current threshold to generate stable CSR. Combining with other techniques such as external pulse stacking cavity, femtosecond laser slicing, the potential for generating ultra-stable, high power, broadband terahertz CSR is very attractive. Beam dynamics issues related to short bunch length operation, and may associated with the high frequency RF system, such as multi-bunch instability are concerned. They could affect bunch length, bunch intensity and beam stability. The SHR is ideal for experimental exploration of these problems. Results of initial test of low momentum compaction lattice and bunch length measurements are presented and compared to expectations.

**RPAE070—Recent Developments at Aladdin**
*Ken Jacobs, Joseph Bisognano, Robert Arthur Bosch, David Eisert, Michael Fisher, Michael Green, Richard Keil, Kevin J Kleman, Robert Legg, Greg Rogers, John Stott (UW-Madison/SRC)*
Following on the success of lower emittance operation at 800 MeV, SRC is pursuing a number of additional enhancements to the performance of the Aladdin storage ring. Work on Aladdin has included development of low emittance lattices at 1 GeV, which will maximize the capabilities of a recently installed spectromicroscopy beamline and a proposed high-resolution keV beamline. Installation of one-meter long insertion devices in the short straight sections within the quadrant arcs of the four sided storage ring is being considered to increase the number of undulator beamlines from four to possibly eight. Studies have been made to determine what is the minimum insertion device gap that does not interfere with nominal ring operation (injection, ramping, and lifetime at full energy), and indicate that smaller-gapped devices for higher photon energy are reasonable. Lifetime increases or further emittance reductions appear possible with modest aperture increases at a small number of points on the ring. Finally, planning is under way for long term projects such as a new injector or a next generation VUV/soft-xray source for the Midwest. Details will be presented.

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**RPAE071—Touschek Lifetime and Undulator Damage in the Advanced Photon Source**
*Michael Borland, Louis Emery (ANL)*
The Advanced Photon Source (APS) has two insertion devices (IDs) with small-aperture vacuum chambers. The full vertical aperture in these chambers is 5 mm, while the inboard horizontal aperture is 15 mm. These devices suffer significant radiation damage, requiring frequent retuning. We recently hypothesized that the damage resulted from loss of Touschek-scattered particles on the horizontal aperture of the chambers. This results partly from the smallness of the aperture and partly from the pattern of the dispersion function in the low-emittance APS lattice. The horizontal scrapers were originally at a high-dispersion location, but, in the low-emittance lattice, they are at a fairly low-dispersion location. Similarly, the dispersion at the IDs was originally zero but is now close to the maximum for the lattice. In this paper, we summarize simulations and experiments that support our hypothesis and discuss plans to remedy the problem.

Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**RPAE072—Simulations of X-Ray Slicing and Compression Using Crab Cavities in the Advanced Photon Source**
*Michael Borland (ANL)*
Recently, Zholents et al. proposed applying to the Advanced Photon Source an x-ray compression scheme based on a pair of crab cavities and asymmetric cut crystals. We have explored the feasibility and potential performance of this scheme through simulation. We used the code elegant to perform 6-D tracking, allowing us to characterize the emittance growth, which is mostly a result of sextupoles between the cavities. We also explored tolerances on alignment, phase, and voltage of the cavities; lifetime effects; tradeoffs between cavity frequency and voltage; and performance with slicing alone instead of compression. Our conclusion is that sub-picosecond rms x-ray pulse lengths should be feasible.

Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**RPAE073—A Novel Method To Generate Picosecond X-Ray Pulses in Storage Ring Light Sources**
*Weiming Guo, Michael Borland, Katherine C. Harkay, Vadim Sajaev, Bingxin Yang (ANL)*
The length of x-ray pulses generated by storage ring light sources is usually tens of picoseconds. For example, the value is 40 ps rms at the Advanced Photon Source (APS). Methods of x-ray pulse compression are of great interest at the APS. One possible method, per Zholents et al., is to tilt the electron bunch with deflecting rf cavities.* Alternately, we found that the electron bunch can develop a tilt after application of a vertical kick in the presence of nonzero chromaticity. After slicing, the x-ray pulse length is determined by the tilt angle and the vertical beam size. In principal, sub-picosecond pulses can be obtained at APS. To date we have observed 6 ps rms visible light pulses with a streak camera. Efforts are underway to attempt further compression of the x-ray pulse and to increase the brilliance. This method can be easily applied to any storage ring light sources to generate x-ray pulses up to two orders of magnitude shorter than the electron bunch length. In this paper, we will present the theory of bunch tilt, particularly the synchrobetatron coupling and decoherence beam dynamics, and the simulation and the experimental results will also be shown as verification.
*A. Zholents et al., NIM A 425, 385(1999).

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**RPAE074—Re-Commissioning of the Duke Storage Ring with a HOM-Damped RF Cavity and a New Straight Section Lattice for FELs**
*Y. K. Wu, Matthew D. Busch, Mark Emamian, Joe Faircloth, J. Gustavsson, Steven M. Hartman, C. Howell, M. Johnson, Jingyi Li, Stepan Mikhailov, Owen Oakeley, J. Patterson, Maurice Pentico, Victor Popov, V. Rathbone, Gary Swift, Patrick Walter Wallace, Ping Wang (DU/FEL), Vladimir Sergeevich Arbuzov, Yuri Evtushenko, Nikolai Gavrilov, Igor Gornakov, I. Ivantcov, Igor Kuptcov, Grigory Yakovlevich Kurkin, Natalya Mityanina, A. M. Pavlenok, Victor Petrov, Igor Sedlyarov, Alexey G. Tribendis (BINP SB RAS)*

The Duke FEL lab operates a unique UV/VUV storage ring FEL and an FEL driven, nearly monochromatic, highly polarized, high intensity Compton gamma-ray source. The Duke storage ring light source is undergoing several phases of upgrade in order to significantly improve light source capabilities and performance. The 2004 phase included an upgrade of the RF system with a high-order mode damped RF cavity and a new 34 meter long straight section lattice to host new FEL wigglers in the next phase. This upgrade was completed in August 2004 and storage ring and light source commissioning were completed in November 2004. This paper will provide an overview of this upgrade project and report our commissioning experience of the storage ring and light sources.

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**RPAE075—Status of Duke Storage Ring Light Sources**
*Y. K. Wu (DU/FEL)*
The Duke FEL storage ring is in a phase of continued upgrades towards improved capabilities and higher performance. In 2004, we upgraded the RF system with a new HOM-damped RF cavity and installed a new 34-meter long straight section lattice for FELs. The commissioning of the upgraded storage ring and light sources started in August 2004 and was successfully completed in November 2004, followed by user operation. At the present time, two major upgrade projects are in full swing: first, the upgrade of the present OK-4 FEL with two 3.4-meter long planar wigglers to the next generation OK-5 FEL with four 4-meter long wigglers with tunable polarizations; second, the development of a full energy booster injector (0.27 to 1.2 GeV) for top-off injection into the storage ring. In this paper we will report the status of these on-going upgrade projects and their impacts on user applications. We will also give a performance overview of the Duke storage ring and related light sources in the present configuration.

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**RPAE076—The Commission of Hefei Light Source After Reconstruction**
*Hongliang Xu, Duohui He, Weimin Li, Zuping Liu, Baogen Sun, Lin Wang (USTC/NSRL)*
After the new four-kicker injection bump system was mounted, it was found that the magnetic field of four–kicker magnet through the same pulse current is different each other, the reason is which the width of pulse magnet fields is not same, so the four-kickers can not form completely local bump, and produce large global orbit distortion,and lead to beam loss. At last we found that the films of ceramic chambers were not plated evenly. The new rf system have two low level control circle circuits, which are the frequency and amplitude automatic adjustment systems. Because the energy of injection electron beam is 200MeV, and radiation damping is weak, so the gain of amplitude circuit was adjusted to the small value not to disturb beam.The beam load is large,and Robinson instability happen easily, so the small detune angle is preset. The Octupoles were inserted in ring for damping instability, and over compensated chromaticity was adjusted.Superconductor wiggler bring the variation of beta function, and the beam life time decreased from 8 hours to about 3 hours. By adjusting the beta functions close to situation ago, the beam lifetime was improved.

**RPAE077—A New Low Emittance Operation Mode with Insertion Devices in HLS Storage Ring**
*He Zhang, Lin Wang (USTC/NSRL), Yongjun Li (DESY)*
Hefei Light Source is a low energy electron storage ring with two insertion devices, a wiggler and an undulator. But the insertion devices do not work well in the low emittance operation mode because of the large beta y in the straight sections. So we tried to find a new low emittance operation mode to suit the request of the insertion devices by reducing the vertical beta function. We can also get much lower emittance in the new mode than in the old twofold symmetric one with zero-dispersion straight sections by using fourfold symmetry and leaving acceptable dispersion in straight sections. The nonlinear effects to beam dynamics of insertion devices are also considered and compensated.

**RPAE078—Commissioning of SAGA Light Source**
*Takio Tomimasu, Shigeru Koda, Yuichi Takabayashi, Katuhide Yoshida (Saga Synchrotron Light Source), Hiroyuki Toyokawa (AIST), Hideaki Ohgaki (Kyoto IAE), Yoshitaka Iwasaki (SAGA)*
The SAGA Light Source (SAGA-LS) consists of a 250-MeV electron linac injector and an eight-hold symmetry 1.4-GeV storage ring with eight double-bend (DB) cell and eight 2.93-m long straight sections. The DB cell structure with a distributed dispersion system was chosen to produce a compact ring of 75.6-m long circumference. The machine construction begun September 29, 2003. The ring magnets of steel laminated structure, vacuum chambers made of aluminum alloy, pumping systems and four temperature controlled cooling water systems for the linac accelerating wave guides etc. were installed in March, 2004. The injector, a 500-MHz ring rf damped cavity, rf klystrons, beam transport systems for injection and their controlled systems were installed in July, 2004. The commissioning begun August 25, 2004. A 250-MeV beam was accelerated on September 29. The beam size is 1-mm in diameter and the energy spread is 0.8 % (FWHM). The first revolution of 250-MeV beam around the ring took place October 22. Beam was stored on November 12. The commissioning continues for beam storage and ramping to 1.4-GeV. We report a brief description of SAGA light source and early commissioning activities.

**RPAE079—Flexible Bunch Frequency for Synchrotron Light Sources**
*Gregory James Portmann, Slawomir Kwiatkowski, David Robin (LBNL/ALS), Walter Barry (LBNL)*
Typically storage ring light sources operate with the maximum number of bunches as possible with a gap for ion clearing. By evenly distributing the beam current the overall beam lifetime is maximized. The Advanced Light Source (ALS) has 2 nanoseconds between the bunches and typically operates with 276 bunches out of a possible 328. For experimenters doing timing experiment this bunch separation is too small and would prefer to see only one or two bunches in the ring. The ALS allocates four weeks every year for dedicated 2-bunch operation. In order to provide more flexible operations and greatly increase the amount of operating time for time-of-flight experimenters, it is being proposed to kick one bunch on a different vertical closed orbit. By spatially separating the light from this bunch from the main bunch train in the beamline, one could potentially have single bunch operation all year round. By putting this bunch in the middle of the ion clearing gap the required bandwidth of the kicker magnets is reduced. Using one kicker magnet running at the ring repetition rate, this bunch could be permanently put on a different closed orbit. Using multiply kicker magnets, this bunch could be local offset at on arbitrary frequency.

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**RPAE080—Diagnostics Plan for the Advanced Light Source Top-Off Upgrade**
*Tom Scarvie (LBNL/ALS), Walter Barry, Warren Byrne, Michael Chin, Robert M. Duarte, Jim Oneill, Fernando Sannibale, Chris Timossi (LBNL)*
The Advanced Light Source (ALS) will soon be upgraded to enable top-off operation,* in which electrons are quasi-continuously injected to produce constant stored beam current. We will upgrade our injector from 1.5GeV to full-energy 1.9GeV, and top-off operation will also require more precise injector beam characterization and control than we are capable of using our current diagnostics system. Therefore, a diagnostics upgrade will be crucial for the success of top-off, and our plan for it is described in this paper. Among the improvements will be the integration of all existing beam current monitors along the accelerator chain into an injection efficiency monitoring application. New booster ring diagnostics will include a tune kick and monitoring system, updated beam position monitor electronics, and a new scraper. Two new synchrotron light monitors and a beam stop will be added to the booster-to-storage ring transfer line, and a dedicated bunch purity monitoring system will be installed in the storage ring. Together, these important diagnostic upgrades will enable smooth commissioning of the full energy injector and a quick transition to high quality top-off operation at the ALS.
*Please see the ALS Top-off Upgrade presentation at this conference.

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**RPAE082—The New Undulator Based fs-Slicing Beamline at the ALS**
*Christoph Steier, Alexander Zholents (LBNL/AFR), David Robin, Weishi Wan, Walter Wittmer (LBNL/ALS)*
The existing Femtoslicing beamline at the ALS employs a femtosecond laser beam interacting resonantly with the electron beam in a wiggler (modulator). The induced energy spread over the femtosecond duration is converted to a transverse displacement by exploiting the storage ring dispersion. The displaced femtosecond pulse radiates and produces femtosecond synchrotron radiation. Up to now a regular bending magnet was used as radiator. To improve the flux, a significant upgrade was implemented, replacing the modulator, installing an in-vacuum undulator as new radiator, and installing a higher repeptition rate laser system. The new beamline will provide 100-200 fs long pulses of soft and hard x-rays with moderate flux and with a repetion rate of 10-40 kHz for experiments concerning ultrafast dynamics in solid state physics, chemistry and biology. To achieve the necessary spatial separation of the energy modulated slice from the rest of the bunch, a sizeable local vertical dispersion bump in the radiator is required. All accelerator physics aspects of the upgrade including challenging issues like the impact on the transverse single particle dynamics will be discussed together with initial results of the commissioning.

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**RPAE083—An Overview of the CANDLE Synchrotron Light Facility Project in Armenia**
*Vasili Mkrtich Tsakanov, Mher Aghasyan, Gayane A. Amatuni, Vardan Avagyan, Arshak Grigoryan, Bagrat Grigoryan, Michael Ivanyan, Vahram Jalalyan, Davit Kalantar Kalantaryan, Vitali Khachatryan, Edouard Laziev, Yuri Lawrent Martirosyan, Raphael Mikaelyan, Sergey Minasyan, Khnkanos N. Sanosyan, Stepan Tatikian, Sergey Tunyan, Ashot Vardanyan (CANDLE)*
CANDLE is a 3 GeV energy synchrotron light facility project in Republic of Armenia. The main design features of the new facility are given. The results of the beam physics study in future facility are overviewed that includes the machine impedance, ion trapping, single and multi-bunch instabilities, beam lifetime etc. The main requirements to the magnetic, RF and vacuum systems are discussed. The report includes the status of the project and the nearest R&D plans.

**RPAE084—Beam Dynamics Aspects of the ASP Booster**
*Soren Friis-Nielsen (Danfysik A/S)*
In the present contribution, beam dynamics aspects of the 3 GeV ASP booster designed and produced by Danfysik A/S are presented. The booster synchrotron, based on a lattice with combined-function magnets, will have a very small emittance of around 30 nm. The dynamical aperture (and admittance) of the booster has been investigated with tracking, and results for different tunes and chromaticities will be presented. Also the reduction in admittance caused by alignment errors of the magnets will be discussed. The nominal tunes and chromaticities are mainly determined by the combined-function magnets to (9.20, 3.25) and (1,1), respectively. Using the trim quadrupoles and sextupoles, the tunes can be adjusted in the ranges (9.05-9.45, 3.05-3.45) and the chromaticities in the range (0-2, 0-2).

**RPAE085—ELETTRA Present and Future Upgrades**
*Carlo Joseph Bocchetta, Daniele Bulfone, Gerardo D'Auria, Giovanni De Ninno, Bruno Diviacco, Alessandro Fabris, Riccardo Fabris, Mario Ferianis, Alessandro Gambitta, Fatma Iazzourene, Emanuel Karantzoulis, Marco Lonza, Fabio Mazzolini, Michele Svandrlik, Lidia Tosi, Alessio Turchet, Roberto Visintini, Dino Zangrando (ELETTRA)*
During the last year, the 3rd generation synchrotron light source ELETTRA has benefitted from several upgrades which have been implemented in the frame of a project to enhance the quality of the light source. The superconducting 3rd harmonic cavity, the feedbacks, the realignment of the whole ring and other improved devices have allowed to further, significantly optimize the beam stability and lifetime, as well as the operability and uptime of the facility. At the same time two large scale projects are underway that will change the perspectives of the whole laboratory, namely the full energy booster injector and the single pass X-ray FEL FERMI@Elettra, based on the existing linac. Their status will be presented here together with the overview of the existing light source.

**RPAE086—Observation of Coherent Synchrotron Radiation at NewSUBARU**
*Yoshihiko Shoji (LASTI)*
Coherent Synchrotron Radiation from a short electron bunch in a storage ring was observed at NewSUBARU. The energy of electron was 1GeV. The ring was operated with quasi-isochronous mode. The linear momentum compaction factor was smaller than 2 X 10^-5 and the bunch length was shorter than 5ps (FWHM). We observed an extremely strong radiation from the weak electron beam, 1 micro A per bunch.

**RPAE087—Progress of the Synchrotron Light Source ALBA**
*Dieter Einfeld, Josep Campmany, Marc Muñoz, Francisco Pérez, Montserrat Pont (CELLS)*
ALBA will be a third generation synchrotron light source built in Spain near Barcelona. Commissioning of the storage ring is foreseen to start at the end of 2008. The design phase of ALBA is almost completed and the first components are ready to be ordered. A 100 MeV LINAC will inject electrons into a nominal

energy booster synchrotron of similar circumference as the storage ring, so that both accelerators will share the same tunnel. The storage ring, working at 3 GeV with a circumference of 268.8 m, has been designed for a maximum current of 400 mA. The lattice is based on an extended DBA structure and has a nominal emittance of 4 nm.rad.The machine has a four fold symmetry with 4 long straight sections (8 m), 12 medium (4.2 m) and 8 short (2.6 m). This report concentrates on recent design developments, component choices and current status. Another paper at this conference deals with accelerator physics issues.

**Poster Session RPAP–Application of Accelerators & Instrumentation**
**Park Concourse, 8:30-12:20**

**RPAP001—First Performance Check of the Heidelberg Medicine RFQ-Drifttube-Combination**
*Alexander Bechtold, Manuela Otto, Ulrich Ratzinger, Alwin Schempp (IAP), Hartmut Eickhoff, Bernhard Schlitt (GSI)*
A test-stand has been built up at the IAP in Frankfurt University for checking some basic performance parameters of the Heidelberg medicine RFQ-Drifttube-Combination for the HICAT therapy center. The RFQ has now been set into operation and successfully accelerated protons from 8 keV to the desired final Energy of 400 keV detected by a 60° spectrometer magnet. Further investigations with a slit-grid emittance measurement system for scanning the transverse beam profile will be reported in detail. A more sophisticated energy measurement following the time of flight (TOF) method is in preparation.

BMBF and GSI

**RPAP002—A CW RFQ Accelerator for Deuterons**
*Philipp Fischer, Alwin Schempp (IAP), Juergen Haeuser (NTG Neue Technologien GmbH & Co KG)*
A four-rod RFQ accelerator is being built to accelerate deuterons from 20 keV to 3 MeV. At an operating frequency of 176 MHz the length is 3.8 m and the power consumption 250 kW, the beam current 5 mA. A special feature is the CW-mode operation. The status of the project and properties of the RFQ will be discussed.

**RPAP003—Conceptual Design of a 352 MHZ-Proton-RFQ for GSI**
*Benjamin Hofmann, Alwin Schempp (IAP)*
Part of the future project of GSI is a p-linac for the production of anti-protons. The first component of this linac is a 4-Rod-RFQ operating at 352 MHz. Design studies have been made using the RFQSim- and Microwave-tudio code to optimize the field distribution and symmetry. A 7 cell copper model with minivane electrodes has been built for measurements of field distribution, RP- and Q-value. Also the tuning of the longitidinal flatness will be analysed. Results of the design studies will be presented.

**RPAP004—Simulations for the Frankfurt Funneling Experiment**
*Jan Thibus, Alwin Schempp (IAP)*
Beam simulations for the Frankfurt Funneling Experiment are done with RFQSim and FUSIONS. RFQSim is a particle dynamic program to compute macro particle bunches in the 6D phase space through a RFQ accelerator. Behind the RFQ the simulation software FUSIONS calculates both beam lines through a r.f. funneling deflector. To optimise beam transport of existing and new funneling deflector structures FUSIONS is presently being developed. The status of the development of FUSIONS and the results will be presented.

BMBF

**RPAP006—X-Band Linac Beam-Line for Medical Compton Scattering X-Ray Source**
*Katsuhiro Dobashi (NIRS), Mitsuo Akemoto, Hitoshi Hayano, Toshiyasu Higo, Junji Urakawa (KEK), Futaro Ebina, Atsushi Fukasawa, Tatsuo Kaneyasu, Haruyuki Ogino, Fumito Sakamoto, Mitsuru Uesaka, Tomohiko Yamamoto (UTNL)*
Compton scattering hard X-ray source for 10~80 keV are under construction using the X-band (11.424 GHz) electron linear accelerator and YAG laser at Nuclear Engineering Research laboratory, University of Tokyo. This work is a part of the national project on the development of advanced compact medical accelerators in Japan. National Institute for Radiological Science is the host institute and U. Tokyo and KEK are working for the X-ray source. Main advantage is to produce tunable monochromatic hard (10-80 keV) X-rays with the intensities of 10^8-10 photons/s (at several stages) and the table-top size. Second important aspect is to reduce noise radiation at the beam dump by adopting the deceleration of electrons after the Compton scattering. The X-ray yield by the electron beam and Q-switch Nd:YAG laser of 2.5 J/10 ns is 10^7 photons/RF-pulse (10^8 photons/sec in 10 pps). X-band beam line for the demonstration is under commissioning. We also design to adopt a technique of laser circulation to increase the X-ray yield up to 10^9 photons/pulse (10^10 photons/s). The construction of the whole system starts. X-ray generation and medical application will be performed in this year.

**RPAP007—Alternating-Phase-Focused Linac with Interdigital H-Mode Structure for Medical Injectors**
*Yoshiyuki Iwata, Takashi Fujisawa, Takuji Furukawa, Satoru Hojo, T. Honma, Mitsutaka Kanazawa, Nobuyuki Miyahara, Takeshi Murakami, Masayuki Muramatsu, Koji Noda, Hirotsugu Ogawa, Masami Torikoshi, Satoru Yamada (NIRS), Tetsuya Fujimoto, Hiroyuki Ogawa (AEC), Valery Kapin (MEPhI), Yusuke Fujii, Toshinori Mitsumoto, Hiroshi Tsutsui (SHI)*
Tumor therapy using Heavy Ion Medical Accelerator in Chiba (HIMAC) has been performed at National Institute of Radiological Sciences (NIRS). With the successful clinical results over ten years, a project on developing compact accelerators has been started. To design these compact accelerators, a size of an injector as well as construction and operation costs plays an important role. To satisfy these requirements, we propose a compact injector consisting of a RFQ and Interdigital H-mode Drift-Tube-Linac (IH-DTL) having the resonant frequency of 200 MHz. The injector will accelerate carbon ion up to 4.0 AMeV. For the beam focusing of the IH-DTL, the method of Alternating-Phase-Focusing was employed. With the IH structure and rather high operating-frequency, the size of the cavities is compact; the radius is approximately 0.4 m, and the length of the RFQ and IH-DTL will be 2.5m and 3.5m respectively. The fabrication of the RFQ is in progress. For the IH-DTL, the full-scale model was fabricated. With the encouraging results of the electric field measurements, we are developing the final design of the IH-DTL. The fabrication of the entire injector will be completed at the end of 2005. The present status of our project will be shown.

**RPAP008—The CBS: The Most Cost Effective and High Performance Carbon Beam Source Dedicated to a New Generation of Cancer Therapy Beams**
*Masayuki Kumada (NIRS), Vasily Parkhomchuk (BINP SB RAS)*
A Carbon ion beam is a superior tool to x-rays or a proton beam in both physical and biological doses in treating a cancer. A Carbon beam has an advantage in treating radiation resistant and deep-seated tumors. Its radiological effect is of a mitotic independent nature. These features improve hypofractionation, typically reducing the number of irradiations per patient from 35 to a few. It has been shown that a superior QOL(Quality Of Life) therapy is possible by a carbon beam.The only drawback is its high cost. Nevertheless, tens of Prefectures and organizations are eagerly considering the possibility of having a carbon ion therapy facility in Japan. Germany, Austria, Italy, China, Taiwan and Korea also desire to have one.A carbon beam accelerator of moderate cost is about 100 Million USD. With the "CBS" design philosophy, which will be described in this paper, the cost could be factor of 2 or 3 less, while improving its performance more than standard designs. Novel extraction techniques, a new approach to a high intensity beam, a new scanning method of a super micro beam and an extremely light weight carbon rotating gantry will be presented.This new CBS will have an impact on the medical accelerator community.

**RPAP009—Present Status of HIMAC and Carbon Ion Therapy**
*Eiichi Takada (NIRS)*
HIMAC, Heavy Ion Medical Accelerator in Chiba, has been in operation since 1994. More than 2000 cancer patients have been treated with carbon beams from HIMAC. Requirements for therapeutical beam and recent development of the beam delivery will be reported together with research utilization of ion beams.

**RPAP010—Development of Femtosecond and Atosecond Pulse Radiolysis by Using Laser Photocathode RF Gun S-Band Electron Linac**
*Yoichi Yoshida (RCNP)*
Femtosecond pulse radiolysis system based on linear accelerator was developed in Osaka University for study of radiation-induced ultra fast physical and chemical reactions. 35 MeV single electron pulse with pulse width of 100 fs was generated by using a laser photocathode rf gun s-band linac with a magnet pulse compression system. Femtosecond laser synchronized with the linac was used as analyzing light. Transient absorption was measured by the equivalent velocity spectroscopy which was a new method to get high time-resolution. Also, we have started the preliminary experiment on atosecond pulse radiolysis The double decker beam which is a new concept to realize the twin linac by using one linac will be used.

Grant-in-Aid for Scientific Research, Japan Society for the Promotion of Science.

**RPAP011—Technical Development of Profile Measurement for the Soft X-Ray Via Compton Backward Scattering**
*Taku Saito, Yoshimasa Hama, Kentaro Hidume, Ryunosuke Kuroda, Shuichi Minamiguchi, Akihiro Oshima, Daisuke Ueyama, Masakazu Washio (RISE), Shigeru Kashiwagi (ISIR), Hitoshi Hayano, Junji Urakawa (KEK)*
A compact X-ray source is called for such various fields as material development, biological science, and medical treatment. At Waseda University, we have already succeeded to generate the soft X-ray of the wavelength within so-called water window region (250-500eV) via Compton backward scattering between 1047nm Nd:YLF laser and 4.2MeV high quality electron beam. Although this method equips some useful characters, e.g. high intensity, short pulse, energy variableness, etc, the X-ray generating system is compact enough to fit in tabletop size. In the next step, there rises two principal tasks, that is, to make the soft X-ray intensity higher, and to progress X-ray profile measurement techniques as preliminary experiments for biomicroscopy. Specifically, we utilize two-pass amp for the former, and irradiate X-ray to a resist film which is previously exposed by UV lamp or get images with X-ray CCD for the latter. In this conference, we will show the experimental results and some future plans.

**RPAP012—Dual Energy X-Ray CT by Compton Scattering Hard X-Ray Source**
*Mitsuru Uesaka, Tatsuo Kaneyasu (UTNL), Katsuhiro Dobashi, Masami Torikoshi (NIRS)*
We have developed a compact Compton scattering hard X-ray source at Nuclear Engineering Research Laboratory, University of Tokyo. The compact hard X-ray source can produce tunable monochromatic hard X-rays. The monochromatic hard X-rays are required in large field of medical and biological applications. We are planning to perform dual-energy X-ray CT, which enables us to measure atomic number Z distribution and electron density re distribution in a material. The hard X-ray source has an advantage to perform dual-energy X-ray CT. The X-ray energy can be changed quickly by introducing a fundamental frequency and a second harmonic frequency lasers. This quick energy change is indispensable to medical imaging and very difficult in a large SR light source and others. The information on the atomic number and electron density will be used for treatment plan in radiotherapy as well as for identification of materials in a nondestructive test. We examined applicability of the dual-energy X-ray CT for atomic number measurement for low to medium Z elements (Z=30) by considering the X-ray profile generated by Compton scattering. Details of the numerical simulations and plans of the dual-energy X-ray CT will be reported in the conference.

**RPAP013—Characteristic Experimentations of Degrader and Scatterer at MC-50 Cyclotron**
*Seok-Ki Lee, Byung-Ho Choi, Kye-Ryung Kim, Hwa-Ryun Lee, Bum-Sik Park (KAERI)*
Building proton beam user facilities, especially deciding beam energy level, depends on the attached proton accelerator and users' needs. To adjust beam energy level, two methods are generally used. One is to directly adjust the beam in the accelerator. The other is to adjust beam energy after extracting from the accelerator. Degrader/Scatterer System has been installed in the MC-50 Cyclotron to adjust energy level of the beam used for various application fields. Its degrader and scatterer are made of Al foils and Au foils, respectively. Al thickness are 2, 1, 0.5, 0.3, 0.2, 0.1, 0.05, 0.03, 0.02, 0.01mm and Au thickness are 0.2, 0.1, 0.05, 0.03, 0.02, 0.01mm, respectively. In this study, suitable beam condition was adjusted through overlapping Al/Au foils of various thickness through simulation results. After that, LET(Linear Energy Transfer) value was indirectly acquired by measuring the bragg peak of the external beam through PMMA plastic Phantom and profile was measured by film dosimetry.

This work is a part of the "Proton Engineering Frontier Project" which is sponsored by the Ministry of Science and Technology of Korea under "21C Frontier R&D Program."

**RPAP014—Uniform Irradiation Systems Using a Rotatable Stage for Test Facilities of PEFP**
*Bum-Sik Park, Byung-Ho Choi, Kye-Ryung Kim, Seok-Ki Lee (KAERI)*
A new irradiation facility has been developed using not only electric magnets but also a rotatable stage. Generally, the scanning method using magnet has been widely used in most of facilities. However, in this study another new methods have been developed: Three scanning method using rotatable stage have been proved to make uniform irradiation-as large as 20 cm in diameter with more than 90% uniformity. The mechanical wobbler system makes the same effect as the wobbler system. And the beam is swept along the spiral path with a fixed and variable angular frequency during the scanning in two spiral scanning systems, respectively.

This work is a part of the "Proton Engineering Frontier Project" which is sponsored by the Ministry of Science and Technology of Korea under '21C Frontier R&D Program."

**RPAP015—Modeling of Internal Injection and Beam Dynamics for High Power RF Accelerator**
*Michael A. Tiunov, Vadim Auslender, Marlen Karliner, Gennady Ivanovich Kuznetsov, Ivan Makarov, Alexander Panfilov, Vladimir V. Tarnetsky (BINP SB RAS)*
A new high power electron accelerator for industrial applications is developed in Novosibirsk. Main parameters of the accelerator are: operating frequency of 176 MHz, energy of electrons of 5 MeV, average beam power up to 300 kW. The accelerator consists of a chain of accelerating cavities, connected by the on-axis coupling cavities with coupling slots in the walls. A triode RF gun on the base of grid-cathode unit placed on the wall of the first accelerating cavity is used for internal injection of electrons. The paper presents the results of modeling and optimization of the accelerating structure, internal injection, and beam dynamics.

The work is supported by ISTC grant #2550.

**RPAP016—High Power Electron Accelerator ILU-12**
*Vadim Tkachenko, Vadim Auslender, Vladimir Cheskidov, Gennady Ivanovich Kuznetsov, Ivan Makarov, Gennady Ostreiko, Alexander Panfilov, Alexey Sidorov, Vladimir V. Tarnetsky, Michael A. Tiunov (BINP SB RAS)*
In recent time the new powerful industrial electron accelerators appear on market. It caused the increased interest to radiation technologies using high energy X-rays due to their high penetration ability. However, because of low efficiency of X-ray conversion for electrons with energy below 5 MeV, the intensity of X-rays required for some industrial applications can be achieved only when the beam power exceeds 300 kW. The report describes a project of industrial electron accelerator ILU-12 for electron energy up to 5 MeV and beam power up to 300 kW specially designed for use in industrial applications. On the first stage of work we plan to use the existing generator designed for ILU-8 accelerator. It is realized on the GI-50A triode and provides the pulse power up to 1.5-2 MW and up to 20-30 kW of average power. In the report the basic concepts and a condition of the project for today are reflected.
The work is supported by ISTC grant #2550.

**RPAP017—Industrial Electron Accelerators Type ILU**
*Vadim Auslender, Alex Bryazgin, Boris Faktorovich, V.E. Nekhaev, Alexander Panfilov, Vadim Tkachenko, Alfred Tuvik, Gorbunov Valentin, Leonid Voronin (BINP SB RAS)*
The report describes the electron accelerators of ILU series covering the energy range from 0.5 to 5 MeV with beam power up to 50 kW. The pulse linear accelerators type ILU are developed since 1970 in Budker institute of Nuclear Physics and are supplied to the industry. The ILU machines are purposed for wide application in various technological processes and designed for long continuous and round-the-clock work in industrial conditions. A principle of acceleration of electrons in the gap of HF resonator is used in the ILU machines. The HF resonator has toroidal form. The electron gun is placed in one of the protruding electrodes forming the accelerating gap of the resonator. The resonator is fed from HF autogenerator realized on the industrial triode, the feedback signal is given from the resonator. The absence of outer beam injection and usage of self-excited HF generator simplify the design of accelerator and ensure its reliable operation.

**RPAP018—Identification of Nano-Objects in Substances by Using of X-Ray Electron Radiation**
*Vladislav Konstantin Grishin (MSU)*
Using opportunity of X-ray emission, arising at process of fast charge interaction with media atomic electrons, for nano-object discovery and diagnostics in substances is discussed. This kind of of X-ray emission termed as polarization bremsstrahlung radiation (PB) depends very strongly on media structure. As result spectra of PB in a media containing nano-inhomogeneities (as fullerenes, nanotubes, composite structures as fullerites) reflex structural characteristics of last ones. Fullerenes in carbon soot as example of an amorphous substance with mentioned structure inhomogeneities are considered. It is shown that spectra of PB on fullerenes contain a series of oscillations which give the valuable information about single- ore multilayers fullerene structures. The main peak of emission is placed in energy area of PB photons less than 1-1.5 keV. Here PB obtains a coherent character due to which one PB intensity is very high because it becomes to proportional square of all fullerene electrons number. Due to PB intensity depends weakly enough on observation angle, that permits to pick up PB signal from traditional bremsstrahlung radiation, and to facilitate measurement conditions.

Russian Foundation for Basic Researches, grant 03-02-16587.

**RPAP019—Further Development of Irradiation Field Forming Systems of Industrial Electron Accelerators**
*Nickolai Georgievich Tolstun, Andrey Ivanov, Valery Pavlovich Ovchinnikov, Michael Pavlovich Svinin (NIIEFA)*
Electron beam irradiation field forming systems where accelerated electron beam is scanned in a constant field of the elongated bending magnets were developed in our institute more than 15 years ago and they have a number of advantages in comparison with traditional ones. Since than they have been applied in two accelerators with energies 300 and 400 keV; version of the similar system with two electromagnets for two-side irradiation of flexible materials – in a number of 750 keV high voltage accelerators ("Electron-10") successfully operating now in several industrial lines. Systems of forming of electron beam irradiation field based on the same principle have been used in several projects, some of them already works. Electron optic characteristics of such systems and their various modifications as well as aspects of their possible usage are discussed in the paper.

**RPAP020—Fixed Field Alternating Gradient Accelerators (FFAG) for Fast Hadron Cancer Therapy**
*Eberhard Keil (CERN), Dejan Trbojevic (BNL), Andrew Sessler (LBNL)*
Cancer accelerator therapy continues to be ever more prevalent with new facilities being constructed at a rapid rate. Some of

these facilities are synchrotrons, but many are cyclotrons and, of these, a number are FFAG cyclotrons. The therapy method of "spot scanning" requires many pulses per second (typically 200 Hz), which can be accomplished with a cyclotron (in contrast with a synchrotron). We briefly review commercial scaling FFAG machines and then discuss recent work on non-scaling FFAGs, which may offer the possibility of reduced physical aperture and a large dynamic aperture. However, a variation of tune with energy implies the crossing of resonances during the acceleration process. A design can be developed such as to avoid intrinsic resonances, although imperfection resonances must still be crossed. Parameters of two machines are presented; a 250 MeV proton therapy accelerator and a 400 MeV carbon therapy machine.

AMS supported by the U.S. Department of Energy under Contract No. DE-AC03-76SF0009 # DT supported by the U.S. Department of Energy under Contract No. DE-AC02-98CH10886.

**RPAP021—A Portable Electron Radiography System**
*Frank Edward Merrill, Christopher Morris (LANL), Alan Wolfe Hunt (ISU)*
The technique of charged particle radiography has been developed and proven with 800 MeV protons at LANSCE and 24 GeV protons at the AGS. Recent work at Los Alamos National Laboratory in collaboration with the Idaho Accelerator Center has extended this diagnostic technique to electron radiography through the development of an inexpensive and portable electron radiography system. This system has been designed to use 30 MeV electrons to radiograph thin static and dynamic systems. The system consists of a compact 30 MeV pulsed electron linear accelerator coupled to a quadrupole lens magnifier constructed from permanent magnet quadrupoles. The design features and operational characteristics of this radiography system are presented as well as the radiographic performance parameters.

**RPAP022—A Study of Storage Ring Requirements for an Explosive Detection System Using NRA Method**
*Tai-Sen Wang, Thomas Kwan (LANL)*
The technical feasibility of an explosives detection system based on the nuclear resonance absorption (NRA) of gamma rays in nitrogen-rich materials was demonstrated at Los Alamos National Laboratory (LANL) in 1993 by using an RFQ proton accelerator and a tomographic imaging prototype.* The study is being continued recently to examine deployment of such an active interrogation system in realistic scenarios. The approach is to use a cyclotron and electron-cooling-equipped storage rings(s) to provide the high quality and high current proton beam needed in a practical application. In this work, we investigate the storage ring requirements for a variant of the airport luggage inspection system considered in the earlier LANL experiments. Estimations are carried out based on the required inspection throughput, the gamma ray yield, the proton beam emittance growth due to scattering with the photon-production target, beam current limit in the storage ring, and the electron cooling rate. Studies using scaling and reasonable parameter values indicate that it is possible to use no more than a few storage rings in a practical NRA luggage inspection system.
*R. E. Morgado et al., SPIE Conf. Proc. 2092, International Society for Optical Engineering, Bellingham, WA, 1993, p. 503.

U.S. Department of Energy.

**RPAP023—RF-Based Accelerators for HEDP Research**
*John William Staples, Andrew Sessler (LBNL), Peter Ostroumov (ANL,), Weiren Chou (Fermilab), Roderich Keller (LBNL/AFR)*
Accelerator-driven High-Energy Density Physics experiments require typically 1 nanosecond, 1 microcoulomb pulses of mass 20 ions accelerated to several MeV to produce eV-level excitations in thin targets, the "warm dense matter" regime. Traditionally the province of induction linacs, RF-based acceleration may be a viable alternative with recent breakthroughs in accelerating structures and high-field superconducting solenoids. A reference design for an RF-based accelerator for HEDP research is presented using 15 T solenoids and multiple-gap RF structures configured with either multiple parallel beams (combined at the target) or a single beam and a small stacking ring that accumulates 1 microcoulomb of charge. In either case, the beam is ballistically compressed with an induction linac core providing the necessary energy sweep and injected into a plasma-neutralized drift compression channel resulting in a 1 mm radius beam spot 1 nanosecond long at a thin foil or low-density target.

This work sponsored by the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**RPAP024—The ORNL Multicharged Ion Research Facility (MIRF) High Voltage Platform Project**
*Fred Wolfgang Meyer, Mark Bannister, Jerry Hale, Jim Johnson (ORNL), Denis Hitz (CEA Grenoble)*
We report on initial testing and implementation of a new high voltage platform recently installed at the ORNL MIRF. The platform is powered by a 250 kV, 30 kVA isolation transformer and features an all permanent magnet Electron Cyclotron Resonance (ECR) ion source, designed and fabricated at CEA/Grenoble, that utilizes microwave power levels of up to 750W in the frequency range 12.75 – 14.5 GHz to provide intense dc beams of singly and multiply charged ions for acceleration to energies up to 270 x q keV. The primary application of these ion beams is to study fundamental collisional interactions* of multicharged ions with electrons, atoms, and surfaces. More applied investigations in the area of ion implantation,** and ion beam development for use in semiconductor doping operations are carried out as well. Design details of the HV platform and the associated beamline-switchyard will be presented at the conference, together with performance characteristics of the all permanent magnet ECR source, of the beam transport from ion source to end-station, and of a novel electrostatic spherical sector beam switcher for directing beam to the various on-line experiments.
*F.W . Meyer, Trapping Highly Charged Ions: Fundamentals and Applications, J. Gillaspy, ed., Nova Science Pub., New York, 2000, pp. 117-164. **F. W. Meyer et al., AIP Conf. Proc. 635, p. 125 (2002).

This research was sponsored by the Office of Basic Energy Sciences, and the Office of Fusion Energy Sciences of the U.S. DOE under contract No. DE-AC05-00OR22725 with UT-Battelle, LLC.

**RPAP025—A 7 MeV S-Band Variable Pulse Length Electron Accelerator**
*Michael Hernandez, Hank Deruyter, Andrey Valentinovich Mishin, Alexander J. Saversky, Dave Skowbo, Richard Smith (AS&E)*
American Science and Engineering High Energy Systems Division (AS&E HESD) has designed and commissioned a variable pulse length 7 MeV electron accelerator system. The system is capable of delivering a 7 MeV electron beam with a pulse length of 10 nS FWHM and a peak current of 1 ampere. The system can also produce electron pulses with lengths of 20,

50, 100, 200, 400 nS and 3 uS FWHM with corresponding lower peak currents. The accelerator system consists of a gridded electron gun, focusing coil, an electrostatic deflector system, Helmholtz coils, a standing wave side coupled S-band linac, a 2.6 MW peak power magnetron, an RF circulator, a fast toroid, vacuum system and a PLC/PC control system. The system has been operated at repetition rates up to 250pps. The design, simulations and experimental results from the accelerator system are presented in this paper.

**RPAP026—Latest Results on X-Band Linac Systems for Radiation Therapy**
*Alexander J. Saversky, Hank Deruyter, Michael Hernandez, Andrey Valentinovich Mishin, Dave Skowbo (AS&E)*
The original design of AS&E X-band linear accelerator for radiation therapy is based on a 50-cm long side-coupled standing wave accelerating structure operating with a 1,5 MW magnetron. The nominal output parameters for this original system are 6 MeV, 300 R/min at 80 cm X-ray beam produced at a repetition rate of 200 pps. The first improvement of the existing accelerator system has resulted in an increased nominal dose rate of 450 R/min at 80cm at 166 pps. In order to further increase the delivered dose rate, a 60-cm waveguide with improved characteristics has been developed. This new waveguide produces dose rate of 600 R/min at 80cm at 166 pps. The accelerator sections performance data are discussed in this paper.

**RPAP027—Portable X-Band Linear Electron Accelerators for Radiographic Applications**
*Alexander J. Saversky, Hank Deruyter, Michael Hernandez, Andrey Valentinovich Mishin, Dave Skowbo (AS&E)*
The MINAC series portable linear electron accelerator systems designed and manufactured at American Science and Engineering, Inc. High Energy Systems Division (AS&E HESD) are discussed in this paper. Each system can be configured as either an X-ray or electron beam source. The powerful 4 MeV and 6 MeV linacs powered by a 1,5 MW magnetron permit operation in a dose rate range from 100 R/min at 80 cm to 600 R/min at 80 cm. Each MINAC is a self-contained source with radiation leakage outside of the X-ray head less than 0,1% of the maximum dose. Along with these systems a 1 MeV ultra compact MINAC has been successfully tested. The unit is available with radiation leakage less then 0.01% and permits producing X-ray beam in an energy range (1…2) MeV at a high output dose rate. Design and experimental parameters are presented. The common and system specific features are also discussed.

**RPAP031—250-MeV FFAG Proton Accelerator as a Medical Facility**
*Alessandro Ruggiero (BNL)*
The paper presents the design of a Fixed-Field Alternating-Gradient (FFAG) Accelerator for protons in the energy range between 25 and 250 MeV that can be used for Medical Applications. The mode of operation is pulsed at the repetition rate of 1 kHz. The proton beam intensity is about 10^11 protons per pulse. The design takes advantages of a modern approach of beam dynamics* concerning chromatic behavior and magnet compactness. Because of the relative low beam energy, and the small ring circumference, care is to be taken to include properly the focusing from the magnet bending curvature on the horizontal plane.
*A. G. Ruggiero, "Design Criteria of a Proton FFAG Accelerator," Contribution to FFAG'04 Workshop Proceedings, October 13-16, 2004, KEK, Tsukuba, Japan.

Work performed under the auspices of the U.S. Department of Energy.

**RPAP032—Hardware Tracking Related to Compact Medical Pulse Synchrotron**
*Kuninori Endo, Kazumi Egawa, Zhigao Fang, Shinji Yamanaka (KEK)*
A compact 200 MeV proton synchrotron for the radiotherapy is being developed. Dipole and quadrupole magnets were already manufactured and are ready to measure their field properties under the pulse excitation. Preliminary field measurement was already done on the prototype dipole. Small RF cavity with a wide bandwidth (2~18 MHz) was successfully developed. Concerning to the simultaneous pulse operation of these components, there are some issues to be solved beforehand. These are the tracking between dipole field and the quadruple field gradient, the RF frequency generation sensing the dipole current (or field), the sextupole field correction of the dipole and etc. These issues studied experimentally using the dipole current will be presented in conjunction with the progress of the development.

**RPAP033—Investigation of X-Ray Harmonics of the Polarized Inverse Compton Scattering Experiment at UCLA**
*Adnan Doyuran, Robert Joel England, Chan Joshi, James Rosenzweig, Sergei Tochitsky, Gil Travish, Oliver Williams (UCLA)*
We are preparing an Inverse Compton Scattering (ICS) experiment, which will investigate nonlinear properties of scattering utilizing a terawatt CO2 laser system with various polarizations at the UCLA Neptune Laboratory. When the normalized amplitude of the incident laser's vector potential a0 is larger than unity the scattering occurs in the nonlinear region; therefore, higher harmonics are also produced. ICS can be used for a polarized positron source by striking a thin target (such as Tungsten) with the polarized X-rays. As such it is critical to demonstrate the production of polarized scattered photons and to investigate the limits of the linear ICS process. We present the description and beam parameters of the experimental set up and equipment utilized including diagnostics for electron and photon beam detection. The results of a calculation tool for this experiment along with the anticipated Double Differential Spectrum (DDS) distribution and total number of photons produced is discussed. Finally, the current status and initial results of the experiment will be presented.

U.S. Dept. of Energy grant DE-FG03-92ER40693.

**RPAP034—Use Recirculator**
*Ivan Guk, Anatoly Nikolayevich Dovbnya, Stanislav Kononenko, Fedor Peev, Alexander Tarasenko (NSC/KIPT), Jan Botman, Marnix Van der Wiel (TUE)*
The opportunity of use developed in NSC KIPT recirculator SALO* with superconducting accelerating structure TESLA for reception of intensive neutron streams surveyed. As an injector it is supposed to use RF-gun with superconducting accelerating structure. An electron beam with the peak energy 130 ÌåÂ is transported on a target located apart of 100 m from recirculator. System of the focusing are designed allowing to gain on a target the required density of a beam. Tolerances on precision of an alignment of magnetooptical devices are calculated.
*I. S. Guk, A. N. Dovbnya, S. G. Kononenko, A. S. Tarasenko, M. van der Wiel, J. I. M. Botman, NSC KIPT Accelerator on Nuclear and High Energy Physics, Proceedings of EPAC 2004, Lucerne, Switzerland, p.761-764.

**RPAP035—Photonuclear and Radiation Effects Testing with a Refurbished 20 MeV Medical Electron Linac**
*Timothy Webb, Jill Ellen Petrisko, Randy Spaulding (IAC, Pocatello), Roger Assink (Sandia National Laboratories)*
An S-band 20 MeV electron linear accelerator formerly used for medical applications has been recommissioned to provide a wide range of photonuclear activation studies as well as various radiation effects on biological and microelectronic systems. Four radiation effect applications involving the electron/photon beams are described. Photonuclear activation of a stable isotope of oxygen provides an active means of characterizing polymer degradation. Biological irradiations of microorganisms including bacteria were used to study total dose and dose rate effects on survivability and the adaptation of these organisms to repeated exposures. Microelectronic devices including bipolar junction transistors (BJTs) and diodes were irradiated to study photocurrent from these devices as a function of peak dose rate with comparisons to computer modeling results. In addition, the 20 MeV linac may easily be converted to a medium energy neutron source which has been used to study neutron damage effects on transistors.

**RPAP036—A Compact 5 MeV S-Band Electron Linac Based X-Ray Source for Industrial Radiography**
*Lucrezia Auditore, Renato Calogero Barnà, Domenico De Pasquale, Umberto Emanuele, Antonio Trifirò, Marina Trimarchi (INFN & Messina University), Antonio Italiano (INFN—Gruppo Messina)*
A compact and reliable X-ray source, based on a 5 MeV, 1 kW, S-band electron linac, has been set up at the Dipartimento di Fisica, Universit\‘a di Messina. This source, coupled with a GOS scintillator screen and a CCD camera, represents an innovative transportable system for industrial radiography and X-ray tomography. Optimization of the parameters influencing the e-gamma conversion and the X-ray beam characteristics have been studied by means of the MCNP-4C2 code. The converter choice is the result of the study of the e-gamma conversion performances for different materials and materials thicknesses. Also the converter position with respect to the linac exit window was studied. The chosen converter consists in a Ta-Cu target inserted close to the linac window. The Cu layer acts as a filter both on the electrons from the source and on the low energy X-rays. The X-ray beam angular profile was studied by means of GafChromic films with and without collimation. In the final source project, a collimation system provides a 14 cm diameter X-ray spot at the sample position and first radiographyc results were obtained by inspecting different density materials and thicknesses.

**RPAP037—Study of the Dynamics in a Linac Booster for Proton Therapy in the 30-62 MeV Energy Range**
*Vittorio Giorgio Vaccaro (Naples University Federico II and INFN), Tarcisio Clauser, Antonio Rainò (Bari University), Vincenzo Variale (INFN-Bari), Maria Rosaria Masullo (INFN-Napoli), Carlo De Martinis, Dario Giove, Marco Mauri (INFN/LASA), S. Lanzone (Naples University Federico II)*
Recent results in accelerator physics have shown the feasibility of a coupling scheme between a cyclotron and a linac for proton acceleration. Cyclotrons with energies up to 30 MeV, mainly devoted to radioisotopes production, are available in a large number of medical centres. These two evidences have suggested the idea to study and design a linac booster able to increase the initial proton energy up to the values required for the treatment of tumors, like the ocular ones. Among the challenges in such a project one of the main ones is related to meet the requirement of having sufficient mean current for therapy from a given injection current coming from the cyclotron. In this paper we will review the rationale of the project in order to optimize the transmittance and to minimize the duty-cycle. In this frame we will discuss the basic design of a compact 3GHz linac with a new approach to the cavities used in a SCL (Side Coupled Linac) structure.

Istituto Nazionale di Fisica Nucleare (Naples, Milan and Bari).

**RPAP038—An Advantage of the Equivalent Velocity Spectroscopy for Femtsecond Pulse Radiolysis**
*Takafumi Kondoh, Yang Jinfeng, Takahiro Kozawa, Seiichi Tagawa, Hiroshi Tomosada, Yoichi Yoshida (ISIR)*
For studies of electron beam induced ultra-fast reaction process, femtosecond(fs) pulse radiolysis• @is under construction. To realize fs time resolution, fs electron and analyzing light pulses and their jitter compensation system are needed. About a 100fs electron pulse was generated by a photocathode RF gun linac and a magnetic pulse compressor. Synchronized Ti: Sapphire laser have a puleswidth about 160fs. And, it is significant to avoid degradation of time resolution caused by velocity difference between electron and analyzing light in a sample. In the ‘Equivalent velocity spectroscopy’ method, incident analyzing light is slant toward electron beam with an angle associated with refractive index of sample. Then, to overlap light wave front and electron pulse shape, electron pulse shape is slanted toward the direction of travel. As a result of the equivalent velocity spectroscopy for hydrated electrons, using slanted electron pulse shape, optical absorption rise time was about 1.4ps faster than normal electron pulse shape. Thus, the ‘Equivalent velocity spectroscopy’ is effective for femtosecond pulse radiolysis.
Grant-in-Aid for Scientific Research, Japan Society for the

Promotion of Science.

**RPAP039—Accelerator and Ion Beam Tradeoffs for Studies of Warm Dense Matter**
*John J. Barnard, Debra Callahan, Alex Friedman, Richard Lee, Max Tabak (LLNL), David Rose, Dale Welch (ATK-MR), Edward Lee, B. Grant Logan, Parthiban Santhanam, Andrew Sessler, John William Staples, Jonathan Wurtele, Simon Yu (LBNL), Ronald Davidson, Larry Grisham (PPPL), Richard J. Briggs (SAIC), Craig Olson (Sandia National Laboratories)*
One approach to heat a target to “Warm Dense Matter” conditions (similar, for example, to the interiors of giant planets or certain stages in Inertial Confinement Fusion targets), is to use intense ion beams as the heating source. By consideration of ion beam phase space constraints, both at the injector, and at the final focus, and consideration of simple equations of state, approximate conditions at a target foil may be calculated. Thus target temperature and pressure may be calculated as a function of ion mass, ion energy, pulse duration, velocity tilt, and other accelerator parameters. We examine the variation in target performance as a function of various beam and accelerator parameters, in the context of several different accelerator concepts, recently proposed for WDM studies.

Work performed under the auspices of the U.S. Department of Energy under University of California contract W-7405-ENG-48 at LLNL, University of California contract DE-AC03-76SF00098 at LBNL, and contract DEFG0295ER40919 at PPPL.

**RPAP040—Design of a Fast Neutral He Beam System for Feasibility Study of Charge-Exchange Alpha-Particle Diagnostics in a Thermonuclear Fusion Reactor**
*Katsuhiro Shinto, Sumio Kitajima, Mamiko Sasao, Hiroshi Sugawara, Shu Takeuchi (Graduate School of Engineering), Satoru Kiyama (AIST), Motoi Wada (Doshisha University), Osamu Kaneko, Masaki Nishiura (NIFS)*

For alpha-particle diagnostics in a thermonuclear fusion reactor, neutralization using a fast (~2 MeV) neutral He beam produced by the spontaneous electron detachment of a He- is considered most promising. However, the beam transport of produced fast neutral He has not been studied, because of difficulty for producing high-brightness He- beam. Double-charge-exchange He- sources and simple beam transport systems were developed and their results were reported in the PAC99* and other papers.** To accelerate an intense He- beam and verify the production of the fast neutral He beam, a new test stand has been designed. It consists of a multi-cusp He+ source, alkali metal gas cell for double charge exchange, a stigmatic 90 degree bending magnet as an ion separator, an accelerating tube and a free-flight tube to produce fast neutral He beam by autodetachment. The beam parameters of the He- beam are planed to be 150 keV of the beam energy and 10 uA of the beam current. A He+ beam of about 10 mA is extracted from the ion source and accelerated up to 15~25 keV for the effective charge exchange. Details of the design of the test stand and the brief result of the beam optics will be presented.
*M. Sasao et al., Proc. of PAC99, pp. 1306-1308. **M. Sasao et al., Rev. Sci. Instr. Vol.69, pp.1063-1065 (1998).

**RPAP041—Accelerator-Driven Thorium-Cycle Nuclear Power-Recent Developments**
*Peter M. McIntyre, Akhdiyor Sattarov (Texas A&M University)*
A system design has been evaluated for a GW power reactor which uses thorium as a fuel and a proton accelerator to transmute the thorium to U233 and stimulate fission. The accelerator is a flux-coupled stack of 7 isochronous cyclotrons, operating independently within a single footprint to deliver 7 2.5 MW beams of 800 MeV protons. The beams are delivered in a 6-on-1 hex pattern into a core array of thorium fuel rods immersed in molten lead. The lead serves as spallation target, moderator for the fast neutrons, heat exchange medium, and shielding. The 6-on-1 beam pattern provides uniform neutron fluence to all regions of the fuel assembly and provide excellent characteristics of fuel use, power uniformity, and cycle stability. Specific design issues for the drive accelerators and neutronics simulations of the core will be presented.

This work was supported in part by the U.S. Dept. of Energy, grant #DE-FG03-95ER40924.

**RPAP043—Beam-Based Alignment in the RHIC eCooling Solenoids**
*Peter Cameron, Ilan Ben-Zvi, William Craig Dawson, Animesh Kumar Jain, Jorg Kewisch, Vladimir N. Litvinenko, William W. MacKay, Christoph Montag, Vadim Ptitsyn, Todd Satogata, Carl Schultheiss, Vitaly Yakimenko (BNL)*
Accurate alignment of the electron and ion beams in the RHIC electron cooling solenoids is crucial for well-optimized cooling. Because of the greatly differing rigidities of the electron and ion beams, to achieve the specified alignment accuracy it is required that transverse magnetic fields resulting from imperfections in solenoid fabrication be down by five orders of magnitude relative to the pure solenoid fields. Shimming the solenoid field to this accuracy might be accomplished by survey techniques prior to operation with beam, or by methods of beam-based alignment. We report on the details of a method of beam-based alignment, as well as the results of preliminary measurements with the ion beam at RHIC

U.S. DOE.

**RPAP044—Linerizing the Response of the NSRL Synchronous Recycling-Integrators**
*Peter Oddo, Adam Rusek, Thomas Russo (BNL)*
The LBNL designed recycling-integrators used for the NSRL dosimetry feature excellent linearity. However, switching transients in the balancing source add a duty-cycle dependence to the response that manifests as a non-linearity near mid-scale and a slope-change above mid-scale. The onset of this non-linearity limits the typical usable dynamic range. Measurements during a recent run showed that at higher intensities the recycling-integrators would operate in the non-linear region enough to exceed the desired tolerance and over count the dose. This report will show how a FPGA, which implements the scalars, was used to compensate the non-linearity allowing higher dose-rates by effectively doubling the dynamic range of the dosimetry system.

Work performed under the auspices of the U.S. Department of Energy.

**RPAP045—Development of Laser-Induced Fluorescence Diagnostic for the Paul Trap Simulator Experiment**
*Moses Chung, Ronald Davidson, Philip Efthimion, Erik P. Gilson, Richard Majeski, Edward Startsev (PPPL)*
The Paul Trap Simulator Experiment (PTSX) is a cylindrical Paul trap whose purpose is to simulate the nonlinear dynamics of intense charged particle beam propagation in alternating-gradient magnetic transport systems. For the in-situ measurement of the transverse ion density profile in the PTSX device, which is essential for the study of beam mismatch and halo particle production, a laser-induced fluorescence diagnostic system is being developed. Instead of cesium, which has been used in the initial phase of the PTSX experiment, barium has been selected as the preferred ion for the laser-induced fluorescence diagnostic. The installation of the barium ion source and the characterization of the tunable dye laser system are discussed. The design of the collection optics with an intensified CCD camera system is also discussed. Finally, initial test results using the laser-induced fluorescence diagnostic will be presented.

Research Supported by the U.S. Department of Energy.

**RPAP046—Real-Time Beam Loss Monitor Display using FPGA Technology**
*Matt Richard William North, Dean Adams, Anthony Kershaw, Christopher M. Warsop (CCLRC/RAL/ISIS)*
This paper outlines the design of a Real-time Beam Loss Monitor Display for the ISIS Synchrotron based at Rutherford Appleton Laboratory (Oxon, UK). Beam loss is monitored using 39 argon filled ionisation chambers positioned around the synchrotron, the levels of which are sampled four times in each cycle. The new BLM display acquires the signals and displays four histograms, each relating to an individual sample period; the data acquisition and signal processing required to build the display fields are completed within each machine cycle (50 Hz). Attributes of the new system include setting limits for individual monitors; displaying over-limit detection, and freezing the display field when a beam trip has occurred. The design is based around a reconfigurable Field Programmable Gate Array, interfacing to a desktop monitor via the VGA standard. Results gained using simulated monitor signals have proven the system.

**RPAP047—DAQ System of BPM and BCT for the BEPCII Linac**
*Jianshe Cao, Qiang ye (IHEP Beijing)*
Following the BEPCII upgrade, total about 19 BPM and 12 BCT have been newly installed in the BEPCII Linac. Also, a set of distributed control system based on EPICS architecture has been built, and the BPM and BCT system are merged into the new

control system for the data acquisition. In order to reduce the effects of RF noise, a special gated integrator was used to measure the beam current. In this paper we will describe the DAQ system of BPM and BCT including calibrations in detail.

**RPAP048—SNS Diagnostics Timing Integration**
*Cary D. Long (Innovative Design), Willem Blokland, Darryl J. Murphy, James Pogge, John David Purcell (ORNL/SNS), Madhan Sundaram (University of Tennessee)*
The Spallation Neutron Source (SNS) accelerator systems will deliver a 1.0 GeV, 1.4 MW proton beam to a liquid mercury target for neutron scattering research. The accelerator complex consists of a 1 GeV linear accelerator, an accumulator ring and associated transport lines. The SNS diagnostics platform is PC-based running Windows XP Embedded for its OS and LabVIEW as its programming language. Coordinating timing among the various diagnostics instruments with the generation of the beam pulse is a challenging task that we have chosen to divide into three phases. First, timing was derived from VME based systems. In the second phase, described in this paper, timing pulses are generated by an in house designed PCI timing card installed in ten diagnostics PCs. Using fan-out modules, enough triggers were generated for all instruments. This paper describes how the Timing NAD (Network Attached Device) was rapidly developed using our NAD template, LabVIEW's PCI driver wizard, and LabVIEW Channel Access library. The NAD was successfully commissioned and has reliably provided triggers to the instruments. This work supports the coming third phase where every NAD will have its own timing card.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**RPAP049—Beam Diagnostics with Optical Fiber Optics**
*Yan Yin (Y.Y. Labs, Inc.)*
Optical fiber has been widely used for communications. It is a waveguide with very high-frequency bandwidth. Therefore, it has broad applications for high-frequency related signals such as high-energy Accelerator beam signls. Research and developments has been done to measure charged particle beam and synchrotron radiation with optical fiber based instruments developed by the author. The paper will describe and discuss the experiments and testing of charged particle beams and synchrotron radiation that haverecently been performed.

**RPAP050—A New Extended-Energy Neutron Dose Equivalent Monitor: The ABC1260**
*David William Flynn, Christopher Brennan, Darius Montvila, Christopher Taylor (Framework Scientific), Francesco d'Errico (Yale University)*
The ABC 1260 is a new extended-energy neutron monitor based on the superheated drop (bubble) detector technology pioneered at Yale University. Superheated drop detectors are uniform emulsions of halocarbon droplets suspended in a gel. The micron-size droplets are superheated, i.e. they are kept above their boiling point; in this thermodynamically metastable state, they can be vaporized by exposure to neutrons, but they are insensitive to photons. Superheated drop detectors present an extremely accurate dose equivalent response to neutrons, which extends to several hundred MeV thanks to the addition of high-Z converters. The device permits an optimal use of superheated drop (bubble) detectors in both research and radiation safety, and it is particularly suitable for area monitoring networks at high-energy accelerators.

## Poster Session RPAT–Instrumentation
## Meeting Room 200 A-C, 8:30-12:20

**RPAT001—Experimental Results of a Non-Destructive Emittance Measurement Device for Negatively Charged H- Beams**
*Christoph Gabor, Horst Klein, Oliver Meusel, Jürgen Pozimski, Ulrich Ratzinger (IAP)*
For the diagnostic of high power ion beams, non-destructive measurement devices should not only provide minimum influence on the beam itself, but also avoid various problems that occur when the high power density of the beam penetrates surfaces like slit- or pinhole plates. On the other hand, measurements of resolution should be comperable with destructive methods. Beams of negative ions offer the use of a non-destructive Emittance Measurement Instrument (EMI) based on the principle of photo detachment. Interaction of laser photons with the negative ions causes electron detachment. Due to moving the postion of the well collimated laser beam acros the ion beam the produced neutral atoms are well suited to detect the transverse beam emittance like a classical slit-grid device. After separation in a magnetic dipole, the neutrals can be viewed on a szintillator screen with a CCD camera. To investigate the use of such a photo detachment EMI and to study the transport of negative ions an experiment consisting of H minus ion source, electrostatic LEBT and EMI was constructed. The paper will present the setup of the experimental hardware and first results of measurements.

**RPAT002—Production of Inorganic Thin Scintillating Films for Ion Beam Monitoring Devices**
*Maurizio Re, Giuseppe A. Pablo Cirrone, Luigi Cosentino, Giacomo Cuttone, Paolo Finocchiaro (INFN/LNS), Alex Hermanne, Hugo Thienpont, Jurgen Van Erps, Michael Vervaeke, Bart Volckaerts, Pedro Vynck (VUB)*
In this work we present the development of two specific types of monitoring devices both consisting of inorganic scintillation films with thicknesses ranging between 1 and 10 microns deposited on an Aluminum support layer. In a first prototype a thin Aluminum support layer of 6 microns allows the ion beams to pass easily through it without significant energy loss and scattering effects. Therefore it turns out to be a non-destructive monitoring device to characterize beam shape and beam position without interfering with the rest of the irradiation process. A second device consists of an Aluminum support layer which is thick enough to completely stop the impinging ions allowing to monitor at the same time the beam profile and the beam current intensity. In order to develop radiation hard beam monitors, we preferred to use inorganic scintillation materials like Al2O3(Cr), CsI(Tl). In this contribution we discuss different deposition techniques to obtain layers with an optimal scintillation quality. Furthermore we present our first scintillation experimental results obtained in a joint irradiation program for Proton and Carbon ion beams from 8 to 60 MeV/u.

**RPAT003—SLIM (Secondary Emission Monitor for Low Interception Monitoring)—An Innovative Non-Destructive Beam Monitor for the Extraction Lines of a Hadrontherapy Centre**
*Laura Badano, Ornella Ferrando (TERA), Gianni Molinari (CERN)*
Real time monitoring of hadrontherapy beam intensity and profile is a critical issue for the optimisation of dose delivery to carcinogenic tissue, patient safety and operation of the accelera-

tor complex. For this purpose an innovative beam monitor, SLIM (Secondary electron emission for Low Interception Monitoring) is being developed in the framework of the EC-funded SUCIMA (Silicon Ultra-fast Cameras for electrons and gamma sources In Medical Application) project. The detector system is based on the secondary emission of electrons by a non-perturbative, sub-micron thick Al foil placed directly in the extracted beam path. The secondary electrons, accelerated by an electrostatic focusing system, are detected by a monolithic silicon position-sensitive sensor, which provides the beam intensity and its position with a precision of 1 mm at a 10 kHz frame rate. The results of the laboratory tests of the first system prototype with thermoionic electrons emitted from a hot Tungsten wire are presented together with the measurements performed on a low intensity hadron beam at the Cyclotron of the Joint Research Centre in Ispra.

This work is supported by the European Commission under the contract G1RD-CT2001-00561.

**RPAT004—Beam Profile Measurement with Wire Scanners for J-PARC Linac**

*Hisashi Akikawa, Kazuo Hasegawa, Tomohiro Ohkawa, Hiroshi Yoshikawa (JAERI), Fumio Hiroki, Junichi Kishiro, Yasuhiro Kondo, Hironao Sakaki, Susumu Sato, Mikio Tanaka, Tetsuo Tomisawa, Akira Ueno (JAERI/LINAC), Zenei Igarashi, Masanori Ikegami, Seishu Lee, Kazuyuki Nigorikawa, Takeshi Toyama (KEK)*

The Japan Proton Accelerator Research Complex (J-PARC) is being constructed. The beam tests and the R&D of the monitors for the J-PARC linac have been performed at KEK. In this paper, we report the measurements of beam profiles with wire scanners at J-PARC linac which was commissioned at KEK. The beam profile of a 3MeV H- beam was measured with four wire scanners on the Medium Energy Beam Transport (MEBT) after the RFQ. Each wire scanner has two 7um-diameter carbon wires. The polarity of signals and the reconstructed profiles from the signals are depend on the bias voltage on the wires. We also discuss the proper bias voltage to measure the profile of a 3MeV H- beam.

**RPAT005—Beam Diagnostics for the J-PARC Main Ring Synchrotron**

*Takeshi Toyama, Dai Arakawa, Yoshinori Hashimoto, Seishu Lee, Takako Miura, Suguru Muto (KEK), Naoki Hayashi, Junichi Kishiro, Ryoji Toyokawa (JAERI/J-PARC)*

Beam diagnostics: beam intensity monitors (DCCT, SCT, FCT, WCM), beam position monitors (ESM), beam loss monitors (proportional chamber, air ion chamber), beam profile monitors (secondary electron emission, gas-sheet) have been designed, tested, and will be installed for the Main Ring synchrotron of J-PARC (Japan Proton Accelerator Research Complex). This paper describes the basic design principle and specification of each monitor, with a stress on how to cope with high power beam (average circulation current of ~12 A) and low beam loss operation (less than 1 W/m except a collimator region). Some results of preliminary performance test using present beams and a radiation source will be reported.

**RPAT006—Design and Initial Tests of a Gas Scattering Energy Monitor in the PEFP RFQ and DTL**

*Sang-Hyo Han, Yong-Sub Cho (KAERI)*

We have developed a gas scattering energy monitor to measure the energy spectrum of the proton beam at the end of 3MeV RFQ and 20MeV DTL for the low energy part of the PEFP(Proton Engineering Frontier Project). The energy monitor is comprised of a Xe scattering chamber, two collimators to reduce the beam intensity, and a surface barrier detector for measuring the proton energy. In order to measure the beam current simultaneously, a faraday cup is incorporated into the energy monitor. The calculated flux attenuation through the 0.2 mm diameter collimator is 3e-4 and the energy loss is 28 keV. We report on design details and multiple gas scattering of proton beams in Xe gas by using a SRIM code.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**RPAT007—Status of Beam Diagnostic Systems for the PEFP**

*Jangho Park, Jung Yun Huang, Woon Ha Hwang, Yong Woon Parc, Sung-Ju Park (PAL), Yong-Sub Cho, Byung-Ho Choi, Sang-Hyo Han (KAERI)*

A proton linear accelerator is currently the construction at the KAERI (Korea Atomic Research Institute) to the PEFP (Proton Engineering Frontier Project) in Korea. We are accomplished the technique development of beam diagnostic system to be currently the construction. We treat beam diagnostics for the high power proton linear accelerator. Prototype beam position & phase monitor (BPPM) electronics was made and tested successfully in one of the beam diagnostic systems. The beam position monitor pickup electrode is a capacitive type (electrostatic type) which has a button form. Button form electrode, in common use around electron synchrotrons and storage rings, are a variant of the electrode with small button form (e.g., sub mm diameter). However, we are designed button form electrode to measure beam position of proton beam. The BCM (Beam Current Monitor) is developed Tuned CT (Current Transformer) for collaborate with Bergoz Instruments. This paper describes the status of beam diagnostic systems for the PEFP.

Supported by the PEFP (Proton Engineering Frontier Project).

**RPAT008—Prototype Digital Beam Position and Phase Monitor for the 100-MeV Proton Linac of PEFP**

*In-Ha Yu, Do Tae Kim, Sung-Chul Kim, In-Soo Park, Sung-Ju Park (PAL), Yong-Sub Cho (KAERI)*

The PEFP (Proton Engineering Frontier Project) at the KAERI (Korea Atomic Energy Research Institute) is building a high-power proton linear accelerator aiming to generate 100-MeV proton beams with 20-mA peak current (pulse width and max. repetition rate of 1 ms and 120 Hz respectively). We are developing a prototype digital BPPM (Beam Position and Phase Monitor) for the PEFP linac utilizing the digital technology with field programmable gate array (FPGA). The RF input signals are down converted to 10 MHz and sampled at 40 MHz with 14-bit ADC to produce I and Q data streams. The system is designed to provide a position and phase resolution of 0.1% and 0.1? RMS respectively. The fast digital processing is networked to the EPICS-based control system with an embedded processor (Blackfin). In this paper, the detailed description of the prototype digital beam position and phase monitor will be described with the performance test results.

Work supported by the PEFP (Proton Engineering Frontier Project), Korea.

**RPAT009—FPGA-Based Instrumentation for the Fermilab Antiproton Source**

*Bill Ashmanskas, Sten Hansen, Terry Kiper, David Peterson (Fermilab)*

We have designed and built low-cost, low-power, ethernet-based circuit boards to apply DSP techniques to several instrumentation upgrades in the Fermilab Antiproton Source. Commodity integrated circuits such as direct digital synthesizers, D/A and A/

D converters, and quadrature demodulators enable digital manipulation of RF waveforms. A low cost FPGA implements a variety of signal processing algorithms in a manner that is easily adapted to new applications. An embedded microcontroller provides FPGA configuration, control of data acquisition, and command-line interface. A small commercial daughter board provides an ethernet-based TCP/IP interface between the microcontroller and the Fermilab accelerator control network. The board is packaged as a standard NIM module. Applications include Low Level RF control for the Debuncher, readout of transfer-line Beam Position Monitors, and narrow-band spectral analysis of diagnostic signals from Schottky pickups.

**RPAT010—Development of a New Data Acquisition System for the Fermilab Beam Loss Monitors**
*Alan Baumbaugh, Craig Drennan, Kelly Knickerbocker, Jonathan Lewis, Alberto Marchionni, Cecil Needles, Marvin Olson, Stephen Pordes, Michael Utes (Fermilab)*
A new digitizing and data acquisition system for the beam loss monitors is being developed for use in several accelerators of the Fermilab complex. In addition to providing diagnostic information about beam loss, the loss monitor system is designed to provide a primary protection against damage to the superconducting magnets of the Tevatron. Protecting the Tevatron magnets over the full set of Collider operating conditions requires the abort logic and thresholds to be flexible and reconfigurable quickly from stored settings. A digitizer card is the core component of the system. It integrates and digitizes the current from the loss monitor chambers each beam revolution period (21 ms), maintains three running sums of up to 64k measurements, and compares the measurements and sums to programmable abort thresholds. In this paper we report on the overall system design.

This work supported by the U.S. Department of Energy under contract no. DE-AC02-76CH03000.

**RPAT011—Digital Signal Processing the Tevatron BPM Signals**
*Gugstavo I. Cancelo (Fermilab)*
The Beam Position Monitor (BPM) readout system at Fermilab's Tevatron has been updated and is currently being commissioned. The new BPMs use new analog and digital hardware to achieve better beam position measurement resolution. The new system reads signals from both ends of the existing directional stripline pickups to provide simultaneous proton and antiproton position measurements. The signals provided by the two ends of the BPM pickups processed by analog band-pass filters and sampled by 14-bit ADCs at 74.3MHz. A crucial part of this work has been the design of digital filters that process the signal. This paper describes the digital processing and estimation techniques used to optimize the beam position measurement. The BPM electronics must operate in narrow-band and wide-band modes to enable measurements of closed-orbit and turn-by-turn positions. The filtering and timing conditions of the signals are tuned accordingly for the operational modes. The analysis and the optimized result for each mode is presented.

Fermi National Accelerator Lab.

**RPAT012—A Hardware Transverse Beam Frequency Response Simulator**
*Jia Ning, Cheng-Yang Tan (Fermilab)*
We build an electronical instrument to get the frequency response close to the pattern of transverse beam frequency response. The method is to apply 1)a time delay circuit with ADC, FIFO RAM and DAC; 2)a phase shift circuit which is an all pass filter with adjustable phase shift in the frequency range of 25kHz to 30kHz; in a feedback loop of 3)a commutating filter which is a high Q band pass filter. We can dynamically adjust the center frequency, the side band distance during the testing. With this instrument, some beam instruments can be tested without using the real beam.

Fermi National Accelerator Lab.

**RPAT013—Signal Processing for Longitudinal Parameters of the Tevatron Beam**
*Stephen Pordes, Brian Fellenz, Robert Henry Flora, Adam Para, Alvin V. Tollestrup (Fermilab)*
The time profiles of the bunches in the Tevatron are obtained by sampling the output of a resistive wall current monitor with a 5GS/s, 2GHz bandwidth, Lecroy 6200 oscilloscope. The techniques for removing the effect of cable dispersion and for extending the dynamic range of the data by splitting the signal and using two input channels at different gains are described. The algorithms for taking these data in the time domain and deriving the momentum spread and longitudinal emittance are also given.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**RPAT014—Measuring Out-of-Bucket Protons in the Fermilab Booster Neutrino Beam**
*Eric Prebys (Fermilab)*
This poster describes a scintillator telescope which is used to monitor the beam structure of the intense 8 GeV proton beam which is used to the MiniBooNE neutrino experiment. The purpose of the spectrometer is to statistically determine the amount of out-of-bucket beam with 10E-5 accuracy, in order to properly characterize background for certain exotic particle searches.

Department of Energy.

**RPAT015—First Results of a Digital Beam Phase Monitor at the Tevatron**
*Jean-Paul Carneiro, Jim Steimel (Fermilab)*
A digital Beam Phase Monitor has been installed on the Tevatron ring. This device will be mainly use to diagnose the energy oscillations of each of the 36 × 36 protons and antiprotons bunches as well as to study the transient beam loading. The first results obtained from the Beam Phase Monitor will be presented on the paper.

**RPAT016—Tevatron PLL Tune Tracking Results**
*Cheng-Yang Tan (Fermilab)*
The Tevatron tune tracker is based on the idea that the phase of the transverse frequency response of the beam can be measured quickly and accurately enough to act as an error source for a phase~locked loop (PLL) that tracks the betatron tune. In this paper, a mathematical model of this idea is discussed and is used as the basis for the realization of the tune tracker hardware. The tune tracker has been successfully tested under different beam conditions in the Tevatron and in particular tracking up the ramp will be highlighted here.

**RPAT017—Using Time Separation of Signals to Obtain Independent Proton and Antiproton Beam Position Measurements Around the Tevatron**
*Robert C. Webber (Fermilab)*
Independent position measurement of the counter-circulating proton and antiproton beams in the Tevatron presents a challenge to upgrading the Tevatron Beam Position Monitor (BPM) system. The inherent directionality of the Tevatron BPM pickup design provides 26dB isolation between signals from the two beams. At the present typical 10:1 proton-to-antiproton bunch intensity ratio, this isolation alone is insufficient to support millimeter accuracy antiproton beam position measurements due to interfering proton signals. An accurate and manageable solution to the interfering signal problem is required for antiproton measurements now and, as machine improvements lead to increased antiproton intensity, will facilitate future elimination of antiproton bias on proton beam position measurements. This paper discusses the possibilities and complications of using time separation of the two beam signals at the numerous Tevatron BPM locations and given the dynamic longitudinal conditions of Tevatron operation. Results of measurements results using one such method are presented.

Fermilab is operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**RPAT018—Simultaneous Position Measurements of Protons and Anti-Protons in the Tevatron**
*Robert Kenneth Kutschke, Michael A. Martens, Jim Steimel, Robert C. Webber, Stephen Wolbers (Fermilab)*
Fermilab has embarked upon a program to upgrade the electronics of the Beam Position Monitor (BPM) system that measures the transverse position of the beams inside the Tevatron collider. The new system improves on the current system in precision, accuracy and reliability. A new feature in the upgraded system is the ability, when both protons and anti-protons are present in the Tevatron, make simultaneous measurements of the closed orbit position of both beam species. The method chosen for achieving the simultaneous measurement is an algorithm that deconvolutes the imperfect directionality of the BPM pickups from the raw measurements. This paper will discuss the algorithm, the calibration of the parameters used by the algorithm and the robustness of the algorithm. It will also present results from the upgraded system which demonstrate that the system meets the requirements set out at the start of the upgrade project.

**RPAT019—Use of a Reconfigurable VME Module To Measure Beam Energy at the Los Alamos Proton Storage Ring**
*Robert Merl, Thomas Spickermann (LANL)*
Custom instrumentation has been developed at the Los Alamos Neutron Science Center to measure the Proton Storage Ring (PSR) beam energy. The PSR accumulates up to 4x10^13 protons from the linear accelerator for delivery to a spallation neutron source. The energy of the beam injected into the PSR must be adjusted so that the revolution frequency matches the ring buncher frequency, otherwise a large momentum spread will cause increased losses in high-dispersion areas. Errors in injected beam energy appear as deviations from the ideal revolution frequency. A low-cost, custom, reconfigurable VME module has been adapted to calculate the PSR revolution frequency in real-time. The module connects directly to an analog wall current monitor output and uses analog signal conditioning electronics, an analog to digital converter, field programmable gate arrays, and an embedded floating-point digital signal processor to calculate the revolution frequency. This is an improvement over the previously used method of manually measuring the frequency with an oscilloscope. Accelerator physicists can now simply observe the PSR frequency, which is dependent on beam energy, on a control room display.
LA-UR-04-8661.

U.S. Department of Energy.

**RPAT020—Development of the LANSCE Injection Line and Transition Region Profile Monitor System**
*Robert Merl, J. Douglas Gilpatrick, John F. Power, Fred E. Shelley (LANL)*
Custom electronics is being developed at the Los Alamos Neutron Science Center (LANSCE) to replace the existing injection line and transition region profile monitors. Each monitor consists of 76 individual wires that can be inserted into the path of the beam. Although there are 28 monitors, there is only electronic support for two. So only two monitors may be used at any one time. The monitors are currently selected by manually connecting several sets of multi-conductor cables between the active monitors and the processing electronics. This requires a control room operator to be present at the injector, which is about a half of a mile from the control room. The new system under development is sufficiently cost effective to allow each profile monitor to have its own set of associated data acquisition and processing electronics. With this new configuration, there is no need to place a person at the accelerator front end to manually patch cables and data may be taken from all 28 monitors simultaneously. Furthermore, the new system allows for a wider range of beam currents, wider bandwidth, and faster recovery time between beam gates.
LA-UR-04-8674

U.S. Department of Energy.

**RPAT021—1-MeV Electrostatic Ion Energy Analyzer**
*Frank Bieniosek, Matthaeus Leitner (LBNL)*
We describe a high resolution (a few x 1e-4) 90-degree cylindrical electrostatic energy analyzer for 1-MeV (singly ionized) heavy ions for experiments in the Heavy Ion Fusion Virtual National Laboratory. By adding a stripping cell, the energy reach of the analyzer is extended to 2 MeV. This analyzer has high dispersion in a first-order focus with bipolar deflection-plate voltages in the range of +-50 kV. We will present 2- and 3-D calculations of vacuum-field beam trajectories, space-charge effects, field errors, and a multipole corrector. The corrector consists of 12 rods arranged in a circle around the beam. Such a corrector has excellent properties as an electrostatic quadrupole, sextupole, or linear combination. The improved energy diagnostic will allow measurements of beam energy spread, such as caused by charge exchange or temperature anisotropy, and better understanding of experimental results in planned longitudinal beam studies. Examples for such experiments include investigations of a beam patching pulser to correct errors in the head and tail of the transported beam bunch, and energy errors derived from ripples in the injector voltage waveform.

Work performed under the auspices of the U.S. Department of Energy by the university of California, Lawrence Berkeley National Laboratory under Contract No. DE-AC03-76F00098.

**RPAT022—Optical Faraday Cup for Heavy Ion Beams**
*Frank Bieniosek, Shmuel Eylon, Prabir Kumar Roy, Simon Yu (LBNL)*
We have been using alumina scintillators for imaging beams in heavy-ion beam fusion experiments in 2 to 4 transverse dimensions.* The scintillator has limitations on lifetime, linearity, and

time response. As a possible replacement for the scintillator, we are studying the technique of imaging the beam on a gas cloud. A gas cloud for imaging the beam may be created on a solid hole plate placed in the path of the beam, or by a localized gas puff. It is possible to image the beam using certain fast-quenching optical spectral lines that closely follow beam current density and are independent of gas density. We describe this technique and show experimental data using a nitrogen line at 394.1 nm. This approach has promise to be a new fast beam current diagnostic on a nanosecond time scale.
*FM Bieniosek, L Prost, W Ghiorso, Beam imaging diagnostics for heavy ion beam fusion experiments, Paper WPPB050, PAC 2003.

Work performed under the auspices of the U.S. Department of Energy by the university of California, Lawrence Berkeley National Laboratory under Contract No. DE-AC03-76F00098.

**RPAT023—Development of Diagnostics for the Neutralized Ion Beam Drift Compression Experiments (NDCX)**
*Shmuel Eylon, Frank Bieniosek, Wayne Greenway, Enrique Henestroza, Prabir Kumar Roy, Simon Yu (LBNL), Ronald Davidson, Erik P. Gilson, Adam Sefkow (PPPL)*
Ion beam neutralization and drift compression experiments are designed to study the feasibility of using compression high energy density ion beams for high energy density physics (HEDP) and Fusion Energy research. In this experiment an ion beam of approximately 300kV, 30mA, K+ is used and compressed into nsec duration by a velocity tilt core and mm size range by a one meter-long plasma column. We are developing several fast diagnostics, such as Faraday cup, wire current monitor (measured response >0.5nsec), Fast photo multipliers system and gas scintillator to measure short beam duration, and to use in the NDCX experiments. Simulation and experimental data of the diagnostic will be presented.

This work was supported by the Director, Office of Science, Office of Fusion Energy Sciences, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**RPAT025—RHIC Zero-Degree Calorimeter Spectrum Analyzer Design**
*Justin Gullotta, Angelika Drees, Thomas Russo, Charles Theisen (BNL)*
The Zero-Degree Calorimeters (ZDCs) are designed to detect the occurance of a collision at the interaction regions of RHIC. They detect the neutron that is created by a neucleon-on-neucleon collision that travels tangent to the ring, being that it is unaffected by the dipole field. In this way the neutron is filtered out from charged particles. In this work, we describe the design and verification of custom electronics intended to create an energy spectrum of the incident neutrons on the ZDC pickup. The signal parameters are given along with the method for the electronics design, and experimental results are presented and interpreted.

Work performed under the auspices of the U.S. Department of Energy.

**RPAT026—RHIC Electron Detector Front-End Electronics Design**
*Justin Gullotta, Ubaldo Iriso, Thomas Russo, S.Y. Zhang (BNL)*
At RHIC, beam induced pressure rises have become a major limitation of beam intensity during normal operations. To characterize this phenomenon, electron detectors have been installed in the ring at several warm straight sections. An effort to design better signal processing hardware has been ongoing, the result of which is the core of this paper. In the past, all the electron detectors have had AC coupled amplifiers in order to withstand the large bias voltages at their inputs. Since valuable information about the electron cloud can be at frequencies lower than the cutoff frequency of the AC coupled electronics, a custom front-end DC amplifier has been designed to withstand and reject relatively large input bias voltages. In this paper, the system parameters are reviewed, the electronics design is explained, and experimental results are presented.

Work performed under the auspices of the U.S. Department of Energy.

**RPAT027—Tomographic Measurement of Longitudinal Emittance Growth Due to Stripping Foils**
*Christoph Montag, Leif Ahrens, Peter Thieberger (BNL)*
During beam acceleration at the Brookhaven accelerator complex, heavy ions are stripped off their electrons in several steps. Depending on the properties of the stripping foils, this process results in an increased energy spread and therefore longitudinal emittance growth. A tomographic phase space reconstruction technique has been applied to quantify the associated emittance growth for different stripping foil materials.

Work performed under the auspices of the U.S. Department of Energy.

**RPAT028—RHIC BPM System Modifications and Performance**
*Todd Satogata, Peter Cameron, Phil Cerniglia, John Cupolo, Anthony J. Curcio, William Craig Dawson, Christopher Degen, Justin Gullotta, Joe Mead, Thomas Russo, Robert Sikora (BNL)*
During beam acceleration at the Brookhaven accelerator complex, heavy ions are stripped off their electrons in several steps. Depending on the properties of the stripping foils, this process results in an increased energy spread and therefore longitudinal emittance growth. A tomographic phase space reconstruction technique has been applied to quantify the associated emittance growth for different stripping foil materials.

Work performed under the auspices of the US Department of Energy.

**RPAT029—Update on RHIC Schottky Diagnostics**
*Kurt Vetter, Peter Cameron, John Cupolo, Christopher Degen, Roger C. Lee (BNL)*
There are two operational Schottky diagnostics systems for the 5th run of RHIC that started in November 2004. A Low Frequency Schottky system processes signals from the 245MHz resonant PLL stripline pickup and a High Frequency system that processes signals from a resonant high-Q 2GHz cavity. Cavity The objective of the Low Frequency system is to provide tune and chromaticity measurements at injection and through the ramp where the narrow linewidth allow greater measurement precision. The High Frequency system is utilized at store to provide tune, tune-spread, chromaticity and emittance as secondary parasitic measurements to other independent methods for each parameter. The High Frequency system will also be used to analyze stochastic beam cooling development during the run. This report will present the system architectures and measurement results.

U.S. Department of Energy.

**RPAT030—Beam Position Electronics for Transfer Lines in the Fermilab Accelerator Complex**
*Nathan Eddy, Claudio Hector Rivetta (Fermilab)*
There are two operational Schottky diagnostics systems for the 5th run of RHIC that started in November 2004. A Low Frequency Schottky system processes signals from the 245MHz resonant PLL stripline pickup and a High Frequency system that processes signals from a resonant high-Q 2GHz cavity. Cavity The objective of the Low Frequency system is to provide tune and chromaticity measurements at injection and through the ramp where the narrow linewidth allow greater measurement precision. The High Frequency system is utilized at store to provide tune, tune-spread, chromaticity and emittance as secondary parasitic measurements to other independent methods for each parameter. The High Frequency system will also be used to analyze stochastic beam cooling development during the run. This report will present the system architectures and measurement results.

U.S. Department of Energy.

**RPAT031—Beam Profile Measurement with Flying Wires at the Fermilab Recycler Ring**
*Martin Hu, Peter Wilson (Fermilab)*
The Fermilab Recycler Ring is a high vacuum fixed energy antiproton storage ring with stochastic and electro cooling systems. Flying wires were installed at the Fermilab Recycler Ring for transverse beam profile measurement. The following note describes the configuration, calibration and resolution of the flying wire system, as well as analysis of the transverse beam profile in the presence of both cooling systems.

**RPAT032—An Ionization Profile Monitor for the Tevatron**
*Andreas Jansson, Mark Bowden, Kwame Bowie, Alan Bross, Robert Dysert, Thomas Fitzpatrick, Richard Kwarciany, Carl Lundberg, Hogan Nguyen, Claudio Hector Rivetta, David Slimmer, Linda Valerio, James Zagel (Fermilab)*
Primarily to study emittance blowup during injection and ramping, an ionization profile monitor has been developed for the Tevatron. It is based on a prototype installed in the Main Injector, although with extensive modifications. In particular, the electromagnetic shielding has been improved, the signal path has been cleaned up, and provisions have been made for an internal electron source. Due to the good Tevatron vacuum, a local pressure bump is introduced to increase the primary signal, which is then amplified by a microchannel plate and detected on anode strips. For the DAQ, a custom ASIC developed for the CMS experiment is used. It is a combined charge integrator and digitizer, with a sensitivity of a few fC, and a time-resolution that allows single bunch measurement. Digitization is done in the tunnel to reduce noise. Preparations for detector installation were made during the long 2004 shutdown, with the installation of magnets, vacuum chambers, vacuum pumps and cabling. The actual detector will be installed sometime during the spring fo 2005. This paper describes the design of the detector and associated electronics and presents various bench test results.

Work supported by the U.S. Department of Energy.

**RPAT033—Beta Function Measurement in the Tevatron Using Quadrupole Gradient Modulation**
*Andreas Jansson, Paul Lebrun, James T. Volk (Fermilab)*
Early in Run2, there was an effort to compare the different emittance measurements in the Tevatron (flying wires and synchtotron light) and understand the origin of the observed differences. To measure the beta function at a few key locations near the instruments, air-core quadrupoles were installed. By modulating the gradient of these magents and measuring the effect on the tune, the lattice parameters can be extracted. Initially, the results seem to disagree with with other methods. At the time, the lattice was strongly coupled due to a skew component in the main dipoles, caused by sagging of the cryostat. After a large fraction of the superconducting magnets were shimmed to remove a strong skew quadrupole component, the results now agree with expectations, confirming that the beta function is not the major error source of discrepancy in the emittance measurement.

Work supported by the U.S. Department of Energy.

**RPAT034—The Upgraded Synchrotron Light Monitor at the Tevatron**
*Eugene Lorman, Randy Thurman-Keup (Fermilab)*
The Synchrotron Light Monitor in the Tevatron has been upgraded as part of the instrumentation improvements for Run II. The new system is able to sample proton and antiproton bunches and the DC Proton Beam in the abort gaps. The improved triggering and gating system as well as a new Video Image Grabber allow the instrument to measure both the bunched and the DC beam which differ by a factor over 10^3 in intensity. The two dimensional profiles produced by the instrument allow users to monitor the transverse position and transverse profile of the beam throughout the length of a store. The features of the system which allow its successful operation are described.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the U.S. Department of Energy.

**RPAT035—Development of an Optical Transition Radiation Detector for Profile Monitoring of Antiproton and Proton Beams at FNAL**
*Victor Scarpine, Carl Lindenmeyer, Gianni Tassotto (Fermilab), Alex Lumpkin (ANL)*
Optical transition radiation (OTR) detectors are being developed at Fermi National Acceleratory Laboratory (FNAL) as part of the collider Run II upgrade program and as part of the NuMI primary beamline. These detectors are designed to measure 150 GeV antiprotons as well as 120 GeV proton beams over a large range of intensities. Design and development of an OTR detector capable of measuring beam in both directions down to beam intensities of ~5e9 particles for nominal beam sizes is presented. Applications of these OTR detectors as an on-line emittance monitor for both antiproton transfers and reverse-injected protons, as a Tevatron injection profile monitor, and as a high-intensity beam profile monitor for NuMI are discussed. In addition, different types of OTR foils are being evaluated for operation over the intensity range of ~5e9 to over 1e13 particles per pulse and these are described.

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**RPAT036—Measurement of the Intensity of the Beam in the Abort Gap at the Tevatron Utilizing Synchrotron Light**
*Randy Thurman-Keup, Thomas Meyer, Stephen Pordes (Fermilab), Stefano De Santis (LBNL)*
The beam bunches in the Tevatron are arranged to provide gaps in time for the abort kickers to ramp to full field. The presence of even a small fraction (few 10^-4)of the beam in the abort gaps can induce quenches of the superconducting magnets and inflict

severe radiation damage on the silicon detectors of the experiments. Techniques for calibrating and measuring the intensity of the beam in the abort gap using synchrotron light and a gated photomultiplier tube are described. Measurements of the evolution and longitudinal profile of the beam in the abort gap are presented.

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the U.S. Department of Energy.

**RPAT037—Development of the Laser Based 3-D Beam Profile Monitor System for the J-PARC Linac**
*Seishu Lee (KEK)*
A Q-switched Nd:YAG laser diagnostic system has been developed in J-PARC (Japan Proton Accelerator Research Complex) linac. The laser beam is scanned across the H- beam to neutralize negative ions, and stripped electrons are guided into the collector by the external dipole magnet. In order to demonstrate the feasibility of laser wire scanner, two prototype electron collectors are constructed. One is a conventional collector with electron repeller grid. The background electrons due to residual gas atoms and/or intense beam loss are discriminated by grid potential. In addition, momentum spread and space potential profile will be evaluated by scanning the grid potential. The other is composed of electron multiplier tube with an entrance slit and deflector plate to resolve the photodetached electrons. The transverse 2-D beam profile can be measured by scanning the laser wire and deflection field. The full 3-D beam profile measurement must be carried out by the mode locked Nd:YAG laser with about 15 psec pulse duration. In this paper, preliminary results of design and experimental study of laser based beam profile monitor system are reported.

**RPAT038—Diagnostic for Electron Clouds Trapped in Quadrupole Magnets**
Robert James Macek (LANL/LANSCE), Andrew Arnold Browman (TechSource)
Simulations have indicated that electron clouds generated by beam-induced multipactor can be trapped in the mirror-like fields of magnetic quadrupoles and thereby contribute significantly to the electron cloud buildup in high intensity accelerators and storage rings. This could be the most important source of electrons driving the two-stream (e-p) instability at the Los Alamos PSR and may also play a significant role in electron cloud effects at some of the new high intensity accelerator projects. We will describe the physics design and optimization of an electron-sweeping detector designed to measure the trapped electrons at various times after the beam pulse has passed. The instrument can also serve as an electro-magnetically shielded detector providing a signal obtained from electrons striking the wall during the passage of beam bunches.

Work supported by a DOE SBIR Phase I grant DE-FG02-04ER84105.

**RPAT039—Feasibility Study of Using an Electron Beam for Profile Measurements in the SNS Accumulator Ring**
*Alexander V. Aleksandrov, Saeed Assadi, Sarah M. Cousineau, Viatcheslav V. Danilov, Stuart Henderson, Michael Plum (ORNL/SNS), Pavel Logatchev, Aleksander Starostenko (BINP SB RAS)*
The design goal for the SNS ring is to accumulate 2e14 protons per 1ms pulse at a 60Hz repetition rate. Achieving the design beam intensity with acceptable losses is a challenging task, which could be tackled more easily if reliable measurements of the beam profile in the ring are available. The high power density of the beam precludes the use of conventional wire scanners or harps and therefore non-interceptive types of profiles measurements are required. The electron beam probe method was suggested for measuring profiles in high power beams. In this method, deflection of a low energy electron beam by the collective field of the high intensity beam is measured. The charge density in the high intensity beam can be restored under certain conditions or estimated by various mathematical techniques. We studied the feasibility of using the electron beam probe for the SNS accumulator ring using computer simulations of the diagnostic setup. A realistic electron gun model and realistic proton beam distributions were used in the simulations. Several profile calculation techniques were explored and the results are reported in this paper.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**RPAT040—Matching BPM Stripline Electrodes to Cables and Electronics**
*Craig Deibele (ORNL/SNS), Sergey Kurennoy (LANL)*
The Spallation Neutron Source (SNS) is an accelerator-based neutron source being built at Oak Ridge National Laboratory. The 805-MHz coupled-cavity linac (CCL) accelerates an H- beam from 86 to 186 MeV, while the 805 MHz superconducting-cavity linac (SCL) accelerates the beam to its final energy of 1 GeV. The SNS beam position monitors (BPMs) which are used to measure both position and phase of the beam relative to the master oscillator, have the dual-planed design with four one-end-shorted stripline electrodes. We argue that the BPMs are optimally broadband matched to the cabling and electronics when the geometrical mean of the sum-mode and quadrupole-mode impedances is equal to the external-line impedance, 50 Ohms. The analytical results, MAFIA and HFSS simulations, wire measurements, and beam measurements that support this statement are presented.

This work was supported by SNS through UT-Batelle, LLC, under contract DE-AC05-00OR22725 for the U.S. DOE. The SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**RPAT041—Microbunch Measurement in the SNS Linac Using BPM Electrodes**
*Craig Deibele, Alexander V. Aleksandrov, John Galambos, Stuart Henderson (ORNL/SNS)*
Several techniques exist for measuring the microbunch structure of the bunches in the SNS Linac. Several standard techniques have limitations on the macrobunch length (Bunch Shape Monitors or Fast Faraday Cups). A technique of using a BPM electrode to measure the bunch length is described which has no bunch limitation. Measurement results comparing the difference between the Bunch Shape Monitor and the BPM electrode is presented.

This work was supported by SNS through UT-Batelle, LLC, under contract DE-AC05-00OR22725 for the U.S. DOE. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**RPAT042—Emittance Scanner Optimization for Low Energy Ion Beams**
*Martin P. Stockli, Robert Welton (ORNL/SNS)*
Ion beam emittances are normally measured as two-dimensional distributions of the beam current fraction within a window dx centered at position coordinate x and a window dx' centered at

trajectory angle x'. Unthresholded rms emittances evaluated from experimental data are very sensitive to noise, bias, and other undesired signals. Undesired signals occur when particles from outside the measured window dx*dx' contribute to the signal from the particles within the measured window. Increasing the window size increases the desired signal while most undesired contributions remain unchanged. However, the decreasing resolution causes an error in the emittance results, especially in the rms emittance. Using theoretical distributions we will present the tradeoff between resolution and accuracy.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**RPAT043—Developments of the Calibration Tools for Beam Position Monitor at J-PARC Linac**

*Susumu Sato, Hisashi Akikawa, Tetsuo Tomisawa, Akira Ueno (JAERI/LINAC), Zenei Igarashi, Masanori Ikegami, Norihiko Kamikubota, Seishu Lee, Takeshi Toyama (KEK)*

In the J-PARC LINAC, there are mainly two requirements for the beam based calibration of beam position monitors (BPMs). One is that BPMs need to be calibrated with the accuracy of about a hundred micro-meters to minimize beam loss for the world highest class of proton intensity. The other is that about a hundred of BPMs need to be calibrated consistently. To achieve these requirements, the calibration tool are being developed with experiences on real beam in a MEBT line set for the DTL commissioning. Tools for simulating the beam trajectory using transport matrix (e.g. T3D) are being developed as well. The calibrated beam positions measured by BPMs are used in the simulation for tuning the beam. Implementation of the calibration tools on the same platform (e.g. SAD) with the simulation tools is important for higher usability during commissioning of whole J-PARC. In this paper, details of these developments around BPMs are to be reported.

**RPAT044—Secondary Emission Monitors for the NuMI Beam Line at Fermilab**

*Sacha Elmer Kopp, Dharmaraj Indurthy, Zarko Pavlovich, Marek Proga, Robert Miles Zwaska (The University of Texas at Austin)*

Segmented Secondary Emission Monitors (SEM's) will be used to monitor the extracted 120 GeV proton beam for the NuMI facility at Fermilab. The SEM's are constructed from 5 micrometer thick Ti foils. The chambers have 10 cm beam aperture, and the foils are designed to result in 4E-6 fractional beam loss when inserted in the beam. The foil strips have dynamic tensioning to withstand the heating from the 400kW proton beam. Results from prototype beam tests as well as from commissioning in the NuMI line will be presented.

**RPAT045—Beam Phase Detector for Proton Therapy Facilities**

*Bachtior Aminov, Markus Getta, Sergej Kolesov, Helmut Piel, Nico Pupeter (CRE), Thomas Stephani, Jan Hein Timmer (ACCEL)*

The industrial application of proton cyclotrons for medical applications has become one of the important contributions of accelerator physics during the last years. This paper describes an advanced vector demodulating technique used for non-destructive measurements of beam intensity and beam phase over 360°. A computer controlled I/Q-based phase detector with a very large dynamic range of 70 dB permits the monitoring of beam intensity, phase and eventually energy for wide range of beam currents down to –130 dBm. In order to avoid interference from the fundamental cyclotron frequency the phase detection is performed at the second harmonic frequency. A digital low pass filter with adjustable bandwidth and steepness is implemented to improve accuracy. With a sensitivity of the capacitive pickup in the beam line of 30 nV per nA of proton beam current at 250 MeV, accurate phase and intensity measurements can be performed with beam currents down to 3.3 nA.

**RPAT046—Development of a Remotely Controllable High Sensitive Electrometer for Beam Current Measurements**

*Nico Pupeter (CRE), Thomas Stephani, Jan Hein Timmer (ACCEL)*

The monitoring of beam currents in particle accelerators and beam transport systems e.g. by wire scanner or harp detectors requires the measurement of very small currents in environments with strong RF-disturbance signals. A remotely controllable electrometer was developed for detector current measurements in the range of pico to micro amperes. As first application, the electrometers will be used in 2 cyclotrons for proton therapy and their related beam lines (PROSCAN at PSI and RPTC in Munich). This paper will outline the design concept and the achieved sensitivity of the electrometers. The main features are the high resolution in the remotely adjustable current ranges (40 nA – 12.5 muA) and the strong blocking of RF-disturbance picked up by the beam current detectors. Because of the long cable distance between beam detector and electrometer special care was taken during the layout for the prevention of ground loops. A very low noise was achieved, also at high measurement frequencies.

**RPAT047—Preliminary Design of a Femtosecond Oscilloscope**

*Edmond David Gazazyan, Karo Ispirian, Amour Margaryan (YerPhI), Edouard Laziev (YerPhI; CANDLE)*

The calculations on motion of electrons in a finite length electromagnetic field of linearly and circularly polarized laser beams have shown that one can use the transversal deflection of electrons on a screen at a certain distance after the interaction region for the measurement of the length and longitudinal particle distribution of femtosecond bunches. In this work the construction and preliminary parameters of various parts of a device that may be called femtosecond oscilloscope are considered. The influence of various factors, such as the energy spread and size of the electron bunches, are taken into account. For CO2 laser intensity 1016 W/cm2 and field free drift length 1m the deflection is 5.3 and 0.06 cm, while the few centimeters long interaction length between 2 mirrors requires assembling accuracy 6 mm and 1.3 micron for 20 MeV to 50 keV, respectively.

**RPAT048—An X-Ray BPM and Accompanying Electronics**

*Haroldo Jose Onisto, Osmar Roberto Bagnato, Marcelo Juni Ferreira (LNLS)*

Recent experiments at the LNLS Ultra Violet and X-Ray beam lines are pushing on the Synchrotron Radiation beam position stability requirements. In the direction of having photon Beam Position Monitor integrated to the orbit closed loop control system, we developed a staggered blades XR BPM and a four channel current measurement electronics. The BPM mechanical design was based on the SR masks previously developed and currently in use at the beam lines front end. By this design reuse, in addition to using an already available and well-tested, low cost construction technique, we expect to have a simple replacement of the SR masks by the XR BPMs in most of the beam lines, shortening the downtimes and the number of line parts to be replaced. We describe the design and the resulting performance of the XR BPM and the accompanying electronics.

**RPAT049—Numerical Studies on the Electro-Optic Sampling of Ultrashort Electron Bunches**
*Sara Casalbuoni, Holger Schlarb, Bernhard Schmidt, Bernd Steffen (DESY), Peter Schmüser, Axel Winter (Uni HH)*
Ultraviolet and X ray free electron lasers require sub-picosecond electron bunches of high charge density. Electro-optic sampling (EOS) is a suitable diagnostic tool for resolving the time structure of these ultrashort bunches. The transient electric field of the relativistic bunch induces a polarization anisotropy in a nonlinear crystal which is sampled by femtosecond laser pulses. In this paper, the EOS process is studied in detailed numerical calculations. The THz and the laser pulses are treated as wave packets which are propagated through the zinc telluride resp. gallium phosphide crystals. The effects of signal broadening and distortion are taken into account. The time resolution is limited by the lowest lattice oscillation frequency which amounts to 5.3 THz in ZnTe and 11 THz in GaP. The shortest bunch length which can be resolved with moderate distortion is about 200 fs (FWHM) in ZnTe and 100 fs in GaP.

**RPAT050—Electro Optic Bunch Length Measurements at the VUV-FEL at DESY**
*Bernd Steffen, Sara Casalbuoni, Ernst-Axel Knabbe, Holger Schlarb, Bernhard Schmidt (DESY), Peter Schmüser, Axel Winter (Uni HH)*
For the operation of a SASE FEL, the longitudinal bunch length is one of the most critical parameters. At the superconducting linac of the VUV-FEL at DESY, we have installed an electro optic sampling (EOS) experiment to probe the time structure of the electric field of the bunches to better than 100 fs rms. The field-induced birefringence of a ZnTe crystal is detected by a femtosecond laser pulse (TiSa) and the time structure is measured by scanning the relative timing of the electron bunch and the TiSa pulse. A synchronization stability of better than 50 fs between laser and accelerator RF has been achieved. First results on the synchronization measurements and for the bunch length as function of the linac parameters are presented.

**RPAT051—Measurement of Dynamic Beta Effects on Horizontal Beam Size at KEKB Using SR Interferometer Equipped with Retrofocus Optics**
*John Walter Flanagan, Hitoshi Fukuma, Shigenori Hiramatsu, Toshiyuki Mitsuhashi (KEK)*
Transverse beam-size enlargement due to dynamic beta and beam-beam effects has been observed in the KEKB Low Energy Ring (LER) and High Energy Ring (HER). In order to observe these effects, a retrofocus optics system has been developed and installed in the horizontal SR interferometers at the HER and LER. This system allows us to vary the apparent beam size to match the dynamic range of the interferometer. We report on the retrofocus optics system and measurement results, and compare the measured effects with those expected from dynamic beta simulations.

**RPAT052—Vertical Beam Size Measurement by Streak Camera under Colliding and Single Beam Conditions in KEKB**
*Hitomi Ikeda, John Walter Flanagan, Hitoshi Fukuma, Yoshihiro Funakoshi, Shigenori Hiramatsu, Toshiyuki Mitsuhashi, Kazuhito Ohmi, Sadaharu Uehara (KEK)*
Beam behavior of KEKB was studied by measurement of the beam size using a streak camera. Effect of the electron-cloud and the parasitic collision on the vertical beam size was examined in beam collision. We intentionally injected a test bunch of positrons after 2 rf buckets of a bunch to enhance the electron cloud effect and changed electron beam conditions to see the beam-beam effect. The beam size was also measured with a single positron beam and compared with that during collision. The result of the measurement is reported in this paper.

**RPAT053—Movement of BPMs Due to Thermal Stress in KEKB**
*Masaki Tejima, Mitsuhiro Arinaga, Hitoshi Fukuma, Shigenori Hiramatsu, Hitoshi Ishii, Makoto Tobiyama (KEK)*
Movement of Beam Position Monitors (BPM) due to thermal stress in high beam current operation is observed in KEKB. For high luminosity operation of KEKB, the beam current as high as 1.6A is accumulated in the positron ring and a precise control of the beam orbit based on the BPM system is required. Though the every BPM chamber is fixed firmly on a support of each quadrupole magnet, the BPM chamber moves several hundred microns from the setting position depending on the beam current due to beam pipe heating by strong synchrotron light irradiation. Such movement introduces an unavoidable offset error in the BPM measurement, and is a serious problem not only for KEKB but also for the next generation of B-factory operated with extremely high beam current. We report the measurement of the movement by distance sensors and an attempt to correct the BPM offset error in real-time operation.

**RPAT054—Beam Position Monitor at the PLS BTL**
*Sung-Chul Kim, Myung-Hwan Chun, Yeung-Jin Han, Jung Yun Huang, Do Tae Kim, Wol Woo Lee (PAL)*
Electron Linac at the Pohnag Accelerator Laboratory (PAL) has been operated continuously as the full energy injector for storage ring. Linac and storage ring energy has been 2.0 GeV since Dec. 1994, and 2.5 GeV since Oct. 2002. In Aug. 2004, thirteen BPMs are newly installed at BTL(Beam Transport Line) for beam trajectory measurement and feedback. These BPMs consist of 100mm strip-line electrodes in 150mm long chamber, and 500MHz log-ratio signal processing circuits. BPM data acquisition system is developed as EPICS IOC using NI S-series data acquisition board and NI LabView 7.1. BTL BPMs will be used for optic correction and beam energy feedback for PLS beam injection. This paper describes on design, test results, installation and data acquisition system of the PLS BTL BPM.

Work supported by the Ministry of Science and Technology, Korea.

**RPAT055—Low-Energy Electron Beam Diagnostics Based on the Optical Transition Radiation**
*Gennady Naumenko, Boris Kalinin, A.P. Potylitsyn, Gennady Saruev, Alexi Sharafutdinov (Tomsk Polytechnic University), Alexander Aryshev (KEK)*
Backward transition radiation (BTR) properties were used for beam profile and beam divergence measurement on the 6 MeV microtron electron beam. A beam profile was measured directly by focusing on the polished conductive target and subsequent optical transport of BTR to the CCD camera. For the beam divergence measurement were used BTR angular characteristics, which depends on an electron beam divergence. Simple commercial CCD camera with sensitivity 0.01 Lux and optical system, consisting on three lenses and one mirror allowed us to measure a beam profile and a BTR angular distribution per each macro-pulse with population 10^12 electrons. There was shown a possibility of simple beam diagnostics station design for measurement of a beam profile and beam divergence of each macro-pulse simultaneously using the same BTR target.

**RPAT058—The IEEE-1394 Digital Camera Application in the Taiwan Light Source**
*Changhor Kuo, Kuo-Tung Hsu (NSRRC)*
The CCD camera with digital interface has been adopted for the diagnostics purpose recently. The long distance transmission with digital interface eliminates image distortion. Without frame grabber in the computer that is also another benefit. These applications include screen monitor and optical transition radiation monitor image for injection study, synchrotron radiation monitor of the booster synchrotron and storage ring. An intensified gated CCD camera is also applied for transient profile study. Wider dynamic range and the flexibility of the newly camera provide various functional enhancements for the diagnostics purpose. The effort and achievement will be summary in this report.

**RPAT059—The SRI Beam Size Monitor Developed at NSRRC**
*Tse-Chuan Tseng, June-Rong Chen, H.C. Ho, Chia-Jui Lin, Shen-Yaw Perng, Duan Jen Wang, Jeremy Wang (NSRRC)*
A beam size monitor based on the synchrotron radiation interferometer (SRI) was installed in the NSRRC TLS. This monitor consists of a simple diagnostic beamline with a water-cooled beryllium mirror inside and a detecting optical system for both vertical and horizontal beam size measurement. The beam sizes measured are 48 micron and 160 micron respectively and are more close to the theoretical values than the synchrotron image monitor. Comparing with other monitors, at least 1 micron beam size variation is detectable. To minimize the thermal effect, the mirror is located far away from the source point and closed to the detecting optical system. The thermal distortion of the mirror is quite small measured by a portable long trace profiler (LTP) and agrees with the simulating analysis. The detailed monitor system design and testing results are presented in this paper.

**RPAT060—Improvement on the Diagnostic System of TLS Transport Line**
*Tzong-Shyan Ueng, Chin-Chun Chang, June-Rong Chen, Hsin-Pai Hsueh, Chien-Kuang Kuan, Tsai-Fu Lin (NSRRC)*
Taiwan Light Source (TLS) is currently in the path of upgrading to operate in the top-up injection mode. In the previous study, the injection efficiency from the booster to the storage ring is shown to be low. The radiation monitored also indicates it has a plenty of room for improvement. The improvement of injection efficiency has become an important task. Recently many beam diagnostic instruments have been installed in the transfer line between the booster and the storage ring to study the beam profile and the beam intensity. It will help to optimize the booster extraction and also the elements in the transfer line, thus, to improve the overall transfer efficiency. In this report, the performance of recently installed optical transition monitors and Faraday cups are discussed.

**RPAT061—New Electron Beam Position Monitoring and Feedback System Upgrades for the Synchrotron Radiation Source at Daresbury Laboratory**
*Robert Smith, Mike Dufau, Brian Martlew (CCLRC/DL/ASTeC)*
The installation of a new APPLE/II undulator with user controlled polarisation has necessitated the upgrade of the Electron Beam Position Monitoring (EBPM) detector electronics and position feedback systems. The upgraded installation will utilise commercially available multiplexed detection electronics, coupled with a two phase control system interface replacement. Phase one involves the replacement of the existing G-64 based read-back system with direct analogue connections to the VME beam steering and Feedback system. This allows existing monitoring and feedback software to work with improved update rates (~ 1Hz -> ~ 8Hz). Phase two will see the installation of new high-performance control system front ends and will allow real-time monitoring at up to 100Hz and provide snapshots with resolution of 1-10 KHz.

ASTeC Department, CCLRC Daresbury Laboratory.

**RPAT062—Design and Operation of a Radiative Bhabha Luminosity Monitor for CESR-c**
***Mark Alan Palmer, Volker Crede,*** *David Rubin, Jeffrey Claiborne Smith (Cornell University), Helmut Vogel (CMU), Melissa Cravey, James Napalitano (RPI), Katherine Laird Dooley (Vassar)*
The CLEO-c experiment at the Cornell Electron Storage Ring (CESR) is presently embarking on a multi-year exploration of charm and QCD physics in the 3-5 GeV center-of-mass energy range. In order to facilitate rapid optimization of machine parameters over this energy range, a luminosity monitor based on the measurement of radiative-bhabha photons coming from the CLEO-c interaction point (IP) has been designed and installed in the CESR ring. Key design criteria of the device include: better than 1% statistical measurements of the luminosity with a 1 Hz update rate over the full range of CESR-c operating conditions; bunch-by-bunch measurement capability; a large horizontal aperture to enable measurements under conditions ranging from single-bunch head-on collisions to multi-bunch collisions with a horizontal crossing angle of up to 4~mrad; and, a segmented readout to provide direct information on beam characteristics at the IP. We review the design and performance of this device and discuss its application to machine tuning and performance studies.

Work supported by the National Science Foundation.

**RPAT063—A Bunch-By-Bunch and Turn-By-Turn Instrumentation Hardware Upgrade for CESR-c**
*Mark Alan Palmer, John Dobbins, Charles Ralph Strohman (Cornell University)*
A key factor in the colliding beam performance of the Cornell Electron Storage Ring (CESR) is the impact of parasitic beam-beam interactions between bunches in the two beams as they follow their electrostatically separated orbits in a single vacuum chamber. In order to better investigate the differential performance of bunches in CESR, instrumentation electronics has been developed to allow acquisition of turn-by-turn data from multiple bunches simultaneously. The electronics consists of a standardized digital board centered around an Analog Devices TigerSHARC family digital signal processor, a communications interface, and an interface to the CESR Precision Timing System. Mated to these components is an analog front end and digitizer board which is customized for the particular diagnostic device of interest. Front ends have been developed for beam position monitor, luminosity monitor, and beam profile monitor applications. We describe the design and characterization of this new hardware.

Work supported by the National Science Foundation.

**RPAT064—Beam-Based Calibration of the Electron Energy in the Fermilab Electron Cooler**
*Sergey Seletsky (Rochester University), Alexander V. Shemyakin (Fermilab)*
Electron cooling of 8.9 GeV antiprotons in the Fermilab's Recycler ring requires precise matching of electron and antiproton velocities. While the final match can be done by optimization of the cooling process, for the very first cooling one should rely on the knowledge of absolute values of electron and

antiproton energies. The upper limit for the energy uncertainty of both beams is determined by the Recycler's momentum aperture and is equal to 0.3%. The paper discusses a method of the electron energy calibration that is based on the measurement of the electron's Larmor wavelength in the field of the cooling section solenoid. The method was tested in an 18 m long cooling section prototype with 3.5 MeV electrons. An accuracy of 0.3% was demonstrated.

**RPAT065—A Wire Scanner Design for Electron Beam Profile Measurement in the Linac Coherent Light Source Undulator**

*James L. Bailey, Thomas Buffington, Bingxin Yang (ANL)*

The Linac Coherent Light Source (LCLS), currently under design, requires beam diagnostic instruments between the magnets in the beam undulator section. Ten wire scanners are planned as one of the primary instruments to characterize electron beam properties. The development of these wire scanners presents several design challenges due to the need for high accuracy and resolution of the wire motion (3 microns tolerance, typical) and the high intensity of the beam (3400 A over an area of 30 micron rms radius). In this paper, we present the technical specification and design criteria for the scanners. We will also present the mechanical design of the UHV-compatible drive and its engineering analysis. Lastly, we present the wire card design and discuss associated thermal and mechanical issues originating from the highly intense x-ray and electron beams.

Work supported by U. S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

**RPAT066—Transverse Emittance Measurements of the AWA RF Photoinjector using a Pepper Pot**

*John Gorham Power, Sergey P. Antipov, Manoel Conde, Wei Gai, Chunguang Jing, Richard Konecny, Wanming Liu, Haitao Wang, Zikri Yusof (ANL)*

In this paper, we describe the new pepper pot system recently installed at the Argonne Wakefield Accelerator (AWA) facility. The AWA facility consists of a 1.5 cell RF photocathode gun followed by a booster linac and is capable of producing short electron bunches with charge up to 100 nC and energy of approximately 15 MeV. The pepper pot method is a reliable technique used for obtaining single-shot measurements of the transverse emittance of a space-charge dominated electron beam when the energy is below approximately 20 MeV. The normal limitation of a small dynamic range of measurable emittances is partially circumvented by using an array of pepper pot plates with different hole separations mounted on a motorized actuator and using multiple imaging screen at various distances after the pepper pot. The complete transverse phase space measurement system, consisting of pepper pot masks, YAG imaging screens, CCD cameras, Matlab-based image acquisition and Matlab-based image processing will be described. Initial emittance measurements of a photoelectron beam with a nominal charge of 1 nC beam will be presented.

This work was supported by the Division of High Energy Physics, U.S. Department of Energy.

**RPAT067—Beam Angle Measurement Using Cherenkov Radiation**

*Takahiro Watanabe, Marcus Babzien, Karl Kusche, Vitaly Yakimenko (BNL)*

A simple beam angle monitor utilizing observation of far-field Cherenkov radiation is being developed. The monitor is independent of beam energy as well as position and requires only modest camera sensitivity. Since the wavefront of Cherenkov radiation is not spherical but planar, the far-field image is supposed to be infinetesimally small in one-dimensional geometrical optics, which may result in high angular resolution. In a practical experiment, however, beam scattering in a radiator and diffraction from a finite size radiation source determine the resolution. Numerical analysis shows that the angular resolution with a 100-um thickness fused silica radiator is 0.8 mrad. The experimental results with 2-mm and 100-um thickness fused silica are shown. The possibility of non-destructive measurement is also discussed.

**RPAT068—Proposed Diagnostics for the NSLS-II**

*Igor Pinayev, Johan Bengtsson, Stephen L. Kramer, James Rose, Timur Shaftan (BNL/NSLS)*

The National Synchrotron Light Source is performing R&D of a new 3 GeV electron storage ring to be used for the facility upgrade. To satisfy the demands for the brightness and stability of the future light source a state-of-the-art diagnostics system is a necessity. We present our preliminary design with focus on the requirements for instrumentation and technical solutions to achieve them.

The U.S. Department of Energy under contract No. DE-AC02-98CH10886.

**RPAT069—Electron Beam Size Measurements in a Cooling Solenoid**

*Thomas K. Kroc, Timofei Borisovich Bolshakov, Alexey Burov, Alexander V. Shemyakin (Fermilab), Sergey Seletsky (Rochester University)*

The Fermilab Electron Cooling Project requires a straight trajectory and constant beam size to provide effective cooling of the antiprotons in the Recycler. A measurement system was developed using movable appertures and steering bumps to measure the beam size in a 20 m long, nearly continuous, solenoid. This paper discusses the required beam parameters, the implimentation of the measurement system and results for our application.

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**RPAT070—Mechanical and Thermal Design of the CEBAF Hall A Beam Calorimeter**

*Michael E. Bevins, Anthony Roland Day, Pavel Degtiarenko, Lawrence A. Dillon-Townes, Arne Freyberger, Arun Saha, Stephanie Slachtouski (Jefferson Lab), Ronald Gilman (Rutgers University)*

A calorimeter has been proposed to provide 0.5% - 1.0% absolute measurements of beam current in the Hall A end station of the Thomas Jefferson National Accelerator Facility (JLab) CEBAF machine. Silver and copper calorimeters built in the 1960's achieved precisions of about 1%. Modern powder metallurgy processes have produced high density, high thermal conductivity tungsten-copper composite materials that will minimize beam loss while maintaining a rapid thermal response time. Heat leaks will be minimized by mounting the mass in vacuum on glass ceramic mounts. A conduction cooling scheme utilizes an advanced carbon fiber compliant thermal interface material. Transient finite difference and finite element models were developed to estimate heat leaks and thermal response times.

DOE.

**RPAT071—Digital Beam Position Monitor for the Happex Experiment**
*Hai Dong, Sherlon Renee Kauffman, John Musson (Jefferson Lab)*
The proposed HAPPEX experiment at CEBAF employs a three cavity monitor system for high-precision (1 mm), high-bandwidth (100 kHz) position measurements. This is performed using a cavity triplet consisting of two TM110-mode cavities (one each for X and Y planes) combined with a conventional TM-010-mode cavity for a phase and magnitude reference. Traditional systems have used the TM010 cavity output to directly down convert the BPM cavity signals to base band. The Multi-channel HAPPEX digital receiver simultaneously I/Q samples each cavity and extracts position using a CORDIC algorithm. The hardware design consists of a digital receiver daughter board and digital processor motherboard that resides in a VXI crate. The daughter board down converts 1.497 GHz signals from the TM010 cavity and X and Y signals from the TM110 cavities to 4 MHz, and extracts the quadrature digital signals. The motherboard processes this data and computes beam intensity and X-Y positions with a resolution of one mm, 100 kHz output bandwidth, and overall latency of ten microseconds. The results are available in both analog and digital format.

This work was supported by DOE contract No. DE-AC05-84ER40150.

**RPAT072—The General ElectroN Induced Emission (GENIE) System**
*Michael Anthony Epps, Paul Gueye, Reza Kazimi (Jefferson Lab)*
A real time beam diagnostic system is proposed for the Jefferson Lab injector region. The General ElectroN Induced Emission System (GENIE) is a package that includes both hardware (beam monitoring devices) and software (for 3D or 4D visualization of the beam transport). This beam diagnostic tool relies primarily on the use of (very small) scintillating fibers placed in different planes to extract the beam profile, beam position, beam current and beam emittance in real time. Accuracies in position and angle could be at the sub- ìm and ìrad levels, respectively. The beam current could be reconstructed within a few percent. A combined Geant4/Parmela simulation will be developed for beam optic studies. While Parmela offers the power of beam transport with phase matching capabilities (among others), Geant4 provides the power for tracking secondary particles, as well as 3D & 4D visualization. A phase I investigation of GENIE using a 100 keV beam line is discussed in this document.

**RPAT073—A Precision Calibration Test Stand for DARHT II Beam Position Monitors**
*Jeffrey Johnson (LANL)*
The Dual Axis Radiographic Hydrodynamic Test facility (DARHT) is located in Los Alamos New Mexico. High energy electrons produced by the DARHT accelerators create the x-ray source for radiographic tests used to certify our Nations nuclear weapon stockpile. Safety and quality requirements demand that the DARHT II Accelerator electron beam position monitors (BPMs) be calibrated with high accuracy. To achieve this task, a calibration test stand was designed and constructed that allows for BPM calibration at the full operating current of the DARHT II accelerator. The calibration test stand consists of the following components: a Pulse Forming Network (PFN) capable of providing a 2kA, 2uS flat top pulse, and a precision gas insulated coaxial test line. This system produces BPM calibrations with positional accuracy of +/- 200 microns for a single pulse. The error is less than 0.1% for the 10 inch diameter beam pipe.

Los Alamos National Laboratory.

**RPAT074—PEP-II SLAC Transverse Feedback Electronics Upgrade**
*Jonah Weber, Michael Chin, Lawrence Doolittle (LBNL), Ron Akre (SLAC)*
The PEP-II B Factory at the Stanford Linear Accelerator Center requires an upgrade of the Transverse Feedback System electronics. The new electronics consist of two 12-bit ADCs and a 12-bit DAC connected to an FPGA running the feedback algorithm. The ADCs sample alternate bunches at 119MHz each and the correction data updates the DAC at 238MHz. The FPGA is also interfaced to 128MB DDR RAM for potential bunch-by-bunch data capture of hundreds of milliseconds. The FPGA contains an on-chip PowerPC to run Control System interface software for data retrieval, running diagnostics, and monitoring the system. The design of this system is based on the Xilinx ML300 Demo Platform, a PCB set containing an FPGA with on-chip PowerPC, DDR RAM, and other peripherals. This paper discusses issues and considerations of designing a digital feedback system based on an FPGA with on-chip PowerPC. Discussion will include specifications, component selection, and integration with the Xilinx ML300 design.

This work was supported by the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

**RPAT075—Optical Synchronization Systems for Femtosecond X-Ray Sources**
*Russell Wilcox, John William Staples (LBNL), Ronald Holzwarth (Menlo Systems GmbH)*
In femtosecond pump/probe experiments using short x-ray and optical pulses, precise synchronization must be maintained between widely separated lasers in a synchrotron or FEL facility. We are developing synchronization systems using optical signals for applications requiring different ranges of timing error. For the sub-100fs range we use an amplitude modulated CW laser at 1GHz to transmit RF phase information, and control the delay through a 100m fiber by observing the retroreflected signal. Initial results show 40fs peak-to-peak error above 10Hz, and 200fs long term drift, mainly due to amplitude sensitivity in the analog mixers. For the sub-10fs range we will lock two single-frequency lasers separated by several teraHertz to a master modelocked fiber laser, transmit the two frequencies over fiber, and lock two comb lines of a slave laser to these frequencies, thus synchronizing the two modelocked laser envelopes. For attosecond synchronization we propose a stabilized, free space link using bulk lens waveguides and high peak power ultrashort pulses.

This work was supported by the Laboratory Directed Research and Development Program of Lawrence Berkeley National Laboratory under the Department of Energy Contract No. DE-AC03-76SF00098.

**RPAT076—Smith Purcell Radiation Bunch-Length Measurement**
*Stephen Korbly, Amit S. Kesar, Roark A. Marsh, Richard J. Temkin (MIT/PSFC)*
Measurements of Coherent Smith-Purcell Radiation (SPR) were performed at the 17 GHz high-gradient accelerator built by Haimson Research Corporation at the MIT Plasma Science and Fusion Center. SPR is a promising radiation source because the radiation intensity is enhanced by the number of grating periods. The radiation produced obeys the SP resonance condition correlating the radiation frequency at each observation angle, allowing SPR to be exploited as a bunch-length measurement. For a 15 MeV 150 mA 125 ns beam in short and long pulse modes, bunch-lengths of 0.6 ps and 1 ps were measured with this method, respectively, with an error of +/- 0.1 ps. Frequency

measurements were also performed using a double Heterodyne system. Heterodyne measurements revealed frequency-locking, which gave a power level enhancement of 1000 at integer multiples of the Accelerator RF frequency. Frequencies up to 514 GHz were measured with a bandwidth of 25 MHz.

This work was supported by the Department of Energy, High Energy Physics, under contract DE-FG02-91ER40648.

**RPAT077—Beam Test Proposal of an ODR Beam Size Monitor at the SLAC FFTB**

*Yasuo Fukui, Paul Bolton, Marc Ross (SLAC), Alexander Aryshev, Pavel Karataev, Toshiya Muto, Makoto Tobiyama, Junji Urakawa (KEK), Ryosuke Hamatsu (TMU), Gennady Naumenko, A.P. Potylitsyn (Tomsk Polytechnic University), David Cline, Feng Zhou (UCLA)*

We design a single bunch transverse beam size monitor which will be tested to measure the 29 GeV electron/positron beam at the SLAC FFTB beam line.The beam size monitor uses a CCD camera to make images of the interference pattern of the optical diffraction radiation from conductive slit target which are placed close to the beam path. In this method, destruction of the accelerated electron/positron beam bunches due to the beam size monitoring is negligible, which is vital to the operation of the Linear Collider project. A dis-phased conductive slit target and a lens system allow us to recover the sensitivity of the transverse beam size with a small photon yield ratio at the valley to that at the peak due to the large gamma*lambda, and with the near field effect due to the large lambda*gamma**2. A solution for non-negligible divergence at the SLAC FFTB is also discussed.

**RPAT078—Bunch Length Measurements Using Coherent Transition Radiation**

*Rasmus Ischebeck, Christopher Barnes, Franz-Josef Decker, Mark Hogan, Richard Iverson, Patrick Krejcik, Caolionn O'Connell, Robert Siemann, Dieter Walz (SLAC), Ian Blumenfeld (Stanford University), Chris Clayton, Chengkun Huang, Devon K. Johnson, Wei Lu (UCLA), Suzhi Deng, Bing Feng, Erdem Oz (USC)*

The accelerating field that can be obtained in a plasma accelerator depends on the current of the electron beam that excites the wake field. In the E-164X experiment, a peak current above 10kA is used at an energy of 28GeV. The bunch has a length of a few ten micrometers and it is a particular challenge to measure its longitudinal profile directly. Therefore, indirect methods are used to infer its length. The beam passes a thin metallic foil, where it emits transition radiation. For wavelengths greater than the bunch length, this transition radiation is emitted coherently. This amplifies the long-wavelength part of the spectrum. The measurement of the coherent transition radiation (CTR) spectrum allows thus to infer the length of the electron bunch. CTR autocorrelation was used to measure the SLAC ultra-short bunch length. However, this method requires the contribution of many bunches to build an autocorrelation trace and was affected by the transmission characteristics of the vacuum window and beam splitter. We present here a detailed analysis of materials appropriate for the vacuum window and beam splitter, as well as preliminary results obtained using a single shot CTR autocorrelator.

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**RPAT079—Resolution Issues in Transverse Electron Beam Measurements Using Optical Transition Radiation**

*Rasmus Ischebeck, Franz-Josef Decker, Mark Hogan, Richard Iverson, Patrick Krejcik, Robert Siemann, Dieter Walz (SLAC), Melissa Lincoln (Stanford University), Chris Clayton, Chengkun Huang, Wei Lu (UCLA), Suzhi Deng, Erdem Oz (USC)*

Optical transition radiation is widely used to measure the transverse profile of the bunches in particle accelerators. The distribution on the detector is often taken as the transverse profile of the particle bunch. However, the resolution of this setup is limited by the two effects. For one thing, the distribution of the electric field from a single electron has a certain extension. This depends on the relativistic factor gamma of the particles, and it has been discussed whether this limits the applicability of these profile monitors at high energies. Additionally, the the resolution of the imaging system is affected by diffraction and by lens errors. The transverse profile of the bunch is thus convoluted with a point spread function (PSF). Algorithms that attempt to undo this can help to improve the image quality. The PSF of different optical setups has been measured directly. The results are compared to the modulation transfer function, obtained by imaging test patterns. Measurements of the optical transition radiation of an ultra-relativistic electron beam are deconvoluted, using the measured PSF.

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**RPAT080—The SPEAR 3 Synchtrotron Light Monitor**

*Jeff Corbett, Cecile Limborg-Deprey, Andrew Ringwall (SLAC), Walter Mok (Life Imaging Technology)*

SPEAR 3 is equipped with an x-ray pinhole camera and a visible/UV beam line to evaluate electron beam properties. The pinhole camera has a 30 x 25 micron Ta aperture and 60% image demagnification on a phosphor screen. The image is captured by a National Instruments frame-grabber on a remote computer with a parallel video signal for control room monitoring. The visible/UV beam line features a horizontal +/- 0.3 mrad 'cold finger' to remove the x-ray core of the beam. The remaining visible/UV light is deflected 18 degrees onto an optical bench where it is focused via refractive Cassegrain optics. The beam is then split into parallel optics for gated- and streak camera measurements. This paper describes the experimental set up and preliminary measurements obtained with both systems.

Work supported in part by DOE contract DE-AC03-76SF00515 and Office of Basic Energy Sciences, Division of Chemical Sciences.

**RPAT081—Initial Scraper Measurements in SPEAR 3**

*Jeff Corbett, James A. Safranek, Andrei Terebilo (SLAC)*

Horizontal and vertical scraper assemblies have been installed in a standard straight section of SPEAR 3 (beta-x=10.2 m, beta-y=4.8 m, epsx=18 nm-rad, 0.1% coupling). Each scraper has stepper motor accuracy and transductor resolution on the order of 1 micron and a MATLAB/EPICS interface to simplify data acquisition. In this paper we present initial scraper measurements and analysis of the results. Of particular importance are comparison of measured dynamic aperture and momentum acceptance with model and measurement of vertical acceptance for future beam lines.

Work supported by Department of Energy Contract DE-AC03-76SF00515 and Office of Basic Energy Sciences, Division of Chemical Sciences.

**RPAT082—Measurement of the SLAC Ultra-Short Bunch Length Using Coherent Transition Radiation (CTR) Autocorrelation**
*Patric Muggli (USC), Holger Schlarb (DESY), Paul Emma, Mark Hogan, Rasmus Ischebeck, Patrick Krejcik, Robert Siemann, Dieter Walz (SLAC)*
Ultrashort electron bunches are now available at Stanford Linear Accelerator Center and are use mainly to produce short bursts of x-rays in a magnetic undulator and for plasma wakefield acceleration experiments. The shortest bunches have an rms longitudinal width of ˜10 microns, and a peak current of about 30 kA. Methods to measure such short bunch lengths include electro-optic modulation of a short laser pulse in a nonlinear crystal and coherent transition (CTR) autocorrelation. The transition radiation spectrum emitted by the bunches when traversing a 1 micron thin titanium foil is coherent for wavelengths longer that the bunch length and extends into the millimeter wavelength range. A CTR far-infrared autocorrelator was used to measure the bunch length as a function of the accelerator. The results obtained with this autocorrelator are the only measurements of the SLAC ultra-short bunches to date. Experimental results, as well as the limitations of the measurements and the future improvements to the autocorrelator will be presented.

Work supported by U.S. DOE.

**RPAT083—Beam Profile Measurements and Simulations of the Laser-Wire Scanner at PETRA**
*Grahame A. Blair, Ilya Agapov, Gary Boorman, John Carter, Chafik Driouichi, Michael T. Price (Royal Holloway), Thorsten Kamps (BESSY GmbH), Klaus Balewski, Hans-Christoph Lewin, Siegfried Schreiber, Kay Wittenburg (DESY), Nicolas Delerue, David Francis Howell (OXFORDphysics), Stewart Takashi Boogert, Stephen Malton (UCL)*
The laser-wire will be an essential diagnostic tool at the International Linear Collider and advanced light sources. It uses a finely focussed laser beam to measure the transverse profile of electron bunches by detecting the Compton-scattered photons (or electrons) downstream of where the laser beam intersects the electron beam. Such a system has been installed at the PETRA storage ring at DESY, which uses a piezo-driven mirror to scan the laser light across the electron beam. Latest experimental results are presented and compared to detailed simulations using Geant4.

**RPAT084—Design of the APS RF BPM Data Acquisition Upgrade**
*Robert M. Lill, Frank Lenkszus, Eric Norum, Anthony Pietryla (ANL)*
The Advanced Photon Source (APS) is a third-generation synchrotron light source in its tenth year of operation. The storage ring employs three different types of beam position monitor (BPM) systems to measure and control beam motion. The monopulse radio frequency (rf) BPM is a broadband (10 MHz) system, which is considered to be the backbone of orbit control. The rf BPM system was designed to measure single-turn and multi-turn beam positions. The rf BPMs are presently suffering from an aging data acquisition system. By replacing only the data acquisition we will revitalize this system for another decade and demonstrate a cost-effective approach to improved beam stability, reliability, and enhanced postmortem capabilities. In this paper we present the design of an eight-channel ADC/digitizer VXI board with a sampling rate of 88 MHz (per channel) and 14-bit resolution coupled with a field-programmable gate array and embedded central processing. We will discuss the upgrade system specifications, design, and prototype test results.

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**RPAT085—Initial Imaging of 7-GeV Electron Beams with OTR/ODR Techniques at APS**
*Alex Lumpkin, William Berg, Nicholas Sereno, Chihyuan Yao (ANL)*
The development of nonintercepting (NI) diagnostics continues to be of interest at the Advanced Photon Source (APS) as well as elsewhere. In the three rings of the APS facility we use optical synchrotron radiation generated as the electron beam transits the dipole magnetic fields as an NI mechanism to image the beam during top-up operations. However, in the straight transport lines an alternative method is needed. Optical diffraction radiation (ODR) is under investigation to monitor 7-GeV beam trajectory and potentially transverse shape in the booster-to-storage ring (BTS) beamline during top-up operations. We have performed our initial measurements with an Al blade/mirror that served as an optical transition radiation (OTR) monitor when fully inserted into the beam and as an ODR monitor when the beam passed near the edge. In the case of ODR, appreciable signal is emitted by the metal when gamma times the reduced ODR wavelength is comparable to the impact parameter, where gamma is the Lorentz factor. Visible light optics and a standard CCD camera could thus be used for a few-mm impact parameter. We attribute the near-field signal for 1.5- to 3.0-mm impact parameters predominately to the ODR mechanism.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**RPAT086—Dual-Sweep Streak Camera Measurements of the APS User Beams**
*Alex Lumpkin, Bingxin Yang (ANL), Fumito Sakamoto (UTNL)*
The Advanced Photon Source (APS) is a hard x-ray user facility based on a 7-GeV storage ring (SR). To accommodate the requests of the diverse user community, the APS normally runs with a 24-singlets fill pattern, a hybrid fill with a singlet and eight septuplets, or a 324-singlet fill pattern. In all cases the total stored beam current is 100 mA, with the lattice providing a natural emittance of about 2.5 nm rad. The first two patterns are used with a top-up mode that involves injection of one pulse of ~2.5 nC every two minutes into the designated SR bucket. Since the partition of bunch current varies for the different fills as well as the loading of the rf cavities, dual-sweep streak camera measurements (Hamamatsu model C5680) have been performed to characterize the average and individual bunch lengths in the fill patterns and the phase slew that occurs within the patterns. The bunch lengths vary from 32 ps (sigma) within the septuplet to 50 ps (sigma) for the singlet in the hybrid fill. The phase slew is significant in the hybrid fill across the eight septuplets. Example streak images of each pattern will be presented and discussed.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract Number W-31-109-ENG-38.

**RPAT087—Design of a High-Resolution Optical Transition Radiation Imaging System for Electron Beam Size Measurements in the Linac Coherent Light Source Undulator**
*Bingxin Yang, James L. Bailey, S. Joshua Stein, Dean Walters (ANL)*
The Linac Coherent Light Source (LCLS), a free-electron x-ray laser, is under design and construction. Its high intensity electron beam, 3400 A in peak current and 46 TW in peak power, is concentrated in a small area (30 micrometer rms in both horizontal and vertical directions) inside its undulator. Ten optical

transition radiation (OTR) imagers are planned between the undulator segments for the characterization of the transverse profiles of the electron beam. In this paper, we present the performance requirements and technical requirements of the OTR imagers. We will discuss in detail the design of the OTR screen, the arrangement and modeling of the imaging optics, and the mechanical design and analysis of the compact camera module. Through a unique optical arrangement, this imager will achieve a fine resolution (12 micrometer rms or better) over the entire field of view (5 mm × 5 mm). The compact camera module will fit in the limited space available with remote focus adjustment. A digital camera will be used to read out the beam images in a programmable region (5 mm × 0.5 mm) at the full beam repetition rate (120 Hz), or over the entire field at a lower rate (15 Hz).

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

**RPAT088—New Energy-Spread-Feedback Control System Using Nondestructive Energy-Spread Monitor at the KEKB Injector Linac**

*Masanori Satoh, Kazuro Furukawa, Tsuyoshi Suwada (KEK)*

New energy-spread feedback system using nondestructive energy-spread monitors have been developed in order to control and stabilize the energy spreads of single-bunch electron and positron beams in the KEKB injector linac. The well-controlled feedback systems of the injector linac are successfully working in dairy operation not only for keeping the injection rate higher along with the beam-orbit and energy feedback systems but also for reducing a background level to the high-energy B-factory experiment. The energy spreads of the injection beams are well stabilized within 0.2%, 0.5% and 0.3% for the electron beam, the positron beam, and the high-current primary electron beam for positron production, respectively, through the energy-spread feedback system under the nominal operation condition. In this paper, we will report in detail the energy-spread feedback system using the nondestructive energy-spread monitors with multi-strip-line electrodes and their performance in the KEKB operation.

**RPAT089—Advances in Optical Transition and Diffraction Radiation Emittance Diagnostics**

*Ralph Fiorito, Anatoly Shkvarunets (IREAP), Takahiro Watanabe, Vitaly Yakimenko (BNL)*

We have performed a series of experiments using Optical Transition Radiation and Optical Diffraction Radiation Interferometry to measure the two orthogonal (x,y) rms divergences of the Brookhaven National Laboratory's Advanced Test Facility electron beam operating at an energy of 50 MeV. Measurement of the rms divergences at the (x,y) beam waist conditions, together with corresponding measurements of the rms beam sizes allows a determination of the rms x and y emittances. A comparison of the results using OTRI and ODTRI are presented.

Office of Naval Research and the DOD Joint Technology Office.

**RPAT090—The Study of New Signal Processing Technique in Photon Beam Position Monitors**

*Shunfu Lin, Hui Gao, Ping Lu, Baogen Sun (USTC/NSRL)*

A log-ratio signal processing technique in photon beam position monitors (PBPM) was presented in this paper. The main performances (e.g. sensitivity, position offset and linearity range) of split PBPM and a pair of wires PBPM were analyzed , and the result of the measurement fit well with the theory. An inexpensive logarithmic amplifier chip which can measure photon currents from 0.1nA to 3.5mA was used in electronic circuits. The logarithmic ratio of the signal amplitudes from the PBPM provides a real-time analog signal that has wider linearity range and higher bandwidth than signal processing technique.

Supported by Natural Science Foundation of China (10275062) and CAS Knowledge Innovation Project (KY4206).

**RPAT091—Longitudinal Electron Bunch Diagnostics Using Coherent Transition Radiation**

*Daniel Mihalcea, Courtlandt L. Bohn (Northern Illinois University), Philippe Regis-Guy Piot (Fermilab)*

The longitudinal charge distribution of electron bunches in the Fermilab A0 photo-injector was determined by using the coherent transition radiation produced by electrons passing through a thin metallic foil. The auto-correlation of the transition radiation signal was measured with a Michelson type interferometer. The response function of the interferometer was determined from measured and simulated power spectra for low electron bunch charge and maximum longitudinal compression. Kramers-Kroning technique was used to determine longitudinal charge distribution. Measurements were performed for electron bunch lengths in the range from 0.3 to 2 ps (rms).

**RPAT092—Conceptual Design of an Insertion Device for Non-Destructive Beam Diagnostics of a Low-Emittance Synchrotron Light Source**

*Mitsuhiro Masaki (JASRI/SPring-8)*

An insertion device is proposed to measure small vertical angular divergence and energy spread (dE/E) of electron beam in a low-emittance synchrotron light source. In accelerators such as the SPring-8 storage ring operated on the small emittance-coupling ratio, vertical divergence of spectral photon flux produced by electron beam in a conventional undulator of several meters long will be dominated by natural divergence of the undulator radiation. Therefore, the divergence of spectral flux is not useful for vertical emittance diagnostics. The proposed insertion device consists of N short undulator sections as x-ray radiators cascaded through vertical deflective sections to make a half-period cosine-like electron trajectory. Two radiation parts of the upper and lower sides are formed due to up-and-down electron orbit by the deflective sections. X-rays emitted from the two radiation parts interfere at observation point far from the insertion device. It was numerically studied that the vertical angular divergence in the sub-micro radian range and the energy spread of the 1e-3 order could be measured by visibility and envelope width of an observed interference pattern, respectively.

**RPAT093—Libera Electron Beam Position Processor**

*Rok Ursic (Instrumentation Technologies)*

Libera is a product family delivering unprecedented possibilities for either building powerful single station solutions or architecting complex feedback systems in the field of accelerator instrumentation and controls. This paper presents functionality and field performance of its first member, the electron beam position processor. It offers superior performance with multiple measurement channels delivering simultaneously position measurements in digital format with MHz kHz and Hz bandwidths. This all-in-one product, facilitating pulsed and CW measurements, is much more than simply a high performance beam position measuring device delivering micrometer level reproducibility with sub-micrometer resolution. Rich connectivity options and innate processing power make it a powerful feedback building block. By interconnecting multiple Libera electron beam position processors one can build a low-latency high throughput orbit feedback system without adding additional hardware. Libera electron beam position processor is ideally suited for the Third and the Fourth generation light sources.

**RPAT094—Femtosecond Synchronisation of Ultrashort Pulse Lasers to a Microwave RF Clock**
*Axel Winter (Uni HH), Ernst-Axel Knabbe, Stefan Simrock, Bernd Steffen (DESY), Nikolay Ignashin, Anatoli Simonov, Sergei Sytov (IHEP Protvino)*
A precise synchronization between the laser repetition rate and the linac-RF is mandatory for electro-optic sampling or pump-probe experiments. The level of stability is usually determined by measuring of the spectral noise power density of the feedback signal when the system is locked. However, an independent measurement is needed to confirm this. In this paper, we present an approach exploiting electronic techniques to synchronize a TiSa laser to the RF of the DESY VUVFEL with sub-50 fs stability. The remaining time jitter is measured by an RF monitoring system independent of the locking PLL.

**RPAT095—Time Resolved X-Ray Spot Size Diagnostic**
*Roger Richardson, Steven Falabella, Frank Chambers, Gary Guethlein, Brett Raymond, John Weir (LLNL)*
A diagnostic was developed for the determination of temporal history of an X-ray spot. A pair of thin (0.5 mm) slits image the x-ray spot to a fast scintillator which is coupled to a fast detector, thus sampling a slice of the X-Ray spot. Two other scintillator/detectors are used to determine the position of the spot and total forward dose. The slit signal is normalized to the dose and the resulting signal is analyzed to get the spot size. The position information is used to compensate for small changes due to spot motion and misalignment. The time resolution of the diagnostic is about 1 ns and measures spots from 0.5 mm to over 3 mm. The theory and equations used to calculate spot size and position are presented, as well as data. The calculations assume a symmetric, Gaussian spot. The spot data is generated by the ETA II accelerator, a 2kA, 5.5 MeV, 60ns electron beam focused on a Tantalum target. The spot generated is typically about 1 mm FWHM. Comparisons are made to an X-ray pinhole camera which images the XRay spot (in 2D) at four time slices.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

**RPAT096—High-Precision Resonant Cavity Beam Position and Emittance Monitor**
*Nikolai Barov, Jin-Soo Kim (Far-Tech, Inc.), Roger Heering Miller, Christopher Dennis Nantista (SLAC)*
Linear colliders and FEL facilities need fast, nondestructive beam position and profile monitors to facilitate machine tune-up, and for use with feedback control. FAR-TECH, Inc. is developing a resonant cavity diagnostic to simultaneously measure the dipole, quadrupole and sextupole moments of the beam distribution. Measurements of dipole and quadrupole moments at multiple locations yield information about beam orbit and emittance. The sextupole moment can reveal information about beam asymmetry which is useful in diagnosing beam tail deflections caused by short range dipole wakefields. In addition to the resonance enhancement of a single-cell cavity, use of a multi-cell standign-wave structure further enhances signal strength and improves the resolution of the device. An estimated rms beam size resolution is sub micro-meters and beam position is sub nano-meter.

Work supported by the U.S. Dept. of Energy.

**RPAT097—2-D Low Energy Electron Beam Profile Measurement Based on CT Algorithm with Multi-Wire Scanner**
*Nengjie Yu, Quanfeng Li, Chuan-Xiang Tang, Shuxin Zheng (TUB)*
A new method for low energy electron beam profile measurement is advanced, which presents a full 2-D beam profile distribution other than the traditional 2-D beam profile distribution given by 1-D vertical and horizontal beam profiles. The method is based on the CT •iComputer Tomography•j algorithm. Multi-sets of data about the 1-D beam profile projections are attained by rotating the multi-wire scanner. Then a 2-D beam profile is reconstructed from these projections with CT algorithm. The principle of this method is presented. The simulation and the experiment results are compared and analyzed in detail.

**RPAT098—Phase-Space Dynamic Tracking by a Two Pickups Data Acquisition System**
*Alessandro Drago, Maria Biagini, Susanna Guiducci, Catia Milardi, Miro Preger, Cristina Vaccarezza, Mikhail Zobov (INFN/LNF)*
A two pickups dynamic tracking data acquisition system has been developed at LNF for the DAFNE Phi-factory. Two oscilloscopes sample horizontal and vertical sum and difference signals from two pickups simultaneously; the sampling clock is locked to the DAFNE timing system. A horizontal kick excites the beam motion and initiates the acquisition. Turn-by-turn signals are converted to beam position and stored on a server in a database using timestamp labels. Oscillation amplitude versus time, phase space distribution and frequency domain analysis are shown for several lattices and different settings of sextupoles and octupoles. Results are used to check the DAFNE non-linear model.

**RPAT099—Novel Method for Phase-Space Tomography**
*Kevin Chalut (Duke University), Vladimir N. Litvinenko (BNL)*
Traditional tomographic methods based on Radon transformation require a full set evenly spaced projections covering full 180-degrees rotation in phase space. We describe a new method for phase-space tomography. This method allows one to restore phase space density using a small number of projections covering a limited angle of rotation or another linear transformation in the phase space. Practical applications of this method for phase-space tomography are discussed.

**RPAT100—Radiation-Hard Beam Position Detector for Use in the Accelerator Dump Lines**
*Pavel Degtiarenko, Danny Wyane Dotson, Vladimir Popov (Jefferson Lab)*
The new proposed method of beam position measurement is particularly suitable for monitoring high energy, and high power accelerated beams of charged particles in the vicinity of power beam dumps. Generally, the beam quality in those areas is very poor, and any equipment positioned there must be extremely resistant to radiation damage. We have found that a plate made of Chemical Vapor Deposition (CVD) Silicon Carbide (SiC) has a set of physical properties that make it suitable for such an application. CVD SiC material is a chemically inert, extremely radiation-hard, thermo-resistive semiconductor capable of withstanding working temperatures up to 2000 degrees Kelvin. It has good thermal conductivity comparable to that of Aluminum, which makes it possible to use it in high-current particle beams. High electrical resistivity of the material, and its semiconductor properties allow characterization of the position of a particle beam crossing such a plate by measuring balance of electrical currents at the plate ends. The design of a test device, and first results are presented in the report.

This work supported by the U.S. Department of Energy under contract DE-AC05-84ER40150

**Oral Session ROPA–Controls and Computing**
**Ballroom A @ 13:50**
**Chair: L. Hoff (BNL)**

**13:50 ROPA001—XAL Application Programming Structure**
*John Galambos, Chungming Chu, Sarah M. Cousineau, Thomas Pelaia, Andrei P. Shishlo (ORNL/SNS), Christopher K. Allen (LANL)*
XAL is an application programming framework used at the Spallation Neutron Source (SNS) project in Oak Ridge. It is written in Java, and provides users with a hierarchal view of the accelerator. Features include database configuration of the accelerator structure, an online envelope model that is configurable from design or live machine values, an application framework for quick-start GUI development, a scripting interface for algorithm development, and a common toolkit for shared resources. To date, about 25 applications have been written, many of which are used extensively in the SNS beam commissioning activities. The XAL framework and example applications will be discussed.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**14:15 ROPA002—CLS: A Fully Open-Source Control System**
*Elder Matias, Russ Berg, Terry Johnson, Robby Tanner, Tony Wilson, Glen Wright (CLS)*
The Canadian Light Source is one of the first major accelerator facility to adopt a fully open source control system. The control system is based on Experimental Physics and Industrial Control System (EPICS) in use at may other facilities. From the outset CLS utilised RTEMS and Linux as the underlying operating systems for real-time control computers, operator interface computers and servers. When communicating with PLC and other intelligent devices CLS has also adopted a policy of using open communications protocols where possible. Combined these strategies have lead to a system that can easily evolve over the life of the facility without being tied to specific hardware or software suppliers. The operational experience over the past few years has indicates the selected architecture is sufficiently robust and reliable.

**14:40 ROPA003—Present Status of the J-PARC Control System**
*Tadahiko Katoh, Kazuro Furukawa, Noboru Yamamoto (KEK), Hiroshi Yoshikawa (JAERI), Hironao Sakaki (JAERI/LINAC)*
Construction of the J-PARC control system is in progress and the present status is reported. The control system is based on EPICS tool-kit used in KEKB and other accelerator control systems at KEK. The control hardware and network system for Linac and RCS(Rapid Cycling Synchrotron) have been installed and software is under development now. The operation of Linac is expected in next year. The test of the first part of the accelerator complex; e.g. ion source, RFQ and the first DTL(20 MeV) were done at KEK site. Development of various software such as device drivers for the new equipment, device support routines, and some application programs for operators were also developed.

**14:55 ROPA004—CEBAF Control Room Renovation**
*Michael Spata, Tom Christopher Oren (JLab)*
The Machine Control Center at Jefferson Lab's Continuous Electron Beam Accelerator Facility was initially constructed in the early 1990s and based on proven technology of that era. Through our experience over the last 15 years and in our planning for the facilities 12 GeV upgrade we reevaluated the control room environment to capitalize on emerging visualization and display technologies and improve on workflow processes and ergonomic attributes. This effort also sets the foundation for the redevelopment of the accelerator's control system to deliver high reliability performance with improvements in beam specifications management and information flow. The complete renovation was performed over a three-week period with no interruption to beam operations. We present the results of this effort.

**15:10 ROPA005—High Level Control Applications for SOLEIL Commissioning and Operation**
*Laurent Stanislas Nadolski, Katy Ho, Nicolas Leclercq, Majid Ounsy, Sylvain Petit (SOLEIL)*
The SOLEIL control system, namely TANGO developed in collaboration with ESRF, is now mature and stable. TANGO has also been chosen now by several other laboratories. High-level control applications implemented in the control room for the storage ring, the two transfer lines, and the booster will be described in this paper. Three kinds of tools for commissioning are used. First the generic TANGO tools (alarms, simple graphical control applications), which allow us to control in a simple way any TANGO Device Server. Secondly a Matlab Middle Layer (adapted from ALS and SPEAR3): Matlab is fully interconnected with TANGO; it is used primarily for writing Physics control applications. Finally Globalscreen, a commercial SCADA software devoted for building operation applications has been selected (panels for controlling or displaying setpoint, readback values, status of equipments). In addition an overview of the historical and short-term databases for the accelerators will be given. They have been developed in house and tested during the first commissioning.

Synchrotron SOLEIL

**Oral Session ROPB–Two-Stream Instabilities and Collective Processes,**
**Ballroom B @ 13:50**
**Chair: G. Rumolo (CELLS)**

**13:50 ROPB001—Suppressing Electron Cloud in Future Linear Colliders**
*Mauro Torino Francesco Pivi Pivi (SLAC)*
Any accelerator circulating positively charged beams can suffer from a build-up of an electron cloud in the beam pipe. The cloud develops through ionization of residual gases, synchrotron radiation and secondary electron emission and, when severe, can cause instability, emittance blow-up or loss of the circulating beam. The electron cloud is potentially a limiting effect for both the Large Hadron Collider (LHC) and the International Linear Collider (ILC). For the ILC positron damping ring, the development of the electron cloud must be suppressed. This paper presents the various effects of the electron cloud and evaluates their significance. It also discusses the state-of-the-art of the ongoing international R&D program to study potential remedies to reduce the secondary electron yield to acceptably low levels.

Work supported by the U.S. DOE under contract DE-AC02-76SF00515.

**14:15 ROPB002—Experiments Studying Desorbed Gas and Electron Clouds in Ion Accelerators**
*Arthur Molvik, John J. Barnard, Ronald Cohen, Alex Friedman, Michel Kireeff Covo, Steven Mocko Lund (LLNL), David Baca, Frank Bieniosek, C. M. Celata, Peter Seidl, Jean-Luc Vay, William Waldron (LBNL)*
Electron clouds and gas pressure rise limit the performance of many major accelerator rings. We are studying these issues experimentally with ~1 MeV heavy-ion beams, coordinated with significant efforts in self-consistent simulation and theory.* The experiments use multiple diagnostics, within and between quadrupole magnets, to measure the sources and accumulation of electrons and gas. In support of these studies, we have measured gas desorption and electron emission coefficients for potassium ions impinging on stainless steel targets at angles near grazing incidence.** Our goal is to measure the electron particle balance for each source – ionization of gas, emission from beam tubes, and emission from an end wall – determine the electron effects on the ion beam and apply the increased understanding to mitigation.
*J-L. Vay, Invited paper, session TICP; R. H. Cohen et al., PRST-AB 7, 124201 (2004). **M. Kireeff Covo, this conference; A. W. Molvik et al., PRST-AB 7, 093202 (2004).

This work was performed under the auspices of the U.S. Department of Energy by University of California, LLNL under contract No. W-7405-Eng-48, and by LBNL under Contract DE-AC03-76F00098.

**14:40 ROPB003—Electron Cloud Dynamics in High-Intensity Rings**
*Lanfa Wang, Jie Wei (BNL)*
Electron cloud due to beam induced multipacting is one of the main concerns for the high intensity rings because the electron multipacting becomes stronger with the increment of beam intensity. Electrons generated and accumulated inside the beam pipe form an "electron cloud" that interacts with the circulating charged particle beam. With sizeable amount of electrons, this interaction can cause beam instability, beam loss and emittance growth. At the same time, the vacuum pressure will rise due to electron desorption. This talk intends to provide an overview of the dynamics of the typical electron multipacting in various magnetic fields and mitigation measures in both long bunch and short bunch rings.

Work performed under the auspices of the U.S. Department of Energy. SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**15:05 ROPB004—Effect of Lattice and Electron Distribution in Electron-Cloud Instability Simulations for the CERN SPS and LHC**
*Elena Benedetto, Gianluigi Arduini, Federico Roncarolo, Frank Zimmermann (CERN), Giovanni Rumolo (GSI), Kazuhito Ohmi (KEK), Bing Feng, Ali Feiz Ghalam, Tom Katsouleas (USC)*
Several simulation codes have been adapted so as to model the single-bunch electron-cloud instability including a realistic variation of the optical functions with longitudinal position. In addition, the electron cloud is typically not uniformly distributed around the ring, as frequently assumed, but it is mainly concentrated in certain regions with specific features, e.g., regions which give rise to strong multipacting or suffer from large synchrotron radiation flux. Particularly, electrons in a dipole magnet are forced to follow the vertical field lines and, depending on the bunch intensity, they may populate two vertical stripes, symmetrically located on either side of the beam. In this paper, we present simulation results for the CERN SPS and LHC, which can be compared with measurements or analytical predictions.

**15:20 ROPB005—Recent Experiment Results on Fast Ion Instability at 2.5 GeV PLS**
*Eun-San Kim, Yeung-Jin Han, Jung Yun Huang, In Soo Ko, Chong-Do Park, Sung-Ju Park (PAL), Hitoshi Hukuma (KEK)*
We present recent experiment results on the fast ion instability that were performed at the PLS storage ring. With higher vacuum pressures of three orders of magnitude than nominal one by He gas injection into the ring, increases of a factor of around three in the vertical beam size were observed by interferometer system. From the various measurement results, we estimated growth times for the instability as a funcion of vacuum pressure and beam current. We also compared the results with those of the computer simulations and analytical calculations.

## Oral Session ROPC–Low- and Medium-Energy Accelerators and Rings, Ballroom C @ 13:50
## Chair: M. Plum (ORNL/SNS)

**13:50 ROPC001—SNS Warm Linac Commissioning Results**
*Alexander V. Aleksandrov (ORNL/SNS)*
The Spallation Neutron Source accelerator systems will deliver a 1.0 GeV, 1.4 MW proton beam to a liquid mercury target for neutron scattering research. The accelerator complex consists of an H- injector, capable of producing one-ms-long pulses at 60Hz repetition rate with 38 mA peak current, a 1 GeV linear accelerator, an accumulator ring and associated transport lines. The 2.5MeV beam from the Front End is accelerated to 86 MeV in the Drift Tube Linac, then to 185 MeV in a Coupled-Cavity Linac and finally to 1 GeV in the Superconducting Linac. The staged beam commissioning of the accelerator complex is proceeding as component installation progresses. The Front End, Drift Tube Linac and three of the four Coupled-Cavity Linac modules have been commissioned with beam at ORNL. Results and status of the beam commissioning program will be presented.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**14:15 ROPC002—J-PARC Commissioning Results**
*Kazuo Hasegawa (JAERI)*
The J-PARC (Japan Proton Accelerator Research Complex) comprises a 400-MeV linac, a 3-GeV rapid-cycling synchrotron (RCS), a 50-GeV main ring synchrotron (MR) and experimental facilities. A peak current of 30 mA was accelerated up to 20 MeV of the DTL beam commissioning at the KEK site. The buildings and conventional facilities will be completed in succession in the Japanese Fiscal Year 2005, when the installation of the accelerator components will be actually started at Tokai site. The beam commissioning of the 181 MeV linac will be started in September, 2006, followed by the RCS and MR beam commissioning. To achieve the high beam power with low beam loss, the J-PARC accelerators are based on many newly developed technologies; pi-mode stabilizing loops in the RFQ, RF choppers in the medium energy beam transport, magnetic alloy loaded RF cavities in the synchrotrons, etc. The recent results of the developments of these new technologies, the present construction status and the commissioning schedule will be presented.

**14:40 ROPC003—RIKEN RI Beam Factory Project**
*Yasushige Yano (RIKEN/RARF/CC)*
The world-top-class radioactive-isotope-beam (RIB) facility, which is called ?RI beam factory (RIBF)?, is under construction at RIKEN. This facility is based on the so-called ?in-flight RI beam separation? scheme. Late in 2006, a new high-power heavy-ion accelerator system consisting of a cascade of three ring cyclotrons with K=570 MeV (fixed frequency, fRC), 980 MeV (Intermediate stage, IRC) and 2500 MeV (superconducting, SRC), respectively, will be commissioned. This new accelerator system will boost energies of the output beams from the existing K540-MeV ring cyclotron up to 440 MeV/nucleon for light ions and 350 MeV/nucleon for very heavy ions. These energetic heavy-ion beams are converted into intense RI beams via the projectile fragmentation or in-flight fission of uranium ions by the superconducting isotope separator, BigRIPS, under construction. The combination of the SRC and BigRIPS will expand our nuclear world into presently unreachable region. Major experimental installations are under priority discussion as the second phase program. Construction of the second phase is expected to start in 2006.

**15:05 ROPC004—Recent Intensity Increase in the CERN Accelerator Chain**
*Elena Shaposhnikova, Gianluigi Arduini, Thomas Bohl, Michel Chanel, Roland Garoby, Steven Hancock, Klaus Hanke, Trevor Paul Linnecar, Elias Métral, Rende Richard Steerenberg, Bernard Vandorpe (CERN)*
Future requests for protons from the physics community at CERN, especially after the start-up of the CNGS experiments in 2006, can only be satisfied by a substantial increase in the SPS beam intensity per pulse. In September 2004 a three weeks beam run was dedicated to high intensity; all accelerators in the chain were pushed to their limits to study intensity restrictions and find possible solutions. New record intensities were obtained in the accelerators of the PS & SPS Complex with this fixed-target type beam which is different from the nominal LHC beam. The challenges in producing this high-intensity beam are described together with the measures needed to make it fully operational.

**15:20 ROPC005—RIA Post Accelerator Design**
*Stan Owen Schriber (NSCL)*
Overall design of the post accelerator for the RIA project is described with emphasis on performance for different ion beams. Characteristics for beams from A=10 to A=240 will be provided with an estimate of output intensities. The rational for selection of different accelerating structures, both for the normal conducting and for the superconducting types, will be provided for a system design that accelerates beams to at least 10 MeV/u.

**Oral Session ROPA (Cont.)–Controls and Computing**
**Ballroom A @ 15:30**
**Chair M. Borland (ANL)**

**15:30 ROPA006—Terascale Beam-Beam Simulations for Tevatron, RHIC and LHC**
*Ji Qiang (LBNL)*
In this paper, we report on recent advances in terascale simulations of the beam-beam effects in Tevatron, RHIC and LHC. Computational methods for self-consistent calculation of the beam-beam forces are reviewed. Applications to the studies of the multiple bunch beam-beam interactions in the Tevatron and the RHIC will be presented. The study of emittance growth due to the beam-beam interactions in the LHC will also be presented.

This work was supported by a SciDAC project in accelerator physics which is supported by the US DOE/SC Office of High Energy Physics and the Office of Advanced Scientific Computing Research.

**15:55 ROPA007—Vlasov Simulations of Beams and Halo**
*Eric Sonnendrucker (IRMA), Jean-Louis Lemaire (CEA/DIF/DPTA/SP2A)*
Even though PIC simulations have proven an efficient tool for beam simulations for many years, they are subject to numerical noise which only decreases slowly when the number of particles is increased. Therefore other methods might be preferable, when one is interested in accurate simulations of high intensity beams especially in the low density part of phase space. We have been developing new methods based on the direct resolution of the Vlasov equation on a grid of phase space. In order for these methods to be efficient special care needs to be taken to optimize the number of necessary grid points. We shall describe two different approaches that are used to this aim: moving grid methods and wavelet based automatic grid refinement. Beam simulations in different configurations using direct Vlasov methods will be presented.

**16:20 ROPA008—The Grid**
*Wolf-Dieter Klotz (ESRF)*
Grid technology is widely emerging. Grid computing, most simply stated, is distributed computing taken to the next evolutionary level. The goal is to create the illusion of a simple, robust yet large and powerful self managing virtual computer out of a large collection of connected heterogeneous systems sharing various combinations of resources. This talk will give a short history how, out of lessons learned from the Internet, the vision of Grids was born. Then the extensible anatomy of a Grid architecture will be discussed. The talk will end by presenting a selection of major Grid projects in Europe and US and if time permits a short on-line demonstration.

**16:45 ROPA009—Bridging Timescales for Simulating Electron Clouds**
*Ronald Cohen, Alex Friedman (LLNL), Jean-Luc Vay (LBNL)*
For a range of acclerator applications, accurate simulation of electron-cloud effects requires self-consistent simulation of electrons and the main positively-charged accelerated species. For systems with multipole focusing magnets, the simulation must span timescales from electron cyclotron periods to the beam duration. We have devised a scheme to bridge over the shortest (electron cyclotron) timescale based on interpolation between full dynamics and drift kinetics.* We describe the method and results for heavy-ion beam simulations. We also discuss options for bridging to ion-transit timescales.
*R. H. Cohen, A. Friedman, S. M. Lund, A. W. Molvik, E. P. Lee, T. Azevedo, L.-L. Vay, P. Stoltz and S. Veitzer, PRST-AB 7, 124201 (2004).

Work performed under the auspices of the U.S. Department of Energy by U. C. LLNL under contract No. W-7405-Eng-48 and by U.C. LBNL under Contract DE-AC03-76F00098.

**17:00 ROPA010—TBD**

Oral Session ROPB (Cont.)–Two-Stream Instabilities and Collective Processes, Ballroom B @ 15:35
Chair: I. Hofmann (GSI)

**15:35 ROPB006—Filling in the Roadmap for Self-Consistent Electron Cloud and Gas Modeling**
*Jean-Luc Vay (LBNL), Miguel Furman (LBNL/AFR), Ronald Cohen, Alex Friedman, David Grote, Arthur Molvik (LLNL), Peter Stoltz, Seth Andrew Veitzer (Tech-X), John verboncoeur (UCB)*
Electron clouds and gas pressure rise limit the performance of many major accelerators. A multi-laboratory effort to understand the underlying physics via the combined application of experiment,* theory, and simulation is underway. We present here the status of the simulation capability development, based on a merge of the three-dimensional parallel Particle-In-Cell accelerator code WARP and the electron cloud code POSINST, with additional functionalities.** The development of the new capability follows a "roadmap" describing the different functional modules, and their inter-relationships, that are ultimately needed to reach self-consistency. Newly developed functionalities include a novel particle mover bridging the time scales between electrons and ions motion.*** Samples of applications of the new capability to the modeling of intense charge dominated beams**** and LHC beams***** will be shown as available.
*A.W. Molvik, these proceedings. **J.-L. Vay, Proc. "ECLOUD04," Napa (California), 2004. ***R.H. Cohen, these proceedings. ****P.A. Seidl, these proceedings. *****M.A. Furman, these proceedings.

This work was performed under the auspices of the U.S. Department of Energy by University of California, LLNL and LBNL under contracts W-7405-Eng-48, and DE-AC03-76F00098.

**16:00 ROPB007—3-D Parallel Simulation Model of Continuous Beam-Electron Cloud Interactions**
*Ali Feiz Ghalam, Tom Katsouleas (USC), Viktor K. Decyk, Warren Mori (UCLA)*
A 3D Particle-In-Cell model for continuous modeling of beam and electron cloud interaction in a circular accelerator is presented. A simple model for lattice structure, mainly the Quadruple and dipole magnets and chromaticity have been added to a plasma PIC code, QuickPIC, used extensively to model plasma wakefield acceleration concept. The code utilizes parallel processing techniques with domain decomposition in both longitudinal and transverse domains to overcome the massive computational costs of continuously modeling the beam-cloud interaction. Through parallel modeling, we have been able to simulate long-term beam propagation in the presence of electron cloud in many existing and future circular machines around the world. The exact dipole lattice structure has been added to the code and the simulation results for CERN-SPS and LHC with the new lattice structure have been studied. Also the simulation results are compared to the results from the two macro-particle modeling for strong head-tail instability. It is shown that the simple two macro-particle model can capture some of the physics involved in the beam- electron cloud interaction qualitatively.

**16:25 ROPB008—Halo Mitigation Using Nonlinear Latices**
*Kiran G. Sonnad, John R. Cary (CIPS)*
This work shows that halos in beams with space charge effects can be controlled by combining nonlinear focusing and collimation. The study relies on Particle-in-Cell (PIC) simulations for a one dimensional, continuous focusing model. The PIC simulation results show that nonlinear focusing leads to damping of the beam oscillations thereby reducing the mismatch. It is well established that reduced mismatch leads to reduced halo formation. However, the nonlinear damping is accompanied by emittance growth causing the beam to spread in phase space. As a result, inducing nonlinear damping alone cannot help mitigate the halo. To compensate for this expansion in phase space, the beam is collimated in the simulation and further evolution of the beam shows that the halo is not regenerated. The focusing model used in the PIC is analysed using the Lie Transform perturbation theory showing that by averaging over a lattice period, one can reuduce the focusing force to a form that is identical to that used in the PIC simulation.

**16:50 ROPB009—Betatron Sidebands Due to Electron Clouds Under Colliding Beam Conditions**
*John Walter Flanagan, Hitoshi Fukuma, Shigenori Hiramatsu, Hitomi Ikeda, Kazuhito Ohmi, Makoto Tobiyama, Sadaharu Uehara (KEK)*
Recently, we have observed vertical betatron sidebands in the transverse beam spectra of positron bunches at the KEKB LER which are associated with the presence of electron clouds. When the LER is operating in single-beam mode (no colliding bunches in the HER), these sidebands are sharply peaked. When the bunches are in collision for physics running, the sidebands are still present but are found to be smeared out. The bunch-by-bunch specific luminosity is lower for bunches with sidebands than for those without sidebands. In this paper, the behavior of the sidebands in collision and the effects on luminosity are discussed.

**17:05 ROPB010—Self-Consistent Electron-Cloud Simulation for Long Proton Bunches**
*Andrei P. Shishlo, Sarah M. Cousineau, Viatcheslav V. Danilov, Stuart Henderson, Jeffrey Alan Holmes (ORNL/SNS), Shyh-Yuan Lee, Yoichi Sato (IUCF), Robert James Macek (LANL/LANSCE)*
The results of numerical electron-cloud simulations for long-bunch proton beams in accumulator rings are presented and compared with data from the Proton Storage Ring at LANL. The frequency spectra and growth rate of proton-bunch transverse instabilities are studied as functions of the RF cavity voltage, external magnetic fields, beam pipe surface properties, and other factors. We used the recently developed electron-cloud module in the ORBIT code. The model includes a fully self-consistent coupled treatment of the "proton bunch – electron-cloud" dynamics and the multipacting process with a realistic secondary emission surface model. Realistic lattices and proton bunch distributions of the PSR and SNS rings are used. The efficiency of electron-cloud instability suppression has also been studied using a new ORBIT model of a feedback system.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

Oral Session ROPC (Cont.)–Low- and Medium-Energy Accelerators and Rings, Ballroom C @ 15:35
Chair: R. Garnett (LANL)

**15:35 ROPC006—Commissioning of Fermilab's Electron Cooling System for 8-GeV Antiprotons**
*Sergei Nagaitsev (Fermilab)*
A 4.3-MeV electron cooling system has been installed at Fermilab in the Recycler antiproton storage ring and is being currently commissioned. The cooling system is designed to assist accumulation of 8.9-GeV/c antiprotons for the Tevatron collider operations. This paper will report on the progress of the electron beam commissioning effort as well as on detailed plans of demonstrating the cooling of antiprotons.

**16:00 ROPC007—Status of the Proton Engineering Frontier Project (PEFP) at KAERI**
*Byung-Ho Choi (KAERI)*
The Proton Engineering Frontier Project (PEFP) approved and launched by the Korean government in July 2002 includes a 100MeV proton linear accelerator development and a program for its utilization. The first phase of the project, running from 2002 to 2005, was the design of a 100MeV proton linear accelerator and a part of development to 20 MeV. This consists of a 50 keV proton injector, a 3 MeV radio frequency quadrupole (RFQ), and a 20MeV drift tube linac (DTL). The 50 keV injector and the 3 MeV RFQ has been installed and tested, and the 20 MeV DTL is being assembled and tuned for beam tests. At the same time, the utilization programs using the proton beam have been planned, and some are now under way. The status and progress of the project are reported in detail.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**16:25 ROPC008—Experimental Progress in Fast Cooling in the ESR**
*Markus Steck, Karl Beckert, Peter Beller, Bernhard Franzke, Fritz Nolden (GSI)*
The Proton Engineering Frontier Project (PEFP) approved and launched by the Korean government in July 2002 includes a 100MeV proton linear accelerator development and a program for its utilization. The first phase of the project, running from 2002 to 2005, was the design of a 100MeV proton linear accelerator and a part of development to 20 MeV. This consists of a 50 keV proton injector, a 3 MeV radio frequency quadrupole (RFQ), and a 20MeV drift tube linac (DTL). The 50 keV injector and the 3 MeV RFQ has been installed and tested, and the 20 MeV DTL is being assembled and tuned for beam tests. At the same time, the utilization programs using the proton beam have been planned, and some are now under way. The status and progress of the project are reported in detail.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**16:50 ROPC009—First Acceleration with Superconducting RF Cavities at ISAC-II**
*Robert Edward Laxdal, Ken Fong, Marco Marchetto, William Reginald Rawnsley, Victor Verzilov (TRIUMF)*
We have demonstrated the first acceleration of ions with superconducting rf at TRIUMF/ISAC. Alpha particles from a radioactive source were accelerated from 2.8MeV through the ISAC-II medium beta cryomodule to a maximum energy of 9.4 MeV. The four 106 MHz quarter wave cavities (beta_o=7%) were set to the ISAC-II specified gradient of 6 MV/m (Leff=18cm, Ep=30MV/m and Veff=1.08MV) with a cavity power of about 6W per cavity. The final particle energy spectra was measured with a silicon detector. The initial alpha energy corresponds to a velocity of beta=3.9% giving an expected T/To efficiency of 0.48, 0.76, 0.92 and 0.99 for the four cavities respectively and an expected final energy of 9.6MeV. The experimental set-up including details of the source and diagnostic boxes and the detector electronics are described. Beam simulations of the unbunched, uncollimated beam indicate a unique spectral fingerprint that can be used to unambiguously determine each cavity voltage.

**17:05 ROPC010—Testing, Installation, Commissioning and First Operation of the ISIS RFQ Pre-Injector Upgrade**
*Alan Letchford, Dan Faircloth, Michael Perkins, Alan Stevens, Mark Whitehead (CCLRC/RAL/ISIS)*
Situated at the Rutherford Appleton Laboratory (Oxon., UK), ISIS is currently the world's most intense pulse spallation neutron source, delivering 160 kW of 800 MeV protons to a tungsten target at 50 Hz. A major facility upgrade programme involves the construction of a second, 10 Hz target and an increase in the total beam power of up to 50% (i.e. up to 240 kW). To achieve the planned increase in average beam current to 300 μA whilst maintaining the current manageable levels of beam loss, four 2nd harmonic RF cavities have been installed in the synchrotron and the ageing Cockroft-Walton pre-injector in the linac has been replaced with a 665 keV, 202.5 MHz, 4-rod RFQ. This paper describes the extensive testing, installation, commissioning and successful initial operation of the RFQ pre-injector upgrade.

Poster Session RPPE–Accelerator Technology
Ballroom E, 13:50-17:10

**RPPE001—The CARE Accelerator R&D Programme in Europe**
*Olivier Napoly, Roy Aleksan, Arnaud Devred (CEA/DSM/DAPNIA), Roland Garoby, Roberto Losito, Louis Rinolfi, Maurizio Vretenar (CERN), Helmut Mais, Dieter Proch (DESY), Andrea Ghigo (INFN/LNF), Terence Garvey (LAL), Andres Den Ouden (Twente University)*
CARE, an ambitious and coordinated programme of accelerator research and developments oriented towards HEP projects, has been launched in January 2004 by the main European laboratories and the European Commission within the 6th Framework Programme. This programme aims at improving existing infrastructures dedicated to future projects such as linear colliders, upgrades of hadron colliders and high intensity proton drivers. An important part of this programme is devoted to advancing the performance of the superconducting technology, both in the fields of RF cavities for electron and proton acceleration and of high field magnets, as well as to developing high intensity electron and proton injectors. We describe the R&D plans of the four main R&D activities and report on the results and progress obtained so far.

This work is supported by the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).

**RPPE002—Install and Radiation Maintenance Scenario for J-PARC Main Ring**
*Masakazu Yoshioka (KEK)*
J-PARC comprises a 400 MeV linac (181 MeV at the first stage), a 3 GeV rapid-cycling synchrotron and a 50 GeV synchrotron (Main Ring), which will provide high power proton beam to the material and life science facility, the neutrino facility and the nuclear and particle physics experimental hall. The installation of the accelerator components for the Main Ring will be started on mid. 2005 and the beam commissioning is scheduled in end of 2007. This paper describes the installation scenario of the accelerator components into the main ring tunnel and the development of radiation maintenance scenario for the beam injection and ejection systems.

Ministry of Education, Culture, Science and Technology, Japan

**RPPE003—Operational Experience of Cooling Water Systems for Accelerator Components at PLS**
*Kyungryul Kim, Hyung-Gyun Kim (PAL)*
The cooling water system has been utilized for absorbing heat generated by a multitude of electromagnetic power delivering networks at PLS. The separate cooling water distribution systems for the storage ring, beam transport line and linear accelerator have been operated with a different operating temperature of supplying water. All water used for heat removal from the accelerator components are deionised and filtered to provide with over 2 MΩ-cm specific resistance. The operating pressures and flows of input water are also controlled with flow balancing scheme at a specified range. The operating temperature of components in the accelerator is sustained as tight as below ±0.1 deg C to minimize the influence of temperature fluctuation on the beam energy and stability. Although the PLS cooling systems were initially installed with a high degree of flexibility to allow for easy maintenance, a number of system improvements have been employed to enhance operational reliability and to incorporate the newly developed operating interfaces such as EPICS accelerator control systems. The important design and operational features of PLS cooling water systems are presented as well as lessons learned from around 10-years normal operation.

Work supported by MOST and POSCO in Republic of Korea.

**RPPE004—A Risk-Oriented Approach for Setting Priorities Among Beneficiaries of Consolidation Funding**
*Pierre Bonnal, John Poole (CERN)*
All scientific facilities around the world have significantly increased in size and complexity over the two last decades. Whilst, public funding for these facilities has not followed at the same rate! As a consequence, labs are asked to deploy much more effective management techniques to be "faster, better and cheaper," to quote former NASA's CEO Daniel Goldin. Labs are now facing the challenge of maintaining and consolidating their existing facilities with less funding, so some selection must be made from systems and equipment to identify those which should benefit from renewal or refurbishing programmes. To manage its accelerator consolidation programme CERN's Accelerators & Beams Department has used a risk-oriented approach to determine priorities among the systems and equipment that should benefit from consolidation funding, so funding goes to the systems and equipment that are most likely to jeopardize operation of the facilities. The advantage of such an approach is that resource allocation is carried out objectively and the outcome of the decision making process is clear and fair. The methodology CERN has used is presented and discussed in the present paper.

**RPPE005—Ions for LHC: Beam Physics and Engineering Challenges**
*Stephan Maury, Maria-Elena Angoletta, Vito Baggiolini, Andre Beuret, Alfred Blas, Jan Borburgh, Hans-Heinrich Braun, Helmut Burkhardt, Christian Carli, Michel Chanel, Tony Fowler, Marine Gourber-Pace, Steven Hancock, Charles E. Hill, Michael Hourican, John M. Jowett, Karsten Kahle, Detlef Kuchler, Alessandra Maria Lombardi, Edgar Mahner, Django Manglunki, Michel Martini, Mauro M. Paoluzzi, Flemming Pedersen, Uli Raich, Carlo Rossi, Jean-Pierre Royer, Karlheinz Schindl, Richard Scrivens, Luc Sermeus, Elena Shaposhnikova, Gerard Tranquille, Maurizio Vretenar, Thomas Zickler (CERN)*
The first phase of the heavy ion physics program at the LHC aims to provide lead-lead collisions at energies of 5.5 TeV per colliding nucleon pair and ion-ion luminosity of 1027 cm-2s-1. The transformation of CERN's ion injector complex (Linac3-LEIR-PS-SPS) presents a number of beam physics and engineering challenges. Conversion of the Low Energy Antiproton Ring (LEAR) to a Low Energy Ion Ring (LEIR) is under way: the high-current electron cooling system, novel broad-band RF cavities and vacuum equipment to achieve 10-12 mbar are the major challenges. Commissioning of LEIR with beam will start in the middle of 2005. Major hardware changes in Linac3 include the installation of the new ECR ion source and of the energy ramping cavity. The PS will have a new injection system and RF gymnastics. A stripping insertion between PS and SPS must not disturb the proton operation. In the LHC itself, there are fundamental performance limitations due to various beam loss mechanisms. To study these without risk of damage there will be an initial period of operation with a reduced number of nominal intensity bunches. While reducing the work required to commission the LHC with ions in 2008, this will still enable early physics discoveries.

**RPPE006—Air Temperature Analysis and Control Improvement for the Storage Ring Tunnel**
*Jui-Chi Chang, June-Rong Chen, Zong-Da Tsai (NSRRC), Ming-Tsun Ke (NTUT)*
The stability of the electron beam orbit had been observed to be sensitive to the utility conditions. The stability of air temperature in the storage ring tunnel is one of the most critical factors. Accordingly, a series of air conditioning system upgrade studies and projects have been conducted at the Taiwan Light Source (TLS). Computational fluid dynamics (CFD) is applied to simulate the flow field and the spatial temperature distribution in the storage ring tunnel. The circumference and the height of the storage tunnel are 120m and 2.8m, respectively. The temperature data and the flow rates at different locations around the storage ring tunnel are collected as the boundary conditions. The k-epsilon turbulence model is applied to simulate the flow field in the three dimensional space. The global air temperature variation related to time in the storage ring tunnel is currently controlled within ±0.1 degree C. However, the temperature difference between two different locations is as high as 2 degree C. Some measures improving the temperature uniformity will be taken according to the CFD simulation results.

**RPPE007—High Precision Temperature Control and Analysis of RF Deionized Cooling Water System**
*Zong-Da Tsai, Jui-Chi Chang, June-Rong Chen (NSRRC)*
Previously, the Taiwan Light Source (TLS) has proven the good beam quality mainly depends on the utility system stability. A serial of efforts were devoted to these studies. Further, a high precision temperature control of the RF deionized cooling water system will be achieved to meet the more critical stability requirement. The paper investigates the mixing mechanism through thermal and flow analysis and verifies the practical influences. A flow mixing mechanism and control philosophy is

studied and processed to optimize temperature variation which has been reduced from ±0.1? to ±0.01?. Also, the improvement of correlation between RF performance and water cooling stability will be presented.

**RPPE008—Water Induced Vibration in NSRRC**
*Duan Jen Wang, H.C. Ho, Zong-Da Tsai (NSRRC, Hsinchu)*
Water flow related vibration was found on the quadrupole magnets in the storage ring. The major vibration source was centrifugal pumps of water chillers. A large amount of vibration was coupled through water pipe and propagated to the magnets. Other vibration propagated along the ground. To reduce the vibration some isolation and damping schemes were evaluated by a test system. A detailed vibration measurement on the magnet in the storage was also included.

**RPPE009—Extremely High Current, High-Brightness Energy Recovery Linac**
*Ilan Ben-Zvi, Donald Barton, Dana Beavis, Michael Blaskiewicz, Andrew Burrill, Rama Calaga, Peter Cameron, Xiangyun Chang, David Mark Gassner, Harald Hahn, Ady Hershcovitch, Hsiao-Chaun Hseuh, Dmitry Kayran, Jorg Kewisch, Robert Lambiase, Vladimir N. Litvinenko, Gary McIntyre, Wuzheng Meng, Thomas Nehring, Tony Nicoletti, Brian Oerter, Jim Rank, Triveni Rao, Thomas Roser, Thomas Russo, Joseph Scaduto, Kevin Smith, Neville Willaims, Kuo-Chen Wu, Kin Yip, Alex Zaltsman, Yongxiang Zhao (BNL), Al Burger, Anthony Favale, Douglas Holmes (AES), Michael Cole, John Rathke, Tom Schultheiss, Alan Murray Melville Todd (AES), Jean Roger Delayen, Warren Funk, Peter Kneisel, Larry Phillips, Joseph P. Preble (Jefferson Lab)*
Next generation ERL light-sources, high-energy electron coolers, high-power Free-Electron Lasers, powerful Compton X-ray sources and many other accelerators were made possible by the emerging technology of high-power, high-brightness electron beams. In order to get the anticipated performance level of ampere-class currents, many technological barriers are yet to be broken. BNL's Collider-Accelerator Department is pursuing some of these technologies for its electron cooling of RHIC application, as well as a possible future electron-hadron collider. We will describe work on CW, high-current and high-brightness electron beams. This will include a description of a superconducting, laser-photocathode RF gun and an accelerator cavity capable of producing low emittance (about 1 micron rms normalized) one nano-Coulomb bunches at currents of the order of one ampere average.

Under contract with the U.S. Department of Energy, U.S. DOD Office of Naval Research and Joint Technology Office.

**RPPE010—Beam Transport Devices for the 10kW Free Electron Laser at Thomas Jefferson National Accelerator Facility**
*Lawrence A. Dillon-Townes, Stephen Vincent Benson, Michael E. Bevins, George Herman Biallas, David Douglas, David Herbert Kashy, Ronald Lassiter, Danny Machie, Stephanie Slachtouski, Karl Smith, Mark Wiseman (Jefferson Lab)*
The beam transport vacuum components for the 10 kW Free Electron Laser (FEL) at Thomas Jefferson National Accelerator Facility (TJNAF) were designed to address 10 MeV electron beam characteristics and maintain an accelerator transport vacuum of 10-9 torr. The components discussed include a novel zero length beam clipper, novel shielded bellows, one decade differential pumping stations with a 7.62 cm (3.0") aperture, and a 50 kW beam dump. Incorporation of these accelerator transport components assist in establishing the environment needed for the electron beam to produce the optical light required to lase at 10 kW.

Department of Energy

**RPPE011—SNS Project Electrical Energy Balance and AC Power Distribution for Major Accelerator Systems**
*Paul Samuel Holik (ORNL/SNS)*
The SNS Project has 45MW of installed power. A design description under the Construction Design and Maintenance (CDM) with regard to regulations (OSHA, NFPA, NEC), reliability issues and maintenance of the AC power distribution system are herewith presented. The SNS Project has 45MW of installed power. The Accelerator Systems are Front End (FE)and LINAC KLYSTRON Building (LK), Central Helium Liquefier (CHL), High Energy Beam Transport (HEBT), Accumulator Ring and Ring to Target Beam Transport (RTBT) Support Buildings have 30MW installed power. FELK has 16MW installed, majority of which is klystron and magnet power supply system. CHL, supporting the super conducting portion of the accelerator has 7MW installed power and the RING Systems (HEBT, RING and RTBT) have also 7MW installed power.*
*SNS SRD. KJ Basis of Design. IEEE Red Book. IEEE Gold Book. IEEE Green Book. NEC NFPA.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**RPPE012—Grounding System of SNS Accelerator Systems and the Entire SNS Site Grounding**
*Paul Samuel Holik (ORNL/SNS)*
Description of site general grounding network. RF grounding network enhancement underneath the klystron gallery building. Grounding network of the Ring Systems with ground breaks in the Ring Tunnel. Grounding and Bonding of R&D accelerator equipment. SNS Building lightning protection.
*SNS SRD *IEEE Green Book *IEEE Emerald Book

UT-Battelle, SNS Collaboration.

**RPPE013—A Proposal for a Novel Air Conditioning of the XFEL Undulator Tunnels**
*Jens-Peter Jensen, Sabahattin Celik (DESY)*
The XFEL undulators are installed in tunnels over a length up to 300 m. The undulators are built and adjusted at 21°C. The magnetic field in the undulator gap allows a tolerance of 10 ppm. The permanent magnets have a temperature gradient of 100 ppm/°C. Therefore the air temperature must be 21°C ± 0.1°C over a long distance. This requires high temperature stability and low temperature gradient of the tunnel air. The temperatures of the tunnel wall and the floor have a big impact on the air temperature gradient. Every warm body transports the tunnel air from the bottom up to the ceiling. Since the tunnels are totally covered by 11°C ground water the tunnel walls are cold. The classical solution is a ventilation system with high air velocity and big turbulence to combat temperature gradients. A novel air conditioning operates with low air velocity. The temperatures of the floor, the wall and the ceiling have to be coordinated. The warm air under the ceiling has to be extracted in a way that avoids turbulences. This leads to a stable lamination of the air with a low gradient. The air flow and the lamination of the tunnel air are investigated by a fluid simulation programme.

**RPPE014—Temperature Regulation of the Accelerating Section in CANDLE Linac**
*Sergey Tunyan, Gayane A. Amatuni, Bagrat Grigoryan (CANDLE)*
The temperature of the CANDLE S-Band Linac high-power RF components will be regulated by stand-alone closed loop (SACL) water system. The RF components are made of oxygen-free high conductivity copper and respond quickly to temperature changes. Temperature stabilization better than ± 0.1 C is required to achieve a good RF phase and energy stability. The temperature regulation and control philosophy along with the simulation results are discussed.

**RPPE015—Diagnostics and Protection Control for IREN Linac Test Facility**
*Victor Zamriy (JINR)*
The diagnostic and protection control systems for the full-scale test facility of the linear electron accelerator are constructed according to the project on pulsed neutron source IREN. Combined control schemes of timed diagnostics of a duty cycle and real-time protection control are created for the linac test facility. Applicability of the diagnostics systems of cycle parameters and deviations of a status for control of the mode of protection is shown. Multichannel control modules of the protection system have been developed for logging and diagnostics of a status change, the alarms and control of a mode of operation. The applied multiway controllers for duty protection with fast locking of cycles of the IREN linac are presented.

**RPPE016—Protection Level During Extraction, Transfer and Injection into the LHC**
*Verena Kain, Brennan Goddard, Ruediger Schmidt (CERN)*
Failures during the LHC transfer and injection process cannot be excluded and beam loss with the foreseen intensities and energies, which are an order of magnitude above the damage limit, could cause serious equipment damage. Consequences of equipment failures such as kicker erratics, power converter faults, etc. are investigated by means of a Monte Carlo based on MAD-X tracking with a full aperture model of the transfer line and the injection region. Geometrical and optical mismatch, orbit tolerances, mechanical tolerances for settings of protection elements, power converter ripples, misalignment of elements, etc. are all taken into account. The obtained beam loss maps and risk levels are presented. The overall protection level for the LHC and the transfer lines during injection is discussed.

**RPPE017—Active and Passive Machine Protection Against Failures During the LHC Injection Process**
*Verena Kain, Helmut Burkhardt, Etienne Carlier, Brennan Goddard, Volker Mertens, Bruno Puccio, Ruediger Schmidt, Jorg Wenninger, Markus Zerlauth (CERN)*
Filling the LHC requires the extraction of high-intensity low emittance 450 GeV proton beams from the SPS extraction systems in LSS6 or LSS4, the transfer of these beams over several km via the beam lines TI 2 or TI 8 and finally their injection in LHC insertion 2 or 8, respectively. The beam energy density is over an order of magnitude above the damage limit, and effective machine protection is essential to prevent failures from leading to expensive and time-consuming equipment damage. Possible failures during the transfer process are described, and the requirements for active protection through interlocks by surveillance of key equipment and beam parameters are presented. The various passive protection devices which are foreseen to capture mis-steered beams are detailed and their function and performance discussed. Requirements for logging and post-mortem to enable rapid fault diagnosis are outlined. Finally, the commissioning of these protection systems is discussed in the context of the likely LHC commissioning strategy.

**RPPE018—Material Damage Test with 450 GeV LHC-Type Beam**
*Verena Kain, Jacques Ramillon, Ruediger Schmidt (CERN), Katharina Vorderwinkler (TU Vienna)*
The design of LHC protection elements is based on assumptions on damage levels, which are derived from simulations. A dedicated experiment was prepared and carried out to cross-check the validity of this approach by trying to damage material in a controlled way with beam. The impact of a 450 GeV beam extracted from the SPS on a specially designed high-Z target with a simple geometry, comprising several typical materials used for LHC equipment, was simulated. The beam intensities for the test were chosen to exceed the damage limits of parts of the target. Results of the simulations are presented and compared with test results.

**RPPE019—Real-Time Beam Loss Monitoring System for TLS**
*Cheng-Kuo Chang, Jenny Chen, Kuo-Tung Hsu, Kuo Hwa Hu, Demi Lee (NSRRC)*
The real-time beam loss monitoring system was upgraded recently. Around 50 PIN diode beam loss monitors are placed around the 120 meters storage ring to locate beam loss. Several plastic scintillator based beam loss monitors are also installed to support various studies. This paper presents the conceptual design and operational experience with the system.

**RPPE020—Beam Loss Monitoring and Machine Protection Designs for the Daresbury Laboratory Energy Recovery Linac Prototype**
*Buckley Stephen, Robert Smith (CCLRC/DL/ASTeC)*
Daresbury Laboratory is currently in the process of constructing an energy recovery linac prototype (ERLP). This has been designed to facilitate the necessary research and development before the fourth generation light source (4GLS) project can be undertaken. The beam loss monitoring and machine protection systems are vital areas for the successful operation of the ERLP. These systems are required, both for efficient commissioning and for hardware protection during operation. This paper gives an overview of the system requirements, options available and details of the final design specification.

ASTeC Department, CCLRC Daresbury Laboratory.

**RPPE021—The SNS Machine Protection System: Early Commissioning Results and Future Plans**
*Coles Sibley III (ORNL), Alan Jones, Dave H. Thompson (ORNL/ASD)*
The Spallation Neutron Source under construction in Oak Ridge TN has commissioned low power beam up to 187 Mev. The number of MPS inputs is about 20% of the final number envisioned. Start-up problems, including noise and false trips, have largely been overcome by replacing copper with fiber and adding filters as required. Initial recovery time from Machine Protection System (MPS) trips was slow due to a hierarchy of latched inputs in the system: at the device level, at the MPS input layer, and at the operator interface level. By reprogramming the MPS FPGA such that all resets were at the input devices, MPS availability improved to acceptable levels. For early commissioning MPS inputs will be limited to beam line devices that will prohibit beam operation. For later operation, the number of MPS inputs will increase both software alarms

and less intrusive MPS inputs such as steering magnets are implemented. Two upgrades to SNS are on the horizon: a 3 MW upgrade and a second target station. Although these are years away the MPS system as designed should easily accommodate the increase in power and pulse-to-pulse target switching at 120 Hz.

Work supported by the U.S. Department of Energy under contract DE-AC05-00OR22725.

**RPPE022—Machine Protection System for Concurrent Operation of RHIC and BLIP**

*Michelle Wilinski, Steven Bellavia, Joseph Glenn, Leonard Mausner (BNL)*

The Brookhaven 200 MeV linac is a multipurpose machine used to inject low intensity polarized protons ultimately ending up in RHIC as well as to inject high intensity protons to BLIP, a medical isotope production facility. If high intensity protons were injected to RHIC by mistake, administrative radiation limits could be exceeded or sensitive electronics could be damaged. In the past, the changeover from polarized proton to high intensity proton operation has been a lengthy process, thereby never allowing the two programs to run simultaneously. To remedy this situation and allow for concurrent operation of RHIC and BLIP, an active interlock system has been designed to monitor current levels in the AGS using two current transformers with fail safe circuitry and associated electronics to inhibit beam to RHIC if high intensity is detected.

Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the U.S. Department of Energy.

**RPPE024—High Resolution Integrated Beam Loss Monitoring System**

*Stephen John Payne (CCLRC/RAL/ISIS)*

Activation of synchrotron components through beam loss affects not only maintenance schedules and safety but can also lead to premature failure of synchrotron components. At ISIS beam loss monitoring of the main ring is achieved using thirty nine (4 metre long) argon gas filled tubes arranged around the inside of the synchrotron. Even with such a system to monitor beam loss, failure of synchrotron components has occurred. A new design of beam loss monitoring system has been recently installed into a known susceptible synchrotron component , a dipole. This new system consists of a number of small rectangular scintillator sheets connected to photomultipliers via optic fibres. The sheets measure 150mm x 100mmm and are spaced 300mm centre to centre and are positioned in-between the ceramic vacuum vessel and the magnetic coils of the dipole. Results show that this new system has the ability to see detailed loss patterns inside the dipole often indicating marked differences between adjacent scintillators. The system has been shown to record loss that is not detectable with the standard argon gas system.

**RPPE025—Beam Loss Monitoring at the CLIC Test Facility 3**

*Anne Dabrowski, Rachel Scheidegger, Mayda Velasco, Matthew Wood (NU), Hans-Heinrich Braun, Roberto Corsini, Marek Gasior, Thibaut Lefevre, Frank Tecker (CERN)*

With its 4kW average beam power, the beam losses along the CLIC test facility 3 (CTF3) linac, must be monitored in order to keep the radiation level and the activation as low as possible. The Beam Loss Monitor (BLM) system currently under development is described. The goal of our effort is to provide quantitative beam loss measurements. Simulation work has been carried out in order to estimate the e+ - e- showers in a realistic accelerator environment. A system based on Radiation Hard Secondary Emission chambers, cross-calibrated online with Faraday Cups was installed along girders in the linac with accelerating structures. The system was tested in CTF3 running conditions in the fall of 2004, and was sensitive to beam loss at the ‰ level. Higher beam loss sensitivity can be achieved by integrating the signal over the beam pulse, but then the time resolution of beam loss within the pulse is lost. The design and the test results are presented.

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**RPPE026—Operating Experience with Meson Production Targets at TRIUMF**

*Ewart W. Blackmore, Alisa Dowling, Roman Ruegg, Mark Cheveley Stenning (TRIUMF)*

High power targets are now required for operation at beam powers in excess of 1 MW for spallation neutron sources and neutrino factories. TRIUMF has been operating beryllium and graphite meson production targets for many years. Although the proton beam power of 100 kW at 500 MeV is lower, the beam densities and fluences are higher than most operating solid targets as other accelerators use rotating targets or larger beam spots. The beam size on the TRIUMF targets is maintained at 0.15 cm2 and this beam density leads to proton fluences of 1e23 protons/cm2 per year. The beryllium targets are rectangular rods immersed in a water-cooled stainless steel jacket. The pyrolytic graphite targets consist of pie-shaped segments bonded to a water-cooled copper saddle. Operating experience shows that the graphite targets suffer thermal damage above beam currents of 120 uA but will operate for long periods at 100 uA. The beryllium targets can operate to 200 uA and appear to survive radiation damage beyond 10 dpa although some targets have failed due to structural damage. This paper will describe the operating experience with these targets and present some thermal and radiation calculations.

**RPPE027—High Intensity High Energy E-Beam Interacting with a Thin Solid State Target: First Results at AIRIX**

*Michel Caron, Frederic Cartier, David Collignon, Laurent Hourdin, Marc Mouillet, Christian Noel, Dominique Paradis, Olivier Pierret (CEA), Eric Merle (CEA; CEA/DIF), Olivier Mouton, Nicolas Pichoff (CEA/DAM)*

AIRIX is a 2 kA, 20 MeV, 60 ns linear accelerator dedicated to X-ray flash radiography. During a regular running phase, the primary electron beam is accelerated to and focused on a high atomic number target in order to generate X-rays by brembtrahlung mainly. The huge energy density deposited into the material is such that temperature rises up to 15000°K and that clusters and particles are violently ejected from the surface. In that mechanism, the backward emission speed can reach 5 km.s-1 and the debris can gradually accumulate and subsequently contaminate some sensitive parts of the machine. In order to protect the whole accelerating line from the detrimental effect of back-ejected particles, we have investigated the technical feasibility of a thin foil implementation upstream the X-ray converter.

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**RPPE028—The Design of an Internally Cooled Lithium Lens Transformer with Radiation Hardened Dielectrics for the FNAL Antiproton Source**

*Ryan Schultz, Patrick Hurh, Salman Tariq (Fermilab)*

In order to increase the rate of antiproton production at the FNAL pbar target station, the intensity of the incident 120 GeV

proton beam on target is scheduled to increase from 5e12 to at least 8e12 protons per pulse. In addition, to produce the required 10 Tesla surface field, the current in the lithium lens and transformer secondary will increase from 500 kA to 670 kA. The average cycle frequency is also expected to increase from 0.3 Hz to 0.5 Hz. These increases in beam and joule heating necessitate a new design of the lithium lens transformer assembly that has better cooling for adequate heat removal. A technology called Aluminum Dip Brazing has made it possible to integrate water-cooling channels into the secondary housing. Fluid test results and thermal simulations suggest that the improved cooling design will significantly reduce the maximum operating temperature. The increased radiation due to the higher beam intensity also necessitates the replacement of most of the organic dielectrics. Electrical and structural test results of aluminum and copper conductors coated with ceramic materials are presented here.

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**RPPE029—Rotating Aperture Deuterium Gas Cell Development for High Brightness Neutron Production**

*Brian Rusnak, James Hall, Stewart Shen (LLNL)*

A project is underway at LLNL to design and build a system for fast neutron imaging. The approach being pursued will use a 7 MeV deuterium linac for producing high-energy neutrons via a D(d,n)3He reaction. To achieve a high-brightness neutron source, a windowless rotating aperture gas cell approach is being employed. Using a series of close-tolerance rotor and stator plates, a differential pumping assembly has been designed and built that contains up to 3 atmospheres of deuterium gas in a 40 mm long gas cell. Rarefaction of the gas due to beam-induced heating will be addressed by rapidly moving the gas across the beam channel in a crossflow tube. The design and fabrication process has been guided by extensive 3D modeling of the hydrodynamic gas flow and structural dynamics of the assembly. Summaries of the modeling results, the fabrication and assembly process for the rotating aperture system, and initial measurements of gas leakage shall be presented.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

**RPPE030—Corrugated Thin Diamond Foils for SNS H- Injection Stripping**

*Robert Shaw, Robert Potter, Leslie Wilson (ORNL), Chong-Jer Liaw (BNL), Charles Feigerle, Michael Peretich (University of Tennessee)*

We have prepared and tested corrugated, thin diamond foils for use in stripping the SNS H- Linac beam. Diamond has shown promise for providing ca. 10X increased lifetime over traditional carbon foils. The preferred foil geometry is 10.5 by 20 mm at 350 microgram/cm2, mechanically supported on preferably one, but no more than two, edges. The foils are prepared by chemical vapor deposition (CVD) on a patterned silicon substrate, followed by chemical removal of the silicon. This yields a foil with trapezoidal corrugations to enhance mechanical strength and foil flatness. Both micro- and nano-crystalline diamond foils have been grown. Microwave plasma CVD methods that incorporate high argon gas content were used to produce the latter. Sixteen foils of a variety of characteristics have been tested using the BNL 750 keV RFQ H- beam to simulate the energy deposition in the SNS foil. Long foil lifetimes, up to more than 130 hours, have been demonstrated. Characterization of the foils after beam testing indicates creation of sp2 defects within the ion beam spot. Current efforts are centered on development of corrugation patterns that will enhance flatness of single-edge supported foils.

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**RPPE031—Target and Horn Cooling for the Very Long Baseline Neutrino Oscillation Experiment**

*Steven Bellavia (BNL)*

Thermodynamic studies have been performed for the beam target and focusing horn system to be used in a very long baseline neutrino oscillation experiment. A 2mm rms beam spot with power deposition of over 18 KW presents challenging material and engineering solutions to this project. Given that the amount of heat transferred by radiation alone from the target to the horn is quite small, the primary mechanism is heat removal by forced convection in the annular space between the target and the horn. The key elements are the operating temperature of the target, the temperature of the cooling fluid and the heat generation rate in the volume of the target that needs to be removed. These working parameters establish the mass flow rate and velocity of the coolant necessary to remove the generated heat. Several cooling options were explored using a carbon-carbon target and aluminum horn. Detailed analysis, trade studies and simulations were performed for cooling the horn and target with gaseous helium as well as water.

This work is performed under the auspices of the US DOE.

**RPPE032—Measurement of the Secondary Emission Yield of a Thin Diamond Window in Transmission Mode**

*Xiangyun Chang (BNL)*

The secondary emission enhanced photoinjector (SEEP) is a promising new approach to the generation of high-current, high-brightness electron beams. A low current primary electron beam with energy of a few thousand electron-volts strikes a specially prepared diamond window which emits secondary electrons with a current two orders of magnitude higher. The secondary electrons are created at the back side of the diamond and drift through the window under the influence of a strong electrical field. A hydrogen termination at the exit surface of the window creates a negative electron affinity (NEA) which allows the electrons to leave the diamond. An experiment was performed to measure the secondary electron yield and other properties. The results are discussed in this paper.

**RPPE033—Engineering the SNS RTBT/Target Interface for Remote Handling**

*M. Holding, Carl Mike Hammons, Graeme R. Murdoch, Kerry G. Potter, Ronald Thomas Roseberry (ORNL/SNS)*

The SNS facility is designed for a 1.4MW 1.0GeV proton beam and the interface region of this beam with the Hg spallation target will be highly activated. This installation is located about fifteen feet below the access floor and the activity levels in the RTBT/Target interface are sufficiently high to warrant the application of Remote Handling techniques. The installed components are manufactured from radiation hard materials with serviceability beyond the lifetime of the machine, and all connections and mechanisms have been simplified to allow remote handling. The application of pneumatics to facilitate the

assembly of major components and to the operation of moveable diagnostics has produced some unique design solutions.

**RPPE034—Precision Measurements of Energy Deposition of U Ions in Cu and Stainless Steel Targets at Energies of 500 MeV/u and 950 MeV/u**
*Edil Mustafin, Ingo Hofmann, Dieter Schardt, Karin Weyrich (GSI), Alexander Fertman, Alexander Golubev, Alexei Kantsyrev, Victor Luckjashin (ITEP), Ludmila Latysheva, Nikolai Sobolevskiy (RAS/INR), Andrey Kunin, Yulia Panova, Vladimir Vatulin (VNIIEF)*
Sub-millimeter wall thickness is foreseen for the vacuum tubes in the magnets of the superconducting dipoles of the SIS100 and SIS300 of the FAIR Project. The Bragg peak of the energy deposition by the U ions in these walls may lie dangerously close to the superconducting cables. Thus the precise knowledge of the dE/dx profile is essential for estimating the heat load by the lost ions in the vicinity of the superconducting wires. Here we present the results of the measurement of the U ion beam energy deposition profile in Cu and stainless steel targets and compare the measured data with the Monte-Carlo simulation using the SHIELD code.

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R**PPE036—Pressure Field Distribution in a Conical Tube with a Transient Gas Source and Outgassing**
*Francisco Tadeu Degasperi (FATEC-SP), Sergio Verardi (IBILCE—UNESP), Marcos Martins, Jiro Takahashi (USP/LAL)*
This work presents numerical results for the pressure field distribution along the axis of conical tube with outgassing plus a transient degassing. Several areas of applied physics deal with problems in high-vacuum and ultra high-vacuum technology that present tubular form. In many cases one finds conical tubes, which are frequently present in particle accelerators, colliders, storage rings and several electron devices. This work presents and describes in detail the pressure field in a conical tube with a transient gas source, for instance, when particles from the beam hit the walls, plus the steady state outgassing. Mathematical and physical formulations are detailed, and the boundary conditions are discussed. These concepts and approach are applied to usual realistic cases, with typical laboratory dimensions.

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**RPPE037—The Vacuum System for PETRA III**
*Mike Seidel (DESY)*
It is planned to rebuild the storage ringe PETRA II, presently used as pre-accelerator of HERA, into a high performance synchrotron light source. By making use of the large circumference and the installation of damping wigglers it will be possible to achieve exceptionally small emittances in the new storage ring. The requirements for the vacuum system are more advanced in the new storage ring as well. Besides the goal to achieve low pressures and fast conditioning times a major key for the new ring is a very high orbit stability which implies high thermal stability of BPM's and other vacuum components. We describe the basic concepts for chamber layout, pumping schemes, synchrotron radiation absorption and mechanical stability for the standard arcs and the experimental octant. Furthermore the expected performance will be discussed.

**RPPE039—Alumina Ceramics Vacuum Duct for the 3GeV-RCS of the J-PARC**
*Michikazu Kinsho (Japan Atomic Energy Institute), Norio Ogiwara (JAERI/J-PARC), Yoshio Saito (KEK), Zenzaburo Kabeya (MHI)*
It was success to develop alumina ceramics vacuum ducts for the 3GeV-RCS of J-PARC at JAERI. There are two types of alumina ceramics vacuum ducts needed, one being 1.5m-long duct with a circular cross section for use in the quadrupole magnet, the other being 3.5m-long and bending 15 degrees, with a race-track cross section for use in the dipole magnet. These ducts could be manufactured by joining several duct segments of 0.5-0.8 m in length by brazing. The alumina ceramics ducts have copper stripes on the outside surface of the ducts to reduce the duct impedance. One of the ends of each stripe is connected to a titanium flange by way of a capacitor so to interrupt an eddy current circuit. The copper stripes are produced by an electroforming method in which a stripe pattern formed by Mo-Mn metallization is first sintered on the exterior surface and then overlaid by PR-electroformed copper (Periodic current Reversal electroforming method). In order to reduce emission of secondary electrons when protons or electrons strike the surface, TiN film is coated on the inside surface of the ducts.

**RPPE040—Development of the Copper Coating Chamber for the 3rd Generation Light Source**
*Hiroshi Sakai, Isao Ito, Hirofumi Kudo, Norio Nakamura, Takashi Shibuya, Kenji Shinoe, Hiroyuki Takaki (ISSP/SRL), Masanori Kobayashi (KEK)*
For the 3rd generation light source, It is essential to reduce the beam instability in order to produce the high bright synchrotron light much stably. Especially, to avoid the coupled bunch instability, the resistive wall impedance must be reduced. The copper coating inner surface of the chamber (especially insertion device section) is much effective method for the reduction of the resistive wall impedance, whose method was already proposed by our group (N. Nakamura et al., EPAC 1998, p984). We have already produced the copper coating chamber. In this paper, we describe the outgas measurement of the copper coating chamber on the test bench to evaluate if this chamber is valid on the ultra-high vacuum condition.

**RPPE041—Design and Construction of the CERN LEIR Injection Septa**
*Jan Borburgh, Bruno Balhan, Piero Bobbio, Etienne Carlier, Michael Hourican, Thierry Masson, Antoine Prost (CERN)*
The Low Energy Ion Ring (LEIR) transforms long pulses from Linac 3 into high brilliance ion bunches for LHC by means of multi-turn injection, electron cooling and accumulation. The LEIR injection comprises a magnetic DC septum followed by an inclined electrostatic septum. The electrostatic septum has been newly designed and built. The magnetic septum is mainly recovered from the former LEAR machine, but required a new vacuum chamber. Dynamic vacua in the 10-12 mbar range are required, which are hard to achieve due to the high desorption rate of ions lost on the surface. A new interlock and displacement control system has also been developed. The major technical challenges to meet the magnetic, electrical and vacuum requirements will be discussed.

**RPPE042—Aperture and Field Constraints for the Vacuum System in the LHC Injection Septa**
*Marcel Gyr, Bernard Henrist, José Miguel Jimenez, Jean-Michel Lacroix, Stefano Sgobba (CERN)*
Each beam arriving from the SPS has to pass through five injection septum magnets before being kicked onto the LHC orbit. The injection layout implies that the vacuum chambers for

the two circulating beams pass through the septum magnet yokes at a flange distance from the chamber of the beam to be injected. Specially designed vacuum chambers and interconnections provide the required straightness and alignment precision, thus optimising the aperture for both the circulating and injected beams, without affecting the quality of the magnetic dipole field seen by the injected beam. The circulating beams are shielded against the magnetic stray field by using μ-metal chambers with a thickness of 0.9 mm to avoid saturation of the μ-metal (0.8 T), coated with copper (0.4 mm) for impedance reasons and NEG for pumping and electron cloud purposes. A sufficiently large gap between the iron yoke and the μ-metal chamber allows an in-situ bake-out at 200°C, based on a polyimide/stainless steel/ polyimide sandwich structure with an overall thickness of 0.2 mm. The constraints will be described and the resulting vacuum system design, the apertures and the residual stray field will be presented.

**RPPE043—Ultrathin Polyimide-Stainless Steel Heater for Vacuum System Bake-Out**
*Christian Rathjen, Sebastien Blanchard, Bernard Henrist (CERN)*
Space constraints in several room-temperature magnets of the LHC required the development of a dedicated permanent heater system for vacuum chamber bake-out. The new system consists of stainless steel bands inside layers of polyimide. The overall heater thickness is about 300 micrometers. The low magnetic permeability is suitable for applications in magnetic fields. The material combination allows for temperature high enough to activate NEG-coated chambers. Fabrication is performed in consecutive steps of tape wrapping. Automation makes high volume production at low costs possible. About 800 m of warm vacuum system of the long strait sections of the LHC will be equipped with the new heater system. The paper covers experiences in CERN's vacuum group from studies up to industrialization.

**RPPE044—Vacuum Modifications for the Installation of a New CESR-c Fast Luminosity Monitor**
*Yulin Li, Yun He, Mark Alan Palmer (Cornell University)*
In order to improve luminosity tuning and maintenance for the CLEO-c high energy physics (HEP) program at the Cornell Electron Storage Ring (CESR), a luminosity monitor using photons from radiative Bhabha events has been installed in the CESR ring. Over 10 meters of CESR vacuum chambers near the interaction region were modified to accommodate this new device. The vacuum modifications were designed to meet two criteria. First, the new vacuum chambers had to provide sufficient horizontal and vertical aperture for photons originating from the IP over a wide range of colliding beam conditions. Secondly, the new vacuum chambers required adequate safety margins for operation at beam energies up to 5.3 GeV for Cornell High Energy Synchrotron Source running. In order to be certain that the vacuum modifications would not give rise to any localized pressure bumps, a detailed calculation of the expected vacuum pressure distribution due to synchrotron radiation flux was carried out. Careful design and planning enabled a successful installation and resumption of CESR operations in record time.

Work supported by the National Science Foundation.

**RPPE045—Vacuum Pumping Performance Comparison of Non-Evaporable Getter Thin Films Deposited Using Argon and Krypton as Sputtering Gases**
*Xianghong Liu, Matthew Raymond Adams, Yun He, Yulin Li (Cornell University)*
Owing to the outstanding vacuum performance and the low secondary electron yield, non-evaporable getter (NEG) thin film deposited onto interior walls has gained widespread acceptance and has been incorporated into many accelerator vacuum system designs. The titanium-zirconium-vanadium (T-Zr-V) NEG thin films were deposited onto the interior wall of stainless steel pipes via DC magnetron sputtering method using either argon or krypton gas as sputtering gas. Vacuum pumping evaluation tests were carried out to compare vacuum pumping performances of the Ti-Zr-V NEG thin films deposited using argon or krypton. The results showed much higher initial pumping speed for the Kr-sputtered NEG film than the Ar-sputtered film, though both films have similar activation behavior. The compositions and textures of both thin films were measured to correlate to the pumping performances.

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**RPPE046—A Summary and Status of the SNS Ring Vacuum Systems**
*Michael Mapes, Hsiao-Chaun Hseuh, Jim Rank, Loralie Smart, Robert J. Todd, Daniel Weiss (BNL), Michael Hechler, Peter Ladd (ORNL/SNS)*
The Spallation Neutron Source (SNS) ring is designed to accumulate high intensity protons. The SNS ring vacuum system consists of the High Energy Beam Transport (HEBT) line, Accumulator Ring and the Ring to Target Beam Transport (RTBT) line. The Accumulator ring has a circumference of 248m with 4 arcs and 4 straight sections, while the RTBT and HEBT have a total length of 350m of beam transport line. Ultrahigh vacuum of 10-9 Torr is required in the accumulator ring to minimize beam-residual gas ionization. To reduce the secondary electron yield (SEY) and the associated electron cloud instability, the ring vacuum chambers are coated with Titanium-Nitride (TiN). This paper describes the design, fabrication, assembly and vacuum processing of the ring and beam transport vacuum systems as well as the associated instrumentation and controls.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**RPPE047—Upgrade of RHIC Vacuum Systems for High Luminosity Operation**
*Hsiao-Chaun Hseuh, Michael Mapes, Loralie Smart, Robert J. Todd, Daniel Weiss (BNL)*
With increasing ion beam intensity during recent RHIC operations, pressure rises of several decades were observed at most room temperature sections and at a few cold sections. The pressure rises are associated with electron multi-pacting, electron stimulated desorption and beam ion induced desorption and have been one of the major intensity and luminosity limiting factors for RHIC. Improvement of the warm sections has been carried out in the last few years. Extensive in-situ bakes, additional UHV pumping, anti-grazing ridges and beam tube solenoids have been implemented. Several hundred meters of NEG coated beam pipes have been installed and activated. Vacuum monitoring and interlock were enhanced to reduce premature beam aborts. Preliminary measures, such as pumping before cool down to reduce monolayer condensates, were also taken to suppress the pressure rises in the cold sections. The effectiveness of these measures in reducing the pressure rises during machine studies and during physics runs are discussed and summarized.

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**RPPE048—Physical and Electromagnetic Properties of Customized Coatings for SNS Injection Ceramic Chambers and Extraction Ferrite Kickers**
*Hsiao-Chaun Hseuh, Michael Blaskiewicz, Ping He, Yong Yung Lee, Chien Pai, Deepak Raparia, Robert J. Todd, Lanfa Wang, Jie Wei, Daniel Weiss (BNL), Stuart Henderson (ORNL/SNS)*
The inner surfaces of the 248 m SNS accumulator ring vacuum chambers are coated with ~100 nm of titanium nitride (TiN) to reduce the secondary electron yield (SEY) of the chamber walls. All the ring inner surfaces are made of stainless or inconel, except those of the injection and extraction kickers. Ceramic vacuum chambers are used for the 8 injection kickers to avoid shielding of a fast-changing kicker field and to reduce eddy current heating. The internal diameter was coated with Cu to reduce the beam coupling impedance and provide passage for beam image current, and a TiN overlayer to reduce SEY. The ferrite surfaces of the 14 extraction kicker modules were coated with TiN to reduce SEY. Customized masks were used to produce coating strips of 1 cm x 5 cm with 1 to 1.5 mm separation among the strips. The masks maximized the coated area to more than 80%, while minimizing the eddy current effect to the kicker rise time. The coating method, as well as the physical and electromagnetic properties of the coatings for both types of kickers will be summarized, with emphasis on the effect to the beam and the electron cloud buildup.
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**RPPE049—Summary on Titanium Nitride Coating of SNS Ring Vacuum Chambers**
*Robert J. Todd, Ping He, Hsiao-Chaun Hseuh, Daniel Weiss (BNL)*
The inner surfaces of the 248 m Spallation Neutron Source (SNS) accumulator ring vacuum chambers are coated with ~100 nm of titanium nitride (TiN) to reduce the secondary electron yield (SEY) of the chamber walls. There are approximately 100 chambers and kicker modules, some up to 5 m in length and 36 cm in diameter, coated with TiN. The coating is deposited by means of reactive DC magnetron sputtering using a cylindrical magnetron with internal permanent magnets. This cathode configuration generates a deposition rate sufficient to meet the required production schedule and produces stoichiometric films with good adhesion, low SEY and acceptable outgassing. Moreover, the cathode magnet configuration allows for simple changes in length and has been adapted to coat the wide variety of chambers and components contained within the arc, injection, extraction, collimation and RF regions. Chamber types, quantities and the cathode configurations used to coat them are presented herein. A brief summary of the salient coating properties is given including the interdependence of SEY as a function of surface roughness and its effect on outgassing. Limitations of this coating method are also discussed.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**RPPE050—Development of NEG Coating for RHIC Experimental Beam Pipes**
*Daniel Weiss, Ping He, Hsiao-Chaun Hseuh, Robert J. Todd (BNL)*
As RHIC beam intensity increases beyond original scope, pressure rises in some regions have been observed. The luminosity limiting pressure rises are associated with electron multipacting, electron stimulated desorption and beam induced desorption. Non-Evaporable Getter (NEG) coated beampipes have been proven effective to suppress pressure rise in synchrotron radiation facilities. Standard beampipes have been NEG coated by a vendor and added to many RHIC UHV regions. BNL is developing a cylindrical magnetron sputtering system to NEG coat special beryllium beampipes installed in RHIC experimental regions. It features a hollow, liquid cooled cathode producing power density of 500W/m and deposition rate of 5000 Angstrom/hr on 7.5cm OD beampipe. The cathode, a titanium tube partially covered with zirconium and vanadium ribbons, is oriented for horizontal coating of 4m long chambers. Ribbons and magnets are arranged to provide uniform sputtering distribution and deposited NEG composition. Vacuum performance of NEG coated pipes was measured. Coating analysis includes energy dispersive spectroscopy, auger electron spectroscopy and scanning electron microscopy. System design, development, and analysis results are presented.

Work performed under Contract No. DE-AC02-98CH10886 under the auspices of the U.S. Department of Energy.

**RPPE051—NEG Pumping Strip Inside Tevatron B2 Magnets**
*Alex Zuxing Chen, Bruce M. Hanna (Fermilab)*
NEG pumping strips were installed inside four Tevatron B2 Magnets in order to improve the vacuum environment in B2 magnets that have embedded unbakable vacuum chamber. The prelimary results shown the total presure in that region was significant reduced. Complelte testing and opertation results will be available soon.

DOE

**RPPE052—Application of Comb-Type RF-Shield to Bellows Chambers and Gate Valves**
*Yusuke Suetsugu, Kyo Shibata, Mitsuru Shirai (KEK)*
A comb-type RF-shield, which was recently proposed for high current accelerators, was experimentally applied to bellows chambers and gate valves. The comb-type RF-shield has a structure of nested comb teeth, and has higher thermal strength and lower impedance than usual finger-type RF shields. The shield is suitable for future high intensity accelerators, such as particle factories aiming a luminosity of 1E35 - 36 /cm^2 /s. Seven bellows chambers with a circular or a racetrack cross section had been installed in the KEKB (KEK B-factory) positron ring since 2003 in series. Some bellows chambers are forced to bend up to 20 mrad during the beam operation. No significant problem had been found with a stored beam current up to 1.6 A (1.25 mA/bunch). On the other hand, a circular-type gate valve with the comb-type RF shield will be installed in the ring in January, 2005. Structures, properties and results of the beam test of the bellows chamber and the gate valve are discussed.

**RPPE053—R&D Status of Vacuum Components for the Upgrade of KEKB**
*Yusuke Suetsugu, Hiromi Hisamatsu, Ken-ichi Kanazawa, Kyo Shibata, Mitsuru Shirai (KEK)*
An upgrade plan of the KEK B-factory (KEKB), Super KEKB, aiming a luminosity over 1E35 /cm^2 /s has been discussed in KEK. To achieve the high luminosity, the stored beam currents are 4.2 - 9.4 A and the bunch length is 3 mm. In designing the vacuum system of the Super KEKB, therefore, the main issues are how to manage the resultant highly intense synchrotron radiation (SR) power, and how to reduce the beam impedance.

The R&Ds for basic vacuum components, such as a beam duct, a bellows chamber, a connection flange, a collimator, a high-capacity pump and so on, are now undergoing to deal with the problems. For examples, a copper beam duct with an antechamber was manufactured to reduce the power density of SR, and to suppress the electrons around the beam for the positron ring. The test chamber was installed in the positron ring of KEKB and tested with a beam. Bellows chambers with a newly developed RF-shield were also installed in the ring and the property was investigated. A special connection flange with little step or gap inside was developed and examined in a test bench. The designs of these components and the results of tests are presented and discussed.

**RPPE054—Vacuum Beamline Conditioning for Long and Narrow Wiggler Chambers on the DFELL Storage Ring**
*Gary Swift, Jingyi Li, Stepan Mikhailov, Y. K. Wu (DU/FEL)*
The Duke Free Electron Laser Laboratory (DFELL) electron storage ring has been in operation (at Duke University, Durham, NC, USA) since 1994. Installation of 4 helical wigglers w/ magnetic lattice (manufactured at BINP, Novosibirsk, Russia) is progressing. The work is planned in 3 stages (phase 1, 2 & 3) in order to allow time for magnetic measurement of the OK5 wigglers and continued operation of the OK4 wigglers. Phase 1 installation and commissioning of the OK5 magnets and vacuum chambers on the DFELL Storage Ring South Straight Section (So. SS) is completed. During commissioning, high pressure (from synchrotron radiation induced, gas desorption) in the So. SS vacuum beam line has limited the electron beam current and lifetime. Our analysis of this condition will be discussed. The steps taken to process the So. SS and results will be reported. Similar effects are expected during phase 2 & 3 commissioning. A survey of vacuum system upgrades to improve pumping and decrease outgassing will be discussed.

U.S. AFOSR MFEL grant F49620-001-0370.

**RPPE055—Further Study of Adsorption Performance of Al2O3 Coating under Vacuum**
*Zhang Hai (USTC/NSRL, Hefei, Anhui)*
It had been found Al2O3 coating by plasma spraying could adsorb gas at room temperature. In HLS such coating had been applied on the pulse septum magnet surface that directly mounted inside the vacuum chamber. Here some experimental and theoretical studies were undertaken to investigate the phenomenon. Gas distribution in the vacuum chamber with the Al2O3 coating in was analyzed by residual gas analyzer (RGA). The possible adsorbed species on the coating surface was studied by laser induced desorption (LID). The results revealed that Al2O3 coating adsorb gas selectively. The amount of H2 adsorbed on the coating is the largest, H2O is the second, and N2 is the third. LID spectrum showed kinds of ions desorbed from the surface. Ions with M/e= 28• A18 and 1 are the highest peaks in the order, which represent N2+• AH2O+ and H+ respectively. Theoretical calculation result manifested that H2• AH2O and N2 could form stable structure with Al2O3 molecule. At the meanwhile H2 molecule is easy to spread into the pore compared with other molecule. The research results give a meaningful reference to design insertion device under vacuum condition.

**RPPE056—Status of the NSRL Storage Ring UHV System After Project-II**
*Yong Wang (USTC/NSRL)*
The NSRL project-II has been finished in December 2004. The UHV system of storage ring has undergone improvement and now provide long beam lifetime and stable operations, the average pressure of ring is better than 2 × 10-8 Pascal without beam and 1 × 10-7 Pascal with beam, The typical beam lifetime is 12 hours at 300 mA and 800 MeV without wiggler and 8 hours at 300 mA and 800 MeV with wiggler on. The improvements and status of NSRL storage ring are described in this paper.

**RPPE057—Resistive Wall Wakefield in the LCLS Undulator**
*Karl Leopold Freitag Bane, Gennady Stupakov (SLAC)*
In the Linac Coherent Light Source (LCLS), a short, intense bunch (rms length 20 microns, bunch charge 1 nC) will pass through a small, long undulator beam pipe (radius 2.5 mm, length 130 m). The wakefields in the undulator, particularly the resistive wall wake of the beam pipe, will induce an energy variation along the bunch, a variation that needs to be kept to within a few times the Pierce parameter for all beam particles to continue to lase. Earlier calculations included the short-range resistive wall wake, but did not include the frequency dependence of conductivity (ac conductivity) of the beam pipe walls. We show that for copper and for the LCLS bunch structure, including the ac conductivity results in a very large effect. We show that the effect can be ameliorated by choosing aluminum and also by taking a flat, rather than round, beam pipe chamber (if the vertical aperture is fixed). The effect of the (high frequency) anomalous skin effect is also considered.

Work supported by the U.S. Department of Energy, contract DE-AC03-76SF00515.

**RPPE058—Upgrade of the Cryomodule Prototype Before Its Implementation in SOLEIL**
*Patrick Marchand, Marc Louvet-Monsanglant, Keihan Tavakoli, Catherine Thomas-Madec (SOLEIL), Pierre Bosland, Philippe Bredy, Stéphane Chel, Guillaume Devanz (CEA/DSM/DAPNIA), Roberto Losito, Pierre Maesen (CERN)*
In the Storage Ring (SR) of the Synchrotron SOLEIL light source, two cryomodules will provide the maximum power of 600 kW required at the nominal energy of 2.75 GeV with the full beam current of 500 mA and all the insertion devices. A cryomodule prototype, housing two 352 MHz superconducting single-cell cavities with strong damping of the Higher Order Modes has been built and successfully tested in the ESRF. Even though the achieved performance (3 MV and 380 kW) does meet the SOLEIL requirement for the first year of operation, it was decided to upgrade the cryomodule prototype before its implementation in the SR. Modifications of the internal cryogenic system as well as the input power and dipolar HOM couplers required complete disassembling, reassembling and testing of the cryomodule, which were carried out at CERN. This refurbishment program, which was achieved in the framework of a collaboration between SOLEIL, CEA and CERN, is reported in this paper. A second cryomodule, similar to the modified prototype, is under manufacturing and will be implemented in the SR by the end of 2006.

**RPPE059—Measurements of Epsilon and Mu of Lossy Materials for the Cryogenic HOM Load**
*Valery D. Shemelin, Matthias Liepe, Hasan Padamsee (Cornell University)*
In high current storage rings with superconducting cavities strong broadband HOM damping has been achieved by using beam-pipe ferrite loads, located at room temperature. Adopting the same damping concept for the ERL with RF absorbers between the cavities in a cavity string will require operating the absorbers at a temperature of about 80 K. This temperature is high enough to intercept HOM power with good cryogenic efficiency, and is low enough to simplify the thermal transition

to the cavities at 2 K. However the electromagetic properties of possible absorber materials were not well known at cryogenic temperatures. We performed a measurement program at Cornell to find possible absorbers for HOMs in the ERL. Measurements were done for 10 different materials in the range from 1 to 40 GHz.

Supported by Cornell University

**RPPE060—Overview of SNS Cryomodule Performance**
*Michael Allen Drury, Edward Daly, Kirk Davis, Jean Roger Delayen, Christiana Grenoble, Robby Hicks, Larry King, Tomasz Plawski, Tom Powers, Joseph P. Preble, Haipeng Wang, Mark Wiseman (Jefferson Lab)*
Thomas Jefferson National Accelerating Facility (Jefferson Lab) has completed production of 24 Superconducting Radio Frequency (SRF) cryomodules for the Spallation Neutron Source (SNS) superconducting linac. This includes one medium-beta (0.61) prototype, eleven medium-beta and twelve high-beta (0.81) production cryomodules. Ten medium-beta cryomodules as well as two high beta cryomodules have undergone complete operational performance testing in the Cryomodule Test Facility at Jefferson Lab. The set of tests includes measurements of maximum gradient, unloaded Q (Q0), microphonics, and response to Lorentz forces. The Qext's of the various couplers are measured and the behavior of the higher order mode couplers is examined. The mechanical and piezo tuners are also characterized. The results of these performance tests will be discussed in this paper.

Supported by U.S. DOE Contract Nos. DE-AC05-84ER40150.

**RPPE061—SRF Accelerator Technology Transfer Experience from the Achievement of the SNS Cryomodule Production Run**
*John Hogan, Tim Cannella, Edward Daly, Michael Allen Drury, John Fischer, Tommy Hiatt, Peter Kneisel, John Mammosser, Joseph P. Preble, Timothy Whitlatch, Katherine Wilson, Mark Wiseman (Jefferson Lab)*
This paper will discuss the technology transfer aspect of superconducting RF expertise, as it pertains to cryomodule production, beginning with the original design requirements through testing and concluding with product delivery to the end user. The success of future industrialization, of accelerator systems, is dependent upon a focused effort on accelerator technology transfer. Over the past twenty years the Thomas Jefferson National Accelerator Facility (Jefferson Lab) has worked with industry to successfully design, manufacture, test and commission more superconducting RF cryomodules than any other entity in the United States. The most recent accomplishment of Jefferson Lab has been the successful production of twenty-four cryomodules designed for the Spallation Neutron Source (SNS). Jefferson Lab was chosen, by the United States Department of Energy, to provide the superconducting portion of the SNS linac due to its reputation as a primary resource for SRF expertise. The successful partnering with, and development of, industrial resources to support the fabrication of the superconducting RF cryomodules for SNS by Jefferson Lab will be the focus of this paper.

**RPPE062—The Use of Integrated Electronic Data Capture and Analysis for Accelerator Construction and Commissioning: Pansophy from the SNS Towards the ILC**
*Joseph Paul Ozelis, Valerie Bookwalter, Bonnie Madre, Charles E. Reece (Jefferson Lab)*
Jefferson Lab has extensively used a proprietary web-based system (Pansophy) that integrates commercial database, data analysis, document archiving and retrieval, and user interface software, as a coherent knowledge management product during the construction of the cryomodules for the SNS Superconducting Linac, providing elements of process and procedure control, data capture and review, and data mining and analysis. With near real-time and potentially global access to production data, process monitoring and performance analyses could be pursued in a timely manner, providing crucial feedback. The extensibility, portability, and accessibility of Pansophy via universally available software components provide the essential features needed in any information and project management system capable of meeting the needs of future accelerator construction efforts, requiring an unprecedented level of regional and international coordination and collaboration, to which Pansophy is well suited.

Work supported by U.S. Department of Energy under contract DE-AC05-84ER40150.

**RPPE063—Concepts for the JLab Ampere-Class CW Cryomodule**
*Robert Rimmer, Edward Daly (Jefferson Lab)*
We describe the concepts and developments underway at JLab as part of the program to develop a new CW cryomodule capable of transporting ampere-level beam currents in a compact FEL. Requirements include real-estate gradient of at least 10 MV/m and very strong HOM damping to push BBU thresholds up by two or more orders of magnitude compared to existing designs. Cavity shape, HOM damping, power couplers, tuners etc. are being designed and optimized for this application. Cavity considerations include a large iris for beam halo, low-RF losses, HOM frequencies and Q's, low peak surface fields, field flatness and microphonics. Module considerations include high packing factor, low static heat leak, image current heating of beam-line components, cost and maintainability. This module is being developed for the next generation ERL based high power FELs but may be useful for other applications such as electron cooling, electron-ion colliders, industrial processing etc.

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**RPPE064—Development of a Cryogenic Radiation Detector for Mapping Radio Frequency Superconducting Cavity Field Emissions**
*Danny Wyane Dotson, John Mammosser (Jefferson Lab)*
There is a relationship between field emissions in a Super Conducting RF cavity and the production of radiation (mostly X-rays). External (room temperature) detectors are shielded from the onset of low energy X-rays by the vacuum and cryogenic stainless steel module walls. An internal measuring system for mapping field emissions would assist scientists and engineers in perfecting surface deposition and acid washing module surfaces. Two measurement systems are undergoing cryogenic testing at JLab. One is an active CsI photodiode array and the second is an X-ray film camera. The CsI array has operated sucessfully in a cavity in liquid Helium but saturated at higher power due to scattering in the cavity. A shield with an aperature similar to the X-ray film detector is being designed for the next series of tests which will be completed before PAC-05.

Work supported by: U.S. DOE Contract No. DE-AC05-84er4015.

**RPPE065—Beam Loss Ion Chamber System Upgrade for Experimental Halls**
*Danny Wyane Dotson, David Seidman (Jefferson Lab)*
The Beam loss Ion Chamber System (BLICS) was developed to protect Jefferson Labs transport lines, targets and beam dumps from a catastrophic "burn through." Range changes and testing was accomplished manually requiring the experiment to be shut down. The new upgraded system is based around an "off the shelf" Programmable Logic Controller located in a single controll box supporting up to ten individual detectors. All functions that formerly required an entry into the experimental hall and manual adjustment can be accomplished from the Machine Control Center (MCC). A further innovation was the addition of a High Voltage "Brick" at the detector location. A single cable supplies the required voltage for the Brick and a return line for the ion chamber signal. The read back screens display range, trip point, and accumulated dose for each location. The new system is very cost effective and significantly reduces the amount of lost experimental time.

Work supported by: U.S. DOE Contract No DE-AC05-84ER4015.

**RPPE066—Development of SCRF Cryomodules at FNAL**
*Donald Mitchell, Evgueni Borissov, Helen Edwards, Timergali N. Khabibouline, Valeri Poloubotko, Nikolay Solyak (Fermilab)*
To enhance the performance of the A0 Photoinjector at Fermilab, we are designing 2 cryomodules to house the 3.9 GHz accelerating, and 3.9 GHz deflecting mode SCRF cavities. A cryomodule for testing the cavities is also being designed. This poster outlines each design with a focus on the vessel layout, input coupler and electronic feedthru designs, SCRF cavity connections, vessel alignment, and assembly procedures. The latest status of this project will be presented.

Fermi National Accelerator Laboratory.

**RPPE067—Design and Fabrication of an FEL Injector Cryomodule**
*John Rathke, Anthony Ambrosio, Michael Cole, Ed Peterson, Tom Schultheiss (AES), Hans Bluem, Alan Murray Melville Todd (AES), Isidoro Enrico Campisi, Edward Daly, John Hogan, John Mammosser, George R. Neil, Joseph P. Preble, Robert Rimmer, Claus Rode, Timothy Whitlatch, Mark Wiseman (Jefferson Lab), Jacek Sekutowicz (on leave), Jacek Sekutowicz (Jefferson Lab; DESY)*
Advanced Energy Systems has recently completed the design of a four cavity cryomodule for use as an FEL injector accelerator on the JLAB Injector Test Stand. Fabrication is nearing completion. Four 748.5 MHz single cell superconducting cavities have been completed and are currently at Jefferson Lab for final processing and test prior to integration in the module. This paper will review the design and fabrication of the cavities and cryomodule.

This work is supported by NAVSEA, MDA, and SMDC.

**RPPE068—A Magnetostrictive Tuning System for Particle Accelerators**
*Chiu-Ying Tai, Jordan Cormier, William Espinola, Zhixiu Han, Chad Joshi, Anil Mavanur, Livia Racz (Energen, Inc.), Kenneth Shepard (ANL), Edward Daly, Kirk Davis (Jefferson Lab)*
Energen, Inc. has designed, built, and demonstrated several fast and slow tuners based on its magnetostrictive actuators and stepper motor. These tuners are designed for Superconducting Radio Frequency (SRF) cavities, which are important structures in particle accelerators that support a wide spectrum of disciplines, including nuclear and high-energy physics and free electron lasers (FEL). In the past two years, Energen's work has focused on magnetostrictive fast tuners for microphonics and Lorentz detuning compensation on elliptical-cell and spoke-loaded cavities, including the capability for real-time closed-loop control. These tuners were custom designed to meet specific requirements, which included a few to 100 micron stroke range, hundreds to kilohertz operation frequency, and cryogenic temperature operation in vacuum or liquid helium. These tuners have been tested in house and at different laboratories, such as DESY, Argonne National Lab, and Jefferson Lab. Some recent results are presented in this paper.

This work is supported by DOE SBIR Program DE-FG02-03ER83648.

**RPPE069—Experimental Research of Multi-Stage Vacuum Insulator Stack Flashover Probability Analysis**
*Meng Wang (CAEP/IFP)*
Established a set of vacuum solid insulator experiment device, and carried out a series basal experimental research of 45 degree standard vacuum insulator specimen. Calculated the pivotal coefficients of the surface flashover empiristic formula by using the experimental data. Based on it, designed a small vacuum insulator stack to validate the analysis motheds of multi-stage vacuum insulator stack flashover probability. And compared the adventages and disadventages of the two different analysis motheds.

**RPPE072—The Improvement and Data Acquisition Systems on Electrical Systems and Grounding Networks in NSRRC**
*Yung-Hui Liu, Jui-Chi Chang, June-Rong Chen, Yu-Chih Lin, Zong-Da Tsai (NSRRC)*
The purpose of this paper is to declare the improvement on electrical and grounding systems in NSRRC. In electrical power system, an Automated Voltage Regulator (AVR) was established to RF system in 2003. The variation of voltage supply from Taiwan Power Company (TPC) is reduced from 3% to 0.2% through the AVR system. And a Supervisory Control and Data Acquisition (SCADA) system was also setup to monitoring the electrical power conditions in each power station. After the high precision grounding systems were constructed in 2004, the stability of beam line was raised. For comprehending the grounding current and noise control, a grounding monitoring system with 32 channels was built in the storage ring. The grounding currents of 4 kickers, one septum and grounding bus are on-line acquisition. Two Electromagnetic Field (EMF) apparatuses were also installed to collect electrical and magnetic fields in the R1 section. It was observed that the electromagnetic field was correlated to grounding currents in certain locations. Injection effects were clearly found in most monitored data. Some improvement works, including expansion of the grounding monitoring system composing analytical software will integrate in the next step.

NSRRC.

**RPPE073—An RF and Timing Distrubution System for the International Linear Collider**
*Josef Frisch (SLAC)*
The proposed 1 TeV, Superconducting electron – positron Linear Collider requires sub-picosecond RF synchronization over a distance of tens of kilometers. In addition control and instrumentation triggers throughout the machine must be synchronized to a fraction of a nanosecond. We present a system design based on the SLAC timing and RF distribution, and on prototypes developed for the room temperature linear collider design. The proposed system uses a phase stabilized fiber optic backbone,

with trigger generation derived from the RF phase distribution. The global components of the system are redundant, providing a high predicted reliability.

Work Supported by Department of Energy contract DE-AC02-76SF00515.

**RPPE074—The Multichannel Deflection Plates Control System for the ALF Facility at the APS**
*Boris Deriy (ANL)*
A deflection plate control system was developed as part of SPIRIT (Single Photon Ionization / Resonant Ionization to Threshold), a new secondary neutral mass spectrometry (SNMS) instrument that uses tunable vacuum ultraviolet light from the ALF (Argonne Linear Free-electron laser) facility at the APS for postionization. The system comprises a crate controller with PC104 embedded computer, 32 amplifiers, and two 1-kV power supplies. Thirty-two D/A converters are used to control voltages at the deflection plates within ± 400 V with 100-mV resolution. An algorithm of simultaneous sweeping of up to 16 XY areas with 10-μs time resolution also has been implemented in the embedded computer. The purpose of the system is to supply potentials to various ion optical elements for electrostatic control of keV primary and secondary ion beams in this SNMS instrument. The control system is of particular value in supplying (1) bipolar potentials for steering ions, (2) multiple potentials for octupole lenses that shape the ion beams, and (3) ramped deflection potentials for rastering the primary ion beam. The system has been in use as part of the SPIRIT instrument at the ALF facility since 2002.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**RPPE075—Injector Electronics for Multi-Turn Operation of the University of Maryland Electron Ring (UMER)**
*Mike Holloway, Terry Godlove, Patrick G. O'Shea, Bryan Quinn, Martin Reiser (IREAP)*
Progress is described toward the development of pulse generators required for injection and extraction of the University of Maryland Electron Ring (UMER). The geometry, described elsewhere, employs a fast ironless dipole at the junction of a Y-shaped section of the ring. The dipole as developed has an inductance of 600 nH. The required +21 A, long pulse generator for multi-turn operation is installed. A pulser providing -42 A for deflection in the opposite sense during injection is under development. It must have a fall time of ~100 ns in view of the 200 ns circulation time for the beam. A similar pulser, having a 100 ns risetime is required for beam extraction. The fast pulsers employ MOSFET switches.

This work is funded by U.S. Department of Energy under grants DE-FG02-94ER40855 and DE-FG02-92ER54178.

**RPPE076—Overview of Electrical Systems for the University of Maryland Electron Ring (UMER)**
*Bryan Quinn, Gang Bai, Santiago Bernal, Terry Godlove, Irving Haber, Mike Holloway, Hui Li, Jonathan Gary Neumann, Patrick G. O'Shea, Martin Reiser, Kai Tian, Mark Walter (IREAP), John R. Harris (University of Maryland)*
Commissioning of the University of Maryland Electron Ring (UMER) is underway (see general abstract on UMER). We discuss the various electrical systems of UMER. The power system includes 114 supplies for 70 air-core magnetic quadrupoles, 36 bending dipoles and 30+ steering dipoles as well as earth's field compensating coils. Systems for data collection comprise multiplexers and fast digitizers for diagnostics including 15 fast beam position monitors (BPMs)and video capture from fluorescent screen monitors. Several pulsers have been built in-house for injection and extraction magnets. The stringent timing schemes are also presented.

This work is funded by the United States Department of Energy under grants DE-FG02-94ER40855 and DE-FG02-92ER54178.

**RPPE077—A Complete System for Operation of a Superconducting Magnet**
*Gerald Codner, Michael Comfort, Daniel Sabol, Theodore VanDerMark, Dwight Widger, Ronald Yaeger (CESR-LEPP)*
A complete system for operating, protecting and monitoring a superconducting magnet is described. This system is used in CESR (Cornell Electron Storage Ring) at Cornell University's Laboratory for Elementary Particle Physics (LEPP) for the CESR superconducting wigglers, part of the accelerator upgrade in pursuit of the CESR charm physics program known as CESR-c.

National Science Foundation.

## Poster Session RPPP—Linear Colliders
## Park Concourse, 13:50-17:10

**RPPP001—Commissioning and First Measurements on the CTF3 Chicane**
*Andrea Ghigo, David Alesini, Gabriele Benedetti, Caterina Biscari, Michele Castellano, Alessandro Drago, Daniele Filippetto, Fabio Marcellini, Catia Milardi, Barbara Preger, Mario Serio, Francesco Sgamma, Angelo Stella, Mikhail Zobov (INFN/LNF), Roberto Corsini, Thibaut Lefevre, Frank Tecker (CERN)*
The transfer line between the linac and the first recombination ring (Delay Loop) of the CTF3 project hs been installed at CERN in spring-summer 2004. In the transfer line a magnetic chicane is used to tune the length of the bunches coming from the linac in order to minimize the Coherent Synchrotron Radiation contribution to the beam energy spread in the recombination system. The first measurements of the beam parameters at several linac and stretcher settings are described. We report the compression curve as a function of the optical parameter R56 representing the dependence of the longitudinal position of a particle on its energy, obtained by measuring the bunch length with a 3 GHz RF deflector.

**RPPP002—RF Sources of Super-conducting Test Facility (STF) in KEK**
*Shigeki Fukuda, Hitoshi Hayano (KEK)*
After the ITRP's technical choice, KEK tried to seek the contribution for the international linear collider and made the plan of super-conducting test facility (STF) in KEK. The STF comprised of phase-I and phase-II; former is the plan for two years from FY2005 and aimed for the quick construction of test facility to evaluate the 4-35MV/m cavity structures and 4-45 MV/m cavity structures with a beam. Phase-II is the next plan of the test facility to extend the several 17m cryomodules. In this paper, general description of the STF is made at first, and rf source plan is shown.

**RPPP003—Proposal of the Next Incarnation of Accelerator Test Facility at KEK for the International Linear Collider**
*Hitoshi Hayano, Yasuo Higashi, Yosuke Honda, Kiyoshi Kubo, Masao Kuriki, Shigeru Kuroda, Mika Masuzawa, Toshiyuki Okugi, Ryuhei Sugahara, Takeshi Takahashi, Toshiaki Tauchi, Junji Urakawa, Vladimir Vogel, Hiroshi Yamaoka, Kaoru Yokoya (KEK), Boris Ivanovich Grishanov, Pavel Logachev, Fedor Podgorny, Valery Telnov (BINP SB RAS), Deepa Angal-Kalinin, Robert Appleby, James Jones, Alexander Kalinin (CCLRC/DL/ASTeC), Olivier Napoly, Jacques Payet (CEA/DSM/DAPNIA), Hans-Heinrich Braun, Daniel Schulte, Frank Zimmermann (CERN), Yoshihisa Iwashita, Takanori Mihara (Kyoto ICR), Philip Bambade (LAL), Jeff Gronberg (LLNL), Masayuki Kumada (NIRS), Nicolas Delerue, Chafik Driouichi, Armin Reichold, David Urner (OXFORDphysics), Philip Burrows, Glenn Brian Christian, Stephen Molloy, Glen White (Queen Mary University of London), Ilya Agapov, Grahame A. Blair, John Carter (Royal Holloway, University of London), Axel Brachmann, Thomas Himel, Thomas Markiewicz, Janice Nelson, Mauro Torino Francesco Pivi, Tor Raubenheimer, Marc Ross, Robert Ruland, Andrei Seryi, Cherrill M. Spencer, Peter Tenenbaum, Mark Woodley, Mike Woods (SLAC), Stewart Takashi Boogert, Stephen Malton (UCL), Eric Torrence (University of Oregon), Tomoyuki Sanuki (University of Tokyo)*
The realization of the International Linear Collider (ILC) will require the ability to create and reliably maintain nanometer size beams. The ATF damping ring is the unique facility where ILC emittancies are possible. In this paper we present and evaluate the proposal to create a final focus facility at the ATF which, using compact final focus optics and an ILC-like bunch train, would be capable of achieving 35nm beam size. Such a facility would enable the development of beam diagnostics and tuning methods, as well as the training of young accelerator physicists.

**RPPP004—Simulation Study of Low Emittance Tuning of ILC Damping Rings**
*Kiyoshi Kubo (KEK)*
For damping rings of the Inter National Linear Collider (ILC), extremely low vertical emittance will be required. The damping rings will have long wiggler sections and the dominant sources of the vertical emittance will be the vertical dispersion at the wigglers and arc sections, and the x-y orbit coupling, caused by various errors. In this paper, simulation studies of a systematic correction method for low vertical emittance on beam position measurement will be reported. Tolerances of magnet misalignment and errors of beam position monitors will be estimated.

**RPPP005—Simulation Study of a Dogbone Damping Ring**
*Yukiyoshi Ohnishi, Katsunobu Oide (KEK)*
Damping ring is one of the major issues in the future linear collider (ILC). We discuss the design of the dogbone damping ring and the performance that includes dynamic apertures, space charge effects, and optics corrections.

**RPPP006—The PITZ Booster Cavity–A Prototype for the ILC Positron Injector Cavities**
*Valentin Paramonov, Leonid Vladimirovich Kravchuk (RAS/INR), Mikhail Krasilnikov, Frank Stephan (DESY Zeuthen), Klaus Floettmann (DESY)*
A critical issue of the design of the Positron Pre-Accelerator (PPA) for the future International Linear Collider (ILC) is the operational reliability of the normal conducting, high accelerating gradient L-band cavities. Now a booster cavity, intended for increasing the beam energy at the Photo Injector Test Facility in Zeuthen (PITZ), and developed by a joined INR-DESY group, is under construction at DESY, Hamburg. With the PITZ requirements (accelerating gradient up to 14 MV/m, rf pulse length up to 900 mks, repetition rate up to 5 Hz) this cavity, which is based on the Cut Disk Structure (CDS), is a full scale, high rf power prototype of the cavities proposed for the PPA. The booster cavity operation will allow us to confirm the main design ideas for the high gradient PPA cavities. A detailed technical study was performed during the booster cavity design, resulting in some modifications for the PPA cavities, which are described in this paper. We also propose a program of rf experiments with the PITZ booster cavity for further improvements of the PPA structures.

**RPPP007—CLIC Damping Ring Optics Design Studies**
*Maxim Korostelev, Frank Zimmermann (CERN)*
Spurious vertical dispersion and betatron coupling arising from random misalignments are a dominant contribution to the damping-ring vertical emittance. In this paper the minimization of vertical dispersion and betatron coupling compensation by skew quadrupole correctors is studied for the CLIC damping ring, taking into account the nonlinear field of the wigglers. Pertinent alignment and tuning tolerances are discussed, together with the expected performance.

**RPPP008—The Short Circumference Damping Ring Design for the ILC**
*Maxim Korostelev, Frank Zimmermann (CERN), Kiyoshi Kubo, Masao Kuriki, Shigeru Kuroda, Takashi Naito, Junji Urakawa (KEK), Marc Ross (SLAC)*
The ILC damping ring tentative design is driven by the operational scenario of the main linac, the beam-dynamics demand of producing a stable and high-quality beam, the injection/extraction scheme and the kicker performance. In this paper, a short circumference damping ring design based on TME cells is described. The ring accommodates injection kickers which provide a flat top of 280 nsec and a 60 nsec rise and fall time and very fast strip-line kickers for beam extraction with a 2 nsec rise and fall time for 3-MHz operation. The potential impact of collective effects and the possible degradation of the dynamic aperture by nonlinear-wiggler fields are estimated.

**RPPP009—Luminosity Tuning Bumps in the CLIC Main Linac**
*Peder Eliasson, Daniel Schulte (CERN)*
Preservation of beam emittance in the CLIC main linac is a challenging task. This requires not only beam-based alignment of the beam line components but also the use of emittance tuning bumps. In this paper the potential use of luminosity tuning bumps is explored and compared to emittance tuning bumps.
We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 “Structuring the European Research Area” programme (CARE, contract number RII3-CT-2003-506395).

**RPPP010—Considerations on the Design of the Decelerator of the CLIC Test Facility (CTF3)**
*Daniel Schulte, Igor Syratchev (CERN)*
One of the main aims of the CLIC Test Facility (CTF3) is to study the beam stability in the drive beam decelerator and to bench mark the performance against beam simulation codes. Particular challenges come from the large drive beam energy spread, the strong wakefields and potential beam losses. The development towards a decelerator design and the required instrumentation is described in this paper.

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 “Structuring the European Research Area” programme (CARE, contract number RII3-CT-2003-506395).

**RPPP011—Different Options for Dispersion Free Steering in the CLIC Main Linac**
*Daniel Schulte (CERN)*
Sophisticated beam-based alignment is essential in future linear colliders to preserve the beam emittance during the transport through the main linac. One such method is dispersion free steering. In this paper different options to implement this method are discussed, based on the use of different accelerating gradients, RF phases and bunch particle types during a beam pulse.

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395).

**RPPP012—Collective Effects in the CLIC Damping Rings**
*Frank Zimmermann, Maxim Korostelev, Daniel Schulte (CERN), Tomonori Agoh, Kaoru Yokoya (KEK)*
The small emittance, short bunch length, and high current in the CLIC damping ring could give rise to collective effects which degrade the quality of the extracted beam. In this paper, we survey a number of possible instabilities and estimate their impact on the ring performance. The effects considered include fast beam-ion instability, coherent synchrotron radiation, and electron cloud, in addition to conventional single and multi-bunch instabilities.

**RPPP013—Tests of the FONT3 Linear Collider Intra-Train Beam Feedback System at the ATF**
*Philip Burrows (Queen Mary University of London)*
We report preliminary results of beam tests of the FONT3 Linear Collider intra-train position feedback system prototype at the Accelerator Test Facility at KEK. The feedback system incorporates a novel beam position monitor (BPM) processor with a latency below 5 nanoseconds, and a kicker driver amplifier with similar low latency. The 56 nanosecond-long bunchtrain in the ATF extraction line was used to test the prototype with delay-loop feedback operation. The achieved latency represents a demonstration of intra-train feedback on timescales relevant even for the CLIC Linear Collider design.

**RPPP014—Multi-Bunch Simulations of the ILC for Luminosity Performance Studies**
*Glen White (Queen Mary University of London), Daniel Schulte (CERN), Nicholas John Walker (DESY)*
To study the luminosity performance of the ILC with different design parameters, a multi-bunch simulation was constructed that tracks a multi-bunch representation of the beam from the Damping Ring extraction point through to the Interaction Point. The simulation code PLACET is used to simulate the LINAC, MatMerlin is used to track through the Beam Delivery System and GUINEA-PIG for the beam-beam interaction. Included in the simulation are ground motion and wakefield effects, intra-train fast feedback and luminosity-based feedback systems. To efficiently study multiple parameters/multiple seeds, the simulation is deployed on the Queen Mary High-Throughput computing cluster at Queen Mary, University of London, where 100 simultaneous jobs can be run.

**RPPP015—Reconstruction of IP Beam Parameters at the ILC from Beamstraahlung**
*Glen White (Queen Mary University of London)*
The luminosity performance of the ILC will be very sensitive to all of the IP parameters of the colliding bunches. Only some of these parameters can be measured using planned instrumentation. This analysis aims to access some of the IP parameters not available by other means and to improve on the resolution of those that are. GUINEA-PIG is used to simulate the beam-beam interactions and produce beamstraahlung radiation (e+/e- pairs and photons). These are tracked to a simulation of the low-angle Beam Calorimeter and event shapes based on the calorimeter hit map are produced. A Taylor map is produced to transform from the event shapes to the simulated beam parameters. To test the Taylor map, it is used on the beam parameters that are produced in realistic multi-bunch ILC simulations.

**RPPP016—Vibration Studies in a Superconducting Quadrupole**
*Ping He, Sevan Aydin, John Escallier, George Ganetis, Michael Harrison, Animesh Kumar Jain, Wing Louie (BNL)*
Compact superconducting (SC) quadrupoles have been proposed as promising candidates for the final focus region of the International Linear Collider (ILC). ILC will operate with nanometer scale beam size at the interaction point. This requires nanometer scale stability of the beam, and a similar mechanical stability in the final focus quadrupoles. A primary concern in using superconducting quadrupoles is the potential for inducing additional vibrations from cryogenic operation. Any efforts for active stabilization are also made difficult by the fact that the measurement of the quadrupole cold mass vibrations also needs to be carried out at liquid helium temperature. As part of the R&D efforts for the ILC, a program has been started at BNL to study the vibration induced by liquid helium flow in superconducting magnets. This paper will present results of vibration measurements in a spare superconducting quadrupole for the Relativistic Heavy Ion Collider at BNL using geophones and optical measurements using a laser Doppler vibrometer.

US-DOE.

**RPPP017—Compact Superconducting Final Focus Magnet Options for the ILC**
*Brett Parker, Michael Anerella, John Escallier, Michael Harrison, Ping He, Animesh Kumar Jain, Andrew Marone (BNL), Yuri Nosochkov, Andrei Seryi (SLAC)*
We present a compact superconducting final focus (FF) magnet system for the ILC based on recent BNL direct wind technology developments. Direct wind gives an integrated coil prestress solution for small transverse size coils. With beam crossing angles more than 15 mr, disrupted beam from the IP passes outside the coil while incoming beam is strongly focused. A superconducting FF magnet is adjustable to accommodate collision energy changes, i.e. energy scans and low energy calibration runs. A separate extraction line permits optimization of post IP beam diagnostics. Direct wind construction allows adding separate coils of arbitrary multipolarity (such as sextupole coils for local chromaticity correction). In our simplest coil geometry extracted beam sees significant fringe field. Since the fringe field affects the extracted beam, we also study advanced configurations that give either dramatic fringe field reduction (especially critical for gamma-gamma colliders) or useful quadrupole focusing on the outgoing beam channel. We present prototype coil winding test results and discuss our progress toward an integrated FF solution that addresses important machine detector interface issues.

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**RPPP018—An Energy Recovery Linear Collider?**
*Byung Chel Yunn (Jefferson Lab)*
We study a scheme of designing a linear collider with an energy recovery. The design making quasi-continuous wave beam

operation possible has a potential for achieving a very high luminosity. We will discuss problems of practicality and/or impracticality of the scheme among others.

Work supported by the U.S. Department of Energy under contract DE-AC05-84-ER40150.

**RPPP019—Revisiting the Cold ILC Parameters**
*Hasan Padamsee (Cornell University)*
At the first ILC Workshop, discussions were underway to re-examine the parameters of the cold ILC. Using the TESLA parameters MathCad program developed in 1991, I examined several variations to explore consequences to the capital and operating costs of the linac (cryomodules, RF, & refrigerator). The cost coefficients were chosen to match the distribution of the above items in the TESLA TDR at 25 MV/m. One parameter varied is the gradient from 25 to 50 MV/m coupled with a realistic Q as well as an optimistic Q (10^10). Other parameters varied are: number of bunches, spacing, and rep rate to decrease the damping ring size. Keeping all other TDR parameters the same, the optimal gradient for the realistic Q curve is about 35 MV/m, yielding a capital cost savings of 16% and a total cost savings of 9% over the nominal gradient of 25 MV/m. If however the Q remains at 10^10, the optimum gradient moves to 50 MV/m where the total cost savings rise to 17.5%, and capital cost savings rise to 35%. Of course, gradients higher than 35 MV/m are extremely challenging, demanding major development efforts, such as control of Lorentz force detuning which increases as the square of the gradient.

**RPPP020—Linear Damping Systems for the International Linear Collider**
*Gerald Dugan (Cornell University)*
The International Linear Collider requires very low transverse emittance beams in order to realize the specified high luminosity. These beams are conventionally produced using radiation damping in specially designed damping rings. A linear damping system, consisting of alternating wigglers and accelerating structures arranged in a straight line, can be considered to replace, or to augment, conventional damping rings. In this paper, the basic features, feasibility, advantages, and disadvantages, of such systems, as applied to the International Linear Collider, will be discussed.

Supported by the National Science Foundation

**RPPP021—Multivariate Optimization of ILC Parameters**
*Ivan Vasilyevich Bazarov, Hasan Padamsee (Cornell University)*
We present results of multiobjective optimization of the International Linear Collider (ILC) which seeks to maximize luminosity at each given total cost of the linac (capital and operating costs of cryomodules, refrigeration and RF). Evolutionary algorithms allow quick exploration of optimal sets of parameters in a complicated system such as ILC in the presence of realistic constraints as well as investigation of various what-if scenarios in potential performance. Among the parameters we varied there were accelerating gradient and Q of the cavities (in a coupled manner following a realistic Q vs. E curve), the number of particles per bunch, the bunch length, number of bunches in the train, etc. We find an optimum which decreases (relative to TDR baseline) the total linac cost by 22 %, capital cost by 25 % at the same luminosity of 3E38 1/m^2/s. For this optimum the gradient is 35 MV/m, the final spot size is 3.6 nm, and the beam power is 15.9 MW. Dropping the luminosity to 2E38 1/m^2/s results in an additional 8 % reduction in the total linac cost. We have also explored the optimal fronts of luminosity vs. cost for several other scenarios using the same approach.

This work is supported by the NSF.

**RPPP022—Combining Scheme for Reduction the Length of Undulator in Positron Production for ILC**
*Alexander A. Mikhailichenko (Cornell University)*
We described here a scheme for combining in longitudinal phase space secondary positrons, created in separate targets irradiated by gammas from undulator. This scheme allows reduction of the length of undulator to ~50 meters. This scheme also can be used for widening safety margins in positron production scheme.

**RPPP023—A Compact Damping Ring Using RF Deflectors for the International Linear Collider**
*Richard W. Helms, David Rubin (Cornell University)*
Current specifications for the International Linear Collider call for bunch trains hundreds of kilometers in length. We describe a scheme for manipulating a compressed bunch train in the damping ring using RF deflectors and multiple transfer lines. The concept is demonstrated in the design of a 4 km damping ring that circulates 2800 bunches spaced 4 ns apart, and we show that injection and extraction of individual bunches is possible with conventional kickers requiring rise/fall times of only 16 ns. The performance and stability of the 4 km damping ring is evaluated and compared with existing machines.

NSF

**RPPP024—Comparison of Beam-Based Alignment Algorithms for the ILC**
*Jeffrey Claiborne Smith, Lawrence Gibbons, Ritchie Patterson, David Rubin, David Sagan (Cornell University), Peter Tenenbaum (SLAC)*
The International Linear Collider (ILC) alignment tolerances require more sophisticated alignment techniques than those provided by survey alone. Various Beam-Based Alignment algorithms have been proposed to achieve the desired low emittance preservation. These algorithms are compared and their merits identified using the TAO accelerator simulation program.

NSF and DOE.

**RPPP025—CESR-c Wiggler Studies in the Context of the International Linear Collider Damping Rings**
*Jeremy Urban, Gerald Dugan (Cornell University)*
We present a picture of the International Linear Collider (ILC) damping ring wiggler dynamics using the experience gained from the experimental and simulation-based research studying the wigglers used in the current configuration of the Cornell Electron Storage Ring (CESR). CESR is currently running at 1.8 GeV with 12 superconducting wigglers that have been designed, fabricated, tested, and simulated on-site. We will present results which include frequency map analyses and conventional dynamic aperture studies of CESR-c and the ILC damping rings. We will also provide results from an initial look at physical limitations in the design of the ILC damping ring wigglers.

Work supported by the NSF.

**RPPP026—Linear Accelerator Simulations with BMAD**
*Jeremy Urban, Laura Fields, David Sagan (Cornell University)*
BMAD is a subroutine library for simulating relativistic charged-particle dynamics. It has been used extensively as a

diagnostic tool at the Cornell Electron Storage Ring (CESR). The BMAD libraries have recently been extended to include modeling of the dynamics of linear accelerators. Calculations of emittance dilution due to orbit offsets and misalignments have been compared with LIAR, Merlin and PLACET, and good agreement is found with both particle and macroparticle tracking through the NLC and Tesla lattices for the bunch compressor, main linac and final focus regions.

Work supported by the U.S. DOE.

**RPPP027—ILC Feedback Simulations with Diverse Timescales**

*Linda Hendrickson, Andrei Seryi, Peter Tenenbaum, Mark Woodley (SLAC), Daniel Schulte (CERN), Glen White (Queen Mary University of London)*

For the International Linear Collider (ILC), feedback stabilization will be essential. Bunch-to-bunch feedback systems will operate at the interbunch period, on a timescale of hundreds of nanoseconds. In addition, train-by-train feedback systems are planned throughout the machine to stabilize beam parameters at the interpulse period of 5 Hz. Higher-order optimization feedback systems will operate on longer timescales. Simulations investigate the integration of the different systems, and evaluate the feedback response and the resulting beam jitter and luminosity. Realistic ground motion models, budgeted component jitter, wakefields and other effects are included.

Work supported by Department of Energy contract DE-AC02-76SF00515.

**RPPP028—Simulation of Wake Field Effects on High Energy Particle Beams**

*Roger John Barlow (SLAC), German Yu. Kourevlev, Adam Mercer (UMAN)*

We discuss the wake fields that are liable to arise in the Beam Delivery System of a Future Linear Collider, and we present studies made using the MERLIN simulation program of the effects such fields would have on the bunch shape and hence the luminosity of the proposed design.

**RPPP029—Analysis of Positron Collection in Linear Collider**

*Yuri Batygin (SLAC)*

In the Linear Collider, the positron capture system includes a positron production target, a flux concentrator, and a linac to accelerate positrons up to the injection energy of the positron damping ring. Two schemes for positron production have been studied: (i) a conventional approach with an electron beam interacting with a high-Z target and (ii) polarized positron production using polarized photons generated in a helical undulator by electron beam which then interact with a positron production target. Efficiency of positron collector is defined by positron yield which is a ratio of positrons accepted into damping ring to the number of incident electrons or photons. The capture system has been optimized to insure high positron yield into the 6-dimensional acceptance of the damping ring keeping the high value of positron polarization. Various parameters affecting the positron capture are analyzed.

Work is supported by Department of Energy Contract No. DE-AC02-76SF00515

**RPPP030—Design of the ILC Extraction Line for 20 mrad Crossing Angle**

*Yuri Nosochkov, Kenneth C. Moffeit, Andrei Seryi, Mike Woods (SLAC), Ray Arnold (University of Massachusetts), Eric Torrence (University of Oregon)*

One of the ILC Interaction Regions will have a large horizontal crossing angle which would allow to extract the outgoing photon and electron beams in a separate beamline. In this report, the extraction line design for 20 mrad crossing angle is presented. The proposed beamline transports the disrupted photon and electron beams from IP to a common dump, and includes instrumentation for energy and polarization measurements. The optics is designed for a large energy acceptance to minimize losses of very low energy particles in the disrupted beam. The optics design, particle tracking simulations and diagnostic instrumentation are described.

Work supported by the Department of Energy Contract DE-AC02-76SF00515.

**RPPP031—ILC Positron Production with Gammas from an FEL Powered by an Energy Recovery Linac**

*Rainer Pitthan (SLAC)*

The full exploitation of the physics potential of future linear colliders, such as the ILC, requires the development of polarized positron beams, in addition to the polarized electron beams. The task here is to generate, external to the target, photons of several MeV with circular polarization, which in turn through pair production, in a relatively thin target, generate longitudinally polarized positrons. Two technical possible sources for the polarized photons are: either ~100 GeV electrons going through a cm-period helical undulator or Compton Photons from the backscattering of polarized eV laser photons from ~GeV relativistic electron beam. The Compton scattering approach seems to be attractive because of the much lower electron energy needed, but the laser power required is in the 10 MW range, a difficult obstacle to overcome for solid state lasers. Here we expand on a proposal made 2 years ago to use an FEL instead. This FEL could be based on an energy recovery linac of the type JAERI has built in Tokai; simulations with CAIN show the validity of such an approach.

Work supported by Department of Energy contract DE-AC02-76SF00515.

**RPPP032—ILC Positron Production Based on an Undulator in the Main Positron Linac**

*Rainer Pitthan, Thomas Himel (SLAC)*

Having both e- and e+ polarized in Linear Colliders offers a higher effective polarization, a smaller polarization error, an enhancement of the effective luminosity, an enhanced signal to background ratio in many studies, a more precise analysis of many non-standard couplings, and the use of transversely polarized beams. The TESLA proposal for an LC from the s from 250 GeVγvery beginning included positron production by external electrons through an undulator in the main electron linac, with the option to go to polarized positrons. Here we propose to move the undulator to the positron linac and use 100 GeV electrons in a separate beam, accelerated by double pulsing 20% of the collider RF. Using a separate non-primary beam allows a smaller period undulator to be used, and consequently a reduced beam energy. Moving the undulator to the positron linac simplifies start-up and recovery and has many advantages in operations and downtime recovery.

Work supported by Department of Energy contract DE-AC02-76SF00515.

**RPPP033—Preservation of the Single-Bunch Emittance in the Main Linac of the International Linear Collider**
*Peter Tenenbaum, Mark Woodley (SLAC), Daniel Schulte (CERN), Nicholas John Walker (DESY), Andrzej Wolski (LBNL)*
In order to achieve its luminosity goals, the International Linear Collider (ILC) must limit growth of the normalized vertical emittance to under 10 nm-rad. The vertical emittance growth is dominated by unwanted dispersion, with additional contributions from wakefields and xy coupling. We present the results of a series of studies on the techniques and instrumentation which will be required to limit the emittance growth to this unprecedented value.

**RPPP034—Two-Stage Bunch Compressor for the International Linear Collider**
*Peter Tenenbaum, Tor Raubenheimer (SLAC), Gerald Dugan (Cornell University), Andrzej Wolski (LBNL)*
We present a bunch compressor design for the International Linear Collider (ILC) which achieves a reduction in RMS bunch length from 6 mm to 0.3 mm in two stages of compression, with an intermediate acceleration from 5 GeV to 15 GeV. The key advantage of two-stage compression is that the maximum RMS energy spread is reduced to under 1%, compared to almost 3% for a single-stage design. Analytic and simulation studies of the proposed two-stage bunch compressor are presented, along with performance comparisons to a single-stage system. Parameters for extending the two-stage system to a larger total compression factor are discussed.

**RPPP035—Machine Protection System Requirements and Architecture for the International Linear Collider Low Emittance Transport**
*Peter Tenenbaum, Marc Ross (SLAC)*
Under normal operating conditions, a single beam bunch in the Low Emittance Transport of the International Linear Collider (ILC) has sufficient charge density to damage materials encountered at normal incidence, and even materials encountered at grazing incidence are potentially vulnerable if struck by a significant fraction of the thousands of bunches in a single bunch train. The challenge of machine protection against such high intensity beams is made greater by the long time of flight from damping ring extraction to collision point (on the order of 30 microseconds), and by the 200 millisecond intra-train "dead time" of the ILC, during which the beam cannot be used to detect unacceptable changes in the machine state. We present an overall system design for the ILC machine protection which will limit single-bunch or single-train damage to levels compatible with prolonged luminosity integration. The instrumentation design, system logic, and design implications for other subsystems are discussed.

**RPPP036—A Test Facility for the International Linear Collider Using SLAC's End Station A for Prototypes of Beam Delivery and IR Components**
*Mike Woods, Roger Erickson, Josef Frisch, Lewis Keller, Thomas Markiewicz, Takashi Maruyama, Nan Phinney, Tor Raubenheimer, Marc Ross, Andrei Seryi, Peter Tenenbaum, Mark Woodley (SLAC), Deepa Angal-Kalinin, Frank Jackson, Alexander Kalinin (CCLRC/DL/ASTeC), Sean Walston (LLNL), Michael Hildreth (Notre Dame University), Philip Burrows, Glenn Brian Christian, Christine Clarke, Anthony Francis Hartin, Stephen Molloy, Glen White (Queen Mary University of London), Yury Kolomensky (UCB), Stewart Takashi Boogert, Alexei Liapine, Stephen Malton, David John Miller, Matthew Wing (UCL, London), Mark Slater, Mark Thomson, David Ward (University of Cambridge), Ray Arnold (University of Massachusetts)*
The SLAC Linac can deliver damped bunches with ILC parameters for bunch charge and bunch length to End Station A (ESA). A 10Hz beam at 28.5 GeV energy can be delivered to ESA, parasitic with PEP-II operation. During the engineering design phase for the ILC over the next 5 years, we plan to use this facility to prototype and test key components of the Beam Delivery System (BDS) and Interaction Region (IR). We discuss our plans for this ILC Test Facility and preparations for carrying out experiments related to Collimator Wakefields, Materials Damage Tests and Energy Spectrometers. We also plan an IR Mockup of the region within 5 meters of the ILC Interaction Point to investigate effects from backgrounds and beam rf higher-order modes (HOMs).

U.S. Department of Energy.

**RPPP037—Analysis of Ions in the Interaction Region of a Multi-Bunch Collider**
*Juhao Wu, Daniel Aaron Bates, Arthur Chang, David Chen, Tor Raubenheimer (SLAC)*
When a positron or an electron beam transports through the Interaction Regions (IR), ions may be generated due to collision ionization, photoionization, and tunneling ionization. The solenoid field in the IR will cause the ions to perform cyclotron motion. In a multi-bunch system, the ions can be further kicked by the subsequent bunches, so that they may reach large amplitude and the detector. This may generate backgrounds or even damage the detector. We study this phenomenon in the paper.

Work is supported by the U.S. Department of Energy under contract DE-AC02-76SF00515.

**RPPP038—Multi-Bunch Electron-Cloud Effects in Transport Lines of a Normal Conducting Linear Collider**
*Juhao Wu, Daniel Aaron Bates, Arthur Chang, David Chen, Mauro Torino Francesco Pivi, Tor Raubenheimer, Andrei Seryi (SLAC)*
In the transport lines of a normal conducting linear collider, the long positron bunch train can generate an electron cloud which can then amplify intra-train offsets. This is a transient effect which is similar to but different from the electron-cloud driven coupled bunch instabilities in a positron storage ring. In this paper, we study this phenomenon both analytically and via numerical simulation. Some criterion on the critical cloud density with respect to given collider parameters is discussed.

Work is supported by the U.S. Department of Energy under contract DE-AC02-76SF00515.

**RPPP039—Heat Deposition in Positron Sources for ILC**
*Vinod Bharadwaj, Yuri Batygin, Rainer Pitthan, David Schultz, John Sheppard, Heinz Vincke (SLAC)*
In the transport lines of a normal conducting linear collider, the long positron bunch train can generate an electron cloud which can then amplify intra-train offsets. This is a transient effect which is similar to but different from the electron-cloud driven coupled bunch instabilities in a positron storage ring. In this paper, we study this phenomenon both analytically and via numerical simulation. Some criterion on the critical cloud density with respect to given collider parameters is discussed.

Work is supported by the U.S. Department of Energy under contract DE-AC02-76SF00515.

**RPPP040—Activation of Positron Source Elements in ILC**
*Vinod Bharadwaj, Yuri Batygin, Rainer Pitthan, David Schultz, John Sheppard, Heinz Vincke (SLAC)*
In an ILC positron source, multi-GeV electrons or multi-MeV photons impinge on a metal target. The incoming beam power is hundreds of kilowatts. Various computer programs - such as FLUKA or MARS – can calculate how the incoming beam showers in the target and can track the particle showers through positron source system. These programs can also calculate the activation of the positron source elements and surrounding vault by the incoming beam and showers. This paper presents results from such calculations and their impact on the design of a positron source for the ILC.

Work supported by Department of Energy contract DE-AC02-76SF00515.

**RPPP041—A Proposed Fast Extraction and Tune-Up Dump Line Design for ILC**
*Mark Woodley, Andrei Seryi (SLAC), Brett Parker (BNL)*
The International Linear Collider will accelerate beams to 250 GeV, providing 11 MW of beam power at the end of each main linac. A variety of different failure modes in the damping rings, bunch compressors and linacs can result in beams with large orbit and/or energy errors, which must be extracted before they enter the beam delivery system and cause potentially serious damage. It will also be necessary to extract the beam at the end of each linac during tuning procedures. Because of the high beam power, the beam must be extracted cleanly and transported without losses to a dump, and the potential for energy errors up to 20% places a challenging requirement on the bandwidth of the extraction line. Another important requirement is for a large transverse beam-size at the dump window to prevent damage to the dump itself; but because of the possibility of large energy errors, this must be achieved without dispersion. We describe a design that meets the major specifications for the extraction beamlines.

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**RPPP042—Emittance Dilution Due to Dipole Mode Rotation and Coupling in the Main Linacs of the ILC**
*Roger Michael Jones, Roger Heering Miller (SLAC)*
The progress of multiple bunches of charged particles down the main L-band linacs of the ILC (International Linear Collider) can be disrupted by wakefields. These wakefields correspond to the electromagnetic fields excited in the accelerating cavities and have both long-range and short-range components. Here we investigate the impact of the long-range wakefields on the trailing bunches caused by the leading bunches. In general, the dipole mode degeneracy will be removed both because of manufacturing errors and because the higher order mode couplers are dipole asymmetric and lie neither in the horizontal nor vertical plane. This creates 2 dipole eigenmodes which are rotated with respect to the horizontal and vertical axes and which may have slightly different frequencies. These eigenmodes can couple the horizontal and vertical dipole excitations. We simulate the progress of the ILC beam down the collider under the influence of these wakefields. In particular, we investigate the consequences on the final emittance dilution of the beam of coupling of the horizontal to the vertical motion of the beam.

This work is supported by Department of Energy grant number DE-AC02-76SF00515.

**RPPP043—Emittance Dilution Due to Many-Band Long-Range Dipole Wakefields in the International Linear Collider Main Linacs**
*Roger Michael Jones (SLAC), Nicoleta Baboi (DESY)*
We investigate the emittance dilution that occurs due to long range wakefields in the ILC L-band linacs. The largest kick factors (proportional to the transverse fields which transversely kick the beam off axis) from the first six bands are included in our simulations. These higher order dipole modes are damped by carefully orientating higher order mode couplers at both ends of each cavity. We investigate the dilution in the emittance of a beam with a random misalignment of cavities down the complete linac. In particular, the impact of a poorly damped dipole mode, on the overall emittance dilution down the complete linac is focused upon. The transverse alignment tolerances imposed on the cavities due to these wakefields are also discussed.

This work is supported by Department of Energy grant number DE-AC02-76SF00515.

**RPPP044—Studies of Room Temperature Accelerator Structures for the ILC Positron Source**
*Juwen W. Wang, Chris Adolphsen, Vinod Bharadwaj, Gordon B. Bowden, Jose Chan, Valery Dolgashev, Zenghai Li, Roger Heering Miller (SLAC)*
There are many challenges in the design of the normal-conducting portion of ILC positron injector system such as achieving adequate cooling with the high rf and particle loss heating, and sustaining high accelerator gradients during millisecond-long pulses in a strong magnetic field. The proposed design for the positron injector contains both standing-wave and traveling-wave L-band accelerator structures for high RF efficiency, low cost and ease of fabrication. This paper presents results from studies of particle energy deposition for both undulator based and conventional positron sources, cooling system design, accelerator structure optimization, RF pulse heating, cavity frequency stabilization, and RF feed system design.

Work supported by U.S. Department of Energy, contract DE-AC02-76F00515.

**RPPP045—Single-Bunch Instability Driven by an Electron Cloud Effect in the Positron Damping Ring of the International Linear Collider ILC**
*Mauro Torino Francesco Pivi, Tor Raubenheimer (SLAC), Frank Zimmermann (CERN), Rainer Wanzenberg (DESY), Kazuhito Ohmi (KEK), Andrzej Wolski (LBNL/AFR), Ali Feiz Ghalam (USC)*
With the recommendation that the future International Linear Collider (ILC) should be based on superconducting technology, there is considerable interest in exploring alternate designs for the damping rings (DR). The TESLA design was 17 km in circumference with a “dog-bone” configuration. Two other smaller designs have been proposed that are 6 km and 3 km in length. In the smaller rings, collective effects may impose the main limitations. In particular for the positron damping ring, an electron cloud may be produced by ionization of residual gas or photoelectrons and increase through the secondary emission process. The build-up and development of an electron cloud is more severe with the higher average beam current in the shorter designs. In this paper, we present recent computer simulation results for the electron cloud build-up and instability thresholds for the various DR configurations.

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**RPPP046—An L-Band Polarized Electron PWT Photoinjector for the ILC**
*David Yu, A. Baxter, Ping Chen, Martin Lundquist, Yan Luo, Alexei Smirnov, Jonathan Yu (DULY Research Inc.)*
A multi-cell, standing-wave, L-band, p-mode, plane-wave-transformer (PWT) photoinjector with an integrated photocathode in a novel linac structure is proposed by DULY Research Inc. as a polarized electron source. The PWT photoinjector is capable of operation in ultra high vacuum and moderate field gradient. Expected performance of an L-band polarized electron PWT injector operating under the parameters for the International Linear Collider is presented. The projected normalized transverse rms emittance is an order of magnitude lower than that produced with a polarized electron dc gun followed by subharmonic bunchers.

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**RPPP047—Global Optimization of Damping Ring Designs Using Parallel Simplex Optimizer**
*Louis Emery (ANL), Aimin Xiao (Fermilab)*
Several damping ring designs for the International Linear Collider have been proposed recently. Some of the specifications, such as circumference and bunch train, are not fixed yet. Designers must make a choice anyway, select a geometry type (e.g., dogbone), an arc cell type (e.g., TME), and optimize linear and nonlinear parts of the optics. The design process includes straightforward steps, and not-so-straightforward steps (when nonlinear optics optimization is affected by the linear optics). A first attempt at automating this process is reported. We first recognize that a circular ring linear optics is defined by a number of primary parameters, such as phase advance in an arc cell, while other parameters simply follow from these parameters, such as a matching section. An optimizer is used to vary these primary parameters (including wiggler parameters) to fulfill the beam dynamics specification of a damping ring. Since the number of variables is moderately high, we use a parallel simplex optimizer on a 100-CPU Linux cluster, which provides the necessary throughput for this and other optics characterizations.

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**RPPP048—Beam Collimation and Machine-Detector Interface at the International Linear Collider**
*Nikolai V. Mokhov, Alexandr I. Drozhdin, Mikhail A. Kostin (Fermilab)*
Synchrotron radiation, spray from the dumps and extraction lines, beam-gas and beam halo interactions with collimators and other components in the ILC beam delivery system create fluxes of muons and other secondaries which can exceed the tolerable levels at a detector by a few orders of magnitude. It is shown that with a multi-stage collimation system, magnetized iron spoilers which fill the tunnel and a set of masks in the detector, one can hopefully meet the design goals. Results of modeling with the STRUCT and MARS15 codes of beam loss and energy deposition effects are presented in this paper. We concentrate on collimation system and mask design and optimization, short- and long-term survivability of the critical components (spoilers, absorbers, magnets, separators, dumps), dynamic heat loads and radiation levels in magnets and other components, machine-related backgrounds and damage in collider detectors, and environmental aspects (prompt dose, ground-water and air activation).

Work supported by the Universities Research Association, Inc., under contract DE-AC02-76CH03000 with the U.S. Department of Energy.

**RPPP049—Bunching for Shorter Damping Rings for the ILC**
*David Neuffer (Fermilab)*
A variant rearrangement of the bunch trains for the ILC that enables much shorter damping rings is presented. In a particular example the ~2280 bunches are regrouped into ~450 subtrains of five adjacent bunches. These subtrains are extracted from the damping rings at ~2.2 ms intervals, obtaining the 1ms macrobunch length of the baseline TESLA collider scenario. If the baseline damping rf frequency is 325 MHz and the kicker rise and fall times are ~20 ns, a ring circumference of ~4.5km is required. Variations of the scheme could easily reduce the circumference to ~3km, and faster kickers could reduce it even further.

**RPPP050—High-Frequency Bunching and Phase Rotation for Muon Collection**
*David Neuffer (Fermilab)*
A new scenario for capture, bunching and phase-energy rotation of muons from a proton source is explored. In an initial example, it consists of a drift section, a changing frequency ~300®~200 MHz bunching section, followed by a fixed or changing frequency (~200 MHz) f-dE rotation section. The method was included in the APS neutrino study as an innovation that can enable an affordable neutrino factory. That example, variations and optimizations will be discussed.

**RPPP051—Characterization of a 6-km Damping Ring for the International Linear Collider**
*Aimin Xiao (Fermilab), Louis Emery (ANL)*
Several damping ring designs for the International Linear Collider have been proposed recently. One particular design has a circumference of 6 km (hoping to take advantage of future kicker technology advances), TME arc cells, and 77 m of 2 T wigglers. Several beam dynamics characterizations and optimizations are reported. We used the accelerator code elegant for matching and tracking, and a 100-CPU linux cluster to provide high throughput.

**RPPP052—Space-Charge Effects in the ILC Damping Rings**
*Marco Venturini, Ji Qiang, Andrzej Wolski (LBNL), Robert Ryne (LBNL/CBP)*
The need to accommodate the long bunch trains suitable for a cold linear collider and limitations to the kicker technology will cause the International Linear Collider (ILC) damping rings to be fairly large. A several Km long circumference and small emittance at extraction will combine to produce a sizeable and potentially harmful vertical space-charge tuneshift - an unusual feature for high-energy electron storage rings. We report on our study of space-charge effects for the lattice designs presently under consideration including the coupling bumps that have been proposed to tame the magnitude of those effects. We employ the code MaryLie/Impact and explore several models of beam dynamics with varying degree of accuracy and self-consistency in the treatment of space-charge.

This work was supported by the Director, Office of Science, High Energy Physics, U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

**RPPP053—Simulations of Resistive-Wall Instability in the ILC Damping Rings**
*Andrzej Wolski (LBNL/AFR), Daniel Aaron Bates (LBNL/CBP)*
Options being considered for the ILC Damping Rings include lattices with circumferences up to 17 km. The circumference, beam current and beam energy place the damping rings in a regime where resistive-wall instability is a concern, particularly as there are very demanding tolerances on the bunch-to-bunch jitter. Generally, it is possible to make good analytical estimates of the coupled-bunch growth rates in a storage ring, but particular features of the damping rings (including the fill pattern, large variations of the lattice functions and beam-pipe cross-section in different parts of the ring, and transverse beam coupling in the long straight sections) make it desirable to study the coupled-bunch instabilities using simulations. Here, we present the results of simulations of the transverse instabilities using a detailed lattice model. A bunch-by-bunch feedback system will be needed to suppress the instabilities, and a model for an appropriate feedback system is included in the simulations.

Work supported by U.S. Department of Energy, Director, Office of Science, Contract No. DE-AC03-76SF00098.

**RPPP054—Achieving Large Dynamic Aperture in the ILC Damping Rings**
*Andrzej Wolski (LBNL/AFR), Yunhai Cai, Tor Raubenheimer (SLAC)*
The Damping Rings for the International Linear Collider have challenging requirements for the acceptance, because of the high average injected beam power and the large beam produced from the positron source. At the same time, the luminosity goals of the collider mean that the natural emittance must be very small, and this makes it particularly difficult to achieve a good dynamic aperture. We describe a design approach and present a lattice design that meets the emittance specification and has a very promising dynamic aperture. We also discuss the potential impact of the damping wiggler and of magnet errors.

Work supported by US Department of Energy, Director, Office of Science - Contract Nos. DE-AC03-76SF00098 and DE-AC03-76SF00515.

**Poster Session RPPT—Light Sources and Free-Electron Lasers; Development in the South, East, and Mid-East; & Secondary Beam Facilities: Neutrons, Muons, and Photons**
**Meeting Room 200 A-C, 13:50-17:10**

**RPPT001—The BESSY Soft X-Ray FEL User Facility**
*Dieter Krämer (BESSY GmbH)*
The user requests for an optimized 2nd generation FEL facility in the VUV to soft X-ray range demand for ultra short photon pulses (t = 20 fs) at a peak power of several GW. A high shot to shot reproducibility of the pulse shape and pulse power allowing for fs-synchronization for pump-probe experiments is feasible in a seeded FEL approach. Free selectable photon polarization and wavelength tuning is essential for any 2nd generation FEL source like the proposed BESSY-Soft X-ray FEL user facility. Freely selectable pulse repetition rates and freely selectable pulse patterns, including fast switching to different parallel operating FEL-Lines are necessary ingredients, feasible with a suitable injector in combination with a CW-superconducting linac. The status of the BESSY HGHG-FEL project will be reviewed.

Funded by Zukunftsfonds Berlin.

**RPPT002—Harmonic Content of the BESSY FEL Radiation**
*Atoosa Meseck (BESSY GmbH)*
BESSY proposes a linac-based cascaded High-Gain Harmonic-Generation (HGHG) free electron laser (FEL) multi-user facility. The BESSY soft X-ray FEL will consist of three undulator lines. The associated tunable lasers will cover the spectral range of 230nm to 460nm. Two to four HGHG stages reduce the seed wavelength to the desired radiation range of 1.24nm < lambda < 51nm. The harmonic content of the high-intensity radiator output can be used to reduce the number of necessary HGHG stages. Moreover the higher harmonic content of the final output extends the offered spectral range and thus is of high interest for the user community. In this paper, the higher harmonic content of the final output as well as of the output of several radiators are investigated. The main parameters such as output power, pulse duration and bandwidth as well as their suitability for seeding are discussed.

Funded by Zukunftsfonds Berlin.

**RPPT003—Radiation Safety Aspects of the Euro-Pet Cyclotron**
*Klaus Ott (BESSY GmbH), Thorsten August, Leander Fluegel, Bruno Willi Simgen, Uta Steinhardt (Euro—Pet)*
Euro-Pet operates a 16.5 MeV 75 microA proton cyclotron to produce radiotracer for the positron emission tomography (PET) since 2003. The mostly used nuclear reaction is 18O(p,n)18F with 95 % 18O in the water target. The radiated water is the basic substance for the synthesis of fluordesoxyglucose (FDG), which is applicated to a patient. Tumors have a higher metabolic activity, so the FDG is concentrated in the tumor tissue. The emitted positrons from the beta+ - decay of the 18F creates with electrons 511 keV annihilation radiation, which can be detected by PET scanners. Therefore tumors and metastases can be located in an early stage of the cancer disease by this method. We discuss here the different aspects of radiation safety of this facility like neutron radiation, neutron induced air and machine activation, handling of the radiotracers with analytical methods, FLUKA simulations and measurements. We describe also the waste air surveillance system and modifications of the synthesis modules with which the very low annual dose of <0.1 mSv/a was reached outside the facility.

**RPPT004—The Shielding Design of the BESSY FEL**
*Klaus Ott (BESSY GmbH)*
The BESSY FEL is a High-Gain Harmonic-Generation (HGHG) based Free Electron Laser that is being built at the BESSY site. This facility will provide Soft X-ray pulses of variable femtosecond duration < 20 fs in the photon energy range 24 eV to 1000 eV. The BESSY FEL will utilize a superconducting CW linac to produce a flexible pulse pattern. It will first operate 3 tunable FEL lines at a pulse repetition rate of 1 kHz each in parallel with a normal conducting gun, with the later possibility to increase the number from 3 to 5 FEL lines and the pulse repetition rate to 25 kHz with a superconducting gun. The maximum electron energy of 2.3 GeV is slightly higher than the maximum energy of the BESSY electron storage ring, so the physical aspects of the ionisating radiation are similar. The main difference is the DC beam power of about 150 kW (if a superconducting gun is used) that has to be absorbed by beam dumps. The aspects of radiation safety are discussed and results from analytical calculations and FLUKA simulations are presented.

Funded by the Bundesministerium fuer Bildung, Wissenschaft, Forschung und Technologie and by the Land Berlin.

**RPPT005—Establishing a Collaborative Planning Procedure for the XFEL**
*Lars Hagge, Jochen Buerger (DESY)*
Building a new accelerator requires a consistent common design of the entire complex, including machine, tunnels, buildings and infrastructure. The efforts involve experts from many disciplines. Complication arises as different expert groups are contributing at different project phases: buildings and technical infrastructure are constructed first, thus their design has to be fixed early in the project and is then imposing constraints e.g. on the machine layout while accelerator R&D is still being continued. In view of these challenges, a dedicated planning and design procedure has to be established which provides "just-enough" details where needed while preserving maximum flexibility for other subsystems, and which can also manage later changes if they become necessary. The poster presents experience from planning the XFEL. Expert groups can create and maintain separate design models of their components, which at the same time can be combined into a common overall design model. The planning procedure relies on commercial tools used in industry (specification database, engineering data management and 3D CAD systems) which are being adapted to the culture and organization of HEP collaborations.

**RPPT006—Commissioning Experiences on TESLA Test Facility Phase 2 (TTF2) Bunch Compressor**
*Yujong Kim (DESY)*
To saturate 30 nm wavelength SASE source within 30 m long TESLA Test Facility Phase 2 (TTF2) undulator, peak current of electron beams should be around 1.3 kA. This high peak current can be generated by bunch compressor. Since coherent synchrotron radiation dilutes projected horizontal emittance in bunch compressor, we should optimize operational conditions of bunch compressor to reduce the emittance growth. In this paper, we describe our various commissioning experiences of TTF2 bunch compressor and compare experimentally measured results with start-to-end simulation ones.

For the TESLA Test Facility FEL team.

**RPPT008—Experimental Measurements Based Injector Simulations for TTF2 Commissioning**
*Yujong Kim (DESY)*
To generate high quality electron beams with a low emittance, a high peak current, and a low energy spread, we should optimize injector properly. During TESLA Test Facility phase 2 (TTF2) commissioning, we recommended injector operational conditions by comparing experimentally measured results and simulation ones. In this paper, we describe our commissioning experiences on experiment based simulations to optimize TTF2 gun and booster linac, and we also discuss possibility of the first experimental demonstration of Ferrario matching principle with Gaussian longitudinal laser beam profile.

For the TESLA Test Facility FEL team.

**RPPT009—S2E Jitter Simulations with an Alternative Linac Layout for European XFEL**
*Yujong Kim, Klaus Floettmann, Torsten Limberg (DESY), Dongchul Son (CHEP)*
To control the microbunching instability in the bunch compresssors and to reduce RF jitter tolerance in linac, we designed an alternative linac layout with two bunch compressor stages for the European XFEL project. In this paper, we describe start-to-end simulations on jitter sensitivity and jitter tolerance in the alternative linac layout.

**RPPT010—Alternative Bunch Compressors for International Linear Collider (ILC) Project**
*Yujong Kim, Klaus Floettmann (DESY), Dongchul Son (CHEP)*
After considering effects of incoherent synchrotron radiation, coherent synchrotron radiation, jitter tolerance, short-range wakefields in TESLA modules, and strong spiky longitudinal beam profile, we have re-designed new bunch compressors for the international linear collider (ILC) project, which are similar to those of XFEL projects. In this paper, we describe our design concepts and simulation results on new bunch compressors for the ILC project.

**RPPT011—Optimized Bunch Compression System for the European XFEL**
*Torsten Limberg, Vladimir Balandin, Reinhard Brinkmann, Winfried Decking, Martin Dohlus, Klaus Floettmann, Golubeva, Yujong Kim, Evgeny Schneidmiller (DESY)*
The European XFEL bunch compressor system has been optimized for greater flexibility in parameter space. Operation beyond the XFEL design parameters is discussed in two directions: achieving the uppermost number of photons in a single pulse on one hand and reaching the necessary peak current for lasing with a pulse as short as possible on the other. Results of start-to-end calculations including 3D-CSR effects, space charge forces and the impact on wake fields demonstrate the potential of the XFEL for further improvement or, respectively, its safety margin for operation at design values.

**RPPT012—Layout of the Diagnostic Section for the European XFEL**
*Holger Schlarb, Michael Roehrs (DESY), Christopher Gerth (CCLRC/DL/ASTeC)*
Fourth generation synchrotron light sources, such as the European Free Electron Laser (XFEL) project, are based on an exponential gain of the radiation amplification in a single pass through a long undulator magnet. To initiate the FEL process and to reach staturation, precise monitoring and control of the electron beam parameters is mandatory. Most challenging are the longitudinal compression processes in magnetic chicanes of the high brightness electron bunch emitted from an RF photoinjector. To measure and control the beam properties after compression, careful consideration must be given to the design of a diagnostic section and the choice of beam monitors. In this paper, the proposed layout of the XFEL diagnostics beamline is discussed and emphasis is put on the possibility of monitoring on-line the slice energy spread, slice emittance and longitudinal bunch profile with high accuracy.

**RPPT013—Status of the SPARC Project**
*Luca Serafini, Franco Alessandria, Alberto Bacci, Simone Cialdi, Carlo De Martinis, Dario Giove, Marco Mauri, Massimiliano Romé (INFN-Milano), Franco Ciocci, Giuseppe Dattoli, Antonio Dipace, Andrea Doria, F. Flora, Gian Piero Gallerano, Luca Giannessi, Emilio Giovenale, Giovanni A. Messina, P.L. Ottaviani, Simonetta Pagnutti, Giovanni Parisi, Luigi Picardi, Marcello Quattromini, Alberto Renieri, Concetta Ronsivalle, Maurizio Rosetti, Elio Sabia, Mauro Sassi, A Torre, Alberto Zucchini (ENEA C.R. Frascati), Luciano Catani, Enrica Chiadroni, Alessandro Cianchi, Carlo Schaerf, Sergio Tazzari (INFN-Roma II), Massimo Petrarca (INFN-Roma), Francesco Broggi (INFN/LASA), David Alesini, Marco Bellaveglia, Sergio Bertolucci, Maria Biagini, Roberto Boni, Manuela Boscolo, Michele Castellano, Alberto Clozza, Giampiero Di Pirro, Alessandro Drago, Adolfo Esposito, Massimo Ferrario, Daniele Filippetto, Valeria Fusco, Alessandro Gallo, Andrea Ghigo, Susanna Guiducci, Maurizio Incurvati, Carlo Ligi, Fabio Marcellini, Mauro Migliorati, Luigi Palumbo, Luigi Pellegrino,*

*Miro Preger, Ruggero Ricci, Claudio Sanelli, Mario Serio, Francesco Sgamma, Bruno Spataro, Alessandro Stecchi, Angelo Stella, Franco Tazzioli, Cristina Vaccarezza, Mario Vescovi, Carlo Vicario (INFN/LNF), Sandro de Silvestri, Mauro Nisoli, Salvatore Stagira (Politecnico/Milano), Andrea Mostacci (Rome University La Sapienza), David Dowell, Paul Emma, Cecile Limborg-Deprey, Dennis Thomas Palmer (SLAC), James Rosenzweig (UCLA), Ilario Boscolo, Cesare Maroli, Vittoria Petrillo (Universita' degli Studi di Milano), Decio Levi, Mario Mattioli, G. Medici, Pietro Musumeci, Daniele Pelliccia (Università di Roma I La Sapienza)*
The SPARC project has entered its installation phase at INFN-LNF: its main goal is the promotion of an R&D activity oriented to the development of a high brightness photoinjector to drive SASE-FEL experiments. The design of the 150 MeV photoinjector has been completed and the construction of its main components is in progress, as well as the design of the 12 m undulator. In this paper we will report on the installation and test of some major components, like the Ti:Sa laser system to drive the photo-cathode, the RF gun, the RF power system, as well as some test results on the RF deflector and 4th harmonic X-band cavity prototypes. Advancements in the control and beam diagnostics systems will also be reported, in particular on the emittance-meter device for beam emittance measurements in the drift space downstream the RF gun. Recent results on laser pulse shaping, obtained with two alternative techniques (DAZZLER and Liquid Crystal Mask), show the feasibility of producing 10 ps flat-top laser pulses in the UV with rise time below 1 ps, as needed to maximize the achievable beam brightness. First FEL experiments have been proposed, using SASE, seeding and non-linear resonant harmonics: these will be briefly described.

**RPPT014—Design and RF Measurements Results of a X-Band Structure for a Longitudinal Emittance Correction at SPARC**

*David Alesini, Bruno Spataro (INFN/LNF), Alberto Bacci (INFN/LASA), Antonio Falone, Mauro Migliorati, Andrea Mostacci, Luigi Palumbo (Rome University La Sapienza,)*
The paper presents the design of an X-band accelerating section for linearizing the longitudinal phase space in the Frascati Linac Coherent Light Source (SPARC). The structure, operating on the pi standing wave mode, is a 9 cells structure feeded by a central waveguide coupler and has been designed to obtain a 5 MV accelerating voltage. The 2D profile has been obtained using the e.m. codes SUPERFISH and OSCARD2D while the coupler has been designed using HFSS. Bead-pull measurement made on a copper prototype are illustrated and compared with the numerical results. Mechanical details of the realized prototype and RF properties of the structure as a function of the assembly characteristics are also discussed.

**RPPT015—Start To End Simulations for the SPARX Project**

*Cristina Vaccarezza, Manuela Boscolo, Massimo Ferrario, Valeria Fusco, Mauro Migliorati, Luigi Palumbo, Bruno Spataro (INFN/LNF), Luca Giannessi, Marcello Quattromini, Concetta Ronsivalle (ENEA C.R. Frascati), Luca Serafini (INFN-Milano)*
The first phase of the SPARX project now funded by Government Agencies, is an R&D activity focused on developing techniques and critical components for future X-ray facilities. The aim is the generation of electron beams with the ultra-high peak brightness required to drive FEL experiments. The FEL source realization will develop along two lines: (a) the use of the SPARC high brightness photoinjector to test RF compression techniques and the emittance degradation in magnetic compressors due to CSR, (b) the production of radiation in the range of 3-5 nm, both in SASE and SEEDED FEL configurations, in the so called SPARXINO test facility, upgrading the existing Frascati 800 MeV LINAC. In this paper we present and discuss the preliminary start to end simulations results.

**RPPT016—Effects of S-Band Linac Wakefield on the Microbunching Instabilities at PAL-XFELs**

*Eun-San Kim (PAL)*
We present effects of the wakefields in accelerating structures of the S-band linac on the microbunching instabilties at the PAL-XFELs. Analytical calculations are performed to investigate the gains of the instabilities in the accelerator system for the PAL-XFELs.

**RPPT017—Wake Field Effect on the SASE Performance of PAL XFEL**

*Jong-Seok Oh, In Soo Ko, Tae-Yeon Lee, Won Namkung (PAL)*
The PAL XFEL will supply coherent radiations from VUV to X-rays. X-ray FEL for 0.3 nm lasing requires a 3-GeV driver linac and a 60-m long in-vacuum undulator with a narrow variable gap. The linac should supply highly bright beams with emittance of 1.2 mm-mrad, a peak current of 3.5 kA, and a low energy spread of 0.03%. The beam quality is degraded along the undulator trajectory due to the energy loss, the wake field, and the magnetic field errors, etc. Especially the wake field effect is most sensitive parameter due to the narrow gap of the undulator. The preliminary design details of undulators for PAL-XFEL are presented with parametric analysis. The temporal SASE performance is analyzed using simulation tools such as GENESIS and SIMPLEX.

Supported by the POSCO and the MOST, Korea.

**RPPT018—On Possibility of Detecting Wakefield Undulator Radiation**

*Anatoliy Opanasenko (NSC/KIPT)*
A new radiation mechanism considered earlier* points to new opportunities for generating ultra-short wavelength light.**,*** It consists in photon emission by a short bunch of relativistic charged particles undulating in alternating wakefields, which are induced as the bunch moves through a periodic waveguide. Therefore there exists an interest in carrying out the proof-of-principle experiments. A possibility to detect the predicted radiation is estimated in this paper. We consider a possibility of using both ultra-bright short electron bunches from table-top accelerators and beams from conventional rf electron linacs with energy about 100 MeV and above. Two approaches are applied to obtain the quantitative radiation characteristics. The wakefield undulator parameter is calculated by using a model of electron beam interaction with a weakly corrugated waveguide. Besides, the relations for wake-force harmonics in the lowest pass-band of a dick-loaded waveguide are derived to estimate the minimal possible magnitudes of photon fluxes. The beam parameters and dimensions of the periodic structures appropriate for experimental study of the wakefield undulator radiation are given.
*A.Opanasenko, Proc. of MMET'02, Kiev, p.642; http://arxiv.org/abs/physics/0209100. **A.Opanasenko, Proc. of EPAC'04, Lucerne, Switzerland, p. 2412. ***A.Opanasenko, Proc. of RUPAC'04, Dubna, Russia.

**RPPT019—Start to End Simulations of the ERL Prototype at Daresbury Laboratory**

*Christopher Gerth, Marion Bowler, Bruno Muratori, Hywel Owen, Neil Thompson (CCLRC/DL/ASTeC), Brian W.J. McNeil (Strathclyde University)*
Daresbury Laboratory is currently building an Energy Recovery Linac Prototype (ERLP) that will serve as a research and development facility for the study of beam dynamics and accelerator technology important to the design and construction of the proposed 4th Generation Light Source (4GLS) project. Two major objectives of the ERLP are the demonstration of energy recovery and of energy recovery from a beam disrupted

by an FEL interaction as supplied by an infrared oscillator system. In this paper we present start-to-end simulations of the ERLP including such an FEL interaction. The beam dynamics in the high-brightness injector, which consists of a DC photocathode gun and a superconducting booster, have been modelled using the particle tracking code ASTRA. After the booster the particles have been tracked with the code GPT which includes space charge in the injector line at 8.3 MeV. The 3D code GENESIS 1.3 was used to model the FEL interaction with the electron beam at 35 MeV.

**RPPT020—Space Charge Effects for the ERL Prototype at Daresbury Laboratory**
*Bruno Muratori, Christopher Gerth, Hywel Owen (CCLRC/DL/ASTeC)*
Daresbury Laboratory is currently building an Energy Recovery Linac Prototype (ERLP) that will operate at a beam energy of 35 MeV. In this paper we examine the space charge effects on the beam dynamics in the ERLP injector line. The low energy section from the DC photocathode gun to the exit of the booster has been modelled with ASTRA. The particle distribution is then tracked with GPT (General Particle Tracer) through the injection line to the main linac. The nominal beam energy in the injection line is 8.3 MeV and the bunch charge 80 pC. The effects of space charge on the transverse and longitudinal emittance are studied for various electron beam parameter settings.

**RPPT021—Inducing Strong Density Modulation with Small Energy Dispersion in Particle Beams**
*Brian W.J. McNeil, Gordon Robb (Strathclyde University), Michael W. Poole (CCLRC/DL/ASTeC)*
We present a possible method of inducing a periodic density modulation in a particle beam with little increase in the energy dispersion of the particles. The method relies upon the Kuramoto-like model of collective synchronism found in free electron generators of radiation, such as Cyclotron Resonance Masers and the Free Electron Laser. The flow of particles in phase space does not then obey Liouville's Theorem. For the case of an FEL interaction, electrons initially begin to bunch and emit radiation energy with a correlated energy dispersion which is periodic with the FEL ponderomotive potential. The relative phase between potential and particles is then changed by approximately 180 degrees. Such a phase shift may be achieved by introducing a small gap along the FEL undulator lattice. The particles continue to bunch, however, there is now a correlated re-absorption of energy from the field. We show that, by changing the relative phase between electrons and ponderomotive potential many times, a significant density modulation of the particles may be achieved with only relatively small energy dispersion.

**RPPT022—Optics for High Brightness and High Current ERL Project at BNL**
*Dmitry Kayran, Ilan Ben-Zvi, Xiangyun Chang, Jorg Kewisch, Vladimir N. Litvinenko (BNL)*
A Energy Recovery Linac (ERL), under development at Brookhaven National Laboratory, will push the ERL concept to high current and high brightness. In high current mode (1.4 nC at 350 MHz, 1 mm mrad) the energy after the gun is 2 MeV, limited by the available RF power. In high charge mode (up to 10nC per bunch at 10MHz repetition rate, about 10 mm mrad normalized emittance) the super-conductive gun accelerates the beam to about 5 MeV, limited by the maximum field in the gun. In this paper we present the optical design of the machine and PARMELA simulation from the cathode to the beam dump. We discuss the design considerations and give parameters that we obtained for different regimes of operation.

Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the U.S. Department of Energy.

**RPPT023—A Proposal for a One Micron High Gain Transverse Optical Klystron Amplifier Free Electron Laser at SDL of BNL Lab**
*Li-Hua Yu (BNL/NSLS)*
We propose a high gain transverse optical klystron single pass FEL configuration for the high energy laser system at SDL of BNL as a first low repetition rate test. The system uses the coherent radiation of pre-bunched electron bunch and the exponential growth of the FEL process to achieve high power without cavity mirrors. The demand on the steering mirrors is much more relaxed than the cavity mirrors in the oscillator configuration, and so the system size can be significantly reduced. The most important advantage is its relaxed requirement on the electron beam quality. Our calculation shows that with beam parameters comparable to that of the JLAB energy recovery linac FEL (charge 150pC, peak current 75 amp, and normalized emittance of 10 mm-mrad), it is possible to achieve 150MW output power with 300 mJ/pulse, using a 0.6 meter modulator, 6 meter radiator with 3% taper while the seed required is only 10kW at 1 mm. This means at 75MHz, the average power is 22kW, with seed average power 1.5W, while at 1 GHz, the average power is 0.3 MW, seed average power is 20 W. We shall compare this proposed configuration with SASE, direct seeding and the oscillator configuration.

**RPPT024—Doubling the Intensity of an ERL Based Light Source**
*Andrew Hutton (Jefferson Lab)*
A light source based on an Energy Recovered Linac (ERL)* consists of a superconducting linac and a transfer line that includes wigglers and undulators to produce the synchrotron light. The transfer line brings the electrons bunches back to the beginning of the linac so that their energy out of 2/λcan be recovered when they traverse the linac a second time, phase. There is another interesting condition when the length of the . In this case, the electrons drift through onλtransfer line is (n±1/4) the zero RF crossing, and make a further pass around the transfer line, effectively doubling the circulating current in the wigglers and undulators. On the third pass through the linac, they will be decelerated and their energy recovered. The longitudinal focusing at the zero crossing is a problem, but it can be canceled if the drifting beam sees a positive energy gradient for the first half of the linac and a negative gradient for the second half (or vice versa). This paper presents a proposal to use a double chicane at the center of the linac to provide this focusing inversion for the drifting beam while leaving the accelerating and decelerating beams on crest.
*G. R. Neil et al., Phys. Rev. Let. 84, 662 2000.

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**RPPT025—Beam Conditioning and FEL Studies Using MAD and Genesis**
*Yury Vinokurov, Gregory Penn, Jonathan Wurtele (LBNL/CBP), Eric Esarey, Andrew Sessler, Andrzej Wolski (LBNL)*
Beam conditioning using a variety of lattices is explored using MAD in conjunction with Genesis. In particular, the conditioning effects of a simple FODO lattice are simulated in MAD and the resulting particle distribution is then used as an input to Genesis to examine the effects of a conditioner on FEL performance. Studies of a plasma-based conditioner have been performed. In this scheme conventional RF accelerating cavities are replaced by a plasma accelerator. The wavelength of the plasma wave is typically shorter than the longitudinal bunch

length, resulting in regions of conditioned and unconditioned beam. Studies were also performed analyzing the sensitivity of FEL performance to changes in various system parameters.

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**RPPT026—Status of a Plan for an ERL Extension to CESR**
*Georg Hoffstaetter, Ivan Vasilyevich Bazarov, Sergey Belomestnykh, Donald Heywood Bilderback, Michael Billing, Joseph Sung-Hwoon Choi, Zipi Greenwald, Sol Michael Gruner, Yulin Li, Matthias Liepe, Hasan Padamsee, David Sagan, Charles Kent Sinclair, Karl William Smolenski, Changsheng Song, Richard Michael Talman, Maury Tigner (Cornell University)*
We describe the status of plans to build an Energy-Recovery Linac (ERL) X-ray facility at Cornell University. This 5 GeV ERL is an upgrade of the CESR ring that currently powers the Cornell High Energy Synchrotron Source (CHESS). Due to its very small electron-beam emittances, it would dramatically improve the capabilities of the light source and result in X-ray beams orders of magnitude better than any existing storage ring light source. The emittances are based upon simulations for currents that are competitive with ring-based sources. The ERL design that is presented has to allow for non-destructive transport of these small emittances. The design includes a series of X-ray beamlines for specific areas of research. As an upgrade of the existing storage ring, special attention is given to reuse of many of the existing ring components. Options of bunch compression are discussed, tolerances for emittance growth are specified, and simulations of the beam-breakup instability and methods of increasing its threshold current are shown. This planned upgrade illustrates how other existing storage rings could be upgraded as ERL light sources with vastly improved beam qualities.

Cornell University.

**RPPT027—A Scheme to Precisely Control the Arrival Timing of Electron Bunches to 10s fs Level for X-Ray FEL**
*Dong Wang (MIT)*
The next generation of x-ray FEL requires very high quality electron beams for producing unprecedented x-ray radiations. In proposed x-ray FEL facilities, especially those that use multi-stage high gain high harmonic (HGHG) principle to obtain coherence in both transverse and longitudinal dimensions, the arrival timing of electron bunches must be very precise to ensure the seed laser overlap the desired sections of the electron bunch. A scheme is proposed to achieve 10s fs level of arrival timing control level.

U.S. Department of Energy.

**RPPT028—Free-Electron Lasers with Slowly-Varying Beam and Undulator Parameters**
*Zhirong Huang, Gennady Stupakov (SLAC)*
In this paper, we present a self-consistent theory of a free-electron laser (FEL) with slowly-varying beam and undulator parameters. A general method is developed to apply the WKB approximation to the beam-radiation system by employing the adjoint eigenvector that is orthogonal to the eigenfunctions of the coupled Maxwell-Vlasov equations. The theory is used to study the performance of a self-amplified spontaneous emission (SASE) FEL when the electron beam energy varies alone the undulator as would be caused by vacuum pipe wakefields and/or when the undulator strength parameter is tapered in the small signal regime until FEL saturation.

**RPPT029—Spectrometers for the LCLS Photoinjector Beamline**
*Cecile Limborg-Deprey, David Dowell, Paul Emma, Stephen Gierman, John Schmerge (SLAC)*
Two spectrometers have been added to the LCLS photoinjector beamline. The first one will be located close to the exit of the Photoinjector RF gun. With this diagnostic, we will measure beam energy, energy spread (correlated and uncorrelated), possibly deleterious structure in the longitudinal phase space induced by longitudinal space charge force, and slice thermal emittance … This extensive characterization of the 5MeV electron bunch will be made possible by combining this spectrometer with other diagnostics (YAG screens and Cerenkov Radiator). A second spectrometer located at the end of the beamline has been designed to characterize the 6 dimensional phase space of the 135MeV beam to be injected in the main accelerator. At that second spectrometer station, we will measure energy, energy spread (correlated and uncorrelated), longitudinal phase space, slice emittances ... Those last two measurements require using this spectrometer in combination with the transverse RF deflecting cavity and with the quadrupole scan emittance station. The designs of these two spectrometers have been supported by simulations from MAD and PARMELA.

This work was supported by U.S. Department of Energy, contract No. DE-AC03-76SF00515A06.

**RPPT030—Alternate Tunings for the LCLS Photoinjector**
*Cecile Limborg-Deprey, David Dowell, Paul Emma, Stephen Gierman (SLAC)*
The Linac Coherent Light Source (LCLS) is an x-ray free-electron laser (FEL) project based on the SLAC linac. The LCLS Photoinjector beamline has been designed to deliver 10 ps long electron bunches of 1nC with a normalized transverse emittance of less than 1 mm.mrad for 80% of the slices constituting the core of the bunch at 135 MeV. Tolerances and regulation requirements are tight for this tuning. The main contribution to emittance is the “cathode emittance which counts for 0.72 mm.mrad for the nominal tuning. As the “cathode emittance” scales linearly with laser spot radius, the emittance will be dramatically reduced for smaller radius, but this is only possible at lower charge. In particular, for a 0.2nC, we believe we can achieve an emittance closer to 0.4 mm.mrad. This working point will be easier to tune and the beam quality should be much easier to maintain than for the nominal one. In this paper, we also discuss how emittance could be further reduced by using the appropriate laser pulse shaping.

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**RPPT031—Recent Results from and Future Plans for the VISA II SASE FEL**
*Gerard Andonian, Ronald Agustsson, Pedro Frigola, Alex Murokh, Claudio Pellegrini, Sven Reiche, James Rosenzweig, Gil Travish (UCLA), Marcus Babzien, Ilan Ben-Zvi, Vladimir N. Litvinenko, Vitaly Yakimenko (BNL), Ilario Boscolo, Simone Cialdi, Alessandro Federico Flacco (INFN-Milano), Massimo Ferrario, Luigi Palumbo, Carlo Vicario (INFN/LNF), Jung Yun Huang (PALg)*
As the promise of X-ray Free Electron Lasers (FEL) comes close to realization, the creation and diagnosis of ultra-short pulses is of great relevance in the SASE FEL (Self-Amplified Spontaneous Emission) community. The VISA II (Visible to Infrared SASE Amplifier) experiment entails the use of a chirped electron beam to drive a high gain SASE FEL at the Accelerator Test Facility (ATF) in Brookhaven National Labs (BNL). The resulting ultra-short pulses will be diagnosed using an advanced FROG (Frequency Resolved Optical Gating)

technique, as well as a double differential spectrum (angle/wavelength) diagnostic. Implementation of sextupole corrections to the longitudinal aberrations affecting the high energy-spread chirped beam during transport to the VISA undulator is studied. Start-to-end simulations, including radiation diagnostics, are discussed. Initial experimental results involving a highly chirped beam transported without sextupole correction, the resulting high gain lasing, and computational analysis are briefly reported.

**RPPT032—High Current Energy Recovery Linac at BNL**
*Vladimir N. Litvinenko, Donald Barton, Dana Beavis, Ilan Ben-Zvi, Michael Blaskiewicz, Joseph Michael Brennan, Andrew Burrill, Rama Calaga, Peter Cameron, Xiangyun Chang, Roger Connolly, David Mark Gassner, Harald Hahn, Ady Hershcovitch, Hsiao-Chaun Hseuh, Peter Johnson, Dmitry Kayran, Jorg Kewisch, Robert Lambiase, Gary McIntyre, Wuzheng Meng, Thomas Nehring, Tony Nicoletti, David Pate, Jim Rank, Triveni Rao, Thomas Roser, Thomas Russo, Joseph Scaduto, Kevin Smith, Neville Willaims, Kuo-Chen Wu, Vitaly Yakimenko, Kin Yip, Alex Zaltsman, Yongxiang Zhao (BNL), Al Burger, Anthony Favale, Douglas Holmes (AES), Hans Bluem, Michael Cole, John Rathke, Tom Schultheiss, Alan Murray Melville Todd (AES), Jean Roger Delayen, Larry Phillips, Joseph P. Preble (Jefferson Lab)*
We present the design and the parameters of a small Energy Recovery Linac (ERL) facility, which is under construction at BNL. This R&D facility has goals to demonstrate CW operation of ERL with average beam current in the range of 0.1 - 1 ampere, combined with very high efficiency of energy recovery. The possibility for future up-grade to a two-pass ERL is being considered. The heart of the facility is a 5-cell 703.75 MHz super-conducting RF linac with HOM damping. Flexible lattice of ERL provides a test-bed for testing issues of transverse and longitudinal instabilities and diagnostics of intense CW e-beam. We present the status and plans for this facility.

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**RPPT033—Potential Use of eRHIC's 10-to-20 GeV ERL for FELs and Light Sources**
*Vladimir N. Litvinenko, Ilan Ben-Zvi (BNL)*
One of the designs of a future electron-hadron collider, eRHIC, is based on a 5-10 GeV high current energy-recovery linac (ERL) with possible extension of its energy to 20 GeV. This ERL will operate with high brightness electron beams, which naturally match requirements for X-ray FELs and other next generation light sources. In this paper we discuss possible scenarios of using the eRHIC ERL in parasitic and dedicated mode for SASE, HGHG and oscillator X-ray FELs.
*http://www.agsrhichome.bnl.gov/eRHIC/, Appendix A: Linac-Ring Option

Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the US Department of Energy.

**RPPT034—High-Resolution Differential Measurements of Undulator Effective K-Parameter Using Spontaneous Undulator Radiation**
*Bingxin Yang (ANL)*
The Linac Coherent Light Source (LCLS) is a fourth-generation light. Its proper operation requires a stringently controlled undulator field. The tolerance for the field parameter K is less than 1.5 × 10-4 for all thirty-three undulator segments totaling 112 meters. Even with the high quality of the LCLS electron beam (x- and y-emittance ~ 44 pm, energy spread ~0.03%), the fluctuation of the electron energy (~0.05%) presents a serious challenge to measurement techniques based on electron or x-ray beams. We propose a differential measurement technique that makes use of the angle-integrated spontaneous radiation intensities from two undulator segments. When the x-ray beams emitted from the two undulator segments are separated but allowed to pass through the same monochromator, the two beam intensities will change almost identically with the change of electron beam energy. As a result, the intensity difference becomes a very sensitive and reliable measure of the difference of the two undulators' K-parameters. Results of comprehensive numerical simulations show that differences in the range of delta-K/K ~ 10-5 can be resolved, well within the tolerance for the LCLS operation.

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**RPPT035—Optimization of the LCLS X-Ray FEL Output Performance in the Presence of Strong Undulator Wakefields**
*Sven Reiche (UCLA), William M. Fawley (LBNL), Karl Leopold Freitag Bane, Paul Emma, Zhirong Huang, Heinz-Dieter Nuhn, Gennady Stupakov (SLAC)*
The Linac Coherent Light Source (LCLS) Free-Electron Laser will operate in the wavelength range of 1.5 to 15 Angstroms. Energy loss due to wakefields within the long undulator can degrade the FEL process by detuning the resonant FEL frequency. The wakefields arise from the vacuum chamber wall resistivity, its surface roughness, and abrupt changes in its aperture. For LCLS parameters, the resistive component is the most critical and depends upon the chamber material (e.g. Cu) and its radius. To study the expected performance in the presence of these wakefields, we make a series of "start-to-end" simulations with tracking codes PARMELA and ELEGANT and time-dependent FEL simulation codes Genesis 1.3 and Ginger. We discuss the impact of the wakefield on output energy, spectral bandwidth, and temporal envelope of the output FEL pulse, as well as the benefits of a partial compensation obtained with a slight z dependent taper in the undulator field. We compare these results to those obtained by decreasing the bunch charge or increasing the vacuum chamber radius. We also compare our results to those predicted in concurrent analytical work.

The work was supported by the DOE Contract No. DE-AC02-76SF00515.

**RPPT036—200 MeV Linac Upgrade for FEL**
*Yingui Zhou, Sai Dong, Ge Li (USTC/NSRL)*
The present status of Hefei 200 MeV RF linac are given. By upgrading its present thermal cathode system into the photo cathode system and implement RF phase locked system, using Hefei 200 MeV RF linac as FEL driver is investigated.

**RPPT037—Technique for the Generation of Attosecond X-Ray Pulses Using an FEL**
*Gregory Penn (LBNL/CBP), Alexander Zholents (LBNL/AFR)*
We describe a technique for the generation of an isolated burst of X-ray radiation with a duration of ~100 attoseconds in a free electron laser (FEL) employing self-amplified spontaneous emission. Our scheme relies on an initial interaction of the electron beam with an ultra-short laser pulse in a one-period wiggler followed by compression in a dispersive section. The result of this interaction is to create a sub-femtosecond slice of the electron beam with enhanced growth rates for FEL amplification. After many gain lengths through the FEL undulator, the X-ray output from this slice dominates the radiation of the entire bunch. We consider the impact of various effects on the effi-

ciency of this technique. Different configurations are considered in order to realize various timing structures for the resulting radiation.

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**RPPT038—Phase Noise Characteristics of Fiber Lasers as Potential Ultra-Stable Master Oscillators**
*Axel Winter, Peter Schmüser (Uni HH), Holger Schlarb (DESY), Jeff Chen, Fatih Oemer Ilday, Franz Xaver Kaertner (MIT)*
Fourth-generation light sources, such as the European X-Ray free electron laser facility (XFEL) require timing signals distributed over distances of the order of kilometers with a timing jitter in the order of femtoseconds. The master clock for the proposed optical distribution system must operate with exceptionally low timing jitter. A promising approach is the use of a mode-locked laser that generates ultrastable pulses which are distributed via timing stabilized fiber links. Candidates for the pulse source are mode-locked Erbium doped fiber lasers, featuring very low high frequency noise. In this paper, we present a study of the phase noise of various fiber lasers in view of their applicability as laser-based master oscillators for femtosecond timing distributions.

**RPPT039—Stabilized Optical Fiber Links for the XFEL**
*Axel Winter (Uni HH), Holger Schlarb, Bernhard Schmidt (DESY), Jeff Chen, Felix Jan Grawert, Fatih Oemer Ilday, Franz Xaver Kaertner (MIT)*
The timing synchronization scheme for the European X-Ray free electron laser facility (XFEL) is based on the generation and distribution of sub-picosecond laser pulses with actively stabilized repetition rate which are used to synchronize local RF oscillators. An integral part of the scheme is the distribution of the optical pulse stream to parts of the facility via optical fiber links. The optical path length of the fiber has to be stabilized against short-term and long-term timing jitter due to environmental effects, such as temperature drifts and acoustic vibrations, to better than 10 fs for distances ranging from tens of meters to several kilometers. In this paper, we present first experimental results for signal transmission through a km-long fiber link with femtosecond stability.

**RPPT040—Weak FEL Gain Detection with a Modulated Laser-Based Beam Heater**
*Paul Emma, Zhirong Huang, Juhao Wu (SLAC)*
For an x-ray free-electron laser (FEL) such as the LCLS, the FEL gain signal is accompanied by spontaneous radiation with a significant power level. Detecting the weak FEL gain among the large spontaneous background in the early stage of the exponential growth or for a low quality electron beam is important in commissioning the FEL. In this paper, we describe a simple "lock-in" method of weak FEL gain detection by slowly modulating the laser power of a designated beam heater that controls the local energy spread of the electron beam. We present numerical modeling that shows the effectiveness of this method and discuss its implementation in the LCLS.

**RPPT041—Ground Motion Expectations for the LCLS Undulator Hall**
*James Welch (SLAC)*
Ground motion, even on a microscopic scale, will cause misalignment of the LCLS undulator components that will eventually degrade the FEL output power. In this paper we estimate the amount of time required between realignment sessions. Extensive local historical data on ground motion are used to support this estimate. Effects due to differential settlement, time since construction, seasonal variations, ATL behavior, atmospheric pressure, and tides are taken into account. The result is that, averaged over the first three years of operation, we expect to realign (remotely) about once a week, with relatively low probability of going out of alignment in between sessions.

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**RPPT042—Beam Acceleration and Undulator Characterization in the CUTE-FEL Project**
*Kamal Kumar Pant, Bhaskar Biswas, Pratima Jain, Umesh Kale, Srinivas Krishnagopal, Arvind Kumar, Vinit Kumar, Shankar Lal, Pravin Nerpagar, Rohin Parkar (CAT)*
We are building a Compact Ultrafast TErahertz Free-Electron Laser (CUTE-FEL) for terahertz applications. For this, we have indigenously built a 21 cm, four cell Plane Wave Transformer (PWT) linac structure operating in the 'pi' mode at 2856 MHz. We have injected a 40 kV, 2 micro seconds, un-bunched electron beam from a thermionic gun into this structure and have observed acceleration up to 3.5 MeV. We have also built and characterized a 5 cm period, 2.5 m long PPM planar undulator, and are readying to tansmit beam through it. We discuss these results as well as our future plans for terahertz lasing.

**RPPT043—Commissioning of the Main Magnet of Kolkata K-500 Superconducting Cyclotron**
*Rakesh Kumar Bhandari, Bikash Sinha (DAE/VECC)*
Main magnet of the K-500 superconducting cyclotron at Kolkata has been fully assembled in the cyclotron vault. The assembly includes alpha and beta superconducting coils inside the liquid helium chamber, coil tank for the outer vacuum, liquid nitrogen shield, support links, cryogenic instrumentation and 80 ton magnet frame forming the pill box structure. Cooling of the coils was started in mid-December. It took about three weeks to fill the liquid helium chamber - fully immersing the coils. All the four temperature sensors embedded in the coil are steady at about 4.4K. At this time the liquid nitrogen line for cooling the shield seems to show a leak. So, we are not cooling the shield. The helium liquefier/regrigerator of 200W capacity has been functioning well and so is the network of vacuum jacketted and liquid nitrogen cooled cryogenic transfer lines. Energization of the main magnet will begin soon. Magnetic field measurement set up is in place to start the mapping. In this presentation, our experiences with commissioning of the largest superconducting magnet in India, with stored energy 22 MJ at peak field of 6T, will be described. Some results of the magnetic field measurements will also be presented.

**RPPT044—Design, Construction and Commissioning of a NEG Coated Wiggler Vacuum Chamber for the LNLS Storage Ring**
*Marcelo Juni Ferreira, Reginaldo de Oliveira Ferraz, Helio Gazetta Filho, Milton Batista Silva (LNLS)*
We present the design of the vacuum chamber for the LNLS 2 T Hybrid Wiggler. The chamber is a 3 m long, 1.2 mm thick 316 SS tube, which was mechanically pressed into an elliptical shape from an originally round tube. In order to provide the necessary mechanical tolerances, the rather flexible tube is welded to lateral supports that run the complete length of the chamber. Special care has been given to the mechanical and magnetic characterization of the chamber and the inner surface of the chamber was NEG-coated at the ESRF. We present the installation procedure as well the vacuum conditioning charge evolution.

**LINAC and Transfer Line**
*Ji-Hao Li, Yong Cao, Duohui He, Ping Lu, Baogen Sun (USTC/NSRL)*
The beam position monitors for HLS LINAC and transfer line are designed to monitor the positions of electron beam passing by. Because of low intensity of beam at HLS LINAC and transfer line, the sensitivity of beam position monitor is the most important parameter during the calibration. This paper will give the performance of HLS LINAC and transfer line beam position monitor, including sensitivity, space resolution and linearity.

**RPPT046—Bunch-by-Bunch Measurement System of HLS**
*Jian Hong Liu, Baogen Sun, Jun Hua Wang, Yong Liang Yang, Kai Zheng (USTC/NSRL)*
This paper is intended to present the newly implemented wideband (100MHz) bunch oscillation measurement system, which is in nature a different method from the narrow-band (<5MHz) facilities employed before. Basic formalism and implementation details of the system is introduced to illustrate the function of observing coupled bunch instabilities in time and frequency domain. The designed function includes detecting of transverse oscillation, synchrotron phase oscillation, as well as bunch filling pattern. Some diagnostics results of machine instabilities and application of this system are also discussed.

**RPPT047—Development of Measurement and Transverse Feedback System at HLS**
*Jun Hua Wang, Weimin Li, Jian Hong Liu, Zuping Liu, Baogen Sun, Yong Liang Yang, Kai Zheng (USTC/NSRL)*
In order to observe and cure coupled bunch (CB) instabilities caused by the high order modes (HOMs) of the RF cavity and the resistive wall impedance of the Ring vacuum chamber, which were ineluctable during the operation of the accelerator, an observer system characterized by bunch by bunch measurement of transverse âoscillation and longitudinal synchrotron phase oscillation has been constructed and commissioned at Hefei Light Source (HLS); meanwhile a transverse bunch-by-bunch feedback system is under construction. The design and development of the systems, as well as diagnostics results of machine instabilities will be presented in this paper.

**RPPT048—Turn-By-Turn System of HLS and Its Application**
*Jun Hua Wang, Weimin Li, Jian Hong Liu, Zuping Liu, Baogen Sun, Yong Liang Yang, Kai Zheng (USTC/NSRL)*
Design and experimental application of the turn-by-turn system of Hefei Light Source (HLS) are presented in this paper. The front-end signal measurement adopts a log-ratio electronics circuitry. The system is designed to be capable of up to 2 seconds data acquisition. Injection kickers are used to excite beam for monitoring â oscillation and damping rate. Some of experimental applications are also illustrated, in commission of both the upgraded injection system of HLS and the lower frequency feedback system. The results shows that in order to improve the accumulation of the injected beam, it is very necessary to investigate integral magnet fields equilibrium of injected system and proper measures to control restrain remnants â-oscillation caused by the injected system error.

**RPPT049—Linear Optics Compensation of the Insertion Devices in HLS Storage Ring**
*Lin Wang (USTC/NSRL)*
Hefei Light Source is a dedicated VUV light source. A superconducting wiggler magnet with 6 Tesla magnetic field was installed on the storage ring to generate hard X-ray radiation. With the compensation of tune shift due to insertion device, beam was successfully stored, but the beam lifetime was decreased much. In order to cure the lifetime, a simple hard-edge model of the wiggler was constructed in lattice simulation code and the compensation scheme was extensively studied again. Calculation showed that it is difficulty to localize the strong focusing effects from wiggler magnet. Then, a new scheme was brought forward and experimental result showed that it can restore the beam lifetime largely. As the application of LOCO method in HLS, a new compensation scheme was calculated by response matrix fitting, and the experimental result also presented in this paper.

**RPPT050—The Measurement of Tune and Phase Space at HLS**
*Yong Liang Yang, Jian Hong Liu, Zuping Liu, Baogen Sun, Jun Hua Wang, Kai Zheng (USTC/NSRL)*
Tune and phase space online monitor at the electronic storage ring of Hefei Light Source (HLS) have been realized by using of turn-by-turn beam position data. In this paper, we have compared many methods to compute tune and discussed how to choose the best fitting method for our online tune computing. We can compute and display tune online, at the same time, beam tracks were obtained on the transverse phase space by using turn-by-turn beam position data at two differently-located beam-position-monitor electrodes. With these instruments we can precise and attractive study machine instabilities

**RPPT051—Electron Demonstration Model of Nonscaling FFAG with 1.3 GHz RF**
*Shane Rupert Koscielniak (TRIUMF), Carol Johnstone (Fermilab)*
The variable-tune linear-field FFAG uses conventional linear magnetic elements, but operates in a very novel way. First, the fixed magnetic field, negative chromaticity and large range of central momenta lead to the crossing of many integer and half-integer betatron resonances. Second, in a machine with fixed rf, the quasi-parabolic time-of-flight variation necessitates acceleration within a rotation manifold, rather than the customary rf bucket. The purpose of the few-MeV electron model is to demonstrate and investigate these novel features in a nonscaling FFAG that is a small fraction of the cost of the multi-GeV muon machine. Previously, to reduce ring size, S-band rf had been adopted for the model. However, three factors favour using L-band: the magnetic lattice elements are a smaller fraction of a wavelength long, leading to reduced phase slip and more turns; there is much development of 1.3 GHz components for TESLA; and last, but not least, there is a 1.3 GHz injector linac at a potential host site. This paper presents lattices re-optimized for a lower rf, and indicates some technology options for realising the electron model.

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**RPPT052—Electron Model Nonscaling FFAG—Analysis of Betatron Resonance Crossing**
*Shane Rupert Koscielniak, Rick Baartman (TRIUMF)*
The reduction of transverse and the elimination of longitudinal cooling, the increased number of beam circulations, and the reduced cost, as compared to RLAs, are arguments to adopt the linear-field FFAG as the acceleration stage of a Neutrino Factory or Muon Collider. Because of the fixed magnetic field, negative chromaticity and large range of central momenta, the non-scaling FFAG will cross many integer and half-integer betatron resonances during the course of the few turns acceleration; and this is considered worriesome because of the potential to degrade the transverse emittances. However, there is the belief

that if driving terms are small enough and crossing is fast enough, then there is insufficient time for the betatron amplitudes to grow. The purpose of the few-MeV electron model is to investigate and benchmark the single-resonance-crossing emittance growth scaling laws in a nonscaling FFAG that is a small fraction of the cost of the multi-GeV muon machine. Ideally, the resonance driving strength and crossing rate should be independently variable. This paper examines the issue of whether the parameter ranges to be accessed by the model are truly representative of the multi-GeV FFAGs.

TRIUMF receives federal funding via a contribution agreement through the National Research Council of Canada.

**RPPT053—Studies of the Injection System in the Decay Ring of Beta-Beam Neutrino Souce Project**
*Jacques Payet, ANTOINE CHANCE (CEA/CEN)*
After being accelerated the beta radioactive ions are accumulated in a decay ring. The losses due to their decay are compensated with regular injections in presence of filled bucket. Without a damping mechanism, the new particles are injected at a different energy from the stored beam energy, then the old and the new buckets are merged with RF manipulation. This type of injection has to be done, in a dispersive region, in presence of closed orbit bump and a septum magnet. The sizes of the injected beam and of the stored beam have to be adjusted in order to minimize the losses on the septum and to maximize the stored intensity keeping small beam sizes. The dispersion has to be large enough in order to decrease the energy difference. The injection system may be located either in the arc or in a straight section, both possibilities have been studied.

**RPPT054—First Radioactive Ion Beam Production at the EXCYT Facility**
*Giacomo Cuttone, Luciano Calabretta, Luigi Celona, Luigi Cosentino, Paolo Finocchiaro, Donatella Garufi, Mariano Menna, Guido Raia, Maurizio Re, Danilo Rifuggiato, Alberto Rovelli, Gaetano Schillaci (INFN/LNS)*
The EXCYT facility (EXotics with CYclotron and Tandem) is based on a K-800 Superconducting Cyclotron (CS) injecting stable heavy-ion beams (up to 80 MeV/u, 1 e-microAmp) into a target-ion source assembly (TIS) to produce the required nuclear species, and on a 15 MV Tandem for post-accelerating the radioactive beams. Beam lines, high voltage platforms and isobaric mass separator were installed at LNS during the last years. Considerable efforts were devoted to improve the performance of the CS and to test some fundamental key devices such as the TIS, the low intensity beam diagnostic and the charge exchange cell. They were successfully tested off-line under the same operational conditions that will be used at the EXCYT facility during the operational run. According to the user requests, the first radioactive ion beams will be 8Li and 9Li. A preliminary stable beam of 7Li beam, at the beginning of 2004, will be necessary to tune and check all the main parameters and devices of the beam line. In this contribution we report the principal results of the preliminary run with stable beam together with the data related to the production of the first 8Li and 9Li radioactive ion beams.

INFN-LNS Catania.

**RPPT055—FFAG Accelerator Based Neutron Source with ERIT**
*Reiko Taki (GUAS/AS), Yoshiharu Mori (KEK)*
Accelerator-based intense thermal or epithermal neutron sources have been strongly requested recently. One of the ideas to generate intense neutrons is an ERIT system using FFAG accelerator. This paper presents the feasibility of this scheme in detail.

**RPPT056—A Proposal of the Chinese Spallation Neutron Source**
*Shouxian Fang (IHEP Beijing)*
We will soon have 3 SR facilities in the mainland China, but no SNS. Chinese scientists share a common sense that China should build an SNS as soon as possible, and it should rank in the world-class but within the limit of financial capability of China, as a developing country. Chinese Spallation Neutron Source(CSNS) has been proposed to our government and some preliminary design studies were conducted. CSNS acclerator of 1.6GeV is designed to provide 100kW proton beam in the 1st phase and then will be upgrated to 200kW. This paper will briefly present the design of the injector linac and the RCS ring, as well as the project plan.

**RPPT057—Tracking Optimisation of a 6D Neutrino Factory Muon Cooling Ring**
*Stephen Brooks (CCLRC/RAL/ASTeC)*
In a neutrino factory, the muon beam generated from the target has a very high emittance, which creates severe difficulties for the subsequent stages of muon control and acceleration. Schemes for handling the beam using large-aperture FFAG synchrotrons are one option under study, but the alternative approach of ionisation cooling is widely seen as an attractive step for creating a beam of improved quality prior to acceleration. This paper investigates one possible solution: the design of a ring incorporating both transverse and longitudinal cooling via wedge-shaped and block absorbers.* 3D simulations of the ring are described, using the model beam from earlier studies of the decay channel and phase rotation systems.** Techniques developed for optimising the ring lattice parameters for this scheme are also described.
*G.H. Rees et al., Features of a Muon Cooling Ring for a Neutrino Factory, Proc. NuFact'03. **S.J. Brooks, Quantitative Optimisation Studies of the Muon Front-End for a Neutrino Factory, Proc. EPAC'04.

PPARC / UK Neutrino Factory

**RPPT058—Kaon Monitoring Using the MiniBooNE Little Muon Counter**
*Terrence Lee Hart (Colorado University at Boulder)*
The Little Muon Counter (LMC) is a permanent magnet spectrometer designed to constrain electron neutrino backgrounds to the MiniBooNE experiment's neutrino oscillation signal. Electron neutrinos from kaon decay are a background to the MiniBooNE signal mode of the oscillation of muon neutrinos to electron neutrinos. MiniBooNE uses collisions of 8 GeV protons from the Fermilab Booster accelerator on a beryllium target to generate a secondary beam of pions and kaons that decay to produce a neutrino beam. The LMC constrains the kaon content of the meson beam, and thus the electron neutrinos from kaon decays, through momenta measurements of muons originating from decays of secondary beam kaons and pions. The LMC, located 7 degrees off-axis from the secondary beam, can distinguish pionic muons from kaonic muons kinematically. A description of the LMC components; analysis milestones including track momenta, muon identification penetration depth, track projection plots, and event displays; and the status of the LMC are presented.

**RPPT059—Spectrum from the Proposed BNL Very Long**

**Baseline Neutrino Facility**
*Stephen Alan Kahn, Milind Diwan (BNL)*
This paper calculates the neutrino flux that would be seen at the far detector location from the proposed BNL Very Long Baseline Neutrino Facility. The far detector is assumed to be located at an underground facility in South Dakota 2540 km from BNL. The neutrino beam facility uses a 1 MW upgraded AGS to provide an intense proton beam on the target and a magnetic horn to focus the secondary pion beam. The paper will examine the sensitivity of the neutrino flux at the far detector to the positioning of the horn and target so as to establish alignment tolerances for the neutrino system.

The work was performed with the support of the U.S. DOE under Contract No. DE-AC02-98CH10886.

**RPPT060—The MuCool Test Area at Fermilab**
*Carol Johnstone (Fermilab)*
A new experimental area designed to develop, test and verify muon ionization cooling using the 400- MeV Fermilab Linac proton beam began construction in spring, 2002. This area will be used initially for cryogenic tests of liquid-hydrogen absorbers for the MUCOOL R&D program and, later, for high-power beam tests of these absorbers and other prototype muon-cooling apparatus. The experimental scenarios being developed for muon facilities involve collection, capture, and cooling of large-emittance, high-intensity muon beams—~1013 muons at a repetition rate of 15Hz, so that conclusive tests of the apparatus require full Linac beam, or 1.6 x 1013 p at 15 Hz. To support the muon cooling facility, a new primary beamline will divert beam from the Linac to the test facility. Located southwest of Wilson Hall between the Linac berm and parking lot, implementation of the facility and associated beamline takes advantage of civil construction and resources that remain from the 400-MeV Linac Upgrade Project. The design concept for the MuCool facility is taken from an earlier proposal, but modifications to the existing proposal were necessary to accommodate high-intensity beam, cryogenics, and the increased scale of the cooling experiments.

Work supported by the US Dept. of Energy under contract No. DE-AC02-76CH03000

**RPPT061—Linear Quadrupole Cooling Channel for a Neutrino Factory**
*Carol Johnstone (Fermilab), Martin Berz, Kyoko Makino (MSU), Debbie Errede (University of Illinois)*
The staging and optimization in the design of a Neutrino Factory are critically dependent on the choice and format of accelerator. Possibly the simplest, lowest-cost scenario is a nonscaling FFAG machine coupled to a linear (no bending) transverse cooling channel constructed from the simplest quadrupole lens system, a FODO cell. In such a scenario, transverse cooling demands are reduced by a factor of 4 and no longitudinal cooling is required relative to acceleration using a Recirculating Linac (RLA). Detailed simulations further show that a quadrupole-based channel cools efficiently and over a momentum range which is well-matched to FFAG acceleration. Details and cooling performance for a quadrupole channel are summarized in this work.

Work supported by the U.S. Dept. of Energy under contract no. DE-AC02-76CH03000.

**RPPT062—Radiation Simulations for the Proposed ISOL Stations for RIA**
*Reginald Ronningen, Valetin Blideanu, Georg Bollen, Don Lawton, Paul Mantica, David Morrissey, Bradley Sherrill, Al Zeller (NSCL), Todd Bredeweg, David Vieira (LANL), Francois M. Nortier (LANL/LANSCE), Lawrence Heilbronn (LBNL), Larry Ahle, Jason Boles, Susana Reyes, Werner Stein (LLNL), James R. Beene, Thomas Burgess, Ken Carter, David Conner, Tony Gabriel, Louis Mansur, Igor Remec, Mark Rennich, Dan Stracener, Mark Wendel (ORNL), Pierre Bricault (TRIUMF)*
The Department of Energy's Office of Nuclear Physics, within the Office of Science (SC), has given high priority to consider and analyze design concepts for the target areas for the production of rare isotopes via the ISOL technique at the Rare-Isotope Accelerator (RIA) Facility. Key criteria are the maximum primary beam power of 400 kW, minimizing target change-out time, good radiological protection, flexibility with respect to implementing new target concepts, and the analysis and minimization of hazards associated with the operation of the facility. We will present examples of on-going work on simulations of radiation heating of targets, surrounding components and shielding, component activation, and levels of radiation dose, using the simulation codes MARS, MCNPX, and PHITS. These results are important to make decisions that may have a major impact on the layout, operational efficiency and cost of the facility, hazard analysis, shielding design, civil construction, component design, and material selection, overall layout, and remote handling concepts.

This work is supported in part by Michigan State University, the U.S. Department of Energy, and the National Research Council of Canada.

**RPPT063—Radiation Simulations and Development of Concepts for High Power Beam Dumps, Catchers and Pre-separator Area Layouts for the Fragment Separators for RIA**
*Reginald Ronningen, Valetin Blideanu, Don Lawton, David Morrissey, Bradley Sherrill, Al Zeller (NSCL), Itacil Chiari Gomes, Anthony Levand, Yoichi Momozaki, Jerry Nolen, Claude Reed (ANL), Hans Geissel, Hiroshi Iwase (GSI), Lawrence Heilbronn (LBNL), Larry Ahle, Jason Boles, Susana Reyes, Werner Stein, Mark Stoyer (LLNL), Georg Bollen (MSU), James R. Beene, Thomas Burgess, Ken Carter, David Conner, Tony Gabriel, Louis Mansur, Igor Remec, Mark Rennich, Dan Stracener, Mark Wendel (ORNL)*
The development of high-power beam dumps and catchers, and pre-separator layouts for proposed fragment separators of the Rare-Isotope Accelerator (RIA) facility are important in realizing how to handle the 400 kW in the primary beam. We will present examples of pre-conceptual designs of beam dumps, fragment catchers, and the pre-separator layout. We will also present examples of ongoing work on radiation simulations using the heavy-ion-transport code PHITS, characterizing the secondary radiation produced by the high-power ion beams interacting with these devices. Results on radiation heating of targets, magnet coils, associated hardware and shielding, component activation, and levels of radiation dose will be presented. These initial studies will yield insight into the impact of the high-power dissipation on fragment separator design, remote handling concepts, nuclear safety and potential facility hazard classification, shielding design, civil construction design, component design, and material choices. Furthermore, they will provide guidance on detailed radiation analyses as designs mature.

This work is supported in part by Michigan State University, the U.S. DOE, and the Gesellschaft für Schwerionenforschung, Germany.

**RPPT064—Holifield Radioactive Ion Beam Facility Devel-**

**opment and Status**
*Alan Tatum, James R. Beene (ORNL)*
The Holifield Radioactive Ion Beam Facility (HRIBF) is a national user facility dedicated to nuclear structure, reactions, and nuclear astrophysics research with radioactive ion beams (RIBs) using the isotope separator on-line (ISOL) technique. An integrated strategic plan for physics, experimental systems, and RIB production facilities have been developed and implementation of the plan is under way. Specific research objectives are defined for studying the nature of nucleonic matter, the origin of elements, solar physics, and synthesis of heavy elements. Experimental systems upgrade plans include new detector arrays and beam lines, and expansion and upgrade of existing devices. A multifaceted facility expansion plan includes a $4.75M High Power Target Laboratory (HPTL), presently under construction, to provide a facility for testing new target materials, target geometries, ion sources, and beam preparation techniques. Additional planned upgrades include a second RIB production system (IRIS2), an external axial injection system for the present driver cyclotron, ORIC, and an additional driver accelerator for producing high-intensity neutron-rich beams.

Managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725.

**RPPT065—Beam Loss Estimates and Control for the BNL Neutrino Facility**
*Wu-Tsung Weng, Yong Yung Lee, Deepak Raparia, Nicholaos Tsoupas, Jie Wei, S.Y. Zhang (BNL)*
BNL plans to upgrade the AGS proton beam from the current 0.14 MW to higher than 1.0 MW for a very long baseline neutrino oscillation experiment. This increase in beam power is mainly due to the faster repetition rate of the AGS by a new 1.5 GeV superconductiong linac as injector, replacing the existing booster. The requirement for low beam loss is very important both to protect the beam component, and to make the hands-on maintenance possible. In this report, the design considerations for achieving high intensity and low loss will be presented. We start by specifying the beam loss limit at every physical process followed by the proper design and parameters for realising the required goals. The process considered in this paper include the emittance growth in the linac, the H- injection, the transition crossing, the ecectron cloud effect, the coherent instabilities, and the extraction losses. Collimation and shielding are also presented.

This work is performed under the auspices of the US DOE.

**RPPT066—Electromigration Issues in High Current Horn**
*Wu Zhang, Steven Bellavia, Jon Sandberg, Nikolaos Simos, Joseph Tuozzolo, Wu-Tsung Weng (BNL), Brigitte Hseuh (JHU)*
The secondary particle focusing horn for the AGS neutrino experiment proposal is a high current and high current density device. The peak current of horn is 300 kA. At the smallest area of horn, the current density is near 8 kA/mm2. At very high current density, a few kA/mm2, the electromigration phenomena will occur. Momentum transfer between electrons and metal atoms at high current density causes electromigration. The reliability and lifetime of focusing horn can be severely reduced by electromigration. In this paper, we discuss issues such as device reliability model, incubation time of electromigration, and lifetime of horn.

Work performed under the auspices of the U.S. Department of Energy.

**RPPT067—A High-Power Target Experiment**
*Harold G. Kirk (BNL), Kirk T. McDonald (PU)*
We describe an experiment designed as a proof-of-principle test for a target system capable of converting a 4 MW proton beam into a high-intensity muon beam suitable for incorporation into either a neutrino factory complex or a muon collider. The target system is based on exposing a free mercury jet to an intense proton beam in the presence of a high strength solenoidal field.

U.S. Department of Energy.

**RPPT068—Pion-Muon Concentrating System for Detectors of Highly Enriched Uranium**
*Sergey Kurennoy, Barbara Blind, Filippo Neri, Andrew John Jason (LANL)*
One of many possible applications of low-energy antiprotons collected in a Penning trap can be a portable muon source. Released antiprotons annihilate on impact with normal matter producing on average about 3 charged pions per antiproton, which in turn decay into muons. Existence of such negative-muon sources of sufficient intensity would bring into play, for example, detectors of highly enriched uranium based on muonic X-rays. We explore options of collecting and focusing pions and resulting muons to enhance the muon flux toward the detector. Simulations with MARS and MAFIA are used to choose the target material and parameters of the magnetic system consisting of a few solenoids.

**RPPT069—The Installation Status of the SNS Accumulator Ring**
*Michael Hechler (ORNL/SNS), William J. McGahern (on leave) (BNL)*
The Spallation Neutron Source (SNS) SNS accumulator Ring, when completed in 2006, will be capable of delivering a 1.0 GeV, 1.4 MW proton beam to a liquid mercury target for neutron production. This paper presents an overview of the issues and logistics associated with the preparation and installation of the accumulator Ring. The preparatory activities which occurred at the Brookhaven National Laboratory, vendors and at the SNS will be discussed as well as the installation sequence and procedures.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge.

**RPPT070—Status Report on the Installation of the Warm Sections for the Superconducting Linac at the SNS**
*Roberto Kersevan, Dayrl P. Briggs, Isidoro Enrico Campisi, John A. Crandall, Debra L. Douglas, Ted Hunter, Peter Ladd, Chris Luck, Robert C. Morton, Kathy S. Russell, Daniel Stout (ORNL/SNS)*
The SNS superconducting linac (SCL) consists of 23 cryomodules (CMs), with possibly 9 additional CMs being added for future energy upgrade from 1 GeV to 1.3 GeV. A total of 32 warm sections separate the comparatively short CMs, and this allows a CM exchange within 48 hours, in order to meet demanding beam availability specifications. The 32 warm section chambers are installed between each pair of CMs, with each section containing a quadrupole doublet, beam diagnostics, and pumping. The chambers are approximately 1.6 m long, have one bellow installed at each end for alignment, and are pumped by one ion-pump. The preparation and installation of these chambers must be made under stringent clean and particulate-free conditions, in order to ensure that the performance of the SCL CMs is not compromised. This paper will discuss the development of the cleaning, preparation, and installation

procedures that have been adopted for the warm sections, and the vacuum performance of this system.

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**RPPT071—Installation of the Spallation Neutron Source (SNS) Superconducting Linac**
*Daniel Stout, Isidoro Enrico Campisi, Fabio Casagrande, Roy I. Cutler, Matthew Howell, Ted Hunter, Roberto Kersevan, Peter Ladd, William Strong (ORNL/SNS)*
The Spallation Neutron Source (SNS) cold linac consists of 11 medium beta (0.61) and 12 high beta (0.81) superconducting RF cryomodules, 32 intersegment quadrupole magnet/diagnostics stations, 9 spool beampipes for future upgrade cryomodules, and two differential pumping stations on either side of the linac. The cryomodules and spool beampipes were designed and manufactured by Jefferson Laboratory, and the quadrupole magnets and beam position monitors were designed and furnished by Los Alamos National Laboratory. The remaining items were designed by ORNL. At present we are installing and testing the cold linac. Experience gained during installation will be presented. The performance in terms of mechanical and cryogenic systems will be described.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge.

**RPPT072—Ion Chamber Arrays To Monitor the NuMI Beam Facility at Fermilab**
*Sacha Elmer Kopp, Dharmaraj Indurthy, Ryan Keisler, Zarko Pavlovich, Marek Proga, Robert Miles Zwaska (The University of Texas at Austin), Mary Bishai, Brett Viren (BNL), Debbie Harris (Fermilab), Albert Erwin, Christos Velissaris (UW-Madison/PD)*
The NuMI beamline and the MINOS experiment will study at a long baseline the possible oscillation of muon neutrinos and provide a precision measurement of the oscillation parameters. Neutrinos are produced from charged pion decays, where the pions are produced from interaction of the 120 GeV FNAL Main Injector proton beam with a graphite target. Ion chamber arrays have been built to monitor the resulting muons from pion decays, as well as remnant hadrons at the end of the NuMI decay pipe. The arrays of ion chambers measure both the intensity and lateral profile of the muon and hadron beams, allowing studies of sytematics of the neutrino beam. We will describe the design, construction, and precise calibration of the ion chamber arrays. Initial data from commissioning of the beam line and experience from long-term operations will be presented.

**RPPT073—Design and Expected Performance of the Muon Beamline for the Muon Ionisation Cooling Experiment**
*Kevin Tilley (CCLRC/RAL/ISIS), Thomas Roberts (Muons, Inc), Kenny Andrew Walaron (University of Glasgow)*
It is proposed to install a Muon Ionisation Cooling Experiment (MICE) at the ISIS facility, at Rutherford Appleton Laboratory (RAL). This experiment will be the first demonstration of ionisation cooling as a means to reduce the large transverse emittance of the muon beam, produced during the early stages of a Neutrino Factory. In order to permit a realistic demonstration of cooling, a beam of muons must be produced, possessing particular qualities, notably in emittance and momenta. This paper describes the current design for the muon beamline, outlining issues particular to the needs of the MICE experiment, and discusses its expected performance.

**RPPT074—Beam Characterizations at Femtosecond Electron Beam Facility**
*Sakhorn Rimjaem, Vitoon Jinamoon, Keerati Kusoljariyakul, Jatuporn Saisut, Chitrlada Thongbai, Thiraphat Vilaithong (FNRF), Michael W. Rhodes, Pathom Wichaisirimongkol (IST), Helmut Wiedemann (SLAC)*
The SURIYA project at the Fast Neutron Research Facility (FNRF) has been established and is being commisioning to generate femtosecond electron pulses. Theses short pulses are produced by a system consisting of an S-band thermionic cathode RF-gun, an alpha magnet as a magnetic bunch compressor, and a linear accelerator. The characteristics of its major components and the beam characterizations as well as the preliminary experimental results will be presented and discussed.

We are grateful to the Thailand Research Fund, the National Research Council of Thailand, the Thai Royal Golden Jubilee Scholarship, the U.S. Department of Energy, and the Hansen Experimental Physics laboratory of Stanford University.

**RPPT075—Generation of Femtosecond Electron and Photon Pulses**
*Chitrlada Thongbai, Vitoon Jinamoon, Keerati Kusoljariyakul, Sakhorn Rimjaem, Jatuporn Saisut, Thiraphat Vilaithong (FNRF), Michael W. Rhodes, Pathom Wichaisirimongkol (IST), Helmut Wiedemann (SLAC)*
Femtosecond electron and photon pulses become a tool of interesting important to study dynamics at molecular or atomic levels. Such short pulses can be generated from a system consisting of an RF-gun with a thermionic cathode, an alpha magnet as a magnetic bunch compressor, and a linear accelerator. The femtosecond electron pulses can be used directly or used as sources to produce electromagnetic radiation of equally short pulses by choosing certain kind of radiation pruduction processes. At the Fast Neutron Research Facility (Thailand), we are especially interested in production of radiation in Far-infrared and X-ray regime. In the far-infrared wavelengths which are longer than the femtosecond pulse length, the radiation is emitted coherently producing intense radiation. In the X-ray regime, development of femtosecond X-ray source is crucial for application in ultrafast science.

We are grateful to the Thailand Research Fund, the National Research Council of Thailand, the Thai Royal Golden Jubilee Scholarship, the U.S. Department of Energy, and the Hansen Experimental Physics laboratory of Stanford University.

# Friday, May 20, 2005

Oral Session FOAA–Accelerator Technology
Ballroom A @ 8:30
Chair: J. Kelley (LANL)

**8:30 FOAA001—New Technology in Hydrogen Absorbers for Muon Cooling Channels**
*Mary Anne Clare Cummings (Fermilab)*
Ionization cooling is the only technique fast enough to cool and focus muons for neutrino factories and muon colliders, and hydrogen is the optimal material for maximum cooling and minimal multiple scattering. Liquid hydrogen absorber R & D for the Muon Colloboration has proceeded on parallel and complementary fronts. The continuing LH2 absorber engineering and technical developments by the MuCool group conducted by ICAR* institutions (NIU, IIT and UIUC), the University of Mississippi and Oxford University, in cooperation with Fermilab, will be summarized, including results from the first hydrogen absorber tests at the newly constructed FNAL Mucool Test Area (MTA). The program includes designs for the high-powered test of an absorber prototype (external heat exchange) at the MTA which are nearing completion to be installed by summer 2005, an alternative absorber design (internal heat exchange) being finalized for the approved cooling experiment (MICE) at Rutherford-Appleton Laboratory, and a novel idea for gaseous hydrogen absorbers being developed at Fermilab for a high powered test at the MTA in 2006.
*Illinois Consortium for Accelerator Research.

National Science Foundation.

**8:55 FOAA002—Technological Improvements in the DARHT II Accelerator Cells**
*Benjamin Arnold Prichard (SAIC), Thomas E. Genoni, Thomas P. Hughes (ATK-MR), Juan Barraza, Mike Kang, Kurt Nielsen (LANL), Frank Bieniosek, Ken Chow, William M. Fawley, Lou Reginato, William Waldron (LBNL), Richard J. Briggs (SAIC)*
DARHT employs two perpendicular electron Linear Induction Accelerators to produce intense, bremsstrahlung x-ray pulses for flash radiography. The second axis, DARHT II, features an 18 MeV, 2-kA, 2-microsecond accelerator. DARHT II accelerator cells have undergone a series of test and modeling efforts to fully understand their sub par performance. These R&D efforts have led to a better understanding of Linear Induction Accelerator physics for the unique DARHT II design. Specific improvements have been identified and tested. Improvements in the cell oil region, the cell vacuum region, and the PFNs have been implemented in the prototype units that have doubled the cell's performance. A series of prototype acceptance test are underway on a number of prototype units to demonstrate that the required cell lifetime is met at the improved performance levels. Early acceptance tests indicate that the lifetime requirements are being exceeded. The shortcomings of the previous design are summarized. The improvements to the original design, their resultant improvement in performance, and various test results are included. The final acceptance test results will also be included.

This work was supported by the U.S. National Nuclear Security Agency and the U.S. Department of Energy under contract W-7405-ENG-36.

**9:20 FOAA003—HOM Effects in Vacuum System with Short Bunches**
*Alexander Novokhatski (SLAC)*
High luminosity in electron-positron factories requires high beam currents of very short bunches. SLAC PEP-II and KEKB B-factories are progressively increasing currents and gaining more and more luminosity. Because of this the interaction of high currents and vacuum chamber elements becomes more important for the operation of the rings. High Order Modes (HOM) excited by short intense bunches propagate along the vacuum chamber, penetrating and dissipating inside vital vacuum elements like shielded bellows, vacuum valves and vacuum pumps. As a result these elements can heat up or have temperature oscillations. Often HOM heating has a resonance character. HOM heating of vacuum pumps can lead to vacuum pressure increases. High frequency modes excited by short bunches "check" the quality of the vacuum chamber by detecting small gaps, weak RF screens or weak feed-through. At these high currents even smooth tapers and smooth collimators become a source of HOM production. We will discuss the physical nature of these very interesting HOM effects.

Work supported by Department of Energy contract DE–AC02–76SF00515.

**9:45 FOAA004—TBD**

**10:00 FOAA005—Mechanical Vibration Measurements on TTF Cryomodules**
*Benjamin Arnold Prichard (SAIC), Thomas E. Genoni, Thomas P. Hughes (ATK-MR), Juan Barraza, Mike Kang, Kurt Nielsen (LANL), Frank Bieniosek, Ken Chow, William M. Fawley, Lou Reginato, William Waldron (LBNL), Richard J. Briggs (SAIC)*
Few of the TTF cryomodules have been equipped with Wire Position Monitors (WPM) for the on line monitoring of cold mass movements during cool-down, warm-up and operation. Each sensor can be used as a detector for mechanical vibrations of the cryostat. A Digital Receiver board is used to sample and analyze with high frequency resolution, the WPM picked up signals, looking to its amplitude modulation in the microphonic frequency range. Here we review and analyze the data and the vibration spectra taken during operation of the TTF cryomodules # 4 and #5.

Oral Session FOAB–Application of Accelerators
Ballroom B @ 8:30
Chair: R. Sah (Siemens Medical Solutions, USA)

**8:30 FOAB001—Compact Neutron Generators for Medical, Home Land Security, and Planetary Exploration**
*Jani Reijonen (LBNL/AFR)*
The Plasma and Ion Source Technology Group at Lawrence Berkeley National Laboratory has developed various types of advanced D-D (neutron energy 2.5 MeV), D-T (14 MeV) and T-T (0 – 9 MeV) neutron generators for wide range of applications. These applications include medical (Boron Neutron Capture Therapy), homeland security (Prompt Gamma Activation Analysis, Fast Neutron Activation Analysis and Pulsed Fast Neutron Transmission Spectroscopy) and planetary exploration in form of neutron based, sub-surface hydrogen detection systems. These neutron generators utilize RF induction discharge to ionize the deuterium/tritium gas. This discharge method provides high plasma density for high output current, high atomic species from molecular gases, long life operation and versatility for various discharge chamber geometries. Three main neutron generator developments are discussed here: high

neutron output co-axial neutron generator for BNCT applications, point neutron generator for security applications, compact and sub-compact axial neutron generator for elemental analysis applications. Current status of the neutron generator development with experimental data will be presented.

This work is being support by U.S. Department of Energy under contract No. DE-AC03-76SF00098.

**8:55 FOAB002—Advances in X-Band and S-Band Linear Accelerators for Medical, Security, NDT Applications**
*Andrey Valentinovich Mishin (AS&E)*
At AS&E High Energy Systems Division, we designed several new advanced high energy e-beam and X-ray sources. Our primary focus has always been in building the worlds most portable commercial X-band accelerators. Today, our X-band systems frequently exceed performance of the similar S-band machines, while they are more portable compared to the latter. The new designs of the X-band accelerators in the most practical energy range from 1 MeV to 6 MeV have been tested delivering outstanding results. Sixty 6 MeV X-band linacs have been produced for Cyberknife radiation therapy system by Accuray. The most compact linac for security is used by AS&E in a self-shielded, Shaped Energy cargo screening system. We pioneered using the X-band linear accelerators for CT, producing high quality images of oil pipes and wood logs. An X-band linear accelerator head on a robotic arm has been used for e-beam radiation curing of an odd-shaped graphite composite part. We developed the broad-range 4 MeV to over 10 MeV energy-regulated X-band and S-band systems for medical and NDT applications. The regulated pulse length systems operating in a range from nanoseconds to microseconds have been built both in X-band and in S-band frequency range.

**9:20 FOAB003—Recent Developments in Hadron Therapy Accelerators**
*Hans-Udo Klein (ACCEL)*
In the last decade interest and investments in Hadron Therapy Systems have been steadily increasing resulting in a substantial number of projects currently under construction or entering detailed planning stage. Main routes are pure proton therapy systems and Carbon ion therapy systems which can also run on protons. While the basic accelerator concept for hadron therapy systems is well established there are many considerations on the type and layout of the particle delivery system including the accelerator, an energy selection system, either a fixed beam set up or a rotating gantry, the "nozzle" containing either a scattering or a scanning system, the patient positioner, and all associated control systems. The requirements for the accelerator include most stable beams to match the demand of modern fast scanning systems as well as fast switching between treatment rooms. Currently an ion/proton synchrotron, a pure proton synchrotron, a normalconducting proton cyclotron and a newly developed compact superconducting proton cyclotron are the accelerators of choice for the various hadron therapy systems, which will be analysed and compared in this paper.

**9:45 FOAB004—Construction of FFAG Accelerators in KURRI for ADS Study**
*Minoru Tanigaki, Kaichiro Mishima, Seiji Shiroya (KURRI), Shinji Machida, Yoshiharu Mori (KEK), Shintaro Fukumoto, Yoshihiro Ishi (Mitsubishi Electric Corp), Makoto Inoue (SLLS)*
KART (Kumatori Accelerator driven Reactor Test) project is in progress at Kyoto University Research Reactor Institute (KURRI) from the fiscal year of 2002. The purposes of this project is the feasibility study of ADS, such as studying the effect of incident neutron energy on the effective multiplication factor of the subcritical nuclear fuel system. We are now constructing a proton FFAG accelerator complex as a neutron production driver for this project. Our accelerator complex consists of a 2.5 MeV FFAG with induction acceleration as an injector, 20 MeV and 150 MeV FFAGs with RF acceleration as a booster and a main ring, respectively. Our FFAG injector is a spiral sector type with 32 trim coils to produce a magnetic field of variable field index. Both booster and main rings are the radial sector type in which the field index is determined by the shape of pole-face. The test operations of the injector and the whole FFAG complex are expected around the spring and summer in 2005, respectively. Then this FFAG complex will be combined with our Kyoto University Critical Assembly (KUCA) in KURRI by the end of March 2006 for the feasibility study.

**10:00 FOAB005—Technology for Fissionable Materials Detection by Use of 100 MeV Variable Linac**
*Sergey Petrovich Karasyov, Anatoliy Nikolajevich Dovbnja, Nikolay Mikhajlovich Kiryukhin, Yuriy Petrovich Melnik (NSC/KIPT), Sergiy Viktorovich Trubnikov (KhNU)*
A new concept for a two-step facility to increase the accuracy/reliability of detecting heavily shielded fissionable materials (FM) in marine containers is presented. The facility will detect FM in two steps. An existing dual-view; dual-energy X-ray scanner, which is based on 7 MeV electron accelerator, will select the suspicious places inside container. The linac with variable energy (up to 100 MeV) will be used for the second step. The technology will detect fissionable nuclei by gamma induced fission reactions and delayed neutron registration. A little-known Ukrainian experimental data obtained in Chernobil' clean-up program will be presented to ground proposed concept. The theoretical calculations of neutron fluxes scale these results to marine container size. Modified GEANT code for electron/gamma penetration and authors' own software for neutron yield/penetration are used for these calculations. Available facilities (X-ray scanners; linac; detectors), which will be used for concept proof, are described. The results of the first experiments by use variable energy linac are cited.

This project is funded by CRDF FSTM UKE2-5023-KH-04.

## Oral Session FOAC–Secondary Beam Facilities: Neutrons, Muons, and Neutrinos, Ballroom C @ 8:30
## Chair: C. Moore (FNAL)

**8:30 FOAC001—High Intensity Muon Beam Facilities with FFAG**
*Yoshitaka Kuno (Osaka University)*
A new highly intense muon source with narrow beam energy spread and high purity, based on a FFAG ring, is under development in Japan. It is called the PRISM project, which stands for Phase Rotated Intense Slow Muon source. The aimed beam intensity is about 10^{11}-10^{12} muons per year, which is about 1000 or 1000 times that presently available. The muon beam energy is low, of 20 MeV in kinetic energy, for stopped muon experiments. In particular, high luminosity would be important, and narrow beam spread can be achieved by phase (bunch) rotation in the FFAG ring. It is expected to compress the beam energy spread from about 30% down to about 3 %. At Osaka university, the PRISM-FFAG ring is now under construction. The special requirements for the PRISM-FFAG ring, compared to other FFAG rings so far developed, is to have large acceptance dedicated for a muon beam, and high-gradient RF to complete phase rotation within a muon lifetime. In this presenta-

tion the present designs of PRISM and status of construction will be presented.

**8:55 FOAC002—Status of Neutrino Factory Design and R&D**
*Derun Li (LBNL/AFR)*
Neutrino physics has become increasingly interesting to the high-energy physics community, as it may provide clues to new physics beyond the standard model. The physics potential of a Neutrino Factory—a facility to produce high-energy, high-intensity, high-brightness neutrino beams from decays of muons stored in a muon storage ring—is thus very high. There has been a global R&D effort aimed at a Neutrino Factory design that meets the physics requirements and addresses the key technologies, such as targetry, muon ionization cooling and acceleration. Tremendous progress has been made in the past few years in many aspects of accelerator technology. In this paper, we will review recent worldwide progress toward a cost-effective Neutrino Factory design, with emphasis on the associated R&D programs under the auspices of the U.S. Neutrino Factory and Muon Collider Collaboration.

Work supported by the U.S. Department of Energy under contract No. DE-AC0376SF00098

**9:20 FOAC003—New Concepts in FFAG Design for Secondary Beam Facilities and Other Applications**
*Michael Craddock (UBC & TRIUMF)*
Fixed Field Alternating Gradient accelerators offer much higher acceptances and repetition rates - and therefore higher beam intensities - than synchrotrons, at the cost of more complicated magnet and rf cavity designs. Perhaps because of the difficulty and expense anticipated, early studies never progressed beyond the stage of successful electron models, but in recent years, with improvements in magnet and rf design technology, FFAGs have become the focus of renewed attention. Two proton machines have now been built, and three more, plus a muon phase rotator, are under construction. In addition, more than 20 designs are under study for the acceleration of protons, heavy ions, electrons and muons, with applications as diverse as treating cancer, irradiating materials, driving subcritical reactors, boosting high-energy proton intensity, and producing neutrinos. Moreover, it has become apparent that FFAG designs need not be restricted to the traditional 'scaling' approach, in which the orbit shape, optics and tunes are kept fixed. Dropping this restriction has revealed a range of interesting new design possibilities. This paper will review the various approaches being taken.

**9:45 FOAC004—Status of the NuMI Neutrino Beam Facility at Fermilab**
*Sacha Elmer Kopp (Univ. of Texas at Austin)*
The Neutrinos at the Main Injector (NuMI) is a conventional neutrino beam facility which will use the intense 120 GeV proton beam from the Fermilab Main Injector accelerator. The facility is envisaged to service a variety experiments, in particular the already-constructed MINOS long baseline oscillation experiment, and the proposed NOvA experiment to observe muon neutrino to electron neutrino oscillations. Summarized will be the design of the primary and secondary beam focusing systems, instrumentation to validate the neutrino beam intensity, direction, and energy spectrum, and considerations for coping with the 0.4 MWatt MI beam. The beam line will be commissioned December, 2004, through February, 2005, whereupon operations may begin. Data from the commissioning and experience from first operations will be presented. Further, the suitability of the facility for accepting beam from a proposed 2MW proton driver is discussed.

**10:00 FOAC005—Reliability and Availability Studies in the RIA Linac Driver**
*Eliane Schnirman Lessner, Peter Ostroumov (ANL)*
The RIA facility will include various complex systems and must provide radioactive beams to many users simultaneously. The availability of radioactive beams for most experiments at the fully-commissioned facility should be as high as possible within design cost limitations. To make a realistic estimate of the achievable reliability a detailed analysis is required. The RIA driver linac is a complex machine containing a large number of SC resonators and capable of accelerating multiple-charge-state beams. At the pre-CDR stage of the design it is essential to identify critical facility subsystem failures that can prevent the driver linac from operating. The reliability and availability of the driver linac are studied using expert information and data from operating machines such as ATLAS, APS, JLab, and LANL. Availability studies are performed with a Monte-Carlo simulation code previously applied to availability assessments of the NLC facility [http://www.slac.stanford.edu/xorg/accelops/Full/LC_opts_full] and the results used to identify subsystem failures that affect most the availability and reliability of the RIA driver, and guide design iterations and component specifications to address identified problems.
*J.A. Nolen, Nucl. Phys. A. 734 (2004) 661.

Work supported by the U.S. Department of Energy under contract W-31-109-ENG-38.

**Oral Session FOAA (Cont.)—Accelerator Technology**
**Ballroom A @ 10:40**
**Chair: W. Oren (JLab)**

**10:40 FOAA006—Digital Low-Level RF Controls for Future Superconducting Linear Colliders**
*Stefan Simrock (DESY)*
The requirements for RF Control Systems of Superconducting Linear Colliders are not only defined in terms of the quality of field control but also with respect to operability, availability, and maintainability of the RF System, and the interfaces to other subsystems. The field control of the vector-sum of many cavities driven by one klystron in pulsed mode at high gradients is a challenging task since severe Lorentz force detuning, microphonics and beam induced field errors must be suppressed by several orders of magnitude. This is accomplished by a combination of local and global feedback and feedforward control. Sensors monitor individual cavity probe signals, and forward and reflected wave as well as the beam properties including beam energy and phase while actuators control the incident wave of the klystron and individual cavity resonance frequencies. The operability of a large llrf system requires a high degree of automation while the high availability requires robust algorithms, redundancy, and extremely reliable hardware. The maintenance of the llrf demands sophisticated on-line diagnostics for the llrf subsystems to minimize downtime.

**11:05 FOAA007—Cryomodule Design Concepts and Operating Experience**
*Claus Rode, Joseph P. Preble (Jefferson Lab)*
Design concepts and operating experience of SRF cryostats will be discussed.

This work was supported by the U.S. Department of Energy under contract #DE-ACO-584ER40150.

**11:30 FOAA008—Superconducting RF Development at Nuclear Science Centre**
*Amit Roy (NSC)*
A Superconducting Linac is being installed as a booster for the 15 UD Pelletron accelerator at Nuclear Science Centre (NSC). The accelerating structure for this linac is a Nb QWR cavity, designed and fabricated as a joint collaboration between NSC and ANL, USA. Initial cavities required for the first linac module were fabricated at ANL. For fabrication of cavities required for future modules a Superconducting Resonator Fabrication Facility has been set up at NSC. Three quarter wave resonator (QWR) cavities have been fabricated using the in-house facility. This facility has been used for repairs on the resonators which sprung leaks. Fabrication of fifteen resonators for the second and third linac modules is under progress. Eight resonators along with a superconducting solenoid has been installed in the first linac cryostat and tested for energy gain with a pulsed beam of 90 MeV Si from the Pelletron. Acceleration of the ions to 96 MeV was measured downstream and beam transmission through the linac was measured to be ~ 100%.

Nuclear Science Centre, New Delhi, India.

**11:55 FOAA009—SRF Performance of CEBAF After Thermal Cycle to Ambient Temperature**
*Robert Rimmer, Jay Benesch, Joseph P. Preble, Charles E. Reece (Jefferson Lab)*
In September 2003, in the wake of Hurricane Isabel, JLab was without power for four days after a tree fell on the main power lines feeding the site. This was long enough to lose insulating vacuum in the cryomodules and cryogenic systems resulting in the whole accelerator warming up and the total loss of the liquid helium inventory. This thermal cycle stressed many of the cryomodule components causing several cavities to become inoperable due to helium to vacuum leaks. At the same time the thermal cycle released years of adsorbed gas from the cold surfaces. Over the next days and weeks this gas was pumped away, the insulating vacuum was restored and the machine was cooled back down and re-commissioned. In a testament to the robustness of SRF technology, only a small loss in energy capability was apparent, although individual cavities had quite different field-emission characteristics compared to before the event. In Summer 2004 a section of the machine was again cycled to room temperature during the long maintenance shutdown. We report on the overall SRF performance of the machine after these major disturbances and on efforts to characterize and optimize the new behavior for high-energy running.

This manuscript has been authored by SURA, Inc. under Contract No. DE-AC05-84ER-40150 with the U.S. Department of Energy.

**12:10 FOAA010—Full Characterization at Low Temperature of Piezoelectric Actuators Used for SRF Cavities Active Tuning**
*Mohammed Fouaidy, Sebastien Blivet, Nourredine Hammoudi, Guillaume Martinet (IPN)*
In the frame of the CARE project (EU funding), IPN Orsay participate to the development of fast cold tuning system for Superconducting RF cavities. The puprpose is the characterization of piezoelectric actuators at low temperature. A new experimental facility was developed for testing various prototypes piezoelectric actuators and successfully operated for T in the range 1.8 K-300 K. Different parameters were measured: piezoelectric actuator displacement vs. voltage V and T, dielectric properties vs. T, thermal properties, and finally heating due to dielectric losses vs. modulating voltage and frequency as function of T. The experimental data show that the full range displacement of the actuator decreases with T reaching a value between 1.8 μm and 4 μm depending on material and fabrication process. Note that both these parameters (material and process) have a strong influence on displacement vs. T dependence. Moreover, the variations of losses tangent with temperature show a maximum at a T in the range 30 K-120 K. Finally a dedicated facility located at CERI (France) for radiation hardness tests of piezo-element with fast neutrons at T=4.2 K is under preparation and the first beam tests are scheduled for mid-February 2005.

EU, CNRS-IN2P3.

**Oral Session FOAB (Cont.)—Application of Accelerators**
**Ballroom B @ 10:40**
**Chair: A. Todd (AES)**

**10:40 FOAB006—Industrial Applications of High Average Power FELS**
*Michelle Diane Shinn (Jefferson Lab)*
The use of lasers for material processing continues to expand, and the annual sales of such lasers exceeds $1 B (US). Large scale (many m2) processing of materials require the economical production of laser powers of the tens of kilowatts, and therefore are not yet commercial processes, although they have been demonstrated. The development of FELs based on superconducting RF (SRF) linac technology provides a scaleable path to laser outputs above 50 kW in the IR, rendering these applications economically viable, since the cost/photon drops as the output power increases. This approach also enables high average power ~ 1 kW output in the UV spectrum. Such FELs will provide quasi-cw (PRFs in the tens of MHz), of ultrafast (pulsewidth ~ 1 ps) output with very high beam quality. This talk will provide an overview of applications tests by our facility's users such as pulsed laser deposition, laser ablation, and laser surface modification, as well as present plans that will be tested with our upgraded FELs. These upgrades will extend operation beyond 10 kW average power in the IR and kilowatt levels of power at wavelengths from 0.3 to 14 microns.

This work supported by the Office of Naval Research, NAVSEA PMS-405, the Joint Technology Office, the Air Force Research Laboratory, the U.S. Night Vision Laboratory, the Commonwealth of Virginia, and by DOE Contract DE-AC05-84ER40150.

**11:05 FOAB007—The Compact Light Source: A Miniature Synchrotron Light Source**
*Ronald Ruth (Lyncean Technologies, Inc.)*
During the past 30 years, synchrotron light sources have become the x-ray probe of choice for physicists, chemists, biologists and research physicians. With their high-quality, intense x-ray beams, these national research facilities have spawned a broad array of applications. Past research at Stanford Linear Accelerator Center has led to a new x-ray source concept that can substantially reduce the size of the required synchrotron.* This research has spawned a new corporation, Lyncean Technologies, Inc. which is now developing the Compact Light Source (CLS). The CLS is a tunable, homelab x-ray source with up to three beamlines that can be used like the x-ray beamlines at the synchrotrons—but it is about 200 times smaller than a synchrotron light source. The compact size is achieved using a laser undulator and a miniature electron-beam storage ring. The photon flux on a sample will be comparable to the flux of highly

productive synchrotron beamlines. At Lyncean Technologies, Inc. we have constructed a prototype of this source with funding from the NIGMS Protein Structure Initiative. I will report on commissioning progress and long-term outlook for the Compact Light Source.
*Z.Huang and R.D. Ruth, "Laser-Electron Storage Ring," Phys. Rev. Lett., 80:976-979, 1998.

Supported by the National Institute of General Medical Sciences, the National Insitutes of Health, R44 GM665011.

**11:30 FOAB008—Muon Radiography**
*Christopher Morris (LANL)*
The interaction of muons with matter is dominated by the Coulomb interaction. The Coulomb interaction can be factored into the interaction with electrons which results in continuous energy loss and eventual stopping of the charged particle with very small changes in the direction while the interaction with the atomic nuclei results in relatively larger angle changes with only small changes in the energy. Each if these interactions provides a radiographic signal which can be used to study the internal structure of objects. These radiographies will be contrasted with each other, and some data obtained with cosmic ray muons will be presented.*
*Borozdin, K.N., Hogan, G.E., Morris, C., Priedhorsky, W.C., Saunders, A., Schultz, L.J., Teasdale, M.E., "Surveillance: Radiographic Imaging with Cosmic-Ray Muons," Nature, Mar 20, 2003, v. 422, no. 6929, p. 277.

U.S. DOE.

**11:55 FOAB009—The Frankfurt Funneling Experiment**
*Jan Thibus, Ulrich Bartz, Norbert Mueller, Alwin Schempp, Holger Zimmermann (IAP)*
Funneling is a technique to multiply beam currents of rf-accelerators in several stages at low energies to prevent problems with space charge. The Frankfurt Funneling Experiment is a prototype of such a stage. Two beams accelerated in a Two-Beam RFQ are combined to one beam axis with a funneling deflector. The last part of the RFQ electrodes of our Two-Beam RFQ has been replaced to achieve a 3d focus of both beams at the beam crossing point behind the RFQ in the center of the deflector. A newly designed multi cell funneling deflector and first results of the new experimental set-up will be presented.

BMBF

**12:10 FOAB010—Present Status of Photo-Cathode RF Gun System and Its Applications**
*Ryunosuke Kuroda, Yoshimasa Hama, Kentaro Hidume, Masaaki Kawaguchi, Ryo Moriyama, Taku Saito, Kazuyuki Sakaue, Masakazu Washio (RISE), Shigeru Kashiwagi (ISIR), Hitoshi Hayano, Junji Urakawa (KEK)*
High quality electron beam generation using photo-cathode rf gun system and its applications have been developed at Waseda University. This system can generate up to 4.6 MeV low emittance electron beam. It is applied for soft X-ray generation using laser Compton scattering and pulse radiolysis experiments based on the pump-probe technique. In the former, Compton scattering experiments between about 4.6 MeV electron beam and 1047 nm laser beam is performed at 20 degrees interaction angle, so that about 370 eV soft X-ray is generated. In the latter, the electron beam is used for the pump beam and the probe beam is generated as white light by concentrating laser beam on the water cell, so that the measurement with about 30 ps (FWHM) time resolution of the pulse radiolysis system is demonstrated for the absorption of hydrated electrons. In this conference, we will present the experimental results, status of this system and future applications.

## Oral Session FOAD—Extreme Beams
## Ballroom C @ 10:40
## Chair: I. Ben-Zvi (BNL)

**10:40 FOAD001—Frozen Beams**
*Hiromi Okamoto (HU/AdSM)*
In general, the temperature of a charged particle beam traveling in an accelerator is very high. Seen from the rest frame of the beam, individual particles randomly oscillate about the reference orbit at high speed. This internal kinetic energy can, however, be removed by introducing dissipative interactions into the system. As a dissipative process advances, the beam becomes denser in phase space or, in other words, the emittance is more diminished. Ideally, it is possible to reach a "zero-emittance" state where the beam is Coulomb crystallized. The space-charge repulsion of a crystalline beam just balances the external restoring force provided by artificial electromagnetic elements. In this talk, general discussion is made of coasting and bunched crystalline beams circulating in a storage ring. Results of molecular dynamics simulations are presented to demonstrate the dynamic nature of various crystalline states. A possible method to approach such an ultimate state of matter is also discussed.

**11:05 FOAD002—Ultra-High Density Electron Beams for Beam Radiation and Beam Plasma Interaction**
*Scott Anderson, Winthrop Brown, David Jeremy Gibson, Fred V. Hartemann, Jeremy Scott Jacob, Aaron Matthew Tremaine (LLNL), Pietro Musumeci (INFN-Roma), Pedro Frigola, Jae Lim, James Rosenzweig, Gil Travish (UCLA)*
Current and future applications of high brightness electron beams, which include advanced accelerators such as the plasma wake-field accelerator (PWFA) and beam-radiation interactions such as inverse-Compton scattering (ICS), require both transverse and longitudinal beam sizes on the order of tens of microns. Ultra-high density beams may be produced at moderate energy (50 MeV) by compression and subsequent strong focusing of low emittance, photoinjector sources. We describe the implementation of this method used at LLNL's PLEIADES ICS x-ray source in which the photoinjector-generated beam has been compressed to 300 fsec duration using the velocity bunching technique and focused to 20 μm rms size using an extremely high gradient, permanent magnet quadrupole (PMQ) focusing system.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

**11:30 FOAD003—Laboratory Astrophysics Using High Energy Density Photon and Electron Beams**
*Robert Bingham (CCLRC/RAL/ASTeC)*
The development of intense laser and particle beams has opened up new opportunities to study high energy density astrophysical processes in the Laboratory. With even higher laser intensities possible in the near future vacuum polarization processes such as photon – photon scattering with or without large magnetic fields may also be experimentally observed. In this talk I will review the status of laboratory experiments using intense beans

to investigate extreme astrophysical phenomena such as supernovae explosions, gamma x-ray bursts, ultra-high energy cosmic accelerators etc. Just as intense photon or electron beams can excite relativistic electron plasma waves or wakefields used in plasma acceleration, intense neutrino beams from type II supernovae can also excite wakefields or plasma waves. Other instabilities driven by intense beams relevant to perhaps x-ray bursts is the Weibel instability. Simulation results of extreme processes will also be presented.

Centre for Fundamental Physics, Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX.

**11:55 FOAD004—Laser Cooling of Relativistic Heavy Ion Beams**

*Ulrich Schramm, Michael Bussmann, Dietrich Habs (LMU), Karl Beckert, Peter Beller, Bernhard Franzke, Fritz Nolden, Markus Steck (GSI), Sergej Karpuk (Johannes Gutenberg University Mainz), Sascha Reinhardt, Guido Saathoff (MPI-K)*

We report on the first laser cooling of a bunched beam of multiply charged C3+ ions performed at the ESR (GSI) at a beam energy of E=1.47GeV. Moderate bunching provided a force counteracting the decelerating laser force of one counterpropagating UV laser beam. This versatile type of laser cooling lead to longitudinally space-charge dominated beams with an unprecedented relative momentum spread of 10-7. Concerning the beam energy and charge state of the ion, the experiment depicts an important intermediate step from the established field of laser cooling of ion beams at low energies toward the laser cooling scheme proposed for relativistic beams of highly charged heavy ions at the future GSI facility FAIR.

Partially funded by the german BMBF (06ML183).

**12:10 FOAD005—Commissioning of the University of Maryland Electron Ring (UMER)**

*Santiago Bernal, Gang Bai, Donald Feldman, Terry Godlove, Irving Haber, Mike Holloway, Rami Alfred Kishek, Jonathan Gary Neumann, Patrick G. O'Shea, Bryan Quinn, Kai Tian, Jayakar Charles Tobin Thangaraj, Mark Walter (IREAP), Martin Reiser (University Maryland), Renee Feldman, John R. Harris (University of Maryland)*

The University of Maryland electron ring (UMER) is a low-energy, high current recirculator for beam physics research. The ring is completed for multi-turn operation of beams over a broad range of intensities and initial conditions. UMER is addressing issues in beam physics with relevance to many applications that rely on intense beams of high quality. Examples are advanced accelerators, FEL's, spallation neutron sources and future heavy-ion drivers for inertial fusion. We review the motivation, ring layout and operating conditions of UMER. Further, we present a summary of beam physics areas that UMER is currently investigating and others that are part of the commissioning plan: from transverse beam dynamics (matching, halo formation, strongly asymmetric beams, space-charge waves, etc), longitudinal dynamics (bunch capture/shaping, evolution of energy spread, longitudinal space-charge waves, etc.) to future upgrades and planned research (acceleration and resonance traversal, modeling of galactic dynamics, etc.) We also emphasize the computer simulation work that is an integral part of the UMER project.

This work is funded by the U.S. Department of Energy under grants DE-FG02-94ER40855 and DE-FG02-92ER54178, and the office of Naval Research under grant N00014-02-1-0914.

**Poster Session FPAE—Low- and Medium-Energy Accelerators and Rings**
**Ballroom E, 8:30-12:20**

**FPAE001—Design Work for the High-Energy Storage Ring for Antiprotons of the Future GSI Project**

*Andreas Lehrach, Klaus Bongardt, Ralf Eichhorn, Rudolf Maier, Siegfried Martin, Dieter Prasuhn, Yurij Senichev, Hans Stockhorst, Raimund Tölle, Evgeny Zaplatin (FZJ/IKP), Markus Steck (GSI), Dag Reistad (TSL)*

The High-Energy Storage Ring (HESR) of the future international Facility for Antiproton and Ion Research (FAIR) at GSI in Darmstadt is planned as an antiproton cooler and storage ring in the momentum range from 1.5 to 15 GeV/c. The design work for the HESR is organized by a consortium with scientists from FZ Jülich, GSI Darmstadt and TSL Uppsala. An important feature of the new facility is the combination of phase space cooled beams with internal targets, resulting in demanding beam parameter in two operation modes: high luminosity mode with beam intensities up to few times 10^11, and high resolution mode with a momentum spread down to 10^-5, respectively. To reach these beam parameters very powerful phase space cooling is needed, utilizing high-energy electron cooling and high-bandwidth stochastic cooling. In this paper an overview of the design work is given, focusing on recent developments and planned R&D work.

**FPAE002—Design of Injection and Extraction Systems of the 3-GeV Rapid Cycle Synchrotron in the J-PARC**

*Taihei Shimada, Seiji Hiroki, Yoshiro Irie, Junichiro Kamiya, Michikazu Kinsho, Fumiaki Noda, Tomohiro Takayanagi, Yuzou Teruyama, Masao Watanabe (JAERI/J-PARC), Yoshio Arakida, Tadamichi Kawakubo, Izumi Sakai (KEK)*

Injection and Extraction Systems of the 3-GeV Rapid Cycle Synchrotron(RCS) in the J-PARC are designing and constructing.The 400-MeV H-beam from the LINAC is injected into the RCS via charge exchange process and phase space painting process. The painting emittance is 216 pi mm mrad. The injection system consists of six DC-septum magnets, ten pulse bump magnets, three foils for charge exchange system and beam monitor system.The beam accelerated to 3-GeV, 1MW is extracted from the RCS via one-turn process. The extraction system is consists of 8 kicker magnets and three DC-septum magnets.These systems are designed with an emphasis on following points:1) a large aperture to allow the high intensity beam pass through with a low beam loss (less than 0.1%).2) protection against the high radiation (100MGy).3) high durability to avoid maintenance after high activation.

**FPAE003—Status of the Rapid Cycling Synchrotron for J-PARC**

*Hiromitu Suzuki (JAERI/J-PARC)*

The rapid cyclimg synchrotron of the J-PARC project accelerates a 400-MeV proton beam from the linac up to 3 GeV and supplies the beam to the main ring and the Material and Life science Facility(MLF). The MLF has a neutron production target in order to produce a high intensity neutron beam. For this purpose, the RCS aims to generate a high power proton beam of 1 MW. The construction of the RCS started in 2002 and will be finished in 2007. The building will be accomplished by April 2005. The machine Installation will be started in August 2005. I will report the status of the RCS building and the machines.

Japan Atomic Energy Research Institute.

**FPAE004—Optical Matching of Slowly Extracted Beam with Transport System at HIMAC**
*Takuji Furukawa, Takuya Naruse, Koji Noda, Masami Torikoshi, Takehiro Uesugi (NIRS), Tetsuya Fujimoto, Shinji Shibuya (AEC)*
The optical matching between the ring and the transport line plays important role in order to control the beam size and profile after the transport. At HIMAC, thus, we have studied the optical matching of the slowly extracted beam. As a result, it was verified that the beam size of the slowly extracted beam were controlled owing to the optical matching. It was also found that small deviation of quadrupole strength in the ring brings orbit distortion at the transport system.

**FPAE005—Characteristics of Injected Beam at HIMAC Synchrotron**
*Takehiro Uesugi, Takuji Furukawa, Koji Noda (NIRS), Takuya Naruse (Seikei University)*
At the HIMAC synchrotron, we have carried out the tune survey with the lifetime measurement in order to obtain the high intensity. Under the relatively high intensity, it was observed that a part of the circulating beam was lost due to the coherent oscillation in both the horizontal and the vertical direction. Taking account of the tune shift and spreads, the working point was optimized so as to avoid resonance line. We will describe the experimental result.

**FPAE006—Optimization of AGS Polarized Proton Operation with the Warm Helical Snake**
*Junpei Takano, Masahiro Okamura (RIKEN), Leif Ahrens, Mei Bai, Joseph Glenn, Haixin Huang, Alfredo U. Luccio, William W. MacKay, Thomas Roser (BNL), Toshiyuki Hattori (RLNR)*
A normal conducting helical dipole partial Siberian snake (Warm Snake) has been installed in the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory (BNL) for overcoming all of imperfection depolarizing resonances and reducing the transverse coupling resonances caused by the solenoidal Siberian snake which had been operated in AGS before the last polarized run. The polarized proton beam has been accelerated successfully with the warm snake and the polarization at extraction of the AGS was increased to 50% as opposed to 40% with the solenoidal snake. The magnetic field and beam trajectory in the warm snake was calculated by using the OPERA-3D/TOSCA software. We present optimization of the warm snake with beam during RUN5.

U.S. DOE and RIKEN Japan.

**FPAE007—A Project of the 2.5 GeV Booster-Synchrotron in BINP**
*Vasily Kvardakov, V. Barbashin, Vladimir Kiselev, Elena Kremyanskaya, Evgeny Levichev, Svyatoslav Mishnev, Victor Petrov, Alexander Skrinsky, Victor Smaluk, Ilya Zemlyansky (BINP SB RAS)*
A project of the 2.5 GeV booster synchrotron to provide effective injection of electron and positron beams into VEPP-2000 and VEPP-4M storage rings, and for future facilities, is developing in BINP. The beams are injected to synchrotron at 510 MeV energy from a damping ring, which is the part of the new injection facility. In this report, the synchrotron parameters are presented, the basic systems are briefly described.

**FPAE008—Iso-Adiabatic Merging of Two pbar Stacks in the Recycler: Simulations and Beam Studies**
*Chandra Bhat (Fermilab)*
Here, I have proposed an efficient scheme to merge two stacks of pbars in the Recycler* with emittance dilution <15%. First I discuss a method to match energy spreads of the two stacks and subsequently merging them. The scheme is illustrated with multiparticle dynamics simulations and beam measurements in the Recycler.
*G. Jackson, Fermilab-TM-1991, November, 1996.

Work supported by the Universities Research Association, Inc., under contract DE-AC02-76CH03000 with the U.S. Department of Energy.

**FPAE009—Bunched Beam Cooling in the Fermilab Recycler**
*David Neuffer, Daniel Robert Broemmelsiek, Alexey Burov, Sergei Nagaitsev (Fermilab)*
Stochastic cooling with bunched beam in a linear bucket has been obtained and implemented operationally in the fermilab recycler. In this implementation the particle bunch length is much greater than the cooling system wavelengths. The simultaneous longitudinal bunching enables cooling to much smaller longitudinal emittances than the coasting beam or barrier bucket system. Characteristics and limitations of bunched beam stochastic cooling are discussed.

**FPAE010—Beam Stacking in the Main Injector Using Barrier RF**
*Weiren Chou, David Wildman (Fermilab), Hai Zheng (CALTECH), Akira Takagi (KEK)*
A wideband RF system (the barrier RF) has been built and installed in the Fermilab Main Injector. The cavities are made of low Q Finemet cores. The modulators use high voltage fast solid-state switches. It can generate +-7 kV single square voltage pulses. It is used to stack two proton batches to double the bunch intensity for pbar production. The stacked high intensity beams have been successfully accelerated to 120 GeV with small losses. A new test to continuously stack 12 batches for the NuMI experiment is under way.

Work supported by the Universities Research Association, INC. under contract with the U.S. Department of Energy NO. DE-AC02-76CH03000 and by the US-Japan Collaboration in High Energy Physics.

**FPAE011—8 GeV H- Ions—Transport, Stripping and Injection**
*Weiren Chou, Alexandr I. Drozhdin, Chris Hill, Mikhail A. Kostin, Jean-Francois Ostiguy, Zhijing Tang (Fermilab), Grahame Rees (CCLRC/RAL/ASTeC), Robert James Macek (LANL/LANSCE), Phil Sung Yoon (Rochester University), Howard C. Bryant (UNM)*
Fermilab is working on the design of an 8 GeV superconducting RF H- linac called the Proton Driver. The energy of the H- beam is an order of magnitude higher than any existing H- beams. This brings up a number of new challenges to the transport, stripping and injection into the next machine (the Main Injector), such as blackbody radiation stripping, magnetic field and residual gas stripping, Stark states of hydrogen atoms, foil stripping efficiency, single and multiple Coulomb scattering, energy deposition, foil heating and stress, radiation activation, collimation, jitter correction, etc. This paper will give a summary of these studies.*
*For details the reader is referred to FERMILAB-TM-2285-AD-T.

Work supported by the Universities Research Association, INC. under contract with the U.S. Department of Energy NO. DE-AC02-76CH03000.

**FPAE012—Experimental Test of a New Antiproton Acceleration Scheme in the Fermilab Main Injector**
*Vincent Wu, Chandra Bhat, Brian Chase, Joseph Dey, Keith G. Meisner (Fermilab)*
In an effort to provide higher intensity and lower emittance antiproton beam to the Tevatron collider for high luminosity operation, a new Main Injector antiproton acceleration scheme has been developed.* In this scheme, beam is accelerated from 8 to 27 GeV using the 2.5 MHz rf system and from 27 to 150 GeV using the 53 MHz rf system. This paper reports the experimental results of beam study. Simulation results are reported in a different PAC'05 paper. Experiments are conducted with proton beam from the Booster to study acceleration efficiency, emittance growth and beam harmonic transfer between 2.5 MHz and 53 MHz buckets. Beam study shows that the overall acceleration efficiency is in the range of 90-100%, the transverse emittance growth is negligible, and the longitudinal emittance growth is less than 20%.
*G. P. Jackson, The Fermilab Recycler Ring Technical Design Report, FERMILAB-TM-1991, November 1996.

Operated by Universities Research Association, Inc. for the U.S. Department of Energy under contract DE-AC02-76CH03000.

**FPAE013—The Calculation of Orbit Length Change of the Recycler Due to Main Injector Ramp**
*Meiqin Xiao (Fermilab)*
Orbit length of beam in the Recycler changes during the Main Injector ramps. The unknown kicks from the effects generated by stray field are distributed around the ring. To estimate the changes, simulated virtual kicks are created around each lambson, C-magnet and bus cable of the Main Injector. The orbit lengths are calculated from measurements of evolution frequency and transverse beam positions. A BPM system distributed throughout the Recycler lattice in both Horizontal and vertical planes are used to take the closed orbit measurement during the ramps. The calculation method and the results of the orbit length changes and the strength of the simulated kicks are presented in this report.

**FPAE014—Acceleration of Polarized Protons in the AGS with Two Helical Partial Snakes**
*Haixin Huang, Leif Ahrens, Mei Bai, Alexendro Bravar, Kevin A. Brown, Gerry Bunce, Ernest D. Courant, Chris J. Gardner, Joseph Glenn, Ramesh C. Gupta, Alfredo U. Luccio, William W. MacKay, Christoph Montag, Jinnouchi Osamu, Vadim Ptitsyn, Thomas Roser, Steven Tepikian, Nicholaos Tsoupas, Erich Willen, Anatoli Zelenski, Keith Zeno (BNL), Hal Spinka, David Underwood (ANL), Igor Gennadievich Alekseev, Dima Svirida (ITEP), Junpei Takano (RIKEN), Masahiro Okamura (RIKEN/RARF/CC), Jeff Wood (UCLA)*
The RHIC spin program requires 2*10^11 proton/bunch with 70% polarization. As the injector to RHIC, AGS is the bottleneck for preserving polarization: there is not enough space in the ring to install a full snake to overcome the numerous depolarizing resonances. An ac dipole and a partial Siberian snake have been used to preserve beam polarization in the past. The correction with this scheme is not 100% since not all depolarizing resonances can be overcome. Recently, two helical snakes with double pitch design have been built and installed in the AGS. With careful setup of optics at injection and along the ramp, this combination can eliminate all depolarizing resonances encountered during acceleration. This paper presents the accelerator setup and preliminary results.

Work supported by U.S. DOE and RIKEN of Japan.

**FPAE015—CW Mode of Operation of a Proton FFAG Accelerator**
*Alessandro Ruggiero (BNL)*
Fixed-Field Alternating-Gradient (FFAG) Proton Accelerators can be operated in a pulsed mode. The largest repetition rate that it is found to be feasible is about 1 kHz*. This mode of operation allows only a duty cycle of no more than 0.1%. But many applications require higher duty cycle and possibly a Continuous Wave (CW) mode of operation. In the case of protons, because of the considerable variation of beam velocity during acceleration, it is difficult to satisfy isochronous conditions. As alternative we have investigated a method based on the Harmonic Jump from one orbit to the next, by using a constant frequency accelerating RF cavity system, and a prescribed voltage program that causes variation of the revolution period from one revolution to the next allowing phase synchronization of the beam motion with the RF cavities.
*A.G. Ruggiero, "A 1-GeV 10-MWatt Proton Driver," Invited talk to ICFA-HB2004, October 18-22, 2004, Bensheim, Germany.

Work performed under the auspices of the U.S. Department of Energy.

**FPAE016—A Summary on the Construction of the Spallation Neutron Source Ring**
*Jie Wei (BNL)*
(J. Wei for the Spallation Neutron Source Collaboration) After six years, the construction of the Spallation Neutron Source (SNS) accumulator ring* and the transport lines is completed in March 2005. Designed to deliver 1.5 MW beam power (1.5 x 10^14 protons of 1 GeV kinetic energy at a repetition rate of 60 Hz), stringent measures have been implemented in the fabrication, test, and assembly to ensure the quality of the accelerator systems. This paper summarizes the construction of the ring and transport systems with emphasis on the challenging technical issues and their solutions.**
*J. Wei, et al, Phys. Rev. ST-AB, Vol. 3, 080101 (2000). **J. Wei, "Synchrotrons and Accumulators for High-Intensity Proton Beams", Rev. Mod. Phys., Vol. 75, 1383 — 1432 (2003).

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**FPAE017—Observation of Longitudinal Diffusion Due to Intra-Beam Scattering at the Fermilab Recycler Ring**
*Martin Hu, Sergei Nagaitsev (Fermilab)*
The Fermilab Recycler Ring is a high vacuum fixed energy antiproton storage ring with both stochastic and electron cooling systems. In this note the technique for diffusion rate measurement, beam parameters and the analysis of data are presented, as well as the effect of intra-beam scattering on the operational considerations for the storage and cooling of the antiproton beam in the Recycler.

**FPAE018—Performance of the Fermilab Booster Synchrotron with a New Extraction System**
*James Lackey, Weiren Chou, Alexandr I. Drozhdin, William Pellico, Eric Prebys (Fermilab)*
Modeling of the Fermilab Booster Synchrotron identified edge focusing in dipoles of the orbit bumps around the extraction septum magnets as a major source of lattice perturbations. After considering a number of more difficult solutions, it was realized that a relatively minor reconfiguration of the extraction channels, made possible by the increased strength of new septum magnets, would allow the bends to be gentler and reduce the

edge focusing dramatically. One extraction point was modified in 2003 and the other in 2004. Each change produced significant improvements in the intensity achievable in the Booster.

Work supported by the U.S. Department of Energy under Contract No. DE-AC02-76CH03000.

**FPAE019—Booster 6-GeV Study**

*Xi Yang, Charles Ankenbrandt, James Lackey, William Pellico (Fermilab)*

Since a wider aperture has been obtained along the Fermilab Booster beam line, this opens the opportunity for Booster running a higher intensity proton beam than ever before. Sooner or later, the available RF accelerating voltage will become a new limit for the beam intensity. Either by increasing the RF accelerating voltage or by reducing the accelerating rate can achieve the similar goal. The motivation for the 6-GeV study is to gain the relative accelerating voltage via a slower acceleration.

Fermi National Accelerator Laboratory, Accelerator Division, Proton Source Department.

**FPAE020—Induction Acceleration of a Single RF Bunch in the KEK PS**

*Ken Takayama, Dai Arakawa, Yoshio Arakida, Susumu Igarashi, Taiki Iwashita, Tadaaki Kono, Eiji Nakamura, Makoto Sakuda, Hikaru Sato, Yoshito Shimosaki, Masashi Shirakata, Tsuyoshi Sueno, Kota Torikai, Takeshi Toyama, Masayoshi Wake, Isao Yamane (KEK), Kunio Koseki (GUAS/AS), Masao Watanabe (JAERI/J-PARC), Junichi Kishiro (JAERI/LINAC), Makoto Shiho (JAERI/NAKA), Atsushi Kawasaki, Akira Tokuchi (NICHICON), Kazuhiko Horioka, Mitsuo Nakajima (TIT)*

A single bunch trapped in an RF bucket was accelerated by induction devices from 500 MeV to 8GeV beyond transition energy in the KEK-PS. This is the first demonstration of induction acceleration in a high energy circular ring. The acceleration was confirmed by measuring a temporal evolution of the RF phase through an entire acceleration.* Key devices in an induction acceleration system are an induction accelerating cavity capable of generating an induced voltage of 2kV/cell, a pulse modulator to drive the cavity (switching driver), and a DSP system to control gate signals for switching. Their remarkable characteristics are its repetition ratio of about 1MHz and duty factor of 50%. All devices have been newly developed at KEK so as to meet this requirement. The pulse modulator employing MOSFETs as switching elements is connected with the accelerating cavity through a long transmission cable in order to avoid a high-dose irradiation in the accelerator tunnel. The induction system has been running beyond more than 24 hours without any troubles. The paper will take an introductive role for related other 6 papers too, which describe more technical aspects and novel beam physics associated with the induction acceleration.

*K.Takayama et al., submitted to Phys. Rev. Lett., http://www.arxiv.org/pdf/physics/0412006.

**FPAE021—Alignment and Steering for Injection and Multi-Turn Operation of the University of Maryland Electron Ring (UMER)**

*Mark Walter, Gang Bai, Santiago Bernal, Irving Haber, Mike Holloway, Rami Alfred Kishek, Patrick G. O'Shea, Bryan Quinn (IREAP), Martin Reiser (University Maryland)*

The injection line and main lattice for the University of Maryland Electron Ring (UMER) has been completed. The electron beam has been guided around the full 360 degrees of the ring. Beam steering and matching in the injection line is achieved with six quadrupole magnets and several small steering dipole magnets. The dipole component of an offset quadrupole and a pulsed dipole are used to achieve the 10 degree bend required from the injection line into the ring. The pulsed dipole is designed to operate with a short pulse (2 kV, -30 A, 100 ns flat top duration) for injection superimposed on a long pulse (300 V, 15 A, 20e-6 s duration) for multiple beam passes. The beam is controlled in the recirculating ring with a regular lattice of 36 dipole and 72 quadrupole magnets. Initial experimental results of the beam transport and control will be presented.

This work is funded by US Dept. of Energy grant numbers DE-FG02-94ER40855 and DE-FG02-92ER54178.

**FPAE022—Cycle-to-Cycle Extraction Synchronization of the Fermilab Booster for Multiple Batch Injection to the Main Injector**

***Robert M****iles Zwaska, Sacha Elmer Kopp (The University of Texas at Austin), William Pellico (Fermilab)*

We report on a system to ensure cycle-to-cycle synchronization of beam extraction from the Fermilab Booster accelerator to the Main Injector. Such synchronization is necessary for multiple batch operation of the Main Injector for the Run II upgrade of anti-proton production using slip-stacking in the Main Injector, and for the NuMI (Neutrinos at the Main Injector) neutrino beam. To perform this task, a system of fast measurement and feedback is used to control the longitudinal progress of the Booster beam throughout its acceleration period by manipulation of the transverse position maintained by the low-level radio frequency system.

**FPAE023—Direct Antiproton Deceleration in the Fermilab Proton Driver**

*Gerald Peter Jackson, Steven Howe (Hbar Technologies, LLC)*

The Fermilab Proton Driver is an 8 GeV kinetic energy H- linear accelerator proposed as a new source of high brightness protons for the Main Injector. The Recycler ring is an 8 GeV antiproton storage ring that resides in the same tunnel as the Main Injector. This paper describes a scenario wherein the current Main Injector proton injection kickers and Lambertson magnet are moved vertically into the Recycler ring to enable antiproton extraction toward the Proton Driver. By employing a pair of intermediate vertical bends at the appropriate vertical betatron phase advance, the vertical dispersion into the Proton Driver can be eliminated and direct antiproton deceleration made possible. Because the H- and antiproton beams have the same charge but opposite direction, matching of the Recycler lattice to the Proton Driver is required to accommodate the reversed effect of the focusing and defocusing quadrupoles.

**FPAE024—Studies Performed in Preparation for the Spallation Neutron Source Accumulator Ring Commissioning**

*Sarah M. Cousineau (ORNL/ASD), Viatcheslav V. Danilov, Stuart Henderson, Jeffrey Alan Holmes, Michael Plum (ORNL/SNS)*

The Spallation Neutron Source accumulator ring will compress 1.5 1014, 1 GeV protons from a 1 ms bunch train to a single 695 ns proton bunch for use in neutron spallation. Due to the high beam power, unprecedented control of beam loss will be required in order to control radiation and allow for hands-on maintenance in most areas of the ring. A number of detailed investigations have been performed to understand the primary sources of beam loss and to predict and mitigate problems associated with radiation hot spots in the ring. The ORBIT particle tracking code is used to perform realistic simulations of the beam accumulation in the ring, including detailed modeling of the injection system, transport through the measured magnet

fields including higher order multipoles, and beam loss and collimation. In this paper we present the results of a number of studies performed in preparation for the 2006 commissioning of the accumulator ring.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**FPAE025—Study of Slow Beam Extraction Through the Third Order Resonance with Transverse Phase Space Manipulation by a Mono-Frequency RFKO**

*Atsushi Miyamoto, Hiroyuki Hama, Fujio Hinode, Masayuki Kawai, Katsuhiro Shinto, Takumi Tanaka (LNS)*

An electron pulse-stretcher ring (STB ring) has a function which converts a pulse beam generated by RF linac into a quasi-continuous beam. Circulating beam in the ring is extracted by the third order resonance. Since there is no accelerating field in the ring, the beam approaches a transverse resonance condition due to synchrotron radiation loss with finite chromaticity. The extracted beam from the ring has some spread in time and space corresponding to injected beam from linac even if the injected beam is perfectly matched to the ring optics. However, the extracted beam emittance can be reduced by applying a phase space manipulation using an RF shaker. Under the influence of perturbation using an RF shaker driven by a mono-frequency, the betatron amplitude of circulating beam can be controlled in order to reduce the extracted beam emittance. The experimental results will be reported in this conference.

**FPAE026—Development of FFAG Accelerator at KEK**

*Yujiro Yonemura, Nobuo Ikeda, Masaru Matoba (Kyushu University,), Shinji Machida, Yoshiharu Mori, Atsutoshi Muto, Joe Nakano, Chihiro Ohmori, Izumi Sakai, Yasuo Sato, Akira Takagi, Takeichiro Yokoi, Masahito Yoshii, Masahiro Yoshimoto, Yoshimasa Yuasa (KEK), Akiyoshi Yamazaki (LNS), Tomonori Uesugi (NIRS), Masamitsu Aiba, Masahiro Sugaya (University of Tokyo)*

Various FFAG (Fixed Field Alternating Gradient) accelerators have been developed at KEK. The 150MeV proton FFAG accelerator among them is under development, and this is to be the prototype for various applications such as proton beam therapy. Beam commissioning has been successfully performed. We are now in preparation for using an extracted beam in the practical applications.

**FPAE027—Status of the ISAC-II Accelerator at TRIUMF**

*Robert Edward Laxdal, Willy Andersson, Pierre Bricault, Iouri Bylinskii, Ken Fong, Marco Marchetto, Amiya Kumar Mitra, Roger Luke Poirier, William Reginald Rawnsley, Paul Schmor, Igor Sekachev, Guy Stanford, Glen Stinson, Vladimir Zviagintsev (TRIUMF)*

A heavy ion superconducting linac is being installed at TRIUMF to increase the final energy of radioactive beams at ISAC. A first stage of 20MV consisting of five medium beta cryomodules each with four quarter wave bulk niobium cavities and a superconducting solenoid is being installed with initial beam commissioning scheduled for Dec. 2005. The initial cryomodule has met cryogenic and rf performance specifications. In addition we have demonstrated acceleration of alpha particles in an off-line test. A 500W refrigerator system has been installed and commissioned in Jan. 2005 with cold distribution due for commissioning in Sept. 2005. A transfer beamline from the ISAC accelerator and beam transport to a first experimental station are being installed. The status of the project will be presented.

**FPAE028—The Design of the High Intensity Exotic Beams SPIRAL 2 Project**

*Alban Mosnier (CEA/DSM/DAPNIA), M.H. Moscatello (GANIL)*

The SPIRAL 2 facility will be able to deliver stable heavy ion beams and deuteron beams at very high intensity, allowing to produce and accelerate light and heavy rare ion beams. The driver will accelerate a 5 mA deuteron beam up to 20 MeV/u and also q/A=1/3 heavy ions up to 14.5 MeV/u. The injector consist of the ion sources, a 4-vane RFQ and the low and medium beam transfer lines. It is followed by an independently phased superconducting linac with compact cryostats separated with warm focusing sections. The overall design and results of simulations with combined errors, the results of tests of prototypes for the most critical components are presented.

**FPAE029—Setup and Performance of the RHIC Injector Accelerators for the 2005 Run with Copper Ions**

*Chris J. Gardner, James Alessi, John Benjamin, Michael Blaskiewicz, Joseph Michael Brennan, Kevin A. Brown, Charles Carlson, Joseph DeLong, Joseph Glenn, Thomas Hayes, William W. MacKay, Gregory James Marr, John Morris, Thomas Roser, Freddy Severino, Kevin Smith, Dannie Steski, Nicholaos Tsoupas, Alex Zaltsman, Keith Zeno (BNL)*

Copper ions for the 2005 run of the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory are accelerated in the Tandem, Booster and AGS prior to injection into RHIC. The setup and performance of this chain of accelerators will be reviewed.

Work performed under the auspices of the U.S. Department of Energy.

**FPAE030—Cost Comparison of 8 GeV Proton Drivers Based on a Superconducting Linac and Fast-Cycling Synchrotron**

*G. William Foster, Weiren Chou, Fernanda Gallinucci Garcia, David J. Harding, Cezary Jach, Elaine McCluskey, Jean-Francois Ostiguy, Richard Stanek (Fermilab)*

A cost comparison was made between 8 GeV, 0.5 MW Proton accelerator designs based on both an 8 GeV superconducting linac and a rapid-cycling synchrotron/linac combination. Identical methodology was used for comparable elements of each design, and wherever possible the same engineers performed the cost estimates. Reasonably detailed "bottom-up" estimates were made of the large technical subsystems unique to each machine (magnets and power supplies for the synchrotron; cryomodules, cryogenics, and RF stations for the SCRF Linac). AC power distribution and operating costs were also evaluated. The results of the comparison are discussed, as are several "reality checks" and "unit costs" from comparable projects.

U.S. Department of Energy.

**FPAE031—Nuclear Physics with Polarized Electron Beams at the MIT Bates Accelerator Center**

*Townsend Zwart (MIT)*

The MIT Bates Accelerator complex is delivering highly polarized electron beams to its South Hall Ring for use in Nuclear Physics Experiments. Circulating electron currents in excess of 200 mA with polarization of 70% are scattered from a highly polarized atomic beam source deuterium target. In the linac a robust diode laser produces quasi CW polarized electrons in us pulses at low duty factors from a strained GaAs photocathode. In the ring a Siberian Snake serves to maintain a high degree of longitudinal longitudinal polarization at the BLAST scattering target. A Compton laser back-scattering polarimeter

measures the electron beam polarization with a statistical acuracy of 6% for each 15 minute run.

U.S. Department of Energy.

**FPAE032—ORIC Beam Energy Increase**
*Merrit Lee Mallory, Jim Ball, Darryl Dowling, Ed Hudson, Dick Lord, Alan Tatum (ORNL)*
The detection of and solution to a beam interference problem in the Oak Ridge Isochronous Cyclotron (ORIC) extraction system has yielded a 20% increase in the proton beam energy. The beam from ORIC was designed to be extracted before the nu r equal one resonance. Most cyclotrons extract after the nu r equal one resonance, thus getting more usage of the magnetic field for energy acceleration. We have now determined that the electrostatic deflector septum interferes with the last accelerated orbit in ORIC, with the highest extraction efficiency obtained near the maximum nu r value. This nu r provides a rotation in the betatron oscillation amplitude that is about the same length as the electrostatic septum thus allowing the beam to jump over the interference problem with the septum. With a thinned septum we were able to tune the beam through the nu r equal one resonance and achieve a 20% increase in beam energy. This nu r greater than one extraction method may be desirable for very high field cyclotrons since it provides ten times the clearance at extraction compared to dee voltage gain, thus allowing the possibility of utilizing a magnetic extractor.

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**FPAE033—Operational Availability of the SNS During Commissioning**
*George W. Dodson (ORNL/SNS)*
The SNS Front End, Drift Tube Linac and most of the Coupled Cavity Linac have been operated during commissioning. Operating statistics were taken and used by system owners to target developments to improve accelerator availability. This progression will be shown along with the overall availability goals of the SNS and a RAM calculation showing the system and subsystem availability required to meet these goals.

This work was supported by SNS through UT-Batelle, LLC, under contract DE-AC05-00OR22725 for the U.S. DOE. The SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**FPAE034—Present Status of the J-PARC Accelerators**
*Junichi Kishiro (JAERI/LINAC)*
The Japan Particle Accelerator Research Complex (J-PARC) is now progressing the construction aiming to initiate the beam commissioning on FY2006 for LINAC and on FY2007 for 3GeV and 50GeV synchrotrons. It has been achieved the new technologies to realize the high intensity acceleration and the careful R/D works to cure the strong eddy current effects. And also the beam dynamical issues are investigating prior to the beam commissioning. It will be presented in this talk the technical and beam dynamical issues caused from the 1MW class high power beam and large bore magnets.

**FPAE035—Steps Towards a 3 mA, 1.8 MW Proton Beam at the PSI Cyclotron Facility**
*Pierre A. Schmelzbach (PSI)*
The PSI Cyclotron Facility produces routinely a 1.8-1.9 mA proton beam at 590 MeV. The beam power reaches 1.1 MW at the the pion production targets and 0.7 MW at the neutron spallation target SINQ. The accelerator complex will be analysed in respect to his potential for future improvements. The ongoing developments aiming to increase the beam intensity to 3 mA and hence the beam power to 1.8 MW will be discussed. Smooth extrapolations of the observed machine parameters as well as recent advances in the theoretical treatment of space charge dominated beams show that this goal can be achieved with available technologies. IA new RF-cavity operated at a voltage in excess of 1 MV has been successfully tested and installed in the Ring Cyclotron. Bunchers for the low energy and the medium energy transfer lines are in the design phase. A conceptual study of new accelerating cavities to replace the obsolete flattop-cavities of the Injector Cyclotron has been performed. While the upgrade of the Ring Cyclotron with four new cavities will be completed in 2008, it is still an open question whether this accelerator will be operated in the “round beam” mode like the Injector Cyclotron or with an upgraded flattopping system.

**FPAE036—Lattice Modification of a 1.2 GeV STB Ring for Generation of High Energy Gamma-Rays Using Internal Target Wire**
*Fujio Hinode, Hiroyuki Hama, Masayuki Kawai, Akira Kurihara, Atsushi Miyamoto, Masakatsu Mutoh, Masashi Nanao, Yoshinobu Shibasaki, Katsuhiro Shinto, Shigenobu Takahashi, Takumi Tanaka (LNS)*
A 1.2 GeV Stretcher-Booster Ring (STB ring) has been routinely operated at Laboratory of Nuclear Science (LNS), Tohoku University. The STB ring has functions of a pulse-beam stretcher and a booster-storage ring. In the booster-storage operation, high energy gamma-ray beam generated via bremsstrahlung from internal target wire is utilized for experiments of nuclear physics. Some fractions of circulating electrons are also deflected in the target wire due to Coulomb scattering without significant loss of the energy. The scattered electrons that are not getting out of the dynamic aperture once can circulate in the ring. Such electrons, however, would hit the chamber walls and supports of the target wire during further turns, because they have very large betatron amplitude. Consequently the Coulomb scattered electrons must be a source of significant background and may cause a degradation of gamma-ray beam quality. The quality of the gamma-ray beam has been improved by modifying the lattice functions of the ring, and we report the improvement in this conference.

**FPAE037—SPIRAL 2 RFQ Prototype Tests**
*Robin Ferdinand, Gérard Congretel, Aline Curtoni, Olivier Delferriere, Alain France, Didier Leboeuf, Jean-Christian Toussaint (CEA/DSM/DAPNIA), Marco Di Giacomo (GANIL)*
The SPIRAL2 RFQ is designed to accelerate at 88MHz two kinds of charge-over-mass ratio, Q/A, particles. The proposed injector can accelerate a 5 mA deuteron beam (Q/A=1/2) or a 1 mA particles beam with q/A=1/3 up to 0.75 MeV/A. It is a CW machine which has to show stable operation, provide the request availability, have the minimum losses in order to minimize the activation constraints and show the best quality/cost ratio. The prototype of this 4-vane RFQ has been built and tested. It allowed to verify the mechanical assembly concept (RFQ without any brazing step). The full power was easily injected in the cavity, with no concerns for the RF joints. The paper describes the different achievements.

**FPAE038—New Four-Section Design Procedure for High Current Radio Frequency Quadrupole Accelerators**
*Chuan Zhang, Alwin Schempp (IAP), Zhiyu Guo (PKU/IHIP)*

The Four-Section Procedure that proposed by Los Alamos National Laboratory has been the classic solution for the beam dynamics design of Radio Frequency Quadrupole (RFQ) accelerators. In the case of high current and the structure length that needs to be short, the beam bunching could not be adiabatic. Therefore, the LANL Four-Section Procedure is not sufficient any more to meet the strict demands e.g. very low beam loss for modern linacs. The New Four-Section Procedure that properly adjusts the old one by some special physical concepts could be an approach to the problem.

**FPAE040—First Operation of PIAVE, the Heavy Ion Injector Based on Superconducting RFQ's**
*Giovanni Bisoffi, Giorgio Bassato, Andrea Battistella, Giampietro Bezzon, Lucia Boscagli, Andrea Calore, Stefania Canella, Osvaldo Carletto, Davide Carlucci, Francesca Chiurlotto, Michele Comunian, Mauro De Lazzari, Alberto Facco, Enrico Fagotti, Augusto Lombardi, Paolo Modanese, M. Francesca Moisio, Andrea Pisent, Marco Poggi, Anna Maria Porcellato, Sergey Stark (INFN/LNL)*
The Positive Ion Accelerator for low-Velocity Ions (PIAVE), based on superconducting RFQ's (SRFQ's), has been completed in fall 2004 with the first acceleration of beams from the ECR ion source. Superconducting RFQ's were used, for the first time, for beam acceleration on a user-oriented accelerator complex. A general status of the injector performances is given: it includes, besides the SRFQ's, eight superconducting (SC) QWR's and three bunchers; the beam is received from an ECR source on a HV platform and is delivered, through the SC accelerator ALPI, to nuclear physics experimental apparatuses. The paper emphasizes, in particular, the technological challenges related to the operation of the SC cavities, the cryogenics, control, diagnostics and vacuum systems.

**FPAE042—Beam Commissioning of the Superconducting RFQs of the New LNL Injector PIAVE**
*Andrea Pisent, Giovanni Bisoffi, Davide Carlucci, Marco Cavenago, Francesca Chiurlotto, Michele Comunian, Enrico Fagotti, Alessio Galatà, Marco Poggi, Anna Maria Porcellato, Emanuele Sattin (INFN/LNL)*
PIAVE is the new injector of the LNL superconducting heavy ion linac ALPI; the injector is able to accelerate ions up to U (Q/q=8.5) with a final energy of more than 1 MeV/u. During the last two months of 2004 the superconducting RFQ, composed by two Nb structures operating at 80 MHz, has been commissioned using the O+3 and Xe+18 beams produced by the ECRIS ALICE. The beam has been accelerated up to 587 keV/u reaching the main design parameters (energy, longitudinal and transverse emittance, transmission) and demonstrating a stable and reproducible operation. This is the first operational beam accelerated by a superconducting RFQ.

**FPAE043—Transverse Tuning Scheme for J-PARC Linac**
*Masanori Ikegami, Zenei Igarashi, Seishu Lee (KEK), Hisashi Akikawa, Kazuo Hasegawa, Yasuhiro Kondo, Tomohiro Ohkawa (JAERI), Hiroyuki Ao, Susumu Sato, Tetsuo Tomisawa, Akira Ueno (JAERI/LINAC)*
In a high-intensity linac, precise transverse matching is essential for beam halo mitigation. In this paper, we present the supposed transverse tuning scheme for J-PARC linac and the planned beam diagnostic layout for it. Relevantly, we briefly touch upon the tuning scenario for the arc section and the transverse halo collimator system which are located between the linac and the succeeding ring.

**FPAE044—Test Results of the PEFP 3MeV RFQ Upgrade**
*Yong-Sub Cho, Sang-Hyo Han, Ji-ho Jang, Han-Sung Kim, Yong-Hwan Kim, Hyeok-Jung Kwon, Mi-Young Park, Kyung Tae Seol (KAERI)*
A 3MeV RFQ upgrade for 100MeV proton accelerator has been fabricated at PEFP (Proton Engineering Frontier Project). The tuning of the cavity was carried out before and after the brazing to meet the condition that the quadrupole field profile is within 1% of design value and dipole component is less than 1% of quadrupole one. The ancillary system such as high power RF including klystron power supply and cooling system were already tested up to operating level. Therefore, the main issues of the tests were cavity conditioning up to full power level and low duty beam test. After the completion of the beam test of RFQ itself, the 20MeV DTL which has been tested independently will be carried out. In this paper, the test results of the PEFP 3MeV RFQ upgrade including high power conditioning and low duty beam acceleration are presented.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**FPAE045—Design of the PEFP MEBT**
*Ji-ho Jang, Yong-Sub Cho, Yong-Hwan Kim, Hyeok-Jung Kwon (KAERI)*
A MEBT system of the PEFP(Proton Engineering Frontier Project) has to be installed after the 20MeV DTL where the beam will be supplied to the user group through a beam extraction system. Until now we don't have a plan to put in some matching devices between the RFQ and 20MeV DTL except using the four quadrupole magnets in the first DTL tank as transverse matching tools. The MEBT plays the key role to match the 20MeV output beam into the next accelerator in the longitudinal direction as well as transverse one. This report shows the basic concept and the design status of the system.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**FPAE046—Initial Test of the PEFP 20MeV DTL**
*Han-Sung Kim, Yong-Sub Cho, Sang-Hyo Han, Ji-ho Jang, Yong-Hwan Kim, Hyeok-Jung Kwon, Mi-Young Park, Kyung Tae Seol (KAERI), Yong-Suk Hwang (SNU)*
A conventional 20MeV drift tube linac (DTL) for the Proton Engineering Frontier Project (PEFP) has been developed as a low energy section of 100MeV accelerator. The machine consists of four tanks with 152 cells supplied with 900kW RF power from 350MHz klystron through the ridge-loaded waveguide coupler. We assembled the fabricated accelerator components and aligned each part with care. We have also prepared the subsystems for the test of the DTL such as RF power delivery system, high voltage DC power supply, vacuum system, cooling system, measurements and control system and so on. The detailed description of the initial test setup and preliminary test results will be given in this paper.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**FPAE047—Test Scheme Setup for the PEFP 20MeV DTL**
*Han-Sung Kim, Yong-Sub Cho, Yong-Hwan Kim, Hyeok-Jung Kwon, Kyung Tae Seol (KAERI), Yong-Suk Hwang (SNU)*
A 100MeV proton accelerator is under development for the Proton Engineering Frontier Project (PEFP). The goal of the first stage of the project is to develop a 20MeV accelerator and the initial test of the 20MeV accelerator will be made. The DTL of 20 MeV accelerator consists of four tanks and will be driven

with single klystron, which gives rise to some unique problems with regard to the way of independent resonance control for each tank. Some changes made in the LLRF for reducing phase or amplitude error of cavities affect all of four tanks simultaneously, for which it is not possible to use LLRF for individual control of phase and amplitude of each tank. For independent control of each tank, we are going to use the temperature control of the drift tubes as a frequency tuner. During the initial test of the DTL, the phase of each tank will be synchronized with the first tank phase, and beam based test will be performed as if all of tanks were single unit. The detailed description of the test scheme and the analysis results will be given in this paper.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**FPAE048—Fabrication of the PEFP 3MeV RFQ Upgrade**

*Hyeok-Jung Kwon, Yong-Sub Cho, Ji-Ho Jang, Han-Sung Kim, Yong-Hwan Kim (KAERI)*

A 100MeV proton accelerator has been developed at PEFP (Proton Engineering Frontier Project) as a 21C Frontier Project. The goal of the first stage of the project is to develop a 20MeV accelerator. The 20MeV accelerator consists of ion source, LEBT, 3MeV RFQ and 20MeV DTL. The 3MeV RFQ was already installed and being tested. During preliminary test, some problems, such as the resonant frequency and field profile tuning, sharp edge in the vane end, inadequate RF seals have been found out. Therefore, it was decided to fabricate another RFQ. The RFQ upgrade includes some characteristics such as constant voltage profile, adoption of transition cell which are different from present one. In this paper, the fabrication of the PEFP 3MeV RFQ upgrade are presented.

This work is supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government.

**FPAE049—Development and Implementation of ÄT Procedure for the SNS Linac**

*Alexander Feschenko, Sergey Bragin, Yuri Kiselev, Leonid Vladimirovich Kravchuk, Olga Volodkevich (RAS/INR), Alexander V. Aleksandrov, John Galambos, Stuart Henderson, Andrei P. Shishlo (ORNL/SNS)*

The Ät procedure is a time of flight technique for setting the phases and amplitudes of accelerating fields in a multi-cavity linac. It was initially proposed and developed for the LAMPF linac in the early seventies and since then has been used in several accelerators. The SNS linac includes four CCL modules (Side Coupled Structure) operating at 805 MHz for the energy range from 86.8 MeV up to 185.6 MeV. The Ät procedure has been implemented for the SNS CCL linac and was used for its initial beam commissioning. Brief theory of the procedure, the results of the design parameter calculations and the experimental results of phase and amplitude setpoints are presented and discussed.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**FPAE050—Injector Linac for the BNL Super Neutrino Beam Project**

*Deepak Raparia, James Alessi, Alessandro Ruggiero, Wu-Tsung Weng (BNL)*

BNL plans to upgrade the AGS proton beam from the current 0.14 MW to higher than 1.0 MW and beyond for such a neutrino facility. We have examined possible upgrades to the AGS complex that would meet the requirements of the proton beam for a 1.0 MW neutrino superbeam facility. We are proposing to replace part of the existing 200 MeV linac with coupled cavity structure from 116 MeV to 400 MeV and then add additional 1.1 GeV superconducting linac to reach a final energy of 1.5 GeV for direct H- injection into the AGS. We will present possible choices for the upgrade and our choice and its design.

This work was performed under the auspices of the U.S. DOE, Contract No. DE-AC02-98H10886.

**FPAE051—Performance of a CW RFQ Injector for the IUCF Cyclotron**

*Vladimir Peter Derenchuk, Vladimir Anferov, Dennis Friesel (IUCF), Robert Wray Hamm (AccSys), John William Staples (LBNL)*

A 750 keV RFQ proton pre-injector was installed in place of a 600 keV Cockroft-Walton high voltage terminal for the IUCF k220 Cyclotron.* The pre-injector consists of a 20 keV microwave ion source and LEBT, a unique design 750 keV CW RFQ, and a short transfer beam line to the k15 injector cyclotron center region.** This pre-injector system was installed and commissioned in June of 2003 and is now in routine service as the sole injection system to the cyclotrons. This contribution will discuss the performance of the CW RFQ pre-injector and the transmission properties of the beam through the cyclotrons. *D.L.Friesel, et al., App. of Acc. in Res. and Ind., eds. J.L. Duggan and I.L. Morgan, Denton, 651(2000). **V.P. Derenchuk, et al., 2003 Particle Accelerator Conference, Portland, OR, (2003), edited by A. Jackson and E. Lee.

The State of Indiana, Indiana University, and the DOE (Grant No DE-FG-02000ER62966) supported this work.

**FPAE052—The LENS 7 MeV, 10 mA Proton Linac**

*Vladimir Peter Derenchuk, David Baxter, Alexander Bogdanov, William Philip Jones, Thomas Rinckel, Keith Solberg (IUCF)*

The Indiana University Cyclotron Facility (IUCF) has constructed and placed in operation a Low Energy Neutron Source (LENS) using a 10 mA, 7 MeV proton beam incident on a beryllium target. The proton delivery system (PDS) consists of a 25 keV proton injector, an AccSys Technology, Inc. PL7 Linac* and a beam transport line with non-linear beam spreading.** The accelerator and beamline equipment used in this construction are refurbished and upgraded components from the IUCF CIS/Cooler synchrotron*** facility. After commissioning the beam current at 7 MeV will be 10 mA with a pulse width of up to 300 μs and > 1% duty factor. The PDS was constructed and commissioning started in 2004. First operating results will be described.
*D.L. Friesel and W. Hunt, Linac98, pp61-63. **W.P. Jones, et. al., "Non-Linear Beam Transport System for the LENS 7 MeV Proton Beam," this proceedings. ***D.L. Friesel, et. al., EPAC2000, pp. 539-541.

This work has been supported by the National Science Foundation under grants DMR-0220560, and DMR-0320627, by the Indiana 21st Century Science and Technology Fund, and by the Department of Defense.

**FPAE053—Isobar Suppression by Photodetachment in a Gas-Filled RF Quadrupole Ion Guide**

*Yuan Liu, James R. Beene, Aaron Havener, Charles Havener, Felix Liang (ORNL)*

A novel method is described for selective suppression of isobar contaminants in negative radioactive ion beams. Negative ion beams extracted from an ion source were decelerated to low energies and injected into a gas-filled radio-frequency quadrupole (RFQ) ion guide where the ions were cooled and unwanted

ions were selectively removed by non-resonant photodetachment with photons of sufficient energy. Simulation studies show that the laser-ion interaction time in a 40 cm long RFQ ion guide can be on the order of milliseconds, thus, high efficiency photodetachment is possible with commercially available CW lasers. There are a number of adjacent-Z species whose negative ions are such that photodetachment can be used to suppress the unwanted negative ion species while leaving the species of interest intact. Examples of particular interest include suppressing the 56Co- component in a mixed 56Ni- + 56Co- beam and the 17O- component in a mixed 17O- + 17F- beam. In a proof–of-principle experiment a CW Nd:YAG laser at 1064 nm wavelength was used to selectively remove Co- ions in the (Ni, Co) pair. With laser power on the order of 3 W, 95% of Co- beams were suppressed while only 10% of Ni- beams were neutralized in a He-filled RFQ guide.

Managed by UT-Battelle, LLC, for the U.S. DOE under contract DE-AC05-00OR22725. Co-author Aaron Havener was under a U.S. DOE Science Undergraduate Laboratory Internship.

**FPAE054—Front End Design of a Multi-GeV H-minus Linac**

*Peter Ostroumov, Kenneth Shepard (ANL), G. William Foster, Ivan Gonin, Gennady Romanov (Fermilab), Andrej Kolomiets (on leave) (ITEP)*

The proposed 8-GeV driver at FNAL is based on ~480 independently phased SC resonators. Significant cost saving is expected by using an rf power fan out from high-power klystrons to multiple cavities. Successful development of superconducting (SC) multi-spoke resonators operating at ~345-350 MHz provides a strong basis for their application in the front end of multi-GeV linear accelerators. Such a front-end operating at 325 MHz would enable direct transition to high-gradient 1300 MHz SC TESLA-style cavities at ~400 MeV. The proposed front end consists of 5 sections: a conventional RFQ, room-temperature (RT) cross-bar H-type (CH) cavities, single-, double- and triple-spoke superconducting resonators. For several reasons which are discussed in this paper there is a large advantage in using independently phased RT CH-cavities between the RFQ and SC sections in the energy range 3-15 MeV.

This work was supported by the U.S. Department of Energy under Contracts No. W-31-109-ENG-38 and DE-AC02-76CH03000.

**FPAE055—Heavy-Ion Beam Dynamics in the RIA Post-Accelerator**

*Peter Ostroumov, Vladislav Aseev (ANL), Andrej Kolomiets (on leave) (ITEP)*

The RIB linac includes two strippers for the heaviest ions and three main sections: a room temperature injector up to an energy of ~100 keV/u, a superconducting (SC) linac for ions with charge-to-mass ratio 1/66 or more up to an energy of ~1 MeV and a higher energy SC linac to produce 10 MeV/u beams up to the mass of uranium. The RIA post-accelerator is a complex system designed for acceleration singly-charged ions before the stripper and includes many different accelerating and focusing structures operating both at room and cryogenic temperatures. Extensive accelerator design studies and end-to-end beam dynamics simulations have been performed to minimize the cost of the linac while providing high-quality and high-intensity radioactive beams. Specifically, we have found that cost-effective acceleration can be provided by several hybrid RFQs in the front end. The hybrid RFQs have been proposed and developed for acceleration of low-velocity heavy ions.* For the beam focusing in the second section it is appropriate to use electrostatic lenses and SC quadrupoles inside common cryostats with the resonators. The electrostatic lenses are most effective in the first cryostat of the SC linac.

*P.N. Ostroumov and A.A. Kolomiets. Proc. of the PAC-2001, Chicago, IL, June 18-22, 2001, p. 4077.

This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. W-31-109-ENG-38.

**FPAE056—Review of a Spoke-Cavity Design Option for the RIA Driver Linac**

*Peter Ostroumov, Kenneth Shepard (ANL), Jean Roger Delayen (Jefferson Lab)*

A design option for the 1.4 GV, multiple-charge-state driver linac required for the U.S. Rare Isotope Accelerator Project based on 345 MHz, 3-cell spoke-loaded cavities has been previously discussed.* This paper updates consideration of design options for the RIA driver, including recent results from numerically-modeling the multi-charge-state beam dynamics and also cold test results for prototype superconducting niobium 3-cell spoke-loaded cavities.

*"High-energy ion linacs based on superconducting spoke cavities," K.W. Shepard, P.N. Ostroumov, and J.R. Delayen, Phys. Rev. ST Accel. Beams 6, 080101 (2003).

This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under Contract No. W-31-109-ENG-38.

**FPAE057—Beam Dynamics Studies and Beam Quality in the SNS Normal-Conducting Linac**

*Stuart Henderson, Alexander V. Aleksandrov, Dirk Alan Bartkoski, Chungming Chu, Sarah M. Cousineau, Viatcheslav V. Danilov, George W. Dodson, John Galambos, Dong-o Jeon, Michael Plum, Martin P. Stockli (ORNL/SNS)*

The Spallation Neutron Source accelerator systems will provide a 1.0 GeV, 1.4 MW proton beam to a liquid mercury target for neutron production. The accelerator complex consists of an H- injector capable of producing 38 mA peak current, a 1 GeV linear accelerator, an accumulator ring and associated transport lines. The linear accelerator consists of a Drift Tube Linac, a Coupled-Cavity Linac and a Superconducting Linac which provide 1.5 mA average current to the accumulator ring. The staged beam commissioning of the accelerator complex is proceeding as component installation progresses. Recently, the normal-conducting linear accelerator was beam commissioned. A number of beam dynamics and beam quality measurements will be reported, including the measurement of transverse emittances in the H- injector, and the evolution of halo and emittance along the linac.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos and Oak Ridge.

**FPAE058—Spallation Neutron Source Superconducting Linac Commissioning Algorithms**

*Stuart Henderson, Isidoro Enrico Campisi, John Galambos, Dong-o Jeon, Yan Zhang (ORNL/SNS)*

We describe the techniques which will be employed for establishing RF and quadrupole setpoints in the SNS superconducting linac. The longitudinal tuneup will be accomplished using phase-scan methods, as well as a technique that makes use of the beam induced field in the unpowered cavity.* The scheme for managing the RF and quadrupole setpoints to achieve a given energy profile will be described.

*L. Young, Proc. PAC 2001, p. 572.

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**FPAE059—Transverse Matching Techniques for the SNS Linac**

*Dong-o Jeon, Chungming Chu, Viatcheslav V. Danilov (ORNL/SNS)*

It is crucial to minimize beam loss and machine activation by obtaining optimal transverse matching for a high-intensity linear accelerator such as the Spallation Neutron Source linac. For matching the Drift Tube Linac (DTL) to Coupled Cavity Linac (CCL), there are four wire-scanners installed in series in CCL module 1 as proposed by the author.* A series of measurements was conducted to minimize envelope breathing and the results are presented here. As an independent approach, Chu et al is developing an application based on another technique by estimating rms emittance using the wire scanner profile data.** For matching the Medium Energy Beam Transport Line to the DTL, a technique of minimizing rms emittance was used and emittance data show that tail is minimized as well.

*D. Jeon et al., "A technique to transversely match high intensity linac using only rms beam size from wire-scanners," Proceedings of LINAC2002 Conference, p. 88. **C. Chu et al., "Transverse beam matching application for SNS," in this conference proceedings.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**FPAE060—Challenges for Vertical Injection and Extraction in the Duke Booster Synchrotron**

*Stepan Mikhailov, Jingyi Li, Y. K. Wu (DU/FEL), Yuri Matveev, Dmitry Shvedov (BINP SB RAS)*

The full energy booster injector for the Duke FEL storage ring is presently under installation. The booster is designed to provide continuous injection in the top-off mode. The injected beam energy from the linac pre-injector is 270 MeV and the extraction energy of the booster varies from 270 MeV to 1.2 GeV. The booster is also designed to provide the single bunch extraction capability. For the single bunch extraction a kicker with a pulse duration of 11 nsec has been developed, which imposes a strict limitation on the maximum kick angle. The compactness of the booster ring propelled us to choose a vertical injection/extraction scheme with a relatively high vertical beta function at kickers and septum magnets. The major disadvantage of such a scheme is a small vertical acceptance for injection and extraction. The paper presents lattice solutions and technical solutions for achieving vertical injection and the single bunch extraction for the booster.

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**FPAE061—Status of the Booster Injector for the Duke FEL Storage Ring**

*Stepan Mikhailov, Matthew D. Busch, Mark Emamian, Joe Faircloth, Steven M. Hartman, Jingyi Li, Victor Popov, Gary Swift, Patrick Walter Wallace, Ping Wang, Y. K. Wu (DU/FEL), Nikolai Gavrilov, Yuri Matveev, Dmitry Shvedov, Nikolay Vinokurov (BINP SB RAS)*

This paper presents the current status of the booster synchrotron for the Duke FEL storage ring. The booster will provide full energy injection into the storage ring in a wide energy range from 0.27 to 1.2 GeV. When operating the Duke FEL storage ring as the High Intensity Gamma Source (HIGS) to produce gamma photons above 20 MeV with Compton scattering, continuous electron loss occurs. The top-off mode operation of the booster injector will enable the continuous operation of the HIGS facility by replenishing the lost electrons. The design requirement for a compact booster with the single bunch extraction capability remains a challenge for the machine development. Presently, the booster project is in the installation phase. The magnetic elements, vacuum chambers, injection and extraction kickers have been fabricated in the Budker Institute of Nuclear Physics, Russia. The diagnostic and control system is being developed in the FEL lab, Duke University. The commissioning of the booster synchrotron is planned for fall 2005.

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**FPAE062—Beam Parameters of a Two-Sectional Electron Linac with the Injector Based on a Resonance System with Evanescent Oscillations**

*Viktor Mytrochenko, Mykola Ivanovich Ayzatskiy, Victor Boriskin, Anatoly Nikolayevich Dovbnya, Igor Khodak, Volodymyr Kushnir, Anatoliy Opanasenko, Sergey Perezhogin, Antonina Savchenko, Dmitriy Stepin, Valeriy Tatanov, Valentin Zhiglo (NSC/KIPT)*

The S-band electron linac has been designed at NSC KIPT to cover an energy range from 30 to about of 100 MeV. The linac consists of a couple of the four-meter long piecewise homogeneous accelerating sections. Each section is supplied with RF power from a separate klystron. The peculiarity of the linac is using of the injector based on evanescent oscillations. The report presents both simulation results of self-consistent particle dynamics in the linac and results of measurement of beam parameters.

**FPAE063—Improvements of Machine Reliability and Beam Quality in SPring-8 Linac for Top-Up Injection into Two Storage Rings**

*Hirofumi Hanaki, Takao Asaka, Hideki Dewa, Toshiaki Kobayashi, Akihiko Mizuno, Shinsuke Suzuki, Tsutomu Taniuchi, Hiromitsu Tomizawa, Kenichi Yanagida (JASRI/SPring-8)*

SPring-8 has started its top-up operation from May 2004 in order to feed constant photon fluxes to users. The SPring-8 linac has been improved to realize stable and uninterrupted top-up injection into the SPring-8 storage ring and the NewSUBARU storage ring. The beam energy instability of 0.01% rms had been achieved by the following stabilization: RF amplitude and phase stabilization, synchronization of beam timing and linac's 2856 MHz RF and introduction of an energy compensation system (ECS). Feedback controls of steering magnets compensate long-term variation of beam trajectories at ends of beam transport lines. The presentation will include also recent improvements.

**FPAE064—An Intense-Beam RFQ Development at IHEP**

*Shinian Fu, Shouxian Fang, Keyun Gong, Jian Li, Huafu Ouyang, Jiming Qiao, Taoguang Xu, Wenwu Xu, Xinan Xu, Yuan Yao, Huasun Zhang, Zhonghua Zhang (IHEP Beijing,), Xialing Guan (CIAE), Jia-Xun Fang, Zhiyu Guo (PKU/IHIP)*

An intense-beam RFQ accelerator is under construction at IHEP, Beijing. It accelerates a proton beam of 3mA average current at 6% duty factor to 3.5MeV from 75keV. This four-vane type RFQ of 352MHz has a length of 4.7m and is separated into two resonantly coupled segments.This paper will present the construction progress of the RFQ, including the manufacture and braze of the RFQ cavity, RF power source, vaccum and water cooling systems.

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**FPAE065—Development of Beam Transport System for High Current RFQ Linac**
*Noriyosu Hayashizaki, Toshiyuki Hattori (RLNR), Robert Jameson (IAP), Masahiro Okamura (RIKEN)*
Direct Plasma Injection Scheme (DPIS) has been studied to accelerate high intense ion beam. In this scheme, a laser ion source and a RFQ linac are connected directly without low energy beam transport system (LEBT). Therefore, high current beam is injected from the laser-induced plasma into the RFQ linac without beam loss at LEBT. We could accelerate high current carbon beam of 60 mA with a CO2 laser ion source and the high current optimized RFQ linac. To diagnose the properties of the accelerated beam, a beam transport system fabricated behind the RFQ linac. This system is composed of electric quadruple lenses, a bending magnet and beam monitors. It is difficult to transport stably high current ion beam in low energy range due to space charge force. Therefore, the positions of each device were optimized by beam trajectory simulation. The results of the beam simulation and the beam acceleration test are presented.

**FPAE066—The IFUSP Microtron New Configuration**
*Mauricio Lima Lopes, Marcos Martins, Paulo Beolchi Rios, Jiro Takahashi (USP/LAL)*
In this work we present a new design for the IFUSP main microtron accelerator. The new configuration improves the maximum output energy and eases the operation of the machine. The accelerator will be able to deliver 38 MeV after 43 turns. The input energy was reduced from 4.9 to 2.5 MeV, so that the first microtron stage, the booster, could be eliminated, reducing the number of synchronous stages and easing the operation. We present results for the energy, energy gain and phase slip per turn, and the beam ellipses. We also discuss the design of the insertion and extraction lines.

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**FPAE067—Present Design and Calculation for the Injection-Dump Line of the RCS at J-PARC**
*Pranab Kumar Saha, Hideaki Hotchi, Yoshiro Irie, Fumiaki Noda (JAERI/J-PARC), Shinji Machida, Izumi Sakai (KEK)*
The RCS(rapid cycling synchrotron) of J-PARC(Japan proton accelerator research complex) acts as an injector to the main ring as well as a high-power beam for the spallation neutron source at a repetition rate of 25 Hz, where at present the injection and the extraction beam energy are chosen to be 0.181 GeV and 3.0 GeV, respectively. The present work concerns on the present design and calculations for the injection-dump line of the RCS, which includes, 1) an accurate aperture list of all elements taking into account a wide range of the betatron tune, effect of changing injection modes, multiple trajectories of different particles after the charge-exchange foil( like H0 from the H- and H- beam itself)and 2) an accurate estimation of the uncontrolled beam losses especially from the H0-excited states, multiple coulomb scattering at the charge-exchange foil and also the lorentz stripping loss at the septum magnets so as to optimize them concerning mainly the radiation issues as well as for the hands-on maintenance

**FPAE068—Charge Strippers in the RIKEN RI-Beam Factory**
*Hiromichi Ryuto, Nobuhisa Fukunishi, Akira Goto, Hiroo Hasebe, Naohito Inabe, Osamu Kamigaito, Masayuki Kase, Yasushige Yano, Shigeru Yokouchi (RIKEN/RARF/CC)*
In the RIKEN RI-Beam Factory, ions from hydrogen to uranium are planned to be accelerated by four cyclotrons and linacs using four stripper sections. The charge stripping schemes for typical ions and the selection of the charge strippers are described. The results of the measurements on charge state fractions are presented.

**FPAE069—DESIREE—A Double Electrostatic Storage Ring for Low Energy Ion-Ion Collisions**
*Leif Liljeby, Guillermo Andler, Lars Bagge, Mikael Blom, Håkan Danared, Anders Källberg, Sven Leontein, Patrik Löfgren, Andras Paal, Karl-Gunnar Rensfelt, Ansgar Simonsson, Örjan Skeppstedt (MSL), Henrik Cederquist, Mats Larsson, Henning Thordal Schmidt, Kjell Schmidt (Stockholm University)*
The advantages of storage rings with only electrostatic elements were first demonstrated in ELISA at Aarhus University and later in other places. At MSL and the Physics Department at Stockholm University the ideas have been developed further in the Double Electrostatic Storage Ion Ring ExpEriment, DESIREE. Beams of negative and positive atomic or molecular ions will be merged in a common straight section of two storage rings for studies of low energy collisions. The whole system may be cooled to below 20 K in order to relax internal excitations in stored molecules. This project is now fully financed and the final design work is in progress. A status report will be given in this paper together with a brief review of the planned physics program.

**FPAE070—A Collimation Scheme for Ions Changing Charge State in the LEIR Ring**
*Jaroslaw Pasternak, Cathelijne Bal, Christian Carli, Michel Chanel, Edgar Mahner (CERN)*
Avalanche-like pressure rise and an associated decrease of the beam lifetime, caused by (i) beam loss due to charge exchange interactions with rest gas molecules and (ii) ion impact induced outgassing, is a potential limitation for heavy ion accelerators operating at low energy. Capture of electrons from the electron cooler is another source of ion losses and thus, of pressure rise. The vacuum system of the LEIR ring has to be upgraded to reach the dynamical vacuum pressure in the low 10-12 Torr range necessary to reach design performance. A collimation system to intercept lost ions by absorber blocksmade of low beam induced outgassing material will be installed. This paper reviews the collimation scheme and simulations of beam loss patterns around the ring.

**FPAE071—Initial Results on Neutralized Drift Compression Experiments (NDCX) for High Intensity Ion Beam**
*Prabir Kumar Roy, Andre Anders, Frank Bieniosek, Shmuel Eylon, Wayne Greenway, Enrique Henestroza, Matthaeus Leitner, B. Grant Logan, Derek Shuman, David Vanecek, William Waldron, Simon Yu (LBNL), David Rose, Carsten Hilmar Thoma, Dale Welch (ATK-MR), William M. Sharp (LLNL), Ronald Davidson, Philip Efthimion, Erik P. Gilson, Igor Kaganovich, Adam Sefkow (PPPL)*
Ion beam neutralization and compression experiments are designed to determine the feasibility of using compressed high intensity ion beams for high energy density physics (HEDP) experiments and for inertial fusion power. To quantitatively ascertain the various mechanisms and methods for beam compression, the Neutralized Drift Compression Experiment (NDCX) facility is being constructed at Lawrence Berkeley

National Laboratory (LBNL). In the first compression experiment, a 260 KeV, 25 mA, K+ ion beam of centimeters size is radially compressed to a mm size spot by neutralization in a meter-long plasma column and beam peak current is longitudinally compressed by an induction velocity tilt core. Instrumentation, preliminary results of the experiments, and practical limits of compression are presented. These include parameters such as emittance, degree of neutralization, velocity tilt time profile, and accuracy of measurements (fast and spatially high resolution diagnostic) are discussed.

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**FPAE072—RF-Kicker System for Secondary Beams at NSCL/MSU**

*Dmitry Gorelov, Vladimir Andreev, Daniel Bazin, Marc Doleans, Terry L. Grimm, Felix Marti, John Vincent, Xiaoyu Wu (NSCL)*

The design and construction of a radio frequency (RF) kicker system at the National Superconducting Cyclotron Laboratory (NSCL), Michigan State University (MSU) has been proposed. This RF kicker system will be used to purify secondary beams of rare isotopes after the existing A1900 Fragment Separator and will open a wide range of possibilities for new experiments at the forefront of nuclear science. The proposed system is studied as an efficient alternative to the traditional approach using Wien Filter. Rare neutron deficient secondary beams are challenging to purify because of the presence of intense contaminants that cannot be removed by the traditional energy loss method. However, velocity differences resulting in time-of-flight differences can be used for the effective separation of the beams transversely using the time-varying electromagnetic fields of the RF kicker. Its technical design will be presented together with the beam dynamics analysis of a secondary beam in realistic 3D electromagnetic fields. The expected purification improvement of the exotic beams for the foreseen nuclear physics experiments will be shown in details.

**FPAE073—A Free Hg Jet System for Use in a High-Power Target Experiment**

*Philip Spampinato, Tony Gabriel, Van Graves (ORNL), Harold G. Kirk, Nikolaos Simos, Thomas Tsang (BNLk), Adrian Fabich, Helmut Haseroth, Jacques Lettry (CERN), Mark Rennich (ORNL/SNS), Kirk T. McDonald (PU)*

We describe a mercury jet system that is suitable for insertion into the 15cm diameter bore of a high-field solenoid magnet. The device features a hermetically sealed primary containment volume which is enclosed in a secondary containment system to insure isolation of mercury vapors from the remaining experimental environment. The jet diameter is 1-cm while the jet velocity will be up to 20 m/s. Optical diagnostics is incorporated into the target design to allow observation of the dispersal of the mercury as a result of interaction with a 24 GeV proton beam with up to 20 x 10**12 ppp.

Work funded by the U.S. Department of Energy.

**FPAE074—Beam Parameter Measurement and Control at the SNS Target**

*Michael Plum, M. Holding, Tom McManamy (ORNL/SNS)*

The spallation neutron production target at the SNS facility is designed for 1.4 MW beam power. Both beam position and profile must be carefully controlled within narrow margins to avoid damage to the target. The position must be within 2 mm of the target center, and 90% of the beam must be within the nominal 70 mm x 200 mm spot size, without exceeding 0.18 A/m^2 peak beam current density. This is a challenging problem, since most of the diagnostics are 9 m upstream of the target, and because the high beam power limits the lifetime of intercepting diagnostics. Our design includes a thermocouple halo monitor approximately 2 m upstream of the target face, and a beam position monitor, an insertable harp profile monitor, and a beam shape monitor approximately 9 m upstream. In this paper we will discuss our strategy to commission the beam delivery system and to meet target requirements during nominal operation.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**FPAE075—Radiation Damage to the Elements of the SIS300 Dipoles**

*Edil Mustafin, Juris Kaugerts, Gebhard Moritz, Gertrud Walter (GSI), Ludmila Latysheva, Nikolai Sobolevskiy (RAS/INR)*

Radiation damage to various elements of the cosine-theta type dipoles of the SIS300 synchrotron of the FAIR Project was calculated. Among the elements under consideration were the superconducting cable, insulating materials, and high-current by-pass protection diodes. The Monte-Carlo particle transport codes MARS and SHIELD were used to simulate propagation of the lost ions and protons, together with the products of nuclear interactions in the material of the elements. It was found that the lifetime of the protection diodes under irradiation is a more restrictive limit for the tolerable level of beam losses than the occurrence of magnet quenches.

Supported by the grant of the GSI-INTAS Project #03-54-3588.

**FPAE076—The System of Nanosecond 280-keV-He+ Pulsed Beam**

*Pimporn Junphong, Vitoon Ano, Banyat Lekprasert, Dusadee Suwannakachorn, Thiraphat Vilaithong (FNRF), Helmut Wiedemann (SLAC)*

At Fast Neutron Research Facility,the 150 kV-pulseds neutron generator is being upgraded to produce a 280-keV-pulsed-He beam for time-of-flight Rutherford backscattering spectrometry. It involves replacing the existing beam line elements by a multicusp ion source, a 400-kV accelerating tube, 45o-double focusing dipole magnet and quadrupole lens. The Multicusp ion source is a compact filament-driven of 2.6 cm in diameter and 8 cm in length. The current extracted is 20.4 μA with 13 kV of extraction voltage and 8.8 kV of Einzel lens voltage. The beam emittance has been found to vary between 6-12 mm mrad. The beam transport system has to be redesigned based on the new elements. The important part of a good pulsed beam depends on the pulsing system. The two main parts are the chopper and buncher. An optimized geometry for the 280 keV pulsed helium ion beam will be presented and discussed. The PARMELA code has been used to optimize the space charge effect, resulting in pulse width of less than 2 ns at a target. The calculated distance from a buncher to the target is 4.6 m. Effects of energy spread and phase angle between chopper and buncher have been included in the optimization of the bunch length.

We would like to acknowledge the support of the Thailand Research Fund, the National Research Council of Thailand, the Thai Royal Golden Jubilee Scholarship Program, the Faculty of Science, and the Graduate School of Chiang Mai University.

**FPAE077—LSP Simulations of the Neutralized Drift Compression Experiment**
*Carsten Hilmar Thoma, Dale Welch (ATK-MR), Shmuel Eylon, Enrique Henestroza, Prabir Kumar Roy, Simon Yu (LBNL), Erik P. Gilson (PPPL)*
The Neutralized Drift Compression Experiment (NDCX) at Lawrence Berkeley National Laboratory involves the longitudinal compression of a singly-stripped K ion beam with a mean energy of 250 keV in a meter long plasma. We present simulation results of compression of the NDCX beam using the PIC code LSP. The NDCX beam encounters an acceleration gap with a time-dependent voltage that decelerates the front and accelerates the tail of a 500 ns pulse which is to be compressed 110 cm downstream. The simulations model both ideal and experimental voltage waveforms. Results show good longitudinal compression without significant emittance growth.

Work supported by the VNL for HIF through PPPL and LBNL.

**Poster Session FPAP—Two-Stream Instabilities and Collective Processes**
**Park Concourse, 8:30-12:20**

**FPAP001—Electron Cloud Build-Up and Instability Study for DAFNE**
*Cristina Vaccarezza, Roberto Cimino, Alessandro Drago, Mikhail Zobov (INFN/LNF), Giulia Bellodi (CCLRC/RAL/ASTeC), Daniel Schulte, Frank Zimmermann (CERN), Giovanni Rumolo (GSI), Kazuhito Ohmi (KEK), Mauro Torino Francesco Pivi (SLAC)*
After the first experimental observations compatible with the presence of the electron cloud effect in the DAFNE positron ring, a more systematic study has been performed regarding the e-cloud build-up and related instability. The measured field map of the magnetic field has been taken into account in the simulation for elements present in the four 10 m long bending sections, representing 40% of the whole positron ring. The simulation results obtained with different codes are presented and compared with the recent experimental observations performed on the beam instabilities and the vacuum behavior of the positron ring.

**FPAP002—A Synchrotron Radiation Study on Photon Reflectivity from Al Vacuum Chamber of DAFNE and its Relevance to E-Cloud Simulations**
*Cristina Vaccarezza, Roberto Cimino (INFN/LNF), Angelo Giglia, Nicola Mahne (ELETTRA), Stefano Nannarone (UNIMORE)*
After the first experimental observations compatible with the presence of the electron-cloud effect in the DAFNE positron ring, an experimental campaign has been started to measure realistic parameters to be used in the simulation codes. Here we present a synchrotron radiation experiment on the photon reflectivity from the actual Al vacuum chamber of DAFNE (same material, roughness and surface cleaning as the one used to manufacture the ring) in the same energy range of photons produced by the accelerator itself. The derived experimental parameter has than been included in the e-cloud simulation codes and the obtained results confirm the relevance of the detailed knowledge of the input parameter to obtain reliable e-cloud simulations.

**FPAP003—Simulation Study of the Electron Cloud Instability in SuperKEKB**
*Hitoshi Fukuma (KEK), Lanfa Wang (BNL)*
The electron-cloud instability (ECI), especially a beam blowup caused by the single-bunch instability, is one of the most important issues faced at existing B factories. In SuperKEKB which is an upgrade plan of the KEK B factory, a positron beam will be stored in the high energy ring after LINAC upgrade to mitigate the ECI and ante-chambers will be effective to reduce the number of electrons. Nevertheless the ECI might be an issue of SuperKEKB because a large beam current of 4.1A will be stored with a short bunch spacing of 2ns. We performed a simulation of the cloud buildup by a program CLOUDLAND. The average electron density and the electron density at the center of a chamber were calculated both in drift space and in various magnetic fields. The result shows that a solenoid field is very effective for reducing the electron density. The simulated electron density will be compared with a threshold electron density of the strong head-tail instability.

**FPAP004—Simulation Analysis of Head-Tail Motion Caused by Electron Cloud**
*Kazuhito Ohmi, John Walter Flanagan (KEK)*
Synchro-beta side band caused by electron cloud instability has been observed at KEK-B factory. The side-band appears between $•_‹+•_s$ and $•_‹+2•_s$ above the threshold of beam size blow up and disappear by applying solenoid field. The side-band is an evidence of strong head-tail instability caused by electron cloud. The side-band is characterized by positive shift, $+1-2•_s$, while general strong head-tail instabilities give frequency with negative shift $•_beta-•_s$. We study the synchro-beta spectrum using a code, PEHTS, which simulates single bunch electron cloud instability.

**FPAP005—Coupled Bunch Instability Caused by Electron Cloud**
*Kazuhito Ohmi, Su Su Win (KEK)*
Coupled bunch instability caused by electron cloud has been observed in some positron storage ring. We discuss the mode spectrum of the coupled bunch instability due to electrons moving in drift space, weak solenoid field and strong bending field. The mode spectrum of the instability is reflected by the electron motion: that is, we understand global characteristics of elecron motion from the mode spectrum.

**FPAP006—Suppression of Electron Cloud Build-Up with TiN Coating in J-PARC**
*Takeshi Toyama, Susumu Igarashi, Takako Miura, Kazuhito Ohmi (KEK)*
Simulation predicts electron clouds might occur and cause beam instability if no care were to be made in synchrotrons of J-PARC. Among some remedies for electron build-up, TiN coating inside the vacuum chambers of the synchrotrons is considered to be very effective. To confirm suppression of electron cloud build-up with the TiN coating that will be adopted in J-PARC, an experiment is going on at the KEK 12 GeV PS. Alumina ceramics pipe without TiN coating was installed in the electron-sweeping detector, and electron cloud build-up has been measured with a proton beam. Then another alumina ceramic pipe with TiN coating will be set. The result in this case will be reported. Impact of this method on the J-PARC synchrotrons will be discussed.

**FPAP007—Measurement of the Electron Cloud Density Around the Beam**
*Ken-ichi Kanazawa, Hitoshi Fukuma, Hiromi Hisamatsu, Yusuke Suetsugu (KEK)*
Under the present operating condition of KEKB LER, most high energy electrons in the electron cloud that hit the chamber wall are produced near the circulating bunch by the single kick. By separating the high energy component of the electron current monitored at a pump port of a vacuum chamber, the density of the electron cloud near the beam is estimated. The estimated density is close to the order of magnitude expected from simulation. At present there still remains an ambiguity that comes from the detector efficiency in the measurement and the assumed secondary electron yield in the simulation.

**FPAP008—Extension of Impedance Concept as Applied to Electron-Cloud Instability**
*Evgueni Perevedentsev (BINP SB RAS)*
Conventional formalism for the coherent beam stability evaluation can be modified so as to account for the cloud-specific differences from the standard description of the beam-environment interaction. Extension of the wake-and-impedance approach aimed at applying to the two-stream problems is presented. It may prove useful for both analytical work and simulation.

**FPAP009—Effects of Localization in Models of Fusion/ Energy** Confinement in Plasma/Beam Physics in Vlasov Framework
*Michael G. Zeitlin, Antonina N. Fedorova (RAS/IPME)*
A fast and efficient numerical-analytical approach is proposed for modeling the complex (nonlinear) collective behaviour in the various forms of the generalized Vlasov-Poisson/Maxwell systems. We compare our approach with previous ones, e.g. nonlinear delta F simulation and PIC modeling and demonstrate its advantages. As the particular limiting cases of our construction we have standard KV and Klimontovich distributions. The solutions are represented via the multiscale decomposition in nonlinear localized eigenmodes, which corresponds to the full multiresolution expansion in all underlying hidden phase space scales. In contrast with different approaches we do not use perturbation technique or linearization procedures. Numerical modeling shows the creation of different internal structures from localized modes, which are related to (meta)stable/unstable type of behaviour and the corresponding patterns (waveletons) formation. Reduced algebraical structures provide the computable control of the (possible/existing) types of behaviour. Controllable (meta) stable waveleton (localized state) configuration represents a reasonable approximation for the realizable confinement state.*
*A. Fedorova, M. Zeitlin, Classical and Quantum Ensembles via Multiresolution. I. BBGKY Hierarchy; II. Wigner Ensembles; arXiv: quant-ph/0406009, 0406010; NIMA, 534A, 1-2, 2004, 309-313, 314-318, 2004 and papers on http://www.ipme.ru/zeitlin.html.

**FPAP010—Collective Dynamics of High-Brightness Beams in RMS Framework**
*Michael G. Zeitlin, Antonina N. Fedorova (RAS/IPME)*
We consider a few reductions from nonlinear Vlasov-like equations to rms/rate equations for second moments related quantities (with or without additional equations or/and constraints for energy and emittance). Our analysis is based on variational approach and adequate choice of reasonable (localized) bases provided us with calculations of reasonable cost. We consider rational (in dynamical variables) approximations with possible related constraint equations. It allows to control contributions to spectrum from each scale of underlying multiscales and represent solutions via multiscale nonlinear eigenmodes expansions. Our approach provides the best convergence properties of the corresponding exact representations and does not use perturbations or/and linearization procedures. Reduced variational-algebraical systems provide the reasonable algebraical control and (in principle) can help to transform the calculable configurations into the reliazable ones, the most important from them are, of course, (meta) stable and localized in the whole phase space.*
*A. Fedorova, M. Zeitlin, Classical and Quantum Ensembles via Multiresolution. I. BBGKY Hierarchy; II. Wigner Ensembles; arXiv: quant-ph/0406009, 0406010; NIMA, 534A, 1-2, 2004, 309-313, 314-318, 2004 and papers on http://www.ipme.ru/zeitlin.html.

**FPAP011—New Vortices in Axisymmetric Beams in Inhomogeneous Magnetic Field**
*Yurii Golub (MRTI RAS)*
We analyzed localized vortices in non-neutral inhomogeneous by density and velocity electron beams propagating in vacuum along the inhomogeneous external magnetic field. These vortices distinguish from vortices, which used in Golub Yu.Ya. et al. and Golub Yu.Ya. because of inhomogeneous external magnetic field. Also new types of vortex are obtained by new solution method of nonlinear equations.** The new method is development of a method described in Golub Yu.Ya. That method distinguish from standard Larichev-Reznik or Reznik method, which used in Golub Yu.Ya. et al. It has been found new expression for electric field potential of vortex in a wave frame. The expression is axisymmetric in a wave frame. New vortices are new solitons in the inhomogeneous external magnetic field.
*Golub Yu.Ya. et al., in Nonlinear world: IV Intern. Workshop on Nonlin. and Turbul. Proc. in Phys., (ed. by V.G. Bar'yakhtar et al.) World Scientific Publishing Co. Pte. Ltd., Singapore, 1990, vol. 2, p. 857. **Golub Yu.Ya., Proceedings of EPAC 2002, Paris, France, p. 1253.

**FPAP012—The Effect of Inhomogeneous Magnetic Field on Budker-Chirikov Instability**
*Yurii Golub (MRTI RAS)*
The two-beams electron - ion system consists of a nonrelativistic ion beam propagating co-axially with a high-current relativistic electron beam in a longitudinal inhomogeneous magnetic field. The effect of the longitudinal inhomogeneous magnetic field on instability Budker-Chirikov (BCI) in the system is investigated by the method of a numerical simulation in terms of the kinetic description of both beams. The investigations are development of investigations in*,**. Is shown, when the inhomogeneity magnetic field results in the decreasing of an increment of instability Budker-Chirikov and the increasing of length of propagation of a electron beam. Also is shown, when take place the opposite result.
*Yu.Ya. Golub, N.E.Rozanov, Nuclear Instruments and Methods in Physics Research, A358 (1995) 479. **Yu.Ya. Golub, Proceedings of EPAC 2002, Paris, France, p. 1497.

**FPAP013—Emittance Growth Caused by Electron Cloud Below the "Fast TMCI" Threshold: Numerical Noise or True Physics?**
*Elena Benedetto, Frank Zimmermann (CERN), Giuliano Franchetti (GSI), Kazuhito Ohmi (KEK)*
Simulations show a persisting slow emittance growth for electron cloud densities below the threshold of the fast Transverse Mode Coupling type instability, which could prove important for proton beams with negligible radiation damping, such as in the LHC. We report on a variety of studies performed

to quantify the contributions to the simulated emittance growth from numerical noise in the PIC module and from an artificial resonance excitation due to the finite number of kicks per turn applied for modeling the cloud-bunch interaction.

**FPAP014—Electron Cloud Measurements in the SPS in 2004**
*Daniel Schulte, Gianluigi Arduini, Vincent Baglin, José Miguel Jimenez, Frank Zimmermann (CERN)*
Novel measurements of the electron cloud have been performed in the SPS in 2004. In this machine the beam consists of a number of short bunch trains. By varying the distance between these trains it is possible to witness the survival of the electrons after the bunch passage. In this paper, results from simulations and experiments are compared.

**FPAP015—Electron and Gas Effects on Intense, Space-Charge Dominated Ion Beams in Magnetic Quadrupoles: Comparison of Experiments and Simulations**
*Peter Seidl, David Baca, Frank Bieniosek, Jean-Luc Vay (LBNL), Ronald Cohen, Alex Friedman, David Grote, Michel Kireeff Covo, Steven Mocko Lund, Arthur Molvik (LLNL)*
Accelerators for inertial fusion energy, high-energy density physics and other high intensity applications have an economic incentive to minimize the clearance between the beam edge and the aperture wall. This increases the risk from electron clouds and gas desorbed from walls. Using the High Current Experiment at LBNL, we have measured the beam (0.18 A, 1 MeV K+) distribution upstream and downstream of a short lattice of magnetic quadrupoles where the 2•rms beam size is =50% of the quadrupole aperture, and the generalized perveance is ˜10^-3. Between magnets, the transverse beam distribution is also imaged. The beam potential is 1-2 kV, large enough to trap electrons produced by, for example, K+ - gas collisions. Gas and electron effects are intentionally induced by varying gas pressure and the bias of e- controlling electrodes.* The measurements are compared to WARP PIC simulations that include the self-consistent tracking of electrons and ions.**
*A. W. Molvik et al., this conference. **J-L Vay et al., this conference.

This work was performed under the auspices of the U.S. Department of Energy by University of California, LLNL and LBNL under contracts W-7405-Eng-48, and DE-AC03-76F00098.

**FPAP016—Initial Self-Consistent 3-D Electron-Cloud Simulations of LHC Beam with the Code WARP+POSINST**
*Jean-Luc Vay (LBNL), Miguel Furman (LBNL/AFR), Ronald Cohen, Alex Friedman, David Grote (LLNL)*
We present initial results from the self-consistent beam-cloud dynamics simulations of a sample LHC beam, using a newly developed set of modeling capability based on a merger of the three-dimensional parallel Particle-In-Cell accelerator code WARP and the electron cloud code POSINST.*,** Although the storage ring model we use as a test bed to contain the beam is much simpler and shorter than the LHC, its lattice elements are realistically modeled, as is the beam and the electron cloud dynamics. The simulated mechanisms for generation and absorption of the electrons at the walls are based on previously validated models available in POSINST.***
*J.-L. Vay, these proceedings. **J.-L. Vay, Proc. "ECLOUD04," Napa (California), 2004. ***M.T.F. Pivi and M.A. Furman, Phys. Rev. STAB, PRSTAB/v6/i3/e034201.

This work was performed under the auspices of the U.S. Department of Energy by University of California, LLNL and LBNL under contracts W-7405-Eng-48, and DE-AC03-76F00098.

**FPAP017—Luminosity Optimization With Offset, Crossing Angle, and Distortion**
*Juhao Wu, Tor Raubenheimer (SLAC)*
In a linear collider, sources of beam jitter due to kicker noise, quadrupole vibration and long-range transverse wakefields will lead to beam offsets and tilts at the Intersection Point (IP). In addition, sources of emittance dilution such as short-range transverse wakefields or dispersive errors will lead to internal beam distortions. When the IP disruption parameter is large, these beam imperfections will be amplified by a single bunch kink instability which will lead to luminosity loss. In this paper, we study the luminosity loss and then the optimization required to cancel the luminosity loss first analytically and then with simulation.

Work is supported by the U.S. Department of Energy under contract DE-AC02-76SF00515.

**FPAP018—Luminosity Loss Due to Beam Distortion and the Beam-Beam Instability**
*Juhao Wu, Alex Chao, Tor Raubenheimer, Andrei Seryi, Christopher Koerner Sramek (SLAC)*
In a linear collider, sources of emittance dilution such as transverse wakefields or dispersive errors will couple the vertical phase space to the longitudinal position within the beam (the so-called 'banana effect'). When the Intersection Point (IP) disruption parameter is large, these beam distortions will be amplified by a single bunch kink instability which will lead to luminosity loss. We study this phenomena both analytically using linear theory and via numerical simulation. In particular, we examine the dependence of the luminosity loss on the wavelength of the beam distortions and the disruption parameter. This analysis may prove useful when optimizing the vertical disruption parameter for luminosity operation with given beam distortions.

Work is supported by the U.S. Department of Energy under contract DE-AC02-76SF00515.

**FPAP019—Simulation of the Electron-Cloud in the SPS with Different Beam Spacing Configurations**
*Mauro Torino Francesco Pivi (SLAC), Miguel Furman (LBNL/AFR)*
We present an update of computer simulation results for some features of the electron cloud at the Super Proton Synchrotron (SPS) at CERN when running with the Large Hadron Collider (LHC) beam configurations. The SPS will be the injector for the LHC. During SPS machine development studies with LHC-type beams, an electron cloud has been observed and subsequently measured in many dedicated experiments. The electron-cloud effect (ECE) is of considerable interest for the LHC, the main issue being the magnitude of the power deposition by the electrons on the vacuum chamber beam screen. A great deal of simulation work has been already devoted to estimating the power deposition under various assumed conditions. In this paper, we focus our SPS simulations on the possibility of operating the accelerators with different bunch and batch spacing configurations aimed at reducing the electron cloud effect in the LHC.

Work supported by the U.S. DOE under contracts DE-AC02-76SF00515 and DE-AC02-76SF00098.

**FPAP020—Close Coupling R-Matrix Approach to Simulating Ion-Atom Collisions for Accelerator Applications**
*Peter Stoltz, Andrew Prideaux (Tech-X)*
We have implemented an R-matrix close coupling approach to calculate capture, ionization, stripping and excitation cross-sections for 0.5 to 8.0 MeV K+ incident on Ar. This is relevant to the High Current Experiment at Lawrence Berkley National Laboratory. These cross sections are used to model accelerator particle dynamics where background gasses can interfere with beam quality. This code is a semi-classical approach that uses quantum mechanics to describe the particle interactions and uses classical mechanics to describe the nuclei trajectories. We compare a hydrogenic approximation for K+ with a pseudo-potential approach. Further we are developing a variational approach to quickly determine the best pseudo-potential parameters. Since many R-Matrix computationalists use this pseudo-potential approach, this approach will be useful for helping generate cross sections for any collision system.

Funded by DOE under grant # DE-FG02-02ER83553.

**FPAP021—A Cross-Platform Numerical Model of Ion-Wall Collisions**
*Seth Andrew Veitzer, Peter Stoltz (Tech-X), Jean-Luc Vay (LBNL), Ronald Cohen, Arthur Molvik (LLNL)*
Ion collisions with beam-pipe walls is a significant source of secondary electron clouds and desorbed neutral gasses in particle accelerators. Ions may reflect from beam-pipe walls and undergo further collisions downstream. These effects can cause beam degradation and are expected to be problematic in the design of heavy ion accelerators. The well-known SRIM code provides physically-based monte carlo simulations of ion-wall collisions. However, it is difficult to interface SRIM with high-performance simulation codes. We present details on the development of a package of Python modules which integrate the simulation of ion-wall interactions at grazing incidences with the high-performance particle-in-cell and electron cloud codes WARP and POSINST. This software package, called GriPY, calculates reflected angles and energies of ions which strike beam-pipe walls at grazing incidences, based upon interpolation of monte carlo statistics generated by benchmark simulations run in SRIM for a variety of relevant incident angles and energies. We present here solutions for 1.8 MeV K+ ions and 1 Gev protons incident on stainless steel.

**FPAP022—Long Time Simulation of LHC Beam Propagation in Electron Clouds**
*Bing Feng, Ali Feiz Ghalam, Tom Katsouleas (USC), Elena Benedetto (CERN), Viktor K. Decyk, Warren Mori (UCLA)*
In this poster, the simulation results of single-bunch instabilities caused by interaction of a proton beam with an electron cloud for the Large Hadron Collider (LHC) using the code QUICKPIC are presented. Two new results are obtained: 1) the effect of the space charge of the beam on itself is tested, and 2) modeling time is extended by an order of magnitude (from 50ms to 500ms of beam circulation time). Compared to the results without space charge, the effect of space charge only changes the results by a few percent. The longer runs indicate that the long term growth of electron cloud instability of the LHC beam cannot be obtained by extrapolating the results of short runs. Finally, the prospects for developing new algorithms to extend the length of simulations will be presented.

**FPAP023—Electron Trapping and Sweeping in Quadrupole Magnet**
*Lanfa Wang, Jie Wei (BNL)*
The main mechanism causing electron cloud inside a quadrupole magnet is electron trapping instead of multipacing. Electron trapping with short bunch ring was found in our previous study. This paper studies the electron trapping and sweeping inside a quadrupole magnet in both long and short bunch rings.

**FPAP024—Electron Cloud at the SNS Collimator Region**
*Lanfa Wang, Hsiao-Chaun Hseuh, Yong Yung Lee, Deepak Raparia, Jie Wei (BNL), Sarah M. Cousineau (ORNL/SNS)*
The beam loss along the Spallation Neutron Source's (SNS's) accumulator ring is mainly located at the collimator region. From the ORBIT simulation, the peak power deposition at the three collimators is about 500, 350 and 240 W/m, respectively. Therefore, a sizeable number of electrons may be accumulated at this region due to the great beam loss. This paper simulated the electron cloud at the collimator region and the possible remedy.

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**FPAP025—The Threshold Condition for the Quadrupole Mode in the Two-Stream EP Model**
*Yoichi Sato, Jeffrey Alan Holmes (ORNL/SNS), Shyh-Yuan Lee (IUCF), Robert James Macek (LANL/LANSCE)*
The analytically solvable two-stream model*,** has explained many features of the electron-proton instability. In the model, we derive different threshold conditions from the centroid oscillation giving dipole mode and the envelope oscillation giving quadrupole mode. We compare these conditions with typical parameters of SNS and PSR rings, and discuss an effective instability feedback system.
*D. Neuffer, E. Colton, D. Fitzgerald, T. Hardek, R. Hutson, R. Macek, M. Plum, H. Thiessen and T.S. Wang, NIM A321, 1-12 (1992). **D. G. Koshkarev and P. R. Zenkevich, Part. Accel. 3 (1972) 1.

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**FPAP026—Multispecies Weibel and Two-Stream Instabilities for Intense Ion Beam Propagation Through Background Plasma**
*Ronald Davidson, Igor Kaganovich, Hong Qin, Edward Startsev (PPPL)*
In application of heavy ion beams to high energy density physics and fusion, background plasma is utilized to neutralize the beam space charge during drift compression and/or final focus of the ion beam. It is important to minimize the deleterious effects of collective instabilities on beam quality associated with beam-plasma interactions. Plasma electrons tend to neutralize both the space charge and current of the beam ions. It is shown that the presence of the return current greatly modifies the electromagnetic Weibel instability (also called the filamentation instability), i.e., the growth rate of the filamentation instability greatly increases if the background ions are much lighter than the beam ions and the plasma density is comparable to the ion beam density. This may preclude using underdense plasma of light gases in heavy ion beam applications. It is also shown that the return current may be subject to the fast electrostatic two-stream instability.

Research supported by the U.S. Department of Energy.

**FPAP027—Hybrid Quantum Mechanical–Quasi-Classical Model for Evaluating Ionization and Stripping Cross Sections in Atom-Ion Collisions**
*Igor Kaganovich, Ronald Davidson, Edward Startsev (PPPL), Steven Kecskemeti (UW-Madison/PD), Amitai Bin-Nun (University of Pittsburgh)*
Ion-atom ionization cross sections are needed in many applications employing the propagation of fast ions through matter. When experimental data or full-scale theoretical calculations are non-existent, approximate methods must be used. The most robust and easy-to-use approximations include the Born approximation of quantum mechanics and the quasi-classical approach utilizing classical mechanics together with the Bohr-Sommerfeld quantization rule.* The simplest method to extend the validity of both approaches is to combine them, i.e., use the two different approaches but only for the regions of impact parameters in which they are valid, and sum the results to obtain the total cross section. We have recently investigated theoretically and experimentally the stripping of more than 18 different pairs of projectile and target atoms in the range of 3-38 MeV/amu to study the range of validity of various approximations. The results of the modified approach agree better with the experimental data than either the Born approximation or the quasi-classical approach, applied separately.
*I. D. Kaganovich et al., "Formulary and scaling cross sections for ion-atom impact ionization," http://arxiv.org/abs/physics/0407140.

Research supported by the U.S. Department of Energy.

**FPAP028—Ion Beam Pulse Interaction with Background Plasma in a Solenoidal Magnetic Field**
*Igor Kaganovich, Ronald Davidson, Edward Startsev (PPPL)*
Background plasma can be used as an effective neutralization scheme to transport and compress intense ion beam pulses, and the application of a solenoidal magnetic field allows additional control and focusing of the beam pulse. Ion beam pulse propagation in a background plasma immersed in an applied solenoidal magnetic field has been studied both analytically and numerically with three different particle-in-cell codes (LSP, OOPIC-Pro and EDPIC) to cross-check the validity of the results. Very good charge and current neutralization is observed for high values of the solenoidal magnetic field.* However, for intermediate values of the solenoidal magnetic field, current neutralization is a complex process, and a sizable self-magnetic field is generated at the head of the beam. Collective wave excitations are also generated ahead of the beam pulse.
*I. D. Kaganovich, E. A. Startsev and R. C. Davidson, Nuclear Instruments and Methods in Physics Research A, in press (2004).

Research supported by the U.S. Department of Energy.

**FPAP029—Nonlinear Delta-f Particle Simulations of Collective Effects in High-Intensity 3D Bunched Beams**
*Hong Qin, Ronald Davidson, Edward Startsev (PPPL)*
The collective effects in high-intensity 3D bunched beams are described self-consistently by the nonlinear Vlasov-Maxwell equations.* The nonlinear delta-f method,** a particle simulation method for solving the nonlinear Vlasov-Maxwell equations, is being used to study the collective effects in high-intensity 3D bunched beams. The delta-f method, as a nonlinear perturbative scheme, splits the distribution function into equilibrium and perturbed parts. The perturbed distribution function is represented as a weighted summation over discrete particles, where the particle orbits are advanced by equations of motion in the focusing field and self-consistent fields, and the particle weights are advanced by the coupling between the perturbed fields and the zero-order distribution function. The nonlinear delta-f method exhibits minimal noise and accuracy problems in comparison with standard particle-in-cell simulations. A self-consistent 3D kinetic equilibrium is first established for high intensity bunched beams. Then, the collective excitations of the equilibrium are systematically investigated using the nonlinear delta-f method implemented in the Beam Equilibrium Stability and Transport (BEST) code.
*R.C. Davidson and H. Qin, Physics of Intense Charged Particle Beams in High Energy Accelerators (World Scientific, 2001).
**H. Qin, Physics of Plasmas 10, 2078 (2003).

Research supported by the U.S. Department of Energy.

**FPAP030—Initial Experience with the Self-Consistent 3D Electron-Cloud Code PARSEC**
*Andreas Adelmann (PSI), Miguel Furman (LBNL/AFR)*
We present simulation results obtained with the code PARSEC, describing the passage of a proton beam through a simplified lattice. Both the beam and the electrons respond dynamically to each other. Space-charge effects are fully included by means of a parallel Poisson solver. The mechanism for the generation and absorption of electrons at the vacuum chamber walls is based on previously validated simulations. Results were obtained form runs on a massively parallel computer at NERSC.

Supported by PSI and by the U.S. DOE under contract DE-AC03-76SF00098.

**FPAP031—Model of Electron Cloud Build Up with Secondary Ion-Electron Emission as a Source of Delay Electrons**
*Vadim Dudnikov (BTG)*
For explanation of anomaly long electron cloud surviving after the gap between bunches it was proposed beam particle leaking to the gap and anomaly high reflectivity of low energy electrons in collision with pipe wall. We will attract an attention to some other possibilities of efficient electron generation in the high vacuum environment and delay electron generation after gap between bunches. Model of electron cloud build up with secondary ion-electron emission as a source of delay electrons is presented and discussed. This model is used for explanation of bunched beam instability in Los Alamos PSR, prediction of e-cloud generation in SNS, and can be important for pressure rise in cold sections of RHIC. A fast desorbtion by ion of physically adsorbed molecules can explain a "first pulse Instability" observed in LA PSR

**FPAP032—Time-of-Flight Plasma-Neutralized Drift Compression of Heavy Ion Beams for High Energy Density Physics**
*David Rose, Thomas C. Genoni, Dale Welch (ATK-MR), Simon Yu (LBNL), John J. Barnard (LLNL)*
The possibility of using heavy ion beams to drive matter to conditions suitable for high energy density physics experiments is being assessed. One scheme under consideration uses time-of-flight longitudinal compression with radial focusing of a heavy ion beam in a magnetized background plasma. Space charge stagnation of the final beam bunch (as envisioned in conventional space-charge-dominated transport schemes) does not occur during neutralized transport; however because of the absence of space charge, shorter pulses can be achieved. The final pulse shape at the target can be programmed by an applied velocity tilt. Two- and three-dimensional particle-in-cell (PIC) simulations have been used to study the beam compression and energy density on target. Here, a 10-cm radius, 200 MeV Ne+1 ion beam with initial currents of ~1 kA is transported and focused to a 1 mm radius, with pulse compression ratios up to

600. The impact of the growth and saturation of the two-stream instability on pulse compression is assessed. A detailed analysis of the two-stream growth is compared directly with the PIC simulations.

This work is supported by the U.S. Department of Energy through the Princeton Plasma Physics Laboratory and the Lawrence Berkeley National Laboratory.

**FPAP033—Beam Energy Scaling of Secondary Electron Yield from K+ Ions Impact on Stainless Steel Surfaces**
*Michel Kireeff Covo, John J. Barnard, Ronald Cohen, Alex Friedman, David Grote, Arthur Molvik, Glen Westenskow (LLNL), David Baca, Frank Bieniosek, C. M. Celata, Joe W. Kwan, Steven Mocko Lund, Peter Seidl, Jean-Luc Vay (LBNL), Jasmina L. Vujic (UCB)*
The cost of accelerators for heavy-ion inertial fusion energy (HIF) can be reduced by using the smallest possible clearance between the beam and the wall from the beamline. This increases beam loss to the walls, generating secondary electrons that could be trapped by beam space charge potential into an "electron cloud," which can cause degradation or loss of the ion beam. In order to understand the physical mechanism of production of secondary electrons we have measured impact of K+ ions with energies up to 400 KeV on stainless steel surfaces near grazing incidence, using the ion source test stand (STS-500) at LLNL. The secondary electron yield will be discussed and compared with experimental measurements from 1 MeV K+ ions in the High-Current Experiment at LBNL.*
*A.W. Molvik et al., PRST-AB 7, 093202 (2004).

This work was performed under the auspices of the U.S. Department of Energy by University of California, LLNL under contract No. W-7405-Eng-48, and by LBNL under Contract DE-AC03-76F00098.

**FPAP034—Space Charge Induced Transport Limits in Periodic Focusing Channels**
*Steven Mocko Lund (LLNL), Sugreev Chawla (UCB)*
It has been observed in both experiment and particle in cell simulations that space-charge-dominated beams suffer strong emittance growth in alternating gradient quadrupole transport channels when the undepressed phase advance sigma_0 increases beyond about 80 degrees per lattice period. Transport systems have long been designed to respect this phase advance limit but no theory has been proposed to date to explain the the cause of the limit. Here we propose a mechanism to parametrically explain the transport limit as being due to classes of halo particle orbits moving close to the beam edge in phase-space when sigma_0 increases beyond 80 degrees. A finite beam edge and/or perturbation acting on an edge particle can then act to move edge particles to large amplitude and lead to large increases in beam phase space area, lost particles, and degraded transport. A core particle model for a uniform density elliptical beam in a periodic focusing lattice was written and is applied to parametrically analyze this process for both periodic alternating gradient quadrupole and solenoidal transport lattices. Self-consistent particle in cell simulations are also carried out to support results.

Research performed under the auspices of the US DOE by the University of California at LLNL and LBNL under contract Nos. W-7405-Eng-48 and DE-AC03-76SF00098.

**FPAP035—A Numerical Study of Ion Hose in the DARHT-II Downstream Transport**
*James F. McCarrick (LLNL), Jonathan J. Witcher (UCD)*
The second axis of the DARHT accelerator facility at Los Alamos carves multiple short pulses from a two microsecond long "macropulse" of 2 kA and 18.4 MeV. Upstream of where the short pulses are created, the electron beam can produce enough ionization of the residual gas in the vacuum system that the ion hose instability can become problematic. A particular concern lies in the transport region downstream of the accelerator, where the macropulse traverses some fourteen meters of beamline without the benefit of continuous magnetic focusing. A series of numerical simulations have been performed to study the beam behavior in this region. Results of this study, including the effect of different types of perturbations in the background pressure and the influence of the beam profile, will be presented.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

**FPAP036—Beam Transport in a Compact Dielectric Wall Induction Accelerator System for Pulsed Radiography**
*James F. McCarrick, George Caporaso, Yu-Jiuan Chen (LLNL)*
Using dielectric wall accelerator technology, we are developing a compact induction accelerator system primarily intended for pulsed radiography. The accelerator would provide a 2-kA beam with an energy of 8 MeV, for a 20-30 ns flat-top. The design goal is to generate a 2-mm diameter, 10-rad x-ray source. We have a physics design of the system from the injector to the x-ray converter. We will present the results of injector modeling and PIC simulations of beam transport. We will also discuss the predicted time integrated spot and the on-axis x-ray dose.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

## Poster Session FPAT—Controls and Computing & Pulsed-Power and High-Intensity Beams/Induction Linacs
## Meeting Room 200 A-C, 8:30-12:20

**FPAT001—Mathematical Model for Beam Dynamics Optimization in RFQ Systems**
*Alexander D. Ovsyannikov (St. Petersburg State University)*
In the area of ion accelerators with low energy, the RFQ linear accelerator becomes more and more important. New approach for optimization of RFQ structures was suggested in paper.* In this paper new set of functionals is considered. It allows to solve problems of maximazing of longitudinal aceptance, maximazing average rate of acceleration, minimazing length of structure and optimazing output beam parameters. For suggested functionals corresponding algorithms, based on optimal control theory methods, were developed and tested.
* A. D. Ovsyannikov, B. I. Bondarev, A. P.Durkin, "New Mathematical Optimization Models for RFQ Structures," Proceedings of PAC99, New York, USA, pp. 2808-2810.

**FPAT002—Automatic Steering of the CLIC Test Facility (CTF3) Linac**
*Ronen David Lifshitz, Daniel Schulte (CERN, Geneva)*
A system for automatic beam steering has been implemented at the CTF3 linear accelerator. Beam position readings are logged while corrector magnet strengths are scanned over a given range,

thus giving a steering response measurement. Assuming linearity, a response matrix is constructed and used to automatically optimize the beam trajectory along the linac. Using a simple BPM-reading minimization for trajectory correction, this system has been tested in the 2004 CTF3 summer run. Although not in routine operation, it has already proved useful as a tool for the machine setup and operation. In this paper, the automatic steering system for the CTF3 linac is introduced, trajectory correction results are presented, and the agreement with a computer model of the machine is discussed.

We acknowledge the support of the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395)

**FPAT003—Joining the RHIC Online and Offline Models**
*Nikolay Malitsky, Kevin A. Brown, Nicholas D'Imperio, Alexei V. Fedotov, Alfredo U. Luccio, Fulvia C. Pilat, Vadim Ptitsyn, Todd Satogata, Steven Tepikian, Jie Wei (BNL), Richard Michael Talman (Cornell University)*
The paper presents an interface encompassing the RHIC online ramp model and the UAL offline simulation framework. The resulting consolidated facility aims to minimize the gap between design and operational data, and to facilitate analysis of RHIC performance and future upgrades in an operational context. The interface is based on the Accelerator Description Exchange Format (ADXF), and represents a snapshot of the RHIC online model which is in turn driven by machine setpoints. This approach is also considered as an intermediate step towards integrating the AGS and RHIC modeling environments to produce a unified online and offline AGS model for operations.

Work performed under the auspices of the U.S. Department of Energy.

**FPAT004—Fermilab Booster Ramp Monitor**
*Linda Coney, Gerald Guglielmo (Fermilab), Chandra Lane Jacobs (Duke University), Ami Choi (UCD)*
The Booster is an 8 GeV proton synchrotron, and is a crucial element of the Fermilab accelerator chain. The recent addition of the MiniBooNE and NuMI/MINOS experiments to the Fermilab program has caused Booster beam requests to increase significantly in terms of proton intensity and repetition rate. This heavy use has challenged the capability of this aging machine and created a need for diagnostic tools which allow careful monitoring of Booster device performance. To this end, the Booster Monitor, a Java-based diagnostic tool, has been developed. It allows the recording and display of simultaneous data streams acquired during each 33 ms acceleration ramp of the synchrotron. This provides the first opportunity to gauge performance of the ramped devices, to monitor machine stability, and to rapidly diagnose Booster problems in ways previously not available. In conjunction with a Datalogger program, it is also possible to monitor long term stability of the machine and its components. We will show how the Booster Monitor and Datalogger programs are used to analyze ramped device performance while the Booster provides beam to the MiniBooNE experiment.

**FPAT005—A Betatron Tune Fitting Package for the Tevatron 21.4 MHz Schottky**
*Paul Lebrun, Tanaji Sen, Jianming You, Zongwei Yuan (Fermilab)*
Accurate control of the Betatron tunes and chromaticities is required to optimize the dynamical aperture of any large synchrotron. The Fermilab Tevatron is equipped with two independent Schottky monitors, one operating at 21.4 MHz and the other 1.7 GHz. While the latter one allows us to characterize individual bunches separated by 396 ns, the former one has a larger Q and can give precise tune measurements. A new front-end and related data acquisition for this 21.4 MHz resonator has been installed and commissioned during the FY04 Collider RunII. Output signal are digitized at 100 KHz. Frequency spectra are transfered to dedicated server nodes and fitted in real time. Such frequency spectra are quite complex, due to inherent noise, horizontal/vertical coupling and synchrotron motion. Sophisticated fitting strategies are required. Optimization of this fitting package on relatively powerful commodity computer allows us to report tune and chromaticity measurements at almost 1 Hz. The architecture of the data acquisition system and this fitting package are described and results taken during the FY04 and FY05 runs are presented.

**FPAT006—CHEF: An Interactive Program for Accelerator Optics Calculations**
*Leo Michelotti, Jean-Francois Ostiguy (Fermilab)*
We introduce CHEF, a program built on a "Collaborative Hierarchical Exploratory Framework" for doing optical calculations in accelerator physics. CHEF organizes and shares information between independent components that employ graphical user interfaces for interactive use. Among them are: a browser to display the beamline model's structure; a site viewer to show a line's geometry; phase space windows to oversee development of tracking calculations; a trace window to display the passage of a probe particle through beam position monitors; a plotter for displaying optical functions; a parser which constructs beamline models defined in MAD8 format and allows for interactive editing and debugging of the lattice files. Calculations are carried out by a hierarchy of C++ class libraries, most notably: MXYZPTLK handles automatic differentiation and differential algebra; BEAMLINE contains classes for modeling accelerator components; PHYSICS_TOOLKIT encapsulates specific calculations. Python bindings to these libraries and to CHEF's components, in conjunction with an embedded interpreter, provide a mechanism to extend and customize CHEF's functionality.

Fermilab is operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**FPAT007—The Fermilab Lattice Information Repository**
*Jean-Francois Ostiguy, Michael Kriss, Michele McCusker-Whiting, Leo Michelotti (Fermilab)*
Fermilab is a large accelerator complex with six rings and sixteen transfer beamlines operating in various modes and configurations, subject to modifications, improvements and occasional major redesign. Over the years, it became increasingly obvious that a centralized lattice repository with the ability to track revisions would be of great value. To that end, we evaluated potentially suitable revision systems, either freely available or commercial, and decided that expecting infrequent users to become fully conversant with complex revision system software was neither realistic nor practical. In this paper, we discuss technical aspects of the recently introduced FNAL Accelerator Division's Lattice Repository, whose fully web-based interface hides the complexity of Subversion, a comprehensive open source revision system. In particular we emphasize how the architecture of Subversion was a key ingredient in the technical success of the repository's implementation.

Fermilab is operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy.

**FPAT008—SDA-Based Diagnostic and Analysis Tools for Collider Run II**
*Vaia Papadimitriou, Timofei Borisovich Bolshakov (Fermilab)*
Operating and improving the understanding of the Fermilab Accelerator Complex for the colliding beam experiments requires advanced software methods and tools. The Shot Data Acquisition and Analysis (SDA) has been developed to fulfill this need. Data is stored in a relational database, and is served to programs and users via Web-based tools. Summary tables are systematically generated during and after a store. These tables, the Supertable, and the Recomputed Emittances and Recomputed Intensity tables are discussed here. This information is also accesible in JAS3 (Java Analysis Studio version 3).

Fermilab (Department of Energy).

**FPAT010—Distributed Beam Steering Algorithm Using Optimal Control**
*Christopher K. Allen (LANL), Eugenio Schuster (Lehigh University)*
We present an optimal control strategy for beam steering where the operator can specify a variety of optimality conditions by selecting a parameter set describing an optimally steered beam. Novel approaches here include the ability to base optimality on the beam state throughout the entire beamline, rather than just at BPM locations. Moreover, we also may use the trajectory slope to base our optimality criteria. To achieve this feature we must introduce model dependency. Specifically, we predict the state of the beam from BPM measurements, the set-point of the steering magnets, and a model of beam behavior. The predictions are then used to calculate the optimum setting for steering magnets. The optimal control problem has rich mathematical structure that can be exploited and we cover some topics as they apply to accelerator systems.

Work supported by the U.S. Department of Energy.

**FPAT011—Fast Automated Decoupling at RHIC**
*Joanne Beebe-Wang (BNL)*
Coupling correction is essential for the operational performance of RHIC. The independence of the transverse degrees of freedom makes diagnostics and tune control easier, and it is advantageous to operate an accelerator close to the coupling resonance to minimize nearby nonlinear sidebands. An automated decoupling application has been developed at RHIC for coupling correction during routine operations. The application decouples RHIC globally by minimizing the tune separation through finding the optimal settings of two orthogonal skew quadrupole families. The program provides options of automatic, semi-automatic and manual decoupling operations. It accesses tune information from all RHIC tune measurement systems: the PLL (Phase Lock Loop), the high frequency Schottky system, and the tune meter. It also supplies tune and skew quadrupole scans, finding the minimum tune separation, display the real time results and interface with the RHIC control system. We summarize the capabilities of the decoupling application, and discuss the operational protections incorporated in the program. We also report the decoupling performances with the application during the RHIC 2005 run.

Work performed under the auspices of the U.S. DOE.

**FPAT012—Multivariate Analysis of Tevatron Beam and Luminosity Lifetimes Using the SDA System**
*Aimin Xiao, Timofei Borisovich Bolshakov, Paul Lebrun, Elliott McCrory, Vaia Papadimitriou, Anna Jean Slaughter (Fermilab)*
The purpose of the Shot Data Analysis (SDA) system is to provide summary data on the RunII Collider Accelerator Complex, and provide related software for detailed analyses. In this paper, we discuss such a specific analysis and present results on the proton and antiproton beam lifetime in the Tevatron based on SDA data, tools and methodology. Lifetimes are good indicators of the overall performance of the collider,and longer beam lifetimes translate directly to improved integrated luminosity. We observe significant beam losses due to other factors than luminosity: beam-gas interactions, transverse motions due beam-beam effects leading to scraping due on limited physical aperture, etc. We describe in detail the analysis technique and salient phenomenological observations on such beam lifetimes.

**FPAT014—Dynamic Visualization of SNS Diagnostics Summary Report and System Status**
*Willem Blokland, Cary D. Long, Darryl J. Murphy, John David Purcell (ORNL/SNS), Andrei Liyu (RAS/INR), Madhan Sundaram (University of Tennessee)*
The Spallation Neutron Source (SNS) accelerator systems will deliver a 1.0 GeV, 1.4 MW proton beam to a liquid mercury target for neutron scattering research. The accelerator complex consists of a 1 GeV linear accelerator, an accumulator ring and associated transport lines. The SNS diagnostics platform is PC-based running Embedded Windows XP and LabVIEW. The diagnostics instruments communicate with the control system using the Channel Access (CA) protocol of the Experimental Physics and Industrial Control System (EPICS). This paper describes the Diagnostics Group's approach to collecting data from the instruments, processing it, and presenting live in a summarized way over the web. Effectively, adding a supervisory level to the diagnostics instruments. One application of this data mining is the "Diagnostics Status Page" that summarizes the insert-able devices, transport efficiencies, and the mode of the accelerator in a compact webpage. The displays on the webpage change automatically to show the latest and/or most interesting instruments in use.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**FPAT015—Beam Trajectory Correction for SNS**
*Chungming Chu, Thomas Pelaia (ORNL/SNS)*
Automated beam trajectory correction with dipole correctors is developed and tested during the Spallation Neutron Source warm linac commissioning periods. The application is based on the XAL Java framework with newly developed optimization tools. Also, dipole corrector polarities and strengths, and beam position monitor (BPM) polarities were checked by an orbit difference program. The on-line model is used in both the trajectory correction and the orbit difference applications. Experimental data for both applications will be presented.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge.

**FPAT016—PASTA – An RF Phase and Amplitude Scan and Tuning Application**
*John Galambos (ORNL/SNS)*
To assist the beam commissioning in the Spallation Neutron Source (SNS) linac, a general purpose RF tuning application has been written to help set RF phase and amplitude. It follows the signature matching procedure described in Ref.* The method involves varying an upstream Rf cavity amplitude and phase settings and comparing the measured downstream beam phase

responses to model predictions. The model input for cavity phase and amplitude calibration and for the beam energy are varied to best match observations. This scheme has advantages over other RF tuning techniques of not requiring intercepting devices (e.g. Faraday Cups), and not being restricted to a small linear response regime near the design values. The application developed here is general and can be applied to different RF structure types in the SNS linac. Example applications in the SNS Drift Tube Linac (DTL) and Coupled Cavity Linac (CCL) structures will be shown.
*T.L. Owens, M.B. Popovic, E.S. McCrory, C.W. Schmidt, L.J. Allen, "Phase Scan Signature Matching for Linac Tuning," Particle Accelerators, 1994 Vol 98, p. 169.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**FPAT017—SNS Diagnostics Tools for Data Acquisition and Display**
*Madhan Sundaram (University of Tennessee), Cary D. Long (Innovative Design), Willem Blokland (ORNL/SNS)*
The Spallation Neutron Source (SNS) accelerator systems will deliver a 1.0 GeV, 1.4 MW proton beam to a liquid mercury target for neutron scattering research. The accelerator complex consists of a 1.0 GeV linear accelerator, an accumulator ring and associated transport lines. The SNS diagnostics platform is PC-based and will run Windows for its OS and LabVIEW as its programming language. The diagnostics platform as well as other control systems and operator consoles use the Channel Access (CA) protocol of the Experimental Physics and Industrial Control System (EPICS) to communicate. This paper describes the tools created to evaluate the diagnostic instrument using our standard programming environment, LabVIEW. The tools are based on the LabVIEW Channel Access library and can run on Windows, Linux, and Mac OS X. The data-acquisition tool uses drop and drag to select process variables organized by instrument, accelerator component, or beam parameters. The data can be viewed on-line and logged to disk for later use. A drag and drop display creation tool supports the quick creation of graphical displays to visualize the data produced by the instruments without the need for programming.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S Department of Energy.

**FPAT018—Rapid Electromagnetic Analysis of Entire Accelerator Structures**
*Simon Cooke, Baruch Levush (NRL)*
We present results of a new method for fast, accurate calculation, in 3-D, of the electromagnetic mode spectrum of long, tapered accelerator structures. Instead of discretizing the entire structure directly and solving a huge matrix eigenvalue problem, we use a new two-step technique that scales much better to long, multi-cavity structures. In the first step we compute a small number of eigenmodes of individual cavities, achieving 0.05% frequency accuracy using a new second-order finite-element code. In the second step we use these 3-D mode solutions as field basis functions to obtain a reduced matrix representation of Maxwell's equations for the complete structure. Solving the reduced system takes just a few minutes on a desktop PC even with more than 100 non-identical cavities, and gives the complete mode spectrum in the first few bands of the structure. By judicious choice of the basis modes, we retain 0.05% frequency accuracy for these global solutions, and can reconstruct the complete 3-D field of each mode in order to perform beam-interaction calculations. Solution times are faster by orders of magnitude than comparable calculations using a direct finite-element method.

Work supported by the U.S. Office of Naval Research.

**FPAT019—Digital Control of Induction Acceleration System**
*Kota Torikai, Dai Arakara, Yoshio Arakida, Yoshito Shimosaki, Ken Takayama (KEK)*
Induction acceleration of a proton bunch from 500MeV to 8GeV was achieved in the KEK-PS in the last October. In this experiment, the proton beam was accelerated with an induction pulse voltage, and the RF voltage was used only for beam confinement. The synchronization between acceleration and beam circulation utilizing a timing-control system, instead of that of a phase-control used in an RF system, was confirmed. The timing-control system was operated at 1MHz, which is extremely fast in comparison with a typical pulse devise, such as a kicker system in circular accelerators of some 10Hz. We propose a novel acceleration method based on the programmable digital feedback-system instead of an analog feedback-system in an RF synchrotron. This method can be applied to conventional large circular accelerators.

**FPAT020—A Fast Chopper for Intensity Adjustment of Heavy-Ion Beams**
*Andrey Valerievich Novikov-Borodin, Valeriy Alexandrovich Kutuzov (RAS/INR), Peter Ostroumov (ANL)*
There are several heavy-ion linac projects being developed worldwide. For example, the Rare Isotope Accelerator Facility [J.A. Nolen, Nucl. Phys. A. 734 (2004) 661] currently being designed in the U.S. will use both heavy-ion and light ion beams to produce radionuclides via the fragmentation and spallation reactions, respectively. With simultaneous beam delivery to more than one target independent adjustment of relative beam intensities is essential. A fast traveling wave chopper can be used to modulate cw beam intensity at low energy ~200 keV/u. Such a device should have high frequency characteristics at high power level. By increasing the wave impedance of the traveling wave structure up to 200 Ohm one can reduce power requirements to the fast voltage pulser. Several design options of the high-impedance structure are discussed.

CRDF Grant.

**FPAT021—Experience with Kicker Beam Coupling Reduction Techniques**
*Enrique Gaxiola, Fritz Caspers, Laurent Ducimetière, Tom Kroyer (CERN)*
SPS beam impedance is still one of the worries for operation with nominal LHC beam over longer periods once the final configuration will be installed in 2006. Several CERN SPS kickers suffer from significant beam induced ferrite heating. In specific cases, for instance beam scrubbing, the temperature of certain ferrite yokes went beyond the Curie point. Several retrofit impedance reduction techniques have been investigated theoretically and with practical tests. We report on experience gained during the 2004 SPS operation with restively coated ceramic inserts in terms of kicker heating, pulse rise time, operating voltage, and vacuum behavior. For another technique using interleaved metallic strips we observed significant improvements in bench measurements. Advantages and drawbacks of both methods and potential combinations of them are discussed and simulation as well as measured data are shown. Prospects for further improvements beyond 2006 are briefly outlined.

**FPAT022—Performance of the CERN SPS Fast Extraction for the CNGS Facility**
*Enrique Gaxiola, Gianluigi Arduini, Peter Burkel, Wolfgang Höfle, Federico Roncarolo, Elmar Vogel, Eugene Vossenberg (CERN)*
The SPS LSS4 fast extraction system will serve both the anti-clockwise ring of the LHC and the long baseline neutrino (CNGS) facility. For the latter two extractions spaced by 50 ms, each affecting half of the ring, are foreseen. During the shut-down 2003-2004 the performance of the fast extraction kickers was improved in order to match more closely the specifications for the kicker pulse shape required for the CNGS and LHC extractions. The rise and fall times were significantly reduced, as well as the post-pulse kick ripple. However, the latter remains outside specifications and oscillations are induced in the leading bunches of the batch remaining in the machine at the moment of the first extraction. While further improving the characteristics of the kicker pulse shape, the possibility of damping the beam oscillations using the transverse feedback system has been explored. We report on the recent pulse form improvements and results of beam tests.

**FPAT023—A Novel Sextupole Switching Power Supply Performance**
*Chen-Yao Liu (NSRRC)*
To meet high performance 1.5GeV TLS requirement, the sextupole power supply of the storage ring synchrotron in NSRRC must be working in accordance with the 1.5GeV high performance state. If the sextuple power supply output current of the storage ring deviates from the normal working point too much, the beam current of the storage ring will be deteriorated. A new parallel air-cooling Agilent-6686A power system instead the Inverpower sextupole power supply in core area and high performance current output. The new parallel Agilent-6686A power system was designed by tree unit power supply parallel output current characteristic. The output current characteristic is perfect when the current command in normal state, and high efficacy is achieved because the Agilent-6686A power system by switching technique. Results and working performance will be presented in this paper.

**FPAT024—Transition Radiation of Relativistic Electrons on the Transversal-Limited Thin Targets; Case of Small-Angle Incinence of Electrons**
*Sergiy Dobrovolskiy, Nikolai Shul'ga (NSC/KIPT)*
The long-wavelength transition radiation produced by relativistic electron on the thin metallic and semi-transparent transverse-bounded target for the case of inclined electron transit is investigated. We analyse a spectra-angular density of transition radiation for the small-angle electron's incidence. We show that as well as for the case of normal electron transit the intensity of "backward" and far-field "forward" radiation are strongly distorted in some region of waves. Spectral-angular distribution of transition radiation for oblique electron incidence* now is factored to the co-factors of normal incidence, angular correction and trasversal target's size influence.
*S.N. Dobrovolsky, N.F. Shul'ga "On the Long-Wavelength Transition Radiation by Relativistic Electrons Oblique Moving Through a Thin Target."

**FPAT025—Electron Dynamics of the Rod-Pinch Diode in the Cygnus Experiment at Los Alamos**
*Lin Yin, Kevin Bowers, R. Carlson, B. G. DeVolder, Thomas Kwan, J. R. Smith, C. M. Snell (LANL), M. J. Berninger (Bechtel Nevada)*
In this work, two-dimensional particle-in-cell simulations are used to examine the electron physics in the rod-pinch diode, a device that can be used to produce a relatively low-energy (a few MeV) radiographic electron source. It is found that with diode parameters for which the electrons' dominant dynamics are approximated well as a magnetized fluid, the diode produces an electron source with a desired small spot size as the electrons drift to and impinge on the anode tip. However, for a large cathode-to-anode radius ratio, a population of electrons that consists predominantly of electrons emitted from the down-stream surface of the cathode is found to propagate in the upstream direction and the diode may perform anomalously as a consequence. A method is proposed for improving the quality of the electron source by suppressing electron emission from the downstream cathode surface to reduce the presence of unmagnetized electrons.

**FPAT026—The Dynamic Aperture of an Electrostatic Quadrupole Lattice**
*C. M. Celata, Frank Bieniosek, Peter Seidl (LBNL), Lionel Prost (Fermilab), Alex Friedman, David Grote (LLNL)*
In heavy-ion-driven inertial fusion accelerator concepts, dynamic aperture is important to the cost of the accelerator, most especially for designs which envision multibeam linacs, where extra clearance for each beam greatly enlarges the transverse scale of the machine. In many designs the low-energy end of such an accelerator uses electrostatic quadrupole focusing. The dynamic aperture of such a lattice has been investigated for intense, space-charge-dominated ion beams using the 2-D transverse slice version of the 3-D particle-in-cell simulation code WARP. The representation of the focusing field used is a 3-D solution of the Laplace equation for the biased focusing elements, as opposed to previous calculations which used a less-accurate multipole approximation. 80% radial filling of the aperture is found to be possible. Results from the simulations, as well as corroborating data from the High Current Experiment at LBNL, will be presented.

Work supported by the U.S. DOE, under contract numbers DE-AC03-76SF00098 and W-7405-Eng-48.

**FPAT027—Particle Simulations of Acceleration Schemes for High-Current, Short-Bunch, Ion Beams**
*David Grote, Enrique Henestroza, Simon Yu (LBNL), Alex Friedman, Scott D. Nelson (LLNL), Richard J. Briggs (SAIC)*
We have begun a campaign to carry out full particle-in-cell simulations of various accelerating schemes for the high-current, short-bunch ion beams that are of interest for HEDP applications. A family of approaches use a slow-wave structure based on a helical winding, on which a voltage pulse is launched and propagated to generate the accelerating fields. In one scenario, likely to be used as a first stage, a pulse moves through the beam, accelerating the tail of the bunch first and acting as a "snowplow" (with "snow" ultimately passing over the top of the "blade" and falling behind). This method has the advantage that the acceleration can be varied in the experiment and can provide significant bunch compression. In later stages, the pulse would move with approximately the beam speed, so that the beam "surfs" on the pulse, continually accelerating as it moves through the structure. The simulations of the first stage scenario will be focused on. An issue which will be examined is control of the space-charge expansion of the bunch. These simulations are helping us develop a capable and flexible experiment, and lend insight into the nature of the beams that may be expected.

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**FPAT028—Extraction and Compression of High Line Charge Density Ion Beams**
*Enrique Henestroza, Joe W. Kwan, Simon Yu (LBNL), Richard J. Briggs (SAIC)*
HEDP applications require high line charge density ion beams. An efficient method to obtain this type of beams is to extract a long pulse, high current beam from a gun at high energy, and let the beam pass through a decelerating field to compress it. The low energy beam bunch is loaded into a solenoid and matched to a Brillouin flow. The Brillouin equilibrium is independent of the energy if the relationship between the beam size (a), solenoid magnetic field strength (B) and line charge density is such that (Ba)^2 is proportional to the line charge density. Thus it is possible to accelerate a matched beam at constant line charge density. An experiment, NDCX-1c is being designed to test the feasibility of this type of injectors, where we will extract a 1 microsecond, 100 mA, potassium beam at 160 keV, decelerate it to 55 keV (density ~0.2 microC/m), and load it into a 2.5 T solenoid where it will be accelerated to 100–150 keV (head to tail) at constant line charge density. The head-to-tail velocity tilt can be used to increase bunch compression and to control longitudinal beam expansion. We will present the physics design and numerical simulations of the proposed experiment

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**FPAT029—High Voltage Operation of Helical Pulseline Structures for Ion Acceleration**
*William Waldron, Lou Reginato (LBNL), Richard J. Briggs (SAIC)*
The basic concept for the acceleration of heavy ions using a helical pulseline requires the launching of a high voltage traveling wave with a waveform determined by the beam transport physics in order to maintain stability and acceleration.* This waveform is applied to the front of the helix, creating over the region of the ion bunch a constant axial acceleration electric field that travels down the line in synchronism with the ions. Several methods of driving the helix have been considered. Presently, the best method of generating the waveform and also maintaining the high voltage integrity appears to be a transformer primary loosely coupled to the front of the helix, generating the desired waveform and achieving a voltage step-up from primary to secondary (the helix). This can reduce the drive voltage that must be brought into the helix enclosure through the feedthroughs by factors of 5 or more. The accelerating gradient is limited by the voltage holding of the vacuum insulator, and the material and helix geometry must be chosen appropriately. The helix must also be terminated into its characteristic impedance, and designs of terminations incorporated into the helix internal enclosure are presented in the paper.
*Briggs, et al, "Helical Pulseline Structures for Ion Acceleration," this conference.

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**FPAT030—Parametric Studies of Image-Charge Effects in Small-Aperture Alternating-Gradient Focusing Systems**
*Jing Zhou, Chiping Chen (MIT/PSFC)*
Image charges have important effects on an intense charged-particle beam propagating through an alternating-gradient (AG) focusing channel with a small circular aperture. This is especially true with regard to chaotic particle motion, halo formation, and beam loss.* In this paper, we examine the dependence of these effects on system parameters such as the filling factor of the AG focusing field, the vacuum phase advance, the beam perveance, and the ratio of the beam size to the aperture. We calculate the percentage of beam loss to the conductor wall as a function of propagating distance and aperture, and compare theoretical results with simulation results from the particle-in-cell (PIC) code PFB2D.
*Zhou, Qian and Chen, Phys. Plasmas 10, 4203 (2003).

The U.S. Department of Energy, Office of High-Energy Physics, Grant No. DE-FG02-95ER40919, Office of Fusion Energy Science, Grant No. DE-FG02-01ER54662, and in part by Air Force Office of Scientific Research, Grant No. F49620-03-1-0230.

**FPAT031—High Energy Pulsed Power System for AGS Super Neutrino Focusing Horn**
*Wu Zhang, Jon Sandberg, Wu-Tsung Weng (BNL)*
This paper present a preliminary design of a 300 kA, 2.5 Hz pulsed power system. This system will drive the focusing horn of proposed Brookhaven AGS Neutrino Super Beam Facility for Very Long Baseline Neutrino Oscillation Experiment. The peak output power of the horn pulsed power system will reach gigawatts, and the upgraded AGS will be capable of delivering 1 MW in beam power.

Work performed under the auspices of the U.S. Department of Energy.

**FPAT032—NuMI Proton Kicker Extraction Magnet Termination Resistor System**
*Scott Reeves, Chris C. Jensen (Fermilab)*
The temperature stability of the kicker magnet termination resistor assembly directly affects the field flatness and amplitude stability of the kick. Comprehensive thermal enhancements were made to the existing Main Injector resistor assembly design to satisfy NuMI performance specifications. Additionally, a fluid-processing system utilizing Fluorinert® FC-77 high-voltage dielectric was built to precisely control the setpoint temperature of the resistor assembly from 70 to 120F, required to maintain constant resistance during changing operational modes. The Fluorinert® must be continually processed to remove hazardous breakdown products caused by radiation exposure to prevent chemical attack of system components. Design details of the termination resistor assembly and Fluorinert® processing system are described. Early performance results will be presented.

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**FPAT033—Numerical Model of the DARHT Accelerating Cell**
*Thomas P. Hughes, Thomas C. Genoni (ATK-MR), Harold Davis, Mike Kang, Benjamin Arnold Prichard (LANL)*
The DARHT-2 facility at Los Alamos National Laboratory accelerates a 2 microsecond electron beam using a series of inductive accelerating cells. The cell inductance is provided by large Metglas cores, which are driven by a pulse-forming network. The original cell design was susceptible to electrical breakdown near the outer radius of the cores. We developed a numerical model for the magnetic properties of Metglas over the range of dB/dt (magnetization rate) relevant to DARHT. The model was implemented in a radially-resolved circuit code, and in the LSP* electromagnetic code. LSP simulations showed that the field stress distribution across the outer radius of the cores was highly nonuniform. This was subsequently confirmed in

experiments at LBNL. The calculated temporal evolution of the electric field stress inside the cores approximately matches experimental measurements. The cells have been redesigned to greatly reduce the field stresses along the outer radius.
*LSP is a software product of ATK Mission Research (www.lspsuite.net).

NNSA/DOE

**FPAT034—Dispersion Analysis of the Pulseline Accelerator**
*George Caporaso, Scott D. Nelson, Brian R. Poole (LLNL), Richard J. Briggs (SAIC)*
We analyze the sheath helix model of the pulseline accelerator.* We find the dispersion relation for a shielded helix with a dielectric material between the shield and the helix and compare it against the results from 3-D electromagnetic simulations. Expressions for the fields near the beam axis are obtained. A scheme to taper the properties of the helix to maintain synchronism with the accelerated ions is described. An approximate circuit model of the system that includes beam loading is derived.
*"Helical Pulseline Structures for Ion Acceleration," Briggs, Reginato, Waldron, this conference.

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**FPAT035—Transverse Beam Instability in a Compact Dielectric Wall Induction Accelerator**
*Yu-Jiuan Chen, James F. McCarrick, Scott D. Nelson (LLNL)*
Using the dielectric wall accelerator technology, we are developing of a compact induction accelerator system primarily intended for pulsed radiography. Unlike the typical induction accelerator cell that is long comparing with its accelerating gap width, the proposed dielectric wall induction accelerator cell is short and its accelerating gap width is comparable with the cell length. In this geometry, the rf modes may be coupled from one cell to the next. We will present recent results of rf modeling of the cells and prediction of transverse beam instability on a 2-kA, 8-MeV beam.

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**FPAT036—An Induction Linac Test Stand**
*William DeHope, Dave Goerz, Ron Kihara, Mike Ong, George Vogtlin, Jan-Mark Zentler (LLNL)*
A single-cell test stand has been constructed to facilitate study and guide improvements of the induction electron linac at the FXR radiographic facility at LLNL.* This paper will discuss how modifications in pulse compression and shaping, pulse power transmission, initial ferrite state, and accelerator cell loading have been performed on the test stand and can be applied to the entire accelerator. Some of the specialized diagnostics being used will be described. Finally, the paper will discuss how computer modeling and judicious timing control can be used to optimize accelerator performance by making only selective changes that can be accomplished at minimal cost.
*"Test Stand for Linear Induction Accelerator Optimization," Ong et al., Pulsed Power Conference, June 16, 2003, Dallas TX.

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**FPAT037—Electromagnetic Simulations of Helical-Based Ion Acceleration Structures**
*Scott D. Nelson, George Caporaso, Alex Friedman, Brian R. Poole (LLNL), William Waldron (LBNL), Richard J. Briggs (SAIC)*
Helix structures have been proposed* for accelerating low energy ion beams using MV/m fields in order to increase the coupling effeciency of the pulsed power system and to tailor the electromagnetic wave propagation speed with the particle beam speed as the beam gains energy. Calculations presented here show the electromagnetic field as it propagates along the helix structure, field stresses around the helix structure (for voltage breakdown determination), optimizations to the helix and driving pulsed power waveform, and simulations showing test particles interacting with the simulated time varying fields.
*"Helical Pulseline Structures for Ion Acceleration," Briggs, Reginato, Waldron, this conference.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

**FPAT038—Electromagnetic Simulations of Dielectric Wall Accelerator Structures for Electron Beam Acceleration**
*Scott D. Nelson, Brian R. Poole (LLNL)*
Dielectric Wall Accelerator (DWA) technology incorporates the energy storage mechanism, the switching mechanism, and the acceleration mechanism for electron beams. Electromagnetic simulations of DWA structures includes these effects and also details of the switch configuration and how that switch time affects the electric field pulse which accelerates the particle beam. DWA structures include both bi-linear and bi-spiral configurations with field gradients on the order of 20MV/m and the simulations include the effects of the beampipe, the beampipe walls, the DWA High Gradient Insulator (HGI) insulating stack, wakefield impedance calculations, and test particle trajectories with low emittance gain. Design trade-offs include the transmission line impedance (typically a few ohms), equilibration ring optimization, driving switch inductances, and a layer-to-layer coupling analysis and its affect on the pulse rise time.

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**FPAT039—Particle Simulations of Dielectric Wall Accelerator Structures**
*Brian R. Poole, Scott D. Nelson (LLNL)*
The dielectric wall accelerator (DWA) is a unique compact induction accelerator structure that incorporates the accelerating mechanism, pulse forming structure, and switch structure into an integrated module. The DWA consists of stacked stripline Blumlein assemblies, which can provide accelerating gradients in excess of 10 MeV/meter. A finite difference time domain code (FDTD) is used to determine the applied acceleration field to the charged particle beam. 3-D particle simulations are used to determine the particle energy distribution, dipole kick, focusing, and emittance growth associated with various DWA configurations for both quasistatic and dynamic regimes. The effect of space charge, image forces, and beam loading impedance for the structures are discussed.

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

**FPAT040—Advanced Electric and Magnetic Material Models for FDTD Electromagnetic Codes**
*Brian R. Poole, Scott D. Nelson (LLNL), Scott Langdon (REMCOM Incorporated)*
The modeling of dielectric and magnetic materials in the time domain is required for pulse power applications, pulsed induction accelerators, and advanced transmission lines. For example, most induction accelerator modules require the use of magnetic materials to provide adequate Volt-sec during the acceleration pulse. These models require hysteresis and saturation to simulate the saturation wavefront in a multipulse environment. In high voltage transmission line applications such as shock or soliton lines the dielectric is operating in a highly nonlinear regime, which requires nonlinear models. Simple 1-D models are developed for fast parameterization of transmission line structures. In the case of nonlinear dielectrics, a simple analytic model describing the permittivity in terms of electric field is used in a 3-D finite difference time domain code (FDTD). In the case of magnetic materials, both rate independent and rate dependent Hodgdon magnetic material models have been implemented into 3-D FDTD codes and 1-D codes. The use of the codes in modeling a dielectric wall accelerating structure (DWA) is demonstrated.

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**FPAT041—Design and Simulation of an Anode Stalk Support Insulator**
*Lisa Wang, Timothy Lee Houck (LLNL)*
An anode stalk support insulator in a magnetically insulated transmission line was designed and modeled. One of the important design criteria is that within space constraints, the electric field along the insulator surface has to be minimized in order to prevent a surface flashover. In order to further reduce the field on the insulator surface, metal rings between insulator layers were also specially shaped. To facilitate the design process, electric field simulations were performed to determine the maximum field stress on the insulator surfaces and the transmission line chamber.

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**FPAT042—Beam Dynamics and Pulse Duration Control During Final Beam Bunching in Driver System for Heavy Ion Inertial Fusion**
*Takashi Kikuchi, Shigeo Kawata, Tetsuo Someya (Utsunomiya University), Kazuhiko Horioka, Mitsuo Nakajima (TIT)*
Beam dynamics is investigated by multi-particle simulations during a final beam bunching in a driver system for heavy ion inertial fusion (HIF). The longitudinal bunch compression causes the beam instability induced by the strong space charge effect. The multi-particle simulation can indicate the emittance growth due to the longitudinal bunch compression. Dependence in the beam pulse duration is also investigated for effective pellet implosion in HIF. Not only the spatial nonuniformity of the beam illumination, but also the errors of the beam pulse duration cause changes of implosion dynamics. The allowable regime of the beam pulse duration for the effective fusion output becomes narrow with decreasing the input beam energy. The voltage accuracy requirement at the beam velocity modulator is also estimated for the final beam bunching. It is estimated that the integrated voltage error is allowable as a few percent.

**FPAT043—Application of Selected Momentum Correction Method Using Induction Voltage Modulator**
*Takashi Kikuchi, Shigeo Kawata (Utsunomiya University), Takeshi Katayama (CNS), Kazuhiko Horioka (TIT)*
A method for momentum correction of a selected beam particle using a controllable induction voltage modulator is proposed for a low flux ion beam. The corrected ion beam has a small momentum error restricted by a detection error at a kinetic energy analyzer and a voltage fluctuation at the induction voltage modulator. The application of this selected momentum correction scheme is discussed by using numerical simulations.

**FPAT044—Low Cost Magnetic Field Controller**
*Alexandre Almeida Malafronte, Mauricio Lima Lopes, Marcos Martins (USP/LAL)*
The Physics Institute of the University of São Paulo (IFUSP) is building a continuous wave (cw) racetrack microtron. This machine has several dipole magnets, like the first and second stage recirculators, and a number of smaller ones in the transport line. These magnets must produce very stable magnetic fields to allow the beam to recirculate along very precise orbits and paths. Furthermore, the fields must be reproducible with great accuracy to allow an easier setup of the machine, though the effects of hysteresis tend to jeopardize the reproducibility. If the magnetic field is chosen by setting the current in the coils, temperature effects over the magnet and power supply tend to change the field. This work describes an inexpensive magnetic field controller that allows a direct measure of the magnetic field through an Hall probe. It includes a microcontroller running a feedback algorithm to control the power supply, in order to keep the field stable and reproducible. The controller can also execute algorithms to ramp up and down the power supply in a specific mode, in order to reduce hysteresis.

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**FPAT045—Upgrade of the ESRF Vacuum Control System**
*Daniela Schmied, Michael Hahn, Roberto Kersevan (ESRF)*
The temperature acquisition as well as the whole vacuum control system of the electron storage ring of the ESRF is in operation since more than ten years now. Apart from difficulties to have appropriate support for the old systems we start facing problems of aging and obsolescence. We have been reviewing our philosophy of data acquisition and remote control in order to update our systems with state of the art technology, taking into account our operational experience. We have started installing shielded “intelligent” devices inside the storage ring tunnel taking benefit from the availability of ethernet connections. Like this we can take advantage of the latest developments linked to these technologies, such as OPC Server, Webpage instrument control, and more.

**FPAT046—RF Control System for the DESY VUV-FEL Linac**
*Valeri Ayvazyan, Gevorg Petrosyan, Kay Rehlich, Stefan Simrock, Piotr Vetrov (DESY)*
In the RF system for the Vacuum Ultraviolet Free Electron Laser (VUV-FEL) Linac each klystron supplies RF power to up to 32 cavities. The superconducting cavities are operated in pulsed mode and high accelerating gradients close to the performance limit. The RF control of the cavity fields to the level of 1e-4 for amplitude and 0.1 degree for phase however presents a significant technical challenge due to the narrow bandwidth of the cavities which results in high sensitivity to perturbations of the resonance frequency by mechanical vibrations (microphonics) and Lorentz force detuning. A digital RF control system has been developed for the VUV-FEL which will demonstrate the required control performance. Presently the Linac is being commissioned, and this effort provides the first full integrated test in the accelerator, including cryogenics, RF, beam transport, and beam diagnostics. The RF control system design and objectives are discussed and compared to the measured performance during the first stage of the VUV-FEL Linac - TESLA Test Facility. Hardware/software design and operational challenges experienced for RF control are presented.

**FPAT047—Control System of 3 GeV Rapid Cycling Synchrotron at J-PARC**
*Hiroki Takahashi, Yuko Kato, Masato Kawase, Hiroyuki Sako (JAERI/J-PARC), Hiroshi Yoshikawa (JAERI), Hironao Sakaki (JAERI/LINAC), Makoto Sugimoto (Mitsubishi Electric Control Software Corp), Yuichi Ito (Total Saport System Corp.)*
Since the 3GeV RCS produces huge beam power of 1 MW, extreme cares must be taken to design the control system in order to minimize radiation due to beam loss. Another complexity appears in the control system, because each beam bunch of 25 Hz is required to be injected either into the MLF* or into the 50GeV MR.** Therefore, each bunch of 25 Hz must be operated separately, and the data acquisition system must collect synchronized data within each pulse. To achieve these goals, a control system via reflective memory and wave endless recorders has been developed. EPICS is adopted in the control system. Since the number of devices is huge, the management of EPICS records and their configurations require huge amount of time and man power. To reduce this work significantly, a RDB*** for static machine information has been developed. This RDB stores (1) EPICS related information of devices, interfaces, and IOC's**** with a capability to generate EPICS records automatically, and (2) machine geometrical information with a capability to generate lattice files for various simulation applications. The status of the control system focusing on the data acquisition system and the RDB will be presented.
*Material and Life Science Facility. **Main Ring. ***Relational Database. ****Input Output Controller.

Japan Society for the Promotion of Science (JSPS).

**FPAT048—Accelerator Control System of J-PARC**
*Hiroshi Yoshikawa, Hironao Sakaki, Hiroyuki Sako, Hiroki Takahashi (JAERI)*
For the extra high current proton accelerator, like a j-parc, it is very important to detect quickly increasing the beam loss and to halt the output of the beam. Accelerators of this type can not be operated with the conventional method of trial and error to search optimal parameters. Parameters must be checked through some simulators so as not to bring about excessive loss with unprepared operation. One shot loss of a maximum beam causes one hour waste of operatting time. Furthermore, foreseeing loss from the variation of the beam and equipments, the parameters are corrected appropriately. Parameters must be managed with the operation privilege not to be changed independently by a local device treatment. These demands are filled only by constructing appropriately the control system that is integrated interlock, timing, database, and operating software. This paper shows not only the contents of each subsystems but also the mutual relations between those subsystems

**FPAT049—Upgrade of the PF Ring Vacuum Control System**
*Yasunori Tanimoto, Takashi Nogami, Takashi Obina (KEK)*
Having been operated for more than two decades, the PF ring vacuum control system had become superannuated. The system reliability had been degraded and the maintenance work had been difficult. In addition, the device operability had not been high because the operating software, written in BASIC, had been running in a stand-alone computer. In the summer of 2004, the vacuum control system was upgraded to solve these problems. In this upgrade, the operating system was constructed in the EPICS environment. And numerous NIM modules composing hardware interfaces between vacuum device controllers and the operating computers were replaced by reliable PLCs.

**FPAT050—Improvement RF Control System for the 20 Mev Proton Linac of PEFP**
*Jong Chel Yoon, Jinhyuk Choi, Jin-Won Lee (PAL, Pohang)*
This paper presents the RF control system for Korea Multi-purpose Accelerator Complex (KOMAC). KAERI (Korea Atomic Energy Research Institute) has been performing the project named KOMAC. As the 3nd phase of the project, 20MeV proton accelerating structure is under development. The new design is based on the use of VME based Multi-function modules connected to the specific low level RF Controllers(LLRF) via distributed I/O modules and Serial communication modules. The control system was based on EPICS (Experimental Physics and Industrial Control System) from the end of 2004. Installation and commissioning of the RF module is scheduled on 2005. Control system to integrated the RF System to the KOMAC control system is implemented. Hardware, software and various applications are upgrade to support the operation of RF Control system. In this paper, We describe control structure and scheme of the current RF Control System and upgraded one.

EPICS, Control, LLRF.

**FPAT051—A New Timing System for the Duke Booster and Storage Ring**
*Grigory Yakovlevich Kurkin (BINP SB RAS), Steven M. Hartman, Stepan Mikhailov, Y. K. Wu (DU/FEL)*
A dedicated booster synchrotron is being constructed at the Duke FEL Laboratory to provide full energy injection into the main electron storage ring. A new timing system has been developed to coordinate the injection of electron bunches from the linac to the booster, the ramping of energy in the booster, and extraction of bunches into the main ring. The timing system will allow the extraction of any bunch in the booster into any selected bucket in the main ring to provide top-off injection for any of the various operational bunch patterns of the main ring. A new master oscillator has also been developed for the RF system of the booster. The oscillator may be tuned independently or phase-locked to the master oscillator of the main ring. The issues of the soft phase locking process of the new master oscillator are discussed. The timing system and new oscillator have been fabricated and tested and are ready for operation.

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**FPAT052—Computer Based Monitoring and Control System for Accelerator Applications**
*Vyacheslav Kurakin, Valery Alekseev, Valery Busygin, Alexander Vladimirovich Koltsov (LPI), Pavel Kurakin (Keldysh Institute of Applied Mathematics)*
We have developed computer monitoring and control system based on modern technologies. Due to its flexibility, the system can be used for data acquisition and control in real time scale in industry and scientific laboratories, the main field of application being pulse RF accelerators and accelerator based devices. Hard ware interface uses CAMAC standard and consists of several base modules. These are fast charge-to-digit converter, multi channel waveform digitizer, multi channel digit-to-analog converter (DAC) with multiplexing precise analog-to-digit converter (ADC), arbitrary form signal generator on the basis of fast DAC, time mark generator used as timer and precise RF synthesizer to be used as master oscillator up to S-band wave range. Software is the computer interface adjustable by user at program run time. Network components and built in interpreter make it possible computer distributed measurements and control as well as desirable data processing before their visualization in real time scale. The system developed is used already at Lebedev Physical Institute Radiation Complex.

**FPAT053—LabVIEW Library to EPICS Channel Access**
*Andrei Liyu (RAS/INR), Dave H. Thompson (ORNL/ASD), Willem Blokland (ORNL/SNS)*
The Spallation Neutron Source (SNS) accelerator systems will deliver a 1.0 GeV, 1.4 MW proton beam to a liquid mercury target for neutron scattering research. The accelerator complex consists of a 1 GeV linear accelerator, an accumulator ring and associated transport lines. The SNS diagnostics platform is PC-based and will run Windows for its OS and LabVIEW as its programming language. Data acquisition hardware will be based on PCI cards. There will be about 300 rack-mounted computers. The Channel Access (CA) protocol of the Experimental Physics and Industrial Control System (EPICS) is the SNS control system communication standard. This paper describes the approaches, implementation, and features of LabVIEW library to CA for Windows, Linux, and Mac OS X. We also discuss how the library implements the asynchronous CA monitor routine using LabVIEW's occurrence mechanism instead of a callback function (which is not available in LabVIEW). The library is used to acquire accelerator data and applications have been built on this library for console display and data-logging.

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**FPAT054—Control System Architecture with Distributed Modular SBC & DSP-Based Nodes**
*Viacheslav Ivanovich Vinogradov (RAS/INR)*
Control System Architecture with System-area Network and distributed nodes with for complex modular equipment is proposed and discussed in this paper. Each Node includes: SBC-based Processor Core Module, DSP-based Control and Data acquisition module. Distributed compact nodes interconnect by System-area Networks in next Architectures: 1) Tradition network Architecture with weak interactions between cores for control applications on the base of message transfer; 2) High-speed parallel-pipeline interconnections according required topology for Data Acquisition and Processing in real time. 3) Using both interconnections at the same system opens new ways to construct complex power systems for integrated Joint Architecture for Control, Data Acquisition and Processing in experimental Area.

Russian Academy of Science.

**FPAT055—The Radiation Safety Interlock System for Top-Up Mode Operation at NSRRC**
*Chien-Rong Chen, Fu-Dong Chang, Sheau-Ping Kao, Joseph Liu, Rong-Jiun Sheu, Jau-Ping Wang (NSRRC)*
The radiation safety interlock systems of NSRRC have been operated for more than a decade. Some modification actions have been implemented in the past to perfect the safe operation. The machine and its interlock system were originally designed to operate at the decay mode. Recently some improvement programs to make the machine injection from original decay mode to top-up mode at NSRRC has initiated. For users at experimental area the radiation dose resulted from top-up re-fill injections where safety shutters of beam-lines are opened will dominate. In addition to radiation safety action plans such as upgrading the shielding, enlarging the exclusion zones and improving the injection efficiency, the interlock system for top-up operation is the most important to make sure that injection efficiency is acceptable. To ensure the personnel radiation safety during the top-up mode, the safety interlock upgrade and action plans will be implemented. This paper will summarize the original design logic of the safety interlock system. Historical modification actions for this system will be mentioned. New design logic to ensure radiation safety for top-up mode operation will be discussed.

**FPAT056—RF Control System Upgrade at CAMD**
*Victor Paul Suller (CCLRC/DL/ASTeC), Mikhail Fedurin, Paul Jines, Daren Launey (LSU/CAMD)*
A description is given of the new control system for the RF system of the CAMD light source. The new design being implemented brings all RF signals into the data acquisition system via a modular, custom made, RF detector and renders the amplitude and tune control loops in the VME computer. On line calculations ensure monitoring of proper operation and display the information to the user in an efficient way. In addition, an advanced load impedance monitoring diagnostic has been implemented, being displayed as a Smith Chart, which is based on the system used at the SRS in Daresbury, England.

**FPAT057—A TCL/TK Widget for Display of MEDM Screens**
*Robert Soliday (ANL)*
A new Tcl/Tk widget has been created to display MEDM screens inside a Tcl/Tk application. Tcl/Tk parses the MEDM input files and the appropriate widgets are created and linked to the associated process variables. One advantage of this approach is that an X-Windows emulator is not required to view and manipulate the MEDM screen under a Windows operating system. Another benefit is that the MEDM screen can now be tightly integrated into a scripting language to attach higher-level logic to various process variable manipulations. Further details and examples of the new widget will be discussed.

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**FPAT058—Creating EPICS Soft Channels the Easy Way with sddspcas: Features and Applications**
*Robert Soliday (ANL)*
Using sddspcas, a portable channel access server that is configured by SDDS input files, it is relatively simple to create process variables (PVs). It can be run in a standalone mode or it can be run so that the PVs are checked to ensure that they don't conflict with other IOCs or portable channel access servers. It can also be run using the Run Control facility to prevent additional instances of the same sddspcas from being run. The SDDS

configuration file provides the PV names, upper and lower limits, units, element counts if the PVs are waveforms, and the types of PVs. Valid types include various precision floats and integers as well as strings. One simple application of this program is that software developers can quickly test their code without requiring the coordination needed to update an IOC database to create PVs. Further details of the features, configuration, and applications of sddspcas will be discussed.

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**FPAT059—Event Driven Automatic State Modification of BNL's Booster for NASA Space Radiation Laboratory Solor Particle Simulator**

*Kevin A. Brown, Severino Binello, Margaret Harvey, John Morris, Adam Rusek, Nicholaos Tsoupas (BNL)*

The NASA Space Radiation Laboratory (NSRL) was constructed in collaboration with NASA for the purpose of performing radiation effect studies for the NASA space program. The NSRL makes use of heavy ions in the range of 0.05 to 3 GeV/n slow extracted from BNL's AGS Booster. NASA is interested in reproducing the energy spectrum from a solar flare in the space environment for a single ion species. To do this we have built and tested a set of software tools which allow the state of the Booster and the NSRL beam line to be changed automatically. In this report we will desribe the system and present results of beam tests.

Work performed under Contract #DE-AC02-98CH10886 with the auspices of the U.S. Department of Energy.

**FPAT060—An FPGA-Based Quench Detection and Protection System for Superconducting Accelerator Magnets**

*Ruben H. Carcagno, Sandor Feher, Michael Joseph Lamm, Andrzej Makulski, Roger Nehring, Darryl Orris, Yuriy Pischalnikov, Mike Tartaglia (Fermilab)*

A new quench detection and protection system for superconducting accelerator magnets was developed at the Fermilab's Magnet Test Facility (MTF). This system is based on a Field-Programmable Gate Array (FPGA) module, and it is made of mostly commericallly available, integrated hardware and software components. It provides most of the functionality of our existing VME-based quench detection and protection system, but in addition the new system is easily scalable to protect multiple magnets powered independently and has a more powerful user interface and analysis tools. First applications of the new system will be for testing corrector coil packages. In this paper we describe the new system and present results of testing LHC Interaction Region Quadrupole (IRQ) correctors.

**FPAT061—CEBAF Distributed Data Acquisition System**

*Trent Allison, Tom Powers (Jefferson Lab)*

There are thousands of signals distributed throughout Jefferson Lab's Continuous Electron Accelerator Facility (CEBAF) that are useful for troubleshooting and identifying instabilities. Many of these signals are only available locally or monitored by systems with small bandwidths that cannot identify fast transients. The Distributed Data Acquisition (DistDAQ) system will sample and record these signals simultaneously at rates up to 1 Msps. Its primary function will be to provide waveform records from throughout CEBAF to the Experimental Physics and Industrial Control System (EPICS). It will be possible to collect the waveforms at given intervals or based on the occurrence of an event such as an accelerator fast shutdown (FSD). The waveforms can then be processed to quickly identify beam transport issues thus, reducing down time and increasing CEBAF performance. DistDAQ will be comprised of 44 data acquisition chassis's with 64 analog inputs each. They will be distributed throughout CEBAF and interconnected via a fiber optic network to facilitate global triggering of events. They will also be connected to the Ethernet in order to communicate with EPICS.

This work was supported by DOE contract DE-AC05-84ER40150 Modification No. M175, under which the Southeastern Universities Research Association (SURA) operates the Thomas Jefferson National Accelerator Facility.

**FPAT062—Application of Configurable Soft Core Processors in Nuclear Physics**

*Hai Dong, Douglas Curry (Jefferson Lab)*

A digital application often consists of fast algorithms on the order of microseconds, and slow algorithms on the order of milliseconds. Fast algorithms can be implemented in Field Programmable Gate Arrays (FPGA), with slow algorithms and other chores such as a host interface being executed on a processor. Traditional designs consisted of an FPGA and processor(s), either on the same circuit board or on a separate board. With commercial processors, designers are often faced with buying more processor than the application requires or settling for less-than-ideal solution to keep the cost down. The advances in FPGAs allow the integration of a Soft Core Processors within the FPGA. This technology allows designers to create a custom processor that is optimized for the application, and integrate fast and slow algorithms in a single FPGA. Furthermore it simplifies board level and system design by using a unified firmware and software development tool set. This paper will focus on the Altera NIOS Configurable Soft Core Processor that will be used in various projects at Jefferson Lab.

This work was supported by DOE contract No. DE-AC05-84ER40150.

**FPAT063—Control System for the ORNL Multicharged Ion Research Facility High-Voltage Platform**

*Mark Bannister, Fred Wolfgang Meyer, John Sinclair (ORNL)*

A control system for the 250-kV platform and beamlines for accelerating and transporting multiply-charged ion beams produced by an all-permanent-magnet ECR ion source has been developed at the ORNL Multicharged Ion Research Facility. The system employs Experimental Physics and Industrial Control System (EPICS) software controlling an Allen-Bradley ControlLogix Programmable Logic Controller (PLC). In addition to the I/O control points of the PLC, other devices are controlled directly by the EPICS computer through RS-232 and GPIB interfaces. PLC chassis are located at each major electrical potential of the facility, that is, at the ECR source potential, at the platform potential, and at ground potential used in the beamlines transporting ions to the various experimental endstations. Connection of the control system components to the EPICS host is accomplished via EtherNet, including fiber optic links to the HV platform. The user interface is designed with the Extensible Display Manager (EDM) software and custom applets perform such tasks as mass-to-charge ratio scans of the platform analyzing magnet and archival of source and beamline operating parameters.

Work supported by U.S. DOE Office of Fusion Energy Sciences and Office of Basic Energy Sciences under contract No. DE-AC05-00OR22725 with UT-Battelle, LLC.

**FPAT064—Experience with the EPICS PV Gateway at the APS**
*Kenneth Evans, Martin Smith (ANL)*
The EPICS PV Gateway has become a stable, high-performance application that provides access to process variables while minimizing the impact on critical IOCs and implementing additional access security. The additional access security typically prevents write access but is highly configurable. The Advanced Photon Source (APS) currently uses 40 Gateways running on 11 machines to provide access to the machine network from the offices and for the individual experimental teams. These include reverse Gateways that allow administration of all 40 APS Gateways from a single MEDM screen, even though the Gateways are running on separate networks. This administration includes starting, stopping, making and viewing reports, and viewing and editing access security files. There is one Gateway that provides process variable renaming. This paper provides an overview of the Gateways at the APS and describes the procedures that have been set up to use and administer them.

Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**FPAT065—Experience of Prototype Control System for the J-PARC Proton Linac**
*Norihiko Kamikubota (KEK)*
The J-PARC, a high-intensity proton accelerator facility, started construction in 2001 as a 5-year project. Though the construction site is JAERI (Tokai), the pre-injector part of the proton linac was constructed at KEK (Tsukuba). Early commissioning studies with proton beams have been carried out at KEK in 2002-2004. A prototype control system based on the EPICS toolkit was developed as a part of commissioning studies. 1) New software and hardware devices, which will be used in J-PARC, were developed and evaluated with real beams. 2) We migrated existing small control systems into a single EPICS-based control system. This paper reports developments and experiences with the prototype control system. Future extensions toward the whole J-PARC facility are also given.

**FPAT066—The SNS Ring RF Control System**
*Sheng Peng, David Gurd (ORNL/SNS), Lawrence T. Hoff, Kevin Smith (BNL)*
The low-level RF control system for the SNS Ring differs considerably from that for the Linac. To accommodate requirements for higher data throughput and improved performance the system is based on a PCI Digital Signal Processor (DSP). In accordance with SNS standards, a VME-based PowerPC© is used, but advantage is taken of the on-board PMC slot which houses a Bittware© Hammerhead© PMC card with four AD-21162 DSPs.The EPICS system handles system configuration and data traffic while the DSP performs the low-level RF controls. Protocol and software to support both the PowerPC and the DSP have been developed. This paper presents the system design and initial testing experience.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a collaboration of six U.S. National Laboratories: ANL, BNL, JLab, LANL, LBNL, and ORNL.

**FPAT067—The Design Performance of the Integrated Spallation Neutron Source Vacuum Control System**
*Johnny Y. Tang, Peter Ladd, Derrick Williams (ORNL/SNS)*
The Spallation Neutron Source vacuum control systems have been developed within a collaboration of Lawrence Berkeley National Laboratory(LBNL), Los Alamos National Laboratory(LANL), Thomas Jefferson National Accelerator Facility(TJNAF), and Brookhaven National Laboratory(BNL). Each participating lab is responsible for a different section of the machine. Although a great deal of effort has been made to standardize vacuum instrumentation components and the global control system interfaces, the varied requirements of the different sections of the machine made horizontal integration of the individual vacuum control systems both interesting and challenging. To support commissioning, the SNS control system team and the vacuum group developed a set of test strategies and the interlock schemes that allowed horizontal vacuum system integration to be effectively achieved. The design of the vacuum control interlock scheme developed will be presented together with the results of performance measurements made on these schemes. In addition, the experience and performance of an industrial Ethernet with real-time control used in this application will be discussed.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**FPAT068—Spallation Neutron Source Drift Tube Linac Resonance Control Cooling System Modeling**
*Johnny Y. Tang, Alexander V. Aleksandrov, Marianne M. Champion, Paul Gibson, James Phillip Schubert (ORNL/SNS), Alexander Feschenko, Yuri Kiselev, A. S. Kovalishin, Leonid Vladimirovich Kravchuk, Adolf Kvasha (RAS/INR)*
The Resonance Control Cooling System (RCCS) for the warm linac of the Spallation Neutron Source was designed by Los Alamos National Laboratory. The primary design focus was on water cooling of individual component contributions. The sizing the RCCS water skid was accomplished by means of a specially created SINDA/FLUINT model tailored to these system requirements. A new model was developed in Matlab Simulink and incorporates actual operational values and control valve interactions. Included is the dependence of RF input power on system operation, cavity detuning values during transients, time delays that result from water flows through the heat exchanger, the dynamic process of water warm-up in the cooling system due to dissipated RF power on the cavity surface, differing contributions on the cavity detuning due to drift tube and wall heating, and a dynamic model of the heat exchanger with characteristics in close agreement to the real unit. Because of the Matlab Simulink model, investigation of a wide range of operating issues during both transient and steady state operation is now possible. Results of the DTL RCCS modeling are presented.

SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy.

**FPAT069—A Control System for the Duke Booster Synchrotron**
*Steven M. Hartman, Stepan Mikhailov, Y. K. Wu (DU/FEL)*
The Duke FEL is developing a booster synchrotron to provide full energy injection into the Duke electron storage ring. In this paper, we describe the development of the control system for the booster. Requirements include the competing needs of simple and reliable turn-key operation for the machine as a booster; and the sophistication and flexibility of operation of the machine as a storage ring for commissioning, machine studies and as a light source. To simplify operations and machine studies, the high level controls will present the system in terms of the physics quantities of the accelerator, allowing a tight integration between the physics model and the low level hardware control, as we have previously implemented for Duke storage ring.

This work is supported by U.S. Department of Energy grant DE-FG02-01ER41175 and by U.S. AFOSR MFEL grant F49620-001-0370.

**FPAT070—Performance of COTS I/O Modules in an Accelerator Control System**
*Steven M. Hartman (DU/FEL)*
We analyze some recent experiences with commercial off the shelf (COTS) I/O hardware modules, comparing manufacturer specifications with our in-house measurements. Discrepancies between quoted specifications and measured performance under accelerator laboratory conditions have been observed. In some cases, design or manufacturing faults have been found which could have impact on the overall performance of the accelerator.

This work is supported by U.S. AFOSR MFEL grant F49620-001-0370 and by U.S. Department of Energy grant DE-FG02-01ER41175.

**FPAT071—Timing System for J-PARC**
*Fumihiko Tamura (JAERI/LINAC), Junsei Chiba, Tadahiko Katoh, Masahito Yoshii (KEK)*
J-PARC has three accelerators running at the different repetition rates; a 400-MeV linac (50Hz), a 3-GeV rapid cycling synchrotron (RCS, 25Hz), and a 50-GeV synchrotron (MR). The linac and the RCS deliver the beam pluses to the different destinations in each cycle. The destinations are scheduled according to the machine operations. We define two kinds of timing, "scheduled timing" and "synchronization timing" so that the accelerators are operated with proper timing and the beam pulses are transported to the experimental facilities or the next accelerators. The J-PARC complex requires a stable and precise timing system. The system is based on a master clock generated by a synthesizer and the triggers are operated independently of the AC-line frequency. We describe the design of the J-PARC timing system and their configuration, and also present the hardware details.

**FPAT072—The Status of HLS Control System**
*Liu Gongfa, Xun Bao, Chuan Li, Weimin Li, Jigang Wang, Dong Xie, Ke Xuan (USTC/NSRL), Jingyi Li (DU/FEL)*
HLS (Hefei Light Source) at NSRL (National Synchrotron Radiation Lab) consists of three parts: 200Mev Linac, transport line and 800Mev storage ring. The control system was upgraded based on EPICS (Experimental Physics and Industrial Control system) from 1999 to 2004. This paper will cover the experience of using PC-based hardware under EPICS, data archiving, and some high level tools for physics and operation use.

**FPAT073—Orbit Correction System Status and Improvement Proposal for HLS Storage Ring**
*Lin Wang (USTC/NSRL)*
Hefei Light Source is a second generation light source; usually its stability requirement of closed orbit is not very high and was achieved by current orbit correction system. In upgrade project of HLS, several new SR experimental stations were very sensitive to the closed orbit stability. Firstly, the status of current orbit correction system was reviewed. Then, the main factors effected the orbit correction were analyzed. And the method adopted in HLS to stabilize the source point of these SR stations was introduced. Finally, the proposed new orbit correction algorithm was presented in this report.

**FPAT074—Linear Optics Model Calibration by LOCO in HLS Storage Ring**
*Lin Wang (USTC/NSRL)*
Hefei Light Source is a low energy electron storage ring. Over a long period of time, the discrepancy between the design lattice model and the real machine were puzzling us and became main obstacle of machine operation and study. Recently LOCO algorithms were applied to HLS storage ring. The main results of numerical simulation and experimental measurement showed that the incorrect measured focusing-gradient of quadrupole magnet and ignored fringe field effect of dipole magnet maybe the main reasons of this discrepancy. The accuracy of linear optics model of HLS storage ring obtained by LOCO now is mainly limited by finite resolution of BPM system and poor beam condition.

**FPAT075—Using a Control System Ethernet Network as a Field Bus**
*William R. DeVan, Gregory S. Lawson, William H. Wagner (ORNL/ASD), Susan E. Hicks, David M. Wantland, Ernest Williams (ORNL)*
A major component of a typical accelerator distributed control system (DCS) is a dedicated, large-scale local area communications network (LAN). The SNS EPICS-based control system uses a LAN based on the popular IEEE-802.3 set of standards (Ethernet). Since the control system network infrastructure is available throughout the facility, and since Ethernet-based controllers are readily available, it is tempting to use the control system LAN for "fieldbus" communications to low-level control devices (e.g. vacuum controllers; remote I/O). These devices may or may not be compatible with the high-level DCS protocols. This paper presents some of the benefits and risks of combining high-level DCS communications with low-level "field bus" communications on the same network, and describes measures taken at SNS to promote compatibility between devices connected to the control system network.

Work supported by the U.S. Department of Energy under Contract DE-AC05-00OR22725.

**FPAT076—PC-LabView Based Control System in SAGA-LS**
*Hideaki Ohgaki (Kyoto IAE), Hiroyuki Toyokawa (on leave) (AIST), Yositaka Iwasaki (on leave), Shigeru Koda (on leave), Yuichi Takabayashi (on leave), Takio Tomimasu (on leave) (Saga Synchrotron Light Source)*
A control system for SAGA Synchrotron Light Source (SAGA-LS) has been constructed. SAGA-LS is a small-medium size light source and is run by local government, which means there are a few number of staff in the laboratory. Thus the control system must be simple and robust, while inexpensive, easy to develop and maintain. The basic ideas of the system are 1) using PCs to build a low cost control system, 2) using off-shelf devices, FieldPoint (National Instrument) and PLCs, (FA-M3, Yokogawa), for robust and replaceable system, 3) using LabView for a quick in-house system development, 4) using channel access protocol between server and client to transparent from regular EPICS utilities, 5) using ActiveX CA to emulate the CA protocol. About 1,000 PVs are employed to control the magnet power supplies, the RF control sub-system, vacuum monitors, BPM data and several LCW data. The system has been operated and tuned at the beginning of the commissioning, spring 2004. MySQL database system also archives data to assist daily operation and to display the trend chart of the machine. The database applications developed by LabView, too.

**FPAT077—An Accelerator Control Middle Layer Using Matlab**
*Gregory James Portmann (LBNL/ALS)*
Matlab is a matrix manipulation language originally developed to be a convenient language for using the LINPACK and

EISPACK libraries. What makes Matlab so appealing for accelerator physics is the combination of a matrix oriented programming language, an active workspace for system variables, powerful graphics capability, built-in math libraries, and platform independence. A number of software toolboxes for accelerators have been written in Matlab — the Accelerator Toolbox (AT) for machine simulations, LOCO for accelerator calibration, Matlab Channel Access Toolbox (MCA) for EPICS connections, and the Middle Layer. This paper will describe the MiddleLayer software toolbox that resides between the high-level control applications and the low-level accelerator control system. This software was a collaborative effort between ALS and Spear but was written to easily port. Five accelerators presently use this software – Spear, ALS, CLS, and the X-ray and VUV rings at Brookhaven. The Middle Layer functionality includes energy ramp, configuration control, global orbit correction, local beam steering, insertion device compensation, beam-based alignment, tune correction, response matrices, and script-based physics studies.

U.S. Department of Energy under Contract No. DEAC03-76SF00098.

**FPAT078—Supporting Cavity Production Using an Engineering Data Management System**

*Lars Hagge, Jochen Buerger (DESY)*

The reliable production of superconducting cavities is an essential issue for any future accelerator applying the "cold" technology. At DESY the complex manufacturing process is supported by an engineering data management system (EDMS). During the mechanical manufacturing process many quality checks are performed and their results are documented in inspection sheets, which are stored in the system and used for controlling. The EDMS further controls the subsequent preparation process by automatically creating and issuing work instructions for the treatment of the surfaces of the cavities. In parallel the necessary documentation for quality assurance is generated. The documentation is linked to the product breakdown structure; this enables users to easily navigate from inspection sheets of selected components forward to their 3D CAD model as well as back to the results of the examination of the original niobium sheet. The poster presents the structural approach for the documentation using a commercially available EDMS. Supporting the lifecycle by electronic workflow techniques is described.

**FPAT079—Data Base Extension for the Ensemble Model Using a Flexible Implementation**

*Wolfgang Ackermann, Wolfgang F.O. Müller, Thomas Weiland (TEMF)*

To guarantee an adequate design and a proper functionality of various machine components it is of great importance to perform detailed studies of charged particle transport. However, it is often not necessary to initiate individual kinetic simulations. When the evolution of integral quantities is of research interest, it is worth treating an investigated particle ensemble as a whole and applying a macroscopic formulation. Using a collision-less kinetic approach, the simplified model is derived from the well-known Vlasov equation. Instead of solving directly this equation, one can use moments of the density function obtained by means of an averaging process. This formalism had been implemented into the beam dynamics simulation program V-Code and a fundamental database of various beam line elements like cavities, drift spaces, solenoids, quadrupoles and steerers was set up. A flexible realization of the C++ code representing the cavities and the drift spaces can be automatically used for an arbitrary order of moments applying a symbolic algebra program. A useful extension to the remaining beam line elements together with appropriate simulation results is presented in the paper.

Work supported by DESY, Hamburg.

**FPAT080—Simulations of Beam Injection and Extraction into Ion Sources**

*Marco Cavenago (INFN/LNL)*

Charge breeding, consistiting of injecting singly charged ion into ECRIS(Electron Cyclotron Resonance Ion Sources) to extract an highly charged ion beam, is a promising technique for rare or radioactive ion beam. Efficiency and extracted beam temperature are dominated by the strong collisional diffusion of charged ion inside source. A computer code, named BEAM2ECR, written to simulate details of the injection, ionization, collision and extraction processes is described.* A model of injection plasma sheath and of source fringe field were recently added. Neutral injection is also supported, for comparison with other techniques, like gas feeding or metal vapor injection. Results, clearly favouring near axis injection for most cases are described. Code is written in C-language and possibility of concurrent execution over a Linux cluster was recently added. *M. Cavenago, O. Kester, T. Lamy and P. Sortais, Rev. Sci. Instrum. 73, 537 (2002).

INFN-LNL

**FPAT081—A New Version of SixTrack with Collimation and Aperture Interface**

*Guillaume Robert-Demolaize, Ralph Assmann, Stefano Redaelli, Frank Schmidt (CERN)*

Simulations of collimation and beam cleaning were so far often performed with simplified computer models. However, the increase in available CPU power has opened the possibility for far more realistic simulations. For large accelerators like LHC it is now possible to track millions of particles, element by element over hundreds of turns. The well established SixTrack code treats the full six-dimensional phase space and considers the non-linear magnet components up to very high order. This code is being used for all LHC tracking simulations and has well developed linear and non-linear error models. SixTrack was extended for tracking of large ensembles of halo particles, taking into account halo interaction with arbitrarily placed collimators. An interface to a program for aperture analysis allows obtaining beam loss maps in the machine aperture. A standardized and portable SixTrack version is now available, providing all functionality of the old SixTrack, as well as the newly added support for halo tracking, collimation and aperture loss maps.

**FPAT082—From Visualisation to Data Mining with Large Data Sets**

*Andreas Adelmann (PSI), John M. Shalf, Cristina Siegerist (LBNL), Robert Ryne (LBNL/CBP)*

In 3D particle simulations, the generated 6D phase space data are can be very large due to the need for accurate statistics, sufficient noise attenuation in the field solver and tracking of many turns in ring machines or accelerators. There is a need for distributed applications that allow users to peruse these extremely large remotely located datasets with the same ease as locally downloaded data. This paper will show concepts and a prototype tool to extract useful physical information out of 6D raw phase space data. ParViT allows the user to project 6D data into 3D space by selecting which dimensions will be represented spatially and which dimensions are represented as particle attributes, and the construction of complex transfer functions for representing the particle attributes. It also allows management of time-series data. An HDF5-based parallel-I/O library, with C++,

C and Fortran bindings simplifies the interface with a variety of codes. A number of hooks in ParVit will allow it to connect with a parallel back-end that is able to provide remote file access, progressive streaming, and even parallel rendering of particle sets in excess of 1Billion particles.

**FPAT083—A Portable Parallel High Performance Data Interface for Particle Simulations**
*Andreas Adelmann (PSI), John M. Shalf, Cristina Siegerist (LBNL), Robert Ryne (LBNL/CBP)*
Largest parallel particle simulations, in six dimensional phase space generate wast amont of data. It is also desirable to share data and data analysis tools such as ParViT (Particle Visualization Toolkit) among other groups who are working on particle-based accelerator simulations. We define a very simple file schema built on top of HDF5 (Hierarchical Data Format version 5) as well as an API that simplifies the reading/writing of the data to the HDF5 file format. HDF5 offers a self-describing machine-independent binary file format that supports scalable parallel I/O performance for MPI codes on a variety of supercomputing systems and works equally well on laptop computers. The API is available for C, C++, and Fortran codes. The file format will enable disparate research groups with very different simulation implementations to share data transparently and share data analysis tools. For instance, the common file format will enable groups that depend on completely different simulation implementations to share custom data analysis tools like ParViT without modification. We will show examples and benchmak data for various platforms.

**FPAT085—The TAO Accelerator Simulation Program Environment**
*Jeffrey Claiborne Smith, David Sagan (Cornell University)*
A new accelerator design and analysis simulation environment based on the BMAD relativistic charged particle dynamics library is in development at Cornell University. Called TAO (Tool for Accelerator Optimization), it is a machine independent program that implements the essential ingredients needed to solve simulation problems. This includes the ability to: 1. Design lattices subject to constraints, 2. Simulate errors and changes in machine parameters, and 3. Simulate machine commissioning including simulating data measurement and correction. TAO is designed to be easily customizable so that extending it to solve new and different problems is straight forward. The capability to simultaneously model multiple accelerator lattices, both linacs and storage rings, and injection from one lattice to another allows for the design and commissioning of large multi stage accelerators. It can also simultaneously model multiple configurations of a single lattice. Single particle, particle beam and macroparticle tracking is implemented. Use of TAO with both the International Linear Collider and the Cornell Energy Recovery Linac are provided as examples.

NSF and DOE.

**FPAT086—Lucretia: A Matlab-Based Toolbox for the Modeling and Simulation of Single-Pass Electron Beam Transport Systems**
*Peter Tenenbaum (SLAC)*
We report on Lucretia, a new simulation tool for the study of single-pass electron beam transport systems. Lucretia supports a combination of analytic and tracking techniques to model the tuning and operation of bunch compressors, linear accelerators, and beam delivery systems of linear colliders and linac-driven Free Electron Laser (FEL) facilities. Extensive use of Matlab scripting, graphics, and numerical capabilities maximize the flexibility of the system, and emphasis has been placed on representing and preserving the fixed relationships between elements (common girders, power supplies, etc.) which must be respected in the design of tuning algorithms. An overview of the code organization, some simple examples, and plans for future development are discussed.

**FPAT087—elegantRingAnalysis: An Interface for High-Throughput Analysis of Storage Ring Lattices Using elegant**
*Michael Borland (ANL)*
The code {\tt elegant} is widely used for simulation of linacs for drivers for free-electron lasers. Less well known is that elegant is also a very capable code for simulation of storage rings. In this paper, we show a newly-developed graphical user interface that allows the user to easily take advantage of these capabilities. The interface is designed for use on a Linux cluster, providing very high throughput. It can also be used on a single computer. Among the features it gives access to are basic calculations (Twiss parameters, radiation integrals), phase-space tracking, nonlinear dispersion, dynamic aperture (on- and off-momentum), frequency map analysis, and collective effects (IBS, bunch-lengthening). Using a cluster, it is easy to get highly detailed dynamic aperture and frequency map results in a surprisingly short time.

Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**FPAT088—Update of Advanced Beam-Dynamics Simulation Tools for RIA**
*Robert Garnett, James Billen, Thomas Wangler (LANL/LANSCE), Peter Ostroumov (ANL), Ji Qiang, Robert Ryne (LBNL/CBP), Richard York (NSCL), Kenneth Crandall (TechSource)*
We are developing multuparticle beam-dynamics simulation codes for RIA driver linac simulations extending from the low-energy beam transport line to the end of the linac. These codes run on the NERSC parallel supercomputing platforms at LBNL, which allow us to run simulations with large numbers of macroparticles. The codes have physics capabilities needed for RIA, including transport and acceleration of multiple-charge-state beams, beam-line elements such as high-voltage platforms within the linac, interdigital accelerating structures, charge-stripper foils, and capabilities for handling the effects of machine errors and other off-normal conditions. In this paper we present the status of the work, describe some recent additions to the codes, and show preliminary end-to-end simulation results for a representative driver-linac design.

U.S. Department of Energy Contract W-7405-ENG-36.

**FPAT089—A Parallel Simplex Optimizer and Its Application to High-Brightness Storage**
*Hairong Shang, Michael Borland (ANL)*
Optimization is commonly used in accelerator design to find linear optics solutions. Such optimizations are usually fairly fast as linear optics computations are themselves fast. For high-brightness storage rings, optimization of nonlinear elements (e.g., sextupoles) is also important in obtaining sufficient dynamic aperture. However, this can be very time onsuming as the basic calculations are time consuming. We have developed an efficient parallel Simplex optimizer that runs on a Linux cluster. It can optimize the result of running essentially any program or script that returns a penalty function value. We have used this optimizer with elegant to optimize dynamic aperture of storage ring designs. We discuss the optimization algorithm and

performance, design of penalty functions, and optimization results.

Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**FPAT090—ExperimentDesigner: A Tcl/Tk Interface for Creating Experiments in EPICS**
*Hairong Shang, Michael Borland (ANL)*
ExperimentDesigner is a Tcl/Tk interface that allows users to easily design and run complicated experiments using a convenient graphical user interface (GUI). Features include: process variable monitoring, which pauses the experiment when values are out of range; user-defined initialization, execution, and finalization sequences; support of complex execution chains containing actions such as setting controls, reading values, running external programs, interacting with the user, etc.; collection of output data for convenient postprocessing; saving and loading of experiment configurations; convenient use of SDDS Toolkit programs; and execution of experiments from the command line without a GUI.

Work supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

**FPAT091—LiTrack: A Fast Longitudinal Phase Space Tracking Code with Graphical User Interface**
*Paul Emma, Karl Leopold Freitag Bane (SLAC)*
Many linear accelerators, such as linac-based light sources and linear colliders, apply longitudinal phase space manipulations in their design, including electron bunch compression and wakefield-induced energy spread control. Several computer codes handle such issues, but most require detailed information on the transverse focusing lattice. In fact, in most linear accelerators, the transverse distributions do not significantly affect the longitudinal, and can be ignored initially. This allows the use of a fast 2D code to study longitudinal aspects without time-consuming considerations of the transverse focusing. LiTrack is based on a 15-year old code (same name) originally written by one of us (KB), which is now a MATLAB-based code with additional features, such as a graphical user interface and output plotting. The single-bunch tracking includes RF acceleration, bunch compression to 3rd order, geometric and resistive wakefields, aperture limits, synchrotron radiation, and flexible output plotting. The code was used to design both the LCLS and the SPPS projects at SLAC and typically runs in <1 minute. We describe the features, show some examples, and provide access to the code.

Work supported by U.S. Department of Energy contract DE-AC02-76SF00515.

**FPAT092—Optimized Beam Matching Using Extremum Seeking**
*Eugenio Schuster (Lehigh University), Christopher K. Allen (LANL/LANSCE), Miroslav Krstic (UCSD)*
The transport and matching problem for a low energy transport system is approached from a control theoretical viewpoint. The beam dynamics and transport section is modeled using the KV envelope equations. Principles of optimal control are applied to this model to formulate techniques which aid in the design of the transport and matching section. Multi-Parameter Extremum Seeking, a real-time non-model based optimization technique, is considered in this work for the lens tuning. Numerical simulations illustrate the effectiveness of this approach.

Oral Session FOPA–Closing Plenary
Ballrooms D-G @ 13:50
Chair: N. Holtkamp (ORNL/SNS)

**13:50 FOPA001—The Spallation Neutron Source: A Powerful Tool for Materials Research**
*Thomas Edward Mason (ORNL/SNS)*
The wavelengths and energies of thermal and cold neutrons are ideally matched to the length and energy scales in the materials that underpin technologies of the present and future: ranging from semiconductors to magnetic devices, composites to biomaterials and polymers. The Spallation Neutron Source (SNS) will use an accelerator to produce the most intense beams of neutrons in the world when it is complete in 2006. The project is being built by a collaboration of six U.S. Department of Energy laboratories. It will serve a diverse community of users drawn from academia, industry and government labs with interests in condensed matter physics, chemistry, engineering materials, biology and beyond. The design goals, current status and anticipated scientific capabilities of SNS will be summarized.

**14:25 FOPA002—XFEL/Short Pulse Science**
*Jochen Schneider (DESY)*
X-rays are a most powerful tool for 3 dimensional imaging of matter on length scales from mm to nanometer. They allow for highly accurate determination of the position of atoms and their correlated motion in samples with complex structure under extreme temperature or pressure condi-tions, they probe either bulk or surface properties including order-disorder phenomena. With high resolution spectro-microscopy electronic properties of inhomogeneous novel materials are studied in great detail. So far equilibrium states are investigated. The logical next step is to extend our methodology to include the investigation of non-equilibrium, of new states of matter with atomic resolution in space and time. The XFELs provide the necessary very intense flashes of X-rays with wave-lengths down to 0.1 nm with pulse durations of 10 or 100 femtoseconds. Examples of the suggested applications of XFELs will be presented. Strategies for performing experiments at LINAC driven light sources will be discussed with emphasis on the synergies expected from a close collaboration between the synchrotron radiation and optical laser communities on one hand, and the accelerator and particle physics communities on the other hand.

**15:00 FOPA003—Challenges and Progress in the FAIR Accelerator Project**
*Peter J. Spiller (GSI)*
An international "Facility for Antiproton and Ion Research (FAIR)" was proposed to be built at GSI, providing unique conditions for experiments involving heavy ion and antiprotons beams. The new accelerator complex consists of the fast ramped s.c. heavy ion synchrotrons, SIS100/300 and a storage ring system for experiments with radioactive ions and antiprotons. The two stage concept for SIS100/300 provides optimum conditions for the generation of beams with high intensities per cycle and in average, over a wide energy range and with various time structures. Bunch compression enables a matching to the production targets and storage rings. The storage ring complex was optimized for fast cooling and accumulation of the generated secondary beams. Unique conditions for internal target experiments with radioactive beams will be provided in NESR and for antiproton beams in the high energy storage ring HESR. The new accelerators require R&D work in various fields of technologies and beam physics, as e.g. operation with low charge state, high intensity, heavy ion beams in dynamic vacuum conditions, development of fast ramped s.c. magnets, powerful, low frequency rf systems, stochastic cooling systems and medium energy electron coolers.

**15:35 FOPA004—Opportunities and Challenges in Neutrino Physics**
*Stanley George Wojcicki (Stanford University)*
During the last decade a number of key experiments revolutionized our ideas about neutrinos and gave the first indication of the physics beyond the Standard Model. This paper will summarize the current situation in neutrino physics and indicate the key questions that need to be addressed and resolved. Different approaches that are being proposed to address these issues will be described with a special emphasis on the technical challenges inherent in them. The paper will conclude with some more futuristic concepts in accelerator physics that are being discussed today as potential new powerful tools for the study of neutrinos in the future.

This work was supported by the National Science Foundation and the Office of Science of the Department of Energy.

**16:10 FOPA005—Science of Rare Isotope Accelerator (RIA) and the Project Status**
*Witold Nazarewicz (UTK)*
Low-energy nuclear physics is undergoing a renaissance. The next-generation tools, such as the Rare Isotope Accelerator (RIA), invite us on the journey to the vast territory of nuclear landscape which has never been explored by science. RIA will allow unique insights into the quantum many-body nature of nuclei by providing access to their most extreme manifestations and by providing precise control of the number of neutrons in these systems. RIA-based science is extremely broad and diverse. It spans the gamut from nuclear structure to astrophysics, tests of fundamental laws of nature, and myriad applications. Nevertheless, it is characterized by several encompassing themes that reflect the major challenges facing modern science today, and it has deep links to many other fields: What is the structure of atomic nuclei and how do complex systems derive their properties from their individual constituents? How are the heavy elements created and how do nuclear properties influence the stars? What are the fundamental symmetries of nature? In this talk, I will briefly touch on these themes and relate them to specific areas of RIA research.

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**16:45 Closing Remarks**
*N. Holtkamp (ORNL/SNS), S. Chattopadhyay (JLab)*

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Brinkmann, R.: RPPT011
Brittian, J.: WPAP045, WPAP048, WPAP051
Broemmelsiek, D.R.: FPAE009
Broggi, F.: RPPT013, TPAE002
Brooks, J.: WPAT044
Brooks, S.J.: RPPT057
Brooksby, C. A.: ROAB008
Bross, A.: RPAT032
Broste, W.: ROAB001
Browman, A. A.: RPAT038
Brown, B.C.: MPPT011
Brown, J.: FOAD002
Brown, K.A.: FPAE014, FPAE029, FPAT003, FPAT059
Bruce, D.R.: WPAE037, WPAE039
Bruce, R.: TPAP012
Brueck, K.: TPPE019
Brugger, M.: TPAP005, TPAP007
Bruhwiler, D.L.: MPPE027, TOPA001, TOPA003, TPAE031, TPAE032, TPAE050, TPAP043, TPAT087, TPAT088, TPAT090, TPAT092, TPPE039
Brunelle, P.: RPAE031
Brunner, I.: WPAE050
Bruno, D.: MOPA007, TPAT093
Bryant, H.C.: FPAE011
Bryazgin, A.A.: RPAP017, WPAP023
Brüning, O.S.: MPPE047
Buechner, A.: TPPT054
Buerger, J.: FPAT078, RPPT005
Buettig, H.: TPPT054, WPAP007
Buffington, T.W.: RPAT065
Bulatov, A.V.: WPAP023
Bulfone, D.: RPAE085
Bullard, D.B.: WPAP050
Bulyak, E.V.: MPPT078, RPAE010
Bunce, G.: FPAE014, MOPA007
Burger, A.: RPPE009, RPPT032, TPAP043, WPAT091
Burgess, W.: RPPT062, RPPT063
Burke, D.L.: ROAC004
Burkel, P.: FPAT022
Burkhardt, H.: MPPE011, MPPE047, MPPE048, RPPE005, RPPE017, TPAP007, TPAP008, TPAP009
Burnet, J.-P.: WPAE063
Burns, M.J.: MPPT055
Burov, A.V.: FPAE009, RPAT069, TPAP043, TPAT087
Burrill, A.: RPPE009, RPPE032, RPPT032, TPAP043, TPPE041, TPPE042, TPPE061, WPAP033, WPAP038
Burrows, P.: RPPP003, RPPP013, RPPP036
Busby, R.: TPAT087
Busch, M.D.: FPAE061, RPAE074, WPAE043
Bussmann, M.: FOAD004
Busygin, V.P.: FPAT052
Butler, J.J.: MOPA007, TPAT093
Buzzo, A.: TPAP020
Byer, R.L.: TOPA008
Bylinskii, I.: FPAE027, WPAT001
Byrd, J.M.: RPAE065, RPAE066
Byrne, W.E.: MPPE074, RPAE060, RPAE063, RPAE080

Cai, Y.: MOPC006, MPPE025, MPPE058, MPPE059, RPPP054, TPAT072, TPAT074, TPPP024
Cakir, O.: TPAT099, WOAB005
Calabretta, L.: RPPT054
Calaga, R.: MPPE062, RPPE009, RPPT032, TPAP043, TPAP045, TPPP043, WPAP033
Calatroni, S.: TPAP004, TPAP007
Calderini, G.: WPAE056
Callahan, D. A.: ROAB003, RPAP039
Calore, A.: FPAE040
Cameron, P.: MOPA007, MOPA009, MPPE033, MPPE061, RPAP043, RPAT028, RPAT029, RPPE009, RPPT032, TPAP043, TPAP050, TPAP052, TPAT093, TPAT095
Campajola, L.: TPAE036
Campbell, B.: WPAE056
Campisi, I.E.: FPAE058, ROAC001, RPPE067, RPPT070, RPPT071, TPPT083, WPAP033, WPAT059, WPAT085, WPAT089
Campmany, J.: RPAE087
Cancelo, G.I.: RPAT011
Canella, S.: FPAE040
Cannella, T.C.: RPPE061
Cao, C.: MPPT001, MPPT004, MPPT074
Cao, J.: RPAP047
Capista, D.: TPAP022
Caporaso, G.J.: FPAP036, FPAT034, FPAT037, ROAB003, ROAB010
Cappi, R.: MOPC001
Carcagno, R. H.: FPAT060, MPPT009, MPPT012, MPPT054, TPAP029
Cardona, J.F.: MPPE028
Carletto, O.: FPAE040
Carli, C.: FPAE070, RPPE005
Carlier, E.: RPPE017, RPPE041, TPAP010
Carlson, C.: ROAB001
Carlson, C.: FPAE029
Carlson, R.C.: FPAT025
Carlsten, B.E.: ROAC006
Carlucci, D.: FPAE040, FPAE042
Carneiro, J.-P.: RPAT015, WPAP006
Carneiro, T.: TPPT075, TPPT076
Caron, M.: RPPE027
Carr, F.S.: MPPT033
Carr, G.: MPPT055
Carr, G.L.: MOPB010, RPAE056, RPAE069
Carron, G.: TPPT020
Carter, H.: ROAC004, TPPT070
Carter, H.K.: RPPT062, RPPT063, TPPE020
Carter, J.: RPAT083, RPPP003
Cartier, F.: RPPE027
Caruso, F.: WPAE011
Cary, J.R.: ROPB008, TOPA001, TOPA003, TPAE031, TPAE050, TPAE051, TPAT087, TPPE039, TPPT033, TPPT098
Casados, J.L.: MPPT055
Casagrande, F.: RPPT071, WPAE005, WPAT085
Casalbuoni, S.: RPAT049, RPAT050
Casey, J.A.: WPAT047, WPAT048
Casey, W.R.: RPAE056
Caspers, F.: FPAT021, MPPP002, MPPP031, TPAP007, TPAP008, TPAP020
Caspi, S.: TOAA001
Cassel, R.: ROAB008
Castellano, M.: RPPP001, RPPT013, TPAE002
Castelli, F.: WPAP012
Castro, J.: WPAP060
Catalan-Lasheras, N.: MPPT042, MPPT043
Catanesi, M.G.: TPAP020
Catani, L.: RPPT013
Cattelino, M.: WPAT031
Catucci, M.: WPAT079
Caudill, L.: ROAB001
Cavenago, M.: FPAE042, FPAT080, TPPE003
Cecchetti, C.A.: TPAE002

Cederquist, H.: FPAE069
Celata, C.M.: FPAP033, FPAT026, ROAB003, ROPB002, TPAT024
Celik, S.: RPPE013
Celona, L.: RPPT054
Cerniglia, P.: RPAT028
Chacon, S.: MPPT055
Chae, Y.-C.: MPPP035, TOAB009
Chai, J.-S.: WPAE062
Chakrabarti, A.: TOPD004
Chalut, K.: RPAT099
Chambers, F.W.: RPAT095
Champion, M.: MPPP016, TPPT039, WPAT057, WPAT058, WPAT059, WPAT060, WPAT062, WPAT085
Champion, M.M.: FPAT068, TPPT039, WPAE038
Chan, J.: ROAC004, RPPP044
Chan, K.-C.D.: ROAB001, ROAB004
Chance, A.: RPPT053
Chanel, M.: FPAE070, ROPC004, RPPE005
Chang, A.: RPPP037, RPPP038
Chang, C. C.: RPAT060
Chang, C.-H.: MPPT032, MPPT076
Chang, C.-K.: MPPT032, RPPE019
Chang, C.-L.: TPAE064
Chang, F.D.: FPAT055, WPAE002
Chang, H.-P.: MPPT032, RPAE047, RPAE048, RPAE049
Chang, J.-C.: RPPE006, RPPE007, RPPE072
Chang, L.-H.: MPPE073, TPPT065, TPPT066
Chang, S. H.: WPAE001, WPAE003
Chang, S.-S.: TPPT065, TPPT066
Chang, X.Y.: RPPE009, RPPE032, RPPT022, RPPT032, TPAP043, TPPE042, TPPE043, TPPP043, WPAP033, WPAT049
Chao, A.: FPAP018, MPPP008, TPAE026
Chao, Y.-C.: TPAP015, TPAP018, TPPP016
Chaput, R.: RPAE031, WPAP001
Charles, D.: WPAP045, WPAP048, WPAP051
Charman, A.E.: TPAE066
Chase, B.: FPAE012, MOPA004, TPAP022
Chattopadhyay, S.: WOPB
Chawla, S. R.: FPAP034
Cheever, dc.: RPAE068, RPAE069
Chel, S.: RPPE058, TPPT053
Chen, A.Z.: RPPE051
Chen, C.: FPAT030, MPPT027, TPAE022, TPAT002, TPAT003, WPAP057
Chen, C.: WPAT049
Chen, C.-T.: MPPT032, RPAE047, TPPT066
Chen, C.R.: FPAT055, WPAE002
Chen, C.W.: MPPP005, TPPT021
Chen, D.M.: RPPP037, RPPP038
Chen, H.: TPAE065, TPPE065, WPAT093
Chen, H.-H.: MPPT032
Chen, H.Y.: MPPP005, TPPT021
Chen, J-R.: MPPT032, RPAE049, RPAT059, RPAT060, RPPE006, RPPE007, RPPE072
Chen, J.: MPPP034, MPPT032, RPAE049, RPPE019
Chen, J.: WPAE080
Chen, J.: RPPT038, RPPT039
Chen, P.: RPPP046, TPPE038, TPPE066
Chen, S.-Y.: TPAE064
Chen, W.: MPPT001, MPPT004, MPPT024
Chen, W.-T.: TPAE064
Chen, Y.-J.: FPAP036, FPAT035, ROAB001, ROAB010
Cheng, G.: TPPT051
Cherbak, E.E.: TPPT035
Cherepanov, V.P.: TPPP009
Chernyakova, L. C.: TPAT043
Cheskidov, V.G.: RPAP016
Chesnokov, Y.A.: TPAP001, WPAE009
Chi, Y.L.: TPPE059
Chiadroni, E.: RPPT013
Chiaveri, E.: TPAP007
Chiba, J.C.: FPAT071
Chien, T.-Y.: TPAE064
Chien, Y.-C.: MPPT032
Chin, M.J.: RPAE080, RPAT074
Chin, Y.H.: MPPP025, WPAT051
Chines, F.: TPPE004
Chiou, W. S.: WPAE001, WPAE003
Chishiro, E.: TPPT062, WPAT008
Chiurlotto, F.: FPAE040, FPAE042
Cho, Y.: WPAT052
Cho, Y.-S.: FPAE044, FPAE045, FPAE046, FPAE047, FPAE048, RPAT006, RPAT007, RPAT008, TPPE005, TPPT017, TPPT018, WPAT012, WPAT015
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Choi, A.: FPAT004
Choi, B.H.: ROPC007, RPAP013, RPAP014, RPAT007
Choi, I. W.: TPAE053, TPAE055
Choi, J.: FPAT050, MPPP003, RPAE046, WPAE061, WPAT014
Choi, J.S.-H.: RPPT026
Choroba, S.: WPAT051
Chou, P.J.: MPPP005, MPPP034
Chou, W.: FPAE010, FPAE011, FPAE018, FPAE030, MPPT011, RPAP023, TPAT015
Chouhan, S.: RPAE056, RPAE058, TOAB010
Chow, K.: FOAA002
Chrin, J.T.M.: MPPP018
Christensen, E.B.: RPAE007
Christian, G.B.: RPPP003, RPPP036
Christina, V.: TPPE045, WPAP033
Christou, C.: RPAE052
Chu, C.: FPAE057, FPAE059, FPAT015, ROPA001, TPAT030
Chun, M.-H.: MPPP003, RPAT054, TPPT064, WPAT013, WPAT014
Chung, C.W.: MPPT075, WPAE015, WPAE016
Chung, F.-T.: TPPT065, TPPT066
Chung, KH.: WPAT071
Chung, M.: RPAP045, TPAT037
Chung, B.H.: WPAT071
Church, M.: TPAP034
Cialdi, S.: RPPT013, RPPT031, TPAE002, WPAP012, WPAP013
Cianchi, A.: RPPT013
Ciftci, A.K.: TPAT099, TPPP010, WOAB005
Cimino, R.: FPAP001, FPAP002
Ciocci, F.: RPPT013
Ciovati, G.: TPPT071, TPPT072, TPPT076, TPPT077
Cirrone, G.A.P.: RPAT002
Citadini, J.F.: WPAE007
Clare, J.: WPAT078, WPAT079
Clark, J.: WPAP045, WPAP048, WPAP051
Clarke, C.C.: RPPP036
Clarke, J.A.: MPPT033, MPPT079
Clarke-Gayther, M.A.: WPAE064
Claudet, S.D.: ROAD001
Clauser, T.: RPAP037, TPPE029, WPAT005
Clayton, C.E.: RPAE019, RPAT078, RPAT079, TOPA002, TOPA006, TPAE024, TPAE025, TPAE034, TPAE035, TPAE041, TPAE042, TPAE046, TPAE058
Clemente, G.: TPPT003
Clendenin, J.E.: TPPE063, WPAP058, WPAP060
Clifft, E.: WPAT030
Cline, D.: MPPT057, RPAT077, TOAD004, TPAE047, TPAT033, TPAT034, TPPP048, TPPP051
Clozza, A.: ROAA001, ROAA003, RPPT013, TPAE002
Codner, G.W.: RPPE077
Cohen, R.H.: FPAP015, FPAP016, FPAP021, FPAP033, ROPA009, ROPB002, ROPB006

Cohen, S.: MPPT055
Colby, E.R.: TOPA008, TPAE014, TPAE028, TPAE029, WPAP059
Cole, M.D.: RPPE009, RPPE067, RPPT032, TPAP043, TPPE061, TPPT078, WPAP033, WPAP038, WPAT091, WPAT092
Colestock, P.: WPAP033
Collier, P.: TPAP016
Collignon, D.C.: RPPE027
Collins, J.T.: WPAE082
Comfort, M.W.: RPPE077
Commins, E. D.: TPAT001
Compton, C.: TPPT096
Comunian, M.: FPAE040, FPAE042
Conde, M.E.: RPAT066, TPAE016, WPAP036
Coney, L.: FPAT004
Congretel, G.: FPAE037
Coniglio, A.: WPAE010
Conner, D.L.: RPPT062, RPPT063
Connolly, R.: MOPA007, RPPT032, TOPC002, TPAP043, TPAP047, TPAP050, TPAT093, TPAT094
Conway, Z.A.: TPPT099, TPPT100
Cook, A.M.: TPAE039, TPPE040
Cook, D.: WPAT079
Cook, E.G.: ROAB008
Cooke, P.: MPPT033
Cooke, S.J.: FPAT018
Cooper, C.C.: TPPT093
Corbett, W.J.: RPAT080, RPAT081
Cordova, J.F.: MPPT055
Corlett, J.N.: WPAP052, WPAP053
Corlett, P.A.: WPAT023
Cormier, J.: RPPE068
Cornelis, K.: TPAP016
Cornuelle, J.: ROAC004
Corsini, R.: RPPE025, RPPP001, TPAT097, TPPT020
Corso, J.-P.: WPAE019
Cosentino, L.: RPAT002, RPPT054
Courant, E.D.: FPAE014
Cousineau, S.M.: FPAE024, FPAE057, FPAP024, MOPC002, MOPC003, ROPA001, ROPB010, RPAT039, TPAT031, WOAC009
Coutrakon, G.: MPPE049
Cowan, B.M.: TOPA008, TOPA010, TPAE029
Cowan, T.E.: TPAE019, TPAE021
Cox, L.: WPAT031
Cozzolino, J.P.: MPPT050
Craddock, M.K.: FOAC003
Crandall, J.A.: RPPT070
Crandall, K.R.: FPAT088, TPAT025
Crane, K.: RPAE013, RPAE014, RPAE015, RPAE020
Cravey, M.: RPAT062
Crede, V.: RPAT062
Creel, J.C.: WPAE005
Crisp, J.: MPPP011, WPAE029
Cristinziani, M.: WPAE056
Crittenden, J.A.: MPPT034, MPPT080, TPPP011, TPPP012
Crofford, M.T.: MPPP016, TPPT039, WPAT057, WPAT058, WPAT059, WPAT060, WPAT062, WPAT085
Cui, Y.: TPAT067
Cultrera, L.: WPAP013
Cummings, M.A.C.: FOAA001, TPPP018, WPAE022, WPAE023
Cuneo, S.: TPAP020
Cupolo, J.: RPAT028, RPAT029
Curcio, A.J.: RPAT028
Curry, D.: FPAT062
Curtoni, A.: FPAE037
Cusick, M.: WPAT031
Cutler, R.I.: ROAB007, RPPT071, WPAE072
Cuttone, G.: RPAT002, RPPT054, TPPE004, WPAE011

D'Arienzo, M.: WPAE010
D'Auria, G.: RPAE085
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d'Errico, F.: RPAP050
D'Imperio, N.: FPAT003
D'Ottavio, T.: MOPA007, TPAT093
Da Già, C.: TPAP020
Dabrowski, A.E.: RPPE025
Dael, A.: RPAE031
Dainton, J.B.: MPPT033
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Dalmas, D.: ROAB001
Daly, E.: RPPE060, RPPE061, RPPE063, RPPE067, RPPE068, TPPT069, TPPT073, TPPT081, TPPT082, WPAP033
Danared, H.: FPAE069
Danilov, V.V.: FPAE024, FPAE057, FPAE059, ROPB010, RPAT039, TPAT030, TPAT031, TPAT032, WOAC009
Dattoli, G.: RPPT013
Davidson, R.C.: FPAE071, FPAP026, FPAP027, FPAP028, FPAP029, MOPC007, MPPE034, ROAB003, RPAP039, RPAP045, RPAT023, TPAT036, TPAT037, TPAT068, TPAT069, WOPA
Davino, D.: TPAE036
Davis, G.K.: RPPE060, RPPE068, TPPT073, TPPT080, TPPT083
Davis, H.: FPAT033, ROAB004
Dawson, W.C.: RPAP043, RPAT028
Day, A.R.: RPAT070
De Gersem, H.: MPPP023
de Jong, M.S.: TPPT089
De Lamare, J. E.: ROAB008
De Lazzari, M.: FPAE040
de Lira, A.C.: WPAE066
De Luca, G.: WPAE011
De Martinis, C.: RPAP037, RPPT013, TPAE002, WPAT005
De Monte, R.: FOAA005
De Ninno, G.: RPAE085
De Pasquale, D.: RPAP036
De Santis, S.: RPAT036
de Silvestri, S.: RPPT013
DeFord, J.F.: TPAT043, WPAT077, WPAT080
DeHart, T.E.: MPPT029
DeHope, W. J.: FPAT036
DeLong, J.: FPAE029, MOPA007, TPAT093, WPAT019
DeVan, W.R.: FPAT075
DeVolder, B.G.D.: FPAT025
Dechow, D.R.: TPAT026, TPAT060
Decker, F.-J.: MPPE058, RPAE019, RPAT078, RPAT079, TOPA002, TPAE024, TPAE025, TPAE034, TPAE035, TPAE041, TPAE042, TPAE046, TPAE058, TPPP038, WPAE079
Decker, G.: RPAE053, RPAE054, TOAB009
Decking, W.: RPAE036, RPPT011, WOAC008
Decyk, V.K.: FPAP022, ROPB007, TPAE046
Degasperi, F.T.: RPPE036
Degen, C.: RPAT028, RPAT029
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Dehler, M.: MPPP005
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Deibele, C.: RPAT040, RPAT041, TPPT039, WPAT063
Deile, M.: TPAP020
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Dejus, R.J.: RPAE001, TOAB009
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Delayen, J.R.: FPAE056, RPPE009, RPPE060, RPPT032, TPAP043, TPPT074, TPPT079

Delerue, N.: RPAT083, RPPP003
Delferriere, O.: FPAE037
Dellapenna, A.: MOPA009, MPPE061, TPAP052
Delle Monache, G.O.: ROAA001, ROAA003
Den Hartog, P.K.: WPAE082
Den Ouden, A.: RPPE001
Denard, J.-C.: RPAE031
Denes, P.: TPAT001
Deng, C.D.: MPPT074
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Derbenev, Y.S.: ROAA005, TPAP042, TPAP043, TPAT019, TPPP013, TPPP014, TPPP015, TPPP044, TPPP052, TPPP055
Derenchuk, V.P.: FPAE051, FPAE052, MPPE021
Deriy, B.: RPPE074, WPAE069
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Deshpande, A.: TPPP022, TPPP042, TPPP043
Devanz, G.: RPPE058, TPPT053, WPAT087
Devon, D.: TPAE041, TPAE046
Devred, A.: RPPE001
Dewa, H.: FPAE063
Dewan, S.: WPAE072, WPAE081
Dey, J.E.: FPAE012, MOPA004, MPPP014, TPAP022, TPPT027
Di Giacomo, M.: FPAE037
Di Nardo, R.: WPAT049
Di Pirro, G.: ROAA001, ROAA003, RPPT013, TPAE002, WPAT006
DiMarco, J.: MOPA001, MPPT044, MPPT053, MPPT054, TOAA004, TPAP029
Diao, C.: RPAE008
Dierker, S.B.: RPAE056
Dillon-Townes, L.A.: RPAT070, RPPE010
Dimitrov, D.A.: TPAE031, TPPE039
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Dinwiddie, R. B.: TPPE016
Dionne, N.J.: TPAT043
Diop, M.D.: WPAT002
Dipace, A.: RPPT013
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Diwan, M.: RPPT059
Dixon, K.: WPAE005
Dobashi, K.: RPAP006, RPAP012, WPAP019
Dobbins, J.: RPAT063, TPPP011, WPAT039, WPAT040
Dobrovolskiy, S.: FPAT024
Dodd, E.S.: TPAE035
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Dohan, D.: ROPA010
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Doleans, M.: FPAE072, MPPE023, MPPE024
Dolgashev, V.A.: ROAC004, ROAC007, RPPP044, TPPT046, WPAT089
Doliwa, B.: MPPP023
Donahue, R.J.: RPAE063, RPAE064
Donald, M.H.: TPPP029
Dong, D.: MPPE071
Dong, H.: FPAT062, RPAT071
Dong, S.: RPPT036, TPPT042
Dooley, K.L.: RPAT062
Dooling, J.C.: TPAT057
Doolittle, L.R.: RPAT074, WPAT057, WPAT060, WPAT062
Doose, C.: MPPT036, MPPT083
Doria, A.: RPPT013
Doria, D.: TPPE002, WPAP010
Dos Santos de Campos, P.M.: MPPT045
Dostovalov, R.V.: TPAP002
Dotson, D.W.: RPAT100, RPPE064, RPPE065
Douglas, D.: RPPE010, TOAC004, WOAC006, WPAP033
Douglas, D.L.: RPPT070
Dovbnja, A.N.: FOAB005
Dovbnya, A.: FPAE062, RPAE011, RPAE012, RPAP034, TPPE050, TPPE052, WPAP028, WPAT021
Dovbnya, N.A.: TPPE052
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Dowell, D.: MOPB008, RPPT013, RPPT029, RPPT030, TPPE041, TPPE058, TPPT031, TPPT032, WPAP060
Dowling, A.S.: RPPE026
Dowling, D.: FPAE032, TPPE020
Doyuran, A.: RPAP033, TOPA006
Drago, A.: FPAP001, MPPP024, ROAA001, ROAA003, RPAT098, RPPP001, RPPT013, TPAE002
Drebot, I.V.: MPPT077, MPPT078
Drees, K.A.: MOPA007, RPAT025, TPAP046, TPAP047, TPAP050, TPAT093, TPAT095
Drennan, C.C.: RPAT010
Driouichi, C.D.: RPAT083, RPPP003
Drozhdin, A.I.: FPAE011, FPAE018, RPPP048, TPAP035
Drumm, P.: ROAA004
Drury, M. A.: RPPE060, RPPE061, TPPT080, TPPT083
Duarte, R.: RPAE063, RPAE080
Ducimetière, L.: FPAT021, ROAB002, WPAE058
Dudnikov, V.G.: FPAP031, TPPE037
Dufau, M.: RPAT061
Dugan, G.: MPPE022, RPPP020, RPPP025, RPPP034
Dujmic, D.D.: TPPP027
Dunkel, K.: TPPE023, TPPE024, WPAT069
Dunning, M.P.: TPPE040
Dunwoodie, W.M.: TPPP023
Duperrier, R.: TPAT005, TPAT047
Durtschi, G.: ROAB001
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Earley, L.M.: ROAC006, TOPA009
Ebert, M.: WPAT003
Ebihara, K.: TPPP007, WPAT009
Ebina, F.: RPAP006, WPAP019
Ecklund, S.: MPPE058, TPPP029, TPPP035
Edamenko, S.: MPPE006
Eddy, N.E.: RPAT030
Edgar, C.L.: WPAE056
Edwards, D.A.: TPAP028
Edwards, H.: RPPE066, TPAE048, TPPE044, TPPT070, WPAP041, WPAP042
Edwards, R.L.: TOPA009
Efthimion, P.: FPAE071, RPAP045, TPAT036, TPAT037
Egawa, K.: RPAP032, TPPP003, TPPP007, WPAE071, WPAT052
Eggert, K.: TPAP020
Eichhorn, R.: FPAE001, MPPT056
Eickhoff, H.: RPAP001
Eidelman, Yu.I.: TPAP043, TPAT090, TPAT091
Einfeld, D.: MPPE069, RPAE087
Eisen, E.L.: WPAT032
Eisert, D.: RPAE070
Ekdahl, C.: ROAB001, ROAB004
El-Ghazaly, El.: TPAE027
Elementi, L.: MPPT054, TPAP030
Eliasson, P.: RPPP009
Elkjaer, A.: WPAE077
Elleaume, P.: RPAE028, RPAE029
Elliott, T.: TPPT082
Ellis, M.: MPPE013, ROAA004
Ellison, J.A.: TPAT042
Emamian, M.: FPAE061, RPAE074, WPAE043
Emanuele, U.: RPAP036

Emery, L.: MPPE064, RPAE002, RPAE003, RPAE071, RPPP047, RPPP051, TOAB009
Emma, P.: FPAT091, MPPP009, RPAT082, RPPT013, RPPT029, RPPT030, RPPT035, RPPT040, TOAB004, TOAC005, TOPA002, TPAE024, TPAT062, TPAT063, TPPP032, WPAT043, WPAT044
Enders, J.: WPAP008
Endo, K.: RPAP032, WPAE071, WPAT052
Eng, W.: WPAE081
England, R.J.: RPAP033, TOPA006, TPPT040
Enokizono, H.: TPAT082
Enomoto, A.: TPPP007, TPPT009
Eppley, K.: TPAT043, WPAT031
Epps, M.A.: RPAT072
Erdmann, J.: MPPT081
Erdélyi, B.: TPAP040
Erickson, R.A.: RPPP036, TPPP032, TPPP038
Ernst, D.: MPPT003
Errede, D.E.: RPPT061
Error, J.J.: WPAE037, WPAE039
Erwin, A.R.: RPPT072
Esarey, E.: RPPT025, TOPA001, TOPA003, TPAE019, TPAE021, TPAE031, TPAE032, TPAE050
Escallier, J.: MPPT038, MPPT046, RPPP016, RPPP017, TOAA006, TOAA009, TOAA010
Espinola, W. J.: RPPE068
Esposito, A.: RPPT013, TPAE002
Esser, F.M.: MPPT056
Euteneuer, H.: TPPE024
Evans, K.: FPAT064
Eversole, S.: ROAB001
Evtushenko, P.: WPAP007
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Eylon, S.: FPAE071, FPAE077, ROAB001, RPAT022, RPAT023
Ezura, E.: ROAC005, TPPT005, WPAT007, WPAT064

Faatz, B.: TOAB002
Fabich, A.: FPAE073
Fabris, A.: RPAE085, WPAT070
Fabris, R.: RPAE085
Facco, A.: FPAE040, TPPT061
Fagotti, E.: FPAE040, FPAE042
Fahmie, M.P.: RPAE063
Faircloth, D.C.: MPPT018, MPPT019, ROPC010, TPPE025
Faircloth, J.F.: FPAE061, RPAE074
Faktorovich, B.L.: RPAP017
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Falone, A.: RPPT014
Faltens, A.: MPPT068, ROAB003, TOAA005
Fan, T.-C.: MPPT020, MPPT032, MPPT076
Fang, J.X.: FPAE064
Fang, S.X.: FPAE064, MPPE046, RPPT056
Fang, Z.: RPAP032, WPAE071, WPAT052
Farias, R.H.A.: MPPE001, MPPE041, MPPP020, WPAE007
Farkas, Z.D.: WPAT067
Farkhondeh, M.: RPAE068, RPAE069, TPPP022, TPPP043
Farvacque, L.: MPPP021, RPAE027, RPAE028, WOAC010
Faucett, J.A.: MPPT055
Faus-Golfe, A.: MPPE009, TPAP003
Favale, A.J.: RPPE009, RPPT032, TPAP043
Fawley, W.M.: FOAA002, ROAB001, RPPT035, TOAB004
Fazekas, J.J.: WPAE037, WPAE039
Fedorova, A.N.: FPAP009, FPAP010, MPPE072, TPAT013, TPAT053
Fedotov, A.V.: FPAT003, TPAP043, TPAP050, TPAT081, TPAT087, TPAT089, TPAT090, TPAT091, TPAT092, TPPP043
Fedurin, M.G.: FPAT056, RPAE050, RPAE051, WPAP056
Feher, S.: FPAT060, MPPT009, MPPT044, MPPT054
Feigerle, C.S.: RPPE030
Feikes, J.: RPAE035
Feitor, R.C.: MPPT045
Feldman, D.W.: FOAD005, MOPC010, TPPE039, TPPE047, TPPE062
Feldman, R.: FOAD005, MOPC010
Fellenz, B.J.: RPAT013
Feng, B.: FPAP022, ROPB004, RPAT078
Feng, J.: MPPE076
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Fenseca, R.: TPAE038, TPAE040
Ferdinand, R.: FPAE037
Ferguson, P.: ROAC006
Ferianis, M.: FOAA005, RPAE085
Fernandez, L.E.: MPPT055
Fernow, R.C.: TPPP040, TPPP041, TPPP047
Ferracin, P.: TOAA001
Ferrando, O.: RPAT003
Ferrari, A.: TPAP007, TPAP014
Ferrario, M.: MOPB006, MOPB008, RPPT013, RPPT015, RPPT031, TPAE002, WPAP009, WPAP011, WPAP012
Ferraz, R.O.: RPPT044, WOAB009
Ferreira, M.J.: RPAT048, RPPT044, WOAB009, WPAE007
Ferrini, G.: WPAP052, WPAP053
Ferro, F.: TPAP020
Fertman, A.: RPPE034
Feschenko, A.: FPAE049, FPAT068
Fieguth, T.: TPPP023, TPPP025, TPPP032
Fields, L.J.: RPPP026
Filho, H.G.: RPPT044
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Filippetto, D.: RPPP001, RPPT013, TPAE002
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Findikoglue, A.: TPPT088
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Fiorito, R.B.: MOPB010, RPAT089
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Fischer, P.: RPAP002
Fischer, W.: MOPA002, MOPA007, MPPE062, TPAP043, TPAP048, TPAP049, TPAP050, TPAT027, TPAT081, TPAT093, TPAT095, TPPP043
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Fitze, H.: TPAT055
Fitzgerald, D.H.: MPPT055
Fitzgerald, J.: WPAE029
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Flacco, A.F.: RPPT031, WPAP012
Flanagan, J.W.: FPAP004, FPAP005, ROPB009, RPAT051, RPAT052, TPPP007
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Floret, I.: WPAE050
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Folwell, N.T.: TPPP028
Fong, K.: FPAE027, ROPC009, TPPT052
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Forest, E.: MPPE005
Forkel-Wirth, D.: TPAP005, WPAE018, WPAE050
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France, A.: FPAE037
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Franklin, W.A.: RPAE068, RPAE069, TPPP022
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Friesel, D.: FPAE051
Frigola, P.: FOAD002, RPAE015, RPPT031, TPPE040
Friis-Nielsen, S.: MPPT087, RPAE084, TPPE054
Frisch, J.C.: ROAC004, RPPE073, RPPP036, TPPP033
Fu, S.: FPAE064, TPPT047
Fuerst, J.D.: TPPT099, TPPT100
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Fuja, R.E.: TPPT039, WPAT059, WPAT061
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Furukawa, T.: FPAE004, FPAE005, RPAP007
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Gabor, C.: RPAT001
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Gassner, D.M.: RPPE009, RPPT032, TPAP043
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Gaxiola, E.H.R.: FPAT021, FPAT022
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Gelfand, N.: TPAP028, TPAP030
Geng, R.L.: ROAC009, TPPT090, TPPT091, TPPT092, TPPT094
Geng, Z.: WPAT075
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Gensch, U.: WPAP006
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Giacone, R.: TOPA003, TPAE031, TPAE050
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Gorelov, D.: FPAE072, MPPE023, MPPE024
Gorev, V.: TPAE007
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Gorman, F.W.: MPPT055
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Gould, O.: MOPB004
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Gräf, H.-D.: WPAP008
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Green, M.A.: MPPT058, MPPT059, TPPP018, WPAE045
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Greenshaw, T.: MPPT033
Greenwald, Z.: RPPT026
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Gulley, M.S.: MPPT055
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Guo, W.: MPPE066, RPAE073, TOAB009
Guo, Z.Y.: FPAE038, FPAE064
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Hahn, H.: MPPT070, RPPE009, RPPT032, TPAP043, TPPE061, TPPT069, WPAP038
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Hama, H.: FPAE025, FPAE036, TPPE060
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Harris, D.: RPPT072
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Harrison, J.: ROAB001
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Hawkey, T.H.: WPAT047, WPAT048
Hawkins, A.: ROAB008, ROAB010
Hayano, H.: FOAB010, MPPE044, RPAP006, RPAP011, RPPP002, RPPP003, TOAD004, TPPT009, WOAA002, WPAP019
Hayashi, K.: WPAT084
Hayashi, N.: RPAT005, TOAD003
Hayashizaki, N.: FPAE065, TPAT075, TPPE027, TPPE031
Hayato, .: ROAD003
Hayden, D.J.: MPPT055
Hayes, T.: FPAE029, MOPA007, TPAT093
Hays, S.: WPAT033
He, H.: RPAE076, RPPT045
He, P.: RPPE048, RPPE049, RPPE050, RPPP016, RPPP017, TPAP049, TPAT095
He, Y.: RPPE044, RPPE045, WPAE025, WPAE030
Hechler, M.P.: RPPE046, RPPT069
Hecht, A.A.H.: TPPE006
Heese, R.: RPAE056
Heikkinen, S.T.: TPPT020
Heilbronn, L.H.: RPPT062, RPPT063
Heimsoth, SH.: TOAA008
Held, B. H.: TPAT043
Helms, R.W.: RPPP023
Helus, S.A.: WPAE037, WPAE039
Hemmer, F.M.: TPAP060
Henderson, D.: MPPT055
Henderson, S.: FPAE024, FPAE049, FPAE057, FPAE058, ROPB010, RPAT039, RPAT041, RPPE048, WOAC009
Hendrickson, L.: MPPP009, RPPP027
Henestroza, E.: FPAE071, FPAE077, FPAT027, FPAT028, ROAB001, ROAB003, RPAT023
Henrist, B.: RPPE042, RPPE043
Henry, J.: TPPT083
Herbeaux, C.: RPAE031
Hermanne, A.: RPAT002
Hernandez, M.: RPAP025, RPAP026, RPAP027
Hernandez-Garcia, C.: WPAP033, WPAP050
Herr, W.: TPAT078
Hershcovitch, A.: RPPE009, RPPT032, TPAP043
Herzog, R.: TPAP020
Hess, M.: RPAE016, WPAP044
Hettel, R.O.: TOAB006
Hiatt, T.: MPPT082, RPPE061
Hickman, B. C.: ROAB008
Hicks, J.: WPAT055, WPAT056
Hicks, R.: RPPE060, TPPT073
Hicks, S.E.: FPAT075
Hidume, K.: FOAB010, RPAP011
Higashi, N.: TOAA006
Higashi, Y.: ROAC004, ROAC007, RPPP003, TPPT046
Higgins, H.: WPAE065
Higo, T.: ROAC004, ROAC007, RPAP006, TPPT009, TPPT046, WPAP019
Hildreth, M.H.: RPPP036
Hill, C.: FPAE011
Hill, C.E.: RPPE005
Hill, S.: WPAT043
Hill, W.: MPPE049
Hillman, A.L.: WPAE069, WPAE070
Himel, T.M.: RPPP003, RPPP032
Hinode, F.: FPAE025, FPAE036, TPPE060
Hiramatsu, S.: ROPB009, RPAT051, RPAT052, RPAT053, TPPP005, TPPP007
Hirashima, T.: WPAT052
Hiroki, H.: RPAT004
Hiroki, S.H.: FPAE002, TOAD003
Hirschmugl, C. J.: RPAE038
Hirshfield, J.L.: TPAE012, TPAE013, TPAE063, WPAT026, WPAT027, WPAT028
Hisamatsu, H.: FPAP007, RPPE053
Hitz, D.: RPAP024
Ho, H.C.: RPAT059, RPPE008
Ho, K.: ROPA005
Hoff, L.T.: FPAT066
Hoffstaetter, G.: RPPT026, TOAC004, TPAP044
Höfle, W.: FPAT022
Hofler, A.S.: TPPT074
Hofmann, A.: MPPP032
Hofmann, B.: RPAP003

Hofmann, I.: MOPC003, RPPE034, TPAT070
Hogan, J.: RPPE061, RPPE067
Hogan, M.J.: RPAE019, RPAT078, RPAT079, RPAT082, TOPA002, TPAE024, TPAE025, TPAE035, TPAE041, TPAE042, TPAE049, TPAE058
Hojo, S. H.: RPAP007
Holder, D.J.: RPAE052
Holding, M.: FPAE074, RPPE033
Holik, P.S.: RPPE011, RPPE012
Holldack, K.: RPAE032, RPAE033, RPAE035
Holloway, M.: FOAD005, FPAE021, RPPE075, RPPE076
Holmes, D.: RPPE009, RPPT032, TPAP043, WPAT091
Holmes, J.A.: FPAE024, FPAP025, MOPC003, ROPB010, TPAT031, TPAT032, WOAC009
Holmes, L.: ROAB010
Holmes, R.: WPAE072, WPAE081
Holtzapple, R.: TPPP026, TPPP027
Holzer, E.B.: TPAP007
Holzscheiter, M.: ROAB001
Holzwarth, R.: RPAT075
Honda, T.: RPAE041
Honda, Y.: MPPE044, RPPP003
Hong, I.-S.: TPPE005
Hong, J.-S.: WPAT071
Hong, S.-M.: WPAE016
Honma, T.: RPAP007
Hooker, S.M.: TPAE019, TPAE021
Horan, D.: TOAB009, TPPT035, TPPT036, WPAT033
Hori, T.: WPAT008
Hori, Y.: RPAE041
Horioka, K.: FPAE020, FPAT042, FPAT043
Hotchi, H.: FPAE067, MPPE004, MPPE005, MPPE043
Hou, H.Mi.: WPAT075
Houck, T.L.: FPAT041, ROAB001
Hourdin, L.H.: RPPE027
Hourican, M.: RPPE005, RPPE041
Hovater, C.: WPAT034, WPAT040
Howe, S.D.: FPAE023
Howell, C.: RPAE074
Howell, D.F.: RPAT083
Howell, M.P.: RPPT071, WPAE005, WPAT085
Hozumi, Y.: WPAP014, WPAP016
Hseuh, B.: RPPT066
Hseuh, H.-C.: FPAP024, MOPA007, MPPT070, RPPE009, RPPE046, RPPE047, RPPE048, RPPE049, RPPE050, RPPT032, TPAP043, TPAP049, TPAT093, TPAT095
Hsiao, F.-Z.: TPPT066, WPAE001, WPAE002, WPAE003
Hsiung, G.-Y.: MPPT032, TPPT066
Hsu, K.-T.: MPPP005, MPPP034, MPPT032, RPAE049, RPAT058, RPPE019, TPPT066
Hsu, S-N.: MPPT032
Hsueh, H. P.: RPAT060
Hu, K.H.: RPPE019
Hu, M.: FPAE017, MPPP011, RPAT031
Hu, Y.: TPAE065
Huang, C.: RPAE019, RPAT078, RPAT079, TOPA002, TPAE024, TPAE025, TPAE034, TPAE040, TPAE041, TPAE042, TPAE046, TPAE058
Huang, C.G.: MPPE071
Huang, F.: MPPT003
Huang, G.: MPPP026, RPPT027, TPPP020, TPPP021, WPAT011
Huang, G.: WPAT065
Huang, H.: FPAE006, FPAE014, MOPA007, TPAP044, TPAP049, TPAP050, TPAP059, TPAT093, TPAT095
Huang, J.Y.: MPPP003, ROPB005, RPAT007, RPAT054, RPPT031, WPAE061, WPAT013
Huang, M.-H.: MPPT032
Huang, X.: MPPE055, WOAC005
Huang, Z.: RPPT028, RPPT035, RPPT040, TOAB004, TOAC005, TPAT062, TPAT063
Hubbard, J.: MPPE049
Hubbard, R. F.: TOPA004
Hubrig, J.G.: MPPT091
Hudson, E. D. H.: FPAE032
Huening, M.: TPPE044, WPAP042
Hughes, T.P.: FOAA002, FPAT033, ROAB001, ROAB004
Hukuma, H.: ROPB005
Hulbert, S.: RPAE056
Humbel, M.: TPAT055
Humphries, S.: ROAC006
Hunt, A.W.: RPAP021
Hunter, T.: RPPT070, RPPT071, TOAA008
Huo, Y.: MOPC010, TPAT067
Hur, M.S.: TPAE054
Hurh, P.: RPPE028
Hurst, D. E.: WPAT055
Hussain, Z.: TPAT001
Hussein, A.: TPAE027
Huttel, E.: MPPP001, RPAE037, RPAE038
Hutton, A.: RPPT024, TPPP015
Hwang, C.-S.: MPPT020, MPPT032, MPPT076
Hwang, I.: MPPP027, TPAT011
Hwang, W.H.: RPAT007
Hwang, Y.-S.: FPAE046, FPAE047

Iazzourene, F.: RPAE085
Ibragim, K.: RPPT076
Ichikawa, A.: TOAA006
Ieiri, T.: MOPC008, TPAT051, TPPP007
Igarashi, S.: FPAE020, FPAP006, MPPT015
Igarashi, Z.: FPAE043, RPAT004, RPAT043
Ignashin, N.: RPAT094
Ihee, H.: TPAE067, WPAP040
Ihloff, E.: RPAE068, RPAE069
Iida, N.: TPPP007
Ike, R.C.: TPPT084
Ikeda, H.: ROPB009, RPAT052, TPPP007
Ikeda, M.: TPPT011, TPPT038, WPAP014, WPAP016
Ikeda, N.: FPAE026
Ikegami, M.: FPAE043, RPAT004, RPAT043, TPAT050, TPPT041, WPAE014, WPAE044
Ilday, F.O.: RPPT038, RPPT039, TOPB003
Illyashenko-Raguin, L.: TPAE008
Inabe, N.: FPAE068
Incurvati, M.: ROAA001, ROAA003, RPPT013, TPAE002
Indurthy, D.: RPAT044, RPPT072
Ingrassia, P.: MOPA007, TPAT093
Inoue, M.: FOAB004
Insepov, Z.: TPPT025
Iqbal, N.: TPPT093
Irie, Y.: FPAE002, FPAE067, MPPT007, MPPT015
Iriso, U.: MOPA007, RPAT026, TPAP049, TPAT093, TPAT095
Irwin, J.: MPPE058
Isagawa, S.: WPAT009
Ischebeck, R.: RPAT078, RPAT079, RPAT082, TPAE024, TPAE049
Ishi, Y.: FOAB004, MPPE005
Ishii, I.: RPAT053, TPPP005
Ishimoto, S.: TPPP018
Ispirian, K.A.: MPPE080, RPAT047
Ispirian, M.K.: MPPE080
Italiano, A.: RPAP036
Ito, I.: RPPE040
Ito, T.: TPAT075, TPPE027
Ito, T.: WPAE044
Ito, Y.: FPAT047
Ivanov, A.S.: RPAP019
Ivanov, P.M.: MPPP042, MPPP043, TPAT064
Ivanov, V.: WPAT080
Ivanov, Yu.M.: WPAE009

Ivantcov, I.A.: RPAE074
Ivanyan, M.: MPPP051, RPAE083
Ivanyushenkov, Y.: MPPT033, MPPT058, MPPT059, TPPP018
Ivashchenko, V.A.: MPPT078
Iverson, R.H.: RPAE019, RPAT078, RPAT079, TOPA002, TPAE024, TPAE025, TPAE034, TPAE035, TPAE041, TPAE042, TPAE046, TPAE058
Iwamoto, Y.: TOAA006
Iwasaki, Y.: FPAT076, RPAE006
Iwasaki, Y.: RPAE078, TPPE048
Iwase, H.: RPPT063
Iwashita, T.: FPAE020
Iwashita, Y.: MPPT025, RPPP003
Iwata, Y.: RPAP007
Izawa, M.: RPAE041, TPPT013, TPPT049, TPPT063, WPAT009

Jach, C.: FPAE030
Jackson, A.: TPPT049, WOAB001, WOAB004
Jackson, F.J.: RPPP036
Jackson, G.P.: FPAE023, MPPE035
Jacob, J.S.: FOAD002, RPAE015
Jacobs, C.L.: FPAT004
Jacobs, K.: MPPP010, RPAE070
Jacquet, D.: TPAP015, TPAP018
Jacquez, E.: ROAB001
Järvinen, M.: TPAP020
Jaeschke, E.: WPAP006
Jago, S.J.S.: MPPT018, MPPT019
Jahnel, L.C.: MPPE001, MPPE041, WPAE007
Jain, A.K.: MPPT038, MPPT046, MPPT050, RPAP043, RPPP016, RPPP017, TOAA006, TOAA009, TPAP043, TPAT087
Jain, L.K.: TPAT032
Jain, P.J.: RPPT042
Jalalyan, V.M.: RPAE083
Jameson, R.A.: FPAE065, TPPE031
Jang, J.-H.: FPAE044, FPAE045, FPAE046, FPAE048
Jankowiak, A.: TPPE024
Janssen, D.: MOPB011, WPAP007, WPAP033
Jansson, A.: RPAT032, RPAT033
Jarlskog, C.: MOAA001
Jarron, P.: TPAP020
Jason, A.J.: RPPT068
Jeanneret, J.-B.: MPPE010, MPPT041, TPAP007
Jensen, C.C.: FPAT032, ROAB009
Jensen, J.-P.: RPPE013
Jensen, K.: TPPE039, TPPE047, TPPE062
Jensen, L.K.: MPPP004
Jensen, M.: WPAT025
Jeon, D.-O.: FPAE057, FPAE058, FPAE059, TPAT030, WPAE040
Jeong, M.H.: WPAT013, WPAT014
Jeong, S.-H.: MPPT017, WPAE016, WPAE060
Jimenez, J.M.: FPAP014, RPPE042, TPAP007, WPAE020
Jin, K.: WPAT065
Jin, L.: TPPP017
Jin, X.: WPAP020
Jinamoon, V.: RPPT074, RPPT075
Jines, P.: FPAT056, RPAE050, RPAE051
Jinfeng, Y.: RPAP038
Jing, C.-J.: RPAT066, TPAE016, TPAE017, TPAE018, TPAE065
Jobe, R.K.: ROAC004, RPPP036
John, J.A.: MPPT010, MPPT011, MPPT013, MPPT051, MPPT053
Johns, G.D.: MPPT055
Johnson, D.: ROAB001
Johnson, D.E.: MPPE052, MPPT011
Johnson, D.K.: RPAE019, RPAT078, TOPA002, TPAE024, TPAE025, TPAE034, TPAE042, TPAE058
Johnson, E.D.: RPAE056, RPAE058, RPAE059
Johnson, G.A.: TPPT039
Johnson, J.: ROAB001, RPAT073
Johnson, J.W.: RPAP024
Johnson, M.: RPAE074
Johnson, M. J.: TPPT096
Johnson, P.D.J.: RPPE032, RPPT032, TPAP043, TPPE042
Johnson, R.P.: ROAA005, TPPP013, TPPP014, TPPP050, TPPP052, TPPP054, TPPP056, WPAT029
Johnson, T.: ROPA002
Johnstone, C.: RPPT051, RPPT060, RPPT061, TPAP024, TPPP046
Johnstone, J.A.: TPAP026, TPAP028
Jones, A.: RPPE021
Jones, F.: MOPC003
Jones, J.K.: MPPE014, RPAE052, RPPP003
Jones, K.: ROAB001
Jones, R.M.: ROAC004, RPPP042, RPPP043, TPPP033, TPPT044, TPPT045, TPPT046
Jones, R.O.: MPPP004, TPAP008
Jones, T.G.: TOPA004
Jones, W.P.: FPAE052, MPPE021
Jordan, K.: TOAC004, WPAP050
Joshi, C.: RPAE019, RPAE021, RPAP033, TOPA002, TOPA006, TPAE024, TPAE025, TPAE034, TPAE035, TPAE038, TPAE041, TPAE042, TPAE043, TPAE044, TPAE046, TPAE058
Joshi, C.H.: RPPE068
Jousse, D.: WPAP001
Jovanovic, I.: RPAE013
Jowett, J.M.: RPPE005, TPAP012
Julian, J.: RPAE063, RPAE067
Jung, J.-Y.: RPAE063
Jung, Y.G.: MPPT017, MPPT075, WPAE016, WPAE060
Junphong, P.: FPAE076
Juras, R.C.: TPPE020
Juul, E.: RPAE007

Kabel, A.C.: MPPE039, TPAT072, TPAT074
Kabeya, Z.: RPPE039, TPPT007
Kachel, T.: RPAE033
Kadi, Y.: TPAP009
Källberg, A.: FPAE069
Kaertner, F.X.: RPPT038, RPPT039, TOPB003
Kaganovich, D.: TOPA004
Kaganovich, I.: FPAE071, FPAP026, FPAP027, FPAP028, ROAB003
Kageyama, T.: TPPP007, TPPT006, TPPT007, TPPT010, WPAT009, WPAT010
Kahle, K.: RPPE005
Kahn, S.A.: MPPT057, RPPT059, TPPP048
Kain, V.: MPPE011, MPPE047, MPPE048, RPPE016, RPPE017, RPPE018, TPAP009, TPAP015, TPAP017, TPAP018, TPAP019
Kakihara, K.: TPPT011, TPPT038
Kako, E.: TPPT062
Kalantaryan, D.K.: MPPE080, RPAE083
Kale, U.K.: RPPT042
Kalinin, A.: RPPP003, RPPP036
Kalinin, B.N.: RPAT055
Kalliopuska, J.: TPAP020
Kallos, E.K.: TPAE057
Kamada, S.: TPPP007
Kamigaito, O.: FPAE068
Kamikubota, N.: FPAT065, ROPA003, RPAT043
Kamitani, T.: TPPP007, TPPT011, TPPT015, TPPT038, WPAP015

Kamiya, J.: FPAE002, MPPT006, MPPT007, MPPT015
Kamps, T. , RPAT083, WPAP007
Kanareykin, A.: TPAE018, TPAE033, TPAE060, TPAE061, WPAT094, WPAT095
Kanazawa, K.-I.: FPAP007, RPPE052, RPPE053
Kanazawa, M.: RPAP007
Kandaswamy, J.: MPPT080
Kaneko, O.: RPAP040
Kaneyasu, T.: RPAP006, RPAP012, WPAP019
Kang, B.-K.: WPAE016, WPAE062
Kang, H.: MPPP015
Kang, H.-S.: MPPP003, MPPT017, RPAE046, WPAE060, WPAT015
Kang, M.: FOAA002, FPAT033
Kang, W.: MPPT005, WPAE080
Kang, Y.W.: TPPT039, TPPT083, WPAT059, WPAT061, WPAT085
Kangas, K.W.: MPPT028, MPPT029
Kantsyrev, A.: RPPE034
Kao, C.C.: RPAE056
Kao, S.-P.: FPAT055, WPAE002
Kapin, V.: RPAP007
Kaplan, D.M.: ROAA005, TPPP052, TPPP054, TPPP056
Kaplan, R.P.K.: TPPT089, WPAT038, WPAT039, WPAT040
Karantzoulis, E.: RPAE085
Karasyov, S.P.: FOAB005
Karataev, V.: RPAT077, TOAD004
Karkera, B.N.: WPAE006
Karl, F.X.: TPAP060
Karliner, M.M.: RPAP015
Karmanenko, S.F.: TPAE061, WPAT095
Karnaukhov, I.M.: MPPT078, RPAE011, RPAE012
Karppinen, M.: MPPT044
Karpuk, S.: FOAD004
Kase, M.: FPAE068
Kasemir, K.-U.: MPPP016, WPAT057, WPAT058, WPAT060
Kashikhin, V.: MPPT047, MPPT054, TOAA004
Kashikhin, V.S.: MPPP012, MPPT010, MPPT011, MPPT012, MPPT013, MPPT054, TOAA004, WPAT033
Kashiwagi, H.: TPPE027, TPPE031
Kashiwagi, S.: FOAB010, RPAP011
Kashy, D.H.: RPPE010
Kasuga, T.: RPAE041, WPAT009
Katagiri, H.: WPAT053
Katayama, T.: FPAT043
Kato, S.: TPPP007
Kato, Y.: FPAT047
Katoh, T.: FPAT071, ROPA003
Katsouleas, T.C.: FPAP022, ROPB004, ROPB007, RPAE019, TOPA002, TPAE024, TPAE025, TPAE034, TPAE035, TPAE040, TPAE041, TPAE042, TPAE046, TPAE057, TPAE058
Kauffman, S.R.: RPAT071
Kaugerts, J.: FPAE075, TOAA009
Kawaguchi, M.: FOAB010
Kawai, M.: FPAE025, FPAE036, TPPE060
Kawai, Y.: TPPE014, TPPE015, TPPE016, TPPE017, TPPE018, TPPE020
Kawakubo, T.: FPAE002, MPPT006, MPPT007, MPPT015, ROAB007
Kawamoto, T.: MOPC008
Kawamura, M.: WPAT008
Kawasaki, A.K.: FPAE020
Kawase, M.: FPAT047
Kawasumi, T.: TPPT007
Kawata, S.: FPAT042, FPAT043
Kayran, D.: RPPE009, RPPT022, RPPT032, TPAP043, TPAP050, TPPE043, TPPP043, WPAP033, WPAP037, WPAP038
Kazakevich, G.: MPPT022
Kazarezov, I.V.: WPAP023
Kazarinov, Yu.: TPPE033, TPPE034
Kazimi, R.: RPAT072, WPAP046
Ke, M.: RPPE006
Kecskemeti, R.: FPAP027
Kedzie, M.: TPPT099, TPPT100
Keil, B.: MPPP017, MPPP018
Keil, E.: RPAP020
Keil, R.G.: RPAE070
Keisler, R.: RPPT072
Kelez, N.: TOPC003
Keller, L.: RPPP036
Keller, R.: RPAP023, TPPE022
Kelley, J.P.: WPAP033
Kelly, M.P.: TPPT099, TPPT100
Kempkes, M.A.: WPAT047, WPAT048
Kempson, V.: RPAE052
Kenjebulatov, E.: WPAT017
Kephart, R.D.: MPPT054, TPAP029
Kerby, J.S.: MPPT044
Kersevan, R.: FPAT045, ROAD005, RPPT070, RPPT071
Kershaw, A.H.: RPAP046
Kerstiens, D.M.: MPPT055
Kesar, A.S.: RPAE016, RPAT076, TOAD005, TOPA009
Kessler, T.: TPPE019
Kewisch, J.: RPAP043, RPPE009, RPPE032, RPPT022, RPPT032, TPAP043, TPAP050, TPPE042, TPPE043, TPPP043
Khabibouline, T.K.: ROAC004, RPPE066, TPPT056, TPPT070, WPAT033, WPAT050
Khachatryan, V.G.: MPPT086, RPAE083
Khan, S.: RPAE032, RPAE033, RPAE034, TOAB007
Khan, S.A.: MPPE078
Khodak, I.V.: FPAE062, WPAP027
Khodyachykh, S.: WPAP006
Khudyakov, A.I.: WPAT021
Kiggans, J. O.: TPPE016
Kihara, R.: FPAT036
Kikuchi, M.: TPPP001, TPPP007
Kikuchi, T.: FPAT042, FPAT043
Kikutani, E.: TPPP007
Kim, C.: TPAE005, TPAE054
Kim, D.E.: MPPT075, WPAE016, WPAE062
Kim, D.T.: RPAT008, RPAT054, WPAT015
Kim, E.-S.: MPPE045, MPPP027, ROPB005, RPPT016, TPAT011, TPPT064
Kim, G.-H.: TPAE005, TPAE053, TPAE054, TPAE055
Kim, H. Y.: WPAE015
Kim, H.-G.: RPPE003, TPPT064
Kim, H.-S.: FPAE044, FPAE046, FPAE047, FPAE048, WPAT012
Kim, J.: TOPB003
Kim, J.B. , TPAE006
Kim, J.S.: RPAT096
Kim, K. R.: RPAP013, RPAP014
Kim, K.-J.: MPPE068, RPAE018, TOAB009
Kim, K.-R.: RPPE003, TPPT064
Kim, M.: RPAE046
Kim, S.-C.: RPAT008, RPAT054, WPAE061, WPAT014, WPAT015
Kim, S.-H.: WPAT071
Kim, S.H.: MPPT035, MPPT036
Kim, Y.: RPPT006, RPPT008, RPPT009, RPPT010, RPPT011
Kim, Y.-C.: MPPP003, WPAE015
Kim, Y.-H.: FPAE044, FPAE045, FPAE046, FPAE047, FPAE048, TPPT017
Kim, Y.-S.: WPAE062
Kimber, A.J.: WPAE078
Kimura, N.: MPPT044, TOAA006
Kimura, W.D.: TPAE057, TPAT034
King, F.K.K.: TPPE057
King, K.: RPPE060, TPPT080
Kinkead, A.K.: TPAE065, WPAT027
Kinsho, M.: FPAE002, RPPE039, WPAE012

Kiper, T.: RPAT009
Kirby, G.: MPPT042, MPPT043
Kirby, R.E.: ROAC004, TPPE057, TPPE063, WPAP058
Kireeff Covo, M.: FPAP015, FPAP033, MPPT068, ROPB002
Kirk, H.G.: FPAE073, MPPT057, ROAD003, RPPT067, TPPP047, TPPP048, TPPP051
Kiryukhin, "N.M".: FOAB005
Kiselev, O.B.: MPPT084
Kiselev, V.: FPAE007, TPPP009
Kiselev, Y.: FPAE049, FPAT068
Kishek, R.A.: FOAD005, FPAE021, MPPE067, TPAT004, TPAT066, TPAT067, TPPE046
Kishiro, J.: FPAE020, FPAE034, MPPE004, RPAT004, RPAT005, TOAD003, TPPT014
Kitajima, S.: RPAP040
Kiyama, S.: RPAP040
Klein, H.: RPAT001, TPPT058
Klein, H.-U.: FOAB003
Kleman, K. J.: MPPP010, RPAE070
Klier, A.: TPPP039
Klotz, W.-D.: ROPA008
Kmak, R.T.: RPAE004
Knaak, M.: TPPT089
Knabbe, E.-A.: RPAT050, RPAT094
Knapic, C.: MPPT089, MPPT090
Kneisel, P.: RPPE009, RPPE061, TPAP043, TPPE061, TPPT056, TPPT071, TPPT072, TPPT075, TPPT076, TPPT077, WPAP033, WPAP038, WPAP039, WPAP047
Knickerbocker, K.L.K.: RPAT010
Knobloch, J.: TPPT054, WPAT088
Knudsen, P.K.: WPAE005
Ko, D.-K.: TPAE053, TPAE055
Ko, I.S.: ROPB005, RPAE009, RPPT017, TPAE005, TPAE006, TPAE067, WPAP021, WPAP022, WPAP040
Ko, K.: TPPT056, WPAT042, WPAT080
Ko, sk.: WPAT071
Kobayashi, K.: RPPE040
Kobayashi, M.: WOPB002
Kobayashi, T.: FPAE063
Kobayashi, T.: TOAA006
Kobayashi, Y.: MPPT016, RPAE041
Kobets, A.P.: TPPT022
Koda, S.: FPAT076, RPAE006, RPAE078, TPPE048
Koester, P.: TPAE002
Koeth, T. W.: TPPE044
Koiso, H.: MPPT037, TPPP002, TPPP003, TPPP007, WOAD001
Kok, A.: TPAP020
Kokin, E.N.: WPAP023
Kolesov, S. K.: RPAT045, WPAT068, WPAT069
Kolomensky, Y.K.: RPPP036
Kolomiets, A.: FPAE054, FPAE055
Koltsov, A.V.: FPAT052, TPAT052
Kondakov, A.A.: WPAT017
Kondo, Y.: FPAE043, RPAT004
Kondoh, T.: RPAP038, WPAP017, WPAP018
Konecny, R.: RPAT066, TPAE016, TPAE017, TPAE060, TPAE065
Konkashbaev, I.: TPPT025
Kono, T.: FPAE020, TPPT014
Kononenko, S.G.: RPAP034, TPPE050
Koop, I.: TPAP043
Kopp, S.E.: FOAC004, FPAE022, RPAT044, RPPT072
Korbly, S.: RPAE016, RPAT076
Korostelev, M.: MPPE044, RPPP007, RPPP008, RPPP012
Koscielniak, S.R.: RPPT051, RPPT052
Koseki, K.: FPAE020
Koseki, T.: TPPT013, TPPT049
Kosovsky, M.: TPPP031
Kosoy, A.I.: WPAT021
Kostin, D.: TPPT054
Kostin, M.A.: FPAE011, RPPP048, TPAP035
Kostka, B.K.: RPAE039
Kotturi, K.D.: WPAT073
Kourbanis, I.: MOPA004, TPAP022, TPPT027
Kourevlev, G.Yu.: RPPP028
Koutchouk, J.-P.: MOPC009
Kovalishin, A.S.: FPAT068
Kozanecki, W.: MOPC006, TPAT076, TPPP023, TPPP024, TPPP025, WPAE056
Kozawa, T.: RPAP038, WPAP017, WPAP018
Kozin, V.P.: MPPT078
Kozub, S.: WPAE029
Kozyrev, E.V.: WPAT026, WPAT027
Kponou, A.: MOPB004
Krämer, D.: RPPT001, WPAP006
Krafczyk, G. E.: ROAB009
Krafft, G.A.: TPPP015, TPPP016, WPAP046
Krainov, G.S.: WPAP023
Kramarenko, K.: TPPE051
Kramer, S.L.: RPAE056, RPAE057, RPAE058, RPAT068
Krasilnikov, M.: RPPP006, WPAP003, WPAP004, WPAP005, WPAP006
Krasnov, A.A.: TPAP002
Krause, H.F.: TPPE019
Krausz, F.: TPAE056
Kravchuk, L.V.: FPAE049, FPAT068, RPPP006
Krawczyk, F.L.: ROAC006, TPPT088
Krejcik, P.: RPAE019, RPAT078, RPAT079, RPAT082, TOPA002, TPAE024, TPAE025, TPAE042, TPAE058
Kremer, F.: TPPE023
Krempasky, J.: MPPP018
Kremyanskaya, E.V.: FPAE007
Krinsky, S.: MPPP036, MPPP038, MPPP039, MPPP040, RPAE056, RPAE058
Krishnagopal, S.: RPPT042
Kriss, M.: FPAT007
Kristensen, J.: TPPE054
Kroc, T.K.: MPPT022, RPAT069, WPAE027
Kronenberg, A.: TPPE020
Kroyer, T.: FPAT021, MPPP031, TPAP008
Krstic, M.: FPAT092
Krushelnick, K.M.: TOPA007
Krutikhin, S.A.: WPAT017
Kuan, C.-K.: RPAT060
Kubat, R.: RPAE038
Kubo, K.: MPPE044, RPPP003, RPPP004, RPPP008
Kubota, C.: WPAE044
Kuchler, D.: RPPE005
Kuchnir, M.: ROAA005, TPPP050, TPPP054, TPPP056
Kudo, H.: RPPE040
Kulagin, V.V.: TPAE054
Kulikov, A.: TPPP038, WPAE079
Kumada, M.: MPPT025, RPAP008, RPPP003
Kumar, A.: RPPT042
Kumar, V.: RPAE018, RPPT042
Kundrát, V.: TPAP020
Kunin, A.: RPPE034
Kuno, Y.: FOAC001
Kuo, C.-C.: MPPT032, RPAE047, RPAE048, RPAE049, TPPT066
Kuo, C.H.: RPAT058
Kuptcov, I.: RPAE074
Kuptsov, I.V.: WPAT017
Kurakin, P.V.: FPAT052
Kurakin, V.G.: FPAT052, TPAT052
Kurennoy, S.S.: RPAT040, RPPT068, TPPE045, WPAP033
Kurihara, A.: FPAE036
Kuriki, M.: MPPE044, RPPP003, RPPP008
Kurita, N.: TPPP031

Kurkin, G.Y.: FPAT051, MPPP047, MPPP050, RPAE074, WPAT016, WPAT017
Kuroda, R.: FOAB010, RPAP011
Kuroda, S.: MPPE044, RPPP003, RPPP008
Kurokawa, S.-I.: FPAP005
Kurtyka, T.: TPAP004
Kurvinen, K.: TPAP020
Kusano, J.: WPAE012
Kusche, K.: RPAT067
Kushnir, V.A.: FPAE062, RPAE011, TPPE051, WPAP027
Kuske, P.: RPAE035, WOAC003
Kusoljariyakul, K.: RPPT074, RPPT075
Kustom, R.: MPPT036, TOAB009
Kutschke, R.K.: RPAT018
Kutuzov, V.A.: FPAT020
Kuzminykh, V.: RPAE036
Kuznetsov, G.F.: WPAE029
Kuznetsov, G.I.: RPAP015, RPAP016, TPPE029, WPAP023
Kvardakov, V.A.: FPAE007
Kvasha, A.I.: FPAT068
Kwan, J. T.: FPAT025, RPAP022
Kwan, J.W.: FPAP033, FPAT028, TPPE009, TPPE011
Kwarciany, R.: RPAT032
Kwiatkowski, S.: RPAE063, RPAE065, RPAE067, RPAE079, WPAT066
Kwon, H.-J.: FPAE044, FPAE045, FPAE046, FPAE047, FPAE048, TPPT017, TPPT018, WPAT012, WPAT015
Kwon, S.I.: WPAT037

LaPointe, M.A.: TPAE063, WPAT026, WPAT027
Labate, L.: TPAE002
Lackey, J.R.: FPAE018, FPAE019, MPPT010, MPPT013
Lacroix, J.-M.: RPPE042
Ladd, P.: FPAT067, RPPE046, RPPT070, RPPT071, TPPT039
Lal, S.: RPPT042
Lambiase, R.F.: RPPE009, RPPT032, TPAP043, WPAE067, WPAE072, WPAE081
Lamm, M.J.: FPAT060, MPPT044, MPPT054, TOAA002, TOAA004, TPAP029
Lamont, M.: TPAP015, TPAP018
Langdon, S.: FPAT040
Lange, R.: FOAA005
Langlois, M.L.: WPAT076
Langton, J.: TPPP028, TPPP030
Lanzone, S.: RPAP037
Lapshin, V.: MPPT078
Larsson, M.: FPAE069
Laskar, J.: WOAC008
Lassiter, R.: RPPE010
Laster, J.S.: MOPA007, MOPA009
Latysheva, L.: FPAE075, RPPE034
Lau, T.: TPAT008
Lau, W.: MPPT058, MPPT059, TPPP018, WPAE045
Lau, W.-K.: MPPP005, TPPT021
Lauhakangas, R.: TPAP020
Launey, D.J.: FPAT056, RPAE050
Lawson, G.S.: FPAT075
Lawton, D.: RPPT062, RPPT063
Laxdal, R.E.: FPAE027, ROPC009, TPPT001, TPPT052
Laziev, E.M.: RPAE083, RPAT047, TPAE001
Le Pimpec, F.: ROAC004
LeBlanc, G.: TPPT049, WOAB004
Lebedev, G.V.: TPAT001
Lebedev, V.: MPPE065, MPPP042, MPPP043, TPAT083, TPAT084
Leboeuf, D.: FPAE037
Lebon, DL.: TOAA008
Lebrun, P.: FPAT005, FPAT012, RPAT033
Leclercq, N.L.: ROPA005
Lee, C.-H.: TPAE064
Lee, D.: RPPE019
Lee, E. P.: ROAB003, RPAP039
Lee, E.-H.: MPPP003, RPAE046
Lee, H.-G.: MPPT017, MPPT075, WPAE060
Lee, H.-S.: WPAE015
Lee, H.S.: WPAE016
Lee, J.: TPAE053, TPAE055
Lee, J.-W.: FPAT050
Lee, K.: WPAT071
Lee, L.: TPPP028, TPPT056, WPAT042
Lee, LHR.: RPAP013
Lee, M.J.: MPPE040
Lee, R.C.: MOPA007, MOPA009, RPAT029, TPAP047, TPAT095
Lee, R.W.: ROAB003, RPAP039
Lee, S.: FPAE043, RPAT004, RPAT005, RPAT037, RPAT043, TOAD003
Lee, S.: TPAE035
Lee, S.-K.: RPAP013, RPAP014
Lee, S.-Y.: FPAP025, MPPE055, MPPP044, ROPB010, TPAP044, WOAC005
Lee, T.-Y.: MPPP003, RPAE046, RPPT017, TPAT010
Lee, W.L.: TPAT069
Lee, W.W.: MPPP003, RPAT054, WPAE016, WPAE062
Lee, Y.Y.: FPAP024, MPPT070, MPPT071, RPPE048, RPPT065, TPPE007, WPAE035
Leemann, S.C.: TPPE026
Leemans, W.: TOPA001, TOPA003, TPAE019, TPAE021, TPAE031, TPAE032, TPAE050, WOPA
Lefevre, T.: RPPE025, RPPP001
Lefferts, R.S.: WPAP039
Legg, R.A.: RPAE070
Lehecka, M.: MPPT026
Lehmann, W.-D.: WPAP007
Lehnert, U.: WPAP007
Lehrach, A.: FPAE001
Leitner, D.: MOPB002, TPPE010, TPPE032
Leitner, M.: FPAE071, ROAB003, RPAT021
Lekprasert, Mr.: FPAE076
Lemaire, J.-L.: ROPA007
Lemuet, F.: MPPE042
Lenci, S.: WPAT032
Lenisa, P.: TPPE030
Lenkszus, F.: RPAT084
Leontein, S.: FPAE069
Lessner, E.S.: FOAC005, MPPE063, TPAT028
Lestrade, A.: RPAE031
Letchford, A.P.: ROPC010
Lettry, J.: FPAE073
Levand, F.: RPPT063
Level, M.-P.: RPAE031
Levi, D.: RPPT013
Levichev, E.: FPAE007, RPAE036, TPPP009
Levush, B.: FPAT018, TPAT043
Lewandowski, J.R.: ROAC004, TPPT044, TPPT045, TPPT046
Lewellen, J.W.: MOPB007, WPAP033
Lewin, H.-C.: RPAT083
Lewis, J.D.L.: RPAT010
Li, C.: FPAT072
Li, D.: FOAC002, MPPT059, RPAE065, TPPE065, TPPP020, TPPP021, TPPT029, TPPT030, WPAE045, WPAT029, WPAT093
Li, G.: WPAE075
Li, H.: RPPE076, TPAT004
Li, H.C.: WPAE001, WPAE003
Li, J.: FPAE060, FPAE061, FPAT072, MPPP047, MPPP048, MPPP049, MPPP050, RPAE022, RPAE023, RPAE074, RPPE054, WOAC004
Li, J.: FPAE064
Li, J.-H.: RPPT045

Li, J.L.: WPAP032, WPAP043
Li, L.: MPPT001, MPPT024
Li, L.G.: RPPT036
Li, N.: MPPT003
Li, Q. F.: RPAT097
Li, R.: TPAT019, TPAT020, TPAT021, TPPP015
Li, W.: FPAT072, RPAE076, RPPT047, RPPT048
Li, X.-P.: TPAT082
Li, Y.: RPPE044, RPPE045, RPPT026, WPAE030
Li, Y.: TOAB009
Li, Y.L.: RPAE077
Li, Z.: ROAC004, RPPP044, TPPE058, TPPT031, TPPT032, TPPT046, TPPT056, WPAT042
Liang, J. F.: FPAE053
Liapine, A.: RPPP036
Liaw, C.J.: RPPE030
Lidia, S.M.: TPAT001, WPAP052, WPAP053, WPAP055, WPAP060
Liebermann, H.: TPPT058, WPAT004
Liepe, M.: ROAC002, RPPE059, RPPT026, TPPT090, TPPT093, TPPT094, WPAT039, WPAT040
Lietzke, A.F.: TOAA005
Lifshitz, R.D.: FPAT002
Ligi, C.: ROAA001, ROAA003, RPPT013, TPAE002
Lilje, L.: TOPE001, TPPT055
Liljeby, L.: FPAE069
Lill, R.M.: RPAT084
Lim, J.: FOAD002, RPAE015, RPAE020
Limberg, T.: RPPT009, RPPT011, TPAT006
Limborg-Deprey, C.: MOPB008, RPAT080, RPPT013, RPPT029, RPPT030, TOAB004, TPAT062, TPPE058, TPPT031, TPPT032, WPAP055
Lin, C.J.: RPAT059
Lin, F.: TPAP044
Lin, F.-Y.: MPPT020, MPPT032
Lin, H.: TPPT043
Lin, J.-C.: TPPT065
Lin, J.-Y.: TPAE064
Lin, K.-K.: RPAE048
Lin, M.-C.: MPPE073, TPPT065, TPPT066
Lin, R.J.: TPPT066
Lin, S.F.: RPAT090
Lin, T. F.: RPAT060
Lin, Y.: TPAE065
Lin, Y.: RPPE072
Lin, Y.K.: TPPT066
Lincoln, M.: RPAT079
Lindberg, R.R.: TPAE066
Lindenmeyer, C.W.: RPAT035
Linnecar, T.P.R.: MPPP033, ROPC004
Lipari, J.J.: WPAE066
Lipka, D.: WPAP006, WPAP007
Lipski, A.R.: WPAP039, WPAP047
Litvinenko, V.: MPPE033, RPAP043, RPAT099, RPPE009, RPPT022, RPPT031, RPPT032, RPPT033, TPAP043, TPAP050, TPAP058, TPAT087, TPAT089, TPAT090, TPAT091, TPAT093, TPAT095, TPPE043, TPPP022, TPPP043, WPAP033, WPAP037
Liu, B.: TPPE059
Liu, C.-Y.: FPAT023
Liu, J.-F.: TPPT088
Liu, J.H.: RPPT046, RPPT047, RPPT048, RPPT050, WOAB010
Liu, Joseph.: FPAT055, WPAE002
Liu, L.: MPPE001, MPPE041, WPAE007
Liu, L.: RPAE076, RPPT047, RPPT048, RPPT050, WOAB010
Liu, S.: WPAP006
Liu, W.: RPAT066, TOPA005, TPAE016, TPAE017, TPAE018, TPAT058, WPAP034
Liu, X.: RPPE045
Liu, Y.: FPAE053, TPPE014, TPPE015, TPPE017, TPPE018, TPPE019, TPPE020, TPPE028
Liu, Y.-H.: RPPE072
Liyu, A.V.: FPAT014, FPAT053
Lo Destro, VLD.: TPAE036
Lockey, R.: MOPB004
Lockman, W.S.: WPAE033, WPAE056
Löfgren, P.: FPAE069
Logachev, P.L.: RPPP003
Logan, B. G.: FPAE071, ROAB003, RPAP039, TPAT036
Logatchev, P.V.: RPAT039
Lokajicek, M. V.: TPAP020
Lombardi, A.: FPAE040
Lombardi, A.M.: RPPE005
Long, C.D.: FPAT014, FPAT017, RPAP048
Lonza, M.: RPAE085
Loos, H.: MOPB008, MOPB010, TOAB003
Lopes, M.L.: FPAE066, FPAT044, MPPE002
Lopes, R.L.: WPAT002
Lord, R. S. L.: FPAE032
Lorman, E.: RPAT034
Lorusso, A.L.: TPPE002
Losito, R.: RPPE001, RPPE058
Louie, W.: RPPP016
Loulergue, A.: RPAE030, RPAE031
Louvet-Monsanglant, M.: RPPE058
Lu, P.: RPAT090, RPPT045
Lu, W.: RPAE019, RPAT078, RPAT079, TOPA002, TPAE024, TPAE025, TPAE034, TPAE038, TPAE040, TPAE041, TPAE042, TPAE045, TPAE046, TPAE058
Lu, X.Y.: TPPE055
Luccio, A.U.: FPAE006, FPAE014, FPAT003, MOPA007, MPPE029, MPPT046
Luciano, N.P.: TPAT094
Luck, C.: RPPT070
Luckjashin, V.: RPPE034
Lüdeke, A.: MPPP017
Luft, P. A.: TPPE022
Luh, D.-A.L.: TPPE063, WPAP058
Luiten, O.J.: TPAE059
Lumpkin, A.H.: RPAE055, RPAT035, RPAT085, RPAT086, TOPC001
Lund, S.M.: FPAP015, FPAP033, FPAP034, ROPB002
Lundberg, C.: RPAT032
Lundquist, M.: RPPP046, TPPE038
Lung, A.: WOAD003
Luo, G.-H.: RPAE047, RPAE048, RPAE049, TPPT065, TPPT066
Luo, Y.: MOPA007, MOPA009, MPPE030, TPAP050, TPAP051, TPAP052, TPAP053, TPAT093
Luo, Y.: RPPP046, TPPE038, WPAT081
Lusk, M.D.: MPPT055
Lutton, fl.: WPAE021
Lyashchenko, V.P.: MPPT078
Lyles, J.T.M.: WPAT037
Lynch, M.T.: WPAT035, WPAT036, WPAT037, WPAT054
Lyneis, C.M.: TPPE032

Ma, H.: MPPP016, TPPT039, WPAT057, WPAT058, WPAT060, WPAT062, WPAT085
Mac Kay, W.: TPAP044
Mac Lachlan, J.A.: MOPA004, TPAP031
MacGill, R.A.: TPPT029
MacKay, W.W.: FPAE006, FPAE014, FPAE029, MOPA007, MPPE029, MPPT046, RPAP043, TPAP043, TPAP050, TPAP059, TPAT093, TPAT095, TPPP022, TPPP043
Macek, R.J.: FPAE011, FPAP025, ROPB010, RPAT038
Machicoane, G.: TPPE033
Machida, S.: FOAB004, FPAE026, FPAE067, MOPC003, MPPE004, MPPE005, MPPE043

Machie, D.: RPPE010
Macina, D.: TPAP020
Mackenzie, G.H.: WPAE008
Macri, M.: TPAP020
Maddock, M.: WPAT025
Madre, B.: RPPE062
Maebara, S.: TPPT004
Maesen, P.: RPPE058, WPAT018
Maestas, A.J.: MPPT055
Maezawa, H.: RPAE041
Magistris, M.: TPAP014
Mahler, G.J.: TPAP043, WPAE035
Mahne, N.: FPAP002
Mahner, E.: FPAE070, RPPE005
Maier, R.: FPAE001, TPAT007
Maines, J.R.: WPAE037, WPAE039
Mais, H.: RPPE001
Majeski, R. M.: RPAP045, TPAT037
Majewski, S.A.: TPPP023
Makahleh, F.: WOAB007
Makarov, A.: MPPT010, MPPT013, WPAT050
Makarov, I.: RPAP015, RPAP016, TPPT019
Makdisi, Y.: MOPA007, TPAT094
Makida, Y.: TOAA006
Makino, K.: RPPT061
Maksyuta, N.: TPAE009
Makulski, A.: FPAT060, MPPT012
Malafronte, A.A.: FPAT044
Malitsky, N.: FPAT003, TPAP043, TPAP050, TPAP058, TPAT081, TPAT090
Mallory, M.L.: FPAE032
Malton, S.: RPAT083, RPPP003, RPPP036
Malyshev, O.B.: MPPT033
Mammosser, J.: RPPE061, RPPE064, RPPE067, TPPT078, TPPT079
Manglunki, D.: RPPE005
Manning, S.: TPPT029, TPPT081
Manno, G.: WPAE011
Mansur, L.K.: RPPT062, RPPT063
Mantica, P.F.: RPPT062
Manus, R.: TPPT029, TPPT081
Mapes, M.: RPPE046, RPPE047
Marcellini, F.: ROAA001, ROAA003, RPPP001, RPPT013, TPAE002, TPPT060
Marchand, P.: RPAE031, RPPE058, WPAT002
Marchetto, M.: FPAE027, ROPC009
Marchionni, A.: MPPP015, RPAT010
Margaryan, A.T.: RPAT047
Markiewicz, T.: RPPP003, RPPP036
Markov, V.: MPPT078
Marlats, J.L.: RPAE031
Marneris, I.: WPAE068
Maroli, C.: RPPT013, TPAE002
Marone, A.: MPPT038, MPPT046, MPPT050, RPPP017, TOAA009
Marquez, H.P.: MPPT055
Marr, G.J.: FPAE029, MOPA007, TPAT093
Marra, L.: WPAP010
Marsh, K.A.: RPAE019, TOPA002, TPAE024, TPAE025, TPAE035, TPAE042, TPAE058
Marsh, R.A.: RPAT076, TOAD005
Marshall, T.C.: TPAE010, TPAE013, TPAE063
Martens, M.A.: MOPA001, MOPA010, RPAT018, TOPC004, TPAP028, TPAP029, TPAP030
Marti, F.: FPAE072, MPPE023, MPPE024, TPAT022, TPPE013, TPPE033, WOPA002
Martin, E.: WPAE065
Martin, I.P.S.: MPPE014, RPAE052
Martin, M.C.: RPAE066, TOPC003
Martin, R.E.: TPPT029
Martin, S.: FPAE001, MPPT056
Martina, L.: WPAP010
Martinelli, G.: WPAE009
Martinet, G.M.: FOAA010
Martinez, D.: MPPT055
Martinez, M.P.: MPPT055
Martini, M.: MOPC001, RPPE005
Martins, M.N.: FPAE066, FPAT044, MPPE002, RPPE036
Martirosyan, Y.L.: MPPP019, RPAE083
Martlew, B.G.: RPAT061
Martovetski, N.: TOAA005
Martí, Z.: MPPT089, MPPT090
Marusic, A.: MOPA007, MOPA009, TPAP052, TPAP055, TPAT093
Maruyama, T.V.M.: RPPP036, TPPE063, WPAP058
Marynina, E.D.: TPPT022
Masaki, M.: MPPE038, RPAT092
Masi, A.M.: TPAP006, TPAP007
Mason, T.E.: FOPA001
Massal, M.: MPPT090
Masson, T.: RPPE041
Mastorides, T.: WPAT041
Mastovsky, I.: TOPA009
Masukawa, F.: WPAE012
Masullo, M.R.: RPAP037, TPAE036, WPAT005
Masunov, E.S.: TPAT012
Masuzawa, M.: MOPC008, RPPP003, TPPP003, TPPP007, TPPP008
Matheisen, A.: TPPT055, TPPT057
Mathis, Y.-L.: RPAE038
Matias, E.: ROPA002, TPPT089
Matkar, A.W.: WPAE006
Matoba, M.: FPAE026
Matsumoto, H.: WPAT084
Matsumoto, T.: WPAT053
Mattafirri, S.: TOAA005
Mattioli, M.: RPPT013
Matuszkiewicz, P.: WPAT019
Matveev, Yu.: FPAE060, FPAE061
Mauri, M.: RPAP037, RPPT013, TPAE002, WPAT005
Maury, S.: RPPE005
Mausner, L.F.: ROAD003, RPPE022
Mavanur, A.: RPPE068
Mayer, M.: TPAP004, TPAP007
Mayer, S.: WPAE018, WPAE050
Mazilov, A.: RPAE012
Mazzitelli, G.: ROAA001, ROAA003
Mazzolini, F.M.: RPAE085
McBrien, R.M.: TOAA008
McCarrick, J.F.: FPAP035, FPAP036, FPAT035, ROAB010, TPAT044
McCarthy, M.P.: TPPT039, WPAT059, WPAT061
McCluskey, E.: FPAE030
McCormick, D.J.: RPPP036, TPPP033
McCrady, R.C.: WPAE036
McCrory, E.S.: FPAT012, TPAP036, TPAP037, TPAP038
McCuistian, B.T.: ROAB001
McCusker-Whiting, M.: FPAT007
McDonald, K.T.: FPAE073, ROAD003, RPPT067
McGahern, W.J.: MPPT071, RPPT069
McGinnis, D.P.: MOAA005
McIntosh, P.A.: WPAT043, WPAT044
McIntyre, G.T.: MOPA007, RPPE009, RPPT032, TPAP043, TPPT069
McIntyre, P.M.: MOPA008, RPAP041, TPAT100
McManamy, T.: FPAE074
McMichael, G.E.: TPAT057
McNeil, B.W.J.: RPPT019, RPPT021
Mead, J.: RPAT028
Medici, G.: RPPT013
Medjidzade, V.: TPPT090, TPPT094
Meidinger, A.: ROAB001

Meigs, M.J.: TPPE020
Meisner, K.G.: FPAE012, MOPA004
Melikian, R.A.: TPAE001
Melissinos, A.C.: TPAE037, WPAP032, WPAP043
Melnik, Y.P.: FOAB005
Meng, W.: MPPT070, RPPE009, RPPT032, TPAP043, WPAE035
Menna, M.: RPPT054, TPPE004
Meot, F.: MPPE042
Mercer, A.: RPPP028
Merl, R.: RPAT019, RPAT020
Merle, E.: RPPE027
Merminga, L.: TOAC004, TPAP043, TPPP015, TPPP016, TPPP044
Merrill, F.E.: RPAP021
Merrill, J.B.: MPPT055
Mertens, V.: MPPE047, RPPE017, TPAP015, TPAP018
Merz, W.: WPAE065
Meseck, A.: RPPT002
Meshkov, I.N.: MOPC004, TPAP043, TPAT090
Messina, E.: TPPE004
Messina, G.: RPPT013
Messmer, P.: TPAE031, TPAE032, TPPE039, TPPT033
Meth, M.: WPAE068
Métral, E.: MOPC001, MOPC003, ROPC004, TOAC001, TPAP007, TPAP008
Meusel, O.: RPAT001
Mexner, W.: RPAE038
Meyer, F.W.: FPAT063, RPAP024, TPPE028
Meyer, R.E.: MPPT055
Meyer, T.: RPAT036
Mezentsev, N.A.: TOAA003
Mi, J.-L.: MPPT070
Micallef, J.: MPPT040
Michel, E.: TPAE019
Michel, F.: TPPT053
Michel, P.: WPAP007
Michel, P.: TPAE019
Michelato, P.: MOPB009, WPAP006
Michelotti, L.: FPAT006, FPAT007
Michizono, S.: WPAT053
Michnoff, R.J.: MOPA007, TOPC002, TPAP055, TPAT093
Miglionico, G.: MPPT071
Migliorati, M. , RPPT013, RPPT014, RPPT015, TPAE002, WPAP011, WPAP012
Mihalcea, D.: RPAT091, TPAT039
Mihara, T.: MPPT025, RPPP003
Mikaelyan, R.H.: RPAE083
Mikhailichenko, A.A.: MPPT034, MPPT060, MPPT061, MPPT062, MPPT063, MPPT064, MPPT065, MPPT066, RPPP022, TOPA011, TPAE011, WPAE024
Mikhailov, S.: FPAE060, FPAE061, FPAT051, FPAT069, MPPP047, MPPP048, MPPP050, MPPT084, RPAE074, RPPE054, WOAC004, WPAE043, WPAE073, WPAE074, WPAT017
Milardi, C.: ROAA001, ROAA003, RPAT098, RPPP001
Miller, D.J.: RPPP036
Miller, R.H.: ROAC004, RPAT096, RPPP042, RPPP044, TPPT046
Miller, T.A.: RPAE050, RPAE051
Millo, D.: MPPT089, MPPT090
Mills, D.M.: TOAB009
Mills, F.E.: MPPT057, TPPP048
Milner, R.: RPAE069, TPPP022, WOAD004
Miltchev, V.: WPAP003, WPAP004, WPAP005, WPAP006
Milton, S.V.: TOAB009
Mimashi, T.: TPPP007
Minamiguchi, S.: RPAP011
Minasyan, S.: RPAE083
Minutoli, S.: TPAP020
Mirabella, K.A.M.: TPAP043
Mishima, K.: FOAB004
Mishin, A.V.: FOAB002, RPAP025, RPAP026, RPAP027
Mishina, A.: RPAE041
Mishnev, S.I.: FPAE007, TPPP009
Mishra, S.C.: ROAC004, TPPT070
Misu, T.: TPPT016
Mitchell, D.V.: RPPE066, TPPT070
Mitra, A.K.: FPAE027, TPPT052
Mitsuhashi, T.: RPAE041, RPAE042, RPAE043, RPAE045, RPAT051, RPAT052
Mitsumoto, T.: RPAP007
Mityanina, N.: MPPP028, MPPP029, MPPP030, RPAE074
Mitzner, R.: RPAE032, RPAE033
Miura, T.: FPAP006, RPAT005, TOAD003
Miyahara, N. M.: RPAP007
Miyajima, T.: MPPT016, RPAE041, RPAE044
Miyake, M. Y.: WPAT051
Miyamoto, A.: FPAE025, FPAE036, TPPE060
Miyauchi, H.: RPAE041
Mizuno, A.: FPAE063, TPPE056
Moblo, A.: TPPT096
Mocheshnikov, N.I.: MPPT078
Modanese, P.: FPAE040
Moeckly, B.: TPPT088
Moeller, K.: WPAP007
Möller, W.-D.: TPPT054, WPAT088
Moffeit, K. C.: RPPP030
Moirshita, T.: TPPT041, WPAE044
Moisio, M.F.: FPAE040
Mok, W.Y.: RPAT080
Mokhov, N.V.: MPPT049, RPPP048, TPAP025, TPAP035
Molinari, G.: RPAT003
Molloy, S.: RPPP003, RPPP036
Molodkin, V.B.: MPPT078
Molodojentsev, A.Y.: MPPE004, MPPE005
Molokoedov, A.M.: WPAP023
Molvik, A.W.: FPAP015, FPAP021, FPAP033, ROPB002, ROPB006
Momozaki, Y.: RPPT063
Monaco, L.: MOPB009, WPAP006
Monroy, M. T.: TPPE022
Montag, C.: FPAE014, MOPA007, MPPE031, MPPE033, MPPE060, RPAP043, RPAT027, TPAP043, TPAP045, TPAP050, TPAP054, TPAP055, TPAP056, TPAP057, TPAP058, TPAT093, TPPP022, TPPP042, TPPP043, TPPP044, TPPP045
Montoya, N.: ROAB001
Montvila, D.: RPAP050
Moody, N.A.: TPPE047, TPPE062
Moog, E.R.: MPPT036, MPPT083, TOAB009
Moore, C.D.: TPAP030
Moore, E.F.: TPPE006
Moore, R.: TPAP026
Moortgat-Pick, G.A.: MPPT033
Moraes, J.S.: TPAT045
Morales Zimmermann, h.: TPPT055
Morel, J.: TPAT014
Morelli, A.: TPAP020
Moretti, A.: ROAA005, TPPP053, TPPP054, TPPP056, WPAT029
Morgan, E.A.: MPPT055
Morgan, S.: TPPT081
Mori, KM.: TPPP005
Mori, W.: FPAP022, ROPB007, RPAE019, TOPA002, TPAE024, TPAE025, TPAE034, TPAE035, TPAE038, TPAE040, TPAE041, TPAE042, TPAE045, TPAE046
Mori, Y.: FOAB004, FPAE026, RPPT055
Morita, A.: TPPP002, TPPP003, TPPP007
Morita, Y.: TPPT008
Moritz, G.: FPAE075, TOAA009
Moriyama, R.: FOAB010
Moriyama, S.: TPPT004

Morozumi, Y.: TPPT056
Morris, A.: WPAE078, WPAT024
Morris, C.L.: FOAB008, RPAP021
Morris, J.: FPAE029, FPAT059, MOPA007, TPAT093
Morrison, L.H.: TPPT036
Morrissey, D.J.: RPPT062, RPPT063
Morton, R.C.: RPPT070
Moscatello, M.H.: FPAE028
Moser, H.O.: RPAE008
Mosnier, A.: FPAE028
Moss, A.J.: WPAT022
Moss, D.A.: RPAE038
Mostacci, A.: RPPT013, RPPT014, TPAE002
Mostrom, C.: ROAB001
Motygin, S.V.: WPAT017
Mouillet, M.: RPPE027
Mouton, O.: RPPE027
Moy, K.: ROAB001
Muchnoi, N.Yu.: TPPP009
Müller, A.-S.: MOPC001, MPPP001, RPAE037, RPAE038, RPAE039
Mueller, F. M.: TPPT088
Mueller, M.: WPAT025
Mueller, N.: FOAB009
Mueller, P.E.: TPPE020
Müller, R.: RPAE035
Mueller, R.S.: RPAE063, RPAE064
Müller, W.F.O.: FPAT079, WPAP006, WPAP008
Muggli, P.: RPAE019, RPAT082, TOPA002, TPAE024, TPAE025, TPAE034, TPAE035, TPAE041, TPAE042, TPAE046, TPAE049, TPAE057, TPAE058
Mulhollan, G.A.: TPPE063
Mulvaney, J.M.: WPAT047, WPAT048
Muñoz, M.: MPPE069, RPAE087
Murakami, T.: RPAP007
Muramatsu, M.: RPAP007
Muratore, J.F.: MPPT038, MPPT046, MPPT050, TOAA006, TOAA009
Muratori, B.D.: RPPT019, RPPT020
Murdoch, G.R.: ROAD002, RPPE033, WPAE041
Murokh, A.: RPPT031
Muroya, Y.: TPPE049
Murphy, D.J.: FPAT014, RPAP048
Murphy, J.B.: MOPB008, RPAE056, RPAE058, RPAE059, TOAB003
Murray, S.N.: MOPB005
Musarra, F.: WPAE011
Musico, P.: TPAP020
Musson, J.: RPAT071
Mustafin, E.: FPAE075, RPPE034
Mustapha, B.: TPAT028, TPAT029
Musumeci, P.: FOAD002, RPPT013, TOPA006, TPAE044
Muto, A.: FPAE026
Muto, S.: RPAT005
Muto, T.: MPPE044, RPAT077, TOAD004
Mutoh, M.: FPAE036
Muttoni, Y.: WPAE019
Myneni, G.: TPPT075, TPPT076, TPPT083
Mytrochenko, V.V.: FPAE062, TPPE051, TPPE052
Mytsykov, A.: MPPT078, RPAE011

Nadji, A.: RPAE031
Nadolski, L.S.: ROPA005, RPAE031, WOAC008
Nagahashi, S.: MPPT016, RPAE041
Nagaitsev, S.: FPAE009, FPAE017, ROPC006, TPAP043
Nagaoka, R.: RPAE031
Nagarathnam, K.: WPAE057
Nagaslaev, V.: MPPE065
Nagler, B.: TPAE019, TPAE021
Naito, F.: WPAE044
Naito, T.: MPPE044, RPPP008
Nakagawa, H.: ROPA003
Nakajima, M.: FPAE020, FPAT042
Nakamoto, T.: MPPT044, TOAA006
Nakamura, E.: FPAE020, MPPT015, TPPT014
Nakamura, K.: TPAE019
Nakamura, N.: RPAE040, RPPE040, TPPT049
Nakamura, T.: TPPT007
Nakamura, T.T.: TPPP007
Nakanishi, H.: WPAT009
Nakano, J.: FPAE026
Nakao, K.: WPAT053
Nakayama, H.: TPPP007
Nakayama, K.: TPPT049
Nam, S.H.: WPAT013
Namkung, W.: RPAE009, RPPT017
Nanao, M.: FPAE036
Nannarone, S.: FPAP002
Nantista, C.D.: ROAC004, ROAC007, RPAT096, TPAE065, WPAT089
Napalitano, J.: RPAT062
Napoly, O.: RPPE001, RPPP003, TPPP033
Naranjo, A.C.: MPPT055
Narsky, I.V.: TPPP024
Naruse, T.: FPAE004, FPAE005
Nash, B.: MPPP008
Nassiri, A.: TPPT024, TPPT037
Nassisi, V.: TPPE002, WPAP010
Naumenko, G.A.: RPAT055, RPAT077, TOAD004
Nazarewicz, W.: FOPA005
Nazaryan, Y.: TPAE001
Necklyudov, I.M.: MPPT078
Needles, C.W.N.: RPAT010
Negri, M.: TPAP020
Nehring, R.: FPAT060
Nehring, T.C.N.: RPPE009, RPPT032, TPAP043
Neil, G.: MPPT082, RPPE067, WPAP033, WPAP050
Nekhaev, V.E.: RPAP017
Nelson, E.M.: TPAT023, TPAT043, WPAT077
Nelson, J.: ROAC004, RPPP003, TPPP037
Nelson, S.D.: FPAT027, FPAT034, FPAT035, FPAT037, FPAT038, FPAT039, FPAT040, ROAB003, ROAB010
Nemesure, S.: TPAP047
Nenasheva, E.: WPAT095
Neri, N.: RPPT068
Nerpagar, P.N.: RPPT042
Neuenschwander, R.T.: WPAE007
Neuffer, D.V.: FPAE009, ROAA005, RPPP049, RPPP050, TPPP047, TPPP055
Neumann, J.G.: FOAD005, MOPB010, MOPC010, RPPE076
Nezhevenko, O.A.: WPAT026, WPAT027, WPAT028
Ng, C.-K.: TPPP028, TPPT056, WPAT042
Ng, K.Y.: MPPP044, TPAT018
Nguyen, D.C.: TPPE045, WPAP033, WPAT036
Nguyen, H.: RPAT032
Nguyen, M.N.: ROAB008
Ni, G.: MPPT001, MPPT024
Nicklaus, D.J.: MPPP012, MPPP015
Nicol, T.H.: MPPT044
Nicoletti, T.: MOPA007, RPPE009, RPPT032, TPAP043, TPAP054, TPAT093, TPAT095
Niedziela, J.: MPPE033, MPPE060
Nielsen, K.: FOAA002, ROAB001
Nieter, C.: TOPA001, TOPA003, TPAE050, TPPT033, TPPT098
Niewiadomski, H.: TPAP020
Nigorikawa, K.: RPAT004
Nikitin, S.A.: MPPE070, TPPP009
Nikitina, T.F.: WPAT021
Nikolaev, I.B.: TPPP009
Nikolenko, D.M.: TPPP009

Ning, J.: RPAT012
Ninomiya, S.: MOPC004
Nishimura, H.: MPPE074, RPAE060, RPAE061, RPAE062, RPAE063, RPAE064
Nishimura, T.: TOPC003
Nishiura, M.: RPAP040
Nisoli, M.: RPPT013
Noble, R.J.: TPAE028, WPAP059
Nobrega, A.: MPPT044, TPAP030
Noda, F.: FPAE002, FPAE067, MPPE004, MPPE005, MPPE043
Noda, K.: FPAE004, FPAE005, MOPC004, RPAP007
Noel, C.: RPPE027
Nogami, T.: FPAT049, RPAE041
Noguchi, S.: TPPT062
Noh, sj.: WPAT071
Nolden, F.: FOAD004, MPPP002, ROPC008
Nolen, J.A.: RPPT063
Nomura, M.: ROAC005, TPPT005, WPAT007, WPAT064
Norem, J.: ROAC008, TPPT025, WPAT029
Norreys, P.A.: TOPA007
North, M.R.W.: RPAP046
Nortier, F.M.: RPPT062
Norum, E.: RPAT084
Noschis, E.P.: TPAP020
Nosochkov, Y.: MPPE025, RPPP017, RPPP030
Novikov-Borodin, A.V.: FPAT020
Novitski, I.: MPPT054, TOAA004
Novokhatski, A.: FOAA003, TPPP026, TPPP028, TPPP029, TPPP030, TPPP031
Nuhn, H.-D.: RPPT035
Nunnally, C.: ROAB010

O'Connell, C.L.: RPAE019, RPAT078, TOPA002, TPAE024, TPAE025, TPAE034, TPAE041, TPAE042, TPAE046, TPAE058, TPPP033
O'Connell, T.I.: MPPT080
O'Grady, C.: TPAT076
O'Hara, J.F.: MPPT055
O'Shea, B.: TPPT040
O'Shea, P.G.: FOAD005, FPAE021, MOPB010, MOPC010, MPPE067, RPPE075, RPPE076, TPAT004, TPAT035, TPAT066, TPAT067, TPPE039, TPPE046, TPPE047, TPPE062
Oakeley, O.: RPAE074, WPAE073, WPAE074
Obana, T.: TOAA006
Obina, T.: FPAT049, RPAE041, RPAE045
Oddo, P.: MOPA007, RPAP044
Oerter, B.: RPPE009, TPAP043, TPAT093, TPAT095
Österberg, K.: TPAP020
Oganesyan, M.K.: TPAE001
Ogawa, H.: RPAP007
Ogawa, H.O.: RPAP007
Ogawa, Y.: TPPP007
Ogino, H.: RPAP006, WPAP019
Ogitsu, T.: MPPT044, TOAA006
Ogiwara, N.: RPPE039, WPAE012
Ogurtsov, A.B.: MPPT084
Oh, J.-S.: RPAE009, RPPT017, WPAP021, WPAP022
Ohgaki, H.: FPAT076, RPAE006, RPAE078, TPPE048
Ohhata, H.: TOAA006
Ohkawa, T.: FPAE043, RPAT004, TPAT050, WPAE014
Ohkubo, T.: TPAE003
Ohmi, K.: FPAP001, FPAP004, FPAP005, FPAP006, FPAP013, MOPC006, MPPP025, ROPB004, ROPB009, RPAT052, RPPP045, TPAT085, TPPP004, TPPP006, TPPP007, TPPP008
Ohmori, C.: FPAE026, ROAC005, TPPT005, WPAT007, WPAT018, WPAT064
Ohnishi, Y.: RPPP005, TPAT051, TPPP002, TPPP005, TPPP007, WPAP015
Ohsawa, S.: TPPT011, TPPT015, TPPT038, WPAP014, WPAP016
Ohuchi, N.: MPPT037, MPPT044, TPPP007, TPPT062
Oide, K.: MPPT037, RPPP005, TPPP002, TPPP003, TPPP007
Ojha, S.C.: WPAE006
Okajima, T.: RPAE006, TPPE048
Okamoto, H.: FOAD001, TPAT082
Okamura, M.: FPAE006, FPAE014, FPAE065, MPPE081, MPPT046, TPAT075, TPPE027, TPPE031
Okugi, T.: RPPP003
Oliva, P.: TPAE002
Olivas, F.R.: MPPT055
Oliver, W.P.: RPPP030
Oljemark, F.: TPAP020
Olson, C. L.: ROAB003, RPAP039, TPAE062
Olson, M.O.: RPAT010, WPAE029
Oneill, J.: RPAE063, RPAE080
Ong, M.M.: FPAT036
Onishchenko, I.N.: TPAE010
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Onisto, H. J.: RPAT048
Ono, M.: WPAT009
Oothoudt, M.A.: MPPT055
Opanasenko, A.: FPAE062, RPPT018
Oppelt, A.: WPAP003, WPAP004, WPAP005, WPAP006
Orava, R.: TPAP020
Oren, T.C.O.: ROPA004
Oriunno, M.: TPAP020
Orlanducci, S.: WPAP013
Oro, D.: ROAB001
Orris, D.F.: FPAT060, MPPT009, MPPT012, MPPT054
Osamu, O.: FPAE014, MOPA007
Oshima, A.: RPAP011
Osipov, V.N.: WPAT017
Ostiguy, J.-F.: FPAE011, FPAE030, FPAT006, FPAT007, MPPT011
Ostojic, R.: MPPT042, MPPT043, MPPT044
Ostreiko, G: RPAP016
Ostroumov, P.N.: FOAC005, FPAE054, FPAE055, FPAE056, FPAT020, FPAT088, MOPB003, MPPE063, RPAP023, TPAT028, TPAT029
Ott, K.: RPPT003, RPPT004
Ottaviani, P.L.: RPPT013
Otto, M.: RPAP001
Ouchi, N.: TPPT062
Ounsy, M.O.: ROPA005
Ouyang, H.F.: FPAE064, TPPT047
Ovchinnikov, V.P.: RPAP019
Ovsyannikov, A.D.: FPAT001
Owen, H.L.: RPPT019, RPPT020
Oz, E.: RPAE019, RPAT078, RPAT079, TOPA002, TPAE024, TPAE025, TPAE034, TPAE041, TPAE042, TPAE046, TPAE058
Ozaki, S.: TPPP022
Ozelis, J.P.: RPPE062, TPPT078, TPPT079, TPPT081, TPPT082

Paal, A.: FPAE069
Padamsee, H.: ROAC009, RPPE059, RPPP019, RPPP021, RPPT026, TPPT088, TPPT089, TPPT090, TPPT091, TPPT094, WOAA005
Padmore, H. A.: MPPE076
Pae, K.H.: TPAE054
Pagani, C.: FOAA005, TPPT059, TPPT060, WPAP006
Page, T.M.: MPPT044
Pagliara, S.: WPAP052, WPAP053
Pagnutti, S.: RPPT013
Pai, C.: MPPT070, RPPE048
Pak, C.O.: RPAE041
Pakter, R.: TPAT045, TPAT046
Palmer, D.T.: RPPT013, TPAE028, TPPE040, TPPE057, WPAP059

Palmer, M.A.: MPPT080, RPAT062, RPAT063, RPPE044, TPPP011, WPAE030
Palmer, R.: TPPP047
Palmieri, V.: TPAP020
Palumbo, L.: RPPT013, RPPT014, RPPT015, RPPT031, TPAE002
Panagos, J. N. P.: TPAT043
Panfilov, A.D.: RPAP015, RPAP016, RPAP017
Panova, Y.: RPPE034
Pant, K.K.: RPPT042
Panzeri, N.: TPPT059
Paoluzzi, M.M.: RPPE005, WPAT018
Papadimitriou, V.: FPAT008, FPAT012
Papaphilippou, Y.: MOPC009, RPAE027, RPAE028, RPAE029, WOAC010
Paparella, R.: TPPP033
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Pappas, G.C.: ROAB008, WPAE079
Para, A.: RPAT013
Paradis, D.P.: RPPE027
Paramonov, V.V.: RPPP006, TPPT041
Parc, Y.W.: RPAT007, WPAP021, WPAP022
Pardo, R.C.: MOPB003, TPPE006, WPAT030
Parisi, G.: RPPT013
Park, B.-S.: RPAP013, RPAP014
Park, B.R.: WPAT014
Park, E.S.: RPAE046
Park, H.J.: WPAT013
Park, I.-S.: RPAT008, TPPT064, WPAT015
Park, J.H.: RPAT007, WPAP021, WPAP022, WPAP040
Park, K.-H.: MPPT017, MPPT075, WPAE016, WPAE060, WPAE062
Park, M.-Y.: FPAE044, FPAE046, TPPT018, WPAT012
Park, P.C.D.: ROPB005, WPAP021
Park, S.: WPAT046
Park, S.J.: ROPB005, RPAT007, RPAT008, TPAE067, WPAP021, WPAP022, WPAP040
Park, S.S.: RPAE009
Park, Y. W.: WPAP040
Parkar, R.: RPPT042
Parker, B.: MPPT038, RPPP017, RPPP030, RPPP041, TOAA006, TOAA010, TPPP022, TPPP043, TPPP045
Parkhomchuk, V.V.: RPAP008, TPAP043
Parma, V.: MPPT045, WPAE021
Parmigiani, F.: WPAP052, WPAP053
Parsa, Z.P.: TPAT040, TPAT041
Parzen, G.: TPAP043, TPAP050, TPAT091
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Pasquinelli, R.J.: MOPA004
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Pate, D.: RPPT032, TPAP043, TPPE041
Pathak, K.: WPAE006
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Patterson, J.: RPAE074
Patterson, R.: RPPP024
Paul, K.: ROAA005, TPPP013, TPPP047, TPPP052, TPPP055, TPPP056
Pavlenok, A.M.: RPAE074
Pavlovich, Z.: RPAT044, RPPT072
Payet, J.: RPPP003, RPPT053
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Peev, F.A.: MPPT078, RPAE012, RPAP034, TPPE050
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Pellegrino, L.: ROAA001, ROAA003, RPPT013, TPAE002
Pellet, D.E.: WPAE034
Pelliccia, D.: RPPT013
Pellico, W.: FPAE018, FPAE019, FPAE022, MPPT010
Pence, T.D.: MPPT055
Peng, S.: FPAT066
Penn, G.: RPPT025, RPPT037
Pentico, M.: RPAE074
Peplov, V.V.: WPAT055, WPAT056
Perazzo, A.: TPAT076
Peretich, M.E.: RPPE030
Perevedentsev, E.: FPAP008, MPPT039, TOAA003
Perez, E.M.: MPPT055
Pérez, F.: MPPP001, RPAE037, RPAE038, RPAE087
Perez, J.C.: MPPT042
Perezhogin, S.A.: FPAE062, TPPE051
Perkins, M.: ROPC010
Perng, S.Y.: RPAT059
Perret, R.: TPAP004, TPAP007
Perron, T.: MPPP021
Perrone, A.: WPAP013
Perrot, A.-L.: TPAP020
Peschke, C.: MPPP002
Peters, J.: TPPE001
Petersen, B.A.: WPAE056
Petersen, B.: TPPT055, TPPT057
Peterson, D.W.: RPAT009
Peterson, E.: RPPE067, WPAT091, WPAT092
Peterson, T.: MPPT044
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Petit, S.: ROPA005
Petra, M.: MPPT083
Petrarca, M.: RPPT013
Petrillo, V.: RPPT013, TPAE002
Petrisko, J.E.: RPAP035
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Petrosyan, B.: WPAP003, WPAP004, WPAP005, WPAP006
Petrosyan, G.M.: FPAT046, TPAE001
Petrosyan, L.M.: TPAE001
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Petrov, V.: FPAE007, RPAE074, WPAT017
Pfeffer, H.: WPAE029
Phillips, H.L.: RPPE009, RPPT032, TPAP043, TPPT029, TPPT082, TPPT084, TPPT085, WPAP033
Phinney, N.: RPPP036
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Pichoff, N.: RPPE027, TPAT047
Piel, C.: TPPE023, TPPE024, WPAT068, WPAT069
Piel, H.: RPAT045, WPAT068, WPAT069
Pieloni, T.: TPAT078
Pierini, P.: FOAA005, TPPT059
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Pikin, A.I.: MOPB004
Pilan, A.M.: WPAT017
Pilat, F.C.: FPAT003, MOPA007, MOPA009, MPPE030, TPAP050, TPAP051, TPAP053, TPAT093, TPAT095, WOAC007
Pile, G.: TOAB009, TPPT036
Pillai, C.: MPPT055
Piller, M.F.: TPPT039, WPAT057, WPAT058, WPAT060, WPAT062
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Piot, P.: MPPE068, RPAT091, TPAE037, TPAE048, TPPE044, WPAP032, WPAP043, WPAT083

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Pischalnikov, Y.M.P.: FPAT060, MPPT009, MPPT012, MPPT054
Pisent, A.: FPAE040, FPAE042
Pitthan, R.: RPPP031, RPPP032, RPPP039, RPPP040, TPPE053
Pivi, M.T.F.: FPAP001, FPAP019, ROPB001, RPPP003, RPPP038, RPPP045, TPPT044, TPPT046
Piwinski, A.: WOPA
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Plum, M.A.: FPAE024, FPAE057, FPAE074, RPAT039, TPAT030, WOAC009
Podgorny, F.V.: RPPP003
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Podobedov, B.: MPPP036, MPPP038, MPPP039, RPAE056, RPAE058, RPAE068, RPAE069, TOAB008, TPAT017
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Poggi, M.: FPAE040, FPAE042
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Poncet, A.: MPPT041
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Poole, J.: RPPE004
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Popov, A.M.: WPAT017
Popov, V.: FPAE061, MPPP047, MPPP050, RPAE074, WPAE073, WPAE074
Popov, V.P.: RPAT100
Popovic, M.: ROAA005, TPPP054, TPPP056
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Porter, W. D.: TPPE016
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Potter, K.G.: RPPE033
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Pottin, B.: WPAP001
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Pozdeyev, E.P.: MPPP045, TOAC004, TPAT022, WOPA002
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Qi, X.: WPAE059
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Ralph, J.E.: TOPA006, TPAE043
Ramillon, J.: RPPE018
Ranjbar, V.H.: MOPC005, MPPP013, TPAT064, TPAT065
Rank, J.: MPPT071, RPPE009, RPPE046, RPPT032, TPAP043, TPPT069
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Rimmer, R.A.: FOAA009, RPPE063, RPPE067, TPPT029, TPPT085, TPPT086, WPAP033, WPAP049, WPAT029
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Ringwall, A.: RPAT080
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Robb, G.R.M.: RPPT021
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Roberts, T.J.: ROAA005, RPPT073, TPPP013, TPPP052, TPPP056
Robertson, S.H.: WPAE056
Robin, D.: MPPE074, RPAE061, RPAE063, RPAE064, RPAE065, RPAE066, RPAE079, RPAE082, TPAT001, WOAC008
Robotham, W.F.: MPPT011, MPPT012, MPPT051, MPPT053
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Rodriguez-Mateos, F.: TPAP011
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Rogers, C.T.: MPPE013
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Roodman, A.: MPPE057
Ropert, A.: RPAE028
Rose, D.: FPAE071, FPAP032, ROAB003, RPAP039, TPAE062
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Rose, J.: MPPP036, MPPP038, RPAE056, RPAE058, RPAE059, RPAT068, TOAB003, TPPT026
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Rosenzweig, J.B.: FOAD002, RPAE015, RPAE020, RPAE021, RPAP033, RPPT013, RPPT031, TOPA006, TPAE039, TPAE043, TPAE044, TPAE048, TPAE049, TPAT033, TPPE040, TPPT040, WPAP059
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Schultheiss, C.: RPAP043, TPAP055, TPAT093
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Schultz, D.C.: ROAC004, RPPP039, RPPP040, TPPE053, WPAP058
Schultz, D.R.: TPPE019
Schultz, R.P.: RPPE028
Schulze, M.E.: ROAB004
Schurig, R.: WPAP007
Schuster, E.: FPAT010, FPAT092
Schweiger, C.: MPPE040
Scott, D.J.: MPPT033, MPPT079
Scrivens, R.: RPPE005, TPAT054
Seaman, A.K.: ROAC009, TPPT090, TPPT092
Sears, C.M.S.: TOPA008, TPAE029
Sears, J.: TPPT089, TPPT090, TPPT091
Sebastian, J.: ROAC008
Seda, T.: TPPT026
Seddon, E.A.: TOAB005
Sedlyarov, I.: RPAE074, WPAT017
Seeman, J.: MOAA003, MOPC006, MPPE058, TPPP024, TPPP029, TPPP030, TPPP031, TPPP032, TPPP034, TPPP035
Sefkow, A.B.: FPAE071, RPAT023, TPAT068
Segalov, Z.: RPPE032, TPPE041, TPPE042
Seidel, M.: RPAE036, RPPE037
Seidl, P.A.: FPAP015, FPAP033, FPAT026, MPPT068, ROPB002, TOAA005
Seidman, D.J.: RPPE065
Seidman, D.N.: ROAC008
Seiya, K.: MOPA004, TPAP022
Sekachev, I.: FPAE027, TPPT052
Sekutowicz, J.: RPPE067, TPAP043, TPPT056, TPPT072, TPPT076, TPPT077, WPAP033, WPAP039, WPAP047
Seletsky, S.: RPAT064, RPAT069
Semenov, A.: MPPP015
Sen, T.: FPAT005, MOPC009, TPAP025, TPAP026, TPAP028, TPAP040, TPAP041, TPAT072
Senanayake, R.: MPPT058
Senderovich, I.: WPAP031
Senichev, Y.: FPAE001, TPAT007, TPAT048, TPAT049
Seol, K.T.: FPAE044, FPAE046, FPAE047, TPPT018, WPAT012, WPAT015
Serafini, L.: MOPB008, RPPT013, RPPT015, TPAE002, WPAP009
Seraphim, R.M.: WOAB009
Sereno, N.: MPPP035, RPAE053, RPAE055, RPAT085, WPAE070
Serio, M.: ROAA001, ROAA003, RPPP001, RPPT013, TPAE002
Sermeus, L.: RPPE005
Sertore, D.: MOPB009, WPAP006
Seryi, A.: FPAP018, RPPP003, RPPP017, RPPP027, RPPP030, RPPP036, RPPP038, RPPP041, TPPP032, WOAA004
Sessler, A.: ROAB003, RPAP020, RPAP023, RPAP039, RPPT025, TPAT082
Setoyama, H.: RPAE006, TPPE048
Sette, G.: TPAP020
Setty, A.S.: WPAP001
Severino, F.: FPAE029
Seville, A.: WPAT024
Seyvet, F.: MPPT041
Sgamma, F.: ROAA001, ROAA003, RPPP001, RPPT013, TPAE002
Sgobba, S.: RPPE042
Shadwick, B.: TPAE032
Shaftan, T.V.: MOPB010, MPPT085, RPAE056, RPAE058, RPAE059, RPAT068, TOAB003
Shalf, J.M.: FPAT082, FPAT083
Shamov, A.G.: TPPP009
Shang, H.: FPAT089, FPAT090
Shao, L.H.: TPAE047
Shapiro, A. H.: TPPT088
Shapiro, M.A.: TOPA009, TPAE023
Shaposhnikova, E.N.: MPPP033, ROPC004, RPPE005
Sharafutdinov, A.: RPAT055
Sharamentov, S.I.: WPAT030, WPAT082
Sharp, W.M.: FPAE071, TPAT024
Shastri, S.D.: TOAB009
Shatilov, D.N.: MPPE070, TPAT083, TPAT084
Shatunov, Y.M.: TPAP043
Shaw, R.W.: RPPE030
Shchelkunov, S.V.: TPAE063, WPAT026
Shchepunov, V.A.: MPPE082
Shcherbakov, A.A.: MPPT078, RPAE011, RPAE012
Sheehy, B.: MOPB008, MOPB010, RPAE056, TOAB003
Shehab, M.M.: WOAB007
Shelley, F.E.: MPPT055, RPAT020
Shemelin, V.D.: ROAC009, RPPE059, TPPT068, TPPT090, TPPT094
Shemyakin, A.V.: MPPT022, RPAT064, RPAT069, TPPE035, WPAE027
Shen, S.: RPPE029
Shen, Y.: MOPB010
Shepard, K.W.: FPAE054, FPAE056, RPPE068, TPPT099, TPPT100
Shepherd, B.J.A.: MPPT079
Sheppard, J.: ROAD003, RPPP039, RPPP040, TPPE053, WPAP058
Sherrill, B.: MPPT031, RPPT062, RPPT063
Sheu, R.J.: FPAT055, WPAE002
Shi, C.: MPPT001, MPPT004
Shi, J.: TPAT079, TPPP017, TPPP022
Shi, J.: WPAT093
Shibasaki, Y.: FPAE036
Shibata, K.: RPPE052, RPPE053
Shibuya, S.: FPAE004, MOPC004
Shibuya, S.: RPPE040
Shiho, M.S.: FPAE020

Shiltsev, V.D.: MOPA001, MOPA010, MOPC009, MPPP042, TPAP030, TPAP032, TPAP033, TPAP034, TPAP038, TPAT072, WPAE029
Shimada, M.: TPPP007
Shimada, T.: FPAE002, MPPT015
Shimosaki, Y.: FPAE020, FPAT019, TPAT009, TPAT096, TPPT014
Shinn, M.D.: FOAB006, WPAP050
Shinoe, K.: RPPE040
Shinto, K.: FPAE025, FPAE036, RPAP040, TPPE060
Shintomi, t.s.: MPPT044
Shioya, T.: RPAE041
Shirai, M.: RPPE052, RPPE053
Shirakata, M.J.: FPAE020, MPPE005
Shiroya, S.: FOAB004
Shishido, T.: TPPT062
Shishlo, A.P.: FPAE049, ROPA001, ROPB010
Shkirida, S.M.: WPAT021
Shkvarunets, A.G.: RPAT089
Shobuda, Y.: MPPE005, MPPE043, MPPP025
Shoji, Y.: RPAE086
Shu, Q.S.: TPPT051
Shubin, E.: TPPP009
Shul'ga, N.: FPAT024
Shuman, D.: FPAE071, MPPT067, MPPT068, MPPT069, RPAE063, RPAE067
Shurter, R.B.: MPPT055
Shvedov, D.: FPAE060, FPAE061
Shvets, G.: RPAE021, TPAE023
Sibley III, C.: RPPE021
Sideris, I.V.: MPPE036, TPAT038
Sidlow, R.: TPPE025
Sidorin, A.O.: TPAP043, TPAT090
Sidorov, A.: RPAP016
Siegerist, C.: FPAT082, FPAT083
Siemann, R.: RPAE019, RPAT078, RPAT079, RPAT082, TOPA002, TOPA008, TPAE024, TPAE025, TPAE026, TPAE028, TPAE029, TPAE035, TPAE042, TPAE049, WPAP059, WPAT089
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Siggins, T.: WPAP033, WPAP050
Sikora, R.: RPAT028
Silva, L.O.: TPAE038, TPAE040, TPAE045
Silva, M.B.: RPPT044, WOAB009
Silva, T.F.: MPPE002
Simeoni, W.: TPAT046
Simgen, B.W.: RPPT003
Simmons, D.: ROAB001
Simonov, A.: RPAT094
Simonsson, A.: FPAE069
Simonyan, G.P.: MPPE079
Simos, N.: FPAE073, ROAD003, RPPT066
Simrock, S.: FOAA006, FPAT046, RPAT094, TOAC004
Sims, J.R.: MPPT055
Sinclair, C.K.: RPPT026, TOAC004, WPAE025, WPAP031, WPAP042
Sinclair, J. W.: FPAT063
Singer, W.: TPPT072, TPPT075
Singer, X.: TPPT075
Singh, B.: MPPE014, RPAE052
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Singh, O.: RPAE054
Sinha, B.: RPPT043, TOPD001
Sinha, S.: TPAE014
Sirigiri, J.R.: TPAE023
Skarbo, B.A.: TPPE029
Skaritka, J.: MPPT021, MPPT026, RPAE056, TOAB003, TPPT026
Skeppstedt, Ö.: FPAE069
Skirda, V.L.: MPPT078
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Skowbo, D.: RPAP025, RPAP026, RPAP027
Skrinsky, A.N.: FPAE007, TPAP043, TPPP009
Slachtouski, S.: RPAT070, RPPE010
Sladen, J.P.H.: TPPT020
Slater, M.S.: RPPP036
Slaughter, A.J.: FPAT012, TPAP036, TPAP038
Slimmer, D.: RPAT032
Slits, I: MPPT045
Smaluk, V.V.: FPAE007
Smart, L.: RPPE046, RPPE047, TPAT093, TPAT095
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Smirnov, A.: TPPT050, WPAT081
Smirnov, A. S.: RPPP046, TPPE066
Smirnova, E.I.: TOPA009
Smith, C.H.: WPAE025
Smith, E.N.: MPPT034
Smith, H.V.: ROAB001
Smith, J.C.: FPAT085, RPAT062, RPPP024
Smith, JR.S.: FPAT025
Smith, K.: FPAE029, FPAT066, MOPA007, RPPE009, RPPT032, TPAP043
Smith, K.: RPPE010
Smith, M.: FPAT064
Smith, R.J.: RPAT061, RPPE020, WPAE004
Smith, R.R.: RPAP025
Smith, S.: RPPP036
Smith, S.L.: RPAE052
Smith, T.I.: TOAC004, TOPA008
Smith, T.J.: ROAC004, TPPP033, TPPP037
Smolenski, K.W.: MPPT034, RPPT026, TPPT090
Snell, CM.S.: FPAT025
Snoeys, W.: TPAP020
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Snyder, M.D.: MPPT082
Snydstrup, L.: MOPB004, TPAT095
Sobieradzki, E.: WPAT072
Sobol, A.: TPAP020
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Sohn, Y.-U.: TPPT064
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Soliday, R.: FPAT057, FPAT058, WPAE070
Solyak, N.: ROAC004, RPPE066, TPPT056, TPPT070, WPAT033, WPAT050, WPAT094
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Song, C.: RPPT026
Song, Y.G.: TPPT018, WPAT012
Sonnad, K.G.: ROPB008
Sonnendrucker, E.: ROPA007
Sotnikov, G.: TPAE010
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Soutome, K.: MPPE038
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Spata, M.: ROPA004
Spataro, B.: ROAA001, ROAA003, RPPT013, RPPT014, RPPT015, TPAE002, WPAP009
Spataro, C.H.: TPAP060
Spaulding, R.J.: RPAP035
Spejewski, E.H.: TPPE020
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Spencer, C.M.: MPPT025, MPPT029, RPPP003
Spencer, J.E.: TOPA008, TPAE015, TPAE027, TPAE028, TPAE029, WPAE034, WPAP059
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Spentzouris, P.: MOPC003, TPAT026, TPAT059, TPAT060
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Spiller, P.J.: FOPA003, TPAT070
Spinka, H.M.: FPAE014
Spinks, A.: TPAP015

Sprangle, P.: TOPA004
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Sramek, C.K.: FPAP018
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Stanek, M.: TPPP038
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Starling, J.W. , TPPT034
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Startsev, E.: FPAP026, FPAP027, FPAP028, FPAP029, MOPC007, RPAP045, TPAT037, TPAT069
Staykov, L.: WPAP003, WPAP004, WPAP005, WPAP006
Stecchi, A.: ROAA001, ROAA003, RPPT013, TPAE002
Steck, M.: FOAD004, FPAE001, ROPC008
Steerenberg, R.R.: MOPC001, ROPC004
Stefanski, R.: TPAP030
Steffen, B.: RPAT049, RPAT050, RPAT094
Steffens, E.: RPAE039
Steier, C.: MPPE075, MPPT067, RPAE061, RPAE063, RPAE064, RPAE065, RPAE067, RPAE082, WOAC008
Steimel, J.: MOPA004, RPAT015, RPAT018, TOPC004
Stein, J.: TPAE056
Stein, S.J.: RPAT087
Stein, W.: RPPT062, RPPT063, TPPE053, WPAE031, WPAE054
Steiner, B.: WPAP008
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Steinhagen, R.J.: MPPP004, TPAP008
Steinhardt, U.: RPPT003
Steinhau-Kuehl, N.: TPPT055, TPPT057
Steinmann, E.: WPAE077
Stella, A.: ROAA001, ROAA003, RPPP001, RPPT013, TPAE002
Stenning, M.C.: RPPE026
Stephan, F.: RPPP006, WPAP003, WPAP004, WPAP005, WPAP006
Stephan, J.: WPAP007
Stephani, T.: RPAT045, RPAT046
Stephen, S. R.: RPPE020
Stepin, D.L.: FPAE062
Steski, D.: FPAE029, TPAT093
Stetson, J.W.: TPPE013, TPPE033
Stevens, A.F.: ROPC010
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Stinson, G.M.: FPAE027
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Stocchi, A.: TPPP023
Stockhorst, H.: FPAE001
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Stockton, J.L.: MPPT055
Stoltz, P.: FPAP020, FPAP021, ROPB006, TPAT026, TPPE039, TPPT033, TPPT098
Stott, J.P.: RPAE070
Stout, D.: RPPT070, RPPT071, TPPT083, WPAT059, WPAT085
Stovall, J.: TPPT039
Stover, G.D.: MPPT067, RPAE063, RPAE067
Stoyer, A.: RPPT063
Stracener, D.W.: RPPT062, RPPT063, TPPE004, TPPE016, TPPE019, TPPE020
Strait, J.: MPPT044, TPAP025
Streun, A.: MPPP018, TPPE026
Strohman, C.R.: RPAT063, TPPP011, WPAT039, WPAT040
Strom, D.: WPAE056
Strong, W.H.: RPPT071, WPAE005, WPAT085
Studebaker, J.: ROAB001
Stuhl, B.K.: WPAT039, WPAT040
Stumbo, S.: TPAE002
Stupakov, G.V.: MPPP046, RPPE057, RPPT028, RPPT035, TPAT062
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Sturrock, J.: MPPT055
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Suetsugu, Y.: FPAP007, RPPE052, RPPE053, TPPP007
Sugahara, R.: RPPP003, TPPP003
Sugawara, H.: RPAP040
Sugaya, M.: FPAE026
Sugimoto, M.: FPAT047
Sugimoto, M.S.: TPPT004
Sugimura, T.: TPPP007, TPPT011, TPPT015, TPPT038, WPAP014, WPAP016
Suh, H.S.: MPPT017, MPPT075, WPAE060
Suh, J.-H.: MPPP003
Suk, H.: TPAE005, TPAE006, TPAE053, TPAE054, TPAE055
Suller, V.P.: FPAT056, RPAE050, RPAE051, WPAP056
Sullivan, G.: ROAB001
Sullivan, M.K.: MPPE058, TPPP024, TPPP029, TPPP034, TPPP035
Sullivan, S.: ROAB010
Sultansoy, S.: TPAT097, TPAT098, TPAT099, WOAB005
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Sun, A.: TPPT087, WPAT086
Sun, B.: RPAE076, RPAT090, RPPT045, RPPT046, RPPT047, RPPT048, RPPT050
Sun, C.: RPAE022
Sun, D.: WPAT033
Sun, X.J.: MPPT001, MPPT024
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Sundaram, M.: FPAT014, FPAT017, RPAP048
Sung, C.: TOPA006, TPAE043, TPAE044
Surles-Law, K.E.L.: WPAP045, WPAP048, WPAP051
Surrow, B.: TPPP042, TPPP043, TPPP049
Susta, J. T.: TPPT051
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Suwada, T.: RPAT088, TPPP007
Suwannakachorn, Dr.: FPAE076
Suzuki, H.: FPAE003, MPPE005, MPPT015
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Suzuki, S.: FPAE063
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Svandrlik, M.: RPAE085, WPAT070
Svendsen, T.L.: RPAE007
Svinin, M.P.: RPAP019
Svirida, D.: FPAE014, MOPA007
Swenson, D.A.: TPPT034
Swift, G.: FPAE061, RPAE074, RPPE054, WPAE043
Swinney, C.: ROAB001
Sylvester, C.: MPPT009, MPPT044, MPPT054
Symon, K.R.: WOPA001
Syphers, M.J.: TPAP027, TPAP028, TPAP030
Syratchev, I.: RPPP010, TPPT020
Syresin, E.: MOPC004
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Tabak, M.: ROAB003, RPAP039
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Takabayashi, Y.: FPAT076, RPAE006, RPAE078, TPPE048
Takada, E.: RPAP009
Takagi, A.: FPAE010, FPAE026, ROAC005, TPPT005, WPAT007, WPAT064
Takahashi, H.: FPAT047, FPAT048, ROPA003
Takahashi, J.: FPAE066, RPPE036
Takahashi, S.: FPAE036
Takahashi, T.: RPAE041, RPPP003, TPPT013, WPAT009
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Takaki, H.: RPAE040, RPPE040, TPPT049
Takano, J.: FPAE006, FPAE014, MPPE029
Takano, S.: MPPE038
Takao, M.: MPPE038
Takasaki, E.: WPAE044
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Takayama, K.: FPAE020, FPAT019, TPAT009, TPAT096, TPPT014
Takayanagi, T.: FPAE002, MPPT006, MPPT007, MPPT015
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Takenaka, T.: WPAT053
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Tamura, F.: FPAT071, ROAC005, TPPT005, WPAT007, WPAT064
Tan, C.-Y.: RPAT012, RPAT016, TOAD002, TPAP033
Tan, Y.E.: WOAB004
Tanabe, T.: MPPT026, RPAE058
Tanaka, H.: MPPE038
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Tanaka, T.: FPAE025, FPAE036, TPPE060
Tang, C.: TPAE065
Tang, C.-X.: RPAT097
Tang, J.: MPPE046
Tang, J.Y.: FPAT067, FPAT068, TPPT039, WPAE038
Tang, Y.: ROAB001
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Tani, N.: MPPE004
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Tanimoto, Y.: FPAT049, RPAE041
Taniuchi, T.: FPAE063
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Taylor, D.J.: MPPT028, MPPT030
Taylor, T.M.: MPPT044
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Tazzioli, F.: RPPT013, TPAE002, WPAP013, WPAT006
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Telegin, Y.N.: MPPT078
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Temple, R.: ROAB001
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Terechkine, I.: TPPT070, WPAT033, WPAT050
Terranova, M.L.: WPAP013
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Teruyama, Y.T.: FPAE002, TOAD003
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Thayer, W.J.: MPPT028
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Thibus, J.: FOAB009, RPAP004
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Thienpont, H.: RPAT002
Thoma, C.H.: FPAE071, FPAE077, ROAB003
Thomas, C.M.: MPPT018, MPPT019
Thomas, K.J.: ROAB006
Thomas, R.: MPPT050, TOAA009
Thomas-Madec, C.: RPPE058
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Thompson, D.H.: FPAT053, RPPE021
Thompson, J.M.: MPPE057
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Thongbai, C.: RPPT074, RPPT075
Thorndahl, L.: MPPP002
Thurman-Keup, R.: RPAT034, RPAT036
Tian, K.: FOAD005, RPPE076, TPAT067
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Tkachenko, V.O.: RPAP016, RPAP017
Tobin Thangaraj, J.C.: FOAD005, MPPE067
Tobiyama, M.: FPAP005, MOPC008, ROPB009, RPAT053, RPAT077, TPAT051, TPPP007
Tochitsky, S.: RPAE021, RPAP033, TOPA006, TPAE043, TPAE044
Toda, M.: ROAC005
Todd, A.M.M.: MOPB011, RPPE009, RPPE067, RPPT032, TPAP043, TPPT078, WPAP033
Todd, B.: MPPT033
Todd, B.: TPAP011
Todd, D.S.: TPPE010, TPPE032
Todd, R.J.: MPPT070, RPPE046, RPPE047, RPPE048, RPPE049, RPPE050
Toge, N.: ROAC004
Tokuchi, A.: FPAE020
Tölle, R.: FPAE001, TPAT048, TPAT049
Tollestrup, A.V.: RPAT013
Tolmachev, S.V.: TOPA006
Tolstun, N.G.: RPAP019
Tom, C.-Y.: ROAB001
Tomaru, T.: TOAA006
Tomas, R.: MOPA007, MPPE009, MPPE028, MPPE062, TPAP048, TPAT027, TPAT093
Tomimasu, T.: FPAT076, RPAE006, RPAE078, TPPE048
Tomisawa, T.: FPAE043, RPAT004, RPAT043
Tomizawa, H.: FPAE063
Tomlin, R.E.: WOAC005
Tommasini, D.: MPPT041
Tommasini, P.: TPAE002
Tomosada, T.: RPAP038
Tompkins, J.: MOPA001, MPPT009, MPPT053, MPPT054, TOAA004, TPAP029
Toporkov, D.K.: TPPP009
Toppinen, A.M.: TPAP020
Tordeux, M.-A.: RPAE031, WPAP001
Torikai, K.: FPAE020, FPAT019, TPAT009, TPAT096, TPPT014
Torikoshi, M.: FPAE004, RPAE006, RPAP007, RPAP012
Torre, A.: RPPT013
Torrence, E.T.: RPPP003, RPPP030, RPPP036
Torun, Y.: WPAT029
Tosi, L.: RPAE085
Tosin, G.: WPAE007
Toth, C.: TOPA001, TPAE019, TPAE021
Toussaint, J.-C.: FPAE037
Tovmasyan, G.K.: TPAE001
Towne, N.A.: MPPP036, MPPP038, RPAE056
Toyama, T.: FPAE020, FPAP006, MPPP025, RPAT004, RPAT005, RPAT043, TOAD003, TPPT014
Toyokawa, H.: FPAT076, RPAE078
Toyokawa, R.: RPAT005, TOAD003
Trakhtenberg, E.: MPPT081, WPAE082
Tranquille, G.: RPPE005
Travish, G.: FOAD002, RPAE015, RPAP033, RPPT031, TOPA006, TPAE048, TPAE049, TPPE040, TPPT040
Trbojevic, D.: MOPA007, MOPA009, MPPE030, RPAP020, TPAP043, TPAP049, TPAP050, TPAP051, TPAP052, TPAP053, TPAP060, TPAT093, TPAT094, TPAT095, TPPP022, TPPP043, TPPP046
Tremaine, A.M.: FOAD002, RPAE014, RPAE015, RPAE020, TPPE053
Tribendis, A.G.: RPAE074, WPAT017
Trifirò, A.: RPAP036
Trimarchi, M.: RPAP036
Trinquart, G.: WPAE017
Trotsenko, V.I.: MPPT078
Troubnikov, G.V.: TPAP043, TPAT090
Trubnikov, S.V.: FOAB005
Tsai, H.-J.: RPAE047, RPAE048
Tsai, M.H.: TPPT066
Tsai, Z.-D.: RPPE006, RPPE007, RPPE008, RPPE072, WPAE003
Tsakanian, A.V.: MPPP051
Tsakanov, V.M.: MPPP019, RPAE083, WOAB008
Tsakiris, G.: TPAE056
Tsakov, I.: WPAP006
Tsang, T.: FPAE073
Tschalaer, C.: RPAE068, RPAE069, TPPP022
Tseng, T.C.: RPAT059
Tsoulou, E.: TPAP014
Tsoupas, N.: FPAE014, FPAE029, FPAT059, MOPA007, MPPT046, MPPT070, MPPT071, MPPT072, RPPT065, TPAT093, WPAE068
Tsuchiya, K.: MPPT037, MPPT044, TPPT062
Tsuchiya, K.: RPAE041
Tsujimoto, K.: TPPT007
Tsung, F.S.: TPAE038, TPAE040, TPAE045, TPAE046
Tsutsui, H.: RPAP007
Tumaikin, G.M.: TPPP009
Tunyan, S.: RPAE083, RPPE014
Tuozzolo, J.E.: MOPA007, MPPT070, MPPT071, RPPT066, TPAT093
Tupikov, V.: MPPT022
Tur, Y.D.: WPAT021
Turchet, A.T.: RPAE085
Turlington, L.: TPPT081
Turner, J.L.: MPPE058, TPPP026, TPPP037, TPPP038
Turner, M.: WOPB
Turrioni, D.: MPPT054, ROAA005, TPPP050
Tuvik, A.F.A.: RPAP017
Tzoufras, M.: TPAE038, TPAE040, TPAE045

Uchiyama, H.: MOPC004
Uchiyama, T.: RPAE041
Ueda, A.: RPAE041, RPAE042
Uehara, S.: ROPB009, RPAT052, TPPP007
Ueng, T.-S.: MPPP034, RPAT060
Ueno, A.: FPAE043, RPAT004, RPAT043, TPPT041, WPAE044
Uesaka, M.: RPAP006, RPAP012, TPAE003, TPAE004, TPPE049, WPAP019
Uesugi, T.: FPAE026, MOPC004
Uesugi, T.H.: FPAE004, FPAE005
Ueyama, D.: RPAP011
Ullrich, F.-R.: WPAT003
Umemori, K.: RPAE041, RPAE045, TPPT013, TPPT063, WPAT009
Underwood, D.G.: FPAE014
Uno, S.: TPPP007
Urakawa, J.: FOAB010, MPPE044, RPAP006, RPAP011, RPAT077, RPPP003, RPPP008, TOAD004, TOPE003, WPAP019
Urban, J.T.: RPPP025, RPPP026
Uriot, D.: TPAT005, TPAT047
Urner, D.: RPPP003
Ursic, R.: RPAT093
Utes, M.J.U.: RPAT010
Uythoven, J.A.: TPAP010, TPAP011, TPAP015, TPAP017, TPAP018

Va'vra, J. J.: TPPP023, WPAE033
Vaccarezza, C.: FPAP001, FPAP002, ROAA001, ROAA003, RPAT098, RPPT013, RPPT015, TPAE002
Vaccaro, V.G.: RPAP037, TPAE036, WPAT005
Valbuena, R. V.: WPAE019
Valente, A-M.: TPPT084, TPPT085
Valentin, V.A.: RPAP017
Valerio, L.: RPAT032
Valishev, A.: MPPE065, TPAT083, TPAT084
Van Erps, J.: RPAT002

Van Tilborg, J.: TOPA001, TPAE019
Van Winkle, D.: MPPP007, WPAT041, WPAT074
Van der Laan, J.: RPAE068, RPAE069, TPPP022
Van der Wiel, M.J.: RPAP034, TPPE050
VanDerMark, T.F.: RPPE077
Vandorpe, B.: ROPC004
Vane, C.R.: TPPE019
Vanecek, D.L.: FPAE071, MPPT069
Vardanyan, A.: MPPP019, RPAE083
Varfolomeev, A.: TOPA006
Variale, V.: RPAP037, TPPE029, WPAT005
Varley, J.A.: RPAE052
Varnasseri, S.: WOAB007
Vasserman, I.: MPPT023, MPPT036, MPPT083
Vassioutchenko, A.V.: TPPT039, WPAT059
Vasyukhin, N.E.: TPAT007, TPAT048, TPAT049
Vatulin, V.: RPPE034
Vay, J.-L.: FPAP015, FPAP016, FPAP021, FPAP033, ROPA009, ROPB002, ROPB006, TPPE046
Veisz, L.: TPAE056
Veitzer, S.A.: FPAP021, ROPB006
Velasco, M.: RPPE025
Velev, G.: MOPA001, MOPA010, MPPT044, MPPT053, MPPT054, TOAA004, TPAP029
Velissaris, C.V.: RPPT072
Veness, R.: WPAE020
Venturini, M.: MPPT072, RPPP052, TPAT071
Venturini Delsolaro, W. , MPPT042, MPPT044
Verardi, L.L.: RPPE036
Verboncoeur, J.: ROPB006
Verdier, A.: MPPE047, TPAP020
Vergara-Fernández, A.: TPAP011
Vermeulen, D.: TPPE026
Vervaeke, M.: RPAT002
Verzilov, V.: ROPC009
Vescovi, M.: ROAA001, ROAA003, RPPT013, TPAE002
Veshcherevich, V.: TPPT089, TPPT094, WPAT038
Vetrov, P.: FPAT046
Vetter, K.: MOPA007, RPAT029, TPAP050, TPAT093
Viaud, B.F.: TPAT076
Vicario, C.: MOPB008, RPPT013, RPPT031, TPAE002, WPAP013
Vieira, D.J.: RPPT062
Vigil, V.P.: MPPT055
Vignola, G.: WOAB007
Vilaithong, T.: FPAE076, RPPT074, RPPT075
Vincent, J.: FPAE072
Vincke, H.: TPAP005, WPAE018, WPAE050
Vincke, H.: RPPP039, RPPP040, TPPE053
Vinogradov, N.: MOPB003
Vinogradov, V.I.: FPAT054
Vinokurov, N.: FPAE061
Vinokurov, Y.: RPPT025
Viren, B.: RPPT072
Virostek, S.P.: MPPT059, TPPT029, TPPT030, WPAE045
Visentin, B.: WPAT087
Visintini, R.: RPAE085
Vlachoudis, V.: TPAP007, TPAP014
Vobly, P.: RPAE036
Voelker, F.: WPAE063
Vogel, E.: FPAT022
Vogel, H.: TPPE024, TPPT089, WPAT068, WPAT069
Vogel, H.: RPAT062
Vogel, R. A.: TPAT001
Vogel, V.V.: RPPP003
Vogtlin, G.E.: FPAT036
Volckaerts, B.: RPAT002
Volk, J.T.: MPPT029, RPAT033, TPAP030, WPAE034
Volkov, V.: MOPB011, WPAP007, WPAT017
Volodkevich, O.: FPAE049
Vomiero, A.: WPAE009
vom Stein, P.: TPPE024, WPAT088
Vorderwinkler, K.V.: RPPE018
Voronin, L.A.: RPAP017
Vossenberg, E.: FPAT022
Vretenar, M.: RPPE001, RPPE005
Vujic, J.L.: FPAP033
Vynck, P.: RPAT002

Wada, M.: RPAP040
Wagner, W.H.: FPAT075
Wait, G.D.: MPPT014, WPAE058
Wake, M.: FPAE020, TPPT014
Walaron, K.a.: RPPT073
Waldron, W.: FOAA002, FPAE071, FPAT029, FPAT037, MPPT069, ROAB003, ROAB005, ROPB002, TPAT036
Waldschmidt, G.J.: TOAB009, TPPT024, TPPT036, TPPT037
Walker, N.J.: RPPP014, RPPP033
Walker, R.L.: WPAP050
Walker, R.P.: RPAE052
Wallace, P.W.: FPAE061, RPAE074, WPAE073, WPAE074, WPAT017
Wallig, J.G.: TPPE022
Walston, S.W.: RPPP036
Walter, G.: FPAE075
Walter, M.: FOAD005, FPAE021, MPPE067, RPPE076, TPAT004, TPAT066
Walters, D.R.: RPAT087
Walz, D.R.: RPAE019, RPAT078, RPAT079, RPAT082, TOPA002, TPAE024, TPAE025, TPAE035, TPAE042, TPAE046, TPAE049, TPAE058, WPAP059
Wan, W.: MPPE074, MPPE075, MPPE076, RPAE065, RPAE082
Wanderer, P.: MPPT038, MPPT046, MPPT049, MPPT050, TOAA006, TOAA009
Wang, C.: TPAE012, TPAE013
Wang, C.: MPPE073, MPPP034, TPPT065, TPPT066, TPPT089
Wang, C.-X.: MPPE016
Wang, D.: RPAE068, RPAE069, RPPT027, TPPP017, TPPP019, TPPP020, TPPP021, TPPP022, TPPP045
Wang, D.: RPAE068, RPAE069, TPPP020, TPPP021
Wang, D.-J.: RPAT059, RPPE008
Wang, F.: RPAE068, RPAE069, TPPP017, TPPP022
Wang, G.: WPAT065
Wang, H.: RPPE060, TOAC004, TPPT078, TPPT084, TPPT085, TPPT086, TPPT087
Wang, H.: RPAT066, TPAE016, TPAE060, TPAT058, WPAP034
Wang, J.: WPAE069, WPAE070
Wang, J.: FPAT072
Wang, J.: TPAE064
Wang, J.: RPAT059
Wang, J.-G.: MPPT072, MPPT073, TOAA008
Wang, J.-M.: MPPP036, MPPP038, RPAE056, RPAE058
Wang, J.H.: RPPT046, RPPT047, RPPT048, RPPT050, WOAB010
Wang, J.P.: FPAT055, WPAE002
Wang, J.Q.: MPPP026, MPPP052, WPAE051, WPAT011
Wang, J.W.: ROAC004, RPPP044, TPPT044, TPPT045, TPPT046
Wang, L.: FPAP003, FPAP023, FPAP024, ROPB003, RPPE048, TPAT095, WPAE035
Wang, L.: FPAT073, FPAT074, RPAE076, RPAE077, RPPT049, TPPT042
Wang, L.: FPAT041
Wang, M.: RPPE069
Wang, M.-H.: MPPP034, RPAE047, RPAE049
Wang, P.: FPAE061, MPPP047, MPPP050, RPAE074, WPAT016, WPAT017
Wang, S.: TPAT057, WPAP035

Wang, S.: MPPE046, TPAT077
Wang, S.: TPAE035
Wang, T.-S. F.: RPAP022
Wang, X.H.: WPAE051
Wang, X.J.: MOPB008, RPAE056, RPAE058, RPAE059, TOAB003, TPAE067, TPPT026, WPAP021, WPAP022, WPAP040
Wang, Y.: RPAE050, WPAP056
Wang, Y.: RPPE056
Wang, Z-F.: ROAC006
Wangler, T.P.: FPAT088, TPAT025
Wantland, D.M.: FPAT075
Wanzenberg, R.: MPPP022, RPPP045
Warburton, D.S.: MPPT070
Ward, D.R.: RPPP036
Warner, A.: MPPT022
Warnock, R.L.: TPAT042, TPAT071
Warsop, C.M.: RPAP046, WPAT024
Warwick, T.: RPAE063
Washio, M.: FOAB010, RPAP011
Watanabe, J.: TPPT049
Watanabe, K.W.: TPPT009
Watanabe, M.: FPAE002, FPAE020, MPPT015
Watanabe, T.: RPAT067, RPAT089
Watkins, A.V.: WPAT025
Watson, J.A.: ROAB010
Watson, N.K.: RPPP036
Watts, S.: TPAP020
Weathersby, S.P.: TPPP030, TPPP031
Weaver, J. T.: WPAE072
Webb, T.: RPAP035
Webber, R.C.: RPAT017, RPAT018, TOPC004
Weber, J.M.: RPAT074
Webster, A.: WPAT063
Wehler, D.: WPAT068
Wei, J.: FPAE016, FPAP023, FPAP024, FPAT003, MOPA009, MPPE030, MPPT070, MPPT071, ROPB003, RPPE048, RPPT065, TOAC003, TPAP043, TPAP049, TPAP050, TPAT081, TPAT082, TPAT095, TPAT096, TPPE007, WPAE035
Wei, X.: WPAE080
Weiland, T.: FPAT079, MPPP023, TPAT008, WPAP006, WPAP008
Weir, J.T.: RPAT095
Weisend, J.: WPAT089
Weiss, D.: MPPT070, RPPE046, RPPE047, RPPE048, RPPE049, RPPE050
Weisser, M.: RPAE039
Welch, D.R.: FPAE071, FPAE077, FPAP032, ROAB003, RPAP039, TPAE062, TPAT068
Welch, J.J.: RPPT041
Welton, R.F.: MOPB005, RPAT042, TPPE022
Wen, X.M.: WPAE051
Wendel, M.: RPPT062, RPPT063
Wendt, K.: TPPE019
Wendt, M.W.: TPPP033
Weng, W.-T.: FPAE050, FPAT031, RPPT065, RPPT066, WPAE068
Wenhui, h.w.h.: MPPP026, WPAT011
Wenninger, J.: MOPA005, MOPC009, MPPP004, RPPE016, RPPE017, RPPE018, TPAP007, TPAP008, TPAP015, TPAP016, TPAP017, TPAP018, TPAP019
Werkema, S.J.: MPPE056, MPPT052
Werner, G.R.: TPAE051, TPPT098
Wesolowski, P.: MPPP001, RPAE037, RPAE038
West, S.: WPAE078
Westenskow, G.A.: FPAP033, TPPE009, TPPE011
Weterings, W.J.M.: TPAP009, TPAP013
Weyrich, K.: RPPE034
Wezensky, M.: WPAT055, WPAT056, WPAT059
Wheeler, P. W.: WPAT078, WPAT079
Wheelhouse, A.E.: WPAT072
White, A. E.: MPPT059, WPAE045
White, G.R.: RPPP003, RPPP014, RPPP015, RPPP027, RPPP036
White, M.: TOAB009, WPAE082
Whitehead, M.: ROPC010, TPPE025
Whitlach, T.: WPAP033
Whitlatch, T.E.: RPPE061, RPPE067
Wichaisirimongkol, P.: RPPT074, RPPT075
Widger, D.W.: RPPE077
Wiedemann, H.: FPAE076, RPPT074, RPPT075
Wienands, U.: MPPE058, TPPP026, TPPP029, TPPP034, TPPP035, WOAD002
Wilcox, R.B.: RPAT075
Wildman, D.: FPAE010, MPPP015, TPPT028, WPAT033, WPAT050
Wilinski, M.: MOPA007, RPPE022
Will, I.: WPAP006, WPAP007
Willaims, N.W.W.: RPPE009, RPPT032, TPAP043
Willen, E.: FPAE014, MPPT046, MPPT050
Williams, D.C.: FPAT067, TPPT039
Williams, E.: FPAT075
Williams, E.: TOPC003
Williams, O.: RPAP033
Williams, T.L.: WPAE042
Wilson, I.: TPPT020
Wilson, J.: RPAT031
Wilson, K.: RPPE061, TPPT082, TPPT083
Wilson, L.L.: RPPE030
Wilson, M.: TOAA009
Wilson, T.: ROPA002
Win, S.S.: FPAP005, TPPP007
Wing, M.W.: RPPP036
Winter, A.: RPAT049, RPAT050, RPAT094, RPPT038, RPPT039, TOPB003
Wipf, S.G.: WPAT083
Wirth, B.D.: WPAE054
Wisdom, J.: TPAE014, TPAE015
Wiseman, M.: RPPE010, RPPE060, RPPE061, RPPE067, TPPT083, WPAP033
Wissmann, M.J.: WPAT034
Witcher, J.J.: FPAP035
Witte, H.: MPPT059
Witte, K.: TPAE056
Wittenburg, K.: RPAT083
Wittmer, W.: RPAE082
Wobst, E.: TPAP020
Wojcicki, S.G.: FOPA004
Wojcik, G.: TPAP030
Wolbers, S.A.: RPAT018, TOPC004
Wolf, R.: MPPT028, MPPT029, WPAE034
Wollnik, H.: MPPE082
Wolski, A.: RPPP033, RPPP034, RPPP045, RPPP052, RPPP053, RPPP054, RPPT025
Wong, R.: WPAT091
Wong, S.: WPAE072, WPAE081
Wood, J.: FPAE014
Wood, M.: RPPE025
Wood, R.L.: TPPE045, WPAP033
Wood, T.W.: TPPE025
Woodley, M.: RPPP003, RPPP027, RPPP033, RPPP036, RPPP041, TPPP037
Woods, M.: RPPP003, RPPP030, RPPP036
Wooldridge, E.: WPAT023
Wormser, G.: WPAE056
Wright, D. H.: WPAE033, WPAE056
Wright, E.L.: WPAT031
Wright, G: ROPA002
Wrulich, A.: TPPE026
Wu, A.T.: TPPT084, TPPT085

Wu, C.-F.: TPPT042, TPPT043
Wu, G.: TPPT029, TPPT077, TPPT082, TPPT084, TPPT085, TPPT086
Wu, J.: FPAP017, FPAP018, MPPP008, MPPP009, MPPP049, RPPP037, RPPP038, RPPT040, TOAB004, TOAC005, TPAT062, TPAT063
Wu, K.-C.: MPPT050, RPPE009, RPPT032, TPAP043
Wu, V.: FPAE012, TPAP022, TPAP031, TPPT028
Wu, X.: FPAE072, MPPE023, MPPE024, TPPE013
Wu, Y.: MPPT002, WOAD005
Wu, Y.K.: FPAE060, FPAE061, FPAT051, FPAT069, MPPP047, MPPP048, MPPP049, MPPP050, RPAE022, RPAE023, RPAE074, RPAE075, RPPE054, WOAC004, WOAC008, WPAE073, WPAE074, WPAT017
Wu, Z.: MOPB008, MOPB010, TOAB003
Wuensch, M.: RPAE038
Wuensch, W.: TPPT020
Wurtele, J.S.: ROAB003, RPAP039, RPPT025, TPAE066, TPPE064
Wyles, N.G.: MPPT079, RPAE052

Xia, J.W.: TOPD003
Xiang, D.: TPAE067, WPAP022, WPAP040
Xiang, R.: TPPE055, WPAP007
Xiao, A.: FPAT012, RPPP047, RPPP051, TPAP036, TPAP038
Xiao, L.: TPPE058, TPPT031, TPPT032, TPPT056
Xiao, M.: FPAE013, MPPE051, MPPE052, MPPE084
Xie, Xie.: FPAT072
Xing, J.: WPAE051
Xu, H.: RPAE076
Xu, H.: WOAB002
Xu, J.Z.: MPPT023
Xu, T.G.: FPAE064, TPPT047
Xu, W.W.: FPAE064
Xu, X.: WPAE059
Xu, X.A.: FPAE064
Xuan, K.: FPAT072

Yaeger, R.J.: RPPE077
Yakimenko, V.: RPAP043, RPAT067, RPAT089, RPPT031, RPPT032, TPAE057, TPAP043, TPAT033, TPAT034, TPPP043
Yakovlev, V.P.: TPAE012, TPAE013, WPAT026, WPAT027, WPAT028
Yamada, R.: MPPT054, TOAA004
Yamada, S.: MPPE081, RPAP007
Yamaguchi, S.: WPAT008
Yamamoto, A.: MPPT044, TOAA006
Yamamoto, K.: MPPE081, TPAT075
Yamamoto, K.: MPPE005, MPPE043, WPAE012, WPAE013
Yamamoto, M.: ROAC005, TPPT005, WPAT007, WPAT064
Yamamoto, N.: ROPA003, TPPP007
Yamamoto, S.: RPAE041
Yamamoto, Y.: TPPP007
Yamamoto, Y.: RPAP006, WPAP019
Yamanaka, S.: RPAP032, WPAE071, WPAT052
Yamane, I.: FPAE020
Yamaoka, H.: RPPP003
Yamazaki, A.: FPAE026
Yamazaki, M.: WPAT008
Yamazaki, Y.: TPPT041
Yan, Y.T.: MPPE040, MPPE058, MPPE059
Yanagida, K.: FPAE063
Yang, B.X.: MPPE066, MPPP035, RPAE073, RPAT065, RPAT086, RPAT087, RPPT034, TOAB009, TOPC001
Yang, J.: WPAP017, WPAP018
Yang, J.S.: MPPP027, WPAT013, WPAT014
Yang, J.Y.: TPPT066
Yang, M.-J.: MPPE052, MPPE083, MPPE084, MPPE085
Yang, S.Q.: MPPT058, MPPT059, TPPP018, WPAE045
Yang, T.-T.: TPPT065, TPPT066
Yang, X.: FPAE019
Yang, Y.L.: RPPT046, RPPT047, RPPT048, RPPT050, WOAB010
Yano, Y.: FPAE068, ROPC003
Yano, Y.: TPPP007, WPAT053
Yao, C.: MPPP035, RPAE055, RPAT085
Yao, Y.: FPAE064
Yarba, V.: MPPT054, ROAA005, TPPP056
Yavas, O.: TPAT097, TPAT099, WOAB005
Ye, Q.: RPAP047
Yeh, M.-S.: MPPE073, TPPT065, TPPT066, WPAT020
Yi, R.: WPAT081
Yilmaz, M.: WOAB005
Yin, L.: FPAT025
Yin, Y.: RPAP049
Yin, Z.: MPPT001, MPPT002, MPPT004
Yip, K.: RPPE009, RPPT032
Yocky, G.: TPPP026, TPPP036, TPPP037
Yoder, R.B.: TOPA006, TPAE039, TPAE049
Yokoi, T.: FPAE026
Yokouchi, S.: FPAE068
Yokoya, K.: RPPP003, RPPP012
Yokoyama, K.: TPPP007, TPPT011, TPPT015, TPPT038, WPAP015
Yonehara, K.: ROAA005, TPPP013, TPPP052, TPPP054, TPPP056
Yonemura, Y.: FPAE026
Yongjun, L.: RPAE036
Yoon, J.C.: FPAT050, WPAT015
Yoon, M.: MPPP027, TPAT011
Yoon, P.S.: FPAE011, TPAT015
York, R.C.: FPAT088, MPPE023, MPPE024, TPAT022, TPPT096, WOPA002
Yoshida, K.: RPAE006, RPAE078, TPPE048
Yoshida, M.: TPPP003, TPPP007
Yoshida, M.: TPPP007, WPAT008, WPAT053
Yoshida, Y.: RPAP010, RPAP038, WPAP017, WPAP018
Yoshii, M.: FPAE026, FPAT071, ROAC005, TPPT005, WPAT007, WPAT064
Yoshikawa, H.: FPAT047, FPAT048, ROPA003, RPAT004
Yoshimoto, M.: FPAE026
Yoshimoto, S.I.: TPPP007
Yoshimura, K.: ROAD003
Yoshino, K.: WPAE044
Yoshioka, M.: RPPE002
You, H.J.: TPPE028
You, J.: FPAT005
Young, K.A.: TPPT039, WPAT054, WPAT061
Young, L.M.: TPPE045, TPPT039, WPAP033
Yu, D.: RPPP046, TPPE038, TPPE066, TPPT050, WPAT081
Yu, I.H.: RPAT008, WPAT013, WPAT014, WPAT015
Yu, J.: RPPP046
Yu, L.-H.: MPPP006, RPAE056, RPAE058, TOAB003
Yu, N.J.: RPAT097
Yu, S.: FPAE071, FPAE077, FPAP032, FPAT027, FPAT028, MPPT069, ROAB001, ROAB003, RPAP039, RPAT022, RPAT023, TPAT036, TPAT068
Yu, T.J.: TPAE055
Yuan, Z.Y.: FPAT005
Yuasa, Y.: FPAE026
Yunn, B.C.: RPPP018, TPPP015, TPPP016, WPAP046
Yuri, Y.: TPAT082
Yusof, Z.M.: RPAT066, TPAE016, WPAP036
Yuzhen, Y.: MOPB008

Zadorozhny, V.: TPAT040, TPAT041
Zagel, J.R.: RPAT032

Zagorodnov, I.: TPAT008
Zajtsev, B.V.: TPPT022
Zakaryan, D.A.: MPPE079, MPPE080
Zakutin, V.: TPPE052, WPAP028
Zaltsman, A.: FPAE029, MOPA007, RPPE009, RPPT032, TPAP043, TPAT093
Zamriy, V.N.: RPPE015
Zanchetta, P.: WPAT078
Zangrando, D.: MPPT089, MPPT090, RPAE085
Zaplatin, E.: FPAE001
ZappalÃ , E.: WPAE011
Zaugg, J.: MPPT055
Zavodszky, P.A.: TPPE033, TPPE034
Zeitlin, M.G.: FPAP009, FPAP010, MPPE072, TPAT013, TPAT053
Zelenski, A.: FPAE014, MOPA007, TPAT094
Zelinsky, A.Y.: MPPT077, MPPT078, RPAE011, RPAE012
Zeller, A.: MPPT031, MPPT048, RPPT062, RPPT063, TPPT096
Zemlyansky, I.: FPAE007
Zenere, D.: TPPT061
Zeng, J.: WPAE072, WPAE081
Zeng, X.: WPAT065
Zeno, K.: FPAE014, FPAE029, MOPA007, TPAT093, TPAT095
Zentler, J.M.: FPAT036
Zepf, M.: TOPA007
Zerlauth, M.: RPPE017, TPAP011
Zhai, X. Z.: TPAT043
Zhang, B.C.: TPPE055
Zhang, C.: TOPD002, TPPE059
Zhang, C.: FPAE038
Zhang, H.: RPAE077
Zhang, H.S.: FPAE064
Zhang, J.F.: MPPT002
Zhang, S.Y.: MOPA007, RPAT026, RPPT065, TPAP049, TPAT093, TPAT095, TPPP043
Zhang, W.: FPAT031, MPPT014, MPPT070, ROAB007, RPPT066, TPAT093
Zhang, X.: TPAP032, TPAP033, TPAP034, WPAE029
Zhang, Y.: TPAP042, TPPP015, TPPP016, WPAP046
Zhang, Y.: FPAE058, TPPE021
Zhang, Y.: TPAT085
Zhang, Z.: TPAE030
Zhang, Z.: WPAE059
Zhang, Z.H.: FPAE064
Zhao, K.: TPPE055
Zhao, Q.: TPPE013
Zhao, Y.: RPPE009, RPPE032, RPPT032, TPAP043, TPPE042, TPPE061, WPAP038, WPAT049
Zhao, Z.: WOAB002
Zheng, H.: FPAE010
Zheng, K.: RPPT046, RPPT047, RPPT048, RPPT050, WOAB010
Zheng, S.: MPPP026, RPAT097, TPPE065, WPAT011, WPAT093
Zhidkov, G.: TPAE003, TPAE004
Zhiglo, Z.V.: FPAE062, TPPE051
Zhiliaev, K.Zh.: MPPT084
Zholents, A.: MPPE074, RPAE065, RPAE066, RPAE082, RPPT037, TOAB009, TOPB001, TPPE064
Zhou, D.M.: MPPP026, MPPP052, WPAT011
Zhou, F.: RPAT077, TPAE047, TPAT033, TPAT034
Zhou, J.Z.: FPAT030, MPPT027, TPAT002, TPAT003
Zhou, M.: RPAE019, TPAE024, TPAE025, TPAE034, TPAE040, TPAE041, TPAE042, TPAE046, TPAE058
Zhou, Y.-B.: WPAT041
Zhou, Y.G.: RPPT036, WPAE075
Zickler, Th.: RPPE005
Zimmermann, F.: FPAP001, FPAP013, FPAP014, MOPC009, MPPE009, MPPE044, ROPB004, RPPP003, RPPP007, RPPP008, RPPP012, RPPP045, TPAP003, TPAP008, TPPP007, TPPP010
Zimmermann, H.: FOAB009
Zinkann, G.: WPAT082
Zisman, M.S.: MPPE056, MPPT059, TPPT029, WPAE045, WPAT029
Zitelli, L.: WPAT031
Zlobin, A.V.: MPPT047, MPPT054, TOAA004
Zobov, M.: FPAP001, MPPP024, ROAA001, ROAA003, RPAT098, RPPP001
Zolfaghari, A.: RPAE068, TPPP020, TPPP022
Zolotariov, K.: RPAE036
Zolotorev, M.S.: RPAE066, TOAB004, TPAT001
Zou, Y.: TPAT067, TPPE046
Zucchini, A.: RPPT013
Zusheng, Z.: MPPE071
Zviagintsev, V.: FPAE027, TPPT001, TPPT052, TPPT061, WPAT001
Zvonarjova, O.D.: MPPT077, MPPT078
Zwart, T.: FPAE031, RPAE068, RPAE069, TPPP020, TPPP021, TPPP022, TPPT095
Zwaska, R.M.: FPAE022, RPAT044, RPPT072