ACCELERATOR PHYSICS OVERVIEW

Stuart Henderson

Accelerator Physics Group Leader

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SNS Accelerator Physics Team

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- S. Nath
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- L.Young

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- <u>J. Delayen</u>
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- <u>D. Raparia</u>
- M. Blaskiewicz
- A.V. Fedotov
- Y.Y. Lee
- N. Malitsky
- W. Meng
- S. Tepikian
- N. Tsoupas
- J. Wei
- S.Y. Zhang

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- P. Chu
- S. Cousineau
- V. Danilov
- M. Doleans
- J. Holmes
- D. Jeon
- S.H. Kim
- W.D. Klotz
- L. Kravchuk
- T. Pelaia
- Y. Sato
- A. Shishlo
- J. Stovall
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Collaborators

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SNS/ORNL Accelerator Physics Organization

S. Henderson ***Group Leader***
J. Galambos ***Deputy Group Leader***
S. Aleksandrov ***Front-End Area Manager***
E. Tanke ***Warm Linac Area Manager***
I. Campisi ***Superconducting Linac Area Manager***
M. Plum ***Ring and Transport Lines Area Manager***
S. An P. Chu S. Cousineau V. Danilov M. Doleans (student) J. Holmes D. Jeon W.D. Klotz (Visiting) S. Kim L. Kravchuk T. Pelaia Y. Sato (student) A. Shishlo

New

SNS Primary Parameters Are Unchanged Since May 2001 DOE Review

Kinetic energy, E_k [MeV]	**1000**
Uncertainty, ΔE_k (95% probability) [MeV]	+/- 15
SRF cryo-module number	11+**12**
SRF cavity number	33+48
Peak gradient, E_p (β=0.61 cavity) [MV/m]	27.5 (+/- 2.5)
Peak gradient, E_p (β=0.81 cavity) [MV/m]	**35 (+2.5/-7.5)**
Beam power on target, P_{max} [MW]	**1.4**
Pulse length on target [ns]	695
Chopper beam-on duty factor [%]	68
Linac beam macro pulse duty factor [%]	6.0
Average macropulse H- current, [mA]	**26**
Linac average beam current [mA]	**1.6**
Ring rf frequency [MHz]	1.058
Ring injection time [ms] / turns	1.0 / 1060
Ring bunch intensity [10^{14}]	1.6
Ring space-charge tune spread, ΔQ_{sc}	0.15

assuming 4% injection loss to dump; 4% target window loss; linac max. -20^o phase

ASAC Recommendations for Accelerator Physics

- Measure the longitudinal emittance in MEBT with greater precision because the initial "upper limit" estimate is a value that could lead to downstream beamloss
  - We plan to measure the bunch length in MEBT by outfitting antichopper box with production fast faraday cup
  - Plans for picosecond laser diagnostic in FE
  - Longitudinal emittance measurement from D-plate BSM (underway)
- It would be useful to compare the extraction channel clearances for all four cases:
  - Ring acceptance > 480 π mm mrad, Septum clearance (extracted beam) > 400 π mm-mrad (as specified)
- We suggest repeating the 1000-turn tracking simulations using measured magnet errors and the foreseen magnet locations instead of random seeds. …..It would be useful to know if the loss patterns change significantly for different operating tunes, chromaticity values…
  - We are continuing ring simulations with improved capabilities
  - In error studies using random seeds, we have explored dynamics with much larger errors than BNL is routinely achieving
  - To proceed with actual measured errors we need
    - i) completion of quad measurements: measurement/sorting of the 21Q40 magnets was recently completed. Measurements/shimming/sorting of remaining 24 ring quads is underway. (D. Raparia's talk)
    - ii) magnet measurement data in database

DOE Recommendations for Accelerator Physics

SNS:

Absolute energy

SPALLATION NEUTRON SOURCE

Recommendation:

- Augment the “hot spare” ion source with a LEBT
  - in the works (A. Aleksandrov’s talk)

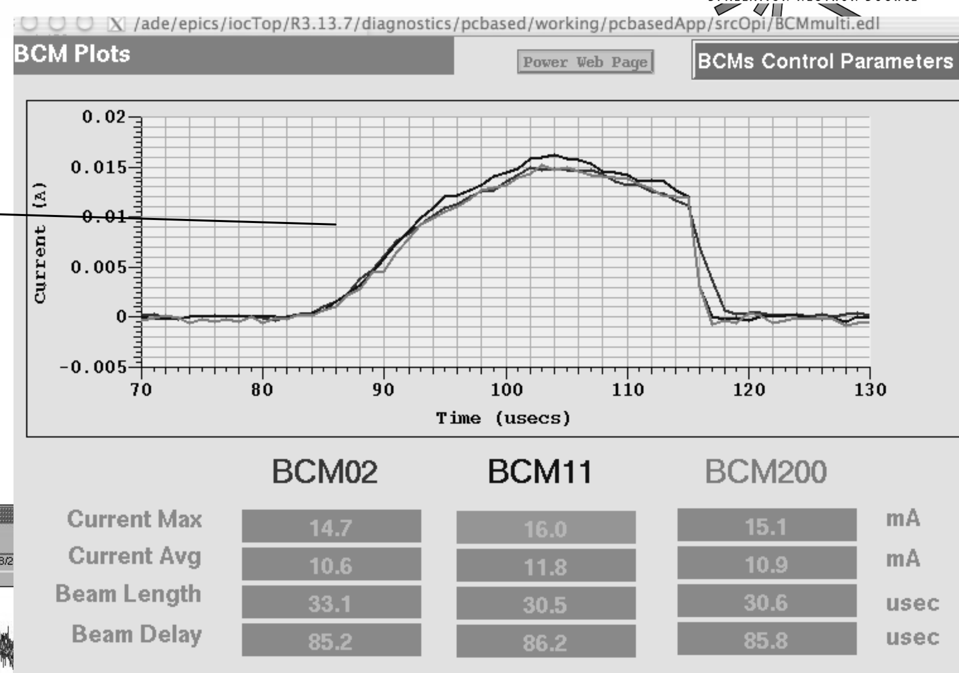
Comments:

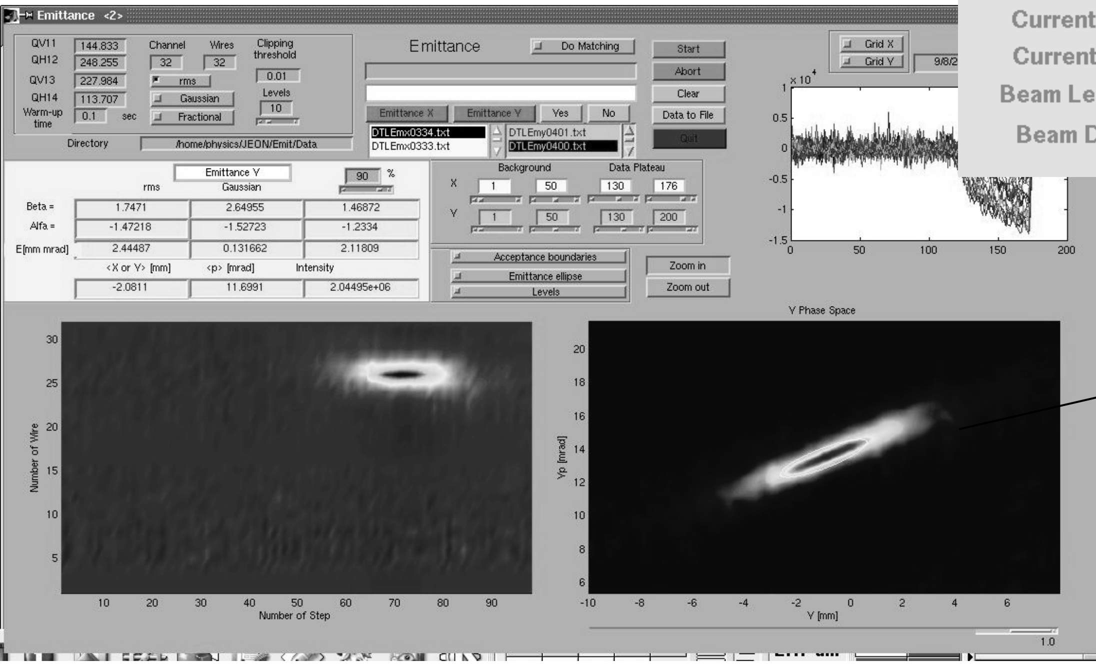
- Laser wire development should continue…the addition of a picosecond pulsed laser can be used to measure the bunch shape in the MEBT
  - Plans are developing for laser system in FE for BIG and bunch length measurements (T. Shea’s talk)
- Absolute, as opposed to relative, energy measurements should be planned; they are necessary in the transitions to each of the 3 different linacs
  - Absolute energy is *possible* with resolution about ???
- Measurements of the bunch length and long. emittance are helpful in DTL/CCL transition because of reduction in longitudinal phase acceptance by x2. Development and installation of BSMs in this transition region are encouraged.
  - Transition region is impossibly tight. However, first BSM is after segment 4 in module 1.

DTL Tank 1 Commissioning Progress
(details in E. Tanke's talk)

Commissioning Run is off to a great start!

– Routinely transport ~100% beam through tank 1 (with ~5% measurement uncertainty)

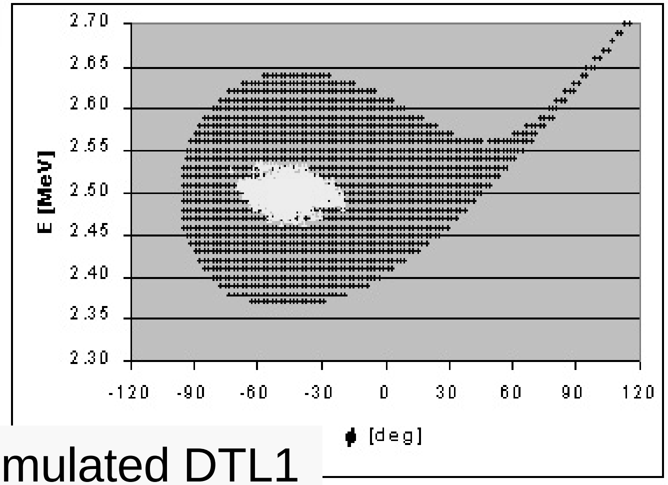




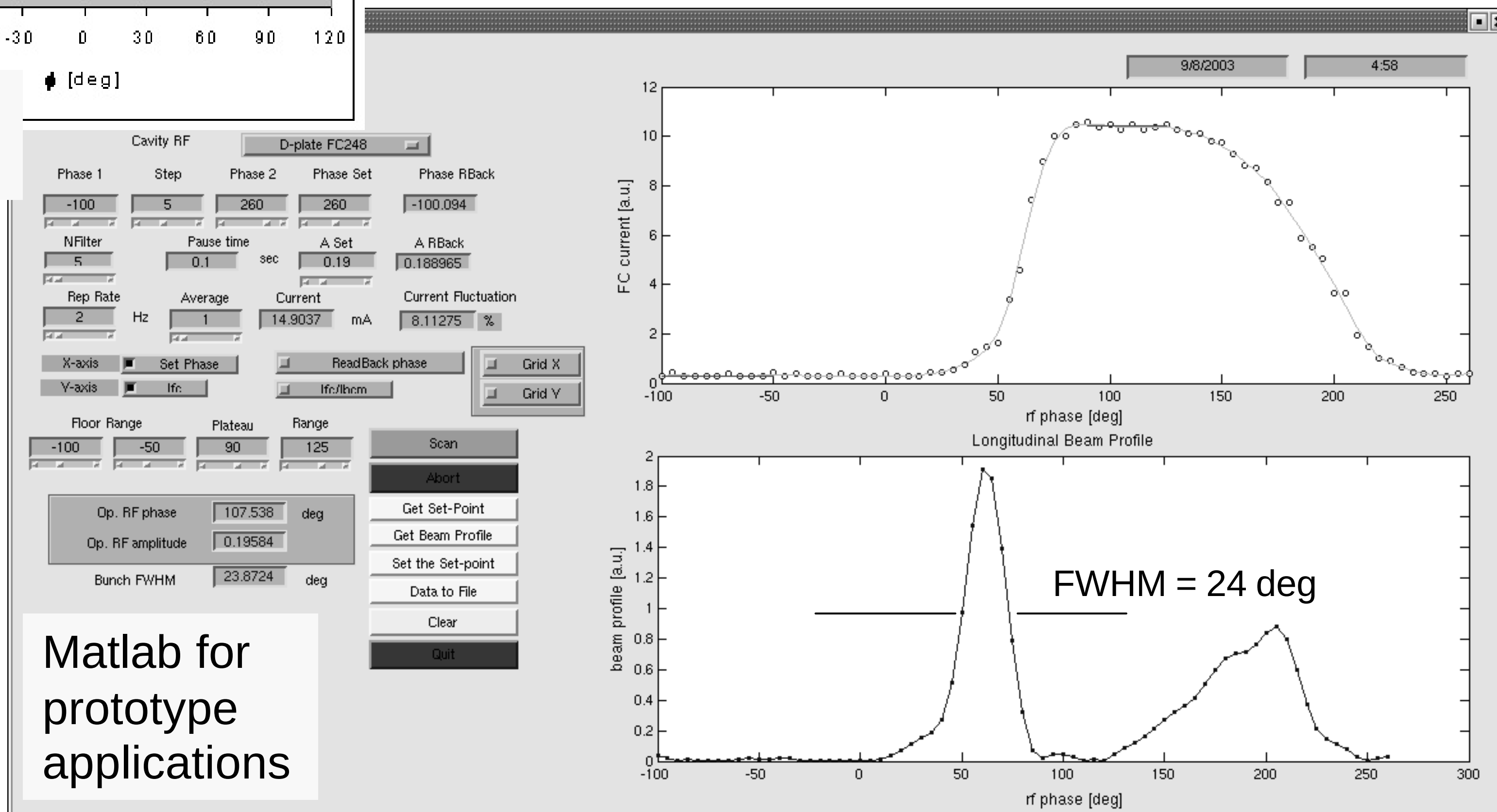
– Preliminary DTL output normalized, rms emittance < 0.2 π mm-mrad in each plane (performance goal is < 0.3)

DTL Tank 1 Commissioning Progress
(details in E. Tanke's talk)

- Acceptance Scan with energy degrader/faraday cup agrees with expectations
- Absorber removes low-energy tail < 7.1 MeV (7.5 MeV output energy)



Simulated DTL1 Acceptance



Matlab for prototype applications

- Produced detailed commissioning plan (~130 tasks enumerated)
- Formed commissioning “Core Team”: meets daily to direct program
- 10 Accelerator Physicists trained as operators
- Very good coordination with Diagnostics, Ops, Controls

SNS 104020000-PR0001-R00

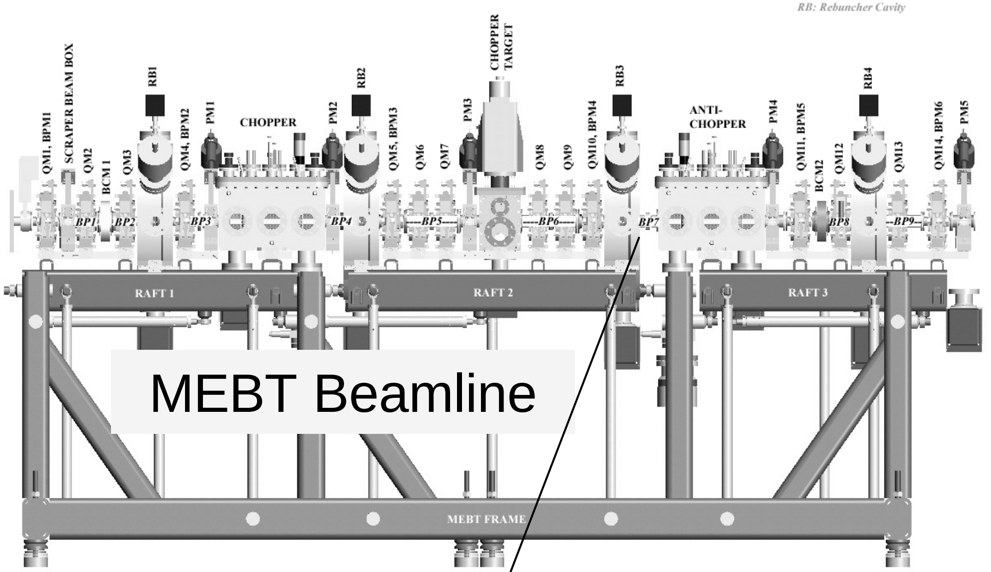
Drift Tube Linac Tank 1
Beam Commissioning Plan

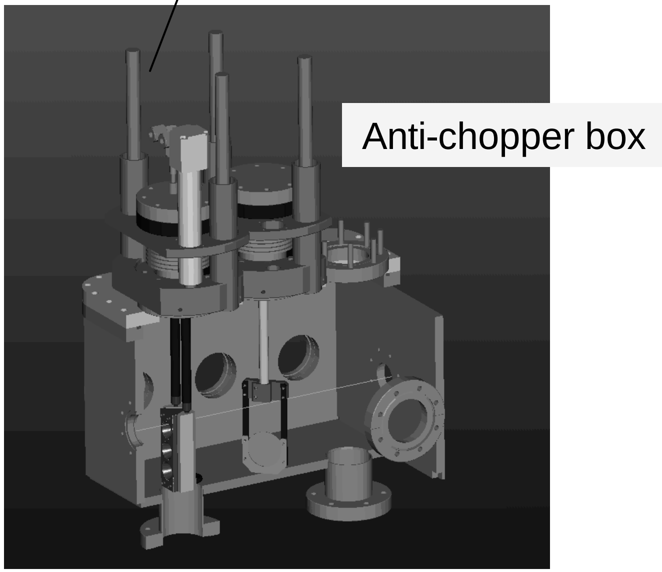
SOURCE

3.9	Perform Beam loading scan	0.5				
4	Beam transport through DTL to D-plate Beamstop	7	20	10	2	0.003 D-plate
4.1	Transport apertured beam to beamstop (&BCM signal)	1	5	10	2	0.00075 D-plate
4.2	Commission D-plate beamstop and Faraday Cup	1				
4.3	Commission Neutron detectors and loss monitors	1				
4.4	Set phase and amplitude of Rebunchers 3 and 4	0.5	5	20	2	0.0015
4.5	Tune for maximum transmission	0.5	5	20	2	0.0015
4.6	Remove MEBT aperture and transport to D-plate beamstop	1	20	20	2	0.006
4.7	Tune for maximum transmission	0.5	20	50	2	0.015
4.8	Commission MEBT Wire scanners 5 and 6	0.3				
4.9	Check MEBT beam profiles	0.3				
4.10	Verify BPM and corrector polarity	0.5				
5	Commission D-plate Diagnostics and MPS	17	20	50	2	0.015 D-plate
5.1	Commission BCMs and Halo monitor	1	20	20	2	0.006
5.2	Center beam on Beamstop using Halo monitors	0.5				
5.3	Commission Differential Current System for MPS	2				
5.4	Verify MPS functionality with beam inputs	1				
5.5	Commission D-plate Energy Degrader/Faraday Cup	1	20	50	2	0.015
5.6	Perform acceptance scan with both Faraday cups and compare	1				
5.7	Commission D-plate emittance system	2				
5.8	Commission Emittance Software and Analysis	2				
5.9	Measure DTL output beam emittance	1				
5.10	Commission Beam-box and D-plate Wire Scanner Systems	1				
5.11	Commission D-plate Wire Scanner Software	1				
5.12	Measure beamsize at WS vs. D-plate quad setting/compare model	1				
5.13	Measure beam profiles in MEBT and D-plate/compare with model	1				
5.14	Commission Viewscreen/Video System	1	20	6	1	0.0009

Front End Physics Progress
(more in A. Aleksandrov’s talk)

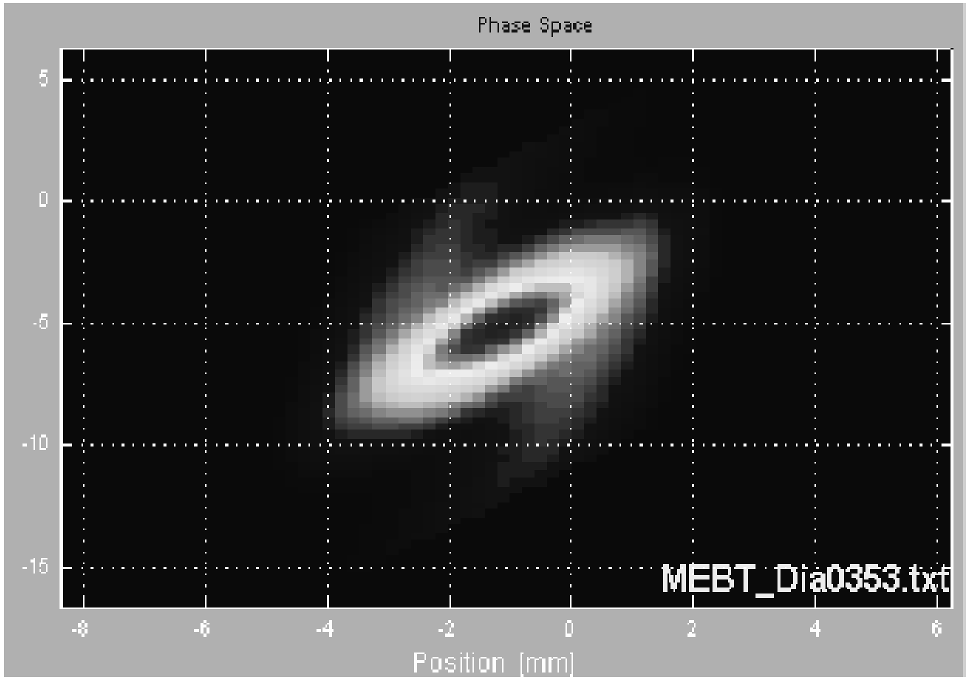
- Proposed diagnostics have been added to antichopper box (good collaboration with diagnostics!)
  - H,V Emittance slits
  - Beamstop/Faraday cup
  - Current and emittance-limiting aperture
  - View-screen
  - Fast-faraday cup for longitudinal measurements (in progress)
- Issues from Front-End Commissioning:
  - MEBT trajectory errors
    - Traced to Source/LEBT alignment, MEBT raft misalignment, and single quad misalignment
    - Now have “flat” trajectory with correctors unpowered
  - “S-Shaped” MEBT output emittance:
    - Have good agreement between measurement and simulation

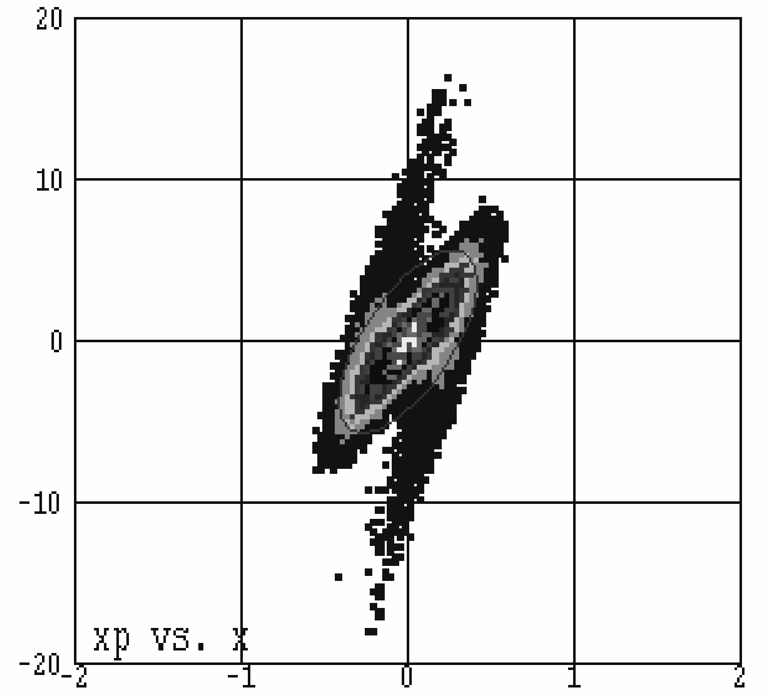




MEBT output emittance: measurement vs. simulation

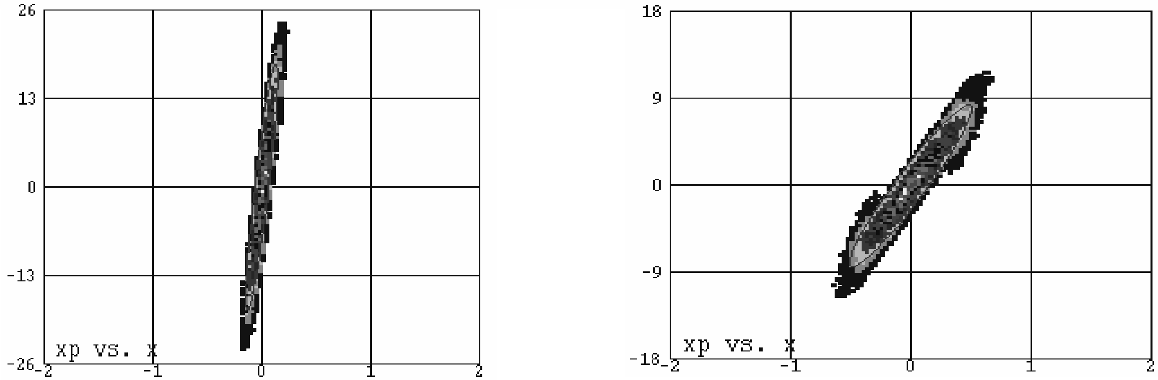
- S-shape formation observed in emittance measurements
- S-shape formation observed in simulation



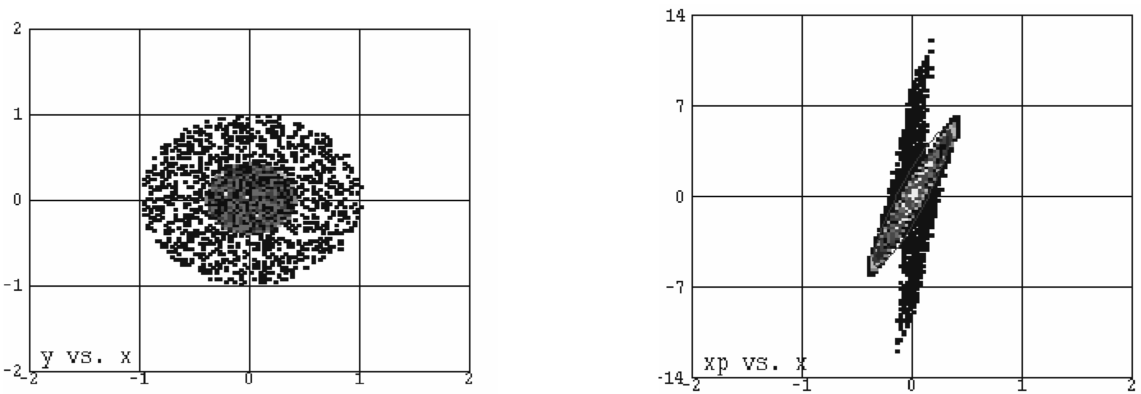


S-shape formation in a drift after quad

(courtesy A. Shishlo)



Water bag distribution doesn’t produce S-shape



Water bag + halo produces S-shape

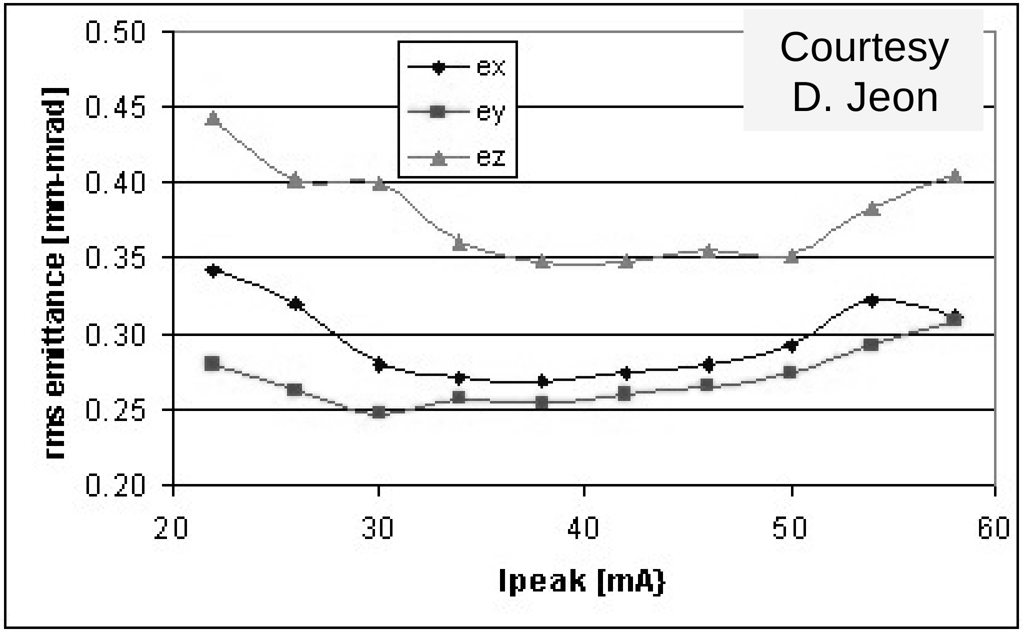
S-shape formed by space charge in the long drift after last quadrupole in the MEBT

S-shape presence in measurements indicates presence of halo before last quad in the MEBT.

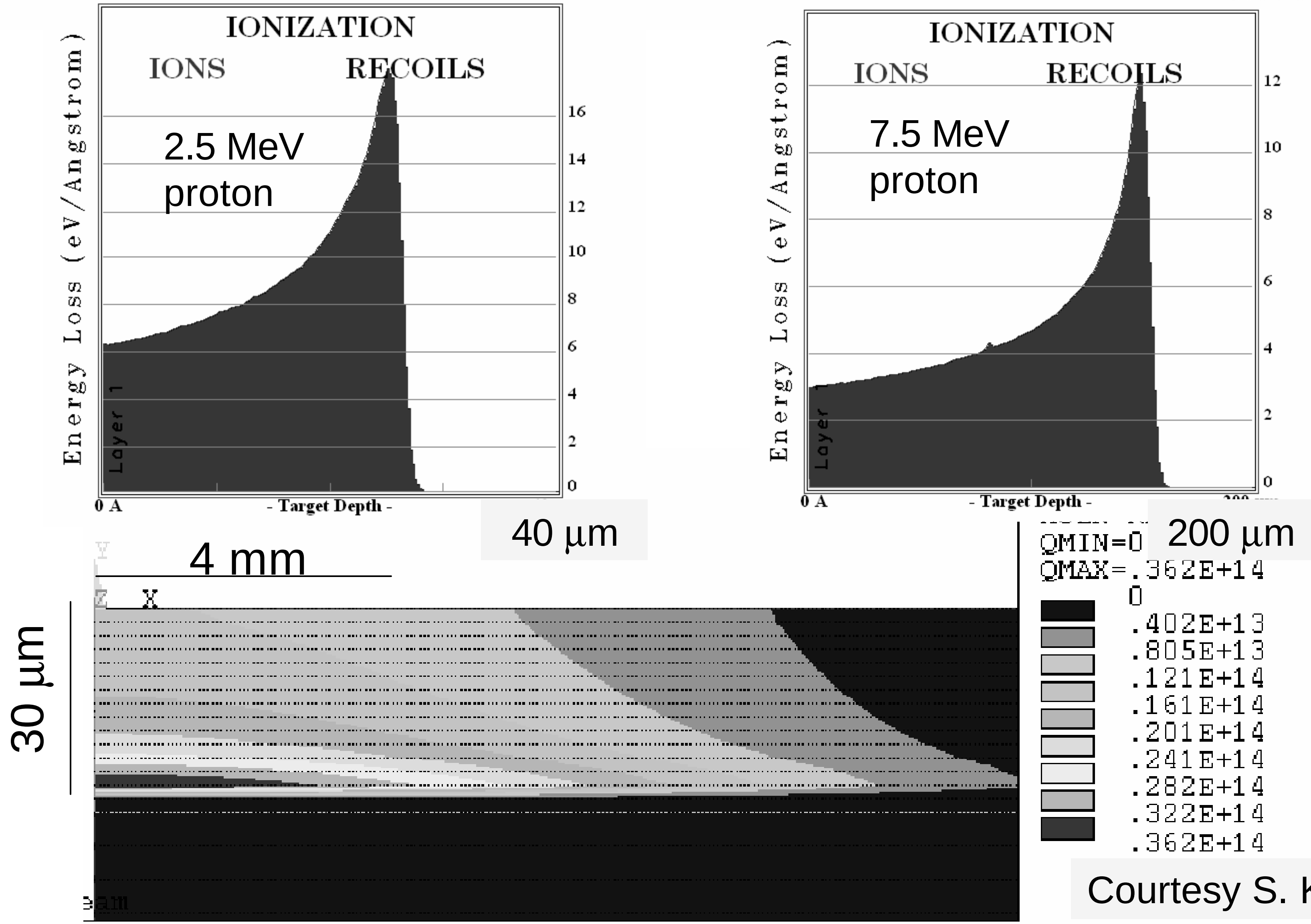
The presence of halo in the MEBT is expected and its prediction was the motivation for the MEBT “Halo scrapers” proposed by Jeon et. al.

Linac Physics Progress

- Commissioning!
- Beam fault scenarios for Tank 1 commissioning
- Investigation of emittance growth due to beam-pulse non-flatness
  - Emittance growth is +/- 5% in current range +/- 20%
  - Can achieve 5% flatness during pulse
- DTL Tuning and measurement issues
- Drift-tube vibration measurement and analysis effort
- Quality Control: cryomodule acceptance



Fault Scenario Evaluation for DTL1: Induced Stress from Single Pulse Sets Beam Limits

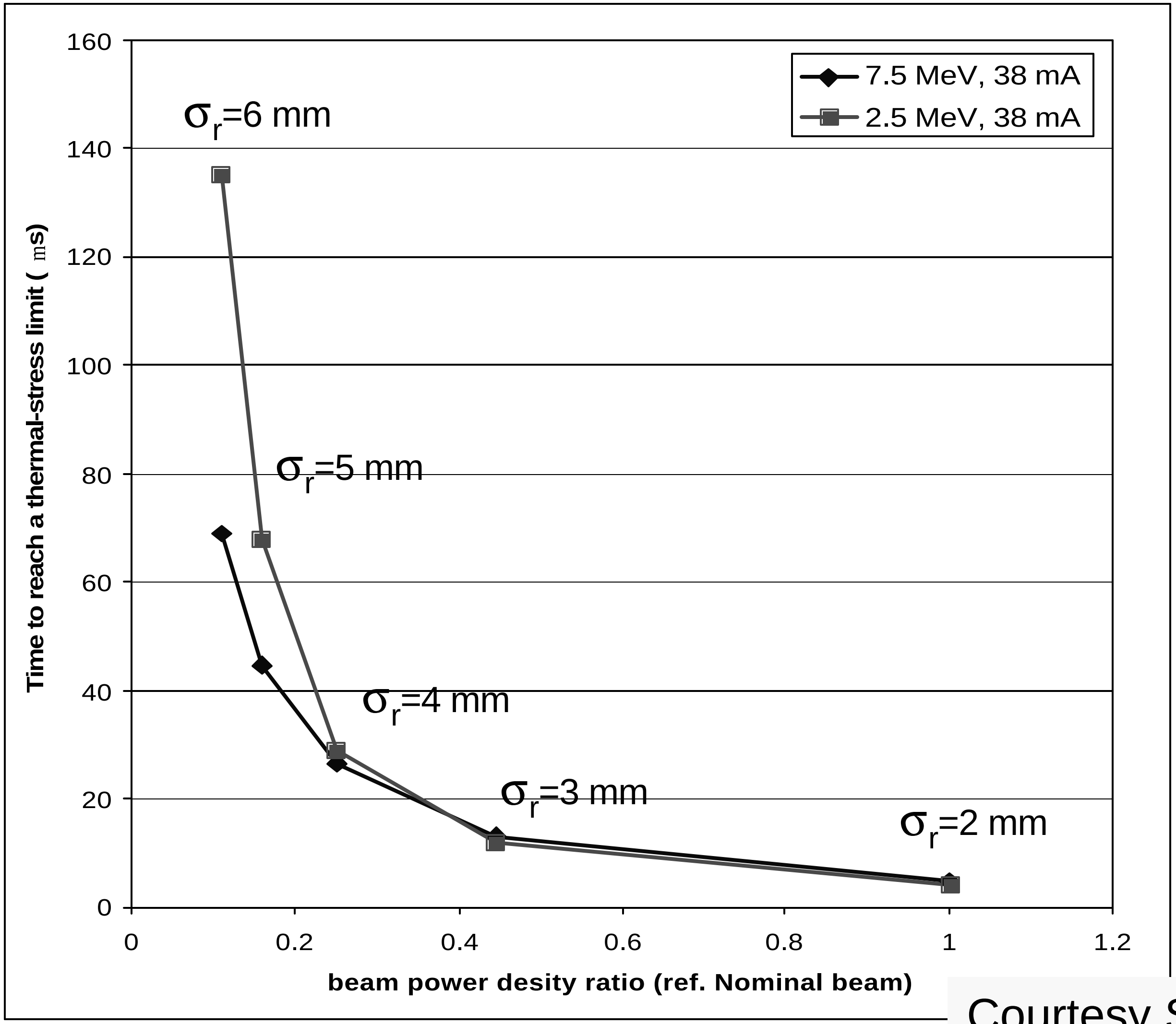


Courtesy S. Kim

Time to Reach Thermal Stress Limit in Copper for Normal Incidence of Circular Beams

2.5 MeV input
7.5 MeV output

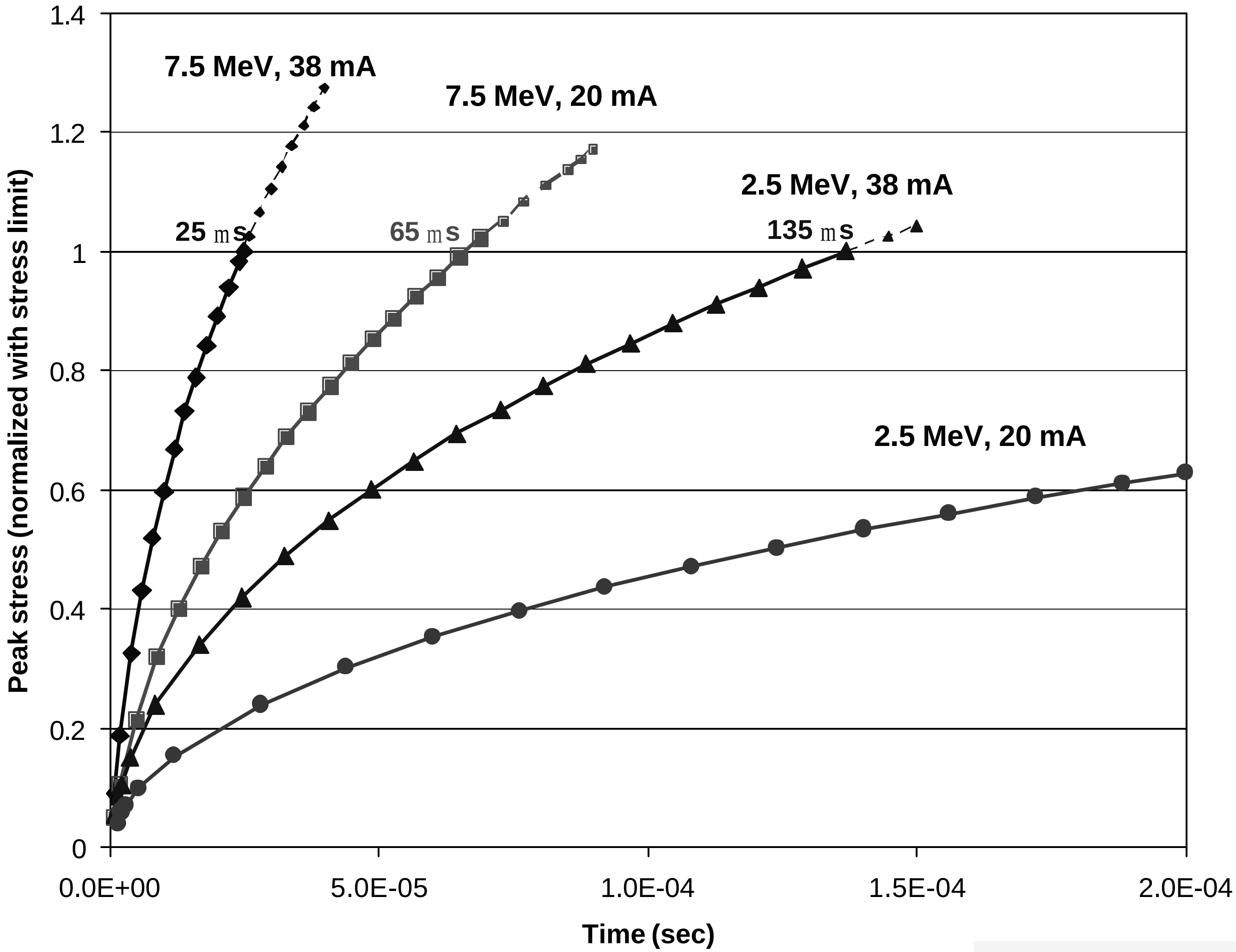
Ref. Nominal Beam
σ_r=2 mm, 90 degree



Courtesy S. Kim

Time to Reach Thermal Stress Limit for Grazing Incidence of 2 mm Circular Beam

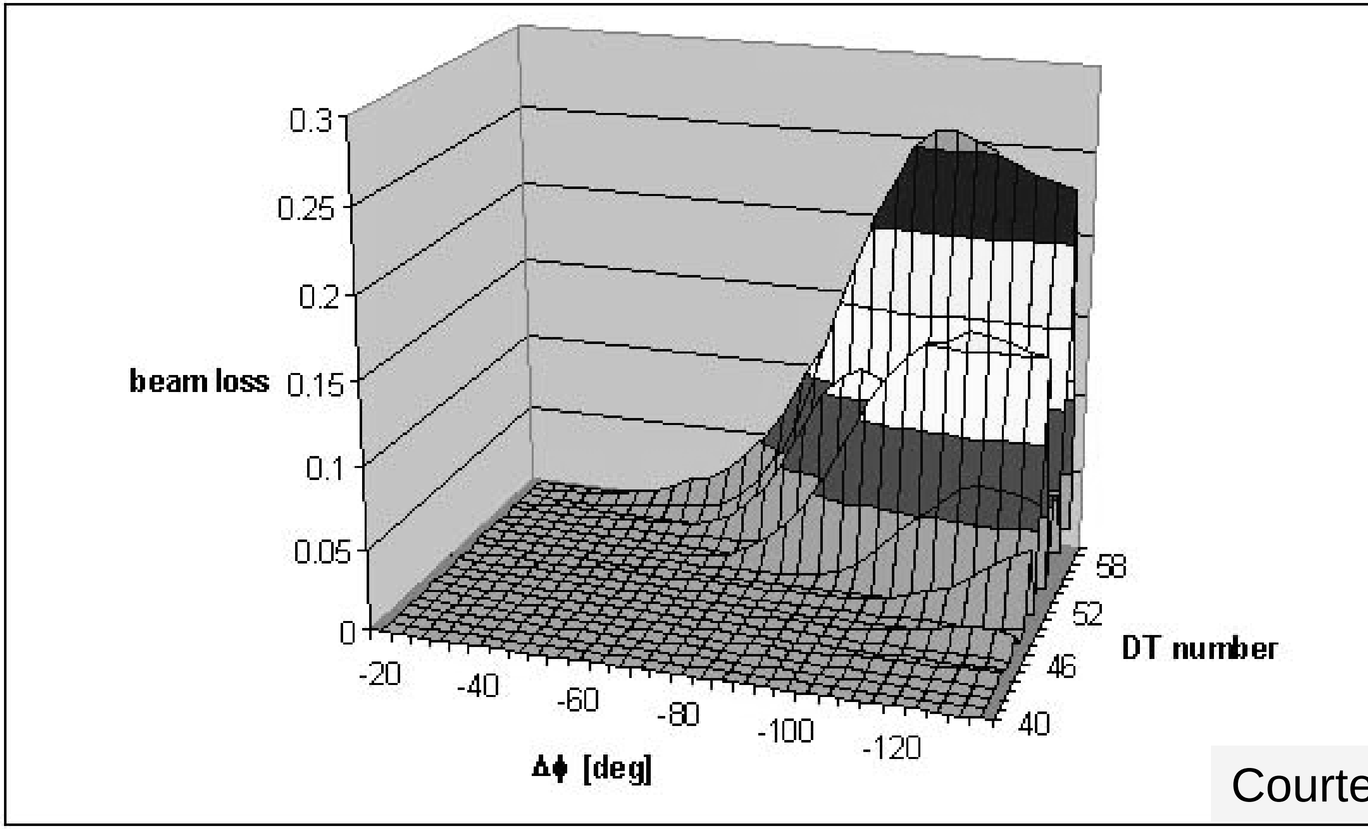
5 degree incident angle



Courtesy S. Kim

Expected Losses During DTL 1 Phase Scan

- We will lose some beam in Tank 1 during a phase scan
- At most 25% of beam is lost on a single drift tube
- We perform phase scans with 50 microsecond beam
- We found that the pulse length limit for losing 50% of beam on a single drift tube was 65 microseconds



Courtesy D. Jeon

Classification of DTL1 Faults and Losses

Result	Produce by Tuning?	Mechanism	Likelihood	MPS Requirement for 38 mA beam
Normal incidence impact of beam core on a drift tube*	No	Gross Trajectory Error (e.g. quad winding short)	Extremely Unlikely	5 μsec
Grazing incidence impact of beam core on inner bore of drift tube	No	Gross Trajectory Error	Unlikely	135 μs (2.5MeV) 25 μs (7.5MeV)
Loss of beam tails on inner bore of drift tubes	Yes	Trajectory error, optical matching errors	Expected	65 μs (50% of 38mA beam at 7.5 MeV)

*Only a portion of 1st drift tube is "visible" to normal incidence

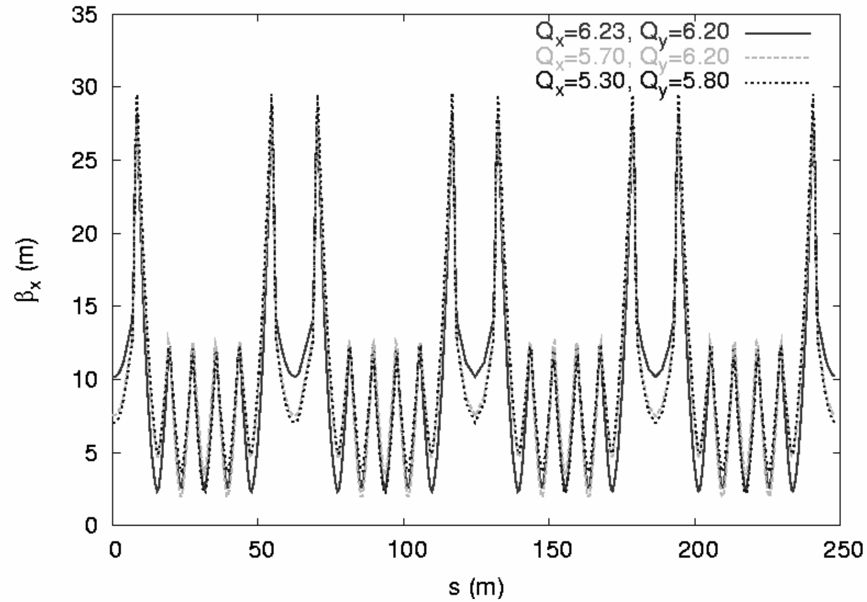
MPS provides two loss thresholds:

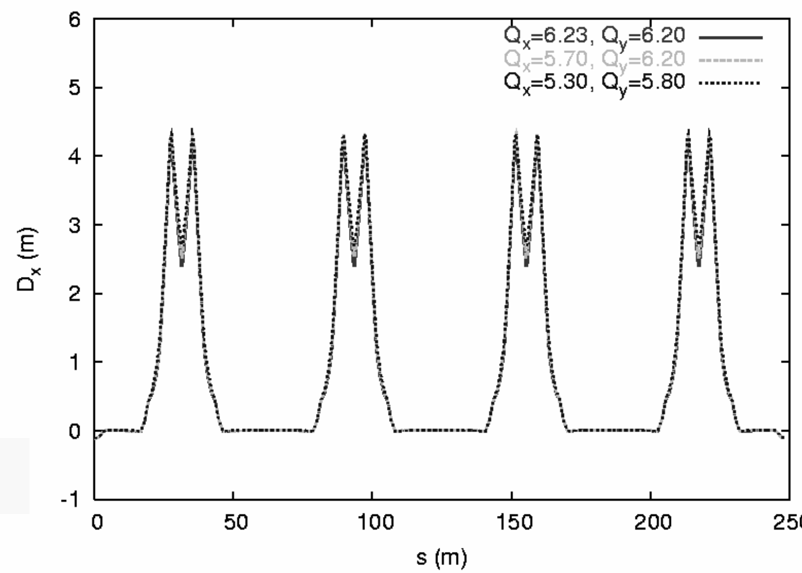
- 190 mA-μs (38mA loss in 5 μs)
- 570 mA-μs (30% of 38mA in 50 μs)

Ring Physics Progress: Lattice

Lots of work related to magnet production and installation!

- Evaluated magnet measurement results
- Preparing database tables including magnet meas data
- Maintaining/updating global coordinates
- 21Q40 Ring quads sorted/assigned
- 12Q45 HEBT quads sorted/assigned
- MAD lattice updated with design updates
- Lattice tuning (local tune control)





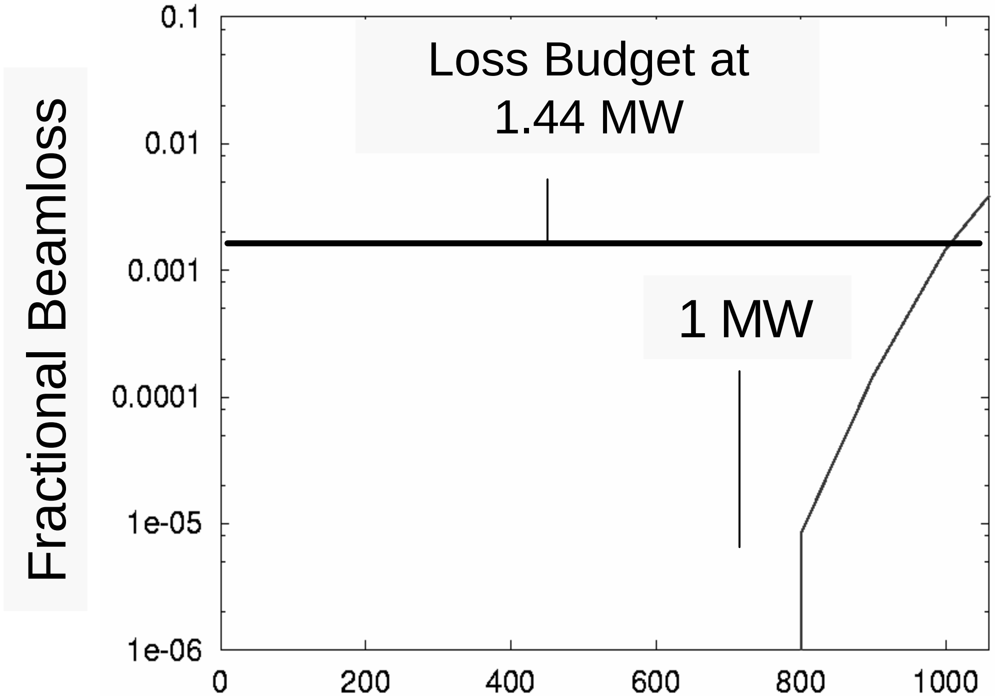
Courtesy S. Cousineau

Ring Beam Dynamics Progress

- Impedance Budget
  - No change!
  - Refined measurement of Ext Kicker provides cleaner data at lower frequencies (conclusions unchanged)
  - Collimator beampipes evaluated: OK
- Resonance correction studies are ongoing
  - Correction methods have been tested (J. Wei's talk)
  - Important for exploring other operating points
- Halo and Losses study
  - A present focus of activity to revisit some previously studied topics with improved capabilities
  - Test correction schemes: dipole and quadrupole errors and correction with loss evaluation
- Exploring some issues related to high-intensity
  - Exploration of self-consistent beam distributions in 3-D (Danilov et. al., PRST-AB)
  - We have proposed a Laser-stripping proof-of-principle experiment
- Impact from delay of Energy Spreader/Corrector Cavities

Impact on Ring Beam Dynamics and Losses for Energy Spreader, Corrector Cavity Delay

- As part of “End-Game Plan” the project would like to delay installation of ECC/ESC until after CD-4.
- One component of CD-4 criteria demands that the machine be capable of 1 MW operation
- Is the SNS capable of 1 MW operation without ECC/ESC?
- The issues comes down to energy jitter from the linac

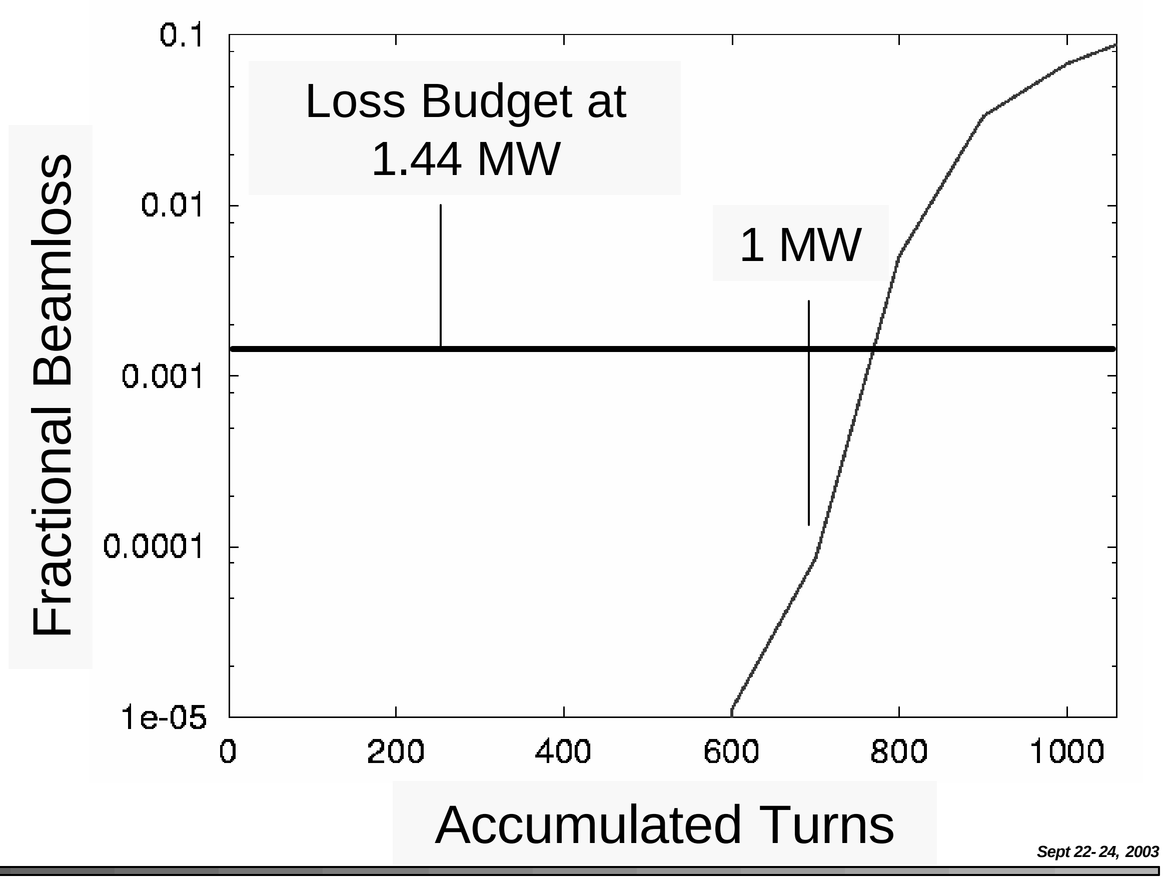


Best Case: Gaussian energy jitter from linac with ECC/ESC removed (courtesy J. Holmes)

Fractional Loss in Ring for No Energy Jitter (Worst Conceivable Case!!)

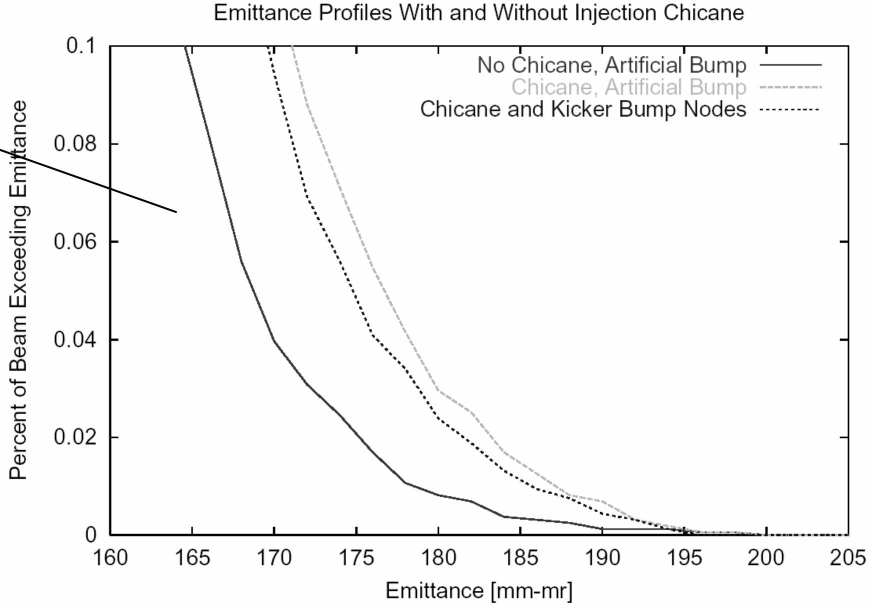
- Conclusions:
  - We can operate the ring up to 1 MW without ECC/ESC
  - The beam power limit is a function of the details of the linac energy jitter, which will not be known in advance
  - Transverse impedance is not an issue – beam is stable
  - Beyond 1 MW we need the additional controlled momentum spread provided by the ECC/ESC

Worst Case: no energy jitter from linac with ECC/ESC removed (courtesy J. Holmes)



Ring Simulation Progress
(J. Holmes' talk)

- Many topics currently under study!
- Added chicane and dynamic injection kickers explicitly
  - Breaks 4-fold symmetry, adds dispersion error
  - Next step: integration through real Chicane fields
- Error study: revisit "older" topics with full force of ORBIT simulation
  - Generate errors, correct errors, evaluate losses in "corrected" lattice: dipole, quad, coupling underway



- Evaluating correction schemes:
  - Simulating "single-turn" injection, tracking linac microbunches to evaluate 402.5 MHz signal
- Exploration of self-consistent uniform elliptical beams
- Y. Sato (student of S.Y. Lee) incorporating electron dynamics in fully self-consistent approach into ORBIT code. Results beginning to emerge

Electron Cloud Instability: Mitigation Plan and Threshold Estimation

Reduce Electron Production

- Baseline:
  - TiN coated vacuum system
  - Stripped electron collection
  - Beam-in-gap cleaning system
  - Good vacuum
  - Electron Detectors
  - Clearing electrodes in injection region
  - Solenoids in collimation region
  - Electron catcher viewing system

Enhance Damping:

- Baseline:
  - Momentum painting with Energy Spreader Cavity
  - High RF voltage 40 kV (h=1) + 20 kV (h=2) for large momentum acc.
  - Chromaticity control with 4 sextupole families
- Under Study:
  - Wideband (200 MHz) feedback system

Threshold Estimation (M. Blaskiewicz)

- Simulation predicts for 2nC/m e- line density threshold of 30 kV RF voltage, versus baseline 40 kV
- This can be considered a conservative estimate since i) similar estimates for PSR give threshold RF voltages a factor of 3-4 larger than observed, ii) doesn't take credit for some mitigative features (i.e. solenoids)

Ring Collective Instability Threshold Summary

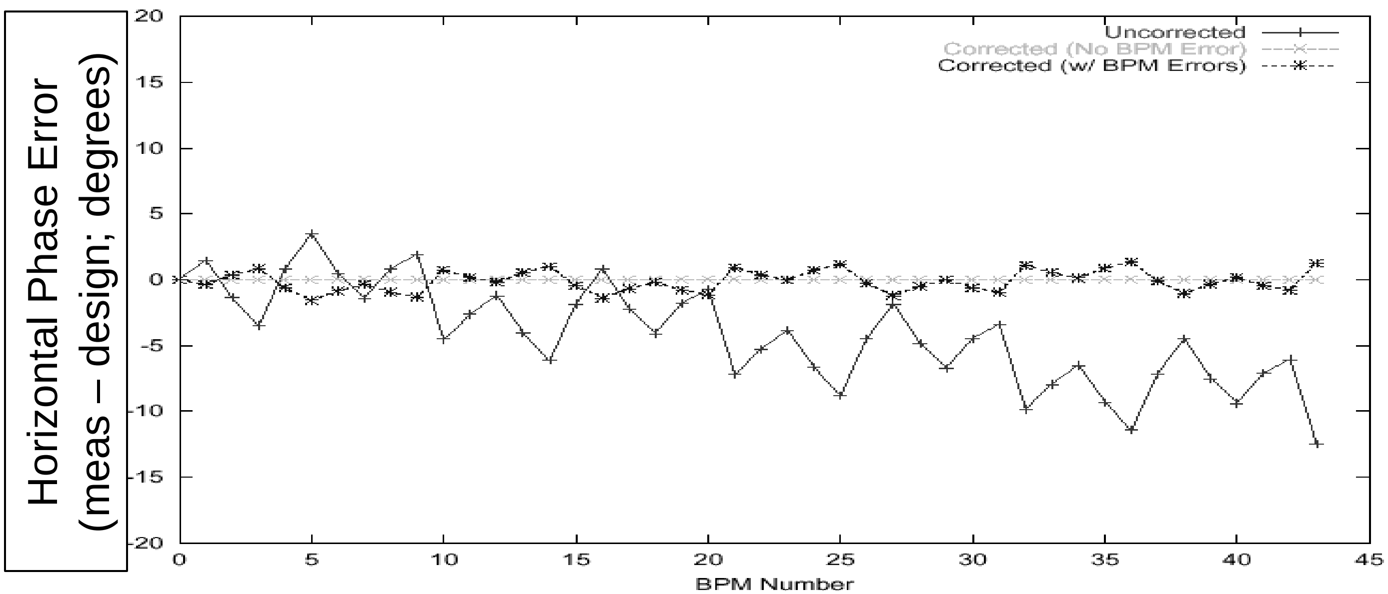
Simulations predict that we will not encounter collective instabilities in the ring up to the baseline intensity (1.44MW, 1.6×10^{14} protons) :

- Transverse Microwave Instability (EK impedance):
  - 3×10^{14} (ξ_{nat}), 2×10^{14} ($\xi=0$)
- Longitudinal Microwave Instability (EK + RF impedance):
  - 3×10^{14}
- Resistive Wall (Walls + EK impedance):
  - Stable at nominal tunes
  - For (6.23, 5.80) stable at ξ_{nat}, unstable at $\xi=0$
- Electron Cloud Instability
  - Stable at 2 nC/m e- line density: threshold is 30 kV RF vs. 40 kV h=1 available
  - Threshold of 5 nC/m e- line density at design intensity
  - Can be considered conservative estimate since not all mitigative features included, and code overestimates required RF in PSR
- Losses due to Space Charge itself set a limit of just above 2 MW *for baseline operating point* in simulations
- Although simulations show stable beam at design intensity:
  - We feel it is prudent to explore the requirements and capabilities of a wideband transverse feedback system
  - Modest power needed to damp resistive wall and double EK impedance (80W)

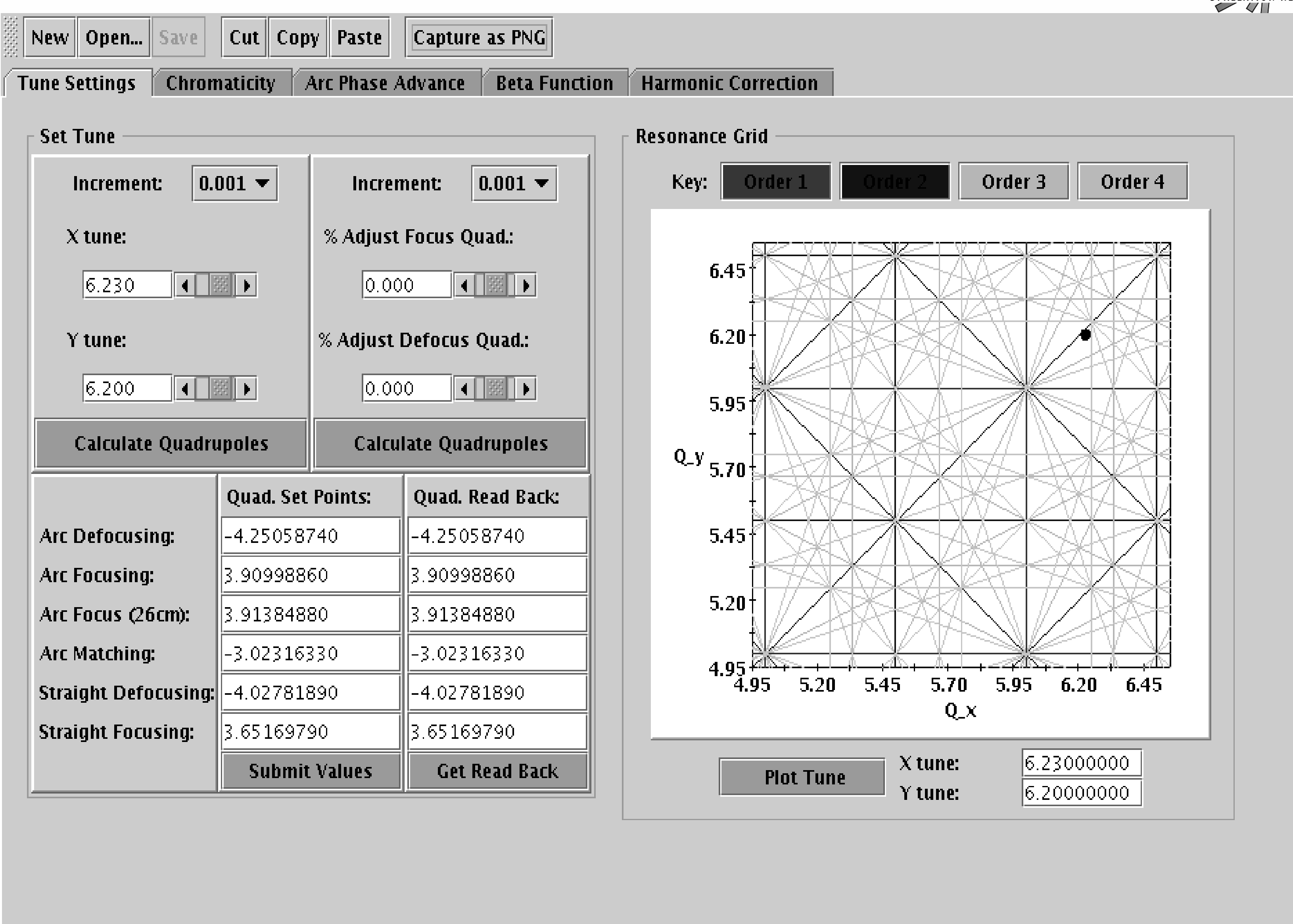
Ring Physics Progress: Commmissioning Preparations

- We are beginning to focus on commissioning preparations:
  - Evaluating commissioning algorithms (linear optics, closed orbit correction, matching etc.)
  - Specifying commissioning software needs
  - Preparing user interfaces and writing applications

Example: Betatron phase advance measurement from TBT data. Plot shows correction of random main quad string setpoint errors

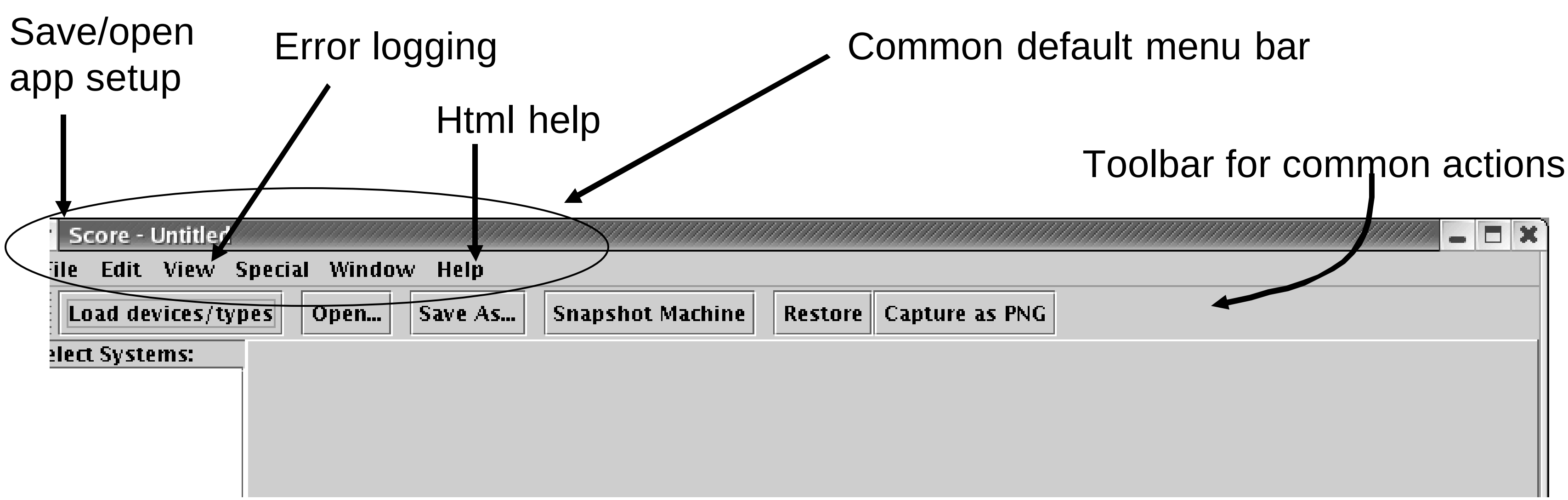


Ring Optics Control Application: “One-stop shopping” for Ring optics adjustments



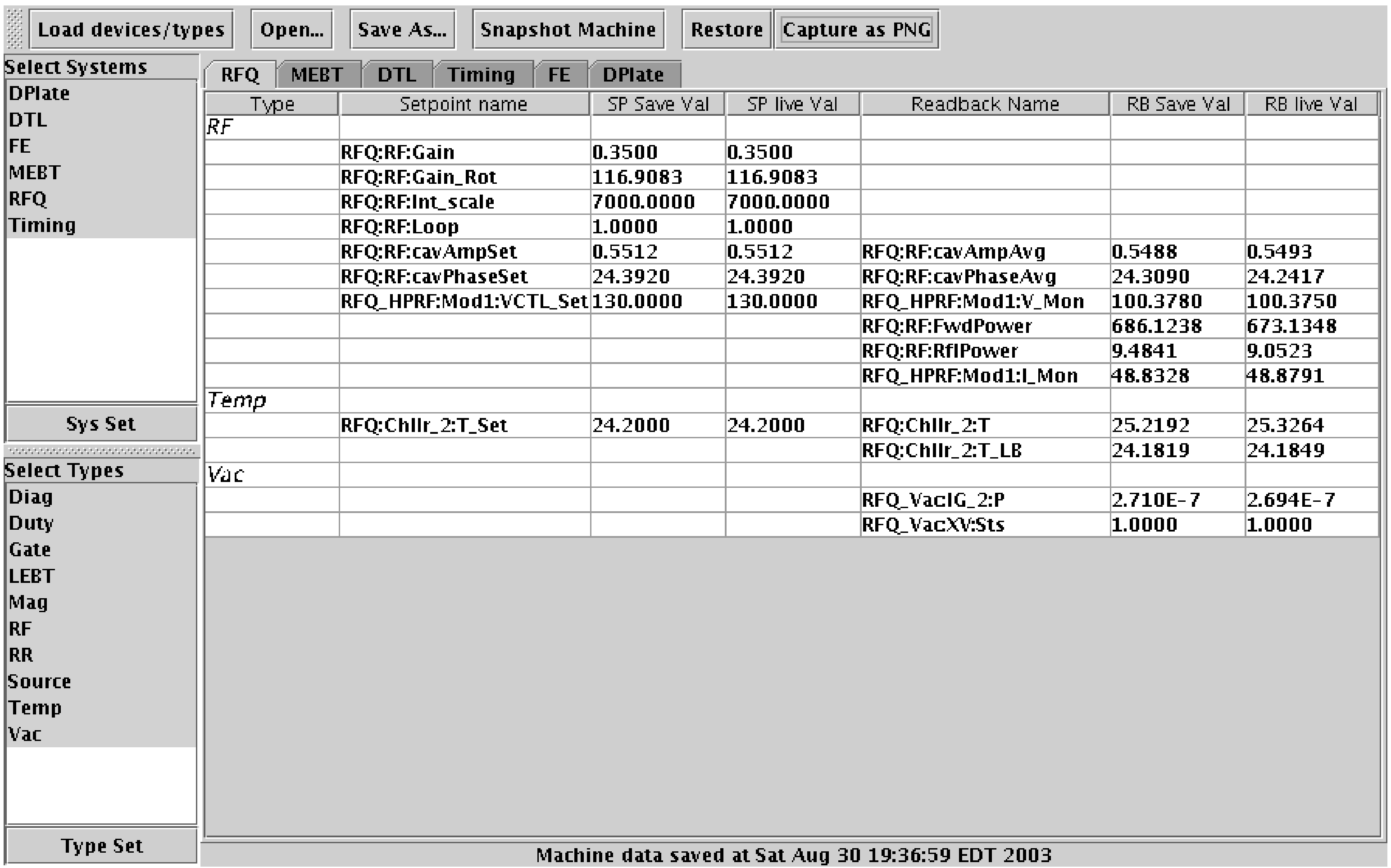
Application Programming Progress

- XAL infrastructure is in good shape
- Focus of the group is on Application Programming needs for commissioning
- An Application Framework has been developed to be used as a common starting point for all applications:
  - Provides a common look and feel
  - Quick jump-start for aps development
  - Uses familiar “windows” look and feel paradigm



Save-Compare-Restore (Score) Application

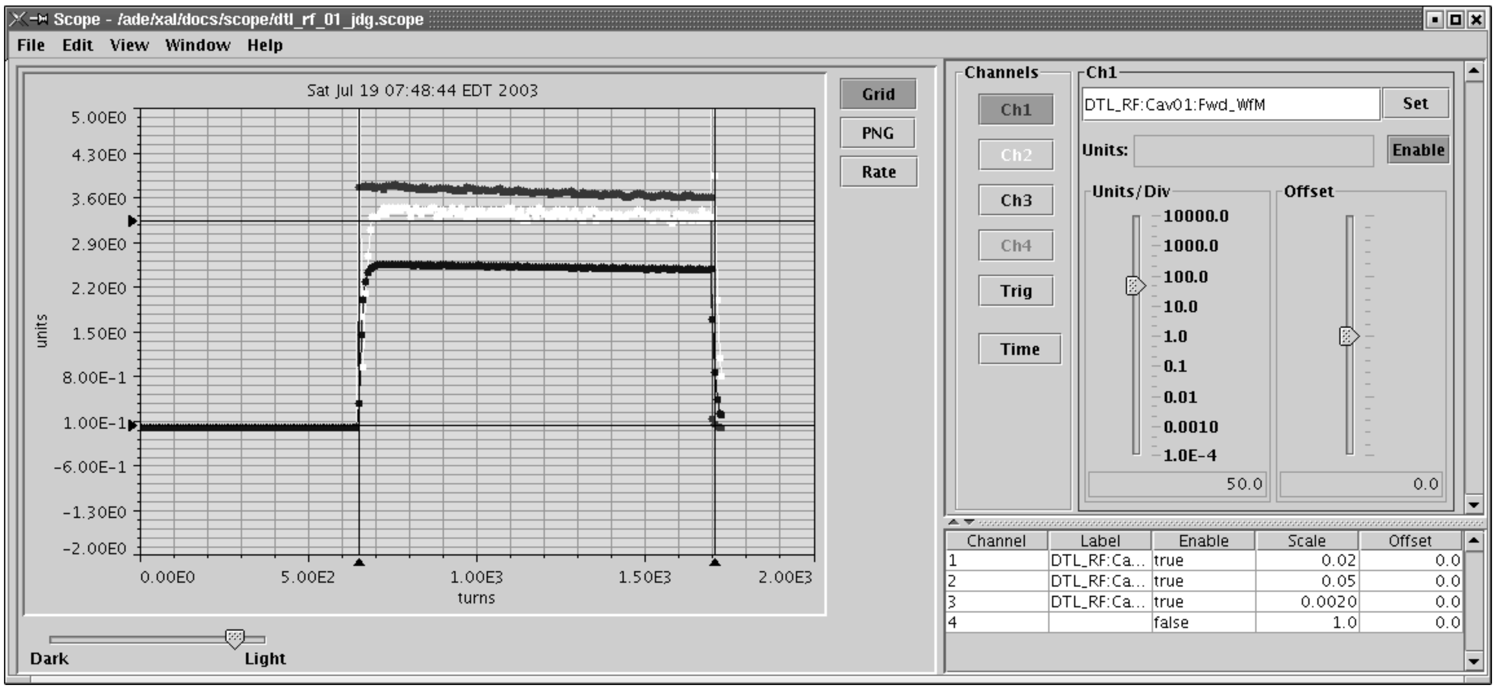
- Provides a means to capture setpoint and readback values, compare live values to a saved set, and to restore values to a saved set
- Can sort by system and device type



Type	Setpoint name	SP Save Val	SP live Val	Readback Name	RB Save Val	RB live Val
RF						
	RFQ:RF:Gain	0.3500	0.3500			
	RFQ:RF:Gain_Rot	116.9083	116.9083			
	RFQ:RF:Int_scale	7000.0000	7000.0000			
	RFQ:RF:Loop	1.0000	1.0000			
	RFQ:RF:cavAmpSet	0.5512	0.5512	RFQ:RF:cavAmpAvg	0.5488	0.5493
	RFQ:RF:cavPhaseSet	24.3920	24.3920	RFQ:RF:cavPhaseAvg	24.3090	24.2417
	RFQ_HPRF:Mod1:VCTL_Set	130.0000	130.0000	RFQ_HPRF:Mod1:V_Mon	100.3780	100.3750
				RFQ:RF:FwdPower	686.1238	673.1348
				RFQ:RF:RflPower	9.4841	9.0523
				RFQ_HPRF:Mod1:I_Mon	48.8328	48.8791
Temp						
	RFQ:Chllr_2:T_Set	24.2000	24.2000	RFQ:Chllr_2:T	25.2192	25.3264
				RFQ:Chllr_2:T_LB	24.1819	24.1849
Vac						
				RFQ_VacIG_2:P	2.710E-7	2.694E-7
				RFQ_VacXV:Sts	1.0000	1.0000

General Purpose Tools: Scope Application

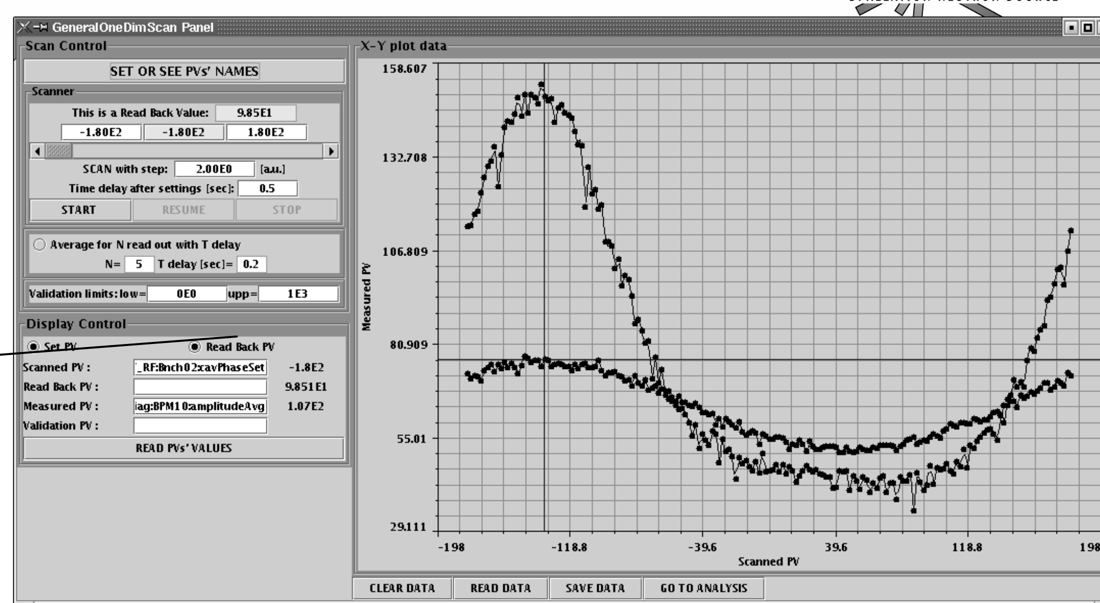
- A Digital Oscilloscope – with a similar user interface as analog scopes
- Useful for comparing/manipulating waveforms from RF, diagnostics, etc.
- Uses the time correlator, has built-in math capability, + many other features



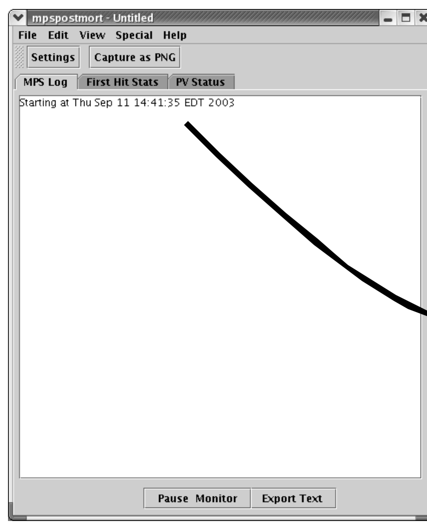
DTL1 RF waveforms

General Purpose Tools: 1-D Scan and MPS Post-Mortem

- Generic "Scanning" application. Scans one quantity while monitoring another
- BPM amplitude vs. MEBT Rebuncher phase



- Captures MPS events, and sorts the signals in order of occurrence – i.e. determines the root cause of a trip
- Logs MPS events
- Provides statistics




Thu, Sep 11, 2003 14:34

JOHN GALAMBOS
Operations

Title: mps event summary JOHN GALAMBOS

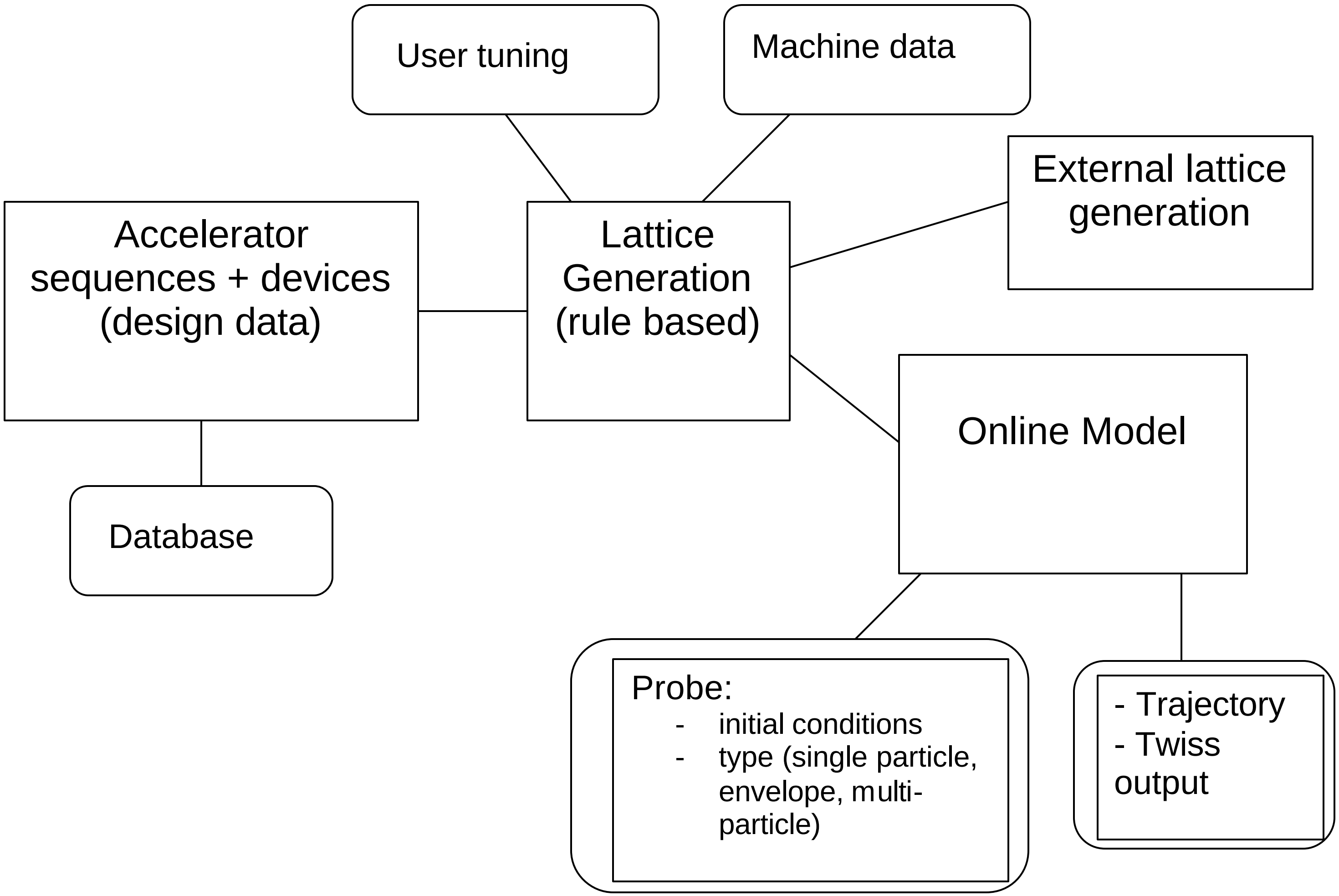
September 04, 2003 07:02 reply bookmark thread

Equipment Category(s): Controls
Logbook(s): Operations

The MPS events this shift are below. A more detailed log of all MPS events since 8/31/03 at 17:30 is attached (with statisics summary at the end).

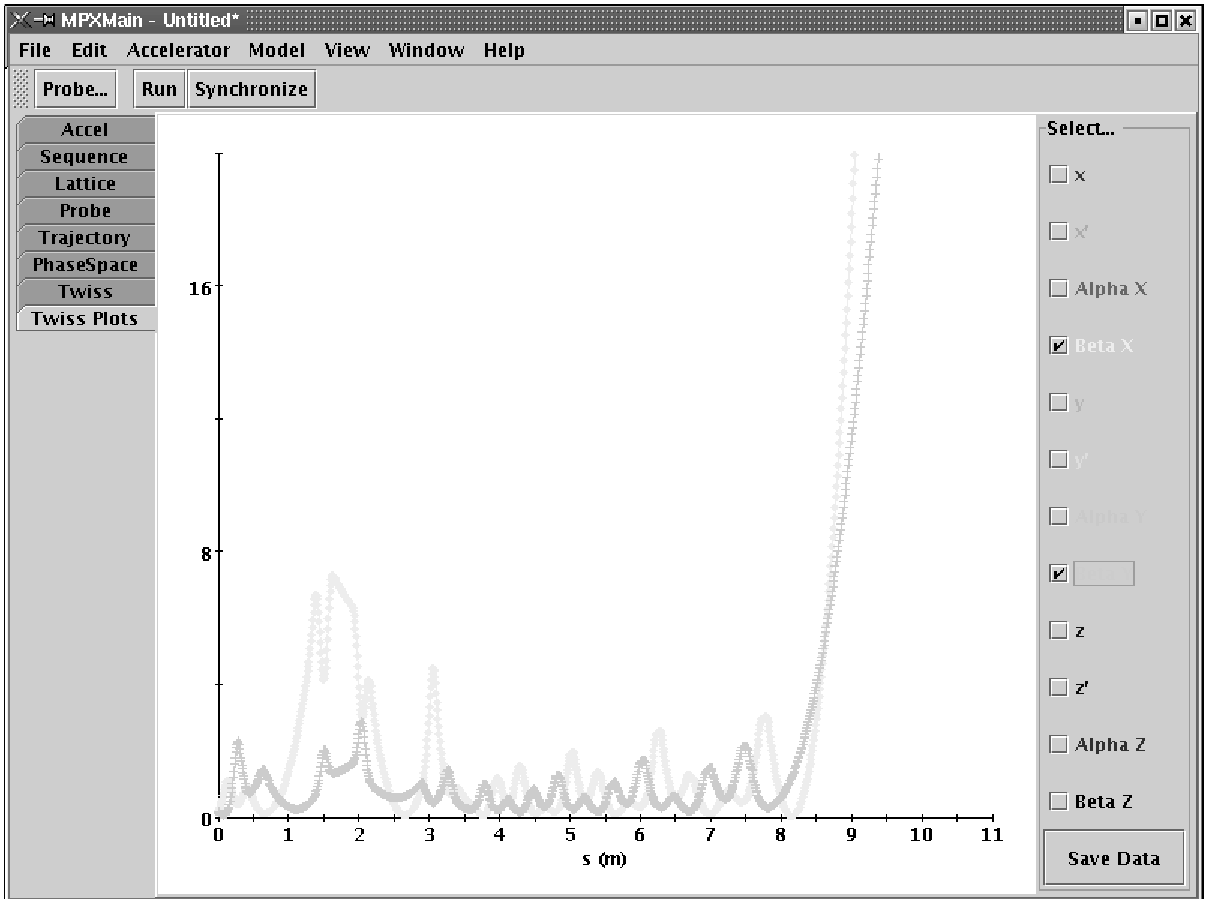
```
Starting at Thu Sep 04 00:21:55 EDT 2003:
RFQ_LLRF:HPM1:FPAR_DPlate:chan_status, counts = 56
MEBT_RF:Bnch1:FPAR_DPlate:chan_status, counts = 26
FE_MPS:Dplate:FPAR_Src:chan_status, counts = 4
MEBT_RF:Bnch4:FPAR_DPlate:chan_status, counts = 2
RFQ_Vac:VSIL:FPL_DPlate:chan_status, counts = 2
DTL_Diag:BLM224:FPAR_DPlate:chan_status, counts = 1
DTL_Diag:VFM_OK:FPL_DPlate:chan_status, counts = 1
DTL_Diag:BLM160:FPAR_DPlate:chan_status, counts = 1
MEBT_Vac:SGV:FPL_DPlate:chan_status, counts = 1
DTL_LLRF:HPM1:FPAR_DPlate:chan_status, counts = 1
DTL_Vac:VSIL1:FPL_DPlate:chan_status, counts = 1
```

Online Model Architecture



Online Model

- An online model is now available within the XAL framework
- Online model can use as input 1) “live” values, 2) design values and 3) user-specified “tuned” values
- Displays/dumps Twiss and trajectory output

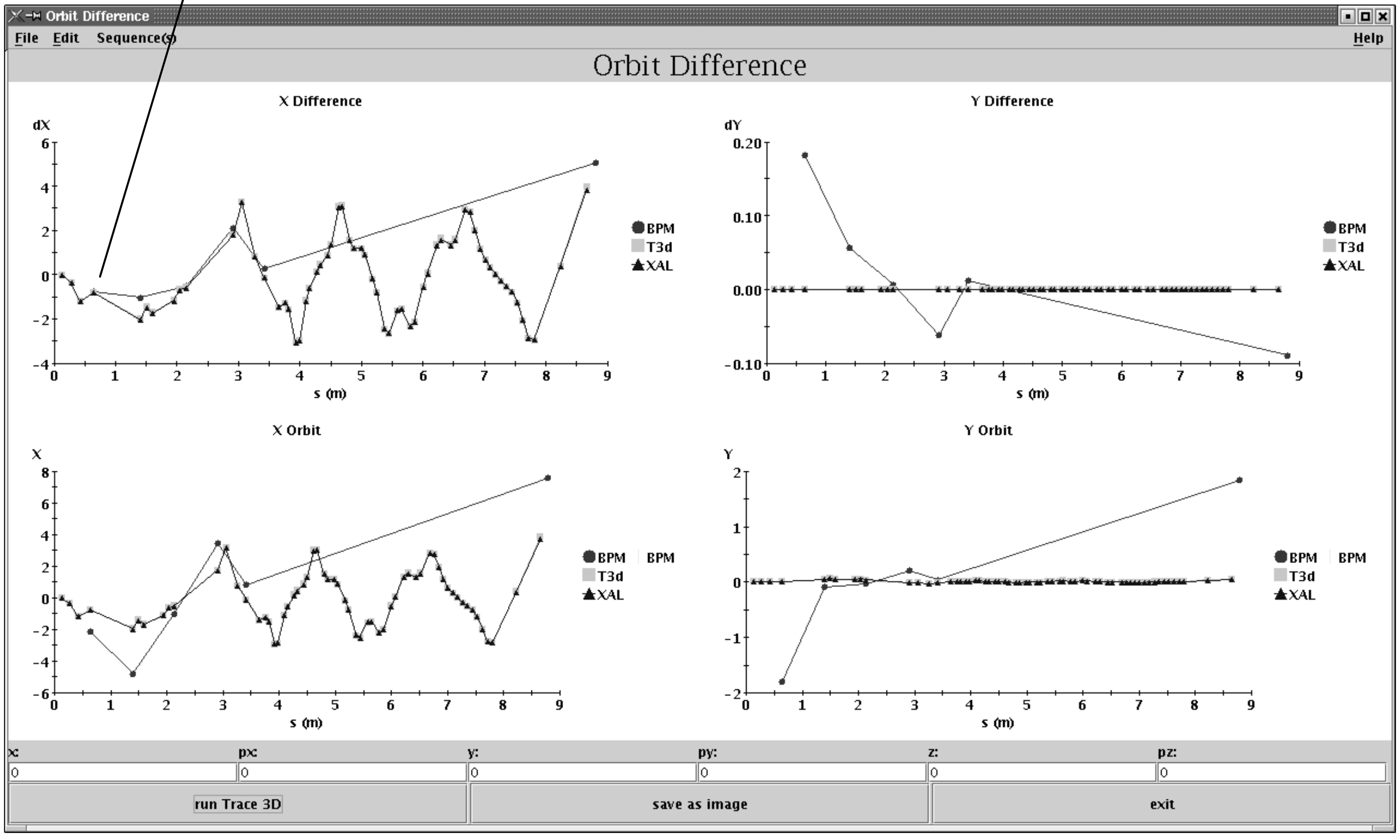


Vertical and horizontal beta functions through the MEBT, DTL + D-plate for live values

Online Model Example

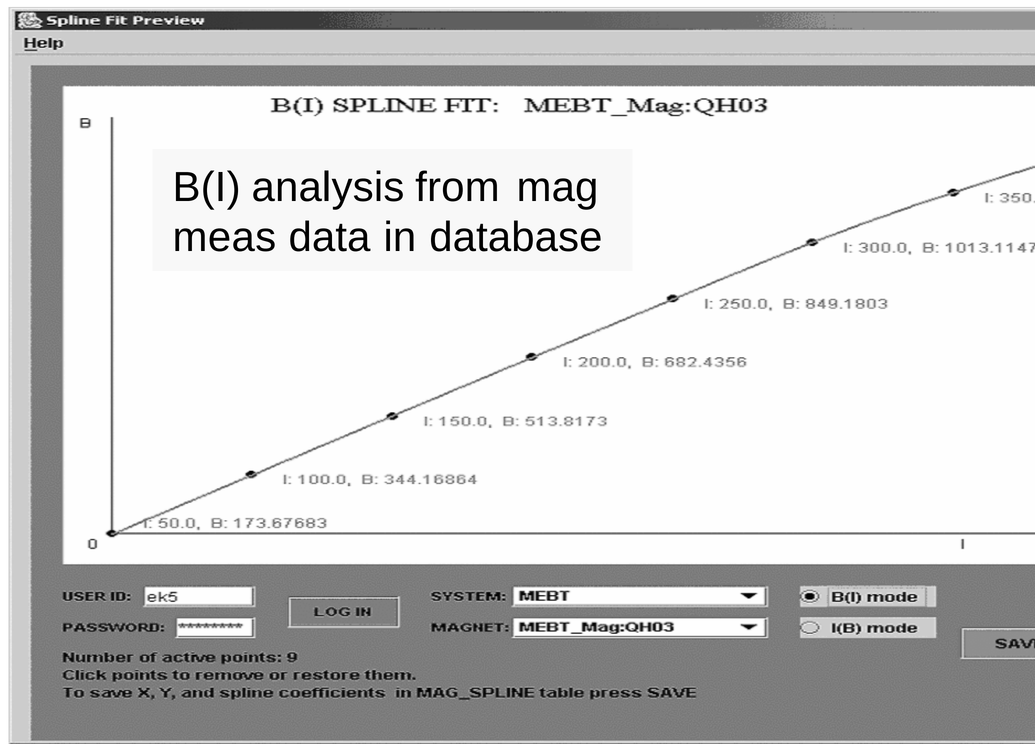
- Online model is also used in the Orbit Difference Application
- Example: model the response of MEBT/D-plate trajectory to MEBT correctors

Power 1st MEBT horizontal corrector



Accelerator Physics Integration: Quality Control, Global Database

- **Parameter List Updated (Rev. 9)**
- **Global Coordinate Maintenance**
  - *Finalized magnet parameters, Target location adjustment*
- **Quality Control:**
  - *Keep on top of magnet measurement results, bead-pull results, etc.*
  - *Work with Target Systems on components that interface with accelerator*
  - *Perform fault studies: MEBT chopper, DTL1 Damage thresholds and MPS*
  - *Interface with technical groups on day-to-day issues: Survey and alignment, electrical mechanical, RF….*
  - *Cryomodule acceptance*
- **Global Database:**
  - *~1500 Lattice elements exist in database (with information necessary for lattice input file)*
  - *Lattice input files written from Global Database info*
  - *Magnet measurement database population started*



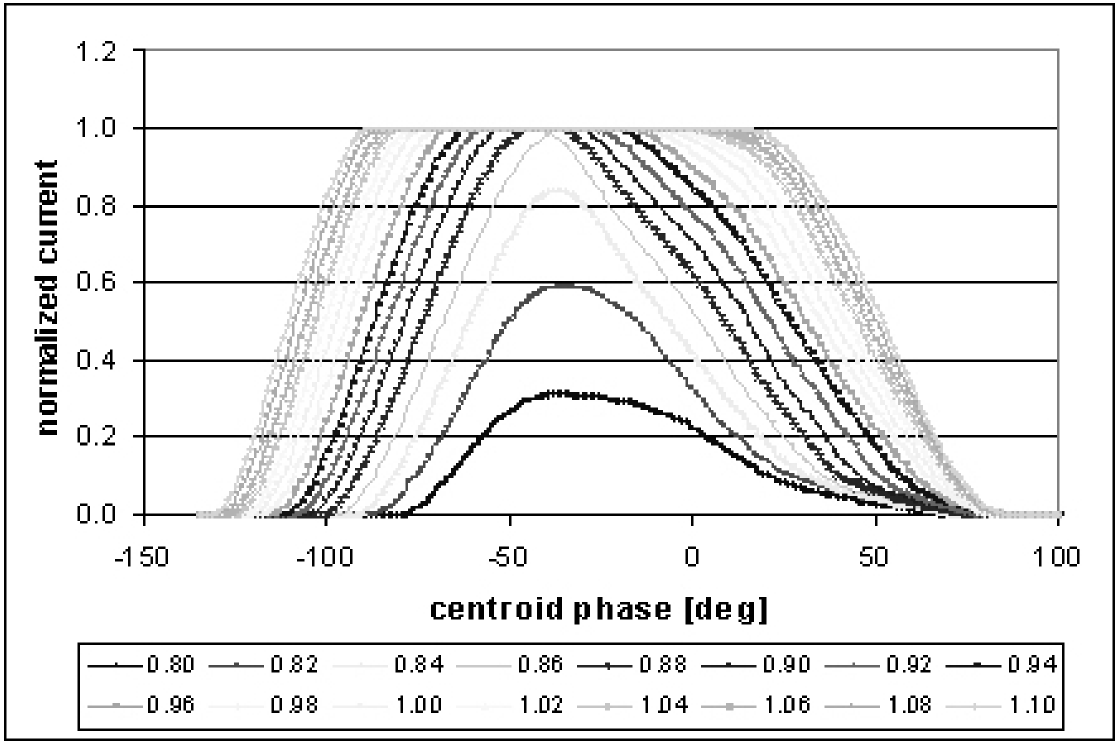
Summary

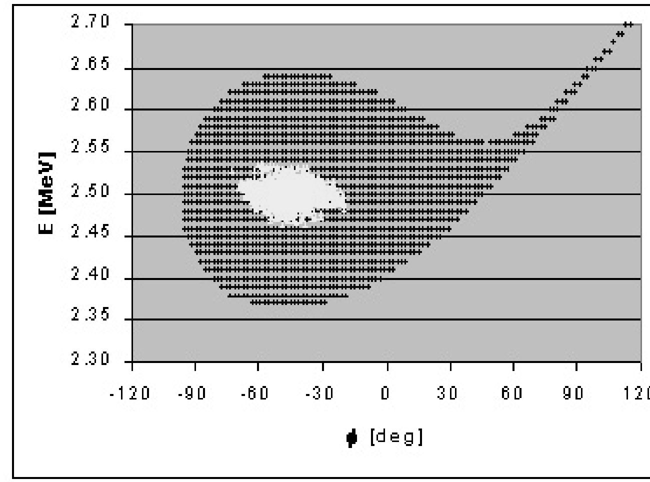
- **DTL1 commissioning run is off to a great start!**
  - Demonstrated transmission consistent with 100% (5% measurement uncertainty)
  - DTL1 RMS normalized output emittance is < 0.2 π mm mrad (commissioning performance goal is 0.3 π mm mrad)
  - DTL1 acceptance agrees with expectations
  - Effort that went into commissioning preparations is paying off
  - Commissioning organization is working very well
  - Good coordination between AP, Ops, Diagnostics, Controls + technical groups
- Physics effort is focused on commissioning work
  - Post-commissioning analysis of FE data has resolved two mysteries: MEBT trajectory and output emittance shape
  - Applications programming focusing on commissioning needs
  - Ring commissioning preparations are underway
- Integration & QA efforts continue to be a priority
  - Database entry, global coordinates, magnet measurements, etc.

Beam Evolution Parameters

	Front End			Linac				Ring			
	IS/LEBT	RFQ	MEBT	DTL	CCL	SCL (1)	SCL (2)	HEBT	Ring	RTBT	Unit
Output Energy	0.065	2.5	2.5	86.8	185.6	391.4	1000	1000	1000	1000	MeV
Relativistic factor b	0.0118	0.0728	0.0728	0.4026	0.5503	0.7084	0.875	0.875	0.875	0.875	
Relativistic factor g	1.00007	1.0027	1.0027	1.0924	1.1977	1.4167	2.066	2.066	2.066	2.066	
Peak current	47	38	38	38	38	38	38	38	$9x10^4$	$9x10^4$	mA
Minimum horizontal acceptance			250	38	19	57	50	26	480	480	πmm mr
Output H emittance (unnorm., rms)	17	2.9	3.7	0.75	0.59	0.41	0.23	0.26	24	24	πmm mr
Minimum vertical acceptance			51	42	18	55	39	26	480	400	πmm mr
Output V emittance (unnorm., rms)	17	2.9	3.7	0.75	0.59	0.41	0.23	0.26	24	24	πmm mr
Minimum longitudinal acceptance			4.7E-05	2.4E-05	7.4E-05	7.2E-05	1.8E-04		19/π		πeVs
Output longitudinal rms emittance		7.6E-07	1.0E-06	1.2E-06	1.4E-06	1.7E-06	2.3E-06		2/π		πeVs
Controlled beam loss; expected	0.05[a]	N/A	0.2[b]	N/A	N/A	N/A	N/A	5[c]	62[d]	58 [e]	kW
uncontrolled beam loss; expected	70	100[f]	2	1	1	0.2	0.2	<1	1	<1	W/m
Output H emittance (norm., rms)	0.2	0.21	0.27	0.33	0.39	0.41	0.41	0.46	44	44	πmm mr
Output V emittance (norm., rms)	0.2	0.21	0.27	0.33	0.39	0.41	0.41	0.46	44	44	πmm mr

Simulated DTL Tank 1 Acceptance Scan

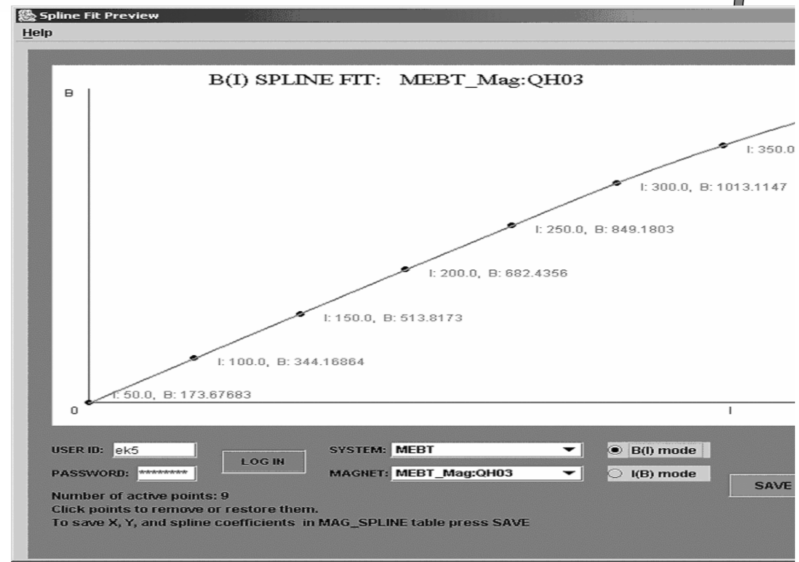




Normalized beam current from the FC

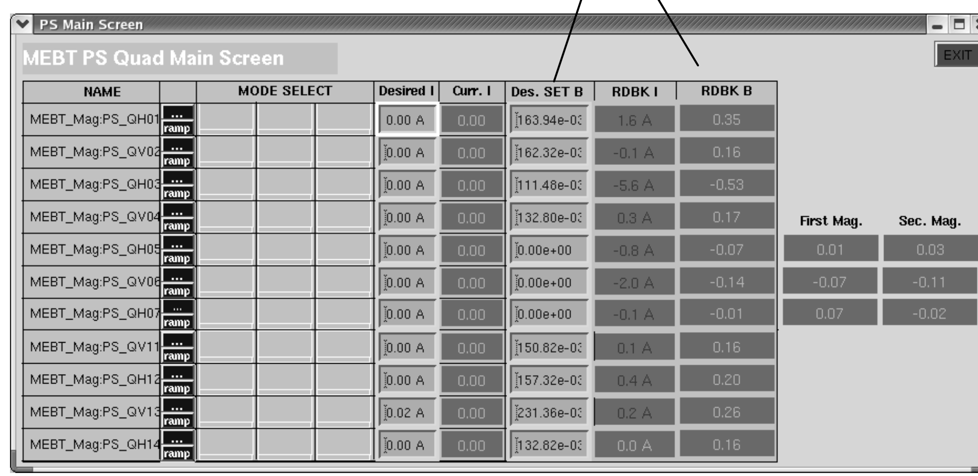
- By comparison with the simulation, rf phase and amplitude of the tank are determined

Magnet Current to Field Tranformation



- Java program reads measurement information from database, displays fit
- Pull-down pick list for magnet selection
- Does averages over magnets in a string

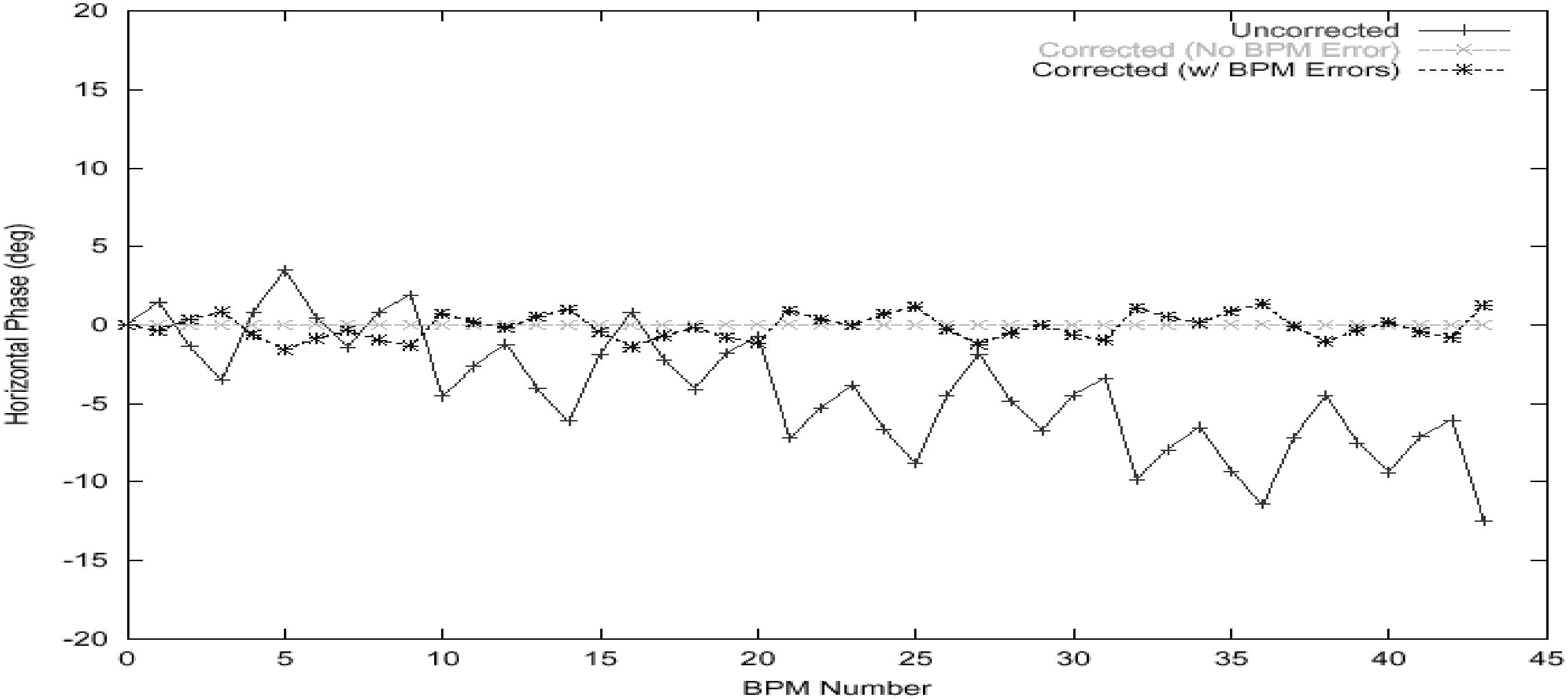
Field PVs



- Magnet settings and readbacks are available in “Field” units as well as current
- Useful for online model purposes

Linear Optics Measurement and Correction

- Measurement of betatron phase advance from TBT data
- Example: setpoint errors in six main quad supplies



- Method under study with loss evaluation in ORBIT (Holmes' talk)

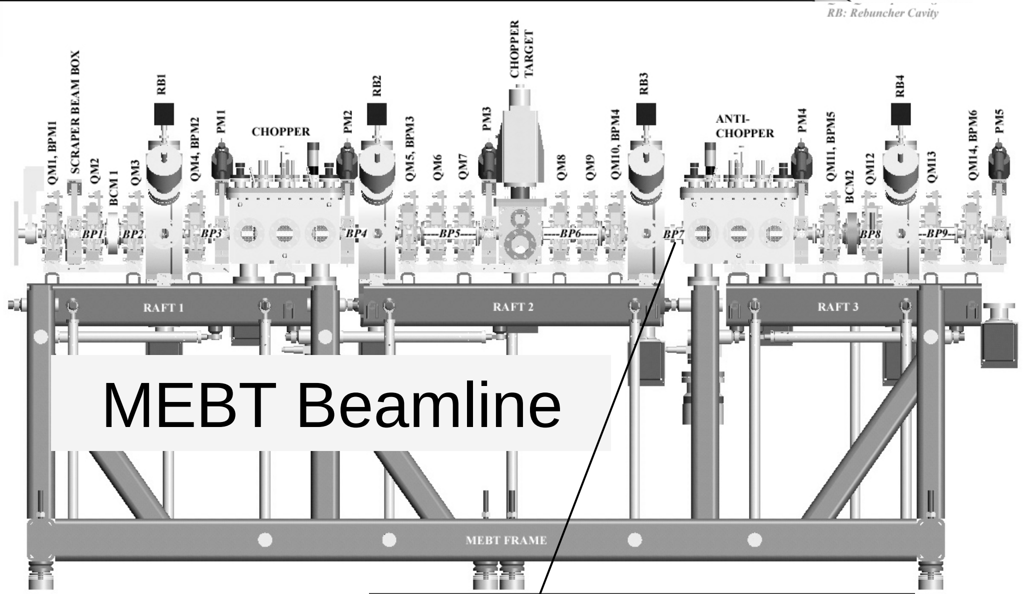
Outline

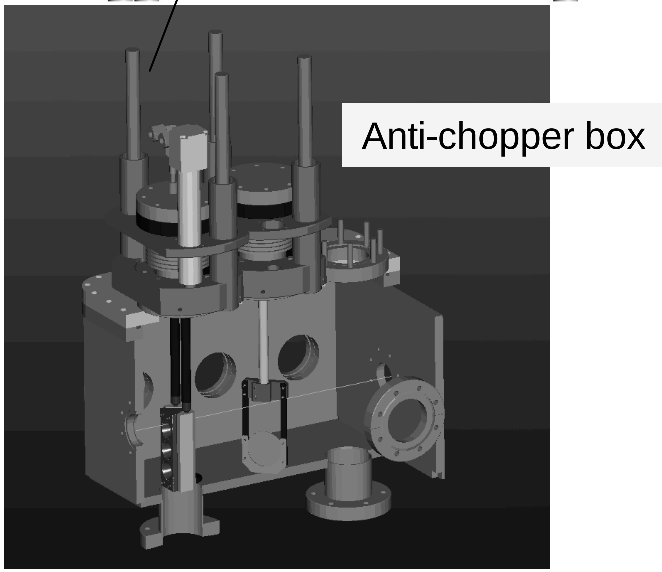
- AP Group & organization (2)
- Baseline parameters (1)
- Review recommendations
  - ASAC (1)
  - DOE (1)
- Front-End Physics Highlights
  - Key commissioning results and further work (2)
- DTL1 Commissioning
  - Key commissioning results (2)
  - Commissioning Preparations (2)
  - DTL fault studies and MPS requirements (2)
- Other Linac physics results
  - Commissioning work??
- Ring Physics Highlights
  - ECC/ESC delay (2)
  - ORBIT applications (2)
  - Tune application (1)
  - Quality Control (1)
  - Commissioning preparations
    - Applications programming
    - Linear optics correction
- Upgrade issues ??
  - Laser-stripping
  - Upgrade ??
- Applications programming
  - Online model (1)
  - Rebuncher phase scan (1)
  - Save/restore (1)
- Database (2)

- Sarah – Tune control
- John – aps programming
  - Online model
  - Database??? Mag measurement
- Sasha/Andre – FE physics results

Front End Physics Progress Since the Last Review

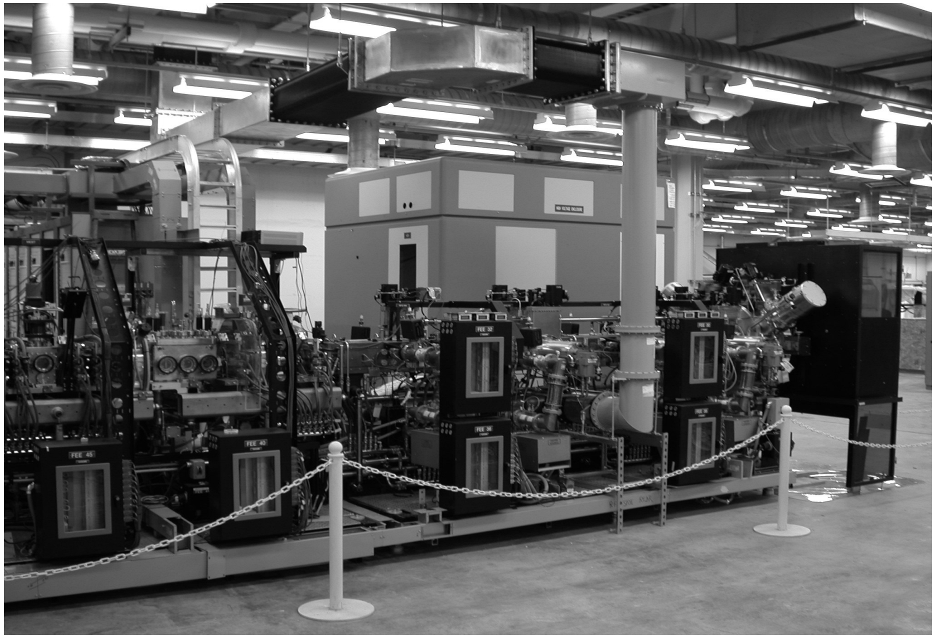
- Front-end commissioning results under study: (S. Aleksandrov)
  - MEBT trajectory errors
  - Sensitivity of emittance to trajectory
  - Further comparison of beam distributions with simulation
- Proposal for diagnostics in Front-End antichopper box: (S. Assadi)
  - H,V Emittance slits (baseline device)
  - Current and emittance-limiting aperture
  - Fast-faraday cup for longitudinal measurements
  - View-screen
- MEBT chopper target fault scenarios evaluated
  - #1: LEBT chopper fails, MEBT stuck ON: 50 μsec
  - #2: LEBT chopper fails, MEBT runs normally: 150 μsec





Front-End Commissioning Activities

ORNL Accelerator Physics Group played an important role in front-end commissioning:



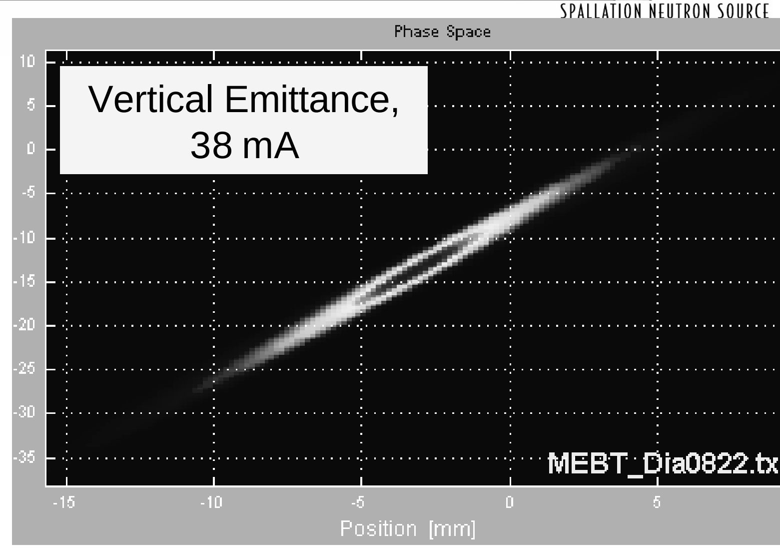
- Large Commissioning Team was assembled:
  - 130 commissioning shifts covered by 19 ASD staff trained as operators
  - 10 operators from AP group staff (of 15)
  - Additional software and analysis support from rest of AP group
- Operator Training:
  - Safety, Front-end subsystem operation, procedures and guidelines in the SNS Operations Procedures Manual, …
- S. Aleksandrov, the Front-End Area Manager
  - Authored “Front-End Commissioning Plan”
  - Led beam commissioning effort
- This approach of involving bulk of AP group in commissioning was very successful and will be followed for remaining commissioning runs

Front-End Commissioning Physics Results
(Details in A. Aleksandrov's talk)

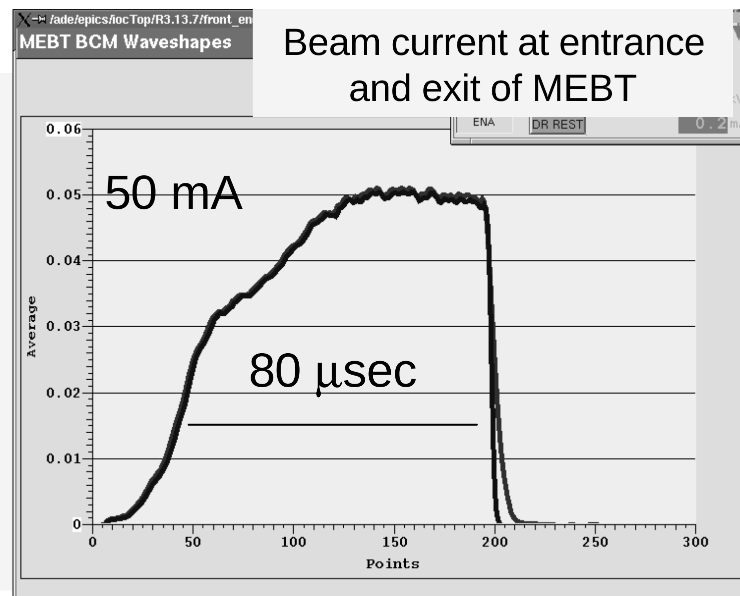
SPALLATION NEUTRON SOURCE

Very Successful Front-End Commissioning Run:

- Achieved peak current and emittance goals
- Exercised lots of software (and of course hardware)
- Successful tests of laser-wire and fast-faraday cup
- Gained invaluable experience by running the machine



Parameter	Baseline	Achieved	
Peak Output Current (mA)	38	51	✓
H, V Emittance (rms, norm, π mm-mrad)	0.27	0.25@30 mA 0.3@ 38 mA	✓
Duty Factor (%)	6	0.5% (6% at LBNL)	
Beam-in-gap	10^{-4}	< 1% (LEBT)	

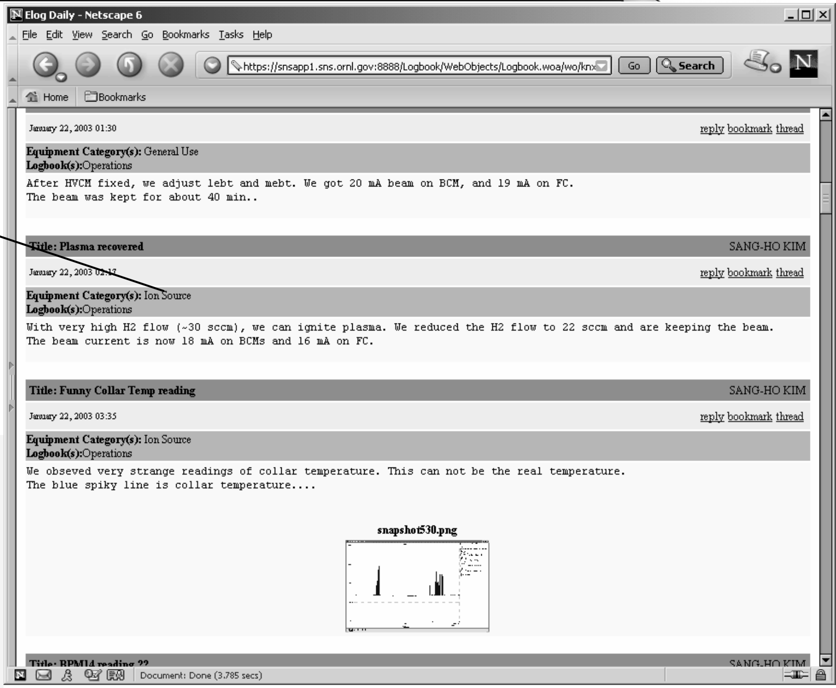


Front-End Commissioning Software Highlights

Web-based Electronic Log Book was used extensively during commissioning (T. Pelaia, J. Patton, M. Giannella)

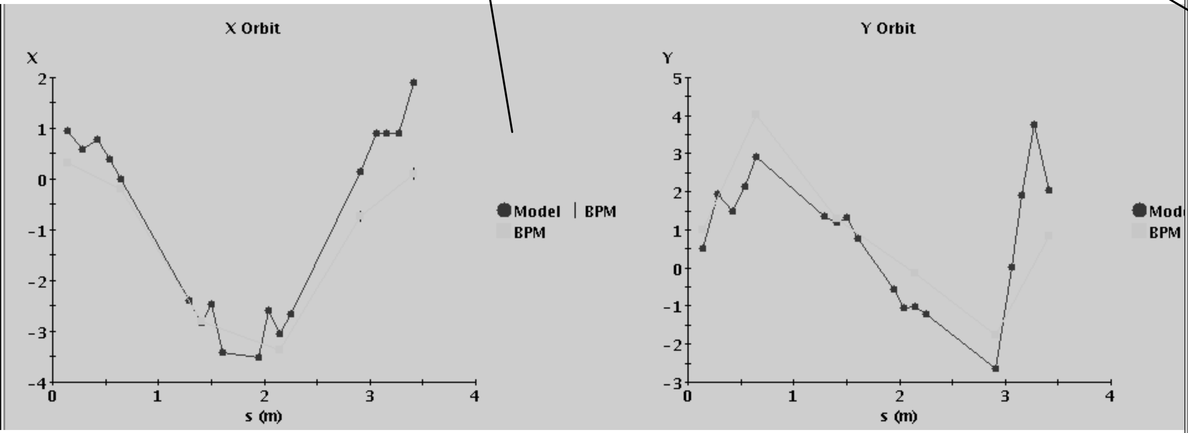
– searchable, insert figures, attach documents, equip categories

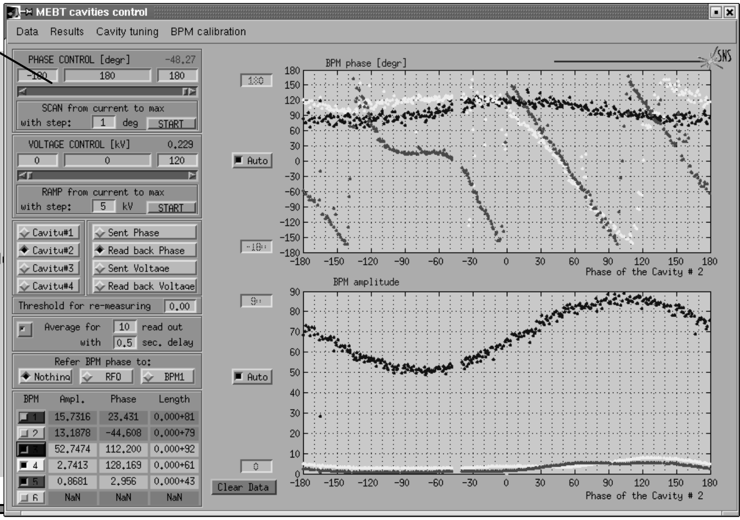
– Available to partner labs



Trajectory application used to verify MEBT optics, study beam at the MEBT entrance (P. Chu)

Rebuncher phase and amplitude setpoint (A. Aleksandrov)





DTL Commissioning Preparations

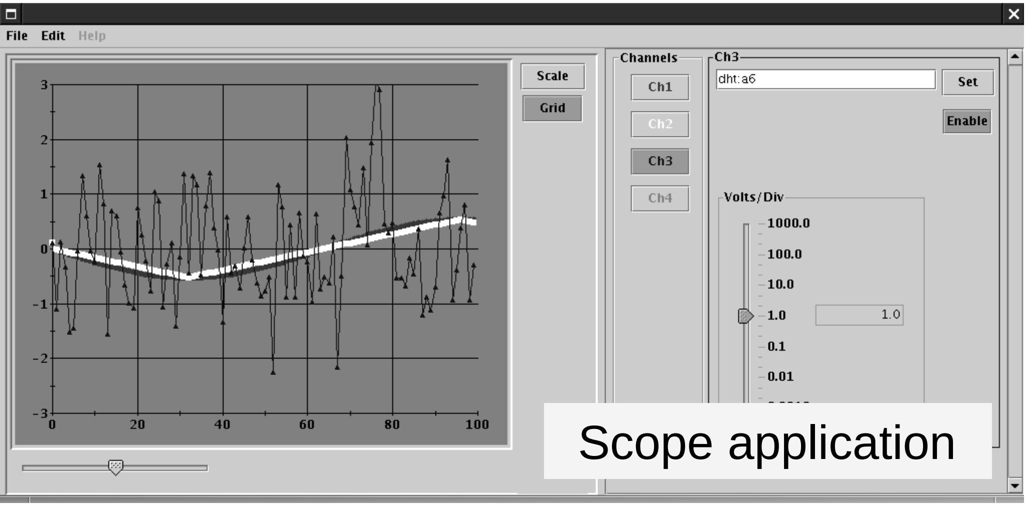
- Organizational Aspects:
  - E. Tanke, Warm Linac Area Manager will coordinate testing and lead beam commissioning effort
  - Assembling “DTL Testing Plan” and “DTL Commissioning Plan”
  - AP group provides 10 operators for DTL tank 1 commissioning, operators will be hired for DTL2-6/CCL commissioning

- AP Group priorities:
  - Linac commissioning algorithms identified and extensively studied (DTL algorithms shown)
  - Now producing commissioning applications

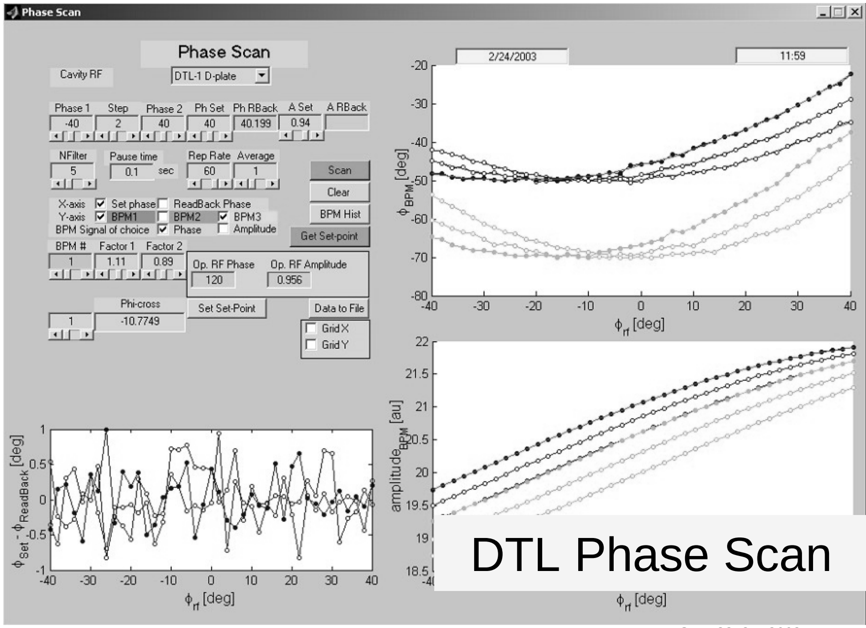
Measurements	Technique	Diagnostics
Rf set-point	Phase scan	BPMs
	Acceptance scan	ED/FC
	Beam loading scan	RF loop
Transverse matching	rms emittance minimization	Slit/collector (DTL D-plate)
Beam transverse profile		WS
Beam longitudinal profile	Secondary emission electron	BSM (INR)
Transverse emittance		Slit/collector (DTL D-plate)
Steering	Orbit deviation minimization	BPMs
Beam transmission	Differential measurement	BCMs
	Beam loss	BLMs
Pencil beam		Apertures

Application Programming Progress

- XAL infrastructure is in good shape
- Focus of the group is on Applications Programming needs for commissioning. High Priority:
  - DTL-specific applications
  - On-line model capability (database or live data) and lattice file generations
  - Save-restore capability (w/controls group)
    - During commissioning this functionality was not well utilized
    - New application under construction
  - “Scope Application” to display and analyze time dependent waveforms



Scope application



DTL Phase Scan

Application Programs for Commissioning

DTL Applications	Responsible	Started	Ready
RF Setpoint (phase scan)	Jeon/Kisselev	☑	☑
RF Setpoint (acceptance scan)	Jeon/Kisselev	☑	☑
RF Setpoint (beam loading scan)	Jeon/Kisselev	☑	☑
Transverse Matching	Jeon/Kisselev	☑	☑
Tank Conditioning	Gurd/Tanke	☑	☑
Emittance Analysis	Jeon	☑	☑

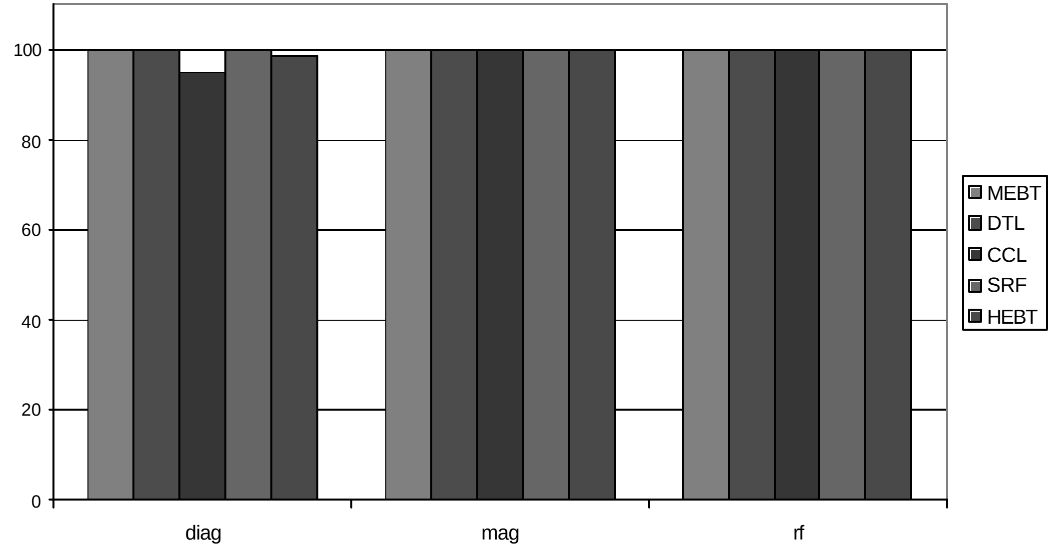
MEBT Applications			
Rebuncher Phase/amplitude	Aleksandrov/Shishlo	☑	☑
MEBT emittance analysis	Aleksandrov	☑	☑

General Applications			
Orbit Difference	Chu	☑	☑
Online model (T3D)	Chu	☑	☑
Online model (XAL)	Allen/Chu	☑	
Lattice View	Klotz	☑	☑
Orbit/Trajectory Correction	Pelaia	☑	☑
Oscilloscope	Pelaia	☑	
Timing Display	Pelaia	☑	
Save/Restore	Lionberger	☑	
XY Correlator	Galambos	☑	☑
3D Display	Chu	☑	☑
Post-Mortem	Galambos	☑	☑

Accelerator Physics Integration: Quality Control, Global Database

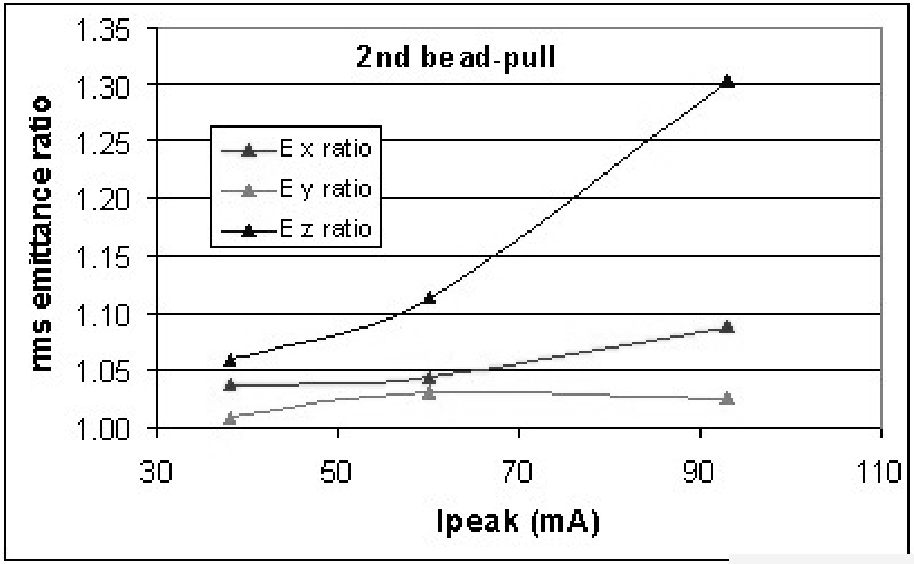
- **Parameter List Updated (Rev. 9)**
- **Global Coordinates Updated (Rev. 2)**
  - *Incorporates measured dipole lengths, final magnet design params, linac diagnostics*
  - *Revised BNL lattice drawing incorporates global coordinates*
- **Quality Control:**
  - *Keep on top of magnet measurement results, bead-pull results, etc.*
  - *Perform independent reviews and checks of design, bid packages, specifications*
  - *Work with Target Systems on components that interface with accelerator*
  - *Perform fault studies: Beam-on-target parameters, SC linac tolerance, MEBT chopper*
  - *Interface with Alignment Group*
  - *Help formulate acceptance criteria*
- **Global Database:**
  - *~1500 Lattice elements exist in database (with information necessary for lattice input file)*
  - *Lattice input files written from Global Database info*
  - *Magnet measurement database population started*

% Beamline Devices in Database



Linac Physics Progress Since the Last Review

- Studied and refined linac commissioning algorithms
- DTL Tuning and measurement issues
- Drift-tube vibration measurement and analysis effort
- Review of Linac Beam Dynamics codes for commissioning
- Specifications for neutron detectors for linac
- Evaluated prototype cryomodule from beam dynamics viewpoint
- Continue modeling of SC cavity dynamics



Courtesy
D. Jeon

DTL Tank 3 bead-pull results (+/- 1%)

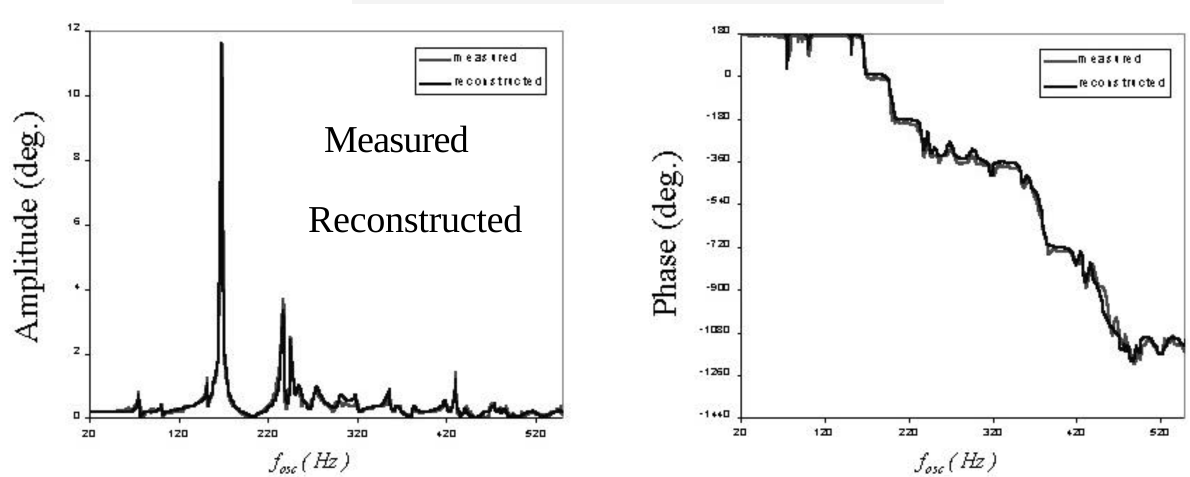
Modeling Superconducting Cavity Dynamics: Lorentz detuning and piezo compensation

- Doleans and Kim have taken the approach of
  - extracting mechanical mode parameters from measurement
  - Using this mechanical basis, calculate dynamic detuning and cavity voltage dynamics from piezo action

→ This "virtual-cavity" model is a useful tool for understanding the cavity dynamics

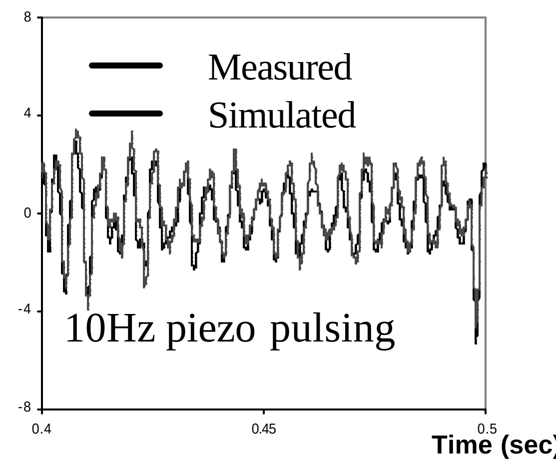
→ Has been used to explore piezo compensation

Sinusoidal Excitation of Cavity #2 by Piezo

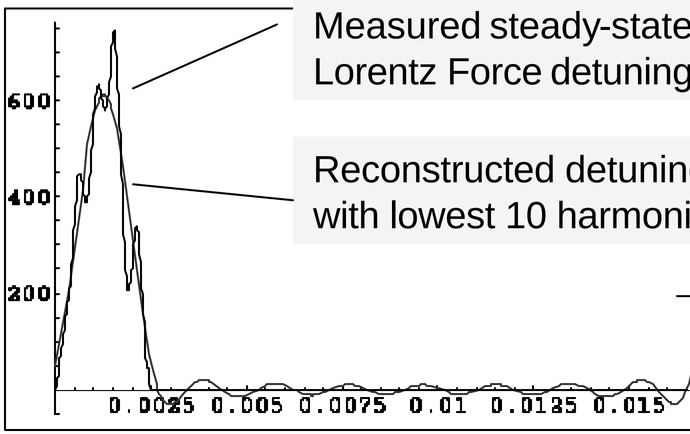


Frequency (Hz)

Square Wave Excitation of Cavity #2 by Piezo

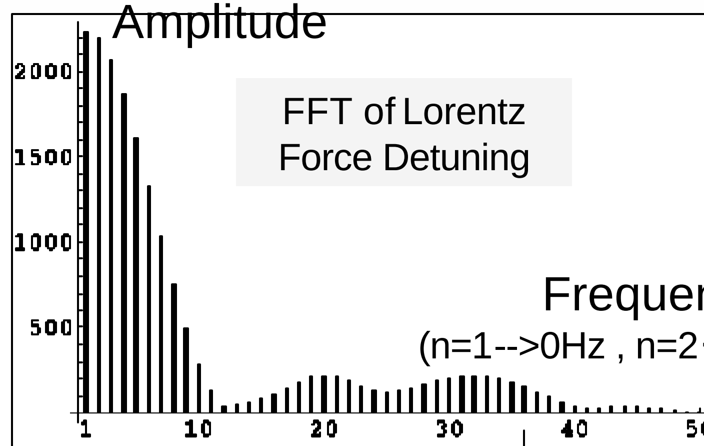


(Nearly) Ideal Piezo Compensation



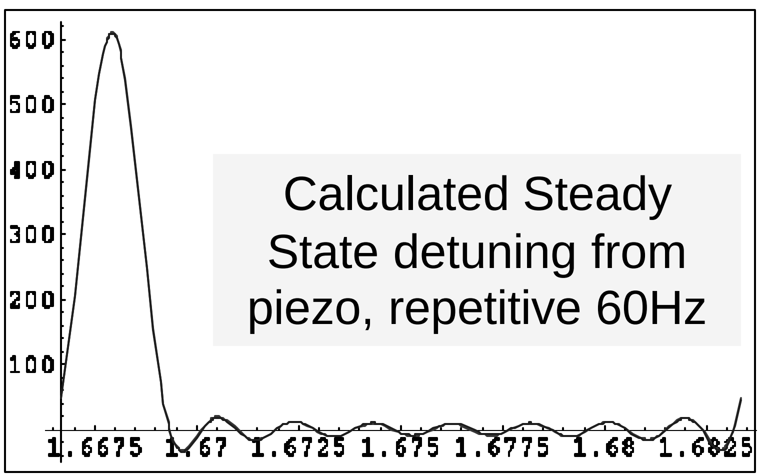
Measured steady-state Lorentz Force detuning

Reconstructed detuning with lowest 10 harmonics

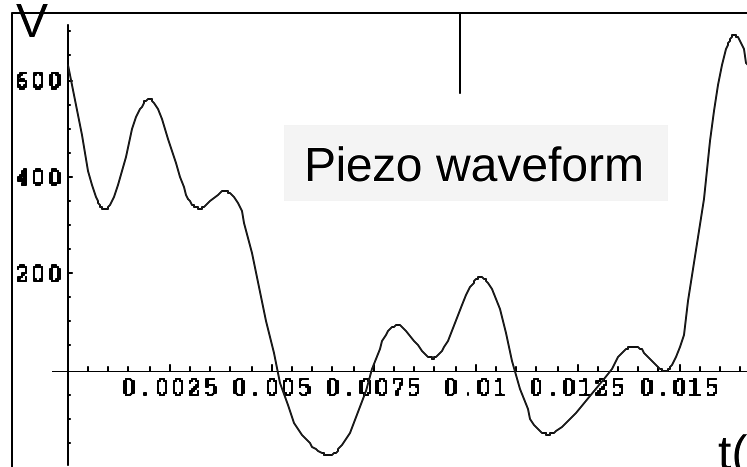


FFT of Lorentz Force Detuning

Use mechanical basis to calculate Piezo amp and phase



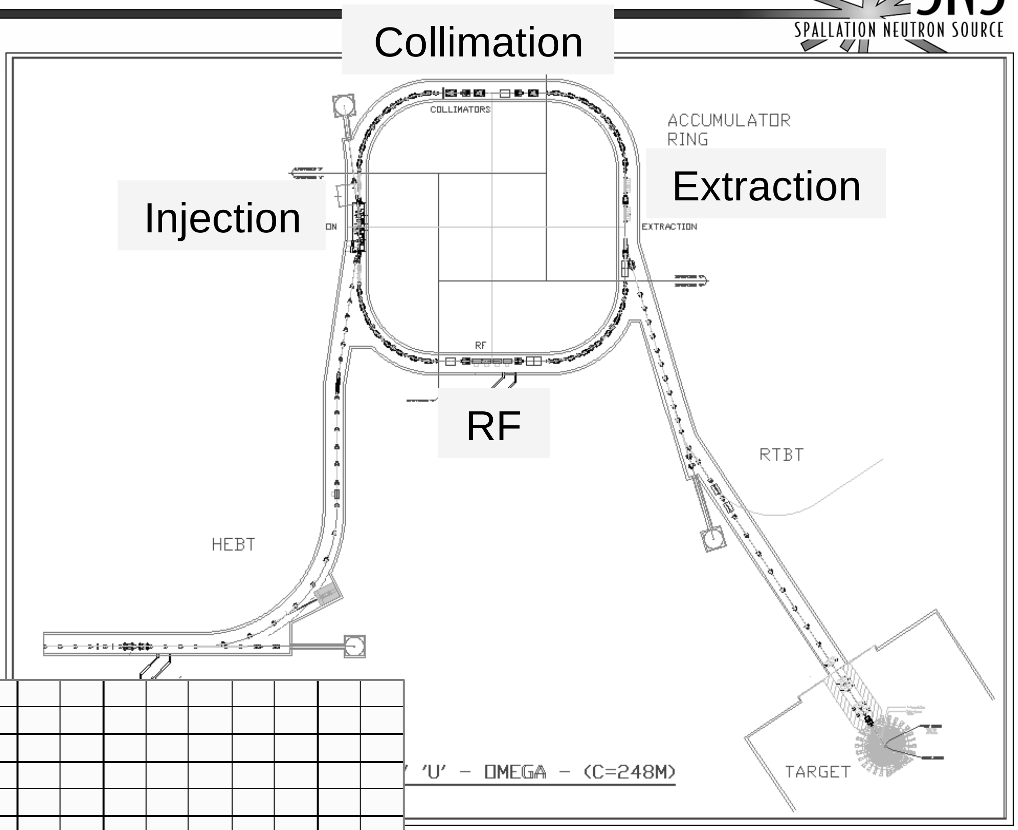
Calculated Steady State detuning from piezo, repetitive 60Hz



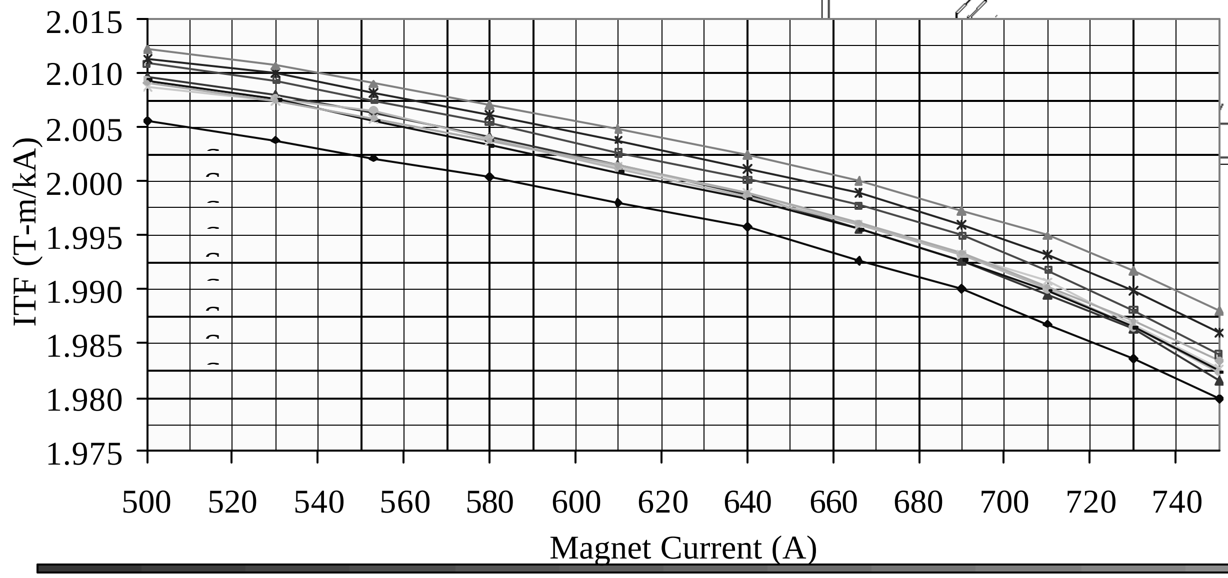
Piezo waveform

Ring Lattice Progress Since the Last Review

- Working with survey/alignment/drafting to incorporate global coordinates
- Magnet measurement results evaluated
- Ring/HEBT dipoles and Ring quads sorted
- Lattice tuning (local tune control)
- BPM offset measurement method



8D533 Excitation Curves

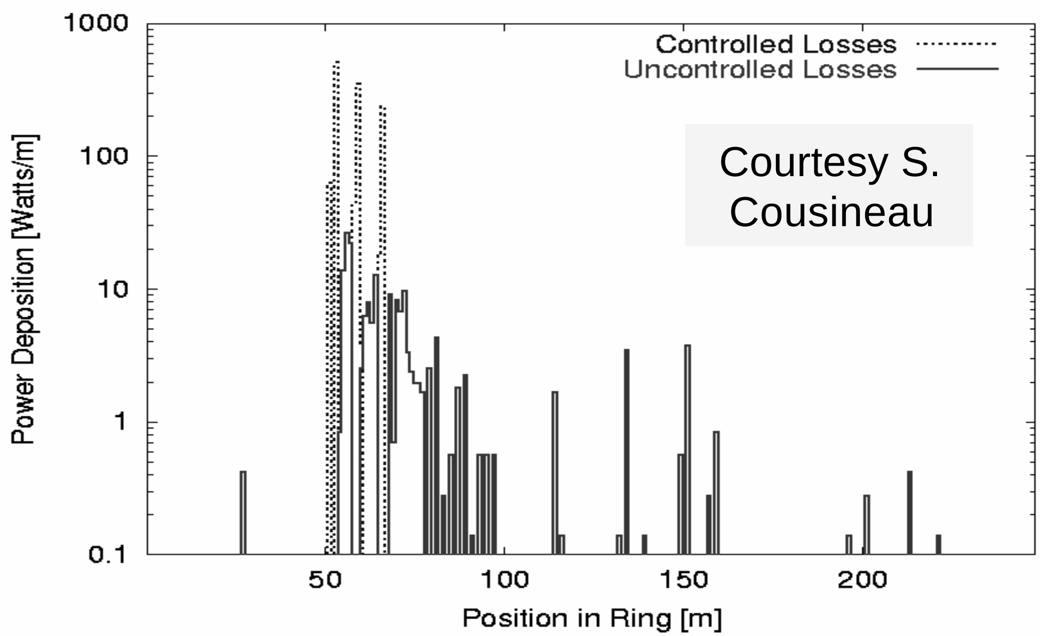


HEBT Dipole Measurements (courtesy J. Wang)

Ring Beam Dynamics Progress
(details in D. Raparia's talk)

- Impedance Budget
  - Dominated by extraction kicker (reported reduction by x2 at last review)
  - Re-measured RF cavity impedances: previously reported HOM's are negligible
  - Collimator beampipes evaluated
- Explored use of octupole tune-spread for damping
  - Some potential benefit despite weak octupoles
- Explored use of wideband feedback
- Higher-order resonance correction studies are ongoing
  - Good progress, correction methods have been tested
  - Important for exploring other operating points
- Halo and Losses study
  - A present focus of activity to revisit with improved capabilities

Lost in Collimation Straight Section	98%
Lost on Collimators	88%
Lost on Quads in Collimation Straight	3%
Lost on Beampipe in Collimation Straight	6%



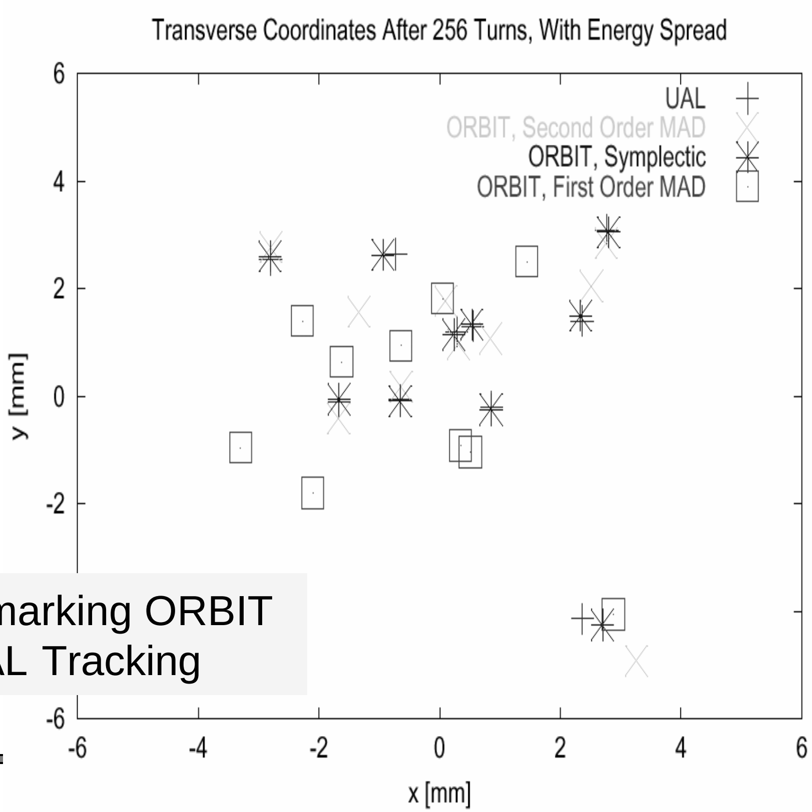
Progress in Ring Beam Dynamics Code Development

Two "workhorse" codes in use

- **ORBIT developed at ORNL** (Holmes, Galambos, Danilov, Cousineau, Shishlo)
  - Runs in parallel on ORNL 16-proc AP cluster + ORNL EAGLE Supercomputer (~720 proc)

- **UAL developed at BNL** (Malitsky, Talman, Shishlo)
  - Runs in parallel on BNL 40-proc cluster

- **Added in last 6-12 months:**
  - TeaPot tracking (thin-lens)
  - Full error capability (misalignments, field errors, orbit correction)
  - Fringe-fields
  - Parallel computation
  - Feedback capability
  - Realistic momentum painting
  - Improved foil scattering physics
  - Beginning electron cloud implementation



Benchmarking ORBIT and UAL Tracking

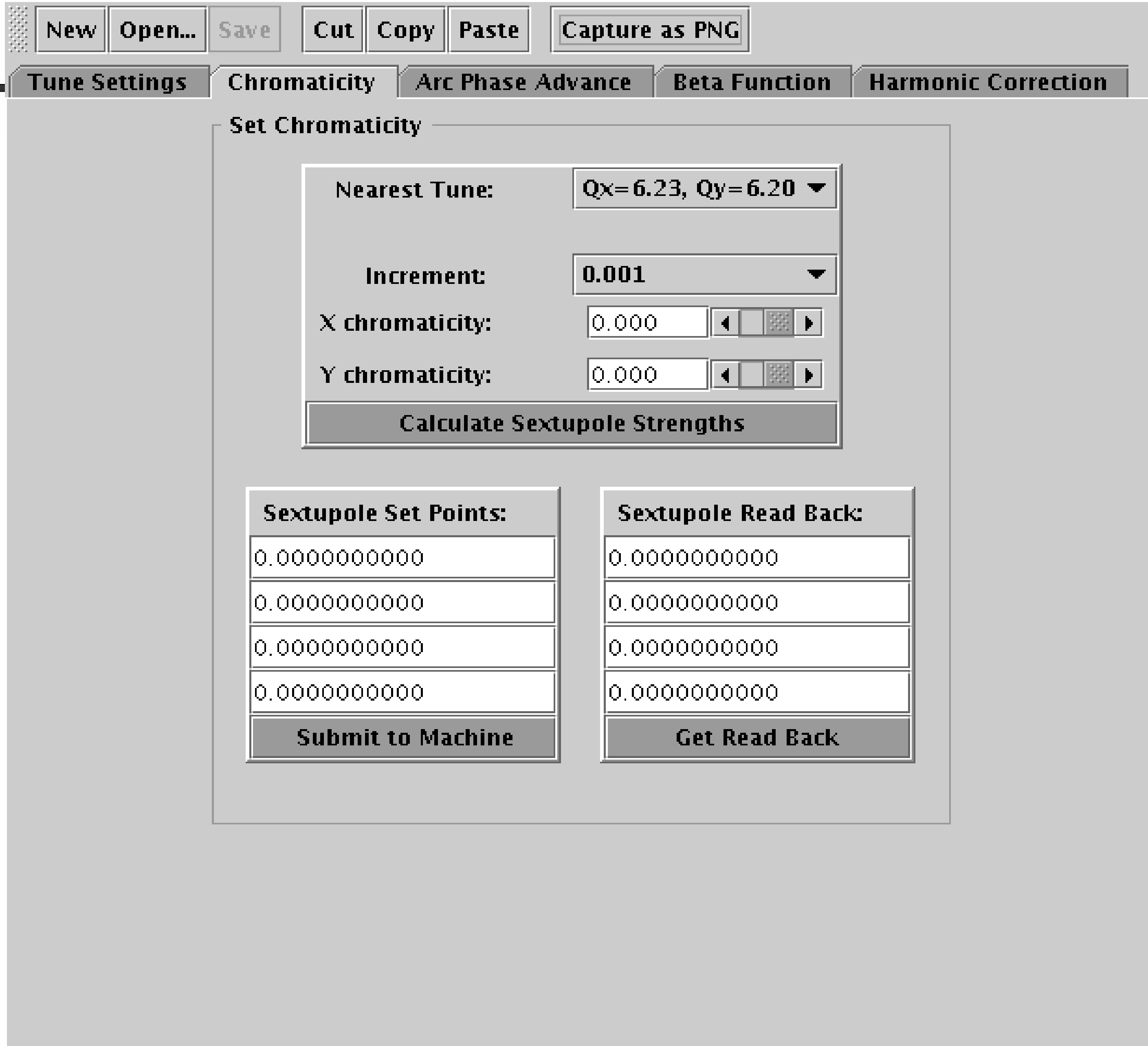
Ring Collective Instability Threshold Summary

Simulations predict that we will not encounter collective instabilities in the ring up to the baseline intensity (1.44MW, 1.6x10^{14} protons) :

- Transverse Microwave Instability (EK impedance):
  - 3x10^{14} (ξ_{nat}), 2x10^{14} (ξ=0)
- Longitudinal Microwave Instability (EK + RF impedance):
  - 3x10^{14}
- Resistive Wall (Walls + EK impedance):
  - Stable at nominal tunes
  - For (6.23, 5.80) stable at ξ_{nat}, unstable at ξ=0
- Electron Cloud Instability
  - Stable at 2 nC/m e- line density: threshold is 30 kV RF vs. 40 kV h=1 available
  - Threshold of 5 nC/m e- line density at design intensity
  - Can be considered conservative estimate since not all mitigative features included, and code overestimates required RF in PSR
- Losses due to Space Charge itself set a limit of just above 2 MW *for baseline operating point* in simulations
- Although simulations show stable beam at design intensity:
  - We feel it is prudent to explore the requirements and capabilities of a wideband transverse feedback system
  - Modest power needed to damp resistive wall and double EK impedance (80W)

Summary

- **Very successful Front-End commissioning run!**
  – Effort that went into commissioning preparations paid off
  – Achieved peak current, emittance goals, successful tests of laser-wire and fast faraday cup, gained experience
  – Commissioning organization worked very well, will continue with this approach in remaining commissioning runs
- Physics effort shifting toward commissioning work
  – Applications programming focusing on commissioning needs
  – Preparing for DTL commissioning
  – Already have much data to be analyzed
- Integration & QA efforts continue to be a priority
  – Database entry, global coordinates, magnet measurements, etc.
- Beam Dynamics/Collective Effects in the Ring continue to be a priority
  – The **baseline intensity is below** present known **limits**


New
Open...
Save
Cut
Copy
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Capture as PNG
Tune Settings
Chromaticity
Arc Phase Advance
Beta Function
Harmonic Correction
Set Chromaticity
Nearest Tune:
Qx=6.23, Qy=6.20
Increment:
0.001
X chromaticity:
0.000
Y chromaticity:
0.000
Calculate Sextupole Strengths
Sextupole Set Points:
0.0000000000
0.0000000000
0.0000000000
0.0000000000
Submit to Machine
Sextupole Read Back:
0.0000000000
0.0000000000
0.0000000000
0.0000000000
Get Read Back

1-D Scan Application

- Provides an easy way to scan one quantity and monitor another
- Can average over pulses, analyze the resulting curve, scan multiple times, …

•BPM position vs. corrector current

BPM amplitude vs. MEBT Rebuncher phase setting