ACCELERATOR PHYSICS OVERVIEW

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February 12-14, 2002

Outline

- Recent activities
  - Identify and resolve "issues" as things become "real"
  - Focus towards device/beam test, measurements, finalization
  - Response to ASAC and DOE/AP comments
- "Hot" topics
  - Low energy halo scraping; laser profile monitor; Lorentz force compensation; ring dipole field quality; ring kicker impedance
- Integration efforts
  - End-to-end simulation with mismatch & measured distribution
  - Master-Lattice; coordinates & conventions; installation support
  - Continue study topics
    - Ring impedance & instabilities; electron cloud; reliability & redundancy; diagnostics interface
- Path towards commissioning

SNS accelerator physics team

- LBNL Accelerator Physics
  - R. Keller, J. Staples, R. Thomae, J. Reijonen
- LANL Accelerator Physics
  - J. Stovall, S. Nath, H. Takeda, J. Billen, L.Young,
- JLAB Accelerator Physics
  - J. Delayen, P. Kneisel
- BNL Accelerator Physics
  - J. Wei, D. Raparia, M. Blaskiewicz, D. Davino, A.V. Fedotov, Y.Y. Lee, N. Malitsky, W. Meng, Y. Papaphilippou, S. Tepikian, N. Tsoupas
- ORNL Accelerator Physics
  - J. Wei, J. Galambos, A. Aleksandrov, S. Cousineau, P. Chu, S. Danilov, M. Doleans, S. Henderson, J. Holmes, D. Jeon, S.H. Kim, L. Kravchuk, T. Pelaia, E. Tanke, R. Welton, S. Assadi, A. Shishlo, J. Stovall
- Collaborators
  - K. Crandall (TechSource), C. Pagani, P. Pierini (INFN), S. Simrock (DESY), K. Bongardt (COSY), R. Ryne, J. Qiang, T. Wangler (LANL), I. Hofmann (GSI), J.M. Lagniel, N. Pichoff, D. Uriot, R. Duperrier (CEA), S. Kurennoy
  - G. Rees, C. Prior (ISIS) S. Machida (KEK), R. Macek (PSR), R. Talman (Cornell), R. Gluckstern (UMCP), S.Y. Lee (IUCF), D. Kaltchev (TRIUMF), J.B. Jeanneret , H. Schonauer (CERN), M. Furman, M. Pivi (LBNL), C. Gardner, H. Hahn, G. Parzen, S.Y. Zhang (BNL)

Where we were at last ASAC Review

- No change of primary parameters (baseline & back-up plans)
- Completed machine physics design
  - – Linac design; end-to-end simulation with errors
- Monitor bid packages, beam tests, device quality & performance, installation/survey status
  - – Specifications, FE results, magnet measurements, cavity tests
- Building Master-Lattice, normalize coordinates and conventions
  - – Integrate optics files (TRACE/PARMILA, TRANSPORT, MAD)
  - – Implement device naming; establish global coordinates
- Identify critical devices & diagnostics for safe, reliable operation
  - – Critical survivability time, critical diagnostics, critical devices
- Strengthen AP links with diagnostics & controls, prepare for commissioning & operations
  - – Area managers preparing detailed commissioning plans
- Pursue AP study topics supporting full-intensity operations & upgrades
  - – Focus on beam power & energy potential, intensity limiting mechanisms and remedies, reliability

Key parameters

	Baseline	Back-up
Kinetic energy, E_k [MeV]	1000	975
Uncertainty, ΔE_k (95% probability) [MeV]	+/- 15	+/- 15
SRF cryo-module number	11+**12**	11+**15**
SRF cavity number	33+48	33+60
Peak gradient, E_p (β=0.61 cavity) [MV/m]	27.5 (+/- 2.5)	27.5 (+/- 2.5)
Peak gradient, E_p (β=0.81 cavity) [MV/m]	**35 (+2.5/-7.5)**	**27.5 (+/- 2.5)**
Beam power on target, P_{max} [MW]	1.4	1.7
Pulse length on target [ns]	695	699
Chopper beam-on duty factor [%]	68	68
Linac beam macro pulse duty factor [%]	6.0	6.0
Average macropulse H- current, [mA]	**26**	**32**
Linac average beam current [mA]	1.6	1.9
Ring rf frequency [MHz]	1.058	1.054
Ring injection time [ms] / turns	1.0 / 1060	1.0 / 1054
Ring bunch intensity [10^{14}]	1.6	1.9
Ring space-charge tune spread, ΔQ_{sc}	0.15	0.20

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

Response to ASAC and DOE/AP comments

- Monitor end-to-end evolution emphasizing beam halo & diagnostics
  – Develop diagnostics/optics layout; investigate beam loss source
- End-to-end simulation with measured distribution & mismatch
  – Starting with measured distribution after ion source
  – Consider mismatch from realistic diagnostics inaccuracy
- Halo scraping plan for the Front End
  – Adjustable scrapers in MEBT; alternative MEBT optics; backup plans
- Linac error studies; linac RF overhead and control
  – Error study performed; R&D started on cavity error compensation using piezoelectric tuners
- Ring magnet measurement data analysis – main focal point
- Ring collective effects – details presented at last ASAC; work continues
- Commissioning planning & applications software
  – Commissioning plans developed, area managers identified
  – Applications software team strengthen at ORNL and partner labs

What else happened since last Review

- Updated parameter list, closely monitoring beam evolution
- Continue Master-Lattice construction, populating global coordinates as detailed design is completed
- Significantly strengthen applications software team & activities (Galambos' talk)
- Identifying and resolving "issues" as design becomes "real"
  - DTL corrector power supply re-baseline (cost issue)
  - LEBT chopper detailed modeling & MEBT chopper performance
  - MEBT adjustable halo scrapers (Jeon's talk)
  - Alternative MEBT optics (with added power supplies) to minimize halo generation (Jeon's talk)
  - Ring dipole transfer function variation; elaborated discussion
  - Ring quadrupole multipole (b_3); vendor feedback and sorting
  - Injection kicker chamber coating
  - Injection stripping electron collection, back-scattering
  - Extraction kicker impedance optimization, rise time, heating
  - Collimation finalization (aperture, location, material, shape) …

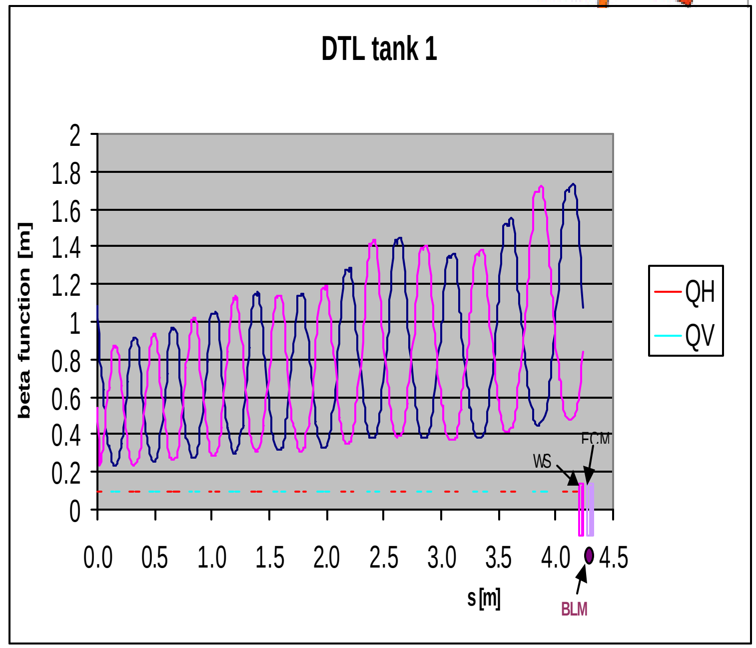
Beam evolution parameter (baseline)

	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 β	0.0118	0.0728	0.0728	0.4026	0.5503	0.7084	0.875	0.875	0.875	0.875	
Relativistic factor γ	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		$19/\pi$		πeVs
Output longitudinal rms emittance		7.6E-07	1.0E-06	1.2E-06	1.4E-06	1.7E-06	2.3E-06		$2/\pi$		πeVs
Controlled beam loss; expected	0.05[a]	N/A	0.2[b]	N/A	N/A	N/A	N/A	5[c]	60[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

- Ensure adequate acceptance-to-emittance ratio to control loss
- Closely monitor emittance growth
- Localize loss with collimation systems

Master-lattice construction (Galambos et al)

Name	Element	length [m]	S [m]	beta_x	beta_y	Global Coord. [m] z	Global Coord. [m] x	Global Coord. [m] y
	SNS lattice file for pseudo periods in the DTL Tank 1							
	Drft	0	0	1.088715	0.539721	19549.945844	1000000.0000	200004.60000
DTL_Mag:QH100	Quad	0.0175	0.0175	0.818302	0.248987	19549.963344	1000000.0000	200004.60000
DTL_Mag:QV102	Quad	0.0175	0.126427	0.250965	0.833298	19550.072271	1000000.0000	200004.60000
DTL_Mag:QV103	Quad	0.0175	0.181321	0.255135	0.838301	19550.127165	1000000.0000	200004.60000
DTL_Mag:QH105	Quad	0.0175	0.292042	0.869919	0.256495	19550.237886	1000000.0000	200004.60000
DTL_Mag:QH106	Quad	0.0175	0.347863	0.878162	0.260305	19550.293707	1000000.0000	200004.60000
DTL_Mag:QV108	Quad	0.0175	0.460471	0.270178	0.887277	19550.406315	1000000.0000	200004.60000
DTL_Mag:QV109	Quad	0.0175	0.517277	0.273679	0.896622	19550.463121	1000000.0000	200004.60000
DTL_Mag:QH111	Quad	0.0175	0.631942	0.926802	0.278309	19550.577786	1000000.0000	200004.60000
DTL_Mag:QH112	Quad	0.0175	0.689822	0.935285	0.284722	19550.635666	1000000.0000	200004.60000
DTL_Mag:QV114	Quad	0.0175	0.806729	0.289232	0.975176	19550.752573	1000000.0000	200004.60000
DTL_Mag:QV115	Quad	0.0175	0.865777	0.294957	0.987749	19550.811621	1000000.0000	200004.60000
DTL_Mag:QH117	Quad	0.0175	0.985121	1.008835	0.309499	19550.930965	1000000.0000	200004.60000
DTL_Mag:QH118	Quad	0.0175	1.04544	1.022362	0.317411	19550.991284	1000000.0000	200004.60000
DTL_Mag:QV120	Quad	0.0175	1.167431	0.320251	1.082362	19551.113275	1000000.0000	200004.60000
DTL_Mag:QV121	Quad	0.0175	1.229128	0.327646	1.09288	19551.174972	1000000.0000	200004.60000
DTL_Mag:QH123	Quad	0.0175	1.353989	1.112369	0.333242	19551.299833	1000000.0000	200004.60000
DTL_Mag:QH124	Quad	0.0175	1.417181	1.120707	0.331327	19551.363025	1000000.0000	200004.60000
DTL_Mag:QV126	Quad	0.0175	1.545152	0.338048	1.096716	19551.490996	1000000.0000	200004.60000
DTL_Mag:QV127	Quad	0.0175	1.60996	0.334213	1.100849	19551.555804	1000000.0000	200004.60000
DTL_Mag:QH129	Quad	0.0175	1.741295	1.109361	0.332097	19551.687139	1000000.0000	200004.60000
DTL_Mag:QH130	Quad	0.0175	1.807852	1.117277	0.333295	19551.753696	1000000.0000	200004.60000
DTL_Mag:QV132	Quad	0.0175	1.94282	0.343937	1.139817	19551.888664	1000000.0000	200004.60000
DTL_Mag:QV133	Quad	0.0175	2.011265	0.35269	1.159274	19551.957109	1000000.0000	200004.60000
DTL_Mag:QH135	Quad	0.0175	2.150156	1.229949	0.369787	19552.096000	1000000.0000	200004.60000
DTL_Mag:QH136	Quad	0.0175	2.220636	1.253179	0.388445	19552.166480	1000000.0000	200004.60000
DTL_Mag:QV138	Quad	0.0175	2.363755	0.394762	1.367649	19552.309599	1000000.0000	200004.60000
DTL_Mag:QV139	Quad	0.0175	2.436429	0.405878	1.388059	19552.382273	1000000.0000	200004.60000
DTL_Mag:QH141	Quad	0.0175	2.584101	1.390707	0.420756	19552.529945	1000000.0000	200004.60000
DTL_Mag:QH142	Quad	0.0175	2.659136	1.39989	0.414387	19552.604980	1000000.0000	200004.60000
DTL_Mag:QV144	Quad	0.0175	2.811706	42.1562	1..11756	195575637000	1000000.0000	200004.60000
DTL_Mag:QV135	Quad	0.0175	88928361	09916429	1.2.0356	195583512945	1000000.0000	200004.60000
DTL_Mag:QH735	Quad	0.0175		1177989	.0323387	195599296145	1000000.0000	200004.60000
DTL_Mag:QH138	Quad	0.0175		12548179	0.7.4587	19 33.326680	1000000.0000	200004.60000
D	Quad			7595878	7427V138	19 315451562	1000000.0000	200004.60000
DTL_Mag:Q7000	Quad	0.0175		40.22429	12481238	19 321.35599	1000000.0000	200004.60000
DTL_Mag:Q5141	Quad	0.0175		0.49478	14906445	193.31999299	1000000.0000	200004.60000
[illegible]	Quad	0.0175		82097755	785.0745	193.4042H735	1000000.0000	200004.60000
DTL_Mag:Q5342	Quad	0.0175		48326361	42860445	193..045H138	1000000.0000	200004.60000
DTL_Mag:Q5144	Quad	0.0175		51648179	45590238	19 356391735	1000000.0000	200004.60000
D	Quad	0.0175		88059562		193.66337599	1000000.0000	200004.60000
DTL_Mag:Q5635	Quad	0.0175		65405141		193.75 (113[illegible]	[illegible]	[illegible] Tj -360.7187 -8.25 TD -0.0665 Tc (DTL_Mag:Q5735) Tj 66.1446 0 TD -0.2721 Tc (Quad) Tj 43.84 0 TD -0.2
[illegible]	Quad	0.0175			93762562	19 393186599	1000000.0000	200004.60000
DTL_Mag:Q5139	Quad	0.0175		77.64355	513Q5142	194332320299	1000000.0000	200004.60000
DTL_Mag:Q6000	Quad	0.0175		79356355	51140355	19431Q566599	1000000.0000	200004.60000
[illegible]		0						

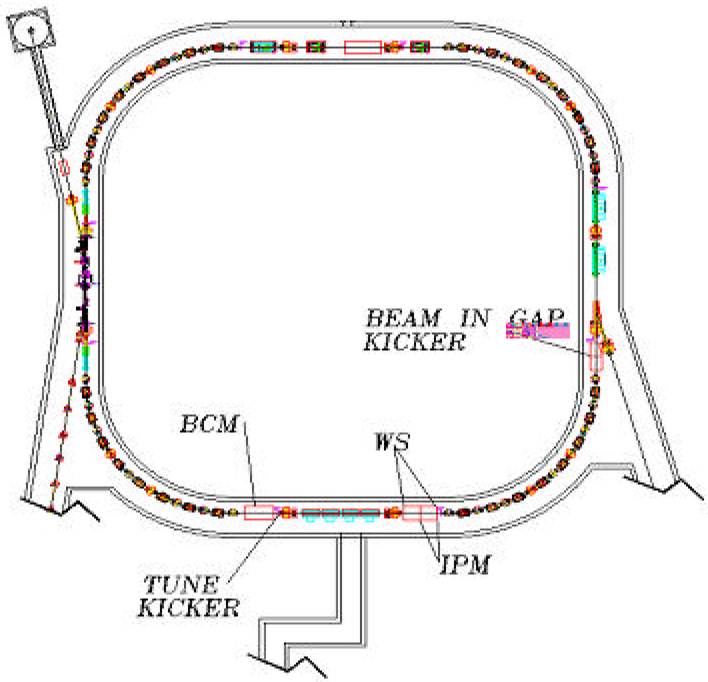


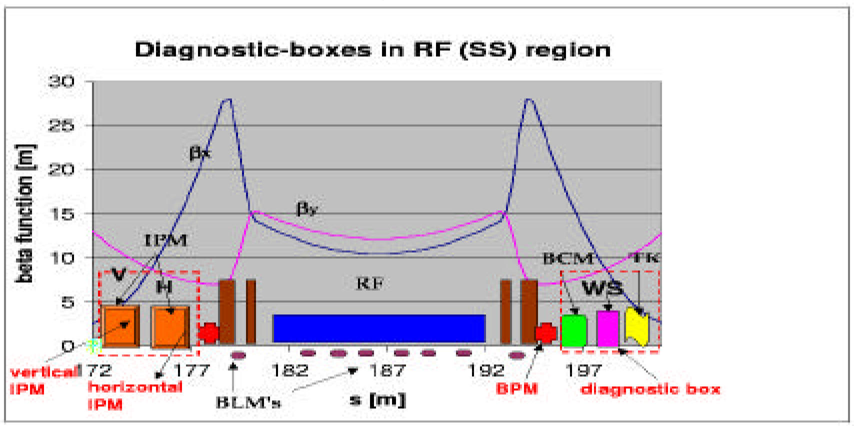
End-to-end simulation (2002)

(using measurement data w/ mismatch; applying front-end scraping)

	IS/LEBT	RFQ	MEBT	DTL	CCL	SCL (1)	SCL (2)	HEBT	Ring	RTBT	Target	Unit
Energy, W (out)	0.065	2.5	2.5	86.8	185.6	391.4	1000	1000	1000	1000	1000	MeV
DW							(+/-)	(+/-)	(+/-)	(+/-)	(+/-)	
e (n, rms)	0.09/0.2	0.21	0.23	0.27-?	0.30-0.34	0.30-0.35	0.32-0.38	0.31-0.42	44+44	44+44		mm mr
e (un, 99%)									120+120	120+120		mm mr
Trans. jitter							0.3 (+/-)	0.3 (+/-)	0.3 (+/-)	0.3 (+/-)		mm
DE (rms)		.005-.01	.007-.015	.09-?	0.12-0.13	0.18-0.24	0.37-0.43					MeV
DE (jitter)							0 - 1.1	0 - 0.4				MeV
DE (full)								4 (+/-)	10 (+/-)	10 (+/-)		MeV
I (out, peak)	47	38	38	38	38	38	38	38	9.e4	9.e4		mA
Length	0.12	3.72	3.66	36.81	57.47	64.229	172.45	169.49	248	150.75		m
Codes used	IGUN	TOUTATIS	PARMILA	PARMILA	PARMILA/	PARMILA/	PARMILA/	PARMILA	UAL/ORBIT	PARMILA		
					LINAC	LINAC	LINAC					
N (macro)	200	1e4/1e6	1e4/1e6	1e6/3e5	1e6/3e5	1e6/3e5	1e6/3e5	1e6/3e5	4.e4/1.e5	1e5		
random seeds	1	10/100	10/100	1/10	1/10	1/10	1/10	1/10	10	10		
Loss (control)	0.27	0	0.05	0	0	0	0	0	0.007 - 0.015	0		
Loss (uncont.)	~ 0.1	0.08	< 0.01	2.e-4??	0	0	0	1.e-5	0.00014	0	0.04	
e (rms) growth		5%	19%	18-%	12-%	14-%	3-%	0-11%	5%	3%		
e (99%) growth								0-20%	10%	5%		
Included	sp. ch.	sp. ch.	sp. ch.	space charge		space charge		sp. ch.	painting	sp. ch.	window	
	Initial	align err.	Quad	rf phase/amp. error		rf phase/amp. error		rf error	space charge	rf error	scatt.	
	electrns		mag. err	quad gradient error		quad gradient error		quad err	magnet error	quad err		
	Ion temp			quad roll		Lorentz detuning		misalign	aperture	misalign		
				cavity-to-cavity tilt		quad roll		quad roll	magnet offset	quad roll		
				quad misalignment		cavity-to-cavity tilt			fringe field			
				multipoles		quad misalignment			quad roll			
						multipoles						
Excluded	Dumping	Fringe errors		DTL/quad vibration		missing cavities		linac H0	impedance	collimator		
	mag field					rematching		foil/collim	collimation	scattering		
	misalign					transient analysis		scatt.	scattering			
	LEBT-RFQ handover					quad vibration			beam loading			
						HOM analysis						
Open issues	will use msrd LEBT distrib.s								ext kicker imp			
									electron cloud			
									fast correction			

Instrumentation interface





Detectors	BNL	Comments
BPM	44	dual plane
	(includes	2 RF radial loop)
BLM	75	ion chamber
FBLM	12	photomultip.
BIG	1	kicker+PMT
IPM	2	H+V
WS	2	H+V
Coherent Tune	1	kick/PU
Incoherent Tune	2	PLL & QMM
BCM	1	FCT
WCM	2	including RF
E-detector	5	
High Moment	1	

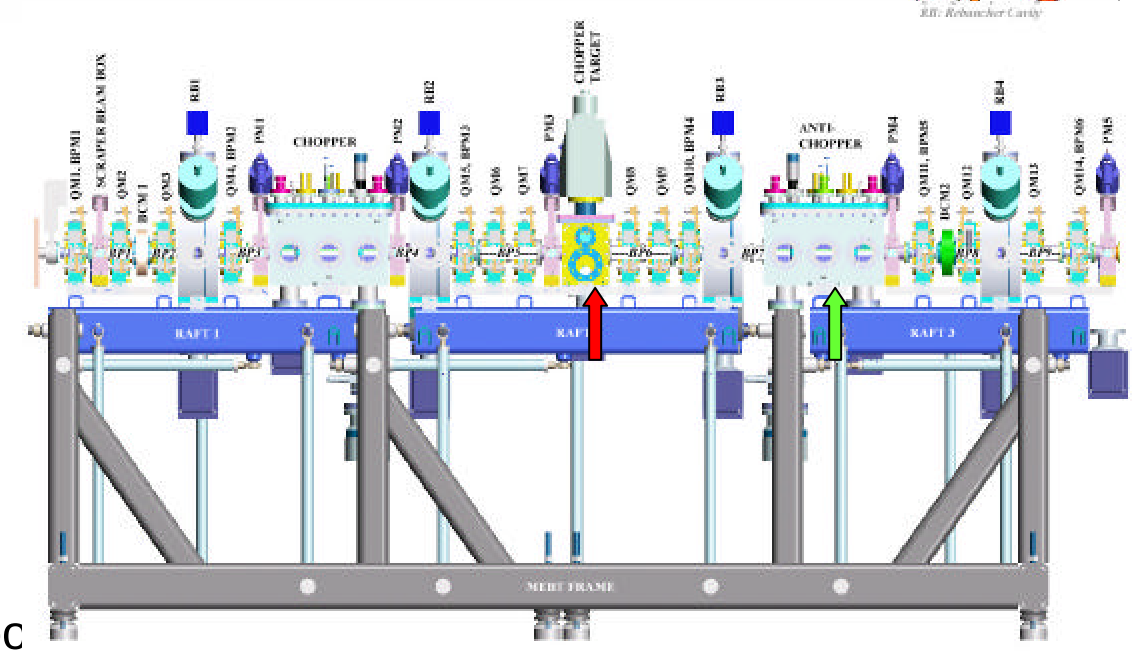
Front end issues R. Keller, J. Staple, D. Jeon's talks

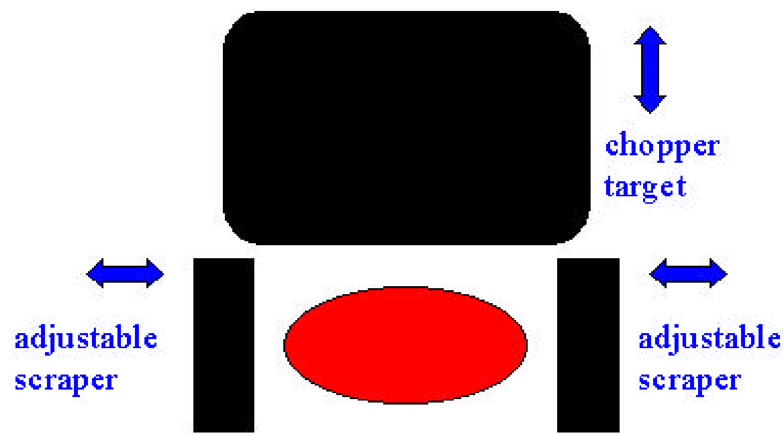
- Front end data for end-to-end simulation
  - Working on a better LEBT/RFQ matching
  - MEBT identified as one of halo-generating sources
- RFQ emittance filtering function & collimation
  - Beam halo can generate/pass across LEBT/RFQ/MEBT
  - Planning on scraping schemes
- Codes improvement & comparison
  - Ion source: H- codes replacing proton codes; 2D vs. 3D (IGUN -> PBGUN, SIMION)
  - RFQ: realistic aperture; 3D space charge (TOUTATIS, revised PARMTEQ)
- Commissioning beam characterization & diagnostics

Front-end halo mitigation

D. Jeon's talks

- Front-end can generate beam halo
  - LEBT/RFQ matching
  - MEBT narrow beam & space charge
- Needs a robust scheme
  - MEBT accommodates adjustable scrapers
  - Scraper 1 easily placed
  - Scraper 2 in swappable bo to anti-chopper box
  - DTL/LEBT fixed scraping as back-pocket plan
- Alternative MEBT optics
  - Reduce halo generation
  - Eliminate anti-chopper
  - Add 3 quad power supplies



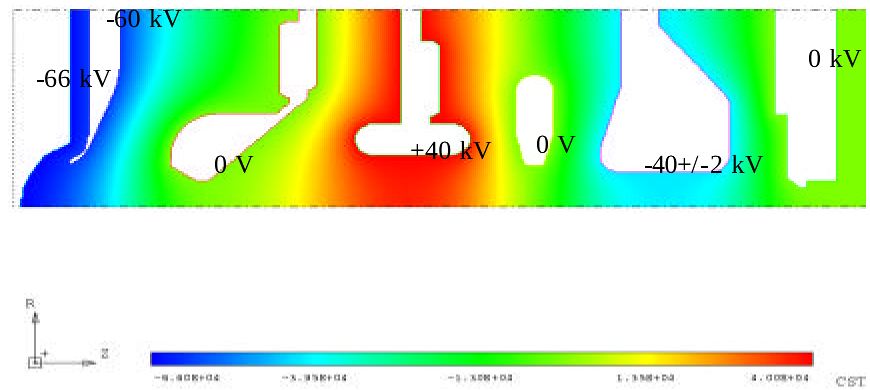


LEBT/MEBT chopper/anti-chopper analysis

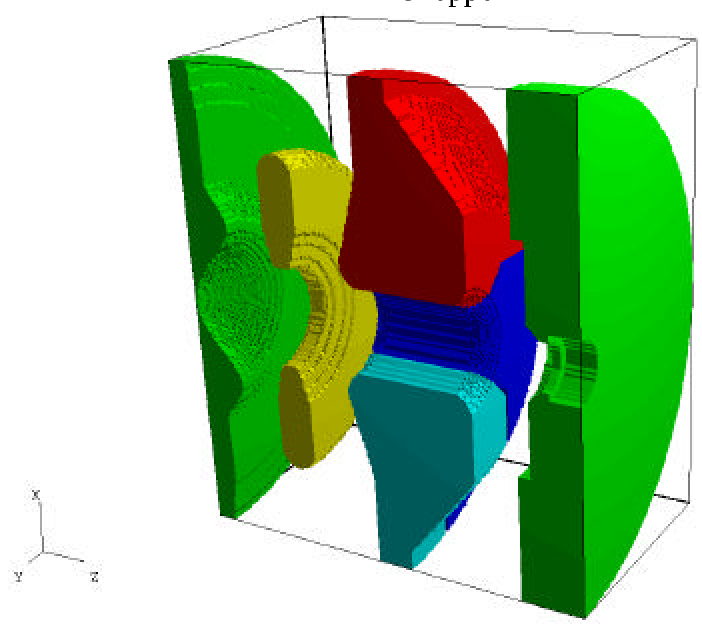
- Chopper performance
  - Shorten LEBT chopper rise time (+/- 25 ns)
  - Study LEBT chopper performance with 2D & 3D modeling of electrods and chopper
  - Investigate LEBT partially chopped beam at MEBT chopper
- Anti-chopper performance
  - Study indicates anti-chopper may not be necessary
  - To be tested during commissioning and early operation

(S. Kim; L. Young, D. Jeon et al)

The chopping electrode have 4 vanes



Chopper

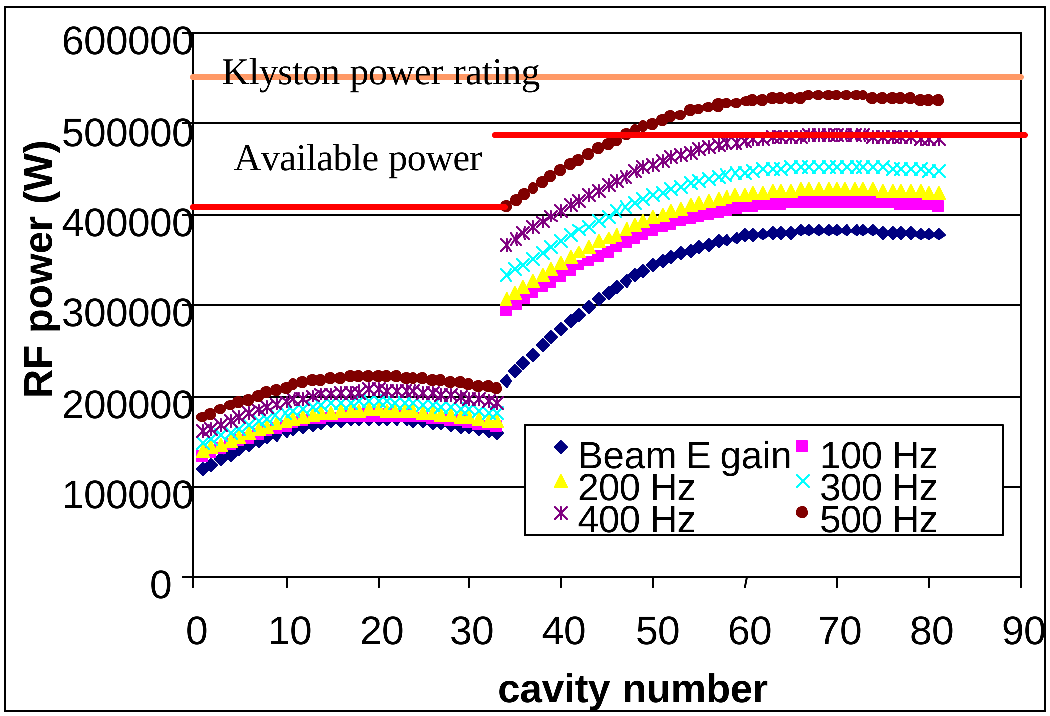


Linac issues J. Stovall, D. Jeon, E. Tanke's talks

- Linac performance & sensitivity to input beam halo
  - Relate to front-end measurement input
  - Relate to commissioning beam tuning procedures and diagnostic errors
- Parametric halo under mismatch condition; space-charge coupling halo
- Codes benchmarking: (LANL, CEA/Saclay)
  - 2D and 3D space charge model; field integration method comparison
- Missing cavity & re-matching -- work to be done
- Investigate RF power reserve & active compensation
  - High-beta SRF cavity overhead 40%; enhanced Lorentz detuning, investigating possible compensation schemes
    - Piezoelectric device; capacitive tuning scheme

RF power overhead for detuning compensation

- Med-beta SRF cavity has more reserve
  - cavity structure susceptible to a larger Lorentz detuning coeff. ($|K|>>2$ Hz/(MV/m)^2)
  - Actual K pending for more realistic measurements
- High-beta cavity performance limited by available RF power
  - 40% total power overhead includes klystron operational margin, circulator loss, waveguide loss (10~15 %)
  - Able to compensate 400 Hz detuning
    - K ~ 2 +/- 1 Hz/(MV/m)^2
    - 6 sigma microphonics
    - Peak field 35 MV/m



Ring issues

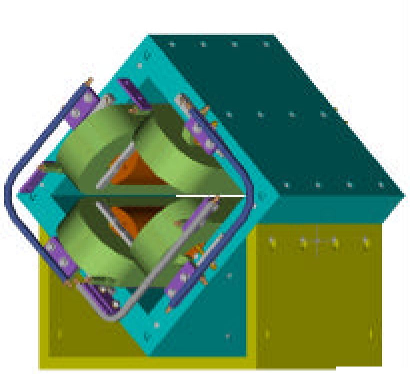
Lee, Davino, Blaskiewicz, Tsoupas, Fedotov's talks

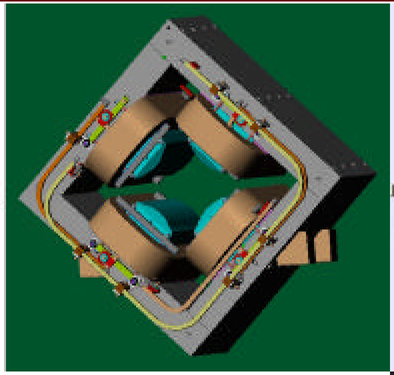
- Magnet measurements & modeling
- Extraction kicker optimization
- Injection kicker chamber coating choice
- Instability and loss control
- Electron cloud
- Full-scale simulation
  - Painting, nonlinear errors, fringe field, space charge, impedance, collimation, (electron-cloud)

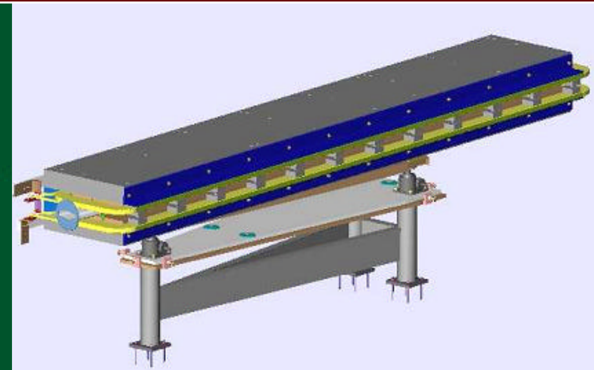
Magnet modeling (HEBT/injection/extraction/RTBT)

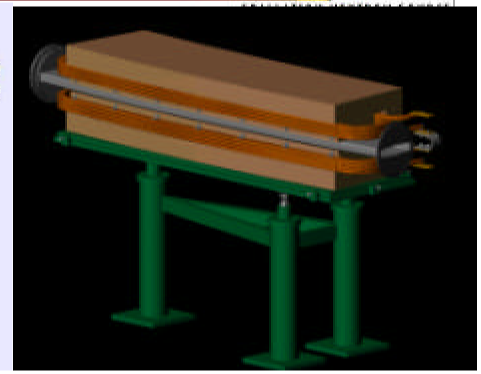
W. Meng, N. Tsoupas et al

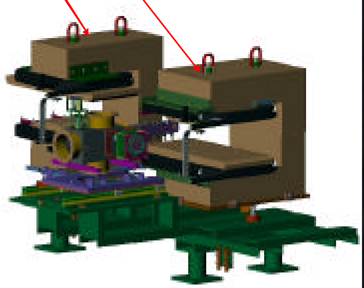
SNS

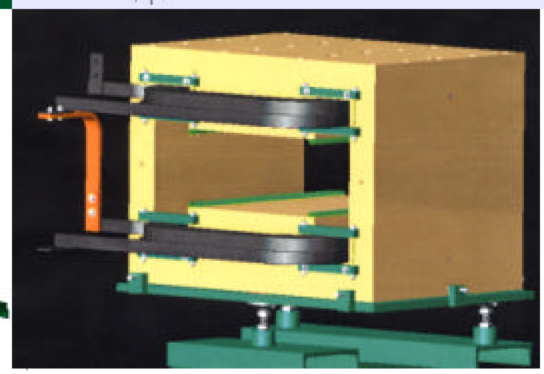


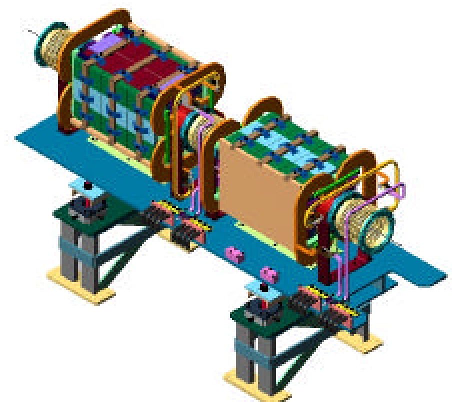


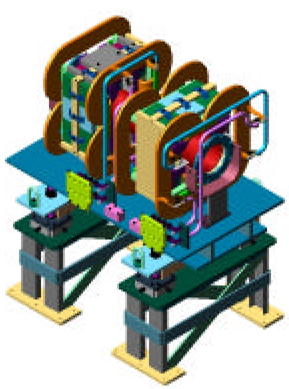


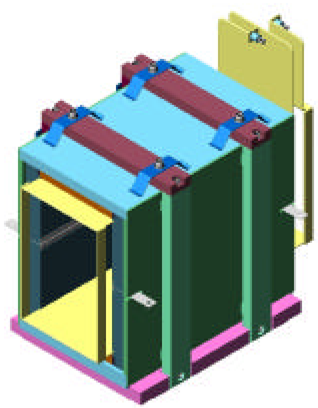


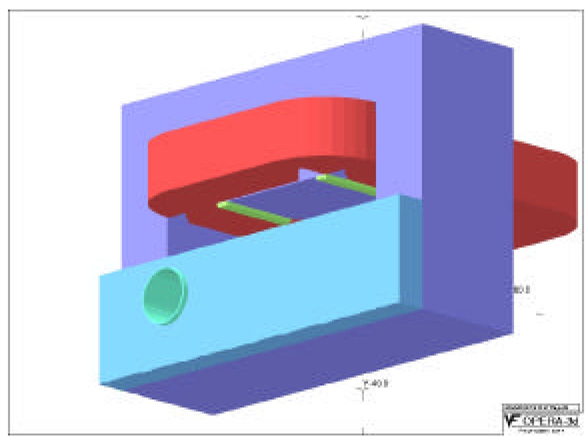


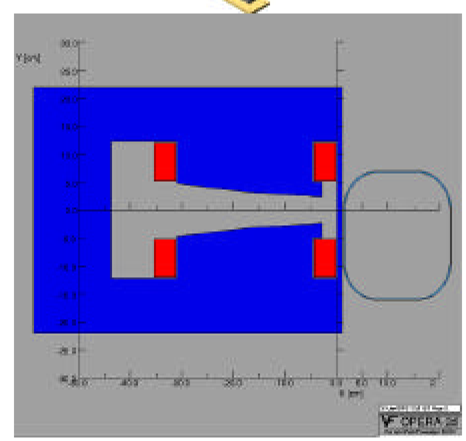






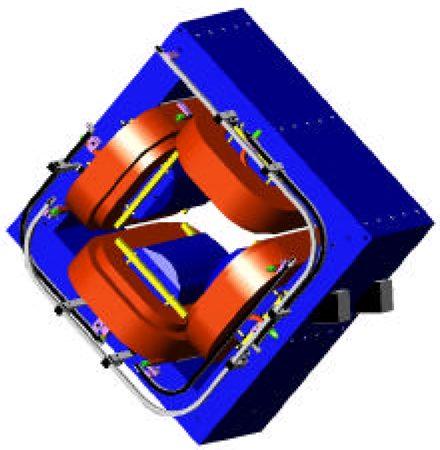


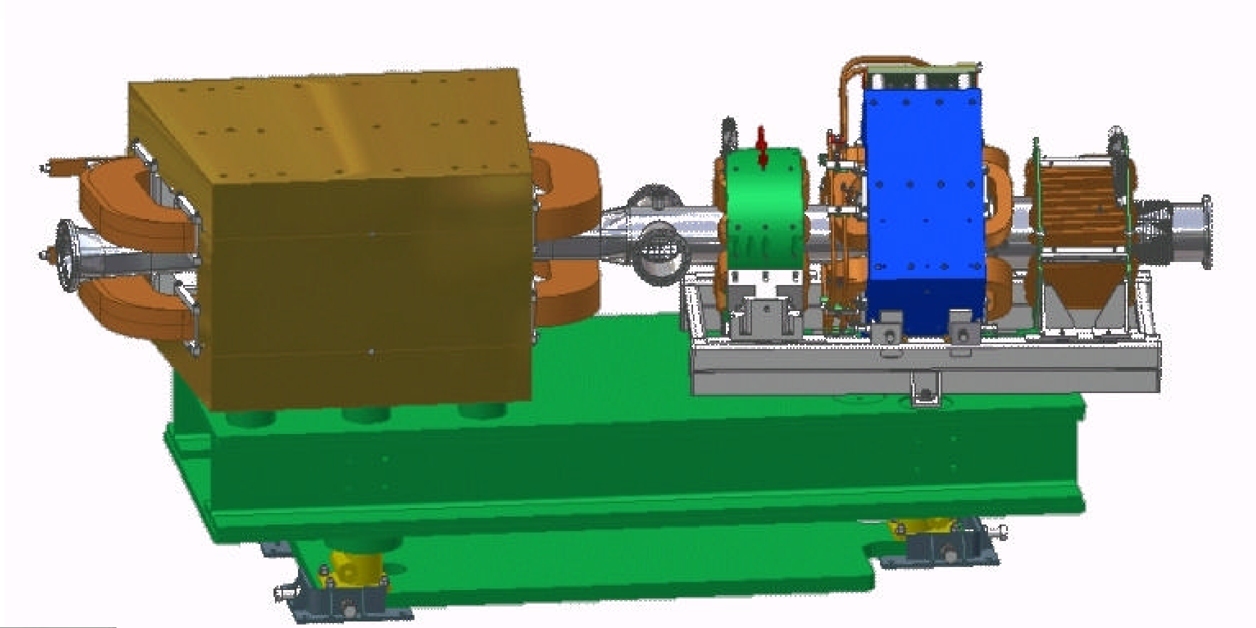


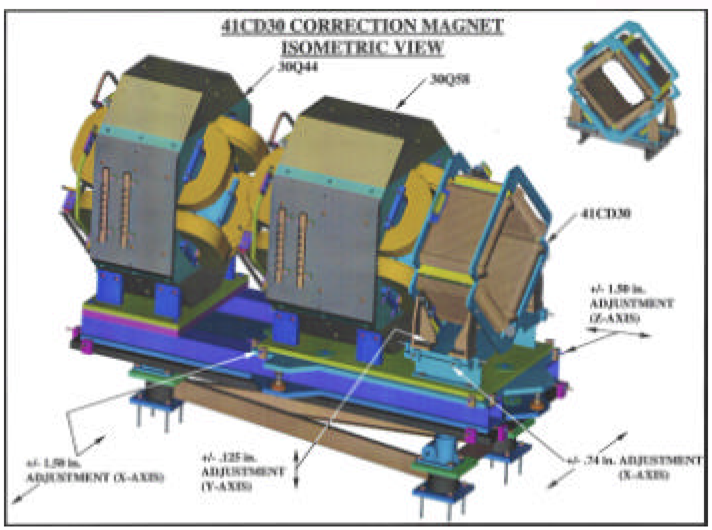


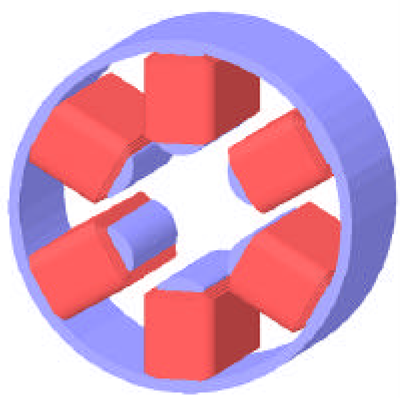
Magnet modeling (Ring)

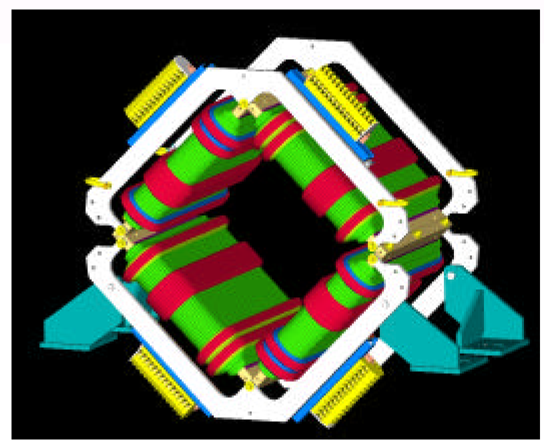
W. Meng, N. Tsoupas et al







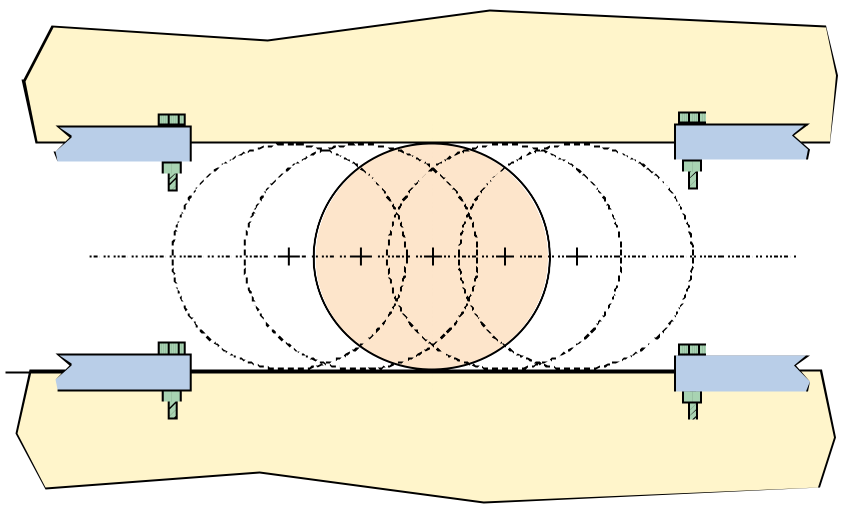




Ring dipole field quality

Wanderer, Jain, Jackson, Papaphilippou et al.

- Findings:
  - Satisfactory multipole values
  - Undesirable variation in dipole ITF (up to 2×10^{-3})
    - Solid-core iron, heats variation
    - Mechanical gap variation
- Effects well under control
  - dc COD (not a RCS ring!)
  - Sector dipole – redefine center



SNS DIPOLE MEASUREMENTS: FIVE HORIZONTAL POSITIONS; 2 INCHES APART

Summary of Field Quality in SD17 Dipoles

Harmonics in "Units" at a reference radius of 80 mm

(10 Magnets; Center Position)

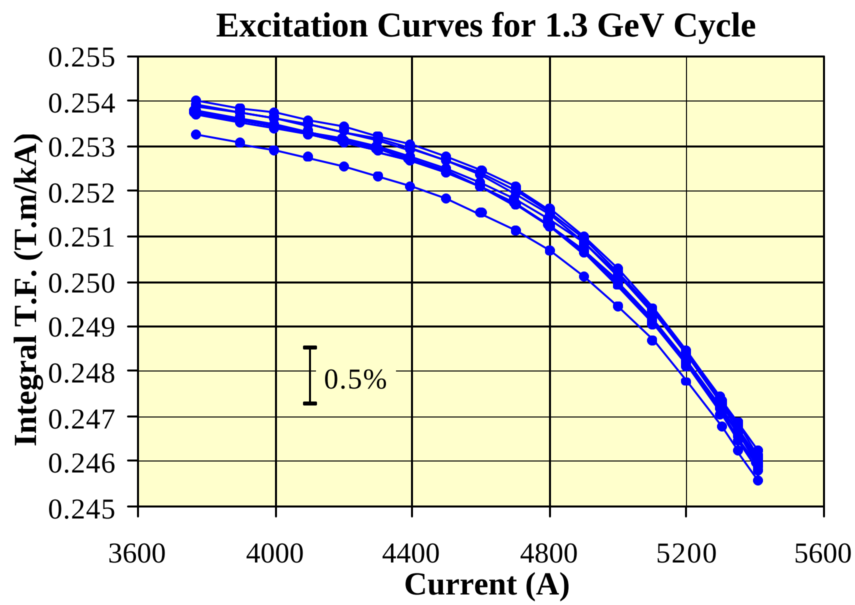
		1.0 GeV		1.3 GeV	
		Mean	Std.Dev.	Mean	Std.Dev.
	I.T.F. (T.m/kA)	0.25241	0.100%	0.24597	0.074%
	Fld Angle (mr)	-0.81	1.06	-0.84	1.06
Normal Harmonics	b_0	10000.0	0.00	10000.0	0.0
	b_1	-105.16	0.14	-103.79	0.17
	b_2	0.30	0.43	-6.13	0.44
	b_3	2.11	0.16	2.54	0.17
	b_4	1.15	0.24	-0.45	0.23
	b_5	0.06	0.10	0.07	0.10
	b_6	-0.32	0.17	-0.51	0.17
	b_7	0.15	0.07	0.14	0.07
	b_8	-0.06	0.17	-0.05	0.17
	b_9	-0.05	0.07	-0.05	0.07
	b_{10}	-0.19	0.20	-0.19	0.20
	b_{11}	0.01	0.08	0.01	0.08
	b_{12}	0.12	0.22	0.12	0.22
	b_{13}	0.01	0.06	0.01	0.06
	b_{14}	-0.09	0.23	-0.09	0.23

coil angle calibr. drifts

Sector dipole

Ring dipole transfer function

- Solutions:
  - Center survey with sorting
    - Large error at low dispersion
    - Compatible with Ring energy acceptance +/-5%
  - Sorting
    - Same offset, 180 deg. Apart
  - Correctors (26)
    - Worst case using 50% strength
    - Uncorrected: max. 4 mm COD
- Fixes, back-pocket plan
  - During re-assembly (all), select a few for gap/sides re-machining & remeasure
  - Back-leg winding after installation
  - Shunts (10 A) after installation

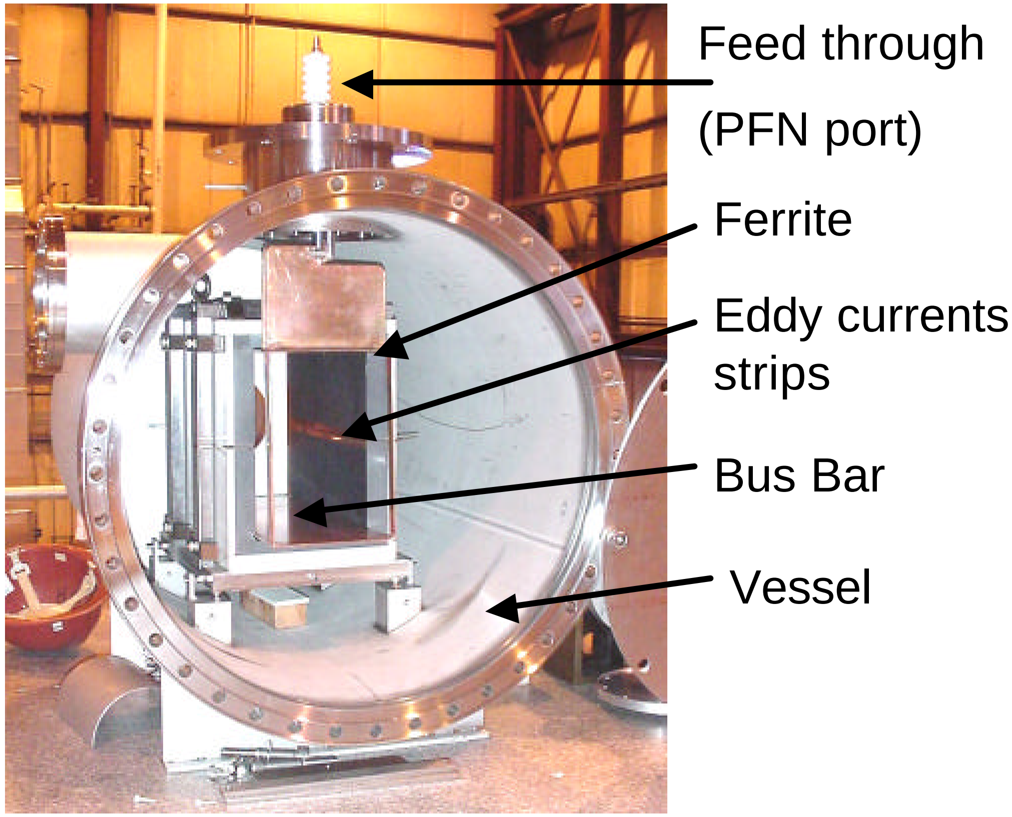


- Further measurement/analysis
  - Multipole conversion from straight to curved system
  - Add short-coil measure (5)
  - Sorting strategy analysis
  - Database entry for installation

Extraction kicker impedance minimization

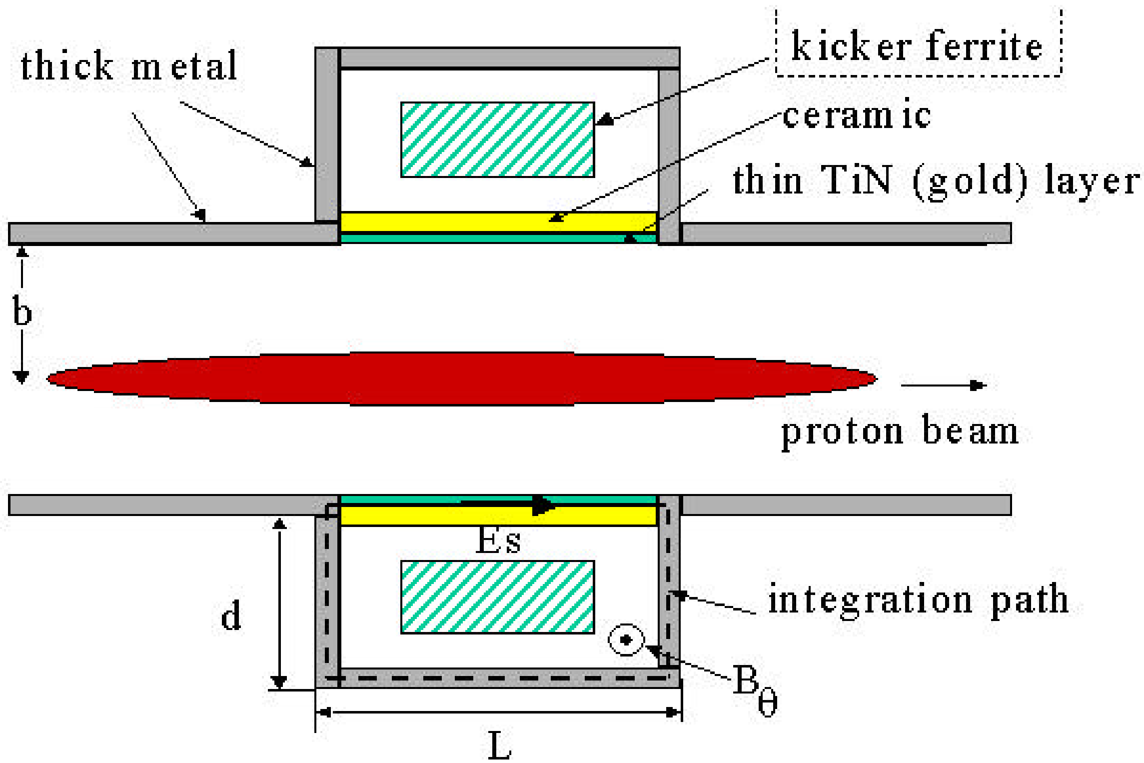
- Kicker rise time optimization
  - Add saturable inductor, reducing rise time by 50 ns
- "Banana" closed orbit
  - Circulating beam offset from kicker center (4.3 cm)
  - Kick proportional to intensity, varying from head/tail to body (COD~2 mm nominal)
  - Possible correction/damping with beam-in-gap kicker
- Ferrite of low-μ to be tested
  - 1 module material ordered
  - Impedance, vacuum, heating, rise time to be measured
- Inductance matching
- Repeated measurements (termination & cable, vacuum chamber effects…

D. Davino's & Fedotov's talks; H. Hahn, Y.Y. Lee, S. Kurennoy, J. Mi



Injection kicker ceramic coating

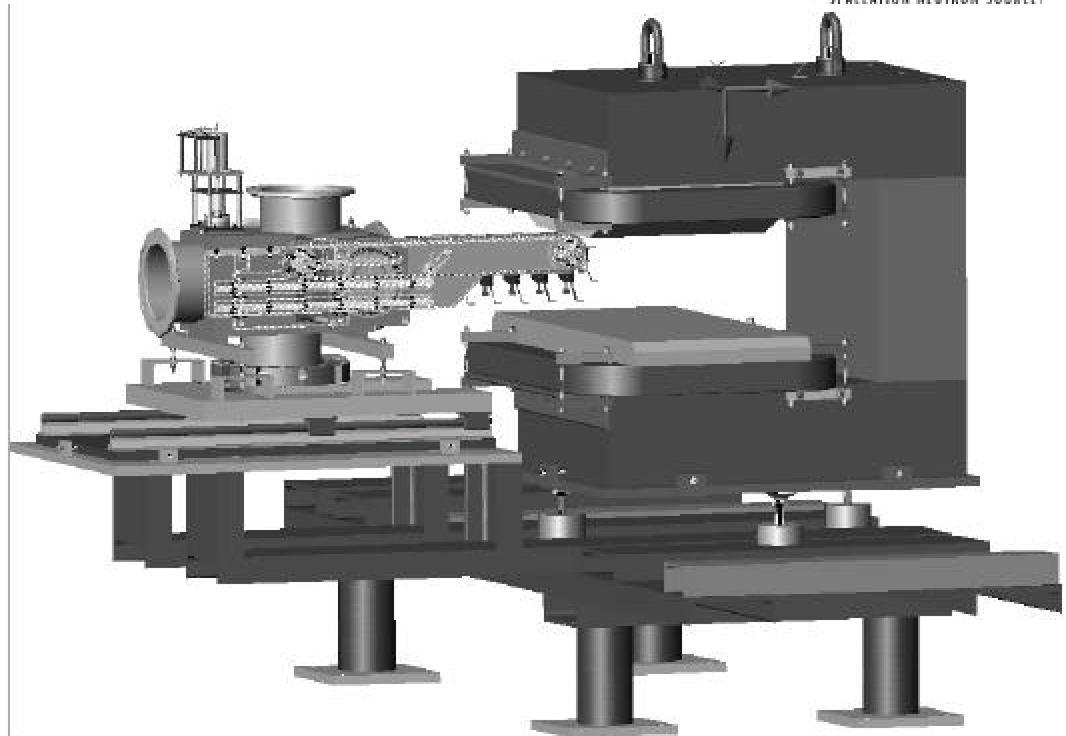
- Ceramic chamber coating
  - TiN layer for electron cloud; low electron SEY but low/ uncertain electric conductivity
  - Thicker gold layer for resistive (200 ~ 600 kHz) and higher
  - External shield for dc
- Coating thickness set by tolerable eddy current heating

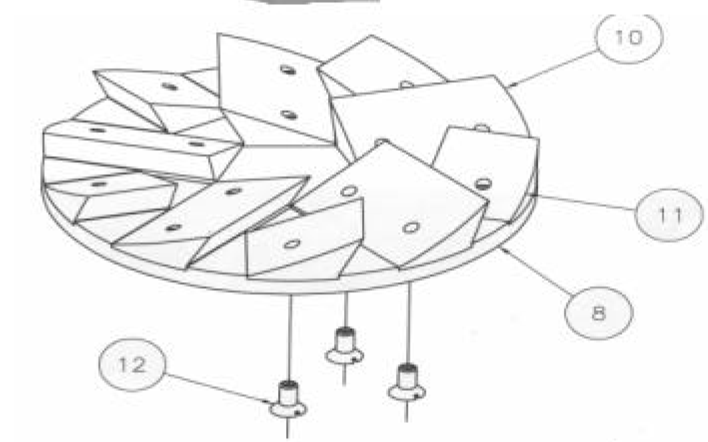


V. Danilov, S. Henderson, H. Hahn, H. Hseuh
D. Davino's talk

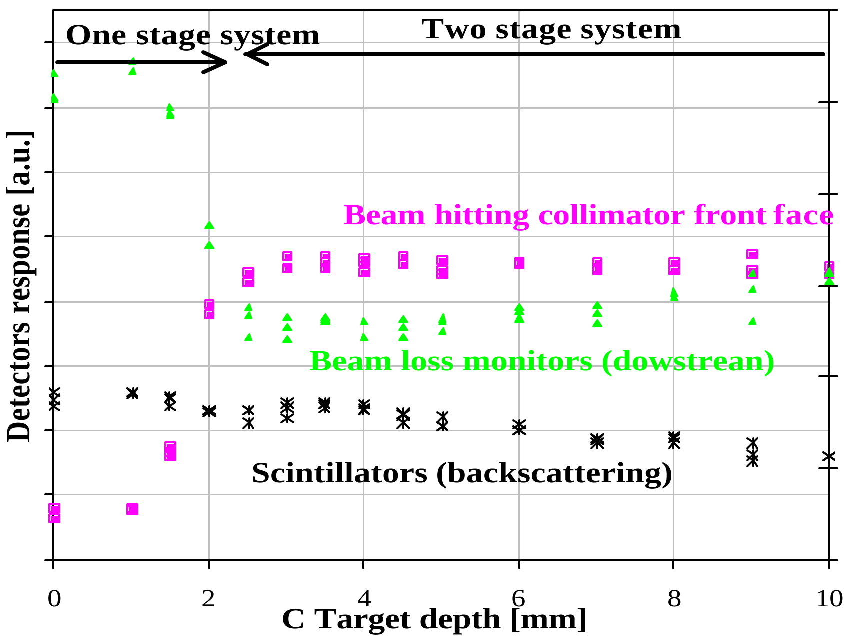
Injection foil stripping electron collection

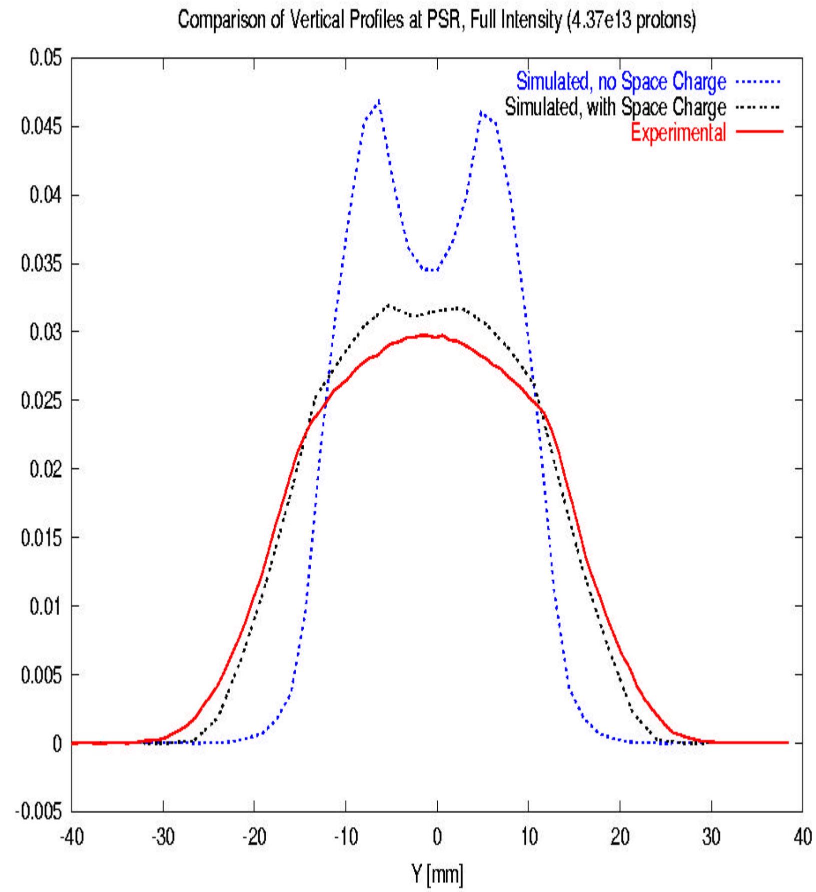
- electrons: 2 kW at 545 keV
  - Collected by water-cooled collector
  - Diverging field steers e-
  - Carbon-carbon catcher
- Tapering & anti-tapering
  - Compensate fields
- Back-scattering electrons
  - May cause heating problem (S. Henderson)
- Electron cloud control
  - Coating with TiN
  - Possible collecting electrods (need ~ 10 kV)?
  - Contain damage, use opposing solenoids?
  - Solenoid guiding field?





Machine study/codes benchmarking





Protvino 2-stage collimation: N. Catalan-Lasheras et al

PSR space charge & resonance benchmarking: S. Consineau, J. Holmes, A. Fedptov, R. Macek et al

Commissioning & Applications software

- Sub-system commissioners identified for Front-end, Linac, and Ring systems
- A collaborative application programming team is formed
  - J. Galambos, P. Chu (ORNL)
  - N. Malitsky, A. Shishlo (BNL)
  - C. Allen, P. McGehee (LANL)
- Weekly video Conferences
  - Also includes controls and diagnostics group participation
- Applications focus areas
  - Application programming infracstructure
  - Time correlated data collection
  - First applications for MEBT commissioning

Safety and reliability

- Possibly trading initial beam power for reliability
  - Possibly reduce duty cycle & peak current to extended ion source & power supply reliability
  - Keep IS and linac klystron PS hot spare
  - Individual matching scheme for missing SRF cavity/klystron
  - Injection foil exchange chain, kicker PFN hot spare
- Evaluate survivability time requirements for safety shut-down
  - 10 μs for MEBT/DTL, 1 – 2 pulses for HEBT/Ring/RTBT
- Evaluate critical diagnostics for Machine Protection Systems
  - Lock on fast loss monitors near stripping foil, collimators
- Evaluate critical devices for Machine Protection Systems
  - LEBT chopper, critical magnet power supplies, RTBT quad set window

Summary

- Main focus: identify and resolve construction issues
  - Feedback to vendor, resolve issues appearing weekly
- Topics resolved/approached
  - Front end beam halo mitigation
  - Chopper performance
  - Full end-to-end simulation
  - Linac Lorentz force compensation & RF overhead
  - Ring magnet measurement & compensation
  - Ring extraction kicker optimization and impedance control
  - Ring electron control
- Shifting focus towards commissioning while continuing efforts for full-intensity operation

Linac beam quality demands

- Output energy within +/- 5% window (avoid ring stripping loss)
- Key challenge: control transverse emittance and jitter
  – Goal: control ring stripping foil miss to 1-2% (Effective beam emittance growth through linac < factor of 2)
  – Compared with other facilities (e.g. 5 –8 times growth at LANSCE), identified transverse jitter as main issue; easier for 402.5 MHz DTL (vibration analysis)
- Control momentum spread and jitter
  – Facilitate longitudinal painting with a narrow paint brush
  – Need to control total energy deviation within +/- 0.3% (3 MeV)
  – Further correct phase error at corrector with feed-forward
- Reduce uncontrolled beam loss across linac
  – About 1 W/m and lower

Diagnostics requirements (general)

Device	Location	Intensity [ppp]	Pulse length [❍sec]	Range	Accuracy	Resolution	Data structure	Comments
BPM	MEBT	5e10 - 2e14	.3 - 1000	+/- 0.5*apert	+/-.5mm	.05mm	inside mini pulse	6, dual plane
(position)	DTL	2e10 - 2e14	.3 - 1000		+/- 1% of a	0.1% of a		?, dual plane
	CCL-SCL	2e10 - 2e14	.3 - 1000		+/- 1% of a	0.1% of a		
	HEBT	5e10 - 2e14	.3 - 1000	+/- 20mm	+/-1mm	0.15mm		20/38 each quad, dual plane, 402.5M
	Ring-RTBT	5e10 - 2e14		+/- 100 mm	+/-1 mm	0.15 mm	turn-by-turn	each quad/doublet, dual plane,402.!
BPM	MEBT	5e10 - 2e14	.3 - 1000	+/- 180 deg	+/-2 deg	0.1 deg		6, 805MHz
(phase)	DTL	2e10 - 2e14	.3 - 1000	+/- 180 deg	+/-2 deg	0.2 deg		?, 805MHz
	CCL-SCL	2e10 - 2e14	.3 - 1000	+/- 180 deg	+/-2 deg	0.2 deg		?, 402.5MHz
	HEBT	5e10 - 2e14	.3 - 1000	+/- 180 deg	+/-2 deg	0.1 deg		2?, 402.5MHz
IPM	Ring	5e10 - 2e14		+/- 64 mm	2 mm	2 mm	few per turn	three planes (H, V, 45 deg.)
Wire	MEBT		.3 - 100	+/- 15mm		0.2mm		three planes
	DTL							
	CCL-SCL		.3 - 100	+/- 15mm		0.2mm		three planes; each cryo.
	HEBT		.3 - 1000	+/- 50mm		0.2mm		three planes
	Ring-RTBT	5e10 - 2e14		+/- 100mm		0.2mm	turn-by-turn steps	three planes
Harp	DTL		.3 - 50	+/- 10 mm		1mm		after tank #3,#6; comissioning
	HEBT,RTBT	3e11-2e14		+/- aperture	1mm p.	.5mm	single shot	
Misc. profile	D-plate		.3 - 1000					video fluorescence
	Ring							foil video
BLM(10 Hz)	Linac-Ring	1e7 - 2e14	.3 - 1000	1-1000 rem/h	1%	0.6%, .5r/h	average at 10Hz	of 1W/m
BLM(35 kHz)	Linac-Ring	6e8 - 2e14	.3 - 1000	30-2.5e5 rem/h		30r/h	once /10 turns	
FBLM	DTL-to-CCL		.3 - 1000	1-1000 rem/h			inside mini pulse	fast; not calibrated
	SCL-to-HEBT		.3 - 1000	1-1000 rem/h			inside mini pulse	fast; not calibrated
	Ring			1-1000 rem/h			intra turn	fast; not calibrated
Current	MEBT-to-HEBT		.3 - 1000	15mA - 52 mA	+/- 1%	.1%	inside mini pulse	
	Ring-RTBT	5e10 - 2e14		15mA-100A	+/- 1%	.1%	turn-by-turn	
Phase width	HEBT		.3 - 1000	0 - 600ps	15ps (5deg)	15ps (5deg)		??? LANL
Tune	Ring				+/- 0.001			tune kicker/pick-up+PLL
Beam-in-gap	HEBT		.3 - 1000	0 - 0.1mA	20%	.5mkA	each midi pulse	laser neutralization
	Ring			0 - 0.1 A	20%			BIG kicker/monitor
Emitance	MEBT		.3 - 10		10%			H & V
	D-plate		.3 - 50		10%			H & V
e - detectors	Ring			2e8 - 2e11 (e-)	5%	1e8 (e-)	turn-by-turn	conspicuous locations
WB BPM	Ring			+/- 1-60 mm?	+/-1 mm	0.5 mm	turn-by-turn	100MHz BW
Laser wire	MEBT, DTL, ...?		.3 - 1000	+/- 15mm		.5mm ?		dual, three plane ?
HM monitor	Ring ?							"High moments" of transverse distr.

Electron cloud & design implementation

- Ring design incorporated all known e-p mitigation features
  - Implementations to minimize electron production
    - Tapered magnets for electron collection near injection foil
    - TiN coated vacuum chamber to reduce multipacting
    - Striped coating of extraction kicker ferrite (TiN)
    - Beam-in-gap kicker to keep a clean beam gap (10^{-4})
    - Relatively good vacuum ($5x10^{-9}$ Torr)
    - ports screening, step tapering
    - Install electron detectors around the ring
    - Possibility of winding solenoids in the collimation section
  - Machine design to enhance damping
    - High RF voltage to provide momentum acceptance:
      40 up to 60 kV (h=1) + 20 kV (h=2); momentum painting
    - Planned lattice sextupole families for chromatic adjustments
    - Reserve space for possible wide band damper system

Ring simulation codes development

N. Malitsky, A. Shishlo (UAL); J. Holmes, V. Danilov, S. Cousineau (ORBIT)

	UAL	ORBIT	FTPOT	MAD 8	MARYLIE 3.0	ACCSIM	SIMPSONS
Interface	PERL API	SuperCode	FTPOT	MAD	MARYLIE	ACCSIM	SIMPSONS
MAD elements	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Errors	Yes	No	Yes	Yes	No	No	Yes
Tracking	Thin lenses	Matrices + nodes	Thin lenses	Lie algebra	Lie algebra	Matrices + nodes	Thin lenses
Mapping	Any order	Second order	Second order	Third order	Third order	Linear order	No
Painting	Yes	Yes	No	No	No	Yes	Yes
Fringe Field	Yes (Maps)	No	No	No	Yes	No	No
Space Charge	3D	3D	No	No	No	2.5D	2D and 3D
Analysis (Twiss …)	Yes	No	Yes	Yes	Yes	No	No
Optimization (Lattice …)	No	No	No	Yes	Yes	No	No
Correction (Orbit …)	Yes	No	Yes	Yes	Some	No	No
Impedance	Yes	Yes	No	No	No	No	No
Collimator	in progress	Yes	No	No	No	Yes	No
Integration of lattices	Yes	No	No	No	No	No	No

[redacted]