RFQ/MEBT Physics Issues

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SNS Front-End Systems

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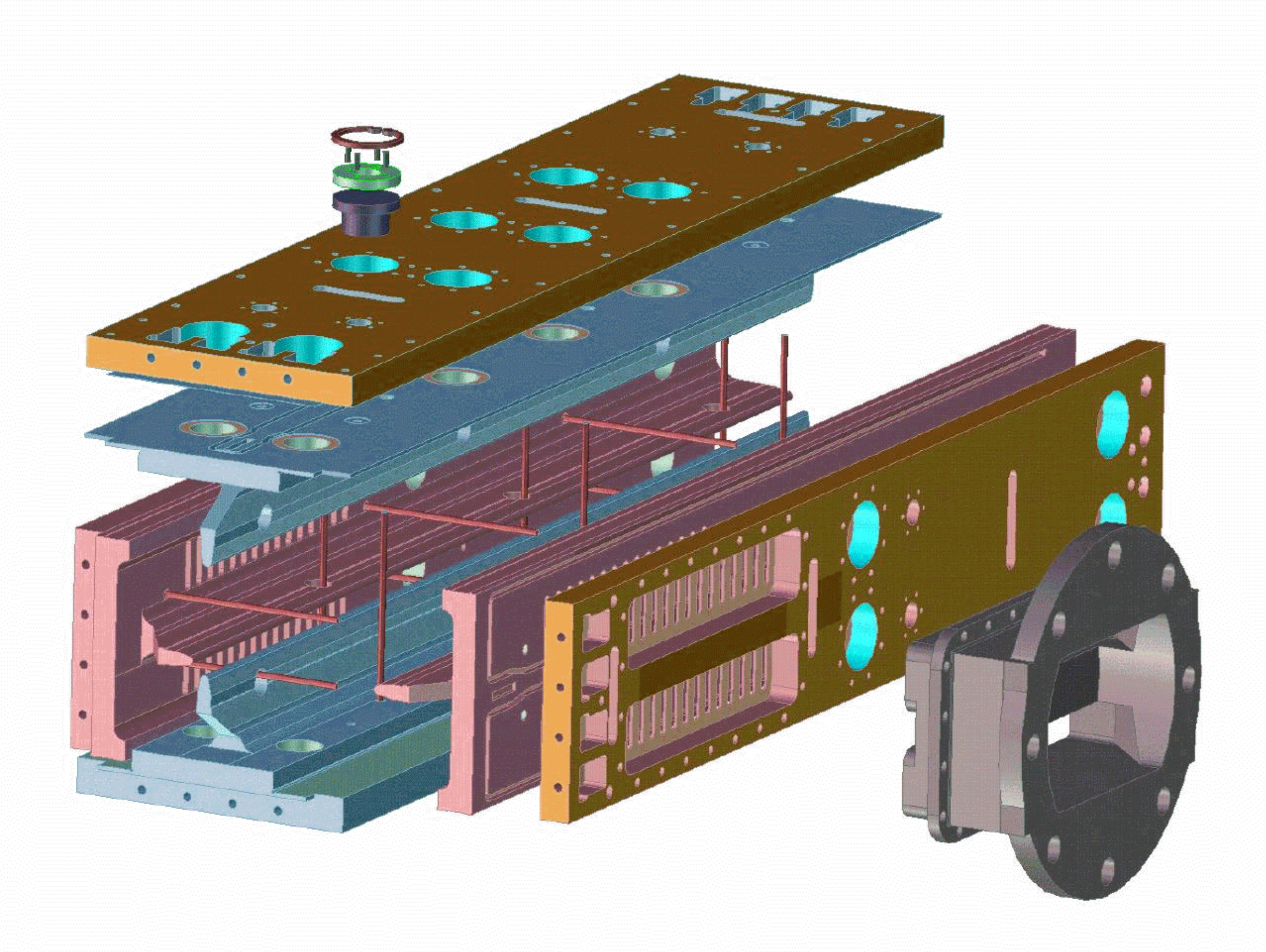
Presentation Overview

- Parameter Table
- RFQ Beam Dynamics
- MEBT Beam Dynamics
- End-to-end particle tracking studies
- Diagnostics
- MEBT Chopper

Parameter Table Summary

- H^- ion source
- 2.5 MeV into DTL
- low to 52 mA current range
- 1 msec pulse with 60 Hz rep rate
- Emittances (normalized, rms):
  - transverse: 0.25-0.27 π mm-mrad, MEBT exit
  - longitudinal: 126 π keV-degree
- Chopper:
  - 68% duty factor, <10 nsec rise/fall
  - $>10^4$ on/off ratio
- 402.5 MHz operating frequency

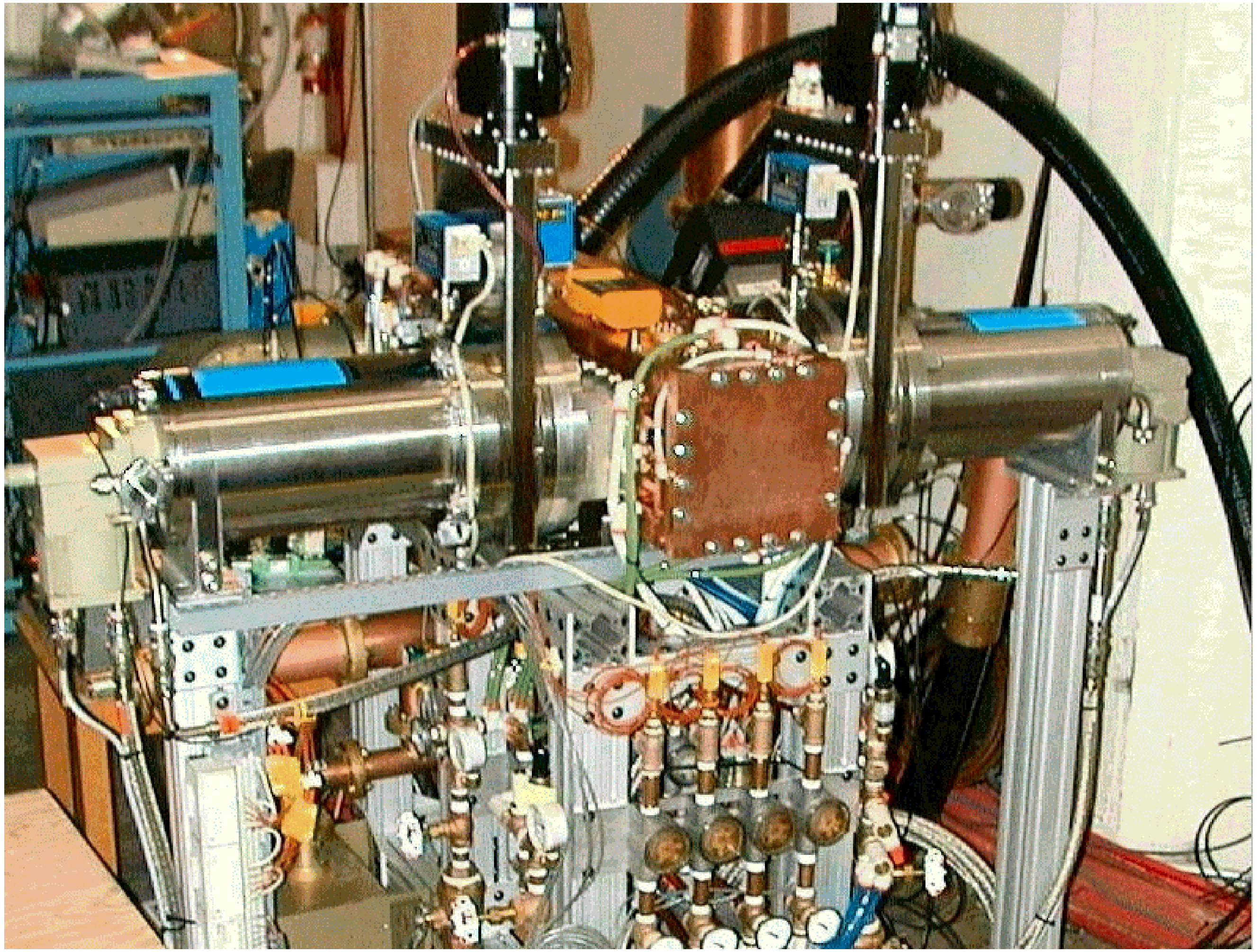
RFQ Components



RFQ Beam Dynamics

- Wide range of input current with low longitudinal output emittance, flat over 14-52 mA
- Choke current ~twice peak output current
- 1.85 kilpatrick surface field
- Simple vanetip shape, good beam performance
- 610 kW cavity power (67% of $Q_{theoretical,}$ measured)
- 130 kW beam power

Alpha Module on RF Test Stand



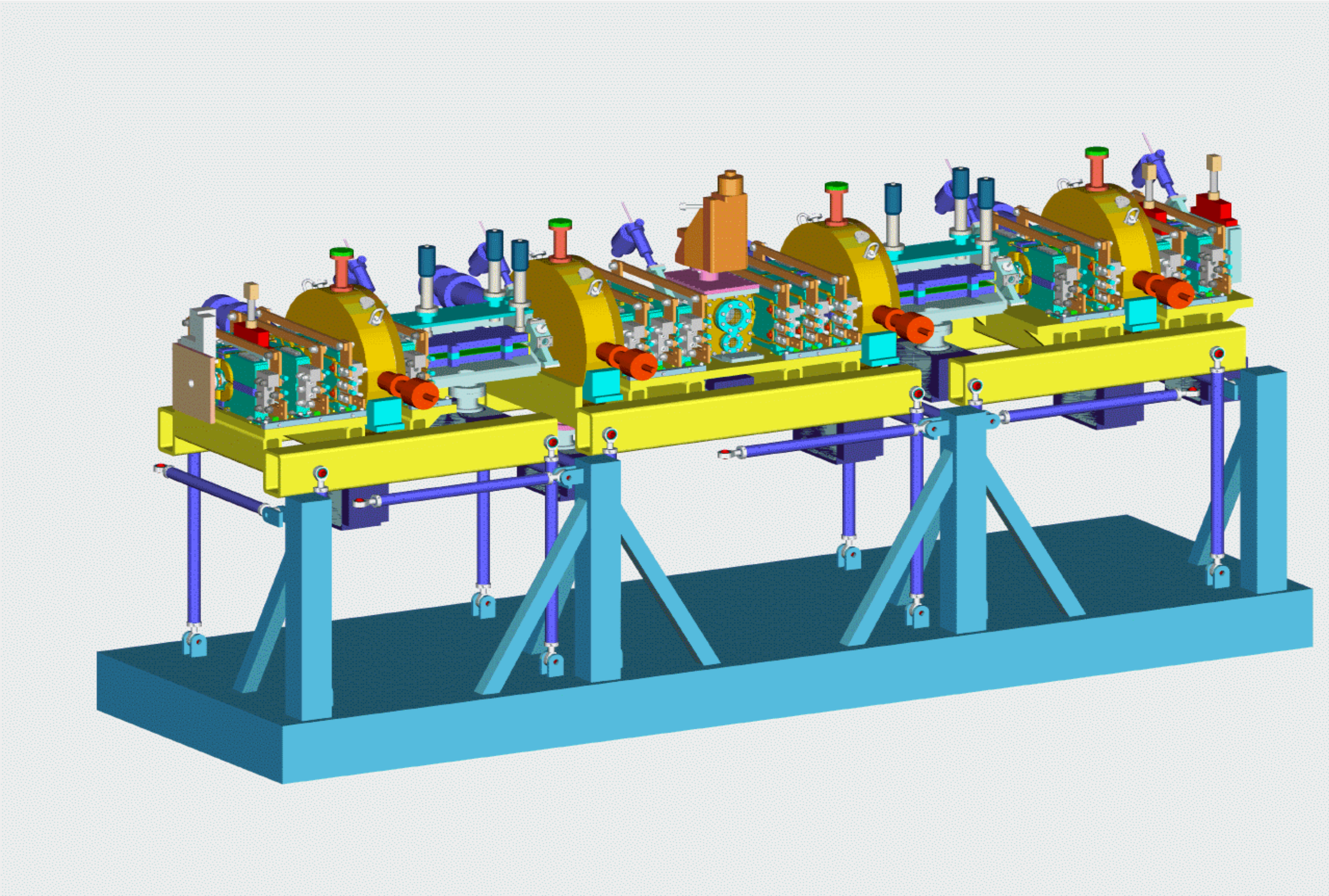
Alpha Model RF Conditioning

- RFQ conditioned with 1 RF drive port
- Brought to full gradient in 10-15 hours, 10 Hz, 100 microsecond pulse
- Quickly brought to 3% duty factor (both 30 Hz, 1 msec, and 60Hz, 0.5 msec).
- After 2 months of operation at full gradient, inside of RFQ looks very clean.

MEBT Beam Dynamics

- Transport beam from RFQ to DTL
- Provide second level (fast) chopping
- To minimize emittance growth:
  - Adiabatic changes in betatron phase advance
  - Minimize drift length (chopper lengths)
  - Strong focusing, regular lattice (as much as possible)
  - Don’t let bunch length grow too much
  - Don’t let charge density get too high

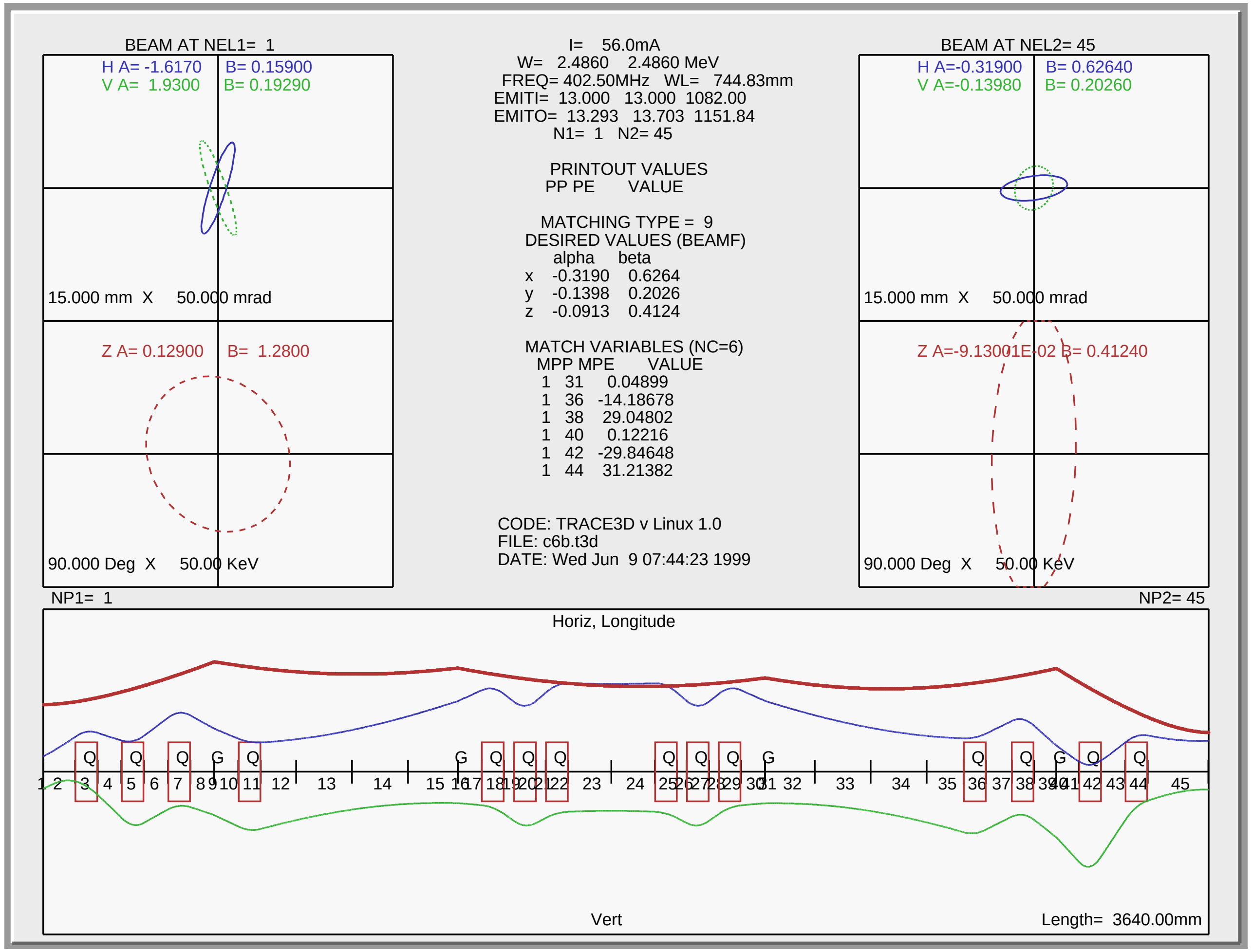
MEBT Configuration



MEBT Design Approach

- Incorporate chopper-antichopper pair
  - don’t need 2 nsec chopper rise
  - partially chopped bunches acceptable downstream
- 4-quad input, output matchers
- Quad triplet each side of chopper target
- Four rebuncher cavities
- No abrupt changes in phase advance
- Sufficient diagnostics for beam-based tuning
- Steering every 90 degrees phase advance

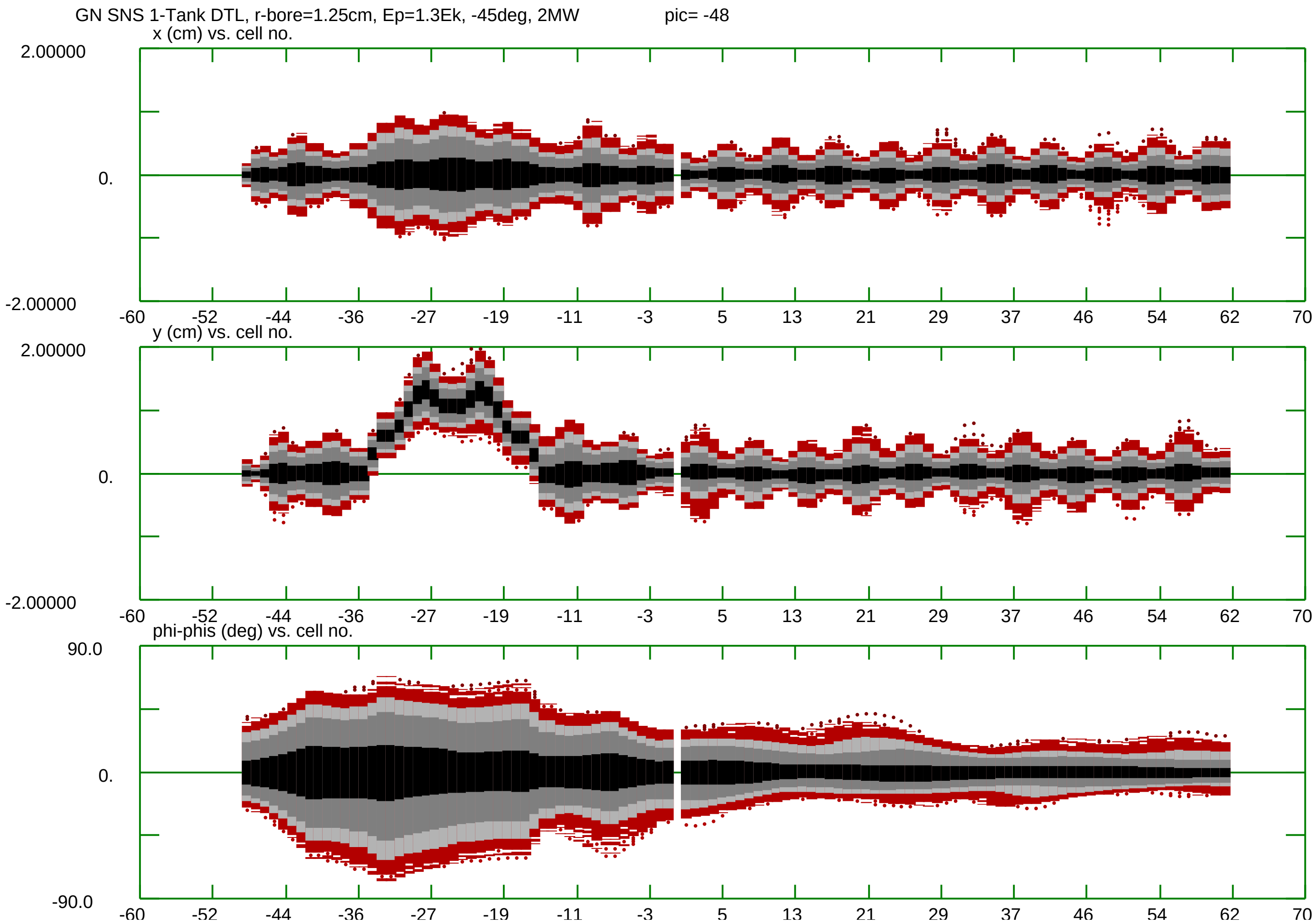
Trace3D Beam Envelope



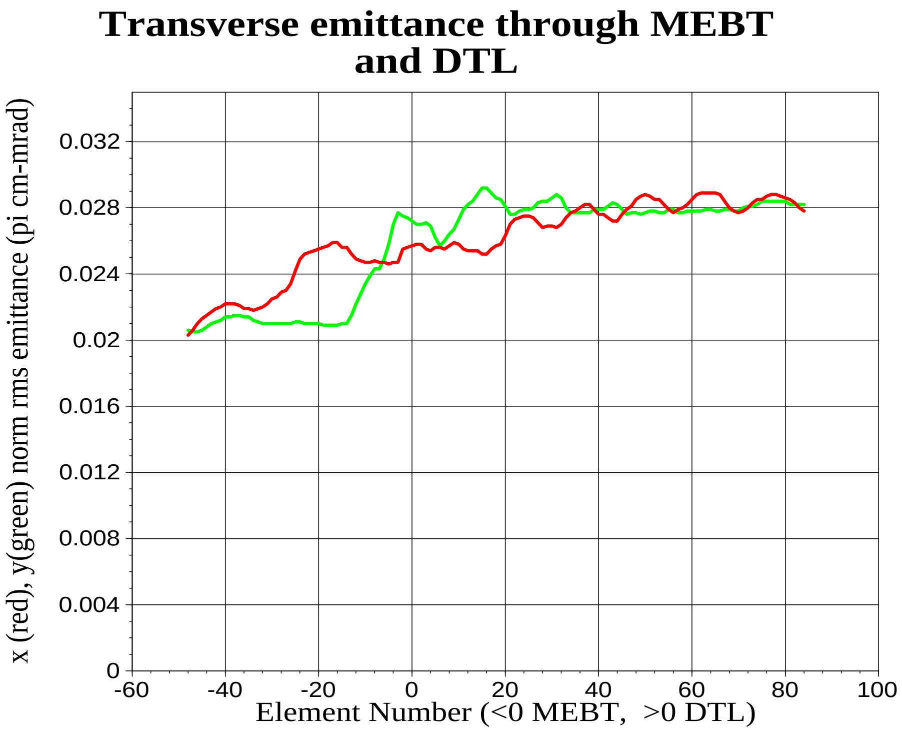
Macroparticle Simulations

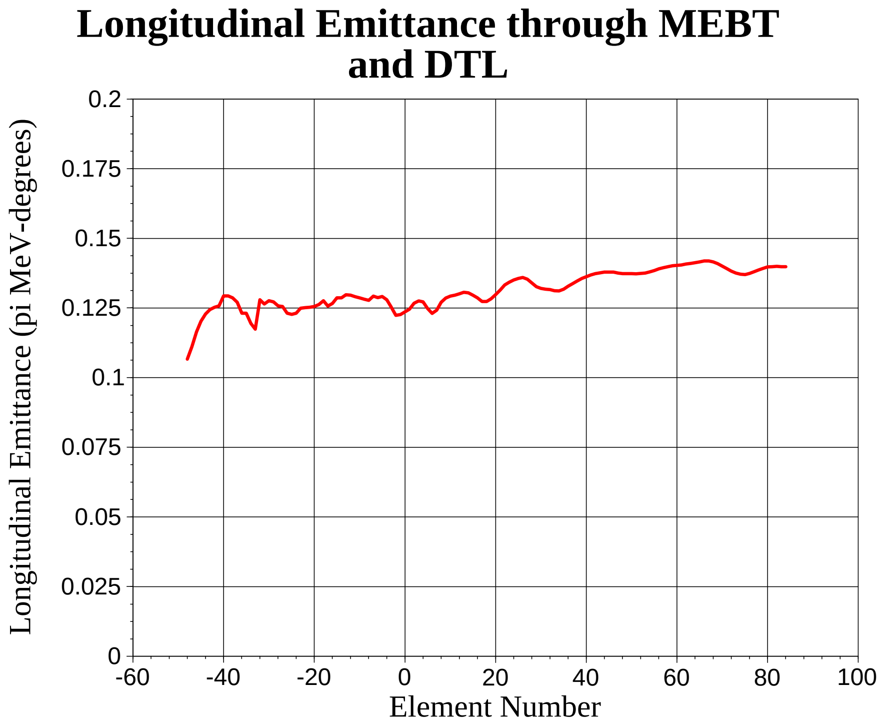
- Use LANL Parmila code
  - Code well benchmarked
  - Unify LBNL and LANL simulations, files
- Include DTL in LBNL MEBT simulations
- LANL gets complete RFQ, MEBT definition files to continue simulations and to suggest improvements
- Error simulations coordinated with LANL

Macroparticle Simulation



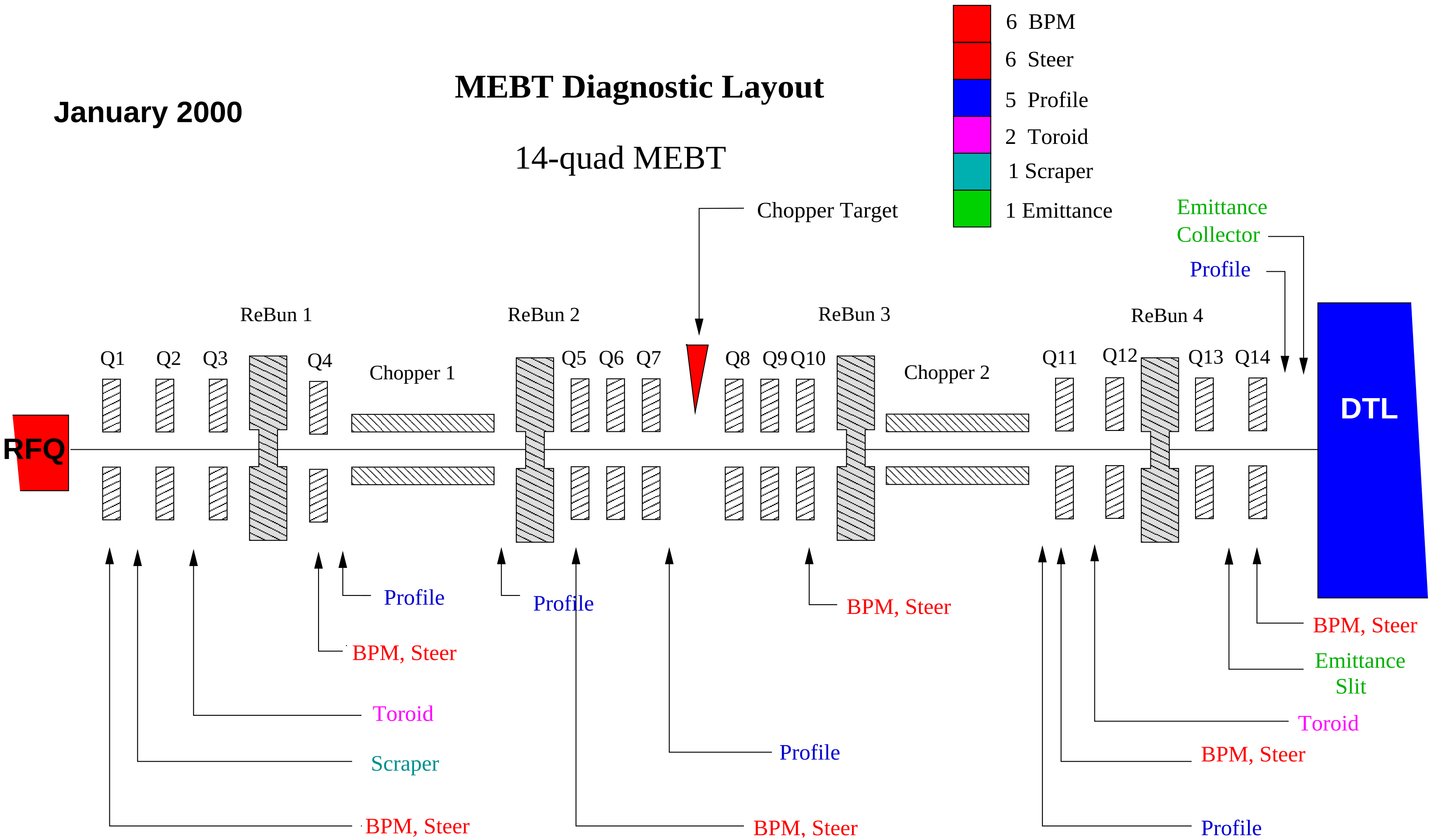
Emittance Growth in MEBT,DTL





MEBT Diagnostics

January 2000



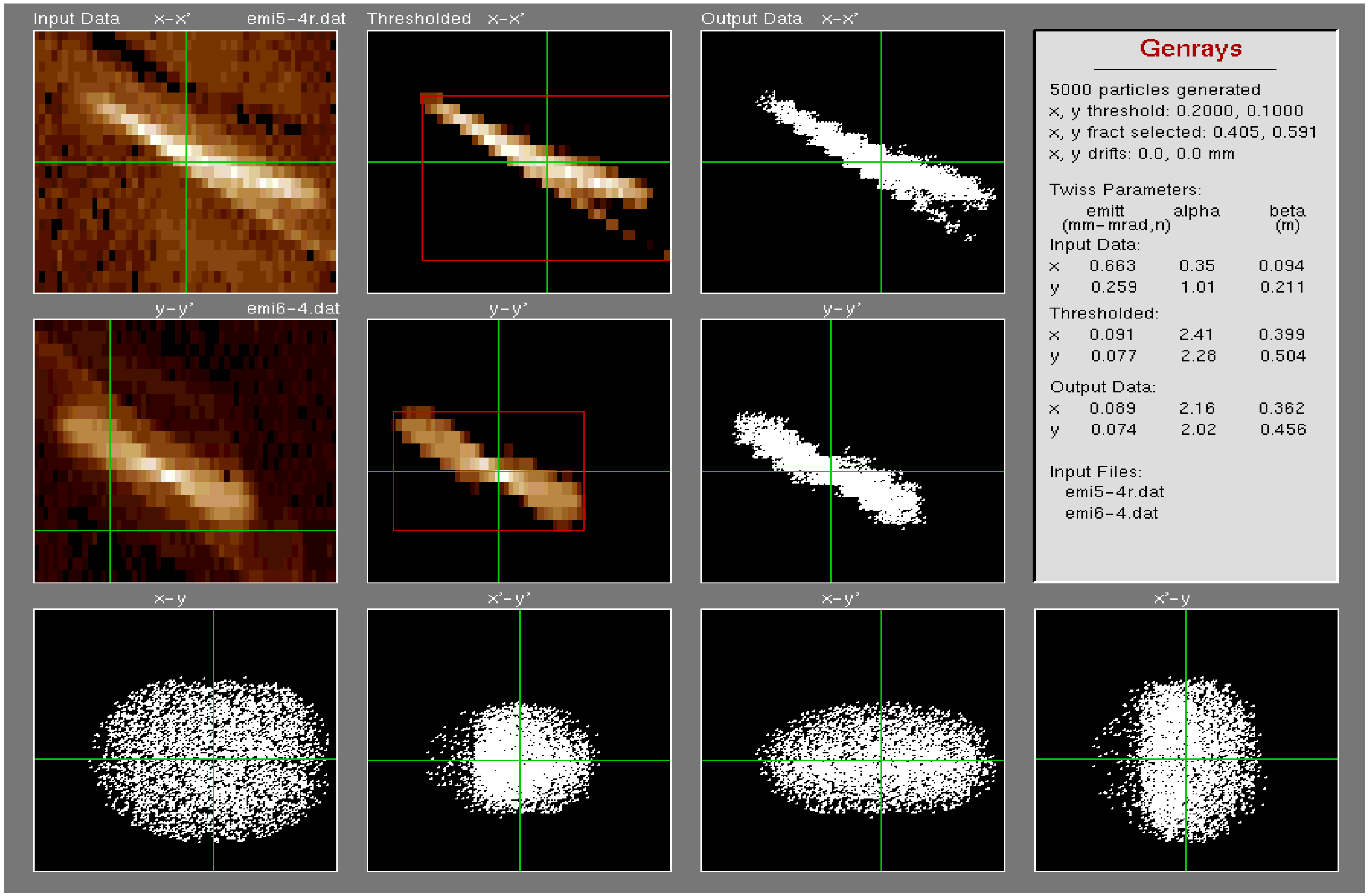
End-to-End Tracking Studies

- Provide 11 (1 with no errors) cases
- 10^4 particles for each case, 60 mA into RFQ
- LBNL can now do 10^6 particles
- LANL runs cases through linac with errors
- The output is then sent to BNL
- Seamless from RFQ entrance through ring
- LBNL, LANL use same linac code for MEBT
- LANL now runs up to 10^6 particles, starting with the RFQ, including RFQ and MEBT errors

Generation of RFQ Input

- All runs so far use waterbag distribution into RFQ. Twiss parameters adjusted for best RFQ output.
- When ion source performance satisfactory and good data available, input distribution will be derived from ion source emittance data
- LBNL codes have been upgraded to 10^6 particles.

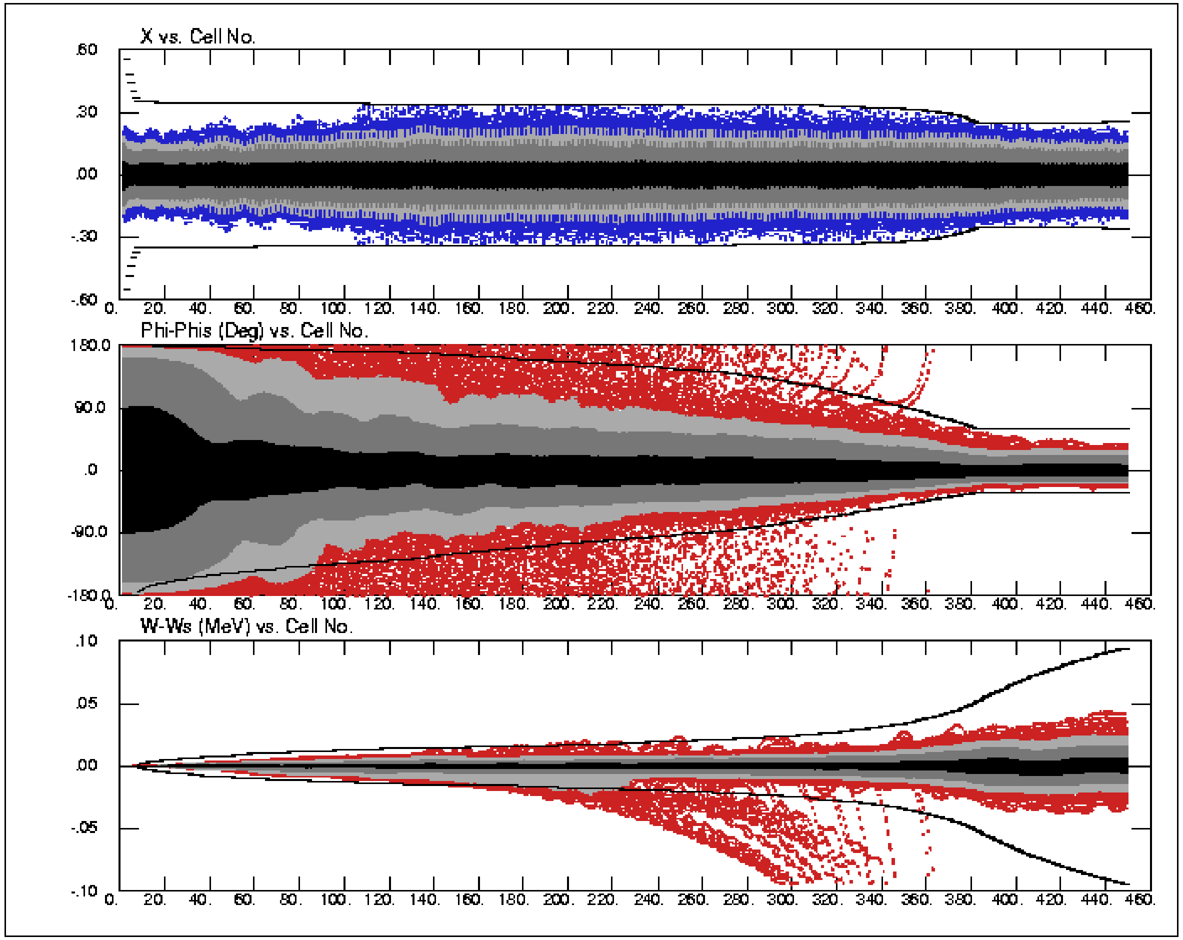
Test of Input Ray Generator



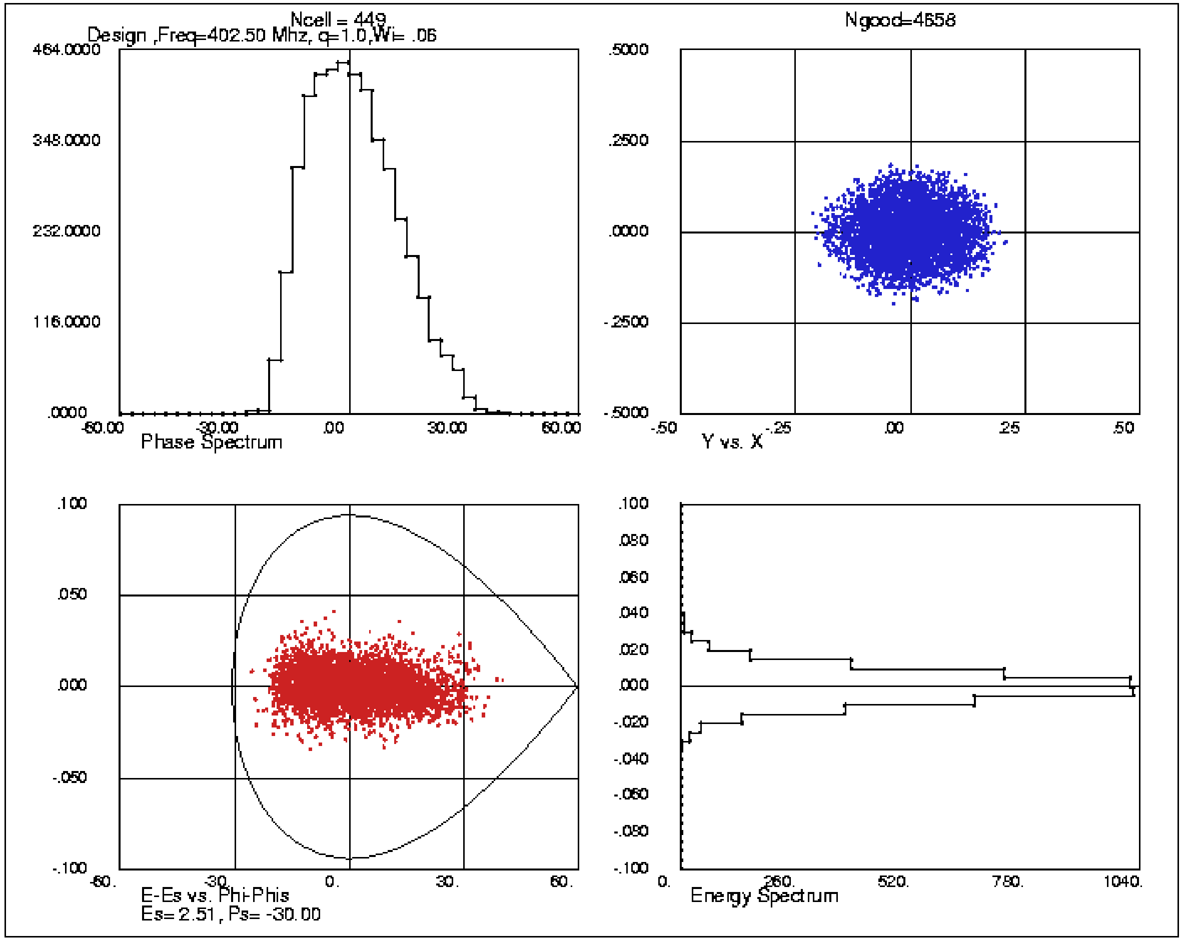
RFQ as an Emittance Filter

- RFQ output phase space essentially independent of input phase space
- Only transmission suffers
- LEBT mismatch or large ion source emittance does not affect gross features or details of RFQ output beam
- Tracking of beam through MEBT and first DTL tank shows no deterioration of 7.5 MeV beam, except for reduced current due to lower RFQ transmission

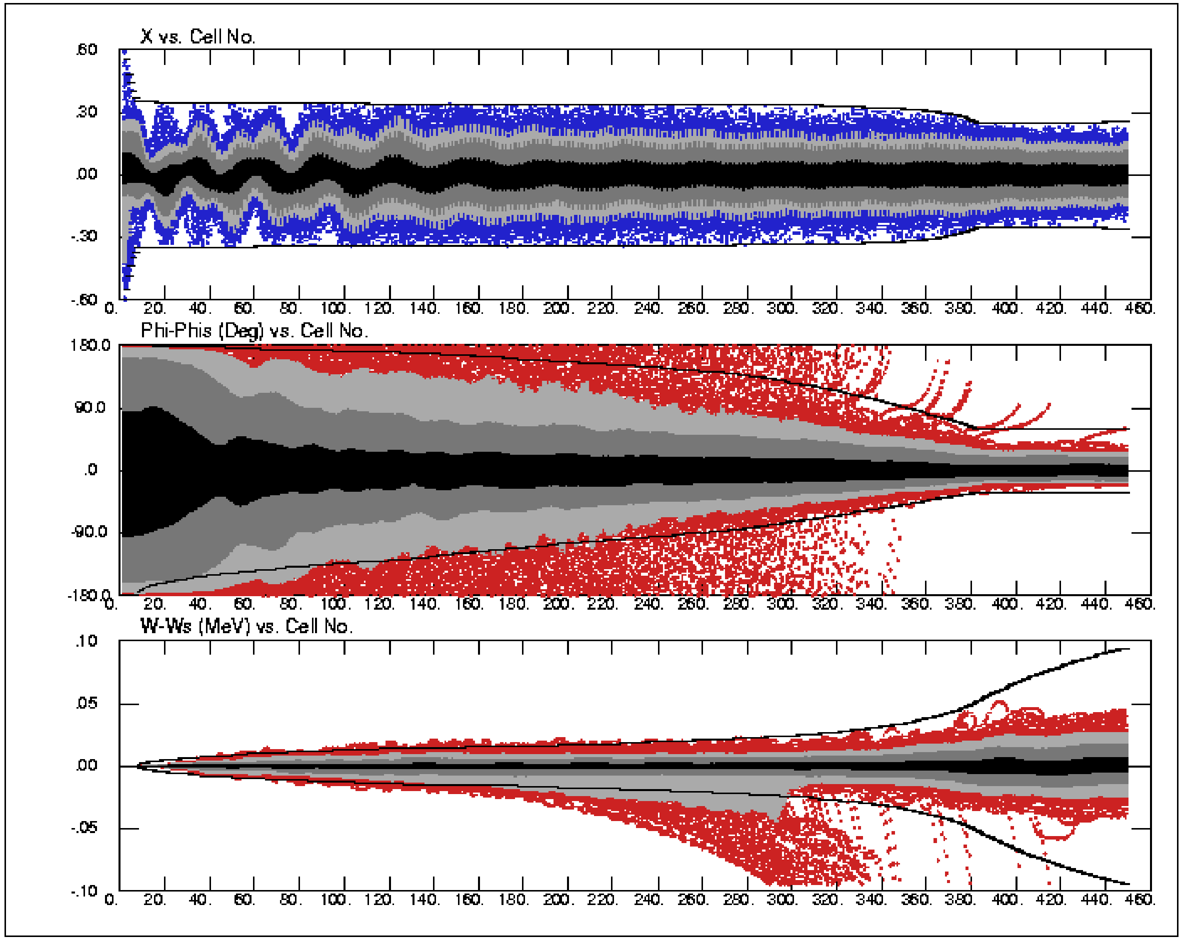
Well Matched Input Beam



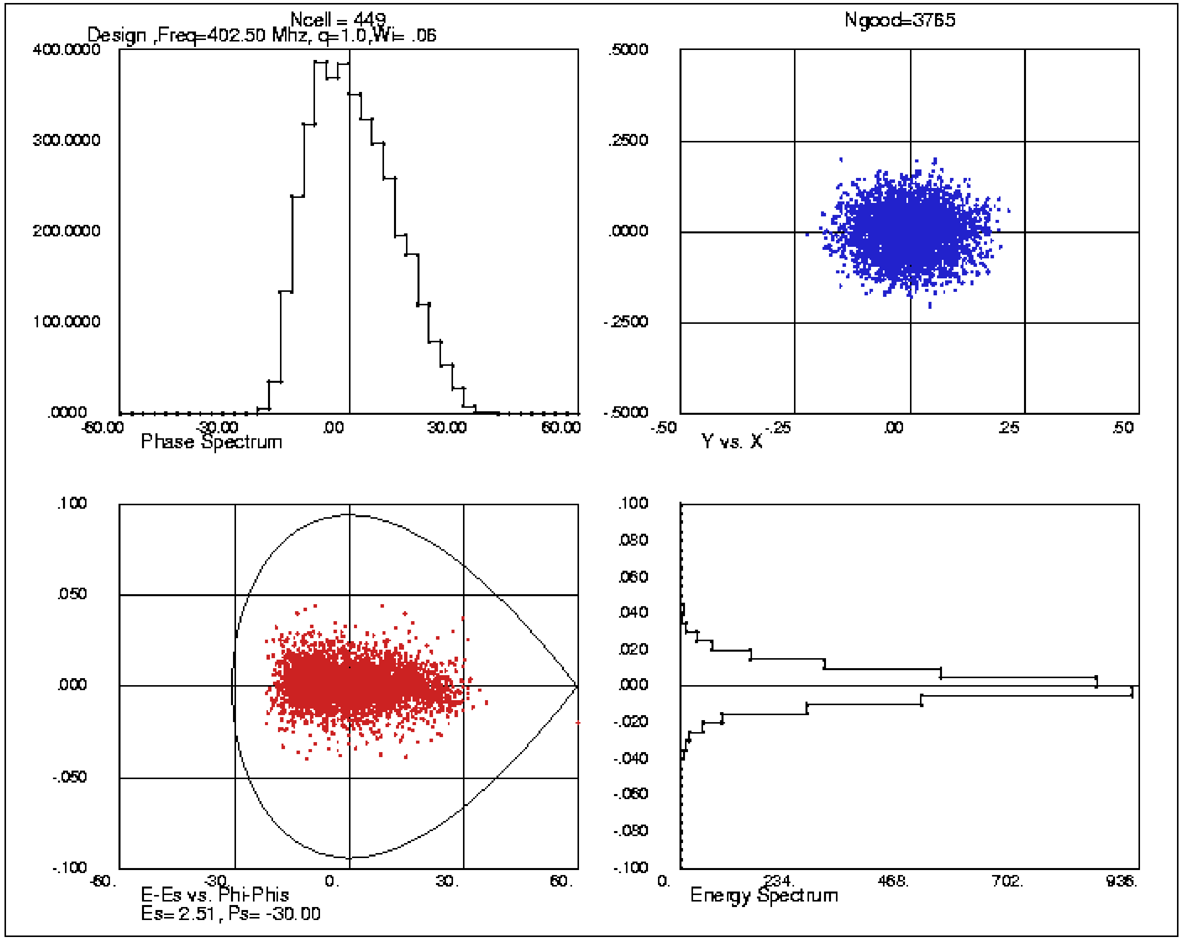
Longitudinal Phase Space



Beam From Actual Ion Source Data



Longitudinal Phase Space



Chopper Requirements

- 945 nsec pulse rate, 302 nsec notch
- 40 nsec LEBT prechop rise/falltime
- MEBT a cleanup chop
  - 10 nsec rise/falltime
  - > 10^4 on/off ratio
- Symmetric chopper-antichopper
- Chopper hardware supplied by LANL

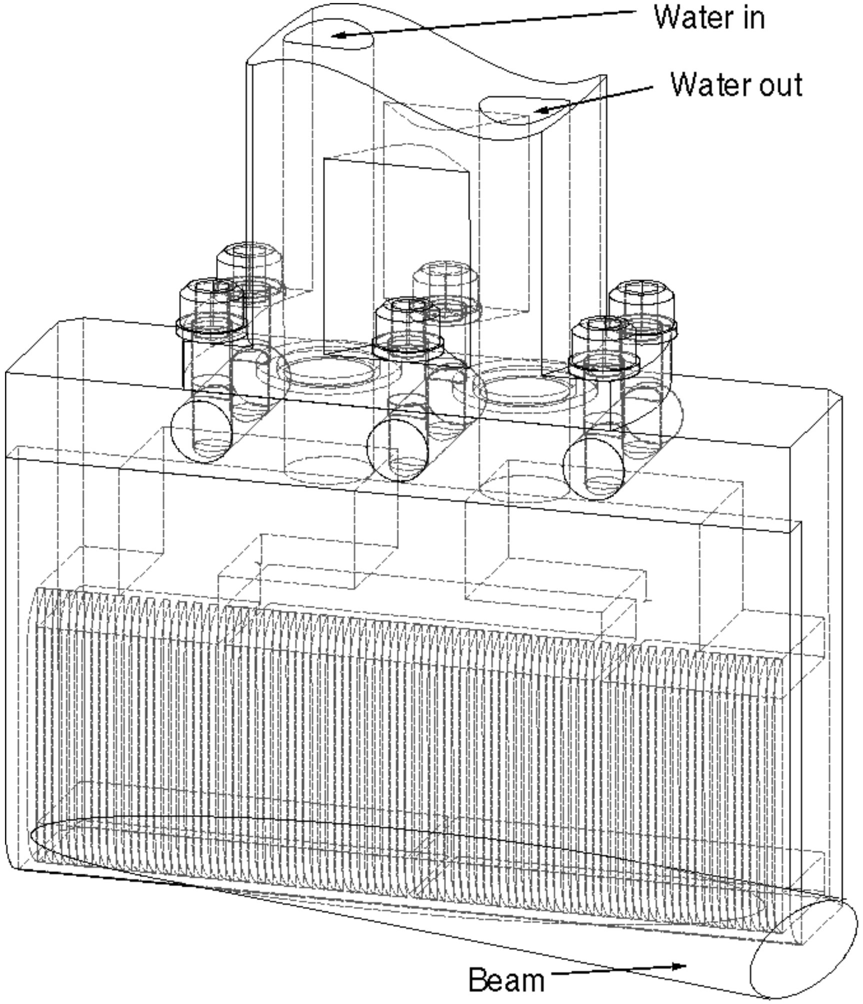
Chopper Implementation

- Dual-chopper system
  - pre-chop in LEBT
  - clean-up chop in MEBT
- Prechop reduces power load on MEBT target
- Dual system insures high on/off current ratio
- LEBT chopper prototyped 2 years ago with actual chopper power supplies

Chopper Target

- Moly (TZM) target used
- Microchannel water cooling
- Beam hits at 75 degree glancing angle
- Maximum stress 35 ksi
  - TZM yield about 90 ksi
  - 30% derating applied for fatigue fracture
  - run at about 50% of derated yield limit
- Sputtering lifetime is years

Chopper Target



Summary

- Parameters stable
- Mechanical design compatible with physics design
- Error tolerances reasonable for FES
- Simulations complete at LBNL
- Seamless end-end simulations thru ring
- Hardware is starting to hit the floor