Ramp-up Progress:
Challenges, Beam-loss overview, AP Topics

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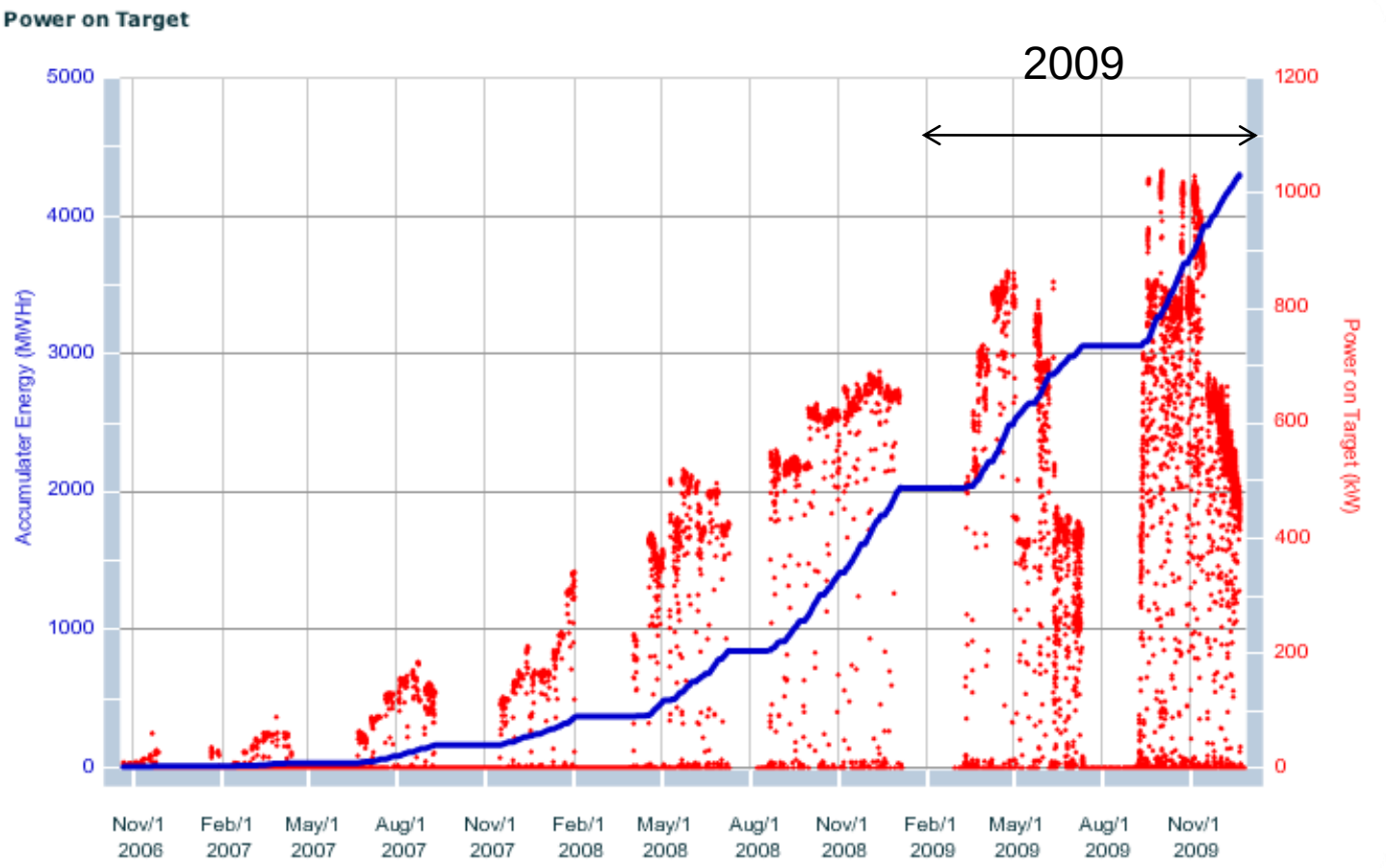
Spallation Neutron Source AAC, February 03, 2010

Action Items (Summary) / Outline

- Understand the origin of observed beam loss
  - Model + measurements
  - Linac + ring
- Continue “R&D” efforts
  - Laser stripping + high intensity
- Misc.
  - Fix collimator
  - Calibrate beam loss

+ beam loss and progress related to action items

Beam Power Ramp-Up

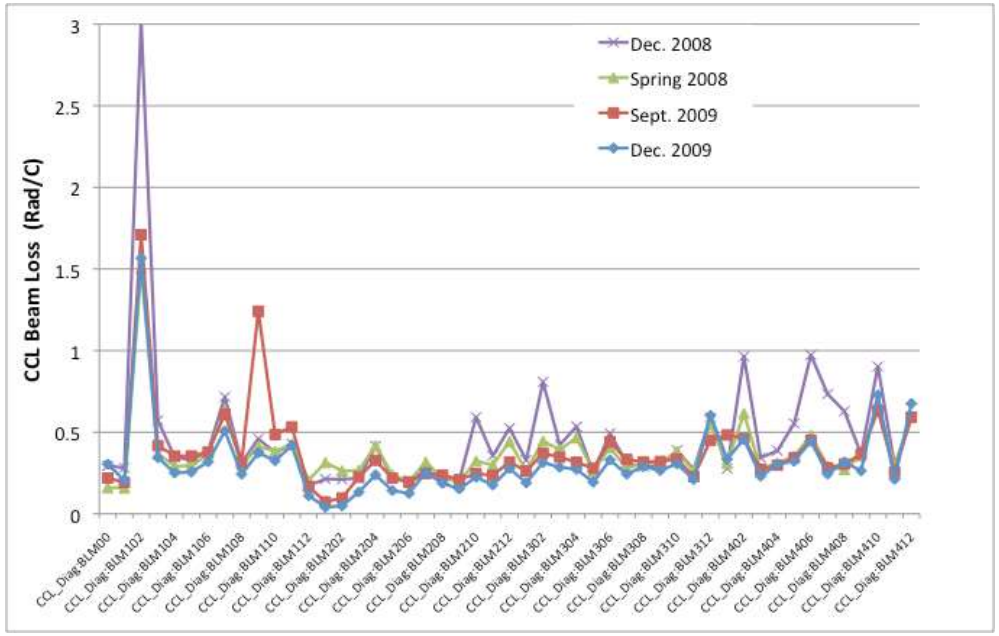


- **The upward climb continues (with some backslides)**
  - **Still had new tune-up settings with power increases**
  - **But some periods of simple setting restorations**

Power Increase During 2009

- Beam Energy (design = 1000 MeV) :
  - Last run in 2008 : 865 MeV with 76 cavities
  - In 2009: 928 MeV with 80 cavities (out of 81)
- Pulse length (maximum beam flattop, design = 1000 μs):
  - End of 2008: 625 μs
  - Spring 2009: 700 μs
  - Fall 2009: 825 μs
- For 1 MW operation, parameters were
  - 928 MeV, 60 Hz, 800 μs , 38 (23) mA peak (Av)

Warm Linac Beam Loss
(see A. Shishlo's talk)

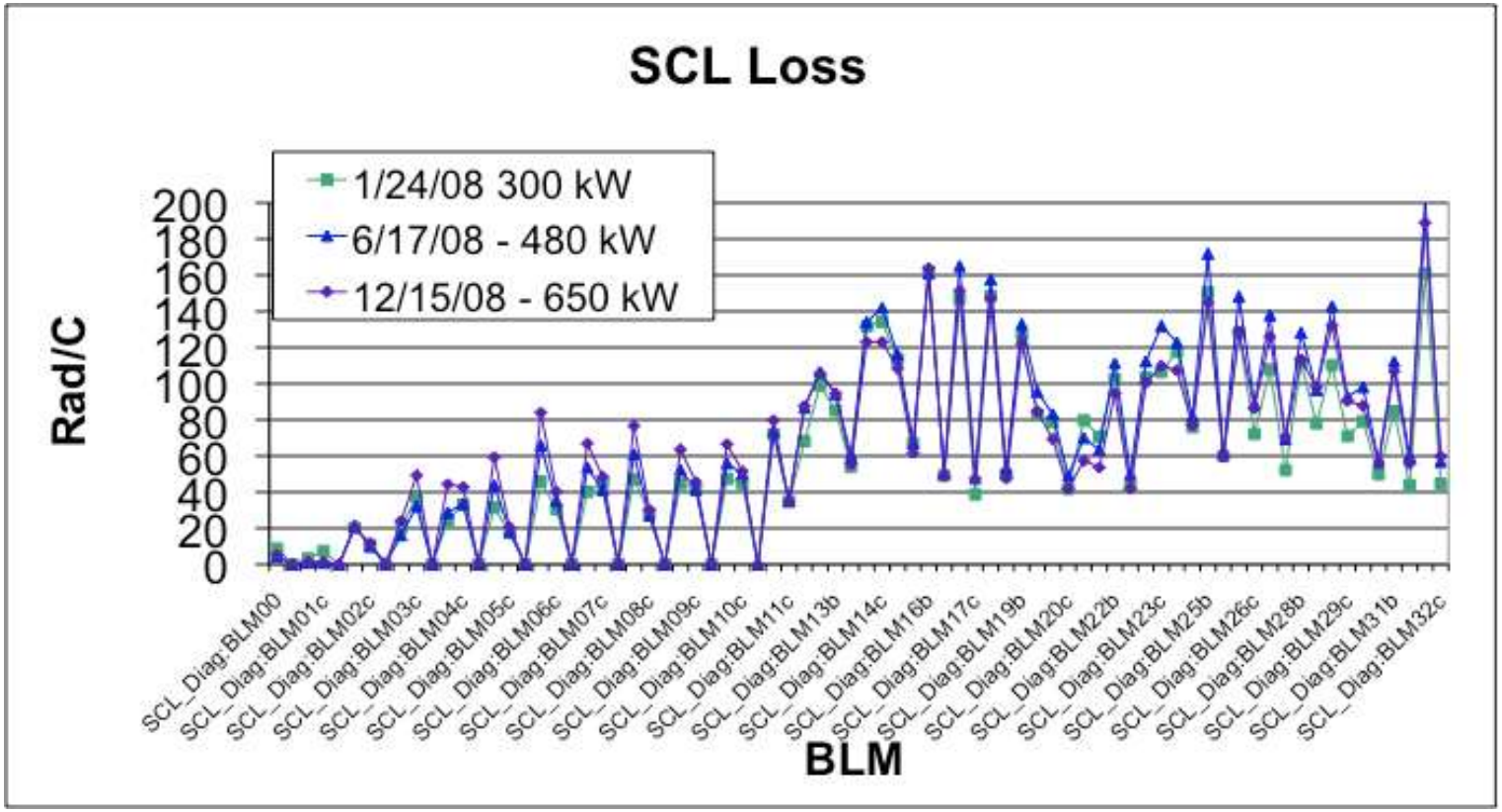


Beam Loss =

$$\int \frac{\text{beam loss signal}}{\text{beam power on target}} dt$$

- Some modest improvement in CCL4 this past year
- MEBT collimation helps
  - Simplifies the production setup

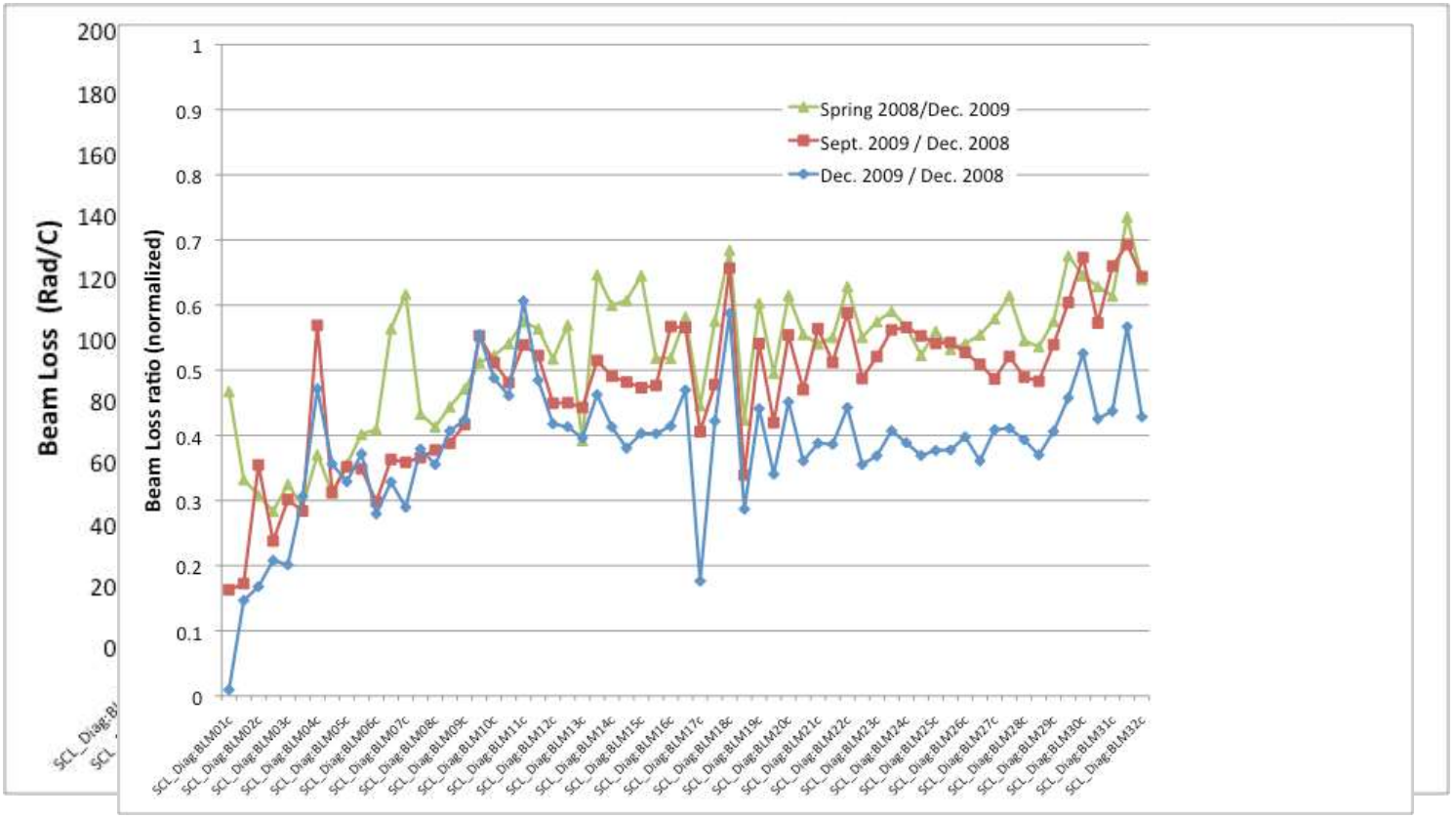
SCL Beam Loss – Historical Base



- **Insensitive to transverse matching**
- **Degrades with slight RF (longitudinal) imperfections**

(hence we suspected longitudinal origin to the loss)

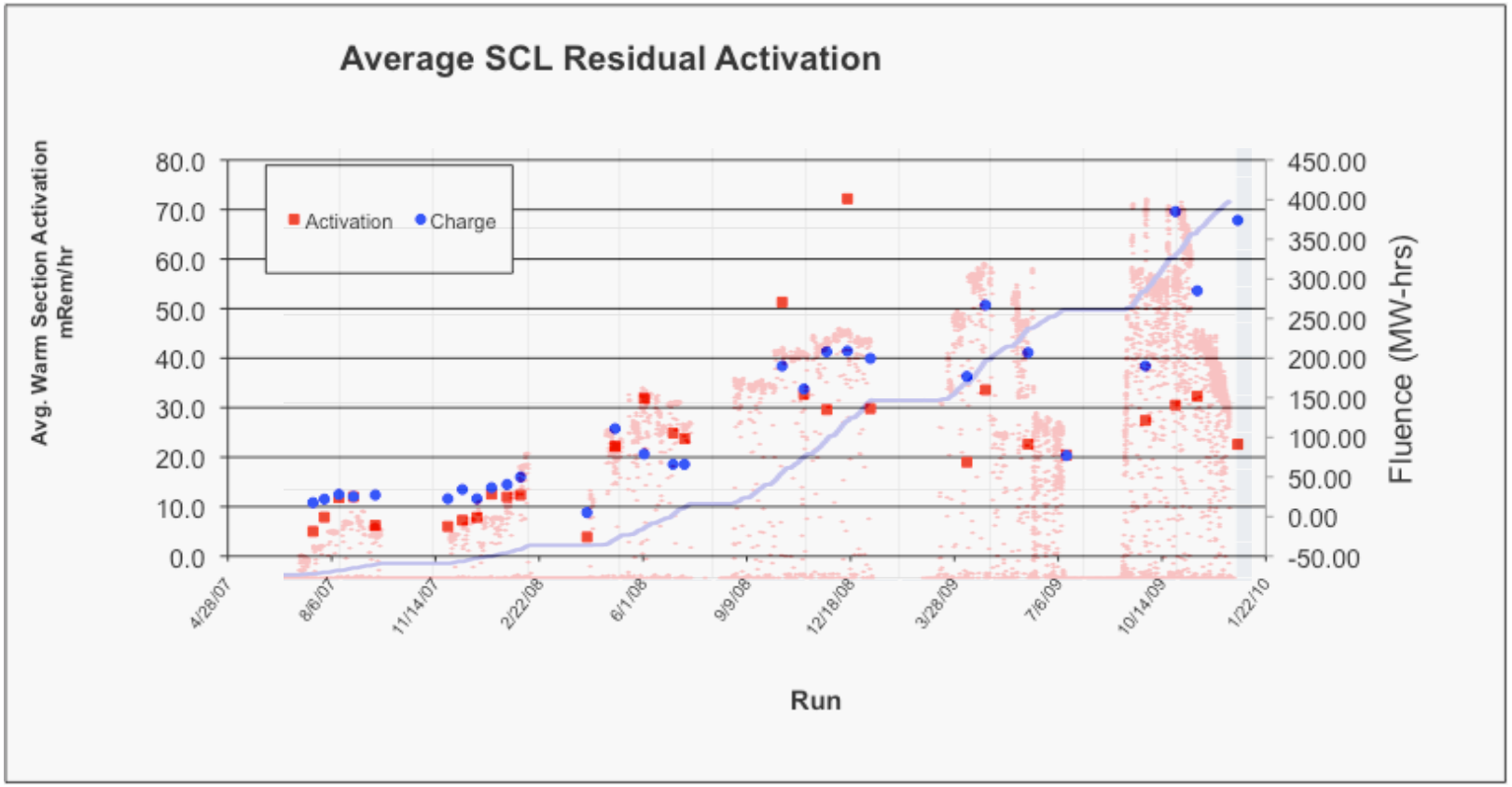
SCL Loss Reductions, Spring – Fall 2009



- ~ 50 % reduction in losses with initial model based quads (Y. Zhang, resonance avoidance)
- Another ~25% reduction with machine specialist empirical quad reduction
  - Maybe more to be gained????

SCL Activation History

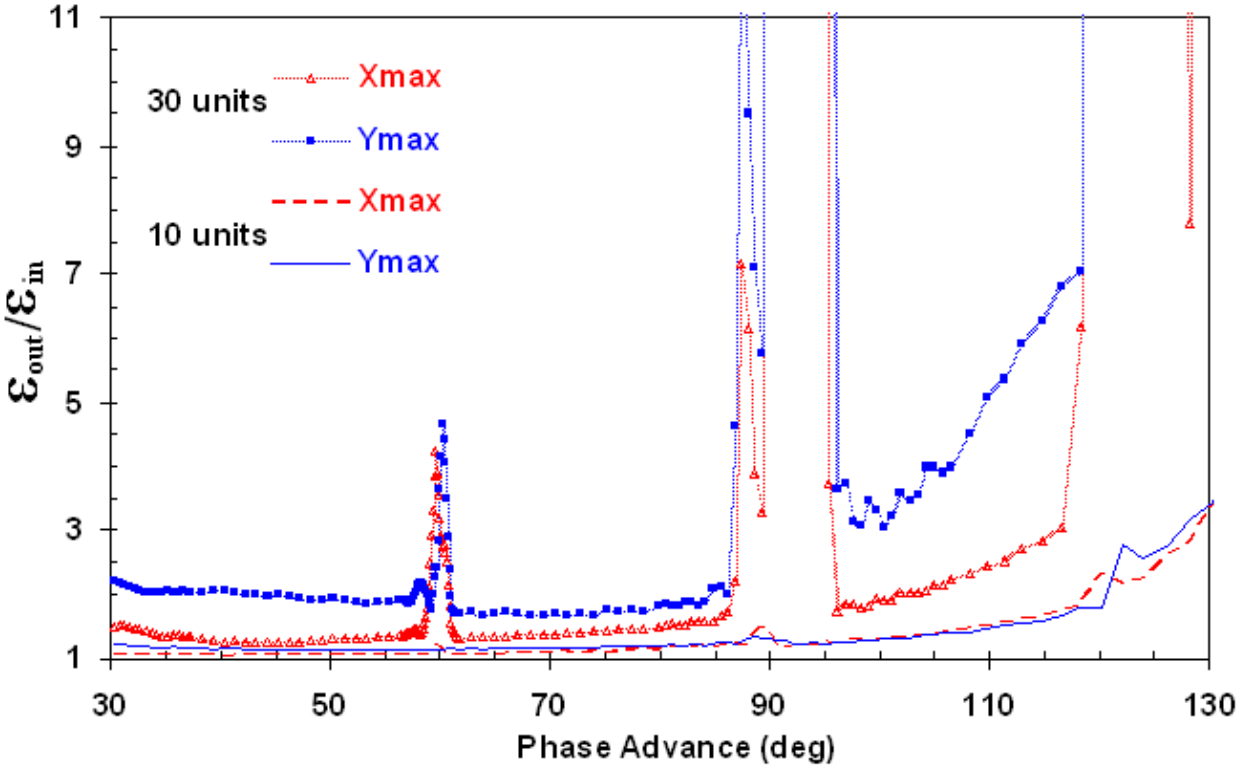
NOT Loss limited



- Over the last year the SCL activation is not increasing, even though the accelerated charge increased
  - Reduced beam loss helps

Linac Modeling: 60-deg. Resonance

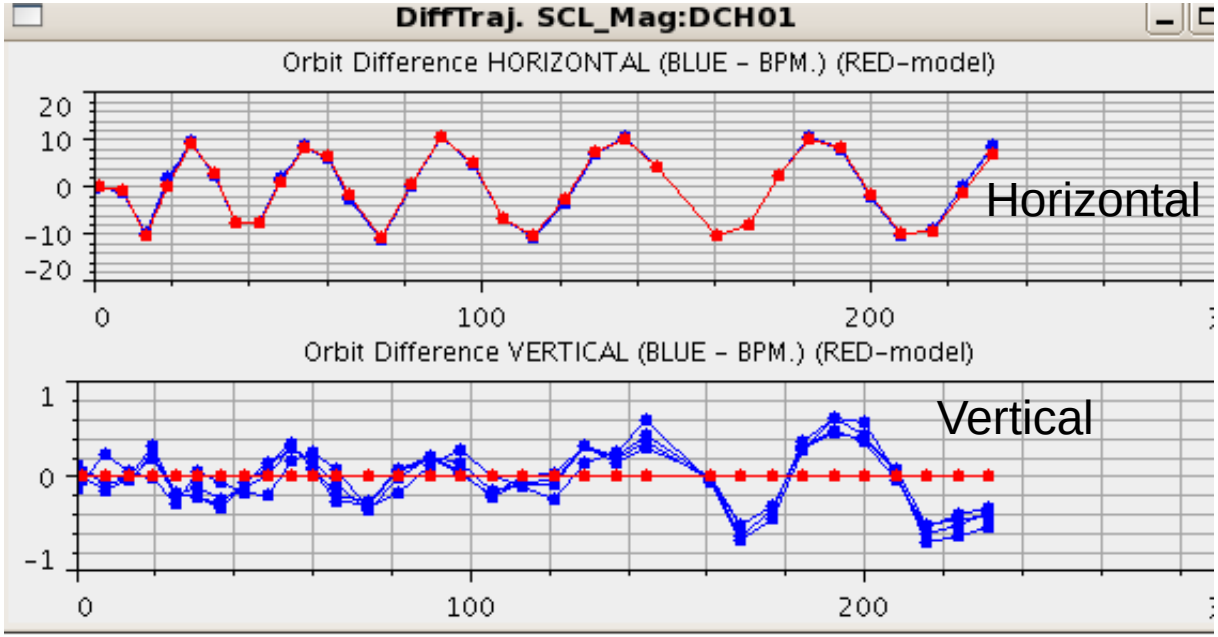
Y. Zhang



Max. beam emittance in simulation, for an ideal transport line, except with SNS duodecopole errors

- Identified a 60-degree resonance with quadrupole duodecapole errors as a possible loss generation mechanism
- See Yan Zhang's talk

Linac Modeling: Beam Based Comparisons (A. Shishlo)



Orbit different SCL example:

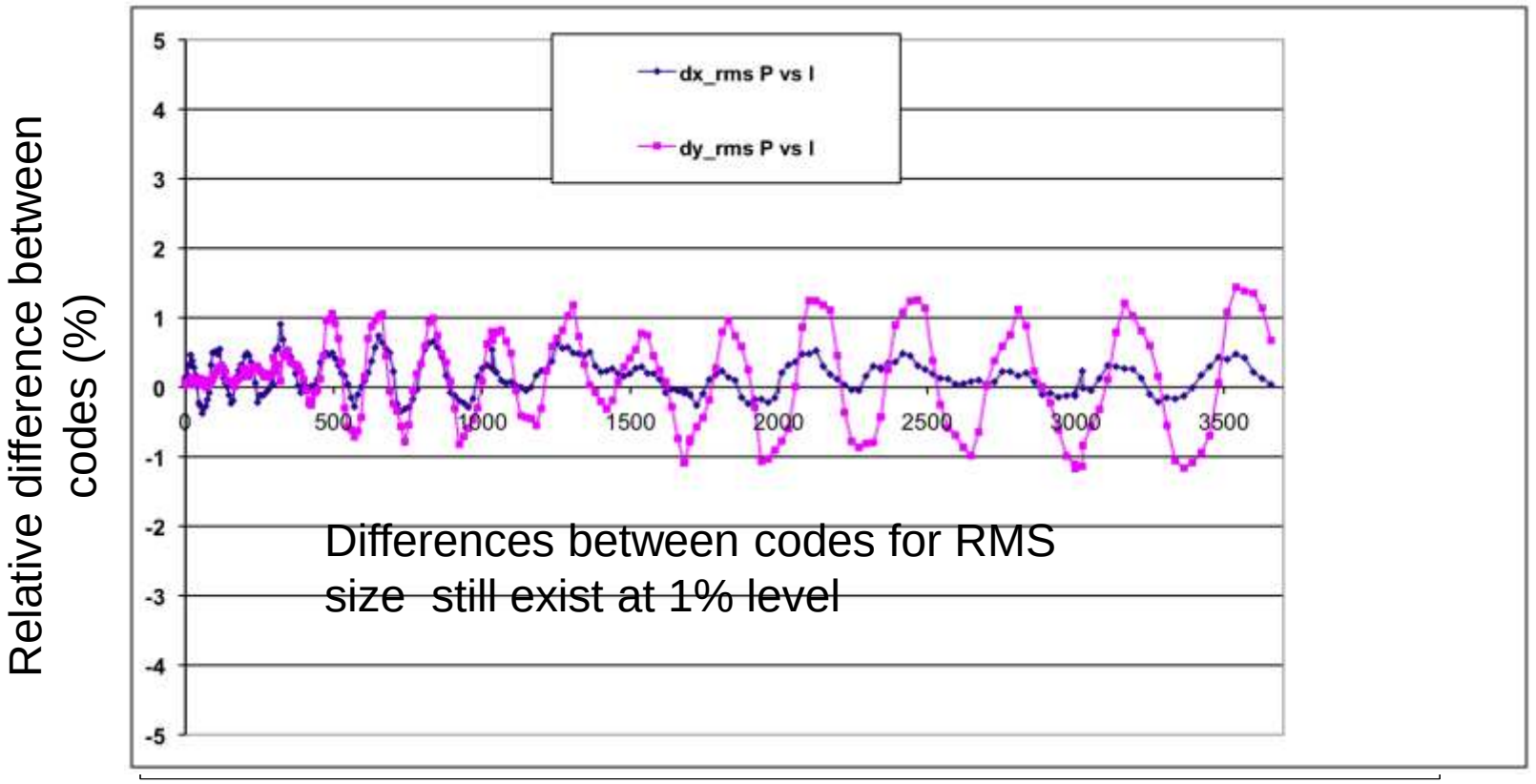
Apply horizontal Kick and compare model and measured differences

Red= model
Blue = BPMs

- Use beam based measurement information to move towards having the right physics in the models
- X-Y coupling from the RF ???? – *Preliminary*

(See Y. Zhang's talk)

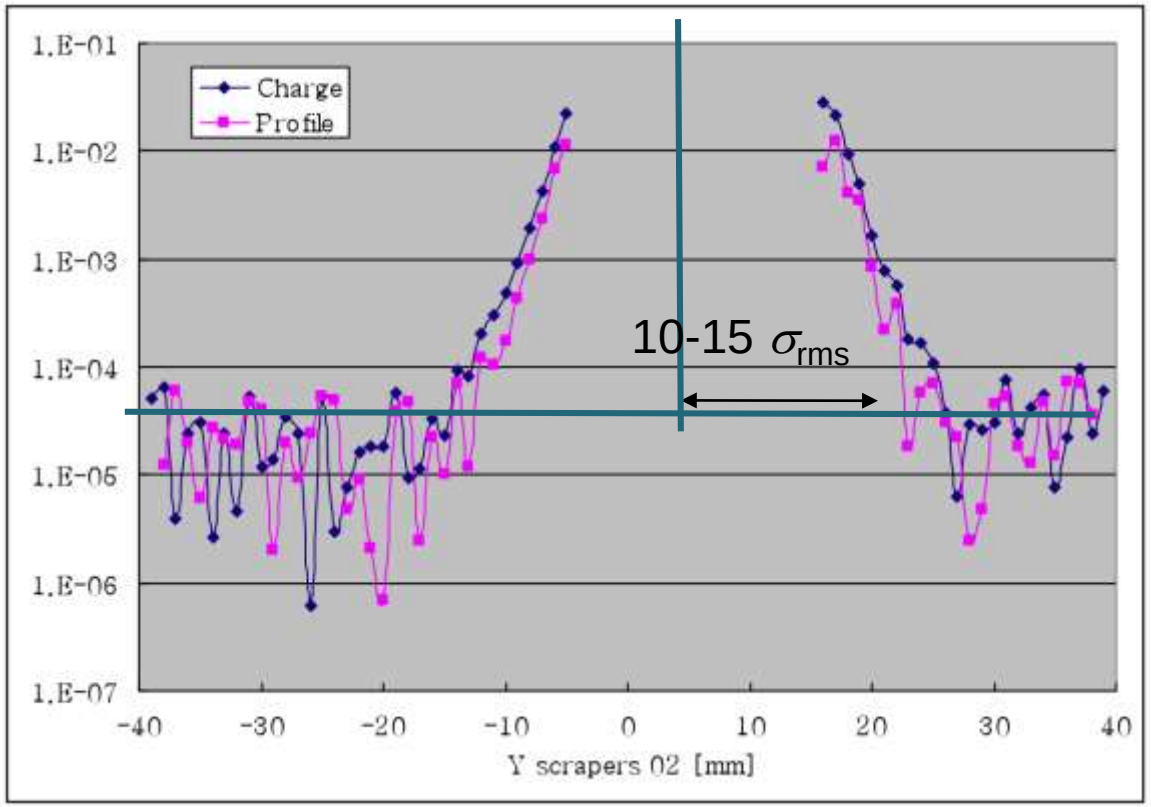
Linac Modeling: Code Benchmark



- Code benchmark
  - First gather a good understanding of how the codes compare with each other with simplest modeling
  - Then add increasing order of modeling complexity (space charge, 3-D RF fields, … etc.)
  - Still preliminary stage

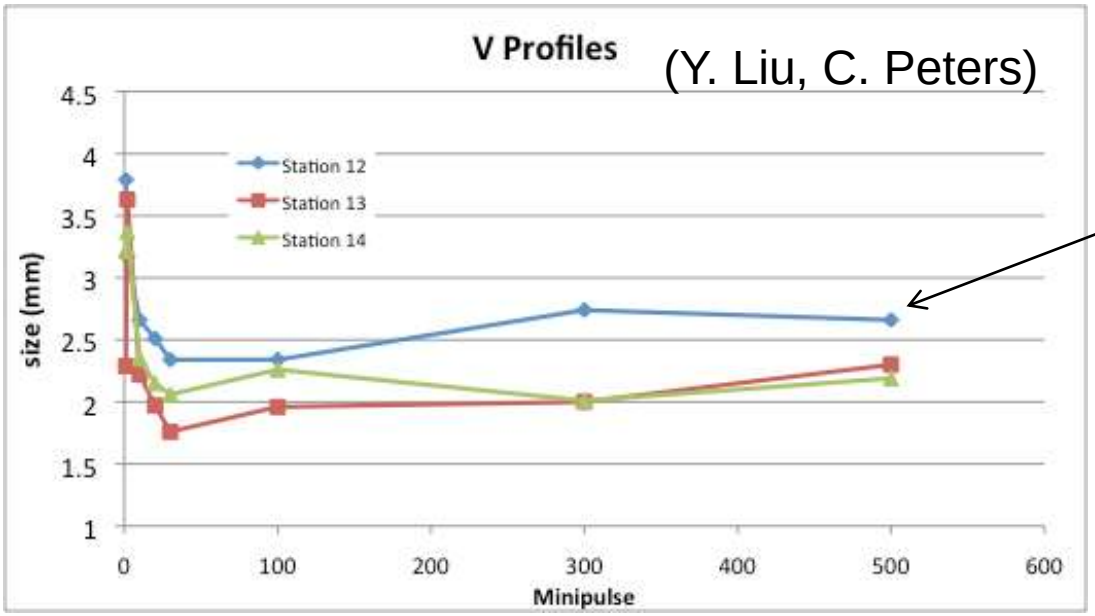
Linac Profile Measurements (Preliminary)

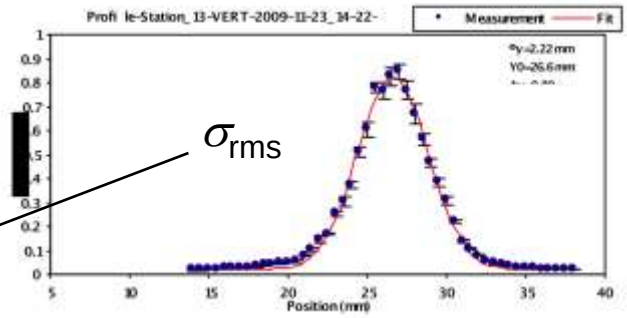
D. Jeon



- Starting to measure halo using the HEBT scrapers (direct measurement of intercepted charge – thanks to BIG group)
- Promise of > 10^4 dynamic range profile measurements

Linac Beam Measurements





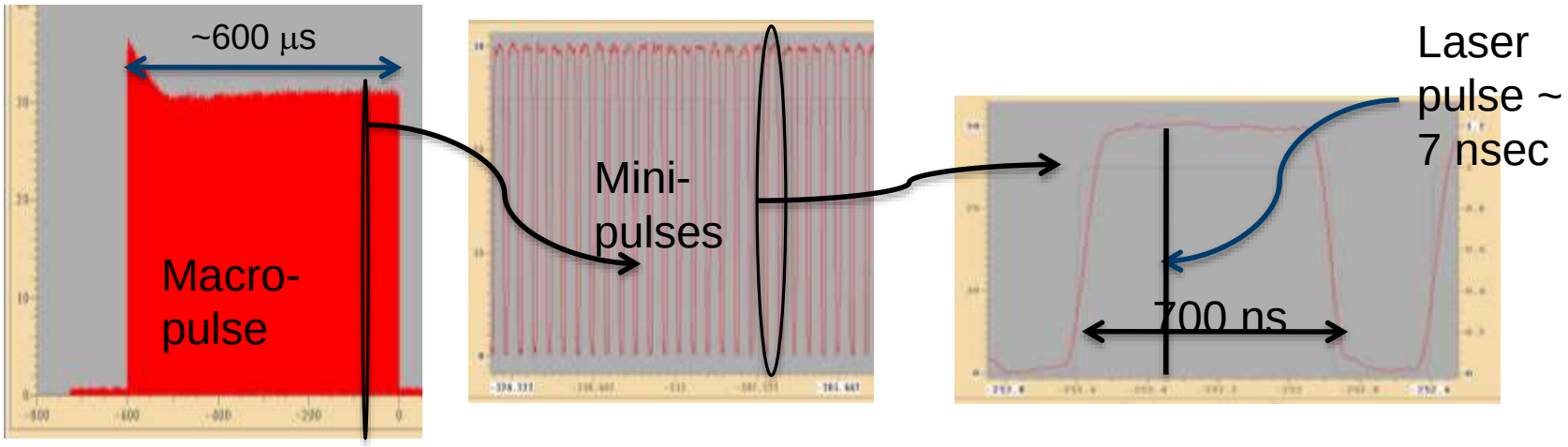
Laser measurements indicate some dependence of profiles (*Y. Zhang's talk)*

Bunch Shape Monitor:

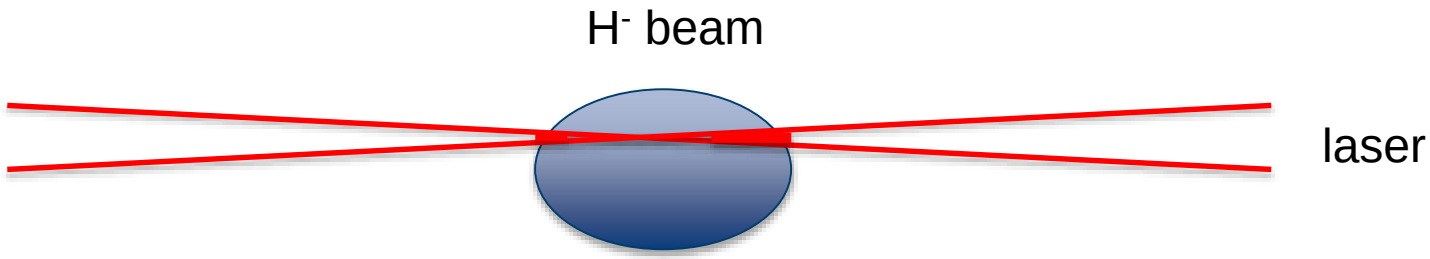
- Ongoing efforts measuring the longitudinal bunch length.
- More recent measurements are closer to the design value than one year ago– *see A. Shishlo's talk*

Calibrating SCL Loss Using Laser Profile System

Small Fraction of Beam Intercepted by Laser



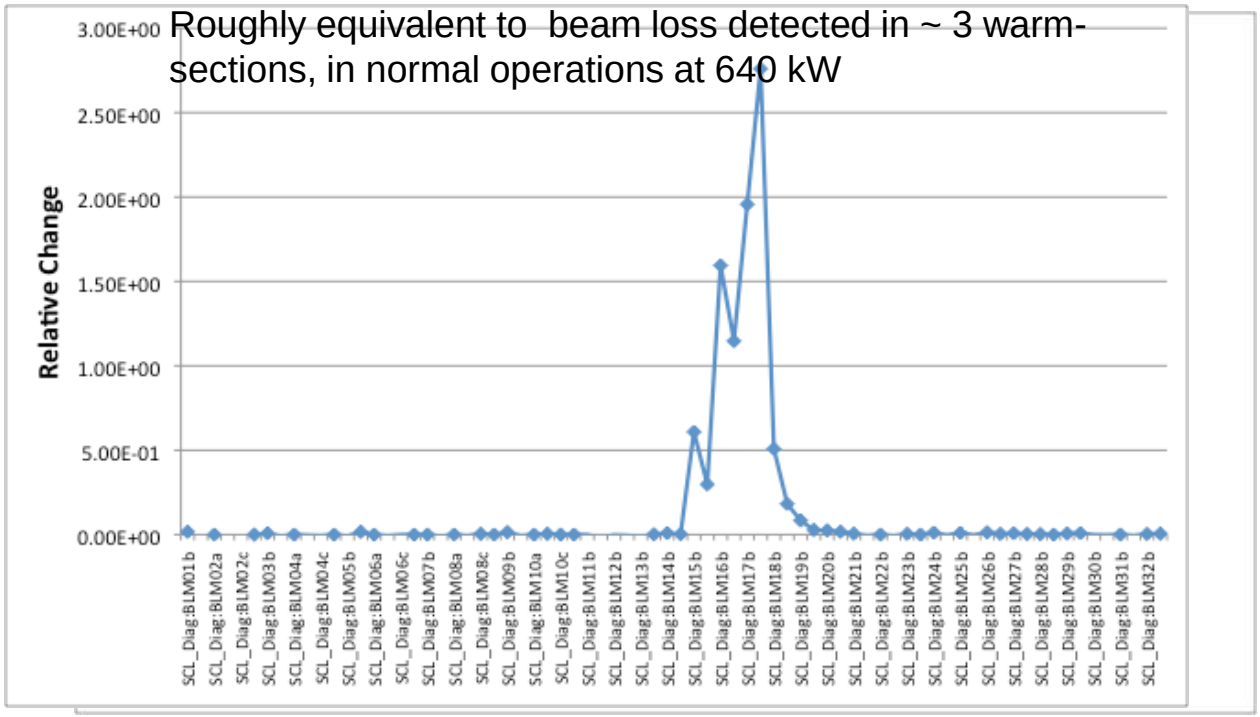
- **Temporal fraction is ~ 1.2x10^{-5} of the H$^-$ macro-pulse**



- **Spatial fraction is < 0.05 of the H$^-$ macro-pulse**
- **Total fraction of the beam intercepted by the laser is < 10^{-6}**

Calibration of SCL beam Loss

Using the laser profile system



Beam Loss with laser on and off

- **Conditions for 11/23/2009, 14:00**
  - **640 kW**
  - **600 μs pulse**
  - **12 μC/pulse in the linac**
- **Maximized BLM response to laser**
  - **Local bump at laser interaction (~ 20% impact)**
  - **Increase laser power to max. safe level (~ 50% effect)**

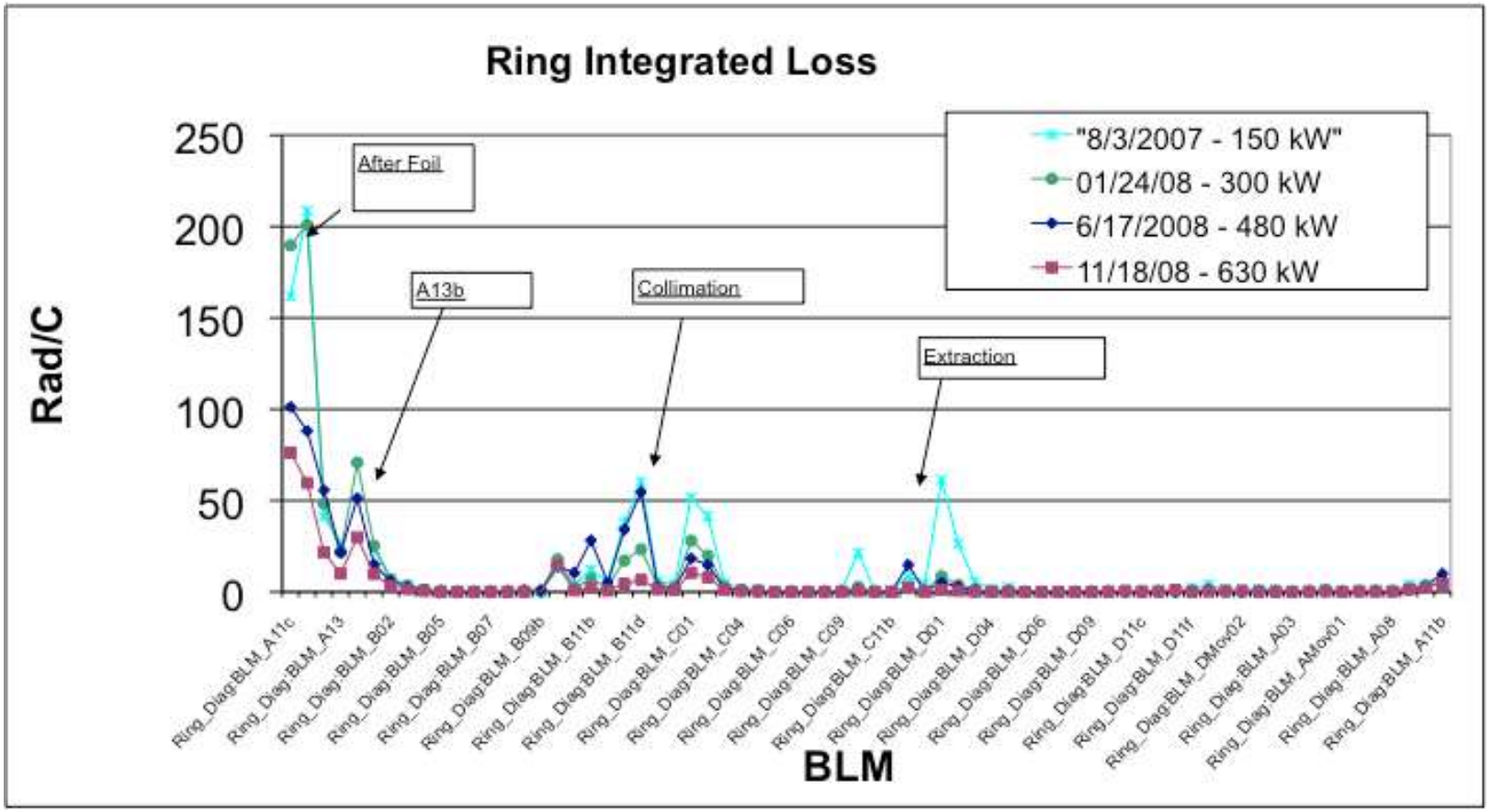
Calibration of Operational Beam Loss

- < 10^{-6} of the beam is intercepted by the laser
- Stripped H^- (i.e. H^0) produces a BLM response corresponding to ~ 10% of nominal BLM response during 640 kW operation
- ➔10^{-5} beam lost in the SCL (~ 4 W, or 0.15 W/warm-section)
- Could be off by a factor of 10
  - Activation measurements indicate 0.1 to 1 W/warm-section at 1 MW

Ring Efforts

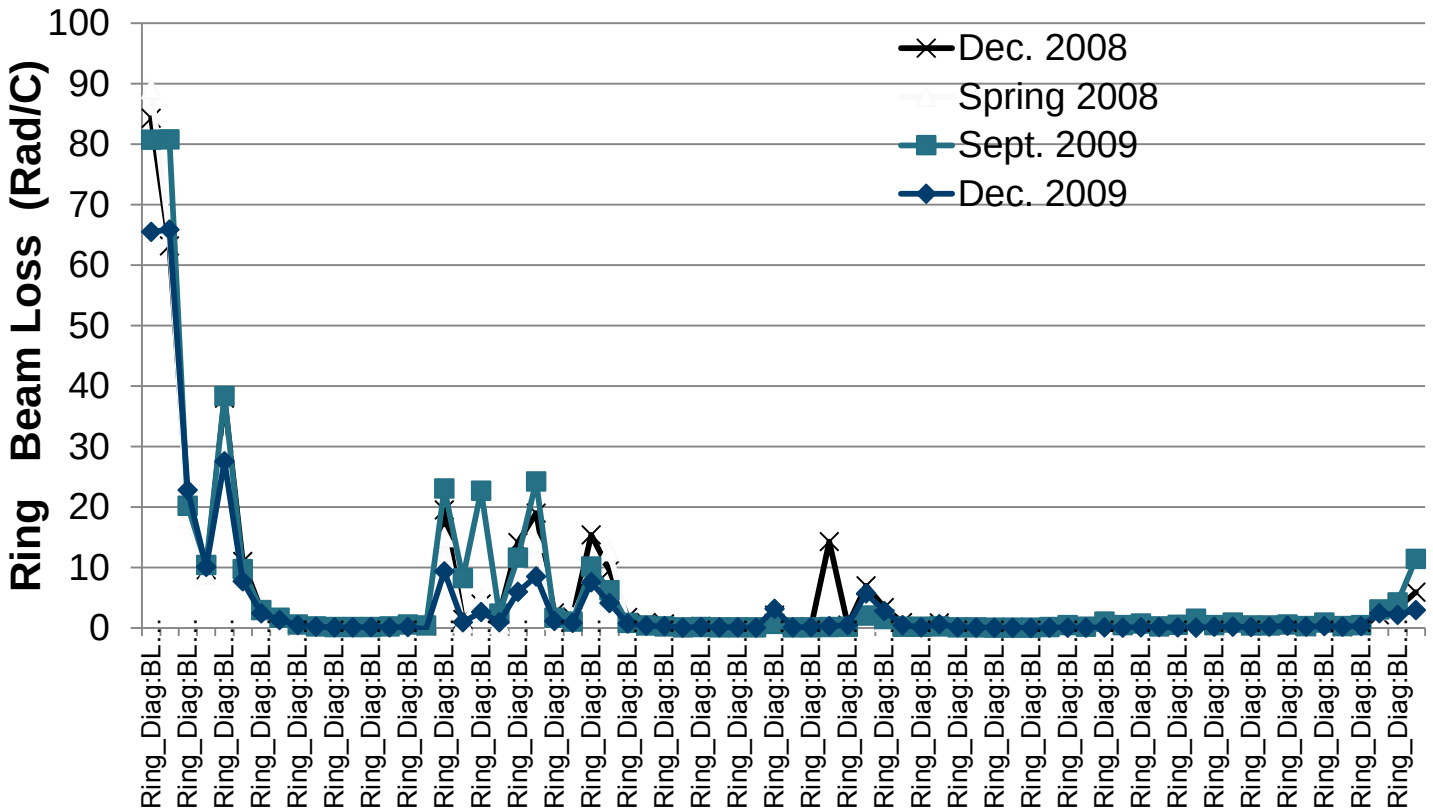
- Beam Loss experience
- Foil Issues
- Understanding Ring Beam properties
- High Intensity Beam Studies

Ring Beam Loss / Historical Perspective



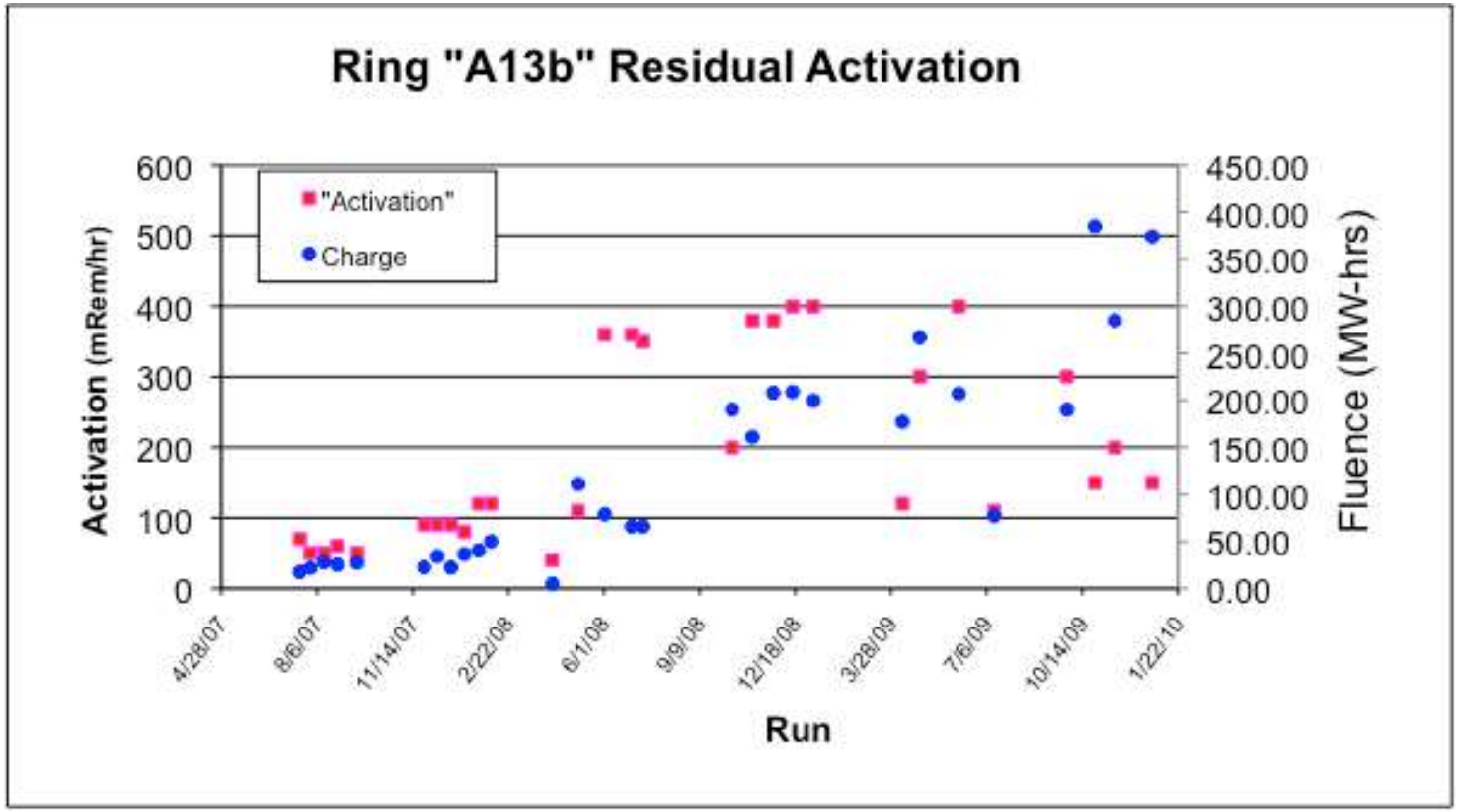
- **Great strides in loss reduction early on**

Ring Beam Loss, 2009



- Losses are fairly constant, but:
  - Injection / storage times have been increasing (~ 600 to 850 us)
  - Collective effects are higher (10 to 18 uC/pulse this past year)
- Injection losses are estimated to be < ~ $3x10^{-4}$
  - Using controlled spills of small amounts of beam to calibrate

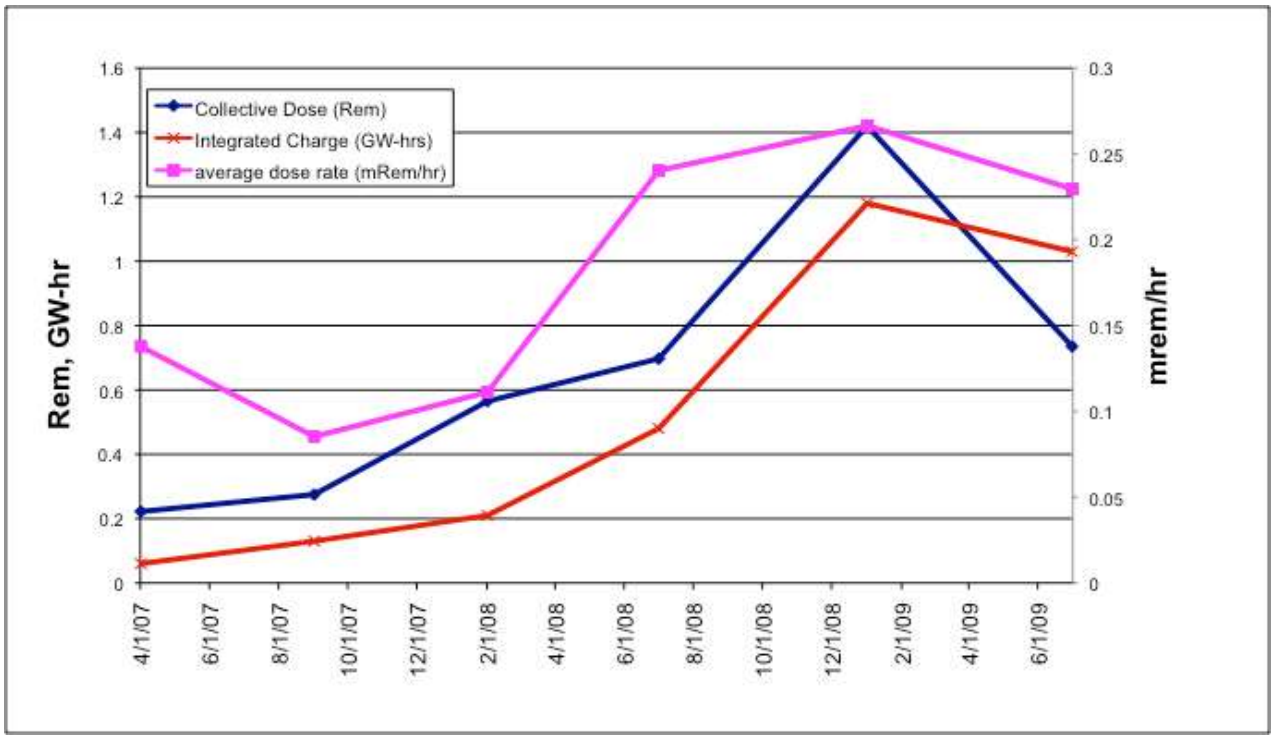
Ring Activation



- Generally the injection losses are increasing with beam power as expected.
  - Activation is also in line with expectations
- A13b is holding steady, despite power increases (J. Holmes will discuss)

Worker Dose History

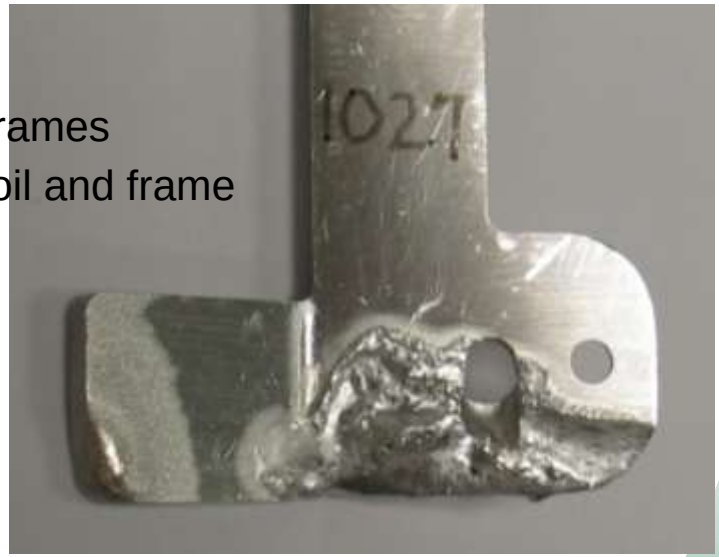
Doses for the extended maintenance periods



- Dose is not increasing over the past year

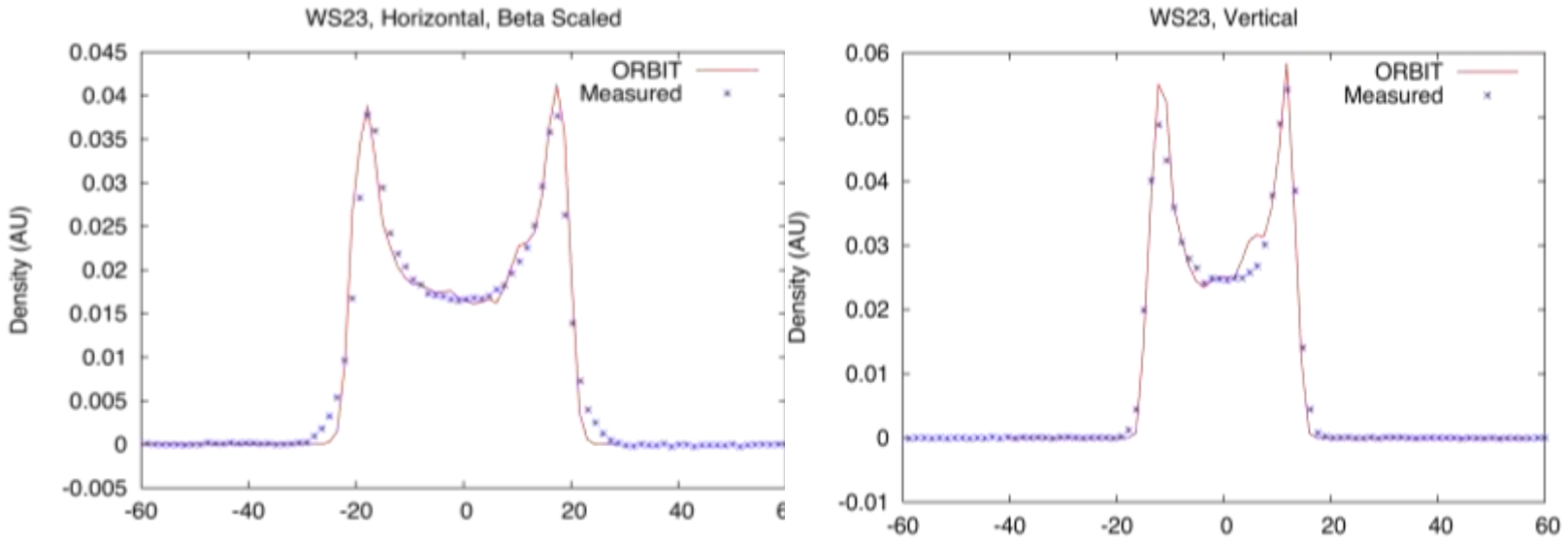
Ring Foil
(See M. Plum's talk)

- May 2009 Experienced Foil Failures
  - Had observed foil "fluttering" before
- Formed a task force, headed by Mike Plum
  - Identified and addressed several issues
    - Maintaining a clear path for stripped electrons
    - Use high temperature material for foil holder frames
    - Good contact (electrical & thermal) between foil and frame
- Fall 2009 run used 1 foil, no failures
- Still an area of concern



Ring Beam Modeling

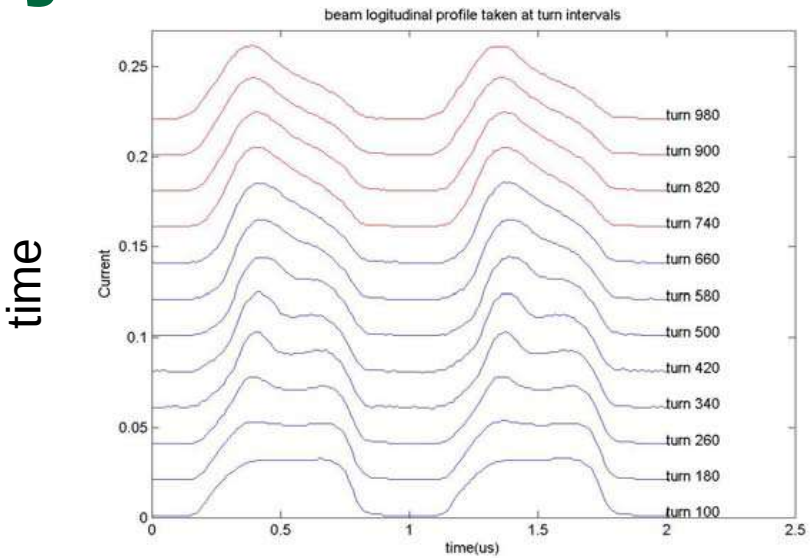
S. Cousineau



- ORBIT simulation comparison of measured beam profiles is progressing
  - Compares well for unpainted beam
  - Useful for identifying equipment issues

See J. Holmes' talk

High Intensity Studies



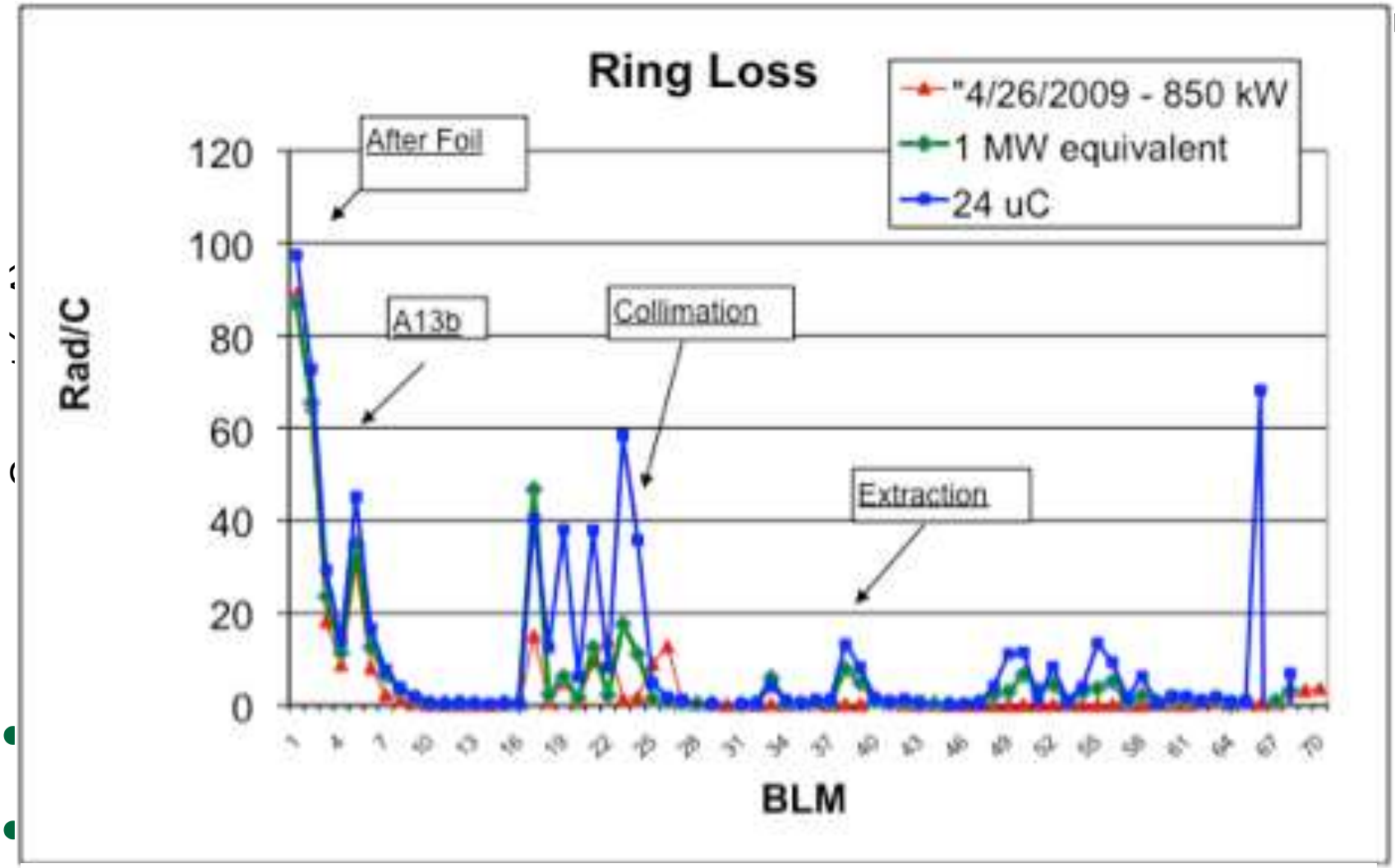
Bunch shape

- Still dedicate beam study time for full pulse length, high intensity studies
  - July 2009 had outside experts participate in a ~ 2 day high intensity effort
  - Now able to do get high intensities with production setup
- Concentrating on understanding the role of the bunch shape on the e-p instability
  - Use of the 2nd harmonic cavity to control the trailing edge shape is an effective way to inhibit the e-p

See J. Holmes talk

High Intensity Beam Studies – 7/11/2009

Beam Pulse Extracted from the Ring:



- Losses at 24 uC (1.44 MW) are not terrible

Other AP Group Activities

- Code support
  - ORBT / XAL
- Laser Stripping

ORBIT Code Support
(J. Holmes talk)

- ORBIT is an in-house multi-particle beam tracking code developed in house
  - Used for Ring Beam Dynamics
  - Open Source
  - Used at many institutes (FNAL, CERN, CSNS, J-Parc, ….)
- Many modules (e-P, H0 excited state, 3-D fields)
  - Users develop their own modules
- Developing a modern easier to use/install version (Python-ORBIT)

XAL – Application Programming Infrastructure *(Tom Pelaia et. al.)*

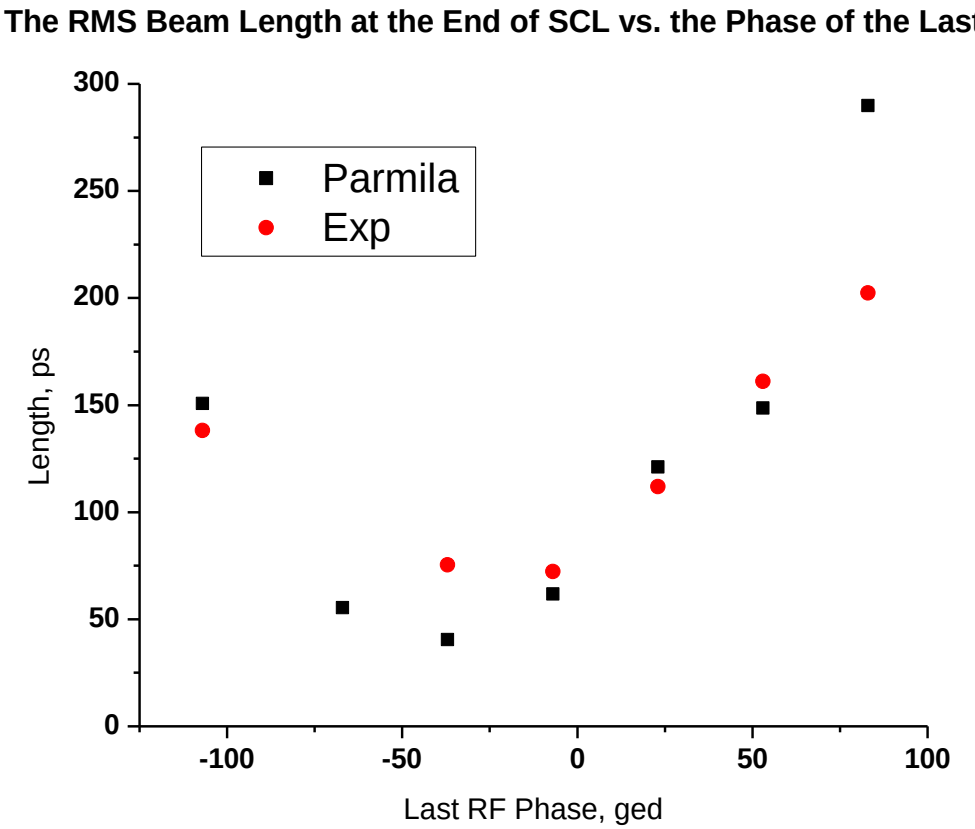
- XAL has been a key to the successful commissioning and rapid power ramp up progress
  - Open Source
  - Integral part of beam studies
- Envelope beam model, user friendly layer on top of EPICS, …
- Continual improvement / upgrades
- Workshop is planned in May
  - BNL(ESS), TRIUMF, SLAC, FRIB, GANIL

Laser Stripping Effort

S. Danilov, T. Gorlov

- Ongoing support of laser stripping studies
- Planning a next step experiment with an intermediate pulse length
  - 10 μs (vs 10 ns for the initial POP experiment)
  - Believe it may be possible without the use of a Fabry-Perot resonator
- Supporting laser stripping modeling for FNL and CERN upgrade studies
- Hosted a laser stripping workshop at SNS in March 2009
  - Experts from CERN, LBNL, FNL, KEK and industry
  - https://wiki.ornl.gov/events/lahbsa/default.aspx

Beam Studies in Support of Laser Stripping *(A. Shishlo, T. Gorlov, S. Danilov)*

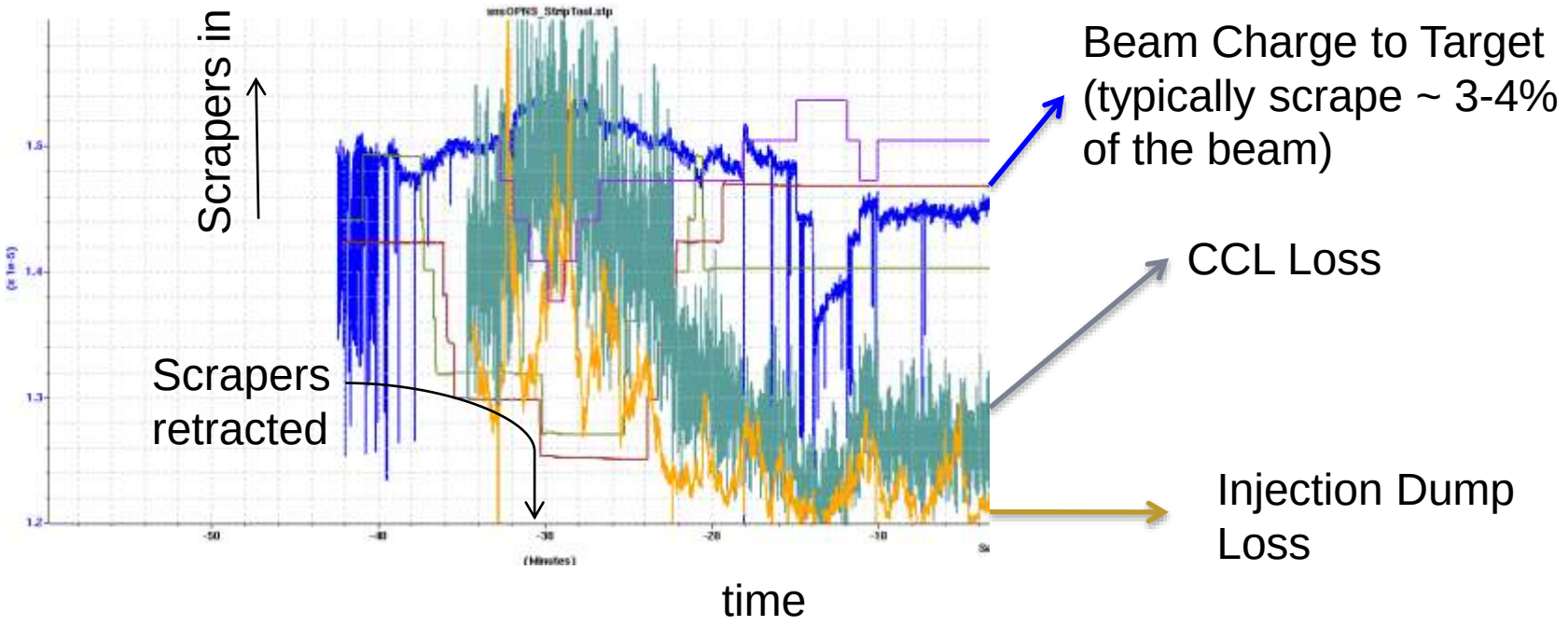


- Can use the last few SCL cavities to provide a smaller bunch at the proposed laser stripping location in our HEBT

Operational Experiences

- **Scraping and chopping**
- **Design vs. production**

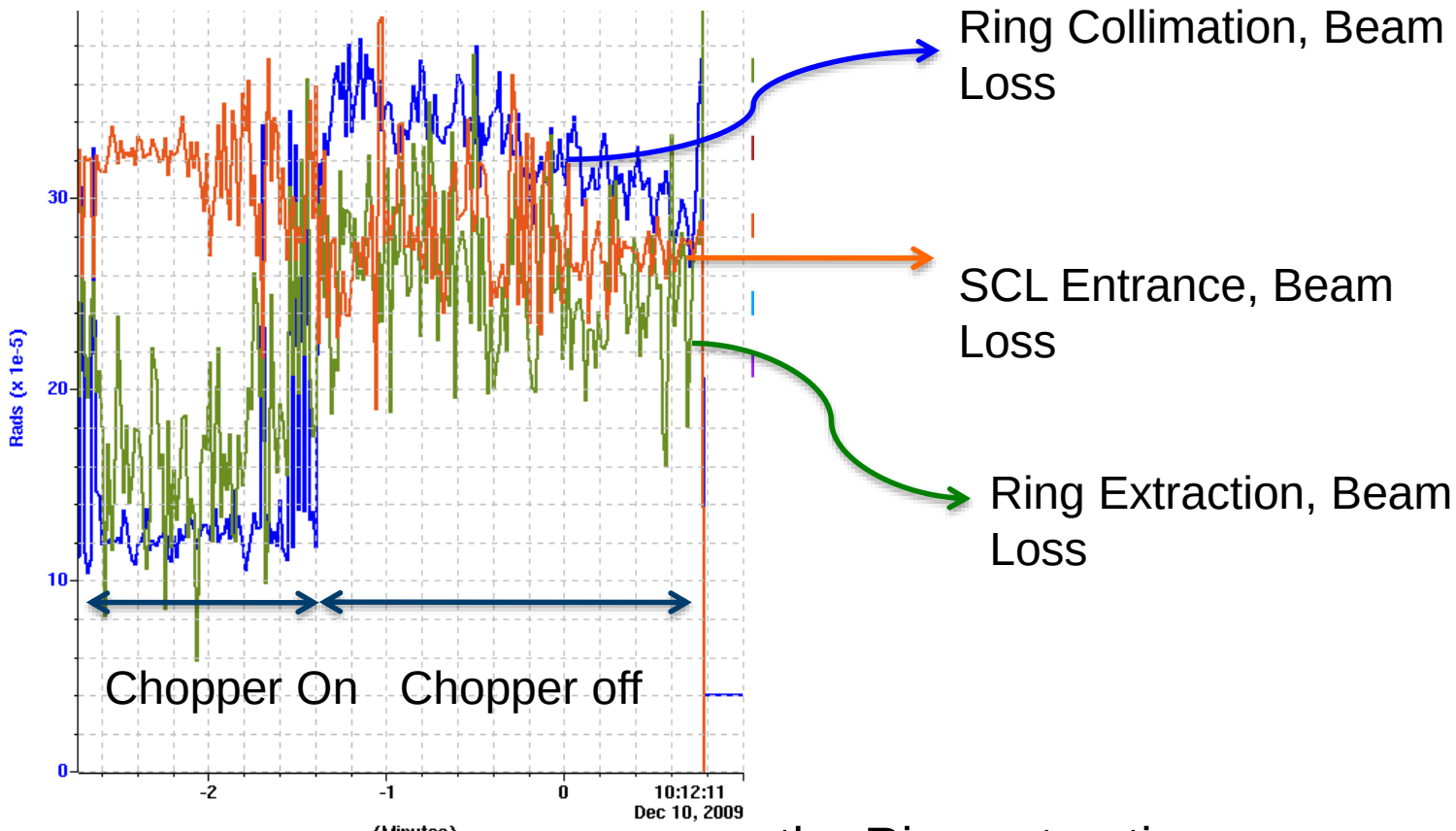
MEBT Scraping



- MEBT scrapers are effective at reducing loss in the CCL, HEBT and Injection dump
- Typically we scrape a few % of the beam
- The MEBT scraper effectiveness varies from tune-up to tune-up (source change)

See A. Shishlo's talk

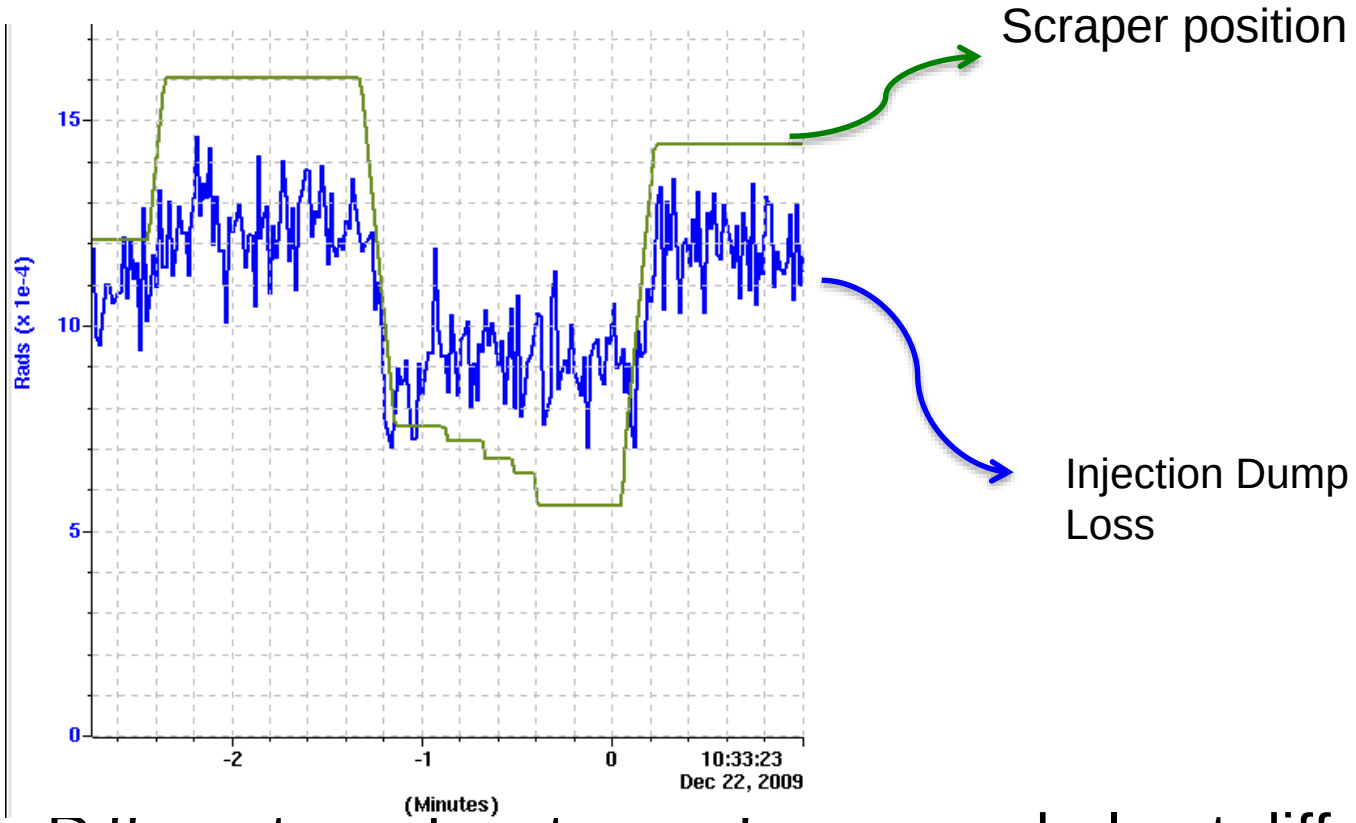
MEBT Chopping *Production Example*



- MEBT Chopping does help clean the Ring extraction gap
  - Depends on the LEBT Chopper quality
  - Depends on the source and fraction of the mini-pulse we are chopping

See A. Shishlo's talk

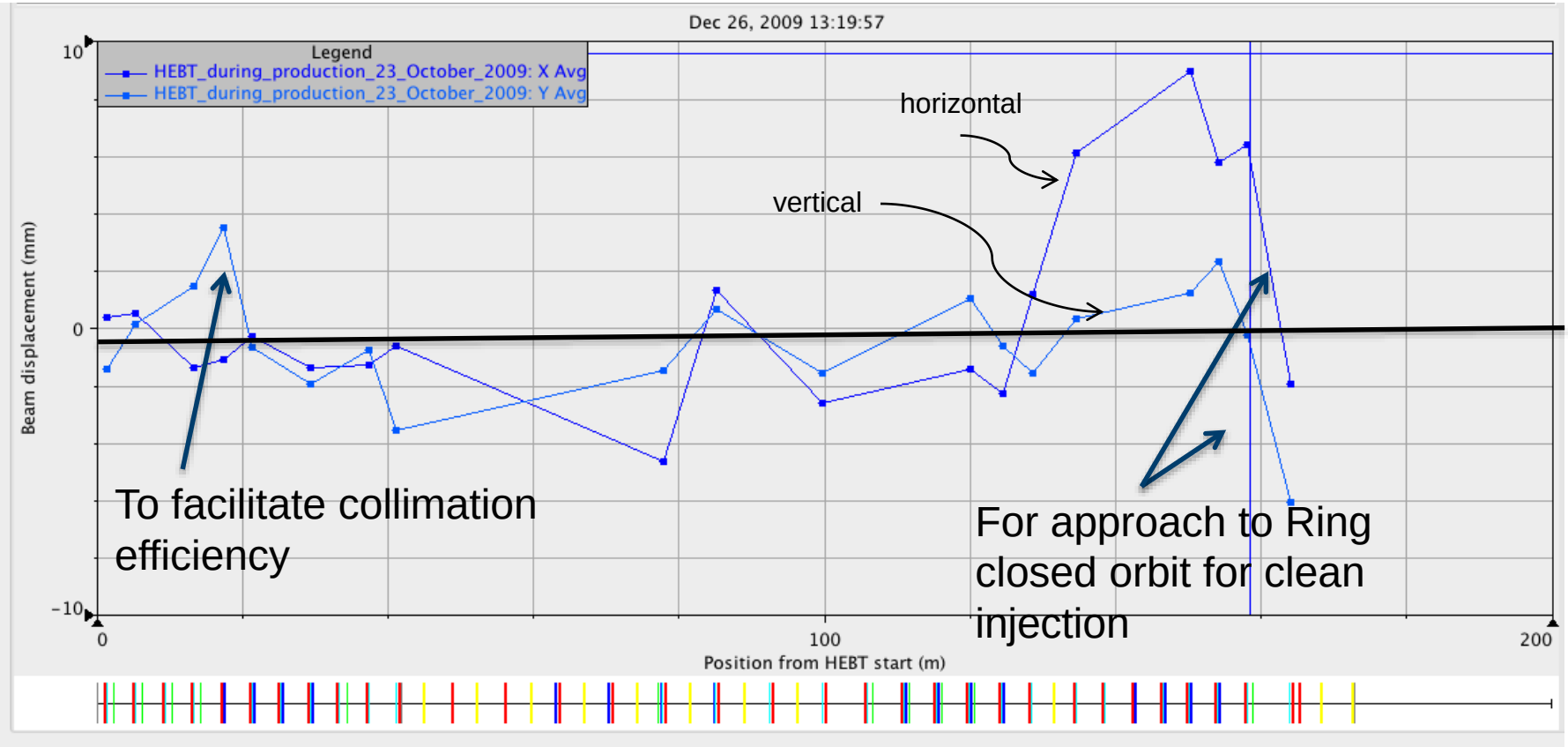
HEBT Scraping



- Different combinations of scrapers help at different times
  - MEBT scraping dependent
  - Source dependent
- Vertical scrapers work better

See M. Plum's talk

Production Setup vs. Design Setup



- Beam trajectories are not always flattened
  - Minimum loss is the final arbiter
- Do not always run with matched beams (see Y. Zhang's talk)

Summary

- Beam Loss
  - SCL: Significant improvement compared to last year
  - Not loss limited (yet)
  - Ring is holding steady – manageable losses at injection
- We are trying to understand what we observe using models
  - Rate of gaining new understanding < rate of new empirical observations