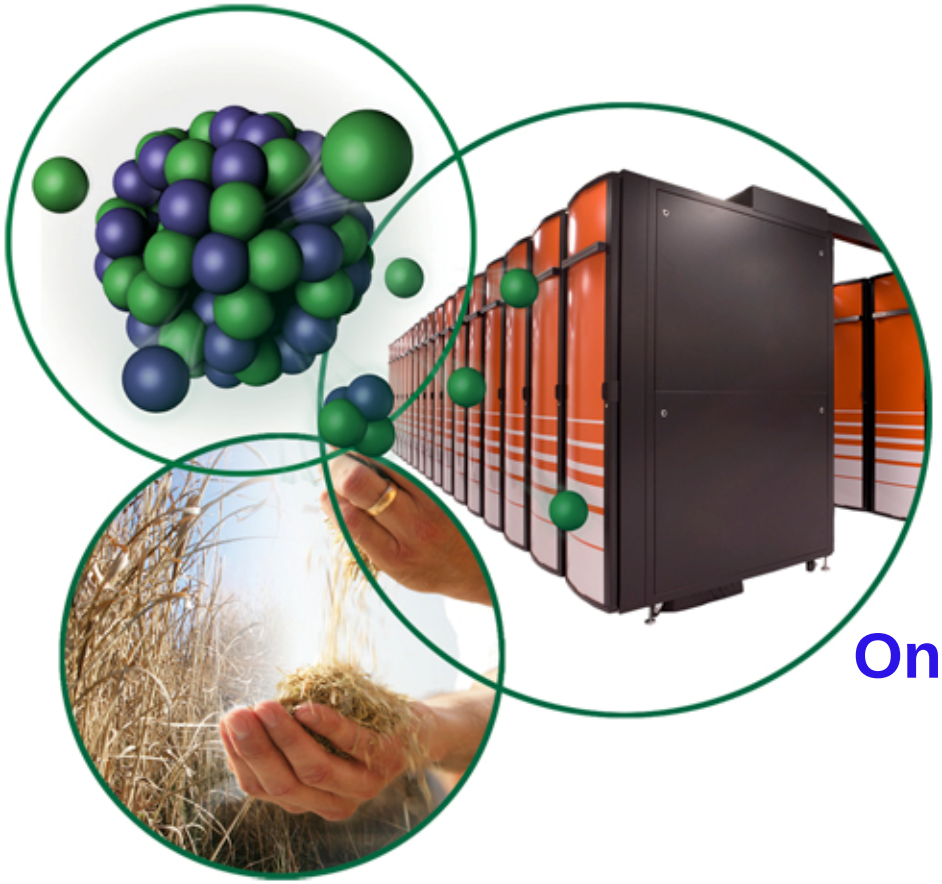
BEAM STUDIES AT THE SNS LINAC



Yan Zhang

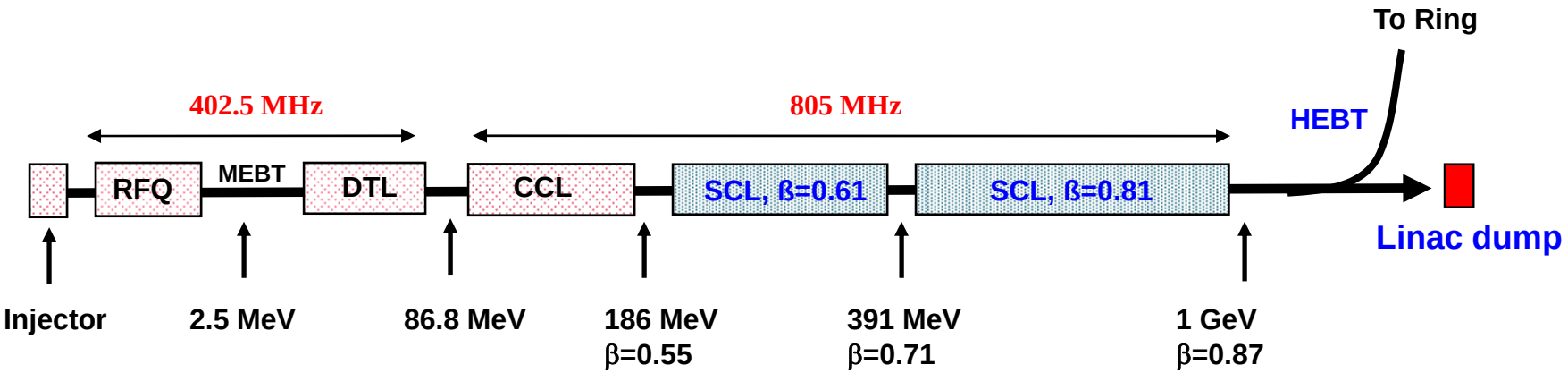
On behalf of the SNS team

42nd ICFA, HB2008, Nashville, USA, August 25-29, 2008

Outline

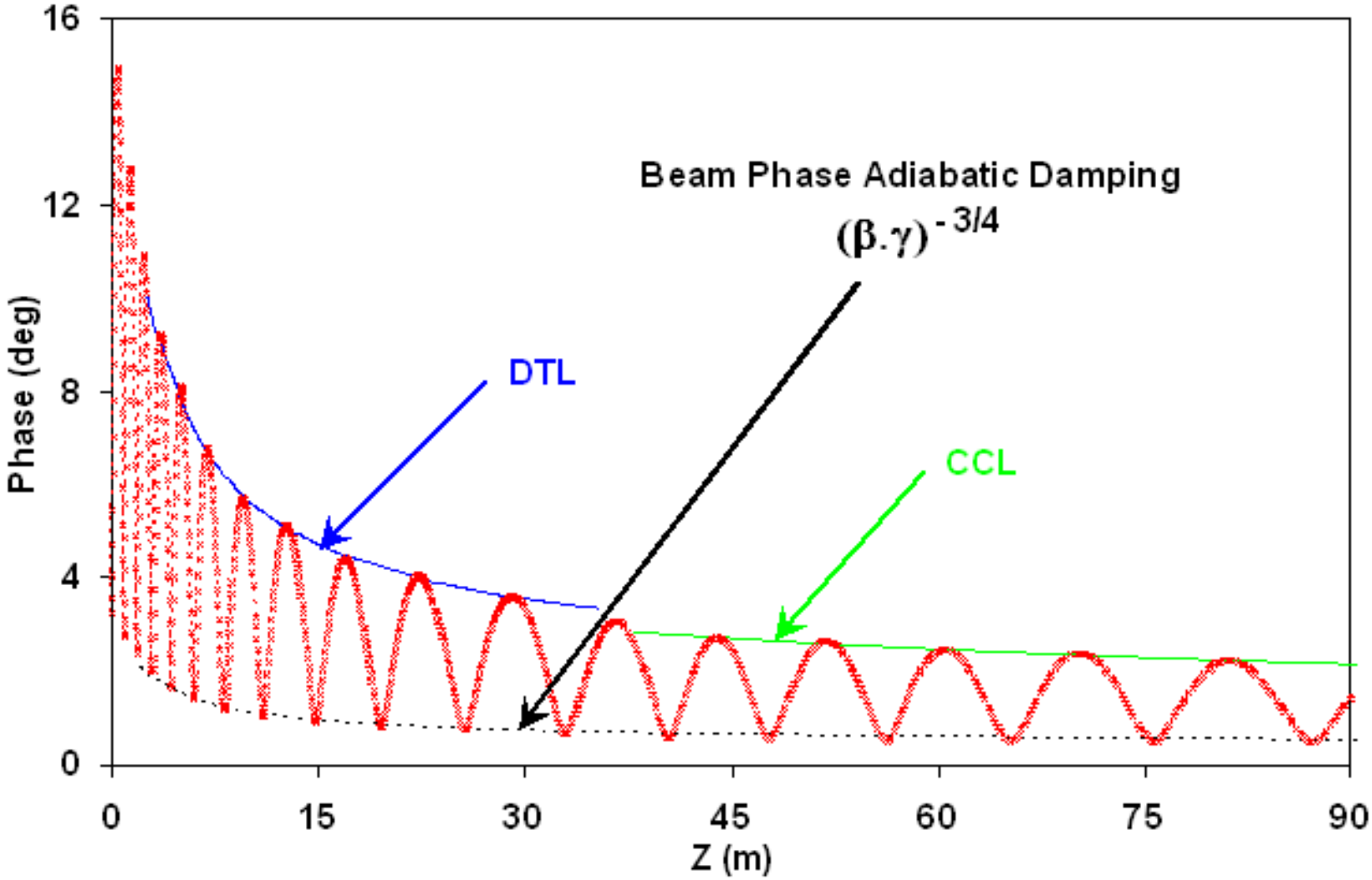
- **Introduction to the SNS Linac**
- **Longitudinal Beam Dynamics Studies**
- **Transverse Beam Dynamics Studies**
- **Unsolved Puzzles**
- **Summary**

The SNS Linac



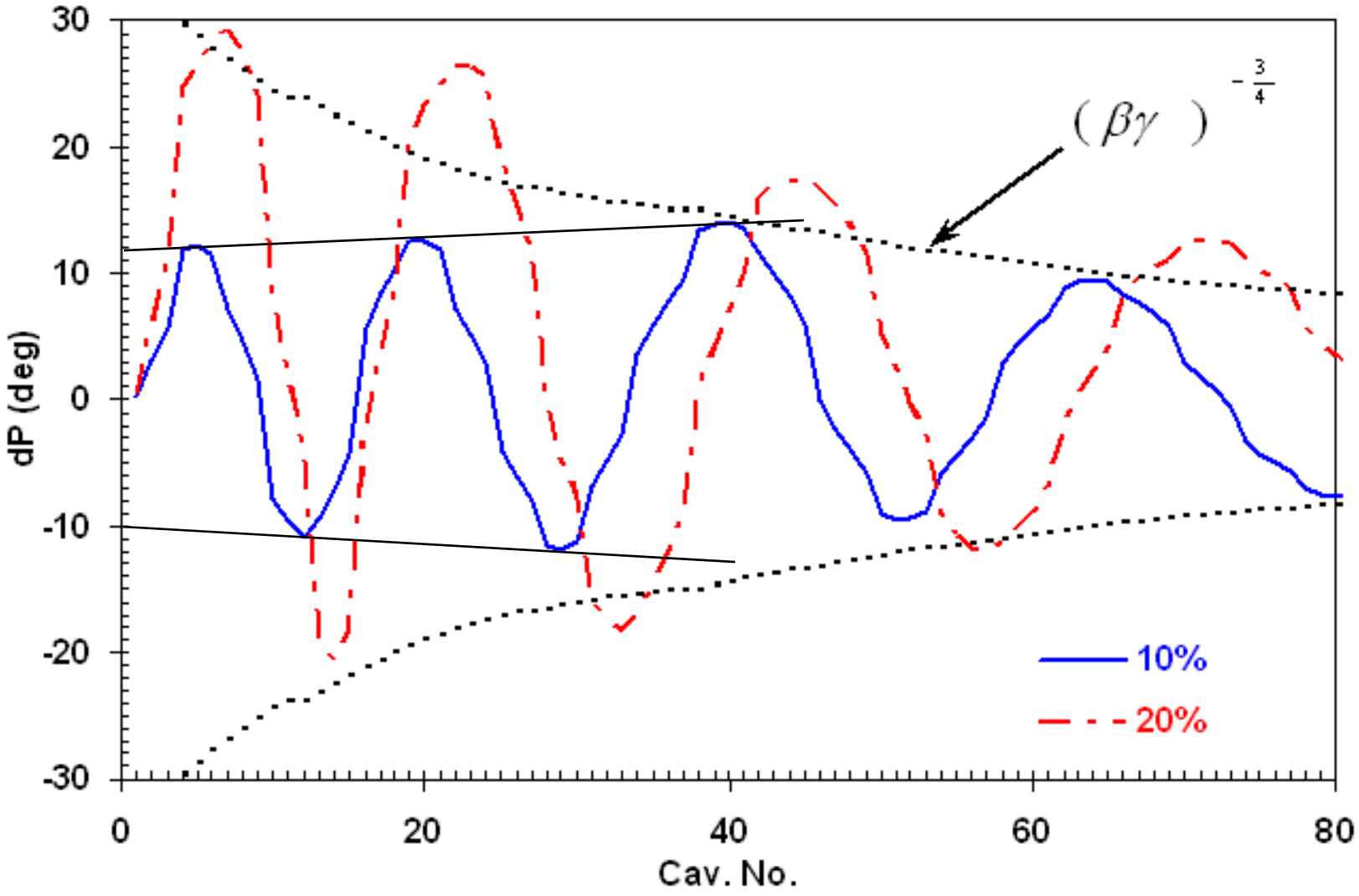
- Length ~260 m, 96 independently phased RF cavity/tanks
- Normal conducting linac from the H^- ion source to 186 MeV
- Superconducting linac from 186 MeV to 1 GeV
- Beam commissioning of the SCL began in August 2005
- Achieved the design repetition rate 60 Hz, maximum beam energy 1.01 GeV, peak beam current 40 mA, pulse length 1 ms, beam power on the mercury target 520 kW.

Longitudinal Lattice



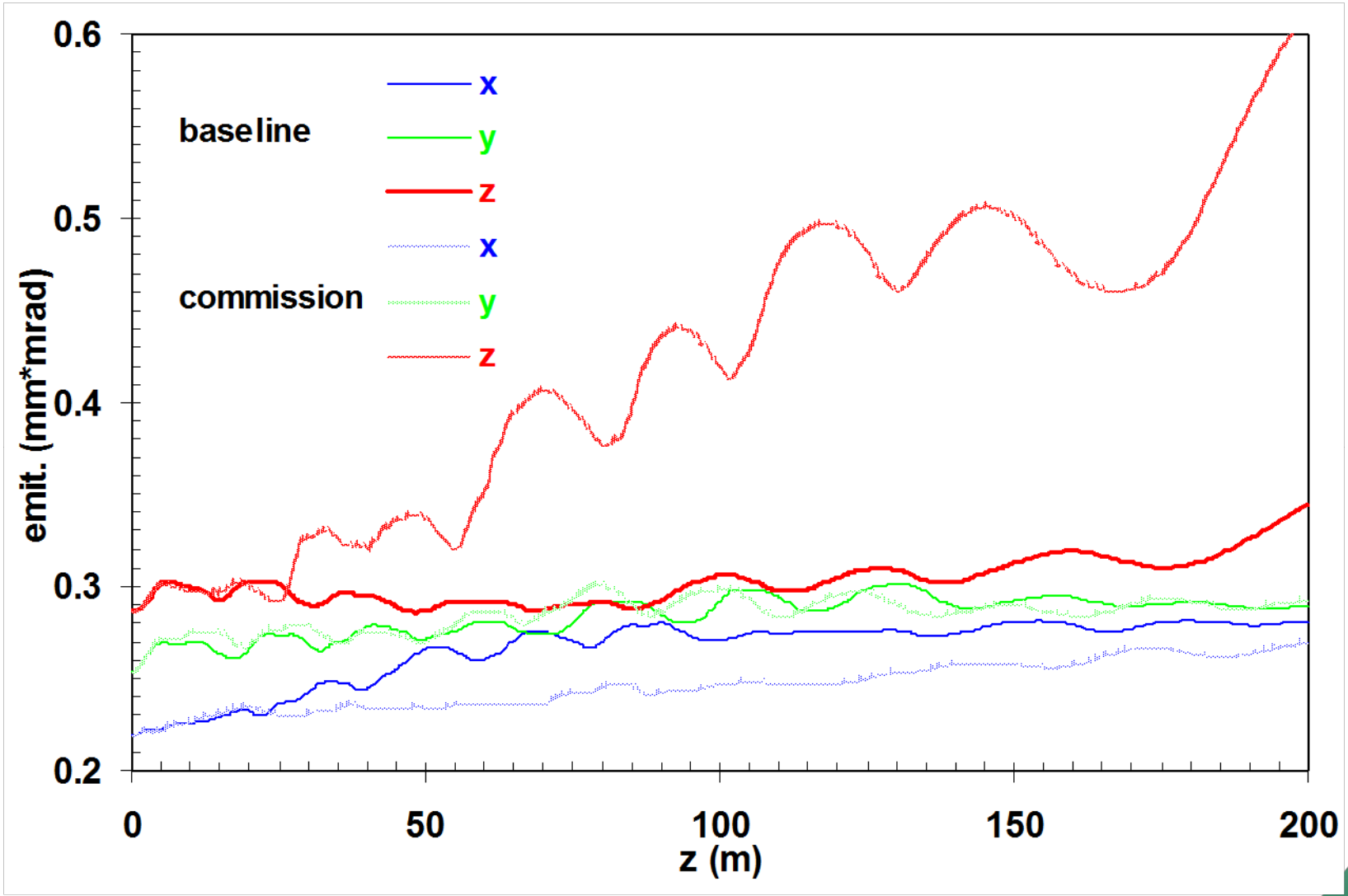
RMS phase in the warm linac, linear map and zero current

Y. Zhang, S. Henderson, this proceedings.



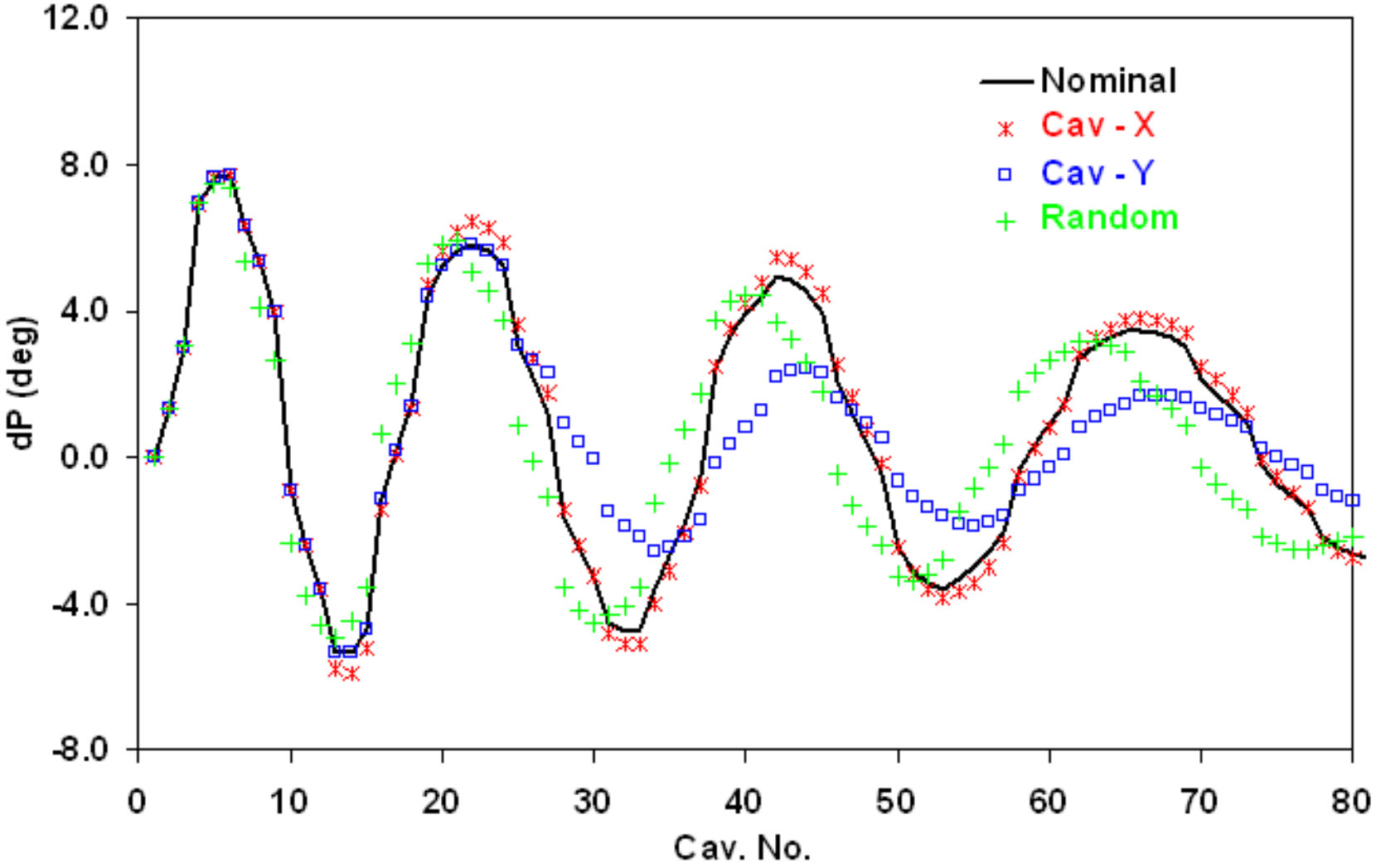
Phase oscillation in one of the SCL commissioning lattice

Longitudinal beam emittance increase in the SCL commissioning lattice



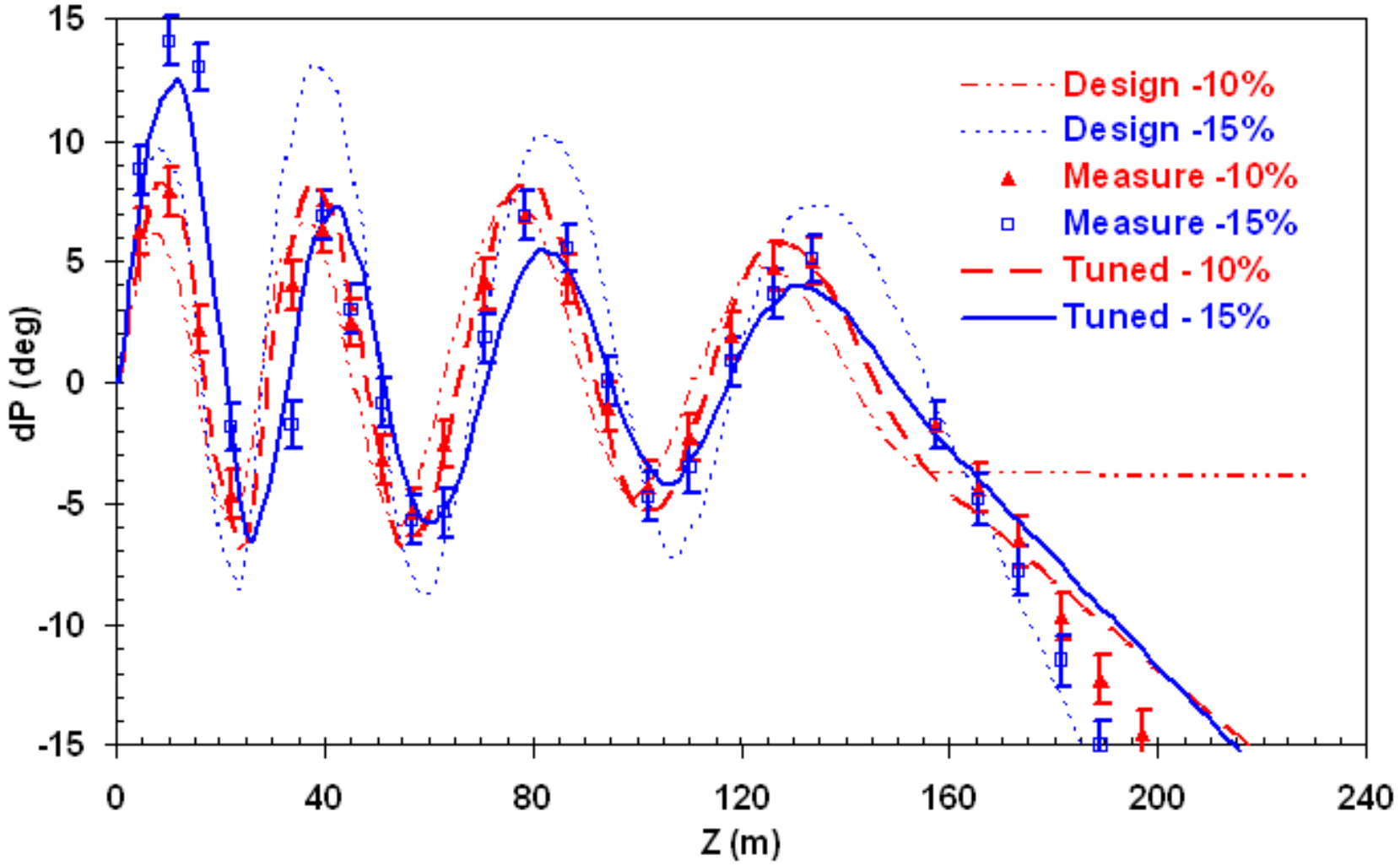
IMPACT, beam current 20 mA

Y. Zhang, et. al., NIM B 261 (2007)



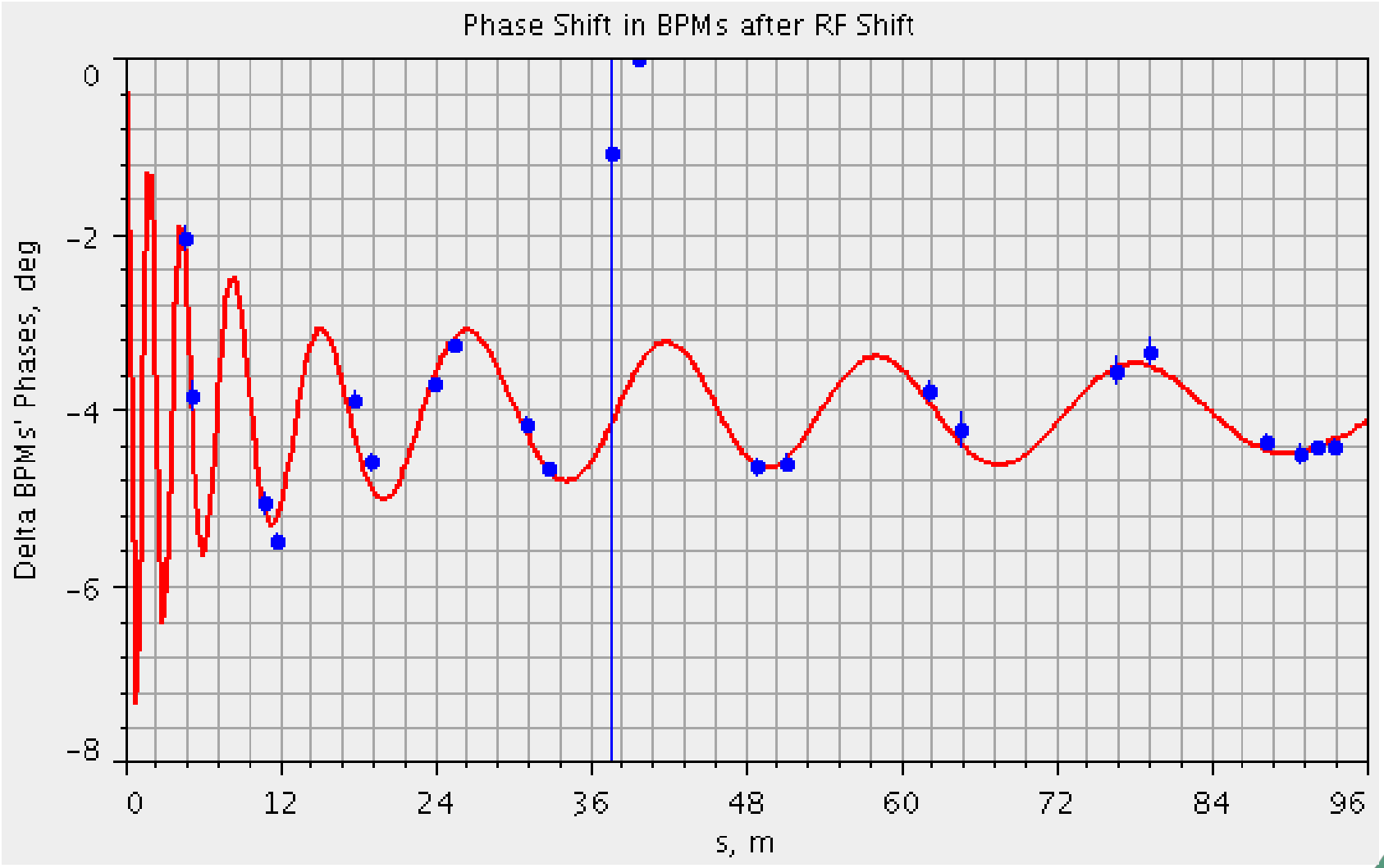
Beam phase oscillation and damping are sensitive to RF errors

SCL phase oscillation measured in February 2006

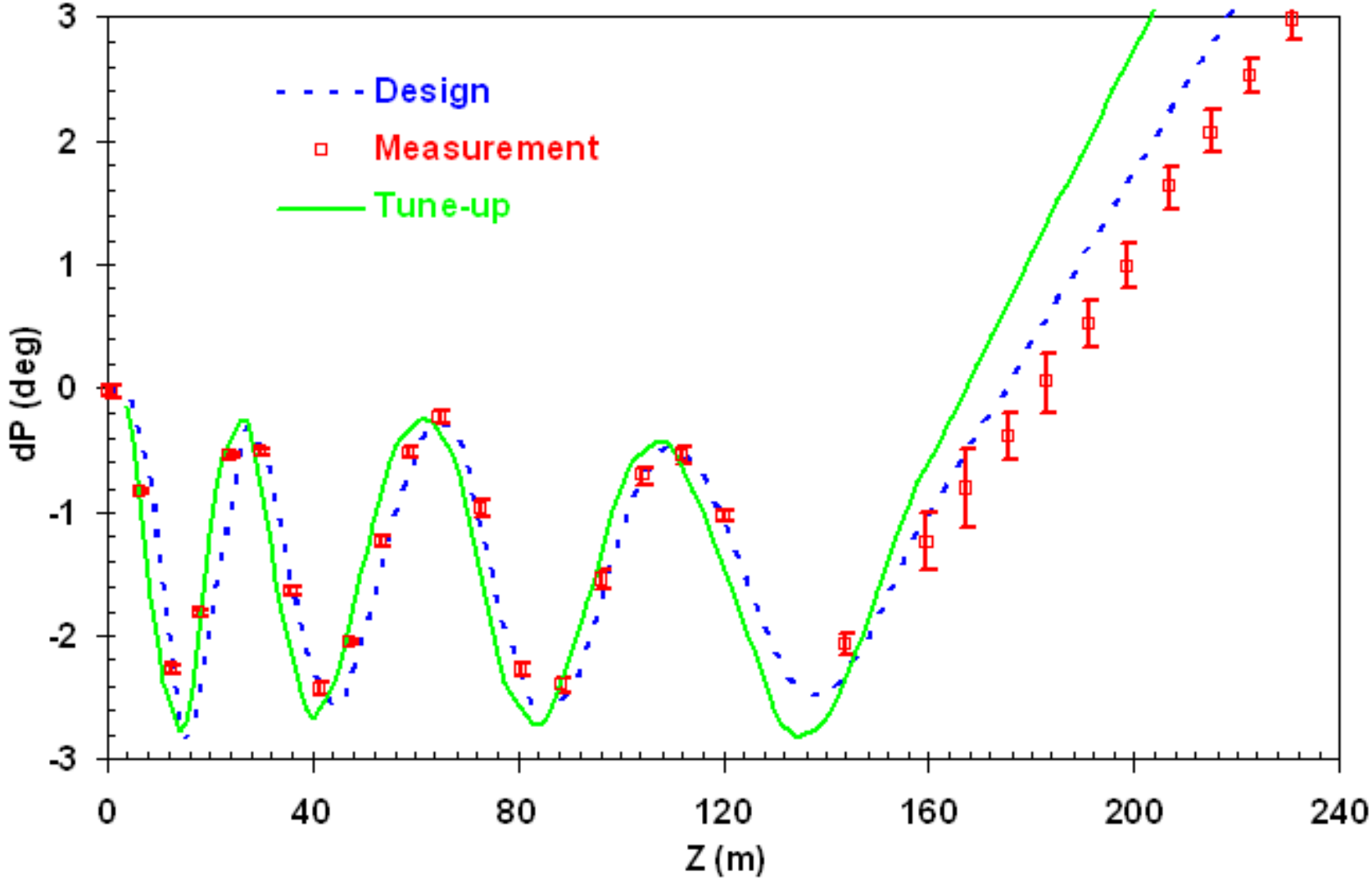


First cavity gradient 10% & 15% reduction, model & measurement

A. V. Aleksandrov, et. al., EPAC2008



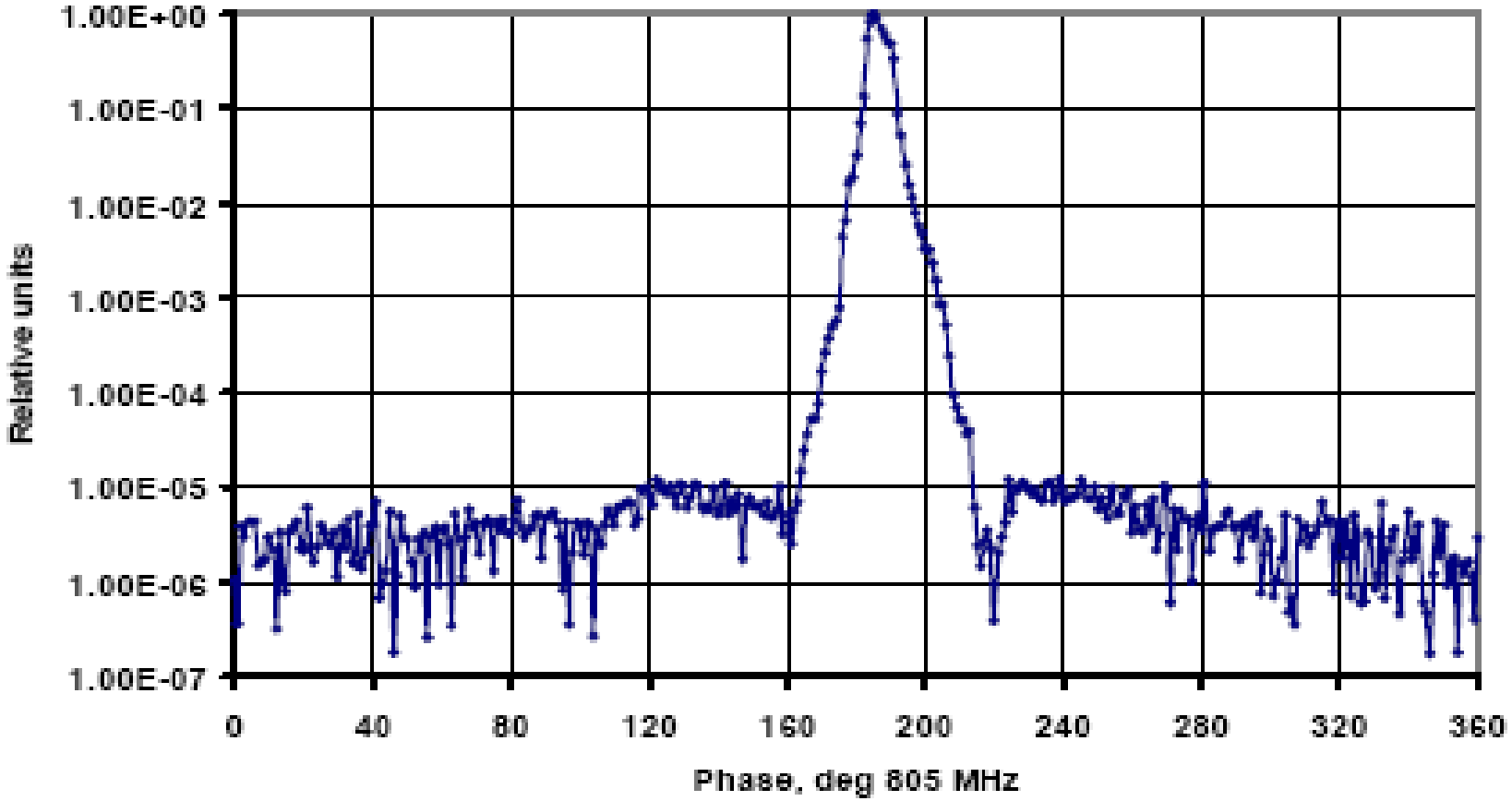
RF Shaker, warm linac model prediction and BPM measurement



SCL phase oscillation, dominated by random errors (~2° phase, ~2% amplitude) and likely caused by RF driftings

Longitudinal Beam Emittance Measurement

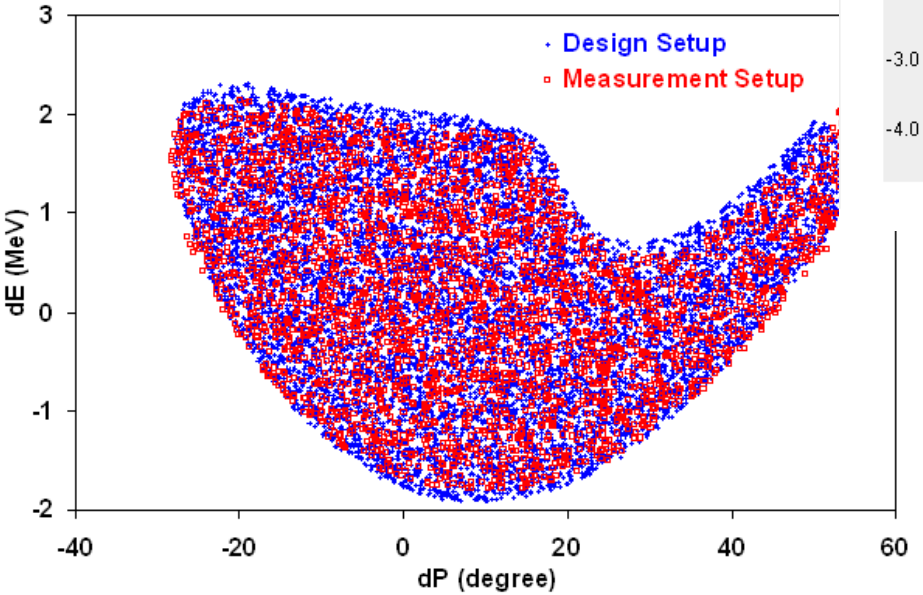
A. V. Feschenko, et. al., PAC2007

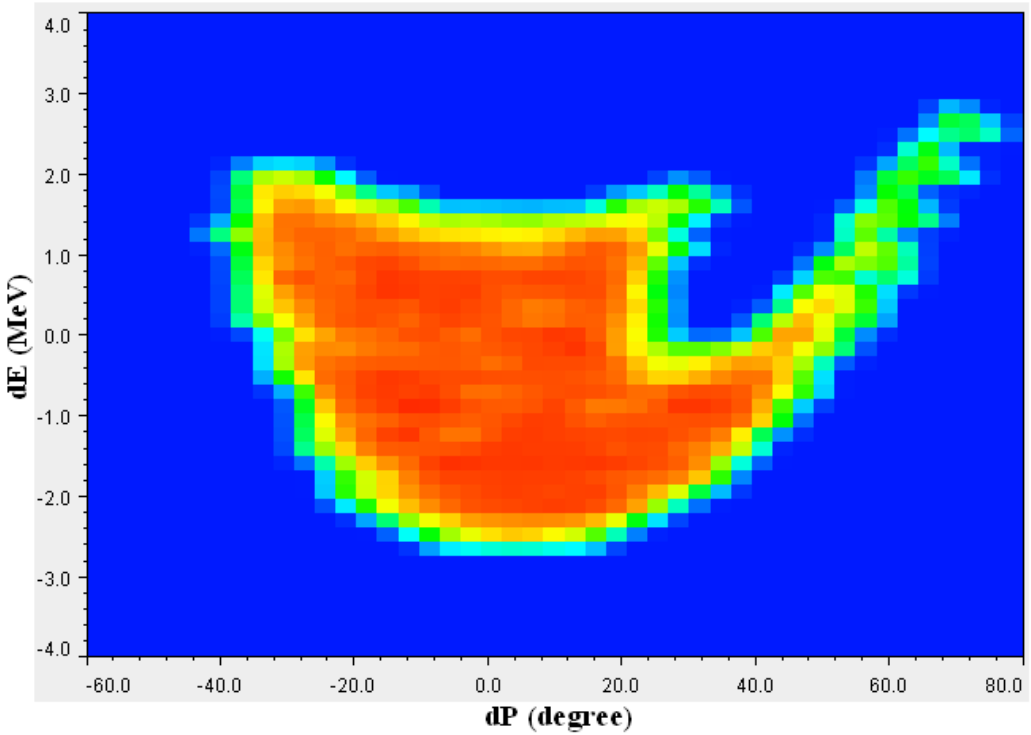


Beam phase profile measured with a BSM in CCL1

Y. Zhang, et. al., submitted to PRST-AB

Model predicted the SCL longitudinal acceptance

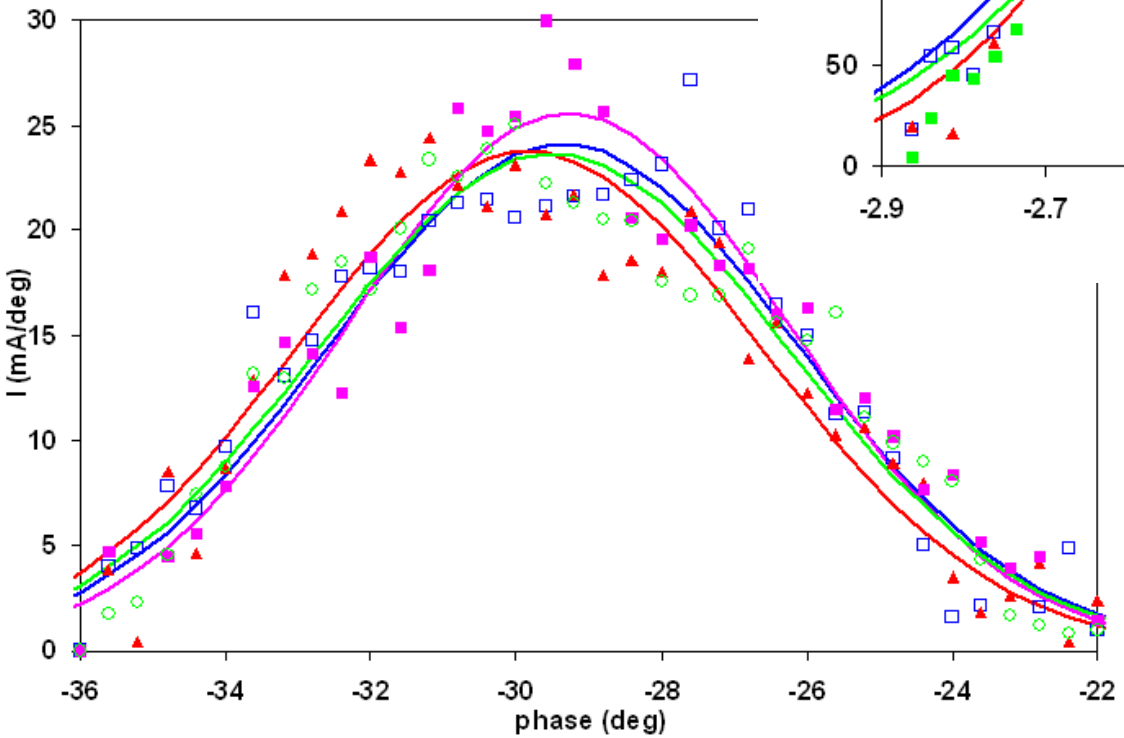


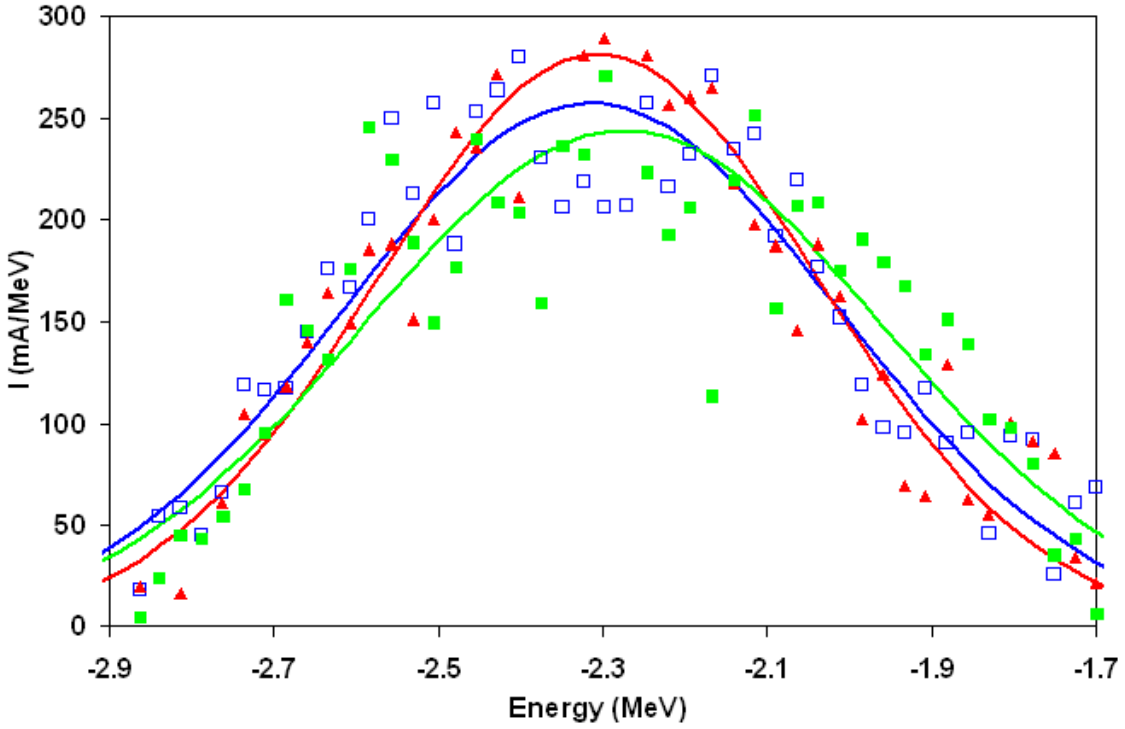


BCM measured acceptance

SCL longitudinal acceptance measurement with BCM and BLMs

Bunch shape measurement



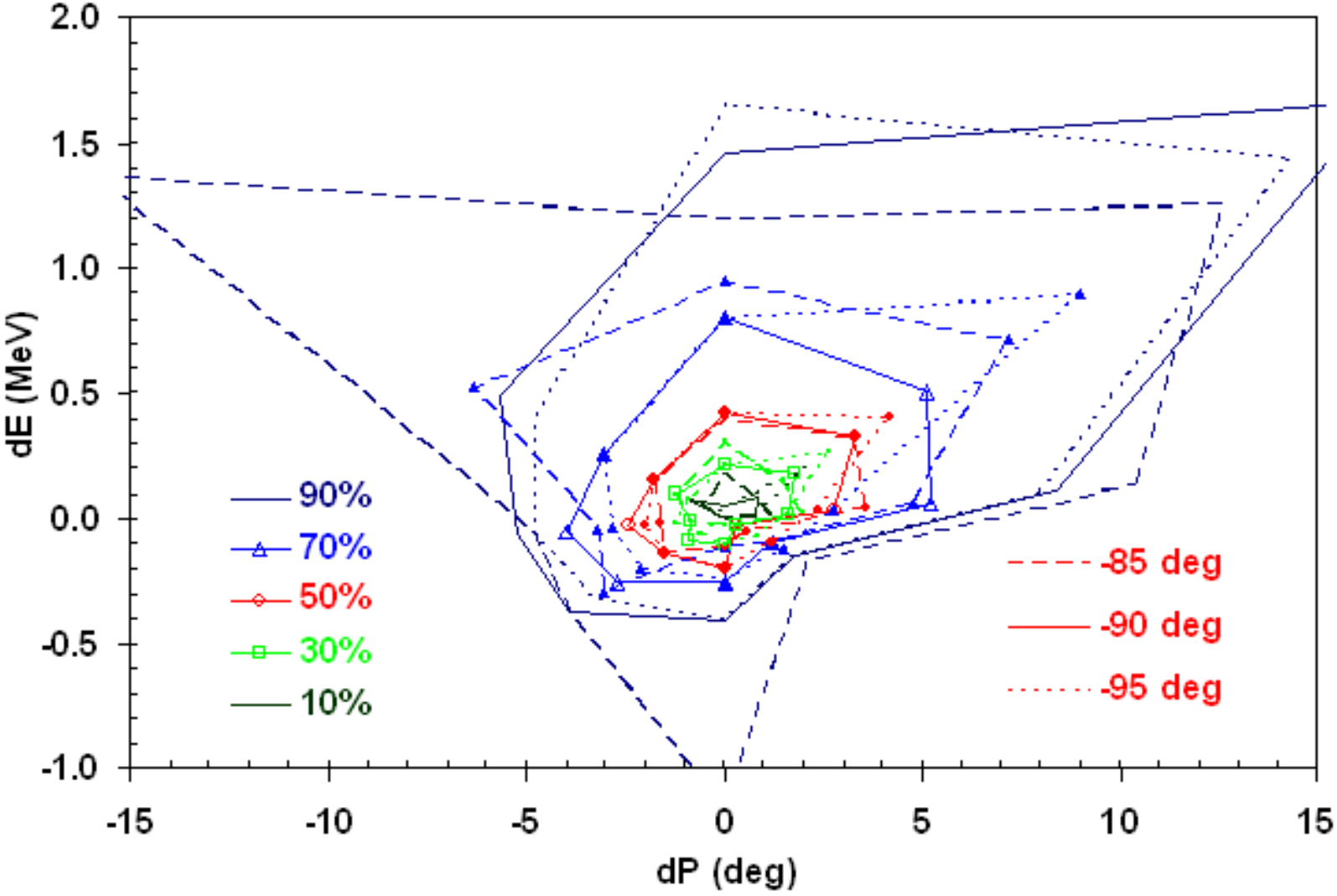


Energy profile measurement

Bunch shape and beam energy profile measured with BCM

Longitudinal beam contours at the SCL entrance (Cav_01b)

RMS emittance: 2.9 MeV*deg ~ 2.2 times the nominal design

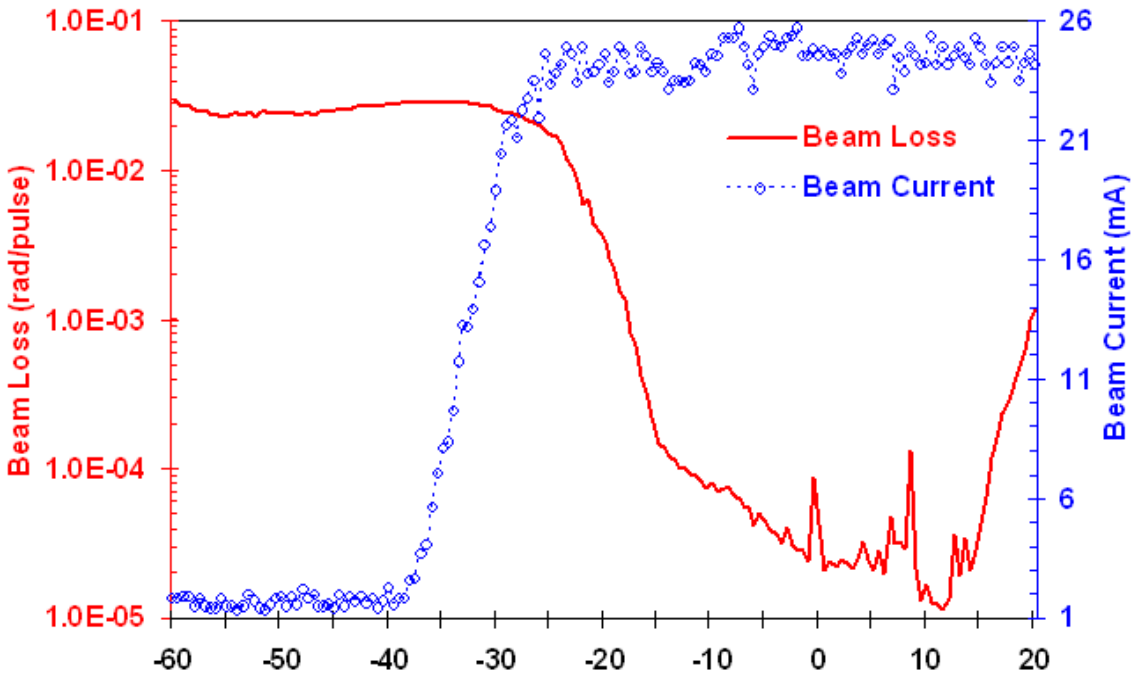


Cav_01a reference phase set at -85, -90 and -95 degree

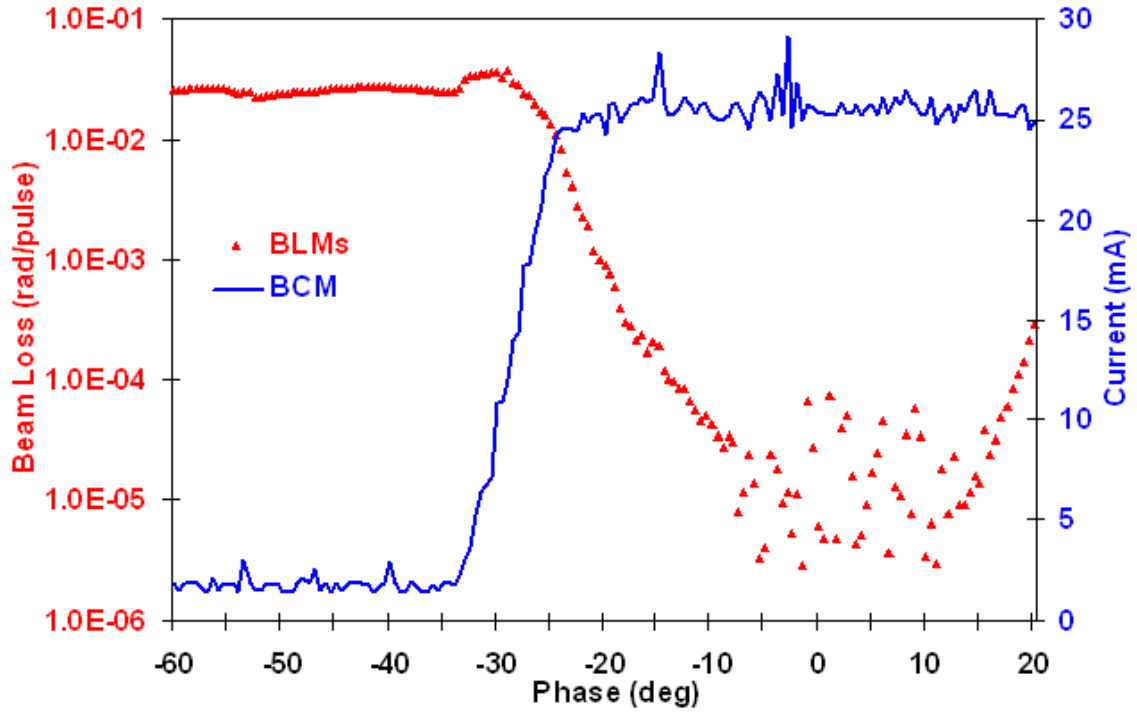
12/23/2007

Phase tails

> 40 deg



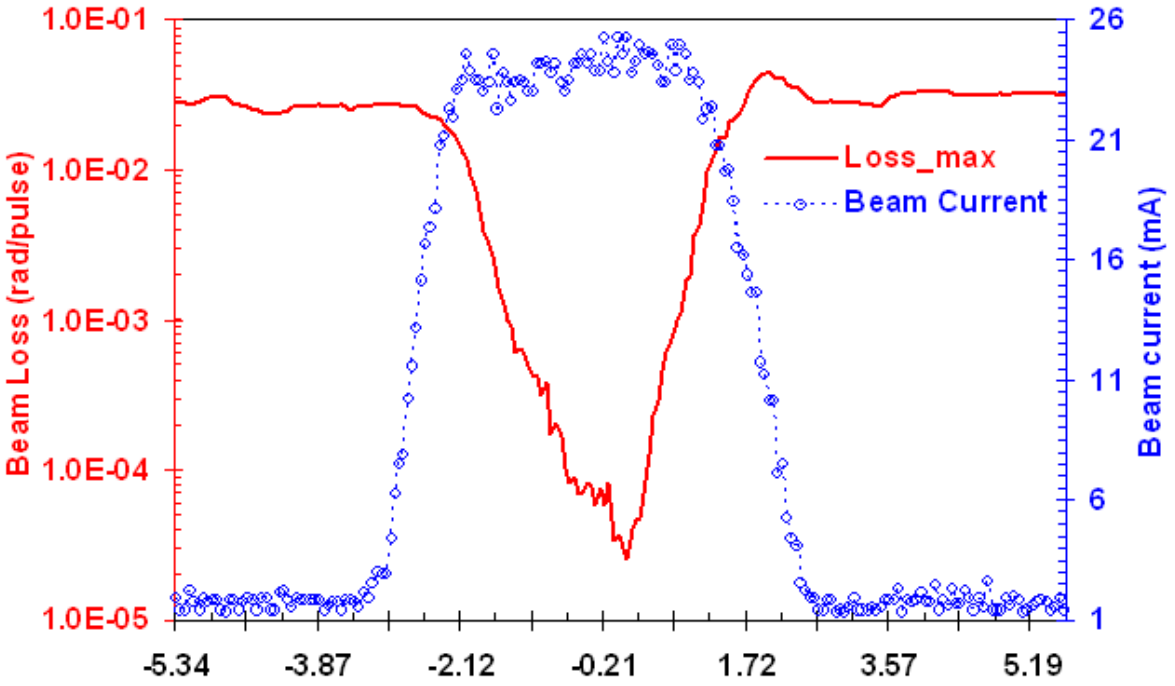
06/15/2008



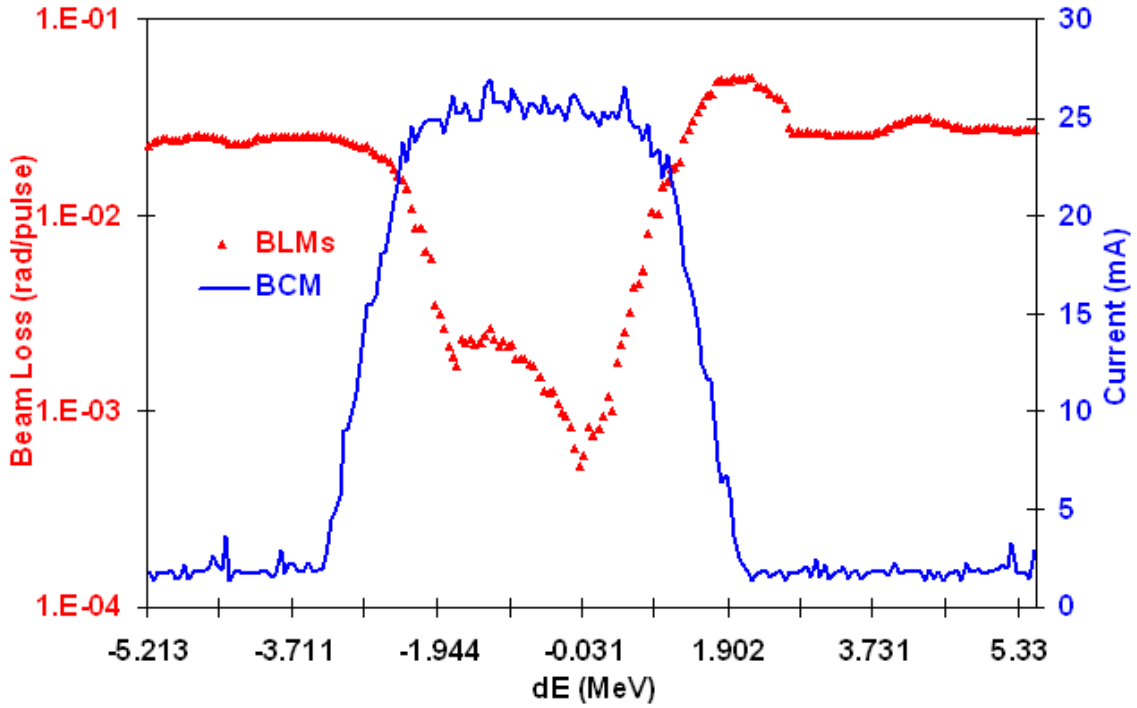
12/23/2007

Energy tails

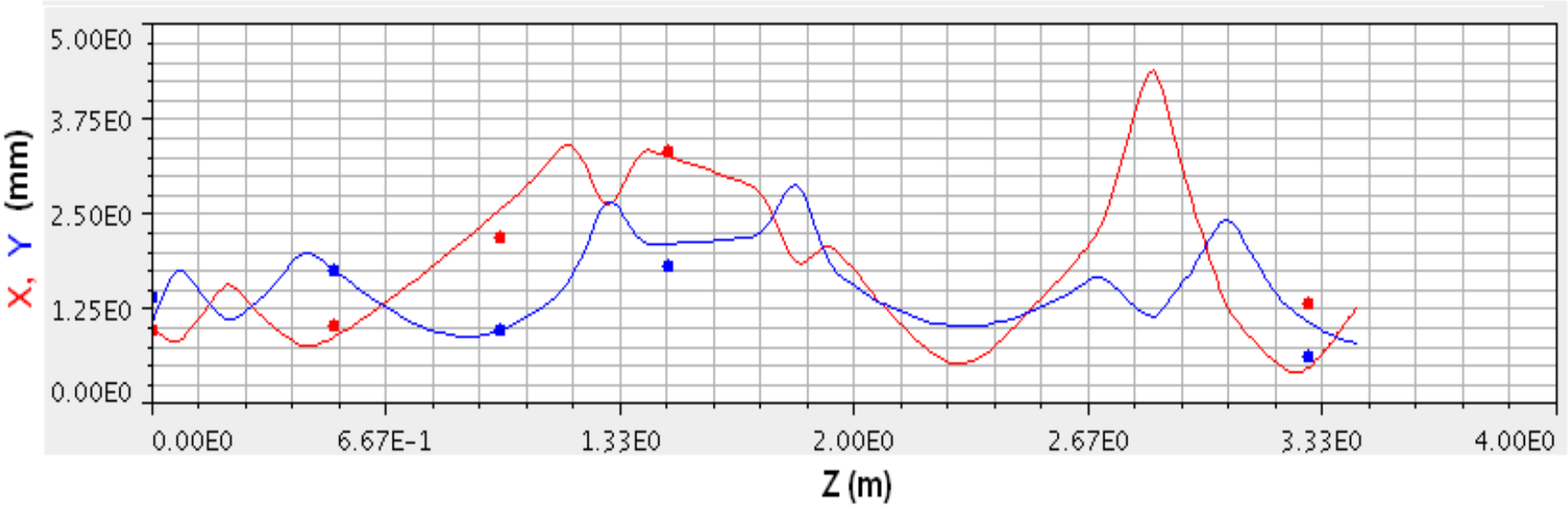
> 3 MeV



06/15/2008



Transverse Beam Dynamics

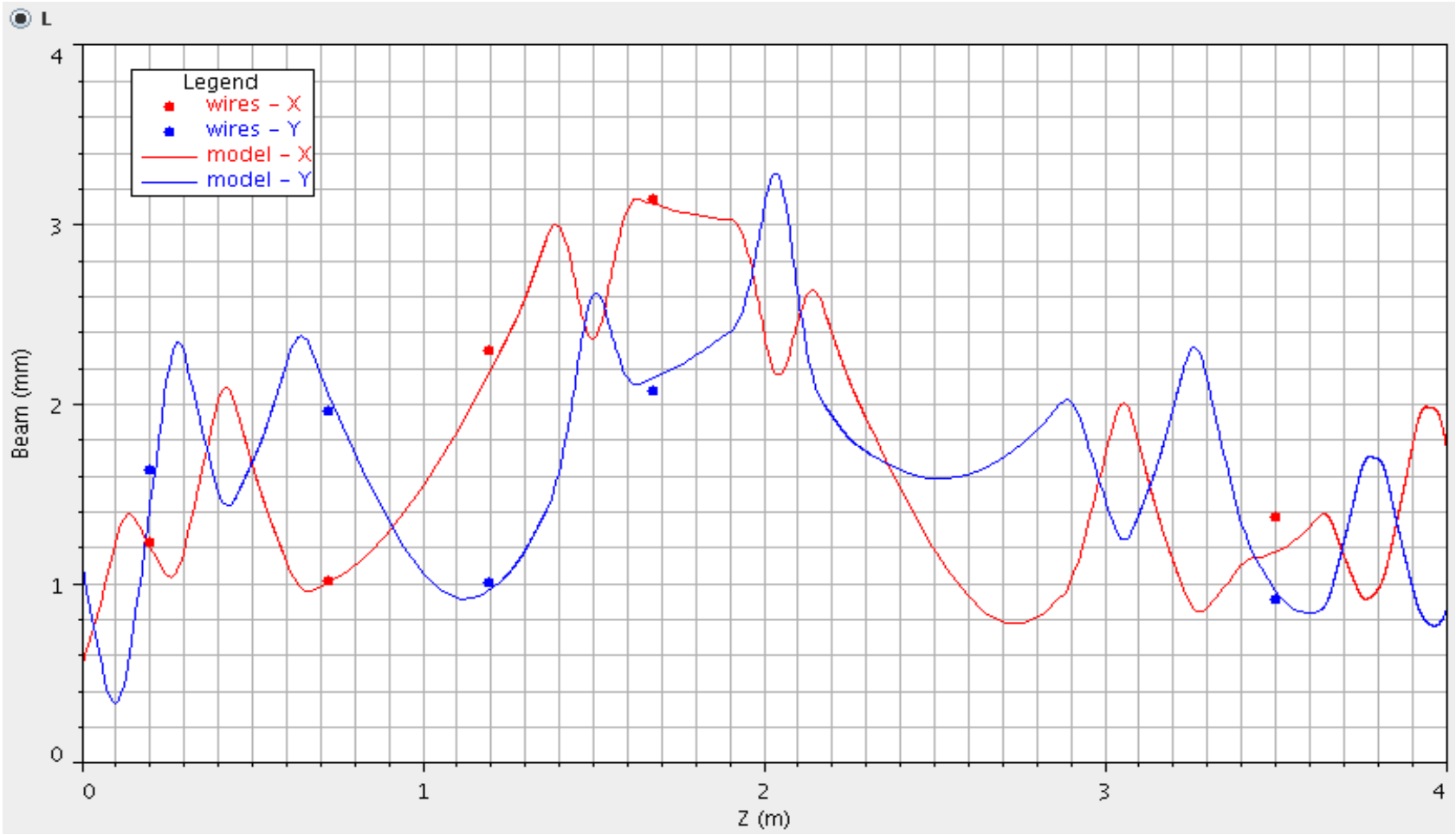


Beam emittance and twiss parameter measurement at MEBT

Multiple wire scans measure beam profiles, and fit the measured beam RMS size with the accelerator models

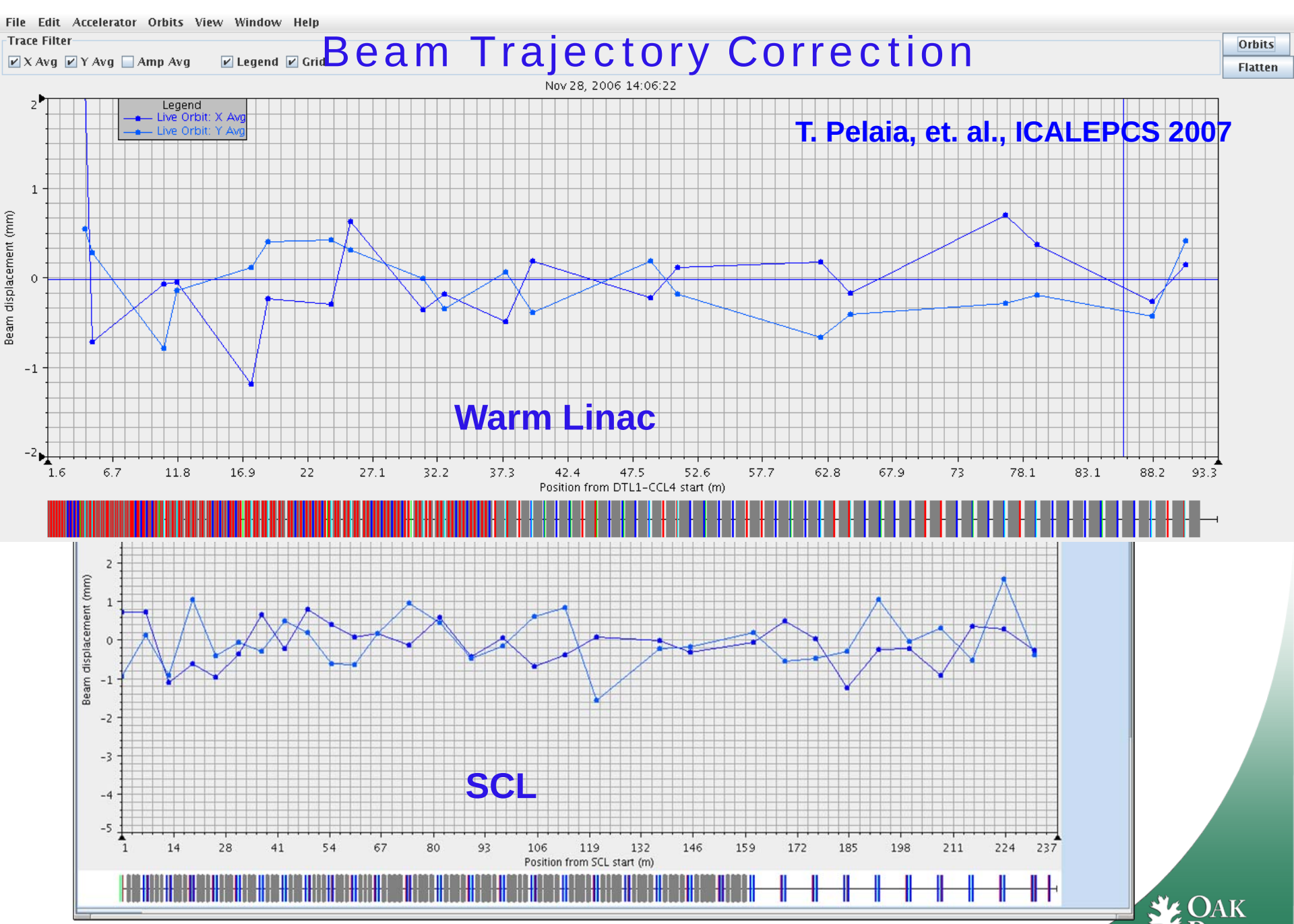
- **On-line model in the XAL is based on TRACE3D.**
- **Transverse – longitudinal phase space coupling.**
- **Higher order effects: emittance growth in RF gaps, chromatic aberrations in "short" quadrupoles.**

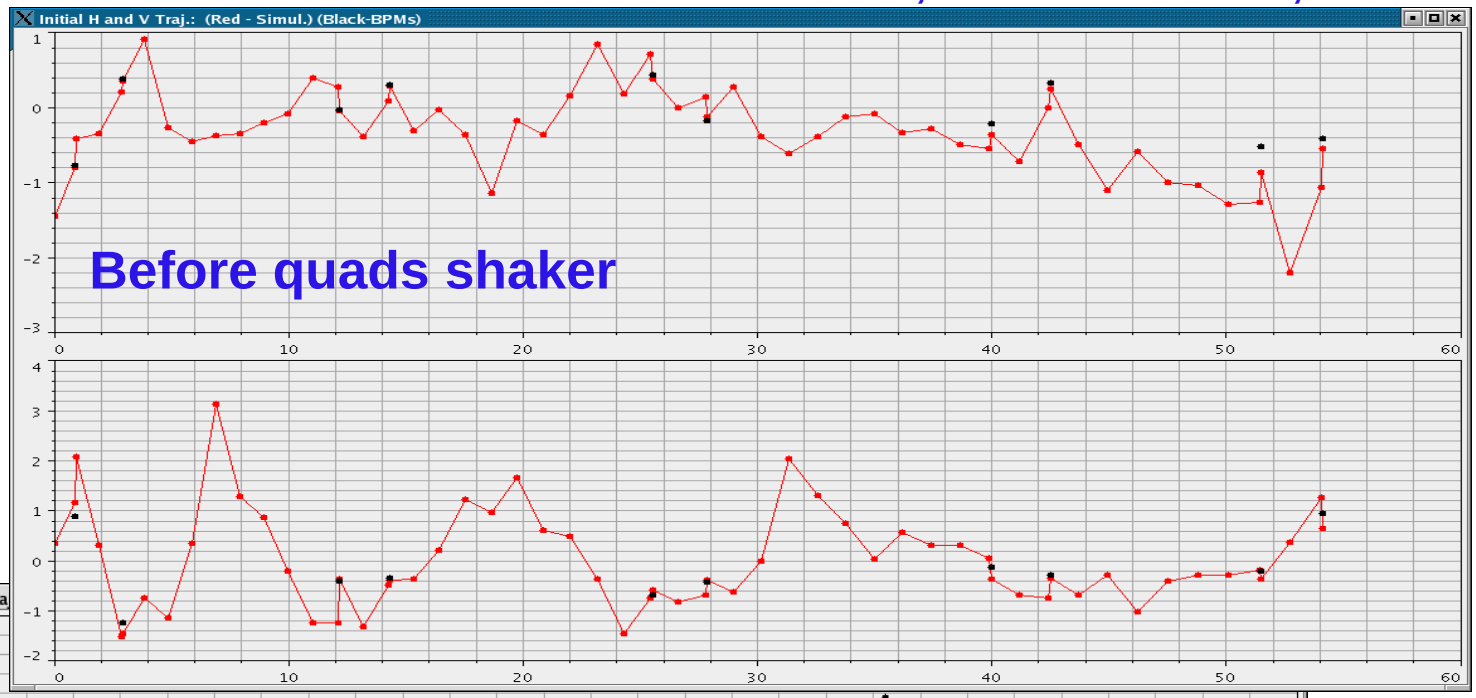
Y. Zhang, J. Qiang, this proceedings

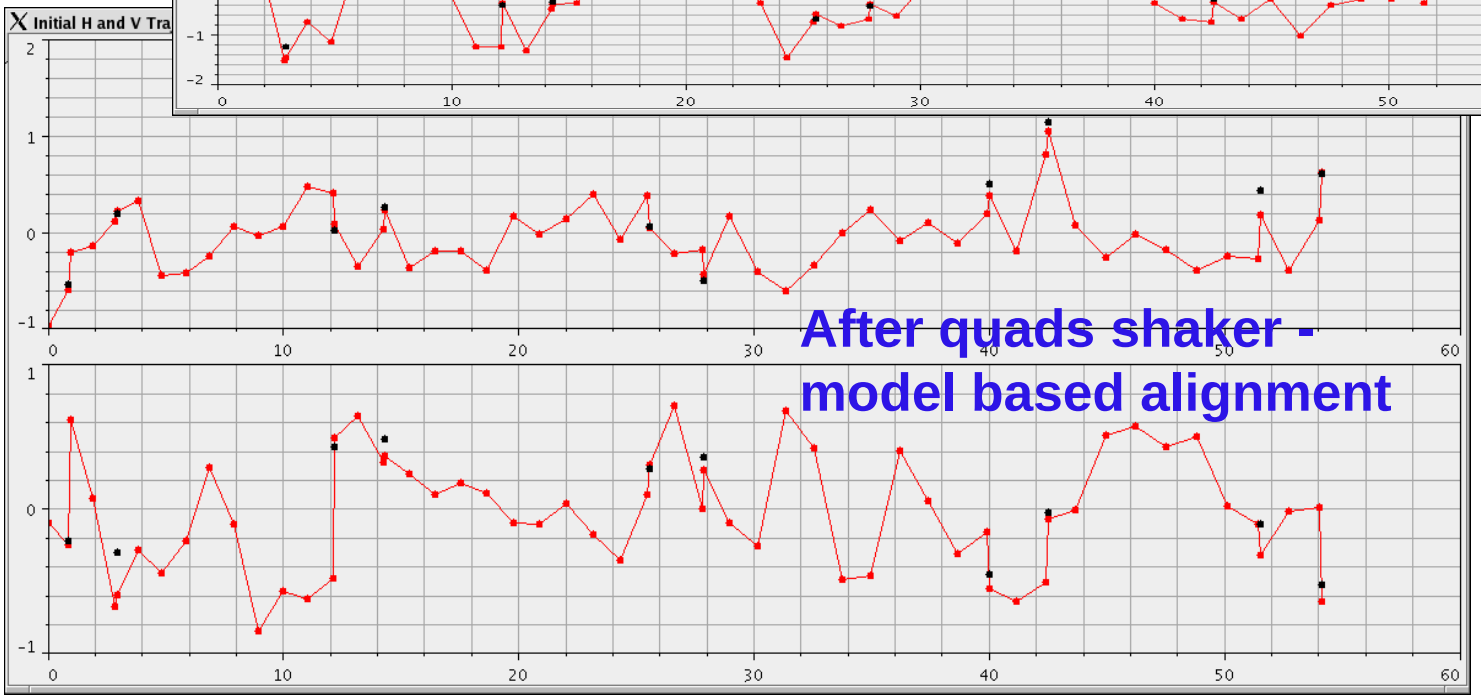


MEBT beam parameter measurement using the IMPACT model

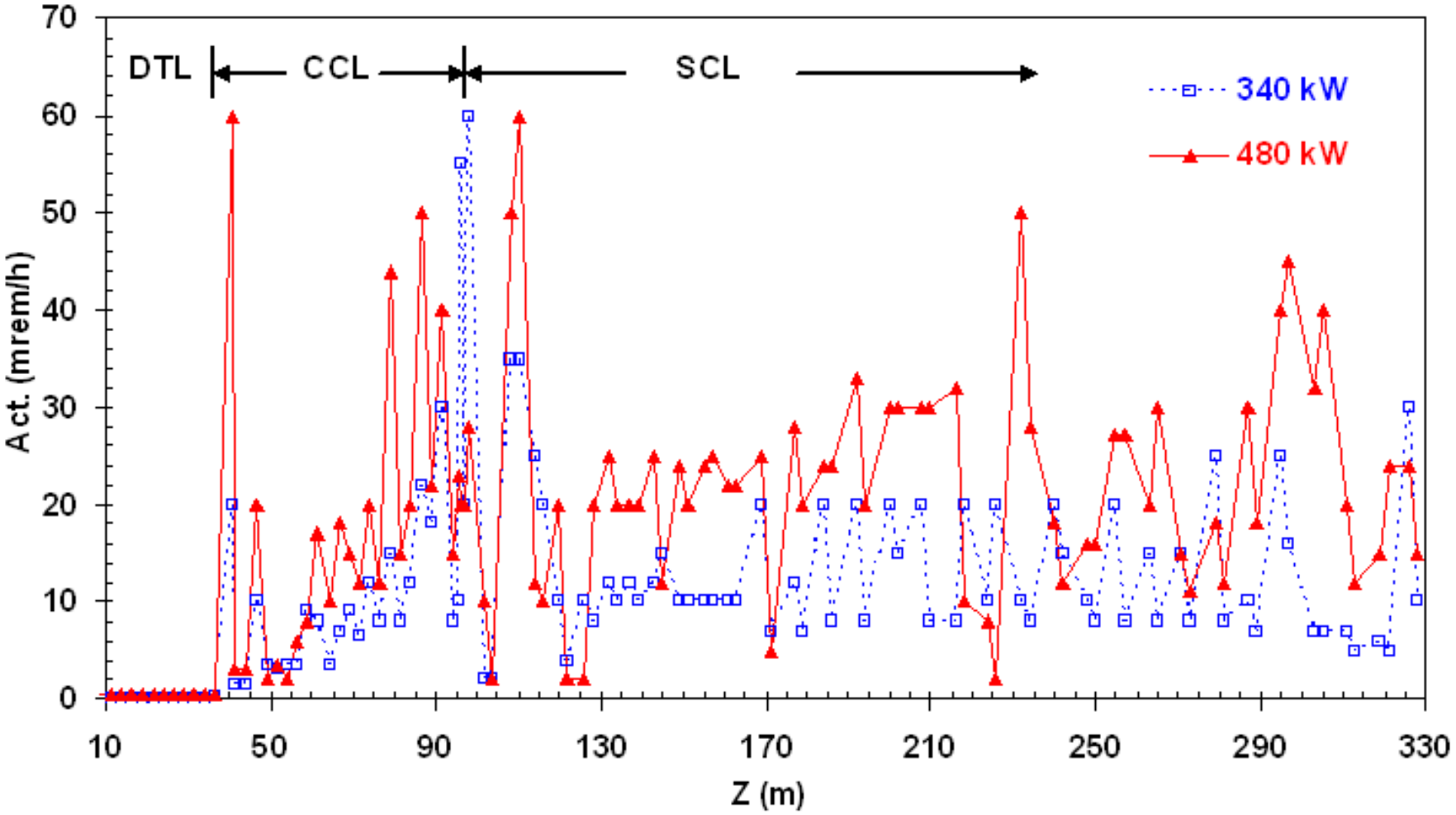
Beam Trajectory Correction




Initial H and V Traj.: (Red - Simul.) (Black-BPMs)
X
Y
Before quads shaker

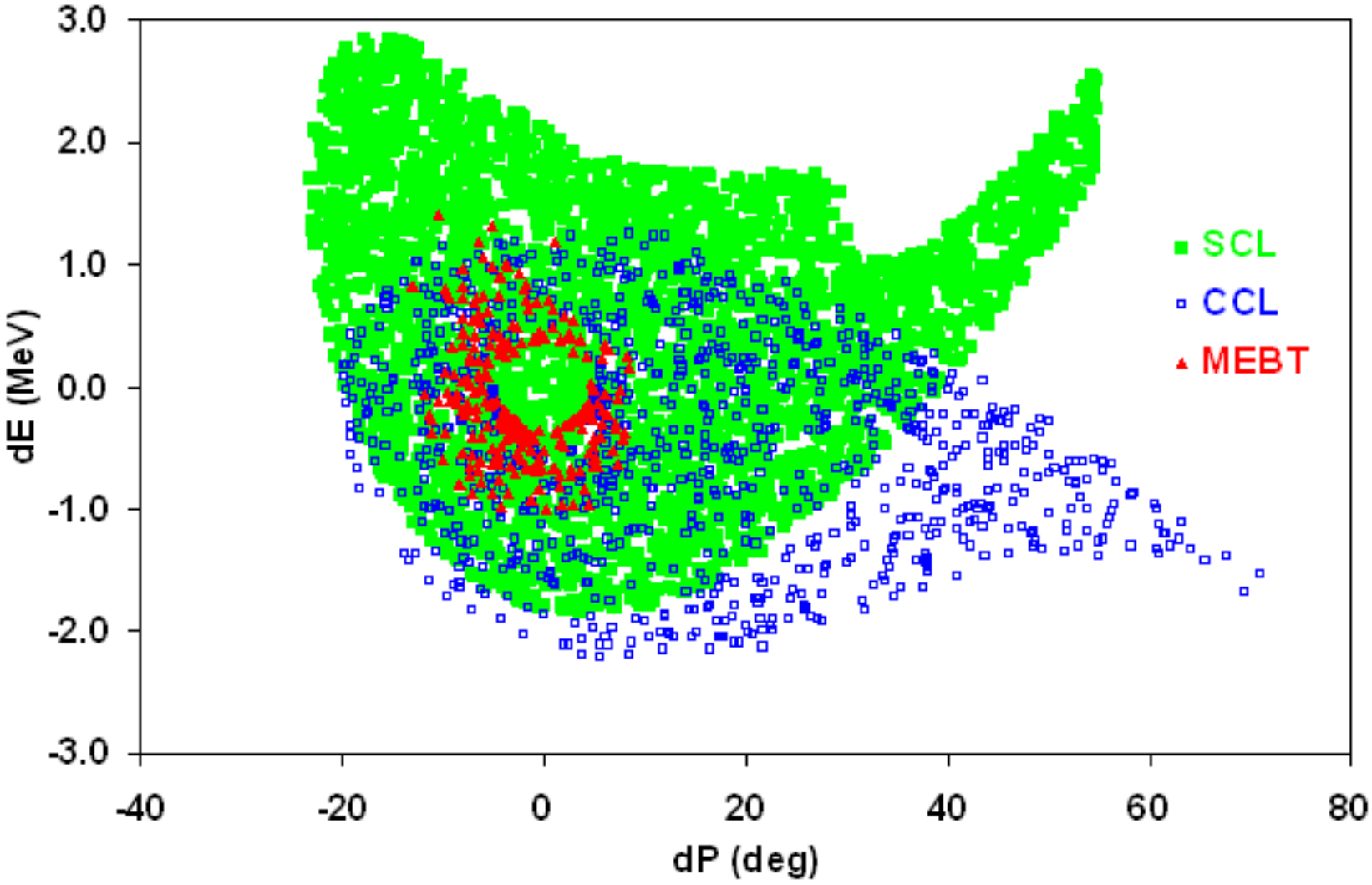

Initial H and V Tra
X
Y
After quads shaker -
model based alignment

Unsolved Puzzles



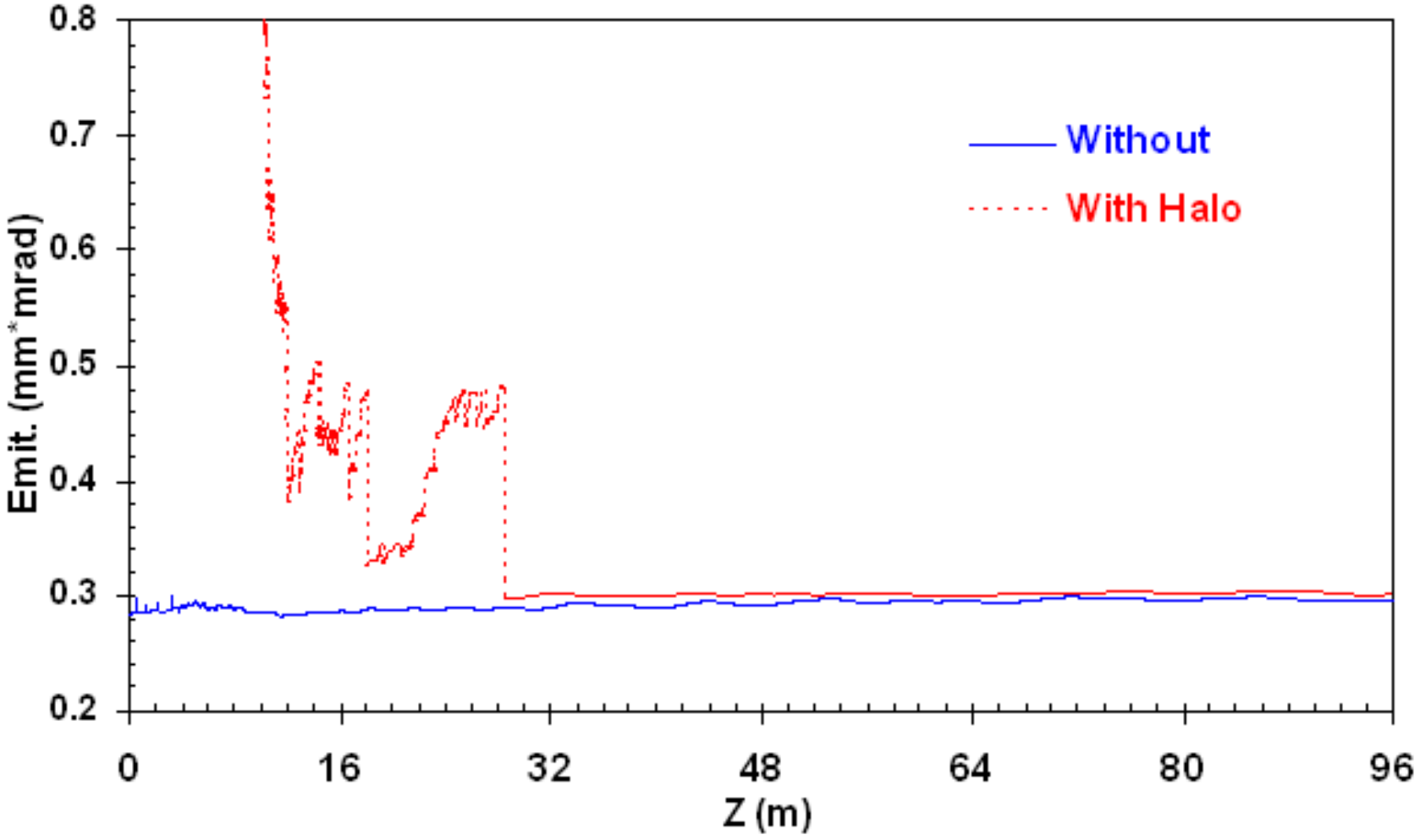
Linac residual activations after neutron productions

SCL Longitudinal Acceptance and ...



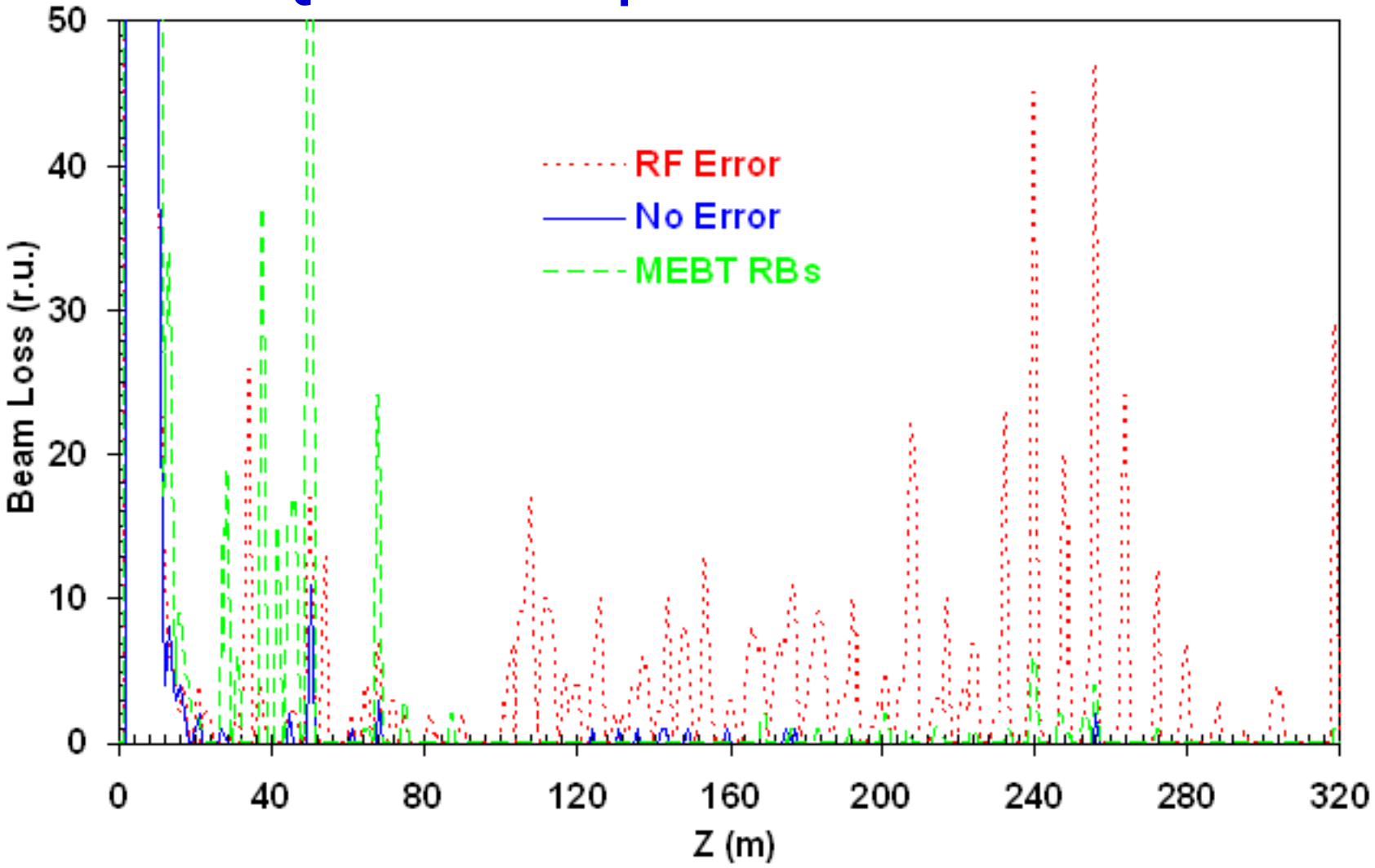
SCL Acceptance, MEBT Particles and CCL Particles

Longitudinal emittance in the warm linac



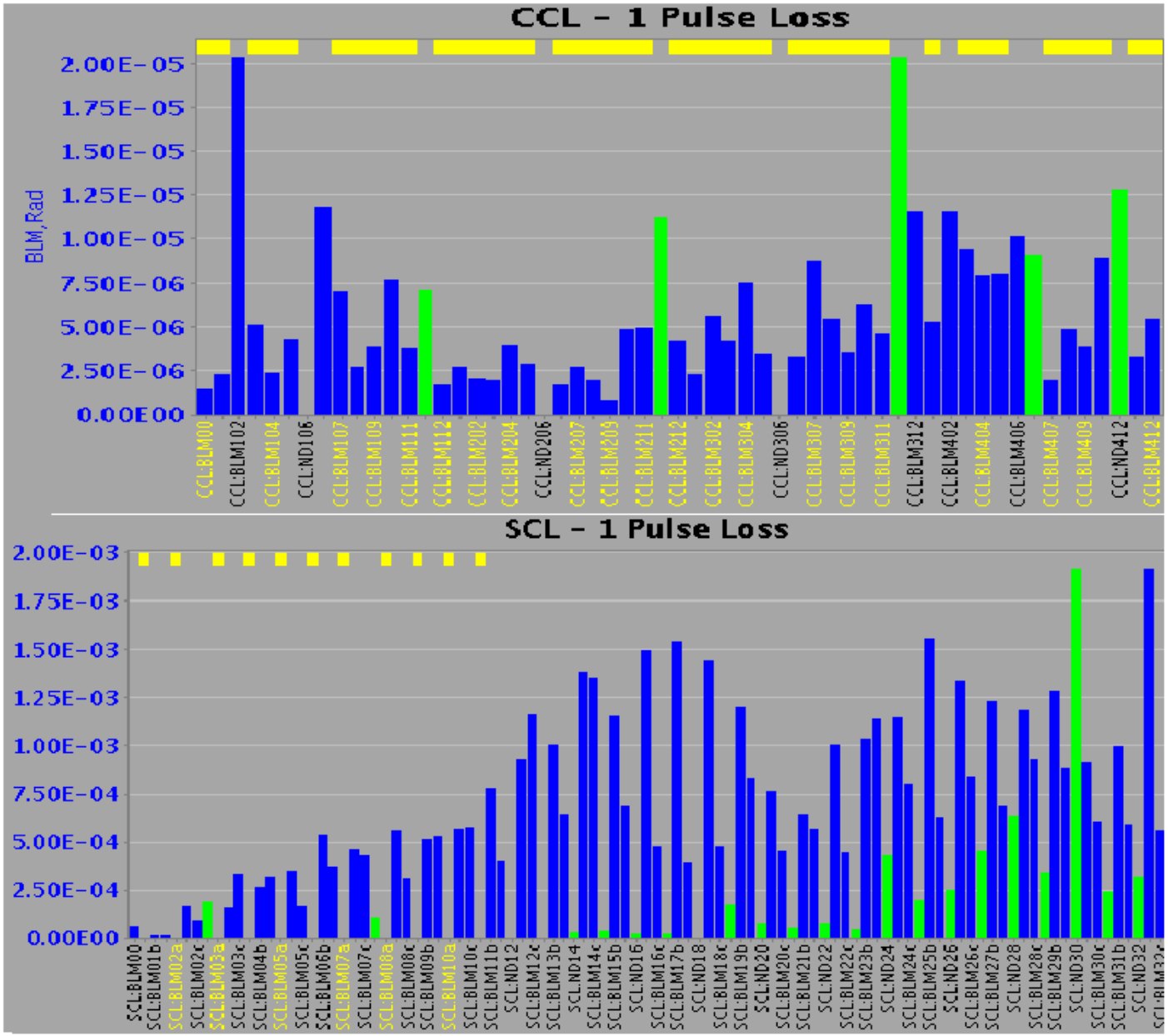
The nc. linac could be a halo filter (scrapper) if no error existed

RFQ Beam Tails plus Linac RF Errors ?

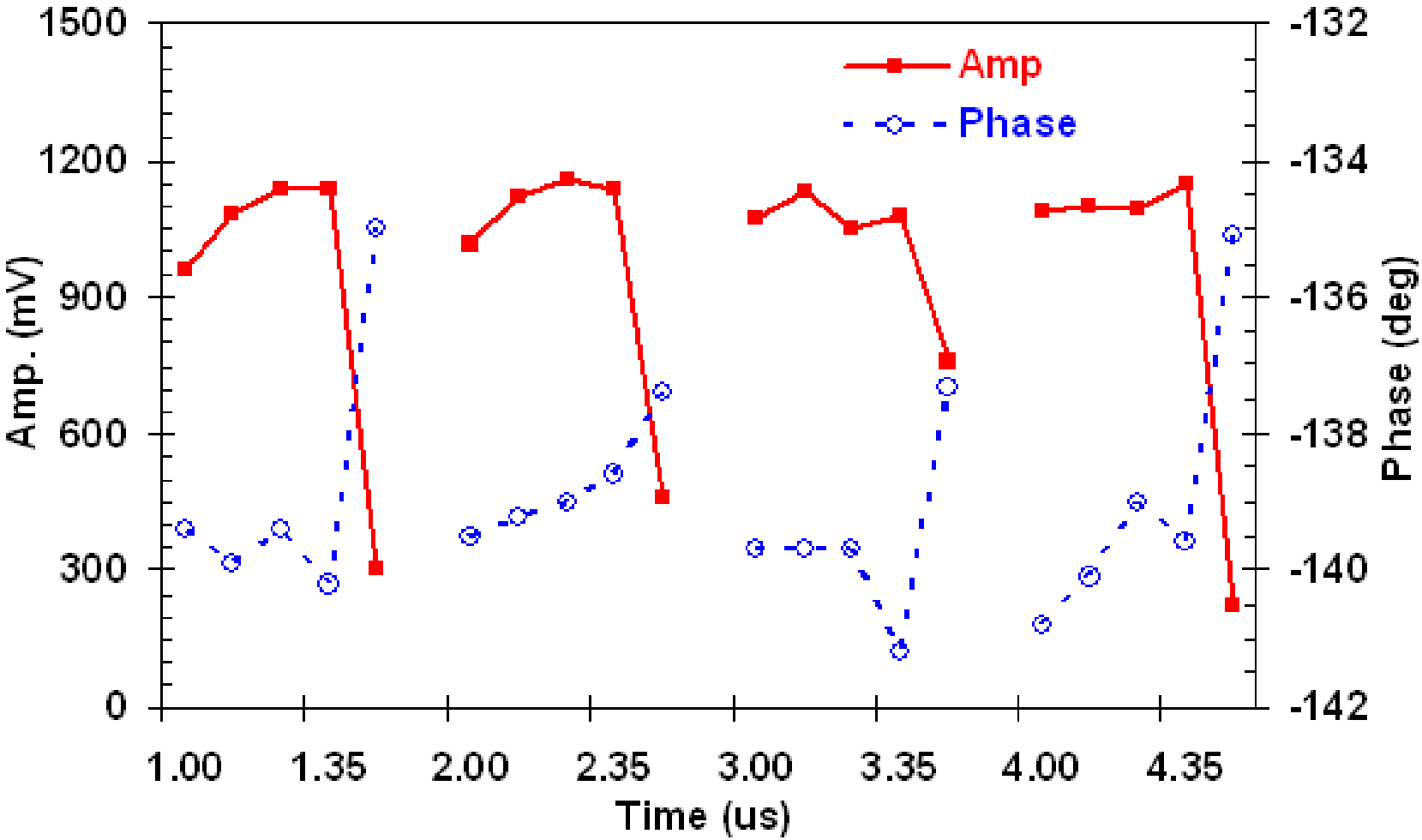


Beam loss in the linac, No Error, RF Error, MEBT RBs gradients

Beam Loss In the SNS Linac (500 kW)

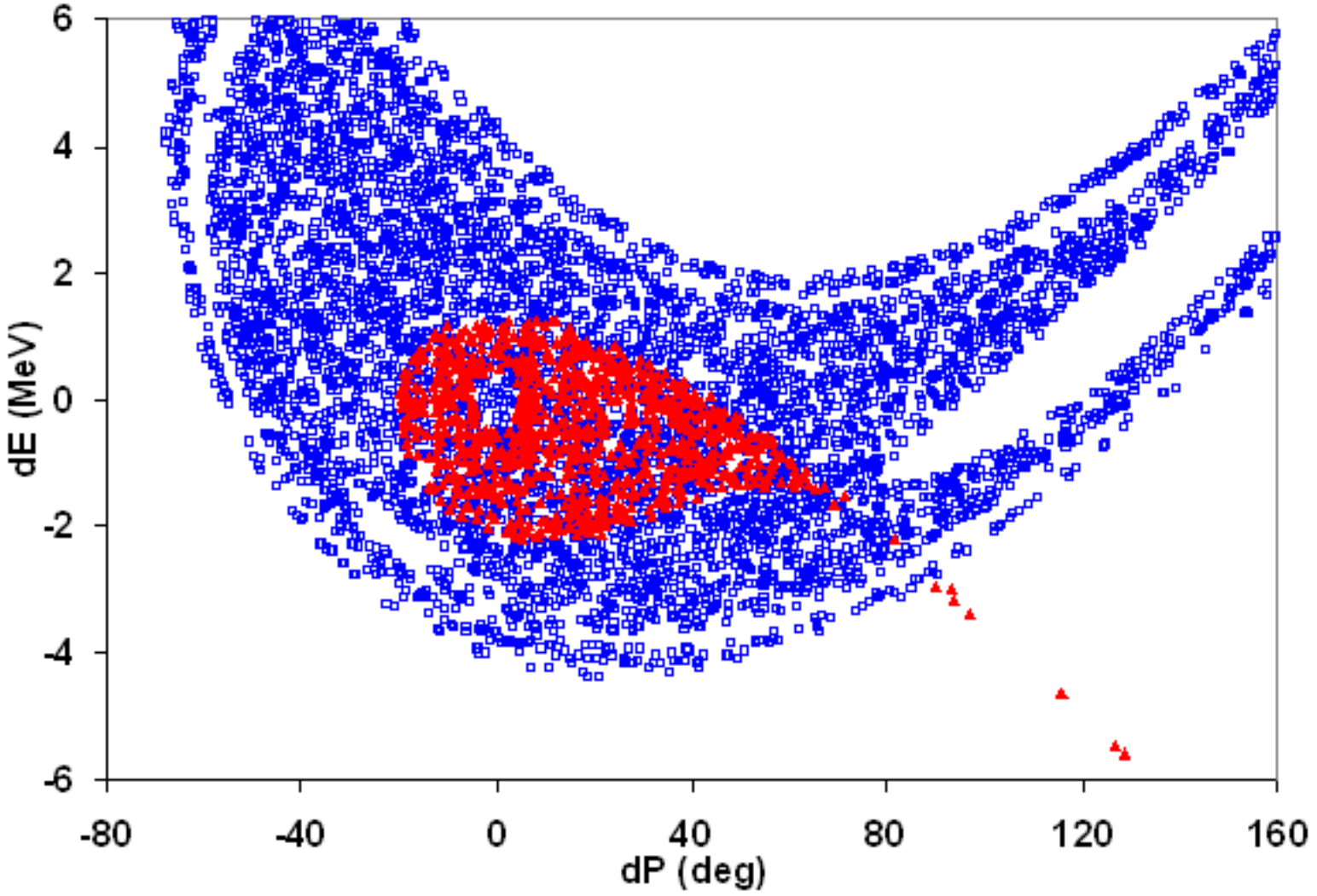


Partially chopped beams ?



CCL1 BPM amplitude and phase measurement for 4 mini-pulse

Increase the SCL acceptance ?



ϕ_s = -35° (design: -20°), sacrifices ~100 MeV output energy

Summary

- **Beam dynamics studies at the SNS linac are performed with several conventional and newly developed techniques.**
- **Beam longitudinal tails/halo shown in the measurements, but the exact cause of the longitudinal halo is not fully understood.**
- **Simulation study of halo in the linac does not have a complete picture, might need 3D particle tracking from the ion source.**
- **Characterize beam halo in the order of 10^{-5} to 10^{-4} and reduce the fractional beam loss to below 10^{-4} in the SCL is a challenge, existing problems should be fixed first. E.g., MEBT rebuncher, LEBT and MEBT beam chopper, performance of the RFQ, and transverse beam matching through the entire linac correctly…**
- **Beam loss in the linac especially in the SC linac is one of the major concerns to further ramp up the beam power, a factor of two to three beam loss reduction is needed. Suggestions and ideas are welcome.**