Welcome to the session on Benchmarking and Experiments!

Beam Dynamics in the SNS Linac and Beam Test Facility

Kiersten Ruisard, ORNL

Benchmarking PIC simulations against the SNS Beam Test Facility

Tony Wood, ORNL

Space-charge dynamics in bare IOTA: Benchmarking among simulations and experiment

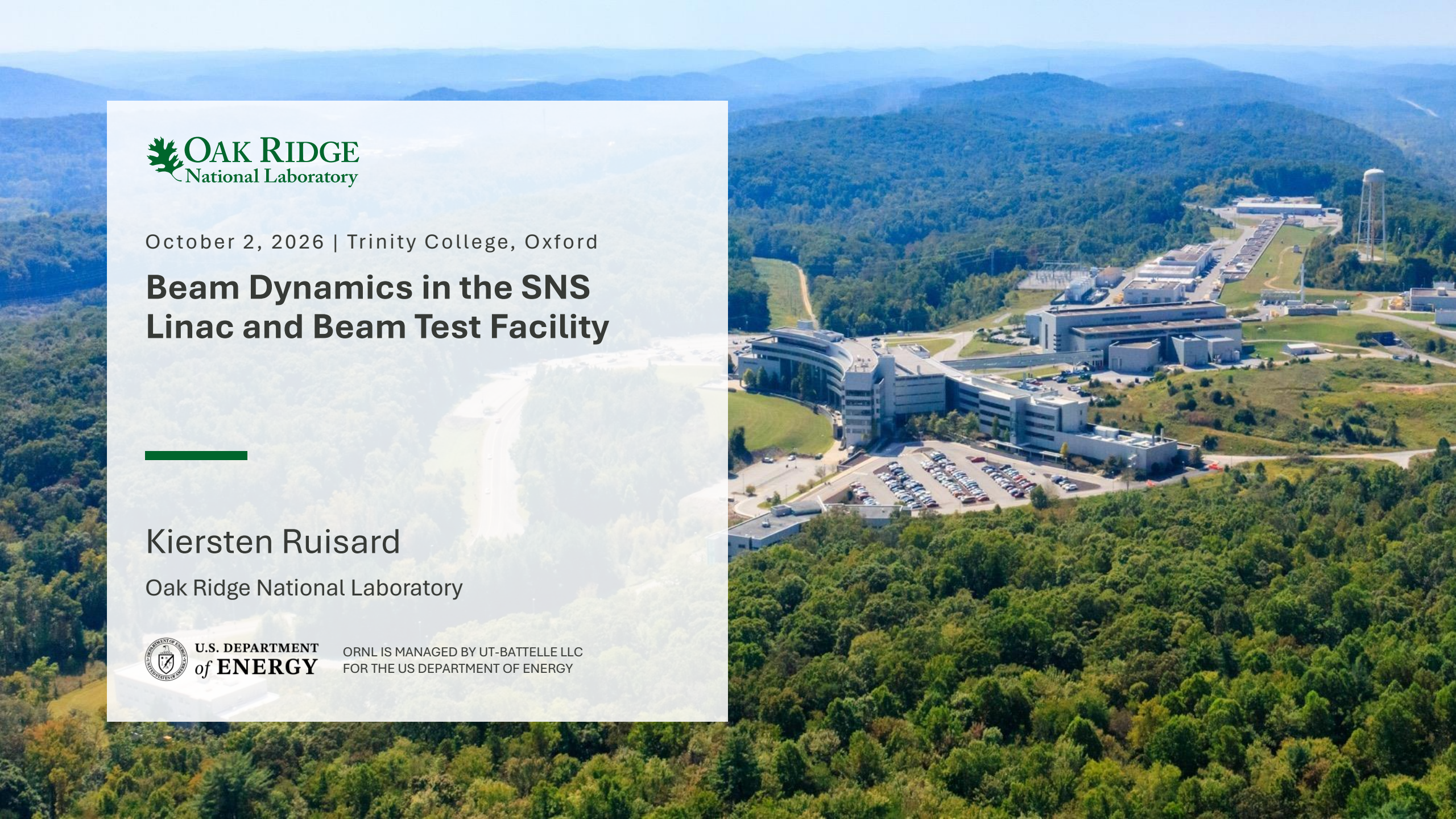
Nilanjan Banarjee, FNAL

Benchmarking Experience with PTC-PyORBIT for High-Intensity Synchrotron Studies

Haroon Rafique, RAL

Space Charge Effects in the Alternating Gradient Synchrotron at injection energies

Yichao Jing, BNL



OAK RIDGE National Laboratory

October 2, 2026 | Trinity College, Oxford

Beam Dynamics in the SNS Linac and Beam Test Facility

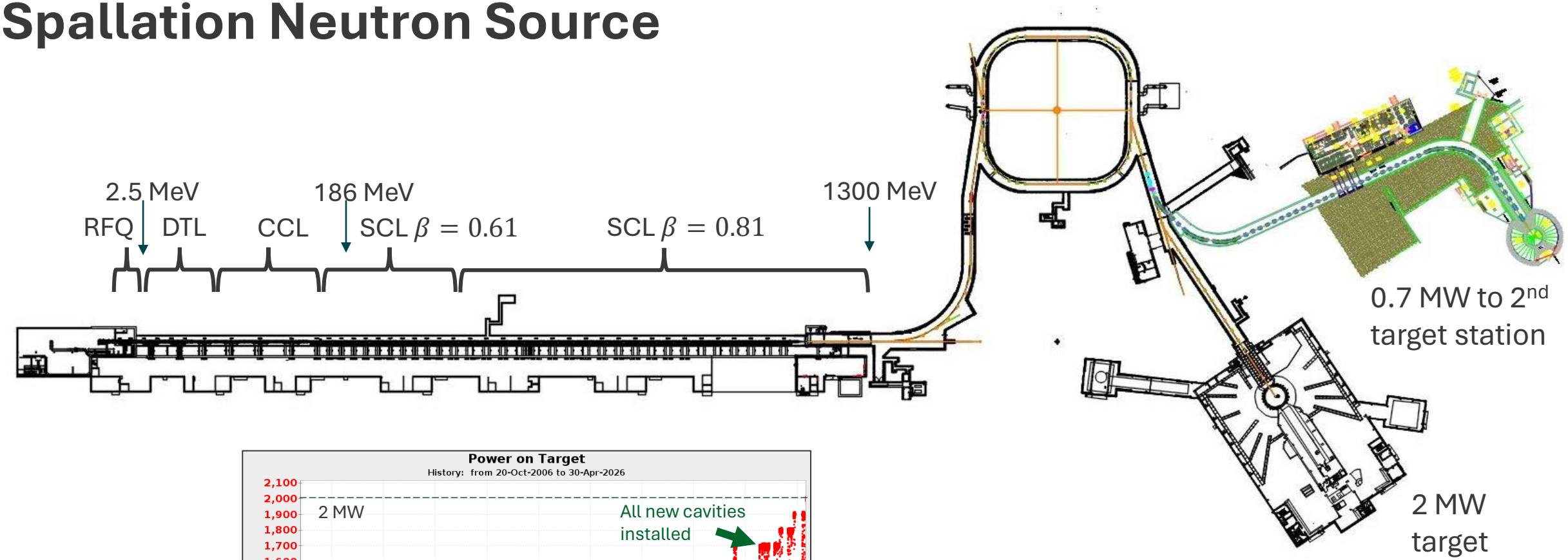
Kiersten Ruisard

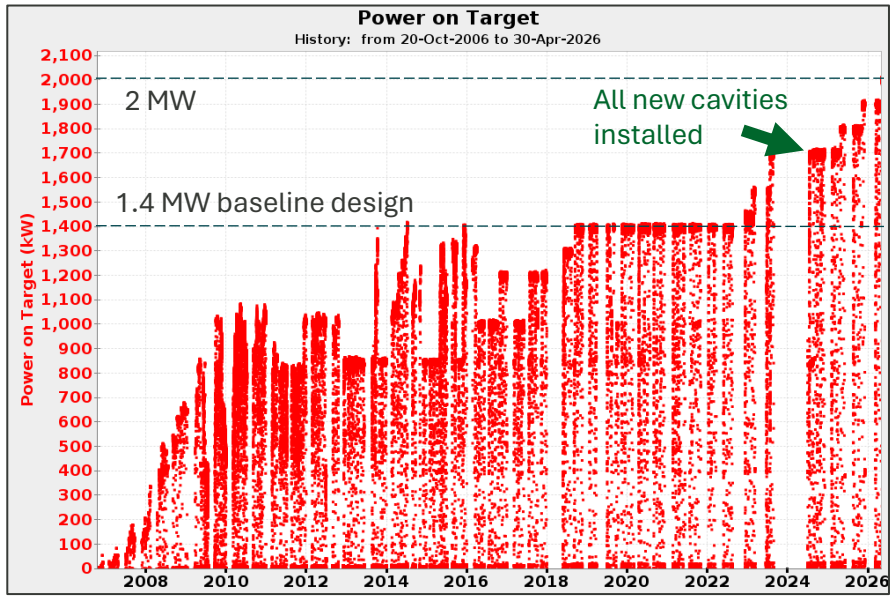
Oak Ridge National Laboratory

U.S. DEPARTMENT of ENERGY

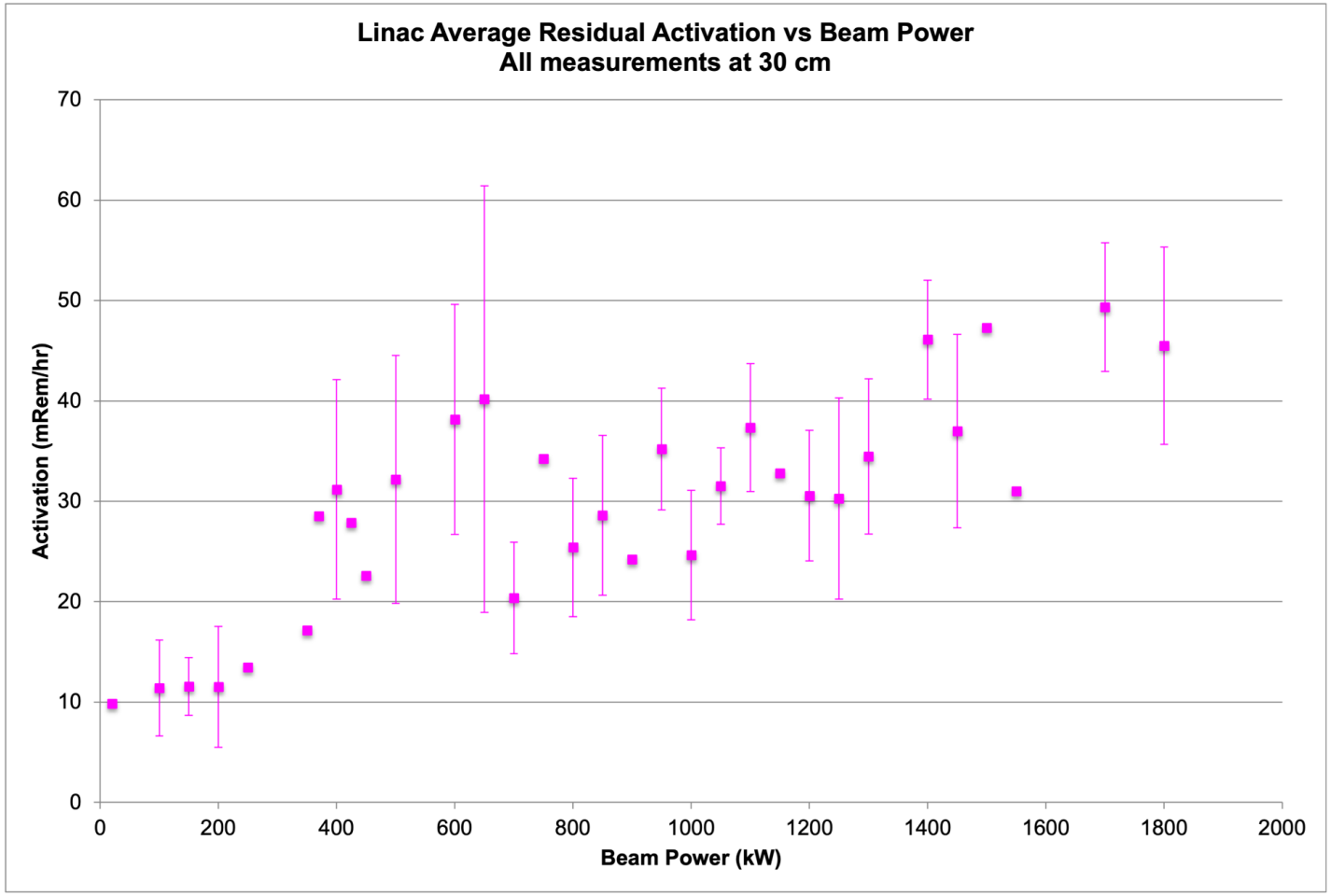
ORNL IS MANAGED BY UT-BATTELLE LLC
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Spallation Neutron Source

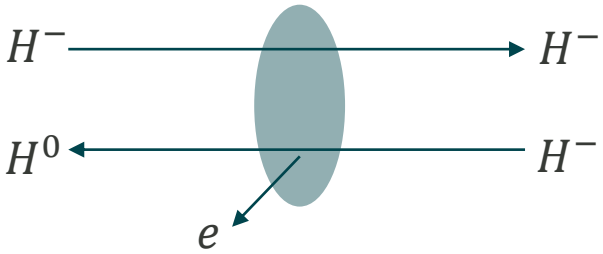


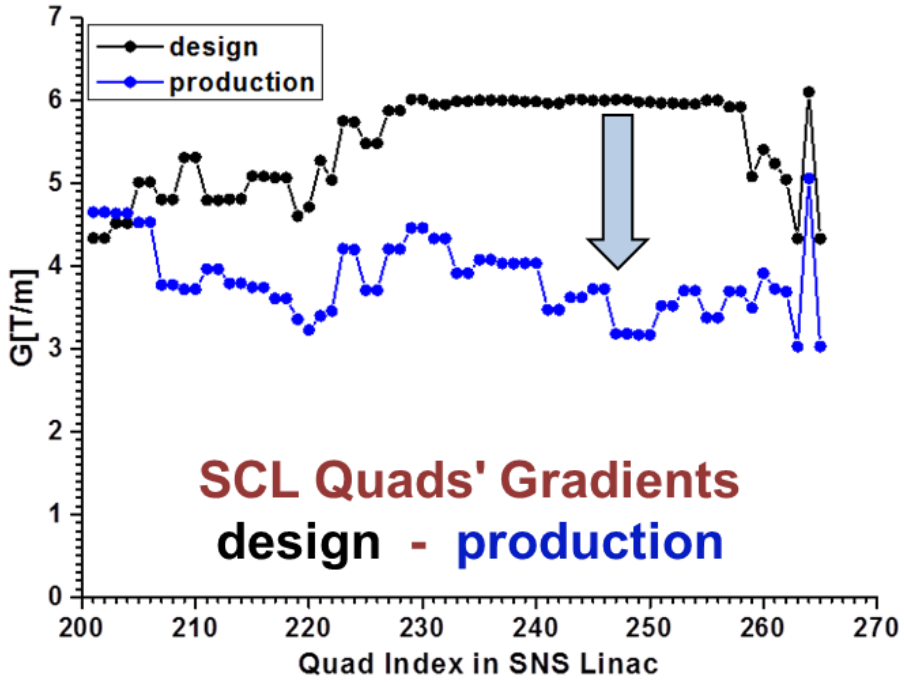


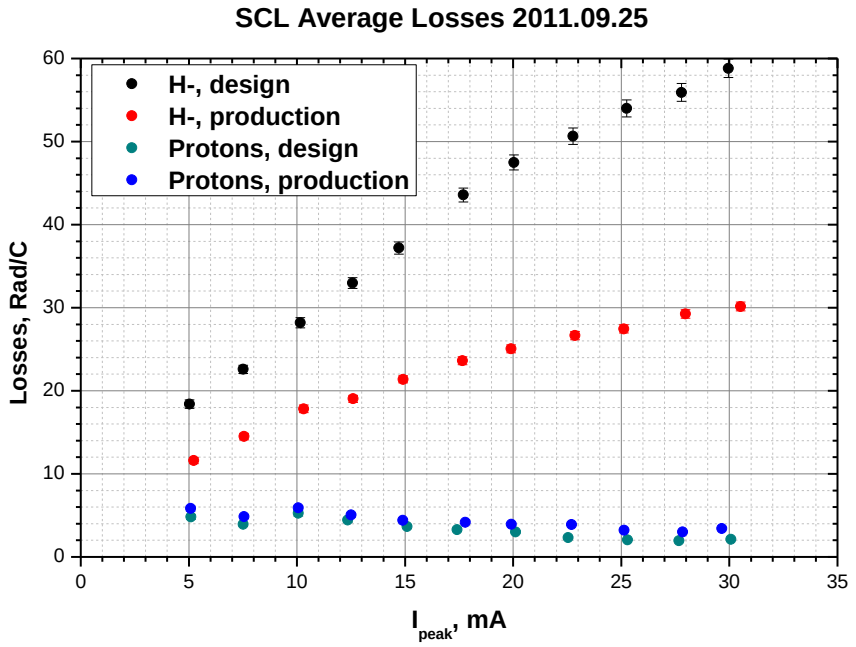
Increased beam loss at 2+ MW increases lost beam and radioactivation in tunnels



Intrabeam stripping loss was a major hiccup in initial commissioning of SNS

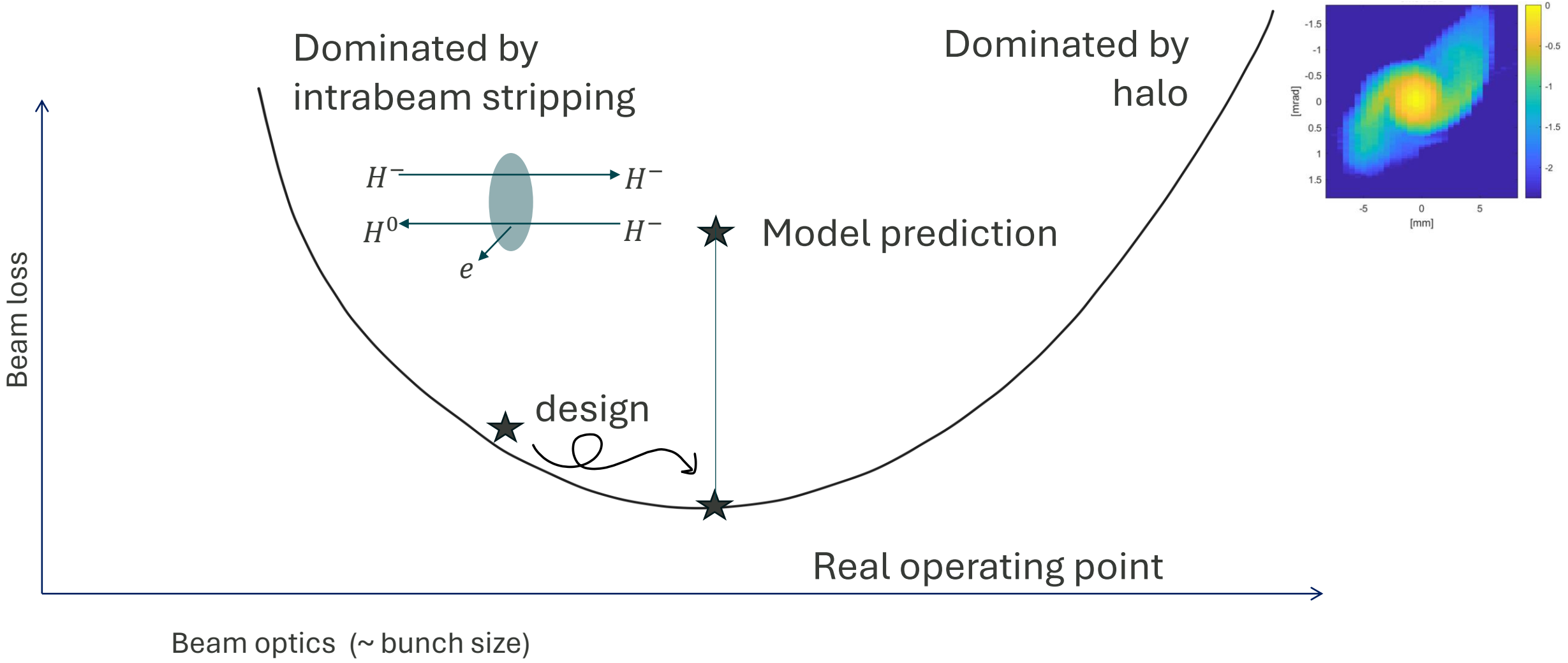




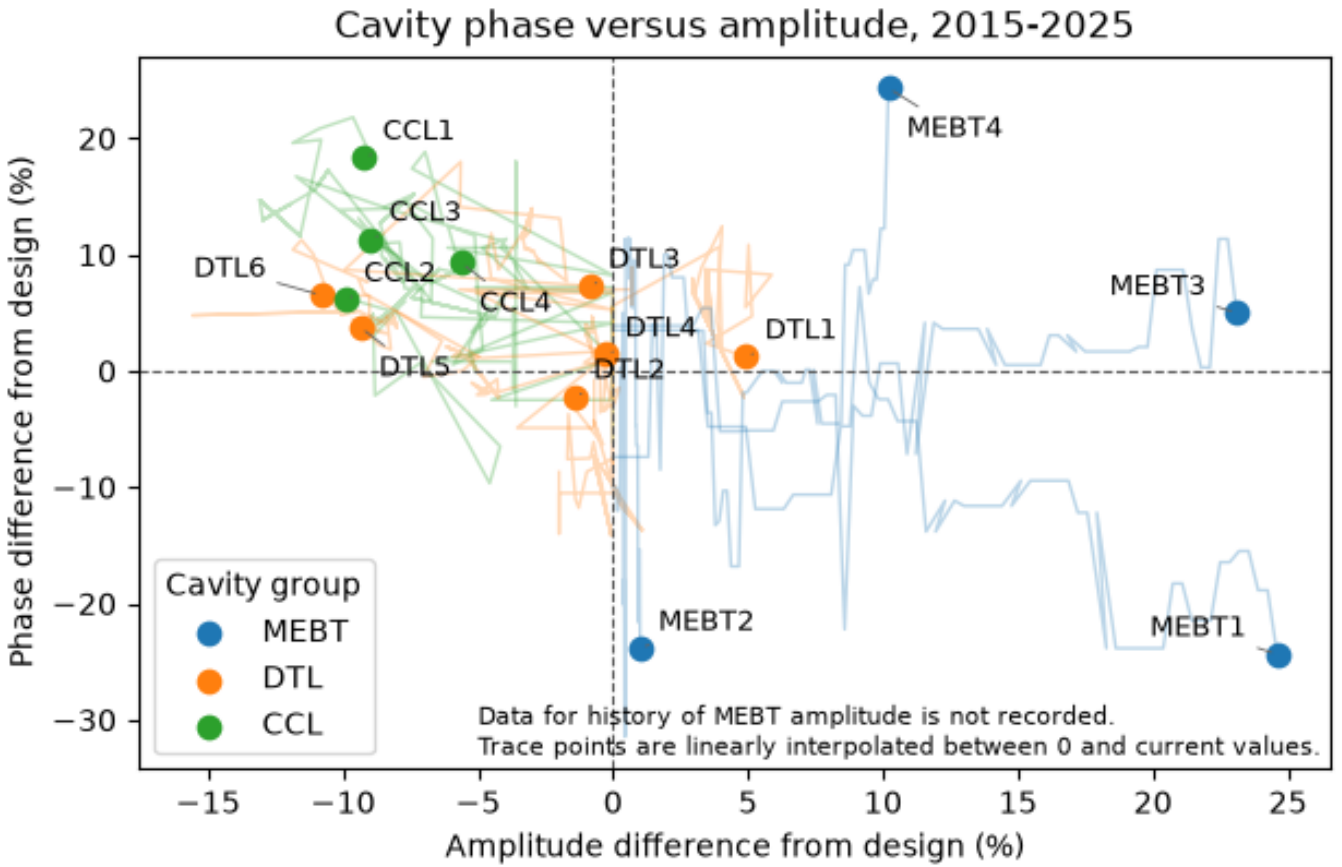


A. Shishlo, J. Galambos, A. Aleksandrov, V. Lebedev, and M. Plum, PRL 108, 1 (2012)

Beam dynamics mechanisms for LINAC beam loss

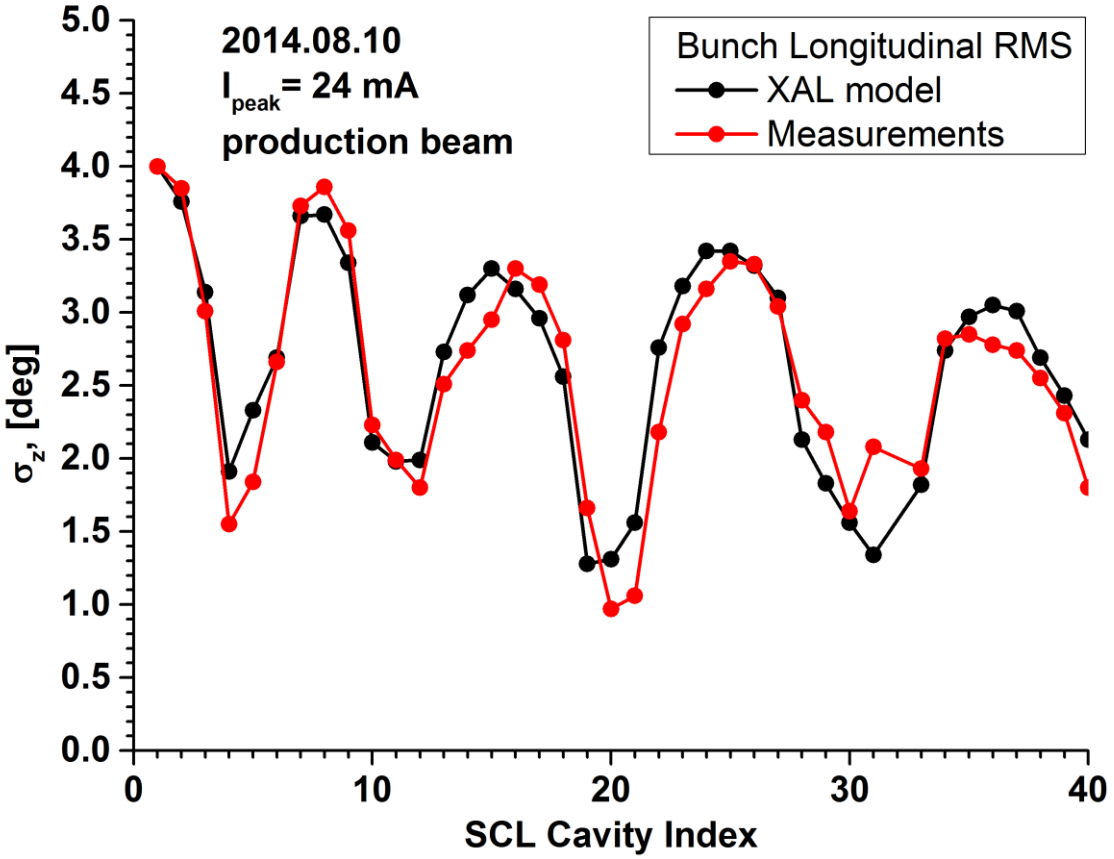


Production optics have been empirically tuned away from design

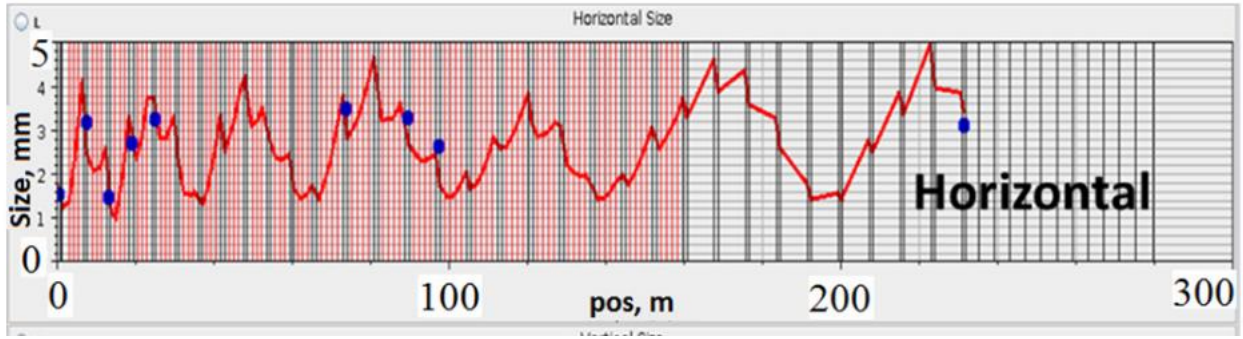


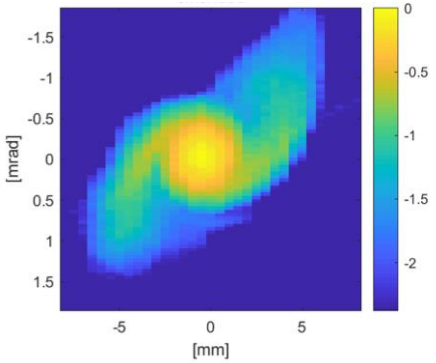
Settings for warm linac cavities from 2015-2025.
(MEBT cavity amplitude settings are approximated, due to missing data)

Beam is not matched!

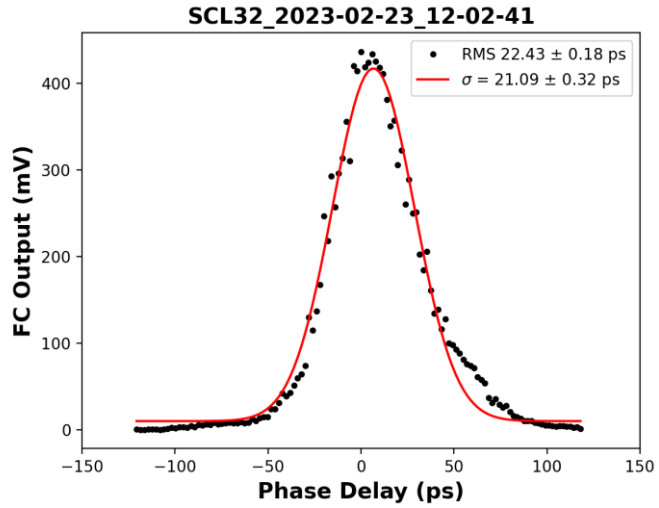


Shishlo, LINAC2014



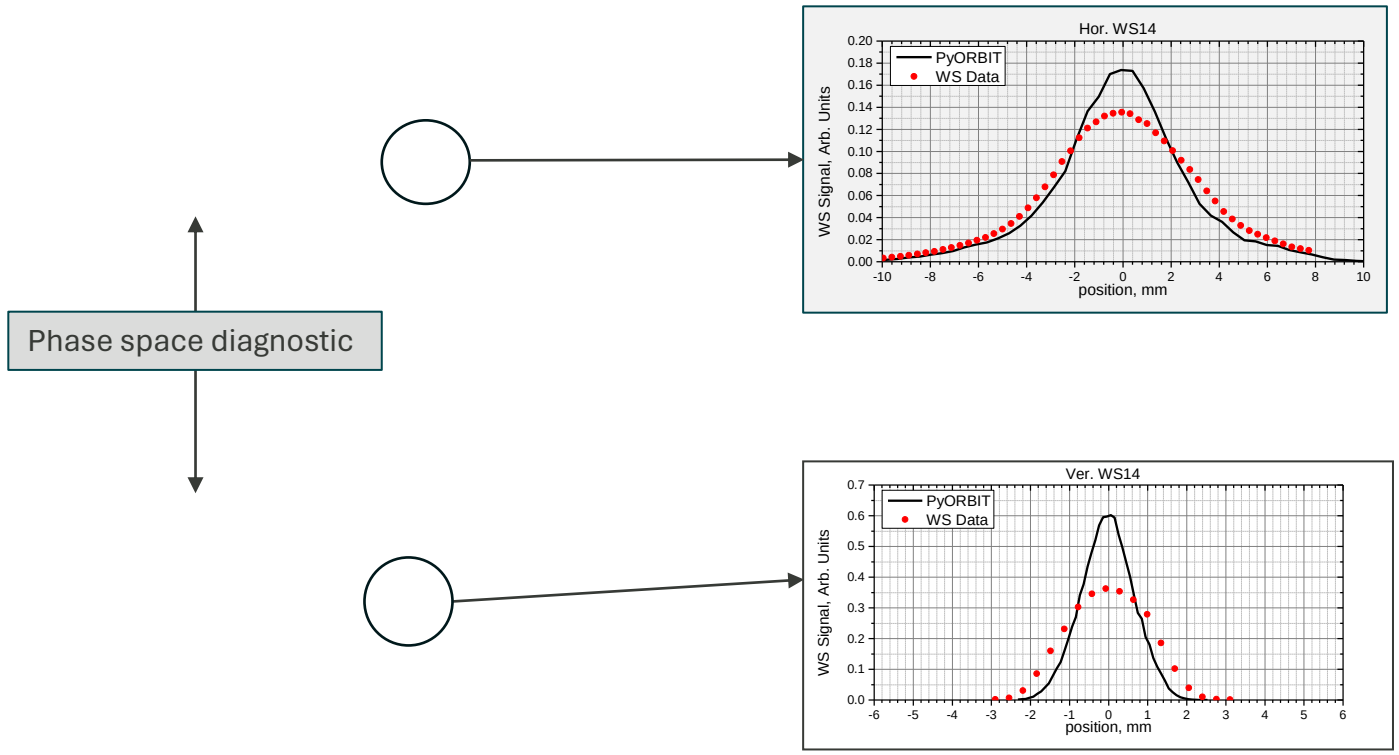


Transverse phase space at end of SCL



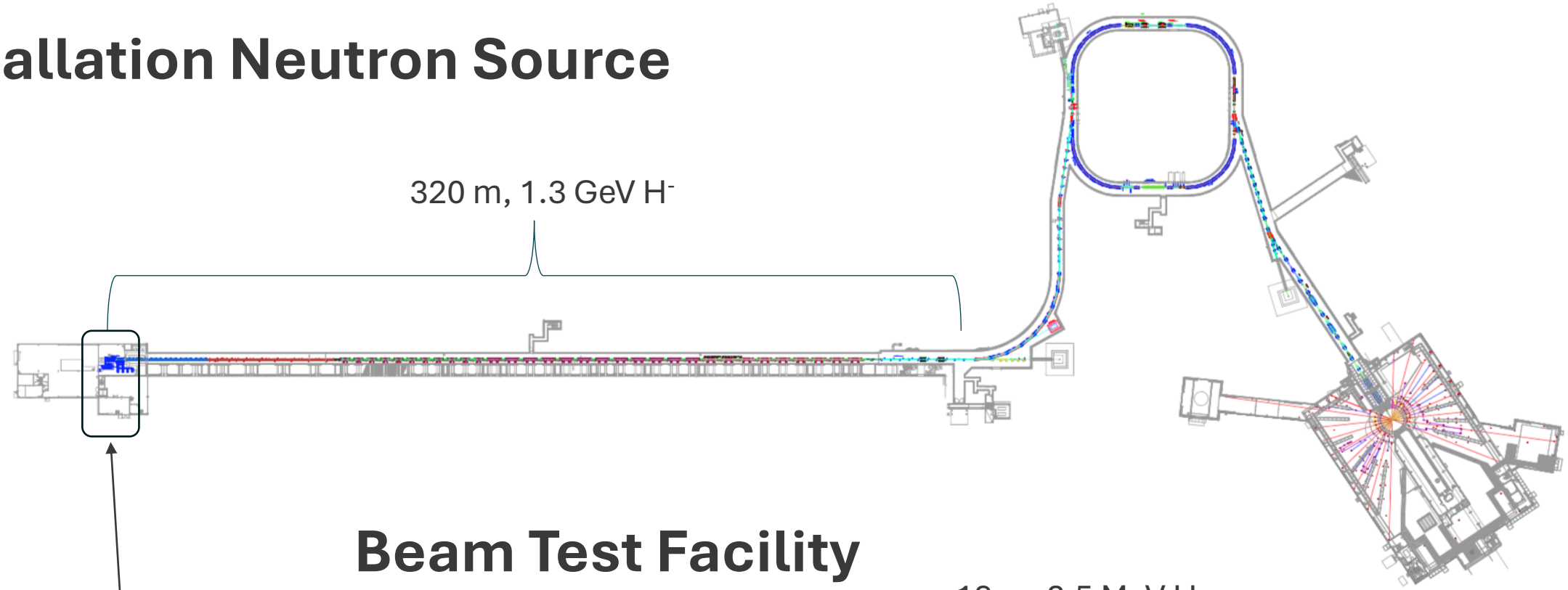
Beam Longitudinal Profile at End of SCL
Shishlo, 2023 HB

MEBT model is also benchmarked – we don't understand the tails here either

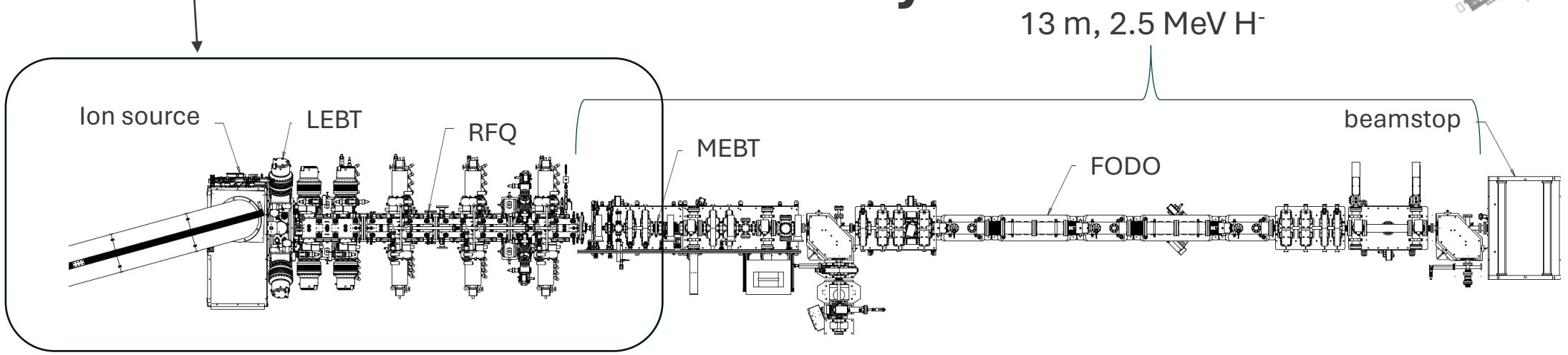


Dots = wire scanner profile measurements

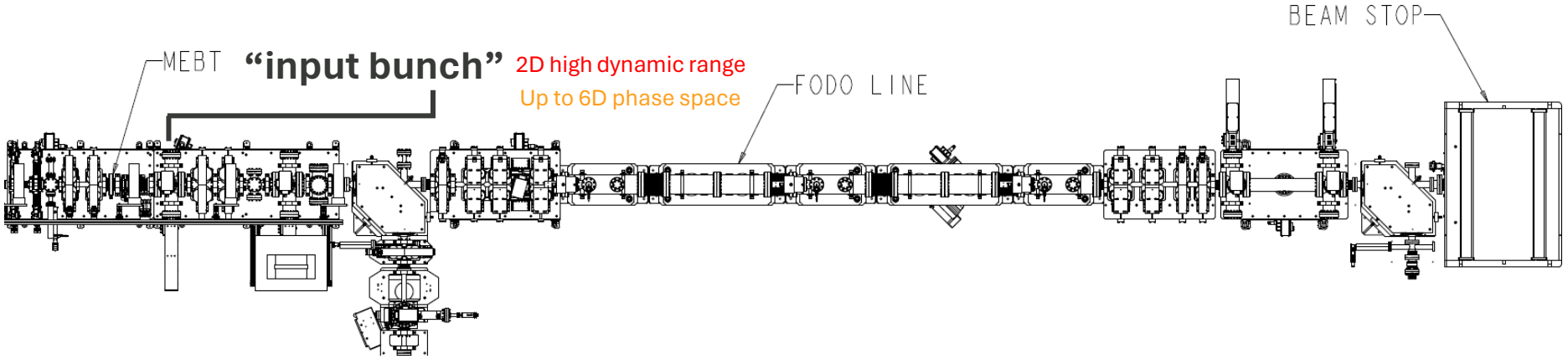
Spallation Neutron Source

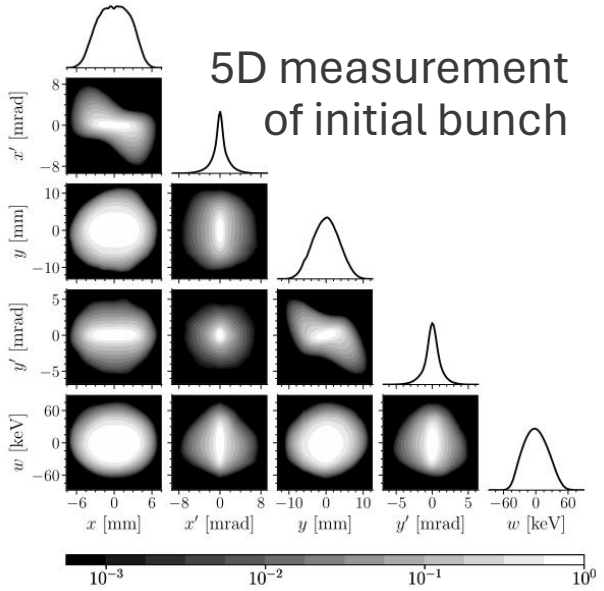


Beam Test Facility



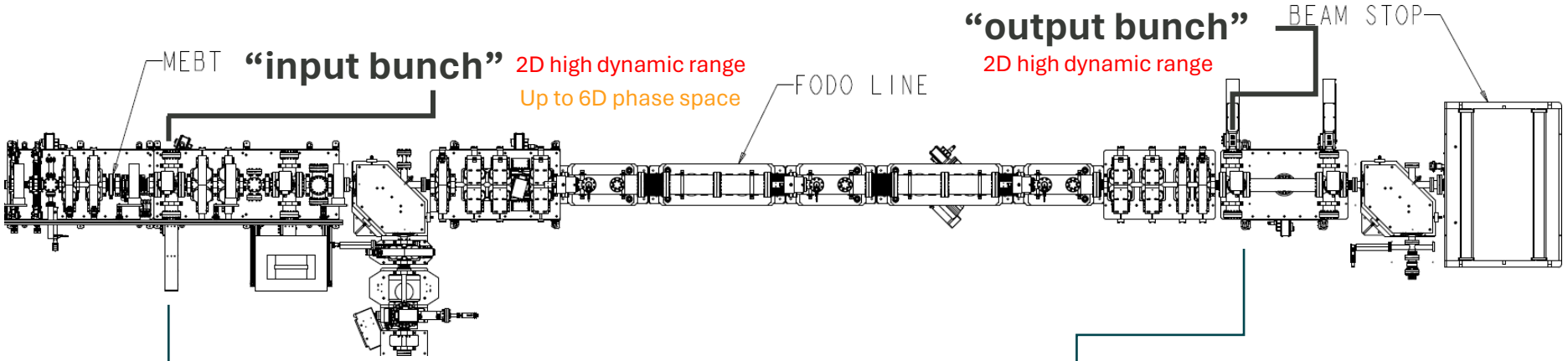
Extensive phase space diagnostics give detailed picture of initial bunch distribution

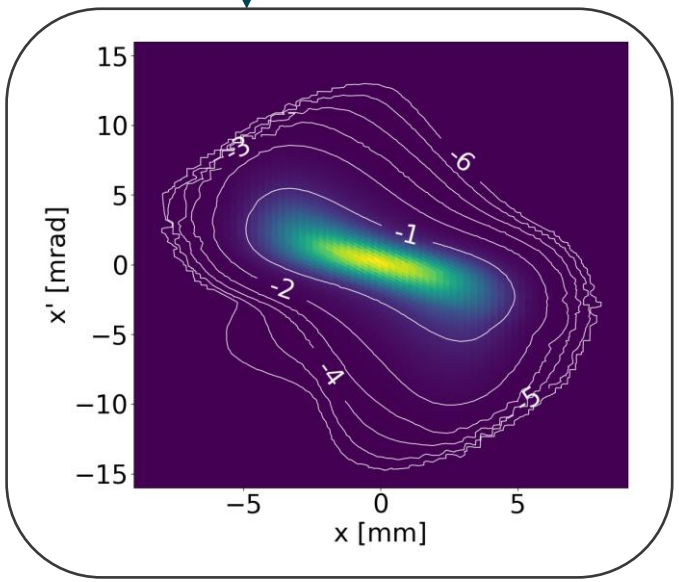


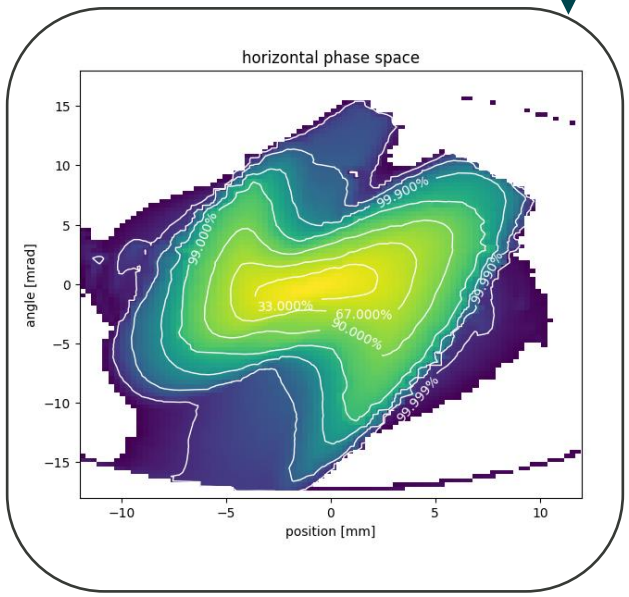


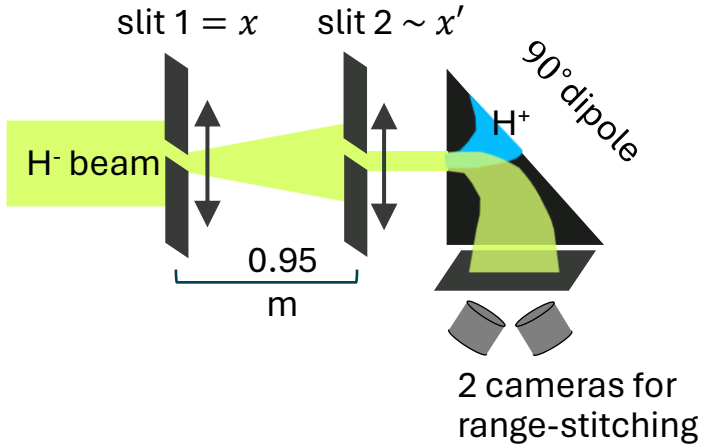
Hoover et. al (2023). PRAB 26, 064202

Extensive phase space diagnostics give detailed picture of initial bunch distribution



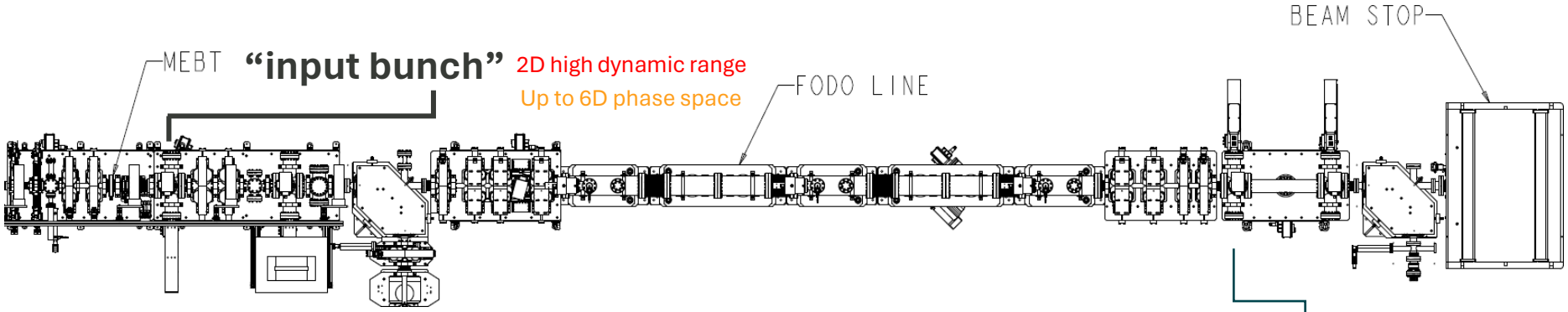




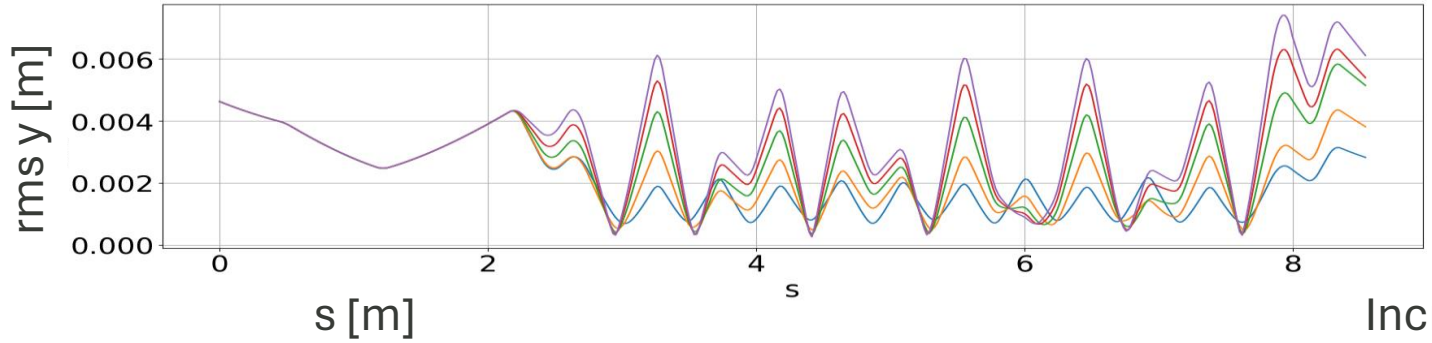


2 cameras for range-stitching

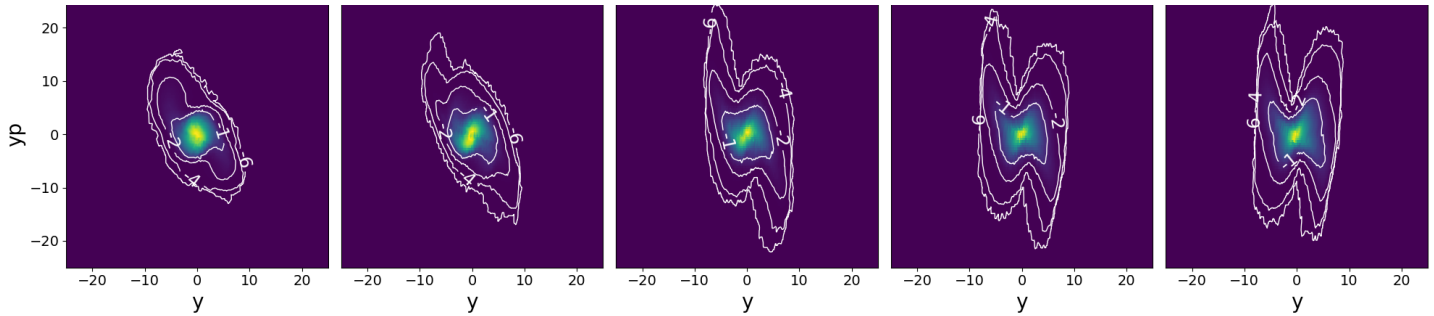
We are currently studying dependence of halo on mismatch and current density



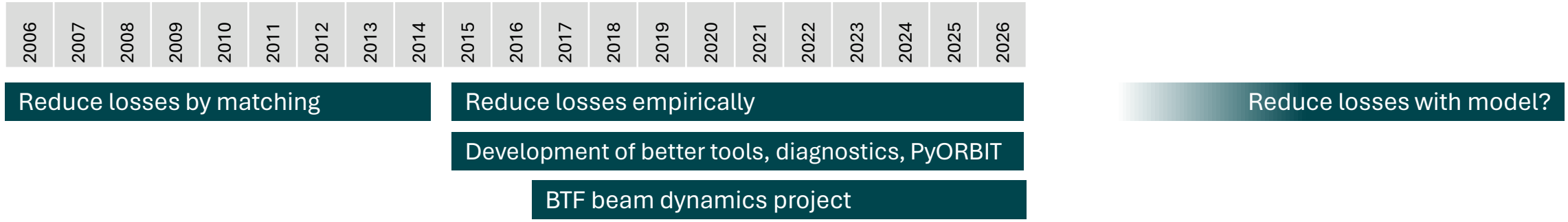
Plot shows 5 optics cases with varying level of mismatch:



Increasing mismatch



Summary



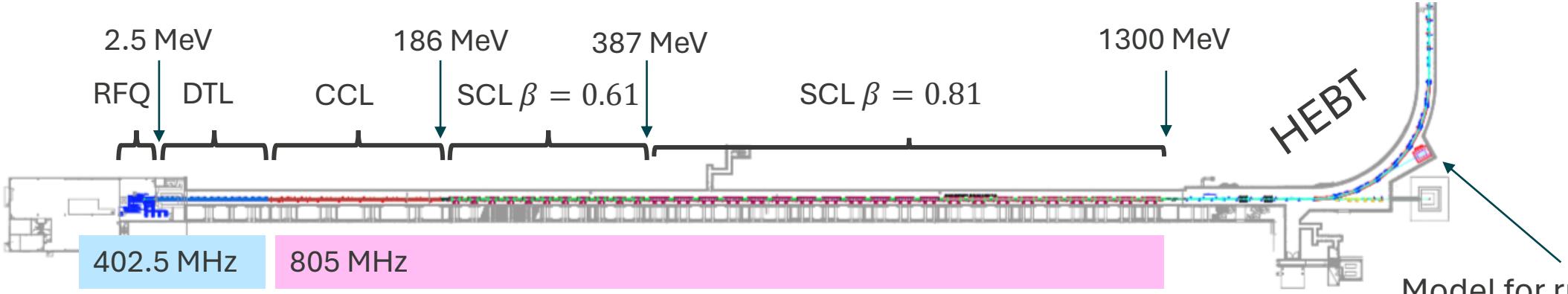
- SNS linac model has not been used to explain H^- losses
  - There is no trusted global model
  - We cannot predict or control losses using model (and we have not matched)
- SNS Beam Test Facility can validate PIC model for bunch evolution
  - Particularly on formation and transport of nonlinear tails and halo
  - Some BTF diagnostics being implemented for SNS MEBT

Will better physics knowledge improve operations?

Thanks for your attention

Remaining slides show additional materials

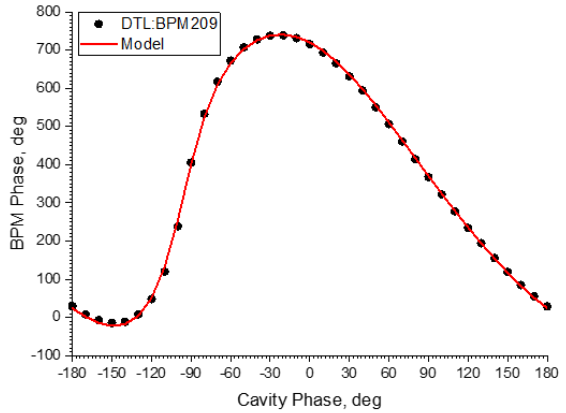




Model for rms Twiss is useful in the HEBT

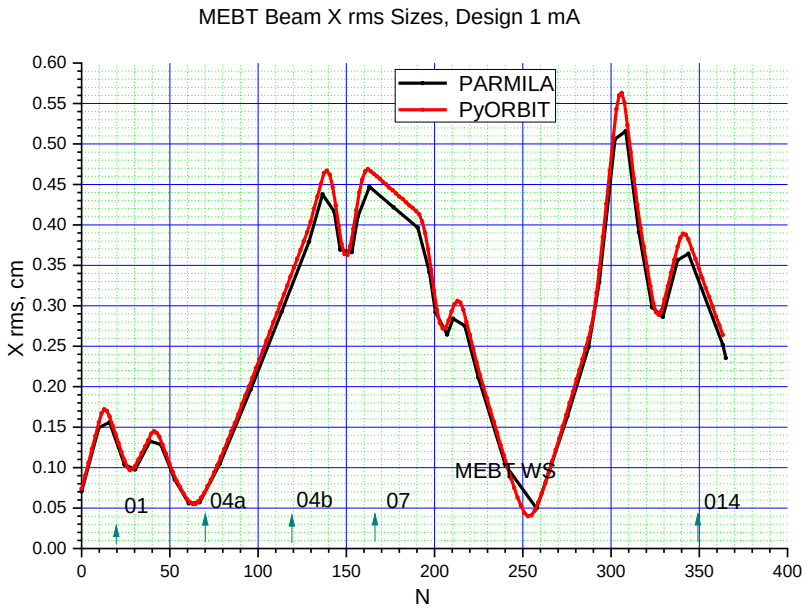
OpenXAL envelope model is online model
This model is useful for tuning and choosing operating point:

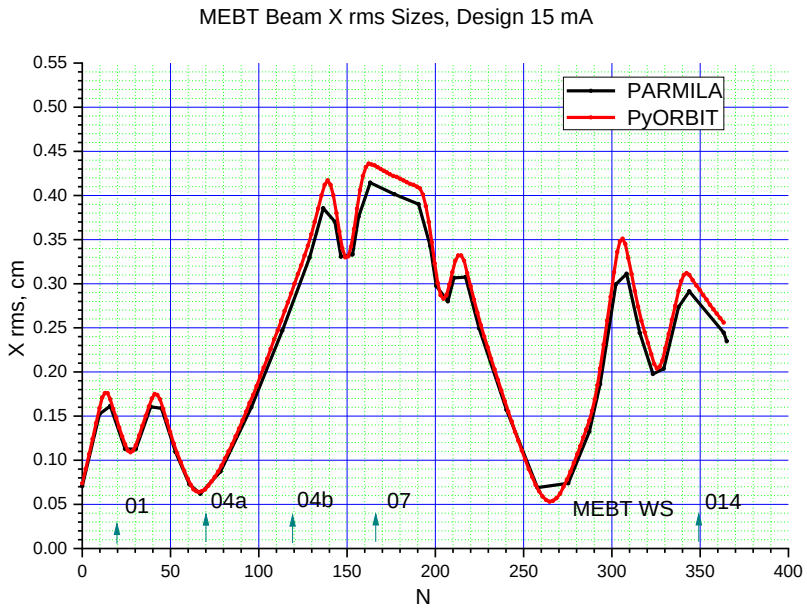
- Transverse centroid model is benchmarked for whole linac, model-based orbit correction works (to within 0.1 mm)
- Model-based tuning of cavity phases/amplitudes is fast and reproducible
  - Re-scaling around tripped cavity achieves accuracy of 1.5 MeV (0.1%)
  - Cavity phase/amplitudes known to within 1˚ / 1%
  - Require only phase scans to calibrate energy, cavity phase, cavity amplitude

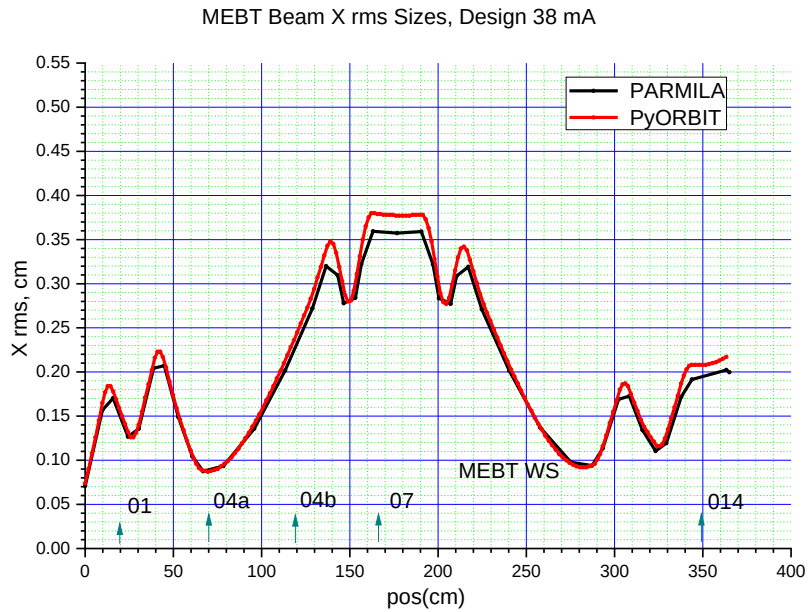


Phase scan of DTL1 fit with OpenXAL model

PARMILA – PyORBIT X RMS (3D Waterbag, 3D FFT SC)



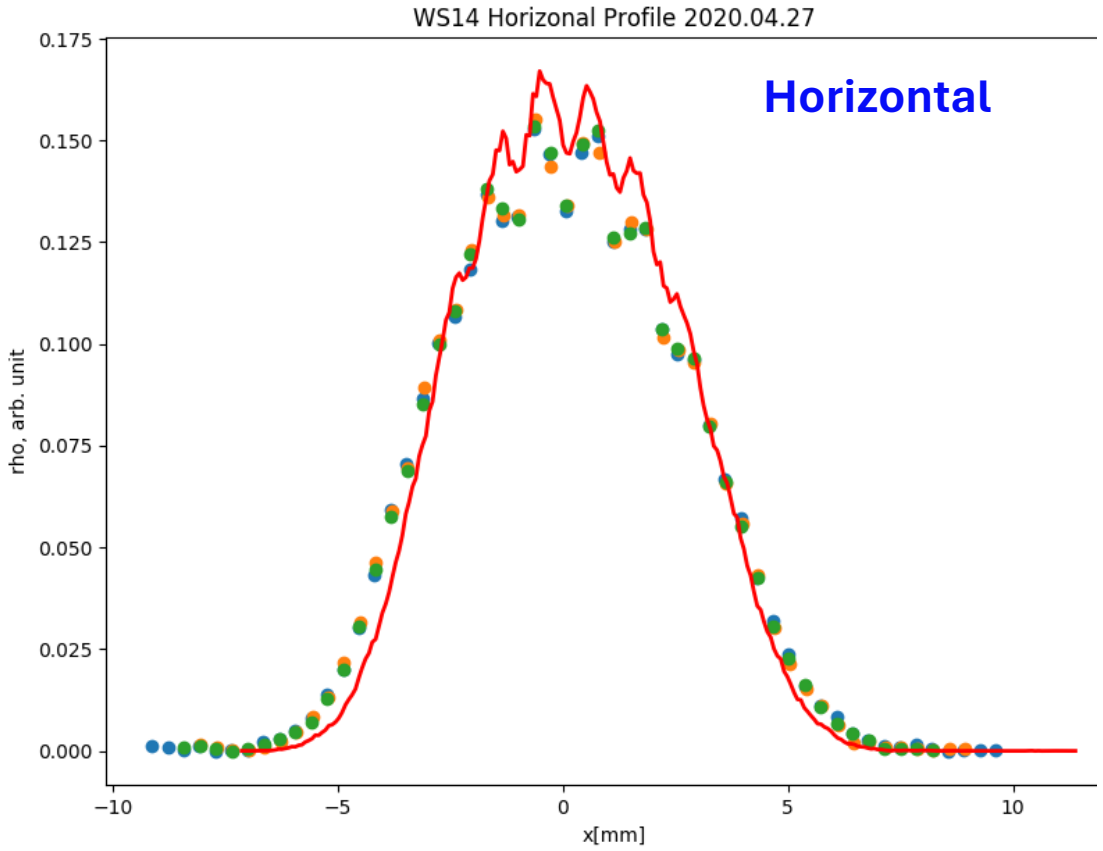


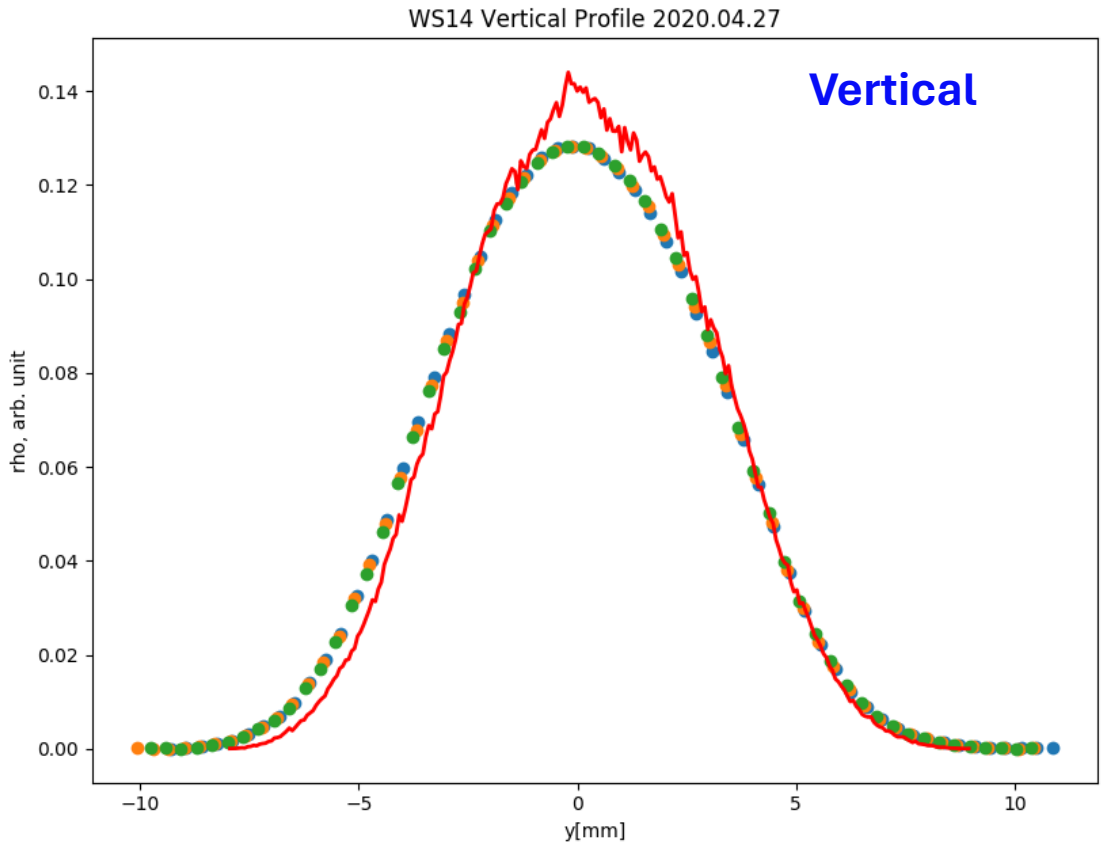


1 mA **15 mA** **38 mA**

Horizontal RMS size

Transport to WS14 – 6 mA (No Quads – just Drift)





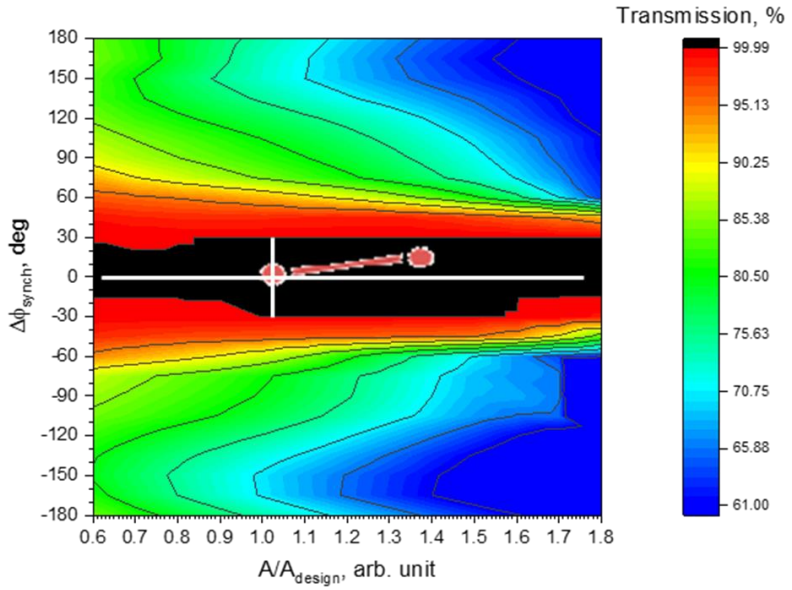
Points – three times measurements of WS14 for all last 4 quads off

Red curve – PyORBIT emittance distribution tracking

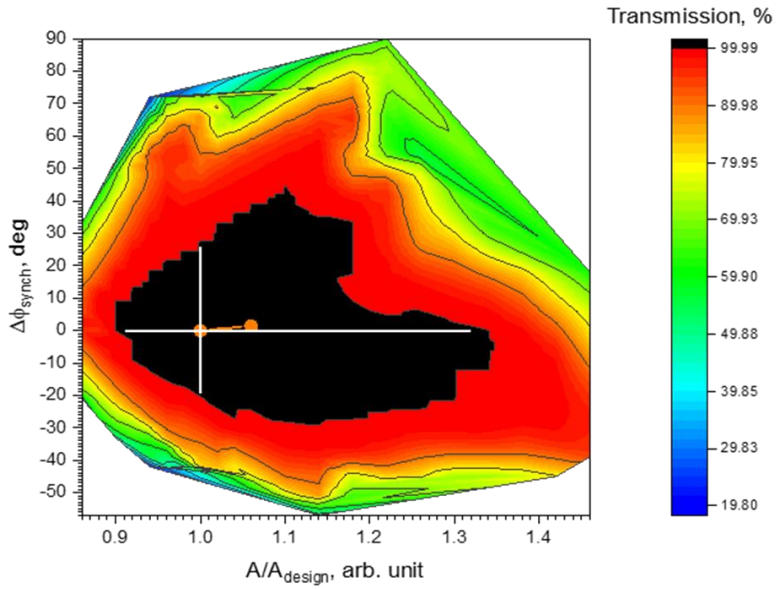
Simulations show too narrow shapes

MEBT/DTL/CCL

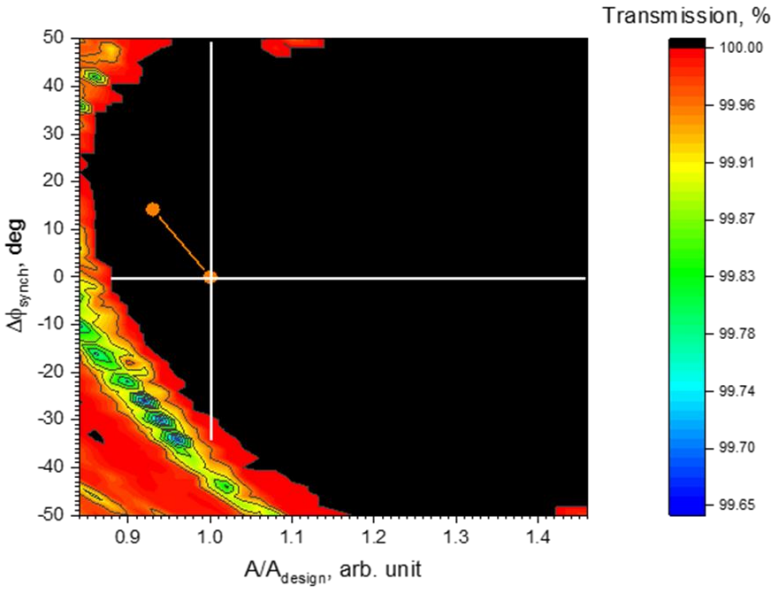
MEBT1



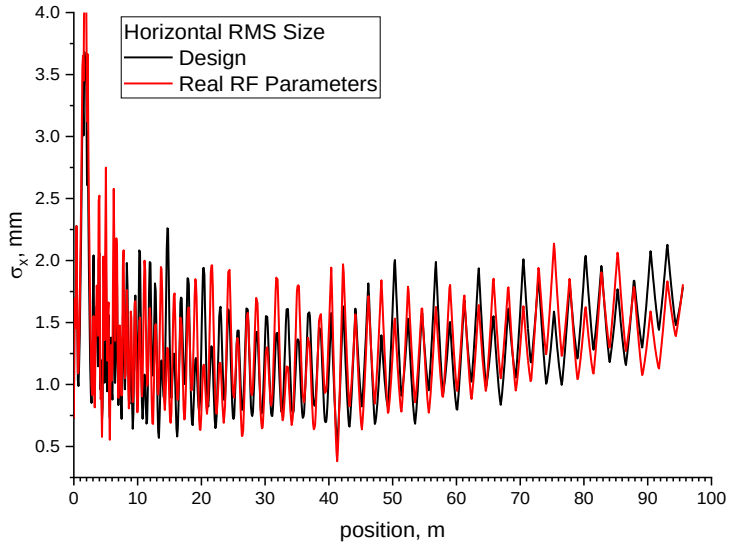
DTL1

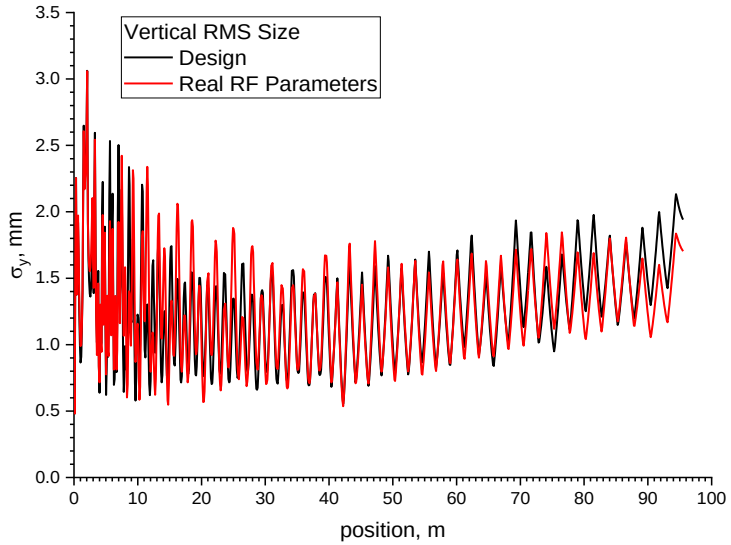


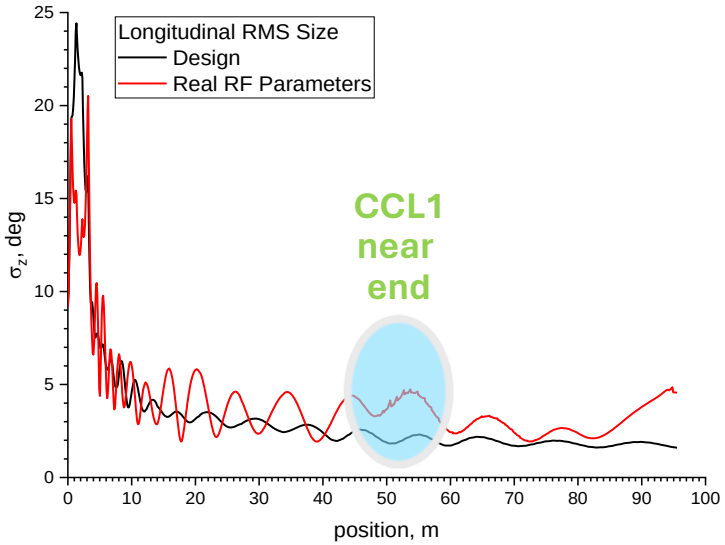
CCL1



Simulations: Design vs. “Real” RF Settings (PyORBIT)

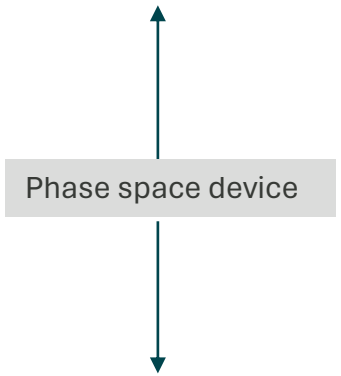


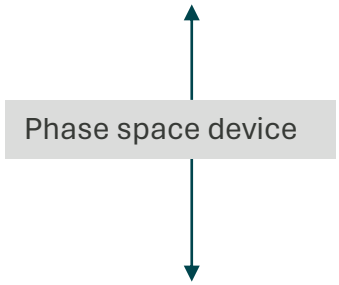




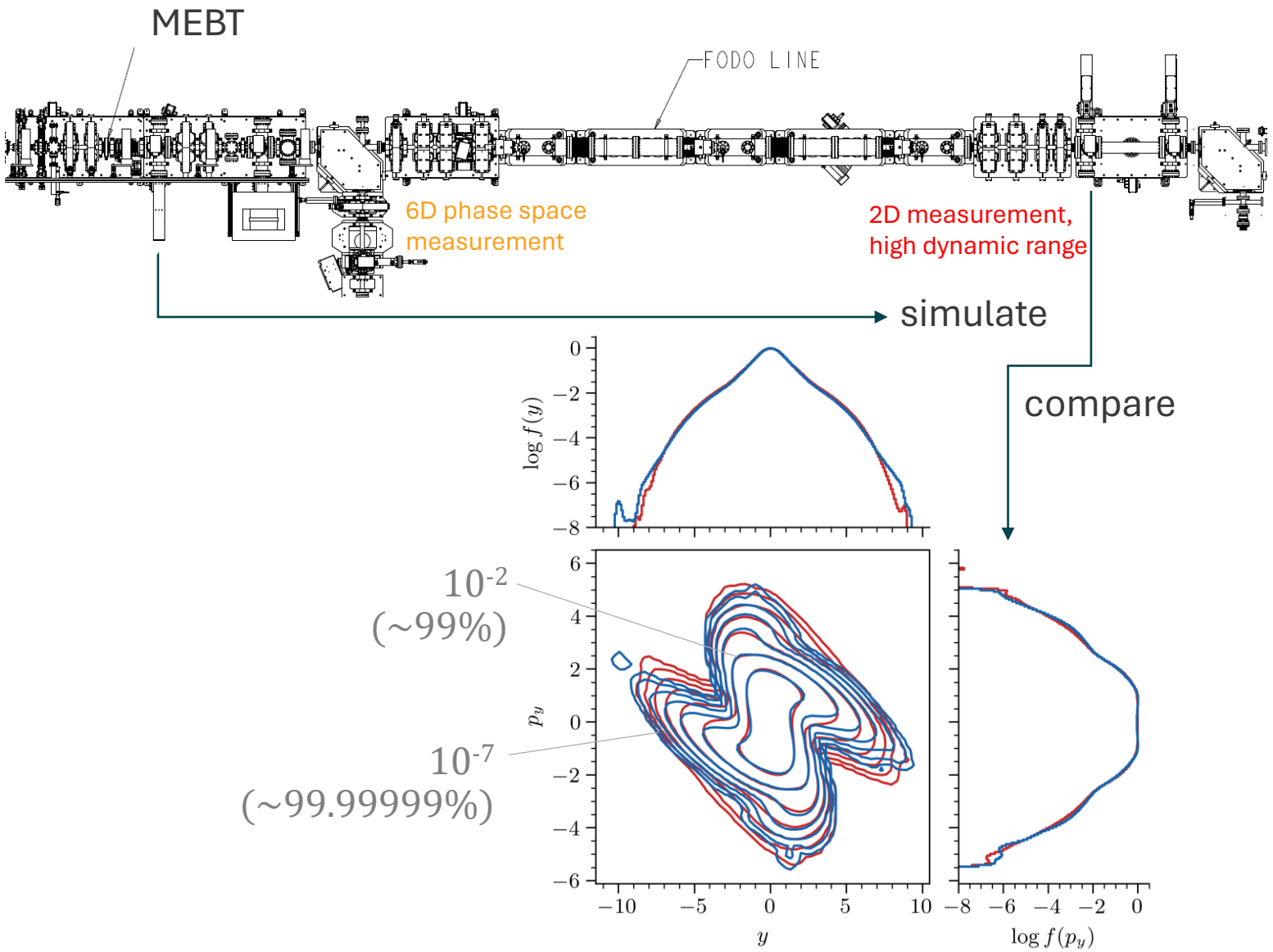
- ❑ Horizontal and Vertical RMS sizes do not show anything dramatic
- ❑ Longitudinal RMS is awful at MEBT and in general
- ❑ Beam loss started in CCL1

MEBT model is not consistent across cases/diagnostics





Dots = wire scanner profile measurements



Hoover et al, High Brightness Workshop, CERN (Oct 2023)

Predicting loss rates is only part-way to predicting detected losses or radiation

Signals of ionization and neutron detector loss monitors along linac:

