Linac Beam Dynamics

J. Galambos

Accelerator Advisory Committee

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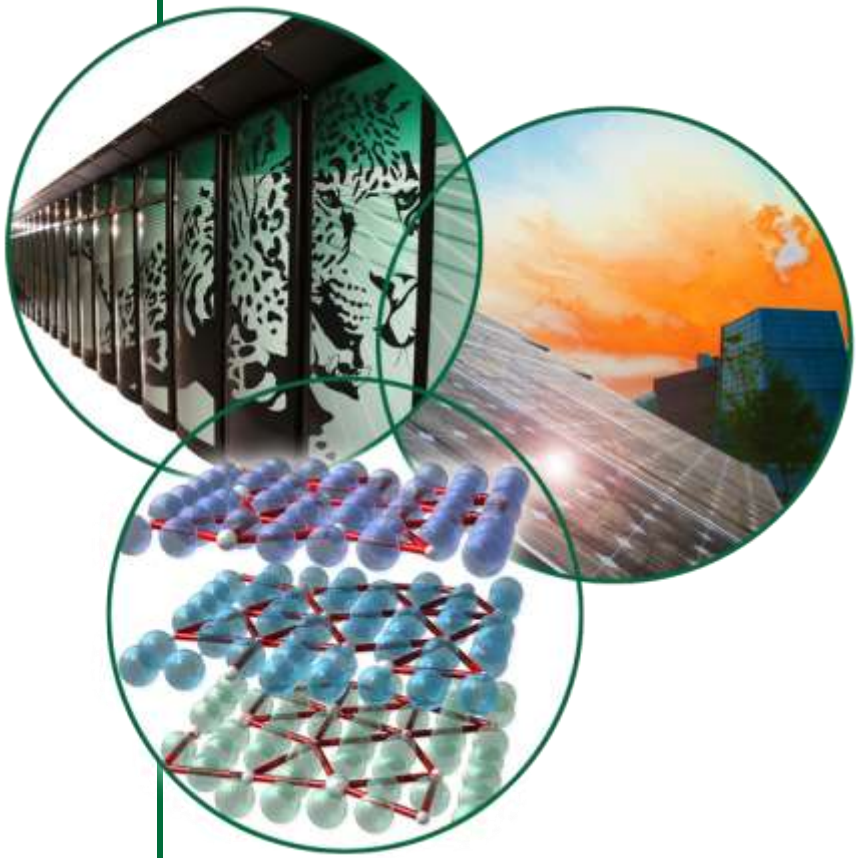


U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Outline:

- SCL Beam loss: Intra-Beam Stripping (IBST)
- Beam simulation / measurement

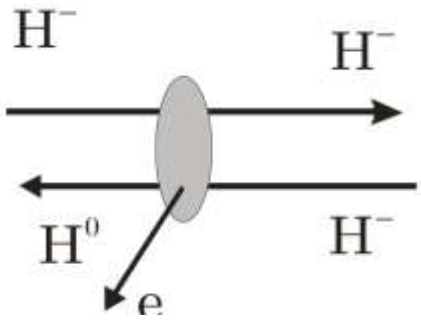
A brief history of beam loss in the SCL

N. Catalan-Lasheras (Ed.), J. Galambos, N. Holtkamp at al. "Accelerator physics model of expected beam loss along the SNS accelerator facility during normal operation" SNS/AP Technical Note 07, 2001

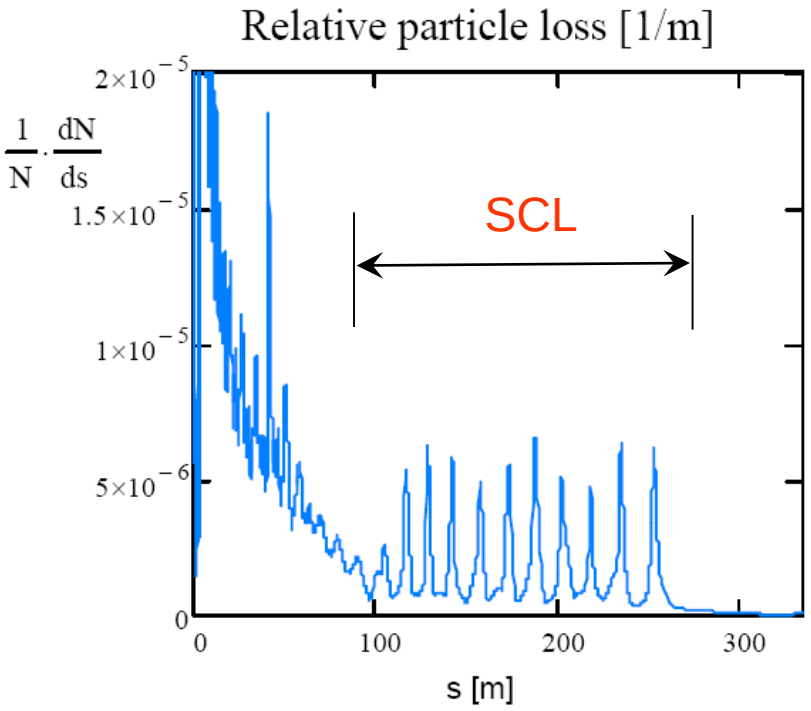
"As for the superconducting linac the bore radius aperture is much larger than the nominal beam …Simulations give a negligible amount of losses. On the other hand, one should be very cautious with our expectations as there is no experience with superconducting proton linacs up to now."

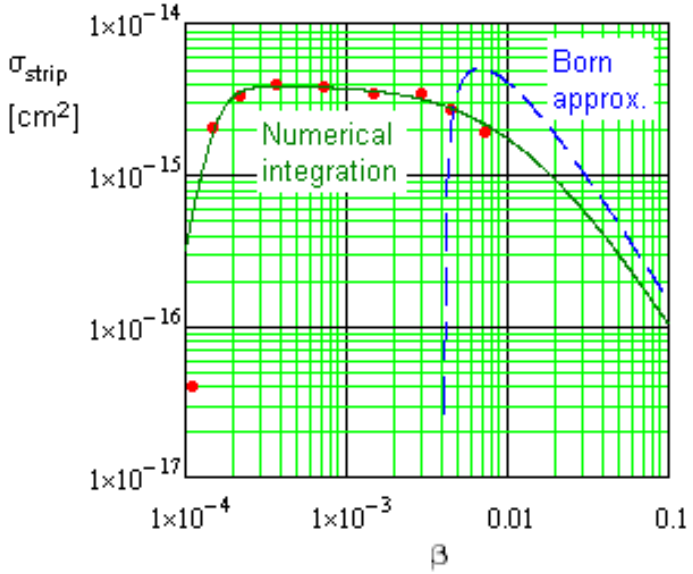
… and we measured a low level beam loss in the SCL !

Intra Beam Stripping (Valeri Lebedev, FNAL)



(Talk at SNS, ORNL, October 2010)



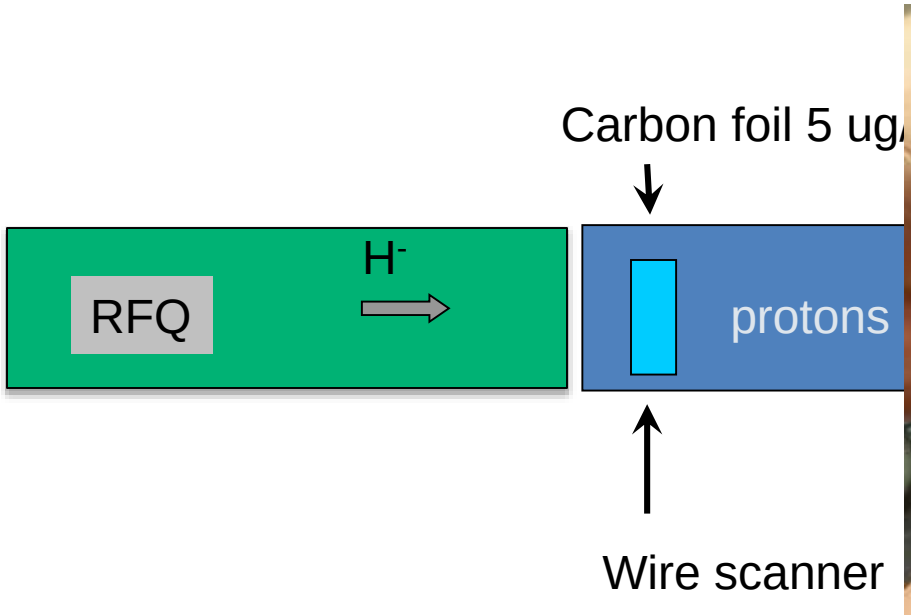


Integral SCL losses estimation: 4x10^{-5}

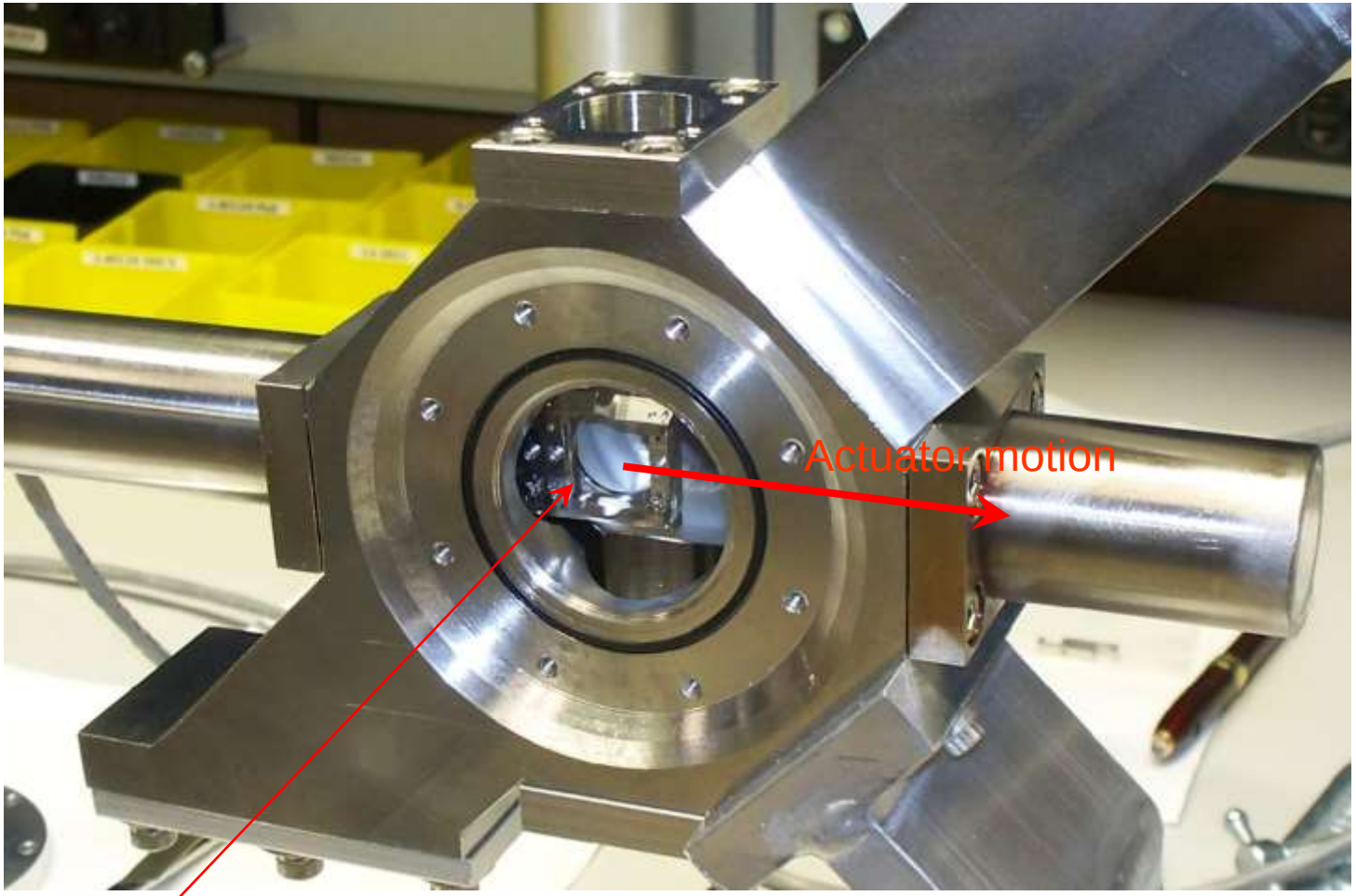
- Loss mechanism we did not consider in the design
- Cross section right order of magnitude to match what we observe

Make a Proton Beam in the SNS Linac and Test the IBST Hypothesis

- First tried a proton ion source
- Next tried adding an insert-able stripper foil
  - 5 ug/cm^2 carbon foil will suffice (our ring injection foils are 340 ug/cm^2)
  - 0.6 keV kinetic energy loss for protons (spread is about 12 keV)
  - 12 % of the emittance growth



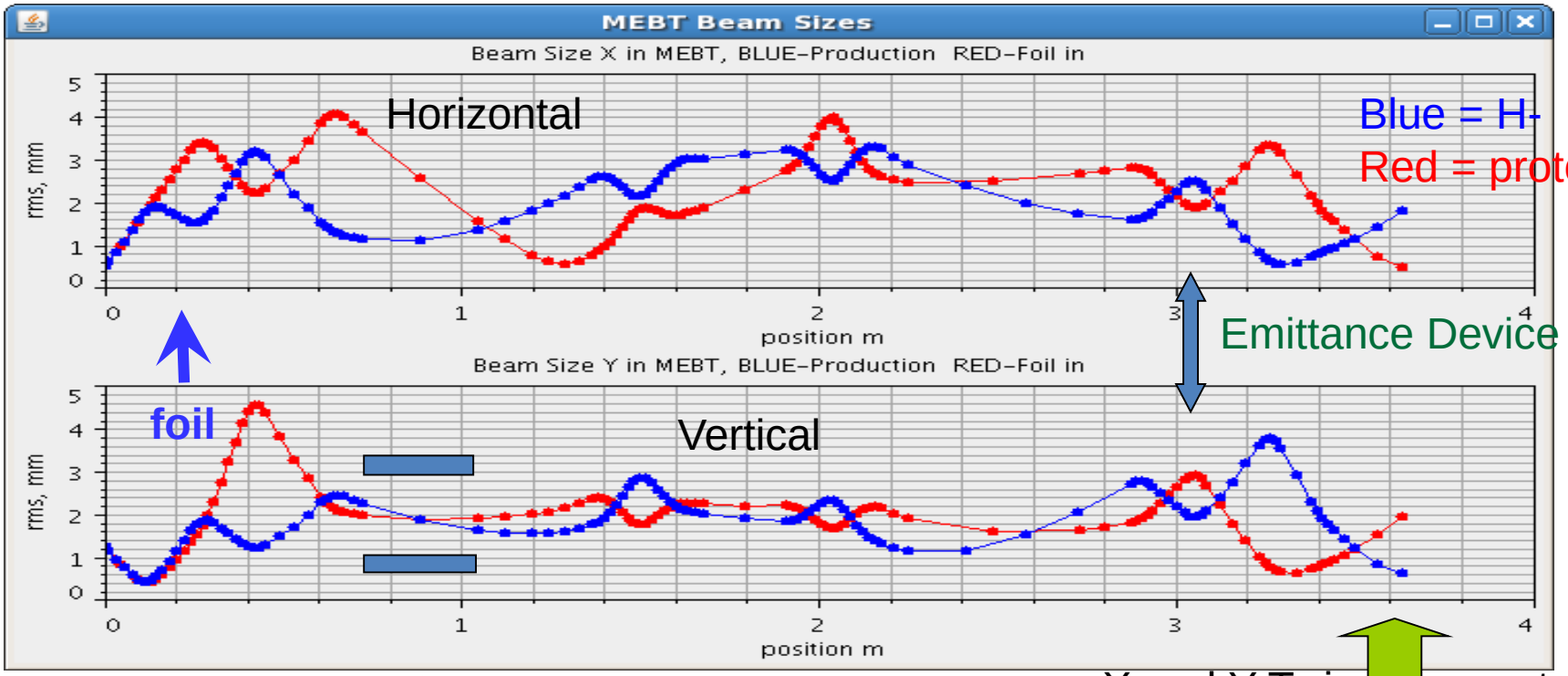
Assembly



The foil frame holder.

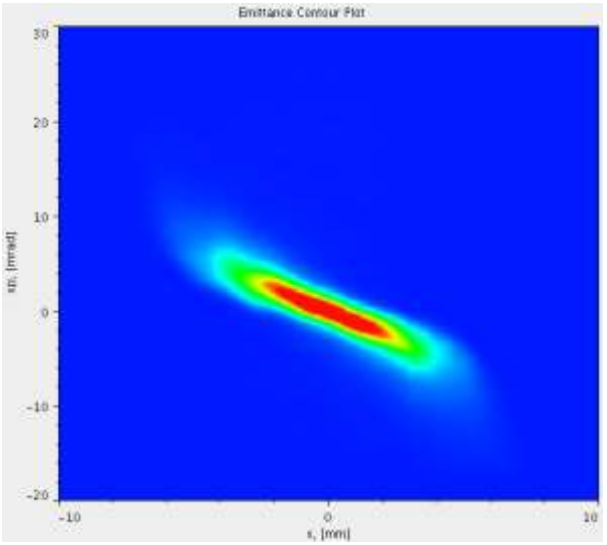
At the moment we have 3 foils installed.

MEBT Optics: Proton Beam Solution

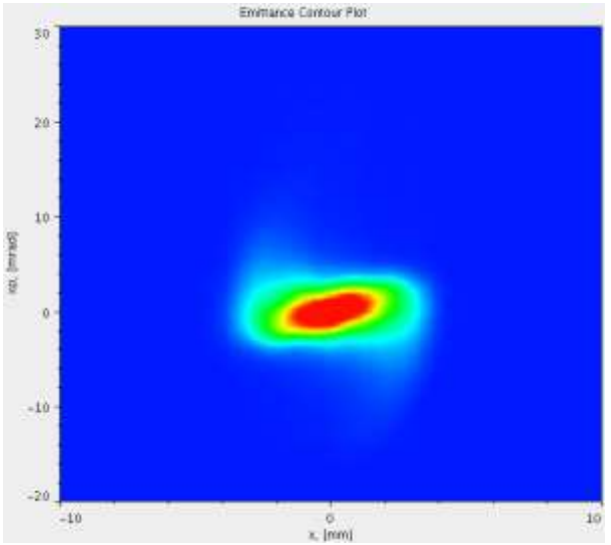


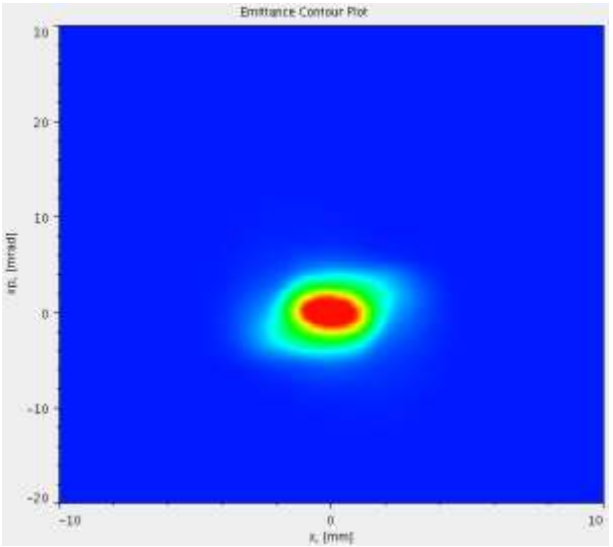
- **Enough independently adjustable MEBT quadrupoles to rematch the proton beam at MEBT exit**
- **Switch all downstream RF by 180 deg**

Emittances in the MEBT for H- and Protons, 30 mA

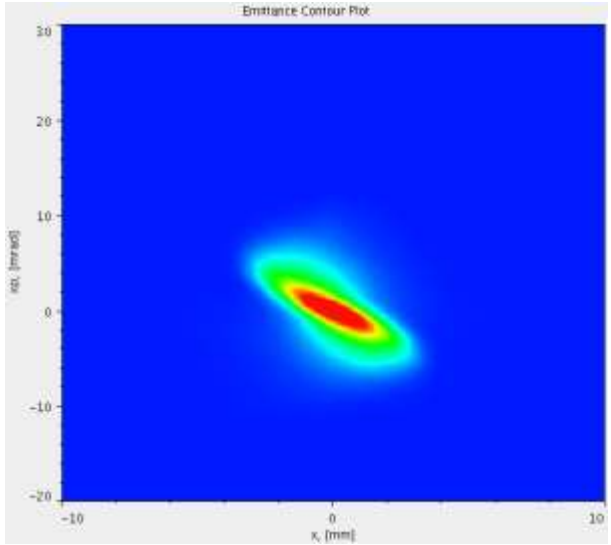


Horizontal





Vertical



H^-

Protons

Twiss Parameters in the MEBT for H- and Protons

H-		
	Horizontal	**Vertical**
Emittance, π*mm*mrad	0.37	0.27
alpha	1.9	-0.06
Beta, m	1.3	0.52

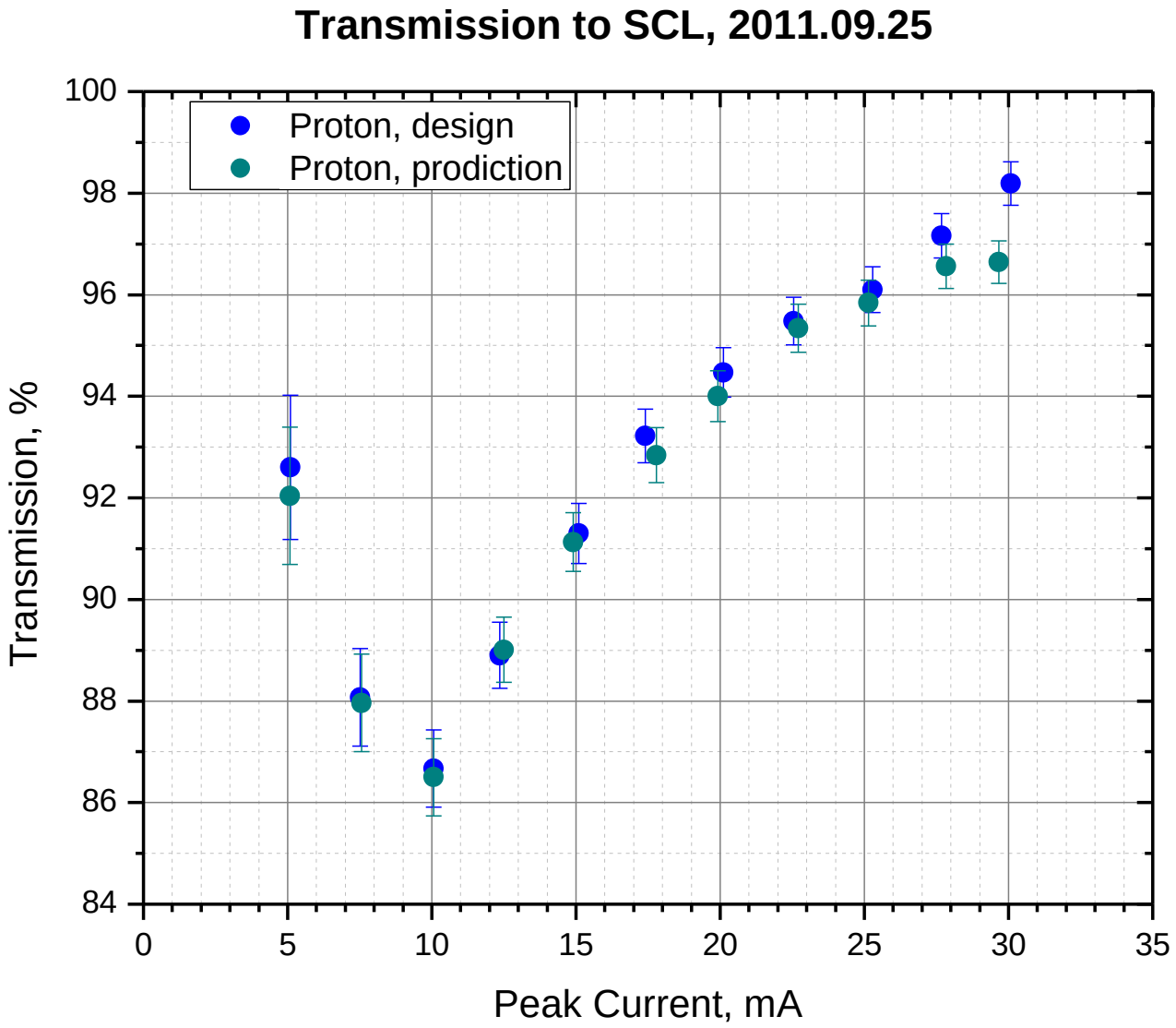
Protons		
	Horizontal	**Vertical**
Emittance, π*mm*mrad	0.39	0.34
alpha	0.14	0.52
Beta, m	0.55	0.45

- The MEBT optics are different for H- and protons
- Peak current = 30 mA
- Data from the MEBT emittance device, cut-off level 0.4%
- The nominal normalized emittance = 0.27 π*mm*mrad

The emittances are different in the MEBT, but not so much.

Presentation_name

Measured Proton Transmission to SCL



It is a peak current dependent

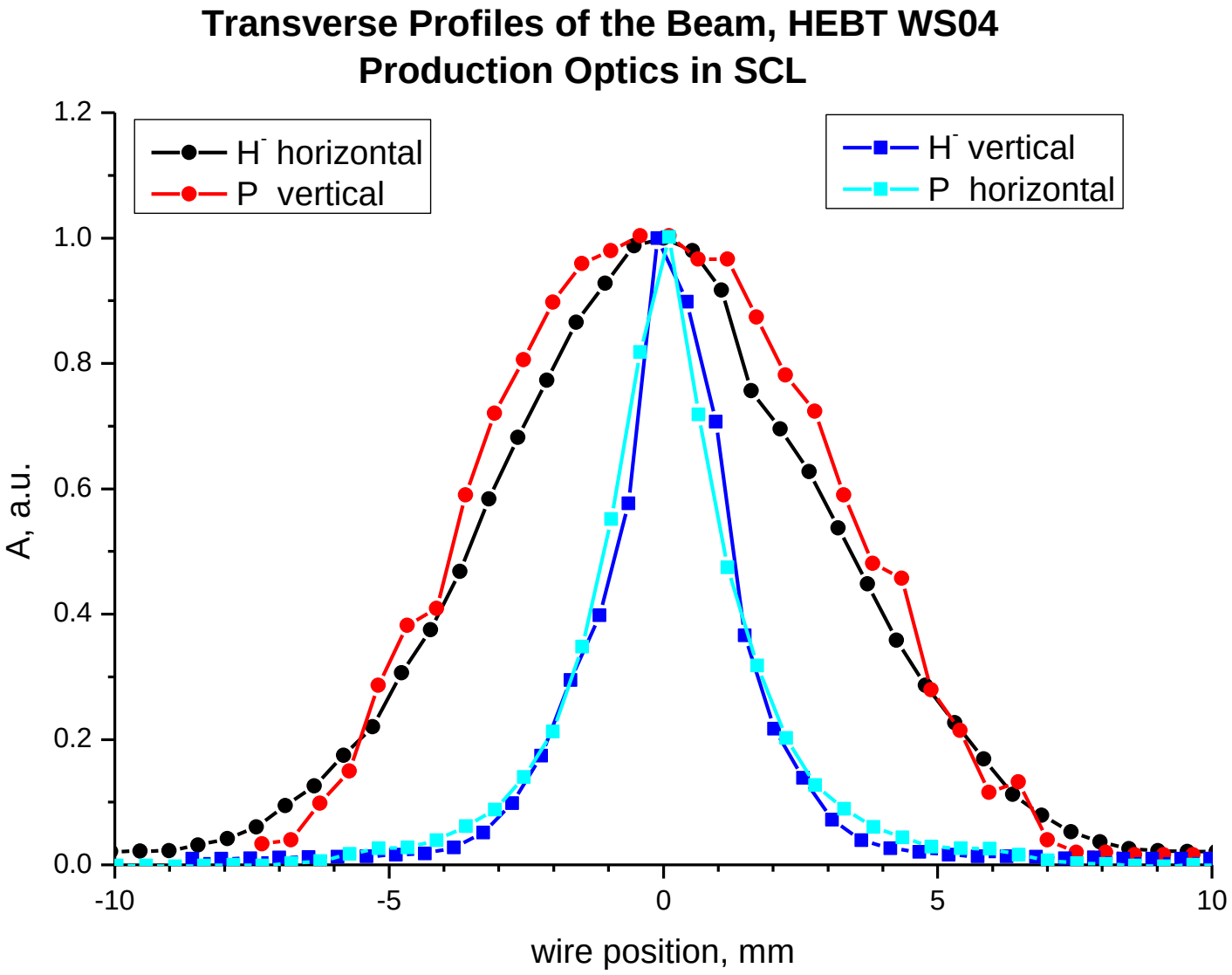
We loose something in MEBT-DTL

They should be the same for design and production SCL optics

Measurements are divided by hours

Proton transmission in the warm linac is not as good as H-

Beam at the End of SCL

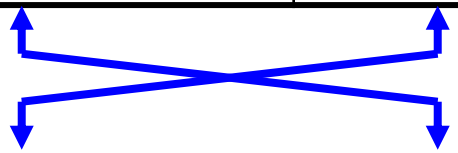


Vertical and horizontal planes are switched for protons in HEBT

Twiss Parameters at the End of SCL for H- and Protons

Production SCL Optics, 30 mA

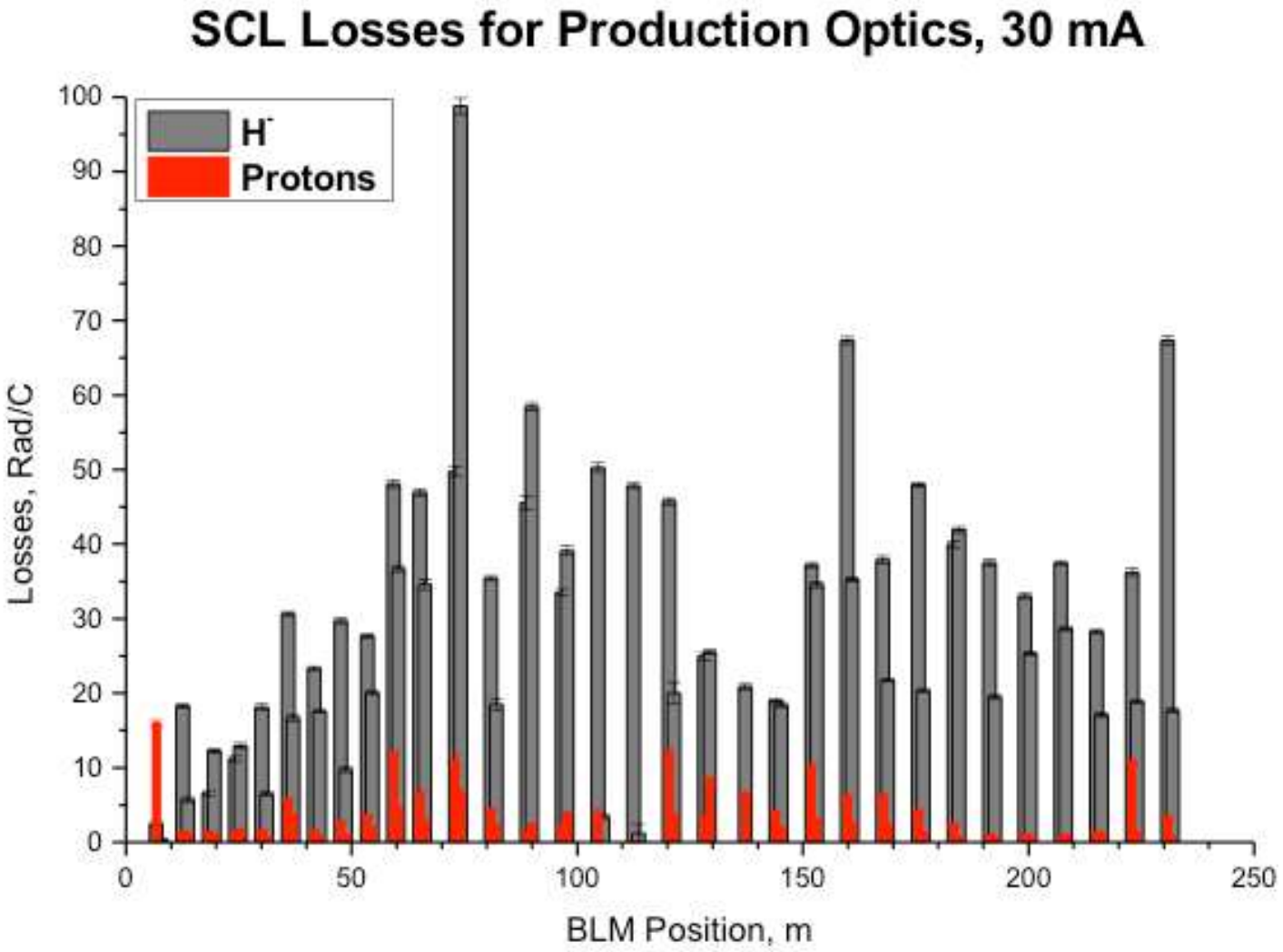
H-		
	Horizontal	Vertical
Emittance, π*mm*mrad	0.71	0.47
alpha	1.8	-2.0
Beta, m	10.0	10.3



Protons		
	Horizontal	Vertical
Emittance, π*mm*mrad	0.55	0.80
alpha	-2.2	2.4
Beta, m	12.9	11.9

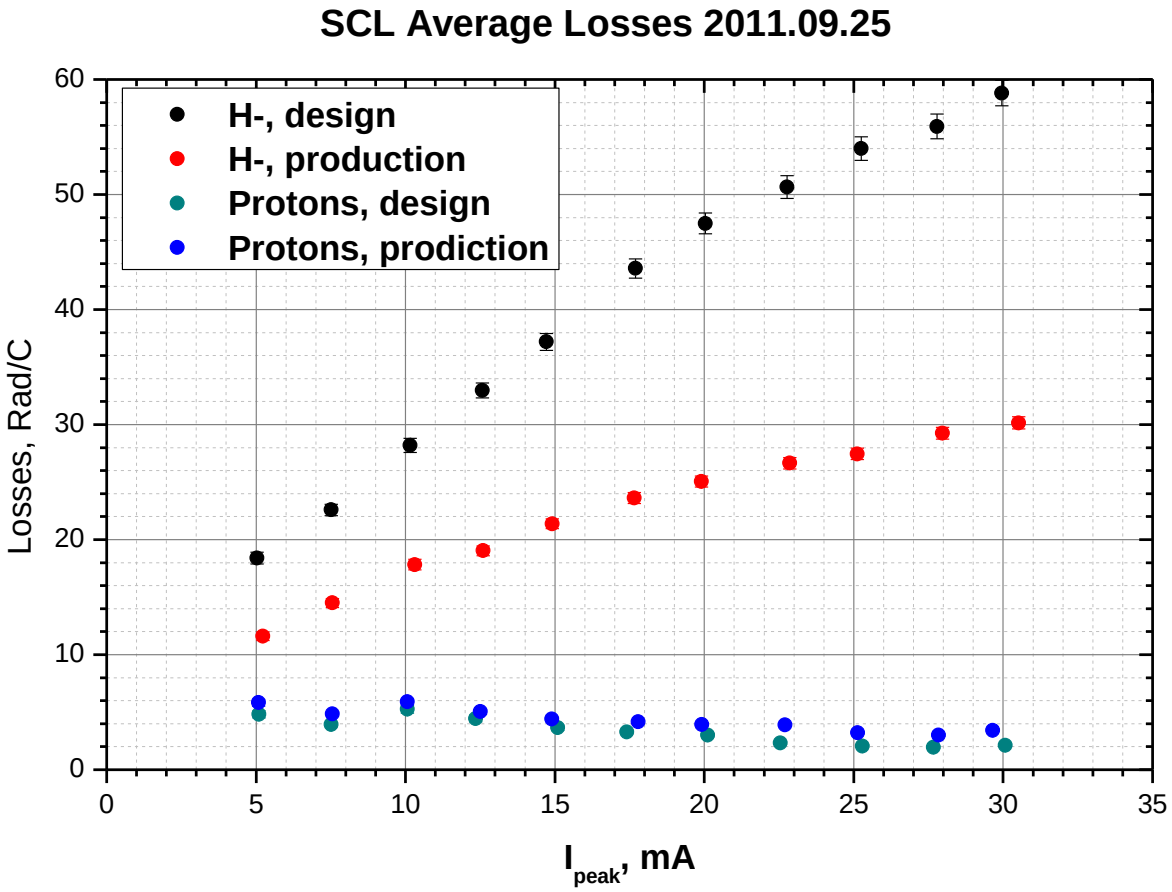
The horizontal and vertical planes are switched for the proton beam.
Remember that the emittances were different in the MEBT.

SCL Losses Protons vs. H- for 30 mA



- Dramatically lower beam loss for protons
  - For both design and production optics

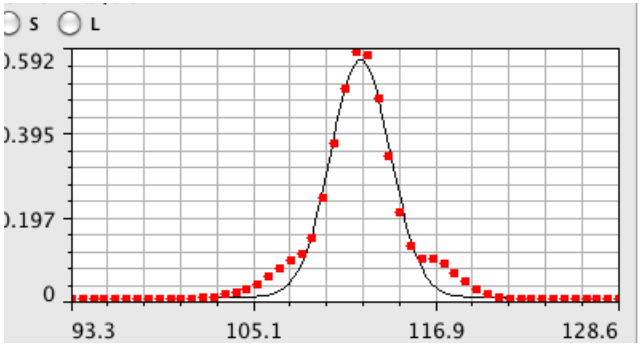
SCL Losses vs. Peak Current

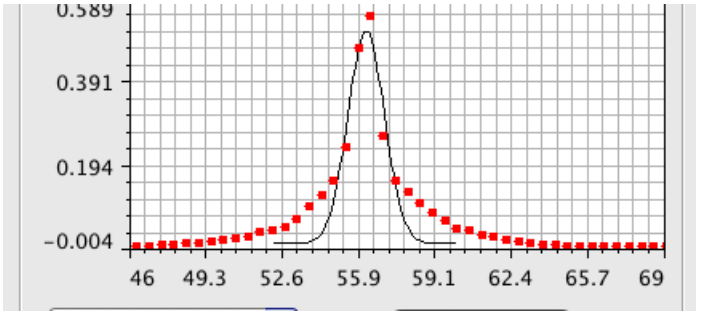


- Proton losses are much lower than H-
- Intensity and focusing strength dependencies are consistent with IBST

We Have Halo / Tails at the HEBT Entrance

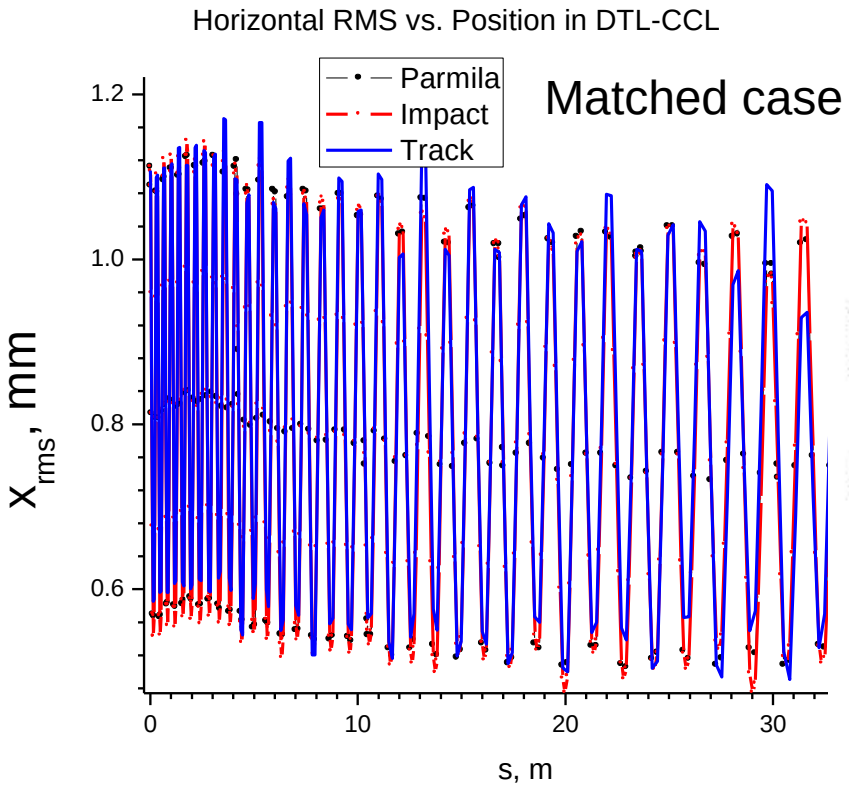
Example beam profiles at the HEBT entrance

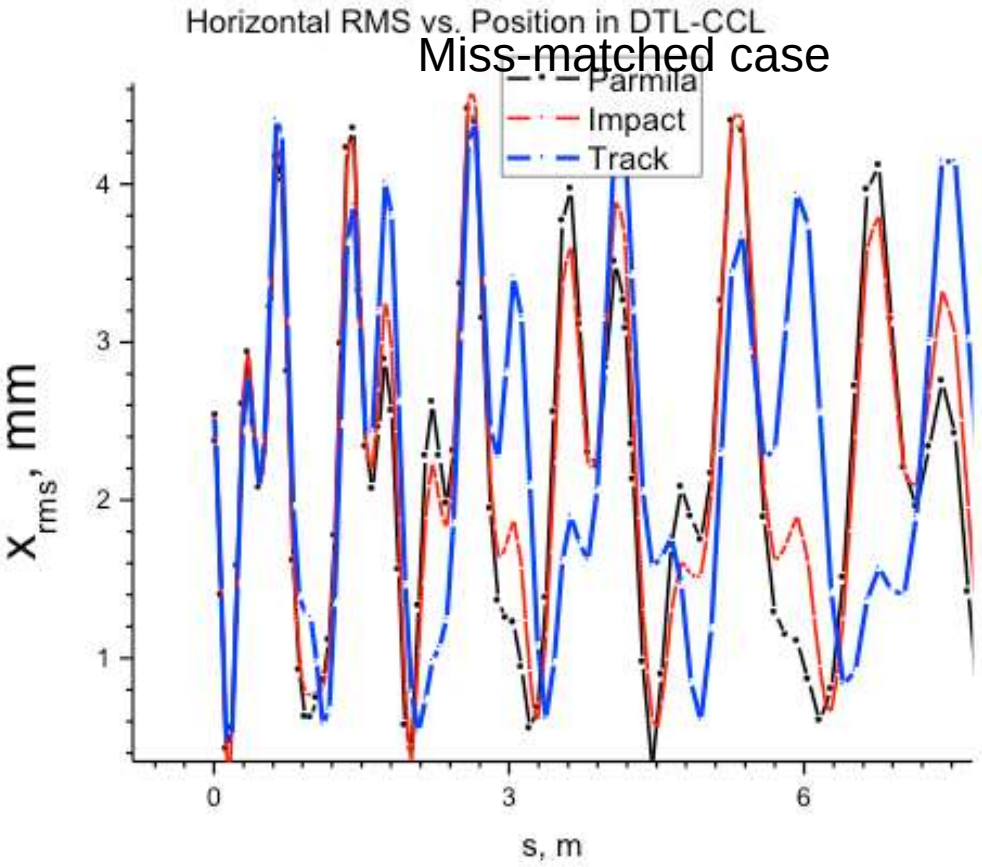




- **To date the focus of attention has been understanding why increasing the beam RMS size reduces beam loss**
- **Now we will shift to understanding and controlling beam tails**

Simulation Code Comparison for SNS Lattice

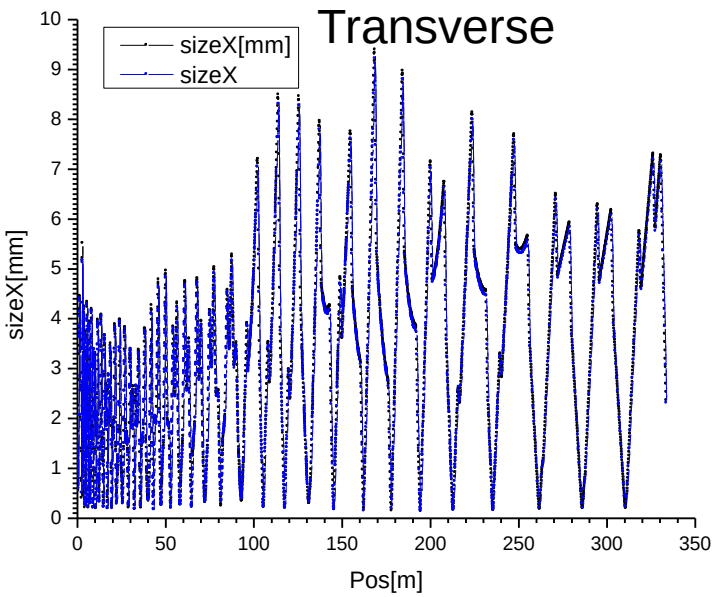


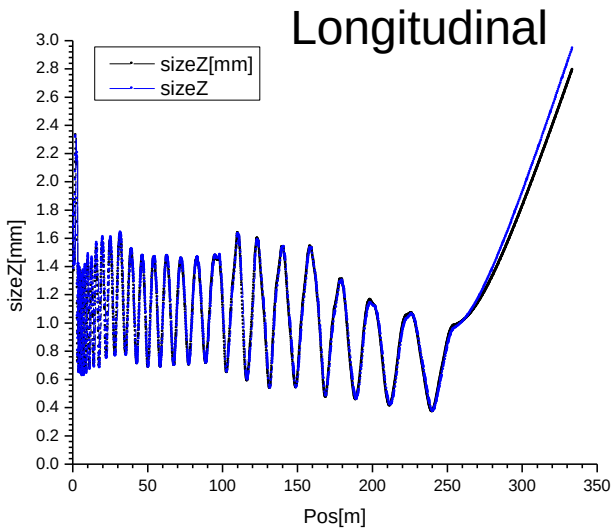


- **Standard linac models agree for matched beam case**
  - **They diverge quickly for miss-matched beam cases**
- **SNS personnel who ran Track, Impact and Parmila have left SNS**
- **Not impressed by any of these codes**

Developing ORBIT for Linac Beam Simulations

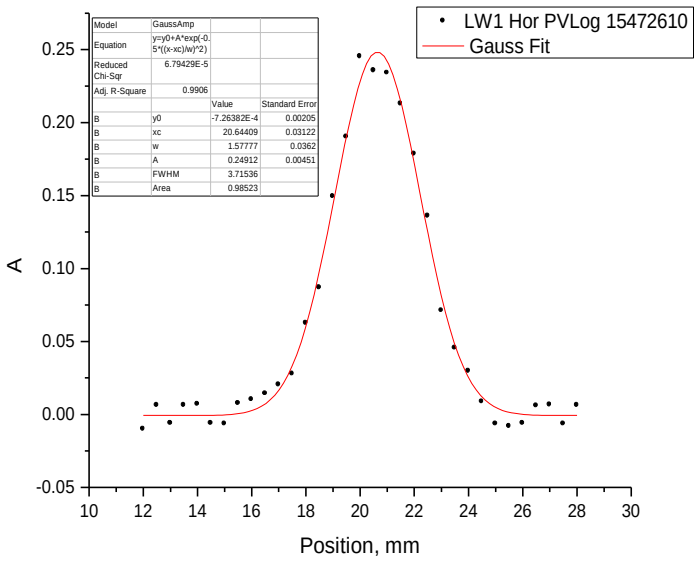
ORBIT Multi-particle simulation vs. Envelope Model

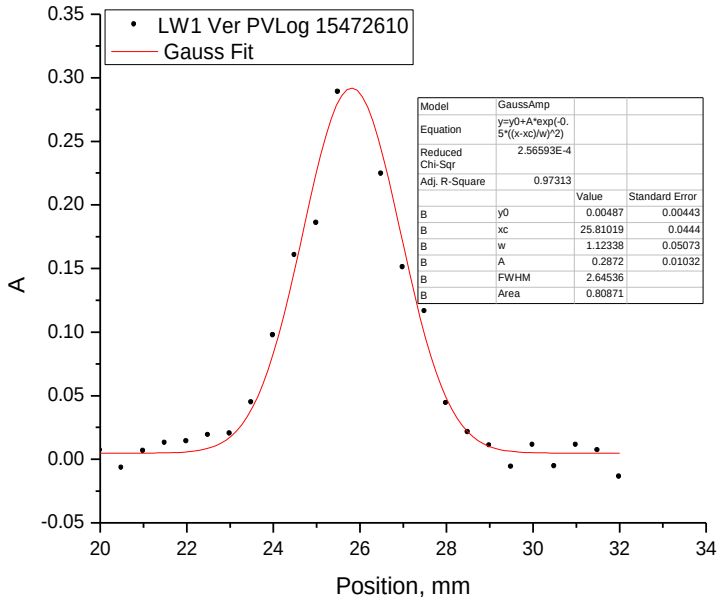




- **Good comparison or RMS beam size throughout the SNS linac: ORBIT multi-particle vs. envelope**

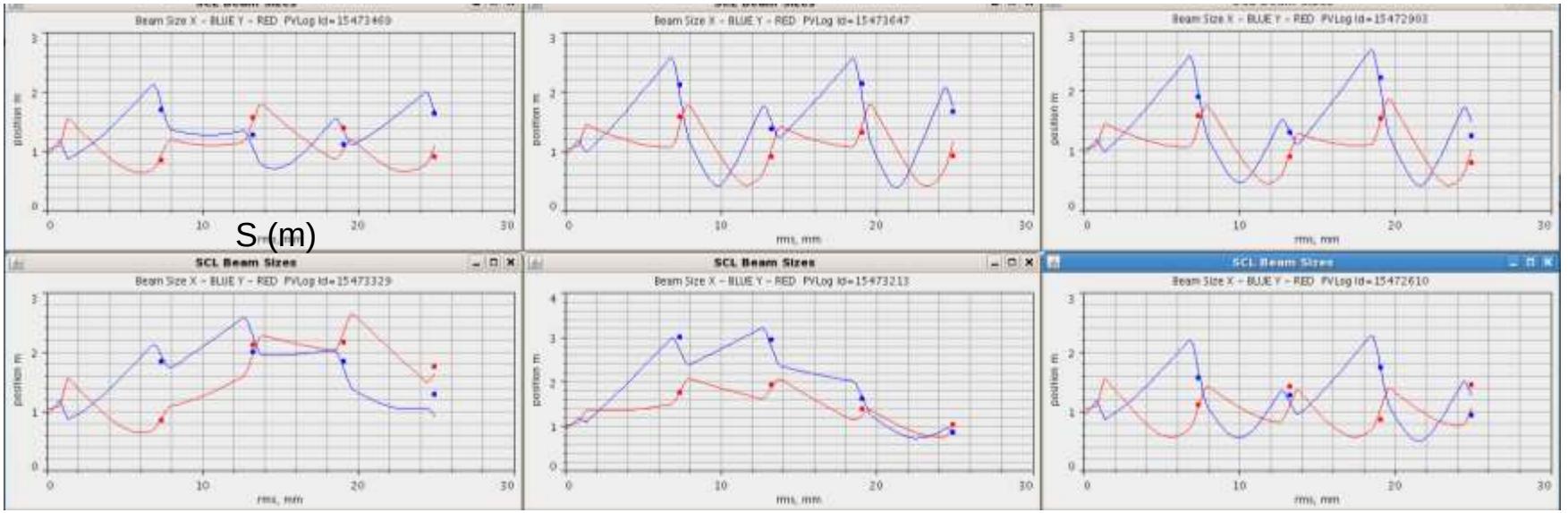
SCL Beam Profiles





- **Laser profile measurements are now "easy" enough to be useful for matching comparison**
- **See S. Aleksandrov + Y. Liu talks**

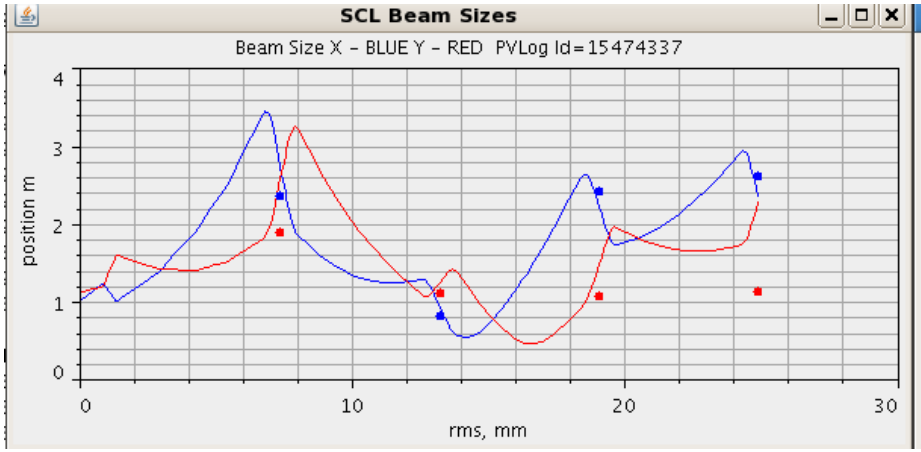
Beam Size Comparison: Measurement and Model: SCL – no RF

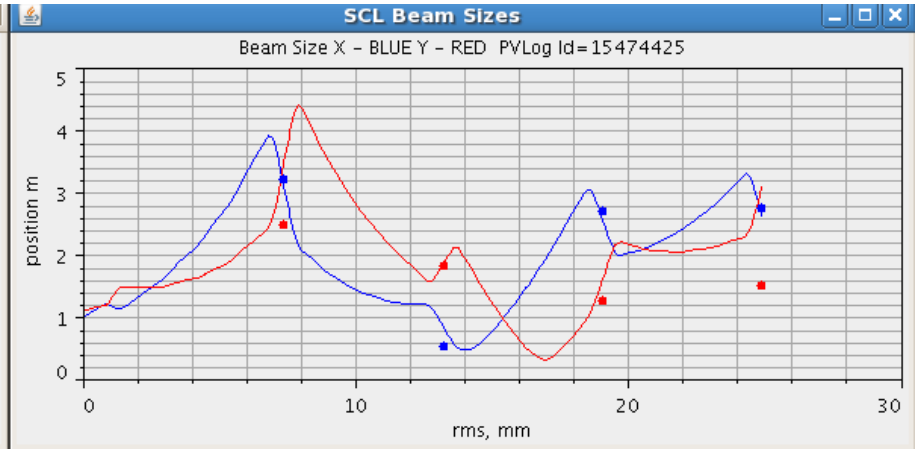


All cases start with the same initial Twiss
Each case has different quadrupole strengths

- **We understand the lattice in the absence of RF**

Beam Size Comparison: Measurement and Model: SCL – with RF





- Transverse optics in the SCL is sensitive to the RF setup (amplitude / phase)
  - Need to have a good knowledge of phase / amplitude
  - Empirical loss tuning destroys this knowledge
    - Sometimes “loss tuning” adjustments change RF settings by O(10 deg)

Summary

- We believe we better understand the source of the SCL beam loss now
- We now need to shift attention to the source of beam tails/halo
  - Eliminating these may permit further beam size increase in the SCL and alleviate Ring injection issues.