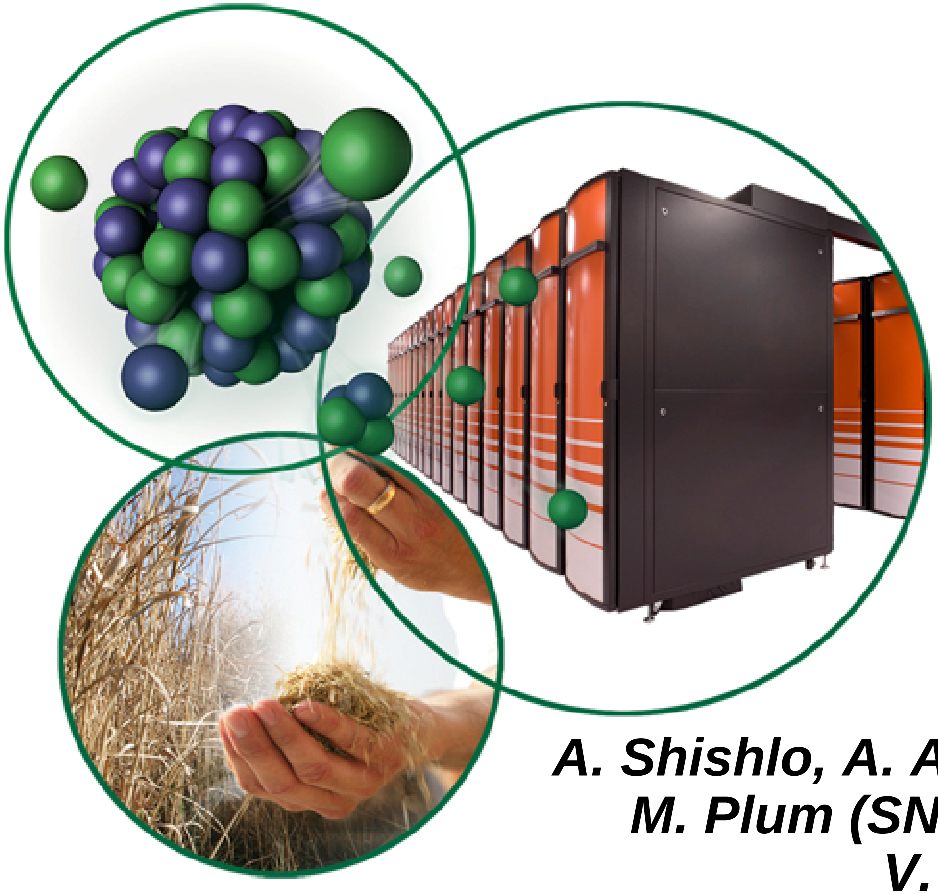
H- and Proton Beam Loss Comparison at SNS Superconducting Linac



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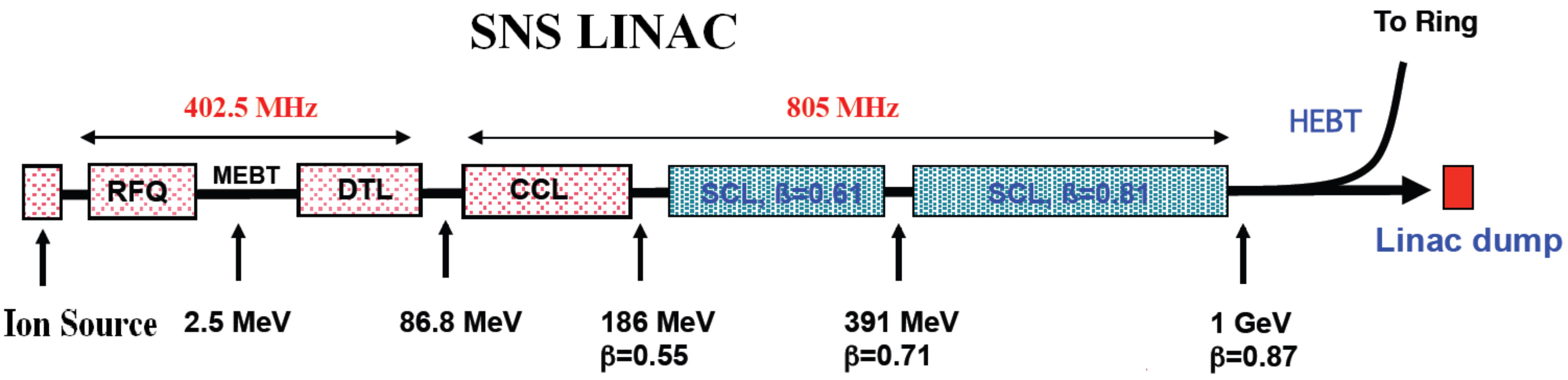
May 22, 2012

OAK RIDGE
National Laboratory

Outline

- **Beam Loss at the SNS Superconducting Linac (SCL): History of Loss Reduction**
- **Intra Beam Stripping (IBST)**
- **Protons in the SNS SCL**
- **H- and Proton Beam Loss Comparison**
- **Conclusions**

SNS Linac Structure



H^- linac

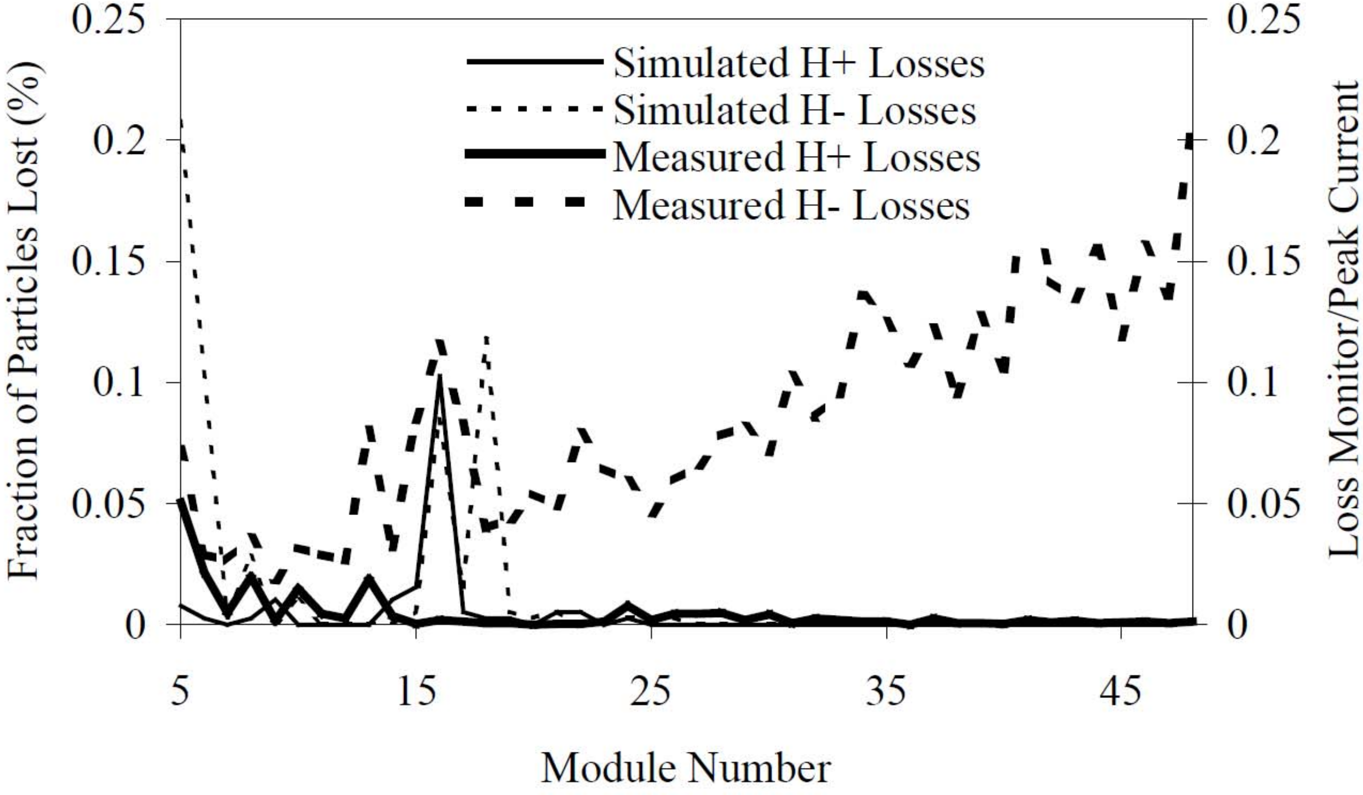
Length: 330 m (Superconducting part 230 m)

Production runs parameters:
Peak current: 38 mA
Repetition rate: 60 Hz
Macro-pulse length: 0.8 ms
Average power: 1 MW

Unexpected Beam Loss at the SCL

- **According to the design the SCL should be loss and activation free**
  - **Beam pipe aperture is about 10 times beam rms**
  - **Vacuum is one order of magnitude better than in DTL, CCL**
  - **Residual gases H^0 instead of nitrogen**
- **Found unexpected beam loss and activation during the SNS power ramp up in 2008**
- **Loss and activation were reduced by reducing the SCL quads' gradients – counterintuitive**
- **Now the SNS power is not limited by these loss and activation**
- **We are not the first – LANSCE, 1998**

H- and Proton Beam Loss at LANSCE



LINAC-98

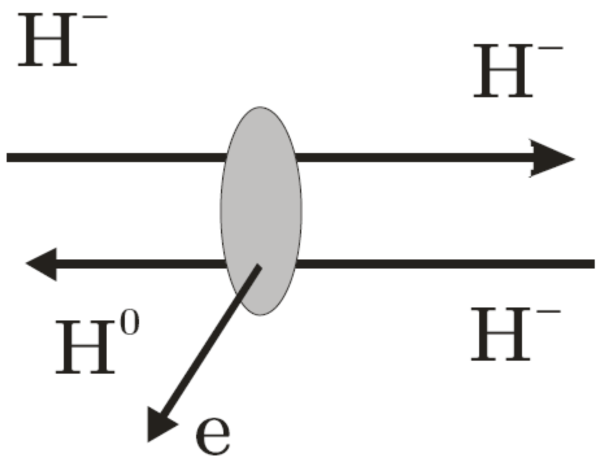
BEAM DYNAMICS SIMULATIONS OF THE LANSCE LINAC

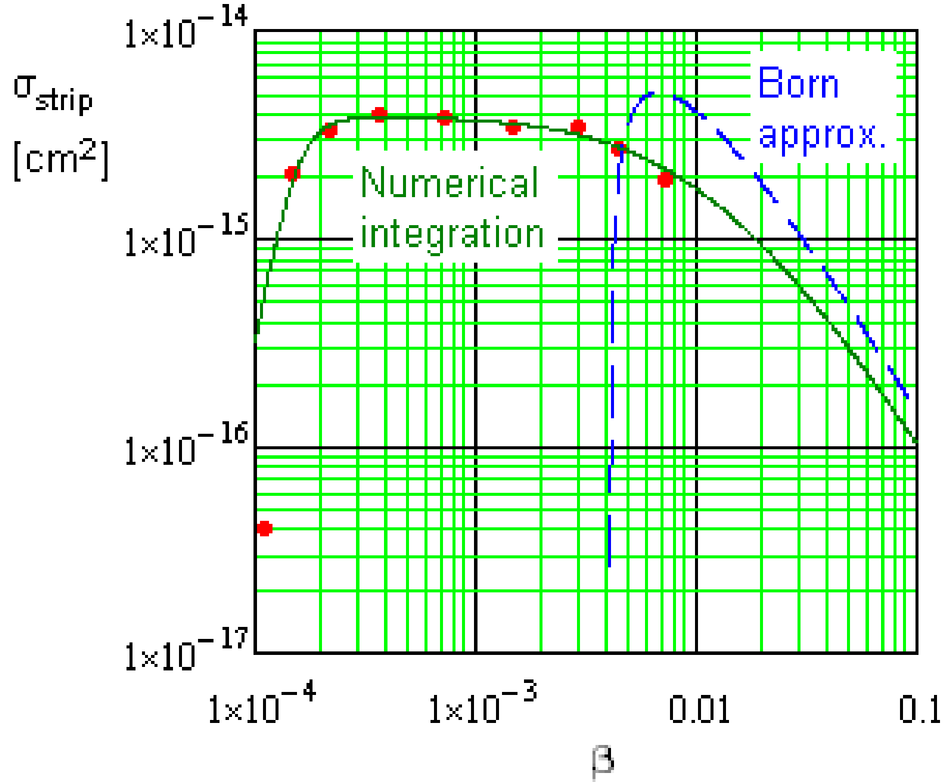
Frank Merrill and Lawrence Rybarcyk

LANSCE Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545

Intra Beam Stripping (Valeri Lebedev, FNAL)

(Talk at SNS, ORNL, October 2010)



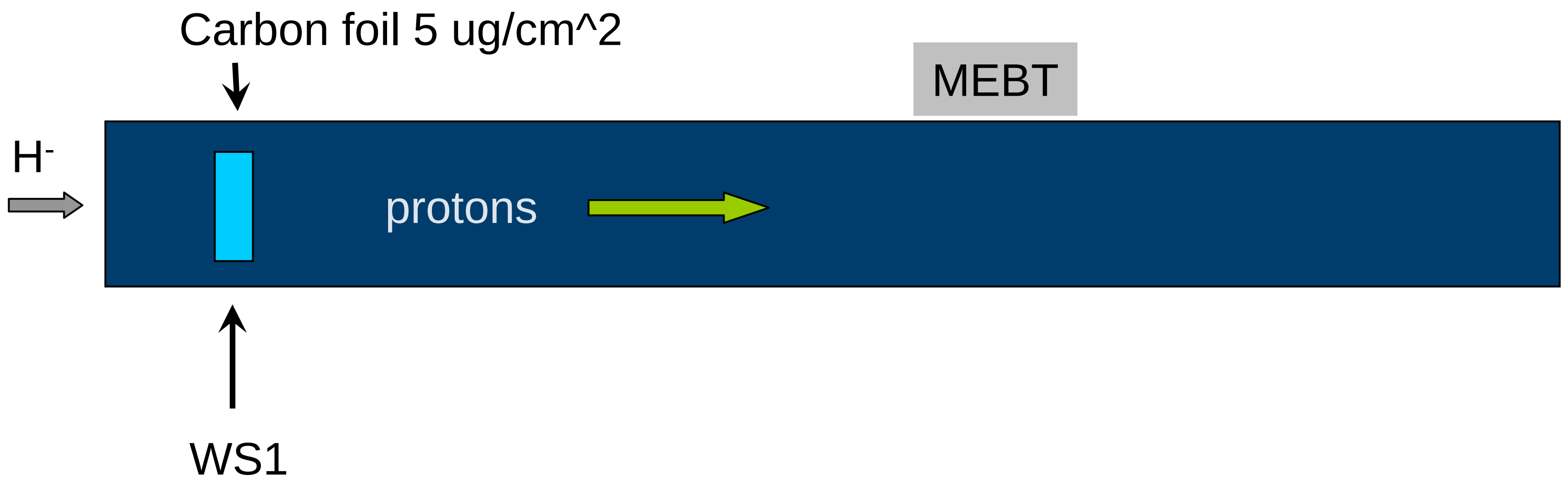


Integral SCL losses estimation:
$4x10^{-5}$

Measured SCL losses
$(2\text{-}7)x10^{-5}$

$$dn/dt \propto \sigma \cdot n^2$$

Proton Beam at the SNS Linac



- **5 ug/cm^2 carbon foil will suffice, 99.98% (our ring injection foils are 340 ug/cm^2)**
- **0.6 keV kinetic energy loss for protons (spread is about 12 keV)**
- **We can put more than 45 mini-pulses without damaging the foil**
- **12 % of the emittance growth expected**

Carbon Foil

Initially it is covered by a protective layer that we will burn off.

Linac Optics for Protons

Charge of the particle

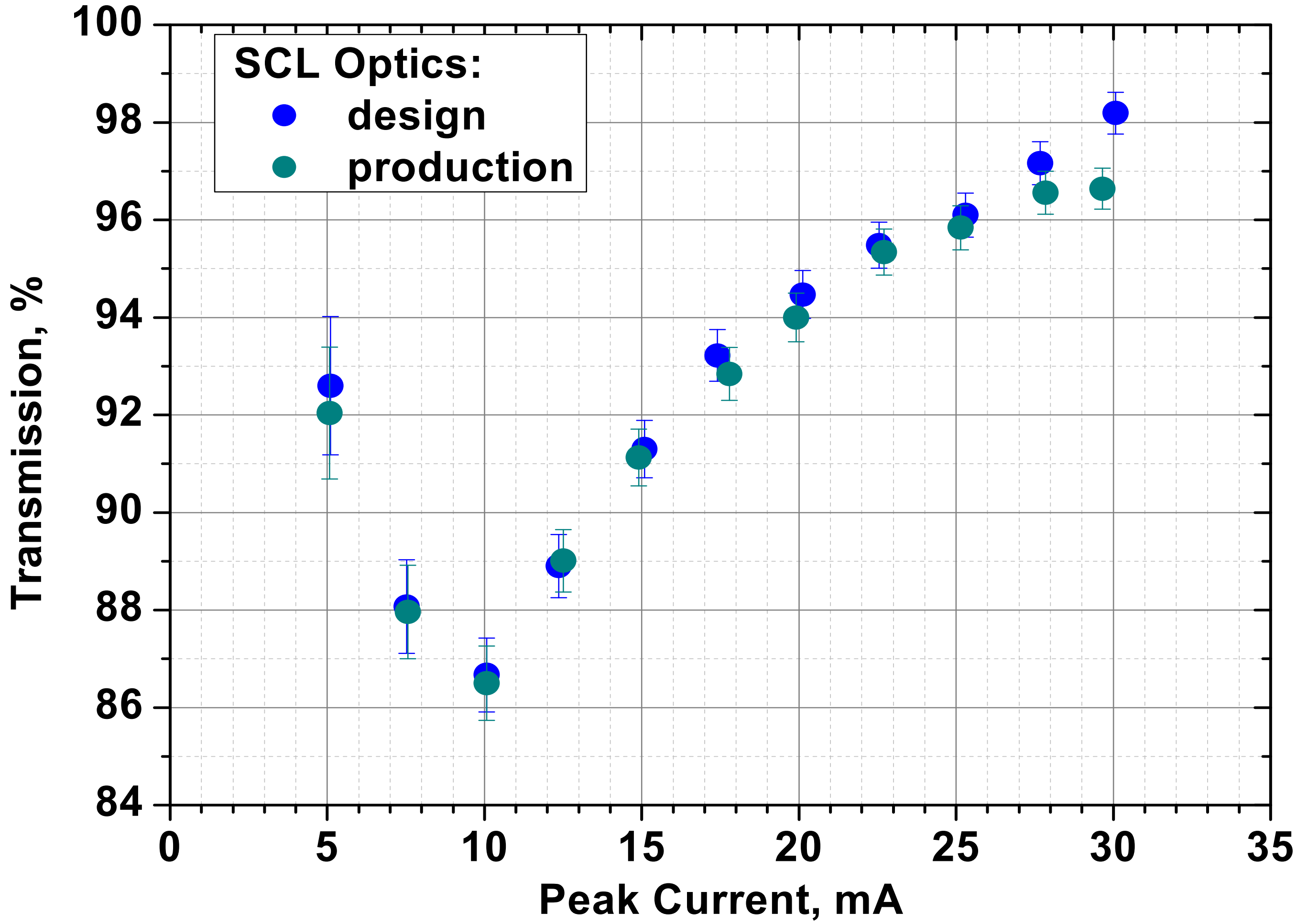
$$d\vec{p}/dt = q\cdot(\vec{E} + \vec{v}\times\vec{B})$$

$$\vec{B}(\vec{E}) = \vec{B}_0(\vec{E}_0)\cdot\exp(i\cdot w\cdot t + \phi_0)$$ **Inside RF Cavities**

$$\vec{E} = 0$$ **Inside quads**

- RF phases shifted by 180 deg.
- DTL quads are permanent magnets
- Horizontal <-> Vertical planes switched for quads polarity
- Used MEBT to match beam into the DTL by switching x⇔y Twiss parameters .

Measured Proton Transmission to SCL



It is not 100%

It is a peak current dependent

We loose beam in MEBT-DTL

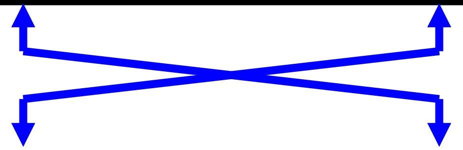
Measurements are separated by hours

Transmission to SCL, 2011.09.25

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

Production SCL Optics, 30 mA

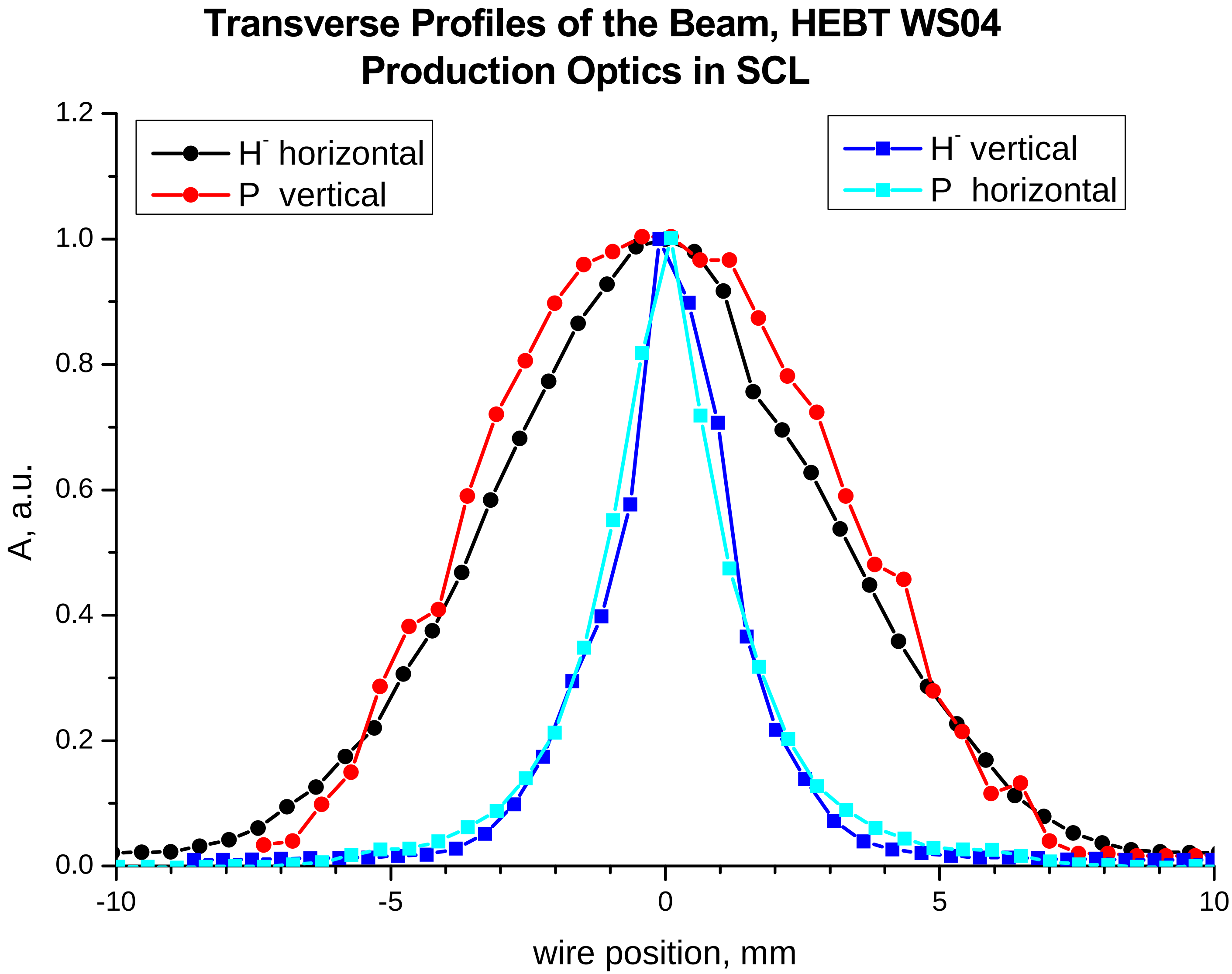
H-		
	Horizontal	Vertical
Emittance, π*mm*mrad	0.71	0.47
alpha	1.8	-2.0
Beta, m	10.0	10.3



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

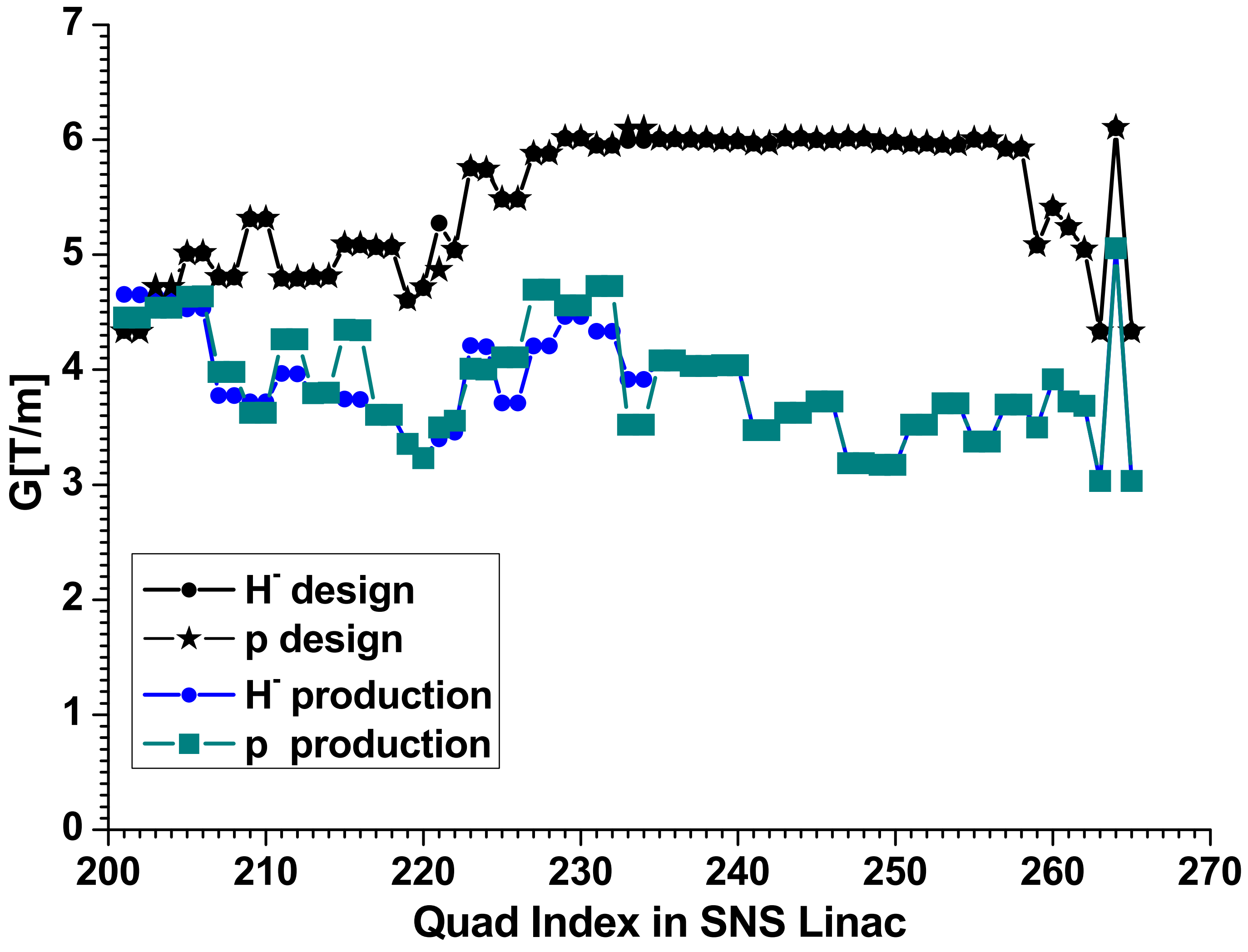
The horizontal and vertical planes are switched for the proton beam.

Beam at the End of SCL



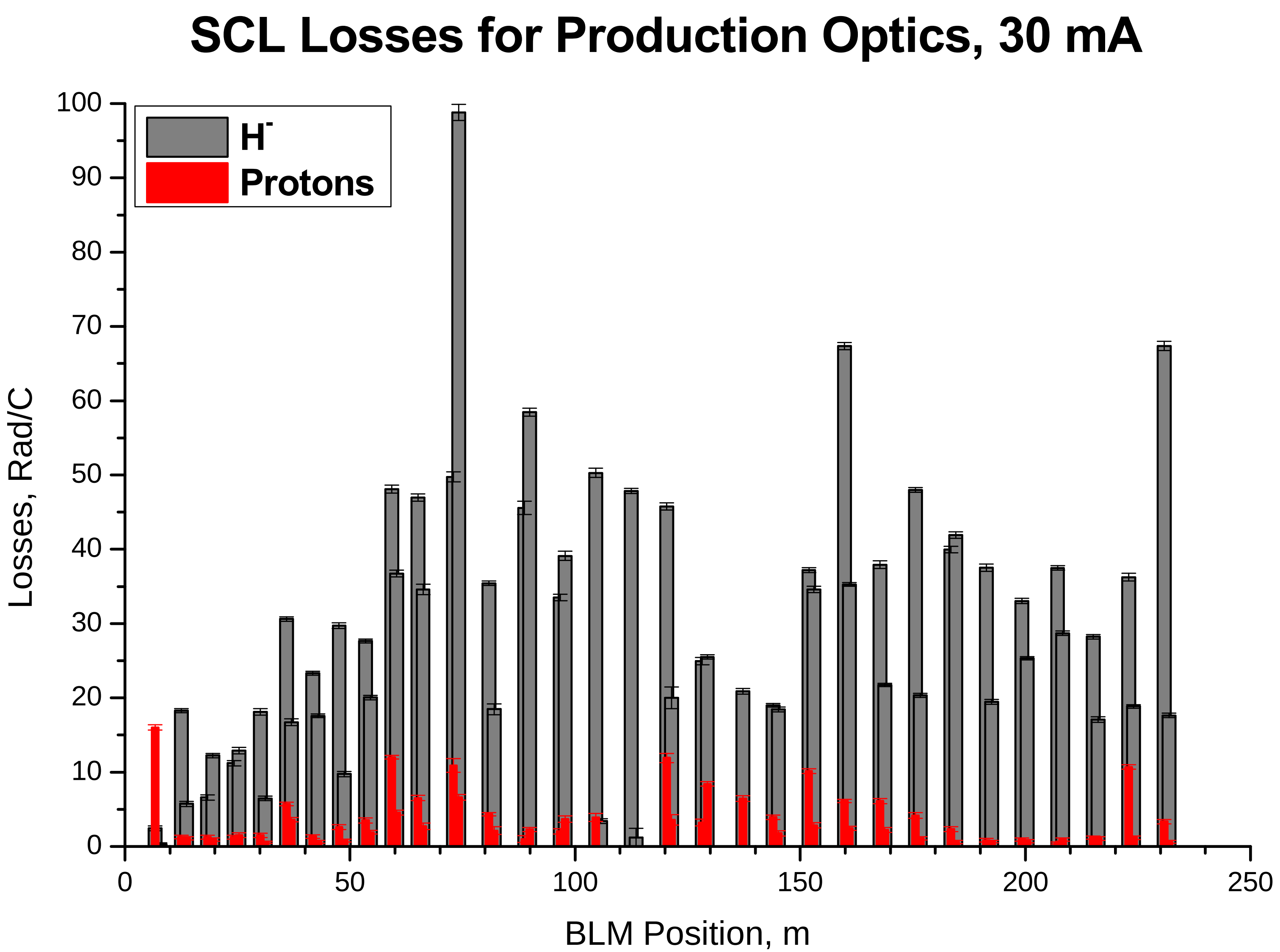
Vertical and horizontal planes are switched for protons in HEBT

Two SCL Optics for both H- and Protons

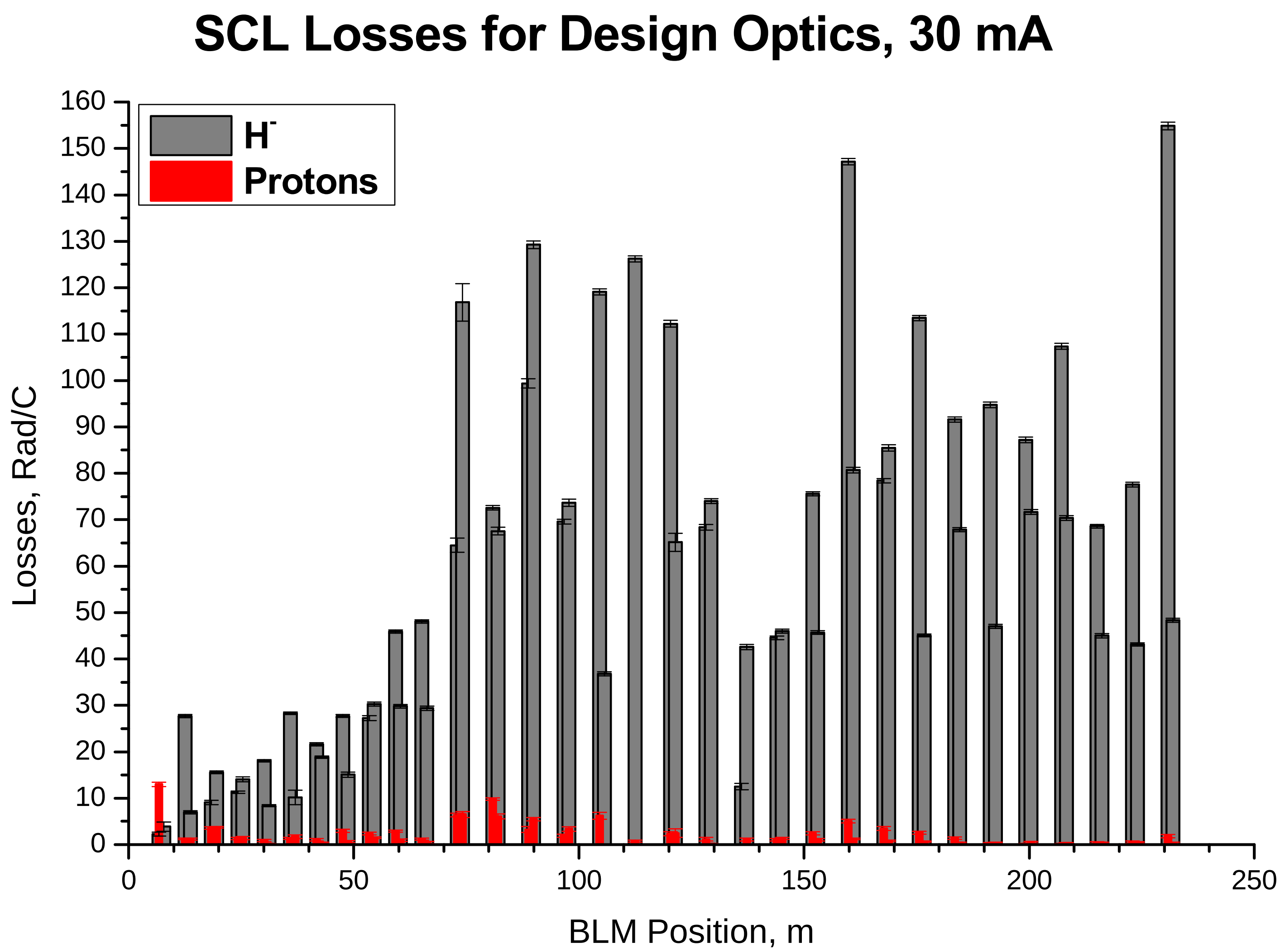


SCL Quads' Gradients for 4 Cases

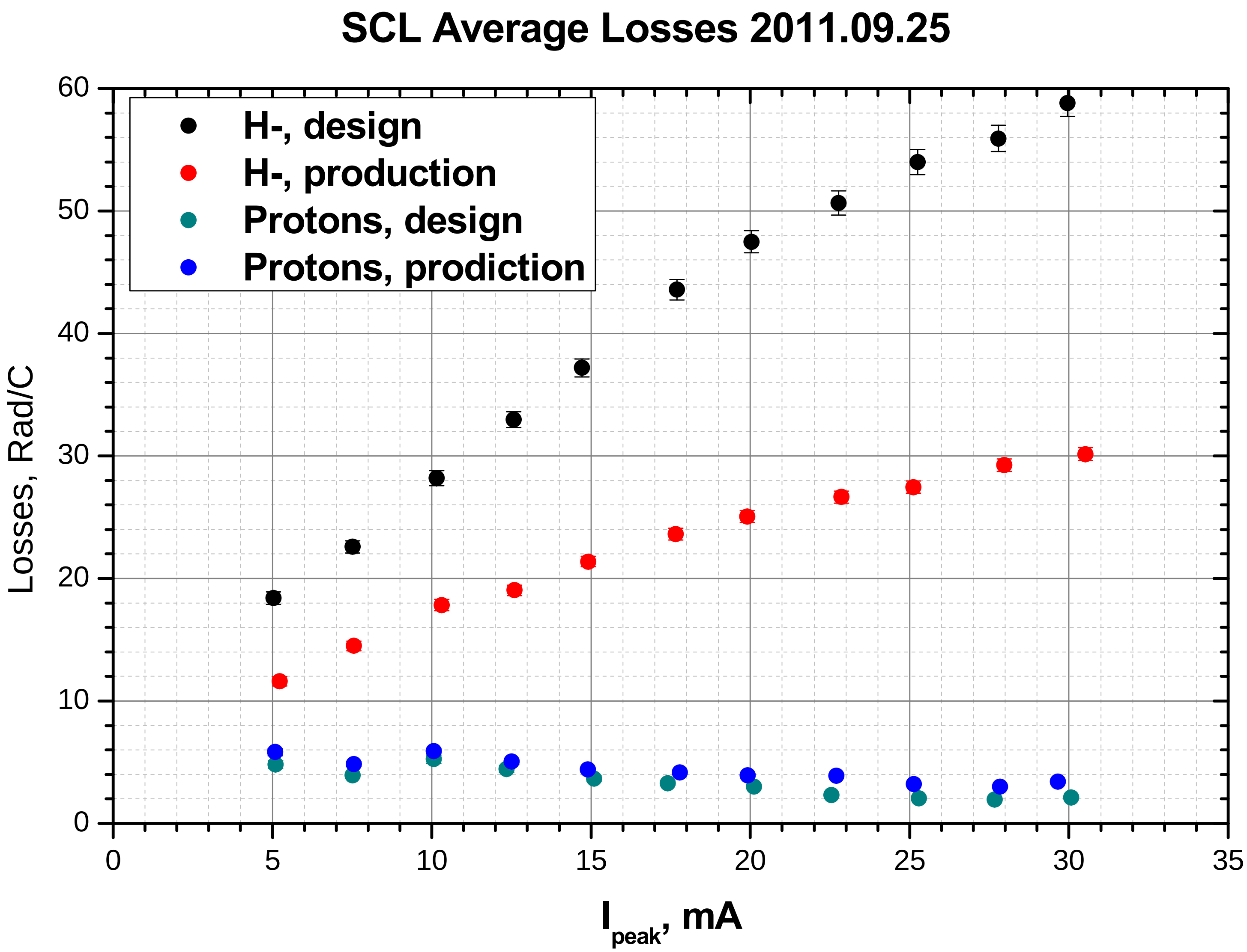
SCL Losses Protons vs. H- for 30 mA



SCL Losses Protons vs. H- for 30 mA



SCL Losses vs. Peak Current



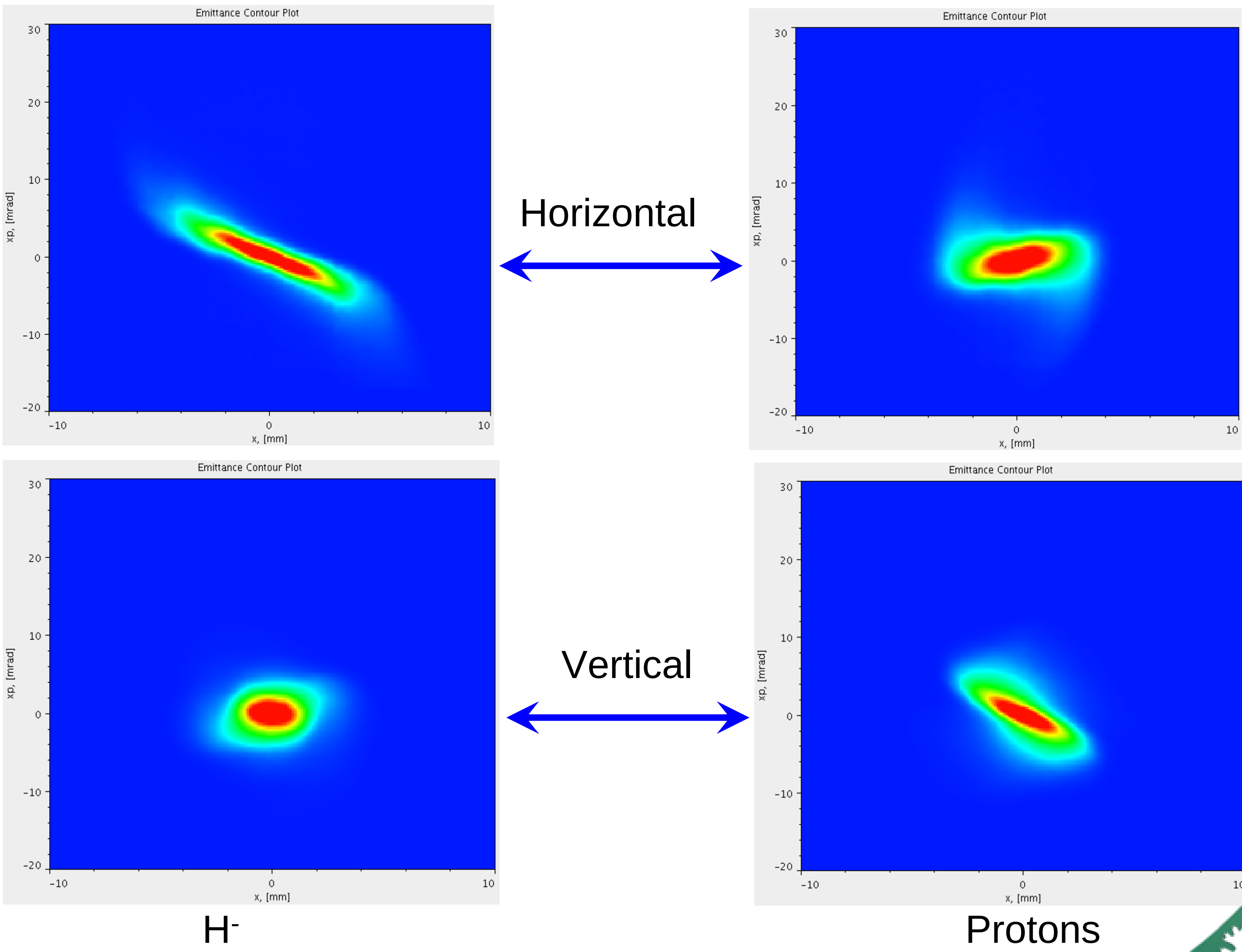
Summary

- **We have the proton beam in the SNS linac**
- **We can achieve a good transmission from MEBT to SCL**
- **The SCL losses are lower for the proton beam by at least one order of magnitude for the 30 mA peak current**
- **The SCL H^- beam loss at SNS is caused mostly by the IBST mechanism**

Thanks!

Backup Slides

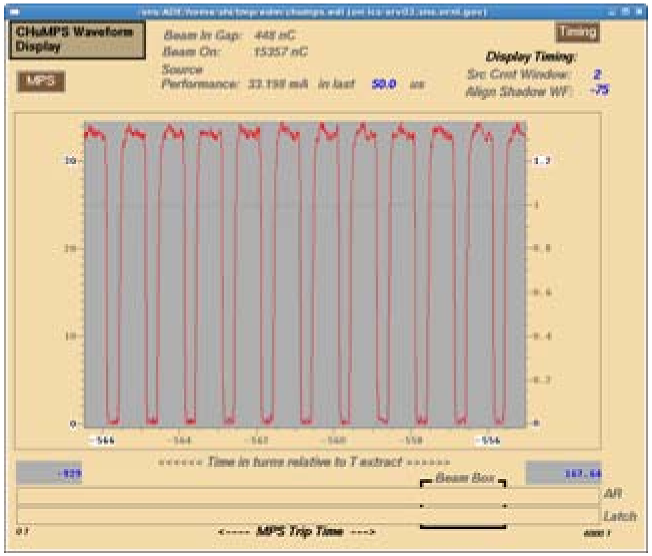
Emittances in the MEBT for H- and Protons, 30 mA

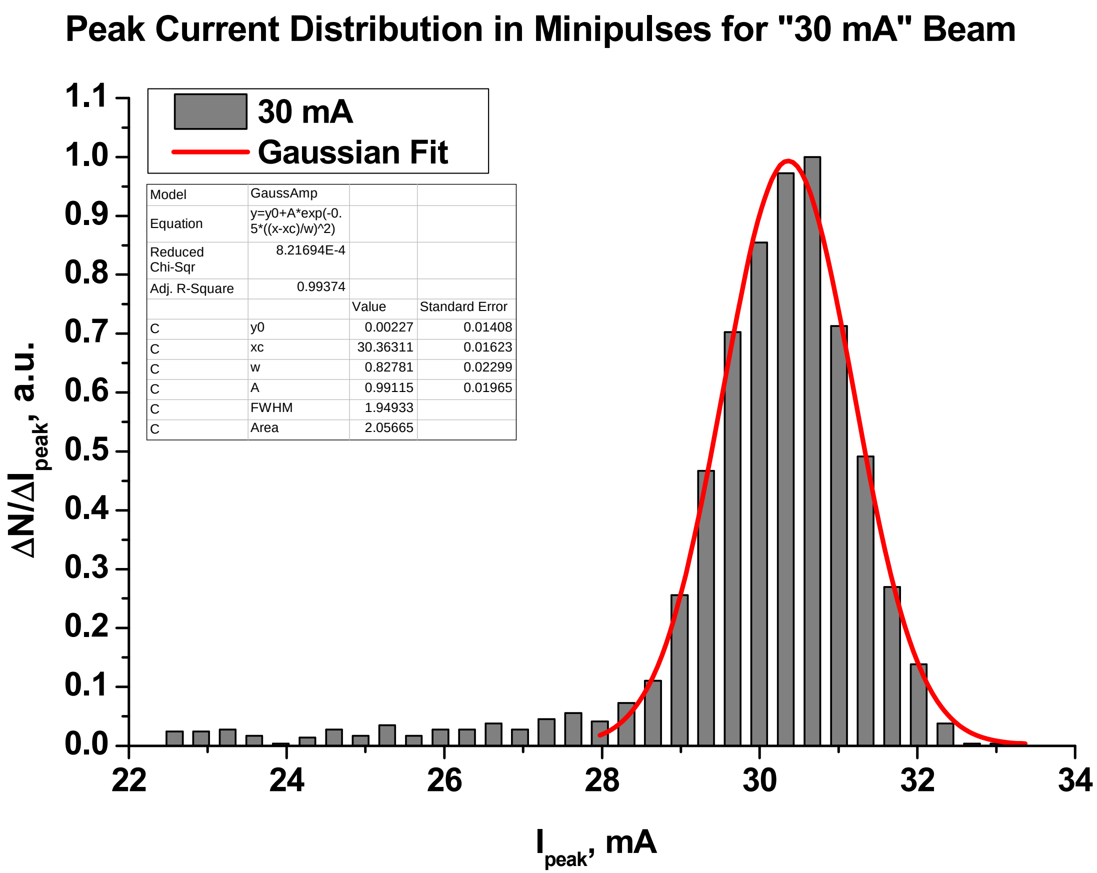


Transmission of the Beam to SCL

- **Not an easy task**
- **The beam is chopped, and we need the peak current as the input parameter for losses.**
- **Beam Current Monitors are not precise enough.**
- **As an original signal we used the first MEBT BPM signal (Chopper und MPS signal). It is before the MEBT foil, and the signal is the same for H- and protons.**
- **In SCL we used all BPM amplitude signals to specify the peak current in SCL.**

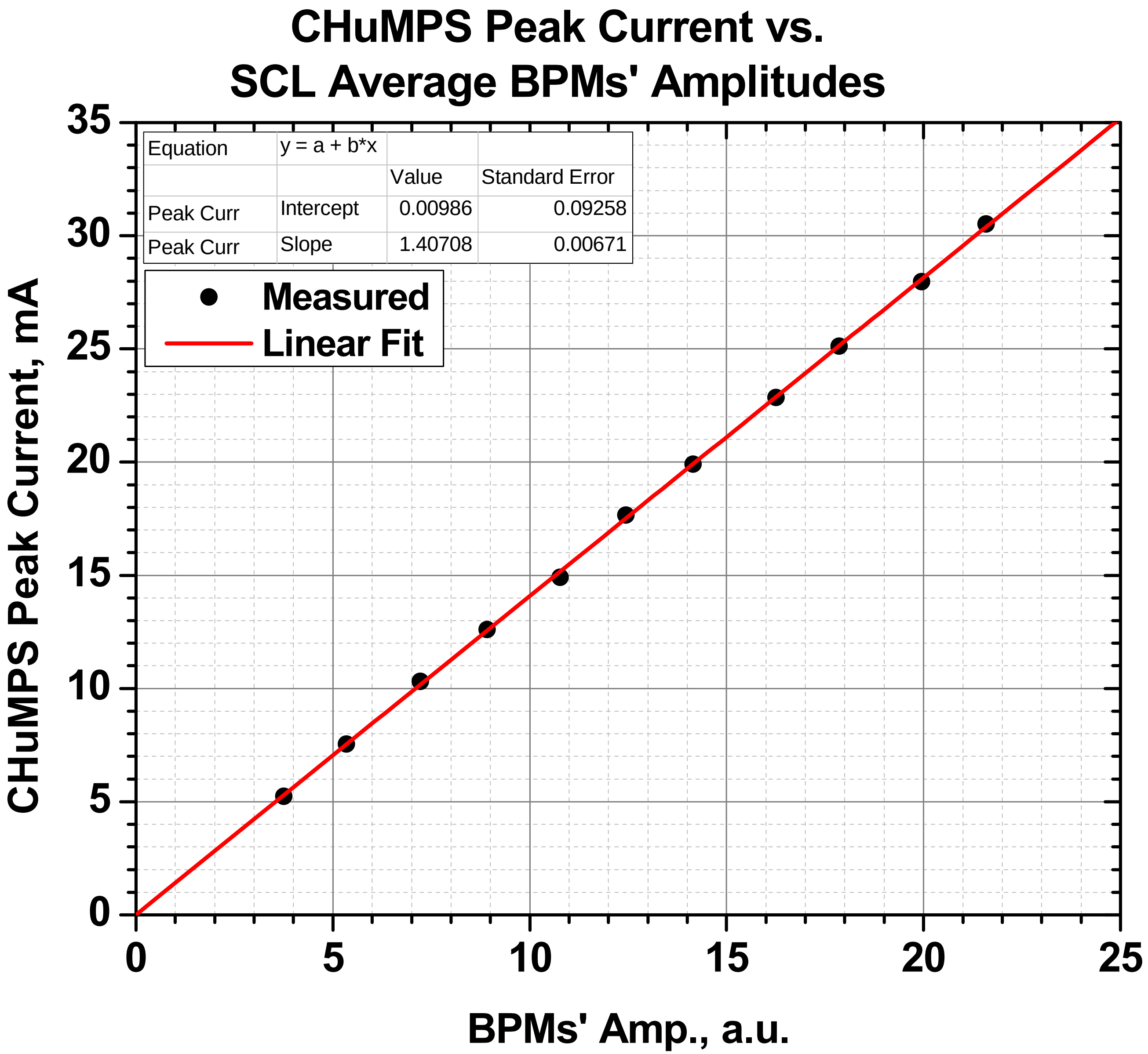
MEBT CHuMPS Waveforms an Peak Current



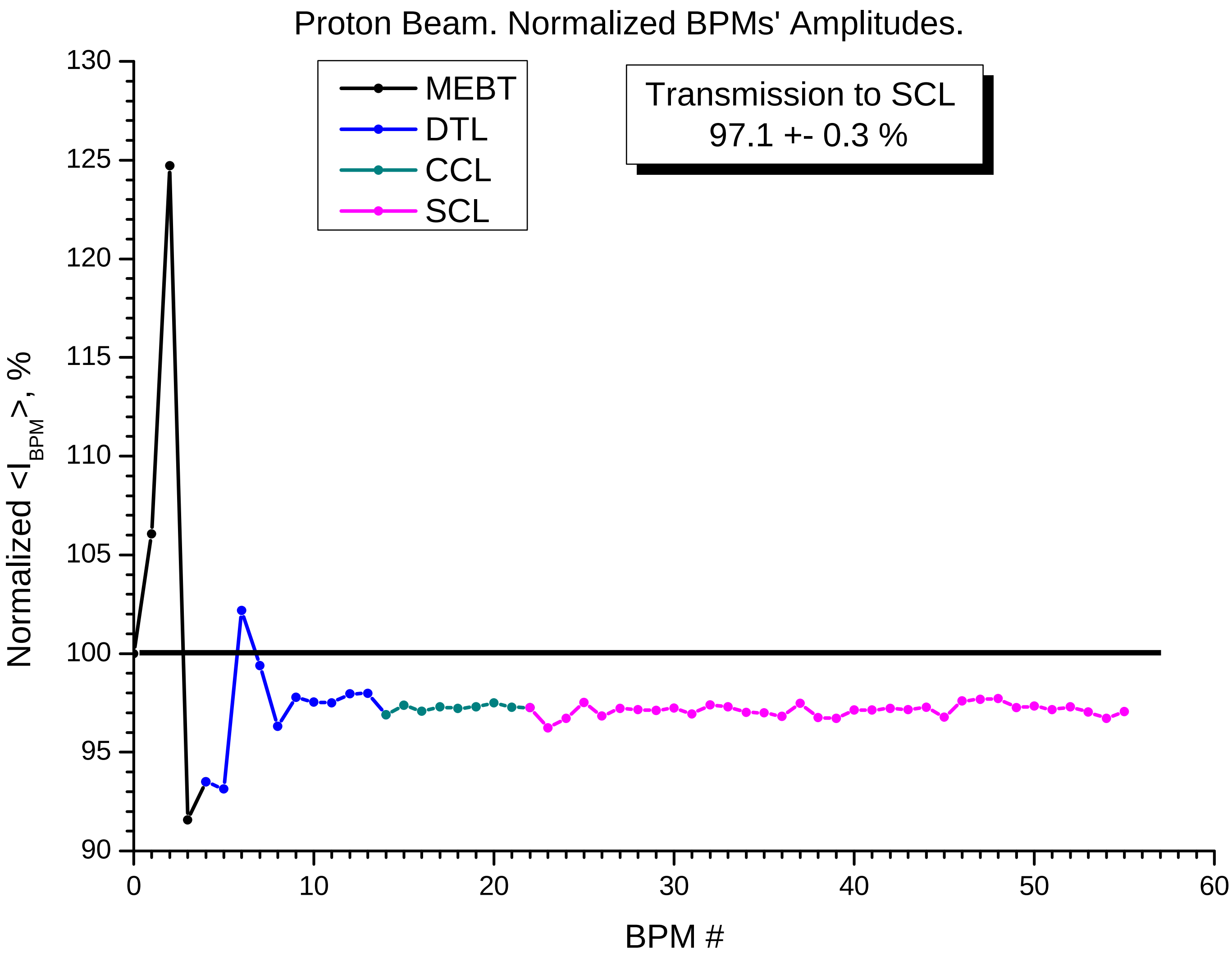


- We used 40 mini-pulses injection
- For each measurement we recorded CHuMPS waveforms to calculate peak current
- For SCL BPM calibration we scan over peak current values from 30 to 5 mA.

SCL BPM Calibration (H-, production)



BPMs Amplitudes along the Linac, 30 mA



We are not sure where we loose 3% of the beam.
The ,most probable place is the DTL-MEBT transition.