THO1A02

Beam Measurement and Simulation at J-PARC Linac

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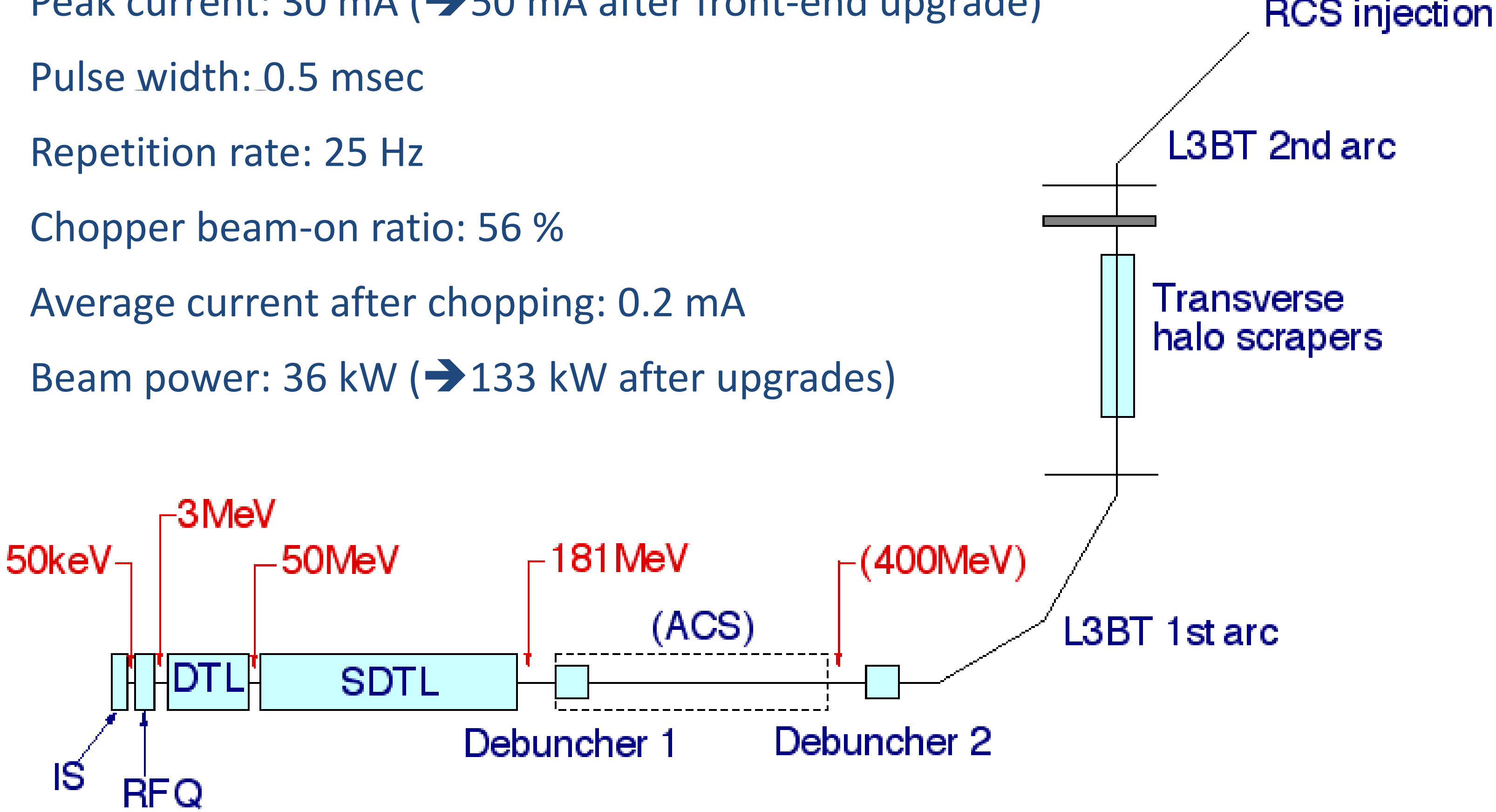
Outline

We have experienced a significant emittance growth in DTL and halo formation in SDTL with high current operation. As an illustrative example for the comparison between simulation and experiment in J-PARC linac, we focus on this topic in this talk.

- Experimental measurements of emittance growth and halo formation
- Particle simulations to find the mechanism behind the emittance growth and halo formation
- Cure for the emittance growth and halo formation and its experimental result

Main parameters for J-PARC linac

- Ion species: Negative hydrogen ion
- RF frequency: 324 MHz (972 MHz for ACS section)
- Output energy: 181 MeV (➔400 MeV by adding ACS section)
- Peak current: 30 mA (➔50 mA after front-end upgrade)
- Pulse width: 0.5 msec
- Repetition rate: 25 Hz
- Chopper beam-on ratio: 56 %
- Average current after chopping: 0.2 mA
- Beam power: 36 kW (➔133 kW after upgrades)



Measured transverse emittance

- **5 mA peak current**

	H	**V**
DTL exit	0.27	0.25
SDTL exit	0.23	0.27
A0BT exit	0.25	0.27

- **30 mA peak current**

	H	**V**
DTL exit	0.42	0.36
SDTL exit	0.35	0.40
A0BT exit	0.37	0.40
Design	0.3	0.3

* Normalized rms in πmm•mrad.

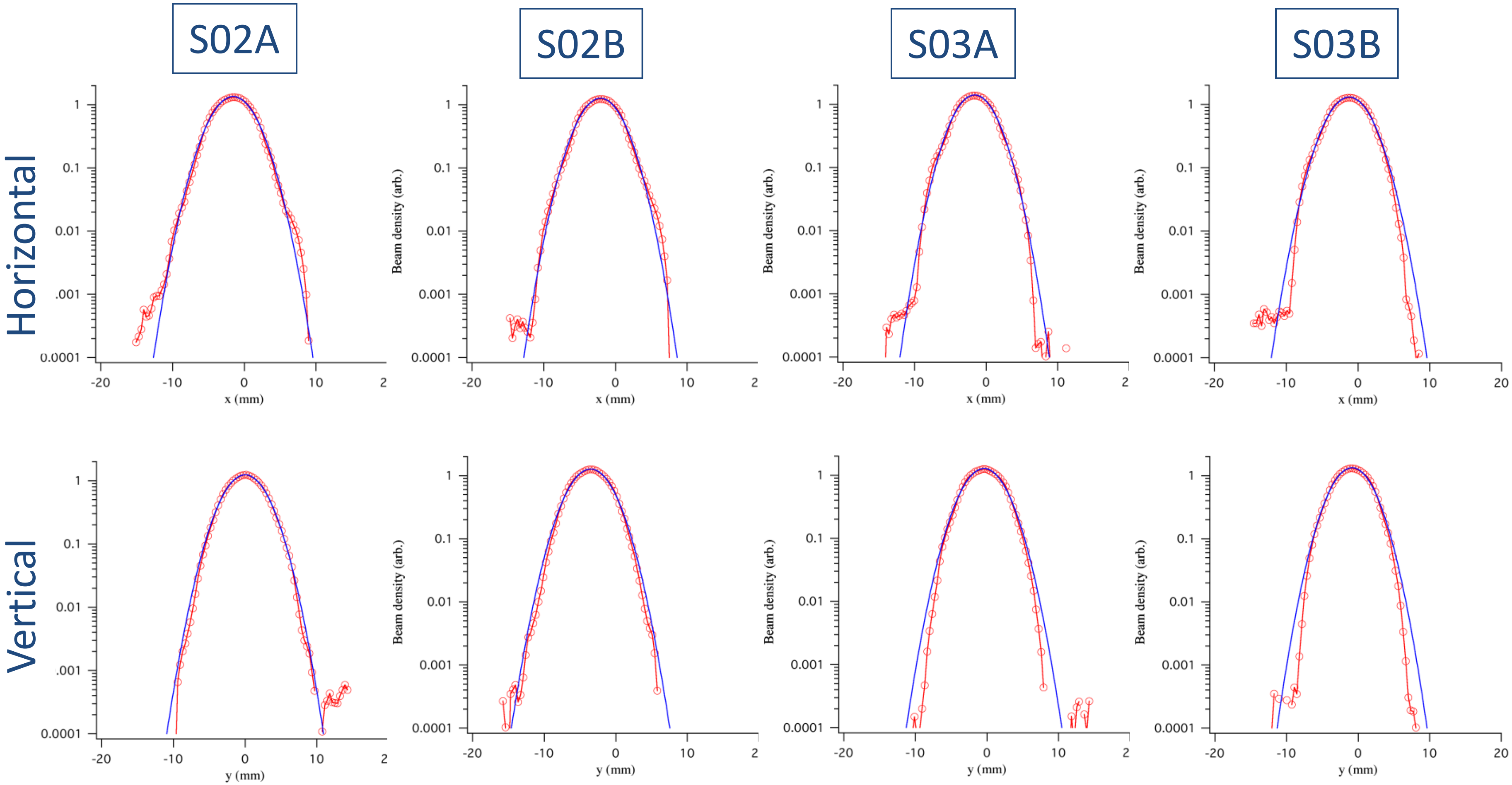
The listed emittances are calculated from rms beam widths measured with an array of wire scanners.

The emittance is also measured at MEBT with a double-slit emittance monitor, and found to be 0.22 to 0.25 both for 5 mA and 30 mA cases.

We have significant emittane growth in DTL especially in the case of 30 mA peak current.

We don't have significant emittance growth after DTL exit.

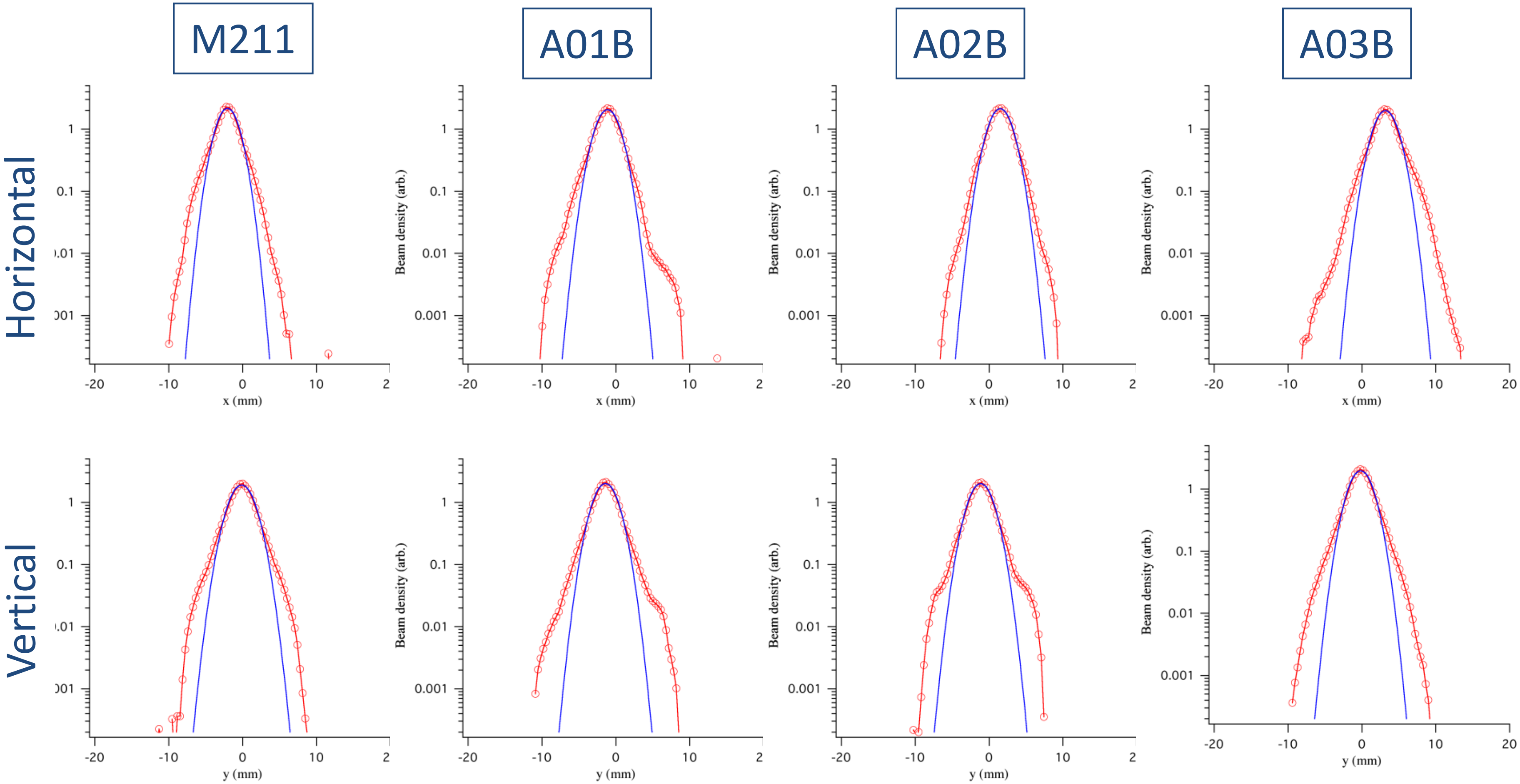
Measured profile at DTL exit



Beam profile is mostly Gaussian at DTL exit.
Red circle: Measurement, Blue line: Gaussian fit

30 mA

Measured profile at SDTL exit



Clear halo is developed at SDTL exit while there is no significant emittance growth.

Red circle: Measurement, Blue line: Gaussian fit

30 mA

Summary of observation

- We have significant emittance growth in DTL in the case of 30 mA peak current.
- Beam profile at DTL exit is virtually Gaussian without beam halo.
- We don’t have significant emittance growth after DTL exit.
- Clear halo is seen at SDTL exit.

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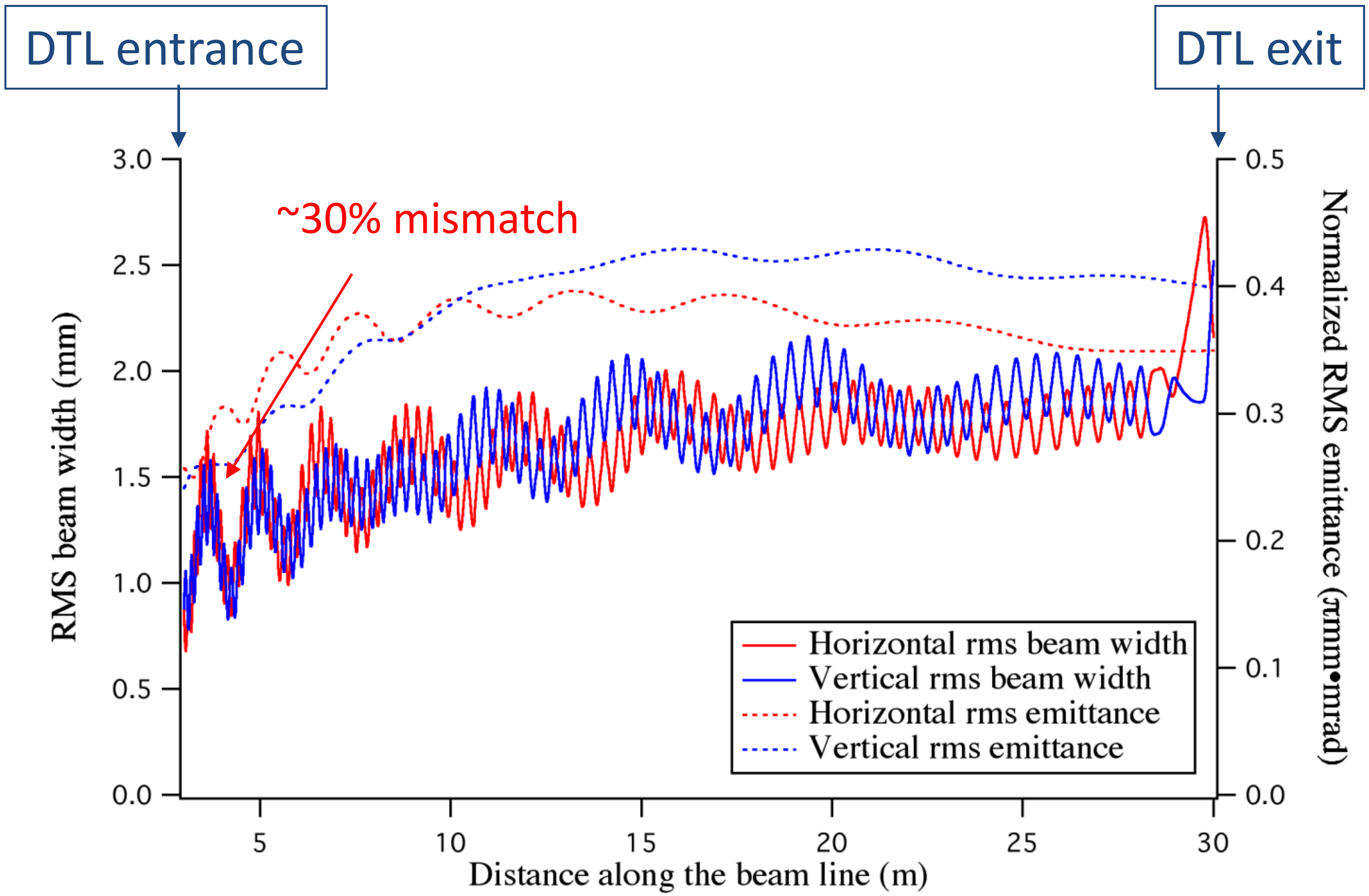
We have tried to reproduce these characteristic features with **IMPACT** simulations to find a possible cause for it.

In the simulation, we have tried various kinds of mismatch at MEBT between RFQ and DTL.

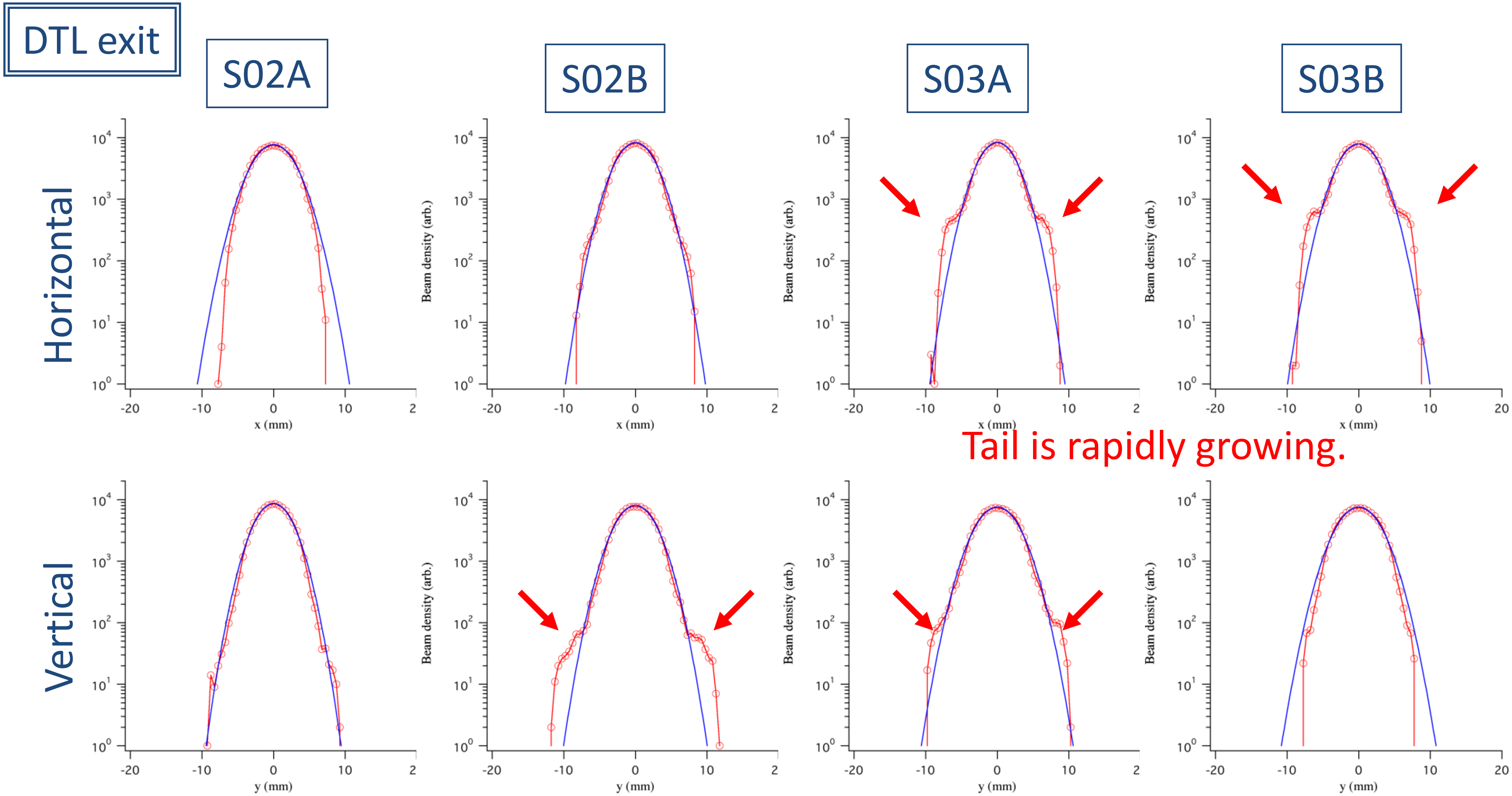
Degree of mismatch



We need to assume 30 to 40 % transverse mismatch oscillation to reproduce the measured emitance growth.

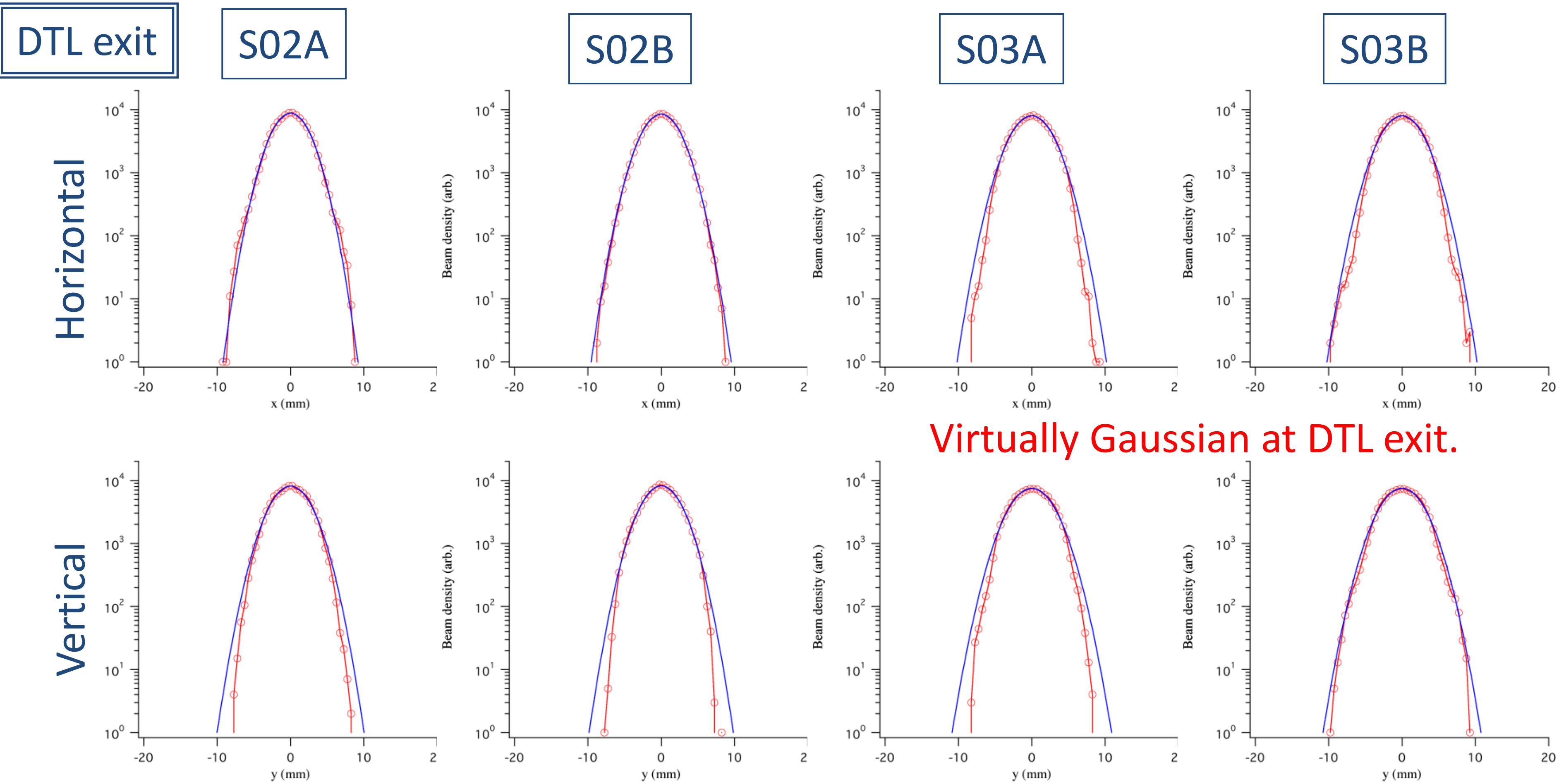
Transverse mismatch oscillation can be driven by both transverse and longitudinal mismatch at MEBT through space-charge coupling.

Typical case with transverse mismatch



In most cases, halo develops faster than the experimental observation with 30 to 40 % mismatch oscillation.

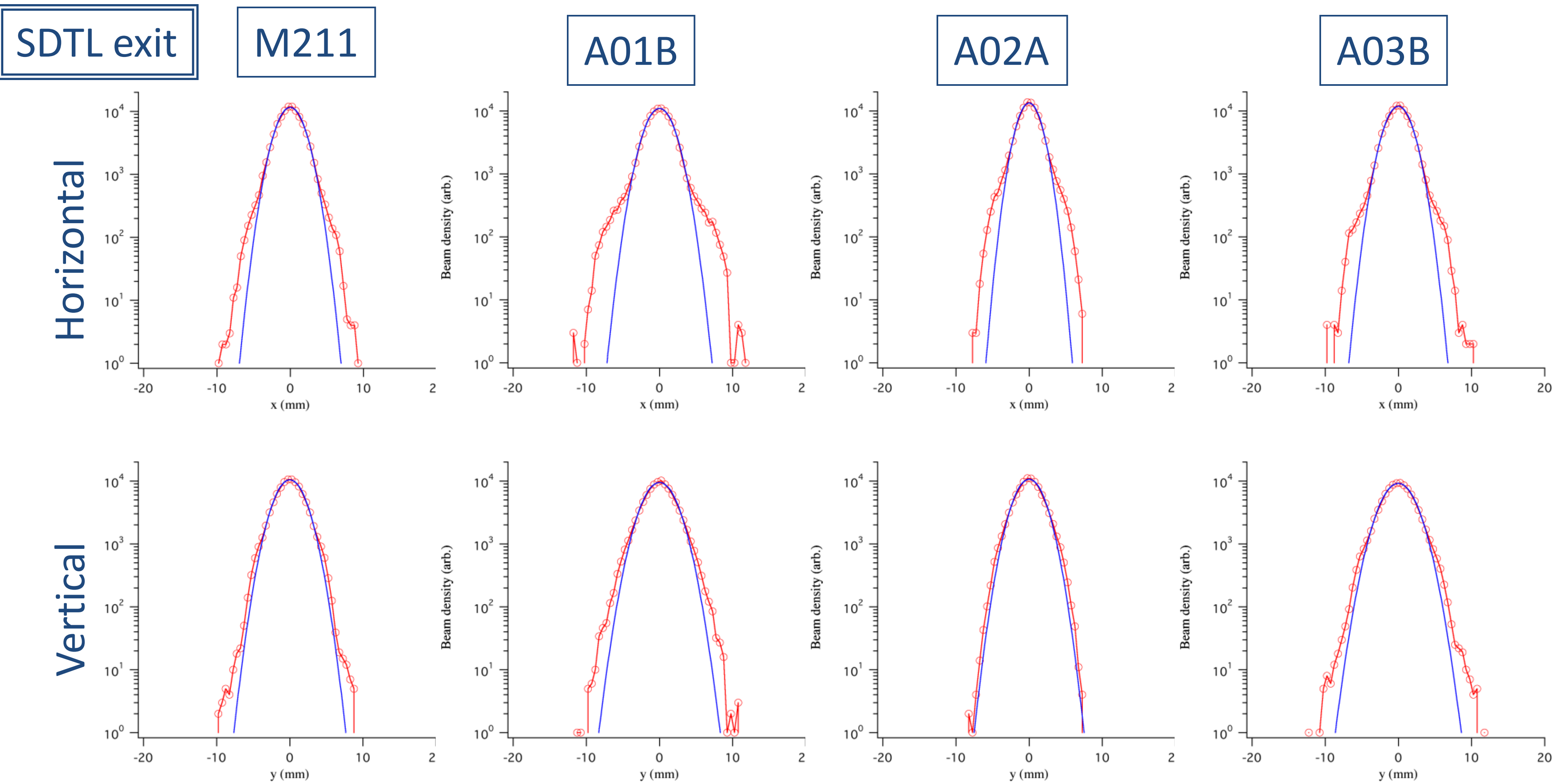
A case with a longitudinal mismatch (I)



Virtually Gaussian at DTL exit.

However, with a certain longitudinal mismatch at MEBT, the onset of halo development has been delayed.

A case with a longitudinal mismatch (II)

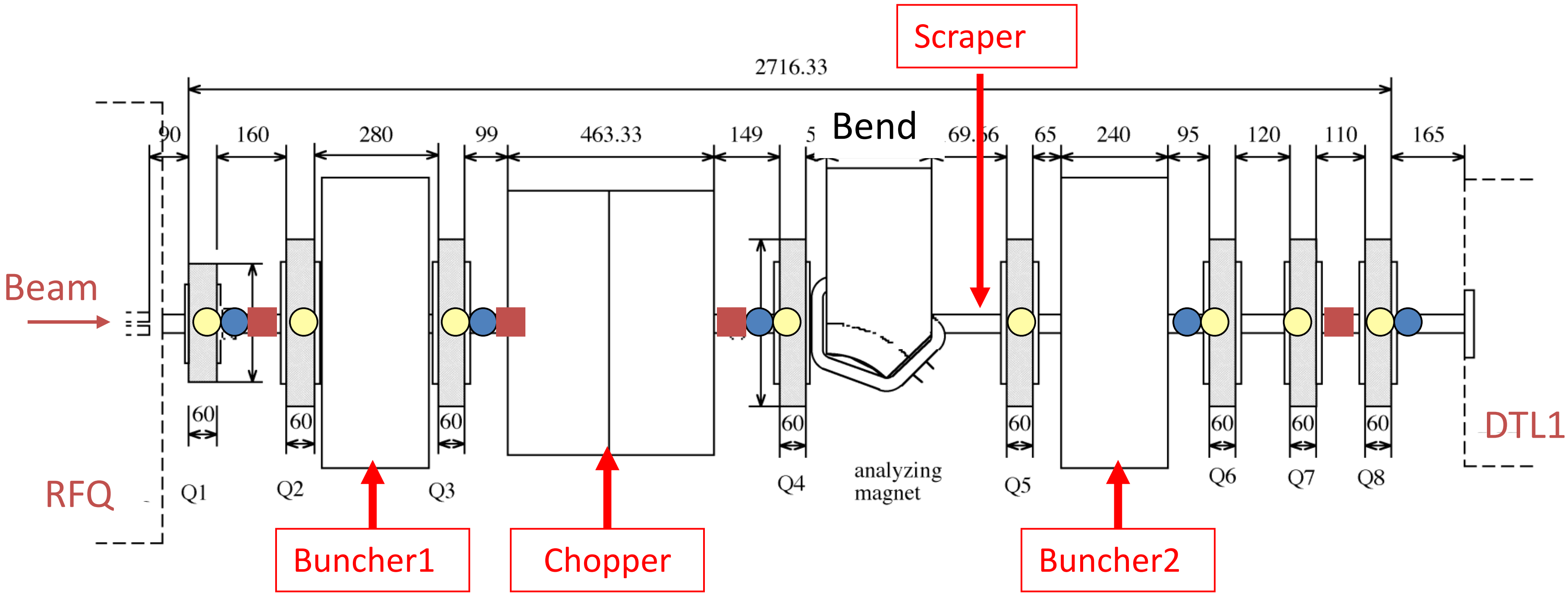


Clear halo is developed at the SDTL exit, while it is a little less pronounced than the experimental observation.

Summery of findings in simulation

- Based on the **IMPACT** simulation, we assume that the substantial emittance growth is caused by a certain type of longitudinal mismatch at MEBT.
- As we lack the longitudinal beam diagnostics in MEBT, it is difficult to confirm this speculation with a direct measurement.
- We have performed a tuning of MEBT buncher amplitude based on this finding.

MEBT buncher tuning



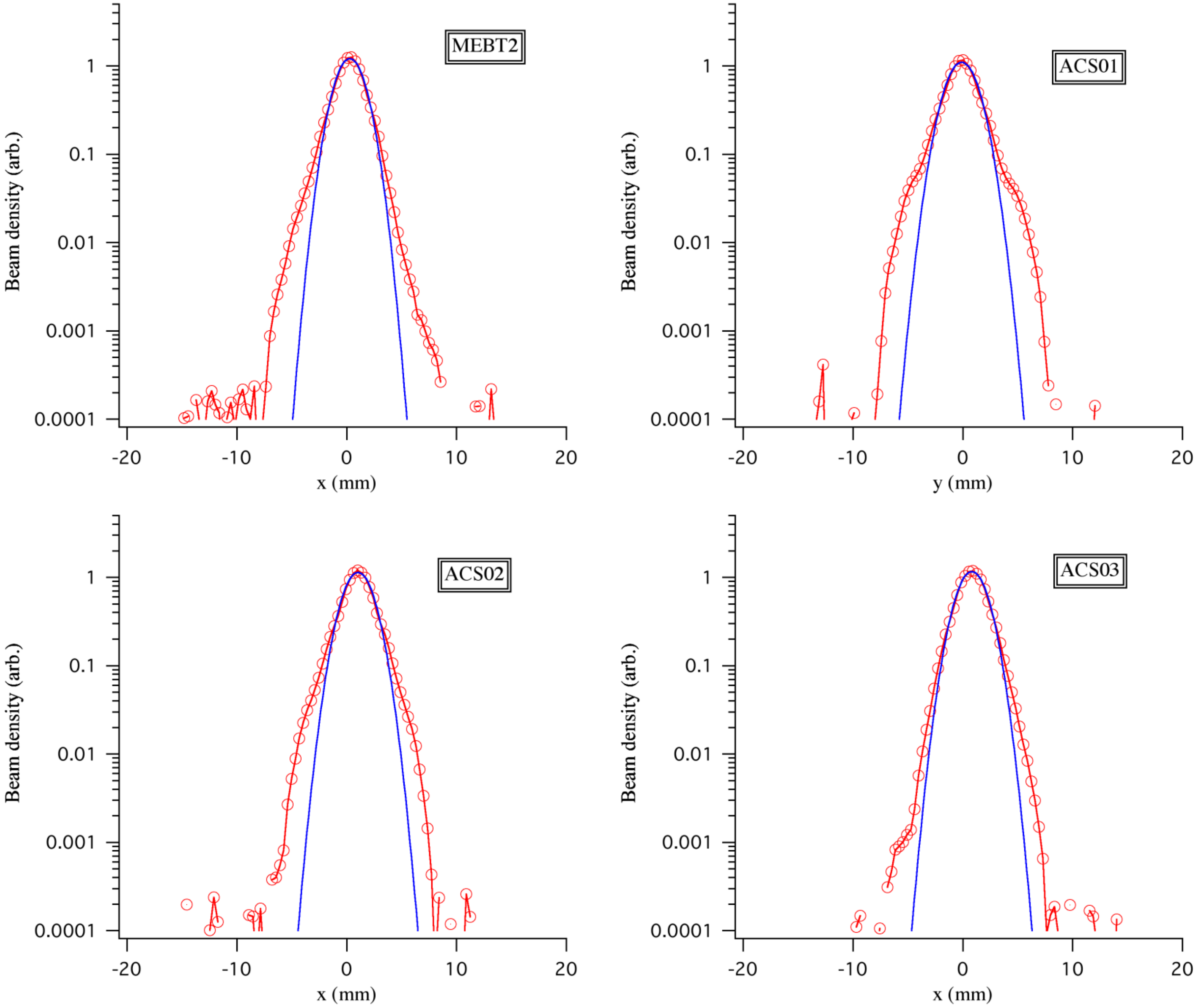
- In the tuning, the amplitude of two MEBT bunchers are tuned with a trial and error method so that the transverse emittance at the exit of DTL is minimized with the peak current of 15 mA.

MEBT buncher tuning (cont.)

- In this tuning, the buncher 1 amplitude is increased by 20 % and the buncher 2 amplitude is decreased by 10 % to minimized the emittance at the exit of DTL. Then, the normalized rms emittance at the exit of DTL was reduced as follows;
  - Horizontal 0.266 → 0.232 πmm•mrad
  - Vertical 0.231 → 0.207 πmm•mrad
- Transverse halo is also reduced at the exit of SDTL as shown in the next a few slides.
- It indicates that it is possible to make a longitudinal matching with transverse diagnostics by taking the advantage of the transverse-longitudinal coupling due to space-charge.
- It also demonstrates that particle simulations are useful in giving a practical guideline in a real beam tuning.

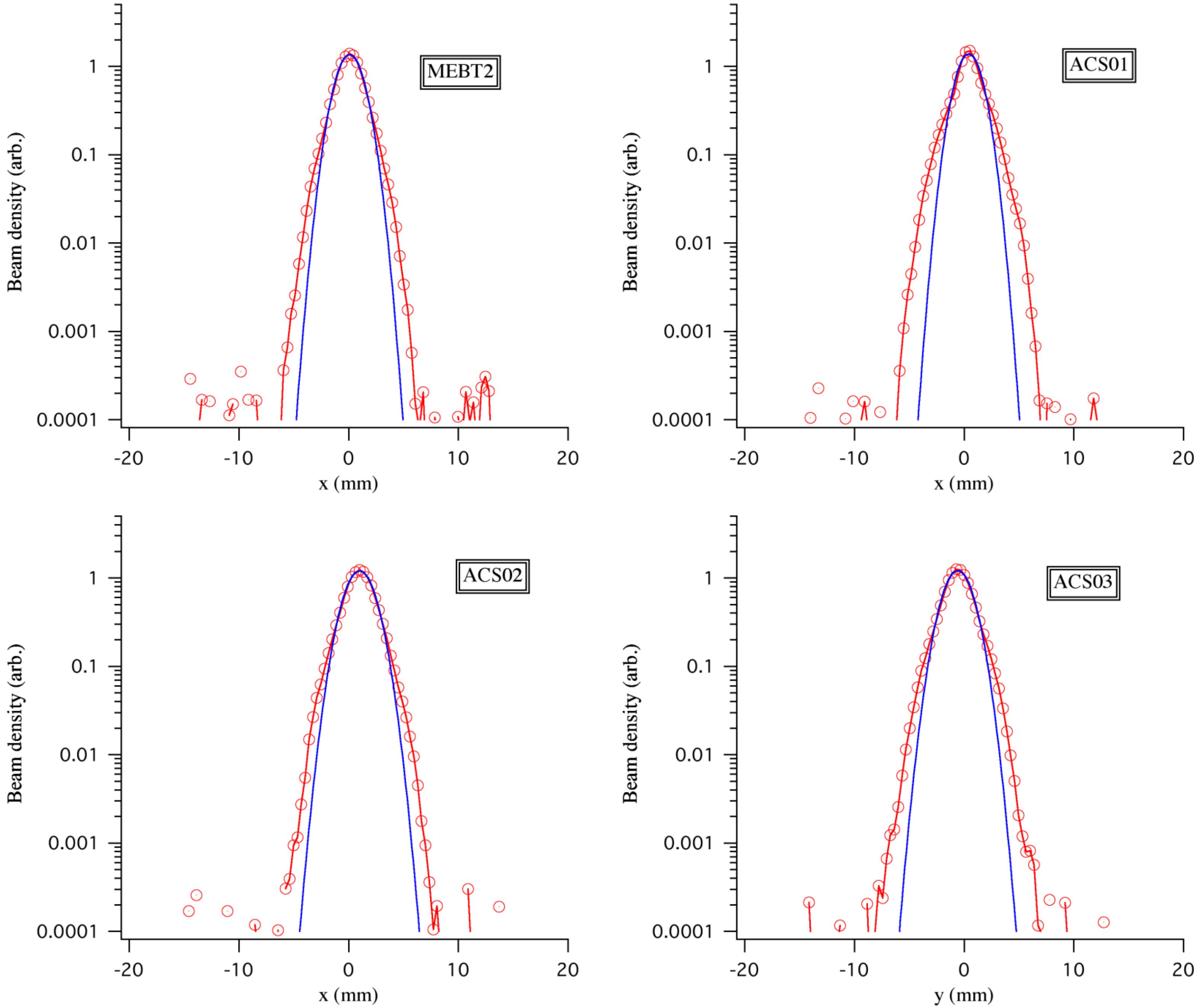
Beam profile at SDTL exit (Horizontal, before buncher tuning)

15 mA



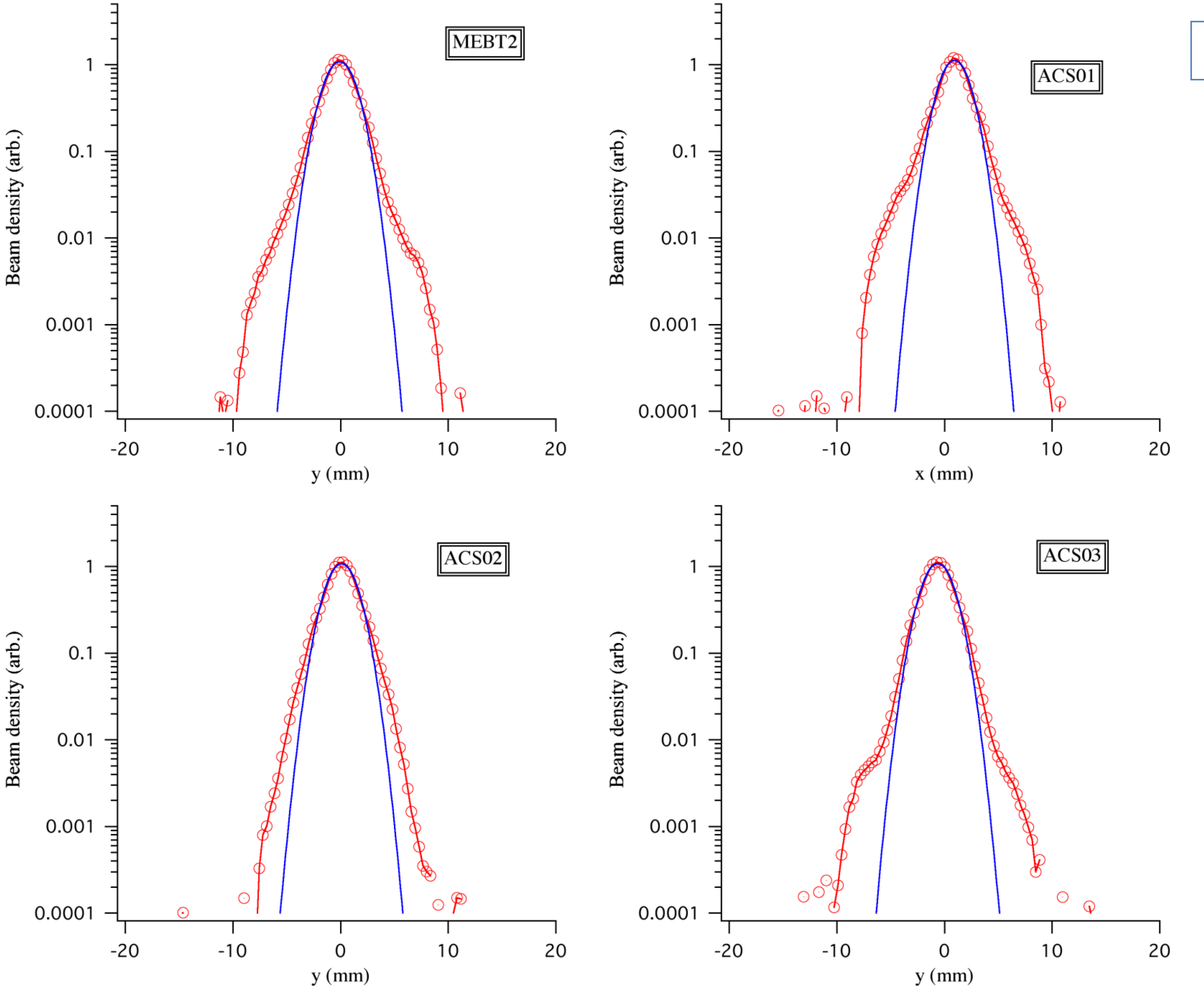
Beam profile at SDTL exit (Horizontal, after buncher tuning)

15 mA



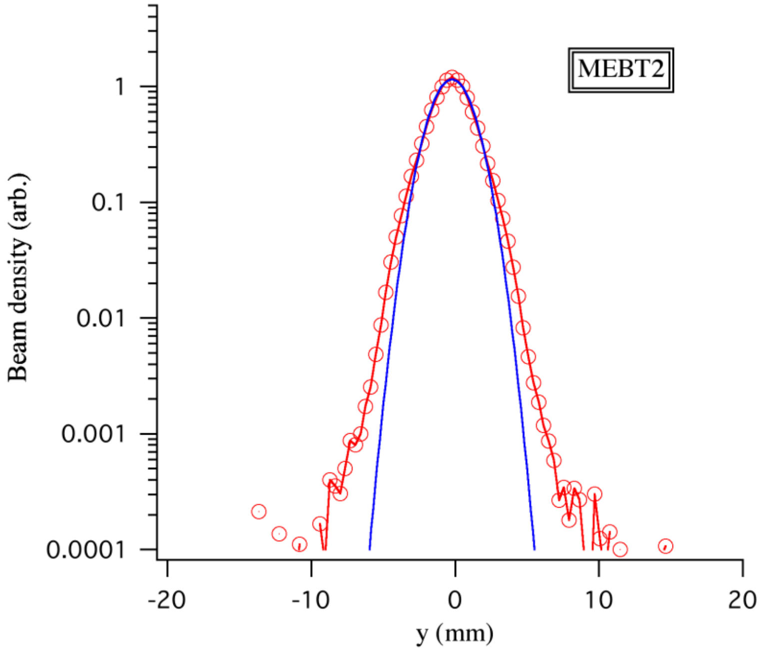
Beam profile at SDTL exit (Vertical, before buncher tuning)

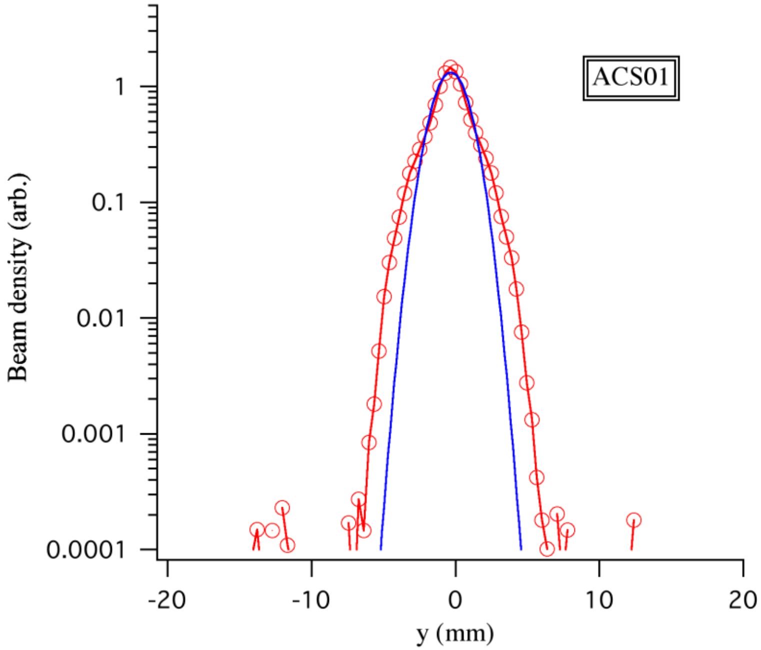
15 mA

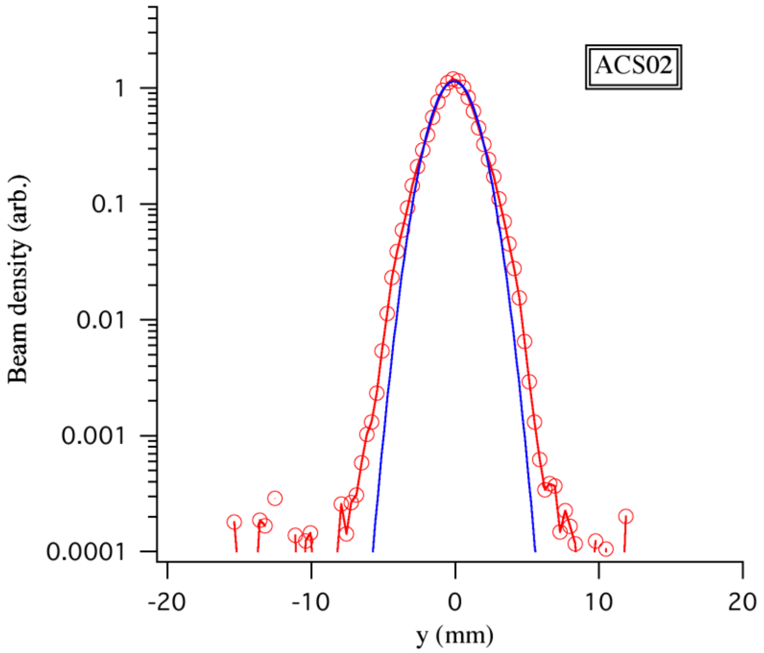


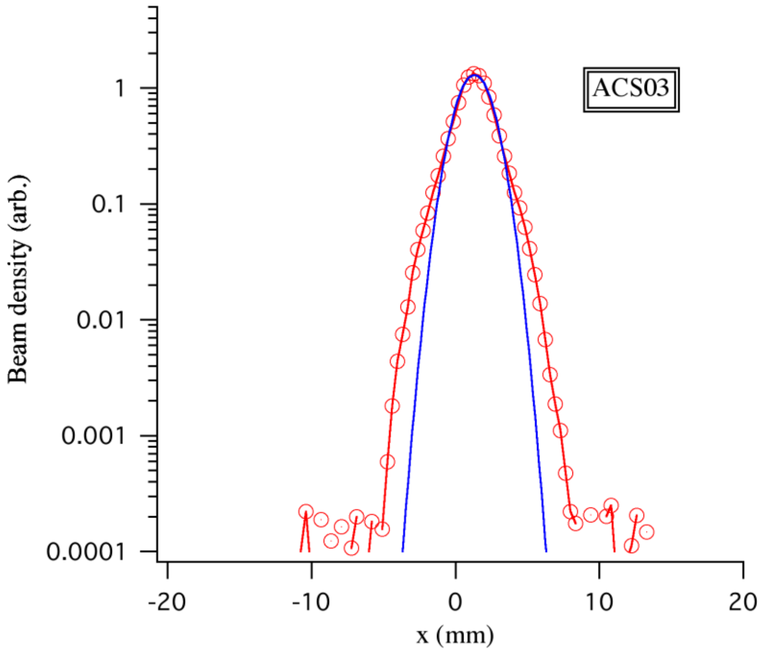
Beam profile at SDTL exit (Vertical, after buncher tuning)

15 mA









Summary

- In high current operation, we have experienced a significant emittance growth in DTL followed by halo formation in SDTL.
- In a particle simulation, the mechanism behind the emittance growth and halo formation is identified as a longitudinal mismatch at MEBT.
- The emittance growth and halo formation have been successfully mitigated by MEBT buncher tuning.
- This example demonstrates that a particle simulation is capable of identifying the source of mismatch and finding the direction for the tuning in a real operation of high intensity linacs.