

Simulation Study for J-PARC Linac

ICFA Advanced Beam Dynamics Workshop
HALO'03

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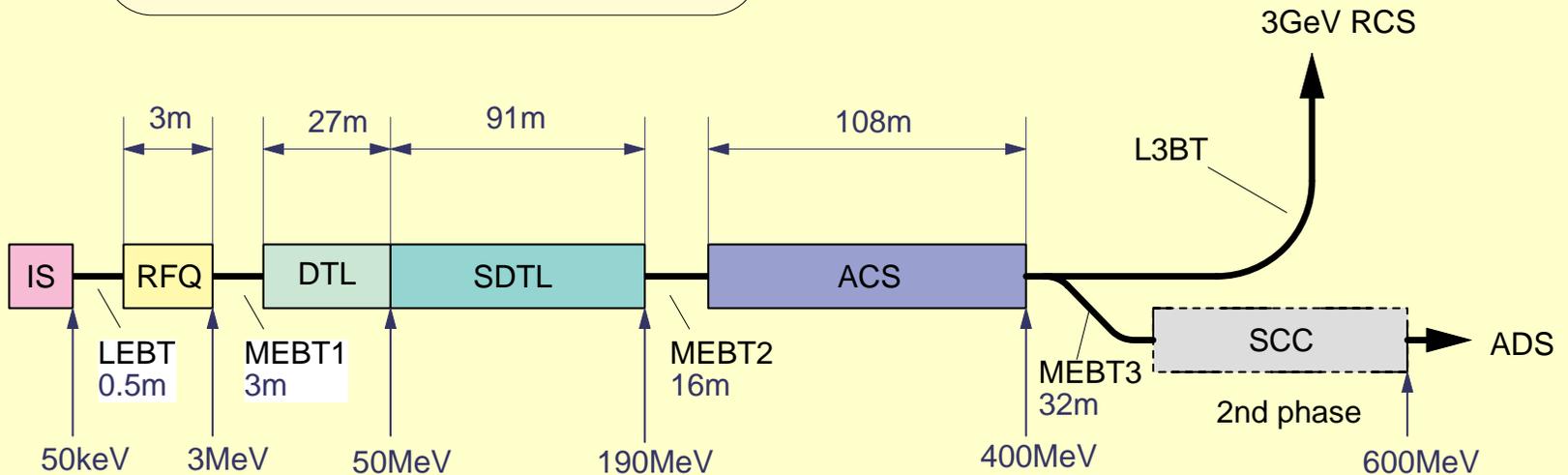
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Contents

- Outline of the J-PARC linac
- Comparison between simulation and MEBT beam test
- End-to-end simulation for the J-PARC linac

Layout of the J-PARC linac

IS: Ion Source
RFQ: Radio Frequency Quadrupole linac
DTL: Drift Tube Linac
SDTL: Separate-type Drift Tube Linac
ACS: Annular Coupled Structure linac
SCC: Super-Conducting Cavity linac
RCS: Rapid Cycling Synchrotron



Main specs. (1st phase)

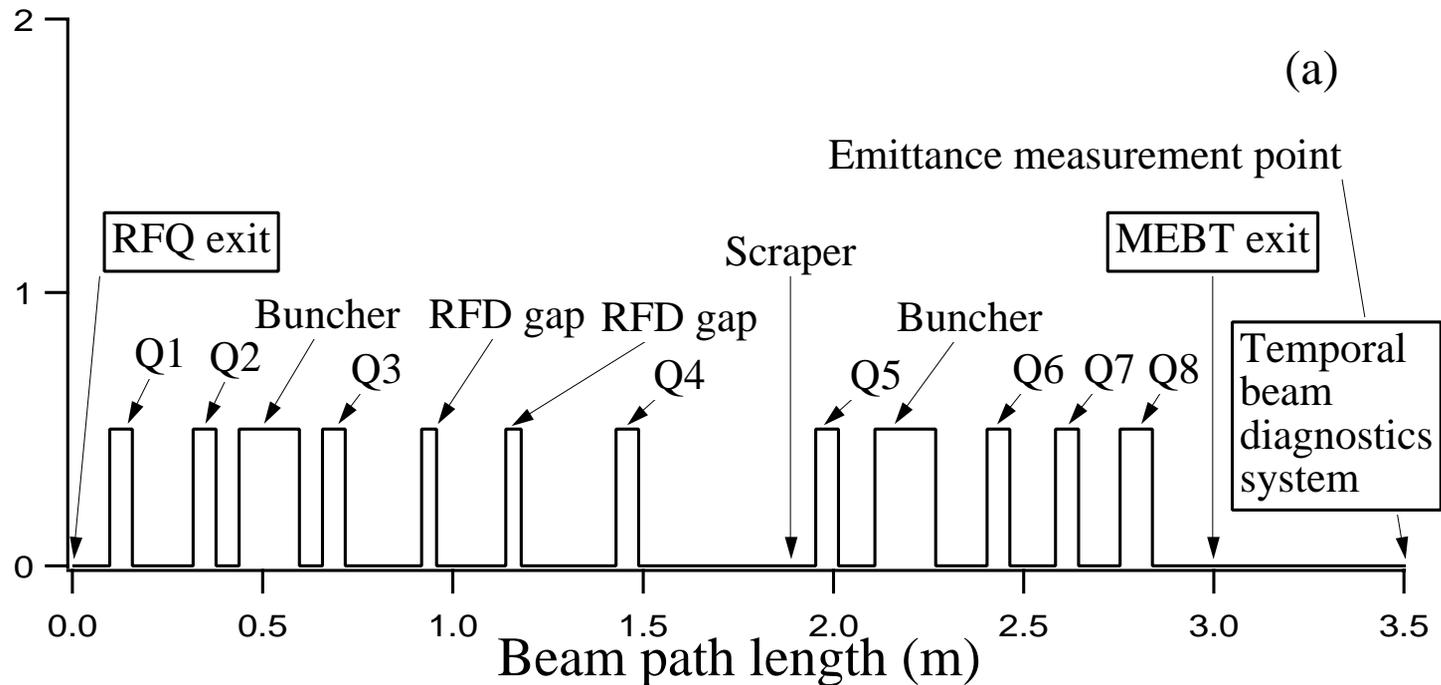
Particle	Negative hydrogen
Peak current	30 mA (50 mA after RFQ upgrade)
Repetition rate	25 Hz
Macro-pulse length	0.5 msec
Duty factor	1.25 % (excluding chopping)
Chopping factor	56 % (beam-on ratio)
Output energy	400 MeV
Frequency	324 MHz for RFQ, DTL, & SDTL 972 MHz for ACS

MEBT beam test

Introduction

- The beam test of the front-end part of the J-PARC linac has been started at KEK site to establish the linac system before moving to JAERI site.
- A 50-keV IS, a 3-MeV RFQ, and a MEBT has already been installed in a KEK accelerator tunnel, and the beam test has been performed in April to July 2002, and January to February 2003.

MEBT Layout

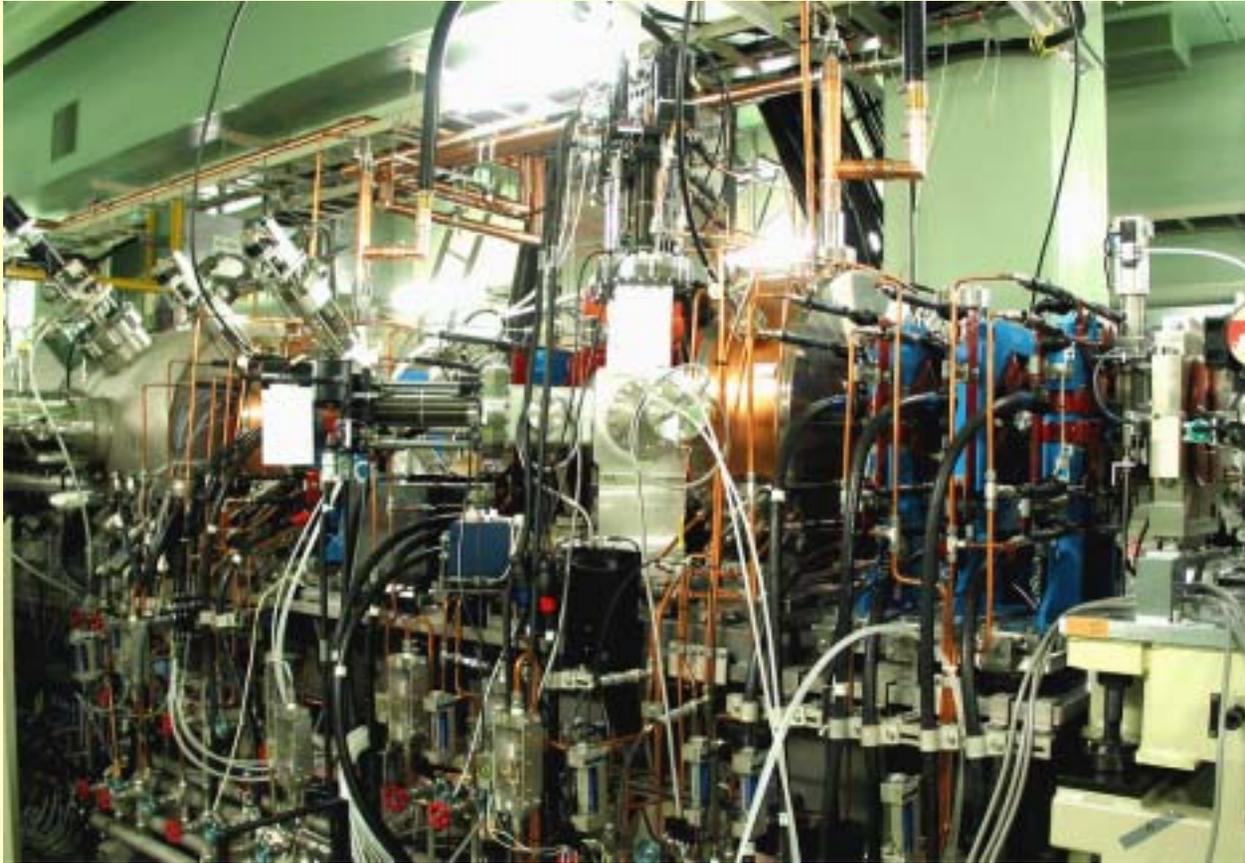


Transverse matching: eight quadrupole magnets

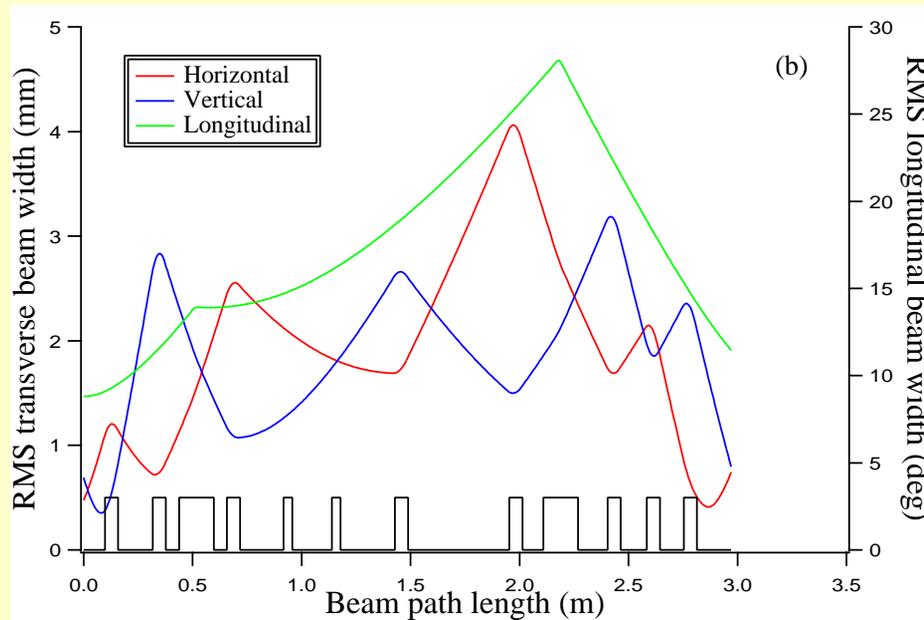
Longitudinal matching: two buncher cavities

Chopping: two RFD cavities and one scraper (before Q5)

MEBT Photo



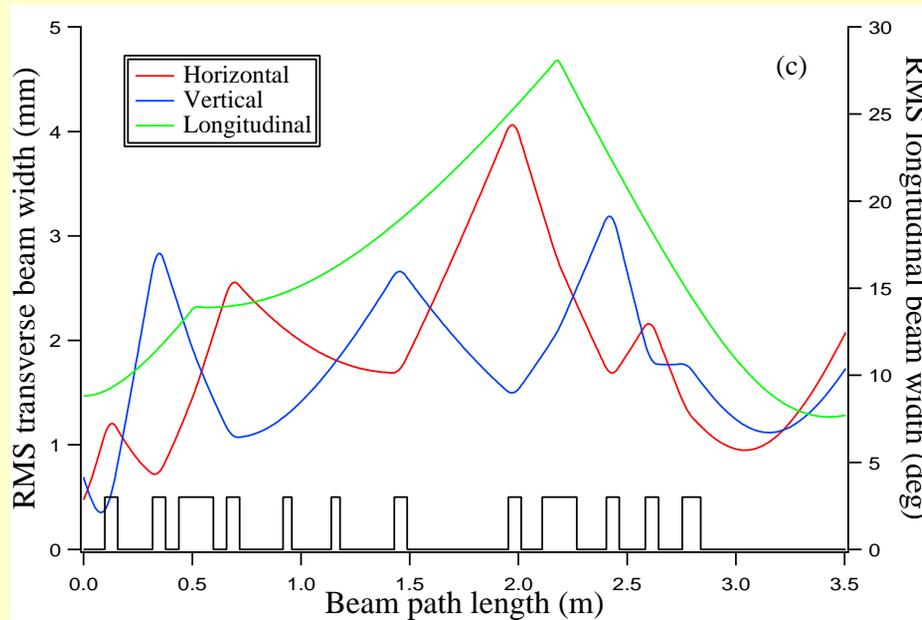
Quadrupole Setting (Matched to DTL)



Typical beam envelope for the matched case.

The beam is strongly focused at the exit of MEBT to satisfy the matching condition to DTL.

Quadrupole Setting (Experiment)



Typical beam envelope in the experiment.

The last two quadrupoles are weakened to enable emittance measurement downstream.

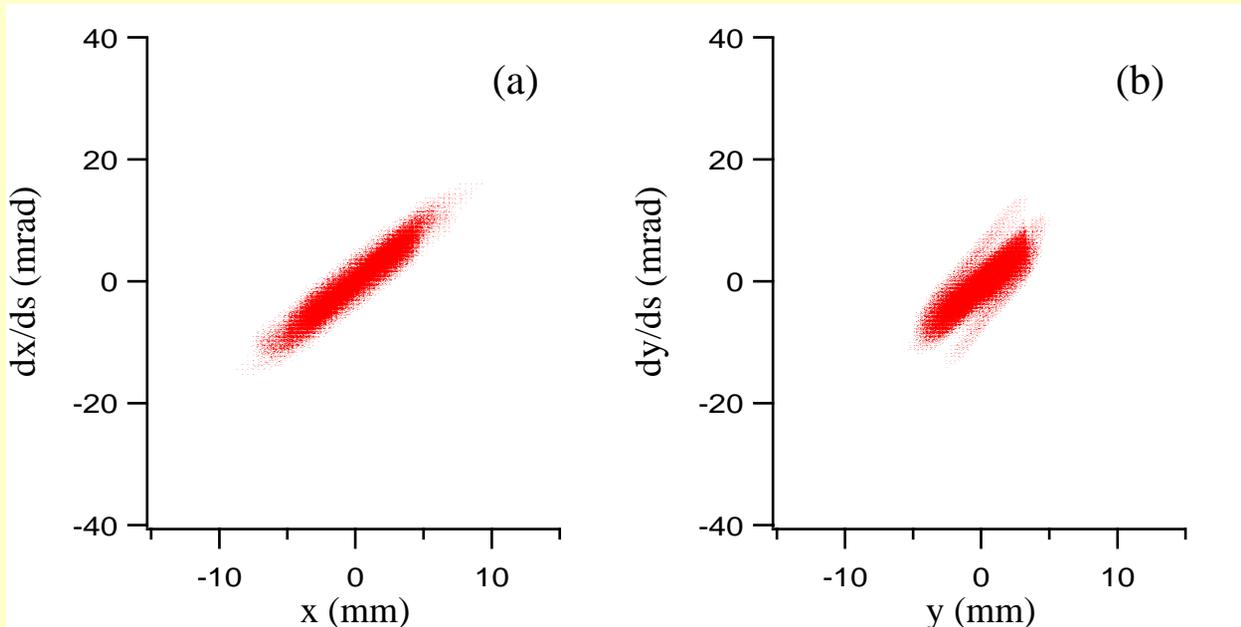
Measured Emittance

Measurement	I	II	III
Location	MEBT exit	MEBT exit	RFQ exit
Peak current	28.7 mA	24.6 mA	10.0 mA
Horizontal	0.252	0.227	0.173
Vertical	0.214	0.220	0.194
Measured	Jan., 2003	Jul., 2002	

Normalized rms emittance ($\pi \cdot \text{mm} \cdot \text{mrad}$)

These emittances are measured with an EM in the temporal beam diagnostic system.

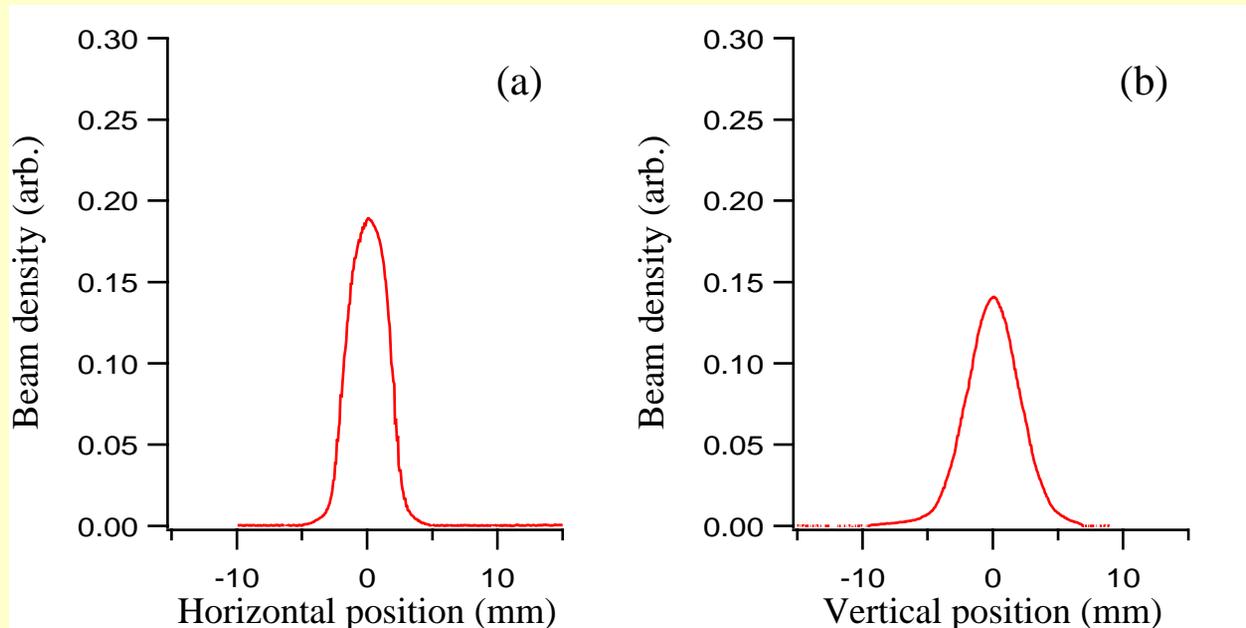
Measured Phase-space Profile



Emittance at the temporal beam diagnostics after MEBT
(28.5mA, 0.1msec, 25 Hz)

Measured phase space density is represented by 100k
dots (particles).

Measured beam profile



Measured with WS (Wire Scanner) #3 located before Q4.

Particle Simulations

PIC Simulations

- Preliminary 3D PIC simulations are performed as a test on the agreement between experiments and simulations.
- IMPACT code has been used. IMPACT is a 3D PIC code developed at LBNL.

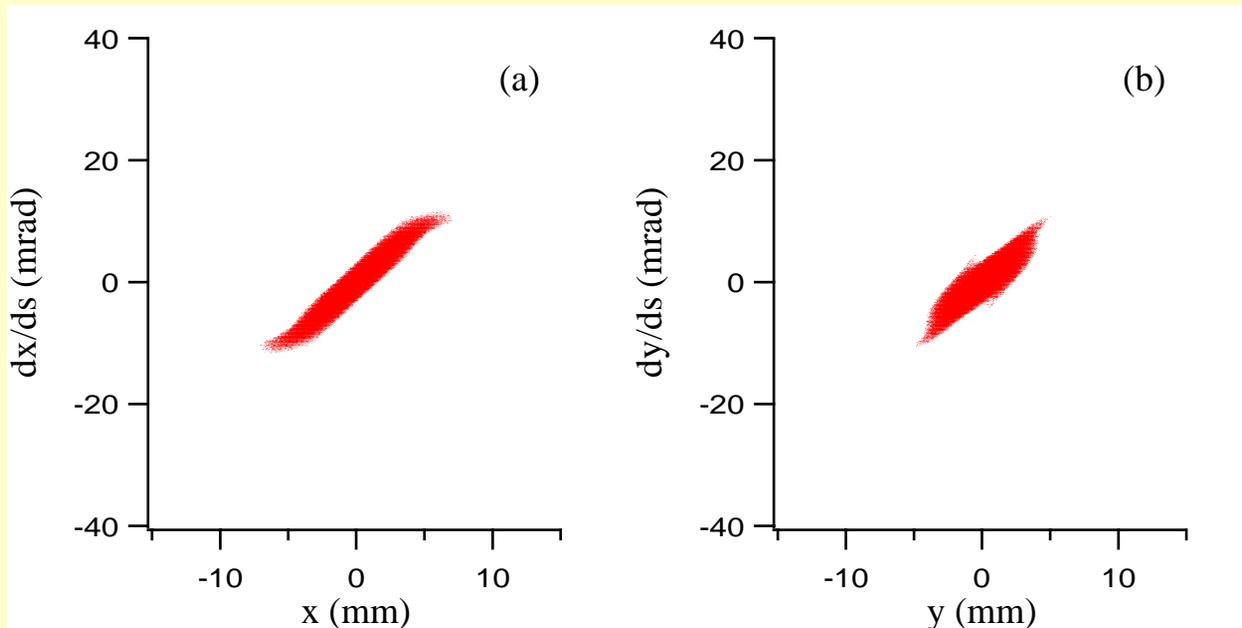
Simulation Condition

- Num. of particles: 1M
- Num. of meshes: 64x64x64
- Step width: $\beta\lambda/10$
- Initial distribution: 6D waterbag / 6D Gaussian
- Lattice parameters and beam conditions are the same with Measurement I.

Simulation Condition (Cont.)

- Initial normalized rms emittance:
 - Adjusted to reproduce measured emittance.
 - Longitudinal emittance is determined with PARMTEQ.
- Initial Twiss parameters:
 - Obtained with emittance measurement at the exit of the RFQ.
 - Longitudinal parameters are determined with PARMTEQ.

Simulated Phase-space profile (WB)



Waterbag

Initial emit.

H: 0.245

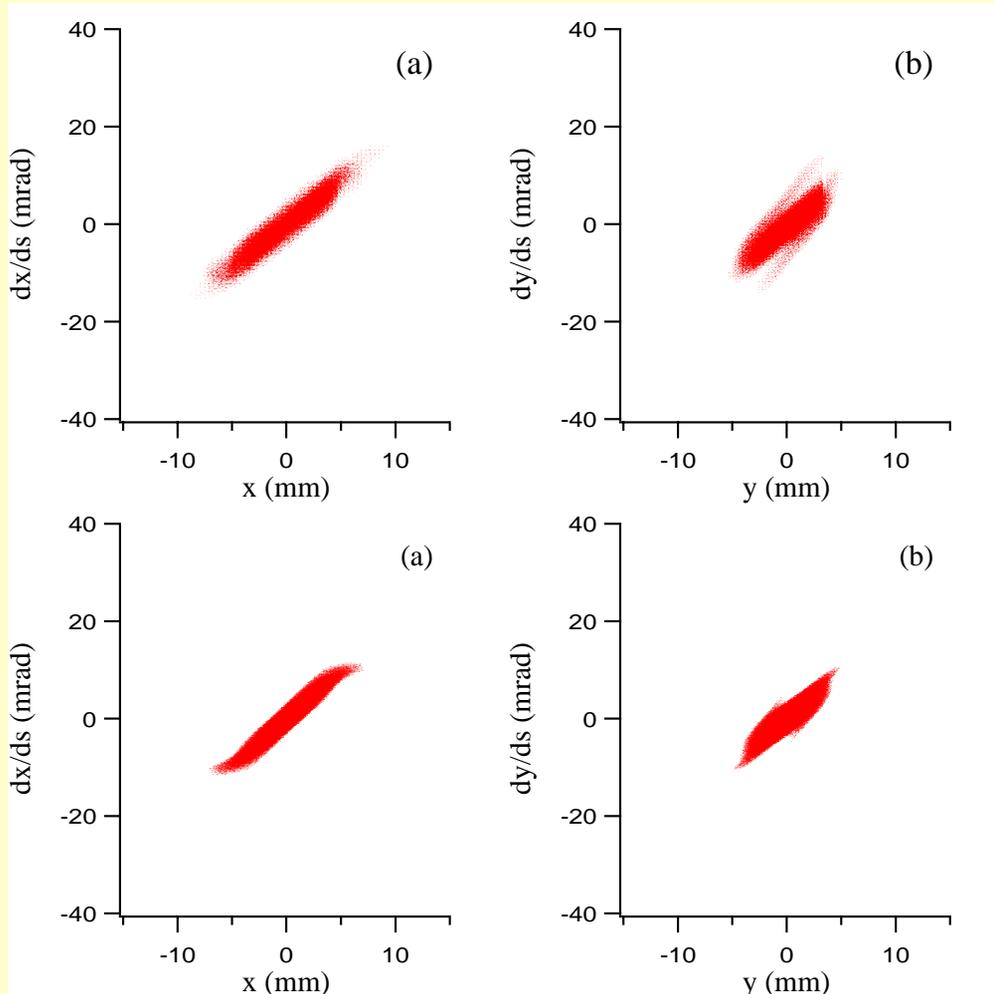
V: 0.208

L: 0.0082

(π mmrad/ π MeVdeg)

Core shape is reproduced, while tail portion is less pronounced.
100k particles are shown out of 1M particles.

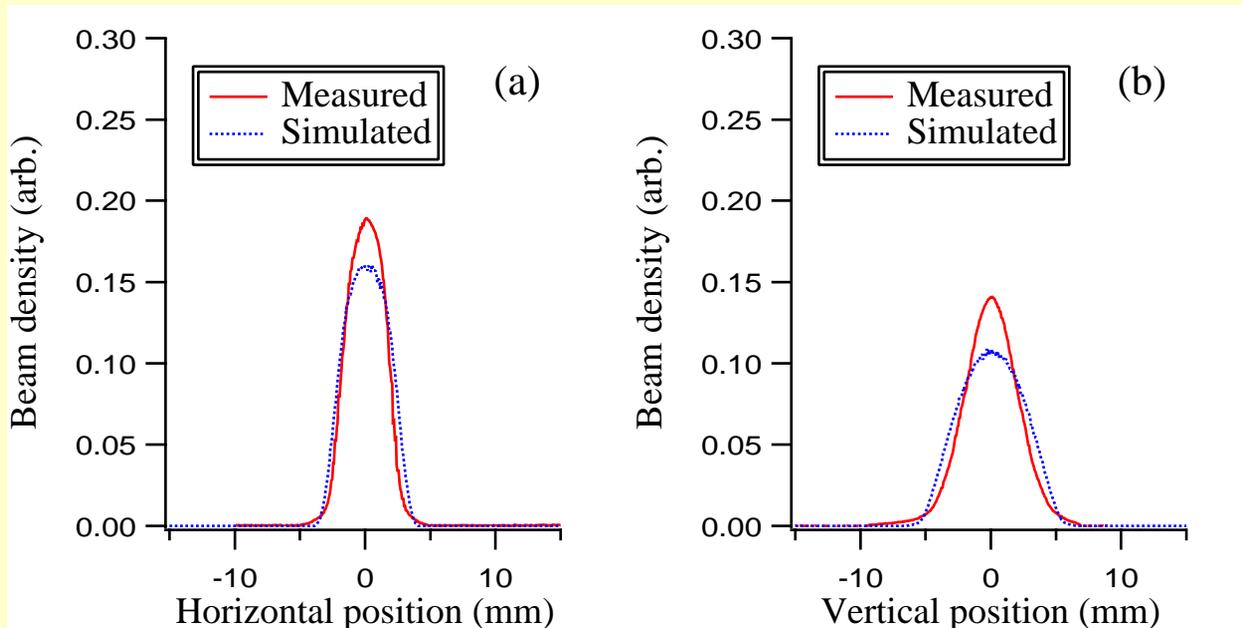
Comparison of phase-space profile (WB)



Experiment

Simulation

Comparison with WS measurement (WB)



Waterbag

Initial emit.

H: 0.245

V: 0.208

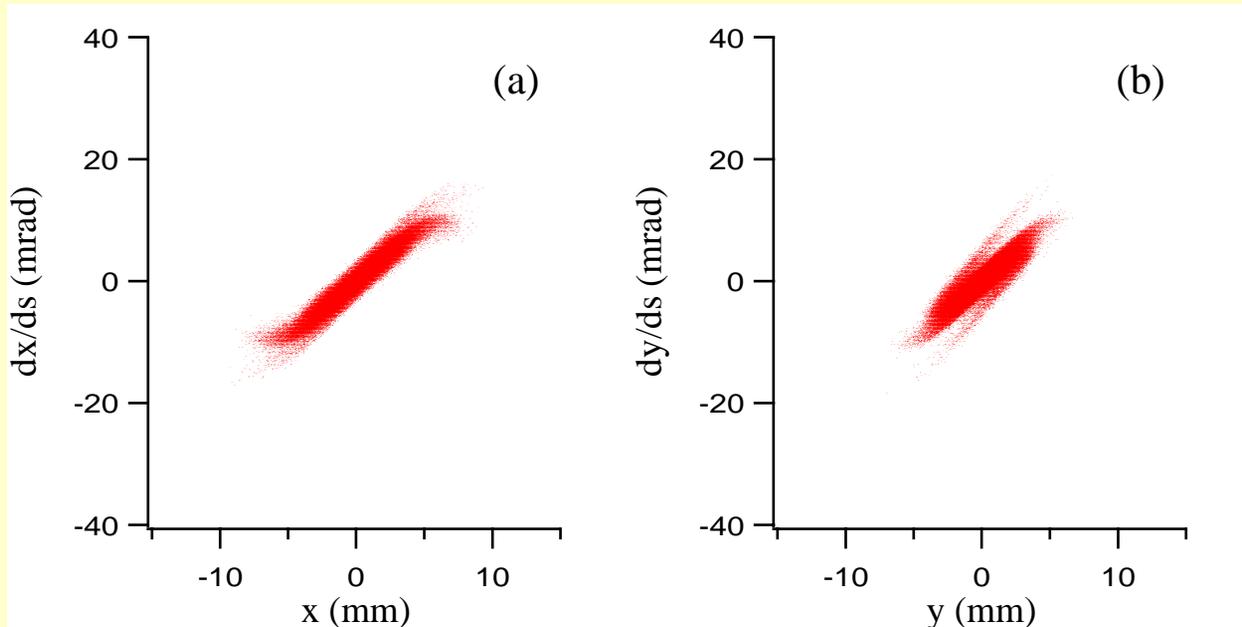
L: 0.0082

(π mmrad/ π MeVdeg)

Beam profile at WS3 (before Q4)

Agreement is not so good especially in the vertical direction.

Simulated Phase-space profile (GA)



Gaussian

Initial emit.

H: 0.234

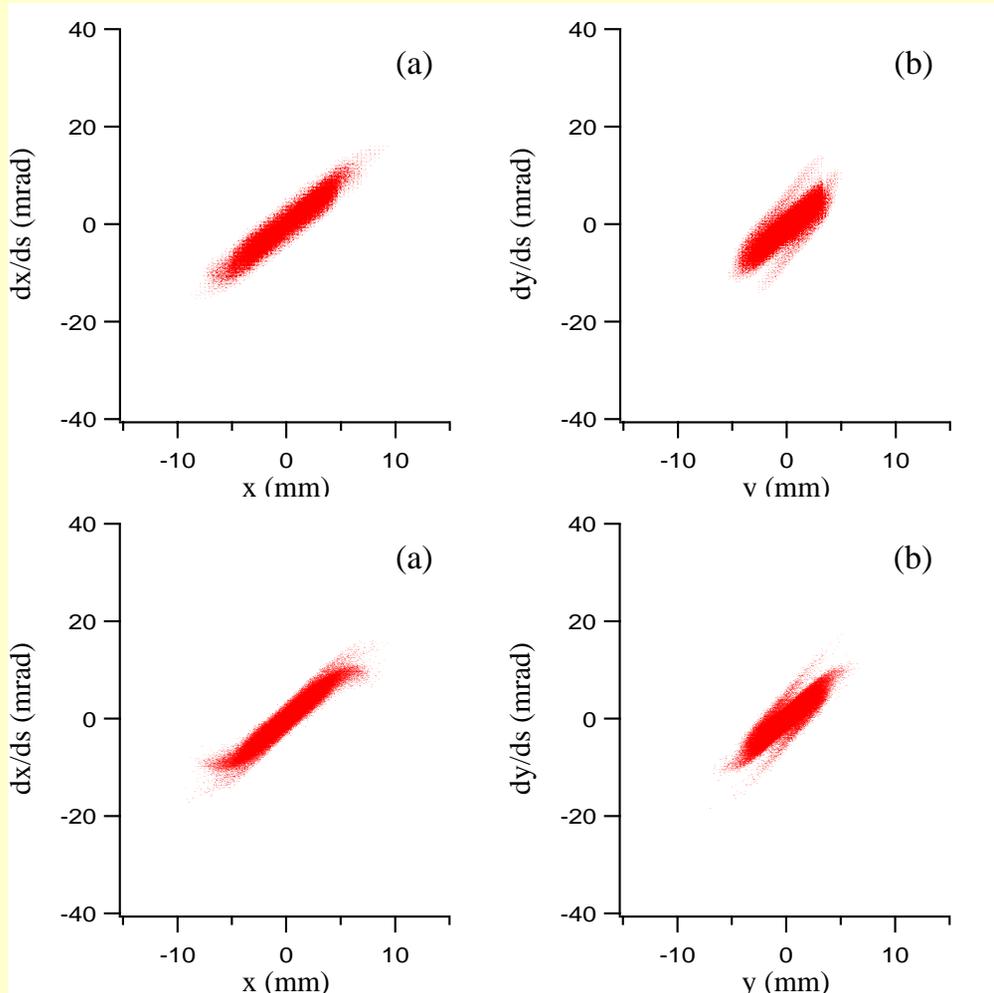
V: 0.193

L: 0.0082

(π mmrad/ π MeVdeg)

Agreement is reasonable, while tail shape is slightly different.
100k particles are shown out of 1M particles.

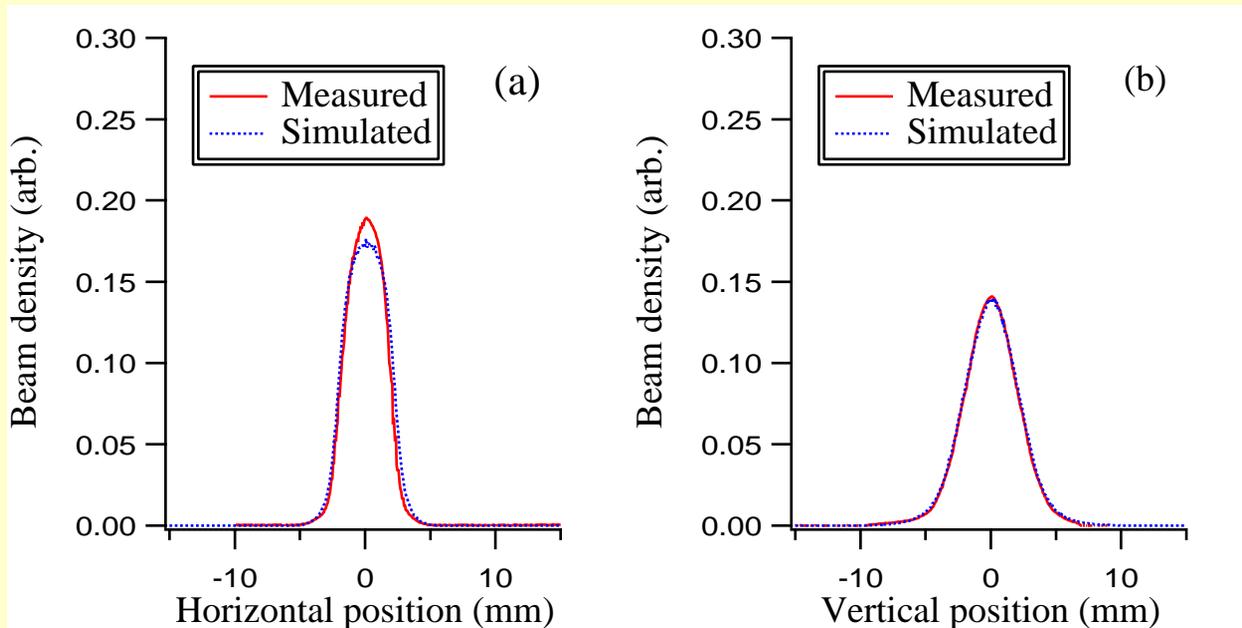
Comparison of phase-space profile (GA)



Experiment

Simulation

Comparison with WS measurement (GA)



Gaussian

Initial emit.

H: 0.234

V: 0.193

L: 0.0082

(π mmrad/ π MeVdeg)

Beam profile at WS3 (before Q4)

Agreement is good especially in the vertical direction.

Summary

- Preliminary comparison between IMPACT simulations and MEBT beam test results has been performed.
- The agreement between simulations and experiments is found reasonable assuming Gaussian distribution as the initial distribution.

End-to-end simulation with IMPACT

First result

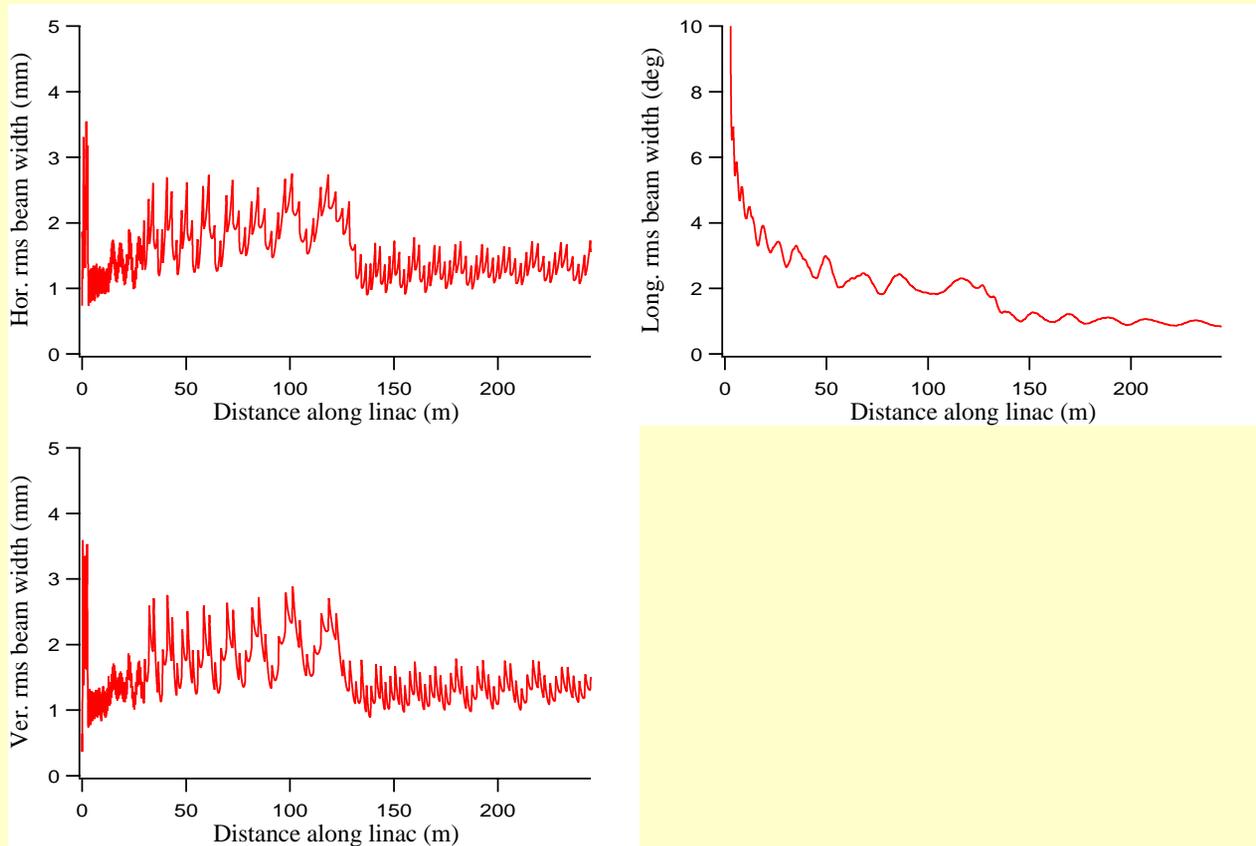
Simulation codes

LINSAC	3D particle-particle	KEK
PARMILA	2D/3D particle-in-cell	LANL
IMPACT	3D particle-in-cell	LBL

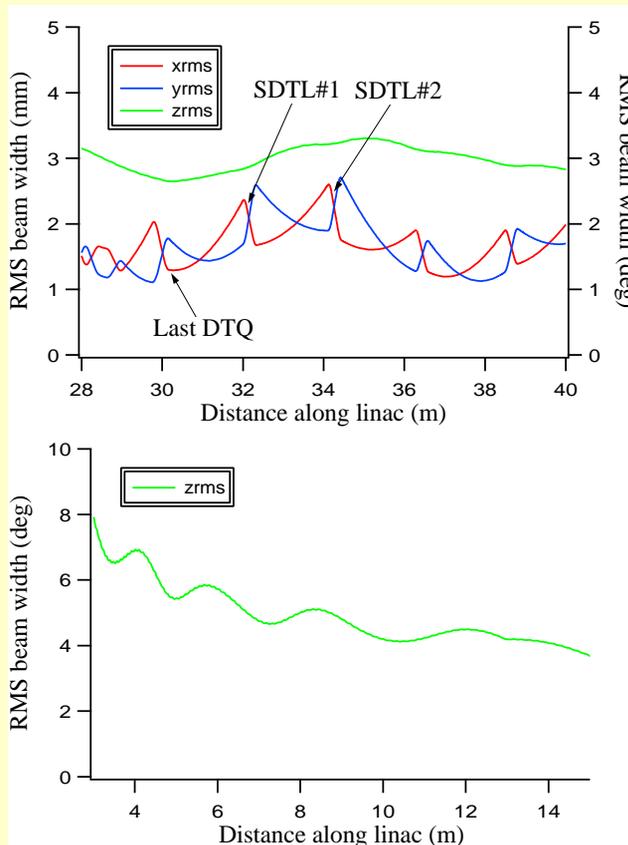
Simulation Condition

- The same with the MEBT simulation, except...
 - From the MEBT entrance to the ACS exit
 - 50 mA peak current
 - Assumed normalized rms emittances at the exit of the RFQ are
 - Horizontal: $0.24 \pi\text{mm}\cdot\text{mrad}$
 - Vertical: $0.24 \pi\text{mm}\cdot\text{mrad}$
 - Longitudinal: $0.153 \pi\text{MeV}\cdot\text{deg}$
- No error is assumed.

RMS Envelope (WB)



RMS Envelope Close-up (WB)

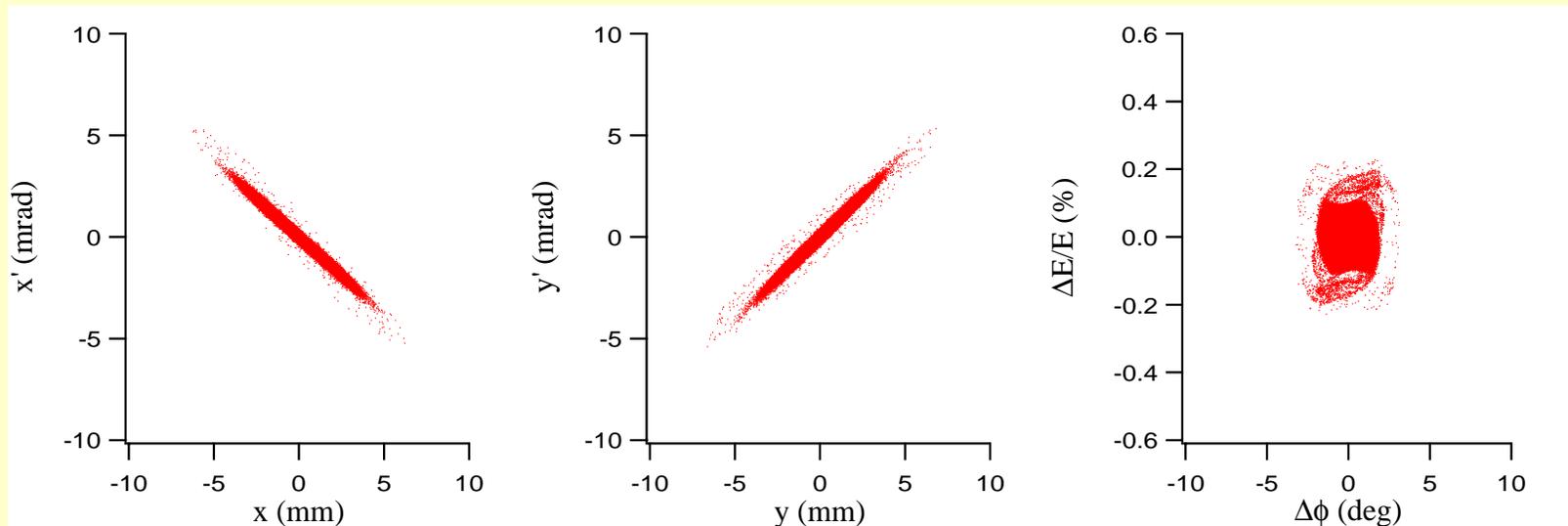


Matching between DTL
and SDTL

Initial longitudinal
mismatch

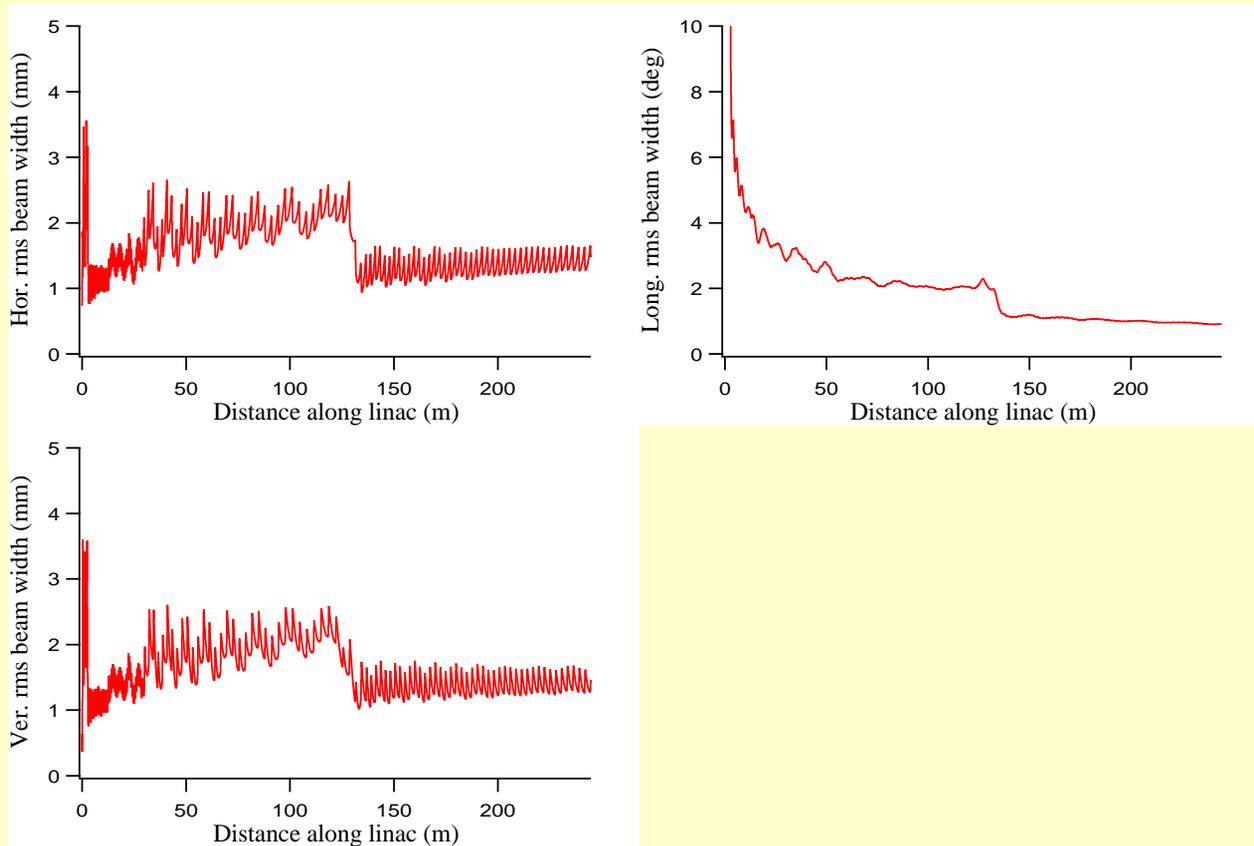
Phase-space distribution (WB)

Exit of the ACS (400MeV):

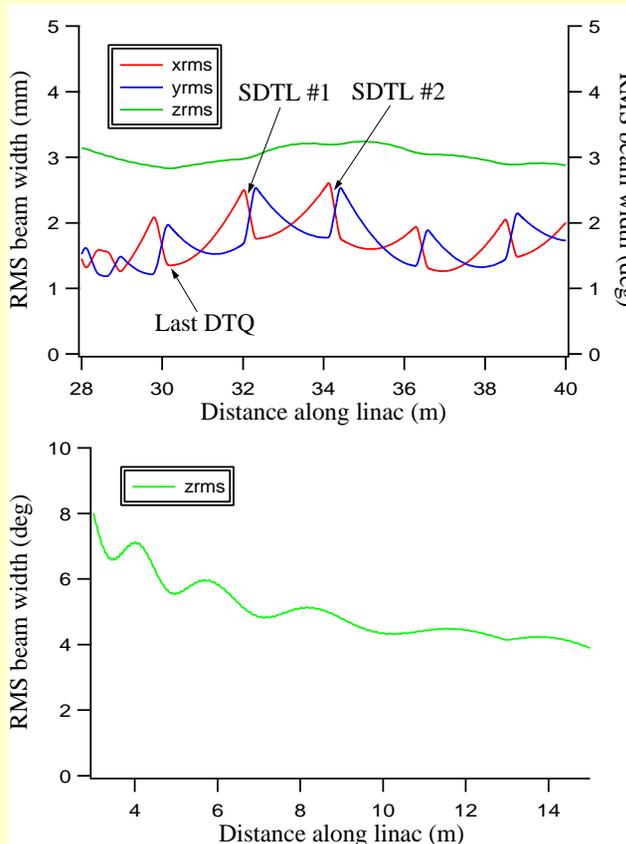


100k particles are displayed out of 1M particles.

RMS Envelope (GA)



RMS Envelope Close-up (GA)

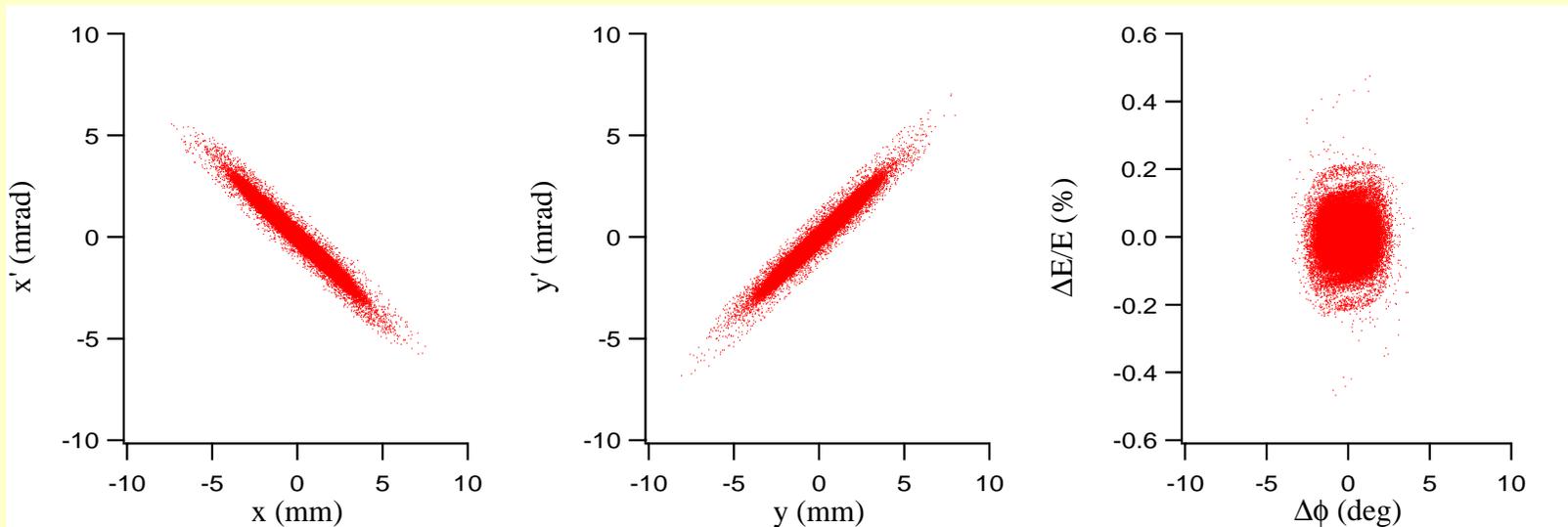


Matching between DTL
and SDTL

Initial longitudinal
mismatch

Phase-space distribution (GA)

Exit of the ACS (400MeV):



100k particles are displayed out of 1M particles.