The impact of linear space charge on the tomographic reconstruction at PITZ.

- > Photo Injector Test facility at DESY, Zeuthen site (PITZ)
- > Tomographic reconstruction of the transverse phase space at PITZ
- > Motivation : refined calculation of rotations
- > V-Code simulations
- > Simulation results
- > Reconstruction results
- > Summary and outlook

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DPG 2013, Dresden
04.03.2013

HELMHOLTZ ASSOCIATION

DESY

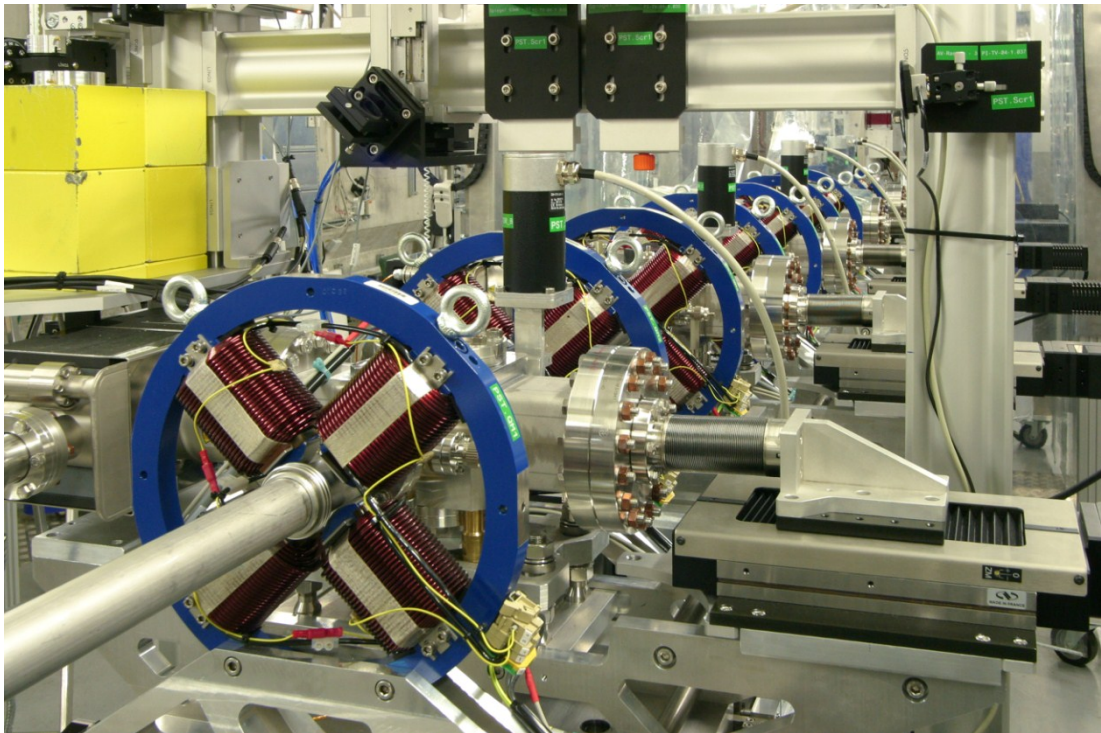
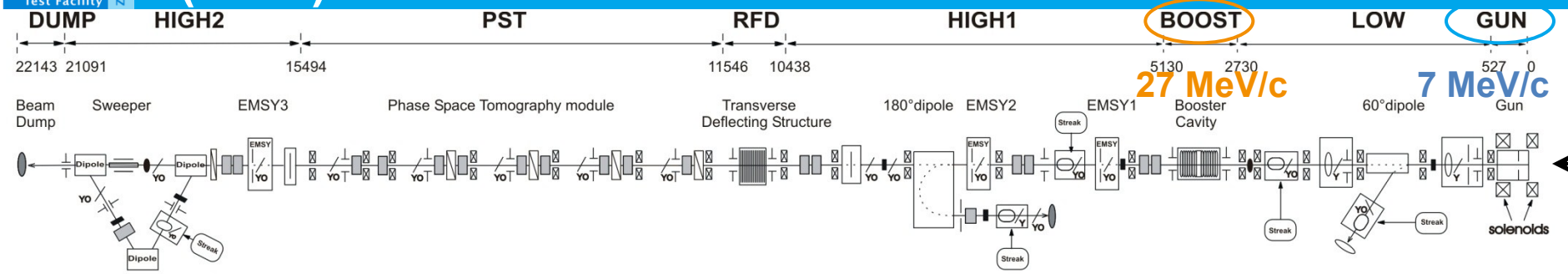


Photo Injector Test facility at DESY, Zeuthen site (PITZ)



> Booster

Cut Disk Structure (CDS)
14 cells
1.3 GHz frequency
14MV/m max accel. grad

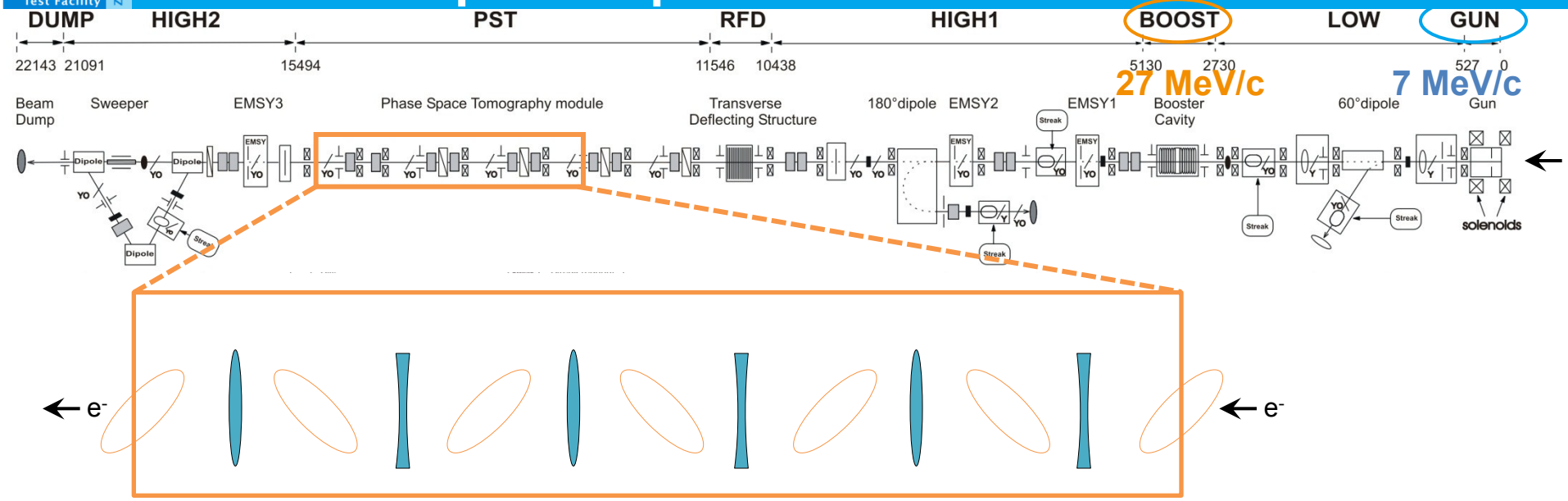
> e⁻ RF-gun

1.6 cell L-band
1.3 GHz frequency
10MW klystron
60MV/m max accel. grad
Cs_2Te cathode
Main+bucking solenoids

> Laser system

Yb:YAG oscillator
800 micro-pulses
1MHz frequency
10 Hz repetition rate
< 4 nC bunch charge
tunable temporal profile:
flat-top 2/24\2 ps
short Gaussian 2.8 ps

Tomographic reconstruction of the transverse phase space at PITZ



1) Quadrupoles form a FODO lattice and oppose a complete 180° rotation in the transverse phase space

Tomographic reconstruction of the transverse phase space at PITZ

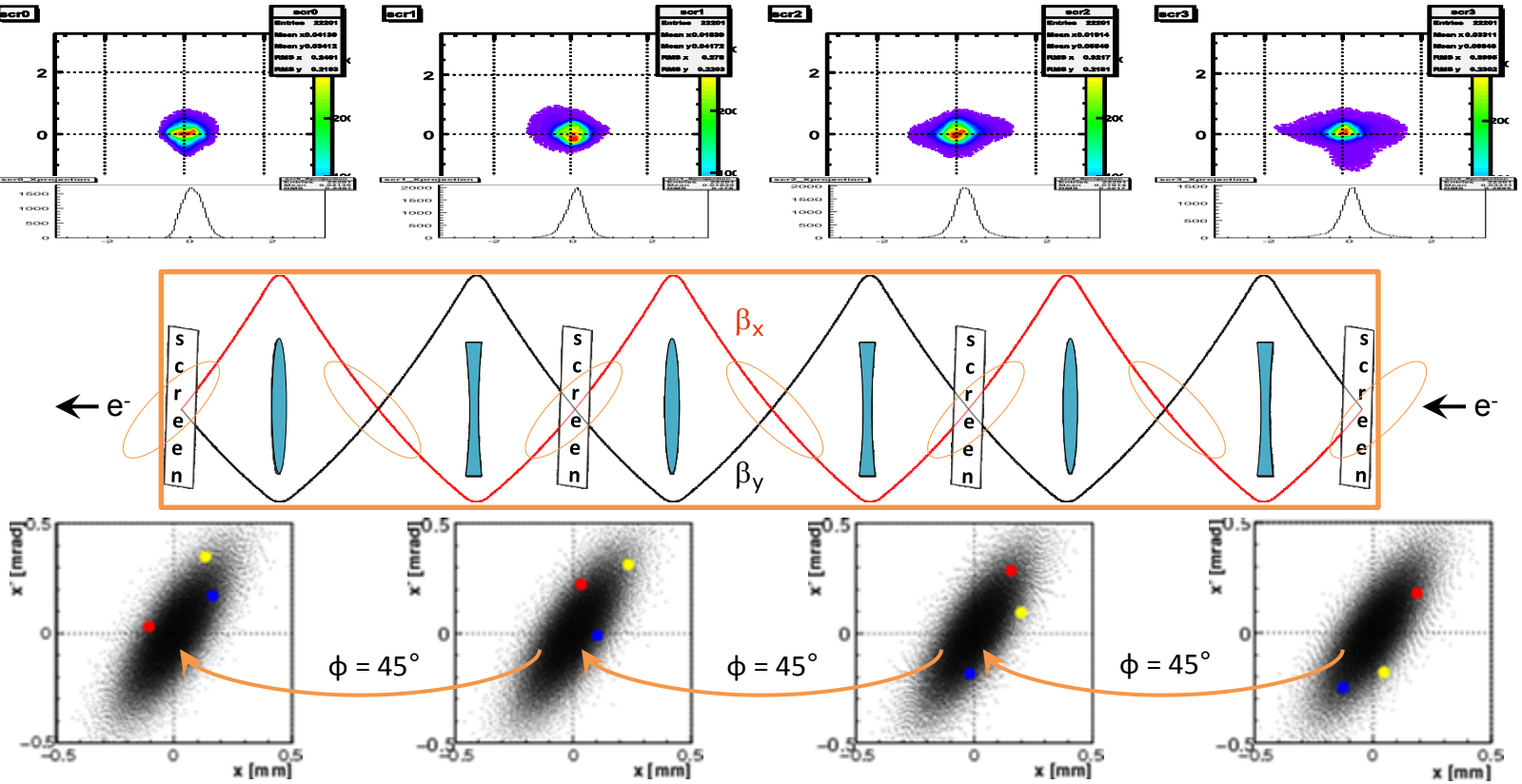
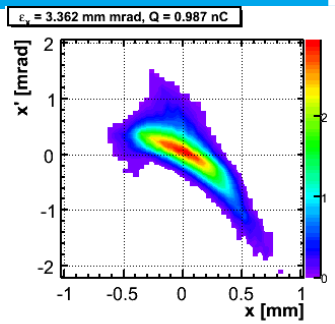
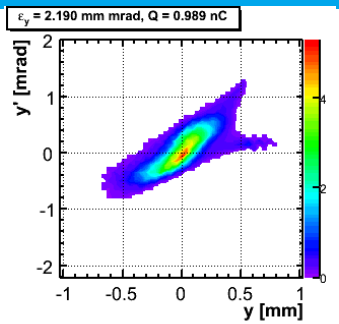


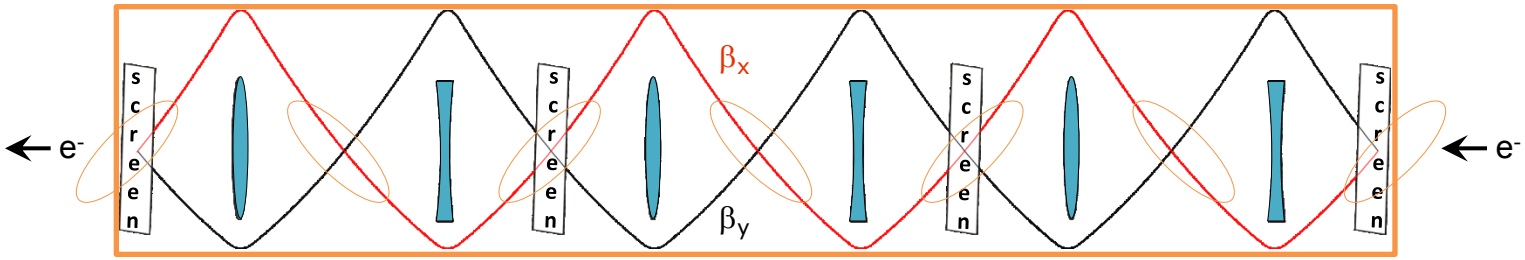
Image courtesy:
G. Asova

2) Screens capture projections of both transverse planes at equidistant phase advance values (= projection angles)

Tomographic reconstruction of the transverse phase space at PITZ







1) Quadrupoles form a FODO lattice and oppose a complete 180° rotation in the transverse phase space

2) Screens capture projections of both transverse planes at equidistant phase advance values (= projection angles)

3) Reconstruction using the Maximum ENTropy algorithm (MENT) with the corresponding transfer matrices (→ description of rotations)

Motivation: refined calculation of rotations

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- Use V-Code for a more realistic beam transport in the FODO lattice → refine the calculation of the phase space transformations

V-Code simulations

- Principle: The beam is treated as a set of moments (up to 2nd order) → fast
  Output: σ matrix (~Twiss parameters) along the beamline
  Highlighted feature: consideration of linear space charge forces

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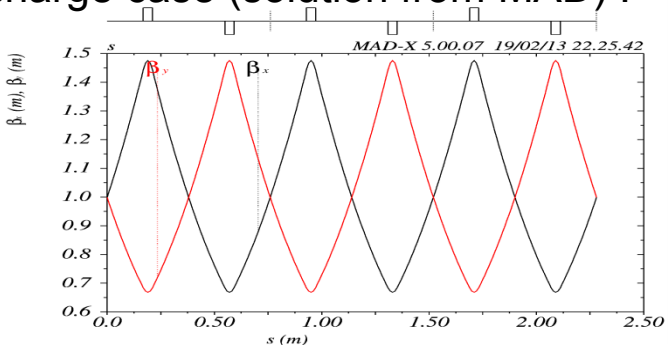
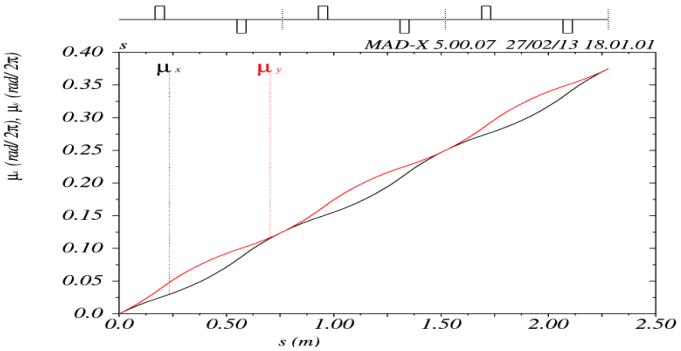
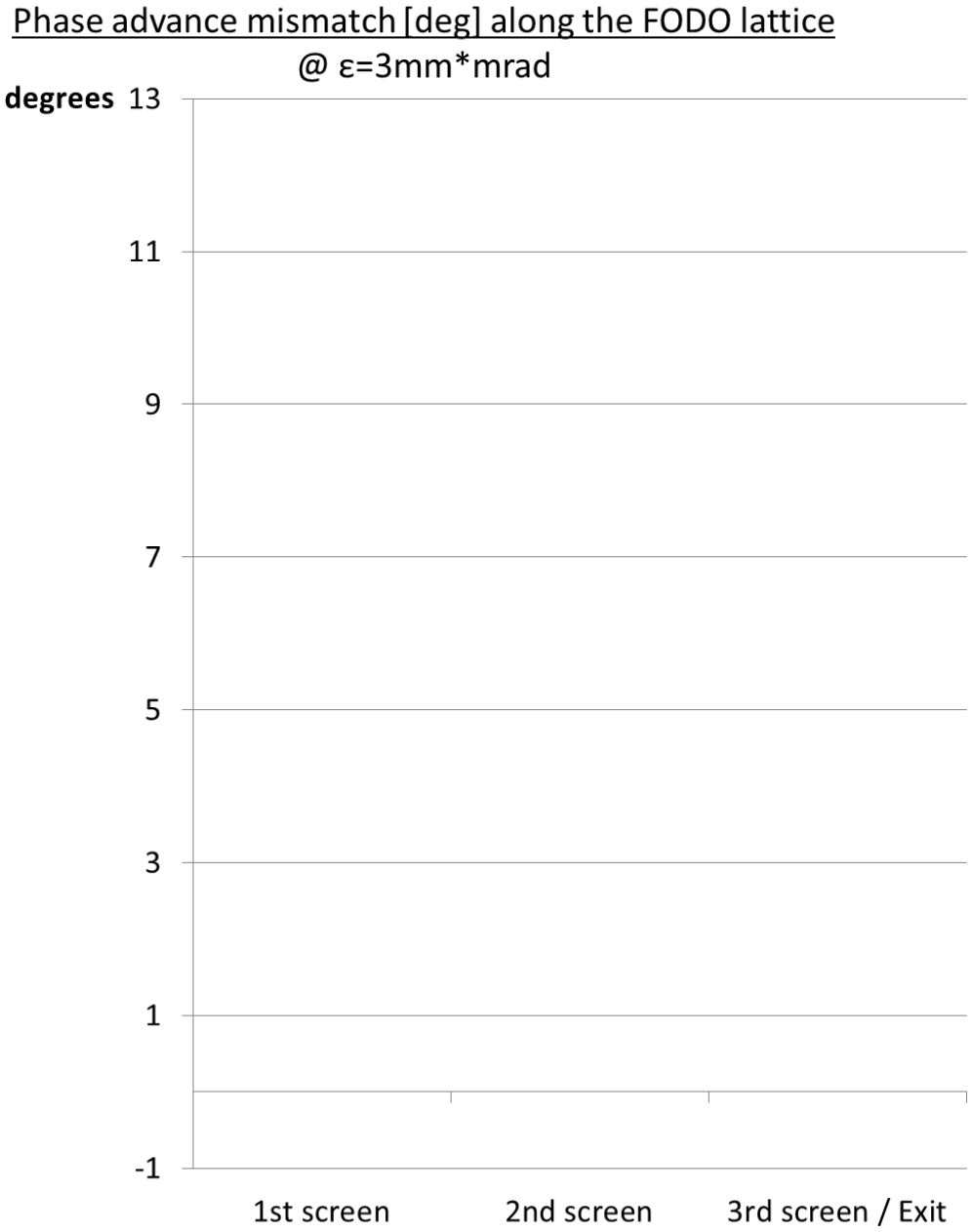
- Simulations parameters:
  - No space charge forces present (current treatment) vs. linear space charge forces
  - Emittance values (~ charge density) of 3mm·mrad (common during measurements) and 1mm·mrad (target value) for 1nC bunch charge, 20ps pulse length, at 25MeV
  - The beam moments at the entrance and the quadrupole strengths are perfectly matched so as to deliver 45° phase advance from screen to screen for the no space charge case (solution from MAD) :





Simulation results (estimator)

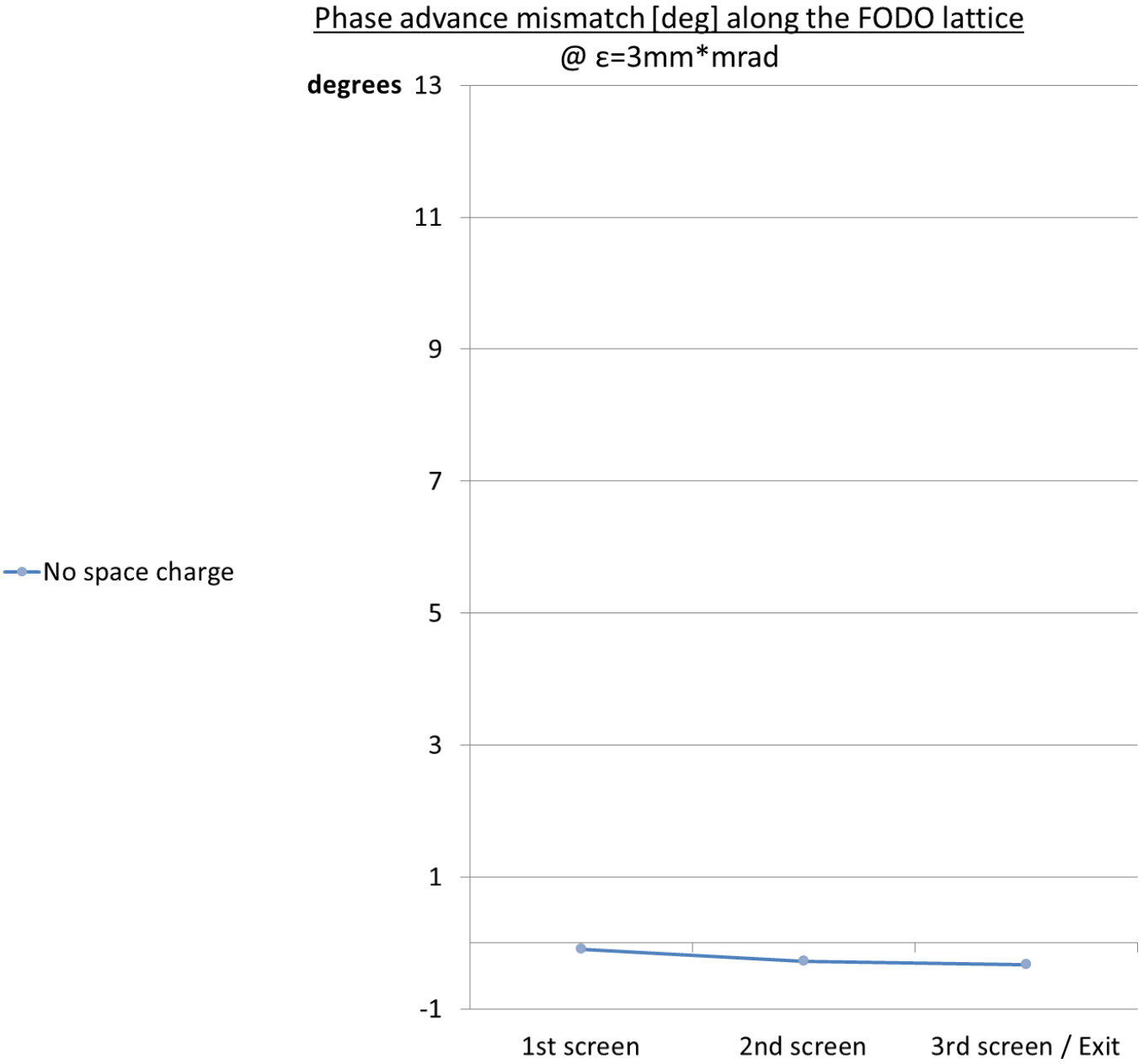


(n=1,2,3)

$$n \cdot 45^{o} - \varphi_n \quad ,$$

$$\varphi_n = \int_{z_0}^{z} \frac{dz}{\beta(z)}$$

Simulation results (25MeV / 1nC / 20ps – X plane)



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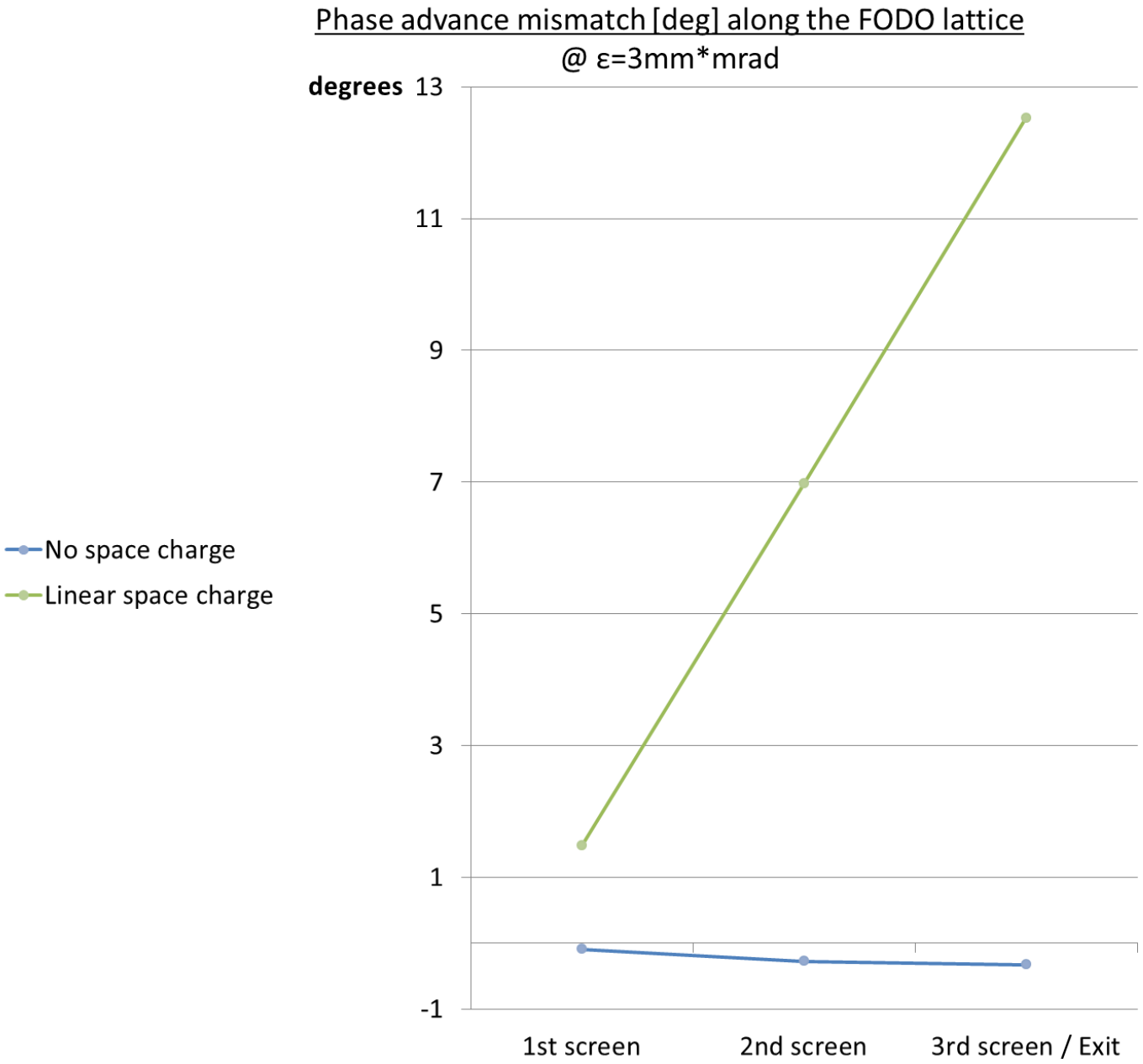

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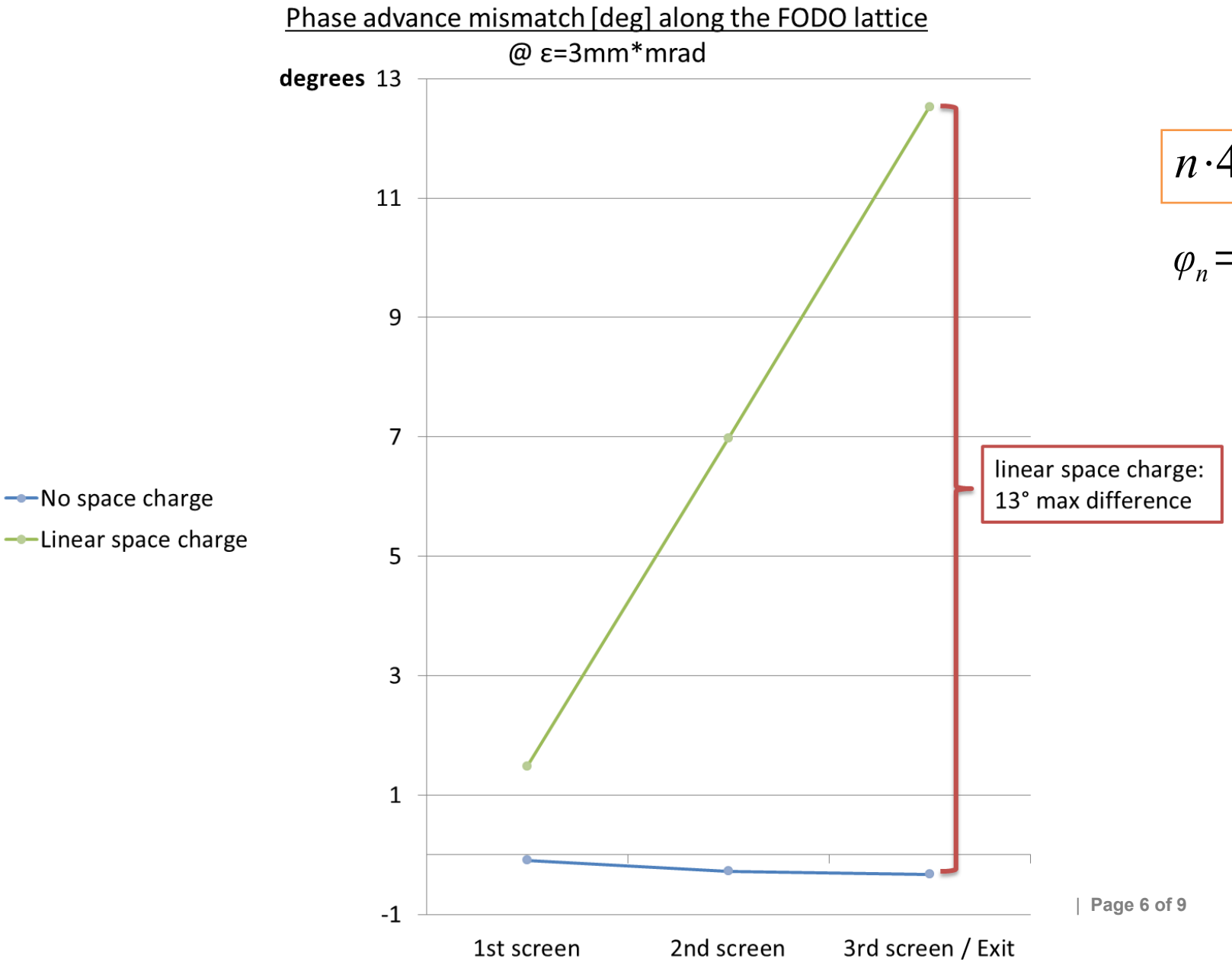

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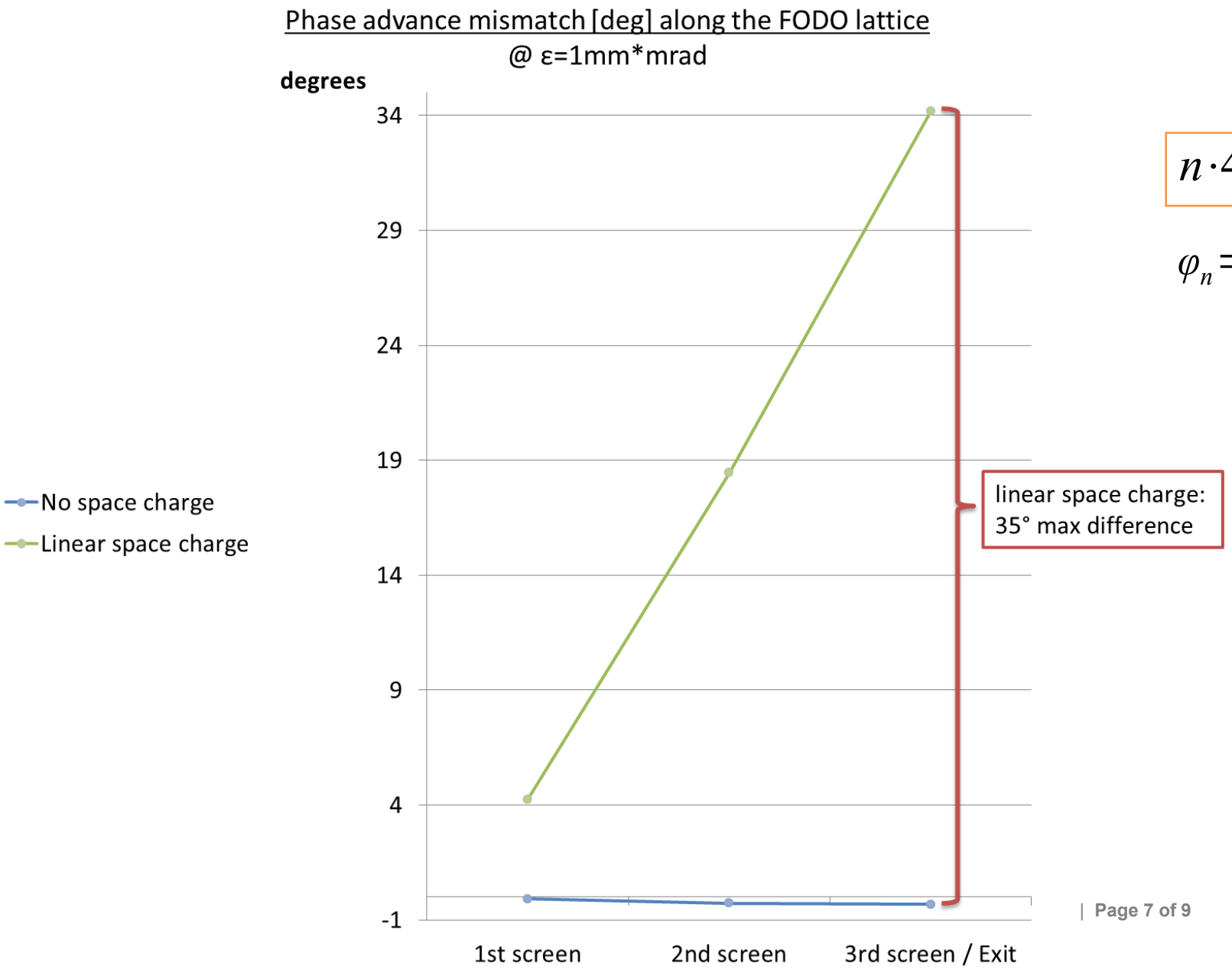

(n=1,2,3)

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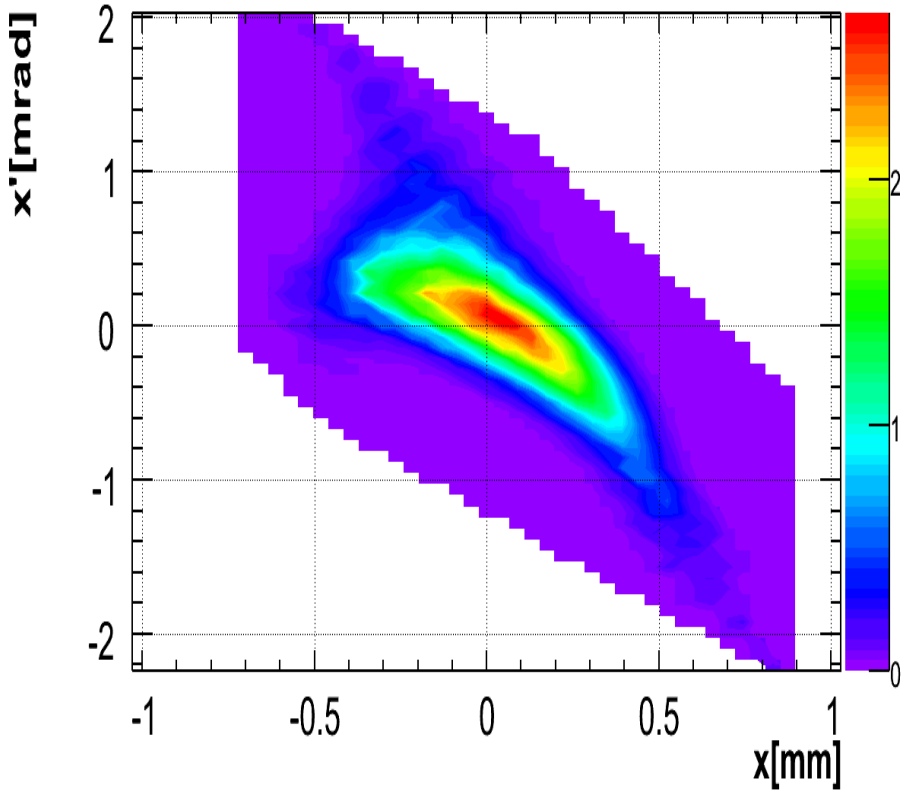
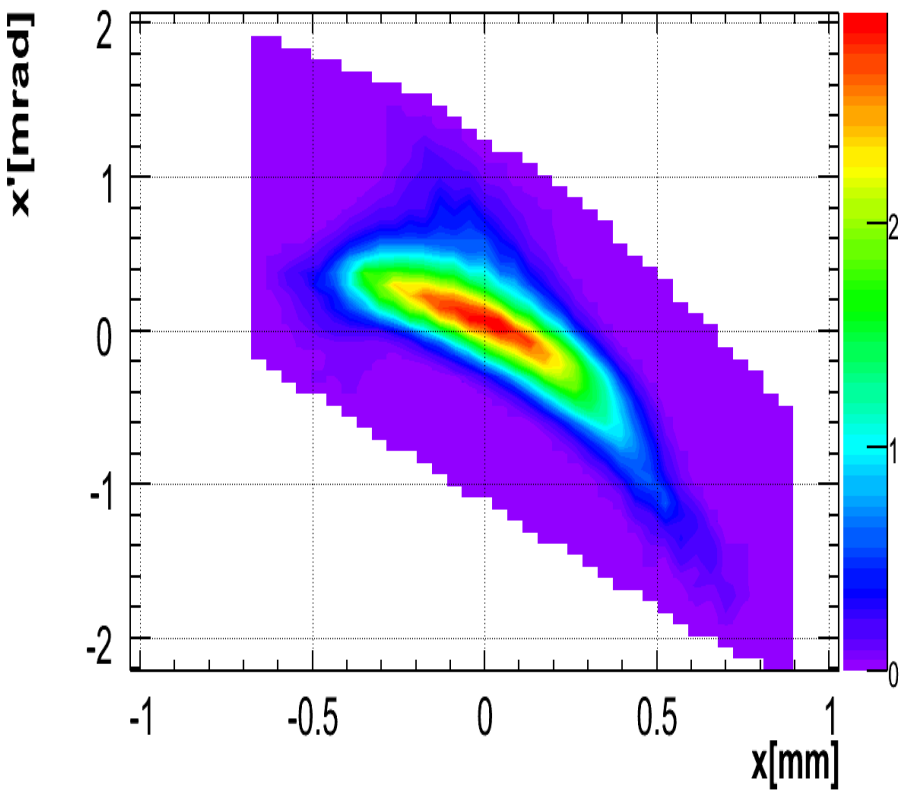
Reconstruction result

Reconstruction of experimental data using the two different approaches:

ε_x = 4.008 mm mrad > No space charge



ε_x = 3.546 mm mrad > Linear space charge



Reduction in the resulted emittance = 11.5%

Summary and outlook

- The linear space charge induces considerable additive mismatches along the FODO lattice
- The tomographic reconstruction of the transverse phase space seems to improve when the linear space charge forces are taken into account
- The non-linear space-charge effect is still excluded, but is expected to have a stronger impact → repeat the simulations using ASTRA for closest-to-reality beam behavior

Thanks to Dmitriy Malyutin, Barbara Marchetti and Grygorii Vashchenko.

THE END.

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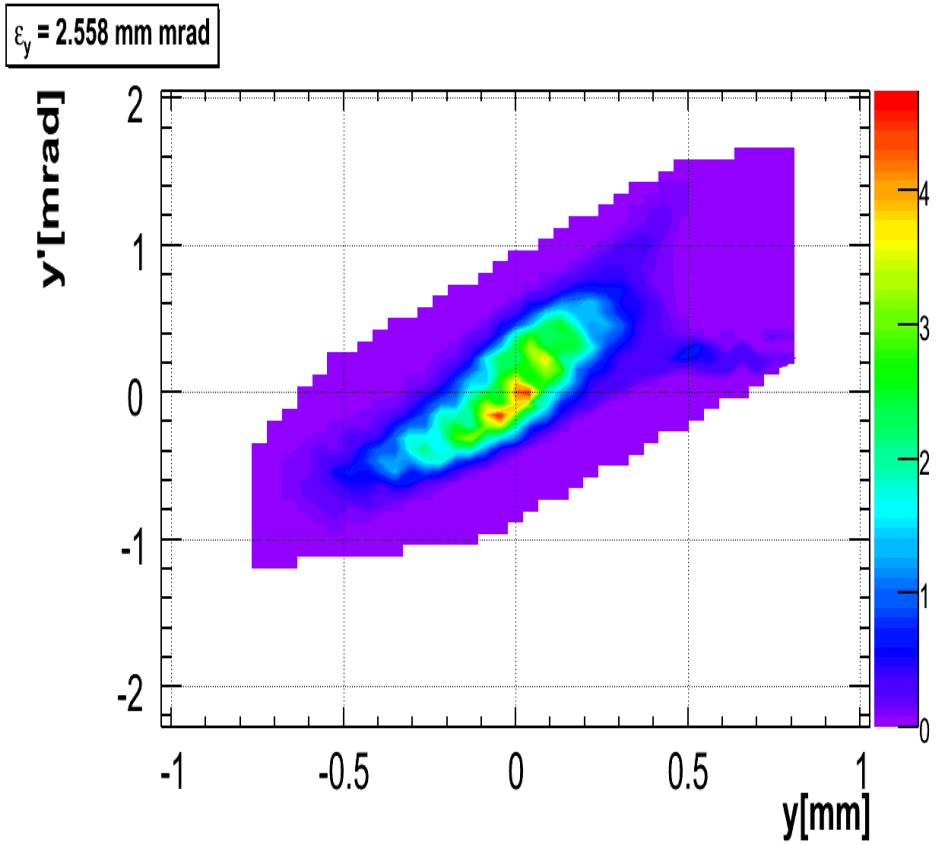
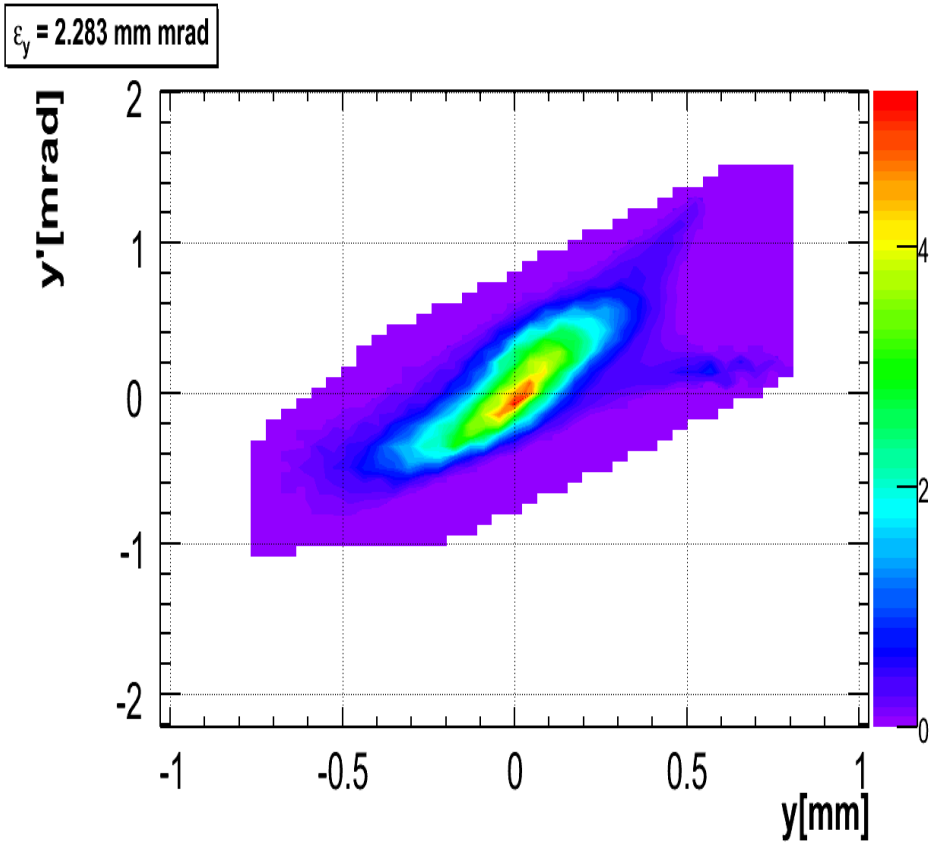
Backup Slides

Reconstruction result – Y plane

No space charge

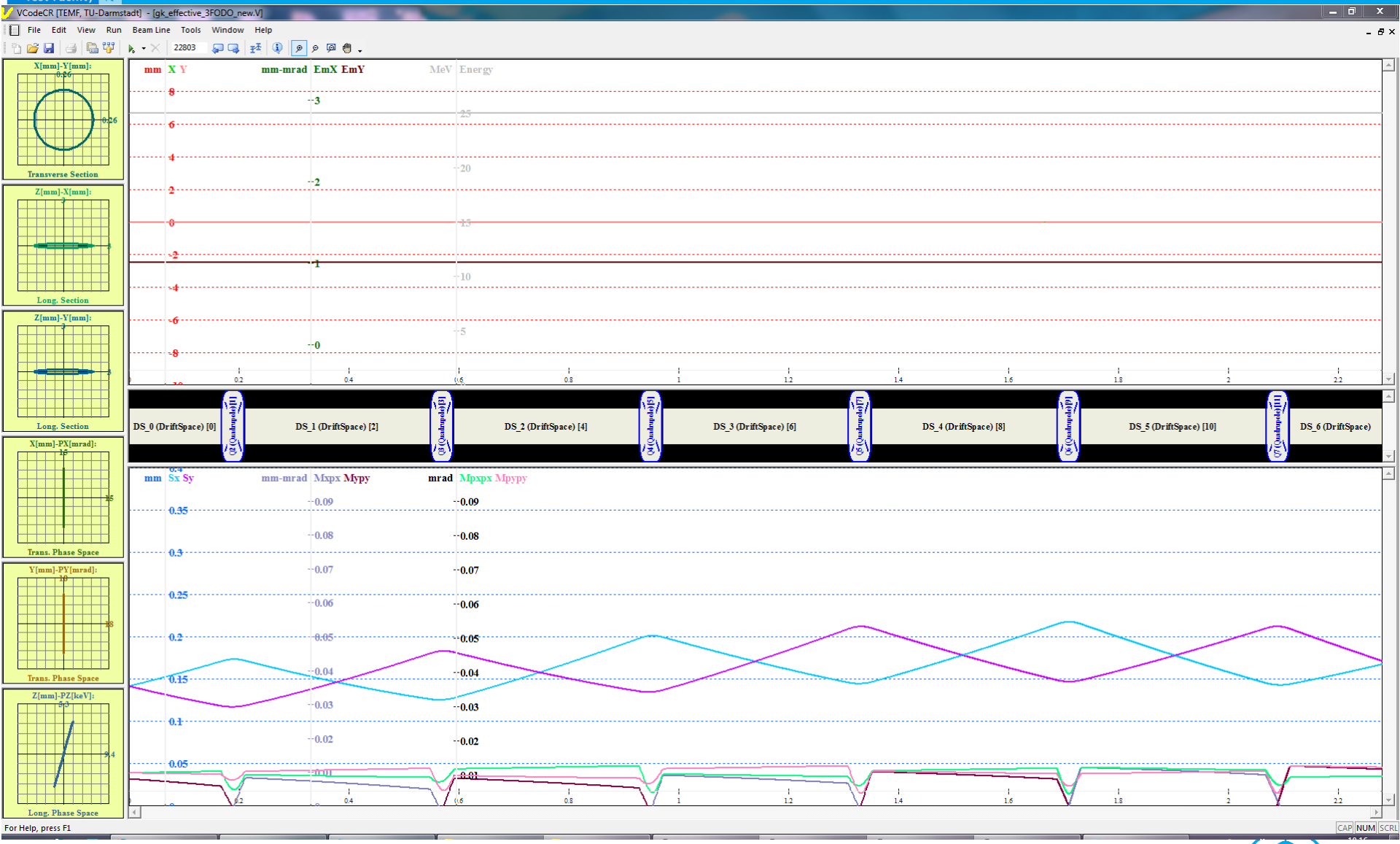


Linear space charge



Reduction in the resulted emittance = 10.8%

V-Code screenshot – linear space charge



Data analysis for Effective quads with no space charge @ 1mm*mrad (same as for 3mm*mrad)