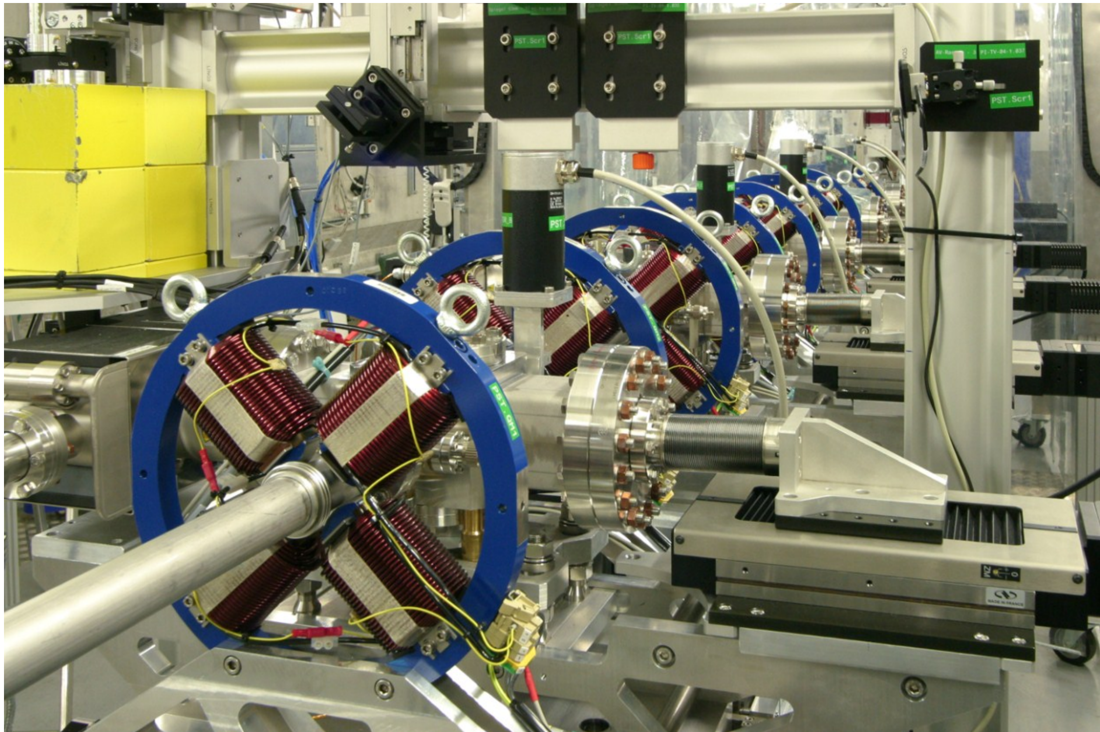
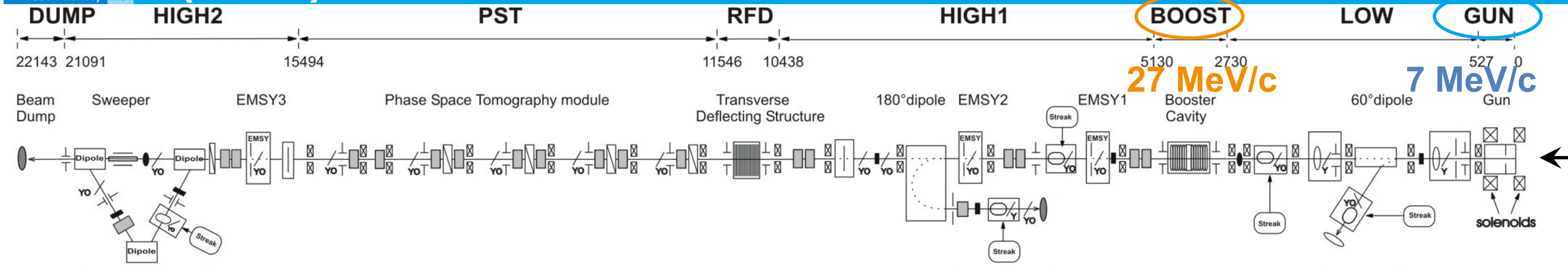
The impact of linear space charge on the tomographic reconstruction at PITZ.

- 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



Georgios Kourkafas
DPG 2013, Dresden
04.03.2013

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

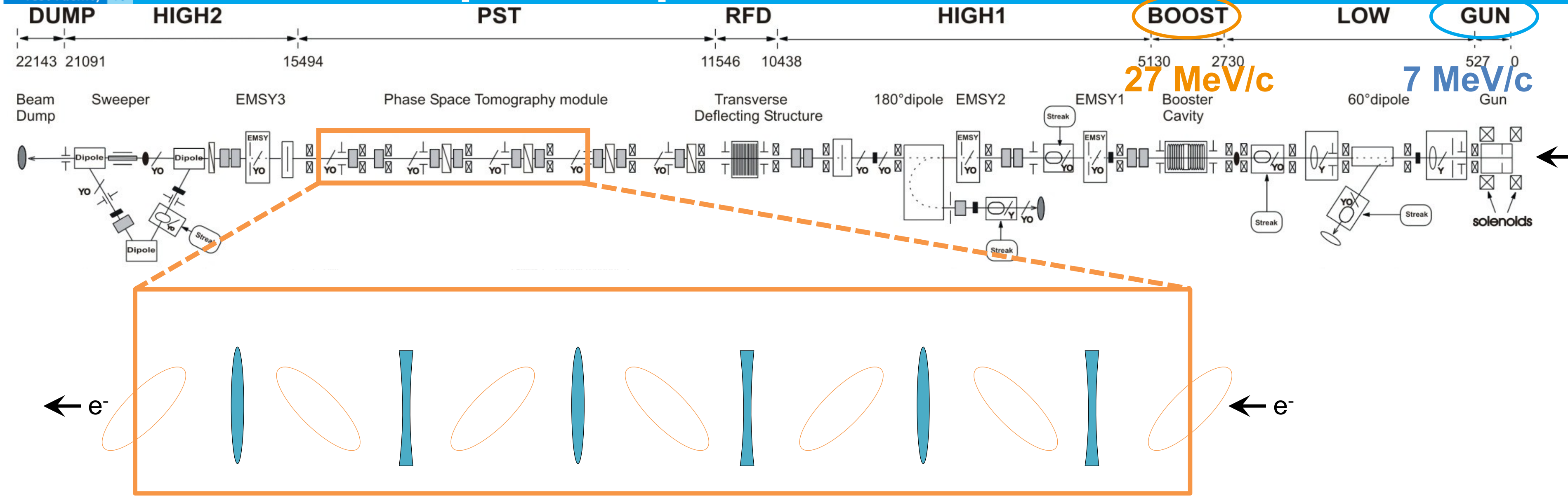
> e^- RF-gun

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

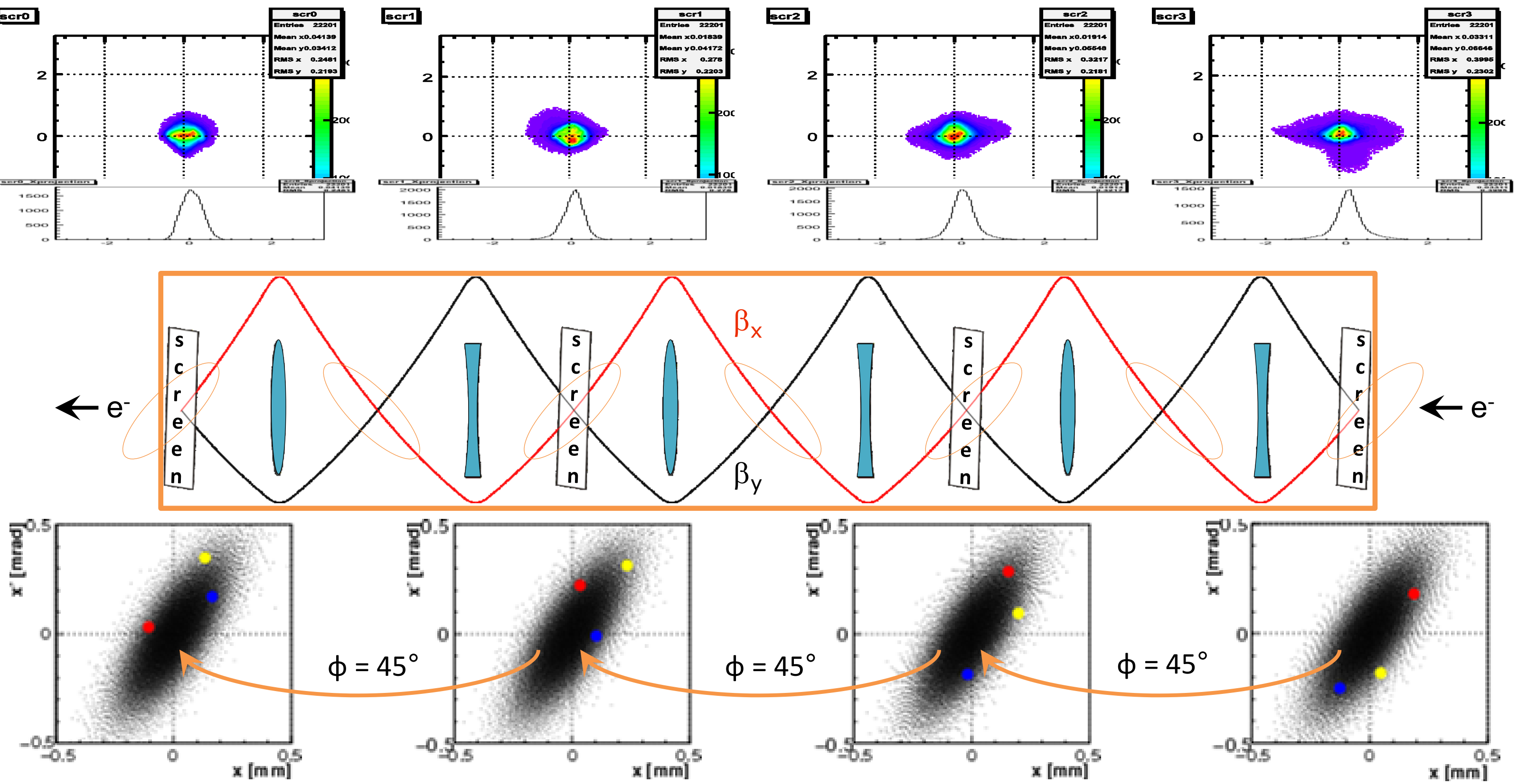


Image courtesy:
G. Asova

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

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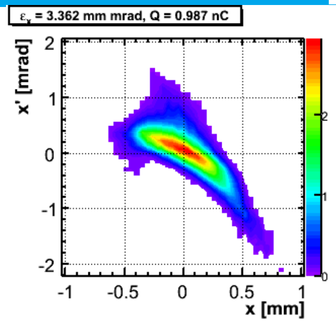

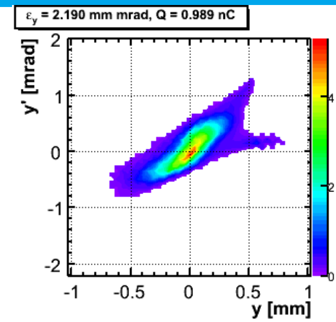

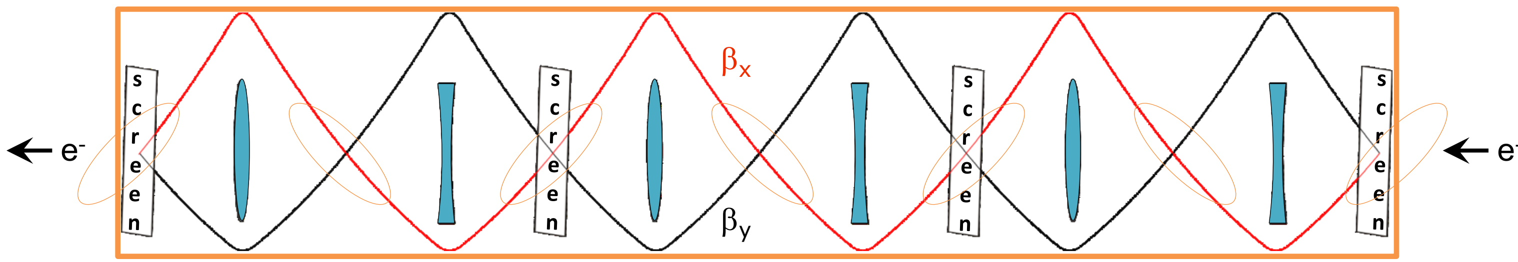

1) Quadrupoles form a FODO lattice and oppose a complete 180° rotation in the transverse phase space

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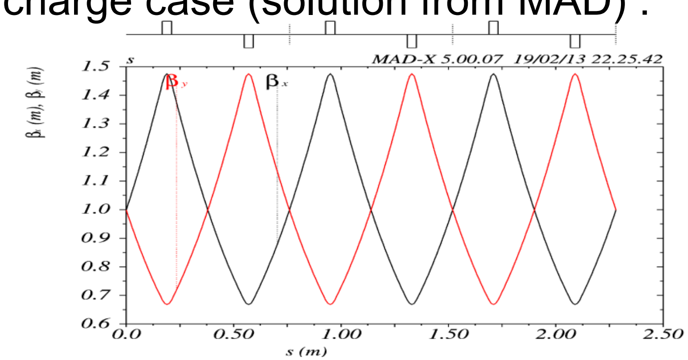
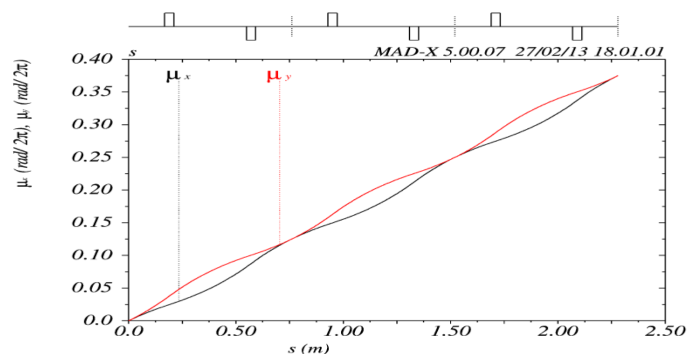
- Simulations parameters:
  - No space charge forces present (current treatment) vs. linear space charge forces
  - Emittance values (~ charge density) of 3mm·mrad (common during measurements) and 1mm·mrad (target value) for 1nC bunch charge, 20ps pulse length, at 25MeV
  - The beam moments at the entrance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





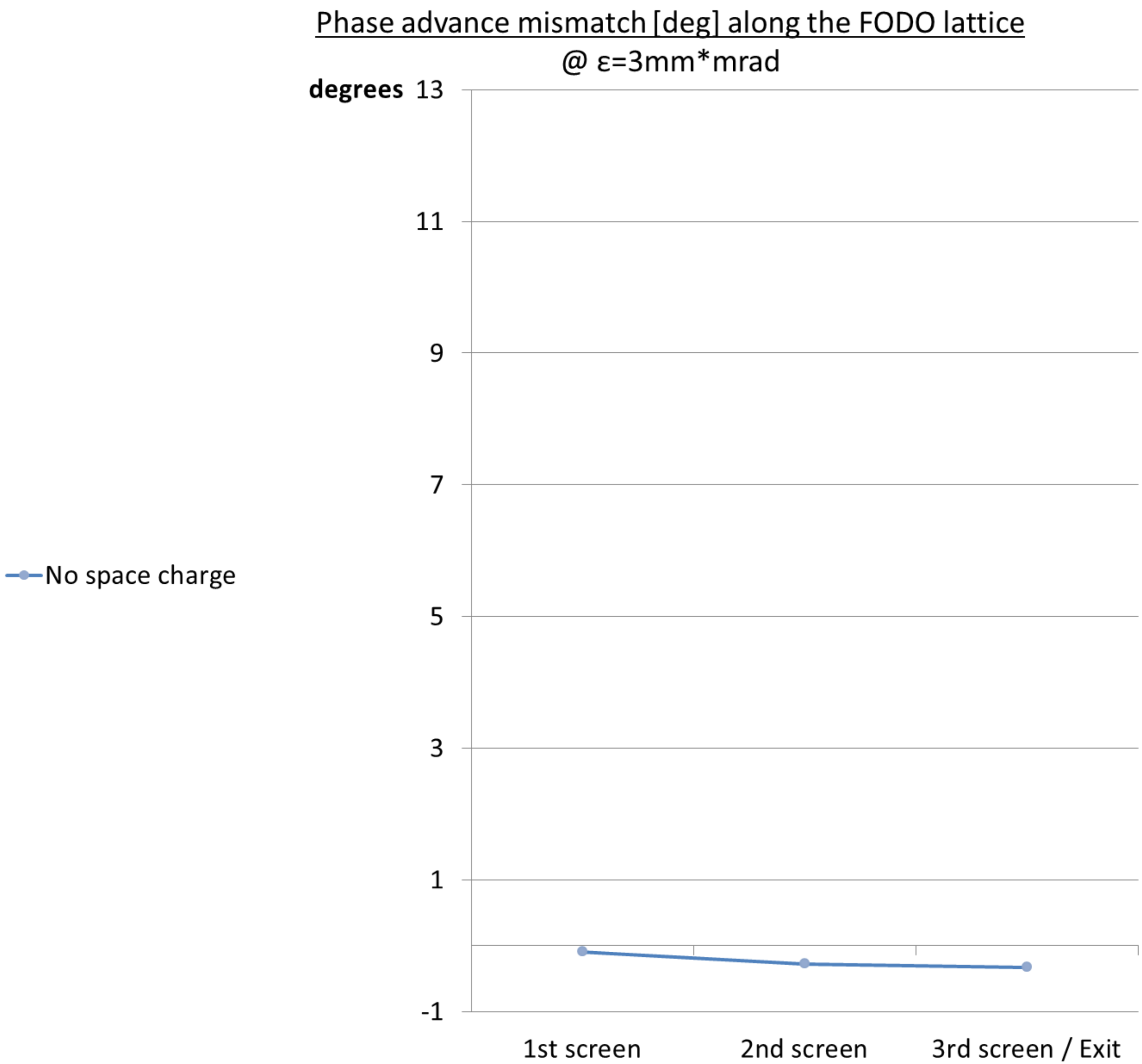
Simulation results (estimator)

(n=1,2,3)

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

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

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



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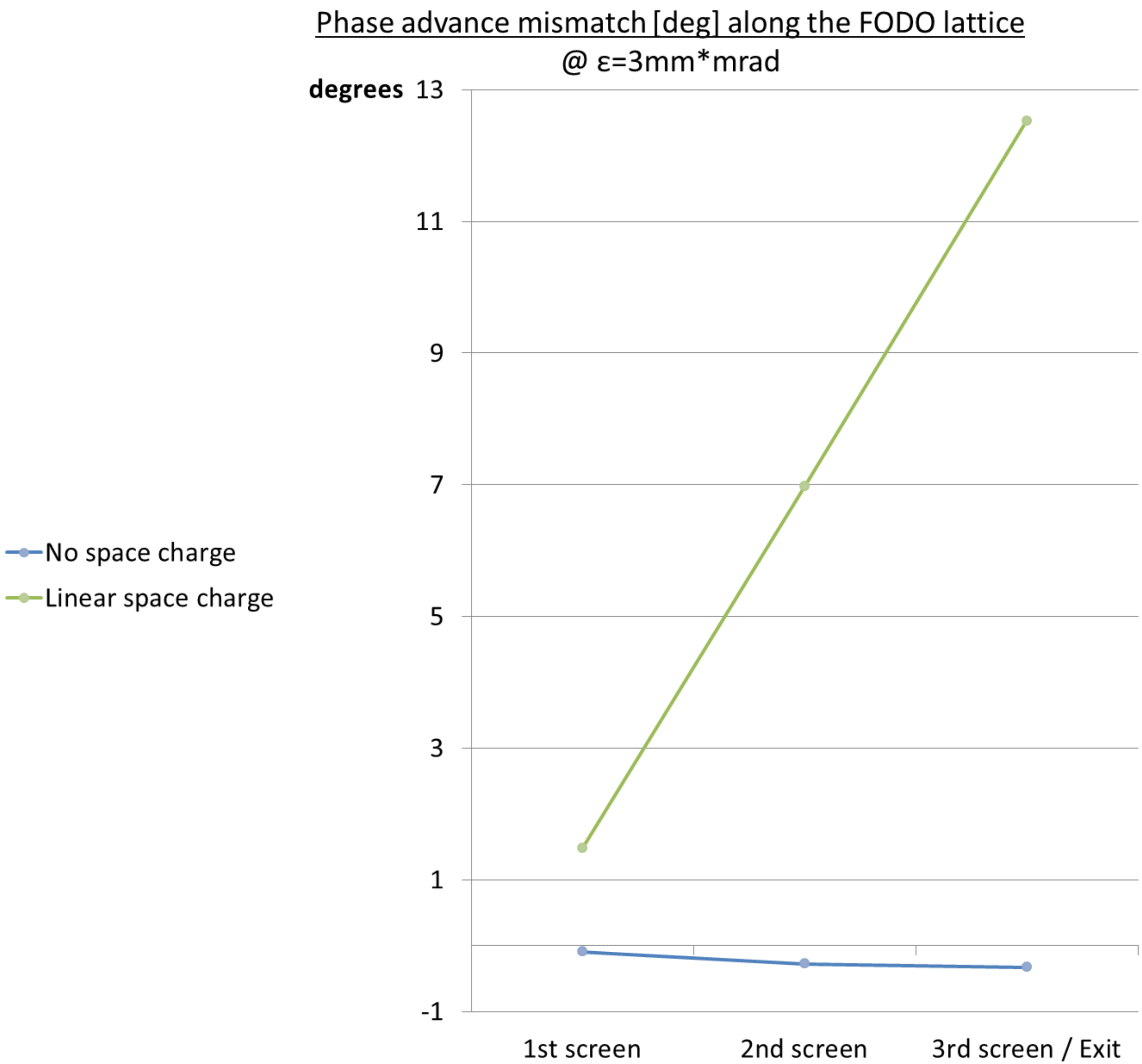

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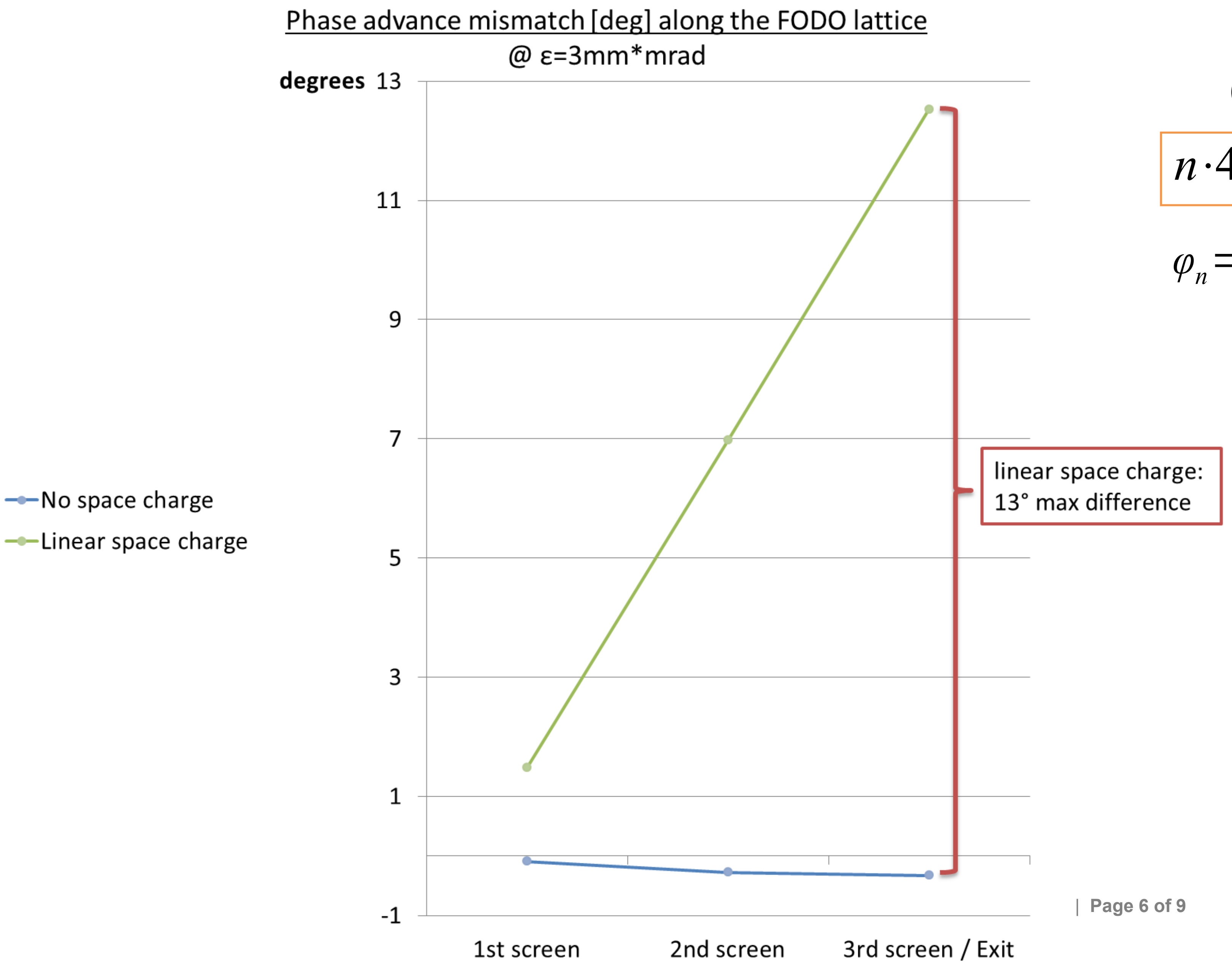

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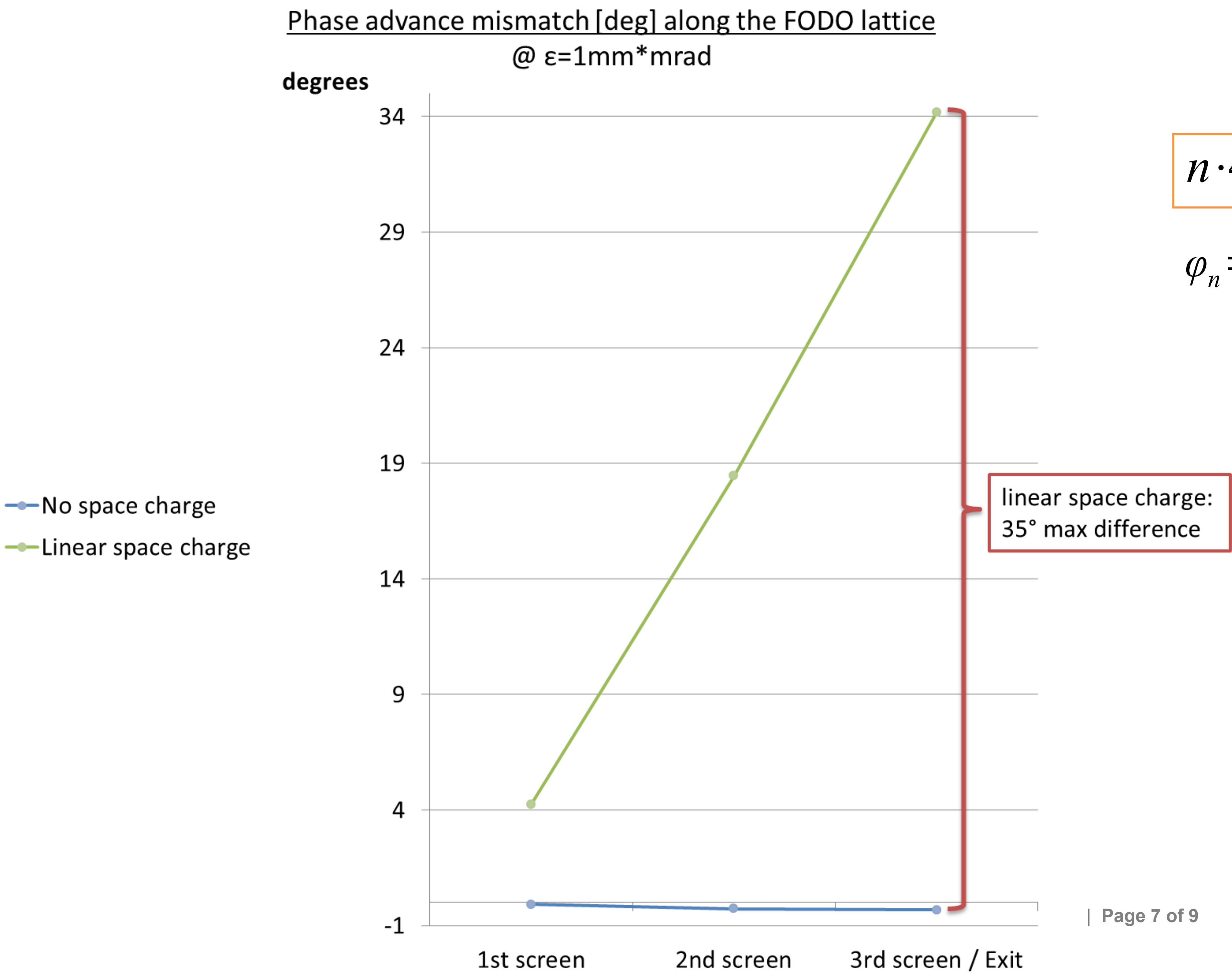

(n=1,2,3)

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

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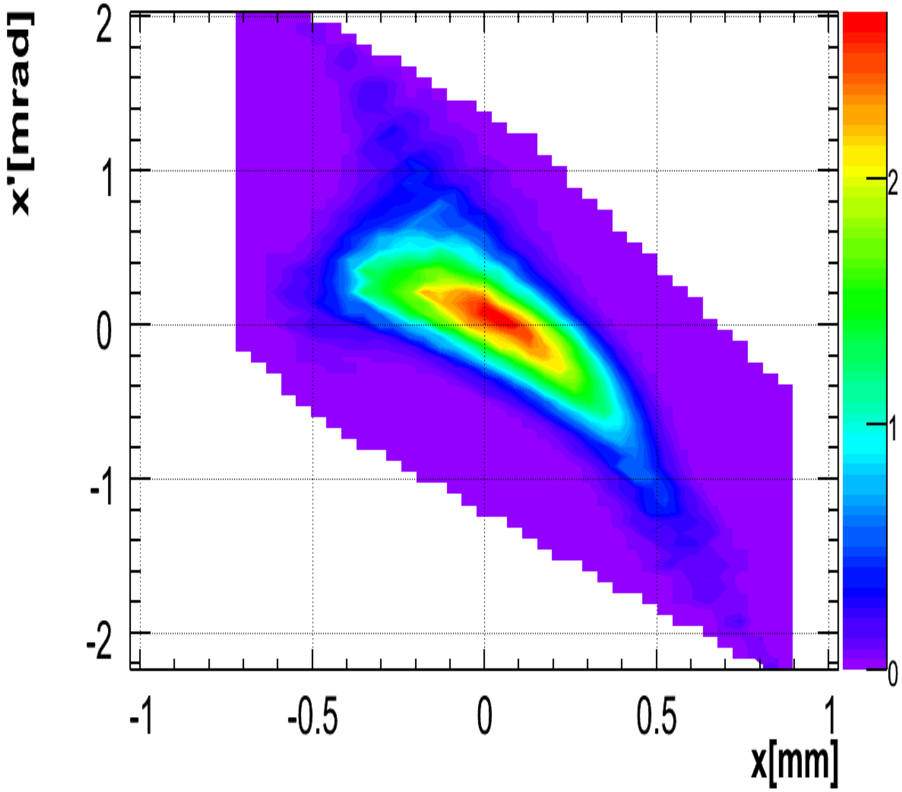
Reconstruction result

Reconstruction of experimental data using the two different approaches:

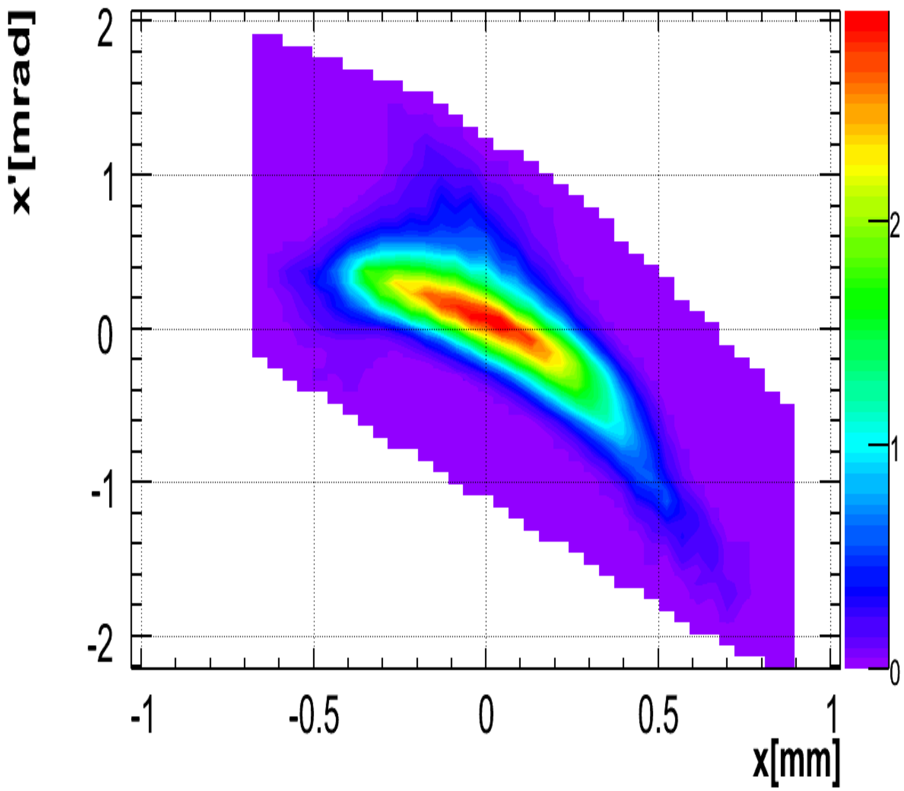
ε_x = 4.008 mm mrad

> **No** space charge



ε_x = 3.546 mm mrad

> **Linear** space charge



Reduction in the resulted emittance = 11.5%

Summary and outlook

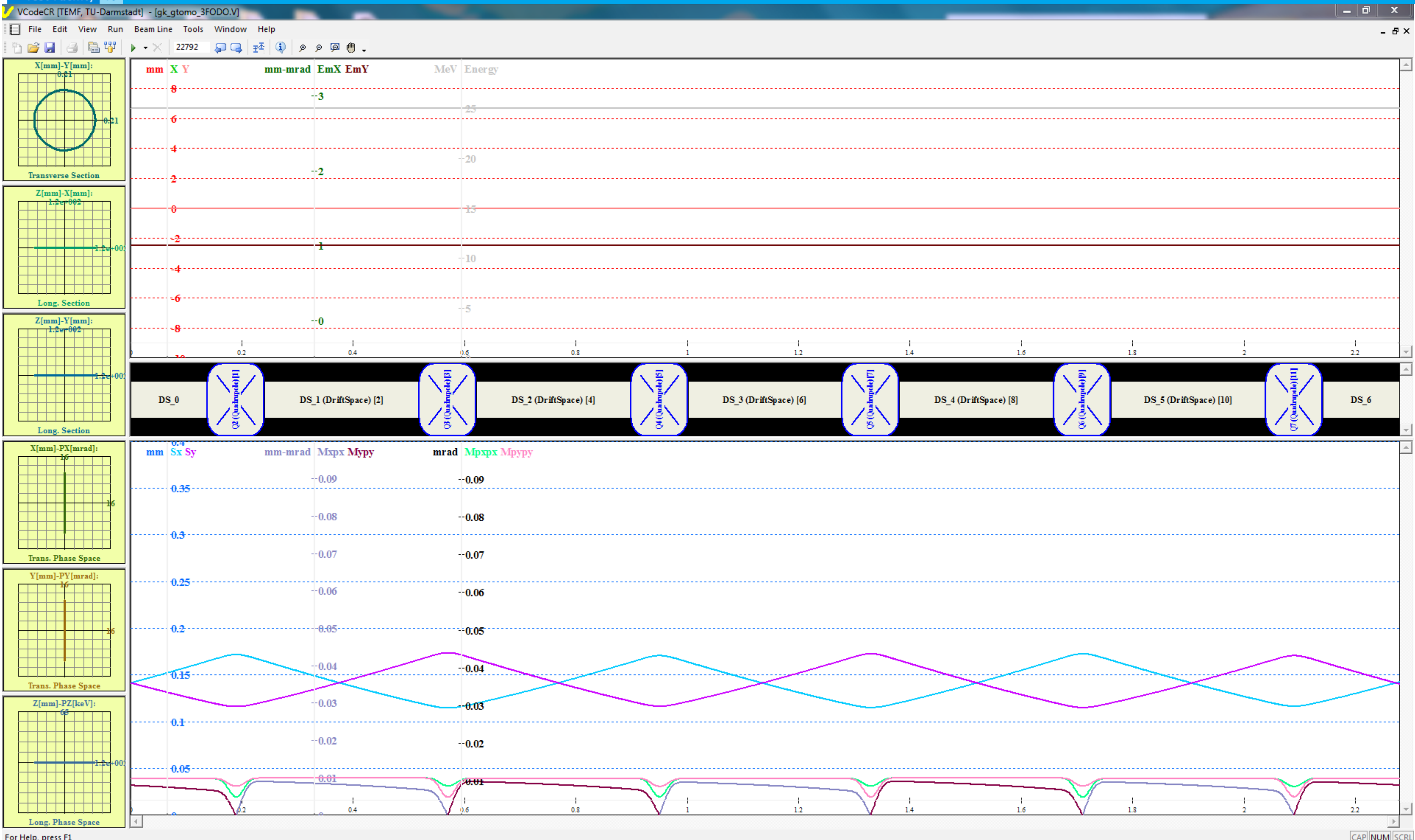
- The linear space charge induces considerable additive mismatches along the FODO lattice
- The tomographic reconstruction of the transverse phase space seems to improve when the linear space charge forces are taken into account
- The non-linear space-charge effect is still excluded, but is expected 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.

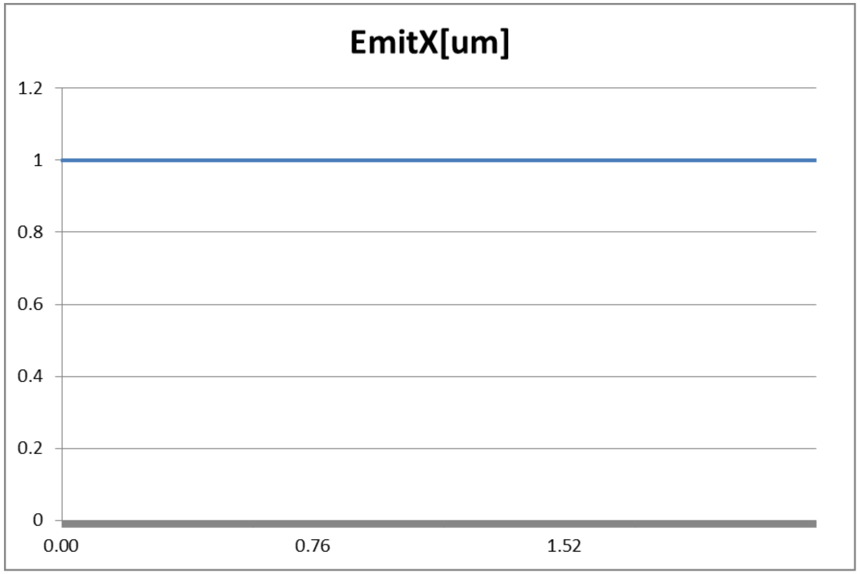
Backup Slides

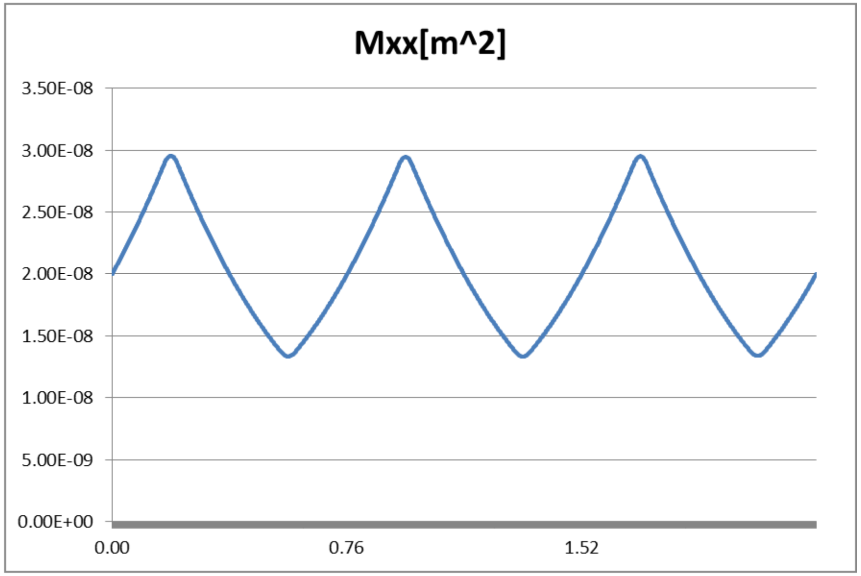
V-Code screenshot – no space charge

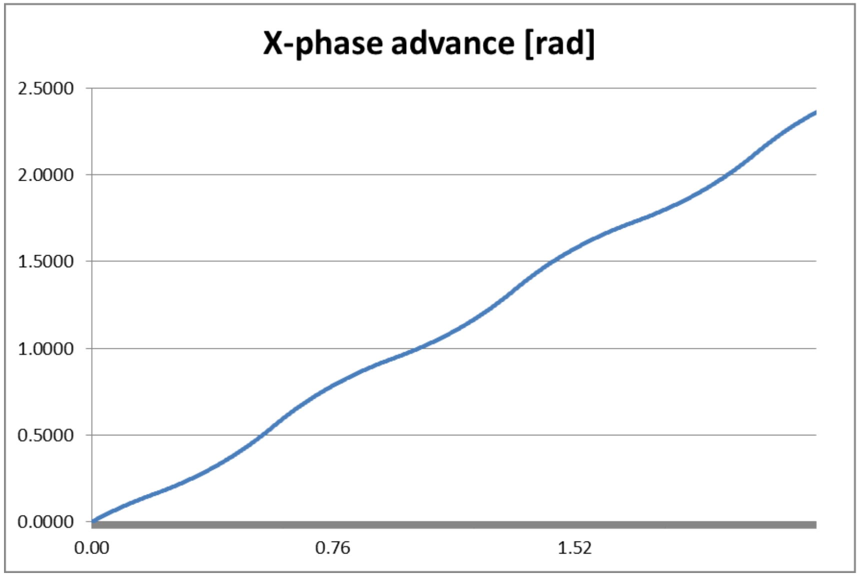


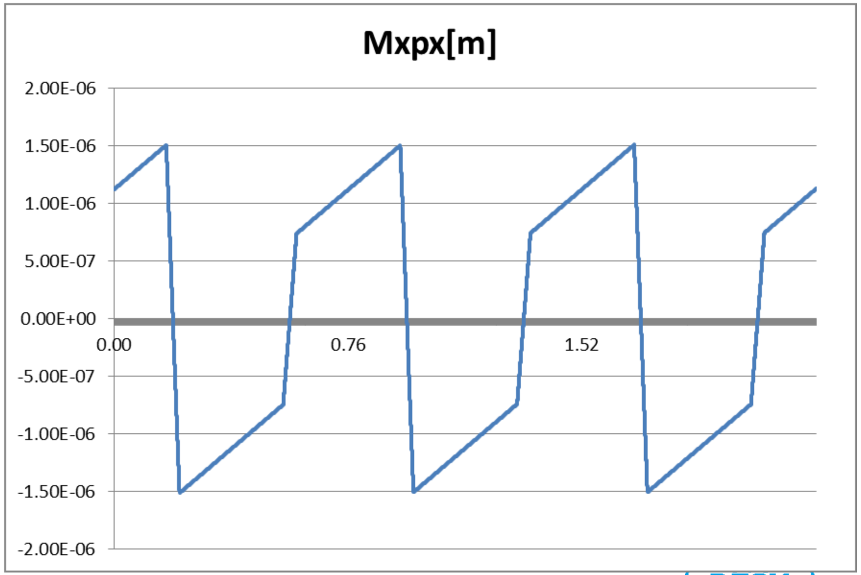
V-Code screenshot – linear space charge

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

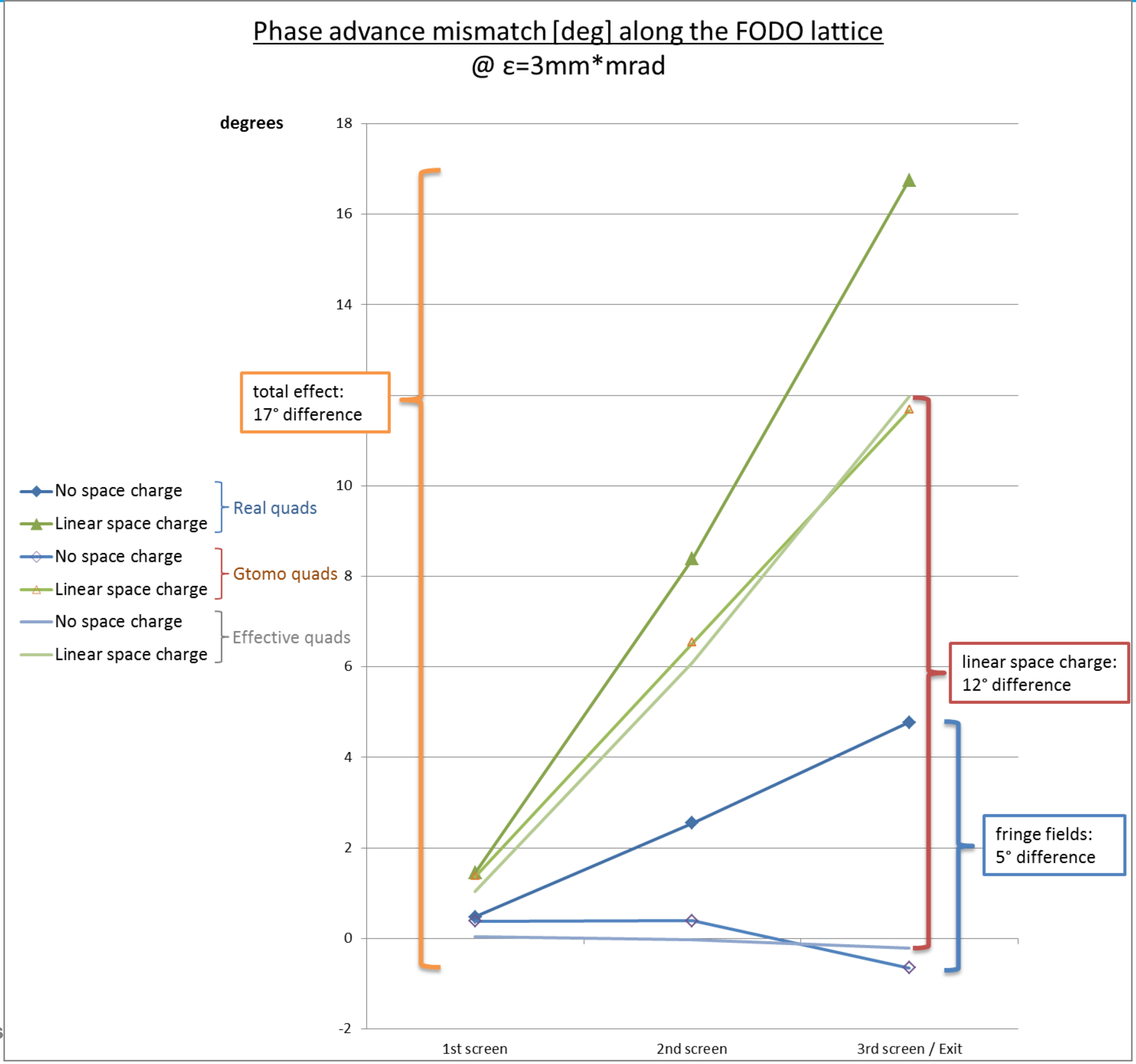








Simulation results (25MeV / 1nC / 20ps – Y plane)



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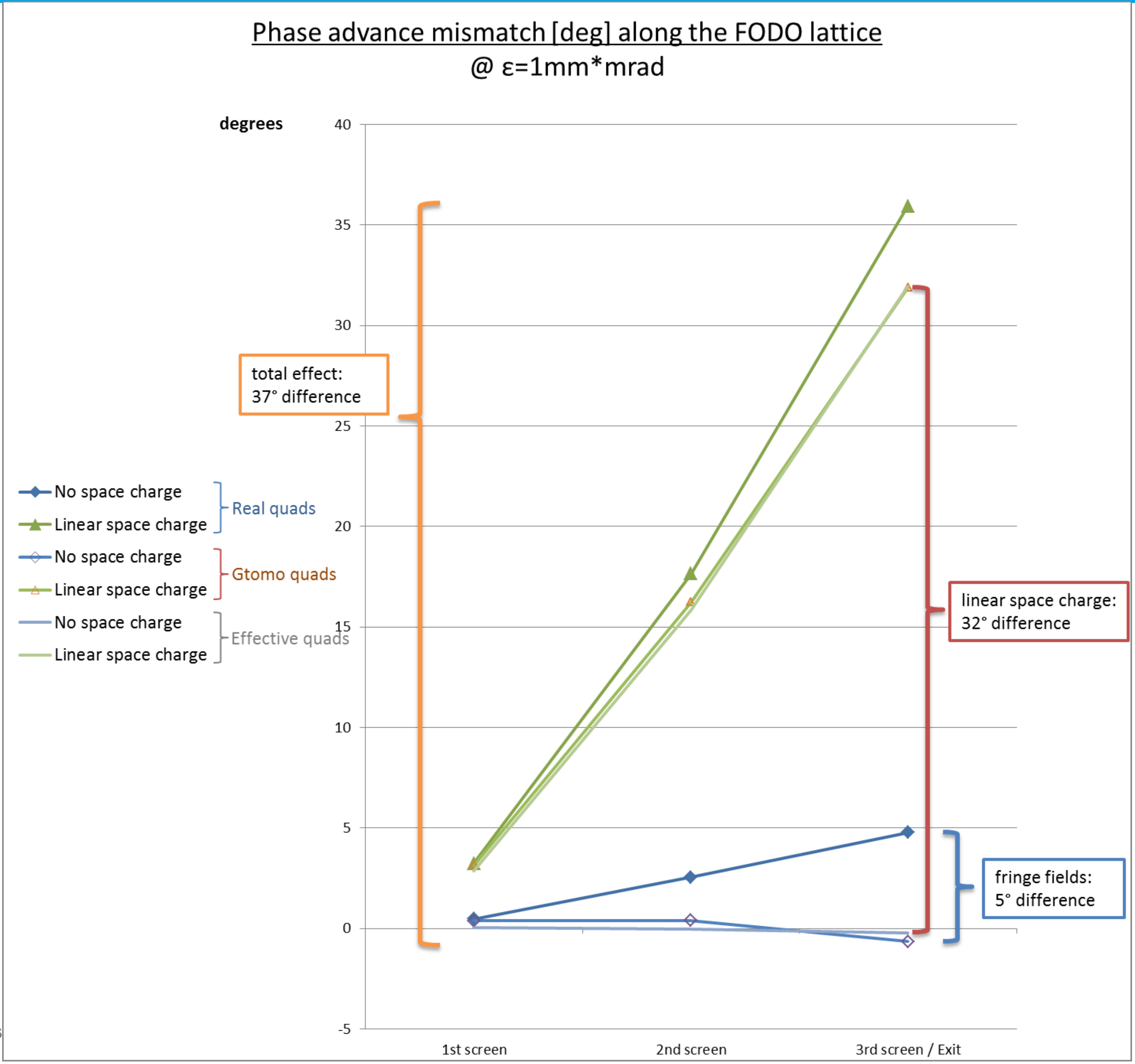
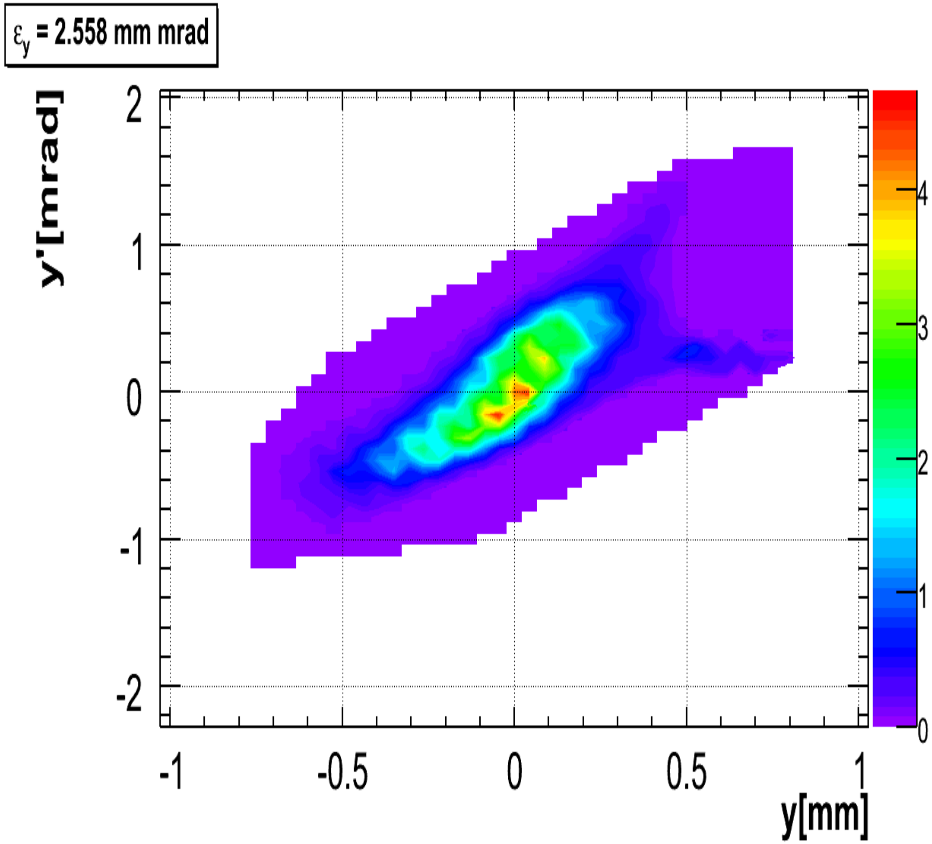


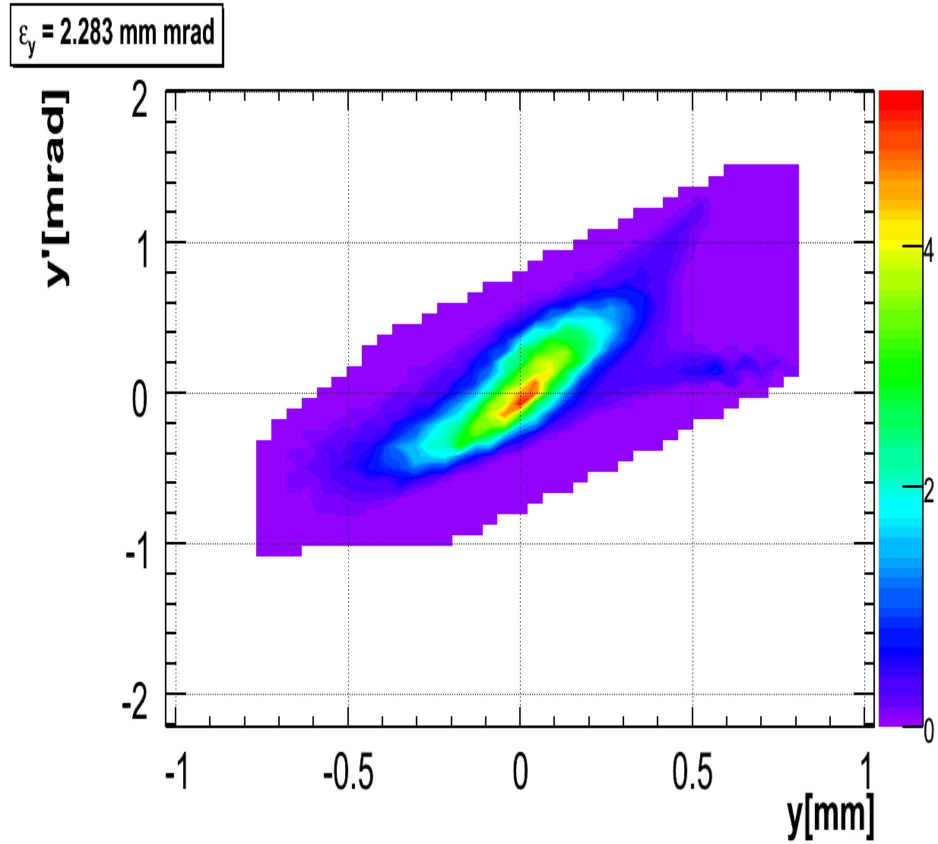
Georgios

Reconstruction result – Y plane

No space charge



Linear space charge



Reduction in the resulted emittance = 10.8%