Improved tomographic reconstruction of measured data.

> Motivation
> Procedure
> V-Code simulations
> Reconstruction results
> Summary and outlook

Georgios Kourkafas
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HELMHOLTZ
ASSOCIATION

DESY

Motivation

- The current calculation of the beam transport in the tomography lattice does not consider:
  - Measured fringe fields of the quadrupoles
  - Linear space charge
  - Non-linear space charge

- Result: Wrong beam optics and dynamics → wrong calculation of the phase space rotation ~ reconstruct projections using wrong angles and scaling

Procedure

1. A set of measured data (m1 389 A - 201100524N) is simulated with V-Code along the FODO lattice for different space-charge and fringe-field parameters.

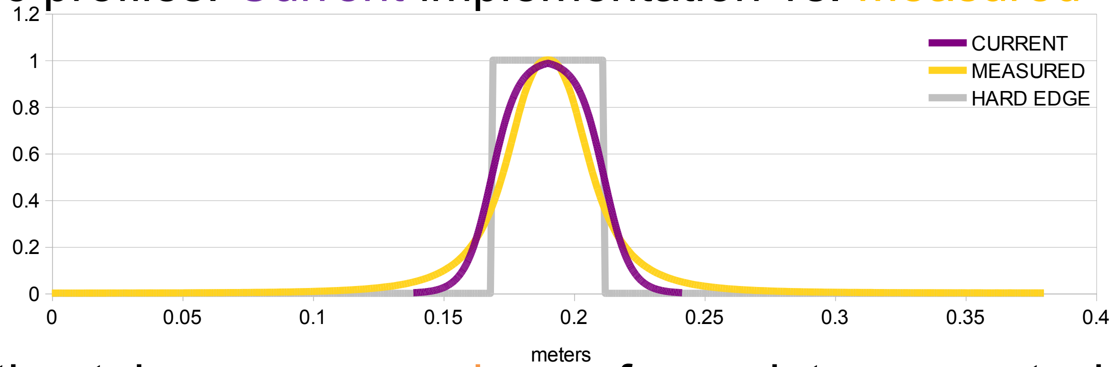
2. The output of V-Code is extracted and translated to transfer matrices at each screen.

3. The data is reconstructed using the obtained transfer matrices for each case.

4. The resulting phase space and the emittance value are evaluated.

V-Code simulations

- The actual quadrupole strengths during the measurement are applied using two longitudinal magnetic profiles: Current implementation vs. Measured profile.



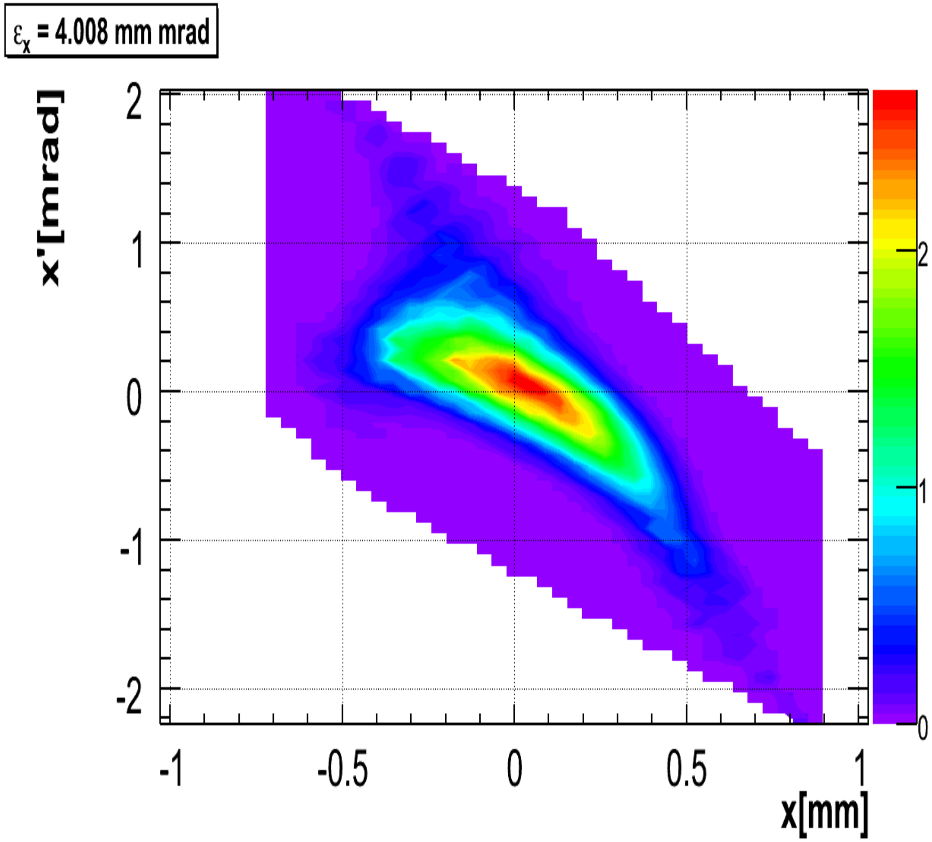
- The current implementation takes no space charge forces into account while the measured profile is simulated with linear space charge forces.

- The input beam [1nC bunch charge, 2/21\2ps pulse length, at 24.67 MeV] is defined by the measured beam size on the entrance of the FODO assuming perfect matching. This gives emittance values of 3.14 / 2.50 mm·mrad for x / y.

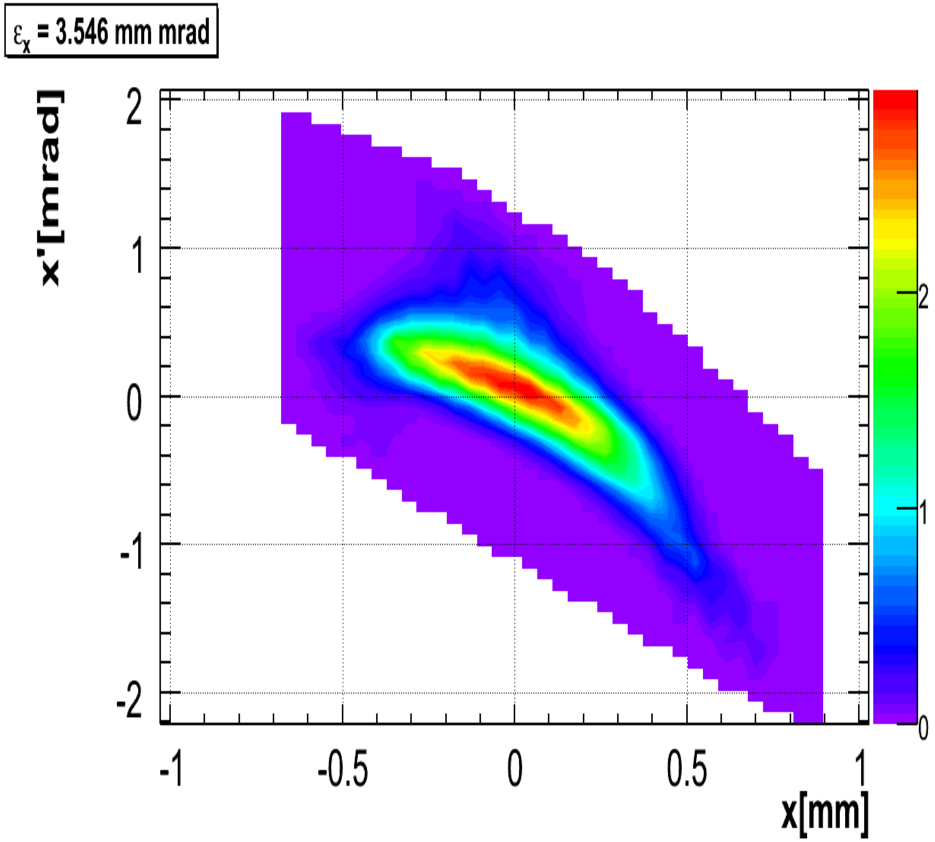
- Further assumptions: same magnetic profile for all quadrupoles, simulation-estimated bunch length, perfectly centered beam with zero dispersion and transverse momenta.

Reconstruction result – X plane

Current quad – no space charge



Measured quad – with space charge

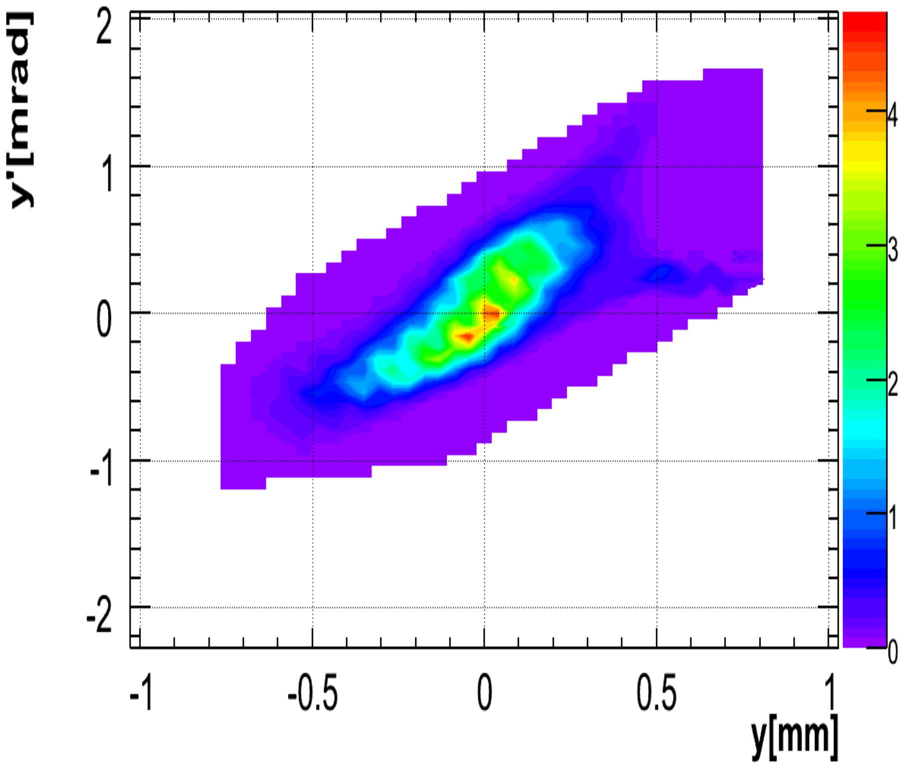


Reduction in the resulted emittance = 11.5%

Reconstruction result – Y plane

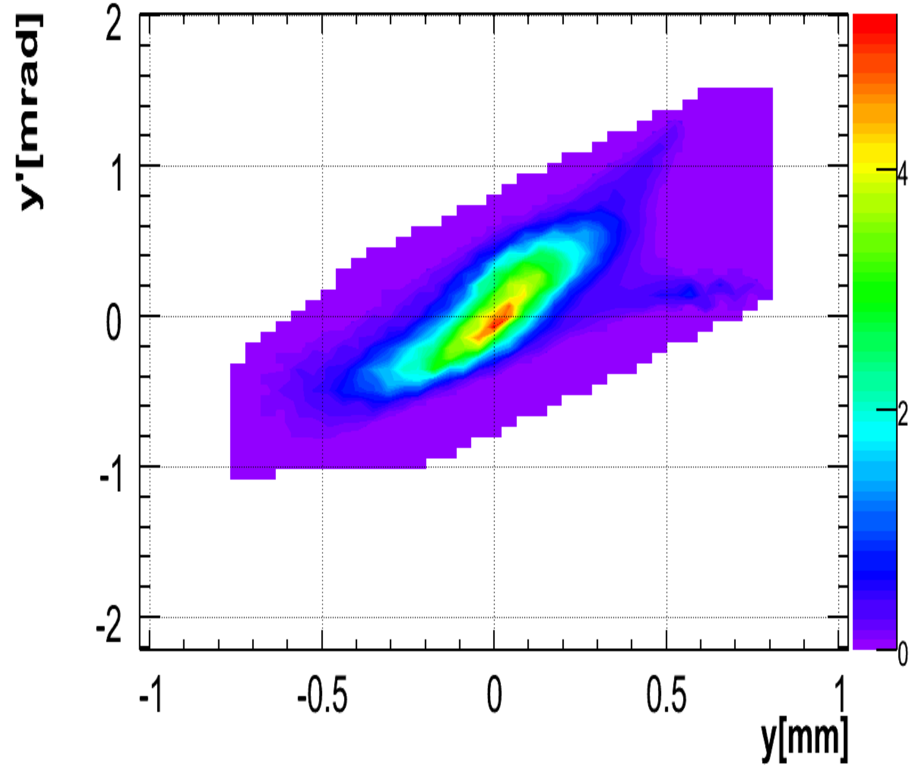
Current quad – no space charge

ε_y = 2.558 mm mrad



Measured quad – with space charge

ε_y = 2.283 mm mrad



Reduction in the resulted emittance = 10.8%

Summary and outlook

> The consideration of fringe fields and linear space charge along the FODO lattice seem to give better reconstruction results.

> Next steps:

- Repeat the investigation using ASTRA instead of V-Code.
- Implement the magnetic profile of each quad individually in the analysis.
- Make the "offline mode" feature in the tomography code (manual input of the transfer matrices) available for the users.
- Implement the new treatment (measured magnetic profile + linear space charge) as default in the tomography code

Thanks to Grygorii Vashchenko and Barbara Marchetti.

THE END.

Backup Slides

V-Code simulations (fields)

Normalized gradient profile calculation:

> Current:

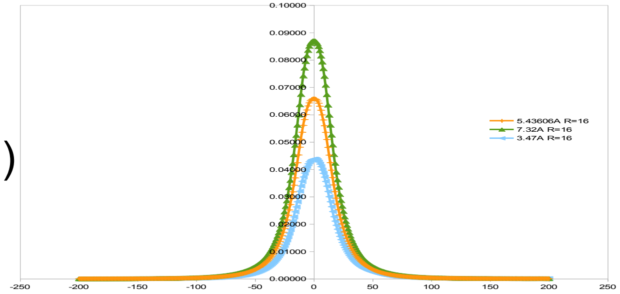
- Profile directly calculated as in the code: and then divided by the strength

$$G(z)=\frac{k}{1+e^{\frac{2\cdot(2\cdot\|\Delta z\|-L_{eff})}{Q_{bore}}}}$$

- Effective length (integrated normalized flux) : 43.11 mm

> Measured:

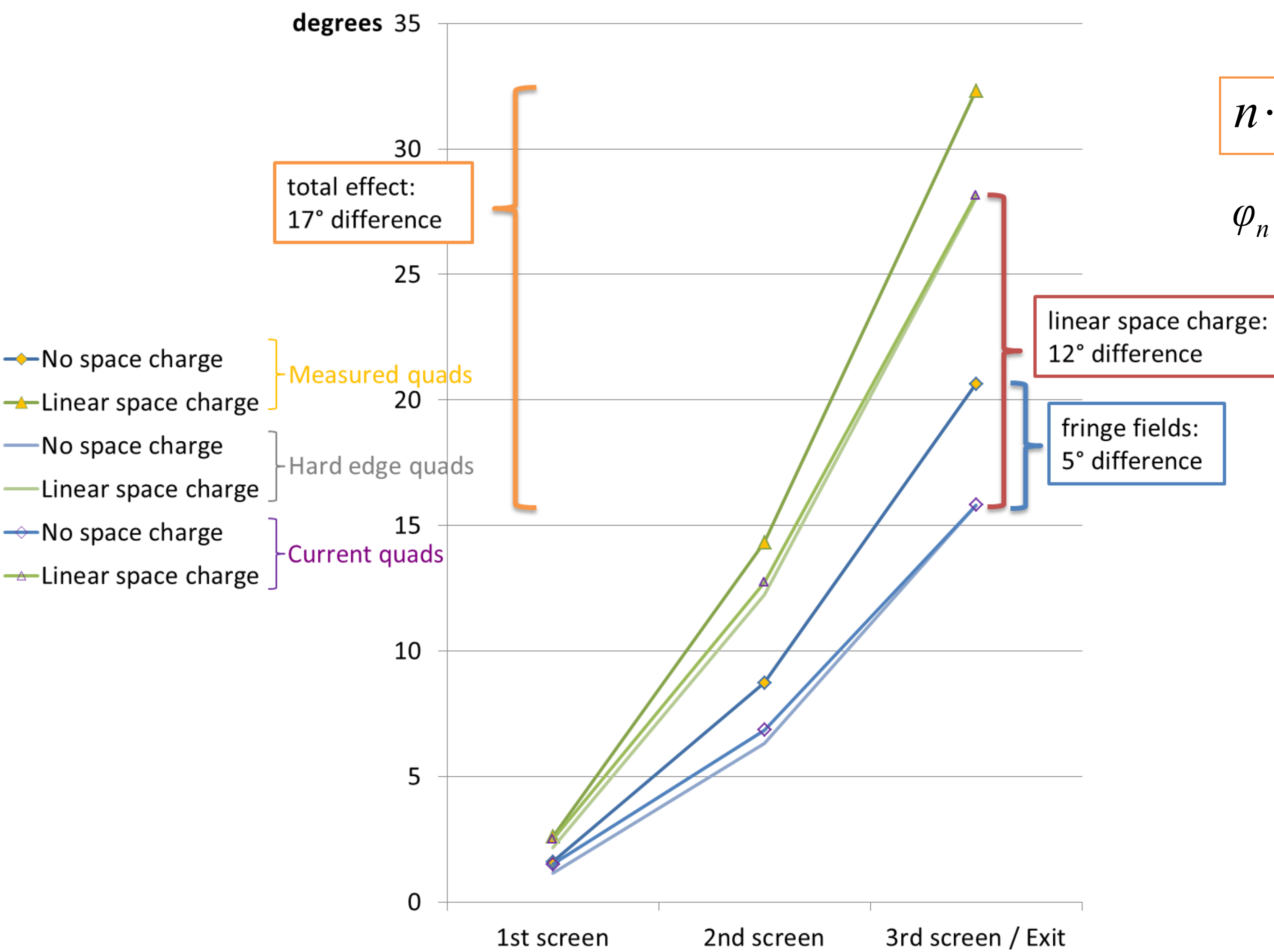
- [grad->I] convert the gradient required for matched solution (g = 4.1455 T/m) to current (average of all tomography quads)
- [I->B] for that current calculate the curve of the longitudinal magnetic profile (interpolate between the measured values)



- [B->B/m] get the gradient by dividing with the radius
- Normalize by dividing with the gradient for matched solution (g)
- Exclude 10mm from the beginning and 10mm from the end, so that the length equals exactly half FODO cell (negligible)
- Effective length (integrated normalized flux) : 43.35 mm

Mismatch results – X plane

Phase advance mismatch [deg] along the FODO lattice

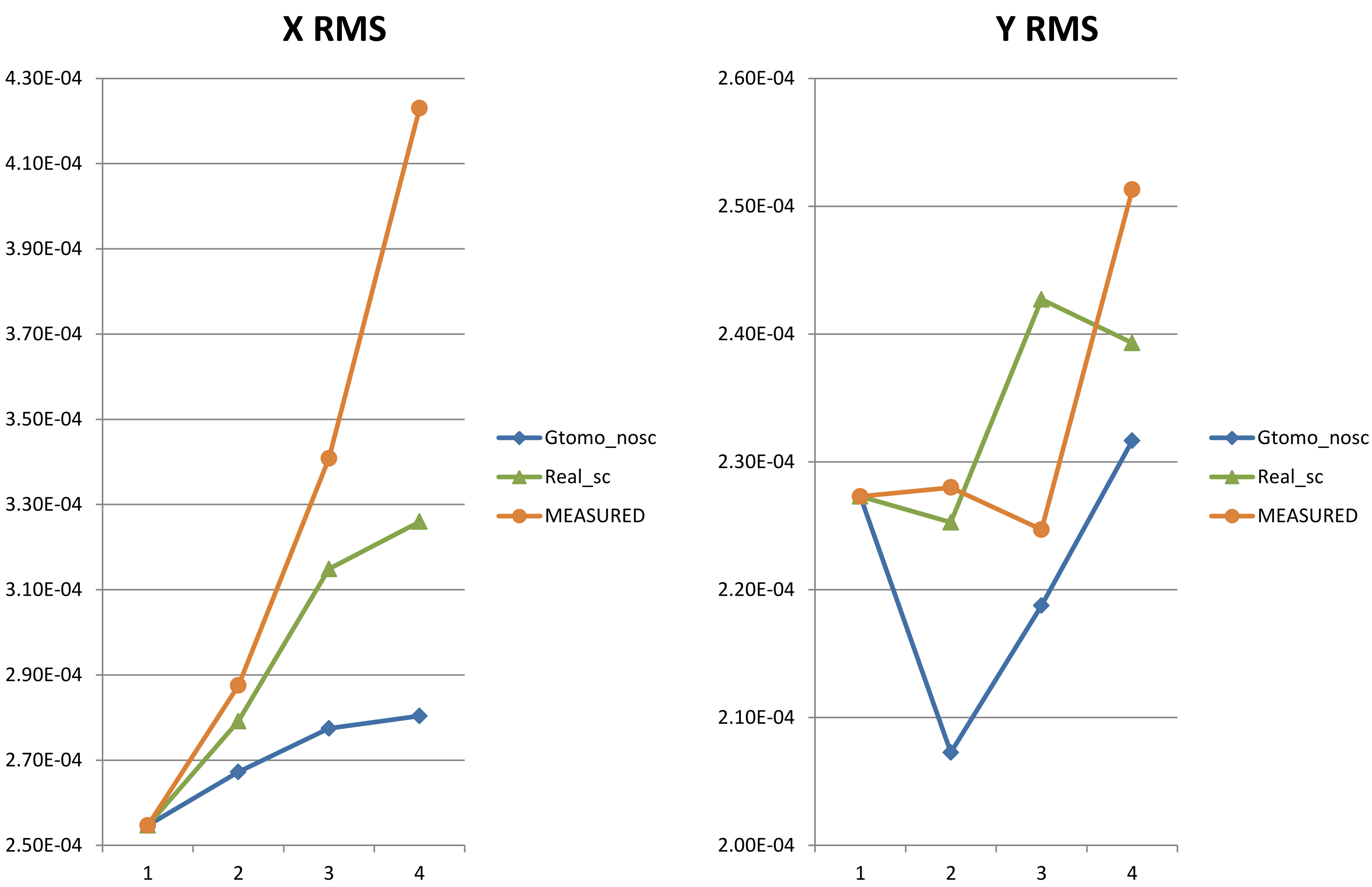


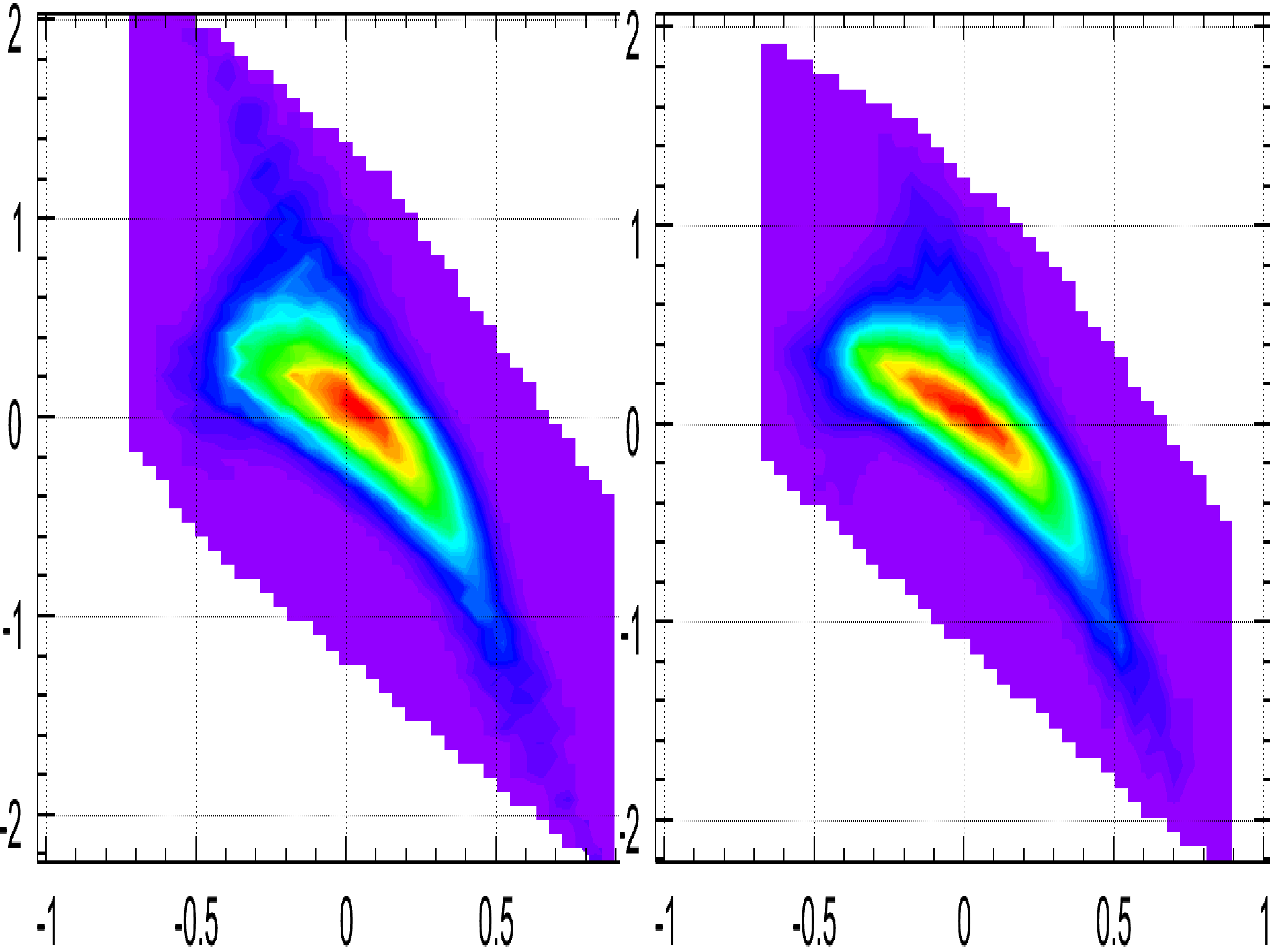
(n=1,2,3)

$$n \cdot 45^o - \varphi_n ,$$

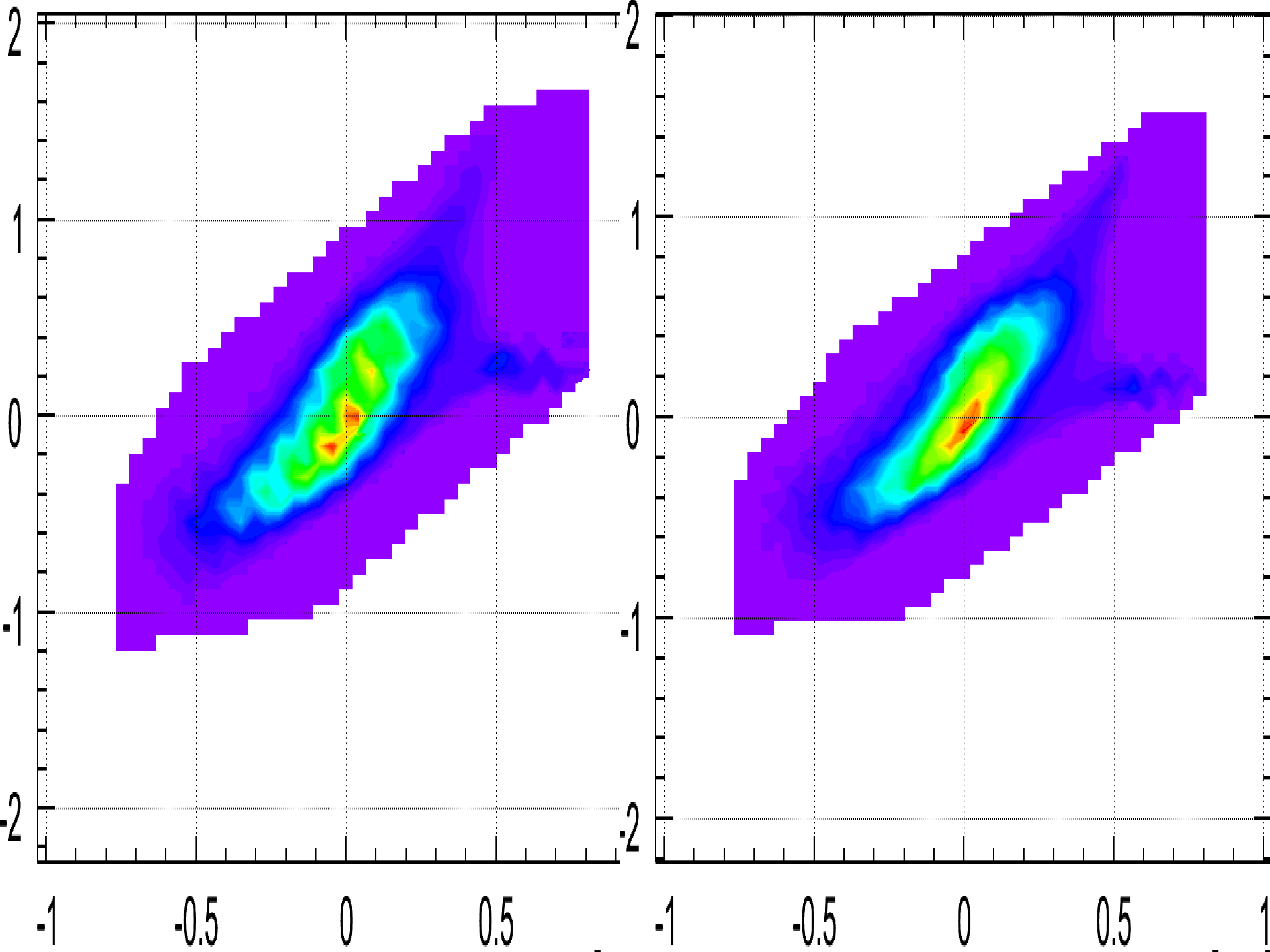
$$\varphi_n = \int_{z_0}^{z} \frac{dz}{\beta(z)}$$

Comparison of beam sizes at each PST screen

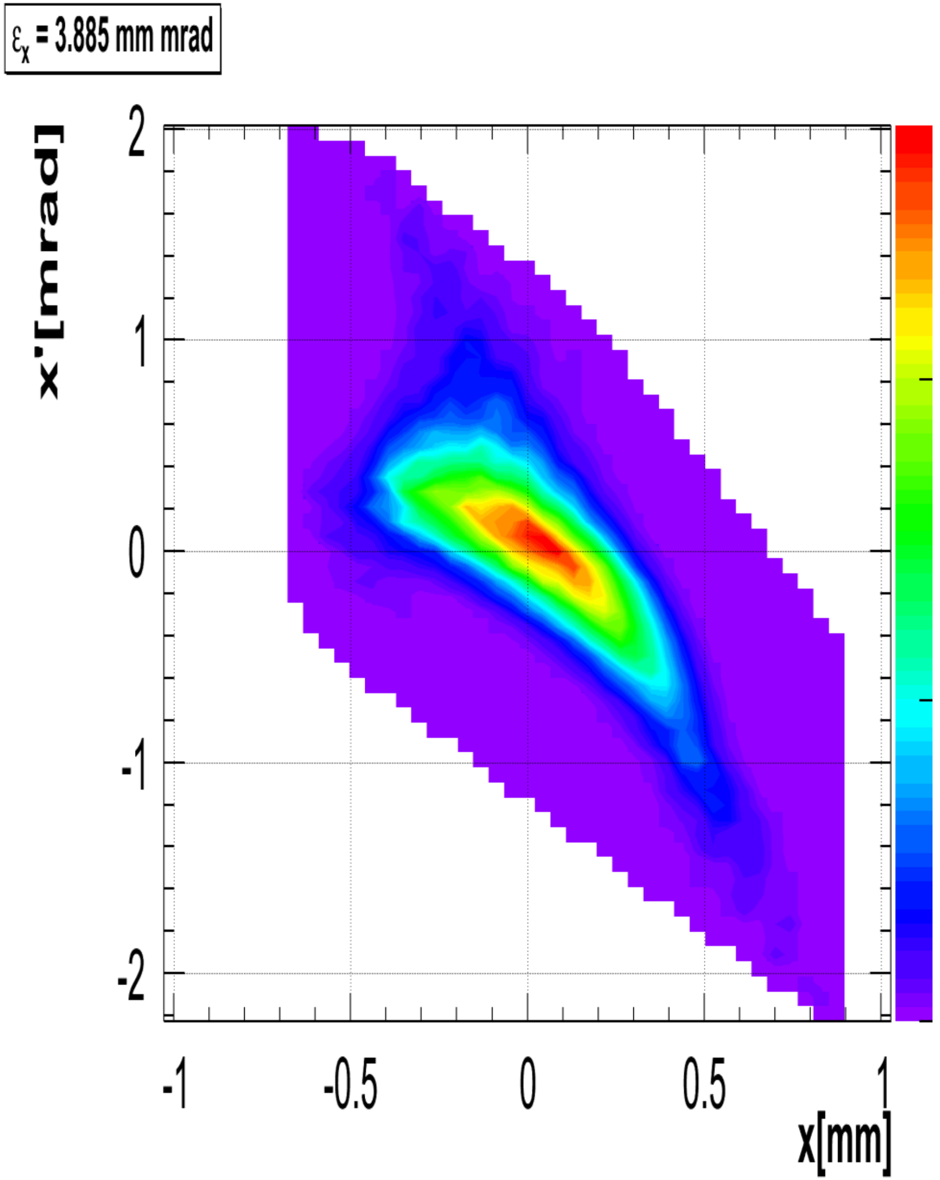


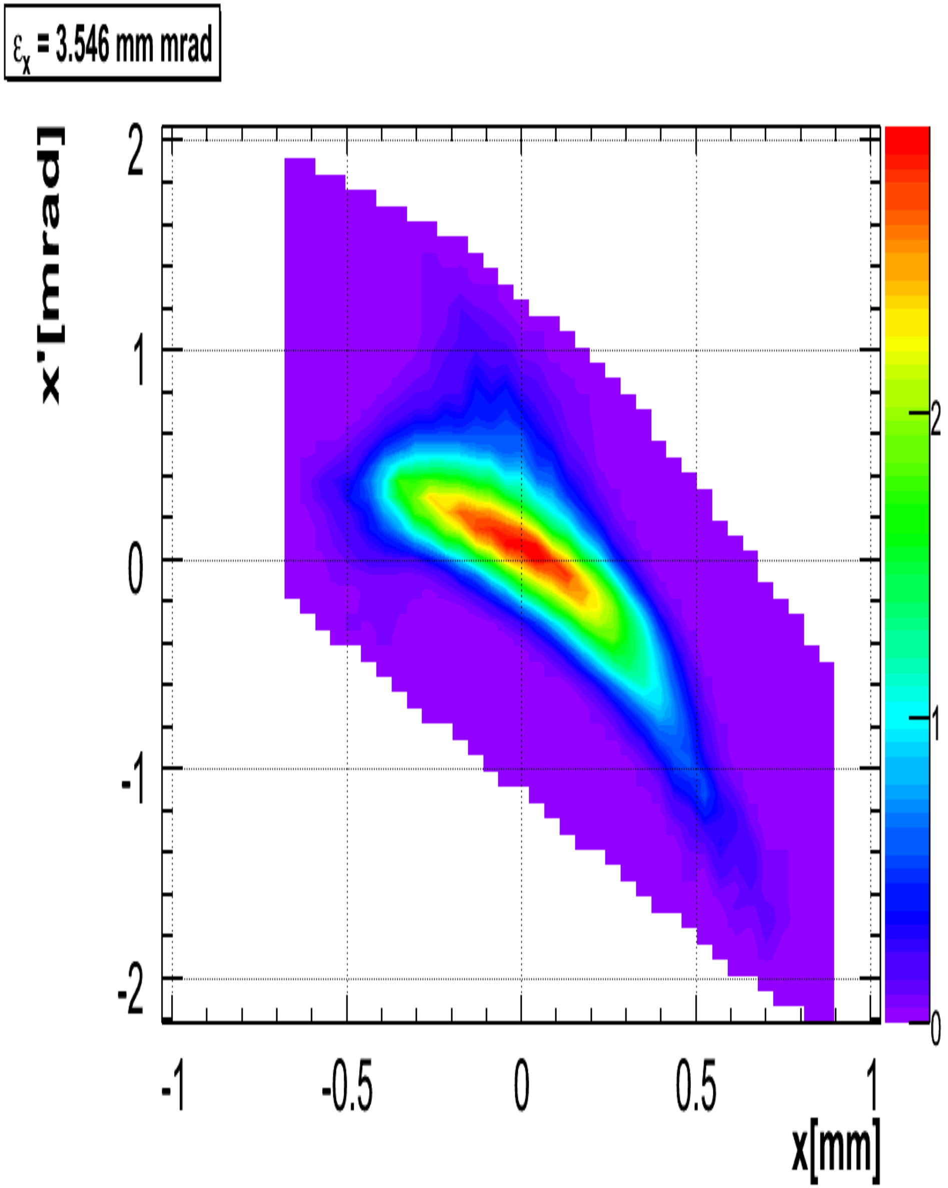


2
1
0
-1
-2
-1
-0.5
0
0.5
1


2
1
0
-1
-2
-1
-0.5
0
0.5
1

Original analysis vs. Measured quads with sp. ch. (without exact quad strengths)





Original analysis vs. Measured quads with sp. ch. (without exact quad strengths)