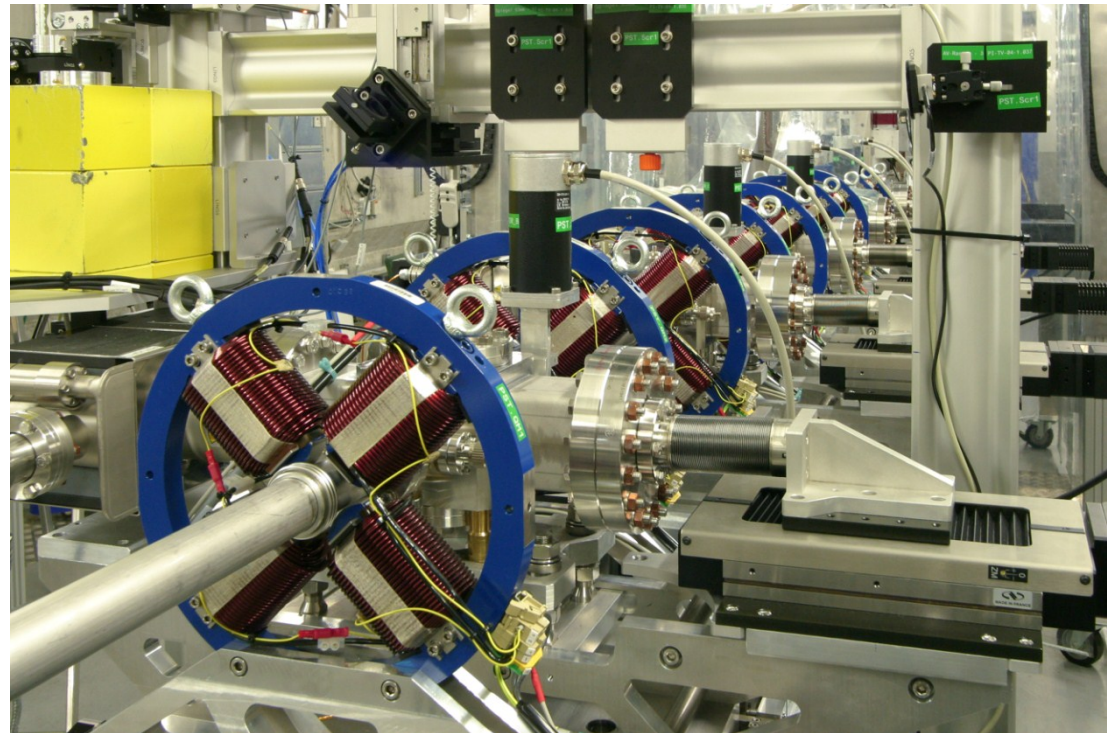


# Tomographic transverse phase space measurements at PITZ.

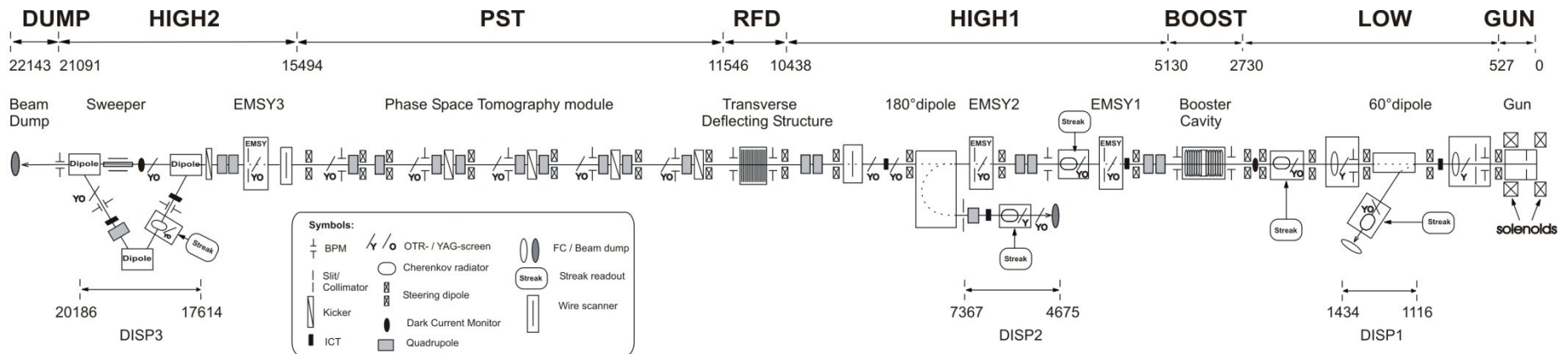
- > Photo-Injector Test facility at DESY in Zeuthen - PITZ
- > Tomography in beam diagnostics
- > Hardware
- > Measurements & evaluation
- > Features & obstacles
- > Summary and outlook

Georgios Kourkafas, for the PITZ team  
DPG – Frühjahrstagung, Göttingen, 28.02.2012



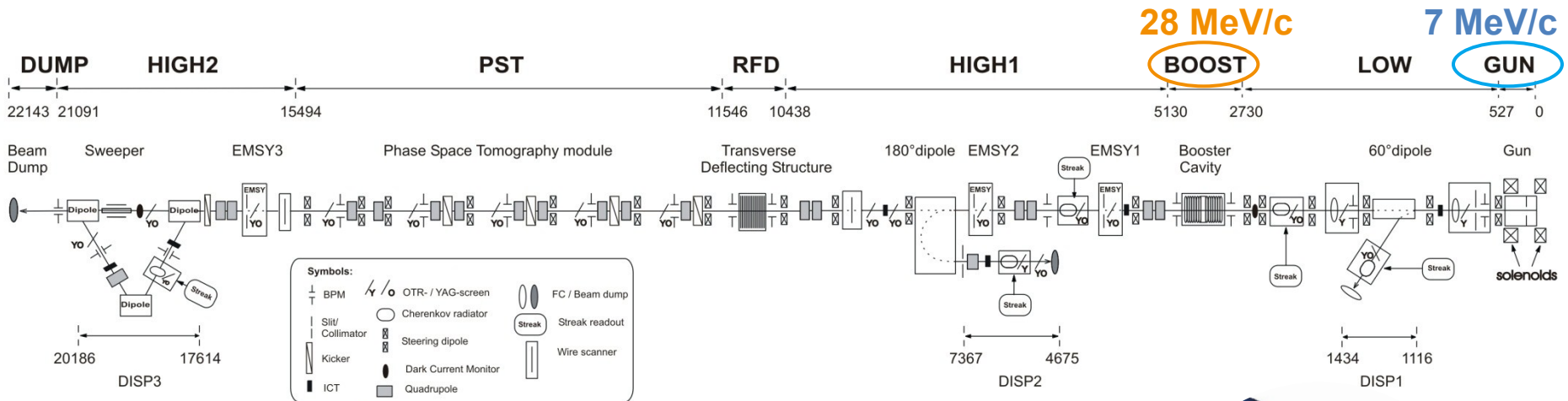
## > Test and optimize sources of high brightness electron beams:

- Minimized transverse projected **emittance** :  $< 1 \text{ mm}\cdot\text{mrad}$  for 1 nC (requirement of the European XFEL photo-injector)

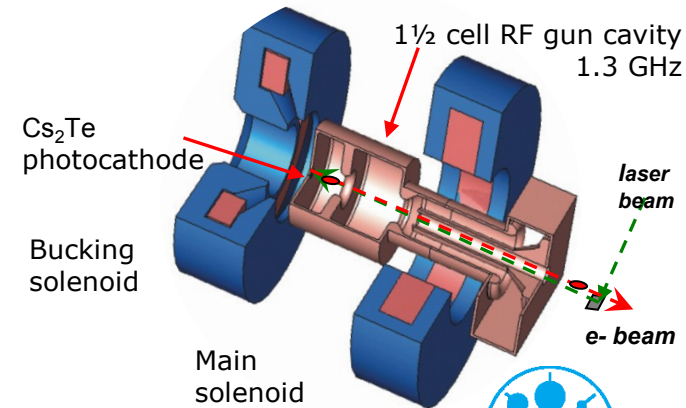
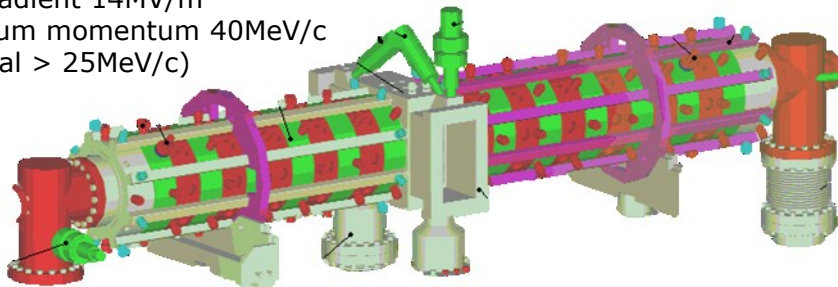


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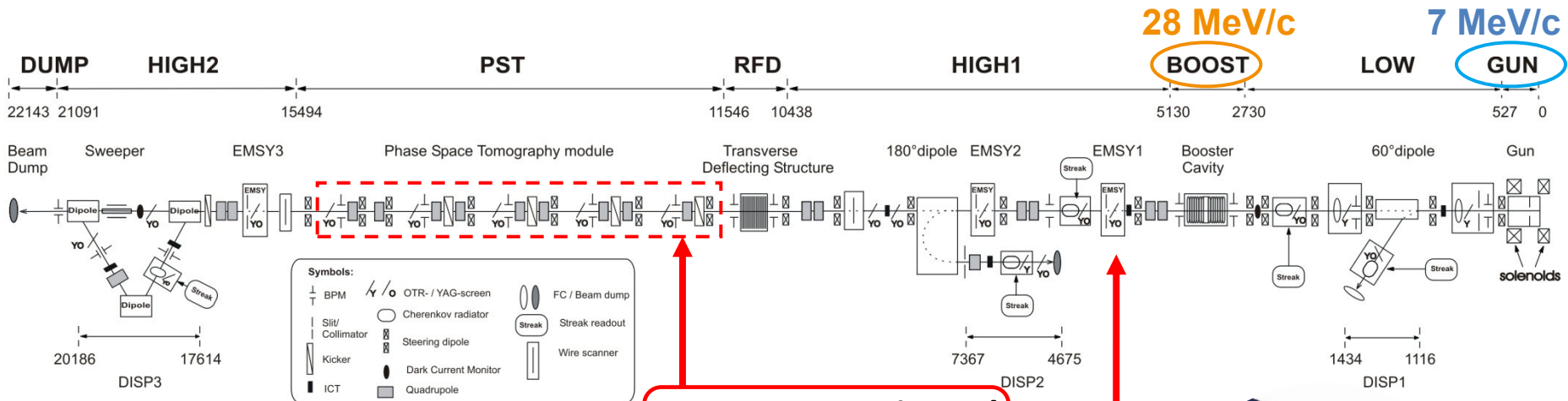


- 14-cell CDS cavity (normal conducting)
- max gradient 14MV/m
- maximum momentum 40MeV/c (nominal  $> 25\text{MeV/c}$ )

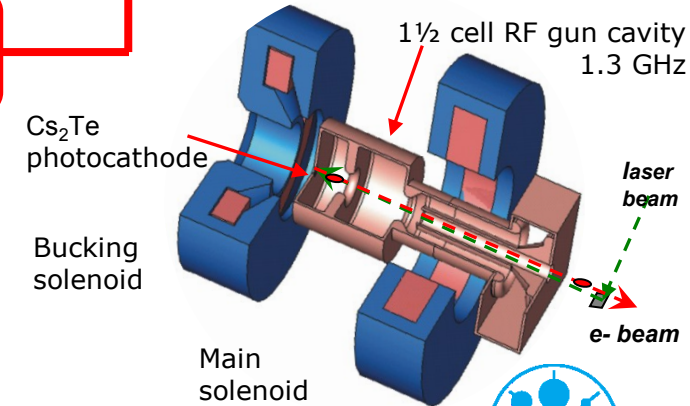
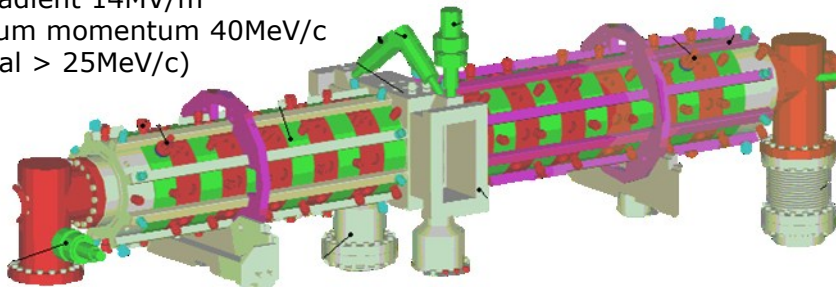


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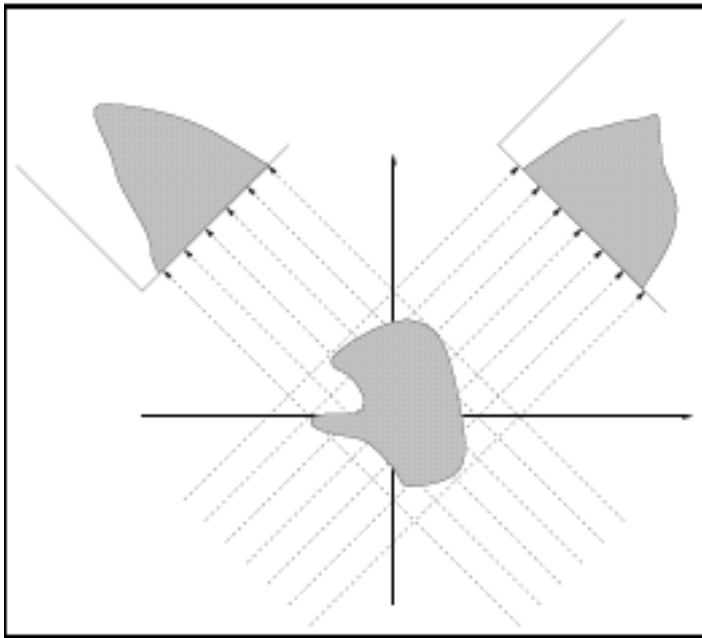


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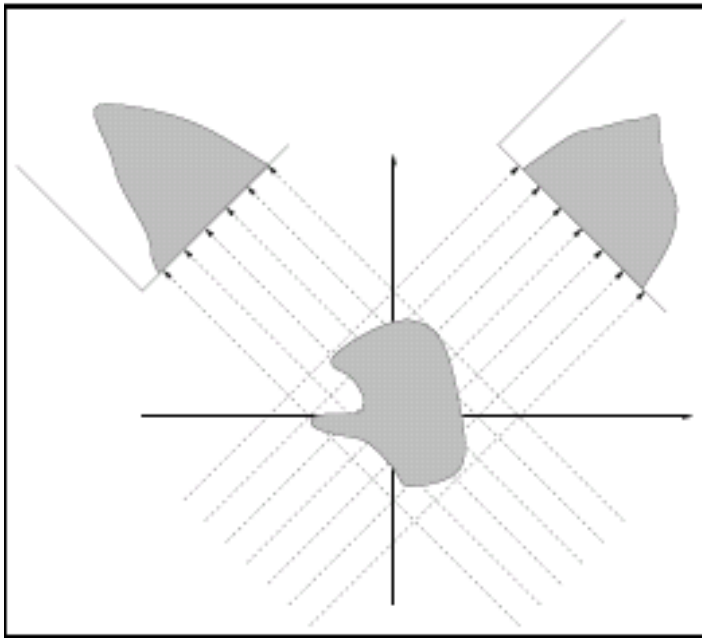
Radon transform ->

Reconstruction of an object from  
its projections at different angles

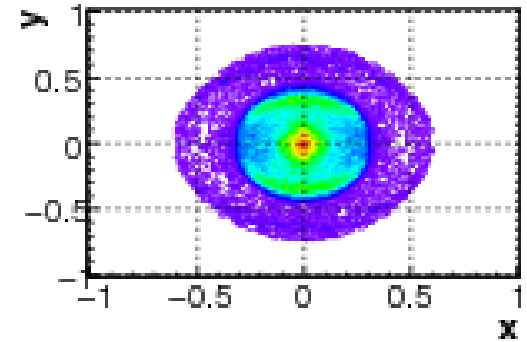


Radon transform ->

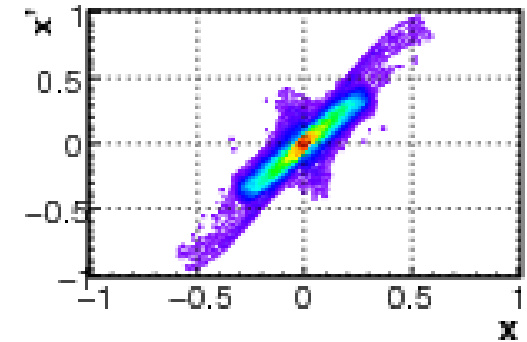
Reconstruction of an object from its projections at different angles



Real space

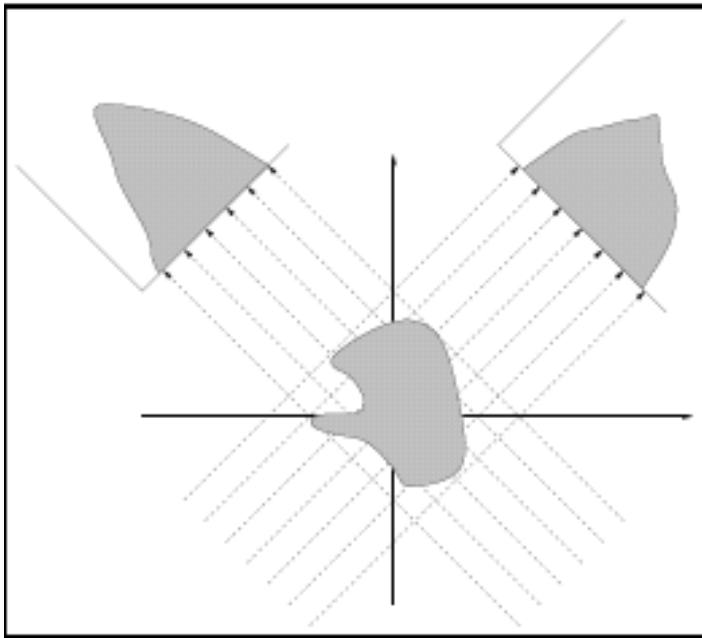


Phase space

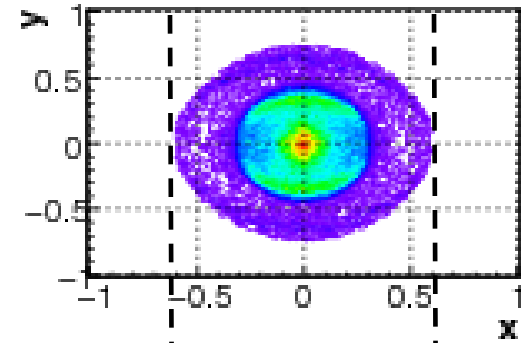


Radon transform ->

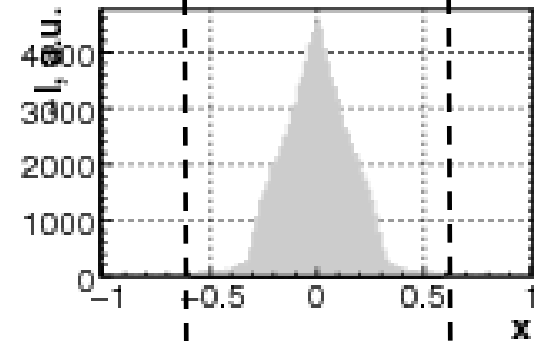
Reconstruction of an object from its projections at different angles



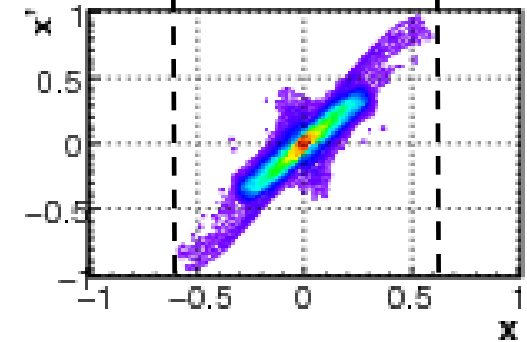
Real space



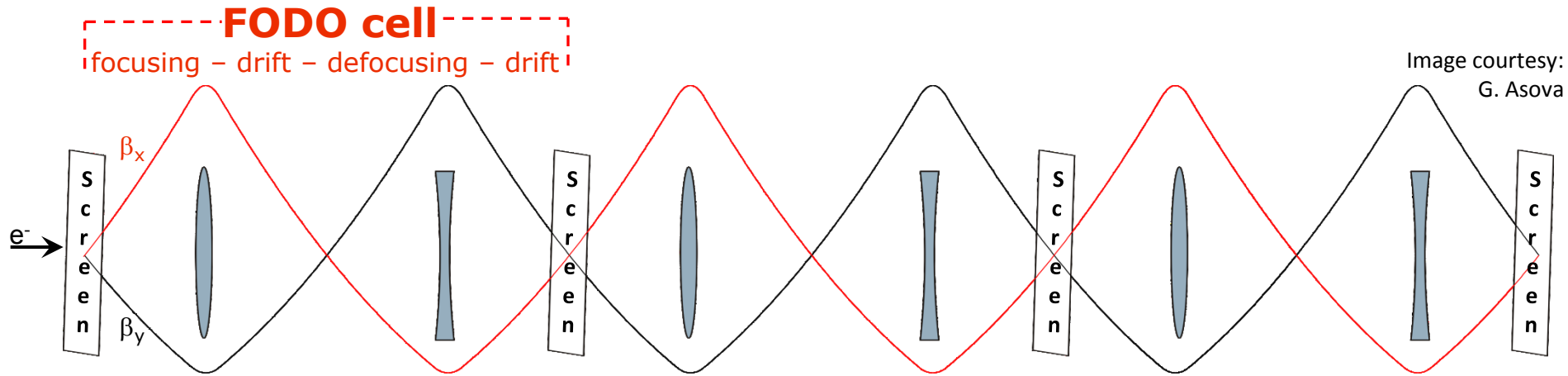
common projection  
in each axis (X/Y)



Phase space



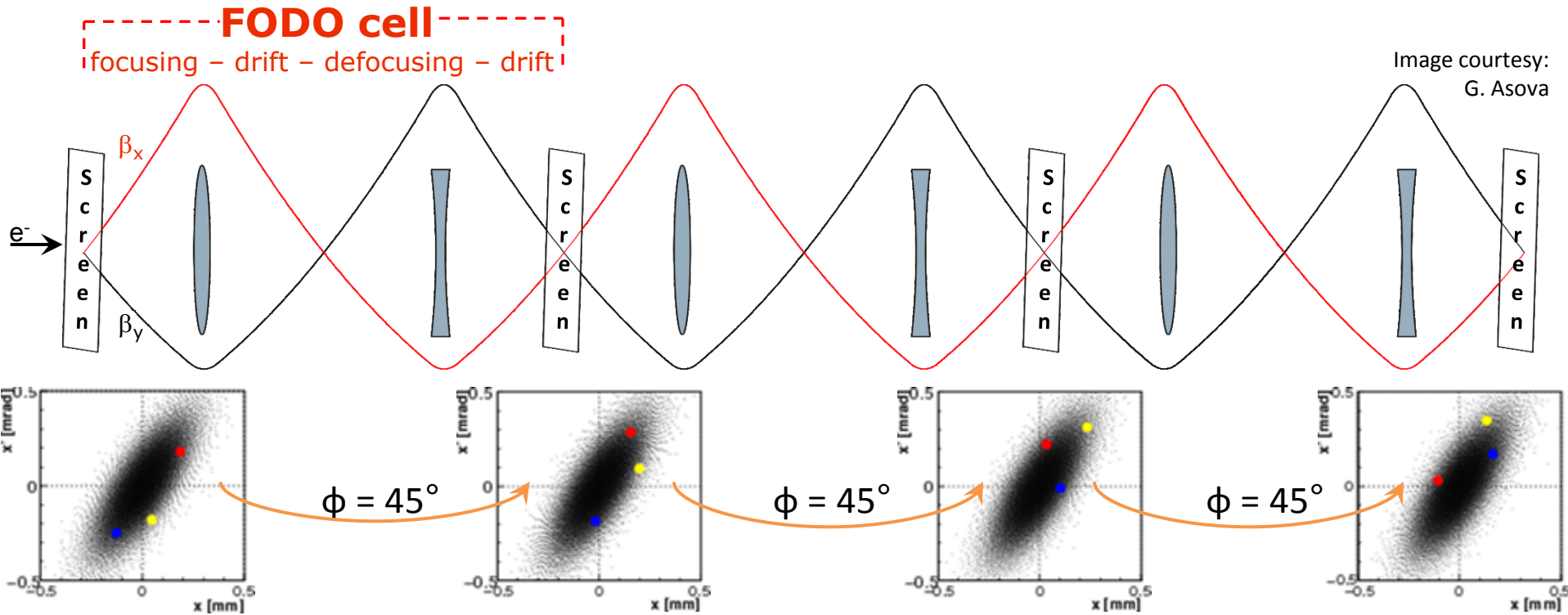
# Tomographic reconstruction of the phase space



> **Quadrupoles**, forming a FODO lattice, oppose a  $180^\circ$  **rotation** in the phase space

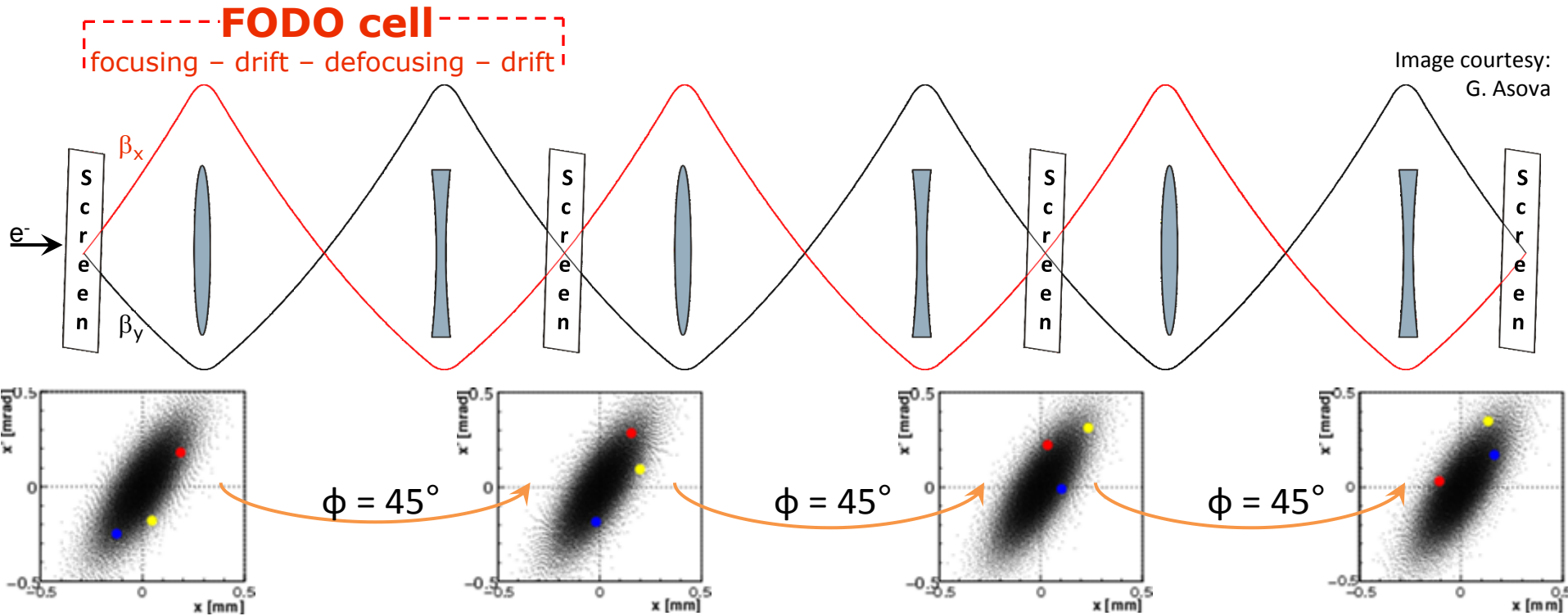


# Tomographic reconstruction of the phase space



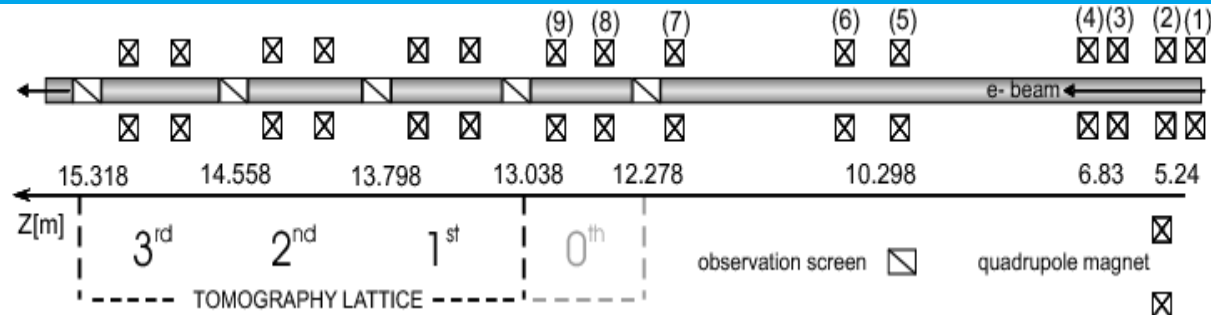
- **Quadrupoles**, forming a FODO lattice, oppose a  $180^\circ$  **rotation** in the phase space
- Screens capture projections, where **beta** value (beam size) and **phase advance** (projection angle) are **constant**

# Tomographic reconstruction of the phase space

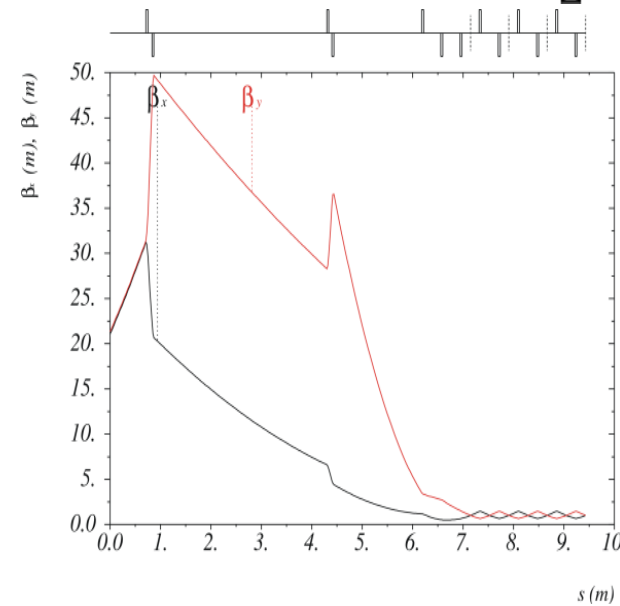


- **Quadrupoles**, forming a FODO lattice, oppose a  $180^\circ$  **rotation** in the phase space
- Screens capture projections, where **beta** value (beam size) and **phase advance** (projection angle) are **constant**
- **Reconstruction** from the corresponding **transform matrices**, using the Maximum ENTropy algorithm (**MENT**)

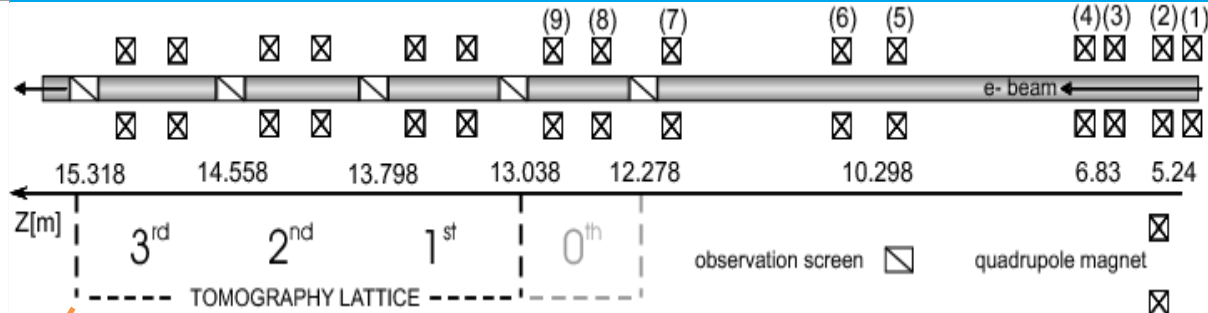
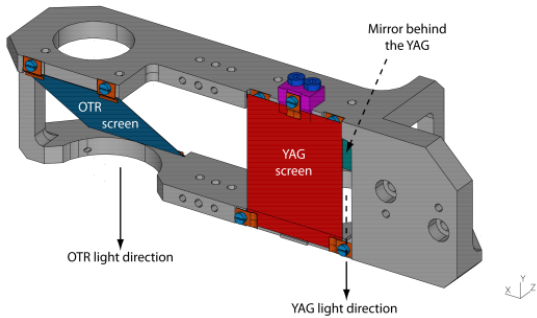
# Hardware description



- > Matching section: Short quadrupoles, with strong focusing



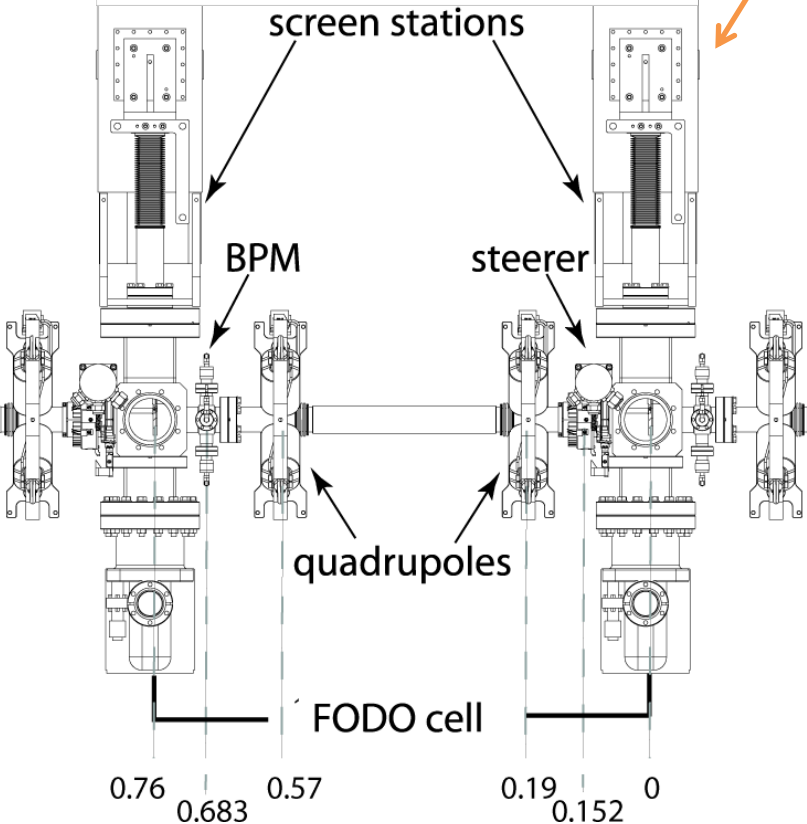
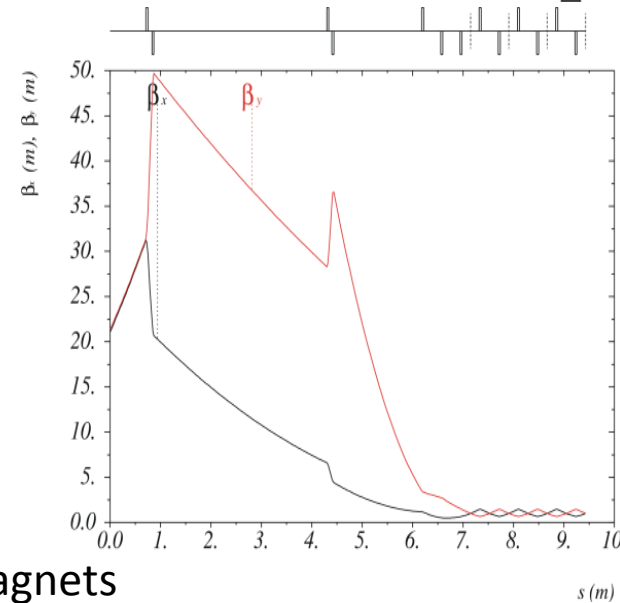
# Hardware description



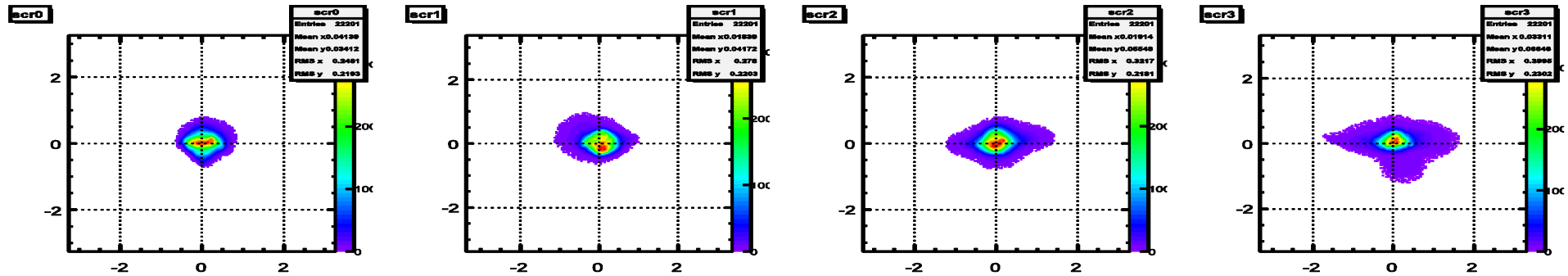
> Matching section:  
Short quadrupoles,  
with strong focusing

> FODO cells:

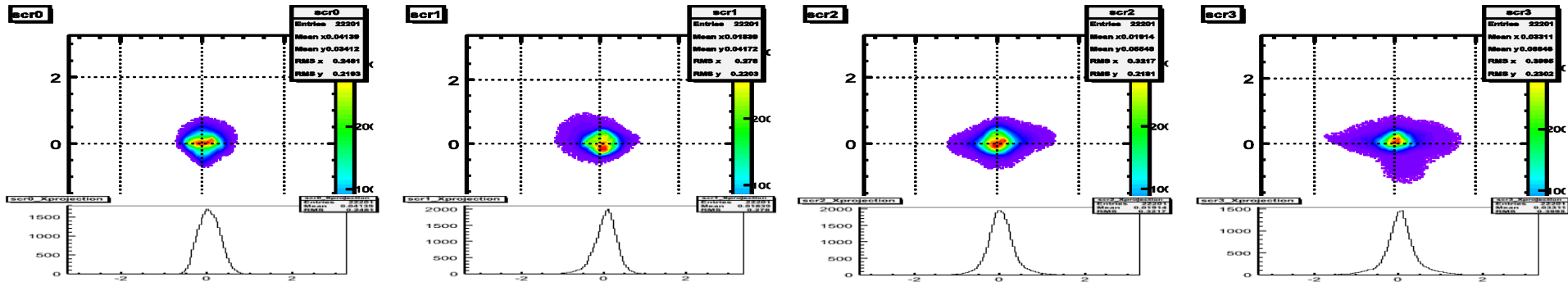
- Quadrupole magnets
- Screen stations
- Steering magnets
- BPMs



## 1. Screen projections

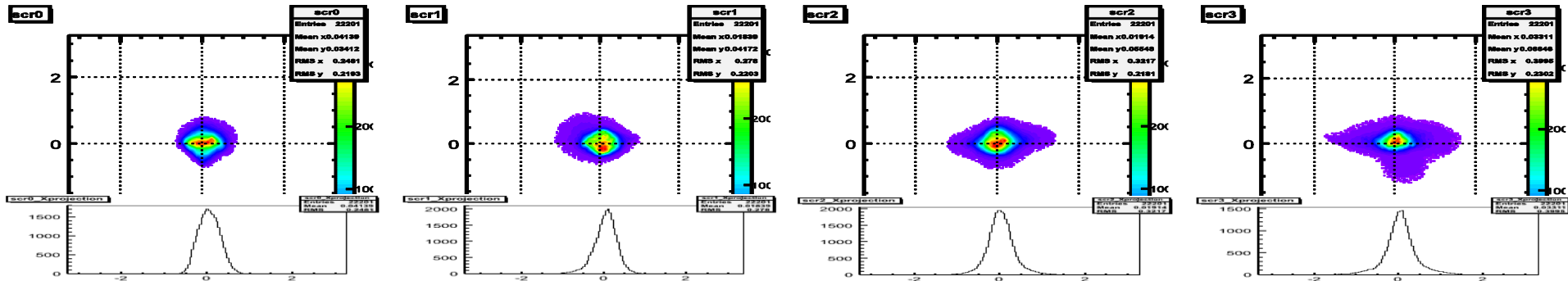


## 1. Screen projections



## 2. Axis projections (X + Y)

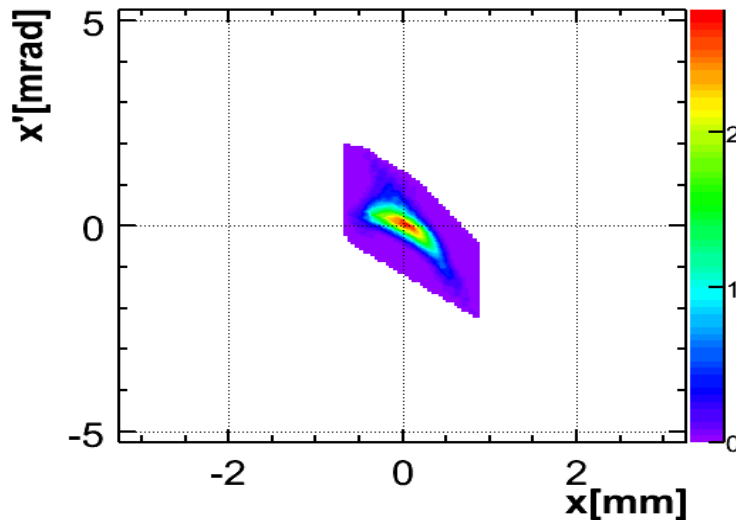
## 1. Screen projections



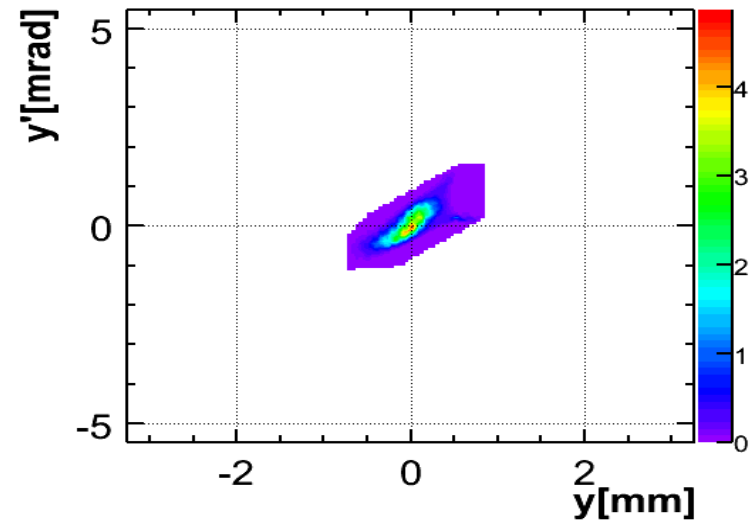
## 2. Axis projections (X + Y)

## 3. Algorithmic reconstruction of the phase space

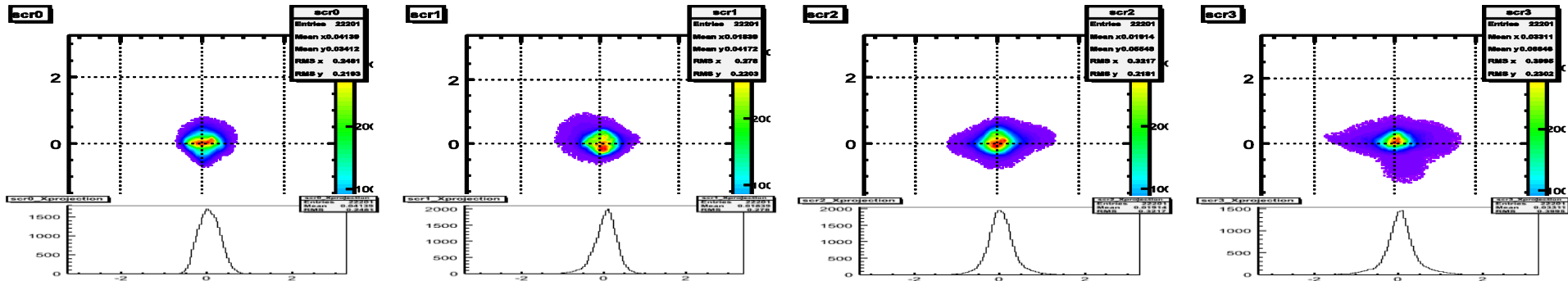
$\epsilon_x = 3.885 \text{ mm mrad}$



$\epsilon_y = 2.473 \text{ mm mrad}$



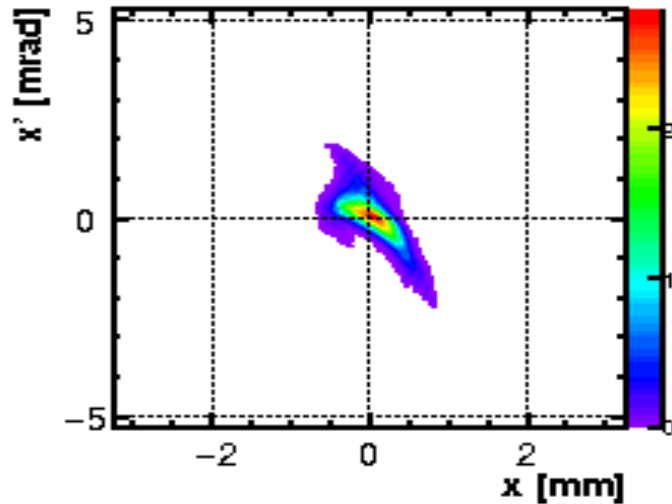
## 1. Screen projections



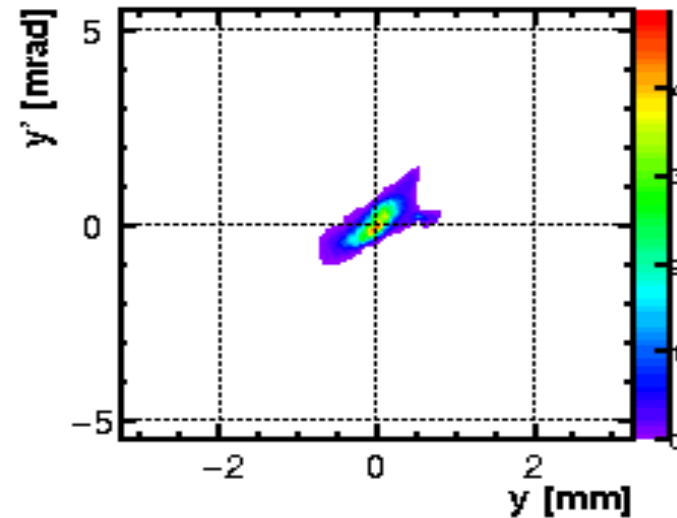
## 2. Axis projections (X + Y)

## 3. Algorithmic reconstruction of the phase space (0.1% Intensity cut)

$\epsilon_x = 3.869 \text{ mm mrad}, Q = 0.999 \text{ nC}$



$\epsilon_y = 2.462 \text{ mm mrad}, Q = 0.999 \text{ nC}$

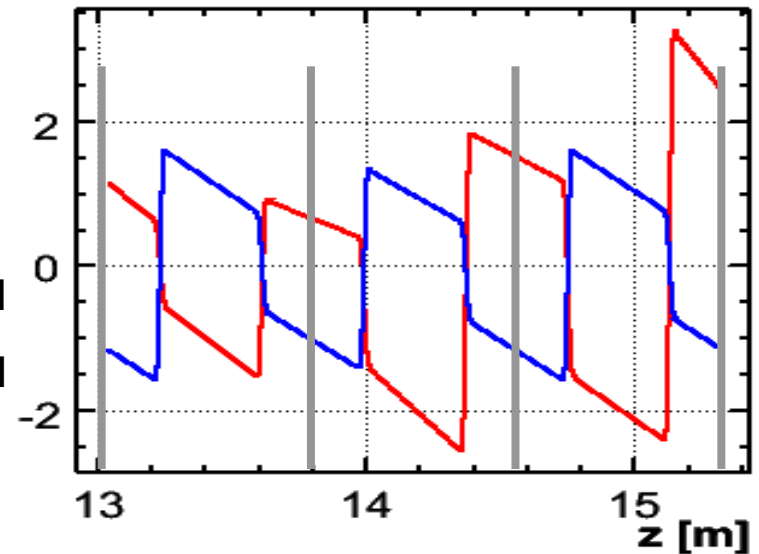
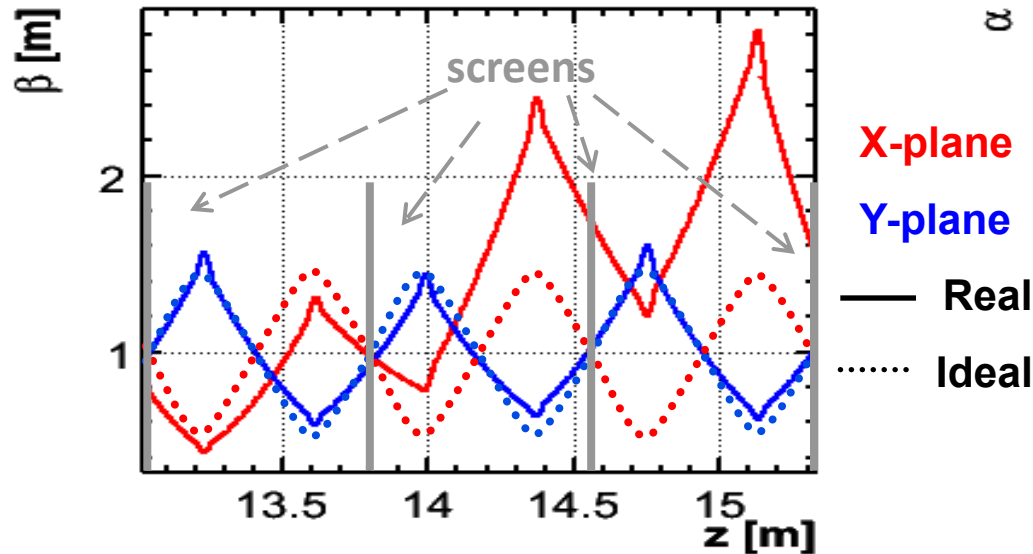




> Is the beam well matched in the 4 screens?

- Compare twiss parameters with the design values
- Evaluate mismatch: for  $\Delta\beta < 20\%$  a solution can always be found

Design Parameter	x-plane	y-plane
$\beta$	0.999	0.999
$\alpha$	-1.125	1.125



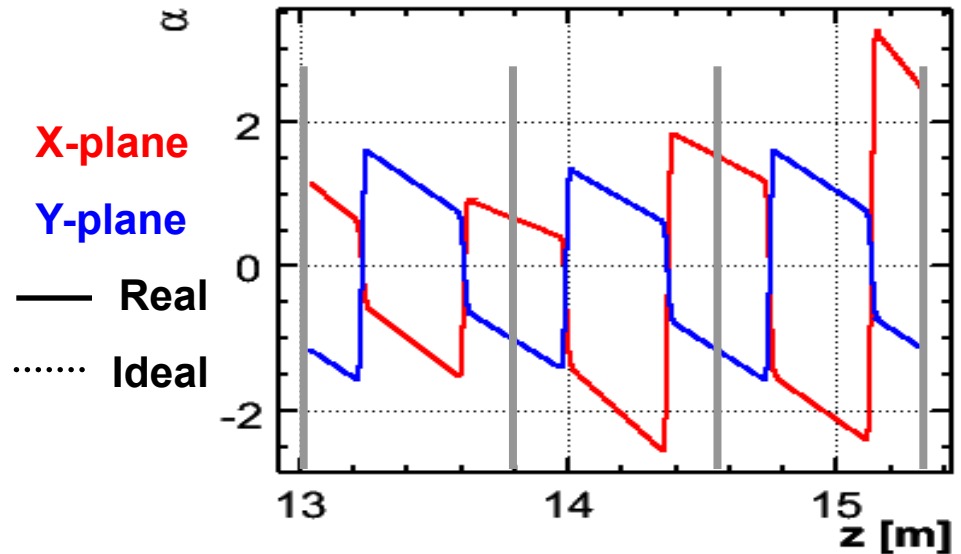
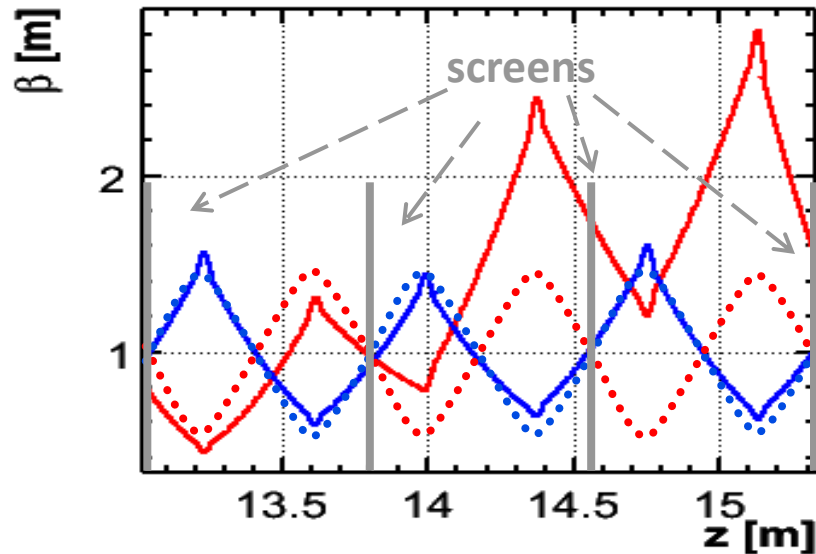
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> Emittance value validation:

- Slit-scan measurements
- Simulations (ASTRA software)



## + Advantages:

- Only one pulse needed -> **reduced Signal-to-Noise** ratio
- Two **transverse planes** can be resolved **simultaneously**

## - Space-charge influence not included:

- Beam characteristics: low emittance, high charge density, moderate energy
- Matching section: strong impact -> **not precise matching** -> manual adjustment
- FODO lattice: emittance dominated region, but small discrepancies in phase calculations -> **not precise reconstruction**

## > Implementations needed:

- Incorporate space-charge impact for the matching procedure
- Refine transport matrix calculations for the phase space reconstruction

- > The tomography module in PITZ is able to **measure** the **phase space** of an electron bunch with **advanced features**
- > Main **obstacle**: Space-charge impact
- > Next **goals** and **improvements**:
  - Include space-charge effect ->
    - 5 available projections instead of 4, due to better matching
    - better reconstruction results
  - Installation of pulse kickers -> measurements of a single pulse from a bunch train

Thanks to G. Asova and the PITZ group.

**THE END.**

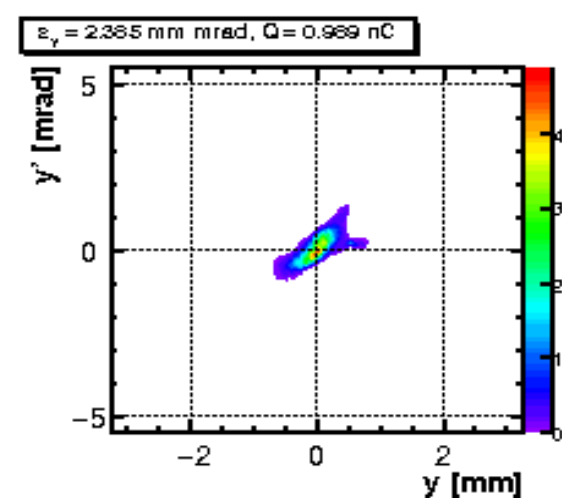
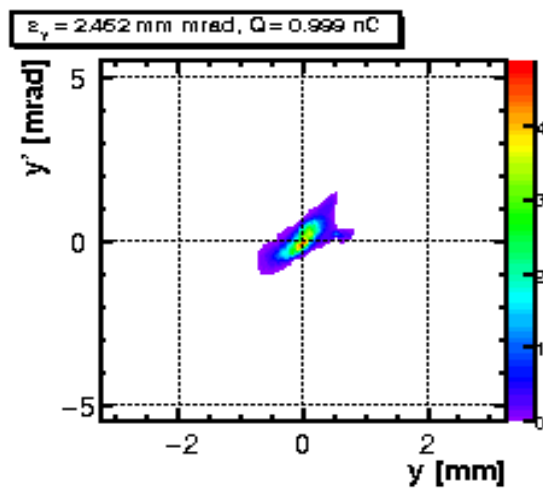
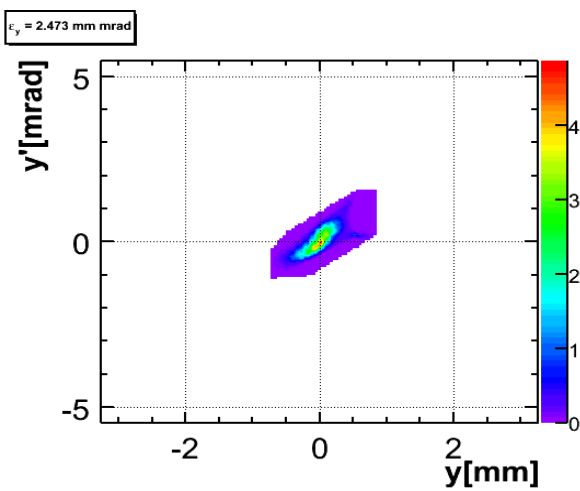
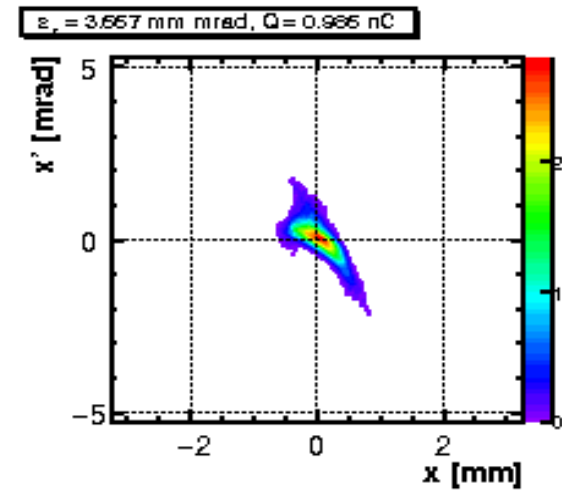
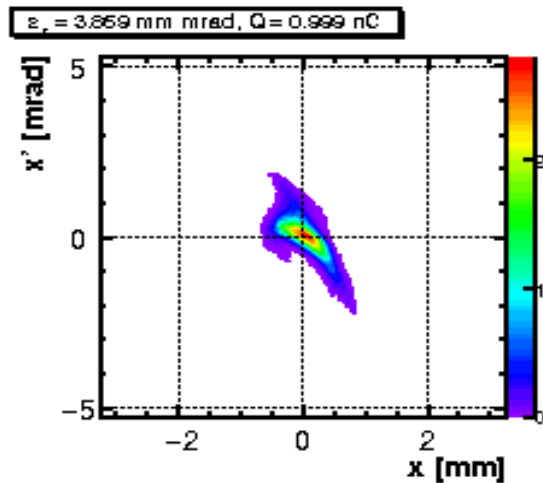
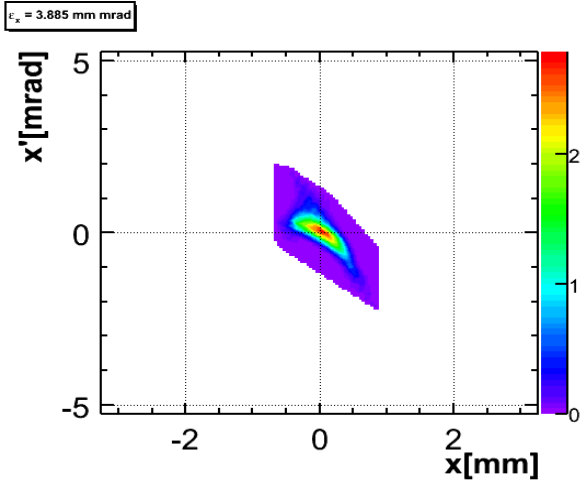
## Backup Slides

# Halo influence on reconstruction

Full charge

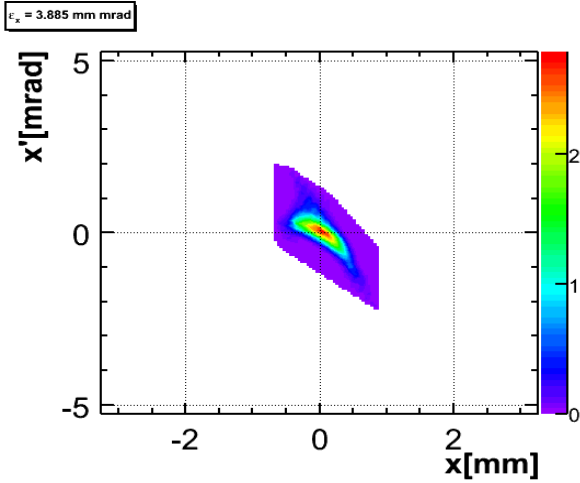
0.1% charge cut

1% charge cut

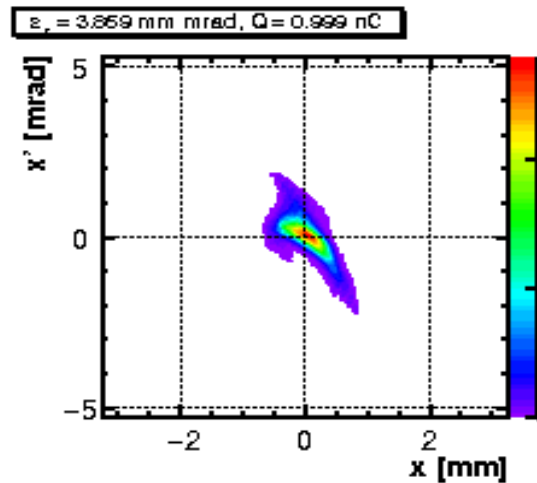


# Hallo influence on reconstruction

Full charge



0.1% charge cut



1% charge cut

