Tomography module for transverse phase-space measurements at PITZ .

> **Photo-Injector Test facility @ DESY in Zeuthen - PITZ**
> **Tomography module**
> **Measurement results**
> **Conclusions and outlook**

G. Asova for the PITZ team

DITANET 2011, Seville

HELMHOLTZ ASSOCIATION
DESY

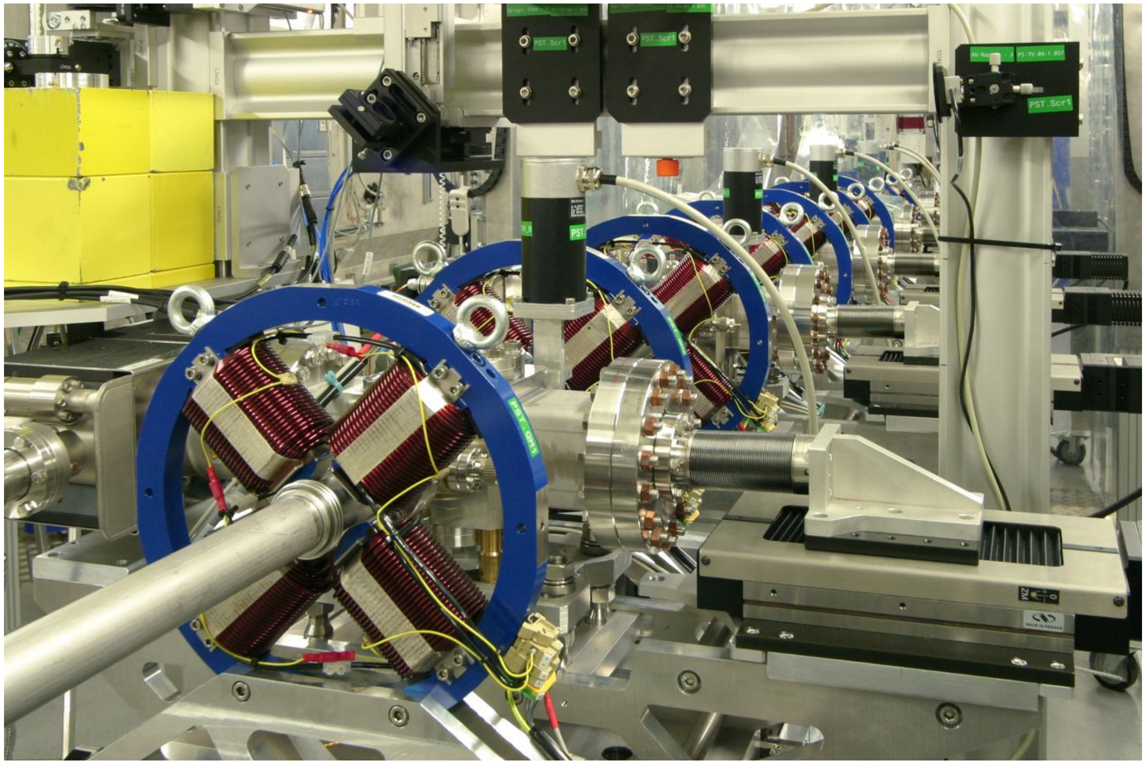
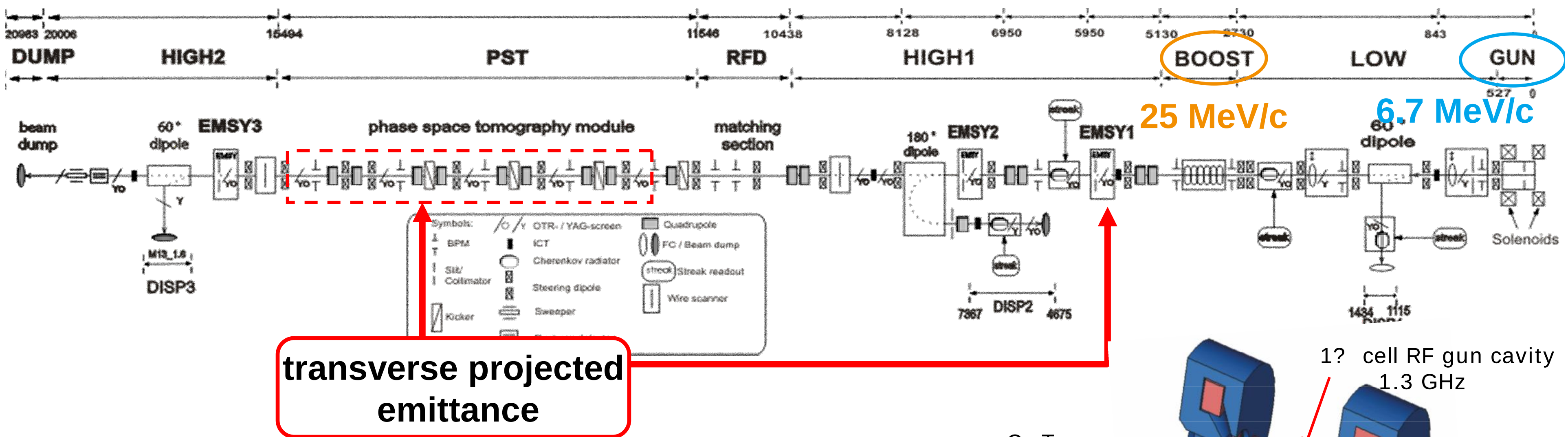
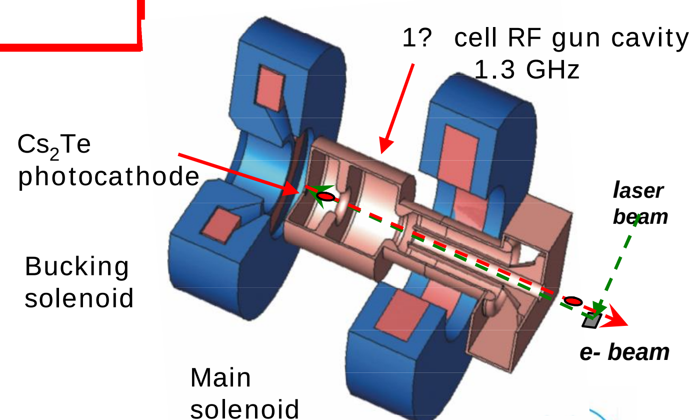


Photo-Injector Test facility

Produce electron beams with minimized transverse emittance as required for the European XFEL photo-injector:

< 1 mm mrad for 1 nC





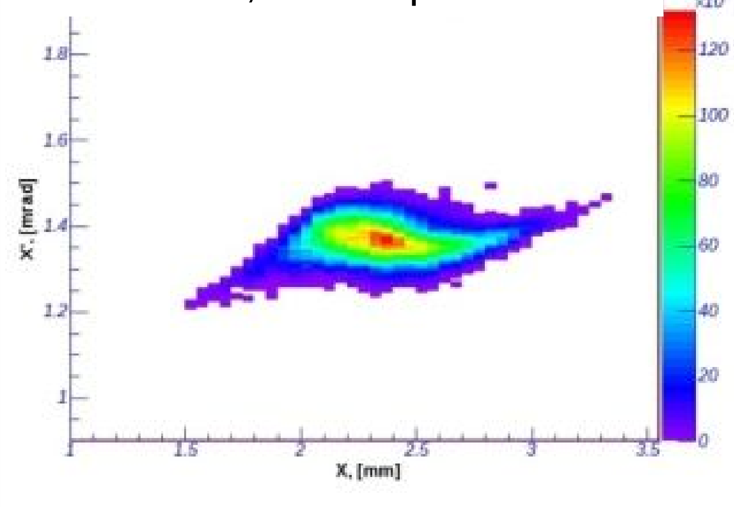
Phase-space portraits

> Standard measurement method – slit scan

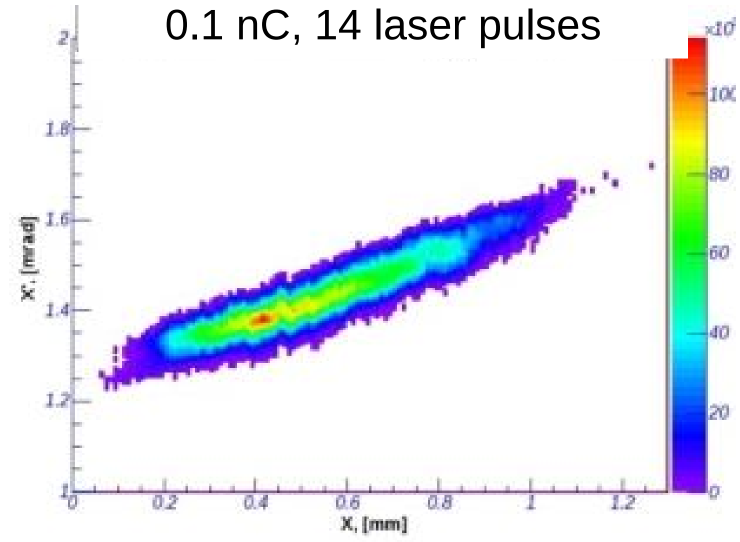
> Separately scan the two transverse planes

> Sensitive to signal-to-noise ratio → multi-shot measurements to collect as full as possible signal → smearing of the phase space due to possible machine fluctuations

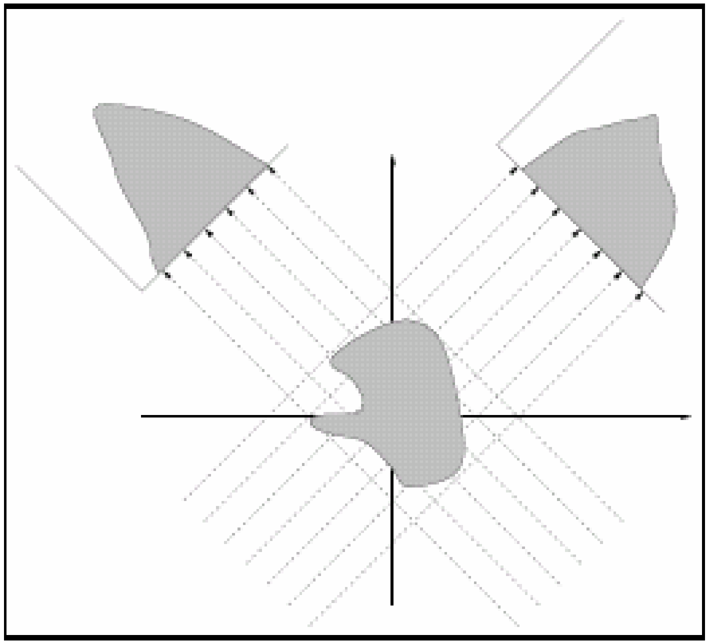
1 nC, 6 laser pulses

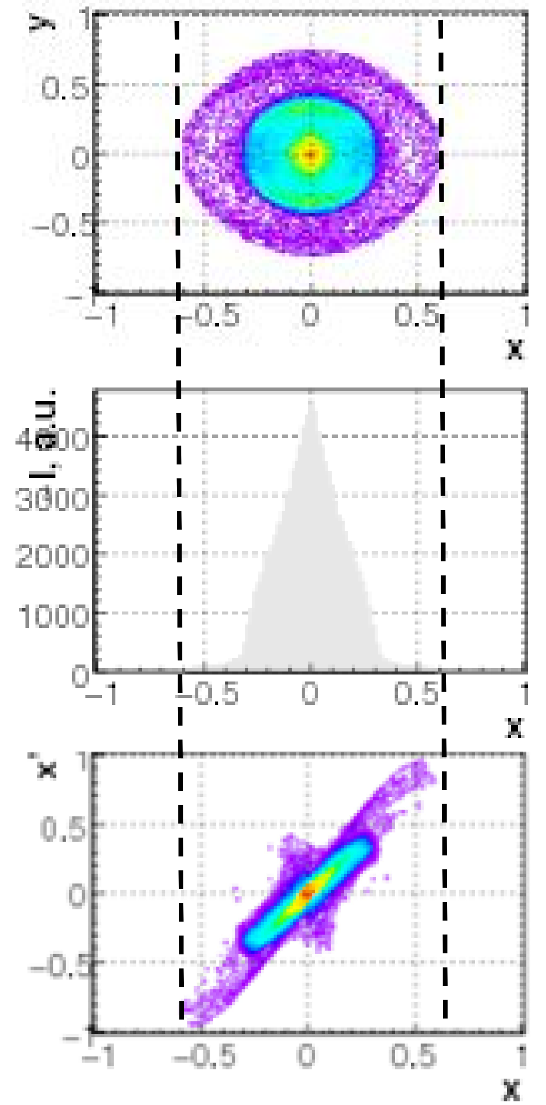


0.1 nC, 14 laser pulses



Tomography

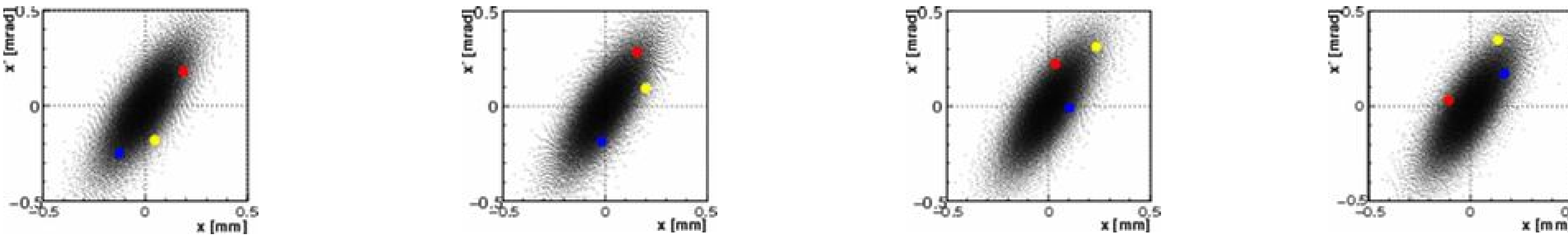


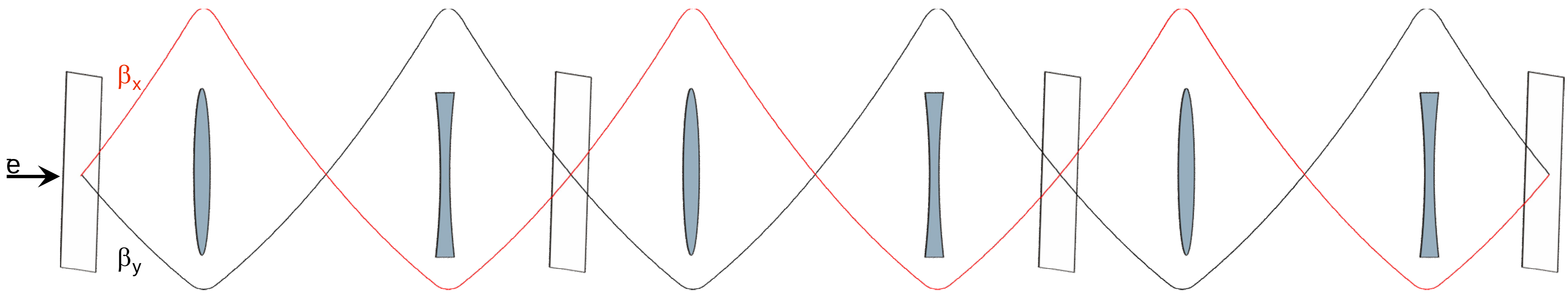


Reconstruction of an object from a number of its projections at different angles -

Radon transform

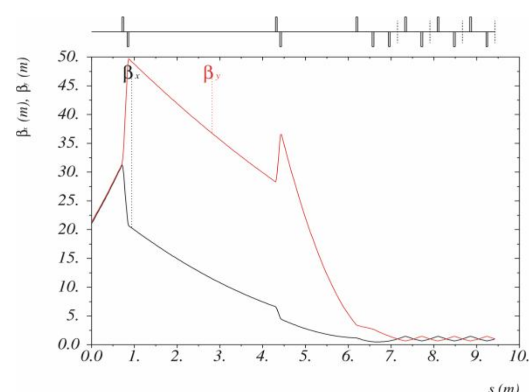
Phase-space tomographic reconstruction





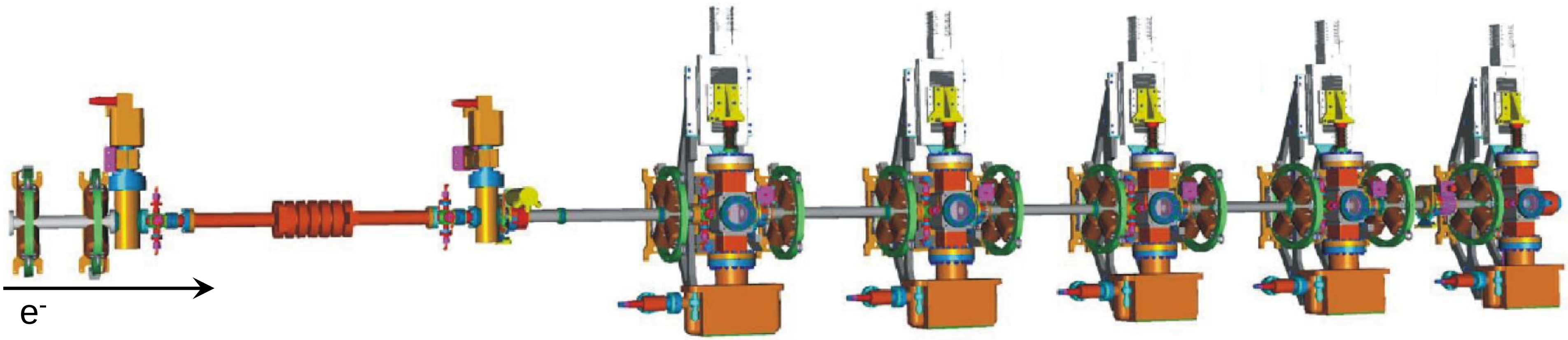
(focusing – drift – defocusing – drift)

FODO cell



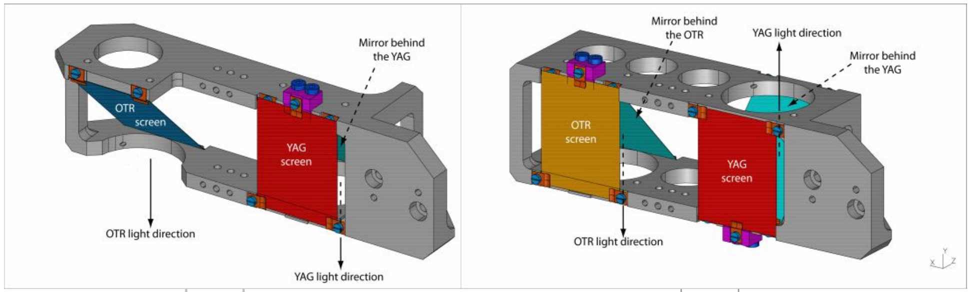
- equidistant angular steps between the screens for both planes (2D)
- the beam parameters at the entrance of the lattice are adjusted

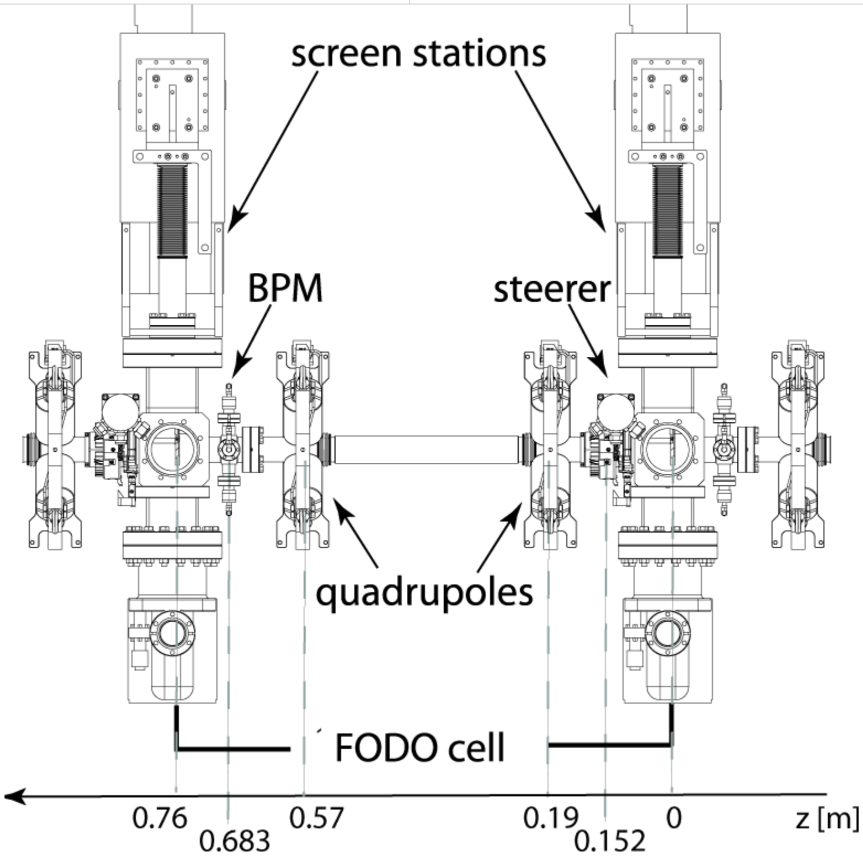
Tomography module



- Design for 15-30 MeV/c, 1 nC
- Challenging matching due to space-charge impact
- Slow and complicated analysis

Major components





x 5 FODO cells

Components (details in poster):

- Quadrupole magnets in FODO cells
- Screen stations
- Steering magnets
- BPMs

Short cells:

- Short quadrupoles L_{eff} = 43 mm
- Strong focusing
- Precise alignment along the full FODO lattice
  - 20 mrad quadrupole angular misalignment
  - 100 μm longitudinal misplacement

Measurements with the setup

> Nominal charge of 1 nC

- Emittance evolution along the beamline- cross check the calculated emittance versus results from slit scans
- Different charge densities at the photo cathode
- Reproducibility of the measurements

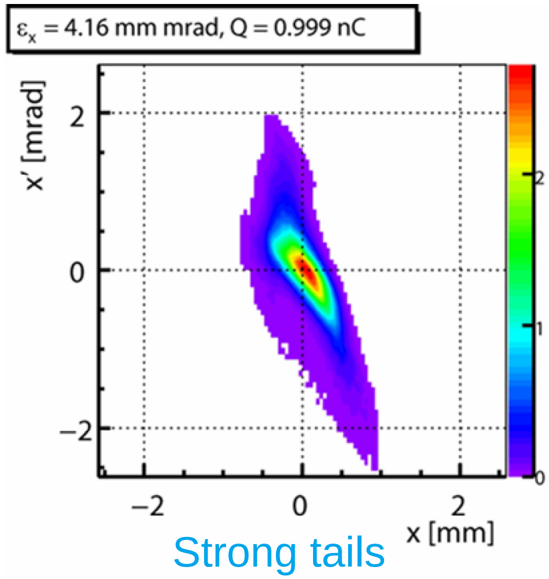
> Lower charges ≥ 100 pC

> Common machine setup:

- Max power from gun and booster, phases for max mean momentum gain, ~ 25 MeV/c
- Laser temporal profile – flat top with 2/22\2 ps

Measured phase spaces, 1 nC

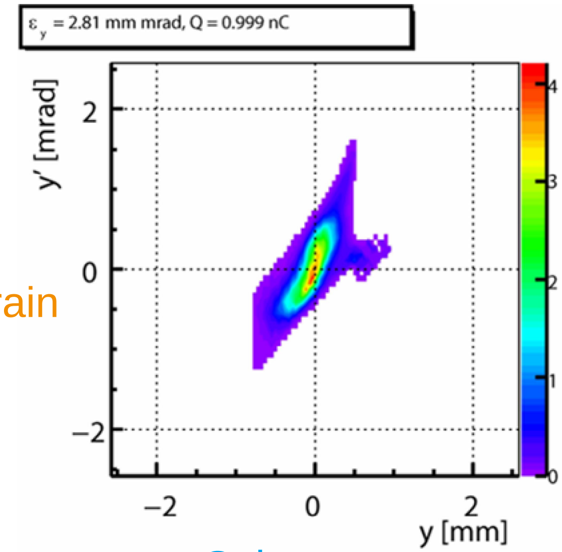
TOMO, z = 13.04 m



Strong tails

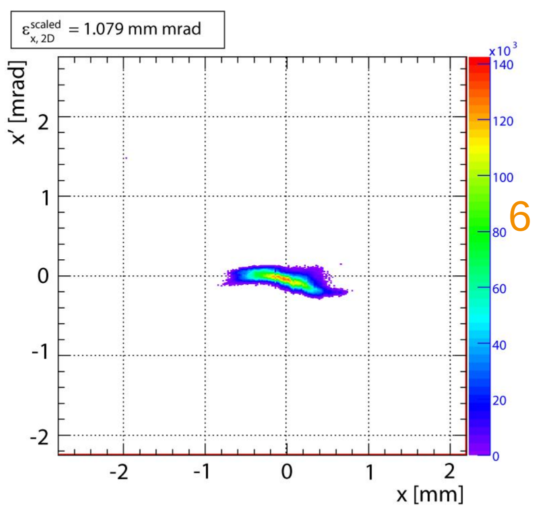
Orthogonal!

1 bunch in the train

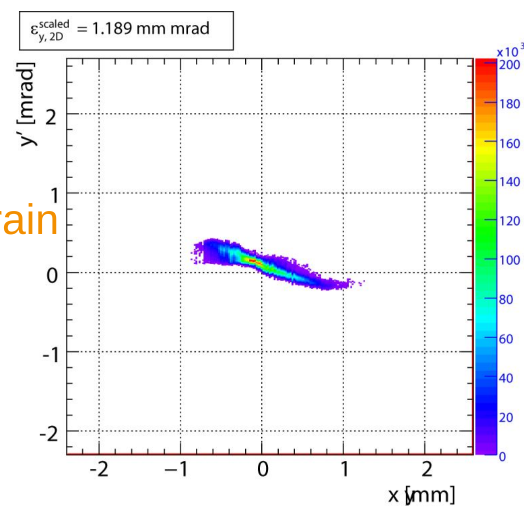


Substructure

Slit scans, z = 5.74 m

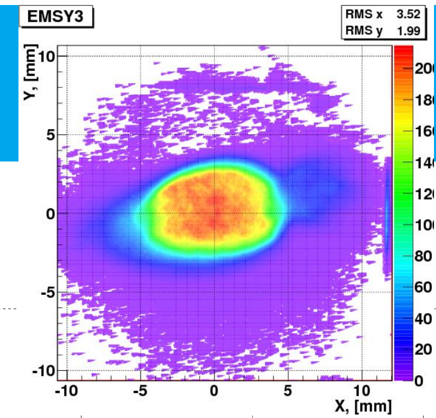


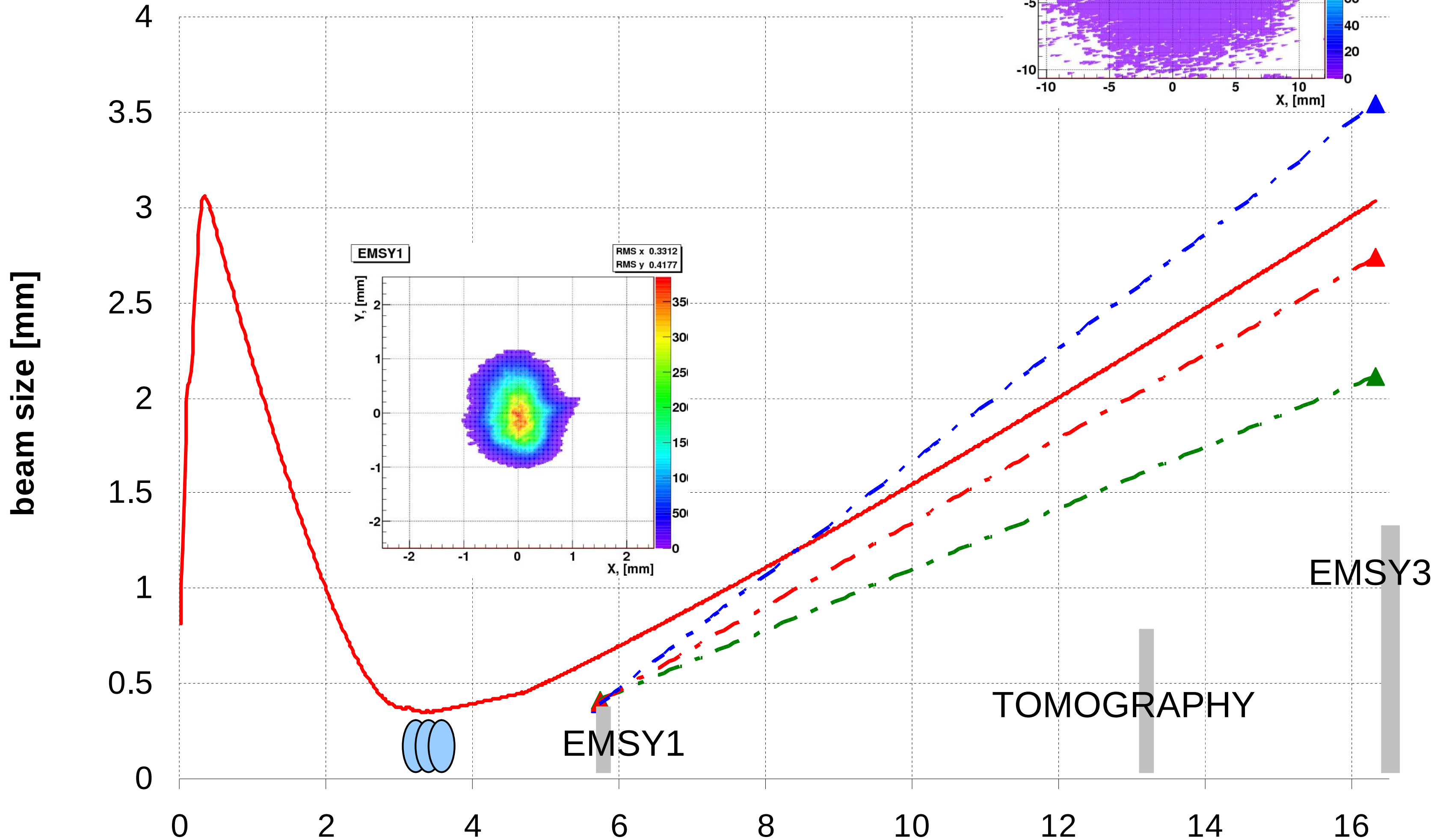
6 bunches in the train



Beam profile along the beamline

1 nC

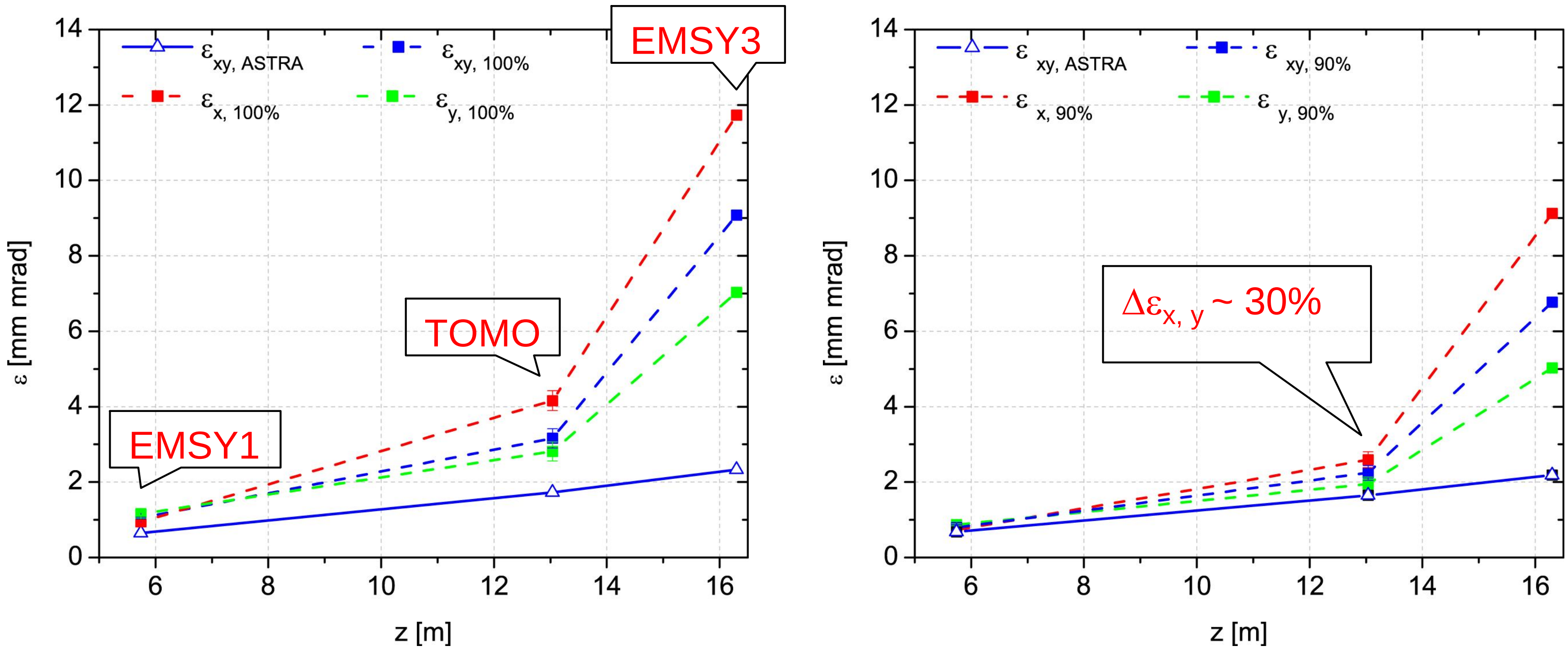




▲ measured σ_x ▲ measured σ_y ▲ measured σ_{xy} — simulated σ_{xy}

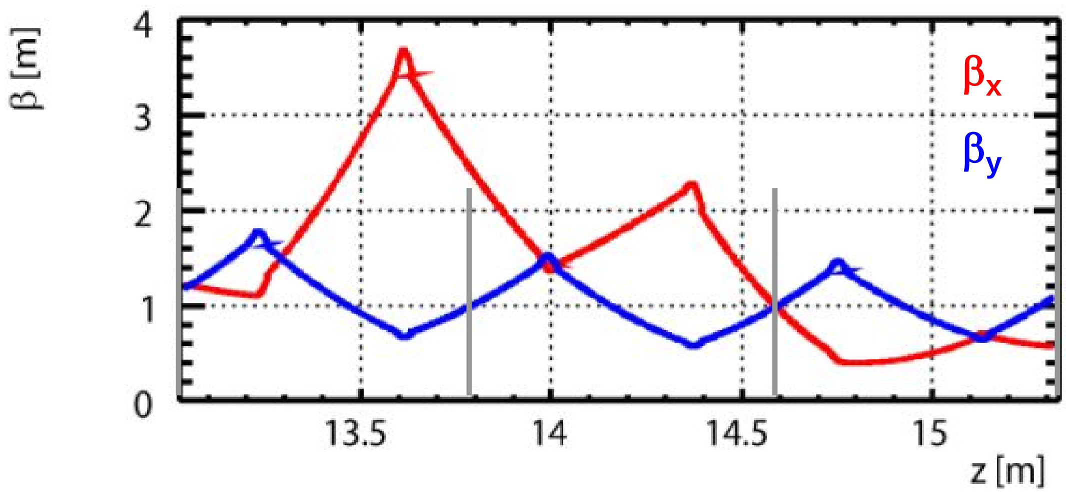
Emittance evolution along the beamline

1 nC



Matching for 1 nC, 25 MeV/c

> Hard to keep both planes periodic along the FODO lattice



$\Delta\beta_y < 20\%$- for such mismatches a solution can always be found

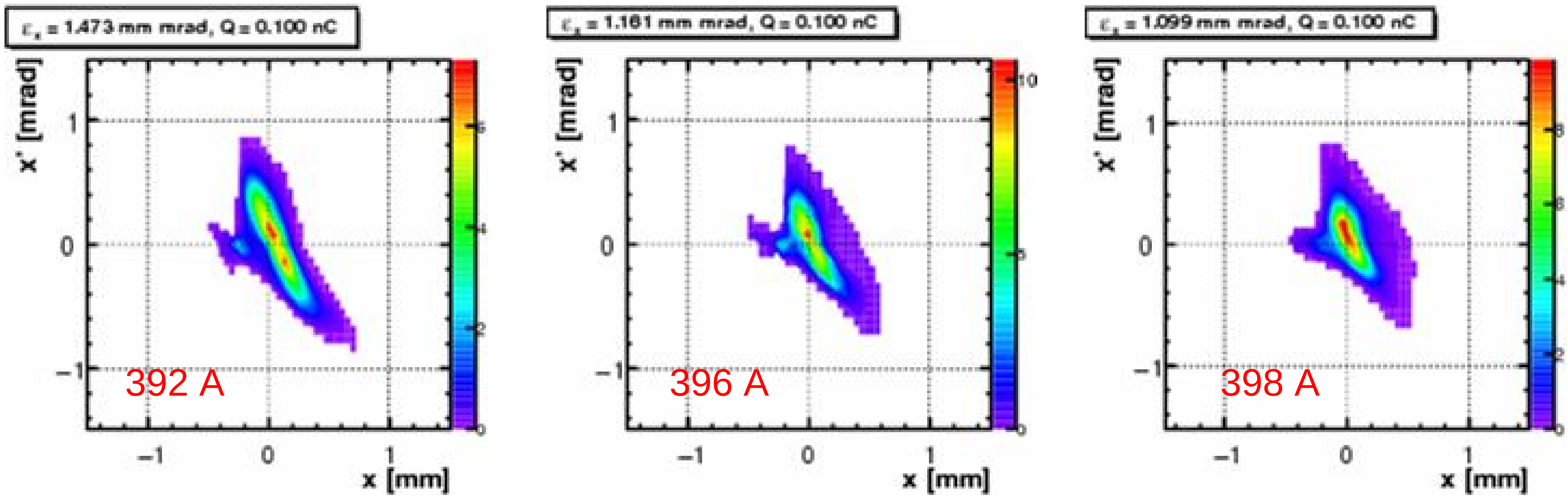
$$\Delta\beta = \frac{\beta_d - \beta_m}{\beta_d} [\%]$$

> β_y matched very good, but not β_x

- consistent for different laser spot sizes, solenoid current, quadrupole settings, bunch charges

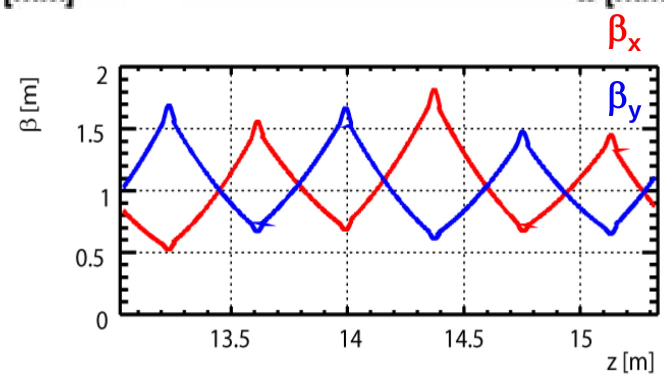
100 pC X-plane

> Emittance decreases with the solenoid focusing



> the orientation of the three distributions

is the same – matching worked in these cases



> As the area of the phase space decreases, the substructure comes closer to the main beam for higher solenoid currents

Conclusions & outlook

- Tomography module successfully commissioned
- Results cross-checked with standard for PITZ slit scans
- Details on the phase spaces downstream the beamline reconstructed in great details for short bunch trains
- The two transverse planes resolved simultaneously

- Kicker magnets to be installed for measurements of selected bunch in the train
- Transverse deflecting cavity for longitudinal phase-space measurements

The PITZ collaboration

Colleagues participating in measurements / new design:

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- **BESSY Berlin:**
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- **ASTeC STFC Daresbury Lab:**
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