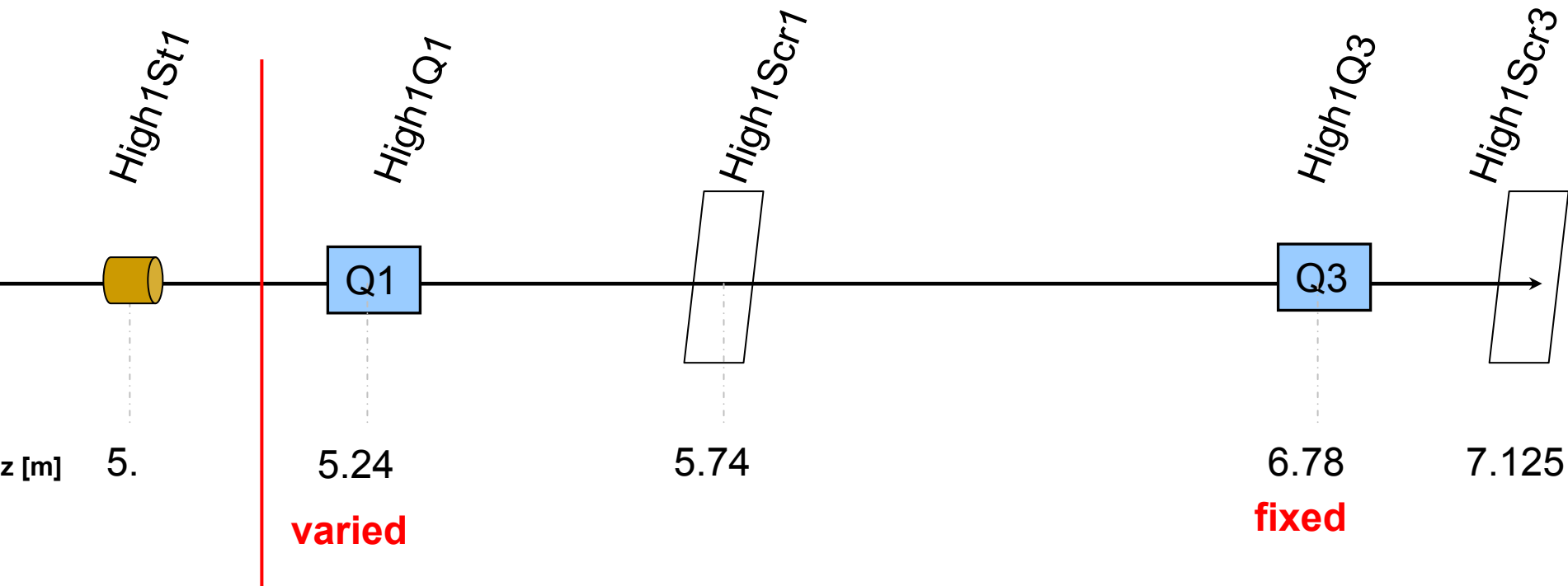# Update on tomography with quadrupole scan data

Setup

500 pC and 1 nC– measurements and simulations

Quadrupole scan setup
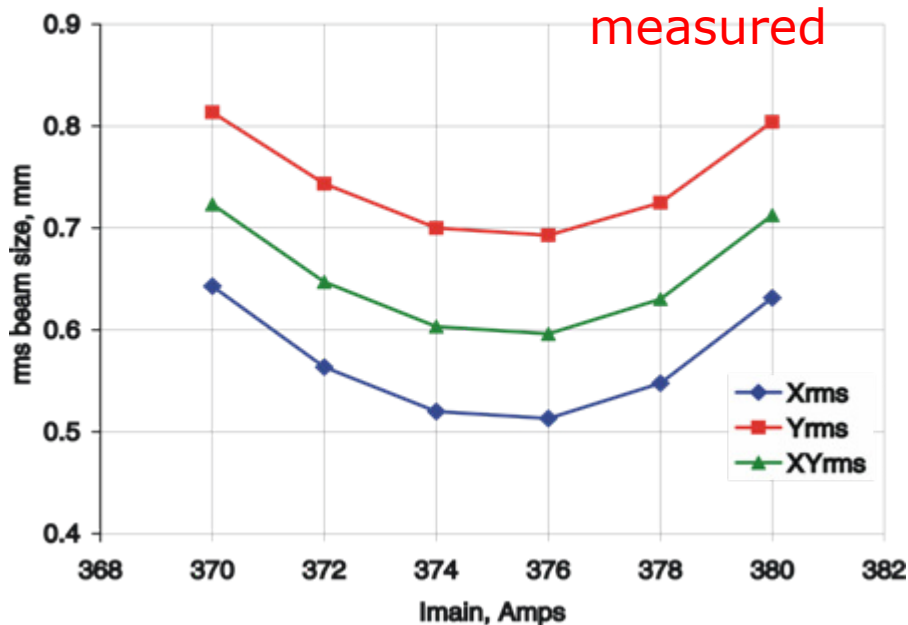

5.15 m – position of reconstruction and then transport to EMSY1

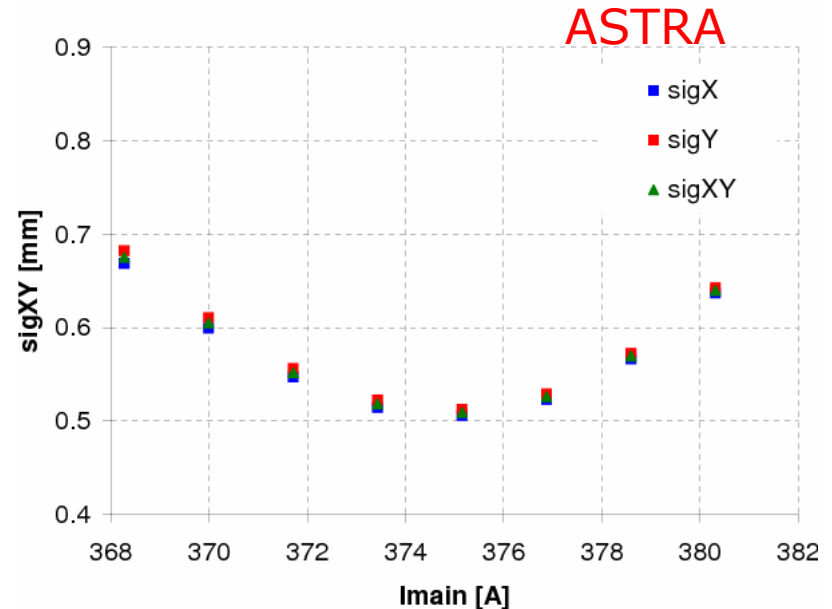**High1Scr3** chosen as the closest screen to the position of reconstruction

Gaussian temporal profile 13 ps, 500 pC

- ϕ_{gun} = -6 deg off crest, $\phi_{booster}$ = on crest
- Solenoid scan at EMSY1
- 3 consequent slit scans for this point (statistics)
- Quad scan for the X-plane
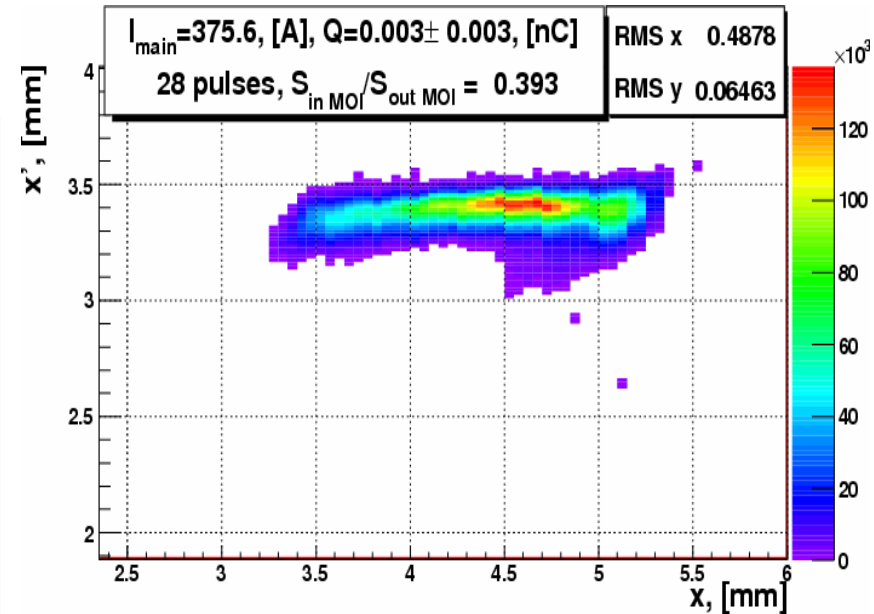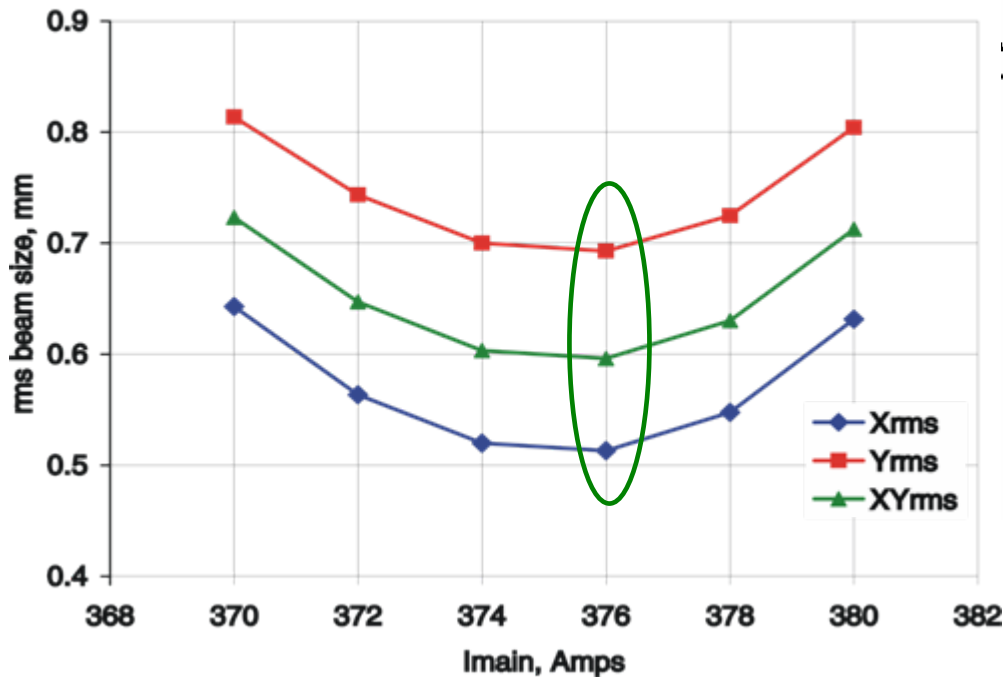
measured

Beam sizes on EMSY1, BSA = 1.5 mm, 500 pC

ASTRA

500 pC @ EMSY1

The focus coincides but not the spot size.

Measurement (x3) for 500 pC
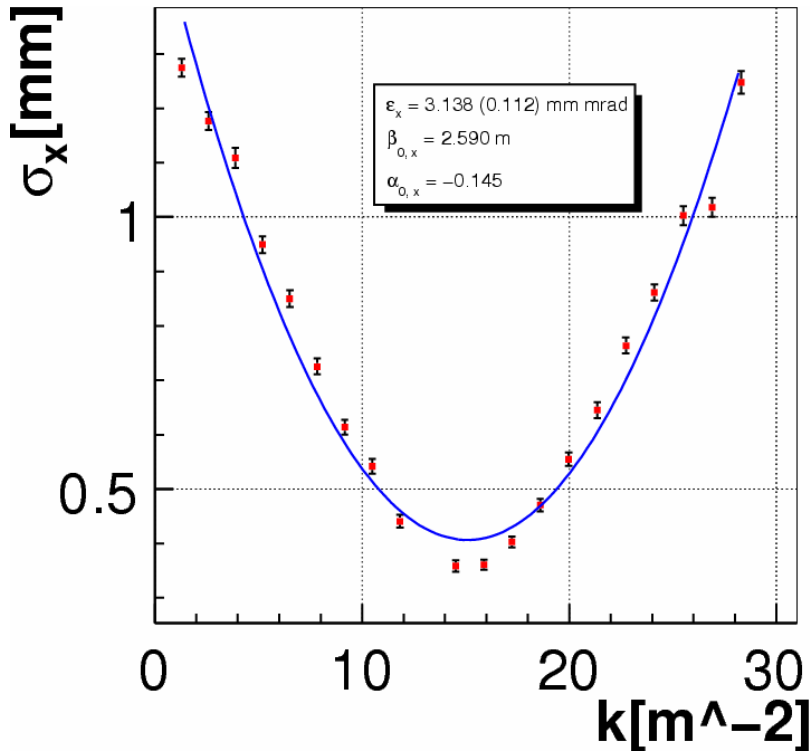

Beam sizes on EMSY1, BSA = 1.5 mm, 500 pC

I_{main}=375.6, [A], Q=0.003± 0.003, [nC] RMS x 0.4878

28 pulses, $S_{in\ MOI}/S_{out\ MOI}$ = 0.393 RMS y 0.06463

σ_x = 0.49 +/- 0.01 mm

$\sigma_{x'}$ = 0.03 +/- 0.001 mrad

$\sigma_{xx'}$ = 0.01 +/- 0.005 mm mrad

$e_{x,\ N}$ = 0.913 +/- 0.025 mm mrad
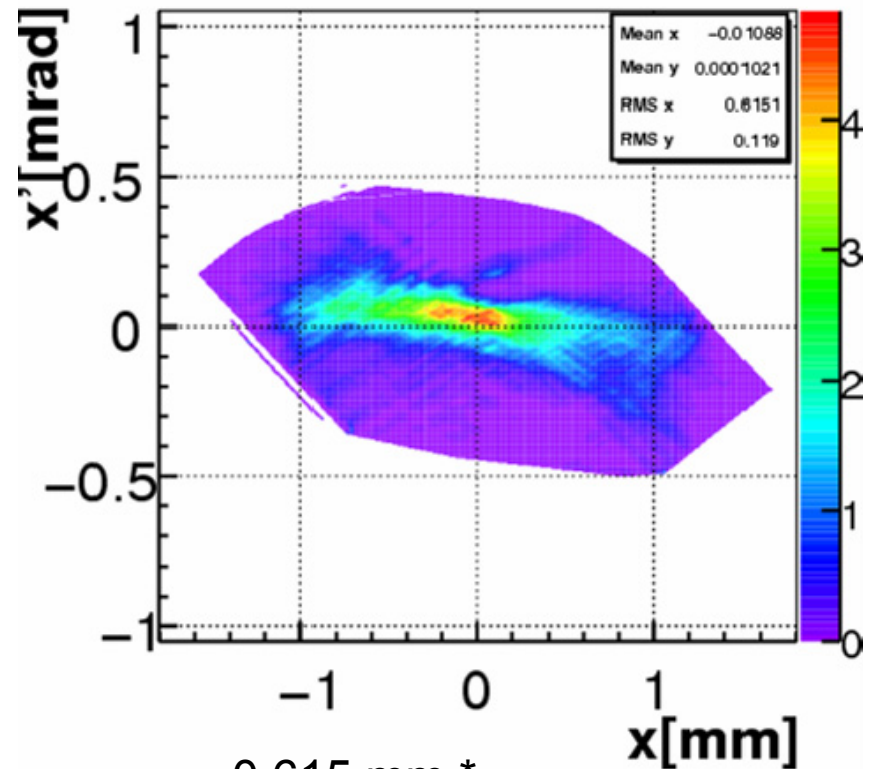
Quadrupole scan

The same data set used for both

ε_x = 3.138 (0.112) mm mrad

$\beta_{0,x}$ = 2.590 m

$\alpha_{0,x}$ = −0.145

σ_x = 0.538 mm *

$\sigma_{x'}$ = 0.210 mrad

$\sigma_{xx'}$ = 0.016 mm mrad

$e_{x,N}$ = 3.138 mm mrad

z = 5.74 m, ASTRA coord., ε_x = 1.823 (0.065) mm mrad

Mean x	−0.01088
Mean y	0.0001021
RMS x	0.6151
RMS y	0.119

σ_x = 0.615 mm *

$\sigma_{x'}$ = 0.119 mrad

$\sigma_{xx'}$ = -0.034 mm mrad
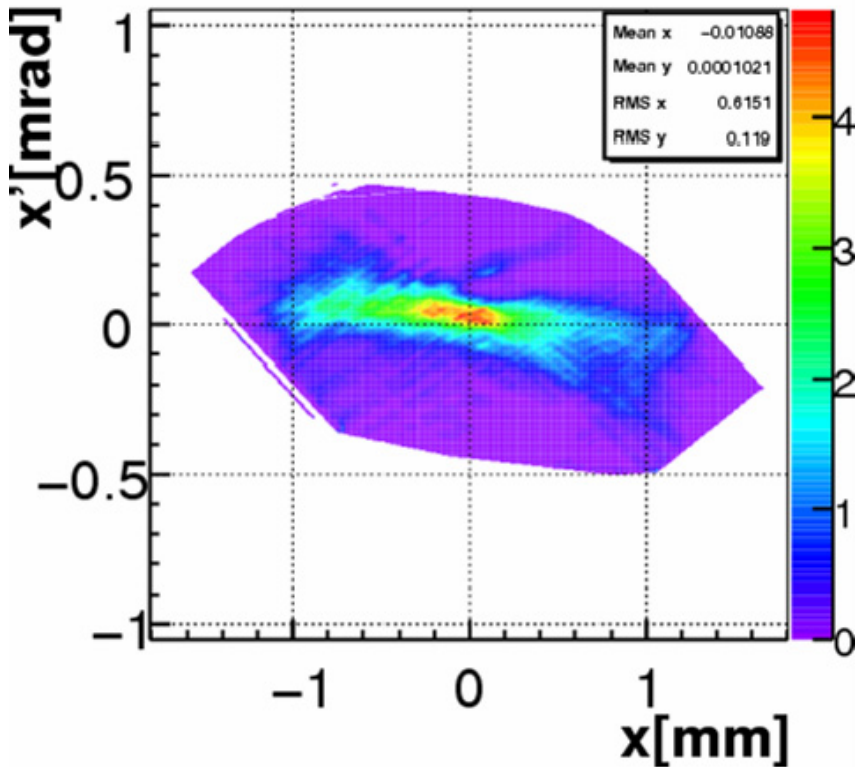
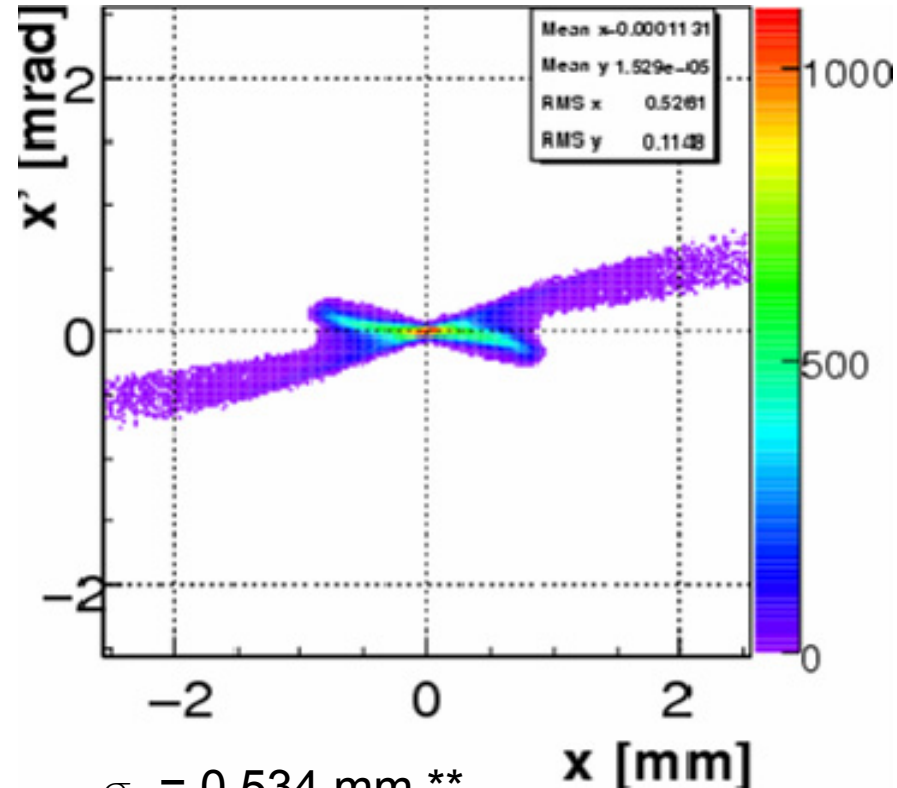$e_{x,N}$ = 1.823 mm mrad   x2 EMSY1

*Measured immediately after the slit scan

Quadrupole scan vs ASTRA @ focus

z = 5.74 m, ASTRA coord., ε_x = 1.823 (0.065) mm mrad

σ_x = 0.615 mm *
$\sigma_{x'}$ = 0.119 mrad
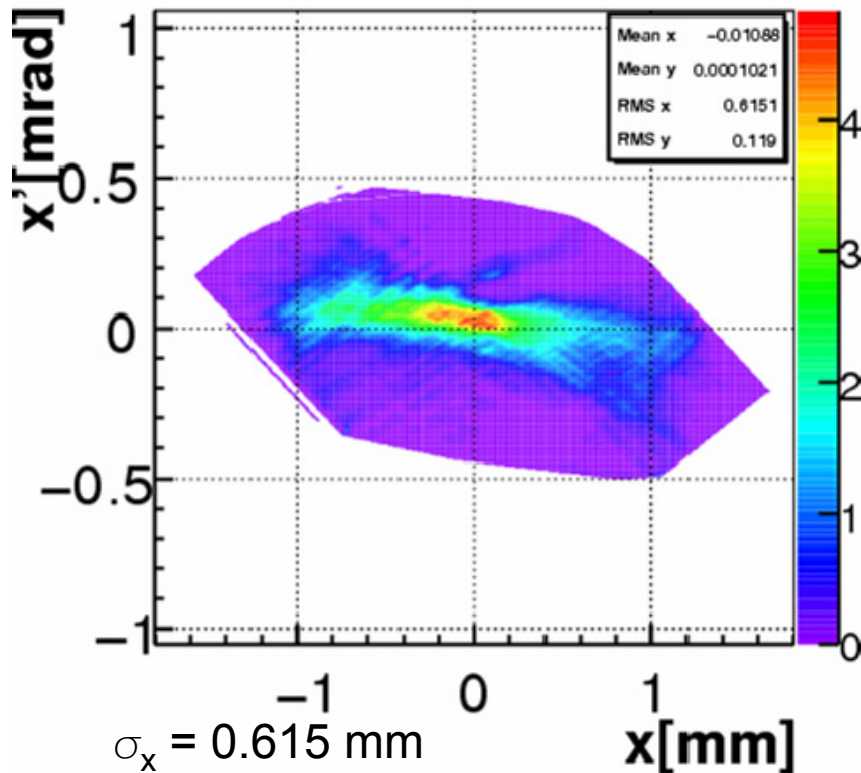$\sigma_{xx'}$ = -0.034 mm mrad
$e_{x, N}$ = 1.823 mm mrad

σ_x = 0.534 mm **
$\sigma_{x'}$ = 0.116 mrad
$\sigma_{xx'}$ = 0.02 mm mrad
$e_{x, N}$ = 1.65 mm mrad

*Tomo values calculated from 2D histogram   **ASTRA values calculated from statisitcs
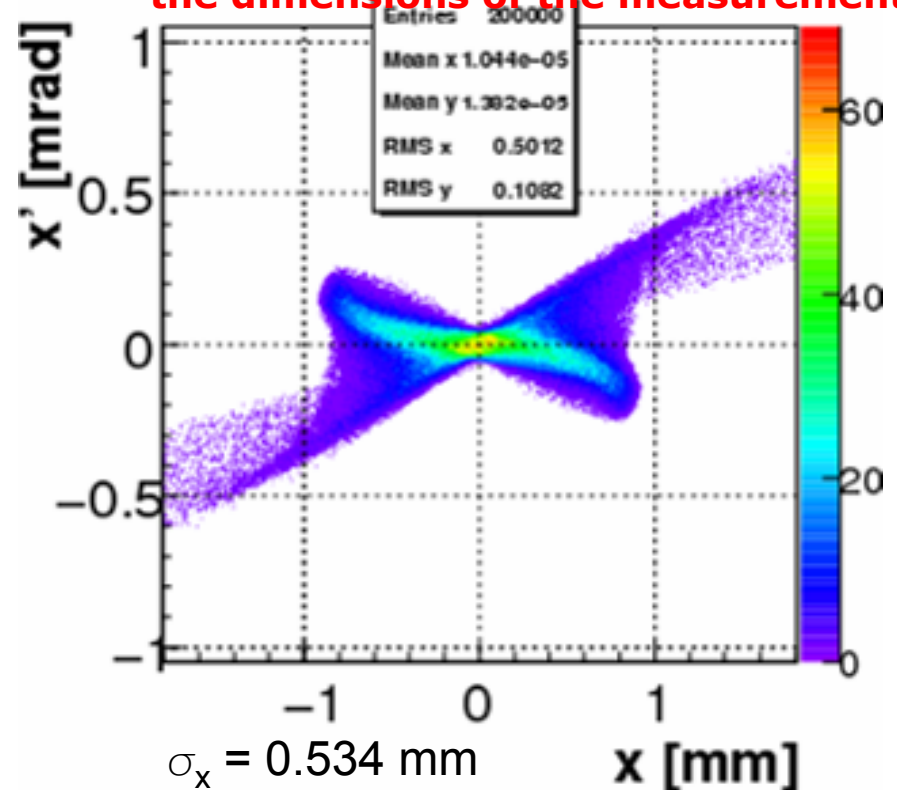
Quadrupole scan vs ASTRA @ focus

z = 5.74 m, ASTRA coord., ε_x = 1.823 (0.065) mm mrad

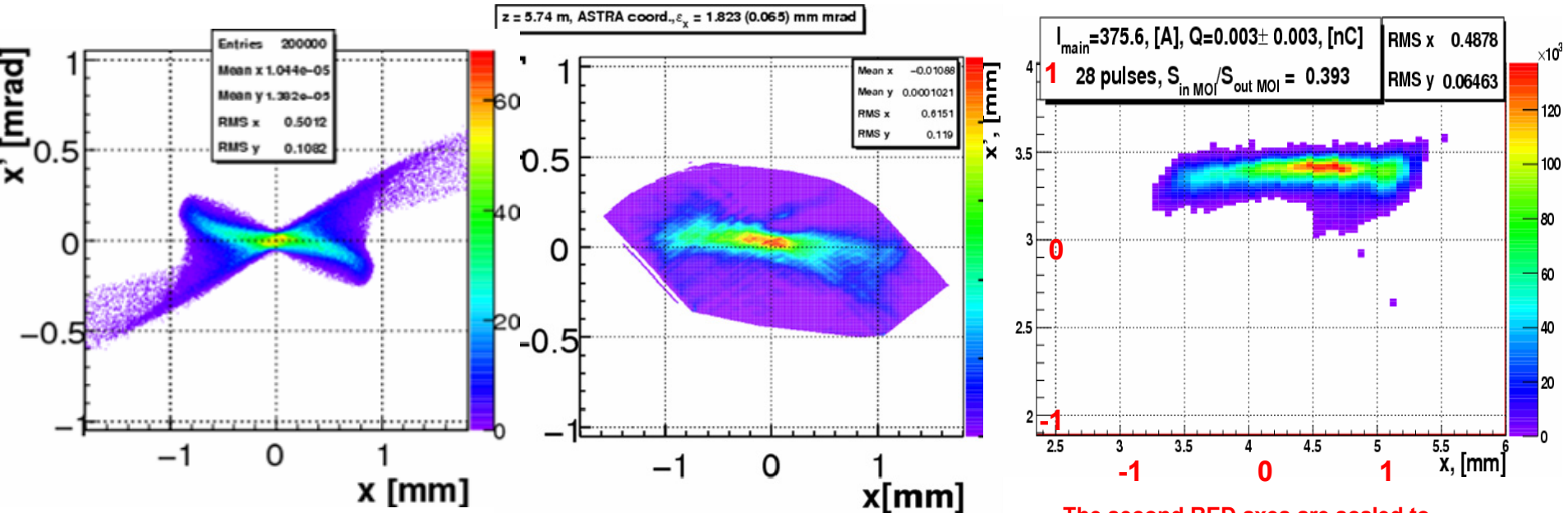| Mean x	−0.01088
Mean y	0.0001021
RMS x	0.6151
RMS y	0.119

σ_x = 0.615 mm

$\sigma_{x'}$ = 0.119 mrad

$\sigma_{xx'}$ = -0.034 mm mrad

$e_{x, N}$ = 1.823 mm mrad

ASTRA @ focus, binned & scaled to the dimensions of the measurement

Entries	200000
Mean x	1.044e−05
Mean y	1.382e−05
RMS x	0.5012
RMS y	0.1082

σ_x = 0.534 mm

$\sigma_{x'}$ = 0.116 mrad

$\sigma_{xx'}$ = 0.02 mm mrad

$e_{x, N}$ = 1.65 mm mrad

ASTRA, EMSY, quads

|	
Entries 200000	
Mean x 1.044e-05	
Mean y 1.382e-05	
RMS x 0.5012	
RMS y 0.1082	

z = 5.74 m, ASTRA coord., ε_x = 1.823 (0.065) mm mrad

Mean x −0.01088	
Mean y 0.0001021	
RMS x 0.6151	
RMS y 0.119	

I_{main}=375.6, [A], Q=0.003± 0.003, [nC]

28 pulses, $S_{in\,MOI}/S_{out\,MOI}$ = 0.393

RMS x 0.4878
RMS y 0.06463

The second RED axes are scaled to the ASTRA and quad scan axes

σ_x = 0.534 mm

$\sigma_{x'}$ = 0.116 mrad

$\sigma_{xx'}$ = 0.02 mm mrad

$e_{x,\,N}$ = 1.65 mm mrad

σ_x = 0.615 mm

$\sigma_{x'}$ = 0.119 mrad

$\sigma_{xx'}$ = -0.034 mm mrad

$e_{x,\,N}$ = 1.823 mm mrad

σ_x = 0.49 +/- 0.01 mm

$\sigma_{x'}$ = 0.03 +/- 0.001 mrad

$\sigma_{xx'}$ = 0.01 +/- 0.005 mm mrad

$e_{x,\,N}$ = 0.913 +/- 0.025 mm mrad

Such a discrepancy is still not conclusive since there is a single complete measurement.

ASTRA, EMSY, quads with 1% cut
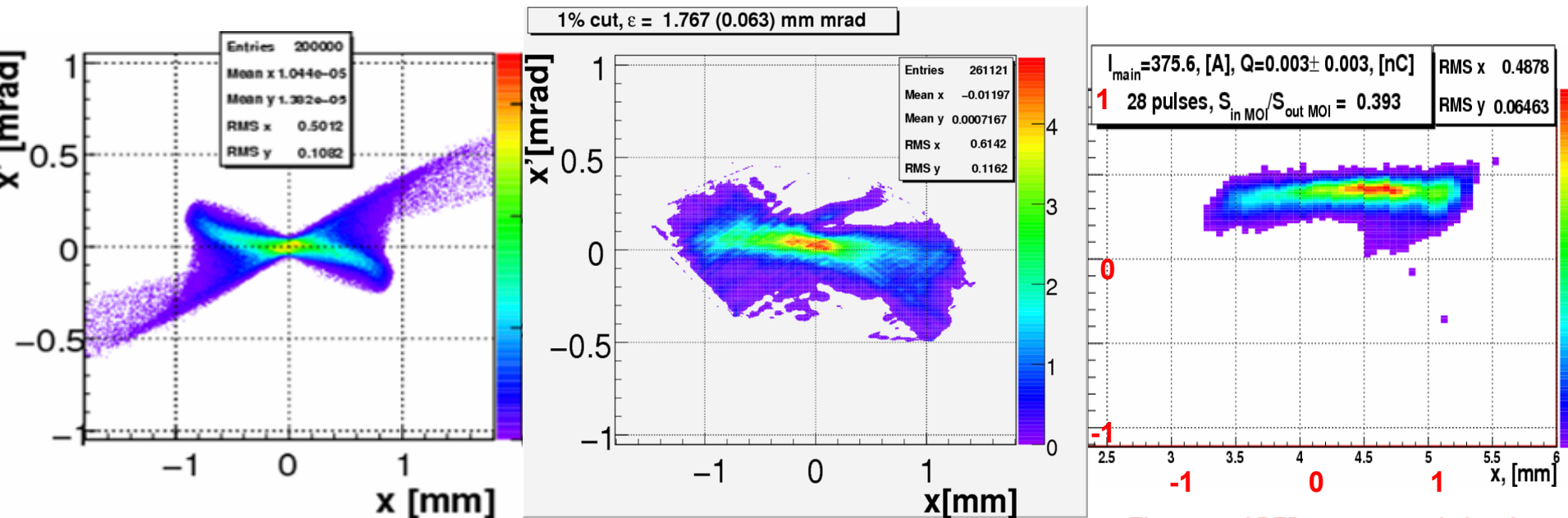
1% cut, ε = 1.767 (0.063) mm mrad

The second RED axes are scaled to the ASTRA and quad scan axes

σ_x = 0.534 mm
$\sigma_{x'}$ = 0.116 mrad
$\sigma_{xx'}$ = 0.02 mm mrad
$e_{x, N}$ = 1.65 mm mrad

σ_x = 0.614 mm
$\sigma_{x'}$ = 0.116 mrad
$\sigma_{xx'}$ = -0.033 mm mrad
$e_{x, N}$ = 1.77 mm mrad

σ_x = 0.49 +/- 0.01 mm
$\sigma_{x'}$ = 0.03 +/- 0.001 mrad
$\sigma_{xx'}$ = 0.01 +/- 0.005 mm mrad
$e_{x, N}$ = 0.913 +/- 0.025 mm mrad

$e_{x, N}$ = 1.823 mm mrad w.o. cut

Doing the cut
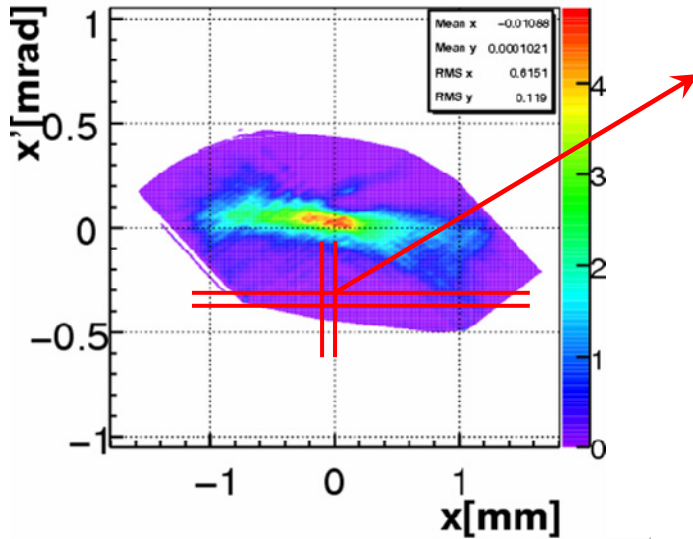
N – the bin content for each bin

If N < 1% of the max histogram bin content set it to 0

↔ cutting like shown on both of the projections simultaneously
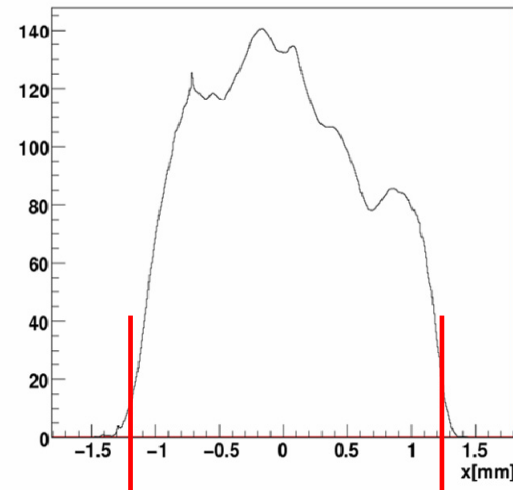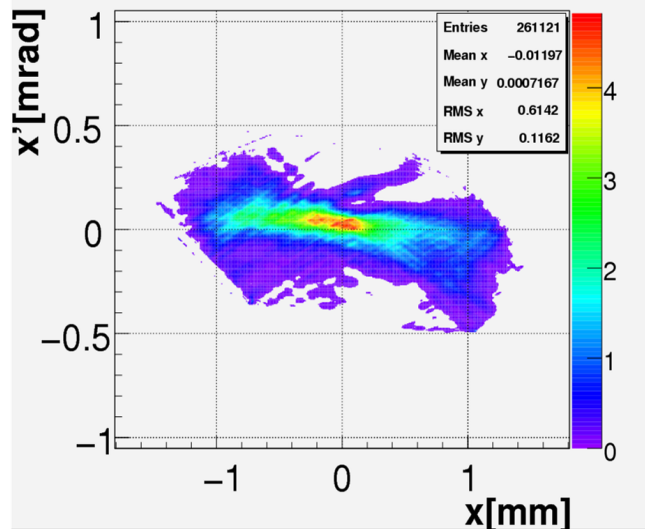
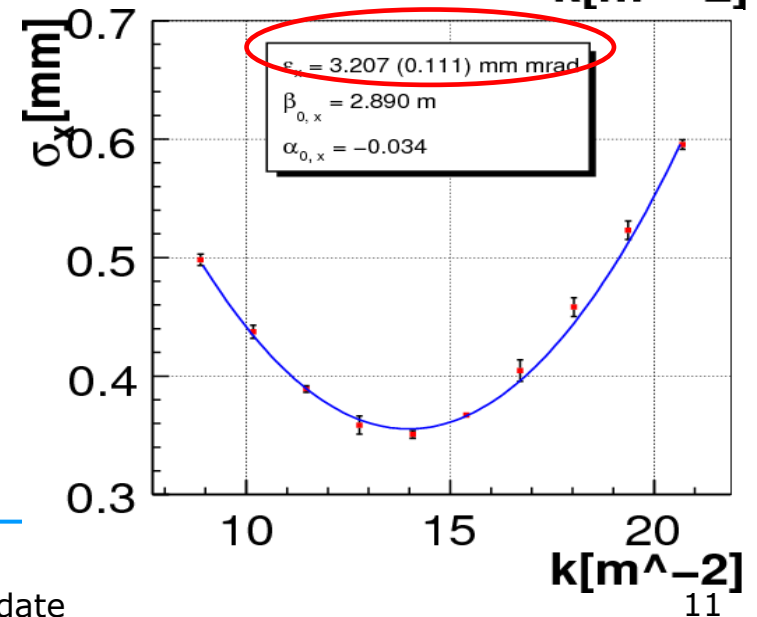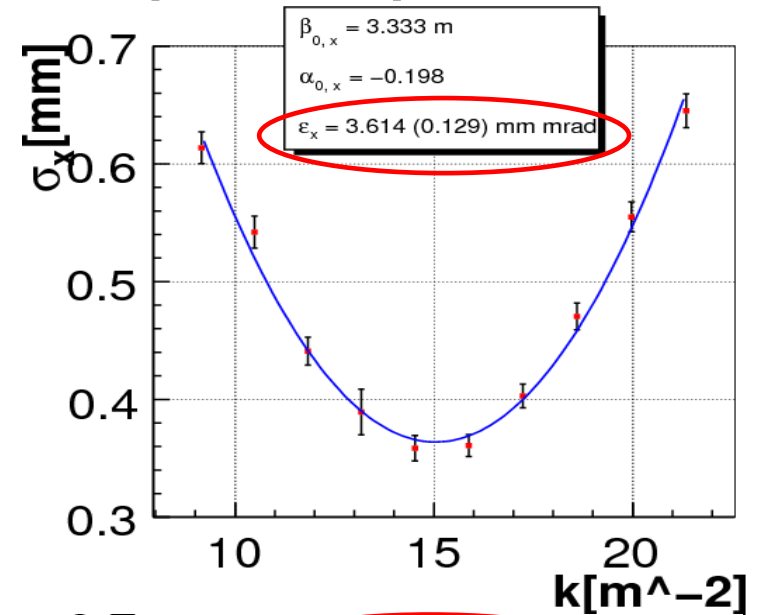# Measured vs ASTRA, 500 pC - qscan

Measured
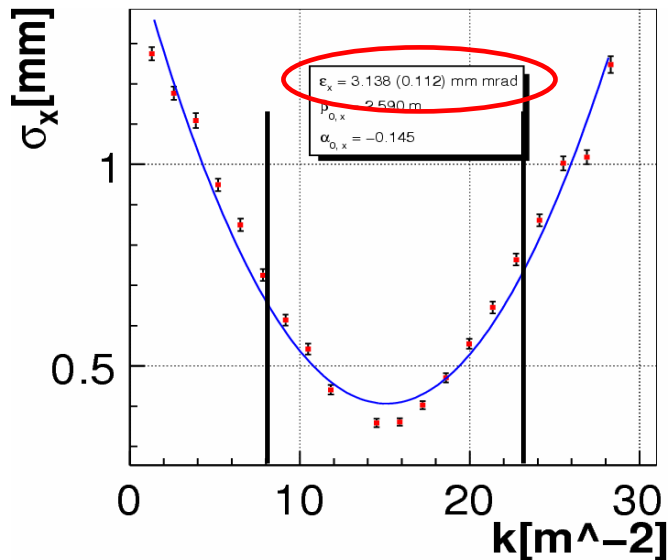
ASTRA

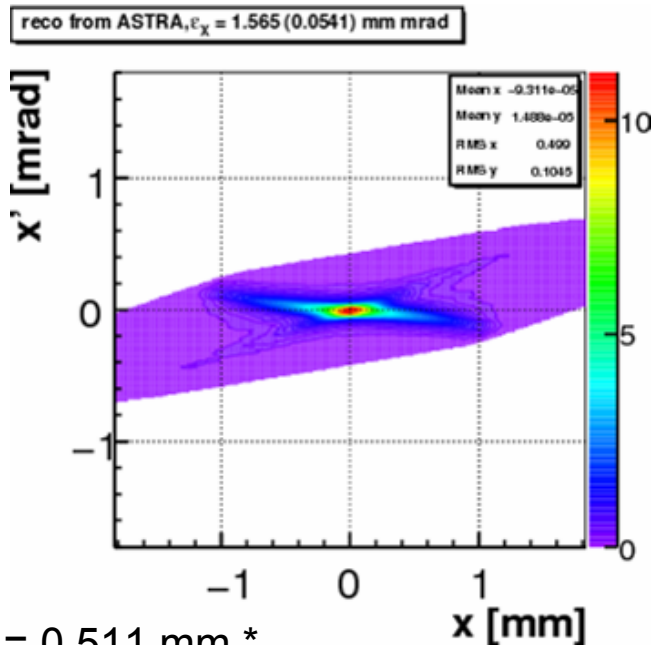**The same focusing conditions used (k$_{quad}$)**

Errors in % assigned randomly in [0, 1)

Reconstructed vs original ASTRA, 500 pC

The same 'reduced' data set as used for the quadrupole scan in previous slide.

For ASTRA: $I \rightarrow grad$ according to the used calibration $\rightarrow k$ for this momentum. Use the strength

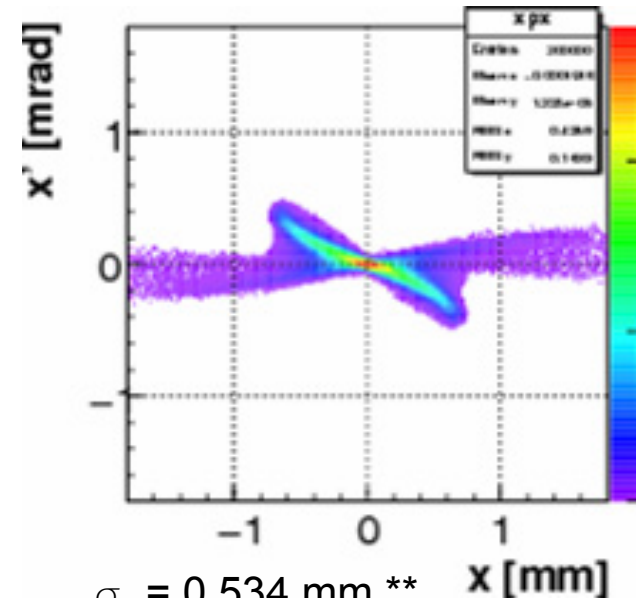reco from ASTRA, $\varepsilon_x = 1.565\ (0.0541)$ mm mrad

$\sigma_x = 0.511$ mm *

$\sigma_{x'} = 0.108$ mrad

$\sigma_{xx'} = 0.009$ mm mrad

$e_{x,\ N} = 1.565$ mm mrad

$\sigma_x = 0.534$ mm **

$\sigma_{x'} = 0.116$ mrad
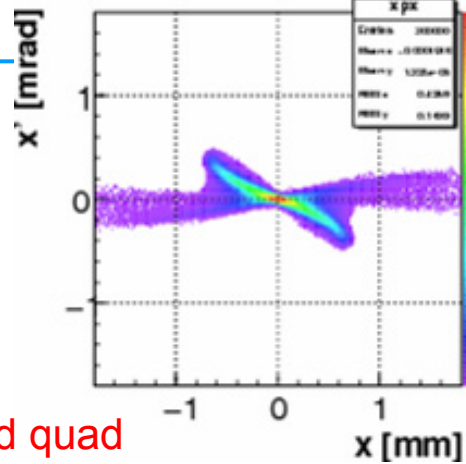
$\sigma_{xx'} = 0.02$ mm mrad

$e_{x,\ N} = 1.65$ mm mrad

*Tomo values calculated from unzoomed 2D distribution   **ASTRA values calculated from statistics

More projections

σ_x = 0.534 mm

$\sigma_{x'}$ = 0.116 mrad
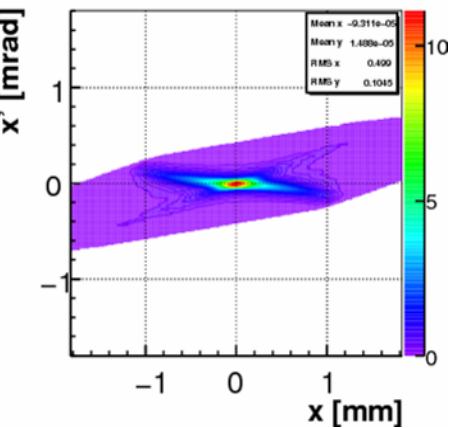
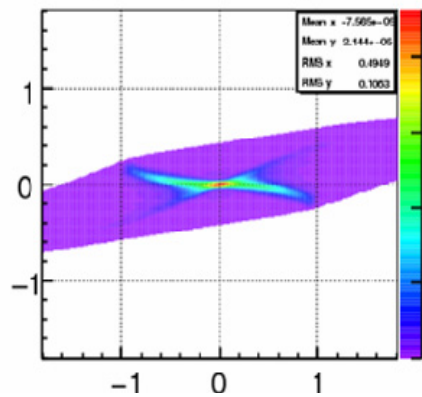$\sigma_{xx'}$ = 0.02 mm mrad

$e_{x, N}$ = 1.65 mm mrad

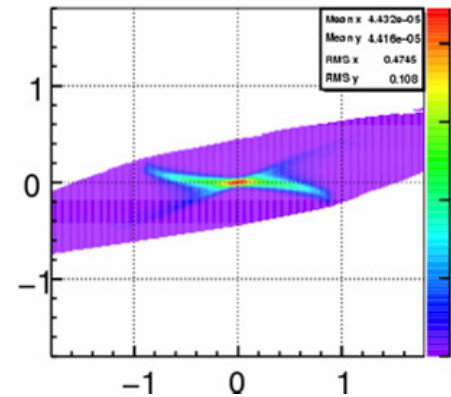**Only negative gradients in the varied quad**   **also positive gradients**

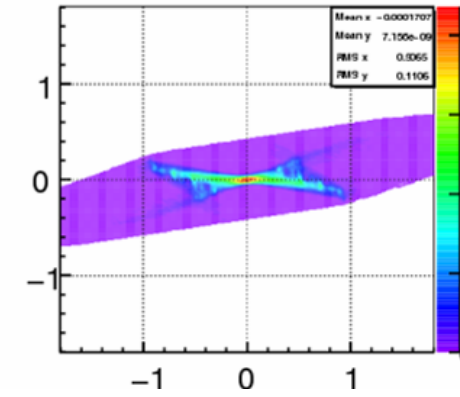reco from ASTRA, ε_x = 1.565 (0.0541) mm mrad

reco ASTRA, ε_x = 1.563 (0.054) mm rad

reco ASTRA, ε_x = 1.512 (0.052) mm mrad

reco ASTRA, ε_x = 1.616 (0.056) mm mrad

σ_x = 0.511 mm

$\sigma_{x'}$ = 0.108 mrad

$\sigma_{xx'}$ = 0.009 mm mrad

$e_{x, N}$ = 1.565 mm mrad

σ_x = 0.503

$\sigma_{x'}$ = 0.109

$\sigma_{xx'}$ = 0.01 closer

$e_{x, N}$ = 1.563

σ_x = 0.486

$\sigma_{x'}$ = 0.111

$\sigma_{xx'}$ = 0.05

$e_{x, N}$ = 1.512

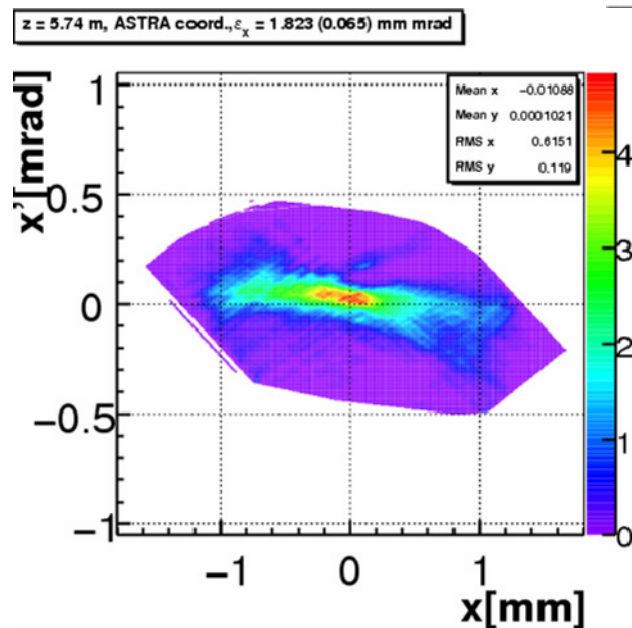σ_x = 0.511

$\sigma_{x'}$ = 0.112

$\sigma_{xx'}$ = 0.012

$e_{x, N}$ = 1.616

Measured vs ASTRA
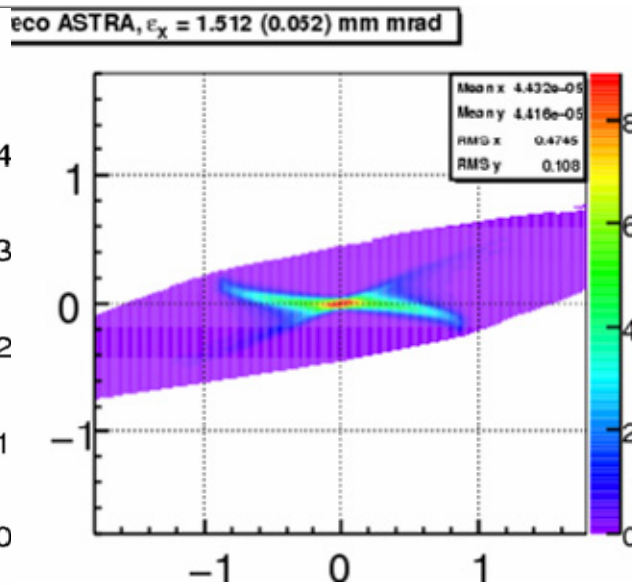
Measured

Reco from ASTRA projections

Original ASTRA

σ_x = 0.615 mm

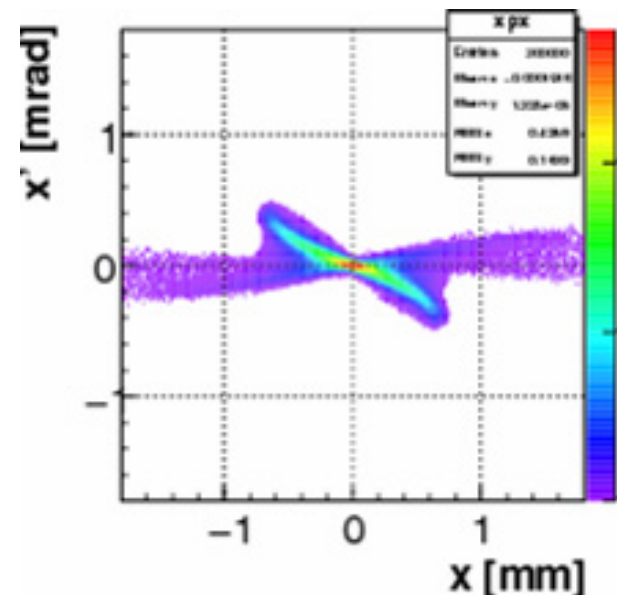$\sigma_{x'}$ = 0.119 mrad

$\sigma_{xx'}$ = -0.034 mm mrad

$e_{x, N}$ = 1.823 mm mrad

σ_x = 0.486

$\sigma_{x'}$ = 0.111

$\sigma_{xx'}$ = 0.05

$e_{x, N}$ = 1.512

σ_x = 0.534 mm
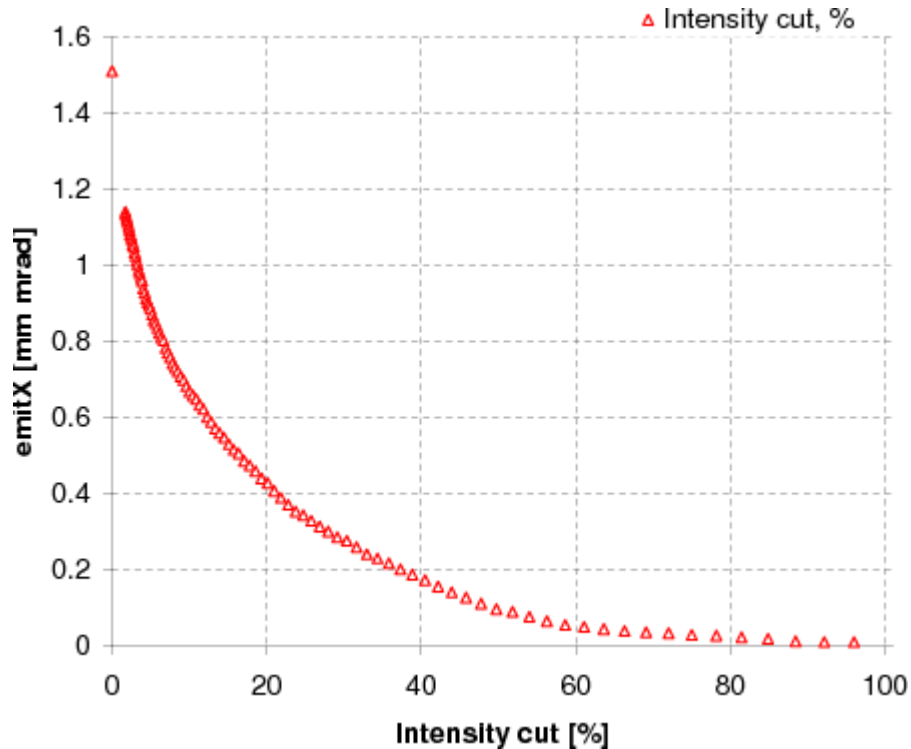
$\sigma_{x'}$ = 0.116 mrad

$\sigma_{xx'}$ = 0.02 mm mrad

$e_{x, N}$ = 1.65 mm mrad

Fractional emittance

Cut:

Intensity_cut:100*exp(-0.0411*k)

k = 99, 98, …1, 0.9, 0.8, …, 0.1

All data from ASTRA