# Gun Calculations by Poisson Model for Non-Uniform Distributions

animation
cathode distributions
tables
many plots

# Gun Calculation with Astra "rz" and restarted "xyz"

rz-case, without/with restart
xyz: shifted solenoid (1mm)
xyz: rotated solenoid (1mrad)
but: more about the rz-case

bunch prototype:
XFEL bunch,
250 pC

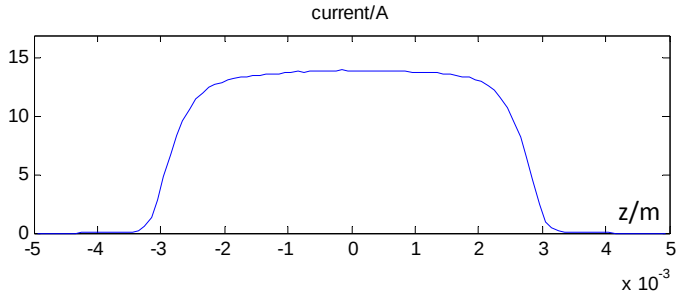
# Gun Calculations by Poisson Model for Non-Uniform Distributions

an exemplary investigation

the bunch (prototype): 250 pC, XFEL type, see http://www.desy.de/xfel-beam/s2e/xfel/Nominal/nom250pC.html

longitudinally:

Astra generator
Lt=20psec, rt=2psec
Gun
60 MV/m, 0.2234 T

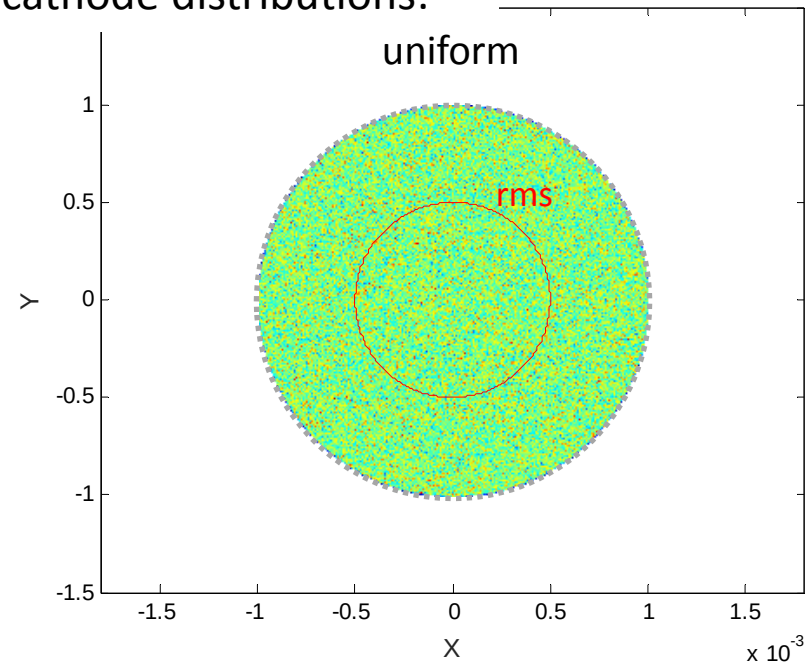


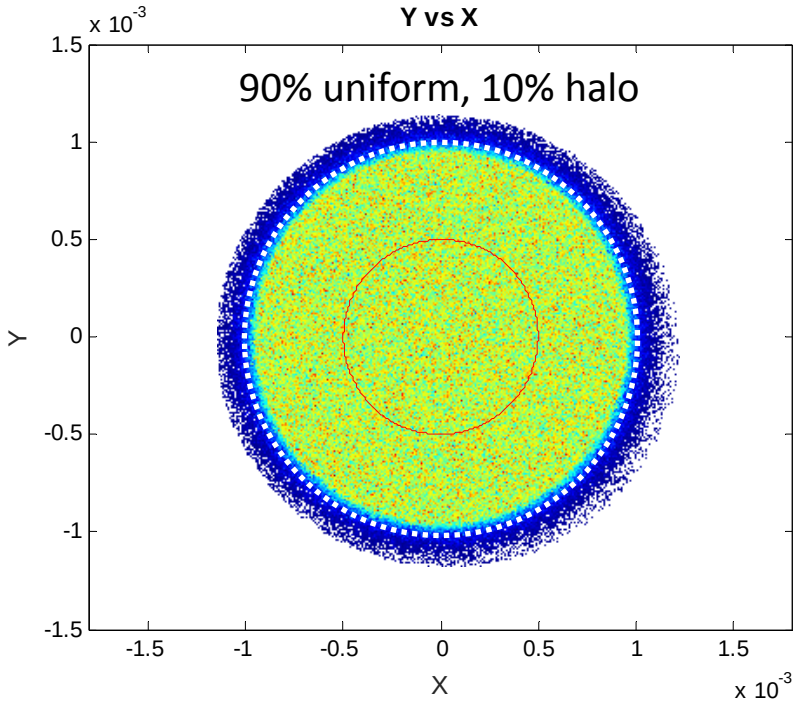

transversely: uniform, R = 1 mm (rms = 0.5 mm)

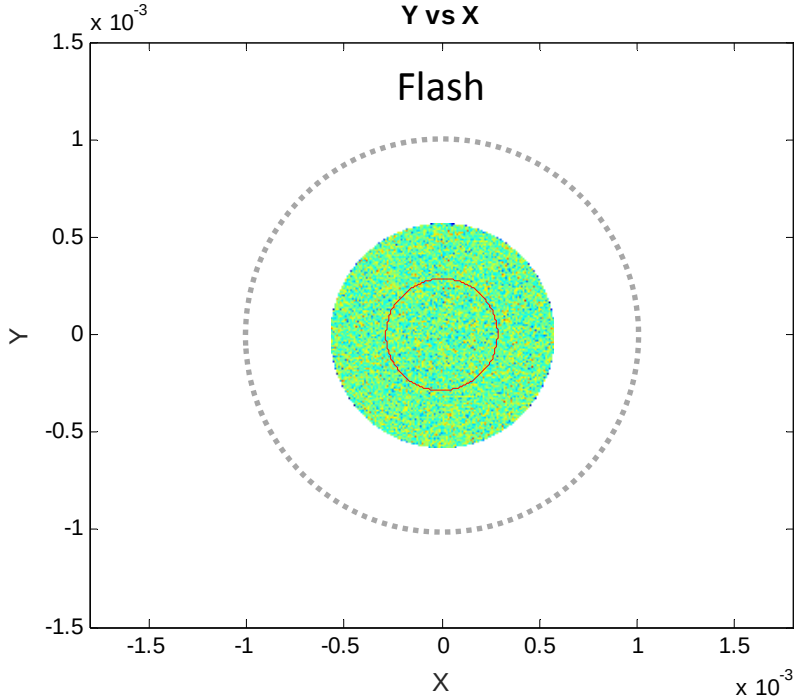
modifications: r(z) $\rightarrow$ halo & FLASH type
xy(z) $\rightarrow$ odd & random fluctuations

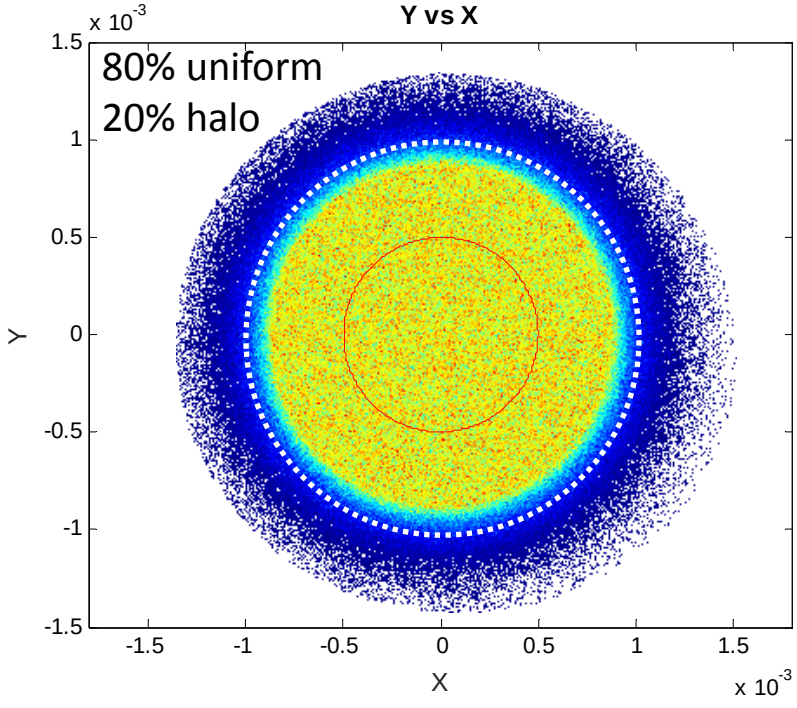
calculations with MATLAB code "**stupid**", version="less stupid"

r(z)-cathode distributions:

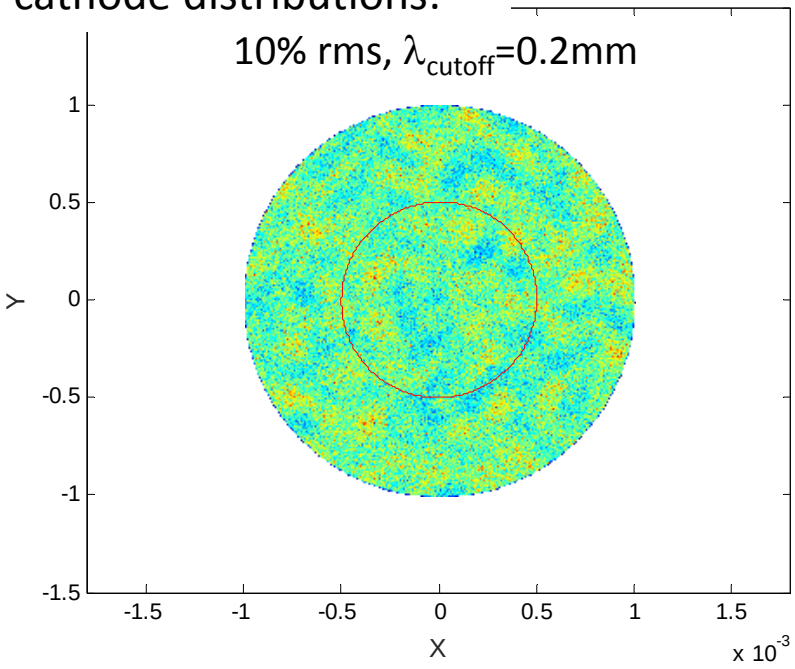


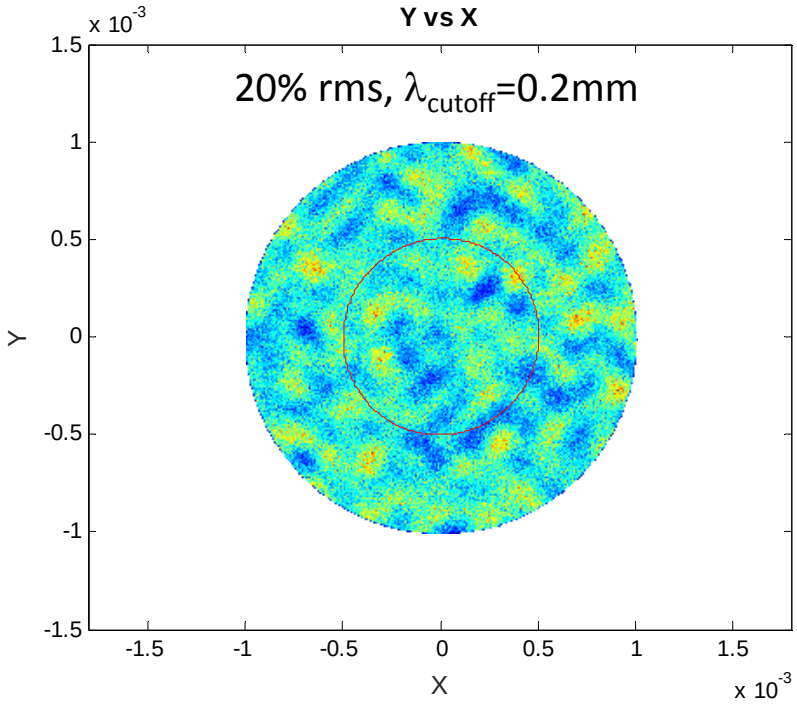



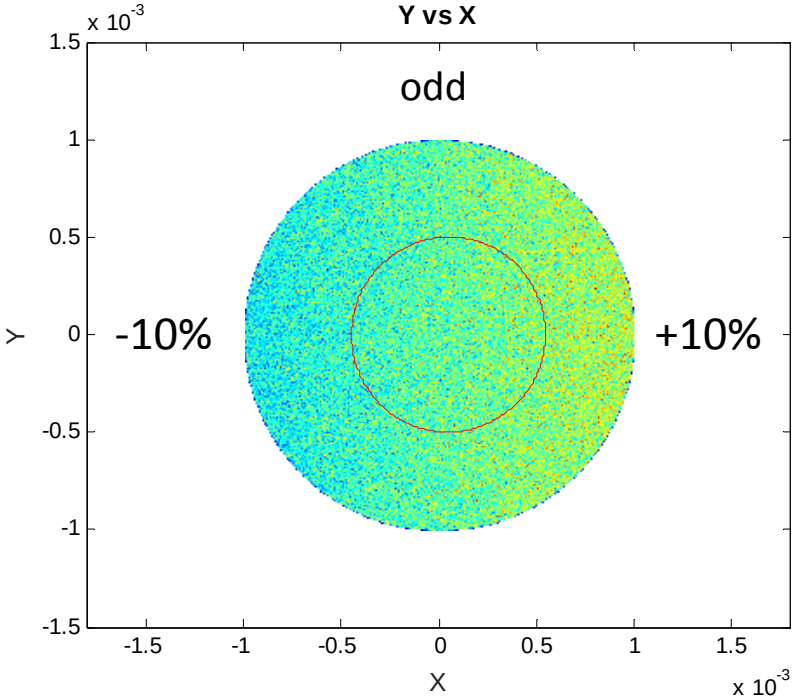



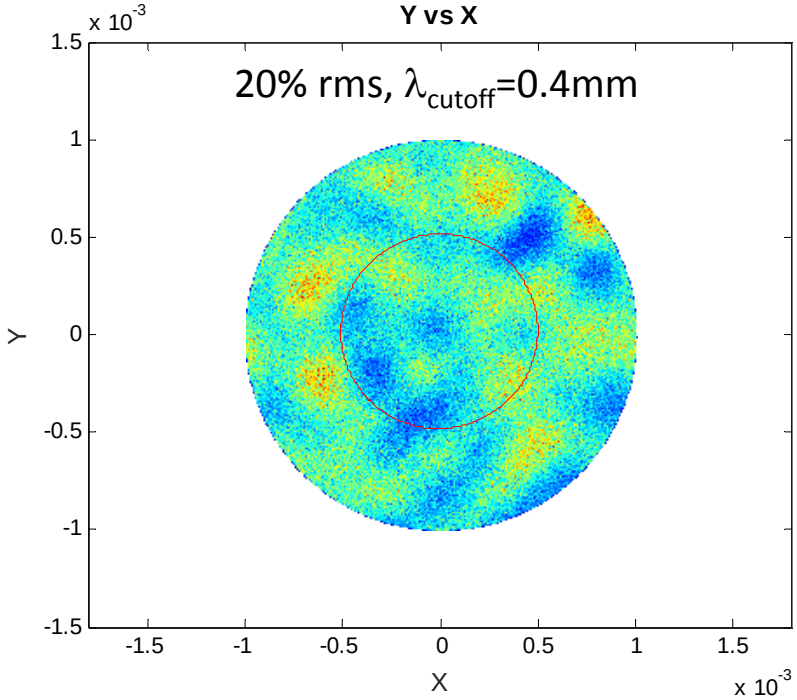



xy(z)-cathode distributions:



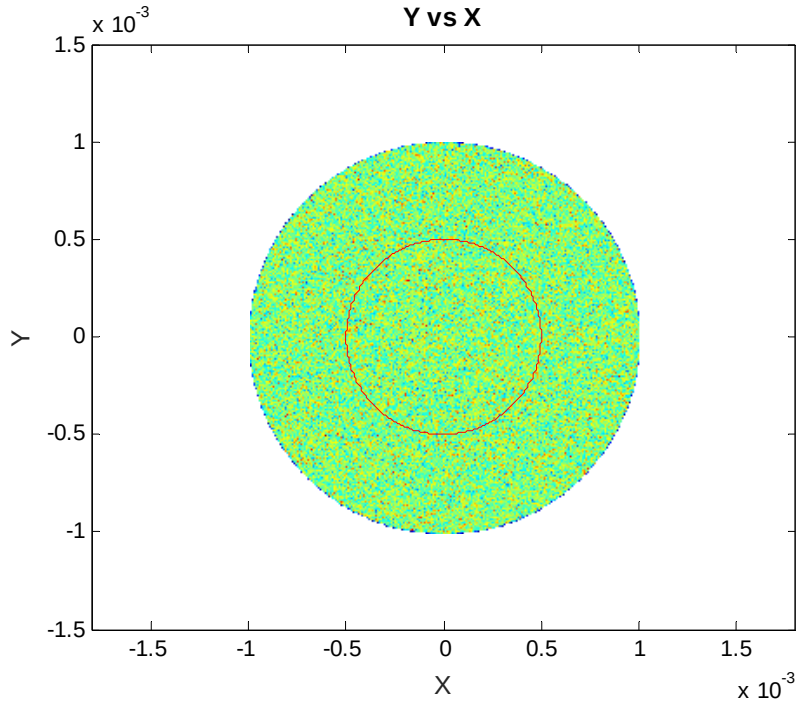



| | projected emittance | | slice emittance | | slice energy spread |
|---|---|---|---|---|---|
| | $\varepsilon_x\gamma\beta/\mu$m | $\varepsilon_y\gamma\beta/\mu$m | $\varepsilon_x\gamma\beta/\mu$m | $\varepsilon_y\gamma\beta/\mu$m | $\mathcal{E}_{\rm rms}$/eV |
| uniform XFEL bunch (60 MV/m) | 0.949 | 0.949 | 0.569 | 0.567 | 443 |
| 90 % uniform, 10 % halo | 0.948 | 0.949 | 0.590 | 0.588 | 436 |
| 80 % uniform, 20 % halo | 1.007 | 1.013 | 0.717 | 0.719 | 460 |
| XFEL bunch, Flash fields ( | 1.061 | 1.056 | 0.593 | 0.593 | 241 |
| uniform FLASH bunch (45 MV/m) | 1.471 | 1.474 | 0.805 | 0.802 | 798 |
| 10 % odd | 0.964 | 0.985 | 0.594 | 0.634 | 463 |
| random, 10 % rms $\lambda_{\rm cutoff} = 0.2$ mm | 0.966 | 0.940 | 0.580 | 0.577 | 461 |
| random, 20 % rms $\lambda_{\rm cutoff} = 0.2$ mm | 0.957 | 1.013 | 0.599 | 0.598 | 479 |
| random, 20 % rms $\lambda_{\rm cutoff} = 0.4$ mm | 1.052 | 0.979 | 0.655 | 0.660 | 478 |

slice parameters for |z|<1mm

| | projected emittance | | slice emittance | | slice energy spread |
|---|---|---|---|---|---|
| | $\varepsilon_x/\varepsilon_1$ | $\varepsilon_y/\varepsilon_1$ | $\varepsilon_x/\varepsilon_2$ | $\varepsilon_y/\varepsilon_2$ | $\mathcal{E}_{\rm rms}/\mathcal{E}_1$ |
| uniform XFEL bunch (60 MV/m) | 1 | 1.000 | 1 | 0.997 | 1 |
| 90 % uniform, 10 % halo | 0.999 | 1.000 | 1.037 | 1.033 | 0.984 |
| 80 % uniform, 20 % halo | 1.061 | 1.067 | 1.260 | 1.264 | 1.038 |
| XFEL bunch, Flash fields | 1.118 | 1.113 | 1.042 | 1.042 | 0.544 |
| uniform FLASH bunch (45 MV/m) | 1.550 | 1.553 | 1.415 | 1.410 | 1.801 |
| 10 % odd | 1.016 | 1.038 | 1.044 | 1.114 | 1.045 |
| random, 10 % rms $\lambda_{\rm cutoff} = 0.2$ mm | 1.018 | 1.000 | 1.019 | 1.014 | 1.041 |
| random, 20 % rms $\lambda_{\rm cutoff} = 0.2$ mm | 1.008 | 1.067 | 1.053 | 1.051 | 1.081 |
| random, 20 % rms $\lambda_{\rm cutoff} = 0.4$ mm | 1.109 | 1.032 | 1.151 | 1.160 | 1.079 |




uniform distribution, XFEL

q/pC = 250

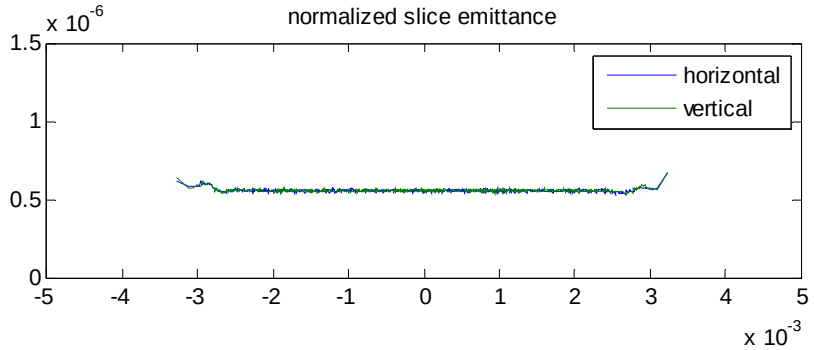
z/m = 2.6038

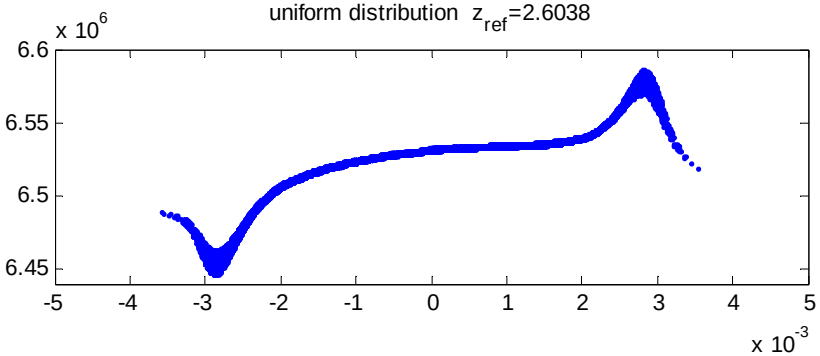
$\varepsilon\gamma\beta/\mu m$ = 0.94869, 0.94893

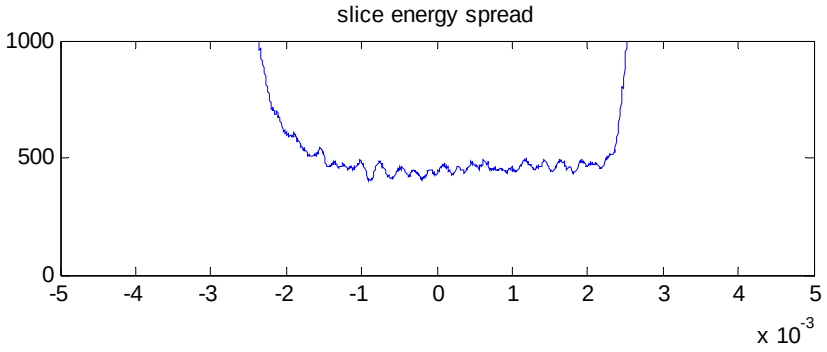
$\beta_{twiss,x,y}/m$= 2.1466, 2.144

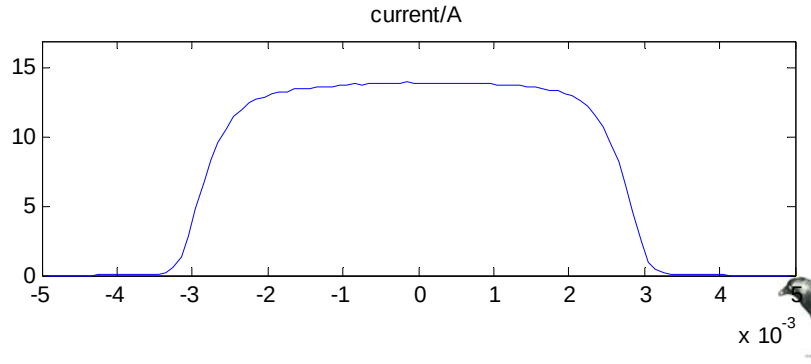
$\sigma_{E,slice}/eV$ = 443.2164

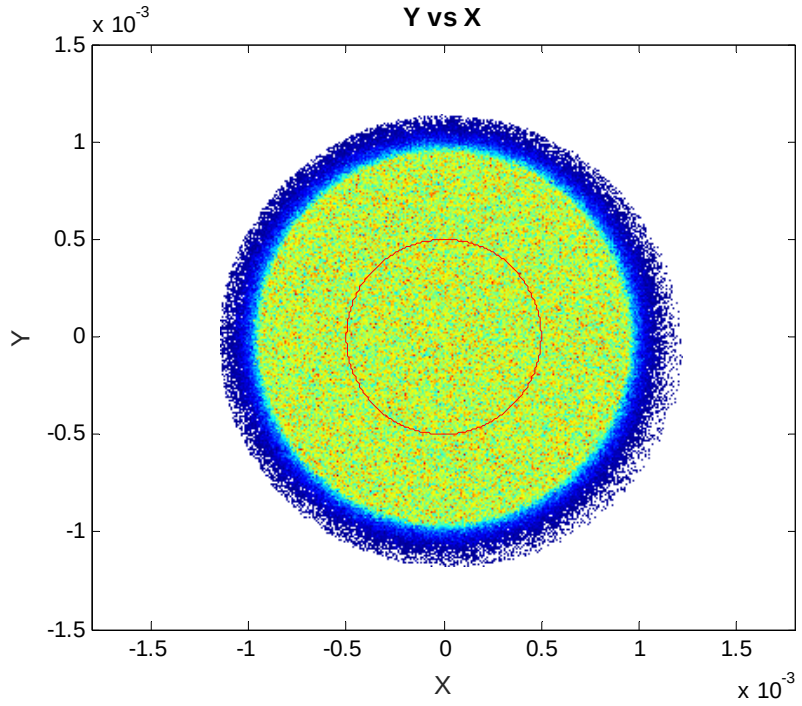
averaged for |z|<1mm






90% uniform, 10% in halo

q/pC = 250

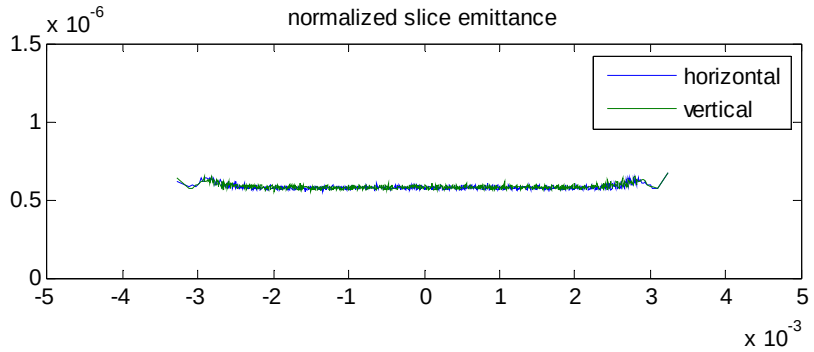
z/m = 2.6038

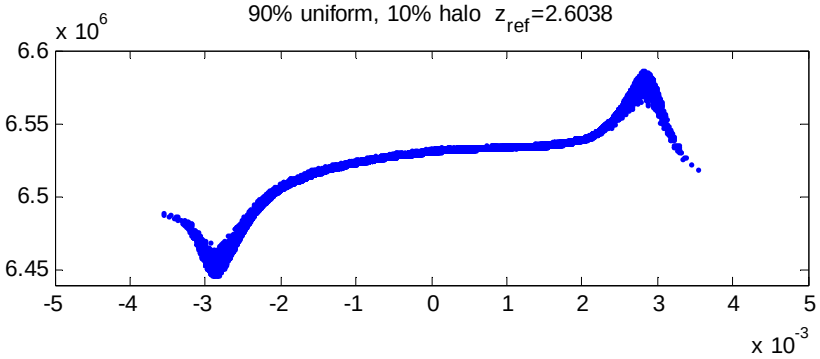
$\varepsilon\gamma\beta/\mu m$ = 0.94742, 0.94869

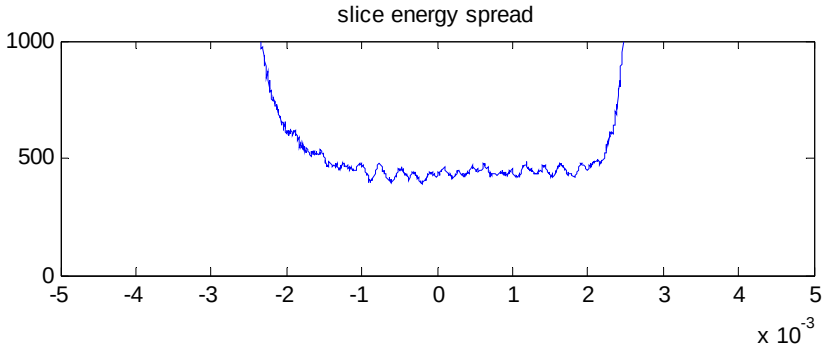
$\beta_{twiss,x,y}/m$= 2.1828, 2.1819

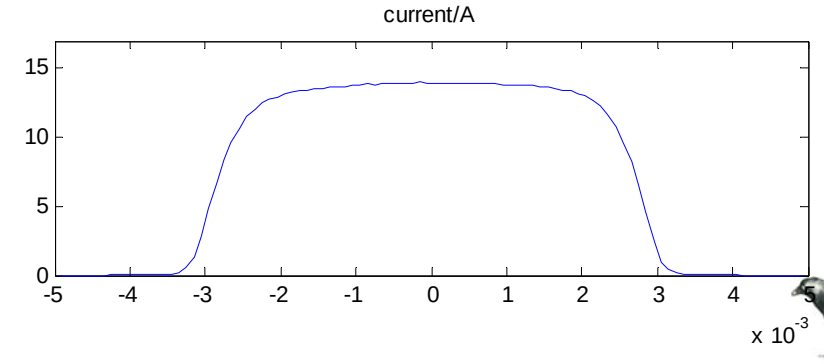
$\sigma_{E,slice}/eV$ = 436.6104

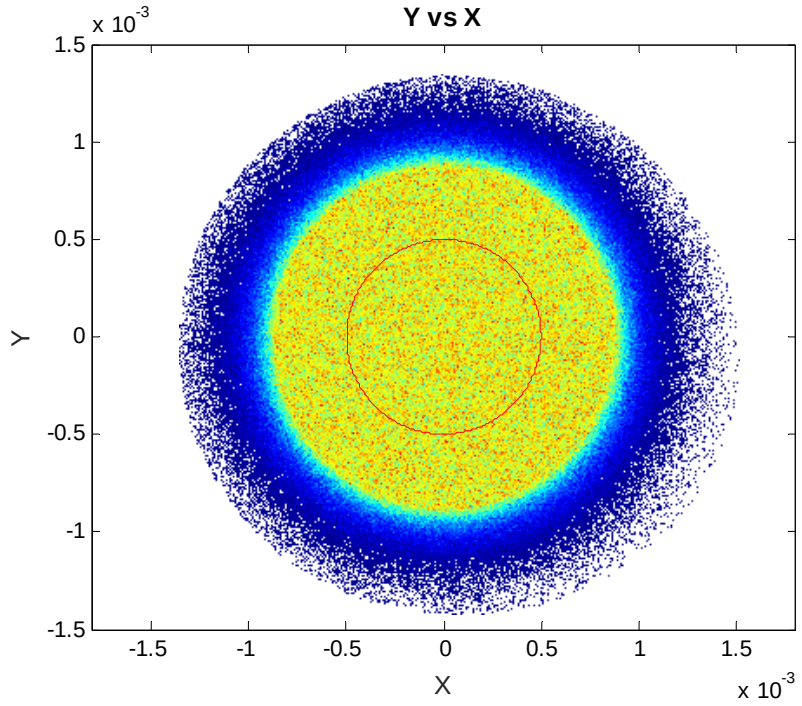
averaged for |z|<1mm






80% uniform, 20% in halo

q/pC = 250

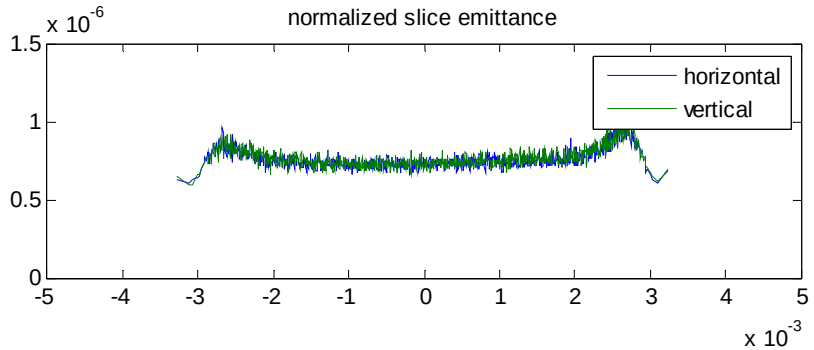
z/m = 2.6038

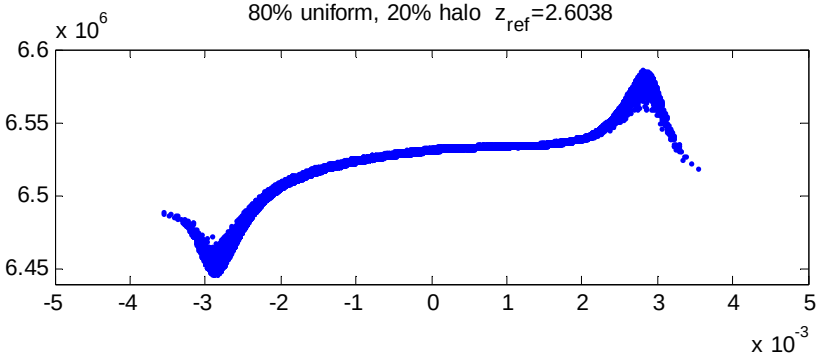
$\varepsilon\gamma\beta/\mu m$ = 1.0071, 1.0132

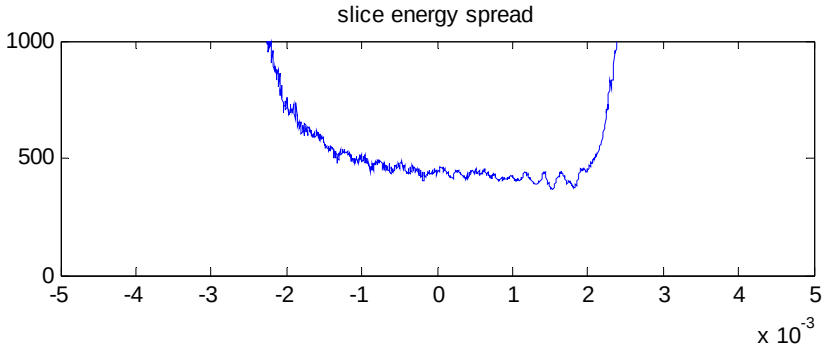
$\beta_{twiss,x,y}/m$= 2.3359, 2.3303

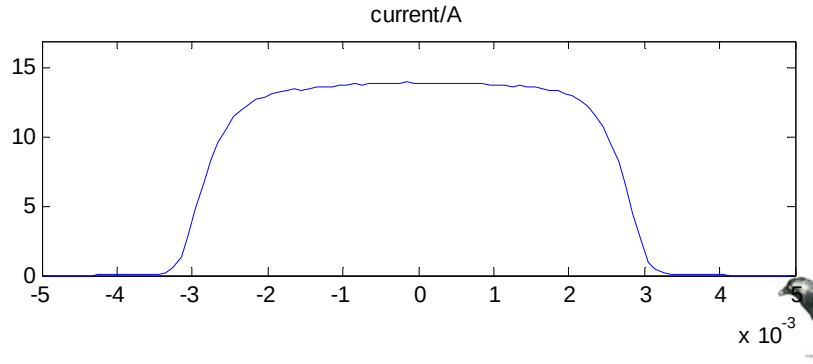
$\sigma_{E,slice}/eV$ = 460.346

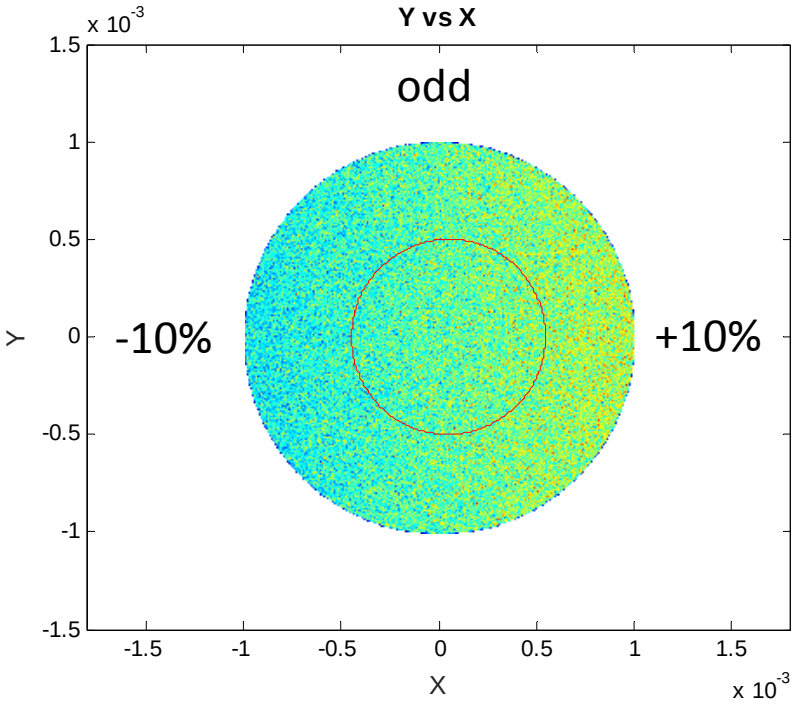
averaged for |z|<1mm






odd

q/pC = 250

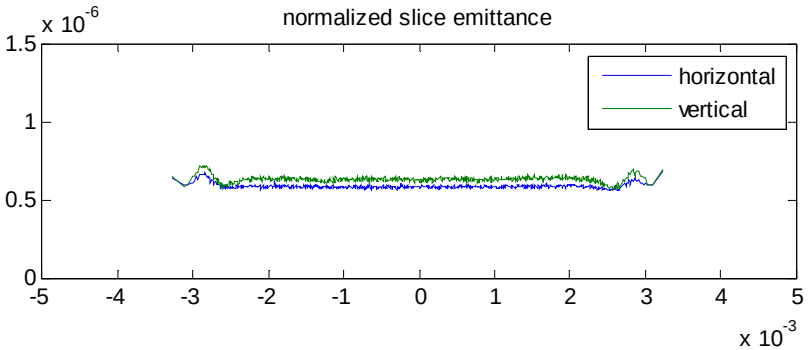
z/m = 2.6038

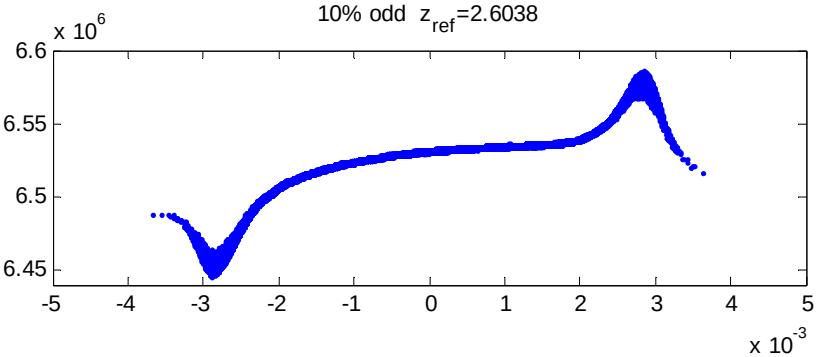
$\varepsilon\gamma\beta/\mu m$ = 0.96395, 0.98515

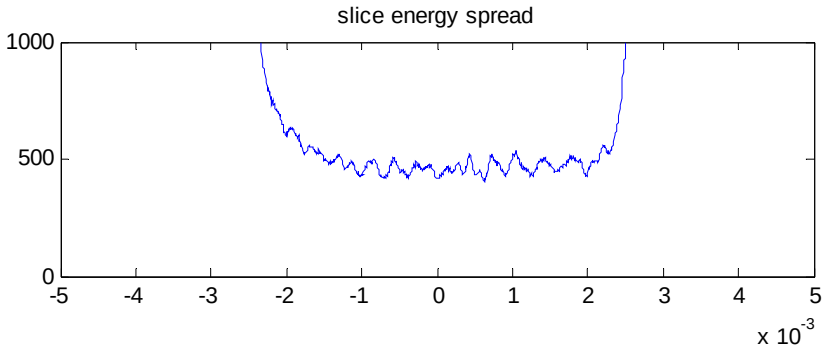
$\beta_{twiss,x,y}/m$= 2.1079, 2.119

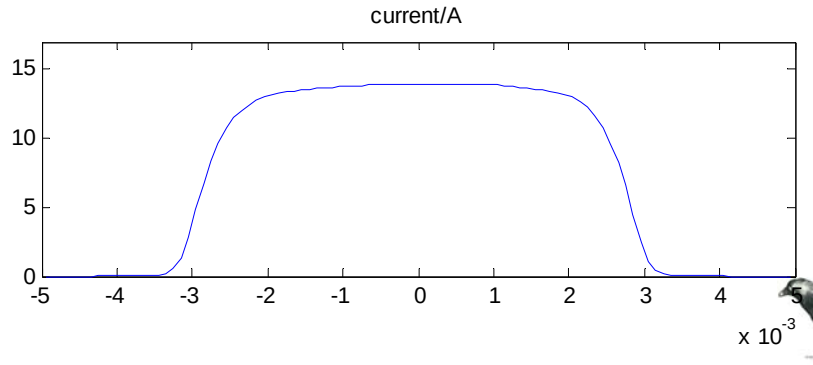
$\sigma_{E,slice}/eV$ = 463.0909

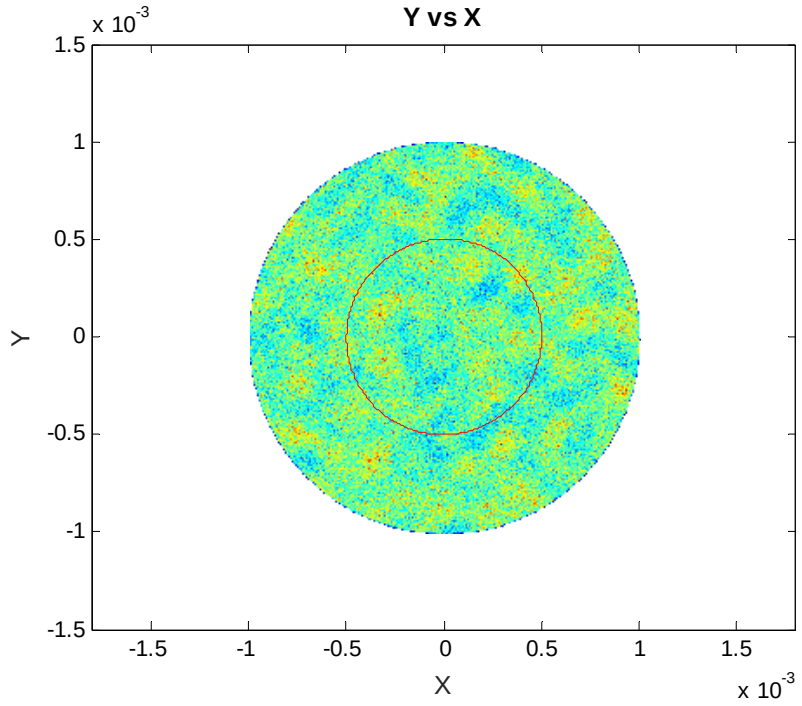
averaged for |z|<1mm






10% rms, λcutoff=0.2mm

q/pC = 250

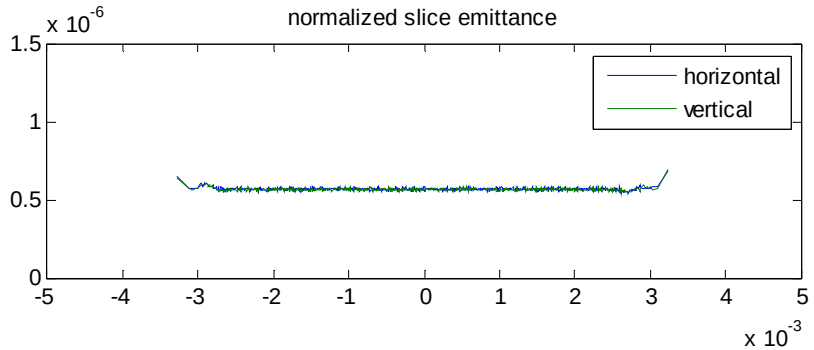
z/m = 2.6038

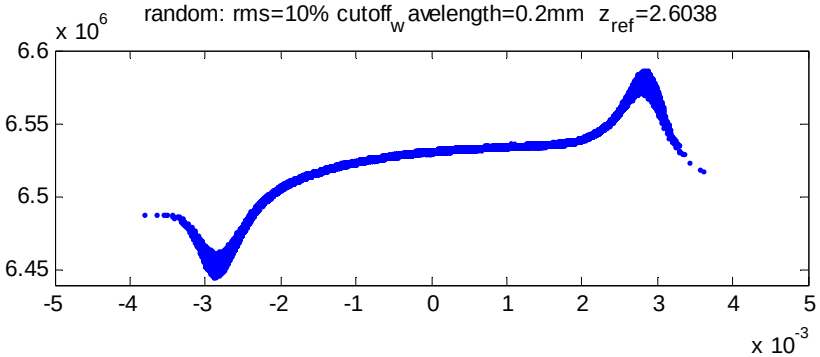
$\varepsilon\gamma\beta/\mu m$ = 0.96612, 0.93976

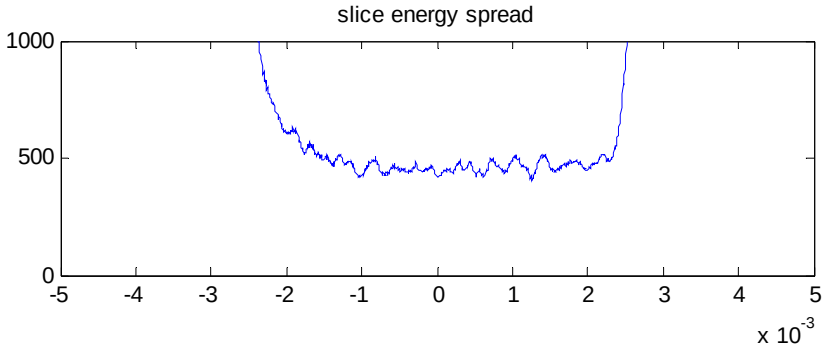
$\beta_{twiss,x,y}/m$= 2.1291, 2.1505

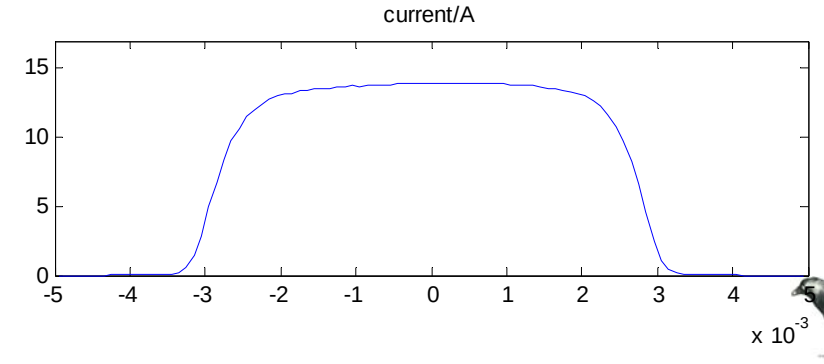
$\sigma_{E,slice}/eV$ = 460.4812

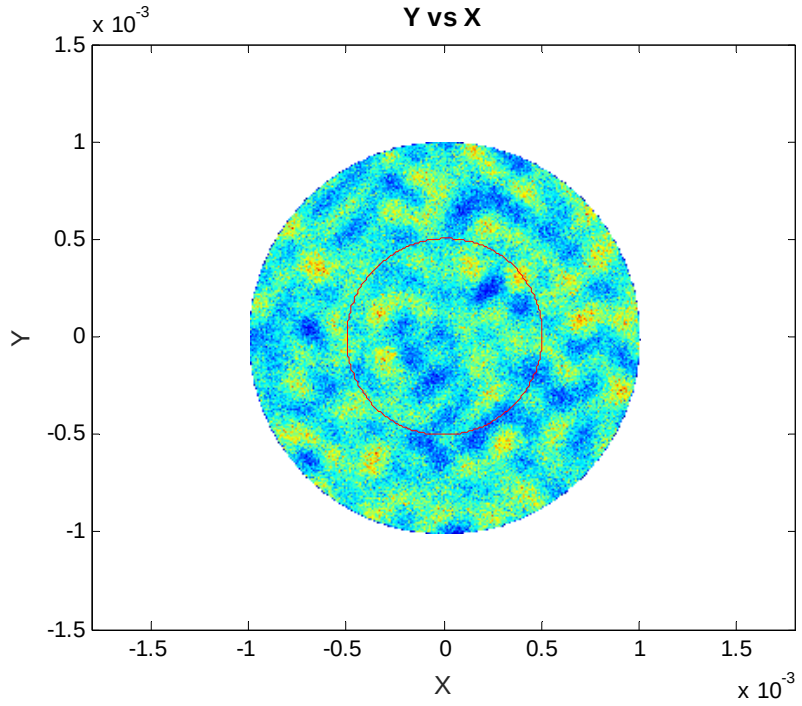
averaged for |z|<1mm






20% rms, λcutoff=0.2mm

q/pC = 250

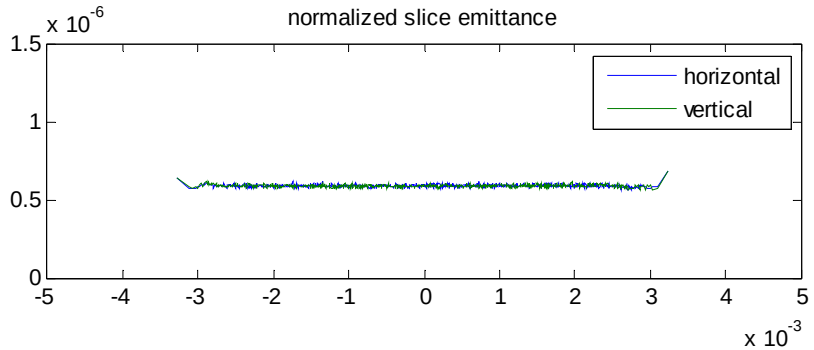
z/m = 2.6038

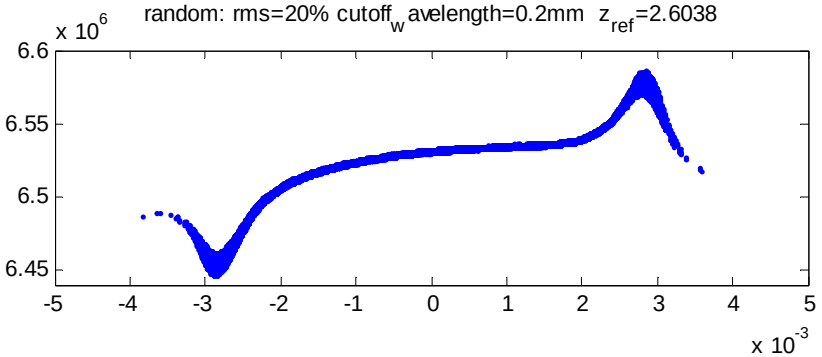
εγβ/μm = 0.9507, 1.0129

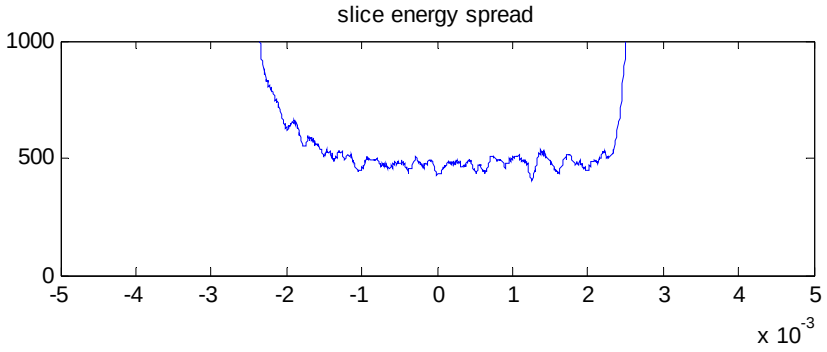
$\beta_{twiss,x,y}$/m= 2.1997, 2.1453

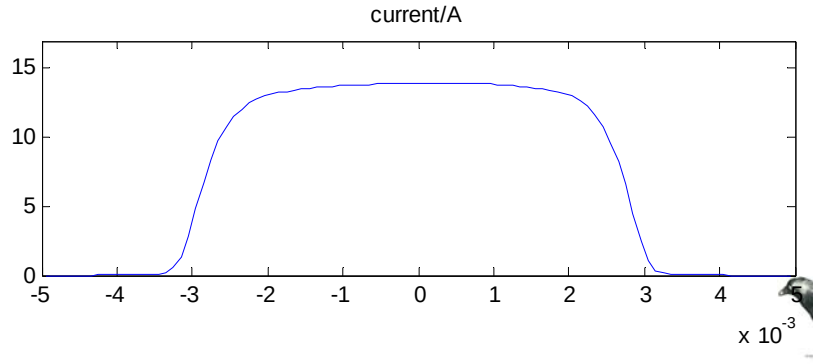
$\sigma_{E,slice}$/eV = 479.0362

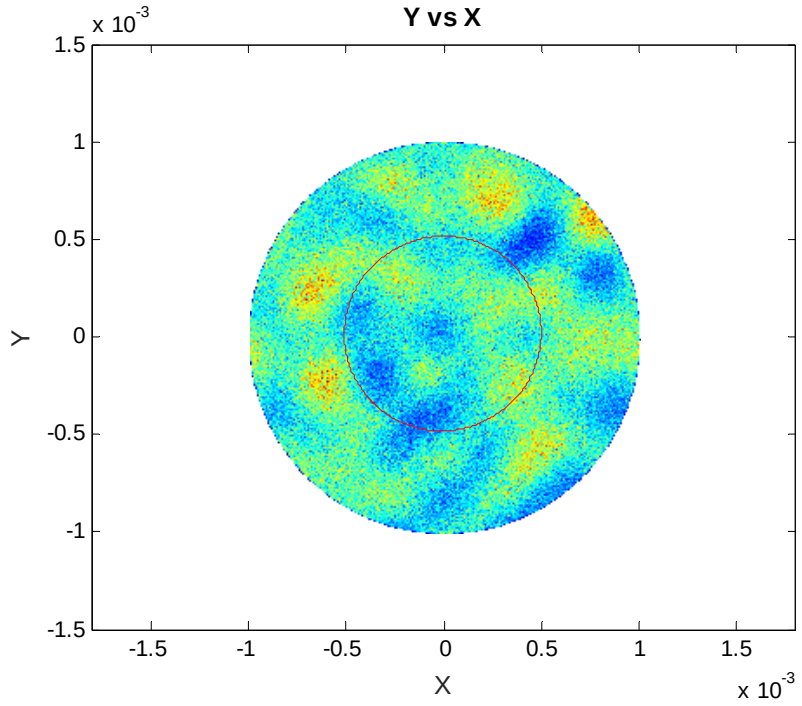
averaged for |z|<1mm






20% rms, λcutoff=0.4mm

q/pC = 250

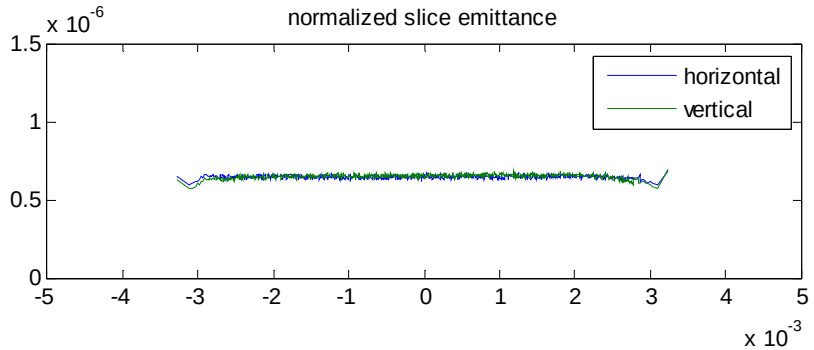
z/m = 2.6038

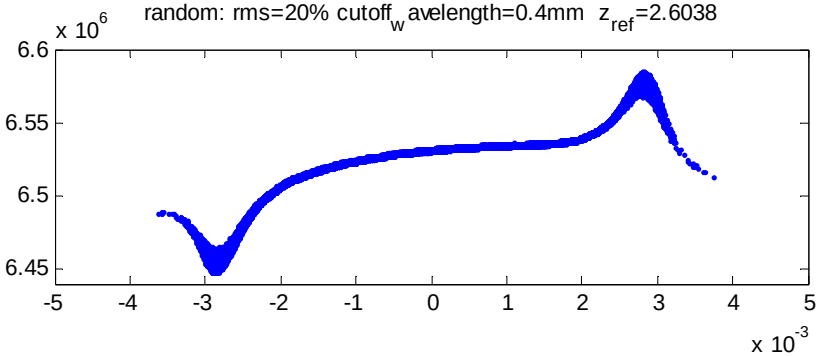
$\varepsilon\gamma\beta/\mu m$ = 1.0518, 0.97886

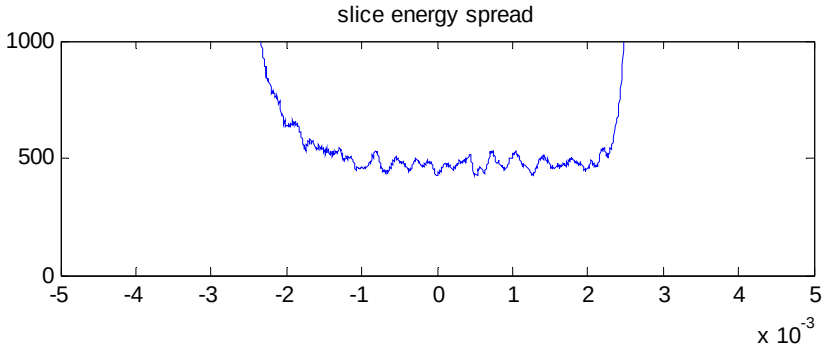
$\beta_{twiss,x,y}/m$= 2.1541, 2.1878

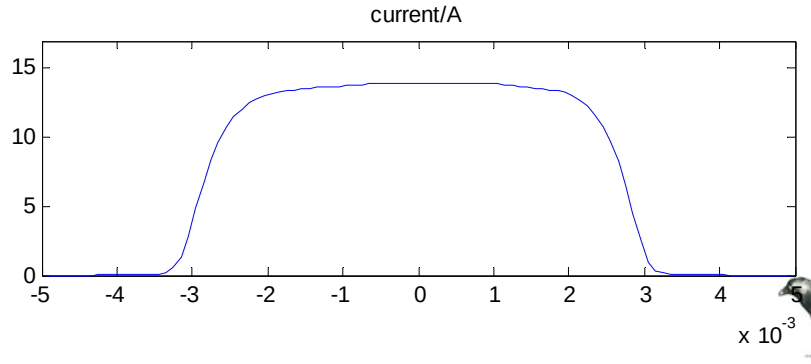
$\sigma_{E,slice}/eV$ = 478.8229

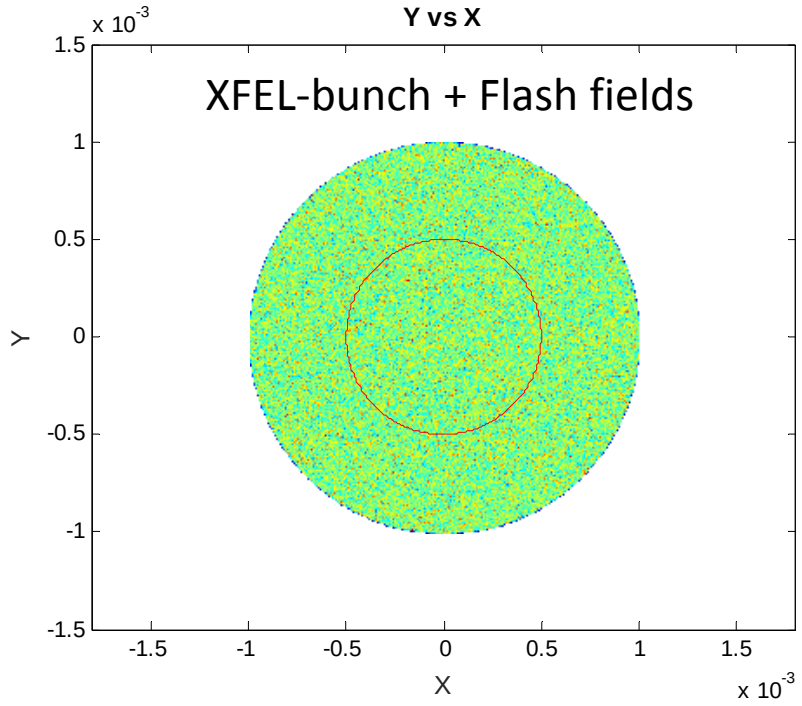
averaged for |z|<1mm






uniform, XFEL-bunch with Flash fields

q/pC = 250

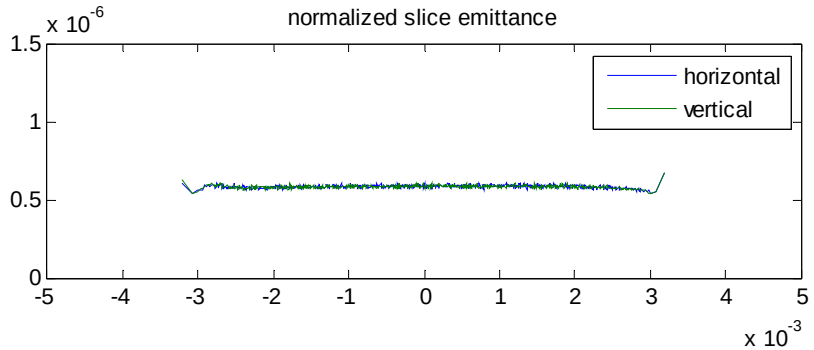
z/m = 1.4553

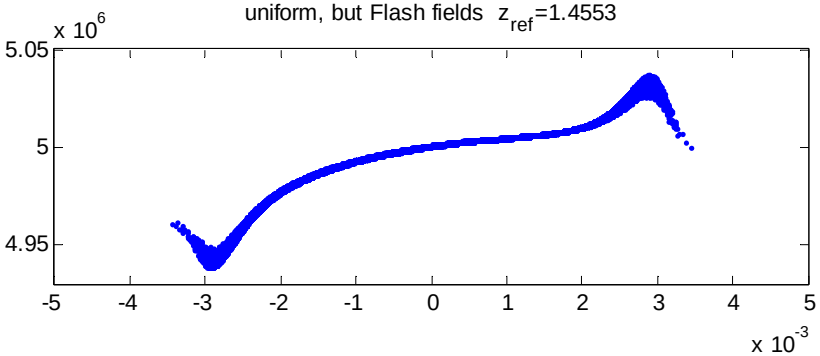
$\varepsilon\gamma\beta/\mu m$ = 1.0605, 1.0562

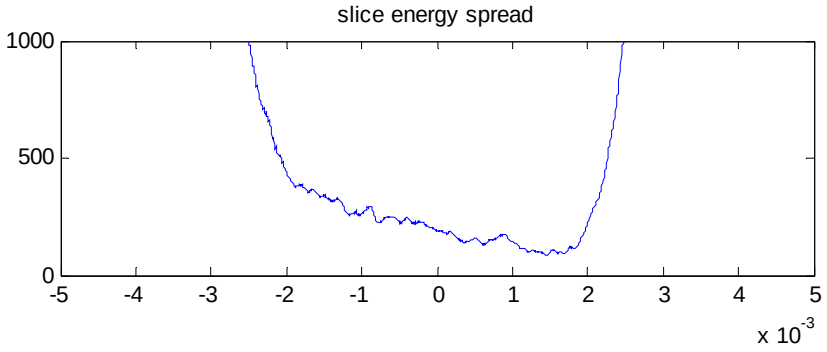
$\beta_{twiss,x,y}/m$= 2.1541, 2.1878

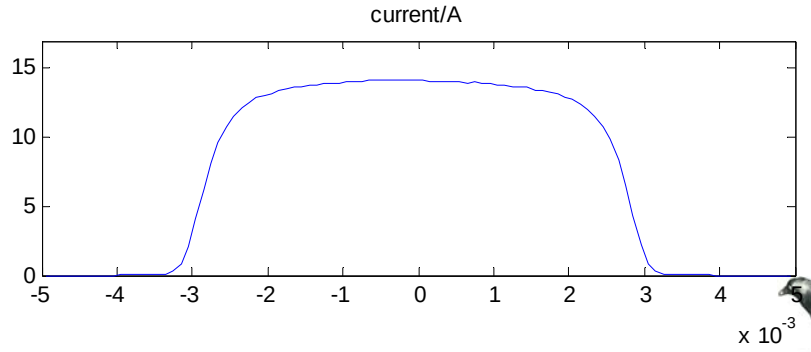
$\sigma_{E,slice}/eV$ = 240.8263

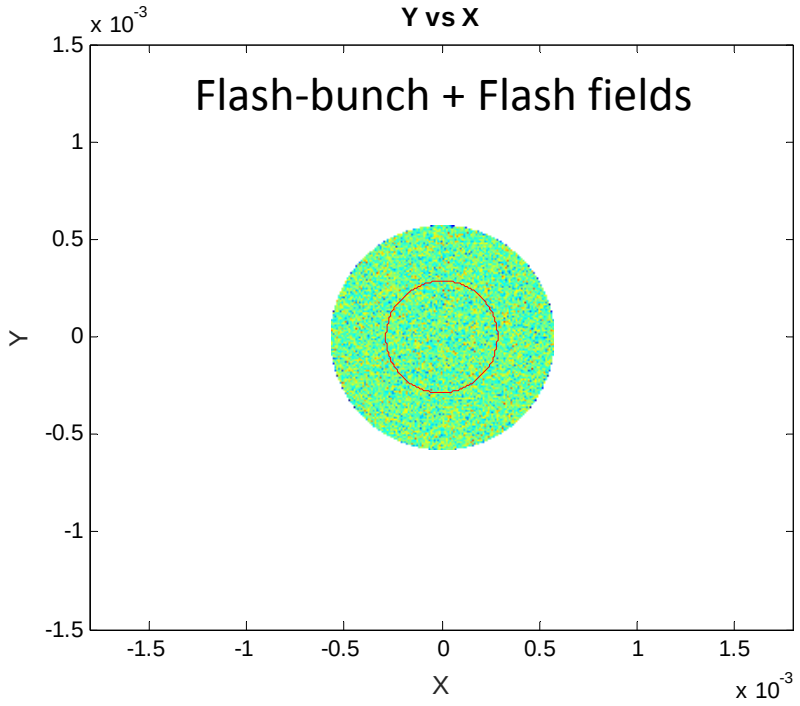
averaged for |z|<1mm






uniform, FLASH-bunch with Flash fields

q/pC = 250

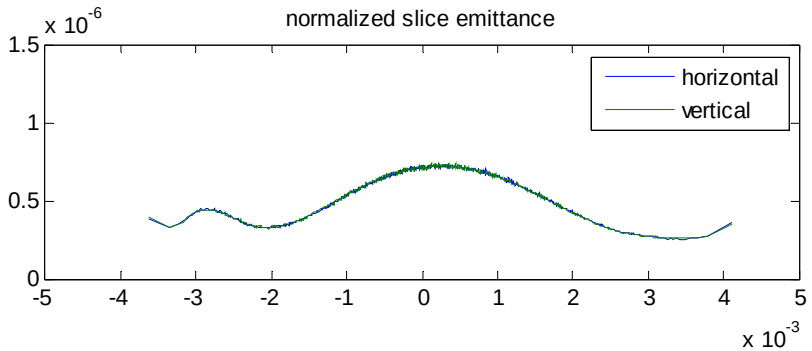
z/m = 1.4553

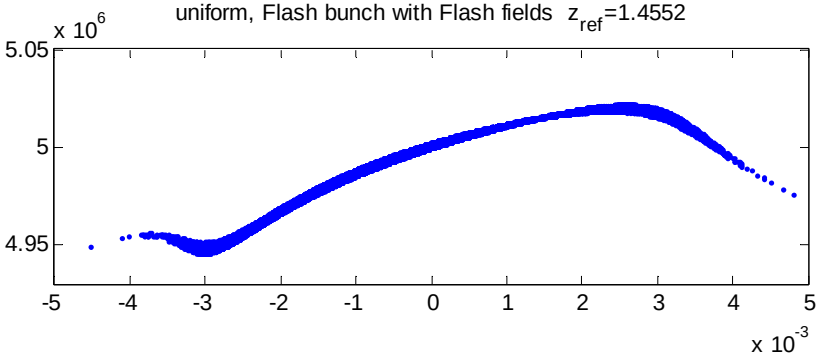
$\varepsilon\gamma\beta/\mu m$ = 1.4711, 1.4739

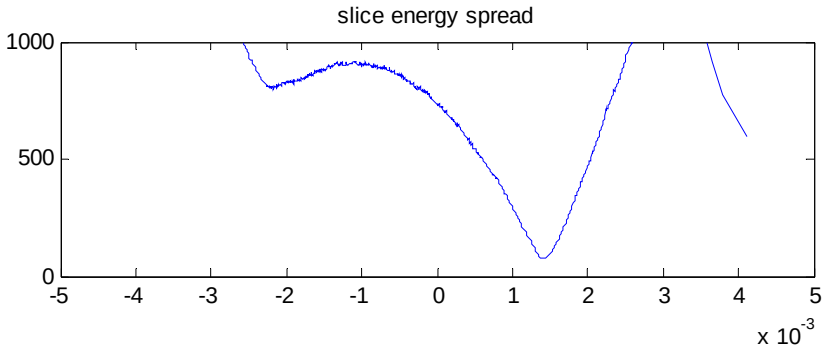
$\beta_{twiss,x,y}/m$= 12.1024, 12.0782

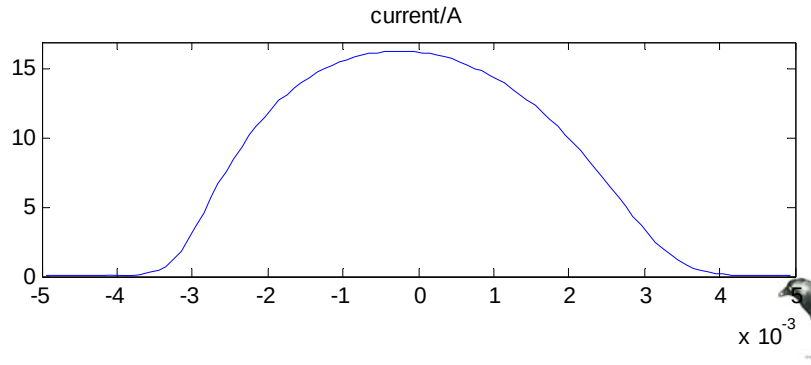
$\sigma_{E,slice}/eV$ = 798.1202

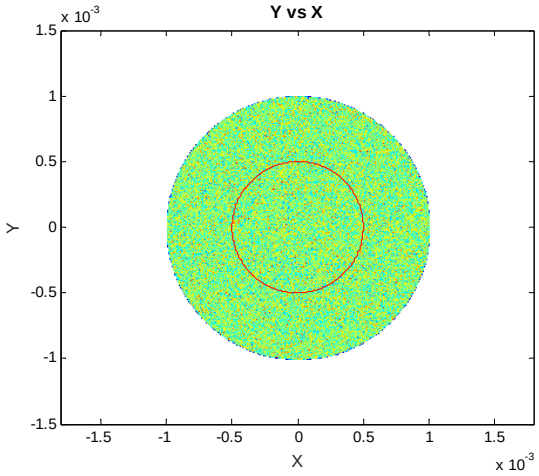
averaged for |z|<1mm

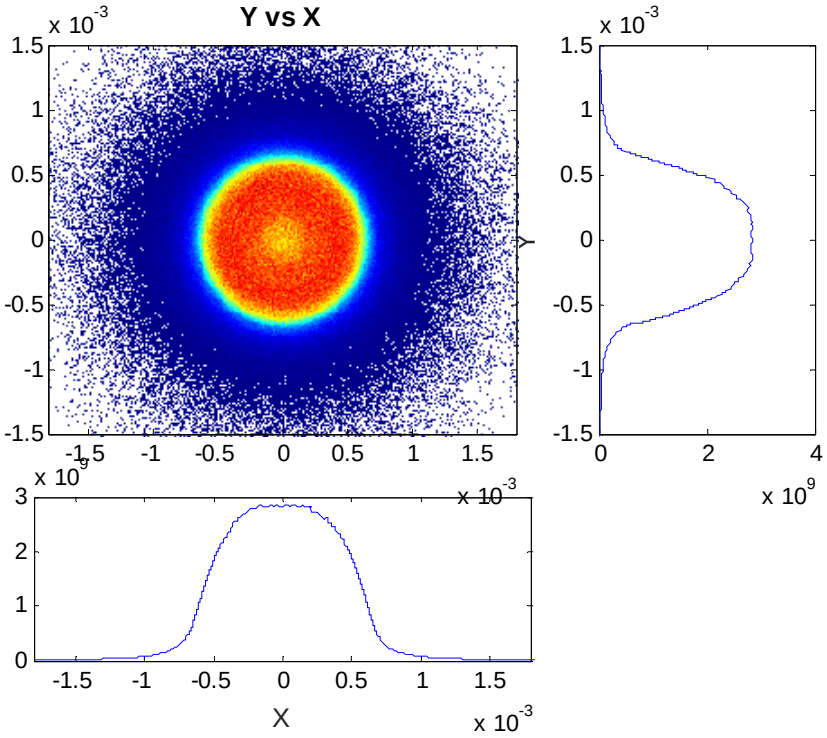


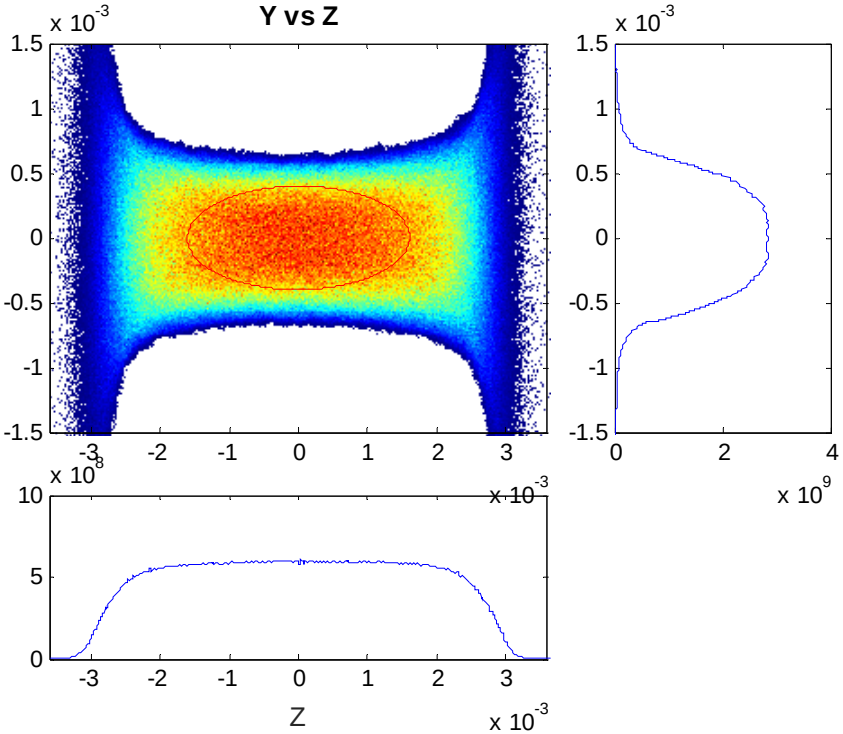






uniform distribution, XFEL

q/pC = 250

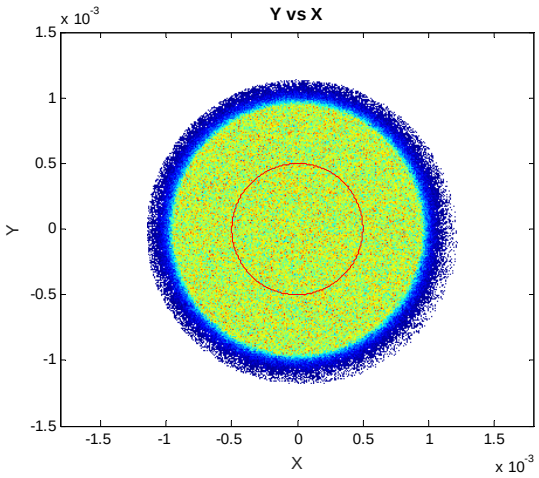
z/m = 2.6038

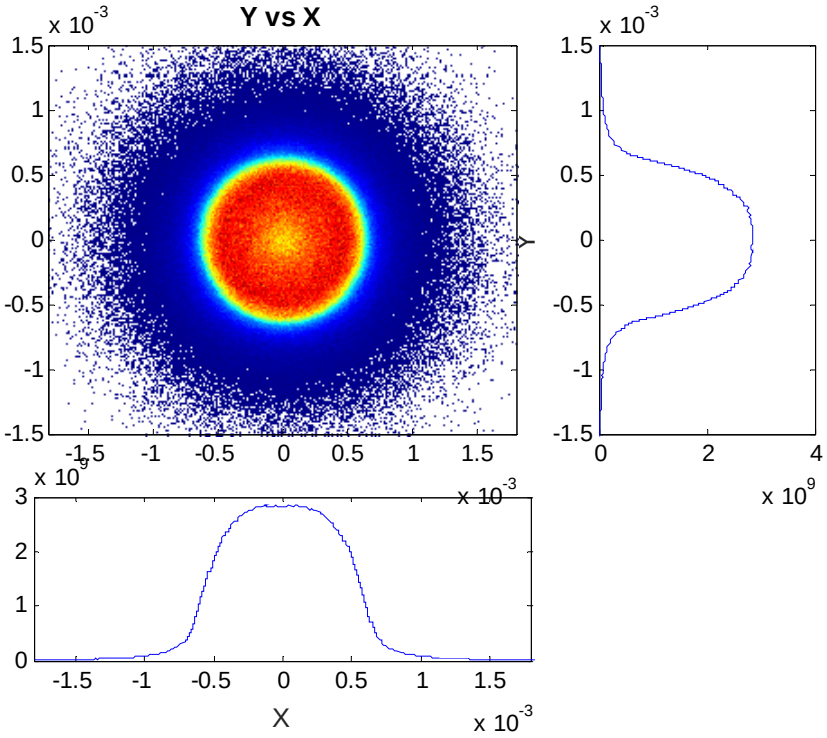
$\varepsilon\gamma\beta/\mu m$ = 0.94869, 0.94893

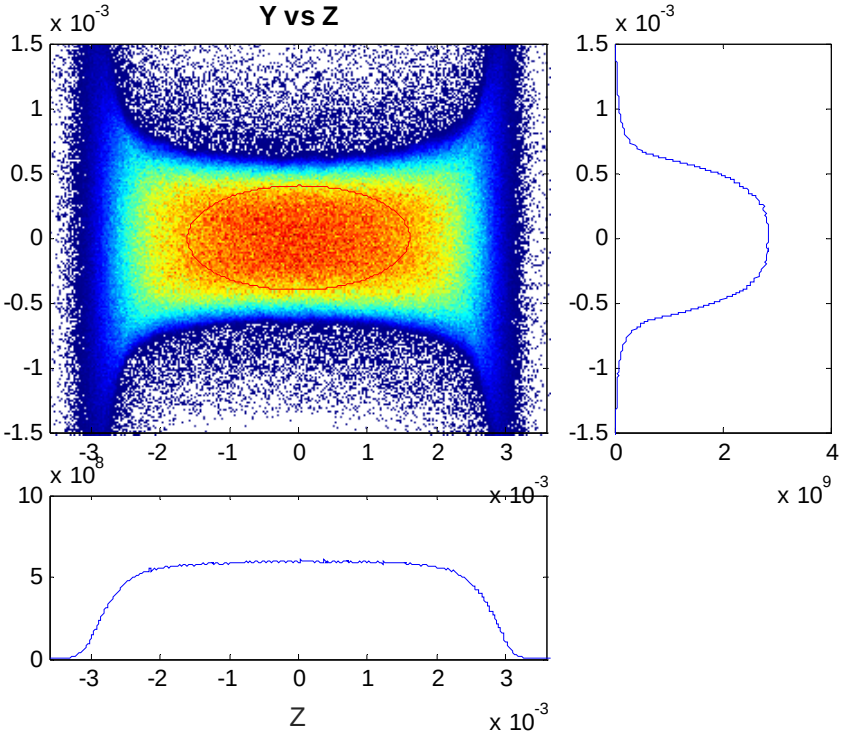
$\beta_{twiss,x,y}/m$= 2.1466, 2.144

$\sigma_{E,slice}/eV$ = 443.2164

averaged for |z|<1mm




90% uniform, 10% in halo

q/pC = 250

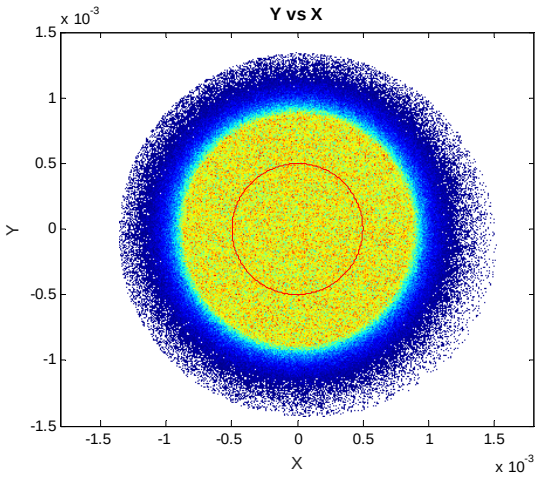
z/m = 2.6038

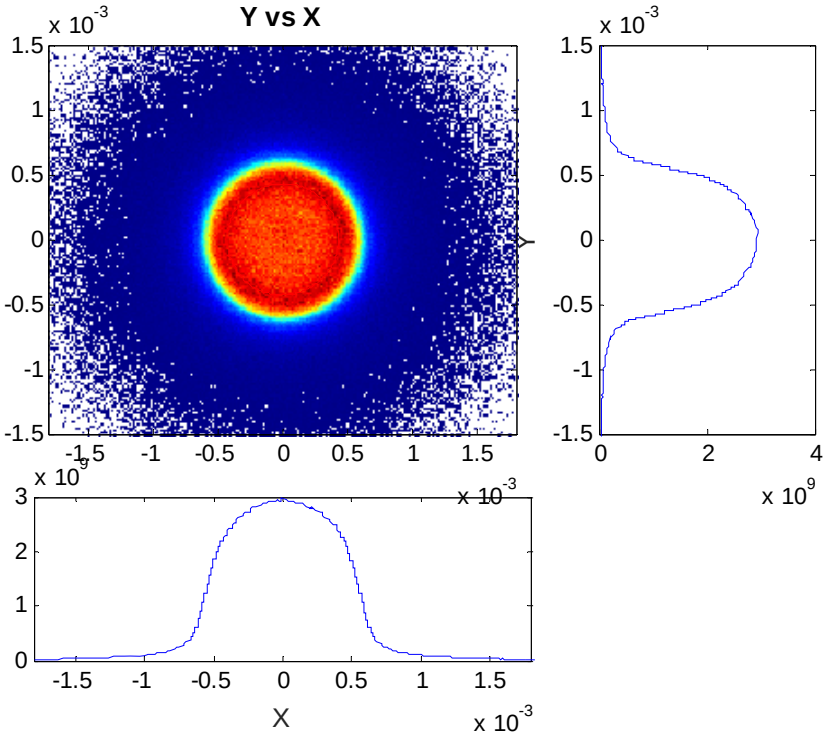
$\varepsilon\gamma\beta/\mu m$ = 0.94742, 0.94869

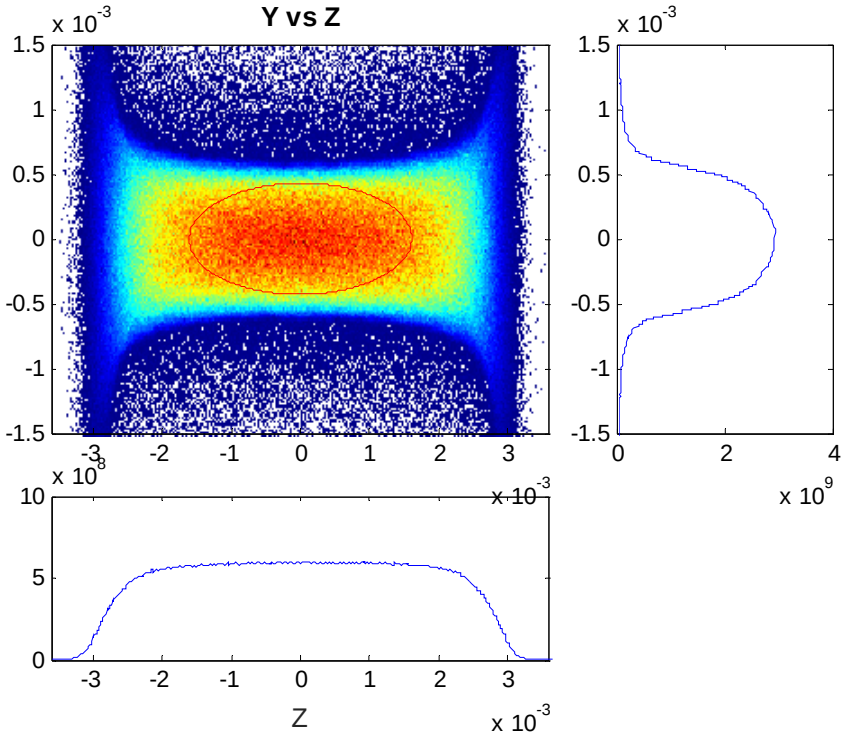
$\beta_{twiss,x,y}/m$= 2.1828, 2.1819

$\sigma_{E,slice}/eV$ = 436.6104

averaged for |z|<1mm




80% uniform, 20% in halo

q/pC = 250

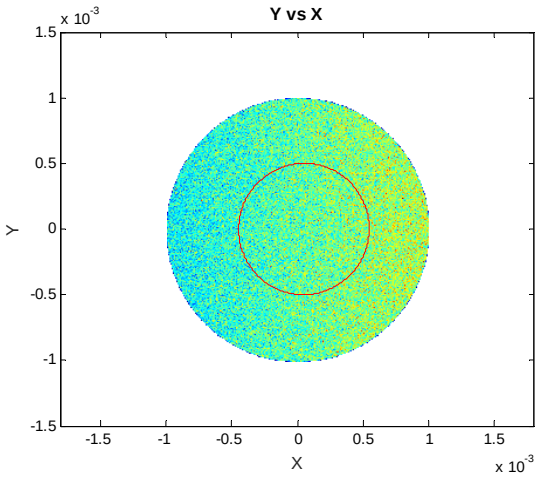
z/m = 2.6038

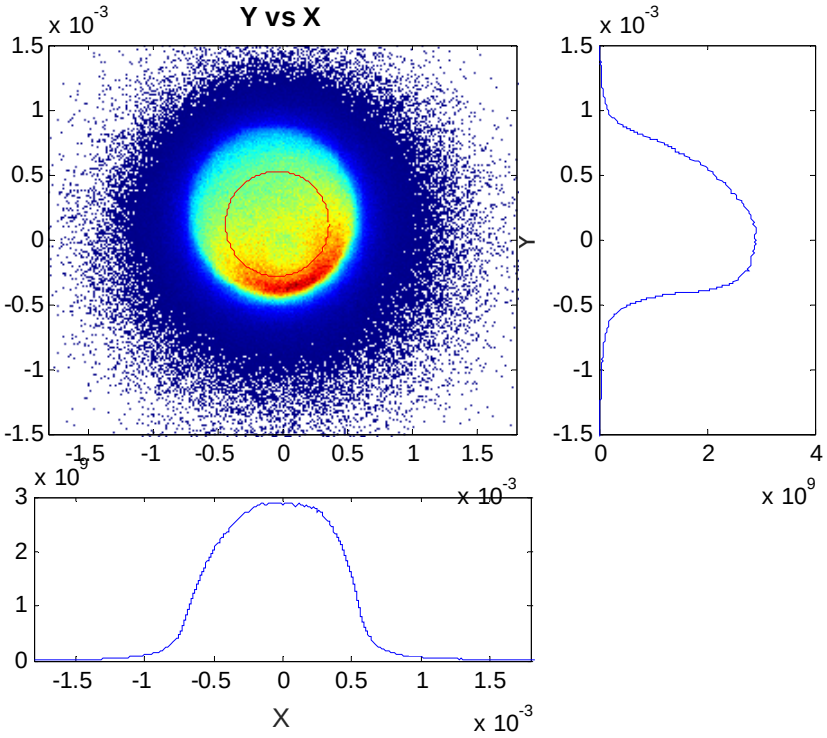
$\varepsilon\gamma\beta/\mu m$ = 1.0071, 1.0132

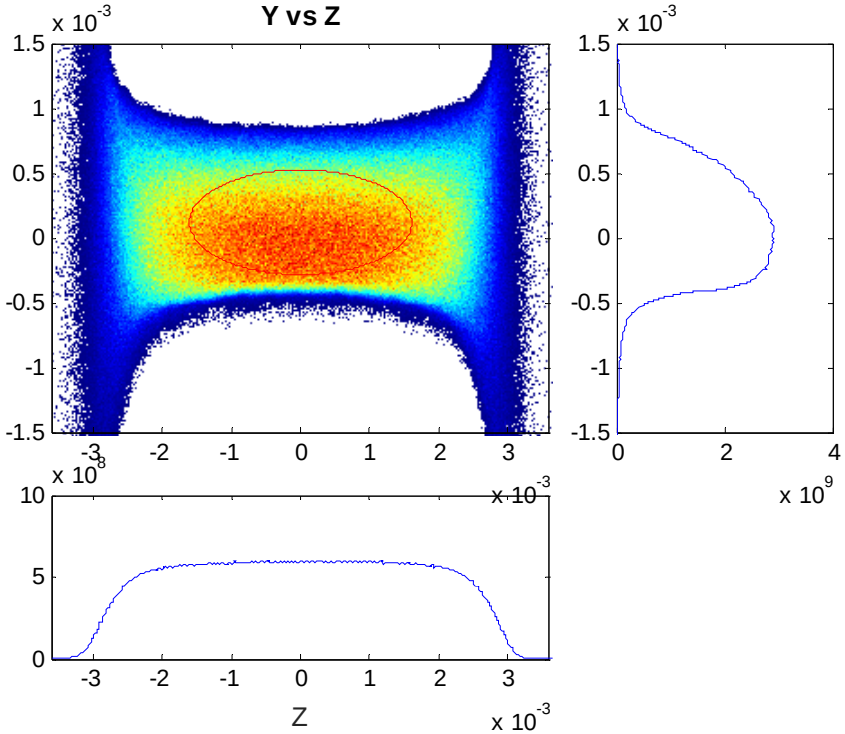
$\beta_{twiss,x,y}/m$= 2.3359, 2.3303

$\sigma_{E,slice}/eV$ = 460.346

averaged for |z|<1mm




odd

q/pC = 250

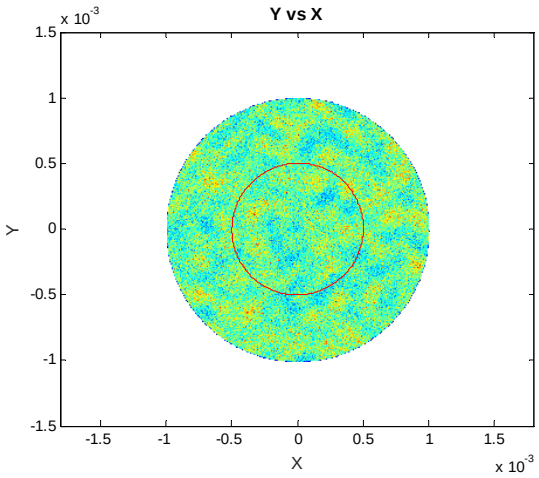
z/m = 2.6038

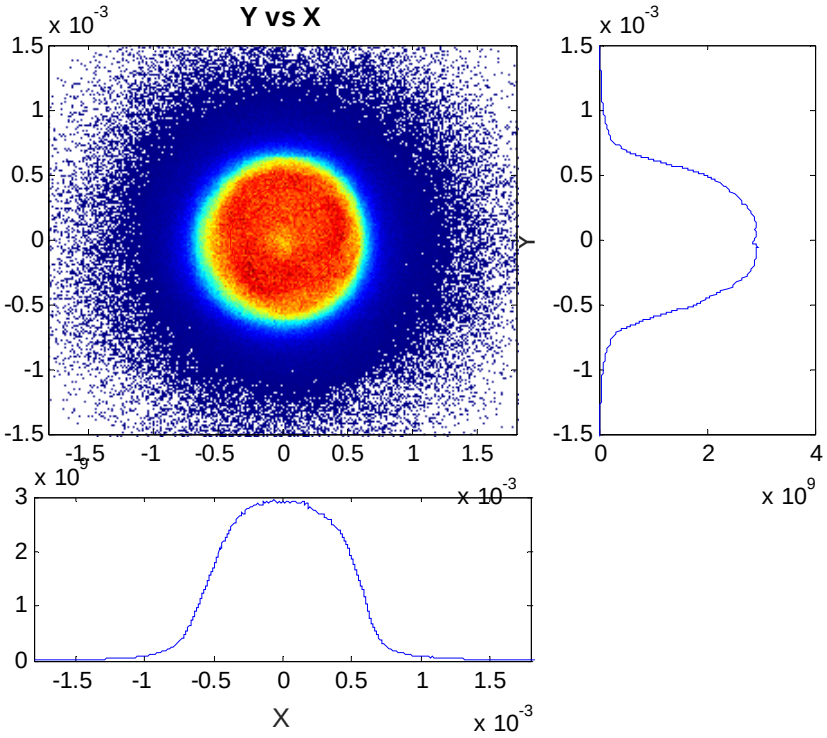
$\varepsilon\gamma\beta/\mu m$ = 0.96395, 0.98515

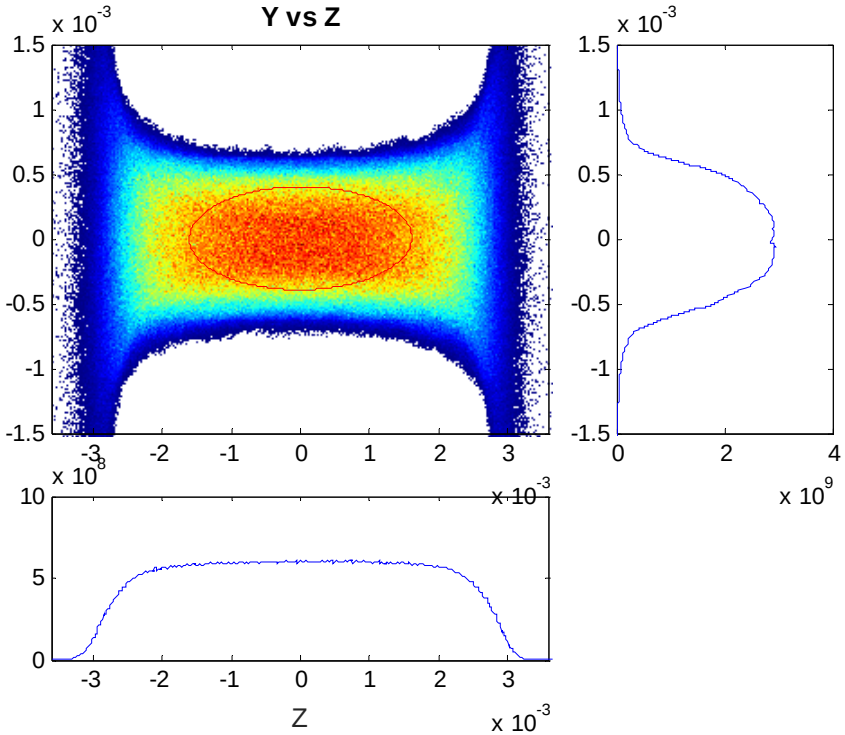
$\beta_{twiss,x,y}/m$= 2.1079, 2.119

$\sigma_{E,slice}/eV$ = 463.0909

averaged for |z|<1mm




10% rms, λcutoff=0.2mm

q/pC = 250

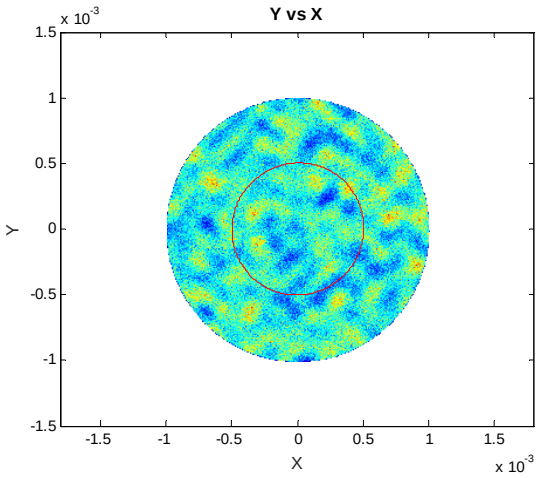
z/m = 2.6038

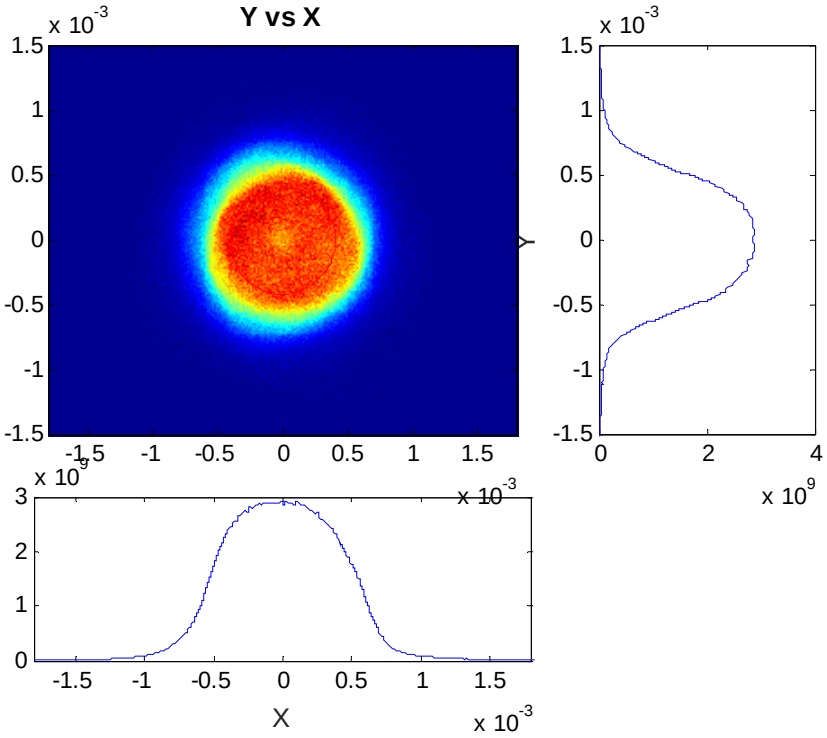
$\varepsilon\gamma\beta/\mu m$ = 0.96612, 0.93976

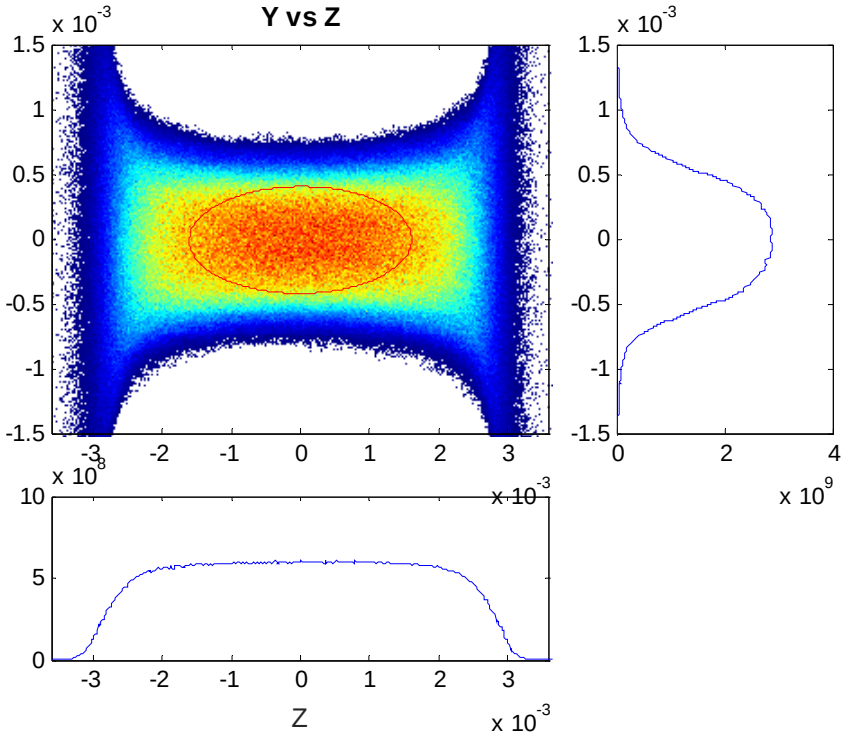
$\beta_{twiss,x,y}/m$= 2.1291, 2.1505

$\sigma_{E,slice}/eV$ = 460.4812

averaged for |z|<1mm




20% rms, λcutoff=0.2mm

q/pC = 250

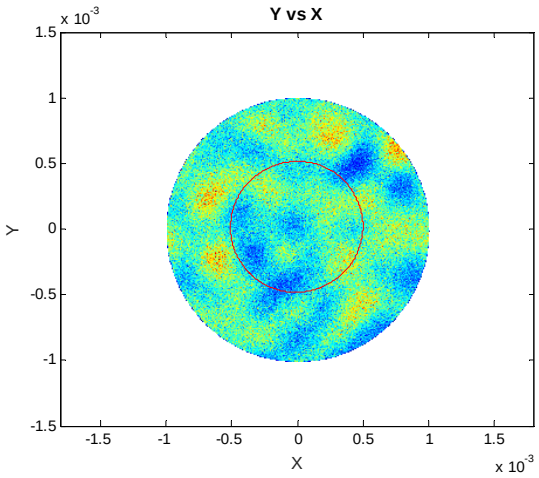
z/m = 2.6038

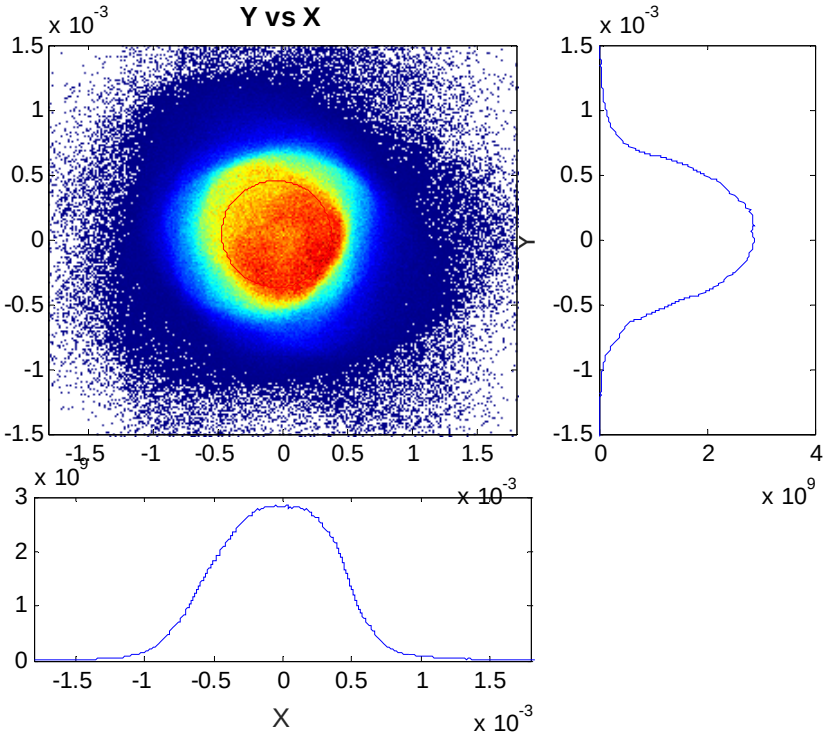
$\varepsilon\gamma\beta/\mu m$ = 0.9507, 1.0129

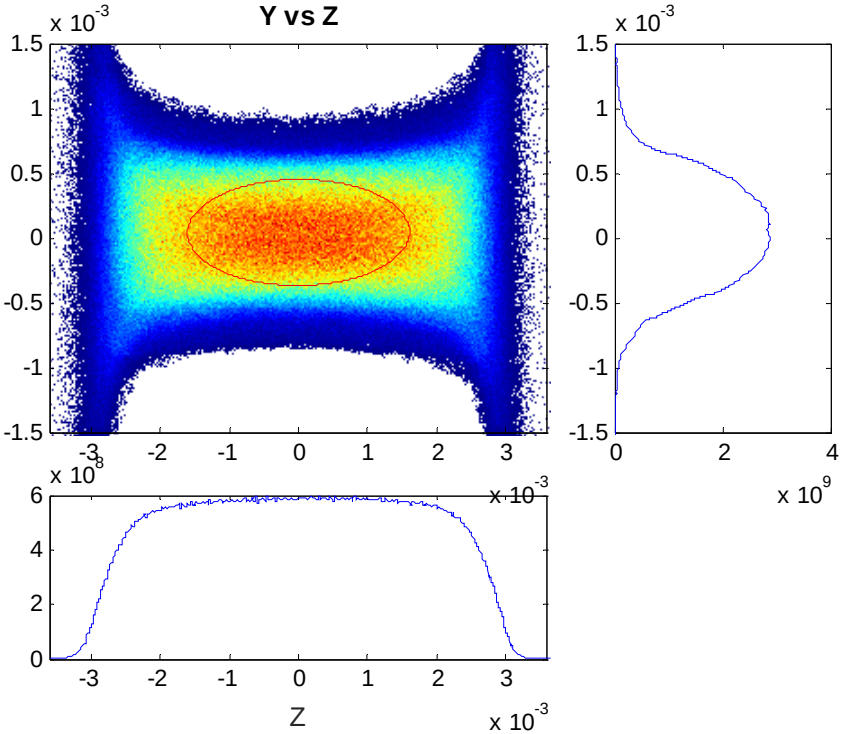
$\beta_{twiss,x,y}/m$= 2.1997, 2.1453

$\sigma_{E,slice}/eV$ = 479.0362

averaged for |z|<1mm




20% rms, λcutoff=0.4mm

q/pC = 250

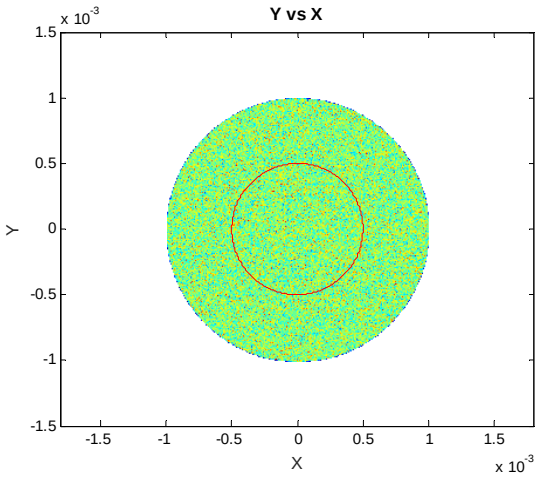
z/m = 2.6038

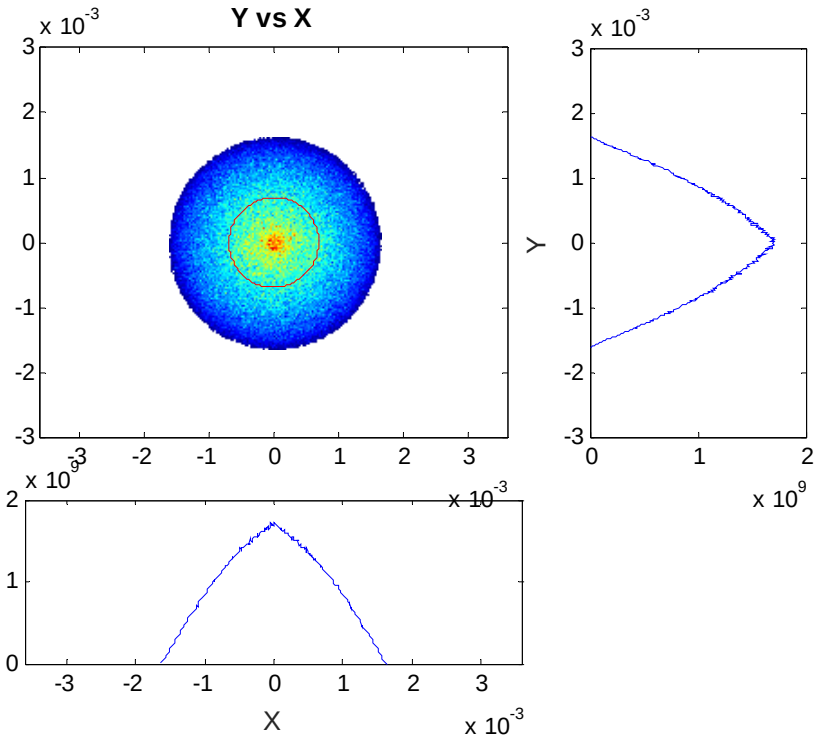
$\varepsilon\gamma\beta/\mu m$ = 1.0518, 0.97886

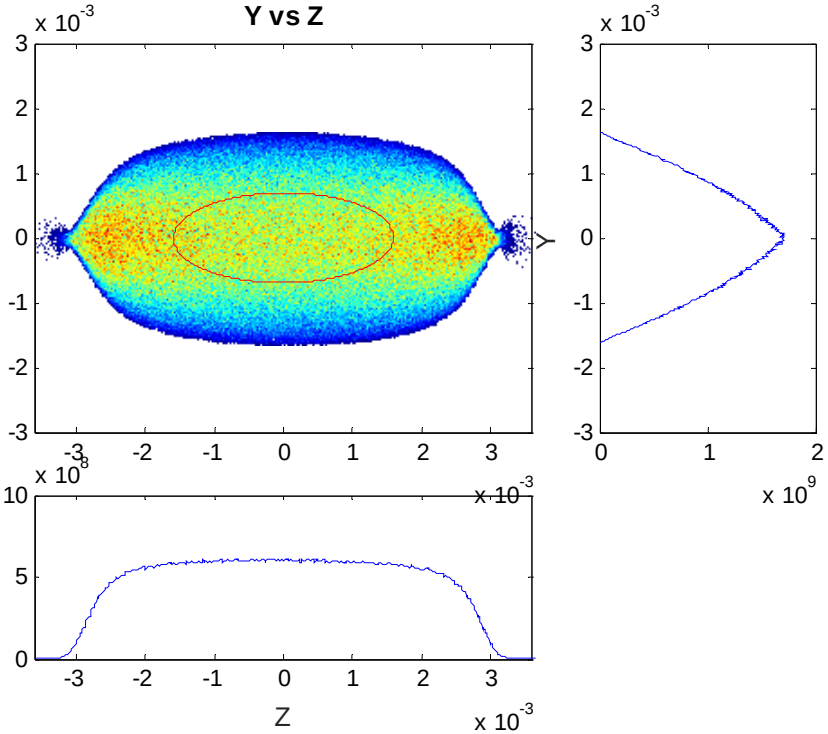
$\beta_{twiss,x,y}/m$= 2.1541, 2.1878

$\sigma_{E,slice}/eV$ = 478.8229

averaged for |z|<1mm




uniform, XFEL-bunch with Flash fields

q/pC = 250

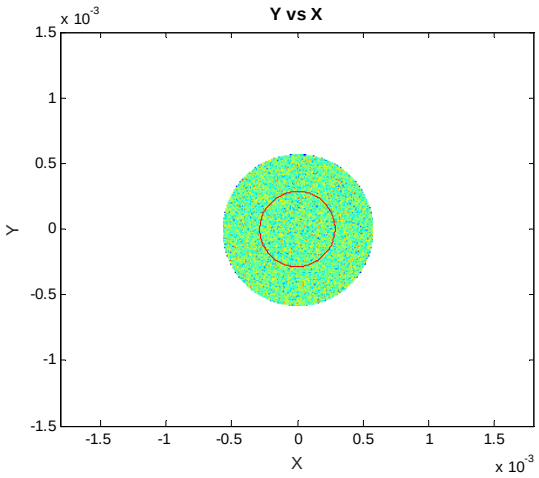
z/m = 1.4553

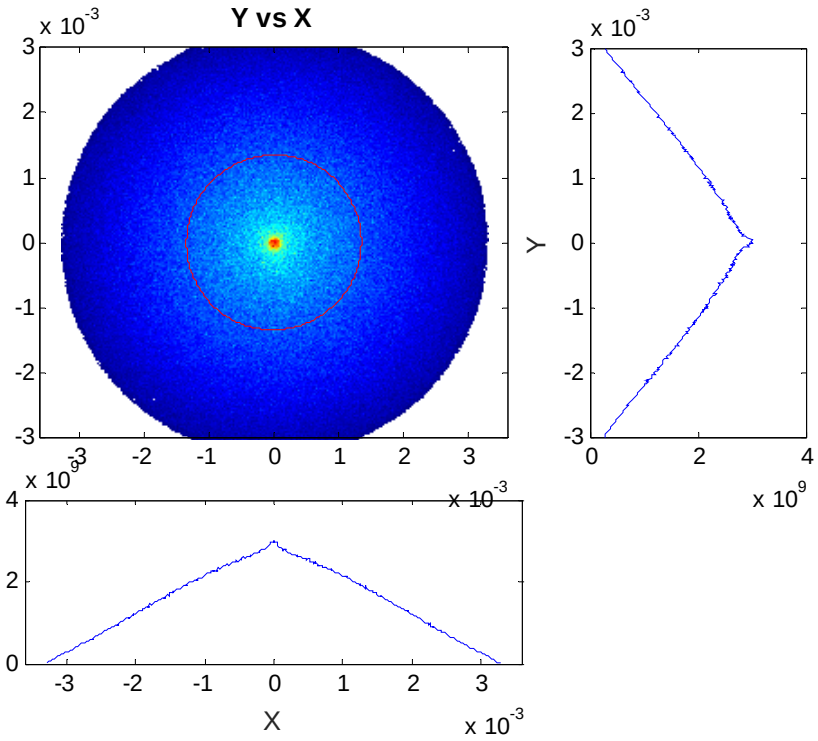
$\varepsilon\gamma\beta/\mu m$ = 1.0605, 1.0562

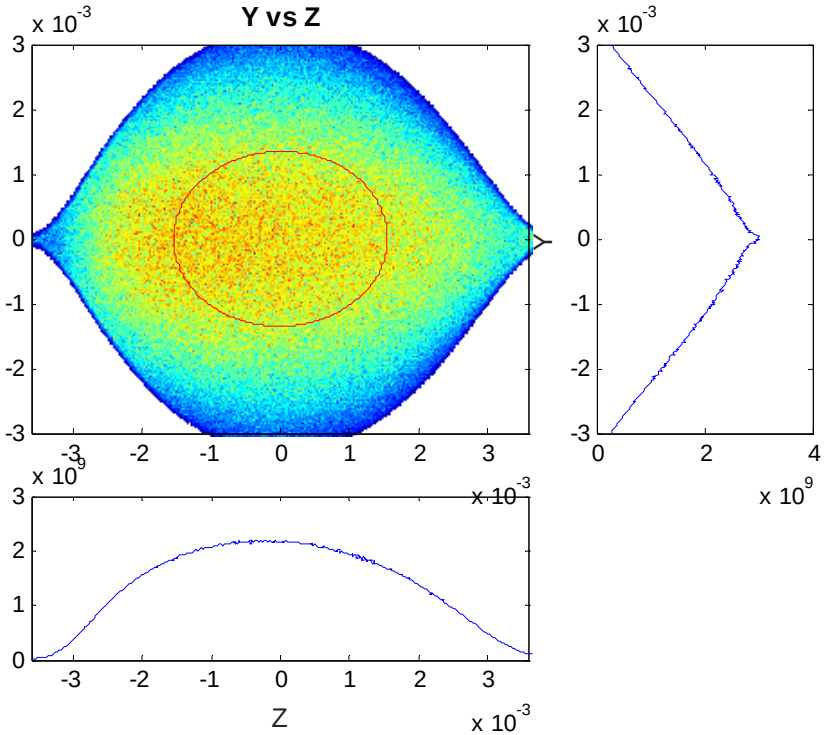
$\beta_{twiss,x,y}/m$= 2.1541, 2.1878

$\sigma_{E,slice}/eV$ = 240.8263

averaged for |z|<1mm




uniform, FLASH-bunch with Flash fields

q/pC = 250

z/m = 1.4553

$\varepsilon\gamma\beta/\mu m$ = 1.4711, 1.4739

$\beta_{twiss,x,y}/m$= 12.1024, 12.0782

$\sigma_{E,slice}/eV$ = 798.1202

averaged for |z|<1mm

# Gun Calculation with Astra
# “rz” and restarted “xyz”

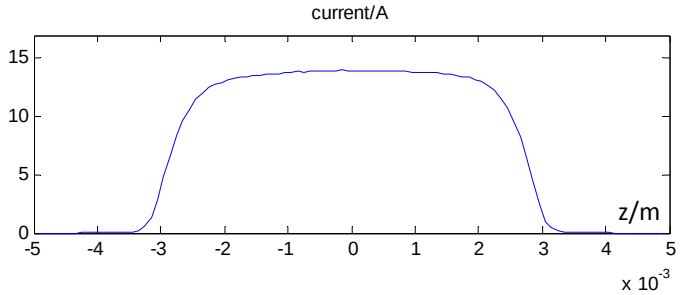
an other exemplary investigation

the bunch: 250 pC, XFEL type, see http://www.desy.de/xfel-beam/s2e/xfel/Nominal/nom250pC.html

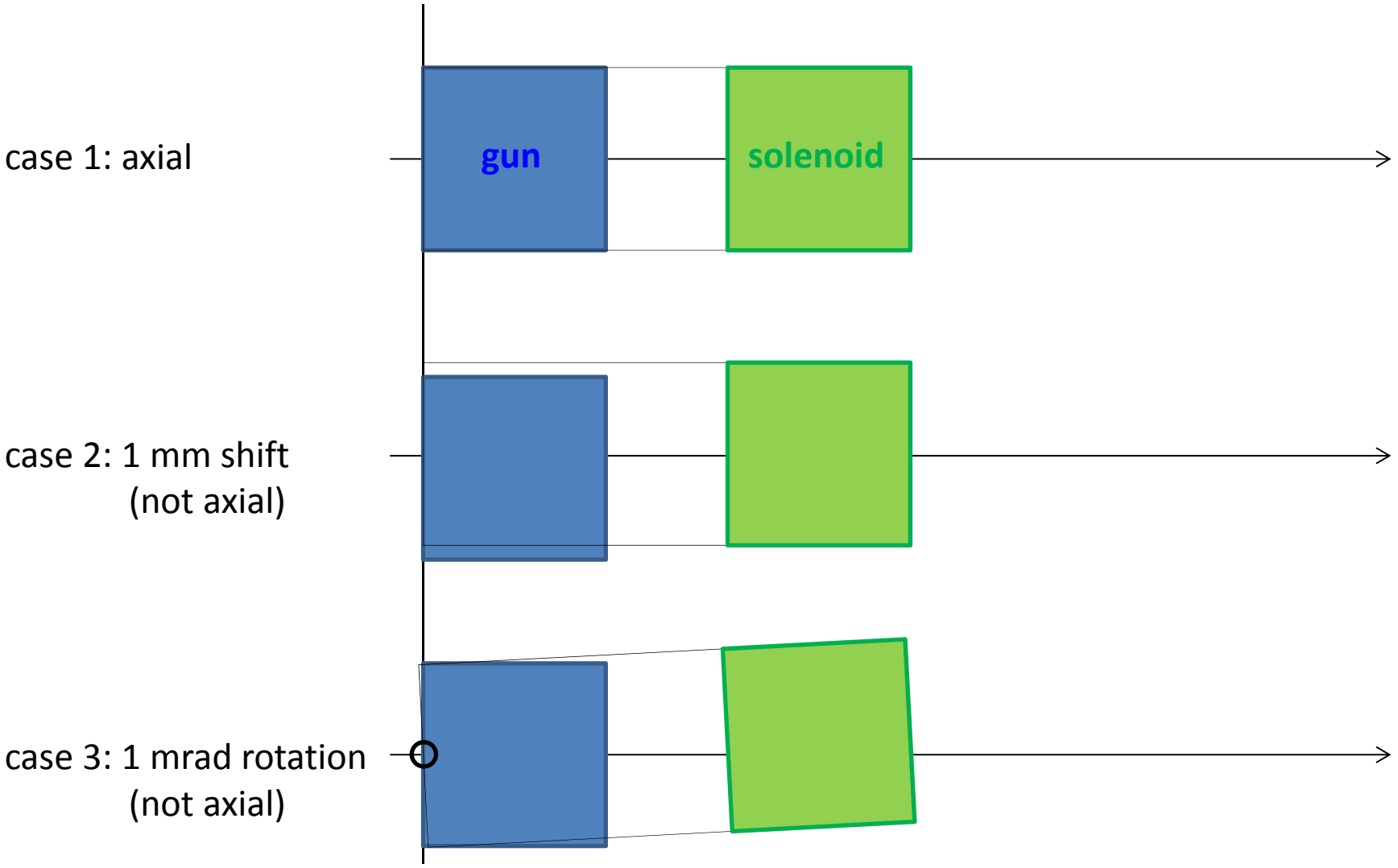
as before

longitudinally:

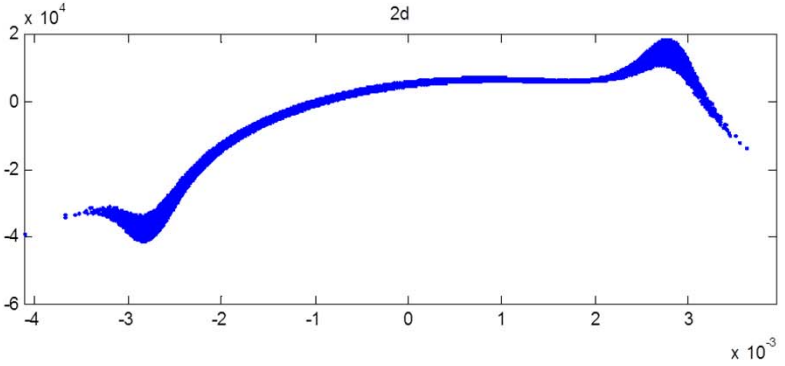
Astra generator
Lt=20psec, rt=2psec
Gun
60 MV/m, 0.2234 T

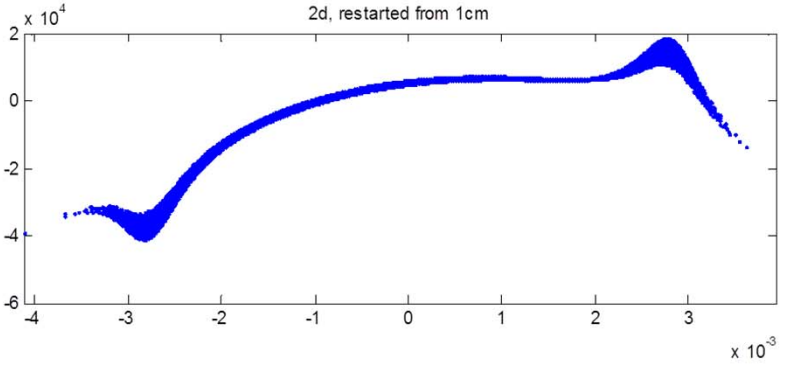


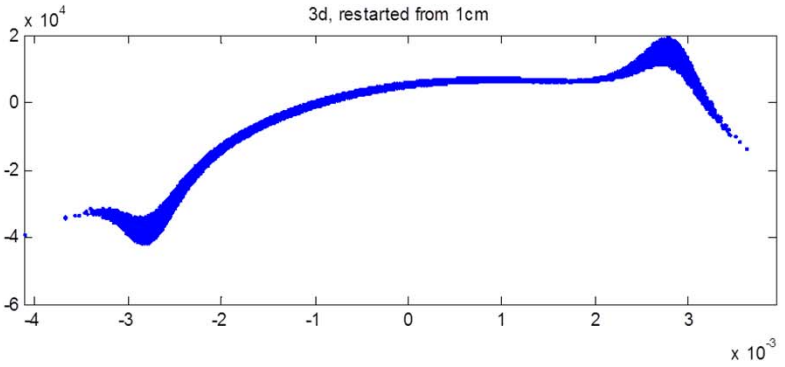

transversely: uniform, R = 1 mm (rms = 0.5 mm)

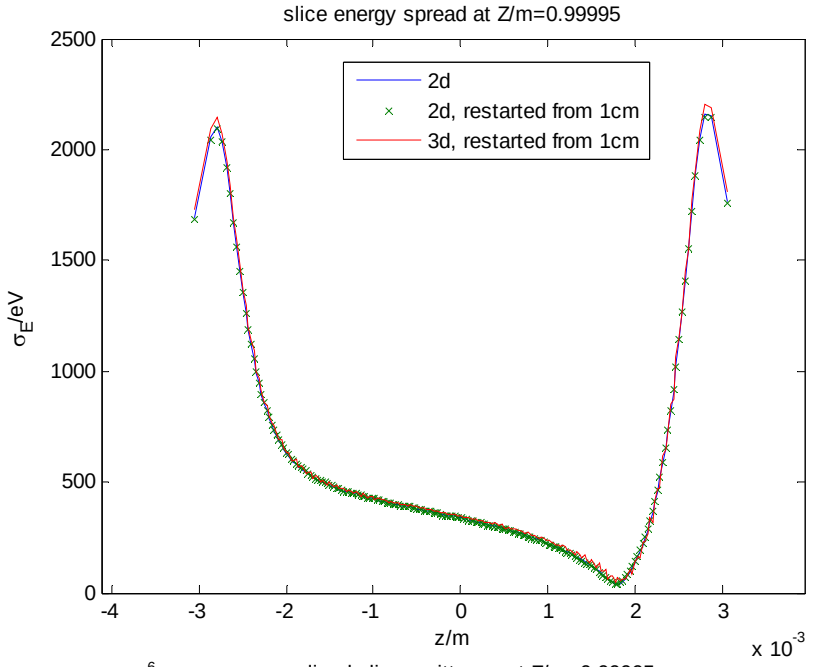

case 1: axial
gun
solenoid
case 2: 1 mm shift
(not axial)
case 3: 1 mrad rotation
(not axial)

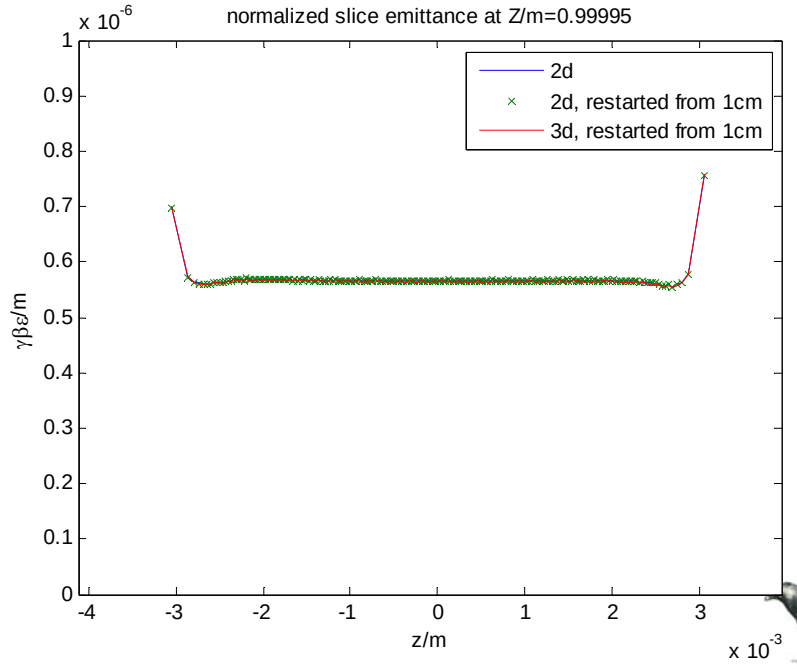
**case 1:** fully 2d, restarted 2d (from z=1cm), restarted 3d (from z=1cm) → z = 1m
mirror charges are switched off at ~ 10cm
but: restart without mirror charges



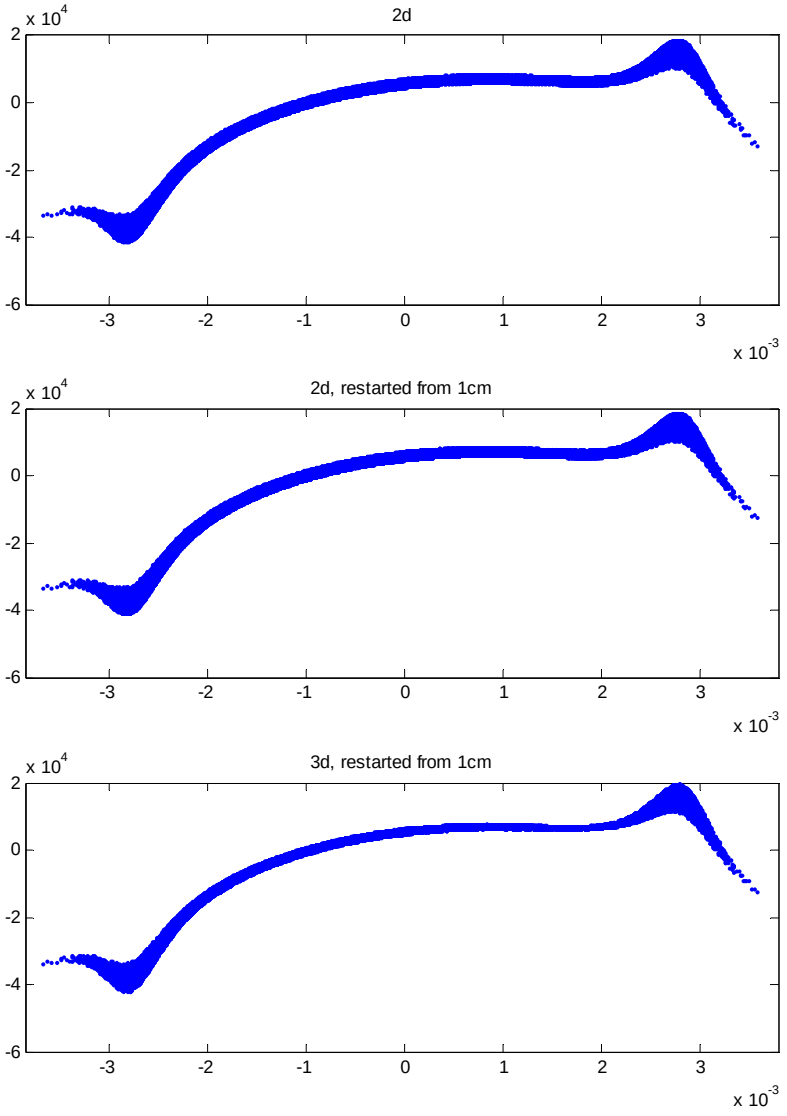



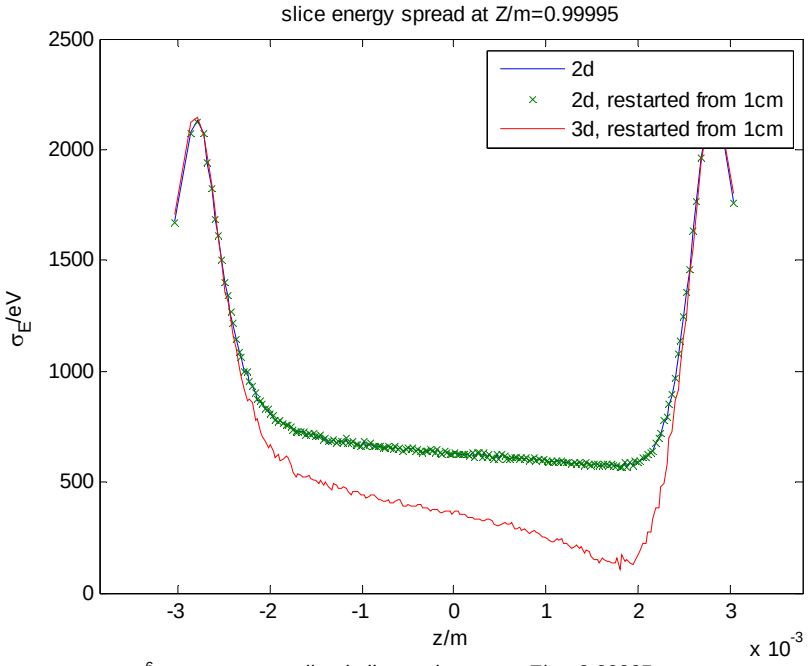



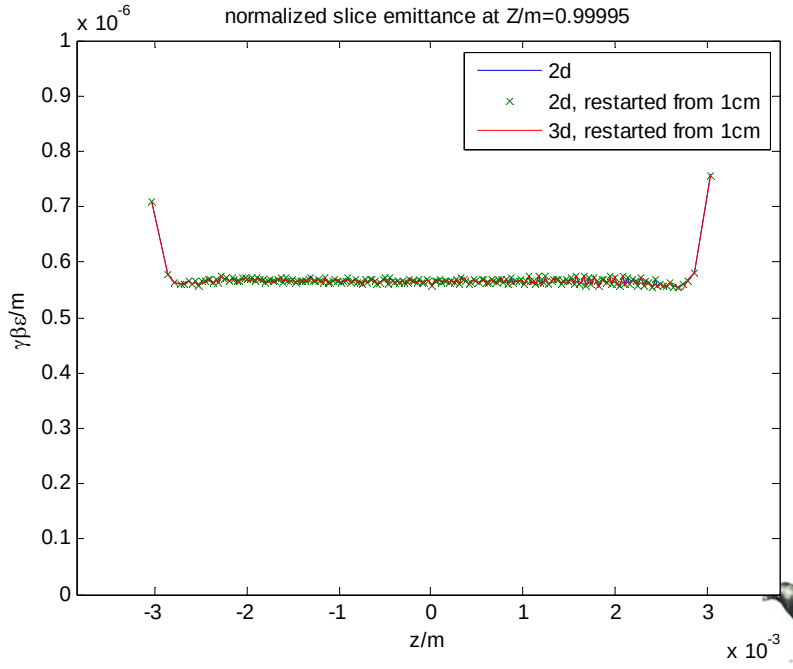

noise reduction (Hammersly), 1MP

**case 2:** fully 2d, restarted 2d (from z=1cm), restarted 3d (from z=1cm) → z = 1m

as before, but solenoid is shifted by 1mm



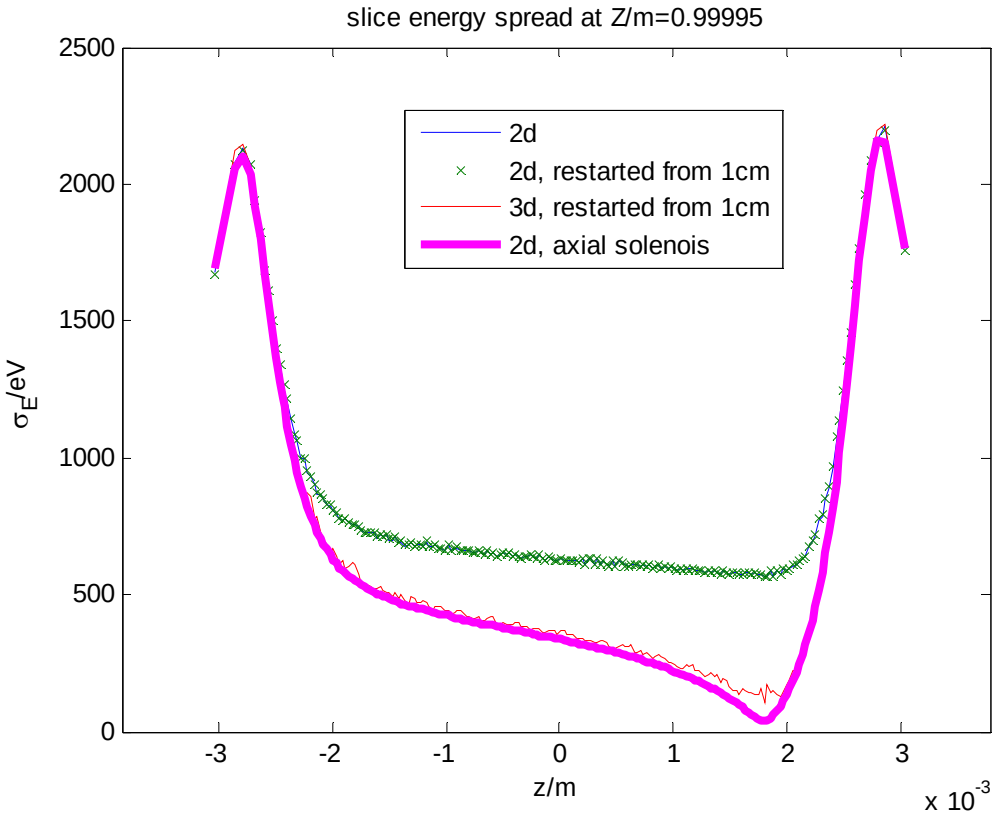




noise reduction (Hammersly), 200kP

case 2 ↔ case 1

z = 1m



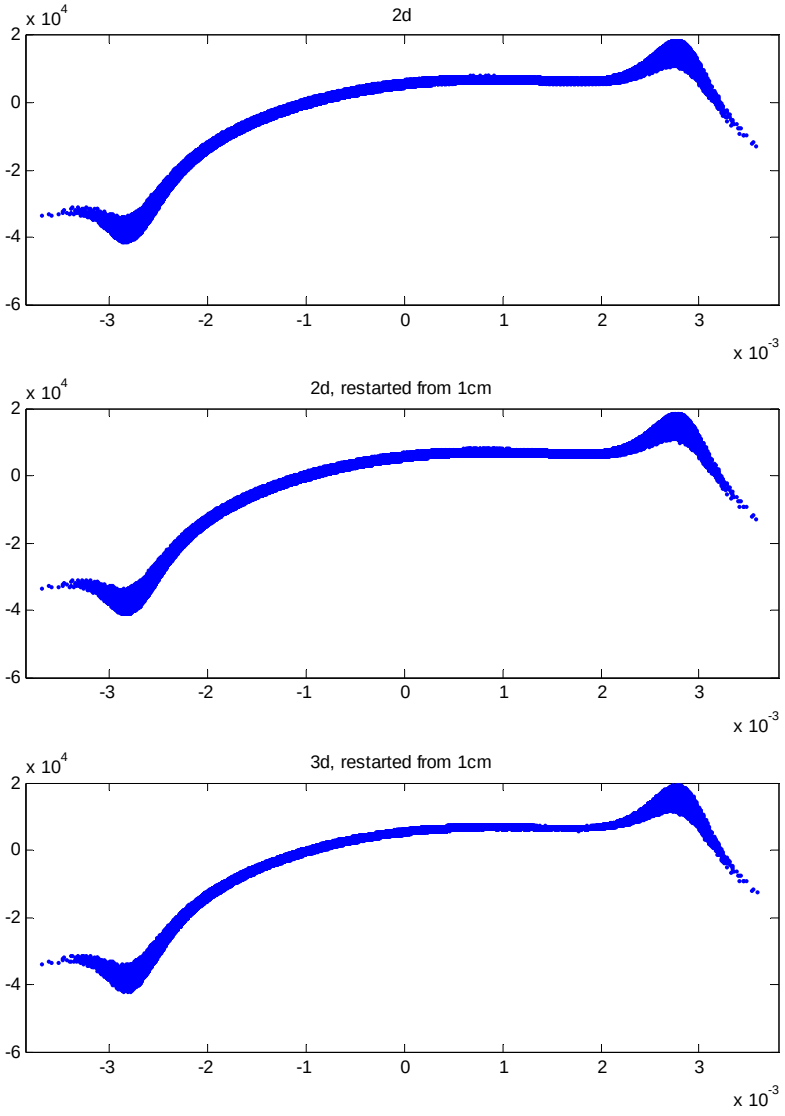

??? noise

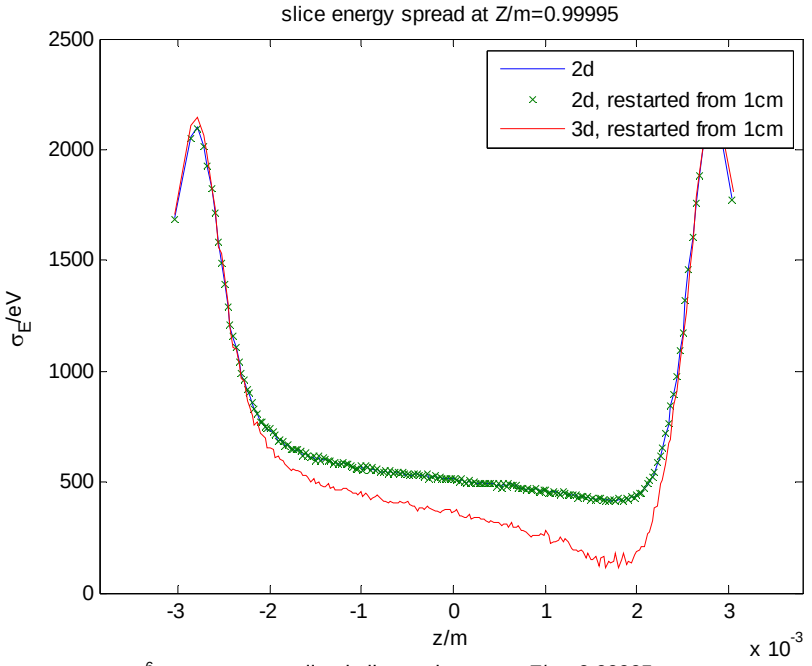
2d, 1MP ↔ 3d, 200kP

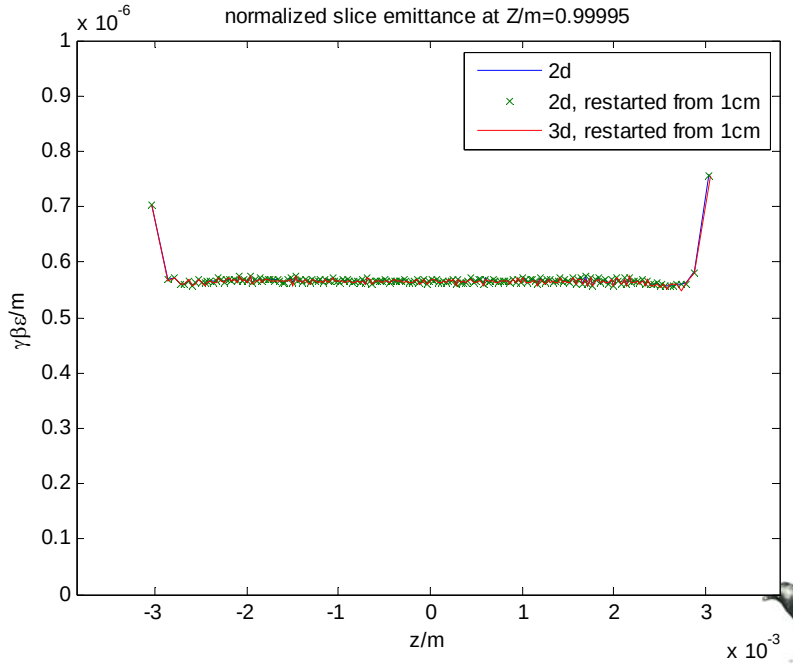
**2d solution, without shift**

**case 3:** fully 2d, restarted 2d (from z=1cm), restarted 3d (from z=1cm) → z = 1m

as before, but solenoid is rotated by 1mrad



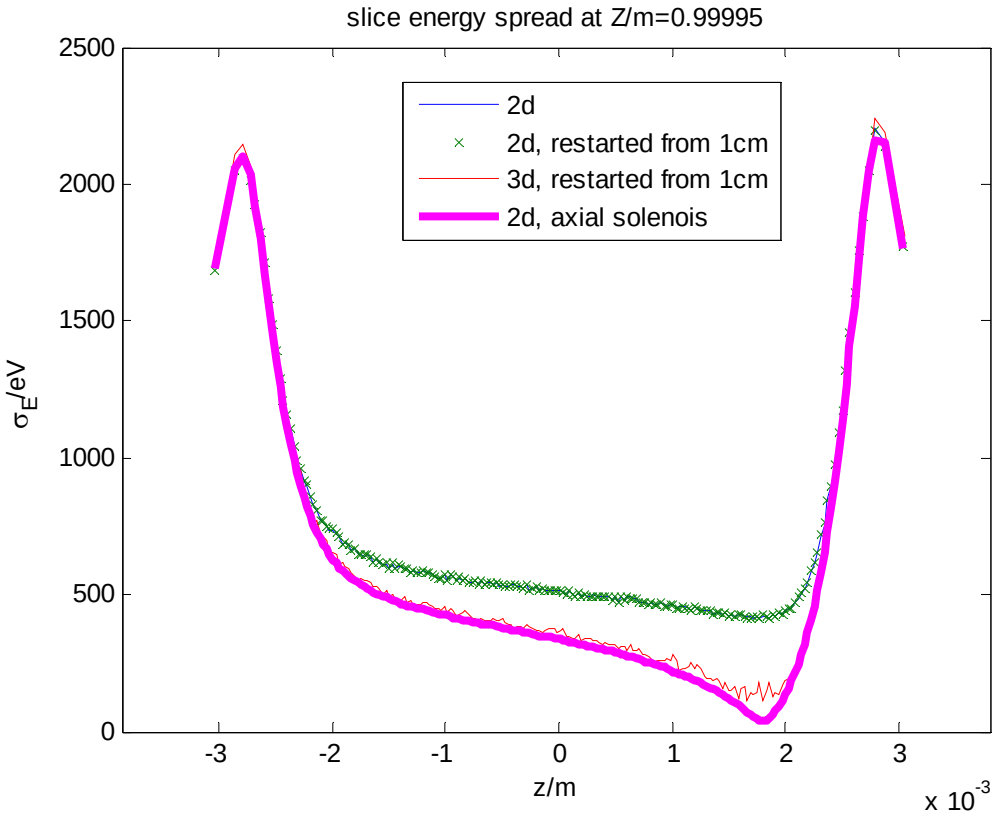




noise reduction (Hammersly), 200kP

case 3 ↔ case 1

z = 1m



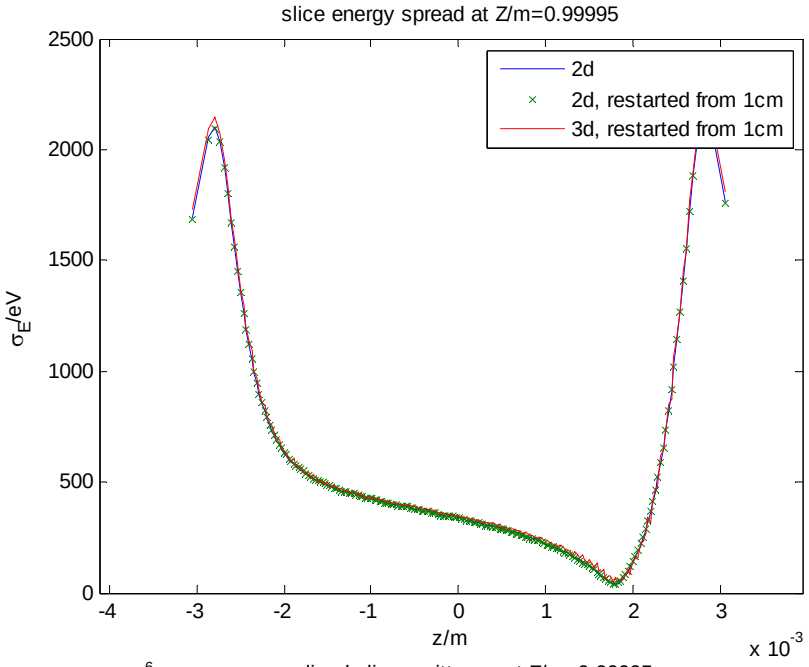

} ??? noise

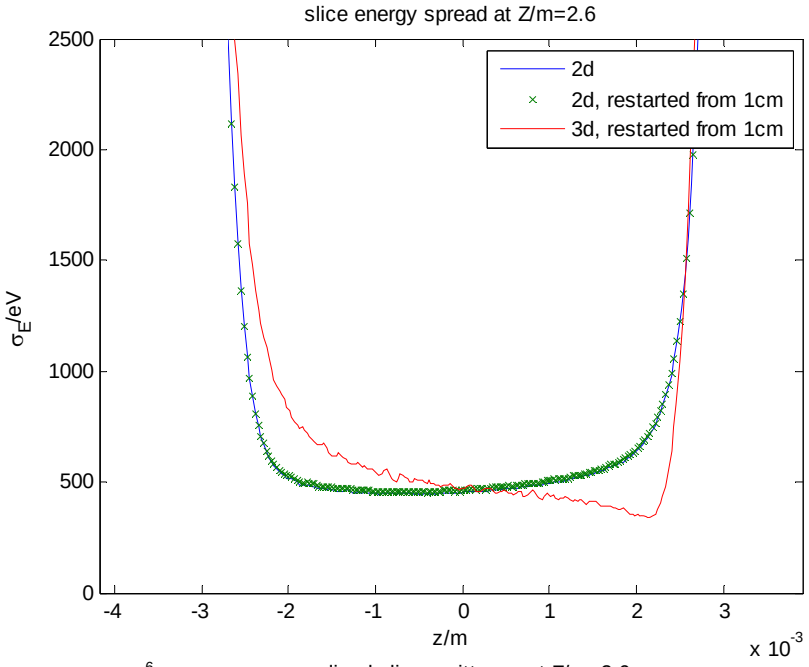
2d, 1MP ↔ 3d, 200kP

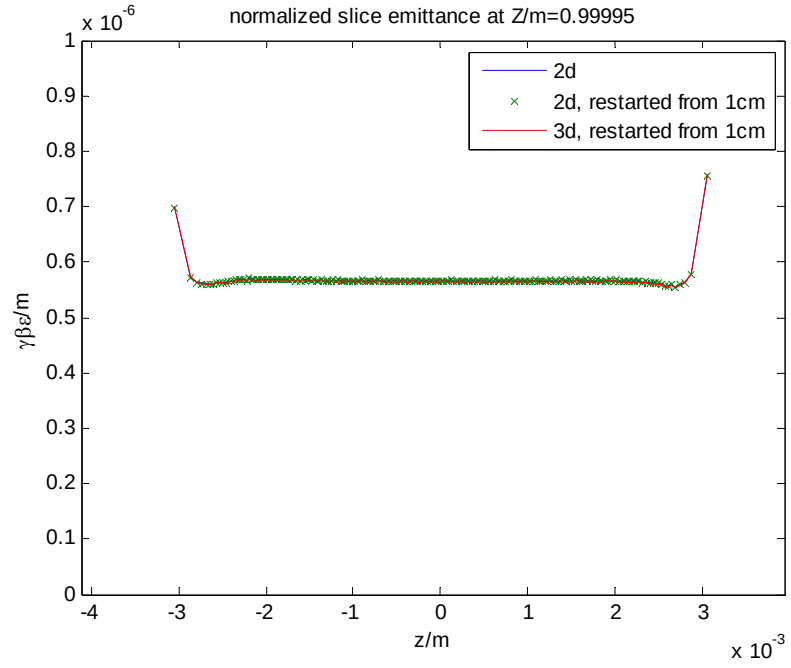
**2d solution, without shift**

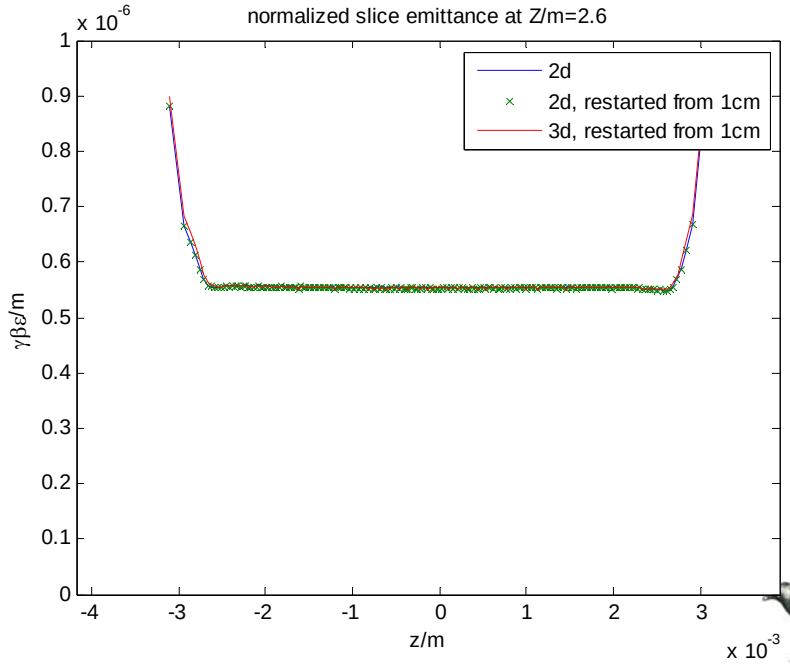
BUT

# **case 1:** fully 2d, restarted 2d (from z=1cm), restarted 3d (from z=1cm) → z = 1m & 2.6m

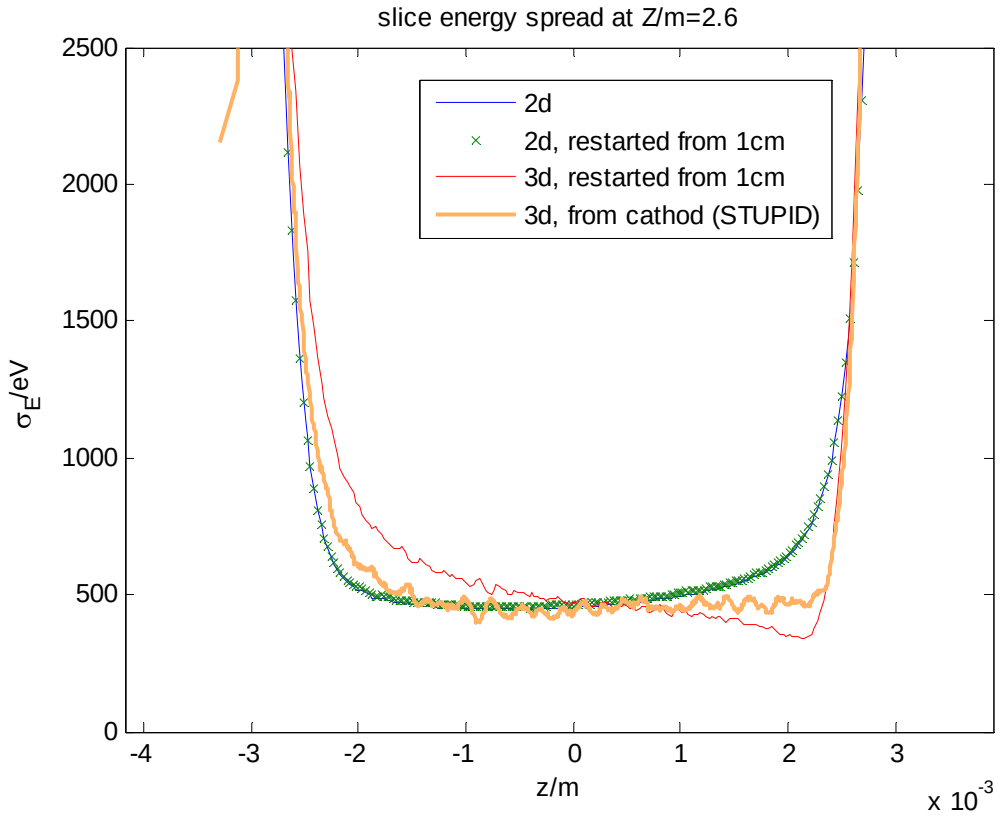


**case 1:** → z = 2.6m

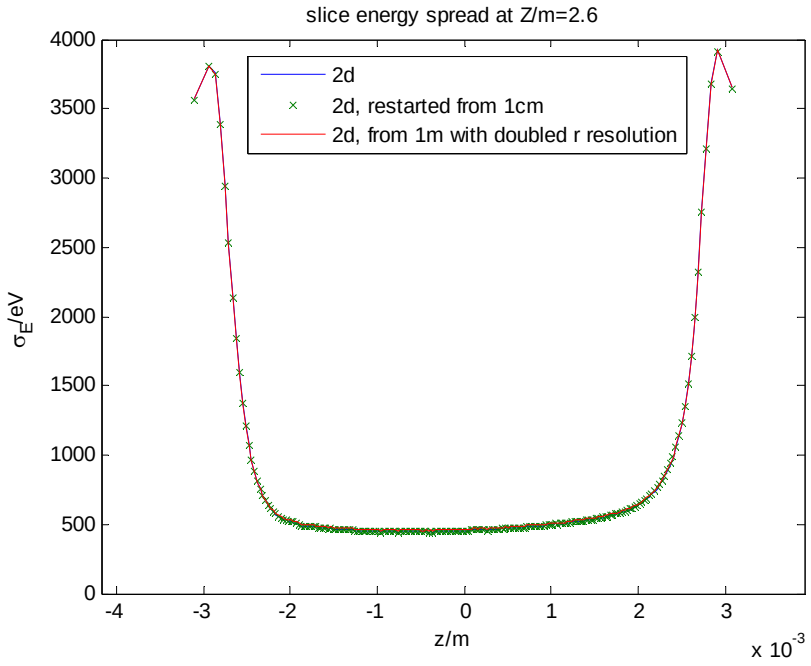



Astra with 1MP, Hammersly

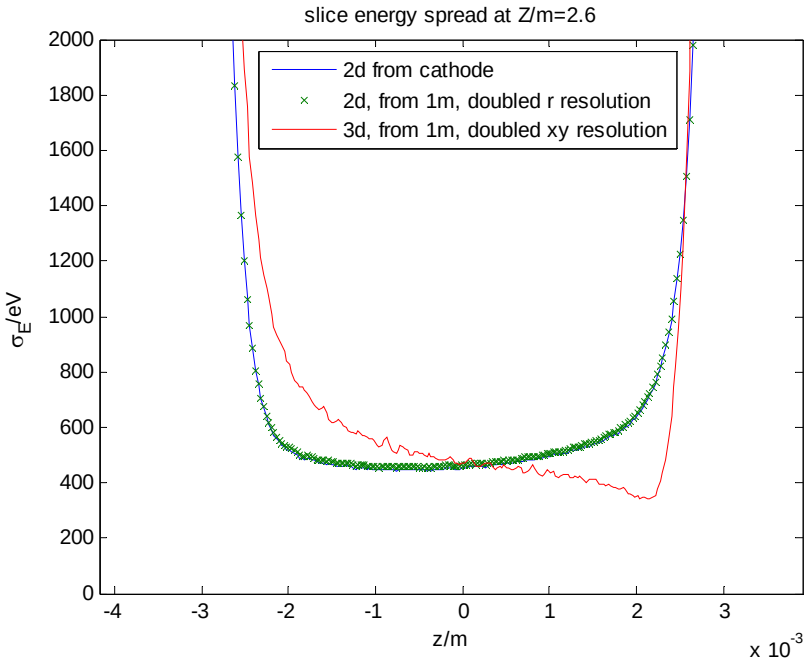
**stupid with 3.2MP, no noise reduction (random generator)**

**case 1:** → z = 2.6m, Astra with 1MP, Hammersly

(a) rz, restart from 1cm & 1m




(b) restart from 1m with doubled transverse resolution

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