

Beam-Dynamics of XFEL-Gun

with PIC code & ASTRA

general remarks

longitudinal particle position

longitudinal phase space

slice: longitudinal momentum vs. offset or radius

transverse phase space

emittance and energy vs. relative position in bunch

emittance and energy vs. geometric length

projected and slice emittance vs. geometric length

summary



General Remarks

configuration:

XFEL-Gun based an ASTRA-Input “K.Floettmann 6. Dec. 2005”

$E_{\max} = 60$ MV/m

$B_{\max} = 0.1988$ T

$q = 1$ nC

calculation:

by Erion Gjonaj, TEMF (Technical University of Darmstadt)

see also: http://www.desy.de/xfel-beam/data/talks/files/EG_DESY_21.12.2010.pdf

method:

ASTRA 200E3 particles

PIC with higher order field approximation

3x3x3 200E3 particles $\text{order}_x = 3, \text{order}_y = 3, \text{order}_z = 3$

2x3x3 500E3 particles 2 2 3

3x3x4 500E3 particles 3 3 4

available data:

particle data for $z_{\text{ref}}/\text{mm} = 5, 10, \dots 295$

particle data for asymmetric initial distribution: not analyzed jet

files: N:\4all\shares\data\data01\dohlus\TEMF_PIC_calculation



General Remarks

E. Gjonaj about order of PIC simulation:

low order (FIT) not applicable:

resolution $dz=10\mu\text{m}$ with $1E7$ particles required for simulation of 5 cm
beyond that: increase of emittance

high order:

nearly no dispersion; weak aliasing (mixing grid & physical spectrum)
noise level not increasing in time
allows less particles, coarser grid

spatial resolution:

ASTRA: 96 radial mesh lines, 256 longitudinal mesh lines

PIC: mesh in bunch $3 \times 3 \times 3$ $dx=dy=200\mu\text{m}$, $dz=50\mu\text{m}$

$2 \times 2 \times 3$ $dx=dy=dz=100\mu\text{m}$

$3 \times 3 \times 4$ $dx=dy=dz=100\mu\text{m}$

mesh in far distance is inhomogeneous

smoothing of external field data:

solenoid and RF-field have been smoothed

first derivative of fields at cathode = 0

PIC & ASTRA simulations with same external field data

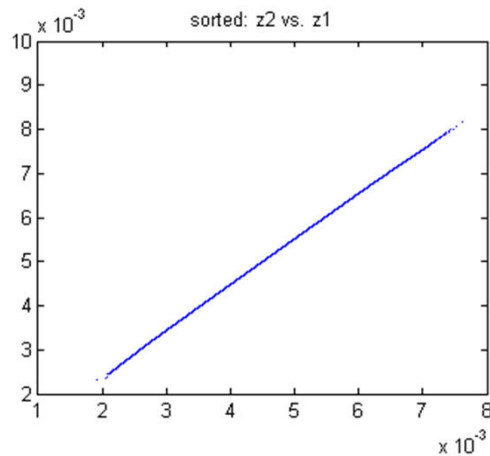


Longitudinal Particle Position

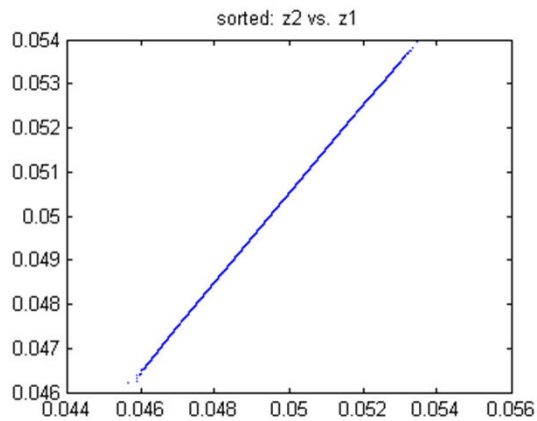
“1” = ASTRA

“2” = PIC 3x3x3

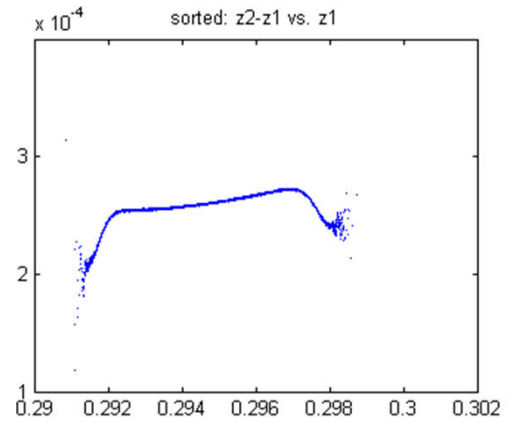
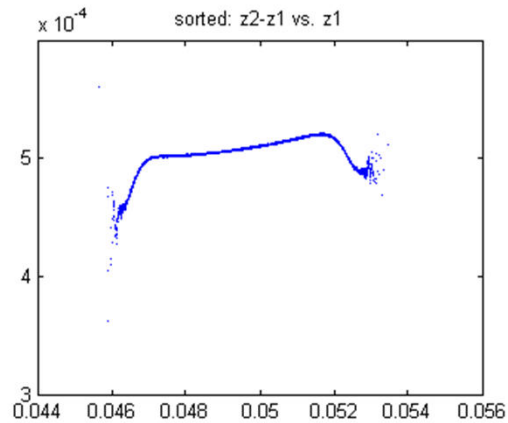
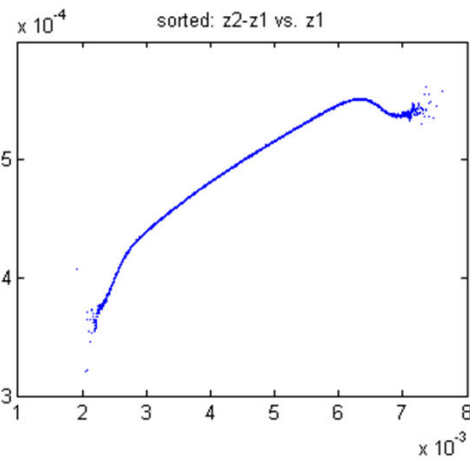
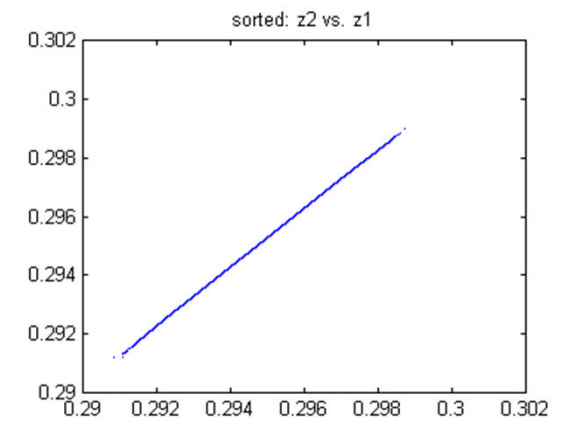
$z_{\text{ref}}/\text{mm} = 5$



$z_{\text{ref}}/\text{mm} = 50$



$z_{\text{ref}}/\text{mm} = 295$

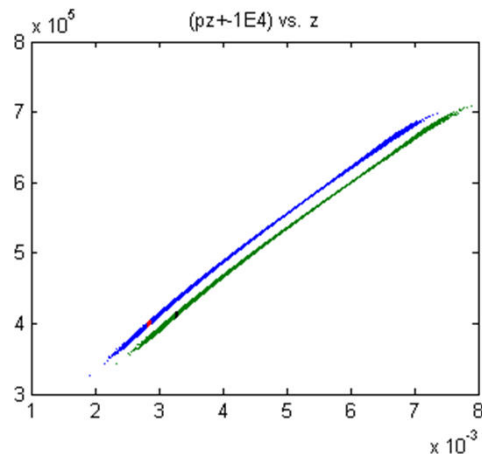


Longitudinal Phase Space

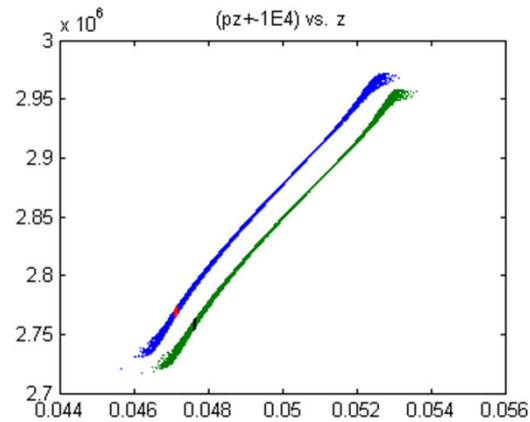
blue = ASTRA

green = PIC 3x3x3

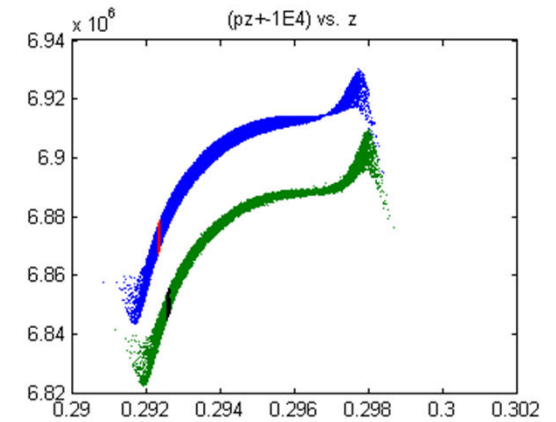
$z_{\text{ref}}/\text{mm} = 5$



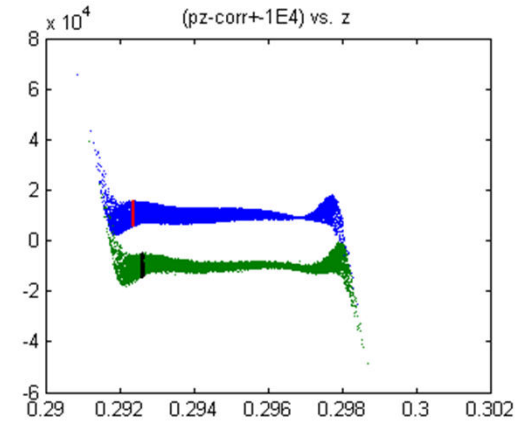
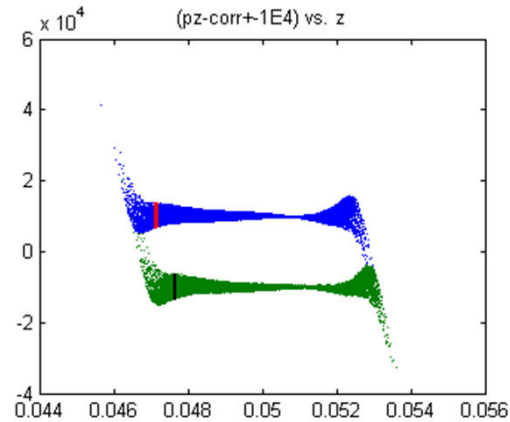
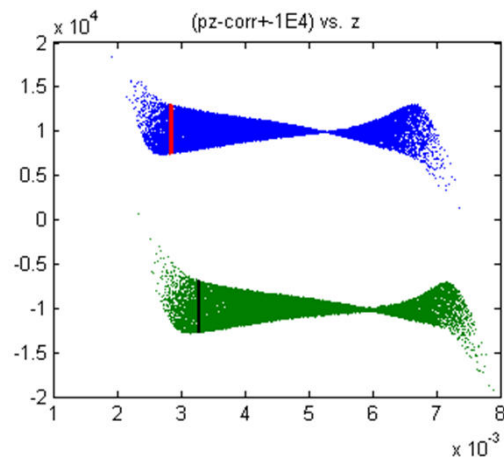
$z_{\text{ref}}/\text{mm} = 50$



$z_{\text{ref}}/\text{mm} = 295$



z-correlation extracted:

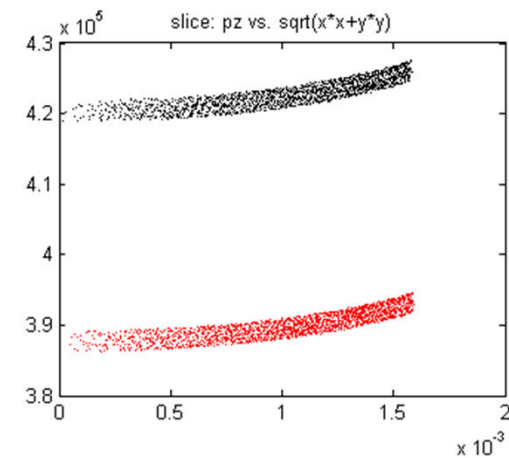
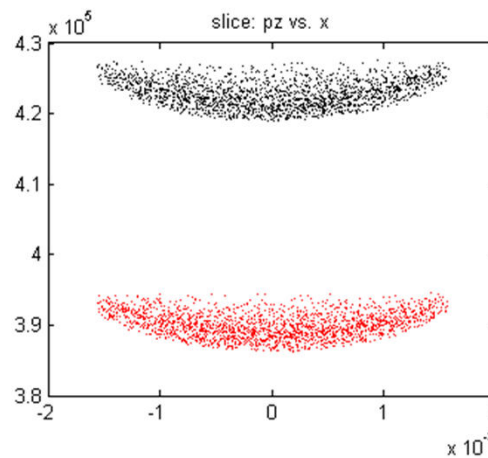
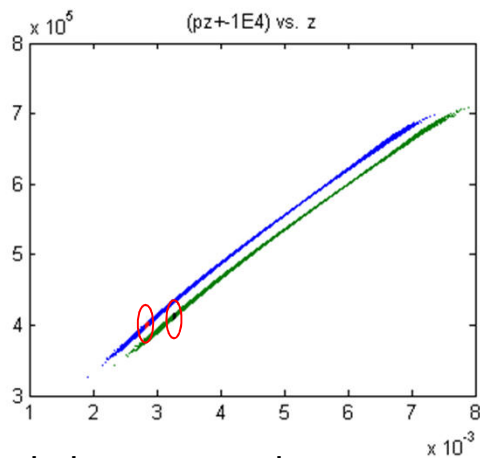


Slice: Longitudinal Momentum vs. Offset or Radius

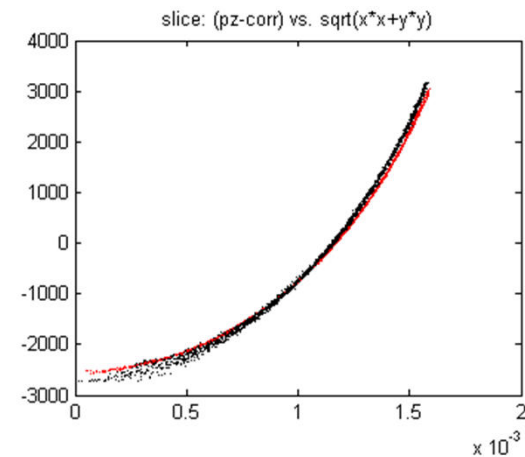
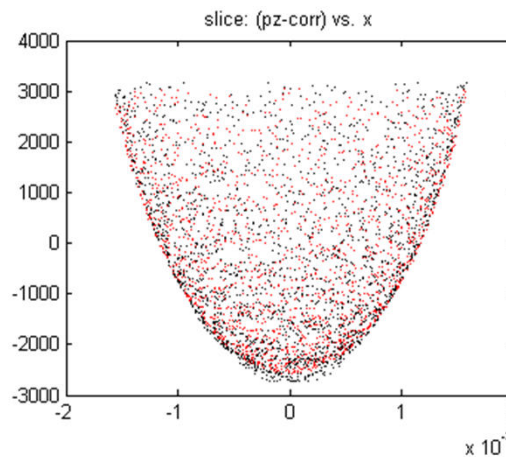
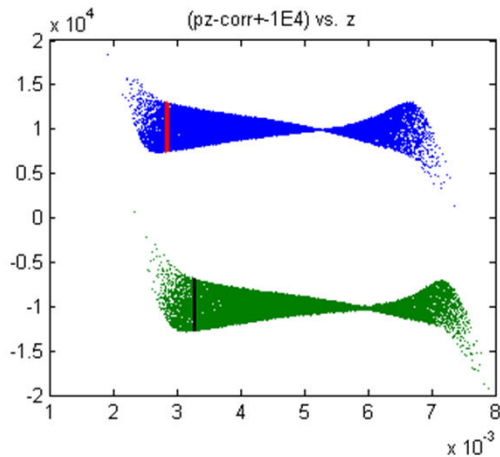
blue/red = ASTRA

green/black = PIC 3x3x3

$z_{\text{ref}}/\text{mm} = 5$



z-correlation extracted:

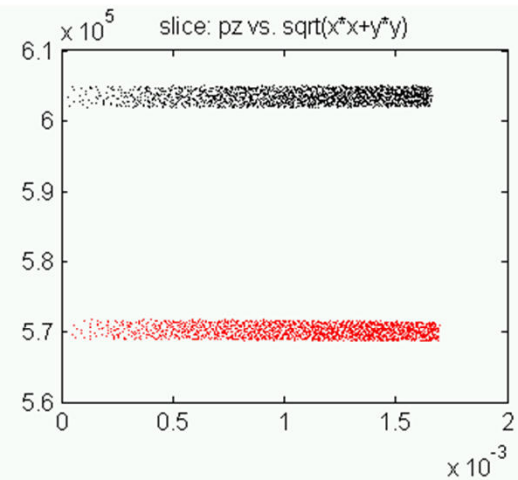
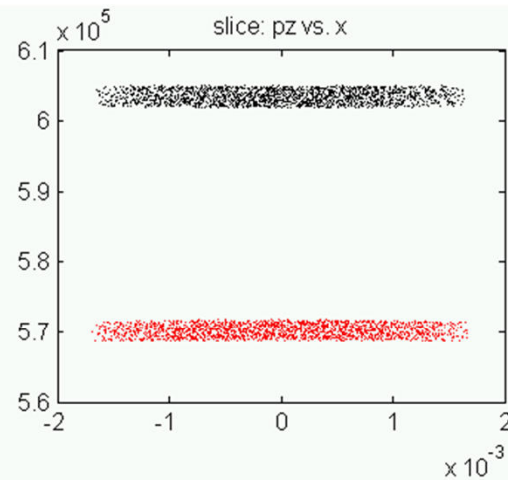
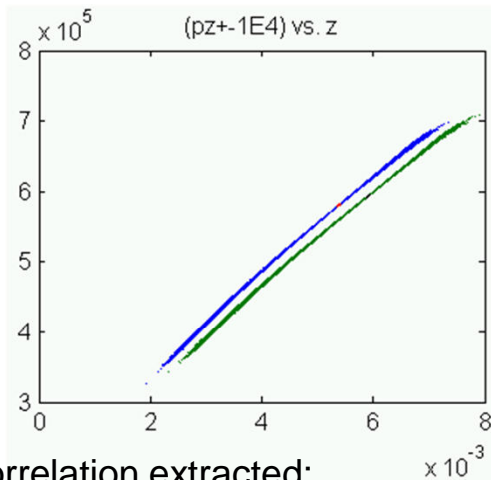


Slice: Longitudinal Momentum vs. Offset or Radius

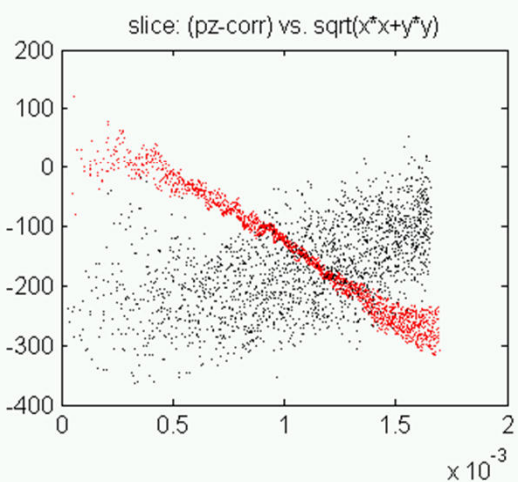
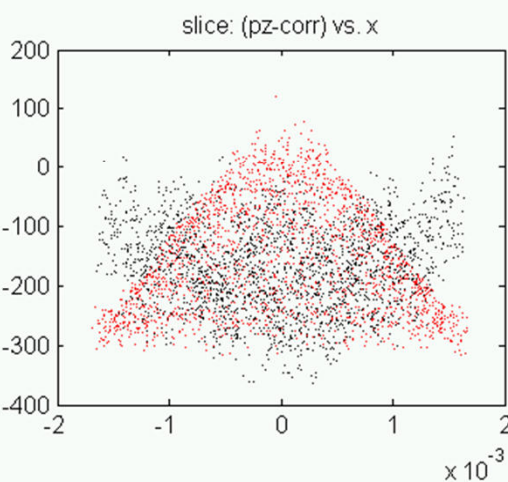
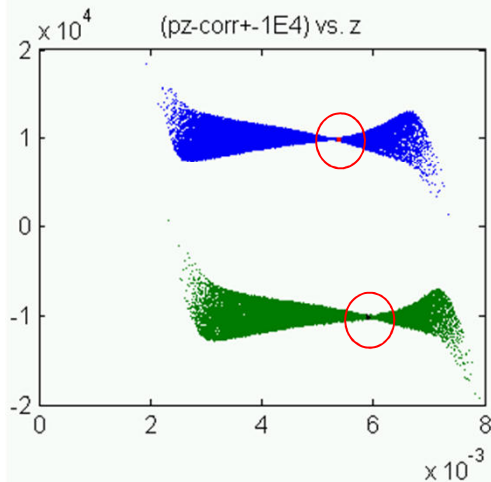
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$z_{\text{ref}}/\text{mm} = 5$



z-correlation extracted:

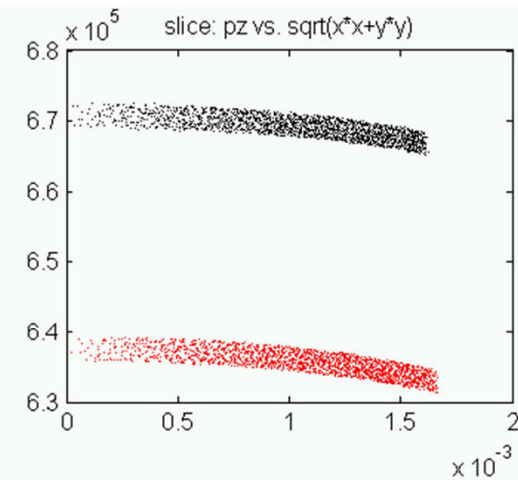
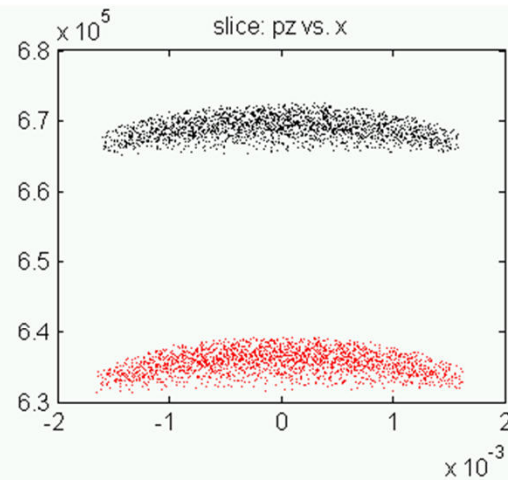
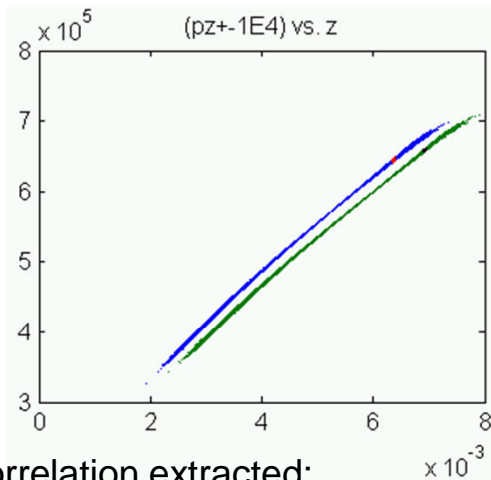


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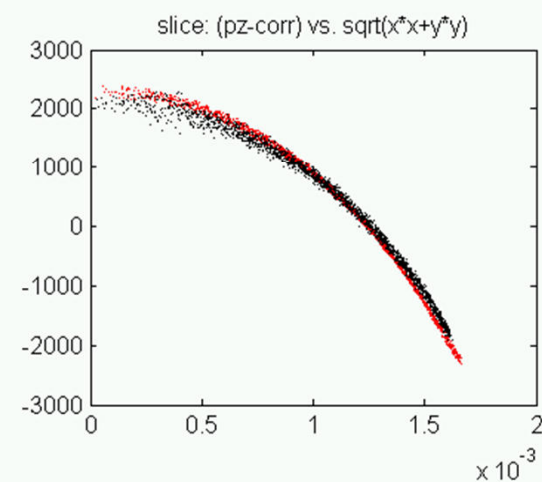
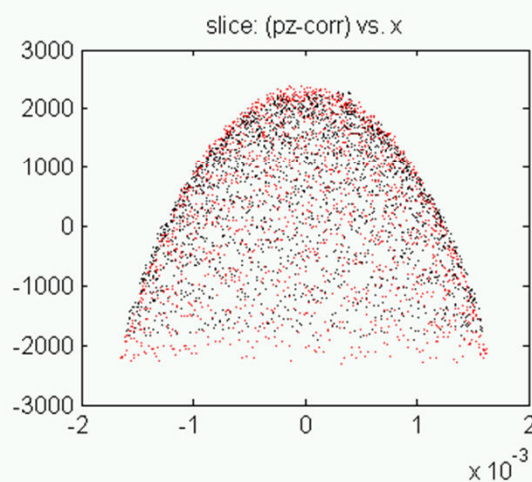
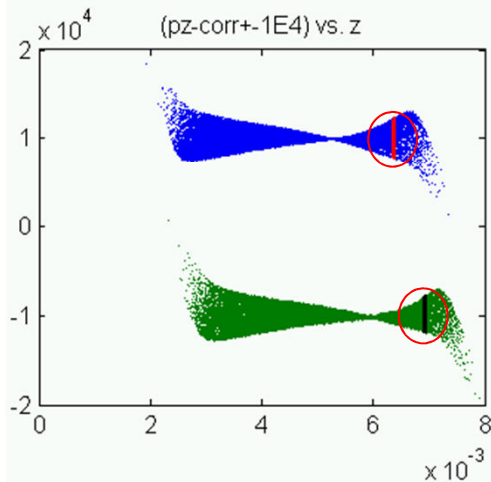
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z-correlation extracted:

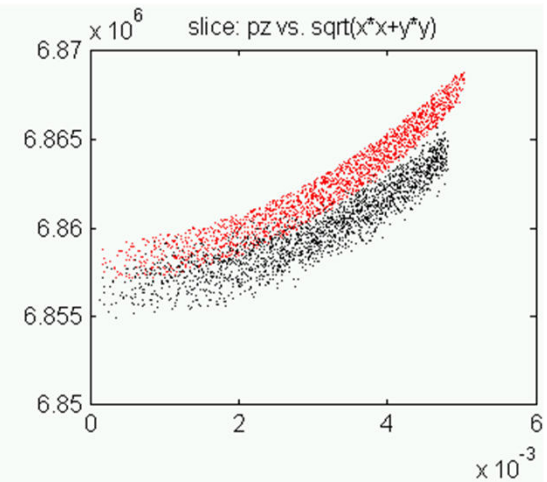
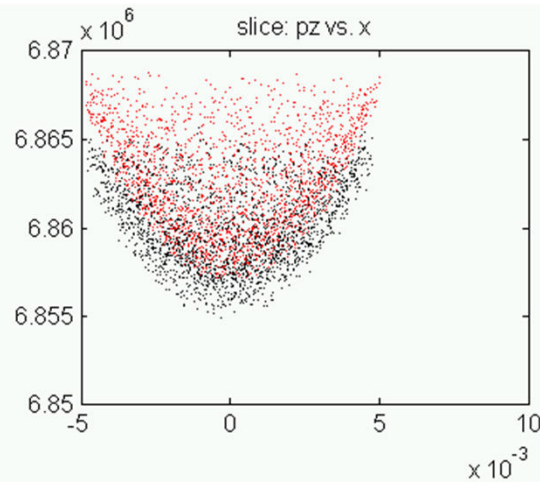
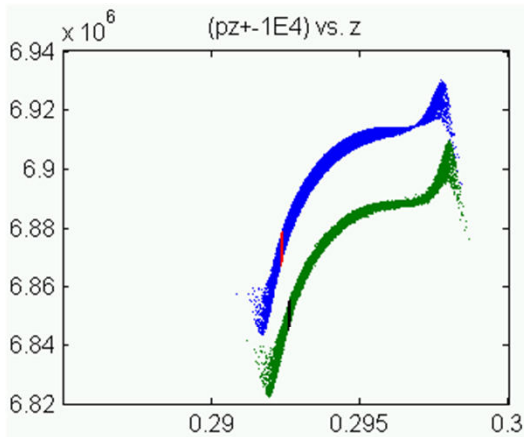


Slice: Longitudinal Momentum vs. Offset or Radius

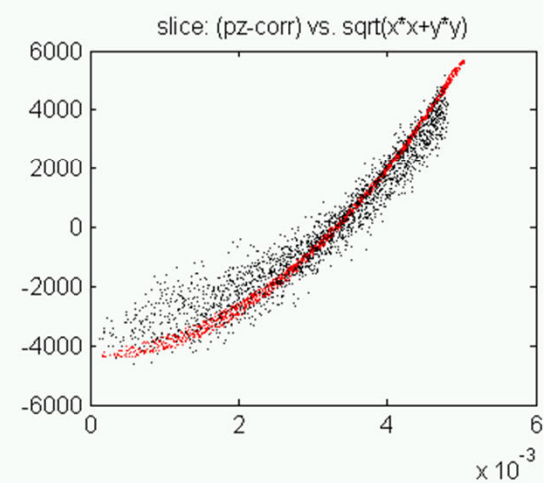
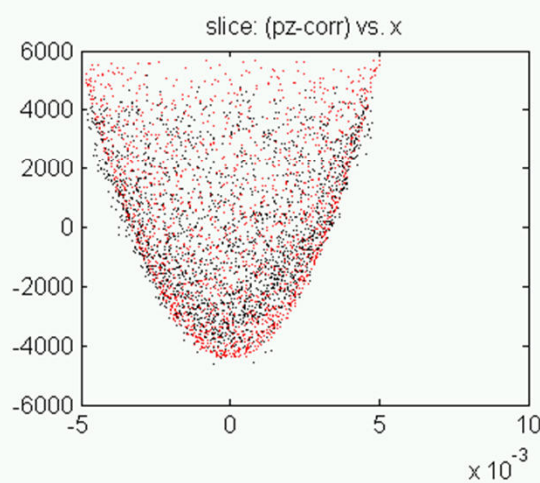
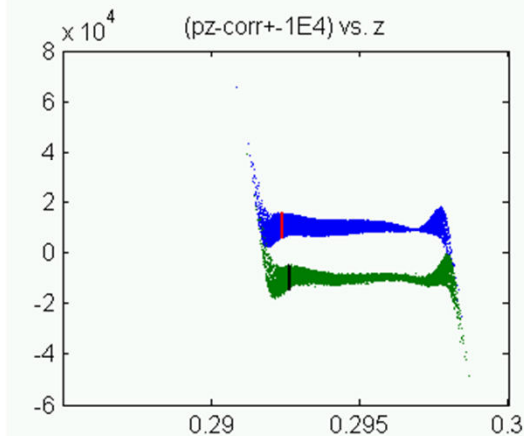
blue/red = ASTRA

green/black = PIC 3x3x3

$z_{\text{ref}}/\text{mm} = 295$



z-correlation extracted:

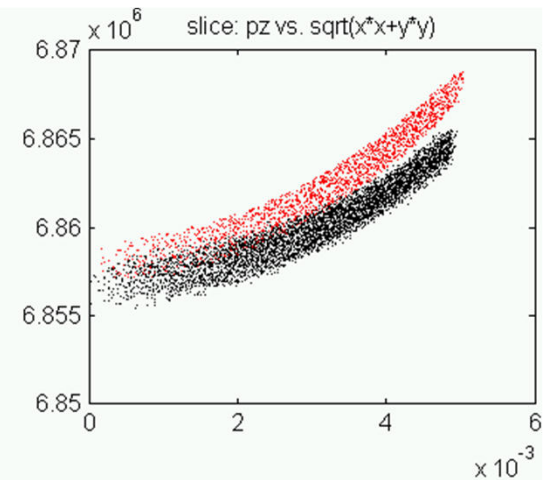
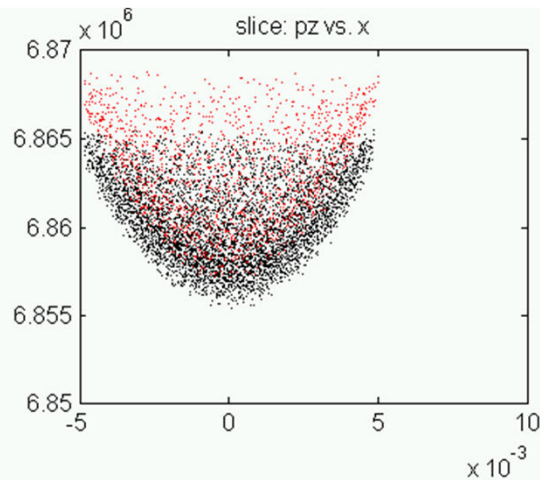
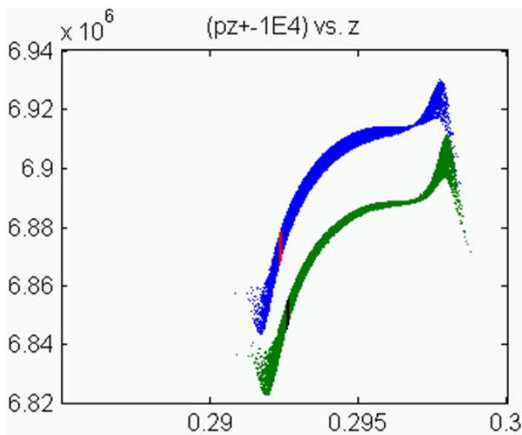


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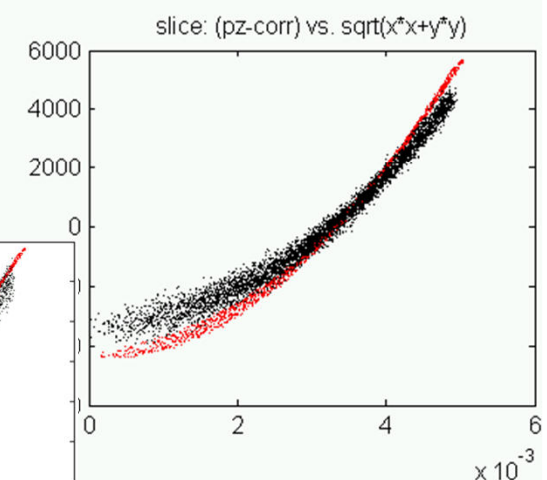
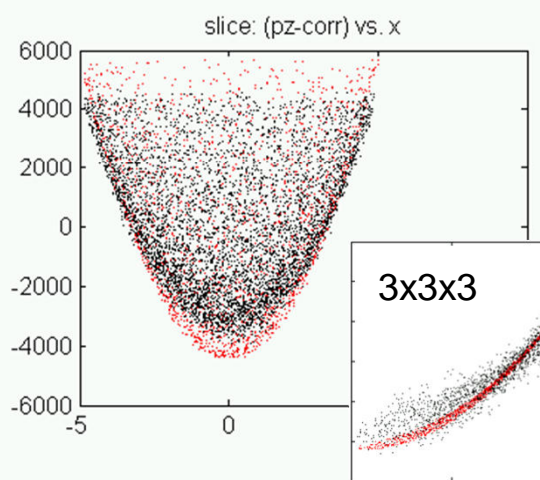
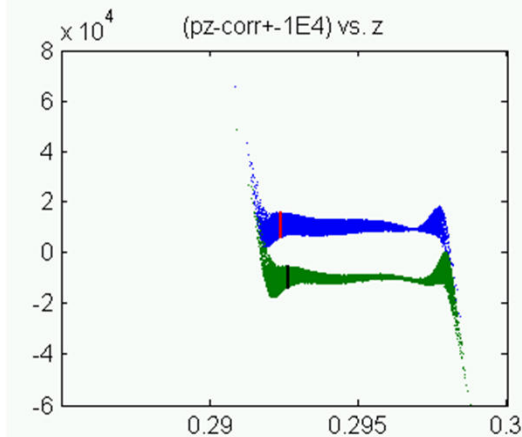
blue/red = ASTRA

green/black = PIC 3x3x4

$z_{\text{ref}}/\text{mm} = 295$



z-correlation extracted:

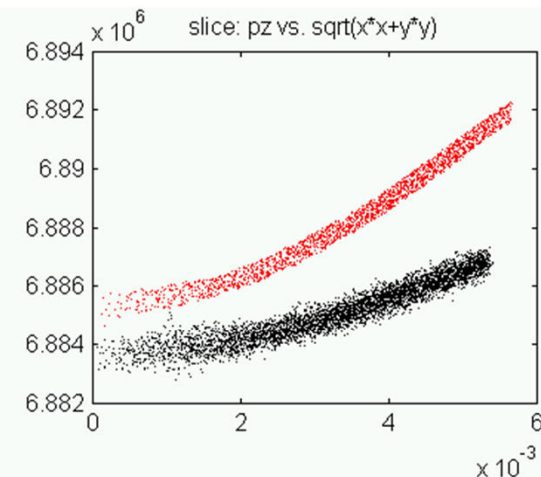
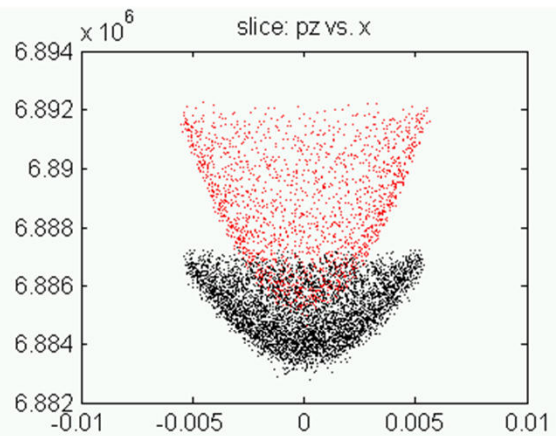
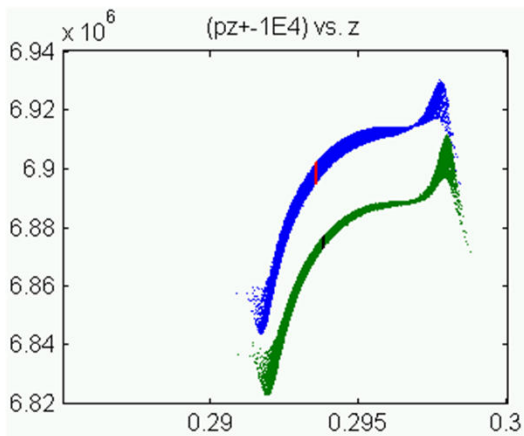


Slice: Longitudinal Momentum vs. Offset or Radius

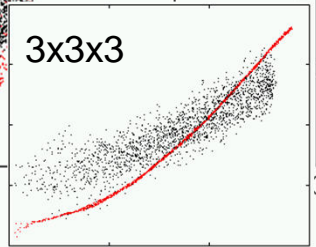
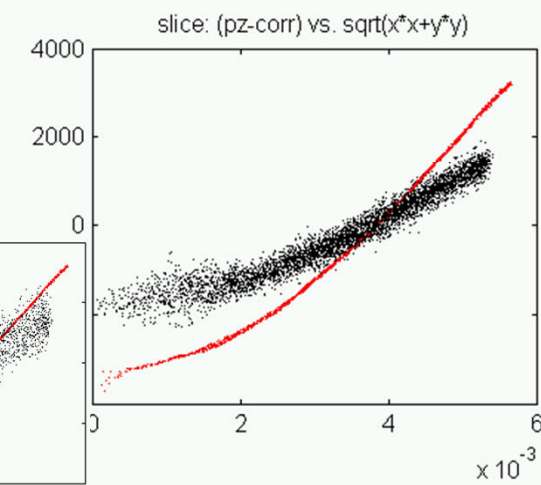
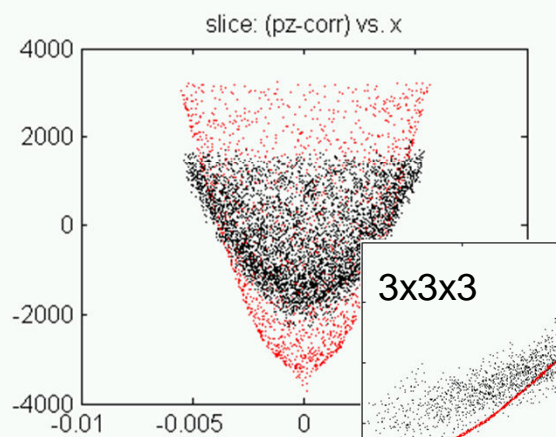
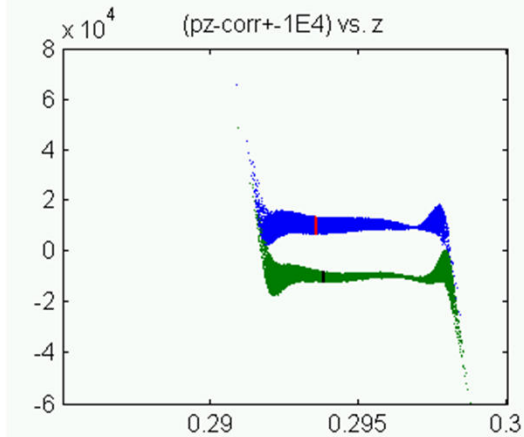
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$z_{\text{ref}}/\text{mm} = 295$



z-correlation extracted:

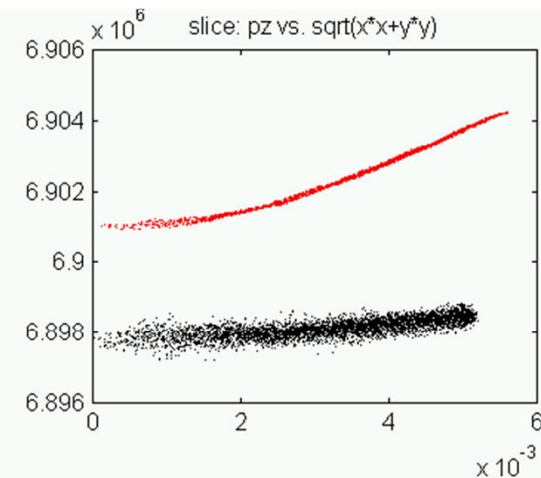
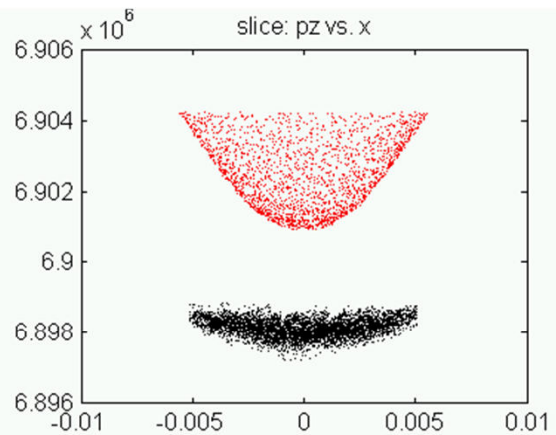
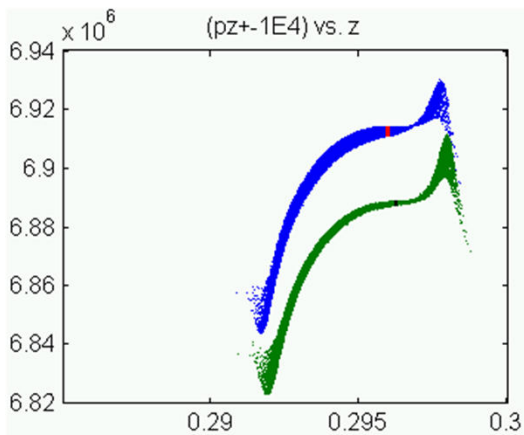


Slice: Longitudinal Momentum vs. Offset or Radius

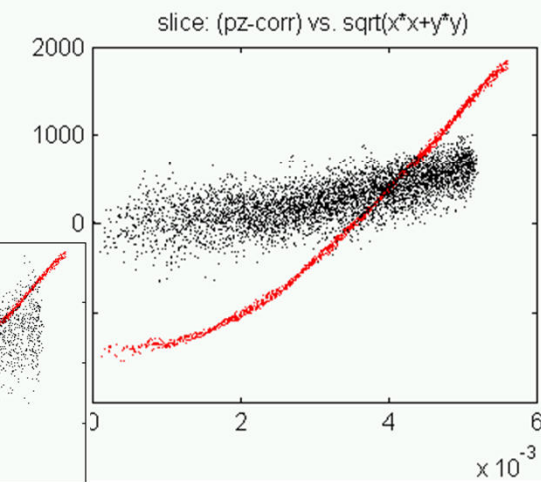
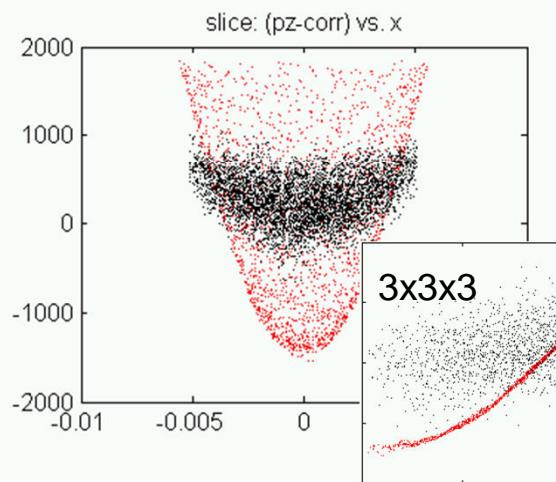
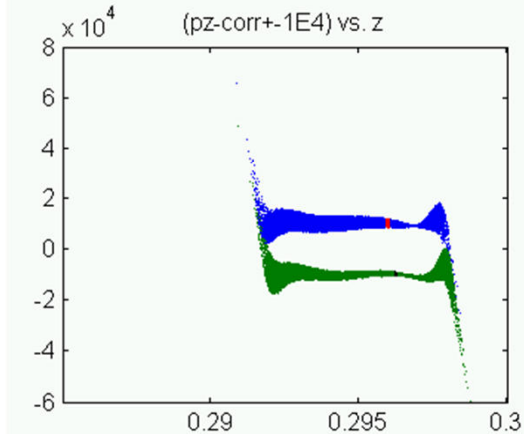
blue/red = ASTRA

green/black = PIC 3x3x4

$z_{\text{ref}}/\text{mm} = 295$



z-correlation extracted:

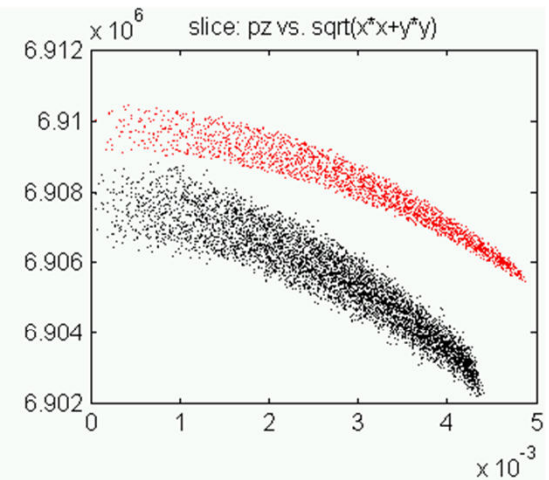
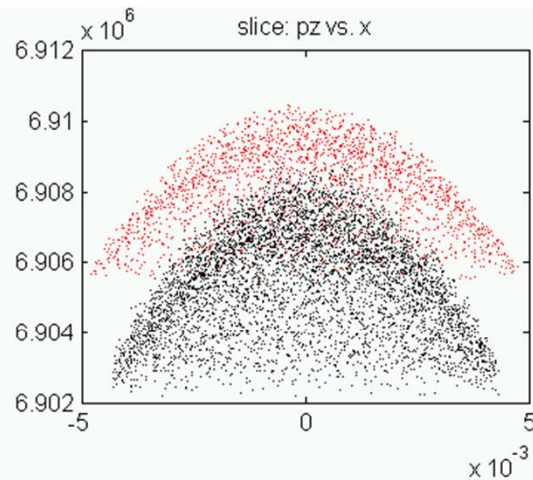
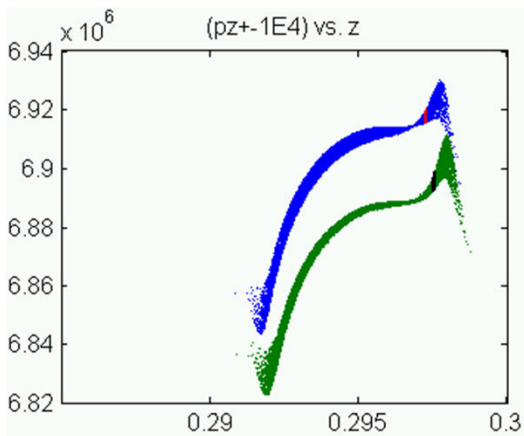


Slice: Longitudinal Momentum vs. Offset or Radius

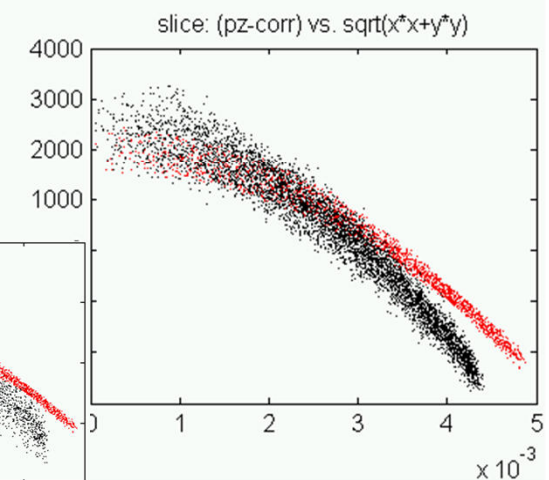
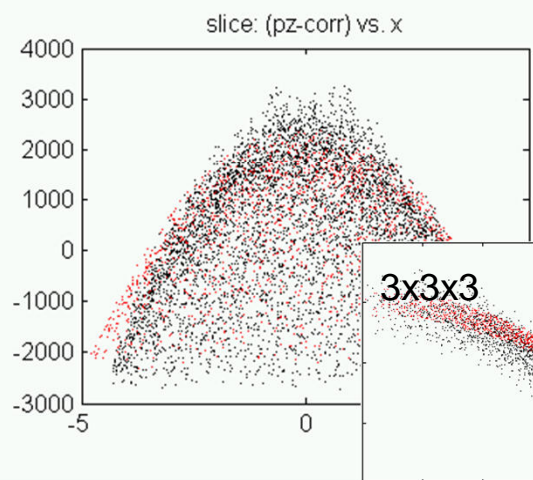
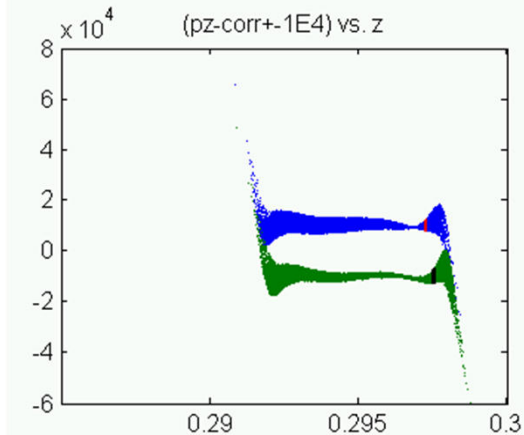
blue/red = ASTRA

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z-correlation extracted:

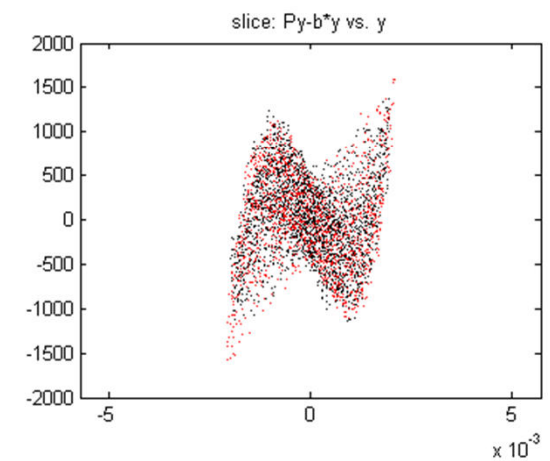
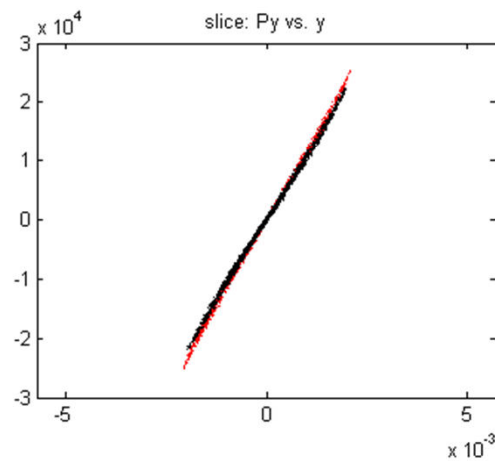
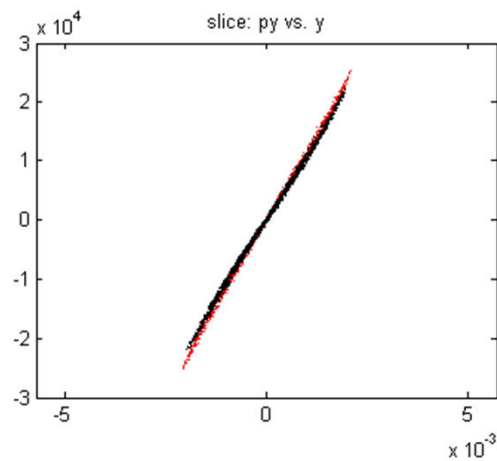
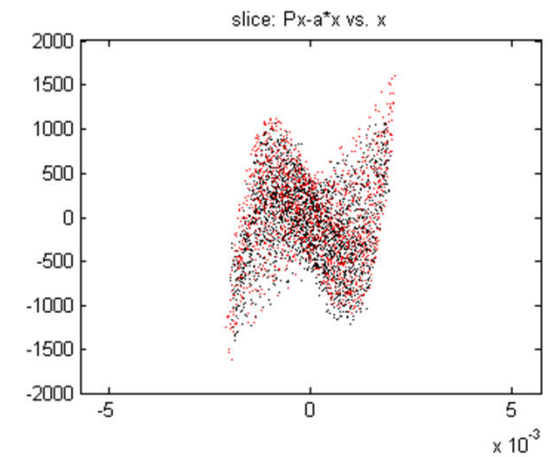
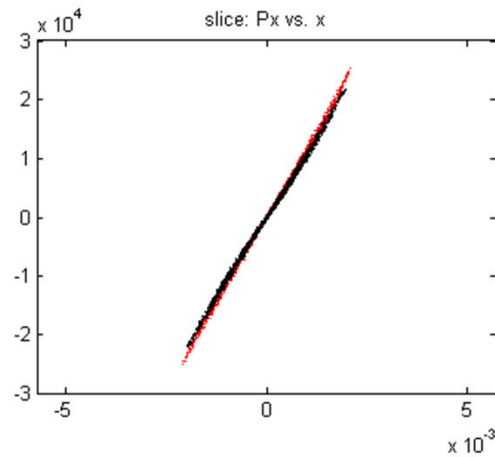
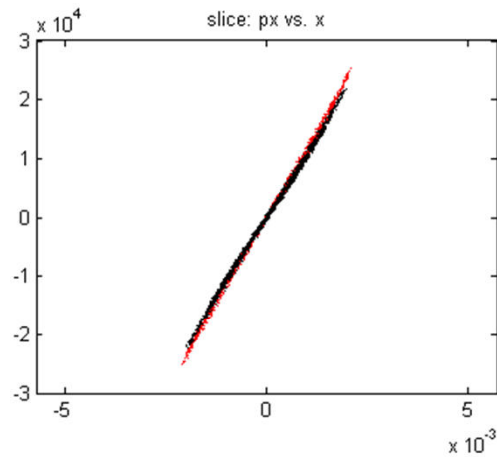
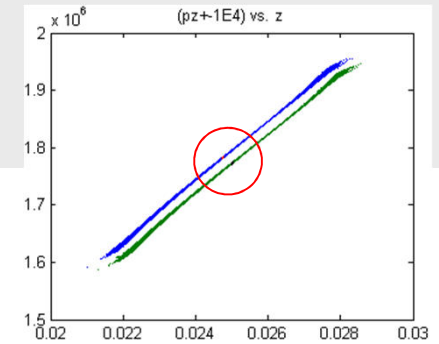


Slice: Transverse Phase Space

blue/red = ASTRA

green/black = PIC 3x3x3

$z_{\text{ref}}/\text{mm} = 25$

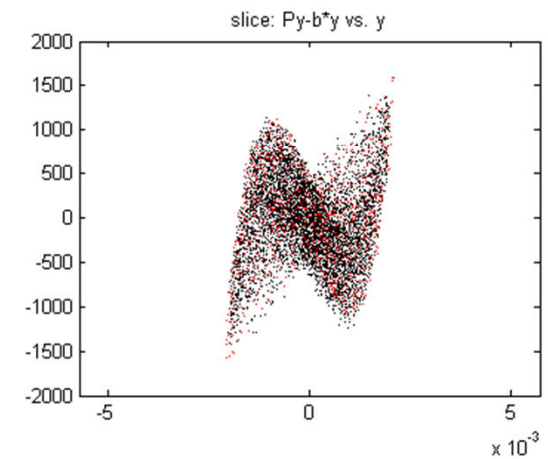
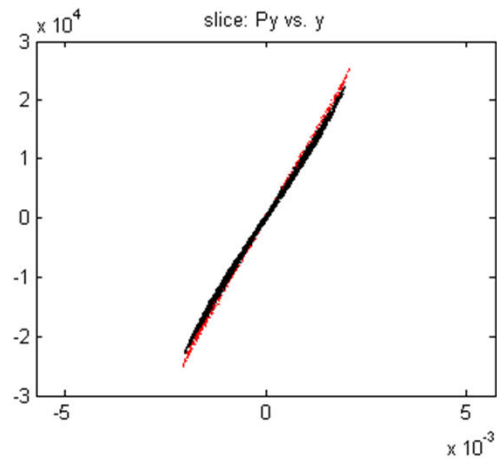
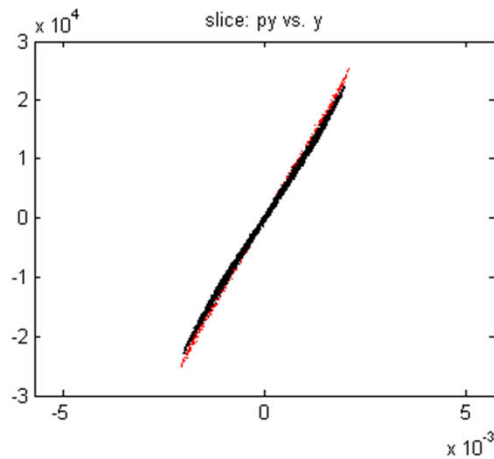
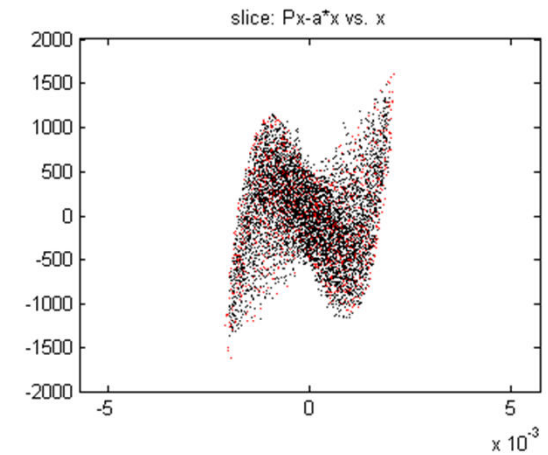
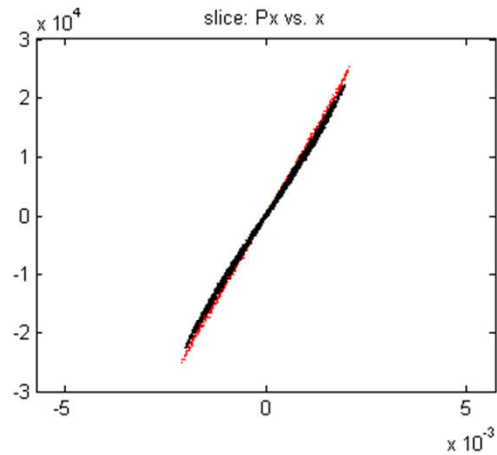
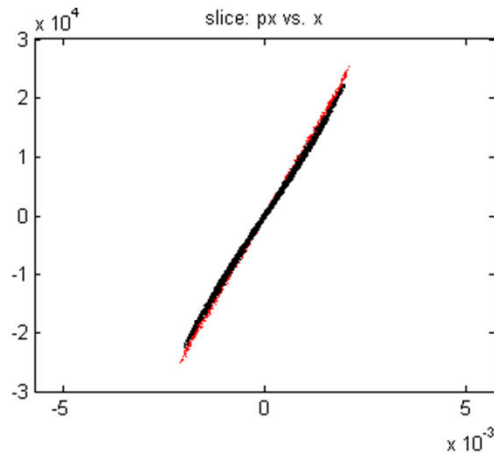
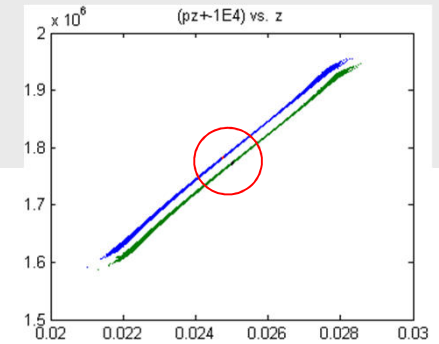


Slice: Transverse Phase Space

blue/red = ASTRA

green/black = PIC 2x2x3

$z_{\text{ref}}/\text{mm} = 25$

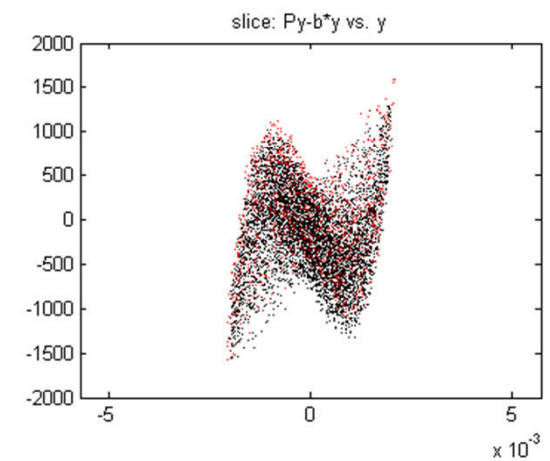
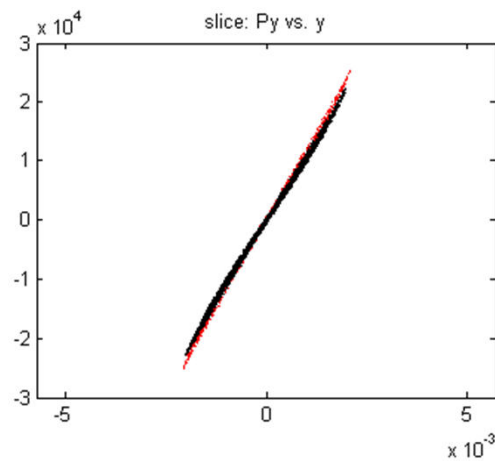
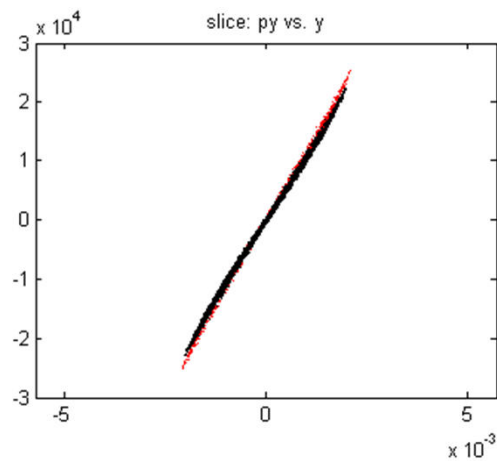
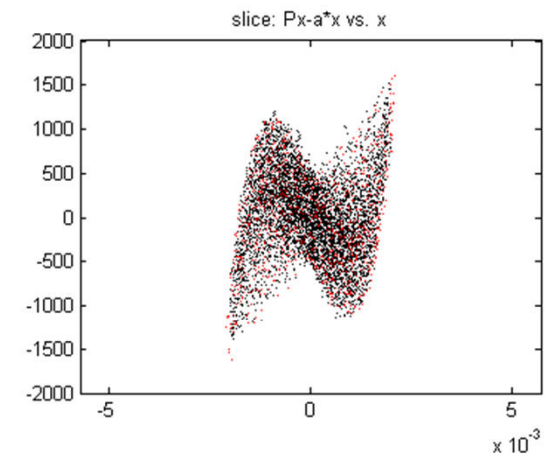
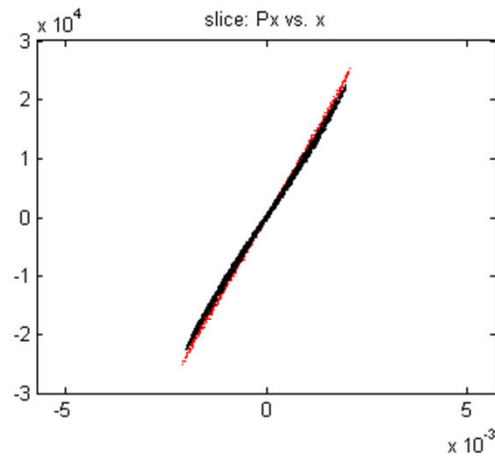
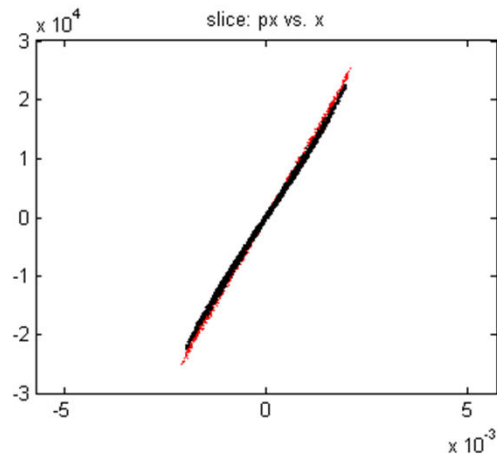
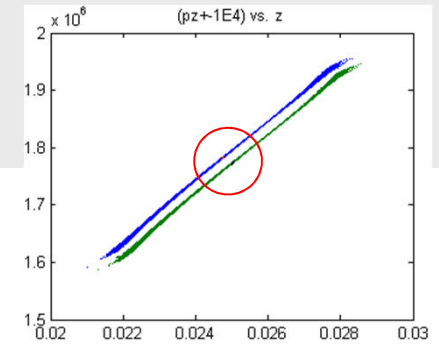


Slice: Transverse Phase Space

blue/red = ASTRA

green/black = PIC 3x3x4

$z_{\text{ref}}/\text{mm} = 25$

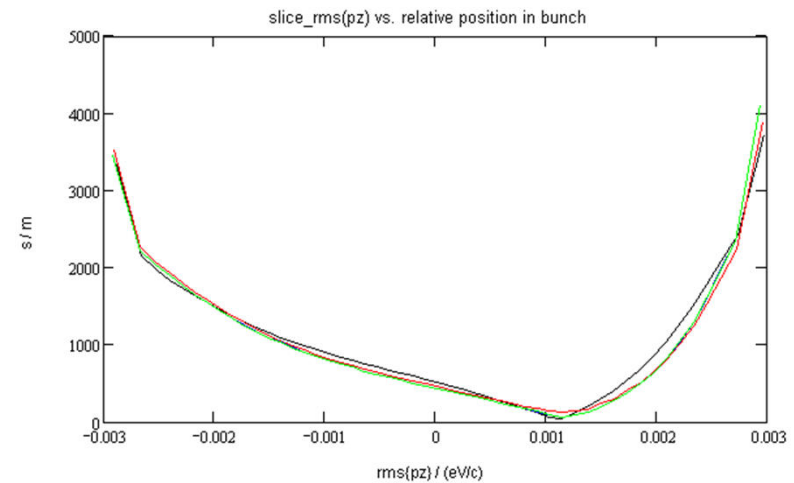
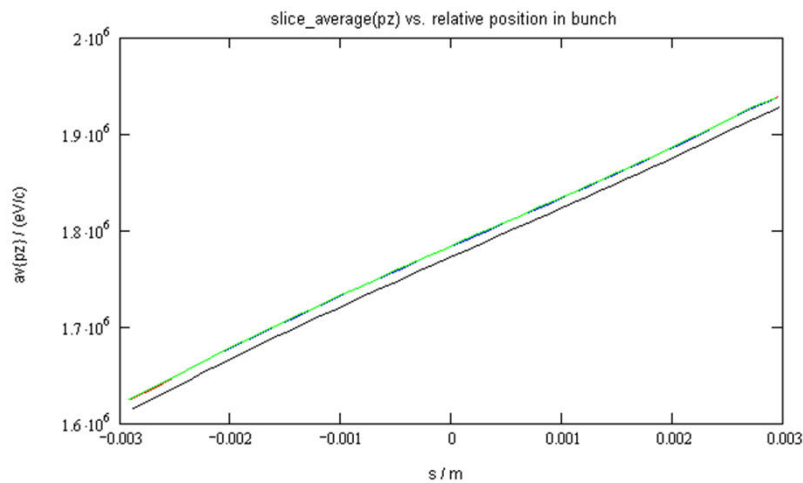
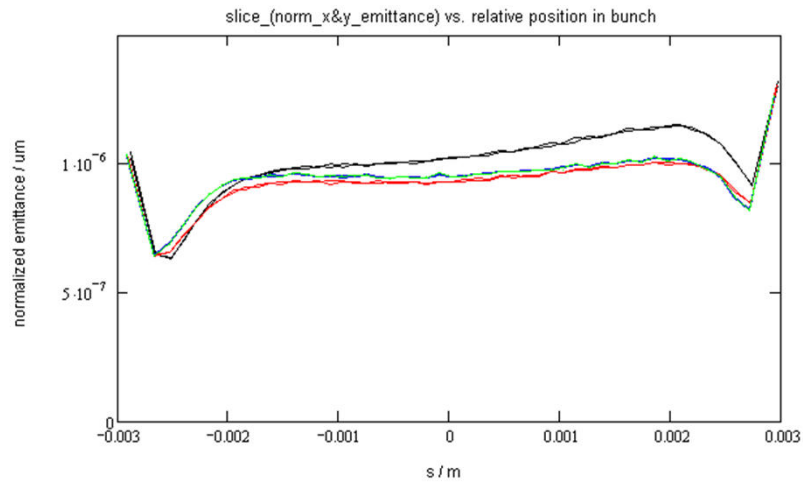


Slice vs. Relative Position in Bunch: Emittance and Energy

black = ASTRA

red/blue/green = PIC 3x3x3 / 2x2x3 / 3x3x4

$z_{\text{ref}}/\text{mm} = 25$

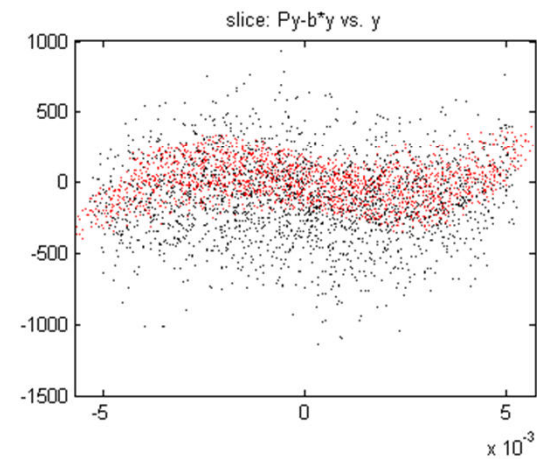
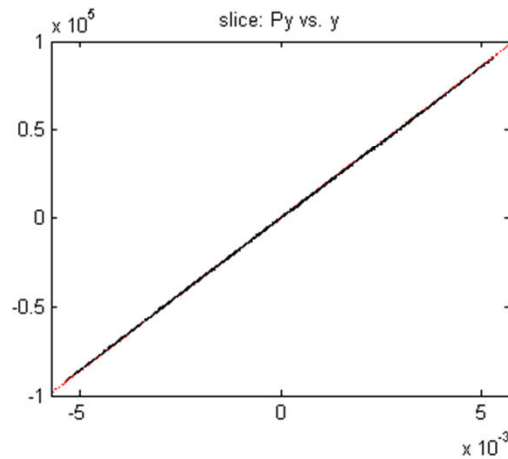
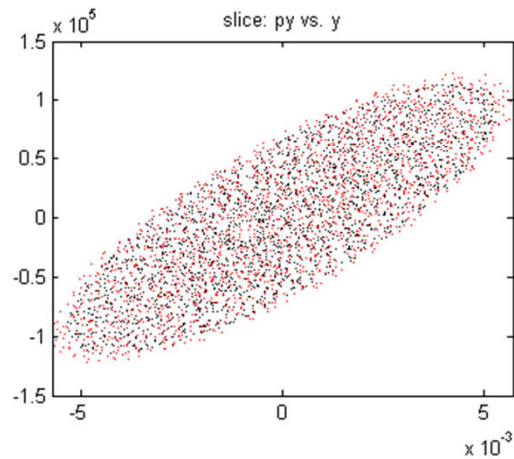
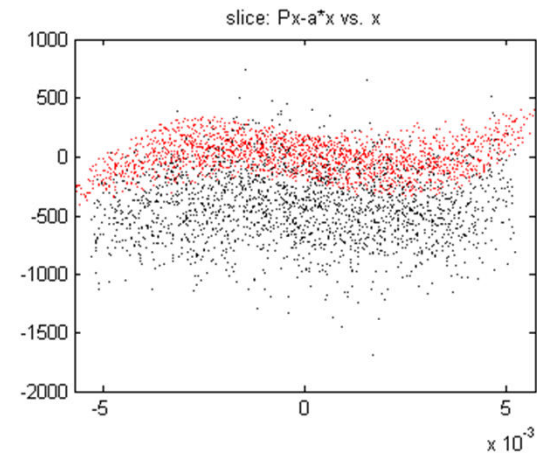
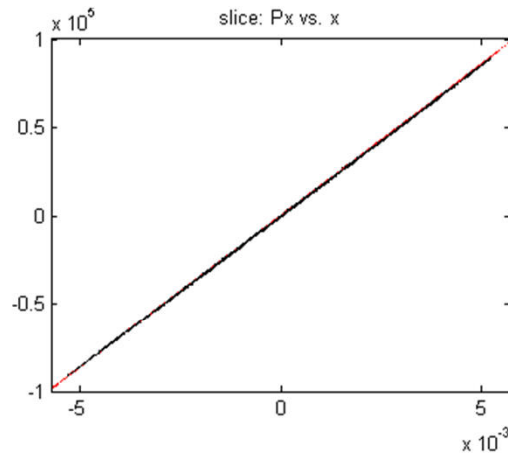
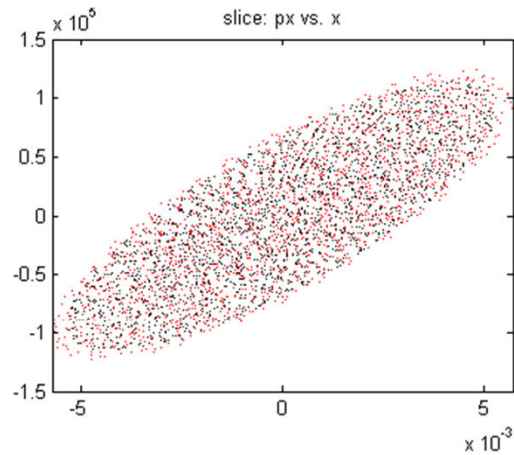
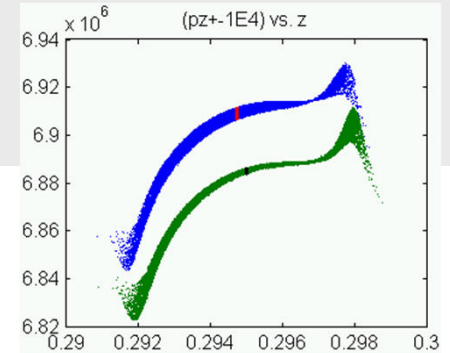


Slice: Transverse Phase Space

blue/red = ASTRA

green/black = PIC 3x3x3

$z_{\text{ref}}/\text{mm} = 295$

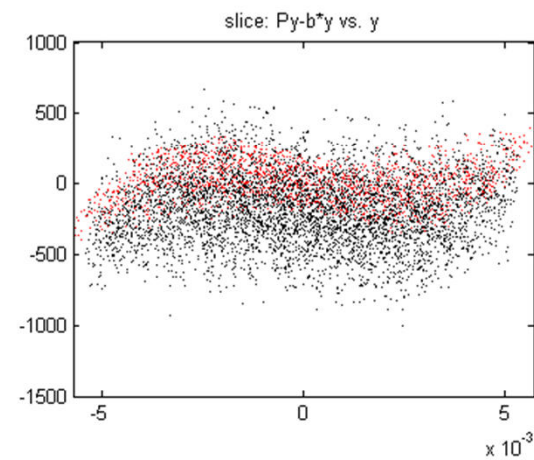
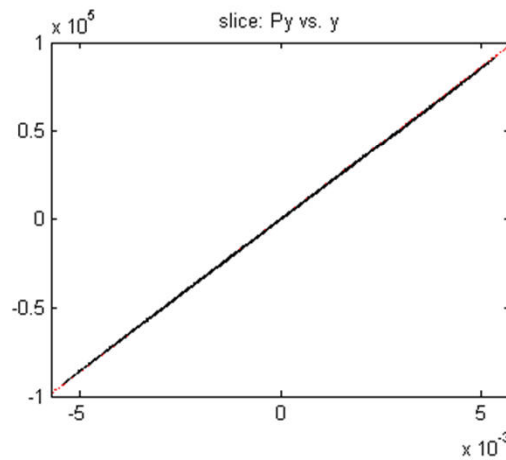
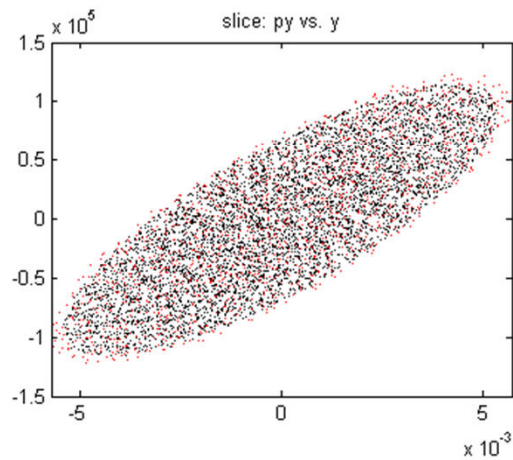
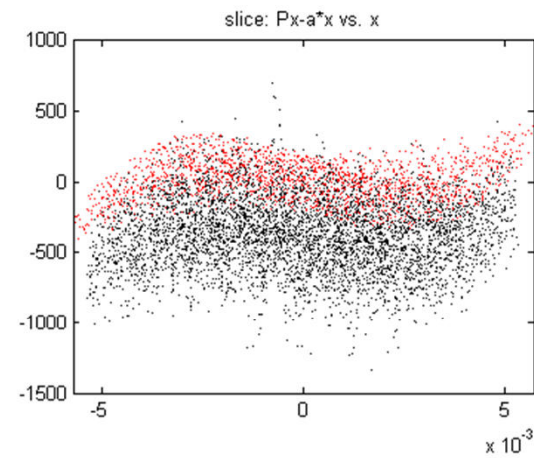
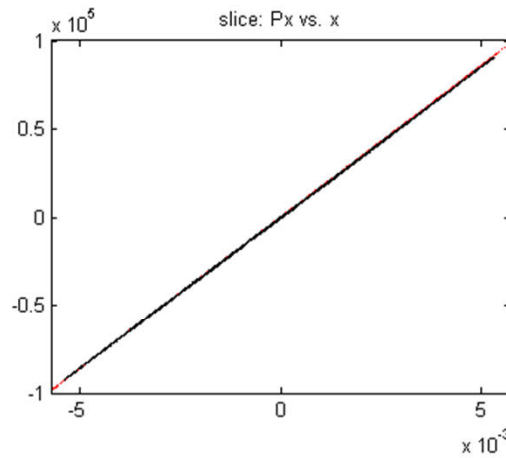
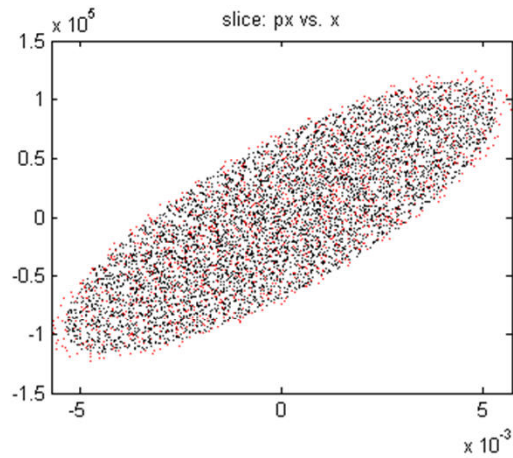
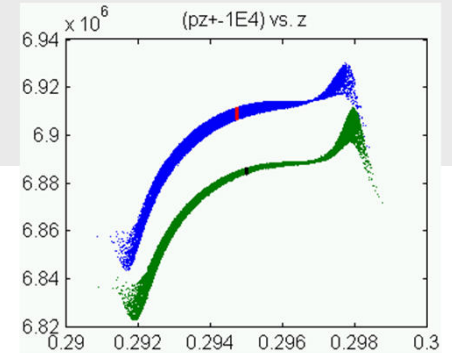


Slice: Transverse Phase Space

blue/red = ASTRA

green/black = PIC 2x2x3

$z_{\text{ref}}/\text{mm} = 295$

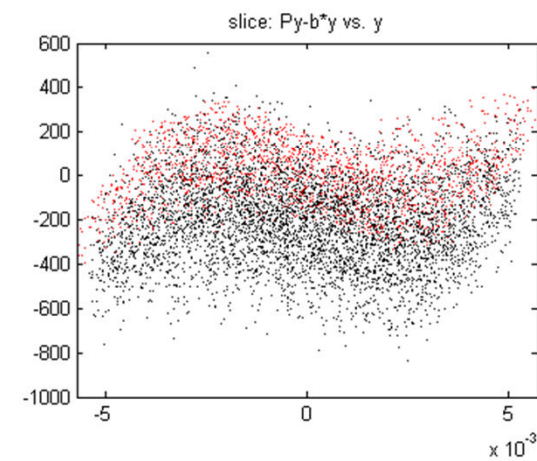
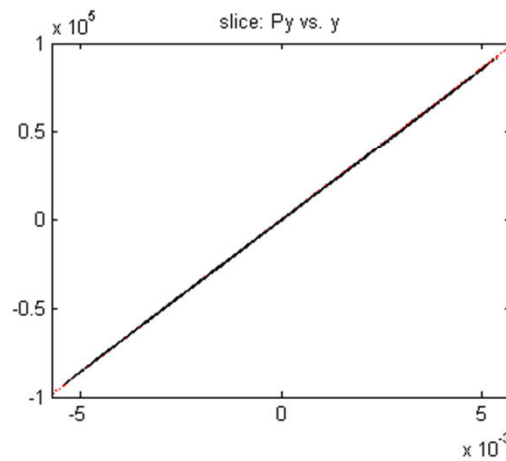
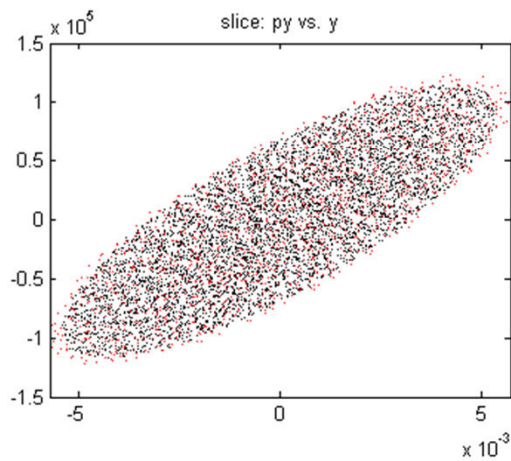
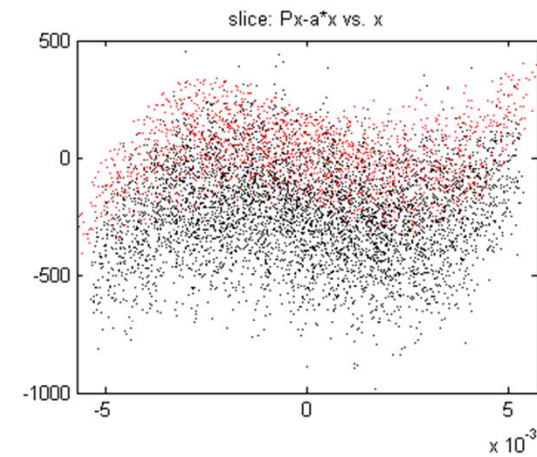
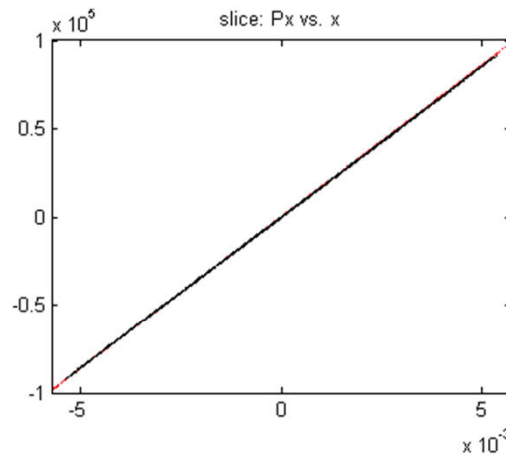
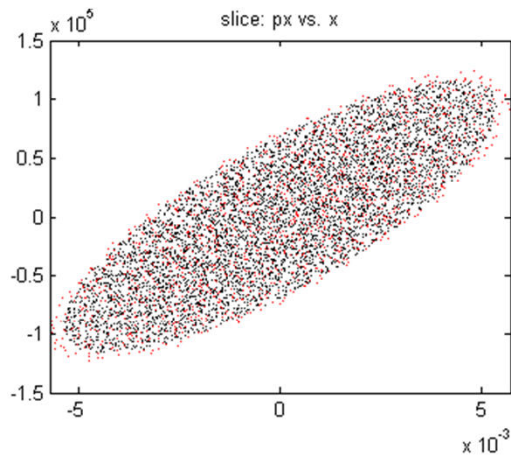
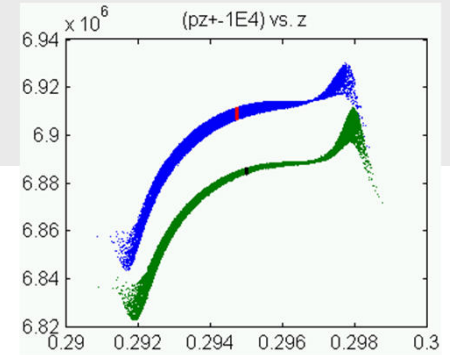


Slice: Transverse Phase Space

blue/red = ASTRA

green/black = PIC 3x3x4

$z_{\text{ref}}/\text{mm} = 295$

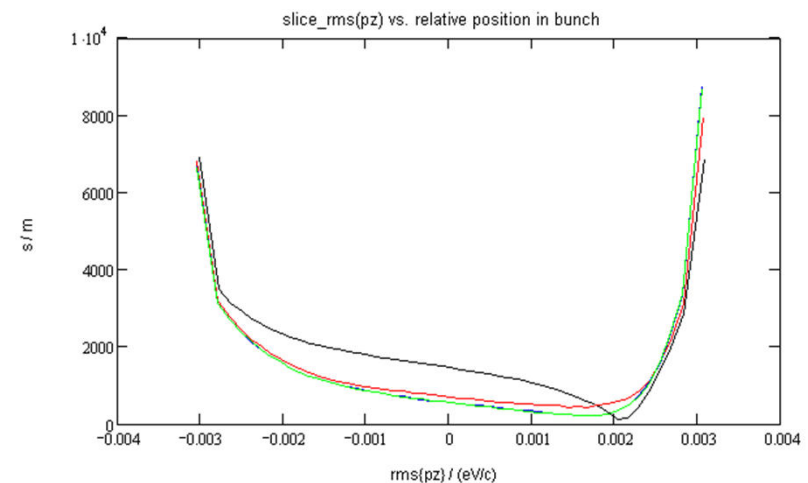
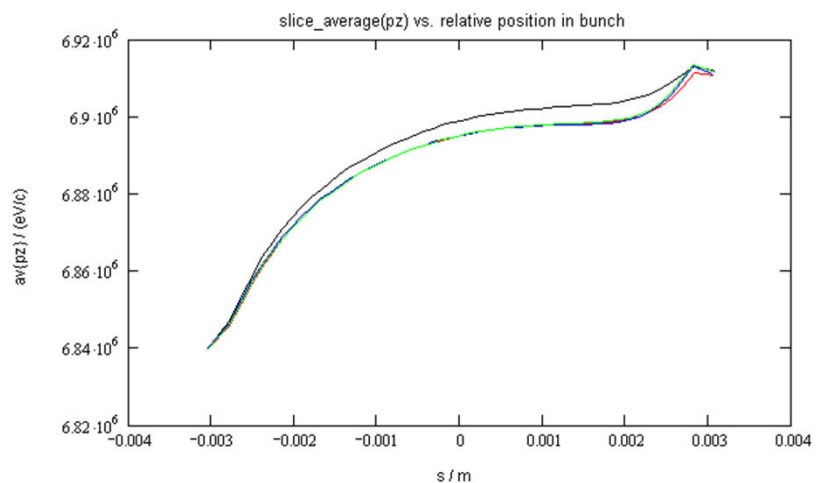
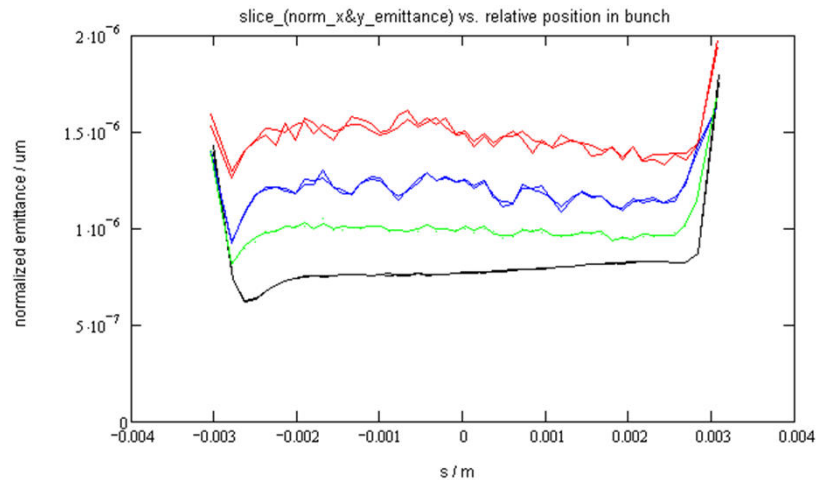


Slice vs. Relative Position in Bunch: Emittance and Energy

black = ASTRA

red/blue/green = PIC 3x3x3 / 2x2x3 / 3x3x4

$z_{\text{ref}}/\text{mm} = 295$

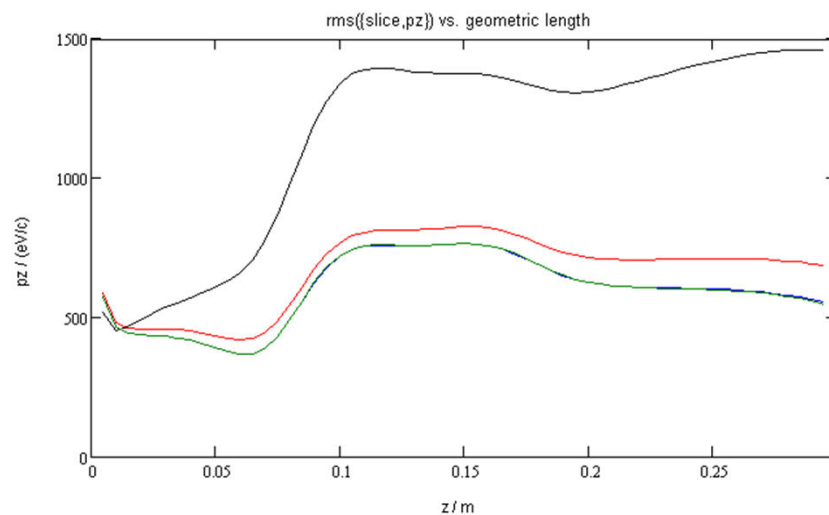
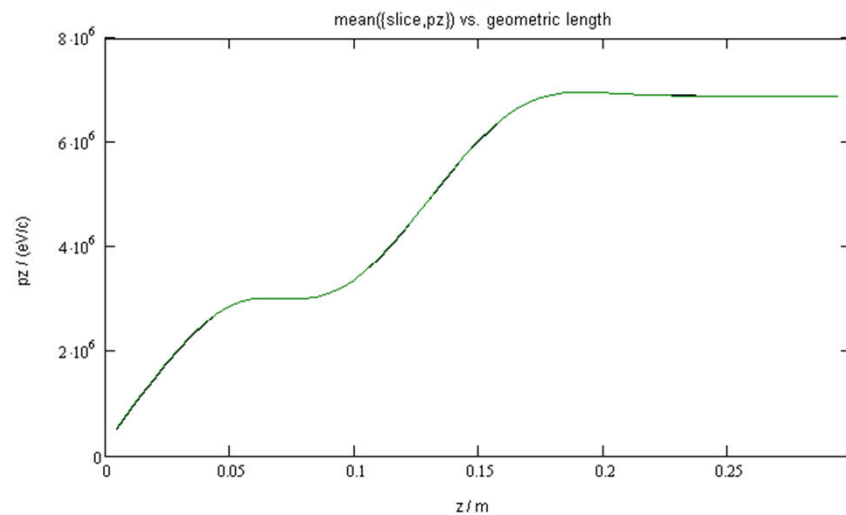
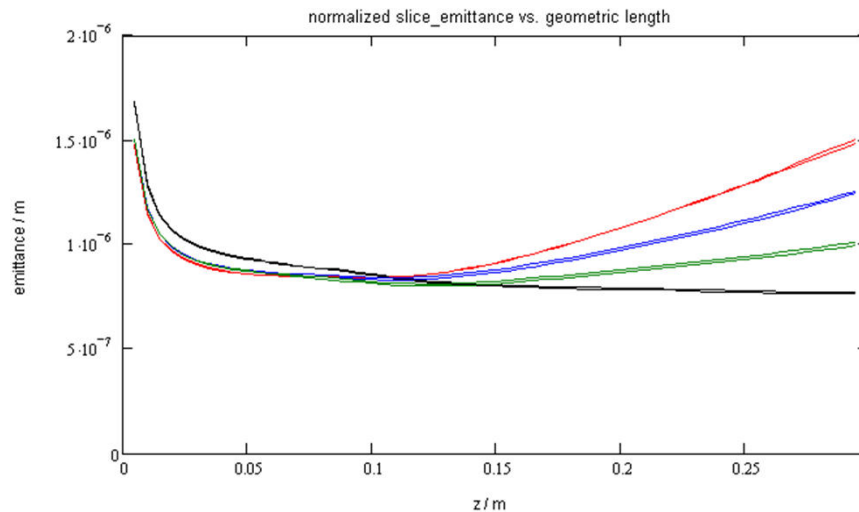


Slice Emittance & Energy vs. Geometric Length

black = ASTRA

red/blue/green = PIC 3x3x3 / 2x2x3 / 3x3x4

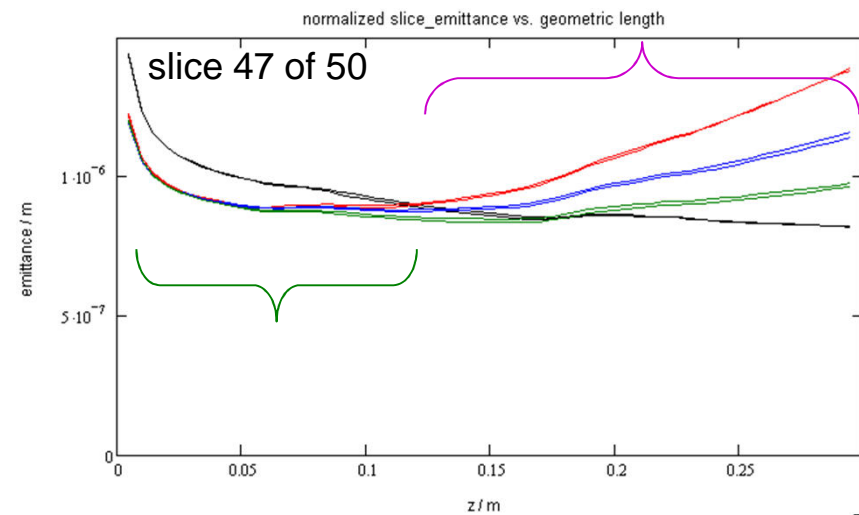
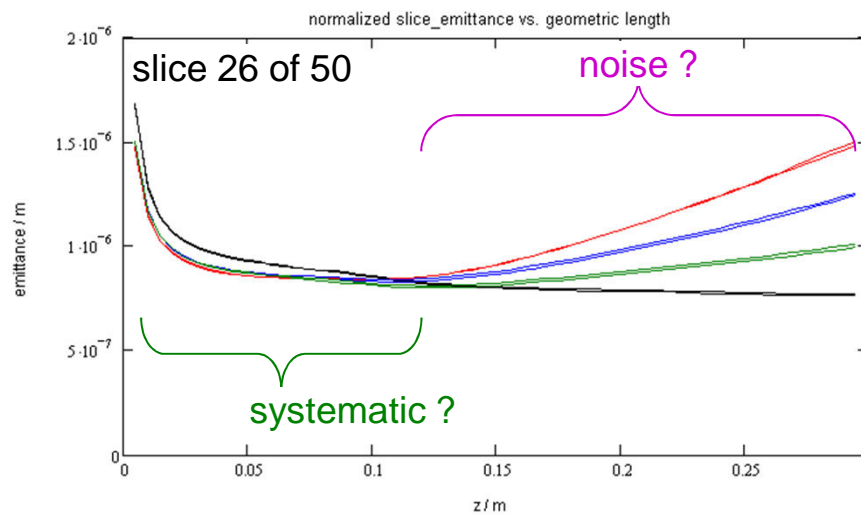
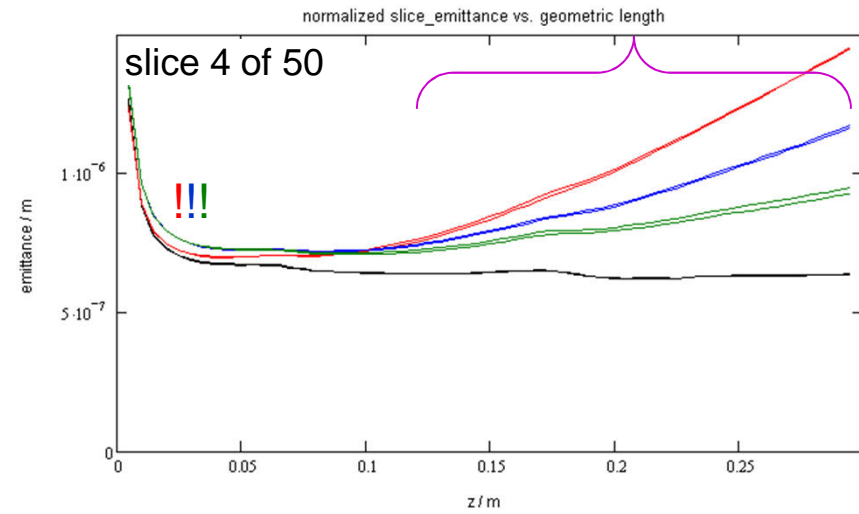
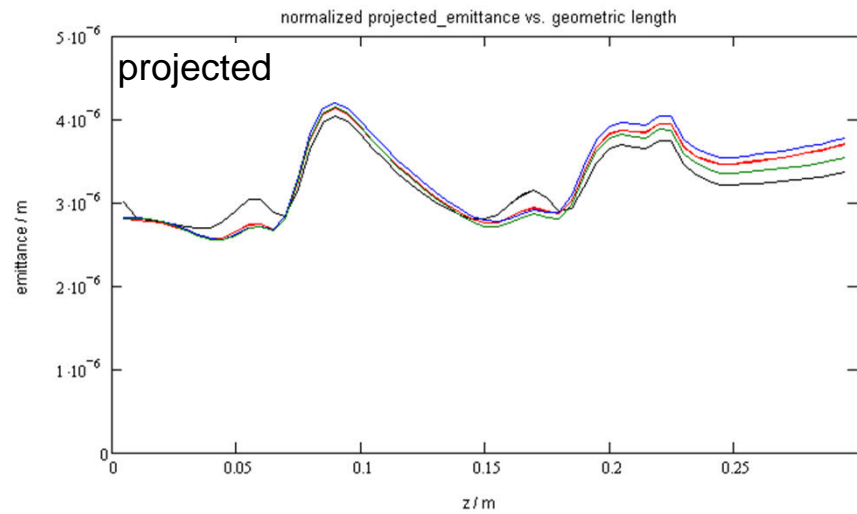
slice 25 of 50



Projected & Slice Emittance vs. Geometric Length

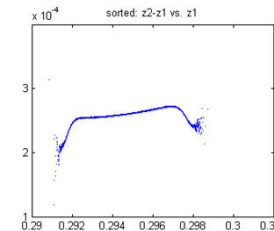
black = ASTRA

red/blue/green = PIC 3x3x4 / 2x2x3 / 3x3x4



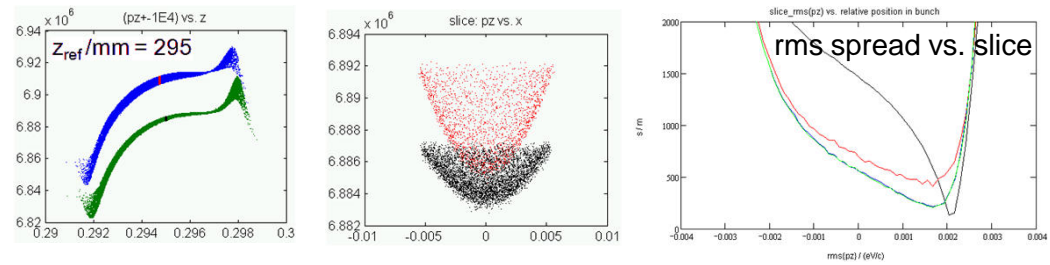
Summary

systematic differences in longitudinal particle position:



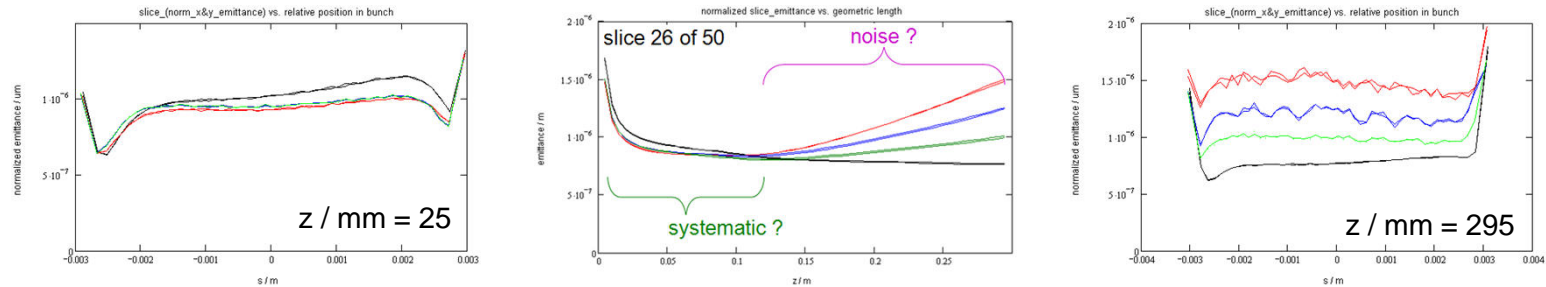
longitudinal phase space:

differences increase with time
 moderate influence of noise
 different qualitative behavior



transverse phase space:

slice emittance: systematic differences can be seen for $z/m < 0.1 \dots 0.15$
 effects of particle noise for $z/m > 0.1 \dots 0.15$?



projected emittance: differences are less obvious

