FLASH Micro-Bunching Simulations
Solenoid Scan

Measurements: shift 2015__08_09M

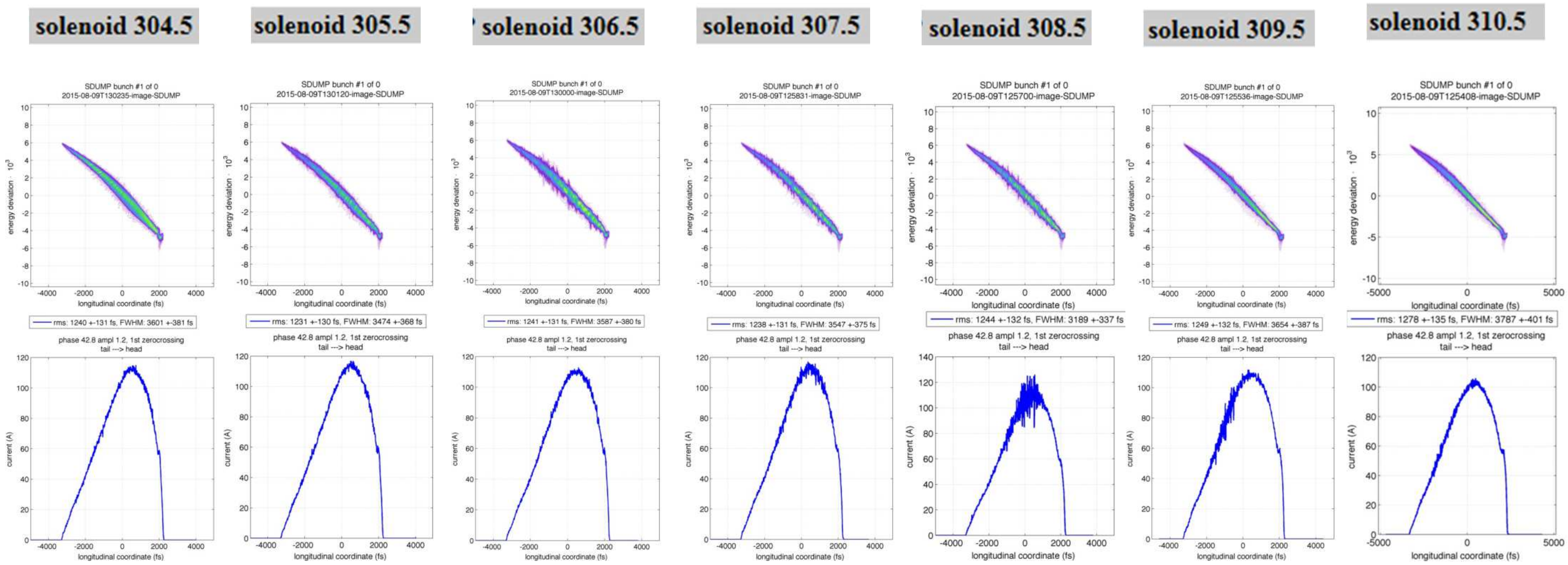
Astra Simulation to End of ACC1

Cold 1D Model for Plasma Oscillations

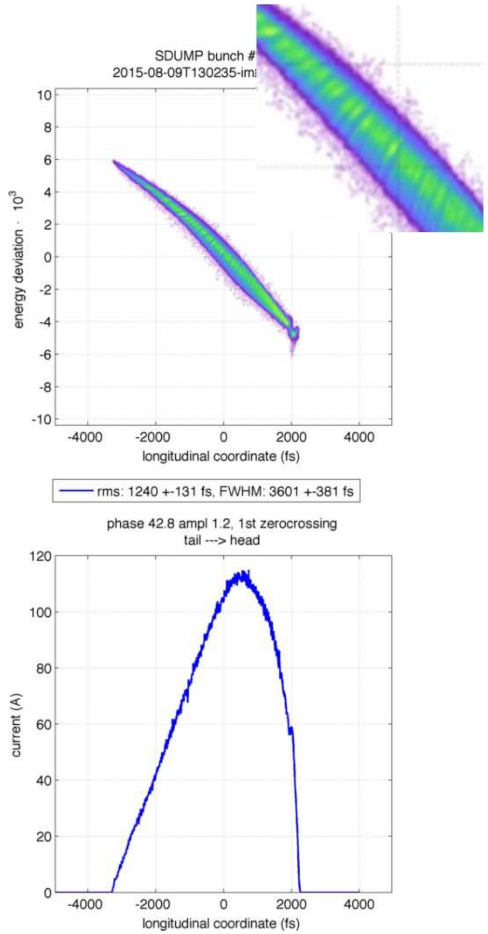
Simulations: Astra
Xtrack
many plots

Measurements shift 2015__08_09M

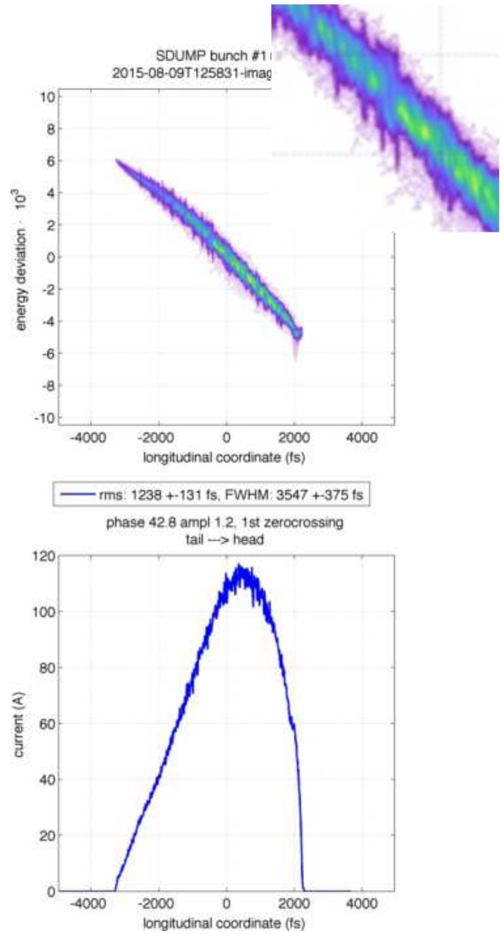
solenoid scan, 0.4 nC



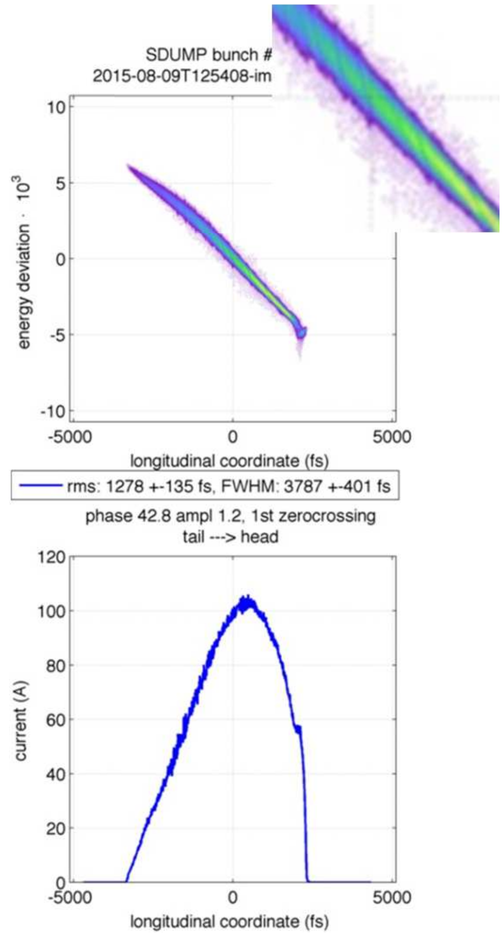
solenoid 304.5



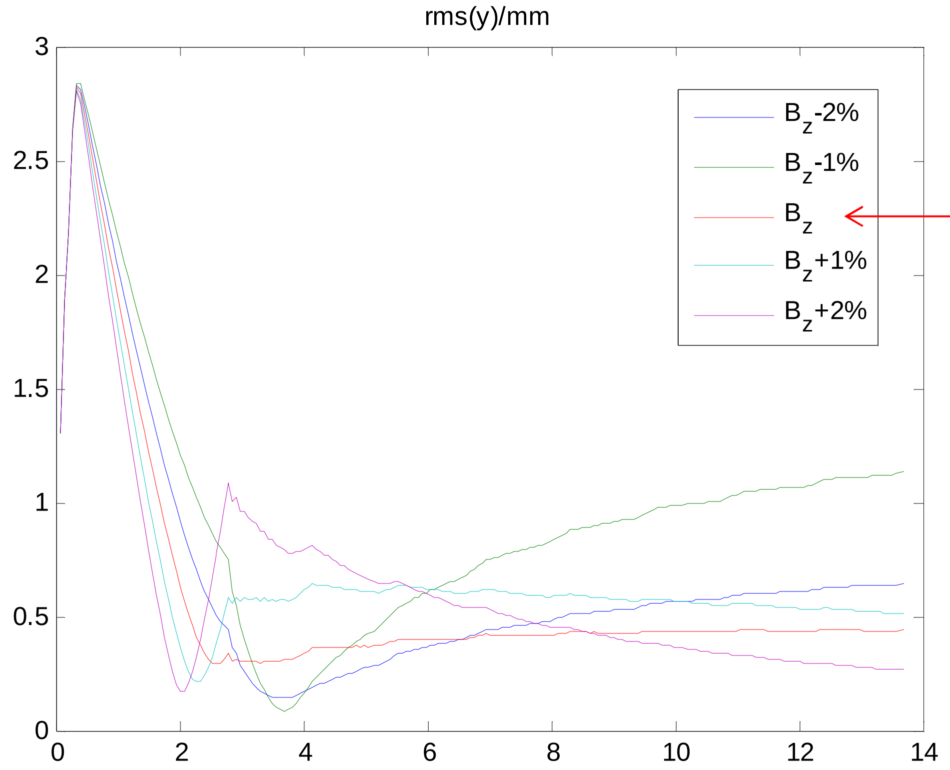
solenoid 307.5



solenoid 310.5



Astra Simulation to End of ACC1



adjusted for optimal emittance

very different optics
for the rest of the machine

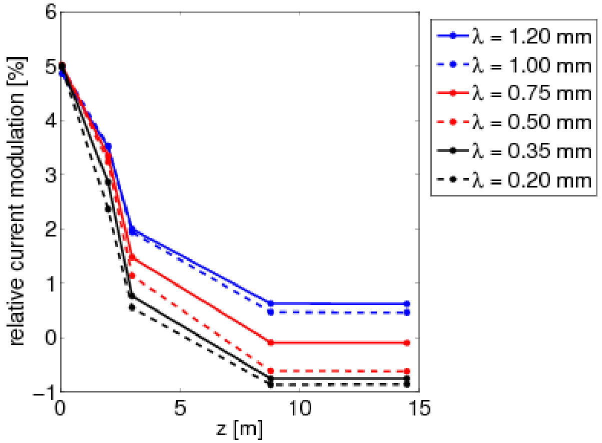
effect 1: plasma oscillations in low energy regime: impedance depends strong on optics

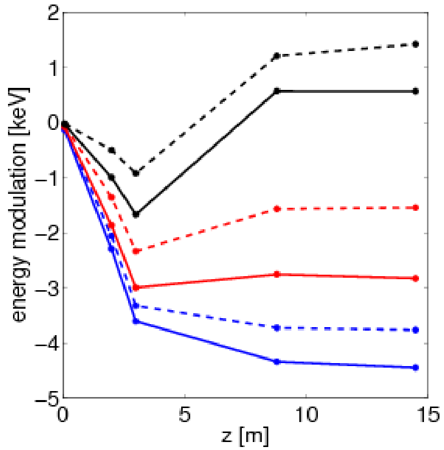
effect 2: amplification in high energy regime: impedance depends weak on optics

effect 3: LOLA resolution depends on optics

Old Simulation (1 nC working point)

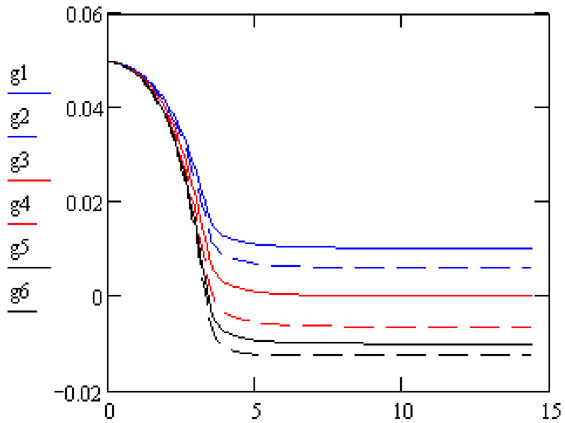
5% initial modulation (Gisela Poeplau)

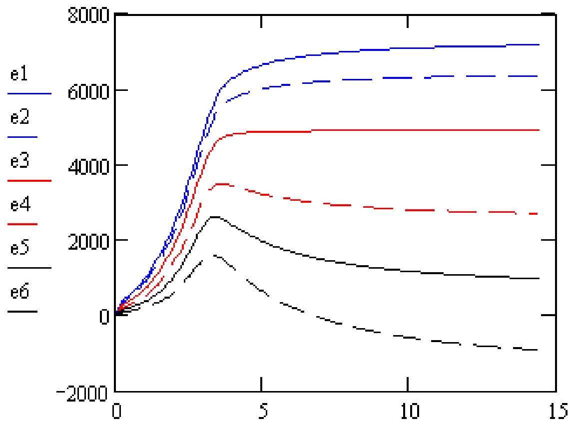




cold 1D model for plasma oscillations

uses one “fummel-parameter” for impedance





Cold 1D Model for Plasma Oscillations

Ansatz $z(Z,z_0) = z_0 + m\delta z(Z)\sin kz_0$ $\qquad \Lambda_0(z_0) = \Lambda_0 \cdot (1 + m\cos kz_0)$

$\tilde{p}(Z,z_0) = m\delta p(Z)\sin kz_0$

$$\frac{\partial}{\partial Z}\tilde{z}(Z,z_0) = \frac{1}{(G(Z))^2}\frac{\tilde{p}(Z,z_0)}{P(Z)}$$

$$\frac{\partial}{\partial Z}\tilde{p}(Z,z_0) = \frac{qE_z(Z,\tilde{z})}{V(Z)}$$

$$E_z(Z,\tilde{z}) = m\tilde{I}_1(Z)X'(Z)\sin kz$$

$$\tilde{I}_1(Z) = V(Z)\Lambda_0 \cdot (1 - \delta z(Z)k)$$

with

$G(Z) = \gamma_{\mathrm{ref}}(Z)$

$P(Z) = p_{\mathrm{ref}}(Z)$

$V(Z) = v_{\mathrm{ref}}(Z)$

$X'(Z) = \mathrm{Im}\{\mathrm{impedance'}\}$

$\Lambda_0 = \text{line charge density}$

$$\delta p'(Z) = q\Lambda_0 \cdot (1 - \delta z(Z)k)X'(Z)$$

$$\delta z'(Z) = \frac{1}{(G(Z))^2}\frac{\delta p(Z)}{P(Z)}$$

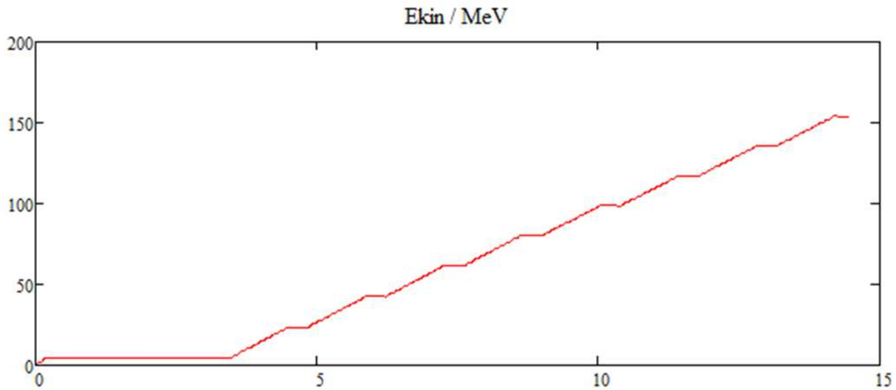
$\rightarrow Gain = 1 - \delta z(Z)k$

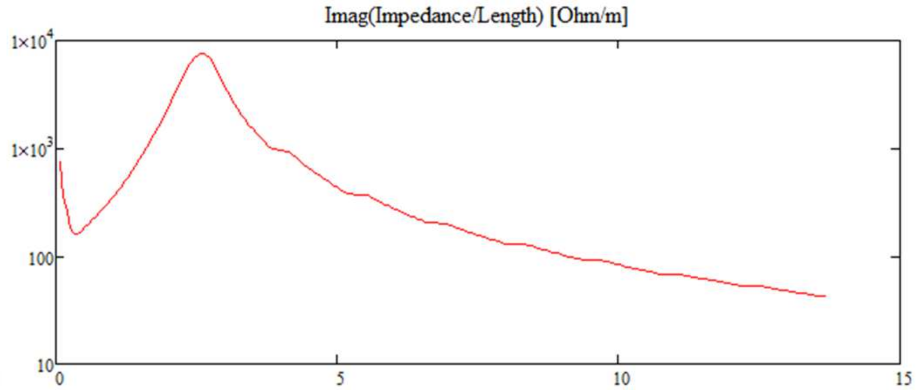
1D Model with Beam Parameters ($\mathcal{E}$, σ_r) from Astra

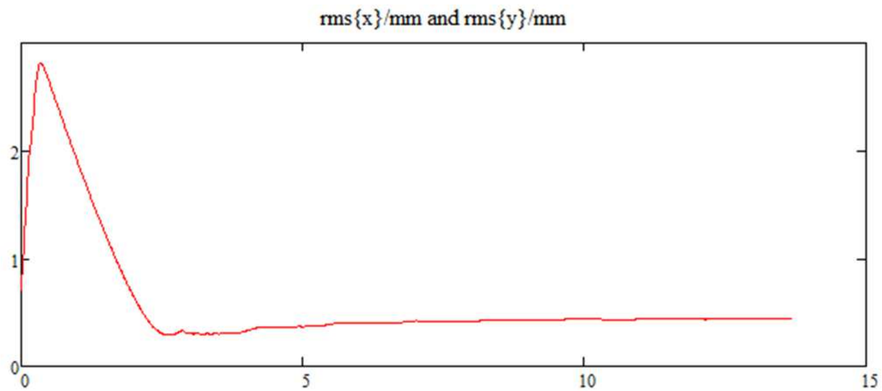
after gun $\rightarrow$ after ACC1

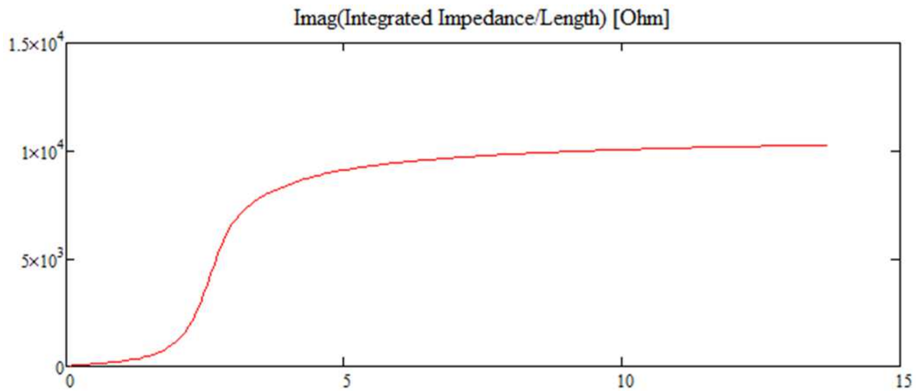
0.4 nC, solenoid for optimal emittance

I0=13.5 A, wavelength = 0.25 mm

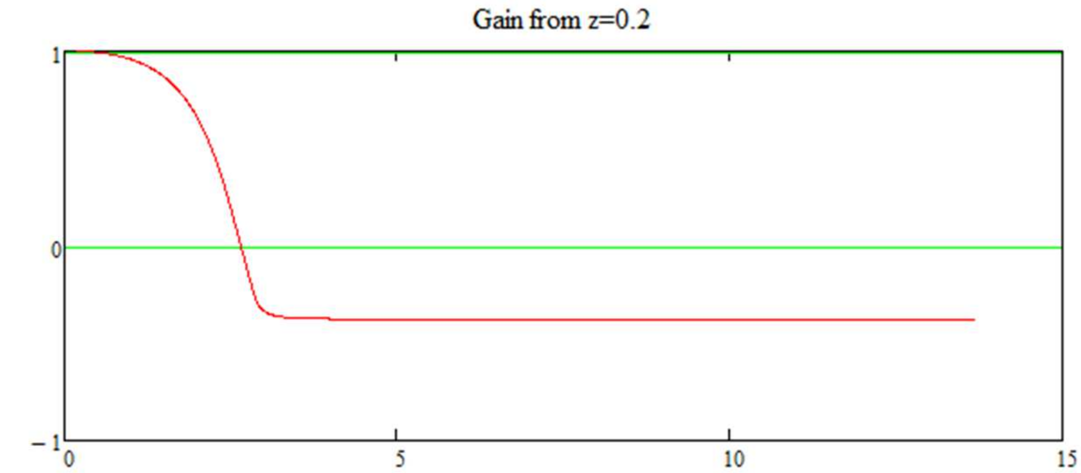


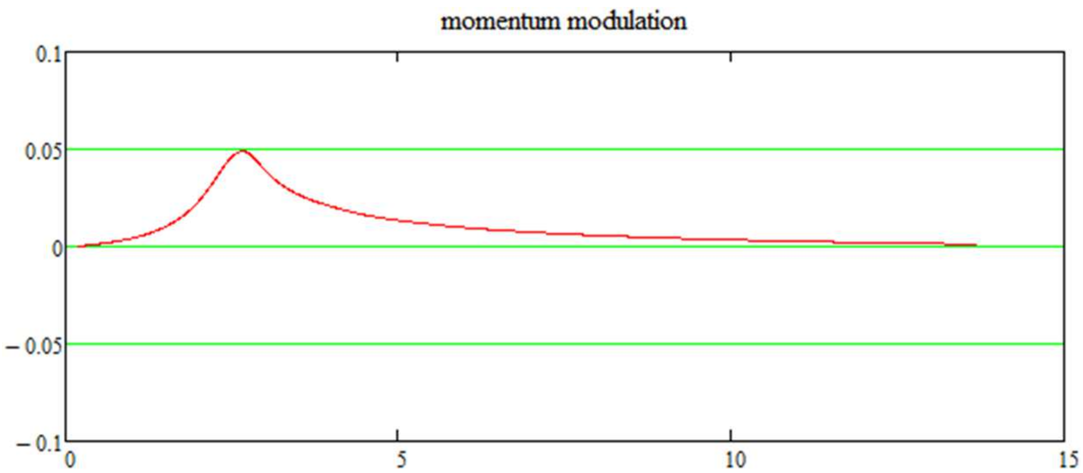


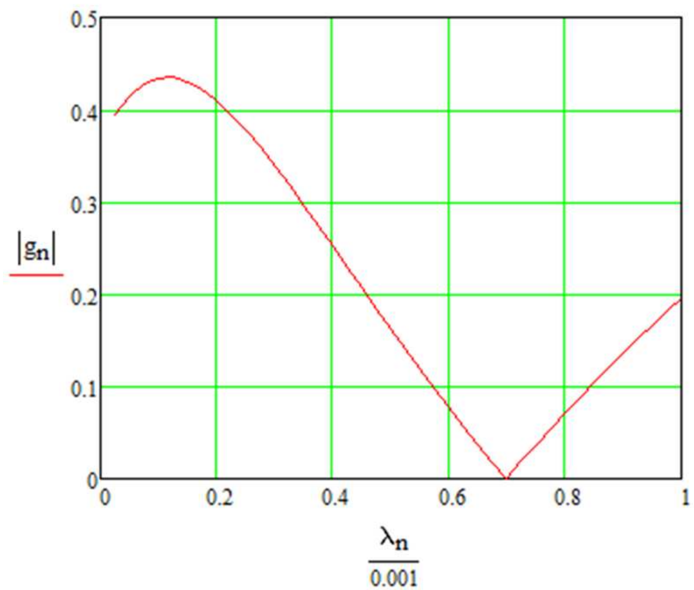


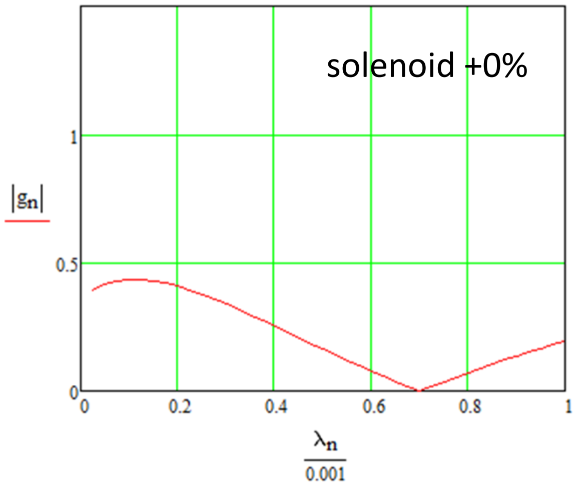


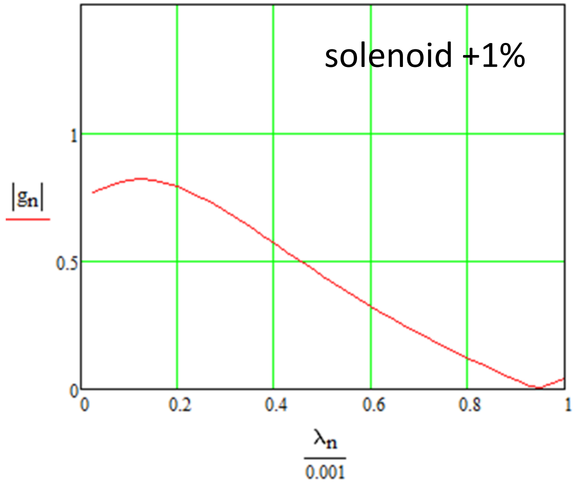
after gun → after ACC1
0.4 nC, solenoid for optimal emittance
I0=13.5 A, wavelength = 0.25 mm

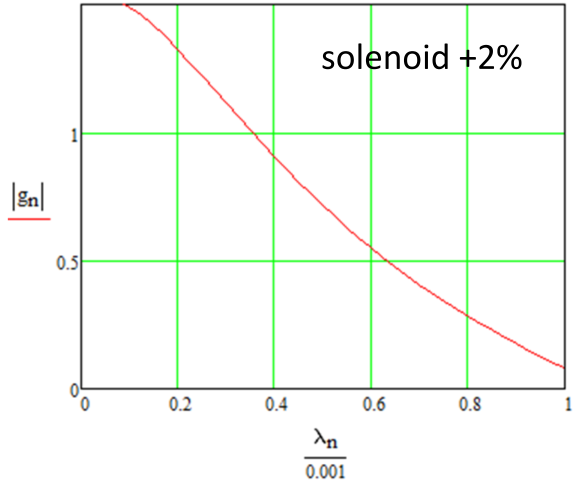


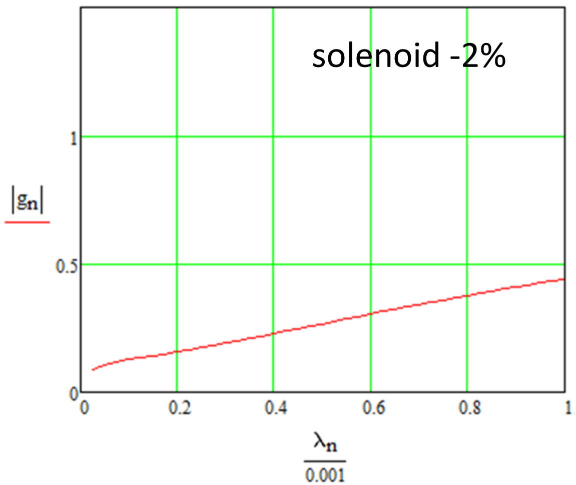


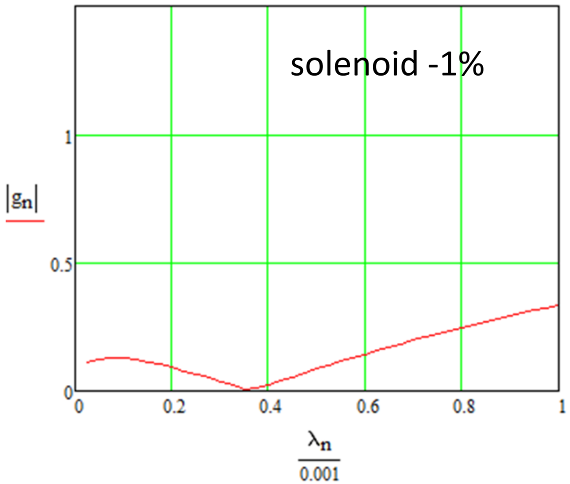




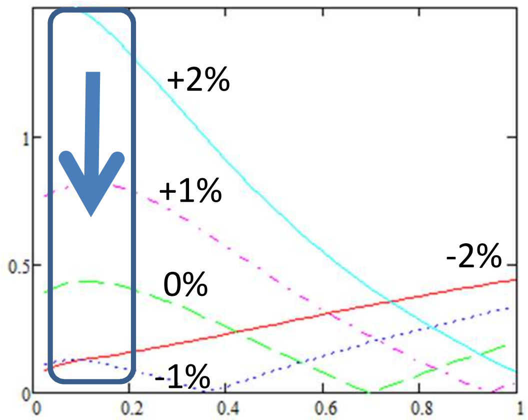








low wavelength:
significant effect, but monotonic behavior !!!



Simulations

Generator (Klaus-Astra-Generator)

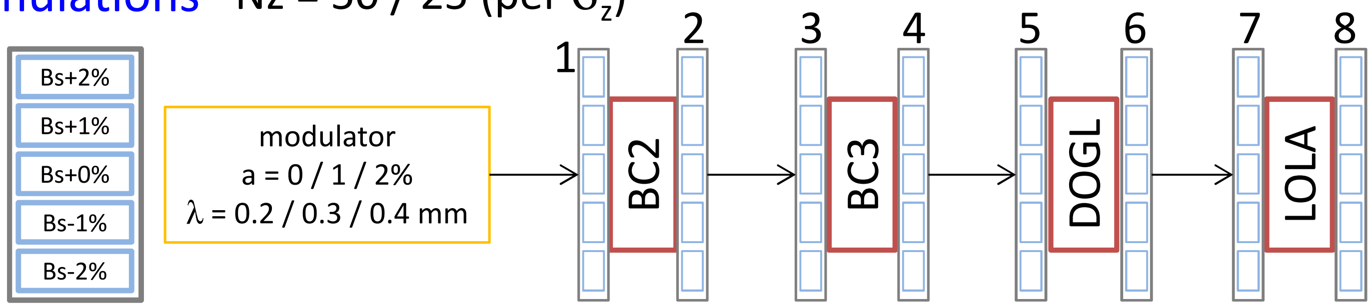
Q = 0.4 nC, N = 200k / 1M

Astra Simulations

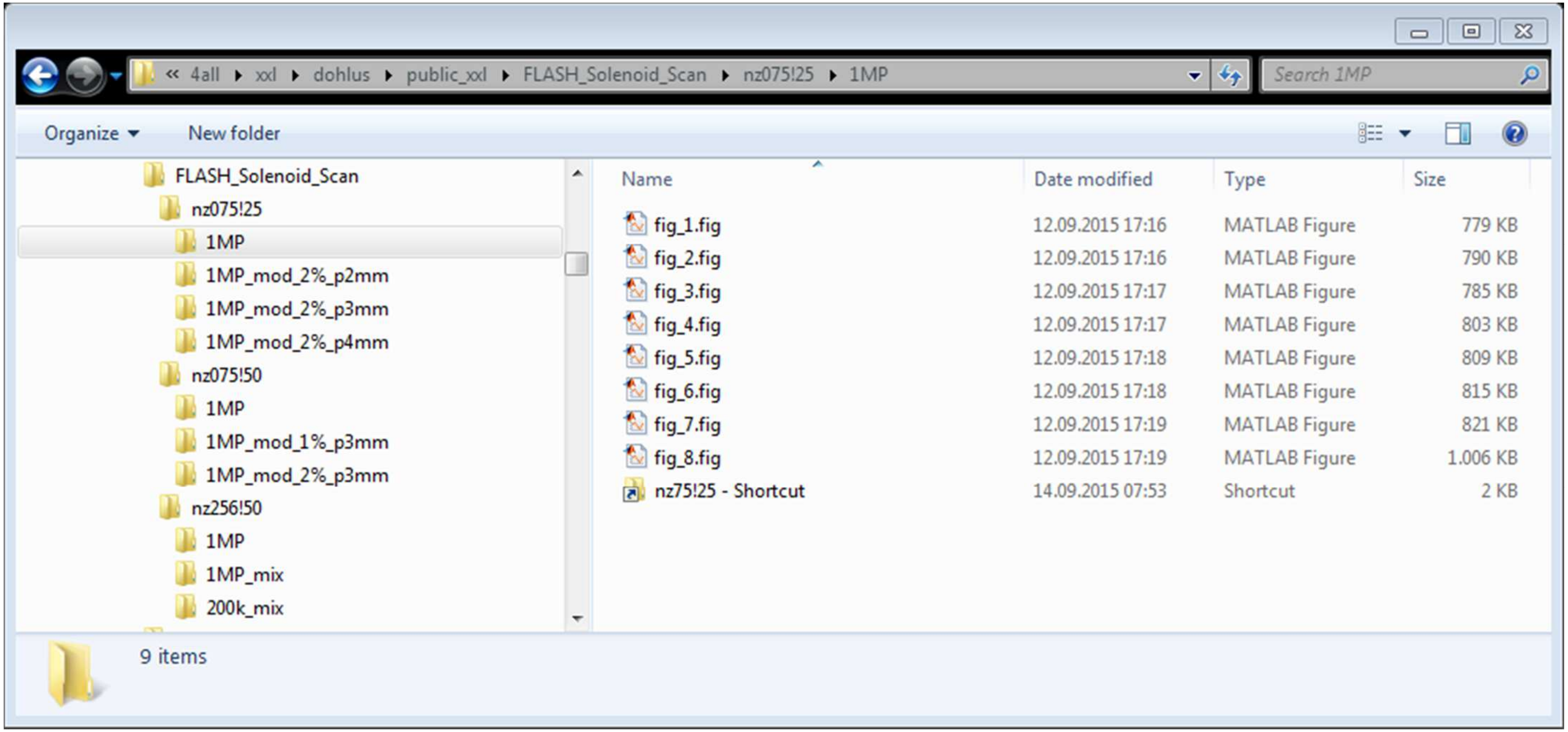
z = 2.6 m (13.88 m)	z = 2.6 m (13.88 m)	z = 2.6 m (13.88 m)	z = 2.6 m (13.88 m)
N = 200k	N = 1M	N = 200k	N = 1M
Nz = 256	Nz = 256	Nz = 75	Nz = 75
Bs-2%	Bs+2%	Bs-2%	Bs+2%
Bs-1%	Bs-1%	Bs-1%	Bs-1%
Bs+0%	Bs+0%	Bs+0%	Bs+0%
Bs+1%	Bs+1%	Bs+1%	Bs+1%
Bs+2%	Bs+2%	Bs+2%	Bs+2%

XTrack Simulations

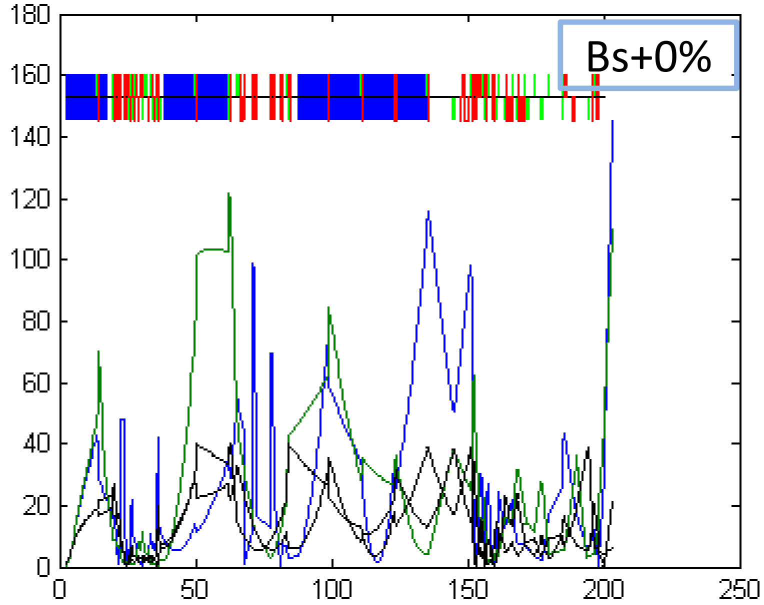
Nz = 50 / 25 (per σ_z)

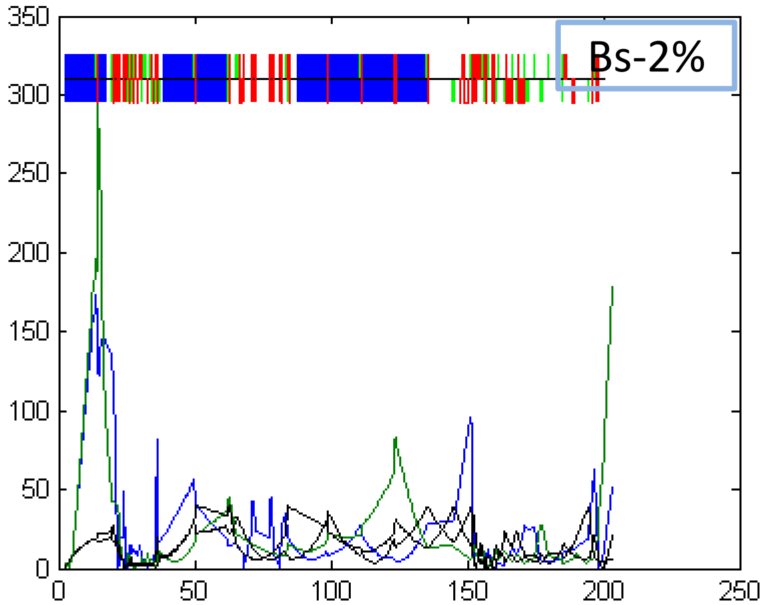


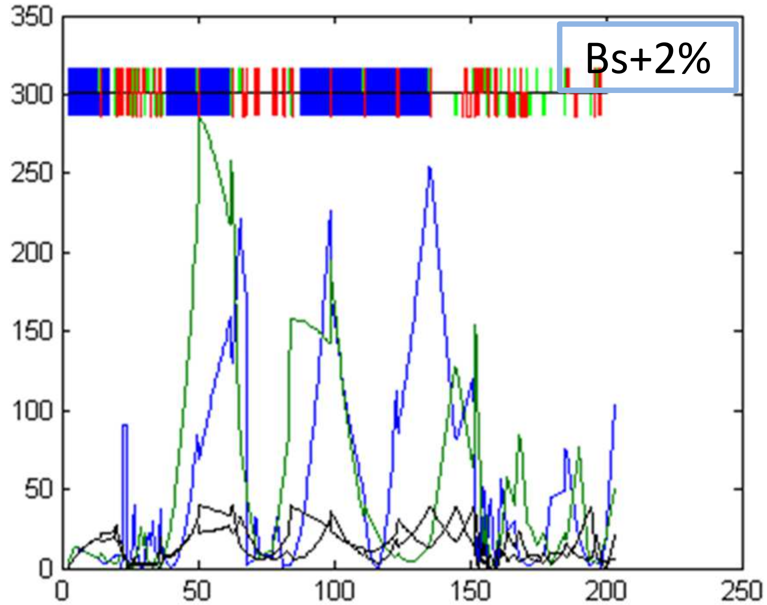
Xtrack-Simulations → many particle dumps + manyMATLAB figures



Xtrack Simulation: optics

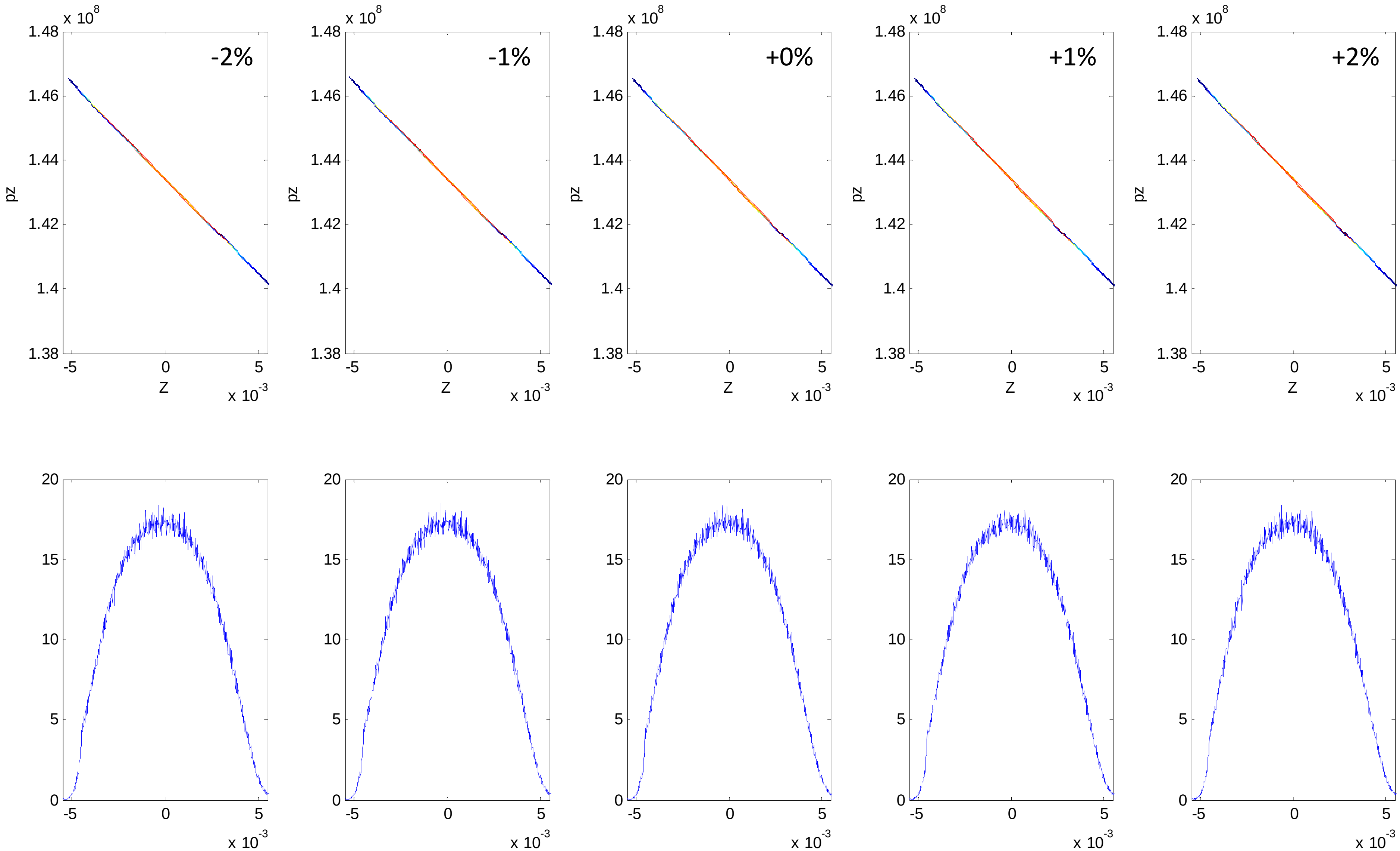




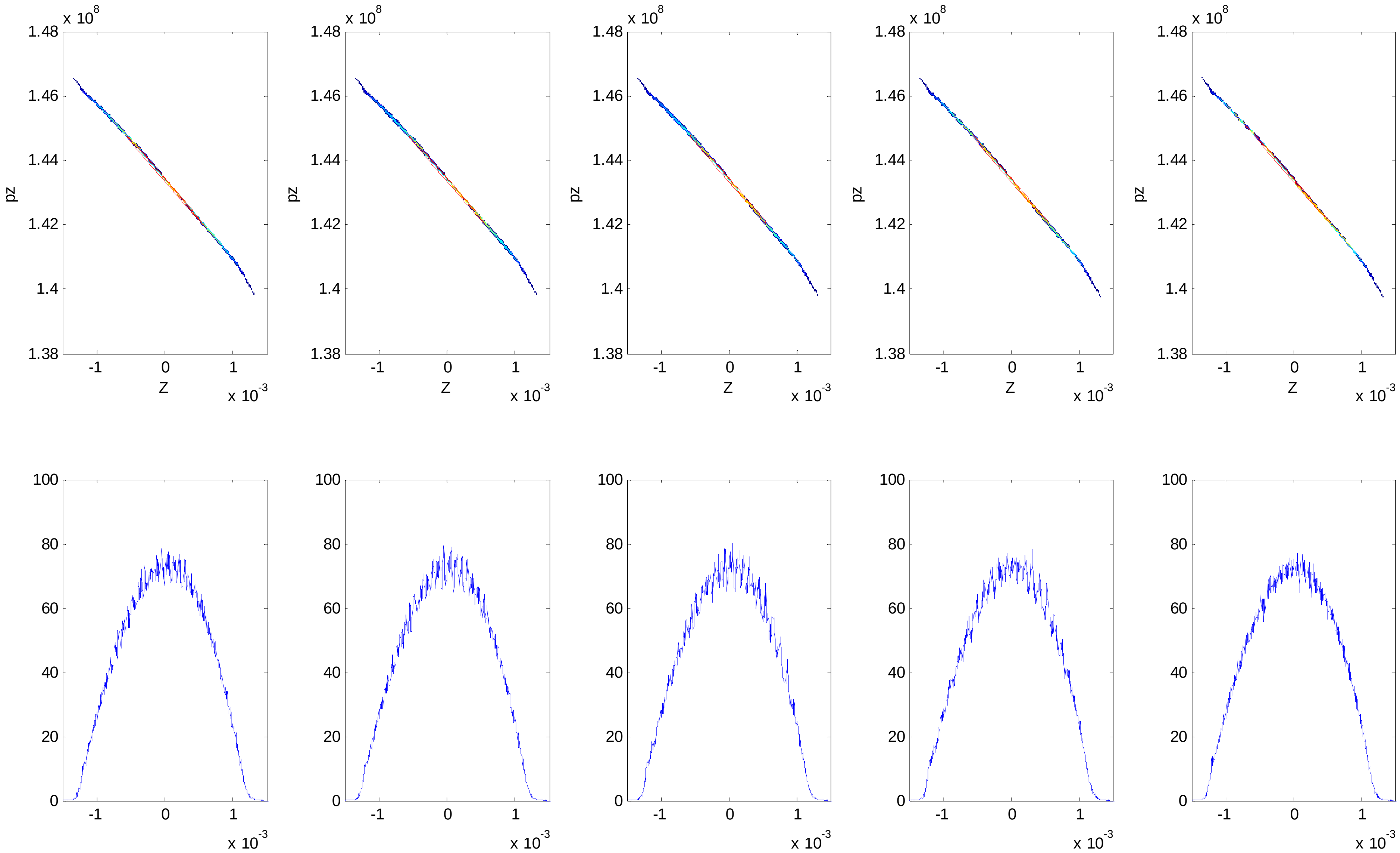


Xtrack Simulation: 1MP, Nz = 75 | 25/σ_z, no modulation

(1) = before BC2

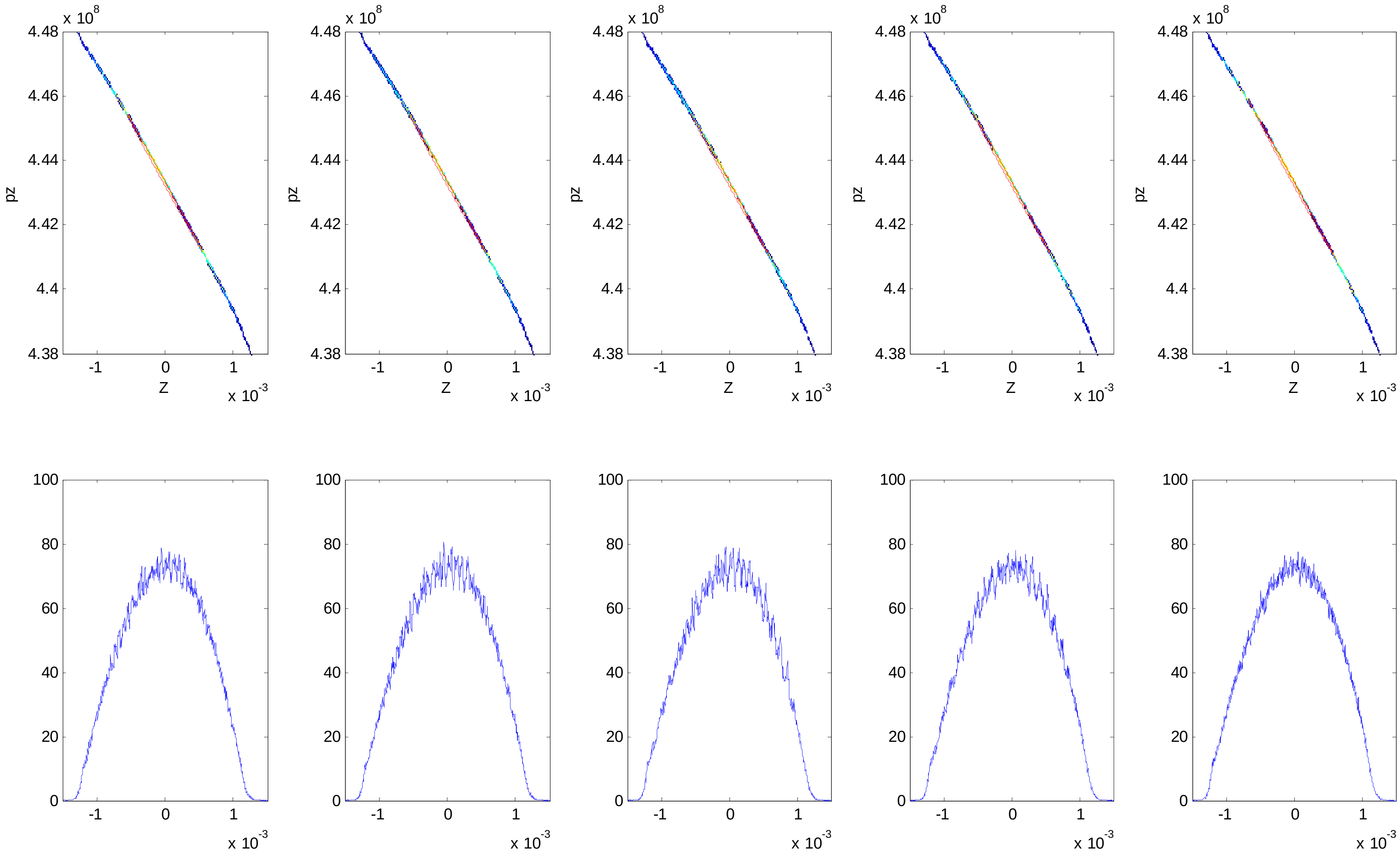


(2) = after BC2

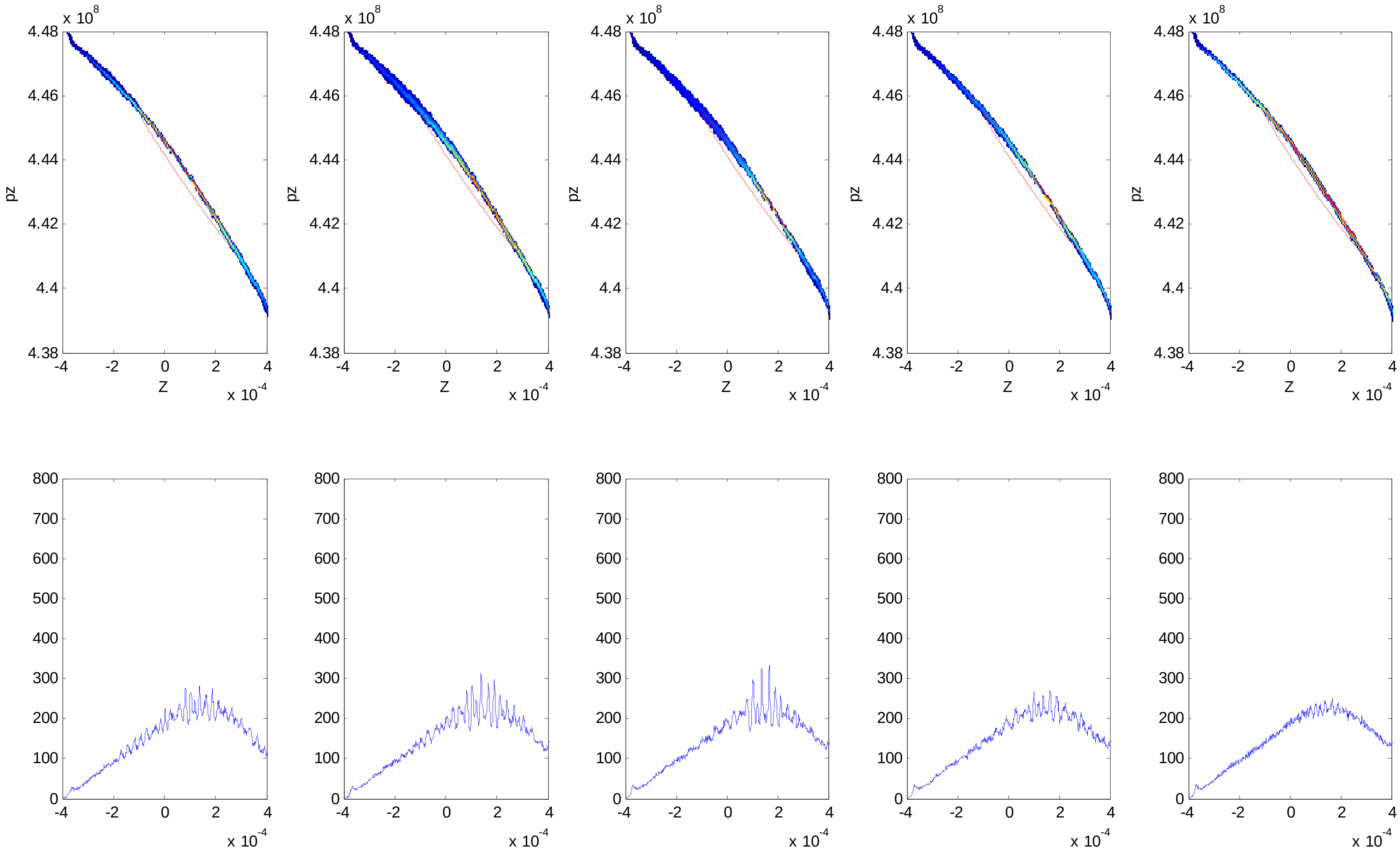


x 10^8
1.48
1.46
1.44
1.42
1.4
1.38
pz
-1
0
1
Z
x 10^-3
100
80
60
40
20
0
-1
0
1
x 10^-3

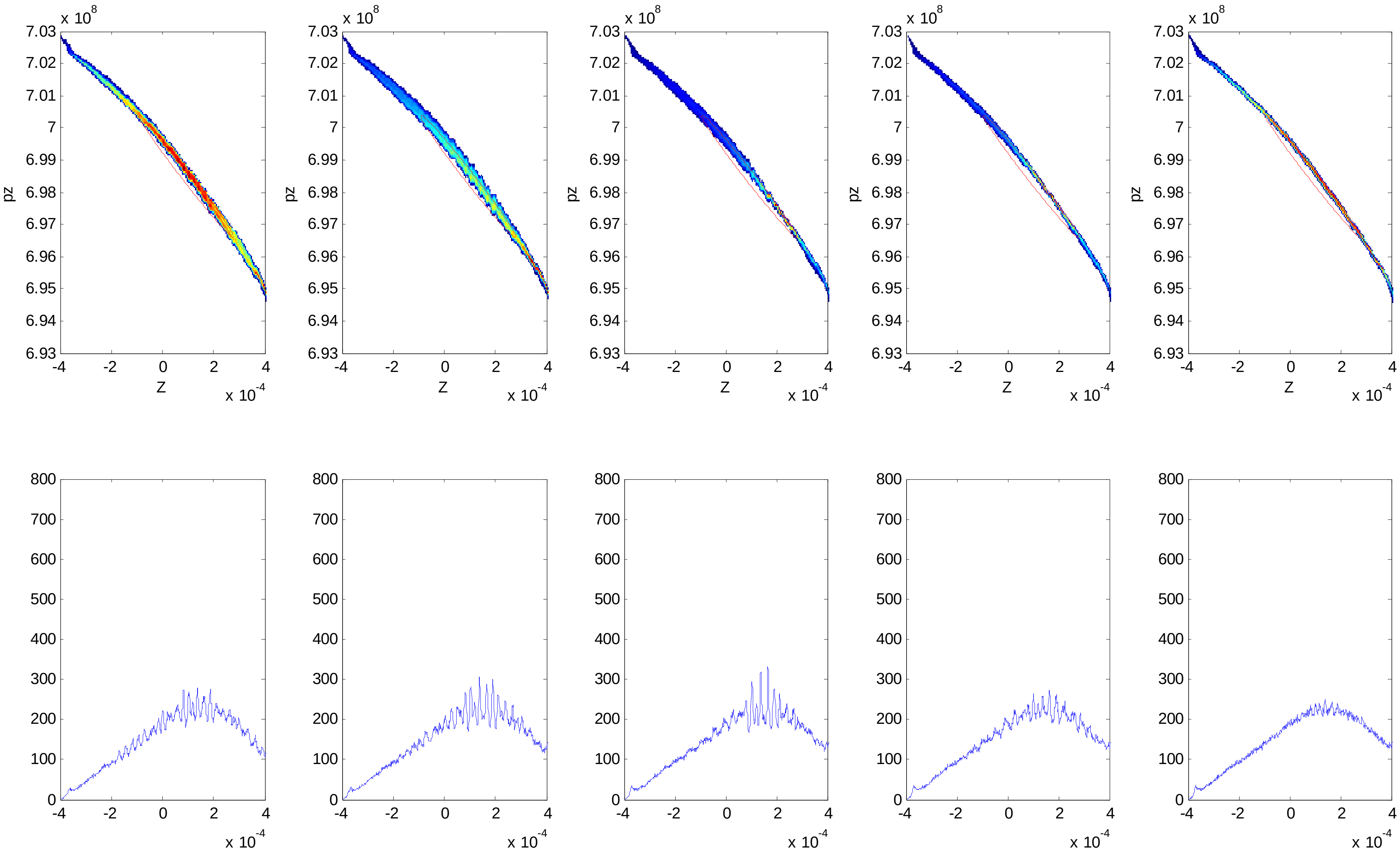
(3) = before BC3



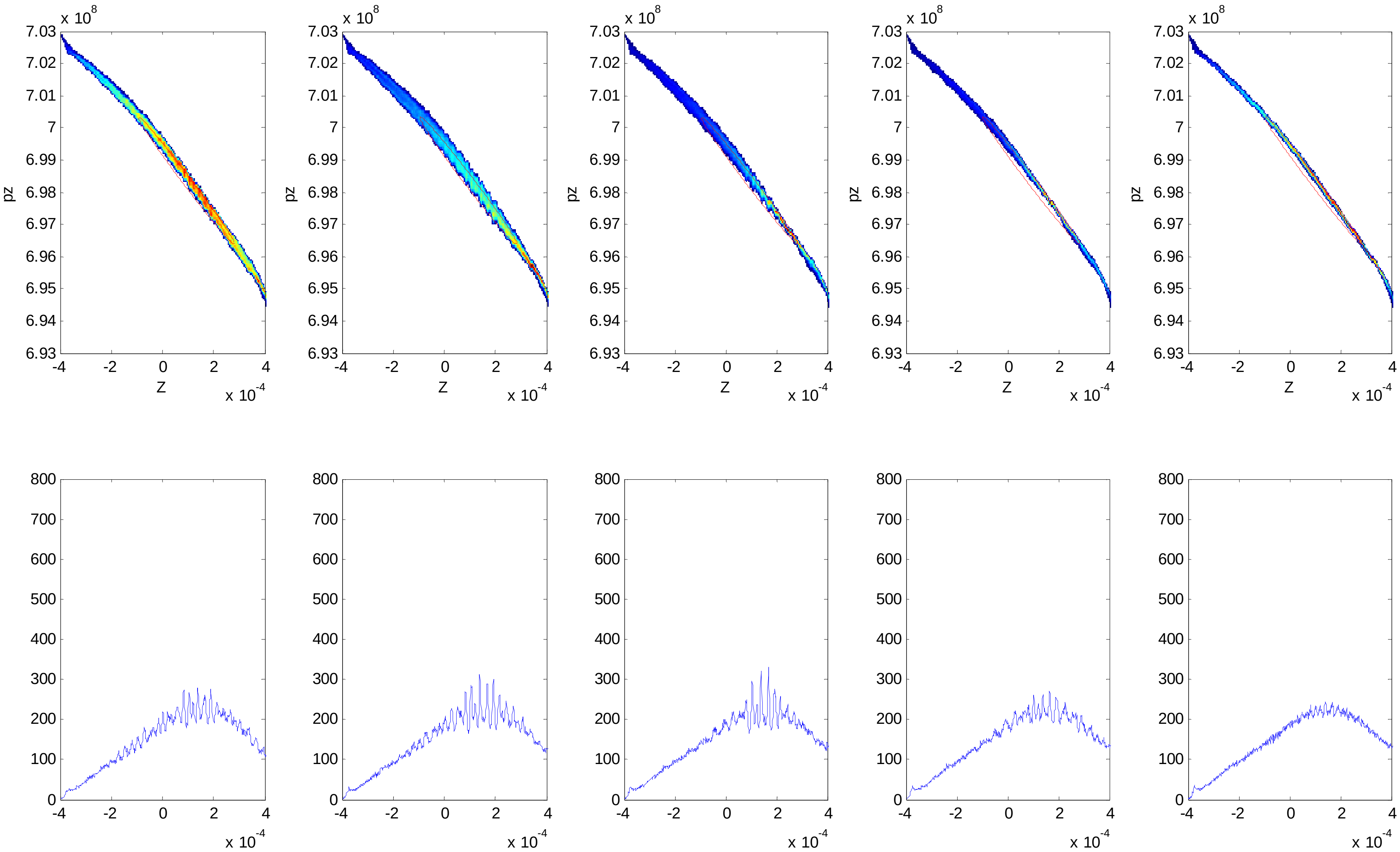
(4) = after BC3


x 10^8
4.48
4.46
4.44
4.42
4.4
4.38
pz
-4
-2
0
2
4
Z
x 10^-4
800
700
600
500
400
300
200
100
0

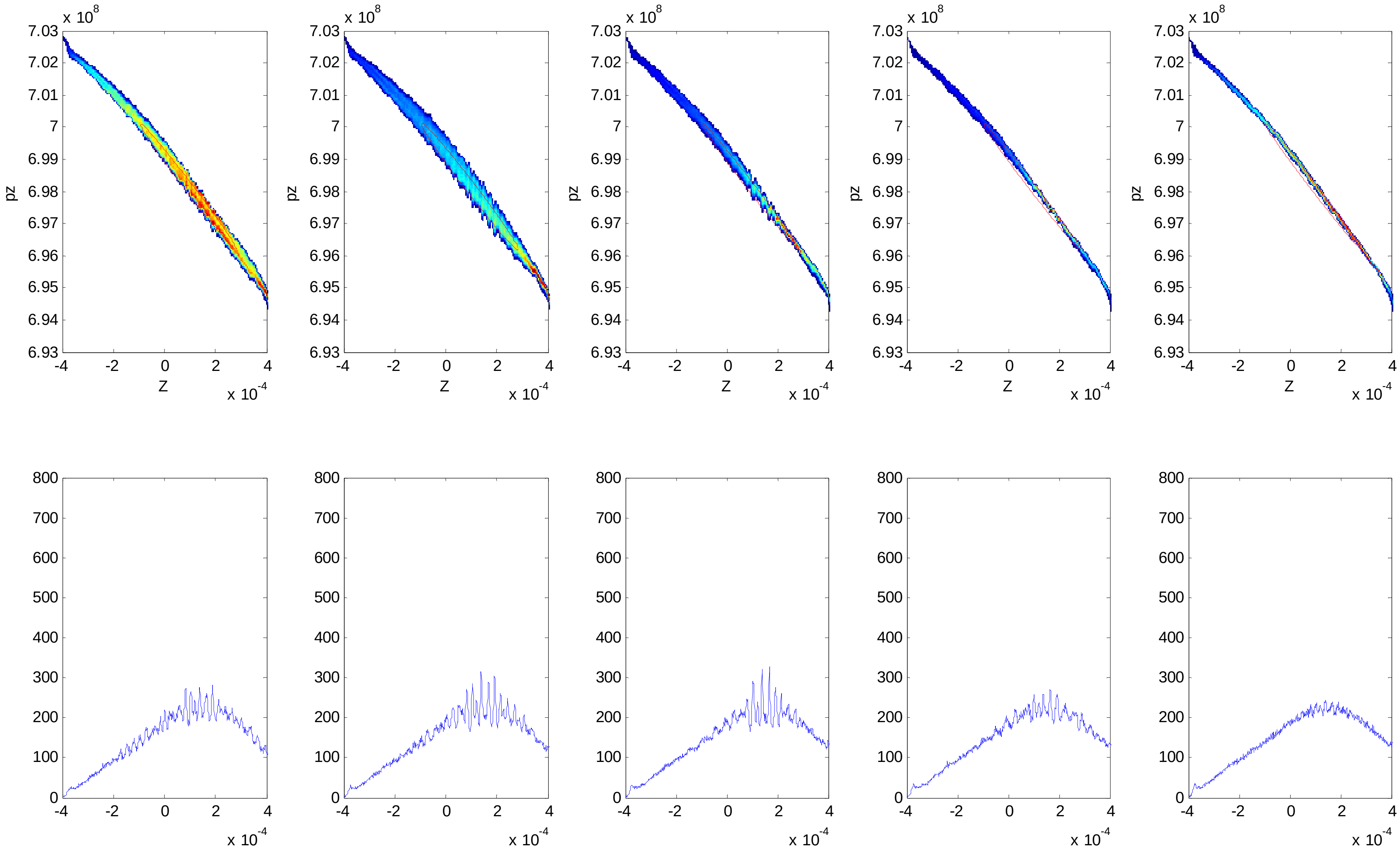
(5) = before DOGLEG



(6) = after DOGLEG

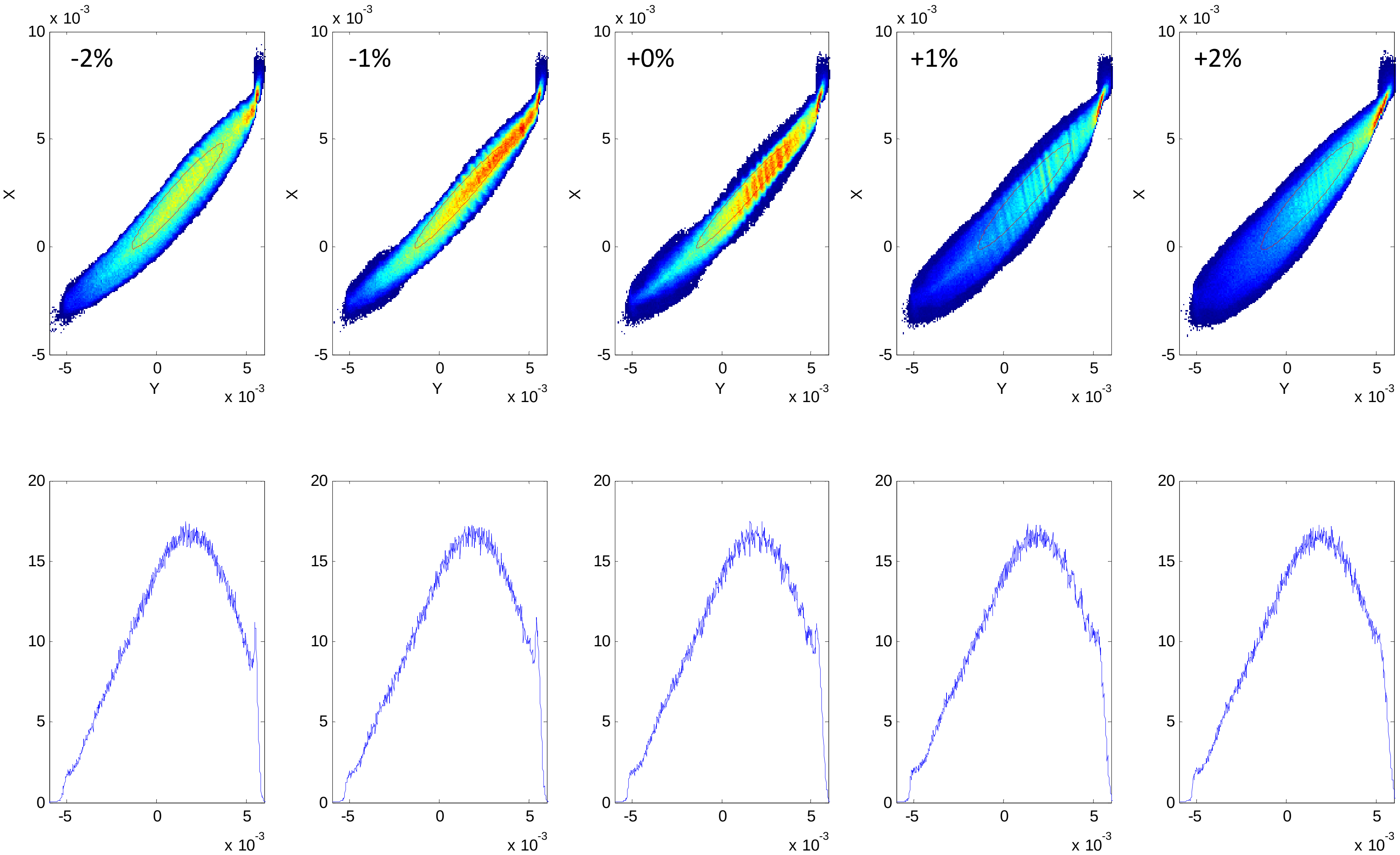


(7) = before LOLA



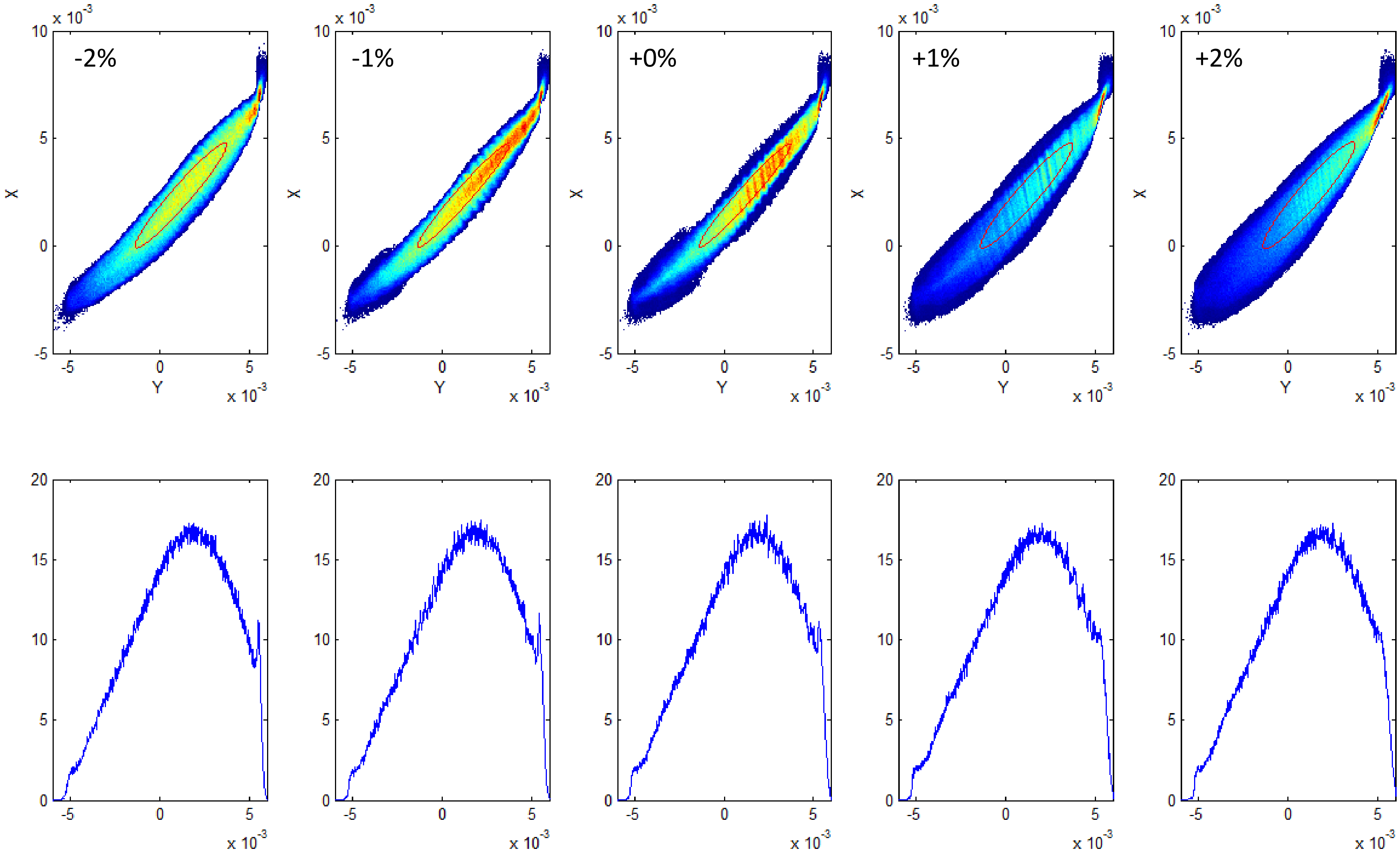
Xtrack Simulation: 1MP, Nz = 75 | 25/σ_z, no modulation

(8) = screen after LOLA



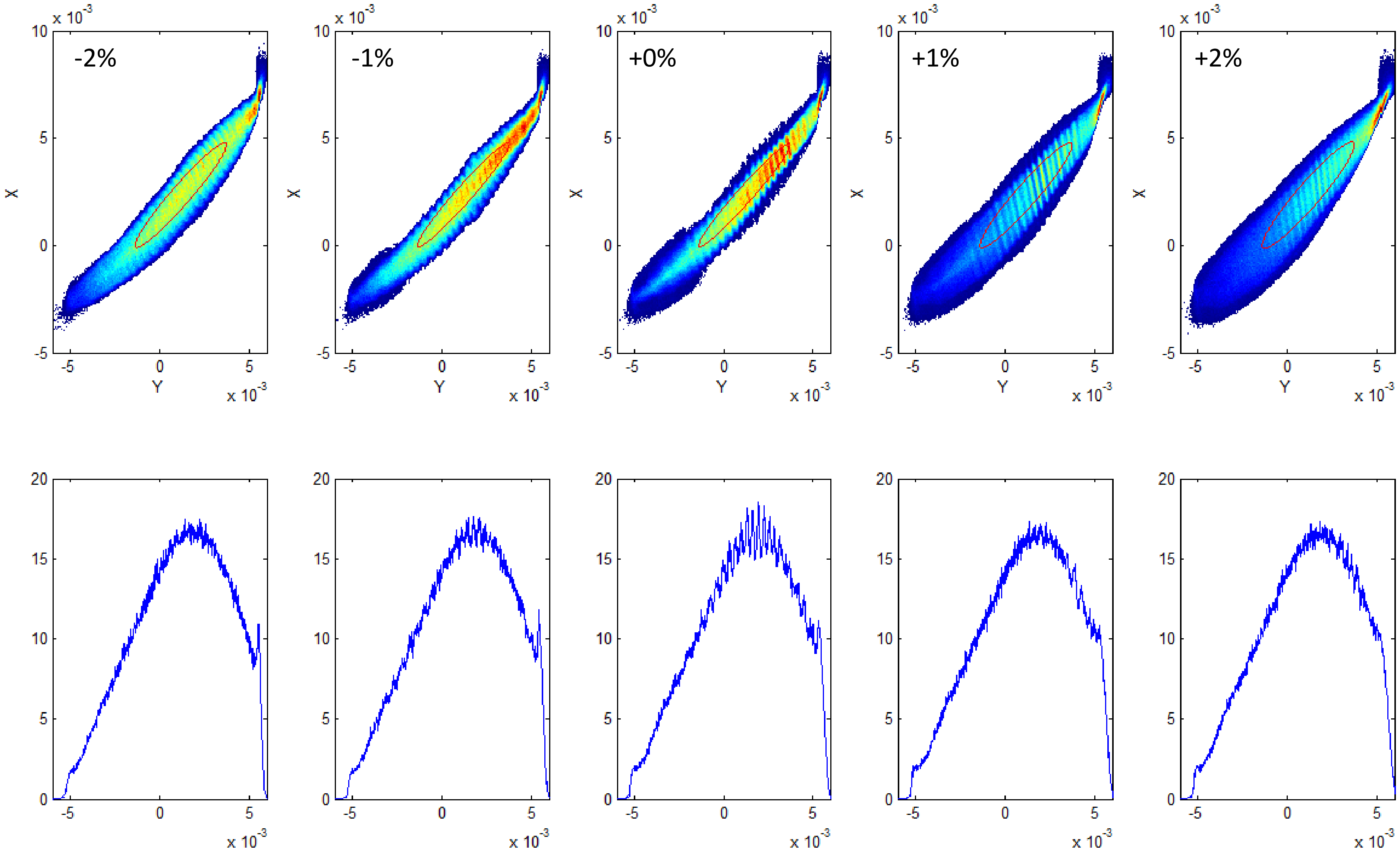
Xtrack Simulation: 1MP, Nz = 75 | 25/σ_z, mod = 2%, 0.2mm

(8) = screen after LOLA



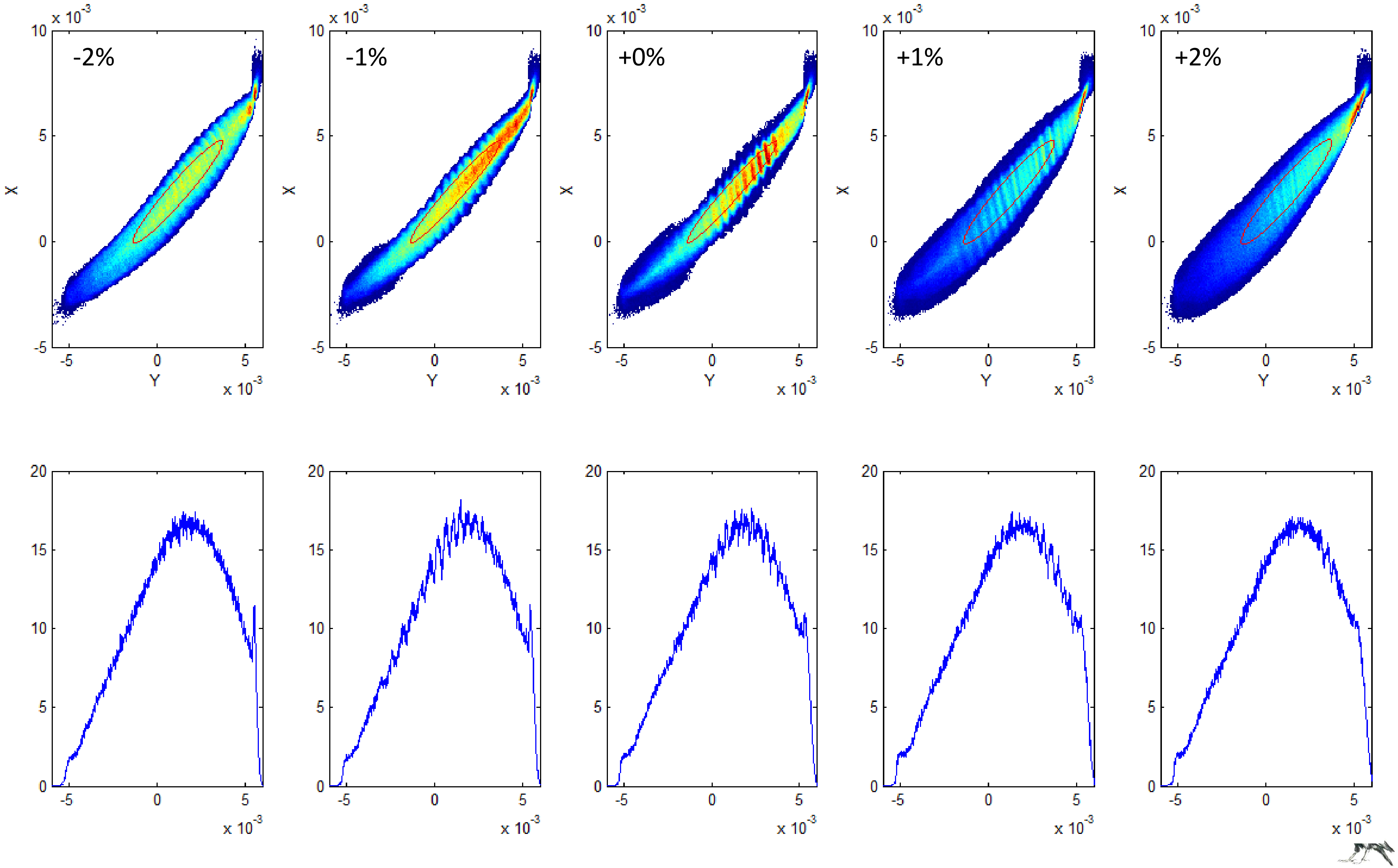
Xtrack Simulation: 1MP, Nz = 75 | 25/σ_z, mod = 2%, 0.3mm

(8) = screen after LOLA



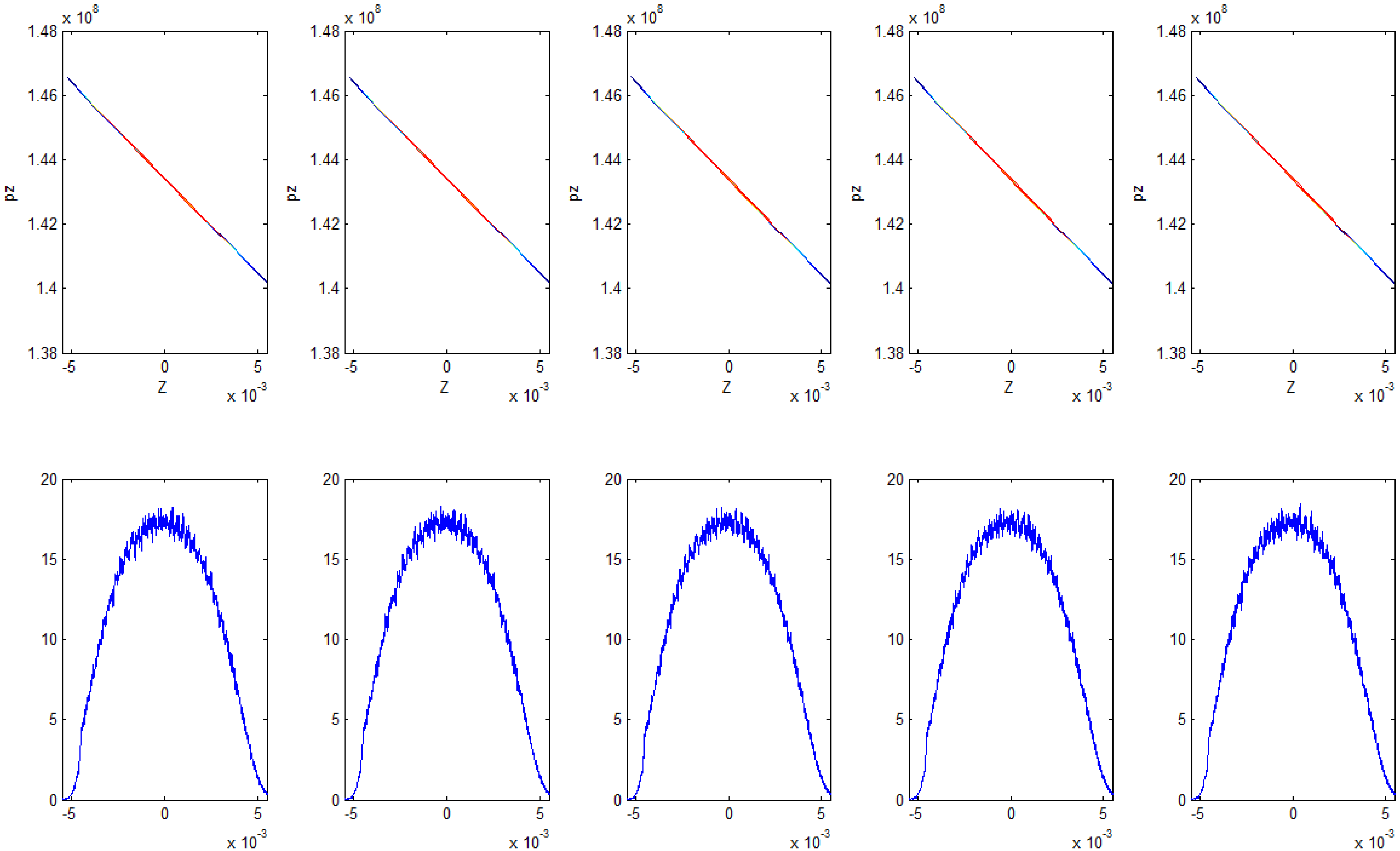
Xtrack Simulation: 1MP, Nz = 75 | 25/σ_z, mod = 2%, 0.4mm

(8) = screen after LOLA

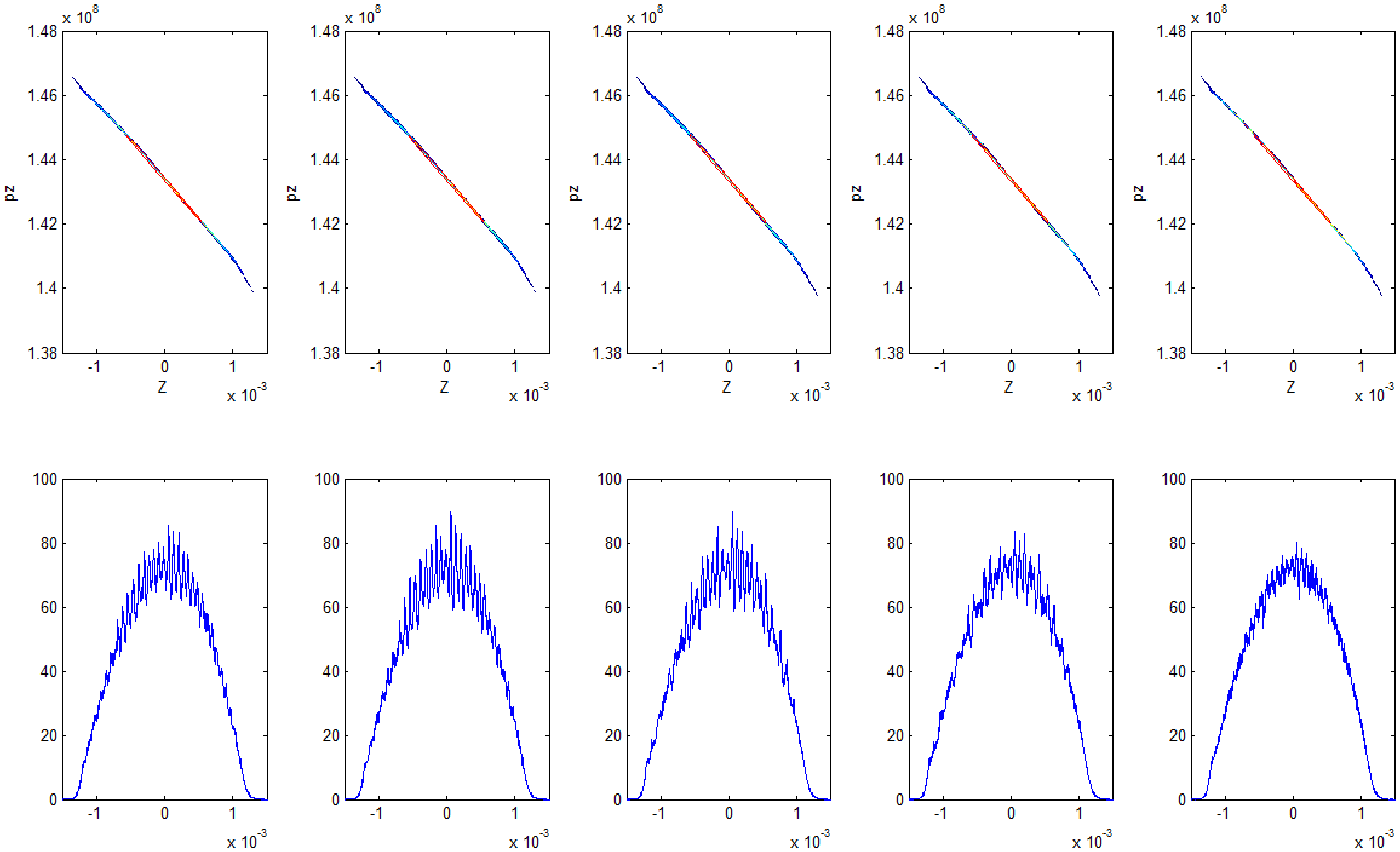


full story: mod = 2%, 0.3mm

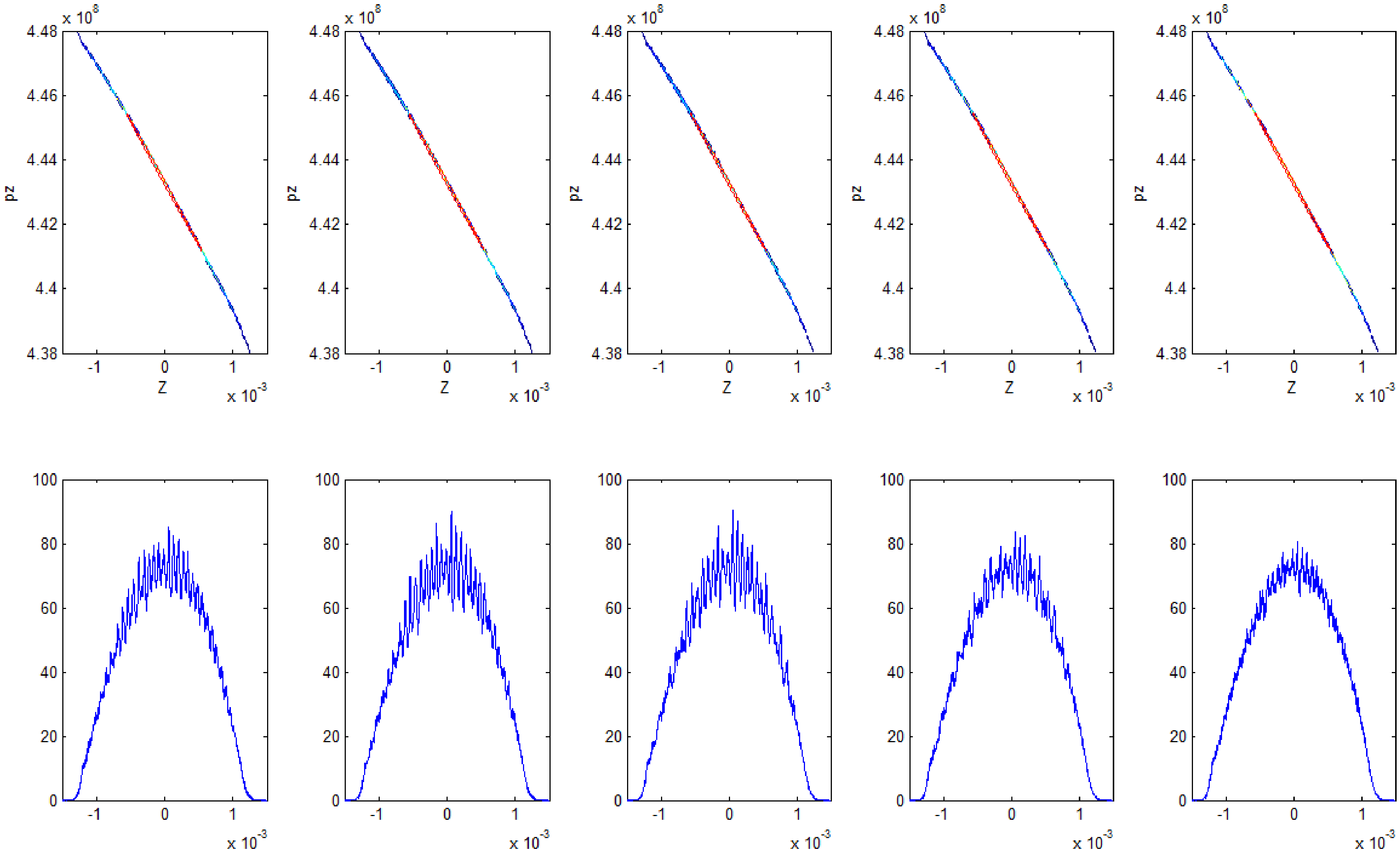
(1) = before BC2



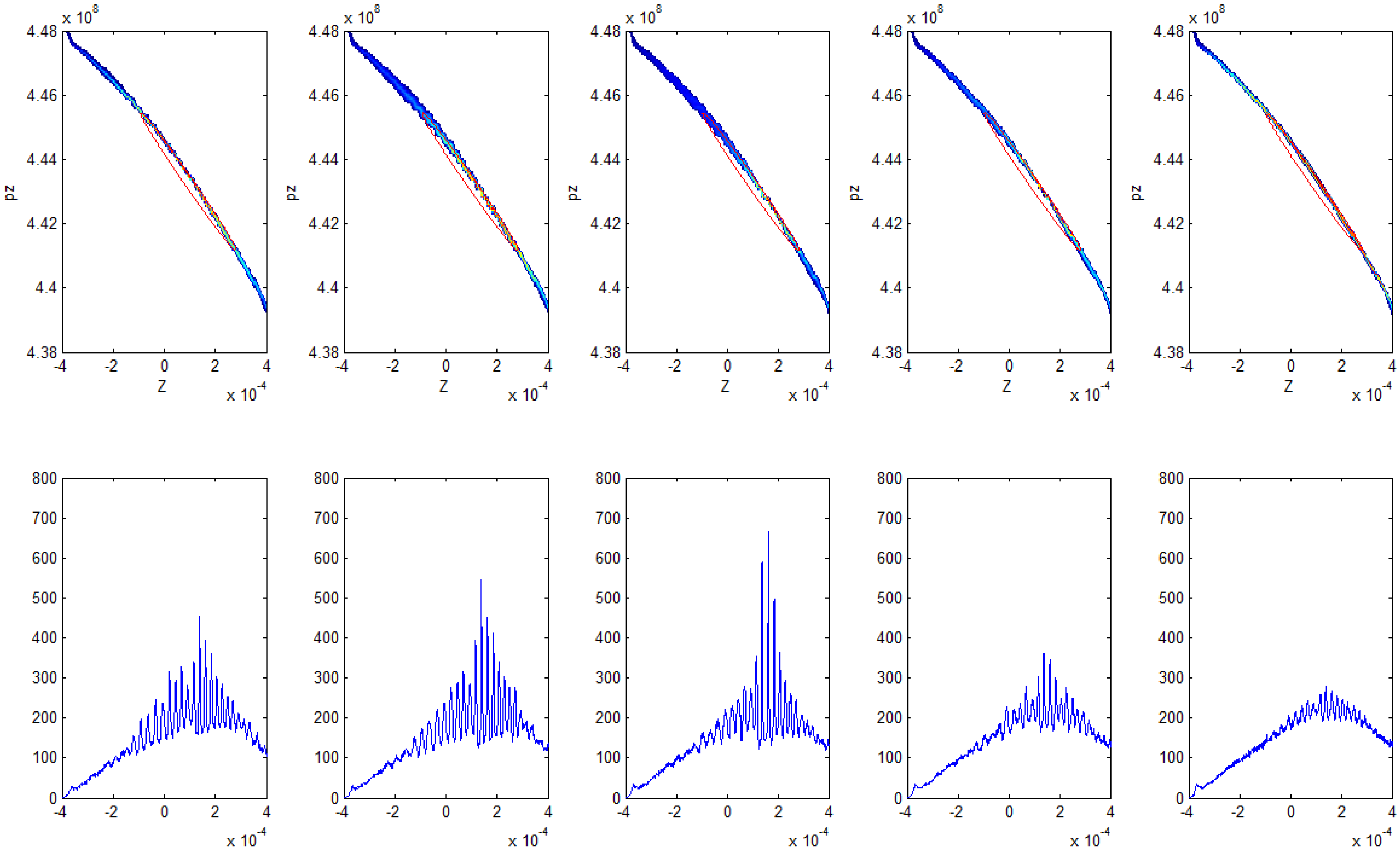
(2) = after BC2



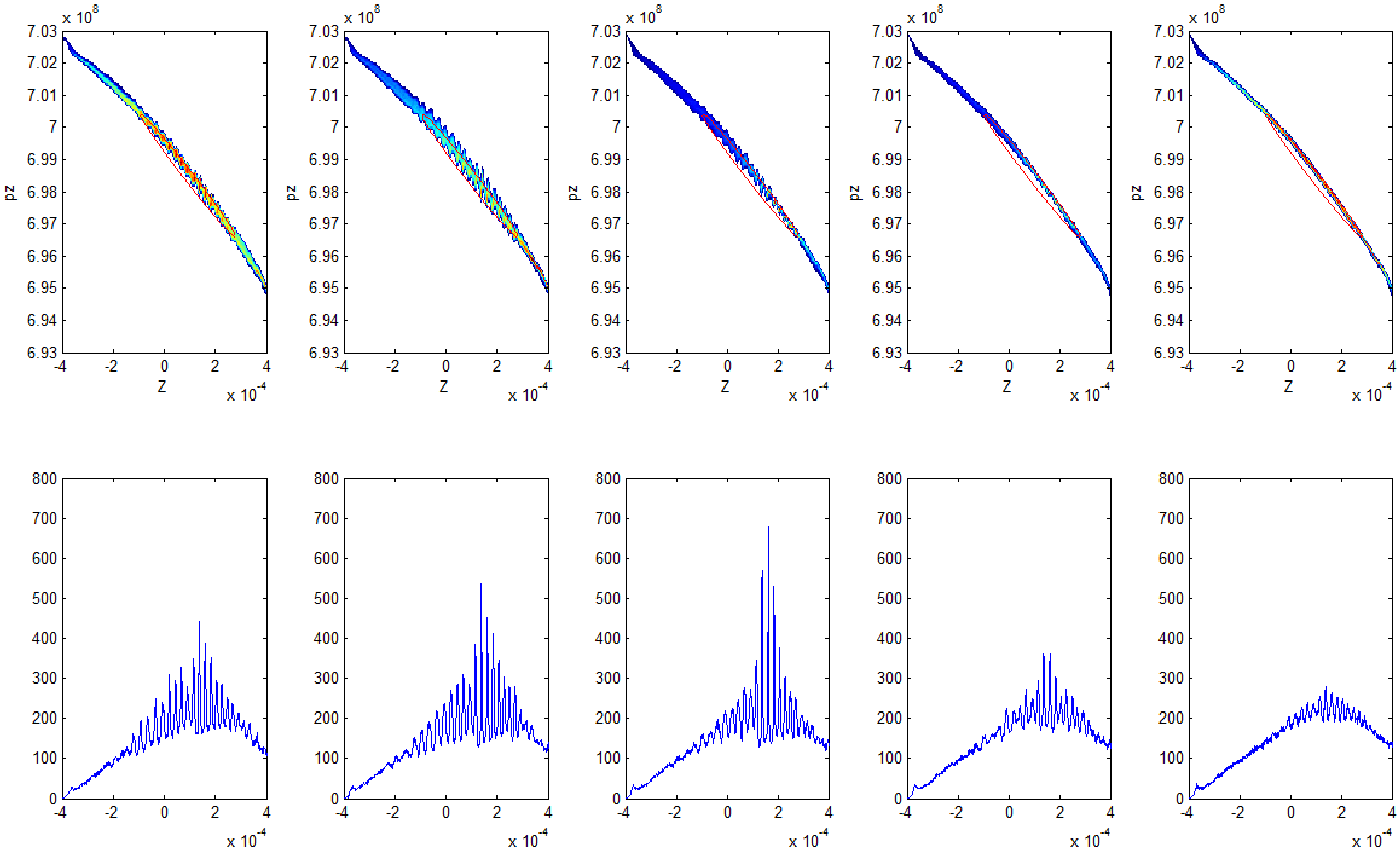
(3) = before BC3



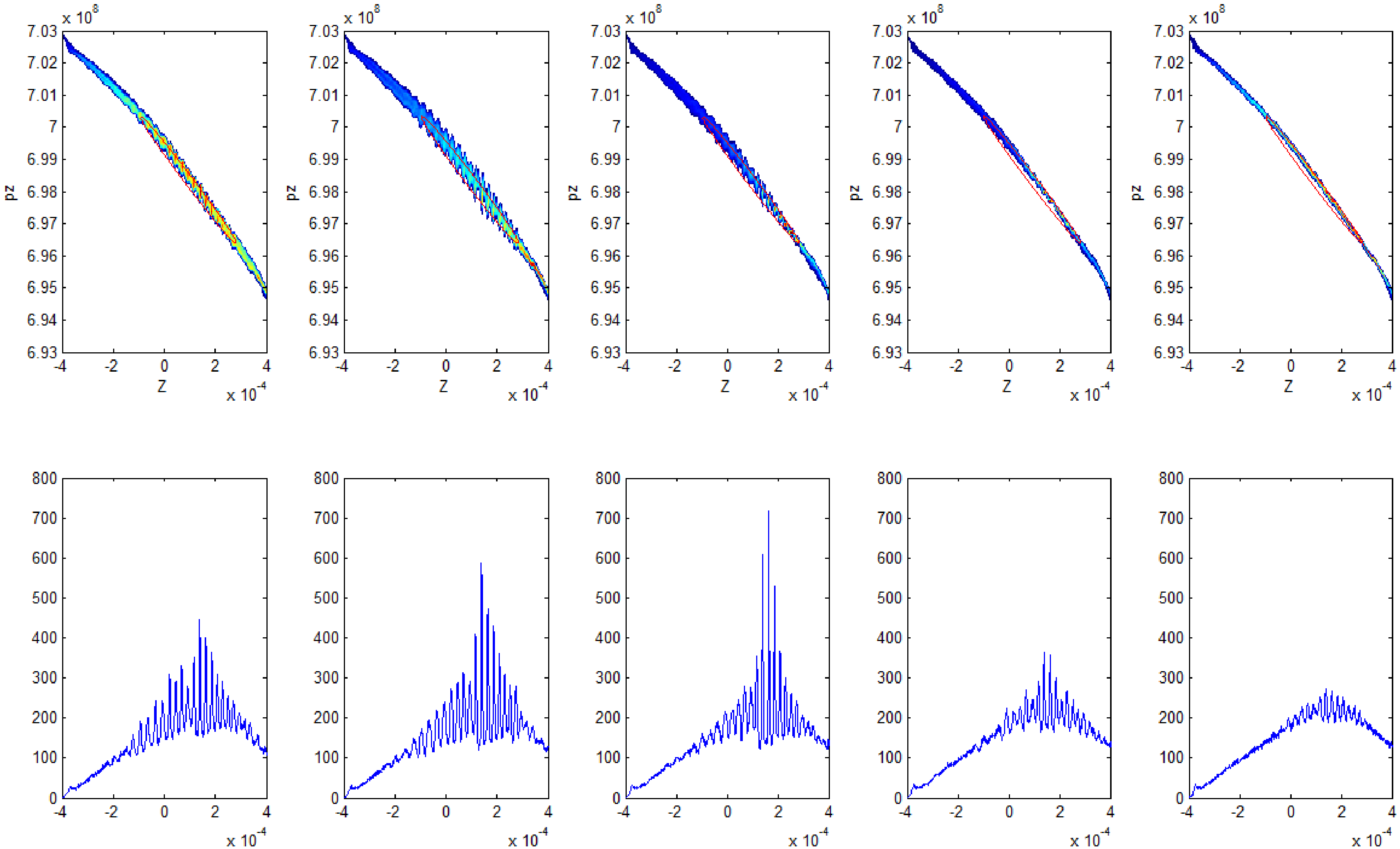
(4) = after BC3


x 10^8
pz
Z
x 10^-4
4.48
4.46
4.44
4.42
4.4
4.38
-4 -2 0 2 4
800
700
600
500
400
300
200
100
0

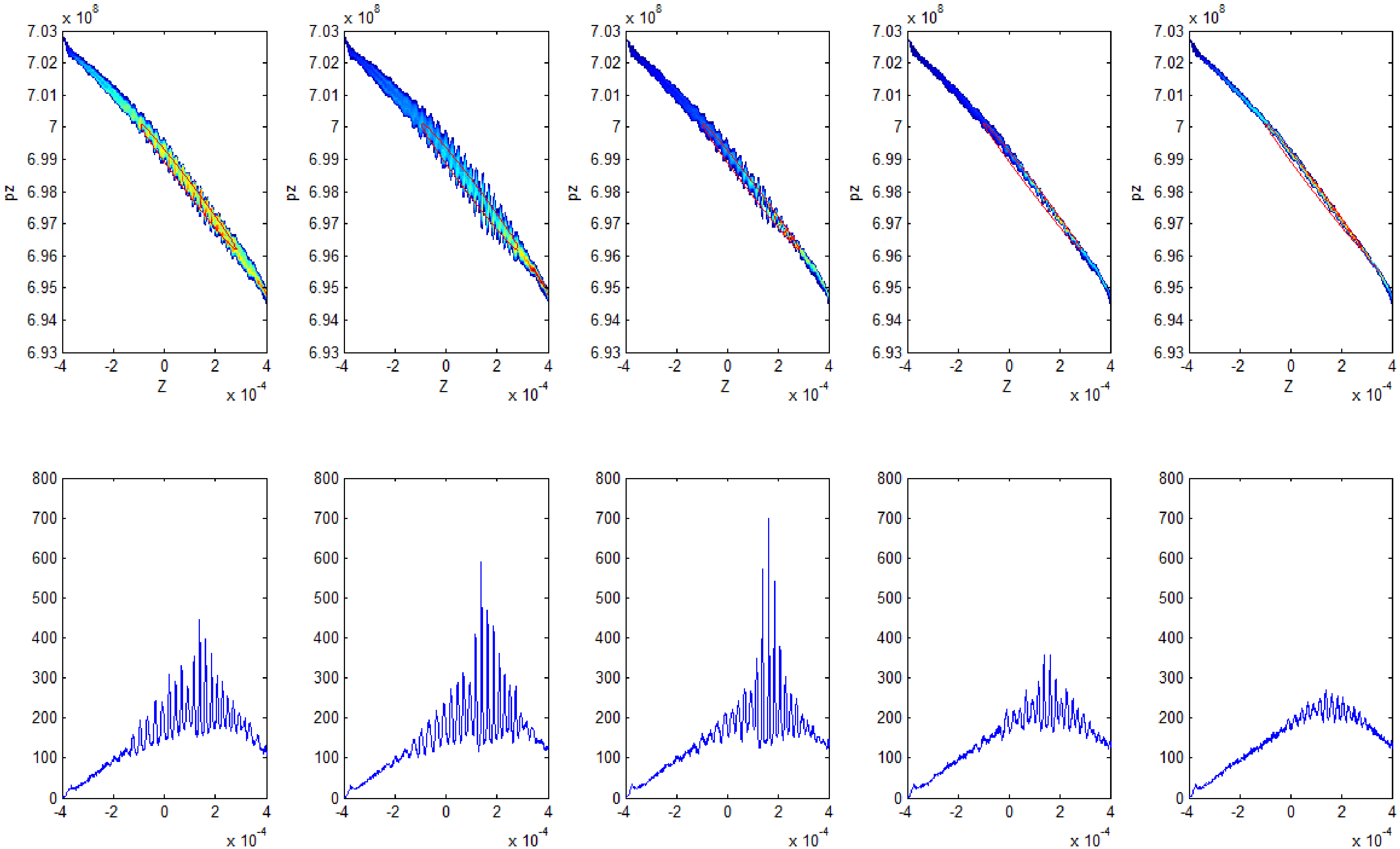
(5) = before DOGLEG



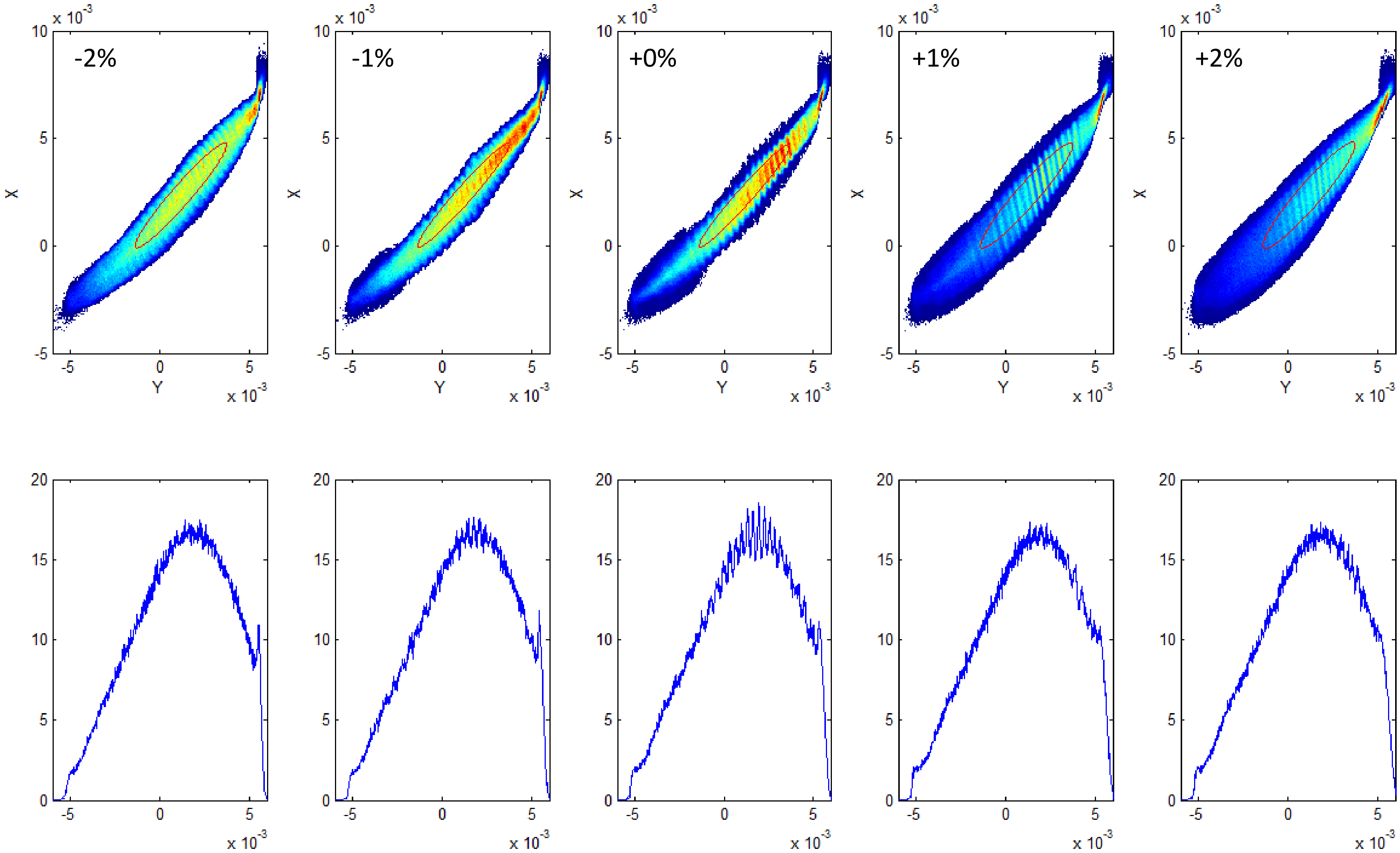
(6) = after DOGLEG



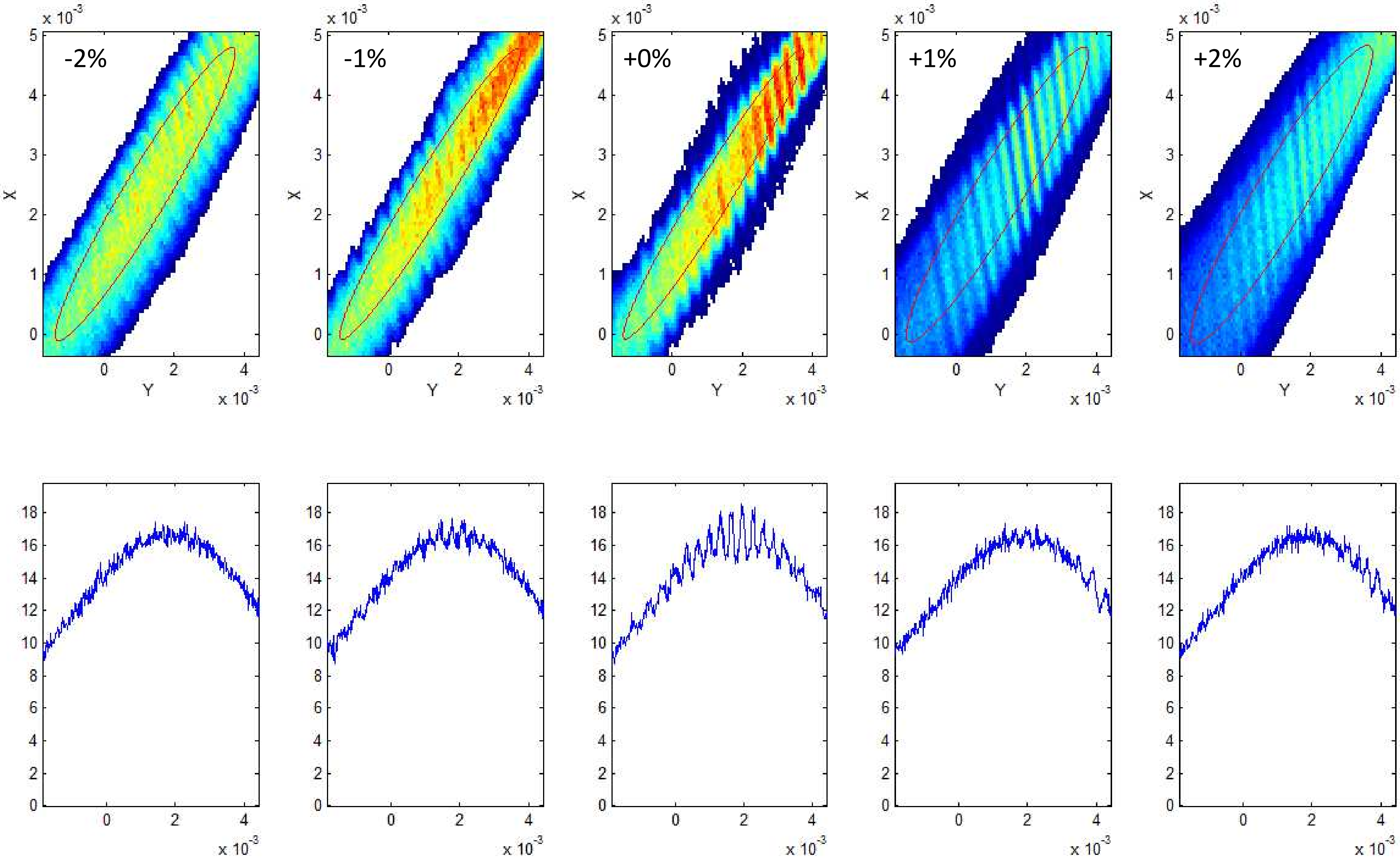
(7) = before LOLA



(8) = screen after LOLA



(8) = screen after LOLA



Xtrack Simulation: optics