Effects of RF coupler kicks in L1 of EXFEL

XFEL measurements and Astra calculations

Astra calculations and discrete coupler kick model

- discrete coupler kick model is not quite satisfying

linearity of coupler kick

a closer look to 1^{st} module of L1

a closer look to one cavity

more

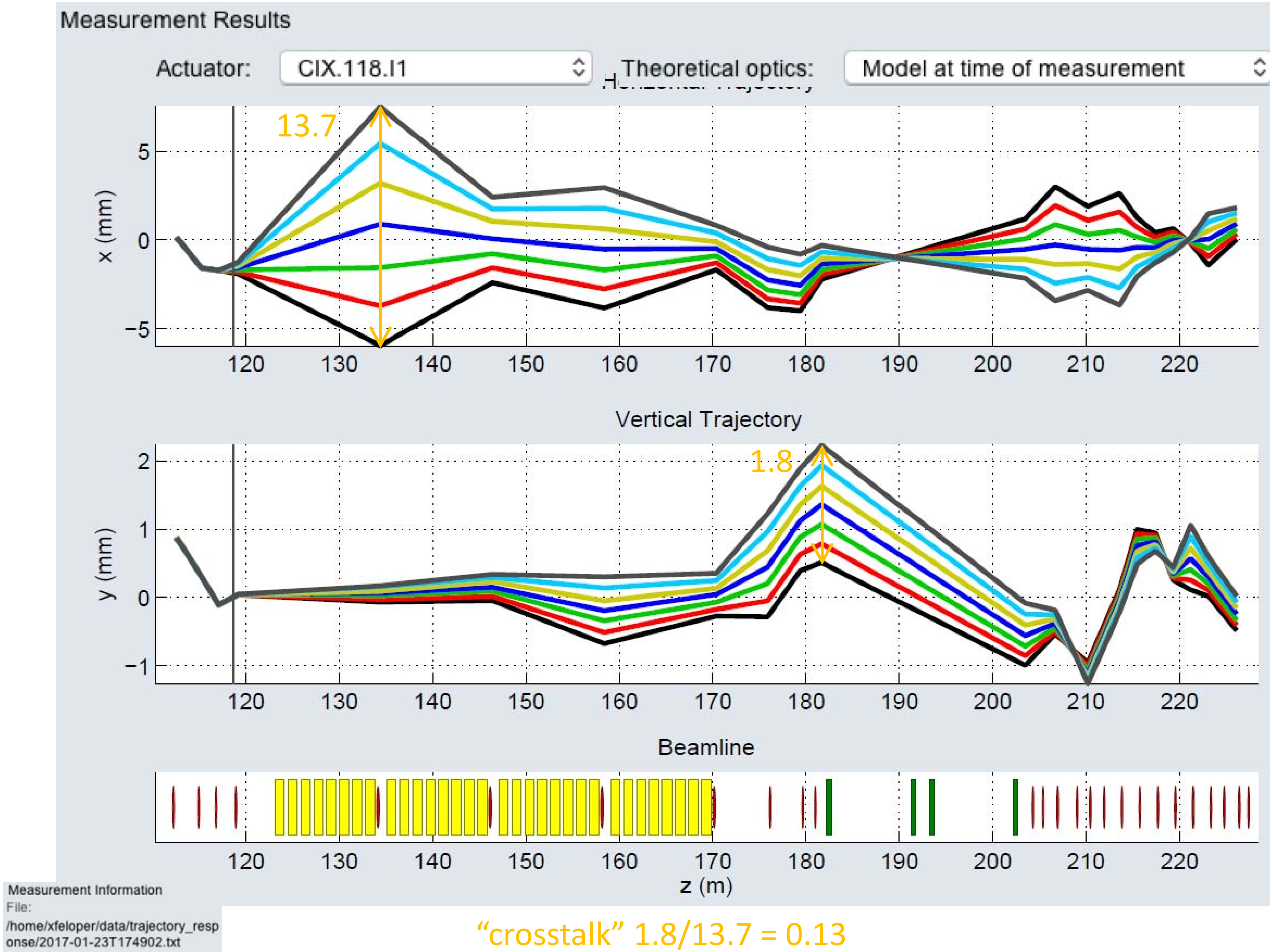
summary/conclusion

XFEL Measurements, 2017.01.23 and Astra Calculations (fieldmap)

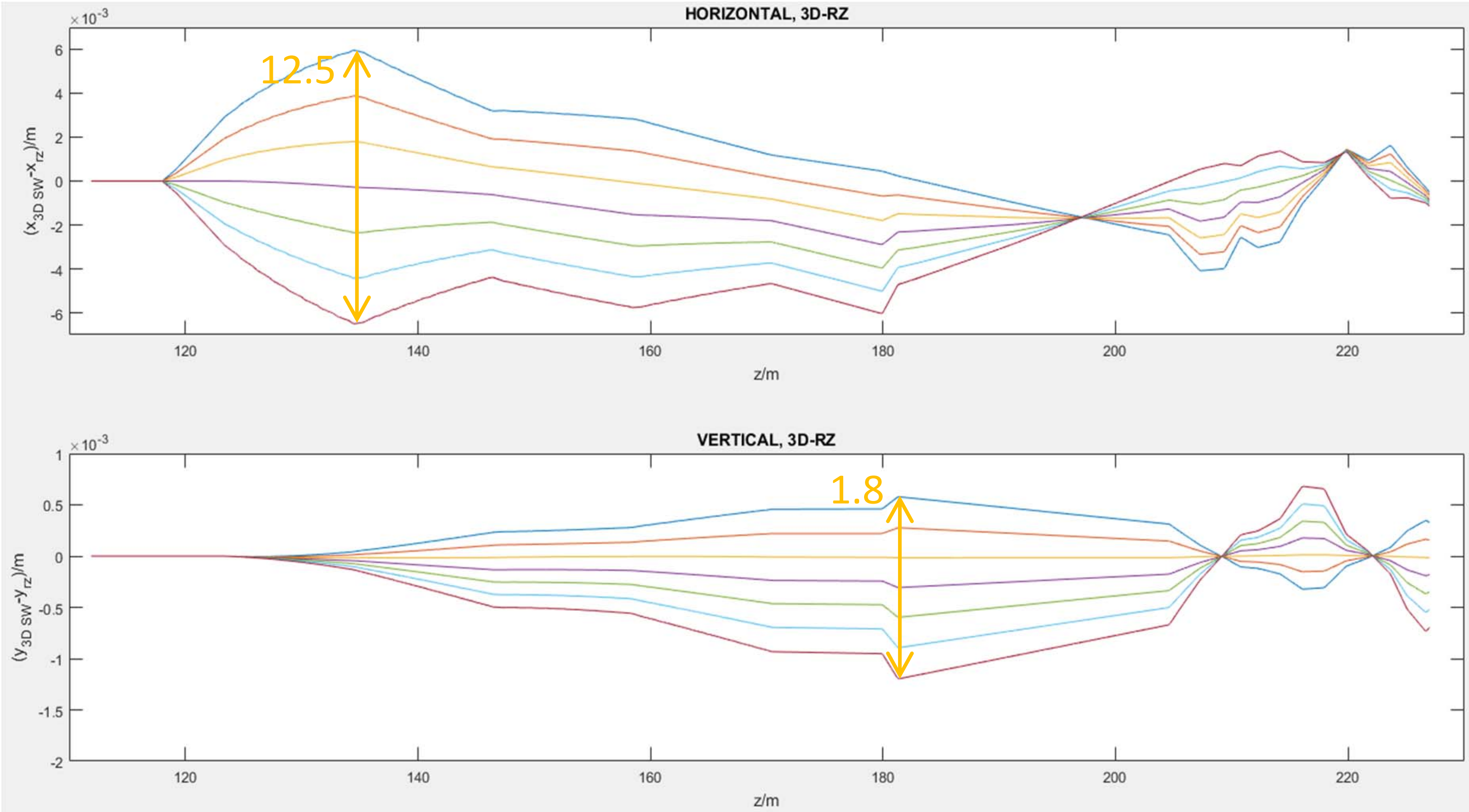
the calculations are based on:

design optics from Nina Golubeva (DesignOptics_G1toB2D_130_600_2500.txt) with effective magnet lengths

fieldmap for SW operation, 8mm penetration depth of main coupler antenna
“on crest”
(E3D_TC_P08mm_SW_zcent_331.dat)

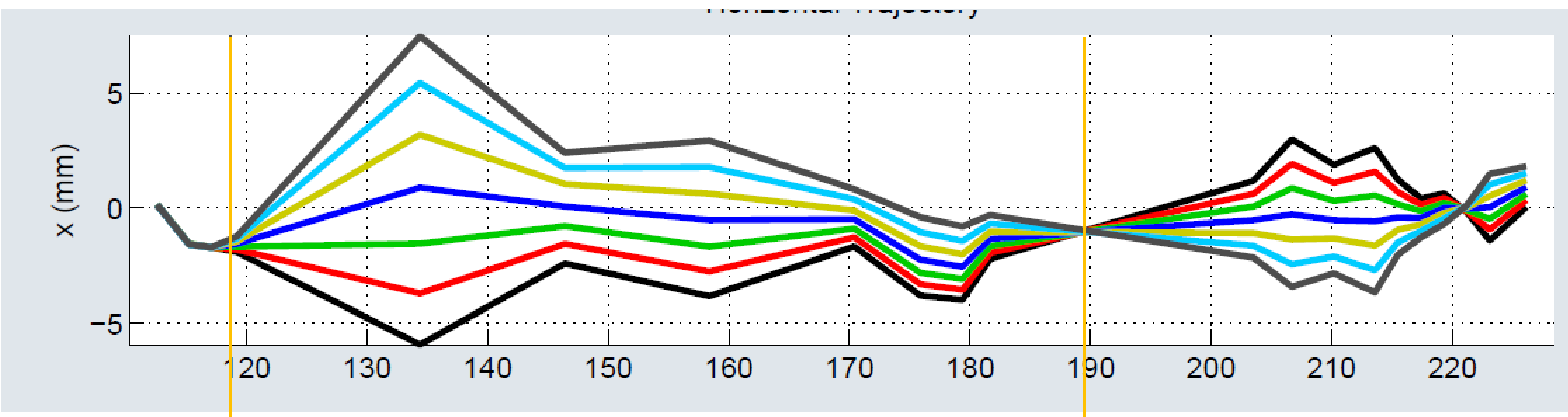


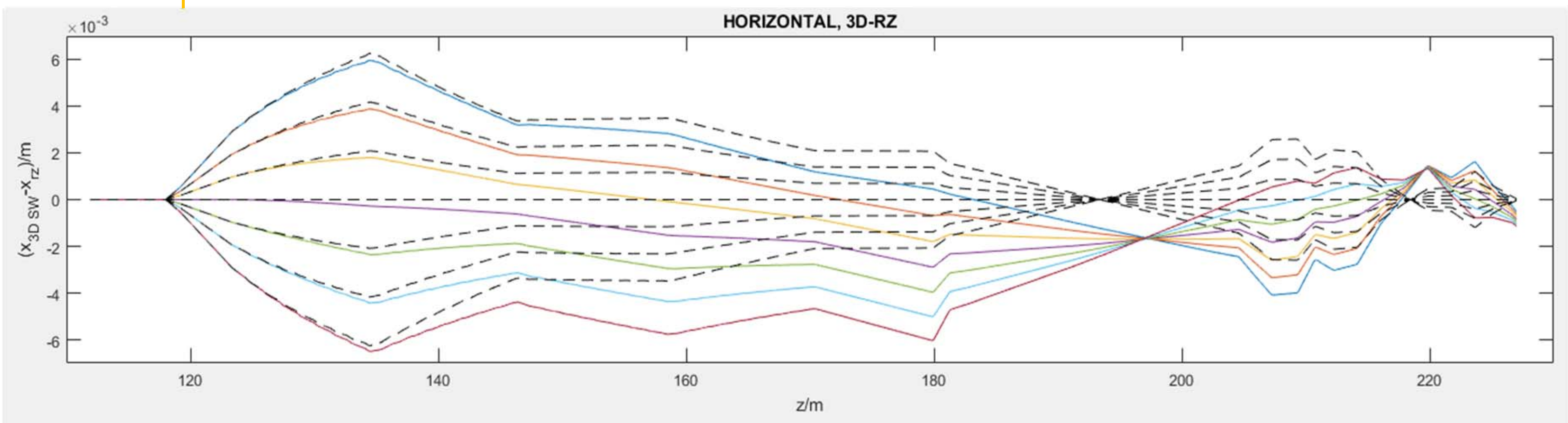
"crosstalk" 1.8/13.7 = 0.13



"crosstalk" 1.78/12.5 = 0.143

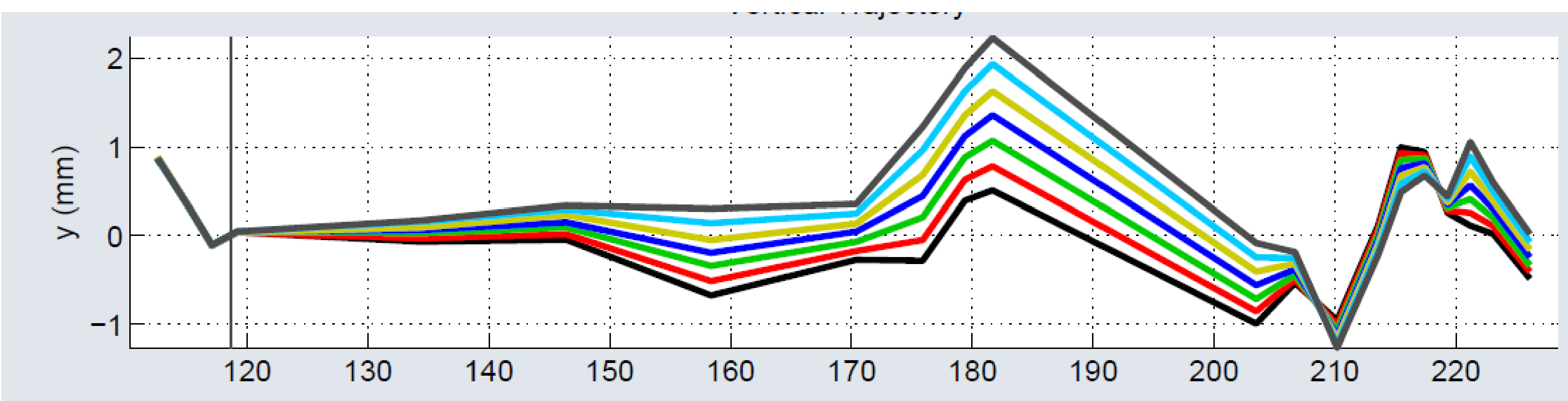
comparison, horizontal:

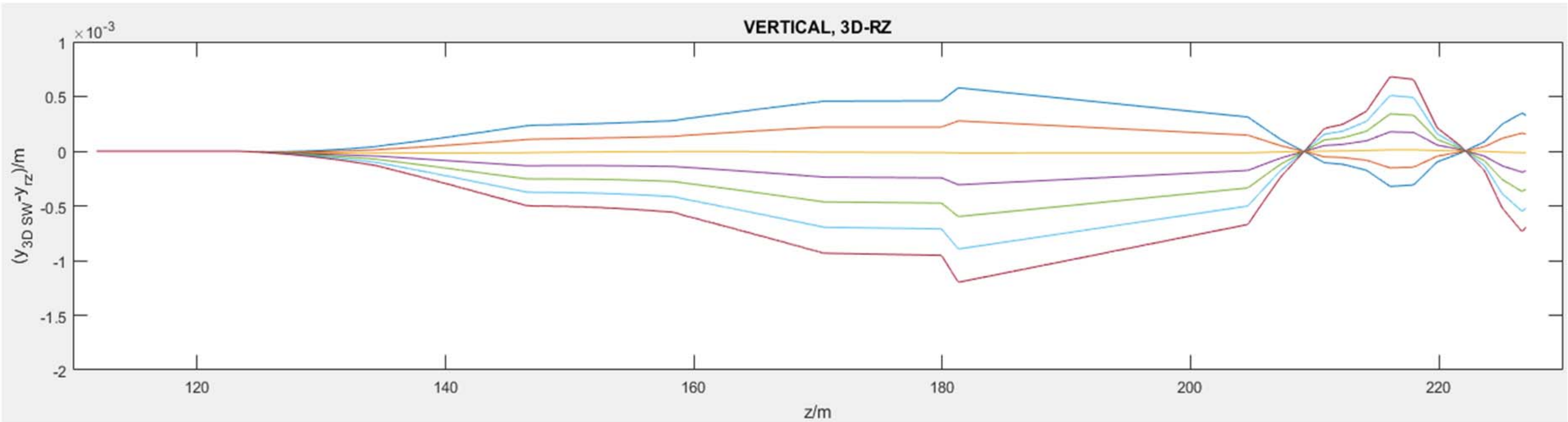


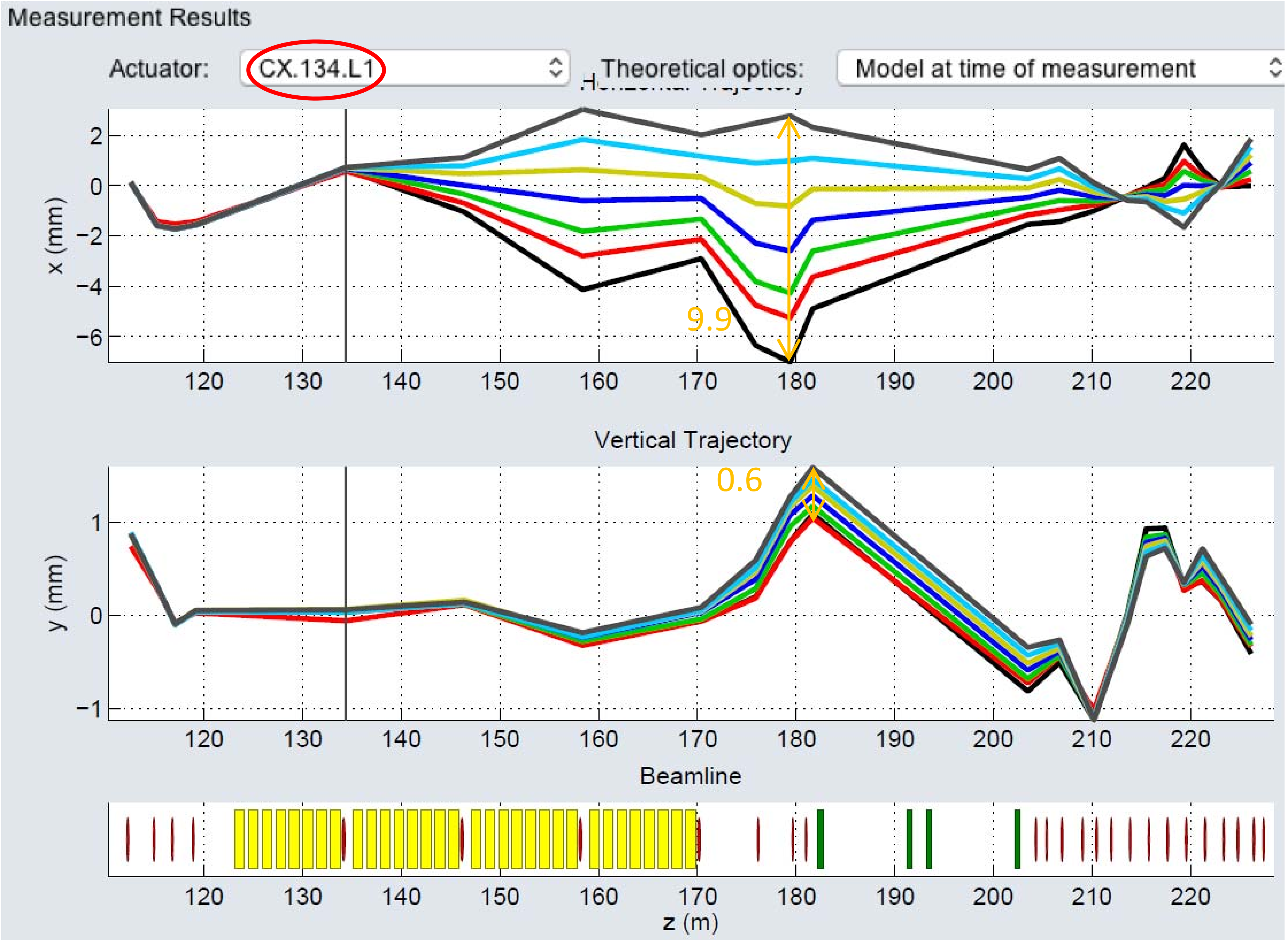


180 deg phase advance is not quite correct

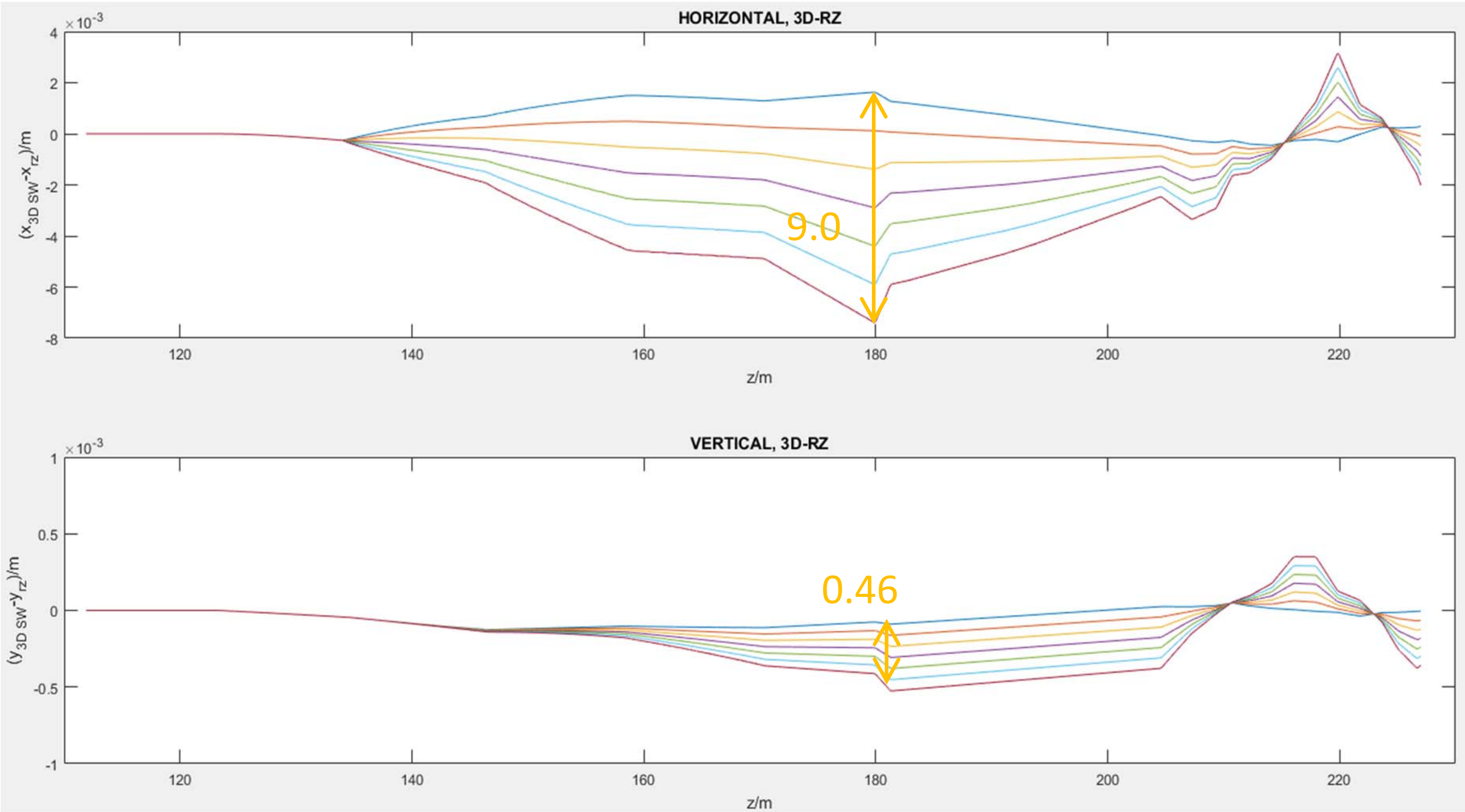
comparison, vertical:



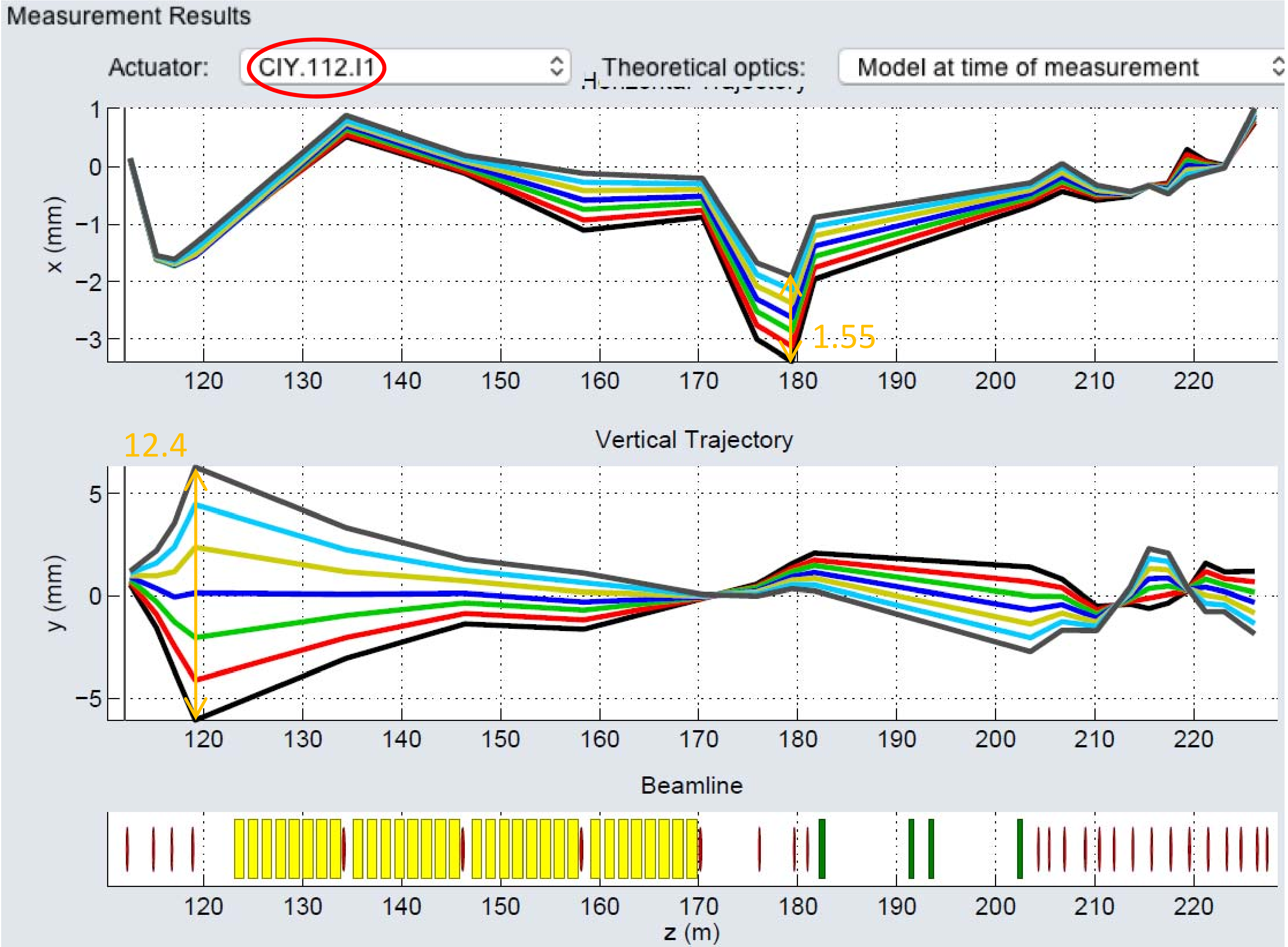




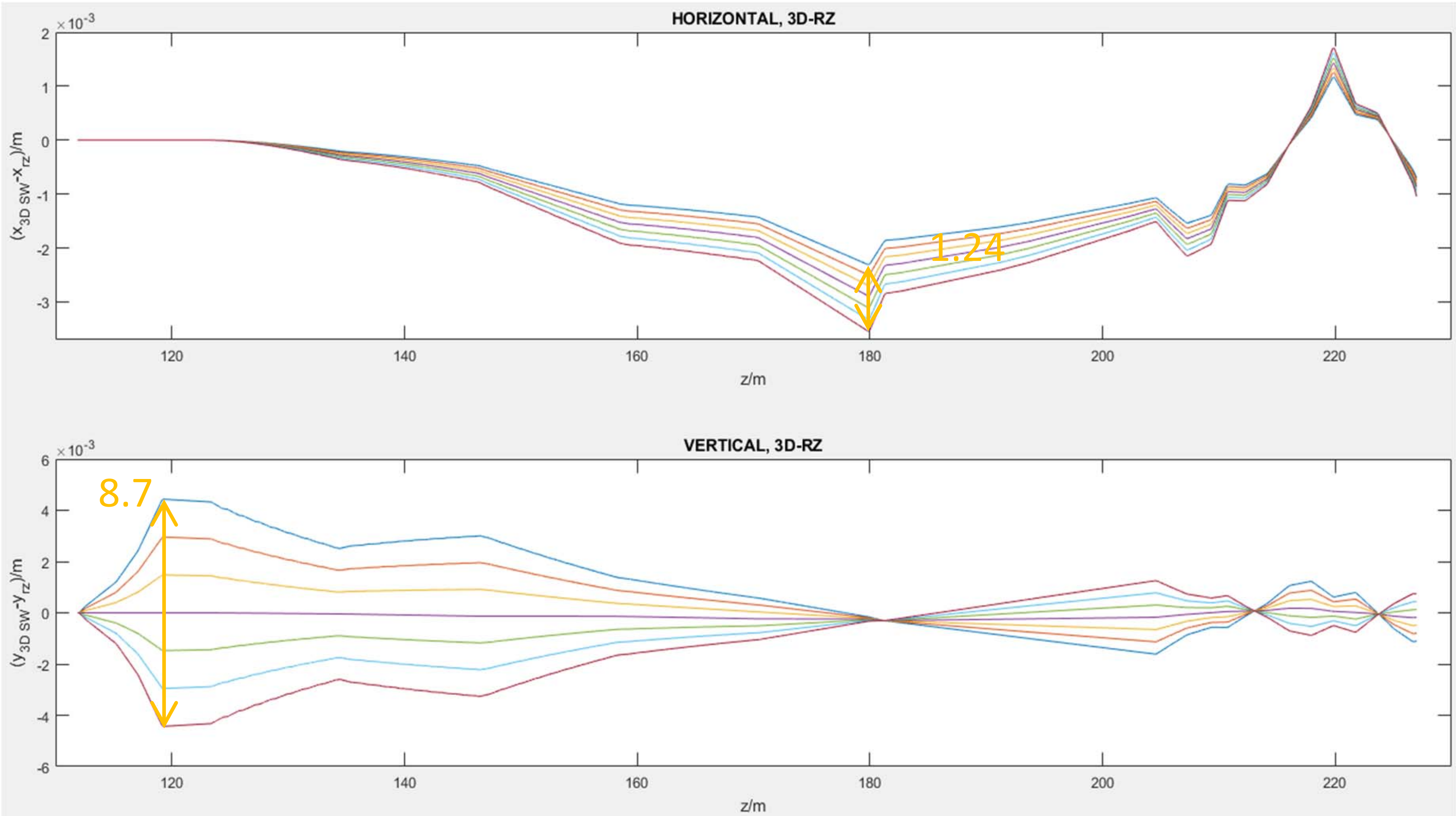
“crosstalk” 0.6/9.9 = 0.06



"crosstalk" 0.46/9.0 = 0.05



“crosstalk” 1.55/12.4 = 0.125



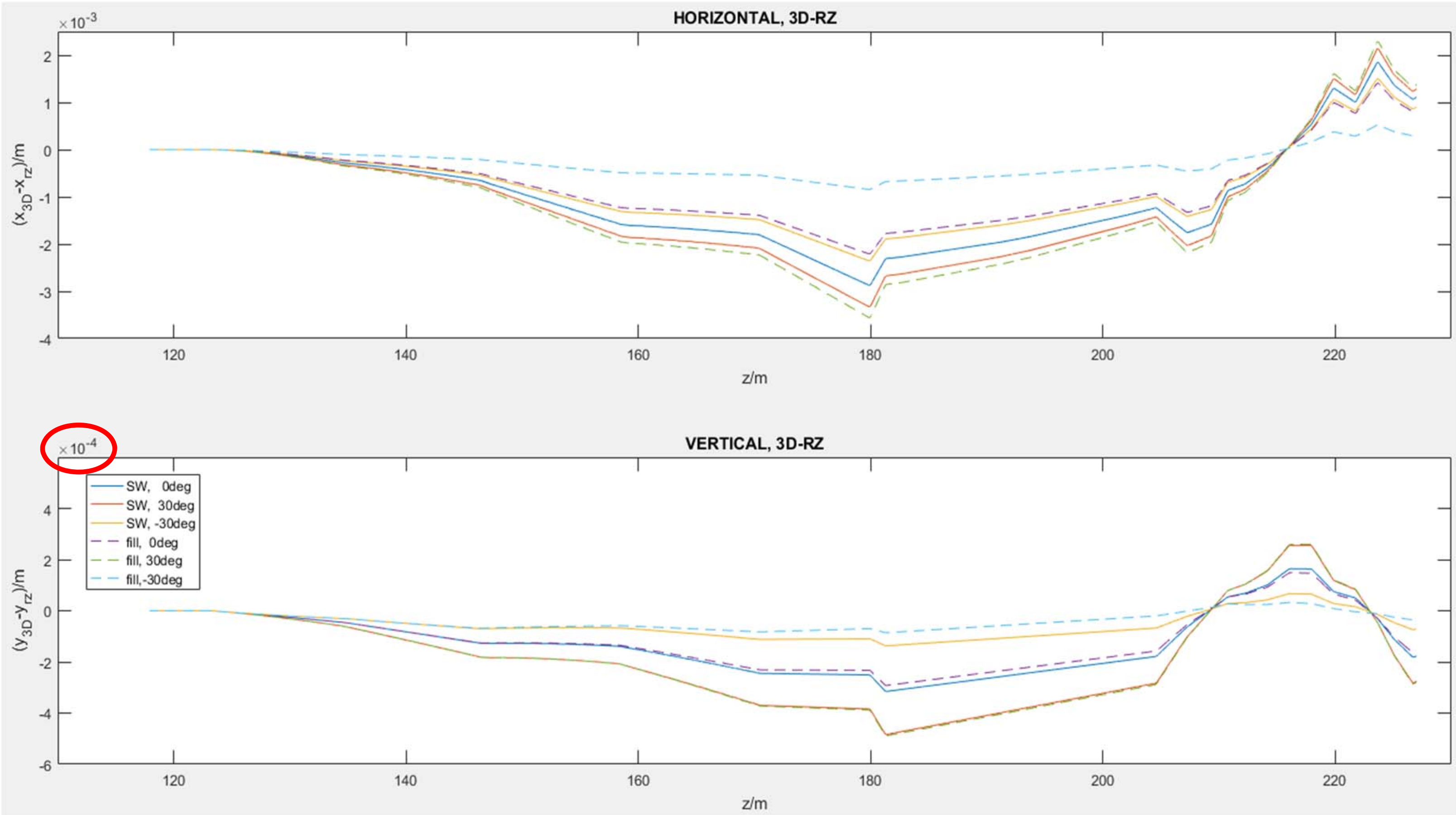
"crosstalk" 1.24/8.7 = 0.143

Astra Calculations (fieldmap) and Discrete Coupler Kick Model

the calculations are based on the optics from
XFEL component-List Version 8.6.1 (21.09.2016)

fieldmaps:
E3D_TC_P08mm_SW_zcent_331.dat
E3D_TC_P08mm_fill_zcent_331.dat

without excitation (by corrector), but for different cavity operation
SW/fill, phase shift -30,0,+30 deg



discrete coupler kick model:

normalized complex coupler kick $\tilde{\mathbf{V}}(x,y) = \int dz \times \left(\mathbf{E}(x,y,z) + c\mathbf{e}_z \mathbf{B}(x,y,z)\right)\exp(j\omega z/c)$

$$\boxed{\begin{aligned} &\mathbf{V}(x,y) = \frac{\tilde{\mathbf{V}}(x,y)}{\tilde{V}_z(0,0)} \\ &V_x(x,y) \approx V_x + V_{x,x}x + V_{x,y}y \\ &V_y(x,y) \approx V_y + V_{y,x}x + V_{y,y}y \\ &V_z(x,y) \approx 1 + V_{z,x}x + V_{z,y}y \\ &V_{y,y} = -V_{x,x} \\ &V_{x,y} = V_{y,x} \end{aligned}}$$

some compensation of vertical coupler kick

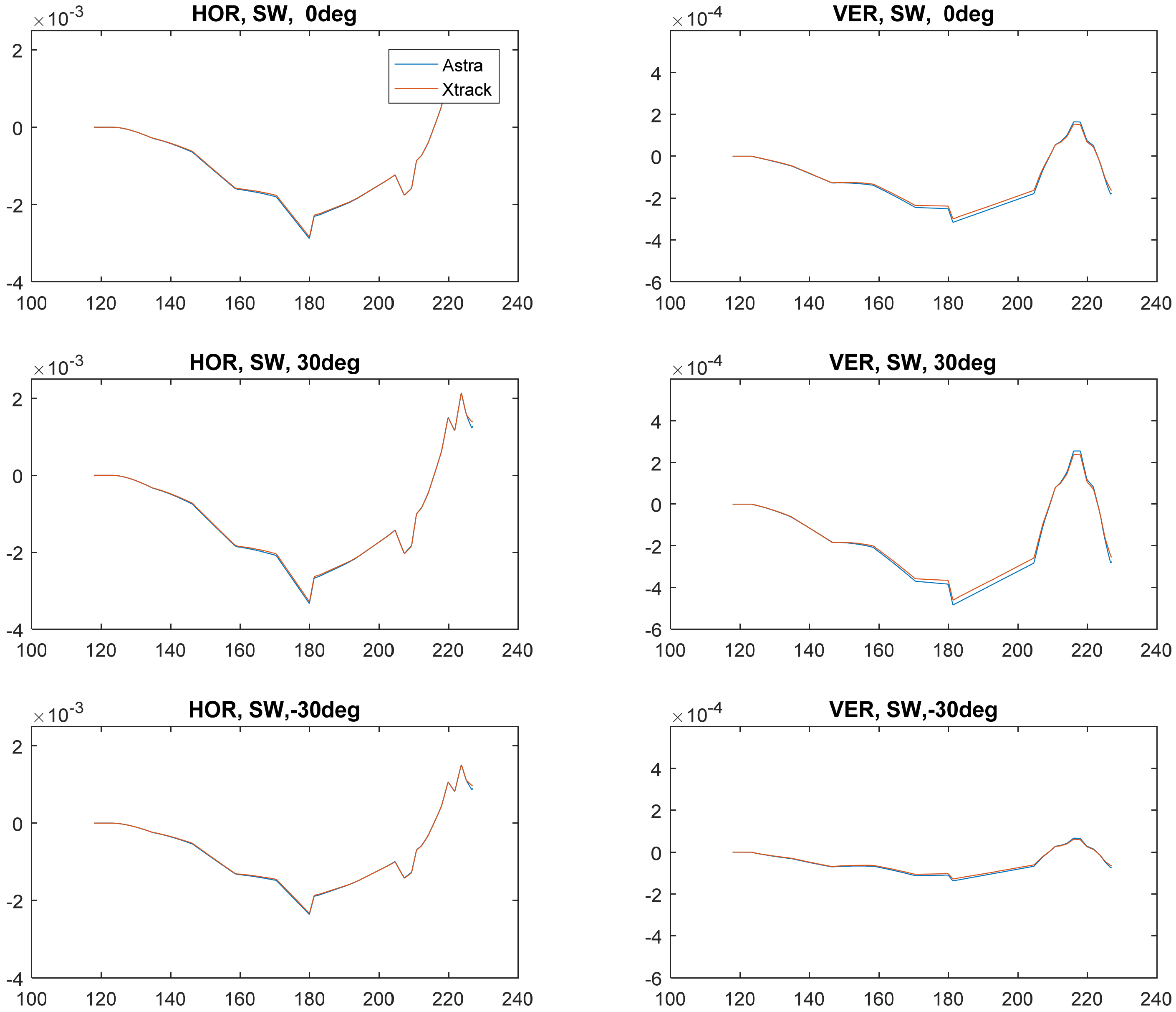
8mm, SW, upstream			8mm, fill, upstream		
Vx/μ	=-56.813	+i*10.751	Vx/μ	=-56.833	+i*10.717
Vy/μ	=$\boxed{-41.091}$	+i* 0.5739	Vy/μ	=-41.102	+i* 0.54654
Vxx*mm/μ=	0.99943	-i* 0.81401	Vxx*mm/μ=	1.0003	-i* 0.8132
Vxy*mm/μ=	3.4065	-i* 0.4146	Vxy*mm/μ=	3.4075	-i* 0.41223

phase sensitivity

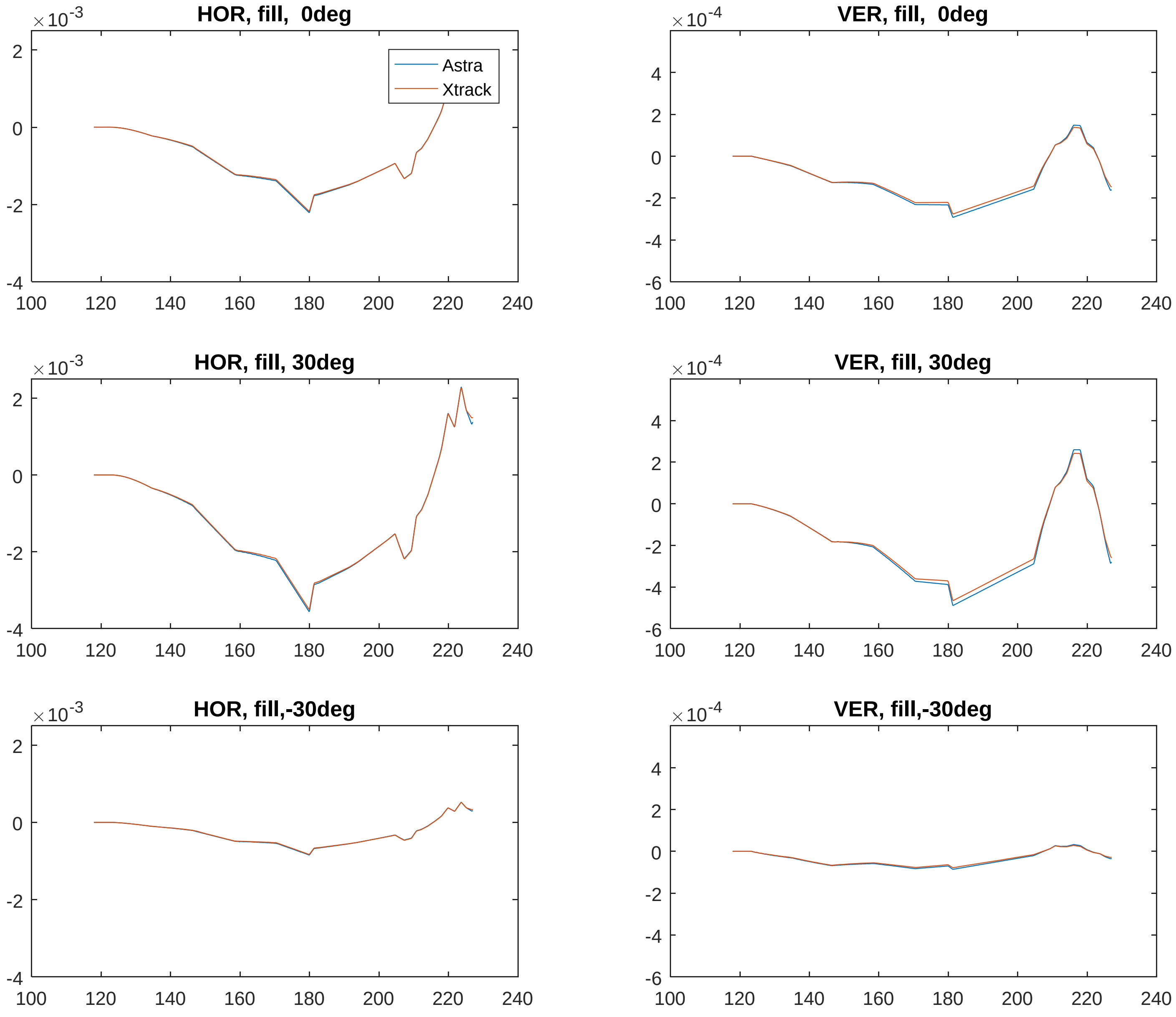
8mm, SW, downstream			8mm, fill, downstream		
Vx/μ	=-24.014	+i*12.492	Vx/μ	=-51.461	+i*$\boxed{56.297}$
Vy/μ	=$\boxed{36.481}$	+i* 7.9888	Vy/μ	= 36.457	+i* 7.7912
Vxx*mm/μ=	-4.057	-i* 0.1369	Vxx*mm/μ=	-4.9278	-i* 2.2112
Vxy*mm/μ=	2.9243	-i* 0.012891	Vxy*mm/μ=	2.9224	-i* 0.027228

insensitive/sensitive to mode of operation (SW, fill, … and penetration depth)

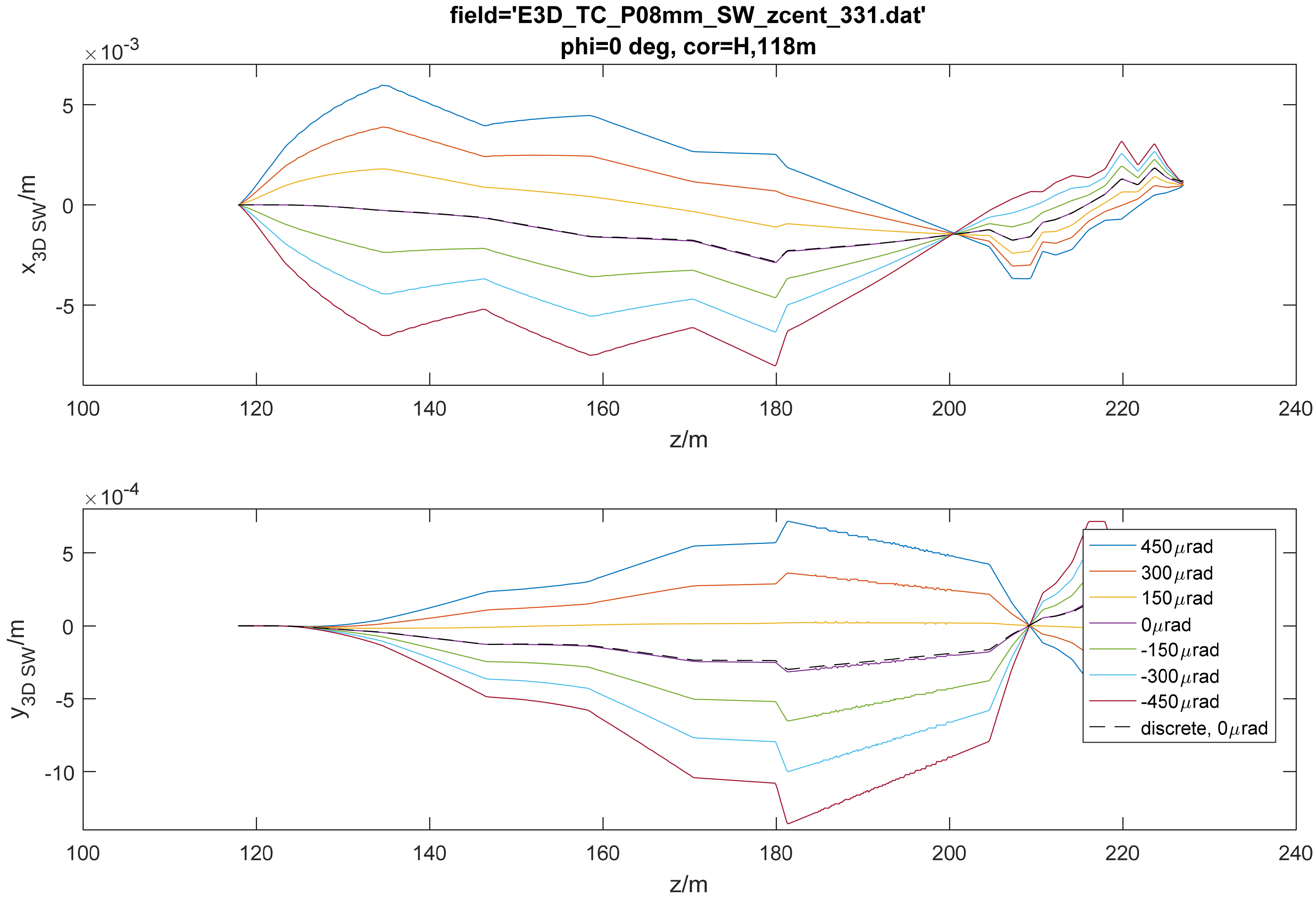
comparison, SW mode

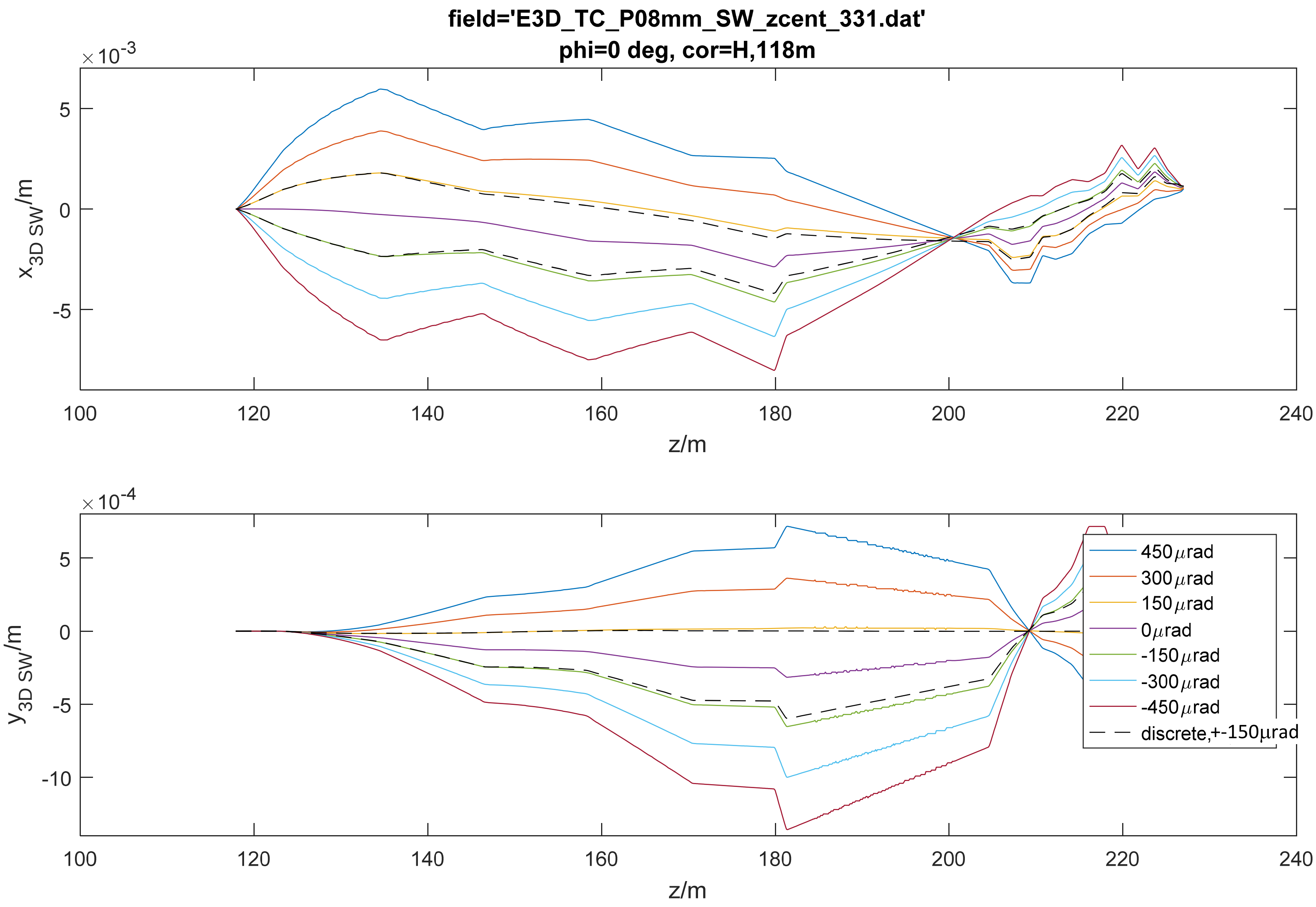


comparison, TW mode

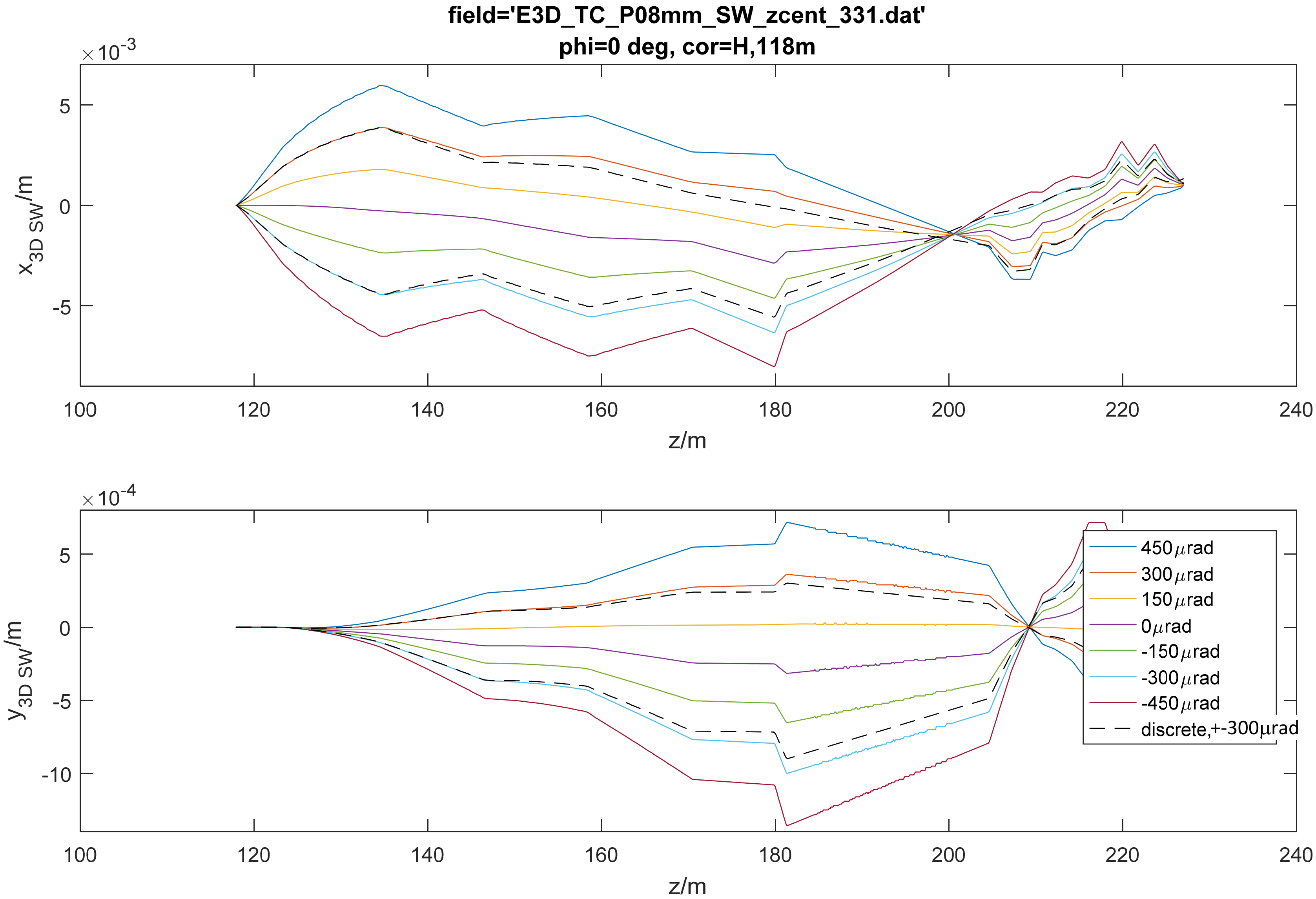


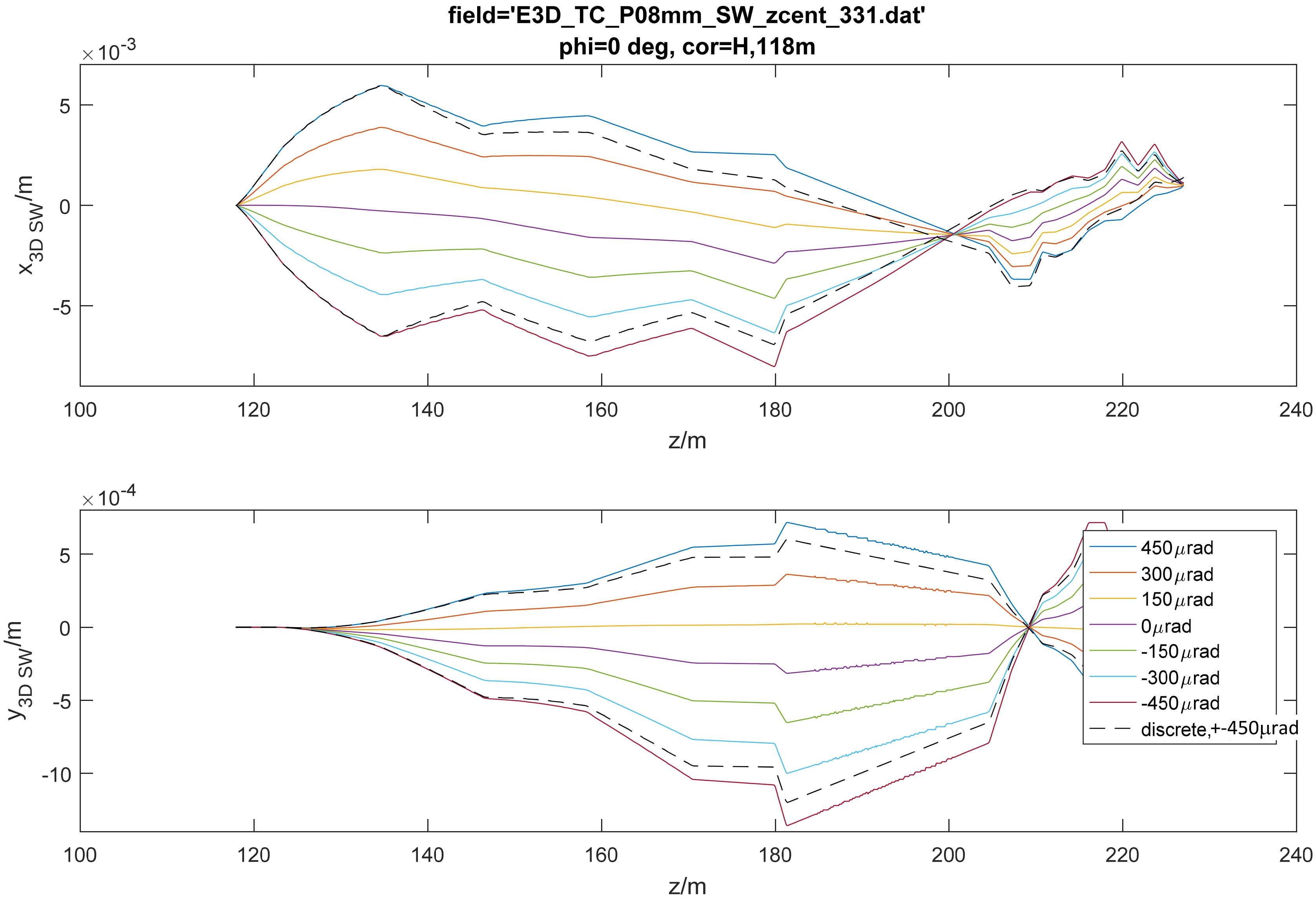
with excitation (by CX118)
SW, 0 deg





field='E3D_TC_P08mm_SW_zcent_331.dat'
phi=0 deg, cor=H,118m
×10-3
5
0
-5
x3D SW/m
100
120
140
160
180
200
220
240
z/m
×10-4
5
0
-5
-10
y3D SW/m
100
120
140
160
180
200
220
240
z/m
450μrad
300μrad
150μrad
0μrad
-150μrad
-300μrad
-450μrad
discrete,+-150μrad


field='E3D_TC_P08mm_SW_zcent_331.dat'
phi=0 deg, cor=H,118m
×10^-3
x_3D SW/m
z/m
×10^-4
y_3D SW/m
z/m
450μrad
300μrad
150μrad
0μrad
-150μrad
-300μrad
-450μrad
discrete,+-300μrad



field='E3D_TC_P08mm_SW_zcent_331.dat'
phi=0 deg, cor=H,118m
×10^-3
x_3D SW/m
z/m
×10^-4
y_3D SW/m
z/m
450μrad
300μrad
150μrad
0μrad
-150μrad
-300μrad
-450μrad
discrete,+-450μrad

discrete coupler kick model
is not quite satisfying

linearity of coupler kick

$$\mathbf{X} = \begin{pmatrix} x \\ y \\ z - z_{r1} \\ p_x \\ p_y \\ p_z - p_{r1} \end{pmatrix}$$

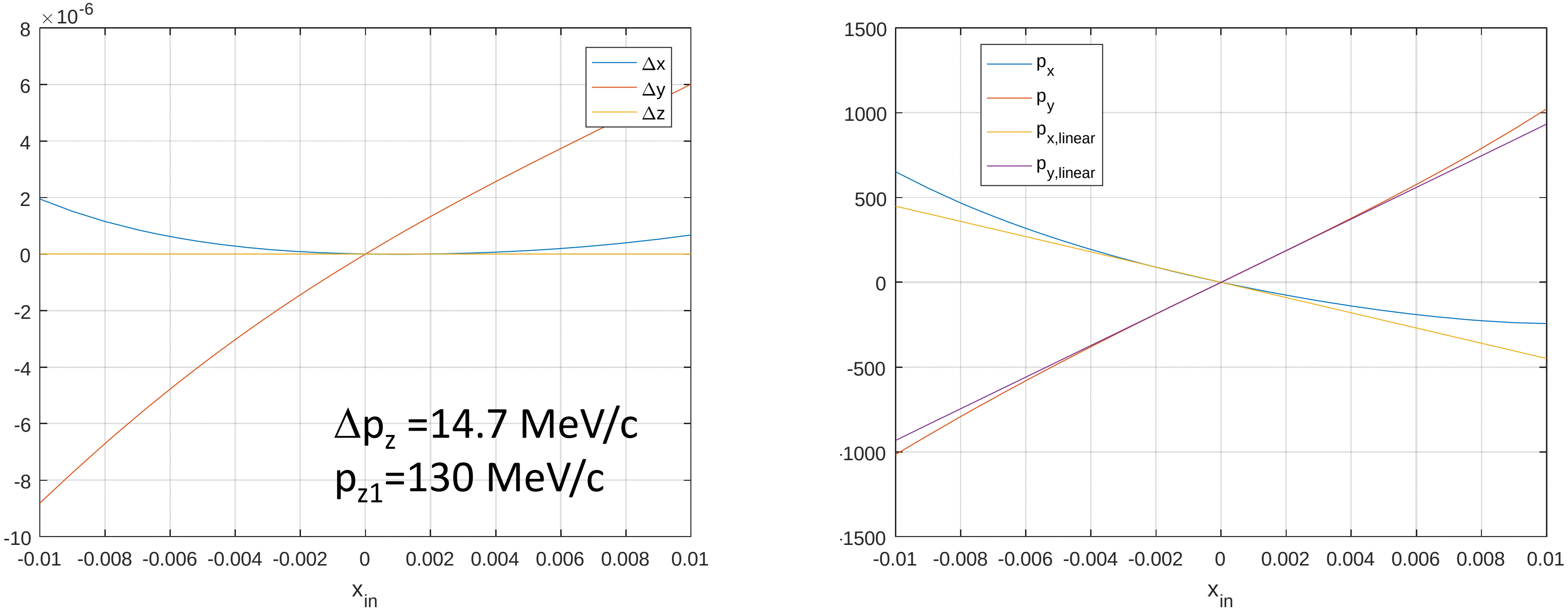
$$\mathbf{Y} = \boxed{\mathbf{Y}_{RZ}(\mathbf{X})} + \mathbf{Y}_{XYZ}(\mathbf{0}) + \boxed{\mathbf{Y}_{CK}(\mathbf{X})}$$

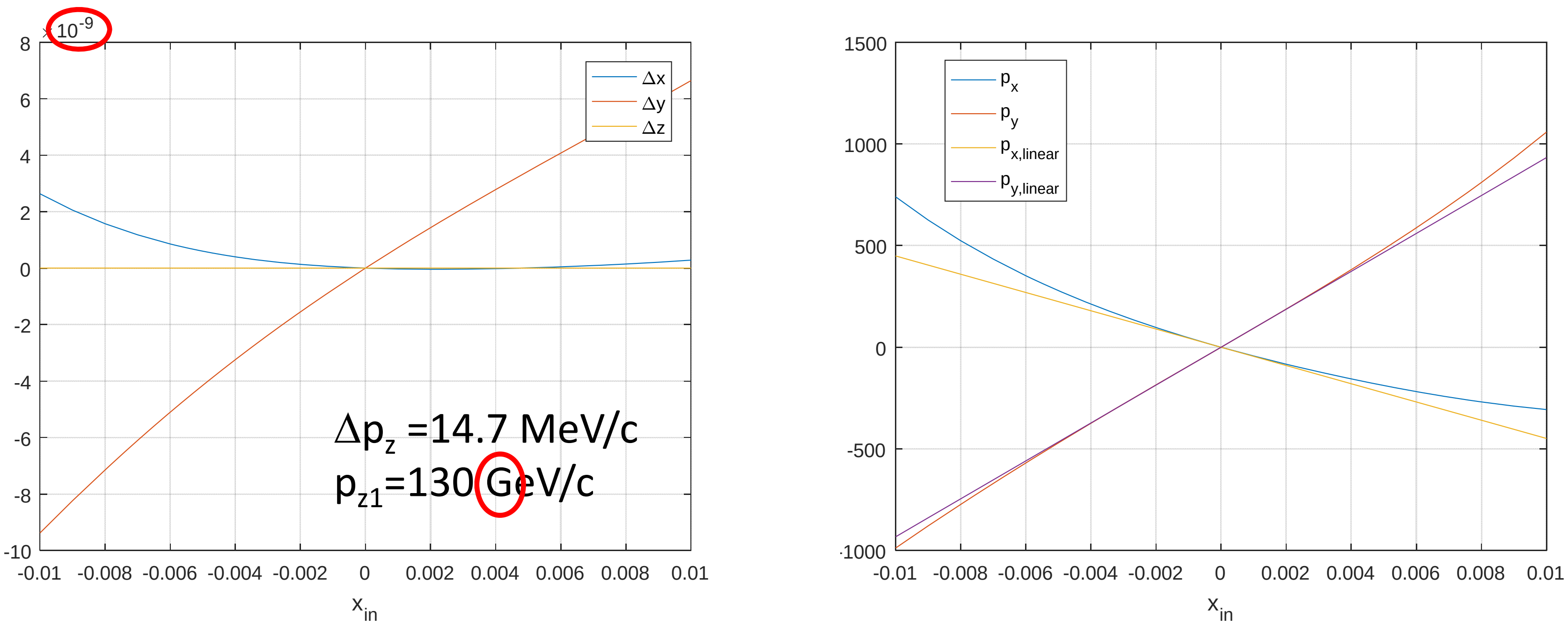
RZ cavity model

coupler kick model

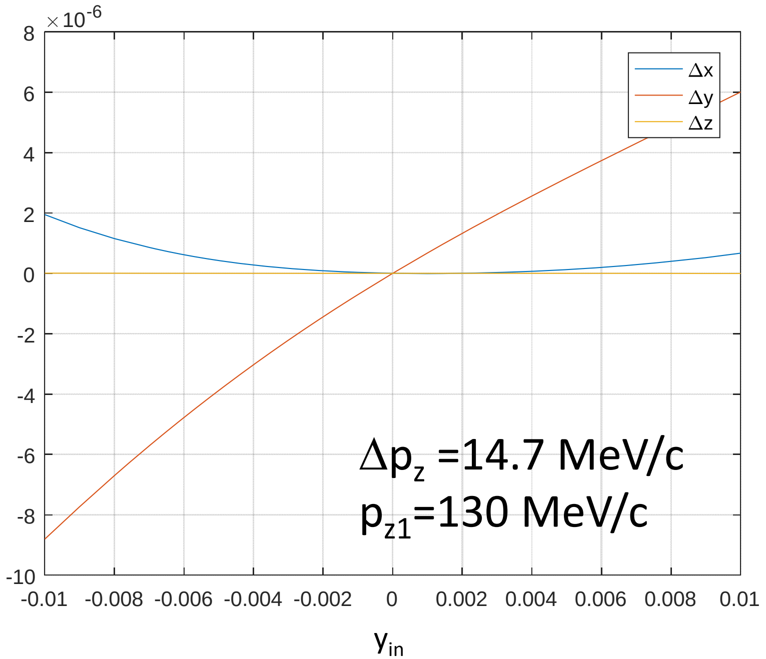
the implementation in Xtrack is different: use Serafini-Rosenzweig for RZ model and apply linear up-/down-stream kick before/after RZ-model

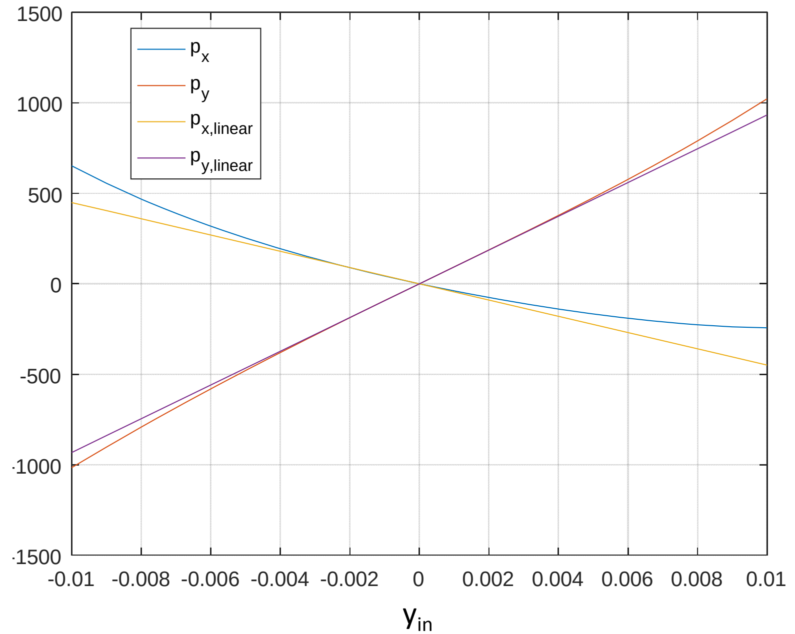
horizontal variation

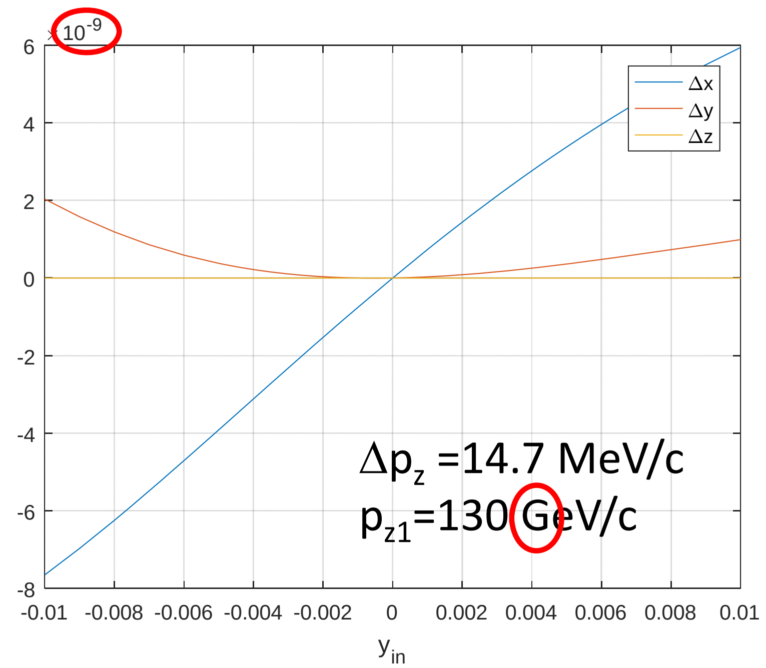


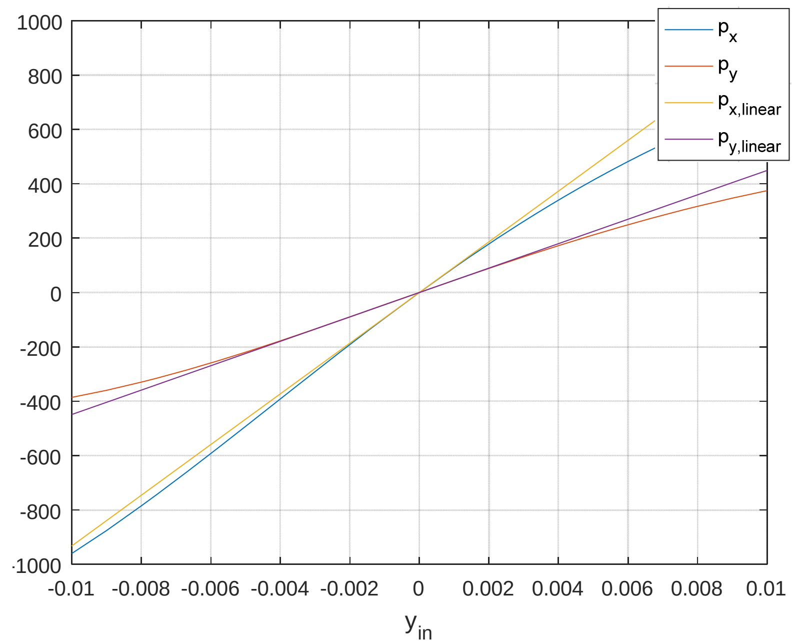


vertical variation



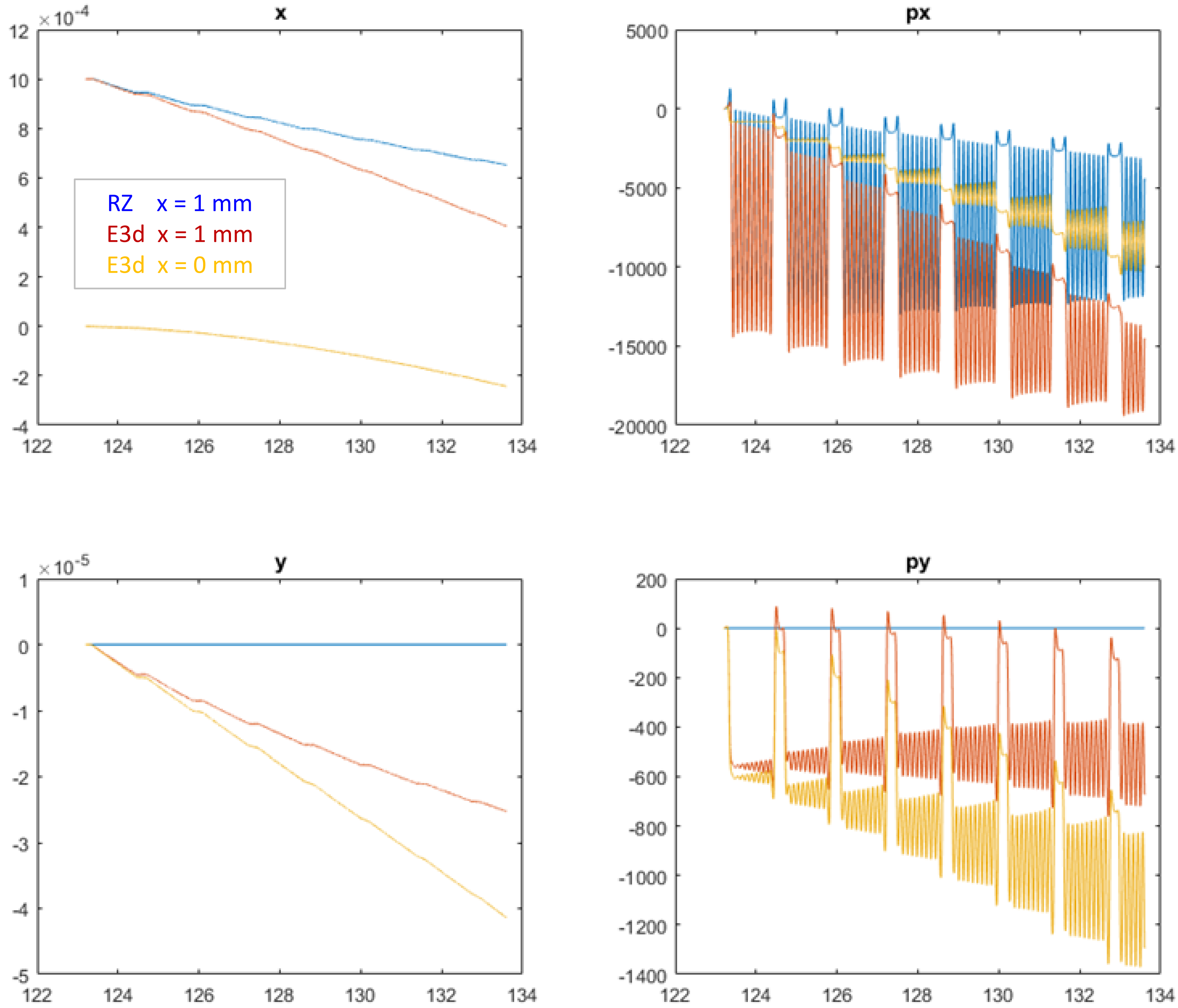


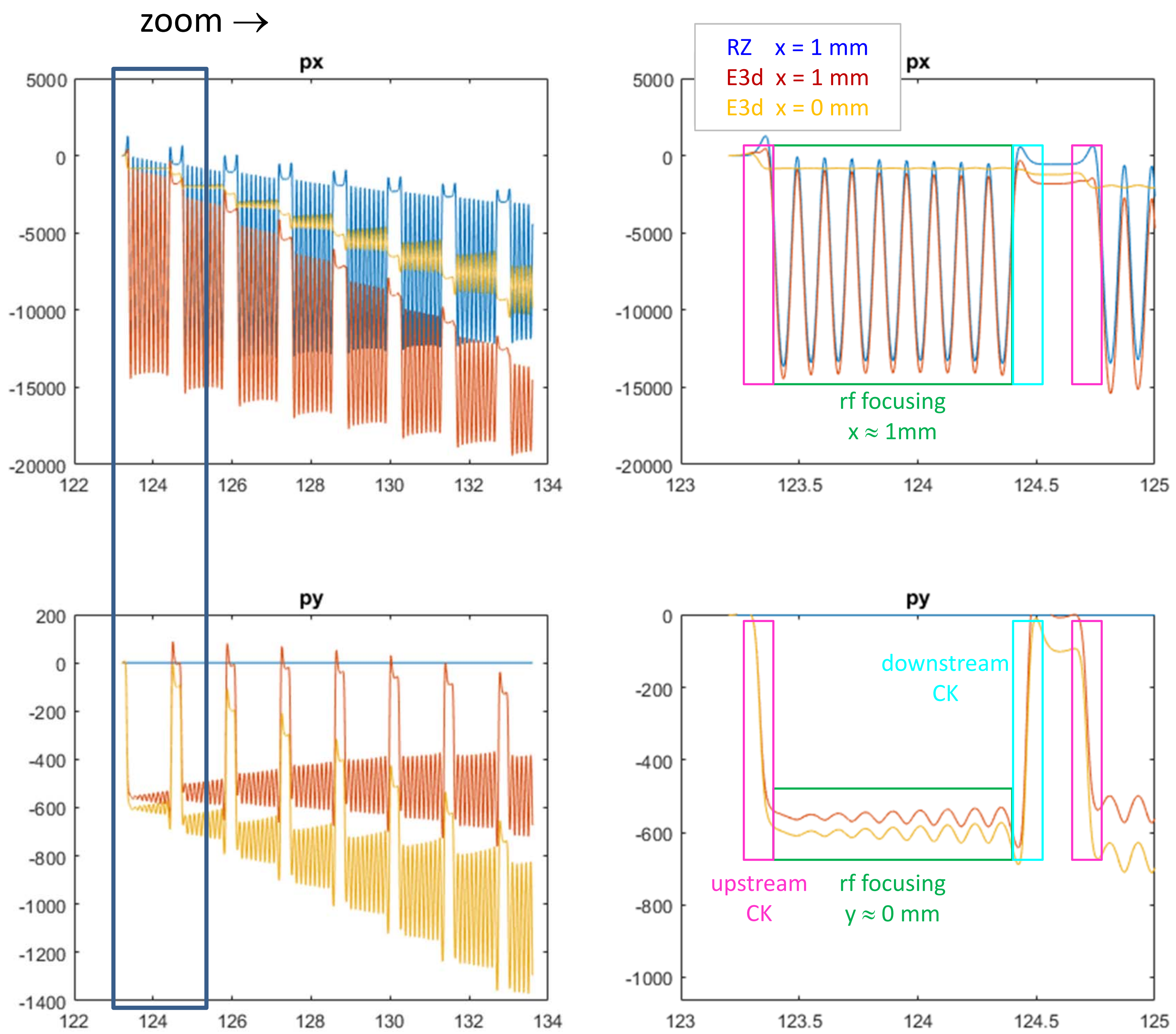




a closer look
to 1^{st} module of L1

initial condition: x = 1 mm, y=0, px=0, py=0

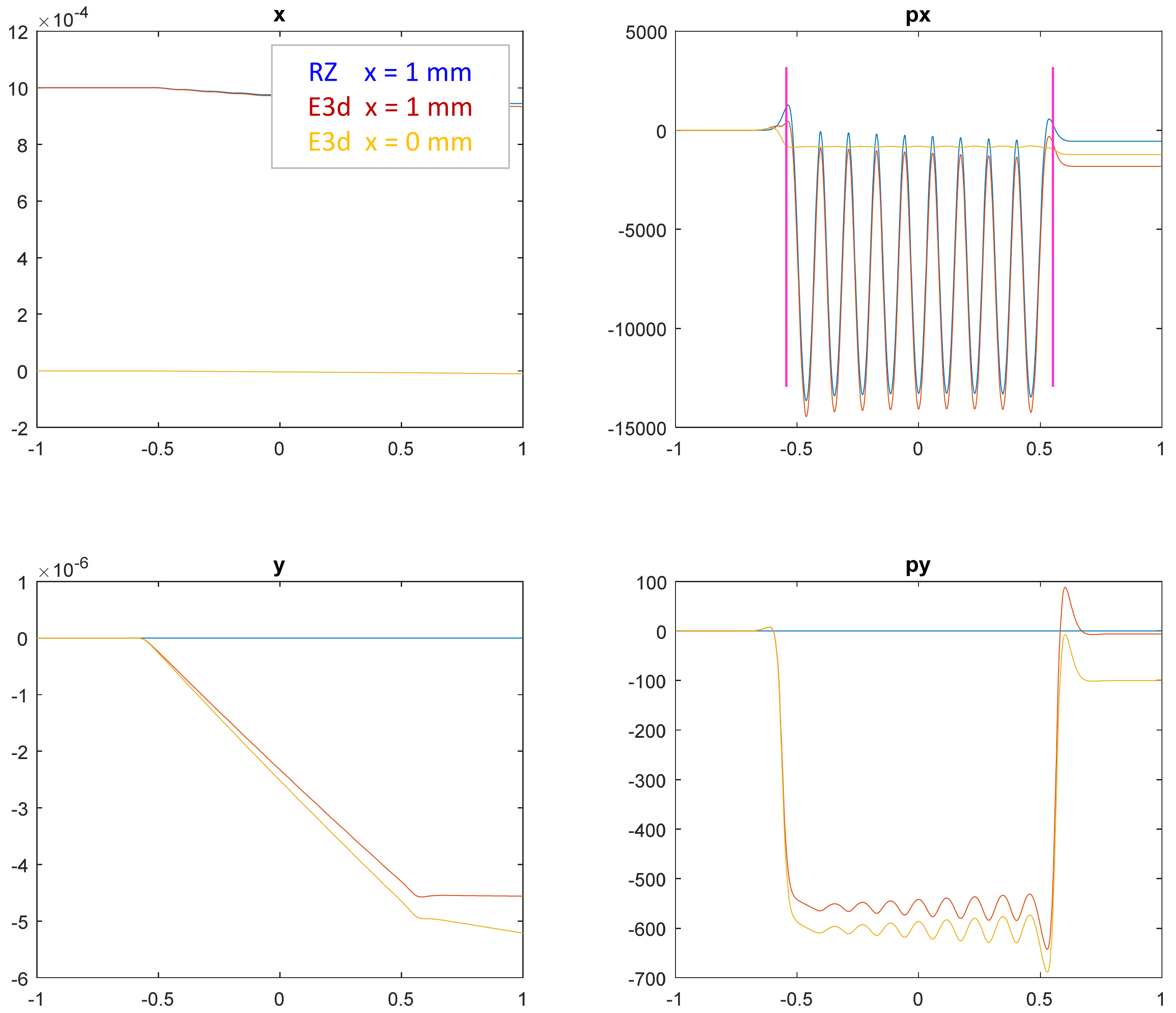




zoom →
px
5000
0
-5000
-10000
-15000
-20000
122
124
126
128
130
132
134
RZ x = 1 mm
E3d x = 1 mm
E3d x = 0 mm
px
123
123.5
124
124.5
125
rf focusing
x ≈ 1mm
py
200
0
-200
-400
-600
-800
-1000
-1200
-1400
py
downstream
CK
upstream
CK
rf focusing
y ≈ 0 mm

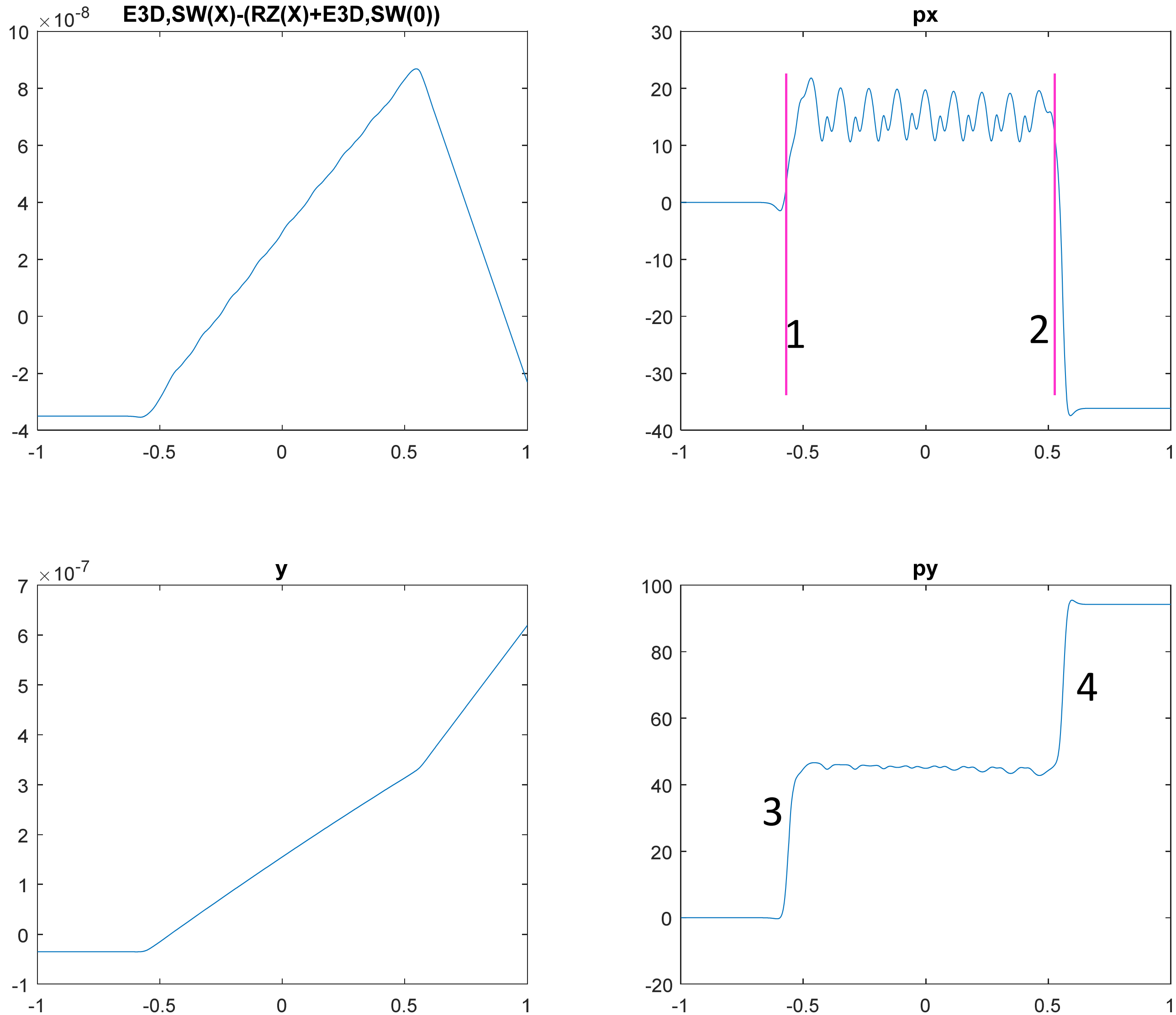
a closer look to one cavity

initial condition: **x = 1 mm**, y=0, px=0, py=0



initial condition: **x = 1 mm**, y=0, px=0, py=0

offset dependent CK: X(3D,offset)-X(3D,0)-X(no CK,offset)

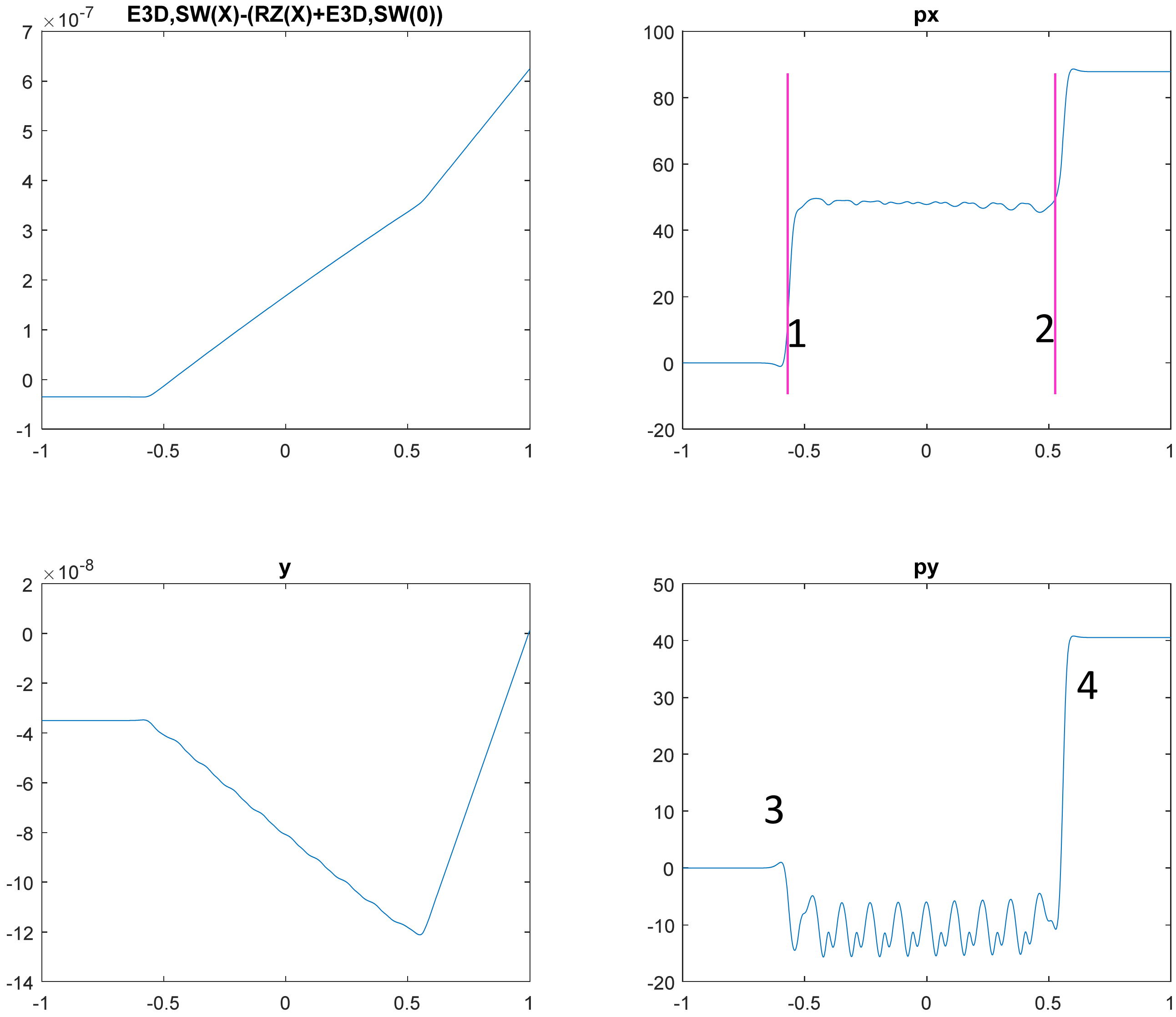



```
  8mm, SW, upstream
  Vx/μ  =-56.813  +…
  Vy/μ  =-41.091  +…
1 Vxx*km=  0.99943+…
3 Vxy*km=  3.4065 +…
```

```
  8mm, SW, downstream
  Vx/μ  =-24.014  +…
  Vy/μ  = 36.481  +…
2 Vxx*km= -4.057  +…
4 Vxy*km=  2.9243 +…
```

initial condition: x=0, **y = 1 mm**, px=0, py=0

offset dependent CK: X(3D,offset)-X(3D,0)-X(no CK,offset)



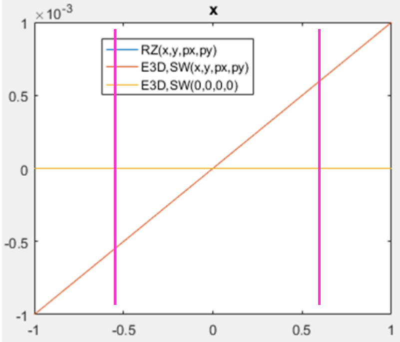

```
  8mm, SW, upstream
  Vx/μ  =-56.813  +…
  Vy/μ  =-41.091  +…
3 Vxx/mm=  0.99943+…
1 Vxy/mm=  3.4065 +…

  8mm, SW, downstream
  Vx/μ  =-24.014  +…
  Vy/μ  = 36.481  +…
4 Vxx*km= -4.057  +…
2 Vxy*km=  2.9243 +…
```

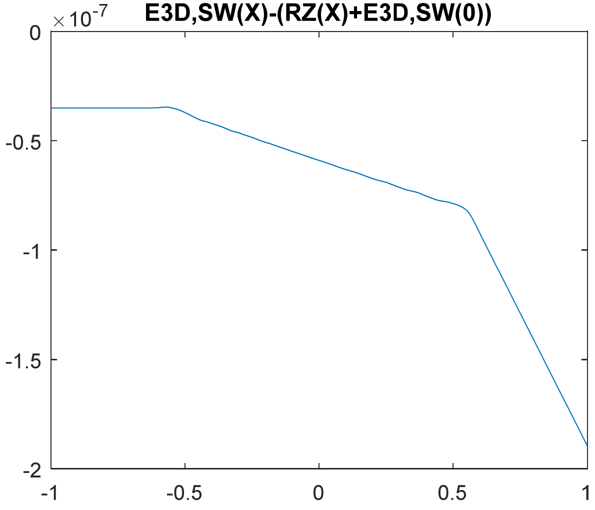
$$V_{y,y} = -V_{x,x}$$

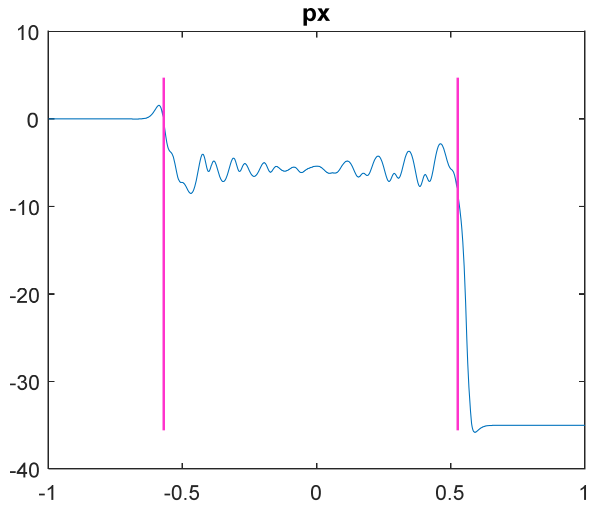
$$V_{x,y} = V_{y,x}$$

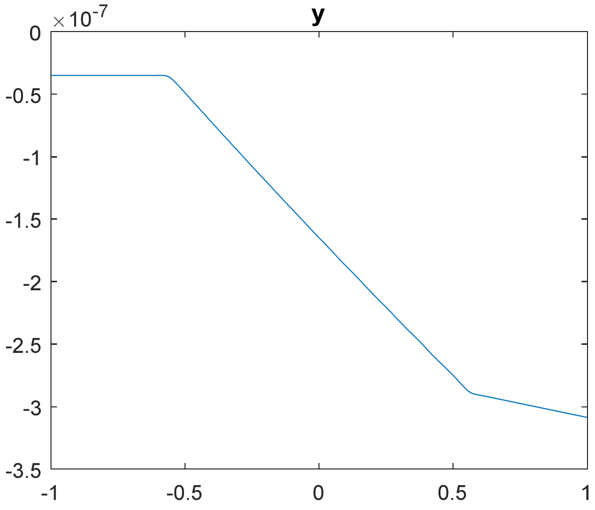
initial condition: x=0, y=0, **px/pz = 1 mrad**, py=0

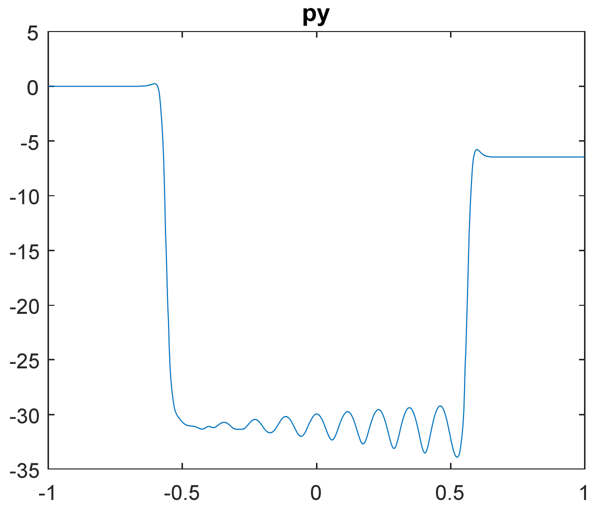
offset dependent CK: X(3D,offset)-X(3D,0)-X(no CK,offset)



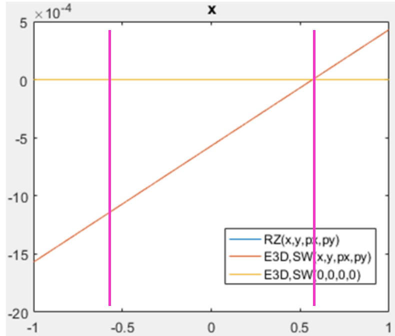


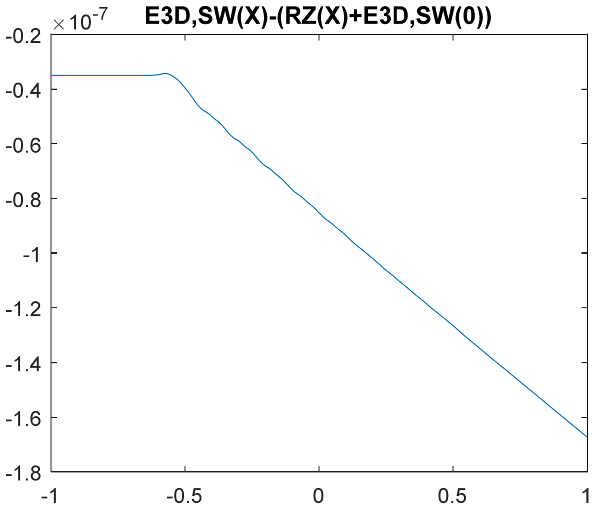


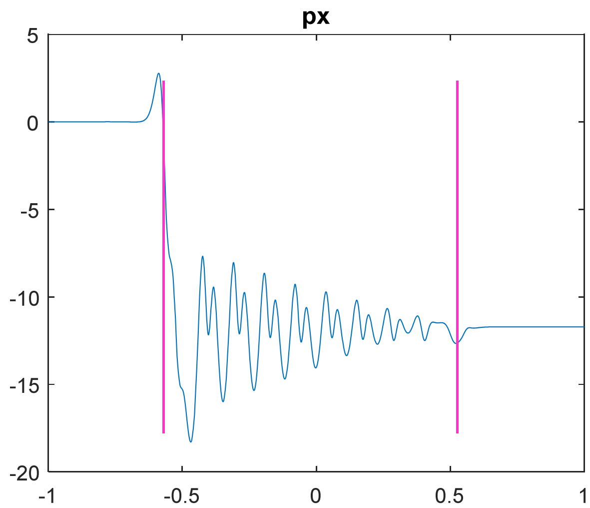


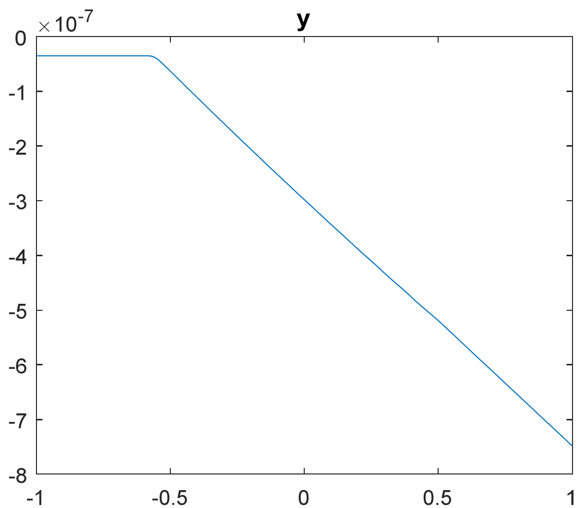


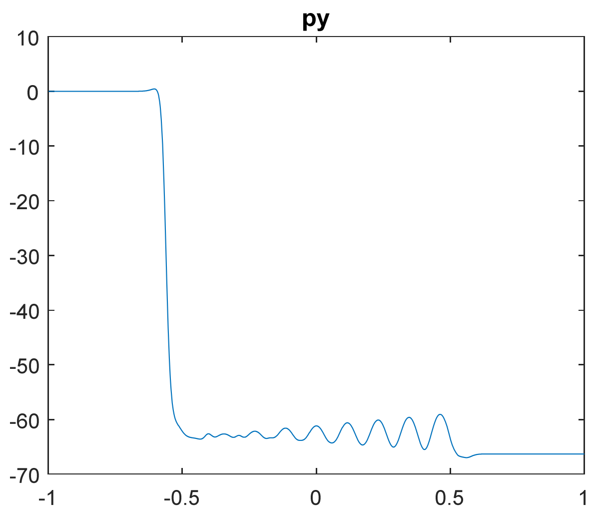
initial condition: **x = 0.57 mm**, y=0, **px/pz=0.001**, py=0
offset dependent CK: X(3D,offset)-X(3D,0)-X(no CK,offset)





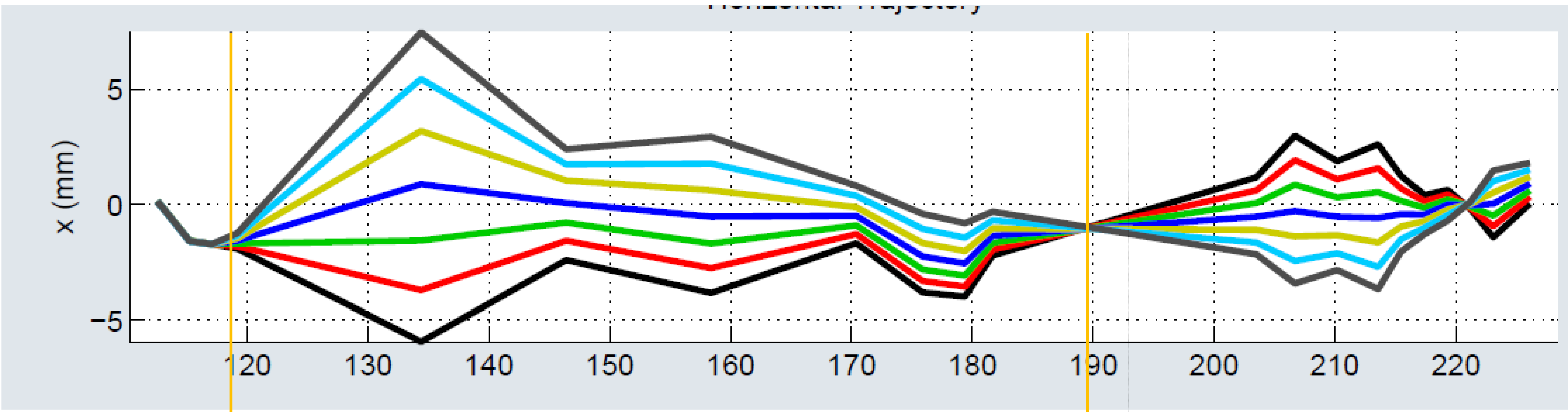




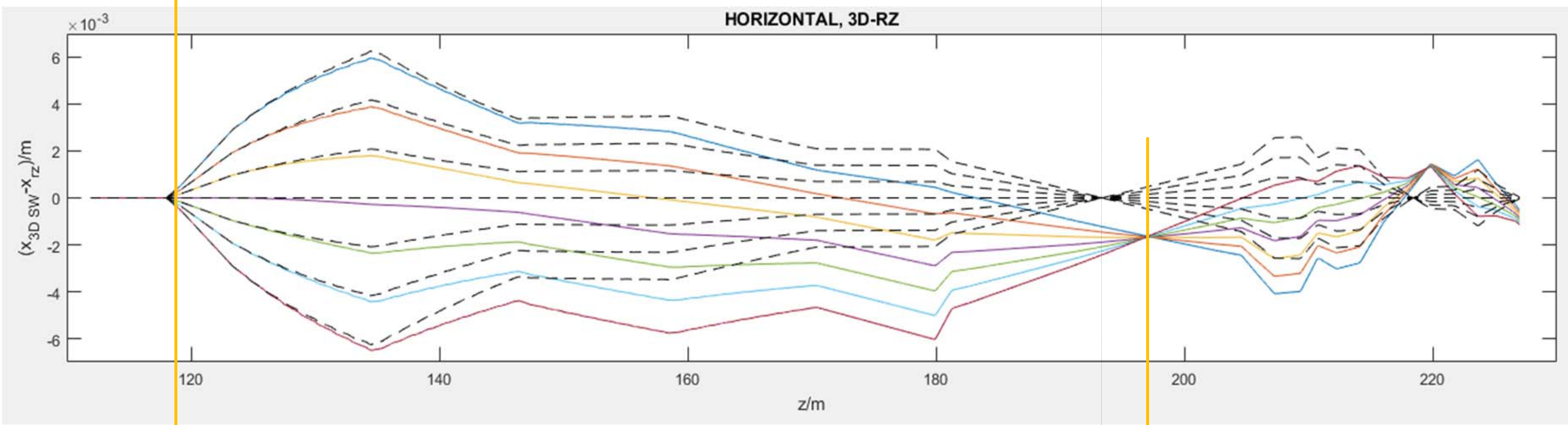


more

CX 118, comparison, horizontal:

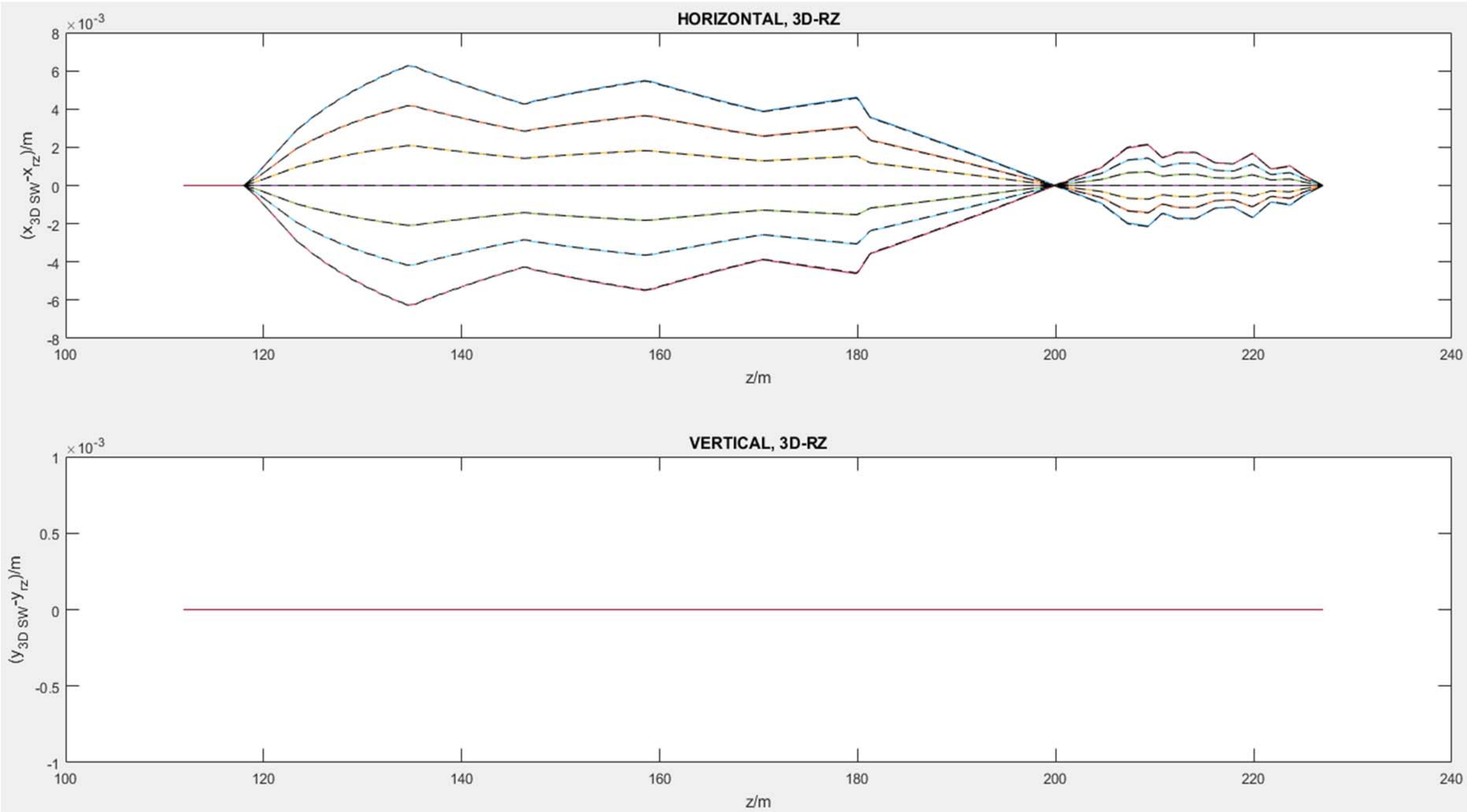


Astra-3D ↔ Astra-rz: **rz fits better for phase advance and width of envelope**



180 deg phase advance is not quite correct

CX 118, comparison, horizontal: **Astra-rz ↔ Xtrack without CK**
but for optics from Winnie's long list



summary/conclusion

measurements ↔ Astra (fieldmap): significant coupling between horizontal & vertical plane ~ 10%; effect is essentially reproduced by tracking; deviations might be explained by different optics and cavity operation

Astra (fieldmap): horizontal trajectory depends on cavity operation (SW/fill & phase); effect to to 3 mm; more severe fore SW; vertical ~ 0.3 mm

Astra (fieldmap) ↔ discrete coupler model: good agreement for different cavity operation but not quite satisfying for large offsets

discrete coupler model:
Xtrack uses discrete localized kicks
CK field is not too linear but should by ok for few millimeters offset

further investigations:
agreement measurement ↔ Astra; optics/cavity operation/CK fields
agreement field-model ↔ discrete model