Transverse Beam Profile after BC3 and in Undulator (for Flash with 3rd harmonic rf)

BC3 → collimator

1. Observations for the 1nC case (see 30th Nov.)
2. Slice Analysis – “Methods”
3. Slice Emittance – “good and bad particles”

Undulator

4. SC Effects
5. Transverse Profile (without SC Effects)

both

6. Summary

6. Summary

BC3 $\rightarrow$ collimator

rms beam properties underestimate real particle density

slice emittance is better than expected

therefore: SC effects are stronger

to be done: optics with SC effects

Undulator

rms beam properties underestimate real particle density

SC effects at 1GeV nearly negligible

peak current density larger than for Gaussian beam

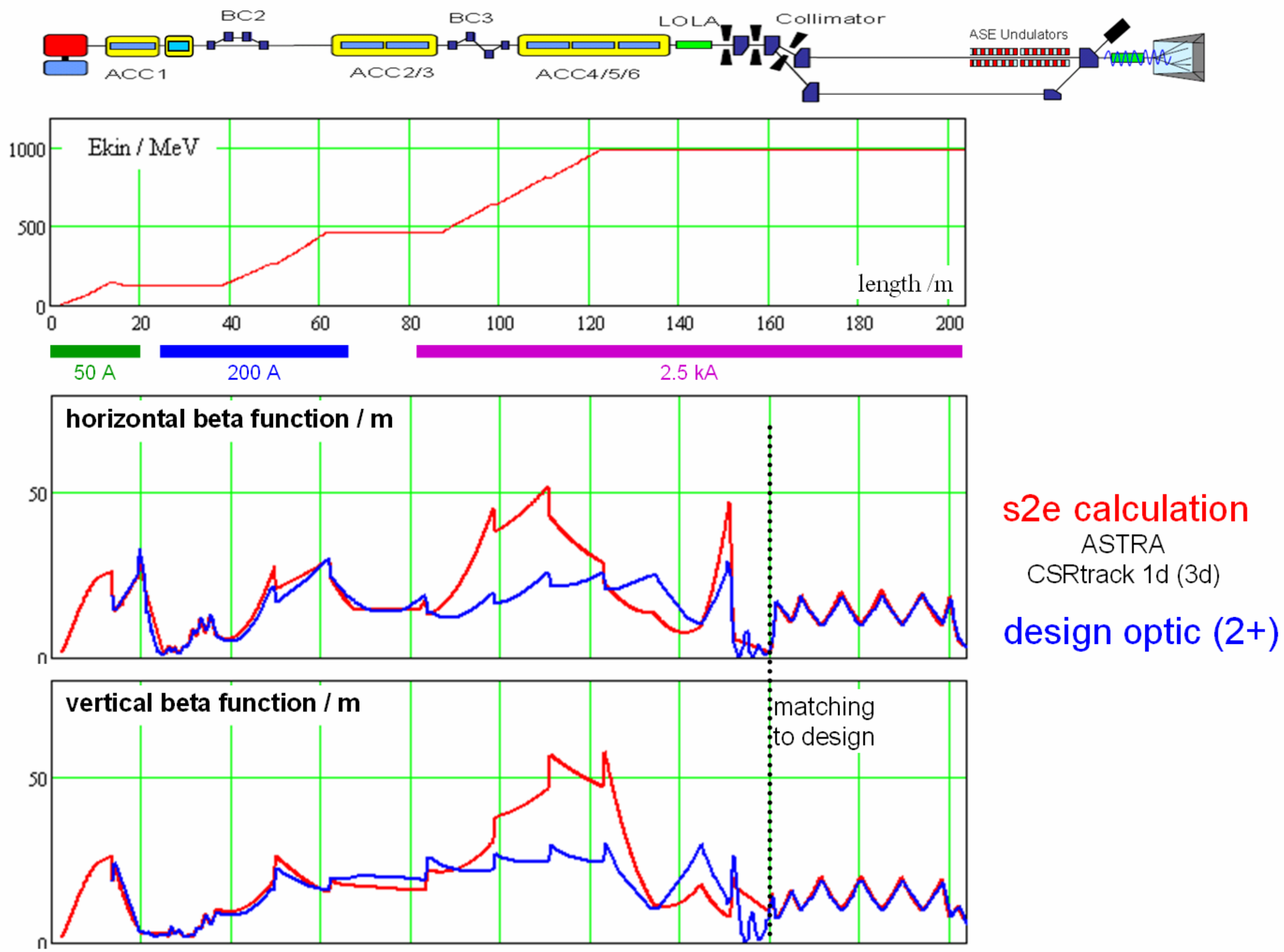
pseudo energy spread (from emittance) larger than real energy spread

pseudo energy spread than for Gaussian beam

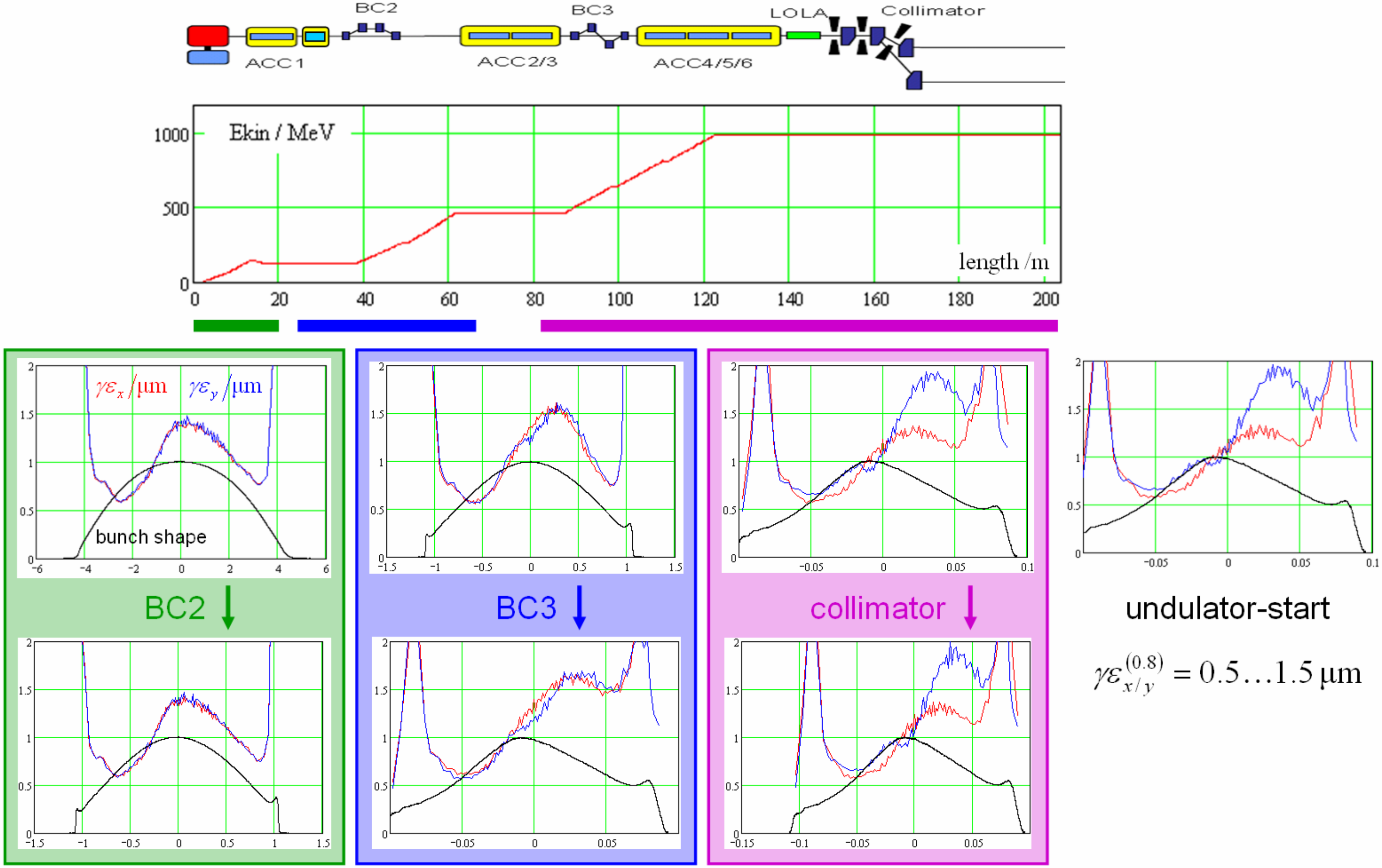
BC3 → collimator

1. Observations for the 1nC case (see meeting 30th Nov.)

Transverse Dynamics



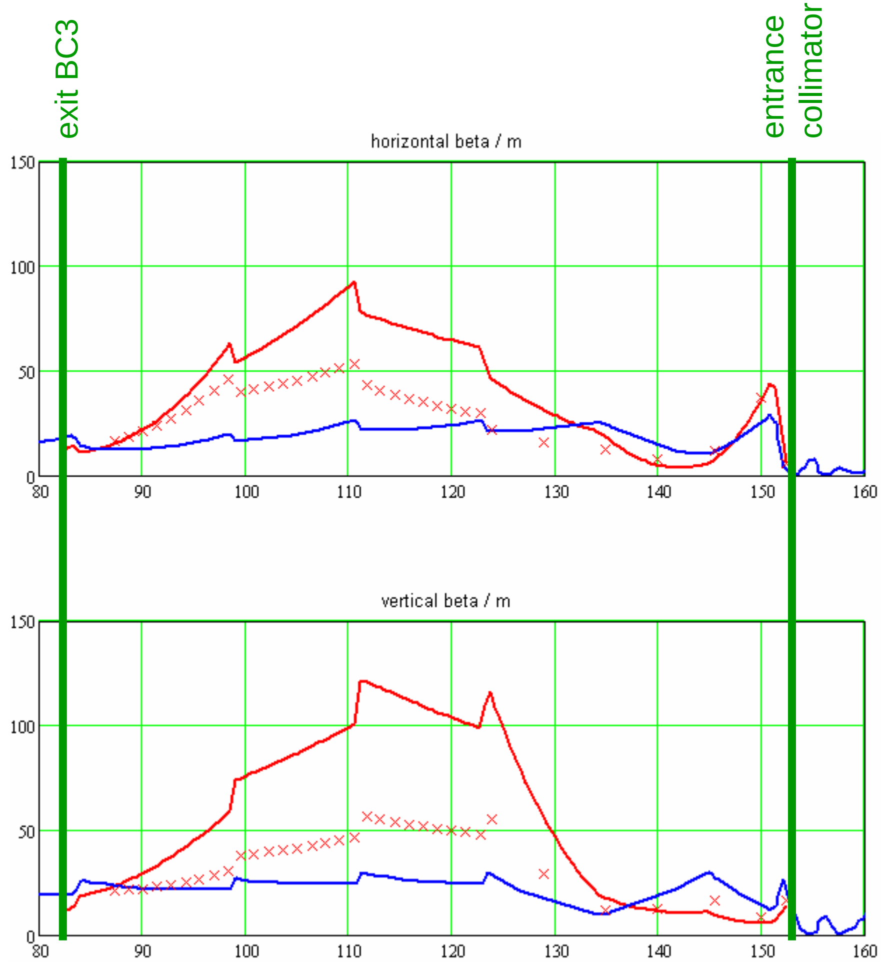
Transverse Dynamics
slice emittance



$$\gamma\varepsilon_{x/y}^{(0.8)} = 0.5\ldots1.5\,\mu\mathrm{m}$$

design optic (2+)

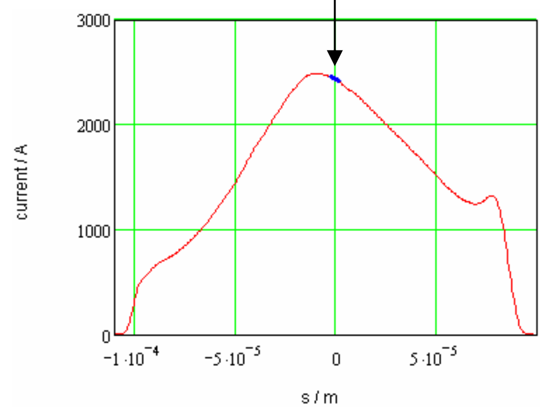
2. Slice Analysis – “Methods”



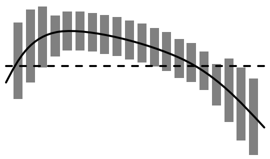
design optic (2+)

slice model

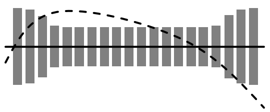
selected slice



x x x x x x x Astra, full bunch



centroids extracted!



slice model
(see meeting 28th Sept.)

slice model for particle dynamics

run Astra with 7 particles without self effects (map many steps)

$$\mathbf{X}_i^{(a)} = \begin{pmatrix} x_i^{(a)} - x_0^{(a)} \\ x_i'^{(a)} - x_0'^{(a)} \\ \vdots \end{pmatrix} \qquad i = 1,2,\cdots 6$$

calculate linear transport matrices

$$\mathbf{T}^{(b\leftarrow a)} = \left(\mathbf{X}_1^{(a)}\ \mathbf{X}_2^{(a)} \cdots \mathbf{X}_6^{(a)}\right)^{-1}\left(\mathbf{X}_1^{(b)}\ \mathbf{X}_2^{(b)} \cdots \mathbf{X}_6^{(b)}\right)$$

select slice particles from initial distribution $\mathbf{X}_p$

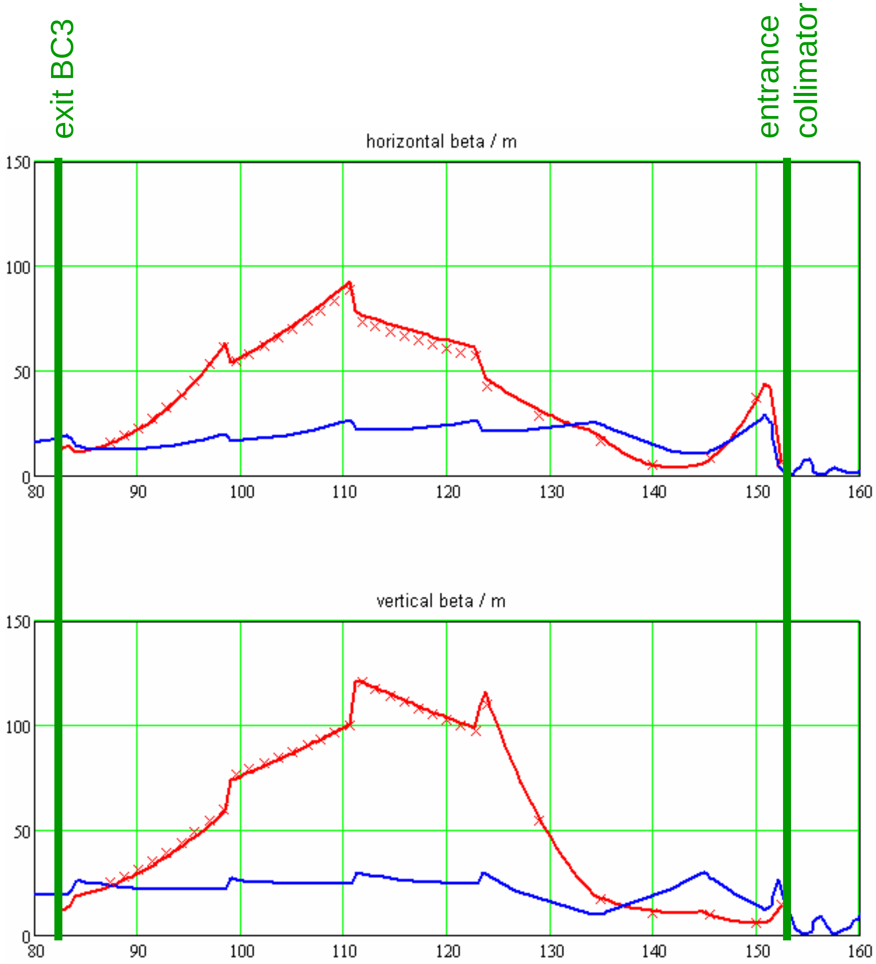
$$\left\{\mathbf{X}_p^{(\mathrm{start})}\right\} = \mathrm{slice}\left\{\mathbf{X}_p^{(\mathrm{start})}\right\}$$

track from a to b with self effect

$$\left\{\mathbf{X}_p^{(\mathrm{a})}\right\} = \mathrm{slice}\left\{\underbrace{0.5\delta\mathbf{X}_p^{(a)}} + \mathbf{T}^{(b\leftarrow a)}\left[\underbrace{0.5\delta\mathbf{X}_p^{(a)}} + \mathbf{X}_p^{(\mathrm{a})}\right]\right\}$$

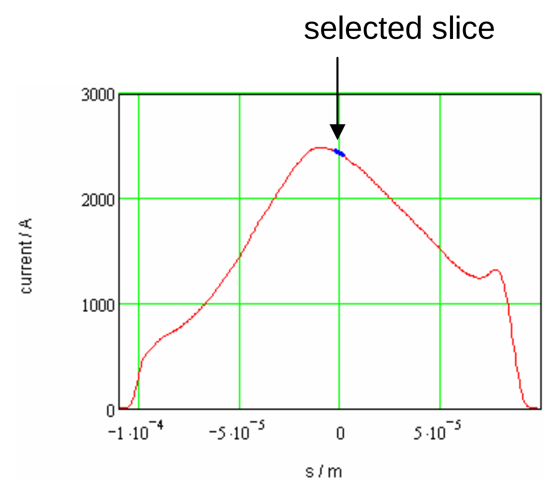
transverse self forces at “a” and “b”

slice model
comparison with Astra

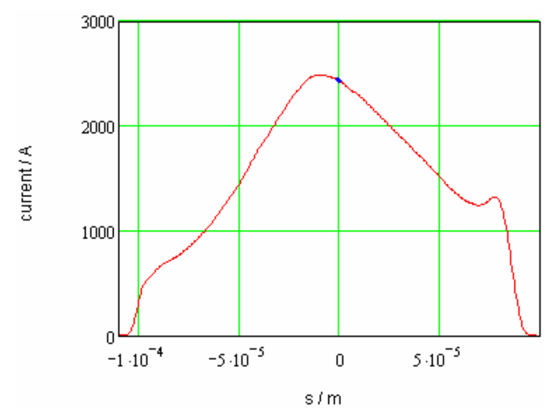


design optic (2+)

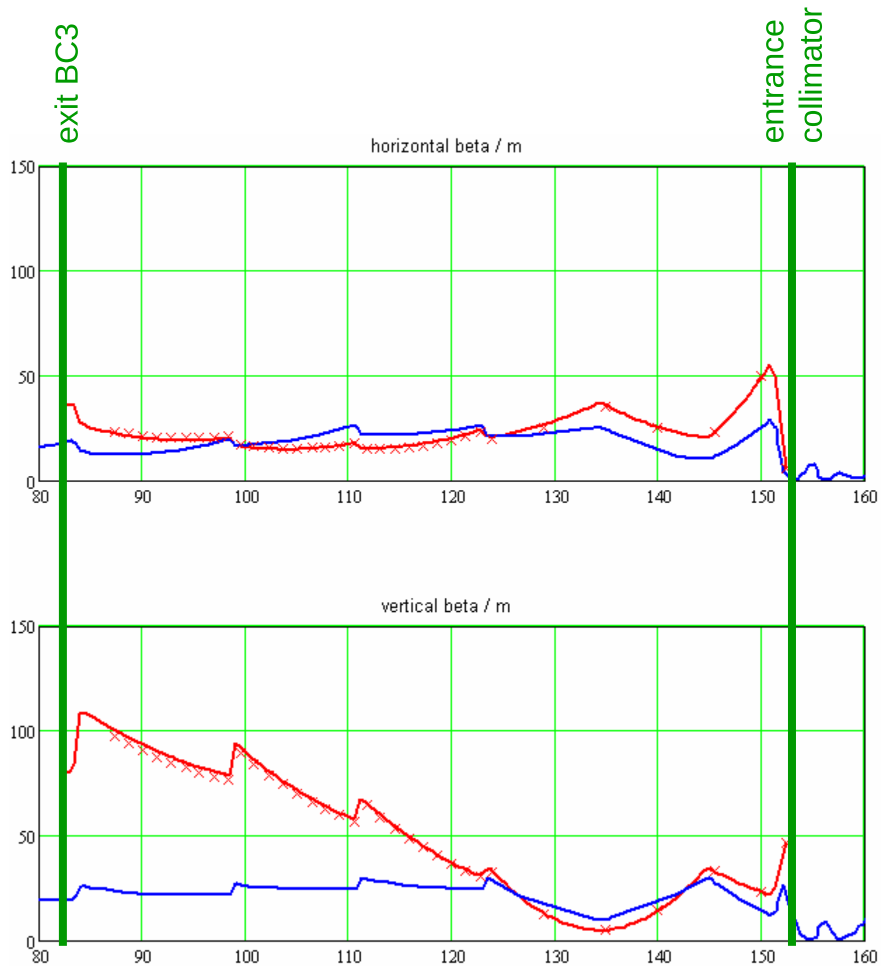
slice model (rz)



x x x x x x x Astra (rz), slice



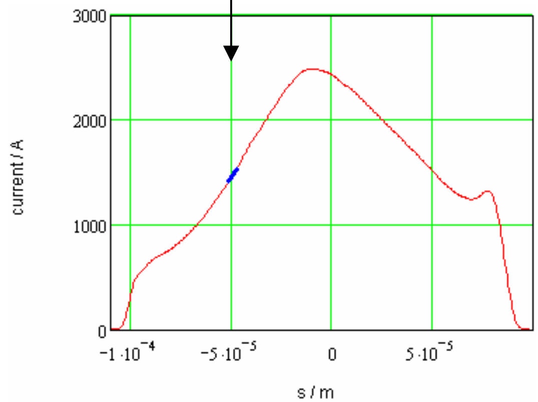
BC3 → collimator



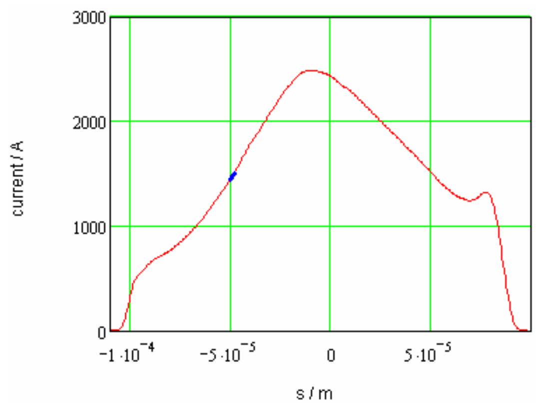
design optic (2+)

slice model (rz)

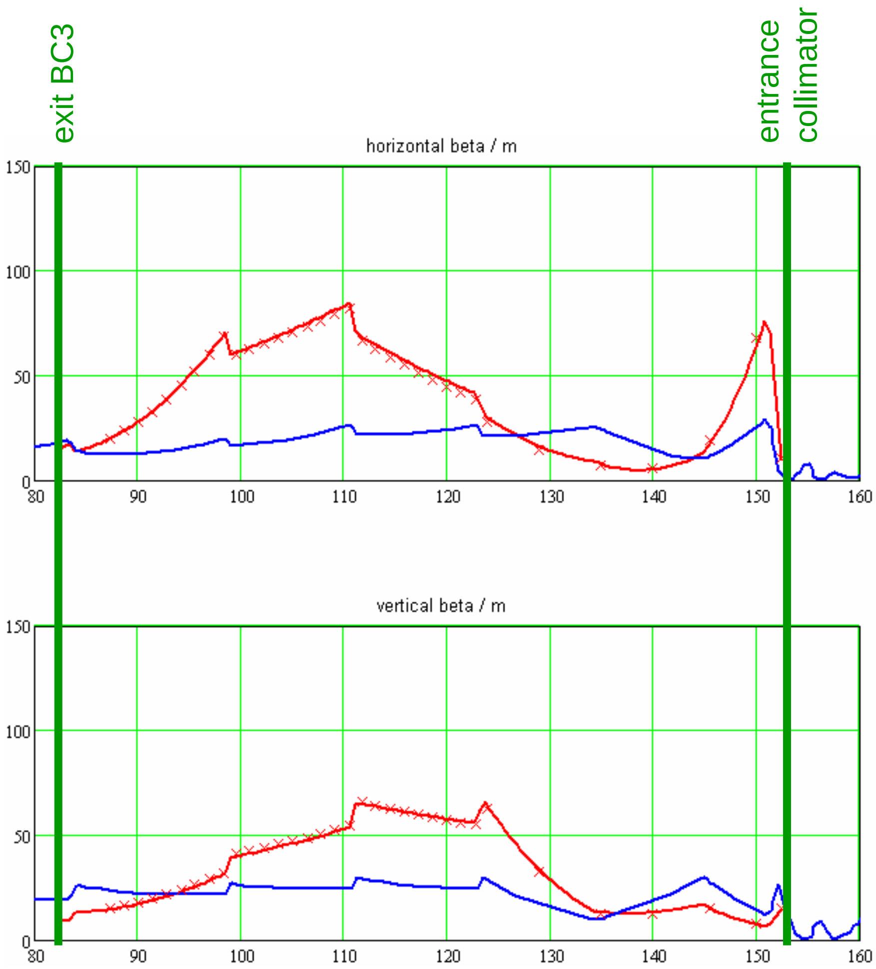
selected slice



x x x x x x x Astra (rz), slice

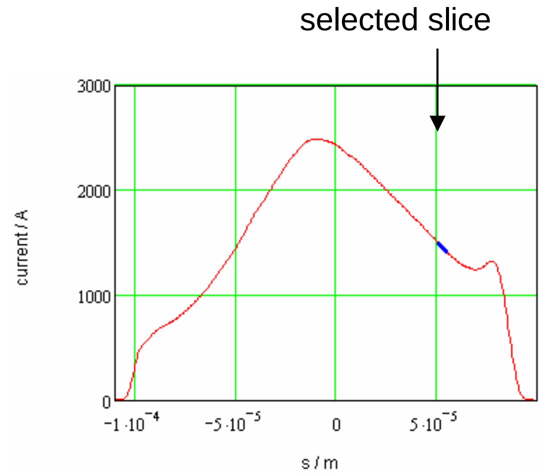


BC3 → collimator

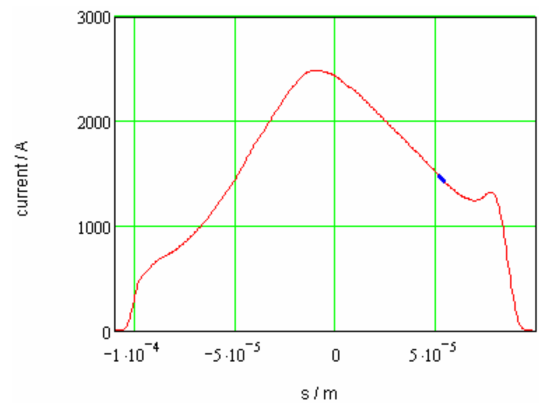


design optic (2+)

slice model (rz)

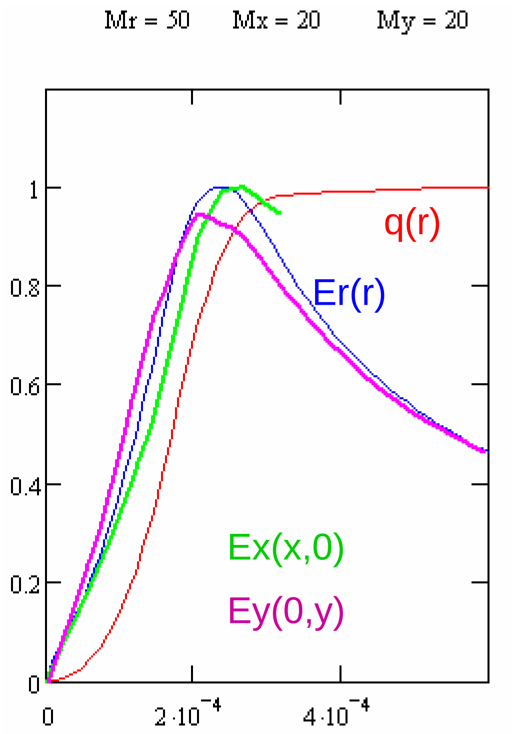


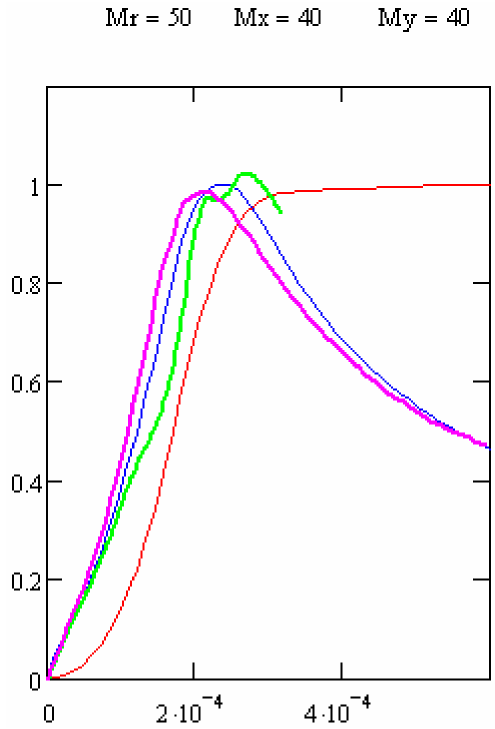
x x x x x x x Astra (rz), slice

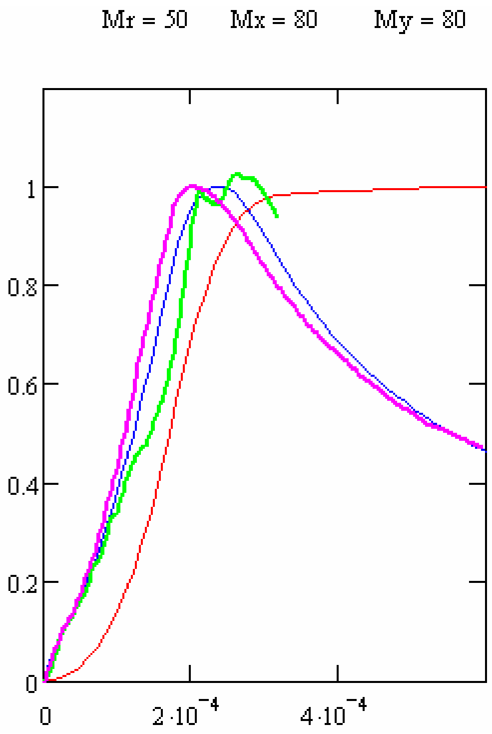


slice model
comparison rz, xyz

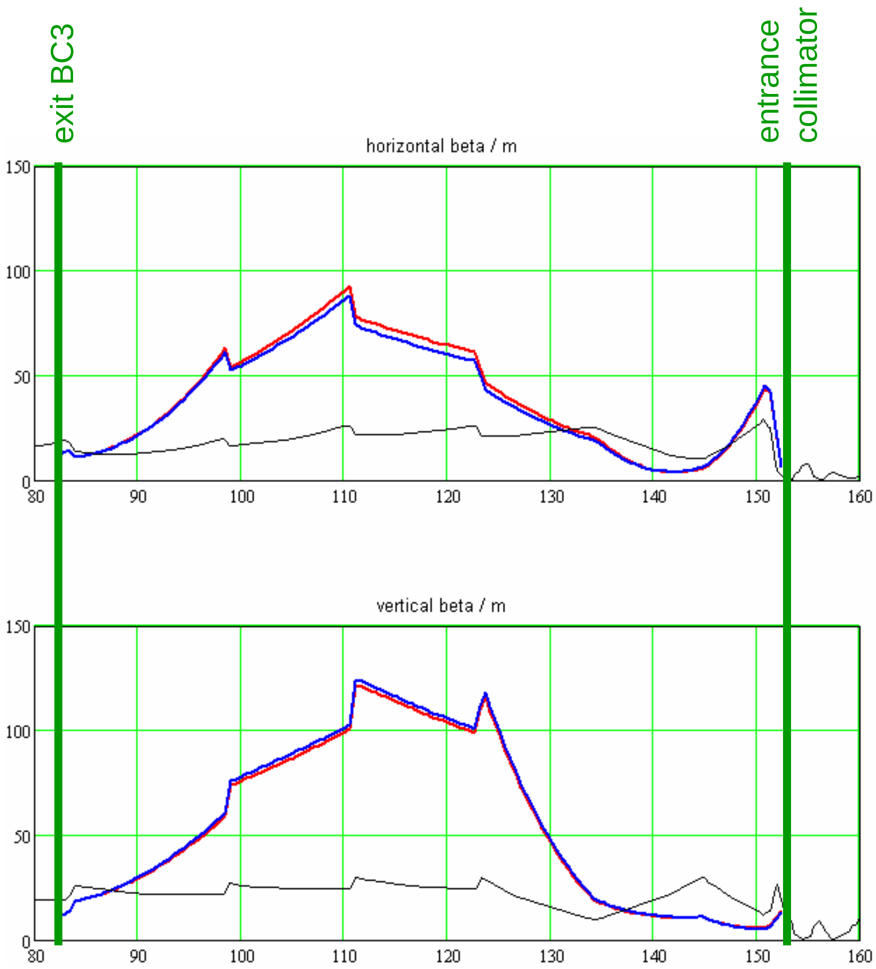
f.i. exit BC3



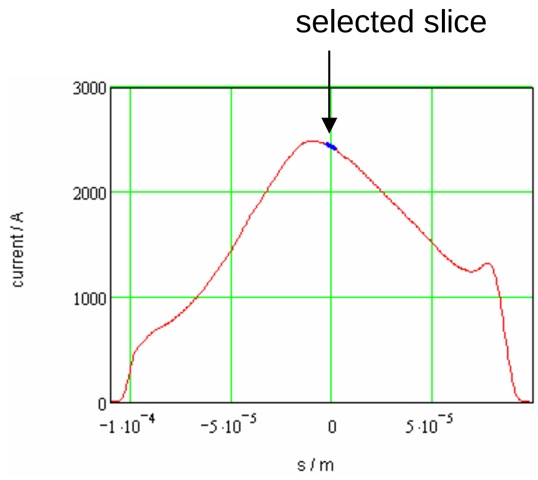




BC3 → collimator

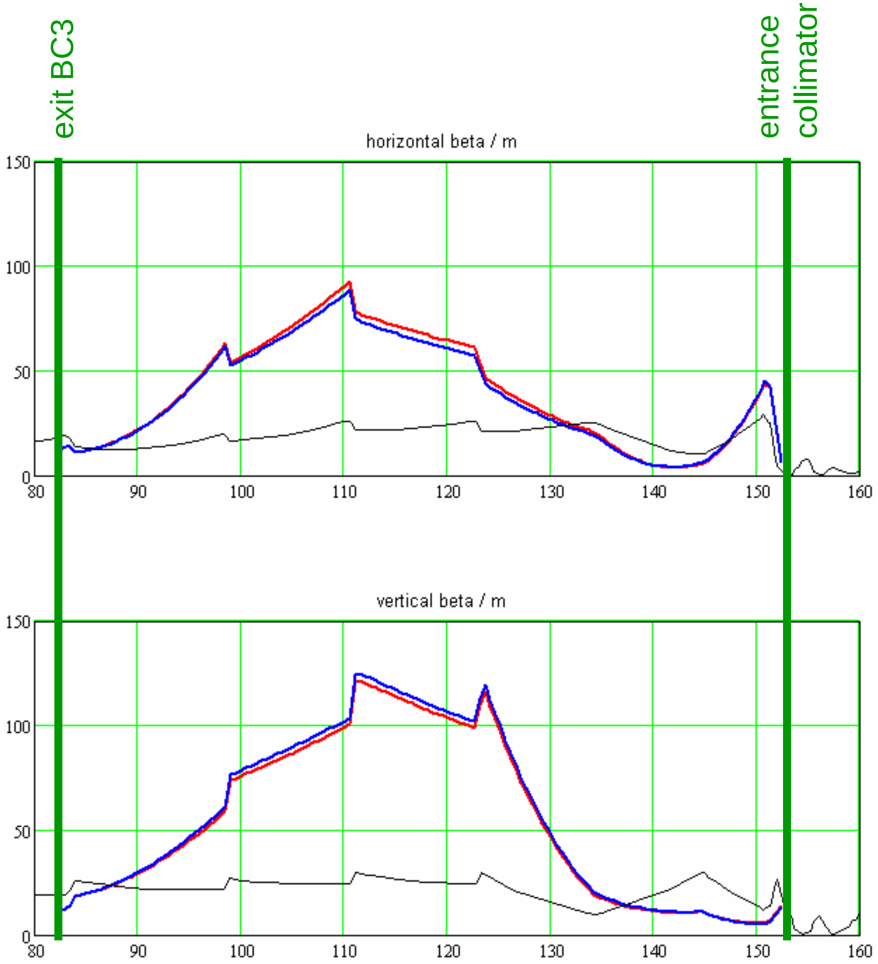


comparison slice model:
rz ↔ xyz ↔ design
red = rz (50 lines in r)
blue = xyz (25 lines in x,y)
black = design

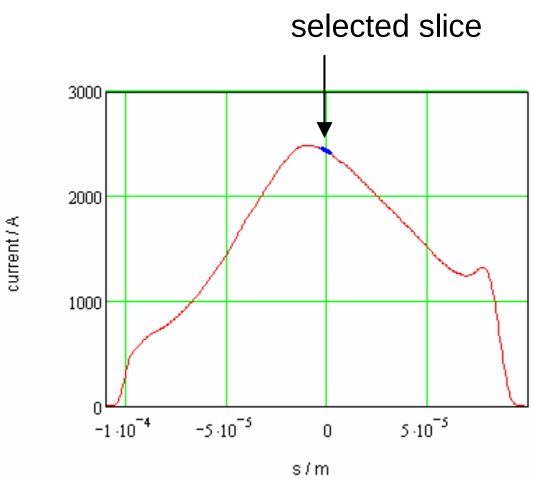


→ rz approach and slice model are roughly ok

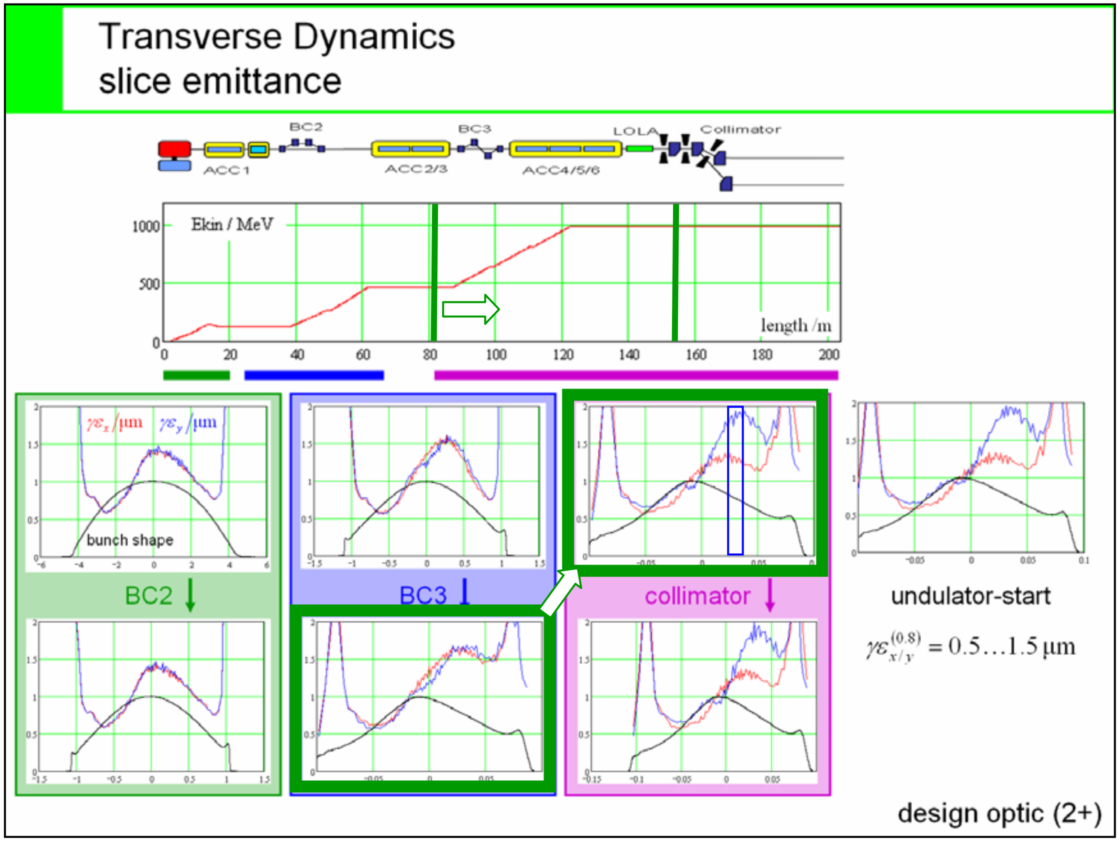
BC3 → collimator



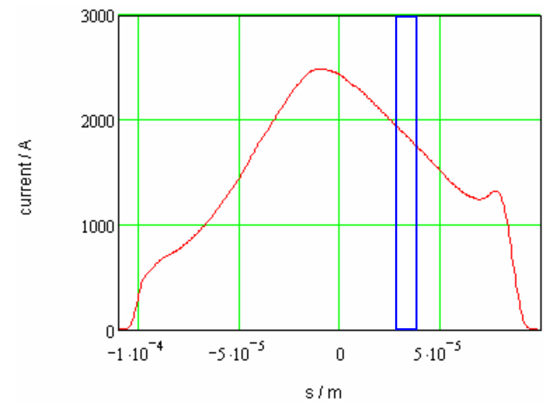
comparison slice model:
rz ↔ xyz ↔ design
red = rz (50 lines in r)
blue = xyz (40 lines in x,y)
black = design



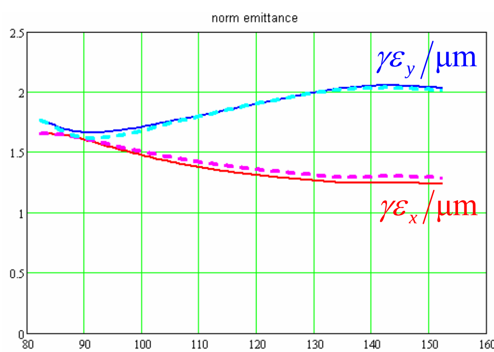
3. Slice Emittance



slice model
“slice” = 28um .. 32um



solid = rz model
dashed = xyz model

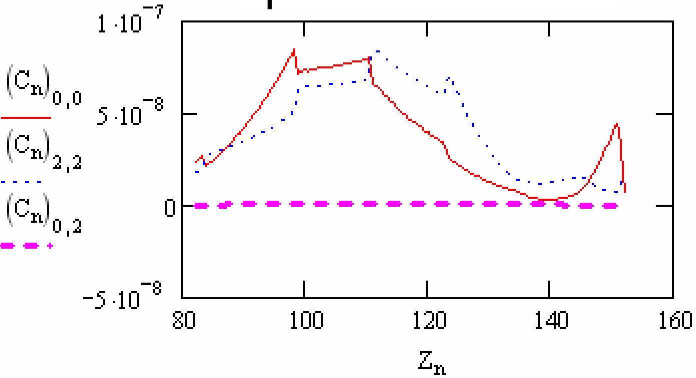


cross coupling ?

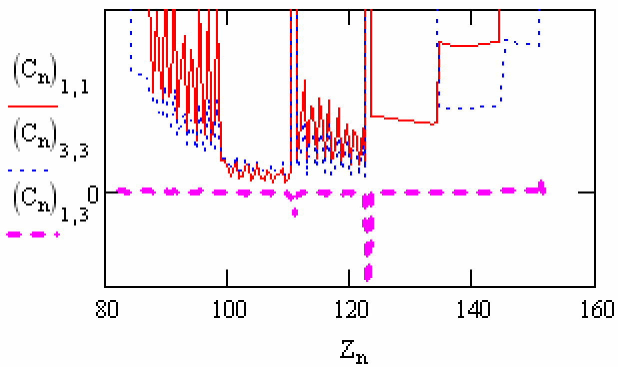
“slice” = 28um .. 32um

xx – correlation
yy – correlation
xy – correlation

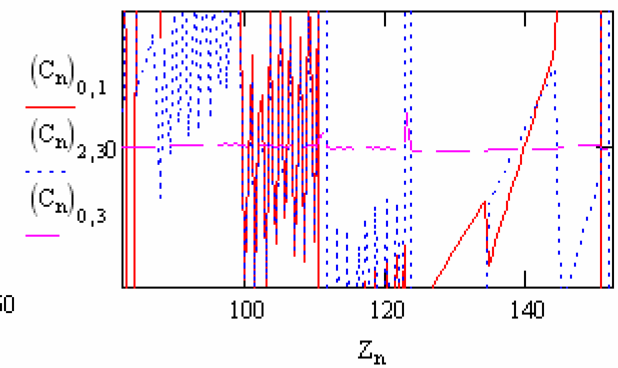
spatial correlation



momentum correlation



spatial-momentum corr.

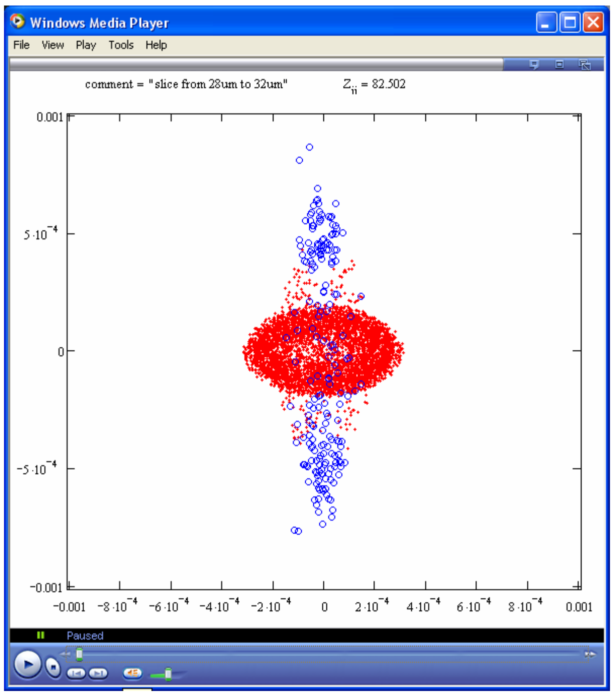


no xy correlation !

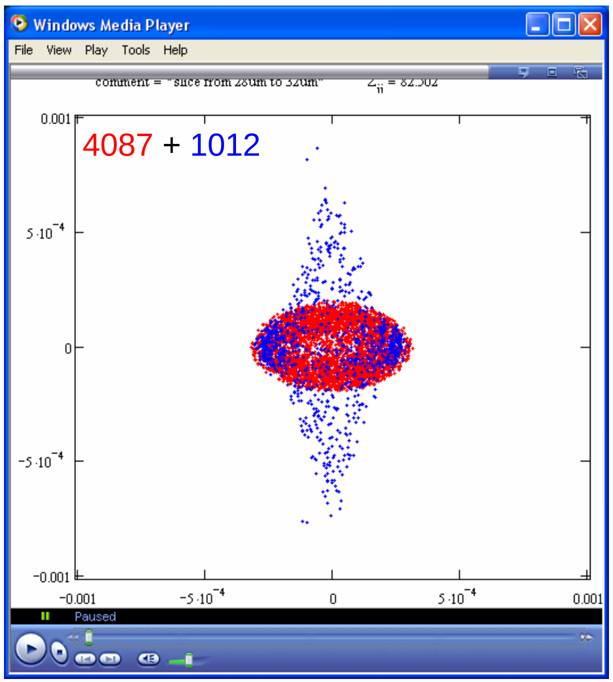
BC3 → collimator

“good” and “bad” particles “slice” = 28um .. 32um

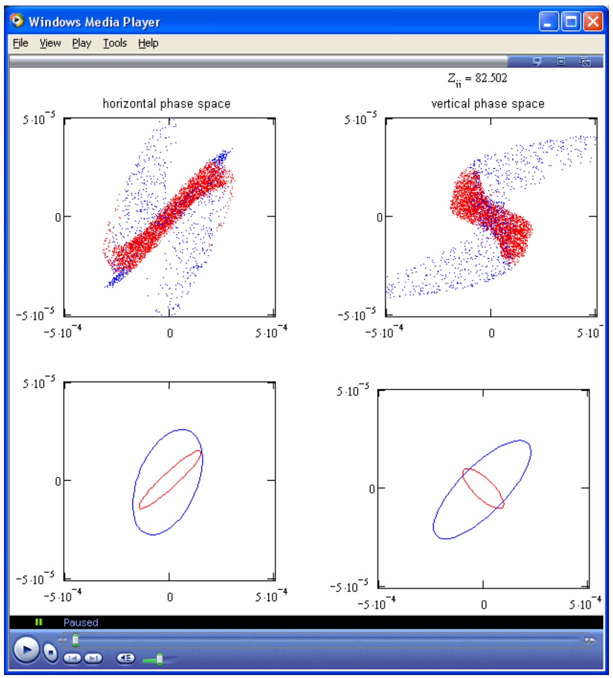
movie 1	movie 2	movie 3



xy space (+- 1mm)

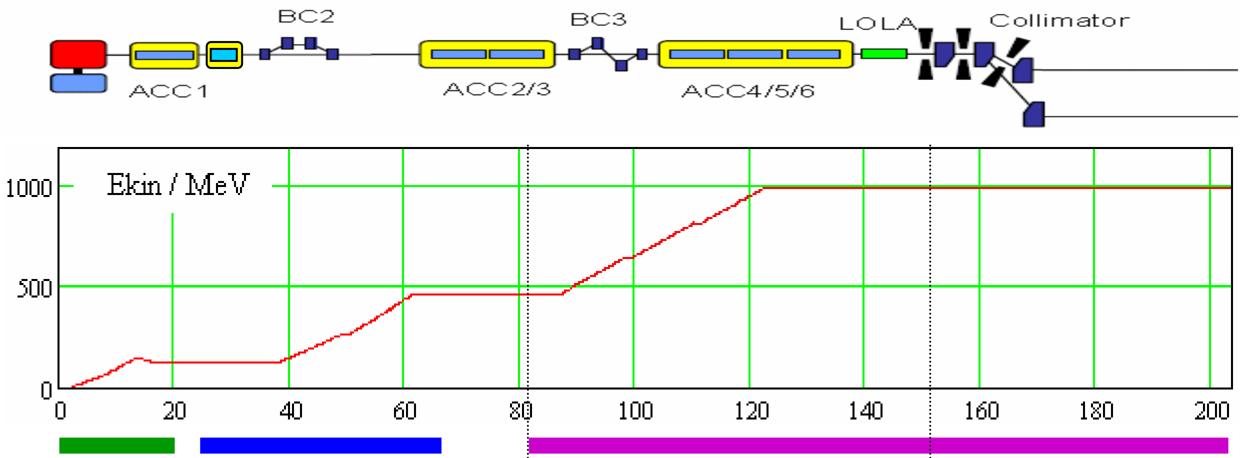


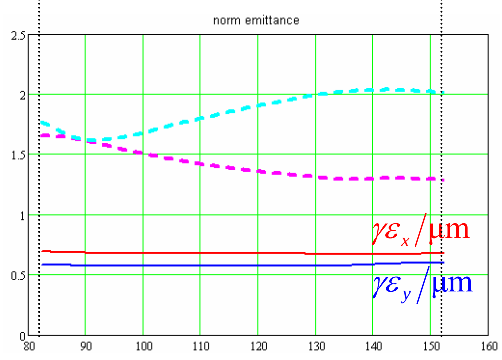
xy space (+- 1mm)



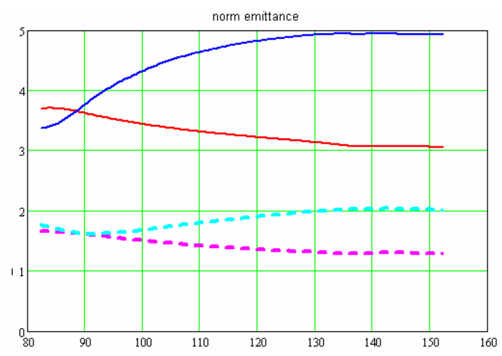
xx’ and yy’ space

slice model (xyz)   "slice" = 28um .. 32um

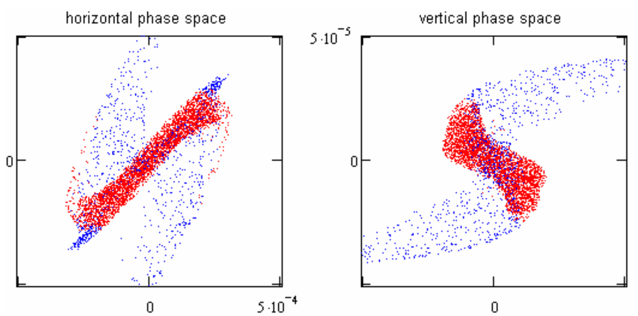




4087 "red" particles



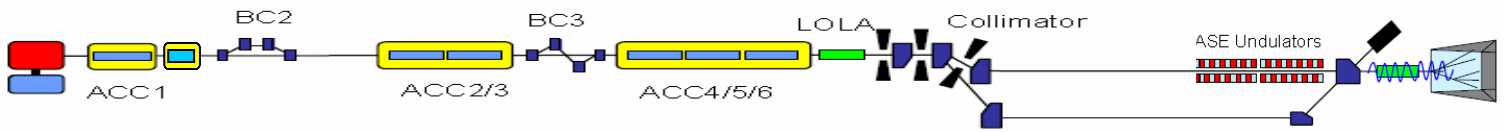
1012 "blue" particles

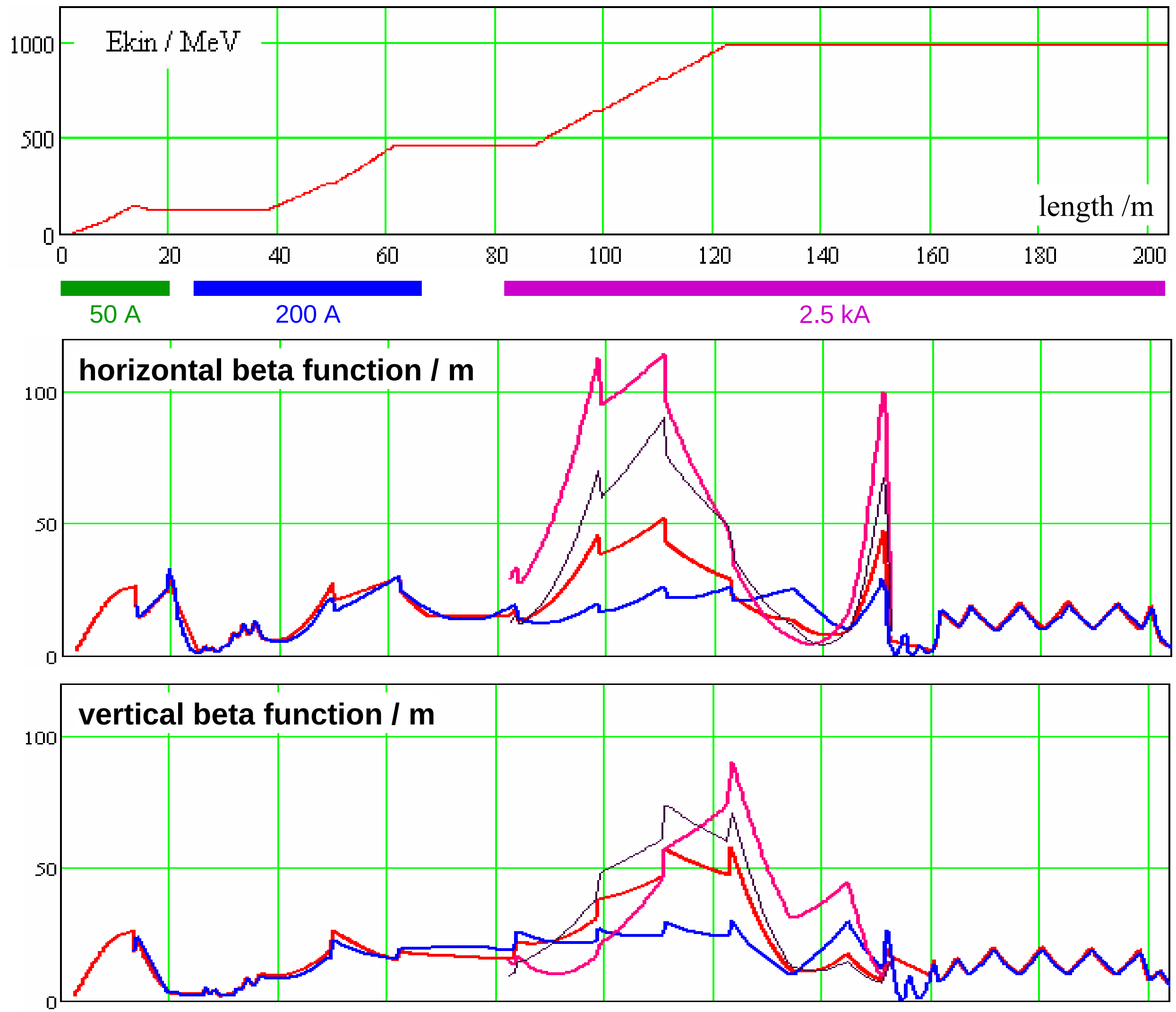


BC3 → collimator

slice model (xyz)

“slice” = 28um .. 32um





s2e calculation
ASTRA
CSRtrack 1d (3d)

design optic (2+)

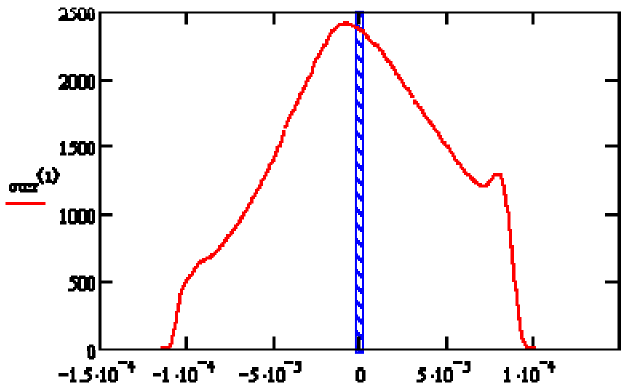
slice: all particles

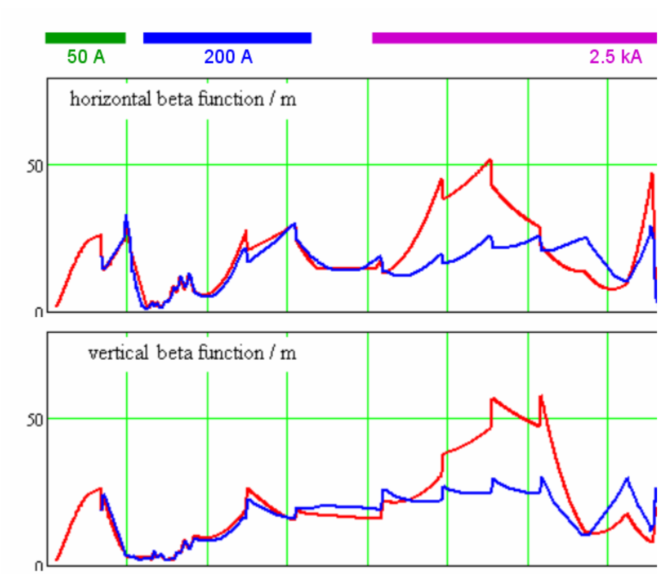
slice: red particles

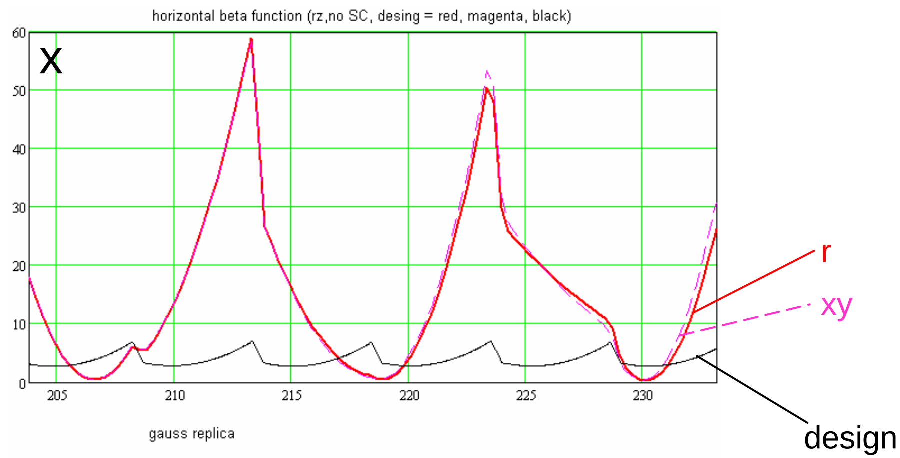
4. SC Effects in Undulator

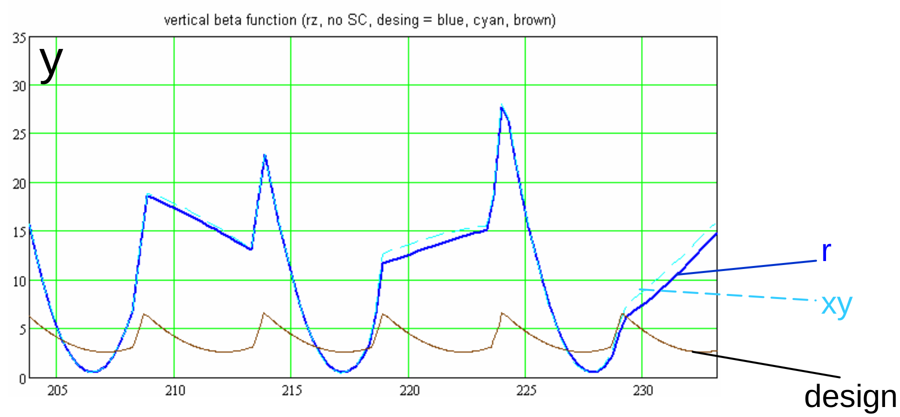
no match at all !

slice = -2um .. +2um







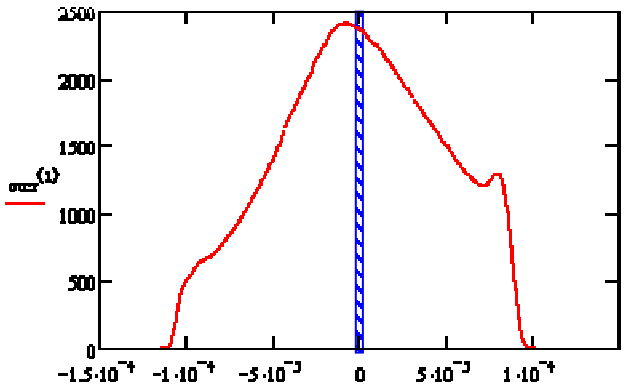


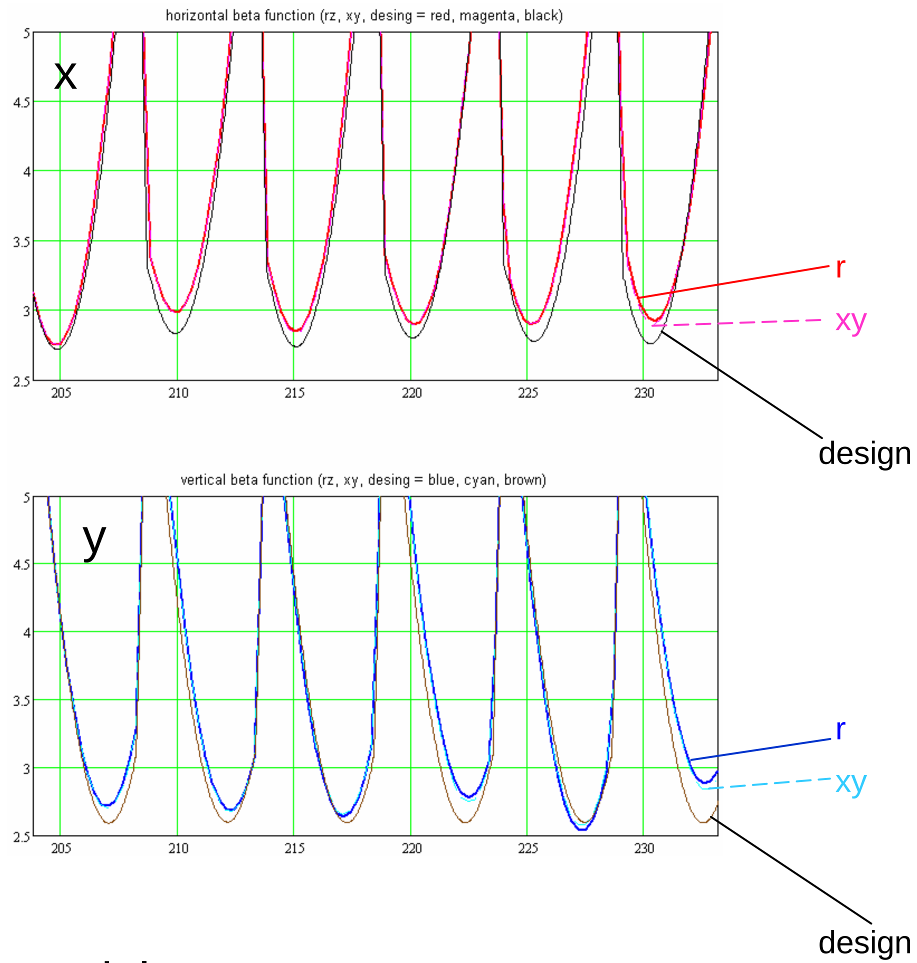
strong effect due to initial mismatch compared to that:
weak effect due to space charge

“match 1”

initial distribution from tracking

match = -10um .. -6um
slice = -10um .. -6um





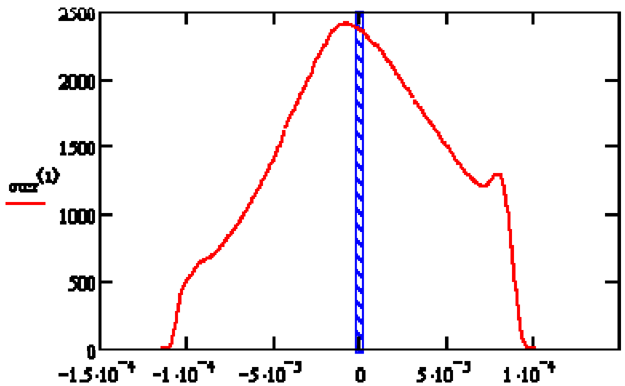
perfect initial match:
$\Delta\beta$ at end < 0.3m
weak difference between r and xy model

“match 1”

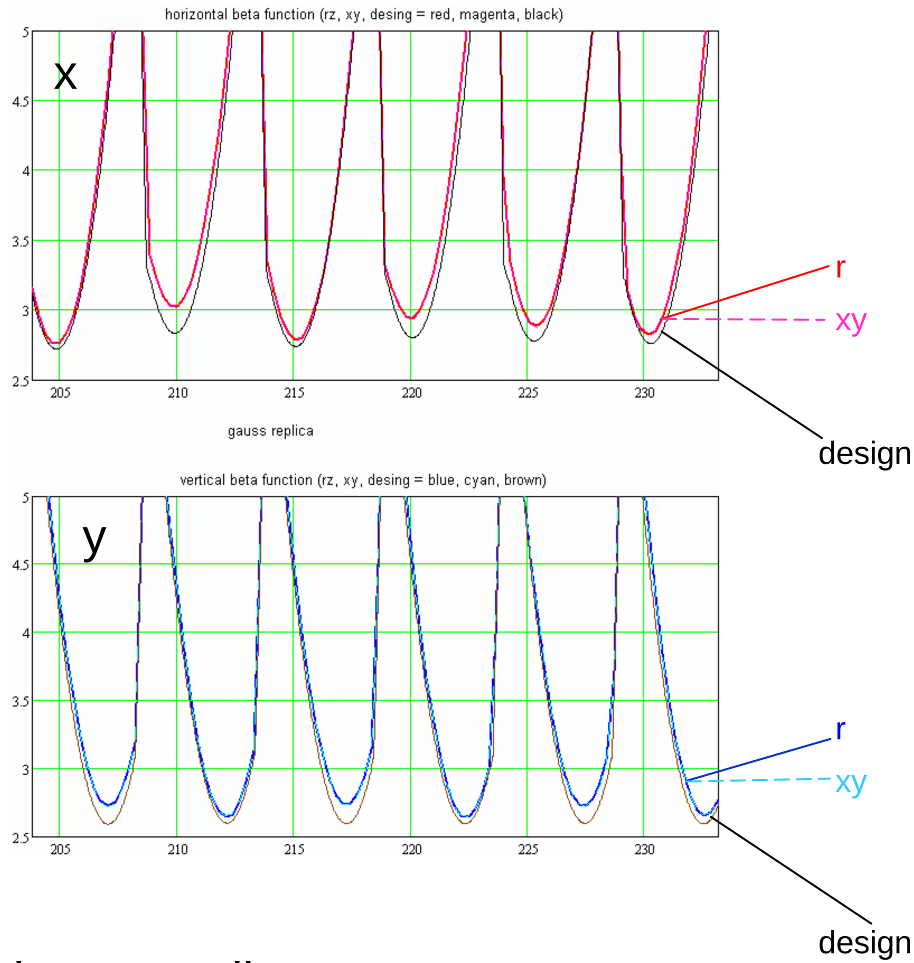
“Gauss replica”

match = -10um .. -6um

slice = -10um .. -6um



= gaussian distribution with same rms properties as initial distribution (slice)



perfect initial match:

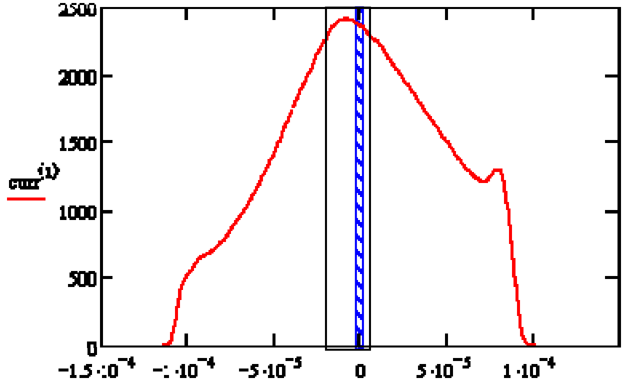
$\Delta\beta$ at end < 0.1m

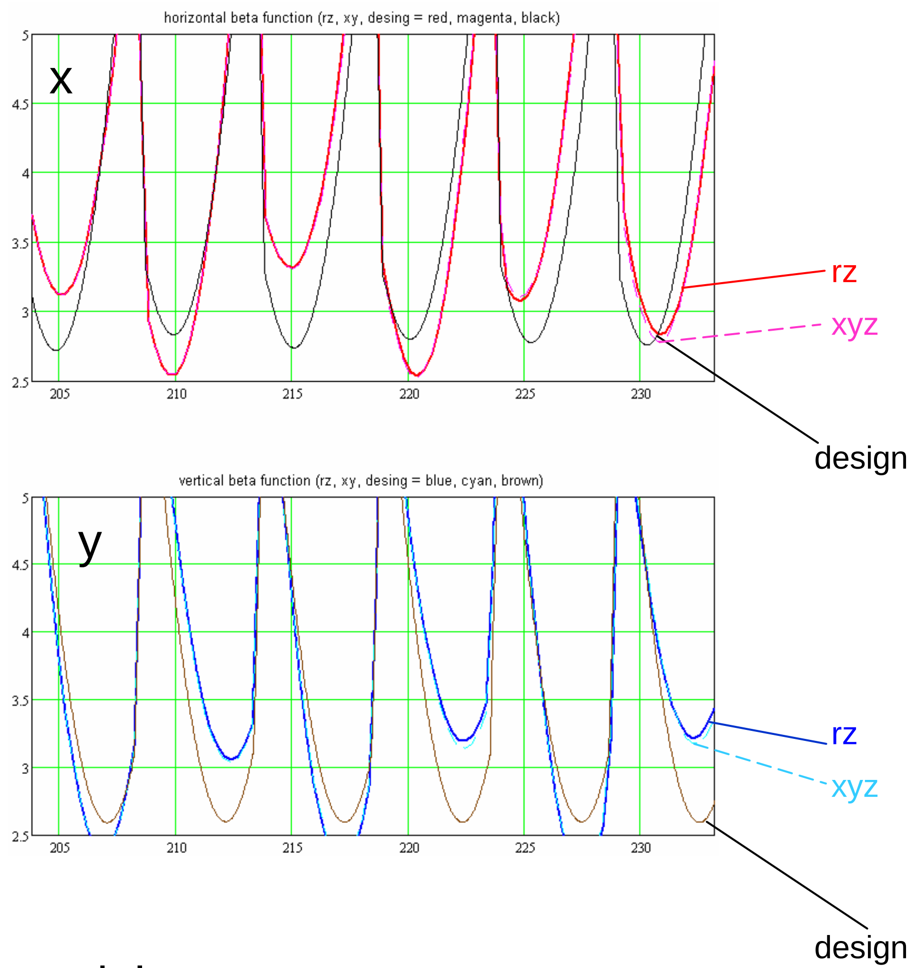
difference between r and xy model very small

“match 2”

initial distribution from tracking

match = -20um .. +7um
slice = -2um .. +2um



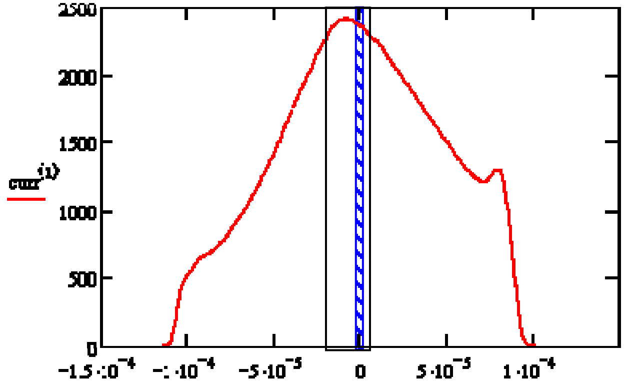


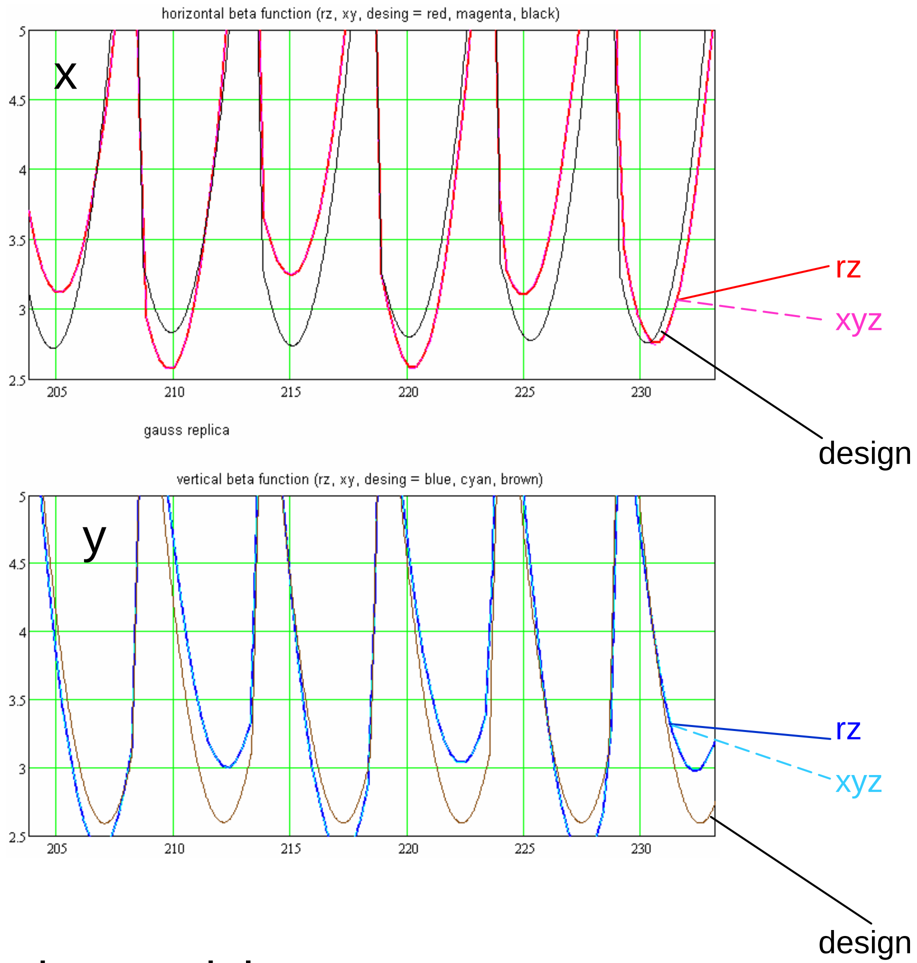
initial mismatch: $\Delta\beta(z0)$ <≈ 0.6m
$\Delta\beta$ along undulator <≈ 0.6m
weak difference between r and xy model

“match 2”

“Gauss replica”

match = -20um .. +7um
slice = -2um .. +2um



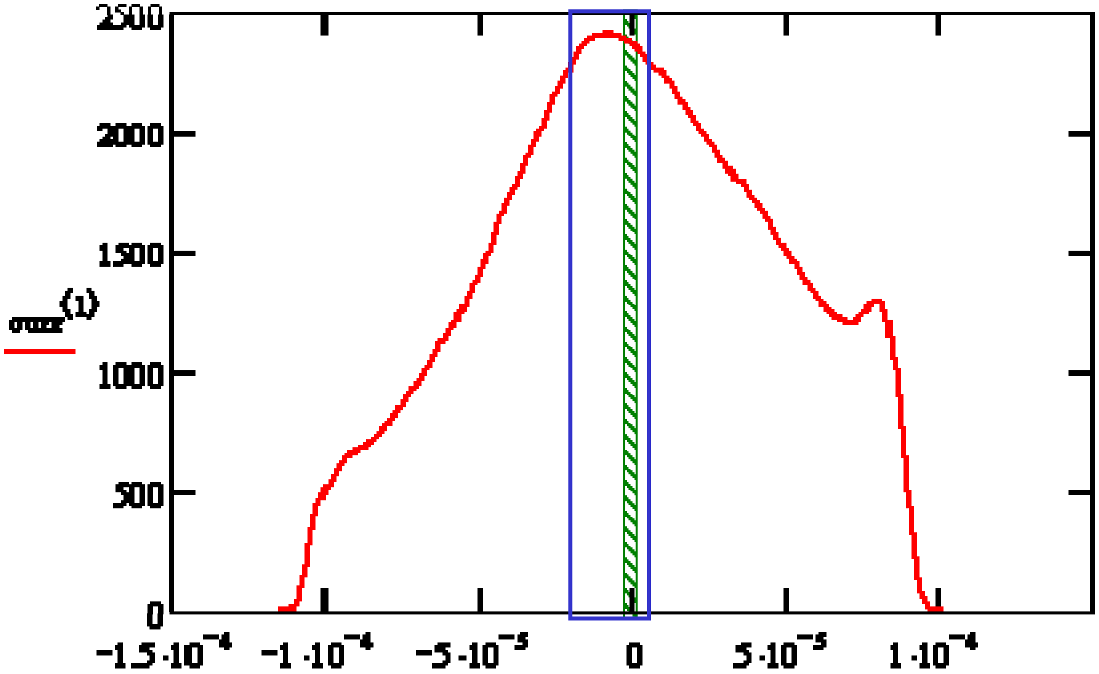


initial mismatch: $\Delta\beta(z0) <\approx 0.6$m
$\Delta\beta$ along undulator $<\approx 0.6$m
very weak difference between r and xy model

5. Transverse Profile (without SC Effects)

for matching:

bunch = 1 .. 200000
core = 68510 .. 111196
slice = 95000 .. 105000



Gaussian replica, slice match

na = 95000   nb = 105000

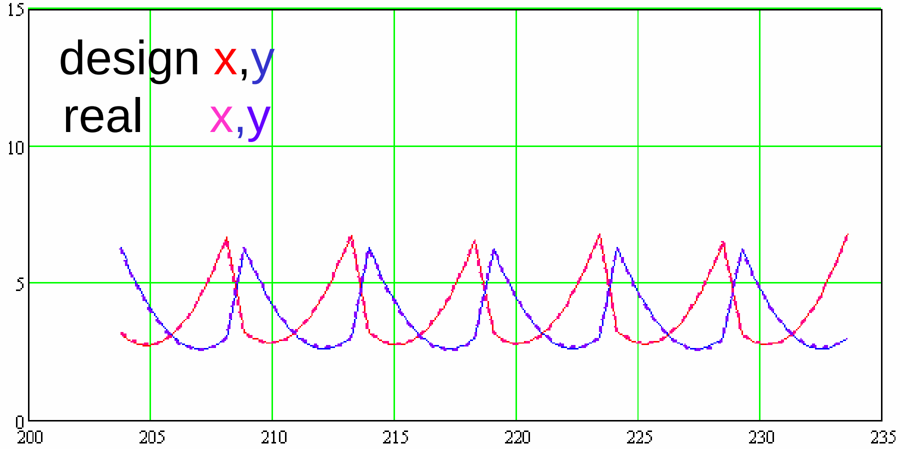
slice

N = 200000

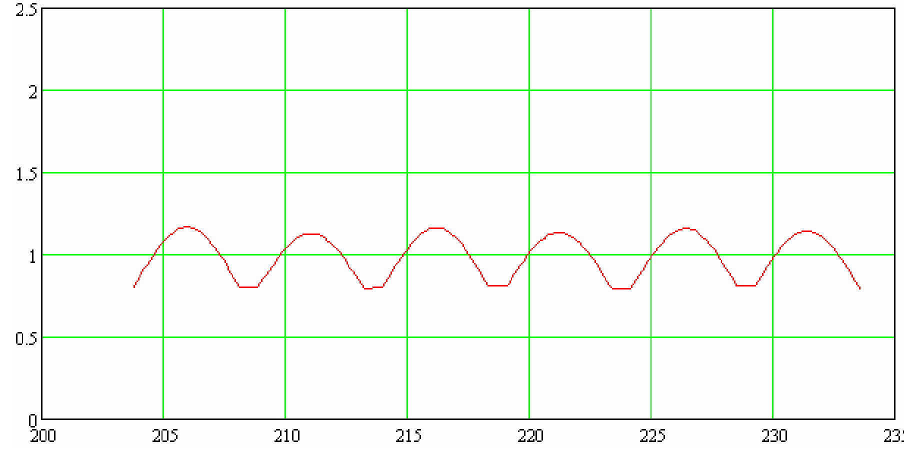
bunch

slice:

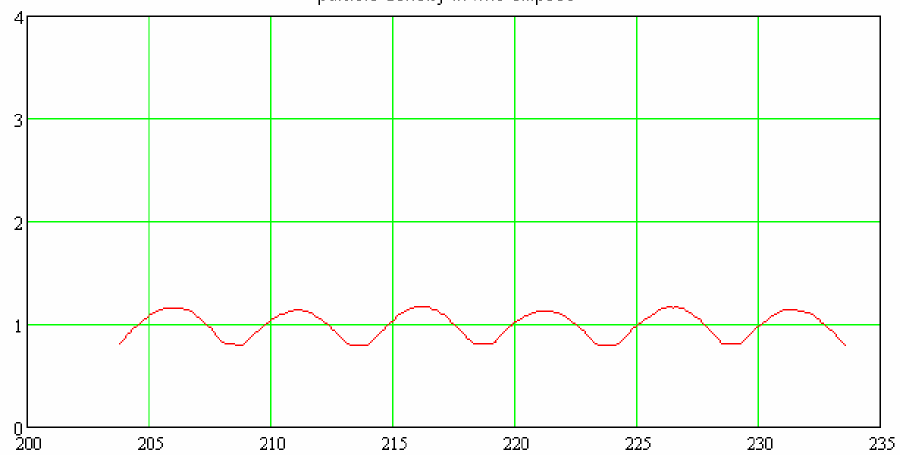
beta functions (real & design)



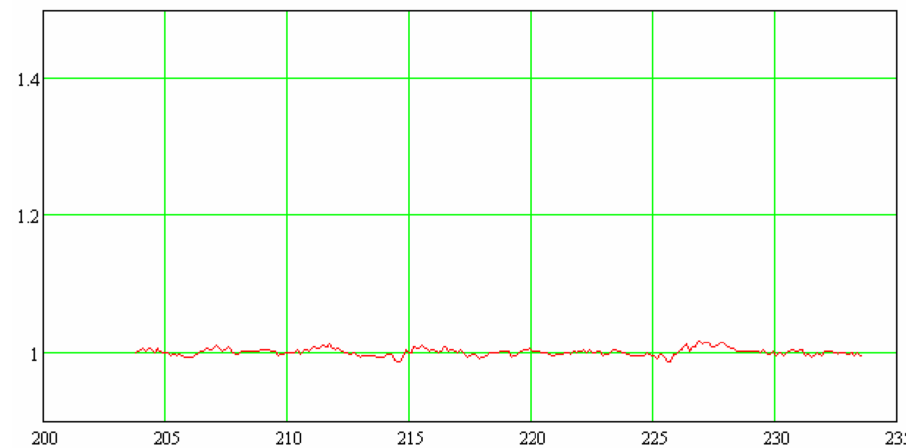
inverse size of rms ellipse



particle density in rms ellipses



particles in rms ellipse



bunch match

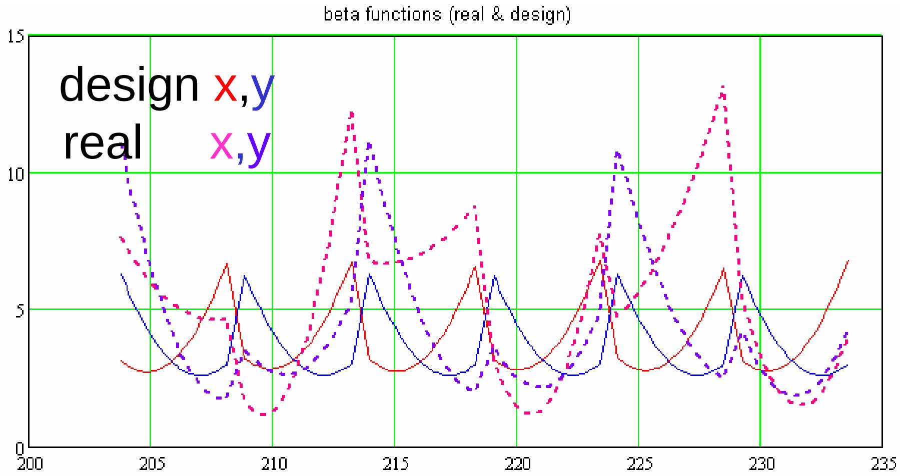
na = 95000 nb = 105000

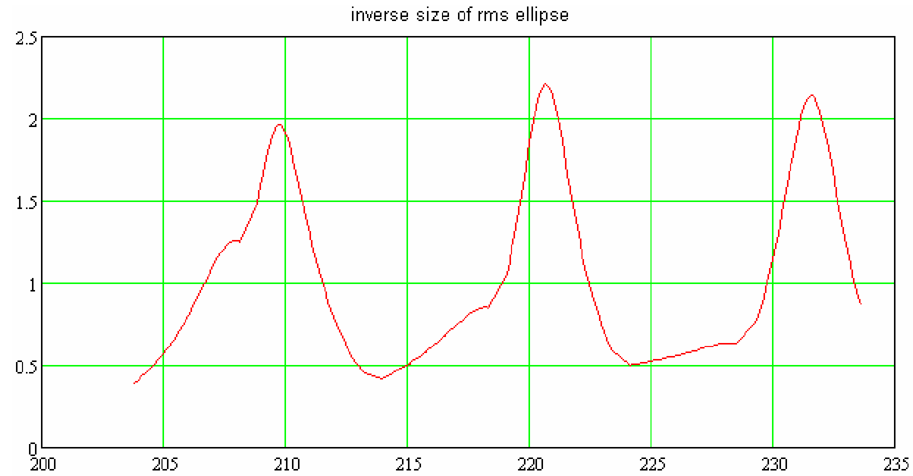
n1 = 68510 n2 = 111196

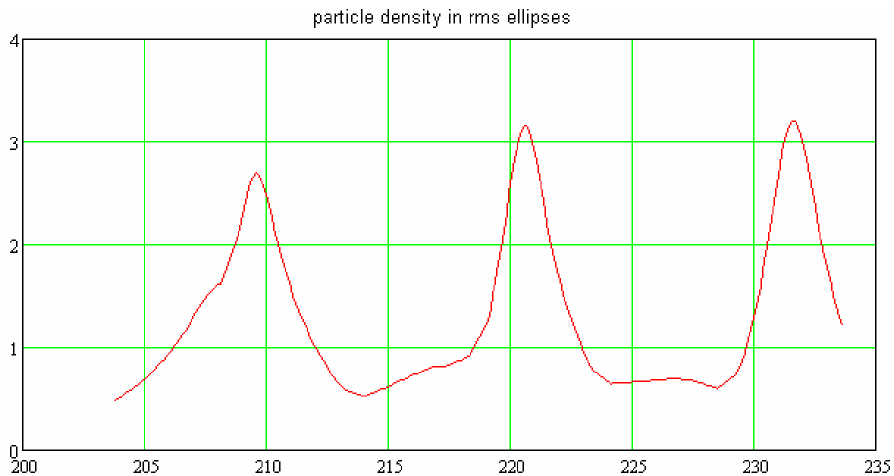
N = 200000

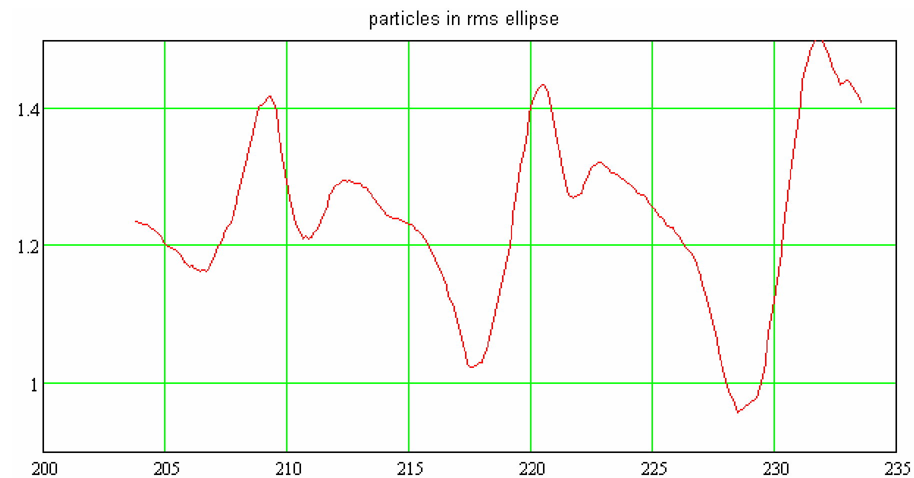
slice core bunch

slice:





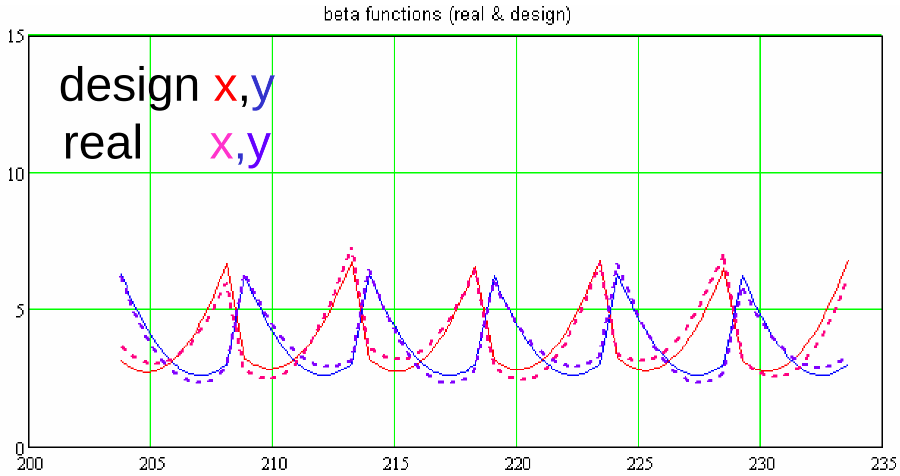


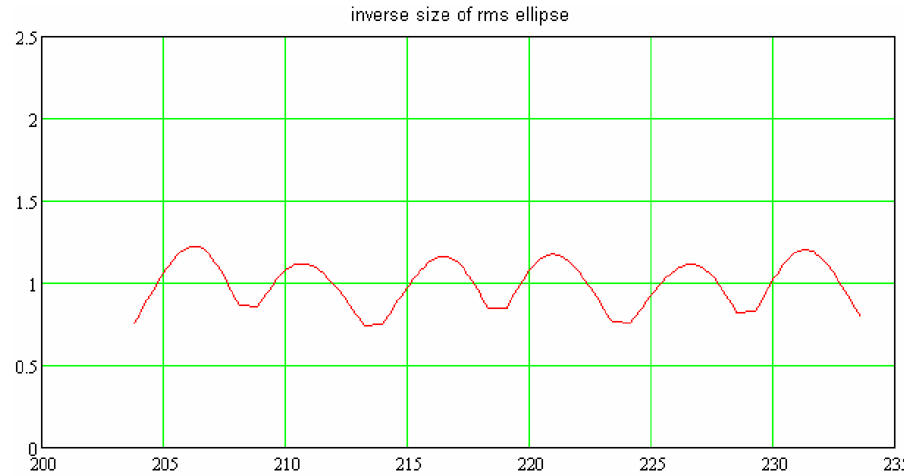


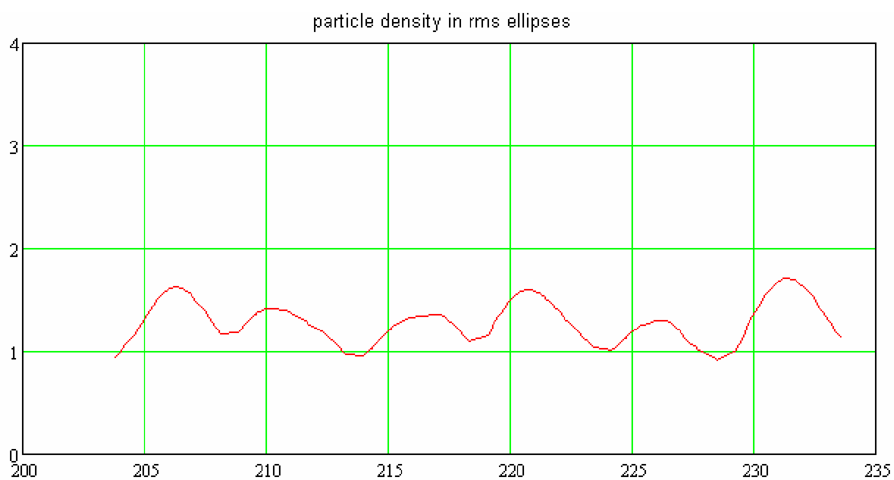
core match

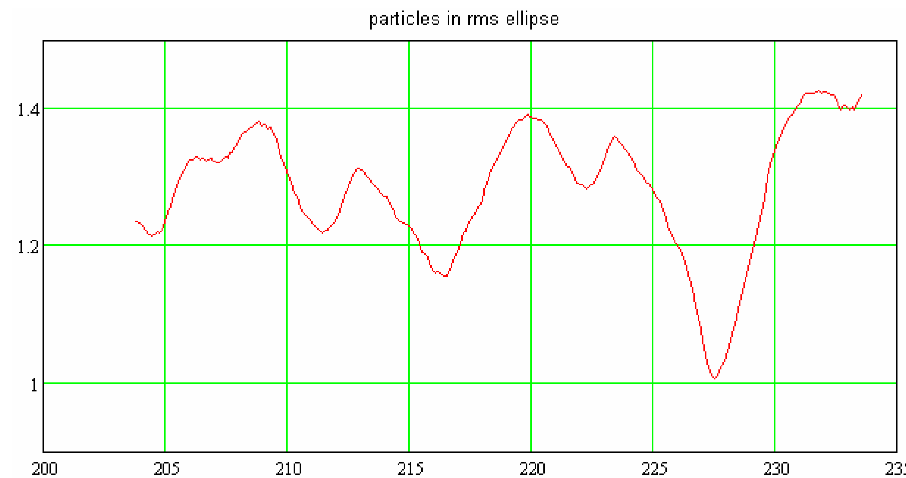
na = 95000 nb = 105000	n1 = 68510 n2 = 111196	N = 200000
slice	core	bunch

slice:

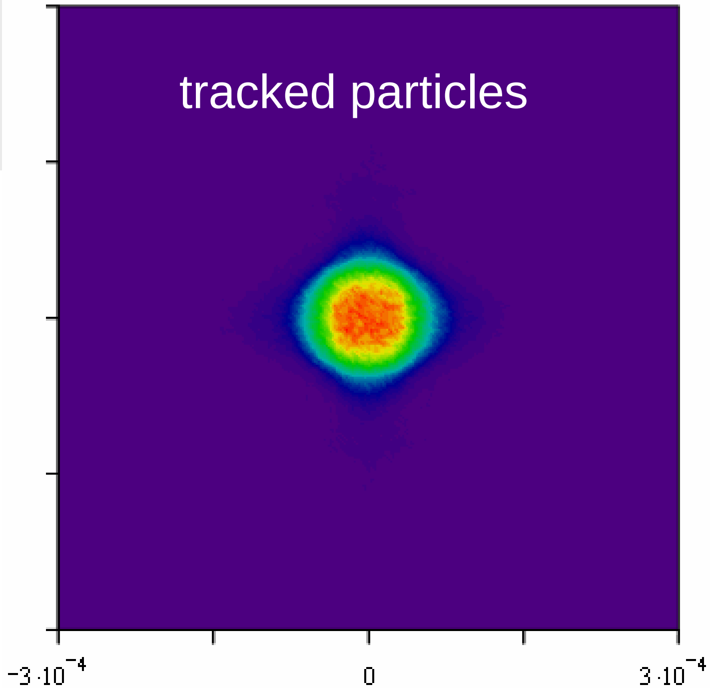


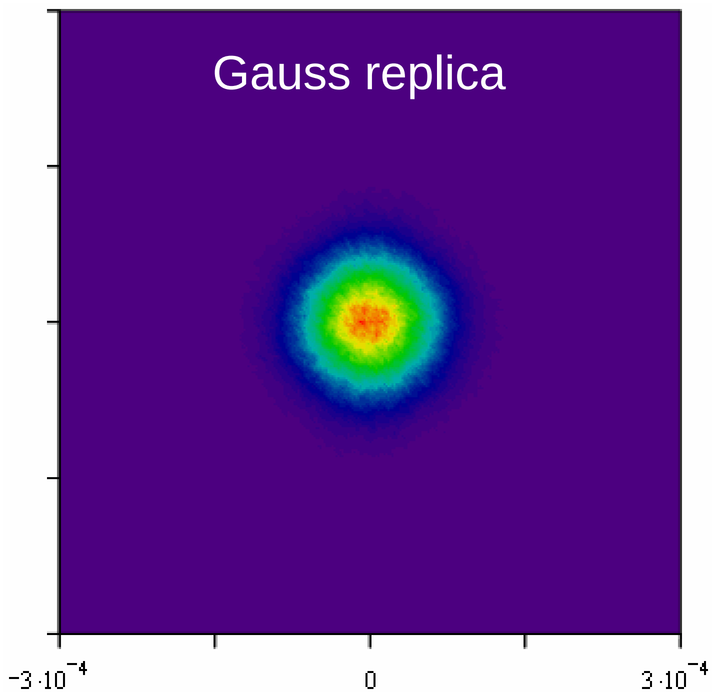


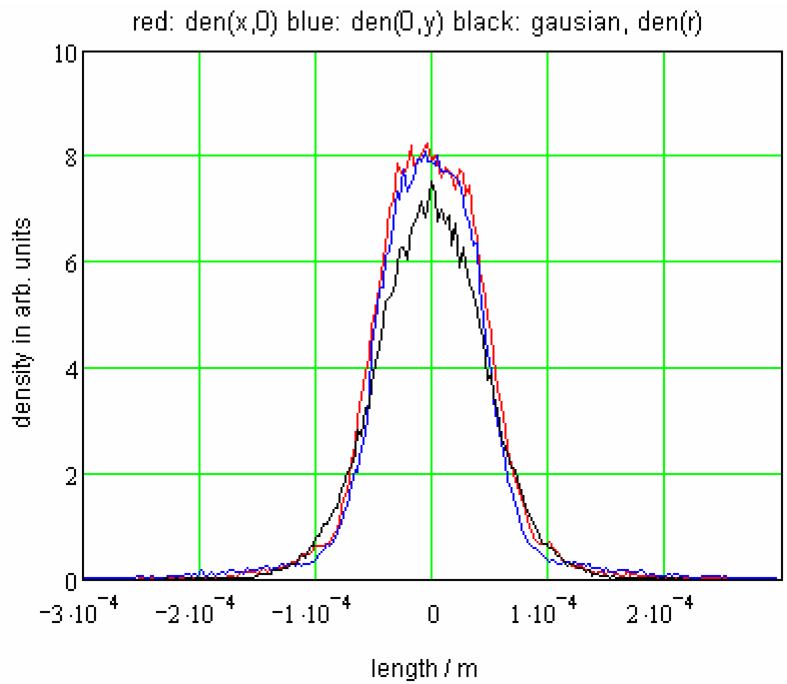


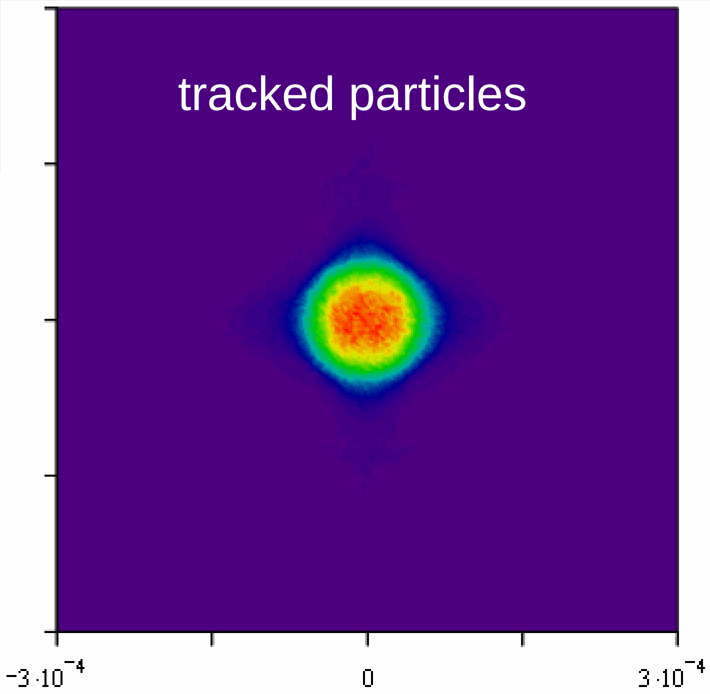


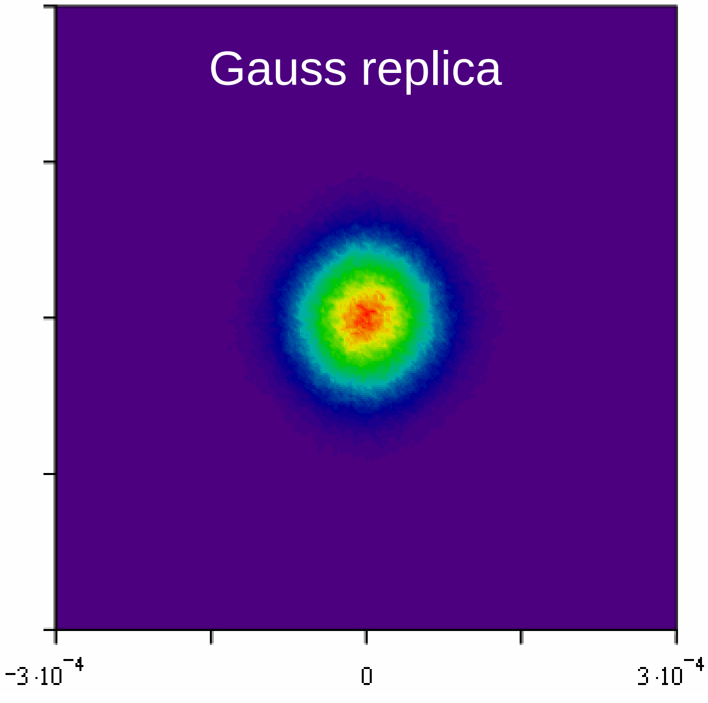
transverse profile – core match – averaged along undulator



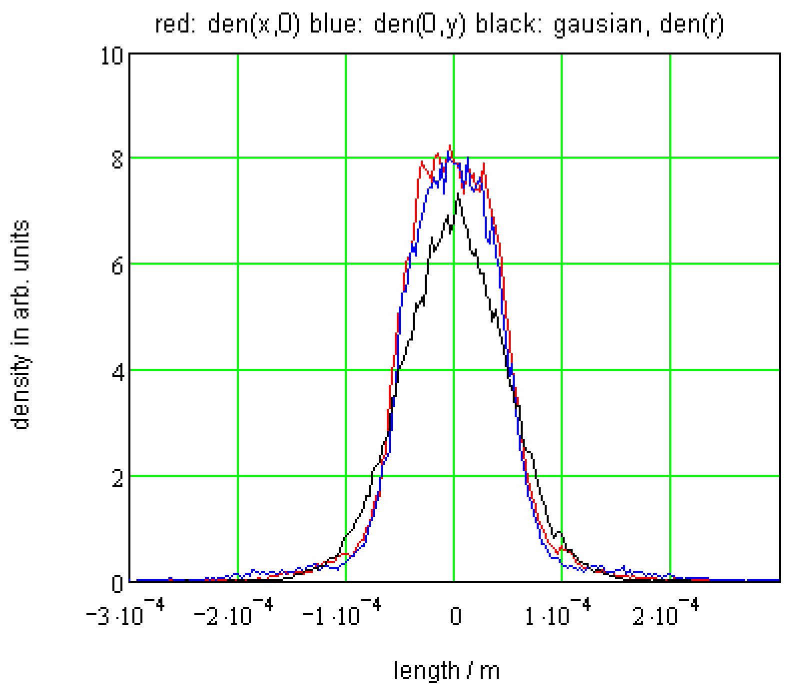








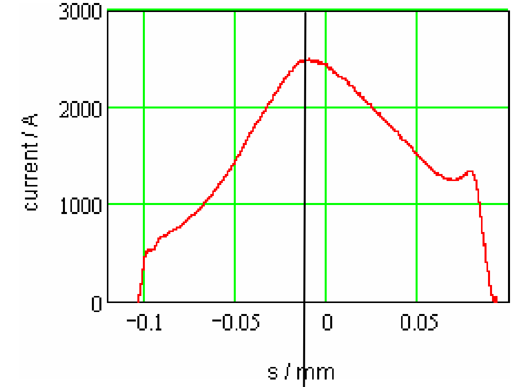
transverse profile – slice match – averaged along undulator

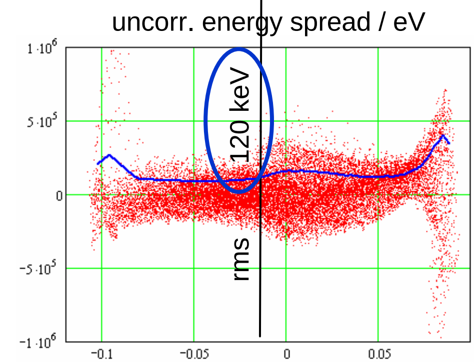


effective energy spread

$$\lambda_{ph} = \frac{\lambda_u}{(\gamma_0 + \delta\gamma)^2}\left(1 + \frac{K^2}{2}\right) + \lambda_u \frac{x'^2 + y'^2}{2}$$

$$\left(\frac{\delta\gamma}{\gamma_0}\right)_{\text{eff}} = \frac{\delta\gamma}{\gamma_0} - \frac{\lambda_u}{4\lambda_{ph}}\left(x'^2 + y'^2\right)$$





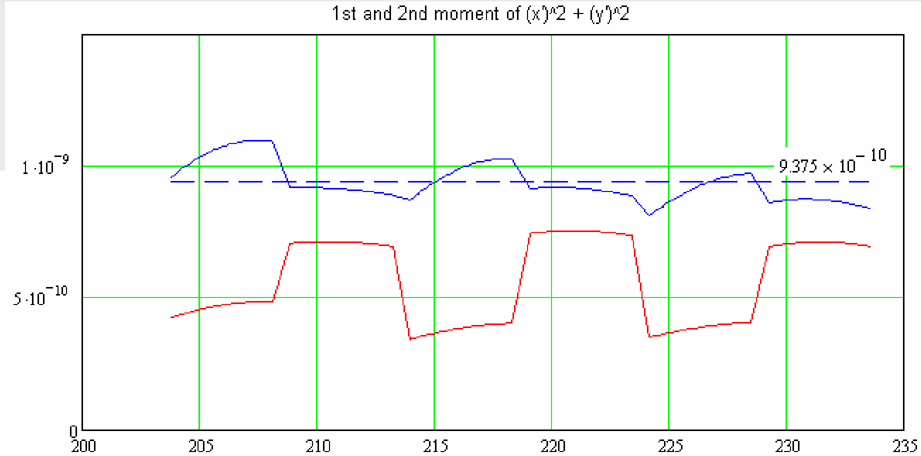
pseudo spread: $\text{rms}\left\{\left(\frac{\delta\gamma_{\text{pseu}}}{\gamma_0}\right)\right\} = \frac{\lambda_u}{4\lambda_{ph}} \text{rms}\left\{x'^2 + y'^2\right\}$

$$\text{rms}\left\{\left(\frac{\delta\gamma}{\gamma_0}\right)_{\text{eff}}\right\} = \sqrt{\left(\text{rms}\left\{\frac{\delta\gamma}{\gamma_0}\right\}\right)^2 + \left(\text{rms}\left\{\frac{\delta\gamma_{\text{pseu}}}{\gamma_0}\right\}\right)^2}$$

Gaussian

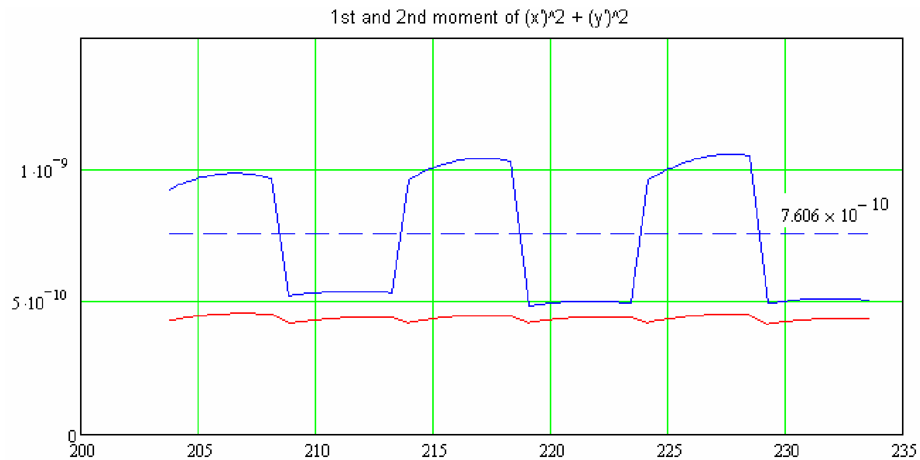
$$\text{rms}\left\{\left(\frac{\delta\gamma}{\gamma_0}\right)_{\text{eff}}\right\} = \sqrt{\left(\text{rms}\left\{\frac{\delta\gamma}{\gamma_0}\right\}\right)^2 + \left(\frac{\lambda_u}{4\lambda_{ph}}\left(\varepsilon_x\gamma_x + \varepsilon_y\gamma_y\right)\right)^2} \cong \sqrt{\left(\text{rms}\left\{\frac{\delta\gamma}{\gamma_0}\right\}\right)^2 + \left(\frac{\lambda_u}{2\lambda_{ph}}\frac{\varepsilon}{\min\{\beta\}}\right)^2}$$

bunch match



$$\mathrm{rms}\{\delta E_{\mathrm{pseu}}\} = 984\ \mathrm{keV}$$

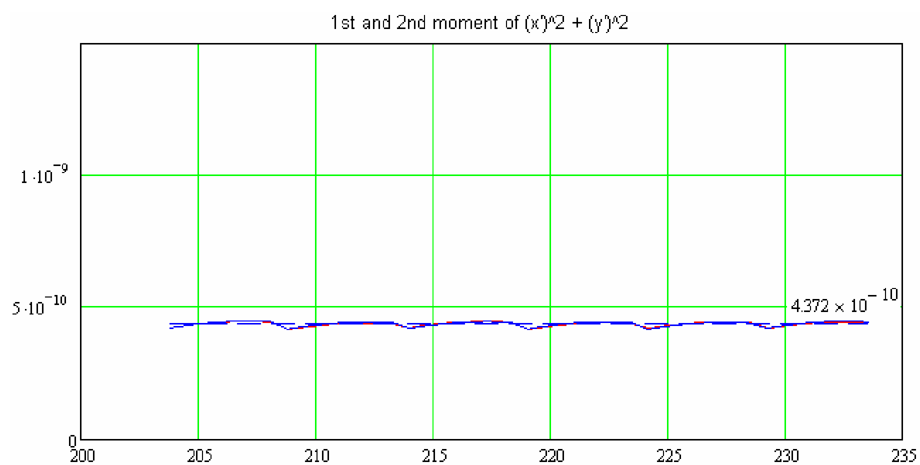
core match



$$\mathrm{rms}\{\delta E_{\mathrm{pseu}}\} = 799\ \mathrm{keV}$$

$$1020\,|\,578\ \mathrm{keV}$$

slice match
Gaussian bunch



$$\mathrm{rms}\{\delta E_{\mathrm{pseu}}\} = 459\ \mathrm{keV}$$

$$E_0 \frac{\lambda_u}{2\lambda_{ph}} \frac{\varepsilon}{\min\{\beta\}} = 437\ \mathrm{keV}$$

$$\varepsilon_n = 1.1\ \mu\mathrm{m}$$

$$\min\{\beta\} = 2.7\ \mathrm{m}$$

6. Summary

BC3 → collimator

rms beam properties underestimate real particle density

slice emittance is better than expected

therefore: SC effects are stronger

to be done: optics with SC effects

Undulator

rms beam properties underestimate real particle density

SC effects at 1GeV nearly negligible

peak current density larger than for Gaussian beam

pseudo energy spread (from emittance) larger than real energy spread

pseudo energy spread than for Gaussian beam