Effects of non-linear transverse space at FLASH

1 Observation of slice emittance growth (in simulation)

2 Analysis of core slice without self effects

slice model for particle dynamics

3 Core slice **with linear** self effects (round approximation)

round & linear slice model

4 Core slice **nonlinear** self effects (round approximation)

4.1 round & nonlinear slice model

4.2 comparison with Astra

5 Core slice **nonlinear** self effects, Cartesian

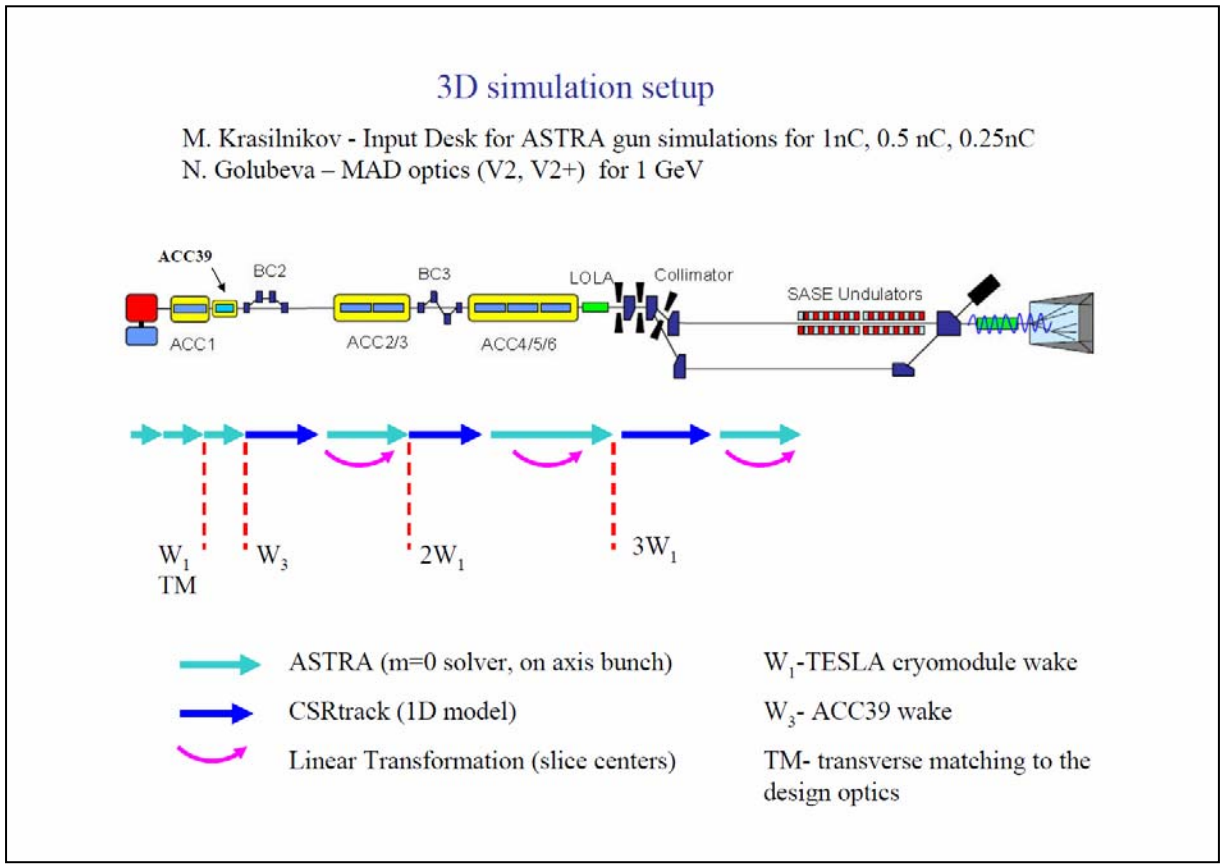
cartesian & nonlinear slice model

6 Emittance calculation

7 Conclusions

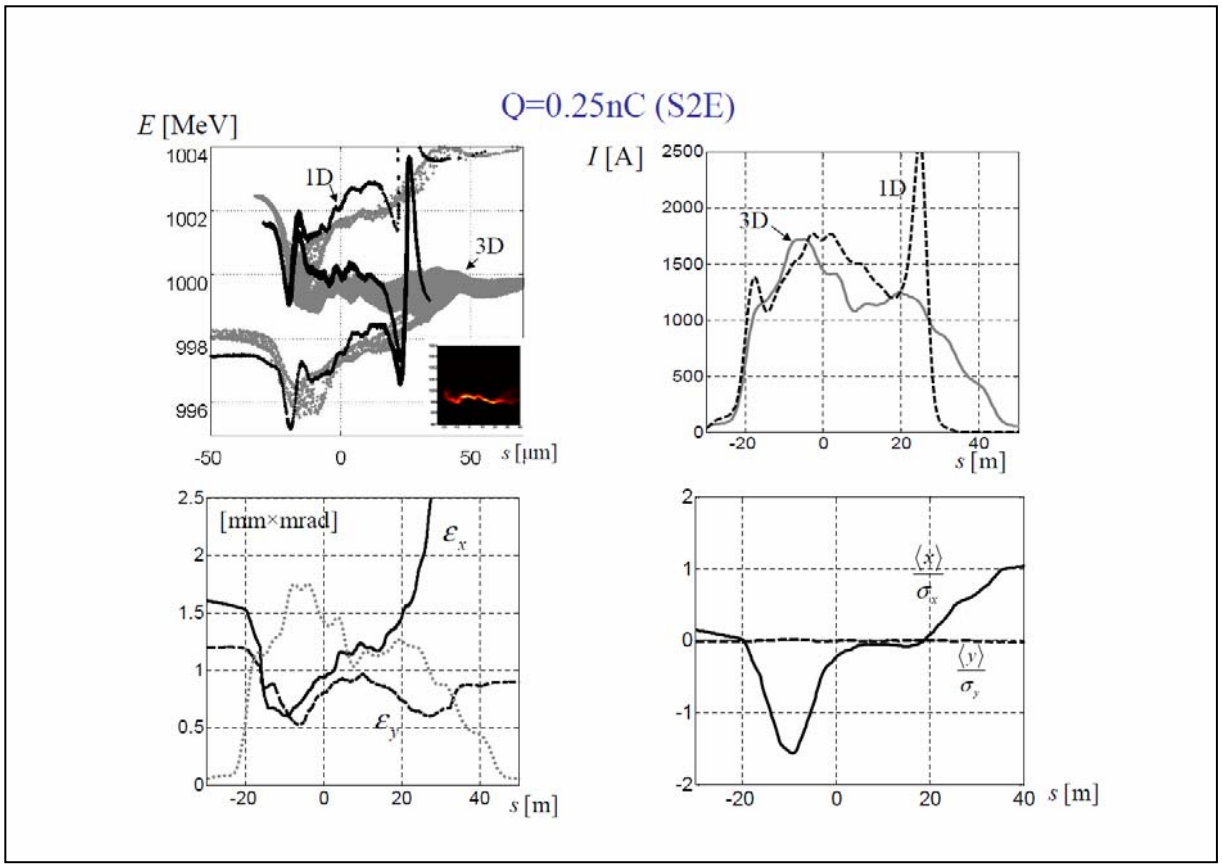
1 Observation of slice emittance growth (in simulation)

Zagorodnov, Igor
Expected Radiation in FLASH with 3rd Harmonic Module
(11.05.2009)



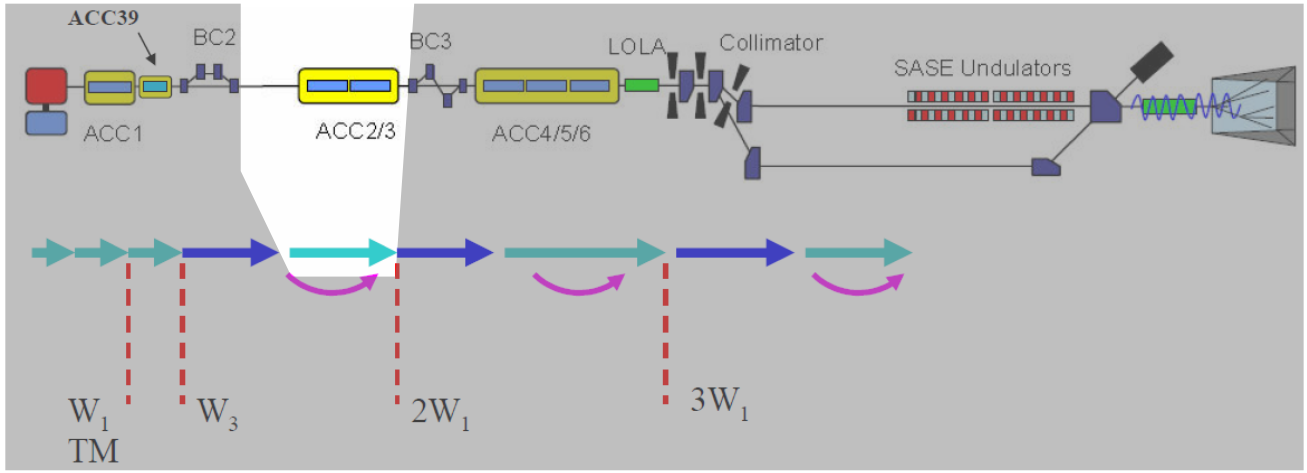
1 Observation of slice emittance growth (in simulation)

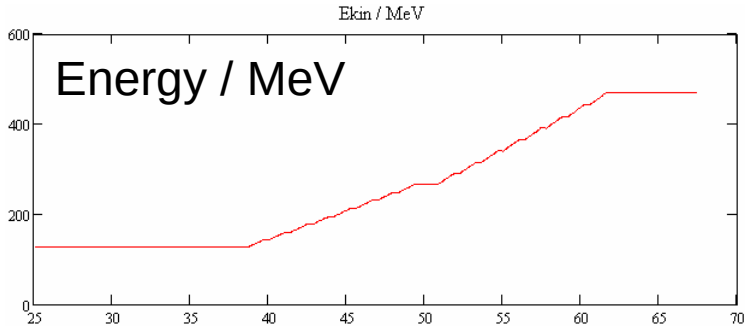
0.25 nC working point

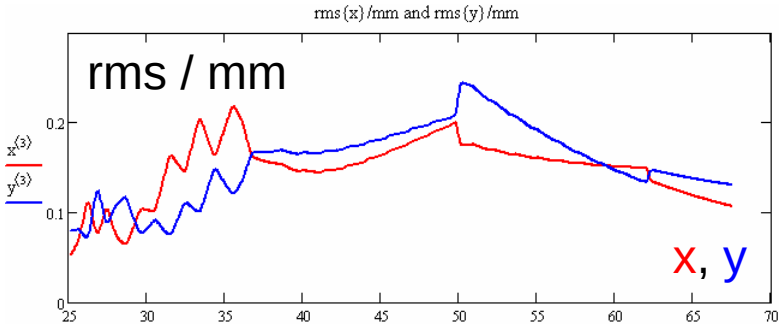


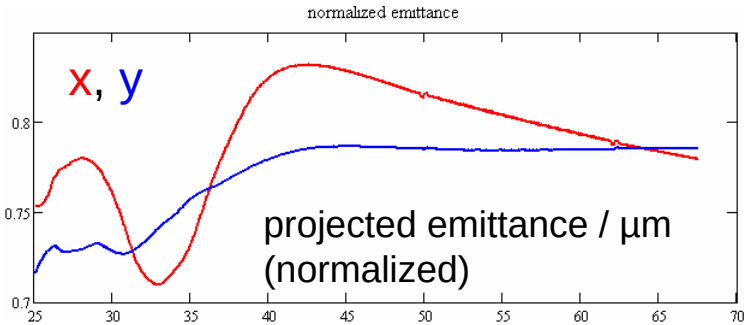
1 Observation of slice emittance growth (in simulation)

0.25 nC working point, after BC2, centroids extracted, ASTRA run

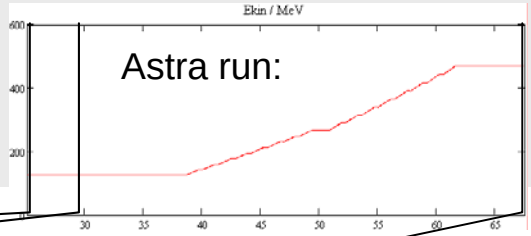


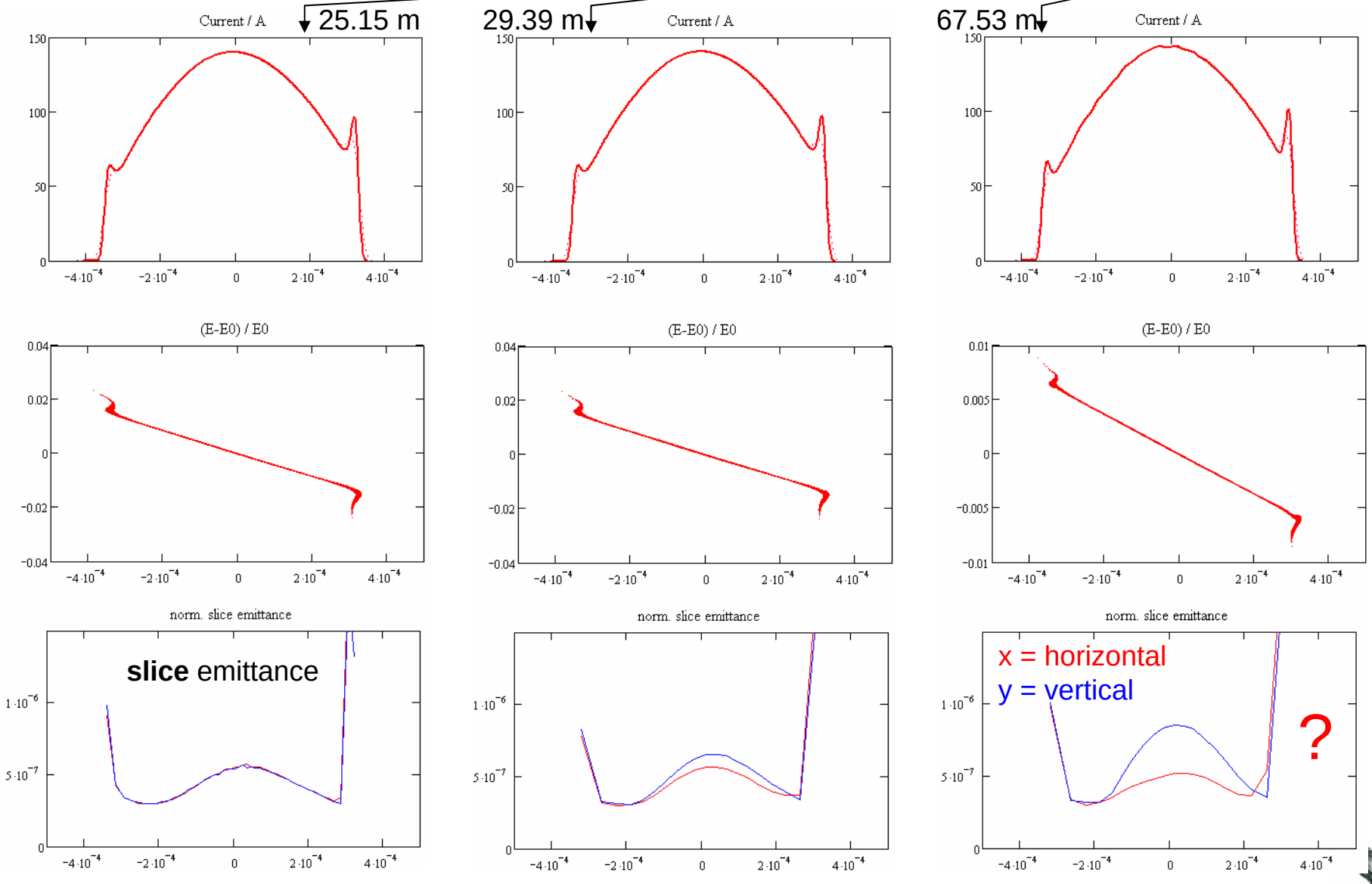




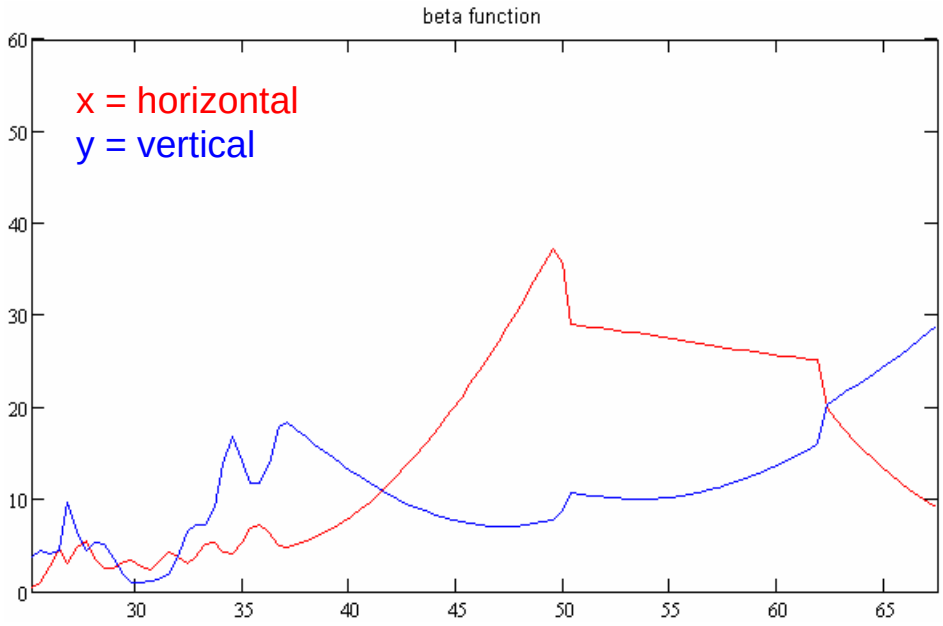


1 Observation of slice emittance growth (in simulation)





2 Analysis of core slice **without** self effects



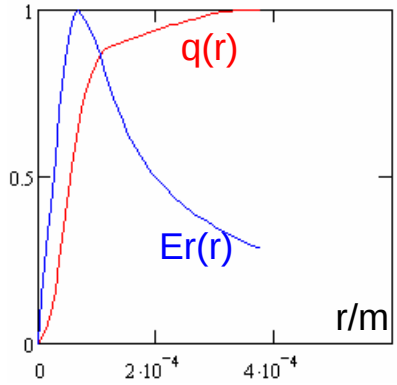
slice:

$$Q(r) = \sum_{\nu} q_{\nu} W_{\nu}$$

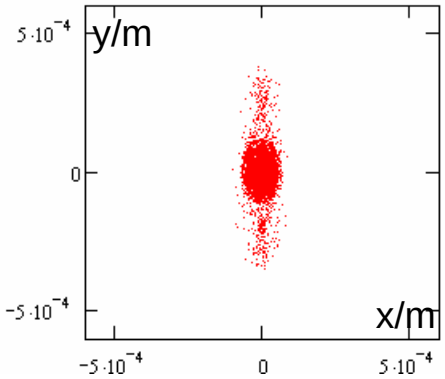
$$W_{\nu} = \begin{cases} 1 & r > \sqrt{x_{\nu}^2 + y_{\nu}^2} \\ 0 & \text{otherwise} \end{cases}$$

z=25 m

normalized radial functions



cut view



$$q(r) = Q(r)/Q(\infty)$$

$$E_r(r) \propto \frac{1}{r} \frac{Q(r)}{Q(\infty)}$$

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 $\mathbf{X}_p$

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

track from a to b with self effect

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

transverse self forces at “a” and “b”

slice model for particle dynamics

calculate transverse self force (r.i. round approximation)

$$E_r(r) \propto \frac{I/c_0}{2\pi\varepsilon}\frac{q(r)}{r}$$

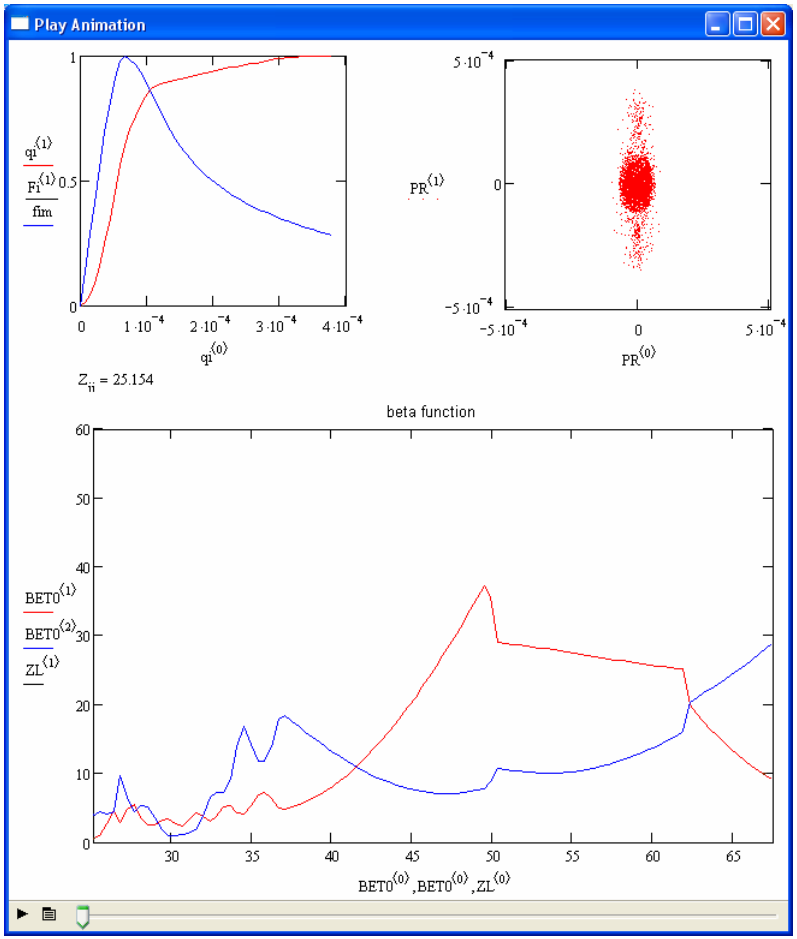
$$F_r(r) \propto \frac{e}{\gamma^2}E_r(r)$$

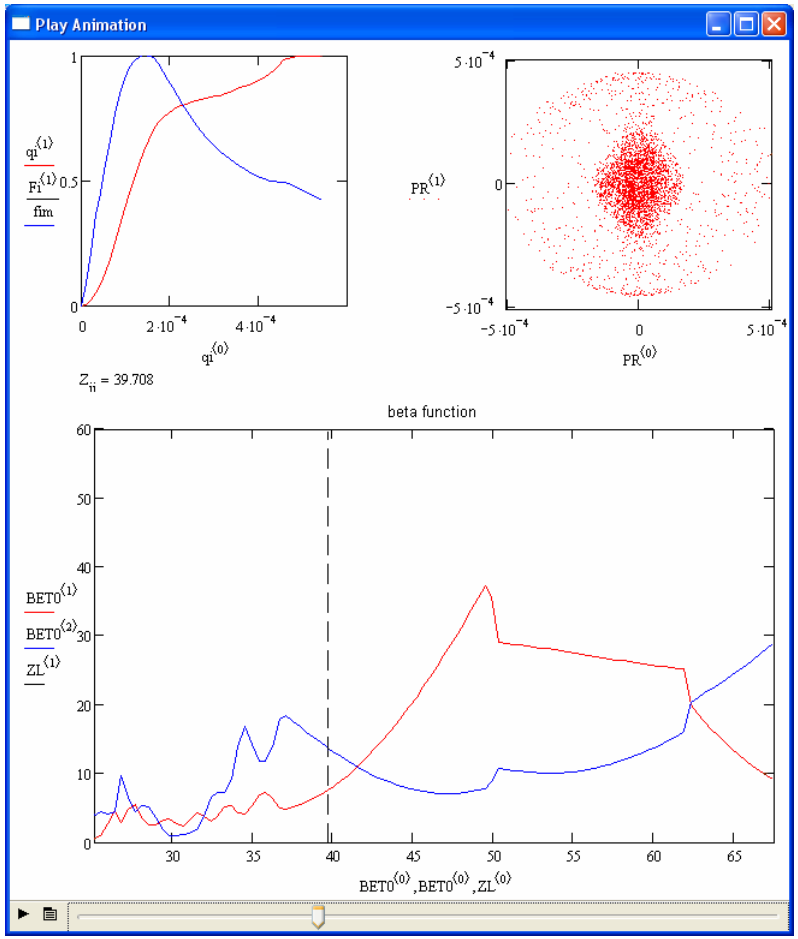
$$\Delta x' = \frac{\frac{x}{r}F_r(r)\Delta T}{P_z}$$

Cartesian calculation with solver on mesh

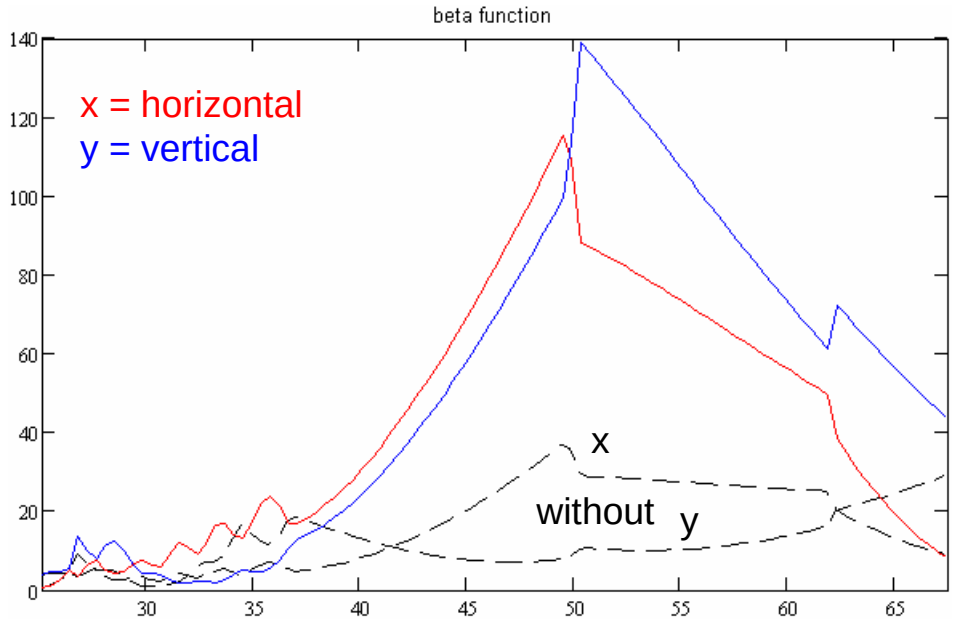
2 Analysis of core slice **without** self effects

Mathcad animation (density_no_force.avi):

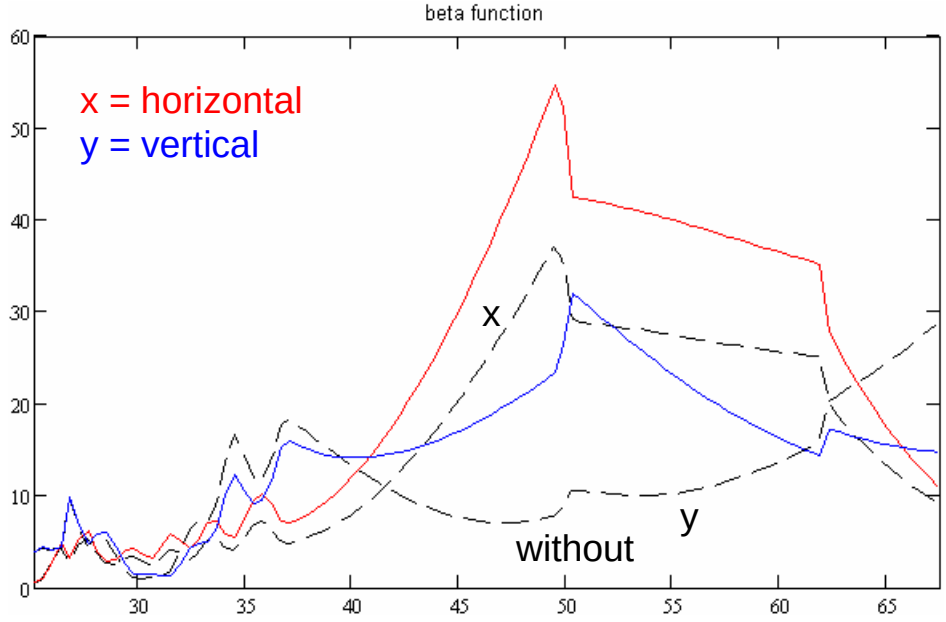




3 Core slice **with linear** self effects (round approximation)

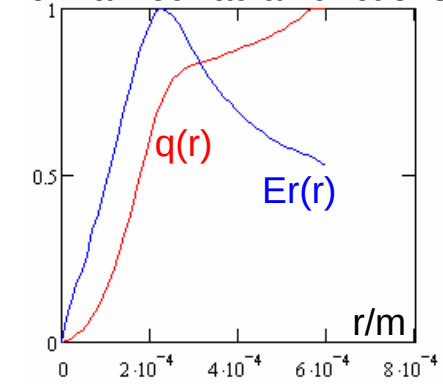


4 Core slice **with nonlinear** self effects (round approximation)

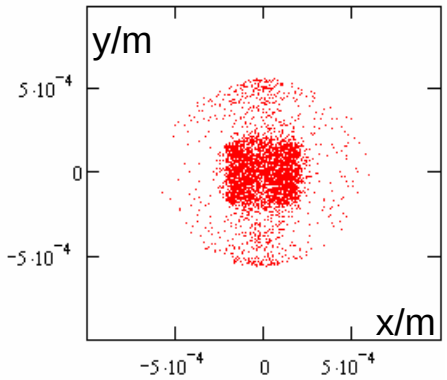


z=39 m

normalized radial functions

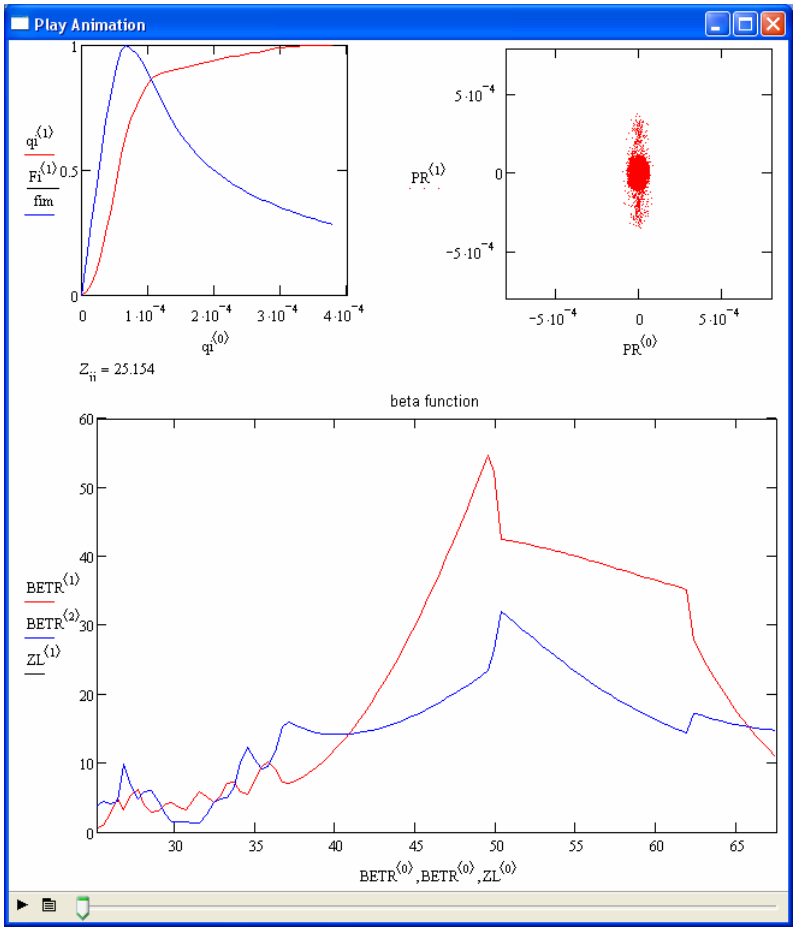


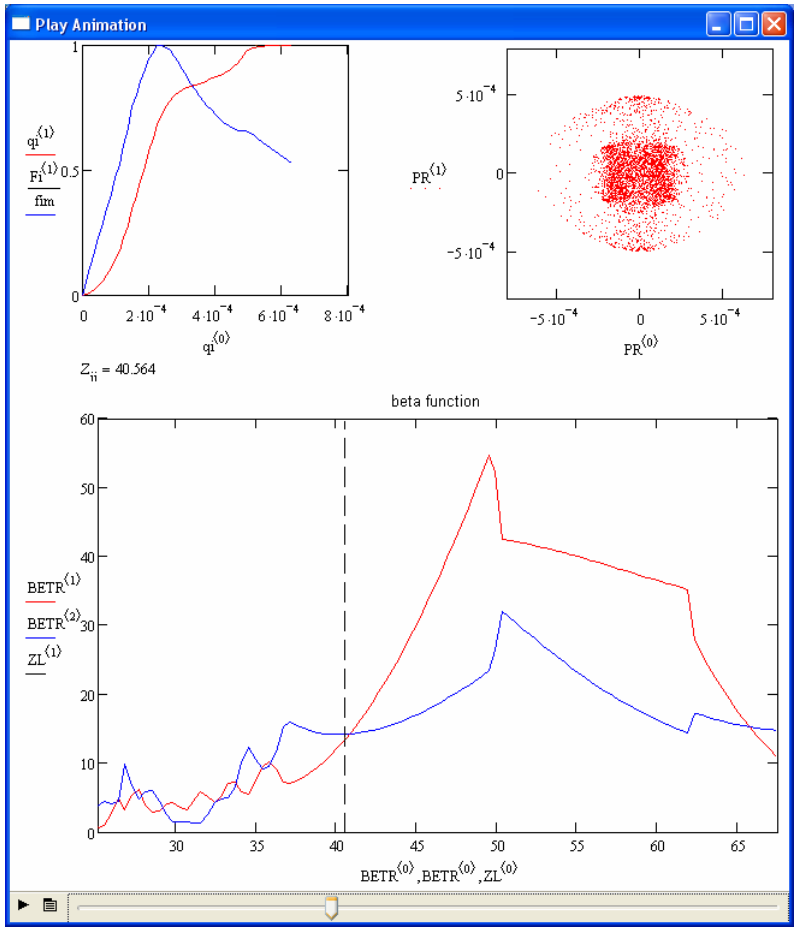
cut view



4 Core slice **with nonlinear** self effects (round approximation)

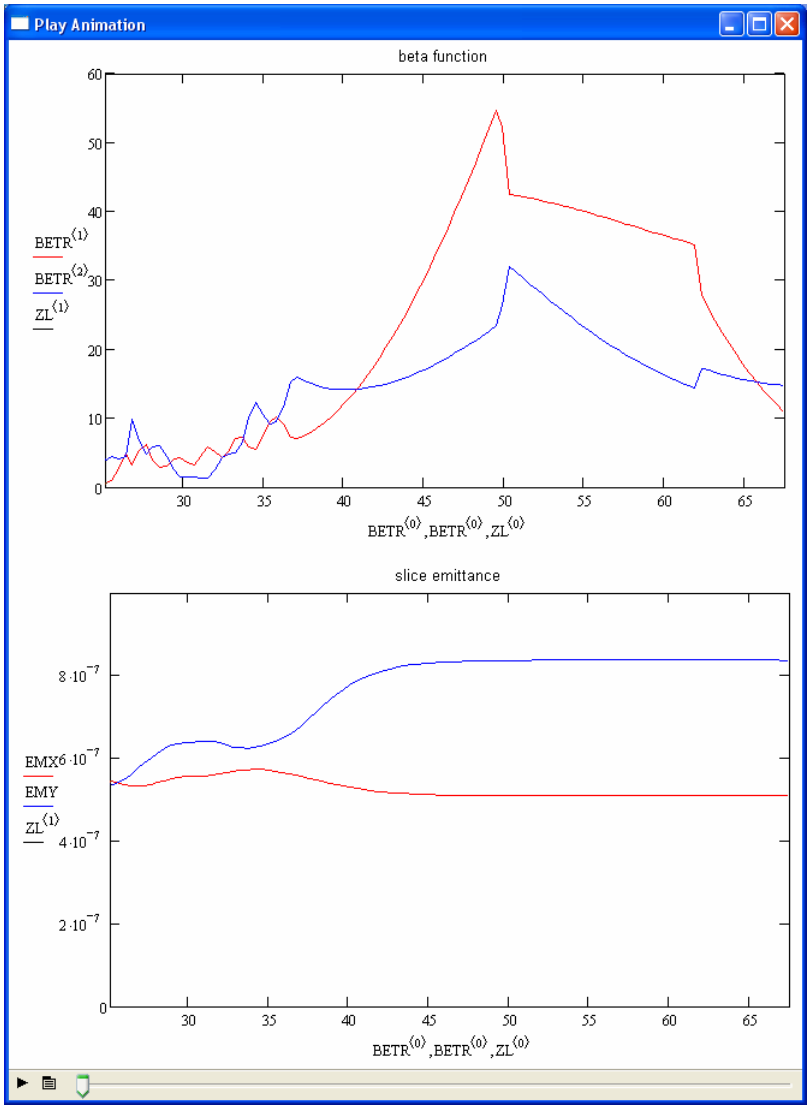
Mathcad animation (density_round_force_slefc.avi):

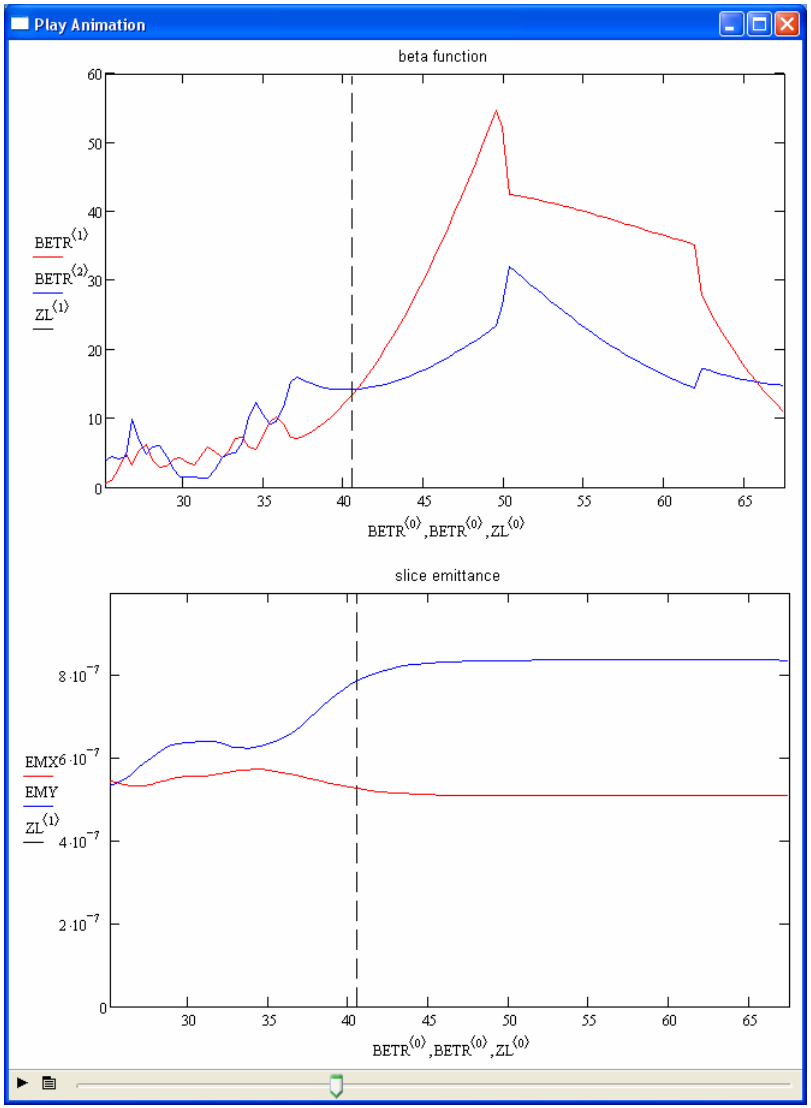




4 Core slice **with nonlinear** self effects (round approximation)

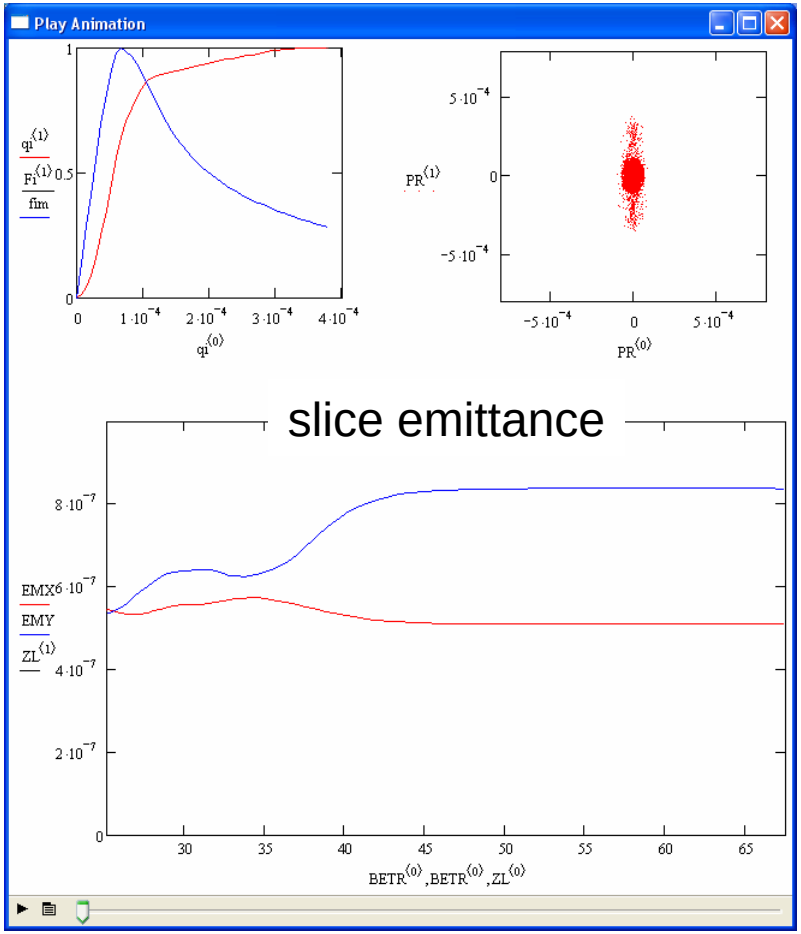
Mathcad animation (beta&emittance_round_force_slefc.avi):

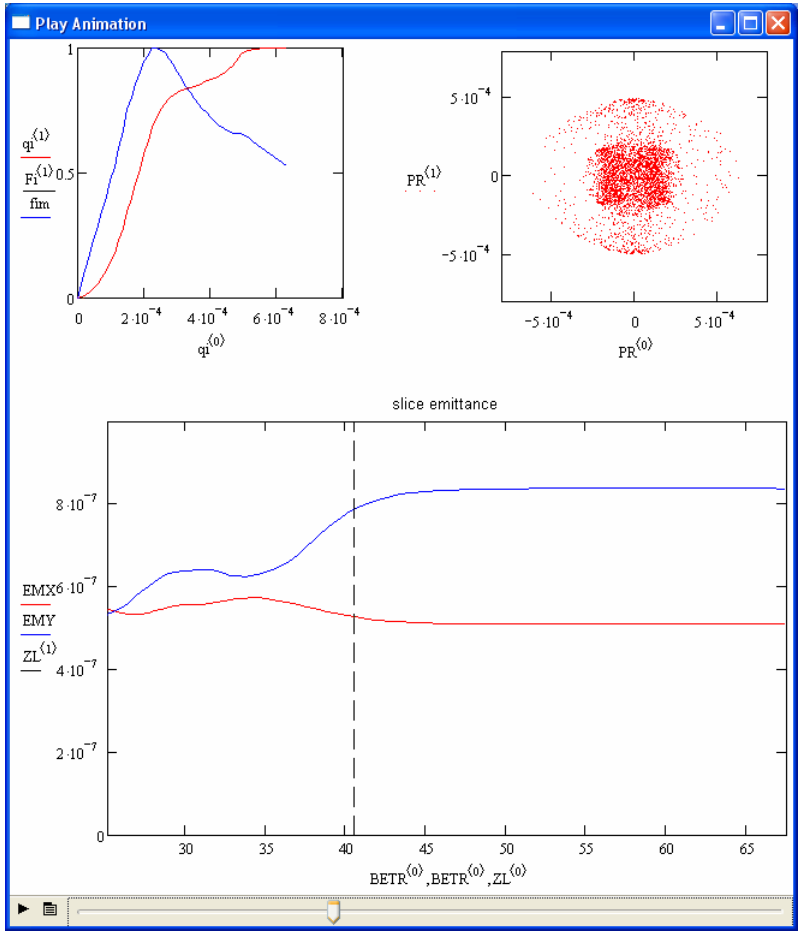




4 Core slice **with nonlinear** self effects (round approximation)

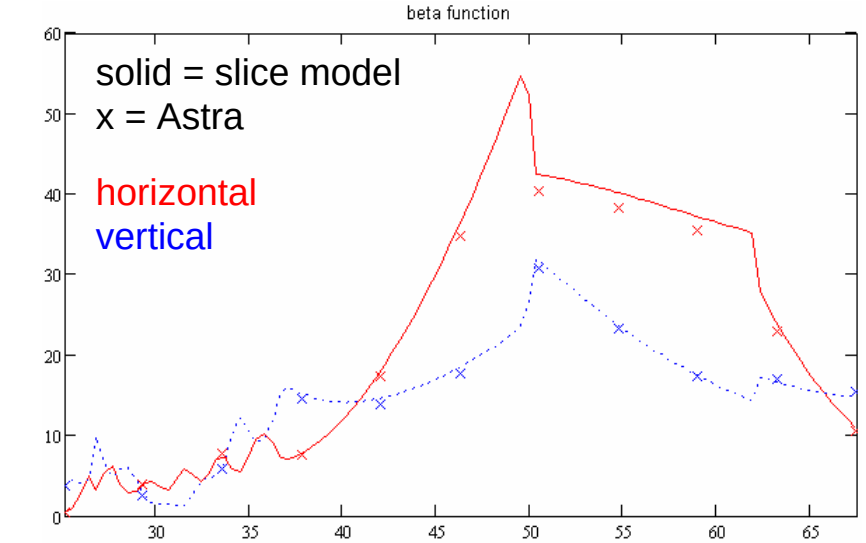
Mathcad animation (emittance_round_force_slefc.avi):

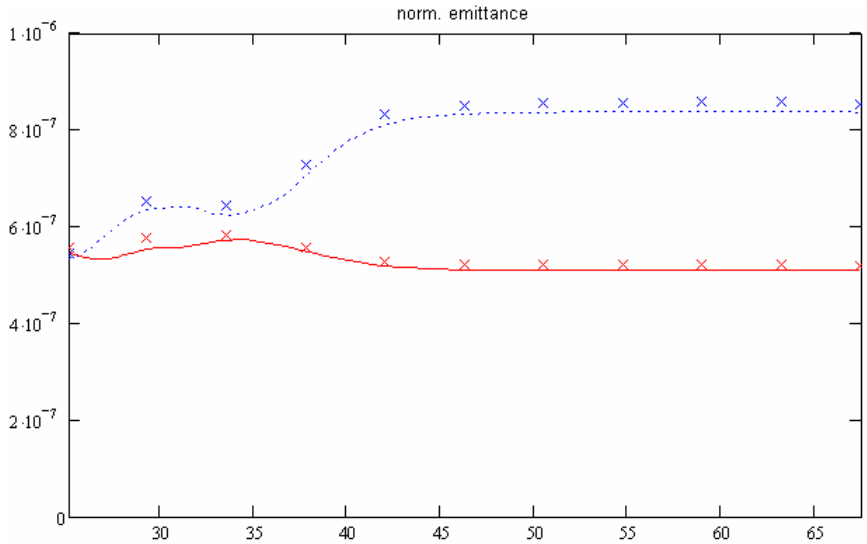




4 Core slice **with nonlinear** self effects (round approximation)

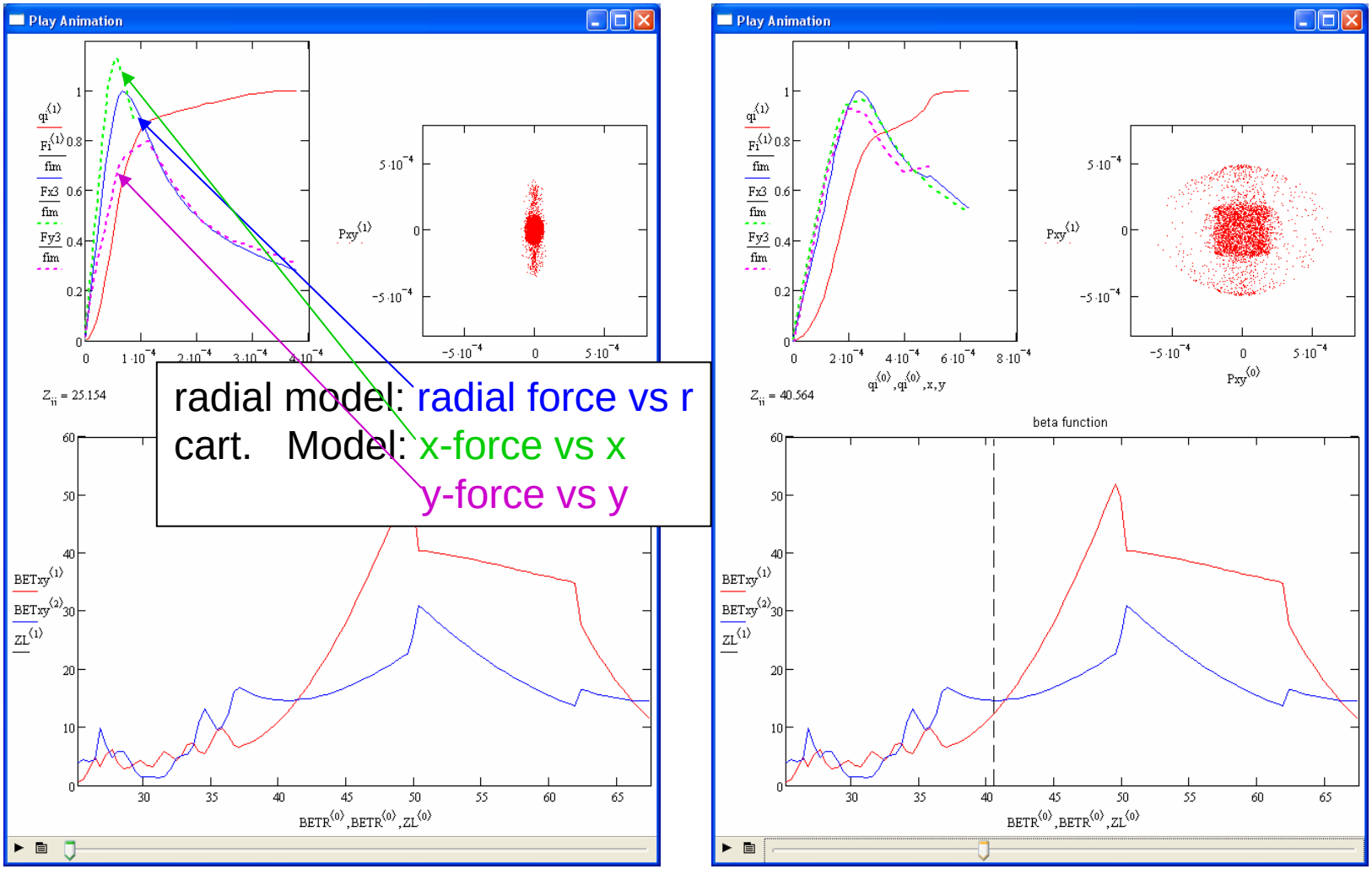
Comparison with ASTRA:



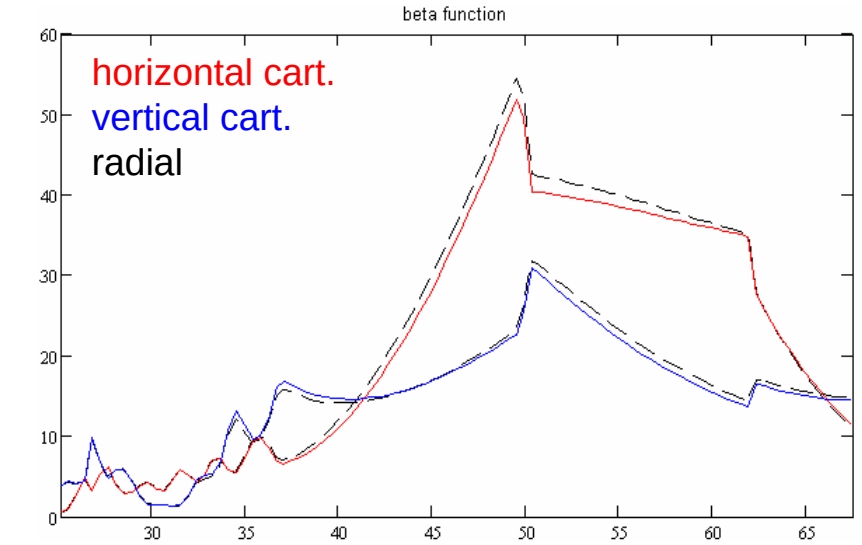


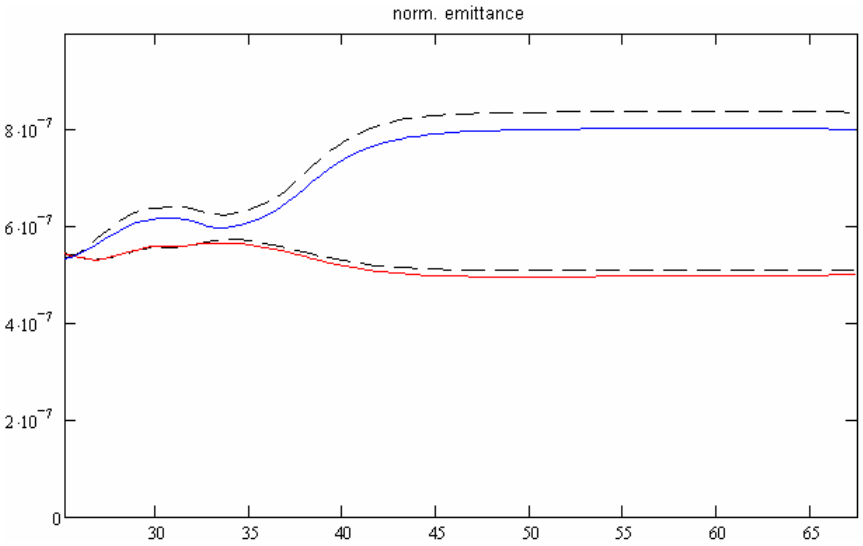
5 Core slice **with nonlinear** self effects, Cartesian

Mathcad animation (density_cartesian_force_slefc.avi):

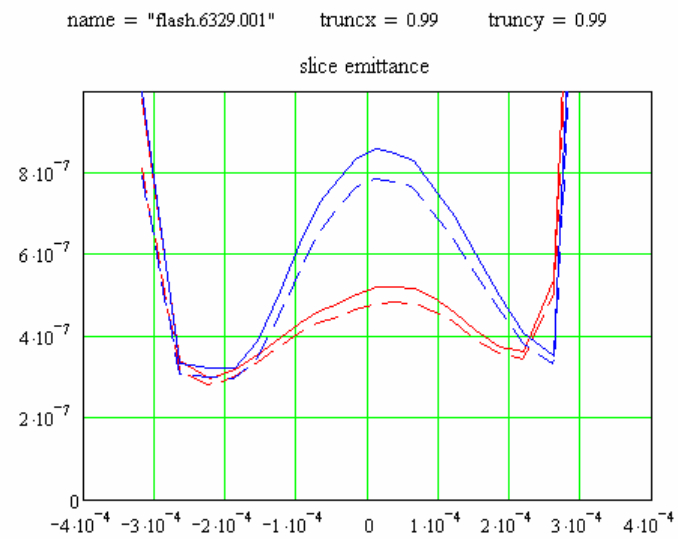


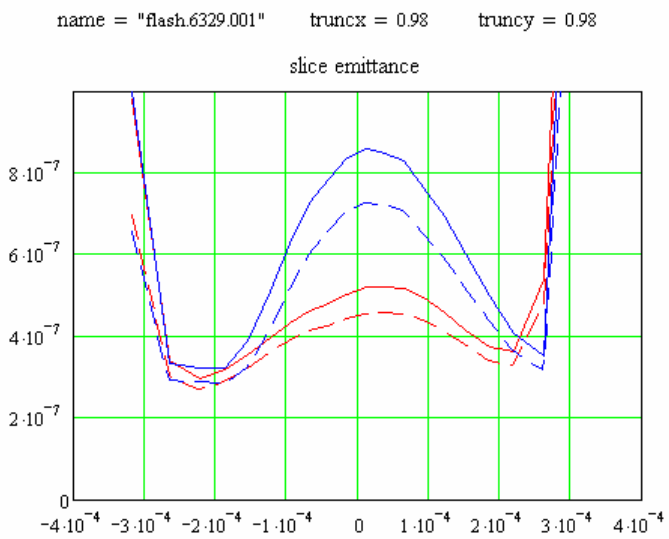
5 Core slice **with nonlinear** self effects, Cartesian

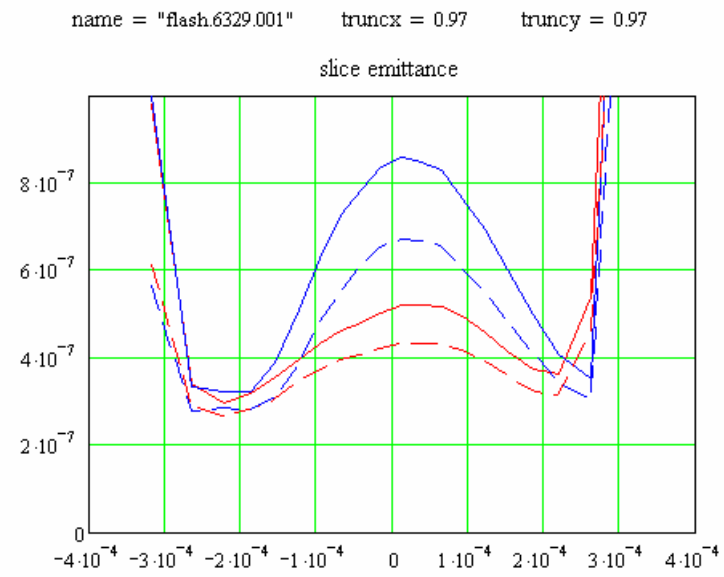


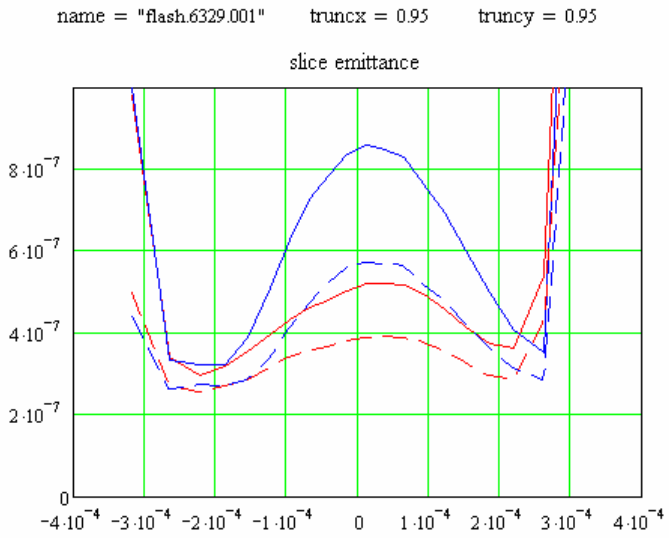


6 Emittance calculation









7 Conclusions

non Gaussian distribution

strong nonlinear SC effects in Flash after BC2

round SC model locally not precise

round SC model roughly ok for macroscopic parameters