Cavity Field Maps (TESLA & 3rd Harmonic Cavity)

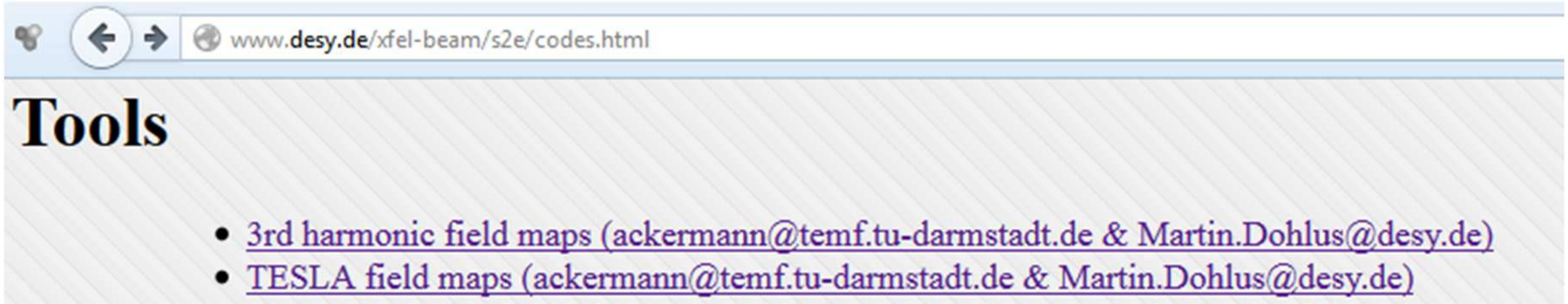
Undulator Wakes

Estimation of CSR Effects for FLASH2HGHG

Cavity Field Maps (TESLA & 3rd Harmonic Cavity)

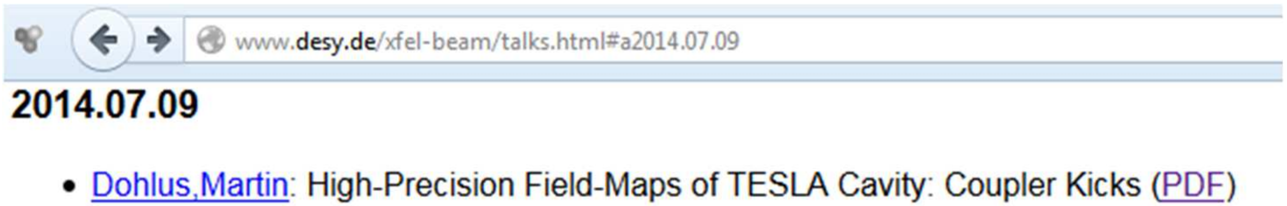
3D field map files for ASTRA in E3D format

files are available on home page



TESLA field maps

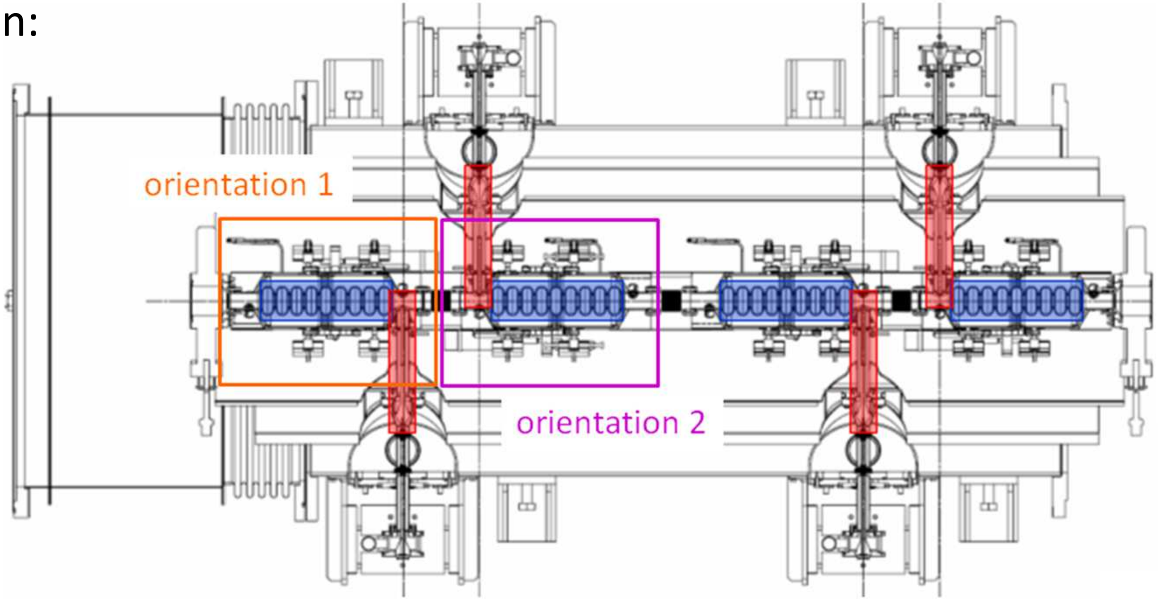
more info (= discrete coupler kicks) in:



3rd harmonic cavity

new calculations from E. Gjonai (DG, 2nd and 3rd order) http://www.desy.de/fel-beam/s2e/data/Harmonic3/CK39.pptx

orientation:



origin: in the middle of cell 5 (= middle of cavity)

files: E3D_3_9GHz-2order.dat — 2nd order, orientation 1
E3D_3_9GHz-3order.dat — 3rd order
E3D_3_9GHz-2order_yrot.dat — 2nd order, orientation 2
E3D_3_9GHz-3order_yrot.dat — 3rd order

mesh:
```
x/m from  -0.009   to 0.009   with stepwidth/m = 0.003
y/m       -0.009      0.009                      0.003
z/m       -0.30875    0.30875 in 2060 steps
```

discrete coupler kicks: see document

Undulator Wakes

matlab function for longitudinal wake of undulator

```
function [ Kern ] = kern_undulator( xy_param,z_param,du,nu1,nu2,gamma,lambda_u,K )
```

calculates kernel function for undulator trajectory for

- finite and infinite undulator,
- local or periode-averaged (only for infinite undulator),
- 1d beam or cross-section averaged,
- on axis or offset (for 1d beam)

"space charge" contribution is excluded by approach

as for all 1d CSR models: rigid bunch approximation !!!

it calculates wake kernel for longitudinal field: $\mathbf{E}((\text{test-length}) \to \text{test}) \cdot \mathbf{e}(\text{test})$

period averaged: $\langle \mathbf{E}((\text{test-length}) \to \text{test}) \cdot \mathbf{e}(\text{test}) \rangle_{\text{test}}$

$$\langle \mathbf{E}((\text{test-length}) \to \text{test}) \cdot \mathbf{e}_z \rangle_{\text{test}} \equiv 0 \quad !!!$$

it is essentially tail $\to$ head interaction

but: for 3d and/or offset, there is a head $\to$ tail contribution files and docu:

http://www.desy.de/~dohlus/UWake/

↓

undulator_docu.ppt   (definition, docu & examples)

Two Methods for the Calculation of CSR Fields (TESLA-FEL-2003-05)

kern_undulator.m	Matlab
example1.m	example
conv_fft.m	convolution

example:

$$\gamma = 500\mathrm{MeV}/m_o c^2$$
$$\varepsilon_x = \varepsilon_y = 1\,\mu\mathrm{m}/\gamma$$
$$\beta_x = \beta_y = 10\,\mathrm{m}$$
$$c_{xx} = c_{yy} = \varepsilon_x \beta_x$$
$$c_{xy} = 0$$

bunch 1:

$$\lambda(s) = \frac{q}{\sqrt{2\pi}\sigma_s} \exp\left(-\frac{1}{2}\left(\frac{s}{\sigma_s}\right)^2\right)$$

$$q = 0.5\,\mathrm{nC}$$

$$\frac{cq}{\sqrt{2\pi}\sigma_s} = 2\,\mathrm{kA}$$

bunch 2:

$$\lambda(s) = \frac{q}{\sqrt{2\pi}\sigma_s} \exp\left(-\frac{1}{2}\left(\frac{s}{\sigma_s}\right)^2\right)(1 + m\cos(ks))$$

$$q = 0.1\,\mathrm{nC} \qquad m = 0.02 \qquad k = 2\pi/(800\,\mathrm{nm})$$

$$\frac{cq}{\sqrt{2\pi}\sigma_s} = 2\,\mathrm{kA}$$

FLASH, SEEDING undulator

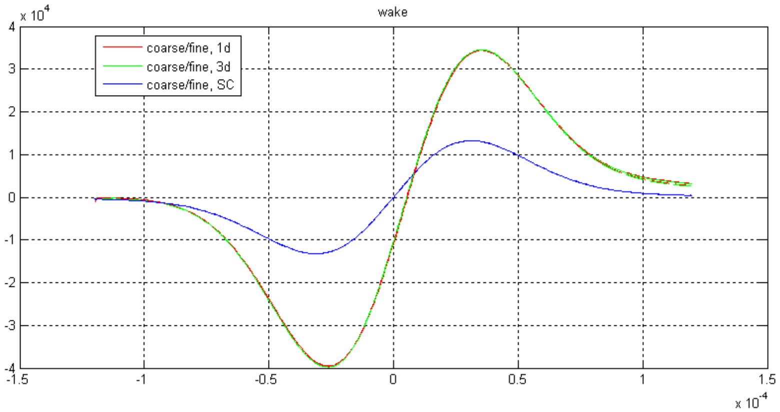
infinite undulator, periodic wake, Nav= 250

$$\gamma = 500\text{MeV} / m_o c^2$$

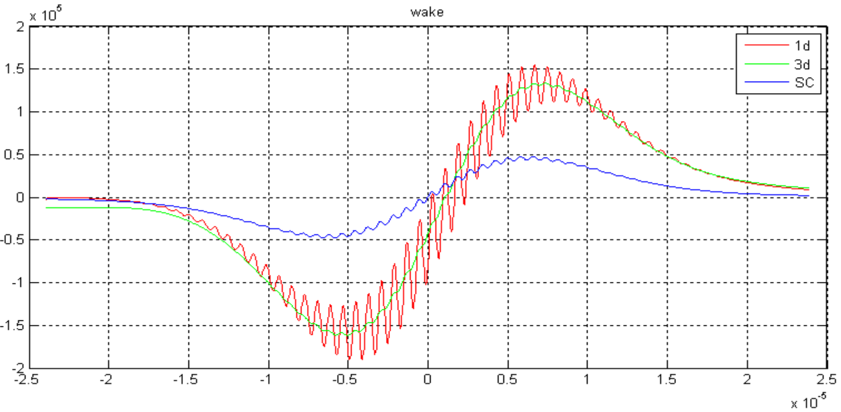
$$\lambda_u = 3.15\,\text{cm}$$

$$K = 2.83$$

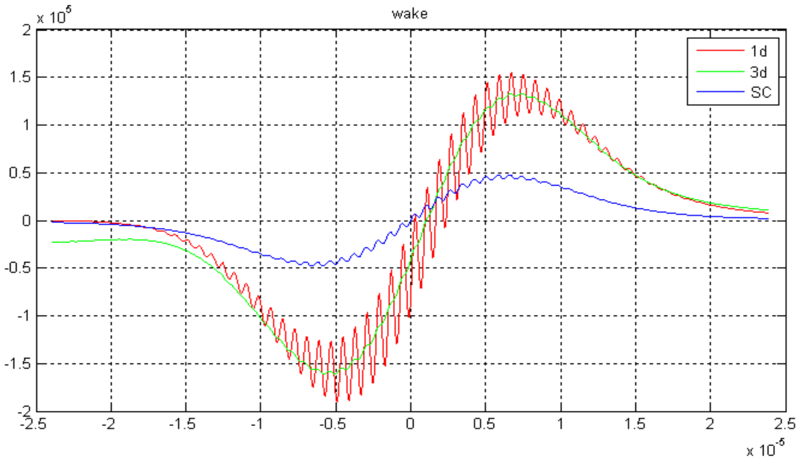
bunch 1 (0.5 nC), coarse du = 1 µm, fine du = 0.25 µm



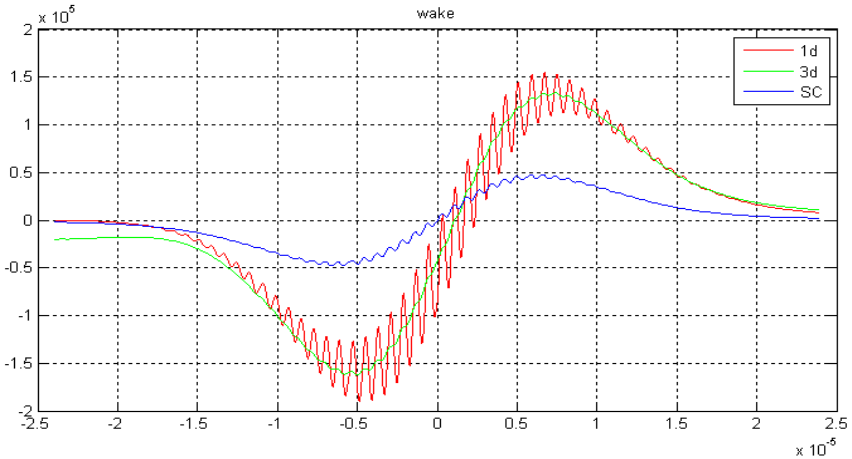
bunch 2 (0.1 nC, modulated), du = 0.040 µm



bunch 2 (0.1 nC, modulated), du = 0.080 µm, Nsigma = 4, Nstep = 25



bunch 2 (0.1 nC, modulated), du = 0.080 µm, (Nsigma = 3, Nstep = 13)



Estimation of CSR Effects for FLASH2HGHG

beam:
- energy ~ 1 GeV
- current ~ 1 kA
- slice energy spread ~ 0.15 MeV
- modulation wavelength ~ 266 nm
- modulation amplitude ~ 0.75 MeV
- sigma_x (before chicane) ~ 110 um
- norm. hor. slice emittance ~ 0.6 um
- norm. vert. slice emittance ~ 0.7 um

chicane:
- magnet length = 0.1 m
- drift length = 0.5 m
- middle drift = 0.2 m
- curvature radius (in magnets) ~ 14.5 m
- R56 ~ 53 um

some estimations:

charge in one wavelength $q_\lambda = I\dfrac{\lambda}{c} \approx 0.89\,\mathrm{pC}$

half of that charge can be compressed $q = q_\lambda/2$ (3)

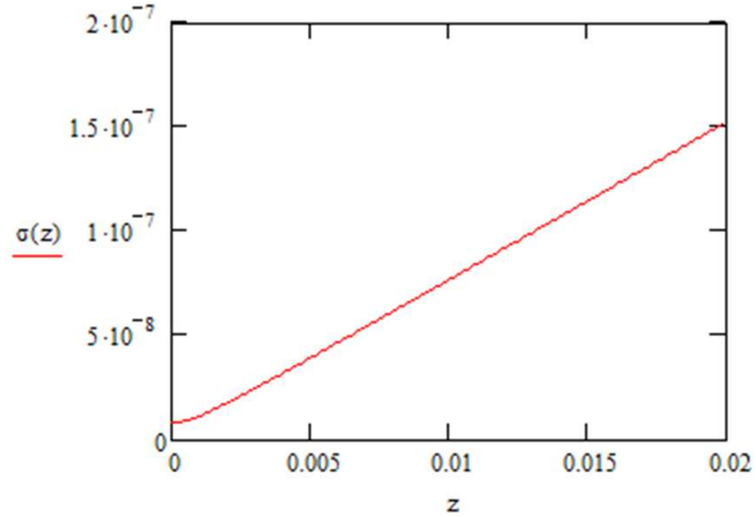
rms length after ideal compression $\sigma = r_{56}\,\sigma_{\mathcal{E}}/\mathcal{E} \approx 8\,\mathrm{nm}$ (1)

scaling of steady state csr of gaussian bunch $E_c := \dfrac{1}{\sqrt[3]{3}\cdot(2\cdot\pi)^{\frac{3}{2}}}\cdot\dfrac{1}{R^{\frac{2}{3}}\cdot\sigma^{\frac{4}{3}}}\cdot\dfrac{q}{\varepsilon} \approx 25\,\mathrm{MV/m}$

current spikes $\hat{I} = \dfrac{cq}{\sqrt{2\pi}\sigma} \approx 6.7\,\mathrm{kA}$ (3)

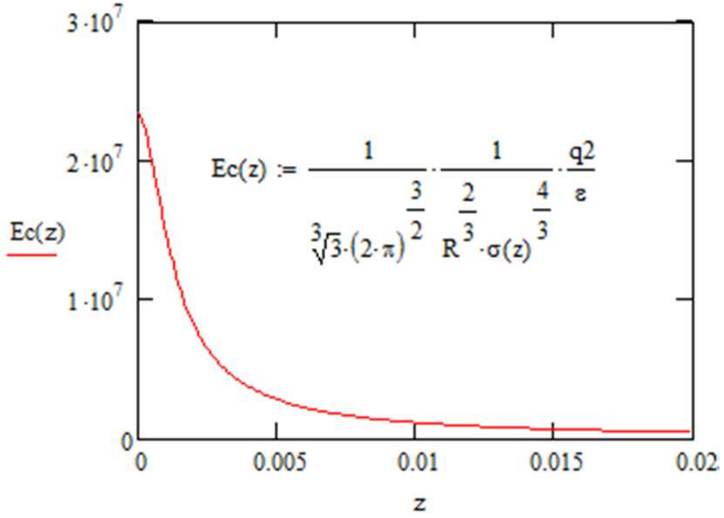
rms length with smearing $\sigma = \sqrt{\left(r_{56}\,\sigma_{\mathcal{E}}/\mathcal{E}\right)^2 + r_{51}^2\sigma_x^2 + 2r_{51}r_{52}\left\langle xx'\right\rangle + +r_{52}^2\sigma_{x'}^2}$

$\approx \sqrt{\left(r_{56}\,\sigma_{\mathcal{E}}/\mathcal{E}\right)^2 + \left(z/R\right)^2\sigma_x^2}$ (2)

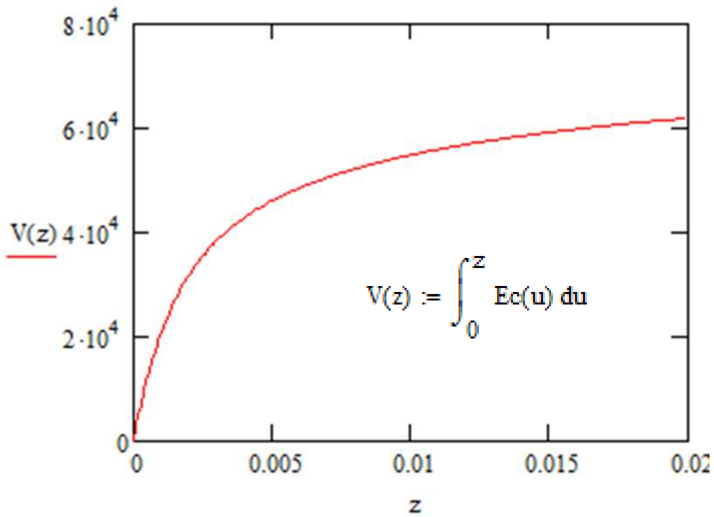


(1) $\rightarrow$ required resolution
(2) $\rightarrow$ required step width $\Delta\sigma \ll \sigma(0)$
(3) rough estimation

“steady state csr”



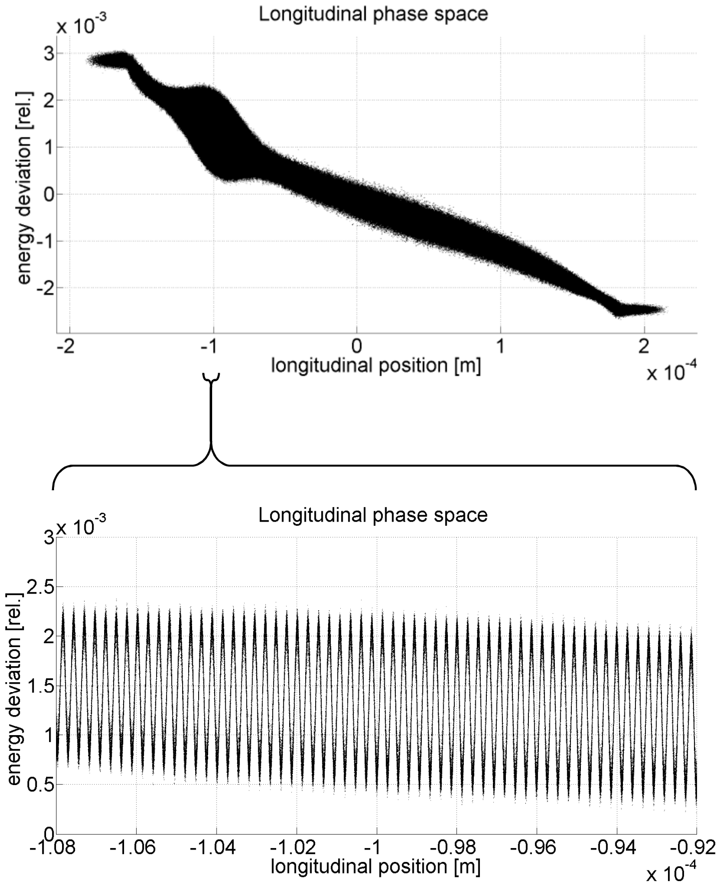
integrated “steady state csr”



CSRtrack simulation:

required resolution ~ 7 nm $\ll \sigma_{min} = r_{56}\, \sigma_{\mathcal{E}}/\mathcal{E}$

required step width ~ 0.3 mm $\ll R_{magnet}\, \sigma_{min}/\sigma_x$



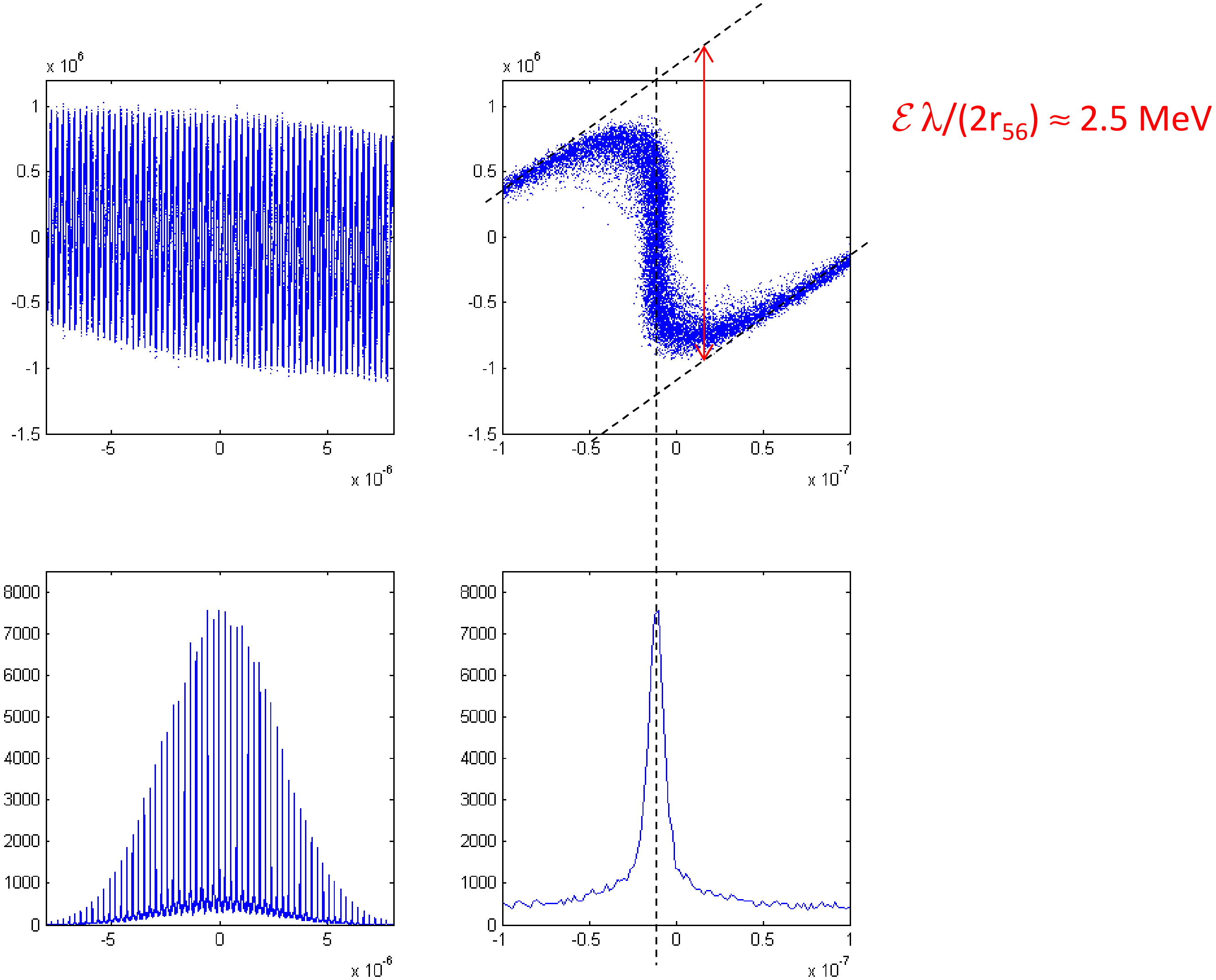
simulation of a short sub-range

length = 16 um

1E6 particles

gaussian profile with 6σ = 16 um

without self effects

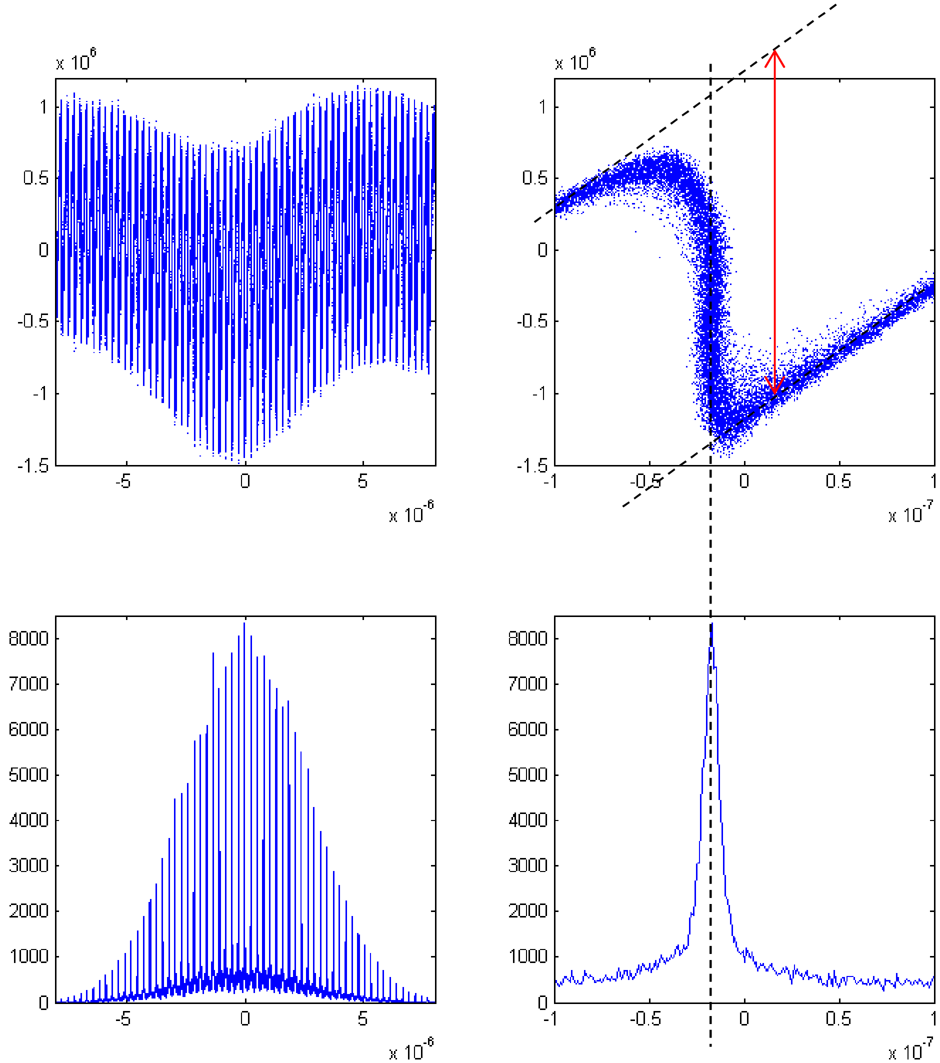


slice ~ 5 wavelength

norm. hor. slice emittance = 0.604 um

norm. vert. slice emittance = 0.706 um

with self effects



$\mathcal{E}\,\lambda/(2r_{56}) \approx 2.5$ MeV

slice ~ 5 wavelength
norm. hor. slice emittance = 0.605 um
norm. vert. slice emittance = 0.706 um