1 GeV FFAG
Space charge studies update
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Space charge

- OPAL 'Object Oriented Parallel Accelerator Library'
- 'Massively' parallel
- 3D space charge
- Interacting orbits

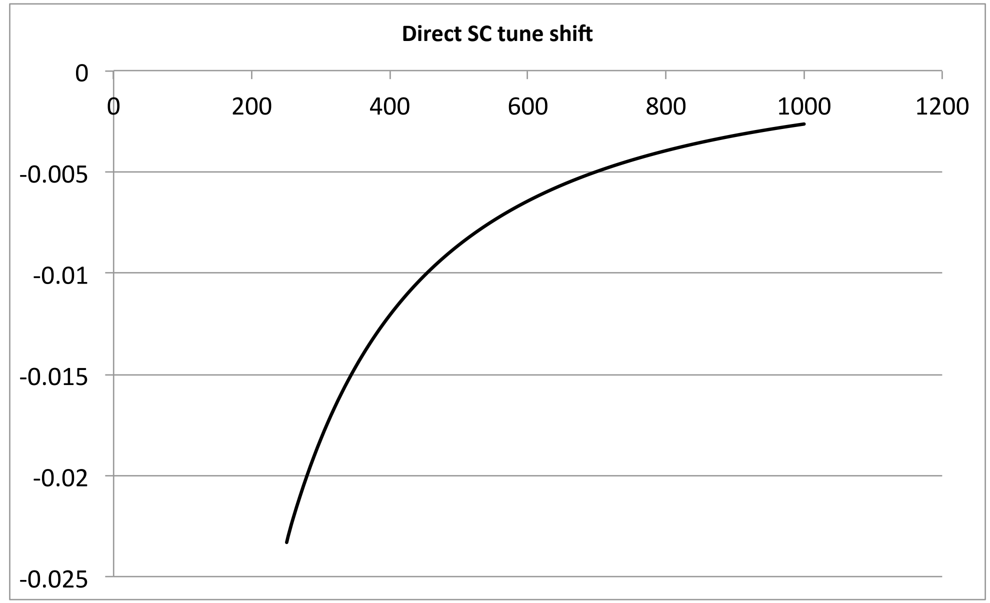
Direct SC for unbunched round beam in synchrotron (pretty unrealistic)

10 mA beam

100 pi mm mrad emittance (100%)

'smallest possible' tune shift is:

$$\Delta Q_{x,y}\left(inj\right) = \frac{-r_0 N}{2\pi\varepsilon_{x,y}\beta^2\gamma^3} = -0.023$$



Rate	Avg. orbit separation
1 MV/turn	0.21 cm
2 MV/turn	0.43 cm
4 MV/turn	0.85 cm
8 MV/turn	1.7 cm

OPAL co-ordinates

X - Horizontal position x of a particle in given global Cartesian coordinates [m].

PX - Horizontal momentum [eV/c].

Y - Longitudinal position x of a particle in global Cartesian coordinates [m].

PY - Longitudinal canonical momentum [eV/c].

Z - Vertical position z of a particle in global Cartesian coordinates [m].

PZ - Vertical canonical momentum [eV/c].

The independent variable is t [s].

Convert $\beta_x\gamma$ [dimensionless] to $[mrad]$,

$$(\beta\gamma)_{\text{ref}} = \frac{P}{m_0 c} = \frac{Pc}{m_0 c^2}, \tag{3.1}$$

$$P_x[mrad] = 1000 \times \frac{(\beta_x\gamma)}{(\beta\gamma)_{\text{ref}}}. \tag{3.2}$$

Convert from $[eV/\text{c}]$ to $\beta_x\gamma$ [dimensionless],

$$(\beta_x\gamma) = \sqrt{(\frac{P_x[eV/c]}{m_0 c} + 1)^2 - 1}. \tag{3.3}$$

This may be deduced by analogy for the y and z directions.

Simulation setup

Binomial distribution governed by a shape parameter, *m*

Table 14.1: Different distributions specified by a single parameter m

m	Distribution	Density	Profile
0.0	Hollow shell	$\frac{1}{\pi}\delta(1-r^2)$	$\frac{1}{\pi}(1-r^2)^{-0.5}$
0.5	Flat profile	$\frac{1}{2\pi}(1-r^2)^{-0.5}$	$\frac{1}{2}$
1.0	Uniform	$\frac{1}{\pi}$	$\frac{2}{\pi}(1-x^2)^{0.5}$
1.5	Elliptical	$\frac{3}{2\pi}(1-r^2)^{0.5}$	$\frac{1}{4}(1-x^2)$
2.0	Parabolic	$\frac{2}{\pi}(1-r^2)$	$\frac{3}{8\pi}(1-x^2)^{1.5}$
$\rightarrow\infty$	Gaussian	$\frac{1}{2\pi\sigma_x\sigma_y}exp(-\frac{x^2}{2\sigma_x^2}-\frac{y^2}{2\sigma_y^2})$	$\frac{1}{\sqrt{2\pi*\sigma_x}}exp(-\frac{x^2}{2\sigma_x^2})$

Dist1:DISTRIBUTION, DISTRIBUTION=BINOMIAL,

sigmax= 10.0e-3, sigmapx=243, corrx=0.0,mx=1.0,

sigmay= 10.0e-3, sigmapy=243, corry=0.0,my=1.0,

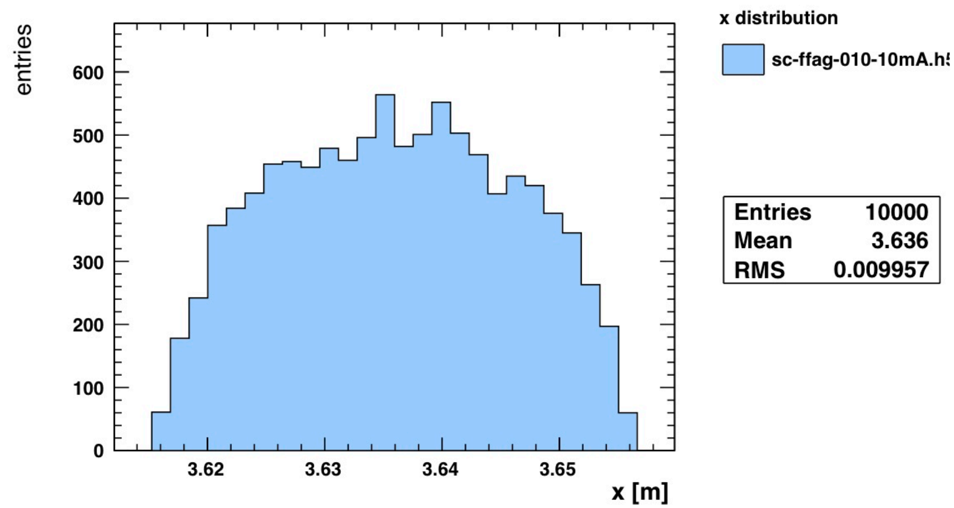
sigmat= 10.0e-3, sigmapt=243, corrt=0.0,mt=1.0;

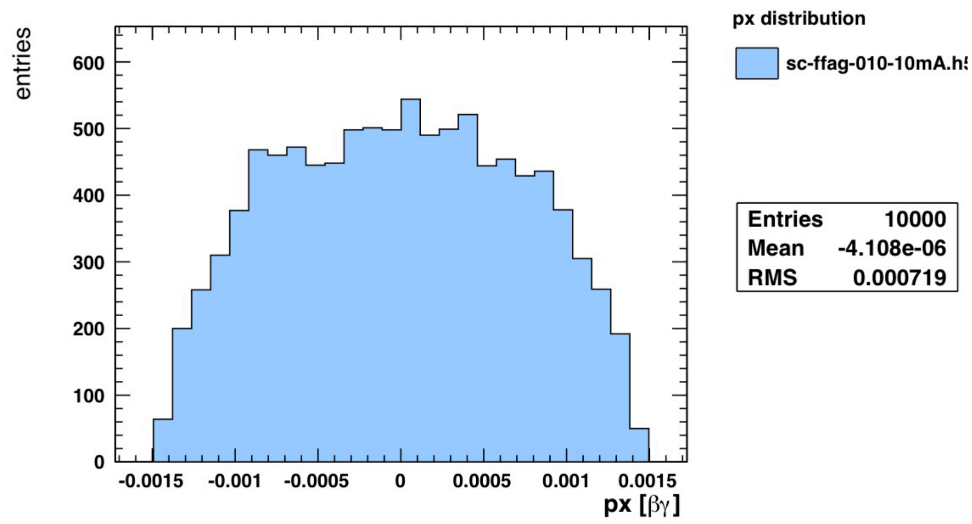
- Using $\varepsilon_{rms}(x,y)$=10 pi mm mrad
- σ_x=10mm σ_{px}=1mrad
- σ_y=10mm σ_{py}=1mrad
- σ_t=10mm σ_{pt}=1mrad ← just a guess, not obvious how to deal with longitudinal

2 different energies: 350 MeV and 500 GeV

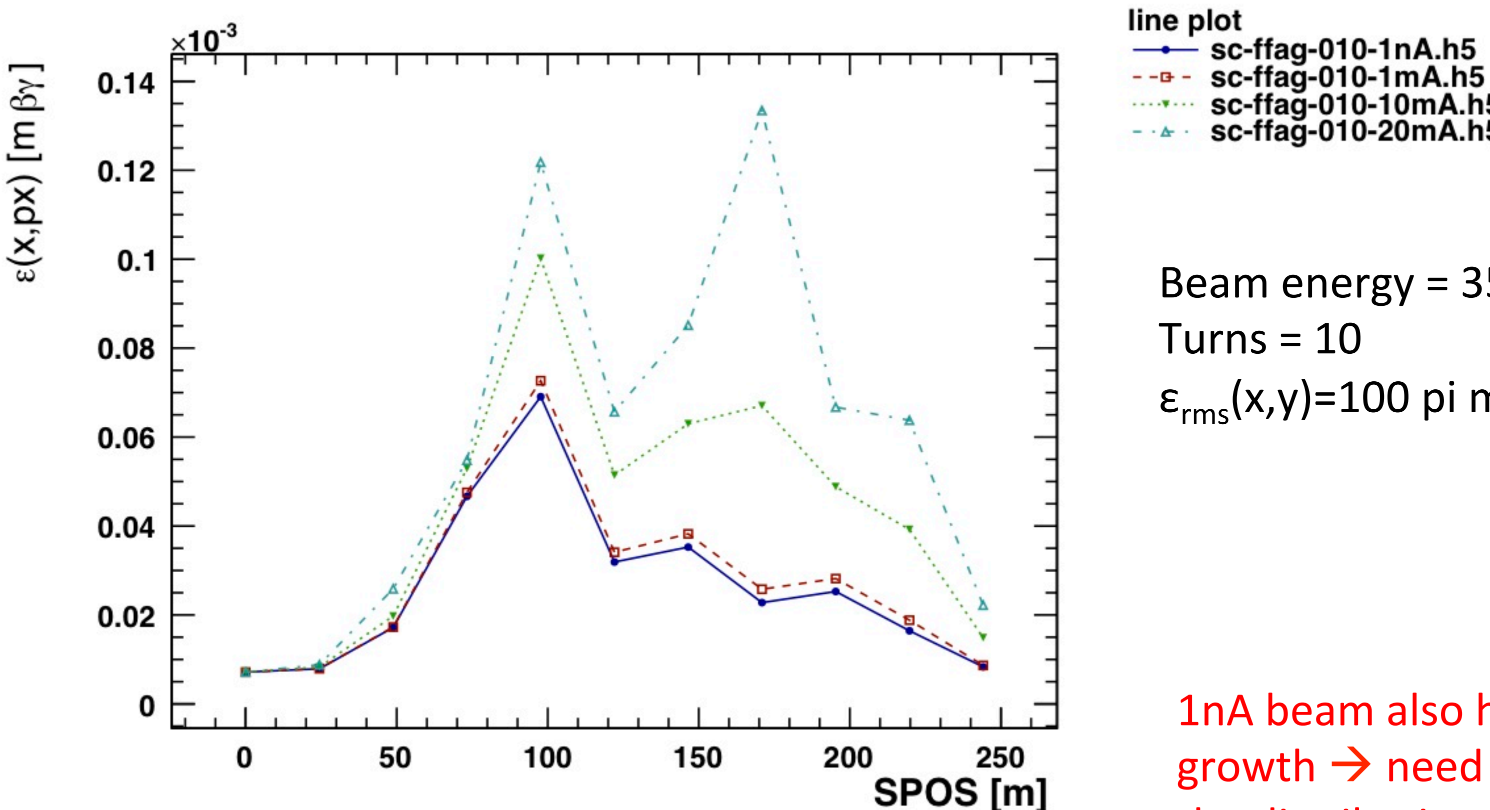
10,000 macro particles, simulating a range of different beam currents.

- **Note: until I have a reasonable way to describe a CW beam, these results should be seen an example of OPAL only!**





Results (for example only)



Beam energy = 350 MeV
Turns = 10
$\varepsilon_{rms}(x,y)$=100 pi mm mrad

1nA beam also has ε growth → need to get the distribution correct in longitudinal!