3D Electron Cloud Simulations at LBNL

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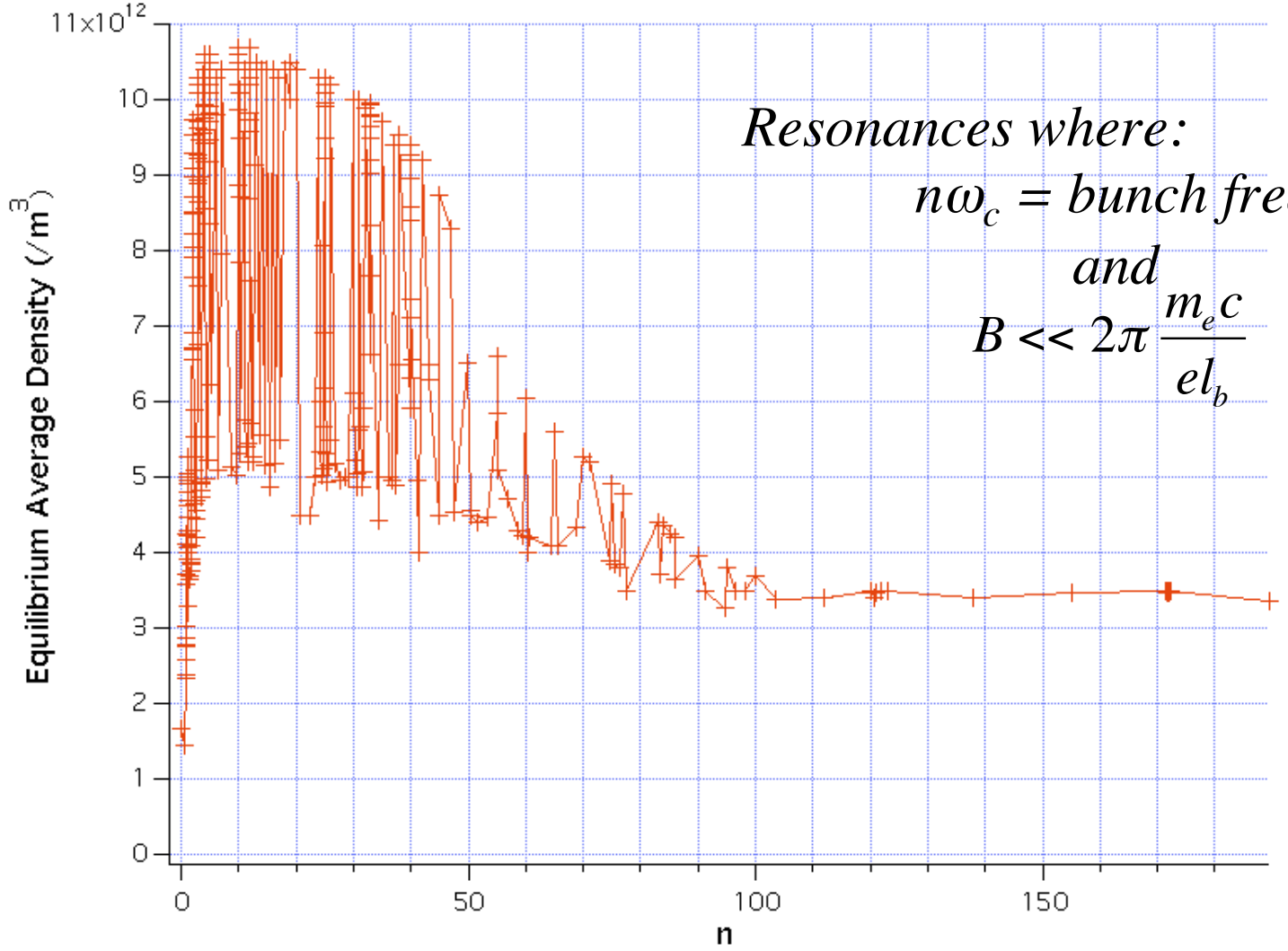
with: Miguel Furman

Jean-Luc Vay

ILC Wiggler will have Electron Cyclotron Resonances. What will they do?



Resonances where:

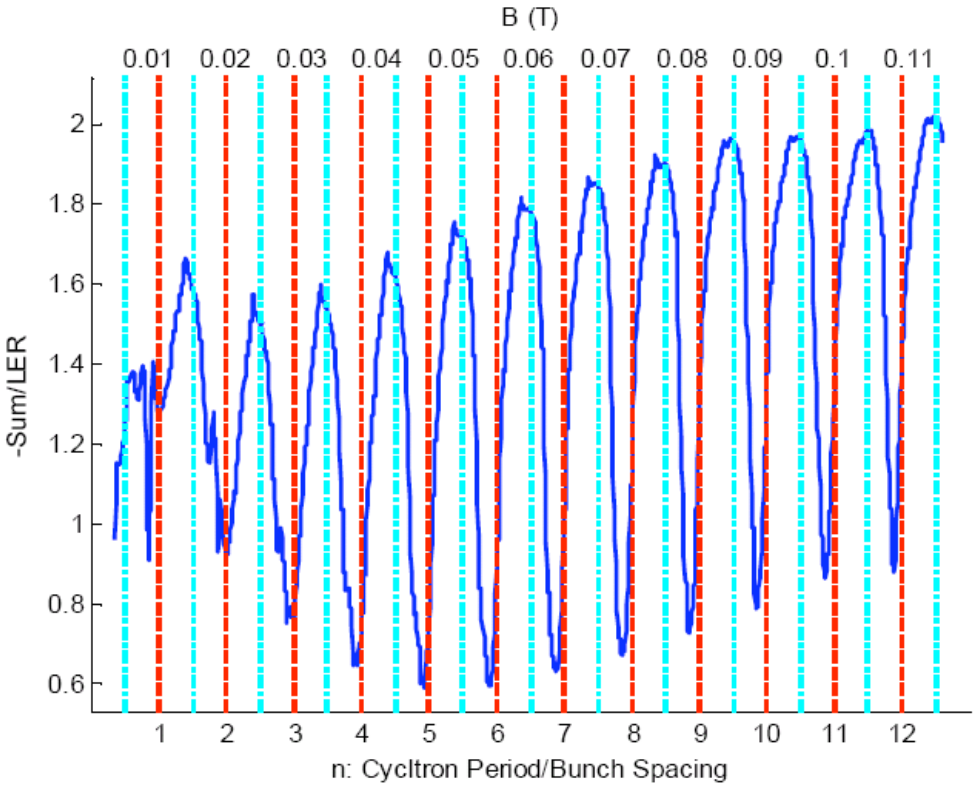
$$n\omega_c = \text{bunch frequency}$$

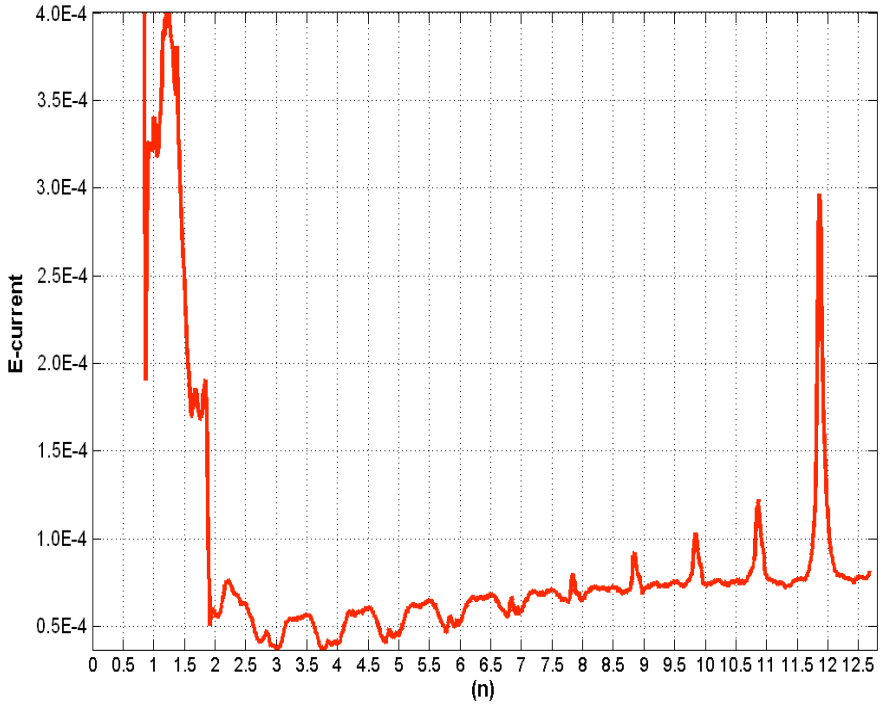
and

$$B << 2\pi \frac{m_e c}{e l_b}$$

Aluminum compared with TiN chamber

slide from Mauro Pivi





Aluminum section, order of magnitude larger electron current.

TiN section.

E-cloud current vs B-field, sum of all stripes.

(Plots are in Volt units. To convert in Ampere, multiply by 1.0E-4)

Ng, Pivi, Wang, SLAC

Electron Cyclotron Resonances Present a Difficult Numerical Problem

ILC wiggler period = 40 cm

B_{max} = 1.6 T

200 resonances in $-0.6 \le B \le 0.6$ T or $\Delta z = 34$ mm

34% of wiggler period is in this regime

FWHM of resonance ≈ 37 μm

Need: z resolution ~ 2 μm

x,y resolution ~ 0.4 mm

Factor of 200 ⇒ Numerical Inaccuracy?

And small z resolution ⇒ very long runs

What resolution is needed, and are the resonances important in 3D?

Parameters of 3D Simulations

ILC e^+ DR Wiggler Parameters

B gradient - linear, 1/10 of physical value

Resolution:

$\Delta x = 0.74$ mm

$\Delta z = 0.022$ mm

$\Delta x/\Delta z = 34$

B_x, B_z neglected

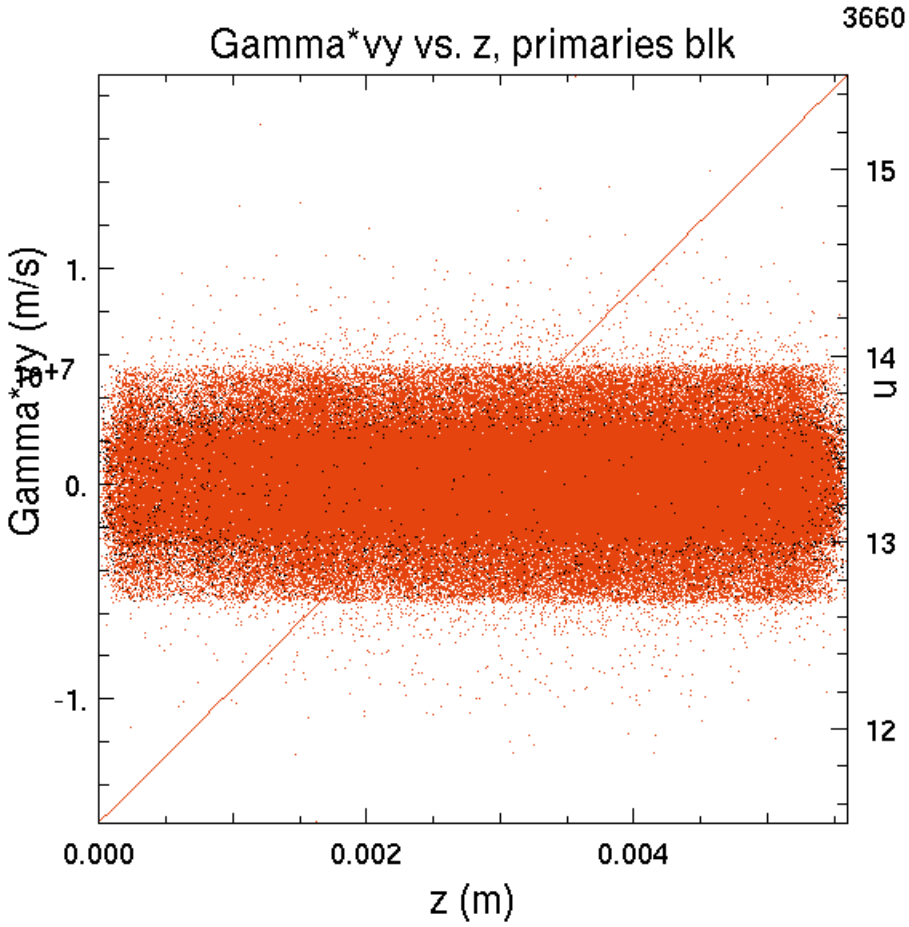
Non-evolving beam (Bassetti-Erskine field used)

PIC algorithm used for Space charge field

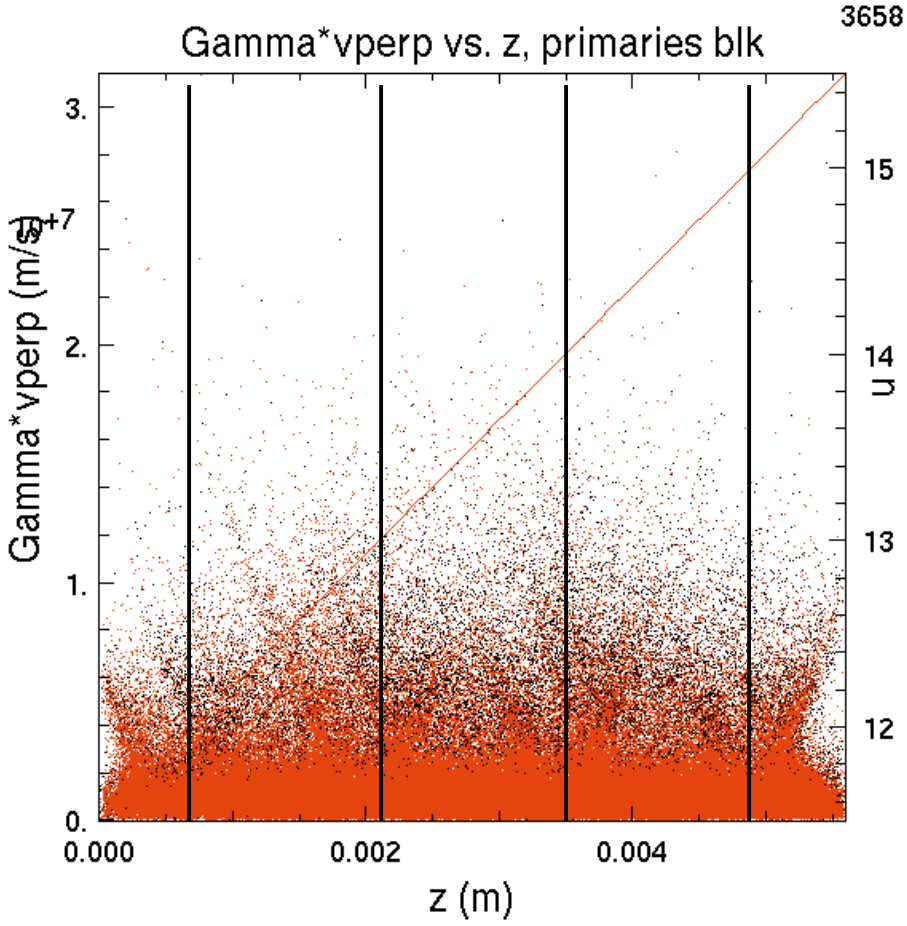
Run in parallel on NERSC computer

Effects of the Resonances are There

after 50 bunch passages

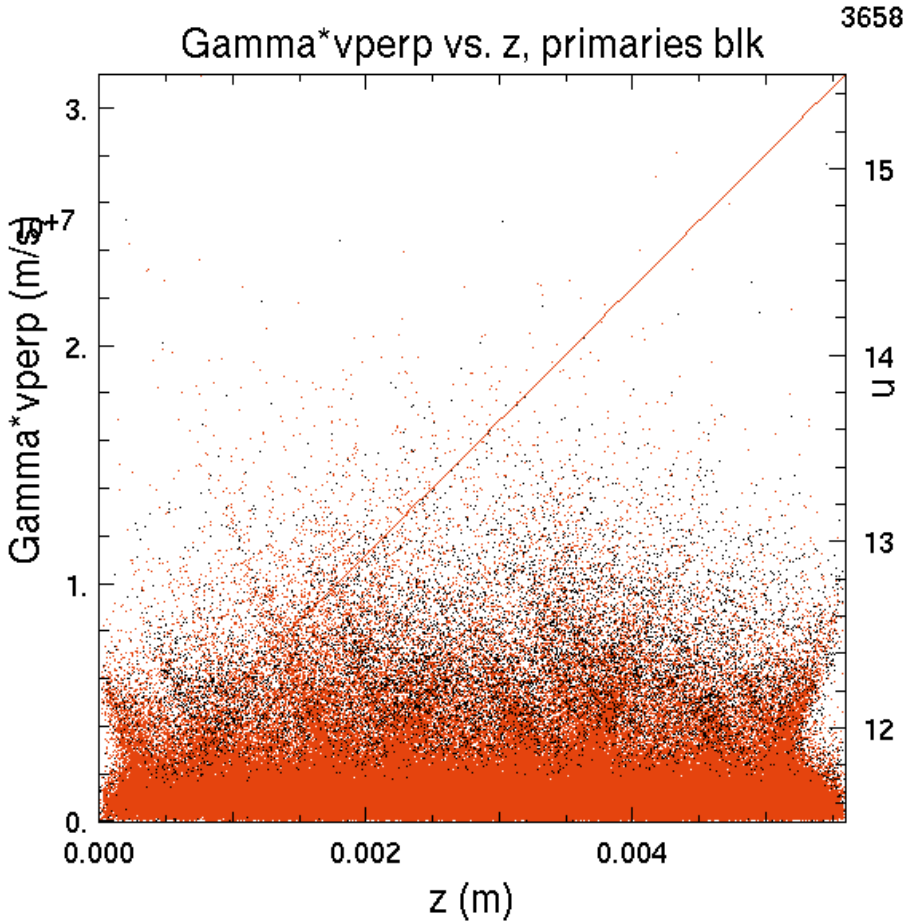


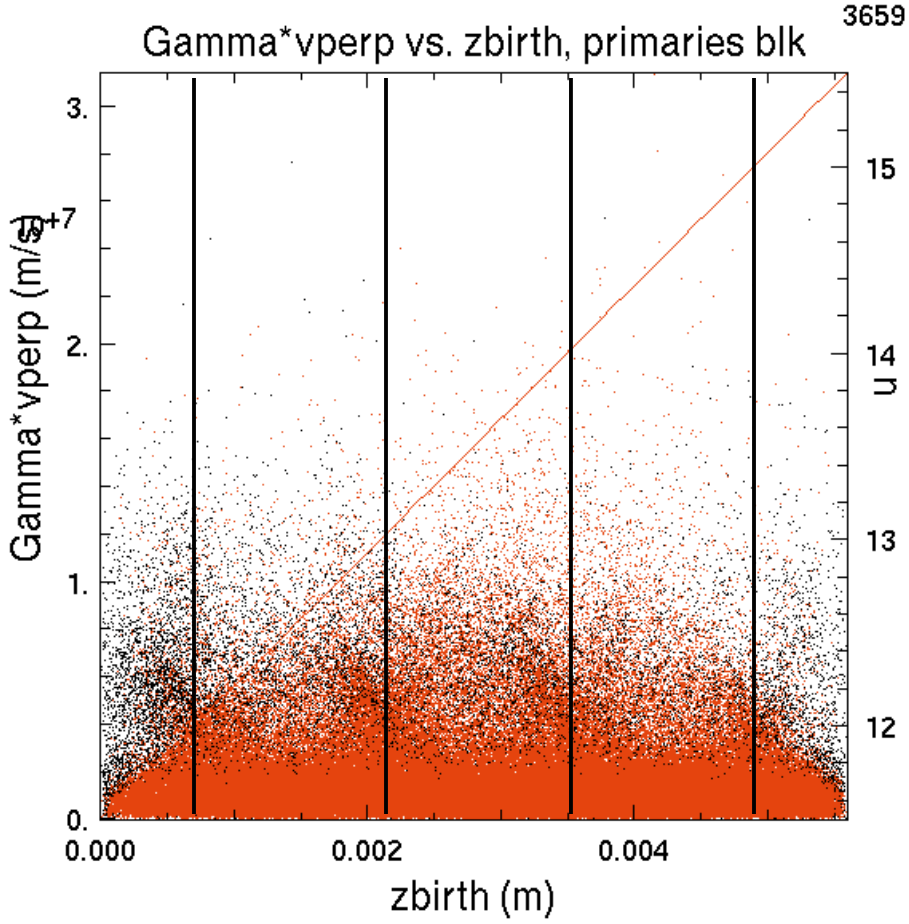
Step 30750, T = 307.6960e-9 s, Zbeam = 0.0000e+0 m



Step 30750, T = 307.6960e-9 s, Zbeam = 0.0000e+0 m

Tracing the vperp back to its birthplace in z





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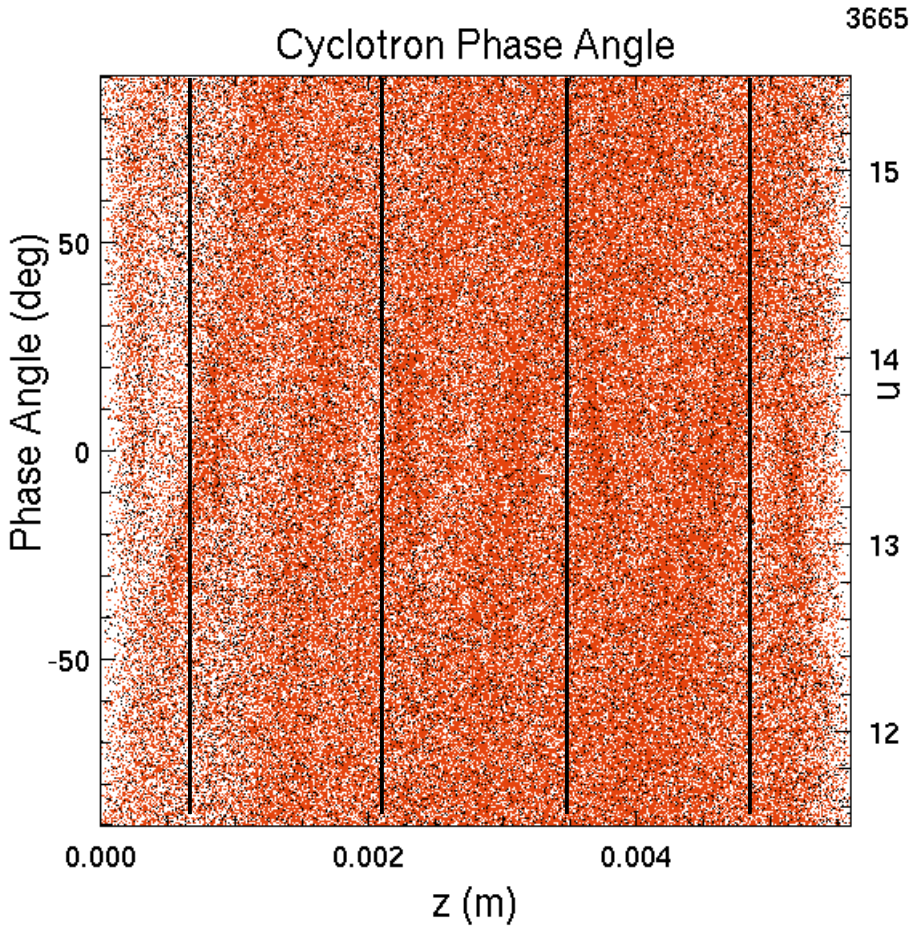
Cyclotron Phase angle vs. z



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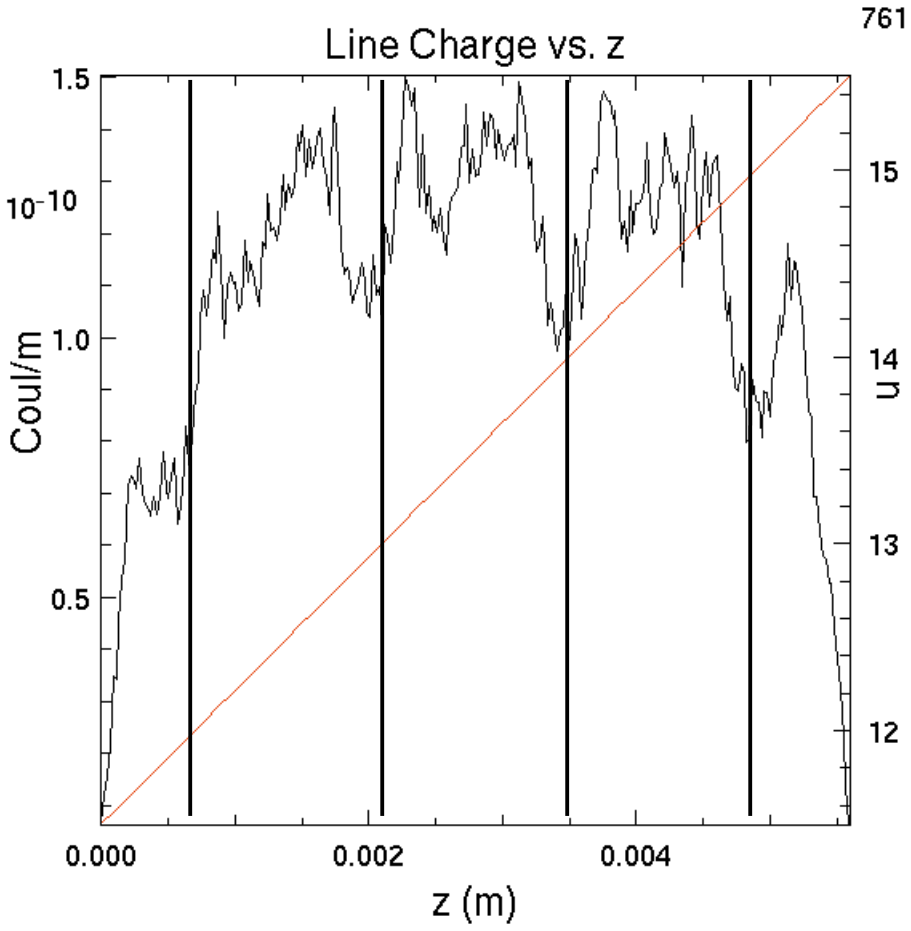
Line Charge Density vs. z



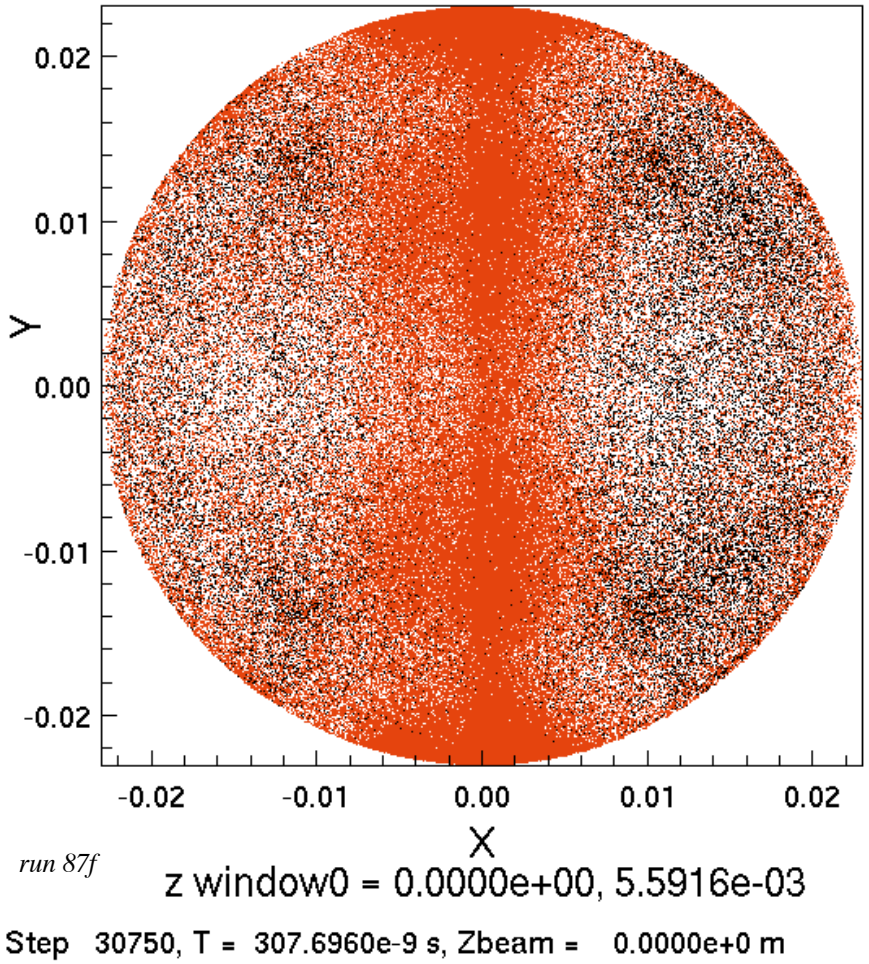
after 9 bunch passages

Variation ~ 30%

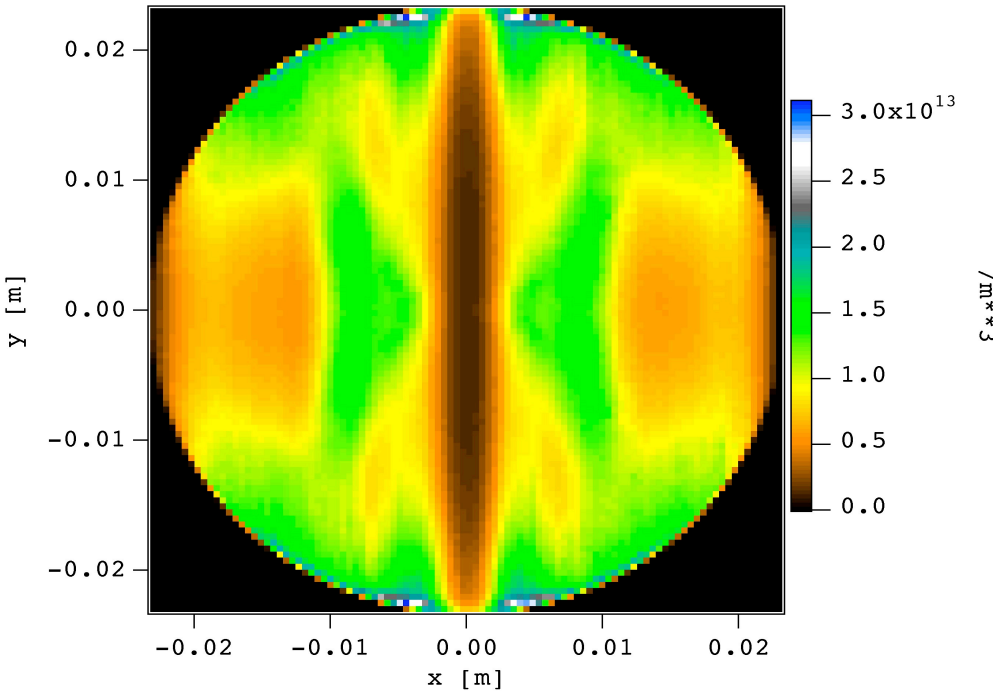
The density pattern in x-y is not the usual "stripes" pattern

Integrated over z

3D, n=12-15

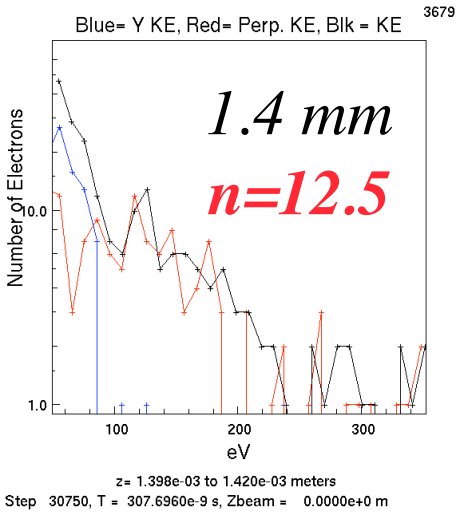


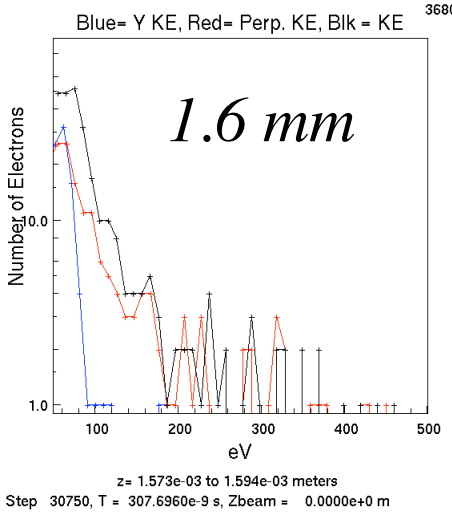
2D at n=12

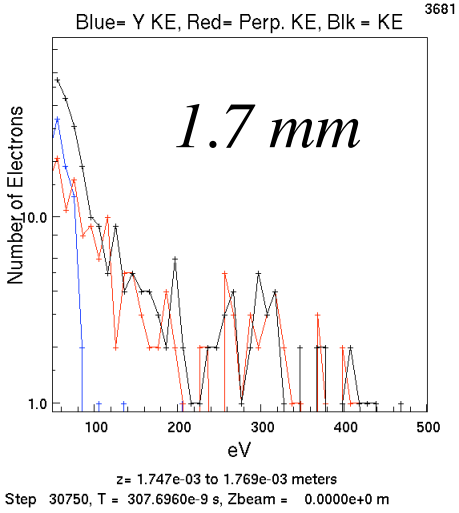


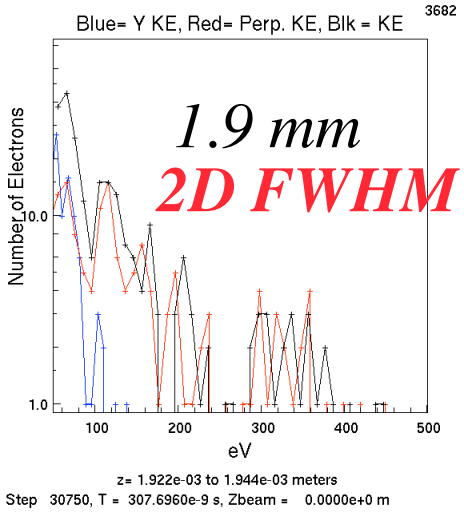
Energy Histograms Near n=13 - Semilog Plots

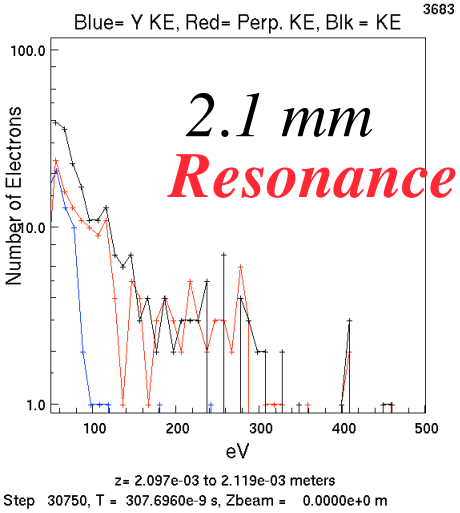
Red = perpendicular, Blue = y, Black = total

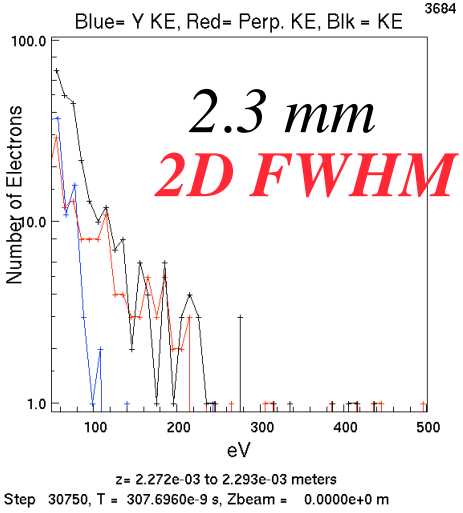






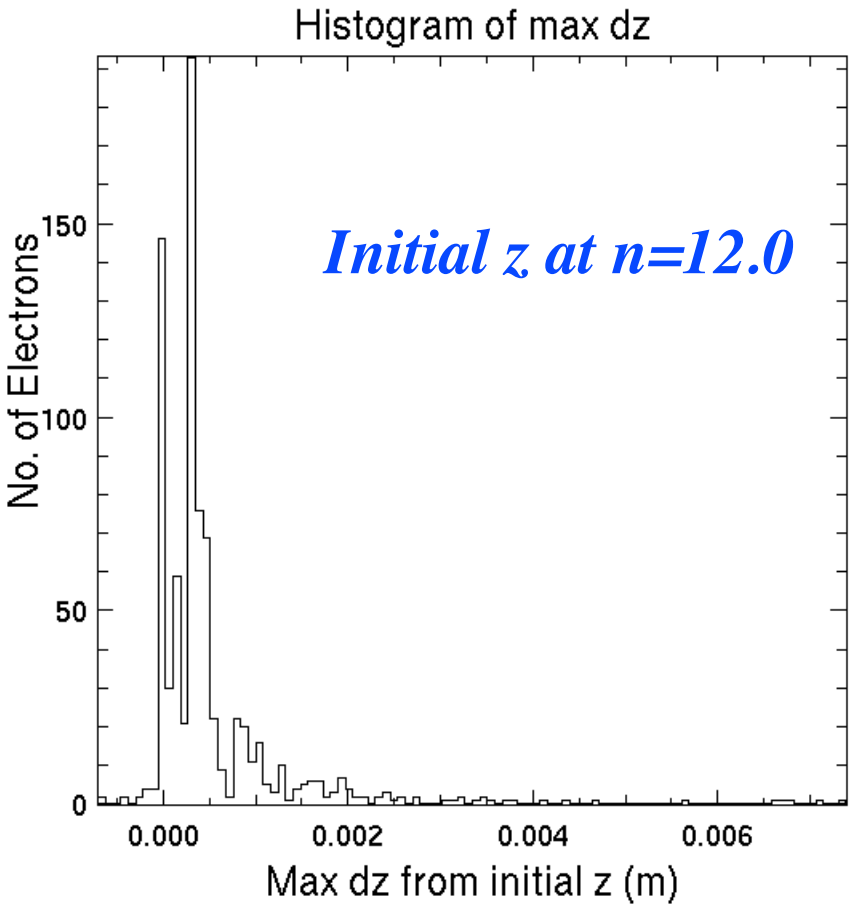


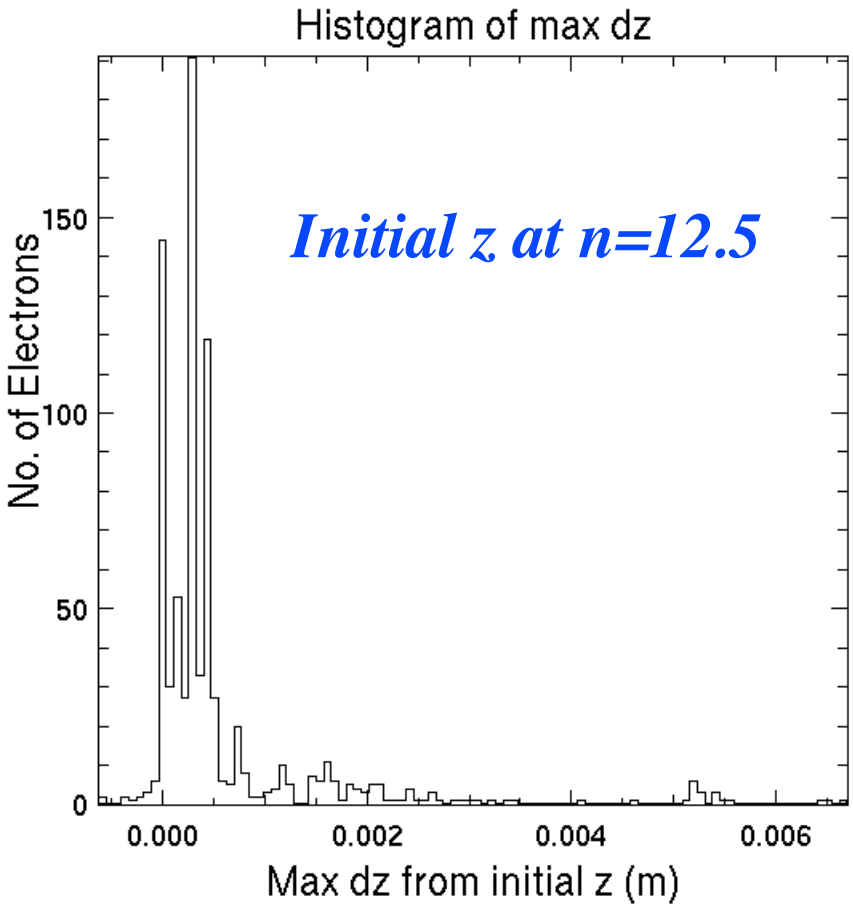




Results from Single Particle Tracker with Linear B Gradient, 50 bunch passages

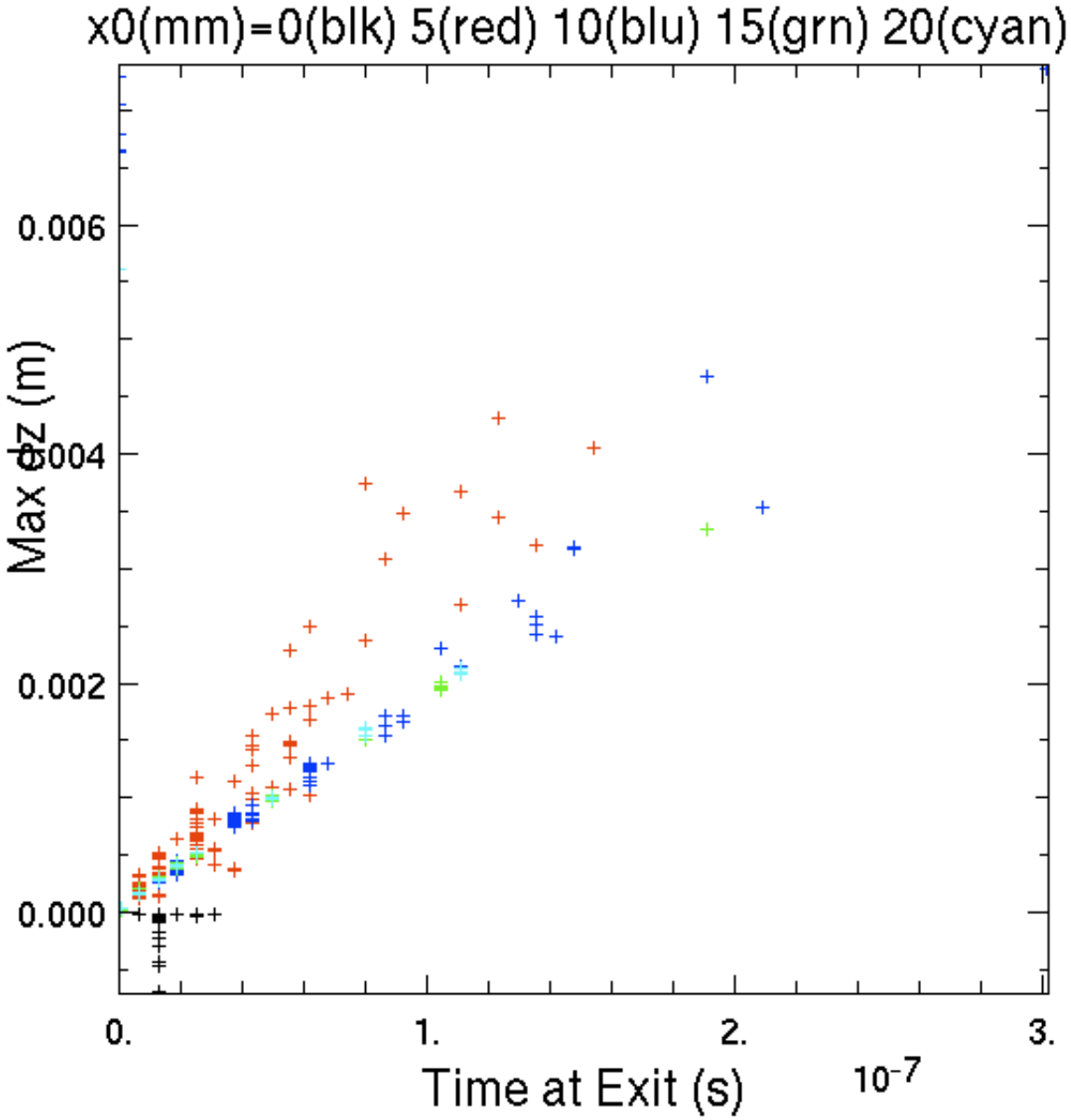
800 electrons launched





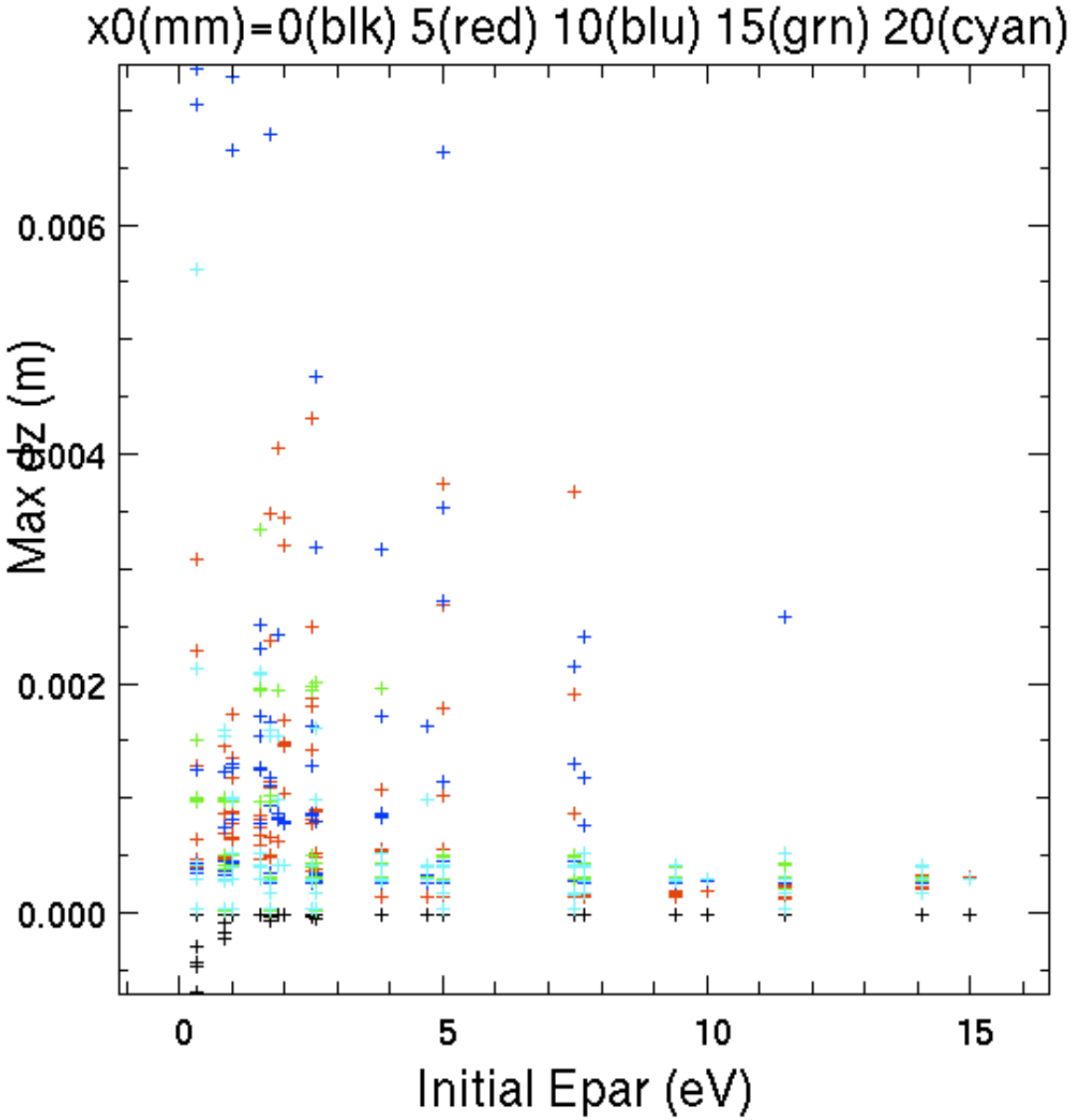
resonances are 1.4 mm apart

dz is linear with length of time electron is in system



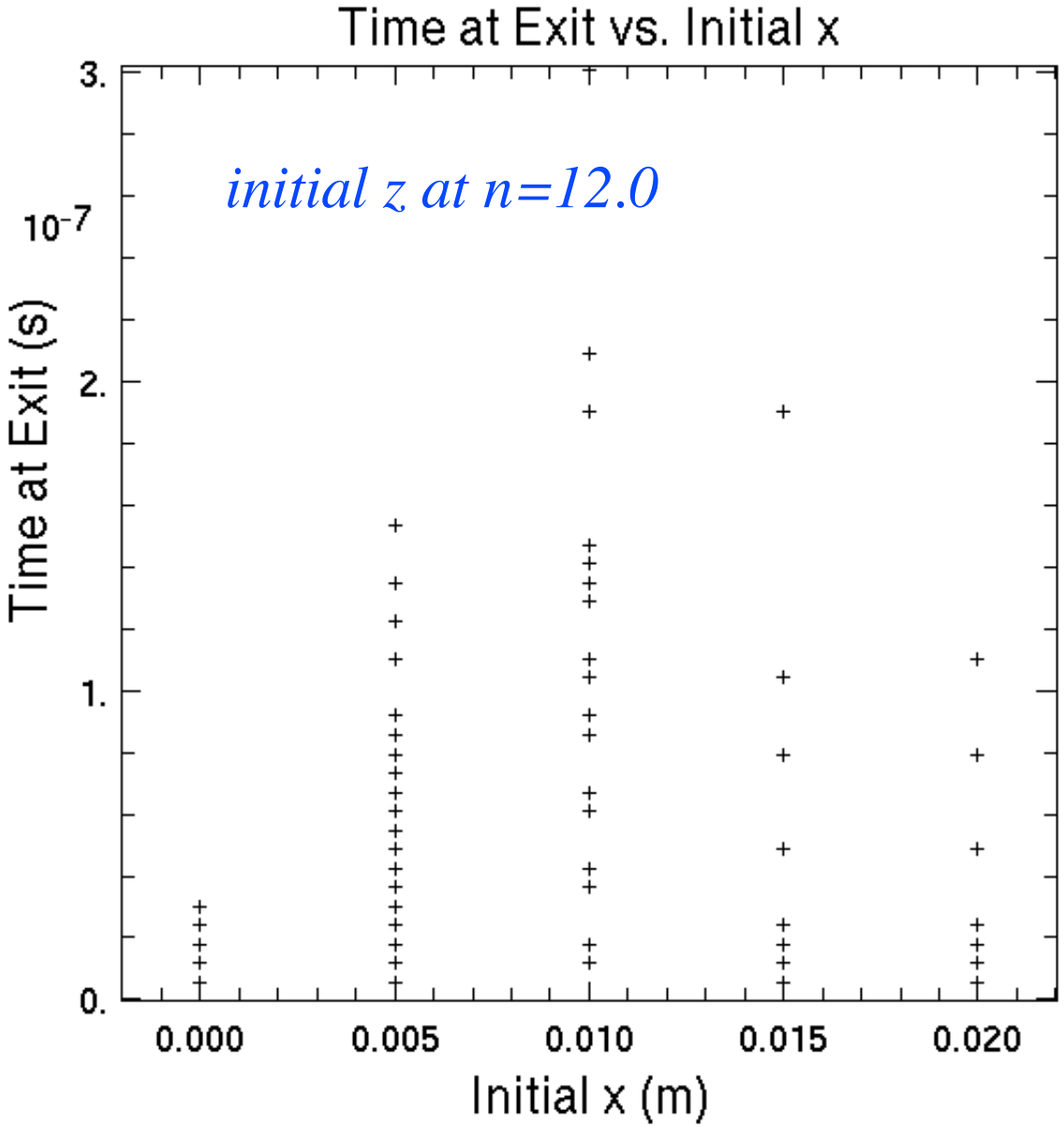
initial z at n=12.0

Time in the system depends on initial E_y



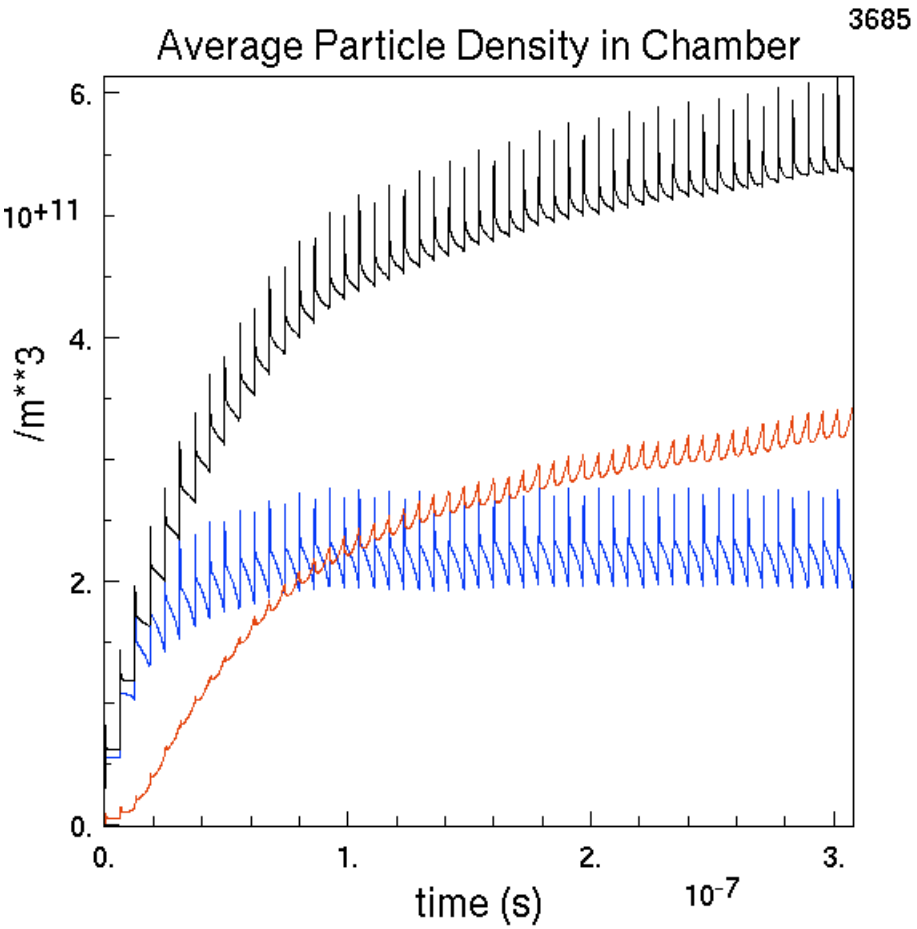
initial z at n=12.0

Time in system is dependent on x



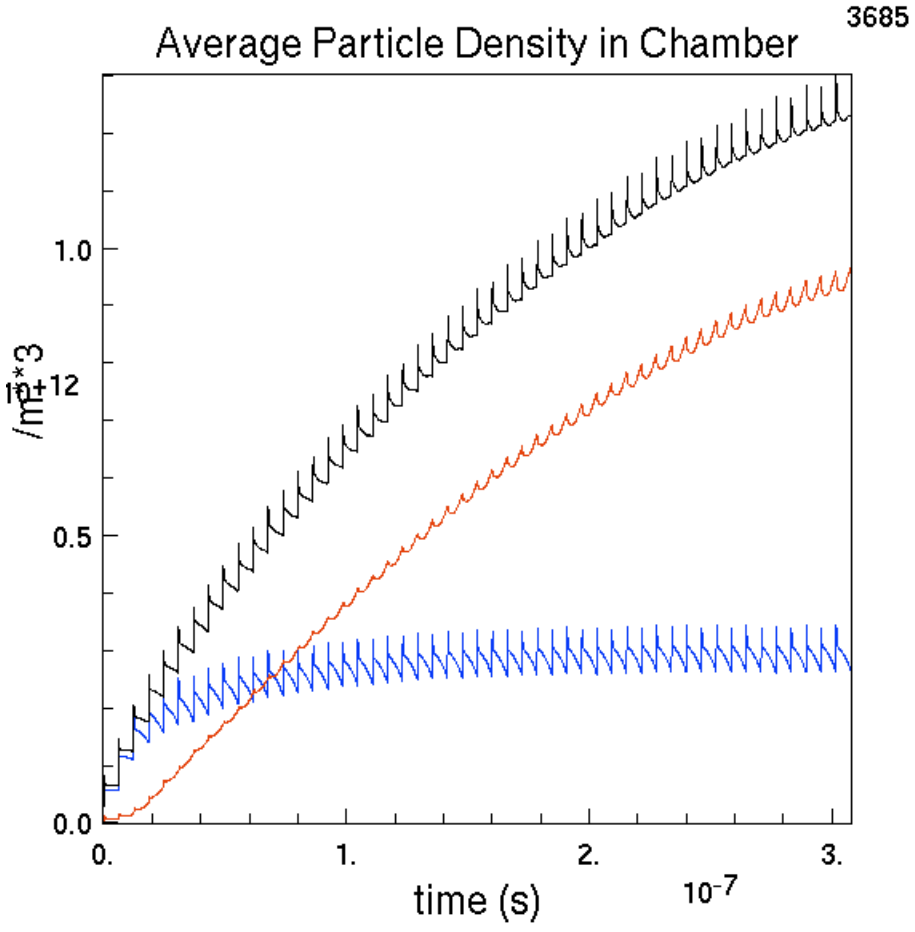
System Length Must be Extended

System length = 2.8 mm



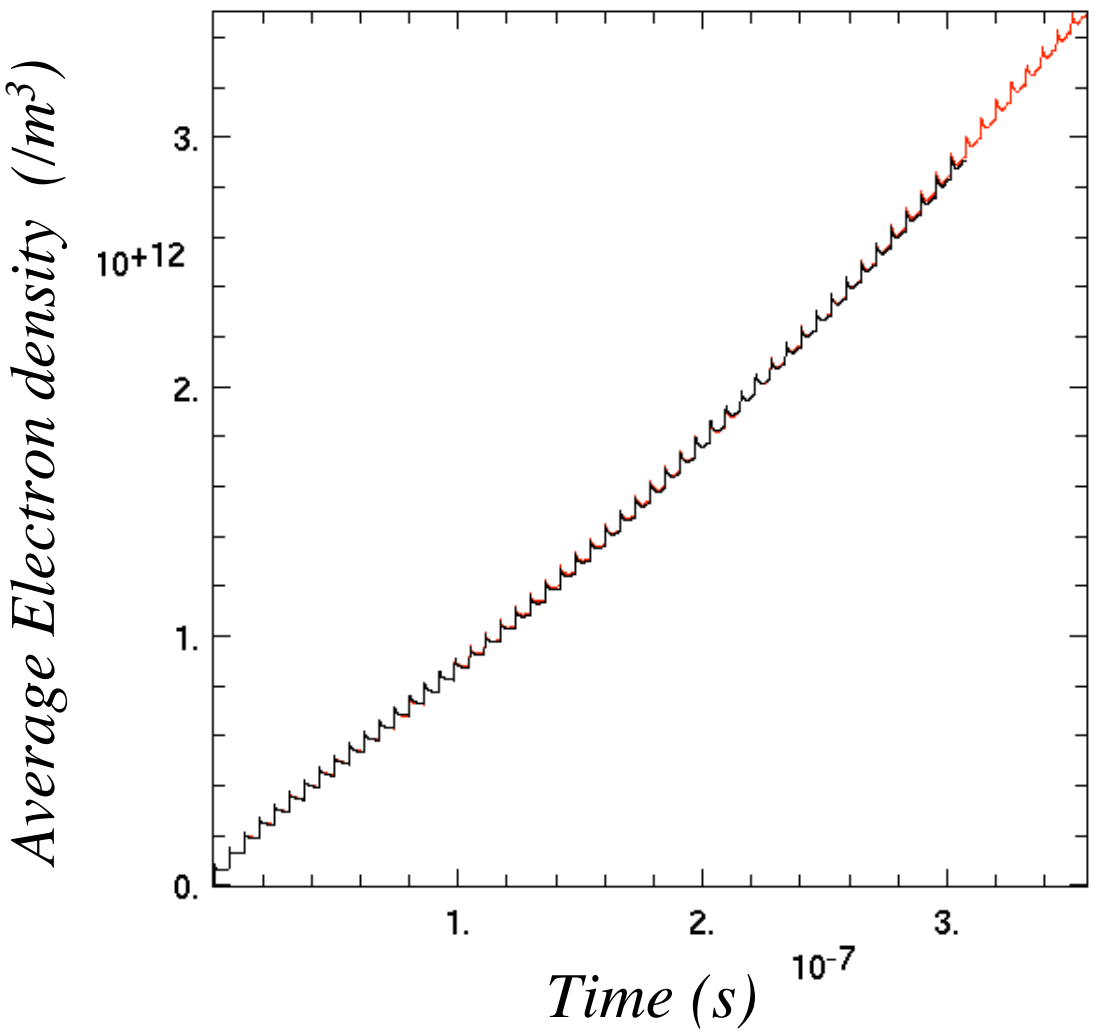
Step 30750, T = 307.6960e-9 s, Zbeam = 0.0000e+0 m

System length = 5.6 mm



Step 30750, T = 307.6960e-9 s, Zbeam = 0.0000e+0 m

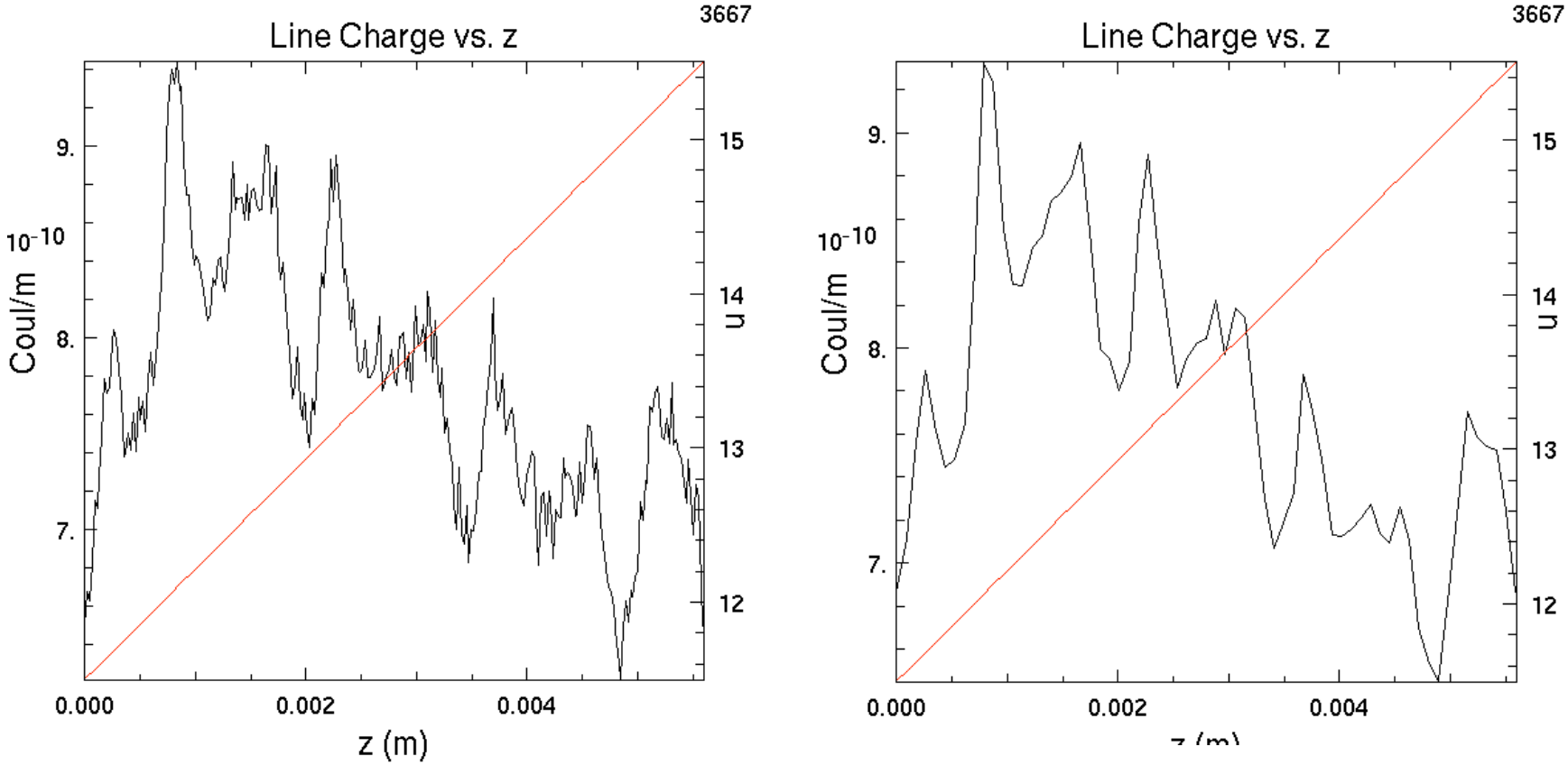
Very Preliminary Results - z Resolution



— Δz = 21 μm

— Δz = 5.2 μm

Other results also look similar after 50 bunches



Particle distribution in x-z plane and $v_\perp$ distribution also look very similar.

Observations

The electron cyclotron resonances do cause differences in cloud density with z in 3D. The differences are much smaller than in dipole magnets on and off resonance because electrons in the wiggler move in and out of resonance.

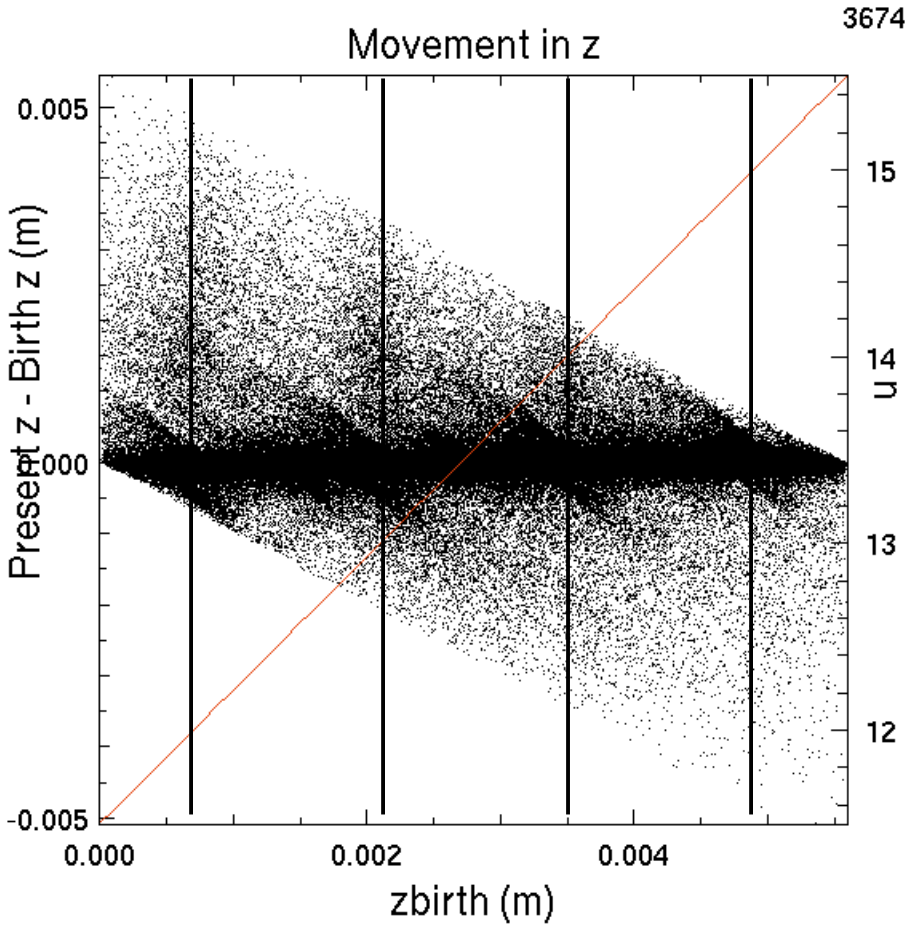
The resonances cause a difference in the density pattern in the x-y plane also.

The resonances are so closely spaced in the wiggler that the beam will surely average over them. But the average density is somewhat different from that in the case with no magnetic field.

Runs with a longer system are needed, and it remains to be determined what z resolution is needed for simulations with the correct B gradient.

BACKUP SLIDES

Delta z vs. zbirth



Step 30750, T = 307.6960e-9 s, Zbeam = 0.0000e+0 m

Distribution of Electrons in x vs. z

after 50 bunch passages

integrated over y