Update on
New Cyclotron Resonances in Electron Cloud Dynamics*

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Collaborators

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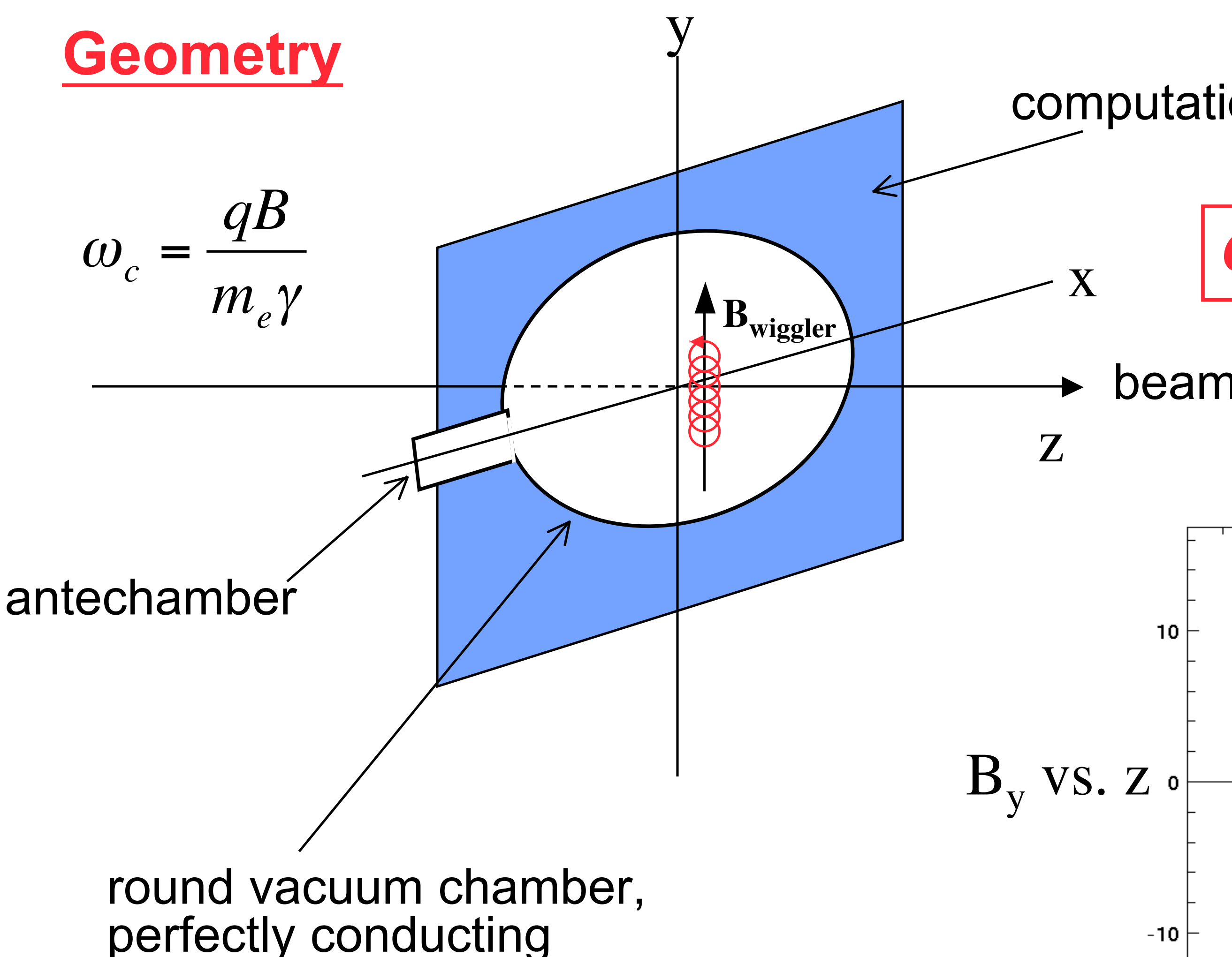
Jean-Luc Vay } LBNL

Jennifer Yu (LBNL summer student & Cornell undergrad)

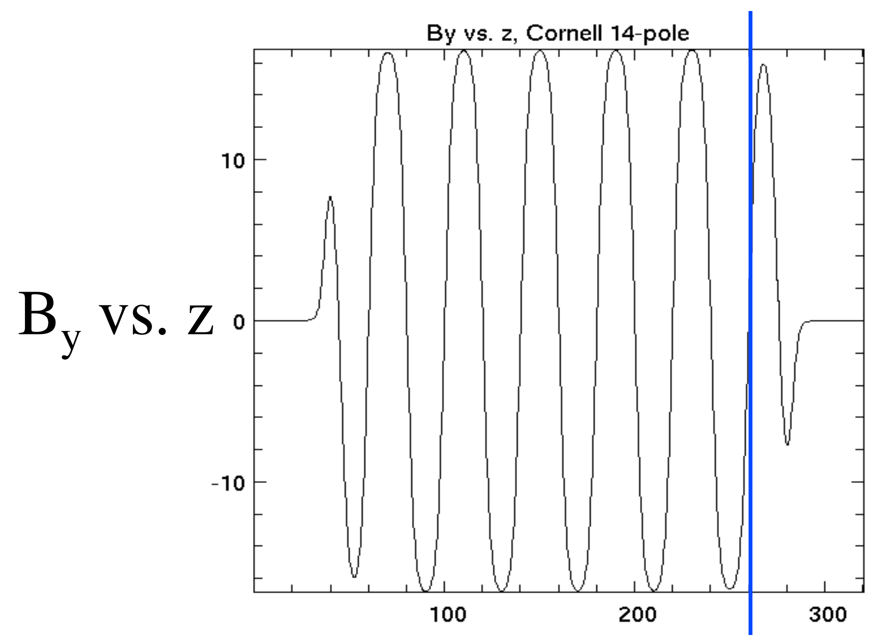
We used POSINST, a 2D Computer Code, to Simulate x-y Slices of the Wiggler

Geometry

$$\omega_c = \frac{qB}{m_e \gamma}$$



Cloud Buildup Only



Cloud Buildup Calculations were done using ILC Damping Ring Parameters

"Wiggler":

$B_y \leq 1.6$ T; $B_x = B_z = 0$ (ideal dipole)

Vacuum Chamber:

R = 2.3 cm (vacuum chamber radius)

Antechamber full height = 1 cm

Beam:

2×10^{10} e+ per bunch

9 GeV

$\sigma_x = 0.112$ mm, $\sigma_y = 4.6$ μm, $\sigma_z = 6$ mm

bunch spacing: 6.15 ns

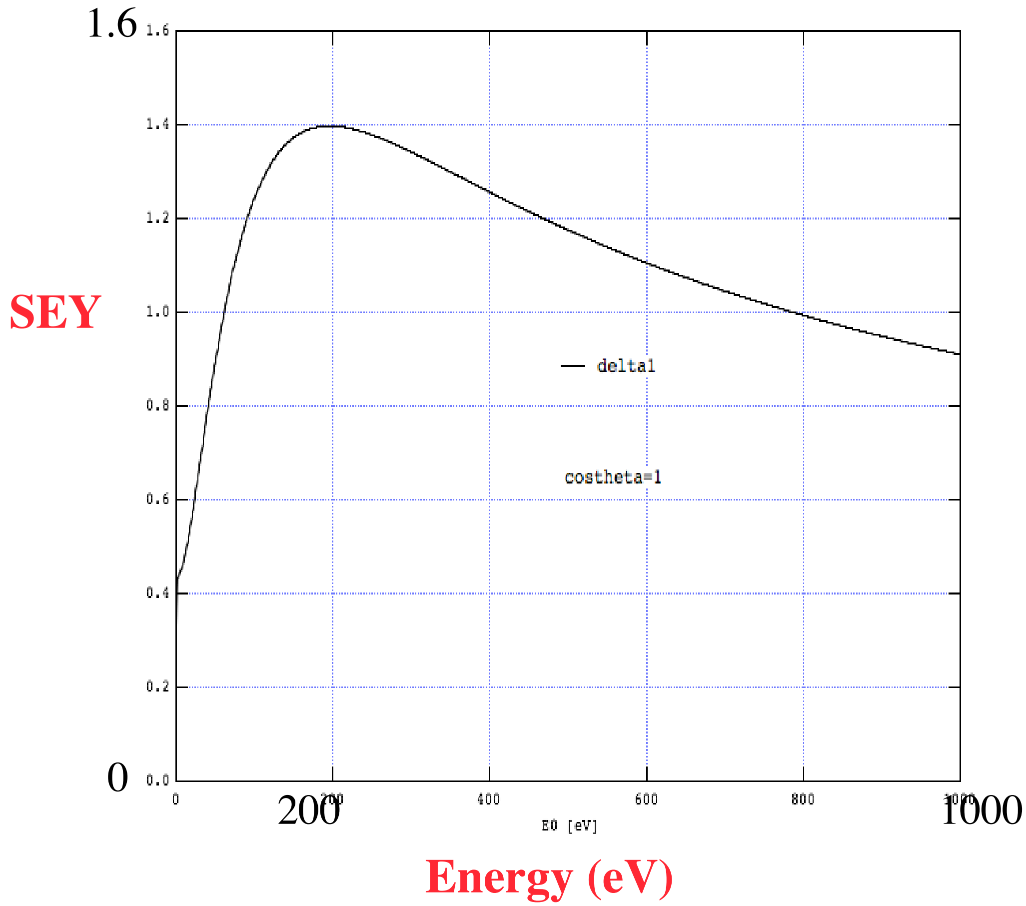
Electron Production:

photon reflectivity = 1

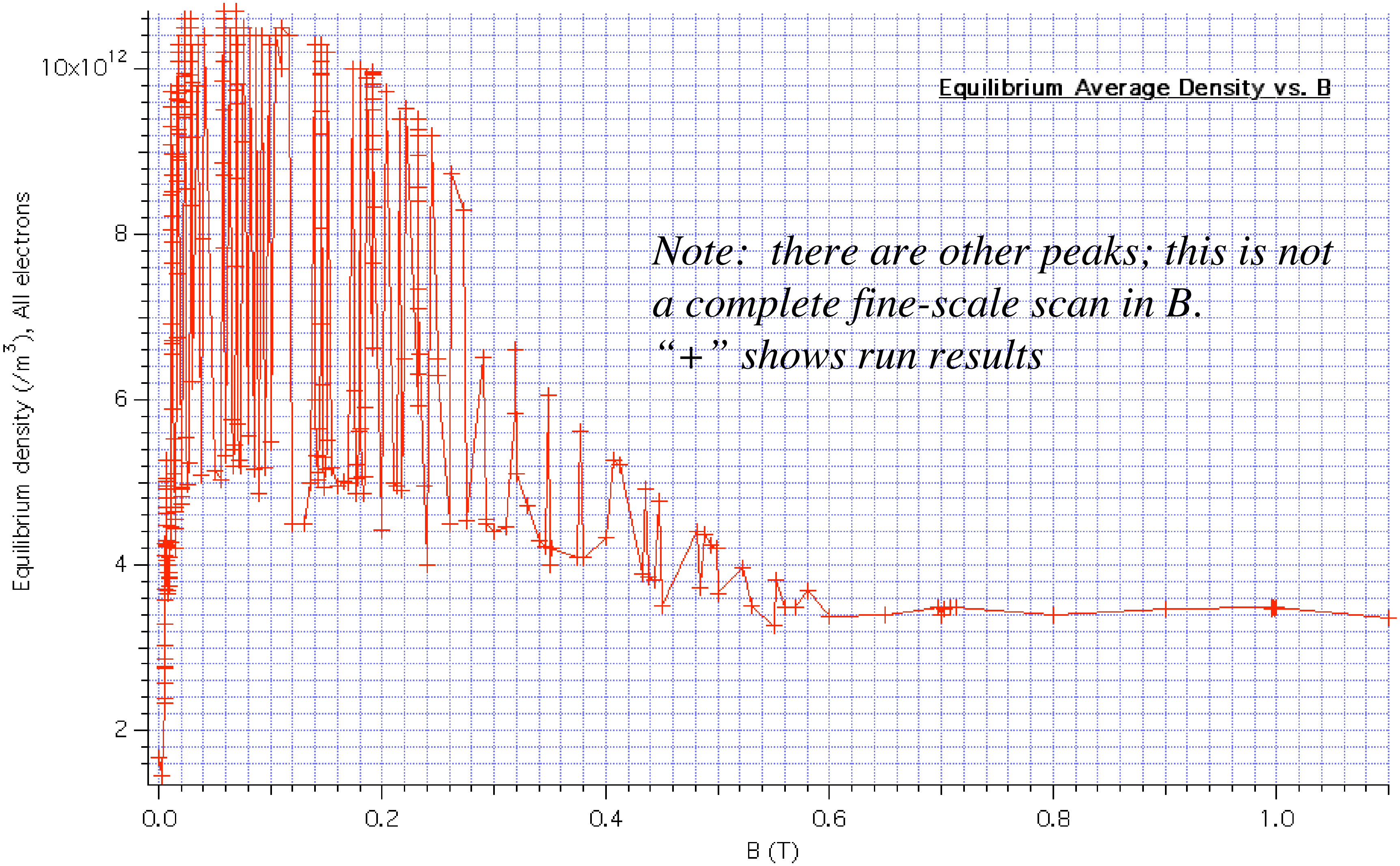
peak SEY @ normal incidence = 1.4

Electron energy & incident angle determine secondary electron yield (SEY)

SEY at Normal Incidence



Average Equilibrium Density vs. B has Peaks at Low B!



Density at peaks is up to 3x its value at high B.

At last meeting:

I showed graphs from a small single-particle tracking code (no space charge) demonstrating:

Increase in perpendicular momentum due to cyclotron resonance ⇒

electron energy increased

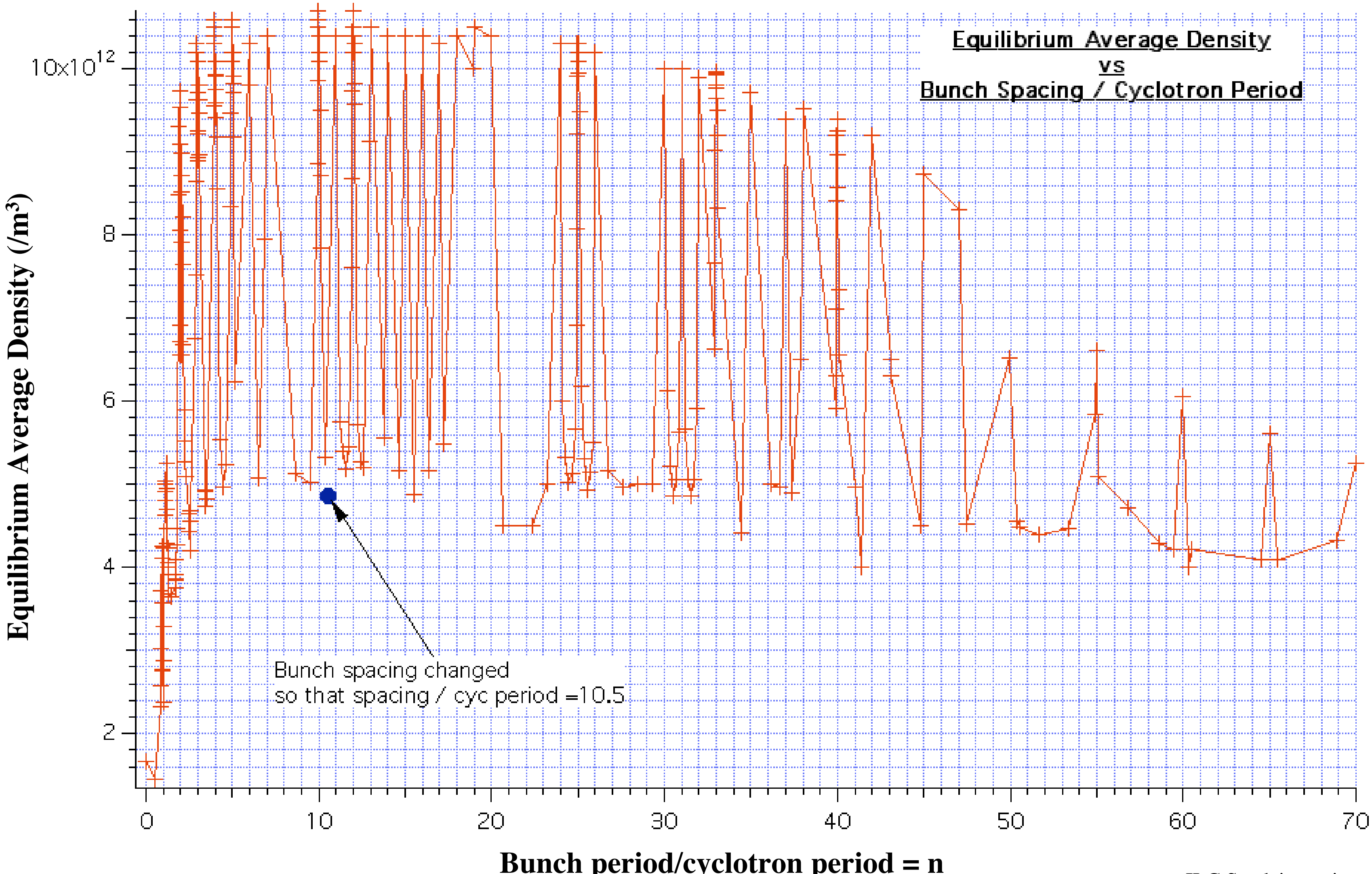
impact angle decreased

⇓

SEY increased

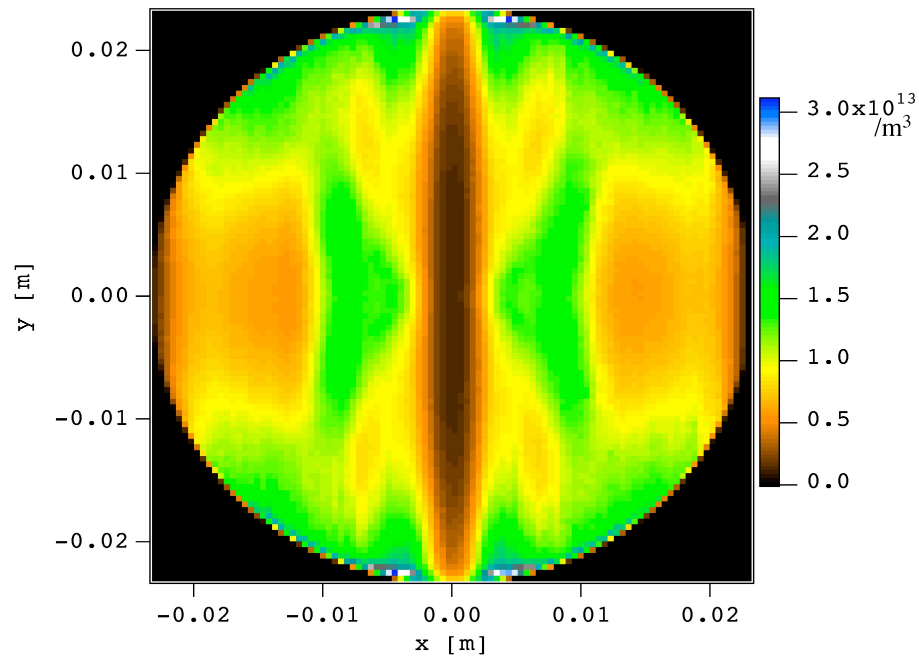
Peaks occur where (bunch period)/(cyclotron period) = integer

Note: some peaks (and dips) missing because runs have not yet been done at that field

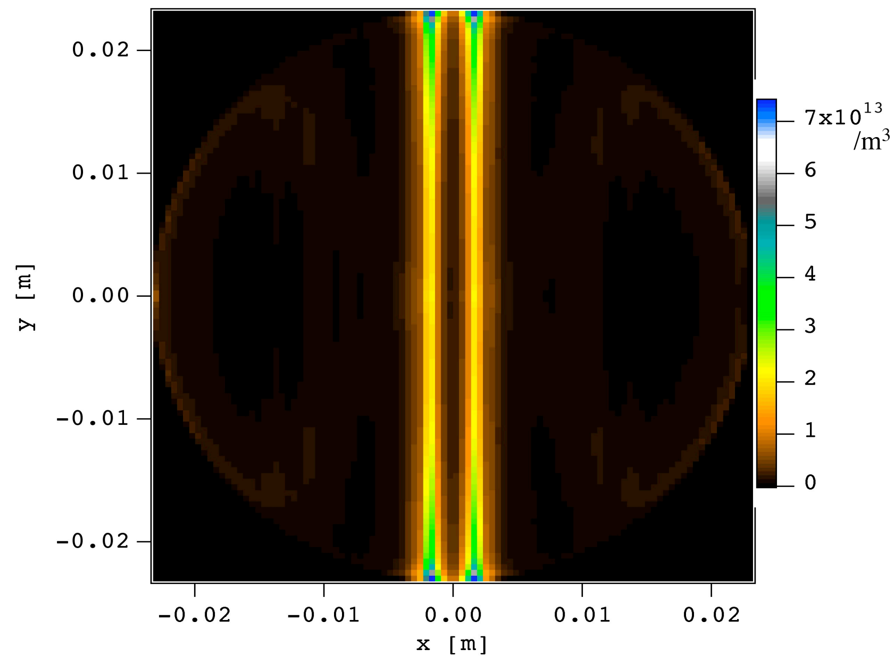


Another effect, from POSINST Simulation: Electrons more Dispersed in Resonant Case

Density Distribution Averaged over Run (POSINST)
X-Y Plane



B at a spike



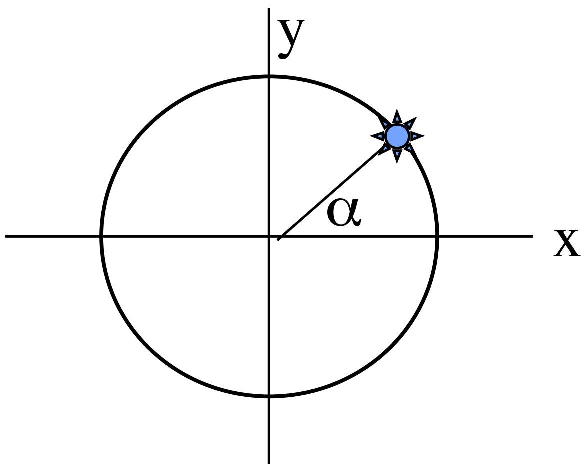
High B

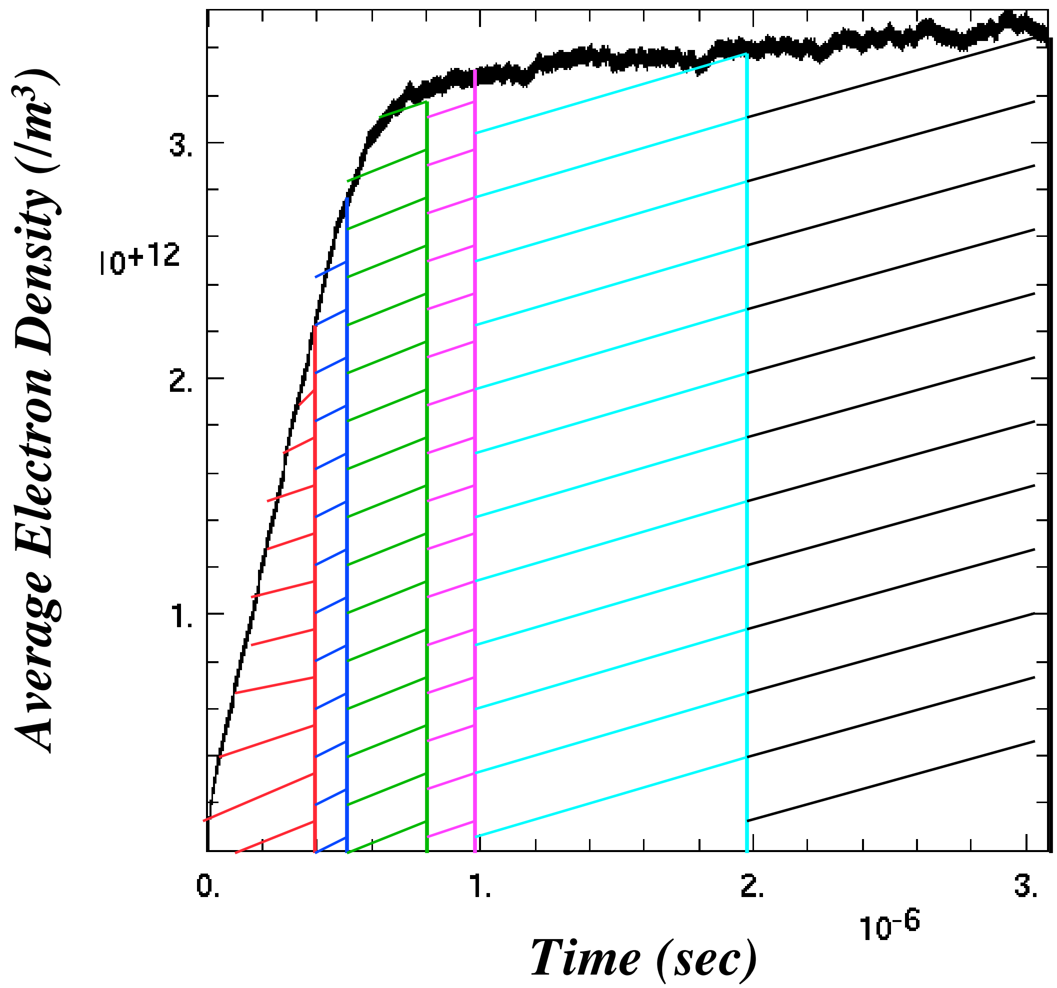
New Work:
Evidence from POSINST

Data will be shown by time interval

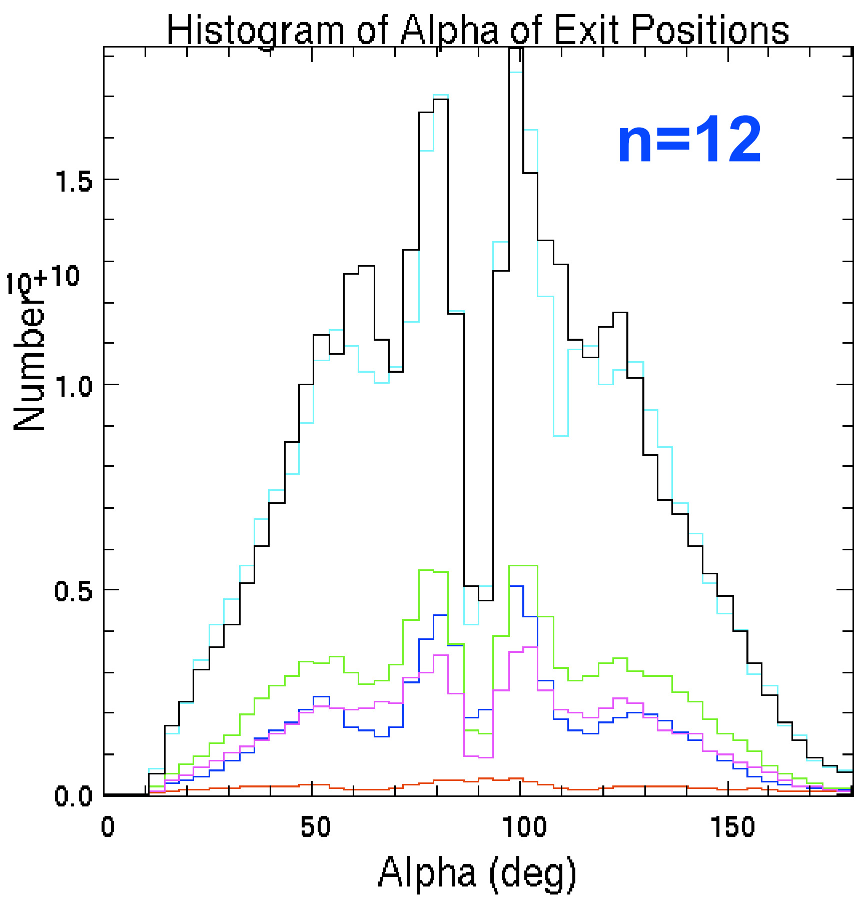
Color code:

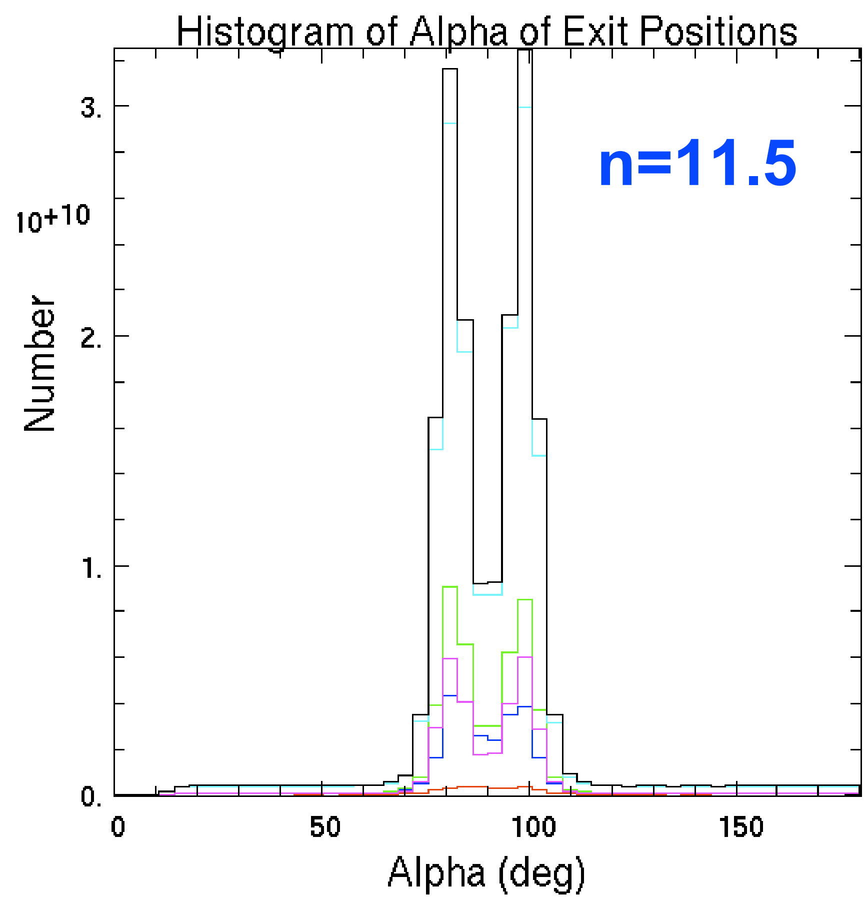
- 0.0 - 0.2 ms
- 0.2 - 0.5 ms
- 0.5 - 0.8 ms
- 0.8 - 1.0 ms
- 1.0 - 2.0 ms
- 2.0 - 3.2 ms





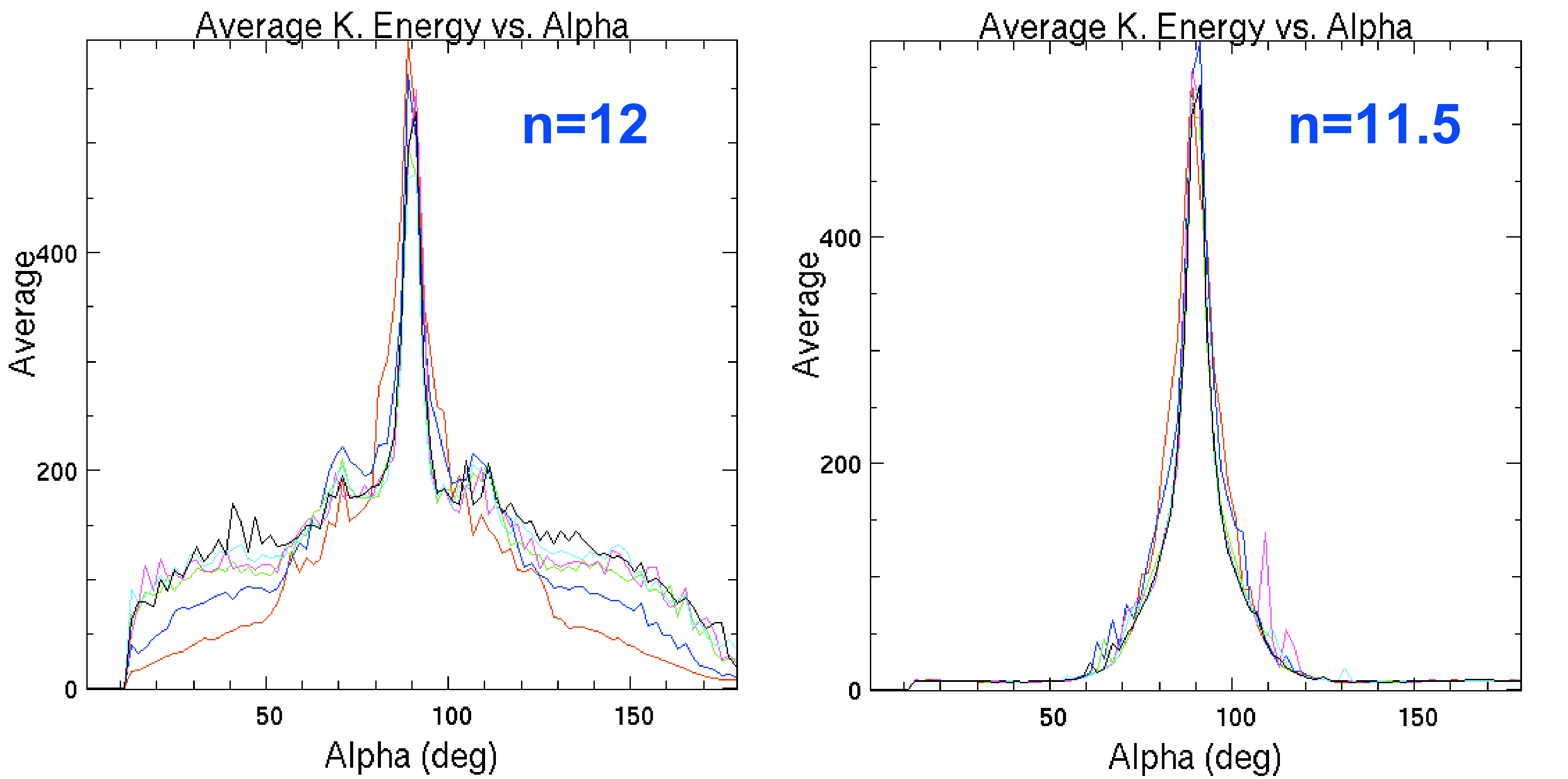
POSINST Data on electrons hitting the wall show very different pattern at resonance





This is consistent with the “stripes” density distribution data that we saw before. Alpha = polar angle measured from x axis of vacuum chamber.

At resonance, electrons over a much bigger area have 100 - 200 eV



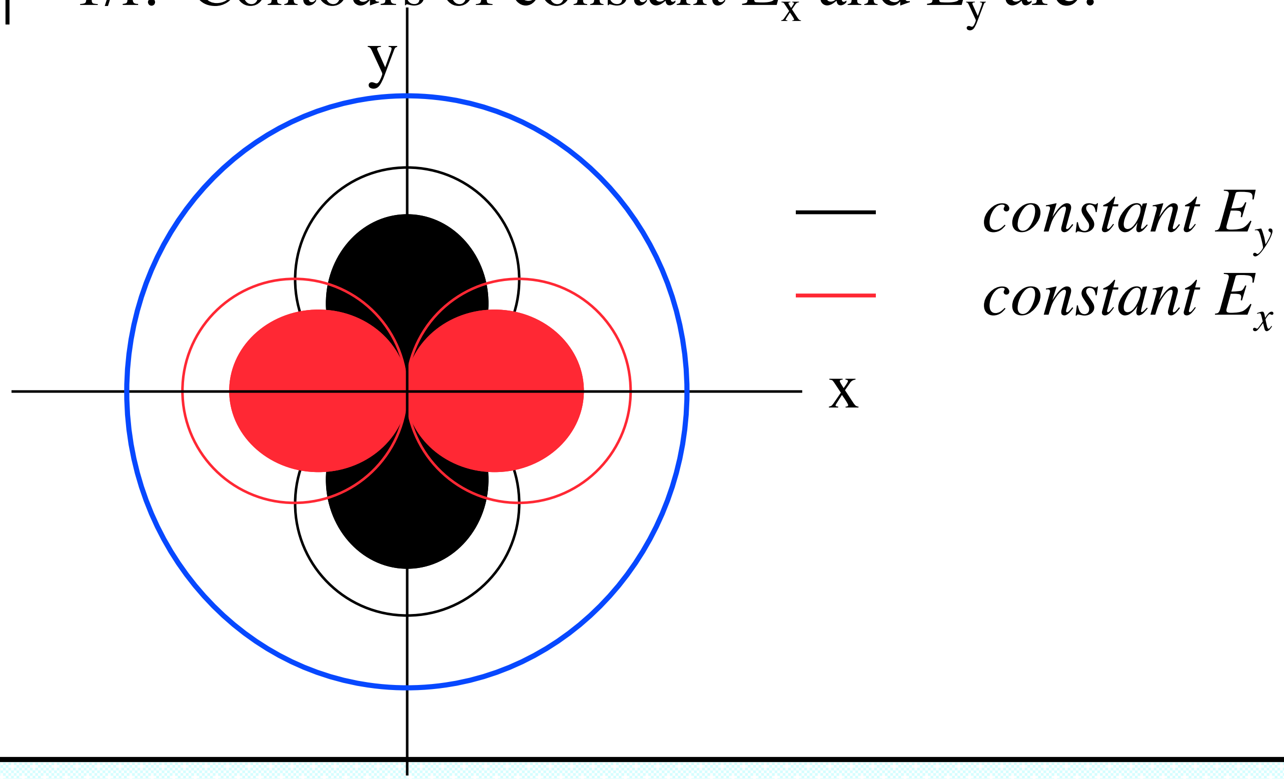
At resonance there is an additional method of adding energy-- the beam E_x can be effective, not just E_y. This changes the locations where electrons feel the greatest effect from the beam.

At resonance both the x and y beam kicks are important to increasing the energy

In what part of the chamber is the beam force most effective?

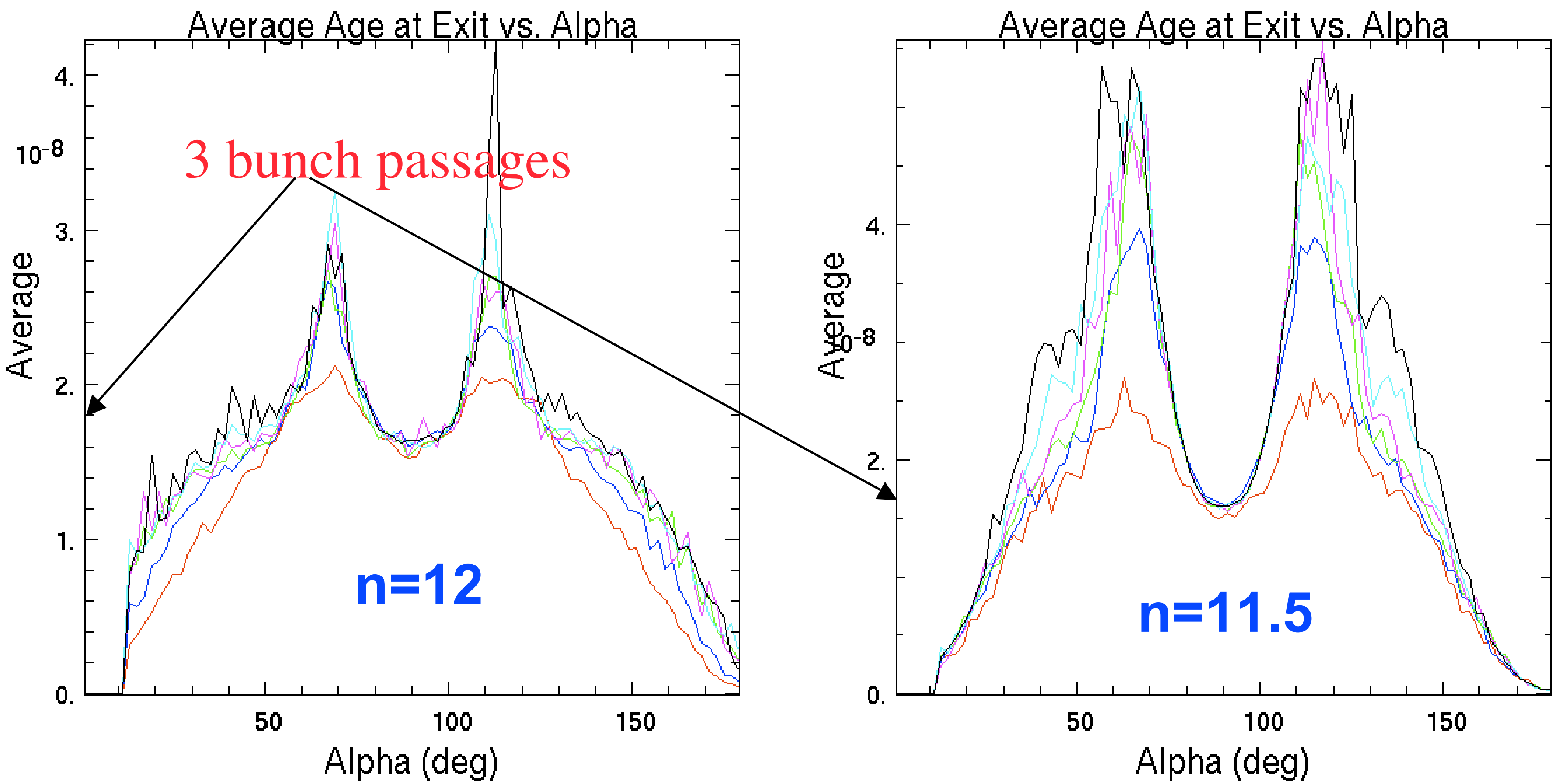
Assume $r >> \sigma_x$, $r >> \sigma_y$.

Then $|E| \propto 1/r$. Contours of constant E_x and E_y are:



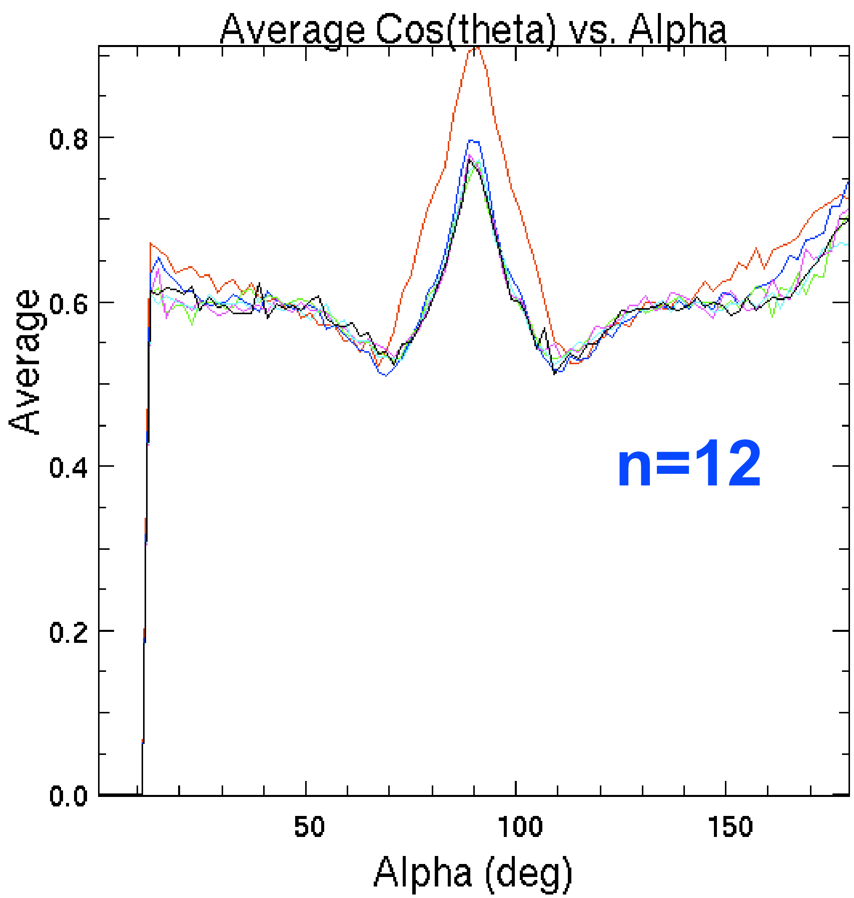
So at resonance, more electrons can pick up the energy needed to make secondaries.

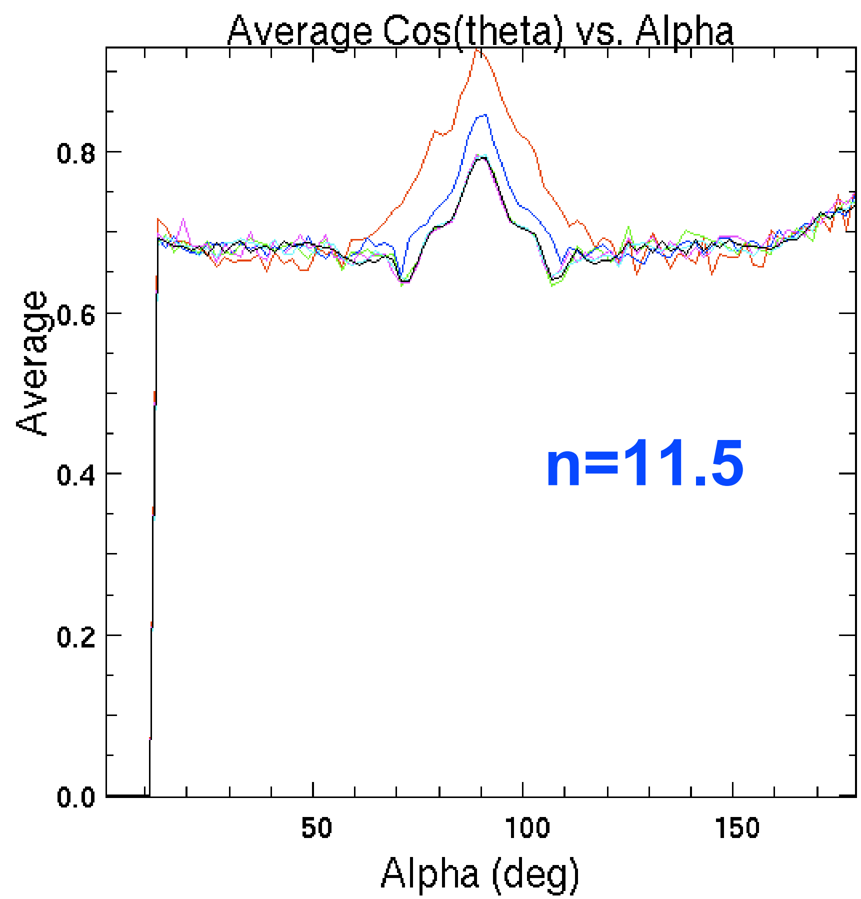
Max energies at wall not very different, probably because electrons exit early for resonant case



- **Early exit is consistent with single particle tracking results.**
- **Though a few electrons with energies up to 30 keV occur in the POSINST simulations, almost all electrons are non-relativistic-- they leave before they attain the very high energies.**

The increase at resonance in perpendicular energy decreases cos(θ), as predicted.





Decreasing the cosine from 0.7 to 0.6 comes from an increase in perpendicular momentum of 30%, assuming $v_{||}$ unchanged.

Conclusions from Posinst Data

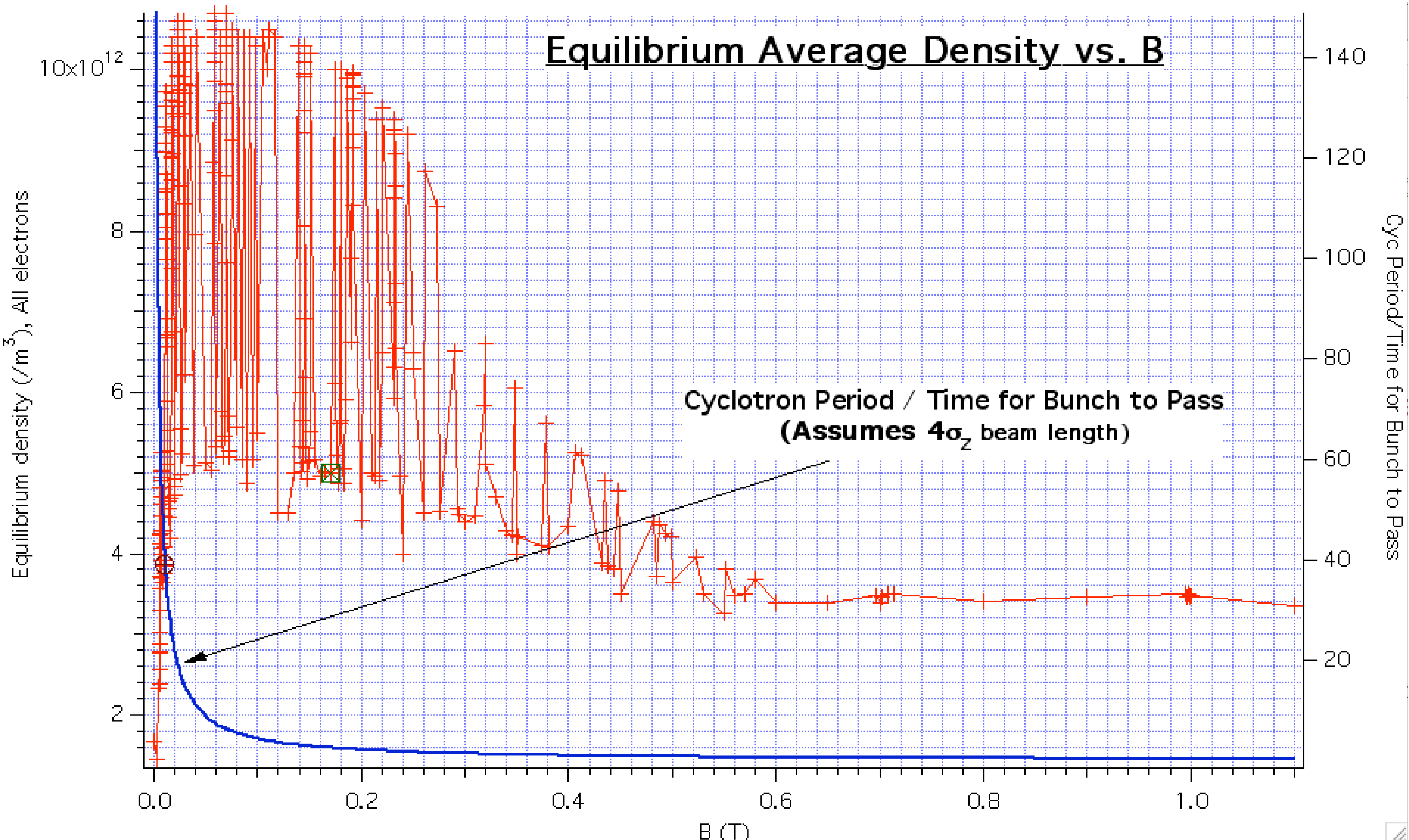
At Resonance:

- Spatially wide distribution of electrons consistent with cyclotron resonance mechanism
- Final energies consistent with single particle tracking for resonance conditions
- Length of time electrons in system consistent with single particle tracking & similar at resonance and non-resonance

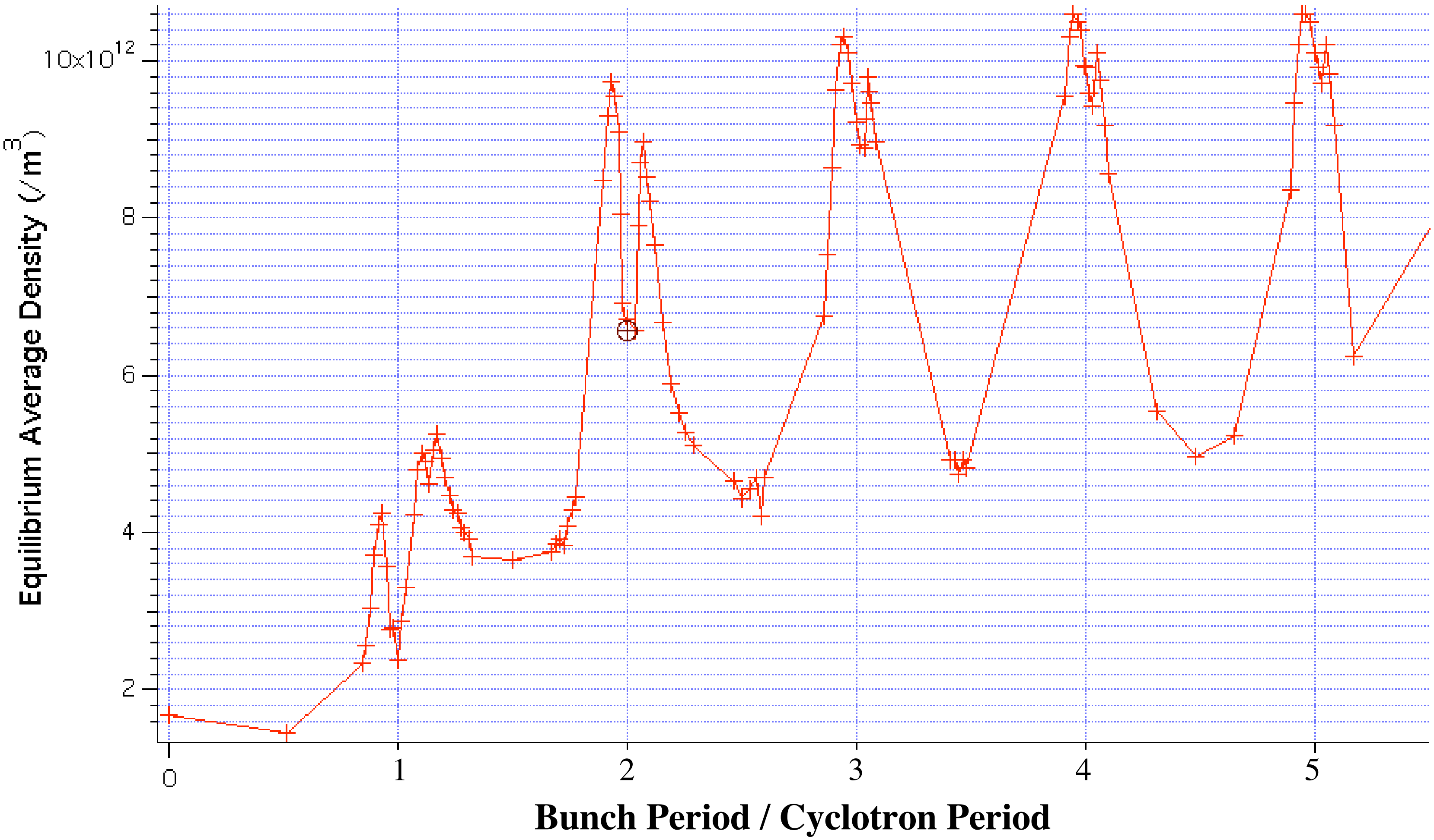
Why do resonance effects disappear at high B?

At high B, cyclotron period similar to the time it takes the bunch to pass ⇒ integrated effect of beam on electron is small.

Note: "time for bunch to pass" is a fuzzy number-- depends on choice of bunch length.



Another new observation--
double peaks at low B



Posinst data seems to indicate that exactly at resonance, at low n, average energy is above the peak of SEY vs. kinetic energy curve, so fewer secondaries are produced.

Resonances measured at SLAC!

Email from Mauro Pivi 2-13-08:

Hi Christine!

Very good news! We did the tests yesterday in the chicane and we *clearly* saw the resonances!!

Periodic peaks in flux (at the RFA) vs. B seen
but B at peaks is not quite what is predicted ...

More work is needed to understand the results.

Comments on Importance

For the wiggler:

This resonant effect produces an increase in the electron cloud density that is not huge (factor of 3), but it is periodic with the wiggler periodicity. Therefore it could possibly cause resonant effects on the beam.

3D calculations (ExB drift will move electrons in and out of resonance) and self-consistent beam-cloud calculations needed.

For dipoles:

Keep the field off resonance. But resonances will occur in the fringe field.

So new news is:

1. Posinst data show broad spatial distribution of electrons in right energy range to make lots of secondaries at B's at resonance. This is due to cyclotron resonance increasing the perpendicular momentum.
2. In the real system as simulated (POSINST), most electrons strike the wall after a few bunch passages, but the resonance causes a significant change in $v_{\perp}$ and in the cloud density.
3. At low n, too many electrons acquire energy beyond the peak of the SEY vs. Energy curve, so there is a minimum in density at the resonance (double peak).
4. Mauro Pivi et. al. have measured higher cloud densities at resonances in the PEP-II chicane ecloud experiment.
5. 3D calculations are necessary to include the ExB drift, which will move electrons along z (in and out of resonance). (Us with WARP3D, and Lanfa Wang with Cloudland).

We hope to see measurements at CESR-TA!

Backup Slides

POSINST uses certain assumptions...

- Beam does not evolve in time (OK for short times, e.g., buildup)
- Beam electric field from Bassetti-Erskine formula
- Beam magnetic field neglected (v_e small)
- PIC model to compute & apply electron space charge
- Electrons generated according to phenomenological models

  secondaries: Furman-Pivi