Highlights from the ILCDR08 Workshop (Cornell, 8-11 July 2008)

report by S. Calatroni and G. Rumolo, in CLIC Meeting 25.07.2008

- Goals of the workshop:
  - 4th of the ILCDR series, on R&D projects necessary for the design of the ILC Damping Rings:
    - Low Emittance Tuning
    - Electron cloud
  - Kickoff meeting for CesrTA:
    - Define the use of CesrTA as test facility for specific subjects related to the above topics
- 4 Electron Cloud Working Sessions:
  - Observations and measurements
  - Status of simulation tools

    Giovanni
  - Mitigation techniques
  - Experimental planning

    Sergio

From: M. Palmer, *ILCDR08 Introduction*

Cornell University
Laboratory for Elementary-Particle Physics

ILCDR08

- Goals for this workshop are two-fold:
  - Continue the reorganization of the ILC Damping Rings Effort for the ILC Technical Design Phase
    - Re-scoped plan
  - Bring together experts on low emittance tuning and electron cloud effects to provide guidance and suggestions for the CesrTA program
    - 2 years of flexible experimental operations - need to maximize the impact of the program
    - Explore synergies with other electron cloud and low emittance tuning groups
    - Explore options for collaboration in the new budget environment
    - Get input to ensure that we carry out the most important experiments to provide a viable damping ring design when it is time to move forward with the construction of a linear collider

From: M. Palmer & D. Rubin, *CesrTA Introduction*

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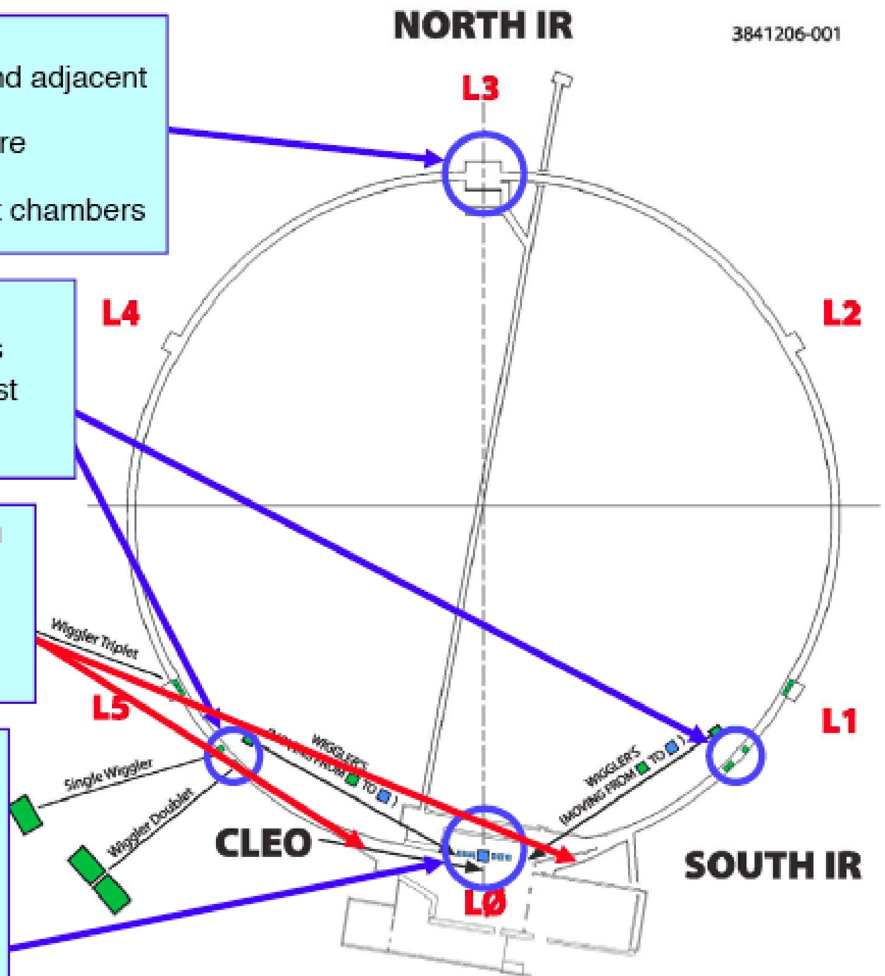
CesrTA Program II

- Down to reconfigure CESR ⇨ CesrTA has just started
- R&D Targets:
  - Now through mid-2009
    - Complete low emittance machine reconfiguration and upgrades
    - Deploy and commission instrumentation needed for low emittance program
    - Study EC growth studies in wigglers, dipoles, quadrupoles and drift regions in CESR
    - Initial EC mitigation studies
  - Mid-2009 through April 1, 2010
    - Work towards progressively lower emittance operation
    - Complete EC mitigation studies
    - EC beam dynamics studies at the lowest achievable emittances
    - Focus shifts much more heavily to experiment versus machine modifications

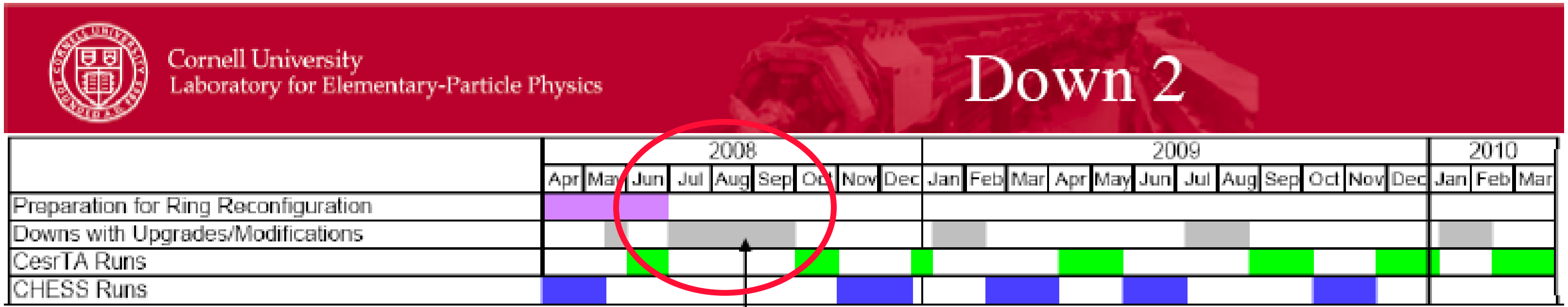
From: M. Palmer & D. Rubin, *CesrTA Introduction*

CESR Reconfiguration

- L3 Straight
  - Instrument large bore quadrupoles and adjacent drifts
  - Install of PEP-II experimental hardware (including chicane) in early 2009
  - Provide location for installation of test chambers
- Arcs where wigglers removed
  - Instrument dipoles and adjacent drifts
  - Provide locations for installation of test chambers
- CHESS line upgrades for x-ray beam size monitor
  - D-line this summer
  - C-line next year
- L0 Straight
  - All wigglers in zero dispersion regions for low emittance
  - Instrumented wiggler straight and adjacent sections



From: M. Palmer & D. Rubin, *CesrTA Introduction*



- Reconfigure CESR for ultra-low emittance
- Install positron xBSM optics line
- Start deployment of new BPM system
- Upgrade survey network and alignment hardware
- Install instrumented vacuum section in L0 (CLEO IP)
- Remove wigglers from arcs and re-deploy in L0
- Deploy first instrumented wigglers in L0 (2?)
- Install instrumented vacuum system in L3 (CUSB IP)
- Deploy L3 diagnostic chicane?
- Deploy vacuum diagnostics with with wiggler replacement chambers in CESR arcs
- Complete upgrade of transverse feedback system for 4 ns bunch spacings

A quick glance to the CesrTA target parameters...

Parameter	***Value***
Energy	1.9 - 5.3 GeV
No. wigglers	12
B_{max}	2.1 T
ε_x (geometric)	2.25 nm
ε_y (geometric)	20 pm (~40 nm normalized)
Q_x	0.59
Q_y	0.63
Q_z	0.070 - 0.098
σ_z	6.8 - 8.9 mm
$\Delta E/E$	$8.1 - 8.6 \times 10^{-4}$
Rf voltage	7.6 MV
$\tau_{x,y}$	~ 60 ms
α_p	6.2×10^{-4}
N_b	$1 - 2 \times 10^{10}$
Bunch spacing	Multiples of 4 ns and 14 ns

- Two years of CesrTA experimental program will be mainly devoted to:
  - **Study of e-cloud formation and instability**
  - Development of low emittance tuning techniques
  - Development of x-ray beam size monitor for ultra-low emittance beams
- Additional possible studies
  - Studies of emittance diluition
  - Ion effects
  - 2D x-ray beam size camera upgrade
  - Tests of ILC prototype hardware
  - Further emittance reduction and further refinement of tuning methodology

- **Electron cloud studies** that can be carried out at CesrTA:
  - Benchmark of modelling tools against experiments (code validation)
  - Verification of mitigation techniques (for ex. coating behavior wrt synchrotron radiation)
  - Development of diagnostics tools
- However
  - Parameter range is different from CLIC-DRs in some respects (larger bunch spacing $\rightarrow$ lower line density, lower energy, larger emittances)
  - Similar scaled bunch parameters $\rightarrow$ Emittance growth studies (due to e-cloud and/or space charge) maybe useful

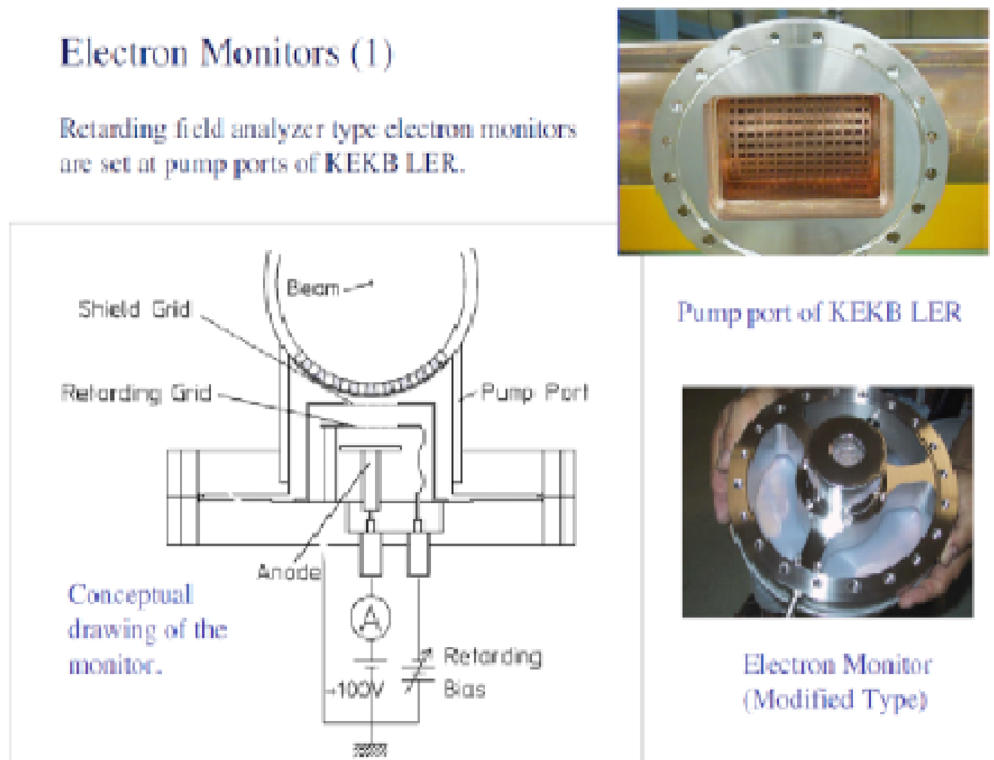
EC Working Group:

Measurement of Cloud and Effects on Beam

- **Direct electron cloud observation**:
  - Measurements with the RFA (KEKB-LER, CesrTA)
  - Microwave diagnostics (CERN-SPS, LBNL-PEPII)
- **Indirect electron cloud observation** (through the effects on the beam)
  - Tune shift along the batch (CesrTA, KEKB)
  - Coherent:
    - Single bunch instabilities (KEKB)
    - Coupled bunch instabilities (CesrTA ?)
  - Incoherent:
    - Emittance growth (KEKB)

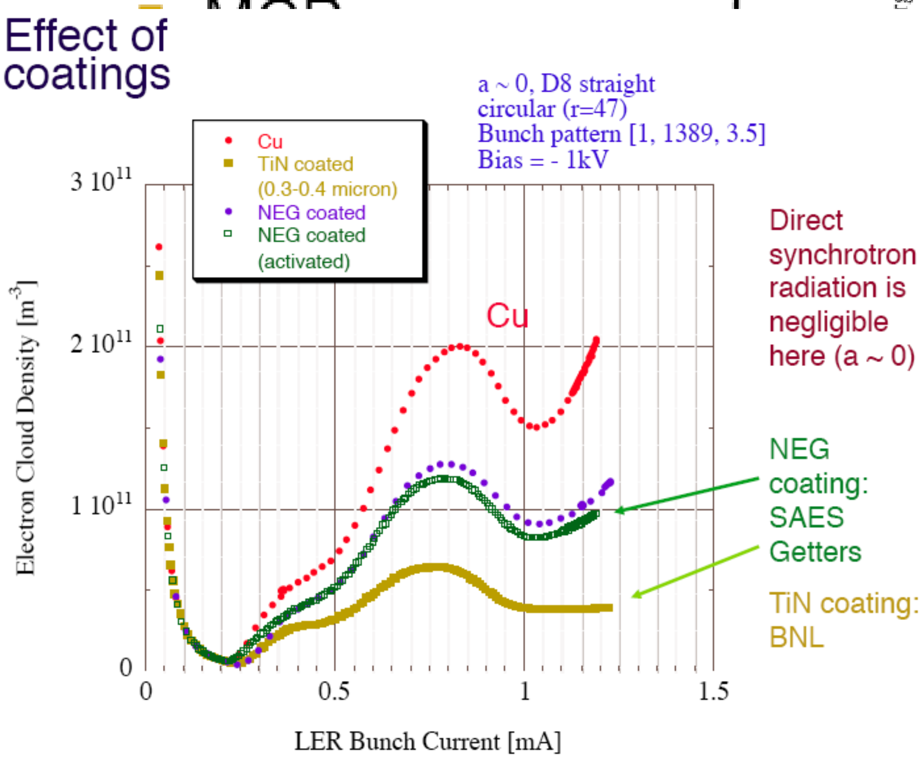
Measurement_Kanazawa_1

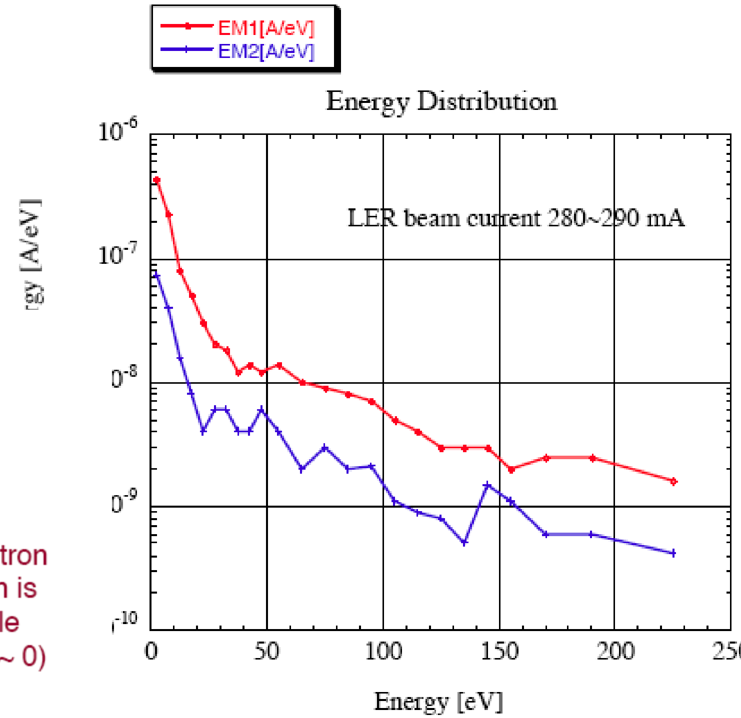
- RFA type electron detectors with Faraday cup or MCP or multi-strip anode are installed in KEKB LER.



Measurement_Ka

- Most electrons that en below 20 eV.





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electron cloud near the

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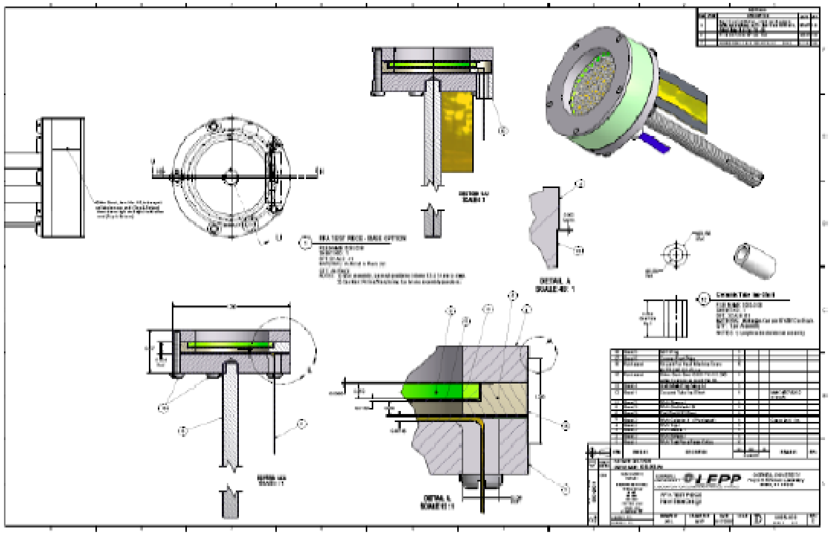
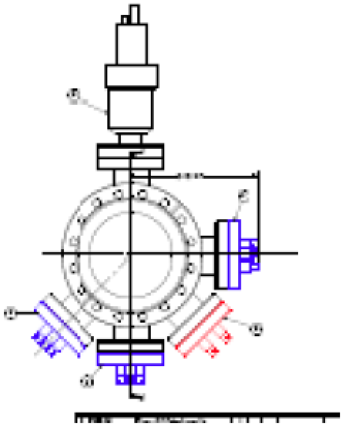
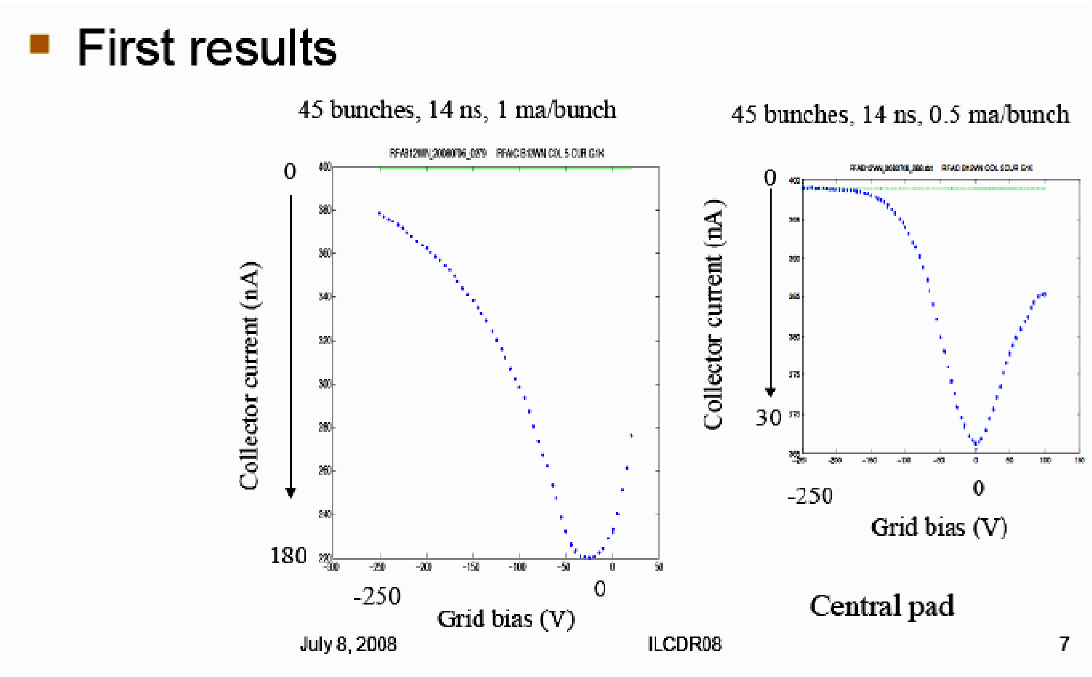
Cornell Thin RFA

From: S. Greenwald, *RFA Development and Experimental Measurements at Cesr-TA*



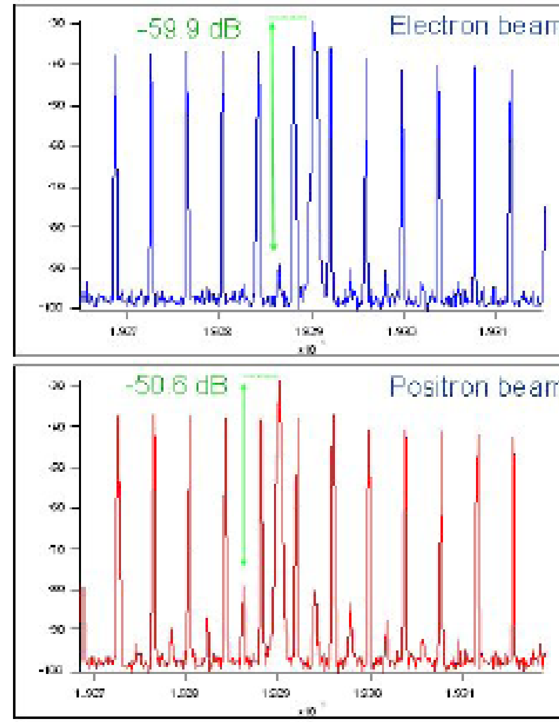
L3 BEAM PIPE INCLUDING THE RFAS

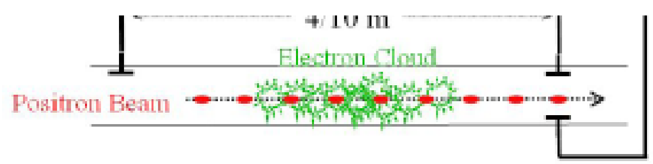




Measurement_Santis_1

- First data:
  - Positron and electron beam
  - Direction of the beam.
  - Dependence on gap length and beam/bunch current
  - Effects of vacuum chamber shapes
  - Dependence on beam energy
  - Cyclotron resonance





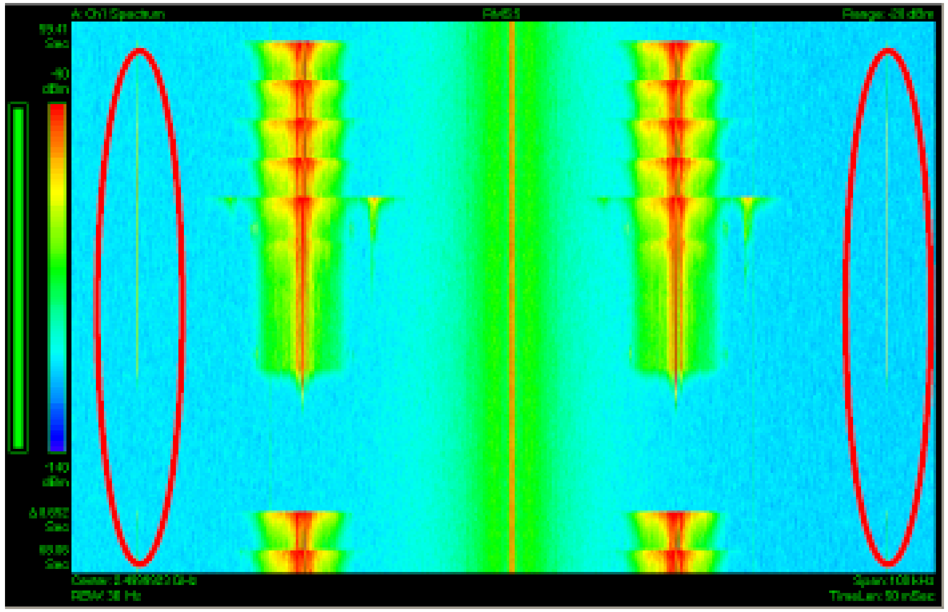
CesrTA dipole/ex-wiggler

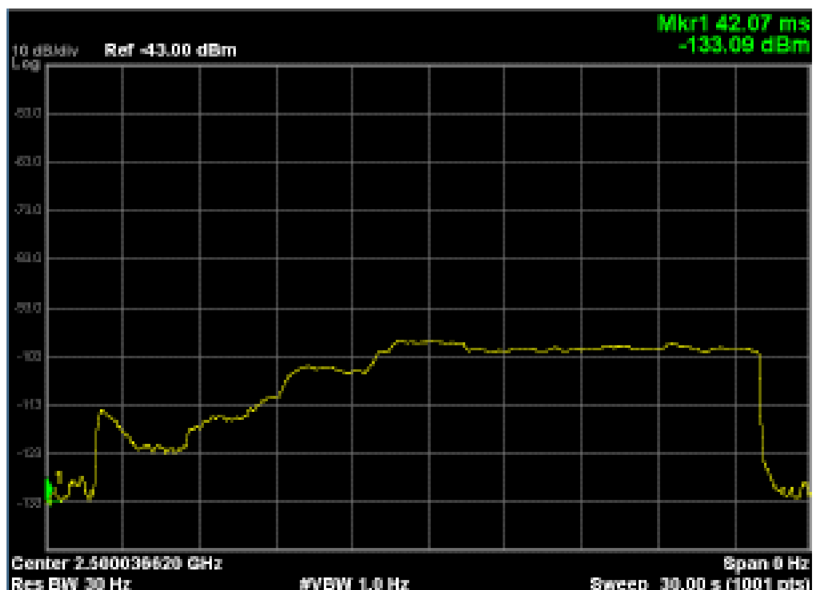
Measur

- TE wave t
measurem
to measur
density at

Principle idea:
“When electromagneti
through a not too
experience a pha
small attenuatior

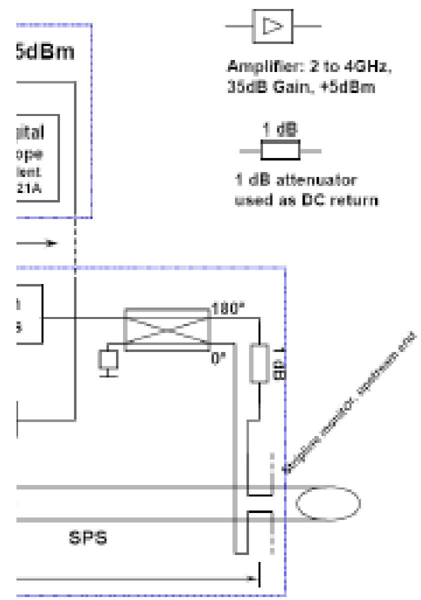
- Setup simi
measurem





Intensity of the modulation sideband
vs time in logarithmic scale

t set-up



vaveguide mode interaction 10

Antenna1

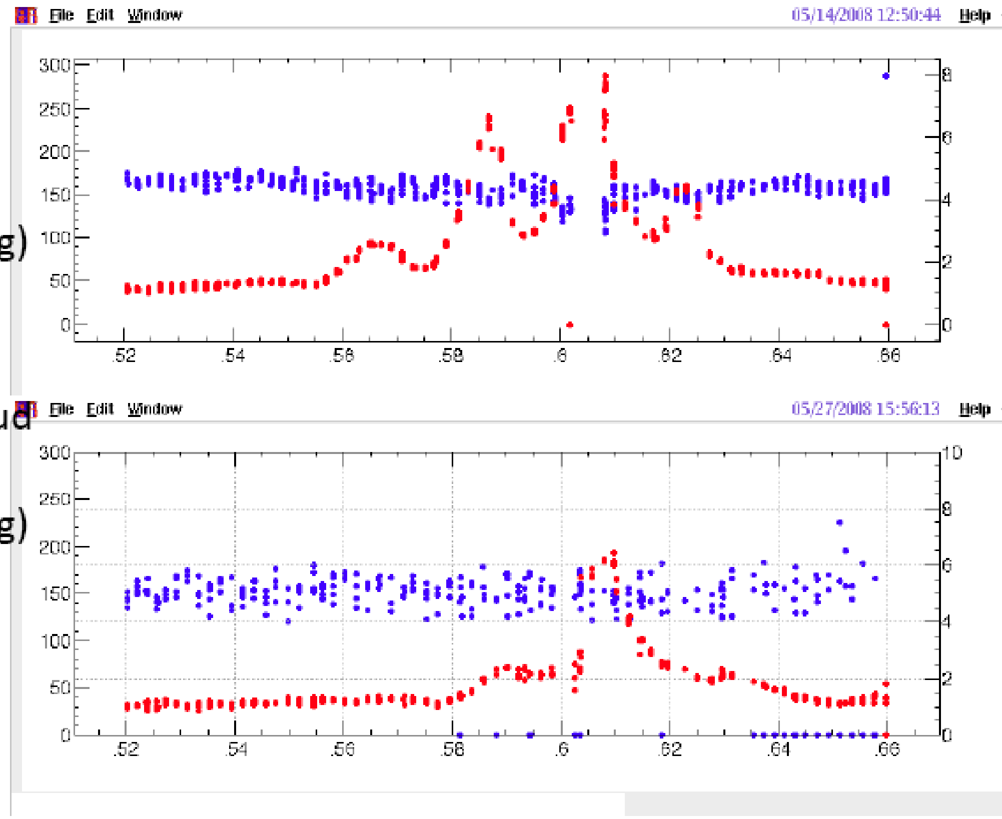
Antenna3

From: K. Ohmi, *Emittance growth due to electron cloud*

- **Emittar**
  - Beam patterı
  - Close
  - 12, 16 the syı by the
  - No en
- **Emittar**
  - No en synchı
  - Tune s bunch instability) observed

H. Tune Scan (at ν_y=0.6)

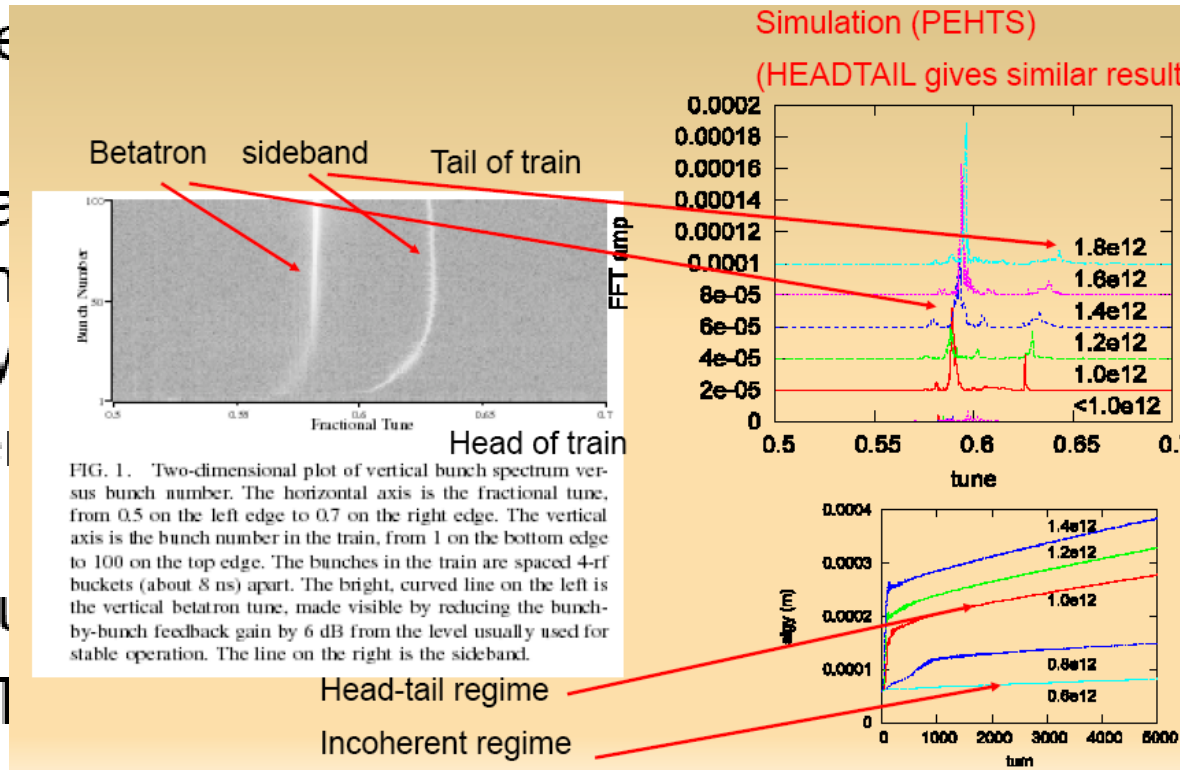
- No e-cloud (5/14) (98ns spacing)
- With e-cloud (5/27) (16ns spacing)



Effects on Beam_Flanagan_1

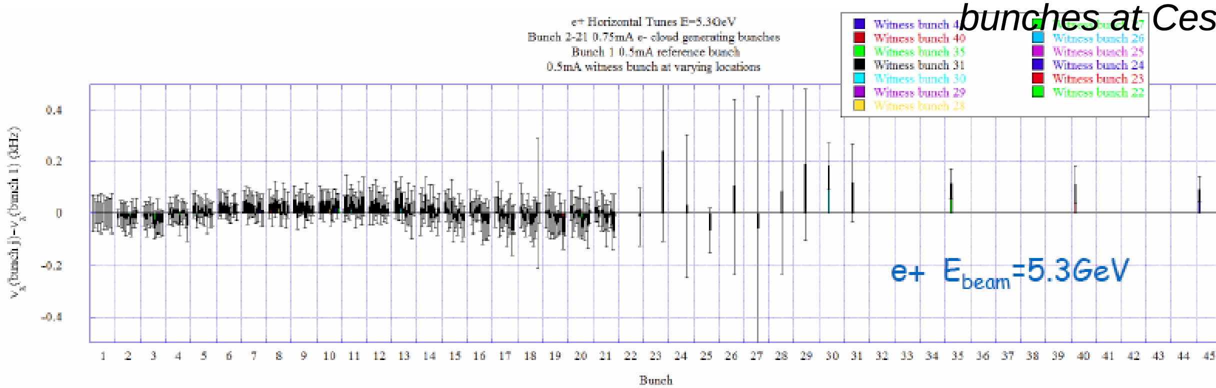
- Vertical synchro-betatron sidebands found at KEKB LER, which are … eam blow-up.
- Signal ha … supportin … ead-tail instability
- Measure … scales is critical
- This shou

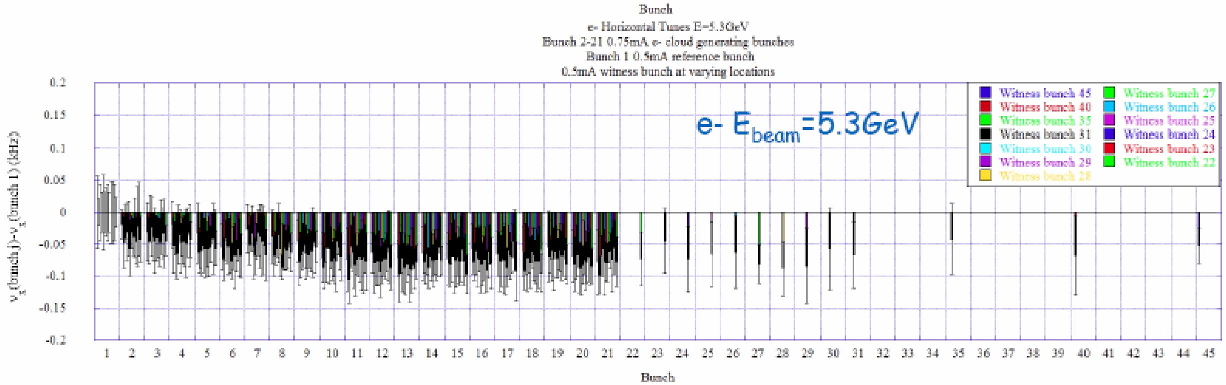
==>T



E=5.3GeV 20 bunch generating train@0.75mA/bunch, reference & witness bunch@0.5mA: ν_x

From: R. Holtzapple, *Studies with winess bunches at CesrTA*





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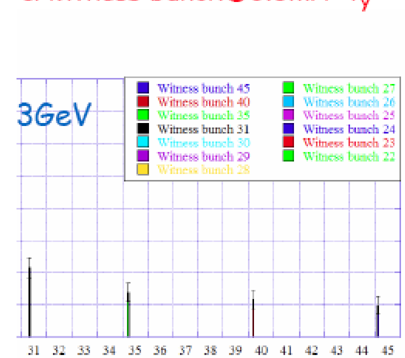
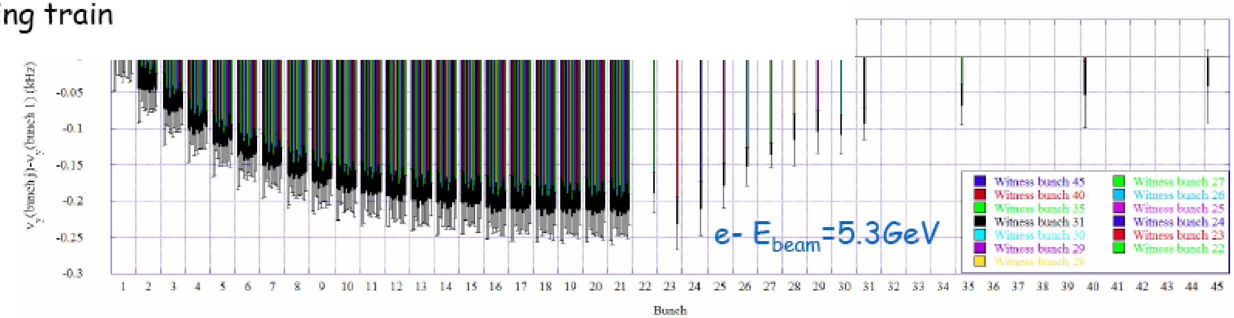
& witness bunch@0.5mA: ν_y



- e+ $\Delta\nu_x$~0kHz along generating train. Large scatter in the tune measurement for the witness bunches.
- e- $\Delta\nu_y$~–0.05kHz along generating train

To characterize …

various witness bu



- e+ $\Delta\nu_y$~0.65kHz along generating train. The decay time of the vertical tune is ~150ns. Slope of the tune shift changes along the generating train. Tune measurement is repeatable!
- e- $\Delta\nu_y$~-0.22kHz along generating train which levels out ~bunch 16. The decay time of the vertical tune ~200ns. Note: In both cases the tune shift does not go to zero by bunch 45.

EC Working Group:

Ecloud Simulations Group: Summary

ECLOUD, POSINST, CLOUDLAND

Talks in simulation session

- G. Dugan: "Simulations at Cornell for CesrTA"
- J. Calvey: "Simulations for RFA studies at CesrTA"
- J. Crittenden: "Simulations for witness bunch studies at CesrTA"
- T. Demma: "Build-up of electron cloud in DAΦNE in the presence of a solenoid field"
- C. Celata: "Electron cloud cyclotron resonances for short bunches in magnetic fields"
- K. Ohmi: "Study of electron cloud instabilities in CesrTA and KEKB"

POSINST

PEHTS, HEADTAIL

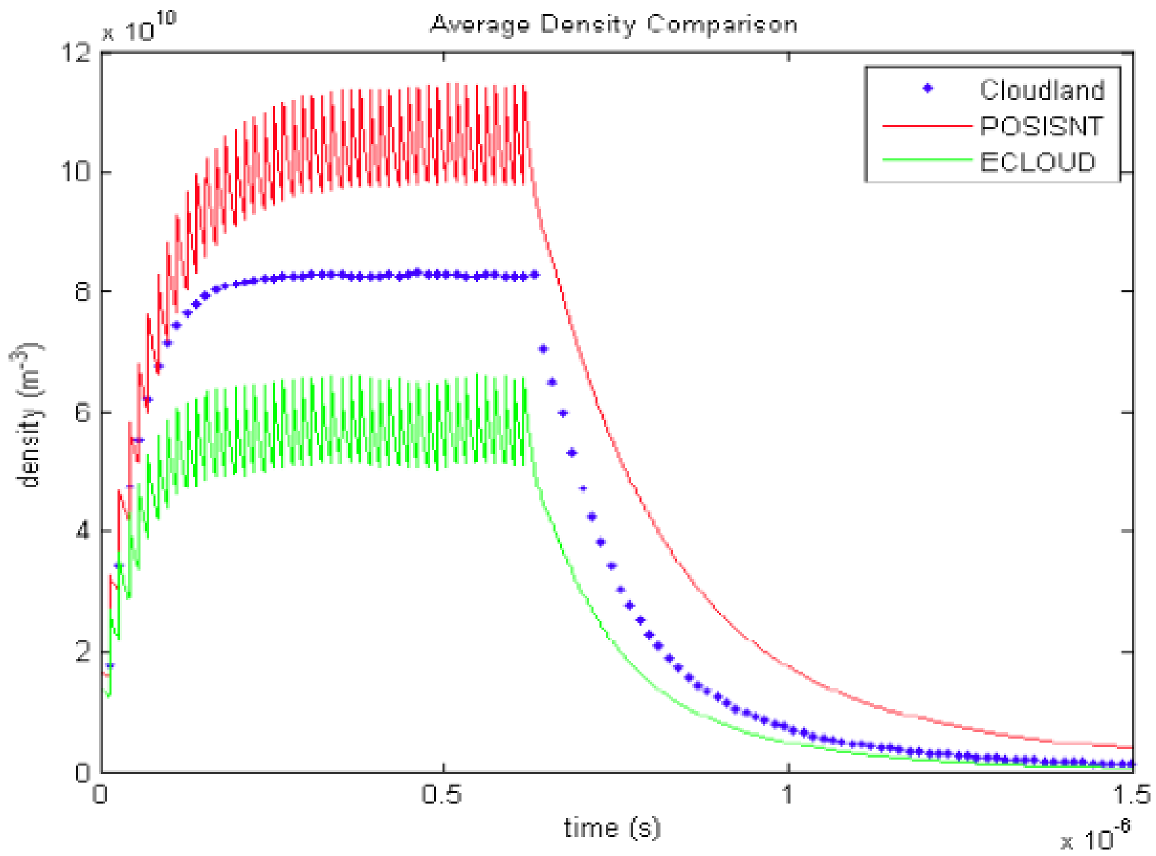
ECLOUD

From: J. Calvey, *Simulations at CesrTA*

Cornell University
Laboratory for Elementary-Particle Physics

L3-1 (45 bunches, 14 ns, 1mA)

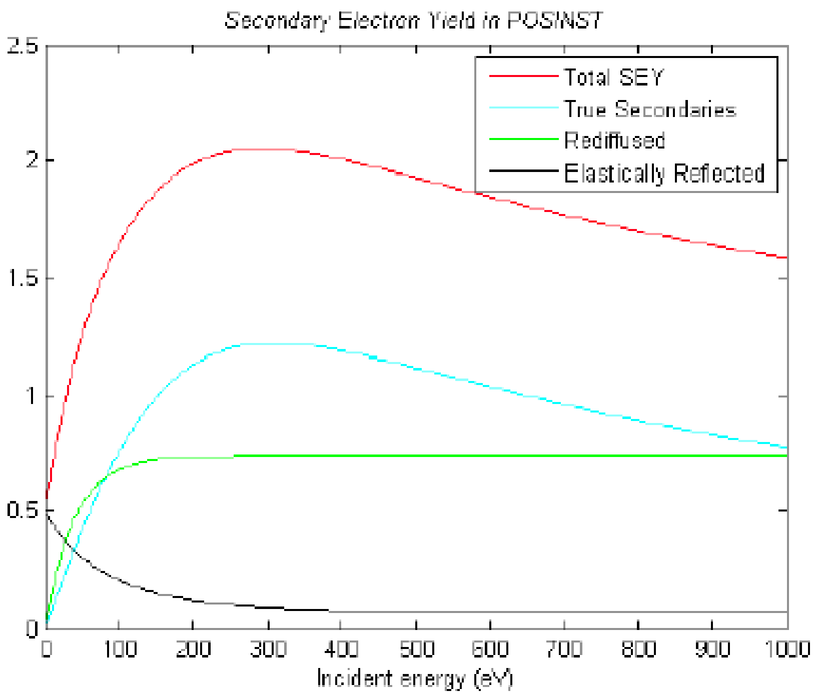
- Match within factor of 2



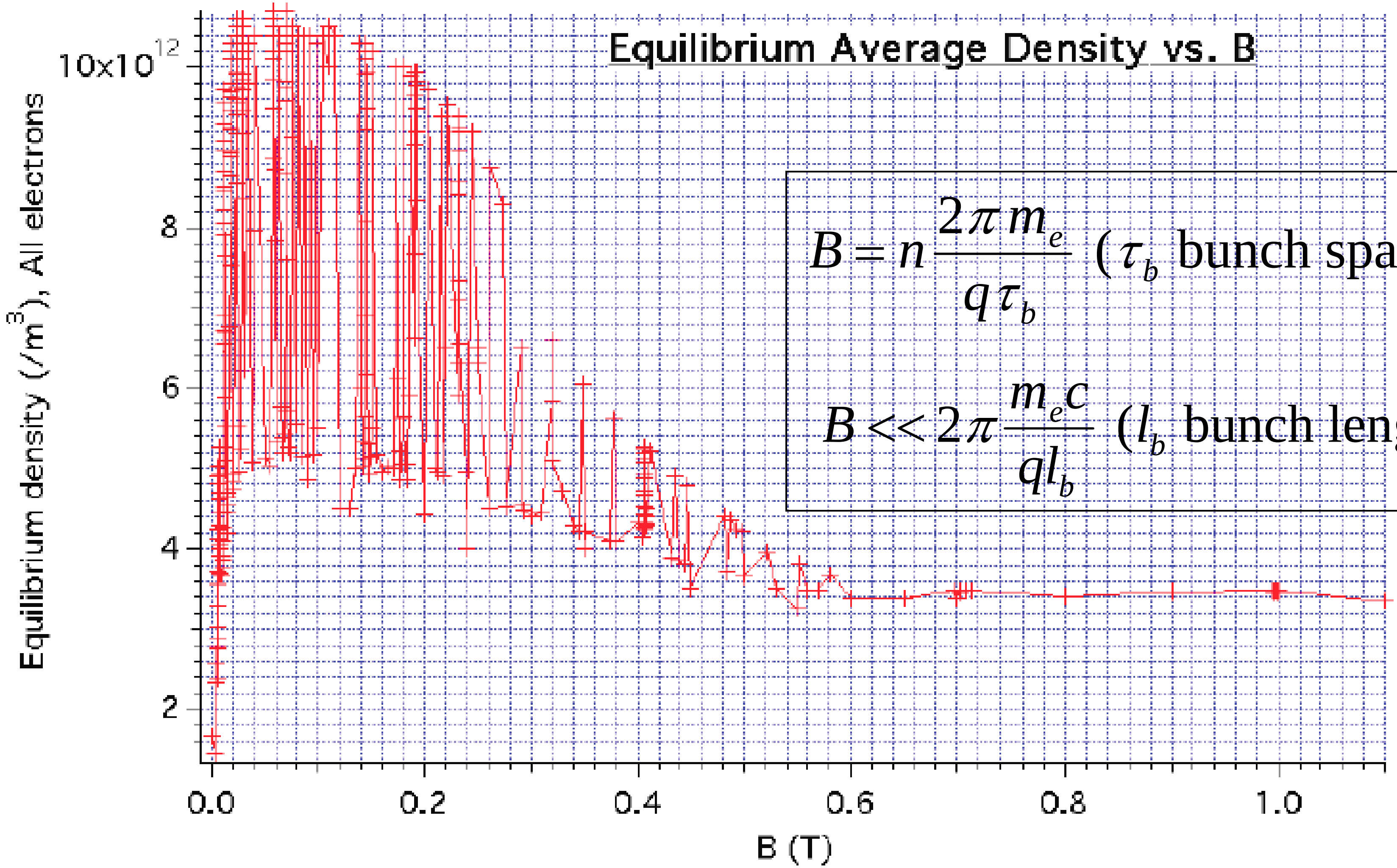
From: J. Calvey, *Simulations at CesrTA*

SEY Models

- Significantly variation between simulation programs
  - Whether rediffused electrons are included
  - How “true secondaries” and reflected electrons are weighted
- Probably main reason for discrepancies



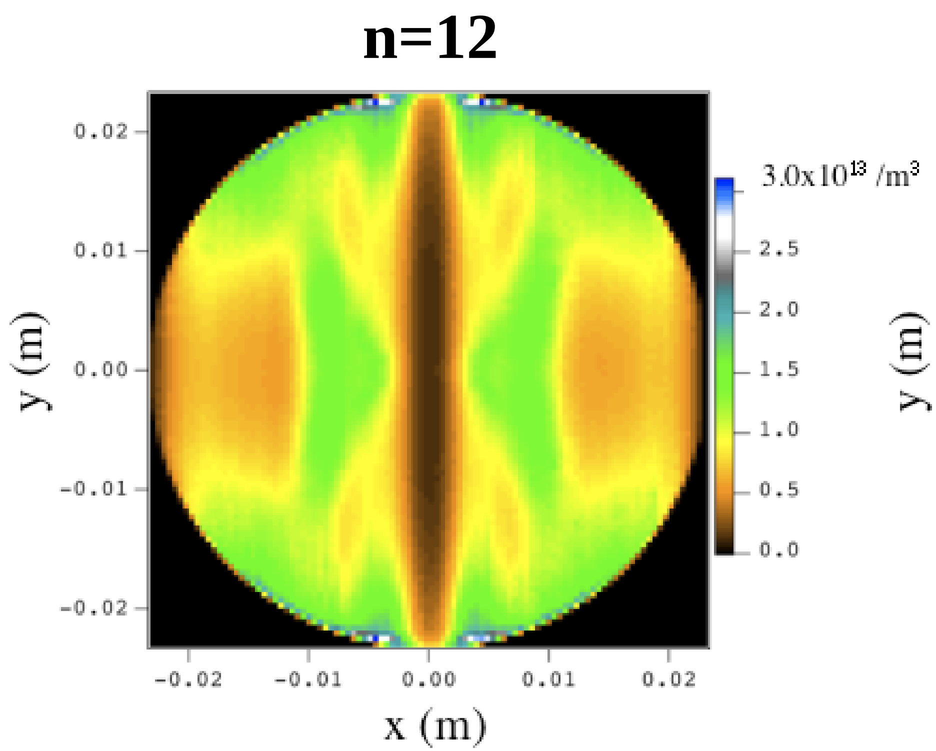
From: C. Celata, *Cyclotron resonances in magnetic fields*

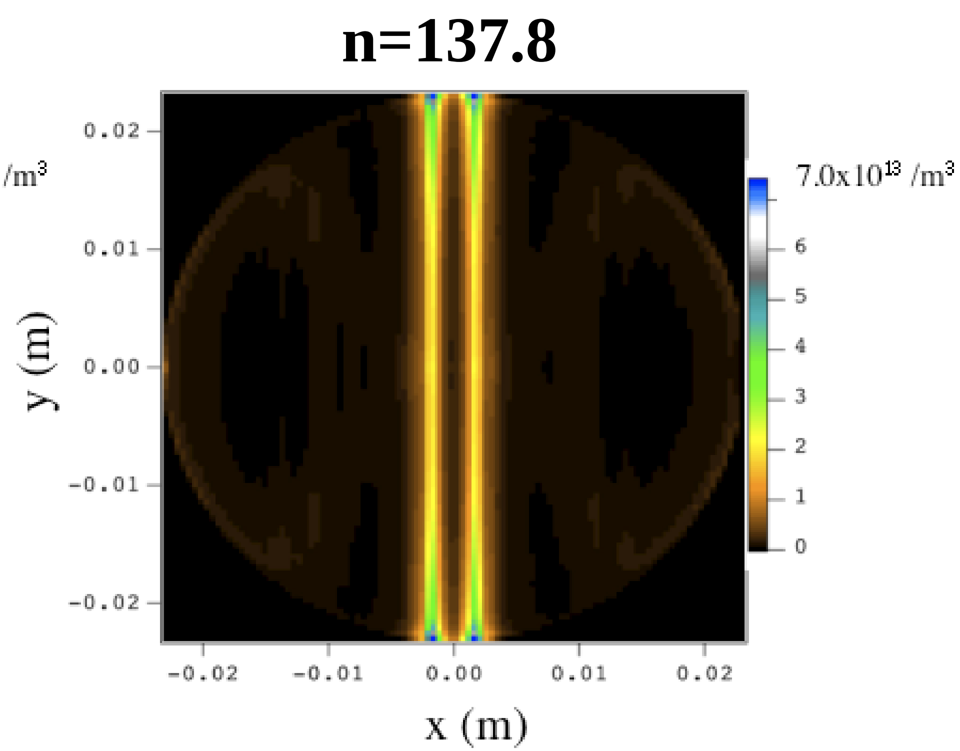


$$B = n\frac{2\pi m_e}{q\tau_b} \quad (\tau_b \text{ bunch spacing})$$

$$B << 2\pi\frac{m_e c}{q l_b} \quad (l_b \text{ bunch length})$$

From: C. Celata, *Cyclotron resonances in magnetic fields*





The high-field (no resonance) case shows the characteristic "stripes" pattern seen in many experiments. At resonance the electrons are much more widely distributed in x.

From: C. Celata, *Cyclotron resonances in magnetic fields*

3D Wiggler Calculations are Essential but Challenging

Need to simulate 3D effects:

- ExB drift ⇒

  e^- s ⇒ different z (and B) ⇒ go in (and out) of resonance.

  Resonance may affect more e^-s, but each gains less energy

  What is the sign of the effect?
- Use correct 3D field:

  B_x and B_z, and variation in B_y across the chamber.

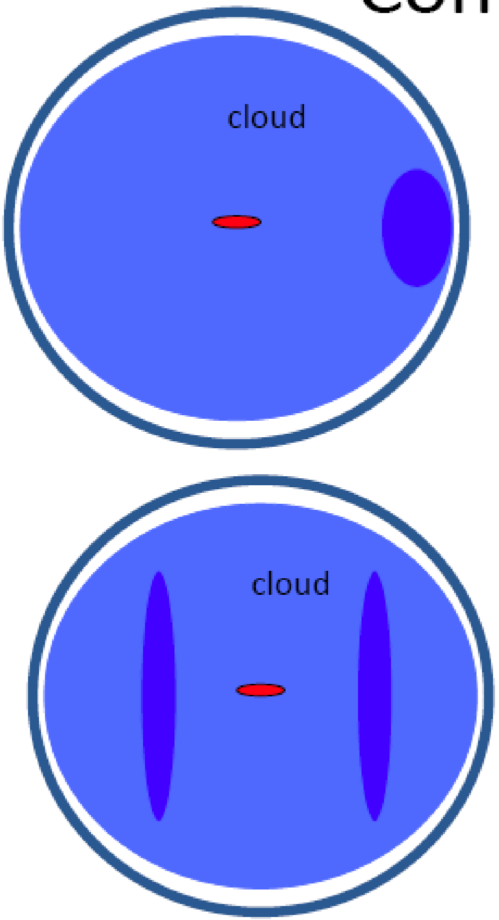
  Can do a lot with POSINST.

But it is hard:

- width of the resonances (ILC DR wigglers) ≈ 10 G ⇒ need z resolution ~ 2 μm! Grid cells asymmetric (350:1:1), leading to possible error, or could instead make huge runs by resolving x and y to μm scale.
- Time step must be ~ 1 x 10^{-11} s to resolve beam and cyclotron motion.

From: K. Ohmi, *Coherent effects of electron clouds*

Combination



- $\Delta\nu_y > 0$ $\Delta\nu_x \sim 0$ can be realized, if $\Delta\nu_x$ is cancelled in two distributions.

From: M. Furman, *Summary of Working Session on Simulations*

The 3 aspects of "benchmarking" (1)

- Do the code simulations agree with…
  1. Analytic results whenever they are available (algorithm validation)
  2. Each other (benchmarking)
  3. Measurements (code validation)

Item 2

✓ Understand the influence of rediffused electrons in build up codes

✓ Instability codes have been benchmarked several times against each other (HEADTAIL, PEHTS, QuickPIC)

Item 3

✓ Many free input parameters, which can be used to fit the experimental results

✓ Long story of qualitative or semi-quantitative agreements (or predictions), both for build up and instability simulations

From: M. Furman, *Summary of Working Session on Simulations*

Questions, odds and ends

- Why does $\Delta\nu$ keep increasing after the end of the train with e^- beams?
  - plausibility argument exists; check it with simulated movies of the ecloud
- Why is $\Delta\nu_x << \Delta\nu_y$?
  - I thought K. Ohmi provided the answer (ecloud distribution concentrated in the midplane, or 2 clumps of electrons on either side of the center)
  - This argument is operative if ecloud in the machine is dominated by dipoles
- Will the cyclotron resonances (C. Celata) be important in wigglers (3D field)?
  - question will be answered by 3D simulations and RFA measurements in wigglers
- Effect on e^- survival time due to ions (longer lifetime than otherwise expected)
  - suspicions at SPS and RHIC (?)
- Secondary ionization
  - ionization X-section of residual gas by ~100 eV electrons is >> than for a ~GeV beam
- Surface roughness of extruded Al surface has a preferential direction ==> SEY depends on (θ,ϕ), not simply θ
  - but please: do <u>not</u> attempt an even more complicated SEY model
  - instead, fit beam data with a few effective parameters