Cornell University
Laboratory for Elementary-Particle Physics

Electron Cloud R&D at Cornell

ILCDR08--7/8/08

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Cornell Laboratory for

Accelerator-Based Sciences and Education

Outline

- Overall program goals
- Diagnostics and capabilities
- Witness bunch measurements of coherent tune shift - *see also talk by R. Holtzapple in EC Measurements working session tomorrow*
- RFA measurements of electron currents - *see also talk by S. Greenwald in EC Measurements working session tomorrow*
- Simulations - *see also talks by J. Calvey, J. Crittenden, and G. Dugan, in EC Simulations working session tomorrow*
- Future plans
- Conclusions

Overall program goals

- Understand cloud buildup in drift, quadrupole, dipole and wiggler sections of CesrTA, with different cloud suppression techniques.
- Understand interaction of the cloud and the beam in CesrTA, including instabilities and emittance growth.
- *Benchmark cloud buildup and cloud dynamics simulations using CesrTA data*, in order to develop confidence in the application of these simulations to predict cloud behavior in the ILC damping ring.
- *Demonstrate cloud suppression techniques* suitable for use in the ILC damping ring.

Diagnostics and capabilities

EC-relevant diagnostics:

- Retarding field analyzers in drifts, dipole, wigglers, quads
- Bunch-by-bunch tune measurement system
- Bunch-by-bunch, turn by turn, beam size monitors
- Ports for microwave measurements
- Spectrum analyzers

Capabilities:

- Flexible bunch patterns are possible: Every other RF bucket (4 ns spacing) can be filled or empty, in an arbitrary pattern, with bunch populations in the range 1-10x10^{11} particles/bunch
- Either electrons or positrons can be loaded in the ring
- The beam energy can be varied from 1.9 GeV to 5.3 GeV
- Mitigation measures, such as chamber coatings and clearing electrodes, can be tested in RFA-equipped areas.

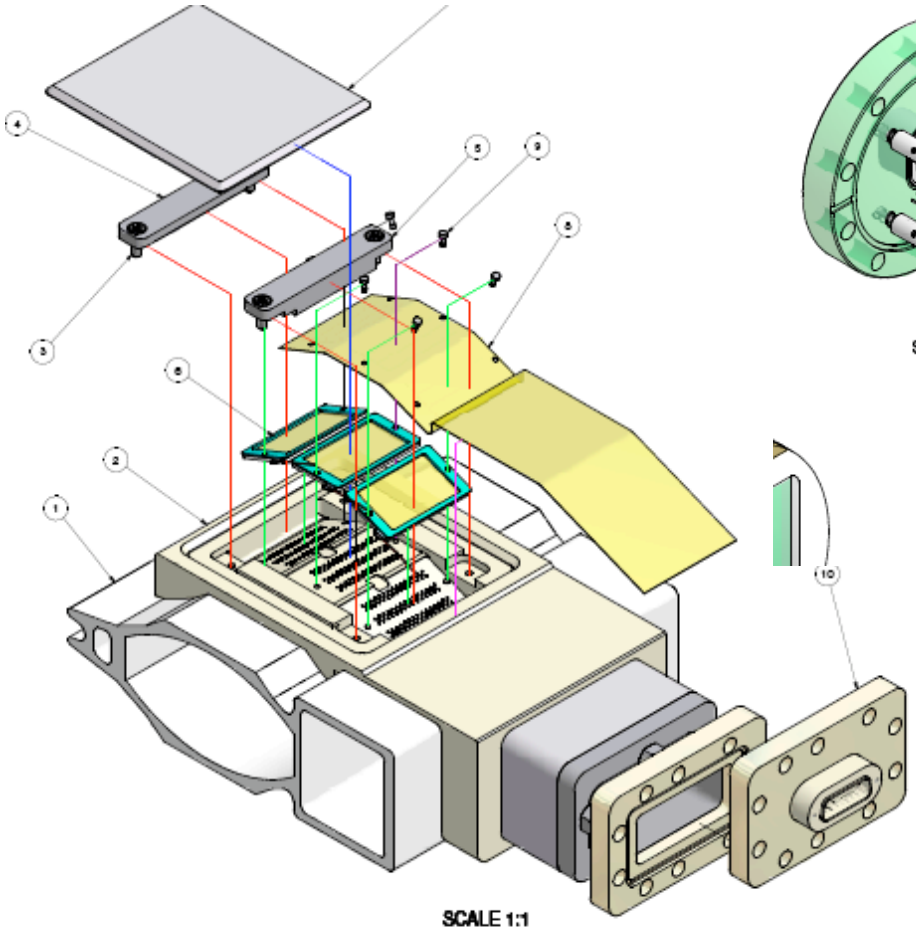
RFA measurements of electron currents

RFA measurements have been made at several drift regions and in a dipole, under a variety of conditions:

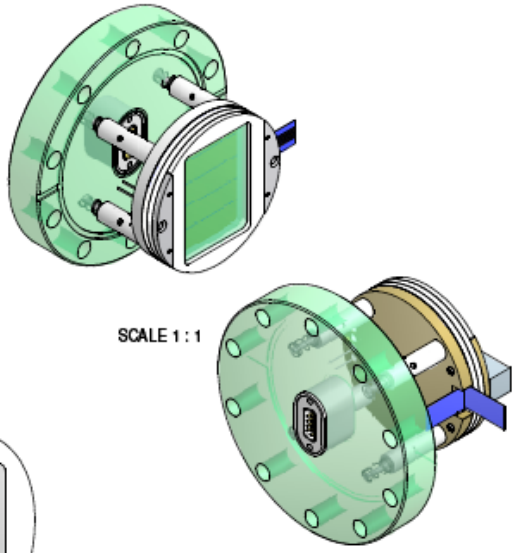
- Electrons and positrons
- 1.9 GeV and 5.3 GeV
- Various loading trains

The devices measure the time-average electron current into the wall at the device location, as a function of energy (via grid bias).

Cornell RFA Deployment

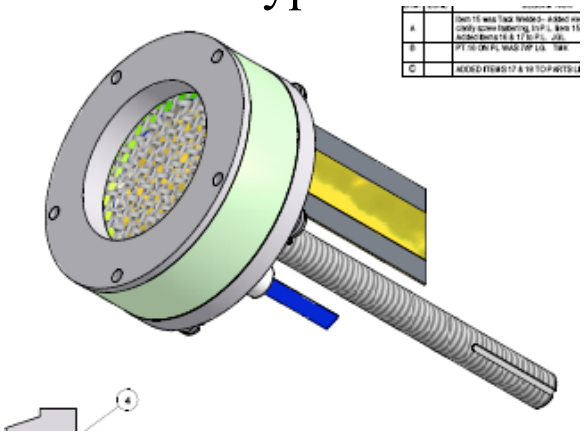


Segmented thin RFA's at B12WN (dipole) and B12NS (drift)



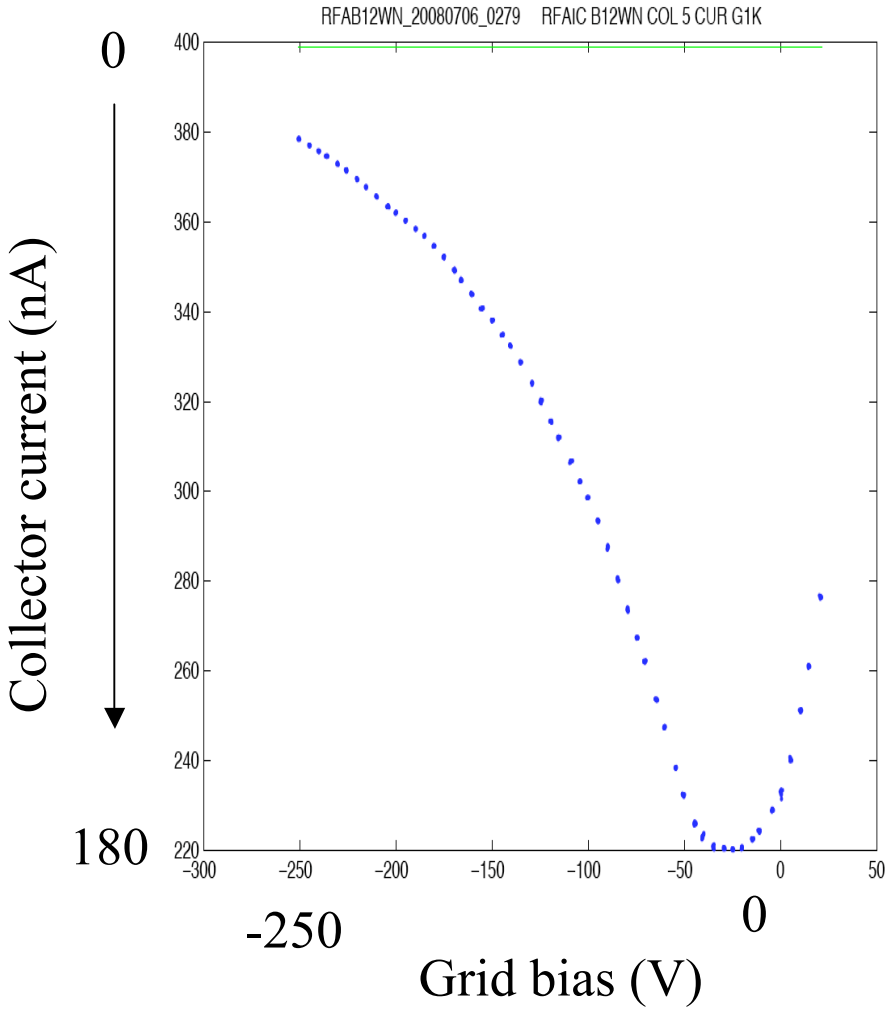
Segmented insertable RFA's at 14BW

Prototype RFA's at L3

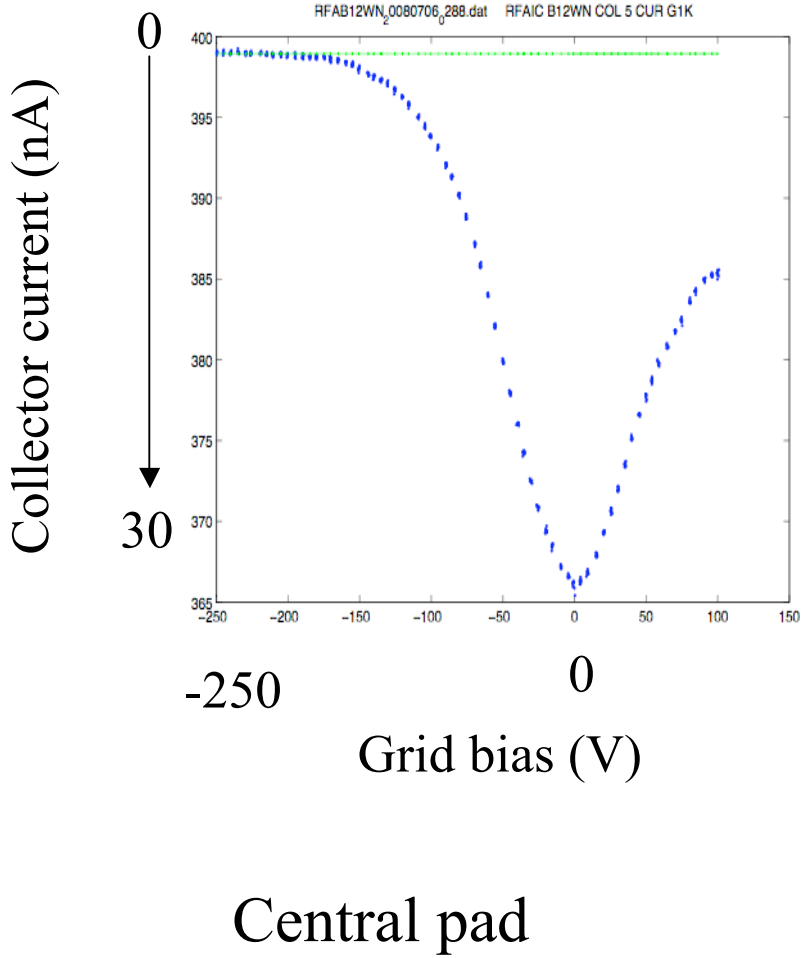


RFA measurements in B12WN dipole: e^+, 5.3 GeV

45 bunches, 14 ns, 1 ma/bunch



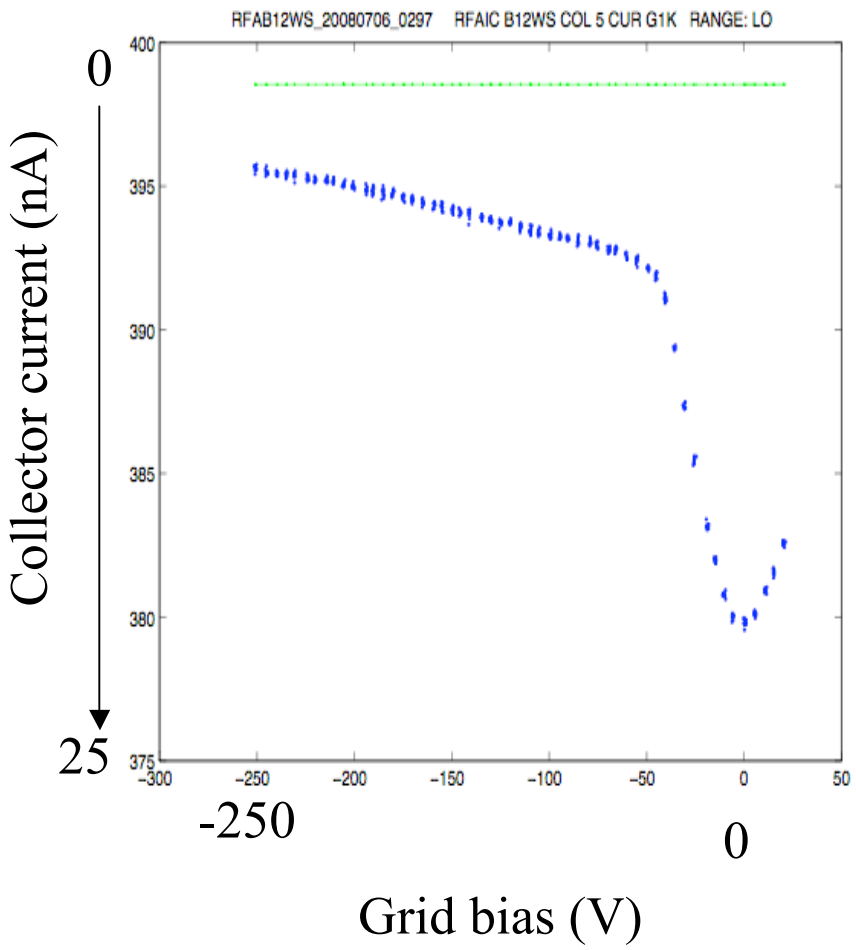
45 bunches, 14 ns, 0.5 ma/bunch



Central pad

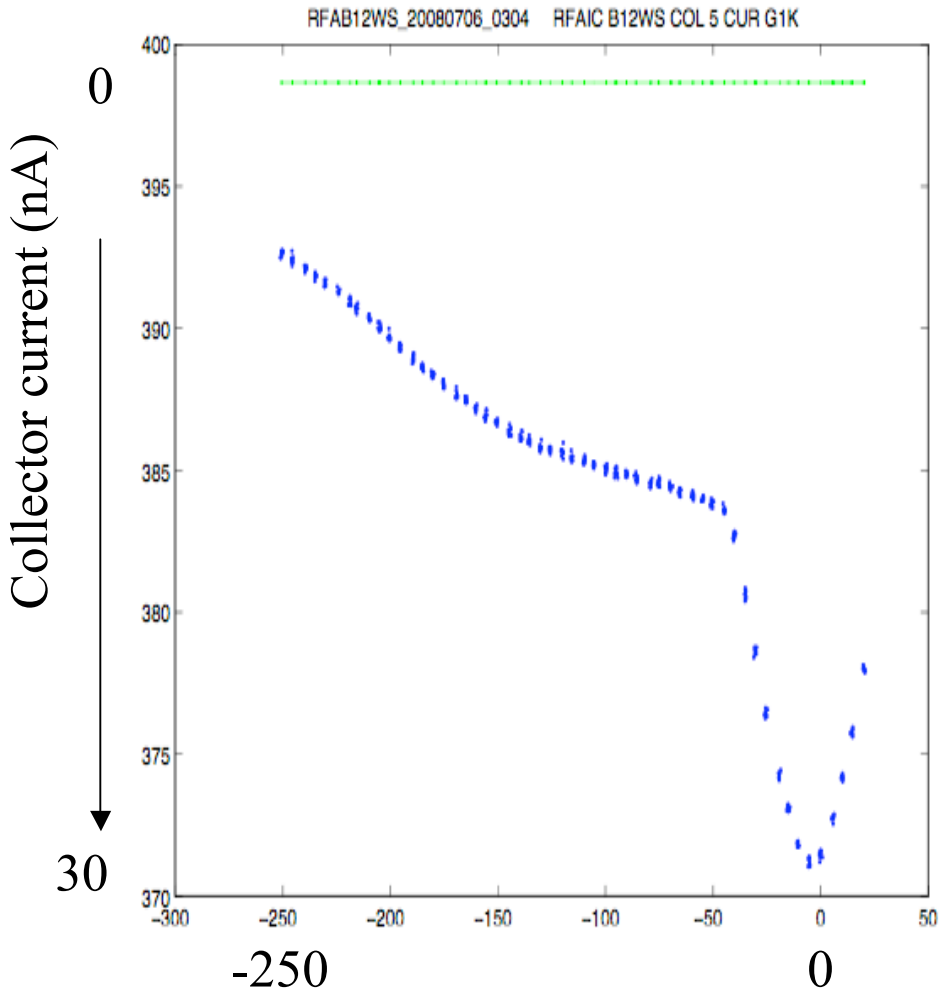
RFA measurements at B12WS (drift): 9 bunches, 280 ns, 5 mA/bunch

Positrons



Central pad

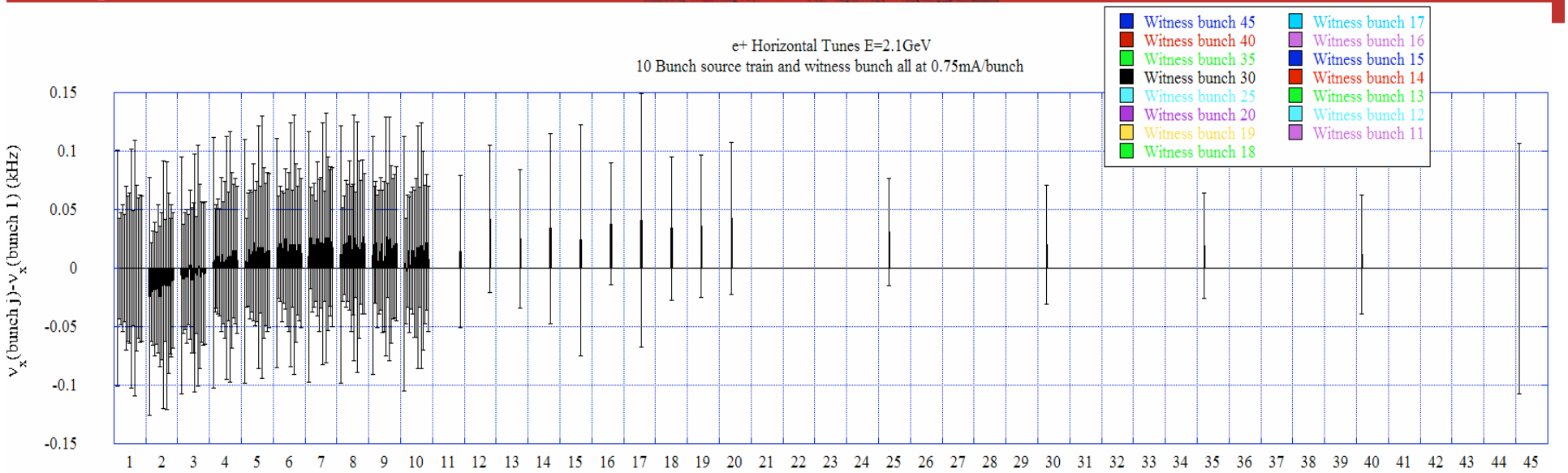
Electrons



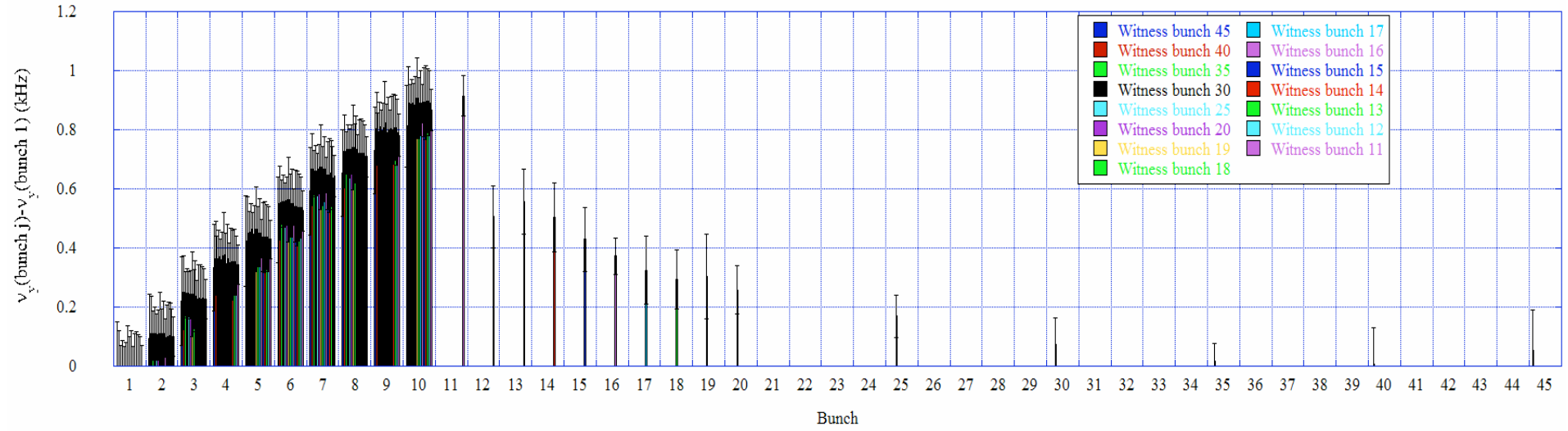
Witness bunch measurements of coherent tune shift

•"Witness bunch" technique:
  • a train of "loading bunches" generates a cloud density around the ring
  • "witness bunches" are placed at variable times after the loading train, and the coherent tune of the witness bunch is measured. The coherent tune shift is a measure of the beam-averaged field gradient due to the cloud charge density at the time of the witness bunch
• Coherent tune shift measurements (both vertical and horizontal tune) using the witness bunch technique have been done in a variety of conditions
  • Electrons and positrons
  • 1.9 GeV and 5.3 GeV
  • Various loading trains
•We have also made measurements of the systematic variation of tune shift along a train vs. bunch current

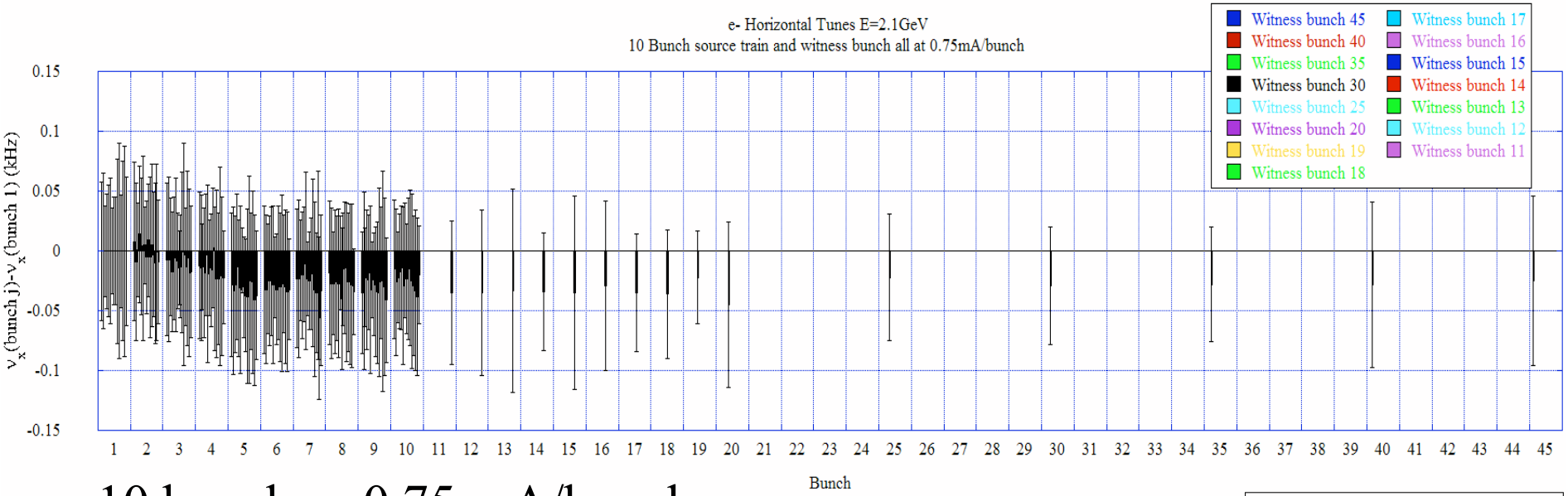
Witness bunch studies-e+@2 Gev



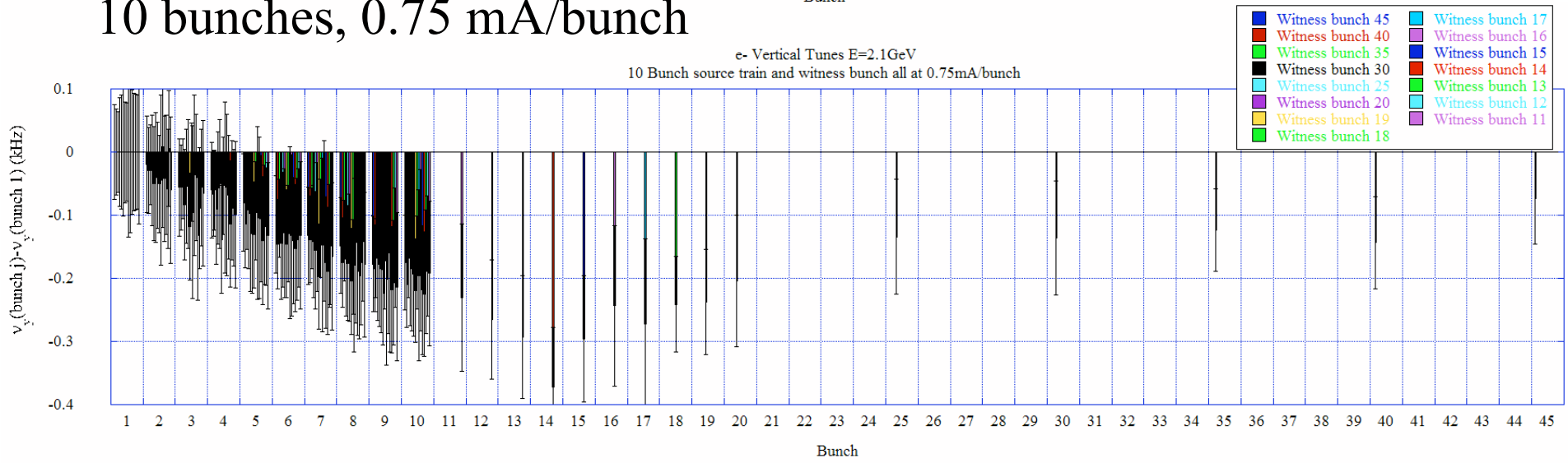
10 bunches, 0.75 mA/bunch



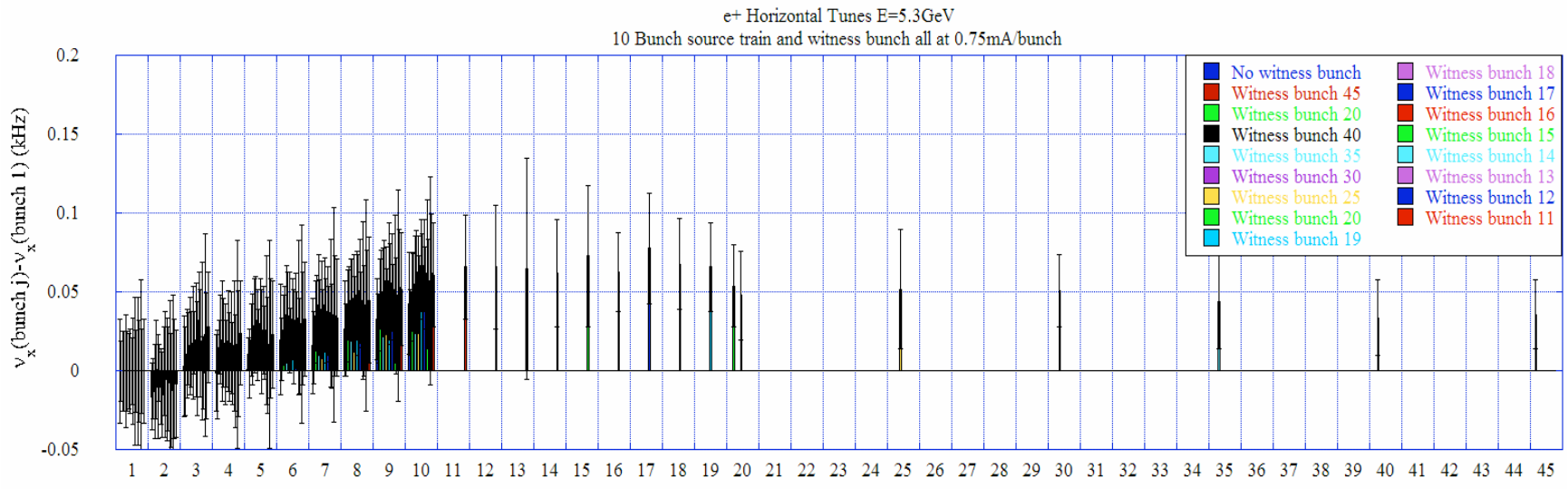
Witness bunch studies-e-@2 Gev



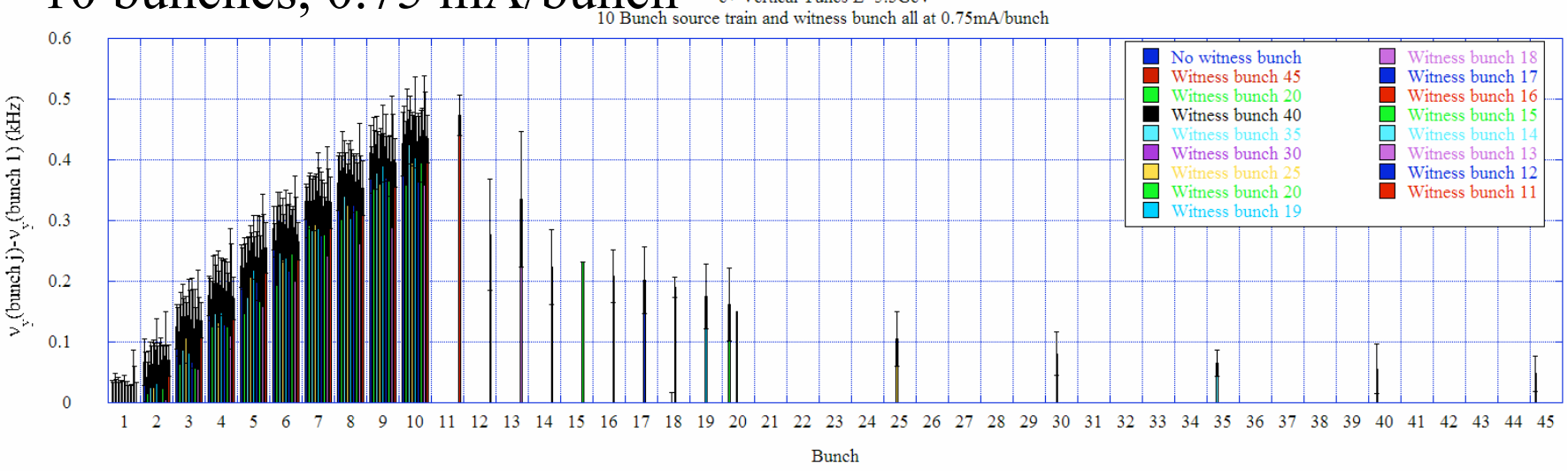
10 bunches, 0.75 mA/bunch



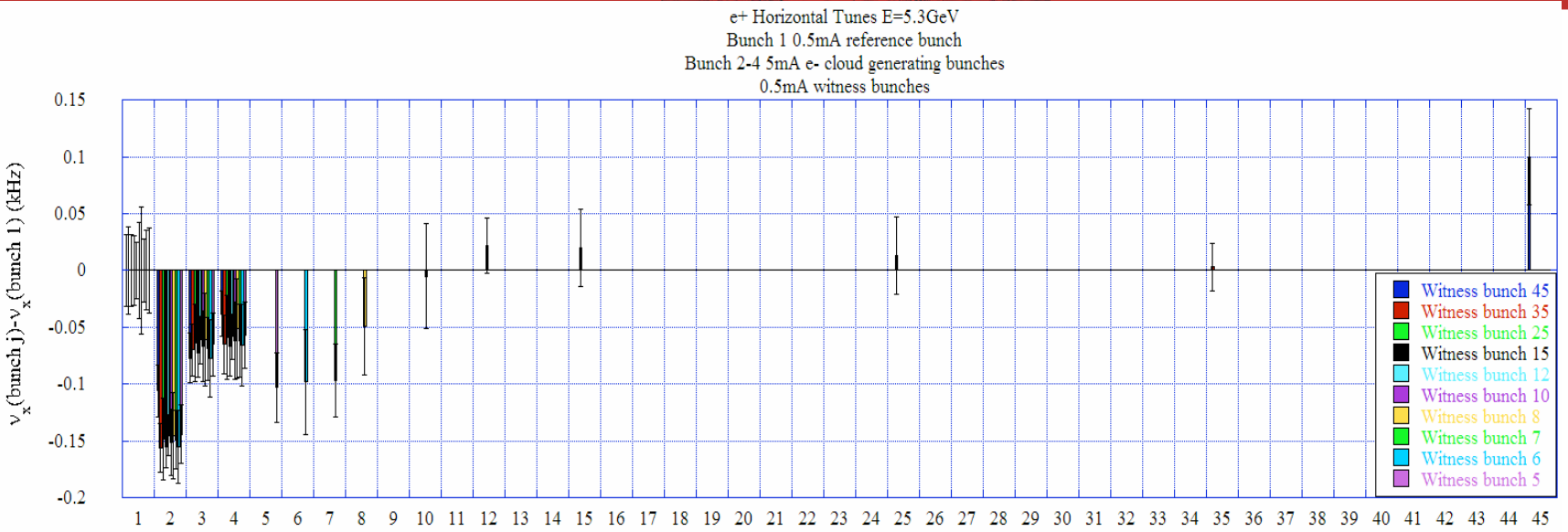
Witness bunch studies-e⁺@5 Gev



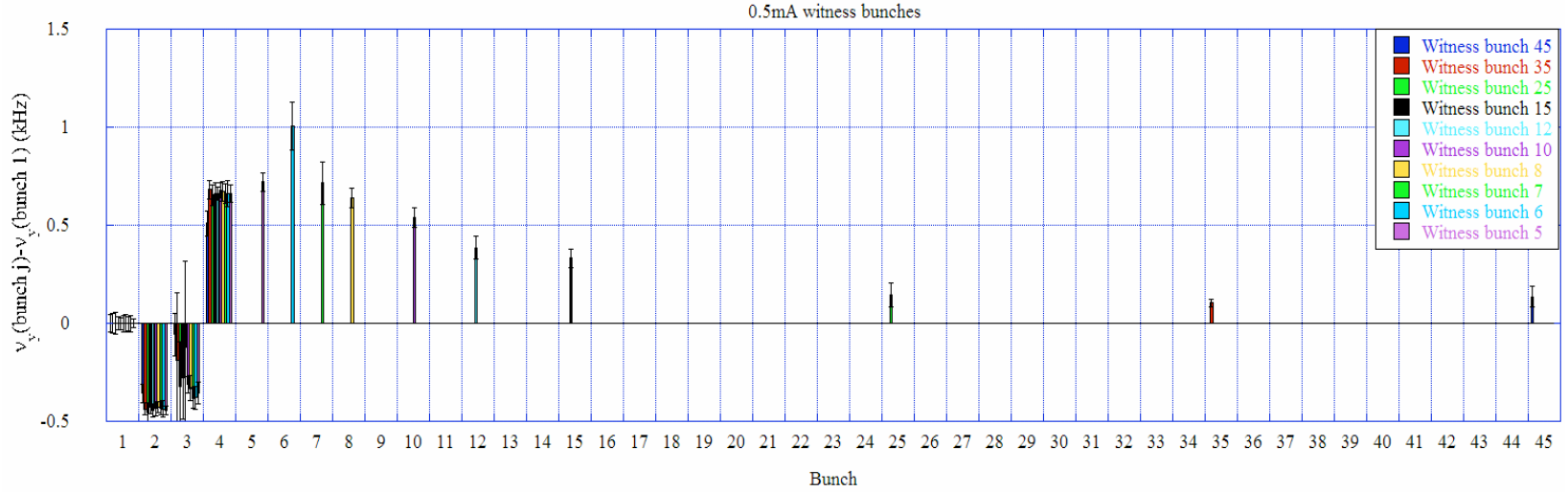
10 bunches, 0.75 mA/bunch



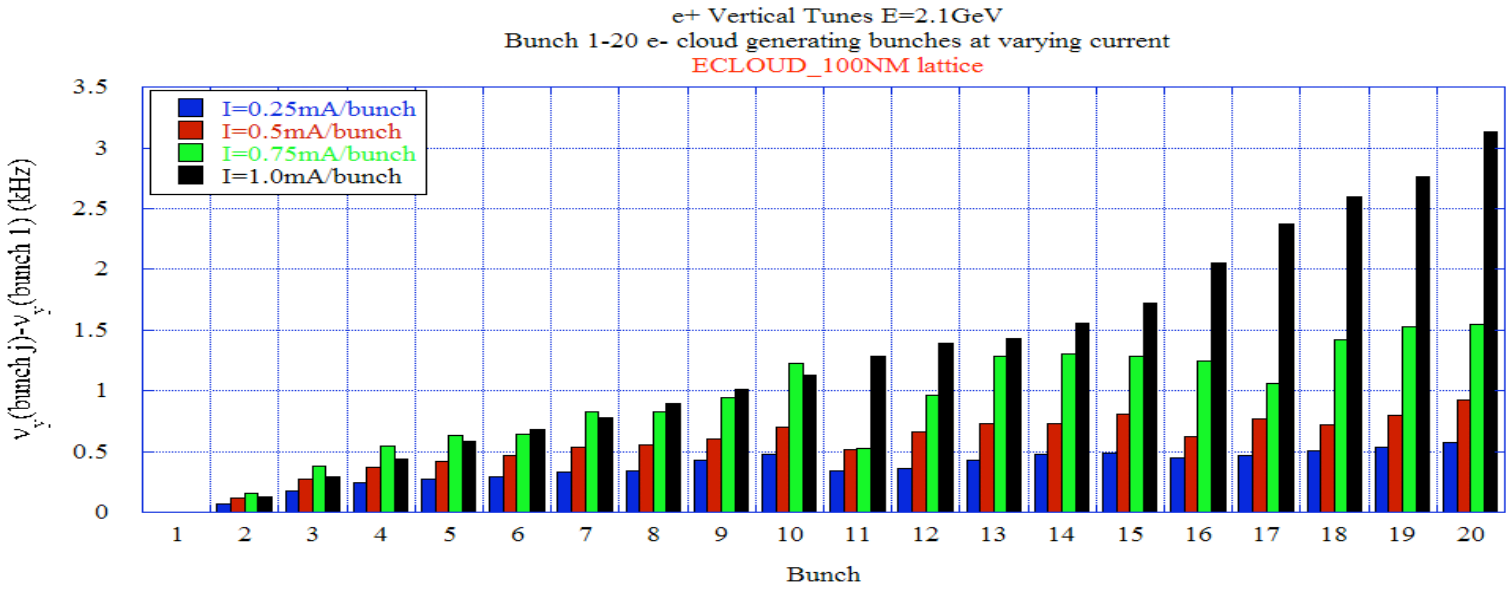
Witness bunch studies-e⁺@5 Gev



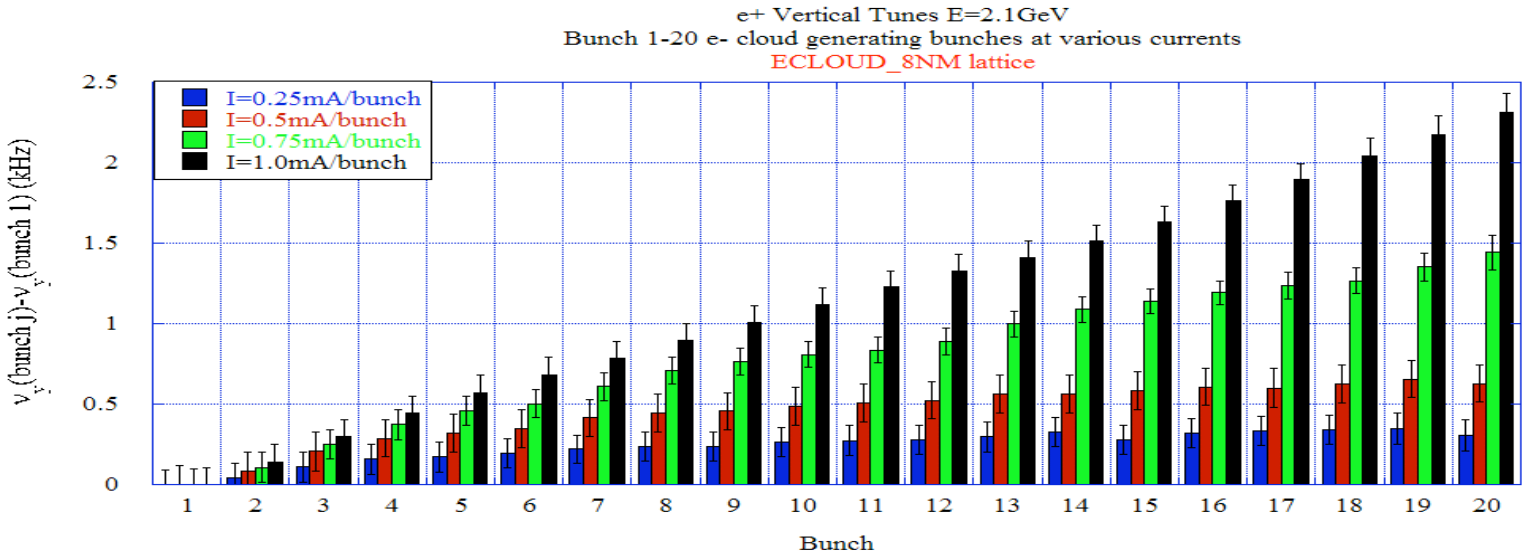
3 bunches, 5 mA/bunch



Current dependence studies-e⁺@2 Gev



100 nm



8 nm

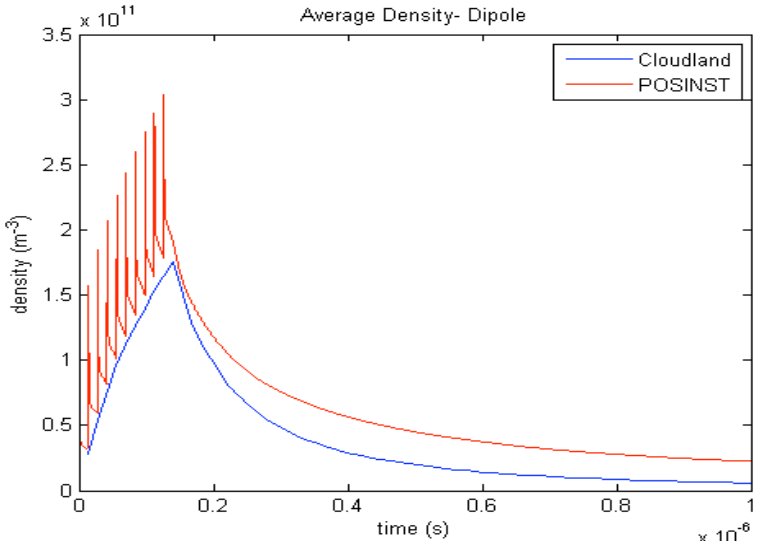
Simulations

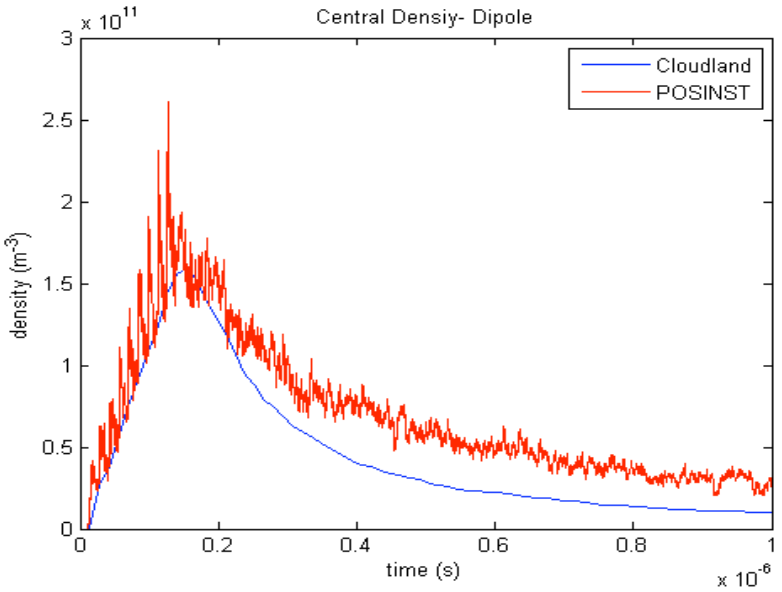
Simulations at Cornell will focus on the following needs:

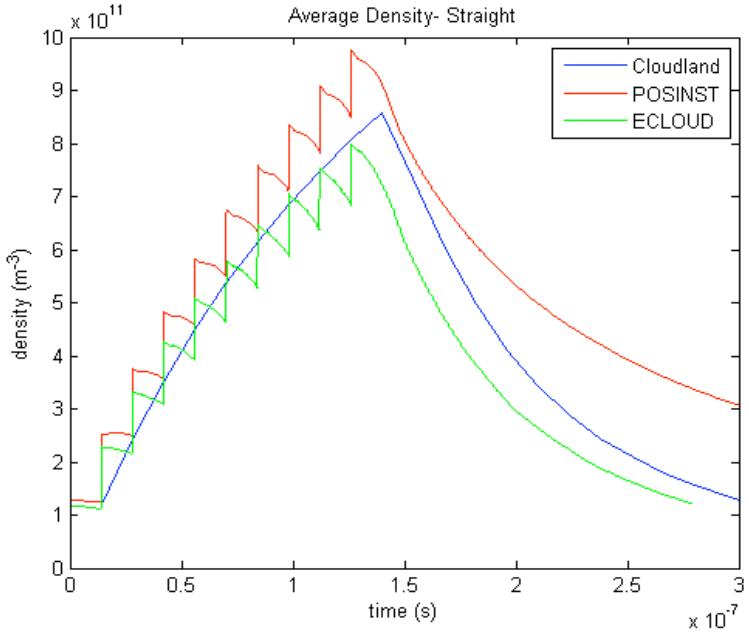
- Defining and guiding the key experiments and related measurements needed to fulfill the overall CesrTA program goals.
- Providing support for understanding the response of instrumentation and diagnostics in terms of fundamental beam and cloud properties
- Understanding the results of experiments in terms of simulation codes, thereby benchmarking the codes for use at ILC and elsewhere

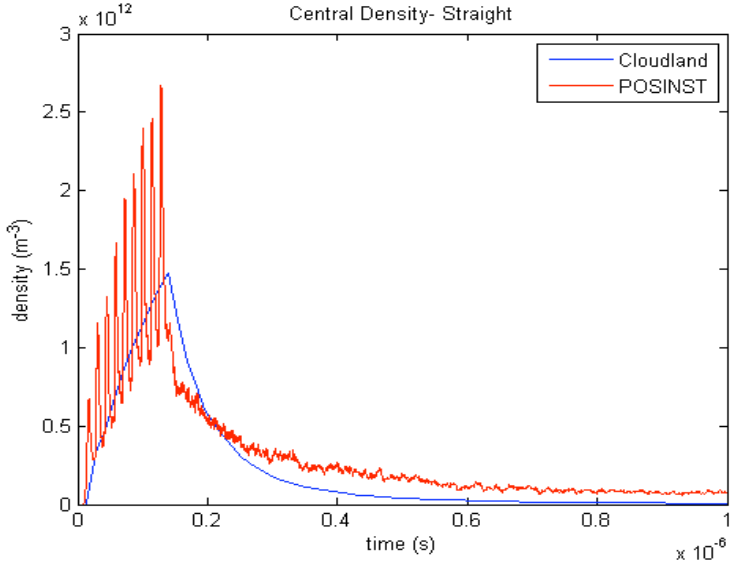
- Initial steps:
  - defining standard set of conditions for CesrTA simulations
  - making simulation code comparisons for simple cases relevant to CesrTA conditions
  - simulating ring-averaged cloud buildup and associated coherent tune shifts, to guide tune shift experiments as probes of cloud density and dynamics
  - simulating cloud buildup in RFA-instrumented chambers, and RFA instrumental response, to guide RFA experiments as probes of average cloud density.

Simulation comparisons-10 bunches, 14 ns, 0.75 mA/bunch



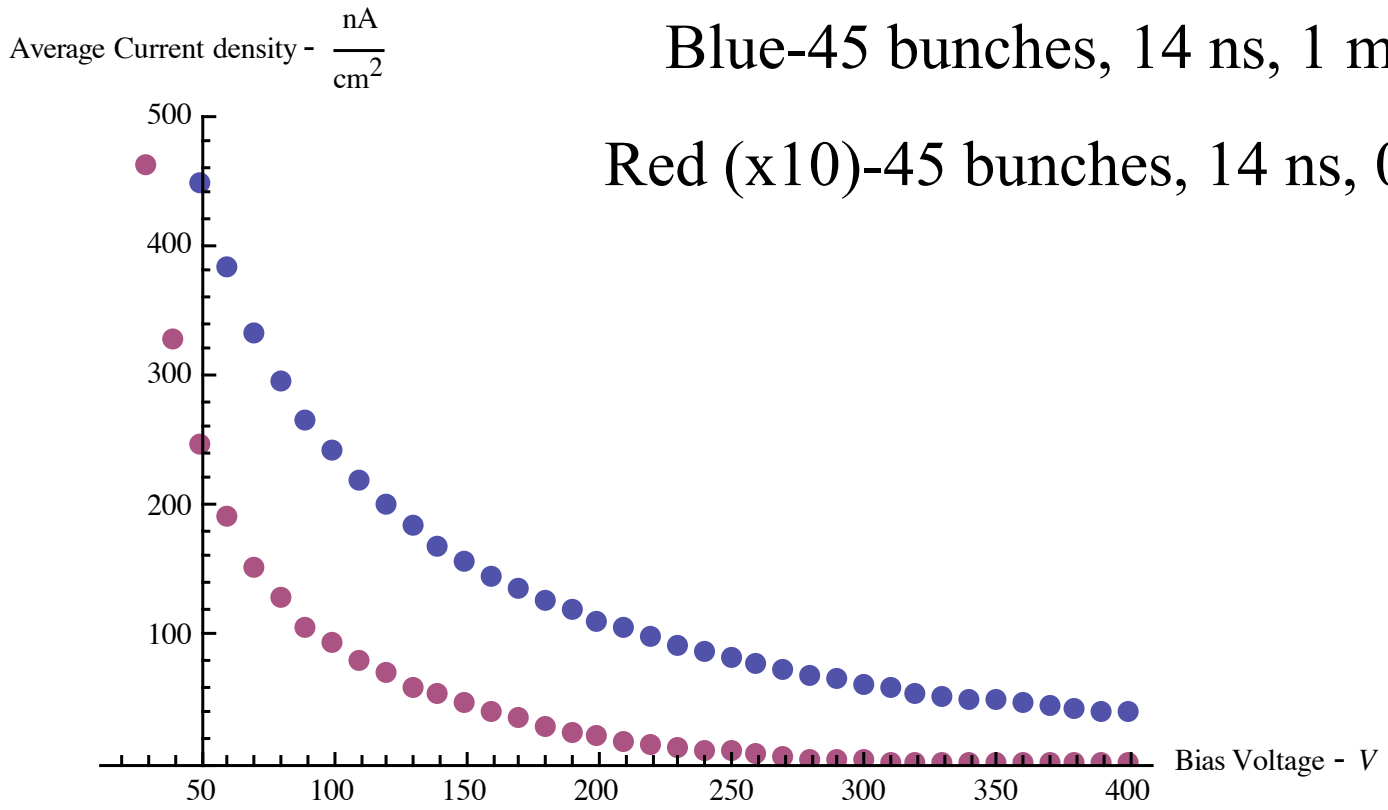






POSINST simulation of cloud current density into wall

Cesr-TA dipole at B12WN 5.3 GeV positrons



Blue-45 bunches, 14 ns, 1 mA

Red (x10)-45 bunches, 14 ns, 0.5 mA

Future plans

•Simulations need to be refined to provide better understanding of tune shift and RFA measurements

• RFA's to be installed in new wiggler chamber will allow measurement of cloud-induced current in a wiggler field

• Mitigation techniques can be applied to a local chamber and their effectiveness measured using RFA

• Measurements of cloud-induced incoherent emittance growth can be made using XBSM

• Measurements of instability thresholds, growth rates, mode spectrum can be made

• Dependence of cloud effects on beam as a function of energy, species, bunch population, bunch spacing, and emittance, in alliance with the simulation program, can provide a comprehensive benchmarking of the codes.

Conclusions

- We are engaged in a broad R&D program to address a key issue for the ILC damping ring: the electron cloud.
- We are developing a robust suite of diagnostics and techniques for measuring features of the electron cloud, and for evaluating mitigation measures. These will capitalize on the capabilities of Cesr-TA, which allow a large range of parameter variations (bunch loading pattern, beam energy, beam emittance, particle species, etc.) to probe many features of the cloud and its interaction with the beam.
- We have continued and expanded our witness bunch measurements, and have just begun to measure cloud-induced currents in prototype RFA arrays.
- In parallel, we are mounting a focused simulation effort, relying heavily on support and codes developed by the worldwide community of EC experts.
- This is a fundamentally collaborative effort. We welcome any and all interested collaborators who would like to suggest experiments, make measurements, or perform simulations in support of the program.