Cornell Laboratory for
Accelerator-based Sciences and
Education (CLASSE)

Incoherent Vertical Emittance Growth from Electron Cloud at CESRTA

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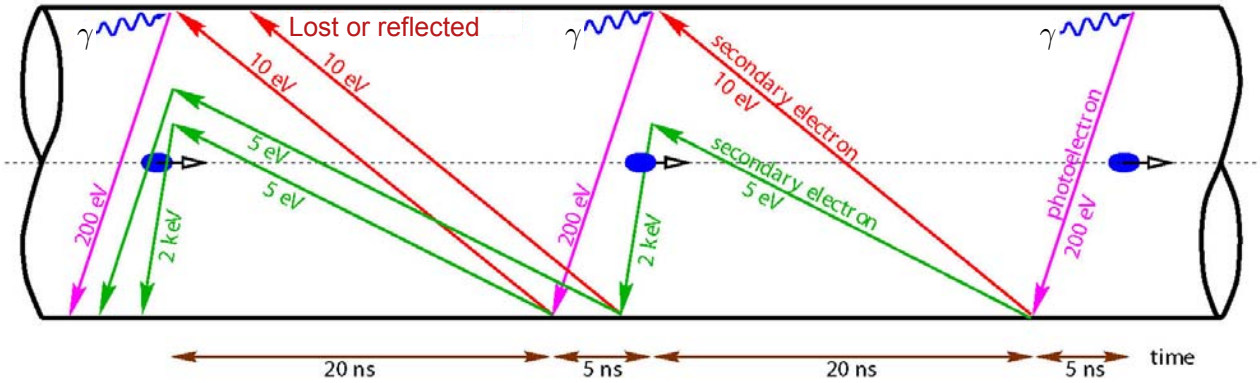
Overview

- An increase in vertical beam size due to electron cloud has been seen in many e+ rings:
  - PEPII, KEKB, DAPHNE, CESR
- Electron cloud (EC) can be a limiting factor and has been studied at CESRTA (the Cornell Electron-Positron Storage Ring Test Accelerator) since 2008
  - Including efforts to inform ILC damping ring design
- Emittance growth from EC not well understood

⇒ We have developed an incoherent model which predicts emittance growth from electron cloud

- This talk will compare simulations to data for tune shifts and equilibrium beam size

Electron Cloud



F. Ruggiero

- Buildup of electrons hitting the vacuum chamber wall and generating secondary electrons
- Main source: photoelectrons from synchrotron radiation
  - Also beam-gas ionization or stray protons hitting the wall
- Bunches accelerate the electrons as they pass
- Positron bunches pull the cloud towards it (“pinch effect”)
- EC builds up along a train of bunches

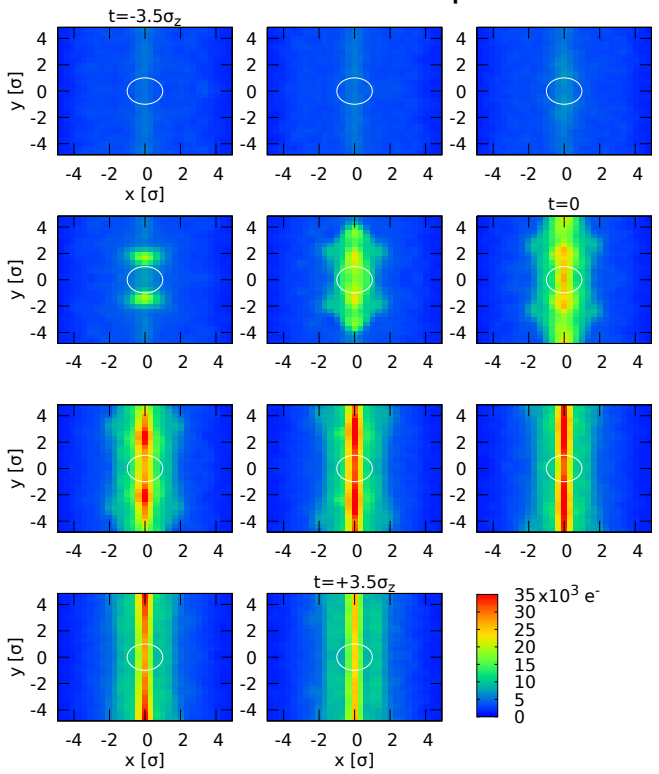
Measurements

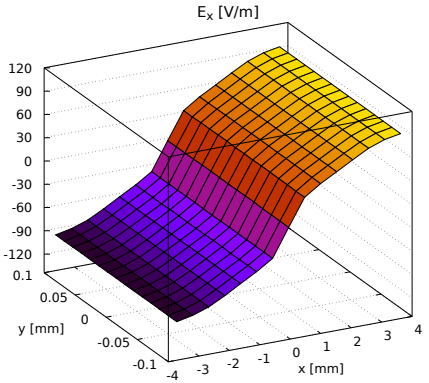
- Beam:
  - 2.1 GeV positrons or electrons
    - ★ Horizontal emittance: 3.2 nm, fractional energy spread: 8×10^{-4}, bunch length: 9 mm
  - 30 bunch train, 0.4 mA/b and 0.7 mA/b, 14 ns spacing
    - ★ (0.64×10^{10} and 1.12×10^{10} bunch populations)
  - 1 witness bunch, 0.25 to 1.0 mA, bunch positions 31 to 60
    - ★ Witness bunch position probes cloud as it decays
    - ★ Witness bunch current controls strength of pinch effect
- Measure:
  - Betatron tunes: from FFTs of bunch centroids from multiple BPMs
    - ★ Bunch-by-bunch, turn-by-turn
  - Vertical bunch size: from X-ray beam size monitor
    - ★ Bunch-by-bunch, turn-by-turn
  - Horizontal bunch size: from visible light gated camera
    - ★ Bunch-by-bunch, single-shot
- Bunch-by-bunch feedback on to minimize centroid motion
  - Disabled for a single bunch when measuring its tune

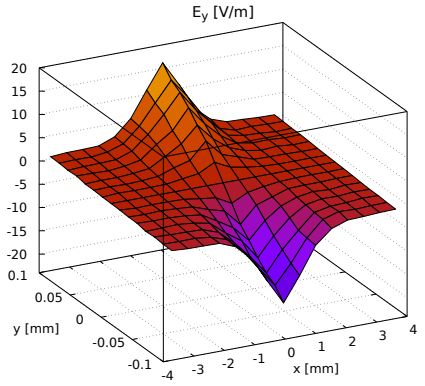
Simulations

- Start with EC buildup simulations with ECLOUD in both dipole and field-free regions
- Use element-type ring-averaged beam sizes
  - Dipole: 730 x 20 um
  - Drift: 830 x 20 um
    - ★ The large horizontal size is dominated by dispersion
- Obtain electric field maps from the EC for 11 time slices during a single bunch passage, in ±5σ of the transverse beam size
  - Δt = 20 ps
- Only ~0.1% of electrons are within this beam region
  - Necessary to average over many ECLOUD simulations

Transverse EC charge distributions in an 800 G dipole for bunch 30 of a 0.7 mA/b positron train

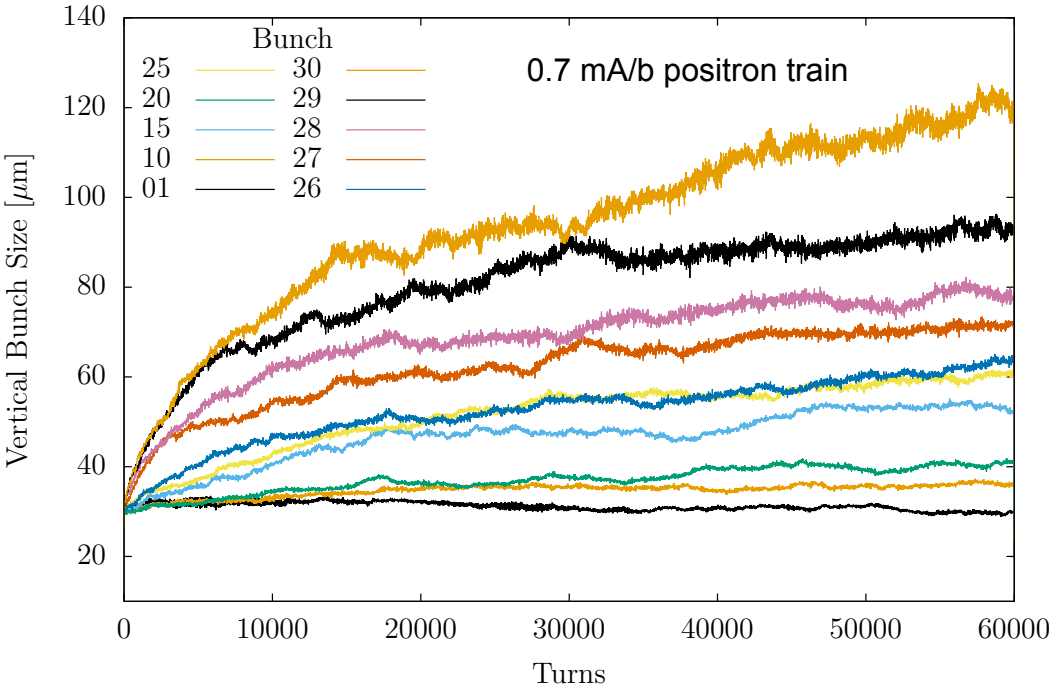






Simulations

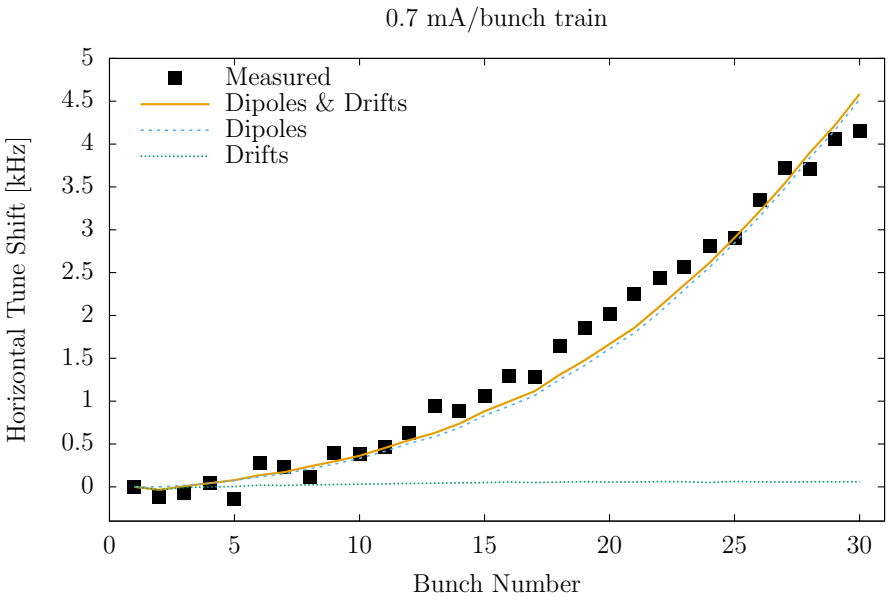
- Use the time-sliced electric fields in EC elements at the dipole and drifts
- Track particles in bunch through the full lattice (using Bmad) for multiple damping times, with radiation excitation and damping
- This model does not take into account effects on the cloud due to changes in the beam ("weak-strong" model)
  - Weak: positron beam; Strong: electron cloud
  - Justification: EC simulations are rather insensitive to vertical beam size
- Strong-strong simulations are too computationally intensive to track for enough turns
  - Damping times at CesrTA are ~20,000 turns

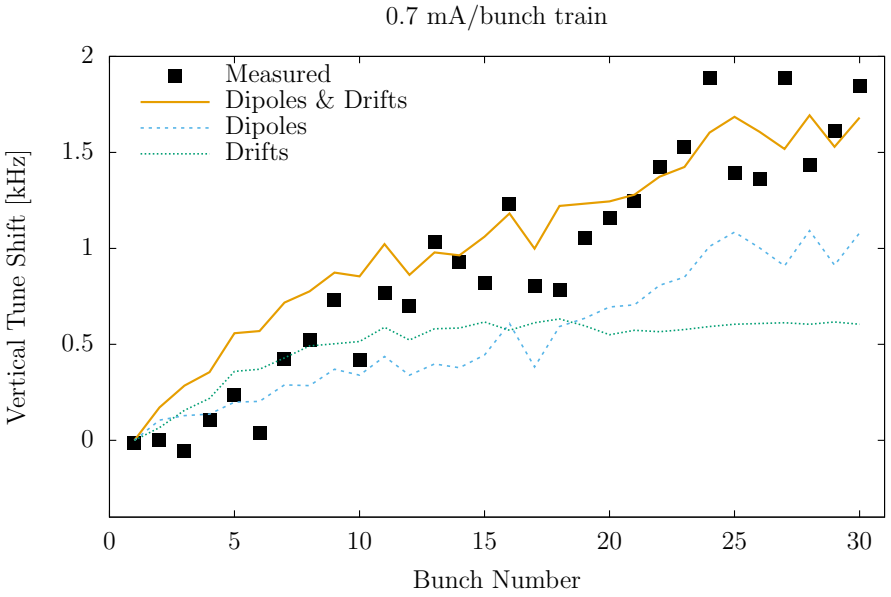


Tune shifts

- Feedback is disabled for a single bunch when measuring its betatron tunes
- Don't use external source to enhance oscillation which can cause the bunch to explore different regions of the cloud
- Rely on the self-excitation of the bunch centroid
  - Avg. RMS motion in the BPMs:
    - ★ x: ~40 um
    - ★ y: ~20 um
- Tunes from simulation calculated from 1-turn transfer matrix or FFTs (good agreement)
- Dipoles (62% of ring) dominate the horizontal tune shift compared to drifts (23%) which contribute to vertical tune shift

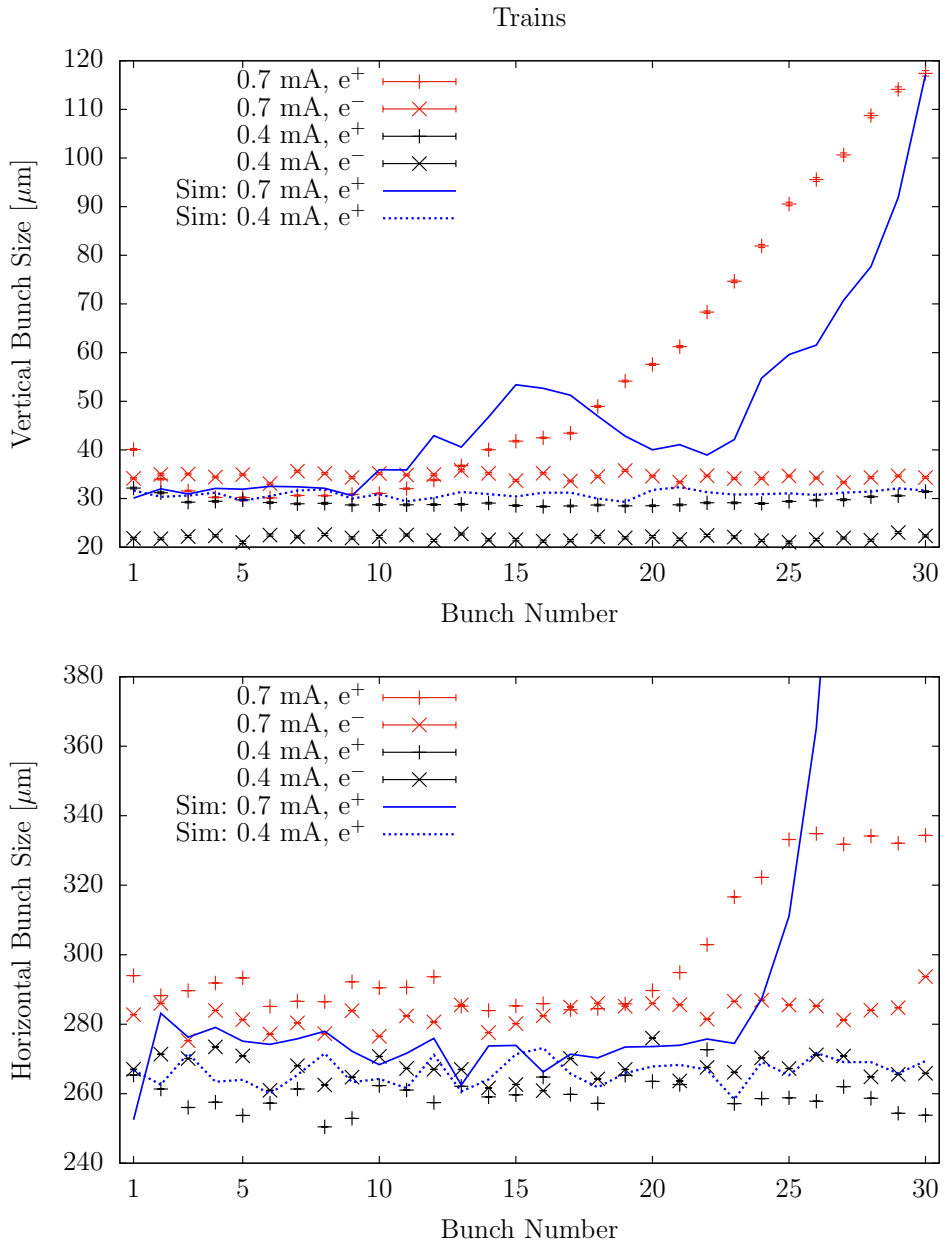
(Revolution frequency: 390 kHz)



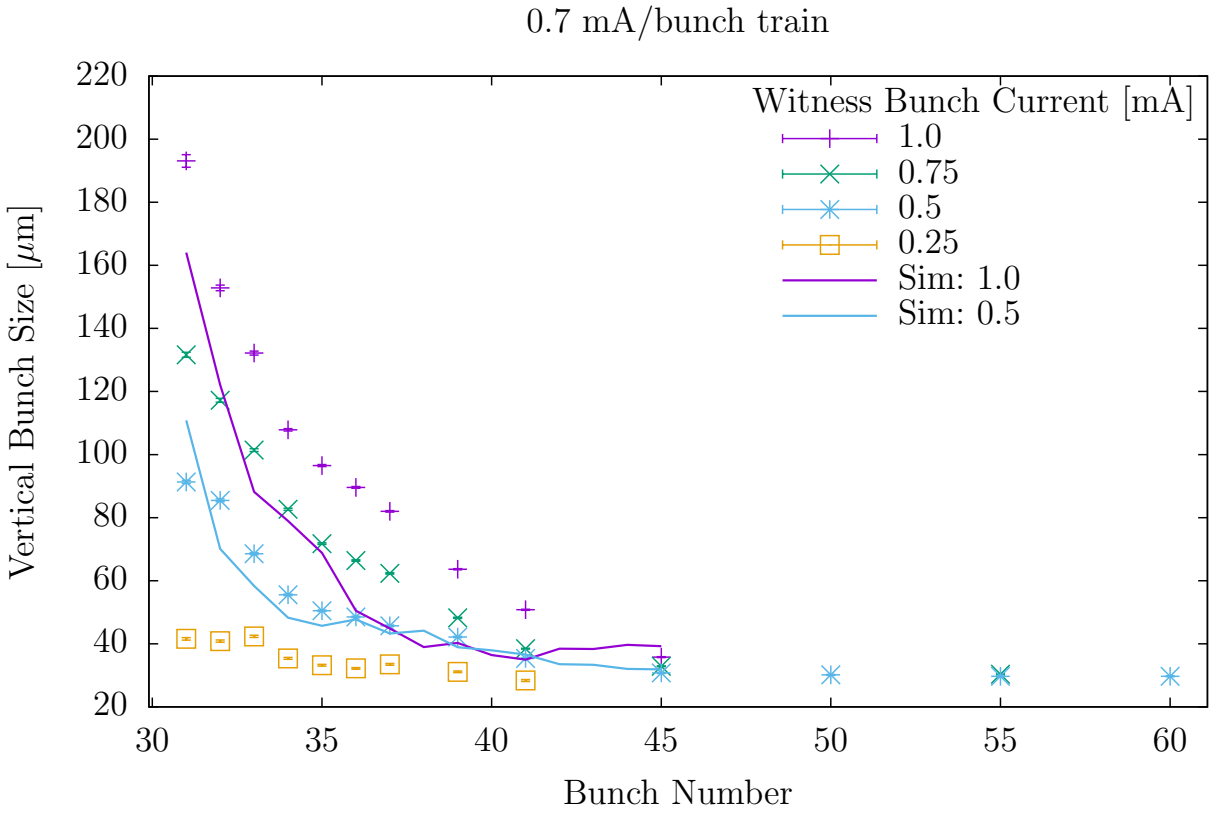


Bunch size growth

- No bunch size growth seen for electron beam
- Growth for 0.7 mA/b positron beam, but not at 0.4 mA/b
  - 0.4 mA/b is just under the threshold for vertical bunch size growth
- Bunch sizes from simulation averaged over last 10k turns (of 60k)
- See growth in 0.7 mA/b simulations though there are discrepancies
  - Under investigation



Witness bunch size



- More emittance growth with:
  - shorter distances from train (more cloud)
  - *higher bunch current (more pinch)*
- Simulations show similar behavior

Summary

- We have measured tune shifts and bunch sizes along 0.7 and 0.4 mA/b trains of positrons and electrons with witness bunches at various currents and distances from the train
- Tune shifts and bunch size growth were seen in the 0.7 mA/b positron trains but not in trains of electrons
- Our weak-strong incoherent model predicts:
  - tune shifts in good agreement to data
  - emittance growth which scales with cloud density and witness bunch current (as seen in data)

- Future work:
  - Reconcile data/simulation discrepancies
  - Revisit emittance growth predictions in ILC damping ring
  - Use model to understand underlying factors driving emittance growth
    - ★ Develop new approaches to mitigating emittance growth from EC