CLASSE
Cornell Laboratory for Accelerator-Based Sciences & Education

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PROGRESS IN MEASUREMENT AND MODELING OF ELECTRON CLOUD EFFECTS AT CESRTA

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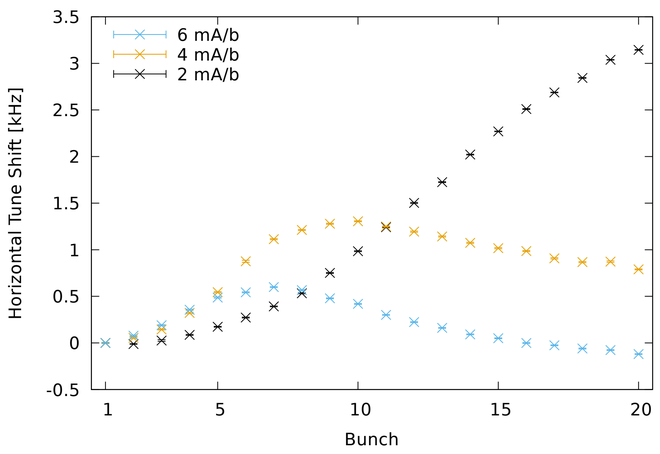
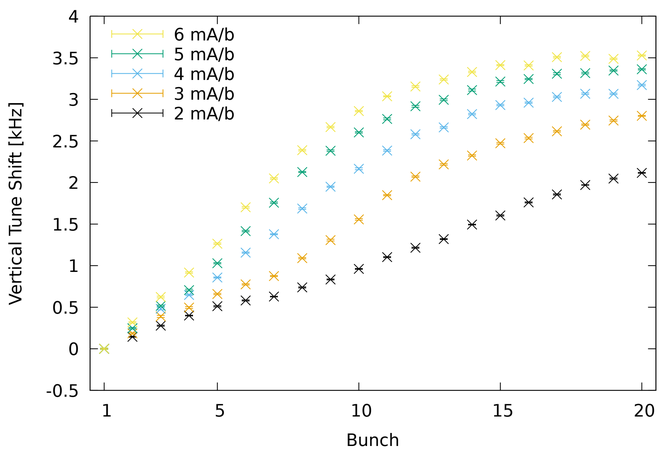
Abstract

The synchrotron-radiation-induced buildup of low-energy electron densities in positron and proton storage rings limits performance by causing betatron tune shifts and incoherent emittance growth. The Cornell Electron Storage Ring (CESR) Test Accelerator project includes extensive measurement and modeling programs to quantify such effects and apply the knowledge gained to the design of future accelerator projects. We report on improved measurements of betatron tune shifts along a train of positron bunches, now accurate in both horizontal and vertical planes. Improved electron cloud buildup modeling uses detailed information on photoelectron production properties obtained from recently developed simulations and successfully describes the measurements after determining ring-wide secondary-yield properties of the vacuum chamber by fitting the model to data with a multi-objective optimizer. Cloud splitting in dipole magnetic fields is seen to be the source of horizontal tune shifts decreasing at higher bunch populations.

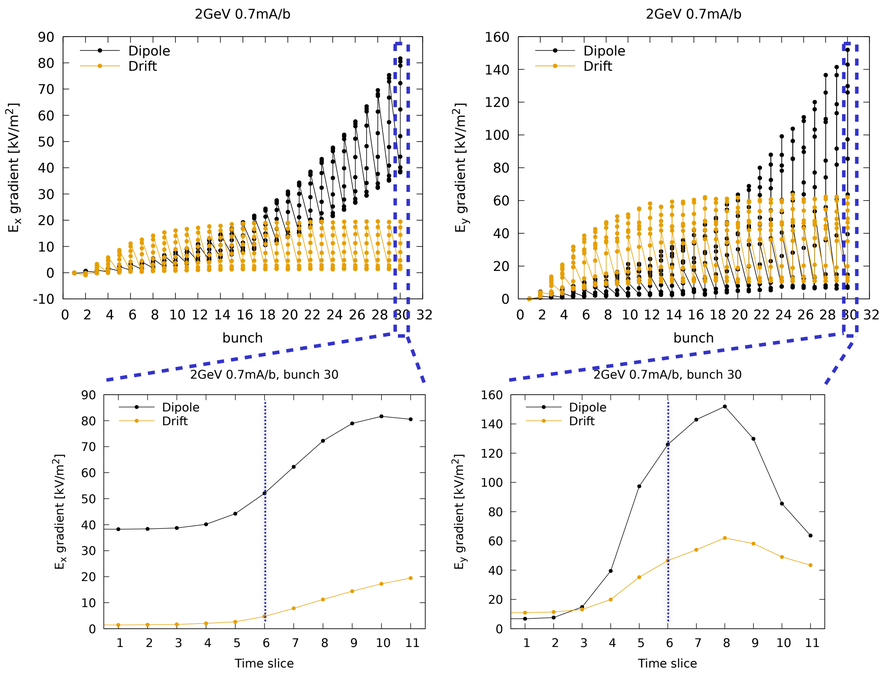
Tune Shift Measurements





- **Beam:**
  - **5.3 GeV positrons**
  - **14 ns spaced 20 bunch trains**
  - **2 - 6 mA/b (3.2 - 9.6 × 10^{10} bunch populations)**
- **Bunch-by-bunch feedback is on**
- **Feedback is turned off, one bunch at a time, for tune measurements**
  - **Bunch is driven by a transverse kicker**
  - **Phase lock loop to BPM signal**
- **Produced better measurements than pinging & measuring tune from an FFT**
- **Horizontal tune shifts show effect of "cloud splitting" at higher bunch populations**

Electron Cloud Simulations

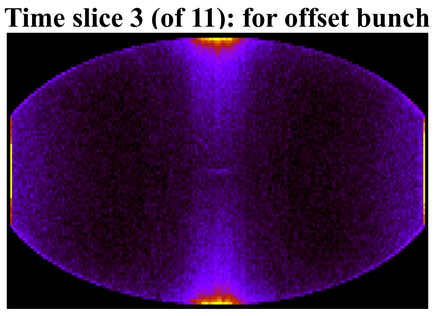


- **Synchrotron radiation analysis with Synrad3D**
- **Primary photoelectrons simulated with Geant4**
  - *S. Poprocki et. al, Modeling Studies for Synchrotron-radiation-induced Electron Production in the Vacuum Chamber Walls at CESRTA, IPAC18: THPAF026*
- **Electron cloud buildup simulations performed using ECLOUD**
  - *F. Zimmermann, G. Rumolo & K. Ohmi, ICFA Beam Dynamics Newsletter, No. 33, p. 14–24 (Apr. 2004)*

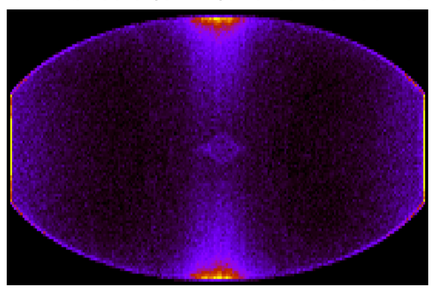
- **Drift regions and 2 kG dipoles**
- **Clearly see "pinch effect" of beam attracting the electron cloud**
  - **Space-charge electric field gradients increase dramatically**
- **However, the pinched cloud is centered on an offset bunch**
  - **Only pre-existing cloud contributes to coherent tune shift**
  - **Pinched cloud can produce tune spread and incoherent emittance growth**
- **Use the field gradients from the 1st time slice in each bunch to calculate the tune shift**

2 kG Dipole

Time slice 3 (of 11): for offset bunch

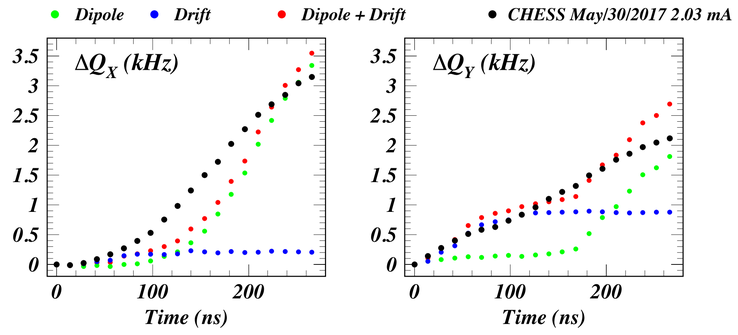


Time slice 6 (of 11): for offset bunch

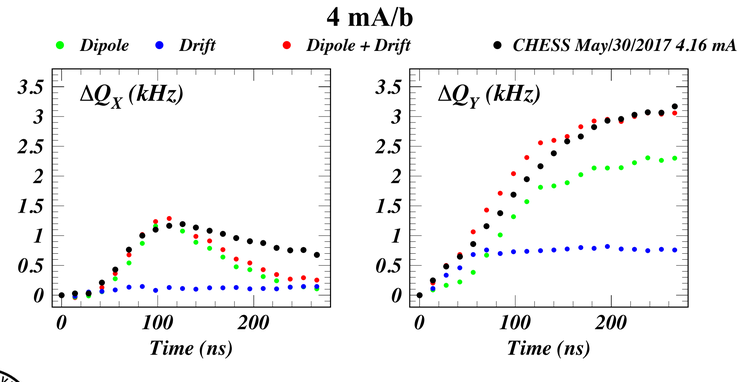


Comparison

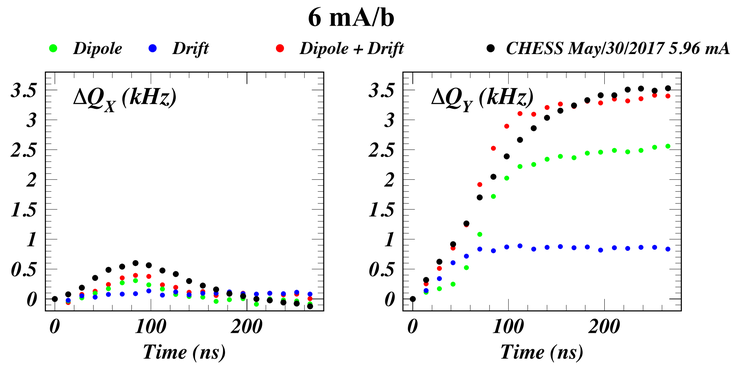
2 mA/b



4 mA/b



6 mA/b



- **Tune shifts sensitive to SEY parameters of vacuum chamber**
- **Hard to measure all parameters accurately**
  - **Ring-wide SEY in actual machine may be different**
- **Optimize SEY parameters input to ECLOUD simulations against the measurements**
- **Good qualitative agreement across range of bunch currents**

Summary

- **Tune shifts measured using digital tune tracker are an improvement over self-excited or pinged measurements**
- **Primary photoelectrons simulated with Synrad3D and Geant4 input to ECLOUD**
  - **Removes ad hoc assumptions and improves predictive power**
- **This work achieves for the first time agreement between simulated tune shifts and the measurements in both horizontal and vertical planes over a broad range in bunch population, identifying quantitatively the cloud splitting effect in dipole magnetic fields.**

Future Work

- **Measurements at other bunch currents and beam energies**
- **Further optimization of SEY parameters to fit model to data**
- **Impact of new model on incoherent emittance growth from electron cloud**

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