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

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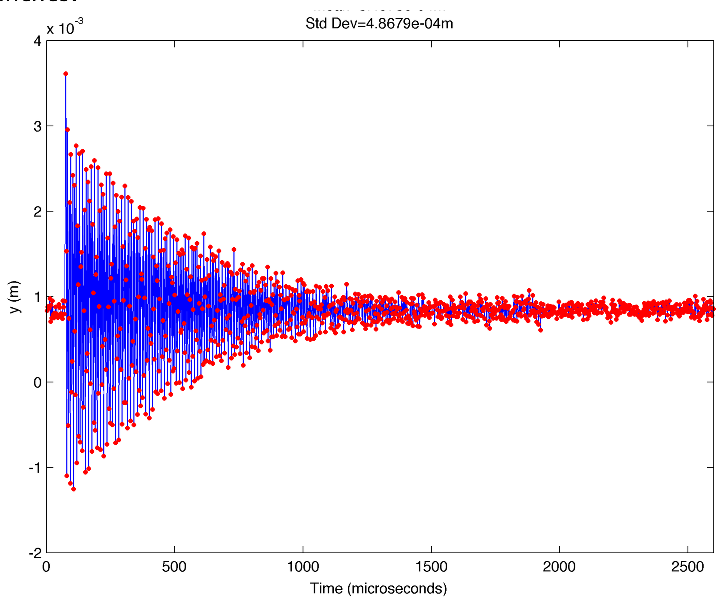
Using Coherent Tune Shifts to Evaluate Electron Cloud Effects on Beam Dynamics at CesrTA

J.A.Crittenden, G.Dugan, D.L.Kreinick, Z.Leong, M.A.Palmer(Cornell),
R.L.Holtzapple, M.Randazzo(Cal Poly), M.A.Furman, and M.Venturini(LBNL)

One technique used at CesrTA for studying the effects of electron clouds on beam dynamics is to measure electron and positron bunch tunes under a wide variety of beam energies, bunch charge, and bunch train configurations. Comparing the observed tunes with the predictions of various simulation programs allows the evaluation of important parameters in the cloud formation models. These simulations will be used to predict the behavior of the electron cloud in damping rings for future linear colliders.

THE MEASUREMENTS

Beams were set into oscillation by displacing them horizontally or vertically for one turn and Fourier transforming their turn-by-turn positions for up to 4096 (but typically 1024) turns measured at up to six places around the ring. Tunes of the bunches of the cloud-inducing train and of "witness" bunches spaced 14 to 490 nsec after the trains passage allowed the cloud buildup and decay to be followed. The graph shows the y displacement vs. time taken at one of the six beam position monitors used for this measurement. The 1024 red dots represent the y displacement of bunch 1 on successive turns around the CESR ring. A measurement would involve six beam position monitors times 45 bunches.



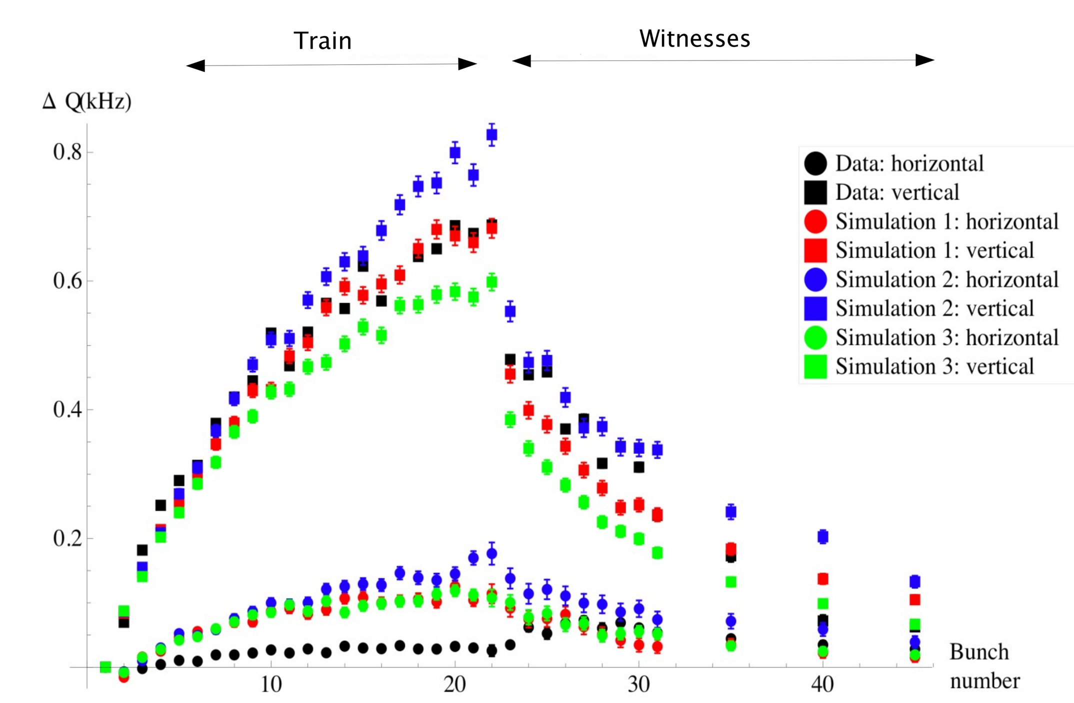
DETERMINING SIMULATION PARAMETERS

Initial parameters for driving the POSINST simulations were determined by trial and error on measurements made at 1.9 GeV with 1.2×10^{10} positrons per bunch. The parameters we varied and their initial values were

Total SEY yield (2.0)
Energy at which the SEY is maximal (310 eV)
Synchrotron radiation rate (0.236 and 0.528 photons/m in drift and dipole)
Quantum efficiency of photoelectron production (0.12)
Fraction of photons reflected (0.15)
Yield of rediffused electrons (0.19)

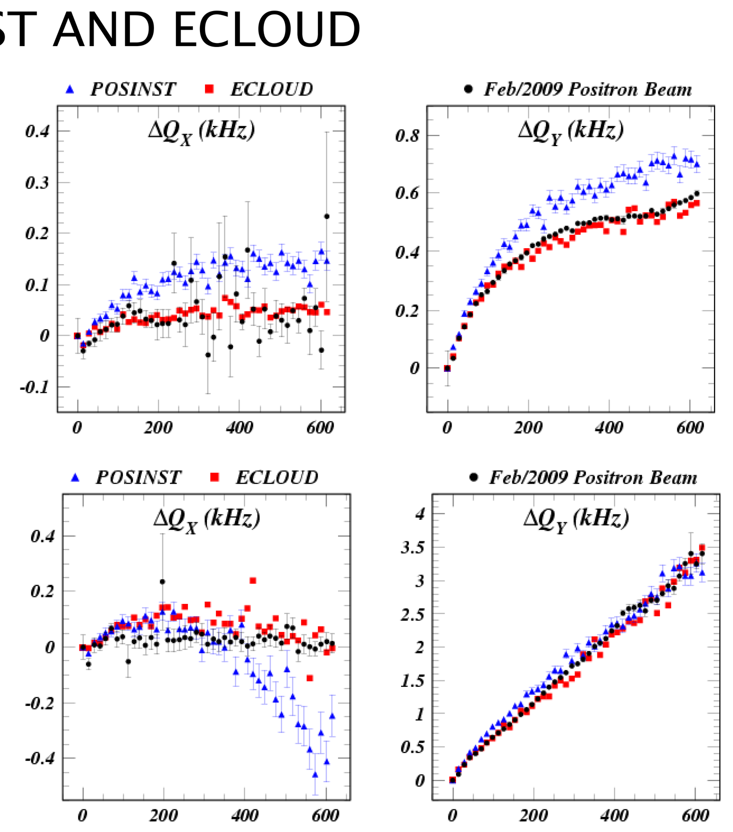
54 data runs with electron and positron beams at 1.9, 2.1, 4.0, and 5.3 GeV energy, in trains of 3 to 45 bunches, with bunch populations of 0.32 to 2.60×10^{10} were simulated and matched to the data. All six parameters were varied ~±10% individually and in selected pairs. As an example, shown at the right are data (in black) for 21-bunch train of 0.8×10^{10} positrons per bunch at 2.1 GeV followed by 12 witness bunches. Three different POSINST simulations with total secondary emission yields of 1.8 (green), 2.0(nominal=red), and 2.2(blue) were run.

The program did not lead to a significantly improved parameter set because 1) The original set did surprisingly well describing all data and 2) It is hard to find an optimum in a 6-dimensional space when the parameters are highly correlated and the error bars on the data are not reliably determined.



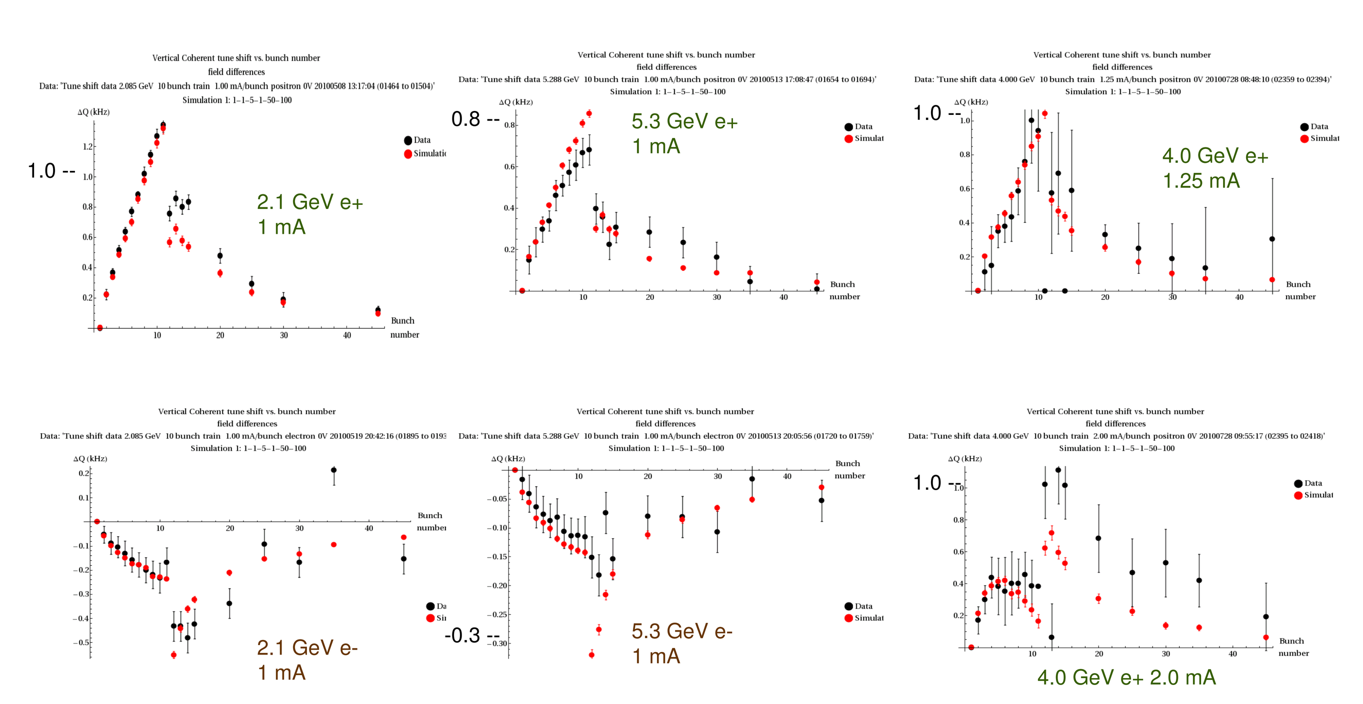
POSINST AND ECLOUD

Two independent simulation codes POSINST and ECLOUD were used to match the data. It was found that the secondary emission model in ECLOUD was too simple, not accounting for the "rediffused" component. Once the more complex model was added to ECLOUD, the two models generally agreed with one another and with the data. These plots show horizontal and vertical tune shifts vs. time for 0.64×10^{10} (top) and 1.28×10^{10} bunch occupancy. Data were taken with 45 bunches of 2.1 GeV positrons and bunch spacing 14 ns.



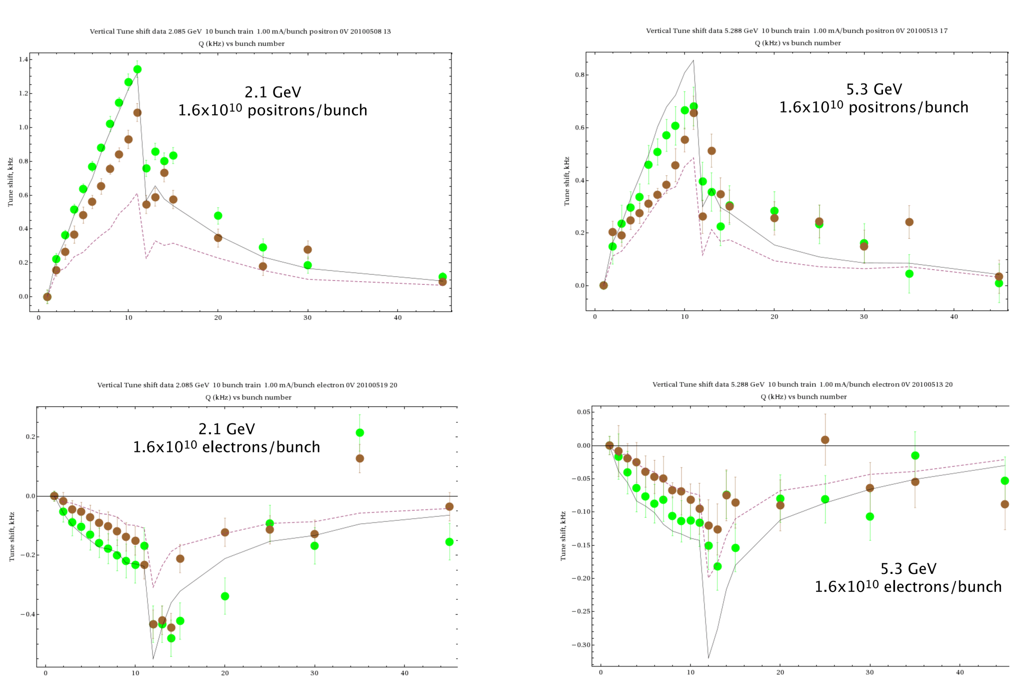
FURTHER MEASUREMENTS

To help parameter determination, we try to create conditions where one of the parameters may dominate. Here are several of the most recent measurements and the default POSINST simulations. Only vertical tune shifts are shown. Data (black) and simulation (red) are shown for 2.1 GeV positron and electron beams (left top and bottom), 5.3 GeV positrons and electrons (middle top and bottom), and 4.0 GeV positrons beams at higher bunch occupation than we have formerly been able to achieve. The nominal POSINST simulations generally mimic this wide range of data well. At the highest bunch occupancy (3.2×10^{10} at the lower right), The qualitative behavior is simulated, but the quantitative discrepancy represents an opportunity to further refine the POSINST input parameters.



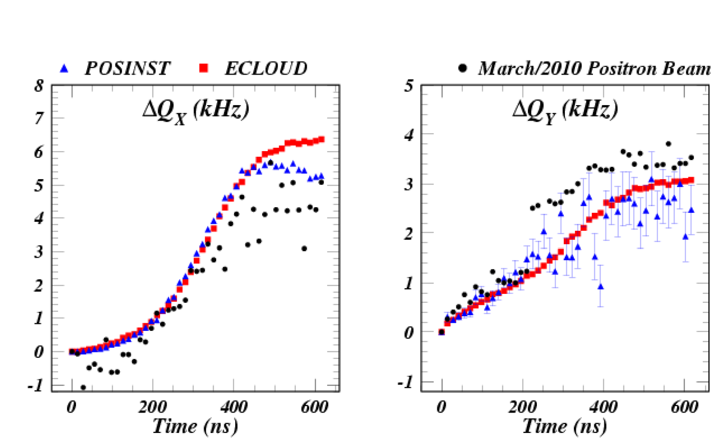
SOLENOIDS IN THE DRIFT REGIONS

Attempts have been made to separate the tune effects in the dipoles as opposed to the drift regions by introducing solenoids in the drift regions. By keeping photoelectrons from hitting the walls, the effects of secondary emission should be neutralized in the drift regions. In the plots below, the green and brown dots represent data taken with solenoids off and on, respectively. Data are shown for 2.1 GeV positrons (top left) and electrons (bottom left) and 5.3 GeV positrons (top right) and electrons (bottom right). The solid curve is the POSINST simulation including both dipoles and drifts, and the dotted curve includes only dipoles.



SPONTANEOUS OSCILLATIONS

As can be seen in the plots under the DETERMINING SIMULATION PARAMETERS and POSINST AND ECLOUD headings, horizontal tune shifts are suppressed in the dipoles in the usual pinging technique, which gives all the bunches in the train the same kick, due to the strong correlation between the horizontal location of the cloud centroid and the beam centroid in the dipoles. Unpinged (self-excited) data allow the observation of sizable horizontal tune shifts. The oscillations in the unpinged bunches are less reliably excited, so the data are less stable. Nevertheless usable tune shifts can be observed. These data were taken with 45-bunch trains of 2.1 GeV positrons with a bunch occupancy of 2.1×10^{10} and a bunch spacing of 14 ns. Note that the tune shifts saturate after about 400 ns (~25 train bunches), a behavior that is modeled by the simulations.



PLANNED IMPROVEMENTS

A new synchrotron radiation modeling code SYNRAD3D should allow for improvement of the estimates of photon fluxes in the drift and dipole regions. More careful estimation of the errors in the incoming data should provide more stability for the goodness-of-fit comparisons used to optimize parameters. Parameter space still remains to be explored with some of the newer data.

Recently, instrumentation to excite bunches individually has been deployed in order to further stress the models. This new technique is the subject of a separate poster.

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