ILC Damping-Ring R&D with the Cornell Electron Storage Ring Test Accelerator:

Investigations of Electron Trapping in a Quadrupole Magnet

The discovery of the Higgs boson at the large Hadron Collider in 2013 has intensified interest in the design and construction of an International Linear Collider (ILC) for high-statistics studies of Higgs decays. The Cornell Laboratory for Accelerator-based Sciences and Education is making a variety of essential contributions to the accelerator R&D for this project.
The buildup of low-energy electron densitiess resulting from synchrotron radiation incident on the vacuum chamber walls has been shown to be an important factor limiting the performance of storage rings such as the B-meson factories KEK-B in Japan and PEP-II at the SLAC National Laboratory. An international collaboration of a dozen laboratories involving hundreds of physicists has been concentrated on solving the problem of understanding and reducing the buildup of such electron clouds since the 1990's.. In particular, the Cornell Electron Storage Ring (CESR) was reconfigured as a test accelerator in 2008 in order to study cloud buildup and its effects on beam dynamics in a controlled setting where beam energy, bunch configuration and bunch population can be varied. Custom vacuum chambers with various types of mitigating techniques such as material choice, coatings and groove patterns have been installed and tested.
In early 2013 we installed a cloud-sensitive shielded pickup detector inside a quadrupole magnet. It had long been surmised that cloud electrons may become trapped in the quadrupole field. With the first analysis of the measurements of cloud buildup in the quadrupole, we realized we had discovered the trapping effect when twenty-bunch-long positron trains showed signals for the first ten bunches larger than those measured for a ten-bunch train. How do those leading ten bunches "know" that another ten bunches are coming? Obviously they produce the measured signal using electrons which have been trapped since the previous passage of the bunch train, a full 2.5 μs earlier.
Since this is the first ever quantitative measurement of such a trapping phenomenon in a positron storage ring, and owing to its potential for operational limitations on the ILC damping ring, a high priority has been put on the further development of these measurements and modeling studies in 2014. This REU project will concentrate on analyzing new data to be recorded in April and employing numerical modeling to understand the physical processes underlying the trapping phenomena.

I. Prerequisites

Familiarity with classical electromagnetism equivalent to two semesters at the undergraduate level. Familiarity with Maxwell's equations, electric and magnetic fields and the Lorentz force.

II. Literature

A. Standard introductory texts on accelerator physics, such as *An Introduction to the Physics of High-Energy Accelerators* by Edwards and Syphers. The physics and formalism of longitudinal and transverse particle motion as described in chapters 1-3 of this text should be studied prior to beginning this REU project.

B. CESR notes and tutorials on CESR design and operation

III. Software Tools

A. UNIX/Linux operating system and Fortran 90 programming language

B. CERN Physics Analysis Workstation data analysis and display package (`(http://wwwasd.web.cern.ch/wwwasd/paw/components.html)`

C. Custom electron cloud modelling software