

STATUS REPORT

Compton polarimeter backgrounds

Personnel and Institution(s) requesting funding

William Oliver, Tufts University

Collaborators

Collaborating personnel who will work on the project, but are not requesting funding here, are Ken Moffeit and Mike Woods of the Stanford Linear Accelerator Center.

Project Leader

William Oliver
william.oliver@tufts.edu
617 627 5364

Project Overview

Beam polarization is an important feature of the International Linear Collider. The beams can be polarized to enhance the expected Standard Model interactions, or can be polarized in the opposite sense to suppress the SM background in the search for new physics processes.

The electron beam polarization is expected to be 80 – 90 % at the ILC; it will be important to measure the polarization accurately. We are designing a Compton polarimeter to achieve an accuracy of 0.25 % in this measurement.

The ILC will have beams that are much more intense and more sharply focused than the beams at the Stanford Linear Accelerator. As a result there will be a greater disruption of the beams at the interaction point due to the collective action of the particles in one bunch on the particles in the colliding bunch. In addition to the disruption of the primary beams, the collective action generates two secondary gamma ray beams (beamstrahlung) that have roughly 5% of the power of the colliding beams and are primarily at angles of less than 0.2 mrad to the beam axis. The disrupted beams and intense beamstrahlung can generate high backgrounds, so it is necessary to carefully incorporate polarimeter design considerations into the design of the extraction line optics. It is the central feature of our proposal that we calculate these backgrounds to determine what design modifications are required for both the extraction line optics and for the polarimeter detector.

The IP Beam Instrumentation Group has described [*Status of Linear Collider Beam Instrumentation Design*, D. Cinabro, E. Torrence and M. Woods (2003), <http://www.slac.stanford.edu/xorg/lcd/ipbi/notes/white.pdf>] current plans for beam diagnostics in the beam extraction line. The extraction line features a chicane to separate the primary beam from the beamstrahlung beam to facilitate beam diagnostic measurements, including a precision Compton polarimeter. Following the chicane the recombined primary and beamstrahlung beams are directed to a common dump. The polarimeter laser beam intercepts the primary beam in the middle of the chicane, roughly 100 meters downstream of the Interaction Point (IP). In this region the charged particle beam has a dispersion of 20 mm, consequently a laser beam of 200-micron diameter samples the primary beam within a narrow momentum range of 1.0%.

The electrons scattered from the laser beam proceed forward to pass through a magnetic spectrometer formed by the downstream bending magnets of the chicane. The laser-scattered electrons emerging from the spectrometer are offset from the recombined charged particle beam (and the beamstrahlung beam).

The laser beam is of course aimed to intercept the vast majority of the primary beam particles that pass through the IP with little disruption. The depolarization suffered by such particles in the collision is small, so the polarization measured downstream is a good indication of the beam polarization upstream of the IP.

The polarimeter detector is a threshold (approximately 10 MeV for electrons) gas Cerenkov counter segmented in the bend plane to provide rate measurements of the Compton-scattered electrons in different momentum bins. The rate asymmetry (comparing rates for electron and photon spins aligned versus anti-aligned) measured by the Cerenkov counter segment with the greatest offset (detecting the back-scattered electrons) from the beam axis provides the greatest sensitivity to the beam polarization.

We propose to calculate the background expected in the segmented Cerenkov counter to determine if the current design provides a signal-to-background ratio adequate to achieve an accurate measurement of the beam polarization. We will calculate the effects of a variety of processes to determine the particular sources that produce the most background in the counter.

The principal concerns to us are the effects of the severely disrupted primary beam particles and of the 500-kW beamstrahlung beam. The inner edge of the Cerenkov counter is approximately 10 cm from the beam axis. At the counter, the beamstrahlung has spread considerably, but remains predominately within 2 cm of the beam axis. However the beamstrahlung is so intense that the relatively low flux of gamma rays outside the core might still be able to produce effects that seriously degrade the performance of the Cerenkov counter. Since the counter is not in the beam vacuum system, there must be a thin window to allow the Compton-scattered electrons to escape the vacuum. The pipe providing the mount for this thin window must necessarily have a wall located between 2 cm and 10 cm from the beam axis. The wide-angle beamstrahlung gamma rays could produce electromagnetic showers in the pipe wall that spray background particles into the Cerenkov counter at a rate such that the signal from the Compton-scattered electrons is significantly obscured.

The disrupted primary beam includes electrons scattered at large angles or with large energy loss. The transport of these particles through the beam extraction system might not be accurately portrayed by a matrix-element approach. We propose to track these highly scattered particles through the system to calculate their effect on the Cerenkov counter. In addition, we will calculate the background due to: 1) synchrotron radiation in the extracton line dipoles and quadrupoles, 2) beam-gas interactions, 3) radiative Bhabha interactions, and 4) pairs generated in the beam-beam interaction at the IP.

Status Report

We began the project by downloading a GEANT-3 model of the proposed beam extraction system for a 20-mrad crossing angle from the web site of the IP Beam Instrumentation Working Group at SLAC. After some development work, we were able to run the GEANT program successfully at Tufts. In the commissioning process, we checked the code carefully and ran numerous tests to verify that the program gives the expected results in simple situations. We added to the program a simple model of the Cerenkov counter and a model of

the beam pipe because this pipe might be an important source of background in the Cerenkov counter.

Originally we supposed that we would use a different frequency laser for each of the primary electron beam energies. However we have now turned to the possibility of using the same laser frequency for all primary beam energies, with the currents in the chicane magnets remaining the same. For each primary electron beam energy the position of the laser beam must be adjusted to strike the electron beam at its different transverse positions in the middle of the chicane. We have performed detailed calculations of the analyzing power of the polarimeter when operated with this fixed-frequency, but adjustable-position, laser beam. We found [as described in detail in *High Energy Physics at Tufts University, Progress Report 2002-2005*, DOE/ER/40702-25] that the Cerenkov counter can be designed with both a fixed segment granularity and a fixed position in the lab, yet give nearly optimal analyzing power for all beam energies in the 46 – 500 GeV range. It was remarkable and surprising to find that the kinematics and dynamics of Compton scattering lead to this optimal performance independent of the primary electron beam energy.

FY2006 Project Activities and Deliverables

As our first effort in 2006 we propose to construct a GEANT-3 model of the beam extraction system designed for the 2-mrad crossing angle option. The designs of the 2-mrad and 20-mrad systems are quite distinct in the region close to the IP. It may well be that the background generated in the Cerenkov counter is significantly different for the two systems. We intend to calculate this difference between the two systems for the various possible background sources; we may learn some lessons from this exercise for improved extraction system design.

We intend to calculate the effect on the Cerenkov counter of the scattered primary particles emerging from the IP as they proceed through the beam extraction system. We will include the effects of electromagnetic shower generation by particles scraping the edges of the aperture of the beam extraction system. We will augment our GEANT model of the Cerenkov counter to include realistic representations of the walls between the segments, and of a possible preradiator to determine if the Compton-scattered signal can be enhanced relative to the background. These calculations will be based on an existing file of 15,000 primary particles emerging from IP as calculated by the GUINEA PIG program.

FY2007 Project Activities and Deliverables

We have already downloaded GUINEA PIG to our Tufts computers. In 2007 we plan to run GP extensively to accurately determine the effects of the most severely disrupted primary beam particles on the Cerenkov counter. We will also include at this stage the effects of the synchrotron radiation generated by the primary particles as they pass through the dipole and quadrupole magnets of the beam extraction system.

We intend then to turn to the calculation of the background due to the interactions of the beamstrahlung beam in the unavoidable material elements in the beam extraction system. We will pay particular attention to the flange that supports the thin window through which the Compton-scattered electrons emerge from the vacuum, and to the wall of the beam pipe adjacent to the Cerenkov counter. We will also consider beam-gas interactions as a source of background.

Budget justification: Tufts University

The requested budget is exclusively for the half-time support (for the academic year) of a graduate student to assist in performing the calculations described above.

Two-year budget, in then-year K\$

Institution Tufts University

Item	FY2006	FY2007	Total
Other Professionals	0	0	0
Graduate Students	8,865	8,865	17,730
Undergraduate Students	0	0	0
Total Salaries and Wages	8,865	8,865	17,730
Fringe Benefits	0	0	0
Total Salaries and Fringe Benefits	8,865	8,865	17,730
Equipment	0	0	0
Travel	0	0	0
Materials and Supplies	0	0	0
Other direct costs	0	0	0
Institution 2 subcontract	0	0	0
Total direct costs	0	0	0
Indirect costs(1)	3,635	3,635	7,270
Total direct and indirect costs	12,500	12,500	25,000

(1) 26% of 50% of direct costs plus 56% of remaining 50% of direct costs