

Compton polarimeter backgrounds

Classification (subsystem)

Accelerator (MDI)

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

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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 80 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 that is 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 500-kW beamstrahlung beam and the severely disrupted primary beam particles. The inner edge of the counter is approximately 10 cm from the beam axis. At the Cerenkov 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 that provides 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.

Broader Impact

The broader impact of the proposed project is the same as the broader impact of the ILC itself. We hope that our work will contribute to the successful operation of the ILC. If the ILC works as designed, it is almost certain to find compelling evidence for the existence of the Higgs boson and to determine a precise value for the mass of the top quark. We think such discoveries are so fundamental that they will be appreciated by both scientists and nonscientists in society at large.

We hope the broader impact of our project at Tufts will be to inspire a graduate student (we will try hard to recruit a student from an underrepresented group) to pursue a career in science and share in the excitement and joy of the great discoveries expected at the ILC.

Results of Prior Research

We began the proposed project by downloading a GEANT-3 model of the proposed ILC beam extraction system 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 beam for each of the primary electron beam energies. However recently we have considered the possibility of using the same laser frequency for all primary beam energies, with the currents in the chicane magnets also remaining the same for all primary energies. The laser beam then must be adjusted to strike the primary beam as its position at the middle of the chicane varies with its energy. 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 more detail at <http://www-conf.slac.stanford.edu/mdi/talks/Polarimetry/oliver.pdf>] that the Cerenkov counter can be set at a fixed position, yet give optimum analyzing power for any beam energy. It was remarkable and surprising to find that the kinematics and dynamics of Compton scattering lead to this optimum performance independent of the primary electron beam energy.

Our recent work at Tufts that is most closely related to the proposed project is research and development work on the detector technology being used in the MINOS neutrino oscillation experiment. The detector technology is the coupling of wavelength shifting optical fiber to 8-m long extruded scintillator slabs. The technology has proven to be successful; the slabs are efficient detectors of minimum-ionizing particles even when the particles strike the far end at a distance of 8 m from the photodetector. The development work was followed by two years of construction work of the optical multiplexing system used at the MINOS far detector to read out the scintillator slabs. This related work was supported over the past five years by the U.S. Department of Energy Grant DE-FG02-92ER40702 titled *High Energy Physics at Tufts University*. The DOE grant totals roughly 800 k\$ per year.

The Fermilab neutrino beam for the MINOS was first turned on in last few days (January 2005) so there has been no time to gather data to analyse for evidence of neutrino oscillations. However the DOE contract to Tufts has supported the operation of the Soudan2 detector for the past 25 years. We have analyzed the Soudan2 data for evidence of neutrino oscillation; our most recent result was published (Phys. Rev. D 68, 113004 (2004)) under the title *Measurement of the L/E distributions of atmospheric neutrinos in Soudan 2 and their interpretation as neutrino oscillations* with authors from the Soudan 2 collaboration. The Soudan 2 data has also recently been analyzed to search for neutrino sources in active galactic nuclei, with results published in *Astropart. Phys.* 20, 533 (2004).

Facilities, Equipment and Other Resources

The proposed project uses two dual-processor DELL PowerEdge computers (models 4400 and 4600) provided at Tufts. We do not see a need for any additional computing power.

FY2005 Project Activities and Deliverables

We propose 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.

FY2006 Project Activities and Deliverables

We have already downloaded GUINEA PIG to our Tufts computers. In 2006 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.

FY2007 Project Activities and Deliverables

In 2007 we propose 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 and the summer) of a graduate student to assist in performing the calculations described above.

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

Institution Tufts University

Item	FY2005	FY2006	FY2007	Total
Other Professionals	0	0	0	0
Graduate Students	10,000	10,000	10,000	30,000
Undergraduate Students	0	0	0	0
Total Salaries and Wages	10,000	10,000	10,000	30,000
Fringe Benefits	0	0	0	0
Total Salaries, Wages and Fringe Benefits	10,000	10,000	10,000	30,000
Equipment	0	0	0	0
Travel	0	0	0	0
Materials and Supplies	0	0	0	0
Other direct costs	0	0	0	0
Institution 2 subcontract	0	0	0	0
Total direct costs	0	0	0	0
Indirect costs(1)	4,000	4,000	4,000	12,000
Total direct and indirect costs	14,000	14,000	14,000	42,000