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STUDIES FOR A DOWNSTREAM COMPTON POLARIMETER AT THE ILC

M. WOODS and K.C. MOFFEIT

Stanford Linear Accelerator Center[a]
Stanford University, Stanford, CA 94309

Polarimetry in the extraction line from the IP is presented. Beam distributions at the Compton detector are shown. We consider spin precession effects and compensation techniques that arise with a crossing angle. Spin alignment, diffusion and depolarization are discussed and estimates of differences between polarimeter measurements and the luminosity-weighted polarization are given.

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1 Introduction

Compton polarimeters are planned in both the warm (NLC/GLC) and cold (TESLA) Linear Collider (LC) designs. The polarimeters can be located upstream or downstream of the Interaction Point (IP) in both designs, though the downstream polarimeter requires a crossing angle at the IP. Compton-scattering for a 250-GeV electron beam with a 532-nm laser beam results in a kinematic endpoint for Compton electrons (back-scattered at 180° in the center-of-mass frame) at 25.1 GeV with a large analyzing power of 98%.

Extraction-line beam diagnostics are highly desirable at the LC. There is more flexibility in the beam optics design downstream of the IP than upstream (less constraints on emittance preservation) for implementing beam diagnostics. High precision is desired for both energy and polarization measurements and independent measurements of these quantities with different systematic errors are desirable. Extraction line diagnostics are needed to provide this and may allow improving systematic errors by $\sqrt{2}$. Beam-beam collision effects are also very important and can be directly measured with extraction line diagnostics by comparing measurements with and without collisions.

2 NLC Extraction Line Polarimeter Design

The current NLC design has a Compton polarimeter located in the extraction line with the Compton IP approximately 60 meters downstream from the Linear Collider IP (see Figure 1).[1] The Compton IP is at a secondary focus in the middle of a chicane with 20 mm dispersion, but with no net bend angle with respect to the e^+e^-collision IP. Compton-scattered electrons are confined to a cone having a half-angle of $\theta \approx 2\mu$rad and are effectively collinear with the initial electron direction. Beam losses in the extraction line are acceptable, both for machine protection and for detector backgrounds.

The Compton laser system[2] utilizes a frequency doubled Nd:YAG laser with a wavelength of 532 nm. The laser fires on every 7^{th} pulse train of the 120 Hz-rate electron beam, but every 10 seconds fires instead on the 6^{th} pulse train; this gives an average repetition frequency of ≈17 Hz. The laser power is 200 milli-joules in a 6-ns pulse and emerges from the laser linearly polarized. The laser spot size at the Compton IP is focused to an rms spotsize of 100 μm. A segmented electron detector sampling the flux of scattered electrons near the kinematic endpoint can provide a good polarization measurement with high analyzing power. The counting rate is high with ≈120 Compton electrons per GeV at the endpoint energy of 25.1 GeV. A threshold Cerenkov detector can be used, similar to that employed in the SLD Compton polarimeter. Fig-

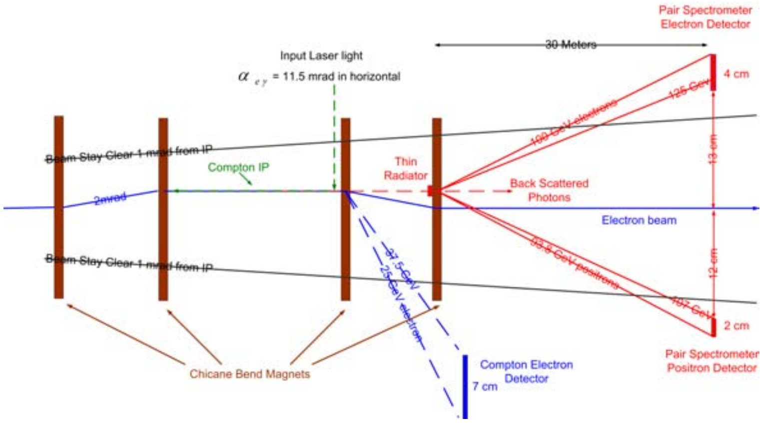

Figure 1: Compton Polarimeter System in the Extraction Line.

ure 2 shows the y-distribution of 25.1-GeV Compton scattered electrons at the Cerenkov detector located ≈ 21 meters downstream of the Compton IP. The Compton-edge electrons peak at ≈ 18 cm, well separated from the tails of the disrupted electron beam.

3 Spin Precession from an IP Crossing Angle

In the NLC-500 design, the beams collide at the IP with a 20-mrad crossing angle and are mis-aligned by 10 mrad with the LC Detector solenoid field. This results in a vertical kick to the beams. The vertical kick from the solenoid in the barrel region of the LC Detector is partially cancelled by a compensating kick in the endcap fringe field. In one study of this effect for NLC-500,[3] the deflection angle with respect to the incoming beam trajectory is 100 μrad at the LC IP and 200 μrad for the outgoing beam to the extraction line. Three problems result if these vertical kicks are not compensated: i) the extraction line must be realigned when the beam energy is changed; ii) there is a 200 μrad vertical crossing angle for e^-e^-collisions, (e^+e^-collide head-on, but at an angle of 100μrad with respect to the incoming beam trajectories) which significantly reduces the luminosity; and iii) there is a net band angle of 100 μrad between the beam trajectory at the (upstream or downstream) polarimeters and the IP. This angle is small compared to the rms divergence of the disrupted beams, but nonetheless is undesirable. Given these problems, vertical kicks from the solenoid in the crossing angle geometry must be compensated.

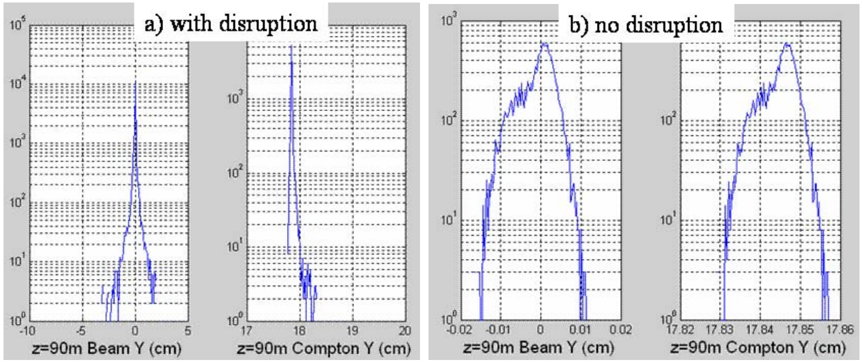

Figure 2: Vertical distributions of disrupted beam and Compton-edge electrons at the Compton detector plane for NLC-500, a) with e^+e^-collisions and b) without collisions.

This can be done with a combination of corrector dipoles, quadrupole offsets and a serpentine solenoid winding.[3]

4 Polarimeter and Lum-wted Polarization Differences

Several effects can lead to differences between the polarimeter measurement and the luminosity-weighted polarization, $dP = P_z^{IP,lum-wt} - P_z^{polarimeter}$.[4] (Estimates of contributions to dP given in this section assume that there is full longitudinal spin alignment at the polarimeter IP. Having both an upstream and a downstream polarimeter will assist in achieving this and estimating the associated systematic error.[4]) Orbit misalignments between the polarimeter IP and the collision IP are expected to be below 50 μrad, which would give $dP = -0.04\%$. Imperfect compensation for the solenoid/crossing angle steering effect with an expected uncertainty of 30 μrad, results in a contribution $dP = -0.01\%$. The effect of Sokolov-Ternov spin flips are expected to contribute $dP = +0.3\%$ ($dP = -0.1\%$) for downstream polarimeter measurements with (without) collisions. The angular divergence of the incoming beam is expected to contribute $dP = -0.03\%$, while the angular divergence of the outgoing beam is expected to contribute $dP = +0.1\%$ ($dP = -0.25\%$) for downstream polarimeter measurements with (without) collisions. Lastly, effects from chromatic aberrations which were important at SLC are expected to be negligible. Adding all these contributions together, we expect a total difference $dP = +0.32\%$ ($dP = -0.43\%$) for downstream polarimeter measurements with (without) collisions. A similar compilation of these effects for an upstream polarimeter leads to $dP = -0.42\%$.[4] The systematic errors associated with dP should be substantially smaller than the size of dP, and having independent information from 3 polarimeter measurements (upstream, downstream with and without collisions) will be important in minimizing this.

5 Conclusions

We have presented results of a study for a downstream Compton Polarimeter at the Linear Collider. Downstream polarimetry is feasible if there is a crossing angle at the IP and improves significantly the polarimetry systematic error. Vertical steering and spin precession due to misalignment of the beam trajectories with the LC Detector solenoid can be compensated. Differences between the polarimeter measurement and the lum-wted polarization are estimated to be $\approx 0.4\%$ with a systematic error smaller than this.

References

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2. K. Moffeit and M. Woods, SLAC IPBI TN-2003-2, 2003.

3. B. Parker and A. Seryi, SLAC LCC-143, 2004.

4. K. Moffeit and M. Woods, SLAC IPBI TN-2004-3, 2004.