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Precision Polarimetry for the International Linear Collider

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The physics program of the International Linear Collider requires the knowledge of the luminosity weighted average polarisation at the electron-positron collision point with a yet unprecedented precision of $\frac{\delta\mathscr{P}}{\mathscr{P}} = 0.25$ % or better. Crucial ingredients to reach this goal are fast and precise Laser-Compton-Polarimeters measuring before and behind the collision point as well as the understanding of the spin transport and depolarising effects at the per mille level. This contribution will review recent developments for the polarimeters, their detectors and calibration systems as well as recent recent results on the spin tracking between the polarimeters and the collision point.

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1. Introduction

At the International Linear Collider (ILC) [1] it is foreseen to collide polarised electron and positron beams with tunable centre-of-mass energy of up to $\sqrt{s} = 500$ GeV. The ILC physics program aims to measure Standard Model parameters as well as possible new phenomena with extremely high precision. This requires a very precise knowledge of the beam polarisation. The most precise polarisation measurement so far, at SLD, reached a precision of 0.5 % [2]. The goal for ILC polarimetry is an improvement by a factor of two over the SLD precision. The overall concept at ILC therefore combines the long-term average from e^+e^- collisions with measurements of Compton polarimeters upstream and downstream of the e^+e^- interaction point (IP) [3].

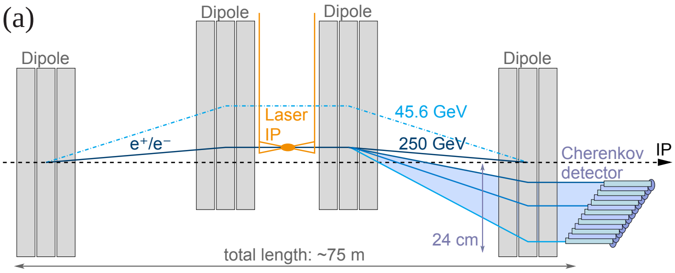
2. Spin tracking simulations

The two Compton polarimeters are located 1.6 km upstream and 150 m downstream of the e^+e^- interaction point. The transport between polarimeters and IP can induce depolarisation due to misalignment of the beam delivery system's elements. The e^+e^- collisions themselves will also affect the polarisation. To quantify these effects, a simulation of the spin transport along the beam delivery system has been set up. The studies show that the spin transport between the upstream polarimeter and the interaction point is unproblematic. At the downstream polarimeter however, the beamstrahlung effects at design luminosity can lead to a difference of $\Delta P_z \approx 0.2$ % between luminosity-weighted polarisation and the polarimeter measurement. This makes a detailed analysis of the interaction between the downstream polarimeter laser and the particle bunch necessary.

3. Compton polarimeters

The planned Compton polarimeters operate by shooting circularly polarised laser light onto the individual bunches, causing typically $\sim 10^3$ electrons or positrons per bunch to undergo Compton scattering. The energy spectrum of the scattered particles depends on the product of laser and beam polarisations. Inside a magnetic chicane, the energy distribution is transformed into a spacial distribution. This distribution can be measured using a multi-channel Cherenkov detector (Fig. 1a). The beam polarisation is directly proportional to the rate asymmetry between measurements with two different laser helicities.

(a)



(b)

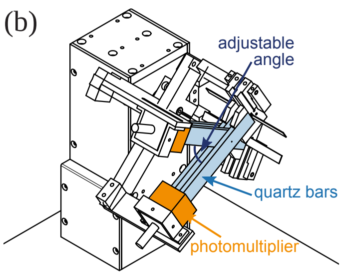


Figure 1: (a) Sketch of the upstream Compton polarimeter. The spacial distribution of the scattered particles inside the magnetic field is measured by an array of Cherenkov detectors. (b) Drawing of the quartz prototype detector. The angle of the detector channels with adjustable angle w.r.t. the beam is adjustable.

4. Detector design and photodetector studies

To reach the envisioned precision for the polarimeter measurements, the limit for the contribution from the Cherenkov detector linearity to the systematic uncertainty is 0.1%. Different detector concepts are investigated to fulfil this requirement, using gas or quartz as Cherenkov material.

A two-channel prototype for a **gas-filled detector** has been designed, comprising U-shaped aluminium channels with a calibration system on one leg and a photodetector on the other. In test-beam operation, a tilt alignment of $0.1\,^\circ$ was reached using the asymmetry between the anodes of a multi-anode photodetector [4]. This fulfils the alignment requirements within 20 % and could possibly allow to calibrate the detector position without need for dedicated beam-time.

To measure the differential non-linearity (DNL) of the **photodetectors**, an LED calibration system has been developed. The DNL is determined by measuring the difference in the detector output with and without a small secondary pulse in addition to a tune-able base pulse. Monte Carlo studies of this method show that non-linearities up to 4 % can be corrected successfully. In a test setup, one of the photomultipliers used with the gas detector prototype was characterised, and a residual non-linearity < 0.2 % in the expected dynamic range of the polarimeter was reached.

In addition, the use of **quartz** as detector material is investigated. The high refractive index of quartz results in a higher photon yield compared to gas. This might allow a fine enough resolution of the photoelectron spectrum to enable an online calibration of the photomultiplier gain. A four-channel prototype (Fig. 1b) has been operated in a first testbeam campaign at the DESY testbeam in 2013. Compared to the preceding simulations, the light yield is smaller than expected, which is currently suspected to be due to surface roughness. The qualitative behaviour under different beam angles agrees with the simulation.

Overall, progress has been reached in all aspects required to reach the precision goal for measuring the polarisation at the ILC. Further studies are needed both on the spin tracking and the detector side, yet reaching per mille level precision seems achievable.

References

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