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The scanning Compton polarimeter for the SLD experiment

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Abstract. For the 1994/95 run of the SLD experiment [1] at SLAC, a Compton polarimeter measured the luminosity-weighted electron beam polarization to be $(77.2 \pm 0.5)\%$. This excellent accuracy is achieved by measuring the rate asymmetry of Compton-scattered electrons near the kinematic endpoint. The polarimeter takes data continuously while the electron and positron beams are in collision and achieves a statistical precision of better than 1% in a three minute run. To calibrate the polarimeter and demonstrate its accuracy, many scans are frequently done. These include scans of the laser polarization, the detector position with respect to the kinematic edge, and the laser power.

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This polarimeter [2] detects Compton-scattered electrons from the collision of the longitudinally polarized 45.6 GeV electron beam [3] with a circularly polarized photon beam. The photon beam is produced from a pulsed Nd:YAG laser with a wavelength of 532 nm. After the Compton Interaction Point (CIP), the electrons pass through a dipole spectrometer; a nine-channel Cherenkov detector then measures electrons in the range 17 to 30 GeV. Figure 1 shows the location of the Cherenkov detector with respect to the Compton spectrum; the response function for channel 6 (as determined from an EGS simulation) is indicated as well.

The counting rates in each Cherenkov channel are measured for parallel and anti-parallel combinations of the photon and electron beam helicities. The asymmetry formed from these rates is given by

$$A(E) = \frac{R(\rightarrow\rightarrow) - R(\rightarrow\leftarrow)}{R(\rightarrow\rightarrow) + R(\rightarrow\leftarrow)} = \mathcal{P}_e \mathcal{P}_\gamma A_C(E)$$

where $\mathcal{P}_e$ is the longitudinal polarization of the electron beam at the CIP, $\mathcal{P}_\gamma$ is the circular polarization of the laser beam at the CIP, and $A_C(E)$ is the Compton asymmetry function.

The laser (Spectra Physics GCR130) has a nominal repetition rate of 17 Hz. It fires on every 7th electron pulse; the electron pulse rate is 120 Hz. Every 7 seconds the laser fires on the 6th pulse rather than the 7th to avoid any synchronization of the laser firing with instabilities in the electron beam. Laser off pulses are used for determining backgrounds. The typical Compton collision rate is approximately 1000 Compton scatters per collision pulse, with approximately 100 Compton scattered electrons detected by each of the 7 Cherenkov channels spanning the Compton spectrum. Typical signal to background ratio in Channel 7 is about 5:1.

The laser is polarized with a linear polarizer and two Pockels cells as shown in Figure 2. The axes of the linear polarizer and the PS Pockels cell are along the x,y axes, while the axes of the CP Pockels cell are along u,v (u,v axes are rotated by 45° with respect to x,y). This configuration can generate arbitrary elliptical polarization, and can compensate for phase shifts in the laser transport optics. Measurements of $\mathcal{P}_\gamma$ are made before and after the CIP (see Figure 2). An harmonic beam sampler (Gentec HBS-532-100-1C-10) transmits 98% of the laser power and generates two 1% beams at forward angles of 10°, which preserve the circular polarization, $\mathcal{P}_\gamma$, of the main beam to better than 0.1%. $\mathcal{P}_\gamma$ is determined from photodiode measurements of the amount of left-polarized and right-polarized light, where the *Right* and *Left*

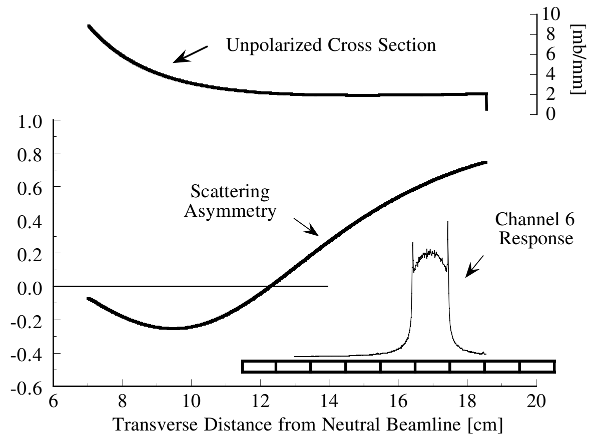

Figure 1: Compton kinematics

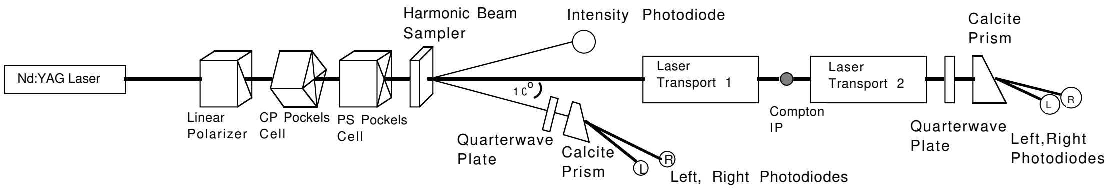

Figure 2: Compton laser system

photodiodes follow an helicity filter. The helicity filter is formed from a quarter waveplate and a calcite prism. The calcite prism has different indices of refraction for x and y linear polarized light and splits these components by 5°.

The *Right* (PD^+) and *Left* (PD^-) photodiode signals and the measured Compton asymmetry in Cherenkov channel 7 (A_7), are well-approximated by the following formulae:

$$PD^{\pm} = \frac{G^{\pm}}{2}[1 \pm sin(\frac{V_{CP} - V_{CP}^T}{V_{\lambda/4}^{CP}} \cdot \frac{\pi}{2})cos(\frac{V_{PS} - V_{PS}^T}{V_{\lambda/4}^{PS}} \cdot \frac{\pi}{2})]$$

$$A_7 = \mathcal{P}_e(A_C^7)[sin(\frac{V_{CP} - V_{CP}^{CIP}}{V_{\lambda/4}^{CP}} \cdot \frac{\pi}{2})cos(\frac{V_{PS} - V_{PS}^{CIP}}{V_{\lambda/4}^{PS}} \cdot \frac{\pi}{2})]$$

where G is the photodiode gain; V_{CP} and V_{PS} are the Pockels cell voltages; $V_{\lambda/4}$ is the Pockels cell quarterwave voltage; V_{CP}^T and V_{PS}^T are the laser transport phase shifts to the photodiode diagnostics; A_C^7 is the analyzing power for Cherenkov channel 7; and V_{CP}^{CIP} and V_{PS}^{CIP} are the laser transport phase shifts to the Compton IP. Measurements of PD^+, PD^- and A_7 are made at different Pockels cell voltages (*Pockels cell scans*) to monitor the laser transport phase shifts and the Pockels cell quarterwave voltages. From these scans we determined that averaged over the 1994/95 SLD run, $< \mathcal{P}_\gamma >= 99.6 \pm 0.2\%$ (syst) at the CIP.

The Compton spectrum is characterized (see Figure 1) by a kinematic edge at 17.4 GeV (180° backscatter in the center of mass frame) where $A_C = 0.754$, and the zero-asymmetry point at 25.2 GeV (90° backscatter in the center of mass frame). $A_C(E)$ is modified from the theoretical asymmetry function [4] by detector resolution effects. This effect is about 1% for Cherenkov channel 7 at the Compton edge. The Compton edge position is accurately determined from Cherenkov detector measurements at different detector positions (*detector position scans*). The Compton edge is in channel 7, and we use this channel to accurately determine $\mathcal{P}_e$. The asymmetry spectrum observed in channels 1-6 is used as a cross-check.

Polarimeter data are acquired continually during SLC operation and SLD data logging. The absolute statistical precision attained in a 3 minute interval is typically $\delta\mathcal{P}_e < 1.0\%$. Two-thirds of the polarimeter data are taken at off-nominal operating conditions (Pockels cell scans, table scans, laser power scans for linearity tests) for polarimeter calibration and systematics studies. The systematic uncertainties that affect the polarization measurement are summarized in Table I for the 1994/95 run.

The average luminosity-weighted electron beam polarization at the SLC IP for this run was found to be $< \mathcal{P}_e^{IP} > = (77.2 \pm 0.5)\%$.

Table I: Systematic Uncertainties for the SLD Compton Polarimeter

Systematic Uncertainty	$\delta\mathcal{P}_e/\mathcal{P}_e$ (%)
Laser Polarization	0.20
Spectrometer Calibration	0.29
Detector Linearity	0.50
Electronics Noise	0.20
SLC IP [5]	0.17
Total	0.67

[1] The SLD Design Report, SLAC-Report-273 (1984).

[2] Descriptions of the Compton polarimeter system can be found in the thesis by R. King, SLAC-Report-452 (1994); and in the thesis by A. Lath, SLAC-Report-454 (1994). New additions to the polarimeter not described in these theses include a higher repetition rate laser, improved laser polarization diagnostics, and modification of the spectrometer magnets to include a quadrupole.

[3] The polarized electron beam for the SLAC Linear Collider (SLC) is described in a contribution to these proceedings by M. Woods, SLAC-PUB-7320 (1996).

[4] S.B. Gunst and L.A. Page, *Phys. Rev.* **92**, 970 (1953).

[5] There is a small difference between the luminosity-weighted electron beam polarization relevant for Z bosons detected by the SLD, and the average electron beam polarization measured by the Compton polarimeter (see reference [3]).

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