

THE COMPTON POLARIMETER AT THE SLC*

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Compton scattering provides a fast and accurate measurement of the longitudinal polarization of electron beams available at linear colliders. At the SLC, green (532 nm) circularly polarized light from an Nd:YAG laser, frequency doubled, collides nearly head-on with electrons after they have passed the e^+e^- interaction point but before they have encountered any dipole bending magnets.

Unique to this application, the recoil electrons, rather than scattered photons, are detected, after being momentum analyzed by the bending magnets nearest to the interaction point. Thus we achieve spatial separation of several centimeters between electrons from scattering at different Compton angles.

The analyzing power of Compton scattering of 2.34 eV photons from 45.6 GeV electrons is 75% at full backward scattering. The analyzing power is zero at 90 degrees in the electron rest frame, and data from this channel helps us correct for luminosity variations in the electron-photon collisions.

The Compton polarimeter is capable of measuring the electron beam polarization to within a few percent of itself. Statistical accuracy of better than 1% in the absolute beam polarization is achieved routinely in runs of three minutes duration, with the laser firing at 11 Hz.

Figure 1 shows the Compton Light Source and the Compton Electron Detectors in relation to the e^+e^- Interaction Point within the SLD detector, and to the nearest bending magnet in the south final focus region of the SLAC Linear Collider.

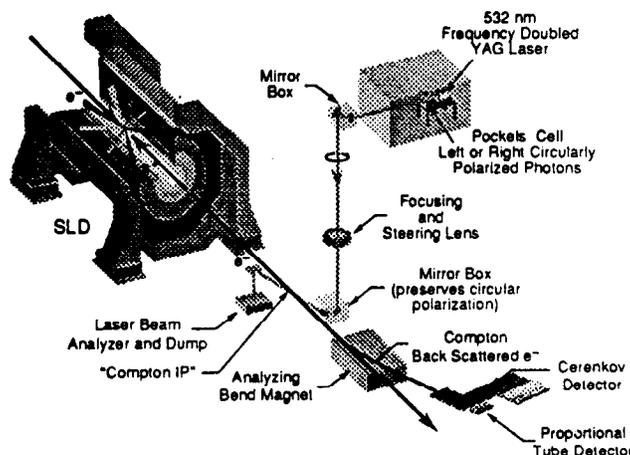


Fig. 1. The Compton Polarimeter

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The Compton Light Source consists of the laser, the evacuated transport line, and hardware and optics for laser beam circular polarization, steering, focusing and diagnostics. The laser is a commercially available SpectraPhysics GCR-11 frequency doubled Nd:YAG laser. The laser pulse width is 7 ns (FWHM), and has a pulse energy of about 45 mJ. The laser is pulsed once every 11 SLC machine cycles. (The SLC operates at 120 Hz.) The laser beam passes through a prism polarizer and Pockels cell combination to circularly polarize the beam. The sign of the circular polarization, determined by the polarity of the high voltage applied to the Pockels, is normally set pulse-to-pulse following a pseudo-random pattern.

Before exiting the laser room, and entering the evacuated transport line, the beam diameter is expanded to 2 cm in order to maintain collimation over the 40-meter pathlength to the Compton interaction point. The beam transport line between the Pockels cell and the Compton interaction point consists of evacuated straight sections connected by 4 sets of phase compensated mirror pairs, 4 windows, and a focusing/steering lens. The compensated mirror pairs preserve the polarization of the photon beam upon reflection. The transport line windows were measured to have negligible birefringence. The 5-meter focal length lens focuses and steers the laser beam onto the electron beam. After leaving the SLC vacuum, the beam is monitored for intensity, steering and polarization. The electron and photon beams cross at an angle of 10 milliradians. At the Compton interaction point, the RMS beam sizes are approximately 350 microns for the electron beam, and 500 microns for the photon beam.

The Compton Cerenkov detector consists of a nine-cell gas threshold Cerenkov counter viewing a retractable 1.4-radiation-length lead radiator. Each $1 \times 1.5 \times 20$ cm mirrorized Cerenkov channel is filled with non-scintillating gas (beta-butylene) at atmospheric pressure, and is viewed by a 1-cm diameter phototube. The mirrorized aluminum walls are thin (250 microns) to minimize showering in the scattering plane. The Cerenkov light collection efficiency is estimated to be over 50%. The electron energy threshold for producing Cerenkov light is 10 MeV, providing good immunity to low energy backgrounds. The phototubes are operated at low gain (100,000) to ensure a linear response function.

The Compton Proportional Tube Detector consists of 16 proportional counter tubes of inside diameter 3.9 mm embedded in a 5-radiation length radiator. The sensitive area of the detector is 60 mm in the horizontal plane by 6 mm in the vertical plane. In order to maintain a linear response, they are operated at very low gain (50-100). The detector is heavily shielded except for a narrow region in the scattering plane. This reduces susceptibility to beam related backgrounds.

Since the laser is pulsed once in 11 machine pulses, the ten intervening pulses provide an accurate measurement of the background. The background in both detectors is due principally to beamstrahlung photons produced at the SLC

interaction point. The signal-to-noise ratio is typically 5-10 for the Cerenkov detector and 1-2 for the Proportional Tube detector.

Figure 2 shows the raw asymmetry as a function of channel in each of the two Compton electron detectors. The data are for a typical three-minute run at a time when the beam polarization exceeded 60%. The raw asymmetries are as high as 45% in the backward scattering channels.

Any channel in either of the two detectors, with large analyzing power, can be used to measure the beam polarization, if the analyzing power for that channel is well understood. The detector position and spectrometer momentum scale are determined from measurements of the kinematic endpoint of the Compton recoil electron energy spectrum, and from the zero-asymmetry point. Corrections to the analyzing power of each channel are made for the finite width of the channel, and for showering in the pre-radiator and channel walls.

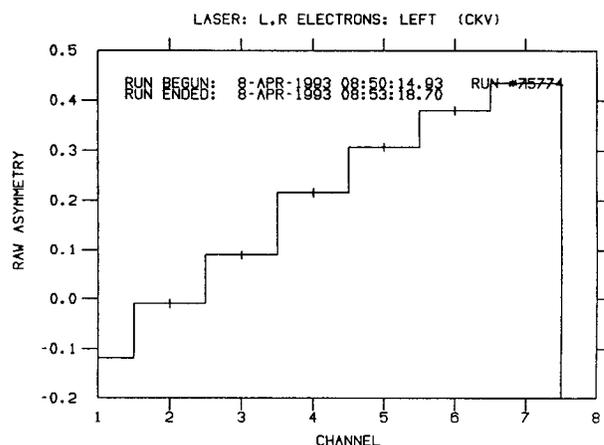


Fig. 2A. Raw asymmetry as a function of channel in the Cerenkov detector.

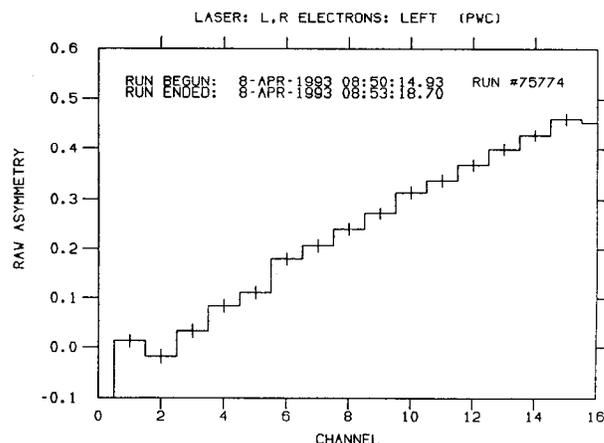


Fig. 2B. Raw asymmetry as a function of channel in the proportional tube detector.

Limits have been placed on the various sources of systematic error associated with the measurement of the electron polarization. The circular polarization of the laser beam at the interaction point is known to within 2.0%. The detector linearity is understood to within 1.5%. Interchannel consistency contributes to the systematic uncertainty at the level of 0.9%. Uncertainties in the Compton recoil energy scale, and corrections for electronic noise are both at the 0.4% level. The total systematic uncertainty of the polarization measurement to the recent SLD measurement of the left-right cross-section asymmetry in Z Boson production [1] was 2.7%. Improvements can be made that will further reduce this contribution to the systematic error.

Performance of the SLC continues to improve. Figure 3 shows the polarization measurement nearest to the production of each Z Boson in the year since polarized beams have been accelerated at the SLC. The first 11,000 Z's, produced from April to September of 1992, were with

[1] K. Abe et al. (SLD collaboration), Physical Review Letters 70, 2515 (1993).

beams whose polarization averaged 22%. The run that began in March, 1993, had polarization in the 55% range at first. This was increased to more than 60% when the wavelength of the laser at the electron source was adjusted.

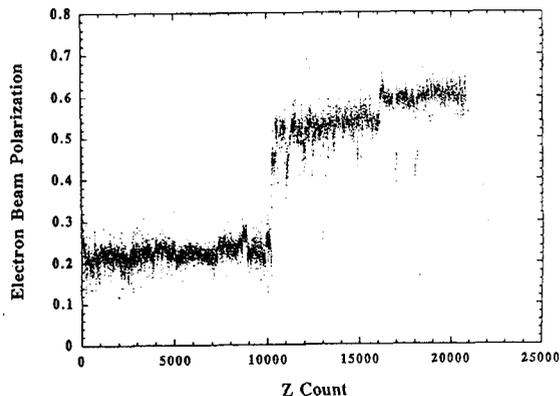


Fig. 3. Beam Polarization for 1992 and 1993 SLD Data