A QUARTZ FIBER / TUNGSTEN CALORIMETER FOR THE COMPTON POLARIMETER AT SLAC

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Both longitudinal and transverse polarization of a high energy electron beam can be measured by the detection of photons produced in Compton scattering of electrons from an intense circularly polarized laser beam. We have built a calorimeter based on the quartz fiber technology and performed polarization measurement at the SLAC Linear Collider. The results obtained with this detector allowed to cross check the polarization measurement by the SLD collaboration at better than 1 % level.

1 Introduction

Availability of a highly polarized electron beam is a key feature for the physics program at the SLD detector at SLAC. The polarization is monitored by the Compton Electron Polarimeter [1] (Figure 1). A circularly polarized laser beam, produced by a pulsed Nd:YAG laser with a wavelength of 532 nm, collides with the high energy electron beam at the Compton IP 33 meters downstream from the SLD IP. Scattered electrons are analyzed by a spectrometer consisting of a pair of dipole magnets and a 9-channel gas Čerenkov detector with a 7.6 mm lead pre-radiator.

With high statistics accumulated during the recent run, the accuracy of many SLD results has increased to the point where it is sensitive to systematics. Since the error in the polarization measurement is a major source of systematic uncertainty for many important SLD results including the measurement of the electroweak mixing angle, it is important to cross check the polarization measurement provided by the Čerenkov electron spectrometer described above.

In order to provide the desired cross check we have built the Quartz Fiber Calorimeter (QFC) which detects scattered Compton photons and determines the longitudinal polarization by measuring the asymmetry in the energy flow between parallel and antiparallel helicity combinations of the electron and photon beams. The calorimeter is also designed to be position-sensitive in both

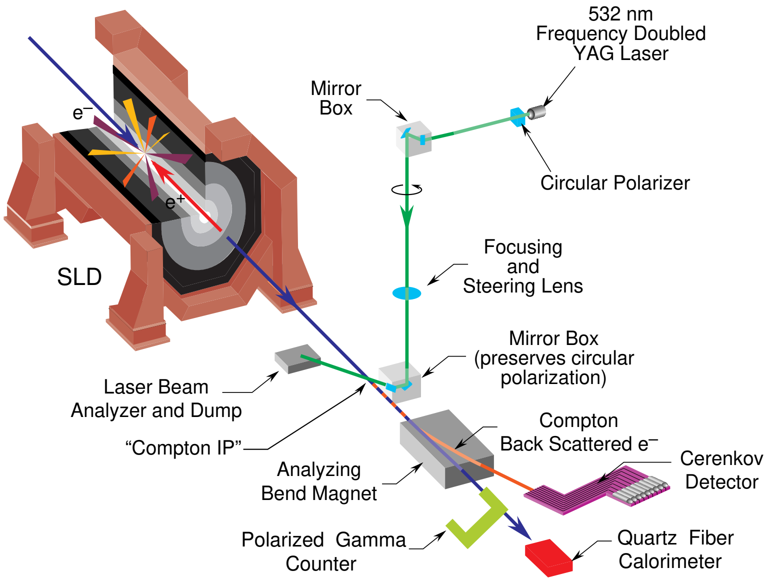

Figure 1: SLD Compton polarimeter.

vertical and horizontal directions to determine the transverse polarization of the electron beam by measuring angular asymmetry.

2 Technology choice and design of the calorimeter

The idea to use a total absorption calorimeter in a Compton polarimeter was first described by C.Prescott [2] in 1973, and conceptual design of a photon polarimeter for the SLD was proposed by M.Fero et al. [3] in 1993. Compared to an electron spectrometer, a calorimeter-based photon polarimeter has several important advantages : it does not depend on the magnet calibration, has very low sensitivity to position and angular misalignments, and does not rely heavily on Monte Carlo for the analyzing power calibration. The disadvantages are lower analyzing power (0.172, compared to about 0.70 for the most sensitive channel of the electron spectrometer), and higher sensitivity to backgrounds. Given the SLC design, high background from the beamstrahlung makes a precise measurement by the photon detector impossible when the electron and positron beams are in collision. Therefore, the detector is only operated during electron-only running and is used to cross check the measurement by the electron spectrometer.

In order to satisfy the requirements imposed by the specific SLD/SLC environment and beam layout in the polarimeter area, we proposed [4] to use a quartz fiber calorimeter with tungsten absorber. Quartz fibers are sufficiently radiation hard [5] to survive an estimated dose of 2 Grad for the lifetime of the detector. Compact shower in such calorimeter allows to make the detector small enough to fit into very limited space available for it while maintaining full containment of the shower required to achieve high linearity. The 200 keV Čerenkov threshold of quartz makes the calorimeter insensitive to the huge flux of soft synchrotron radiation from the upstream magnets. Finally, sandwich design with fibers perpendicular to the direction of the beam allows for fine granularity and good position resolution.

The calorimeter is formed by a longitudinal stack of thirty four 3.5 mm thick tungsten plates with precisely machined 14 mm wide grooves in alternatingly horizontal and vertical directions. Thirty eight quartz fibers fit tightly inside each groove. We used commercially available [6] polyimide buffered quartz fibers with the outer diameter of 360 microns.

Čerenkov light produced in the quartz fibers is read out by 24 PMTs placed in a lead-shielded box. The box also contains an LED calibration system [7].

3 Detector performance

The QFC was installed in the SLC South Final Focus in January 1996 and commissioned during the SLD 1996 run. Following the run, the shielding around the calorimeter was modified [8] to improve its signal-to-background ratio, and the detector took data in 1997.

Our preliminary results show excellent agreement between the measurements by the QFC and by the SLD's standard polarimeter. For the data sample taken during the dedicated study in December 1997 (2 hours of beam time), the average polarization measured by the QFC was $0.735 \pm 0.004 \pm 0.005$. The average polarization measured for the same data sample by the electron spectrometer was $0.732 \pm 0.001 \pm 0.008$.

In 1998 the QFC was taken to the FFTB facility at SLAC for a beam test. The energy response function of the calorimeter was measured in the 2 - 25 GeV region, which allowed us to set a limit on the systematic uncertainty in the polarization measurement due to possible non-linearity in the QFC response at 0.2 % level. The beam test was also used to study the readout linearity, calorimeter uniformity, position sensitivity, and possible effects of angular misalignment.

4 Conclusion

A calorimeter-based photon polarimeter has been successfully implemented. We were able to provide a high precision cross check of the SLD's polarization measurement which is important for the overall accuracy of the SLD physics results.

The SLAC Linear Collider is the only polarized linear collider in existence and will be a prototype for the next generation of high energy linear colliders. Beam polarization is an essential feature of any such collider. Our experience with the QFC demonstrated the usability of this technique for high precision polarization measurements, and revealed a number of technical problems that should be addressed in the design of future colliders and polarimeters.

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