UNDULATOR-BASED PRODUCTION OF POLARIZED POSITRONS

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Abstract

A proof-of-principle experiment has been performed in the Final Focus Test Beam (FFTB) at SLAC to demonstrate production of polarized positrons in a manner suitable for implementation at the ILC. A helical undulator of 2.54-mm period and 1-m length produced longitudinally polarized photons of 1st-harmonic endpoint energy = 8.5 MeV when traversed by a 46.6-GeV electron beam. The polarized photons were converted to polarized positrons in a 0.2-radiation-length tungsten target. The polarization of these positrons was measured at several energies, with a peak value of $\approx 80\%$ according to a preliminary analysis of the transmission polarimetry of photons obtained on reconversion of the positrons in a second tungsten target.

INTRODUCTION

The requirements for an intense positron beam at the ILC place severe demands on the "conventional" method of (unpolarized) positron production in which few-GeV electrons are incident on a thick lead or tungsten target.

A technique for copious production of polarized positrons was suggested some time ago by Mikhailichenko [1], but has never been demonstrated until now. As sketched in Fig. 1, an electron beam of ≈ 150 GeV energy passes through a helical undulator to produce a beam of circularly polarized photons of energies up to 10 MeV. These MeV photons are incident on a thin target, in which there is good polarization transfer to the positrons (and electrons) that are pair-produced. The low-energy positrons are collected for injection into one arm of the linear collider, while the high-energy electron beam (which is largely undisturbed by its passage through the undulator) is directed into the other arm.

In addition to the accelerator-physics advantages of polarized positron production, the full potential of the ILC

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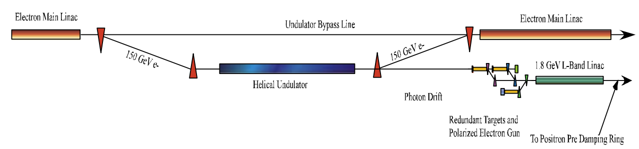

Figure 1: The concept of undulator-based production of polarized positrons. From [3].

(explore electroweak symmetry breaking, unravel possible new phenomena as supersymmetry at the TeV energy scale. *etc.*), can be realized only if both beams are polarized [2].

THE E-166 EXPERIMENT

The scheme of SLAC experiment E-166 [3] to demonstrate production of polarized positrons is sketched in Fig. 2. By use of a helical undulator with 2.54-mm period (shown in Fig. 3), circularly polarized photons of energy up to 10 MeV are produced by the 46.6-GeV SLAC electron beam, with energy spectrum and polarization identical to that appropriate for the ILC; only the intensity of these photons is lower in the demonstration experiment.

The calculated energy spectrum and helicity of photons produced by a 50-GeV electron beam and a 2.4-mm period undulator of strength parameter $K = 0.17$ is shown in Fig. 4. The polarization of photons is transferred to that of positrons by conversion of the photons in a thin target, with expectations as shown in Fig. 5. The positron polarization varies between 40 and 80% as the energy varies between 3 and 8 MeV.

The flux and polarization were measured for both the photons and the positrons, using so-called transmission polarimeters, as sketched in Fig. 6. In this technique, the photon flux is attenuated by magnetized iron leading to a small asymmetry in the transmitted flux for photons with spin aligned parallel or antiparallel to the magnetization of the iron. To measure the polarization of positrons by this

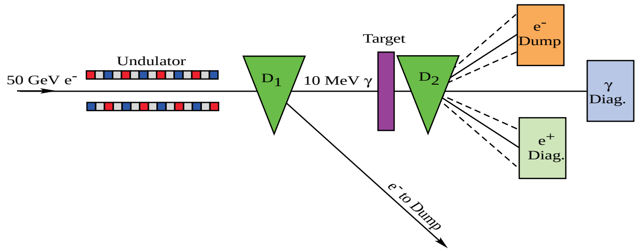

Figure 2: Conceptual layout (not to scale) of SLAC experiment E-166. 46.6-GeV electrons enter from the left and pass through an undulator to produce a beam of circularly polarized photons of ≈ 10 MeV energy. Some of the photons are converted to electrons and positrons in a thin target. The polarization of the positrons, and of the photons, are measured in polarimeters based on Compton scattering of photons in magnetized iron.

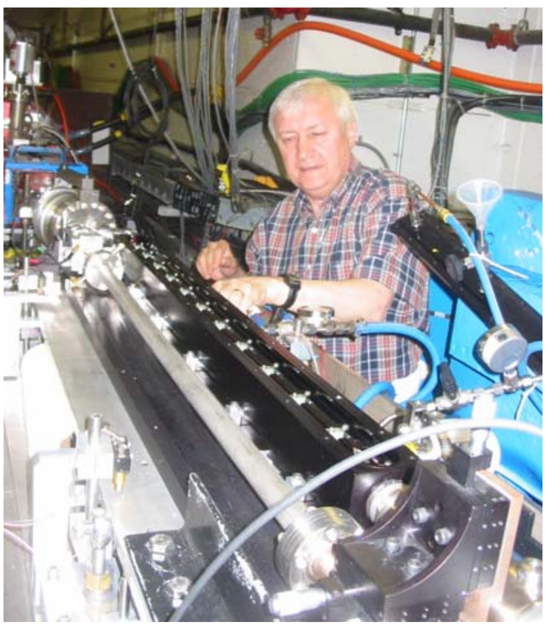

Figure 3: The helical undulator during installation. The undulator bore has an ID of 0.8 mm.

method, they must first be reconverted to photons in a thin target. Figures 7 and 8 show the photon and positron polarimeters during installation.

RESULTS

The experiment collected data during June and September 2005. Figure 9 shows the photon signal in the central CsI detector from converted positrons from single electron beam pulses with the undulator off and on. Figure 10 shows a preliminary analysis of the asymmetry of the positron signal upon reversal of the magnetic field in the analyzer magnet. The results are consistent with a peak positron polarization in excess of 80%.

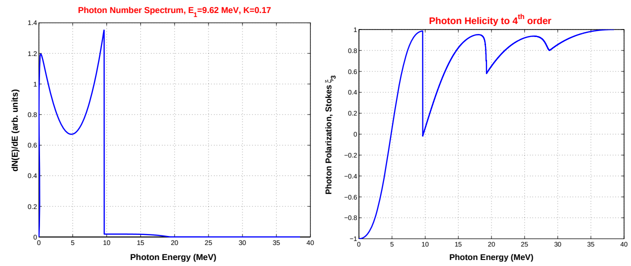

Figure 4: **(a)** The photon number spectrum of undulator radiation, integrated over angle, for electron energy $E_e = 50$ GeV, undulator period $\lambda_u = 2.4$ mm and undulator strength parameter $K = 0.17$. The peak energy E_1 of the first harmonic (dipole) radiation is 9.62 MeV. **(b)** The polarization P_γ of the undulator radiation as a function of energy.

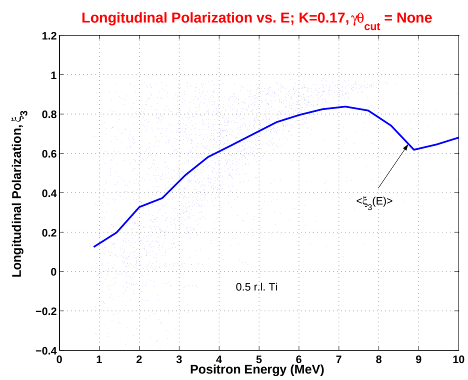

Figure 5: Calculated positron longitudinal polarization as a function of energy. The solid lines are polarization averaged over a 0.5-MeV energy slice. The dip in the polarization at 8.7 MeV is due to the corresponding dip in photon polarization at 9.6 MeV as seen in Fig. 4(b).

ILC POSITRON SOURCE

Following preliminary reports of the successful demonstration in E-166 of undulator-based production of polarized positrons, this concept has been adopted as the baseline positron source for the ILC [4]. A conceptual implementation of this scheme is shown in Fig. 11.

REFERENCES

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[2] G. Moortgat-Pick *et al.*, *The role of polarized positrons and electrons in revealing fundamental interactions at the Linear Collider* (July 1, 2006), hep-ph/0507011.

[3] G. Alexander *et al.*, *Undulator-Based Production of Polarized Positrons*, approved as SLAC E-166 (June 18, 2003), http://puhep1.princeton.edu/~mcdonald/e166/e166prop03.pdf

[4] ILC Baseline Configuration Document, http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd_home

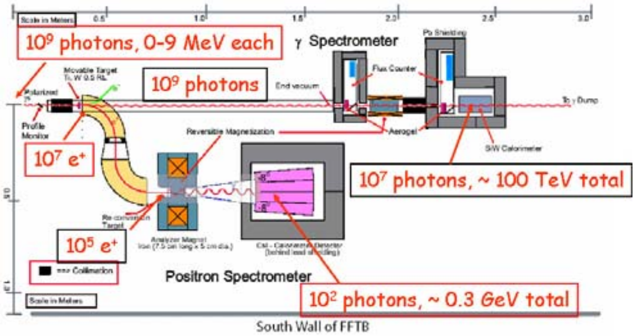

Figure 6: Conceptual layout of the E–166 positron generation and photon and positron diagnostic systems. Typical rates are shown at various locations in the apparatus.

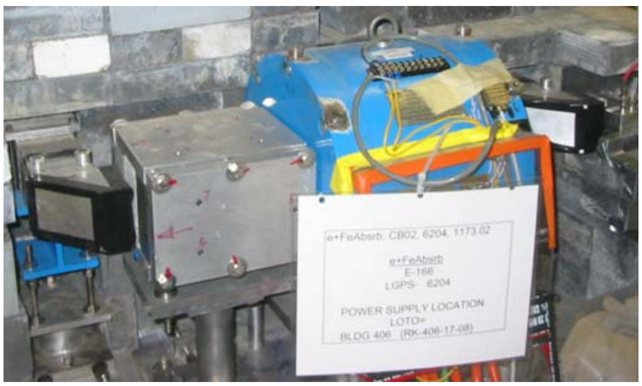

Figure 7: The photon transmission polarimeter during installation. The blue object is the iron-core solenoid whose magnetization is reversed periodically.

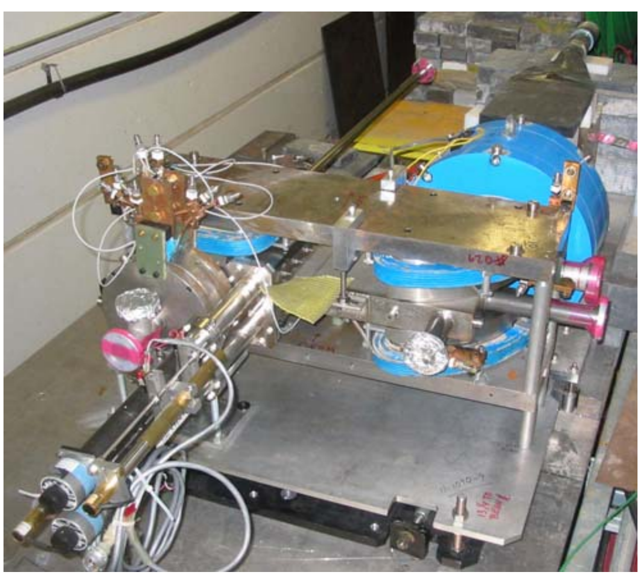

Figure 8: The positron spectrometer and transmission polarimeter during installation. The positron production target is mounted in front of the focusing solenoid on the left. The iron-core solenoid and the CsI detector are at the upper right. Between is the magnetic spectrometer.

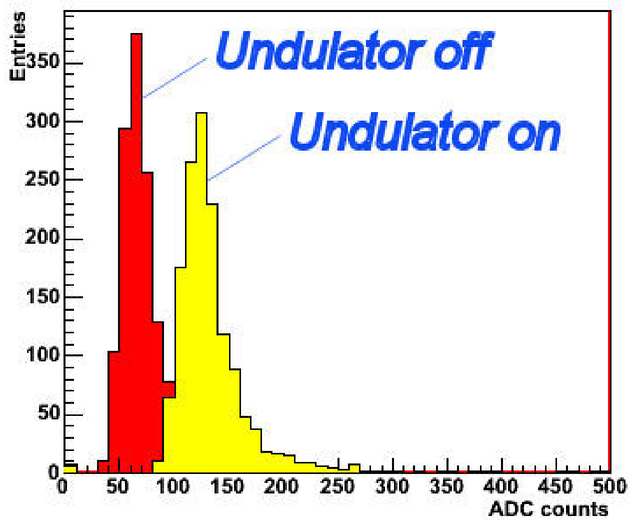

Figure 9: Comparison of the signal in the central CsI crystal for single electron beam pulses with undulator on and off. One ADC count is approximately 1.7 MeV.

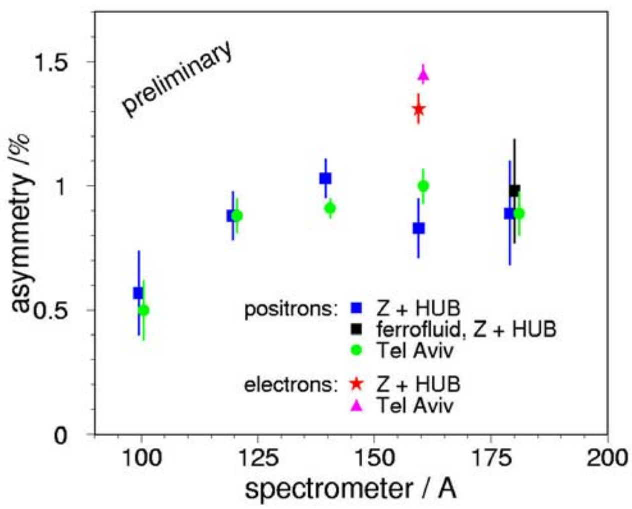

Figure 10: Preliminary analysis of the positron asymmetry as a function of spectrometer current (100 A ≈ 4.5 MeV).

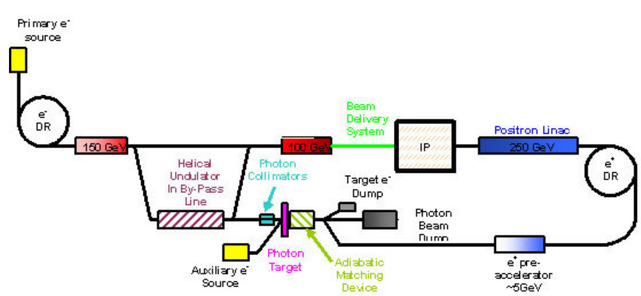

Figure 11: Scheme of the undulator-based source of polarized positrons for the ILC [4].