Project name:

Study of Polarized Positron Production for the LC

Classification (accelerator/detector: subsystem)

L.E.P. (Luminosity/Energy/Polarimetry)

Institution(s) and personnel

University of Tennessee at Knoxville, Department of Physics and Astronomy:
William Bugg (Professor), Steve Berridge (engineer),
Yury Efremenko (Research Professor), Thomas Handler (Professor),
Stefan Spanier (Professor), Yuri Kamyshkov (Professor)

University of South Carolina, Department of Physics and Astronomy:
Milind V. Purohit (Professor), Achim Weidemann (Research Professor),
Graduate Student

Stanford Linear Accelerator Center:
John Sheppard (Staff Physicist), Rainer Pitthan (Staff Physicist),
Michael Woods (Staff Physicist)

Contact person

William Bugg
bugg@slac.stanford.edu
(865) 974-7799

Achim W. Weidemann
achim@SLAC.Stanford.EDU
(650) 926-3391

Motivation

'The physics potential of an e^+e^- linear collider can be significantly enhanced if both the electron and positron beams are polarized.' [1] The effective polarization and hence the measured asymmetries are larger, if positrons are polarized in addition to electrons; the measurement error on the effective polarization will decrease. This is essential for a proposed 'Giga-Z' run of the LC at the Z^0-energy. The direct control over the initial helicity states allows the separation of the four helicity contributions to any physics process, and the suppression of backgrounds generated by certain helicity states, e.g. from W production.

Several methods are known to produce (unpolarized or polarized) positrons. The conventional methods are based on the production of electromagnetic showers by high energy electron beams impinging on heavy-metal targets. For LC conditions, these targets are close to their (thermo-)mechanical limits and therefore cannot be used to generate polarized positrons. The assumption that an ultra-relativistic positron beam - e.g. made by the conventional method - could be easily polarized by multiple Compton scattering on circular polarized laser beams was recently shown to be based on a misconception.[2]

Therefore, another method based on a two-step scheme has become quite attractive and is the basis for this proposal.[3] In the first step, an unpolarized electron beam passes through a helical undulator and generates circular polarized photons with an energy of 30 to 50 MeV. In the second step these photons then undergo pair production in a thin target. The resulting positrons are expected to be longitudinally polarized, with a polarization of 45-70% in the high-energy part of the spectrum [4]. Together with highly polarized electrons the effective polarization will be significantly higher than 90%.

Project Overview

John Sheppard and Rainer Pitthan from SLAC have proposed to test this attractive concept in an experiment at the Final Focus Test Beam (FFTB) at SLAC [5] together with university groups from South Carolina and Tennessee. The goal of this experiment is to demonstrate the viability of undulator-based positron production and to measure the achievable polarization.

In this experiment, the low-emittance beam of the FFTB would be threaded through a helical undulator of period 1 - 2 mm to produce the circularly-polarized photons; a target in the photon beam (e.g. titanium) - after the deflection of the electron beam by existing magnets - would then produce the positrons. With the present electron flux in the FFTB (10^{10} electrons/bunch) the expected yield of positrons from an helical undulator is about $3\ 10^{7}$/m/bunch.

Devices are needed to measure the flux, energy spectrum, and polarization of the photons and positrons; all of which are expected to be in the energy range up to 50 MeV. Several options exist for each of these, but these options still have to be investigated in detail.[7] Most of these options involve the transmission of the photon or electron/positron through a magnetized ferromagnetic foil or by their scattering on polarized electrons. The measurement of the polarization of positrons employs Bhabha scattering and two-photon annihilation (Mott scattering is not well suited for this energy range, single arm Møller measurements have a high background. Double arm Møller measurements are difficult because of the low SLC duty cycle). Another attractive concept for the SLAC site is the measurement of the polarization of photons from re-converted polarized positrons. The photon polarization can be detected by their transmission through a magnetized foil; this method has recently been demonstrated at the KEK Accelerator Test Facility [8]; its implementation at FFTB would have the advantage of significantly higher rates.

This experiment is now in the conceptual design stage. A collaboration between SLAC, University of South Carolina, and University of Tennessee has been formed. The actual experiment would be performed in the next 2-3 years during which the FFTB is available.

Work to be performed by South Carolina

For the first year, we propose to work on the following:

- Survey of polarimetry schemes
- Development of simulations tools for pair production, polarimetry e.g. polarization transport in Geant 4, Geant4 simulation of proposed polarimeters.

Once the experiment is approved, we expect to be involved in

- Data acquisition for the polarimeters,
- Data taking and analysis, comparison to simulations.

This work is to be performed mainly by Achim W. Weidemann, who will supervise a graduate student (typically half-time, for a year, or full-time for shorter periods).

Work to be performed by Tennessee

Tennessee plans to work on the following items:

1) Diagnostic techniques for the measurement of polarization of photons and positrons.

- Simulation of the detection scheme.
- Setup of the detector with mostly recycled instruments from ORNL and SLAC/Stanford Campus. Engineering support from the University will be provided.
- Data acquisition and analysis.

2) Alternative scheme for high energy gamma production based on undulators [9].

Both university groups have experience with (Compton) polarimetry from SLD (high energy beam at 45 GeV), and with the FFTB beam line through previous experiments (E-144, E-150).

Our future interest is in the contribution to the detection of polarization at LC energies. Precision measurement of polarization has successfully been demonstrated by the SLD experiment at SLC resulting in the world's most precise single measurement of the Weinberg angle. As demonstrated by SLD experience, it is crucial that other polarization measurement techniques with different systematics be utilized to periodically check the accuracy of the primary measurements. Such checks are crucial to the proper understanding of the error budget for the measurement.

The University of Tennessee proposes to construct for LC a quartz fiber calorimeter similar to the one built for SLD for this purpose. The device uses the integrated energy asymmetry of the Compton scattered photons to provide a relatively independent polarization measurement. While some details of LC operation require a modified design the basic device is similar to that used at SLD. The potential of a suitably designed quartz fiber device for measurement of beamstrahlung angular and energy distribution is also under study by our group.

Budget

Institution	Item	Cost
Tennessee	Acquisition/recycling of instrumentation (e.g. ORNL)	$5,000
Tennessee	1 month engineer work (includes benefits & overhead)	$10,000
Tennessee	Travel	$8,000
Tennessee	Indirect Cost (25%)	$2,000
S. Carolina	Graduate Student Housing Subsidy – 6 Months	$8,000
S. Carolina	Travel	$3,000
S. Carolina	Indirect Costs (Off-site rate 25%)	$2,750
SLAC	SLAC total	$0
	Grand total	$38,750

References:

[1] J. Erler et al., Positron polarization and low energy running at a Linear Collider, Contribution to Snowmass2001, hep-ph/0112070, P.C. Rowson, Assessing the merits of positron Polarization at a Linear Collider, Contribution to Snowmass2001, SLAC-PUB-9200, April 2002

[2] G.L. Kotkin, V.G. Serbo, V.I. Telnov, hep-ph/0205139, May 2002

[3] U. Amaldi, C. Pellegrini, CERN-EP/80-65, May 1980, Submitted to 2nd ICFA Workshop on Possibilities and Limitations of Accelerators, Les Diablerets, Switzerland, Oct 4-10, 1979. Published in ICFA Workshop 1979:21; V.E. Balakin, A.A. Mikhailichenko, Preprint INP-79-85, Novosibirsk, 1979

[4] TESLA TDR, pt 2; T. Hirose et al. Nucl. Inst. Meth. A455, 15 (2000); T. Omori, Talk at LC02, SLAC, Feb.5, 2002

[5] R. Pitthan, J. Sheppard, Use of a Microundulator to Study Positron Production, Talk at LC2002, February 5, 2002; R. Pitthan, Use of Polarized gammas to Produce Polarized Positrons at Collider Energies - How to test it Sensibly with 50 GeV e- in the FFTB, Talk at SLAC NLD meeting 26 March 2002 J. Sheppard, Towards an Undulator-based LC Positron Source, Talk at SLAC NLD meeting 25 June 2002 Note: These and some related references are available at http://www.slac.stanford.edu/~achim/positrons/

[6] A.V. Koroli, A. V. Solov'yov and W. Greiner Photon Emission by an Ultra-relativistic Particle Channeling in a Periodically Bent Crystal Int. J. Mod. E, Vol.8,No. 1 (February 1999) 49-100

[7] H. Schopper, Measurement of Circular Polarization of gamma Rays, Nucl. Instr. 3, 158-176, 1958; Ullman, Frauenfelder, Lipkin, Rossi, Determination of Electron and

Positron Helicity with Moeller and Bhabha Scattering, Phys.Rev 122, 536-548, 1961; J.M.Hoogduin, Electron, Positron and Photon Polarimetry, Thesis, Rijksuniversiteit Groningen, 1997.; Circular photon polarization has recently been measured at the KEK ATF, see A.S. Arychechev, A.P. Potylitsyn, M.N. Strikhanov, Determination of circular polarization of gamma-quanta with energy > 10 MeV using Compton Polarimeter, physics/0112060.

[8] M. Fukuda et al., Polarization Measurement of Short Pulse Gamma-Rays produced at KEK-ATF, Talk at ISG-8.

[9] A. V. Koroli, A. V. Solov'yov, and W. Greiner, Int. J. Mod. E. 8, 49 (1999).