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Polarization Setup and Polarimetry for 2 IRs, and Status of Downstream Polarimeter Designs

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A spin rotation scheme for the ILC is presented that allows the polarization spin vector to be tuned independently for different Interaction Regions (IR). A scheme to allow rapid helicity switching for polarized positrons is discussed. Comments on the downstream polarimeter designs are given.

1. MDI WORKSHOP AT SLAC

At the Machine Detector Interface workshop at SLAC in January 2005 there were five presentations on polarization: [1]

Physics motivation and polarization measurements from annihilation by Klaus Moenig, DESY/LAL-Orsay.

Overview on Compton Polarimetry at the ILC by Peter Schuler, DESY.

Spin transport and depolarization by Kaoru Yokoya, KEK.

Detector analyzing powers for upstream and downstream polarimeters by William Oliver, Tufts University.

Design issues and measurement strategy by Ken Moffeit, SLAC.

The results are summarized in this presentation and in reference [2].

2. SPIN ROTATION SCHEMES AT THE ILC FOR TWO IRS

Two interaction regions are planned for the ILC. A possible configuration is to have one IR with a crossing angle of 20 mrad and one with 2 mrad. The beams will point in different directions at the two IRs. The BMT spin precession [3] with respect to the electron momentum vector is given by $\theta_{spin} = \gamma \frac{g-2}{2} \cdot \theta_{bend} = \frac{E(GeV)}{0.44065} \cdot \theta_{bend}$. The spin direction of the beams at the two IRs will be different at all energies, except for multiples of $0.44065 \cdot \pi / \theta_{bend}$. For an angle of 11 mrad between the two IRs, this corresponds to 125.85 GeV. Physics will dictate at what energy we run the ILC. This may not correspond to these magic energies. We want to design spin rotation systems to have optimum polarization at both IRs at any energy. Polarization direction can be tuned for each IR by introducing separate spin rotation systems for the two IRs at the exit of the damping rings and switch the beams to the different spin rotation systems between pulse trains. [4] The system to do this at the ILC is described briefly below.

The electron beam is made longitudinally polarized and accelerated to 5GeV; then it enters a transport line (LTR) to the damping ring. The electrons are stored between pulse trains in the damping ring. Only electron spin directions

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parallel or anti-parallel to the magnetic field—that is, transverse to the plane of the damping ring—will preserve their polarization in the damping ring. A spin rotation system, consisting of a combination of dipole and superconducting solenoid magnets, will orient the spin vector parallel (or anti-parallel) to the magnetic field of the damping ring as the electrons traverse the injection line to the ring.

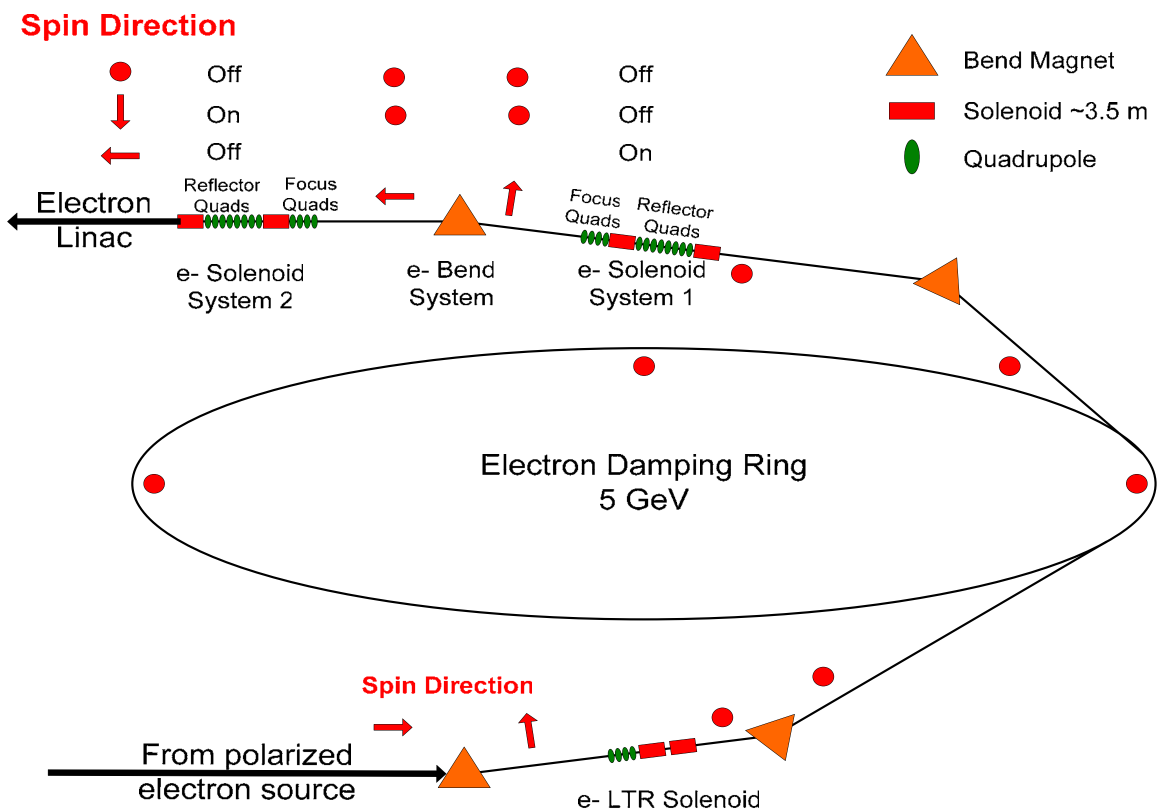

Figure 1: Layout of electron damping ring system showing the spin rotation solenoids.

The 5 GeV longitudinal polarized electrons are deflected in a bend system before they enter the solenoid system (see Figure 1). The electron spin component in the plane normal to the applied magnetic field will precess 90^o in that plane for every 7.9317^o of rotation of the momentum vector at 5 GeV. An axial solenoid field integral of 26.2 Tesla-meters will rotate the spin direction parallel to the field of the DR, i.e., by 90^o. Two half solenoids 3.5 meters in length with maximum field strength of $\pm 38.5 \cdot kGauss$ will be used; each will rotate the spin by 45^o at a beam energy of 5 GeV. In the linac-to-ring (LTR) transfer line, the paired solenoids will be located after a bend of $n \times 7.9312^o$, where *n* is an odd integer. Following the DR, two additional spin rotator systems are needed to achieve arbitrary spin orientation in the Linac or at the electron-positron interaction point. To establish longitudinal polarization after the damping ring, one solenoid pair will be installed in the ring-to-linac transfer line and the in-plane precession will be accomplished by a subsequent bend of 7.9317^o. Another solenoid pair is used to give arbitrary transverse polarization to the beam. To achieve full longitudinal polarization at the IR, and to compensate for the spin precession in the transport lines to the IR, requires all 3 sets of spin rotators.

In order to achieve the ability to set the polarization at each IR, parallel spin rotation beam lines from the damping ring to the linac are introduced. A schematic of the scheme is shown in Figure 2. A pair of kicker magnets is used to deflect the beam into the IR2 chicane beam line and its set of spin rotation magnets. Normal bend magnets of opposite polarity deflect the beam into the chicane with the IR1 spin rotation magnets.

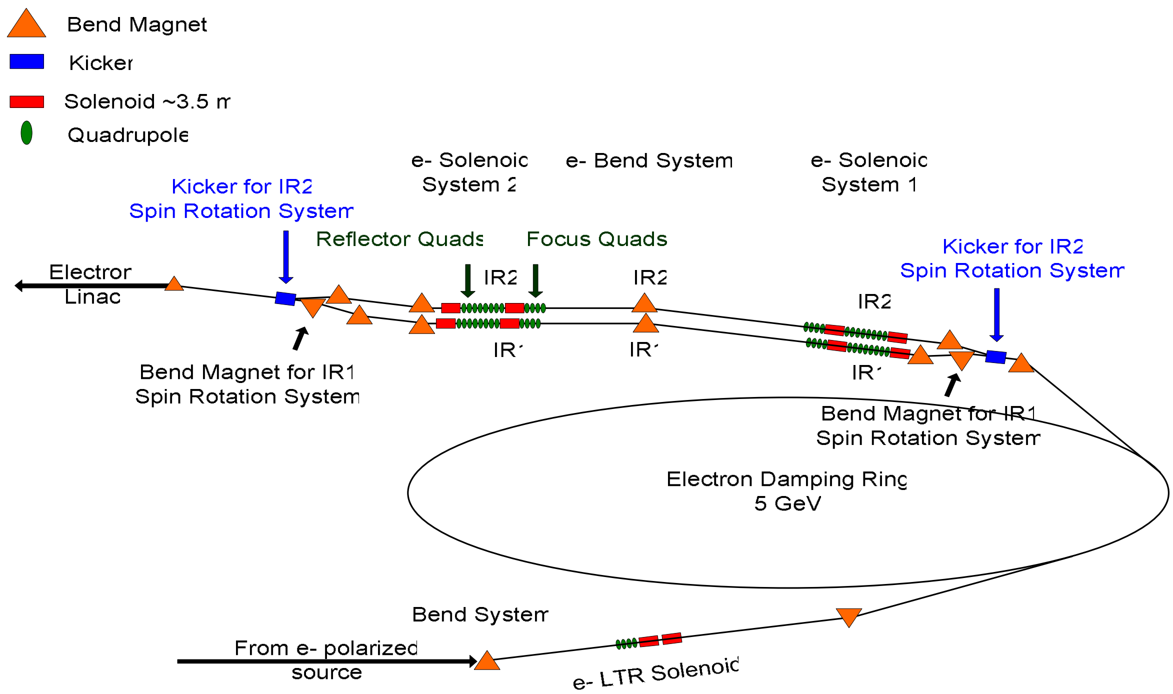

Figure 2: Layout of electron damping ring system showing the parallel spin rotation beam lines for IR1 and IR2. A pair of kicker magnets is turned on between pulse-trains to deflect the beam to the spin rotation solenoids for IR2.

3. POSITRON POLARIZATION WITH BOTH HELICITIES

At the ILC, the direction of the longitudinally polarized positrons may not be changed easily from right- to left-handed longitudinally polarized positrons at the source. For example, the helicity of an undulator-based polarized positron source is fixed by the winding sense of the helical undulator. [5] A system to randomly flip the spin direction of the positrons is described here and details can be found in reference. [6]

Selecting the direction of the spin vector can be accomplished in the input line to the positron damping ring by introducing parallel LTR spin rotation solenoid beam lines. The axial solenoid fields are equal but opposite directions in the two lines. A pair of kicker magnets is used to deflect the positrons into the beam line, with the B-field in the superconducting solenoids having opposite polarity.

As already described for the electron beam, parallel spin rotation beam line systems can be introduced between the positron damping ring and the positron linac to achieve the desired polarization direction at IR1 and IR2 and be able to switch between IRs on a pulse-train basis. A schematic of the positron spin rotation systems is given in Figure 3.

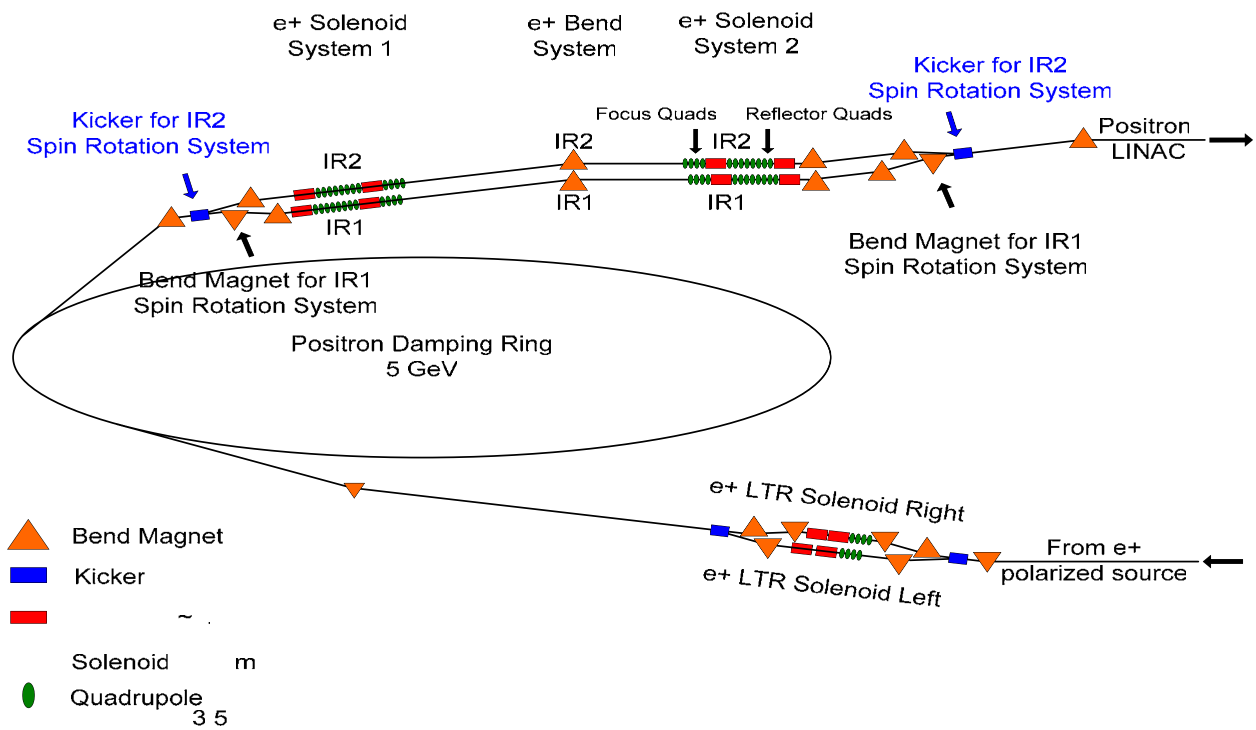

Figure 3: Layout of positron damping ring system showing the parallel spin rotation beam lines for selecting the helicity of the positron in the input line to the damping ring. Also shown are the parallel spin rotation beam lines for IR1 and IR2 between the damping ring and the positron linac.

4. ENERGY AND POLARIZATION MEASUREMENTS IN THE EXTRACTION LINE

The diagnostics planned for the 20 mrad extraction lines, from the IP to the beam dumps, will measure the energy and polarization of the electron and positron beams. The diagnostics are designed to accommodate a beam stay clear of a ±0.75mrad cone from the IP. A schematic for these diagnostics in the extraction line is shown in Figure 4.

The energy spectrometer measures the average beam energy by producing synchrotron radiation in wiggler magnets along the ±2 mrad beam directions in the energy chicane. Two dipole magnets bend the beam up to the positive 2mrad direction and an additional four magnets bend the beam down to the negative 2mrad direction. The distance between the synchrotron radiation stripes is approximately 40cm at the detectors located at z~157 meters near the 2nd focus and is inversely proportional to the energy of the beam. The proportionality factor uses the accurate measurements of $\int Bdl$ giving the angles of the beam at the wiggler magnets producing the synchrotron and the distances between the magnets and the synchrotron stripe detectors. A precision of 100 ppm is the design goal for the energy measurement in the extraction line.[7]

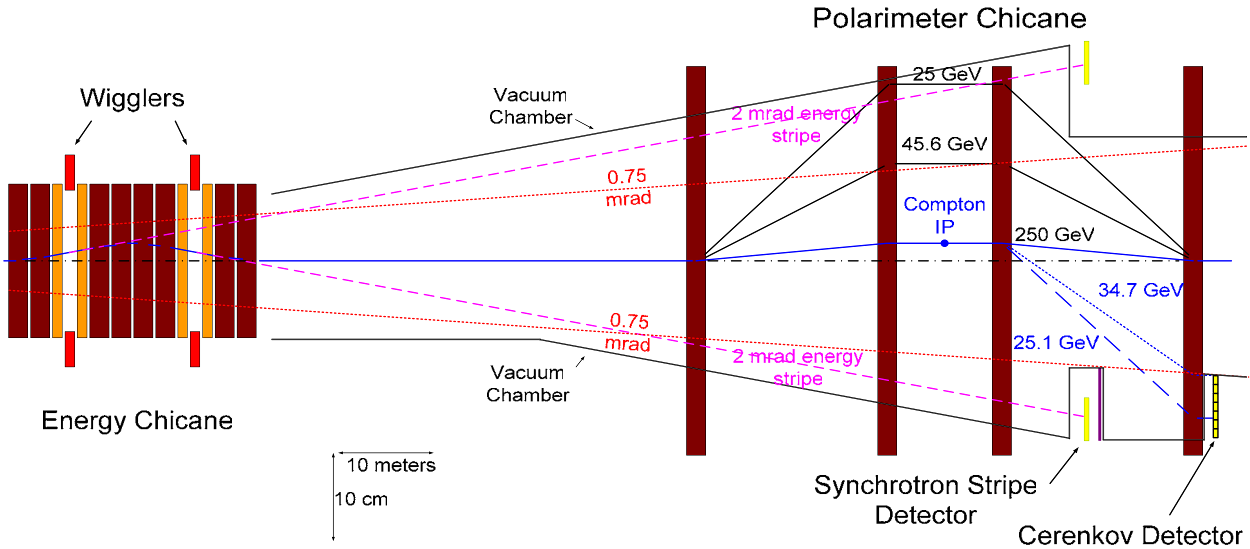

Figure 4: Diagram of the Energy Chicane and Polarimeter Chicane in the 20 mrad extraction line.

The polarization measurement will be performed by a Compton polarimeter, with the Compton IP located at a 2nd beam focus 142 meters downstream from the Interaction Point. An accuracy of $\frac{dP}{P} = 0.25\%$ should be achievable. The vertical dispersion at the Compton IP is 20 mm for 250 GeV beam energy and there is no net bend angle with respect to the primary IP. Compton-scattered electrons near the kinematic edge at 25.1 GeV are detected in a segmented detector located at z~170 m. Beam-beam depolarization effects can be measured directly by comparing beams in and out of collision. Also, spin precession effects due to the final focus optics and beam-beam deflections can be studied by correlating the polarization and IP beam position monitor measurements.

The R-transport matrix from the collider IP to the extraction line Compton IP allows one to compare the beam parameter phase space between the two locations, $|x\rangle_{chicane} = R|x\rangle_{IP}$ for beam parameters $(x, x', y, y', z, {dE}/{E})$. R22 and R44 give the angular magnification from the IP to the Compton IP. R22 is most important since horizontal angles dominate. For R22=0.5 the polarimeter measurement is close to the luminosity-weighted polarization and is sensitive to both BMT and spin flip depolarization effects. For R22 close to zero the polarimeter will only measure spin flip depolarization.

The effect of misalignment of the spin direction at the IR has been studied. [8] For this study R22=-0.512 and R44=-0.093 was used. Figure 5 shows the depolarization for the spin aligned and misaligned as a function of the horizontal offset of the beams at the IP. When the spin direction and beam direction are aligned the depolarization due to horizontal offsets of the beam are small. However, when the spin direction is 50 mrad misaligned with the beam direction the depolarization for a horizontal offset becomes large and the luminosity weighted values are largest at positive offset while the depolarization measured by the Compton polarimeter is largest at negative offsets. This is a direct result of R22 being negative.

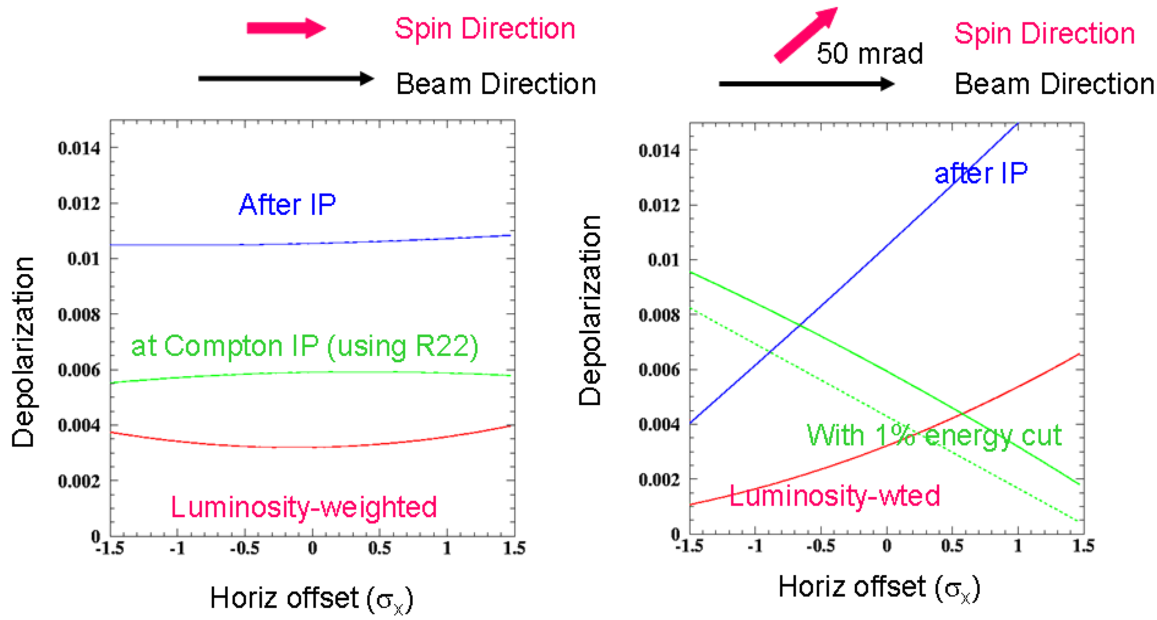

Figure 5: Depolarization for spin aligned and misaligned as a function of the horizontal offset of the beams at the IP. The blue curve labeled "After IP" shows the depolarization after collisions have occurred. The green curve labeled "At Compton IP" shows the depolarization as measured at the Compton IP. The red curve gives the result for luminosity weighted.

It is important to limit spin angle misalignment and horizontal offsets. The measurement of polarization with respect to beam offset can be used as a diagnostic for spin misalignment at the interaction point. The impact of misalignment and horizontal offsets are minimized for positive R22 with the changes correlated instead of anti-correlated. However, it may be difficult to design the extraction line optics having R22=+0.5.

A preliminary optics design for the 2 mrad crossing angle interaction region extraction line has been made. [9] The optics allows one to extract the beam and it includes a section with the beam in the same direction as that at the interaction point for location of a polarimeter. The present design does not include chicanes for the measurement of the energy and polarization and R22 and R44 are not optimized for polarization measurement at the second focus. We are working with the beam design group to include energy and polarimeter chicanes for these measurements and to optimize the optics for these measurements.

5. SUMMARY

Between the damping ring at 5 GeV and the linac two parallel spin rotation beam lines allow the spin to be tuned separately for IR1 and IR2. A set of kicker magnets activated between pulse trains is used to direct the beam into the appropriate spin rotation beam line. The helicity of the positron beam can be selected by introducing parallel spin rotators in the input line to the positron damping ring.

The 20 mrad extraction line optics is being optimized for reducing systematic errors on polarization measurement. A preliminary optics design has been made for the 2 mrad crossing angle interaction region extraction line. We are working with the optics design group to include energy and polarization measurements, and to have a favorable R22 at the Compton IP. Backgrounds at the Cerenkov detector will need study.

Ackowledgments

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References

[1] MDI Workshop, Polarimetry Session, SLAC, January 2005.

[2] Nobert Meyners, “Upstream Compton Polarimetry”, 2005 International Linear Collider Workshop (LCWS05).

[3] V. Bargmann, L. Michel, and V.L. Telegdi, “Precession of the polarization of particles moving in a homogeneous electro-magnetic field”. Phys. Rev. Lett. 2(10):435-436, 1959.

[4] Moffeit, K. C., Woods, M., Schuler, P., Moenig, K., Bambade, P., SLAC-TN-05-045, Feb 2005

[5] V.E. Balakin and A.A. Mikhailichenko, “Conversion system for obtaining highly polarized electrons and positrons”, Preprint INP 79-85, Novosibirsk 1979.

[6] Ibid., Moffeit et al., Feb 2005.

[7] D. Cinabro, E. Torrence and M. Woods, “Status of Linear Collider Beam Instrumentation Design”, IPBI TN-2003-1, 2003.

[8] Woods, “IP Beam Instrumentation Working Group”, presentation at the 2 February 2005 meeting of the IPBI, SLAC, February 2005.

[9] Yuri Nosochkov, “Extraction Line Designs for 2mrad and 20mrad IRs”, 2005 International Linear Collider Workshop (LCWS05).