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Polarimeters and Energy Spectrometers for the ILC Beam Delivery System*

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Abstract

This article gives an overview of current plans and issues for polarimeters and energy spectrometers in the Beam Delivery System of the ILC. It is meant to serve as a useful reference for the Detector Letter of Intent documents currently being prepared.

1 Introduction and Overview

The ILC will open a new precision frontier, with beam polarization playing a key role in a physics program that demands precise polarization and beam energy measurements. [1] The baseline configuration of the ILC, as described in the Reference Design Report (RDR), [2] provides polarized electron and positron beams, with spin rotator systems to achieve longitudinal polarization at the collider IP; upstream and downstream polarimeters and energy spectrometers for both beams; and the capability to rapidly flip the electron helicity at the injector, using the source laser. The possibility of fast positron helicity flipping is not included in the baseline configuration. A scheme for fast positron helicity flipping has been proposed. [3]

The electrons will be highly polarized with $P(e^-) > 80\%$. Positrons will also be produced with an initial polarization $P(e^+) \sim 30 - 45\%$. This expected small positron polarization can be used with great benefit for physics measurements if the possibility of fast helicity flipping of the positron spin is also provided. Excellent polarimetry for both beams, accurate to $\Delta P/P = 0.25\%$, is planned. [1, 4] Polarimetry will be complemented by e^+e^- collision data, where processes like W pair production can provide an absolute scale calibration for the luminosity-weighted polarization at the IP, which can differ from the polarimeter measurements due to depolarization in collision.

Precise beam energy measurements are necessary at the ILC in order to measure particle masses produced in high-rate processes. Measuring the top mass in a threshold scan to order 100 MeV or

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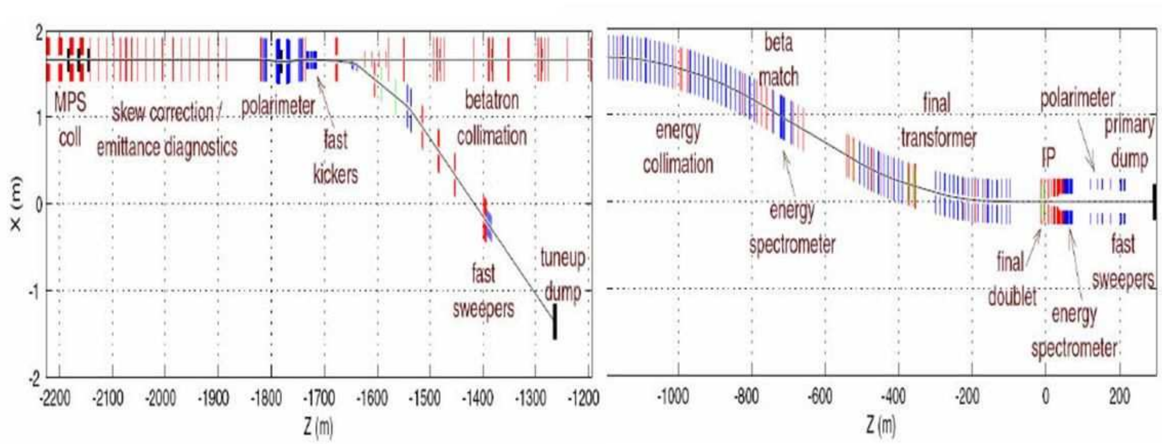

Figure 1: Beam Delivery System as described in the RDR, showing the locations of the polarimeter chicane 1800m upstream of the IR and the upstream energy spectrometer 700 m upstream of the IR. The location of the extraction line energy spectrometer and polarimeter are shown on the right side of the figure.

measuring a Standard Model Higgs mass in direct reconstruction to order 50 MeV requires knowledge of the luminosity-weighted mean collision energy $\sqrt{s}$ to a level of $(1-2)\cdot 10^{-4}$. [1, 4] Precise measurements of the incoming beam energy are a critical component to measuring the quantity $\sqrt{s}$ as it sets the overall energy scale of the collision process.

The baseline ILC described in the RDR provides collider physics with beam energies in the range 100-250 GeV. Precise polarization and energy measurements are required for this full energy range. The ILC baseline also provides for detector calibration at the Z-pole with 45.6 GeV beam energies. However, the RDR does not require accurate polarimetry or energy spectrometer measurements at the Z-pole. A proposal to modify the baseline ILC to require precise polarimetry and energy measurements at Z-pole energies was made at the *2008 Workshop on Polarization and Beam Energy Measurements at the ILC*. [4] The motivation for this includes polarimeter and energy spectrometer calibration, and physics measurements to improve on Z-pole results from LEP and SLC. The downstream polarimeter described in the RDR is expected to perform well at the Z-pole, while the upstream polarimeter is severely impacted due to inclusion of the laserwire detector and the energy collimator in the system design as noted below. For energy measurements, the downstream energy spectrometer should perform well while the upstream spectrometer needs further evaluation for how accurately the lower chicane magnetic fields can be measured.

Precise polarimeters and energy spectrometers will be installed in the Beam Delivery System (BDS) at the locations shown in Figure 1. These systems will need to be a joint effort of the ILC BDS team and the Detector collaborations, with collaboration members responsible for the performance and accuracy of the measurements. Data from the polarimeters and spectrometers must be delivered to the Detector DAQ in real time to be logged and permit fast online analysis. Fast online analysis results must also be provided to the ILC controls system for beam tuning and diagnostics. Details for the DAQ systems and assigning of responsibilities between the ILC and Detector collaborations remain to be worked out. Costing for the beamline components, conventional facilities and polarimeter laser systems are included in the ILC cost estimate. Costing for the detectors for the polarimeters and downstream energy spectrometer, and for the DAQ are expected to be provided by the Detector collaborations.

The 2008 workshop [4] also included presentations and discussions on i) physics requirements, ii) polarized sources, spin rotators and low energy polarimetry, iii) spin transport studies and iv) physics-based measurements of beam polarization and beam energy from collider data. Workshop participants included both detector and accelerator physicists. The need for close collaboration between the accelerator and detector efforts was demonstrated, as well as the need for detector physicists to play an active role in the design and evaluation of accelerator components that impact beam polarization and beam energy capabilities in addition to the polarization and energy diagnostics. Seven recommendations emerged from the workshop that need follow-up evaluations and actions from the GDE, the Detector collaborations and the Research Director. Specifically, these recommendations were:

- Relocate the laser-wire emittance diagnostic and MPS energy collimator away from the upstream polarimeter chicane.
- Modify the extraction line polarimeter chicane from 4 magnets to 6 magnets to allow the Compton electrons to be deflected further from the disrupted beam line.
- Include precise polarization and beam energy measurements for Z-pole calibration runs into the baseline configuration.
- Realize the physics potential for the initial positron polarization of 30-45%.
- Implement parallel spin rotator beamlines with a kicker system before the damping ring (DR) to provide rapid helicity flipping of the positron spin.
- Move the pre-DR positron spin rotator system from 5 GeV to 400 MeV to eliminate expensive superconducting magnets and reduce costs.
- Move the pre-DR electron spin rotator system to the source area to eliminate expensive superconducting magnets and reduce costs.

The importance of multiple energy and polarization measurements was also emphasized to realize the precision physics capabilities of the ILC. The importance of similar redundant measurements at LEP, SLC, JLAB and HERA was noted as well as similar desires for complementarity, redundancy and cross checks that two ILC Detectors provide.

2 Polarimetry

Both upstream and downstream BDS polarimeters will use Compton scattering of high power lasers with the electron and positron beams. [1, 2] Figure 2 shows the Compton cross section versus scattered electron energy for 250 GeV beam energy and 2.3 eV photon energy. There is a large polarization asymmetry for back-scattered electrons near 25.2 GeV, the Compton edge energy. The large asymmetry and the large difference between the Compton edge and the beam energy facilitate precise polarimeter measurements. The Compton edge does not change significantly for higher beam energies; this dependence is also shown in Figure 2. A spectrometer with segmented Cherenkov detectors that sample the flux of scattered electrons near the Compton edge will be used to provide good polarization measurements with high analyzing power. Compton polarimetry, utilizing measurements of back-scattered electrons near the Compton edge, is chosen as the primary polarimetry technique for several reasons:

- The physics of the scattering process is well understood QED, with radiative corrections less than 0.1% [5];
- Detector backgrounds are easy to measure and correct for by using laser off pulses;
- Compton-scattered electrons can be identified, measured and isolated from backgrounds using a magnetic spectrometer;

- Polarimetry data can be taken parasitic to physics data;
- The Compton scattering rate is high and small statistical errors can be achieved in a short amount of time (sub-1% precision in one minute is feasible);
- The laser helicity can be selected on a pulse-by-pulse basis; and
- The laser polarization is readily determined with 0.1% accuracy.

Each polarimeter requires a laser room on the surface with a transport line to the beamline underground. A configuration proposed for the extraction line polarimeter is shown in Figure 3. A similar configuration is planned for the upstream polarimeter. The polarimeters employ magnetic chicanes with parameters shown in Table 1.

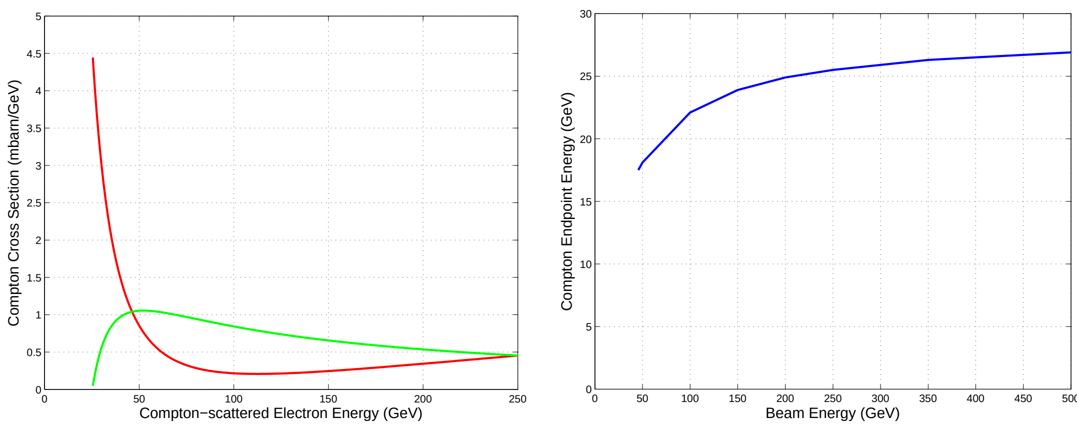

Figure 2: Left Figure: Compton differential cross section versus scattered electron energy for same (red curve) and opposite (green curve) helicity configuration of laser photon and beam electron; beam energy is 250 GeV and laser photon energy is 2.3 eV. Right Figure: Compton edge energy dependence on beam energy.

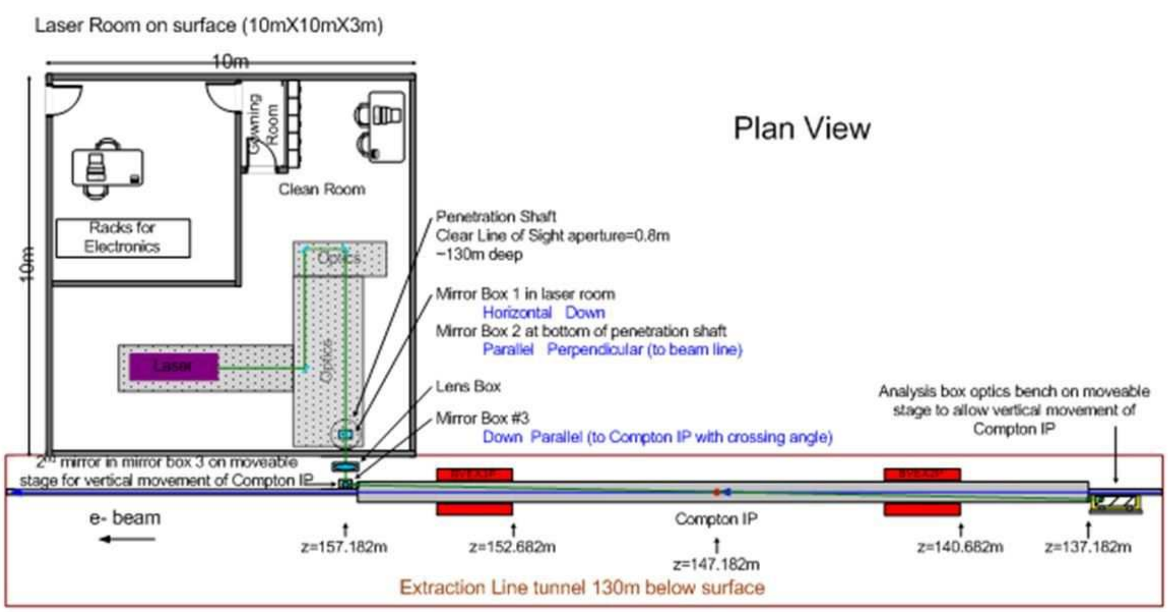

Figure 3: Proposed configuration of laser room, penetration shaft and extraction line layout for the downstream Compton polarimeter.

Table 1: Magnetic chicane parameters for the BDS Compton polarimeters.

Chicane Parameters	Upstream Polarimeter	Downstream Polarimeter
Chicane Length (m)	75.6	72.0
No. magnets	12	6
Magnetic Field (T)	0.0982	0.4170 (1, 2)
		0.6254 (3, 4)
		0.4170 (5,6)
Magnet Length (m)	2.4	2.0
Magnet 1/2-gap (cm)	1.25	11.7 (1-3)
		13.2 (4)
		14.7 (5,6)
Magnet pole-face width (cm)	10.0 (1-3)	40.0 (1-3)
	20.0 (4-9)	54.0 (4)
	30.0 (10-12)	40.0 (5-6)
Dispersion at mid-chicane at 250 GeV (mm)	20	20

2.1 Polarimeter Detectors

Design options for Cherenkov detectors are being studied: one uses gas tubes for the radiator with the Cherenkov light detected by conventional photomultiplier tubes (PMTs) or newer types of photo detectors. Figure 4 shows a schematic drawing of one such detector channel as well as the arrangement of 18 channels covering the whole exit window for the Compton electrons. The gas tubes would have a cross section of 1cm^2. C_4F_{10} is one gas being considered, which has a high Cherenkov threshold of 10 MeV. Consideration also needs to be given to gases that do not scintillate from lower energy particles. Propane was a gas chosen for the SLD polarimeter detector [6] that had a high Cherenkov threshold and low scintillation, but had a drawback of being flammable.

An alternative detector is a multi-anode photomultiplier (MAPM), where the anode is segmented into multiple pads that can be read out independently. An issue may be cross talk between the anodes, however, and will need to be studied.

Another alternative is silicon-based photomultipliers (SiPM) coupled to quartz fibers as radiator. SiPMs have excellent single photon detection capabilities and outmatch conventional PMTs in terms of robustness, size and cost. However the quartz fibers constituting the radiator material have a much lower Cherenkov threshold of 200 keV that would make them more susceptible to background radiation. [7] This may be acceptable for the upstream polarimeter, but is less likely to be acceptable for the downstream polarimeter.

Linearity and longterm stability of various photodetectors are currently studied in an LED test setup as well as in the DESY testbeam with a two channel prototype of the Cherenkov detector [7].

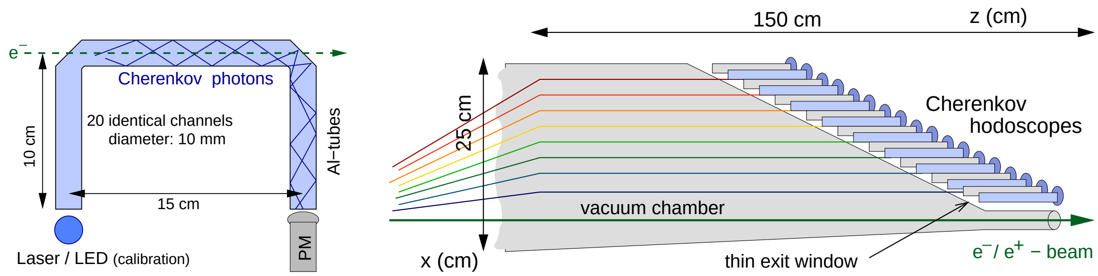

Figure 4: Schematic of a single gas tube (left) and the complete array of 18 tubes(right) as foreseen for the Cherekov detector for the polarimeters.

2.2 Upstream Polarimeter

The upstream Compton polarimeter is located at the beginning of the BDS, upstream of the tuneup dump 1800 meters before the e^+e^- IP. In this position it benefits from clean beam conditions and very low backgrounds. The upstream polarimeter configuration in the RDR is shown in Figure 5. It will provide fast and precise measurements of the polarization before collisions. The beam direction at the Compton IP in both the vertical and horizontal must be the same as that at the IP within a tolerance of $\sim 50\mu$rad.

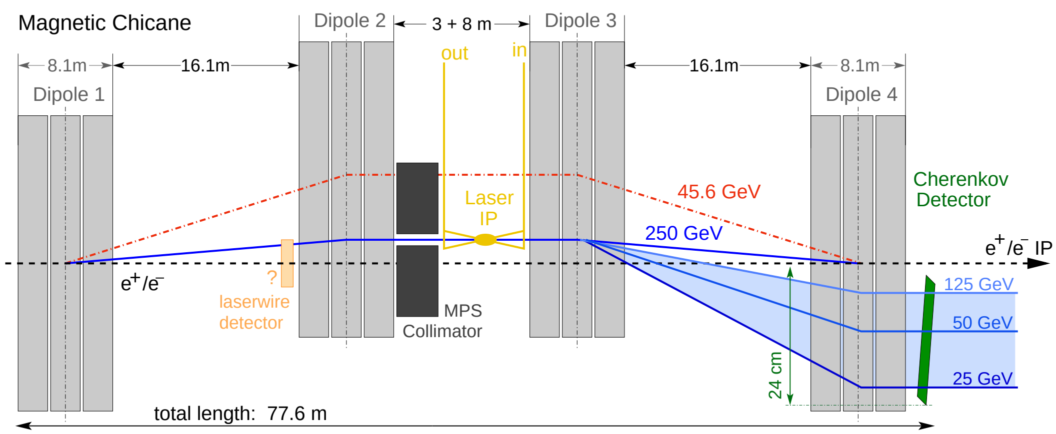

Figure 5: Schematic of the upstream polarimeter chicane [8] described in the Reference Design Report. This system combines functions for the laserwire detector, machine protection collimator and the Compton polarimeter.

The chicane has been designed such that the Compton spectrum covers 18 detector channels. This is independent of the beam energy if the magnetic field is kept constant. Instead the Compton IP moves laterally with the beam energy. Figure 6 shows a setup to adjust the laser accordingly.

The upstream polarimeter can be equipped with a laser similar to one used at the TTF/Flash source in operation at DESY. It can have the same pulse structure as the electron beam allowing measurements of every bunch. This permits fast recognition of polarization variations within each bunch train as well as time-dependent effects that vary train-by-train. The statistical precision of the polarization measurement is estimated to be 3% for any two bunches with opposite helicity, leading to an average precision of 1% for each bunch position in the train after the passage of only 20 trains (4 seconds). The average over two entire trains with opposite helicity will have a statistical error of $\Delta P/P = 0.1\%$. The systematic error goal is to achieve an uncertainty of $\Delta P/P = 0.25\%$ or better with the largest uncertainties coming from the analyzing power calibration (0.2%) and the detector linearity (0.1%). [8]

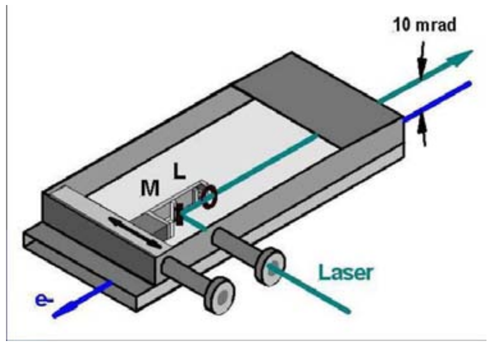

Figure 6: Movable mirror and lense focussing the laser onto the electron beam.

The RDR design for the upstream polarimeter chicane includes capability for a laserwire detector for beam emittance measurements and a machine-protection system (MPS) energy collimator. The combined functionality for these devices in the polarimeter chicane compromises some aspects of the polarimeter capabilities and operation, and recommendations to resolve this need evaluation. [4, 8]

2.3 Downstream Polarimeter

The downstream polarimeter, shown in Figure 7, is located 150 m downstream of the IP in the extraction line and on axis with the IP and IR magnets. It can measure the beam polarization both with and without collisions, thereby testing the calculated depolarization correction which is expected to be at the $(0.1 - 0.2)\%$ level.

A complete conceptual layout for the downstream polarimeter exists, including magnets, laser system and detector configuration. [9] The downstream polarimeter chicane successfully accommodates a detector for the downstream energy spectrometer and provides magnetic elements for the GAMCAL system. [9]

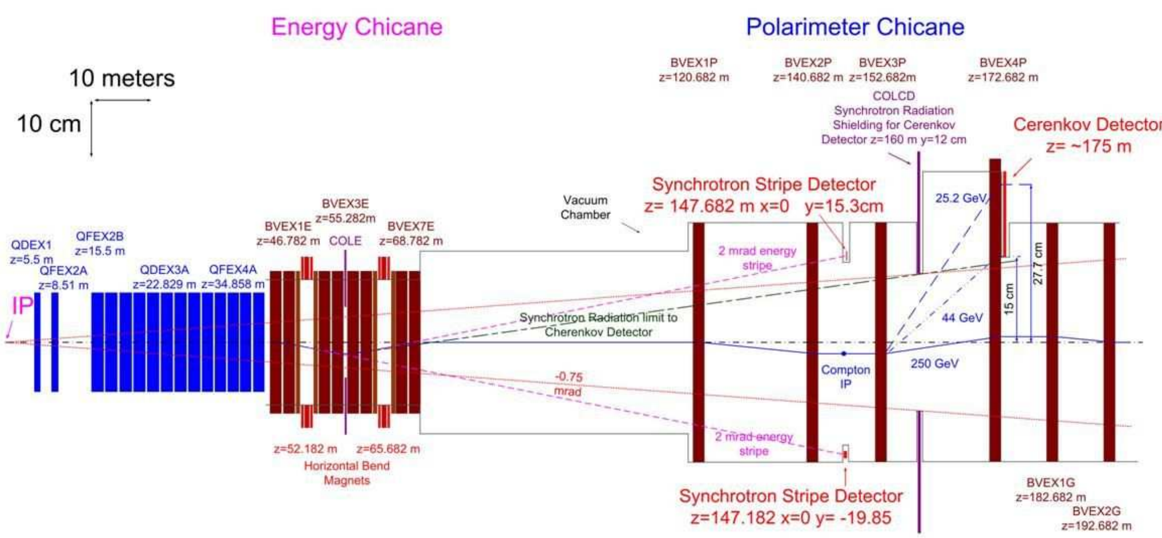

Figure 7: Schematic of the ILC extraction line diagnostics for the energy spectrometer and the Compton polarimeter.

The laser for the downstream polarimeter requires high pulse energies to overcome the larger backgrounds in the extraction line. Three 5-Hz laser systems will be used to generate Compton collisions for three out of 2800 bunches in a train. Each laser is an all solid-state diode-pumped Nd:YAG, with a fundamental wavelength of 1064 nm that will be frequency-doubled to 532nm. Each laser will sample one particular bunch in a train for a time interval of a few seconds to a minute, then select a new bunch for the next time interval, and so on in a pre-determined pattern. The Compton statistics are high with more than 1000 Compton-scattered electrons per bunch in a detector channel at the Compton edge. With this design, a statistical uncertainty of less than 1% per minute can be achieved for each of the measured bunches. This is dominated by fluctuations in Compton luminosity due to beam jitter and laser targeting jitter and to possible background fluctuations.

Background studies have been carried out for disrupted beam losses and for the influence of synchrotron radiation (SR). There are no significant beam losses for the nominal ILC parameter set and beam losses look acceptable even for the low power option. An SR collimator protects the Compton detector and no significant SR backgrounds are expected. The systematic precision is expected to be about 0.25%, with the largest uncertainties coming from the analyzing power calibration (0.2%) and detector linearity (0.1%).

2.4 Impact of Crossing Angle and IR Magnets on Polarimetry

A crossing angle between the colliding beams means that the beam trajectory and the detector solenoid axis will be misaligned. This causes a vertical deflection of the beam and also impacts the trajectory of low energy pairs produced in the collision. [10] A detector-integrated dipole (DID) can be included in the solenoid to compensate either for the beam trajectory at the IP or the trajectory of low energy pairs as they leave the IR. To reduce backscattering of this pair background into the vertex and tracking detectors at the e^+e^- IP it is preferable to align the trajectory of low energy pairs with the extraction beamline (anti-DID solution). However, this results in a significant vertical beam angle at the IP. An example of this is shown for the SiD in Figure 8.

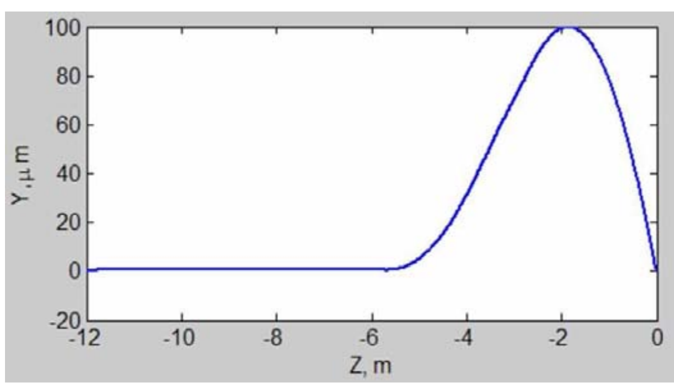

Figure 8: Vertical trajectory of the beam in SiD with anti-DID and 14-mrad crossing angle. Collider IP is at Z = 0 meters. (Taken from Figure 9 in Reference [10].)

With the anti-DID solution, additional orbit compensation is needed to achieve the goal of less than 50 μrad misalignments between the beam trajectory at the collider IP and the polarimeter Compton IPs. This compensation is energy-dependent and is not easily done by compensating the orbit at the upstream polarimeter with correctors due to tolerances on emittance growth. Corrector compensation is more easily done for the downstream polarimeter. For the upstream polarimeter, it is highly desirable to implement local orbit compensation near the IR to align the incoming vertical beam trajectory with the trajectory at the collider IP. Such a scheme looks feasible, but has not yet been fully described. [10] For the downstream polarimeter, the following procedure can be used to set the extraction line corrector magnets:

- Obtain an extraction line reference orbit with the solenoid, anti-DID and correctors off.

- Then use correctors to reproduce the reference orbit as the solenoid and anti-DID are ramped to nominal settings (can compare calculated and actual corrector settings).
- Then adjust correctors to match beam angle at the Compton IP with the collider IP angle (if non-zero).

3 Beam Energy Measurements

The ILC RDR design provides redundant beam-based measurements of the incoming beam energy, capable of achieving 10^{-4} accuracy. The measurements would be available in real time as a diagnostic tool to machine operators and would provide the basis for the determination of the luminosity-weighted center-of-mass energy for physics analyses. Physics reference channels, such as a final state muon pair resonant with the known Z-mass, are then foreseen to provide valuable cross checks of the collision scale, but only long after the data has been recorded.

The two primary methods planned for making precise beam energy measurements are a non-invasive BPM-based spectrometer, located upstream of the interaction point just after the energy collimators (Figure 1), and a synchrotron imaging detector which is located downstream of the IP in the extraction line to the beam dump (Figures 1 and 7). The BPM-based device is modeled after the spectrometer built for LEP-II, which was used to calibrate the energy scale for the W-mass measurement, although the parameters of the ILC version are much more tightly constrained by allowances on emittance dilution in the beam delivery system. The synchrotron imaging detector is similar in design to the spectrometer used at SLAC for the SLC program. Both are designed to provide an absolute measurement of the beam energy scale to a relative accuracy of 10^{-4} (100 parts per million, ppm). The downstream spectrometer, which observes the disrupted beam after collisions, can also measure the energy spectrum of the disrupted beam.

3.1 Upstream Energy Spectrometer

The RDR includes a BPM-based energy spectrometer, shown in Figure 9, located $\sim$ 700 meters upstream of the interaction point. It is important that the energy spectrometer be able to make precision energy measurements between 45.6 GeV (Z-pole) and the highest ILC energy of 500 GeV. However, due to operation with a fixed dispersion the spectrometer magnets will need to operate at low magnetic fields when running at 45.6 GeV where the magnetic field measurement may not be accurate enough. There is a research program to determine how to perform accurate magnetic field measurements for low fields.

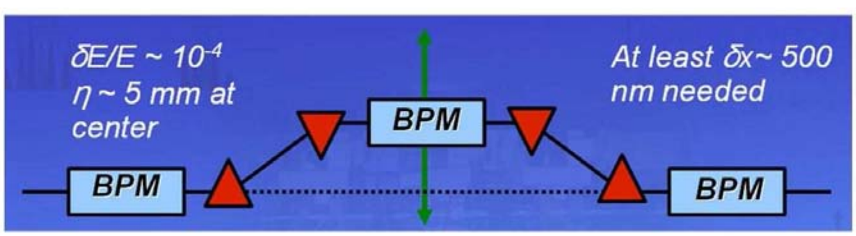

Figure 9: Schematic for the upstream energy spectrometer using precision BPMs.

A prototype test setup for such an instrument was commissioned in 2006 and 2007 in the T-474 experiment in the End Station A beamline at SLAC. The setup involved four dipole magnets and high-precision RF cavity BPMs in front, behind and in between the magnets. ESA test beams operated at 10 Hz with a bunch charge of $1.6 \cdot 10^{10}$ electrons, a bunch length of 500 μm and an energy spread of 0.15%, i.e. with properties similar to ILC expectations. The beam energy is directly deduced from the beam offset measurements normalized to the 5 mm dispersion (same dispersion as for the present ILC baseline energy spectrometer). When combining all the BPM stations to measure the precision of the orbit over the whole ESA-chicane beamline, a resolution of 0.8 μm in x and 1.2 μm in y was achieved. The system turned out to be stable at the micron level over the course of one hour, which would translate to an energy precision of 200 ppm. [11] Additional studies are being conducted to measure and correct for motions much smaller than 1 micron.

3.2 Extraction Line Energy Spectrometer

At the SLC, the WISRD (Wire Imaging Synchrotron Radiation Detector) [12] was used to measure the distance between two synchrotron stripes created by vertical bend magnets which surrounded a precisely-measured dipole that provided a horizontal bend proportional to the beam energy. This device achieved a precision of $\Delta E_b/E_b \sim 2 \cdot 10^{-4}$ (200 ppm), where the limiting systematic errors were due to relative component alignment and magnetic field mapping. The ILC Extraction-Line Spectrometer (XLS) design [13] is largely motivated by the WISRD experience. The energy spectrometer will make precision energy measurements between 45.6 GeV (Z-pole) and the highest ILC energy of 500 GeV.

The analyzing dipole for the XLS is provided by a vertical chicane just after the capture quad section of the extraction line, about 55 meters downstream of the interaction point (see Figure 7). The chicane provides a ± 2 mrad vertical bend to the beam and in both legs of the chicane horizontal wiggler magnets are used to produce the synchrotron light needed to measure the beam trajectory. The optics in the extraction line is designed to produce a secondary focus about 150 meters downstream of the IP, which coincides with the center of the polarimeter chicane and the Compton interaction point. The synchrotron light produced by the wigglers will also come to a vertical focus at this point, and position-sensitive detectors in this plane arrayed outside the beampipe will measure the vertical separation between the synchrotron stripes.

With a total bend angle of 4 mrad, and a flight distance of nearly 100 meters, the synchrotron stripes will have a vertical separation of 400 mm, which must be measured to a precision of 40 μm to achieve the target accuracy of 10^{-4}. In addition to the transverse separation of the synchrotron stripes, the integrated bending field of the analyzing dipole also needs to be measured and monitored to a comparable precision of 10^{-4}. The distance from the analyzing chicane to the detectors needs to only be known to a modest accuracy of 1 cm. For the XLS spectrometer, it has been proposed to use an array of radiation-hard 100 μm quartz fibers. These fibers do not detect the synchrotron light directly, but rather detect Cherenkov radiation from secondary electrons produced when the hard photons interact with material near the detector. At ILC beam energies, the critical energy for the synchrotron radiation produced in the XLS wigglers is several tens of MeV, well above the pair-production threshold, and copious numbers of relativistic electrons can be produced with a thin radiator in front of the fiber array. The leading candidate for reading out these fibers is multi-anode PMTs from Hamamatsu, similar in design to those used in scintillating fiber calorimeters. The advantage of this scheme over wires (as used in the SLC energy spectrometer) is to produce a reliable, passive, radiation-hard detector which does not suffer from cross talk or RF pickup, and still allows for easy gain adjustment and a large dynamic range.

The energy spectrum of the beam after collision contains a long tail as a result of the beam-beam disruption in the collision process. This disrupted beam spectrum is not a direct measure of the collision energy spectrum, but it is produced by the same physical process, and direct observation of this disrupted tail will serve as a useful diagnostic for the collision process. The position-sensitive detector in the XLS is designed to measure this beam energy spectrum down to 50% of the nominal beam energy. Near the peak, for a beam energy of $E_b = 250$ GeV, each 100-micron fiber spans an energy interval of 125 MeV. Given a typical beam energy width of 0.15%, this means the natural width of the beam energy will be distributed across at least a handful of fibers, which will allow the centroid to be determined with a precision better than the fiber pitch, and some information about the beam energy width can be extracted as well.

3.3 Alternative Methods for Energy Measurements

R&D on three alternative methods for precise beam energy measurements with 100 ppm accuracy is being carried out by different groups. The first method utilizes Compton backscattering, a magnetic spectrometer and precise position measurements of the electron beam, the centroid of the Compton photons and the kinematic edge of the Compton-scattered electrons. [14, 15] The spectrometer length needed is about 30 m and would be located near the upstream polarimeter (or may utilize the upstream polarimeter chicane). Precise position measurements approximately 25 meters downstream of an analysis magnet are needed with accuracies of 1 μm for the Compton photons, 10 μm for the Compton edge electrons and 0.5 μm for the beam electrons.

The second method utilizes the SR emitted in the dipole magnets of the upstream BPM-based spectrometer. [16] Accurate determination of the edges of the SR fan is needed. Studies include a direct measurement of the SR fan as well as the use of mirrors to deflect soft SR light to detectors located away from the beamline. Novel high spatial resolution detectors are considered.

A third method relies on the Resonance Absorption method. [17, 18] Under certain conditions, laser light can be absorbed by beam particles when both co-propagate in close proximity in a solenoid. The beam energy can be inferred from the measured dependence of light absorption on the magnetic field and laser wavelength.

4 Summary

Concepts for high precision polarization and energy measurements exist. These concepts have resulted in detailed system layouts that are included in the RDR description for the Beam Delivery System. The RDR includes both upstream and downstream polarimeters and energy spectrometers for both beams. This provides needed complementarity and redundancy for achieving the precision required, with adequate control and demonstration of systematic errors.

The BDS polarimeters and energy spectrometers need to be a joint effort of the ILC BDS team and the Detector collaborations, with collaboration members responsible for the performance and accuracy of the measurements. Details for this collaboration and assigning of responsibilities remain to be worked out. There is also a demonstrated need for Detector physicists to play an active role in the design and evaluation of accelerator components that impact beam polarization and beam energy capabilities, including the polarized source and spin rotator systems. A workshop was held in 2008 on ILC Polarization and Energy measurements, which resulted in a set of recommendations for the ILC design and operation. Additional input and action is needed on these from the Detector collaborations, the Research Director and the GDE.

Work is continuing during the ILC engineering design phase to further optimize the polarimeter and energy spectrometer concepts and fully implement them in the ILC. This includes consideration for alternative methods, detailed design and cost estimates, and prototype and test beam activities.

References

[1] G. Moortgat-Pick et al. The role of polarized positrons and electrons in revealing fundamental interactions at the linear collider. *Phys. Rept.*, 460:131–243, 2005.

[2] N. Phinney, N. Toge and N. Walker Editors, *International Linear Collider Reference Design Report - Volume 3: Accelerator*, http://www.linearcollider.org/cms/?pid=1000437 (2007).

[3] K.C Moffeit, P. Bambade, K. Moenig, P. Schuler, M. Woods, *Spin Rotation Schemes at the ILC for Two Interaction Regions and Positron Polarization with both Helicities*, LCC-159, SLAC-TN-05-045 (2005); K.C. Moffeit, D. Walz and M. Woods, *Spin Rotation at lower energy than the damping ring*, ILCNOTE-2008-040 IPBI TN-2008-1 (2008); and K.C. Moffeit, *Spin Rotation before the Damping Ring*, IPBI TN-2008-3, Proceedings of Workshop on Polarization and Beam Energy Measurements, Zeuthen (2008).

[4] B. Aurand et al., *Executive Summary of the Workshop on Polarisation and Beam Energy Measurement at the ILC*, DESY-08-099, ILC-NOTE-2008-047, SLAC-PUB-13296 (2008); Workshop website is https://indico.desy.de/conferenceDisplay.py?confId=585.

[5] M.L. Swartz. A complete order alpha**3 calculation of the cross-section for polarized compton scattering. *Phys. Rev.*, D58:014010, 1998.

[6] SLD Collaboration, Phys. Rev. Lett. **70**, 2515 (1993); SLD Collaboration., Phys. Rev. Lett. **8678**, 11622075 (20011997); R. Elia, SLAC-Report-429 (1994); R. King, SLAC-Report-452, 1994; A. Lath, SLAC-Report-454, 1994; E. Torrence, SLAC-Report-509, 1997.

[7] D. Kaefer, *Compton Cherenkov Detector Development for ILC Polarimetry*, Proceedings of LCWS08, Chicago (2008), arXiv:0902.3221v1 [physics.ins-det].

[8] J. List and D. Kaefer, *Improvements to the ILC Upstream Polarimeter*, Proceedings of LCWS08, Chicago (2008), arXiv:0902.1516v1 [physics.ins-det]; J. List, *The ILC Upstream Polarimeter*, Proceedings of Workshop on Polarization and Beam Energy Measurements, Zeuthen (2008).

[9] K.C. Moffeit et al., *Proposal to modify the polarimeter chicane in the ILC 14 mrad extraction line*, SLAC-PUB-12425, IPBI TN-2007-1, (2007); K.C Moffeit, *Downstream Extraction Line Polarimeter*, IPBI TN-2008-5, Proceedings of Workshop on Polarization and Beam Energy Measurements, Zeuthen (2008).

[10] A. Seryi, T. Maruyama, and B. Parker, *IR Optimization, DID and anti-DID*, SLAC-PUB-11662 (2006).

[11] M. Slater et al., Nucl. Instrum. Meth. **A592**, 201-217 (2008).

[12] F. Rouse et al. *Measuring the Mass and Width of the Z0: The Status of the Energy Spectrometers*, SLAC-PUB-4977 (1989).

[13] E. Torrence, *Downstream Synchrotron Radiation Stripe Spectrometer Status*, Presentation at 2008 Workshop on Polarization and Energy Measurements at the ILC.

[14] N. Muchnoi,H.J. Schreiber, M. Viti, *ILC Beam Energy Measurement by means of Laser Compton Backscattering*, e-Print: arXiv:0812.0925 [physics.ins-det] (2008).

[15] N. Muchnoi, *Proposal for Eb Measurement at Novosibirsk Using Compton Backscattering*, Presentation at 2008 Workshop on Polarization and Beam Energy Measurements at the ILC.

[16] K. Hiller, R. Makarov, H.J. Schreiber, E. Syresin, and B. Zalikhanov, *ILC Beam Energy Measurement Based on Synchrotron Radiation from a Magnetic Spectrometer*, Nucl. Instrum. Meth. **A580** 1191 (2007).

[17] R. Melikian, *Development of the Theory of Measurement of Electron Beam Absolute Energy by Resonance Absorption Method*, Presentation at 2008 Workshop on Polarization and Beam Energy Measurements at the ILC.

[18] A. Ghalumyan, *Experiment Proposal for Eb Measurement using the Resonance Absorption Method*, Presentation at 2008 Workshop on Polarization and Beam Energy Measurements at the ILC.