STATUS REPORT

Extraction Line Energy Spectrometer

Personnel and Institution(s) requesting funding

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Project Overview

A measurement of the absolute collision energy with a relative precision approaching 10^{-4} is a critical component of the linear collider physics program. Measurements of the top quark and Higgs boson masses to 50 MeV can only be performed if this level of precision is achieved. The ongoing project described here will carry out the conceptual design of a downstream beam energy spectrometer capable of this level of precision, initial beam tests to validate this design, and simulation studies to show how this beam energy measurement can be combined with other available information to determine the luminosity-weighted collision energy.

The downstream spectrometer design is based on the WISRD spectrometer which provided a continuous absolute energy scale measurement with a precision of 2×10^{-4} during the eight years of SLC operation at SLAC.[1] In the WISRD scheme, shown in Figure 1, two horizontal dipole magnets produce stripes of synchrotron radiation that are detected at a downstream wire array. The separation between these stripes, provided by the bending of a third vertical dipole magnet, is then inversely proportional to the beam energy.

In the current strawman design for the ILC, we propose to insert a 4-magnet chicane in the extraction line and use additional wiggler magnets to produce the signal synchrotron stripes. The detector plane would be constructed from a quartz fiber array which would detect Cherenkov radiation from secondary electrons produced by the incident synchrotron radiation. The advantages of quartz fibers over wires include simple readout with multi-anode PMTs, reduced RF pickup from the beam passage, and a natural energy threshold at 200 keV from the Cherenkov threshold in quartz.

In addition to the design and optics layout in the extraction line for the ILC spectrometer, beam tests of the detection of O(1 MeV) photons via secondary electron Cherenkov radiation in quartz fibers are starting at SLAC End Station A (ESA). This beam test will run in FY05 or FY06, and is the first step towards a full-scale spectrometer prototype which is foreseen in the future.

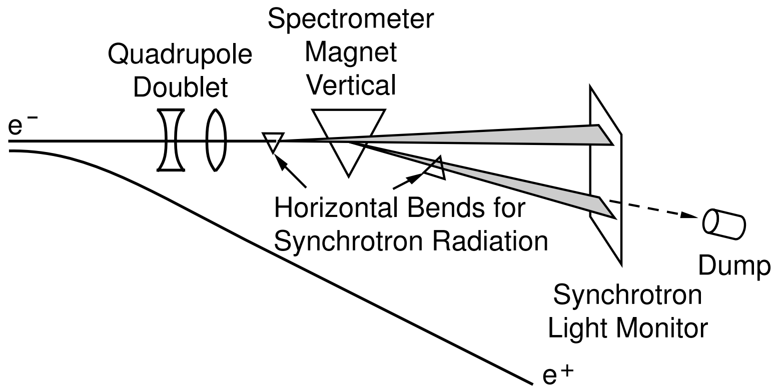

Figure 1: The SLC WISRD energy spectrometer

This work is being proposed as a single component of a broader coordinated effort to provide the beam instrumentation necessary for the LC physics program. The downstream spectrometer is seen as a complimentary effort to the upstream BPM-based spectrometer which is being pursued by other groups. In addition, the critical question of how to stitch together the various beam-based measurements and physics reference reactions to determine the luminosity-weighted collision energy at the interaction point must also be answered. Coordination of a world-wide effort to demonstrate an answer this question, as well as involvement with the Machine-Detector Interface activities of the GDE, is also funded by this project.

Status Report

This project has been funded since FY03 by DOE with University LC R&D funds. In that time, the Oregon group has constructed a prototype quartz fiber detector with eight 100 micron fibers and eight 600 micron fibers on a 1 mm pitch, read out using a Hamamatsu R6568 (16 channel) multi-anode PMT. Figure 2 shows the R6568 with the 16 fibers from the prototype detector coupled in from the right. This detector was installed in Fall 2005 in the bend line leading the ESA as shown in Figure 3. Initial checkout with beam shows signals on all 16 fibers, although it is too early to claim that these signals are the direct result of Cherenkov production in the detector head, and not background beam pickup from other sources. More complete studies of this prototype will be performed during the ESA test beam run in January 2006.

The primary motivation of this initial beam test is to measure directly the yield of Cherenkov photons in order to validate the Monte Carlo models needed to design the ILC extraction-line spectrometer. A secondary motivation is to test the detector design concept and look for other unexpected sources of background in the detector. Possible examples include stray beam particles, scintillation, or RF pickup. We have also assembled a small test-stand with light box to test various coupling schemes of quartz fibers to MAPMTs. This installation is a "phase zero" configuration of the proposed ESA beam test (SLAC T-475) [3]. The complete

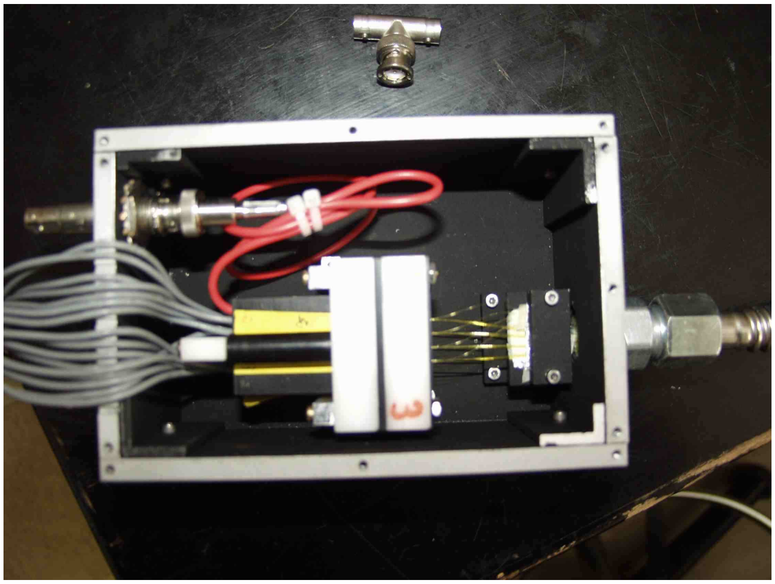

Figure 2: The PMT used to read out the prototype Quartz fiber detector is shown.

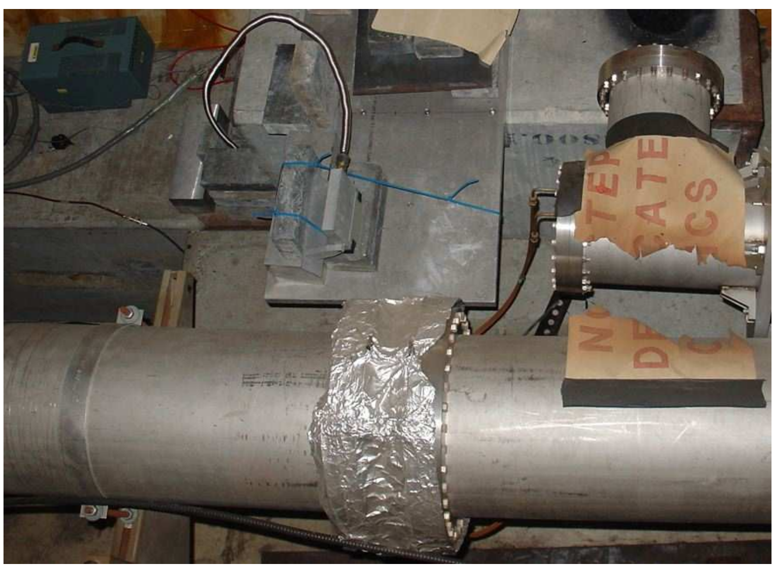

Figure 3: The prototype Quartz fiber detector installed at SLAC. Synchrotron radiation from the ESA bend magnets exits from the port shown at the right. The PMT box is installed below the beam line in a shielded cave.

chicane and wiggler layout shown in Figure 4 which would run in parallel with BPM-based spectrometer tests (SLAC T-474) has been delayed due to costs.

In addition, work is ongoing using the extraction line optics decks produced at SLAC for the ILC strawman beam delivery design to asses the ILC spectrometer performance and provide feedback to the optics design. An example of a 20 mRad extraction line, produced by Yuri Nosochkov at SLAC, is shown in Figure 5. The first bump would be the location of the spectrometer dipoles and wigglers. This spectrometer bump has been separated from the polarimeter chicane in this design to allow the synchrotron radiation detectors to be situated near the secondary focal point. Designs also exist for a 2 mRad extraction line with diagnostics, and both are currently being evaluated for performance. A first report on this work was presented at Snowmass in 2005 [5].

FY2006 Project Activities and Deliverables

The project goals for 2006 are to finish the first round of design and evaluation for the extraction line spectrometer for the GDE baseline document, as well as to analyze the first test beam data from ESA and make direct comparisons to a Geant4 simulation.

A complete beam simulation based on Geant4 for the ILC extraction line is currently under development at Oregon with significant help from other people working on beamline simulations. It is expected to have a G4 simulation of the optics decks finished early in the year, with increasing levels of detail of the spectrometer detectors and the complicated extraction line geometry being added later as necessary. It is expected that for adequate validation of the 20 mRad and 2 mRad performance, a rather detailed description of the material, collimation scheme, and magnetic fields (including detector solenoid and final doublet fringe fields) between the IP and the spectrometer will be necessary. Obtaining G4 descriptions of all of these components is a significant amount of work, which we will steadily work towards in collaboration with MDI activities of the GDE. This simulation will be the primary tool for refining the spectrometer design and leading the the specifications for the extraction line spectrometer technical design.

One critical part of this simulation is a validation of the Cherenkov signal rate observed in the quartz fibers. Since the efficiency of converting O(1 MeV) synchrotron radiation into Compton electrons then observing the Cherenkov radiation in 100 micron fibers is very small, a data-derived calibration of this yield is essential. Investigating other sources of background in a dirty accelerator environment is also important, as these could easily swamp the signal if they are larger than expected. By the end of 2006, it is expected to have a detailed simulation of the ESA prototype detector which has been validated with the T-475 ESA data.

FY2007 Project Activities and Deliverables

The specific project activities for 2007 are somewhat unclear at this point, as they depend upon many factors, not the least of which is the results obtained in 2006. Some of the key future milestones for this project are listed here. A second, larger prototype detector based on 8x8 MaPMTs must be built, and construction techniques suitable for a final detector

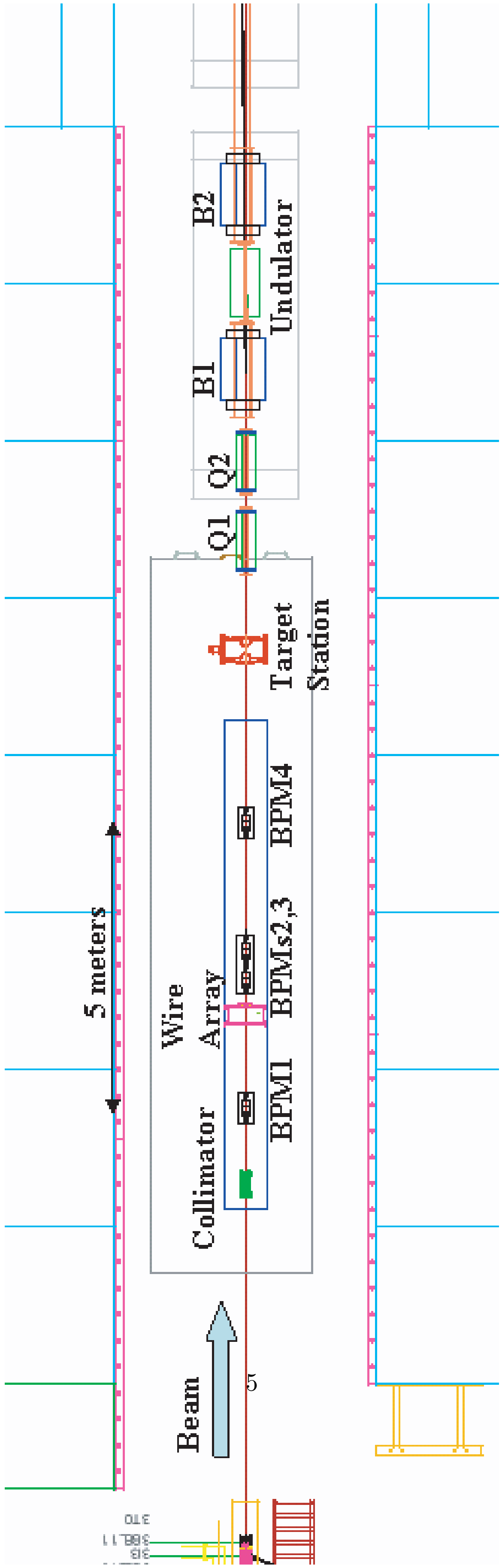

Figure 4: Layout of end station A including magnets for T-475 at the far downstream end. The quartz fiber detector will sit an additional 30 meters downstream.

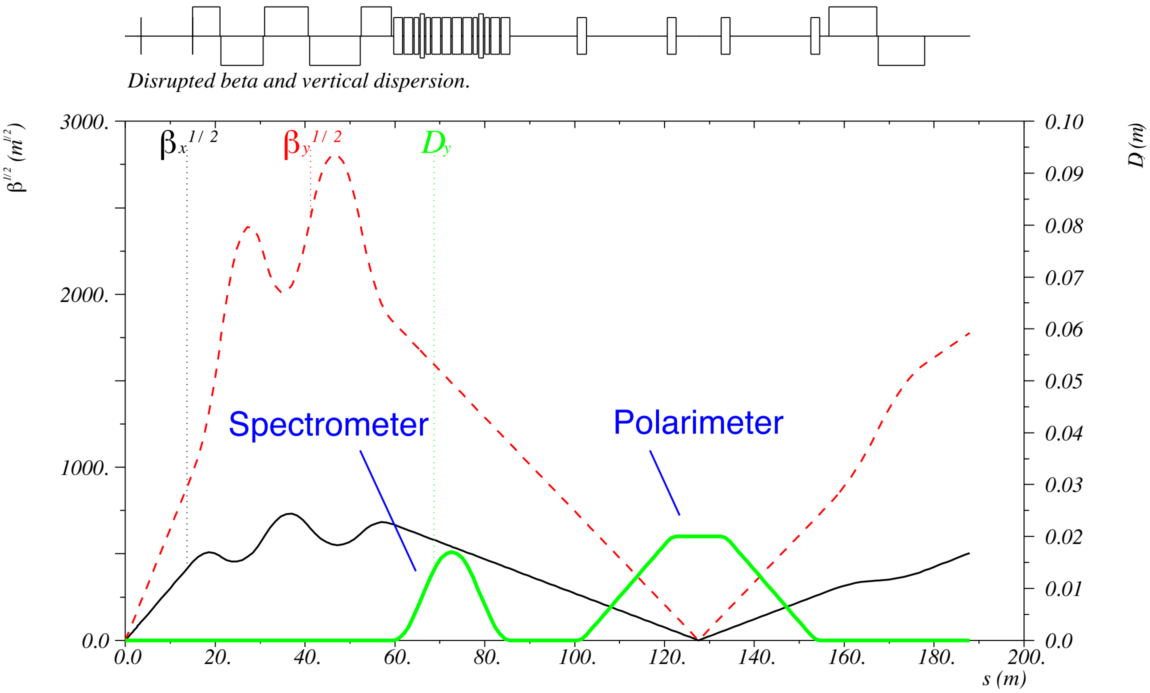

Figure 5: Current ILC extraction line layout for 20 mRad crossing angle.

employing around 1000 fibers must be developed. Front-end electronics readout including digitization and buffering for the 64-channel PMTs must be designed and validated. This work has actually begun at a low level in the Oregon electronics shop, and will be more vigorously pursued when it becomes clear that the quartz fibers are a suitable detection technology.

A design and implementation of a full spectrometer prototype in ESA in conjunction with the BPM-based proposals must also be started. By 2007, we will need a concrete proposal and justification for this rather large undertaking, which will require significant resources beyond what is currently available. This full-scale ESA test to demonstrate 100 ppm accuracy is seen as a critical demonstration of the beam instrumentation plan for the ILC, and significant work will be needed on this time scale to get this phase of the project funded and moving forward.

Additionally, a technical engineering design for the extraction line spectrometer must be completed for the GDE, including costing.

No matter what the results of the 2006 tests are, it is rather likely that a second prototype of some sort will be produced by 2007, and significant design effort for both the full ESA prototype and the GDE design will be necessary.

Budget justification:

We are requesting support for one undergraduate student and half of a graduate student to continue the design work which has been ongoing at the University of Oregon. The other half of the graduate student will either be supported by the University of Oregon physics department as a teaching assistant, or will be funded out of our main DOE grant.

Travel funds are requested to allow Torrence to more fully participate in the ILC Machine-Detector Interface activities which are being held on the machine side. These funds ($2500 per year) would allow Torrence to attend one additional meeting in Europe or Asia per year, and have good continuing contact with the GDE planning and activities. In FY05, this funding was used to allow Torrence to attend the ILC Snowmass workshop, where among other things he gave the final plenary talk on MDI activities [6]. In addition, $800 of travel funds are requested to allow a student to participate in a one-week test beam run at SLAC.

Equipment money of $2000 per year is requested to continue work on prototype detectors and begin the electronics prototype for the 64 channel PMT readout.

Two-year budget, in then-year K$

Item	FY2006	FY2007	Total
Graduate Students	21.5	22.5	44.0
Undergraduate Students	6.4	6.4	12.8
Total Salaries and Wages	27.9	28.9	56.8
Equipment	2.5	2.5	5.0
Travel	1.0	1.0	2.0
International Travel	2.8	2.8	5.6
Total costs (1)	34.2	35.2	69.4

(1) All costs include benefits and 26% overhead

References

[1] J. Kent *et al.*, "Precision Measurements of the SLC Beam Energy," Presented at IEEE Particle Accelerator Conf., Chicago, Ill, Mar 20-23, 1989.

[2] Y. Kolomensky *et al.*, "Beam Instrumentation Tests for the Linear Collier using the SLAC A-Line and End Station A," SLAC-LOI-2003.2, October 2003.
`http://www.slac.stanford.edu/grp/rd/epac/LOI/LOI-2003.2.pdf`

[3] E. Torrence, "Test Beam Request for a Synchrotron Stripe Energy Spectrometer," SLAC-T-475, June 2004.
`http://www.slac.stanford.edu/xorg/lcd/ipbi/notes/syncspec_T475.pdf`

[4] R. Arnold and E. Torrence, "Rough Layout and Rate Estimate for Beam Test in SLAC ESA of Synchrotron Radiation Detector Prototypes for LC Beam Monitor," IPBI TN-2004-7, July 2004.
`http://www.slac.stanford.edu/xorg/lcd/ipbi/notes/tn_synchrate.pdf`

[5] E. Torrence, "Extraction Line Spectrometry," to appear in proceedings of 2005 ILC Physics and Detector Workshop and Second ILC Accelerator Workshop, Snowmass, August 2005. http://http://physics.uoregon.edu/˜torrence/talks/Snow05/torrence_xline.pdf

[6] E. Torrence, "Interaction Regions, Backgrounds, IP Beam Instrumentation," to appear in proceedings of 2005 ILC Physics and Detector Workshop and Second ILC Accelerator Workshop, Snowmass, August 2005.
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