

**Project name**

Energy Spectrometer Design Study for the Linear Collider Extraction Line

**Classification (accelerator/detector:subsystem)**

Accelerator (ID: 47) and/or Beam Instrumentation (L.E.P.)

**Institution(s) and personnel**

University of Massachusetts at Amherst, Department of Physics:  
Stanley S. Hertzbach (professor), Melissa Motew (undergraduate student)

**Contact person**

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650-926-2507 (at SLAC) until ~20 January 2003; then 413-545-0511.

**Project Overview**

The physics program of the Linear Collider (LC) includes measurement of the masses of newly observed particles, *e.g.*, the SUSY mass spectrum, and an accurate and precise measurement of the top quark mass in a  $t\bar{t}$  threshold scan. These require calibration of the LC beam energy and knowledge of the luminosity spectrum. The luminosity spectrum will be measured using a simple physics process, *e.g.*, Bhabha scattering, but the beam energy spectrum will be useful in extracting this from the data.

An energy spectrometer in the LC extraction line can make real-time measurements of both the nominal beam energy (to 200 ppm) and the disrupted beam energy distribution. The disrupted beam energy distribution is sensitive to details of the collision process, and can be used as one of several real-time diagnostics to stabilize machine operation. A stable beam energy distribution will be particularly important during a threshold scan.

We propose to study the feasibility of an energy spectrometer in the LC extraction line. The goal of the study is to simulate the extraction line and the spectrometer in order to understand the changes required in the extraction line design, the requirements on the spectrometer, and the tradeoffs between the two. In this manner we expect to produce specifications for the spectrometer, just as the physics detector design is driven by specifications from the simulation of important physics processes.

**The energy spectrometer concept**

The study will consider a spectrometer similar to that used to measure the beam energy in the Stanford Linear Collider (SLC) at SLAC. Before the spectrometer analyzing magnet, the beam passes through a dipole magnet with its field perpendicular to that of the analyzing magnet. The resulting SR "stripe" marks the direction of the incoming beam. Similarly, SR generated in a dipole magnet beyond the analyzing magnet marks the

direction of the outgoing beam. Measurement of the stripe separation determines the bend angle and the beam energy. With appropriate beam optics, the SR stripe from the incoming beam is narrow, and the dispersion due to the analyzing magnet produces a broad stripe from the outgoing beam, which is a measure of the beam energy distribution.

At SLD the SR stripe separation was measured by detecting the secondary emission signals resulting from SR incident on fine wire arrays. Although we are unlikely to address specific detector technologies in this study, we suspect this is not the optimal technology in the LC environment.

The accuracy of the spectrometer depends primarily on the analyzing magnet field map, knowledge of the relative orientation of the SR stripes, the SR detector resolution, and surveys of the detector geometry and magnet locations. In operation, the beam trajectory must be controlled within constraints set by these considerations. At SLC the dominant systematic error was the uncertainty in the SR stripe rotations.

### **Description of first year project activities**

The NLC extraction line design includes a chicane as the location for beam diagnostics. Nosochkov and Raubenheimer studied measurement of the disrupted beam energy distribution with a wire scanner at the secondary focus in the chicane. The results are promising, but a wire scanner is invasive, and cannot provide real-time information.

We will initially reproduce the above study. Existing files of disrupted beam trajectories generated by the Guinea Pig code simulate the beam entering the extraction line. After the additional spectrometer magnets are added to the DIMAD deck, we can compute the SR at the spectrometer detector plane, and study the required SR detector resolution.

The dominant systematic error from SR stripe rotations can be studied by simulating the effect of magnet rotations. We will simulate measurement of the relative SR stripe rotation with a beam scan, and again study the effect of the SR detector resolution.

Changes in the extraction line might be required if the current small chicane bends require a small detector with the resolution of solid state devices, which are not suitable for this environment. Larger bends might be required to allow for a SR exit window in the beam pipe, and for the detector to be placed in the SR beam. Alternatively, one could use a mirror to get the SR away from the chicane, and reduce constraints on the detector. In this case we must know the SR heat load on the mirror under a range of conditions.

For a fixed bend angle the SR energy scales as the cube of the beam energy, a factor of  $\sim 23$  from  $t\bar{t}$  threshold to 1 TeV c.m. energy. As this might be a problem for some detector technologies, we will explore varying the geometry to reduce the energy range. However, the disrupted beam energy tail is so broad that the detector must always handle a large range of SR energies, and a correlated range of SR power.

We will consult accelerator physicists and others to develop a figure of merit for the quality of the energy distribution measurement, and use this as one of our criteria. Certain assumptions are made to interpret the SR stripe width as the energy distribution. We will

want to understand the effect of the beam optics, and of any correlations among beam parameters, *e.g.*, energy and angle, that might result in an incorrect interpretation.

At the end of this study we should understand the requirements on the SR detector resolution and on other aspects of the spectrometer in order to achieve the desired accuracy on the beam energy and energy distribution measurements. We will also determine how well the beam trajectory must be controlled in the spectrometer, and will provide information on the SR photon energies and fluxes to be expected. We should also understand the tradeoffs among the choices, including changes to the extraction line.

## Personnel

Prof. Hertzbach is one of two UMass faculty who shared on-site responsibility for the SLC energy spectrometer during 1996-1998, the last 3 years of SLD running. As part of ongoing work on NLC backgrounds, he is interfacing the DIMAD beam tracking code with the old standalone QSRAD code for computing SR fluxes. This will also be useful in the proposed study.

Melissa Motew is a senior UMass physics major, who will complete her degree requirements in December 2002, and is available to work on this project until starting graduate school in fall 2003. The project is a good match to her background and an interest in instrumentation. Ms. Motew shared the Physics Department Hasbrouck Award for the outstanding junior major, and was awarded the Youngren Scholarship for undergraduate research by the College of Natural Sciences and Mathematics.

Ms. Motew has worked with the UMass experimental HEP group since the summer of 2001, when Profs. Blaylock, Dallapiccola, and Willocq organized an undergraduate research program. The students were introduced many aspects of high energy physics, accelerators, detectors, statistics, and the tools of HEP analysis. The goal of her most recent project is to study and document the behavior of neural networks, and to use neural networks to improve the spatial and energy resolution of the BaBar calorimeter.

The budget request includes salary for Ms. Motew, and funds for trips to SLAC early in the project, and to a Linear Collider workshop in the spring or summer.

## Budget

<b>Institution</b>	<b>Item</b>	<b>Cost</b>
UMass	Salary	\$ 10,240
UMass	Fringe Benefits (FICA, Workers' Comp)	244
UMass	Travel	2,500
UMass	<b>Subtotal: Total Direct Cost</b>	<b>12,984</b>
UMass	UMass Indirect costs (55%)	7,141
UMass	<b>Total</b>	<b>\$20,125</b>

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