April 28, 2000

Renewal Proposal
R&D for Linear Collider Detector Calorimetry

University of Oregon

We made excellent progress in 1999 in addressing some key issues of LCD calorimeter design by simulation analyses of multi-jet final states. We propose to continue these studies in 2000-2001 with the goal of achieving useful design criteria. Our original proposal from March 1999, part of a joint proposal from the LCD calorimeter group, is attached for reference. For 2000, the calorimeter group has decided to submit separate proposals.

It has been assumed within LC detector circles that the best technique for achieving the excellent multi-jet event reconstruction required by the LC physics is that of "energy flow." This method requires that calorimetric energy depositions due to charged and neutral particles be readily separated. The implications of this assumption on detector designs are significant. A very finely segmented, small Molière radius, EM calorimeter is required, and is placed within the magnet coil. In addition, the charged-neutral separation is aided by sagitta, so designs tend to have large BR^2, where R is the inner radius of the EM calorimeter. Hadron calorimetry is de-emphasized, as the charged hadrons are to be measured in an excellent tracker.

While this technique is widely used at LEP II, its implications for LC physics and detectors has seen only limited study. Masako Iwasaki has spearheaded the efforts to study these issues, both within the Oregon group and in the LCD community. She began by studying energy flow within the context of the LCD Fast MC. This work has beed carried over to the Full MC more recently. We have initially chosen to use the process $e^+e^- \to t\bar{t}$ both because of the multi-jet states and because of the group's interest in the physics issue of extracting anomalous top-quark couplings. Her results, a sampling of which is shown in Fig. 1, have been presented in 1999 at the LCD meetings at Fermilab, Ann Arbor, and SLAC, and in March 2000 at LBNL. And Masako presented her work at the LCWS99 at Sitges.

The key work for 2000 will be to make significant progress on the reconstruction studies involving the Full MC. The results from Fig. 1 indicate a start in this direction, but are still far from being well understood. This will take some work, as it requires careful understanding and development of the details of the simulations and of the calorimeter clustering algorithms. In addition to these studies, Masako has been the 'czar" of the MC generators at SLAC, and Frey has been co-leader of the LCD calorimeter group; see `http://www.slac.stanford.edu/xorg/lcd/calorimeter/`.

Here are some of the main goals of this research in 2000-2001, some of which will clearly extend beyond this period:

- continue studies of energy flow with Full MC
  - ≫ analyze for LCD Large and Small
  - ≫ use to calibrate a fast MC-based parameterization of configurations

- write a memo to LCD of pertinent results
- extend these studies to other processes (besides $t\bar{t}$):

  $\gg$ *e.g.* $WW/ZZ/Zh$ and $WWee/ZZ\nu\nu$ separation

- look at capability to reconstruct non-pointing γ's (GMSSB)

<u>Personnel</u>

- Raymond E. Frey, Associate Professor
- David M. Strom, Associate Professor
- Masako Iwasaki Abe, Research Associate, based at SLAC

<u>Proposed Budget</u>

30 k$	50% support for research associate (includes benefits and overhead)
10 k$	Travel to LC meetings and Oregon (Iwasaki), and to SLAC (Strom)
40 k$	**Total Request**

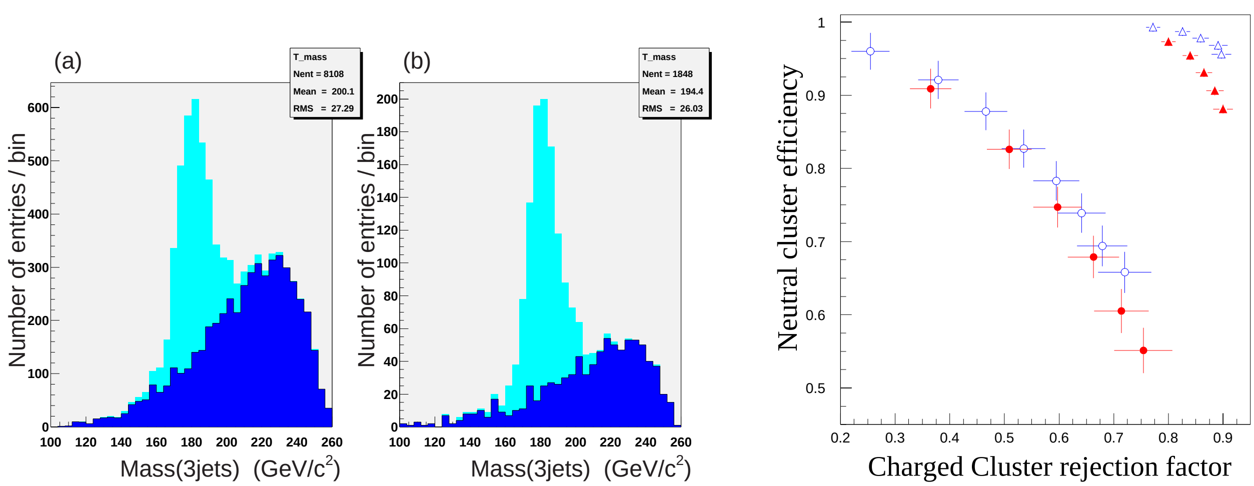

Figure 1: Left: Reconstructed 3-jet mass in $t\bar{t} \to 6$ jets (a) and $t\bar{t} \to \ell\nu 4$ jets (b) for the LCD Small detector with the Fast MC simulation. The background is combinatorial. The typical reconstructed top mass and angular resolutions are about 9.5 GeV/c^2 and 55 mrad, respectively. Right: Charged/neutral cluster separation performance in the LCD calorimeters. Open triangles: Fast MC, LCD Large. Closed triangles: Fast MC, LCD Small. Open circles: Full MC, Large. Closed circles: Full MC, Small. The Full MC results are very preliminary.

March, 1999

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We propose to perform simulation studies to characterize and optimize calorimetry for a LC detector with particular emphasis on the measurement of multi-jet final states.

Reconstruction of multi-jet final steps is expected to be a key element of the analysis of events at a future e^+e^- collider. New physics processes, as well as their backgrounds, often include W, Z, t, or Higgs decays to jets. Examples include the associated Higgs production process, Zh, and $t\bar{t} \to b\bar{b}W^+W^-$, versus W^+W^- continuum background. Extracting the signals calls upon the ability to identify a reconstructed multi-jet mass with a parent mass, not only for signal to background considerations, but also to separate candidate processes, such as $W \to$jets compared with $Z \to$jets.

A major difficulty of calorimetric jet measurement is the very different response to photons and charged hadrons. The close spacing of these particles within jets can give overlapping energy depositions which are not easily corrected for response. One approach to this problem is to measure the energy of charged hadrons in the tracker, the photons in the EM calorimeter, and use excellent calorimeter granularity, combined with the tracker position measurement, to isolate the energy depositions of the charged hadrons in the calorimeter. This technique is sometimes called the "energy flow" method, and has been used extensively at LEP, for example.

We wish to study this method using fully-simulated Monte Carlo events and to compare it with other methods. A compact detector design, with finely segmented EM calorimetry and large magnetic field, was proposed at Snowmass 1996. It implicitly assumes the use of an energy flow, or very similar, method, and a first step was taken to study this design.[1] We propose to now do a complete study and characterize the results in such a way that design optimizations concerning calorimeter segmentation, distance from the collision point (*i.e.* tracker radius), Molière radius, magnetic field, *etc.* have a rational basis. We will study a number of different physics "benchmark" processes and as many different detector configurations as is feasible.

We also plan to study the requirements on calorimetry which are brought about by measurement of wide-angle ($\theta > 10°$) Bhabha scattering events. In particular, the acollinearity distribution of these events is the leading candidate[2] for measuring the luminosity spectrum, $L(E)$, at the LC.

Personnel

- Raymond E. Frey, Associate Professor
- David M. Strom, Associate Professor
- Masako Iwasaki Abe, Research Associate, based at SLAC

Proposed Budget

30 k$	50% support for research associate (includes benefits and overhead)
10 k$	Travel to LC meetings and Oregon (Abe), and to SLAC (Strom)
40 k$	**Total Request**

[1] J.E. Brau, A.A. Arodzero, and D.M. Strom, Proc. of Snowmass 1996, "New Directions for High Energy Physics".

[2] N.M. Frary and D. Miller, DESY 92-123A, Vol. I, 1992, p. 379.