Project name

Particle Identification and Software Infrastructure for Linear Collider Physics and Detector Studies

Classification (accelerator/detector:subsystem)

Detector: Particle ID & Software

Institution(s) and personnel

Colorado State University, Department of Physics:
Robert J. Wilson (professor), Abner Soffer (research scientist)

Stanford Linear Accelerator Center:
Anthony Johnson (staff scientist), Gary Bower (staff scientist)

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Project Overview

In its broadest sense, particle identification is one of the primary goals of a Linear Collider detector. Particles at the sub-detector level are restricted to the directly observable subset, e, μ, π, K, p, n, and γ, but the real interest lies with the more complex reconstructed particles such as D, B, W, Z^0 *etc.* and, of course, exotics such as Higgs and SUSY particles. The main mission of the US Linear Collider Detector Particle ID working group (WG), as outlined by Wilson at the recent LC Retreat, is to investigate and coordinate the cross subsystem aspects of particle identification. Many of the associated issues have low priority in the individual detector WGs, but taken together they represent an important part of the overall detector design optimization. The purpose of this proposal is to support a core of activity in this working group.

An example of where information from several sub-systems is required is that of muon identification over the full momentum range of physics interest, which ranges from a few GeV/c for some SUSY processes to tens of GeV/c for Z^0 or Higgs decays. Particular attention is required in the range where few muon detector layers are hit, in which case combined information from the tracking, calorimeter and the muon systems can improve the acceptance. It is important to understand what can be done in the momentum region below which charged particles do not reach the muon system due to the magnetic field (4-5 GeV/c in the TESLA design).

A longstanding question has been the need for hadron identification for high energy Linear Collider physics. This question is particularly acute for an LCD design with silicon as the primary tracking device, since this would lack even the basic hadron ID capabilities provided by gas-based trackers. There have been a few modest efforts (by Wilson and others) to address this issue, with no compelling result. However, the investigation is clearly incomplete, in large part due to the lack of a sustained effort. One of the tasks of the PID WG is to establish the benefits and costs of hadron identification to the experiment. This should include: identification of benchmark physics processes that benefit from this capability; quantifying the hadron ID potential of gas and silicon-based tracking systems, and specialized detectors such as scintillator time-of-flight or quartz-based Cerenkov ring-imaging devices; and quantifying the negative effects these systems may have on others e.g. photon resolution degradation in the calorimeter due to additional material.

At this stage, we believe that it is premature to embark on hardware R&D related to the primary particle ID issues. Rather, we propose to assist with the construction of the necessary software infrastructure that will allow us to address these questions most effectively. One of us (Wilson) has been making contributions to the Java Analysis Studio (JAS) based package developed at SLAC towards this end. We wish to expand on that effort in parallel with addressing the specific goals of the Particle ID working group.

In this Expression of Interest we can provide only a brief summary of basic ideas, we would appreciate feedback on the level of details that would be appropriate for the proposal.

Description of first year project activities

The most pressing activities for the Particle ID group fall into the two broad categories of software infrastructure and the physics requirements that must drive the overall detector design. Below we list the focus areas for the first year of this proposal in each of these categories:

- Software infrastructure – we will base our initial work on extending the existing JAS LCD framework developed by Tony Johnson *et al.* at SLAC.
  - We will help to design and implement the ReconstructedParticle class. This is a central concept in the simulation and analysis code, but one that has not yet been fully developed. It is a natural place for the PID group to be involved. Soffer has significant experience with OO design and implementation. Since Soffer is based at SLAC (his office is in close proximity to Johnson and Bower) this is likely to be a very efficient collaboration.
  - We will extend the existing hadron identification fast simulation (developed by Wilson). The first task will be make it more accessible to a general user and to facilitate the implementation of new models, particularly energy loss in different gases.
  - We will improve the integration of existing PID code with the core LCD s/w.

- We will integrate the lepton, photon and hadron ID s/w components into a uniform particle ID package and provide a mechanism for combining ID information from all detector subsystems.
- We will enhance the WIRED event display to represent the output of PID algorithms (which will facilitate debugging those algorithms). Wilson has done this for the first JAS/LCD event display.

- Physics requirements
  - We will perform a review of the pan-detector particle ID requirements for benchmark physics topics. As an example, we will work closely with the detector sub-system working groups to develop strategies for muon ID across the entire range of momentum called for by physics. We will investigate the importance to SUSY studies of muon ID below the momentum cut-off of the muon detector.
  - We will pursue the physics justification for hadron identification. This will extend Wilson's previous work. Soffer will spend much of his time on this topic. During his two forays into the area (for the Snowmass '01 and Santa Cruz '02 meetings) he was able to make useful contributions in a short time.
  - In his role as the Particle ID working group leader, Wilson will develop communication with the physics WGs to develop a list of benchmark processes that challenge the PID capabilities of the detector.

Budget

Most of the resources for this project will come from a redirection of effort of personnel currently supported by an existing DoE grant. Prof. Wilson will devote at least 50% of his research time. Dr. Soffer, with no teaching responsibilities, will devote 50% of his time, up from essentially zero currently. The funds requested would allow Dr. Soffer to remain at Colorado State University as a Research Scientist II; this is a full-time research position analogous in rank to an Assistant Professor. The current grant contains only sufficient salary funds for a junior post doc. and has insufficient travel budget to support a high level of linear collider involvement.

Preliminary budget estimate:

Institution	Item	Cost
CSU	Research Scientist salary increment	$x
CSU	Travel (x int'l, y dom.)	$x
CSU	Indirect costs	$x
CSU	Total	$32,000