STATUS REPORT

Dual-Readout Calorimetry for the ILC

Personnel and Institution(s) requesting funding

Texas Tech University: N. Akchurin, H. Kim and R. Wigmans

Collaborators

University of California at San Diego: H.P. Paar
Iowa State University: J. Hauptman and J. Lamsa
INFN Trieste (Italy): A. Penzo
University of Pavia (Italy): M. Livan
University of Rome, La Sapienza (Italy) : C. Ciapetti
University of Cosenza (Italy): G. Susinno

Collaborating personnel will work on the project but are not requesting funding here.

Project Leader

Name of project leader Dr. Richard Wigmans
Richard.Wigmans@ttu.edu
(806) 742-3779

Project Overview

The DREAM (Dual-REAdout Module) calorimeter was developed as a device that would make it possible to perform high-precision measurements of hadrons and hadron jets, while not subject to the limitations imposed by the requirements for compensating calorimetry, and thus addresses one of the most critical Detector R&D needs of the ILC..

The DREAM detector is based on a copper absorber structure, equipped with two types of active media which measure complementary characteristics of the shower development. Scintillating fibers measure the total energy deposited by the shower particles, while Čerenkov light is only produced by the charged, relativistic shower particles. Since the latter are almost exclusively found in the electromagnetic (em) shower component (dominated by π^0s produced in hadronic showers), a comparison of the two signals makes it possible to measure the energy fraction carried by this component, $f_{\rm em}$, event by event. As a result, the effects of fluctuations in this component, which are responsible for all the traditional problems in non-compensating calorimeters (non-linearity, poor energy resolution, non-Gaussian response function), can be eliminated, and an important improvement in the hadronic performance is achieved.

In the context of the approved ILC R&D component of this project, we concentrate on two aspects:

1. *The electromagnetic section.* The benefits of the dual-readout method are by no means limited to fiber calorimeters. Any medium that generates both Čerenkov light and scintillation light can be used for this purpose. And since the sampling fraction does not have to have a specific value (as in compensating calorimeters), there is no reason why a calorimeter based on the dual-readout principle could not have excellent electromagnetic energy resolution. In particular, homogeneous detectors generating both scintillation and Čerenkov light are an attractive option. The challenge is then of course to separate these two types of signals. This is the main topic of our studies.
2. *The readout of a fiber-based hadronic section.* The fiber-based DREAM calorimeter could in principle form an excellent and cost-effective solution for the hadronic section of a calorimeter system for a Linear Collider experiment. However, the readout of its many fibers would present a substantial challenge. The scintillating fibers and the Čerenkov fibers have to be grouped in separate bunches for readout by their respective light detectors. The prototype that was extensively tested in particle beams was equipped with standard photomultipliers (PMTs), two per tower. An attractive readout alternative for application in an ILC detector is offered by silicon photomultipliers. We want to equip the existing DREAM calorimeter with such a readout and study its performance.

Status Report

Because of the very limited ILC Detector R&D funds received, we have had to choose what to concentrate on in FY05/06, and we have decided that the electromagnetic section would be our main priority. This decision was also inspired by the fact that several other groups in the ILC Detector R&D program are working on SiPMs. We would like to wait and take advantage of their results before embarking on the hadronic-readout program. We will reconsider this situation again one year from now.

The current status of our project can be summarized as follows.

- We have concluded the analysis of dedicated measurements with the existing DREAM module, aimed at unraveling mixed scintillation/Čerenkov signals into their components. We used the time structure of the signals and the angular photon distribution for this purpose. This analysis was recently published:
  Separation of Scintillation and Čerenkov Light in an Optical Calorimeter,
  N. Akchurin *et al.,* Nucl. Instr. and Meth. **A550** (2005) 185 – 200.
- We have started studies to find suitable candidates for a homogenous electromagnetic calorimeter that can be used in a dual-readout mode. There are two possible configurations:
  1) A relatively poor scintillator that generates sufficient Čerenkov light, and whose scintillating properties are conveniently different from those of the Čerenkov light. $PbWO_4$ is the prime candidate. We are looking into ways to selectively reduce the scintillation light in this crystals.
  2) A suitable Čerenkov detector that can be doped with a proper scintillating agent. Lead glass and PbF_2 are the leading candidates.

- We have requested and been allocated beam time at the CERN SPS during the summer of 2006 to perform tests with the selected detectors. If time permits, these tests will be carried out in conjunction with the existing DREAM module, which will then serve as hadronic section in the measurements. Most likely, the latter measurements will be continued and completed in 2007.
- We have enlarged our collaboration with a number of Italian groups (Pavia, Rome, Cosenza), who have agreed to take prime responsibility for preparing these beam tests at CERN.

FY2006 Project Activities and Deliverables

Project activities and milestones:

- Order candidate detector samples (see previous section, January 2006)
- Study the signals from these detectors with sources and electron beams from the TTU Van de Graaff accelerator (February - April 2006)
- Study techniques to separate scintillation and Čerenkov signals from these detectors in the TTU lab environment (February - April 2006)
- Build full size em calorimeter based on selected technology (May - July 2006)
- Test this detector at the CERN SPS with high-energy electron and hadron beams (August 2006)

Deliverables: A homogeneous dual-readout electromagnetic calorimeter, as well as test results obtained with this instrument.

FY2007 Project Activities and Deliverables

We plan a combined electromagnetic and hadronic prototype test at the CERN SPS. The new em calorimeter followed by the existing DREAM hadron calorimeter, possibly equipped with three different types of fibers, will be exposed to beams of electrons, hadrons and "jets" (secondaries from interactions in an upstream target). The viability of the dual-, and possibly triple-readout techniques for improving hadronic performance will be tested.

Budget justification: Texas Tech University

The requested budget only concerns work on the em section, and is thus significantly lower than in the original proposal. Depending on the funding situation and on progress made elsewhere in the development of SiPMs, we may decide to revise our FY2007 request later on.

Texas Tech University will be the lead institution in this project. In order to reduce paperwork and complexity, no subcontracts will be used. Travel for our UCSD and ISU collaborators will be handled by TTU, which charges no overhead on travel.

Equipment, materials and supplies, and travel dominate the cost of this project.

We are using professional expert assistance (colleagues in our chemistry department, as well as outside consultants) in scintillator dopants and doping techniques. Undergraduate students are involved in the (preparations for the) tests planned for next year. The fringe benefits rate is assumed to be 25% on salaries.

There will be no overhead charged on equipment and travel. TTU will charge overhead on salaries, materials and supplies at the off-campus rate (26%).

Two-year budget, in then-year K$

Institution: Texas Tech University

Item	FY2006	FY2007	Total
Other Professionals	5.0	3.0	8.0
Graduate Students	0	0	0
Undergraduate Students	3.0	3.0	6.0
Total Salaries and Wages	8.0	6.0	14.0
Fringe Benefits	2.0	1.5	3.5
Total Salaries, Wages and Fringe Benefits	10.0	7.5	17.5
Equipment	10.0	5.0	15.0
Travel	20.0	20.0	40.0
Materials and Supplies	15.0	15.0	30.0
Other direct costs	10.0	5.0	15.0
Total direct costs	65.0	52.5	117.5
Indirect costs	6.5	5.9	12.4
Total direct and indirect costs	71.5	58.4	129.9