Proposal to the University Consortium for a Linear Collider

August 23, 2002

Proposal Name

Fast Response Tile Scintillation Development for Calorimetry and Tracking in NLC Detectors

Classification (accelerator/detector: subsystem)

Detector:Calorimetry/Tracking

Personnel and Institution(s) requesting funding

B. Baumbaugh, M. Hildreth, D. Karmgard, A. Kharchilava, J. Marchant,
M. McKenna, R. Ruchti, M. Wayne, J. Warchol, M. Vigneault
University of Notre Dame, Notre Dame, Indiana 46556

Contact Person

D. Karmgard
karmgard.1@nd.edu
(574)631-3362

Project Overview

Scintillation detection has a long history in particle physics. Scintillators are used for example in particle tracking and calorimetry (e.g.; the DØ fiber tracker and the Compact Muon Solenoid (CMS) calorimeters), and many other particle measurement systems. High luminosity accelerators such as the Next Linear Collider (NLC) present a new set of challenges for the development of scintillation detectors which can function effectively in short time, high radiation environments. The challenge is to develop new types of Wave Length Shifting (WLS) fibers which are fast, radiation hard, and efficient. Such a development would have immediate application to both Calorimetry and particle track triggering. The effort to develop such materials requires efforts in the chemistry of scintillating plastics and the geometry of the WLS. This proposal concentrates on the study of the geometric properties of WLS fibers.

These proposed studies have a possible application in many parts of an LC detector. They could be applied to fast triggering and particle tracking as well as calorimetry and calorimeter based clustering. They also have many possible applications outside of high energy physics (e.g.; fiber optic communications). A complimentary study which is necessarily a part of our proposal is that of the photo-sensor system. We shall, in undertaking this study, also have to consider the various possible methods of photo-detection (HPDs, APDs, Photomultiplier's, VLPC, etc.) to find the best possible match for an improved system of WLS fibers.

This proposal seeks to incorporate fast wave-shifting fibers to read out small scintillating tiles for fast timing in calorimetry and preshower/track-triggering applications in LC detectors.

Our objectives are several-fold:

1. Compare and study the performance of conventional Y11/K27 wave-shifter fiber embedded in small standard scintillation tile materials such as Bicron 408 with new, much faster and brighter wave-shifters. If successful, these new materials would provide superior timing information to conventional materials for calorimetry and triggering applications;

2. Develop improvements in fiber-optic light timing by special shaping of the ends of fiber waveguides;
3. Reduce the number of readout channels for fiber-based detectors through the chaining of spaced, non-adjacent scintillating tiles on a single wave-shifting fiber.

The first task involves comparative studies of BC408 scintillator tiles read out with Y11 wave-shifter fiber and BC408 tiles read out with fiber containing recently developed wave-shifter dyes such as DSB1 and DSF1. The new wave shifters are a factor of 3 faster than Y11 (2.5 ns vs. 8 ns), with a brightness improvement of up to 50%. These would afford significantly improved timing information for preshower and triggering detectors. Tests will be carried out using radioactive sources to study efficiency and uniformity of response. Photo-sensors will be conventional, red-extended multialkali photomultiplier tubes.

The second task involves optical interface modification at the ends of wave-shifter fibers. In most detector applications, the bulk of the light signal within a scintillating or wave-shifter fiber propagates near the critical angle. In a multiclad fiber with core of index 1.59 and outer clad of index 1.42, this angle is approximately 27 degrees relative to the fiber axis. By tapering the end of the fiber (like sharpening a pencil) to approximately this angle, light trapped at the critical angle will emerge from the surface parallel to the fiber axis. This axial light can then be injected into any fiber waveguide (for example PMMA core or even quartz fiber) and can be transmitted with less optical absorption and over a potentially shorter optical path than would otherwise be possible. Such a technique is also applicable to improved timing performance for a calorimeter or trigger detector. For these studies, light excitation would be via blue LEDs and light detection via pin diodes.

The third task is a scheme to reduce the number of readout channels in a multi-channel scintillation tile detector through the multiplexing of non-adjacent scintillating tiles of small size through a common wave-shifter fiber. For example, a series of 100 small, optically isolated, scintillation tiles of 2.5 cm length and 2.5 cm width are arranged end-to-end in a column and lying in a plane. Rather than having 100 individual fiber readouts for these tiles, every 20th tile is read out by a common wave-shifter fiber. (Tiles 1, 21, 41, 61, 81 have a common readout; tiles 2, 22, 42, 62, 82 have a common readout, etc.) In this configuration, the tiles are spaced 50 cm apart along a fiber, corresponding to a light signal timing difference of approximately 3 ns between successive tiles. If the signal arrival time at a photosensor is measured, then the tile producing the signal (and its location) is identified. In this example, a factor 5 reduction in the number of electronics channels results. Our objective is to determine the minimum effective tile separation possible for a given combination of scintillator and wave-shifter. Here, the identification of new, fast wave-shifter materials (first task above) is a major aid to such readout scheme. The optical signals can be detected with photomultipliers or visible light photon counters (VLPC).

FY2003 Project Activities and Deliverables Project activities for the first year are the preliminary testing of the described systems. We intend to conduct an extended feasibility study to determine if the ideas presented have merit. In addition to the construction of a test stand and basic measurements, we will use the data gathered to generate software simulations of the systems. We may then use these to more rapidly study the details of various design possibilities. The first year deliverable is a complete feasibility study.

FY2004 Project Activities and Deliverables Presuming that the first years efforts bear fruit, project activities in the second year center around building a working prototype system using the elements described in this proposal. The deliverables are the prototype and documentation of the physics capabilities of the system.

FY2005 Project Activities and Deliverables In the third year the project aims to take the lessons learned from the working prototype system to design a detector subsystem compatible with the needs of an NLC detector. The deliverables are a Technical Design Report of such a system.

Budget justification

Because of the long-range of the Linear Collider Program, we are anxious to leverage on the QuarkNet program and draw in high school teachers and students (in the summer between their junior and senior years) to work on the project, under the supervision of an experienced technician and guided by part-time graduate students. This will afford a direct education/outreach component to the R and D program and will afford the teachers and students the opportunity to participate directly in the development of state-of-the-art new techniques for particle detection and measurement.

We request half-time support and later full-time support for a technician to coordinate the design and fabrication of the test assemblies of the scintillation tile and wave-shifter arrays. This individual will, with the assistance of a graduate student, supervise the work of a high school teacher and several high school students during the summer to construct tile/fiber networks and to develop a test station to evaluate the performance of these structures. The graduate student will be supported from base grant funds.

An additional facility will be developed to shape the ends of optical fibers with the aim of developing optical connectors to adjust the phase space of the light propagating in the fibers to reduce propagation time and improve light transmission in optical fibers of long length.

Funds are requested for summer support of a high school teacher and two high school students. Equipment funds for the purchase of fast photo-sensors and materials funds for scintillating tiles and wave-shifting fibers are requested. A very modest travel budget is included to support several laboratory and vendor visits.

Indirect costs are estimated at 48.5% of modified total direct costs according to University of Notre Dame Accounting Practices.

Three-year budget, in then-year $

Institution: University of Notre Dame

Item	FY2003	FY2004	FY2005	Total
Technician	19,200	19,700	40,700	79,600
HS Teacher	5,200	5,350	5,500	16,050
HS Students (2)	3,000	3,100	3,200	9,300
Travel	1,000	1,500	2,000	4,500
Equipment	2,500	2,500	2,500	7,500
M&S	2,500	2,500	2,500	7,500
Indirect Costs	11,010	11,495	21,922	44,426
Total	44,410	46,145	78,322	168,876