Proposal to the
University Consortium for a Linear Collider

August 22, 2002

Proposal Name

Scintillator Based Muon System R&D

Classification (accelerator/detector: subsystem)

Detector: Muon

Personnel and Institution(s) requesting funding

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Project Overview The linear collider detector design includes a muon system that will identify muons, as distinct from hadrons, primarily by their penetration through the iron flux return. Because the proposed calorimeters are thin in terms of interaction lengths, hadronic showers will leak into the muon steel. The proposed energy-flow algorithms anticipate measuring jet energies by using charged particle momenta, EM shower energies for neutral pions, and hadron calorimetry for neutrons and K_L's. Fluctuations of the neutral hadron energies leaking from the hadron calorimeter will degrade the energy resolution. An adequately designed and proven muon system could be used to measure the energy escaping detection and improve the energy resolution of the detector. It is in this context that we propose an R&D program for a scintillator-based muon detection and identification system.

The general layout of the barrel muon detectors consists of planes of scintillator strips inserted in gaps between 10 cm thick Fe plates that make up octagonal barrels concentric with the e+e- beamline. The scintillator strips, with nominal width of 5 cm and 1 cm thickness, will contain one or more 1 mm diameter wavelength shifting (WLS) fibers. The investigation of optimal strip properties and sizes is a part of this project.

Light produced by a charged particle will be transported via clear fibers to multi-anode photomultipliers located outside the Fe yoke where it will be converted to electronic signals. Nominally there are 14 planes of scintillator with alternating strips oriented at 45° with respect to a projection of the beam line onto the planes.

Given a substantial knowledge base from experiments like MINOS, CDHS and others one might ask if an R&D effort on a scintillator-based muon system is necessary. In fact, it is. There are significant differences in the environments for neutrino experiments and the proposed linear colliders. For the LCD, detectors must be robust and ready to withstand 20 years of beam time in a radiation environment. The geometry and packaging of the scintillator detectors are very challenging. There is much in the way of mechanical engineering of the iron, fiber and cable routing, etc. that needs to be determined at an early stage to ensure that important details for the largest LC detector system are not overlooked.

FY2003 Project Activities and Deliverables

NIU Software Development: a C++/GEANT4 stand-alone representation of a preliminary muon detector sub-subsystem. Package framework, and implementation of (i) modularity towards an easy plug-in of different sub-detectors (trackers, calorimeter) (ii) detector geometry and parameter input as decoupled as possible (e.g. external data bases) from simulation code, for easy changes in detector characteristics. This project is to be coordinated with other LCD sub-detector developers, towards a sub-systems compatible and flexible full detector simulation package. In parallel, development of muon tracking algorithm for continuous assessment of detector model development.

The first year deliverable will be an initial package for the GEANT4 based physics event simulation; a general framework capable of hosting all subdetectors, a preliminary description of the muon subsystem, and a muon stand-alone tracking algorithm.

NIU Hardware Development: joint work with Fermilab for the commissioning of a scintillator extrusion facility. Design of a Test Stand for the Quality Control of extruded scintillator plates. Initial studies of techniques to embed fibers into the muon strips.

Deliverables will include the production of extruded scintillator strips and inital measurements of their properties compared to standard methods of producing counters. This will require the manufacture of a die.

UND Hardware Development: Devise a fiber routing scheme. Create a technique for the splicing/joining of WLS and Clear fibers. Decide on the specifications, and order the WLS fibers.

FY2004 Project Activities and Deliverables

NIU Software Development: Continued development of the simulation package described in the previous item. Completion of the muon system representation according to the then current detector design. Coupling to the other subdetectors. Simulation based studies of detector parameter trade-offs and optimization.

The second year deliverable will be a simulation package providing fast and reliable access to different detector design characteristics and parameter choices. With it, we expect to achieve a solid understanding of the muon system tracking ability, fake rates, and sub-systems integration, such as the inter-dependence of parameter choices and the mutual assistance with calorimetry and cenral tracking for particle ID, energy flow and energy/momentum resolution.

NIU Hardware Development: Measurements of the performance (such as light yield and resultant efficiencies and time resolutions) as a function of paramters such as position along the strip, fiber placement and number of fibers, and counter length. Comparisons will be made between extruded and non-extruded strips. At least one additional size die will be made and prototype strips manufactured.

Deliverables will include a better understanding of the performance of strips of various lengths, widths, and fiber placement. Combined with the simulation effort, this can be used as a guide for an initial choice of counter dimension and mechanical properties.

UND Hardware Development: Quality assurance on WLS and Clear fibers. Design and use a system to measure optical transmission. Engineering design of prototype light guide manifolds.

FY2005 Project Activities and Deliverables

NIU Software Development: Completion of the muon simulation, track reconstruction and analysis software. Completion of all simulation based studies of detector design characteristics and parameter optimization.

The third year deliverable will be a mature package for the GEANT4 based physics event simulation, reconstruction and analysis; documented, external user friendly, able to host the then available non muon sub-detectors, and with a version-controlled description of the muon sub-system, holding the necessary detail for physics reach studies.

NIU Hardware Development: Produce a significant number of pre-production prototypes to understand production details, costs, and uniformity. Depending on the needs of other R&D efforts, these counters could then be installed and used in test beams (e.g. calorimeter tests).

Deliverables will include the produced counters. Also a third year deliverable (both hardware and software) should be a significant contribution to the muon system TDR.

UND Hardware Development: Production of prototype manifolds for eight planes. Test manifolds, install the manifolds with light guides for the eight planes.

Budget justification

All NIU salaries for professional support staff (including electronics, computing, and machine shop personnel) will be provided by the Department, the State, or other grants. The NIU budget requests support for an undergraduate student through the REU program and for the summer support for a masters graduate student. It is our experience that students at this level are well-matched to the R&D tasks in this proposal. Three NIU undergraduates worked on LC muon related tasks (both simulation and detector R&D) during the Summer of 2002, and this request will aid in continuing student involvement.

The NIU budget requests K$4 in materials and supplies which will be used to purchase needed material for constructing prototype counters (such as scintillator, fiber, or PMTs). Travel funds of K$3 are requested to support international and domestic travel.

NIU grant matching funds for the support on LC muon R&D are primarily from the State of Illinois' HECA program. This provides the salary for Dychkant, and partial support for Maciel and Hedin. In addition, HECA funds will provide K$9 for student support, K$15 for equipment and M&S, and K$2 for domestic travel.

UND requests support for the mechanical engineering associated with fibers: routing and layout, optical coupling of clear and WLS fibers. Manifold engineering, such as mold development using carbon fiber, epoxy techniques. The UND budget must also cover materials such as fibers, manifold parts etc.

Three-year budget, in then-year K$

Institution: Northern Illinois University.

Item	FY2003	FY2004	FY2005	Total
Other Professionals	0	0	0	0
Graduate Students	4.5	4.5	4.5	13.5
Undergraduate Students(REU)	3.0	3.0	3.0	9.0
Total Salaries and Wages	7.5	7.5	7.5	22.5
Fringe Benefits	0	0	0	0
Total Salaries, Wages and Fringe Benefits	7.5	7.5	7.5	22.5
Equipment	0	0	0	0
Travel	3.0	3.0	3.0	9.0
Materials and Supplies	4.0	4.0	4.0	12.0
Other direct costs	0	0	0	0
Total direct costs	14.5	14.5	14.5	43.5
Indirect costs (*)	5.9	5.9	5.9	17.7
Total direct and indirect costs	20.4	20.4	20.4	61.2

(*) 25% on REU (=K$0.8) and 44% on remainder (=K$5.1)

Institution: University of Notre Dame

Item	FY2003	FY2004	FY2005	Total
Other Professionals(1)	7.0	8.0	10.0	25.0
Graduate Students	3.0	7.0	8.0	18.0
Undergraduate Students	0	2.0	2.0	4.0
Total Salaries and Wages	10.0	17.0	20.0	47.0
Fringe Benefits(2)	2.0	2.5	3.0	7.5
Total Salaries, Wages and Fringe Benefits	12.0	19.5	23.0	54.5
Equipment	0	0	0	0
Travel	0	0	0	0
Materials and Supplies	9.0	9.0	5.0	23.0
Other direct costs	0	0	0	0
Total direct costs	21.0	28.5	28.0	77.5
Indirect costs(3)	4.8	7.2	8.6	20.6
Total direct and indirect costs	25.8	35.7	36.6	98.1

(1) Engineering work
(2) 25% of "Other Professionals" and "Undergraduates".
(3) 48% of "Other Professionals" and "Graduate Students".