Proposal to the University Consortium for a Linear Collider

November 17, 2003

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 particle-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 "punch-through" hadron energy escaping the calorimeter 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 16 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.

FY2004 Project Activities and Deliverables

NIU Software Development: The first year deliverables will be a preliminary description of the muon subsystem for the overall GEANT4-based simulation of the full detector simulation package, which is described in Project 5.5 *Development of particle-flow algorithms, simulation and other software for the LC detector*, and a stand-alone muon 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.

FY2005 Project Activities and Deliverables

NIU Software Development: Continued development of the muon module for the full-detector simulation package. Coupling to the other subdetectors. Simulation-based detector optimization. In the second year, we'll carry out extensive simulation-based comparisons between different detector designs. 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 central tracking for particle ID, particle 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 parameters 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.

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.

FY2006 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 "muon system" module for the GEANT4-based full-detector simulation package, muon reconstruction software, results of design optimization studies, and complete documentation.

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 $5.4K in materials and supplies (such as scintillator, fiber, PMTs) which will be used in the construction of prototype counters. Travel funds of $3K 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 $9K for student support, $15K for equipment and M&S, and $2K for domestic travel.

The University of Notre Dame requests support for the mechanical engineering associated with fibers: routing and layout, optical coupling of clear and WLS fibers, support structures and light-tightning, and the mapping of the readout fibers into the multianode PMTs. A total of $25K over three years is requested for this engineering and associated technical work. The fringe benefit rate applied to this engineering and technical support is 20%. The UND budget also requests support for a graduate and undergraduate student, with 3-year totals of $18K and $4K respectively. A total of $23K is requested for constructed equipment, which includes the cost of the clear waveguide fiber, material and costs for the splicing of wavelength shifting fiber to clear fiber, and the material and costs of the routing and support structure for the readout fibers. An indirect cost rate of 49% is applied to the engineering and technical costs. This indirect rate is also applied to the first $25K of the subaward to NIU.

Three-year budget, in then-year K$

Institution: Northern Illinois University.

Item	FY2004	FY2005	FY2006	Total
Other Professionals	0	0	0	0
Graduate Students	4.635	4.774	4.917	14.326
Undergraduate Students(REU)	3.000	3.000	3.000	9.000
Total Salaries and Wages	7.635	7.774	7.917	23.326
Fringe Benefits	0	0	0	0
Total Salaries, Wages and Fringe Benefits	7.635	7.774	7.917	23.326
Equipment	0	0	0	0
Travel	3.000	3.000	3.000	9.000
Materials and Supplies	5.300	5.400	5.402	16.102
Other direct costs	0	0	0	0
Total direct costs	15.935	16.174	16.319	48.428
Indirect costs (*)	4.113	4.175	4.213	12.501
Total direct and indirect costs	20.048	20.349	20.532	60.929

(*)totals: 25% on REU (=K$2.250) and 26% on remainder (=K$10.251)

Institution: University of Notre Dame

Item	FY2004	FY2005	FY2006	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)	1.4	1.6	2.0	5.0
Total Salaries, Wages and Fringe Benefits	11.4	18.6	22.0	52.0
Equipment	9.0	9.0	5.0	23.0
Travel	0	0	0	0
Materials and Supplies	0	0	0	0
Other direct costs	0	0	0	0
Subcontract	20.048	20.349	20.532	60.929
Total direct costs	40.448	47.949	47.532	135.929
Indirect costs(3)	15.252	11.423	10.670	37.345
Total direct and indirect costs	55.700	59.372	58.202	173.274

(1) Engineering work

(2) 20% of "Other Professionals".

(3) 48.5% of "MTDC" and "1st $25,000 of Subcontract".