# Scintillator Based Muon System R&D - EOI

Alan Bross, H. Eugene Fisk (Co-contact Person), Kurt Krempetz, Caroline Milstene, Adam Para, Oleg Prokofiev, Ray Stefanski, Fermilab**, Batavia, Illinois;** Gerald Blazey, Dhiman Chakraborty, Alexandre Dychkant, David Hedin, Arthur Maciel, **Northern Illinois University**, DeKalb, Illinois; Mitchell Wayne, **Notre Dame University**, South Bend, Indiana; Paul Karchin (Co-contact Person) **Wayne State University**, Detroit, Michigan; Mani Tripathi, **University of California, Davis**, California

**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 $K_L^o$. 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, ~5 cm wide and 1 cm thick, would contain one or more ~1 mm diameter wavelength shifting (WLS) fibers. Light produced by a charged particle would be transported via clear fibers to multi-anode photomultipliers located outside the Fe yoke where it will be converted to electronic signals. There would be 14 planes of scintillator with alternating strips oriented at $\pm 45^o$ 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 insure that important details for the largest LC detector system are not overlooked.

This is what we will do:

- Continue work on the development of detector event generation software for final states with muons and algorithms for the identification of muons.
- Develop the mechanical and electronics specifications for a test set-up of 8 (4u & 4v) full width, but short-length strip scintillator planes.

- Procure finished strip scintillator, WLS and clear fiber sufficient for the 8 planes by adding to existing MINOS orders to achieve about a 50% cost savings.
- Procure approximately 16 multi-anode (64 channel ea.) photomultiplier tubes to instrument most of the 8 prototype planes.
- Borrow existing electronics for the tests we need to do, inasmuch as this is possible. This would include tube bases, discriminators, ADCs, trigger counters, trigger logic, etc.
- Use the existing cosmic ray test-stand facilities in Lab 3 that were used in the D0 fiber-tracker testing to do our cosmic ray tests.
- Obtain cosmic ray data that can be used to further define software algorithms for muon identification.
- Define the need for additional Fe in future cosmic ray and beam testing of the prototype modules.
- Develop the detailed mechanical and electronics specifications for the LC muon system.

**Goals, Work to be done and deliverables**:

| Work to be Performed | By | Deliverables |
|---|---|---|
| Detector Simulation Software | Arthur Maciel - NIU<br>Dhiman Chakraborty - NIU | Gismo code for muon detector event generation |
| Muon ID & Tracking Algorithms | David Hedin - NIU<br>Caroline Milstene - Fermilab | Gismo muon tracking and ID code |
| Fe Layout, Mechanical Engineering Analysis, Cable & Fiber Routing. Costs. | Kurt Krempetz - Fermilab<br>Ray Stefanski - Fermilab<br>Oleg Prokofiev - Fermilab | Stress/deflection calcs.,<br>Engineering drawings.<br>R&D Cost Estimate . |
| Scintillator strip extrusion Processing using the NIU Machine at Fermilab. | Jerry Blazey & Alexandre Dychkant - NIU<br>Alan Bross - Fermilab | Scintillator spec. document.<br>1 T prototype scint. devel.<br>1 T prototype scint. prod'n. |
| WLS R&D, Insertion in Strips; Testing; Clear fiber Splicing; Waveguide prod'n. | Alan Bross - Fermilab<br>Dychkant - NIU<br>Mitch Wayne - Notre Dame | Finished prototype scint. for prototype planes.<br>Test results document. |
| Engineering &design of Prototype muon detector Planes. | Kurt Krempetz, Adam Para,<br>Gene Fisk - Fermilab<br>Others TBD | Engineering drawings & specification document. |
| Photomultiplier, electronics, logic, procurement, setup, etc.. | P. Karchin - Wayne State<br>Adam Para - Fermilab<br>Mani Tripathi - UC Davis | Logic & test procedures for cosmic ray tests. Develop specs for LC Mu electronics |
| Cosmic ray test stand for Prototype module testing. (Utilize Lab 3 test stand) | Mitch Wayne - Notre Dame<br>Caroline Milstene - Fermilab<br>Paul Karchin - Wayne State | Mechanical layout of test stand modules. Test data analysis/results document. |

**Future Plans**

This R&D program will take two years to complete. Future plans would include testing of muon planes with hadron and muon beams with Fe plates.

**Initial Budget**

The budget requested here assumes cost sharing between Fermilab and the collaborating universities. No LCD R&D funds are requested to support the work of Fermilab staff. The costs are to cover FY03 & FY04 although the materials costs require major commitments in FY03.

| Item | Total | UC Davis | NIU | Notre Dame | Wayne St |
|---|---|---|---|---|---|
| **Agency which funds group's base grant** | | DOE | NSF | NSF | DOE |
| | | | | | |
| **M&S Costs** | | | | | |
| Software development - use existing facilities | | | | | |
| | | | | | |
| Scintillator - Shared between the univs & Fermilab | | | | | |
| a. One ton finished scintillator strips ($10/kg) | 10,000 | | 5,000 | | |
| b. WLS fiber - for eight short modules ($3.5/m) | 12,000 | | 4,000 | 4,000 | |
| c. Clear fiber | 15,000 | | | 7,500 | |
| d. Light guide manifolds | 20,000 | | 6,000 | 6,000 | |
| e. Al for skins, tooling, handling fixtures, | 10,000 | | 5,000 | | |
| e. Raw materials for extrusion facility start-up | | | | | |
| | | | | | |
| Electronics - for 768 channels = 12 PMs | | | | | |
| a. Multi-anode PMs /alternate, based on M64 PM | 24,000 | 8,000 | 8,000 | | 8,000 |
| b. Modifications to use existing electronics | 10,000 | 3,000 | 3,000 | | 4,000 |
| | | | | | |
| **M&S Cost (sub-totals)** | 101,000 | **11,000** | **31,000** | **17,500** | **12,000** |
| | | | | | |
| **Personnel Costs - over two years** | | | | | |
| Software development | | | | | |
| a. Travel to SLAC/Fermilab | | 3,000 | 3,000 | 2,000 | 2,000 |
| b. Engineering costs | | 5,000 | | 5,000 | 5,000 |
| c. Graduate student - half on LC R&D * 2 years | | 30,000 | 15,000 | 25,000 | 30,000 |
| | | | | | |
| **Personnel Costs - over two years (sub-totals)** | 125,000 | **38,000** | **18,000** | **32,000** | **37,000** |
| | | | | | |
| | | | | | |
| **Totals** | | **49,000** | **49,000** | **49,500** | **49,000** |
| | | | | | |

**Grand Total (2 years) $196,500**