American Linear Collider Physics Group
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Stanford Linear Accelerator Center

Scintillator Based Muon System R&D
for a Linear Collider

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Scintillator Based Muon System Collaboration

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http://www-d0.fnal.gov/~maciel/LCD/awg_lcdmu.html
NIU simulation study

500 GeV ZH event

$Z \rightarrow \mu \mu$

$H \rightarrow b \bar{b}$

($\mu$ tag)
LC Muon System Goals

• muon identification via penetration of iron flux return

• high efficiency over wide momentum range

• rejection of pions

• improvement of calorimeter resolution for hadronic jets

• long term stable operation of inaccessible detector

• integration of large, expensive detector subsystem
Muon System Design

- octagonal iron barrel with scintillator strips in slots
- 1 cm thick scintillator strips; 10 cm thick iron plates
- wavelength shifting (WLS) fiber readout of strip
- clear fiber link between WLS fiber and photodetector
- multi-anode photomultiplier tube opto-electrical conversion
SD Configuration

M. Breidenbach @ Cornell 2003
Instrumented Iron Barrel

Fe Cross Section

Steel Cross-section

Fe Thickness = 10 cm
Gap = 5 cm

4.45 m
6.55 m

Gap View

µ

5 cm

1.5 cm
NIU/FNAL Single Muon Simulation

10 GeV μ
Muon Efficiency

NIU/FNAL Simulation

Single Muon

energy loss ignored in tracking

energy loss included in tracking
Single Pion Simulation

50 GeV
π
Pion Misidentification

10/700 = 1.4%
Scintillator Layout and Strips

U/V strips with wls shifted light exiting both ends. Add left/right signals from clear fibers to provide the pulse height sum.

Scintillator: 4.1 X 1 cm² co-extruded strips with 1 mm dia. WLS fiber and outer reflector of TiO₂.
Photo-electron Yield from MINOS

Number of observed photoelectrons

Distance along the module (m)

Near 11±3 p.e.

Far (3.6 m for the proposed layout) 6±2 p.e.

MINOS Scintillator

Measured light output using the complete MINOS optical system:
Connectors, clear fibers, multi-anode PMT’s
NIU/FNAL Extruded Scintillator R&D

Lab 5 at Fermilab
Berstorff Extrusion Machine

purchased by NIU; first pieces produced using existing die
Procurement of Scintillator at FNAL

- 4.5 km of Kuraray WLS and 3.0 km of Kuraray clear fiber are delivered

- ~700 pieces of 3.5m X 4.1cm X 1cm MINOS type extruded scintillator was produced at Itasca Plastics in St. Charles, IL on Dec. 10th. Enough for 8 planes 2.5m X 5.0m.

- We requested a ~3 ft. long piece for testing every hour of production. There are 25 such pieces.
Optical Fiber Work at Notre Dame

- 64 long pieces of clear fiber polished and tested with LED-Photodiode system. $\sigma$ of < 0.5% for all fibers.

- WLS-clear fiber splicing at Fermilab; transmission tests at ND

- Fabricate small mockup by mid-January to study:
  - $180^\circ$ turn at end of scintillator
  - Protection of chamber edges
  - Channeling of clear fibers back to PMT
  - Interface between scintillator/routing plate/outer skin
Fiber Coupling to PMT

- Depends upon choice of tube - if appropriate follow the MINOS design
  - Obtain samples from MINOS
  - Copy/improve, fabricate in ND machine shop
  - Develop test procedures for fiber/tube interface
  - Design light-tight sheathing between chamber and PMT

- For long-term, need to think about optical finish of the PMT “cookies”
A Hamamatsu R5900-M16 MAPMT mounted in a MINOS (far detector) base. The assembly has been modified to accommodate an aluminum guide for optical fibers. The 16 holes in the aluminum block are aligned with the MAPMT photocathode grid. Ambient light or pulses from an LED are injected into individual pixels. Cables are visible for HV bias and anode signal readout.
PMT Test and Calibration at WSU

M16 PMT with MINOS base – response to LED pulse

![Graph showing PMT and LED pulses with measurement details]
UC Davis Pre-amp Board housing 16 channel PMT and Amplifiers

- 4.5” x 4.5”
- Dynode resistor chain built-in
- 16 amplifier chips on-board
Alternative Photodetectors

- geiger mode avalanche photo diodes (R. Wilson)
- silicon photomultiplier (B. Dologshein)
- silicon target hybrid photo tubes

Additional Studies Needed

- high resolution innermost detector plane needed?
- forward detector design
- backgrounds in forward detector
- is MINOS scintillator optimal for LC muon detector?
SUMMARY: Three Year Collaboration Plan

**FY04**
- assemble and test several prototype detector planes and electronics
- simulate detector with realistic geometry using GEANT4

**FY05**
- extensive measurements of prototype plane performance
- assembly of system for cosmic ray tests
- parametric optimization using simulation
Summary:
Three Year Collaboration Plan

FY06

- complete cosmic ray measurements
- assemble prototype system with 8 planes and absorber in test beam