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A SCINTILLATOR BASED MUON DETECTOR FOR THE LINEAR COLLIDER

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on behalf of the Scintillator Based Muon Collaboration[1,2]

The requirements for a linear collider muon detector are discussed and a solution is presented based on solid scintillating strips with embedded wavelength shifting optical fibers. Multi-anode photo-multiplier tubes are a good candidate for photon detection. Their single photo-electron response can be calibrated using fast pulses from light-emitting diodes.

1. Overview

The identification and precise measurement of muons is critical to the physics program of the linear collider (LC). The muon system will identify muons, as distinct from hadrons, primarily by their penetration through the iron flux return yoke. The muon system should operate over the widest possible momentum range with high efficiency for muons and low contamination from pions. Because the calorimeters proposed for the LC are thin in terms of interaction lengths, hadronic showers will leak into the muon steel. With an adequately designed and proven muon system, it may be possible to measure the leakage and hence improve the energy resolution of hadronic jets. The muon system must maintain stable operation with high reliability since the detectors are largely inaccessible. These are challenging requirements for operation over a span of perhaps 20 years. Since the muon system is the largest sub-detector, cost is a factor in its design. Integration of the muon system with the other detector sub-systems is important in optimizing the physics performance of the detector as a whole.

A promising design for the muon system is suggested by the successful operation of scintillator - iron calorimeters used in neutrino experiments to measure the energy of jets. A scintillator strip calorimeter based on MINOS[3] style detectors may provide the resolution required for a useful measurement of shower leakage, as well as muon position that is limited only by the multiple scattering in the iron flux return yoke.

We propose a muon detector which 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, $\sim$5 cm wide and 1 cm thick, are embedded with a wavelength shifting (WLS) fiber with diameter of $\sim$1 mm. A section of a prototype scintillator strip is shown in Figure 1. A charged particle traversing the strip produces scintillation light, some of which is captured by the embedded WLS fiber. Outside the strip, the WLS fiber is fused to a clear fiber which transmits the WLS light to a photo-detector located outside the Fe yoke. There are 14 planes of scintillator with alternating strips oriented at $\pm 45°$ with respect to a projection of the beam line onto the planes.

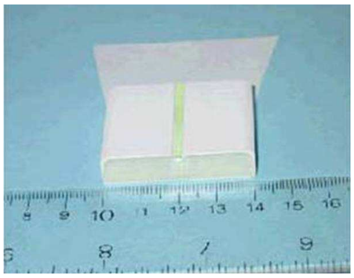

Fig. 1. A section of a prototype scintillator strip with titanium oxide coating and groove for a wavelength shifting optical fiber. The coating and groove are produced as part of the extrusion process.

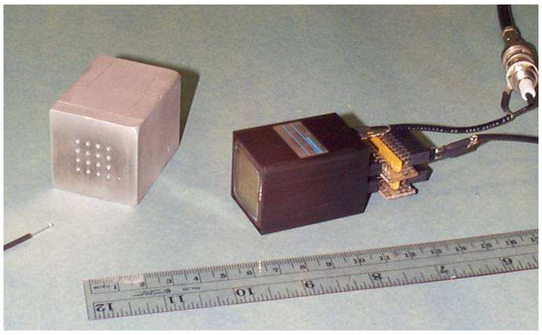

Fig. 2. Test setup with clear fiber, fiber guide, MAPMT, connector assembly, HV and signal cables.

2. Photon Detection

A well established device for photon detection is the Hamamatsu multi-anode photomultiplier tube (MAPMT). We developed a scheme to calibrate the single photoelectron response of a MAPMT using fast pulses from a light-emitting diode (LED). The 16-channel Hamamatsu H8711 MAPMT and associated components are shown in Fig. 2. A clear fiber transmits light from an LED and is aligned to the photocathode face by an aluminum guide with an array of holes corresponding to the cathode pixel grid. A mass termination connector provides a transition from the anode pins to a miniature (RG174) coaxial cable. The single-shot digital oscilloscope trace in Fig. 3 shows the voltage pulse driving the LED and the response from a single anode channel, for a high voltage bias of 850 volts. The anode response for this single primary photo-electron is seen to be narrow (width at half max is about 4 ns) with a peak amplitude of about 30 mV. Electronic noise is visible with peak-to-peak amplitude of about 8 mV. Tests with a high quality Faraday cage show that the noise can be reduced with improved electromagnetic shielding.

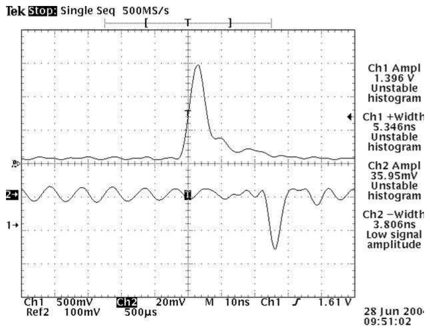

Fig. 3. Single-shot digital oscilloscope trace for LED voltage pulse (top) and single anode response (bottom).

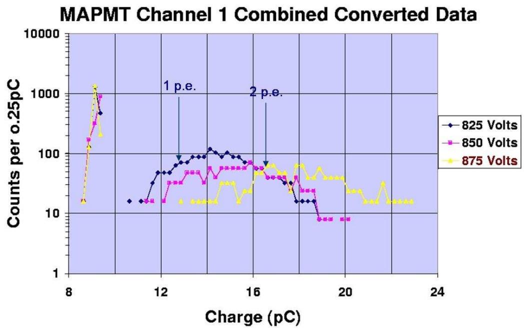

Fig. 4. Charge spectra from anode pulses for three different cathode bias values. For 825 volts bias, the mean charges corresponding to 1 and 2 photo-electrons are indicated in the figure.

Charge spectra from anode pulses, initiated by the LED, were recorded with a LeCroy QVT. Spectra for three different high voltage bias values are shown in Fig. 4. The spectra were analyzed under the assumption of Poisson statistics for the number of primary photo-electrons produced during a timing gate centered on the LED pulse. For 825 volts bias, the charges corresponding to 1 and 2 photo-electrons are indicated in the figure. The gain is measured to be about 23×10^6, consistent with data provided by Hamamatsu.

The technique presented here, using LED pulsing, can be used to calibrate the single photo-electron response. We plan to extend this technique for an in-situ calibration scheme, injecting LED light into the scintillator strips.

References

1. The Scintillator-Based Muon Collaboration. *Fermilab*: Alan Bross, H. Eugene Fisk (Co-contact Person), Kurt Krempetz, Caroline Milstene, Adam Para, Oleg Prokofiev, Ray Stefanski; *Northern Illinois University*: Gerald Blazey, Dhiman Chakraborty, Alexandre Dychkant, David Hedin, Arthur Maciel; *University of Notre Dame*: Mitchell Wayne; *Rice University*: B. Paul Padley, Mikhail Matveev, Jabus Roberts; *University of California*, Davis: Mani Tripathi, Richard Breedon; *University of Texas, Austin*: Karol Lang, *Wayne State University:* Ray Brockhaus, Alfredo Gutierrez, Paul Karchin (Co-contact Person).
2. Website for the Scintillator-Based Muon Collaboration, http://www-d0.fnal.gov/∼maciel/LCD/awg_lcdmu.html.
3. "MINOS Technical Design Report", NuMI-NOTE-GEN-0337, Fermilab, 1998.