TESTS OF A LARGE SCALE SCINTILLATING FIBER TRACKER

B. BAUMBAUGH, I. BERTRAM, A. BROSS, S. CHOI, M. CHUNG,
S. GRÜNENDAHL, J.S. KANG, C.L. KIM, S.K. KIM, D. KOLTICK, F. LOBKOWICZ,
S. MARGULIES, Y. PARK, Y. PISCHALNIKOV, R. RUCHTI, J. SOLOMON,
J. WARCHOL, M. WAYNE*, Y. YU

Fermi National Accelerator Laboratory, University of Illinois at Chicago, Korea University, Kyungsung University, University of Notre Dame, Purdue University, Rice University, University of Rochester, Seoul National University

We report on results of a cosmic ray test of a scintillating fiber tracker using Visible Light Photon Counter (VLPC) readout. Two different detector configurations have been constructed and operated, the first with a total of 3,072 channels and the second with 1,785 channels. The 3,072 channel system is a prototype for the DØ detector tracking upgrade and represents a configuration that is similar to that in the final detector. The second, smaller test was specifically designed to study the position resolution capabilities of the fiber tracker. Final results from the 3,072 channel test will be presented, including measurements of resolution, light yield per minimum ionizing particle, singlet and doublet efficiency, and long-term stability. Resolution results from the second, 1,785 channel test will be compared to the predicted resolution from Monte Carlo studies.

1 Motivation

The DØ collaboration is anticipating a great physics opportunity with the completion of the Main Injector project at Fermilab. In order to take full advantage of this physics potential, DØ has embarked upon a major upgrade of the current detector[1]. A key part of this upgrade will be the replacement of the central tracking system with a system containing a silicon microvertex detector surrounded by a scintillating fiber outer tracker, both located inside a 2 Tesla superconducting solenoid.

2 Cosmic Ray Test Stand

To demonstrate the performance characteristics of the scintillating fiber tracker, a 3,072 channel system, known as the Cosmic Ray Test Stand, has been built and operated by the DØ Fiber Tracking group. Two scintillating fiber superlayers are located on a 20 inch diameter carbon-fiber support cylinder. A third superlayer was mounted on a flat board and placed along the cylinder axis. A superlayer contains 2 doublet ribbons of axially oriented fibers and a doublet ribbon each of $\pm 2^{o}$ stereo

* Representing the DØ Collaboration

fibers. Each scintillating fiber is mated with a clear waveguide fiber which transports the scintillation light to the photodetector, the Visible Light Photon Counter (VLPC)[2].

The support cylinder sits upon a 2 meter high stack of steel. Trigger counters above and below select cosmic ray muons with a minimum momentum of 2.5 GeV/c. The test stand also includes three planes of Iarocci tubes for additional tracking. Additional details of the VLPCs, cassettes and cryostat, fiber ribbon construction and mounting, and data acquisition are reported elsewhere[3].

3 Results

Data were collected using the cosmic ray test stand described above during the period between May, 1994 and December, 1994. A total of 18.2 million cosmic ray triggers were recorded. In addition, 4.6 million calibration triggers and 3.6 million random triggers for noise measurements were recorded. During this data run the cryosystem was warmed up and cooled back down a total of 5 times.

3.1 Photoelectron Yield

The cosmic ray pulse height spectrum for all channels is shown in Fig. 1. A fit to the spectrum gives a mean value of 9.6 photoelectrons, which is approximately a factor of 4 larger than the minimum number required for an efficient fiber tracker[4].

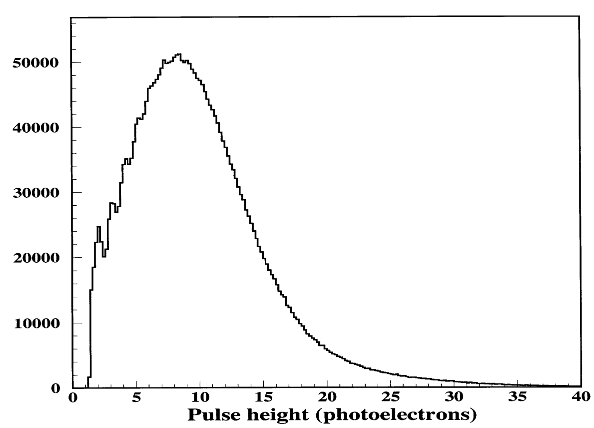

Fig. 1: Photoelectron spectrum for cosmic rays.

3.2 *Efficiency*

The singlet and doublet fiber layer efficiencies are given for a variety of thresholds in Table 1. The singlet efficiency of approximately 85% reflects the geometric efficiency of a single fiber layer. The doublet efficiency is nearly unity for the entire range of thresholds. Regions containing non-functioning channels were excluded from the study.

Table 1: Singlet and doublet efficiencies

Noise Level in %	Singlet Efficiency	Doublet Efficiency
0.025	83.5 %	99.5 %
0.050	83.9 %	99.5 %
0.075	84.4 %	99.5 %
0.100	84.6 %	99.6 %
0.125	84.8 %	99.6 %

3.3 *Position Resolution*

The initial measurements of fiber doublet position resolution in the cosmic ray test stand yielded results on the order of 130 μm, about 30% larger than the predicted value. The poorer resolution was due to a flaw in the construction of the scintillating fiber ribbons. In an attempt to achieve the predicted resolution, a second, simpler fiber detector was constructed using "interlocked" ribbons, in which the second layer of fibers is placed directly into the grooves of the first layer, thus guaranteeing the relative registration of the two layers. All 1,785 fibers are oriented in the axial direction, with a total of 7 doublet fiber layers mounted on three flat carbon-fiber boards. Aside from the different fiber ribbon geometry, everything else in the system was identical to the original cosmic ray test stand.

A total of 9.9 million cosmic ray triggers were recorded with this new configuration, along with 0.7 million calibration triggers and 1.5 million random triggers. The position resolution was measured for the four inner doublets. The resolutions for all four doublets are given in Table 2. Also shown are the predicted resolutions from a simple geometric Monte Carlo simulation, and for a GEANT simulation with multiple scattering included. The measured resolutions for doublets 5 and 6 are very close to their predicted values of 101 μm and 91 μm, while the resolutions for doublets 3 and 4 are larger. These data, however, have not been corrected for ribbon location as a function of position along the axial direction. Once these corrections are implemented it is expected that the resolutions for doublets 3 and 4 will also be consistent with the predicted values.

Table 2: Position resolutions for doublets 3-6

Doublet	Geometric Monte Carlo	GEANT Simulation	Measured Resolution
3	90 µm	90 µm	101 µm
4	91 µm	101 µm	132 µm
5	91 µm	101 µm	104 µm
6	91 µm	91 µm	92 µm

3.2 Stability Studies

The extended running with the two cosmic ray test stand configurations enabled the stability of the VLPC readout system to be monitored for nearly a year of operating time. Variations in the average gain, gain dispersion and noise rates of the fiber tracker were all within 1% over the entire running period of nearly 300 days.

4 Summary

A large scale test of a scintillating fiber tracker with VLPC readout has been carried out. Two different detector configurations, with total channel counts of 3,072 and 1,785 have been operated for a combined running time of nearly 300 days.

The mean number of photoelectrons detected per fiber was 9.6. The fiber doublet efficiency was better than 99% with a corresponding noise rate of 0.1%. Utilizing interlocked ribbons in the second cosmic ray test stand, doublet resolutions of order 100 µm were measured, in agreement with the predicted value. The VLPC readout system operated stably throughout the running period, with variations in gain, gain dispersion and noise rates less than 1% over the entire run.

References

1. S. Abachi et al., FERMILAB-CONF-95-177-E, July 1995, Submitted to International Europhysics Conference on High Energy Physics (HEP 95), Brussels, Belgium.
2. M.D. Petroff et al., Appl. Phys. Lett. **51**, 406 (1987) .
3. D. Adams et al., IEEE Trans. on Nucl. Sci. **42**, 401 (1995) .
   D. Adams et al., IEEE Trans. on Nucl. Sci **43**, 1146 (1996) .
4. B. Abbot et al., Conceptual Design Report of the Scintillating Fiber Outer Tracker, SDC-92-174 (1992).