CLAS-NOTE 2002-01

Light yield measurements with extruded grooved scintillators

(Spring 1996, JLAB)

S. Majewski, R. Wojcik, B. Kross, H. Fenker, A.G. Weisenberger, and C. Zorn.
TJNAF, 12000 Jefferson Ave., Newport News, VA 23606

S. Stepanyan, G. Asryan, M. Tarverdyan, E. Araratyan, K. Egiyan, and S.Mailyan
Yerevan Physics Institute, Yerevan, Armenia.

Abstract:

Results are presented of an extruded grooved scintillator module produced at TJNAF from scintillators produced at the Yerevan Physics Institute. For a 1 cm thick scintillator with ten 1 mm waveshifting fibers an average signal of 35-40 photoelectrons per cosmic particle was measured.

1. *Introduction*

Embedded waveshifting fiber readout of scintillators is a well known technique [1]. Usually a waveshifting plastic fiber is placed into a groove that is machined in a plastic scintillator to capture and transmit the light to a photomultiplier tube (PMT). This technique has a great advantage in the ease of manufacture and assembly of large sized calorimeters. The action of machining the scintillator, however, raises the costs of production while also exposing the scintillator to the possibility of damage from handling and solvents. In the case where one needs long scintillators with straight grooves or a detector made from such pieces, these problems can be mitigated by using extruded scintillators with the grooves produced automatically during the extrusion process. By using a special attachment, designed and made at TJNAF, the Yerevan Physics Institute has produced such extruded grooved scintillators for tests at TJNAF.

2. *Scintillator modules*

About 2 meter long extruded polystyrene scintillator modules of a 1 cm by 10 cm cross-section were produced at the Yerevan Physics Institute. Five equally spaced 2 mm half-circular grooves were created during the extrusion process with a special extrusion head [2]. The grooves are spaced 16.7 mm from each other and the edge of the scintillator. This spacing results in about a 5% drop in the signal at the edges of the scintillator as compared to a distribution with the outer fibers shifted more towards the sides [2]. The optical quality of the surface of the grooves was found to be as good as that of the flat surfaces.

The production procedure was intentionally simplified without strict purification steps normally undertaken to demonstrate the immunity of the waveshifting fiber method to the attenuation quality of the plastic. We have already demonstrated in the past that poor quality acrylic scintillators with attenuation components of 105 and 130 cm showed much longer attenuation lengths characteristic of the BCF92 waveshifting fibers when the waveshifting fiber readout method was used [2]. The emission and transmission of the Yerevan scintillator is shown in figure 1.

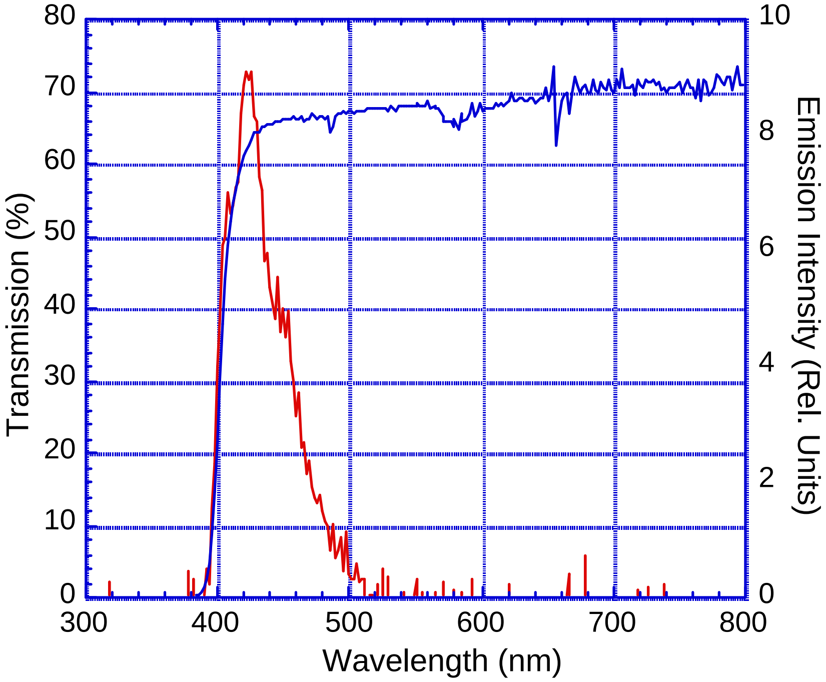

Figure 1: Emission and transmission of Yerevan scintillators.

To demonstrate the flexibility of scintillator module design, two scintillator modules were prepared by gluing two 1 meter long pieces at a 60 degree angle (figure 2). Waveshifting fibers were glued in the grooves using the UV/visible curable adhesive, Dymax 3-20262 [3]. This adhesive is specifically designed to glue acrylic to polystyrene, however, it has a slightly milky appearance after curing. Transmission through a 2.2 mm layer of this glue after curing is shown in figure 3 in comparison to a clearer 1.6 mm sample of Dymax 4-20260 adhesive. It matches the emission spectrum of the scintillator used quite well (figure 1 above). Two 30 mm R580-17 Hamamatsu PMTs with extended green bialkali photocathodes were used to detect light from the fibers.

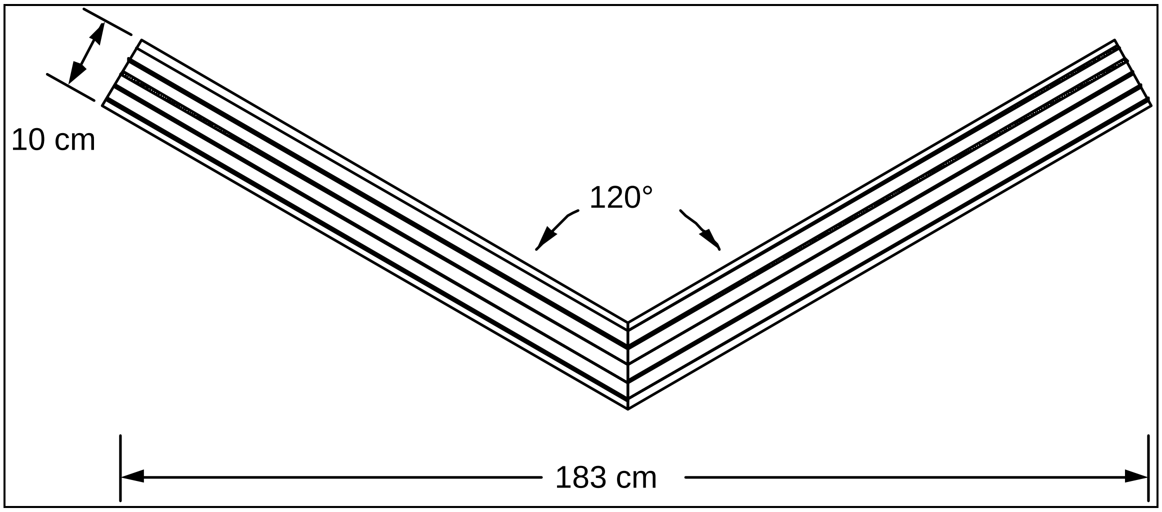

Figure 2: Extruded grooved scintillator module with waveshifting fibers glued into the grooves.

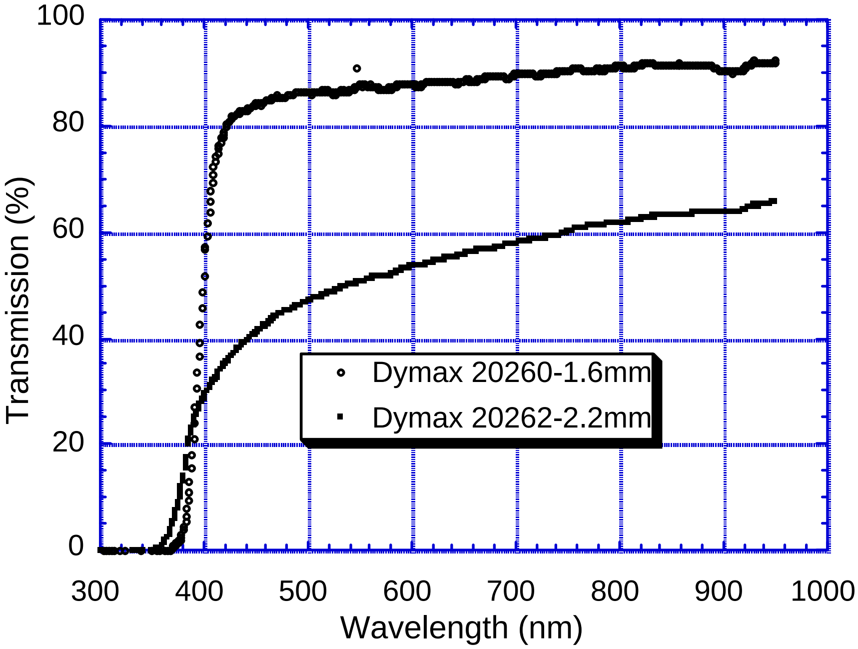

Figure 3: Comparison of transmission through Dymax UV curable glues.

2. Results

The first module was made with 2mm diameter fast Bicron BCF-92 waveshifting single clad fibers. The fibers extended 1 meter beyond the scintillator on both ends. After gluing, the module was tightly wrapped with Tyvek white diffusing paper. Both scintillator ends were left unpainted and also covered with Tyvek paper. The average amplitude measured with cosmic particles was practically stable for positions before the bend. Figure 4 shows the amplitude spectra obtained for 5 equidistant (20 cm spacing) positions starting 5 cm from the right end of the module as measured with the right PMT. An average number of 10 photoelectrons were measured per cosmic particle. For the positions of the cosmics trigger placed on the other side the bend the signal dropped dramatically and analysis showed that the fibers were damaged during bending and the light was poorly transmitted from the left part of the module to the right PMT and vice versa.

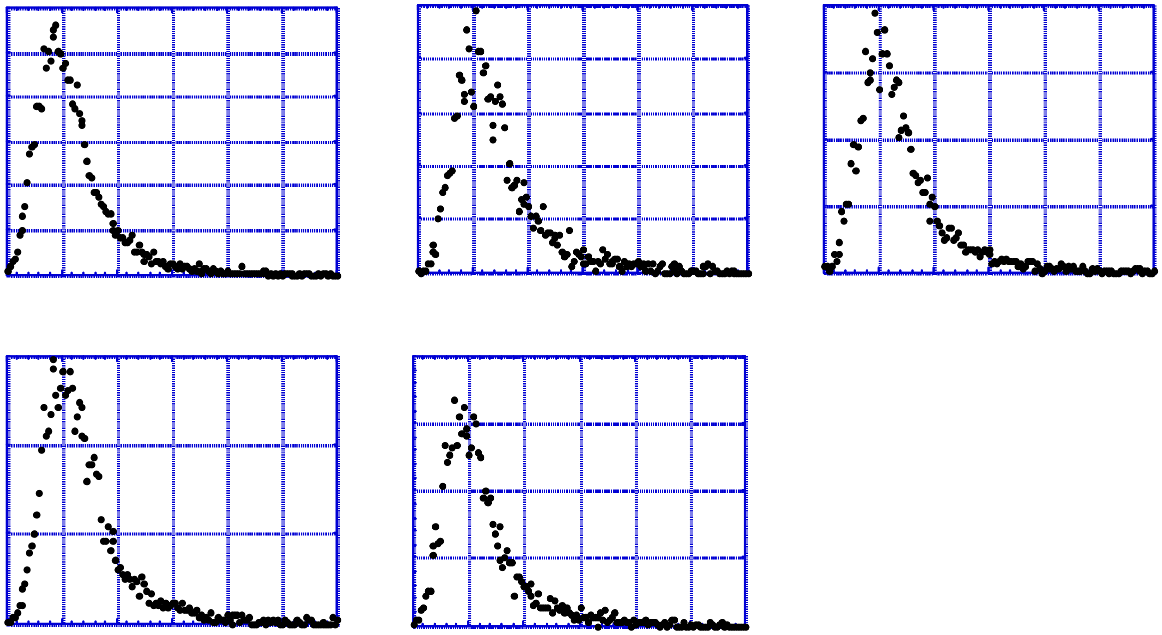

Figure 4: Amplitude spectra obtained for 5 equidistant (20 cm spacing) positions with five 2 mm diameter embedded fibers.

A second module was made using ten 1 mm diameter double-clad Y11 waveshifting fibers from Kuraray. Two fibers were glued in each groove. The fibers extended about 50 cm from both ends of the modules and the module was wrapped with white diffusing Teflon tape. Again R580-17 Hamamatsu PMTs were used to measure the light output. Summing both outputs produced a reasonably uniform response across the module (figure 5). A 20% drop in light output was observed in the scintillator "knee" which is blamed on not sufficiently careful treatment of the fibers during bending. Examples of cosmic spectra obtained from the sum of both PMTs for 6 positions of the cosmics trigger along the module is shown in figure 6. One also sees the great stability of the summed response along the scintillator module. An average summed signal of 35-40 photoelectrons per cosmic particle was measured.

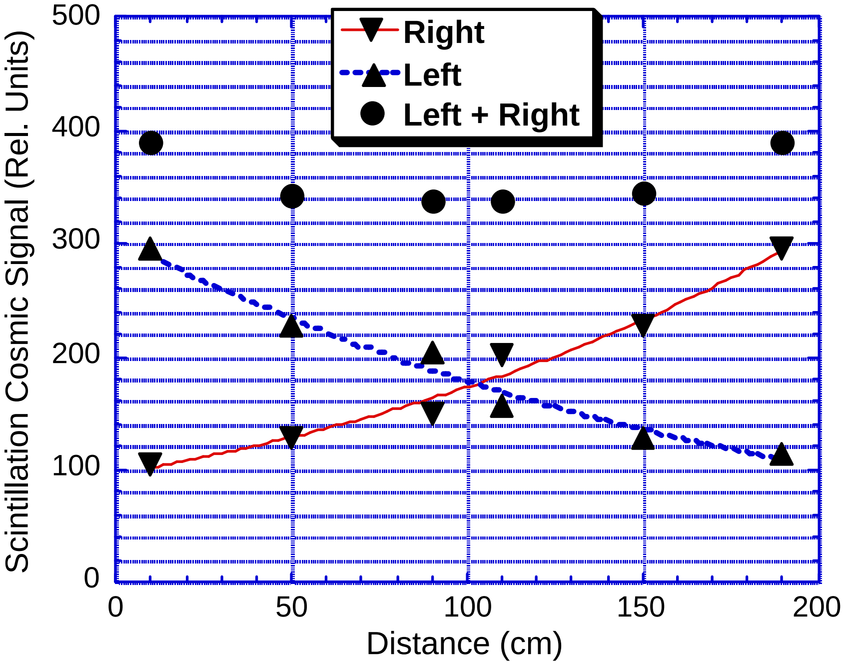

Figure 5: Left, right and summed output of the scintillator module using ten 1 mm diameter embedded fibers.

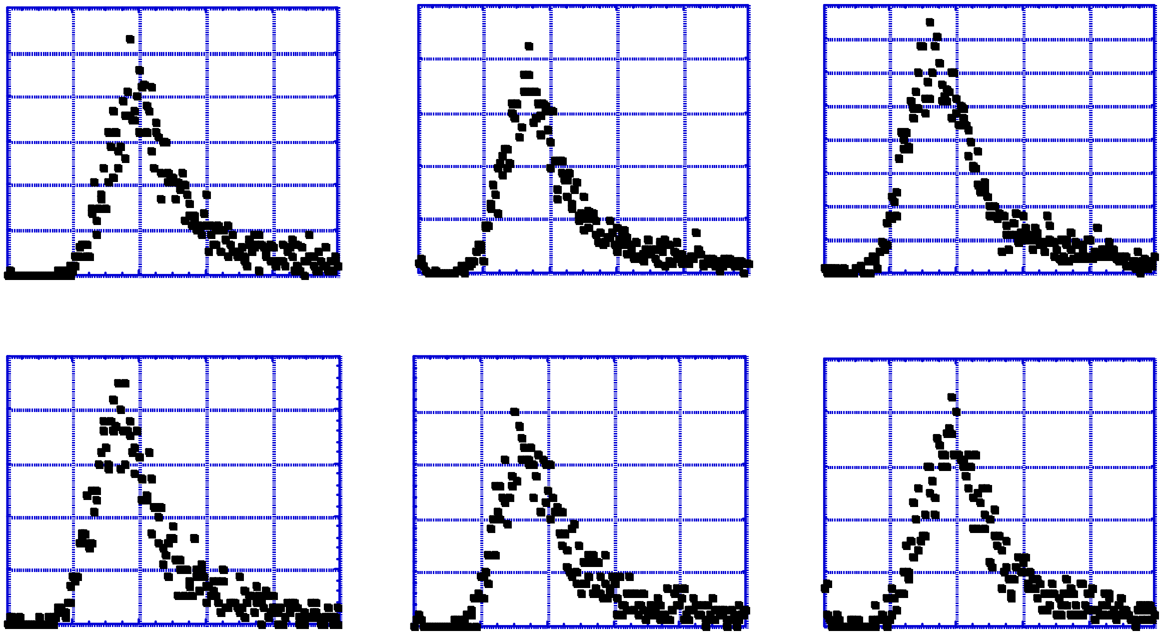

Figure 6: Summed (left + right) amplitude spectra obtained using ten 1 mm diameter embedded fibers.

Summary

It was confirmed that when using glued waveshifting fibers, the light attenuation of scintillators with rather poor transmission properties (attenuation length, in this case, of under 160 cm) can be overcome. Due to waveshifting fiber flexibility, modules of complicated shapes are possible provided that proper care is taken during fiber bending. UV/visible cured adhesives offer a practical economical and time-saving method for gluing in the fibers.

References

[1] M. G. Albrow et al., Nucl. Instr. and Meth. A256 (1987) 23.
J. Simon-Gillo et al., Nucl. Instr. and Meth. A309 (1991) 427.
J. E. Simon-Gillo, The Construction, Testing and Performance of a Pb/Scintillator Calorimeter with Fiber Optic Readout Built for Relativistic Heavy Ion Studies, Ph. D. Thesis, UMI-92-17024, 1991.
P. de Barbaro et al., Nucl. Instr. and Meth. A315 (1992) 317.
D. Fox et al., Nucl. Instr. and Meth. A317 (1992) 474.
M. Albrow, The CDF Plug Calorimeter Upgrade and Beam Tests of Tile-Fiber Calorimeters, contribution to the 1992 International Conference on Advanced Technology and Particle Physics, Como, Italy, June 1992.
M. Lindgren, The CDF Plug Calorimeter Upgrade, Proceedings of the Third International Conference on Calorimetry in High Energy Physics, Sept 29-Oct 2, 1992, Corpus Christi, Texas, p. 61.
J. Proudfoot, The SDC Central Calorimeter, ibid, p.77.
P. Cushman, Particle Identification in SDC: Shower Maximum and Preshower Detectors, ibid, p.321.
D. G. Underwood, Some Fiber-Tile Optical Studies for SDC Electromagnetic Calorimeter, ibid, p.593.
T. Camporesi et al., Prototype Design, Construction and Test of a Pb/ Scintillator Sampling Calorimeter with Wavelength Shifter Fiber Optic Readout, CERN-PPE-92-212 (Dec. 1992).
J. P. Sullivan et al., Nucl. Instr. and Meth. A324 (1993) 441.
G. Apollinari et al., Nucl. Instr. and Meth. A324 (1993) 475.
G. Apollinari et al., IEEE Trans. Nucl. Sci. NS40 (1993) 484.
D. Autiero, et al., Characteristics and Performance of an Electromagnetic Shower.
Sampling Calorimeter with Wavelength Shifting Fiber Readout, INFN-PI-AE-93-05, March 1993.
A. Byon-Wagner et al., Study of Hadronic Shower Development Using the Reconfigurable- Stack Calorimeter, presented at the Fourth International Conference on Calorimetry in High Energy Physics, Isola d'Elba, Italy, September 19-25, 1993.
L. Poggioli et al., Preliminary Results of an Iron / Scintillating Tiles Hadron Calorimeter, ibid.
P. De Barbaro et al., Tile-Fiber R&D Results and the Hadron Calorimeter Production, ibid.
M. Mishina et al., New Plug of CDF, ibid.
G. Apollinari et al., CDF Plug Upgrade: The Shower Maximum Detector, ibid.
[2] R. Wojcik, B. Kross, S. Majewski, A.G. Weisenberger, C. Zorn, Embedded waveshifting fiber readout of long scintillators, Nucl. Instr. and Meth. A342 (1994) 416.
[3] Dymax Corporation, 51 Greenwood Rd., Torrington, CT 06790.