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FIBER-OPTIC LIGHTGUIDES IN SCINTILLATOR TELESCOPES FOR CHARGED PARTICLE DETECTION

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The use of flexible fiber-optic bundles as lightguides for thin scintillators in a telescope is described. The telescopes will be used in the pion induced fission experiment $\pi^{+6}\text{Li}\rightarrow 2^3\text{He}$. The fiber-optic lightguide detector was tested, under identical conditions, against a conventional lightguide-detector arrangement and for α-particles of 5.5 MeV. An efficiency >99% was obtained with a relative transmission efficiency of ~45% compared to the conventional lightguide arrangement.

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The use of fiber-optic lightguides, coupled to thin scintillators, has been reported in the literature. Lightguides of this type have been used in a 1 mm granularity hodoscope array for 200 GeV minimum ionizing hadrons [1]; they have also been used to discriminate between highly ionizing (low energy) muons and minimum ionizing positrons [2]. Here we report, for the first time, the use of fiber-optic lightguides in a telescope array where particle identification is necessary (fig. 1). Fiber-optic bundles used as lightguides for thin scintillators can provide an attractive alternative to the standard plexiglass UVT lightguides. For lengths up to 60 cm they have been shown to provide good overall transmission when properly matched to the scintillator material [3]. They are easy to machine and couple to the plastic and are light weight and flexible. These last two properties are important in applications where the rigidity and weight of the UVT plexiglass lightguides pose structural stress and space problems. In addition the equal length of the strands in a bundle of fibers provides the potential of excellent timing due to decreased path length of reflections as compared to adiabatic plexiglass lightguide strips. Due to the same effect, attenuation within the narrow confines of each fiber strand is more uniform, resulting in slightly improved resolution when monochromatic light is transmitted.

In our case a scintillator of NE102 [4] of 300ℓ × 90w mm^2 and 0.8 mm thickness was coupled to two fiber-optic bundles, on one end only, covering the 90 mm width. An identical detector was coupled to a standard adiabatic UVT lightguide with a 90° bend. The peak emission wavelength of 423 nm matches the 400-2000 nm transmission spectrum of the DuPont Crofon fibers. The fiber bundle of 91.4 cm length contains

5880 strands of 50 μm diameter each [5]. The bundle ended in 6.3 mm epoxied and polished edges contained in nickel plated metal tips. The bundle was cut in half and the strands were fanned out and dipped in epoxy (Econobond 24) and allowed to dry. They were subsequently sanded and then cleaned by using 600 emery cloth. They were coupled to the NE102 plastic with the same Econobond 24 epoxy and were given extra rigidity and support with the use of a plexiglass clamp also epoxied onto the plastic and the fibers. A sketch of the detector and fiber-optic lightguide arrangement is given in fig. 2. The metal tips were inserted in a plexiglass UVT rod (12.7 cm × 4.1 cm ϕ) as shown in fig. 2. The rod was coupled to a Philips XP2230H PMT with optical cement [6]. For reasons of consistency the same PMT and base assembly were used for the tests of the two detectors; in this way the differences were isolated to the fiber-optic vs. UVT plexiglass performance.

The tests were conducted under controlled conditions, using two sources: an α-source (^{241}Am) with ~5.5 MeV energy and a β-source (^{106}Ru) with a spectrum of electrons in the 20 keV to 3.5 MeV range. The α-source was positioned directly on top of the plastic and under the 25.4 μm aluminized mylar and 0.25 mm black vinyl wrapping of the scintillator. The β^--source was always positioned with the light tight wrapping between it and the plastic scintillator. In both cases the light tightness of the detectors was assured and verified on an oscilloscope. The α-particles were used in order to imitate the energy loss expected from the ^{3}He nuclei in the $^6\mathrm{Li}(\pi^{+3}\mathrm{He})^3\mathrm{He}$ reaction while the electrons from the ^{106}Ru were used to test the sensitivity and efficiency of particles expected from the $\pi^{+6}\mathrm{Li}\to X_1 X_2$ reaction where X_1, X_2 are protons, deuterons or tritons.

Two characteristic ADC spectra which were taken with the α-source, and the same PMT bias for each detector-lightguide combination, are shown in fig. 4. Compared to the scintillator-UVT lightguide detector, the scintillator-fiber-optic combination exhibits 45% transmission efficiency and approximately 34% improved resolution. Since the noise level is dependent on PMT, dynode chain, temperature and high voltage value, the threshold for both cases on the leading edge discriminator was the same. The efficiency of the fiber-optic coupled scintillator, as compared to the UVT standard, was checked with both sources and found to be >99%.

The detectors mounted on a telescope as shown in fig. 1, will be used for particle identification and therefore any significant pulse height variation over the 30 cm length of scintillator will degrade the identification capability. In order to test for any absorption effects the α-source was positioned at varying locations on the plastic along its length. The resulting variation in the ADC located mean of the peak was less than 5% over the whole length whereas the resolution (FWHM) was typically 25% and as a result the particle identification is not hampered by the shape of the scintillator; otherwise two more fiber bundles could have been coupled to the other end of the scintillator and fed into the same PMT for cases where the expected energy loss would be much smaller than ~5.5 MeV.

In the final experimental configuration the thickness of the dE/dx counter is 1 mm and wrapped with 21.6 μm of aluminum foil. In order to ensure complete area coverage for increased transmission efficiency, three fiber-optic lightguide bundles are coupled to one end of each

Figure Captions

Fig. 1. A schematic drawing showing the counter arrangement for one telescope arm for the four detectors. A total of six arms are deployed in the experiment arranged in three pairs of two associated telescopes each.

Fig. 2. The 300 × 90 × 1.0 mm^3 scintillator coupled to three fiber-optic bundles in the final configuration (a) overall view (not to scale), (b) side view showing details of the coupling arrangement and (c) detail of the coupling between the fiber bundles and the 4.1 cm θ plexiglass rod to be optically coupled to the photomultiplier tube.

Fig. 3. (a) ADC spectrum obtained with an α-source and the scintillator coupled to UVT plexiglass adiabatic lightguide.
(b)ADC spectrum as above but for the counter with the fiber-optic (twin bundle) lightguide.

Fig. 4. Energy loss spectrum for 1 mm thick, three fiber optic bundle lightguide counter as in fig. 2, indicating the resolving power for 80 MeV pions and 109 MeV protons as described in the text.

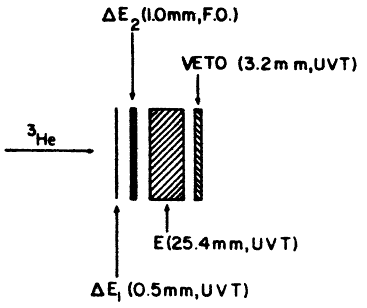

Figure 1

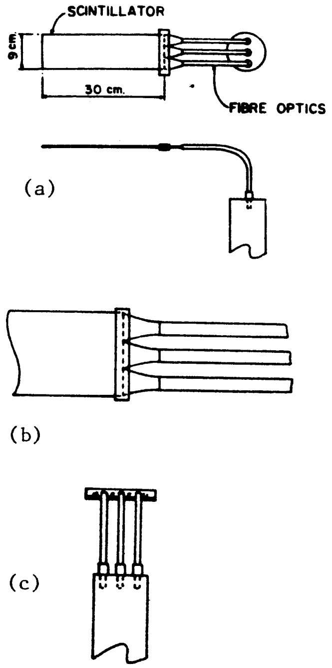

Fig. 2

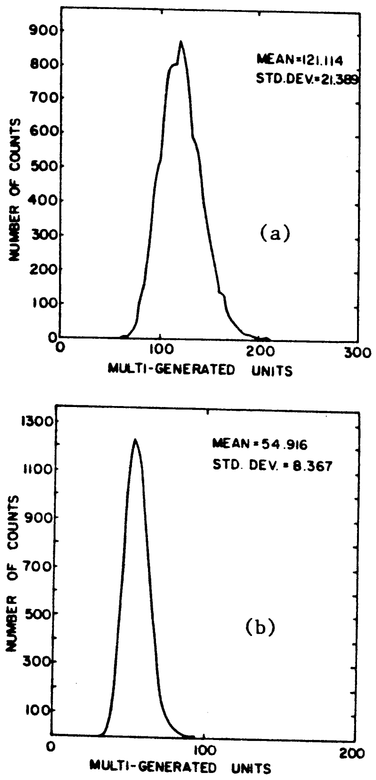

Fig. 3

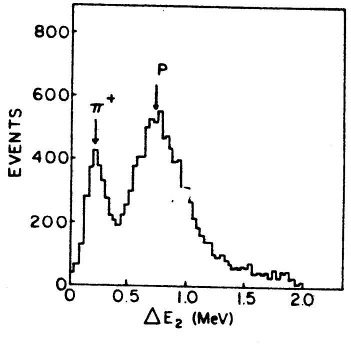

Fig. 4

counter. In all respects the arrangement is similar to the two bundle case described in this paper. In this 1 mm thick-3 bundle configuration the counter was tested, as part of the whole telescope, in the M11 pion channel at TRIUMF under operational conditions of beam intensity, background and target thickness. As can be seen from fig. 4 the ΔE_2 counter easily separates in a one dimensional plot the 700 keV mean energy loss of the protons from the $\pi^+ d \rightarrow pp$ reaction (T_p = 109 MeV) from the minimum 300 keV energy loss from elastically scattered pions ($T_\pi \lesssim 80$ MeV) from the $\pi d \rightarrow \pi d$ reaction and the target surrounding material. The efficiency under these conditions was also measured to be >99%. It is worth noting here that for the expected ^{3}He energy loss (6 MeV $< \Delta E_2 <$ 11 MeV) the corresponding peak would be off the ADC scale.

In conclusion, we have tested fiber-optic lightguides for energy loss counters in telescope arrays to be used in pion absorption experiments at the M11 high energy TRIUMF pion channel. We have found that fiber-optic lightguides can replace rigid plexiglass lightguides with relative transmission efficiency of ~45% and absolute efficiency >99%. These numbers are in good agreement with the results of refs. 1 and 2.

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References

[1] J.E. Elias, G. Mikenberg, T. Minto and G.A. Weitsch, IEEE Trans. Nucl. Sci NS-25 (1978) 543.

[2] M.J. Yang, R. Gabriel, W.W. Kinnison, H.S. Matis and H.L. Anderson, Nucl. Instr. and Meth. 185 (1981) 115.

[3] R.G. Brown and B.M. Derick, App. Opt. 7 (1968) 1567.

[4] Obtained from Nuclear Enterprises, Edinburgh, Scotland

[5] Obtained from Efstonscience, Toronto, Ont., Canada.

[6] Dow-Corning QZ-3067 optical couplant obtained from Dow-Corning Corp., Michigan, USA.