Tests of a Pre-Prototype ILC Muon Detector Module

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Results are presented of source and cosmic ray tests of a pre-prototype muon detector intended for use in ILC detectors. The detector is composed of strips of scintillator arranged diagonally across a panel, with wavelength-shifter fibers imbedded in grooves along the lengths of the strips.

1. DESCRIPTION OF TEST MODULE

The module tested was built by Notre Dame University as a reduced-sized mechanical pre-prototype. Its main purpose was to learn construction techniques and, as such, it was not designed for optimal light collection efficiency. The module is rectangular, 0.5m by 1.25m in size, and consists of 27 strips of scintillator arranged diagonally across the module. The central 9 strips are of equal length and run across the full width of the module. The other 18 strips are of varying lengths at the corners. Light produced in the scintillators is collected and transmitted to a cookie by wavelength-shifter fibers, as shown in Figure 1.

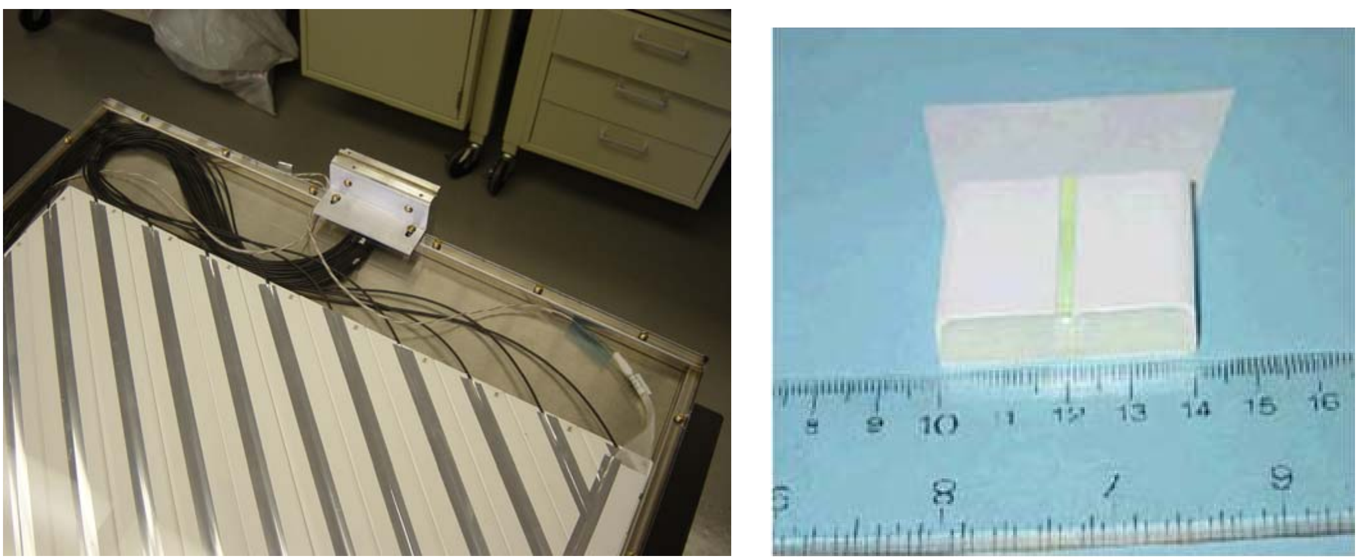

Figure 1. Test Module and cross-section of scintillator strip

A detailed picture of the end of a scintillator strip is also shown in Figure 1. The strips are 10mm by 41mm cross-sction, doped with a blend of PPO and POPOP dopants. The strips are coated with titanium dioxide for diffuse reflectivity. The wavelength shifter fibers are 1.2mm diameter polystyrene doped with p-terphenyl and have dual cladding.

2. TEST RESULTS

2.1. Calibration of Photomultipler

A single Hamamatsu E934 PMT (Photo-Multiplier Tube) was used to detect the light from the test counter. The gain of the PMT was measured using a PMT test facility at Fermilab. The light from a cell pumped into fluorescence by a laser and filtered to produce single photons is received by the PMT and monitored by photodiodes. The signals from the PMT are analyzed by an ADC (analog-digital converter), and the resulting gain is calculated from the ratio of the variance of the distribution to the mean. The gain was measured as a function of HV (high voltage) from 1400V to 2000V. At the operating HV of 1800V the gain is 34 x 10**6, which corresponds to a mean charge of about 18 pC (pico Coulombs).

2.2. Cosmic Ray Pulse Height Analysis

The cosmic ray test setup is shown in Figure 2. A cosmic ray trigger consists of a triple coincidence of signals from 3 counters (A, B, and C) above and below the test counter. Counter B is the same width as a single strip and it is oriented along the strips. Signals from the ILC test counter are analyzed by a LeCroy LRS 2249 ADC,which is gated by ABC triples.

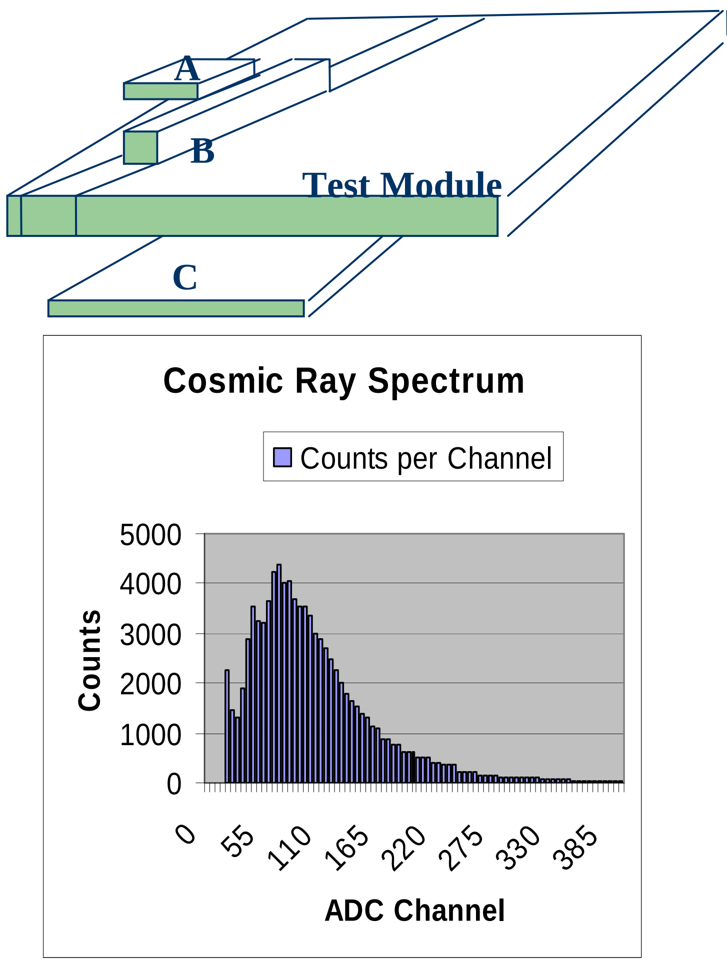

Figure 2. Cosmic Ray Test Setup and Spectrum

2.3. Cosmic Ray Uniformity Tests

The efficiency for cosmic rays was measured at a number of points on the test counter to check for uniformity of response. Measurements were made at the points illustrated in Figure 3.

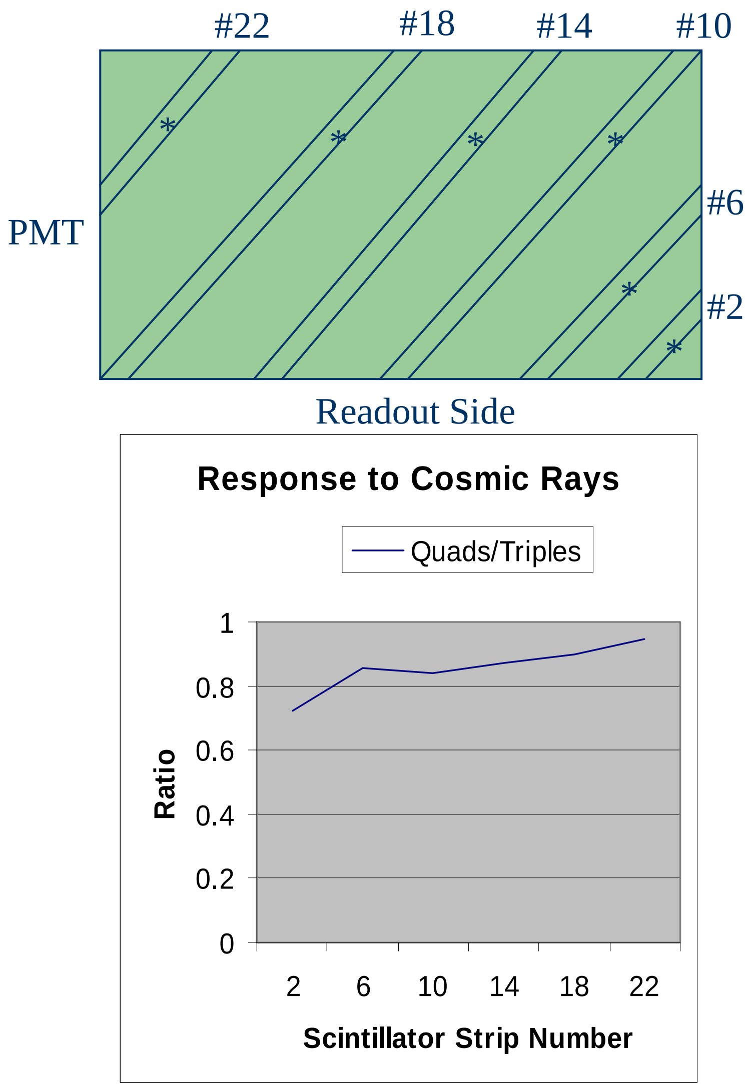

Figure 3. Test Points for Cosmic Ray Tests and Results

The results of the tests are shown in Figure 3. The tests were made at a discriminator setting of 30 mV. There is a falloff in efficiency with distance from the end at which the PMT is located. We interpret this as due to attenuation in the wavelength shifter fibers that run all the way from the scintillator to the PMT. In the future prototypes clear fibers will be spliced to the wavelength shifter fibers between the scintillator and the PMT.

2.4. Source Tests

Tests were also made with a 1 mCi Cs137 source, which produces gamma rays, predominantly at 660 keV. The source was positioned at various points on the ILC counter, with a collimator 2 inches thick between the source and the counter. At the center of strip #22 the source gave a peak response of about 75 pC as measured on an Lecroy qVt analyzer. To measure the response to the source, we measured the singles rates with a discriminator set at 300 mV threshold. A series of measurements was made to map the response at many different points on the counter.

The first set of measurements was made at the centers of the even-numbered strips, as illustrated in Figure 4.

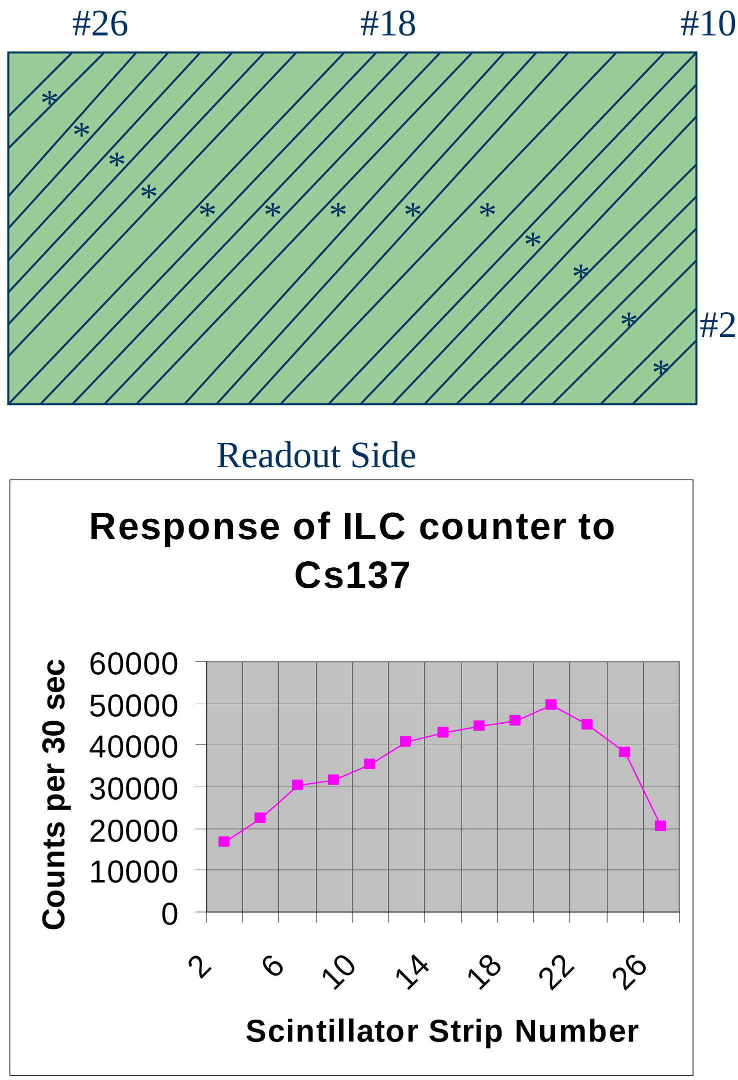

Figure 4. Positions of source and measurements at centers of strips.

The data show a significant variation across the detector, with rates decreasing with distance from the PMT except for another decrease in the shorter strips near the PMT strips. The behavior is similar to the cosmic ray data, although more pronounced

Measurements were also made as a function of distance along the strips, as illustrated in Figure 5. Three equal length strips were measured - #10, #14, and #18. The results are shown in Figure 5. There is a falloff with distance from the readout end, and a falloff at the near end, possibly due to light collection loss at the near end.

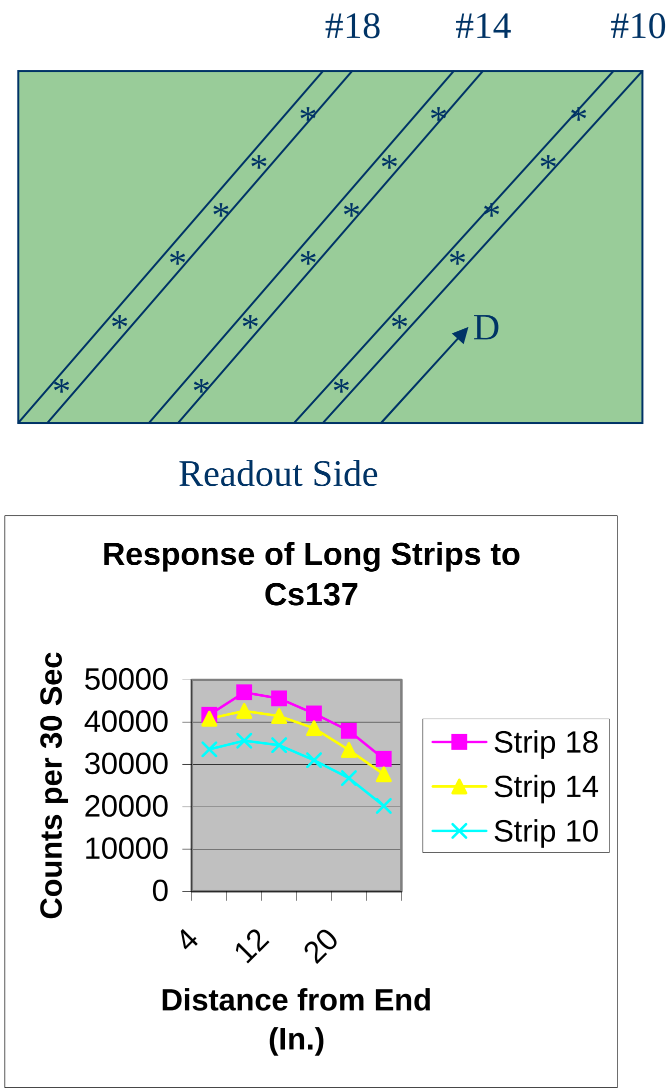

Figure 5. Positions of source and measurements along lengths of strips

3. CONCLUSIONS

Test results showed lower light output than required for a production module, and there were significant variations of response at various points on the module. As this was a mechanical pre-prototype, not designed to be optically efficient, the results are not unexpected. The next detector plane, a half-scale prototype, will have clear fibers spliced to the wavelength-shifting fibers and other optical improvements. It will be completed in the summer of 2005 and we will perform similar tests on it, using a multi-anode PMT and prototype readout and analysis techniques.

Ackowledgments

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