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Development of a Detector Prototype for future High Energy Gamma Ray Experiments

Abaz Kryemadhi,[a,*] Matthew Farrar,[a] Brandon Weindorf,[a] Aeowyn Kendall[a] and Al Mokris[a]

[a] *Messiah University,*
One University Ave, Mechanicsburg, PA, USA
E-mail: akryemadhi@messiah.edu

Future high energy gamma ray experiments propose a rich physics program ranging from understanding the particle accelerators, detecting very high energy gamma ray bursts,and probing new physics beyond the Standard Model. Water Cherenkov detectors with photomultiplier tubes have been the traditional detector technology owning to the large sizes the photomultiplier tubes can be manifactured, hence higher light yields. The drawbacks of these devices is their higher voltage of operation and a small number of manifacturers. Silicon photomultipliers are the solid-state equivalents which operate at lower voltage with large number of vendors producing them. The main drawbacks of SiPMs is their small surface area and higher dark rate. We constructed a Cherenkov detector prototype readout by silicon photomultipliers as an alternative to traditional detectors. In order to circumvent the silicon photomultipliers small area we used a light-trap and wavelength shifting block to increase light collection efficiency.

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1. Introduction

In order for next generation indirect high energy gamma ray experiments to reach a vast scientific potential they have to cover large area and operate at higher elevation under higher trigger rates. (See [1]) More numerous smaller water Cherenkov detectors (WCDs) readout by silicon photomultipliers (SiPMs) could be adventagous for ease of installation of such an array while maintaining a smaller rate per detector. A direct readout of Cherenkov light by the SiPMs is untenable due to their small area so light-traps and blocks of wavelength shifters (WLS) were investigated to increase the light collection efficiency. We characterize the detector's performance and report a preliminary light yield. This study was motivated by previous work where 5.0 mm WLS fibers were used to increase the light yield, and the results with fibers were encouraging. [2]. Thus the goal was to pursue other configurations with the purpose of optimizing light collection efficiency.

2. Experimental Setup

Our detector prototype is an open top cylindrical polyethylene tank with diameter of 71 cm and height of 106 cm. The tank was filled with about 380 liters of water which underwent 1 micron and 5 micron filtering followed by reverse osmosis and de-ionization. All the inner surfaces of the tank were wrapped with Tyvek 1085D chosen for its highly reflective and diffuse surface. The tank was translucent so it was wrapped on the outside by layers of light proof plastic and black cloth as shown in figure 1.

A silicon photomultiplier (SiPM) array from SensL (2x2 ArrayJ60035) detects the photons. The readout board was custom made as described in ref [3]. The waveforms from the detector were captured by CAEN V1720 digitizer and data processed with CERN ROOT software.

For the light-trap detector configuration we used two short pass filters from Andover Corporation (400FL07-50S) with a cutoff wavelength of 400 nm. We used EJ-286 WLS block with dimensions 10 mm x 50 mm x 100 mm, which shifts wavelengths to larger than 400 nm, hence light is trapped from opacity of filters at larger wavelengths. All the other areas of WLS block are covered with teflon tape apart from filters area and readout area. Figure 2(Left) shows a picture of the light-trap mounted on the lid with custom made 3-D printed hardware. Similar approach was taken for light-trap in reference. [4]

For the WLS block detector configuration we used EJ-286 WLS block with dimensions 10 mm x 40 mm x 1000 mm embedded directly in water. The SiPM board is mounted to the side of the bar. Figure 2(Right) shows a picture of the bar with 3-D printed casing for SiPM mounting.

3. Measurements & Analysis

We measure the amplitude and consequently the light yield. In a previous work we determined the single photon calibration of ~ 2 voltage ADC. Figure 3 shows the normalized amplitude spectrum obtained when a cosmic ray muon passes through our detector for our light-trap configuration, the dark spectrum and the difference. Cosmic ray muons were triggered by plastic scintillators on top and bottom of the detector. The plastic scintillators had a length of 25 cm, a width of 25 cm, and a

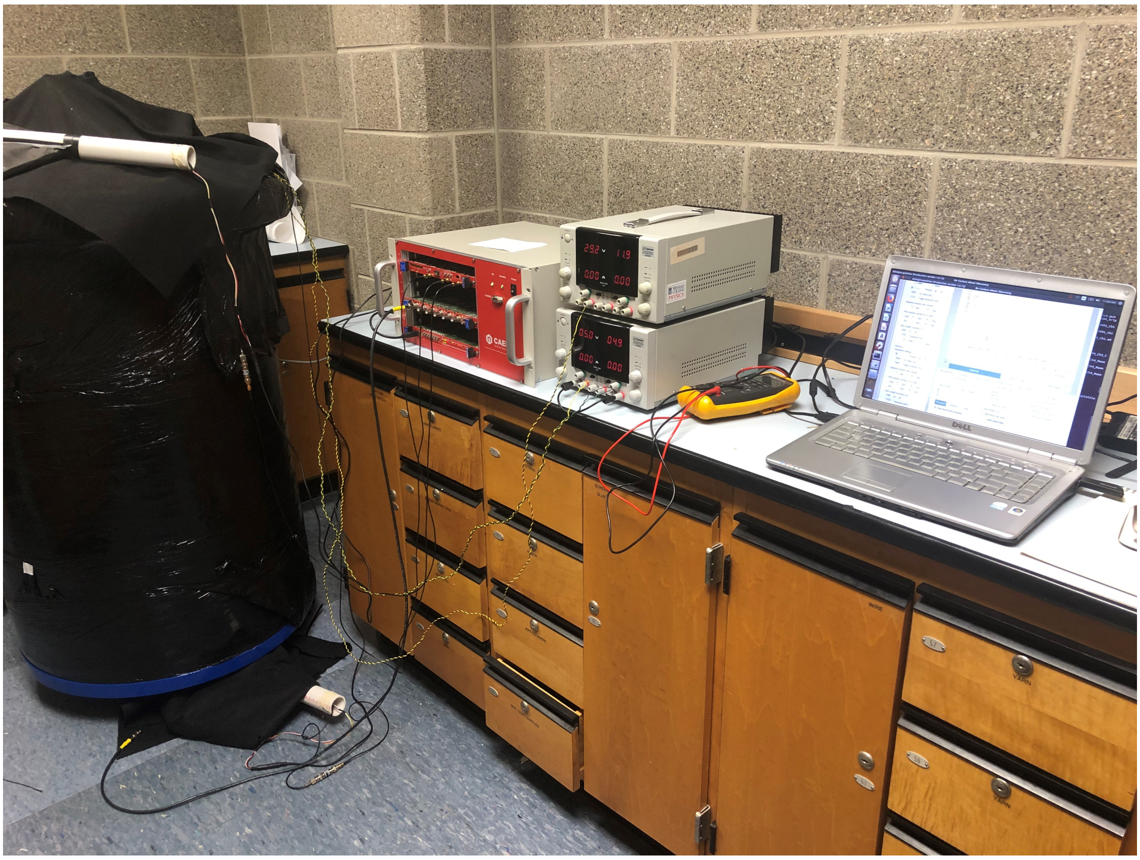

Figure 1: (Left) A picture of our setup. The 380 liter barrel is wrapped in black, the scintillator paddles are on top and bottom and the readout is using CAEN V1720 digitizer. (Right) The dark rate ADC spectrum.

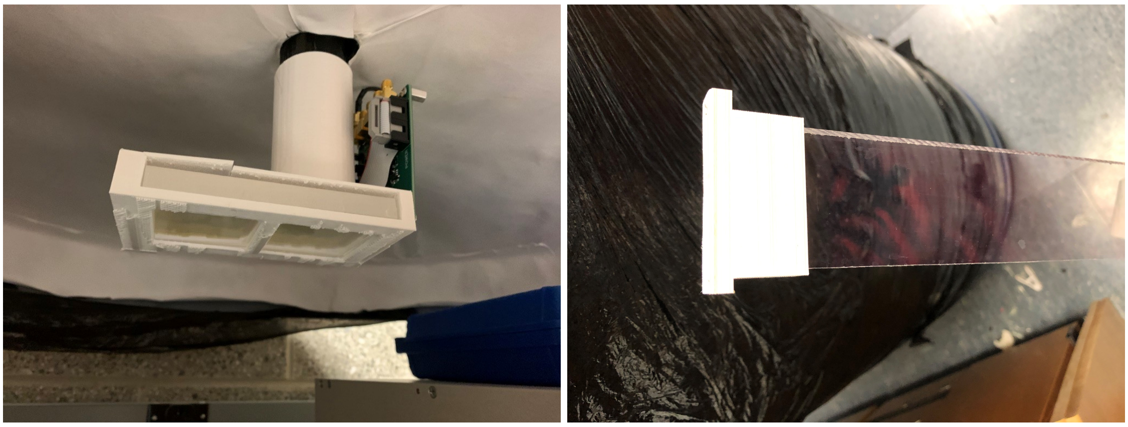

Figure 2: (Left) Picture of the light-trap system. (Right) Picture of Light bar block.

thickness of 1 cm. The muon detectors are placed in such a way that the muons will not pass directly through the WLS material. An excess over dark spectrum is observed resulting in a light-yield of greater than 20 ADC (greater than 10 photo-electrons)

Figure 4 shows the amplitude spectrum obtained when a cosmic ray muon passes through our

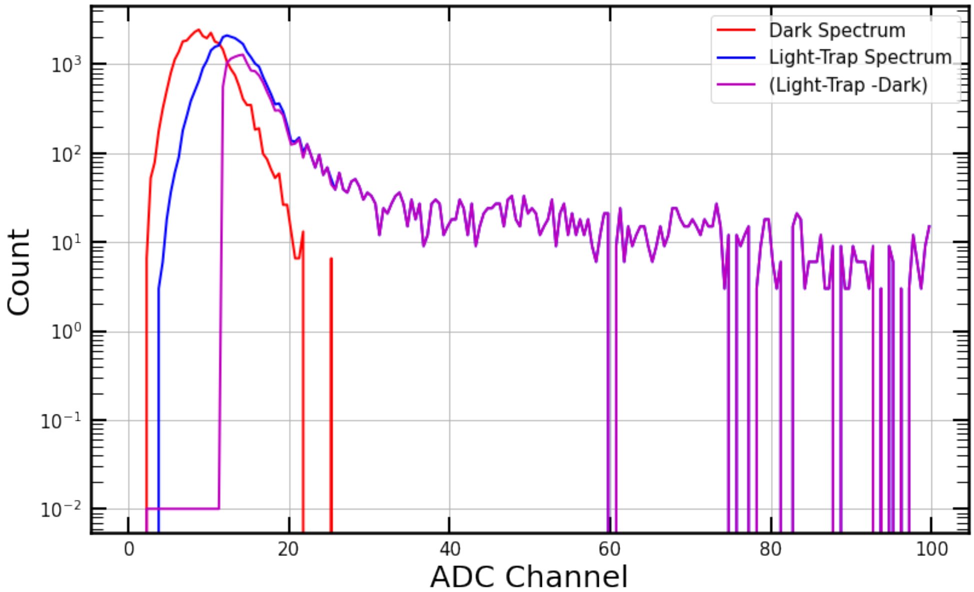

Figure 3: Muon ADC spectrum for light-trap configuration.

detector for our light-bar configuration. A similar excess over dark spectrum is observed here too resulting in a light-yield of greater than 20 ADC (greater than 10 photo-electrons)

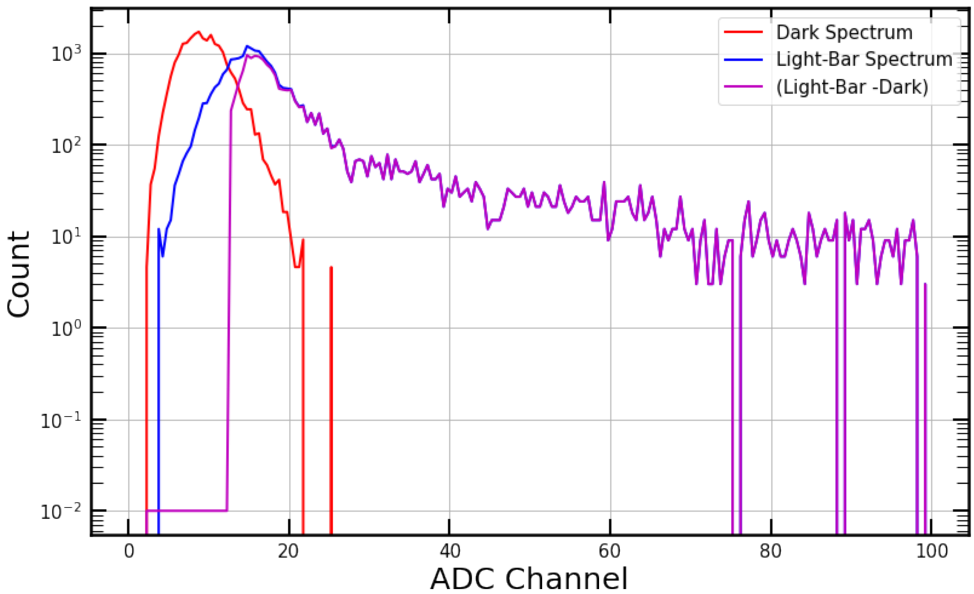

Figure 4: Muon ADC spectrum for light-bar configuration.

While the light yield observed is certainly encouraging, further analysis is needed to exclude correlated shower events that pass through the WLS material and cause Cherenkov radiation directly on those materials.

4. Conclusion

We constructed a WCD using a light-trap technique and WLS bar technique with a SiPM readout where we were able to separate the cosmic ray muon signals from the dark rate noise. The light yield observed is encouraging however further investigation is needed about its source.

5. Acknowledgement

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