Four channel Cosmic Ray detector based on polymaq

K N Herrera-Guzman, R A Gutierrez-Sanchez, J Felix

Department of Physics Engineering, University of Guanajuato, Leon, GTO 37150
felix@fisica.ugto.mx

Abstract. The Cherenkov radiation has been widely studied in transparent materials, and applied to detect and identify elementary particles. But it has not been widely studied in opaque materials. A four channels radiation detector has been designed, built, characterized, and operated; based on four polymaq (UHMW-PE) bars of 2.54 cm X 5.08 cm X 25.4 cm, which is an opaque material to visible radiation to the human eye. Silicon photo detectors, Hamamatsu, avalanche type (APD) are used to detect the radiation produced by the passage of particles in the detector blocks. The design, construction, characterization, operation, and preliminary results of this cosmic ray detector details are presented.

1. Introduction

The cosmic rays are particles coming from outer space and can be charged or neutral particles. There are two types of cosmic rays: primary and secondary. The primary are generated by astrophysical sources such as supernovae, stars, pulsars, etc. The secondary are generated by collision of primary cosmic rays with interstellar gas, this means that earth atmosphere is a source of secondary cosmic rays [1].

The Cherenkov radiation is produced when a charged particle travels faster than light in a medium (radiator), this radiation can be detected by photomultipliers [2].

There are several types of cosmic ray detectors using Cherenkov radiation [3] [4] [5], but most of them are based on transparent materials. New radiator materials can allow us to explore different energetic regions of detection and particles.

The aim of this work is to know if Cherenkov radiation is produced in an opaque material like polymaq [6], if so, it must be detectable. Due to that, a prototype with this characteristic (an opaque material as Cherenkov radiation producer) was built tested and characterized.

2. Design

The design consists in four detection channels made of Aluminum tubes with polymaq bars inside, in a vertical arrangement. Two types of polymaq bars are used: White and black. The arrangement is as follow: One tube with a white polymaq bar, on it, a tube with a black polymaq bar and so on up to four.

Each polymaq bar has a cavity in middle of one of its faces and one photodiode is placed in that cavity. The photodiode is supported in its cavity by an electronic support card (PSC) that has two right angle pins for supplying voltage (Figure 1).
Two Aluminum caps, for each tube, are used for inclosing completely the polymaq bars. The objective of the Aluminum tubes and caps is isolate as much as possible the photodiode of external radiation. The tubes are between two Aluminum angles and on an Aluminum sheet for supporting them.

The design is made so the electronic cards can be located in one support angle, the left angle. The photodiode electronic reading and power cards (PRPCs) are placed as near to the PSCs as possible. Each PRPC can be used to supply two photodiodes at the same time. The discriminator card is on the same Aluminum angle that the reading and power card, in the other end. Figure 2 shows the detector and its pieces.

3. Construction

The Aluminum tubes, which were used in the construction, has the following dimensions: 24.92 cm long, 5.08 cm width (outwards), 2.54 cm height (outwards) and 1 mm thick. The photodiodes used for this detector were the MPPC S12572-100P of Hamamatsu. [7]

First, polymaq bars were manufactured, so that, they fit inside the tubes and a square cavity was made on one of its faces. The dimensions of the cavity are 5 mm, 5 mm and 1.2 mm, being long, width and thick respectively.

Then, the PRPC were made in a phenolic board Steren 405. The Figure 3 shows the necessary circuit to read out the photodiode signal. The values of resistors and capacitors are C1=C2=100 pF, R1=2.2 MΩ, R2=1.2 kΩ and VR1=10 kΩ; these values give the desired output signal. In order to connect the PRPCs and a leading edge discriminator [8] card, SMA connectors were welded.

A measurement of the internal dimensions of the Aluminum tubes was made with a Vernier. The internal width of the tubes were between 48 mm and 49 mm and the heights between 23 mm and 24 mm. It was decided that all the Aluminum caps (8) was going to be cut with 49 mm width and 24 mm height from a 1 mm thick Aluminum sheet.
The Aluminum angles and the base were drilled and the holes sanded so the angles and the base could be screwed.

Due to the size of PRPC (7.8 cm x 4.9 cm, 1.59 mm thick), Aluminum sheet was added to the left Aluminum angle. This sheet is 10.16 cm width and 20.32 cm long. The base was welded to the angle with JB Weld. Eight nuts for placing PRPC were welded on the sheet with JB Weld.

By looking at PSCs it was clear that a second cavity in polymaq bars was required because the right angle pins weld hindered to join PSC to polymaq. That cavities were made with knives.

Before assembling the detector it was necessary to isolate, as possible, the photodiode from external radiation. That was done with Aluminum and electric tape, using electrical tape where Aluminum tape could cause an electroshock.

A second Aluminum sheet was welded to the angle because, when the first sheet was cut, the size of the discriminator card and its needed separation with the PRPC was not considered; the second sheet has the same width and thickness than the first one but is 2 in long. Four nuts were welded to this new sheet, the nuts for supporting discriminator in the angle. Figure 4 shows discriminator card.

With aid of the new sheet, the full detector was assembled and fixed the trigger voltage in 100 mV. The tubes in the assembled detector were named CH1, CH2, CH3 and CH4 from bottom to top respectively, showed in Figure 5.

4. Results

4.1. Photodiode characterization

For characterization, the discriminator trigger voltage was fixed. Oscilloscope voltage scale was modified to observe the noise of the photodiode analogical signal and it resulted around 20 mV, because of that, trigger voltage was fixed to 70 mV for avoiding noise goes through the discriminator card. With the four discriminator channels, it was possible to count pulses, and due to that, to take data and make a photodiode characterization.
Figure 5. Assembled detector.

The discriminator card outputs were connected to a 32 channels compact-RIO, and the voltage source is connected to the PC. The automatic characterization program (ACP) user have to input the initial and final supply voltage in the program and it takes data for 10 minutes and changes the source output voltage by 5 V, takes another 10 minutes data and so on until finished. The initial and final values given to ACP for characterization was 60 V and 100 V respectively. The characterization curves obtained are shown in Figures 6, 7, 8 and 9.

Figure 6. Characterization graph for CH1, corresponding to white polymaq.

Figure 7. Characterization graph for CH2, corresponding to black polymaq.

Figure 8. Characterization graph for CH3, corresponding to white polymaq.

Figure 9. Characterization graph for CH4, corresponding to black polymaq.
4.2. **Data acquisition**

Half an hour of data was taken with cRIO -the program takes data for the time the user indicates and collects them- in 30 minutes files (.txt format). Data histograms are shown in Figures 10, 11, 12 and 13.

![Figure 10. Histogram for CH1.](image)

![Figure 11. Histogram for CH2.](image)

![Figure 12. Histogram for CH3.](image)

![Figure 13. Histogram for CH4.](image)

4.3. **Second Characterization**

A second photodiode characterization was performed. This time the polymaq bars configuration were changed; so that, channels that had black polymaq now have white and vice versa. The characterization curves obtained are shown in Figures 14, 15, 16 and 17.

![Figure 14. Characterization graph for CH1, corresponding to black polymaq.](image)

![Figure 15. Characterization graph for CH2, corresponding to white polymaq.](image)
5. Conclusions

It can be noted that the characterization graphs of CH1 and CH3 are very similar, CH2 and CH4 too, for both configurations, i.e. characterization graphs of channels with white (or black) polymaq resemble each other and this resemblance is independent of polymaq bars configuration.

From Figures 6, 7, 8 and 9 can be seen that some differences are present between detection channels with white or black polymaq, like that the maximum number of counts in black polymaq is higher than in white for each voltage supply, and these differences can be confirmed from the histograms in the Figures 10, 11, 12 and 13. Besides, it is clear that number of counts increases linearly with voltage.

Figures 14, 15, 16 and 17 show that the maximum number of counts was lower with the second configuration and that may be attributed to the photodiodes. The more important result is that black polymaq still has a bigger number of counts for every supply voltage than the white one. These results indicate that black polymaq is a better detector than the white one.

References

[1] Particle Data Group
http://pdg.lbl.gov/2015/reviews/rpp2015-rev-cosmic-rays.pdf

[2] Mark Chen, Queen's University. Scintillation and Light Sensitive Detectors.
http://neutron.physics.ucsb.edu/docs/scintillation_presentation_info.pdf

[3] Kurtz S M 2004 The UHMWPE Handbook: Ultra-High Molecular Weight Polyethylene in Total Joint Replacement (California: Elsevier Academic Press) chapter 12 pp 263-286

[4] Butslov M M, Medvedev M N, Chuvilo I V and M Sheshuno V 1963 Nucl. Instr. Meth. Phys. Res. 20 263-266

[5] Aseev A A, Devitsin E G , Komar A A, Kozlov V A, Hovsepyan Y I, Potashov S Y, Sokolovsky K A and Uvarova T V 1992 Accelerators, spectrometers, detectors and associated equipment Nucl. Instr. Meth. Phys. Res. A 317 143-147

[6] Katharina Müller, University of Zurich. Cherenkov radiation.
http://www.physik.uzh.ch/lectures/empp/14/lectures/empp14_KM_cherenkov.pdf

[7] Photodiode. Hamamatsu S12572-100P.
http://www.hamamatsu.com/jp/en/product/category/3100/4004/4113/S12572-100P/index.html

[8] Hoagland T A Brief Description of Discriminators (National Superconducting Cyclotron Laboratory)
http://docs.nscl.msu.edu/daq/samples/Discriminators.pdf