Cu Hybrid 4 Channel Cosmic Ray Detector

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Abstract. There are, in the universe, several sources that produce very energetic cosmic rays that interact with the Earth’s atmosphere and create new low energy particles. To detect them there are different methods, according to the interaction with a medium such as the ionization of a material and Cerenkov radiation, among others. In this work a hybrid cosmic ray detector of 4 channels was designed, built and tested at the Laboratorio de Partículas Elementales of the Universidad de Guanajuato. A Copper bar was used as detection material, both smaller area faces have an ionization and a Cerenkov radiation detection channel. To detect the Cerenkov radiation, Hamamatsu silicon photodiodes were used, and for the ionization channels an RC circuit was developed to measure the signal. The ionization channels were tested simultaneously, observing the analogic signal on an oscilloscope. The RC circuit and discriminator were designed to be on the same board; with the discriminator we can digitize the analogic signal. Details of the design, construction and testing of the ionization channel are presented.

1. Introduction
Cosmic rays consist of particles that come from the outer space; large number of them interacts with the atmosphere of the Earth. These particles are classified into primary and secondary, the primary particles are those created in an astrophysical source. The secondary are those that are generated by the interaction between primary cosmic rays and the atmosphere of the Earth [1].

To detect them, they have to interact with a medium, such is the case in the detection method of ionization of a material and Cerenkov radiation. Ionization takes place when a particle has enough energy to ionize an atom of a material, which results in an electron and an ion generating a flow of current. This flow of current is amplified if it is immersed in an electric field.

For the detection of Cerenkov radiation a photodiode [2] is used. A photodiode is a device that transforms light into voltage or current. For the detection by ionization we use an RC circuit that operates when a pulse is produced by a particle interacting with the material immersed in an electric field.

2. Design
The complete design consists of one copper bar and two plastics scintillator, all with a length of 1 meter. The copper bar is among the plastics scintillator, they are isolated with an aluminum cube, and the copper bar with electrical tape. Using this design the signal of the copper bar can be validated (see Figure 1).
Figure 1. Design of the three bars in SketchUp software.

On the smaller faces of the copper bar, a board is placed with the soldered photodiode in the center and the connections for the electric field, and the collectors of signals of the ionization channel in the bottom and top of the board (see Figure 2).

Figure 2. Design of the photodiode board

The board is connected to a second board that has the RC circuit, the discriminator and the power supply connections of the system (see Figure 3).

Figure 3. Design of the three bars in SketchUp software.

The board with the RC circuit is connected forming a 90 degrees angle with respect to the photodiode board. These boards were designed using OrCAD software [3]. On the left side, the connections with the photodiode board are shown. The analog-digital comparator is located in the center. The power supply and signal output connections to the data acquisition system are shown on the right. (see Figure 4).
Figure 4. Board with RC circuit for signal reading, discriminator to convert the analog signal to digital pulses, BNC connectors for high voltage of the power supply and regular BNC for signals.

3. Construction
The copper bar was cut and cleaned of impurities to have the following dimensions: 101 cm X 3.8 cm X 1.2 cm. Holes were drilled in the smaller faces of the bar to put two screws that will hold the photodiode board in place. A small subsidence was made in the center of the face to place the photodiode (see Figure 5).

Figure 5. Drillings and subsidence in the bar. Clean copper bar. Screws set in the bar.

The bar was then cleaned again to put electrical insulating tape. To make the arrangement for the electric field, copper tape was used, and to have the connections to obtain the signal in the ionization channels (see Figure 6).

Figure 6. Copper bar with final configuration.
A test board was built to activate the ionization channels. It has 4 pins to make the connections, two for the signal and two for the high voltage to feed the system. Cables are connected to the pins that go to the high voltage source and to the RC circuit (see Figure 7).

![Figure 7. Test board to set on copper bar.](image)

The detector was built in the Laboratorio de Partículas Elementales of the División de Ciencias e Ingenierías, Campus León of the Universidad de Guanajuato.

4. Testing
For the first tests, a high voltage source, Ultravolt 3M24-P1 M SERIES [4], is connected to the test board to activate the electric field. The voltage used was 1500V. The RC circuit was connected in a breadboard to change the values of the resistors and capacitors until finding the best values. The output signal was observed on an oscilloscope (see Figure 8).

![Figure 8. Copper bar connected to RC circuit and power supply.](image)

The RC circuit is made up of two resistors and a capacitor. A manifold of the copper bar is connected to a capacitor, followed by a resistor. In this route the oscilloscope tip is connected. The other collector connects a resistor which is then grounded and at that point the oscilloscope reference is placed (see Figure 9).
With this RC circuit and with a fixed input voltage of 2000 V to generate the electric field, signals with decaying exponential form were obtained. The pulse amplitude is 300 mV and with a discharge time of 1 μs. This was the best configuration to reduce the pulse discharge time without totally deforming the signal (see Figure 10).

5. Conclusions
The copper bar was set to activate the ionization channels. The capacitance of the copper bar was measured, which is 3 nF. It was possible to operate the ionization channels and to observe the signal on an oscilloscope. The values of the resistors and capacitors in the RC circuit were varied until the best performance of the ionization channels was achieved.

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