Cosmic Flux: Geiger Counter

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Abstract

In this experiment, we built Geiger Counters that detect various types of ionizing radiation: Beta particles, Muons, and Gamma rays. Using the coincidence method with the Geiger counter's interface, we designed a method to measure the respective flux of cosmic radiation through a conical range produced when the two counters are arranged in coincidence. We calibrated the Geiger Counter using a test source.

Background

Countless particles from various cosmic events reach Earth every day, but most are deflected by Earth's magnetic field.

Only the highest energy particles penetrate the atmosphere.

When said particles enter the atmosphere, they collide with nuclei and create a cascading effect of particles called an air shower.

Many new elementary particles and gamma rays are created by the collision and decay quickly as they continue to fall.

We will primarily detect muons and gamma rays as they contain enough energy to activate our Geiger Counters.

Our project consists of 4 main components: Our Geiger Muller Tube, the Coincidence Method, Circuit Boards from the kits, and the homemade case to house the tubes. Each component will be explored in the sections below.

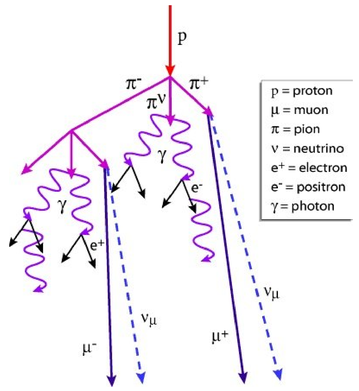


Figure 1. Cosmic Shower Diagram

Geiger Muller Tube

The Geiger Muller tube works as follows:

1. The tube is filled with a mixture of inert gases like argon, neon, or helium at a low pressure.
2. High voltage is applied across the electrodes of the tube, creating an electric field within the gas-filled chamber.
3. When ionizing radiation such as gamma rays or beta particles enters the tube, it interacts with the gas molecules causing ionization of the gas molecules, producing positively charged ions and free electrons.
4. The electric field accelerates the free electrons toward the positively charged anode in the center of the tube.
5. Electrons move through the gas, colliding with other gas molecules, causing further ionization. This process is known as an electron avalanche.
6. The culmination of free charges results in a detectable electrical pulse.
7. The electrical pulse generated by the electron avalanche is then detected by external circuitry connected to the GM tube.
8. For re-calibration, a quenching gas or substance is often added to the gas mixture, dissipating the ionization and reverting the gas to its original state.

GM Tube: SBM-20 Length: 10.8 cm Diameter: 1cm

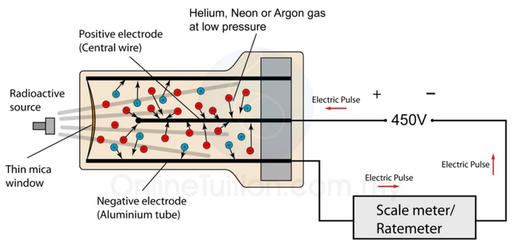


Figure 2. Geiger Muller Tube Diagram

Coincidence Method

We will utilize two tubes connected in coincidence to ensure that the radiation we receive from the Geiger counters is not from background sources. By stacking the two counters on top of one another, we can create a designed range that we will be surveying for cosmic flux.

Lead Plate

A lead plate will be placed between the two counters to limit Compton scattering and possible noise. To vary the portion of the sky we are monitoring, we can change the distance between the two counters. By increasing the distance we survey a smaller range and by decreasing the distance we survey a larger range.

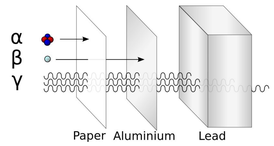


Figure 3. Lead Plate Diagram

Flux Range

By using a sensitivity dial built into the Geiger counter, we can calibrate for the flux due to over-saturation or under-saturation. Another advantage to using the coincidence method is that we can reduce noise from stray sources of radiation.

$$\arctan\left(\frac{l}{x+2d}\right)$$

- The coincidence method ensures that a cosmic air shower particle is counted if it hits and excites both tubes.
- If one tube is hit and the second is not, the counter will not register the particle.
- When cosmic particles hit both tubes within a very short amount of time, only then will we know that the particles came from within our range.

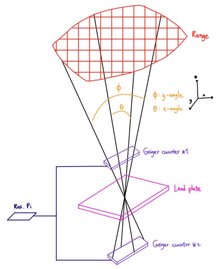


Figure 4. Diagram of Generated Range

Circuit Boards

The circuit boards have a variety of components including:

- Resistors, Diodes, Slide switches, capacitors, transistors
- IC sockets, Inductors, Piezos
- Tube holder clips, along with LED
- Battery holder and push buttons
- Specific IC circuit

After completing the soldering, we began data collection.

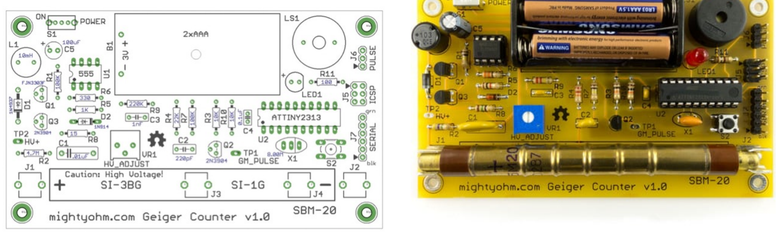


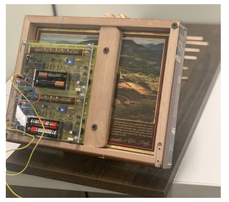
Figure 5. Circuit Board Diagram

Wooden Apparatus

In order to hold the two Geiger counters in coincidence, we constructed a homemade wooden apparatus that could the detectors angle from the center of the sky.

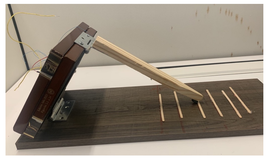
Structure

The wooden case carries the two counters stacked side by side. Between the two is a lead plate to prevent Compton scattering. A wooden peg attached by a metal hinge props the case up so that stacked counters can be set at an angle. The wooden plank below has designated slots so that the wooden peg can slide into each in turn creating a different angle

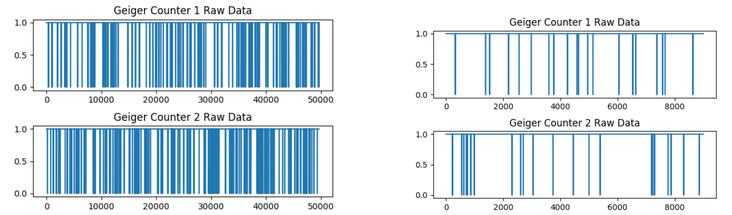


Adjustable Angle

The wooden apparatus can lower the Geiger counters to the ground in 10-degree increments, up to 70 degrees. The number of coincidences is expected to vary by $cos^2(\theta)$ where θ is the angle from the normal of the ground.

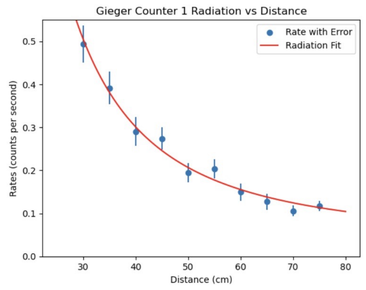


Results



The figures above show the raw data received from the two separate Geiger counters with the one on the left at a sample rate of 10KHz, and the one on the right at 1 kHz. The Raspberry Pi then receives the data and filters only the samples when both counters are excited.

Using a test source, we expected the rate of radiation detection would vary as $1/d^2$. We measured the rates in increments of five centimeters and took our error to be $1/\sqrt{N}$, where N was the number of counts. We then fit a line to our data according to our hypothesized relationship and found that it matches quite well.



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Another experiment we could perform with our setup is a measurement of a muon's velocity using special relativity. This would be done by getting a ratio of count rates from high and low elevations, and then comparing that to the ratio of expected counts given a muon's rest lifetime. Using that, we can find the muon's relativistic lifetime and solve for its velocity.