The Effect of Lead Shielding on the Count Rate and Energy Levels of Muons

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Introduction

In this work the effect of lead shielding on the count rate and energy levels of muons is studied. Muons are subatomic particles created when cosmic radiation impacts the Earth's upper atmosphere. Some characteristics of muons include[2]:

- The same charge as electrons
- A mass of over 100 times an electron
- Muons produced by cosmic rays travel at a significant fraction of the speed of light.
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Lead was used to shield the muon detector setup. If there is any positive correlation between density of shielding and stopping power, lead should produce the clearest and most dramatic effects.

Method of Detection

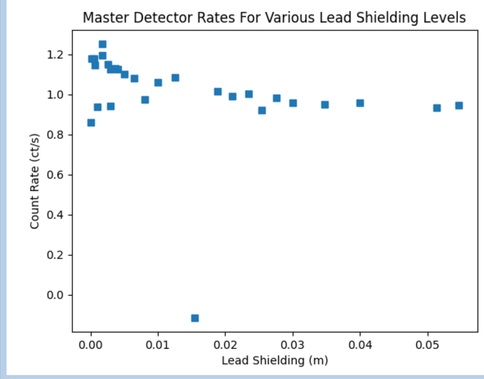
So how exactly does one detect both the presence and energy levels of a muon? The process used for this research is actually very similar in concept to a Geiger counter, but with some differences in the hardware.

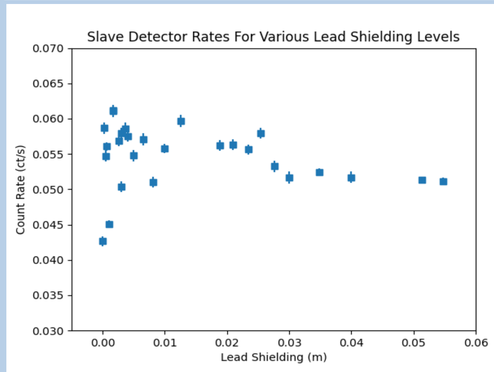
Pictured to the right are two completed muon detectors. These detectors were constructed using MIT's CosmicWatch[1, 2] design, and detect particles through the following process:

How Muons are Detected?

- **Foil Layer Reflects light back into the Silicon Photo-Multiplier**
- **Electrical Tape Layer prevents outside light from getting in**

If a muon travels through both detectors in less than ~30 nanoseconds it is a "coincidence count."





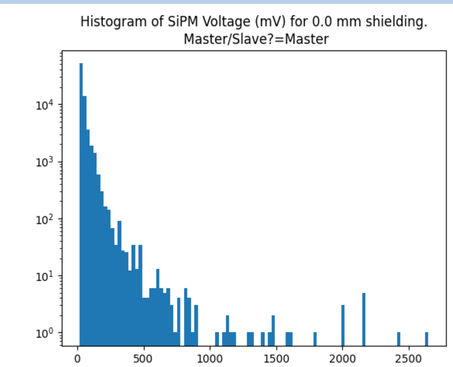
Results

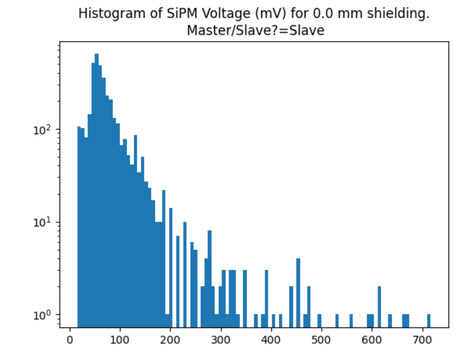
To the left are the master and slave rates for muons vs the thickness of shielding present above the detectors.

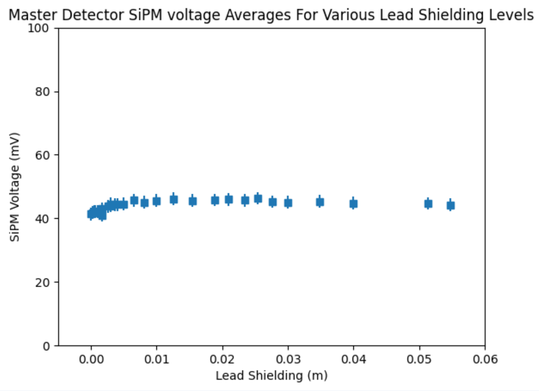
The reasons for the scatter in the slave rate are currently unknown, but possibilities are discussed in the conclusion.

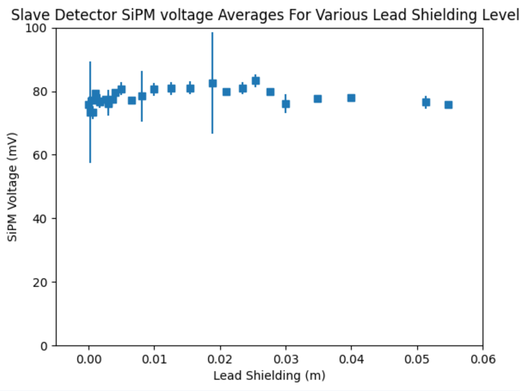
Right are histograms of the SiPM voltages in the 0mm (no shield) lead trial. These voltages should correlate with the energy of the detected particle.

Unlike the background radiation, which peaks before the 25 mV range[2], the muons most frequent energy is significantly higher than zero.









Left are plots of average SiPM voltage vs thickness of shielding, which should correspond with muon energy levels.

The error bars in the averages represent the extent of 90% of the peak (average) value for each trial

Conclusion and Further Research

Further measurements are required to reduce the uncertainty in the count rate and to better quantify any energy shifts associated with the thickness of shielding. At ~mm of thickness the measured average count rates show too much scatter to develop a trend line. Further trials will attempt to determine the reason for these inconsistent rate measurements, primarily by conducting longer trials per shielding thickness.

Possible sources of error in this research include:

- Detector sensitivity threshold was set too high
- Angular dependence of muons (proportional to cosine squared)[2] causing uncertainty in large thicnkesses
- Barometric Pressure is altering count rates and is not accounted for

After this research is concluded, the detectors used for this project will remain with the physics department for use in a larger project to create an array of synchronized muon detectors.

[1] Many thanks to Spencer Axani. Learn more about CosmicWatch at http://cosmicwatch.lns.mit.edu
[2] Axani, Spencer. "The Physics Behind the CosmicWatch Desktop Muon Detectors," (2018).
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