Building & Testing a Cosmic Ray Muon Detector

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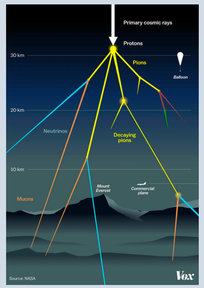
INTRODUCTION

What are muons?

- Muons are elementary particles under the lepton group with two charge types and a spin of ½. They are intermediate between the proton mass and the electron mass. [2]
- Muons have a lifetime of 2.2 μs, the second longest lifetime among all of the fundamental unstable particles.

Difference between solar and cosmic ray muons

- Solar ray muons are much less frequent, and lower energy than ones from cosmic rays
- Only detectable because they're going so fast that they experience time dilation



[1]

What is a cosmic ray detector?

- In general, most sensitive detectors work by some kind of "avalanche" process where one excitation gets cascaded into a bunch of excitations.
- Scintillators emit light when they absorb particles or electromagnetic waves that create "free" electrons in the material [3]

OBJECTIVES

- Set up and build a cosmic ray detector designed by QuarkNet
- Perform the calibration tests in order to test functionality
- Lay the foundation for more complex tests in the future

METHODS / DATA

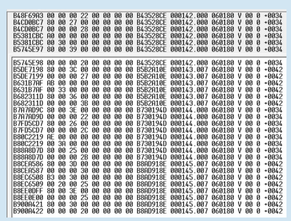
Building the detector

- We wrapped the scintillators in duct-tape to keep out light while leaving an opening for muons to enter.
- Next, we plugged in the photomultiplier and attached it with the PVC pipe.

Setting up the DAQ and the software

- We plugged the photomultipliers into the Data Acquisition Computer Board (DAQ card).
- After this, we plugged in a power distribution unit (PDU) and a GPS module.
- Next, we downloaded Putty, a terminal emulator, in order to gather the data.

Gathering data



- During our initial calibration experiment, we set the energy threshold to an arbitrary value at which we were beginning to see the count of muon going up.
- Next, we got the raw data from Putty, and saved it as a text file to our laptop. The next step is to import this raw data into the QuarkNet website in order to get a graph of muons vs time (min) and threshold.

REFLECTIONS

While we were unable to complete our tests for the muon detector due to limited time and the complexity of the tests, we were able to get to the stage at which we can acquire data. This detector will be used in the future by school and future students to study the effects of cosmic events on the muon flux. Our exploration here has led to a strong pathway being formed for future testing.

APPLICATIONS

- Muons have already been used to identify a void in the Egyptian pyramids, since it has the ability to see through solid objects
- Can be used as a method for creating 3D models of the interiors of solid objects
- Muon detectors can see through damaged nuclear power plants to find dangerous nuclear material.

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REFERENCES

[1] Resnick, Brian. "Cosmic Ray Physics: Extremely Powerful Particles Are Slamming into the Earth." Vox, 16 July 2019

[2] Introductory Muon Science. Cambridge University Press, 2007.

[3] "What are Scintillators? How Does Scintillation Work?" Hilger Crystals, Sept. 2020