Muon Detectives ☺

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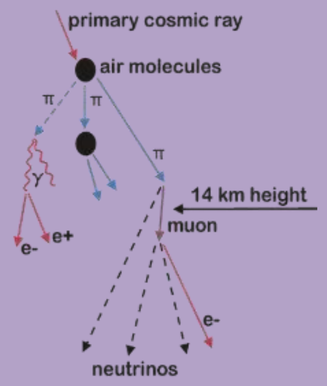
Introduction

A muon is an unstable subatomic particle with the charge of an electron but a much larger mass.

Muons are created when high energy cosmic rays collide with atoms in Earth's upper atmosphere.

After creation, Muons falling to earth rapidly decay. As falling muons experience more atmospheric pressure and particle interactions, more muons decay. Thus their flux (amount that reaches earth) decreases.

Our aim is to successfully construct a Cosmic Watch Muon detector, enabling us to understand and quantify muon flux at different altitudes in Denver, Boulder, and the surrounding areas.



Materials

1	0 Ohm resistor	5
2	49.9 Ohm resistor	4
3	249 Ohm resistor	2
4	1K resistor	4
5	10k resistor	5
6	24.9k resistor	2
7	100k resistor	3
8	226k resistor	2
9	10pF capacitor	2
10	22pF capacitor	2
11	0.47uF capacitor	2
12	20 nF capacitor	6
13	0.1uF capacitor	4
14	1uF capacitor	3
15	10nF capacitor	4
16	10uF capacitor	3
17	Feritte bead	2
18	47uH inductor	1
19	Schottky diode	2
20	4 pin header for OLED	1
21	6-pin connector	1
22	6pin header	1
23	Reset button	1
24	3.5mm coincidence jack	1
25	BNC header + Nut	1
26	3.3 V regulator	1
27	Standoff for SiPM PCB	2
28	Standoff threaded screws 0-80	4
29	Plastic scintillator screws	4
30	LT-3461 DC-DC Booster	1
31	LT 1807 Op-Amp	1
32	Non-Inverting Buffer	1
33	5mm LED	1
34	Arduino Nano	1
35	Temperature sensor	1
36	microSD card socket	1
37	OLED screen	1
38	SiPM	1
39	Plastic scintillator	1
40	Main PCB + SiPM PCB	1

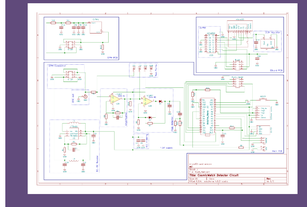
Methodology

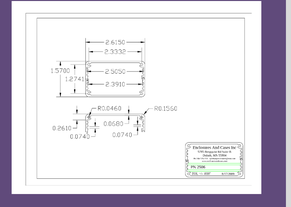
To construct the device, we soldered our components to the Main PCB for the cosmic watch,. The case was modeled using CAD software and 3D printed at the CU Boulder Ideaforge.

All code was migrated to Python 3, and we used an Arduino Nano to process our data.

For simulated data, we used public use data from Advances in High Energy Physics. All data is available at https://onlinelibrary.wiley.com/doi/10.1155/2013/256230

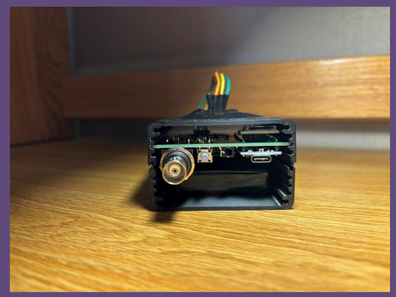
This data was taken various underground labs in locations listed, and shows muon flux at a variety of depths around the globe.

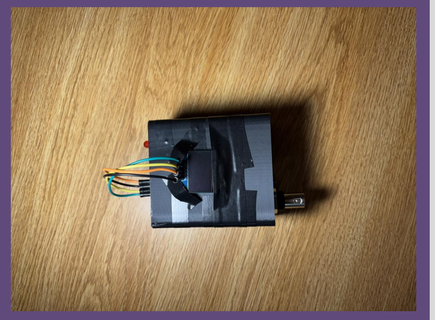




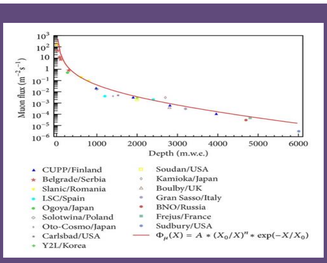
Cosmic watch circuit diagram (Left) and case dimensions (Right). All code, CAD files, and supporting information are available at http://www.cosmicwatch.lns.mit.edu/detector

Results





Our completed device has not yet performed any measurements, but we hope to get it up and running soon. We predict that our collected data will follow the above curve, with higher muon flux at higher altitudes.



Muon Flux represented as a function of depth in various global locations. Graph is open access from Advances in High Energy Physics journal. Our expected data should show a similar correlation between depth and flux.

Conclusion and Future Directions

Although we have yet to take a measurement with our device, the construction of this device has provided us with new technical skills and device knowledge which will be undoubtedly useful in our future endeavors.

This project also taught us about shipping delays.

In the future, we hope to use our device to measure the local muon flux in here Boulder as well as in Denver.

Hopefully, we can construct our own model of muon flux as a function of altitude.

Additionally, this project helped us provide helpful feedback to the MIT Cosmic Watch project, making it easier for future users.

References and Acknowledgments

A huge thanks to Sarah Bruce for being our mentor and providing countless helpful tips and insights.

Thank you to Jack Farrell, Maggie Huber, and CU prime for overseeing this project and making it a possibility.

Additional thanks to Pat and the CU Boulder Ideaforge for providing us with missing parts and a place to solder.

Full cosmic watch data, code repositories, and schematics can be found on the website: http://www.cosmicwatch.lns.mit.edu/detector

Data displayed can be found at:
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