

EFFECT OF ZENITH ANGLE ON COINCIDENT MUON DETECTION RATE

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ABSTRACT:

Muons, created when cosmic rays collide with atmospheric nuclei, can be detected at Earth's surface using paired Cosmic Watches. These detectors show that muon counts decrease with increasing angle from the vertical, reflecting the longer travel distances and greater decay losses for non-vertical muons.

Introduction

Muons, aka fast electrons, constantly shower Earth's surface as a result of the interaction of cosmic rays with atmospheric nuclei. "Most cosmic rays are produced in our galaxy and are nuclei expelled in supernova explosions. About 90% of cosmic rays are protons, 9% are helium nuclei, and the remaining 1% are heavier nuclei. When the cosmic rays hit the nuclei of the atmosphere, a shower of particles are produced including pions and kaons. These are the progenitors of the muons." Cosmic Watches (CW) are compact particle detectors; when used in pairs, the reading from the secondary (S) detector shows the rate of scintillator hits that are coincident on both detectors.

Materials

- Cosmic Watch pair that can read in two-fold coincidence
- Protractor
- Spacer between CWs
- Rotatable stand for CWs or everyday materials to support the CW at different angles

Resources

- <http://www.cosmicwatch.lns.mit.edu/about>
- <https://www.thingiverse.com/thing:2378188>

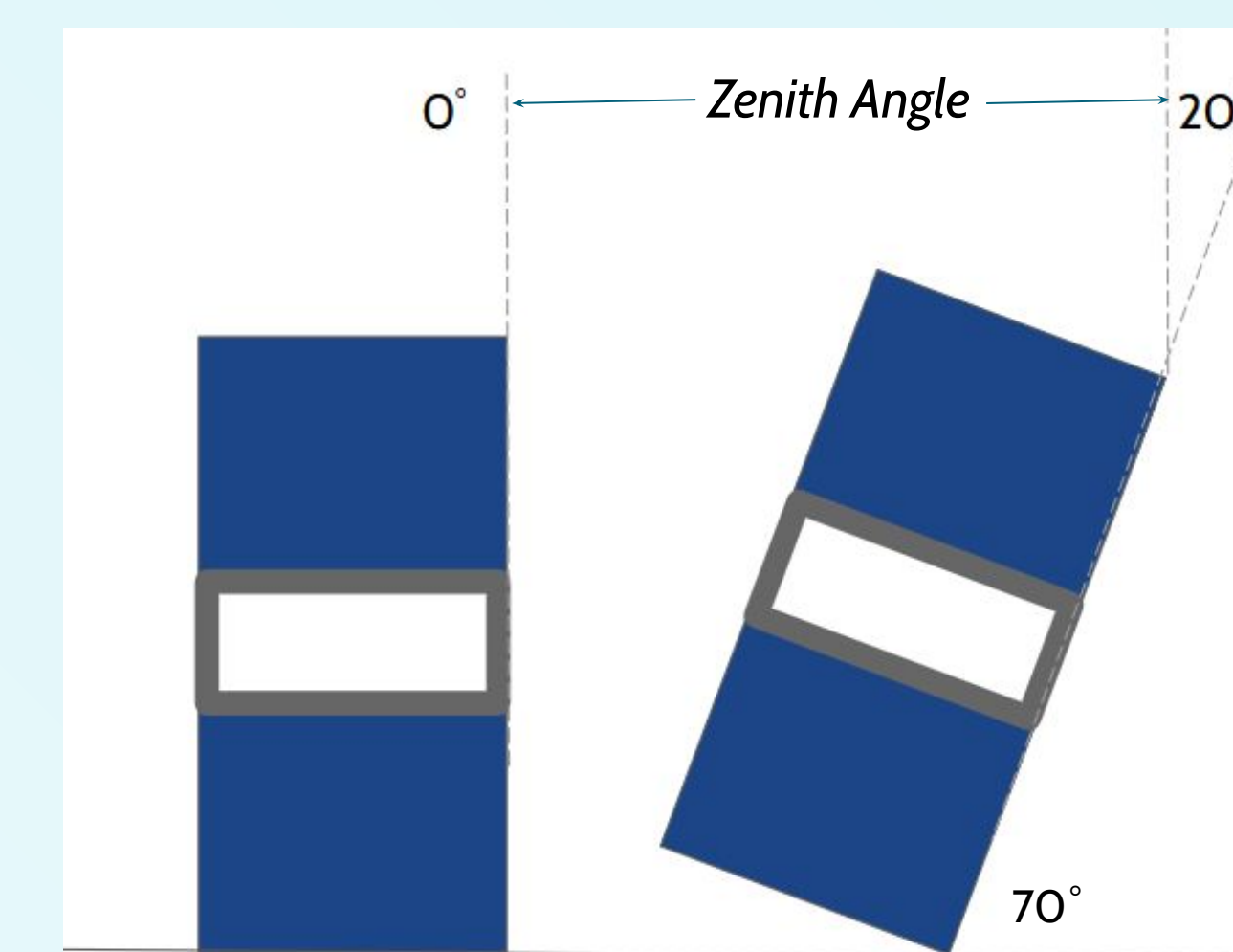
Methodology

1. Stack CWs vertically and pair them for twofold coincidence
2. Power the CWs and reset both of them (reset - red buttons on the back of the machines).
3. Let the CWs run for 5 minutes.
4. Record the coincidence rate (the rate from the secondary machine). See Fig.1
5. Repeat at different angle from the normal. See Fig. 2

Fig. 1



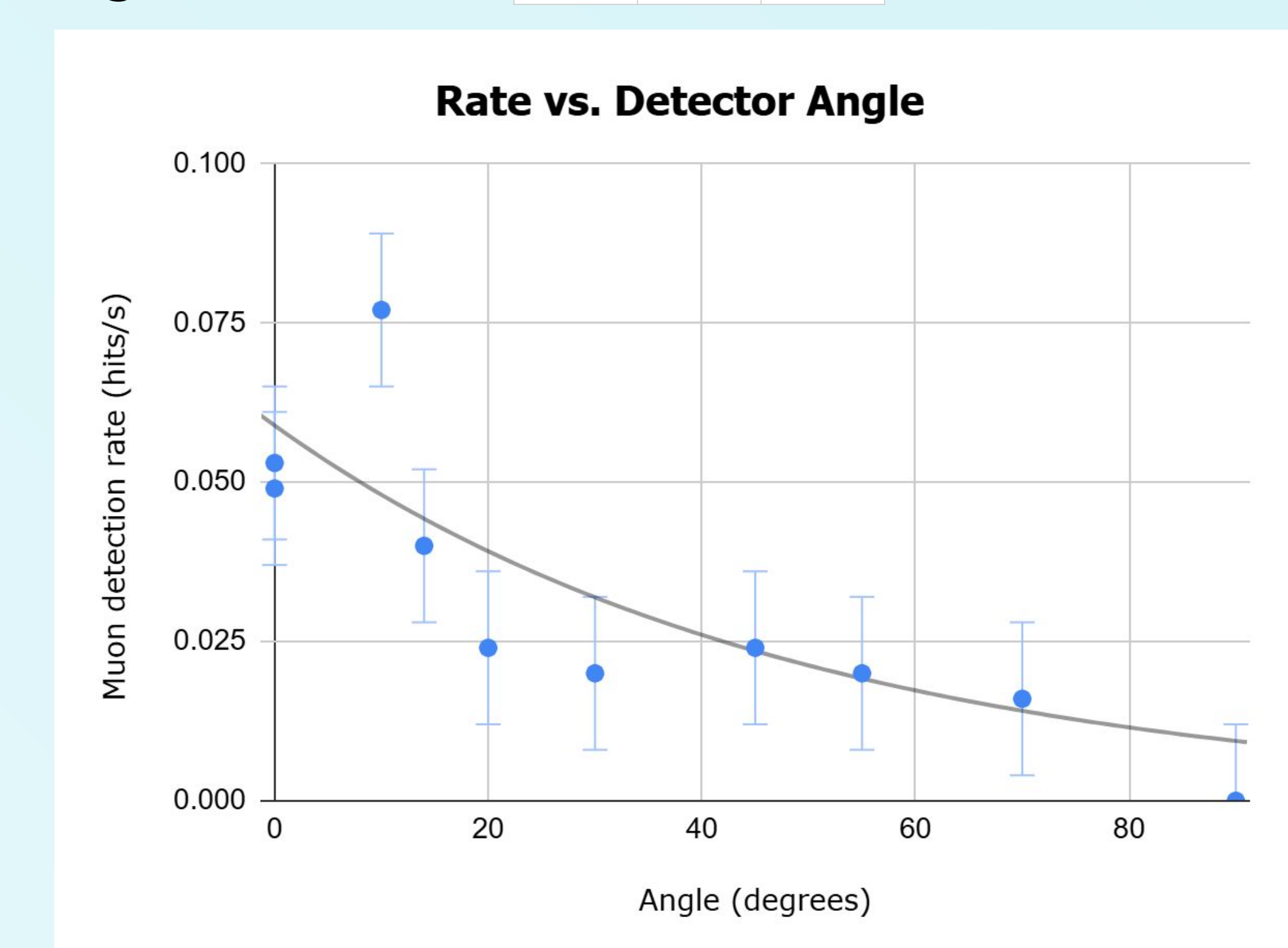
Fig. 2



Results

Angle (degrees)	Rate (muons/s)	error
0	0.053	0.015
0	0.049	0.014
10	0.077	0.017
14	0.04	0.013
20	0.024	0.01
30	0.02	0.009
45	0.024	0.01
55	0.02	0.009
70	0.016	0.008
90	0	0

Fig. 3



Conclusions

The number of muons detected decreases as the angle away from the zenith increases. Since the source of muons is over 10 km above Earth's surface, we expect that most of the muons that "survive" the trip to the surface are traveling at angles closer to the vertical, and this result agrees with that assumption.

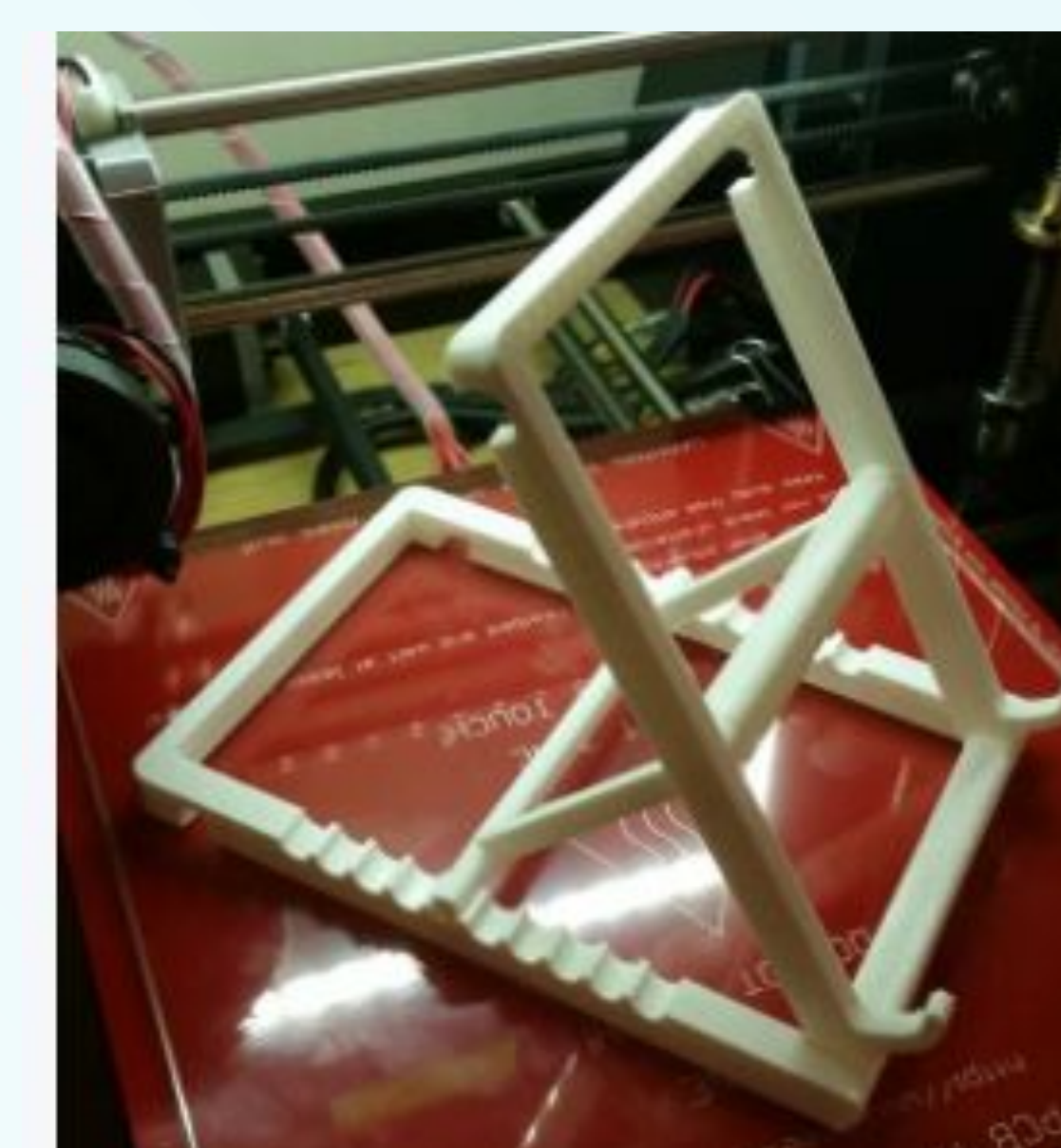
Adjustments to consider to improve data accuracy:

- Repeat the trials for each angles multiple times
- Increase the detection time length
- Have a standard way to support the CW and change the angle. Maybe modify a stand similar to the device shown in Fig. 4.
- Hold the CWs together with a rubber band.
- Perform experiment in the absence of any potassium-rich food or beverage.

Further questions to investigate:

- How does the distance between the detectors combine with the angle of the detectors to influence muon rate?
- Did the proximity of several cans of beverage sweetened with acesulfame potassium confound the results, as the position and quantity of the soda was not controlled during the trials?

Fig. 4

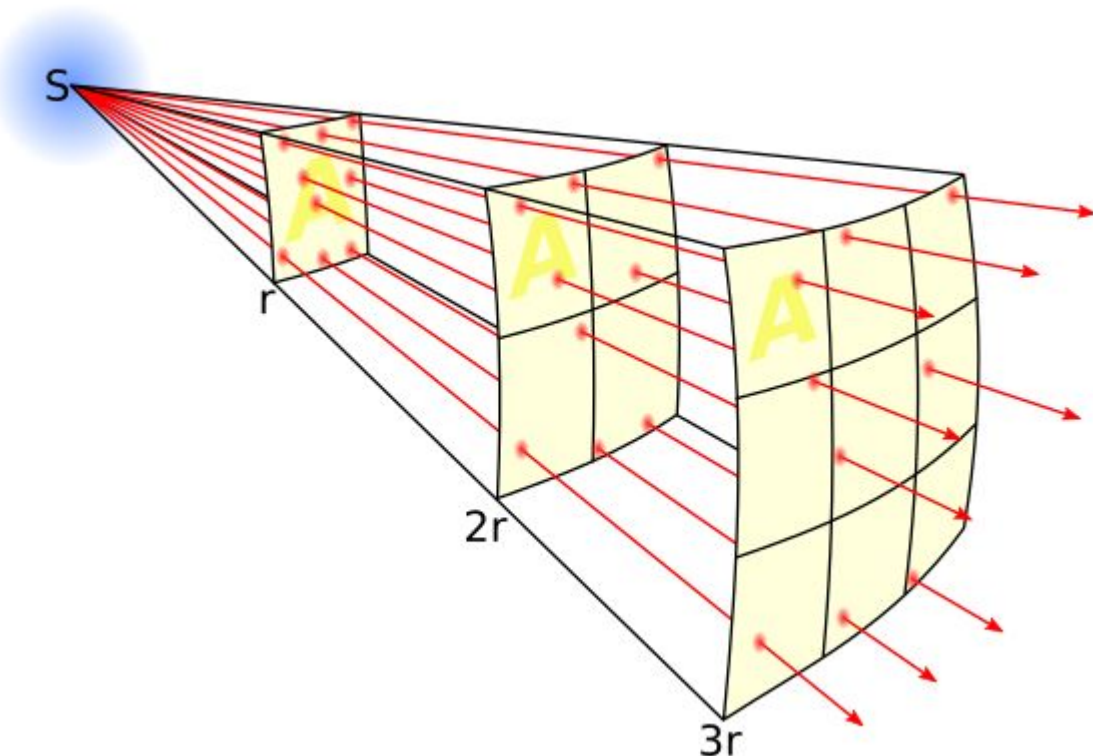


Potassium Salt Radiation

Dan Kurzen and Rob Jaspersohn

Abstract

The rate of beta emission from potassium-40 is measured using a pair of Cosmic Watches at various distances from the source. The Cosmic Watches are placed on their side, facing a cylindrical canister of “No Salt” which contains trace amounts of K-40 and both the primary and secondary rates are recorded. Upon increasing the distance between the Cosmic Watches and the “No Salt,” both rates demonstrate a decrease.



Method

We used a “Cosmic Watch” cosmic ray detector that was laid on its side in the “Two-fold” setup to capture more data, as seen in the figure below. The secondary detector is closer to the potassium salt.



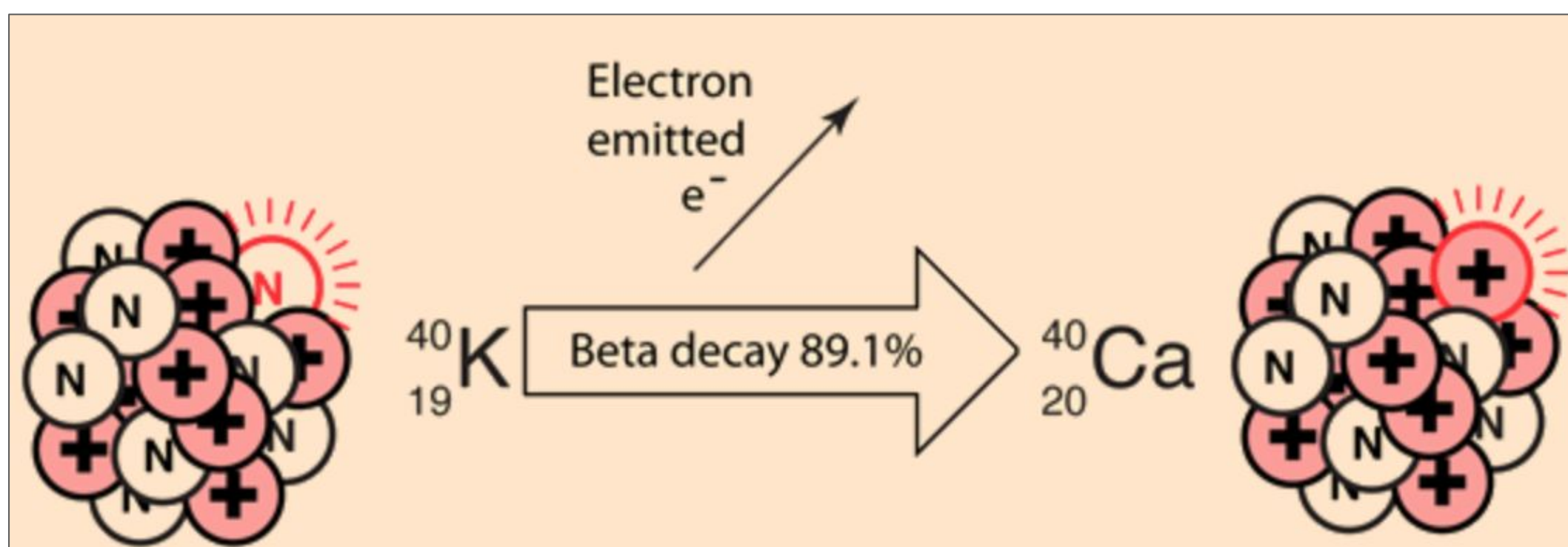
The distance from the potassium source and the detector was varied by 0.5 cm each trial. We captured the counts and rates from the Cosmic Watches at the end of 10 minutes of data collection for each trial.

We adjusted the distance data to account for the thickness of the case and the secondary CW (in the case of the primary). Our data are shown below

Time (s)	Primary Count	Secondary Count	Primary Rate (counts/second)	Primary Rate Error	Secondary Rate (counts/second)	Secondary Rate Error	Distance From Potassium Salt (m)	Total Distance from K Salt (m)	Distance from K Salt Squared (m ²)	Total Distance from K Salt Squared (m ²)	Total Secondary Distance from K Salt Squared (m ²)
600	1108	9	2.2	0.065	0.018	0.006					
600	1360	16	2.821	0.076	0.032	0.008	0.000	0.067	0	0.004489	0.000225
600	1314	11	2.73	0.074	0.022	0.007	0.005	0.072	0.000025	0.005184	0.0004
600	1210	7	2.5	0.071	0.014	0.005	0.010	0.077	0.0001	0.005929	0.000625
600	1270	13	2.64	0.073	0.026	0.007	0.015	0.082	0.000225	0.006724	0.0009
600	1290	10	2.67	0.073	0.02	0.006	0.020	0.087	0.0004	0.007569	0.001225
600	1231	6	2.549	0.072	0.014	0.005	0.025	0.092	0.000625	0.008464	0.0016
600	1220	9	2.52	0.072	0.018	0.006	0.030	0.097	0.0009	0.009409	0.002025
600	1211	8	2.52	0.072	0.02	0.006	0.035	0.102	0.01225	0.010404	0.0025
600	1222	10	2.52	0.072	0.022	0.007	0.040	0.107	0.0116	0.011449	0.003025
600	1208	10	2.5	0.072	0.02	0.006	0.045	0.112	0.002025	0.012544	0.0036
600	1255	7	2.58	0.073	0.014	0.005	0.050	0.117	0.0025	0.013689	0.004225

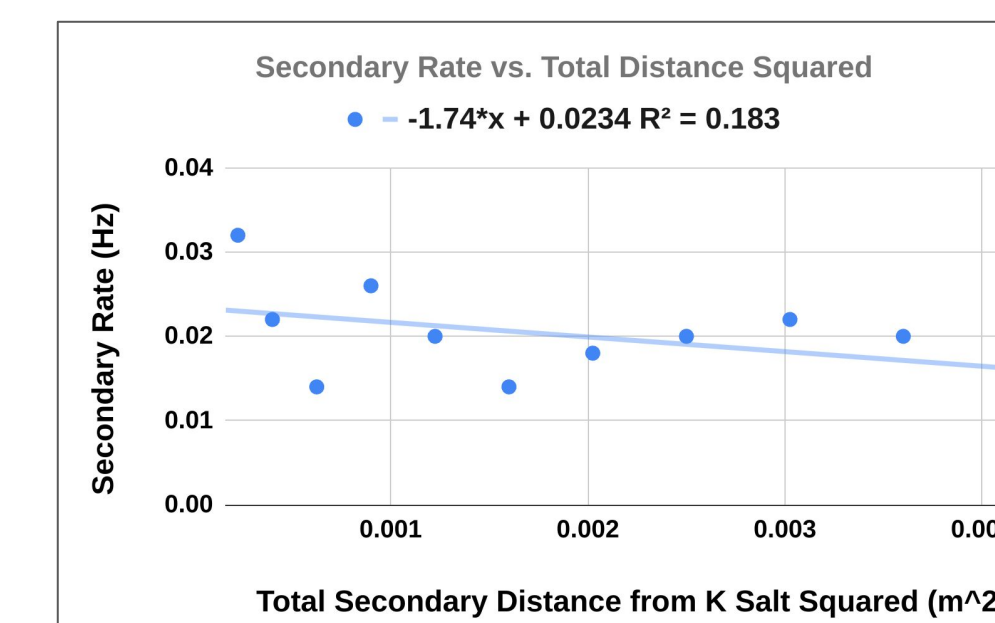
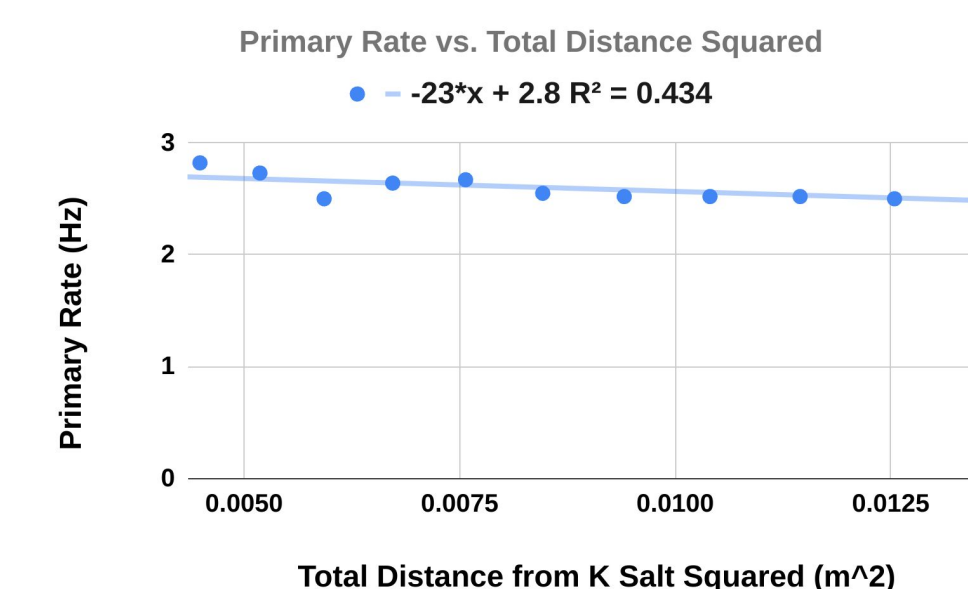
Background

“No Salt” is a salt substitute that relies on potassium chloride. Of the three natural potassium isotopes, K-40 appears 1.17% of the time. K-40 decays primarily, 89.1% of the time, via beta emission.



Data

After some data analysis, we were able to graph the count rate vs the adjusted distance squared, to linearize the data.



We fit a linear trendline to the data.

Conclusion

While the general trend of decreasing rate with increasing distance was expected, the exact nature of the trend has yet to be fully analyzed.

Future Work

Given more time to work on the experiment, we would try removing the “No Salt” from its container, to see if the cardboard and foil blocks some of the emitted electrons. We would also like to try surrounding the salt with multiple detectors to test directionality. We would also repeat the experiment using only one CW, set in singles mode to keep the distance as close as possible.