

Cosmic Watch Radiation Experiments

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USD 268 and USD 383

Abstract

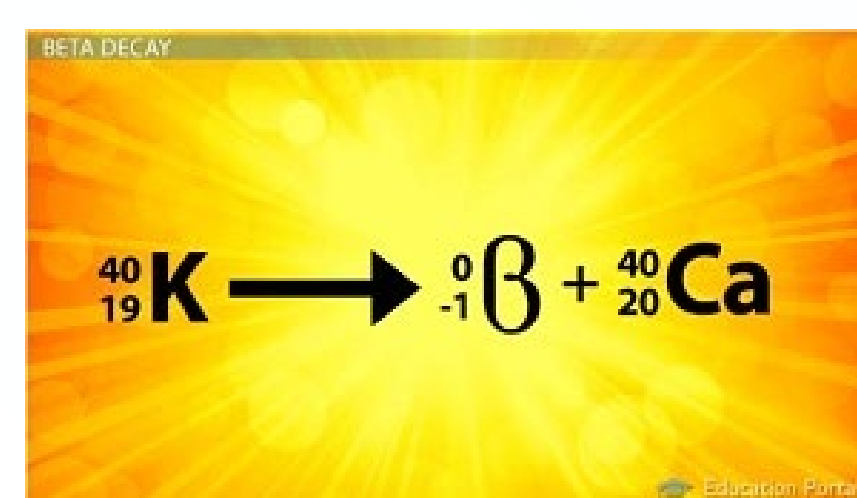
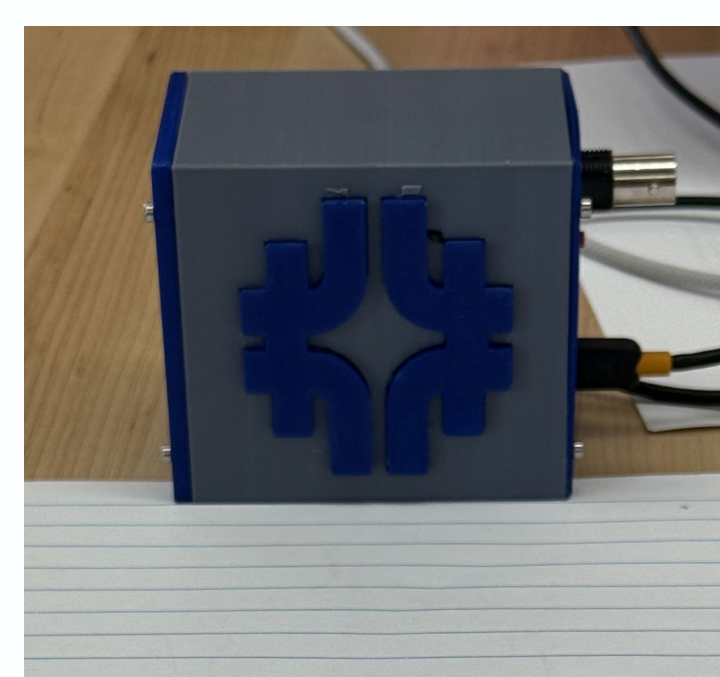
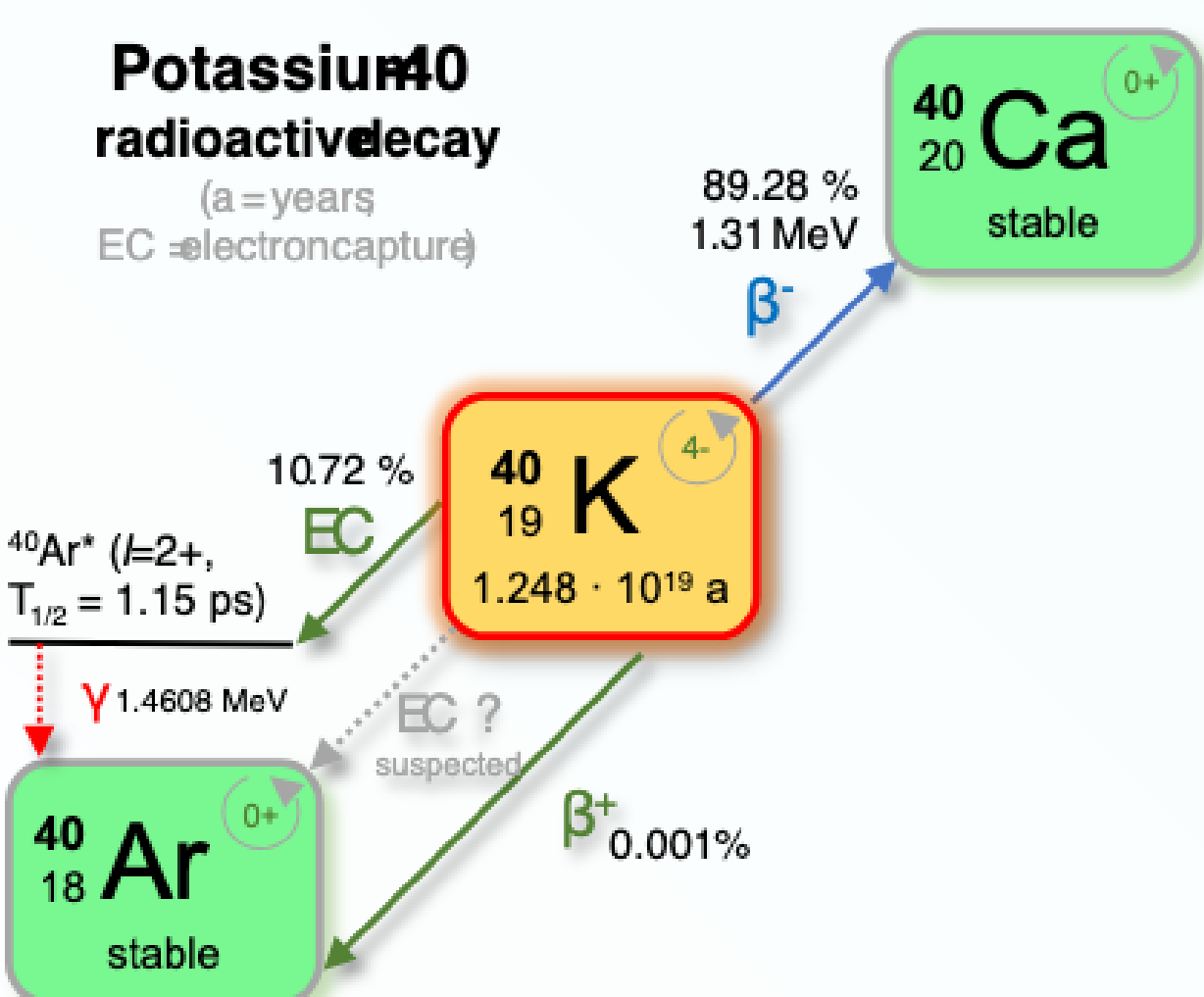
Cosmic Watches provide an accessible, lower-cost platform for student detector experiments. In part 1 of this study, a single Cosmic Watch detector was used to investigate the relationship between radiation intensity and distance from a radioactive source, aiming to verify the inverse square law. The background radiation was measured initially over a three-minute interval. Then a radioactive salt source was placed at increasing linear distances—ranging from 1 to 10 line units—from the detector; the counting rate at each position was recorded. The resulting data were plotted as counting rate versus distance and fitted using an inverse square model. A mismatch between the fit constant and the initial background rate led us to remeasure the background over a longer 10-minute interval. Anomalous data at a distance of 3 lines prompted a repeat measurement, which yielded a value more consistent with the model, though with noticeable count fluctuations. Findings suggest that increasing counting time and improve the reliability of the inverse square law validation using Cosmic Watch detectors. In part 2 of this experiment, the coincidence count rate between two coupled detectors was determined at three different detector spacings to compare it to the acceptance angle for each geometry.

Introduction

Cosmic watches allow students to conduct radiation experiments with relatively low cost detectors and little prior experience. Students can start with single detector experiments to measure radiation versus distance or to map muon rates for a building or geographical feature. The watches can also be operated in two-fold coincidence to investigate zenith angles or acceptance angles for vertically separated detectors.

Materials

- Cosmic Watch
- Lined paper
- No Salt (active ingredient Potassium Chloride)



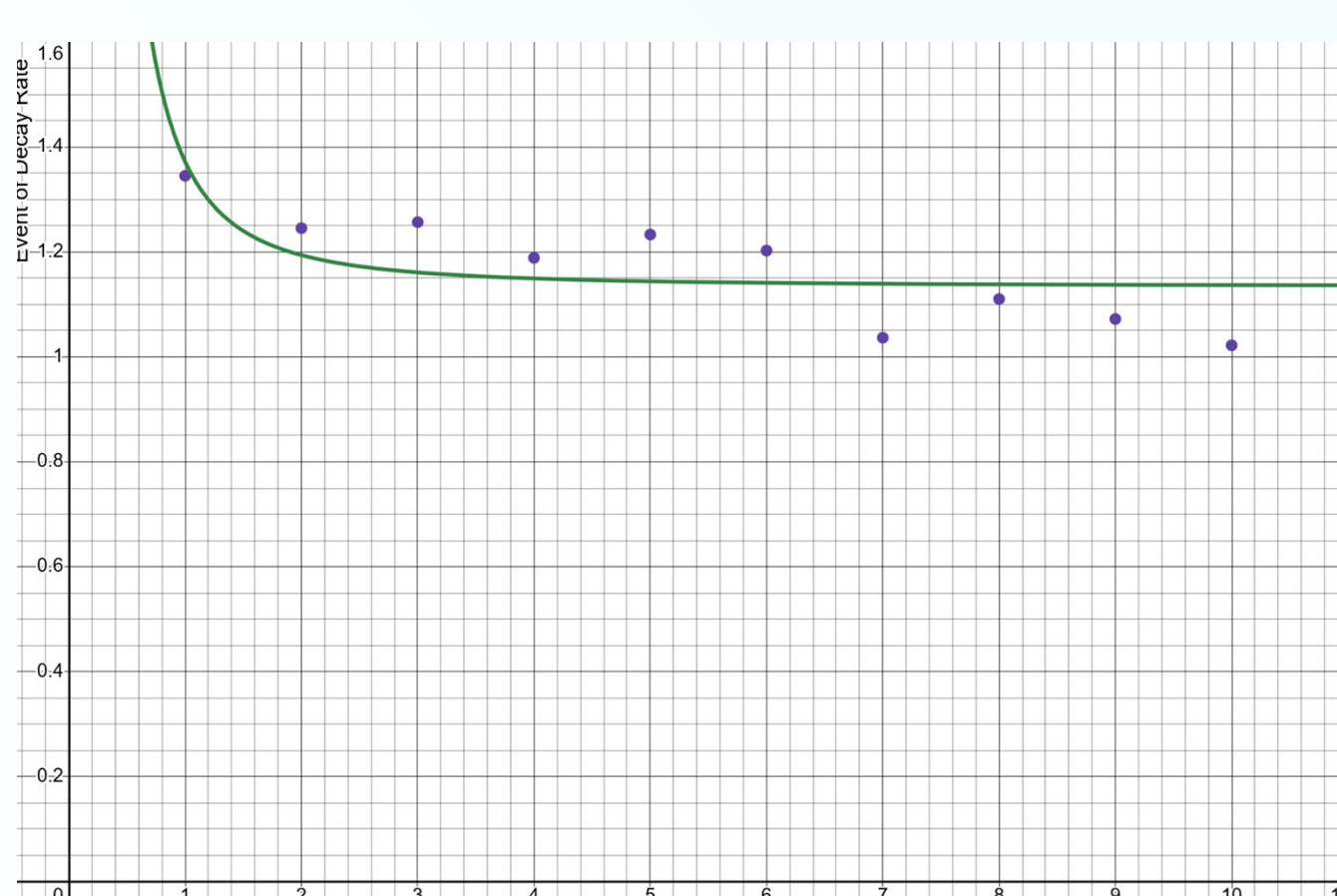
Methodology

Experiment 1: Radiation vs Distance

A single detector was used to measure background counting rates for three minutes. Then, we positioned the No Salt beta emitter one line distance away from the detector and measured the new counting rate for three minutes. We continued to take data for linear distances until we were 10 lines away.

We initially graphed counting rates versus distance. (figure 1). We expected to see an inverse square relationship and so used that as a fit model. After comparing the constant from the best fit graph to the background rate, we determined that we might need to more accurately measure the background rate. We did this by extending the sampling time to 10 minutes. We did observe an outlier at a distance of 3 lines. We took data again at this distance and observed a number closer to the best fit but also observed significant fluctuations in counts.

Figure 1: Experiment 1 Results



$$y = 0.2373x^{-2} + 1.134$$

Experiment 2: Vertical Separation of Two Detectors

This experiment will determine the coincidence count rate of two detectors with varied distances between scintillators as shown in the diagrams below.

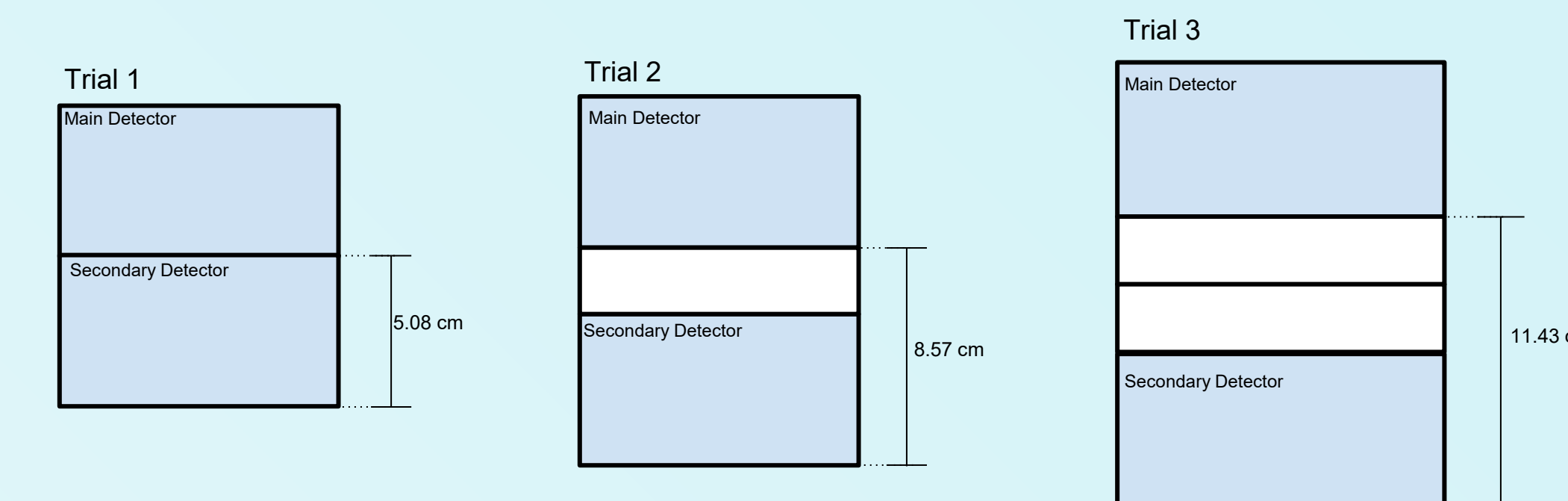
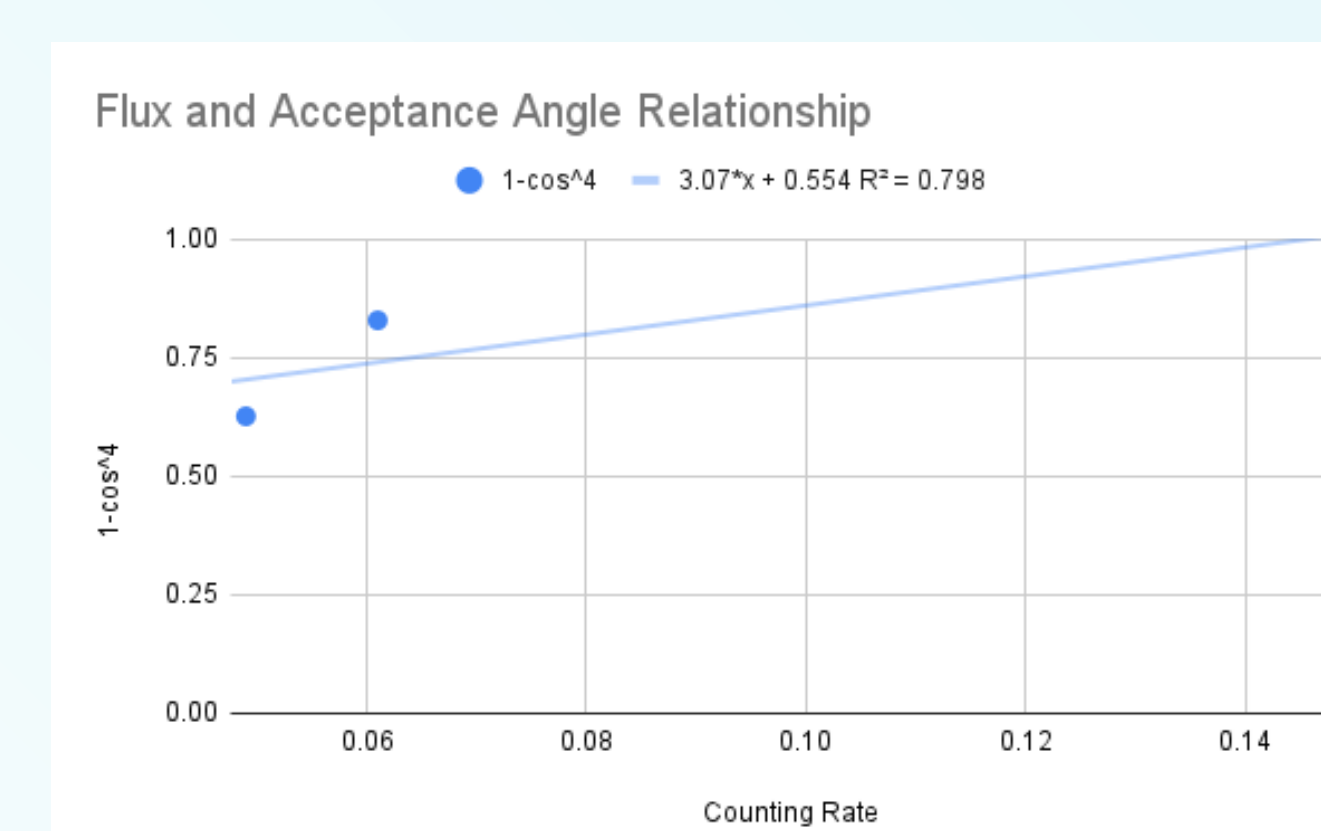


Figure 2: Experiment 2 Results



Reference:

https://courses.washington.edu/phys433/muon_counting/counting_telescope.pdf

Conclusion

Two experiments were completed in less than two hours. For both experiments, increasing the counting time for all distances might improve the data. As well as increasing the number of distances in the first experiment and spacing for the second experiment. The results of experiment one do fall in line with the inverse square law. The results of experiment two do show a linear relationship between counts and cosine raised to the fourth power of the angle of incidence. This was derived from the referenced article. The results of these experiments do show that students can get generally good results in a very



Effect of Radial Distance on Coincidence Detection Rate

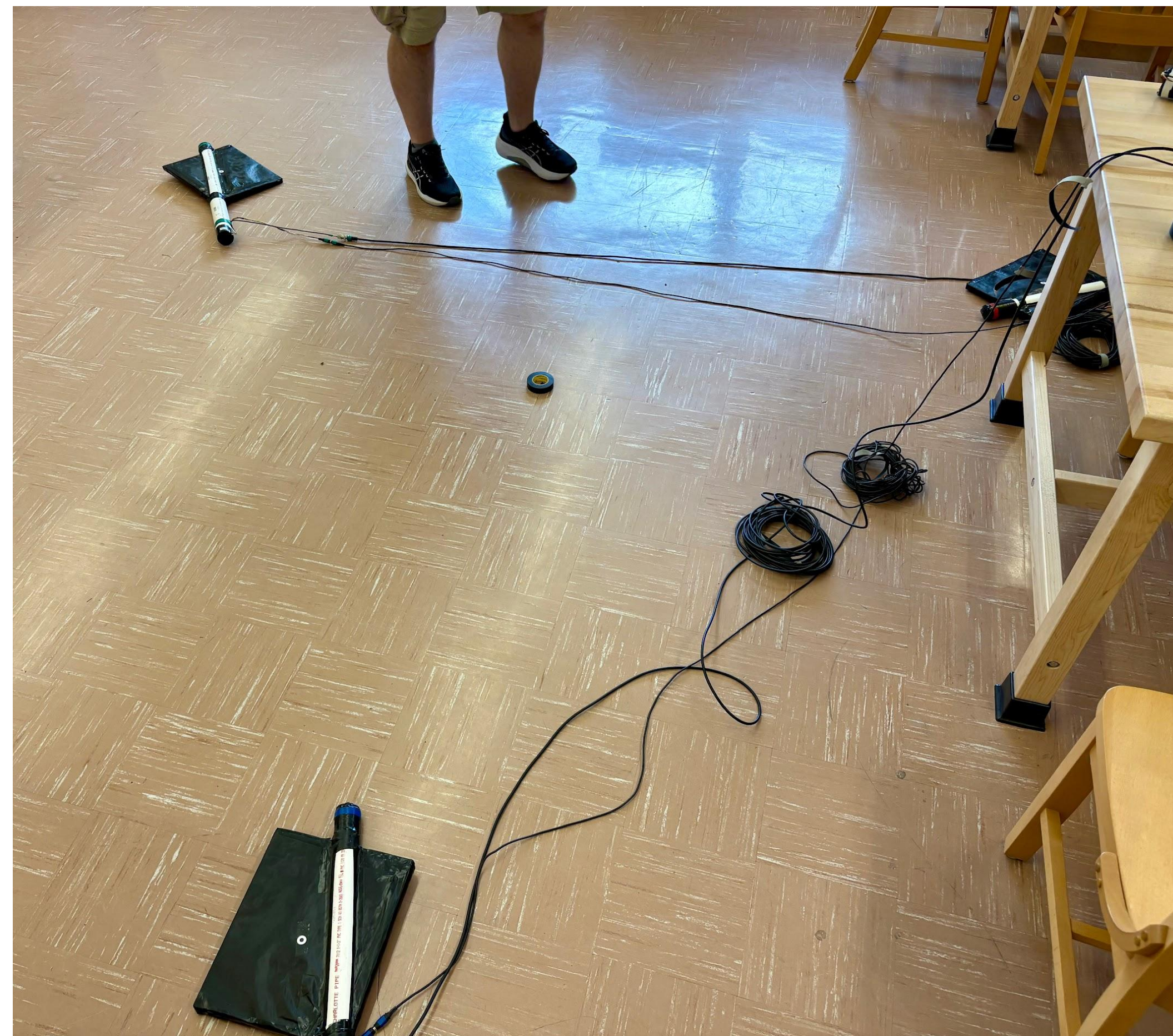


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PROCEDURE:

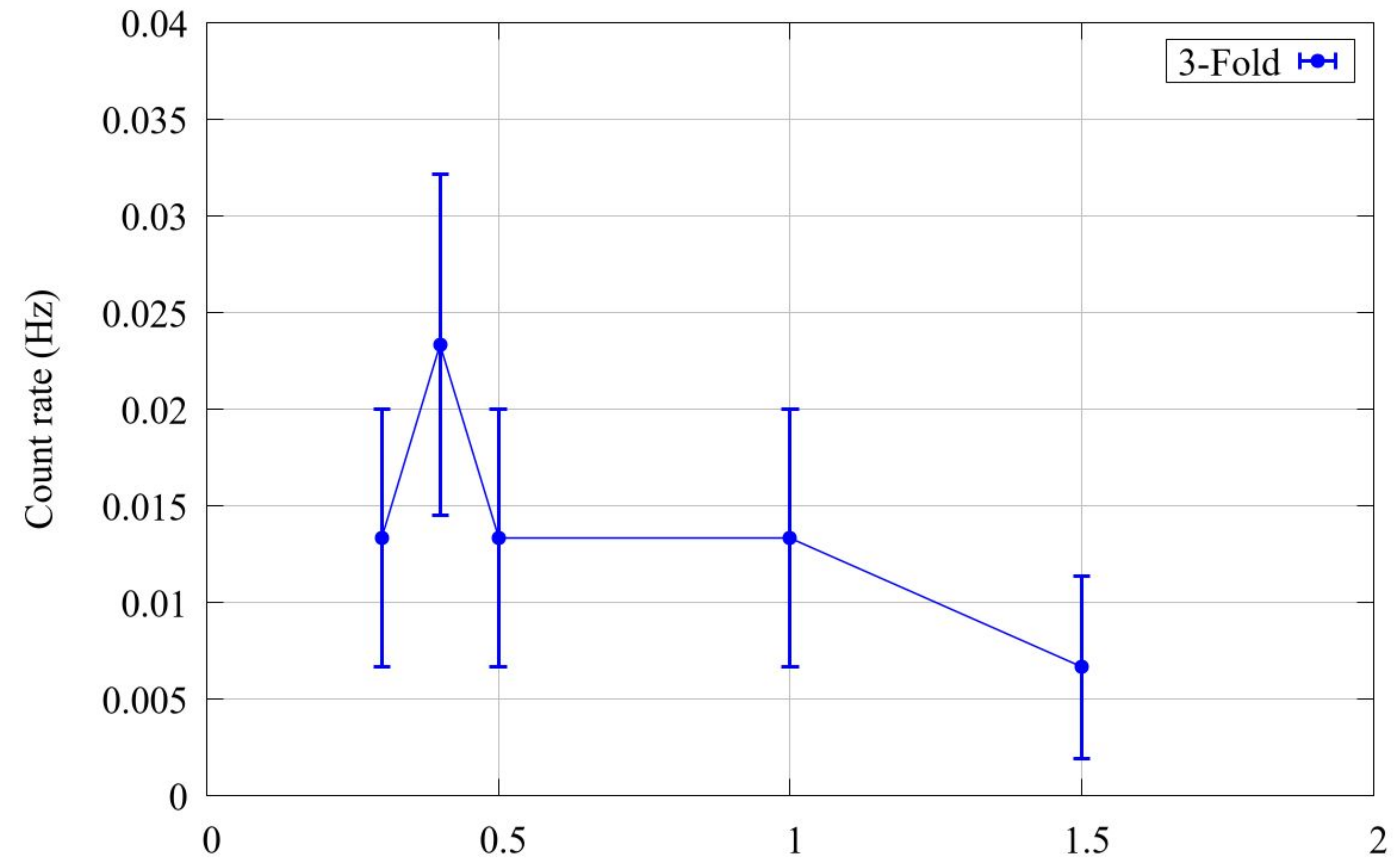
CRMD detector pads were arranged in an equilateral triangle configuration. The radial distance was measured to the center of the triangle. A five minute sampling was conducted at each distance recording 2-fold and 3-fold coincidences.



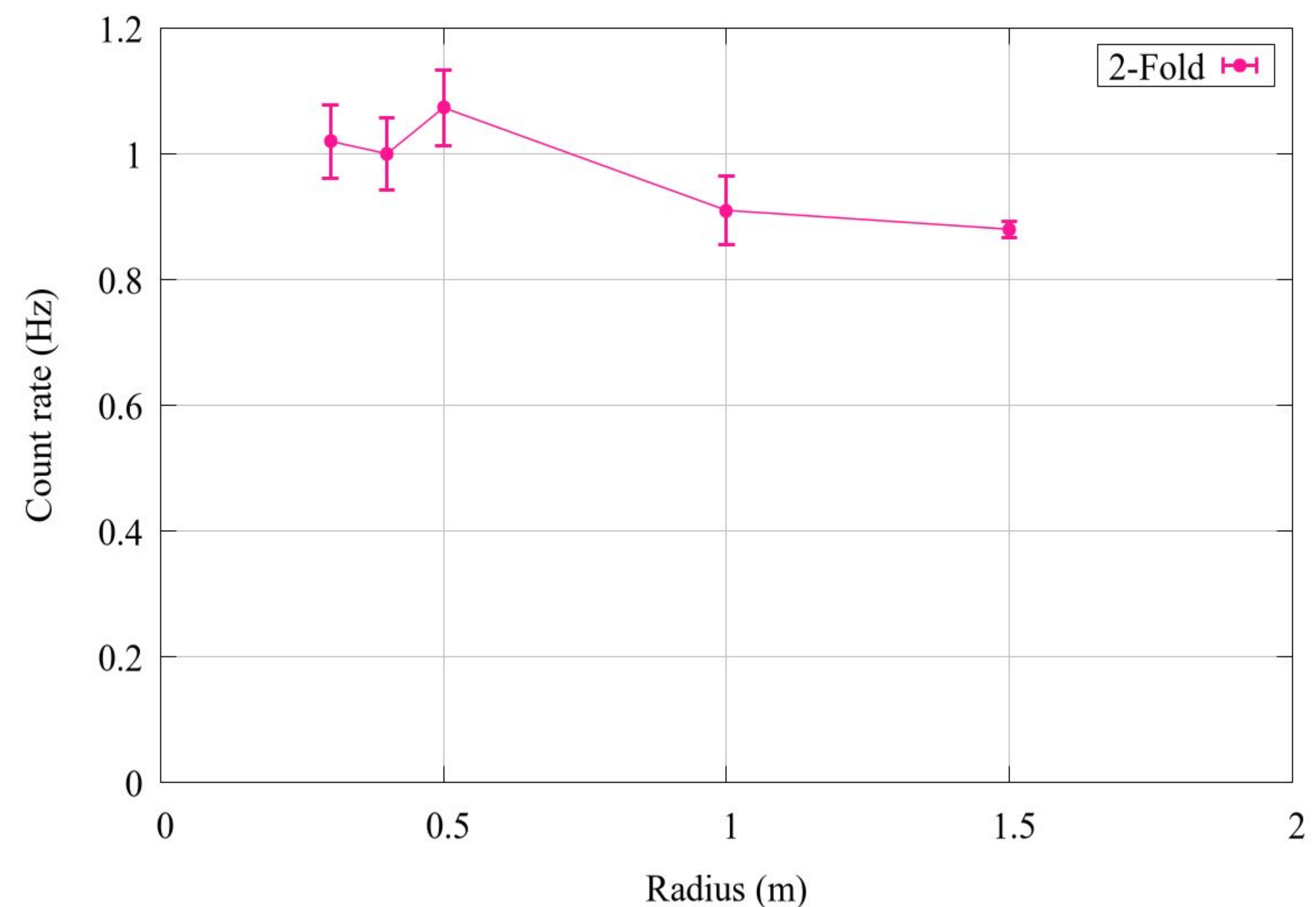
DATA:

Radial Distance	2-fold coincidence	3-fold coincidence
0.30 m	306	4
0.40 m	300	7
0.50 m	322	4
1.00 m	273	4
1.50 m	264	2

3-FOLD COINCIDENCE:



2-FOLD COINCIDENCE:



Cosmic Watch: Effect of Zenith Angle on Muon Rate

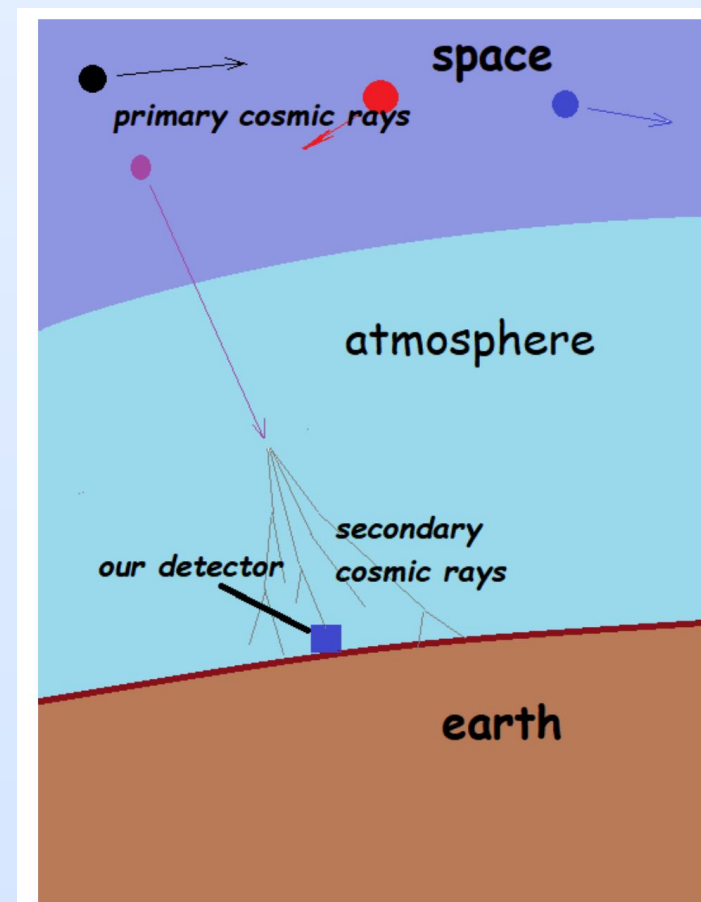
Jeanette Bosch, Sundara Ghatty
Quarknet Workshop: Kansas State University
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Abstract

Cosmic Watch is simple, physics-motivated machine - a small version of cosmic ray detector with which college and high school physics students can perform experiments on muons. The effectiveness of the zenith angle on the muons per sec (rate) was studied by stacking the two cosmic watches vertically for two-fold coincidence. At each zenith angle, the cosmic watch was stabilized, then ran for 5 minutes and the rate in hertz was measured. It was observed that there is an inverse relation between the zenith angle and the rate.

Introduction

Cosmic rays are primarily high-energy protons and ions. When primary cosmic rays collide with the atmospheric nuclei muons are produced 10 km above the surface of the earth. Cosmic Watch is simple, physics-motivated machine- a small cosmic ray detector designed for university students and schools for performing cosmic ray studies. This cosmic watch- a muon detector contains a plastic scintillator which acts like a detection medium and a silicon photomultiplier for light collection. When muons pass through the scintillator, encounter heavy organic molecules, through Coulomb interaction, they give some energy to electrons. Then electrons jump to higher energy levels, and muons jump back down and emit light. The photo multiplier converts light to electric current and then turns in to signals.



Materials and Methods

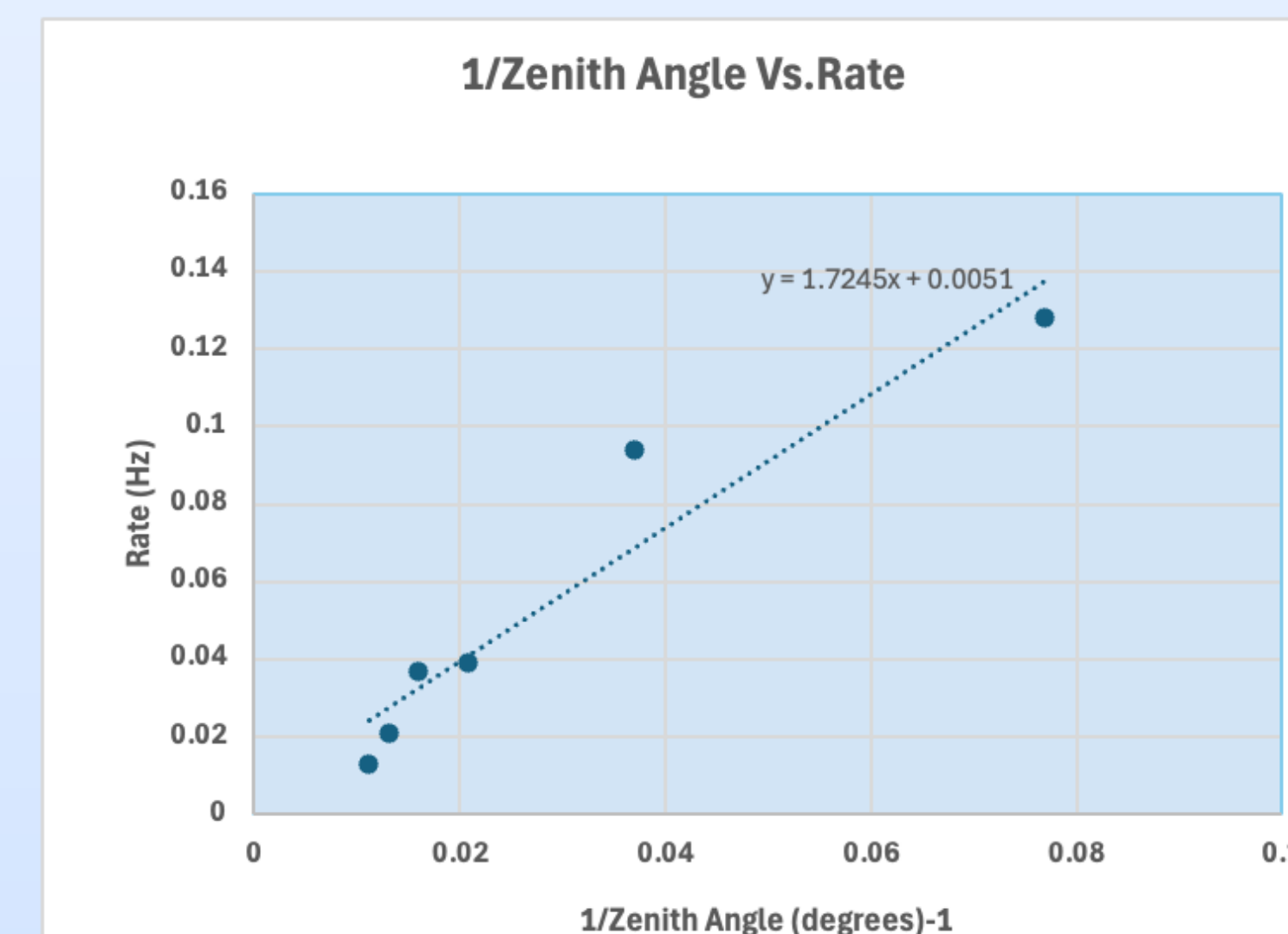
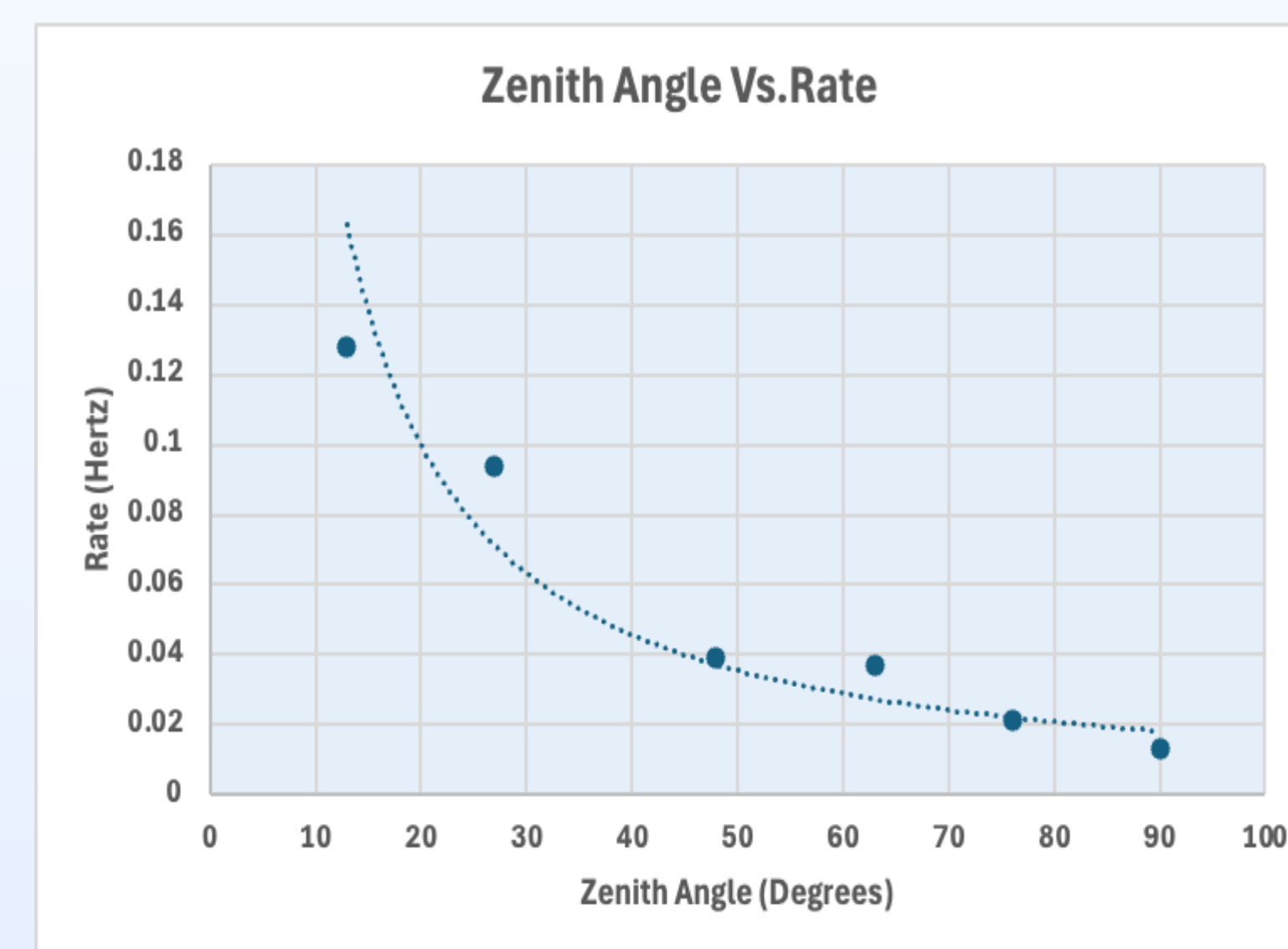
Pair of cosmic watches
Protractor
Timer

The pair of cosmic watches were stacked vertically for two fold coincidence. Initially, the two watches are stacked so that the zenith angle is zero degrees. From this position, the stack of watches are rotated for different zenith angles, and for each angle, the muon rate was recorded for 5 minutes. A graph was made with the independent variable (zenith angle) on the x-axis and the dependent variable (muon rate) on the y-axis.



Results

Zenith Angle (Degrees)	Muon Rate (Hz)
13	0.128
27	0.094
48	0.039
63	0.037
76	0.021
90	0.013



Conclusions

The Cosmic Watch is a vital device that can be used in a classroom setting to conduct cosmic ray experiments on a smaller scale. Students can carry out experiments on cosmic rays and even design their own. The Cosmic Watches are user friendly with easy to read display for data collection. Students would need a basic understanding of the Sun and how light travels with an introduction into muons.

From the current experiment, it was observed that as the zenith angle increases, the muon rate decreases. This may be because, as the zenith angle increases, muons have to travel longer distances through the atmosphere to reach the detector. During this journey, they may undergo interactions or decay, thereby reducing the number of muons that reach the detector.

As a teacher, it is important to develop a deeper understanding of how the watch functions and the characteristics of muons. Then, experiments should be conducted following proper procedures to yield more accurate results.

Discussion

From the data and the shape of the graph, it is observed that as the zenith angle increases, the muon rate decreases. However, the shape of the graph supposed to be different. These were the possible errors made during the experiment.

Possible Errors:

- Main Cosmic Watch is on bottom and Secondary is on top.
- Not all data points taken at the same time.
- After resetting, the uptime was not the same for each trial.
- Started taking data for 2 minutes, which did not allow for enough trials.
- Switched to 5 minutes for each trial, but 10 minutes would have been more accurate.
- Collected 7 data points. More data points are needed for accuracy.
- In using a smart phone as the protractor, we had the button edge down. This made a difference in the angle. The buttons of the phone need to be away from the surface being measured.
- Cosmic Watches may not have been aligned the same each time. As the angle increased, there tended to be separation of the two Cosmic Watches.

Future study

- Is it better to angle the Cosmic Watches towards a wall of windows or an interior solid wall for a high rate of muon detection?
- Does the movement of air in room by fans change the rate of muon detection?
- How do barometric pressure changes effect the muon detection rate?
- How does extreme temperature changes effect the muon detection rate?
- Does the number of people moving about in a room effect the muon detection rate?
- Does the angle of the Sun to the collection point effect the muon rate?
- Should the Cosmic Watches be reset between each data point?
- What is the optimal time for length of Uptime to allow for stabilization of rate detection before starting data collection time?
- Does the humidity level effect the muon rate detection?
- Do lights in the room interfere with the rate of muon detection?
- Does the elevation of the Cosmic Watches within a building change the rate of muon detection
- Change in height of counter from vertical position to horizontal position (As angle increases, collection height from surface decreases)
- Do lightning strikes affect rate?
- Cosmic Ray data collection on Earth vs. Mars or Moon
- Place another detector over the setup to rule out vertical muon showers as the angles change.

References

Cosmic rays: https://quarknet.org/sites/default/files/file-uploads/RiceCW_11jun2025.pdf
Cosmic Watch: <http://www.cosmicwatch.lns.mit.edu/>
Cosmic muons: https://quarknet.org/sites/default/files/file-uploads/RiceCW_11jun2025.pdf
Cosmic Watch Lab Suite Teacher Notes - Draft Document

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