Determining the Relativistic Effects of Muons via a High-Altitude Experiment

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1. Background

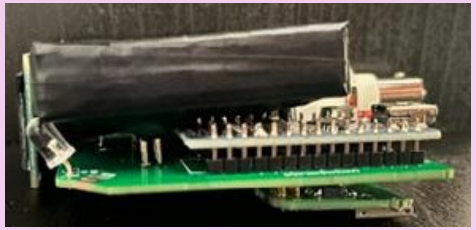
- According to the standard model, a muon is the second generation of charged lepton, and one of the six fundamental leptons featured in the model.
- Muons are encountered daily as the sun's cosmic rays collide with the atoms within the stratosphere to create pions, kaons, and muons.
- This experiment measures the count rate and decay patterns of muons, to inform interpretations related to special relativity.

2. Hypothesis to be tested

- Special relativity states that the laws of physics are the same for all observers relative to each other. Given the speed of light remains constant, time dilation is a product of special relativity.
- This explains how muons could be detected at altitudes where their lifetime should not allow.
- To a stationary observer, a muon travelling near the speed of light appears to experience time moving slower.
- Accordingly, muons can be detected at lower altitudes as a muon lifetime appears to be longer to an observer.

3. Apparatus

- A homemade muon detector



4. Methodology

Step 1: Power the detector through the Arduino nano and wait for two minutes for the count rate to even out.

Step 2: Record the count rate in 2 minute intervals.

Step 3: Eliminate the risk of a false readings from the connection between the SiPM PCB & the corresponding HV connector by completing a 'power off' interval.

Step 4: After the count rate drops as the plane descends, stop taking measurements.

5. Critical formulae

Gamma Factor

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{1}{\sqrt{1-\beta^2}} = \frac{dt}{d\tau},$$

Time dilation

$$T = \frac{T_0}{\sqrt{1-\frac{V^2}{C^2}}}$$

6. Conclusion

- The results in Figure 1 show an increased muon count (to ~21.5 - 22) as the airplane altitude increases.
- Taking v to be 0.99c, we get gamma = 7.09
- The graph in Figure 2 predicts the count rate of muons without taking the gamma factor into account.
- The graph in Figure 3 takes gamma into account to perform accurate predictions of count rate based on altitude.
- From this, we can conclude that time dilation allows us to observe muons at relatively low altitude, though some will decay before being detected at the surface.

7. Figures

Figure 1: Muon Count Rates at altitude

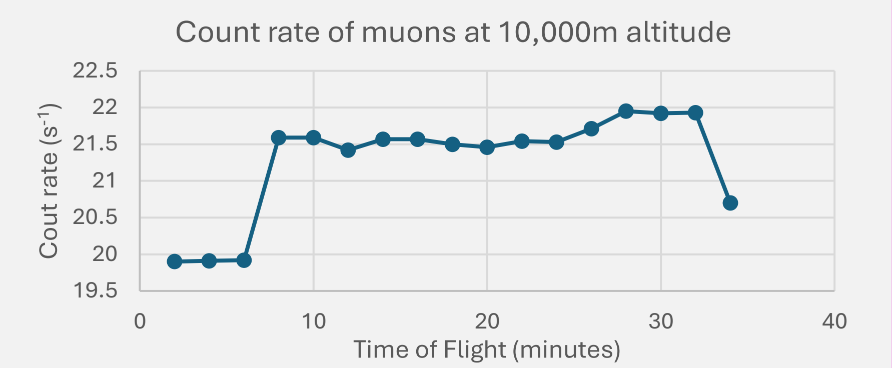


Figure 2:
Non-relativistic curve

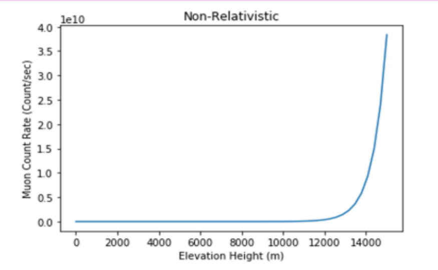
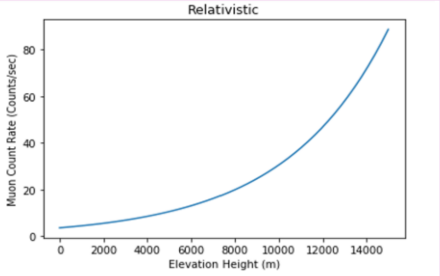


Figure 3:
Relativistic curve



8. References

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