INVESTIGATING MUON LIFETIME AND DECAY USING A COSMIC-RAY MUON DETECTOR

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INTRODUCTION

- Muons are fundamental particles that make up most of the cosmic radiation the earth receives.
- Muons belong in the lepton family with electrons and neutrinos.
- Muons can facilitate nuclear fusion at relatively low temperatures in a process called muon-catalyzed fusion.

OBJECTIVE

- Muons will come in contact with the detectors, thus producing light in the scintillating material that is amplified by paddles connected to the photomultiplier tube (PMT).
- Data will be collected from the DAQ board[1] that is connected to the paddles. (Fig. 3)

BACKGROUND

- A counter is comprised of a plastic scintillator wrapped in foil and a photomultiplier tube, which provides the operating voltage and sends signal to the DAQ board[1].
- It is necessary to calibrate the PMT (operating) voltages with a procedure called "plateauing the counter."
  - Calibration minimizes the drift effects (counting variations resulting from drifts in tube gain or voltage over time).
  - Plotted count rate vs potentiometer dial values, measured from the power distribution box, results in a semi-log graph with a horizontal portion – the "plateau."
- Voltage comparators must be set to a precise threshold .
  - Threshold voltages determine whether a collision is counted by establishing an energy the colliding particle must reach.
  - Plotted count rate vs threshold voltage directly, "plateau" once again indicates the correct value. (Fig. 1)

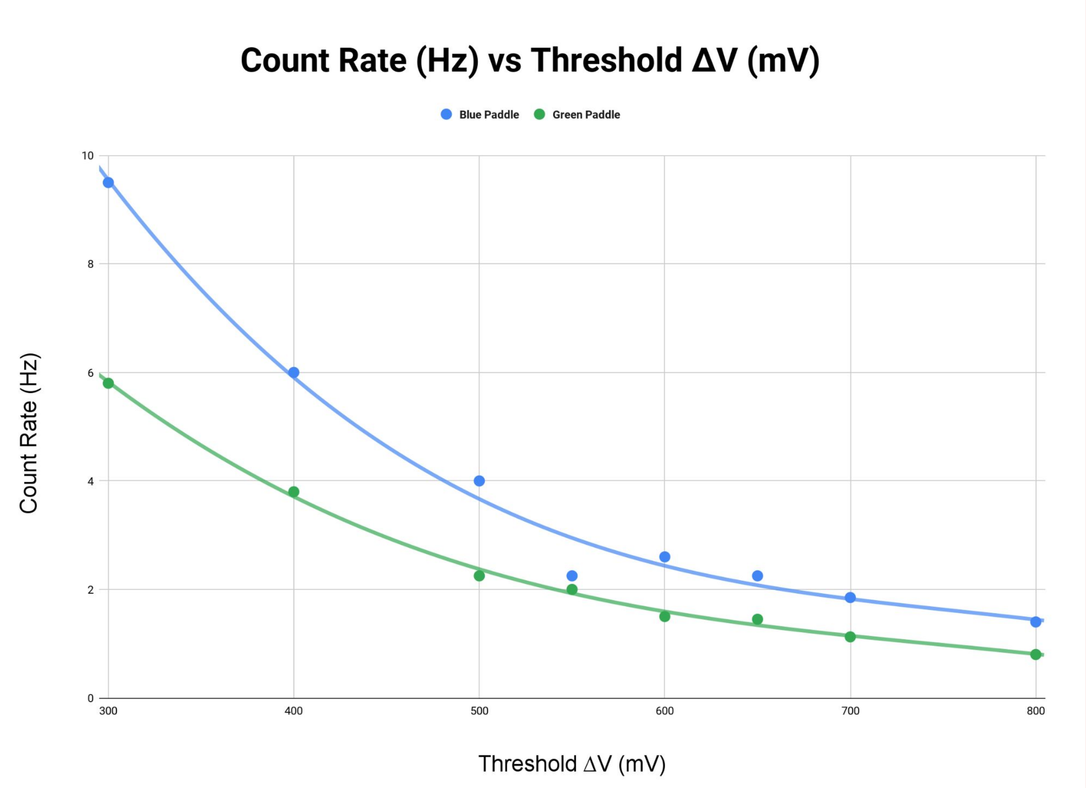

Fig. 1: Threshold Voltage Graph
Blue paddle -600 mV, Green paddle -650 mV

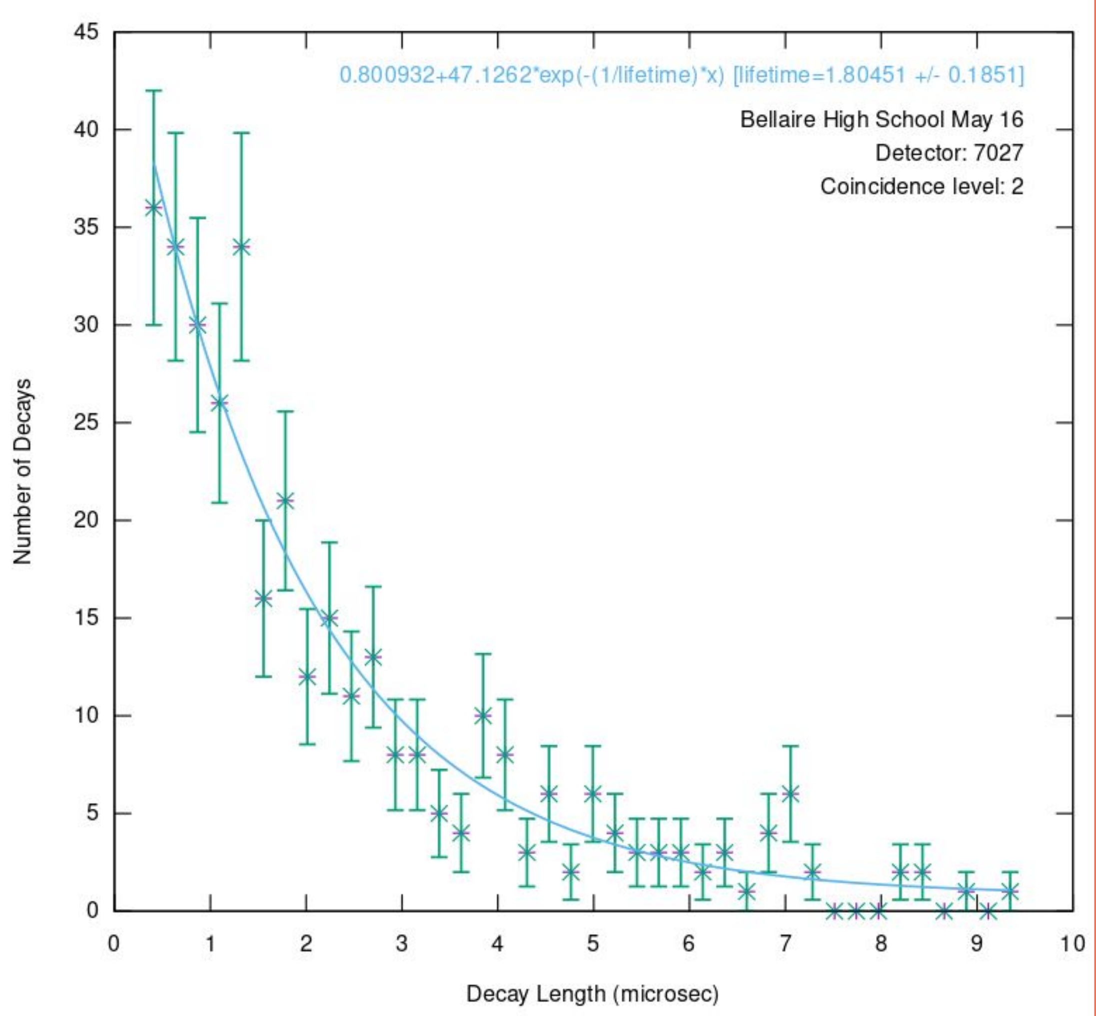

Fig. 2: Muon Lifetime Approximation

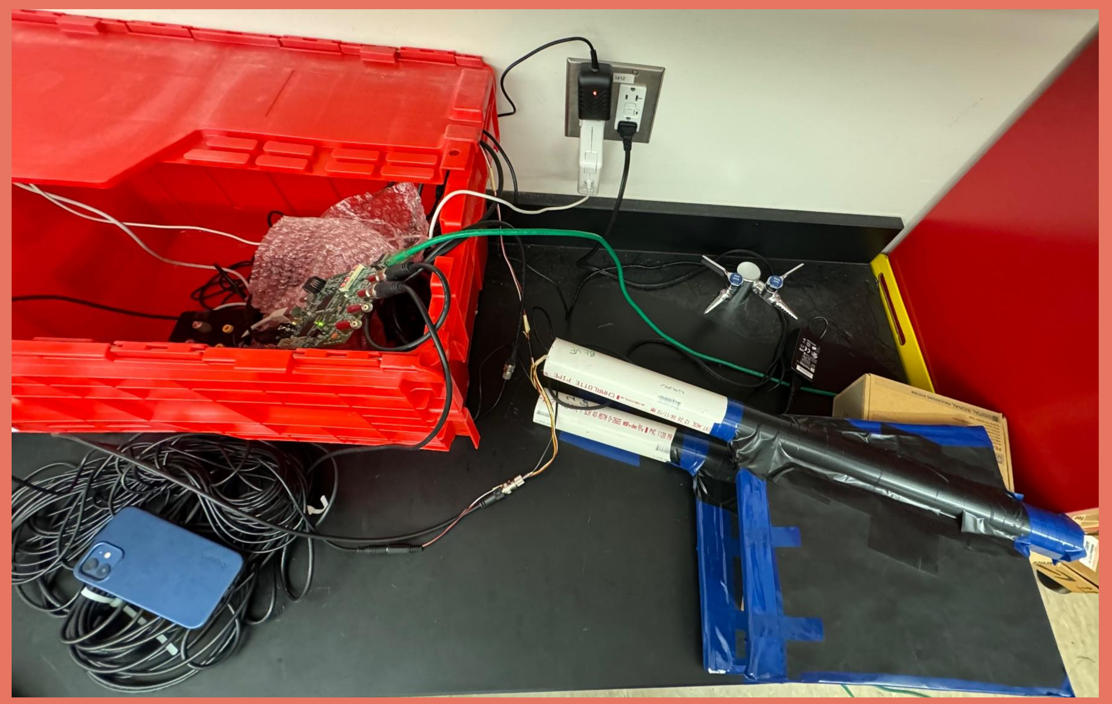

Fig. 3: Detectors Setup

PROCESSES & RESULTS

- Muon lifetimes can be measured by vertically stacking scintillators.
  - With two scintillators, a muon will enter the top paddle, producing a "count." It will then travel to the second paddle, producing another "count." If the muon decays in the second paddle, it will emit a third "count." When a muon decays, it breaks down into an electron and two neutrinos.
  - Quarknet calculates mean muon lifetime by plotting number of decays versus decay length. (Fig. 2)
  - A veto scintillator can be used to improve accuracy by checking whether the muon has decayed in the second paddle or whether the third "count" was caused by another cosmic ray.
- Based on the data collected, the average muon lifetime is around 1.80451 μs (Fig. 2), and there seem to be higher count rates at lower threshold voltages. (Fig. 1)

CONCLUSION

- Muon lifetime has been scientifically agreed upon to be 2.2 μs; our result of 1.8 μs includes error that likely resulted from the short runtime (~20 hours) or other errors during data collection.
- Error can be reduced with longer runtime and a veto paddle.

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[1] Rylander, et al. "QuarkNet Cosmic Ray Muon Detector User's Manual Series "6000" DAQ Version 1.1" (January, 2010)