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An Exploration Into Muon Detection

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Introduction

This investigation delved into the theoretical aspects of muons, exploring their origin, decay characteristics, charge ratio, and connection to the Fermi coupling constant. The study further examines external factors influencing muon counts, such as solar flares and stopping ranges, and concludes with the determination of the positive muon half-life. This study aims to enhance our understanding of fundamental particle and astrophysical processes through unravelling the intricate interplay between cosmic ray muon detection and external factors.

Methods

Muon count and decay data were collected using a plastic scintillator muon detector, connected to a readout electronics module. The data processing involved timestamped muon events and timeouts, all which were then analysed using custom Python scripts.

Result A: Muon Half-Life

Muon decay data was analysed. It was found that muon half-life comprises a mixture of both the positive and negative muon lifetimes. Therefore, we separate these two to find the positive muon half-life τ^+.

$$\tau^+ = \frac{\rho \cdot \tau^- \cdot \tau_{obs}}{\tau^-(\rho + 1) - \tau_{obs}}$$

Negative muon half-life in carbon.

Observed half-life.

Muon Flux ratio.

The final calculated value for $\tau^+ = 2.174 \pm 0.015\,\mu s$. Systematic error of 1% caused by τ^- & ρ approximation.

Result B: Forbush Decrease

Muon count data was analysed to investigate Forbush decreases (sudden drop in counts) after a solar flare. A large X2.3 class solar flare showed a 13% muon count reduction, a significant 8σ deviation from norm as shown:

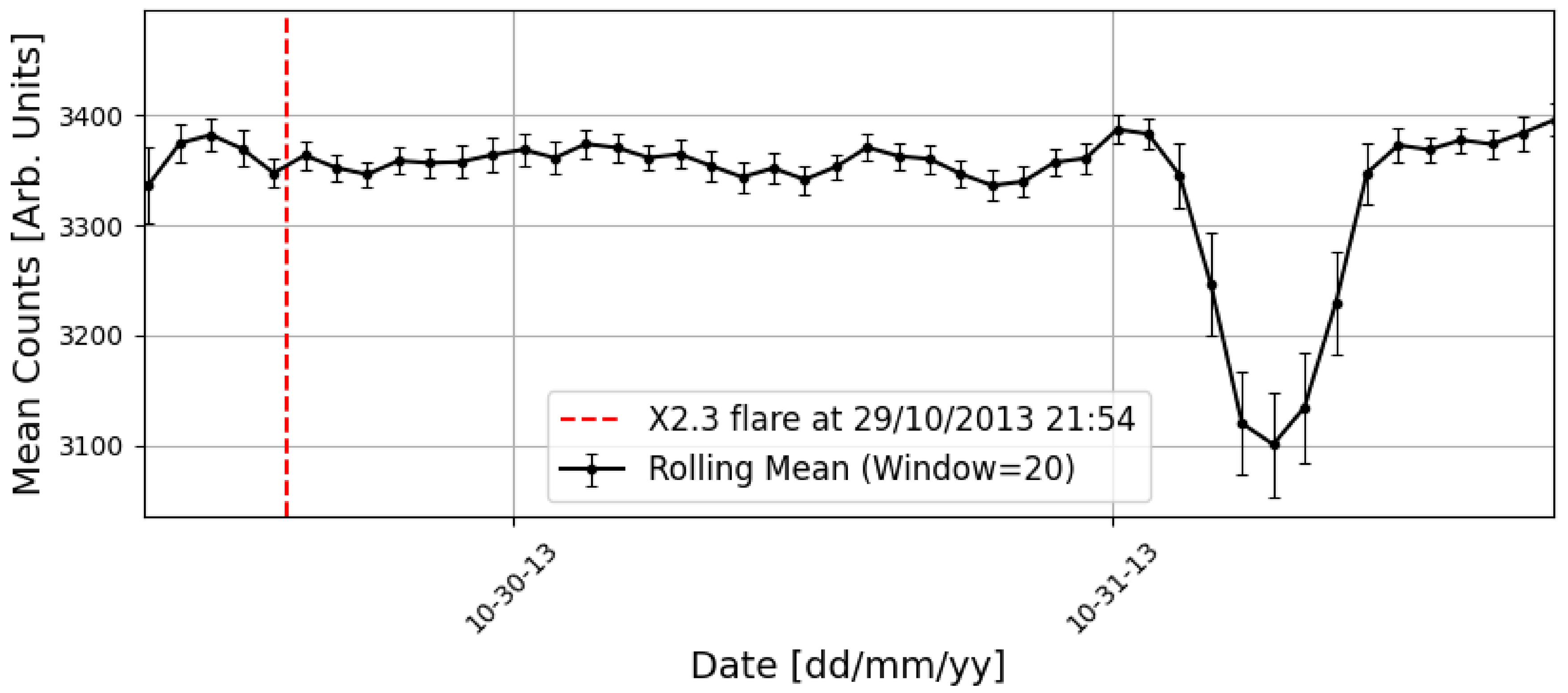

Fig. 1: Points show rolling mean of muon counts in 45-minute bins with a sliding window of 20; error bars show the standard error within each bin. The vertical line indicates the flare.

Result C: Muon Counts Vs. Pressure

Count data was analysed to investigate the negative correlation between muon counts and barometric effects.

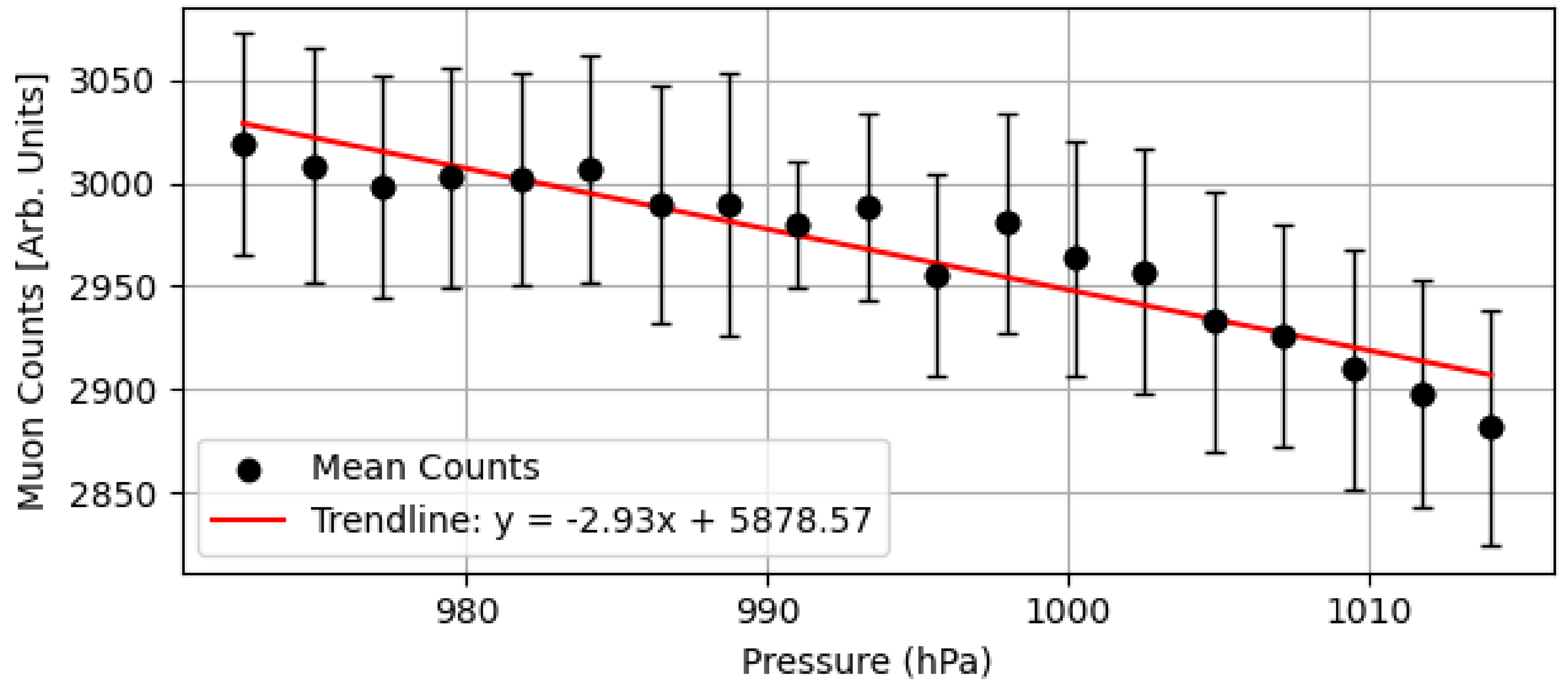

Fig. 2: Points show muon counts in 20 equal bins; error bars show the standard error within each bin. The line is a linear fit.

Result D: Muon Momentum Spectrum

Muon count data was analysed under varying steel shielding with the aim to partially construct the muon momentum spectra.

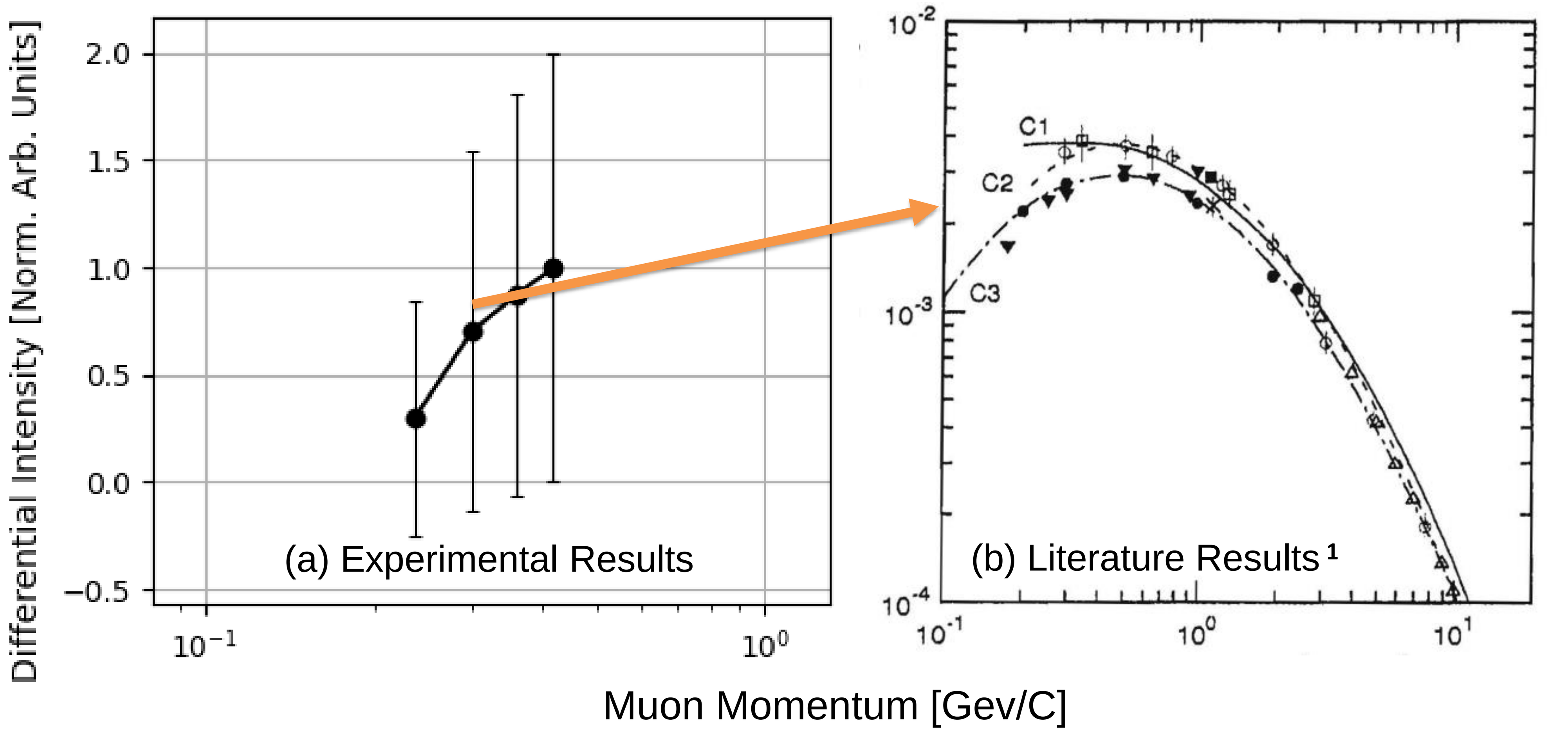

Fig. 3: Plots compare differential intensity varying with muon spectra; error bars are determined by Poisson statistics.

Conclusions

The study revealed correlations between muon counts and solar flares and atmospheric pressure, providing valuable insights into the complex relationship that underlies muon detection and external events. The muon half-life was calculated to a 0.5% error from literature and a partial reconstruction of the muon momentum spectrum was obtained. Further research could attempt to measure a larger range of muon momentums and investigate the nature behind what exactly causes a Forbush.

References

[1] P.K.F. Greider, "Cosmic Rays At Eath" ISBN 0-444-50710-8 British Library (2001) pg 254.

Acknowledgements

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