

Identifying Significant Muon Events

1 Introduction

I have been able to set up three pairs of Cosmicwatch muon detectors within 1m of each other on the bench. Each pair operated independently as a coincident pair. These are two pairs of UKRAA's development and test units and one pair of my own. All six detectors were in the same environment at the same temperature. The results were recorded on either a RaspberryPi or Beaglebone using the same Python script. Each of the computers all took their time from a common local time server. The server took its time from the UK internet time pool.

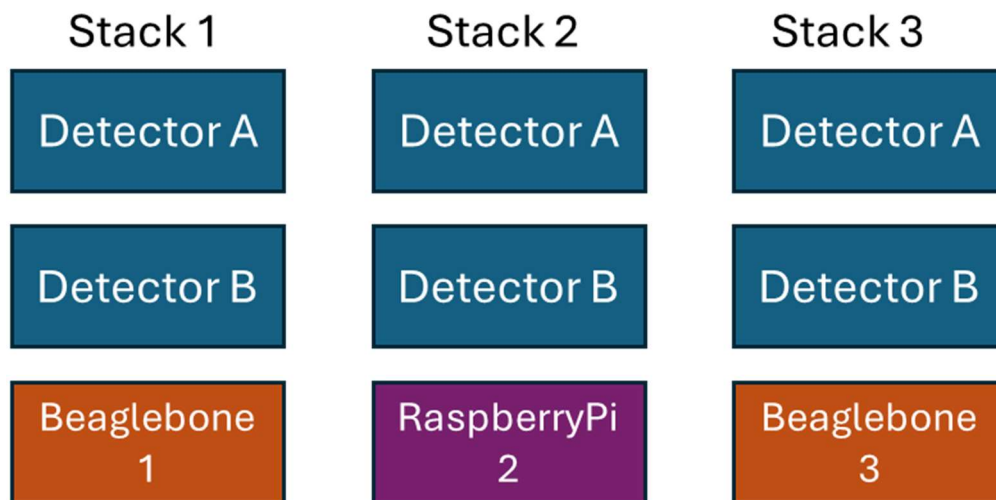


Figure 1: Detector configuration

The software recorded every event in the coincident detector and counted the number in each minute from midnight 00:00:00 to the following midnight 23:59:00.

The objective was to look at two questions:

- Do all three detectors record high per minute counts in the same minute?
- If so is this a coincidence or a significant event.

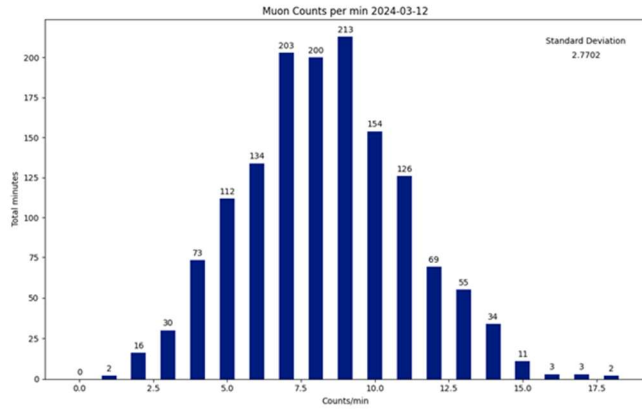
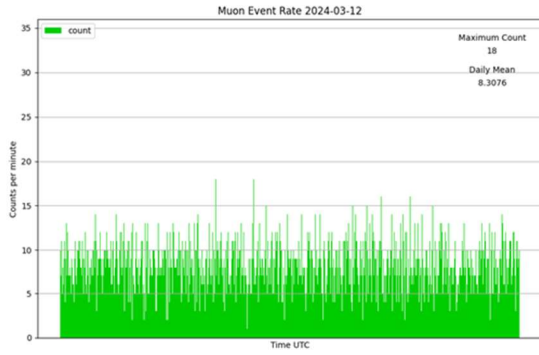
2 Typical results

Data was recorded for 46 days from 2024 February 15 to March 31. During that run there were two days with no data which were discounted.

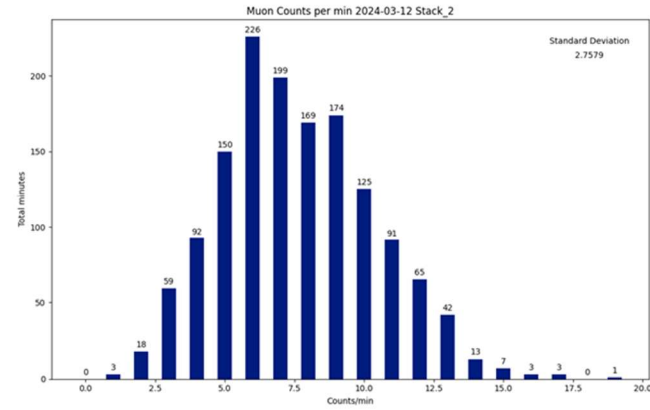
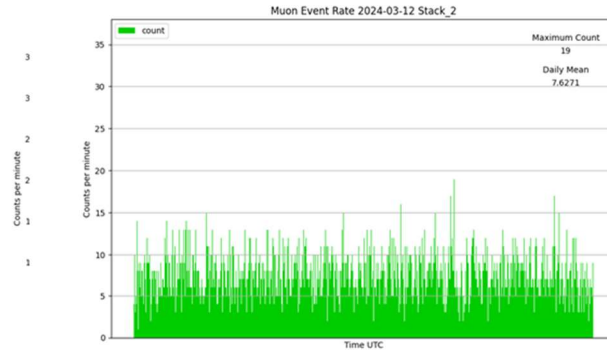
Figure 2 shows a typical days results. The top graphs show the per minute count plotted over 24 hours. The bottom graph shows the frequency of each per minute count over 24 hours.

Figure 2: Data recorded on 2024 March 12

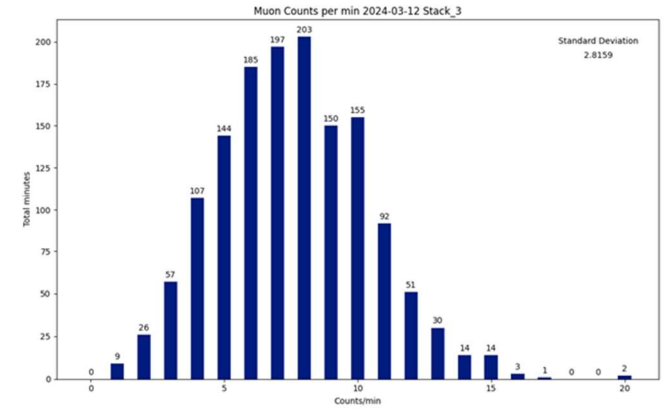
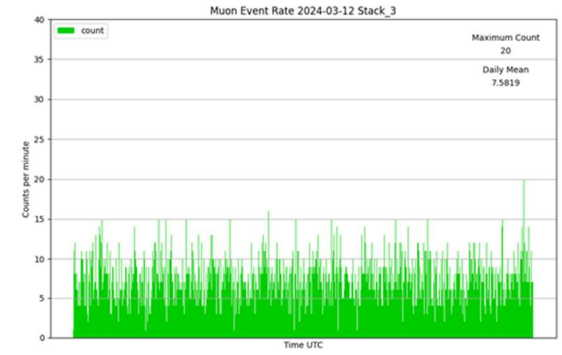
Stack 1



Stack 2

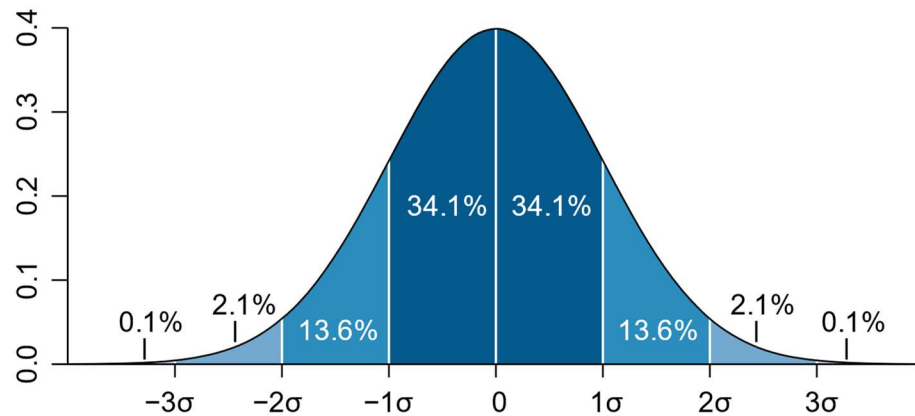


Stack 3



3 Analysis

My knowledge of statistical methods is very limited, but the counts/minute frequency looks like a normal distribution curve. With the assistance of online resources (Wikipedia) I found this explanation of the curve



Dark blue is one standard deviation on either side of the mean. For the normal distribution, this accounts for 68.27 percent of the set; while two standard deviations from the mean (medium and dark blue) account for 95.45 percent; three standard deviations (light, medium, and dark blue) account for 99.73 percent; and four standard deviations account for 99.994 percent. ¹

The mean counts/minute and the standard deviation were computed for each detector.

- Only minutes where the count exceeded 2 standard deviations above the mean were considered interesting.
- The days data was filtered to remove minutes below 2σ .
- A match in time from all three detectors is considered interesting.
- A match in time from any two detectors is recorded but not considered interesting.

Results for 2024 March 12

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Stack 1: Max counts/min = 18: Standard Deviation = 2.7702: Mean counts/min = 8.3076: High Count = 14.0
Stack 2: Max counts/min = 19: Standard Deviation = 2.7579: Mean counts/min = 7.6271: High Count = 13.0
Stack 3: Max counts/min = 20: Standard Deviation = 2.8159: Mean counts/min = 7.5819: High Count = 13.0
Match Stack 1 ['2024-03-12 02:55:00', 14] : Stack 2 ['2024-03-12 02:55:00', 13]
Match Stack 1 ['2024-03-12 03:12:00', 15] : Stack 3 ['2024-03-12 03:12:00', 13]
Match Stack 1 ['2024-03-12 05:00:00', 14] : Stack 3 ['2024-03-12 05:00:00', 13]
Match Stack 1 ['2024-03-12 07:11:00', 14] : Stack 3 ['2024-03-12 07:11:00', 13]
Match Stack 1 ['2024-03-12 14:10:00', 14] : Stack 2 ['2024-03-12 14:10:00', 14]
Match Stack 1 ['2024-03-12 15:21:00', 15] : Stack 3 ['2024-03-12 15:21:00', 20]
Match Stack 1 ['2024-03-12 21:19:00', 14] : Stack 2 ['2024-03-12 21:19:00', 14]
Match Stack 2 ['2024-03-12 04:19:00', 14] : Stack 3 ['2024-03-12 04:19:00', 13]
Match Stack 2 ['2024-03-12 13:56:00', 16] : Stack 3 ['2024-03-12 13:56:00', 13]
Match Stack 2 ['2024-03-12 15:32:00', 13] : Stack 3 ['2024-03-12 15:32:00', 13]
```

¹ By M. W. Toews - Own work, based (in concept) on figure by Jeremy Kemp, on 2005-02-09, CC BY 2.5, <https://commons.wikimedia.org/w/index.php?curid=1903871>

Over the 42 days where a full days data was recorded on all three detectors:

- Two detectors recorded simultaneous counts over 2σ occurs every day
- There were four days where all three detectors recorded counts above 2σ
- No results were obtained for 2024/02/20 and 2024/02/28.

This is illustrated in Figure 3 below.

4 Comments

I am now at the limit of my understanding of statistics which stops me drawing any conclusions from these results.

The outstanding question is:

Are the occasions where each detector recorded a high count in the same minute a coincidence or a significant event?

Any assistance from the readers of this note would be most welcome. My contact email is andrew.thomas@ukraa.com

Figure 3: Daily numbers of matching events.

