Baseline: Looking For the Cosmic Ray Moon Shadow

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Introduction

The Moon is a large barrier that should create a cosmic ray shadow. From previous experiments, the shadow does not align with the center of the Moon[1], however, experiments sensitive to 1-TeV and higher energy ranges have found evidence of the shadow[2]. QuarkNet detectors are sensitive in the GeV range. Earth's magnetic field changes the path of the primary cosmic ray, and then causes particle showers at different points of the sky. This experiment looks for the cosmic ray shadow of the Moon at energies above 2 GeV.

Motivation

To locate the lunar cosmic ray shadow in the 2 – 200 GeV energy range.

Methods

Using multiple cosmic ray muon detectors, a collaboration of schools recorded cosmic ray muon data along the lunar path in the sky. Each detector was set at one of four angles of elevation. Centering on the daily meridian passage of the Moon, data were aggregated into monthly, then yearly averages. Graphs of ± 10 hours from meridian passage were then analyzed and compared to search for a drop in muon count, indicating the presence of a cosmic ray shadow.

We used four muon detectors in the geometry as shown in Diagrams 1 and 2. This geometry allowed for looking frontward and rearward along the lunar path, and for measuring the flux at large and small angles of acceptance. The detectors were placed at angles of elevations of 26, 55, 60, and 70 degrees. This design allowed for data collection without daily angle adjustment of any detector. Data were gathered over a period of 13 months.

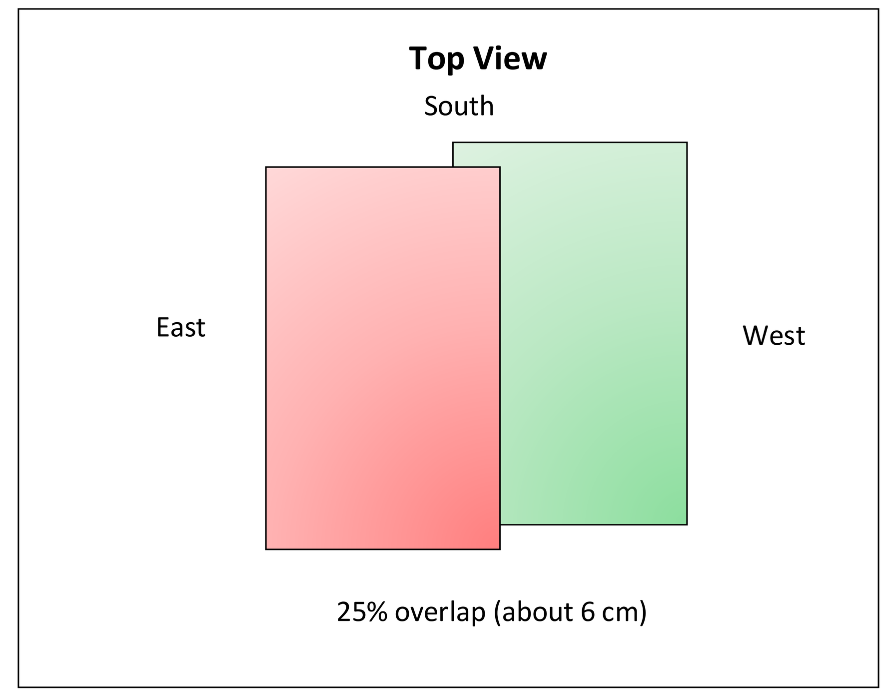


Diagram 1. **Top view of counter geometry showing ¼ overlap**. The central overlap allows for different angles of acceptance.

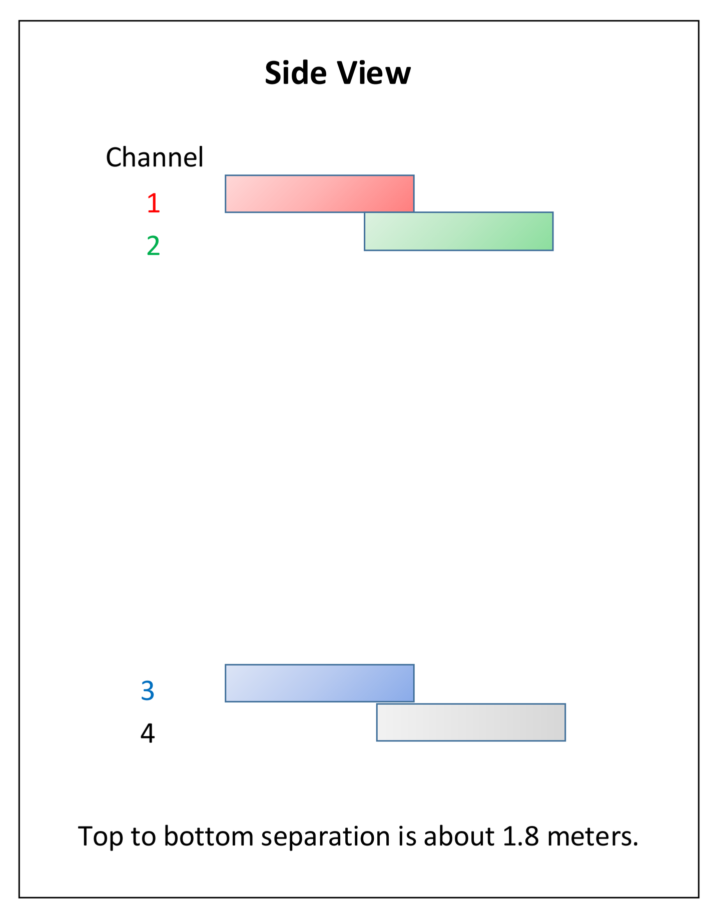


Diagram 2. **Side view geometry**. Counters 2-3 and 1-4 look to the west and east of the zenith point. Counters 1-3 and 2-4 give a wide angle view of the zenith, while counters 1-2-3-4 yields higher resolution.

Results

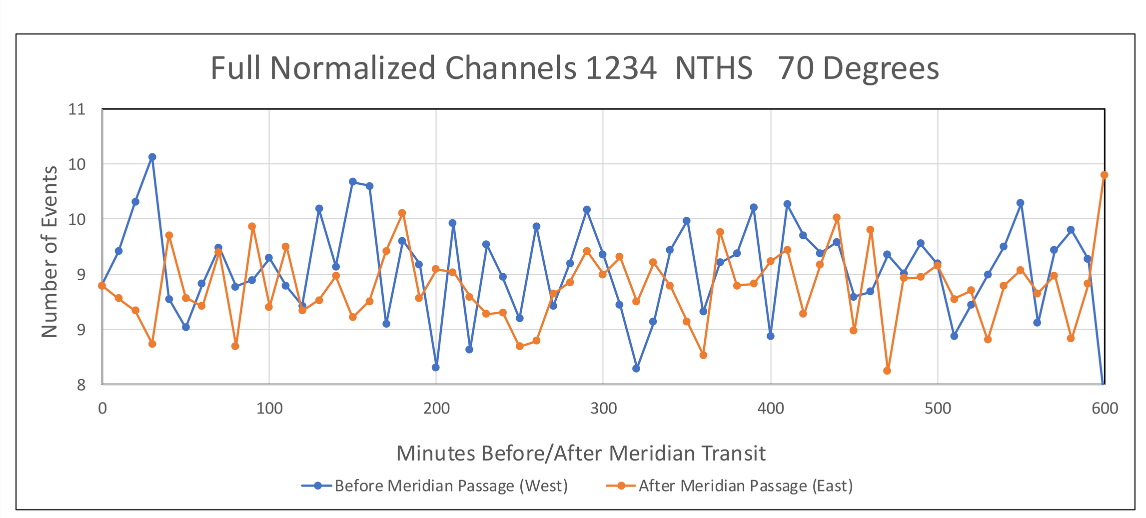
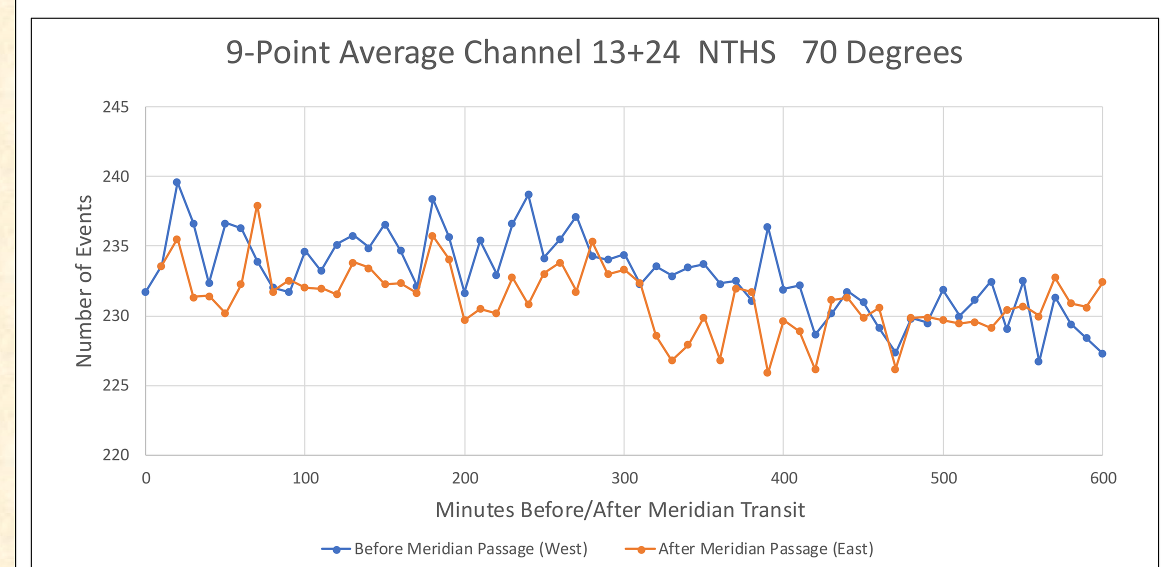
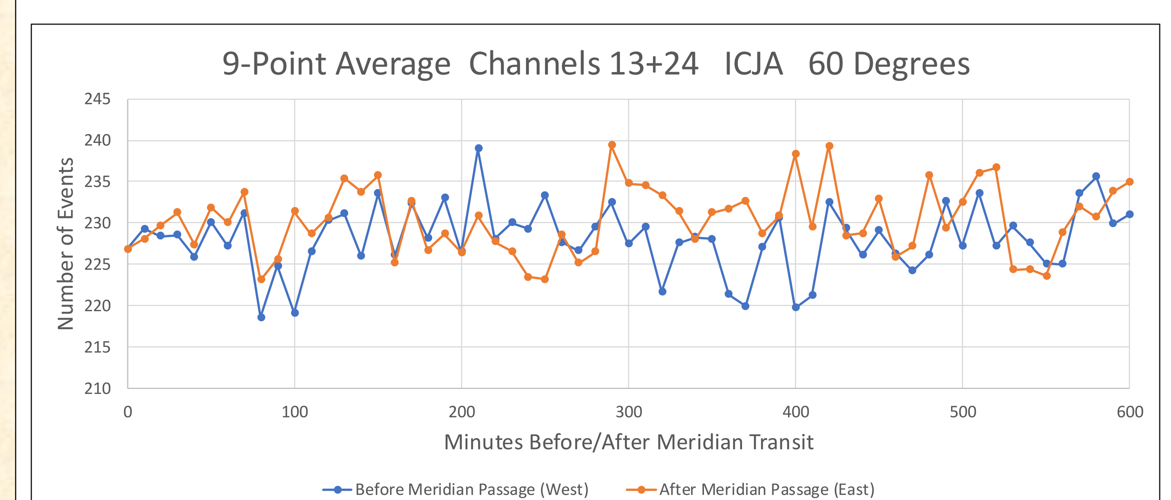


Diagram 3. **Graph of 4-fold central part at highest elevation**. Variation was indistinguishable from signal.

Results (continued)





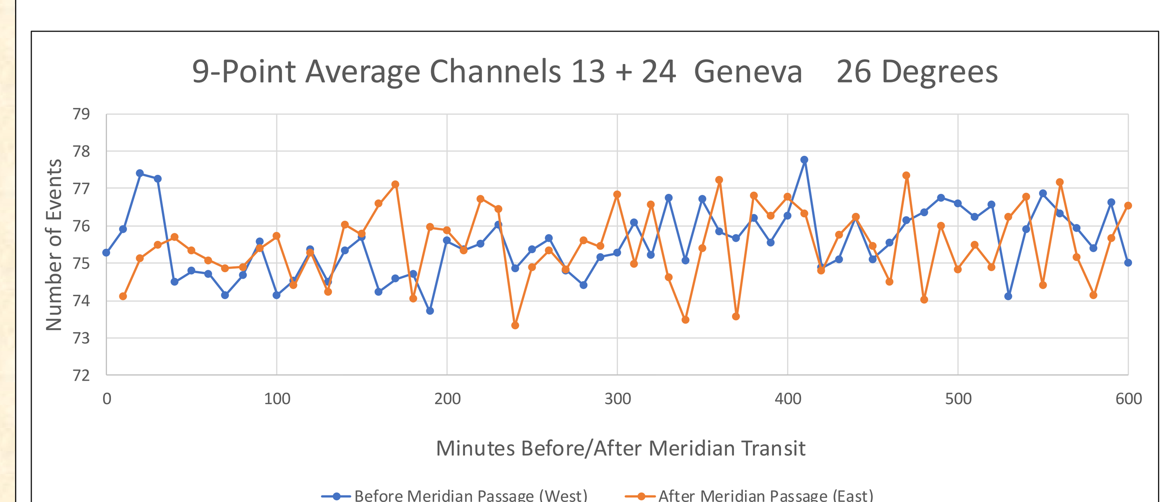


Diagram 4. **Comparison of three detectors at different elevations.** One detector had limited data and was not statistically significant. The lowest elevation (bottom graph) has fewer counts due to atmospheric shielding of muons.

At our energy sensitivity, no discernable signal was found in the graphs. The statistical error was calculated (3-bin width; 30 minutes) to be 2.2% which matched the variation in the graphs. There may have been hints suggesting the existence of a signal at roughly 340 minutes after the meridian crossing, but there was not definitive data to claim it was beyond a confirmation bias.

Next Steps

1. Aim six of the seven detectors at the same angle of elevation. This will increase the number of measured events.
2. Consider aiming at a large angle of elevation, such as 70 degrees, or consider the plane of the ecliptic during a solar eclipse.
3. Reduce the angle of acceptance by extending the distance between the top and bottom counters. This will increase the size of the Moon's path as compared to the background.

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