



Testing of Time Synchronization Across Scintillating Muon Detectors

Lucas Kearns, Dr. Daniel Vanden Berk, Dr. David Grumbine, Fr. Michael Antonacci
Saint Vincent College: Department of Physics

Abstract

We performed analysis of the recorded time difference between separate particle detectors with synchronized input signals as part of the Saint Vincent College cosmic shower detection array project. We have started developing and utilizing more sophisticated and precise methods of collecting large sets of data from the devices. A major requirement that has risen from the development of the project is to obtain extremely precise timestamps, which are recorded to the microsecond, for all active detectors. This is needed to verify the detection of cosmic rays from the same shower and to filter out other unwanted noise and sources that can trigger the devices. We found that the average time difference between same-time detections using a clock synchronized over the internet to be 2.03 ms. Cosmic showers trigger multiple detectors over an area at the same time; therefore, the lowest possible time difference between detections will allow us to eliminate non-synchronous events which are commonly caused by unwanted background radiation. We are also developing a new method of collecting timestamps through GPS data to further lower the time difference between simultaneous detections.

Muons and Detectors

The Muon is a particle with a charge magnitude equal to an electron; however, the mass of a muon is approximately $105.7 \text{ MeV}/c^2$, nearly 207 times greater than the mass of an electron. To detect these particles, we constructed devices using the design of the MIT CosmicWatch Desktop Muon Detector.

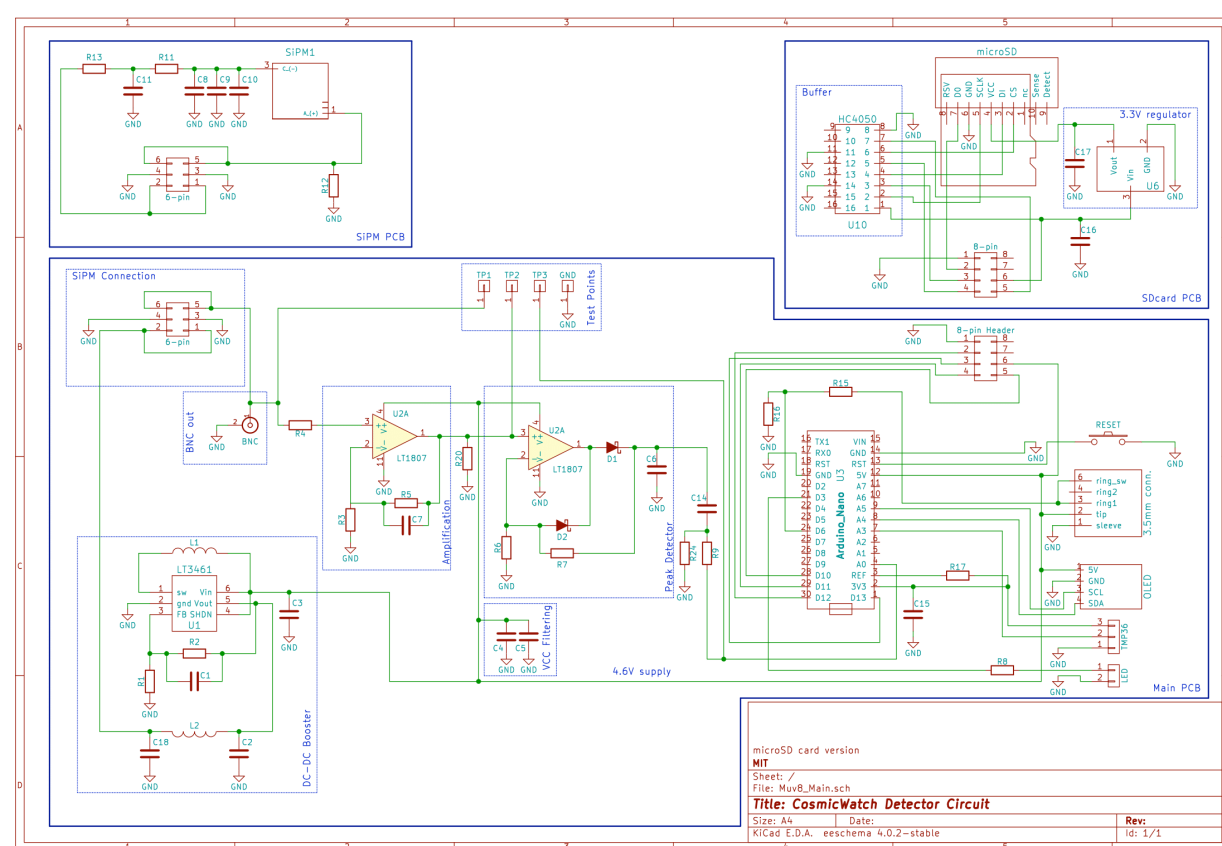


Fig 1. Circuit Schematic of the CosmicWatch Desktop Muon Detector

Coincidence Detection and Timing

Because our devices trigger upon the detection of other forms of radiation as well as muons and cosmic showers, it's important for us to have a method of filtering out unwanted noise. To do this, we can attach each detector to a computer with a timestamp obtained through an internet connection. To find a baseline, we sent regular pulses from one central computer to four separate receiving computers each with their own internet connection to observe the difference in receiving timestamps between them.

Time Variance Across a 4 Computer Cluster

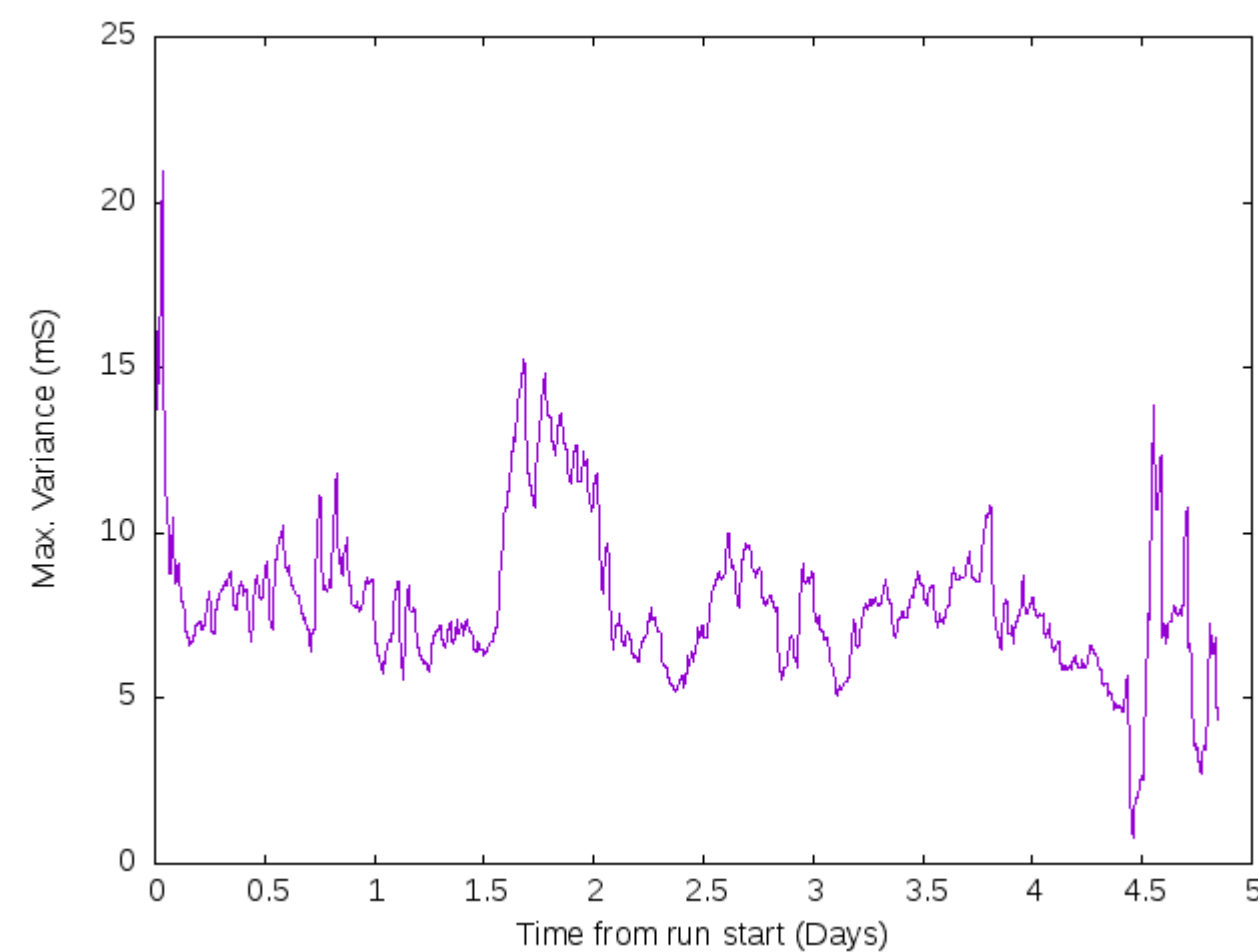


Fig 2. Maximum time difference between generated synchronous events sent to 4 receiving computers

To measure the accuracy of the timing between the detectors themselves, we ran another experiment where the source computer sent a signal to two muon detectors simultaneously and recorded their outputs to two internet connected computers.



Fig 3. Image of the experimental setup with one central computer, two muon detectors (green), and two signal receiving computers

Results

Time Difference Between Simultaneous Events

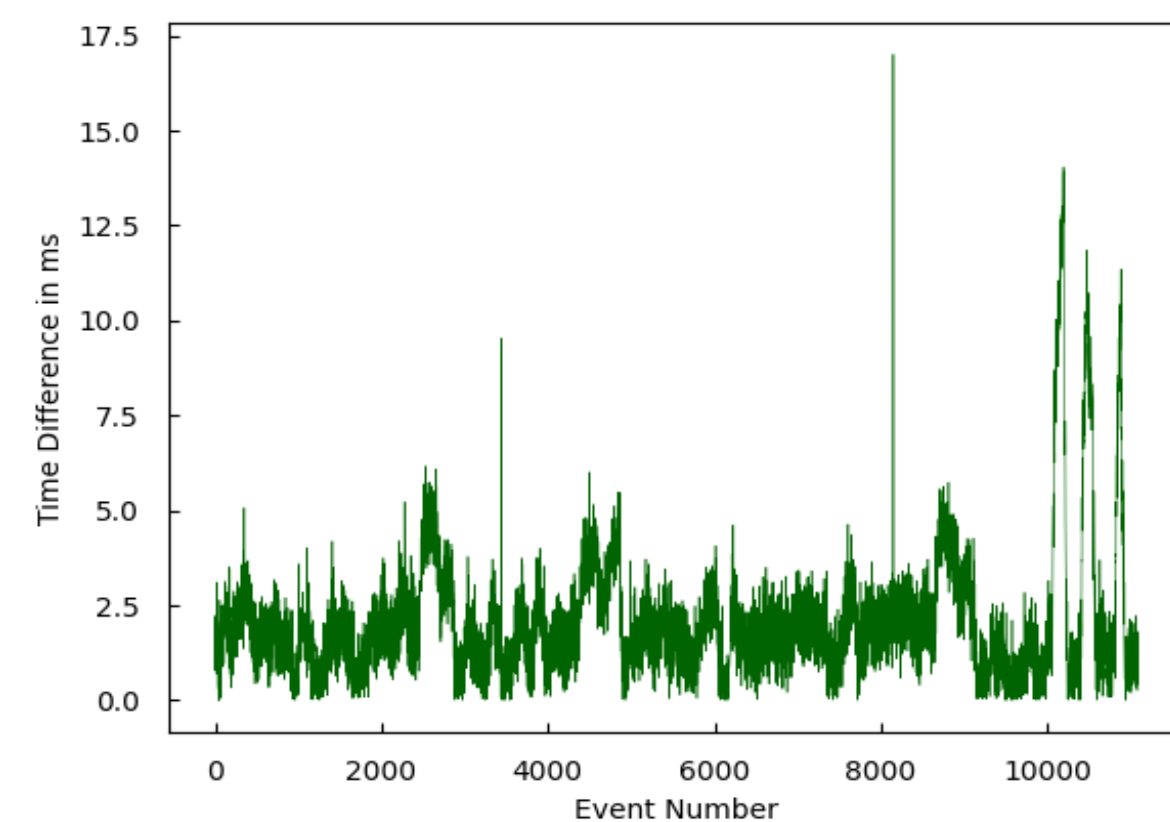


Fig 4. Measures time differences between two detectors when given synchronous pulses

The Experiment was run for approximately 92 hours with pulses output at 30 second intervals. We found the average time difference between the two detectors to be $2.0325 \pm 1.671 \text{ ms}$.

Conclusion

The time averages for the two-detector experiment in Figure 4 show a small time difference, far exceeding the reliability of the detector's built in clocks. However, to accurately measure the detection of cosmic showers across separate detectors, we would want to further increase the precision of distant devices operating simultaneously.

The development of a GPS clock to more accurately provide time stamps instead of an internet connection. is currently being designed to further improve the reliability and accuracy of the cosmic shower detectors for future projects.

References and Acknowledgements

1. Figure 1 – CosmicWatch GitHub (circuit.pdf)
2. Porter, Nathan, 2020, A Preliminary Analyses of Shielding and Detector Orientation Effects on Scintillation-Based Muon Detection
3. Axani, Spencer, 2018, The Physics Behind the CosmicWatch Desktop Muon Detectors

Special Thanks to the A.J. Palumbo Grant for supporting this project