Cosmic ray muon shower rates measured vs. coincidence level, counter separation, gate width, and number of DAQs

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Cosmic ray muon shower measurements were made at the Queensborough Community College (QCC) using QuarkNet detectors consisting of plastic scintillators, photomultiplier tubes, and QuarkNet data acquisition electronics (DAQ). Cosmic rays are predominantly protons but do consist of heavier elements emitted from the sun, supernovae, and black hole regions; muons are part of the secondary particle shower created when the incoming particle collides with atmospheric particles. The detectors were spread out over a distance of 1m, a 30 mV equivalent discriminator threshold and 100 ns coincidence timing gate were used. While using one DAQ and one GPS antenna-receiver system to time-stamp events the 2-fold coincidence rate was 250 per hour, 3-fold coincidence 20 per hour, and 4-fold coincidence 3 per hour. When two separate 2-channel DAQs were used simultaneously the 4-fold coincidence rate was 9 per hour; whether one GPS antenna-receiver signal was daisy chained to both DAQs, or two GPSs were used, one per DAQ, the two-DAQ results was still 9 per hour. Tests are being conducted to determine why the 4-fold coincidence rate is lower when a single 4-channel DAQ is used. The purpose of the study was to learn how to measure showers and define a strategy for the 1 - 10 km measurements which will be made with the CUNY Cosmic Ray Detector Array (CUNY-Cosmic). A cosmic ray detector is used to conduct research in particle physics, astrophysics, atmospheric and space weather physics.

1. Introduction

Cosmic Rays are high energy particles that come from outside our solar system and interact with earth's atmosphere. These primarily proton particles collide with other protons and heavy elements in the atmosphere and produce secondary particles such as pions, mesons, neutrinos and muons. Muons reach the ground due to time dilation and are detected with plastic scintillators. These muons showers can describe various properties of the primary cosmic ray. During the period of June 6th – August 9th 2018, a variety of experiments were performed to measure the muon shower rates for different configurations of detector arrays.

2. Methodology

A Cosmic Ray Detector consists of plastic scintillator, photomultiplier tube, GPS receiver, and Data Acquisition Board (DAQ). A cosmic ray detector is an instrument used to educate and conduct research in particle physics, astrophysics, and atmospheric physics, to study solar activity, lightning, and the earth's magnetosphere. Experiments were done with 1 and 2 DAQ boards, as well as with 1 and 2 GPS receivers. All counters used were 800 square centimeters, with all signal cables and GPS cables being the same length.

3. Results

The first study done was to determine the shower rate for one data acquisition board and 2 counters with a 1-meter separation between counters. The measured shower rate for this configuration was approximately 0.07 Hz or 250 per hour. In subsequent weeks, additional DAQ boards and counters were added to measure the muon shower rate as a function of: number of counters used, gate width and pipeline delay parameters, and distance between counters.

A 1 square meter formation, with 1 DAQ and 4 counters were used to compare the shower rate of this configuration to the previous one. This formation was used for one week with a gate width of 100ns and pipeline delay of 50ns, and the results were consistent and repeatable. A muon shower rate of approximately 0.001 Hz or 3 per hour was measured throughout the whole week. This configuration was then moved to 3 meters and resulted in 0.17 showers per hour. Next, a second DAQ board was added to measure the rate of the same configuration but with 2 counters per DAQ. In the 1 square meter formation, with 2 counters each 1-meter separation for both DAQs, a 2-fold rate of 250 per hour and a 4-fold rate of 9 per hour were measured.

The same experiment was repeated, except the two counters of the hypotenuse of the square were connected to each DAQ. The distance between the counters for this run is now square root 2 meters. This resulted in the same 4-fold rate of 9 per hour but it reduced the 2-fold shower rate slightly to 200 per hour. An experiment with 1 DAQ and 3 counters, with a 3-fold coincidence was run to compare this rate to the 2-fold and 4-fold rates. The counters were arranged into an equilateral triangle, each 1 meter apart and then 3 meters apart. The results from this study showed a muon shower rate of approximately 0.0055 Hz or 20 per hour for 1 meter, and approximately 0.00012 Hz or 0.4 per hour for 3-meter.

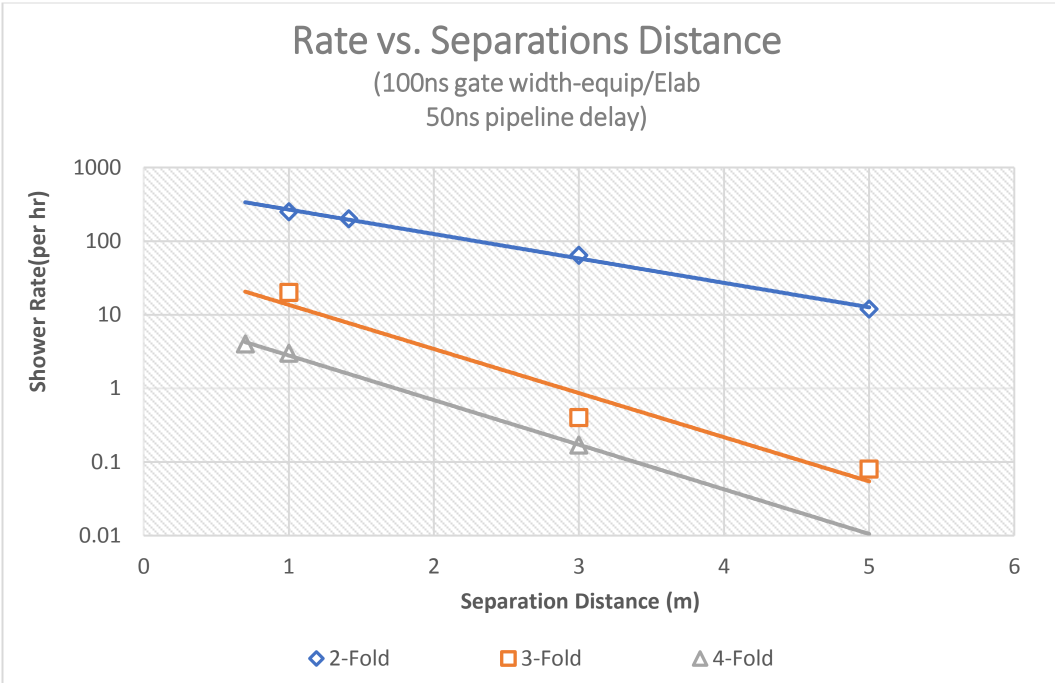

Fig 1: Shower rate vs. separation distance for 2-fold, 3-fold, and 4-fold coincidences

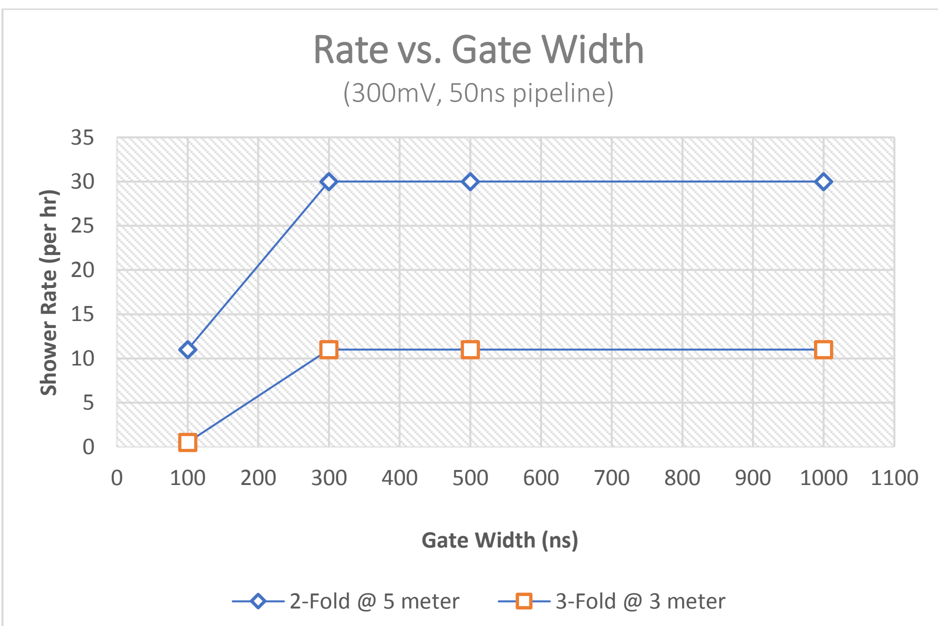

Fig 2: shower rate vs. gate width for 2-fold and 3-fold coincidences

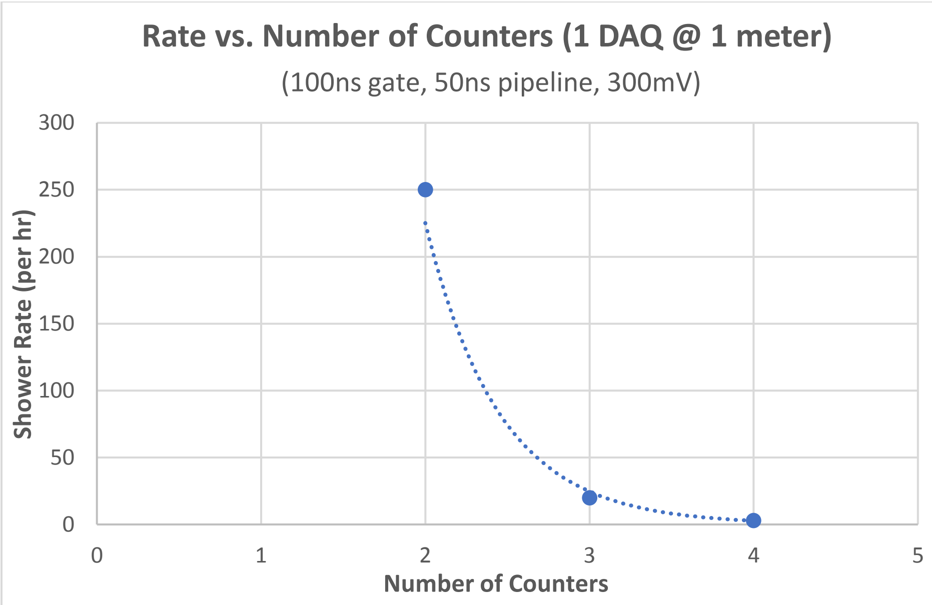

Fig 3: shower rate vs number of counters measured with 1 DAQ at 1 meter.

4. Conclusion

While using 2 GPS receivers during the data collection process, it was noted that when the number of satellites of one GPS falls below 5, the timing information of the shower study may be affected. One possible solution to this problem is to make sure all GPS are receiving at least 5 satellites during data collection and they are in clear view of half the sky. Multiple experiments were performed to test the effect of gate width on a few configurations. A 5-meter, 2-fold, and 3-meter, 3-fold shower study was performed with gate widths of 100ns, 300ns, 500ns, and 1μs. It was observed that an increased gate width will result in an increase of shower candidates from 100ns-300ns. However, increasing the gate width further than 300ns did not result in more showers for either array. For each detector configuration, it was found that adding counters to the DAQ reduced the number of showers seen.

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References

Abbrescia, M., Agocs, A., Aiola, S., Antolini, R., Avanzini, C., Baldini, R.,…Zuyeuski, R (2014), Cosmic Rays Monte Carlo Simulation for the Extreme Energy Events Project, The European Physical Journal Plus, 129: 166, DOI 10.1140/epjp/i2014-14166-3