QuarkNet

Stories from the classroom

At Wheeler we have recently performed several speed, flux, and zenith angle experiments. All Wheeler students who take physics perform at least one experiment using the detectors and do the CMS data analysis activity, each analyzing their own 100 events. We participate each year in International Cosmic Day and the CERN Masterclass at Northeastern University. We have a "Cosmos Club" where students regularly perform experiments using the muon detectors and pursue related interests. We also had a student spend her summer studying cosmic rays at Wheeler. She performed all of the standard experiments, including a shower study involving Rick at Roxbury Latin and Mike at Medford High School, and she created her own study of the earth's magnetic field's effect on east flux versus west flux. We really appreciate our detectors and the QuarkNet support as it provides our students the opportunity to do modern physics experiments well beyond the typical high school experience. It has greatly increased enthusiasm for physics at Wheeler!

Our Cosmos Club proposed using our muon detectors at CERN as part of the CERN Beamline for Schools competition, and our proposal earned an honorable mention. We then traveled to Kennedy Space Center to participate in a symposium involving our proposal to use our muon detectors to test materials for NASA had we won the CERN Beamline competition. The students were recognized by NASA for their contributions and were treated to two days of VIP tours. All of this happened because of the QuarkNet program!

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QuarkNet

Stories from the classroom

Wheeler Cosmic Ray Studies using QuarkNet Detectors

QuarkNet is an NSF and DOE program based out of FermiLab that provides schools around the country with scintillation paddles in order to conduct cosmic ray research. In the summer of 2015, I used these detectors to perform various experiments.

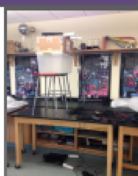
Cosmic rays are highly energetic charged particles, mostly protons, that primarily come from sources outside of our solar system. They enter our atmosphere from every direction, interacting with air molecules to produce showers of secondary cosmic rays. A common type of secondary cosmic ray is the muon, an unstable particle similar to an electron. Our QuarkNet cosmic ray detectors measure properties of the visible Cherenkov light produced as muons travel at high speed through acrylic paddles.

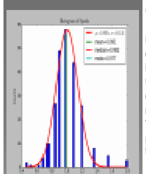
Speed Study

Muons are produced in the upper atmosphere from primary cosmic rays. With a lifetime of 2.2 µs, these muons should decay before they can reach the surface of the earth. However, due to time dilation, a consequence of Special Relativity, time passes at a significantly slower rate in a muon's frame of reference as it travels near the speed of light. This speed study is conducted to determine the speed of the muons as they pass through the detectors and show that they are traveling at relativistic speeds. I placed the first two paddles 2 meters above the second pair of paddles. The muon speed is calculated using

$$muon\ speed = \frac{distance}{time}$$

where time is measured from the top pair of paddles to the bottom pair of paddles.
The graph to the right shows an analysis of about 3 hours worth of data. The results show that the muons were indeed travelling very close to the speed of light at 1.001*c*. Since it is impossible that the muons were travelling faster than *c* (the speed of light), more data would be needed to obtain more accurate results.

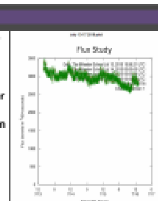




Flux Study

The Flux Study is a basic experiment to monitor the rate of flow of cosmic rays through the detectors to learn about cosmic rays and possible defects in the detector system.

The four paddles are stacked directly on top of one another and an event is counted when a muon is detected in all 4 (four-fold coincidence). I collected data for 4 days, shown in the graph to the right. Originally, I believed that the peaks around noon each day were caused by increased activity from the sun. Later, I learned that one paddle was not sealed sufficiently, allowing light to leak in, meaning that these peaks were actually a result of me turning on the classroom lights when I arrived each day.



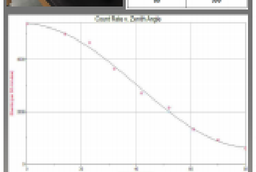
Zenith Angle Study

Cosmic rays entering the atmosphere at greater zenith angles, the angle measured from the vertical, travel greater distances before reaching earth's surface. Because the lifetime of a muon is only 2.2µs, most incoming at larger zenith angles will decay before reaching the surface. This means that more incident muons will be detected vertically.

By attaching two paddles to a crate hung from a horizontal pole, I was able to adjust the angles by tilting the crate. Data was collected for a half hour at each of nine different angles.
The graph to the left confirms the predicted relationship between flux and zenith angle.

$$flux \propto \frac{1}{\cos^2\theta}$$

zenith angle (degrees)	events (per 30 minutes)
0	5040
14	4861
20	4840
32	3600
42	2700
52	2180
61	1000
79	915
89	590

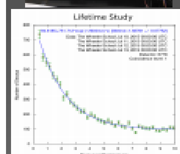


Lifetime Study

This experiment analyzes muon decays that occur within the detector paddles. Although the muons travel extremely fast, we are able to detect some decays within this small space. The accepted lifetime of muons is 2.2µs.

Using three paddles stacked at equal distances, events are recorded when a muon enters the stack of detectors but does not exit. I collected four days worth of data.

The average lifetime according to this data was 1.93 +/- 0.08 µs, slightly less than the accepted value.



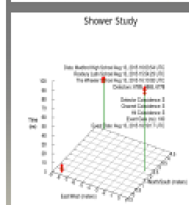
Shower Study

Higher energy primary cosmic rays produce larger showers of secondary cosmic rays. Partnering with other schools allows us to detect showers over a larger area using multiple detectors. Precise GPS data is used to coordinate timing and location information for the separate detectors.

At the Boston QuarkNet group meeting in Roxbury, MA on August 13, I performed a shower study with teachers from two other schools, Roxbury Latin and Medford High School. We arranged our detectors a few meters apart in a classroom and collected data for approximately three hours.

We detected three shower events in that time; one is shown in the graph to the right. In all three events, one detector recorded the event first, then the second detector recorded it approximately 50 nanoseconds later, and the third detector approximately 45 nanoseconds after that. This was probably due to having slightly different GPS cable length measurements, which we will correct in the future. It is impressive that we were able to successfully detect three shower events in that short period of time.

East/West (meters)	North/South (meters)	Time (nanosec)	Detector	Channel
-8.2	4.1	0.8	[illegible]	4
-8.2	4.1	2.5	[illegible]	1
-8.2	4.1	2.5	[illegible]	3
-8.2	4.1	5.8	[illegible]	2
-8.0	4.5	52.5	[illegible]	4
-8.0	4.5	50.8	[illegible]	1
-8.0	4.5	50.3	[illegible]	2
-8.0	4.5	50.3	[illegible]	3
0.1	2.2	88.8	[illegible]	4
0.1	2.2	86.5	[illegible]	1
0.1	2.2	86.5	[illegible]	3
0.1	2.2	90.8	[illegible]	2

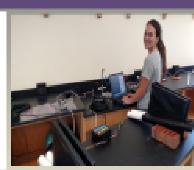


East-West Asymmetry Study

The East-West Asymmetry Study is an experiment that tests if there is a difference in the cosmic ray flux coming from east versus west. As cosmic rays travel downward through the atmosphere, they experience a force directed from west to east from earth's magnetic field, causing the flux to be higher from the west. This is not one of the QuarkNet experiments, so I developed my own procedure to see if the difference in flux was noticeable at our geomagnetic latitude.

The setup is similar to the speed study, oriented horizontally east to west. I collected 23.5 hours worth of data with the paddles arranged in the order 1, 2, 3, 4 and then again arranged in the opposite order 4, 3, 2, 1.

The results showed that coming from the east, there were 978 events and 1135 events from the west, a 16% increase in the number of detected muons coming from the west. Therefore, at my location in Providence, RI, the eastward force on positively charged particles from earth's magnetic field is noticeable.



Acknowledgements

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