

University of Illinois/Chicago State University 2023-2025

Examples of Student Work and Results of Analyses

The following pages present an excerpt from the program of the AAPT Winter Meeting January 2023 at New Orleans, Louisiana where two posters and talks were presented by students at high schools where a teacher has participated in QuarkNet at the time of these presentations.

This is followed by an example of an analysis of muon flux that was conducted during the summer workshop.

As reported in the UIC-CSU Annual Report 2024-2025 (prepared by Mark Adams): During the January 2025 AAPT conference in St. Louis students presented three posters on **The Effect of Coronal Mass Ejections on Cosmic Ray Muon Flux** ref 1 (Figure 1), **Total Solar Eclipse Effects on Cosmic Ray Showers** ref 2, and **Removing the Effect of Barometric Pressure on Muon Flux to Isolate the Coronal Mass Ejection Event** ref 3. During the late spring, results were completed for our **Moon Shadow project** (Figure 2) and a final poster was created. Data was collected in Indiana by a group of ten students from the schools during the 2024 total eclipse and results were finalized June 2025 (Figure 3).

SAT-POSE-713 | Poster Presentation Traditional | An Examination of Two Professional Learning Communities of Physics Teachers Developing Culture-Based Approaches to Instruction

Presenting Author: Clausell Mathis, Michigan State University

Co-presenting Author | Andrea L Wooley, Michigan State University

Additional Author | Mathilda Smith, Michigan State University

Additional Author | Maria Horak, Michigan State University

Additional Author | Maya Patel, Michigan State University

Additional Author | Lauren Collins, Michigan State University

Understanding how to make physics instruction more equitable has been an ongoing challenge for teachers. We highlight the work of two professional learning communities (PLCs) of physics instructors who have attempted to incorporate culture-based teaching approaches in their classrooms. The first PLC focuses on the critical examination of physics ideas and recognizing non-Eurocentric contributions to physics as a discipline. The second PLC focuses on developing curricula that identify students' cultural resources and incorporate them into physics curricula. We will describe our methodology and findings from the analysis of PLC meetings around developing and enacting culture-based physics instruction. We also will highlight the different types of lessons, artifacts, and statements from teachers on what challenges and affordances they had in participating in the PLC.

SAT-POSE-715 | Poster Presentation Traditional | Using Factor Analysis to Gauge Validity of a Laboratory Exam

Presenting Author: Ari Kaye, University of Northern Colorado

Additional Author | Jennifer Delgado, University of Kansas

Additional Author | Christopher Fischer, University of Kansas

Additional Author | Keita Todoroki, University of Kansas

We present initial validation of an assessment evaluating student understanding of experimental uncertainty in undergraduate physics laboratory courses. This assessment arranges multiple-choice problems in a nested system linking a set of "minor" questions to a "major" question with a common focus. Factor analysis of student responses to this assessment verifies this linking while revealing the correlational network connecting "minor" questions to one another. Isolating each skill needed to answer problems in experimental uncertainty as separate "minor" questions identifies specific pitfalls in student understanding—providing insight for future instructional changes in laboratory courses.

SPS Poster Session (6–7 p.m.) Saturday

SAT-SPS-101 | Poster Presentation Traditional | Baseline: Looking For the Cosmic Ray Moonshadow

Presenting Author: Aitak Mosen Harzandi, New Trier High School

Co-presenting Author | Garrett Chong, New Trier High School

Co-presenting Author | Benjamin Baronofsky, Ida Crown Jewish Academy

Co-presenting Author | Jedidiah Marcus, Ida Crown Jewish Academy

Additional Author | Nathan A. Unterman, New Trier High School

Using multiple detectors set at different angles of elevation, the schools in the collaboration observed a large portion of the sky, collecting moon data to look for the moon's cosmic ray shadow. Each school used one of four angles of elevation, each producing their own sets of data and graphs for each day. These graphs were combined into monthly, then yearly averages. These four graphs were then analyzed and compared to find a consistent dip in moon count, which would hint at the presence of a cosmic ray shadow. The data are consistent with no signal, so an upper limit was determined to guide future experiments.

SAT-SPS-105 | Poster | Method for Measuring Low-Energy Cosmic Rays Using Time

Presenting Author: Ash Eliaser, Rochelle Zell Jewish High School

Co-presenting Author | Miriam Bush, Rochelle Zell Jewish High School

Co-presenting Author | Dalya Frank, Rochelle Zell Jewish High School

Co-presenting Author | Dory Marshall, Ida Crown Jewish Academy

Additional Author | Nathan A. Unterman, New Trier High School

Additional Author | Allen Sears, Ida Crown Jewish Academy

A collaboration of high school students set up cosmic ray detectors to measure low-energy cosmic rays using time with the goal of locating the moon's cosmic ray shadow. The detectors were arranged at different elevation angles aiming south to capture the moon's passage each day. As Earth rotates, the detectors swept the sky daily. Lower energy primary cosmic rays bend more due to magnetic fields and should be found as a shadow well before the moon crosses the meridian. The shadow was not expected after the moon passed the meridian since there are almost no anti-protons in the primary rays. Experiment methods are discussed in this poster.

SAT-SPS-107 | Poster | How Spatial Disorder Affects Quantum Eigenvalue Statistics

Presenting Author: Noah Koch, Berry College

Additional Author | Todd K Timberlake, Berry College

The objective of this project is to illustrate the role of spatial disorder in determining statistical properties of the energy spectrum for a quantum system. We investigate the distribution of energy level spacings in a simple quantum system consisting of several Dirac delta barriers placed

SUN-DB-03 (3:24 to 3:36 PM) | Contributed Talk | Using AI in a University Physics Course

Presenting Author: Alexander Kusenko, UCLA

My colleagues and I use AI powered hints and AI generated practice problems in Physics classes at UCLA. I will review this innovative practice, the lessons learned, and the steps we take to make the best use of AI for all students, especially, for underrepresented minorities.

SUN-DB-04 (3:36 to 3:48 PM) | Contributed Talk | Could AI Radically Change Physics Education

Presenting Author: Ali Tuna, Freelance

AlphaGo beat the best Go player in the world while humans were thinking Go was a game machines could not mess with. AlphaFold analyzed and mapped out the structures of proteins better, faster, and more accurately than human beings could for decades. Google's DeepMind found ways to reduce the amount of energy used in its data centers by 40% after some of the best engineers reduced it significantly. Could AI be used to help us devise new methods in Physics teaching the way it started developing proof for Kazhdan-Lusztig polynomials or the way it brought a new perspective to knot theory? By using AI, can we find unconventional ways to solve multi-step Physics problems using shorter and clearer ways that are prone to fewer errors? Can humanity maybe come up with new interpretations of fundamental Physical laws the way Einstein did with gravity? These are the questions I will try to start a discussion on by using the literature authored by some of the brightest researchers of AI.

Session SUN-DG: Authentic Research Across the Spectrum Sunday, Jan. 7, 3–4 p.m.

Fulton - 3rd Floor Moderator: Darsa Donelan Sponsor: Committee on Space Science and Astronomy

SUN-DG-01 (3:00 to 3:24 PM) | | Unlocking the Cosmos with Radio JOVE: Bridging the Gap for Tomorrow's Astronomers

Presenting Author: Samantha Blair, Dalton State College

Co-presenting Author | Chuck Higgins, Middle Tennessee State University

Co-presenting Author | Derek Thornton, Dalton State College

Astronomy is evolving, breaking free from the confines of expensive equipment and elusive telescope time. Radio JOVE, a NASA Partner project, empowers aspiring scientists, including high school students, to explore the cosmos through radio astronomy. Chuck Higgins, a Radio JOVE Project mentor, will guide us through this transformative journey. Radio JOVE participants construct and operate their multi-frequency radio telescopes, accessing celestial wonders like Jupiter, the Sun, and the Milky Way. Beyond observation, Radio JOVE equips participants to contribute scientific data while immersing in the universe. Samantha Blair, Associate Professor of Physics and Astronomy at Dalton State College, will share her experience integrating Radio JOVE into education, enhancing students' scientific literacy. Dr. Blair's students will join the panel to vividly recount their hands-on experiences and the excitement of conducting research under her guidance. Radio JOVE aims to expand its telescope network, demonstrating the scientific process and providing real-time data access.

Join us on this thrilling cosmic exploration. Discover how Radio JOVE ignites citizen science, nurtures science literacy, and fosters collaboration. Hear from high school teachers and students who ventured into radio astronomy, conducted research, and published findings. Learn how to introduce such projects to your classroom, unlocking the mysteries of the universe for the next generation.

Session SUN-DA: Cosmic Ray Studies in the Classroom Sunday, Jan. 7, 3–4 p.m.

Commerce - 3rd Floor Moderator: Shane Wood Sponsor: Committee on Contemporary Physics

SUN-DA-01 (3:00 to 3:12 PM) | Contributed Talk | Use of Time to Measure Momentum/Energy of Cosmic Rays

Presenting Author: Miriam Bush, Rochelle Zell Jewish High School

Co-presenting Author | Dalya Frank, Rochelle Zell Jewish High School

Co-presenting Author | Ash Eliaser, Rochelle Zell Jewish High School

Co-presenting Author | Dory Marshall, Ida Crown Jewish Academy

Additional Author | Nathan A. Unterman, New Trier High School

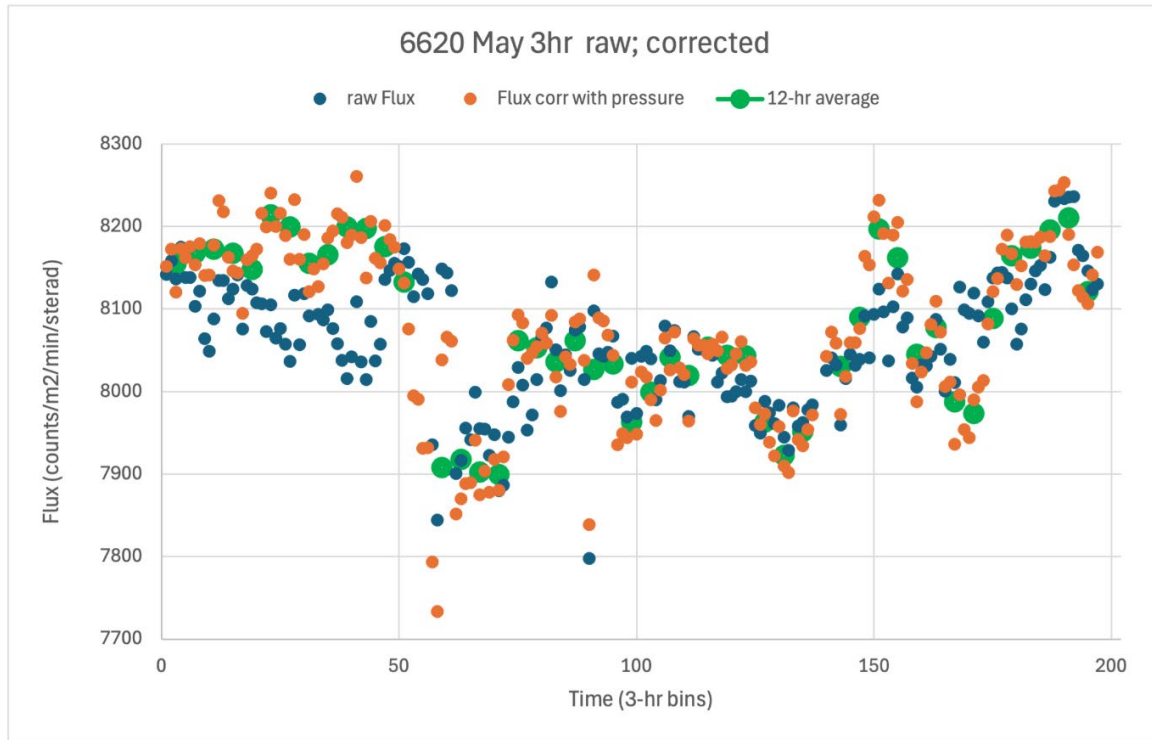
Additional Author | Allen Sears, Ida Crown Jewish Academy

During the total eclipse of 2017, students reported that the anticipated cosmic ray shadow was not in line with the moon (and sun)¹. It was suggested that the lunar shadow may be elsewhere in the sky. An experiment was designed to look for the cosmic ray lunar shadow to the west and east of the Moon to account for effects from the Earth's magnetic field. Low energy primary cosmic rays would be bent more than those of higher energy. This allowed the experiment to use time ahead of lunar meridian passage to measure a range of cosmic ray energies—a novel approach. The design of such an experiment will be discussed.

(1) Dallal, Tamar A., et al.; Solar Eclipse and Cosmic Ray Flux, *The Physics Teacher*, volume 60, pp 100-104. February 2022

SUN-DA-02 (3:12 to 3:24 PM) | Contributed Talk | The Cosmic Watch in the Classroom

Presenting Author: Kenneth Cecire, University of Notre Dame



UIC-CSU QuarkNet Summer Workshop: CME Affect on Muons

From an email from Mark Adams (November 13, 2024)

Plot: muon flux versus time (7-31May in 3-hr bins) for flux (blue), flux corrected for atmospheric pressure (orange), and corrected flux in 12-hr bins (green). DAQ 6620 is a muon lifetime experiment running at Fermilab.

The plot (presented in the workshop agenda page) is a sample of what we were working on and the status of our effort at that time. During the workshop the group looked at 25 different CRMDs active in May during a Coronal Mass Ejection event; selected ten to analyze further. We've held 4 additional 1/2-day workshops since then and results are better understood and much improved.

The figure plots the muon rate versus time in 3-hr bins and covers 7-31May 2024. The CME ejection reached earth on the 10th, disturbed the magnetic field causing the muon rate to drop. The blue points are the muon flux (# events/min/m2/steradian) and orange and green are corrected for atmospheric pressure.



The Effect of Coronal Mass Ejections on Cosmic Ray Muon Flux

Evangeline Selking[†], Rex Paster[†], Kristian Qirko[†], Zoya Siddiqui[†], Sydney Stapleton[†], Maya Zacks[†], Marybeth Sensert[†], Nathan A. Unterman[†], Mark Adams[†]

[†]Downers Grove South High School, Downers Grove, IL, [†]Rochelle Zell Jewish High School, Deerfield, IL, [†]New Trier High School, Northfield, IL, [†]Fermilab, St. Batavia, IL



Abstract

This study investigates the effects of coronal mass ejections (CMEs) on cosmic ray muon flux using QuarkNet detectors. Our analysis characterizes the flux change from time of onset to recovery of the CME event of May 2024. We compare the atmospheric-pressure corrected cosmic ray flux with disturbances of the geomagnetic field. Results show the structure of flux change during a CME event.

Motivation

This study characterizes the Forbush decrease that follows a coronal mass ejection (CME). Knowing that CMEs impact cosmic ray flux, we studied the CME event of May 10, 2024. We investigate time of onset, duration of drop, percentage of drop, and duration of recovery.

How do fluctuating values of the magnetic Kp-index affect the change in muon flux? What is the minimum magnetic disturbance needed to observe the Forbush decrease?

Hypothesis

QuarkNet detectors characterize the Forbush decrease when the Kp-index is greater than 6.

Equipment

Data were collected from various Cosmic Ray Muon Detectors, with the majority in Illinois. Detectors employed a variety of geometric arrangements.

Methodology

A search was conducted for all QuarkNet detectors surrounding the May 2024 CME event. Detectors in the database with sufficient and reliable data were selected for further study. The selection criteria included the number of days data were collected and checking limits in the blessing charts in eLab.

The selected data were corrected for barometric pressure changes¹. When comparing the uncorrected data (Figure 1) with the corrected data (Figure 2), a clearer pattern of the CME event is revealed. Further analysis in our experiment utilizes the corrected data.



Figure 1
Graph of raw data before pressure corrections

Results

Kp Index	Top Average	Bottom Average	Percent Error	Recovery Time (Days)	Duration of Drop (Days)	Percentage of Drop
4.0-5.0	521	544	5.0%	10	3.75	4.17
5.0-6.0	764	768	0.5%	14	3.57	3.57
6.0-7.0	155	144	7.7%	17	3.53	3.67
7.0-8.0	54	53	1.9%	25	4.14	4.28
8.0-9.0	76	79	3.8%	24	3.33	3.33
9.0-10.0	812	821	1.1%	30	3.00	3.00
10.0-11.0	145	142	2.1%	33	4.55	3.00

Table 1
Results showing the structure of onset and recovery of a CME event

To determine characterizations of the Forbush decrease from each corrected Flux and Planetary-K versus Time graph, flux values of Top Average and Bottom Average are determined as shown.

Averaging the flux values immediately before the onset of the CME yields the Top Average, while averaging flux values immediately after the onset time gives the Bottom Average. In order to gain a broader understanding of the behavior of muons during onset, we determine the Average Flux during onset, which is the mean of the Top and Bottom Averages (Table 1, column 4).

The changes in muon counts before and after the onset time are represented in column five as the difference between the Top and Bottom Average. We identify the percent decrease of drop and it ranged from 1.7% to 4.6% (Table 1, column 6), using the formula:

$$\text{Percent decrease} = \left(\frac{\text{Top Average} - \text{Bottom Average}}{\text{Top Average}} \right) \times 100 \quad (1)$$

This was for a Kp-index of 9.



Figure 2
The cosmic ray flux compared with the Kp-index, small error bars due to large sample size



Figure 3
Flux data compared with the Kp-index, displaying large error bars due to small sample size

There are statistical errors due to sample size. Percent error is calculated using the formula and shown in column seven:

$$\text{Percent error} = \left(\frac{\text{Standard Deviation}}{\text{Top Average}} \right) \times 100 \quad (2)$$

The Forbush decrease of flux was an average of 3.14%. The recovery time is the duration from onset until the flux returns to pre-event levels. For the May 10th event, the recovery time was about 14 days. Smaller geomagnetic storms of Kp-index 6 on May 18 - 20th extend the flux recovery time (Figure 4). There are indications that Kp-indices as low as 4 show this effect.



Figure 4
Flux and Kp-index levels showing the influence of smaller geomagnetic storms following the CME

Graphs which included error bars larger than the signal itself were omitted from the above analysis, since the data derived from the graph would not reach the desired level of specificity. Figure 2 depicts the ideal size of error bars, while Figure 3 depicts a situation where analysis of Forbush decrease will be unreliable due to the large error bars obscuring the structure of flux recovery.

Conclusion

As values of the Kp-index increased above 4, QuarkNet detectors displayed a decrease of the cosmic ray muon flux. The decreases were typically averaged 3% and statistical errors were 1%. We are confident of measuring the Forbush decrease when the Kp-index is greater than 4. For further research, we need to conduct more processing for lower Kp-indices.

References

¹Zacks, Maya et al., *Removing the Effect of Barometric Pressure on Muon Flux to Isolate the Coronal Mass Ejection*, AAPT Winter Meeting, POS-SAT-A105, 1/18/2025

Contacts

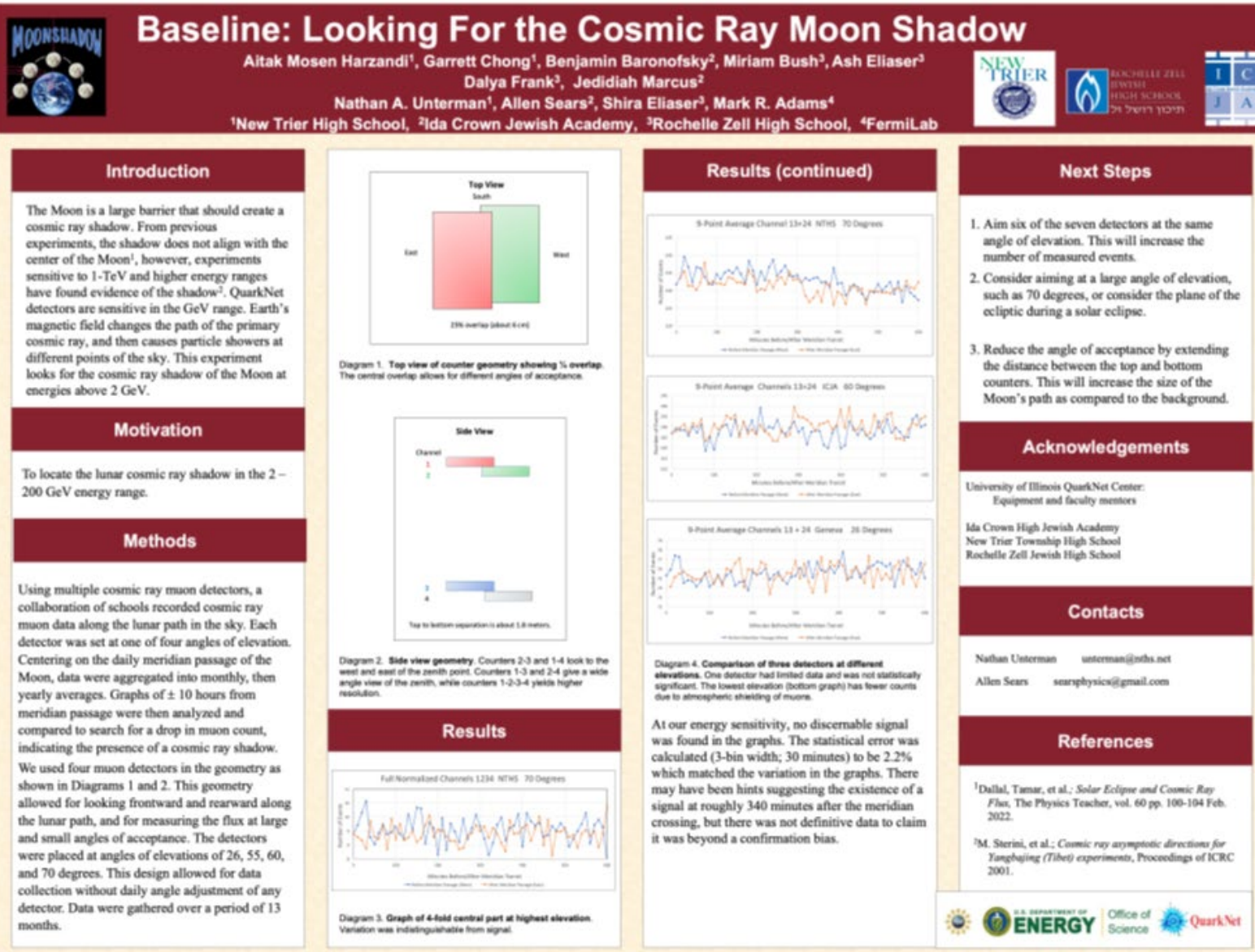
Evangeline Selking: esel1780@cd99.org
Zoya Siddiqui: zsid2761@cd99.org
Rex Paster: rpaster@students.rzjhs.org
Kristian Qirko: kristianqirko@gmail.com
Sydney Stapleton: sta1501@cd99.org
Maya Zacks: 20270054@student.ozhs.net
Marybeth Sensert: msensert@cd99.org
Nathan A. Unterman: nunterman@gmail.com

Acknowledgements

University of Illinois QuarkNet Center
Downers Grove South High School
New Trier High School
Rochelle Zell Jewish High School
Fermilab
Mark Adams, QuarkNet, for advocacy and guidance



Figure 1. Image of poster presented at AAPT Jan. 2025 CME experiment



Acknowledgements

University of Illinois QuarkNet Center:
Equipment and faculty mentors

Ida Crown High Jewish Academy
New Trier Township High School
Rochelle Zell Jewish High School

Contacts

Nathan Unterman unterman@ntrhs.net
 Allen Sears searsphysics@gmail.com

References

¹Dallal, Tamar, et al.; *Solar Eclipse and Cosmic Ray Flux*, *The Physics Teacher*, vol. 60 pp. 100-104 Feb. 2022.

²M. Sterini, et al.; *Cosmic ray asymptotic directions for Yangbajing (Tibet) experiments*, *Proceedings of ICRC* 2001.



Figure 2. Final poster summarizing the 18-month Moon shadow experiment



Total Solar Eclipse Effects on Cosmic Ray Showers



Sydney Stapleton¹, Monika Afredeen², Garrett Chong², Aitak Mosen Harzandi², Anna Halwax², Tara Hecht², Layla Hodgdon², Anna Panferova², Maya Zacks², Marybeth Senser¹, Nathan A. Unterman², Mark R. Adams³

¹Downers Grove South High School, Downers Grove, IL; ²New Trier High School, Northfield, IL; ³FermiLab, Batavia, IL

Introduction

We sought to discover the effects that a total solar eclipse (April 24, 2024) had on cosmic ray shower energy. Six cosmic ray detectors were set up in equilateral triangle nested arrays. Each detector array was concentric with different side lengths, except one, with a single control detector in a stack (See blue detector in Figure 1). The size of the detector triangle corresponded to an energy range of sensitivity, with larger triangles probing higher energies. We began collecting data two weeks prior to the eclipse and completed data collection 90 minutes after totality. Although a previous lunar shadow experiment provides evidence that the flux does not change as a result of the Moon's passing in the sky¹, this experiment measured cosmic ray shower energy changes during a total solar eclipse.

Motivation

To investigate any changes in cosmic ray shower energies during a total solar eclipse.

Methodology

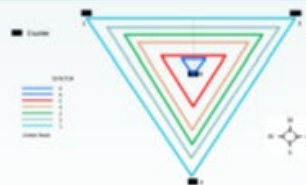


Figure 1. Layout diagram of counters for each of the six detectors.



Figure 2. Partial triangle layout during feasibility study at New Trier High School.



Figure 3. View looking east of the detector array in Woodport, IN. The stack of Counter 4 (B) from each detector is at the centroid of the respective triangles. The top vertices are Counter 2 of each detector.

The configuration employed six nested equilateral triangles of counters with a common centroid, except for the 0.6m side where the apex had two counters. One counter from each detector was placed at each vertex with the fourth counter at the common centroid. The side lengths of the equilateral triangles were 0.6m, 1m, 3m, 4m, 5m, 6m. We used equilateral triangles because the distance between vertices would be equal, simplifying the analysis. The fourth counter was placed at the centroid of the triangles to facilitate comparison among the different detectors. Count rates from each equilateral triangle were compared for results.

Results

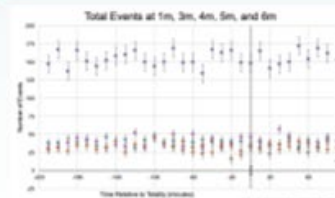


Figure 4. Total events in each detector equilateral triangle. For clarity, the detector with a 0.6-meter side is not shown, due to its high count rate.

Results (continued)

Beginning with the period of 200 minutes prior to the eclipse, and for 90 minutes after totality, the total number of events recorded by each detector during 10-minute bins remained constant (See Figure 4). This was consistent with the two weeks of measurements prior to the eclipse.

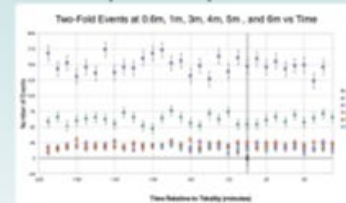


Figure 5. Two-fold events in the different equilateral triangles.

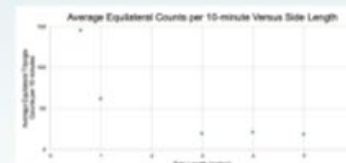


Figure 6. Average counts per 10-minute bin in each equilateral triangle.

Following this trend, the number of only double coincidence events per 10-minute bin throughout this same time period also remained constant (See Figure 5). Double coincidence counts were used to reduce error due to a larger number of events. In calculating error ($1/\sqrt{n}$), no significant change was found for any of the detectors during the eclipse (See Figures 4 and 5). Additionally, it was found that as the side length of the triangular arrays decreased, the number of events detected increased (See Figure 6).

Conclusion

This experiment investigated the impact of the total solar eclipse on the energy of cosmic ray showers. Our data revealed no significant change in the count rates of cosmic ray showers detected by any of the arrays throughout the eclipse period. The observed trend showed an increase in the number of detected events as the side lengths of the triangular arrays decreased, which correlates to the increased number of lower energy cosmic ray showers in smaller triangles. These findings indicate that the solar eclipse did not change the distribution of the energies of cosmic ray showers, consistent with a previous total solar eclipse experiment which showed no change in flux due to the Moon's transit².

Acknowledgements

Maya Zacks for use of her home and facilities, Woodport, IN
New Trier High School, Northfield, IL
Downers Grove High School, Downers Grove, IL
QuarkNet University of Illinois Center, Chicago, IL
National Science Foundation



Figure 7. Group photo at the Glover Farm High Energy Physics Laboratory, April 24, 2024.

Citations

¹Mason-Hessell, Aitak, Garrett Chong, et al., "Search for the Cosmic Ray Moon Shadow," American Association of Physics Teachers Winter Meeting, 4 January 2016, New Orleans, LA.

²Urbat, Tamer A., et al., "Solar Eclipse and Cosmic Ray Flux," The Physics Teacher, Feb 2022.

Contacts

Sydney Stapleton: sst1501@cod99.org
Marybeth Senser: msenser@cod99.org
Nathan A. Unterman: unterman@gmail.com



Figure 3. Poster describing final results from the solar eclipse experiment completed June 2025.