QuarkNet

An Inspiring Story

Special Cosmic Ray Projects

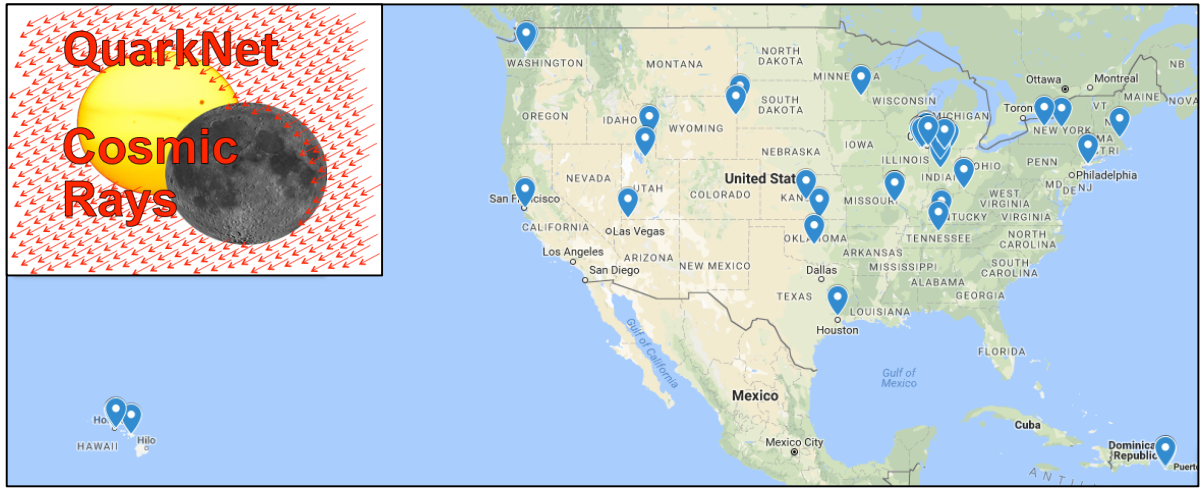
Solar Eclipse Project

Cosmics at Fermilab's 50th Open House

Marge Bardeen
Fermilab

QuarkNet

Eclipse Path and Telescope Locations



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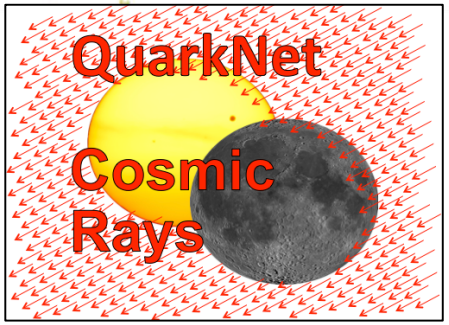
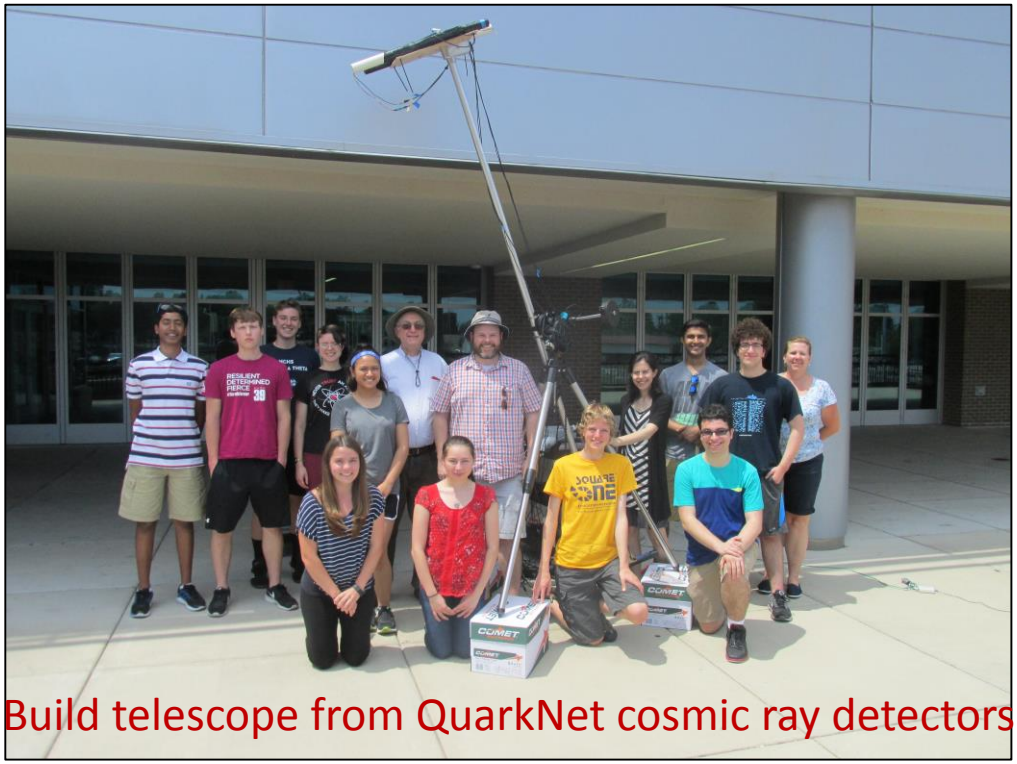
Solar Eclipse Goals



Measure cosmic ray rates near the sun during the August 21st solar eclipse. Never done before!

- **Compare eclipse muon rates to rates for an empty sky, moon only and sun only.**
- **Show sun is not a major source of cosmic rays.**
- **Search for global changes in muon rates.**
- **Over 45 groups participate.**



Build telescope from QuarkNet cosmic ray detectors

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Eclipse Project Stats

Solar Cosmic Ray experiment was an idea from teachers.
Muons at surface never measured before during eclipse.
Designed and prototyped by students.

Data from 55 detectors
48 QuarkNet centers
4 tracking telescopes
Over 20 fixed angle telescopes
Remaining detectors were vertically stacked.

Mississippi

Missouri

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Timeline

Feb. - Idea originated with a teacher at an APS conference. Brand new research question! No previous publications on surface muons during an eclipse exist!

Feb.-Aug. - 6 months to design experiment & assemble collaboration of teachers & students

Spring – Teachers & students design measurement goals & techniques.

Invite QuarkNet participants.

Create website to host instructions, logbook, collaborator comments.

Summer - Assemble prototypes during workshops.

Aug. 21 - ECLIPSE

Sept.-Dec. – Analyze independent site results; combine results.

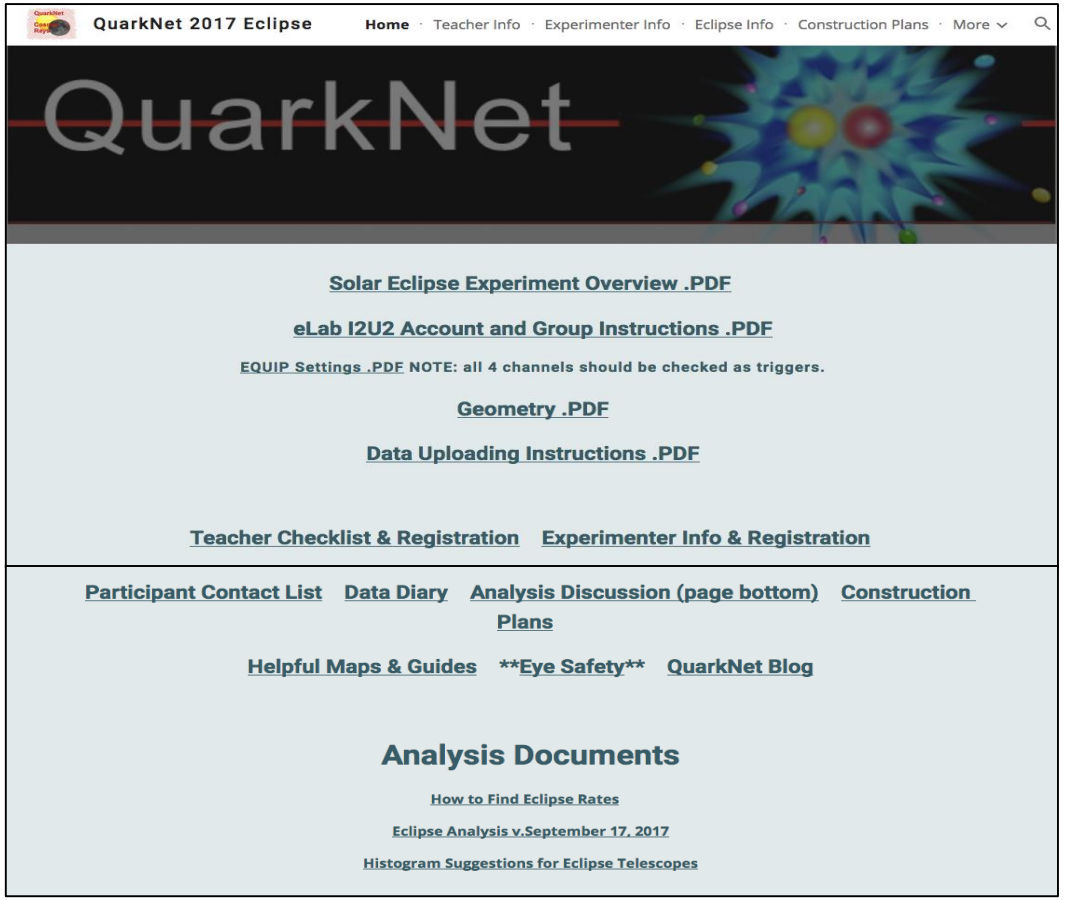
Jan. 2018 - Announce results.

Central Logbook

Communication Required!

Eclipse Website:

- Goals
- Instructions
- Collaborator information
- Eclipse maps & info
- Analysis tools & examples
- Logbook for datasets



https://sites.google.com/view/quarknet2017eclipse/

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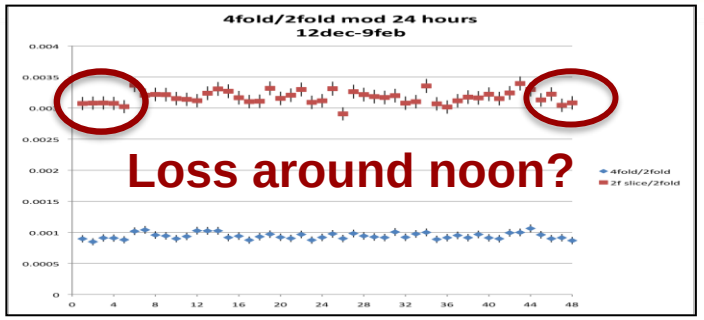
Design and Prototypes

Build on ICD, IMW & previous attempts to measure muon shadow caused by sun.



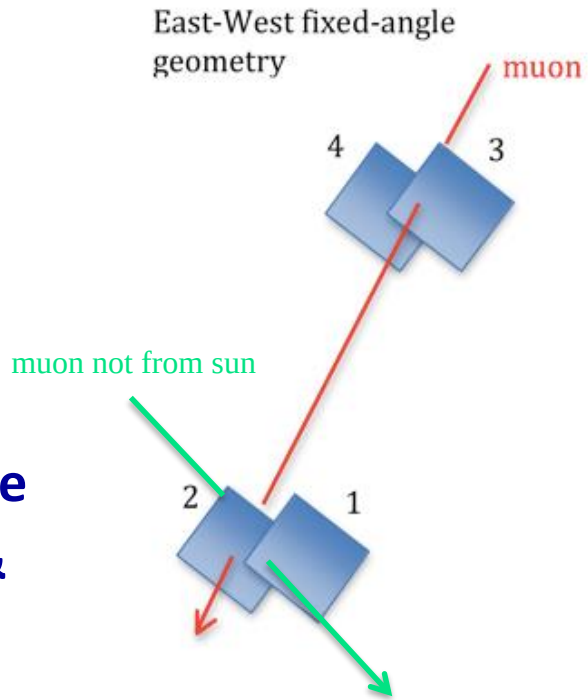
Muons in direction of sun vs. 30-minute bins, 30 days overlapped (2016)
Will any effect be 0.5 degrees (moon size) or wider due to earth's magnetic field?

- **All high school groups can contribute: use existing detectors & design telescope frames.**
- **Three telescope designs: tracking to follow sun; fixed angle to let sun move across acceptance; normal stack**
- **Telescope frame: cheap; light; parts available at local hardware stores; support with telescope mount**
- **Students improved design with three stages of prototype.**

QuarkNet Student-designed Prototypes

Design Challenges:

- Muon rates vs. pointing resolution
- Overlap of counter pairs
- Separation of counters
- Normalization with pairs



Constructed telescope frames for Tracking & Fixed Telescopes.

Measured muon rates to identify optimum separation.

(10 feet for tracking; 6 feet for fixed telescopes)

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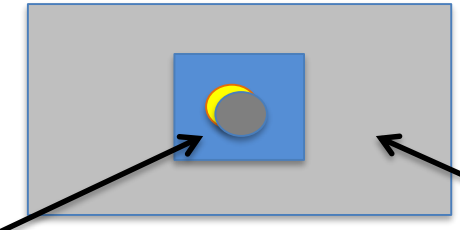
Tracking Telescope



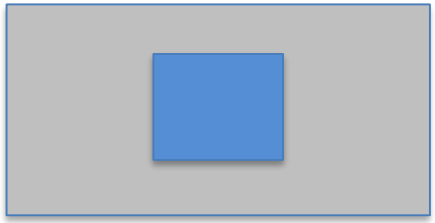
Using a shadow of a target on the frame, adjust the the telescope to follow the position of the sun. Monitor the region around the sun continuously.

Muons traversing all 4 counters come from the blue region.

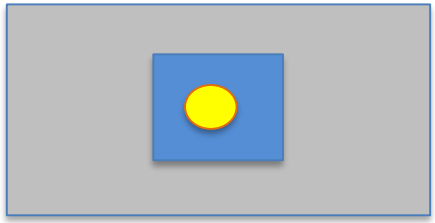
Muons traversing one counter from each end come from the gray region.

Compare muon rates during eclipse above to rates under conditions below.

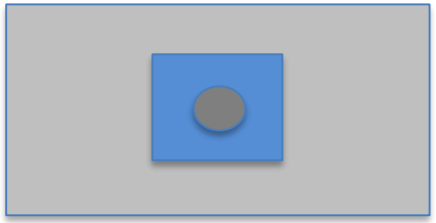
Empty Sky



Sun only in Sky



Moon only in Sky



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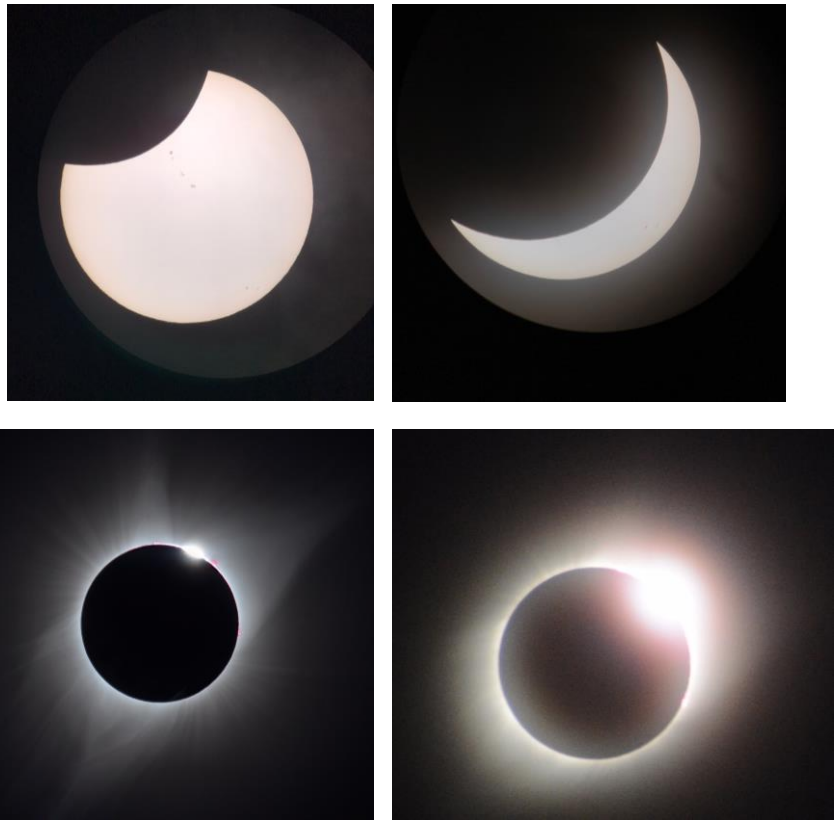
Tracking Telescope



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Student Preparation

Provided directions for building telescopes.

Measured muon rates during empty sky, sky with moon & sky with sun.

Developed tracking procedures—align with telescope's shadow; laser to transfer position vs. time to ground; use laser to reproduce during eclipse if cloudy.

Measured 2-muon backgrounds to be < 3% of muons reconstructed in direction of the sun.

4-day trip to total eclipse location, so baselines could be measured ahead of the eclipse.

QuarkNet staff helped by developing an e-Lab analysis tool the students requested to measure rates vs. time for various combinations of counters.

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Eclipse Analysis

Students measured initial muon rates vs. time using normalization techniques to reduce effects due to changes in atmospheric pressure.

Learned that normalization counter pairs could identify periods when counters were working stably and help correct counter efficiencies when problems occurred.

Identified & solved new problems—due to intense heat buildup in sun during eclipse, counters were wrapped in dark bags—led to disconnected counters & flakey connections.

Future—combine results from sites around the U. S.

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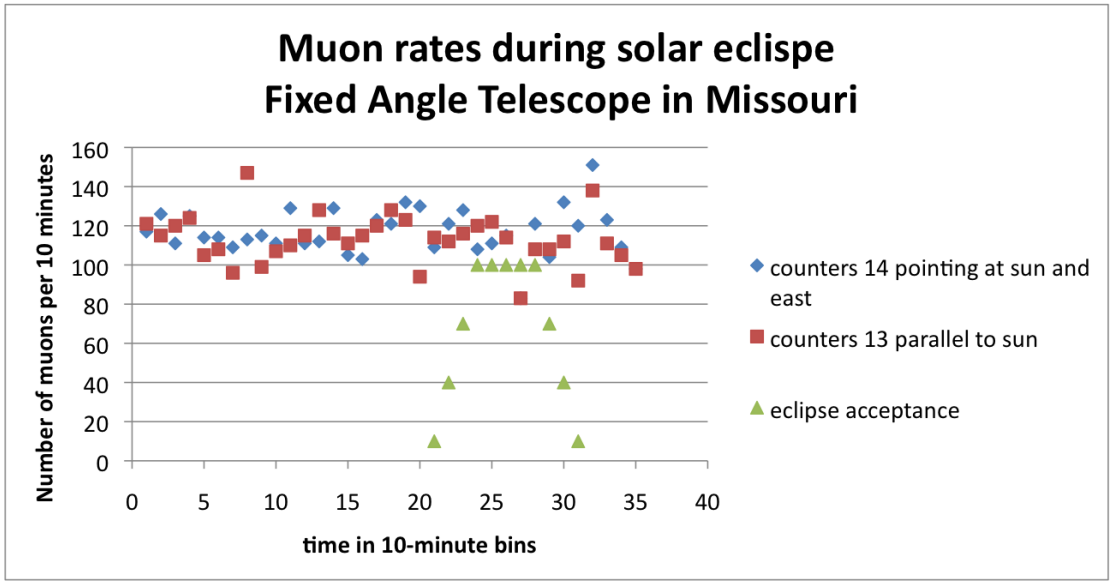
Fixed-Angle Telescopes

Rates of muons from the direction of the sun during the eclipse

Compare with empty sky, moon or sun

- Muons every 10 minutes
- Parallel to the sun
- 5 degrees east of the sun



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Solar Project Summary

Teachers and students around the U. S. collaborated to carry out original research with QuarkNet cosmic ray detectors during the 2017 total solar eclipse.

Developed analysis tools and detectors.

Constructed prototypes.

Collected data - during summer break!

Observed the total solar eclipse.

Analysis taking place during fall, results in Jan. 2018

If that is not enough—groups have telescopes and are currently trying to observe the muon deficit around sun and rate changes due to solar activity.

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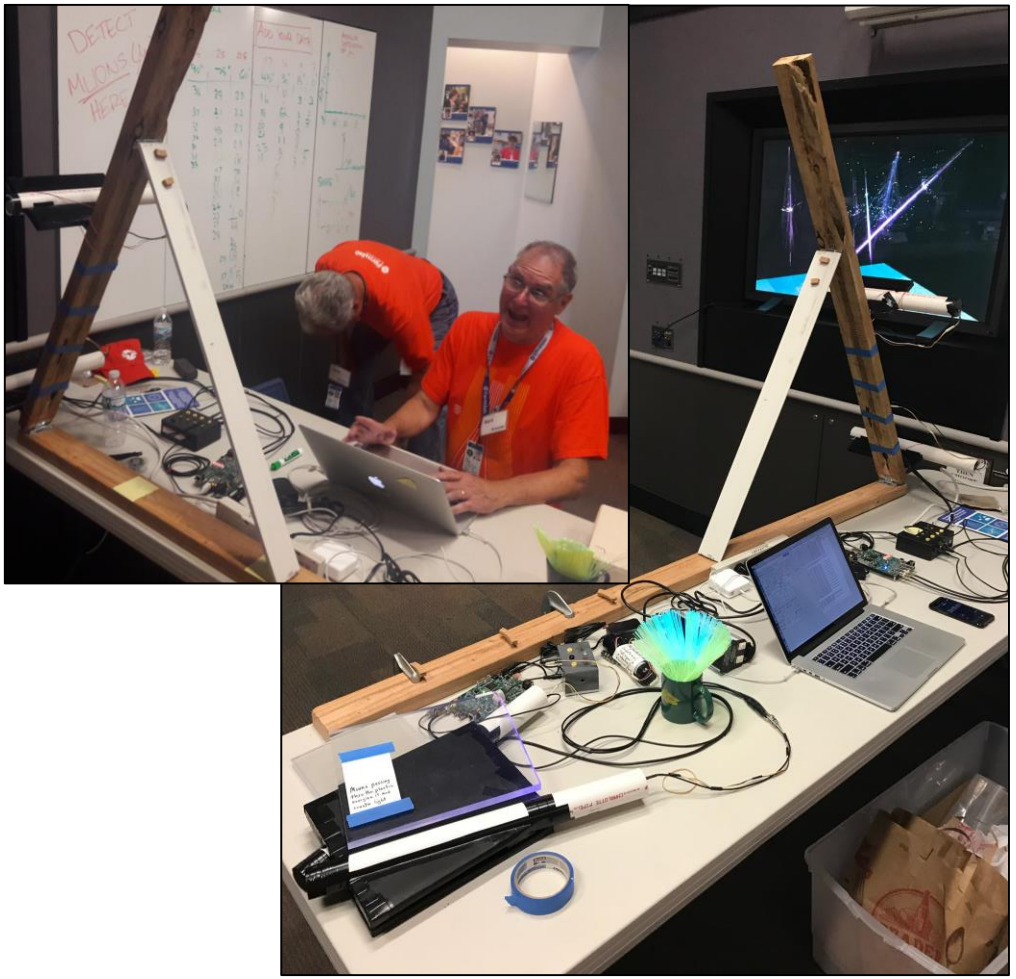
Cosmics at Open House

Families used scintillators to prove muons come form the sun.

The average of children measuring muon rates vs. zenith angle was 8 (OK maybe 9). They recorded their data too.



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CR Data at Open House