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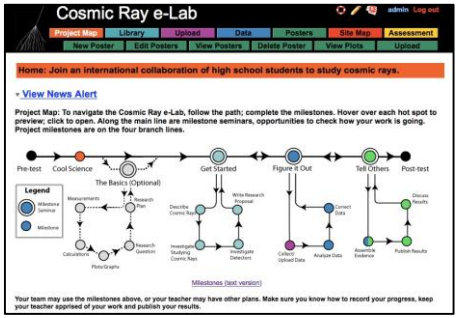
Exploring Cosmic Rays with a High School Student Global Detector Project



Mark Adams
Fermilab

U.S. DEPARTMENT OF ENERGY | Office of Science | QuarkNet

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Outline

Where QuarkNet detectors are located around the world

Examples of cosmic ray muon experiments and analyses

Solar Eclipse Project

Proposal for global cosmic ray measurements to inspire more high school participation

Helping Develop America's Technological Workforce

Recent QuarkNet Data

QuarkNet schools are part of a large HEP-like collaboration.

M. Adams, DPF at Fermilab, August 2017

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Experiments and e-Lab Analysis Tools

Students perform web-based analyses after collecting data in schools.

Flux – Cosmic ray rates versus time

Shower – Correlate events from different locations.

Lifetime – Muon lifetime

Time of Flight – Relative time between counters: speed of muon

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Data Analysis Flow

Design experiment with muons.

Take data with cosmic ray detector.

Define geometry of setup.

Upload data.

Select data.

Run an analysis.

Save plots.

Make poster with results.

Flux & shower lead to possible worldwide measurements.

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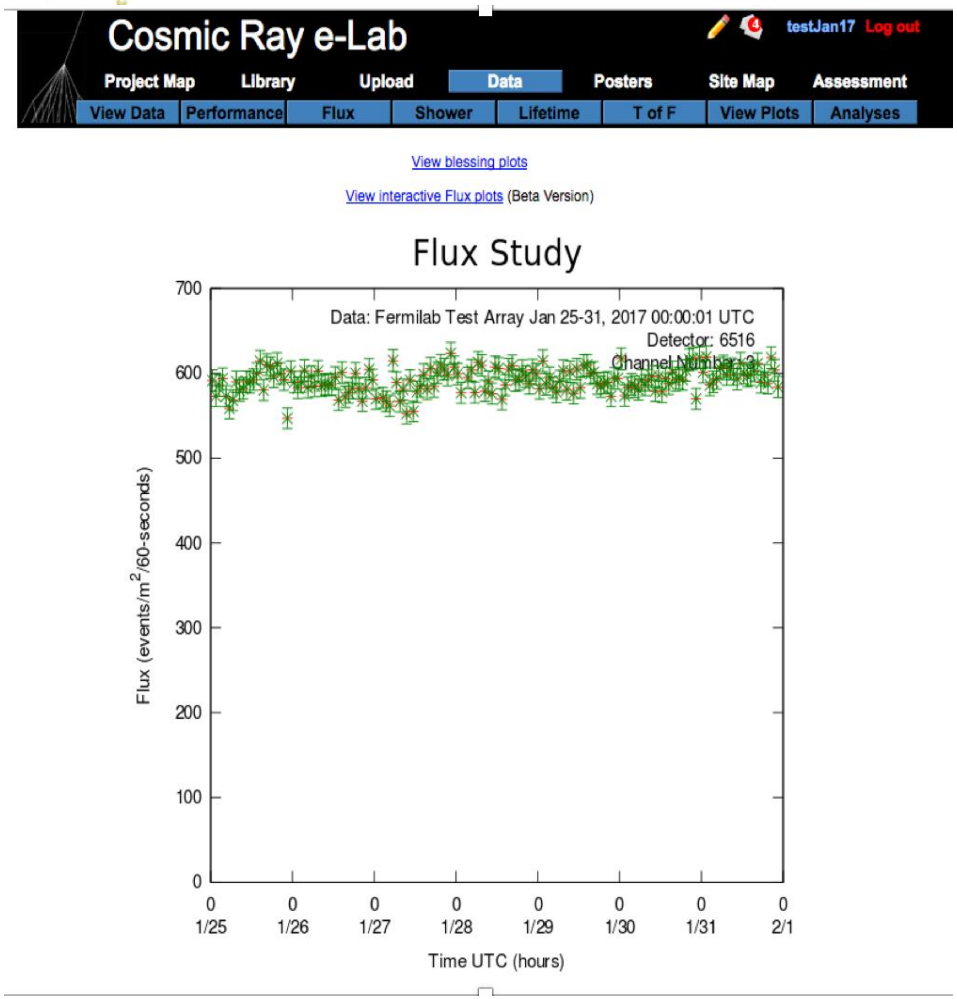
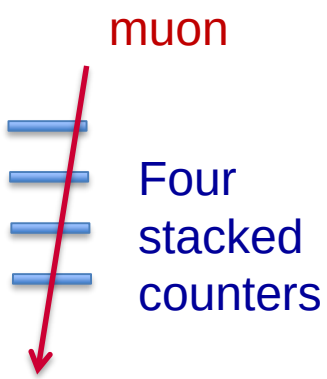
Run Flux – Muon Rate



Rate versus time over 7 days



Students also verify that data collection looks normal via blessing process.

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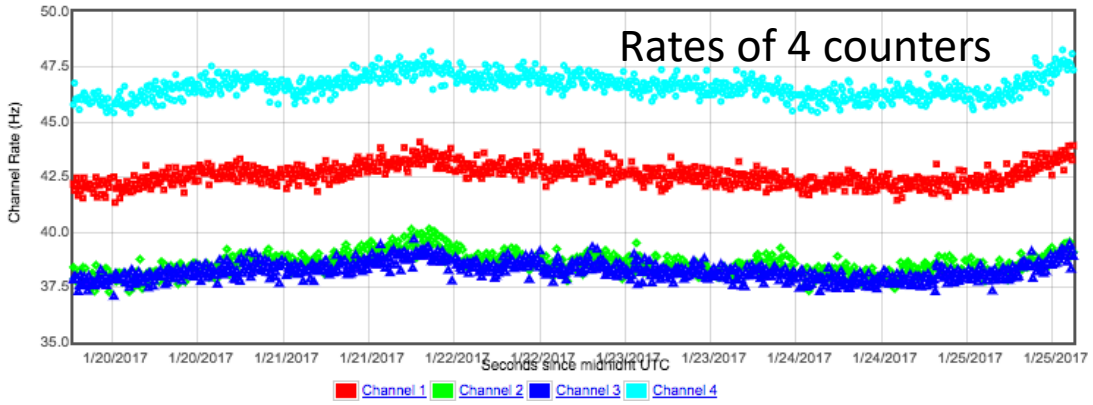
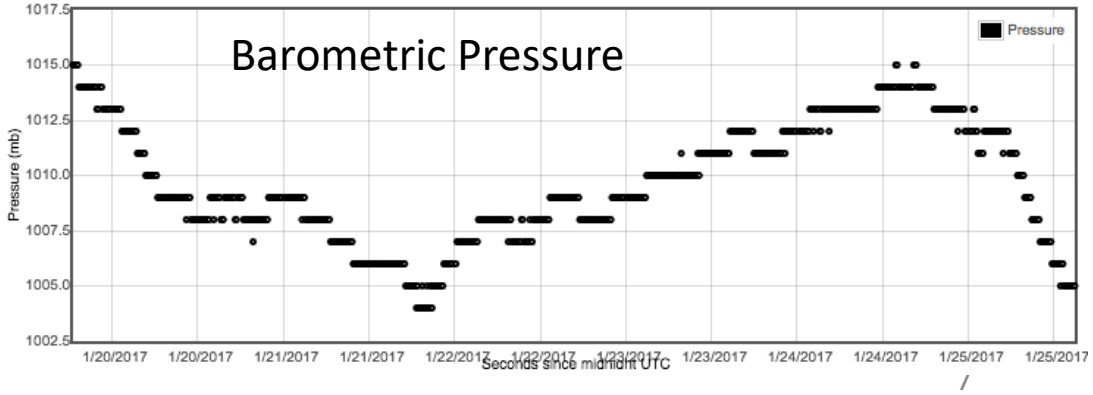
Rate vs. Pressure

Counter rates versus time are inversely proportional to pressure.



After correcting for barometric pressure, students can also study dependences on other variables (temperature).



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Shower e-Lab Tool

Search for coincidences in time using detectors located at different positions.

Find very large showers in detectors separated by large distances or measure muon multiplicity of a large number of detectors located in a smaller space.

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Shower Result

Cosmic Ray e-Lab

CRdata Log out

Project Map | Library | Upload | Data | Posters | Site Map | Assessment

View Data | Performance | Flux | Shower | Lifetime | T of F | View Plots | Analyses

4 shower study candidates *Event List References*

Event Date	Hit Coincidence	Detector Coincidence [Channel Multiplicity]
		View Multiplicity Totals
Jan 10, 2017 23:48:56 UTC	4	2 (6148[2] 6663[2])
Jan 27, 2017 23:58:06 UTC	5	2 (6148[2] 6663[3])
Jan 28, 2017 16:14:48 UTC	4	2 (6148[2] 6663[2])
▶ Jan 29, 2017 13:49:09 UTC	5	2 (6148[2] 6663[2])

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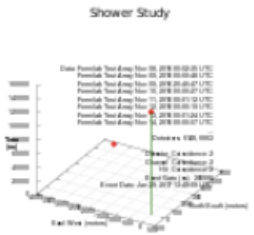
Click on image for a larger view



View raw data or geometry for Jan 29, 2017 13:49:09 UTC for detector ID 6148 6663

Plot datapoints:

East/West (meters)	North/South (meters)	Time (nanosec)	Detector	Channel
-3590.4	580.5	0.0	6663	4
-3582.2	581.9	57.5	6663	2
2.1	1.1	150344.7	6148	1
4.0	-4.1	150346.7	6148	4
4.0	-4.1	150376.7	6148	4

Search for correlated shower in detectors located 5 km apart.

300 microsecond time window

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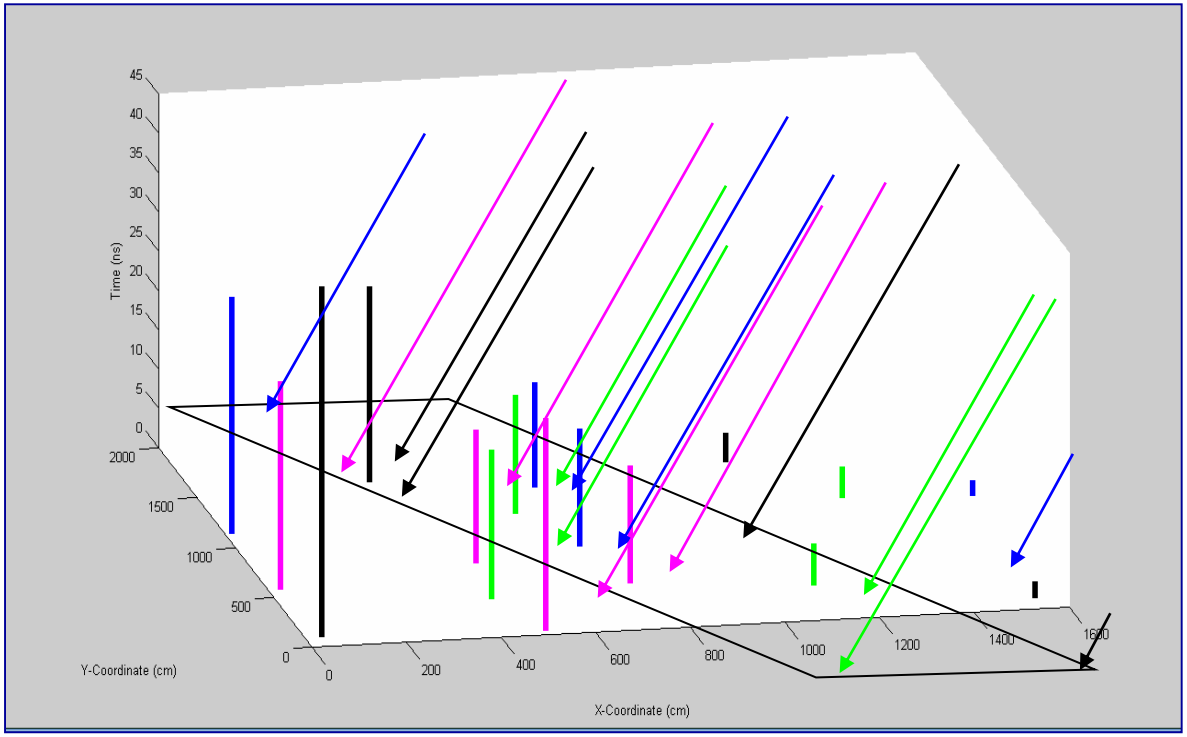
Cosmic Ray Shower

16 counters observing 16 muons in one shower using 5 separate DAQs

Vertical scale is time of muon arrival.

Horizontal plane is detector position.

Consistent with 16 muons from the same direction



The educational journey required lots of collaboration and calibration effort.

QuarkNet Global Data Collection Efforts

More Global, Larger Collaboration

QuarkNet has over 500 detectors worldwide.

First priority: Student-designed experiments in schools, but we aspire to do more!

Students have undertaken increasingly more sophisticated experiments and have built a larger collaboration sharing data globally.

Large air shower studies within/among schools:

- International Cosmic Day – shared data taking
- International Muon Week – shared muon experiments
- Cosmic rays during the solar eclipse
- Sharing data worldwide

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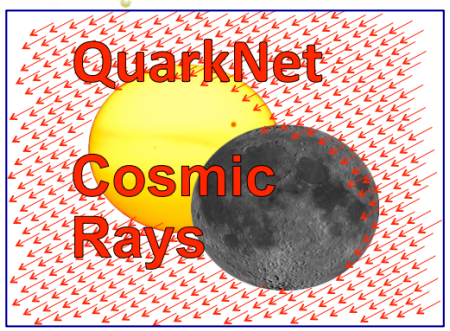
Solar Eclipse Project



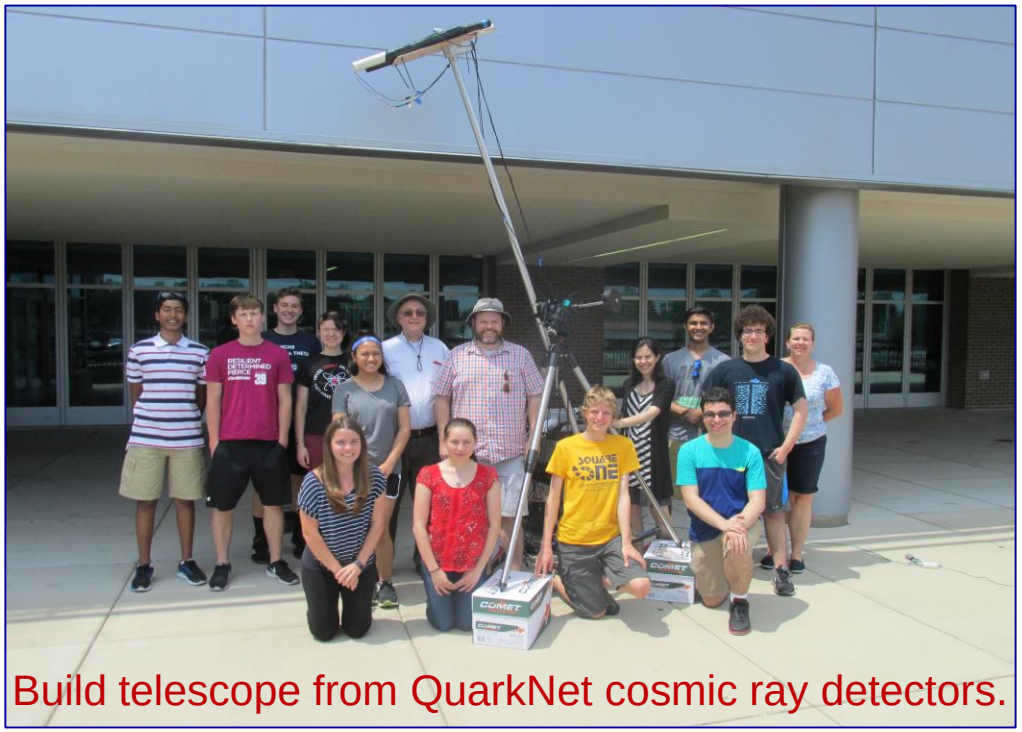
Measure cosmic ray rates near the sun during the August 21st solar eclipse. Never done before!

Compare eclipse muon rates to rates when there is 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 30 groups participating



Build telescope from QuarkNet cosmic ray detectors.

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Global Proposal

Current Collaboration of High Schools:

High schools take cosmic ray data and share with other sites around the world.

High schools analyze data and share results with others around the world.

Use shared global data to encourage more participation and strengthen collaboration.

What can a globally dispersed detector accomplish?

1. Single muon rates
2. Large Array correlated air showers

IPPOG supported the first workshop for potential collaborators.

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Events That Change Muon Rates Worldwide

Single Muons

Take standard flux data over a long period of time: establish baseline; perhaps correct for pressure dependence.

1. Search for change in nominal rate, e.g., due to a coronal mass ejection on the sun that changes the earth's magnetic field.

When an abnormal rate is observed, send an e-mail request to detectors worldwide to capture rate histograms for a day surrounding the target time and share via a website.

2. Study rates versus pressure; altitude; latitude

Tailored for rates from single muon setups

QuarkNet Correlated Events World-wide

Correlated Large Array Data –

Search for showers that cover a large area on the earth.

3. Rare Events Study

Search for a cosmic ray air shower event worldwide correlated in time or for clusters of showers anywhere.

If found in any set of detectors, ask groups worldwide to search for similar cluster within ~1 millisecond of the target time.

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Summary

Students all over the world thrive doing research with QuarkNet cosmic ray detectors in their schools.

This is inquiry-based learning at its best.

Global cosmic ray experiments are well underway.

Students understand the technology and the process of science in a big collaboration.

Next steps:

Encourage closer global collaboration.

Increase periods of sustained data taking.

Explore what global cosmic ray coverage can accomplish.

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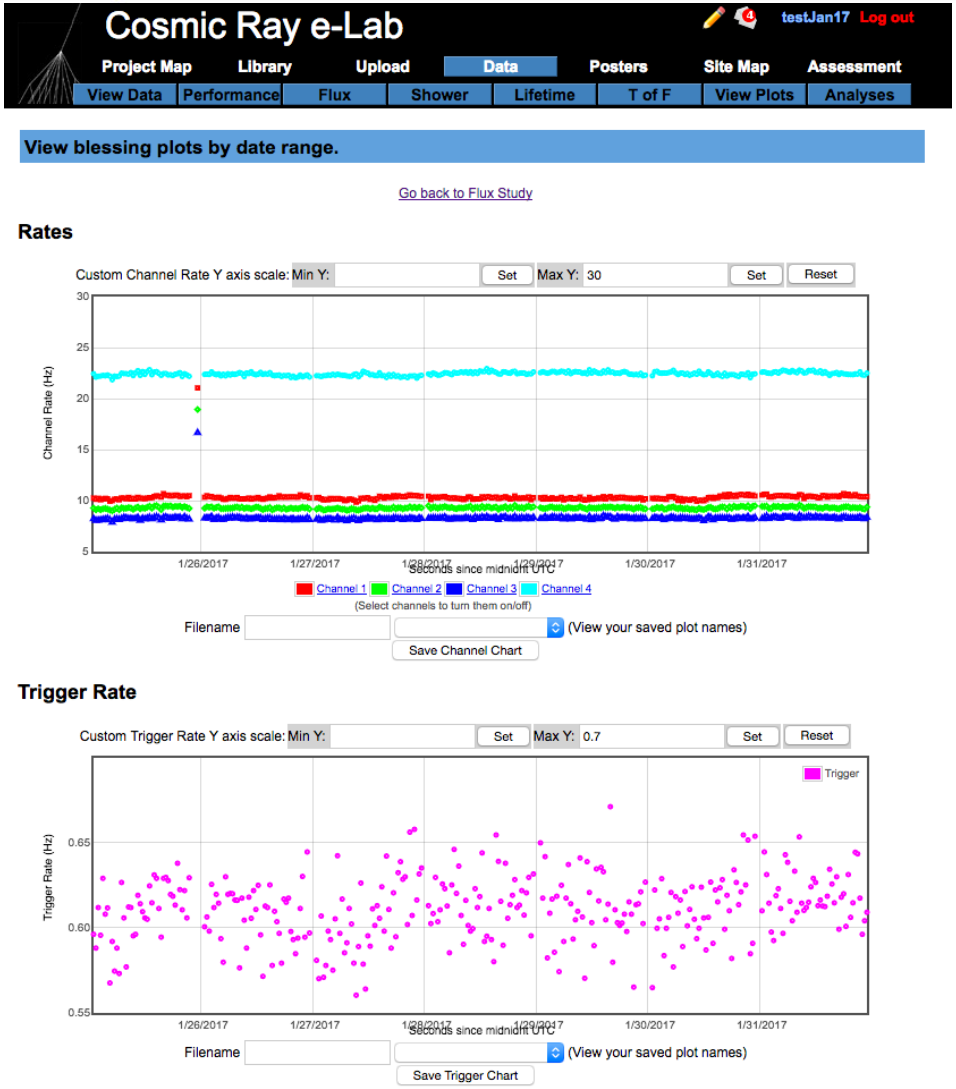
Check Blessing Plots



Quality of Data Measures

plus temperature & pressure information

Frequency of individual counters independent of triggered events

Trigger rate versus time (selected events)