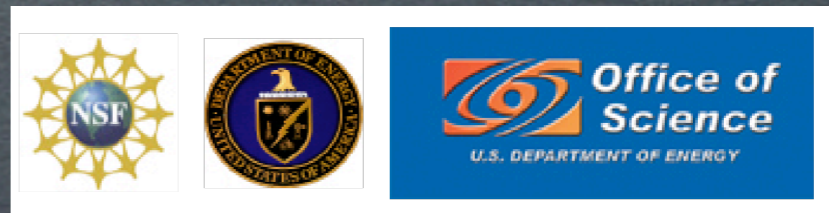


THE QUARKNET CLASSROOM COSMIC RAY MUON DETECTOR AND E-LAB ANALYSIS PORTAL

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ELIZABETH QUIGG



Cosmic Ray Studies

- ✿ The Collaboration
- ✿ The Hardware
- ✿ Typical Setup
- ✿ Student Use and Tabletop Experiments
- ✿ e-Lab Data Portal
- ✿ Conclusions and Future Work



Cosmic Ray Studies

- ☼ We want students to think critically by engaging science questions that are:
 - ☼ Open-ended.
 - ☼ Answered by data.
 - ☼ Messy.

We help teachers learn how to do this.



The Collaboration

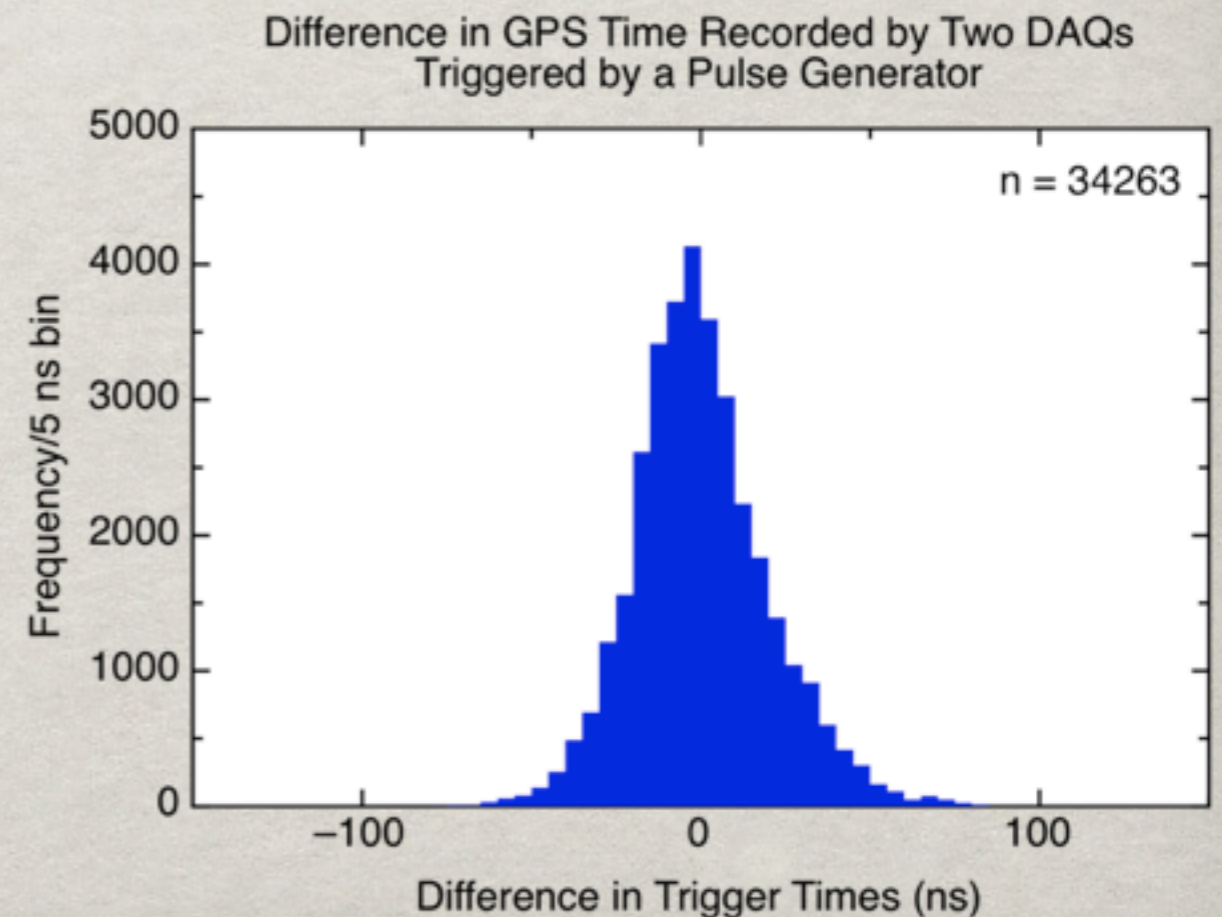
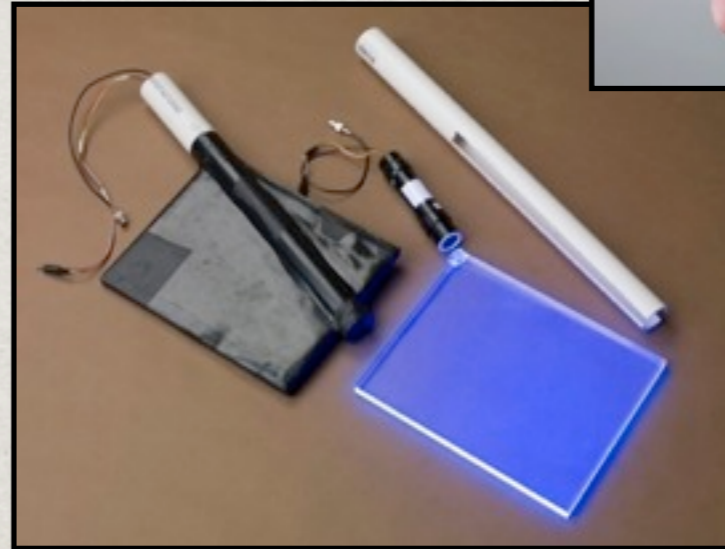
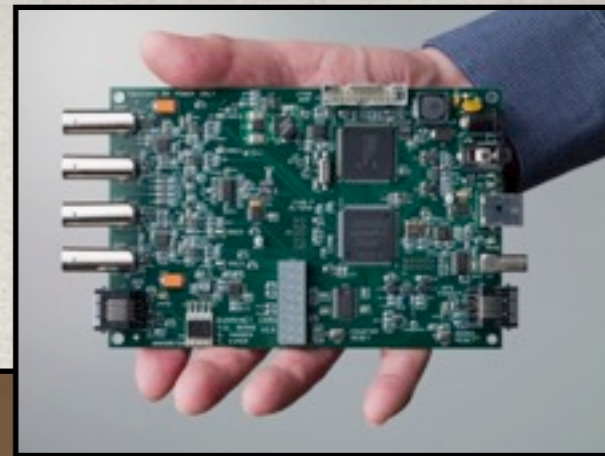
- ☼ QuarkNet started in 1998 as an outreach program for the U.S. particle physics community.
- ☼ We have grown to 52 centers and > 550 active teachers.
- ☼ Some teachers asked for hardware.



- ☼ QuarkNet provides hardware to teachers in the project. (red at left)
- ☼ Others have purchased the hardware at our cost. (blue at left)

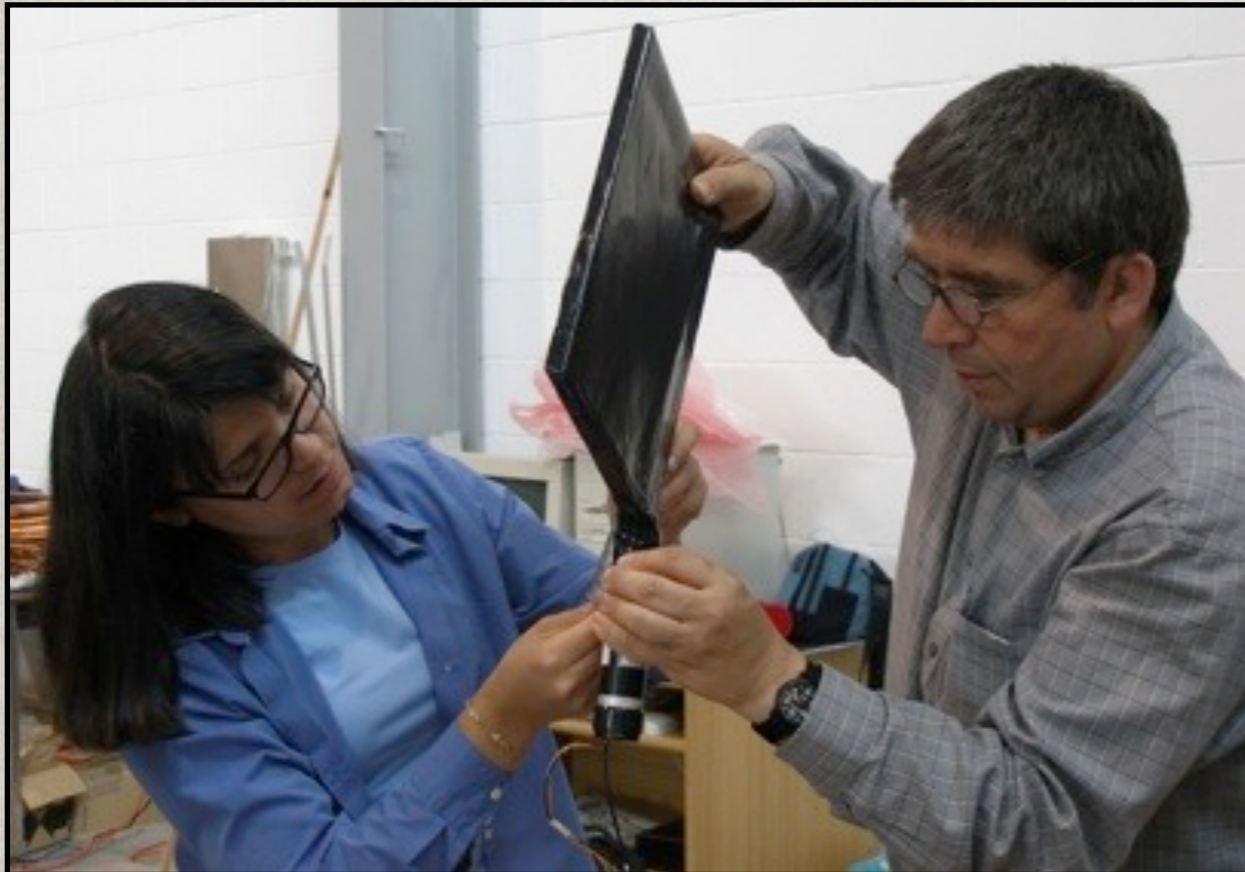
The Hardware

- ✱ Four channels of A2D
- ✱ PMT pulse edges are matched to a local clock.
- ✱ The local clock is synced to GPS time.
- ✱ Selectable trigger logic
- ✱ User-accessible scalars to check rates
- ✱ Scintillation-based counters
- ✱ Low-voltage PMTs (5 VDC)



Teacher Workshops

- ✿ 94 teacher workshops since 2004
- ✿ Three to five days in duration
 - ✿ Detector assembly
 - ✿ Guided practice



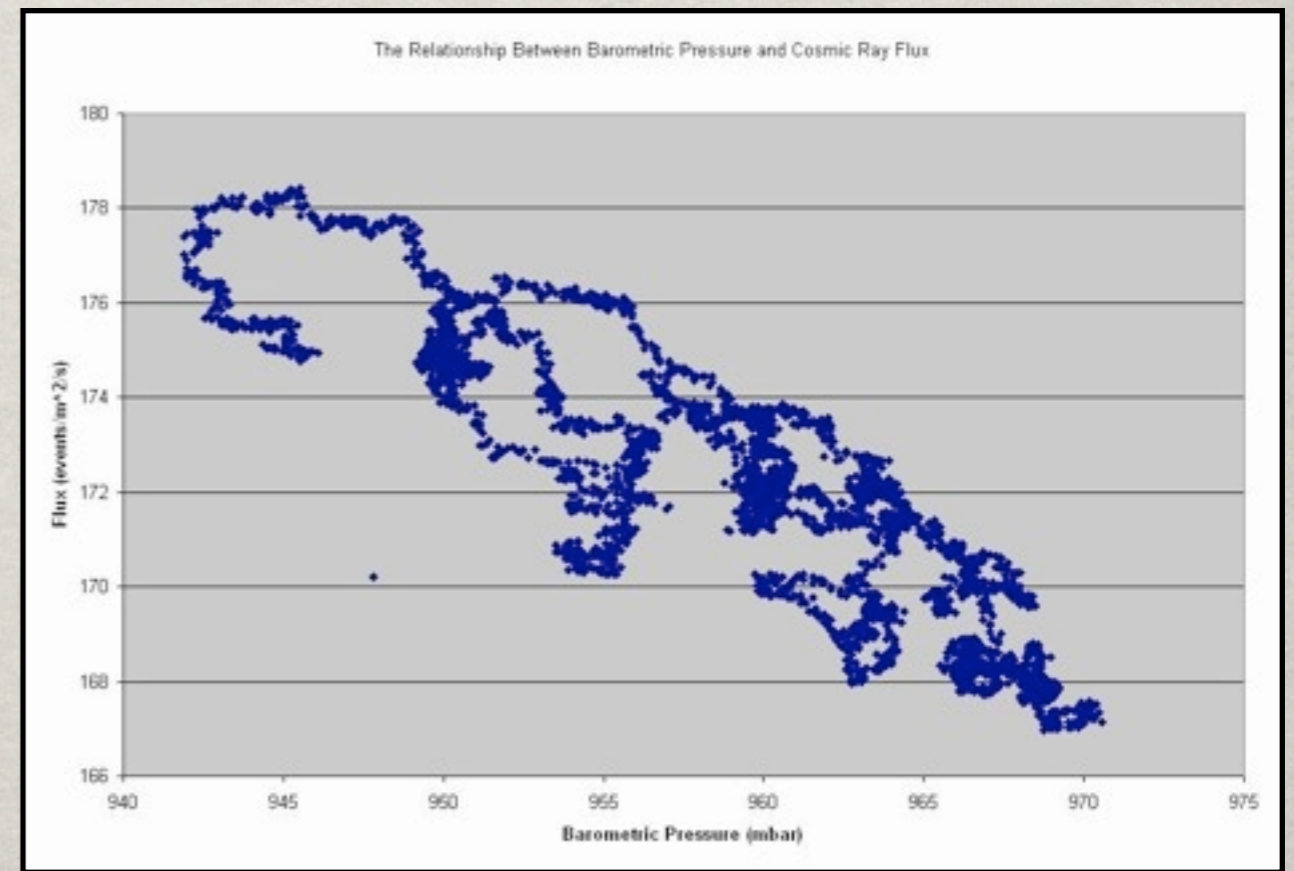
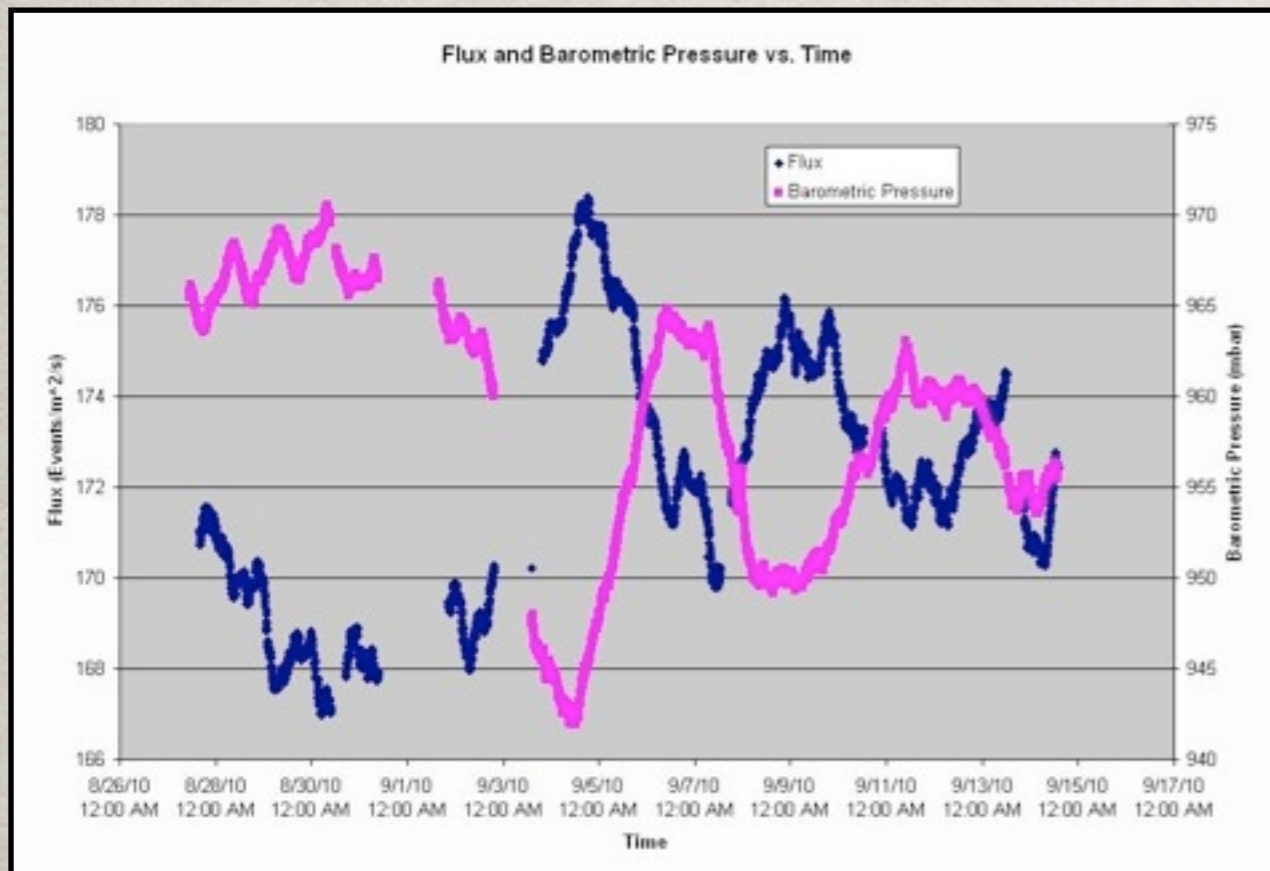
Teacher Workshops

- ✿ Wrap scintillating plates
- ✿ Install PMT's
- ✿ Connect cables
- ✿ Acquire GPS signal
- ✿ Plateau PMT performance



Typical Setup

- ☼ Counters are in the classroom for easy access.
- ☼ Students can ask their own questions—such as:
 - ☼ Are there more cosmic ray muons during the day than there are at night?
 - ☼ Will the muons penetrate this thick steel table?
 - ☼ Are there more cosmic ray muons during thunderstorms?



e-Lab: an Electronic Laboratory

☼ Allow access to "inscrutable data"

☼ Users just want to get to the physics.

```
423A4BA0 00 01 01 35 01 34 00 01 4084C878 190554.524 120706 A 06 0 -0570
4274E8F8 80 01 2D 01 2D 01 00 01 4084C878 190554.524 120706 A 06 0 -0570
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```

e-Lab: an Electronic Laboratory

☼ Allow access to "inscrutable data"



✎ guest Log out

Project Map

Library

Data

Posters

Site Map

Assessment

Text Version

Cool Science

About Us

Home: Join a national collaboration of high school students to study cosmic rays.

Project Map: To navigate the Cosmic Ray e-Lab, follow the path; complete the milestones. Hover over each hot spot to preview; click to open. Along the main line are milestone seminars, opportunities to check how your work is going. Project milestones are on the four branch lines.

Milestones (text version)

Your team may use the milestones above, or your teacher may have other plans. Make sure you know how to record your progress, keep your teacher apprised of your work and publish your results.

24 +/- 0.01268]

:36:58 UTC

:10:56 UTC

:55:24 UTC

ector: 63

nce level: 1

423A4BA0 00
 4274E8F8 80
 4274E8FA 00
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 4449D306 00
 4484702B 80
 4484702E 00
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 44F9AB06 80

e-Lab: an Electronic Laboratory

☼ An e-Lab is a web-based tool that allows:

☼ Data uploads

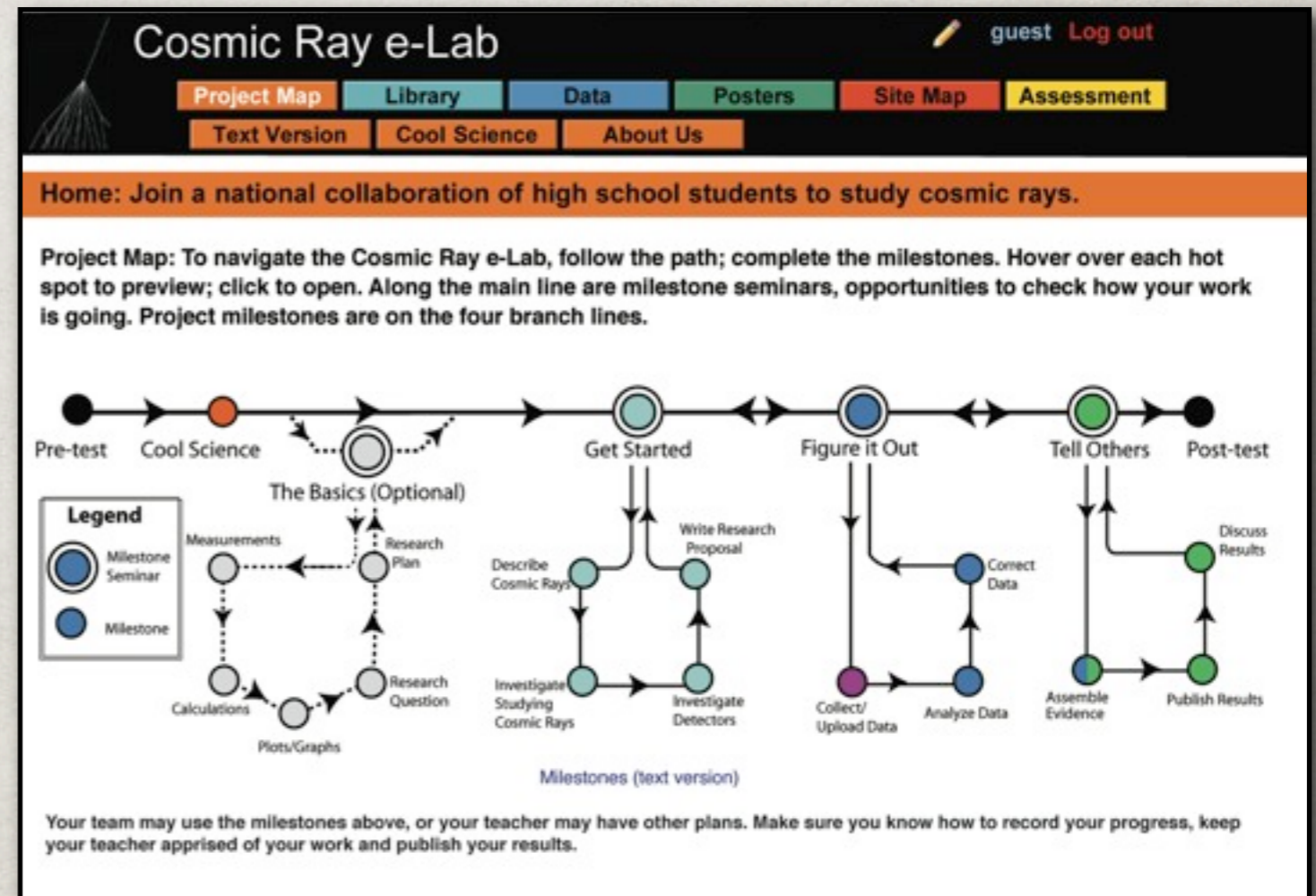
☼ Data blessing

☼ Analysis tools

☼ Publication of findings

☼ On-line logbooks

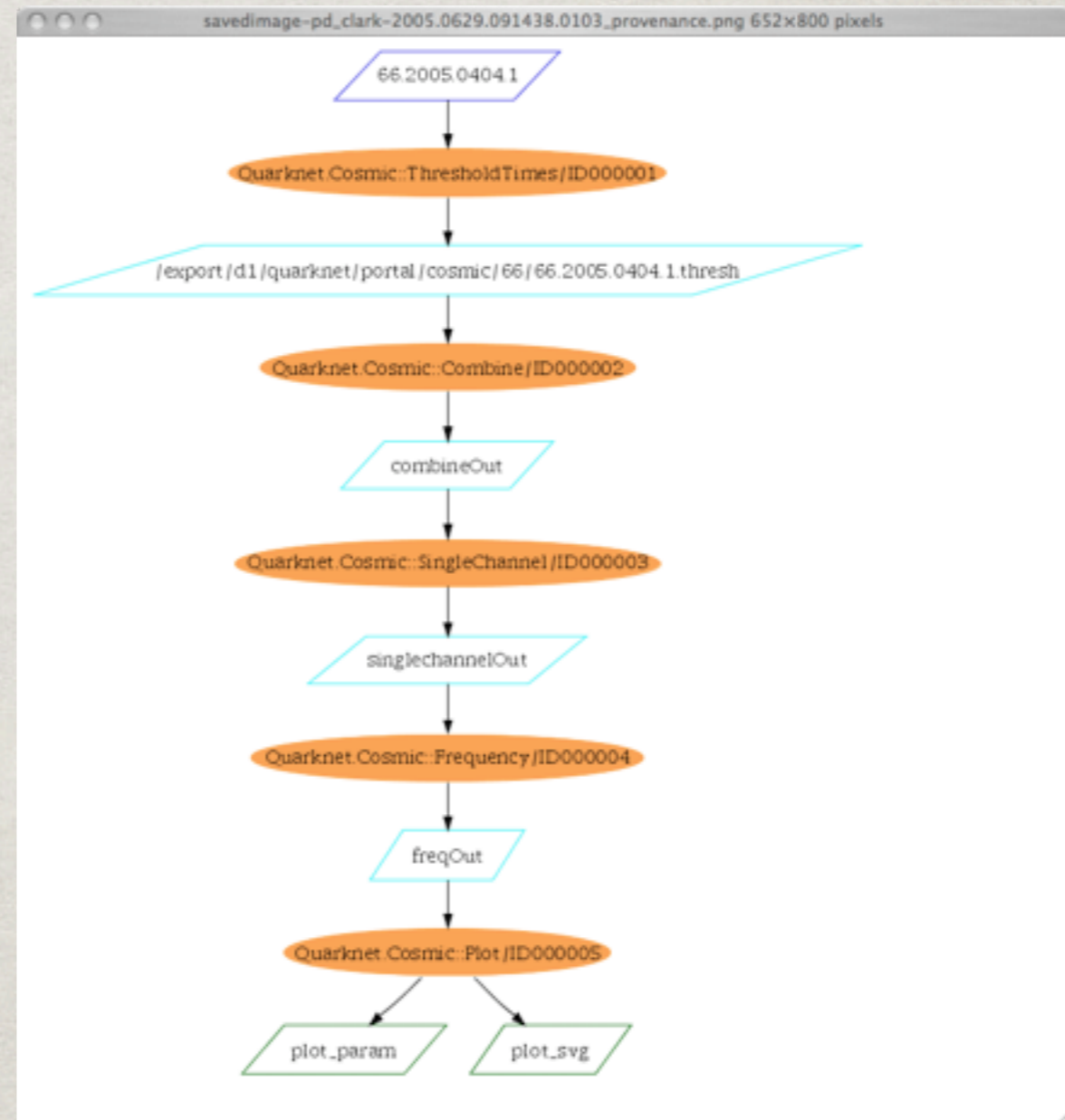
☼ Collaboration



e-Lab: an Electronic Laboratory

Workflows include:

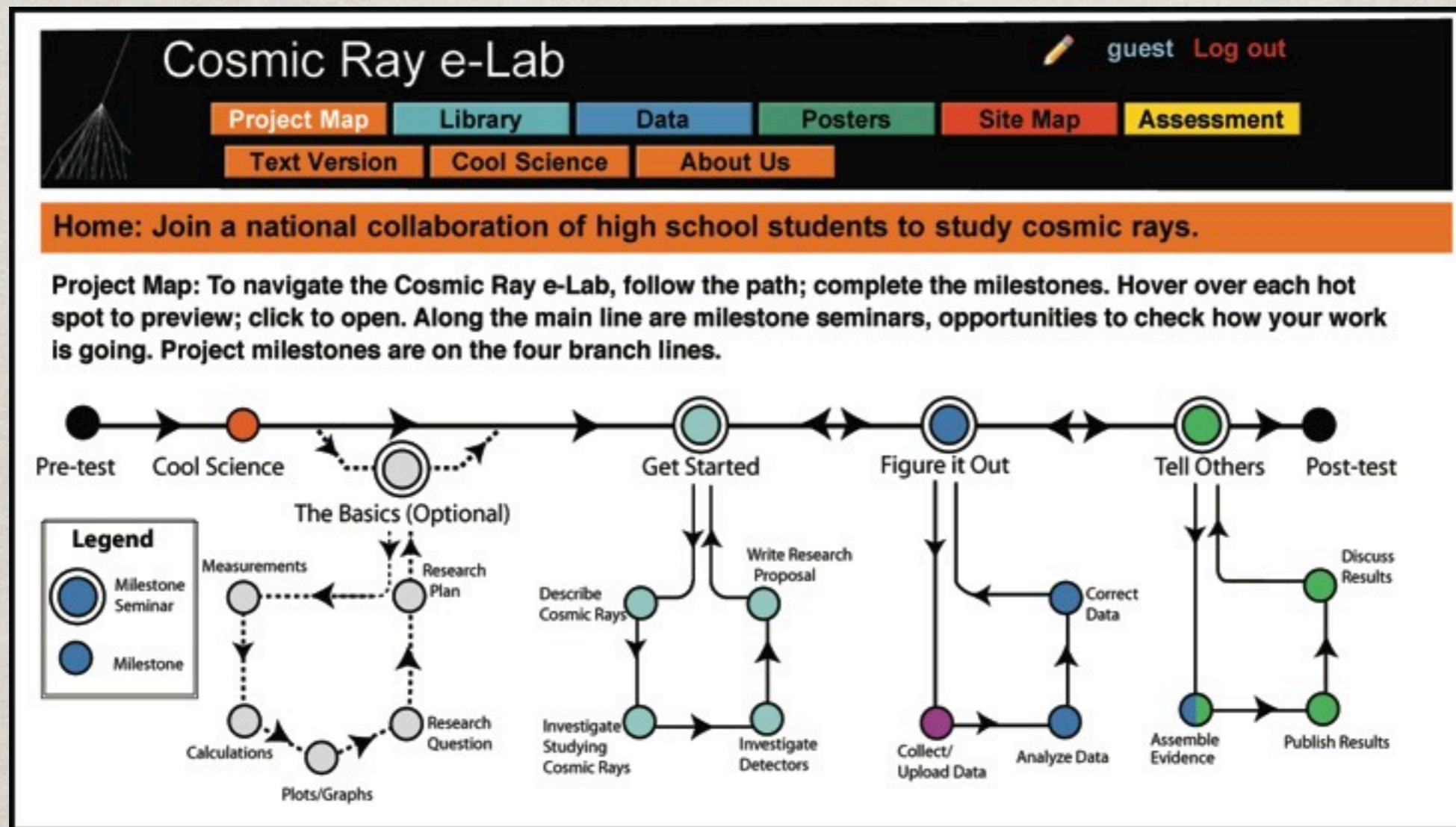
- ☼ Performance
- ☼ Flux
- ☼ Shower
- ☼ Lifetime



Users can also access intermediate files for analysis in spreadsheets or with their own code.

e-Lab: an Electronic Laboratory

- ✿ Provides a “metro map” to researching a topic
- ✿ Each “station” is clickable and yields additional resources.



e-Lab: an Electronic Laboratory

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Cosmic Ray e-Lab ✎ guest Log out


[Project Map](#) [Library](#) [Data](#) [Posters](#) [Site Map](#) [Assessment](#)

[Text Version](#) [Cool Science](#) [About Us](#)

Milestone: Assemble evidence for your results.

Scientists must convince each other that their conclusions make sense. Data, analysis and interpretation are tools that show the research details and defend results.

Look at the plots you saved using the **View Plots** submenu under **Data**. Also check your logbook for plots that support or do not support your ideas. Based on your notes, list plots that you think should appear in your published results.

[Log it!](#) 

To Learn More:

[Defend your research](#), from *MacSci Network*

High school students to study cosmic rays.

Follow the path; complete the milestones. Hover over each hot spot to see milestone seminars, opportunities to check how your work progresses.

Get Started → **Figure it Out** → **Tell Others** → **Post-test**

Get Started tasks: Investigate Detectors, Write Research Proposal

Figure it Out tasks: Collect/ Upload Data, Analyze Data, Correct Data

Tell Others tasks: Assemble Evidence, Publish Results, Discuss Results

e-Lab: an Electronic Laboratory

- ✿ Provides a student logbook
- ✿ Entries are linked to “stations” on the metro map.
- ✿ Teachers can read and comment on entries.

C: Tell Others

assemble evidence - Evidence for our results

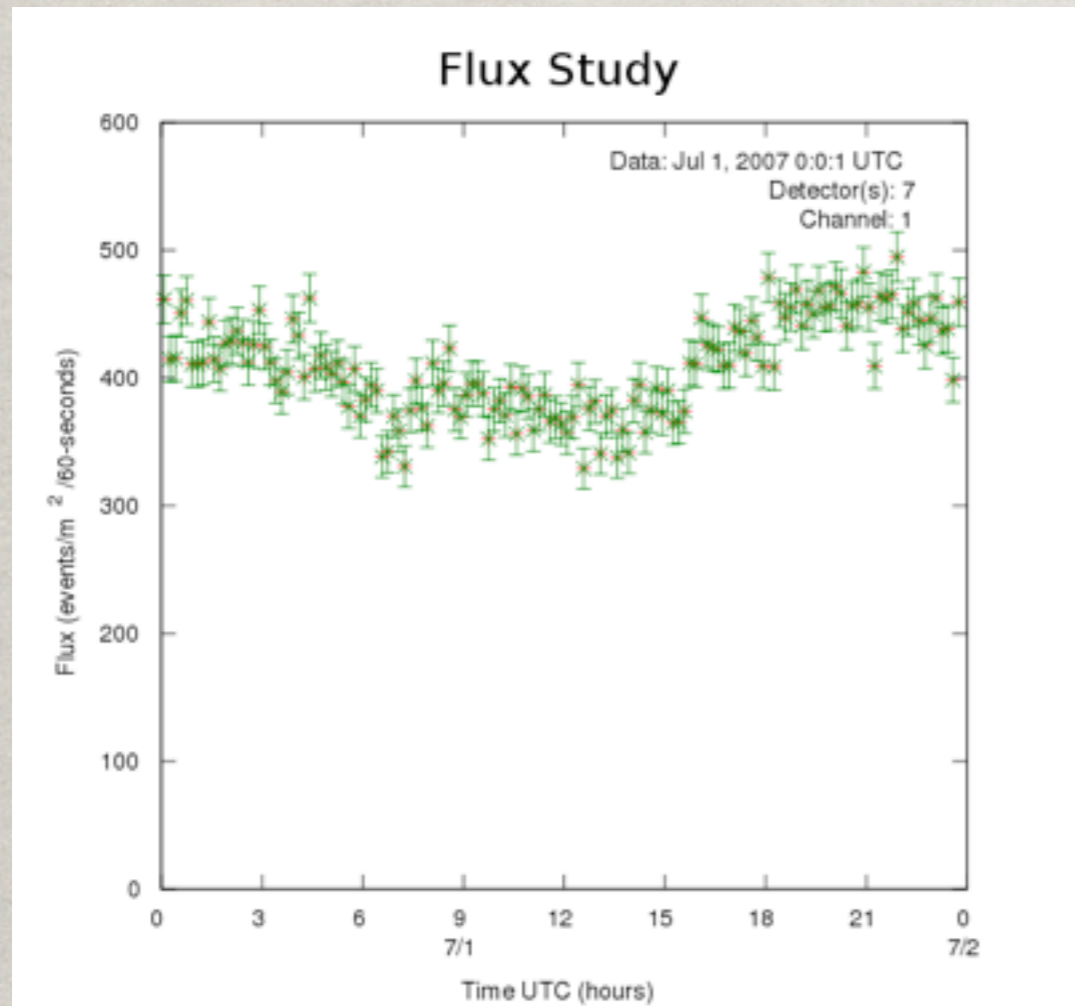
09/13/2010 07:13

Performance Study

In order to be meaningful, data from each channel of a cosmic ray detector must be matched, so they are all counting comparable numbers of events. The process of matching the channels is called plateauing. To do it, the voltage that each plate is running on is adjusted and measured against one of the other plates as a constant. The higher the voltage, the more sensitive the plate is and so it will detect more low-energy particles. . . .

e-Lab: an Electronic Laboratory

☼ Users can “publish” findings.



Poster

http://quarknet.uchicago.edu/elab/cosmic/displayPoster.jsp?type=p

FNAL @ Work QuarkNet Chiron UAL EventPlot VDL UF MSDS SIS AppleSeed Bridge DAQ Cosmics Astro

April Showers Do Not Equal Lesser Muon Flux

Effects of Weather on Muon Flux

11/15/2005
Alex Belshaw, Nic Campos, Aaron Sun, Josh Watzman

Abstract

We hypothesized that weather phenomena would affect muon flux enough to be detected. Specifically, we thought that cloud cover would slightly decrease muon flux. However, we have found that weather does not affect muon flux at all.

Procedures

Using a classroom muon detector, we measured muon flux over a couple of weeks and correlated that to weather data available for our area (zip code 45255) at <http://www.wunderground.com/>. We checked specific points at which the weather changed significantly, such as from sunny to rainy, and looked at those points on the various muon flux graphs.

Results

On November 1st, it was cloudy after 8 GMT. However, the muon flux did not change appreciably at this time, as can be seen in the first figure. On November 2nd, it was foggy until 14 GMT; again, there was no change at this time. Even during a thunderstorm, there was no appreciable change, as can be seen in the third figure. (The drop shown does not correlate to the storm; it was when the data file was changed.)

- **Figure 1:** It became cloudy after 8 GMT on Nov. 1
- **Figure 2:** It was foggy until 14 GMT on Nov. 2
- **Figure 3:** There was not even a change during a thunderstorm

Discussions & Conclusions

As shown by the three figures, weather changes do not affect muon flux as far as we can measure. In the first figure, there were clouds after 8 GMT. However, the muon flux did not change during this interval. In the second figure, fog at 14 GMT didn't change the flux either. A thunderstorm, shown in the third figure, didn't change the flux at any point during the observation period. Cloud cover, rain, and even thunderstorms do not change the flux, which seems to remain at about an average of 18 events/(m²*s) no matter what the weather is.

e-Lab: an Electronic Laboratory

- ✻ By the numbers
 - ✻ 1707 student research groups
 - ✻ 851 teacher accounts
 - ✻ 615 posters
 - ✻ 30,106 raw data files



T. Jordan, Cosmic Ray Detectors for Education, CERN, October 2010



Conclusions

- ✻ Our students *explore* high-energy cosmic rays.
- ✻ Our teachers use e-Lab scaffolding to *guide* students.
- ✻ Sustaining interest and success is quite difficult.
 - ✻ Sometimes the detector doesn't behave.
 - ✻ Sometimes the software doesn't work.
 - ✻ Sometimes the school wants the teacher to do something else.

Future Work

- ✻ Can we build a collaboration?
- ✻ Can we create a common data format?
- ✻ Can we create an international “Masterclass-like” event?
 - ✻ Contemporaneous data collection, analysis, interpretation
 - ✻ Public sharing of results
 - ✻ Videoconferences?