Classroom Cosmic Rays: Detectors and Analysis

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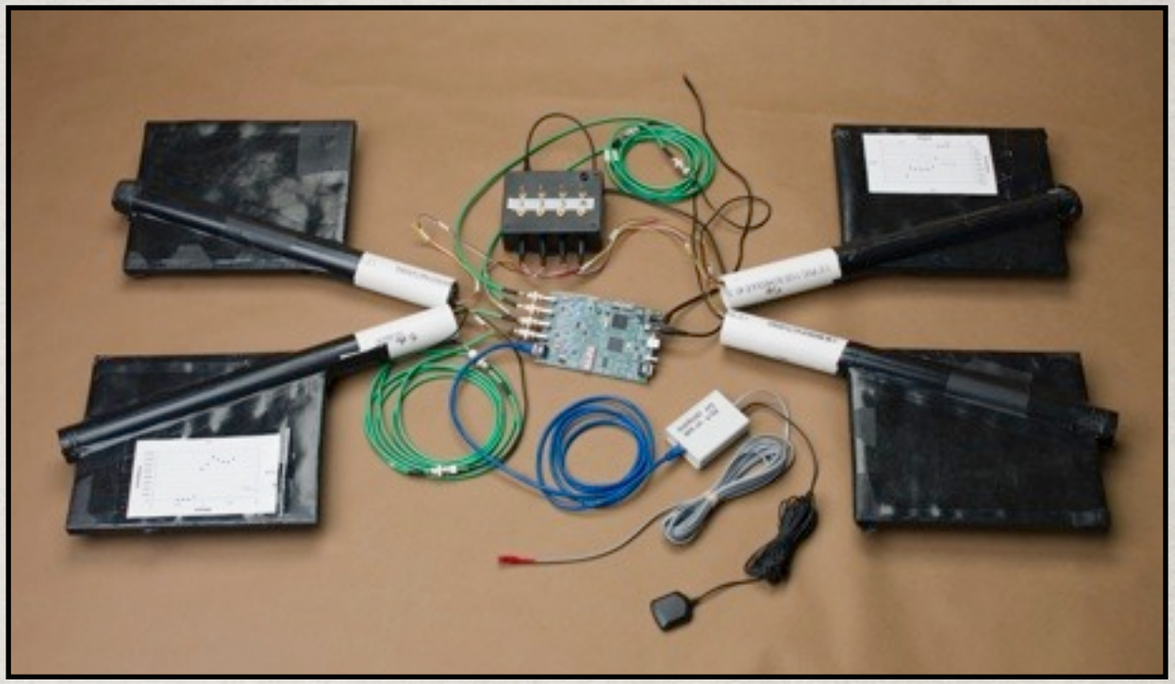
Cosmic Ray Studies



- 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.

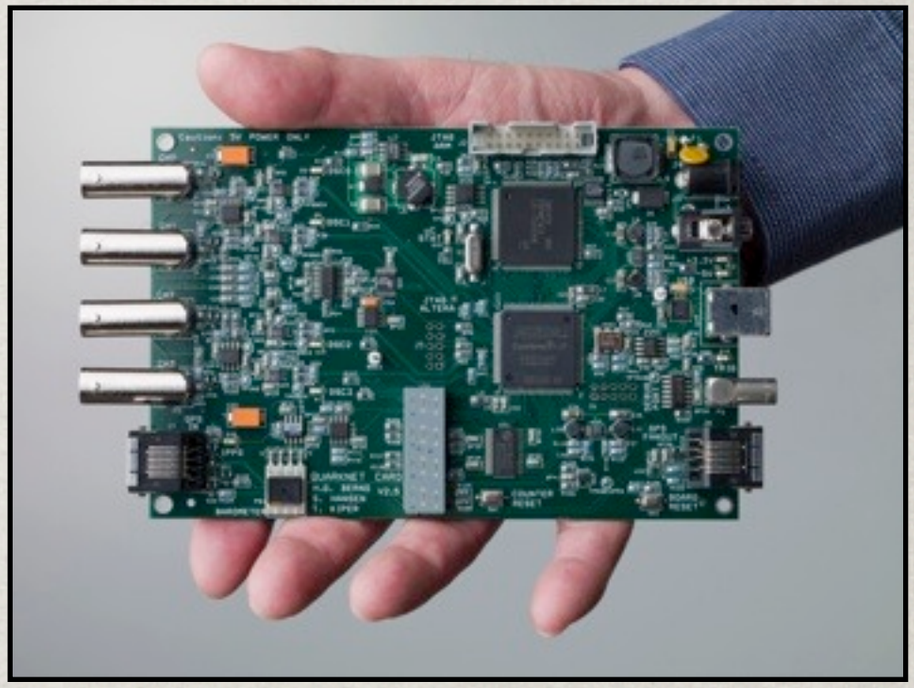
- Some teachers asked for hardware.

- QuarkNet provides hardware to teachers in the project. (red at left)

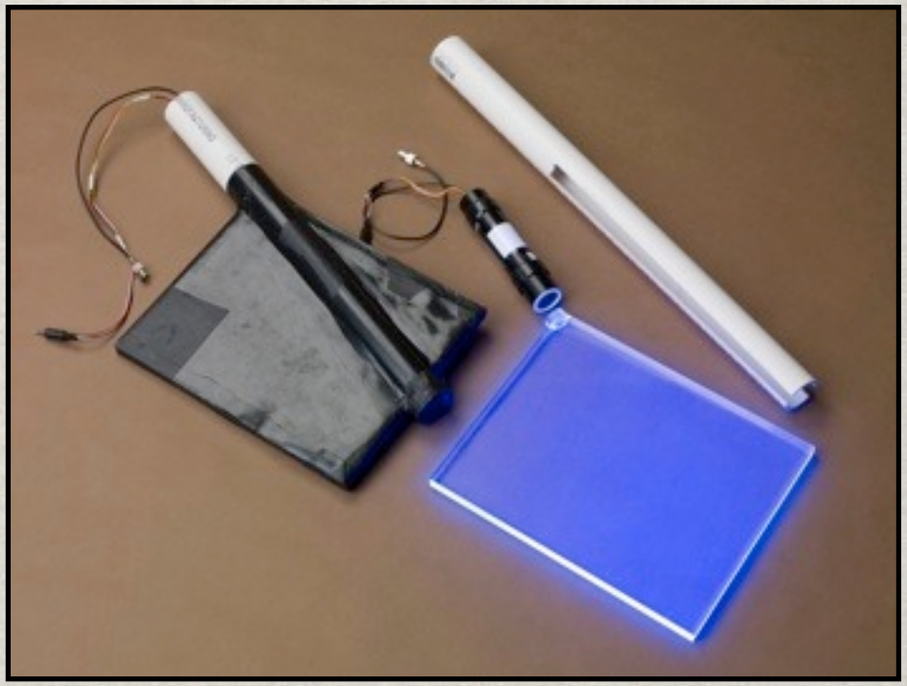
- Others have purchased the hardware at our cost. (blue at left)

The Hardware

- Four channels of A2D
- PMT pulse edges are matched to a local clock.
- The local clock is synced to GPS time.

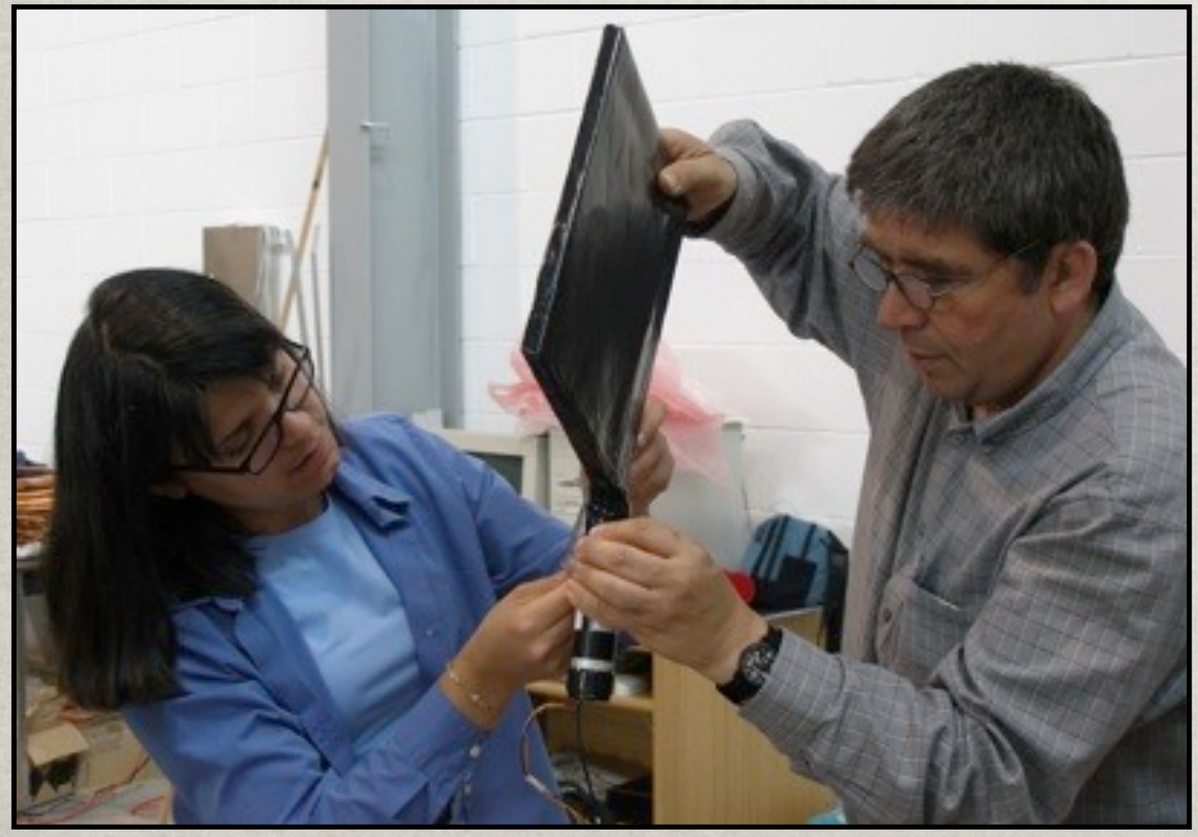


- Selectable trigger logic
- User-accessible scalars to check rates
- Scintillation-based counters



Teacher Workshops

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



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.

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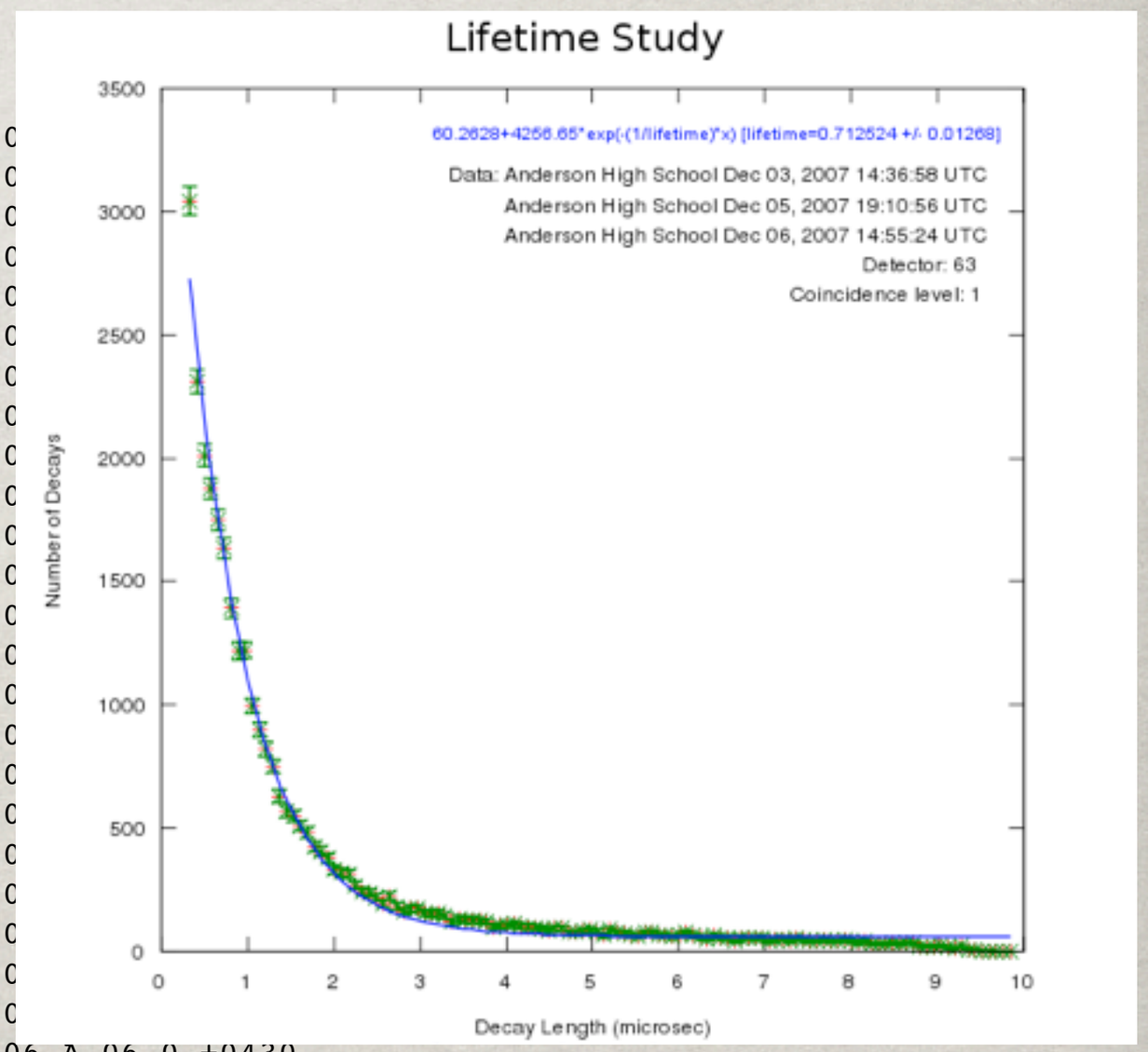
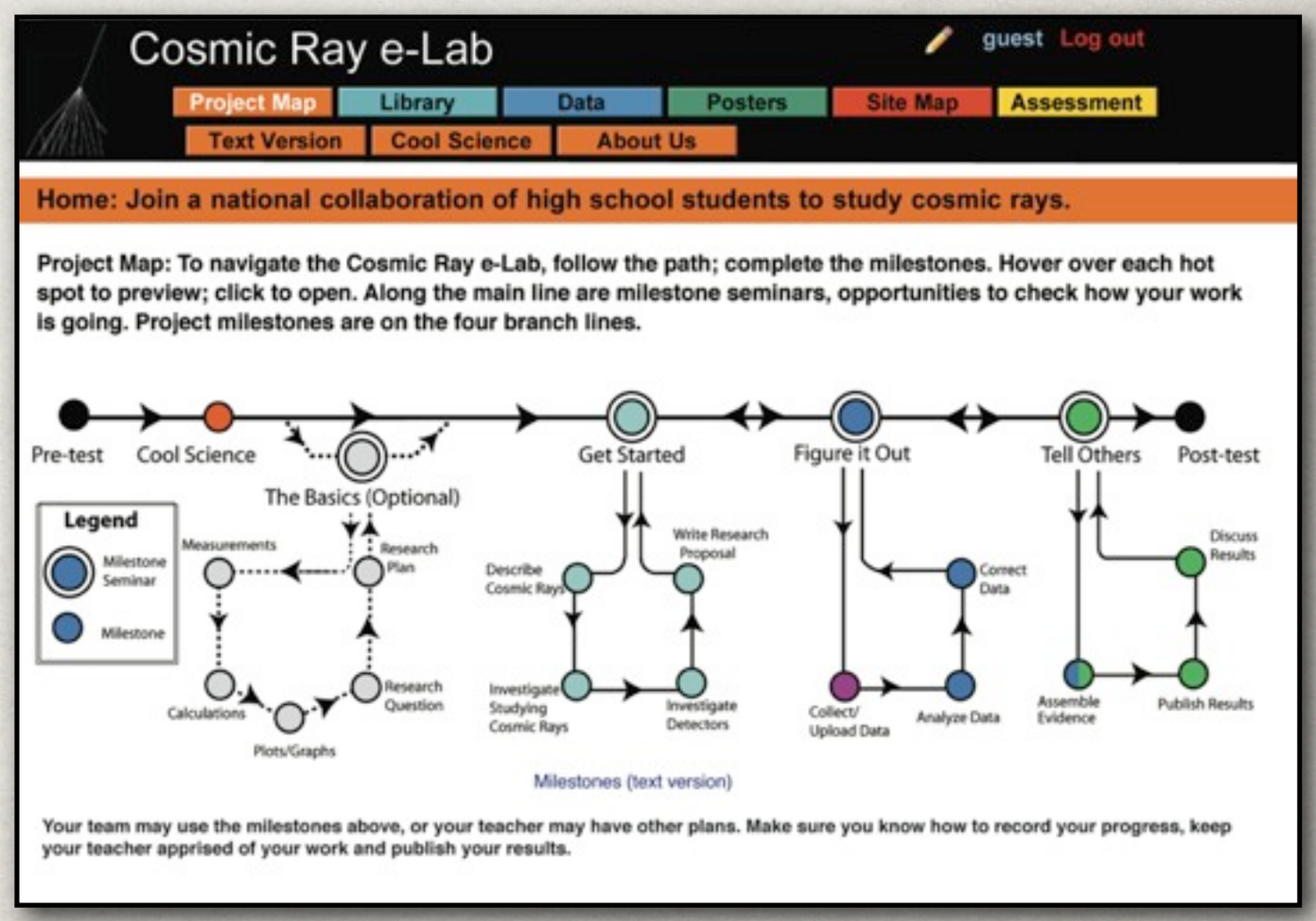


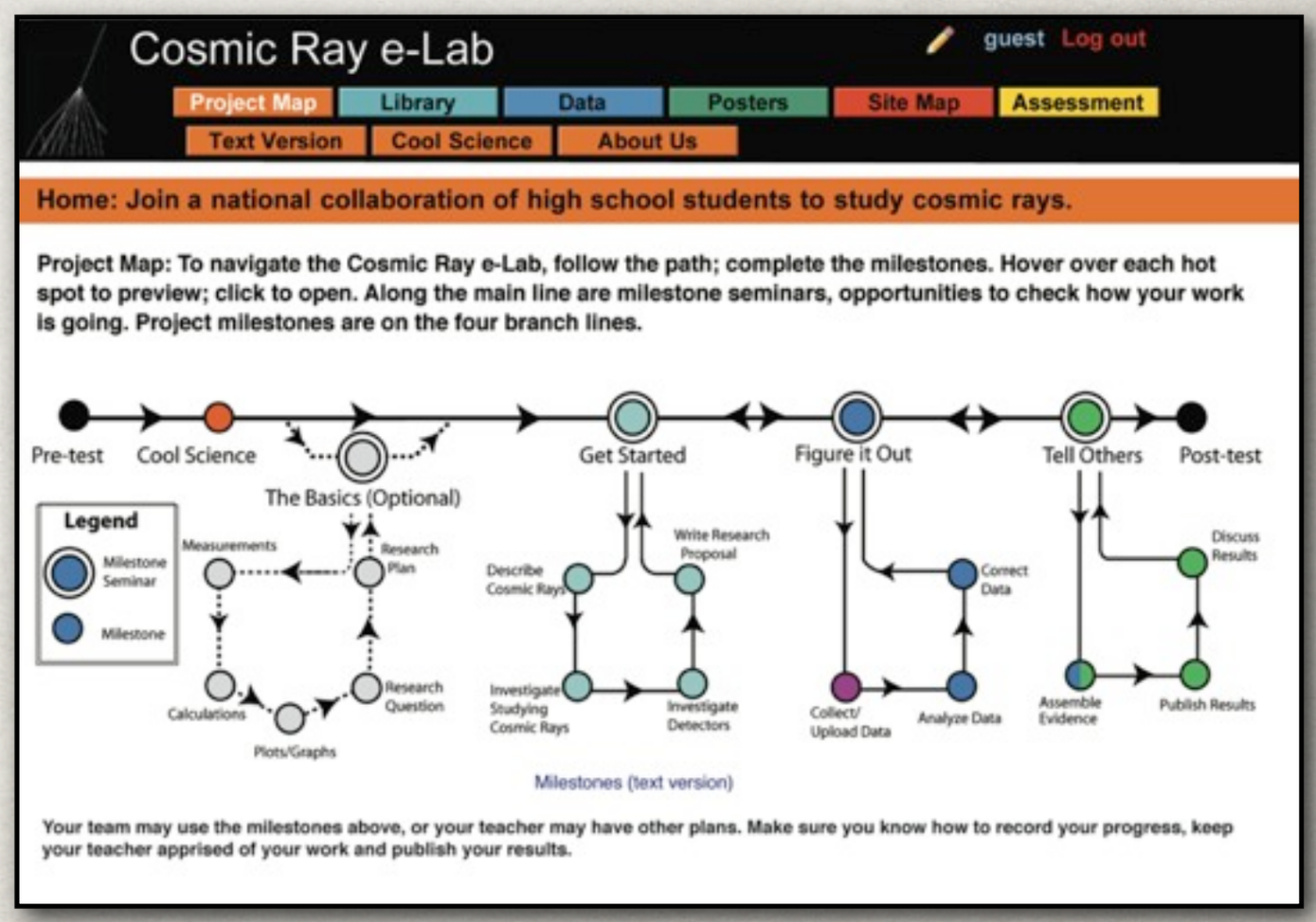
e-Lab: an Electronic Laboratory

- 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

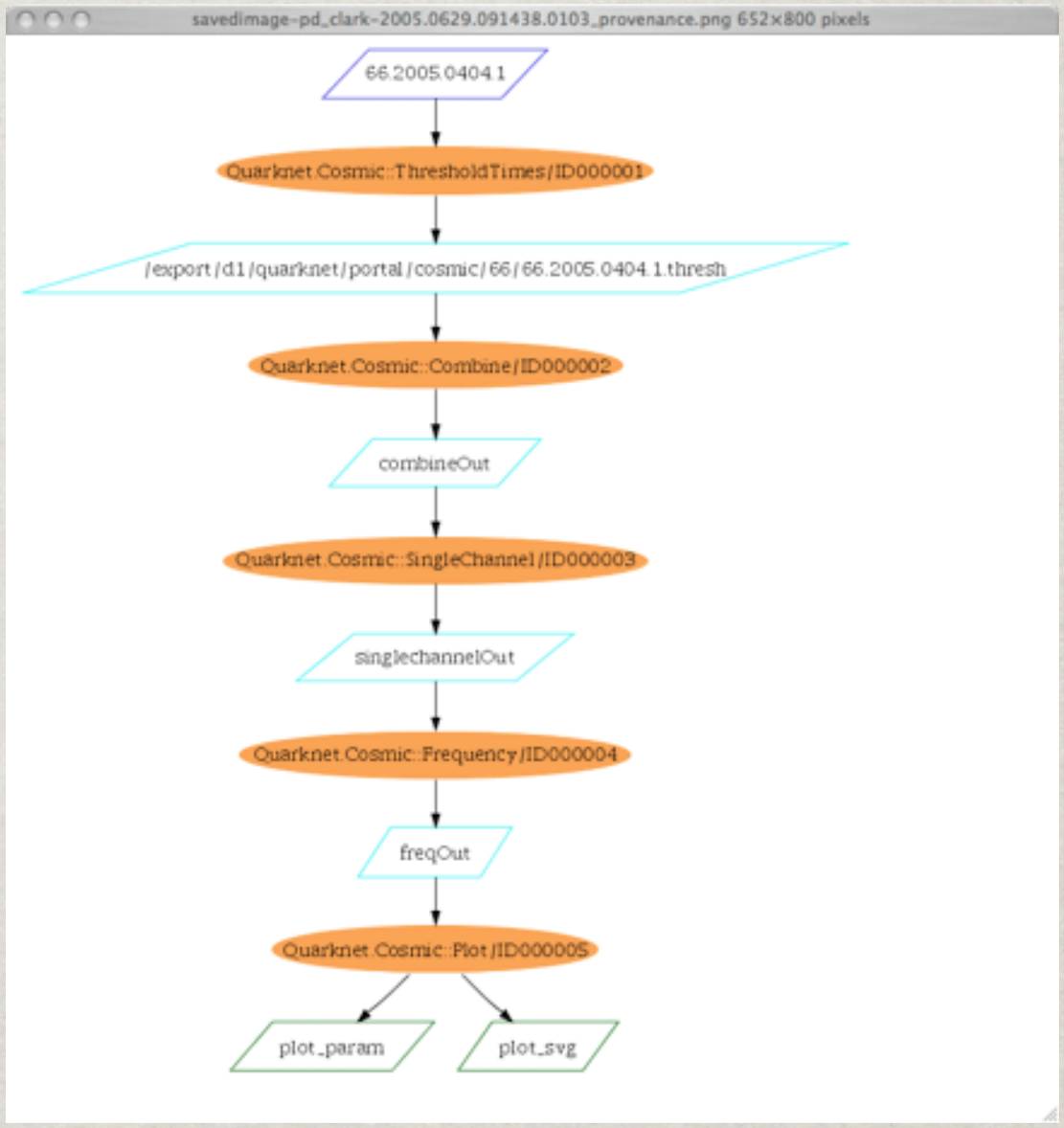
- Users can:
  - Search data
  - Select files
  - Set analysis parameters
  - Interpret results
  - Save plots



e-Lab: an Electronic Laboratory

Workflows include:

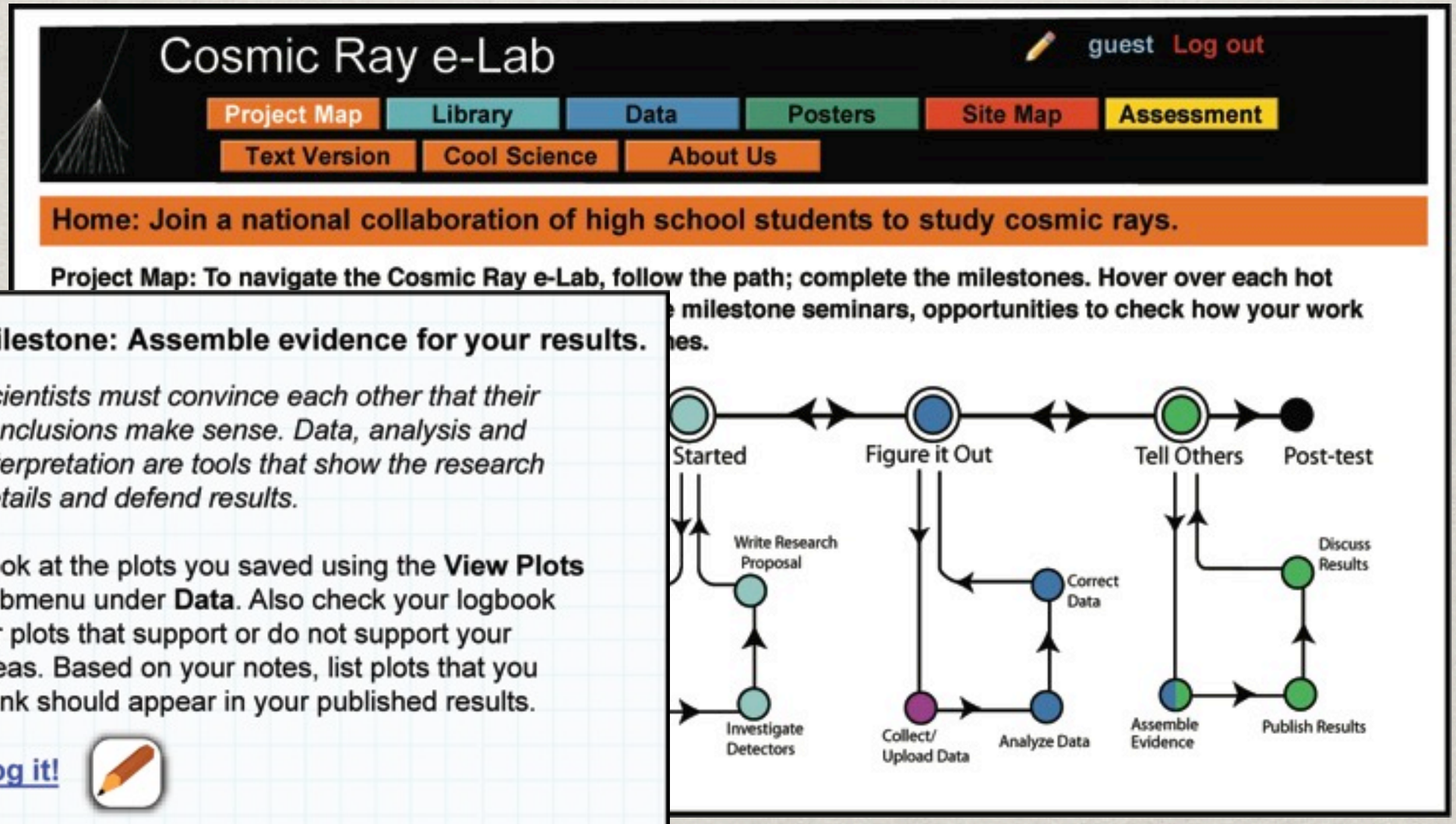
- Performance
- Flux
- Shower
- Lifetime



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

- 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

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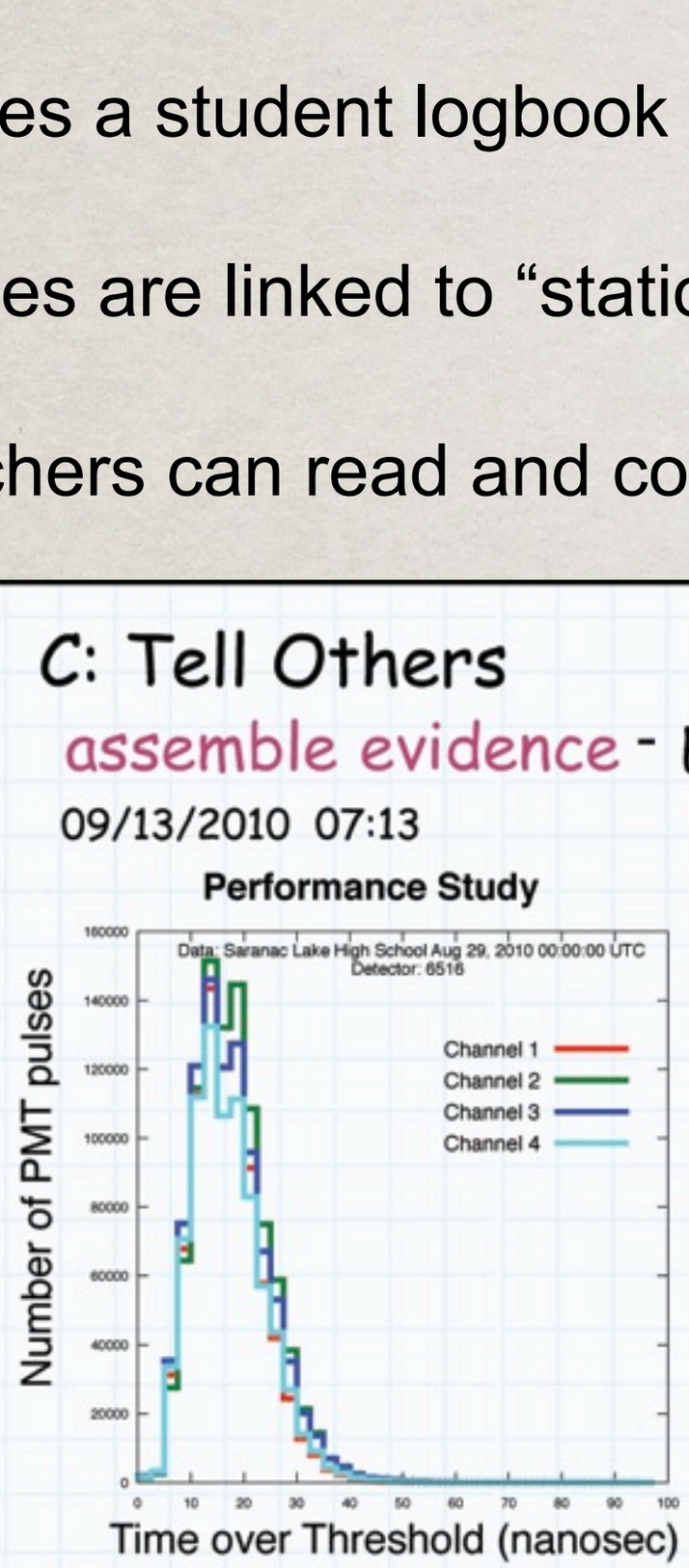
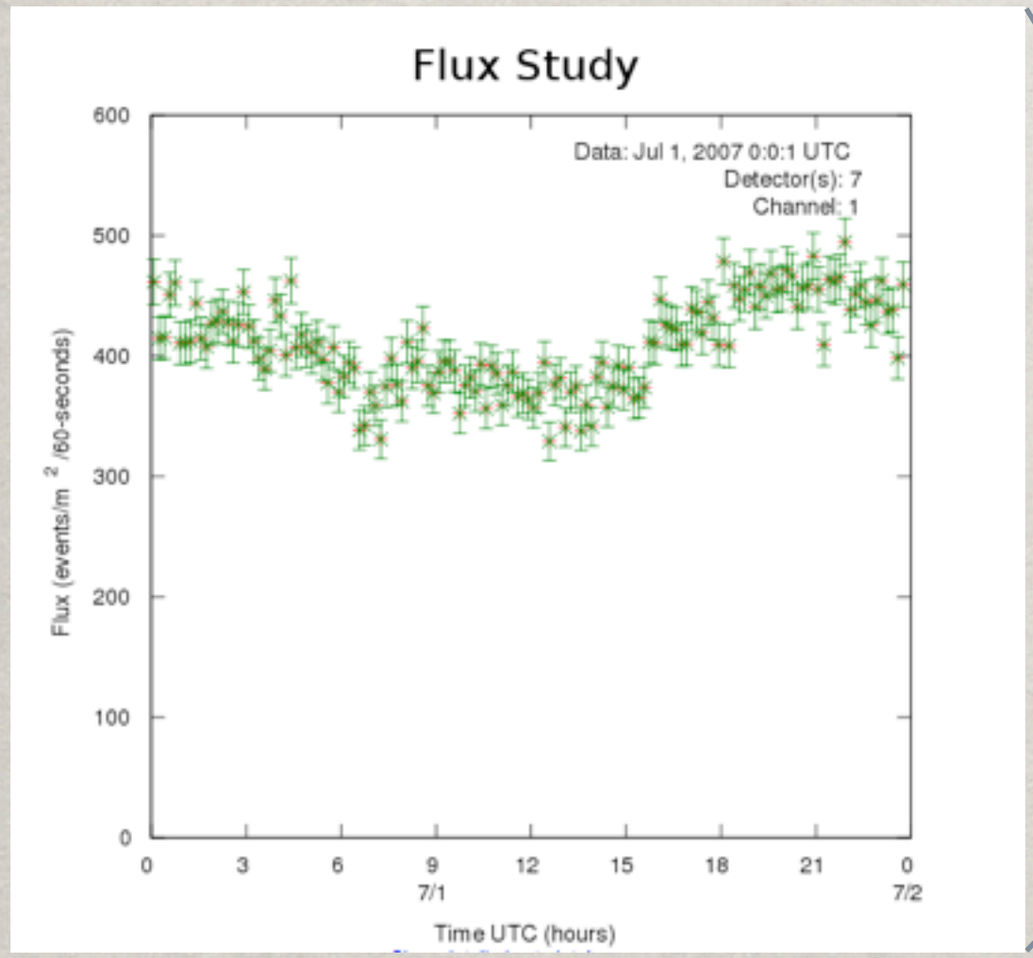
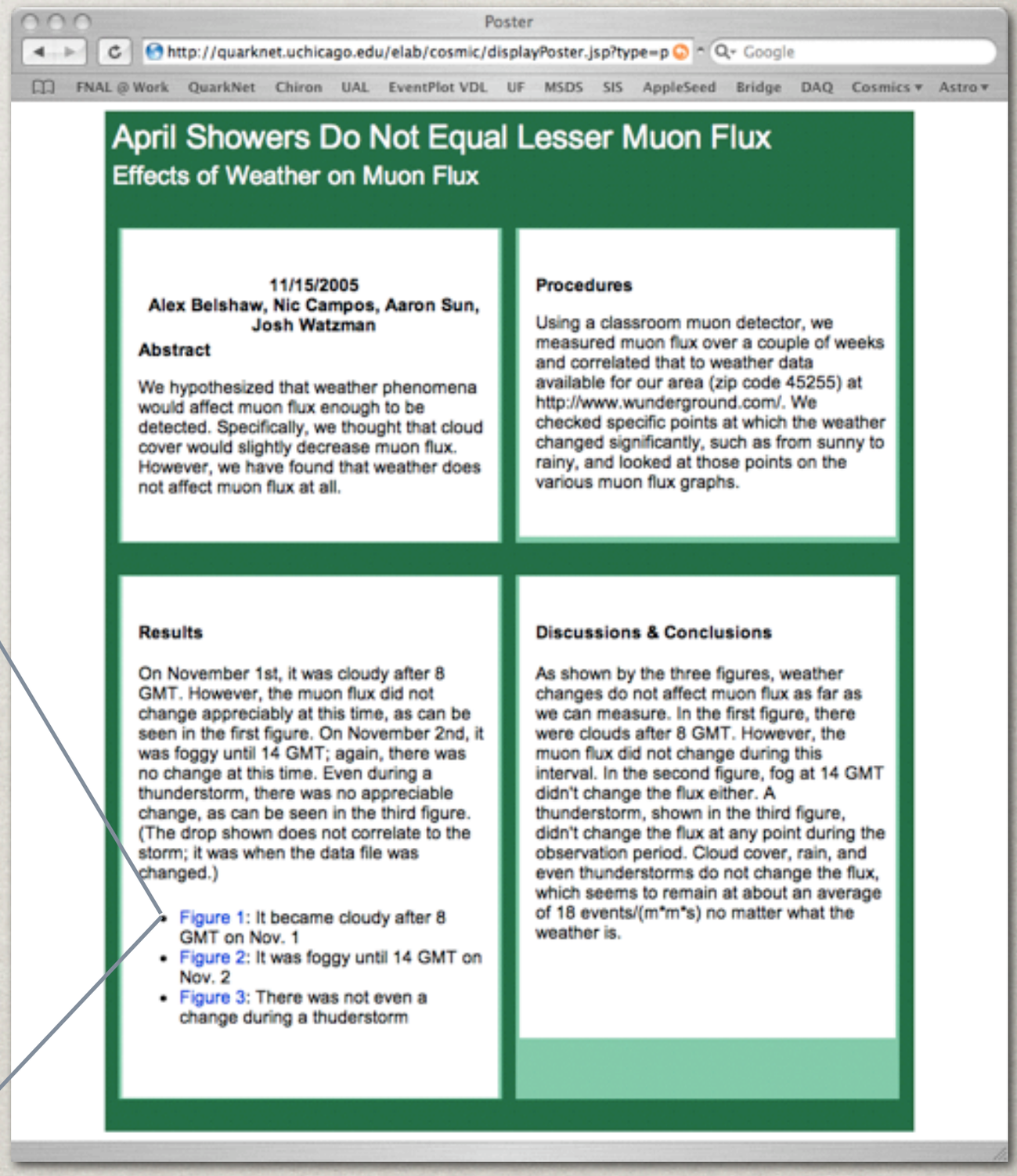


In order to be meaningful, data from each channel of a cosmic ray detector must be matched, so they are all counting comparable numbers of events. The process of matching the channels is called plateauing. To do it, the voltage that each plate is running on is adjusted and measured against one of the 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.





e-Lab: an Electronic Laboratory

- By the numbers
  - 1800 student research groups
  - 900 teacher accounts
  - 700 posters
  - 31,000 raw data files

Conclusions and Future Work

- Our students *explore* high-energy cosmic rays.
- Our teachers use e-Lab scaffolding to *guide* our students.
- They can study performance, lifetime, flux, shower.
- We can build new analysis workflows.
- We are seeking collaborators and partners.

http://www.i2u2.org/elab/cosmic