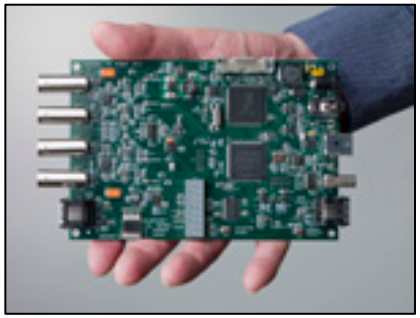
QuarkNet

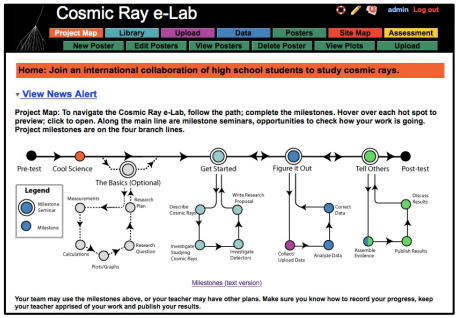
Cosmic Ray Studies I

QuarkNet Student Investigations



DAQ

Detector



e-Lab

Marge Bardeen
Fermilab

Helping Develop America's Technological Workforce

What is QuarkNet?

QuarkNet (quarknet.i2u2.org)

A long-term national professional development program for U.S. high school physics teachers supported by the particle physics research community

50+ centers at universities and labs across the U.S.
82 physicists as volunteer mentors
563 active teachers & their students

+ International outreach

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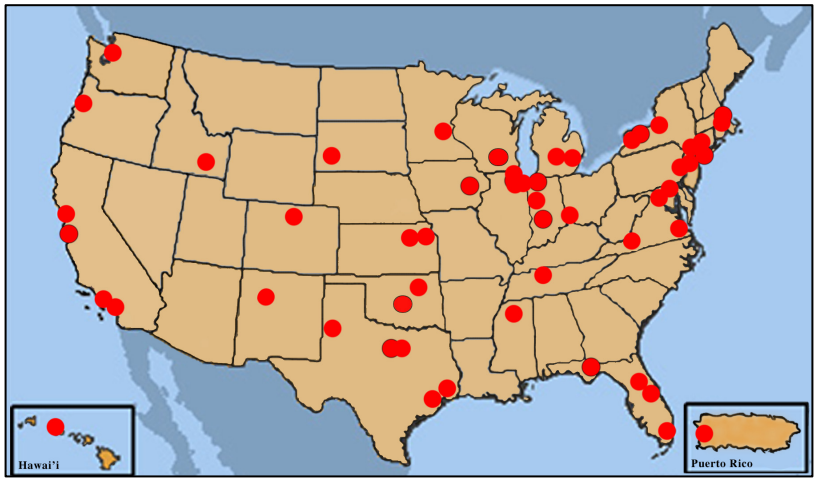
QuarkNet

What is QuarkNet?



50+ centers at universities and labs across the U.S.

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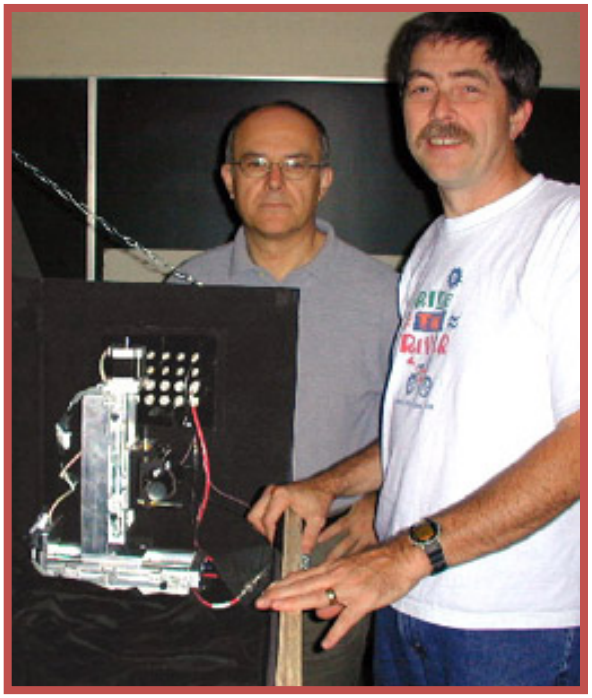
QuarkNet

QuarkNet Program

Engagement with Scientific Investigations

- Building long-term relationships
- *Research internships*
- *Research-based workshops*
- Masterclasses
- *Cosmic Ray Studies*
- Instructional materials
- Access to authentic online datasets
- Ongoing support



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Research Opportunities

Experiencing the Environment of Scientific Collaboration

- **Joining research teams**
- **Making real contributions to experiments**
- **Learning how scientists make discoveries**

Who:	Teachers	Students
How Long:	8 weeks	6 weeks, typically
When:	Year 1 - 2 teachers/center	
	Years 3+ 1 teacher with	4-student team
	(up to 25 teams per year)	

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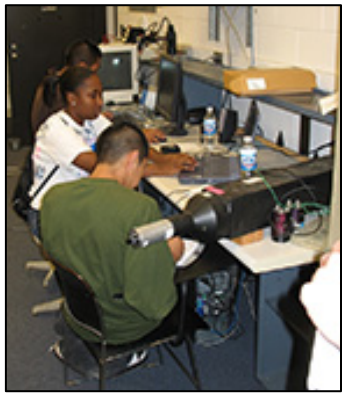
Research Opportunities

Attending Research Scenario Workshops

- **Jumping in to learn by doing science**

	Teachers	Students
Who:		
How Long:	2–3 weeks	1 week, typically
When:	Year 2 - ~8 teachers/center	Year 3+

Future detector experts



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Cosmic Ray Studies

Education Program

High school students develop their own research questions, conduct investigations, analyze data & reports results.

Materials Include:

- **Hardware – portable & configurable**
- **Data Analysis Tools – online, browser-based**
- **Cosmic Ray e-Lab – instructional tool for teachers**
- **Professional Development – workshops & help desk**

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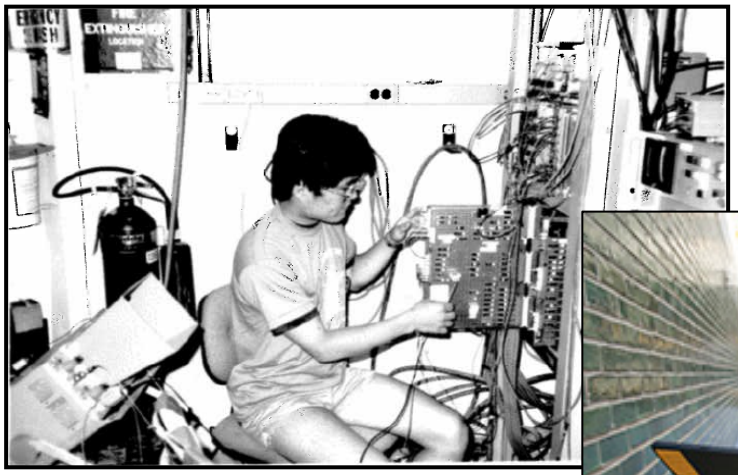
Hardware

Something Old: Something New

1988



1999

Detector Kit

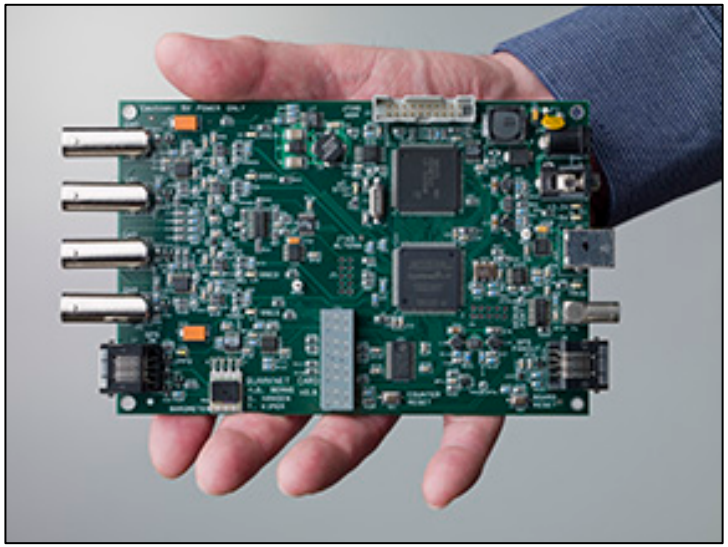
4 counters w/PMTs
Power box (low voltage)
DAQ (developed by FNAL)
GPS w/antenna
Temperature & pressure sensors
Cables
(Raspberry Pi w/EQUIP)

DAQ creates formatted message sent to a computer & collected in text data file through USB interface. EQUIP computer commands set parameters for each investigation, monitor data stream & display parameter settings & other info.

QuarkNet

Hardware

Detector Kit



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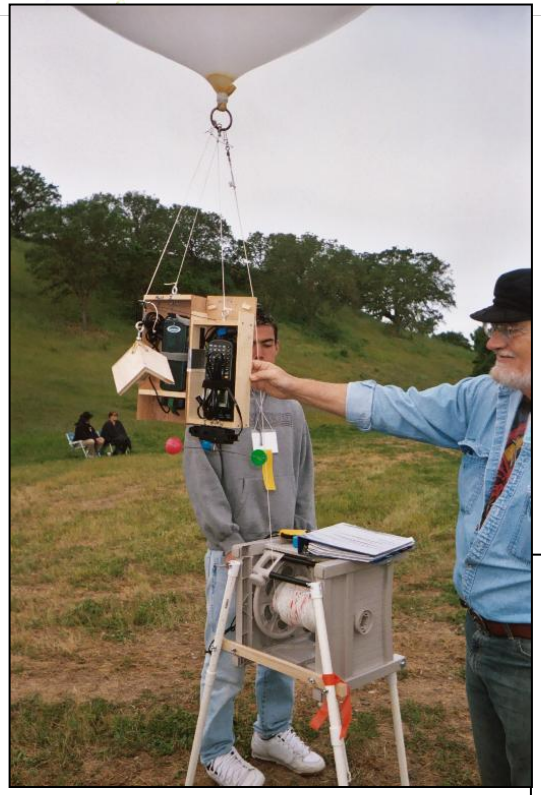
Where are the 840 DAQs?



- 260 detectors deployed in QuarkNet
- 450 in 32 countries:
  - Education - 294
  - Science
  - Museums - 13
- 130 in inventory

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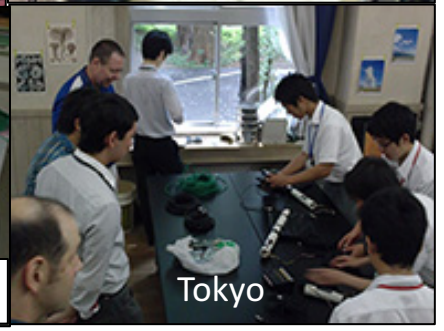
Users World-Wide



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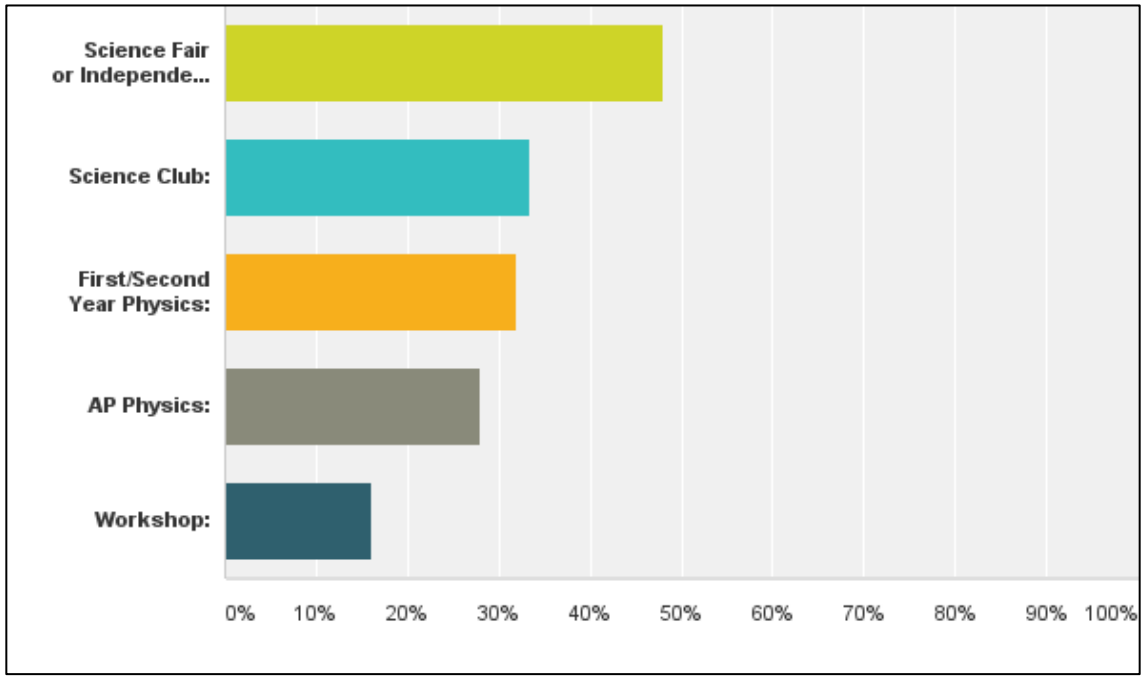
Usage in QuarkNet

Which students used the detectors.



47% of the students uploaded data.
25% used data from other schools.

QuarkNet

Cosmic Ray e-Lab

e-Lab

Enables:

- Guided inquiry
- Data sharing
- Flux, shower, lifetime, time-of-flight studies
- Sharing with posters
- Global collaboration

Students draw conclusions supported by evidence and provide reasoning.

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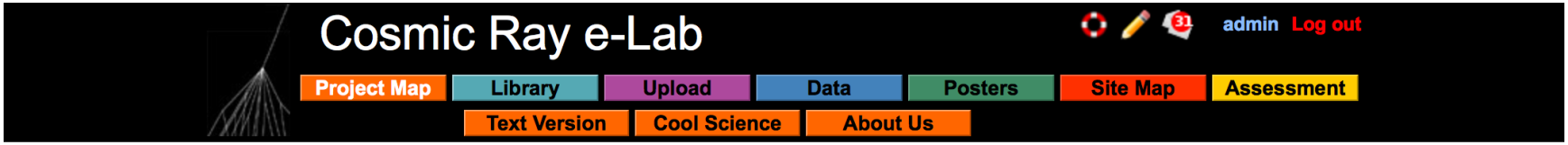
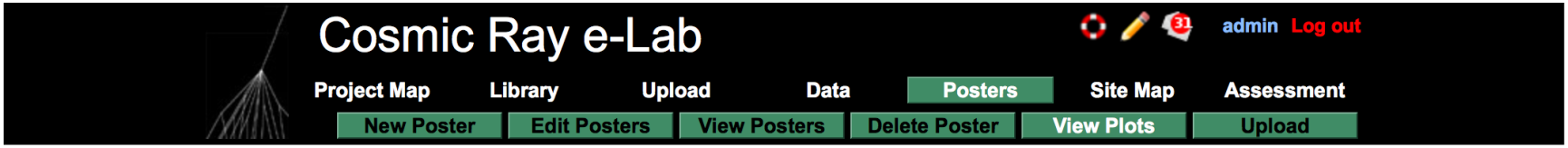
QuarkNet

Cosmic Ray e-Lab





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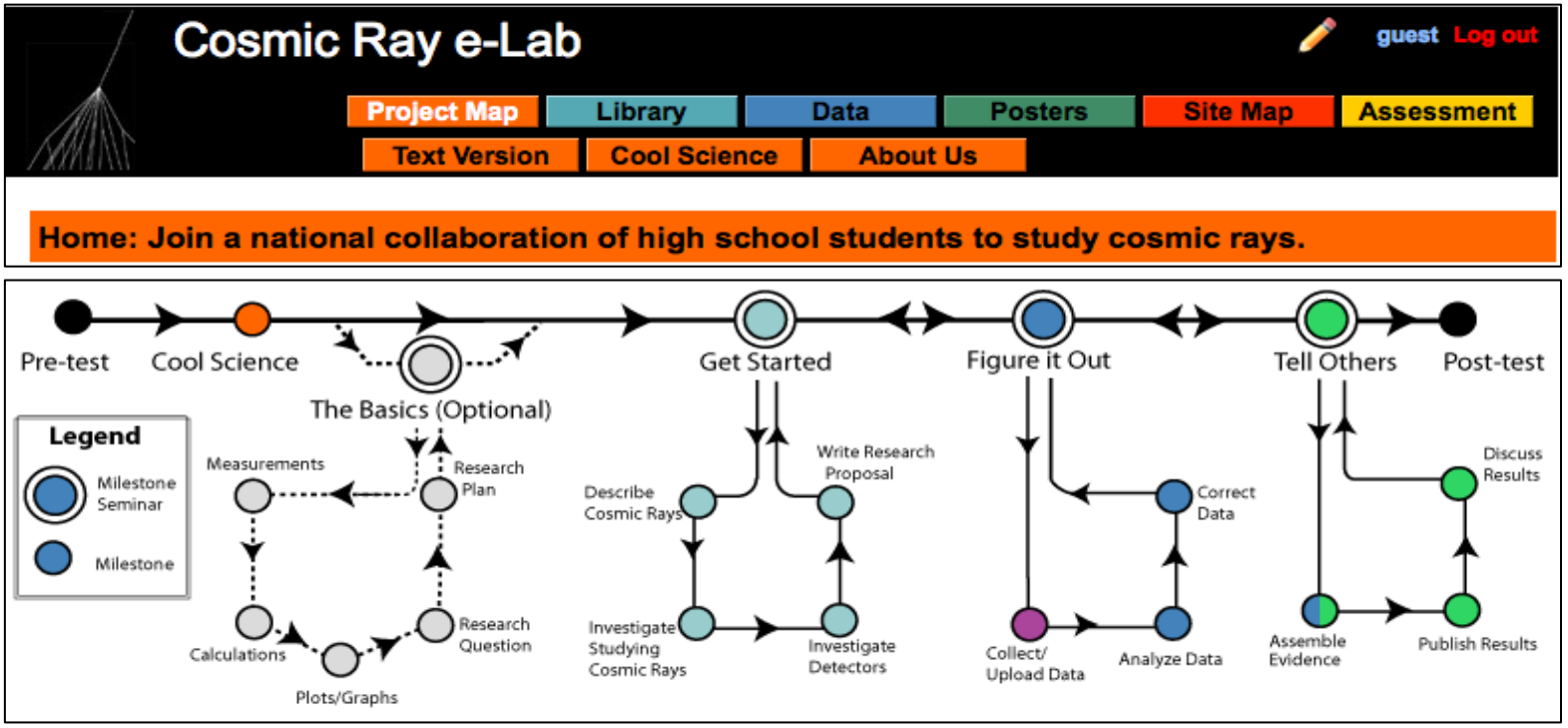
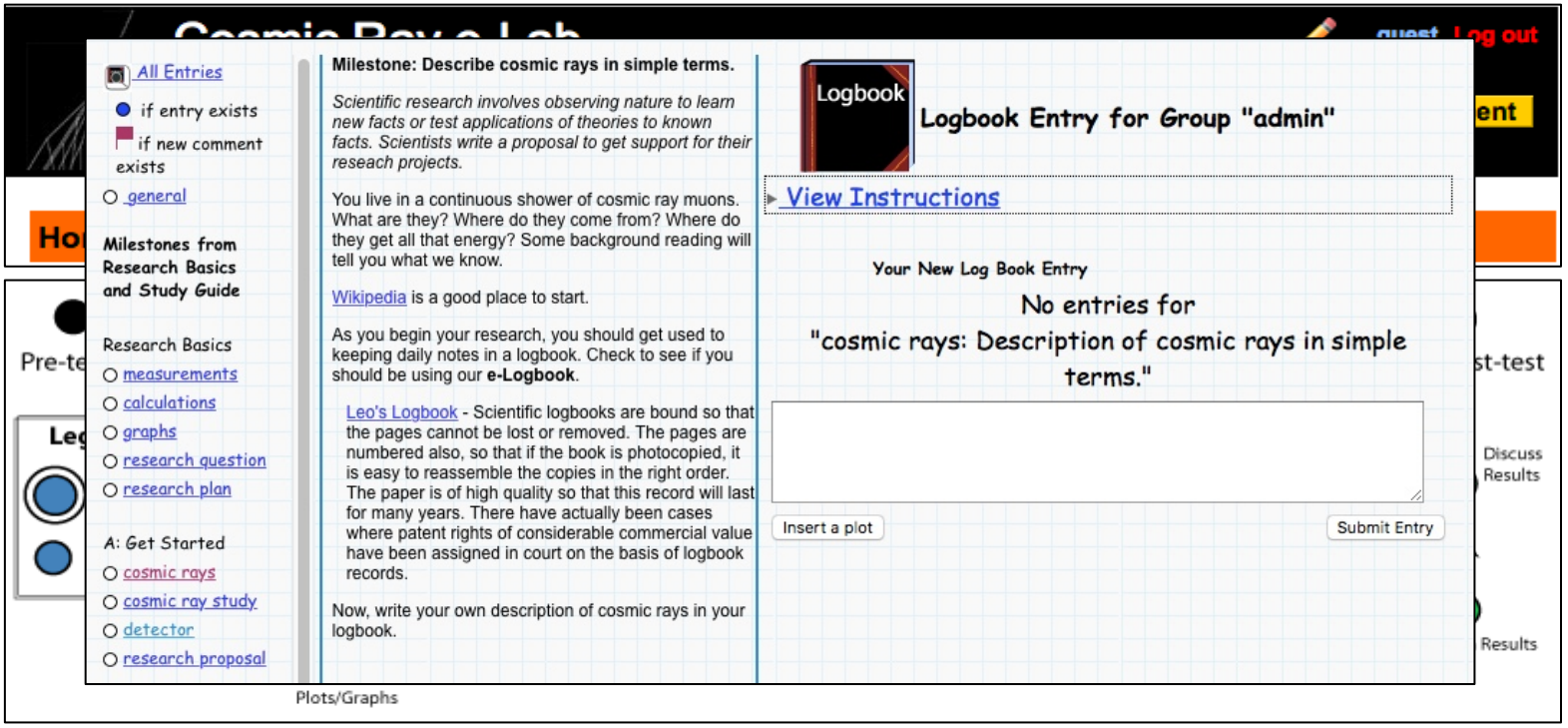
Guided Inquiry



We jumped in deep with this *exploration* of the data.

QuarkNet

Guided Inquiry



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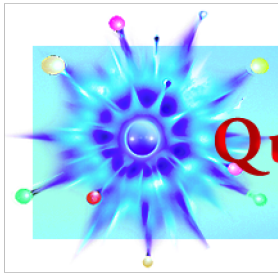

Professional Development

3-Day Workshop: CR 101

Student Hat

- Assemble detector.
- Take data overnight.
- Use analysis tools.
  - Upload data.
  - Analyze data.
  - Create plot.
  - Create poster.
- Conduct mini-project.

Teacher Hat

- Reflect each day.
- Present results.
- Develop classroom plan.
- Share plan.

We also offer CR 102.

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Professional Development

To be successful teachers need to be:

- Confident - to use the detector and analysis tools.
- Comfortable - to step back.
- Clever - to convince administrators.

Our *Data Portfolio* offers a broad approach.

A range of student engagement:

Introduction – Survey – Investigation – *Exploration*

e-Lab

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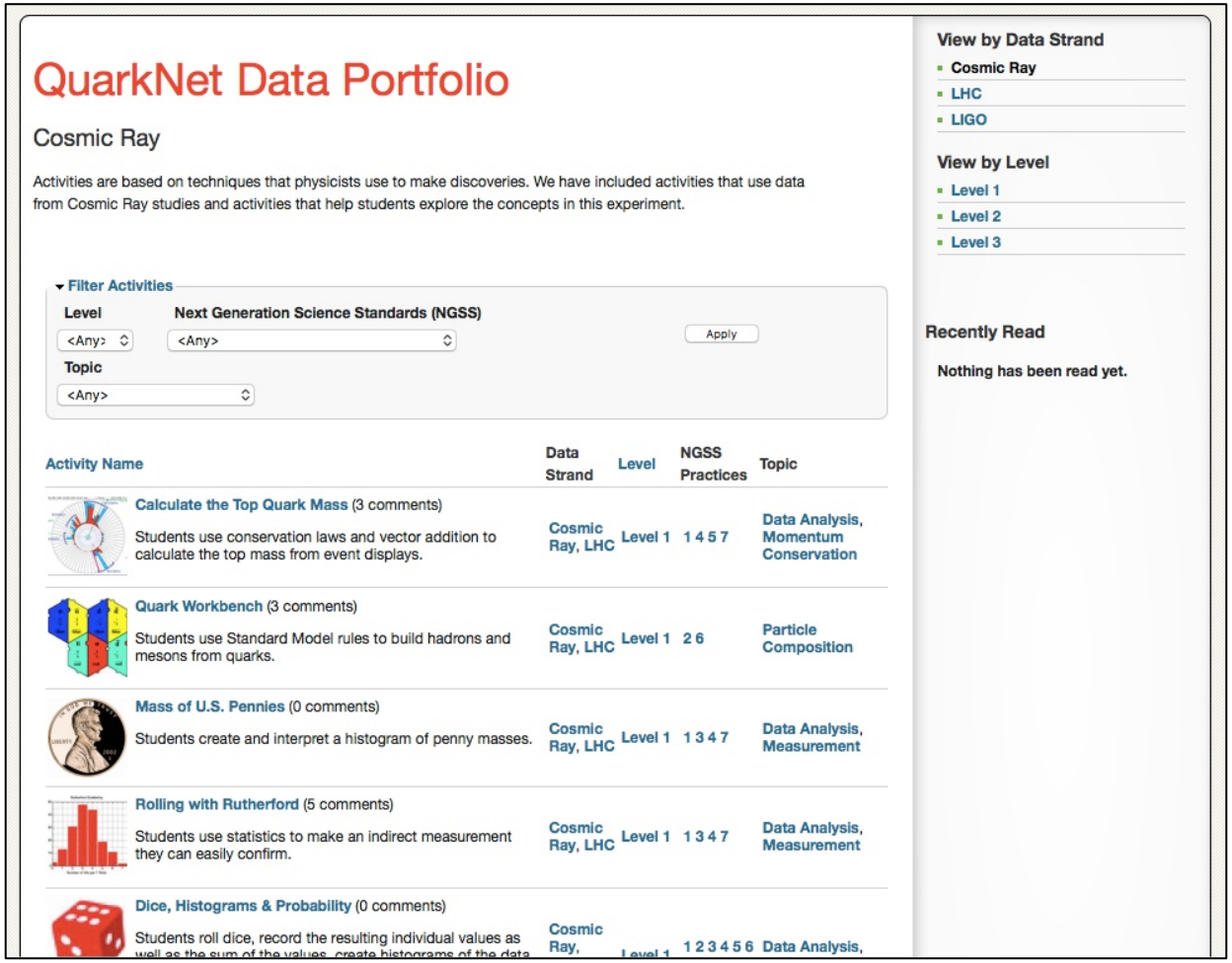
Data Portfolio



QuarkNet Data Portfolio

Cosmic Ray

Activities are based on techniques that physicists use to make discoveries. We have included activities that use data from Cosmic Ray studies and activities that help students explore the concepts in this experiment.

Filter Activities

Level: <Any>

Next Generation Science Standards (NGSS): <Any>

Topic: <Any>

Apply

View by Data Strand
- Cosmic Ray
- LHC
- LIGO

View by Level
- Level 1
- Level 2
- Level 3

Recently Read

Nothing has been read yet.

Activity Name	Data Strand	Level	NGSS Practices	Topic
Calculate the Top Quark Mass (3 comments) — Students use conservation laws and vector addition to calculate the top mass from event displays.	Cosmic Ray, LHC	Level 1	1 4 5 7	Data Analysis, Momentum Conservation
Quark Workbench (3 comments) — Students use Standard Model rules to build hadrons and mesons from quarks.	Cosmic Ray, LHC	Level 1	2 6	Particle Composition
Mass of U.S. Pennies (0 comments) — Students create and interpret a histogram of penny masses.	Cosmic Ray, LHC	Level 1	1 3 4 7	Data Analysis, Measurement
Rolling with Rutherford (5 comments) — Students use statistics to make an indirect measurement they can easily confirm.	Cosmic Ray, LHC	Level 1	1 3 4 7	Data Analysis, Measurement
Dice, Histograms & Probability (0 comments) — Students roll dice, record the resulting individual values as well as the sum of the values, create histograms of the data	Cosmic Ray,	Level 1	1 2 3 4 5 6	Data Analysis,

M. Bardeen, Cosmic Ray Meeting, February 2017

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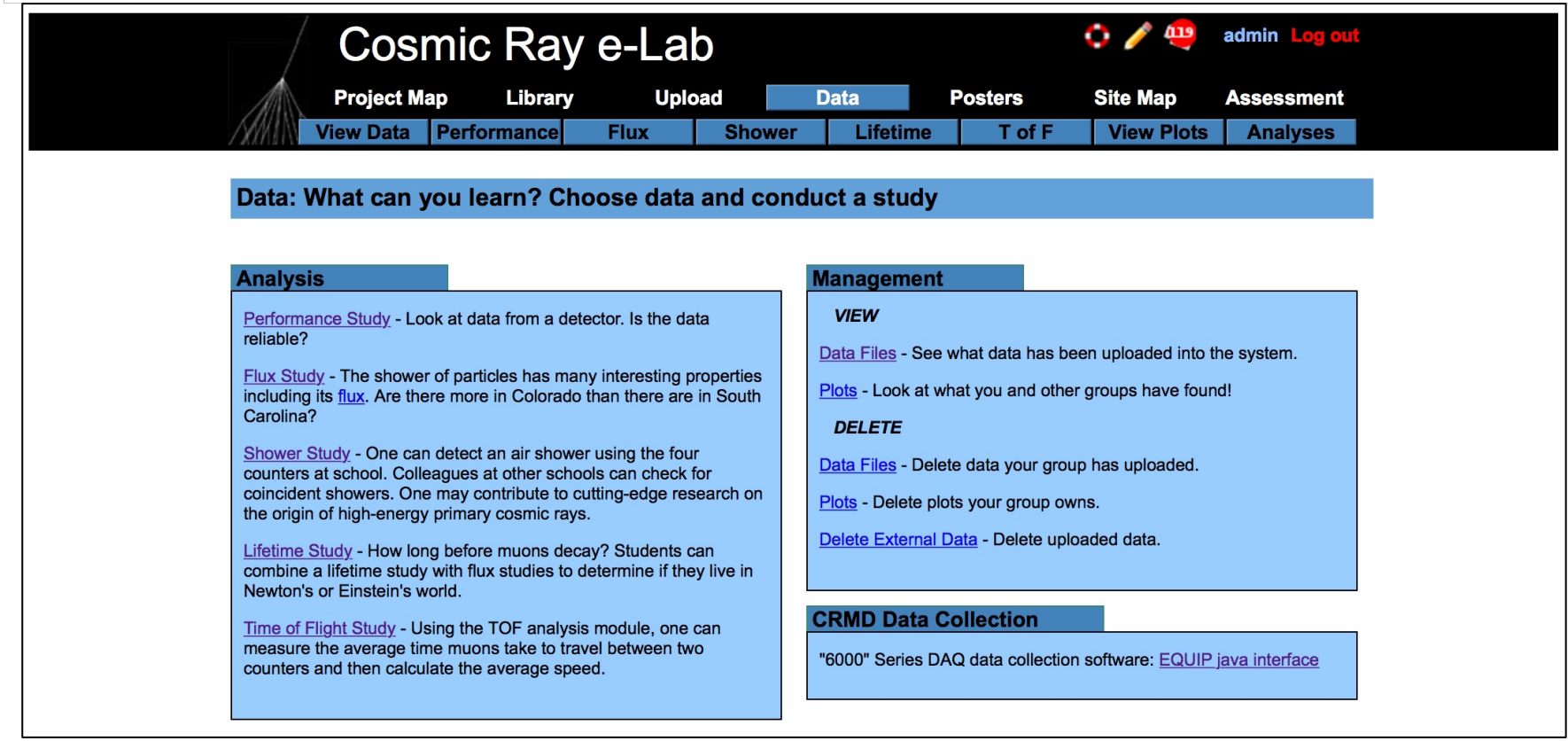
e-Lab Data Interface



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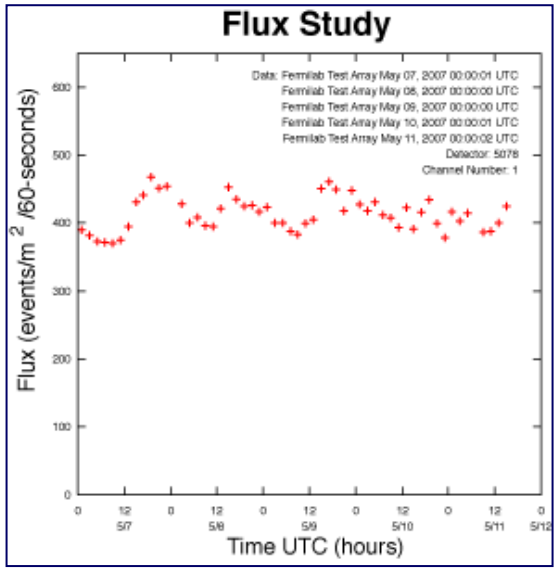
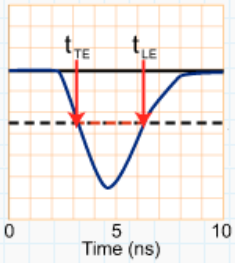
Data Stats

- 81,000 e-Lab data files
- 20,000 plots
- 1,700 posters
- World-wide data: 21 countries & the Antarctic



Columns

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
80EE0049	80	01	00	01	38	01	3C	01	7EB7491F	202133.242	080803	A	04	2	-0390
80EE004A	24	3D	25	01	00	01	00	01	7EB7491F	202133.242	080803	A	04	2	-0389
80EE004B	21	01	00	23	00	01	00	01	7EB7491F	202133.424	080803	A	04	2	-0289
80EE004C	01	2A	00	01	00	01	00	01	7EB7491F	202133.242	080803	A	04	2	-0389
80EE004D	00	01	00	01	00	39	32	2F	81331170	202133.242	080803	A	04	2	+0610



The hardware measures times very, very well. It detects when the photomultip (PMT) signal starts and ends. We can use that to calculate signal width.

The first 10 columns represent "clock ticks." Ticks in columns 1 & 10 are 24 nanoseconds; ticks in 2-9 are 3/4 nanoseconds.

The last 6 columns provide other information. Many columns are hexadecima numbers.

Column 1 indicates the tick during which everything in columns 2-9 happened.

Columns 2-9 indicate pulse start (even columns) and end (odd columns) times for channels 1-4.

Column 10 is the tick that corresponds to the Global Positioning System (GPS) time in column 11.

Column 11 is the Coordinated Universal Time (UTC) of the last GPS update.

Column 12 is the date of the last GPS update.

Column 13 shows the validity of the last GPS update.

Column 14 shows the number of GPS satellites in view.

Columns 15 and 16 show data status (15) and time offset information (16).

QuarkNet

Cosmics Team @ FNAL

Over to Mark

Dave Hoppert
All Things Detector

Mark Adams
Cosmics Leader

Sudha Balakrishnan
IT Specialist