



Opportunities to Learn Scientific Literacy (What QuarkNet Data Show)

Marge Bardeen
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QuarkNet, a Partnership!

Creates a long-term “research community”

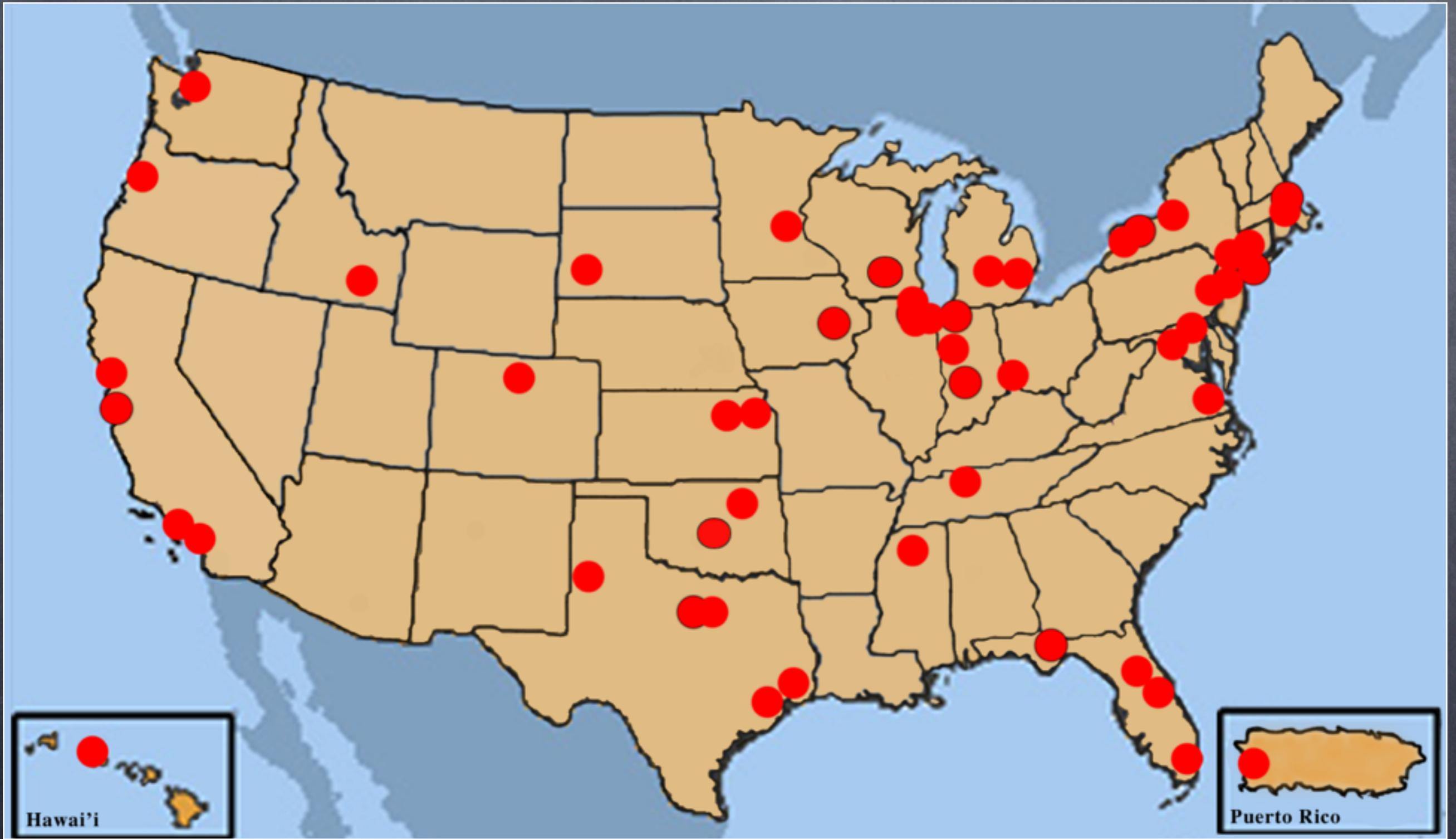
Develops links between experiments & classrooms

Engages students in scientific investigations

Develops scientific literacy



QuarkNet



quarknet.fnal.gov

QuarkNet

Program Design Models Research Experiments

Distributed effort with central management

Each center strategy matches local needs & resources.

The whole $>$ Σ (parts).

Communicate findings across centers.

- - -

Physicists are mentors & colleagues.

Teachers are researchers & facilitators in classrooms.

Students are researchers.

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Scientific discovery is a journey, not an event!



1. What we know
2. Questions we ask
3. Tools we build and use
4. How we know
5. What we learn

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1. What we know
2. Questions we ask
3. Tools we build and use
4. How we know
5. What we learn

Activities from QuarkNet

For High School Students*

Data in Masterclasses

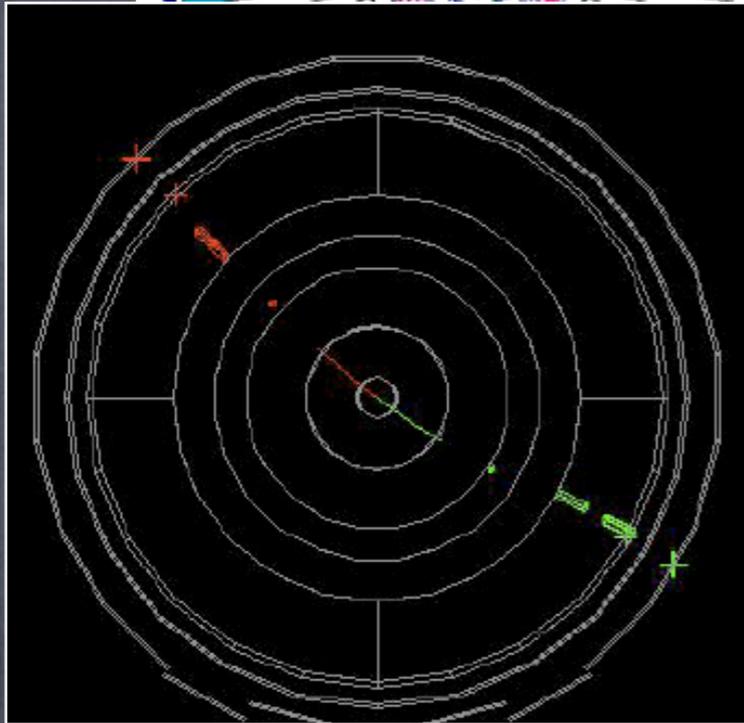
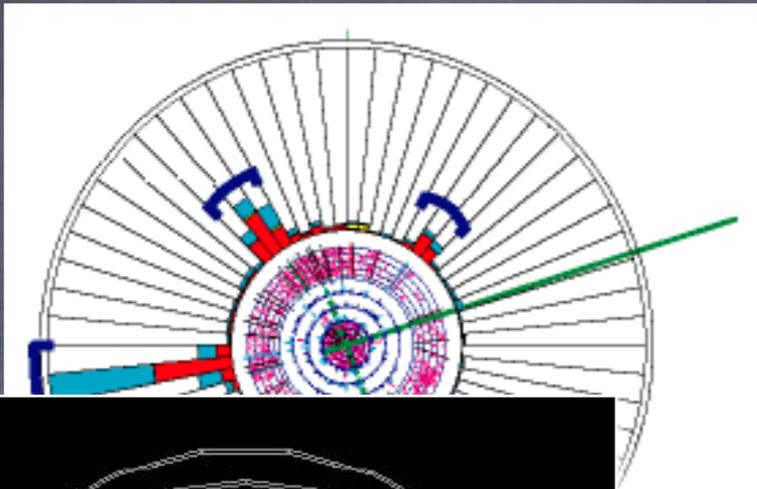
Data in Investigations

Research Experiences

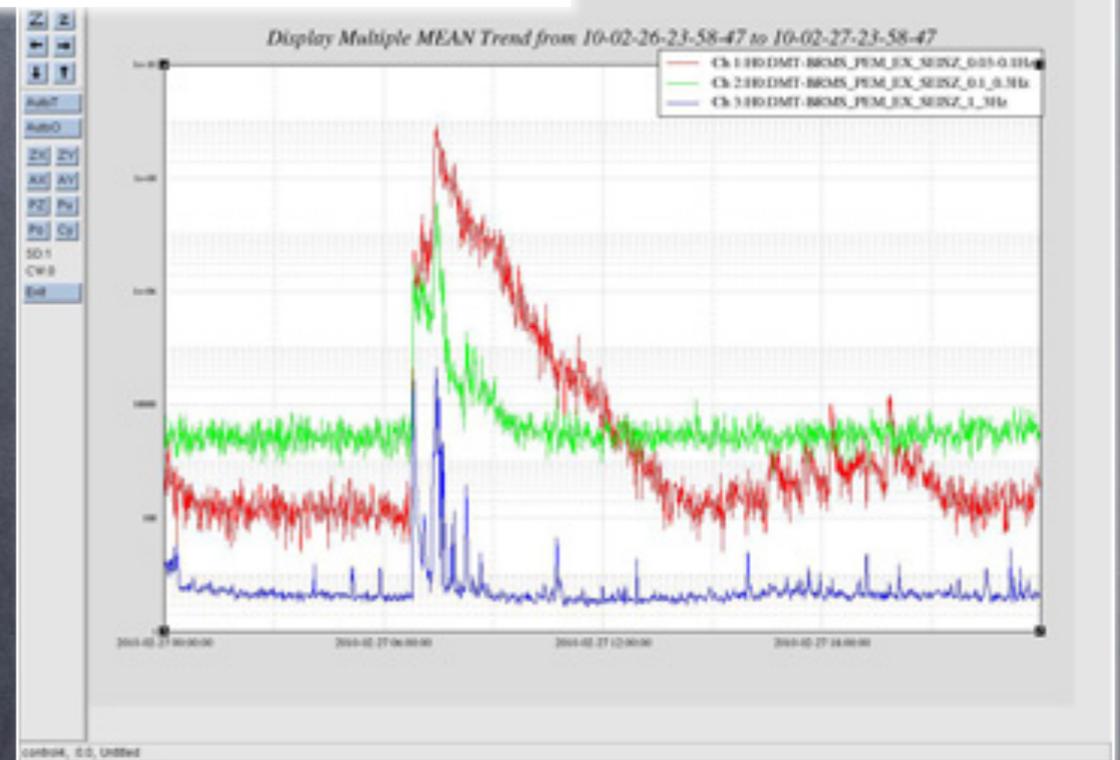
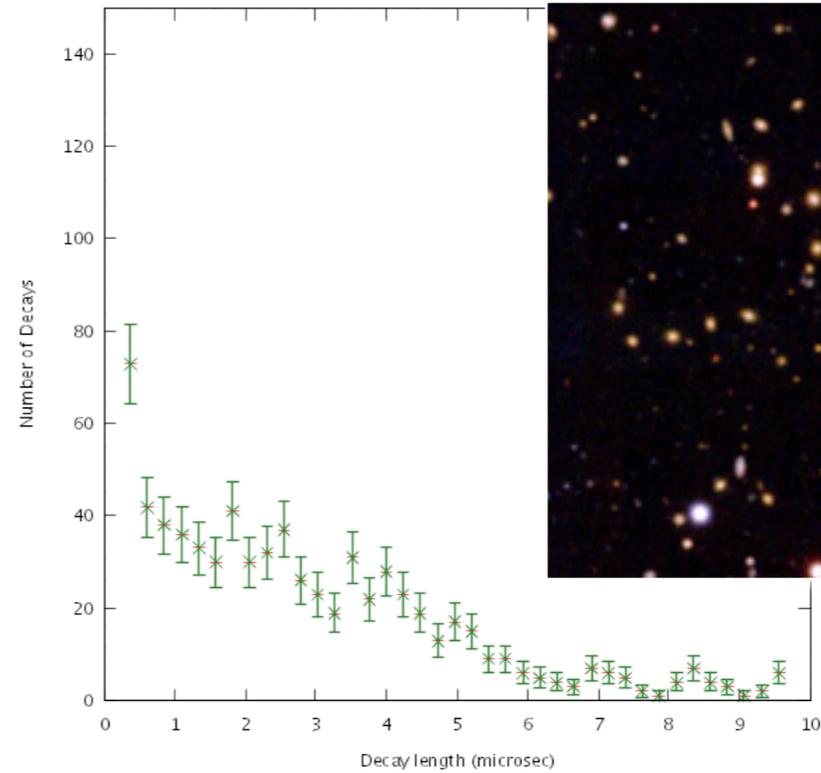


*These kids are already interested in science.

Engaging Students in Science

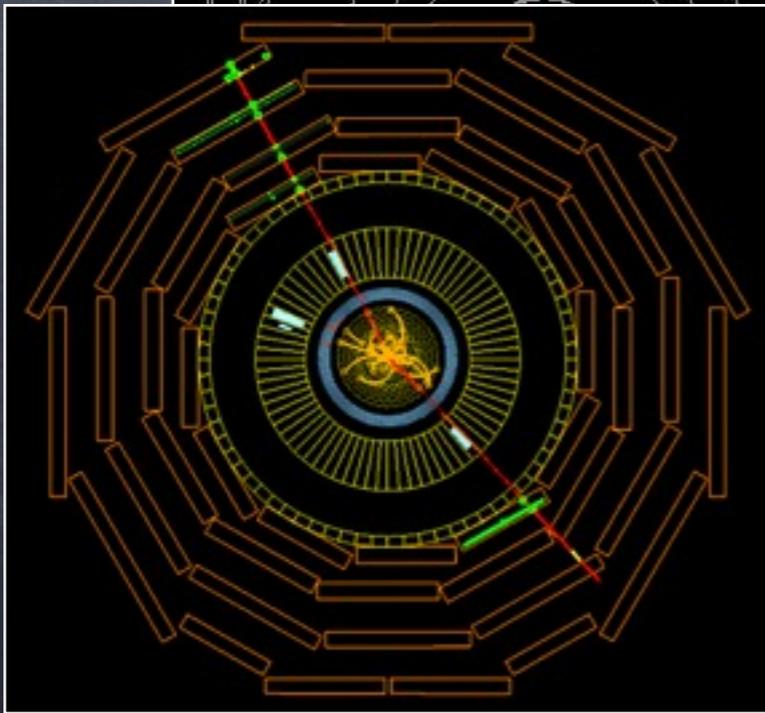
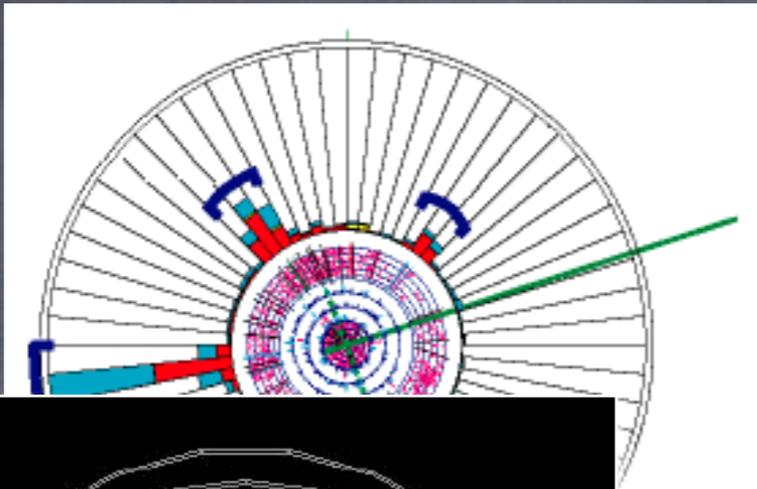


Lifetime Study

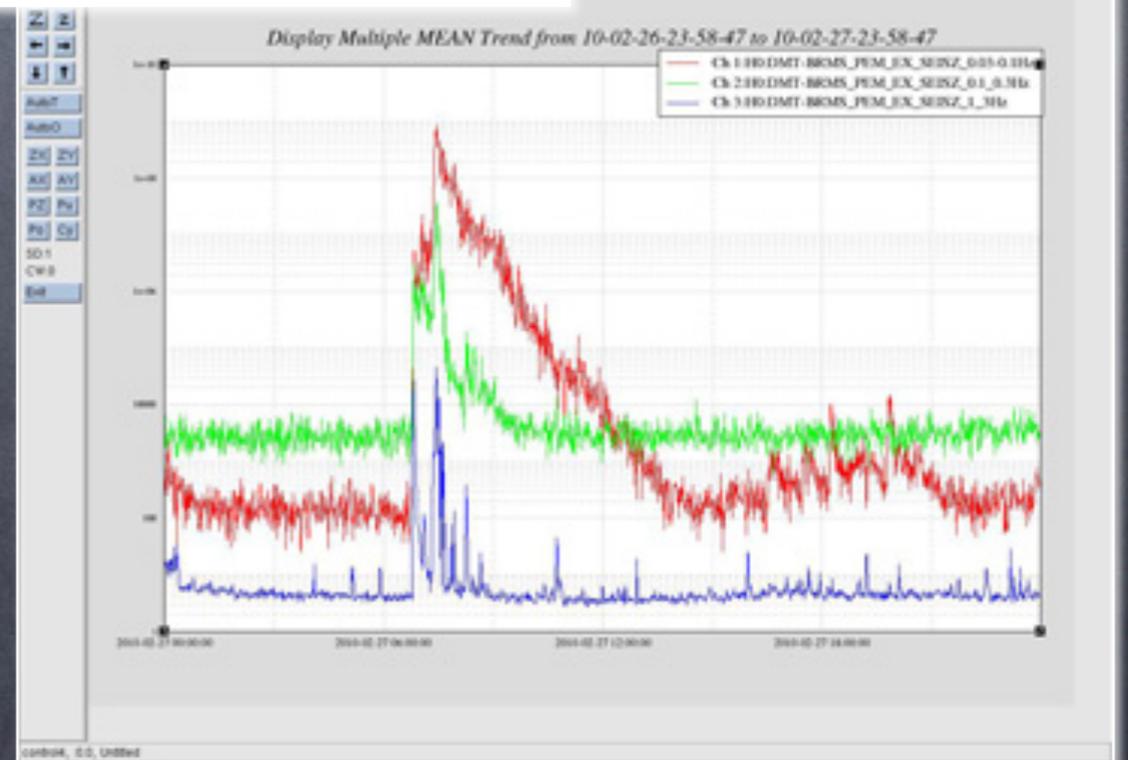
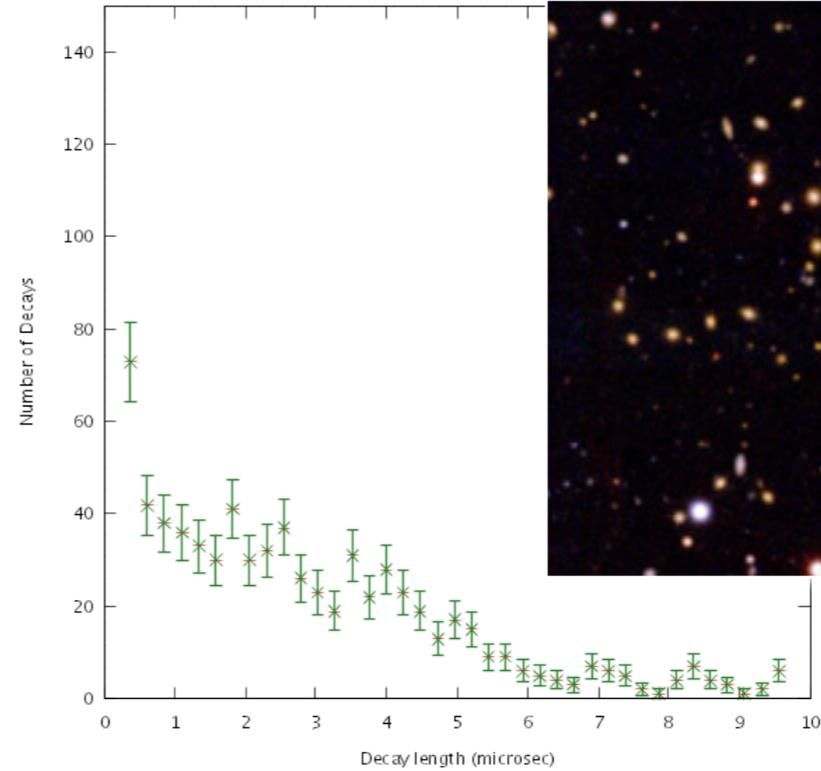


Data for Students

Engaging Students in Science

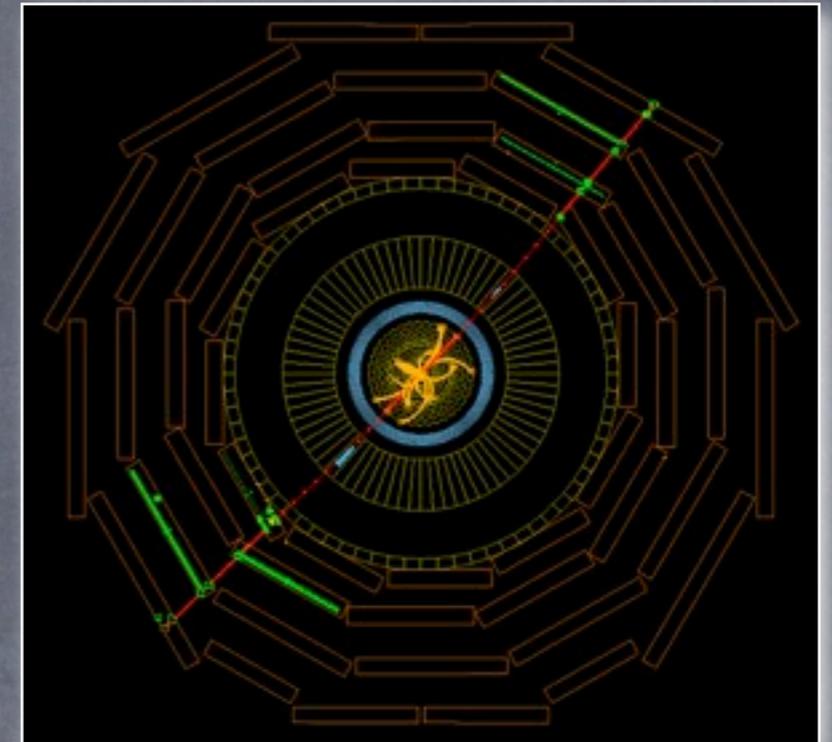


Lifetime Study



Data for Students

Hands-on analysis with real data and you.



U.S. Masterclass

Town (COUNTRY)	DELPHI	OPAL	Electrons	Muons	Taus	Quarks	enable institutes	OPAL institutes
Coimbra (PT)	0						0	0
Crete (GR)	0	162	116	178	2234		1	0
Lisboa LIP (PT)	0						0	0
Trencin (SK)	0	66	62	93	779		1	0
Baltimore (US)	1	28	43	35	897		1	1
Witwatersrand (SA)	1	148	131	94	424		1	1
xx(YY)	0						0	0
xx(YY)	0						0	0
xx(YY)	0						0	0
Sum (corr)			#VALUE!	#VALUE!	#VALUE!	#VALUE!	all	4
Stat. Uncertainty			#####	#####	#####	#####	#####	#####



Tips for Effective Masterclasses

- Correlate data to something real.
- Bring students into your environment.
 - Tour, visit research areas.
- Talk about your experiences, personalize.
- Give interactive presentations at students' level.
 - Focused, short, engaging
- Share useful examples & show relationships to everyday life.
- Answer questions . . . at their level.
- Some preparation at school helps.

Guided Student Investigation

CMS e-Lab

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 CMS data.

Project Map: To navigate the CMS 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. [Getting Around the e-Lab](#)

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.

LIGO e-Lab
Build Your Own Research Project Using Professional Science Data

Join a national collaboration of students to study LIGO seismic data.

Orbiting Black Holes Creating Gravitational Waves
Credit: Henze, NASA

LIGO seeks to detect gravitational waves from orbiting black holes, neutron stars and other sources. Scientists must distinguish gravitational waves from "noise" caused by seismic waves passing through the ground underneath LIGO's detectors.

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Online Investigations with I2U2

Cosmic Ray e-Lab

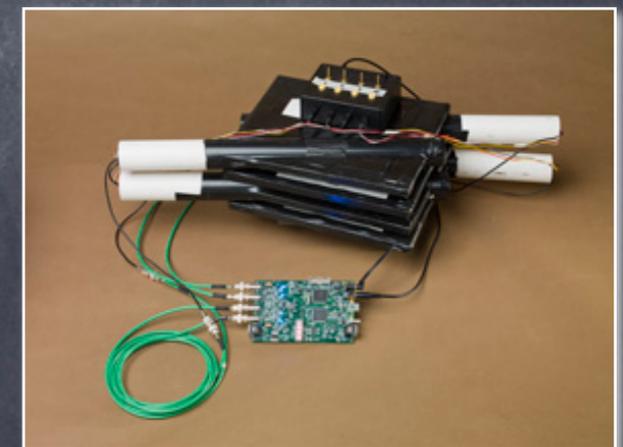
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Home Library Data Posters Site Map Assessment
Site Index Explore!

Explore! Click on hotspots in this site map.

You can always return to this page by clicking "Explore!" on the Site Index submenu.

Home Library Data Posters Assessment
Assessment



Guided Student Investigation

CMS e-Lab

Project Map Library Data Posters Site Map Assessment

Text Version Cool Science About Us

guest Log out

Home to investigate and collaboration of high school students to study CMS data.

Milestone: Select appropriate data from the data set.

Scientists need data to answer their research questions.

CMS data comes in runs of varying length and consists of events. Physicists filter the data so they can look at specific event types (e.g., events with two muons).

Your study question will guide the data you choose.

Click on "Calibration" under "Data" in the navigation bar to select simulated data.



Click on "Exploration" to select experimental data.

This [screencast demo](#) shows how to use the analysis tool.

Keep track of data appropriate for your inquiry in your logbook. Exploring the available data may lead you to refine or revise your study.

[Log It!](#) 

Complete the milestones. Hover over each hot spot to see one seminar, opportunities to check how you are doing. [Getting Around the e-Lab](#)

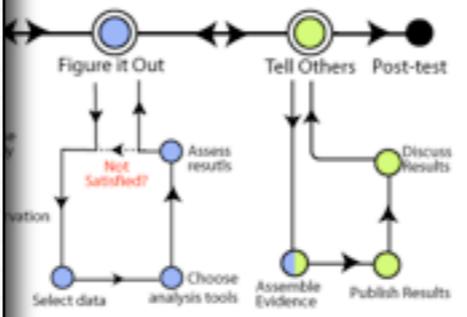


Figure it Out Tell Others Post-test

Select data analysis tools Assemble Evidence Publish Results

Assess results

Not Satisfied?

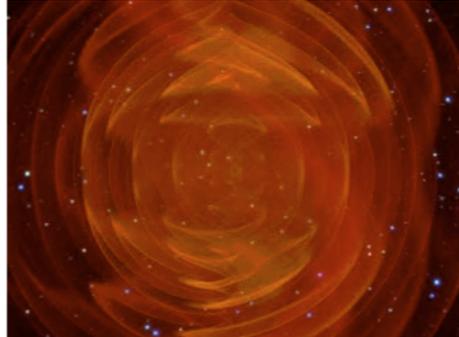
Discuss Results

plans. Make sure you know how to record your data.

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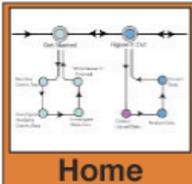
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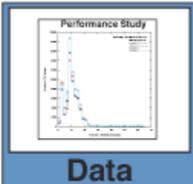
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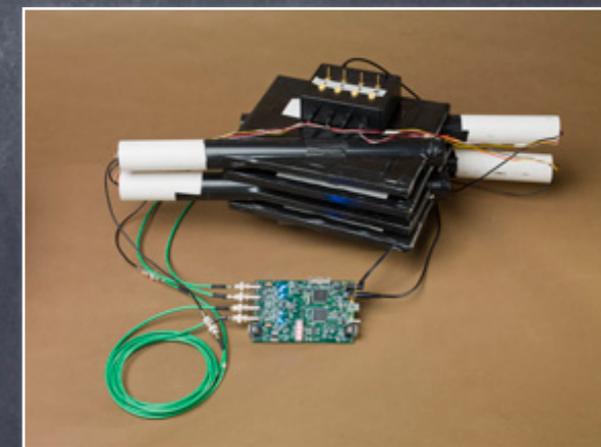






Home Library Data Posters Assessment

Assessment



Guided Student Investigation

CMS e-Lab

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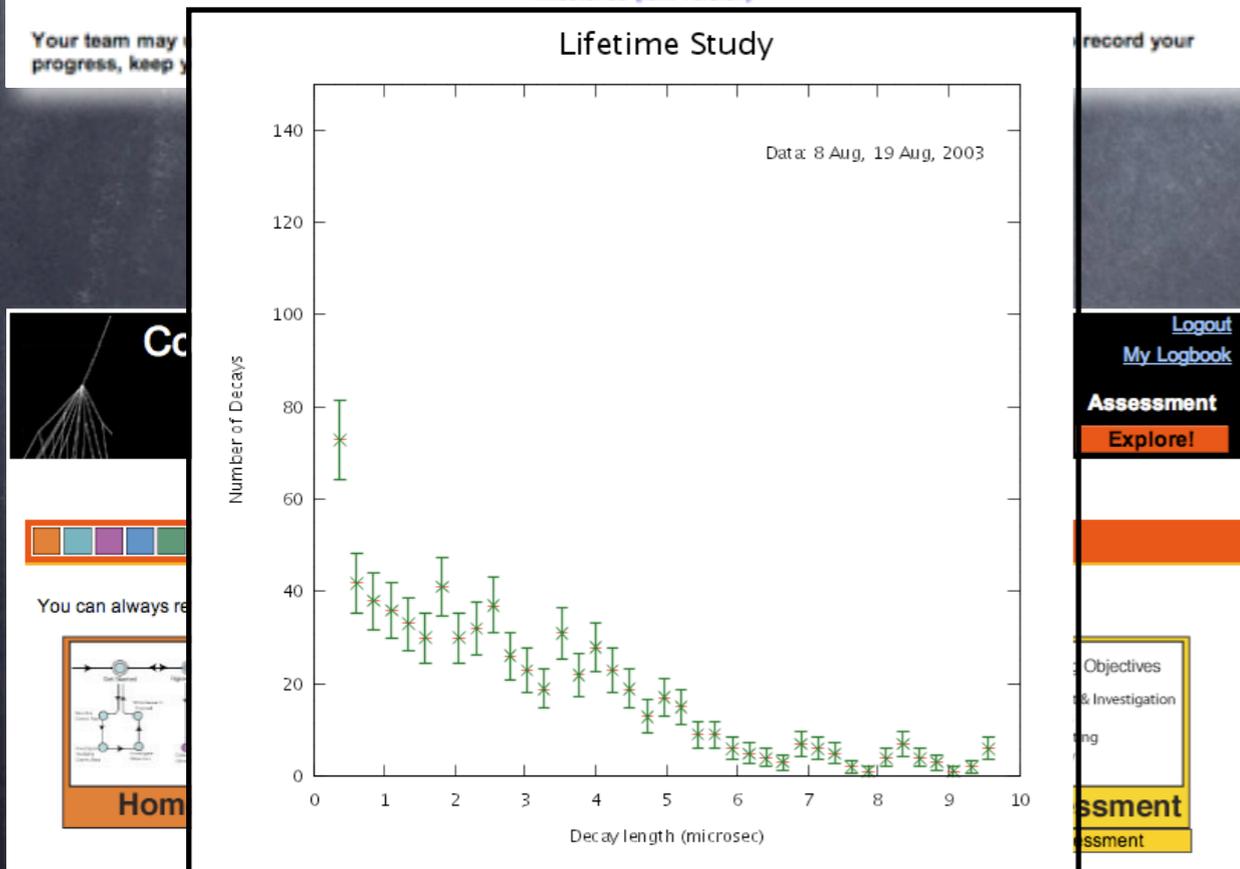
Password:

Login

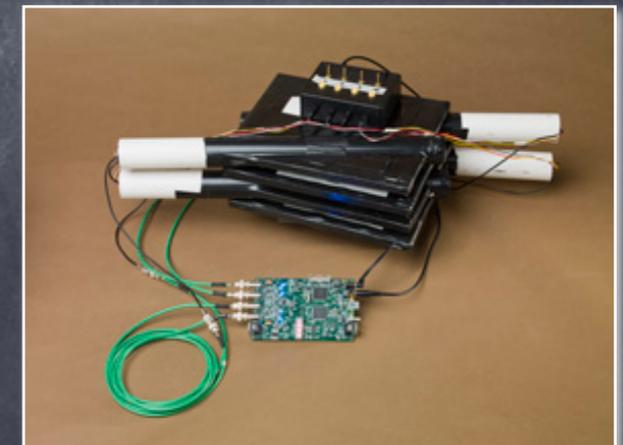
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Online Investigations with I2U2



Guided Student Investigation

CMS e-Lab

Project Map Library Data Posters Site Map Assets

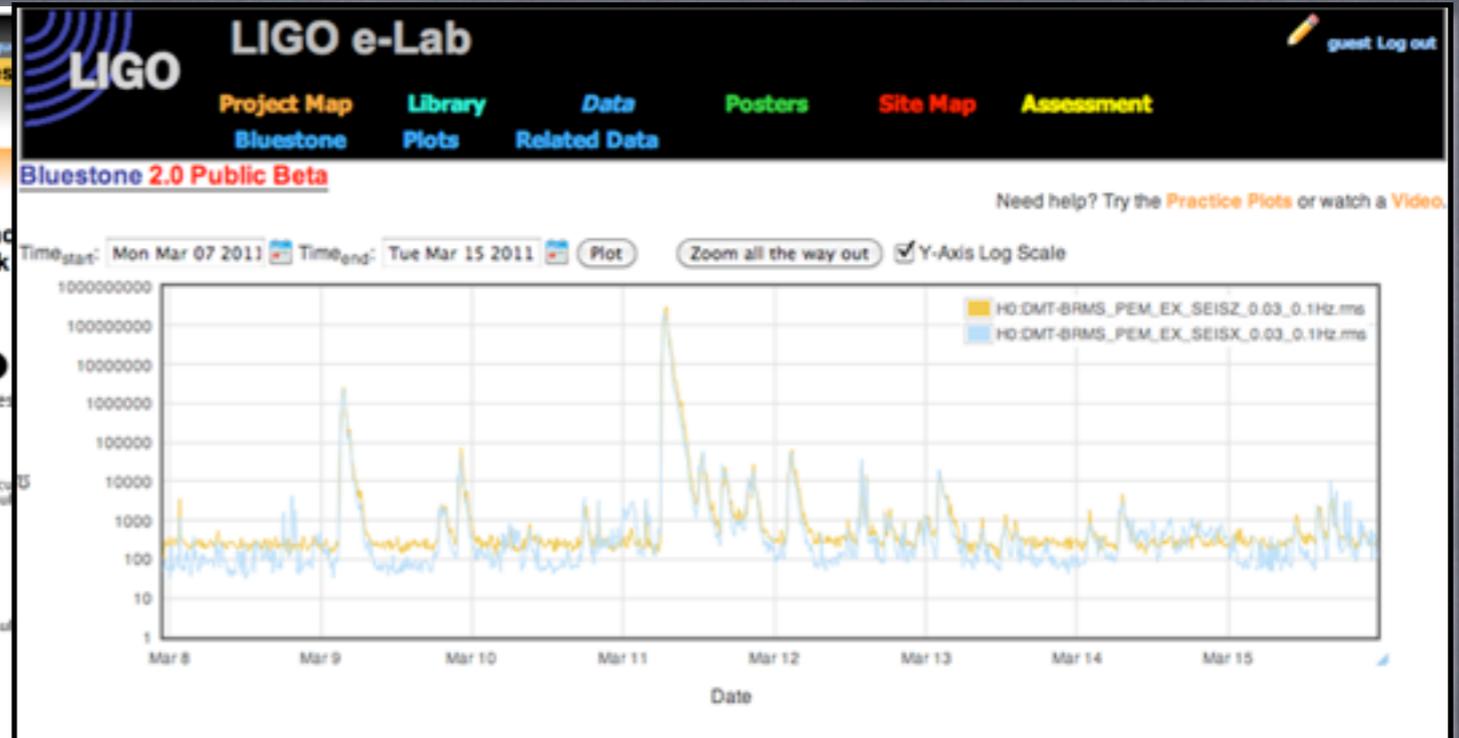
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Cosmic Ray e-Lab

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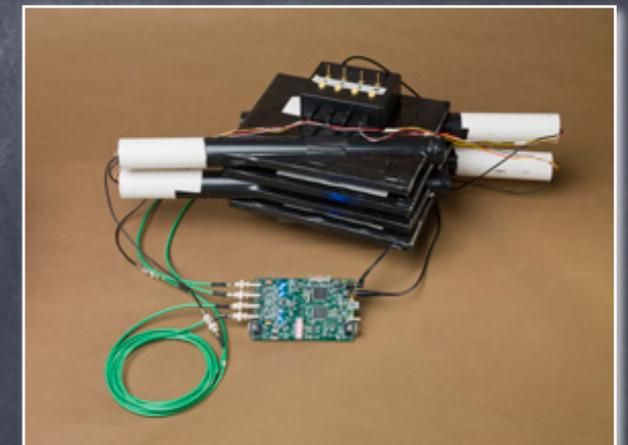
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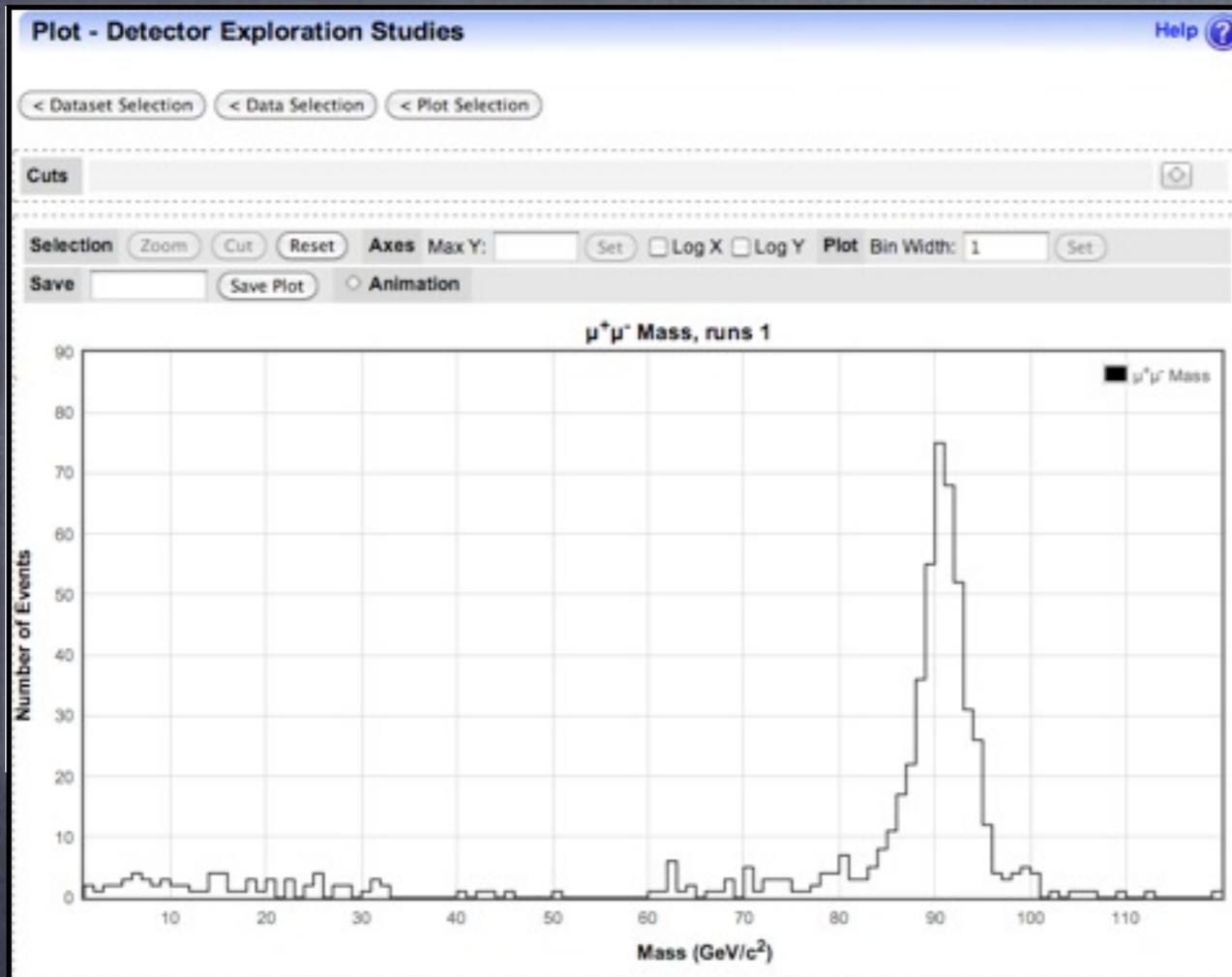
Learning Objectives

- Content & Investigation
- Process
- Computing
- Literacy

Assessment

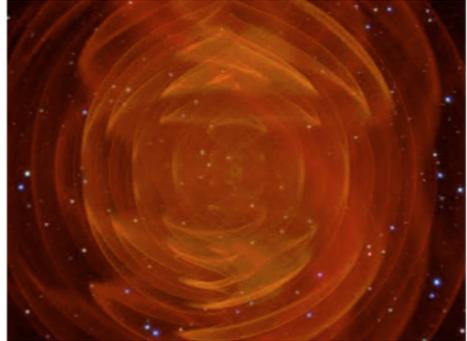


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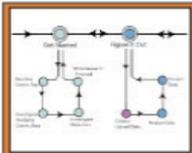
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Library
Data
Posters
Site Map
Assessment

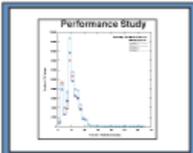
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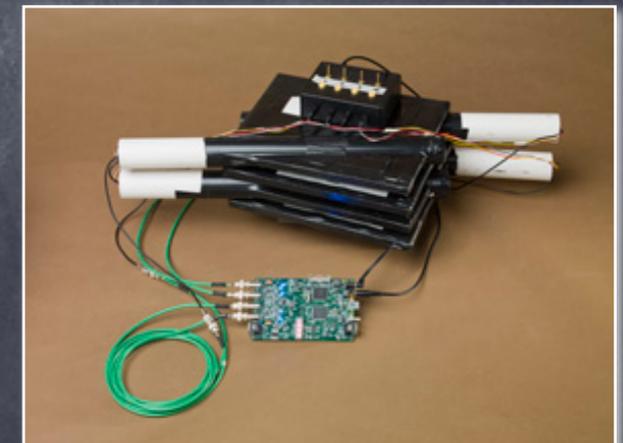
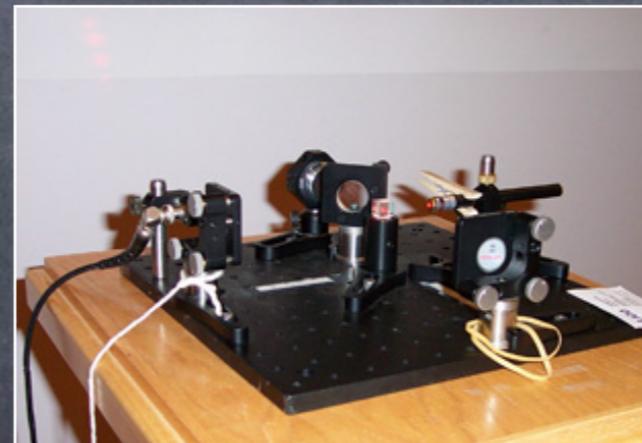

Home


Library


Data


Posters


Assessment



Explore an Event

Explore an Event

/cms-geometry.lg:Geometry/detector-model-geometry.js

Detector Model ?

- Tracker
- ECAL Barrel
- ECAL Endcap
- ECAL Preshower
- HCAL Barrel
- HCAL Endcap
- HCAL Outer
- HCAL Forward
- Drift Tubes (muon)
- Cathode Strip Chambers (muon)
- Resistive Plate Chambers (muon)

Tracking ?

- ECAL ?
- HCAL ?
- Muon ?
- Particle Flow ?
- Physics Objects ?

Controls:

- rotate
- Ctrl** + → pan x / y
- Shift** + → pan z

+

Explore an Event

The screenshot shows a software interface for exploring a detector model. The main window title is `/cms-geometry.lg:Geometry/detector-model-geometry.js`. On the left, there is a 'Detector Model' sidebar with a tree view of components: Tracker, ECAL Barrel, ECAL Endcap, ECAL Preshower, HCAL Barrel, HCAL Endcap, HCAL Outer, HCAL Forward, Drift Tubes (muon), Cathode Strip Chambers (muon), and Resistive Plate Chambers (muon). Below this are sections for 'Tracking', 'ECAL', 'HCAL', 'Muon', 'Particle Flow', and 'Physics Objects', each with a question mark icon. A toolbar at the top contains icons for file operations and navigation. An 'Open Event' dialog box is open in the center, displaying a list of files and events. The 'Files' column lists files like `jpsi-jan25_R000140124_T00000003.lg` through `T00000020.lg`. The 'Events' column lists events such as `Events/Run_140124/Event_909725856` through `Event_910152695`. At the bottom of the dialog, the selected event path is shown: `/jpsi/jpsi-jan25_R000140124_T00000020.lg:Events/Run_140124/Event_909725856`. 'Close' and 'Load' buttons are at the bottom right of the dialog. In the bottom right corner of the main window, there is a 3D coordinate system with x, y, and z axes.

Detector Model ?

- Tracker
- ECAL Barrel
- ECAL Endcap
- ECAL Preshower
- HCAL Barrel
- HCAL Endcap
- HCAL Outer
- HCAL Forward
- Drift Tubes (muon)
- Cathode Strip Chambers (muon)
- Resistive Plate Chambers (muon)

Tracking ?

ECAL ?

HCAL ?

Muon ?

Particle Flow ?

Physics Objects ?

Open Event

Files	Events
<code>jpsi-jan25_R000140124_T00000003.lg</code>	<code>Events/Run_140124/Event_909725856</code>
<code>jpsi-jan25_R000140124_T00000004.lg</code>	<code>Events/Run_140124/Event_909804930</code>
<code>jpsi-jan25_R000140124_T00000005.lg</code>	<code>Events/Run_140124/Event_909808274</code>
<code>jpsi-jan25_R000140124_T00000006.lg</code>	<code>Events/Run_140124/Event_909821639</code>
<code>jpsi-jan25_R000140124_T00000007.lg</code>	<code>Events/Run_140124/Event_909851167</code>
<code>jpsi-jan25_R000140124_T00000008.lg</code>	<code>Events/Run_140124/Event_909884612</code>
<code>jpsi-jan25_R000140124_T00000009.lg</code>	<code>Events/Run_140124/Event_909885178</code>
<code>jpsi-jan25_R000140124_T00000010.lg</code>	<code>Events/Run_140124/Event_909905614</code>
<code>jpsi-jan25_R000140124_T00000011.lg</code>	<code>Events/Run_140124/Event_909914973</code>
<code>jpsi-jan25_R000140124_T00000012.lg</code>	<code>Events/Run_140124/Event_909971356</code>
<code>jpsi-jan25_R000140124_T00000013.lg</code>	<code>Events/Run_140124/Event_909986907</code>
<code>jpsi-jan25_R000140124_T00000014.lg</code>	<code>Events/Run_140124/Event_910005019</code>
<code>jpsi-jan25_R000140124_T00000015.lg</code>	<code>Events/Run_140124/Event_910043391</code>
<code>jpsi-jan25_R000140124_T00000016.lg</code>	<code>Events/Run_140124/Event_910110429</code>
<code>jpsi-jan25_R000140124_T00000017.lg</code>	<code>Events/Run_140124/Event_910134521</code>
<code>jpsi-jan25_R000140124_T00000018.lg</code>	<code>Events/Run_140124/Event_910148878</code>
<code>jpsi-jan25_R000140124_T00000019.lg</code>	<code>Events/Run_140124/Event_910152695</code>
<code>jpsi-jan25_R000140124_T00000020.lg</code>	

`/jpsi/jpsi-jan25_R000140124_T00000020.lg:Events/Run_140124/Event_909725856`

Close Load

Controls:

- rotate
- Ctrl + → pan x / y
- Shift + → pan z

Explore an Event

~/psl/psl-jan25_R000140124_T00000020.Ig:Events/Run_140124/Event_910214790

Left Sidebar (Component List):

- HCAL Forward
- Drift Tubes (muon)
- Cathode Strip Chambers (muon)
- Resistive Plate Chambers (muon)
- Tracking**
- Tracks (reco.)(190)
- Electron Tracks (GSF)(1)
- Clusters (Si Pixels)(1120)
- Clusters (Si Strips)(7272)
- Rec. Hits (Tracking)(2656)
- ECAL**
- Barrel Rec. Hits(1363)
- Endcap Rec. Hits(875)
- Preshower Rec. Hits(976)
- HCAL**
- Barrel Rec. Hits(885)
- Endcap Rec. Hits(268)
- Forward Rec. Hits(382)
- Outer Rec. Hits(367)
- Muon**
- DT Rec. Hits(1)
- DT Rec. Segments (4D)(0)
- CSC Segments(8)
- RPC Rec. Hits(11)
- CSC Rec. Hits (2D)(52)
- Particle Flow**
- Physics Objects**
- Tracker Muons (Reco)(2)

Bottom Control Panel:

Controls:

- rotate
- Ctrl + → pan x / y
- Shift + → pan z

3D View: A central detector volume is shown with a complex internal structure. To the left, several vertical cylindrical structures represent the muon system. To the right, a large, circular, multi-layered structure represents the calorimeter. A red line indicates a particle track passing through the detector. A 3D coordinate system (x, y, z) is visible in the bottom right corner.

Explore an Event

./psl/psl-jan25_R000140124_T00000020.lg:Events/Run_140124/Event_910214790

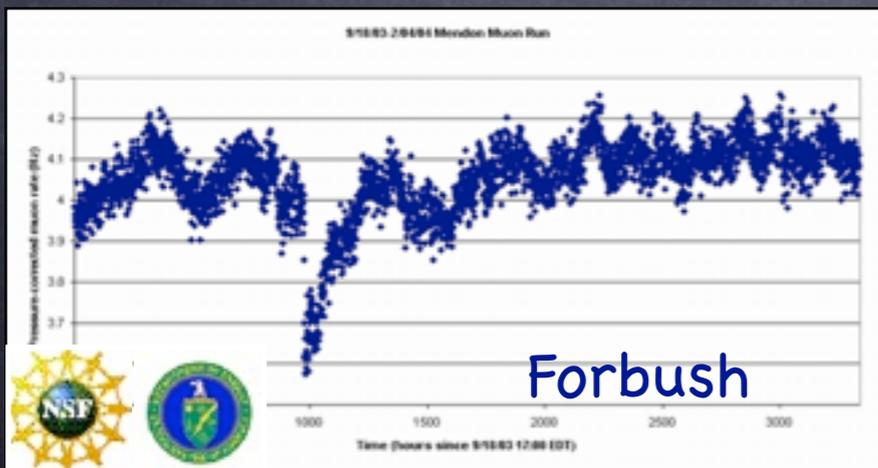
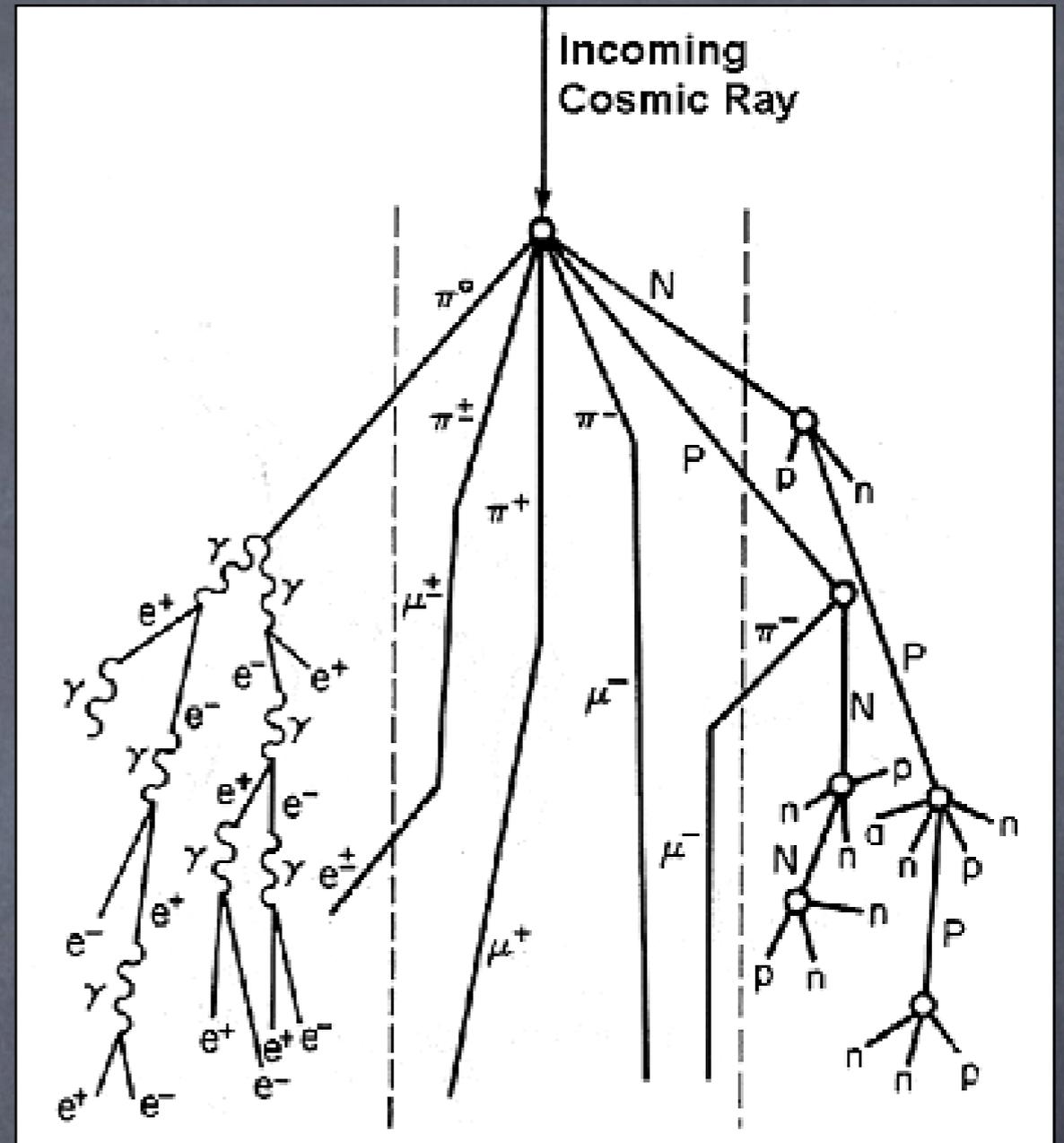
The interface displays a list of detector components on the left, each with a checkbox and a question mark icon. The components are grouped into sections: HCAL Forward, Tracking, ECAL, HCAL, Muon, Particle Flow, and Physics Objects. The main visualization area shows a 3D representation of the detector with yellow tracks and hits. An 'Energy Range Selector' dialog is open, showing a histogram and the following information:

Energy range for Barrel Rec. Hits
Low cut: 0.06 GeV (3%)
High cut: 2.23 GeV (100%)

Controls:

- rotate
- Ctrl + → pan x / y
- Shift + → pan z

Cosmic Ray Studies



Tips for Effective e-Labs

A 2-3 day teacher workshop is essential for effective classroom implementation.

- Let them experience the e-Lab as their students will.
- Correlate data to the real detectors.
- Provide interactive, engaging presentations.
- Background material
- Answer questions at their level of understanding.
- Provide time for teachers to talk about teaching strategies.

Research Experiences

QuarkNet Research Team

4 students

1 teacher

6 weeks

Engaged in all aspects of research



Tips for Effective Research Programs

Students become part of your research team:

- They experience all aspects of the scientific process.
 - Troubleshooting
 - Calibrating equipment
 - Use of journals or logbooks
 - Why data are analyzed in a particular way
 - Importance of communicating ideas & results
 -
- They report findings.
 - Presentations
 - Posters
 - Abstracts & papers
- They work least 4 weeks.

What's Effective?

Authentic experiences!

Working directly with students

In the short term—creating interest

In the longer term—building understanding
and relationships, scientific literacy

QuarkNet Center Success Factors

- ① Strong teacher leader
- ① Strong mentor
- ① Regular meetings
- ① Meaningful activities
- ① Address classroom implementation.
- ① Staff support & follow-up
- ① Stable participant base
- ① Address professionalism.
- ① Establish a learning community.
- ① Additional funding

Particle Physics Outreach to Secondary Education

Marjorie G. Bardeen, K. Erik Johansson and M. Jean Young

Annual Review of Nuclear and Particle Science

2011.61:149–70

(nucl.annualreviews.org)