Helping Develop America's Technological Workforce

QuarkNet

The QuarkNet Story

Developing our "e-Lab" for High School Students & Their Teachers

Marge Bardeen, Fermilab
Mike Wilde, Argonne & U. Chicago

NSF

Office of Science
U.S. DEPARTMENT OF ENERGY

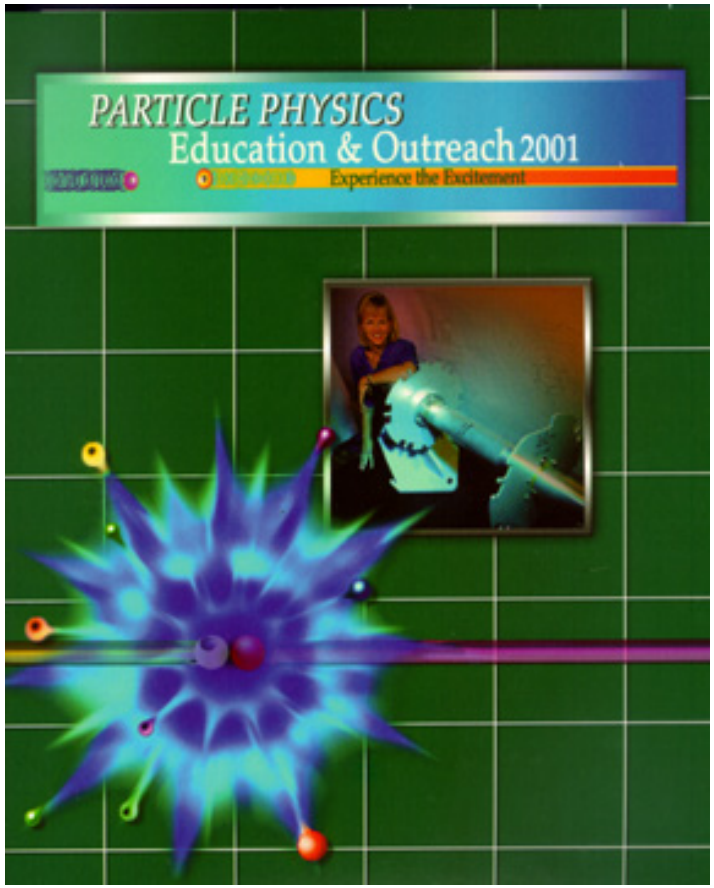
LHC Education Commitment

Neal Lane

"Major discoveries like the Top Quark and antimatter make headlines on the front pages of the world's major newspapers. Whether readers fully appreciate the significance of these breakthroughs is another matter altogether. That is why this agreement places such a high priority on public education and outreach. Each of the U.S. detectors has named an education coordinator to its senior project management teams. You'll also see that the integration of research and education stands out as a primary objective and responsibility within the overall U.S. investment strategy—just as it now guides NSF's programming in general."

(at the signing of the LHC agreement)

Particle Physics Education & Outreach



What are particle physicists doing in education and outreach?

Survey

FY96-97: 172 major activities

FY00-01: 255 major activities

M. Bardeen, M. Wilde, UUEO Meeting, April 2004

A Coherent Education Program

2 DOE labs host project offices.

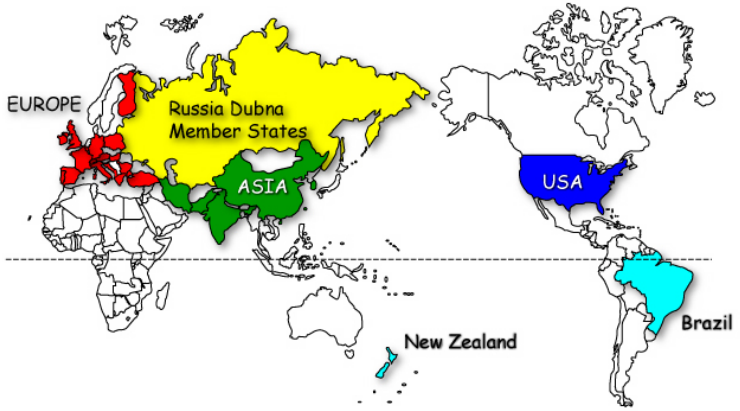
4 Experiments (ATLAS, CMS, CDF, DØ)

10 Years just to build detectors

60 Research groups

1,000s of scientists worldwide

Petabyte-scale computing



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QuarkNet Design Team

Physicists:
Keith Baker, Hampton University
Michael Barnett, ATLAS Ed Coordinator
Randy Ruchti, CMS Ed Coordinator

Educator:
Marge Bardeen, Fermilab Ed Office

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QuarkNet Design Team

Physicists brought experience with:

- **Science.**
- **Research.**
- **Data.**

Educator brought experience with:

- **High schools, students & teachers.**
- **Education reform.**
- **Best practice professional development.**

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The QuarkNet Collaboration

A lasting research community of physicists, high school teachers & their students

- **Physicists as mentors & colleagues**
- **Teachers as researchers & classroom research leaders**
- **Students as researchers**

- **Engaging teachers, and subsequently their students, in scientific investigations**
- **Confronting particle physicists with current issues in science education**

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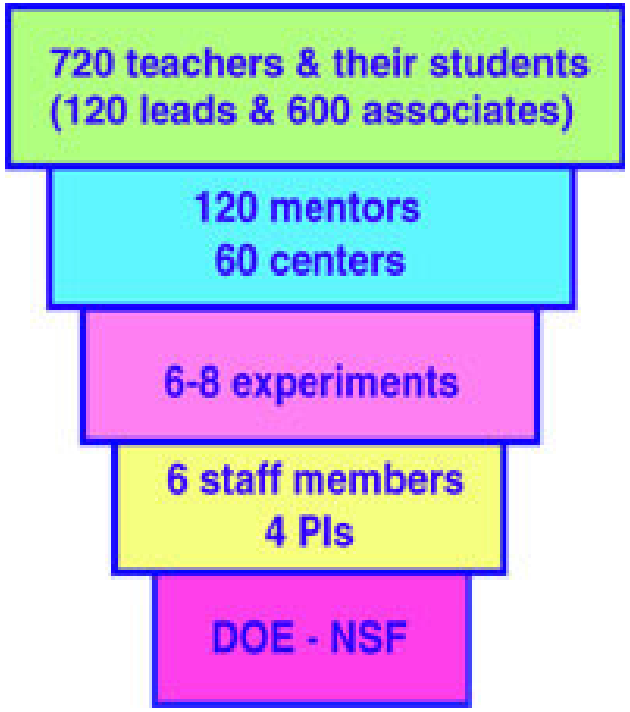
The QuarkNet Collaboration

Program Profile



Managed Like an HEP Project

- Long-term
- Central oversite, resources & support
- Flexible local programs
- Distributed among 60 research groups
- Leveraged local resources
- Research-based professional development
- Online instructional resources for student research

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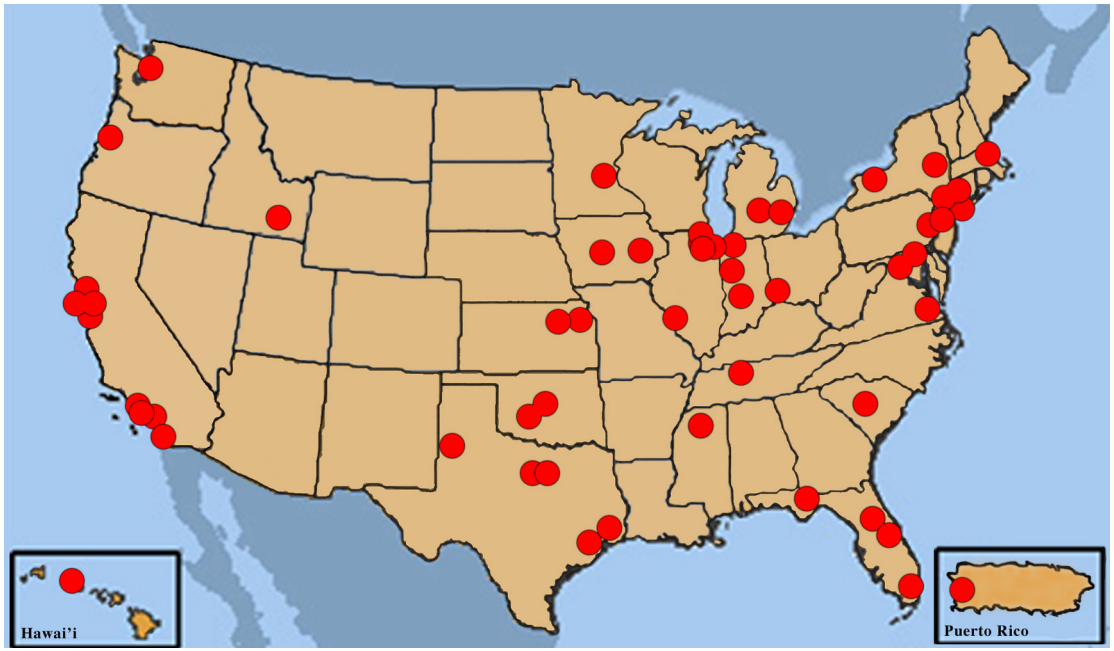
QuarkNet Infrastructure



48 centers: 208 mentors & 474 teachers

+ 4 new centers in FY04

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Student Outcomes

Students learn fundamental physics by:

- **Analyzing real data delivered online.**
- **Collaborating with students worldwide.**
- **Participating in inquiry-oriented investigations.**
- **Experimenting using classroom cosmic ray detectors.**
- **Visiting research groups & experiments.**
- ***Constructing & testing detector components.***

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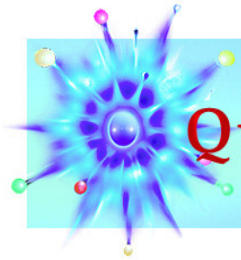

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Teacher Programs

Year 1 — 2 lead teachers

- One-week summer institute at Fermilab
- Seven-week summer research appointments

Year 2 — 2 lead teachers and 10 assocaite teachers

- Three-week research-based summer institutes

Following Years

- One-week follow-on activities

QuarkNet Website

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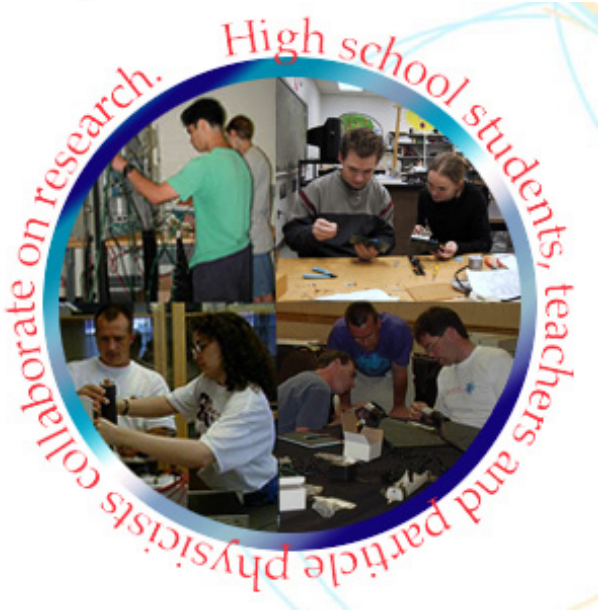
Website



quarknet.fnal.gov

At Work

Join Us

For Educators

For Students

This project is supported in part by the National Science Foundation and the Division of High Energy Physics, Office of Science , U.S. Department of Energy. Opinions expressed are those of the authors and not necssarily those of the Foundation or Department.

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Online Data Delivery

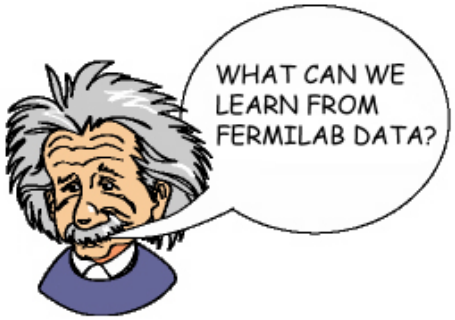
Technology supports problem-based student investigations.

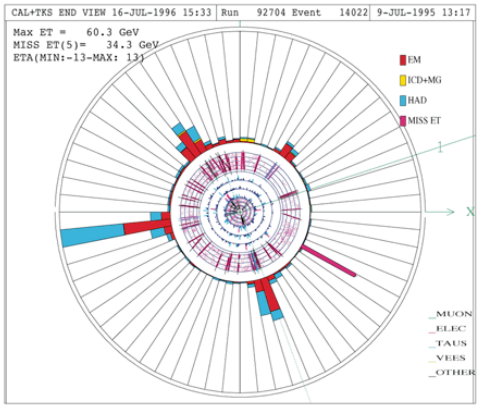
Searching for Top

How do today's scientists use conservation of momentum?

Particle physicists verify Einstein's famous equation $E=mc^2$ every day in accelerators around the world. They convert energy into mass almost as commonly as you flip through channels on the television.

In 1995 physicists who work at Fermilab created the last and most massive quark ever discovered, the top quark, by converting mass into energy and then energy into mass!





You can use the principle of conservation of momentum which you have been studying and 1995 experimental data to determine the mass of the top quark. The D-Zero Experiment

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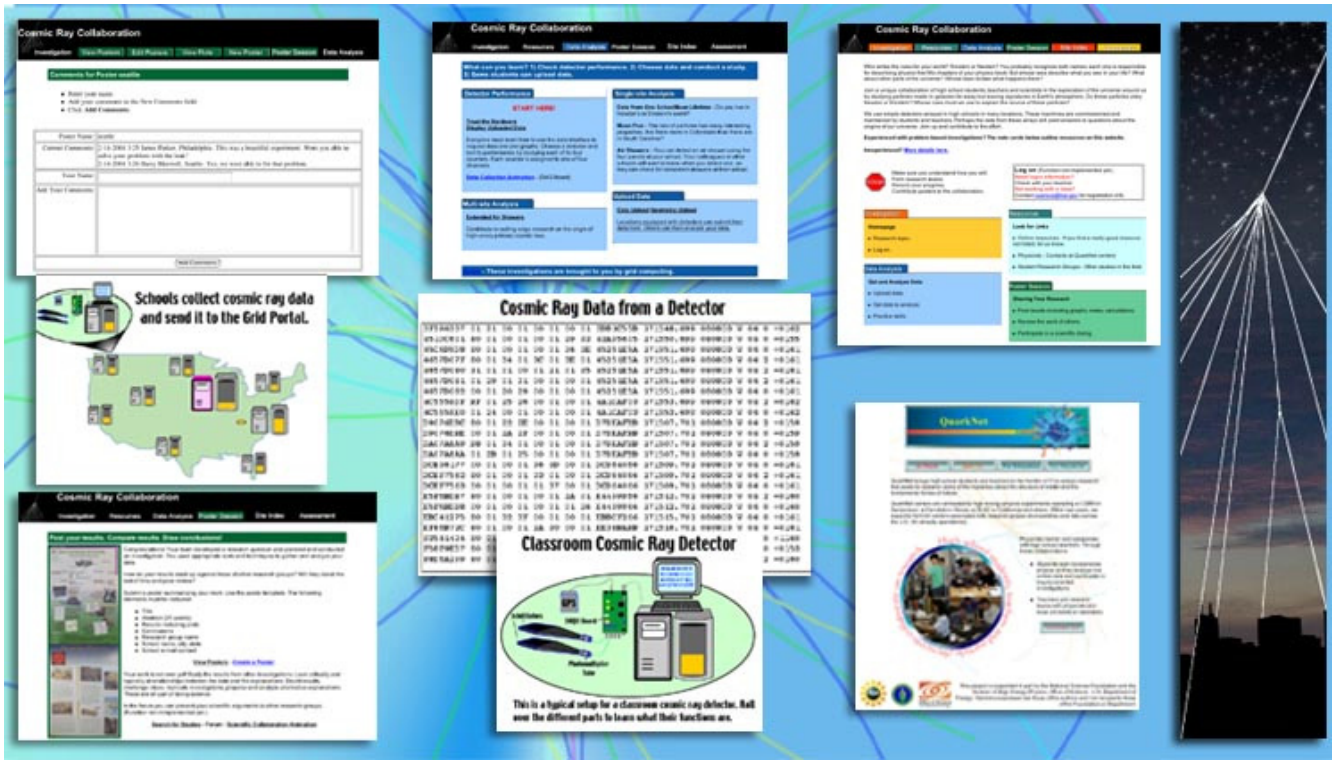
Along Came Grids

New players bring virtual data tools & techniques.



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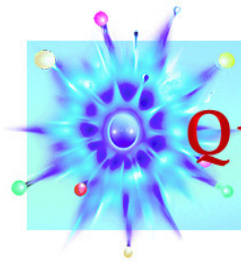

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What makes a virtual data portal special?

- Data processing tools are neatly packaged and described.
- Workflows can be cataloged to describe and reuse processes.
- Facilitates search and discovery through uniform interfaces.
- Steps are logged automatically for reference and uniform communications.
- Provides a "backplane" for science modules.
- Can run larger computations on the Grid, seamlessly – simulations and real science codes.

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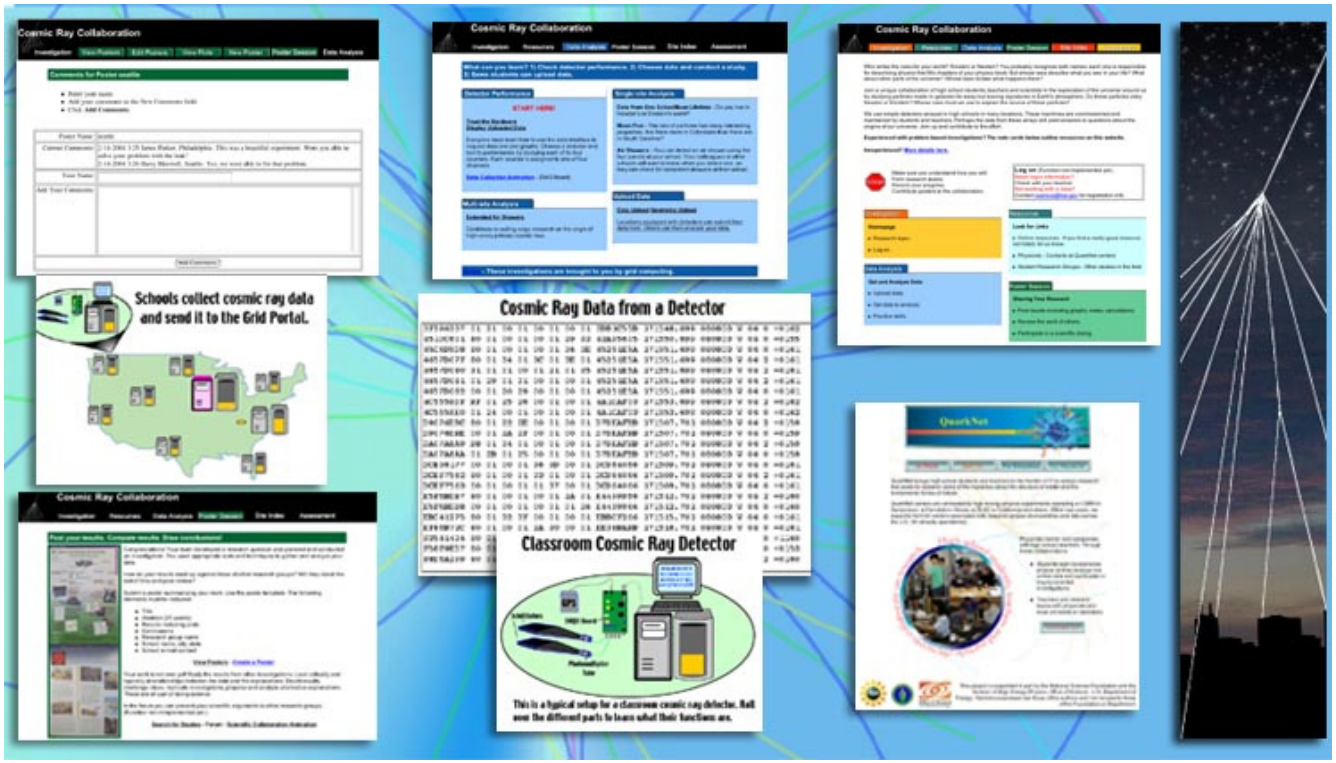
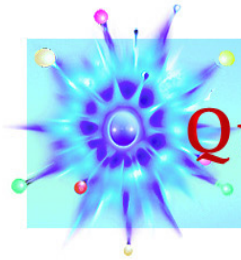
Along Came Grids

New players bring virtual data tools & techniques.



M. Bardeen, M. Wilde, UUEO Meeting, April 2004



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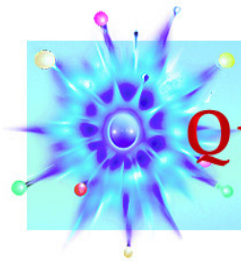
QuarkNet/Grid Project

Provides access to innovative computing and *real* scientific data for students who would not otherwise have such opportunities.

Uses the potential of frontier science and Grid computing to transform science teaching and learning.

May provide infrastructure for "federating" with other experiments using the Grid.



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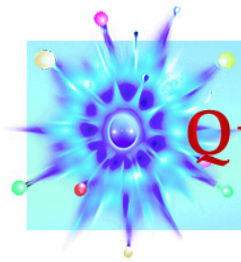
Goals

Students participate in a scientific collaboration and make real contributions to a scientific field.

Students use virtual data tools and techniques to upload, access, process and publish data, report their results as online posters, and have online discussions about their work with peers.

Educational researchers evaluate the effectiveness of such an endeavor.

Grid specialists explore interface designs that enhance accessibility to Grid data and computational resources.



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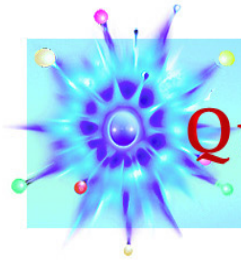
Applying Virtual Data Tools

It's an experiment—a scientific workstation—that gives students the means to:

- **Discover and apply datasets, algorithms and data analysis methods.**
- **Collaborate by developing new ones and sharing results and observations.**
- **Learn data analysis methods that will ready and excite them for a scientific career.**

And in later steps, we may actually use *the* Grid!



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"Virtual Data Workstation"

It's just a web site! ☺ . . . and more. It's a place to:

- **Keep and organize datasets.**
- **Perform computations on the data.**
- **Create new computations and analyses.**
- **View and share results.**
- **Experiment and discover.**
- **Annotate and enquire (using metadata).**
- **Communicate and collaborate.**

It's easy to use, ubiquitous, no tools to install.

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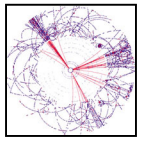
QuarkNet e-Lab

V 0.3 Cosmic ray studies with student data (Virtual data tools and techniques)

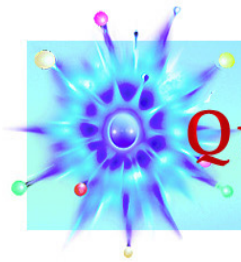
SRCH EPCF

V 1.0 α - Professional development
Collaboration meeting simulation
Test beam data
Data simulations



V 2.0 pre-α - HEP Data from the Grid

Tools for "federation" with other physics experiments?



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Development Team

Computing/Web/Design
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- M. Clayton - FNAL

Physicist
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QNet Educators
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- L. Rose - Penn HS

Grad Student
- Y. Zhao - UC

Undergrad Students
- P. Nepywoda - U of I
- E. Peryshkin - U of I
- Y. Wu - MIT

High School Students
- A. Bahal - IMSA
- J. Frankle - LaLumiere HS
- J. Shreve - LaLumiere HS

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V 0.3 Science

Cosmic Ray Mysteries

Where do highly energetic cosmic rays come from?

Where do they get their energy?

What secrets do they hold about the early universe?

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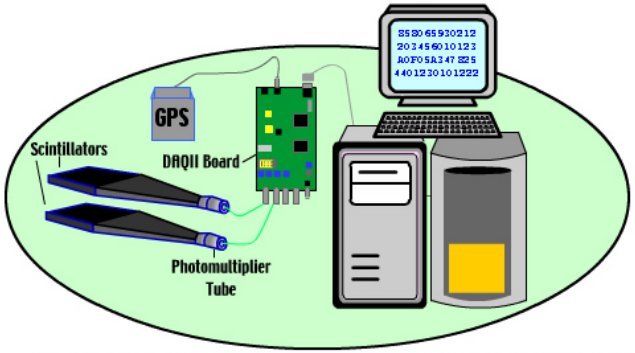
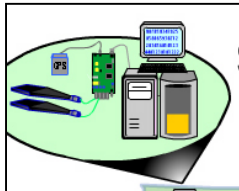
V 0.3 Experiments

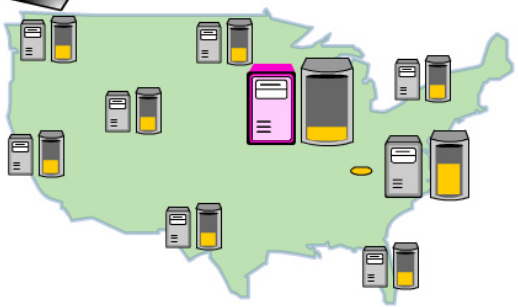
Classroom Cosmic Ray Detector



This is a typical setup for a classroom cosmic ray detector. Roll over the different parts to learn what their functions are.



Schools collect cosmic ray data and send it to the Grid Portal.



Cosmic Ray Collaboration

Investigation | Resources | Data Analysis | Poster Session | Site Index | Assessment

Who writes the rules for your world? Einstein or Newton? You probably recognize both names; each one is responsible for describing physics that fills chapters of your physics book. But whose laws describe what you see in your life? What about other parts of the universe? Whose laws dictate what happens there?

Join a unique collaboration of high school students, teachers and scientists in the exploration of the universe around us by studying particles made in galaxies far away but leaving signatures in Earth's atmosphere. Do these particles obey Newton or Einstein? Whose rules must we use to explain the source of these particles?

We use simple detectors arrayed in high schools in many locations. These machines are commissioned and maintained by students and teachers. Perhaps the data from these arrays will yield answers to questions about the origins of our universe. Join up and contribute to the effort.

Experienced with problem-based investigations? The note cards below outline resources on this website.

Inexperienced? More details here.

STOP

Make sure you understand how you will:
Form research teams.
Record your progress.
Contribute posters to the collaboration.

Log on (Function not implemented yet.)
Need logon information?
Check with your teacher.
Not working with a class?
Contact cosmics@fnal.gov for registration info.

Investigation

Homepage

- Research topic.
- Log on.

Data Analysis

Get and Analyze Data

- Upload data.
- Get data to analyze.
- Practice skills.

Resources

Look for Links

- Online resources - If you find a really good resource not listed, let us know.
- Physicists - Contacts at QuarkNet centers
- Student Research Groups - Other studies in the field

Poster Session

Sharing Your Reseach

- Post results including graphs, notes, calculations.
- Review the work of others.
- Participate in a scientific dialog.

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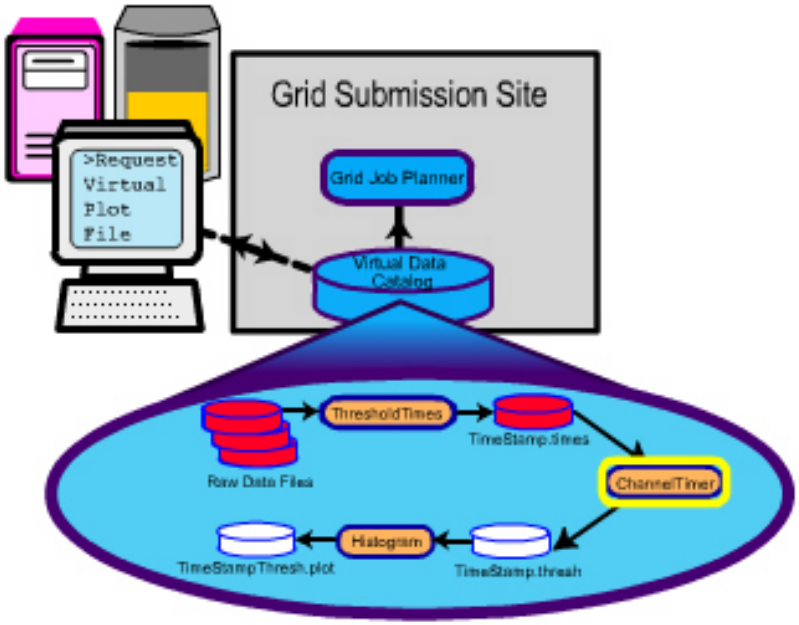
V 0.3 Demo

Grid Virtual Data techniques underly web-based analysis tools for students.



quarknet.fnal.gov/grid

Homepage

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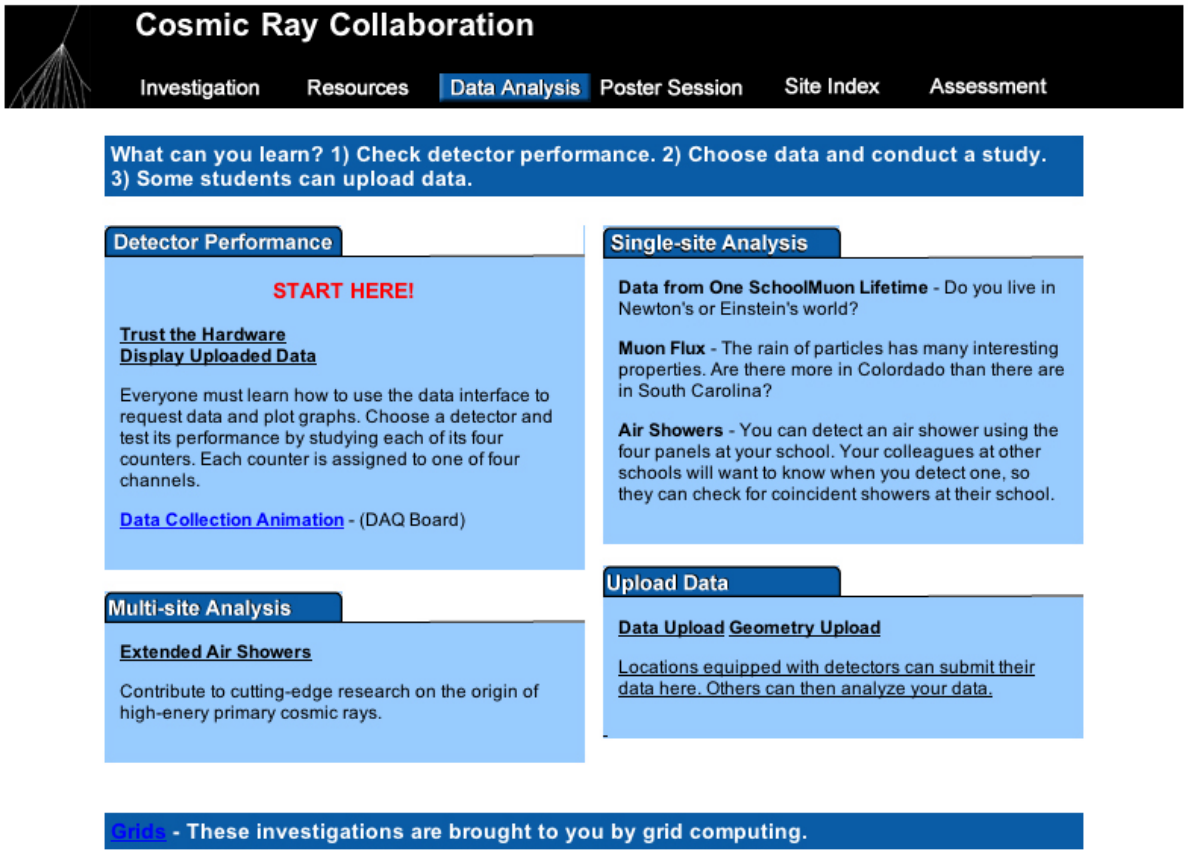
Data Analysis



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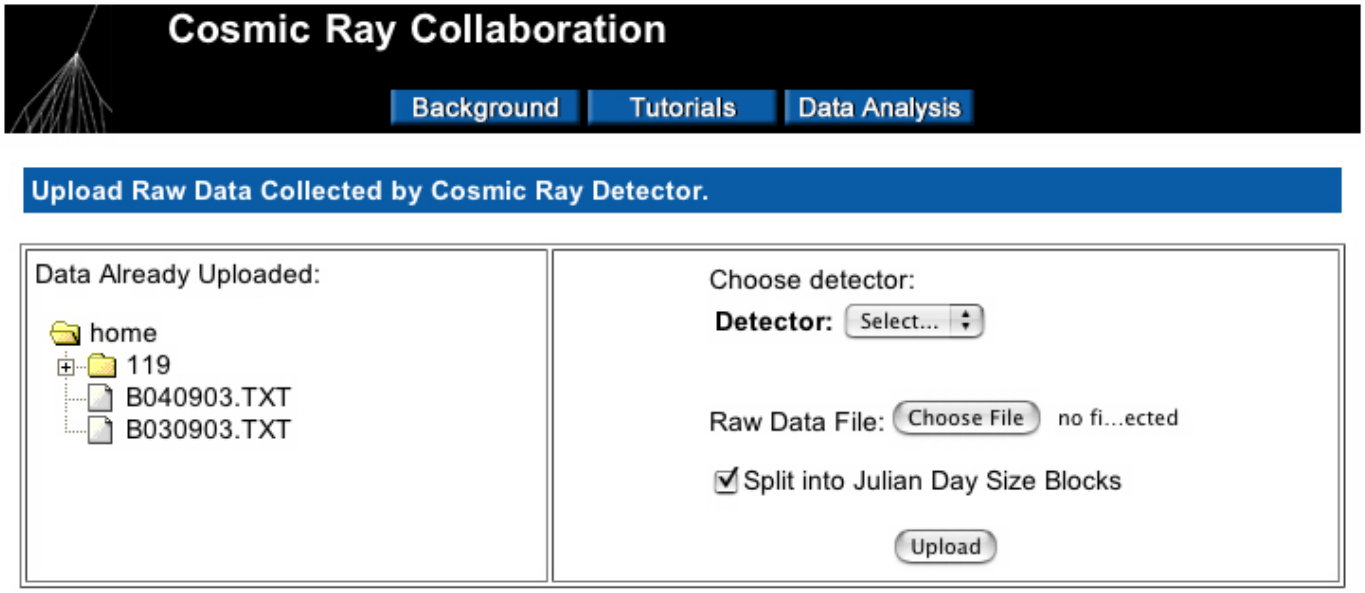
Data Upload



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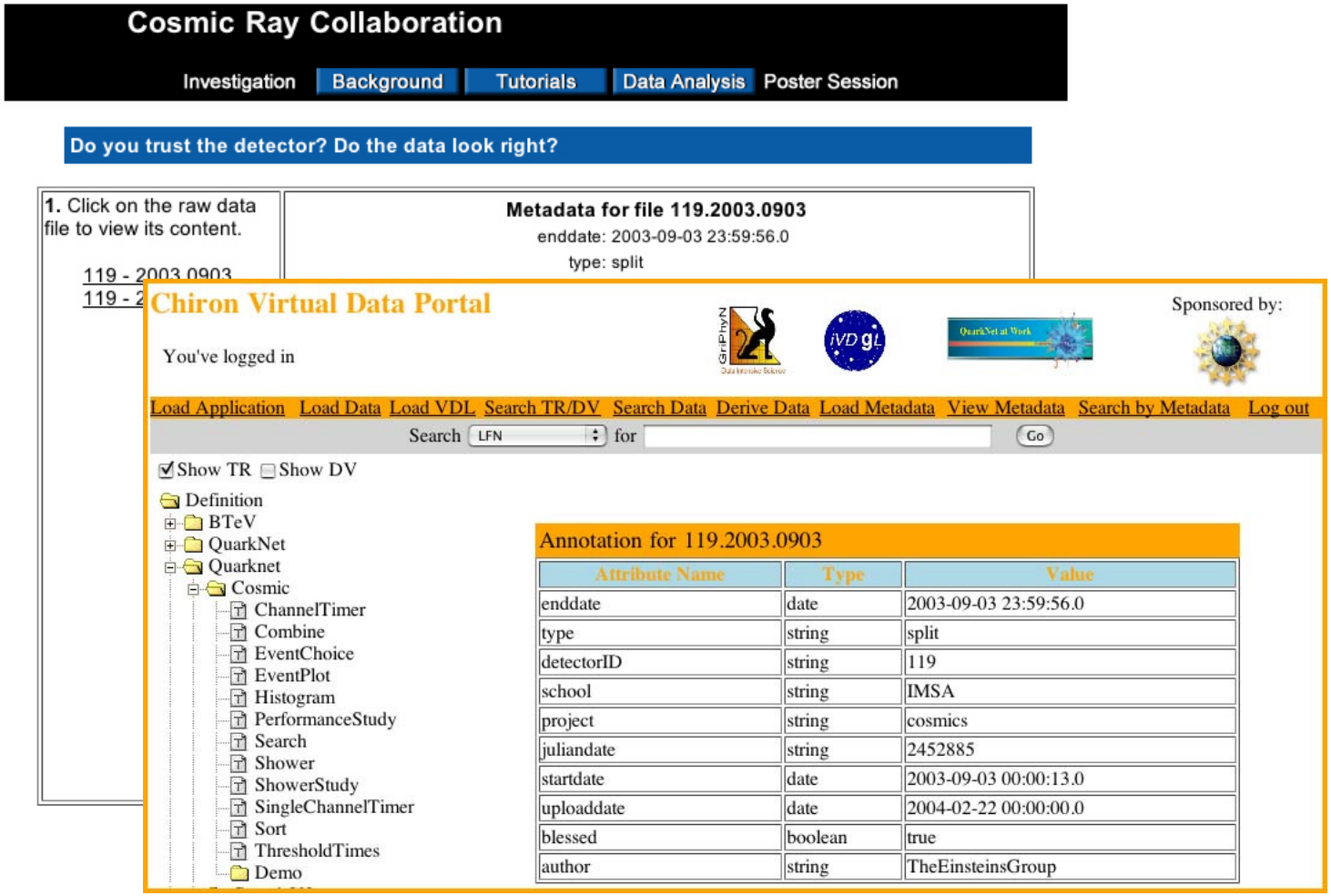
Data Display



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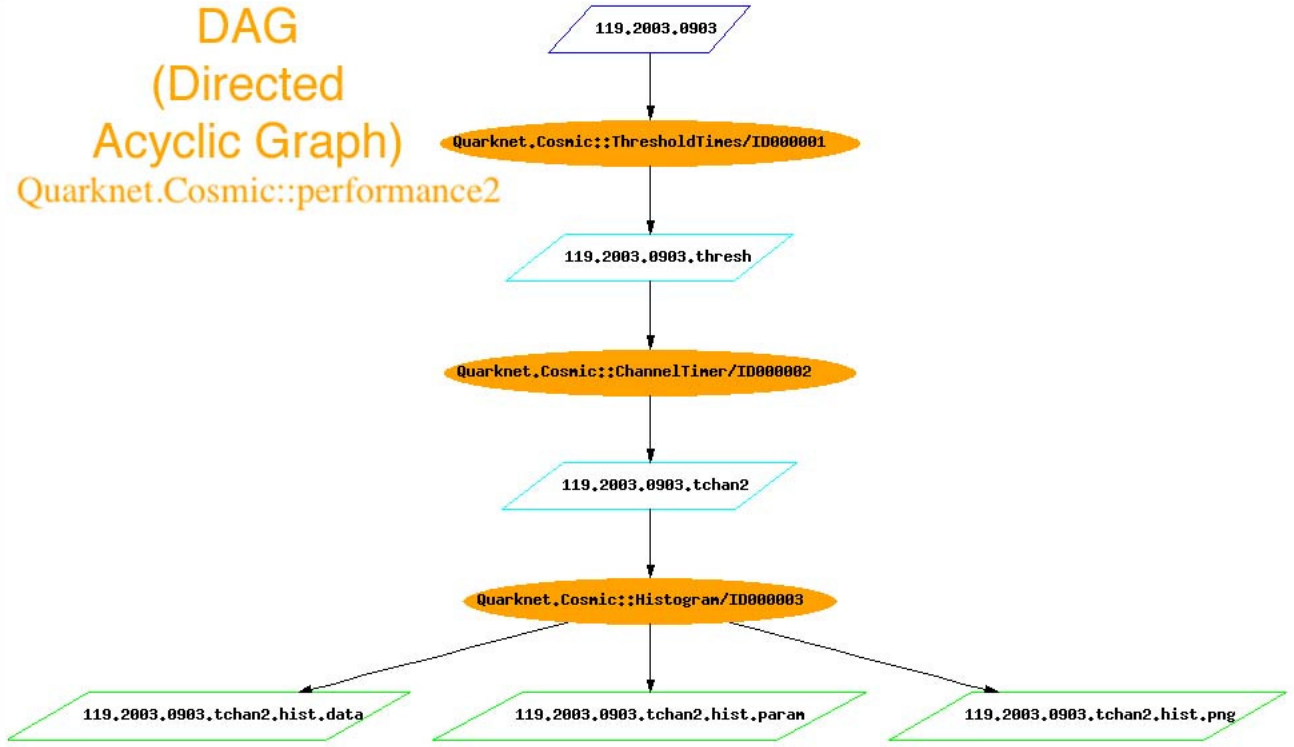
Equipment Test

DAG
(Directed
Acyclic Graph)
Quarknet.Cosmic::performance2



Transformation

```
TR Quarknet.Cosmic::Perfor
detector, none divisions, no
plotParam, input rawData, ir
{
  call Quarknet.Cosmic::Thre
thresholdAll=${output:thres
  call Quarknet.Cosmic::Char
thresholdChan=${output:thr
  call Quarknet.Cosmic::Hist
comment=${comment}, dete
histData=${output:histData}
plotParam=${output:plotPar
}
```

Derive

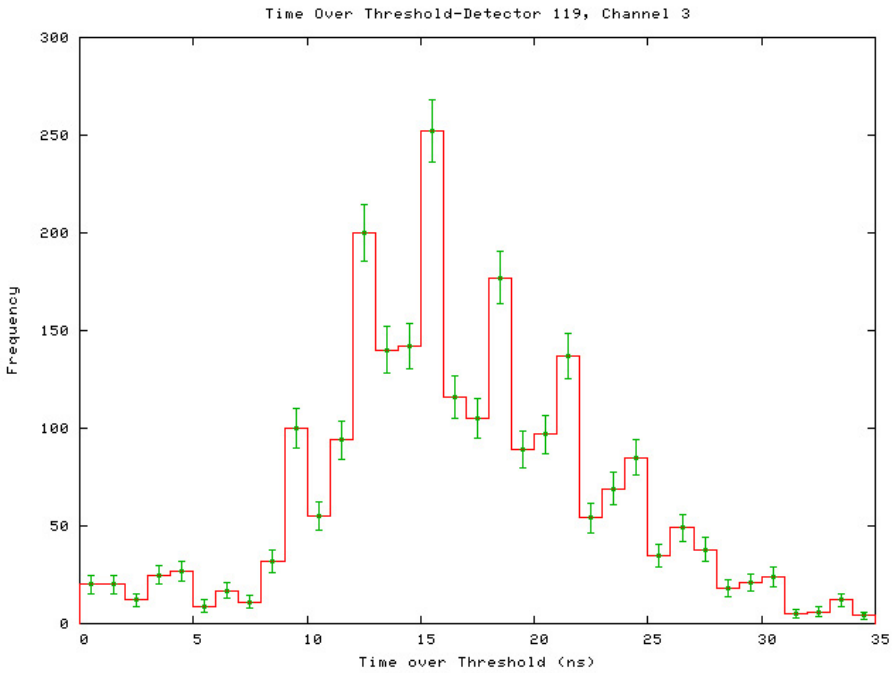
```
divisions="51",
high="50",
histData=@{output:"119.2003.0903.tchan2.hist.data"|rt},
low="0",
plotFile.png=@{output:"119.2003.0903.tchan2.hist.png"|rt},
plotParam=@{output:"119.2003.0903.tchan2.hist.param"|rt},
rawData=@{input:"119.2003.0903"|rt},
thresholdAll=@{inout:"119.2003.0903.thresh"|rt},
thresholdChan=@{inout:"119.2003.0903.tchan2"|rt},
ymax="300"
);
```

Typical Plot

The data table

```
0.5 20 4.47213595499958
1.5 20 4.47213595499958
2.5 12 3.46410161513775
3.5 25 5
4.5 27 5.19615242270663
5.5 9 3
6.5 17 4.12310562561766
7.5 11 3.3166247903554
```

The graph



To save this plot permanently, enter the new file name you want.
Then click **Save Plot**.

Save Plot

Metadata for Plot as seen in Portal

Annotation for 119-9-3-2003-3.png

Attribute Name	Type	Value
detectorID	int	119
date	date	2003-09-03 00:00:00.0
source	string	119.2003.0903
project	string	cosmics
ymax	int	275
channel	int	3
bins	int	35
author	string	The Einsteins

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Studies

Multi-site Analysis

Extended Air Showers

Contribute to cutting-edge research on the origin of high-enery primary cosmic rays.

Single-site Analysis

Data from One SchoolMuon Lifetime - Do you live in Newton's or Einstein's world?

Muon Flux - The rain of particles has many interesting properties. Are there more in Colordado than there are in South Carolina?

Air Showers - You can detect an air shower using the four panels at your school. Your colleagues at other schools will want to know when you detect one, so they can check for coincident showers at their school.

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Poster Session

Cosmic Ray Collaboration

Investigation | Resources | Data Analysis | Poster Session | Site Index | Assessment

Post your results. Compare results. Draw conclusions!

Congratulations! Your team developed a research question and planned and conducted an investigation. You used appropriate tools and techniques to gather and analyze your data.

How do your results stack up against those of other research groups? Will they stand the test of time and peer review?

Submit a poster summarizing your work. Use the poster template. The following elements must be included:

- Title
- Abstract (25 words)
- Results including plots
- Conclusions
- Research group name
- School name, city, state
- School e-mail contact

View Posters - **Create a Poster**

Your work is not over yet! Study the results from other investigations. Look critically and logically at relationships between the data and the explanations. Doubt results, challenge ideas, replicate investigatons, propose and analyze alternative explanations. These are all part of doing science.

In the forum you can present your scientific arguments to other research groups. (Function not immplemented yet.)

Search for Studies - Forum - Scientific Collaboration Animation

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Student Poster

Cosmic Ray Showers in Seattle

A Quarknet Collaboration Experiment
August 25, 2003

We describe a cosmic ray shower in the Seattle area on March 12th.

Materials & Methods

We set up an 8x8 array of 1 meter x 0.5 meter scintillation detectors with the detectors 2 meters apart. This covers an area of 396 square meters. We numbered the 64 individual detectors 1-64 going across by rows. We used the electronics board developed at Fermilab to collect data (see Figure 3). Our test stand is pictured in Figure 4. We uploaded the data to the grid and used the grid analysis tools to find the shower. We used the UWashington transform to analyze the data and the Auger transform to plot the data.

Results

We saw a large cosmic ray shower at 10 AM, March 12, 2003. It lasted from 10:00.02 until 10:00.05 (?). There were coincidences in detectors 1, 2, 4, 9, 10, 11, 12, 17, 18, 19, 20 and 51. The other detectors did not show any coincidences in this same time frame.

- Figure 1: Detector 119 - Channel 1 7-21-2003
- Figure 2: Detector 119 - Channel 1 7-22-2003

Discussions & Conclusions

The accompanying Figures 1 and 2 show the plot of particles that hit our detectors. This array works well as we can identify cosmic ray showers with it. We also searched the data from nearby Gig Harbor to see if they had detected the same shower. It turned out that they did not. We are hoping that another school installs a cosmic ray detector closer to us so that we can compare our data to theirs in the future. There were no coincidences in detector 3 which we would expect, and there were coincidences in detector 51, which we did not expect. After further study, we realized that the pmt had come separated from the scintillator in detector 3. Also, there was a small light leak in detector 51, which could be the cause of coincidences there.

Authors

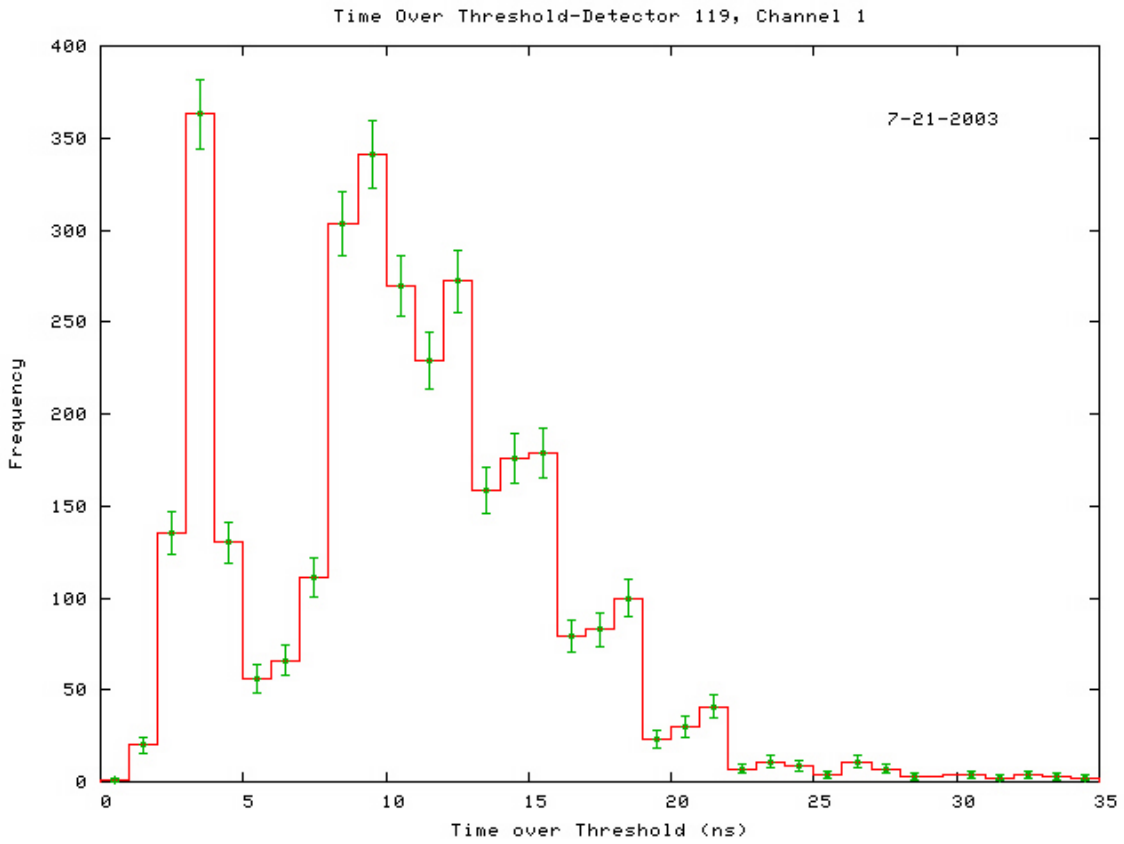
Cosmic Ray Project/Seattle Prep Johnson1/A Team
johnson@seaprep.edu

Figure

Metadata for file 119-7-21-2003_c1.png

detectorID: 119
date: 2003-07-21 00:00:00.0
source: 119.2003.0721
project: cosmics
ymax: 400
channel: 1
bins: 35
author: The Einsteins

Plot file 119-7-21-2003_c1.png



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Peer Comments

Cosmic Ray Collaboration

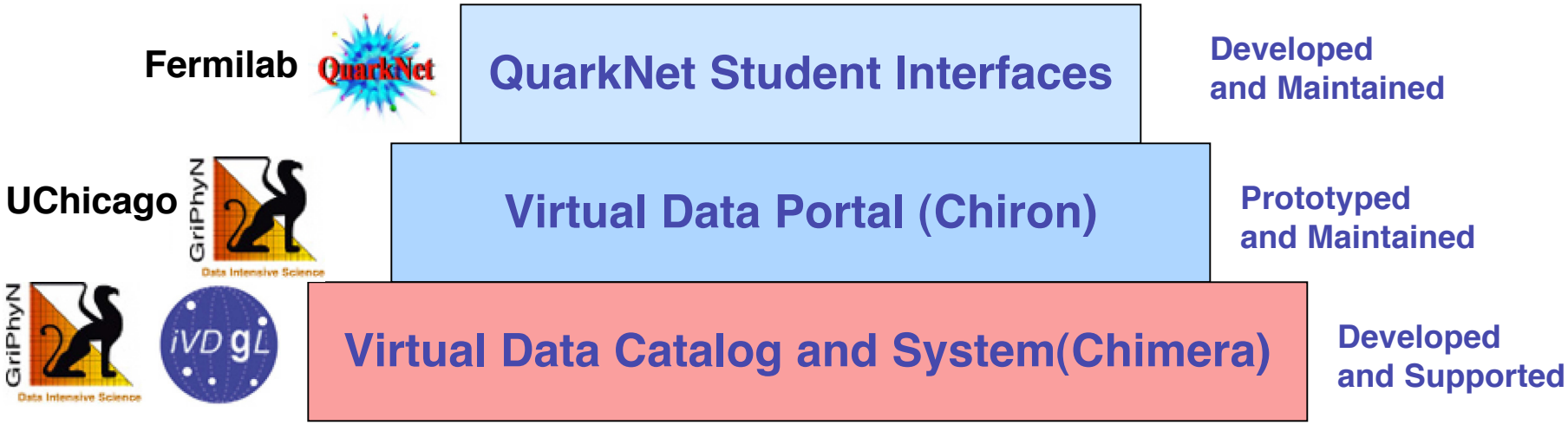
Investigation | View Posters | Edit Posters | View Plots | New Poster | Poster Session | Data Analysis

Comments for Poster seattle

- Enter your name.
- Add your comments in the New Comments field.
- Click **Add Comments**.

Poster Name:	seattle
Current Comments:	2-14-2004 3:25 James Parker, Philadelphia- This was a beautiful experiment. Were you able to solve your problem with the leak? 2-14-2004 3:26 Harry Maxwell, Seattle- Yes, we were able to fix that problem.
Your Name:	
Add Your Comments:	
	Add Comments

Architecture



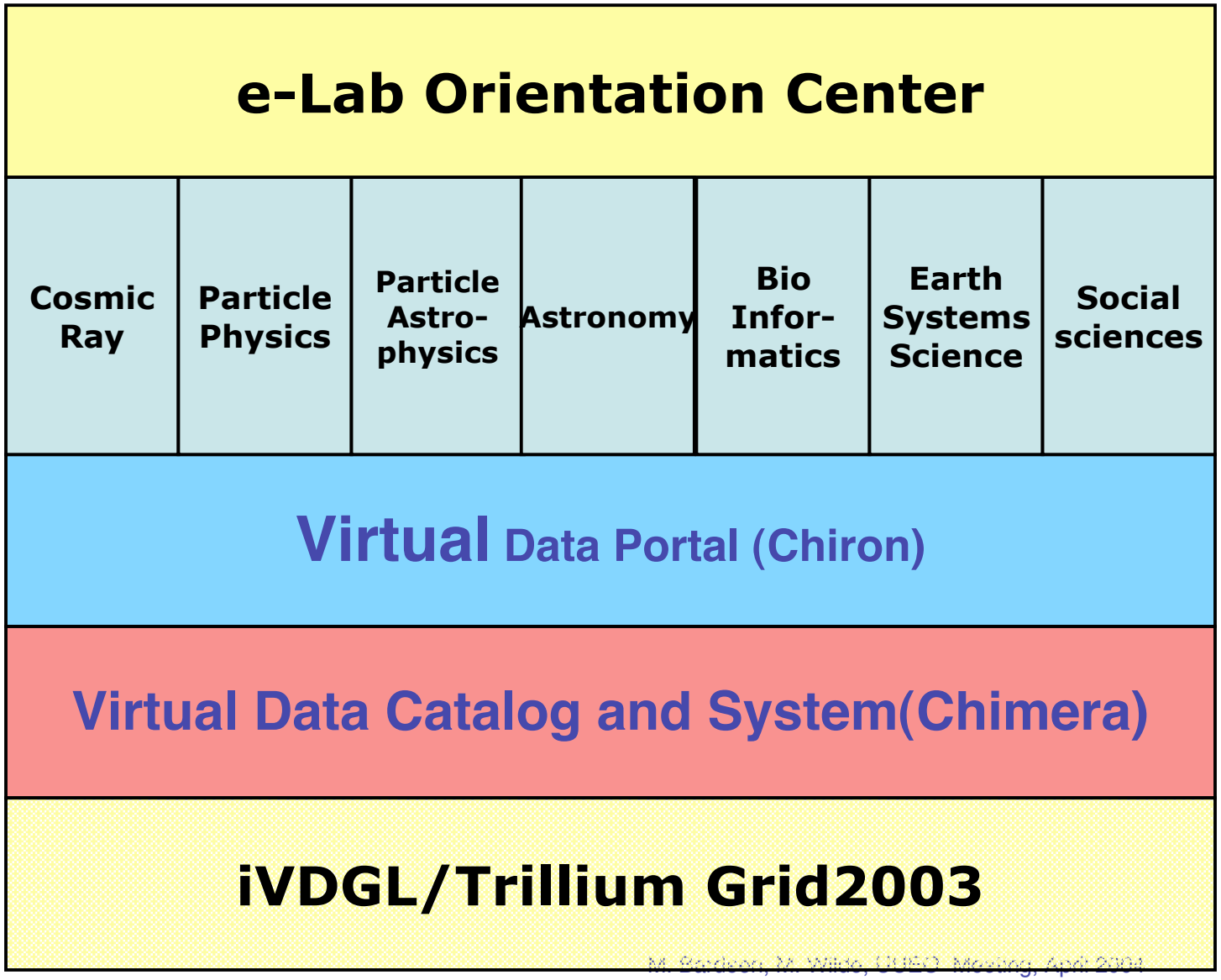
Building an e-Lab

Application modules Need 1 FTE support

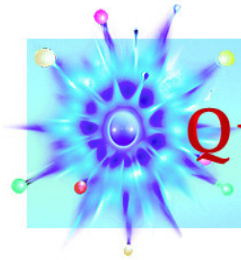
Portal needs 1 FTE developer

GriPhyN to provide virtual data research & support through 8/2005

iVDGL to support Grid testbed through 8/2006



M. Bardeen, M. Wilde, (UEC) Meeting, April 2004

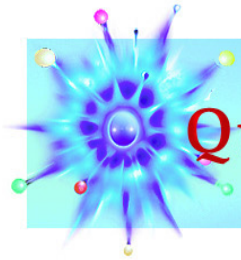


Helping Develop America's Technological Workforce

Everybody Wins

Education — A new style of collaborative learning:

- Investigating highly motivating science content
- Modeling scientific research
  - Analyzing data
  - Publishing and defending results
  - Reviewing results of others
  - Synthesizing findings
- Using Grid tools and techniques
  - Computing resources
  - Data on the Grid
  - Systematized data analysis (metadata)
  - Collaboration tools



Helping Develop America's Technological Workforce

Everybody Wins

Scientific Research and Computer Science Research

- **Non-traditional participants in the research process**
  - Enriches collaboration in experimental, theoretical and computer science groups
  - Invigorates experiment and software design and construction
  - Invigorates beam tests, experiment operation, simulation studies, data analysis and publication
- **Potential students**
  - Early key contacts in the education system
  - Means to reach underrepresented groups
- **Workforce development**
  - Future research scientists and computer scientists
  - More than just scientists "do science"
  - Proactive response to the question "Where are the Americans?"
- **Public support for scientific research**
  - Participants as Goodwill Ambassadors for science
  - Funding and sustaining science initiatives (often long-term)