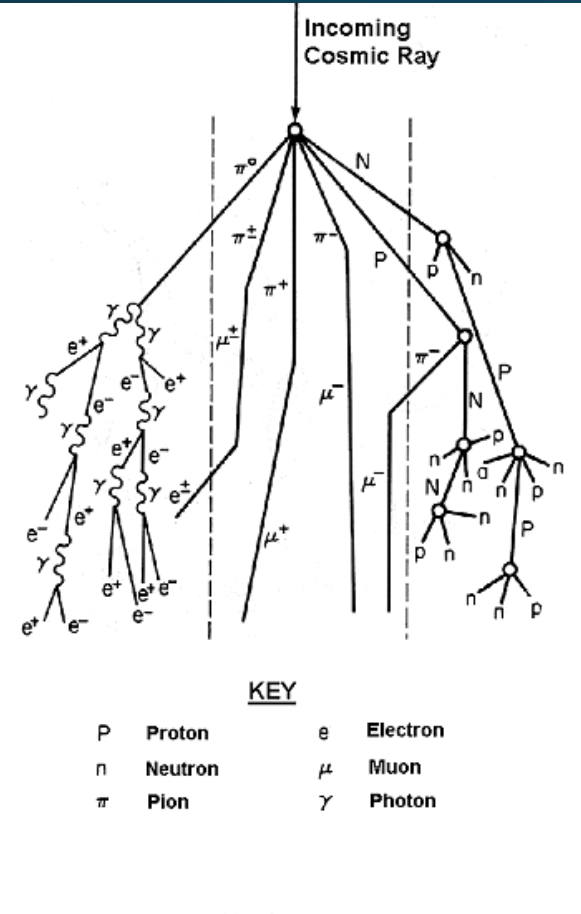
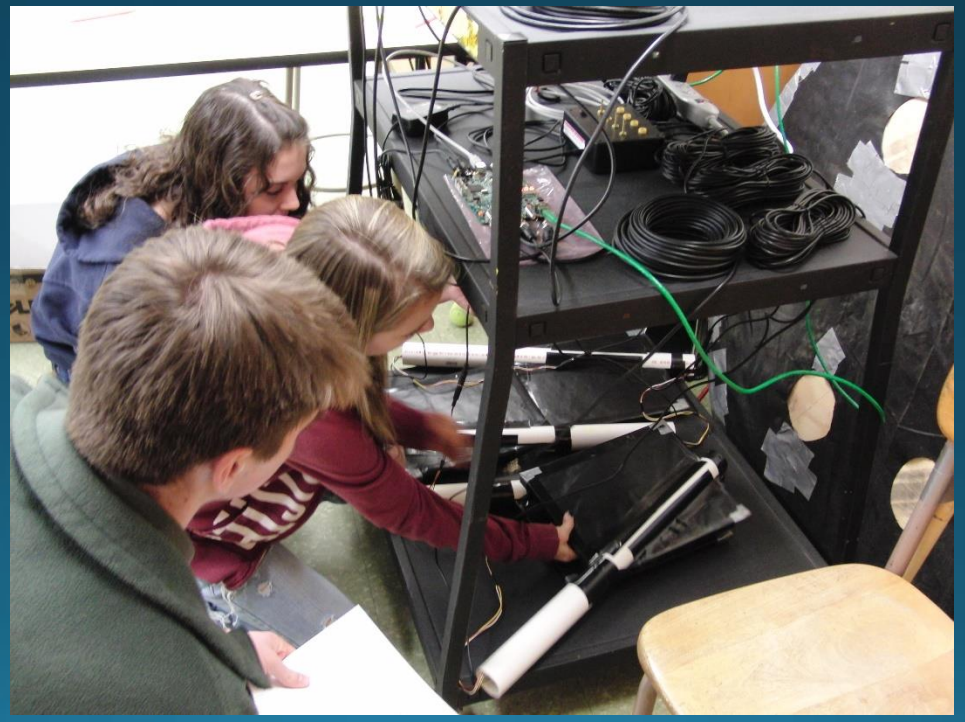
Cosmic Ray e-Lab

Nathan A. Unterman
Rice University
26-28.June.2017





Housekeeping

- Safety briefing
- Keep the area clean
- Label all of your cords, etc. (NOW)
- Sign in and other forms
- Schedule (Drupal)
- Survey (on your last day)
- Stipends

Teaching and Learning with Cosmic Rays

Agenda

- Rice University Cosmic Ray Workshop

Workshop Objectives:

- Configure a cosmic ray detector appropriately for acquisition of data for calibration and analysis of measurements
- Identify and describe the e-Lab tools available for conducting studies with data collected using a cosmic ray detector
- Create, organize and interpret a data plot to make a claim based on evidence; provide reasoning and identify data limitations
- Develop a plan for taking students from their current level of data use to subsequent levels using activities and/or ideas from the workshop.

Teaching and Learning with Cosmic Rays

Active QuarkNet Centers

http://physicsweb.phy.uic.edu/quarknet/mapUS_international.html

http://quarknet.fnal.gov

Teaching and Learning
with Cosmic Rays

- QuarkNet creates a collaboration of users:
  - Teachers ←→ Students
  - Teachers ←→ Mentor Scientists
  - Detector Schools ←→ Non-Detector Schools
  - World-wide Network: Students ←→ Students

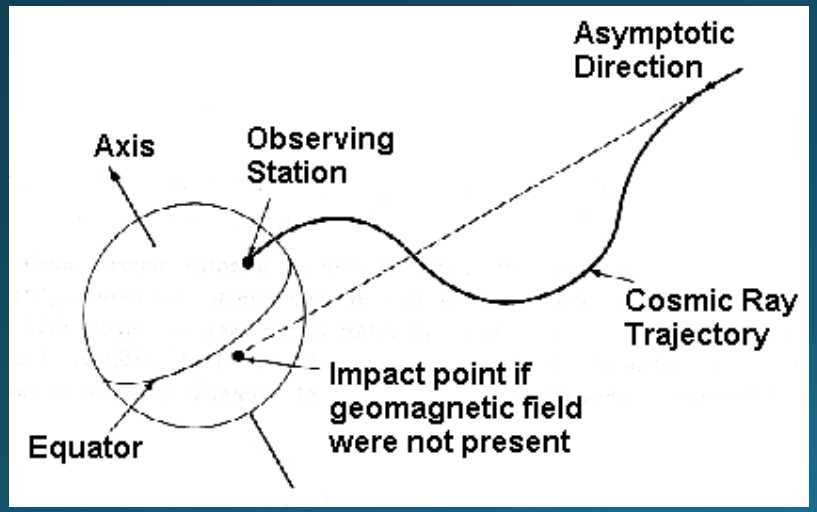
Paradigm: a good way to learn science?

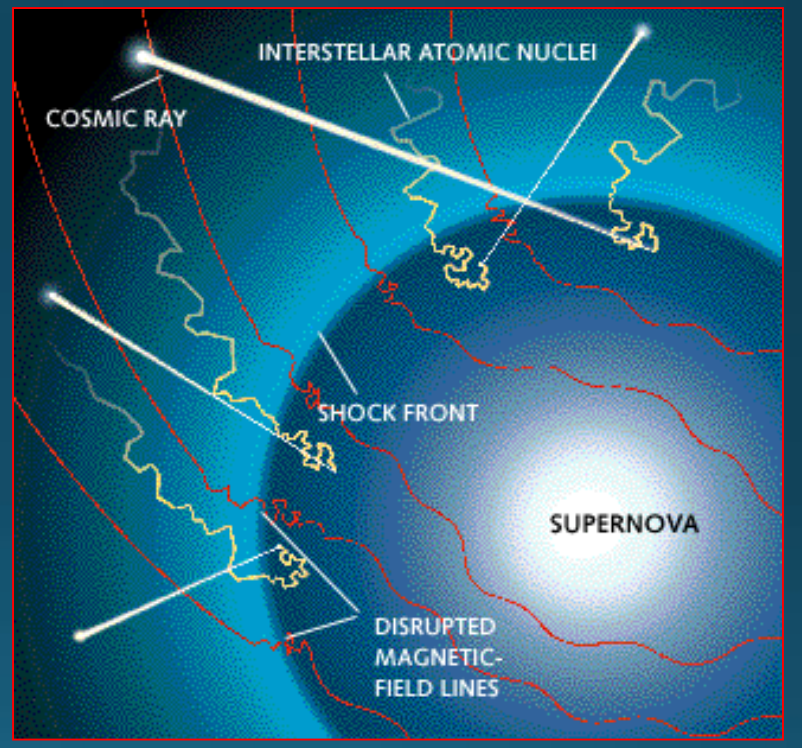
- → Participate in data-based science.
- – Ask cosmic ray questions.
- – Marshal a research plan.
- – Engage hardware and technology.
- – Analyze realistic, not simulated data.
- – Share results with collaboration.

Teaching and Learning with Cosmic Rays

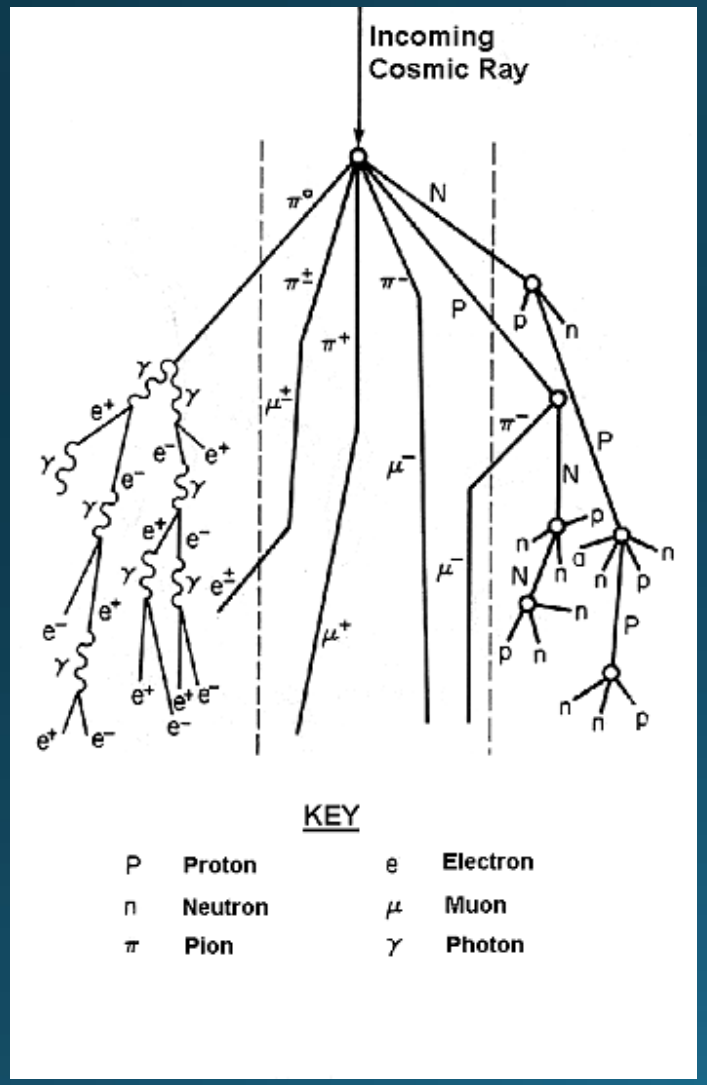
Sources of Cosmic Rays

- Supernova remnants
- Active galaxies (?)
- Quasars (?)
- Gamma Ray Bursters (?)
- Dark Energy (?)



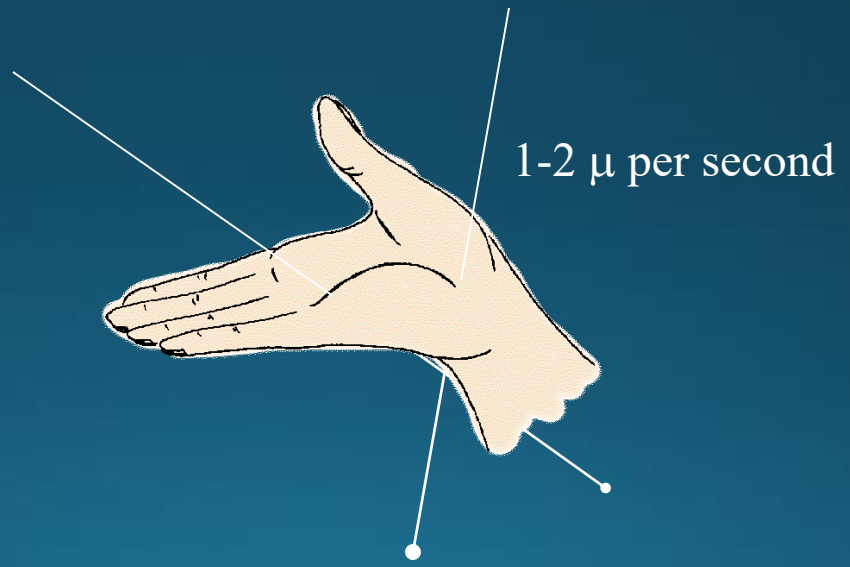


Teaching and Learning with Cosmic Rays



Cosmic Rays at Earth

- Primaries (protons, nuclei)
- Secondaries (pions)
- Decay products (muons, photons, electrons)

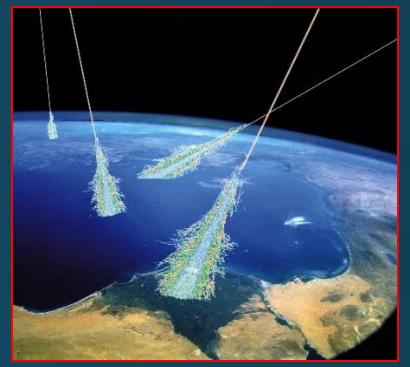


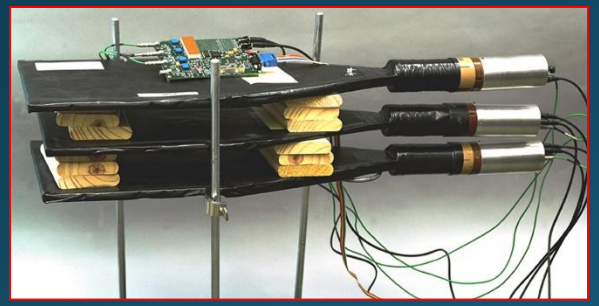
Run: Cosmic Ray shower video

http://astro.uchicago.edu/cosmus/projects/aires/protonshoweroverchicago.mpeg

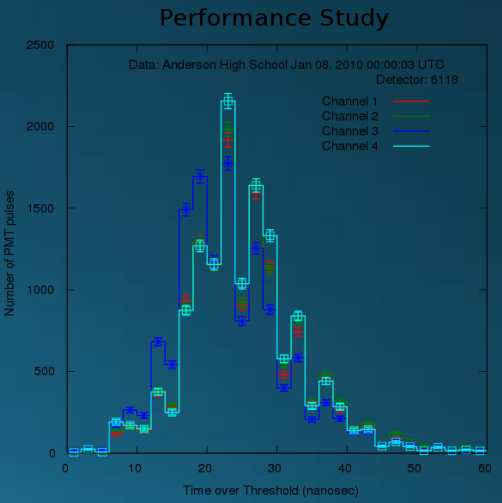
Teaching and Learning with Cosmic Rays

- Cosmic Rays
  - Sources
  - Composition, energy spectrum
  - Detection
  - Current experiments





- **The QuarkNet Classroom Detector**
  - **Hardware overview**
  - **Classroom use**
  - **Experiments, measurements**



- **Data Analysis**
  - **Upload, analyze data & save data products.**
  - **Share results.**
  - **Enter logbook notes.**

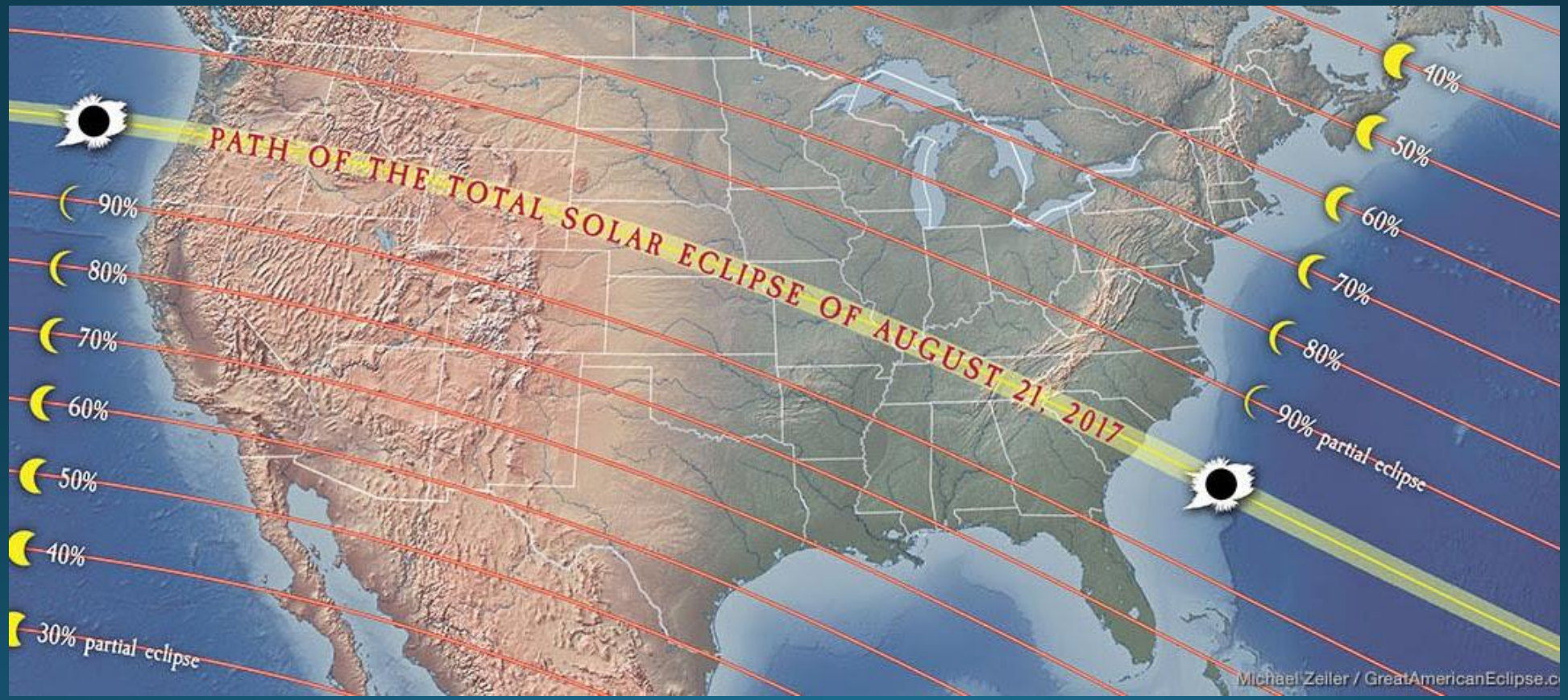
Wealth of open, cool science questions

- Weather, lightning, eclipses, biology, climate, data bits, solar storms, scaling, refraction, Faraday Cage, …

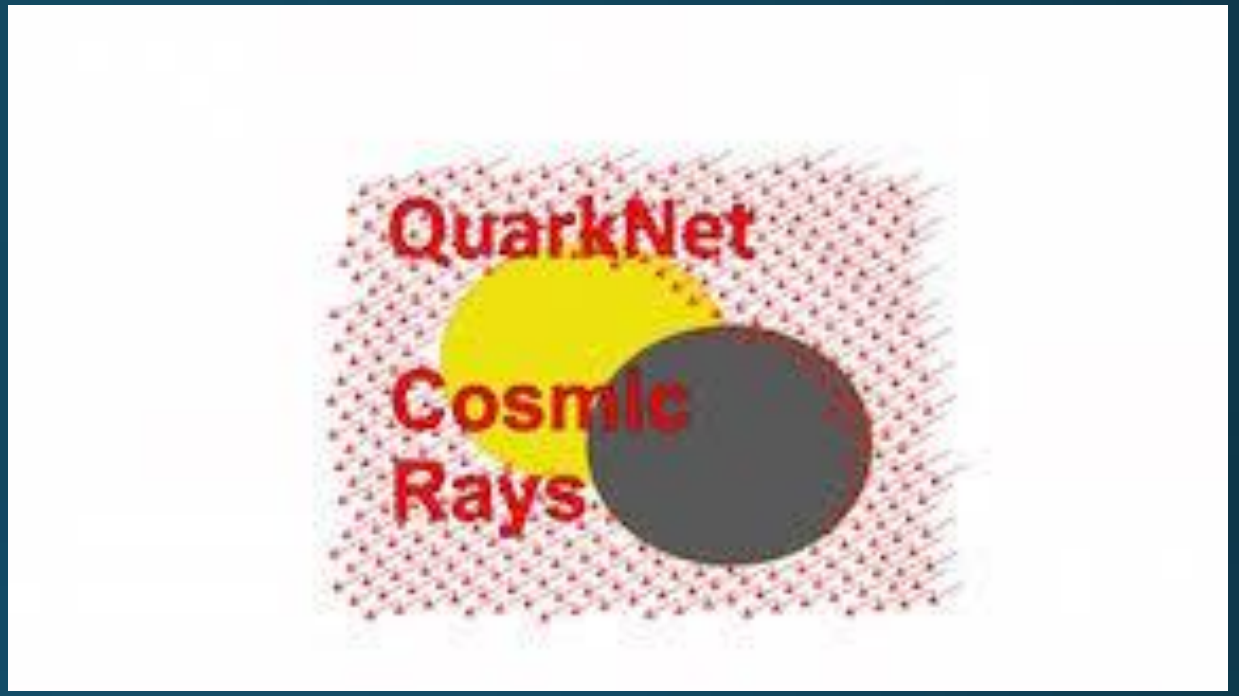
CR e-Lab → not prescriptive, not recipes

- Provides resources and analysis tools
- Trusts the teacher to guide research

Eclipse Project



Home Site

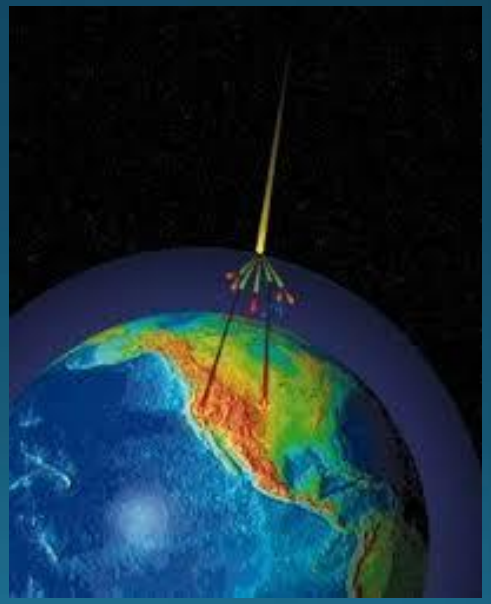


[QuarkNet Eclipse Home Site]

https://sites.google.com/view/quarknet2017eclipse/home

Hypothesis

- The muon flux will change during a total eclipse of the sun.



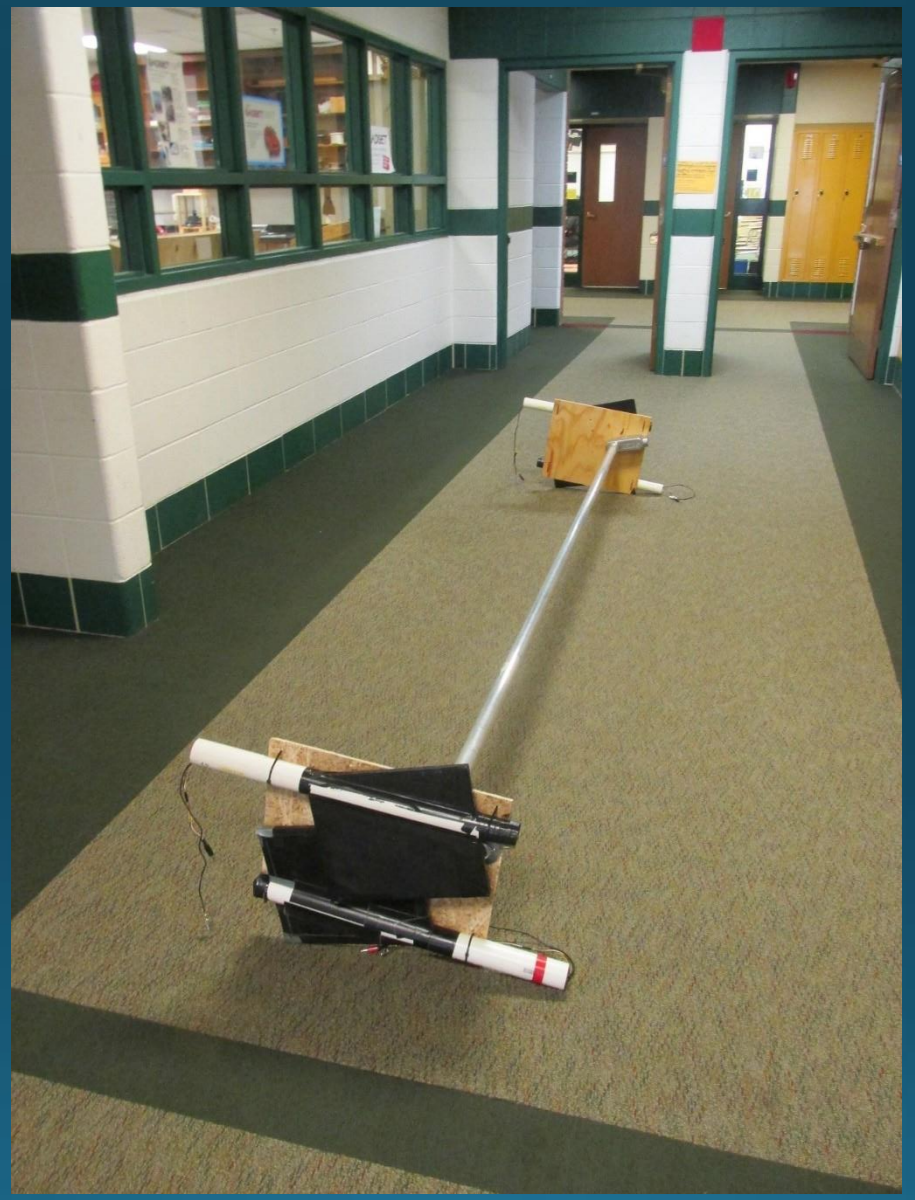
Proof of Concept

- Ida Crown Jewish Academy did proof of concept
  - DAQ 6994 Starting about 9.April.2017

- Two telescope designs and configurations
  - Fixed
    - East-West
  - Tracking
    - East-West
    - North South
- Vertical stack

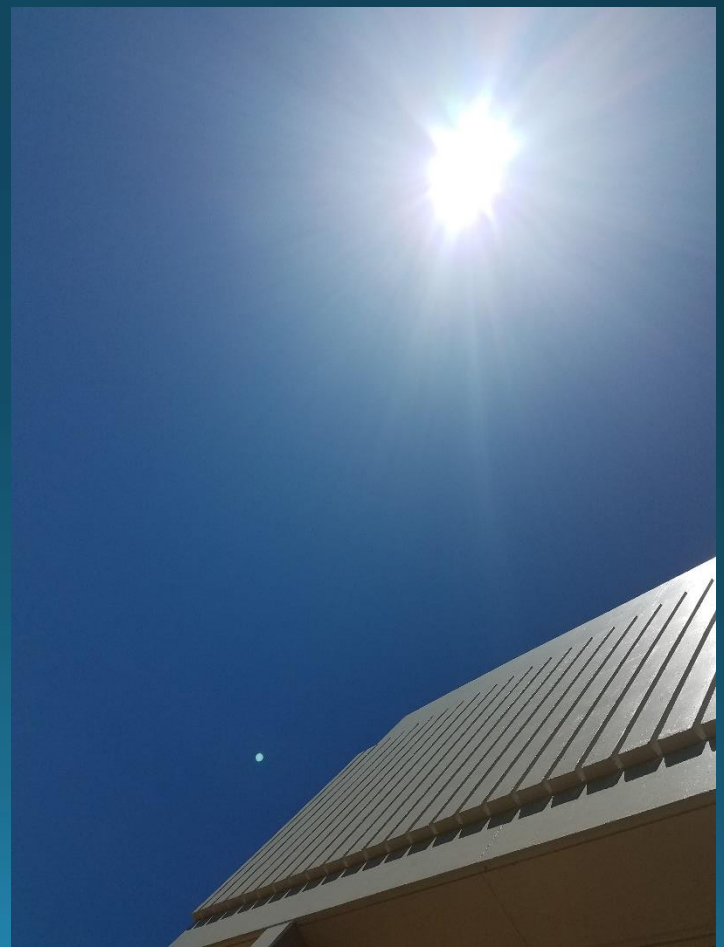
Board Assembly

Complete Tracking Assembly



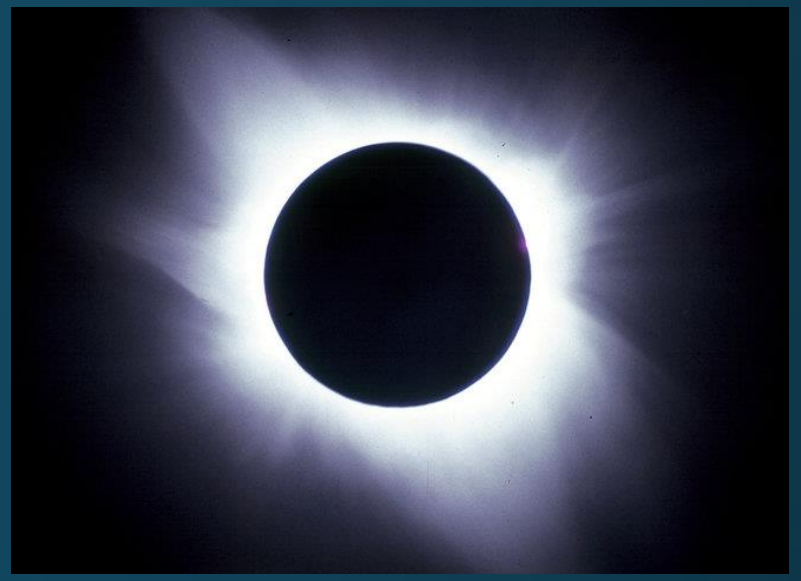
Baseline Measures

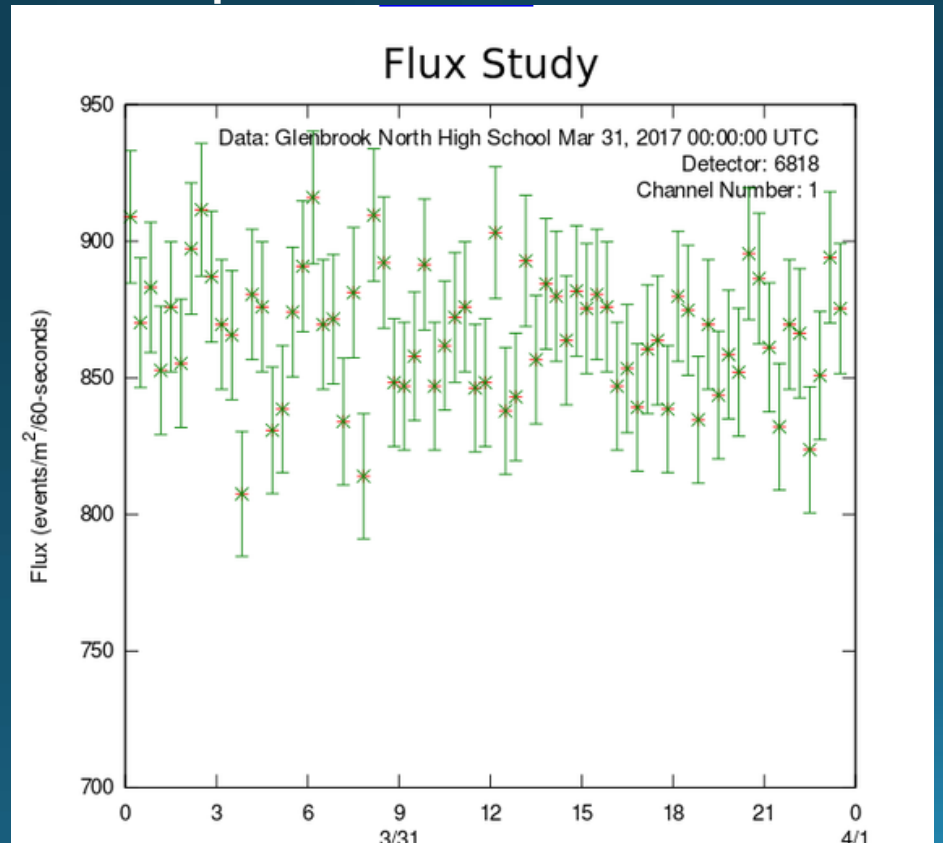
- Empty sky near position sun will be in for eclipse
- Moon in position of eclipse
- Sun in position of eclipse
- Vertical stack for background



Experiment

- Take data during eclipse
- Make flux comparisons





Needed

- Calibrated barometer
- Plateaued counters
- Stand
- Data

TASK

- Build 3 fixed position telescopes

Questions???

Break??→

Cosmic Ray eLab

- EQUIP

- Sign in to eLab
- Teachers: Create group: Eclipse#### where #### is DAQ number

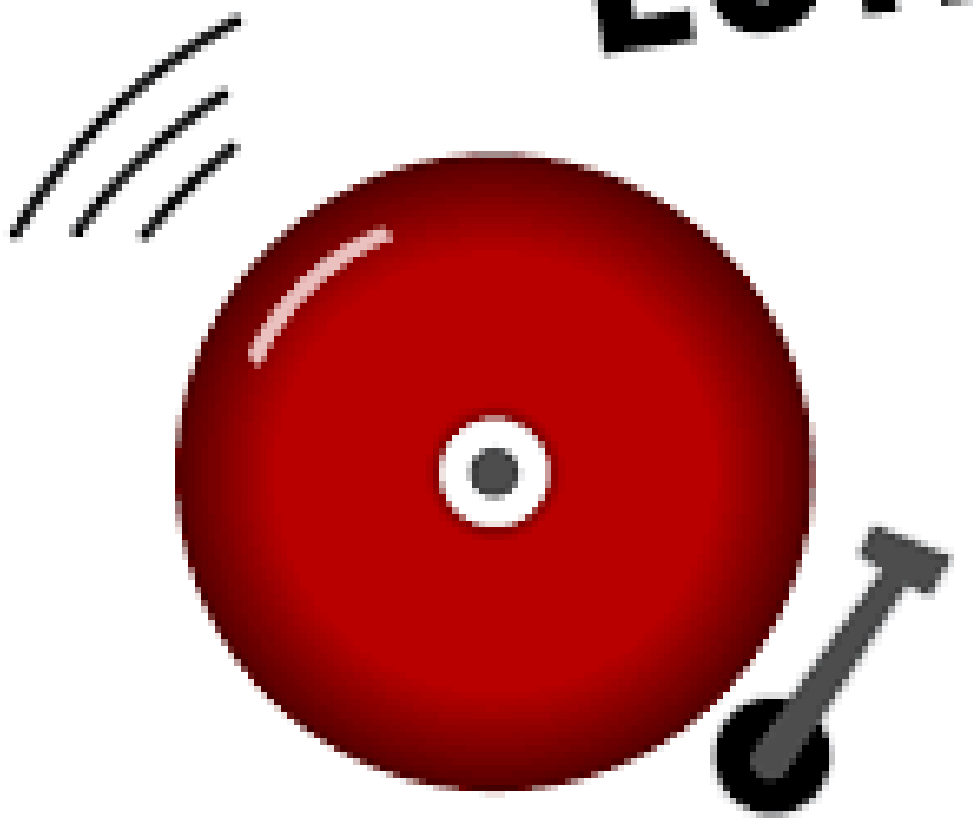
- Review Geometry (must be uploaded before start of data file)
- Uploading Data
- Comment Field
- Additional Data Diary on Google Site

- Aiming

Calibration

- Barometer (absolute, not corrected for sea level pressure)
- Plateau counters

TIME *for* LUNCH



Classroom Activities

- Histograms
- Flux experiments
  - Overlap
  - Separation
    - Horizontal
    - Vertical
  - Refraction
  - Barometric Pressure
  - Faraday Cage
  - Angle (declination, direction)
  - Solar Activity
  - Materials Science

Classroom Activities (continued)

- Shower
  - Direction
  - Among detectors
- Time of Flight
- Muon Lifetime (not half-life)
- International Muon Day
- Eclipse Experiments

Small Group Experiment

- Create an experiment.
- Set up for overnight data

- IF doing something eclipse related, be sure to sign in through the Eclipse Site

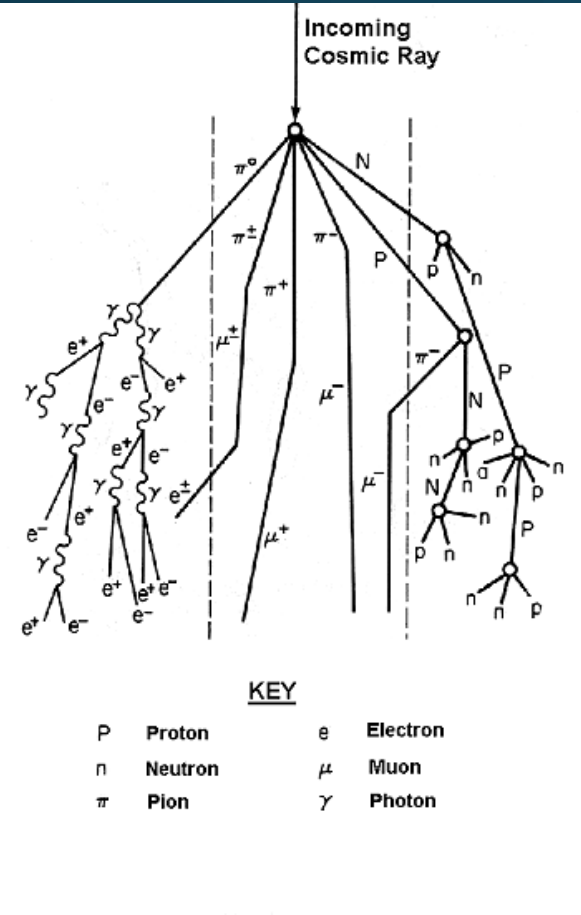
Reflection

- How are we doing?
- Are we on target with the Objectives?
- What next?

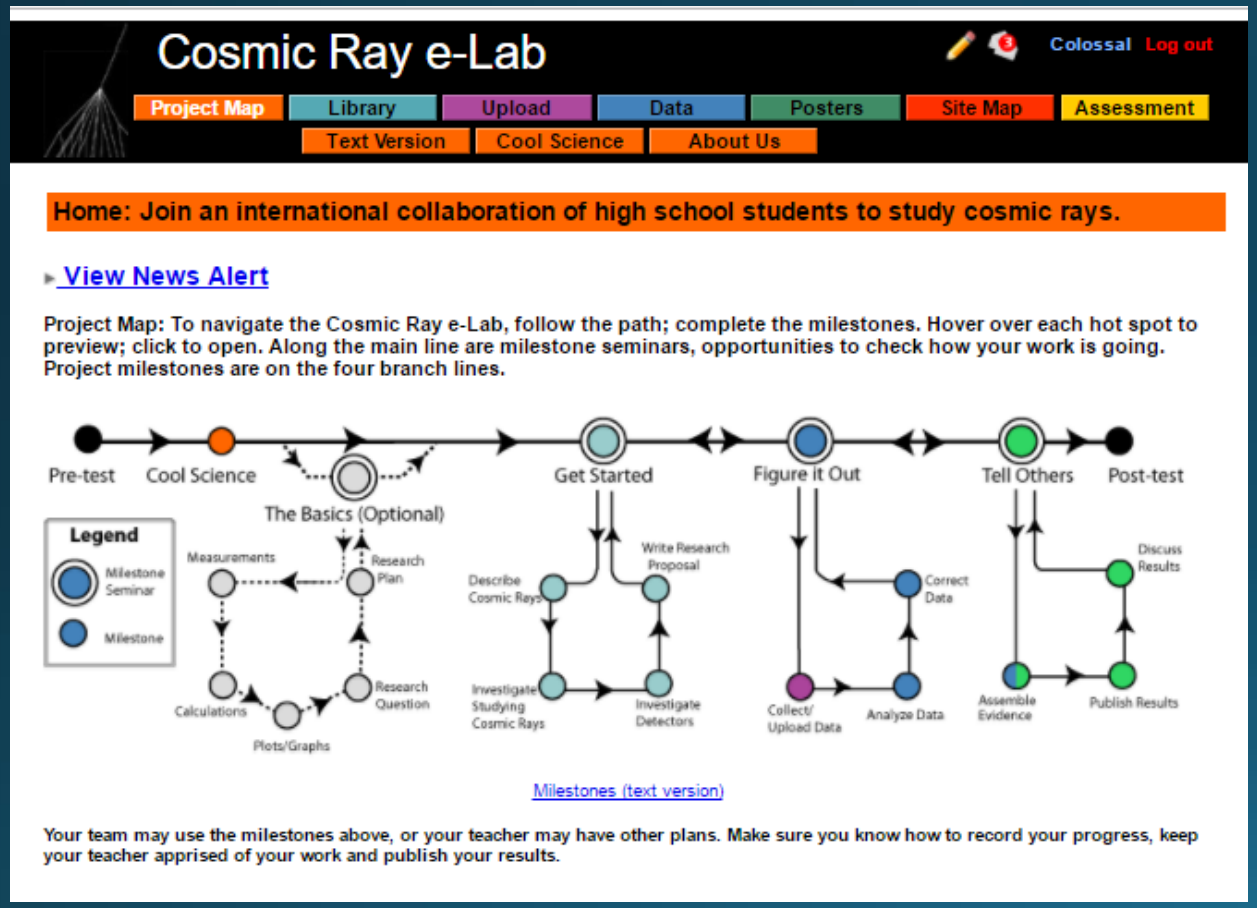
Teaching and Learning
with Cosmic Rays

Overview: Cosmic Ray Muon Detector

Nathan A. Unterman
Rice University
27.June.2017



Lids up!


Cosmic Ray e-Lab
Colossal Log out
Project Map
Library
Upload
Data
Posters
Site Map
Assessment
Text Version
Cool Science
About Us
Home: Join an international collaboration of high school students to study cosmic rays.
View News Alert
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.
Pre-test
Cool Science
The Basics (Optional)
Get Started
Figure it Out
Tell Others
Post-test
Legend
Milestone Seminar
Milestone
Measurements
Research Plan
Calculations
Research Question
Plots/Graphs
Describe Cosmic Rays
Write Research Proposal
Investigate Studying Cosmic Rays
Investigate Detectors
Collect/ Upload Data
Analyze Data
Correct Data
Assemble Evidence
Publish Results
Discuss Results
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.


Total Eclipse of the Sun

Thermographic ink (UV degrades)

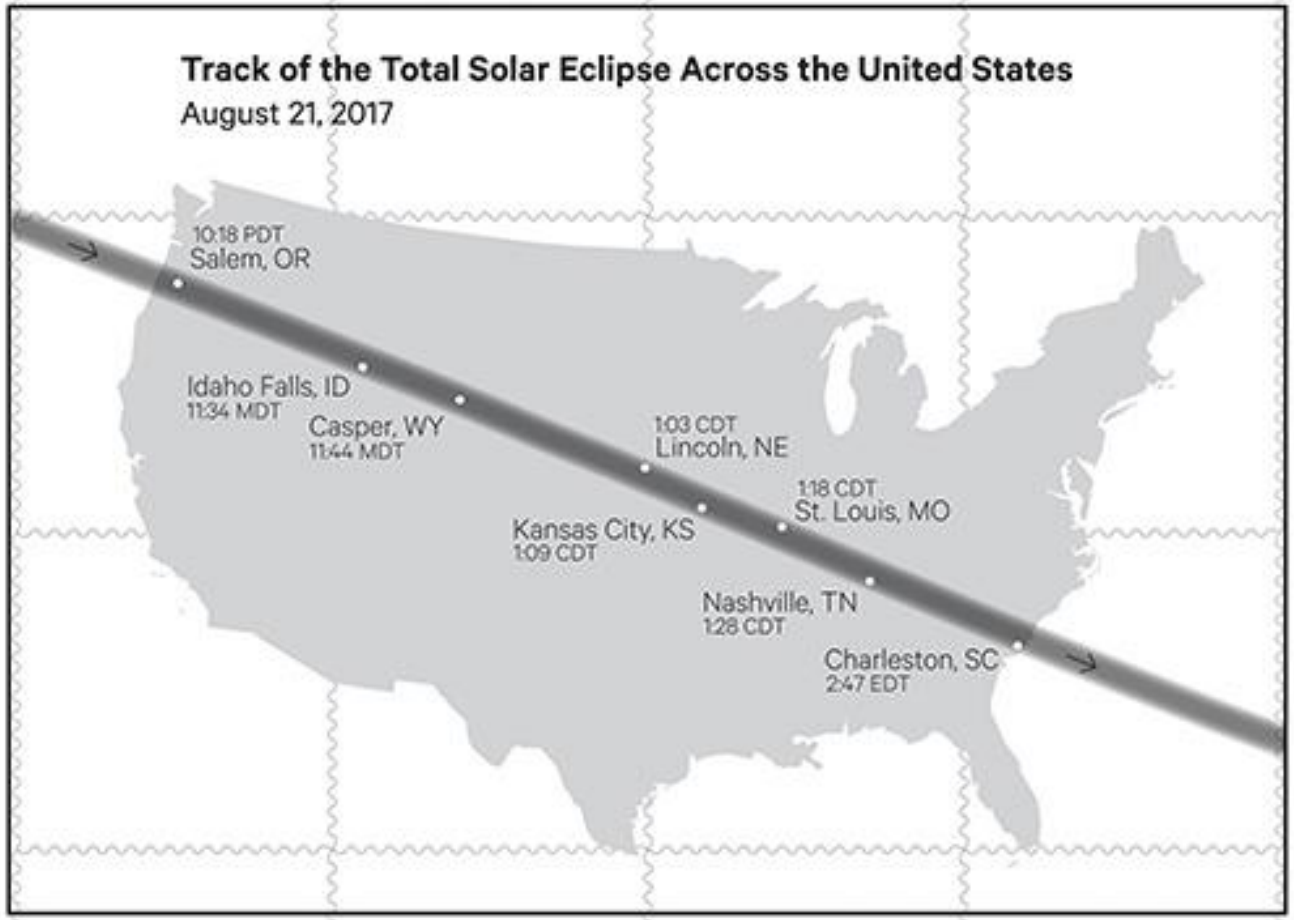


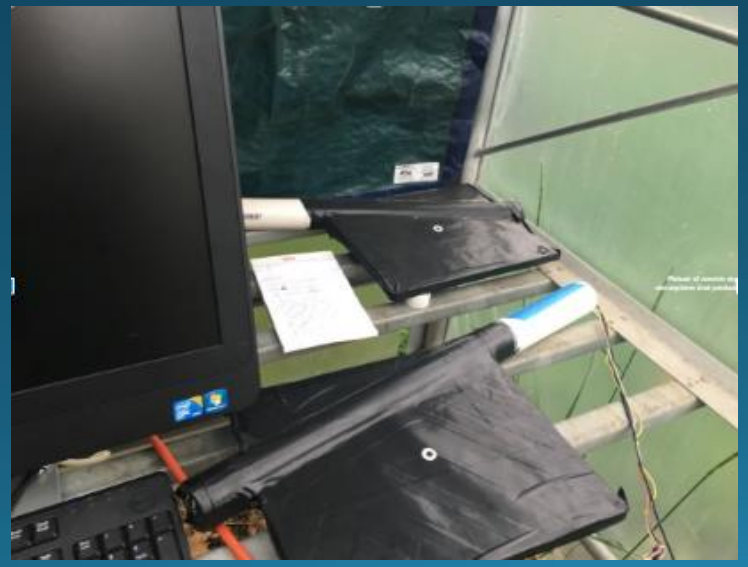
PLATE POSITION

UNITED STATES POSTAL SERVICE®

From Parking Lot

- What is the parking lot?
- Velcro cable ties

- Registration
- https://goo.gl/forms/dZsRjQq1fWSilxJD2
-
- Dots



Geometry

Edit Detector 6818 Entry 18 Dec 2016 @ 00:54 UTC:

Detector Geometry

If you are using EQUIP for data acquisition, you still need to enter geometry data on this page for use in the Cosmic Ray e-lab.

GPS is @ (0,0,0).

Each point (x,y,z) represents the center of a counter.

Confused? Seeing errors? Please consult the Geometry Tutorial.

Active Channels:	1 ✔	2 ✔	3 ✔	4 ✔
Cable Length (m)	Area(cm²)	x:E-W(m)	y:N-S(m)	z:Up-Dn(m)
1	15.24	773.99999	-1.2	-.23	-2.97
2	15.24	773.99999	-1.2	-.23	-3.27
3	15.24	773.99999	-1.2	-.23	-3.57
4	15.24	773.99999	-1.2	-.23	-3.87

Stacked Orientation Unstacked

Visualize geometry

GPS Coordinates

GPS Coordinates Tutorial Find GPS Coordinates

Latitude: 42:06.697765 N e.g., 47:39.234736 N

Longitude: 087:49.830054 W e.g., 122:18.68 W

Map GPS Coordinates

Altitude (m): 194.453 GPS Cable Length (m): 35.05

Commit Geometry

Cosmic Ray e-Lab

gbnteacher Log out

Project Map | Library | Upload | Data | Posters | Site Map | Assessment

Upload | Geometry | Benchmark | Blessing

Detector 122
- Mar 15, 2010 @ 17:22
- Jan 09, 2010 @ 00:00
- Nov 12, 2009 @ 16:34

Detector 5099
- May 03, 2011 @ 15:28
- Feb 02, 2011 @ 00:00
- Mar 18, 2010 @ 16:21
- Mar 17, 2010 @ 17:15
- Mar 16, 2010 @ 17:10
- more...

Detector 6429
- Oct 28, 2015 @ 18:15
- Dec 06, 2014 @ 00:53
- Dec 01, 2014 @ 15:23
- Jan 22, 2013 @ 12:00
- Nov 20, 2012 @ 16:00
- more...

Detector 6690
- Jul 29, 2016 @ 01:35
- Jul 28, 2016 @ 14:19
- Jul 26, 2016 @ 20:00
- Jul 25, 2016 @ 02:14
- Apr 15, 2016 @ 14:00
- more...

Detector 6703
- Jun 22, 2014 @ 22:36
- Nov 19, 2012 @ 12:00
- Jul 11, 2012 @ 00:00
- Jul 10, 2012 @ 14:12
- Jul 10, 2012 @ 14:00
- more...

Detector 6818
- Dec 18, 2016 @ 00:54
- Dec 05, 2016 @ 00:00
- Oct 26, 2016 @ 17:37
- Oct 20, 2016 @ 20:22
- Oct 19, 2016 @ 20:50
- more...

New Detector 6818 Entry:

Date: June / 18 / 2017 @ 00 : 54 UTC *Detector Geometry*

If you are using EQUIP for data acquisition, you still need to enter geometry data on this page for use in the Cosmic Ray e-lab.

GPS is @ (0,0,0).

Each point (x,y,z) represents the center of a counter.

Confused? Seeing errors? Please consult the Geometry Tutorial.

Active Channels:	1 ☐	2 ☐	3 ☐	4 ☐
Cable Length (m)	Area(cm²)	x:E-W(m)	y:N-S(m)	z:Up-Dn(m)
1				
2				
3				
4				

Stacked Orientation Unstacked

Visualize geometry

GPS Coordinates

GPS Coordinates Tutorial Find GPS Coordinates

Latitude: 0:0.0 N e.g., 47:39.234736 N

Longitude: 0:0.0 W e.g., 122:18.68 W

Map GPS Coordinates

Altitude (m): 0 GPS Cable Length (m): 0.0

Please activate channels.
Non-zero values are required for cable length and counter area.

Commit Geometry

Teaching and Learning with Cosmic Rays

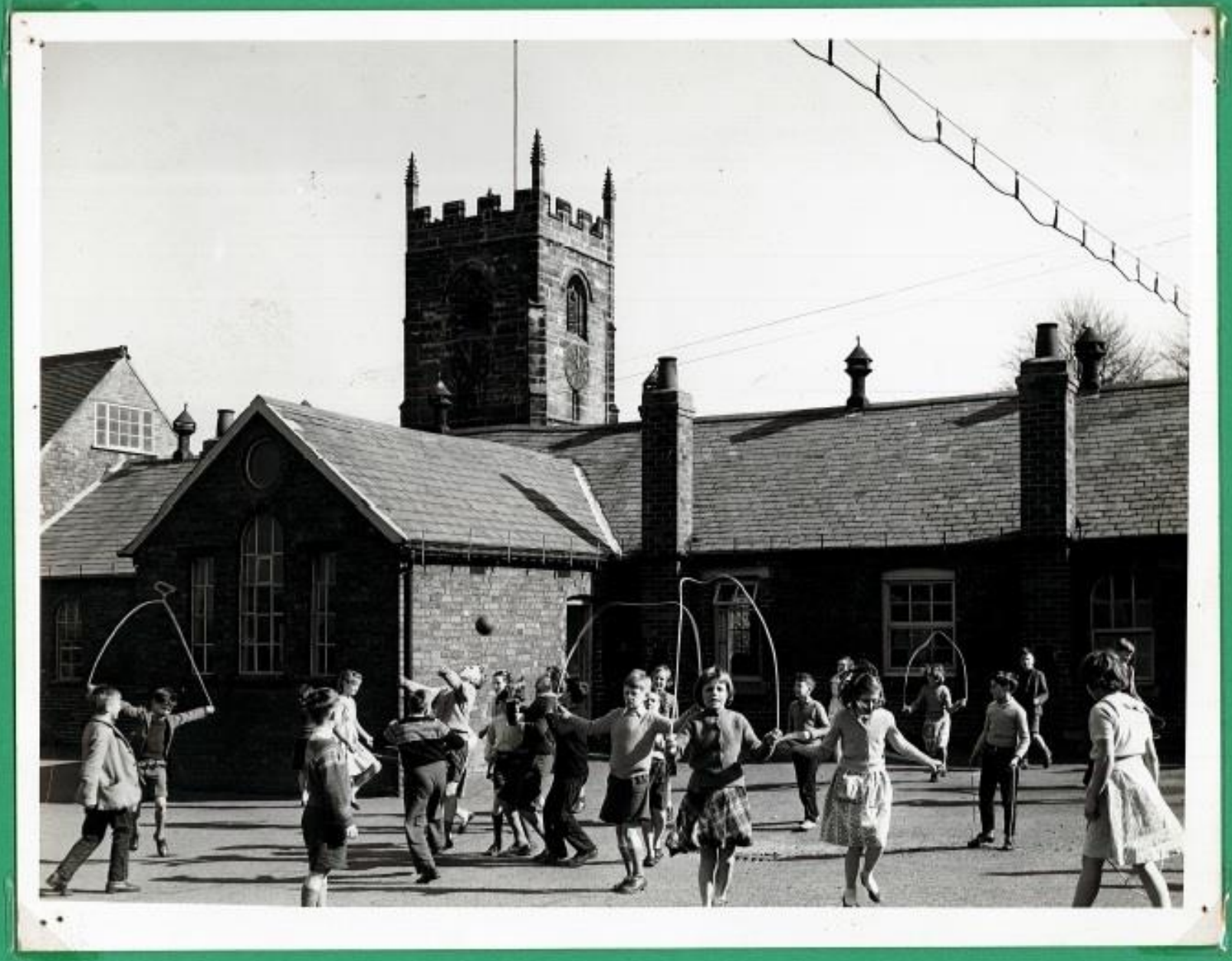
Workshop Objectives:

- Configure a cosmic ray detector appropriately for acquisition of data for calibration and analysis of measurements
- Identify and describe the e-Lab tools available for conducting studies with data collected using a cosmic ray detector
- Create, organize and interpret a data plot to make a claim based on evidence; provide reasoning and identify data limitations
- Develop a plan for taking students from their current level of data use to subsequent levels using activities and/or ideas from the workshop.

Tour of eLab

- Creating groups
- Advanced Searching
- Performance
- Blessing
  - Blessing charts
- Time of Flight
- Requests?

Dr. Stan Sazykin



Breaktime

Upload Data From Overnight

How to evaluate worth of data

- View Data
  - Blessing Charts
- Performance

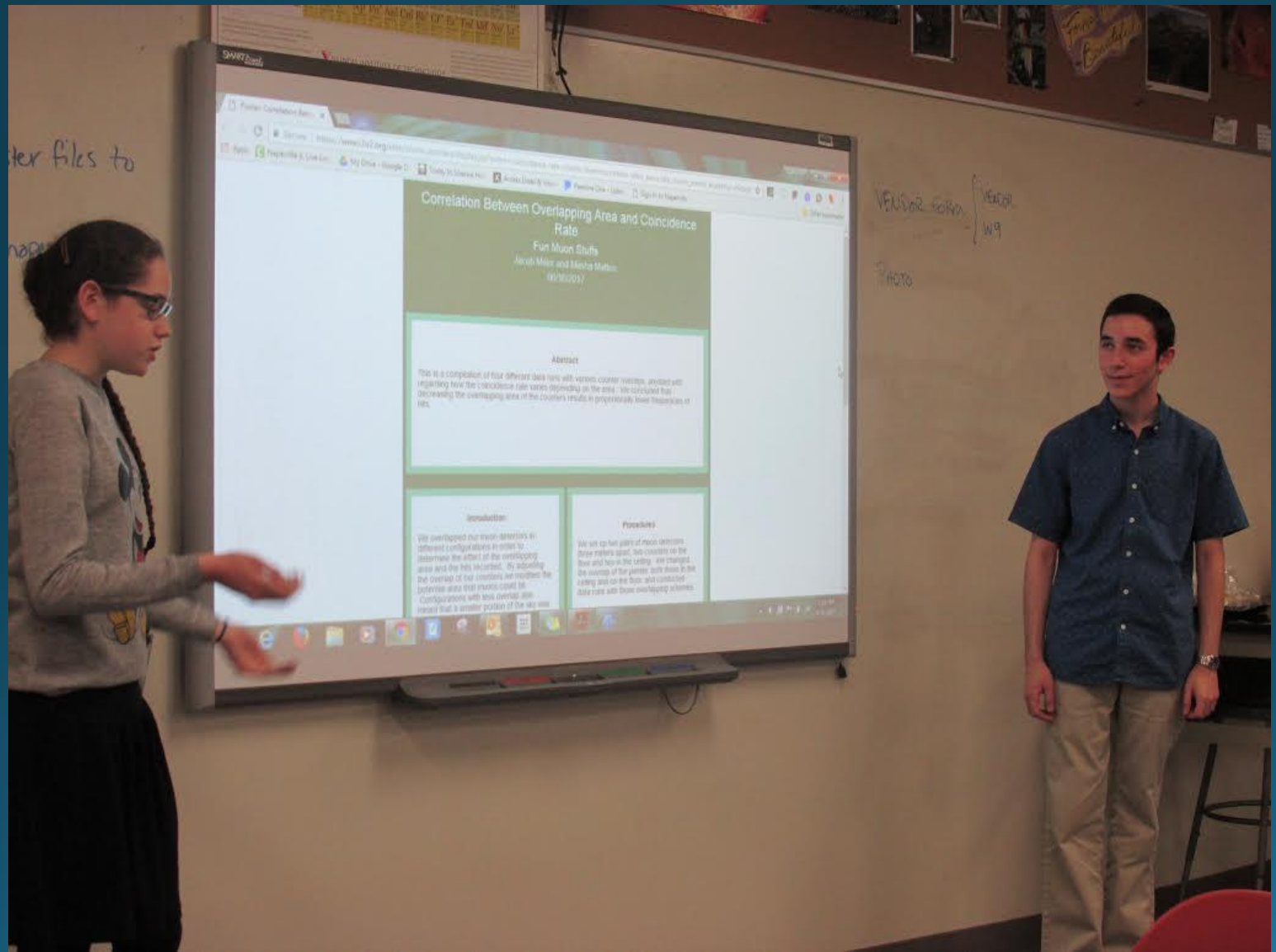
- What experiment do you want to do?

Setup for Second Data Run

Questions?

- What questions do you have?
- Quick whip around on what you are studying

eLab Poster


Correlation Between Overlapping Area and Coincidence Rate
Fun Muon Stuffs

Make Signs http://www.makesigns.com/tutorials/

Cosmic Ray Study: the Effect of Detector Area on Shower Rates

Kamryn Abraskin, Brian Burke, Kendall Crispin, Tony Valsamis, Nathan Unterman
Glenbrook North High School, Northbrook, IL 60062

Abstract

The researchers measured the relationship between the number of cosmic ray showers per unit time and separation distance. Our initial findings suggested the burden of material above the counters might have an effect, so we repeated the experiment outdoors. By testing shower rates outside in a greenhouse with very thin roofing material, it would be possible to detect what, if any, effect roofing material has on shower rates.

Background

Cosmic rays consist of high energy particles, mainly protons, alpha particles, beta particles, and HZE ions (heavy atomic nuclei). These primary cosmic rays produce secondary particle showers through interaction with Earth's atmosphere. When cosmic rays enter Earth's atmosphere, they often collide with oxygen or nitrogen. This high energy collision creates the secondary shower which consists of electromagnetic radiation, pions, anti-particles, and other exotic forms of matter. Some of these secondary particles decay into muons, which reach the surface and can be easily detected by scintillators. Muons are second generation leptons with a mass of 105.7 MeV/c^2. They are unstable, with a lifetime on the order of microseconds. Even though they have such a short lifetime, they are able to reach Earth's surface through temporal dilation and spatial contraction described by Einstein's theories of relativity. On average, 10,000 muons reach every square meter of Earth's surface every minute.

Picture of cosmic rays hitting atmosphere and producing showers.

Motivation

The researchers investigated the effect of detector area on the cosmic ray shower rates measured by the occurrence of multiple muons. Detectors were also operated both indoors and outdoors, examining the differences in data with and without a roof. We wanted to see if the separation of counters changes the number of muon hits per hour. We hypothesized that if the area of the detector is increased, then the shower rates of incoming cosmic rays will decrease.

Procedure

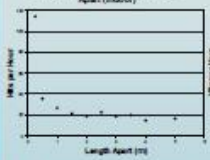
Three cosmic ray counters were arranged in an equilateral triangle, starting with all the counters in contact. After each trial, the counters were moved such that the length of each side of the triangle is increased by 0.5 meters as measured from a fixed position at the center of each counter. The final trial was 5 meters separation. The indoor trials took place in a room with 15 centimeters of roofing material located above the detector. Each counter had identical setups. Shower hits per hour were plotted against both length of the triangle and effective area of the triangle. The same procedure was duplicated outside in a greenhouse, with a 0.25 millimeter plastic roof. The outdoor trial was 30 meters west from the indoor trial.

Three detectors used in indoor data testing that are 30 centimeters apart from one and another.

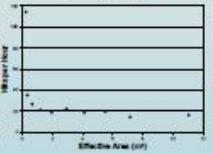
Indoor Data

Length (m)	Effective Area (m^2)	Hits per Hour
0.25	0.26	114.1
0.5	0.34	35.4
1.0	0.87	26.7
1.5	1.21	21.3
2.0	1.96	18.7
2.5	2.94	22.4
3.0	4.13	18.6
3.5	5.54	19.9
4.0	7.16	14.6
5.0	11.06	16.4

Average Events per Hour vs Length Apart (Indoor)



Average Events per Hour vs Effective Area (Indoor)



The rate cosmic rays detected per hour as a function of the length of the equilateral triangle of detectors (meters).

The rate cosmic rays detected per hour as a function of the effective area (meters).

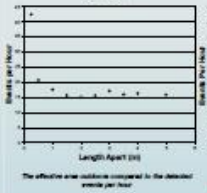
The trend of the data shows as the effective area and length increased, the number of coincident showers per unit of time decreases, thus there is an inverse relationship. Two field findings are hinted, one until about 2.5 meters^2, and the other greater than 2.5 meters^2. It is hypothesized that interactions in the overburden of the roof may cause this increase at small separation. In order to verify if that is true, testing will be continued in a greenhouse with 0.25 millimeters of plastic roof.

Outdoor Data

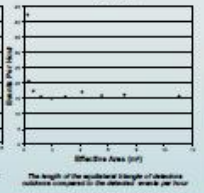
Setup of the outdoor trial within the greenhouse. Counters were 30 centimeters apart.

Length (m)	Effective Area (m^2)	Events Per Hour
0.25	0.26	42.4
0.5	0.34	20.7
1.0	0.67	17.5
1.5	1.21	15.7
2.0	1.96	15.1
2.5	2.94	15.6
3.0	4.13	17.2
3.5	5.54	16.0
4.0	7.16	16.2
5.0	11.06	15.8

Average Events per Hour vs. Length (Outdoor)



Average Events per Hour vs Effective Area (Outdoor)



The effective area outdoors compared to the detected events per hour.

The length of the equilateral triangle of detectors outdoors compared to the detected events per hour.

While the graphs of the indoor and outdoor data have a similar curve, there is a significant displacement along the y-axis. The graphs appear to have an inverse-squared relationship.

References

Cosmic Rays Bombard the Earth. Grande Grok. Web. 19 May 2010.

Mark Adams
Physics Department Emeritus, University of Illinois, Chicago, Illinois 60607

Results

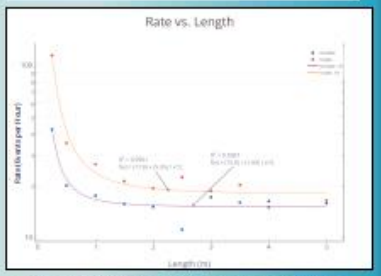


Figure 1. Graph of counts vs. length of triangle formed by the counters. Both inside and outside data are shown.

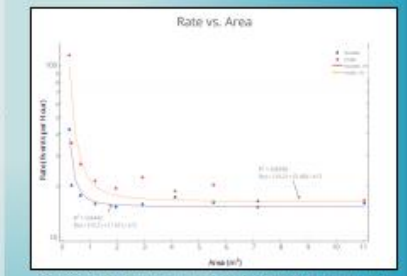


Figure 2. Graph of counts vs. area of triangle formed by the counters. Both inside and outside data are shown.

Conclusion

There is a significant difference (Figures 1 and 2) between the outdoor and indoor data sets. Although rates from each data sets are similar at large separations, the indoor detector had a greater number of events than the outdoor detector. This difference is likely due to roofing material; the indoor detector had about 15 centimeters of roofing material, while the outdoor detector was only covered by a thin plastic roof of about 0.25 millimeters thick. Because there was less roofing material in the outdoor data, the events per hour are significantly lower than that of the indoor data. The roof can be proposed to have caused an increase in showers thus making more events occur in the indoor data set. This also suggests that the increase in events at small separation in both data sets are due to additional interactions close to the surface of Earth, so that the muons do not have a long vertical distance in which to separate.

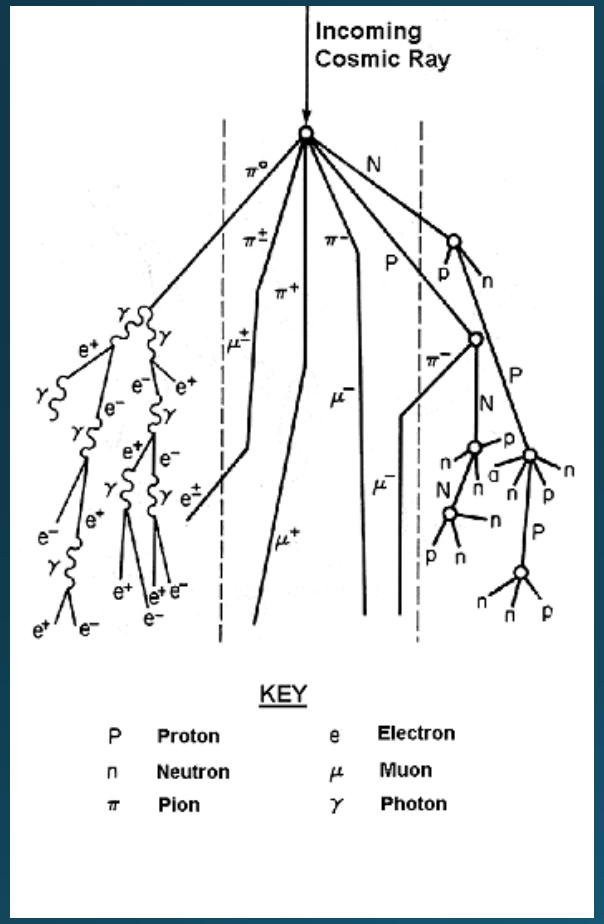
Work on Experiment

Classroom Implementation

- Drupal
- Original experiments
- Club
- Mining Data Base
- Data Portfolio
- https://quarknet.i2u2.org/data-portfolio

Reflection

- How are we doing?
- Are we on target with the Objectives?
- What next?
- Homework: Write an implementation plan.



Cosmic Ray e-Lab

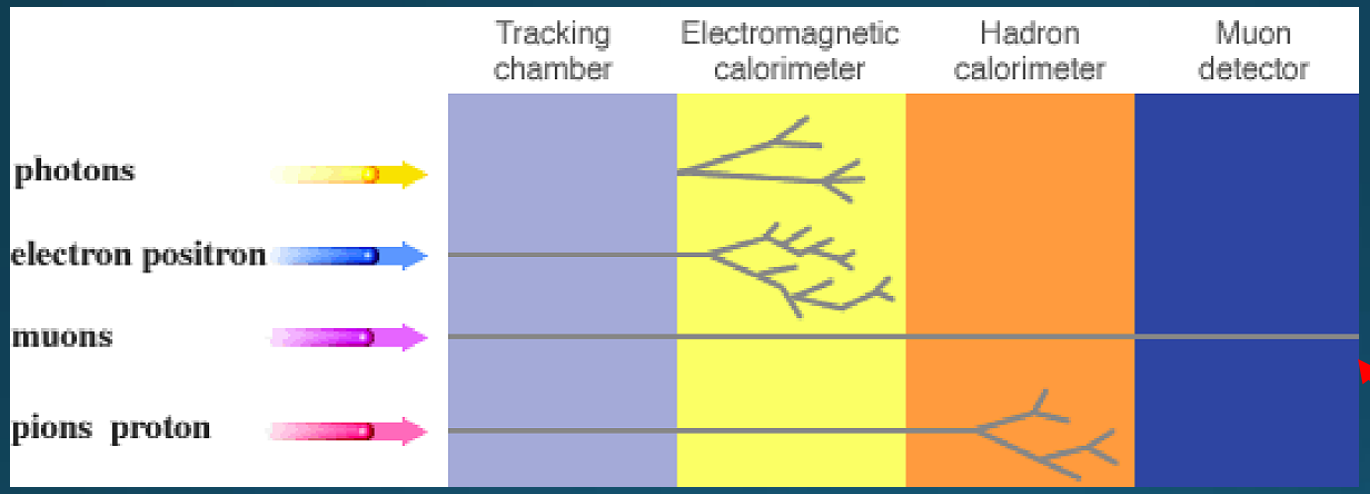
Nathan A. Unterman
Rice University
28.June.2017

Workshop Objectives:

- Configure a cosmic ray detector appropriately for acquisition of data for calibration and analysis of measurements
- Identify and describe the e-Lab tools available for conducting studies with data collected using a cosmic ray detector
- Create, organize and interpret a data plot to make a claim based on evidence; provide reasoning and identify data limitations
- Develop a plan for taking students from their current level of data use to subsequent levels using activities and/or ideas from the workshop.

Upload Data From Overnight

Passage of particles - summary



measurement by missing energy

undetected neutrinos...

electromagnetic shower

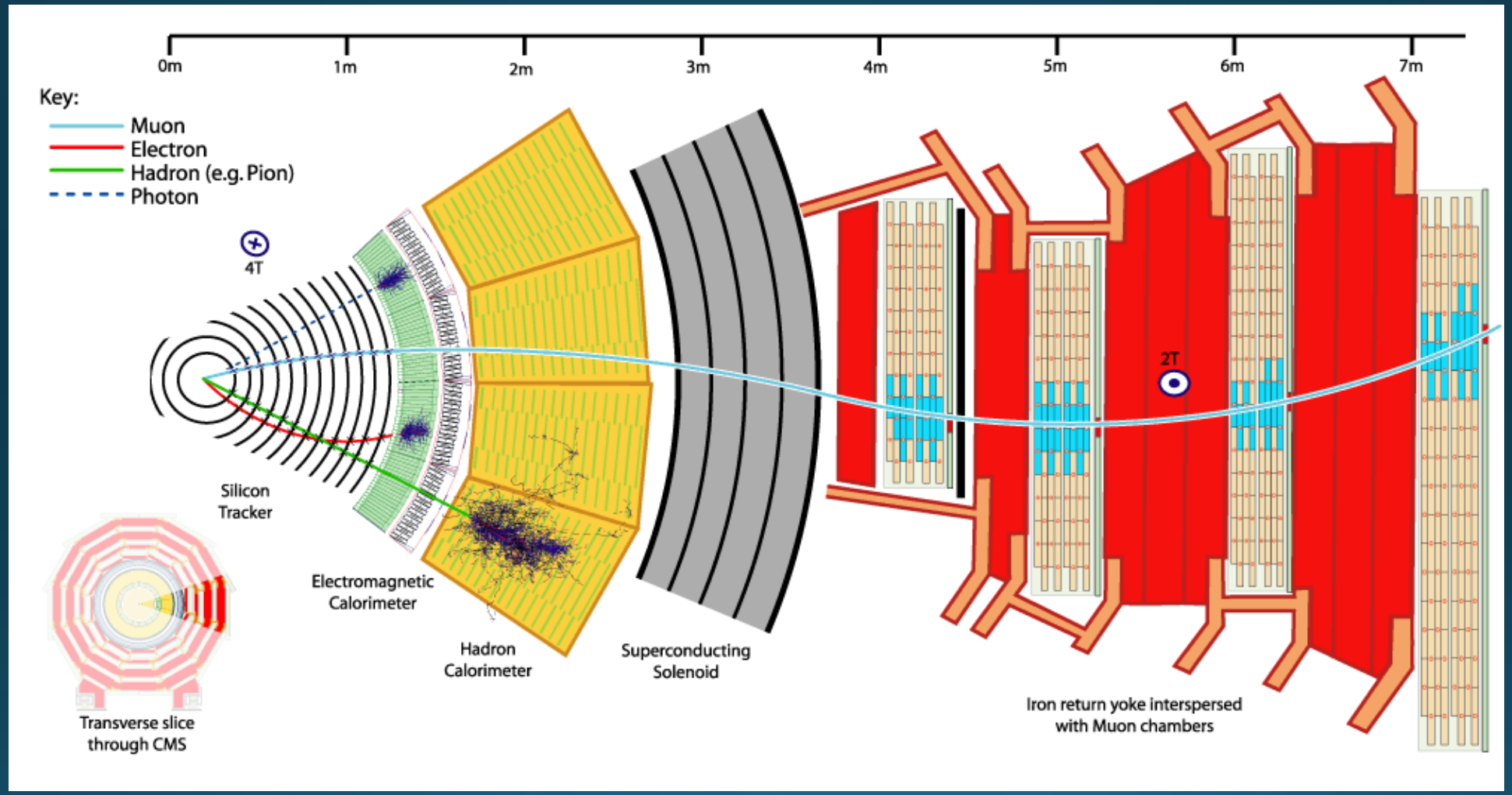
hadronic

momentum measurement by curvature in magnetic field

energy measurement by creation and total absorption of showers light amount and penetration depth

muon detection with improved momentum measurement (long lever arm); measure momentum

'Generic' experimental set-up



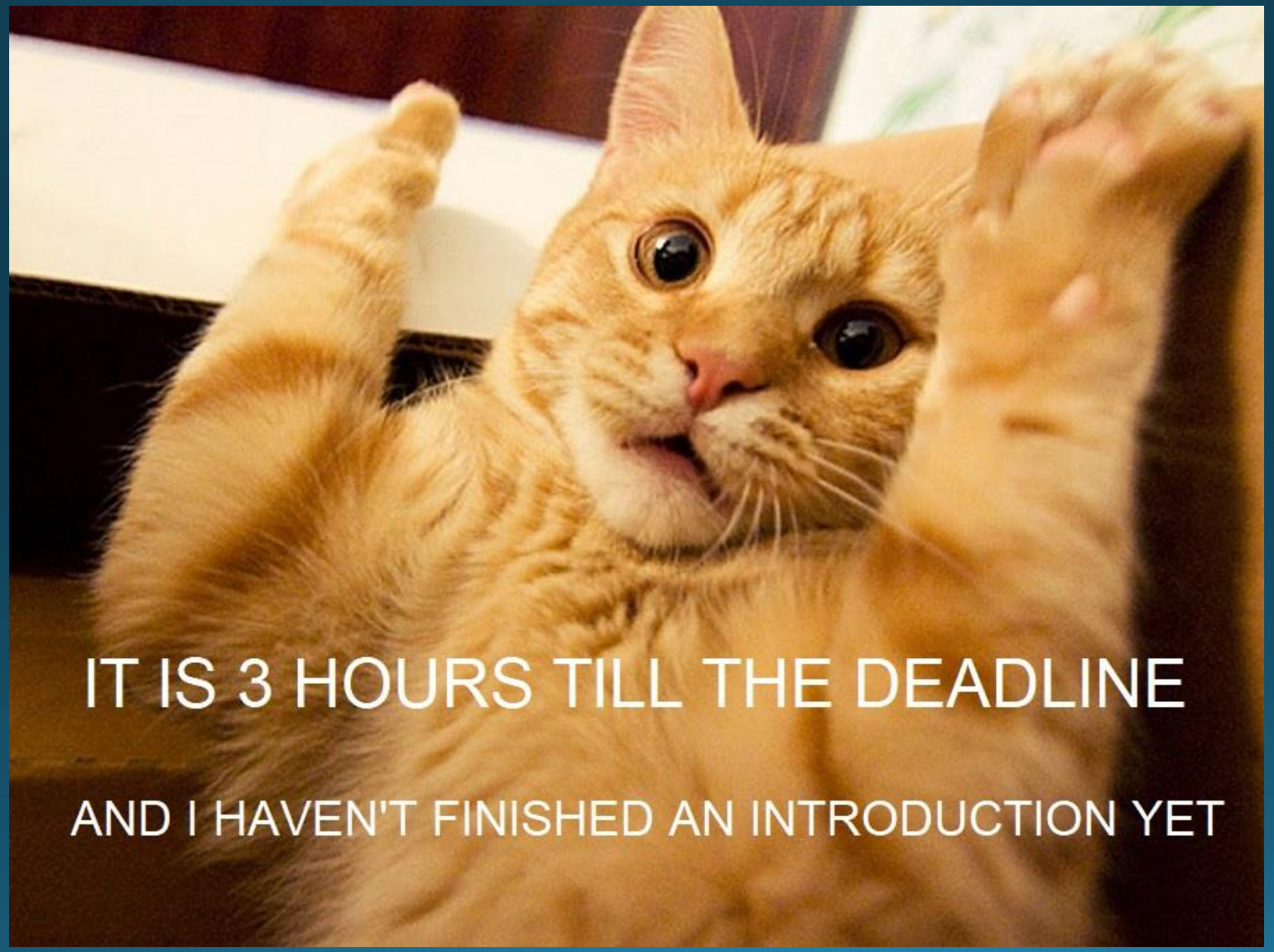
Deflection ~ BL^2/p → need high B (s.c.) and large magnets; need high resolution position measurements (10 -100μ) at large p; also energy and position measurement through total absorption (photon, electron, hadron)

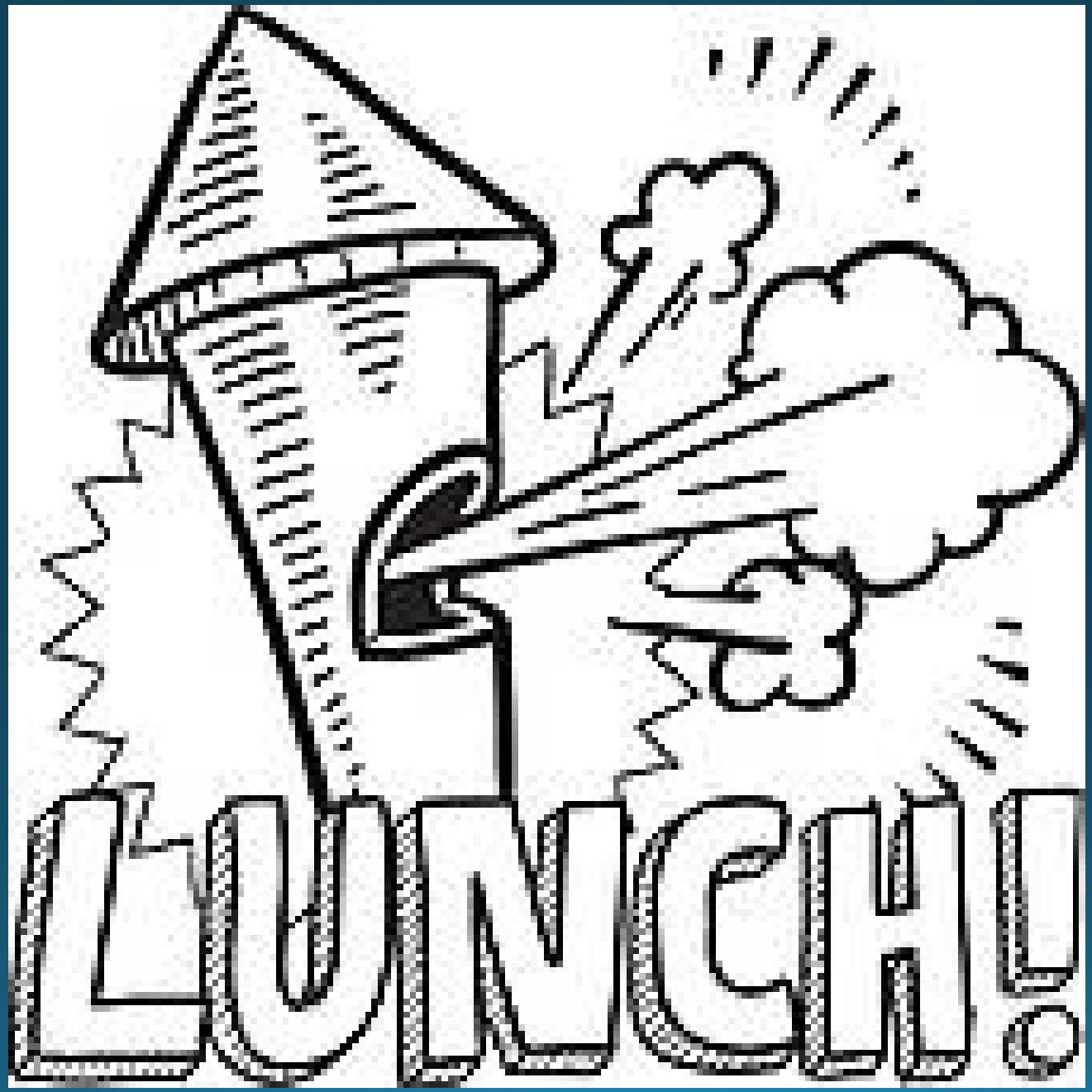
And real life in CMS

Detectors interleaved with the magnet yoke steel layers

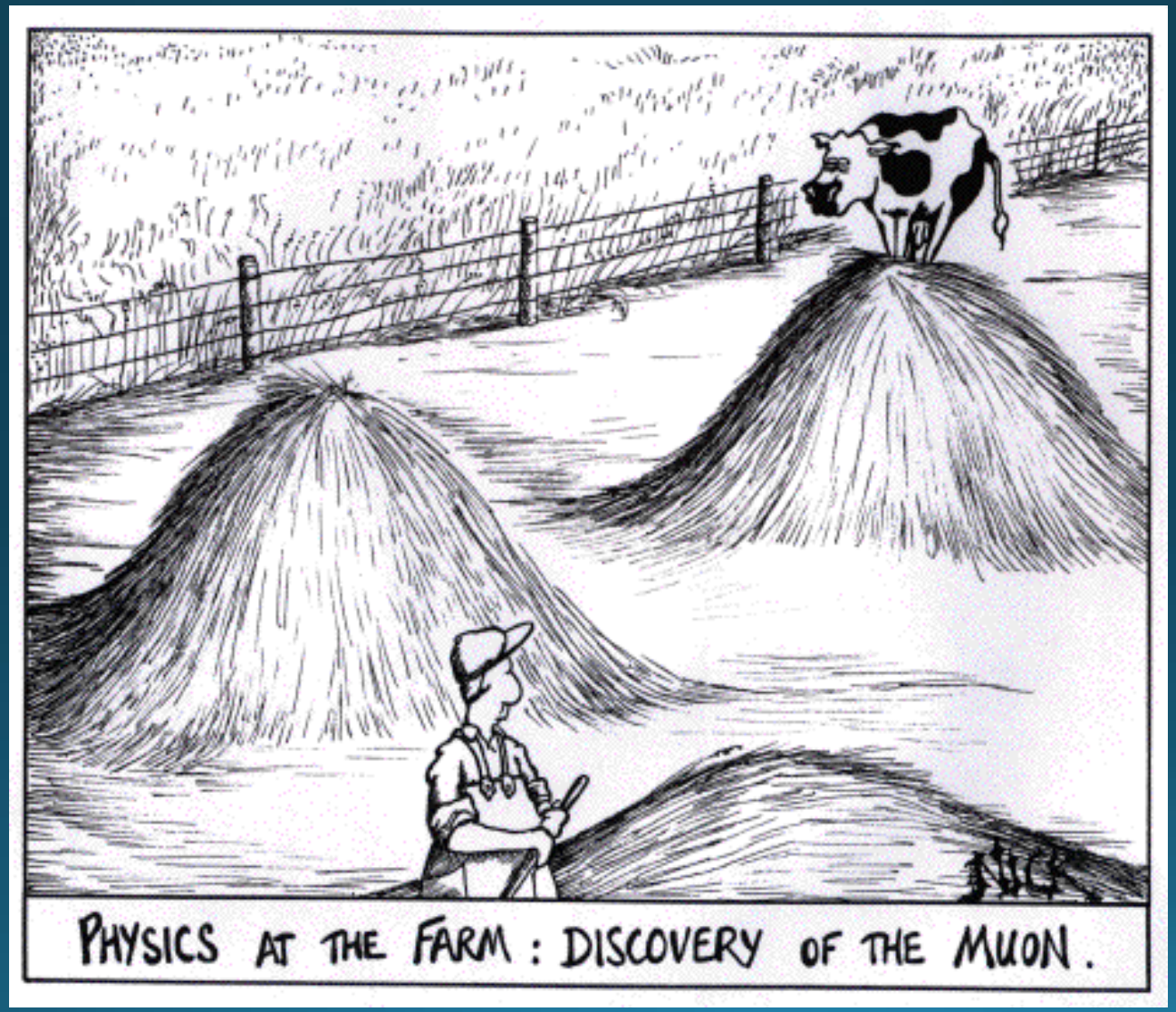
Prof. Paul Padley

Conclude Research




LUNCH!

Poster Creation



Implementation Plans

- Edit your plan
- Share

Teaching and Learning with Cosmic Rays

Workshop Objectives:

- **Configure a cosmic ray detector appropriately for acquisition of data for calibration and analysis of measurements**
- **Identify and describe the e-Lab tools available for conducting studies with data collected using a cosmic ray detector**
- **Create, organize and interpret a data plot to make a claim based on evidence; provide reasoning and identify data limitations**
- **Develop a plan for taking students from their current level of data use to subsequent levels using activities and/or ideas from the workshop.**

Summary

- What was good about this workshop?
- What needs improvement?
- Have we met the objectives?

Evaluation

- https://www.surveymonkey.com/r/NV726DM

CLEAN UP


"Thats all Folks!"


adidas