



# Cosmic Ray Program

Of **52** centers, **47** have hundreds of detectors (CRMDs) for experiments: muon flux; lifetime; speed.

High school long-term collaboration using the HEP model

Inquiry-based learning with authentic research tasks

Fermilab QuarkNet Support – **3** Half-Time Positions:

- Hardware support
- Cosmic ray coordinator/teacher
- IT & analysis tools support



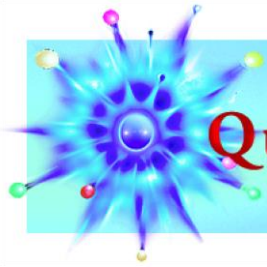
# Cosmic Ray e-Lab

## Analysis Tools

- Encourage new research ideas with IT maintenance & e-Lab design.
- Serve high schools without CRMDs (**500k** logins).
- Existing data in e-Lab: **106,000** CRMD files (DAQ days)

**Develop new tools & enhancements that users request/need.**

- Rates for Eclipse Project (**>30** U.S. schools joint project)
- Shower module for cosmic ray air showers
- Rate versus pressure (CME search & storm tracking)
- Improve Muon Lifetime user interface (ongoing)
- Integrate Muon Underground Shielding Experiment (MUSE) data.



**QuarkNet**

# **e-Lab Progress This Year**

## **In Addition to COVID Response**

**Monitor data uploads; fix files with incorrect dates.**

**Add absolute time to modified Shower.**

**Repair Lifetime decay selection & fitting.**

**Test Notre Dame Cosmic Watch prototype.**



# Usage Last Two Years

## Three Eras: Before GPS – After GPS – COVID

6 April 19: U.S. GPS hardware failure – Interrupted uploads; firmware update reprogrammed, mostly by Dave at FNAL (**175** units).

March 20: COVID-19 – Very limited access to CRMDs; teachers in survival mode; don't ask too much.

### DAQ/Uploads Comparison for 6-Month Periods Apr.–Oct.:

- < GPS failure      Apr.–Oct. 2018      **74** DAQs/**2,860** uploads
- > GPS failure      Apr.–Oct. 2019      **66** DAQs/**2,173** uploads
- COVID              Apr.–Oct. 2020      **27** DAQs/**2,733** uploads

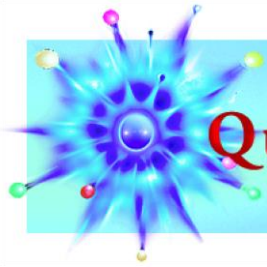
### Conclusions:

- Most data uploaders remained active after GPS failure.
- During COVID, fewer but more active users!
- **2,182** analyses in last month from **23** groups; **26** DAQs (from new tool)



## Future Projects

- **Expand simple e-Lab analyses to offer customized data taking upon request; serve those without CRMDs; university labs?**
- **Inexpensive detector (Cosmic Watch or OSECHI) – Establish requirements for classroom use; work with expert users; build & evaluate next prototype; build classroom set.**
- **Post-Processing – More complex analyses by coding fellows**
  - **Upward Muon Search; Shower Direction Reconstruction**
- **g-2 at home**
- **Pyramid Archaeometry at Chichen Itza has NSF provisional approval. QuarkNet will host data: Chicago State U. (Black students) & Dominican U. (Hispanic students); Detector – 2024 Solar Eclipse.**
- **American Indian Center in Chicago (FNAL project; may offer cosmic ray mentorship.)**



**QuarkNet**

# **Fellows & Special Projects**

## **Cosmic Ray Fellows & Staff Spawn Exciting Projects.**

**International Muon Week (CU; JHU)**

**Storm Tracking (KSU; UPRM; HI)**

**Solar Eclipse 2017 (UIC plus many around U.S.)**

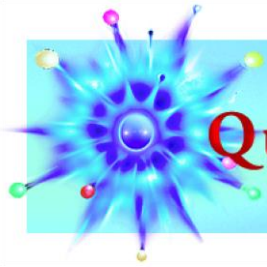
**MUSE 2019 – Cosmic rays in MINOS tunnel (UIC)**

- **First proposal to Fermilab from a high school group**
- **Link between Cosmics & FNAL's focus on neutrinos**

**g-2 (CU, future)**

**Some results were presented at conferences.**

**Fellows developed virtual workshop; ran one over summer.**



**QuarkNet**

# **Cosmic Rays – International**

## **Global Outreach Activities**

**IPPOG – Global Cosmics follows masterclass examples.**

**International Cosmic Day (DESY) in November**

**International Muon Week (QuarkNet-Fermilab) in March (fellows run)**

**Eclipse Project 2017 (30 U.S. high schools plus several non-U.S. locations)**

**Teacher presentations at AAPT & ICRC2019**

## **DAQ Licensing (Goodwill for FNAL)**

**400 DAQs in 31 countries used for outreach & research**

**Uploads from 92 DAQs in 27 countries**



## **COVID Response**

**Created simple experiments using existing data & e-Lab analyses.**

**Collected standard data sets for classroom use; teachers moved CRMDs home.**

**Lecture/Activity on how to perform several e-Lab experiments:  
muon speed; rates; lifetime**

**New tool to monitor files accessed by users**

**Fellows developed virtual cosmic workshop (1 summer workshop;  
virtual template customized for 1- to 5-day workshops).**