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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**

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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.

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.

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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)**

Adams, Hoppert, Peronja, 2020 Ad Board Meeting

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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.)

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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.

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).