The Cosmic Watch for QuarkNet and the World

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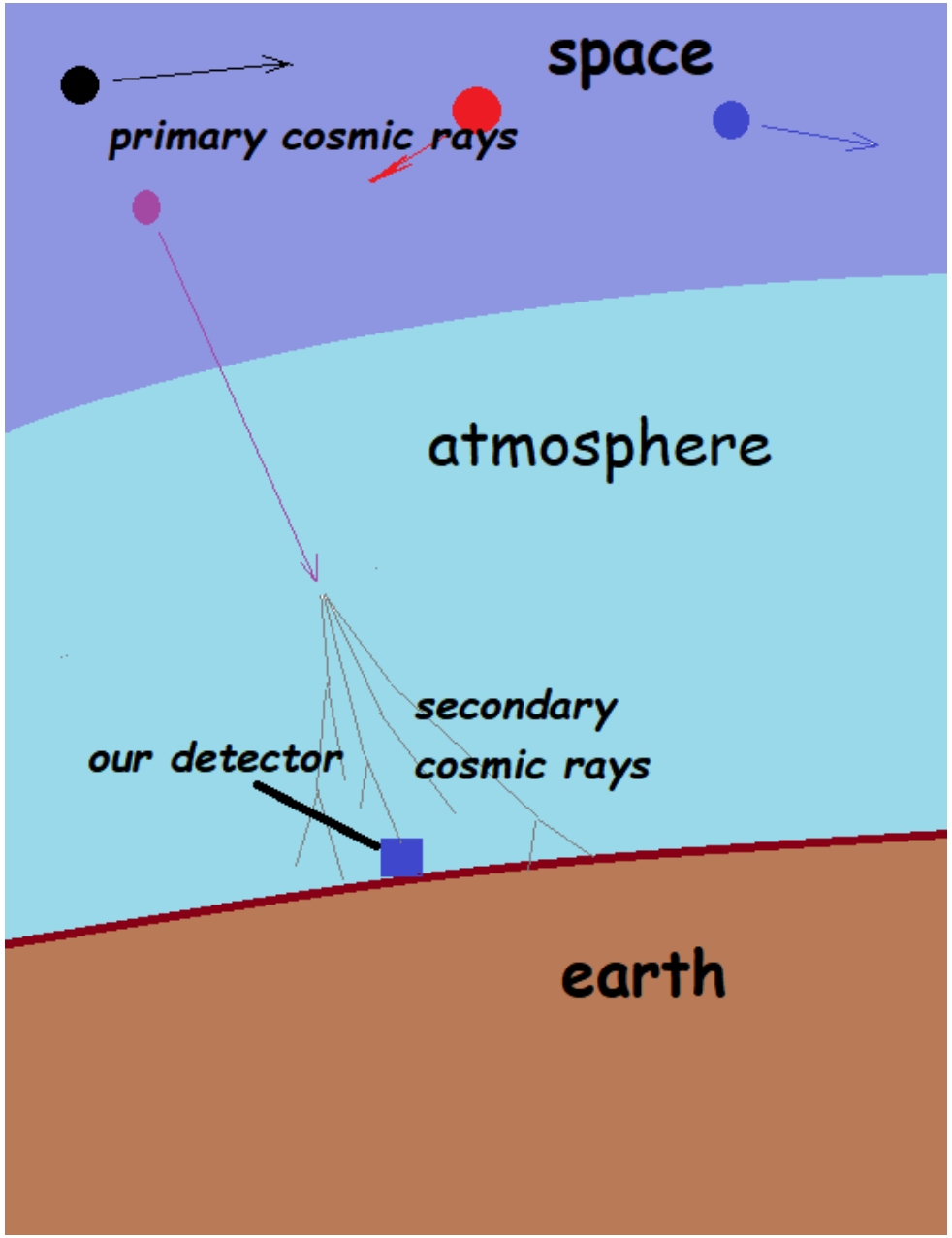
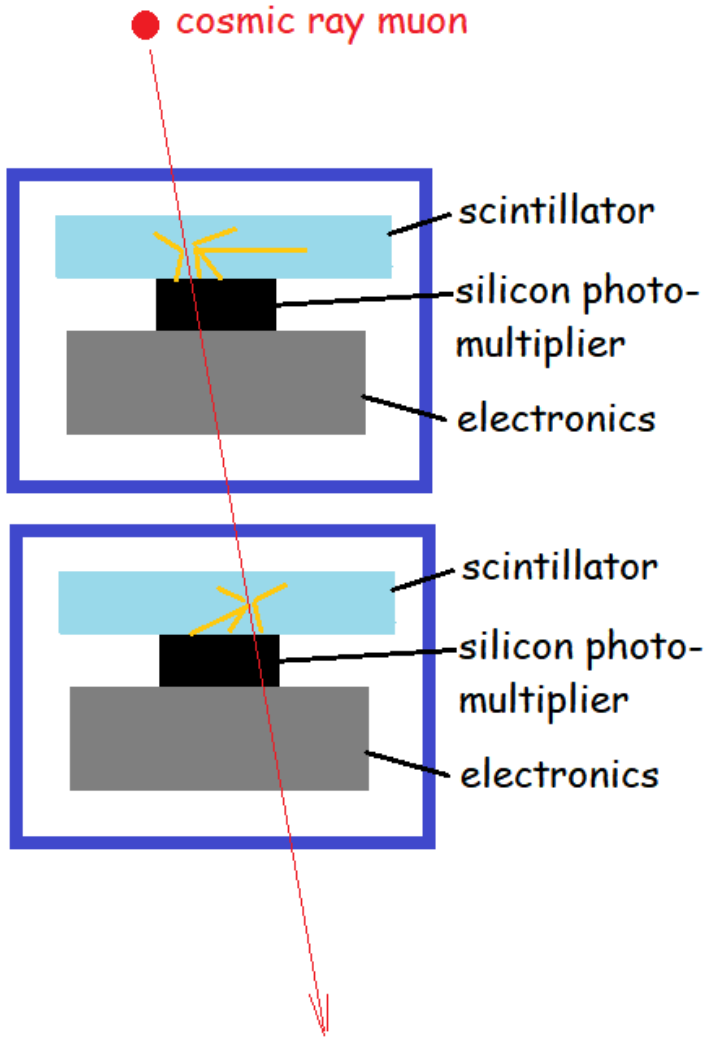
What are Cosmic Rays?

- Primary: energized protons, ions in space
- Secondary: muons produced ~10 km about the surface of earth when primary cosmic rays hit atmospheric nuclei



How do we detect cosmic ray muons?

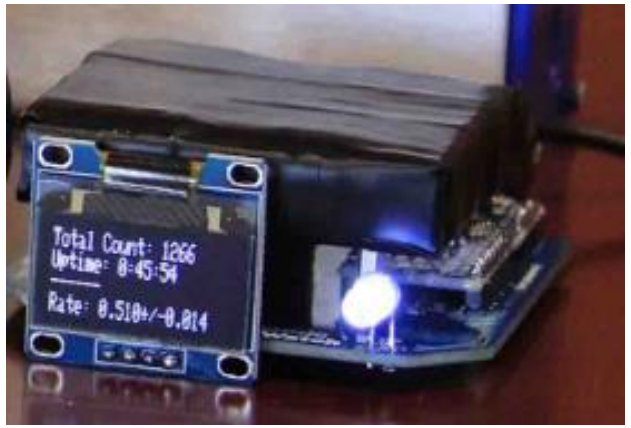
- Muons pass through scintillator
- When they encounter heavy organic molecules, they give some energy through Coulomb interaction: electrons jump to higher energy levels
- Muons jump back down, emit light
- Photomultiplier converts light to electric current
- Electronics sort out, read, record signals

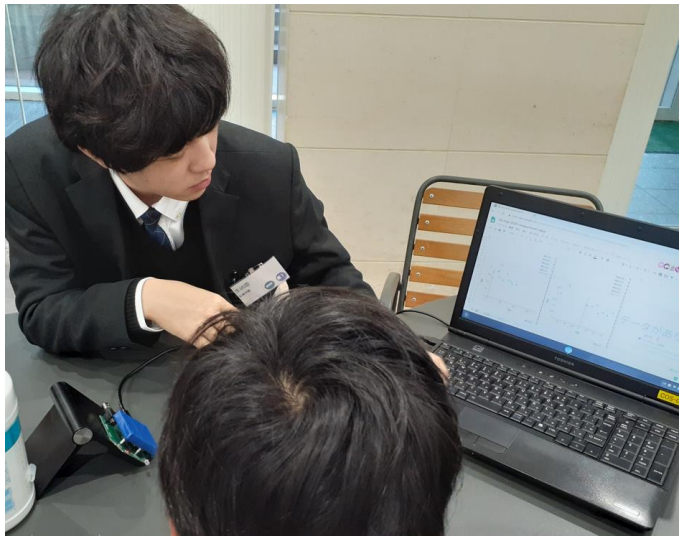


What is the Cosmic Watch (CW)?

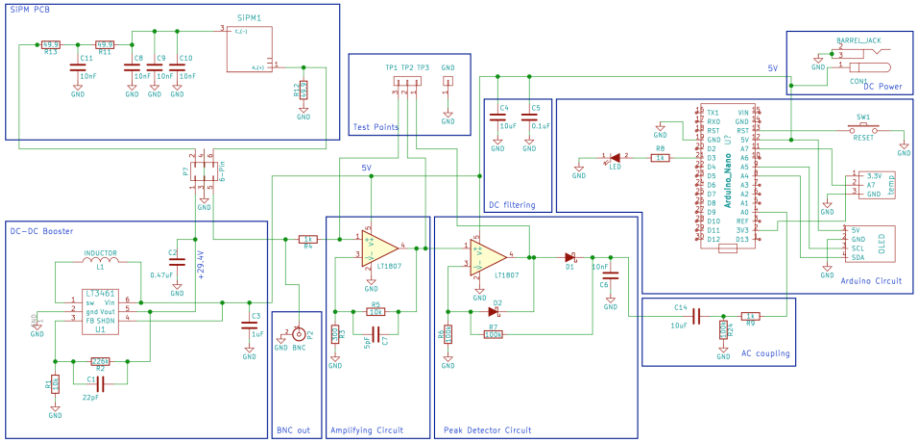
- A SiPM- and Arduino-based Cosmic Ray Detector
- Small
- Capable of two-fold coincidence (CW #1 triggers on CW #2)
- Computer-readable via Arduino
- Developed by Spencer Axani at Massachusetts Institute of Technology
- Limited number available through QuarkNet
- Open-source and available as DIY project

What is the Cosmic Watch (CW)?



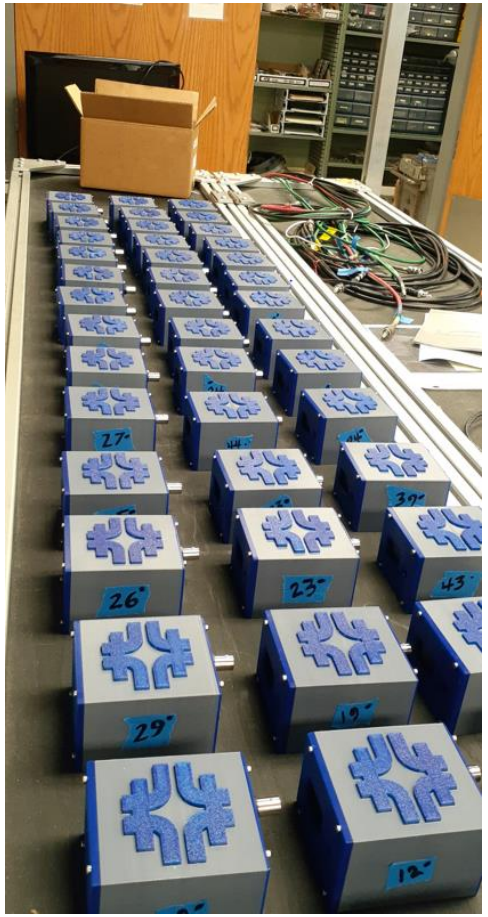


Images above and below from http://www.cosmicwatch.lns.mit.edu/.

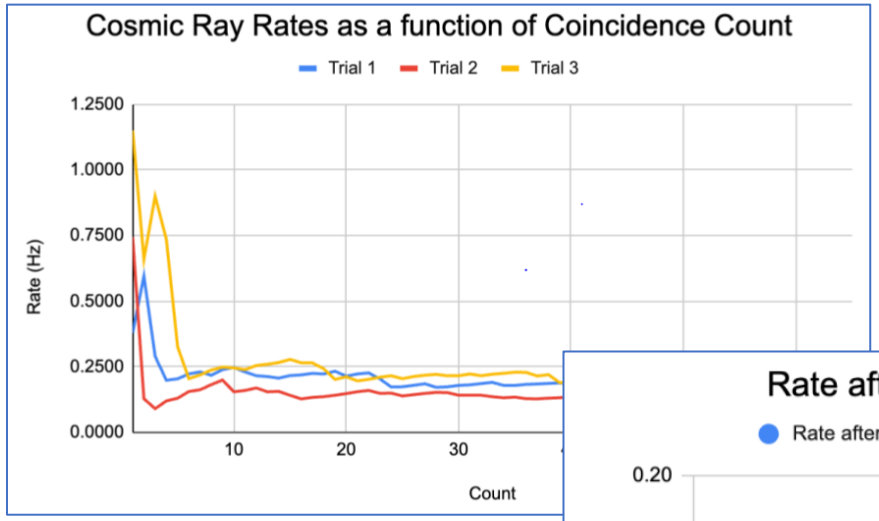


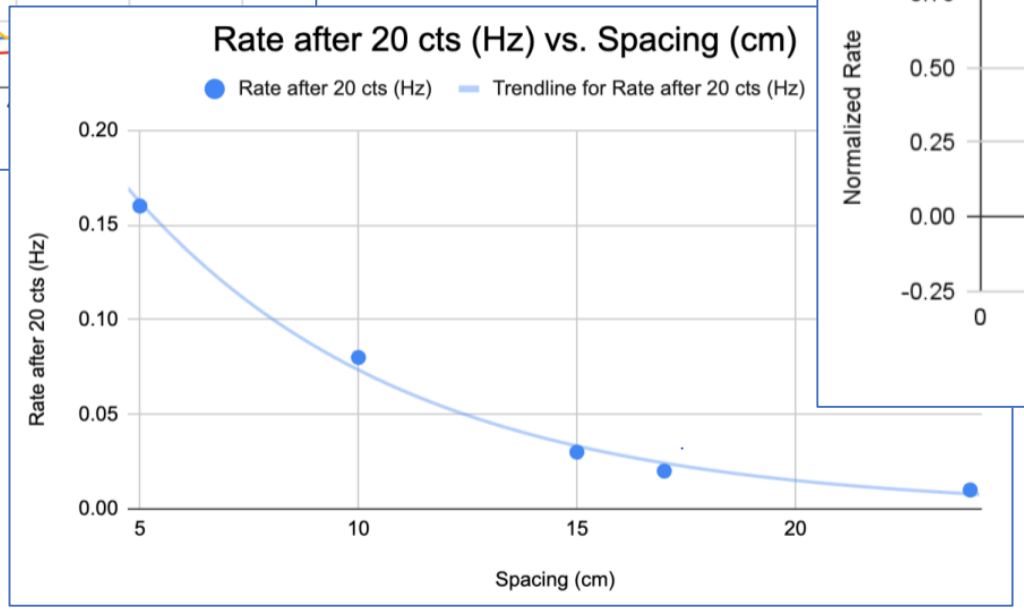
Testing the Cosmic Watch

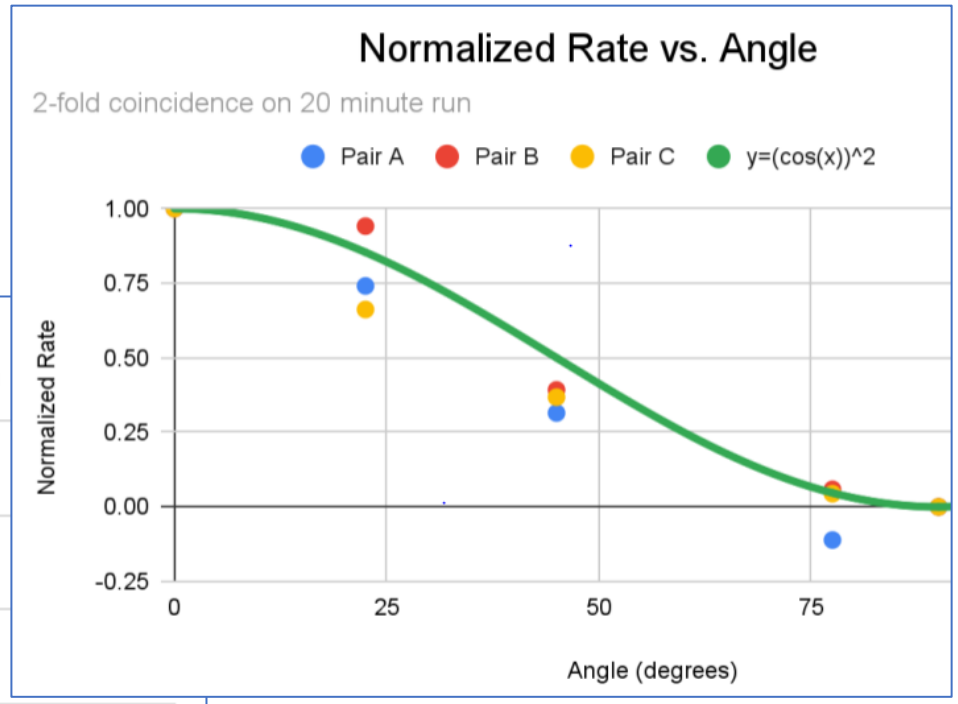
- June-July 2022: QuarkNet and Fermilab had 48 CWs produced at University of Notre Dame
- September 2022 – May 2023: a few QuarkNet teachers used CWs in classes
- June-July 2023: testing at Notre Dame of characteristics and specific laboratory practical exercises
- September 2023: new, more systematic in-class use
- July 2024: first CW workshop at Colorado State



Testing the Cosmic Watch

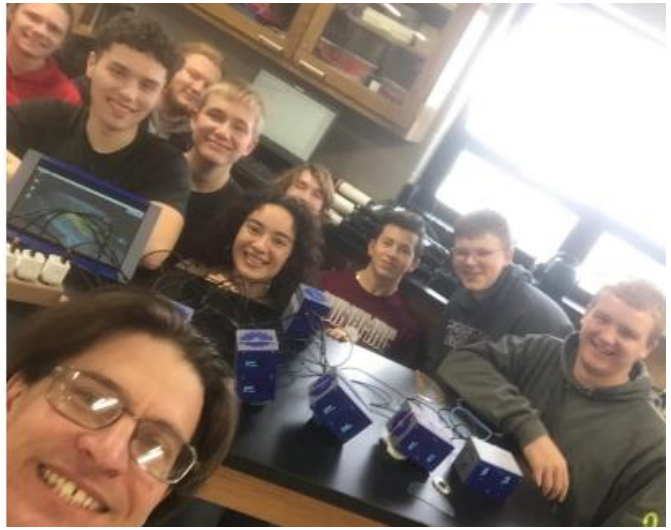


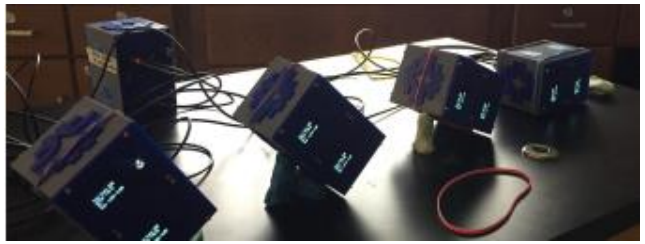




Use cases

- Labs
  - Rate vs. Zenith Angle
  - Rate vs. Separation
  - Detect, investigate beta
- Investigations
  - Muography
  - Variations with natural conditions
  - Instrumentation physics
- More



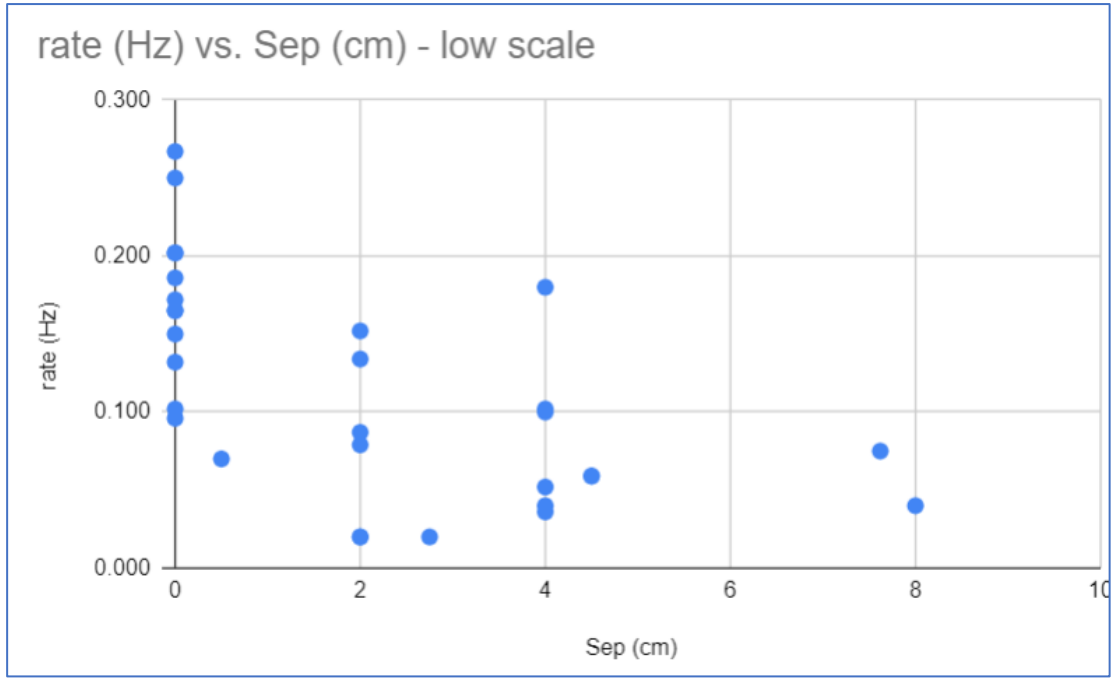


Wegner, Jeremy, and students, *Angular Distribution of Cosmic Rays*, International Cosmic Day 2022

Ohtsuka, Miki, et al, *墳Q(fun-Q) project : muography of Japanese ancient mounds by high school students*, 38th International Cosmic Ray Conference (ICRC2023)

Use case: Lab at Watervliet High School

- 14 September 2023: Separation of counters at 2-fold coincidence
- We learned a lot from the experience! (e.g. Not plug-and-play.)



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  - Watervliet High School
  - Winamac Community High School