Can an Aluminum Shield Stop High-Energy Muons?

Muon versus Aluminum: Who will survive?

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WALTA

- WAshington Large-scale Time coincidence Array
- Purpose: To look at the toe region of the cosmic ray spectrum and collect data.
- Procedure: Put cosmic ray detectors in local schools and use the Internet to gather data.
What are Cosmic Rays?

• Cosmic rays are charged particles from outer space
• Cosmic rays can range from gamma rays to iron nuclei
• Some Cosmic rays can have as much energy as a fastball
Fluxes of Cosmic Rays

Flux \( \text{m}^2 \text{s}^{-1} \text{sr}^{-1} \text{GeV}^{-1} \)

(1 particle per m\(^2\)-second)

Knee
(1 particle per m\(^2\)-year)

Ankle
(1 particle per km\(^2\)-year)

Energy (eV)
Extensive Air Showers (EAS)

- Caused by a Cosmic Ray hitting the upper atmosphere.
- When the particle hits it causes a particle shower of secondary particles which in turn produce more particles.
- The higher the energy of the initial Cosmic Ray the bigger the air shower.
Muons

• Basically a heavy electron
  – Mass of an electron: 0.511 MeV
  – Mass of a muon: 106 MeV
• Typically produced by pion decay in EAS
• Highly Penetrating
• Mean-lifetime: $2.2 \times 10^{-6}$ sec
Equipment

- **Scintillator**
  - Fluorescent Plastic which releases photons when impacted by a charged particle
- **Photomultiplier Tubes (PMT)**
  - Detects the photons and changes the light into an electrical signal
- **Matter Slab (In this case Aluminum)**
  - Used to select higher energy particles
Equipment (Continued)

• Data Acquisition Card (DAQ card)
  – Gather data from the detectors and change it into a format that is able to be read by the computer

• GPS Unit
  – Nanosecond timing

• Boxes
  – Protect the detectors from the weather
Boxes

• Black Plastic Boxes
  – Dimensions (BWH):

  44 in. X 48 in. X 30.75 in.
Muon Telescope

- Location: Top of Physics Building B-wing
Muon Momentum

• Energy Loss through materials
  – Scintillator: 2.89 MeV
  – Aluminum (1.5 cm): 6.54 MeV
  – Total Energy Loss through Entire Setup with
    atmosphere above: 37 MeV

• Minimum Muon Momentum: 95.85 MeV/c

Muon Energy Loss computed by RJ Wilkes
Muon Rate

- “Vertical” Muon Rate for .096 GeV/c ~ .0102 cm$^{-2}$ sr$^{-1}$ sec$^{-1}$
- Solid Angle of Rooftop Setup: 1.82 sr
- Rate if Muons are Uniform across sky ~ 66 Hz
- Rate if Muons follow $\cos^2$ (zenith angle) ~ .1 Hz

Vertical Muon Rate extrapolated from data given by the book Physics Data: Cosmic Rays on Earth by PKF Grieder
Solid Angle Calculated by RJW
Current Issues

• Figure out expected rate

• Compute actual rate with error

• Compare the two rates