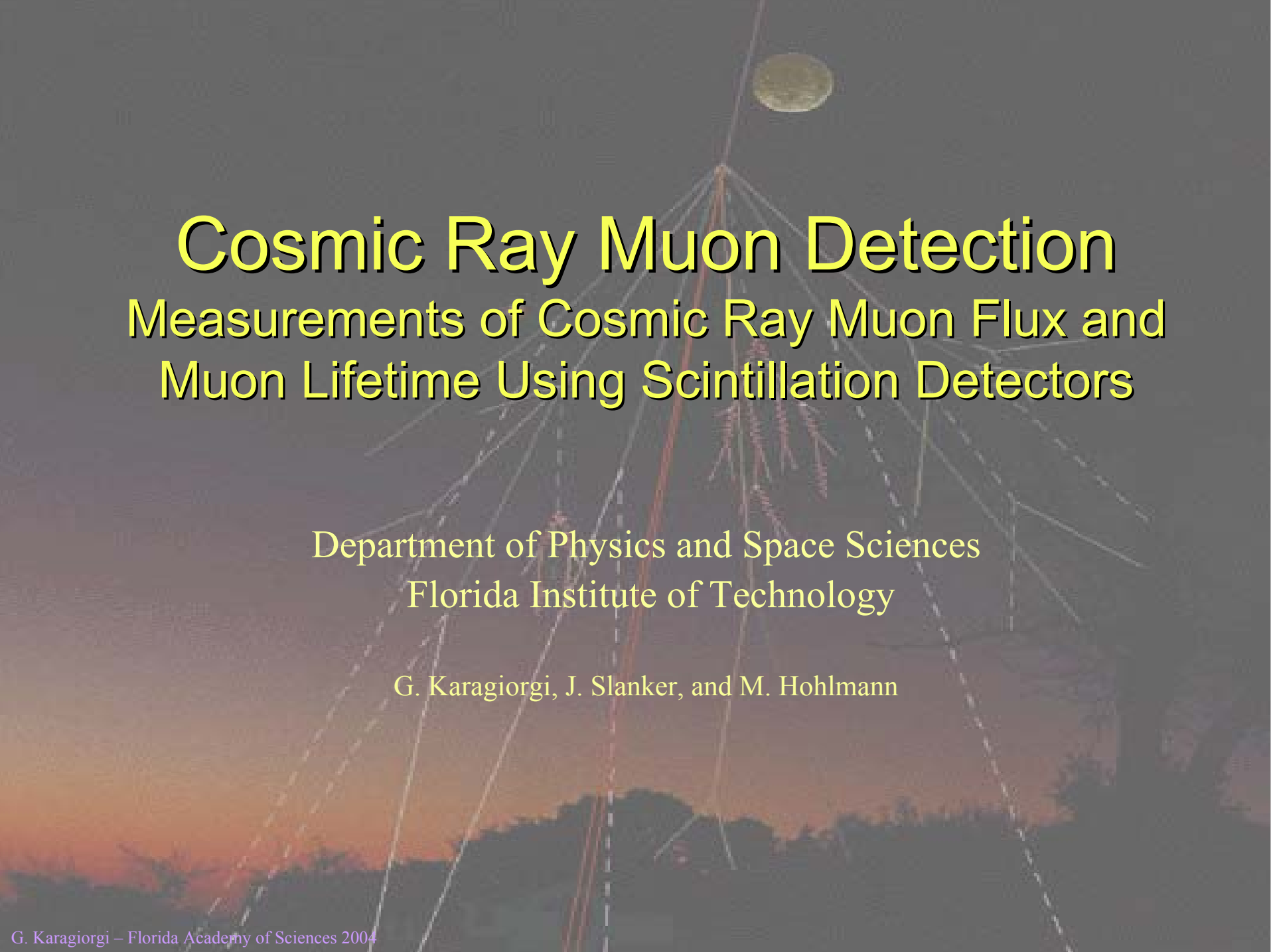

Cosmic Ray Muon Detection

Measurements of Cosmic Ray Muon Flux and Muon Lifetime Using Scintillation Detectors

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Cosmic Ray Muons: μ^- μ^+

- Cosmic rays

  mostly protons that come from outer space
- Air shower

  different subatomic particles are created

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

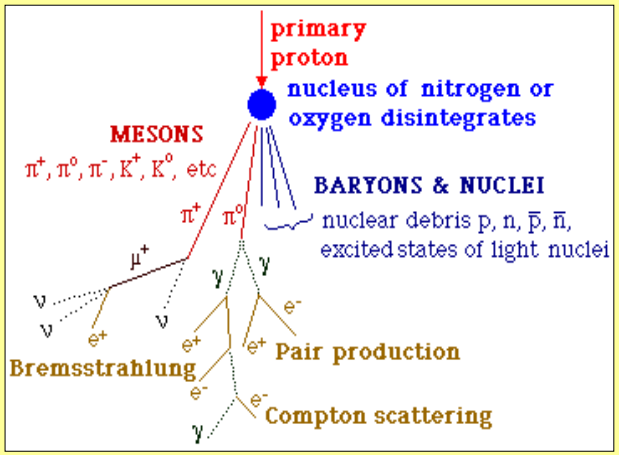


Figure 2: Development of Cosmic Ray Air Shower

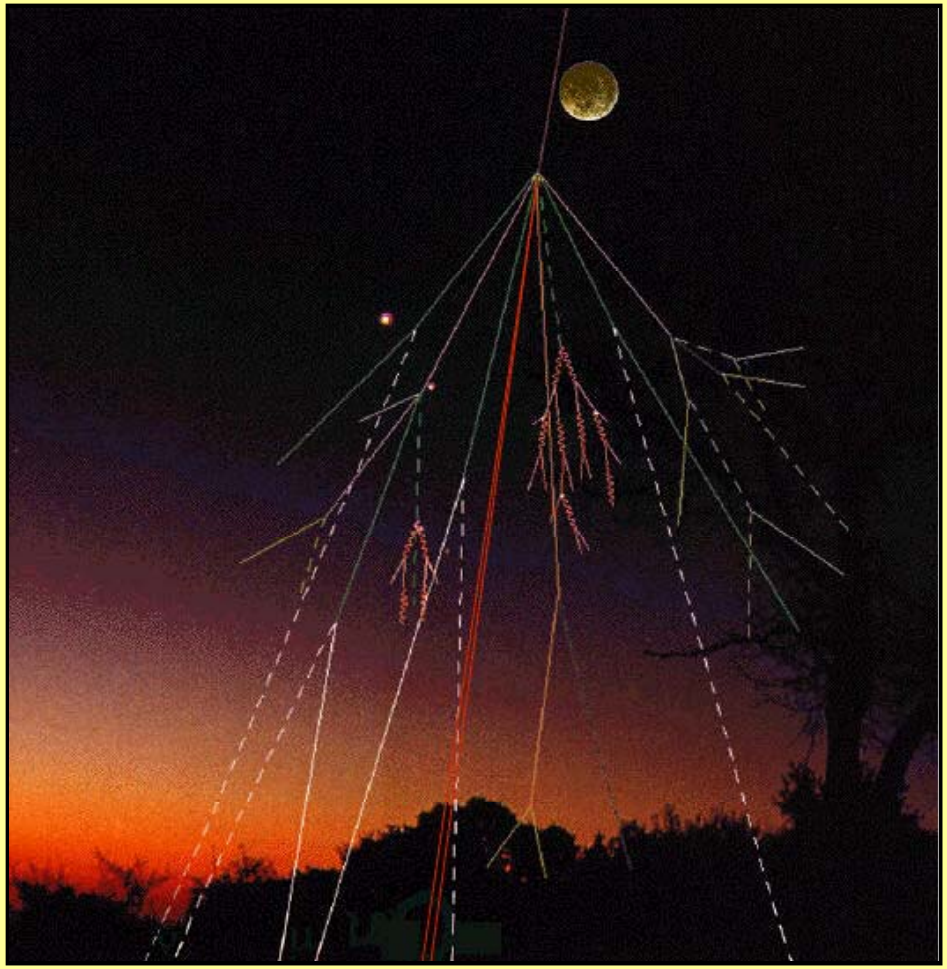


Figure 1: Cosmic Ray Air Shower

Summary

Using a setup of two scintillation detectors

- Flux
- Count rate
- Energy Variation

of muons originating from cosmic ray air showers were investigated.

The factors considered were:

- Amount of material muons travel through
- Zenith angle
- Setup configuration of the detection system (overlap area and separation distance)

Finally, the method of detection allowed for verification of the theoretical value for the muon lifetime.

Background

Flux

Muons reach the surface of the Earth with typically constant flux Fμ:

- $$F_\mu = \frac{\text{(count rate) } d^2}{\text{(area of top panel) (area of bottom panel)}}$$

[Horizontal detectors]

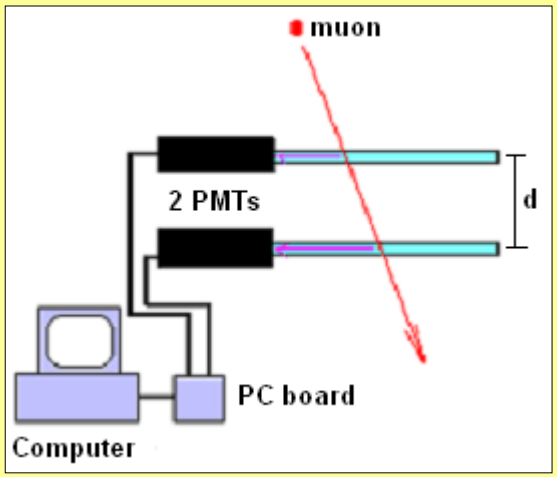


Figure 5: Detector Setup

Fμ = 0.48 $cm^{-2}min^{-1}sterad^{-1}$ (PDG theoretical value)

Count rate: 0.585$cm^{-2}min^{-1}$ (for horizontal detectors)

Our experimental value: 36min^{-1} (8% efficiency)

The flux varies with zenith angle θ as:

$$F_\mu \sim \cos^2\theta$$

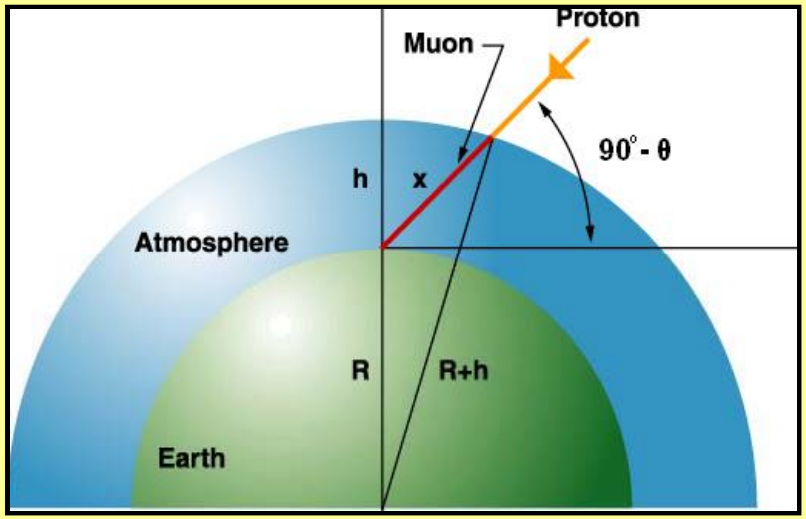


Figure 6: Zenith Angle θ

Setup Specifications

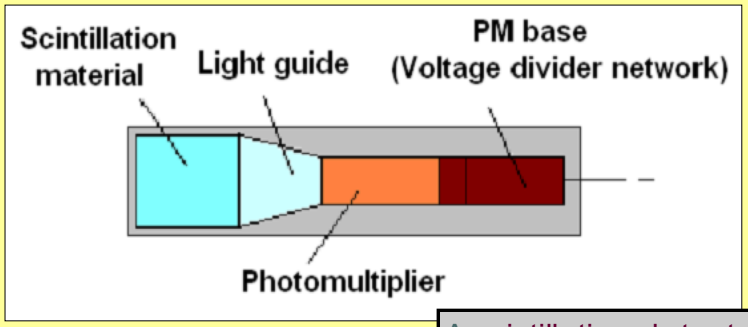


Figure 3: Schematic Diagram for the Scintillators

A scintillation detector has the property to emit a small flash of light (i.e. a scintillation) when struck by ionizing radiation.

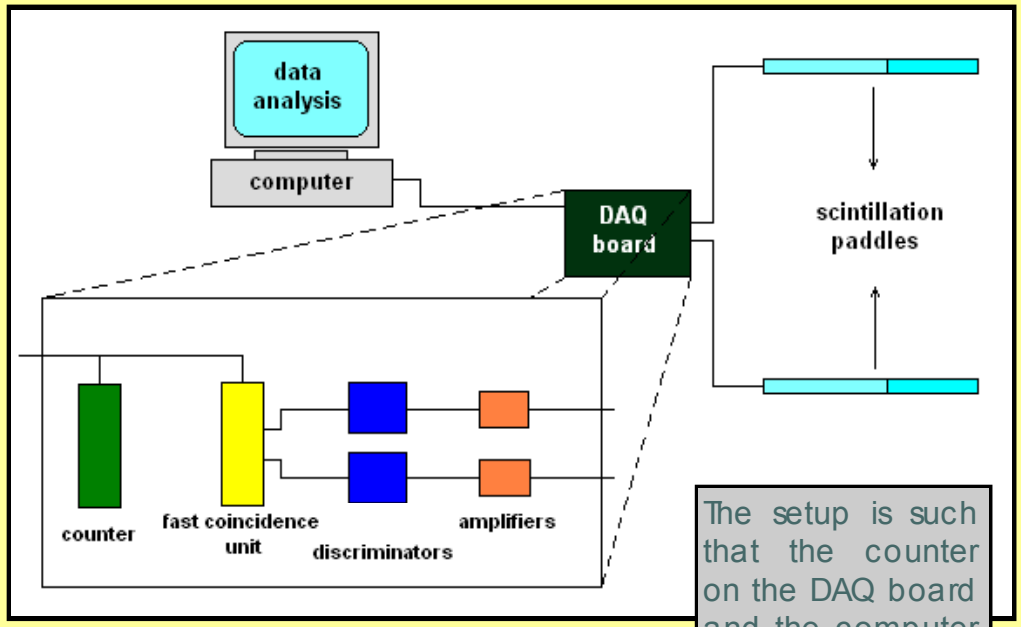


Figure 4: Detector Setup

The setup is such that the counter on the DAQ board and the computer are recording "coincidences", i.e. signals sent from both detectors at the same time.

The technique of recording "coincidences"

- Results in elimination of background noise
- Offers a great number of possible experiments

Results

Investigation of Flux Variation

- **With zenith angle**

A rotational mount was constructed that allowed variation of the zenith angle of the setup keeping all other parameters constant

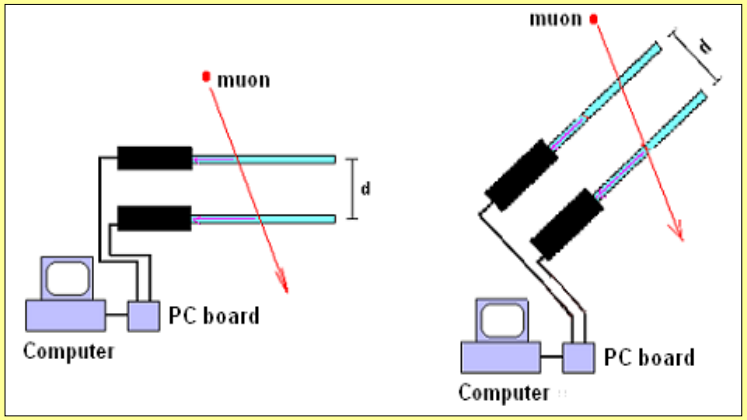
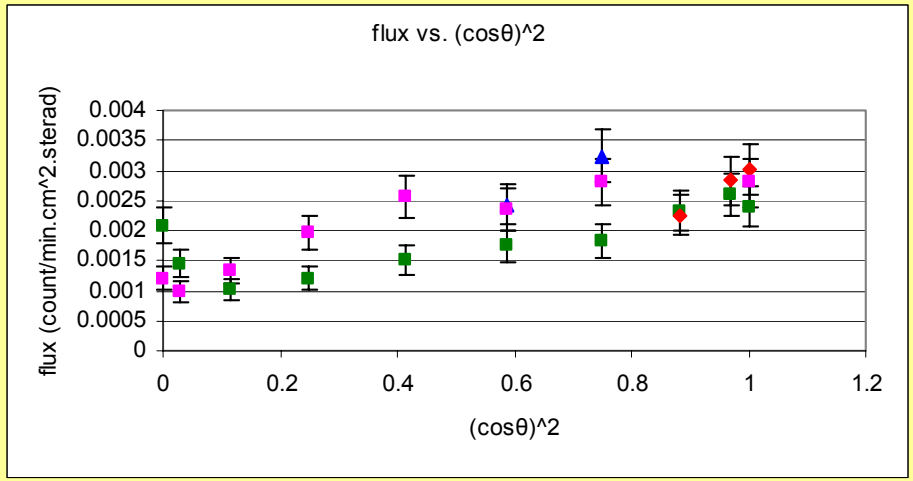
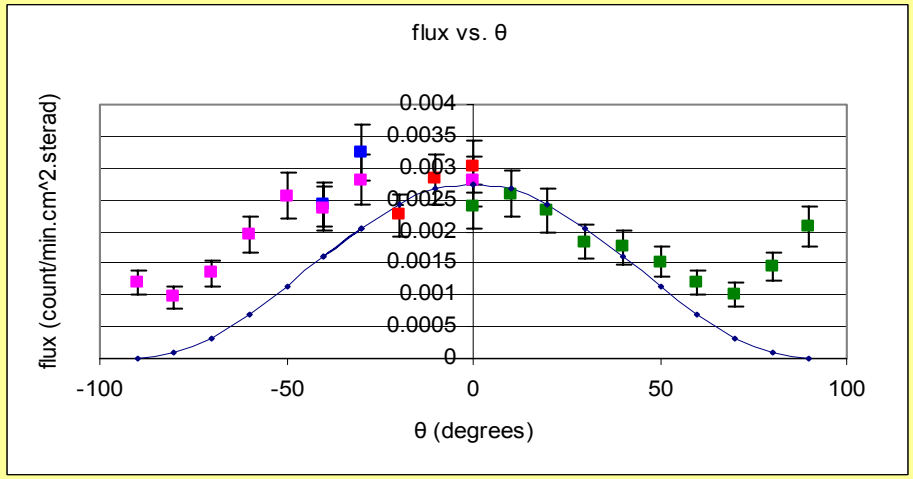


Figure 8: Rotation Configuration



Plot 2: Flux Dependence on Zenith Angle Θ



Plot 3: Flux Dependence on Cosine Squared of Zenith Angle Θ

Results

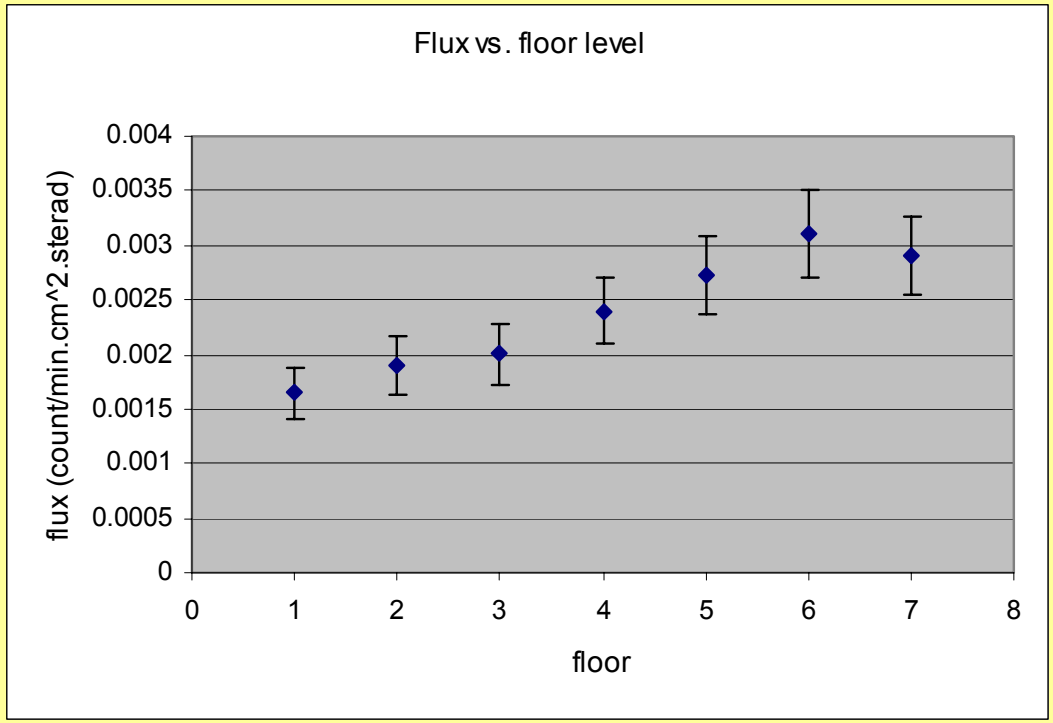
Investigation of Flux Variation

- **With material above detectors**

  Data were collected on the 7 different floors* of Crawford Building, on the Florida Tech Campus

Figure 7: 7th floor, Crawford Building, Florida Tech Campus

*All measurements were taken along the same vertical axis, **except** for the one on the **7th** floor



Plot 1: Flux Dependence on Material Above Detectors

Results

Investigation of Flux Variation

- **With overlap area**

The measurement was conducted to confirm the independence of flux with detection area, as well as to define any possible non-uniformities in the active area of the scintillation paddles

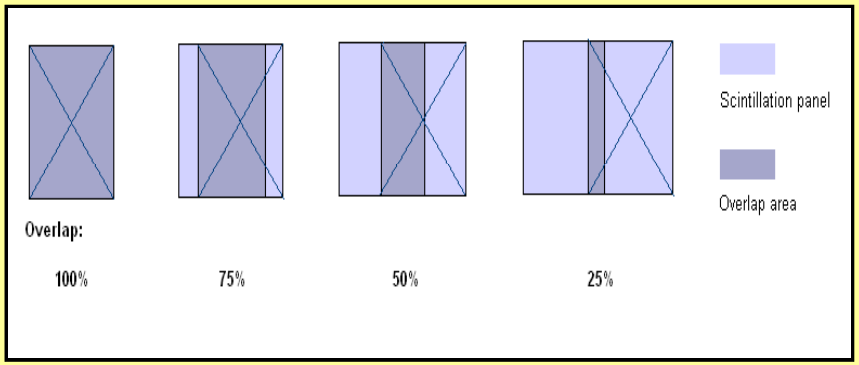
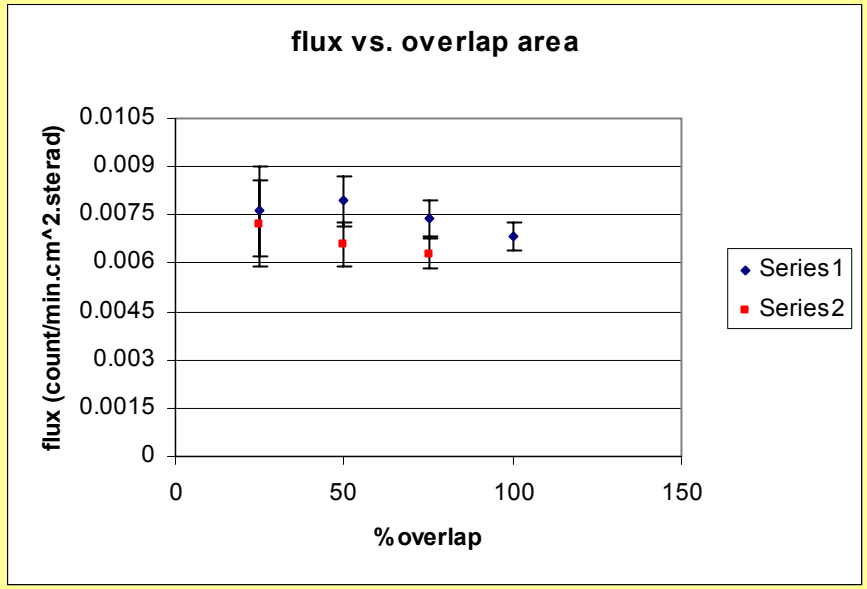


Figure 9: Scintillation Paddle Configuration for Overlap Area Measurement



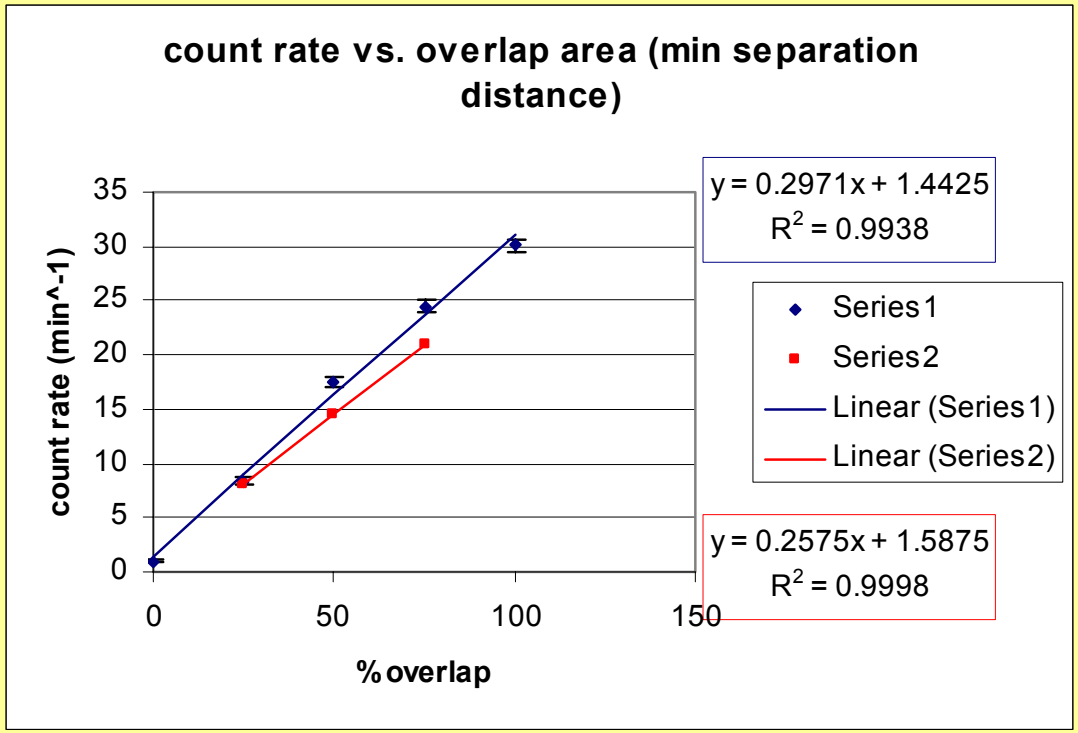
Plot 4: Flux Dependence on Overlap (Detection) Area

Results

Investigation of Count Rate Variation

- **With overlap area**

  The measurement was conducted to confirm the linear dependence of count rate with detection area



Plot 5: Count Rate Dependence on Overlap (Detection) Area

Results

Investigation of Count Rate Variation

- **With separation distance between the two paddles**

The paddles were placed in a rectangular arrangement. The active area (horizontal) was kept constant (lxl), and the separation distance d was altered in multiples of l

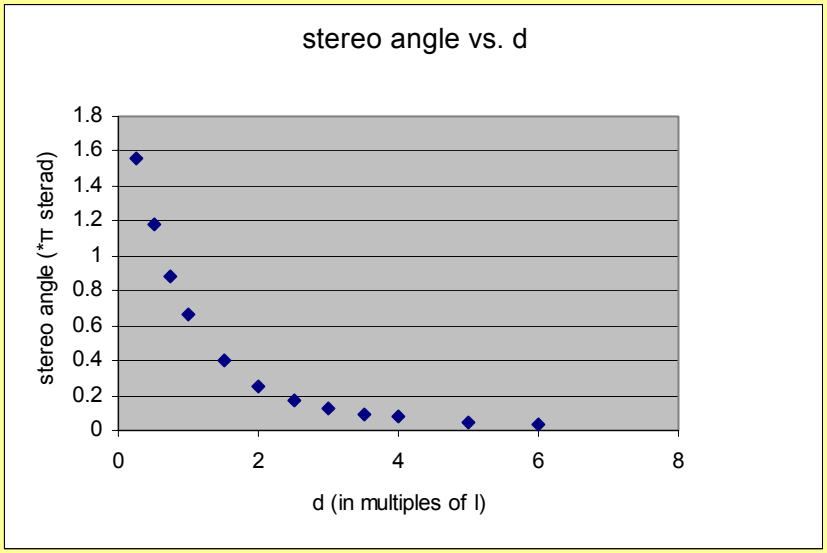
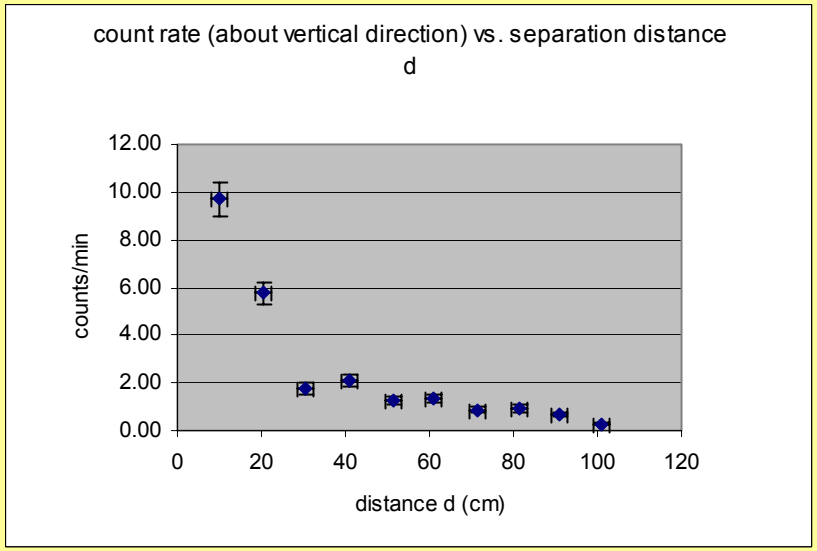


Figure 10: Theoretical Dependence of Stereo Angle, Calculated Using Mathematica Integral Output



Plot 6: Experimental Count Rate Dependence on Separation Distance d

Results

Investigation of Energy Variation

Using a QuarkNet DAQ v.1 board, low energy (decaying) muon events were recorded on the computer. These events are called "doubles"

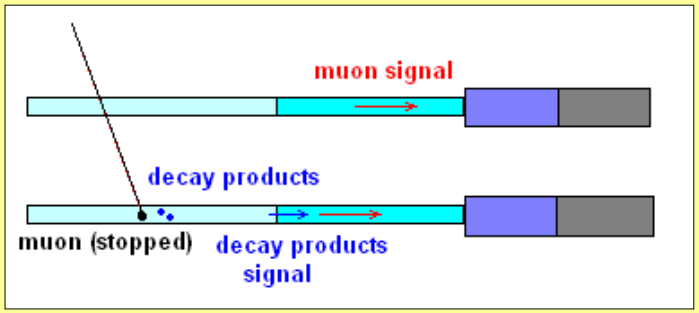
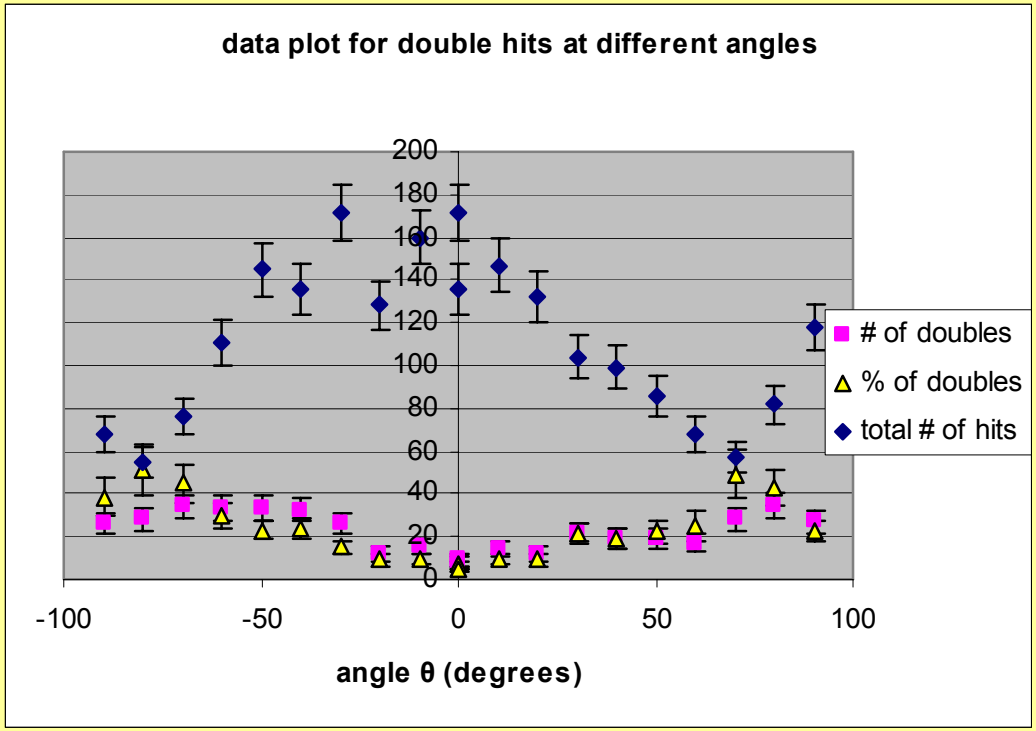


Figure 11: Coincidence Event from a Decaying Muon, Recorded as a Double Event



Plot 7: Double Event Flux Dependence on Zenith Angle Θ

Results

Muon Lifetime Measurement

The muon lifetime was calculated using the QuarkNet DAQ v.1 board data for double events.
The decay time t_{decay} of an initial sample N_0 of decaying muons was recorded.
N(t) was plotted and the data were fitted to an exponential curve of the form:

$$N(t) = N_0 e^{-t/T}$$

where T = muon lifetime

Results:

Fit line:

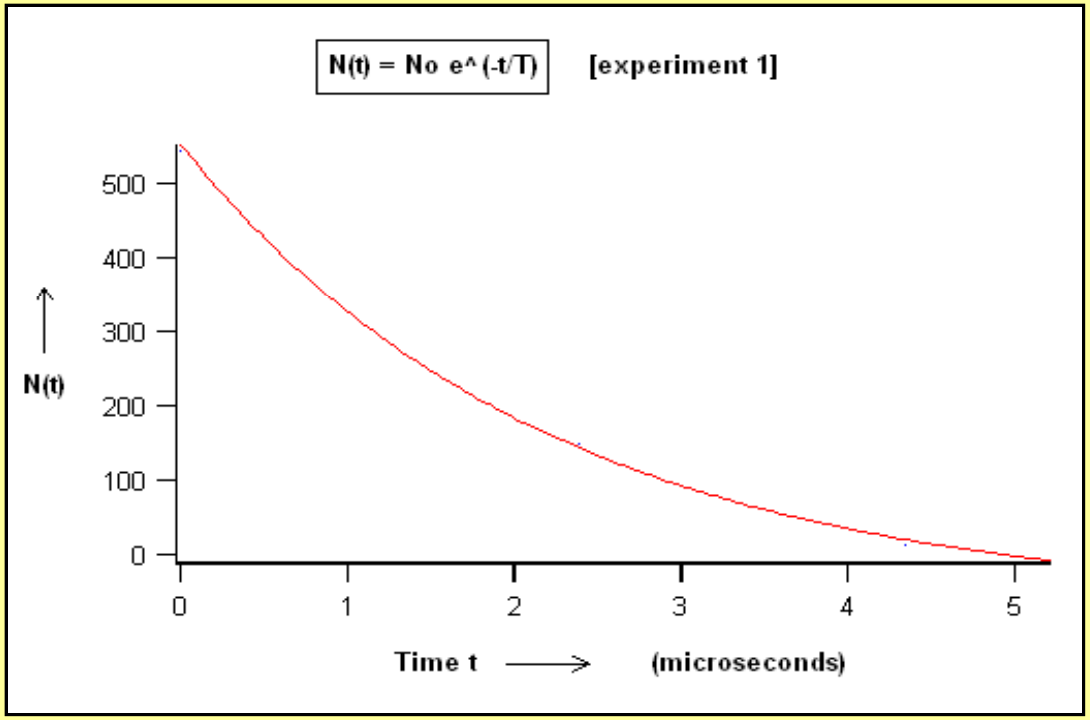
$y = -63.856 + 616.791e^{-0.4552x}$

Lifetime T:

T = 2.1965μs

Theoretical lifetime T_{th}:

T = 2.1970μs

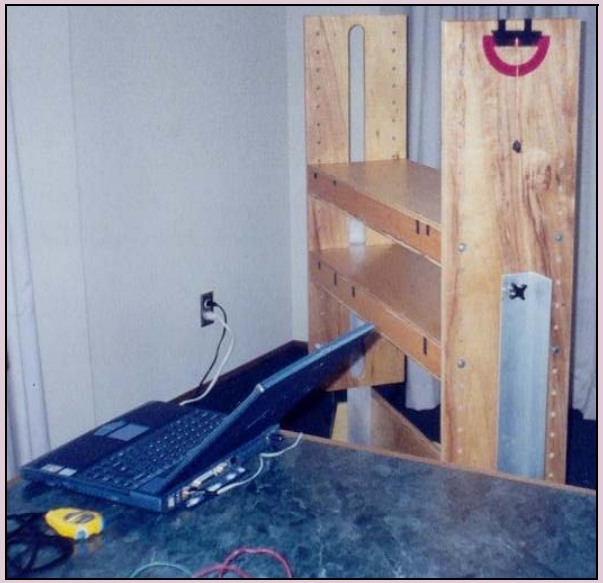


Plot 8: Muon Lifetime Experiment Curve

Photos

Rotation Mount

Flux Measurements, Ground Floor of Crawford Building



Rotation Mount and Setup for Flux Measurement

The End

Acknowledgements

- http://pdg.lbl.gov/2002/cosmicrayrpp.pdf
- http://www2.slac.stanford.edu/vvc/cosmicrays/crdctour.html
- http://hermes.physics.adelaide.edu.au/astrophysics/muon/

Questions?