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# Characterization of Quartz Radiators for Mu2e Upstream Extinction Monitor

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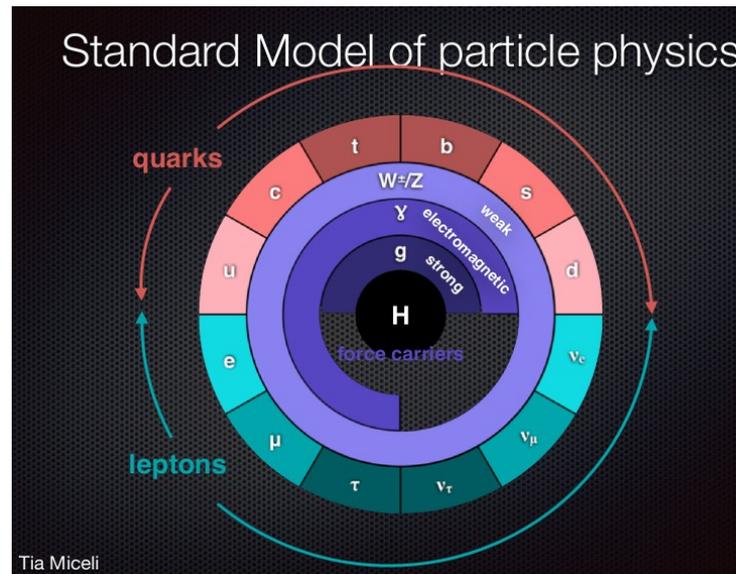
## Overview

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- CLFV and the Mu2e experiment
- Extinction monitoring and quartz radiators
- Cosmic ray telescope
- DAQ and NIM setup
- Results and discussion
- Future Work

# Charged Lepton Flavor Violation (CLFV)

- SM requires preservation of leptonic flavor numbers  $\square\square$  neutrinos were massless.
- LF numbers are only approximate.
- Lepton conservation laws must hold for interactions containing charged leptons.
- Should be possible to observe rare decays such as  $\mu N \rightarrow e N$ .
- Opens up many new models of physics

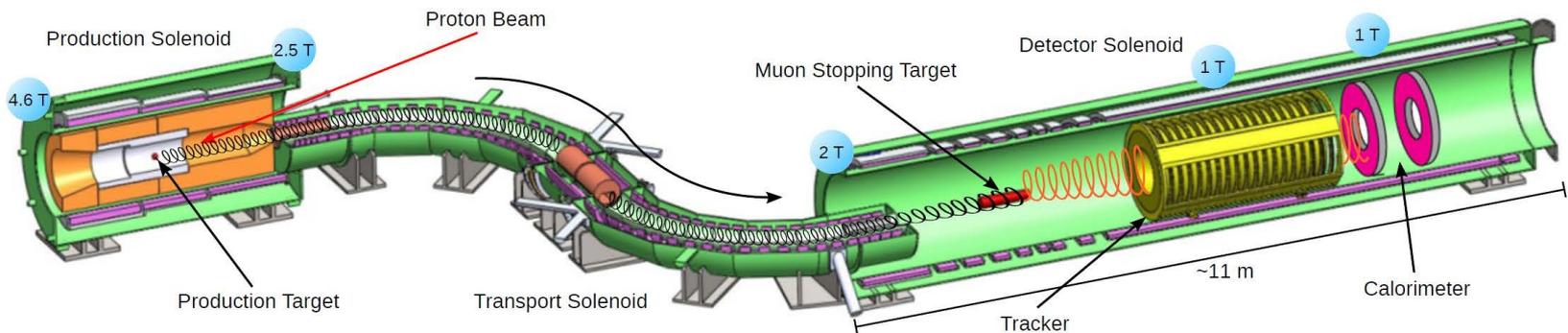


## Mu2e Experiment

- Will measure the ratio of direct conversion of muons to electrons in the presence of a nucleus with respect to the rate of typical muon capture,

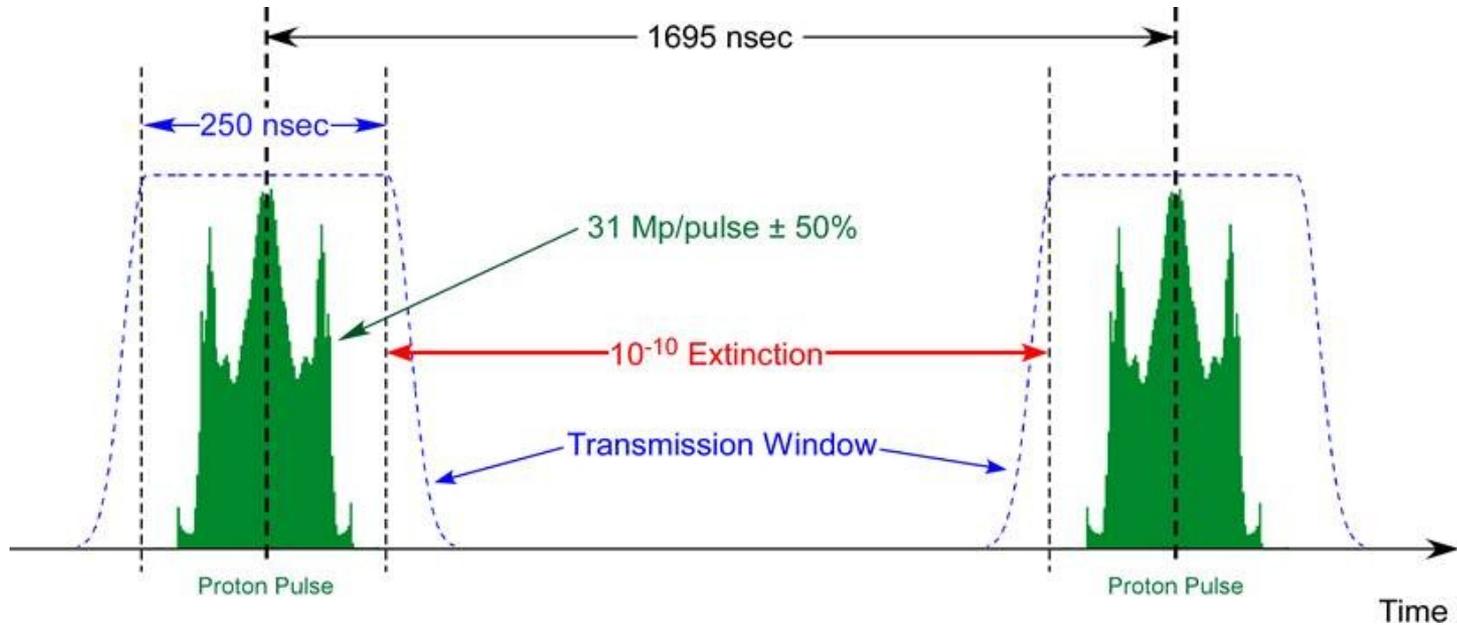
$$R_{\mu e} = \frac{\mu^- + A(Z, N) \rightarrow e^- + A(Z, N)}{\mu^- + A(Z, N) \rightarrow \nu_\mu + A(Z - 1, N)}$$

- Four orders beyond SINDRUM II, with  $R_{\mu e} \approx 2.87 \times 10^{-17}$ .



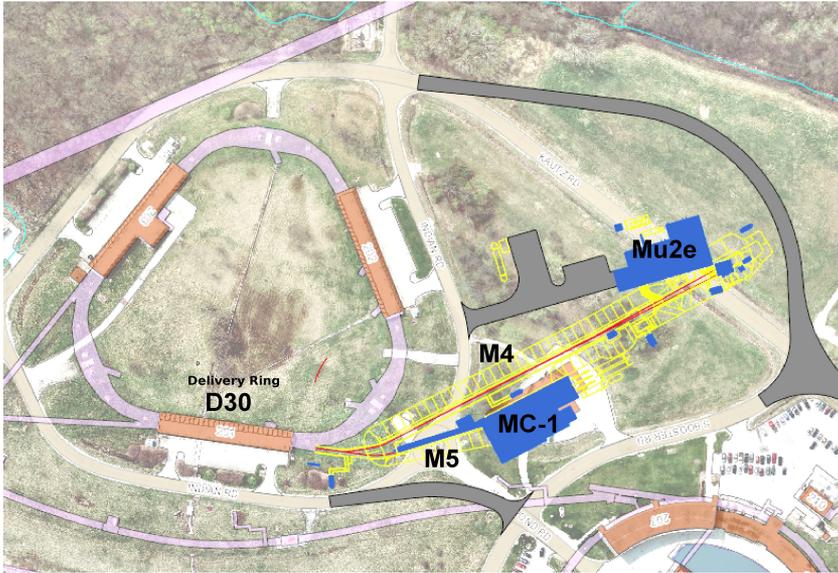
## Extinction Monitoring

$$Extinction \equiv \frac{N_p \text{ b/w pulses}}{N_p \text{ in pulse}} < 10^{-10}$$



- Target Extinction Monitor and Upstream Extinction Monitor
  - Measure extinction on the level of 10<sup>-10</sup> and 10<sup>-5</sup> respectively

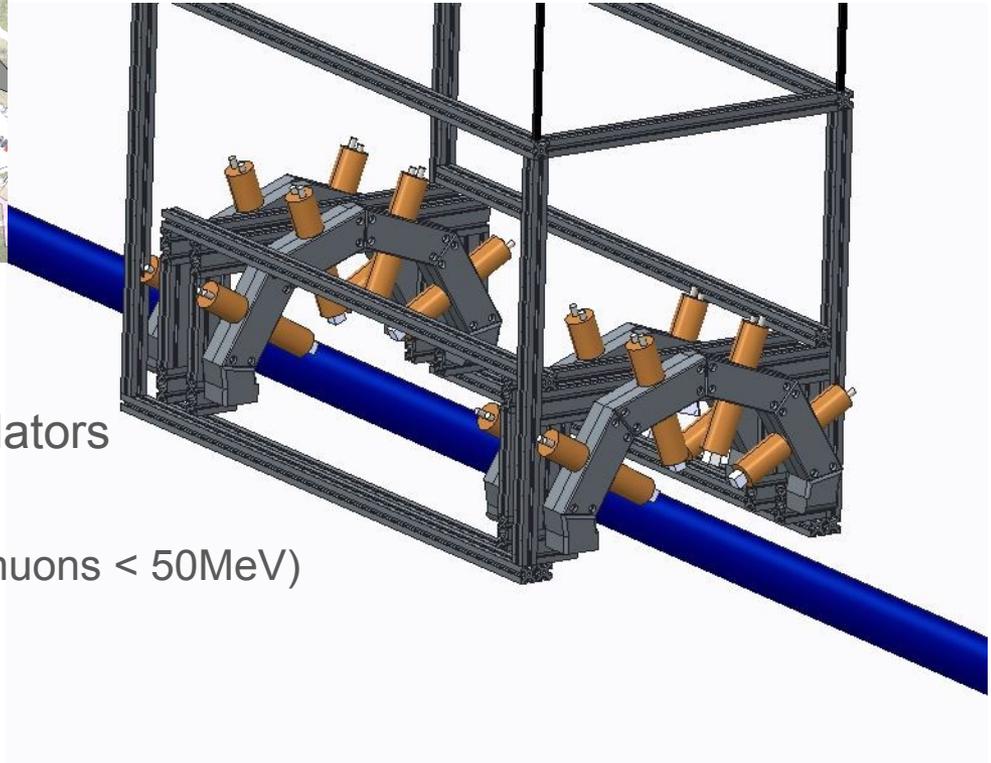
## Upstream Extinction Monitor



- Placed in M4 beam line.
- Designed to use a series of quartz radiators connected to PMTs

- Quartz radiators chosen over scintillators for three main reasons:

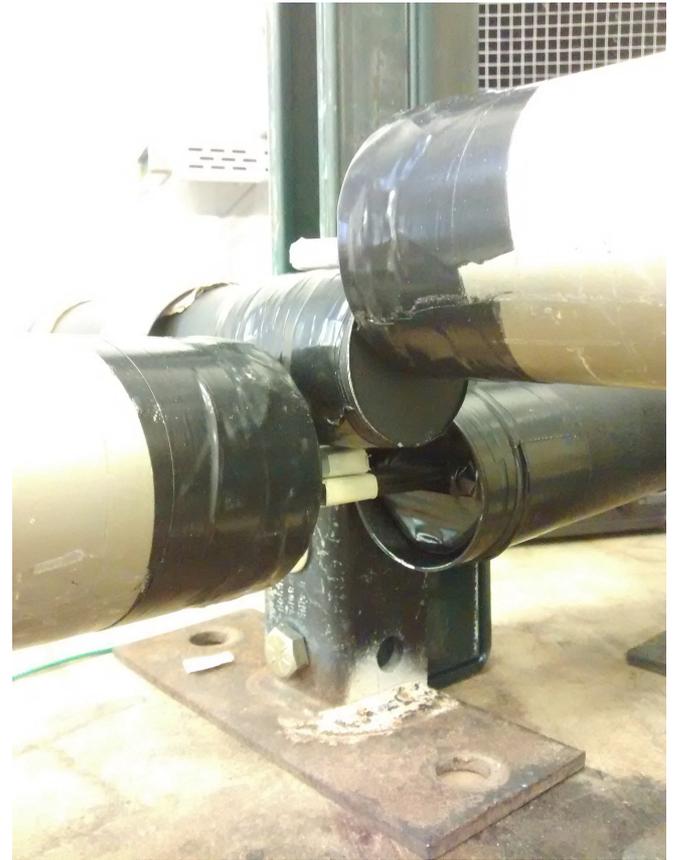
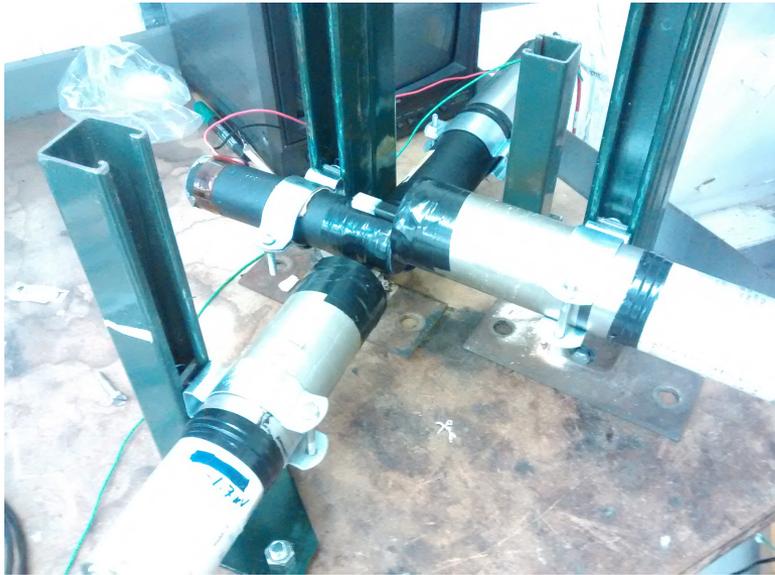
- Blind to soft particles (eg: muons  $< 50\text{MeV}$ )
- No intrinsic after pulses
- Fast response time



## Cosmic Ray Telescope

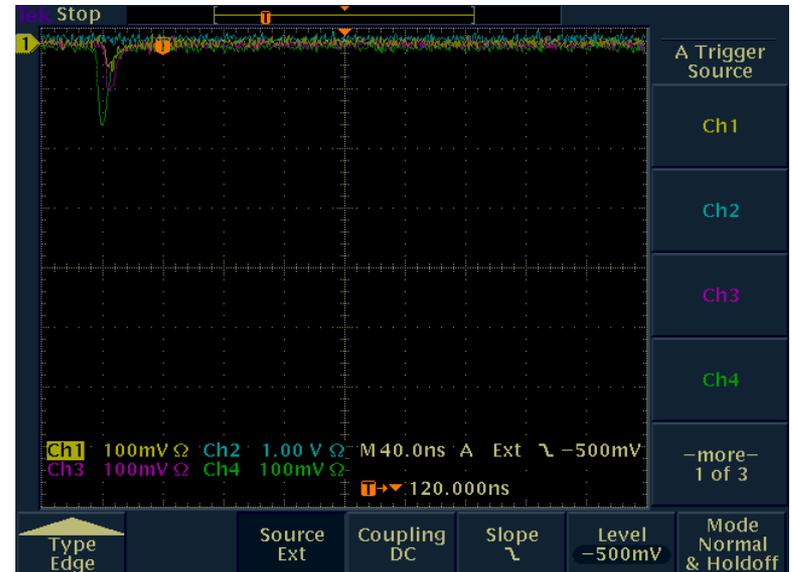
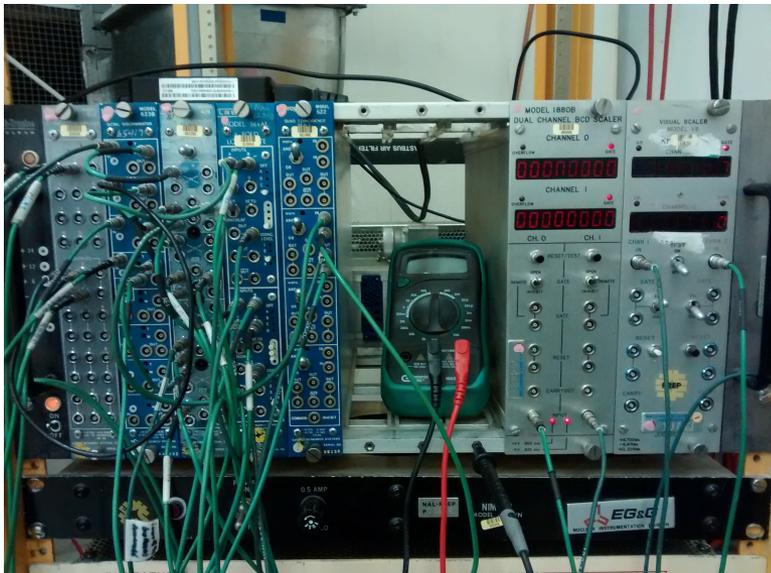
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- Stands were constructed using Unistrut metal framing.
- Main components connected to PMTs are:
  - (3) 1cm x 1cm x 0.5cm scintillators
  - (1) 2cm x 2cm x 0.5cm quartz radiator



# NIM and DAQ Setup

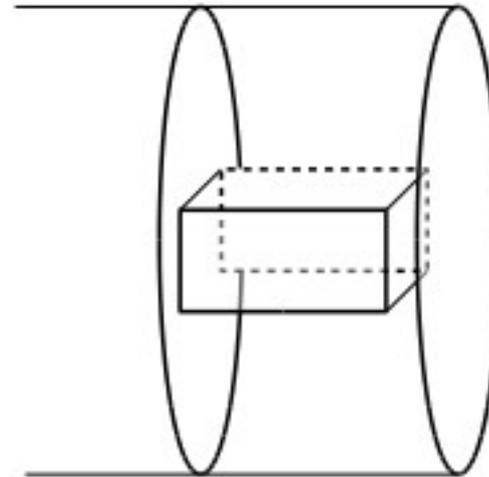
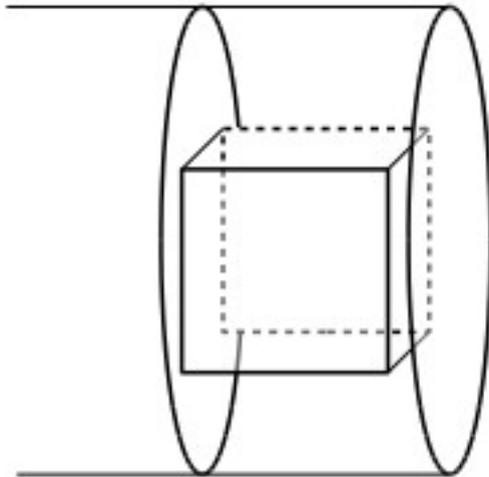
- Nuclear Instrumentation Modules (NIMs):
  - Discriminator, Fan In / Fan Out, Logic Units, Scalers
  - Filter out noise
  - Count both triple coincidences and accidental triple coincidences.
  - Provide external trigger for scope
- C++ program configures scope and stores triggered events for later analysis.



## NIM and DAQ Setup (cont.)

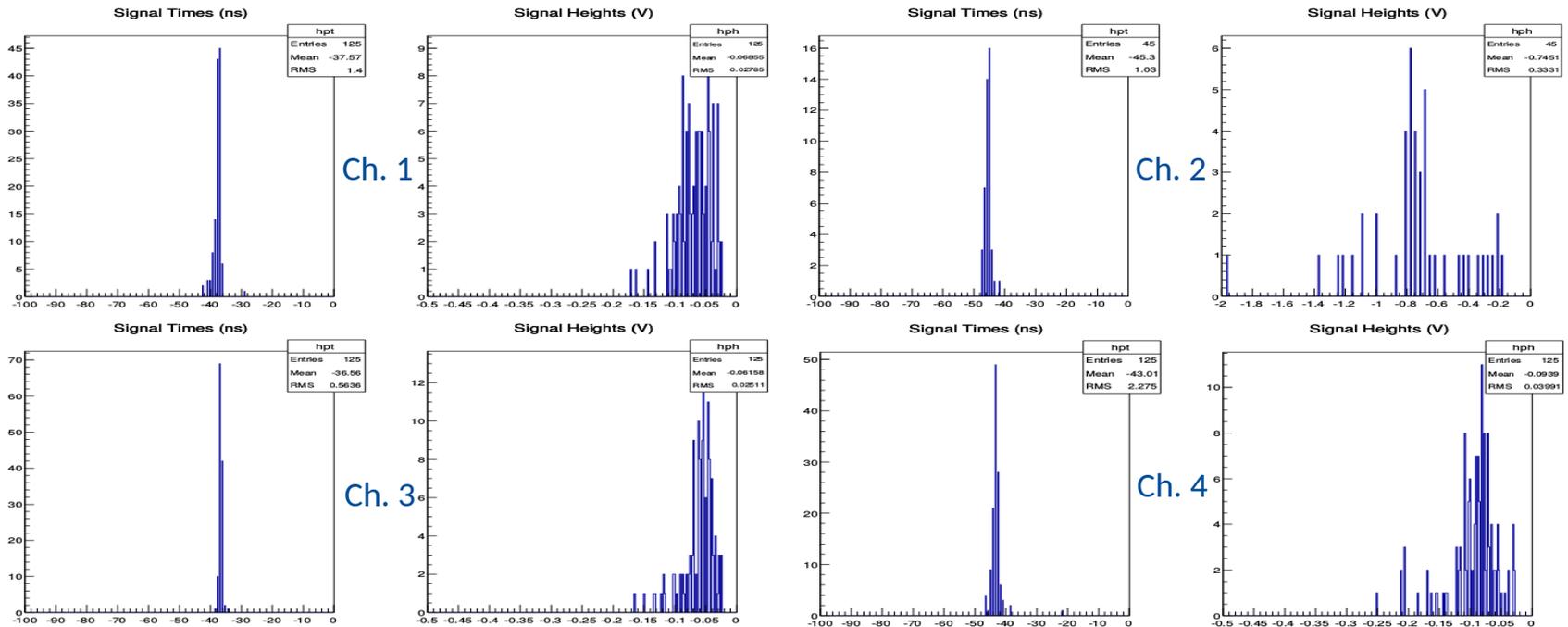
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- Data was collected with both vertical and horizontal orientations of the quartz radiator.



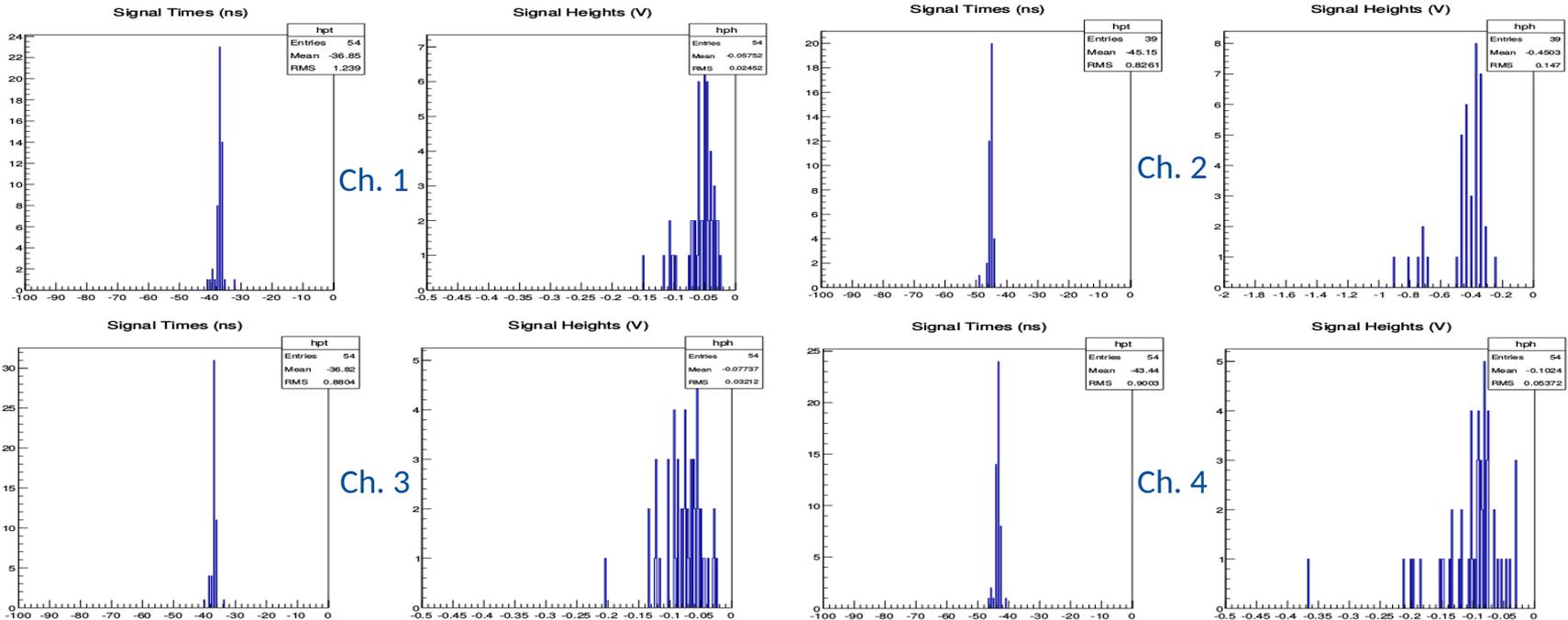
# Results (Vertical Orientation)

- Scaler showed 130 triple coincidences and 3 accidental triple coincidences.
- Data analysis shows that about 36% of triggered events are quadruple coincidences.
- Rate of 1.11 quadruple coincidences/hour over ~40.5 hours.



# Results (Horizontal Orientation)

- Scaler showed 66 triple coincidences and 8 accidental triple coincidences.
- Data analysis shows that about 72% of triggered events are quadruple coincidences.
- Rate of 1.48 quadruple coincidences/hour over ~26.3 hours.



## Discussion and Conclusion

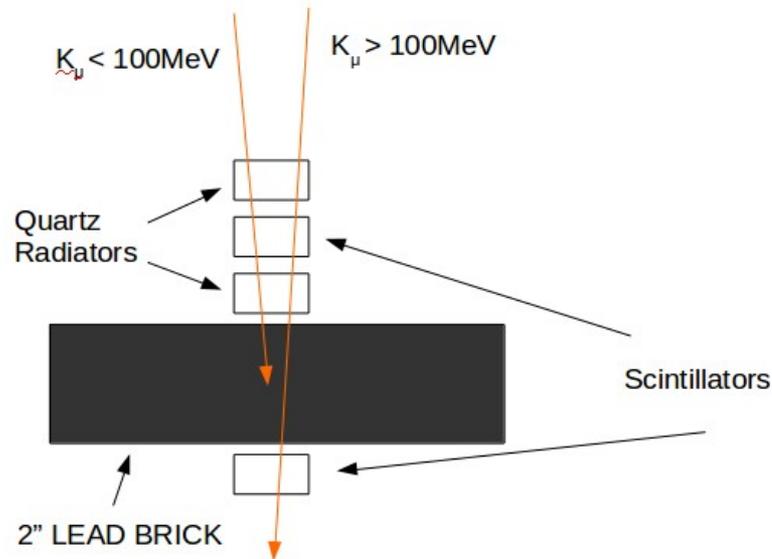
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- Time was mostly spent developing and optimizing telescope, and NIM and DAQ setup, including C++ programs.
- Geometry of telescope and particle energies are the largest factors for quadruple coincidences.
- Preliminary results are very rough figures:
  - Scalers don't agree with number of records
  - Little data collected
  - Accidental rates are too few and not recorded by DAQ
- Expect rates for muons  $> 1\text{GeV}$ :
  - 0.64/hour (Horizontal Orientation)
  - 0.16/hour (Vertical Orientation)
- Large signals from quartz:
  - Mean of scintillator signals  $\sim 77\text{mV}$
  - Mean of quartz signals  $\sim 450\text{mV}/740\text{mV}$

## Future Plans

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- Implement another quartz radiator.
- Implement 2" lead brick to filter out muons below 100MeV.
- Improve analysis code to filter out high voltage signals from scintillators.
- Look at ms after pulses associated with the PMTs.



## Acknowledgements

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- Illinois Accelerator Institute
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- Particularly grateful for my mentor Eric Prebys, for his dedicated assistance and guidance.
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  - Mu2e collaboration
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  - Eric Ramberg
  - Roger Dixon

# Vertical Cosmic Flux

