Mu2e - Extinction Monitor Research & Development

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SULI Oral Presentation

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Report #: **FERMILAB-SLIDES-23-382-STUDENT**

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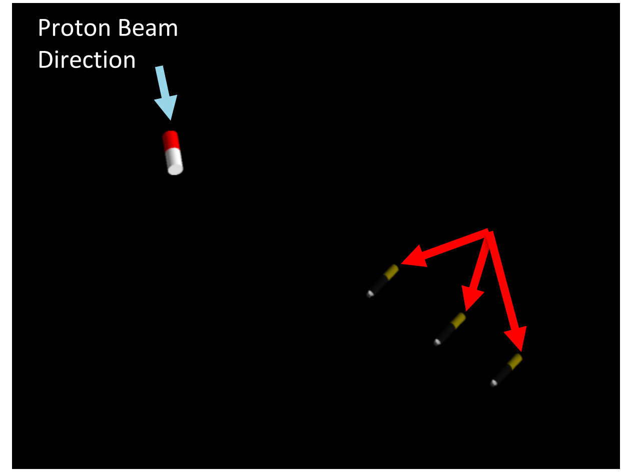

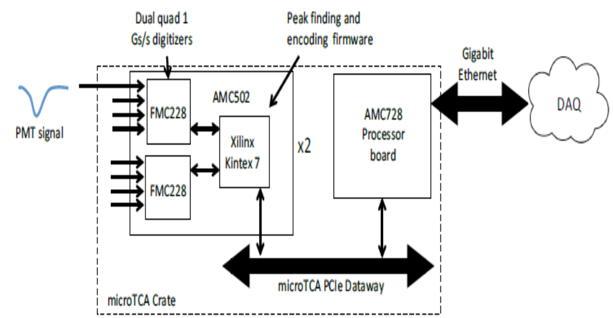

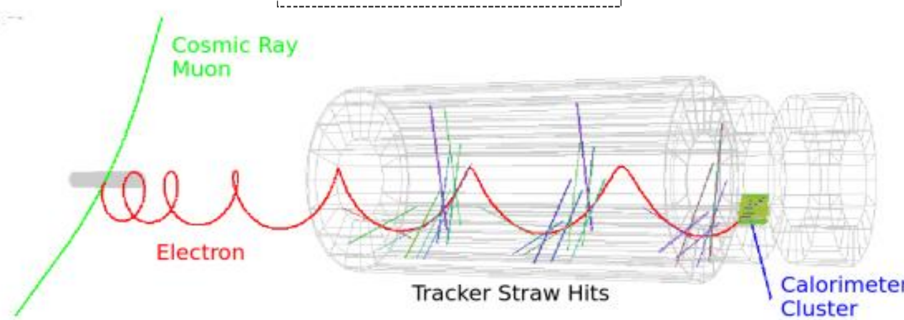

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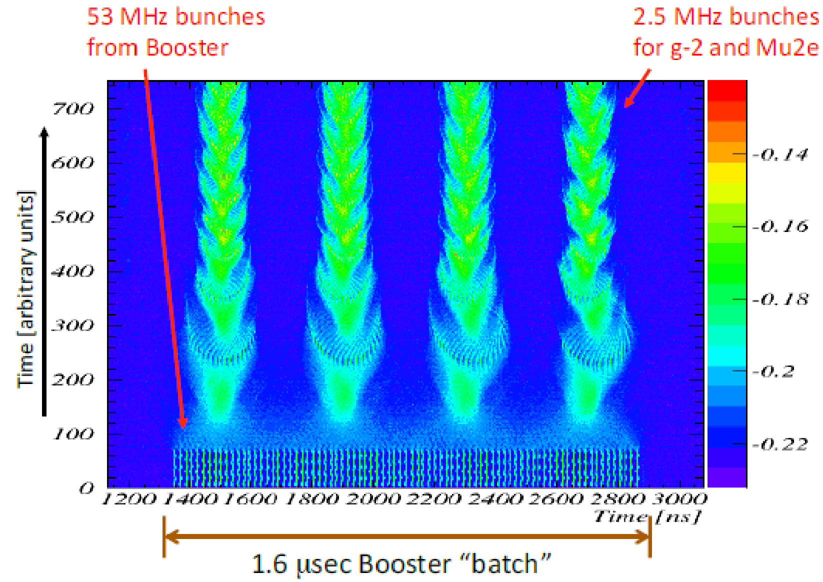
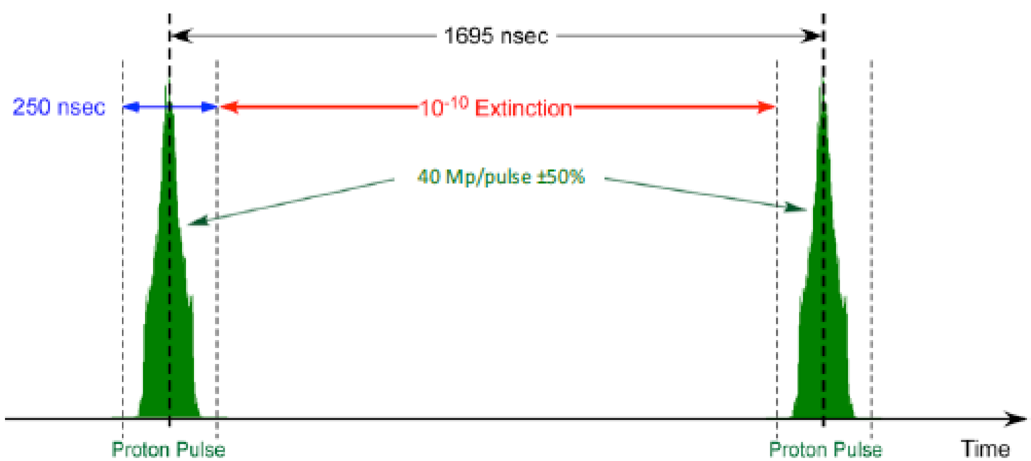
Extinction Rate Analysis

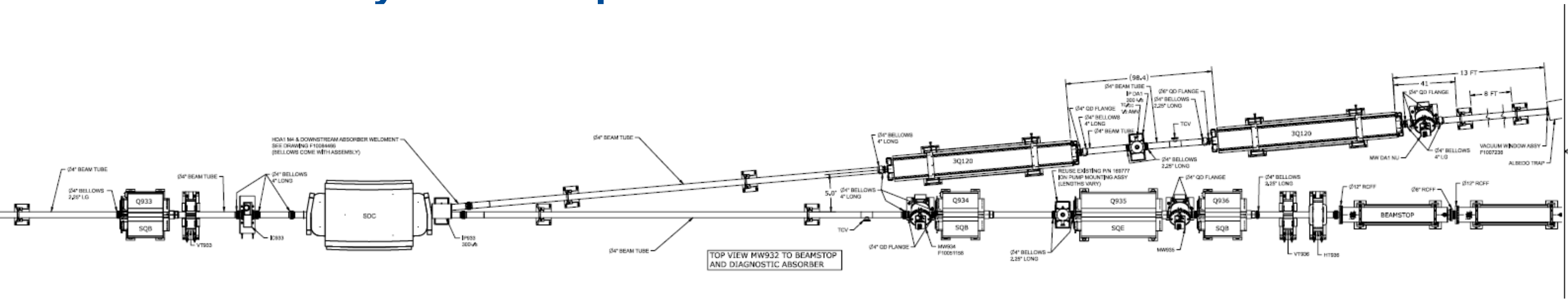
Purpose of Extinction Rate Analysis

- **Mu2e Extinction Requirement:**
  - out-of-time beam be less than 10^{-10}.
- **Recycler Extinction**
  - Re-bunching is expected to provide extinction in the order of 10^{-5}.
- **AC & collimator extinction**
  - Downstream from Recycler Ring.
  - AC dipole and collimator system will provide an additional factor of 10^{-7}.
- **Coincidence Rate Analysis**
  - G4Beamline is a simulation program designed for accurate and realistic evaluation of beamlines based on Geant4 toolkit.
  - Simulation to determine coincidence rates to analyze out-of-time beam ratio with in-time beam for preliminary verification prior to making extinction measurement.





Location of Physical Setup



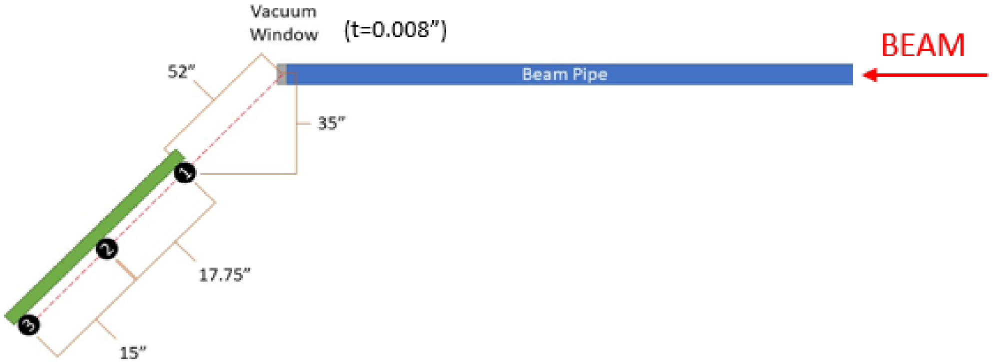
Vacuum Window

Vacuum Window

Detector

Setup & Code Execution

- **G4Beamline Code & Parameters**
  - Gaussian beam
    - σ_x=0.25mm σ_y =0.25mm
  - Kinetic Energy=8000 MeV
  - Events=1E9
  - Titanium target
    - Radius = 38.1mm
    - Thickness = 0.2032mm
  - Numbers 1, 2, 3 are the detectors
    - Quartz crystals used
    - PMT signals use Cherenkov radiation
  - 2/3 & 3/3 – fold coincidence rate calculations
- **Code Execution**
  - Supercomputer 10 trial execution
  - Uses BLTrackFiles package to output results in .txt format
    - Supercomputer was unable to output root files



Fermilab

Filter Calculations

- **Coincidence Filtering**
  - 2/3 & 3/3 – fold coincidence convergence was done using Excel Power Query.
  - Power Query is an Excel extension used for importing and connecting external data for data processing.
- **Note**
  - PDGid is the assigned ID value of the particle from the Particle Data Group.

$n = 1.47$ $\beta = 0.680$

$v_{th} = 2.03E8$ m/s $T_{const} = 0.362$

(Kinetic Energy) $$T = \left[\underbrace{\left(1 - \frac{v_{th}^2}{c^2}\right)^{-\frac{1}{2}}}_{T_{const}} - 1 \right] m_0 c^2$$

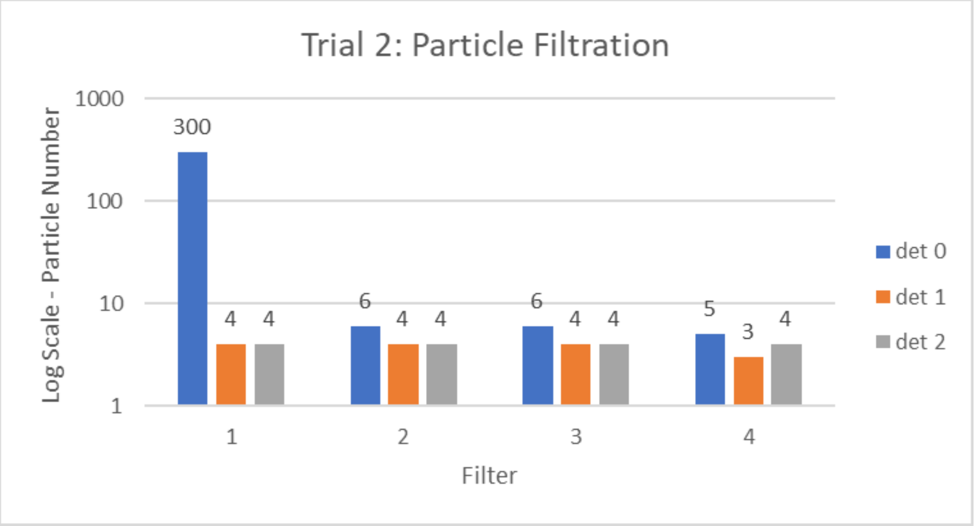
(Momentum) $$P_{th} = \sqrt{(E_0 + T)^2 + E_0^2}$$

Particle Parameters					
	m_0 (MeV/c^2)	E_0 (MeV)	T (MeV)	P_{th}(MeV/c)	PDGid
e	0.511	0.511	0.185	0.473	11
μ	105.700	105.700	38.266	97.742	13
π	140.000	140.000	50.683	129.460	211
p	938.272	938.272	339.673	867.635	2212

Data Filters

- **Filters:**
  - 1st filter displays only charged particles (done on program).
  - 2nd filter outputs charged particles that only interact with 2 or all 3 crystals (Power Query Excel).
  - 3rd filter eliminates photon results in rate count analysis (Power Query Excel).
  - 4th filter selects particles that meet momentum threshold, respectively (Power Query Excel).

Filter	N particles		
	det 0	det 1	det 2
1	300	4	4
2	6	4	4
3	6	4	4
4	5	3	4



- These images correspond to the data from trial 2.

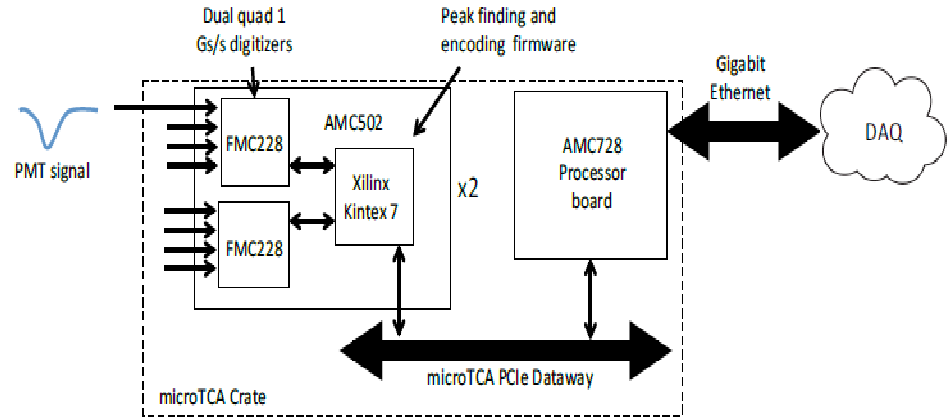
Conclusion

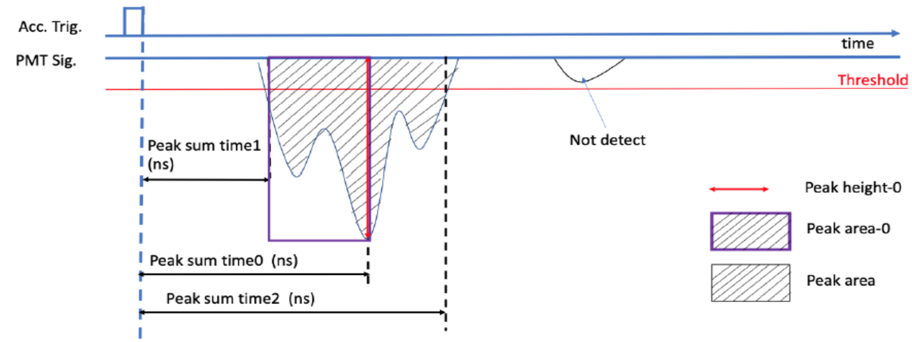
- **Coincidence Rates**
  - 2/3 – Fold: (2.2 $\pm$ (stat) 1.5)E-9
  - 3/3 – Fold: (3.0 $\pm$ (stat) 2.1)E-10
- **To do: Background Measurements**
  - Detector can now be calibrated to accommodate for background rates.
  - Both coincidence rates and background rates can be used to physically verify the upstream extinction rates.

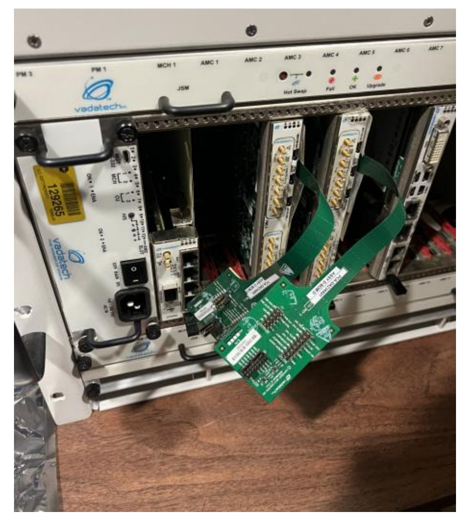
Supplemental Work

MicroTCA Development

- **MicroTCA (Micro Telecommunications Computing Architecture)**
  - Processes & filters PMT signal to output to DAQ
  - Check VHDL code in Vivado 2016.2 to achieve peak finding algorithm.
  - Test physical crate when beam is up & running.
- **Contribution**
  - Installed Linux operating system to check proper functionality of peak finding algorithm.
  - Gathered components needed to begin assembly of crate.
- **Status**
  - Ongoing

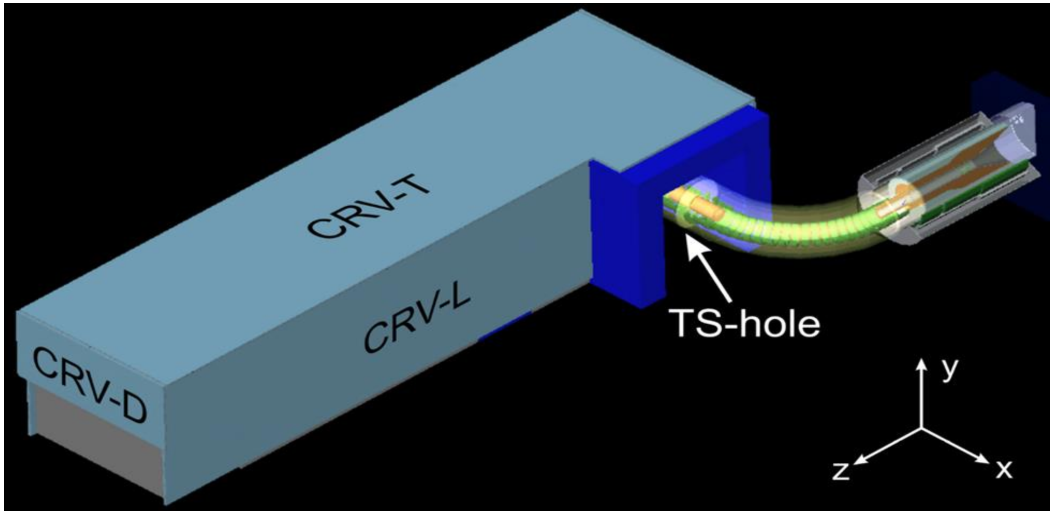


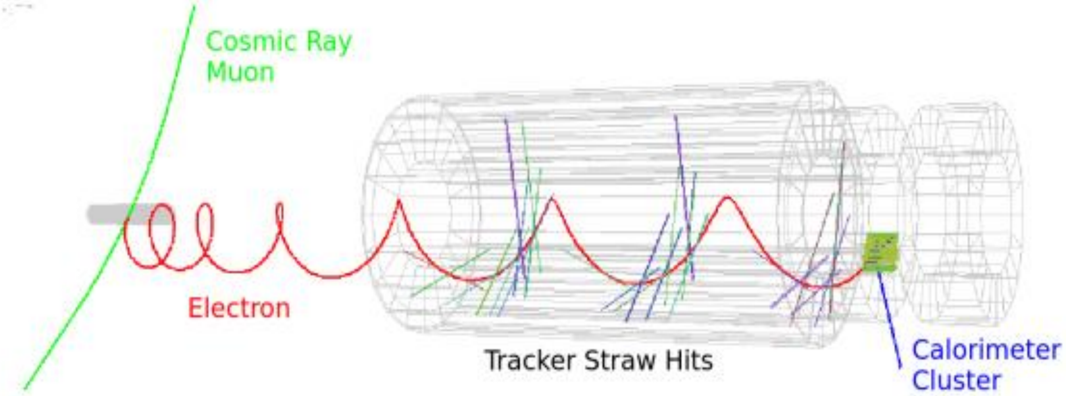




CRV Development

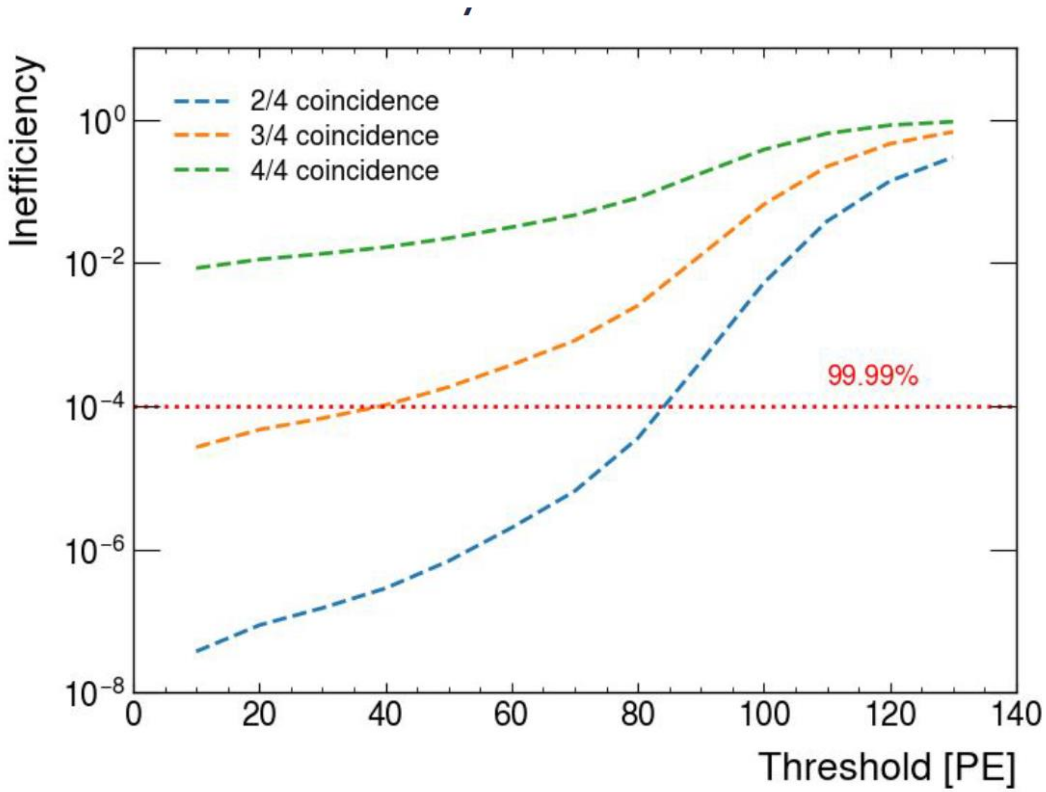
- **Purpose & Setup:**
  - Minimize cosmic-ray muon activity in offline analysis in Detector/Transport Solenoid.
  - Use long extruded scintillation modules to detect and veto cosmic-ray muons.
  - Must be overall 99.99% efficient.
  - Contribution: Testing triangular and 4 rectangular counters for their inefficiency using cosmic muons.





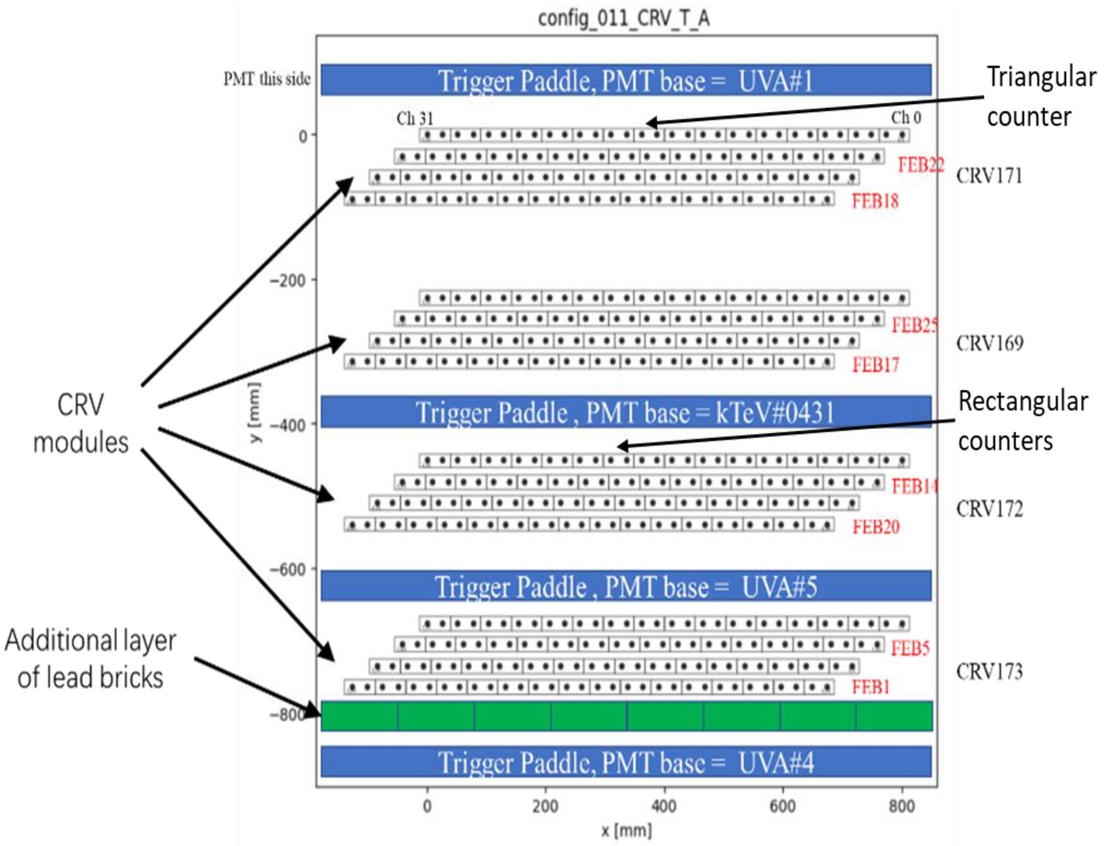
CRV Inefficiency Analysis

- **Inefficiency Analysis:**
  - Cosmic-ray signals are filtered through photoelectron (PE) yield requirements to meet efficiency requirement of 99.99% or overall inefficiency of 1E-4.
  - Single-layer inefficiency of 0.4% for a four-layer veto is required to meet the 1E-4 inefficiency.
  - Cosmic-ray Muon: coincidence hits in three locally adjacent counters in the four layers.



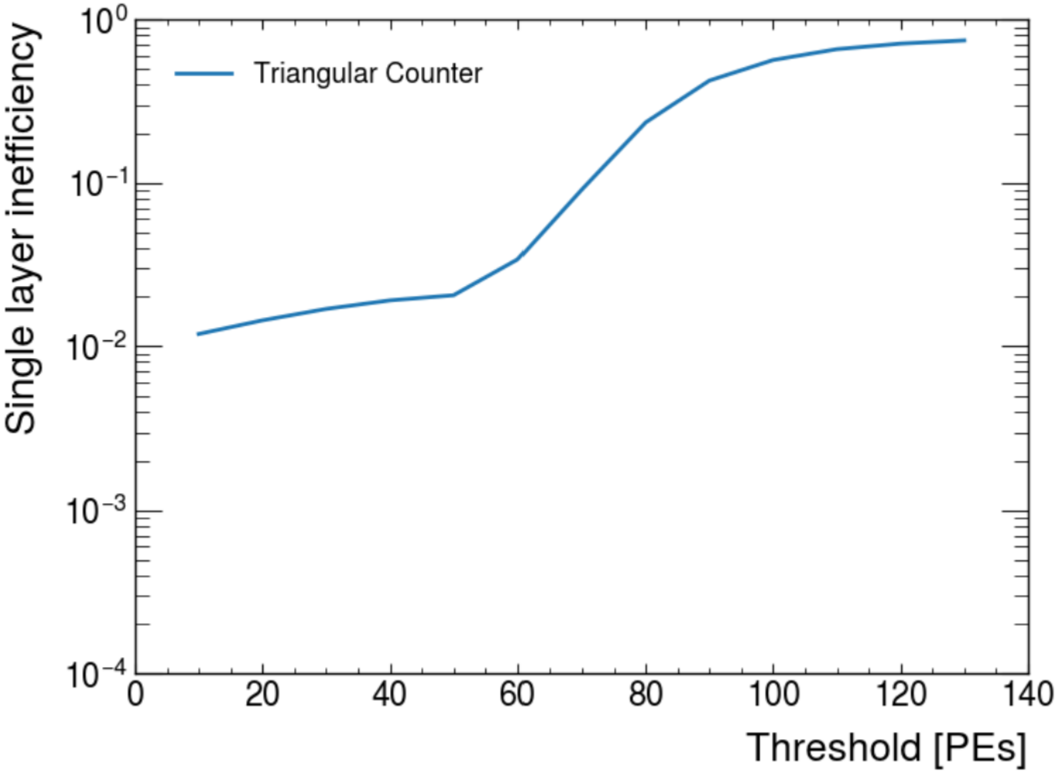
CRV Inefficiency Analysis

- **Inefficiency Analysis:**
  - Testing triangular counters on detection inefficiency.
- **Aging Analysis:**
  - Testing new rectangular di-counters on aging impacts on inefficiency.
- **Both processes use coincidence-based analysis & use 4 averaged runs.**
- **All other modules are used as triggers.**



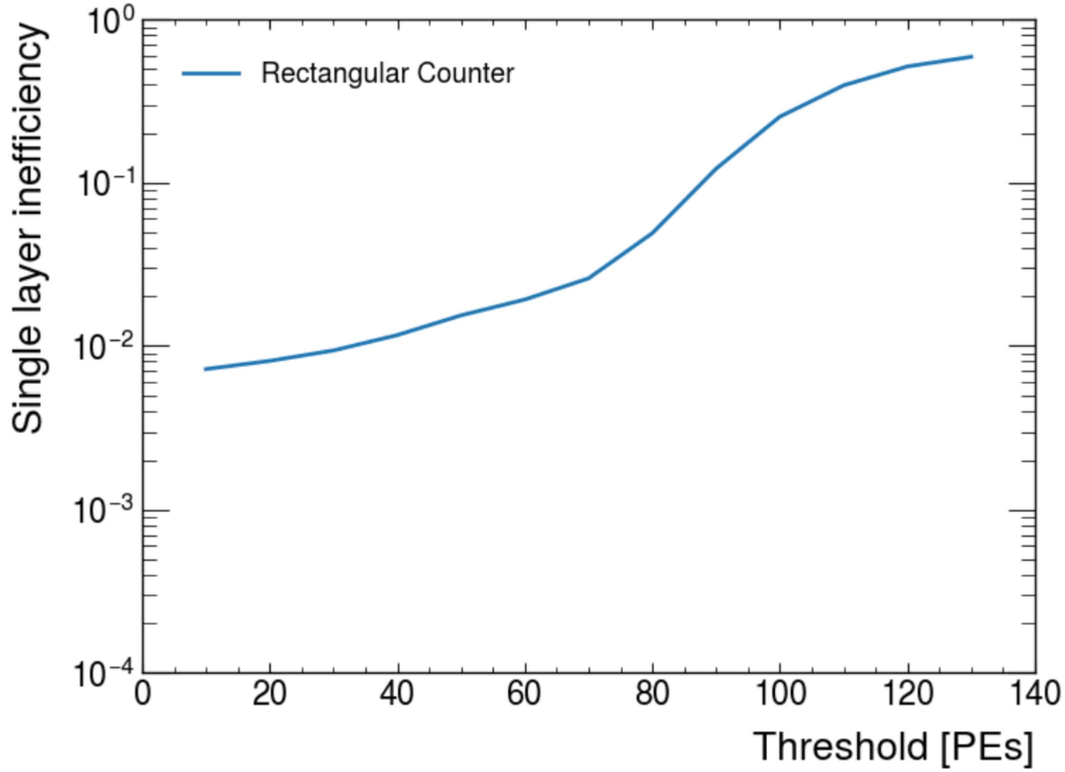
CRV Inefficiency Analysis

- **Triangular Counter Inefficiency Analysis:**
  - Used to determine how geometry affects inefficiency of counter.
  - All other modules are used as triggers.
  - PE threshold is set to a hit being >10 PEs.



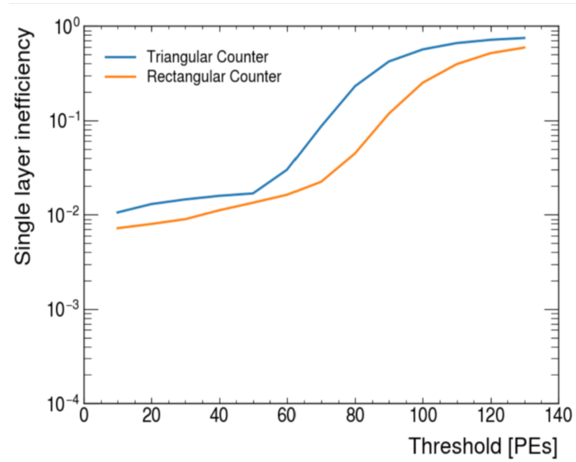
CRV Analysis

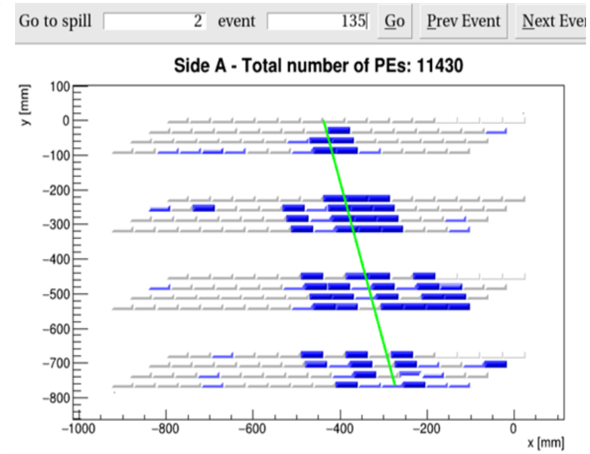
- **Rectangular Counter Inefficiency Analysis:**
  - Used to characterize aging effects on four new rectangular counters along with wrapping effects.
    - 2 counters are wrapped with light sealing tape.
    - 2 counters are wrapped with black plastic.
  - Will be compared to inefficiencies a couple of months from now.

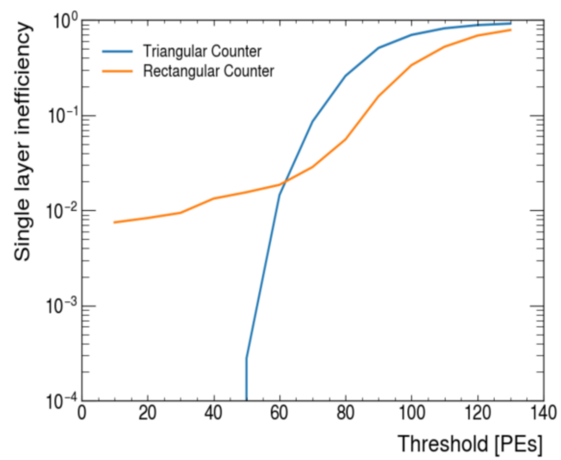


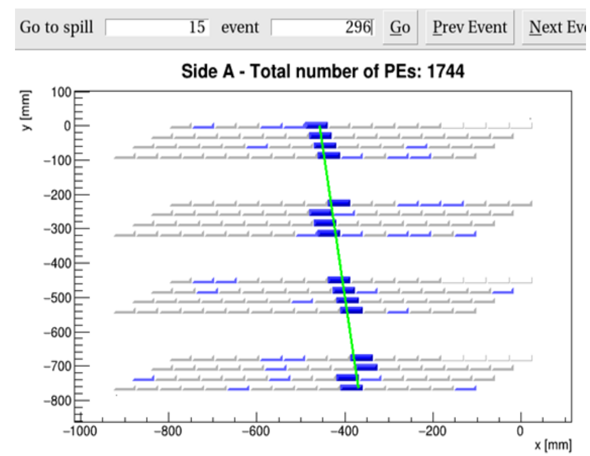
CRV Analysis

- **Conclusion:**
  - Linear track filter was implemented to minimize other non-muon activity.
  - Both studies don’t meet 1E-4 inefficiency requirement.
    - Data includes showers and other cosmic activity.
  - Concerns: Memory on Mu2e CRV server is at its limit processing 4 runs thus, script implementation will be needed to process more runs.









- With linear track filter