

Flash Finding Efficiencies for PDK events

$$p^+ \rightarrow K^+ \bar{\nu}$$

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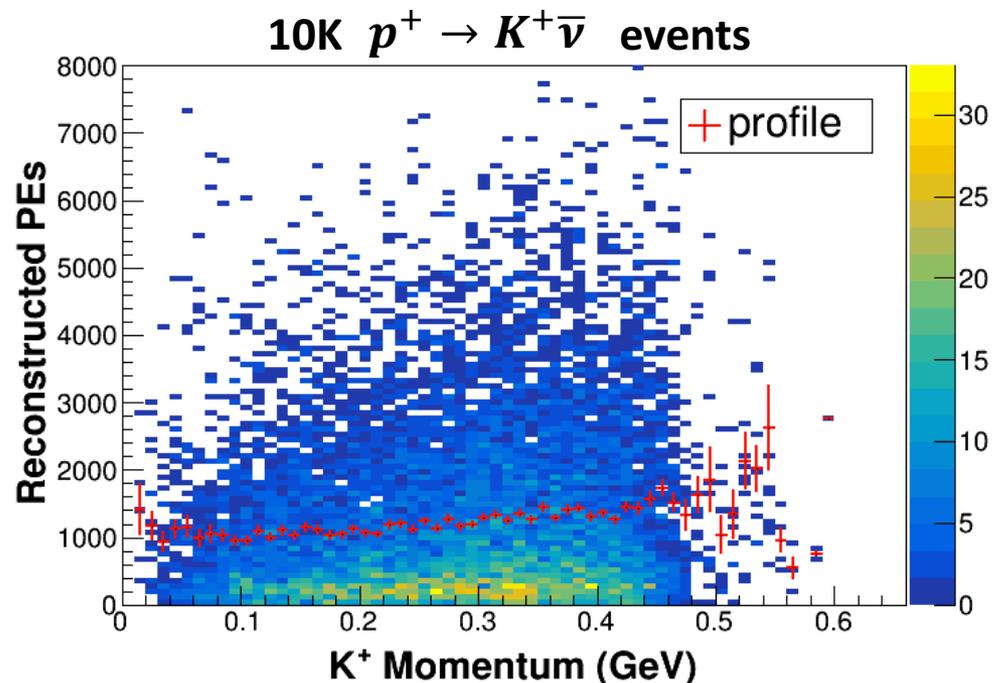
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Outline

- Flash finding reconstruction efficiency
 - For proton decay (PDK) events, we rely on **flash finding** for t_0 determination which enables 3D reconstruction
- ^{39}Ar flash finding rates
 - ^{39}Ar decays yield light which can be misidentified as the t_0 -defining flash
- Setting the threshold
 - Cosmogenic background to PDK considerations

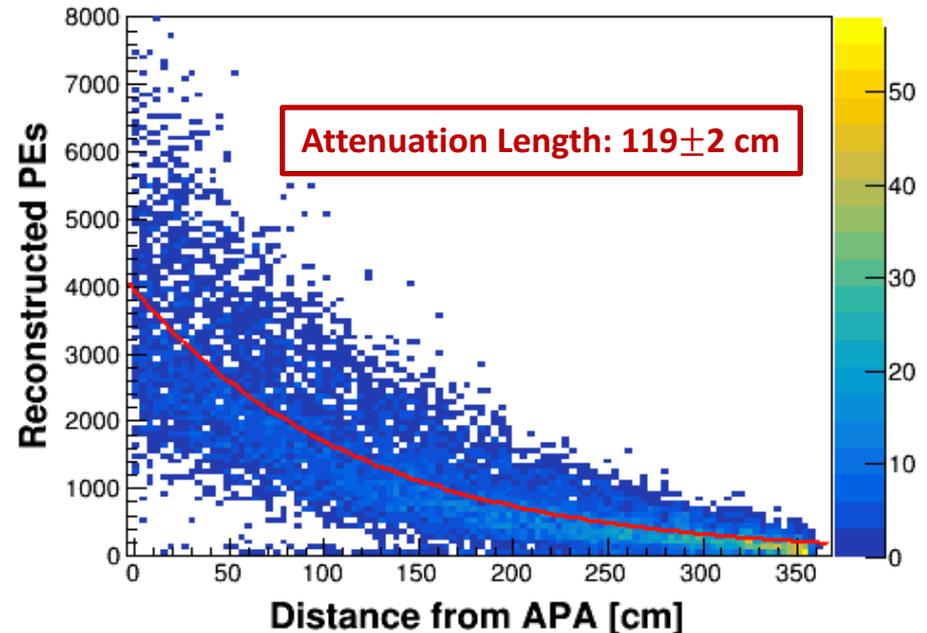
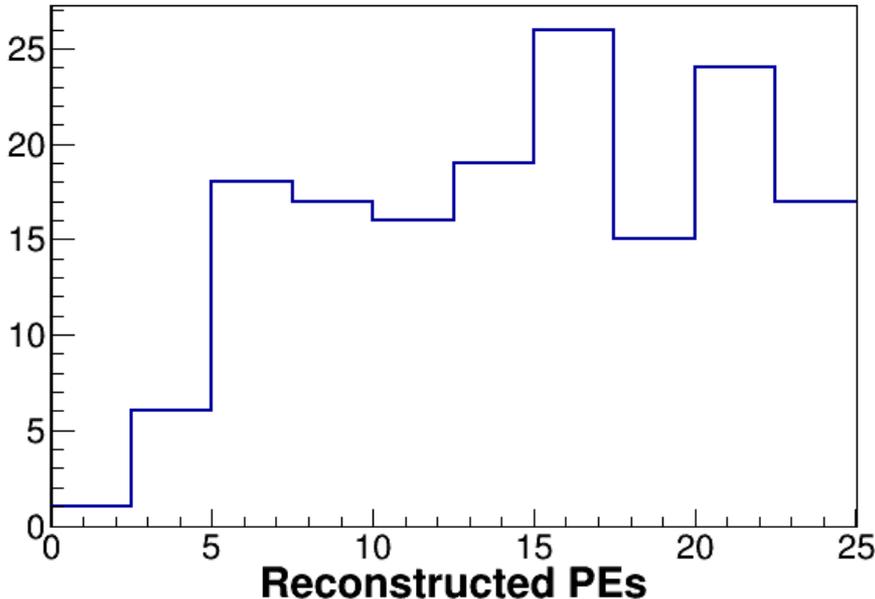
Flash Finding Efficiency

- A **flash** is a reconstructed object from the photon detector system
- Should correspond to a single light source within the detector
 - Time
 - **Light yield**
 - Approximate position
- Observe some low PE flashes (much like ^{39}Ar flashes)



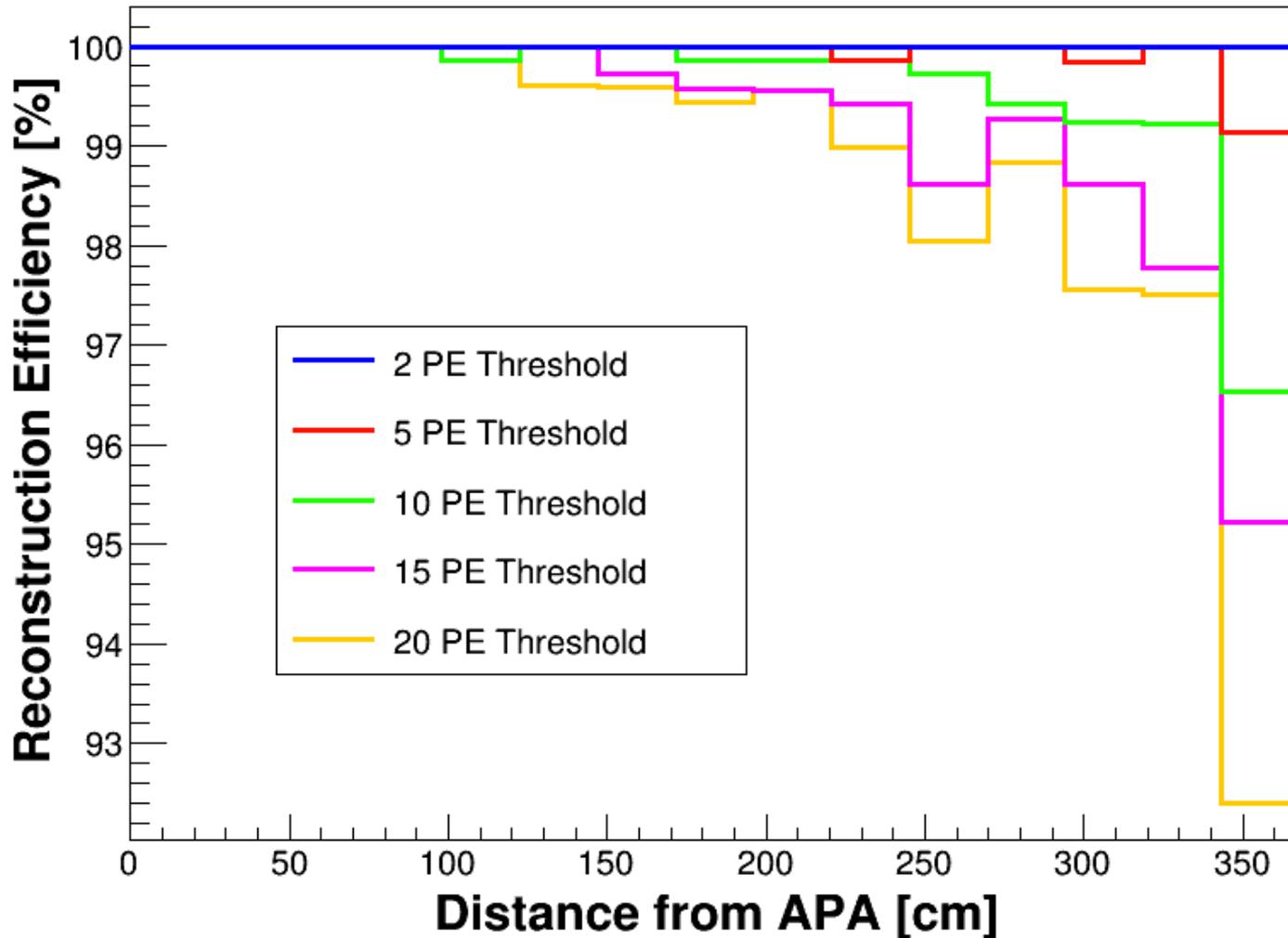
Flash Finding Efficiency

10K $p^+ \rightarrow K^+ \bar{\nu}$ events



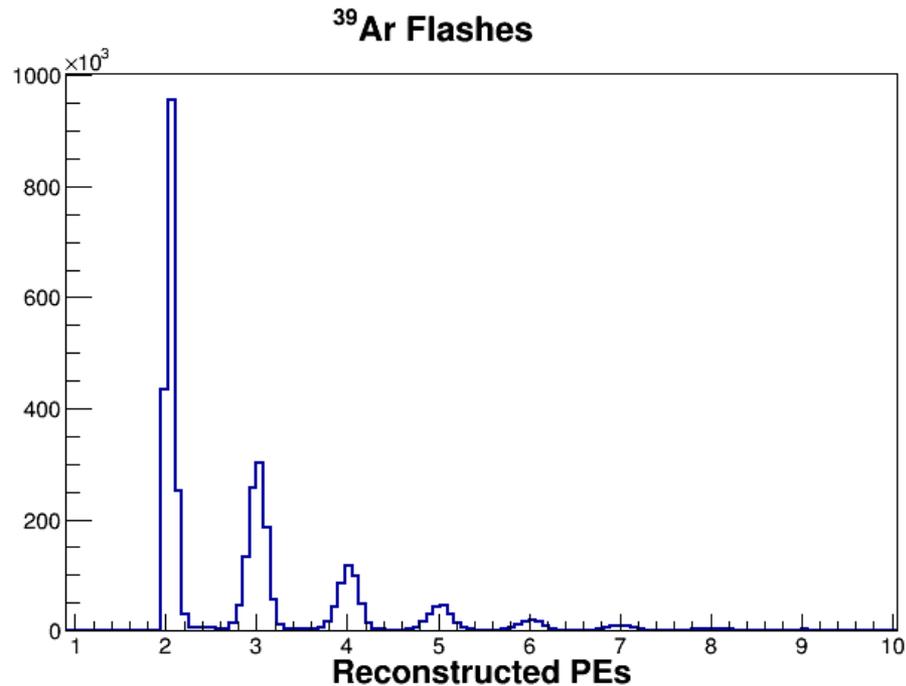
- The further the PDK event is from the optical detectors, the less PEs we reconstruct due to attenuation
- The higher our flash finding threshold, the more of these events we miss

Flash Finding Efficiency



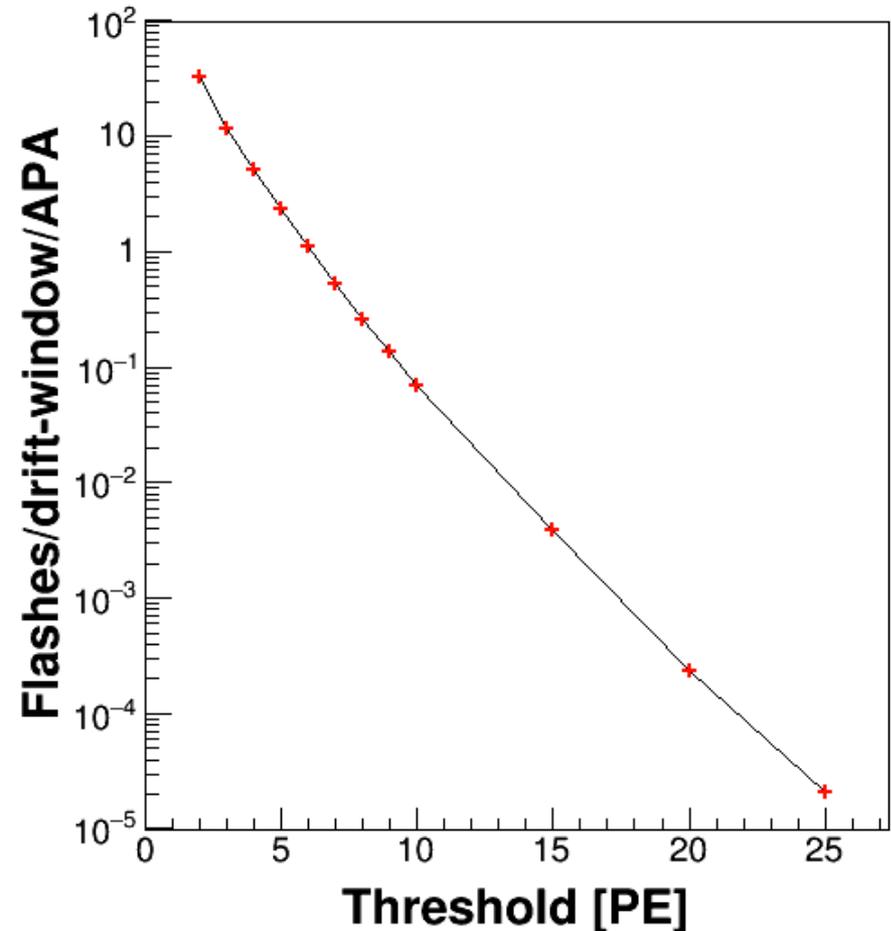
^{39}Ar Flash Finding Rates

- Why raise the threshold if we lose efficiency?
 - We must also think about **purity**
- ^{39}Ar decay produces light in the detector which can be reconstructed into flashes



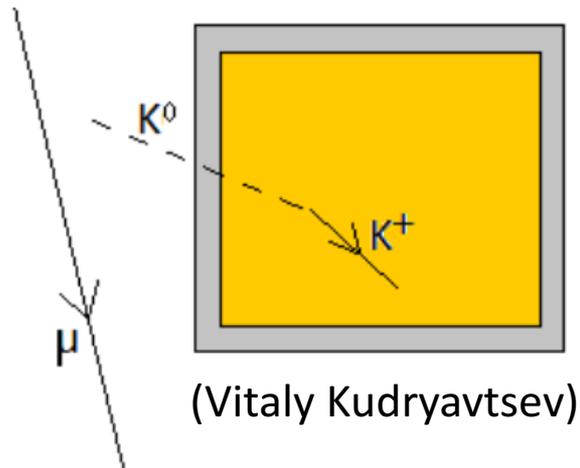
^{39}Ar Flash Finding Rates

- Rates are suppressed an order of magnitude by increasing the threshold by ~ 4 PE
- The question is: **which threshold is appropriate for PDK flash finding** given these rates and efficiencies (on slide 5)
- These “false-flashes” are an issue for PDK cosmogenic backgrounds



Cosmogenic Background

- Cosmic muons can interact in the rock and produce a neutral kaon which enters the detector before undergoing charge exchange, turning into a K^+ , and mimicking this proton decay channel

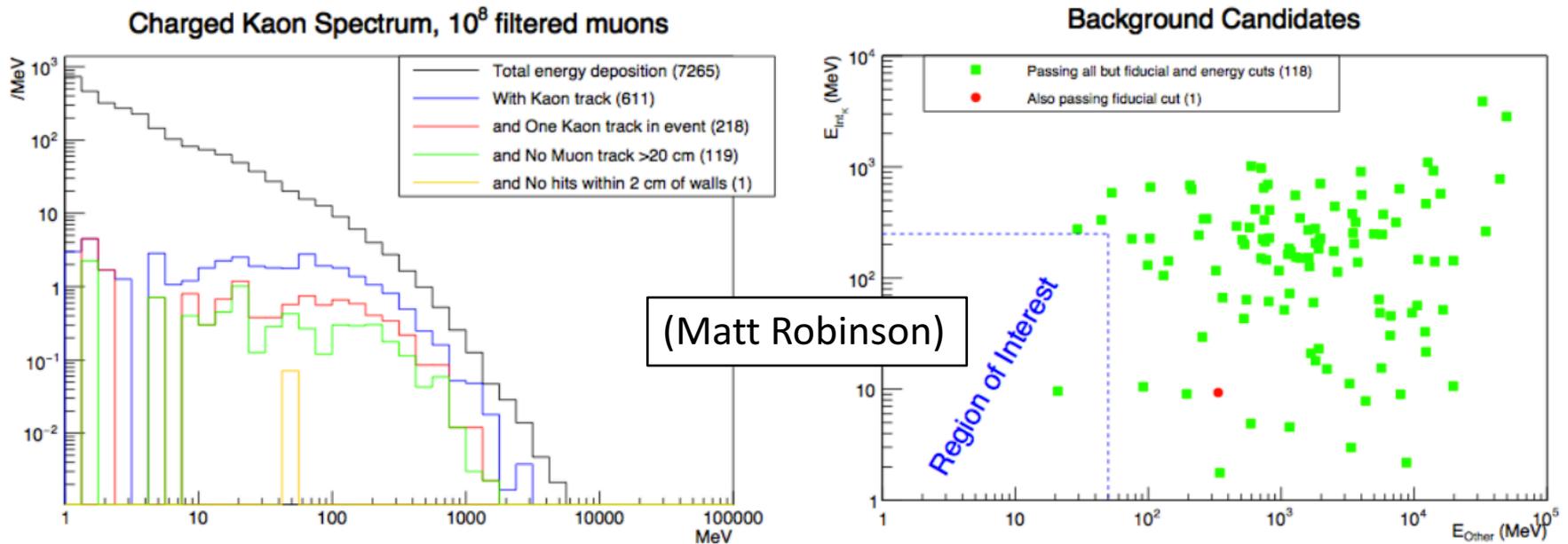


- Sheffield group has been studying this background using MC information
- Energy deposition at the edge of the detector is a good handle to cut off of...
- ... if you have the right t_0

Cosmogenic Background

- If an ^{39}Ar is misidentified as the t_0 -defining flash for one of these events, the track can seemingly get pulled into the fiducial volume (drift direction)
- How many of these backgrounds do we expect in 400 kt-years:
 - Without fiducial cut?
 - With fiducial cut?
- Then, what threshold should we set on flash finding to keep this number $\lesssim 1$ event/400 kt-years?
- Finally, what is the efficiency at *this* threshold?

Cosmogenic Background



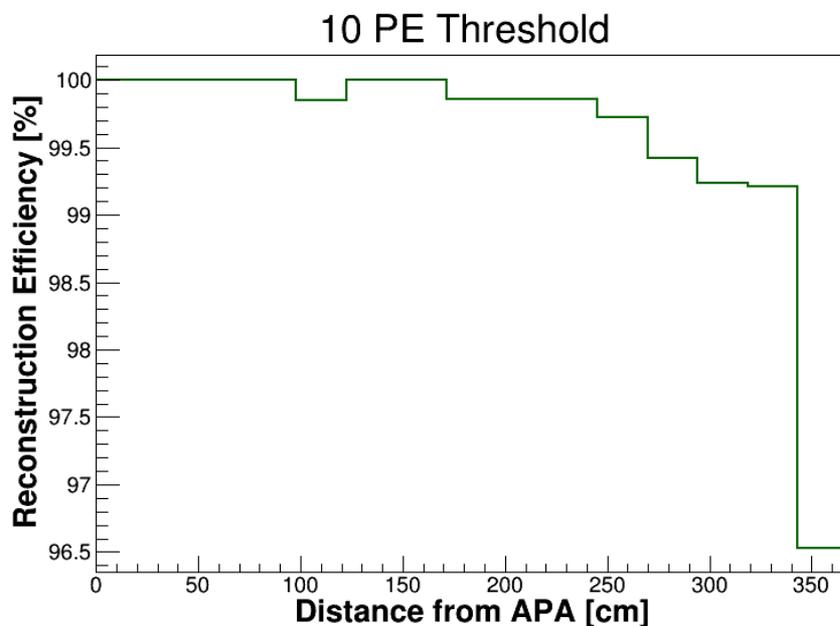
- 0.05 Hz muon rate per 10kt module @4850ft.
- Out of 10⁸ muons, 1 passed all cuts except fiducial (doesn't pass fiducial)
- So the rate of cosmogenics we need a fiducial cut to reject is $\sim 5 \times 10^{-10}$ Hz

Setting the Threshold

- Back of the envelope:

$$0.05 \cdot 10^{-8} \cdot (10 \cdot 365 \cdot 24 \cdot 60 \cdot 60) \cdot 4 = 0.63 \text{ events/400kt-years}$$

- Poisson analysis gives ≈ 8 events/400kt-years (90%)
- ~ 10 PE gives an order of magnitude suppression



- 99% efficiency up to ~ 3.5 m from APA
- 96.5% efficiency at CPA

Summary

- We have great flash finding efficiency across the entire drift distance at a reasonable threshold
- The threshold was set to control the number of flashes we reconstruct from ^{39}Ar
 - Such flashes are problematic for rejecting cosmogenic backgrounds if they occur too frequently