DEEP UNDERGROUND NEUTRINO EXPERIMENT

UNIVERSITY of HOUSTON
YOU ARE THE PRIDE
DEPARTMENT OF PHYSICS

Proton Decay at DUNE FD

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar

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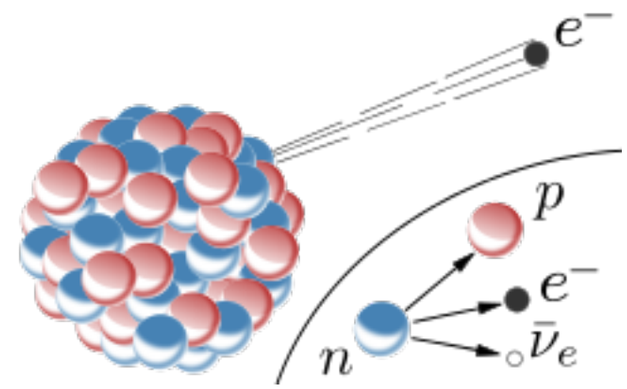
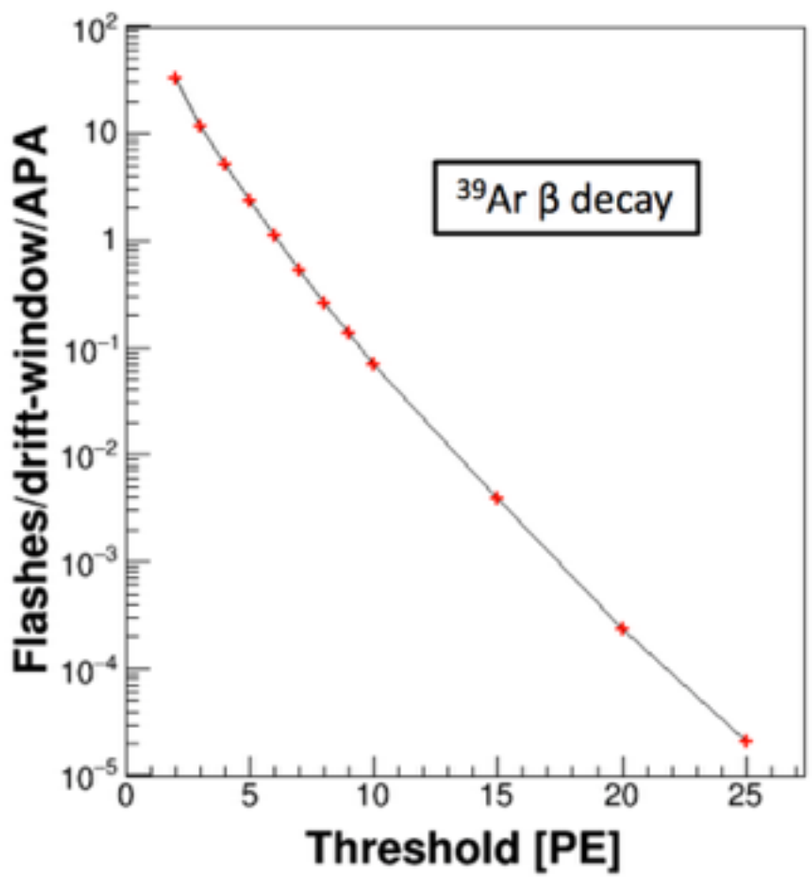
$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar

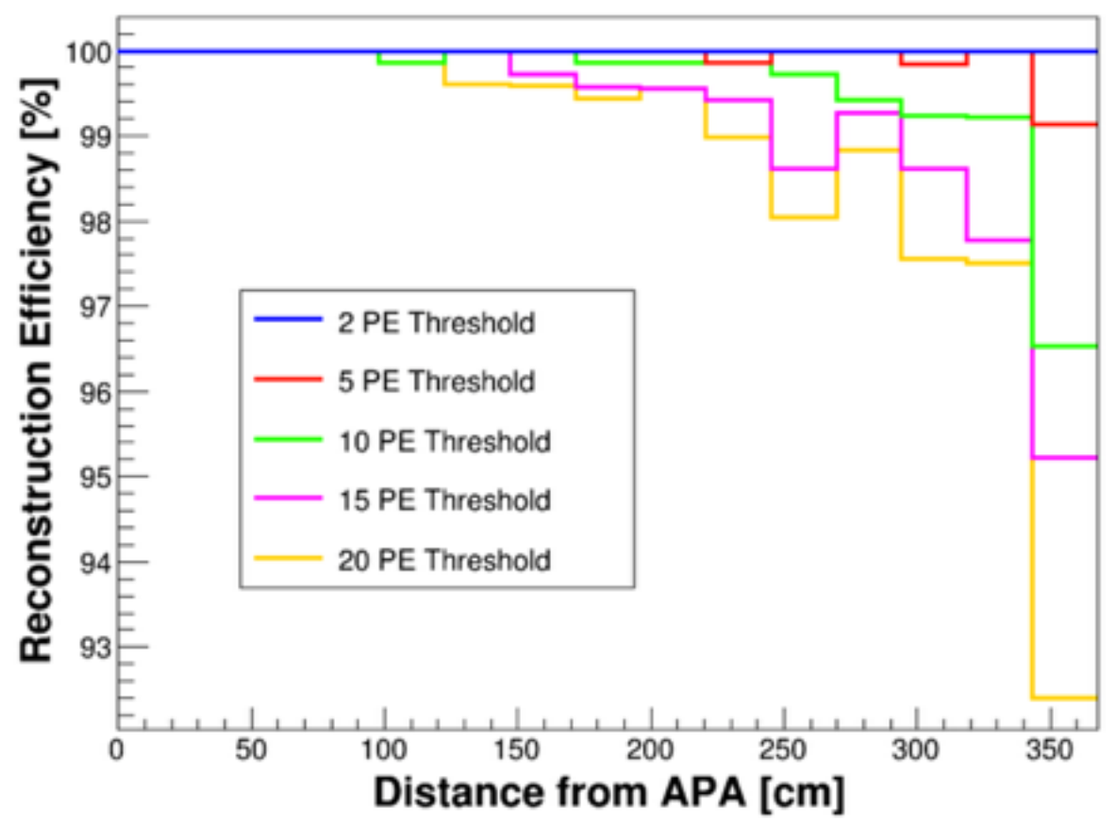


- For non-beam events, in order to obtain the drift time we rely on detecting the scintillation light (t0) using PDS information
- ^{39}Ar beta decay is an intrinsic contamination in DUNE and can produce light sensitive to the PDS, then it can be a potential issue for non-beam events
- What is the impact of ^{39}Ar background for nucleon decay searches?

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar

- Previous studies were done by Kevin Wood by simulating ^{39}Ar and proton decay events separately
- Uses the most intense OpFlash if there is more than one OpFlash
- In reality we will have ^{39}Ar on top of a potential proton decay event





$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar

- Simulation of ^{39}Ar and proton decay events

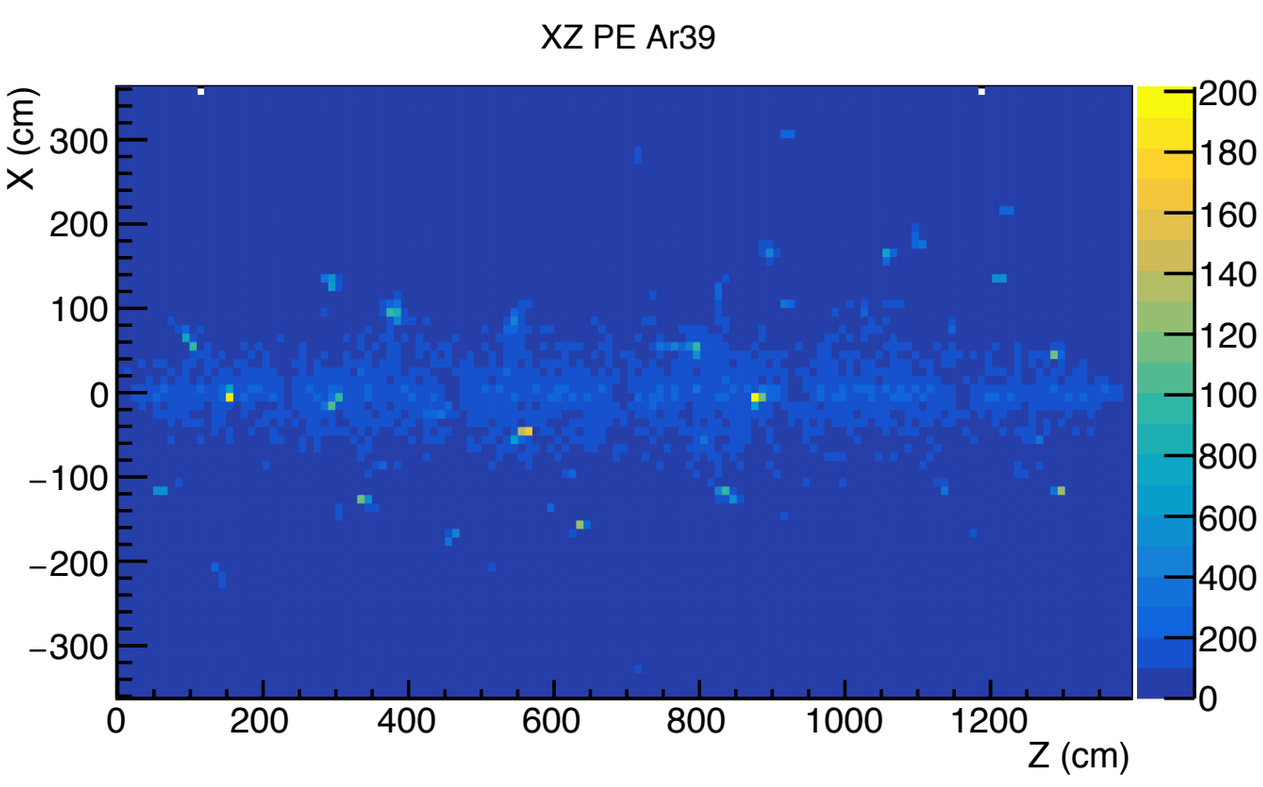
```
generator:  @local::dunefd_1x2x6_ar39
generator2: @local::standard_ndk
```

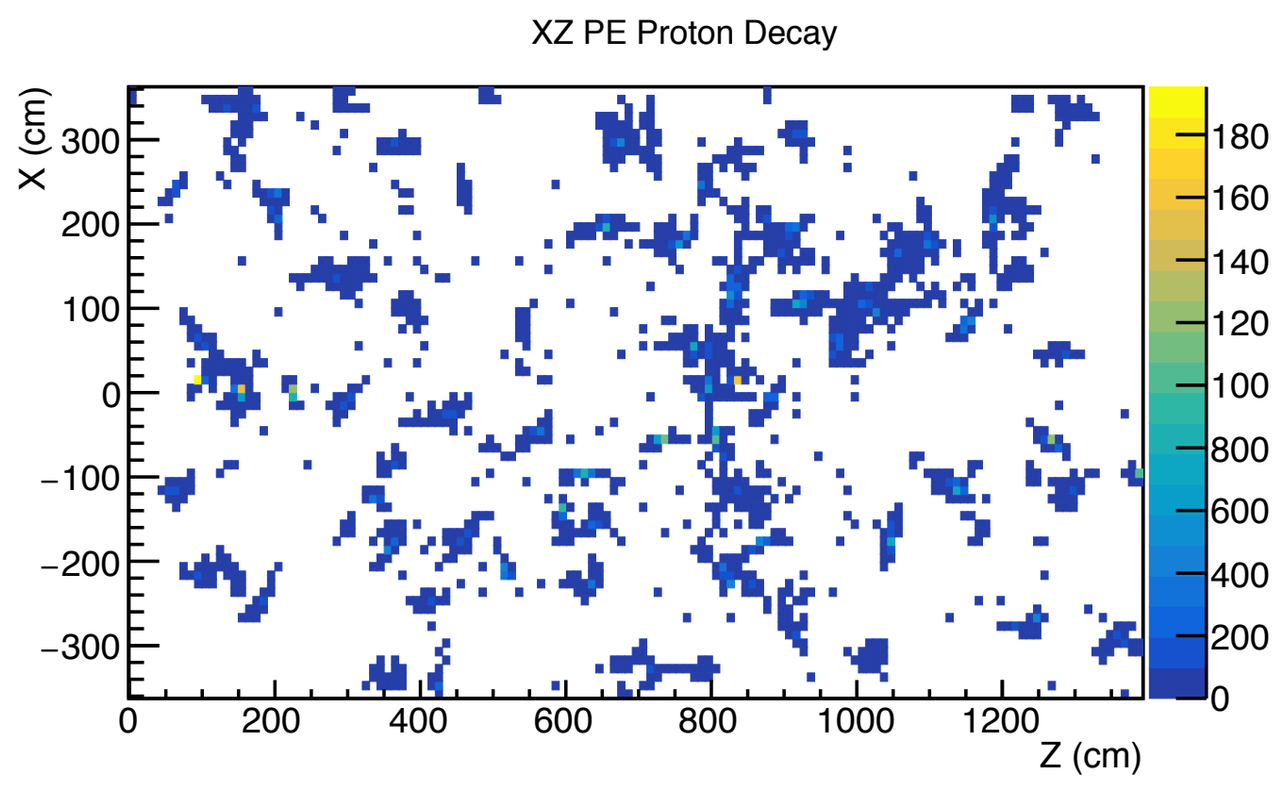
- How much of ^{39}Ar?

- 1.01 Bq/kg per drift window (±2.25ms) using 1x2x6 geometry plus 1K proton decay events

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar

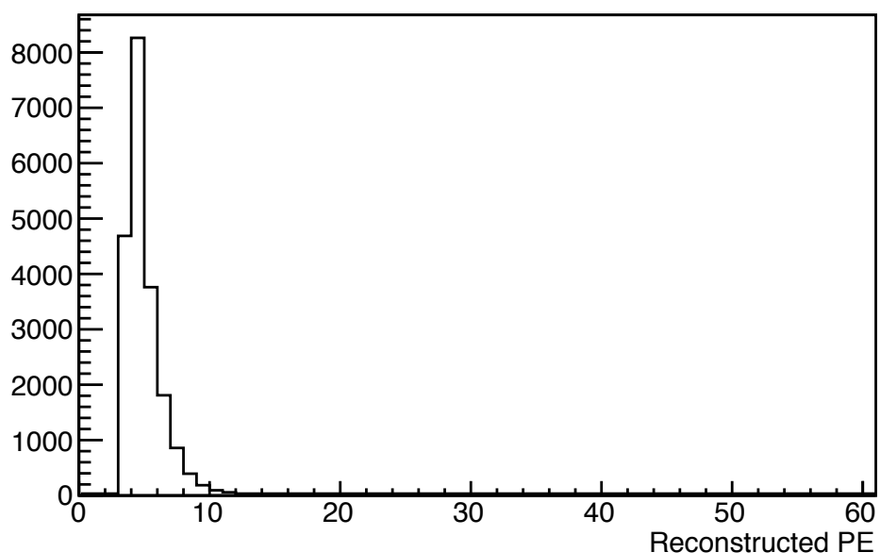
- Reconstructed OpHit



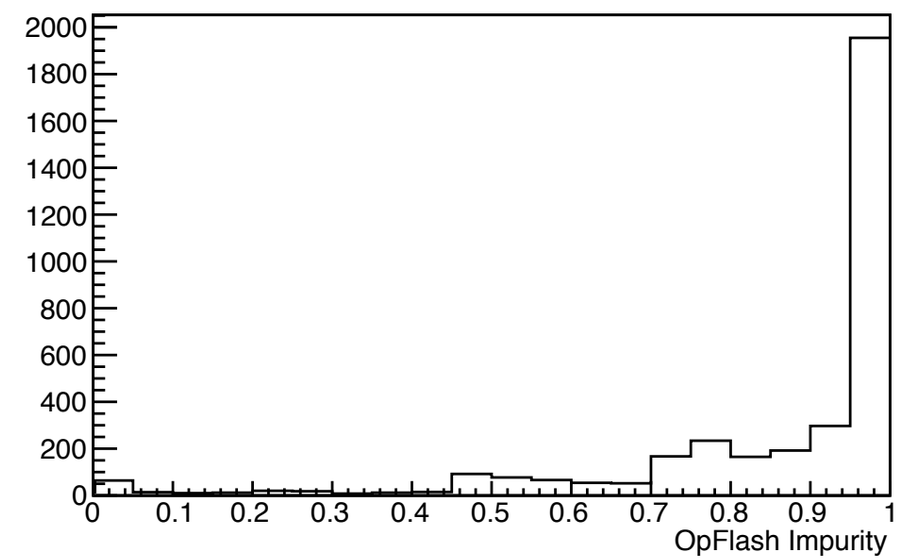


$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar

- OpFlash reconstruction in presence of ^{39}Ar and proton decay events
- OpFlash is a collection of OpHits in time
- PE threshold (default is 3.5 PE)



Impurity = ^{39}Ar PE/total PE

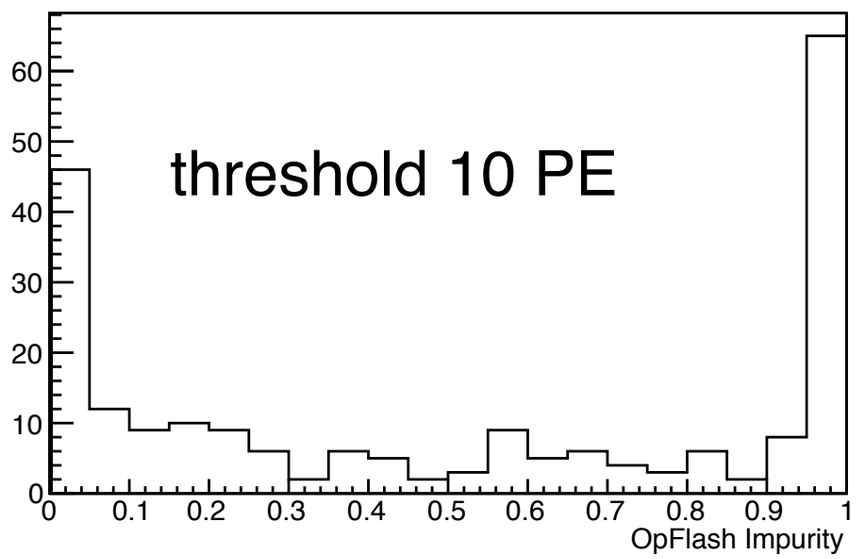


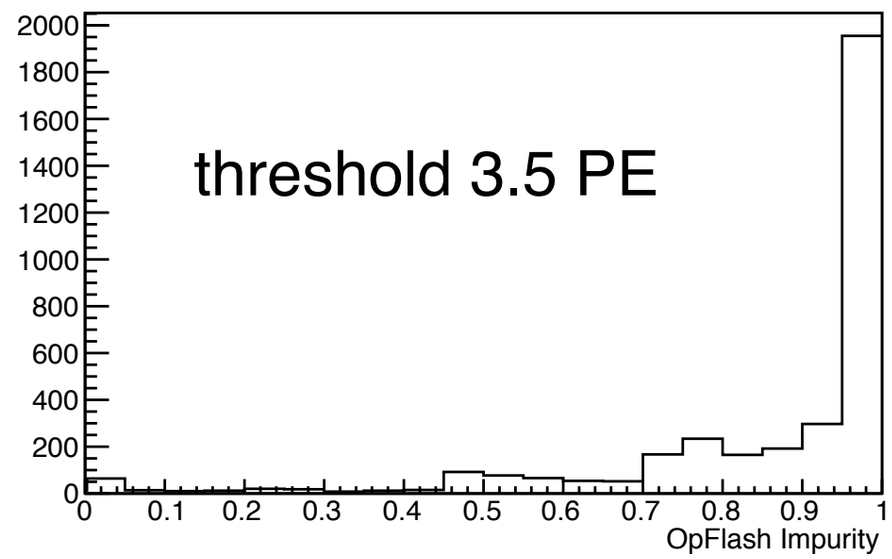
- Kevin's studies show that a 10PE threshold will reduce significantly the number of ^{39}Ar Opflashes

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar

- OpFlash reconstruction in presence of ^{39}Ar and proton decay events
- All OpFlashes, still some flashes are only due to ^{39}Ar

Impurity = ^{39}Ar PE/total PE

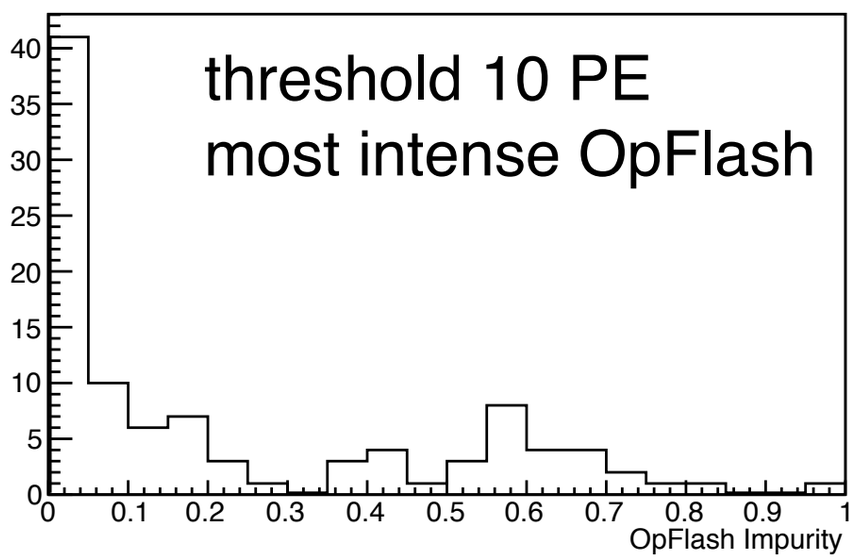




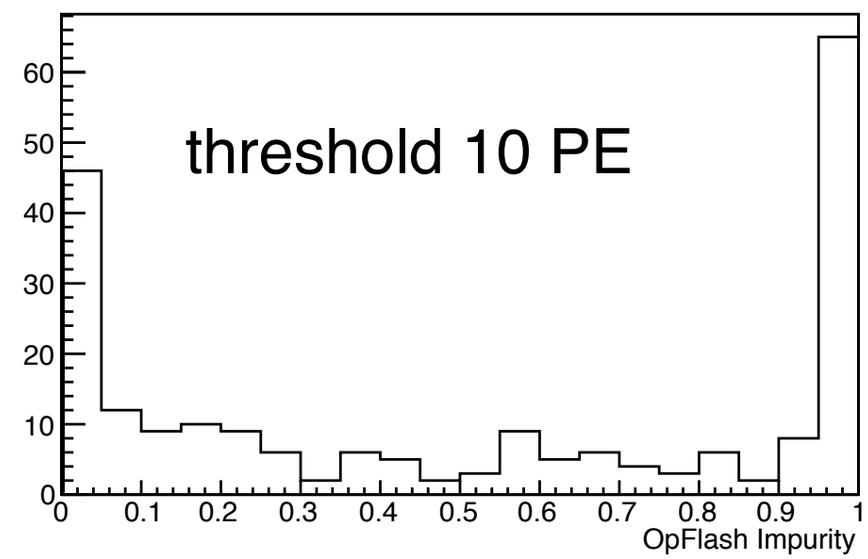
- With ^{39}Ar and proton decay events, most of event tend to have more than one OpFlash
- Lets pick up the most intense OpFlash

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar

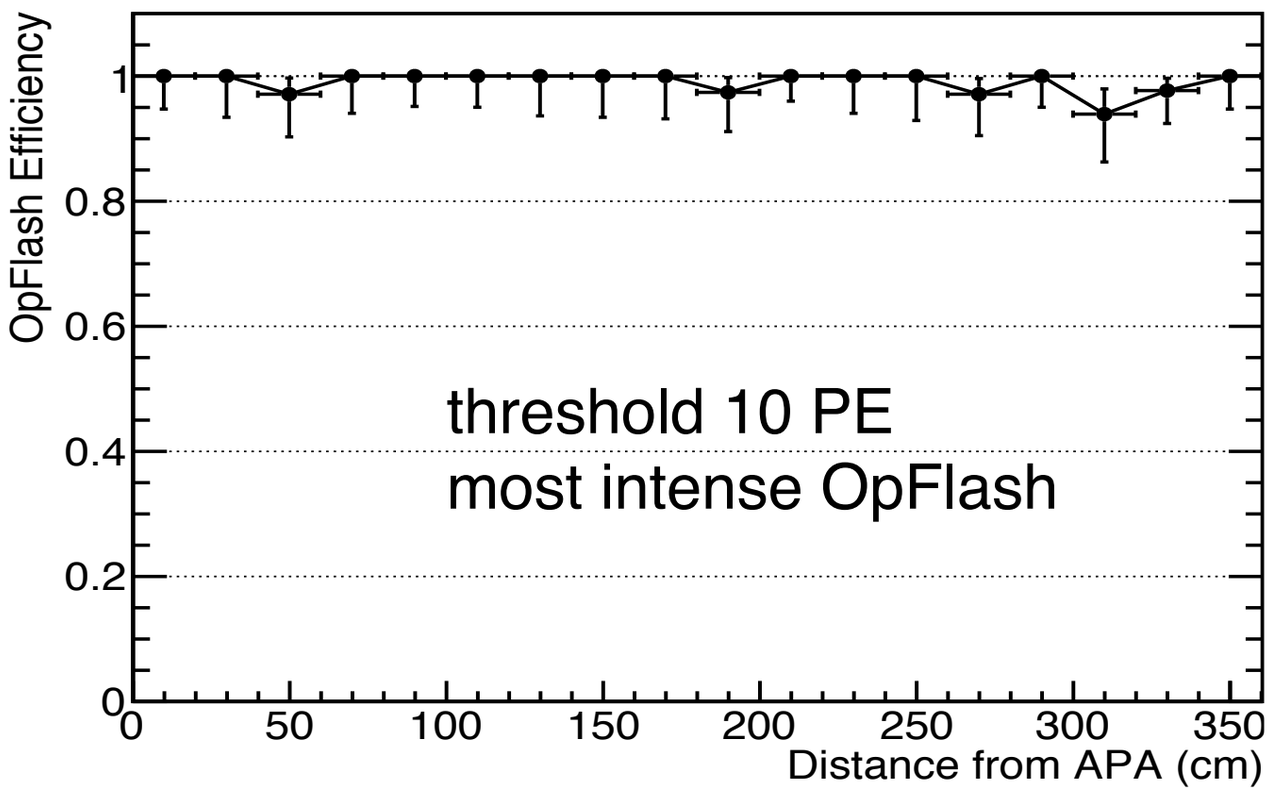
- OpFlash reconstruction in presence of ^{39}Ar and proton decay events

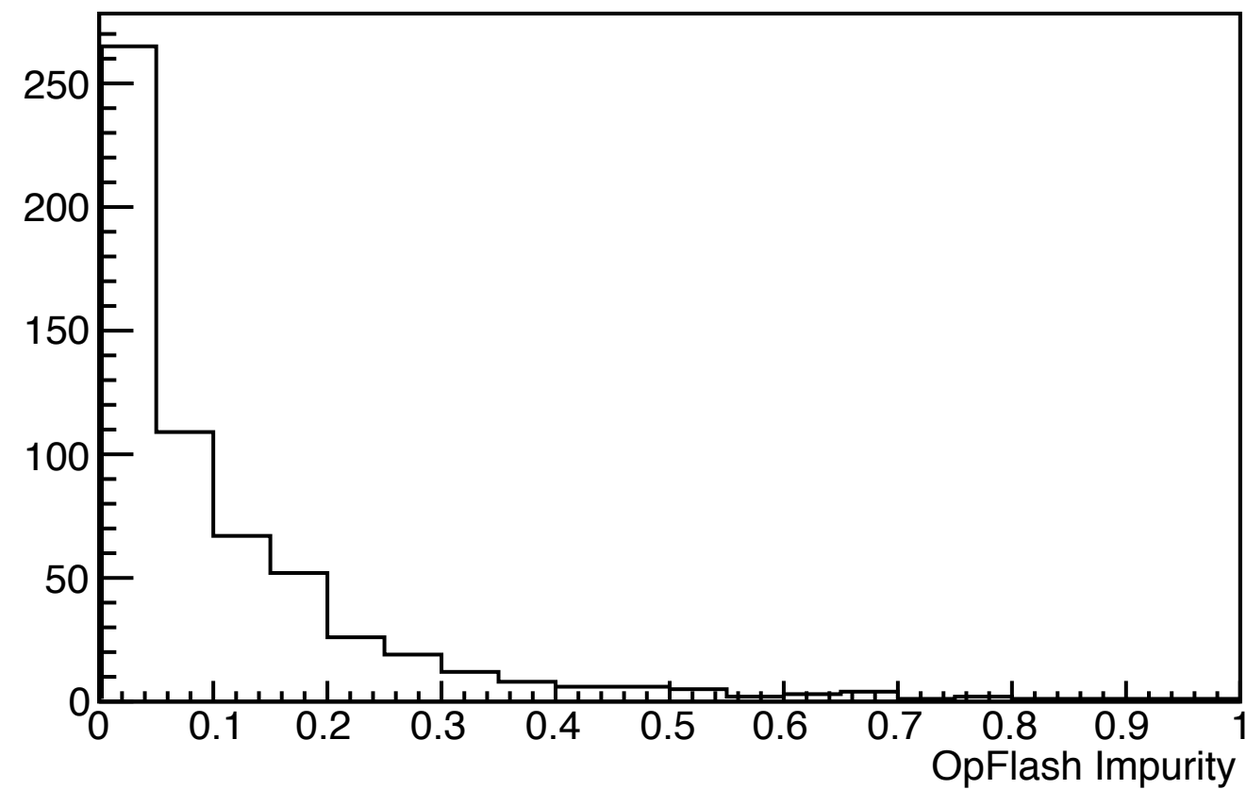


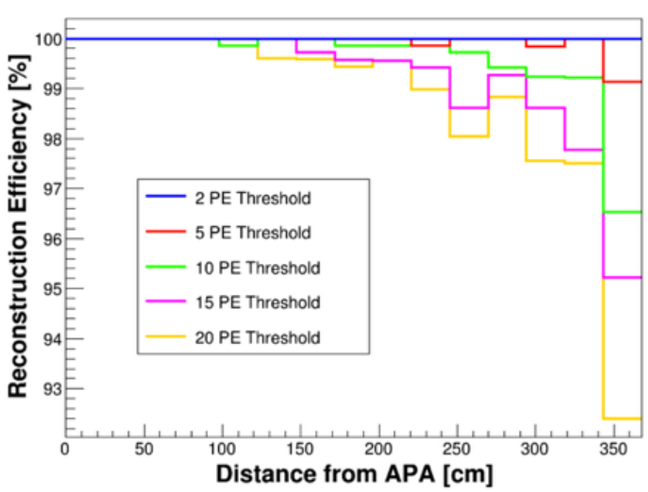
Impurity = ^{39}Ar PE/total PE



$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash Matching Eff







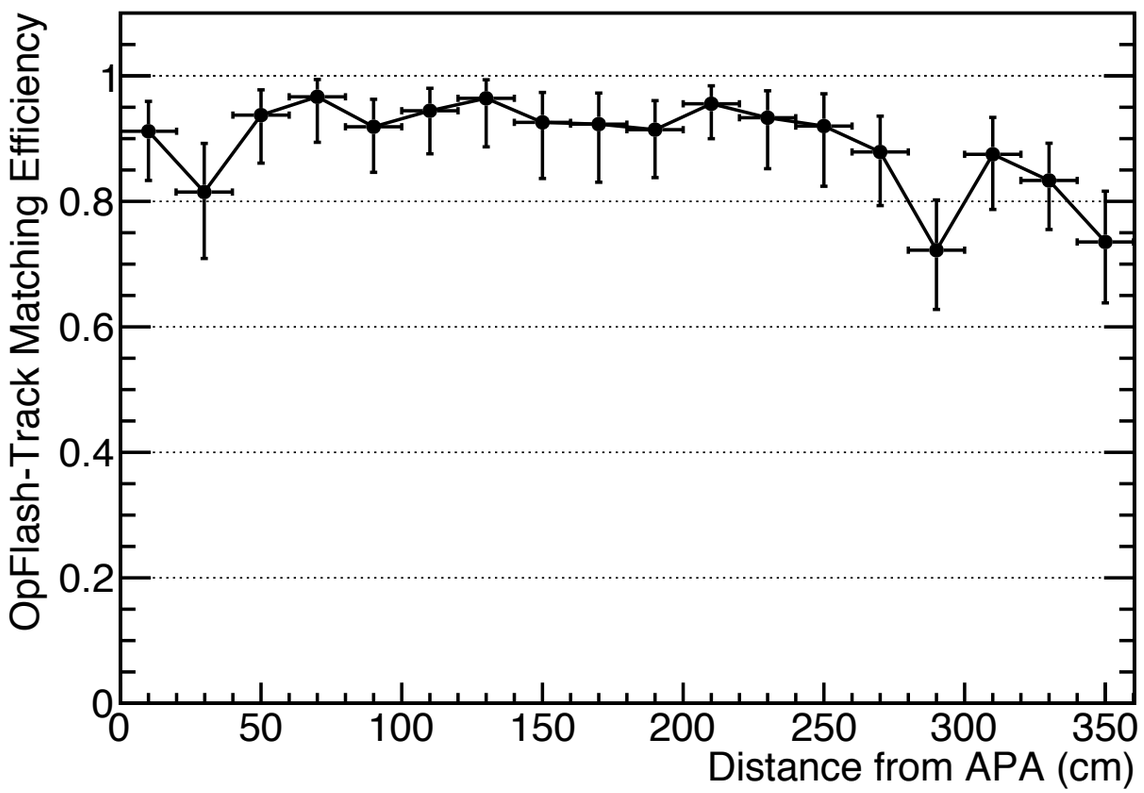
- Sometimes an OpHit contains PE from K, μ ,e^+ and ^{39}Ar (electron)

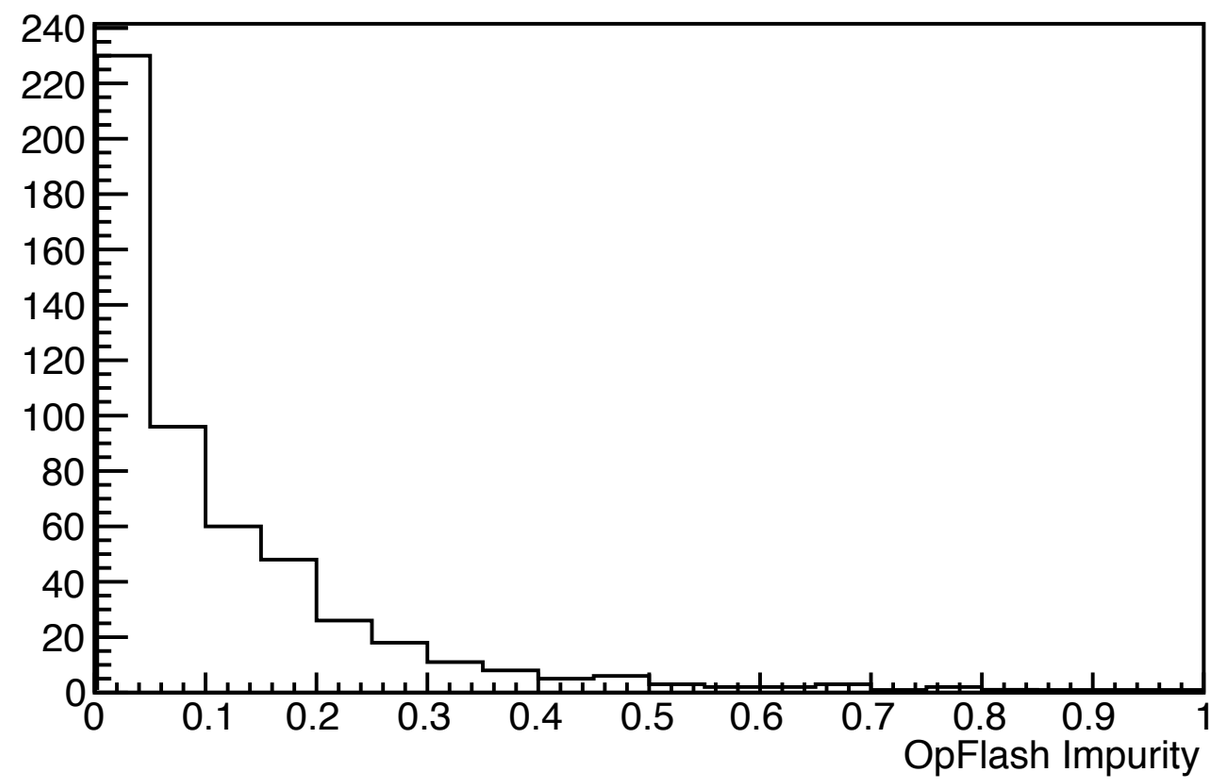
$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-Track Matching Eff

- OpFlash reconstruction in presence of ^{39}Ar and proton decay events
- Select the most intense OpFlash and require that OpFlash yz center overlap with the yz muon track vertex (loop at reco tracks and pick up the reco track associated to a muon base on true)
- Only K → μ events (low statistics 595 events)
- Plot OpFlash-Track matching efficiency as function of distance from the APA using true muon vertex

$$eff \sim \int OpFlash\ Eff \otimes Trk\ Eff$$

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-Track Matching Eff

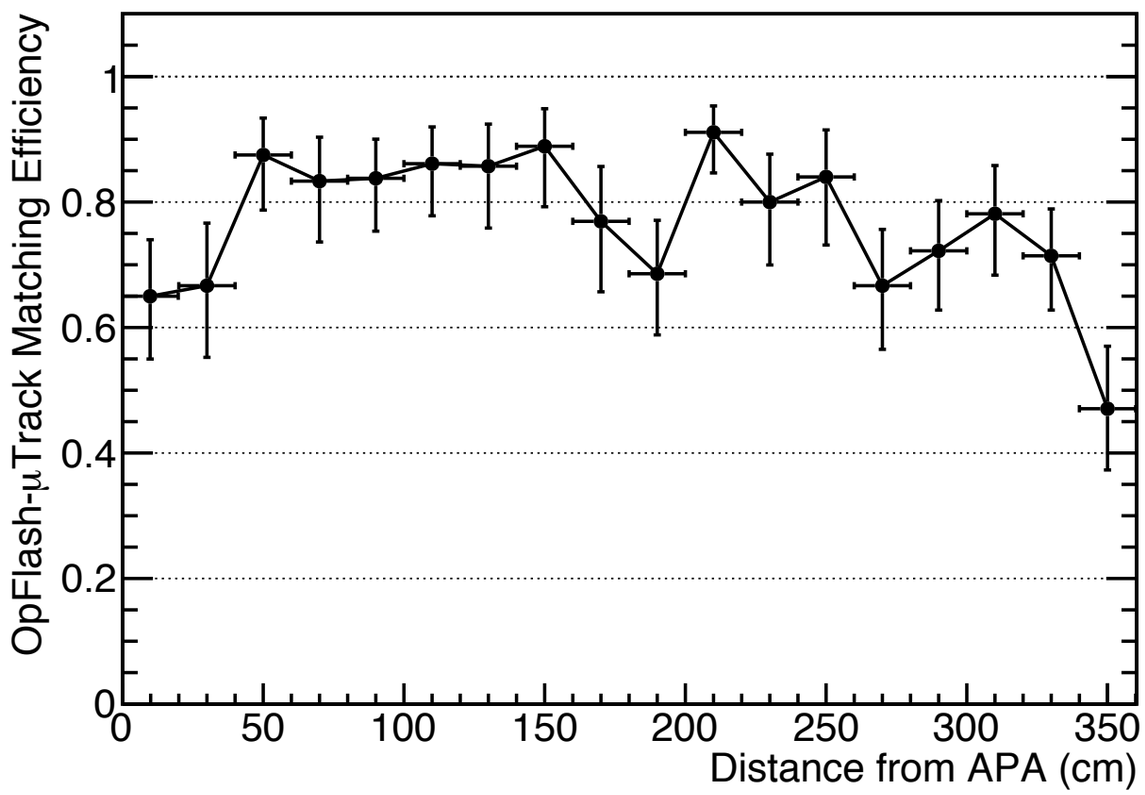


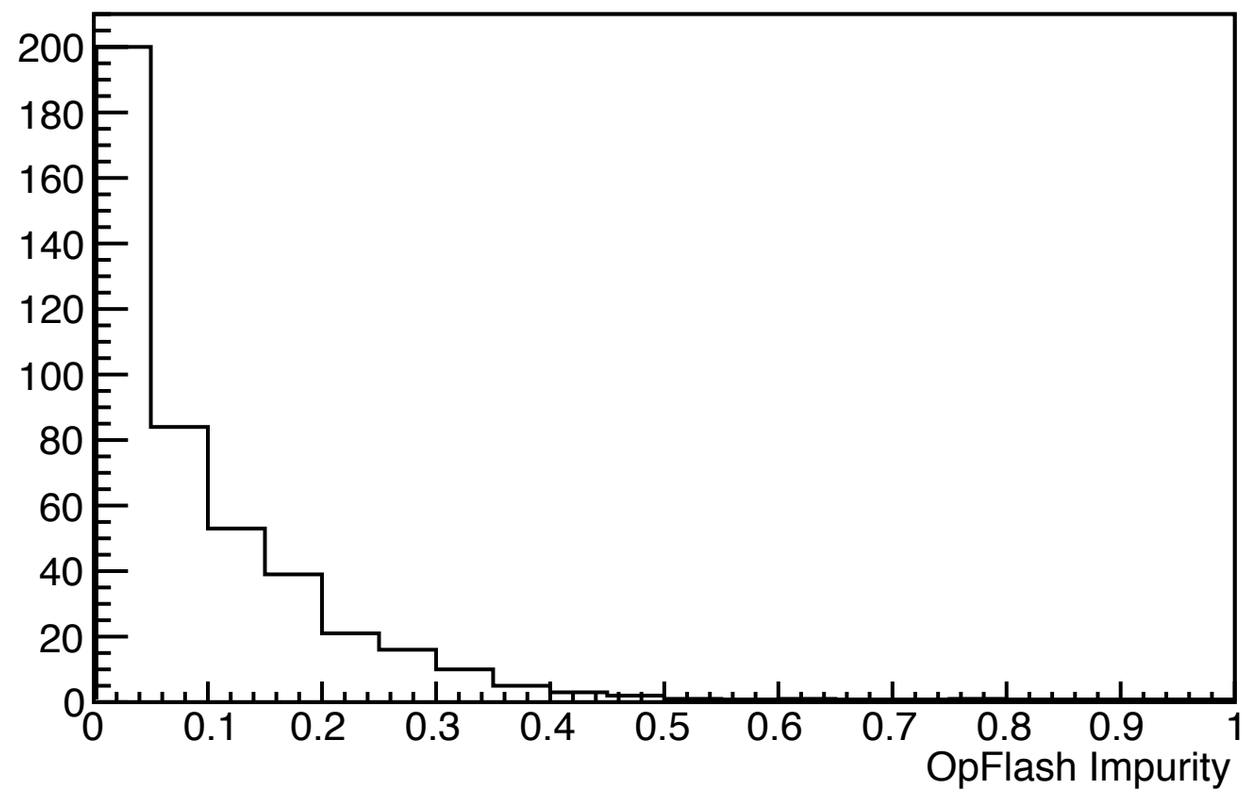


Loss in efficiency is due to track reconstruction

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-MuonTrack Matching Eff

- Select the most intense OpFlash and require that OpFlash yz center overlap with the yz muon-like track vertex (muon PID)





$$eff \sim \int OpFlash\ Eff \otimes Trk\ Eff \otimes PID\ Eff$$

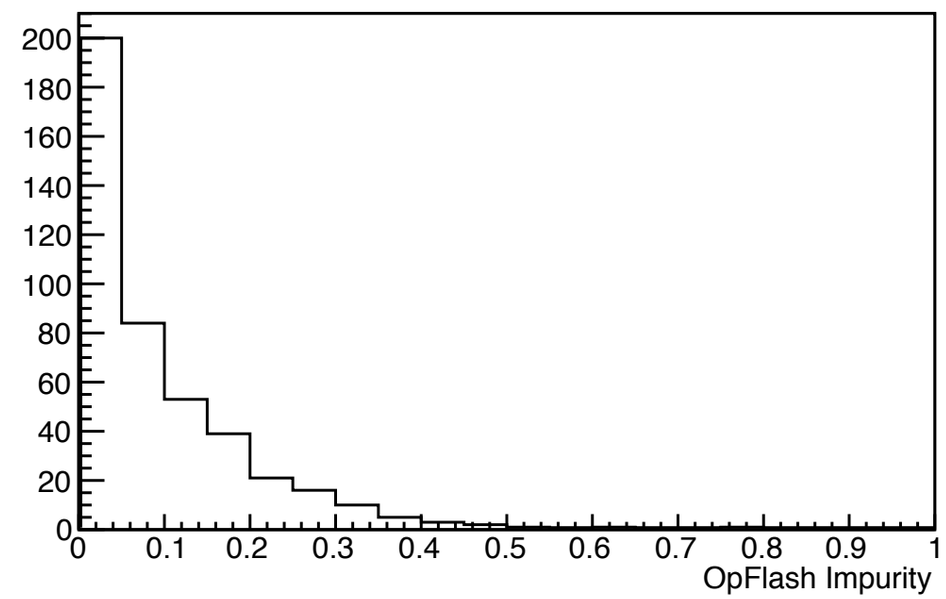
Overall efficiency 74.0%

Loss in efficiency is due to track reconstruction and PID eff

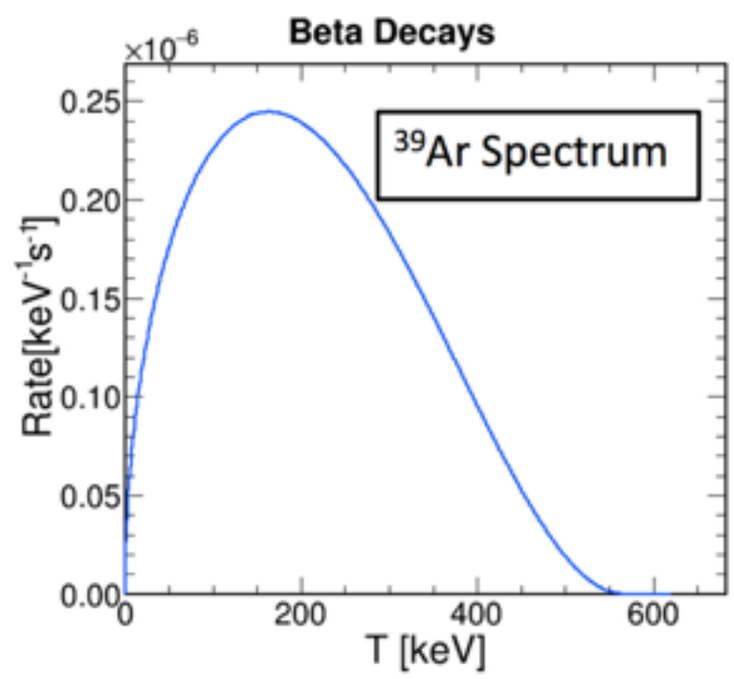
$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-MuonTrack Matching Eff

Why muon-tack matching OpFlash does have ^{39}Ar contamination?

Are we choosing the right flash?



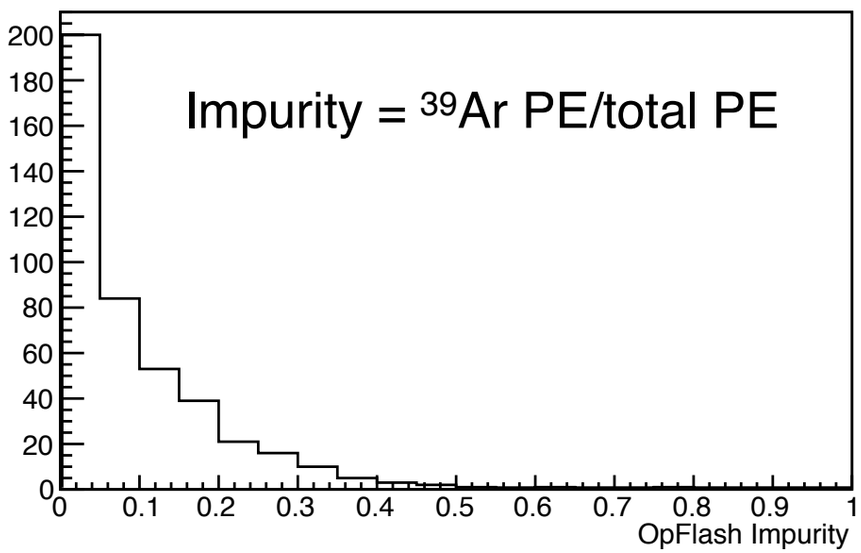
βs are low energy but visible if close to PDS

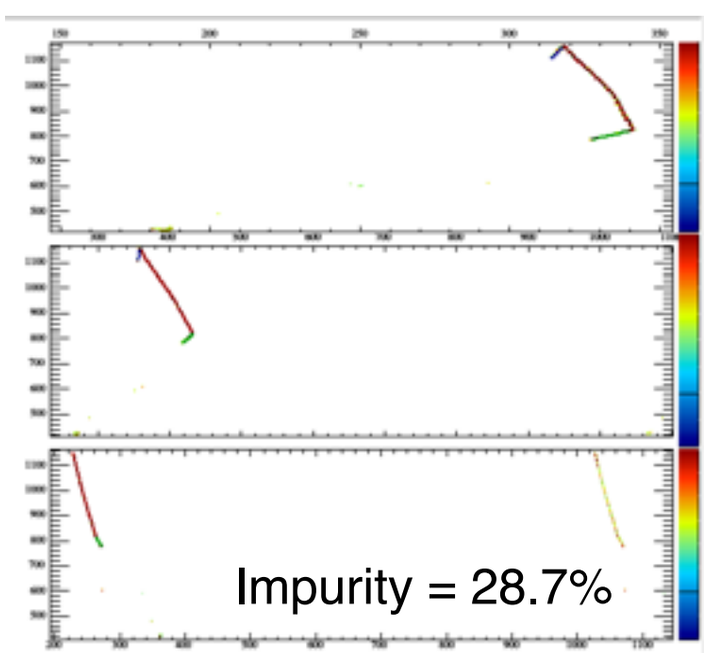


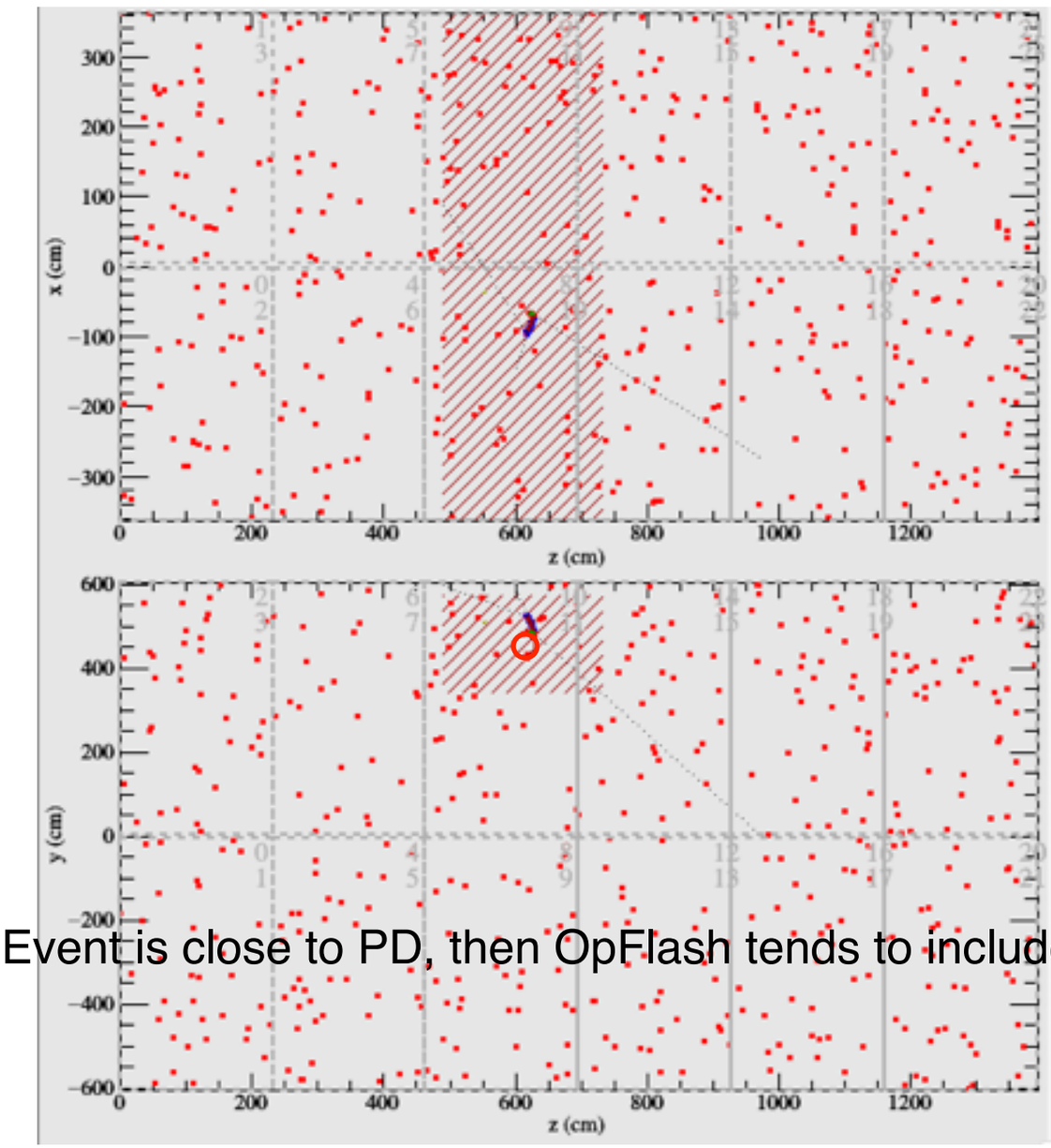
Alex Himmel

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-MuonTrack Matching Eff

Why muon-tack matching OpFlash does have ^{39}Ar contamination?





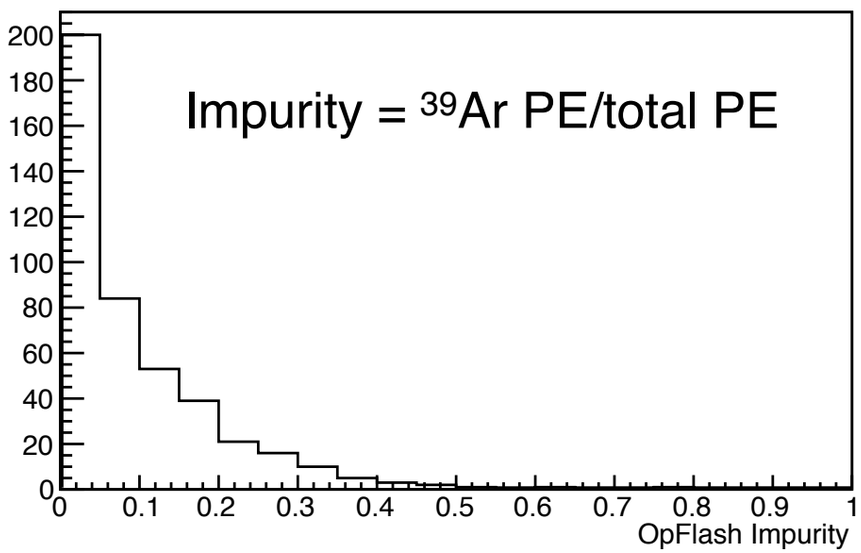


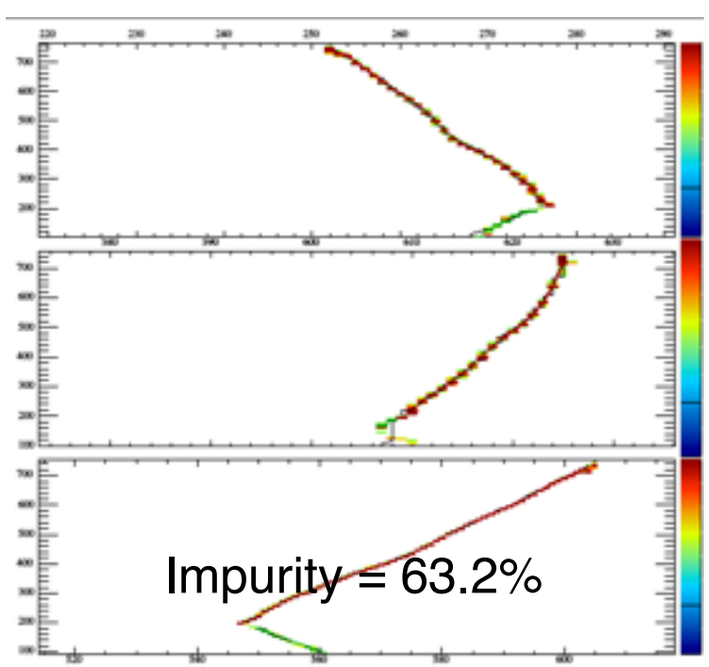
Event is close to PD, then OpFlash tends to include β's

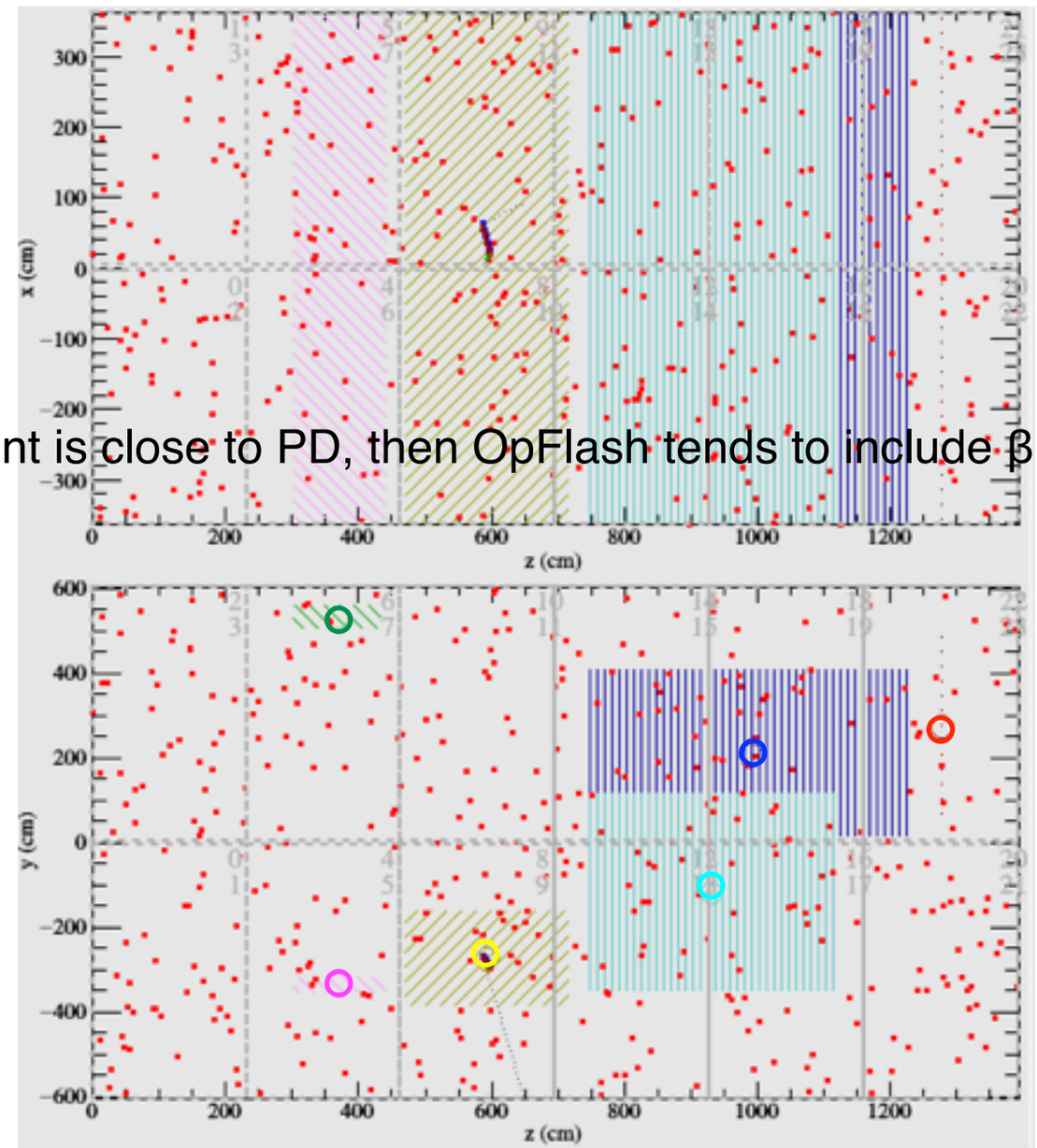
energy deposition > 200KeV

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-MuonTrack Matching Eff

Why muon-tack matching OpFlash does have ^{39}Ar contamination?







Event is close to PD, then OpFlash tends to include β's

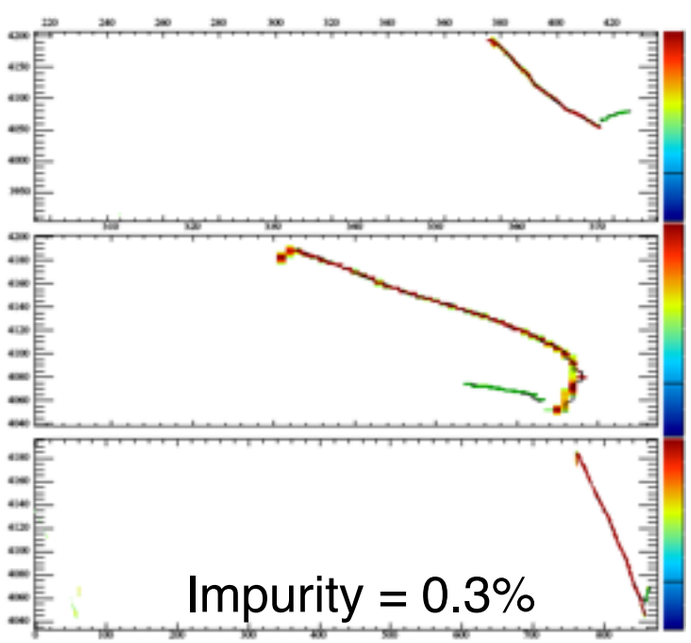
energy deposition > 200KeV

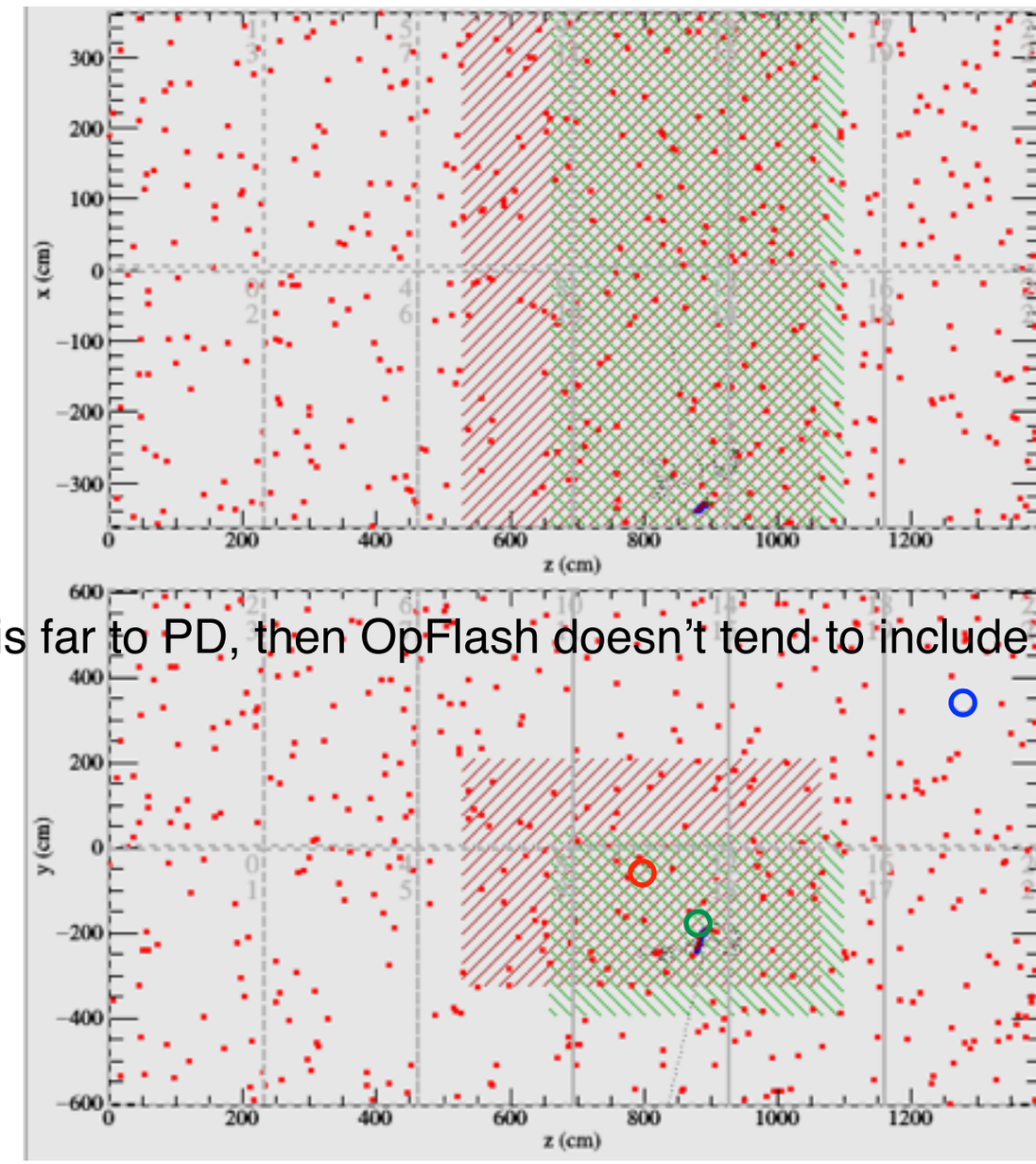
$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-MuonTrack Matching Eff

Are we choosing the right flash?

- Select the most intense OpFlash and require that OpFlash yz center overlap with the yz muon-like track vertex

```
flash Y: -61.2863 Z: 798.231 impurity 1
flash Y: -179.963 Z: 879.654 impurity 0.00331385
flash Y: 342.962 Z: 1277.27 impurity 1
```





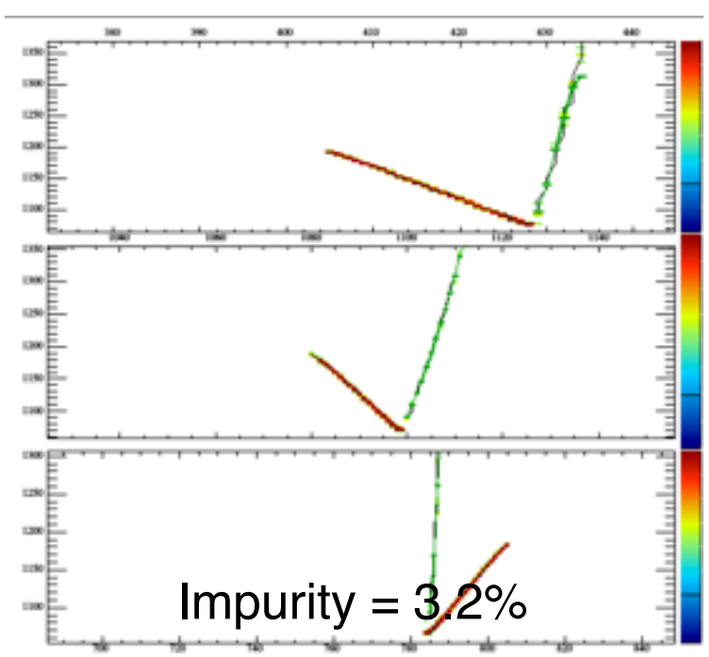
Event is far to PD, then OpFlash doesn't tend to include β's

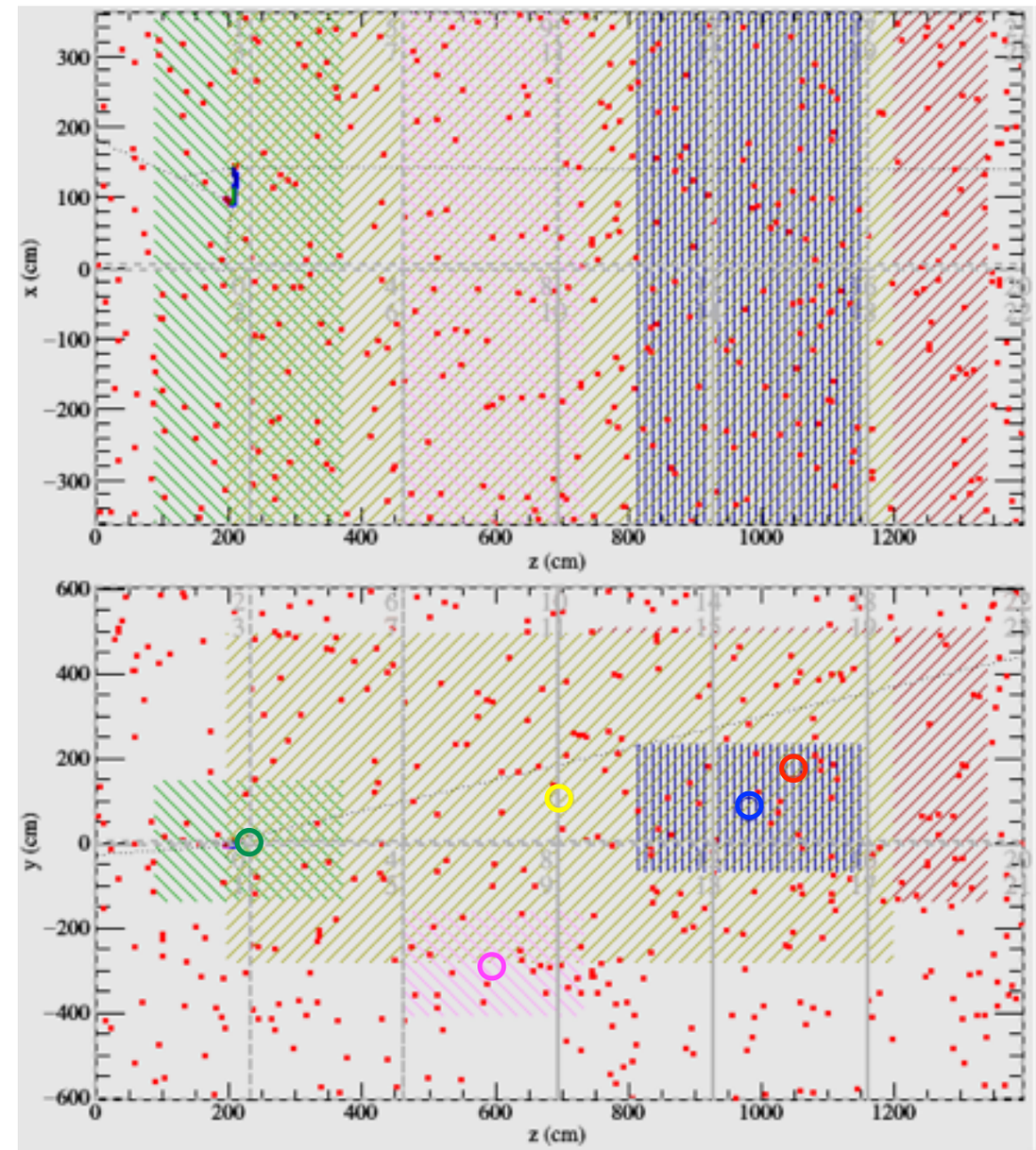
energy deposition > 200KeV

$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-MuonTrack Matching Eff

Are we choosing the right flash?

```
flash Y: 182.944 Z: 1046.4 impurity 1
flash Y: 2.25198 Z: 229.491 impurity 0.0323352
flash Y: 81.1264 Z: 981.191 impurity 1
flash Y: 105.19 Z: 697.754 impurity 1
flash Y: -285.943 Z: 596.808 impurity 1
```





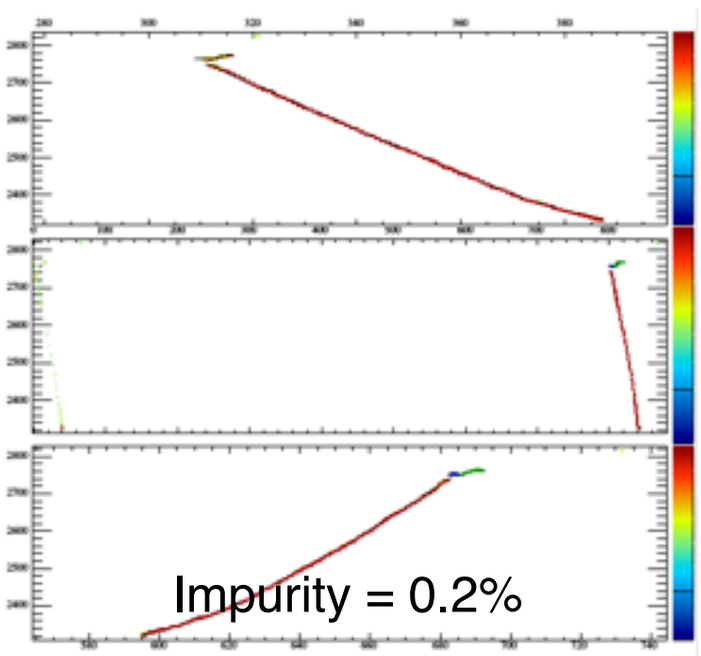
energy deposition > 200KeV

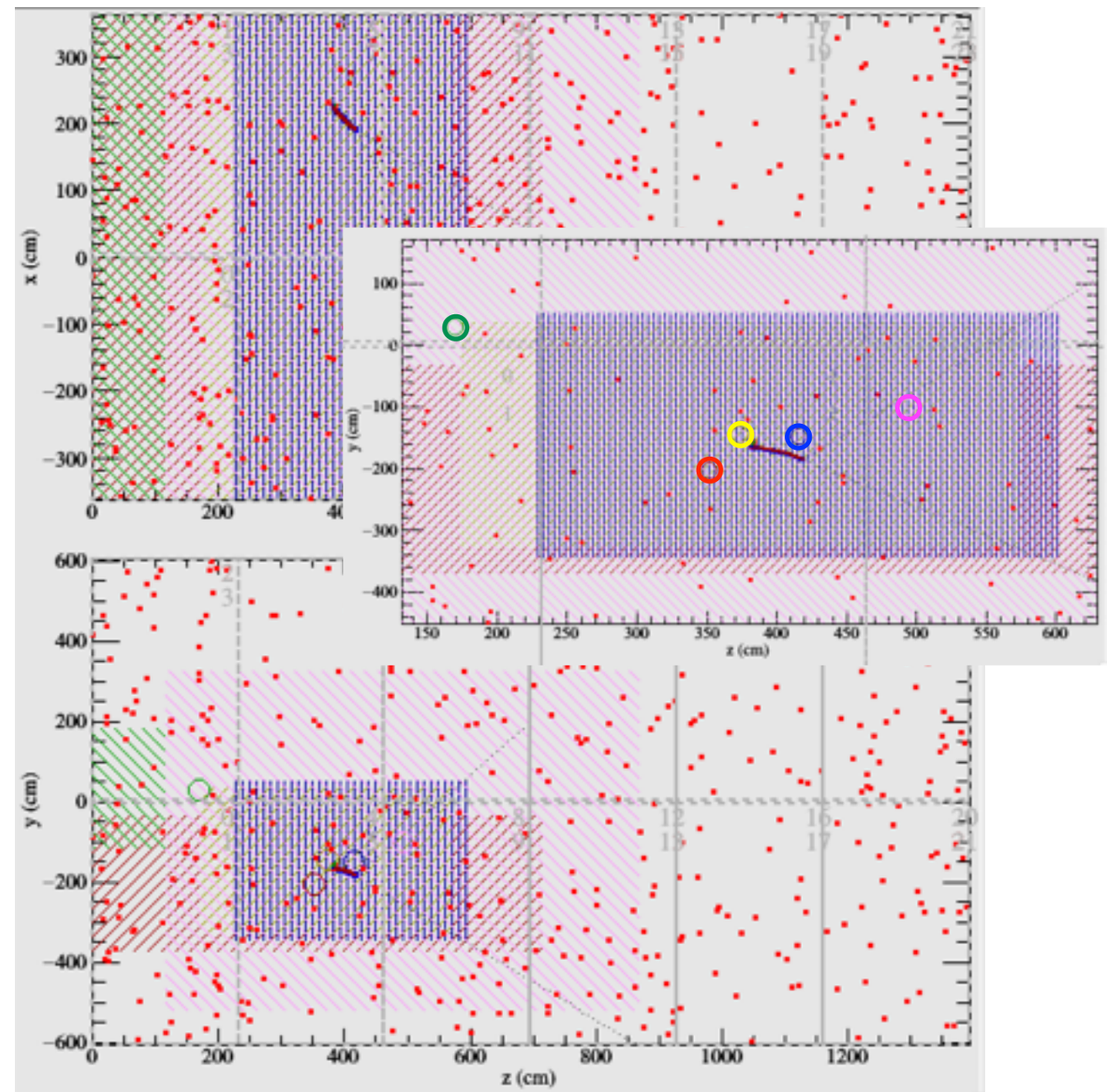
$p \rightarrow K+ \bar{\nu}$ & ^{39}Ar OpFlash-MuonTrack Matching Eff

Are we choosing the right flash?

```
flash Y: -203.565 Z: 351.112 impurity 1
flash Y: 30.1301 Z: 169.74 impurity 1
flash Y: -148.131 Z: 415.72 impurity 0.00197962
flash Y: -145.708 Z: 373.544 impurity 0.534554
flash Y: -99.9889 Z: 492.76 impurity 1
```

```
flash total PE: 409.809 time: 0.354594
flash total PE: 106.758 time: 7.87395
```





energy deposition > 200KeV

Comments

- If we assume that additional radiological background is one order of magnitude below the intrinsic ^{39}Ar background at any place in the active volume of the TPC

- Then, from this preliminary studies it seems that we can handle ^{39}Ar background and we are cover from additional radiological background (i.e. we can search for NDK)

- Using track(TPC) + OpFlash(PDS) we can get the correct t0

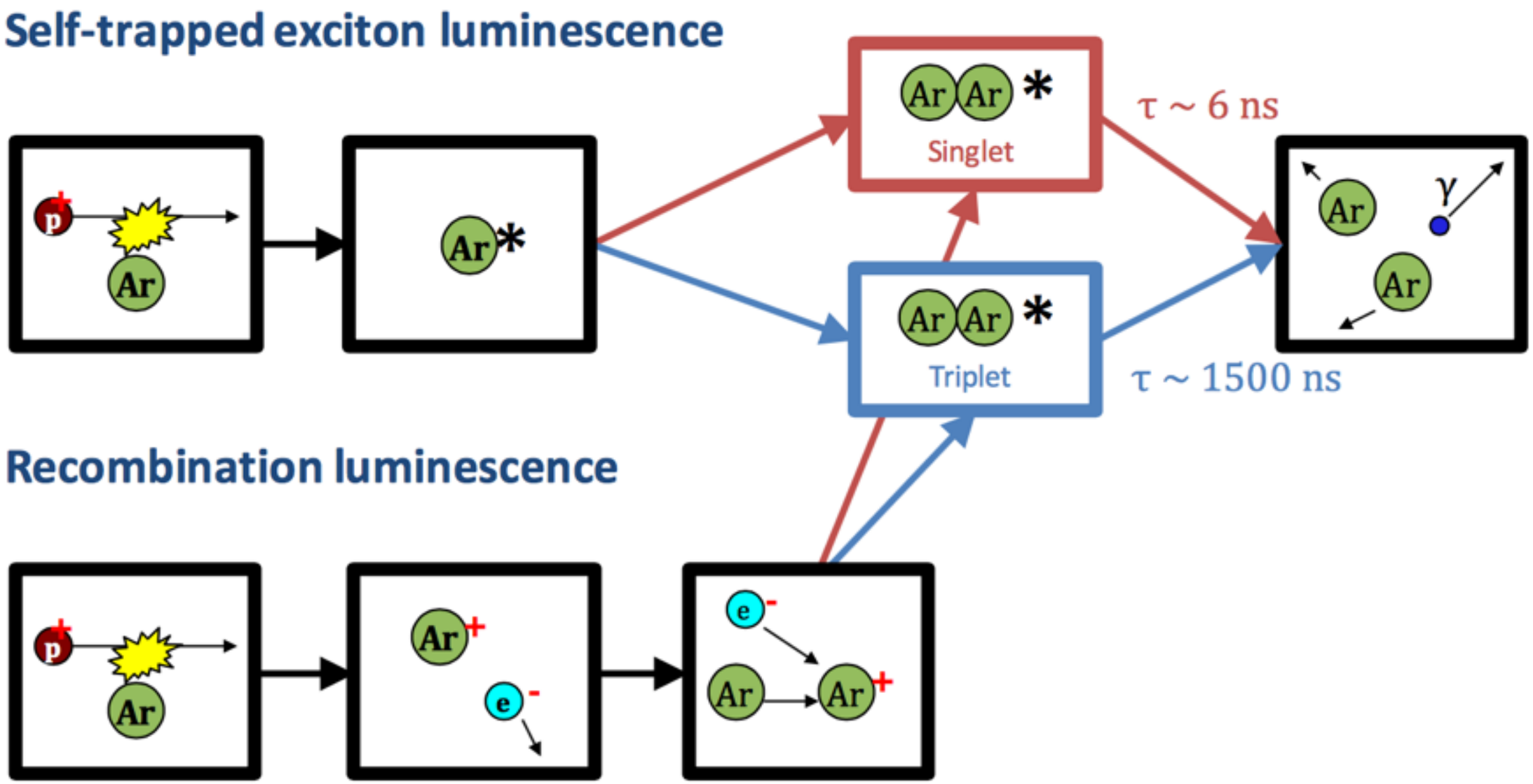
- Requiring that the OpFlash yz center overlap with the yz muon-like track vertex seems a very robust selection (no need to use OpHit and Hit like the SN group?)

- Still need to study impact of cosmogenic + ^{39}Ar background

- Suggestions?

There are 3 key points for this analysis
- ☑ Flash reco (vs Background)
- ☑ Kaon ID (and muon)
- ☑ No Shower-like

The End

Extras

Mechanisms of Scintillation in Argon