

Calibration at Low Energy with DUNE prototypes

For Workshop June 2024



Laboratoire de Physique
des 2 Infinis



I. Physics context

1. Goals
2. Background

III. Results on ProtoDUNE

1. PDHD
2. PDVD

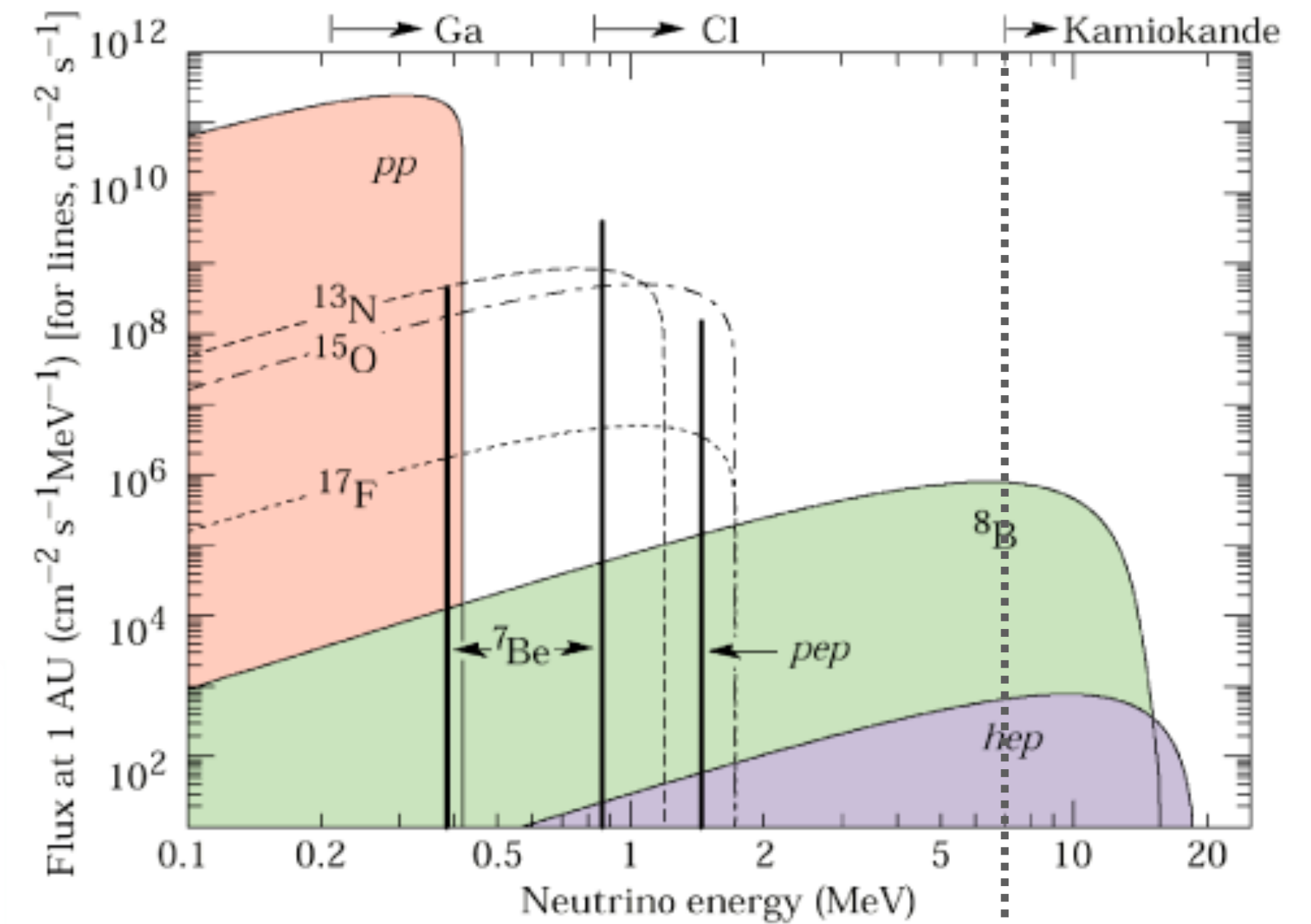
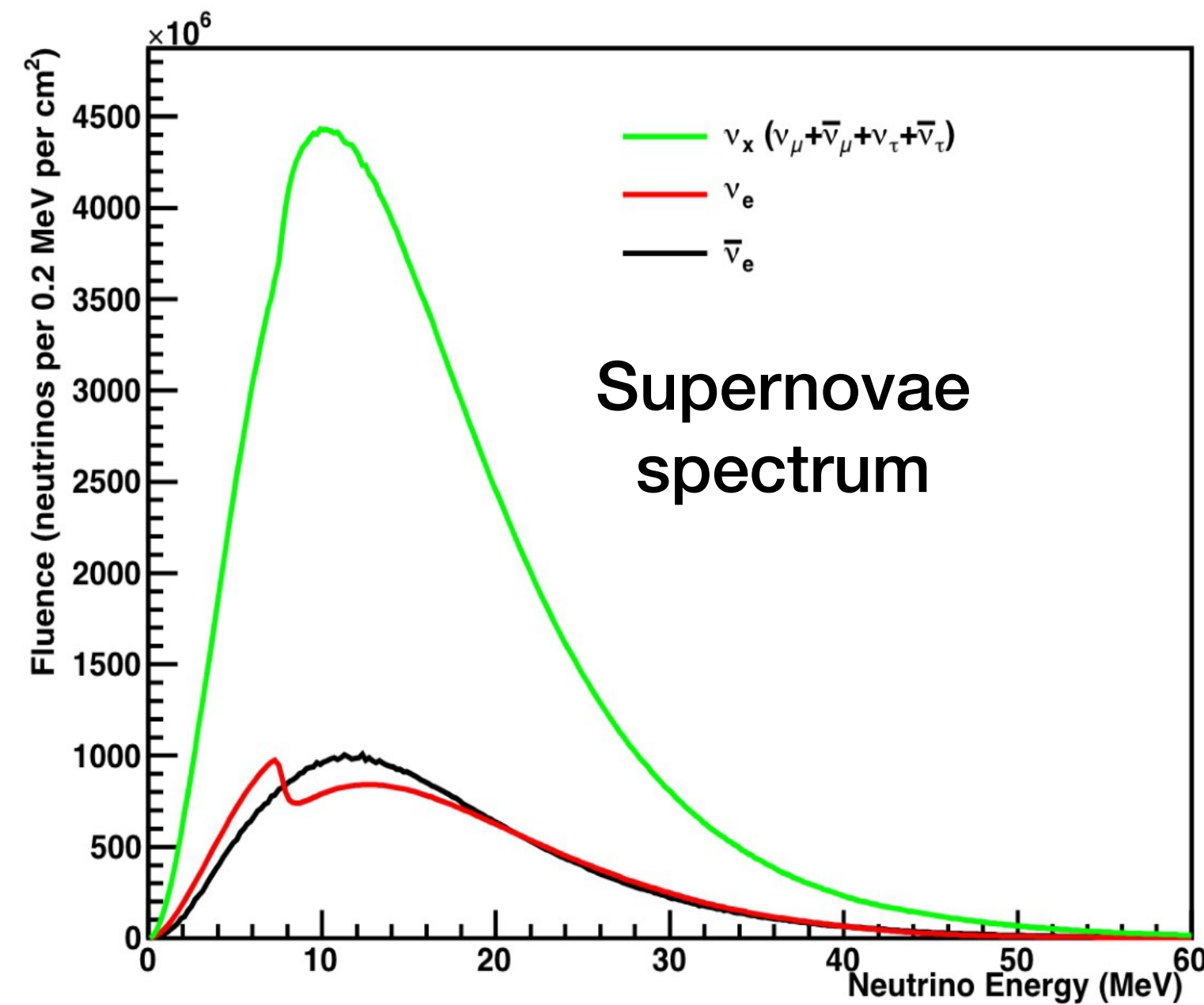
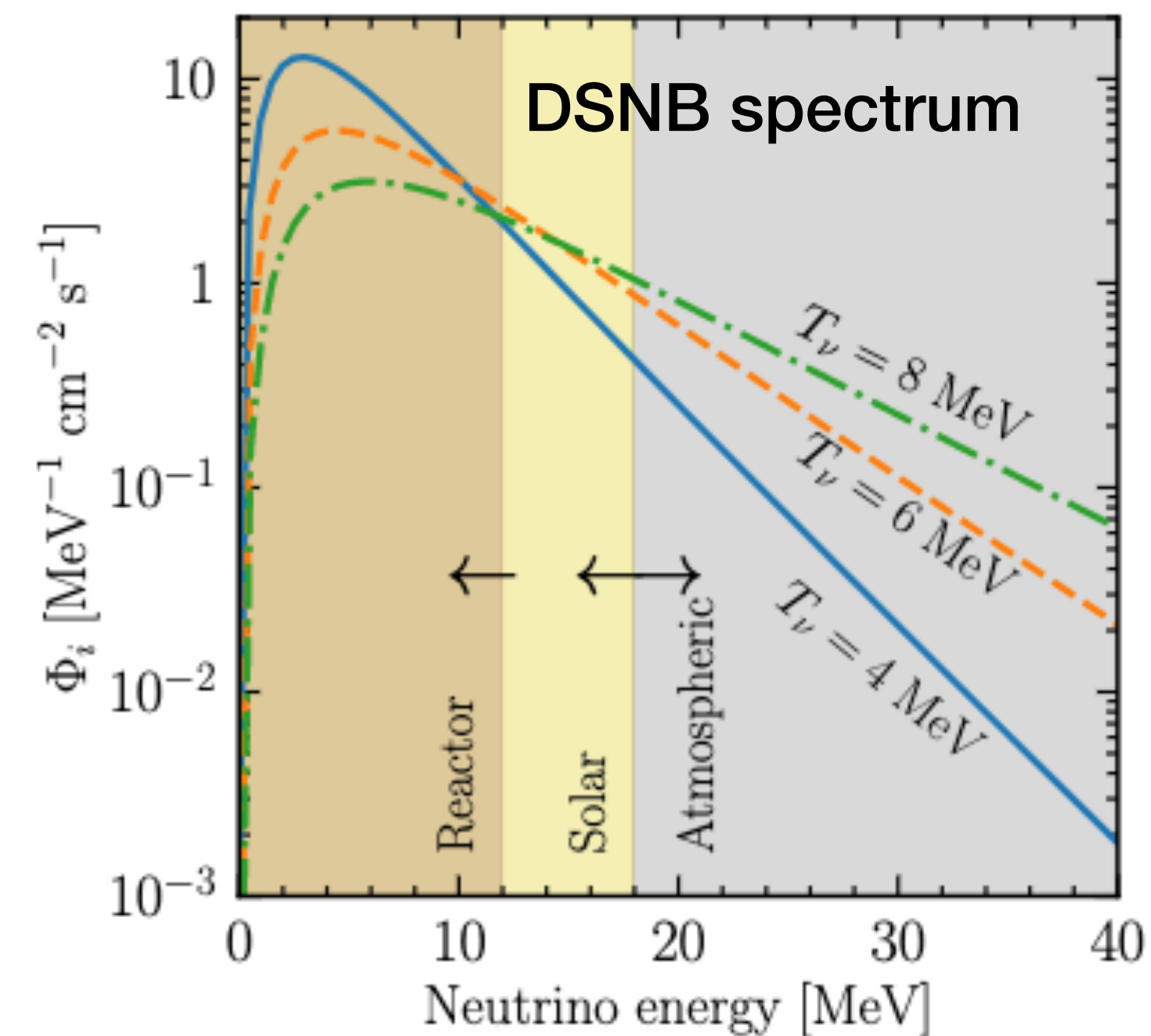
II. SingleHit module

1. How to
2. Event summary
3. Cluster

Conclusion

Physics context

- Solar neutrino's : may see **hep neutrino** for 1st time
- Supernovae :
 - Supernovae burst
 - Diffuse Supernovae Background (DSNB)



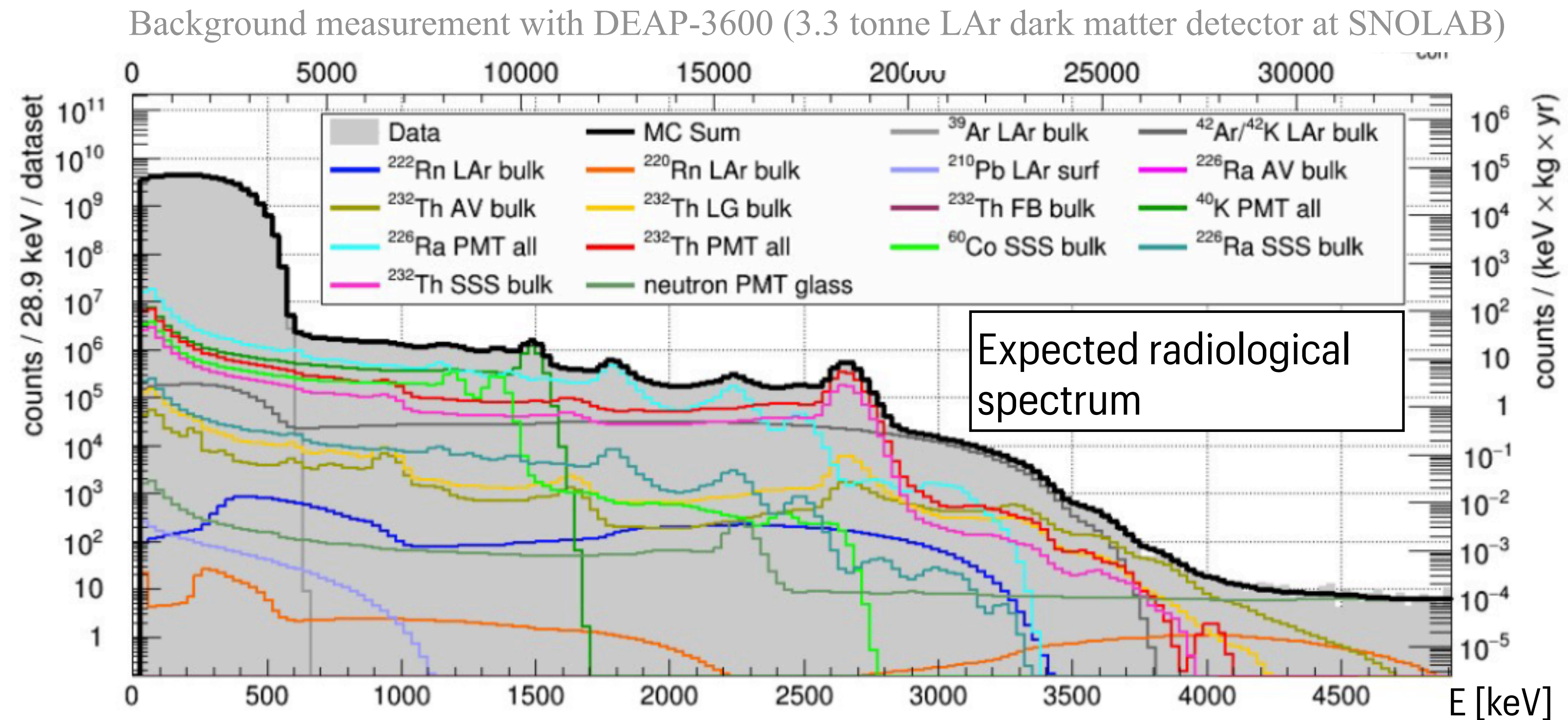
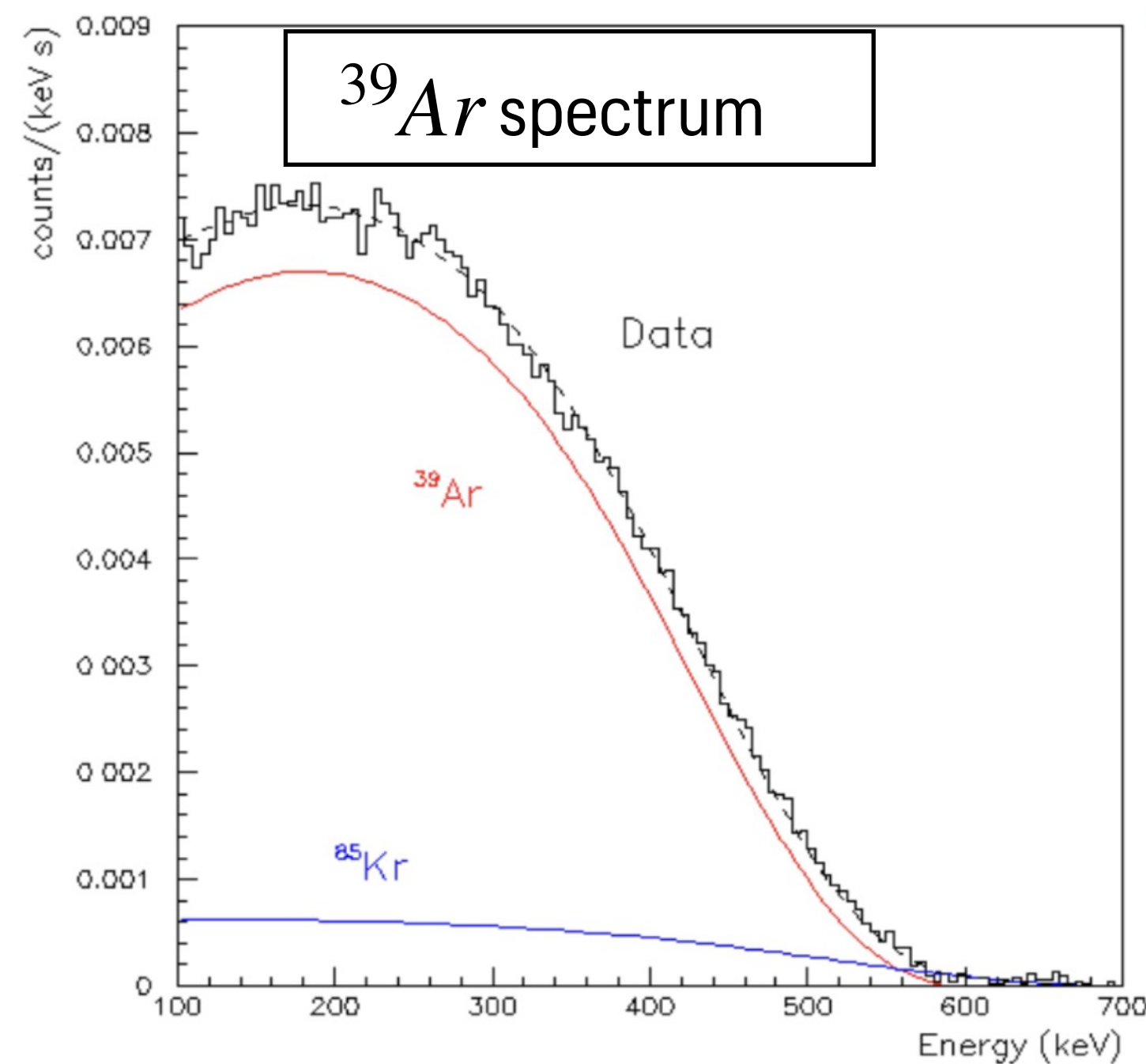
CC threshold for
 $\nu_e + {}^{40}\text{Ar} \rightarrow {}^{40}\text{K} + e^-$

the energy spectrum of solar neutrinos.
 Image reprinted from J. Bahcall,
 A.M. Serenelli, and S. Basu Ap. J. 621, L85 (2005)

Figure from arXiv:1205.6003 [astro-ph.IM]

arXiv:2207.09632 [astro-ph.HE]

- **Cosmics/radiologicals** (suppressed a lot in FD) but important for prototypes (PD) @CERN
- Intern radioactivity, in LAr mainly ^{39}Ar
 - FD : $\sim 10^7$ decays/s
 - PD : $\sim 10^5$ decays/s
- From detector components (cathode, photodetector ...) mainly ^{42}K , ^{222}Rn chain and ^{238}U chain
- Radioactivity from the cavern rock (neutron...)



SingleHit Module

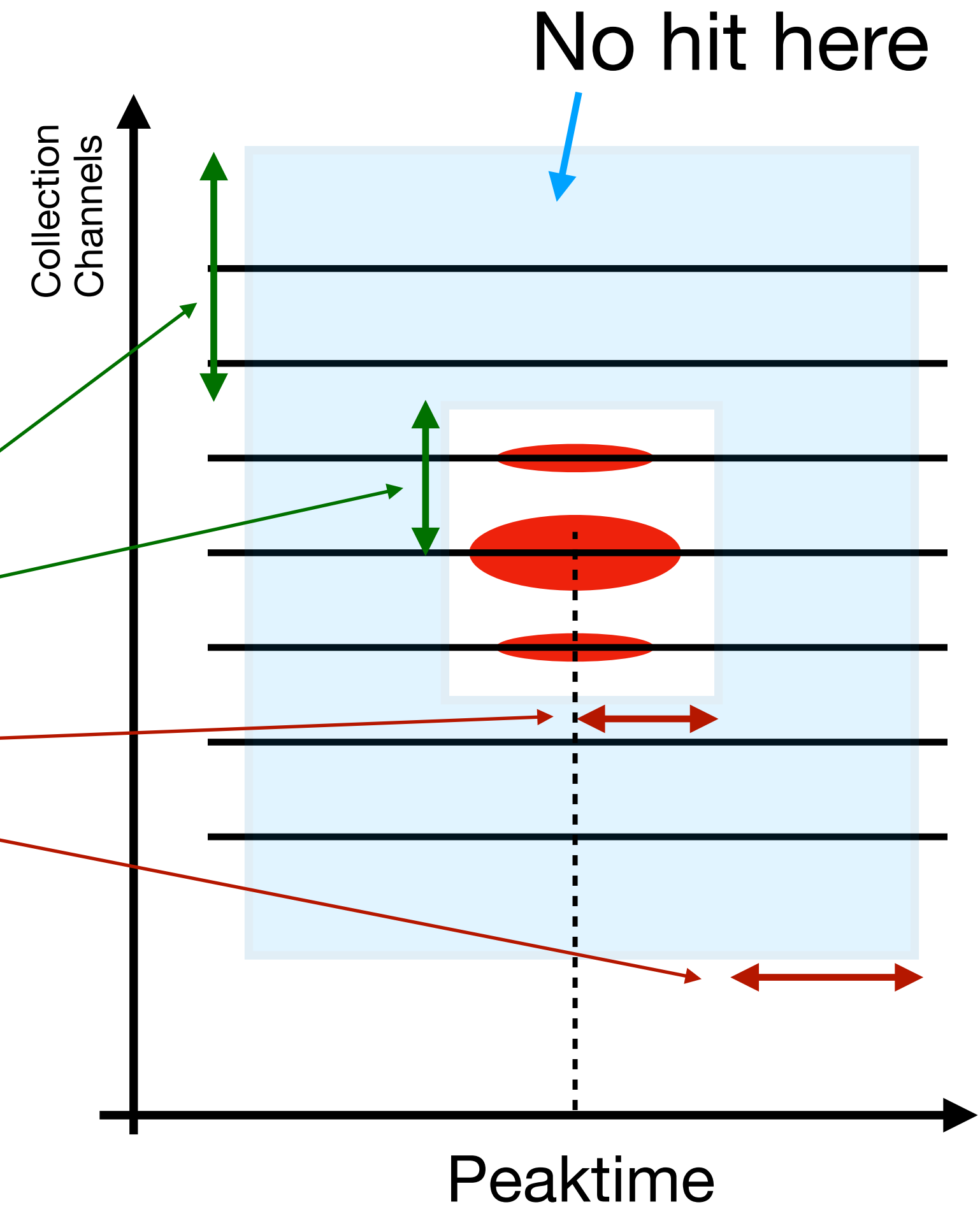
- Available in version **v09_90_01d00** of LArSoft
- Search for single isolated hits candidate for :
 - beta decay (Ar39, K40, radiological ...)
 - Solar ν 's ? SNB ?

```

services.Geometry.Name: "protodunevd_v4"
physics:
{
  analyzers:
  {
    ana:
    {
      module_type: "SingleHit"
      LogLevel: 5

      SpacePointLabel: "reco3d"
      ClusterLabel: "pandora"
      TrackLabel: "pandoroTrack"
      HitLabel: "gaushit"

      ChannelWindowInt: 3
      ChannelWindowExt: 2
      HitMultiplicity: 3
      PeakTimeWindowInt: 20
      PeakTimeWindowExt: 20
      CoincidenceWindow: 10
      Pitch: 0.9 #in cm
      PitchMultiplier: 1.2
      tagPD: 0 # = 1 ->PDHD = 0
    }
  }
  analysis: [ ana ]
  end_paths: [ analysis ]
}
    
```



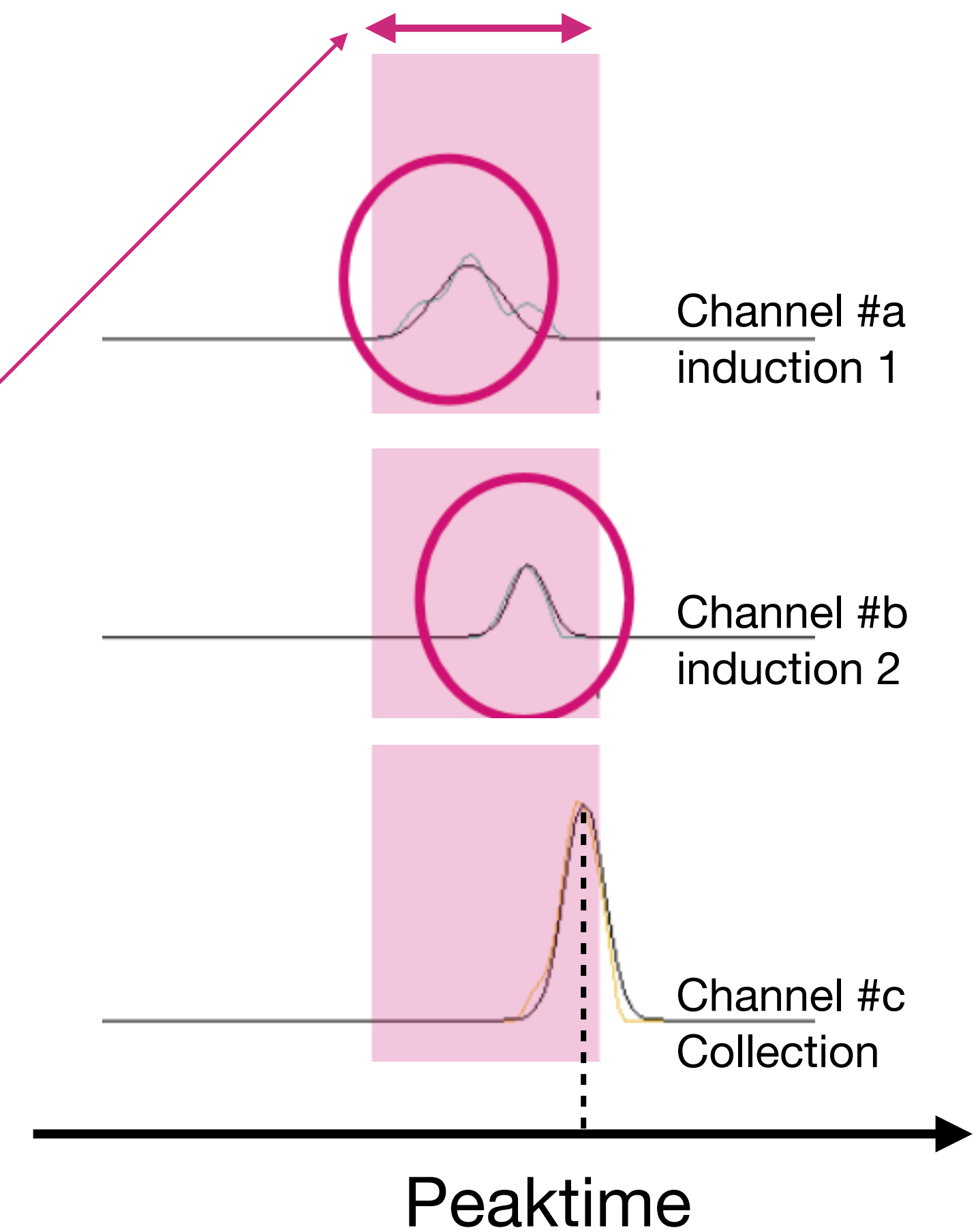
- Available in version **v09_90_01d00** of LArSoft
- Search for **single** isolated hits candidate for beta decay (Ar39, K40, radiologicals ...)
- Time coincidence (tt) tuned → mean time for an electron to travel from induction 1 to collection

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- Available in the last version of LArSoft
- Search for single isolated hits candidate for beta decay (Ar39, K40, radiological ...)
- Time coincidence (tt) tuned for PDVD
→ mean time for an electron to travel from induction 1 to collection
- Spatial coincidence → want a signal in the **3 views**
- SpacePoint is a **barycentre** of the intersection point (with ind. energy)

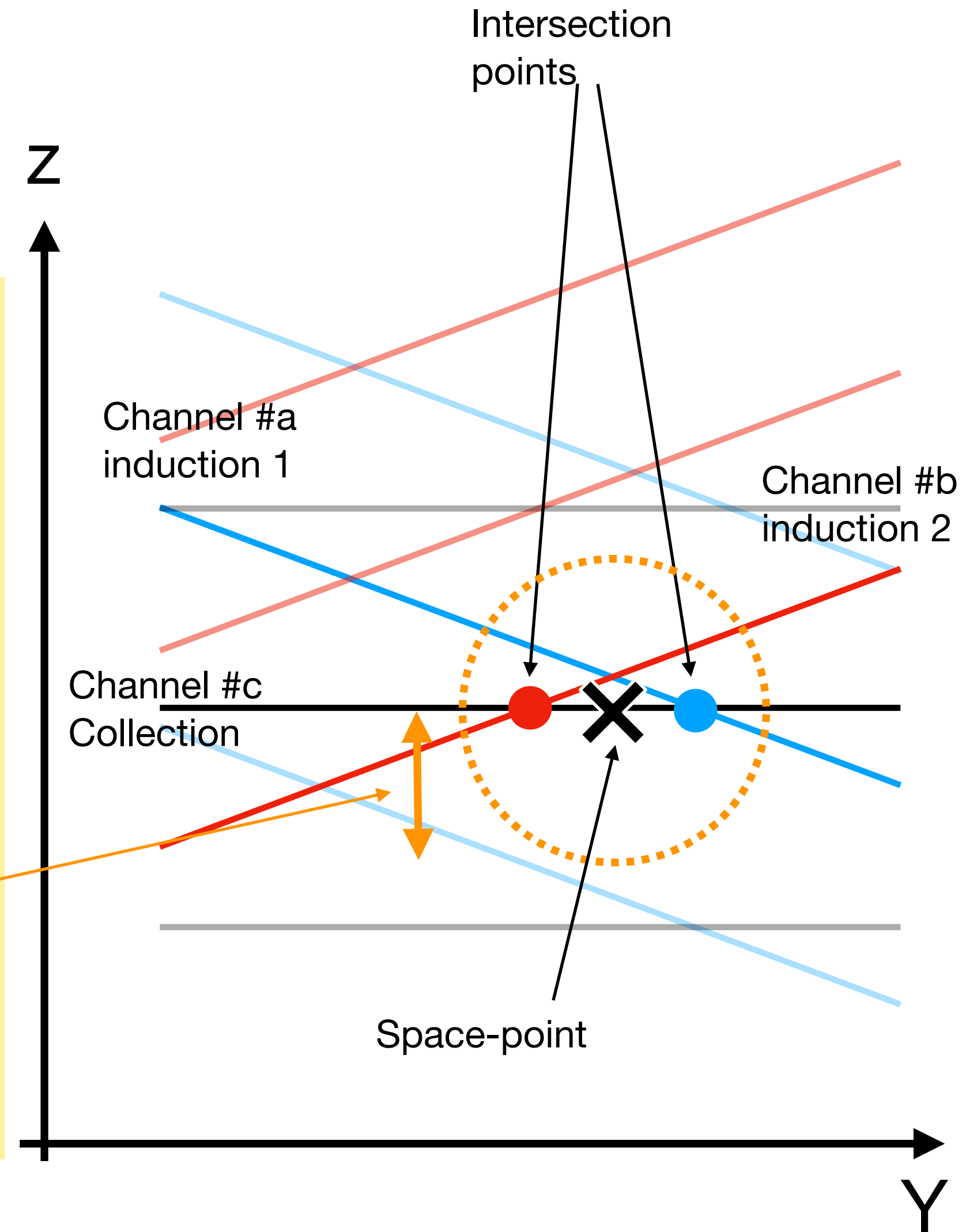
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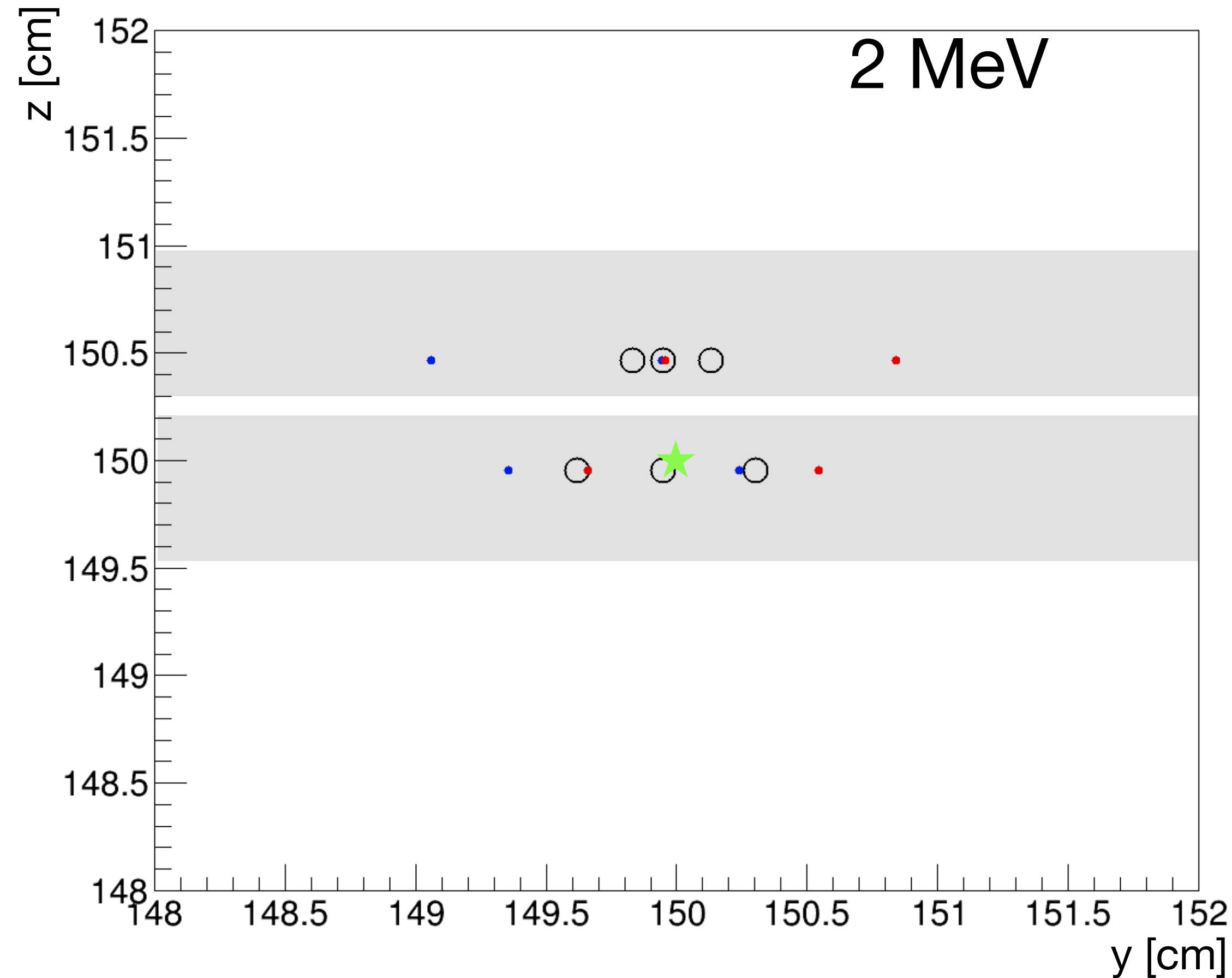
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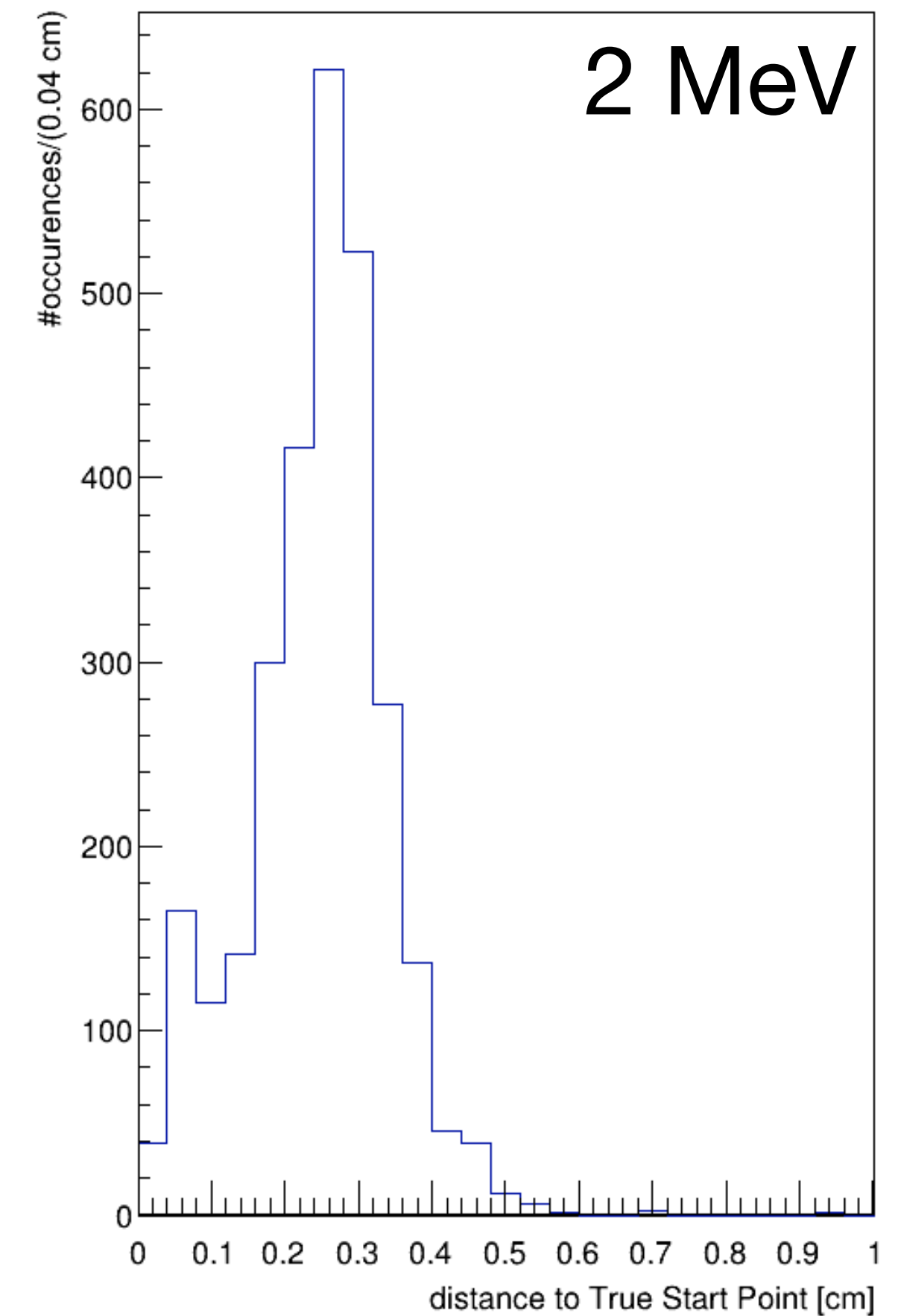
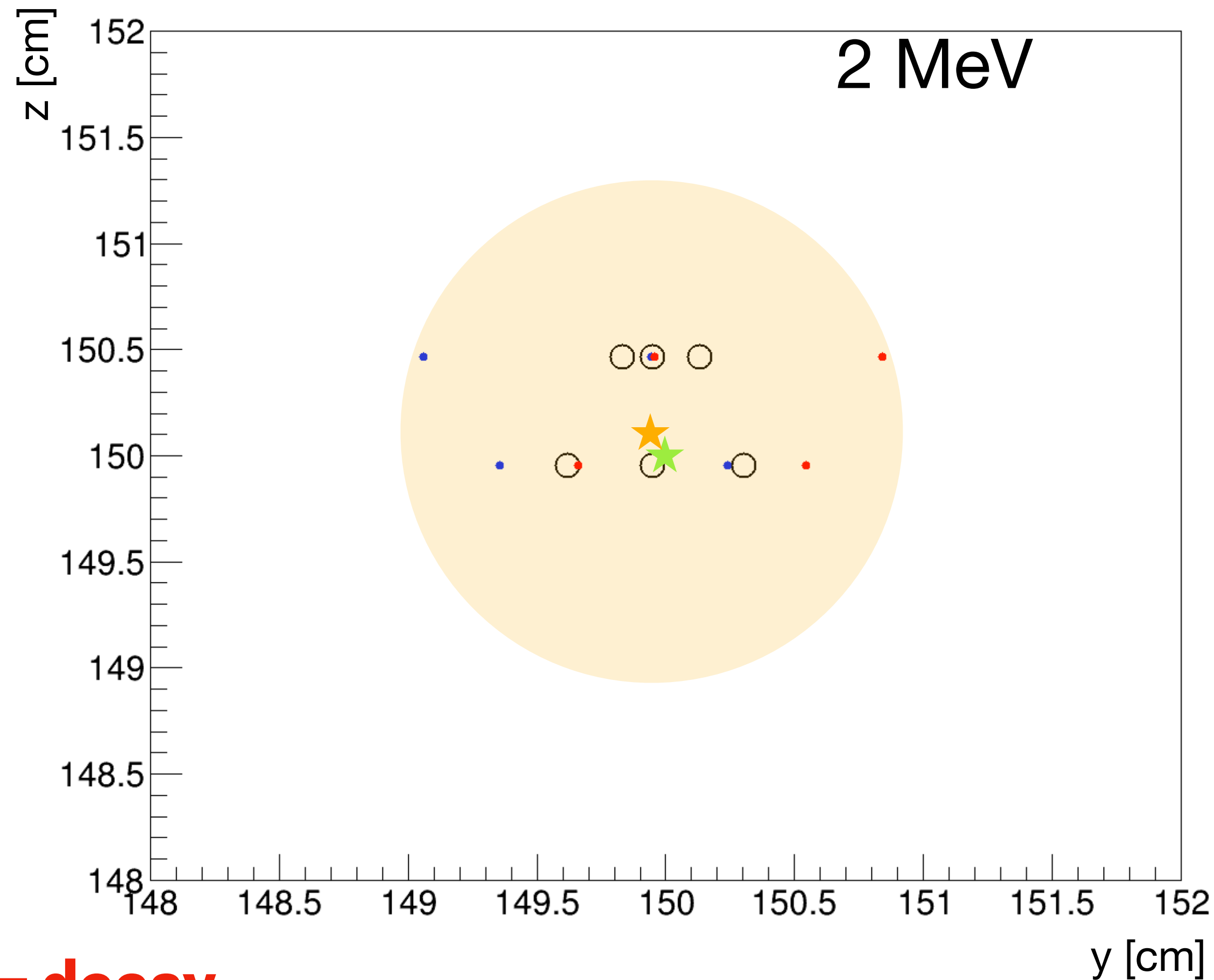
tagPD → to use the good ElectronToADC coefficient

- ★ True Start Point (Gen)
- Ind1/Col. Intersection
- Ind2/Col. Intersection
- SingleHit SpacePoint



- Simulated 2 MeV electron in PDVD
- Next step : clustering all these SpacePoints for calorimetry

- ★ True Start Point (Gen)
- Ind1/Col. Intersection
- Ind2/Col. Intersection
- SingleHit SpacePoint
- ★ Reco. Cluster (SingleHit)



- **Goal → 1 cluster = decay**
- **Cluster position is a barycentre of SpacePoint (with collection energy)**
- Spatial resolution for PDVD/HD : $R_s \lesssim 1\text{cm}$

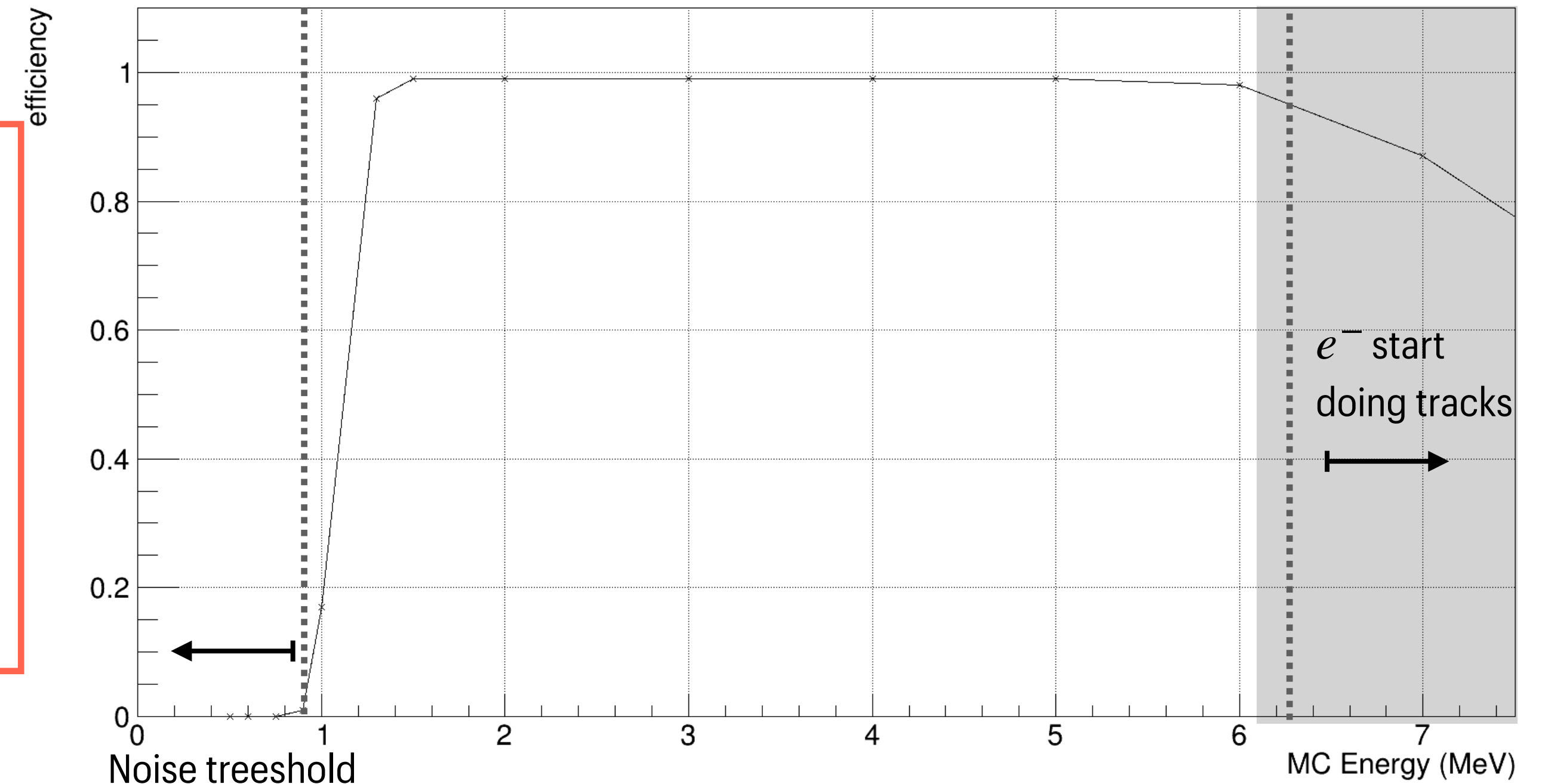
Results on ProtoDUNES

- $\sim 2500 e^-$ for a given energy E_{e^-} from 0.5 MeV to 10 MeV

$$\text{efficiency} = \frac{\sum^{N_{event}} \min(1, N_{cluster})}{N_{event}}$$

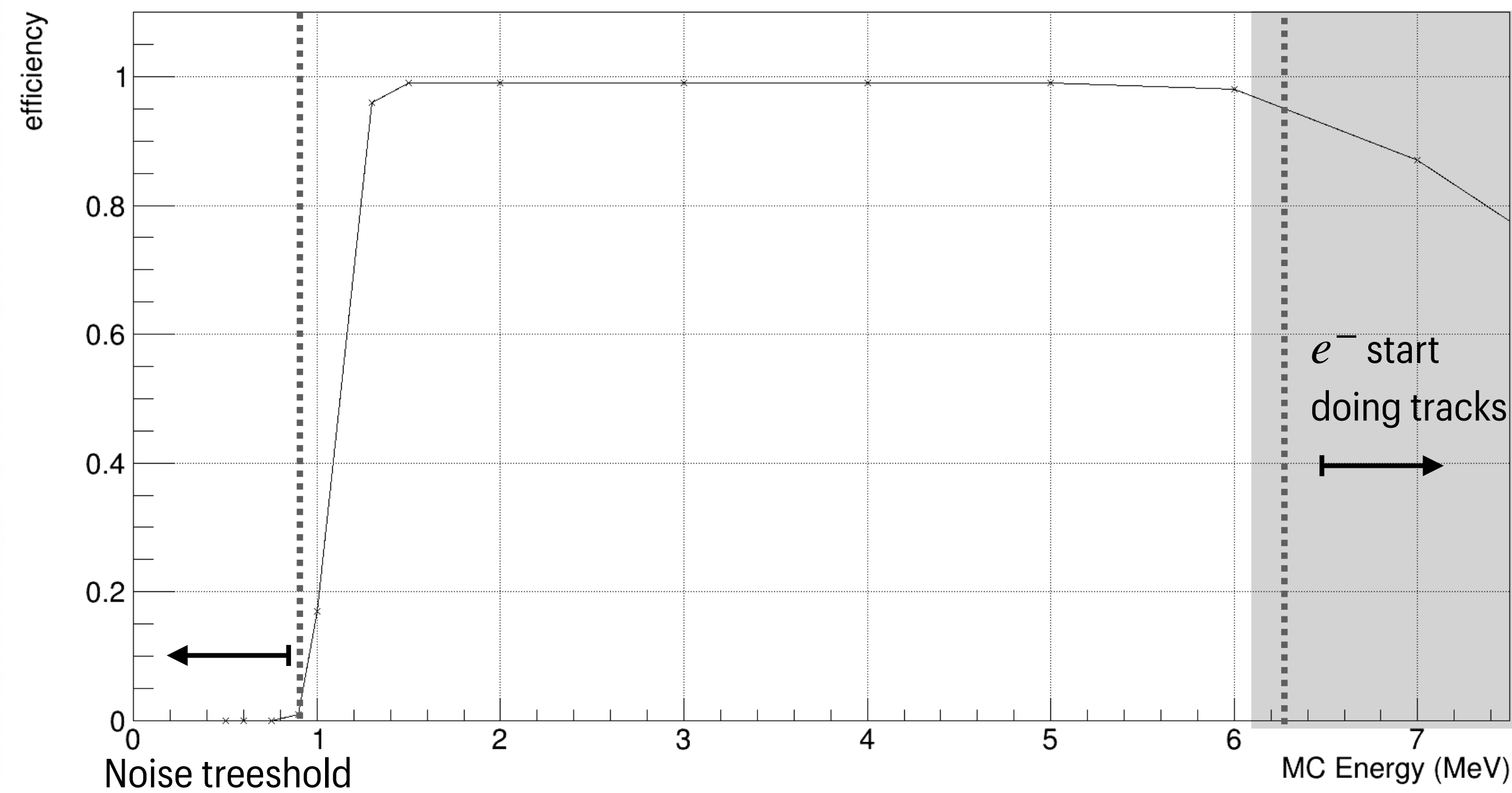
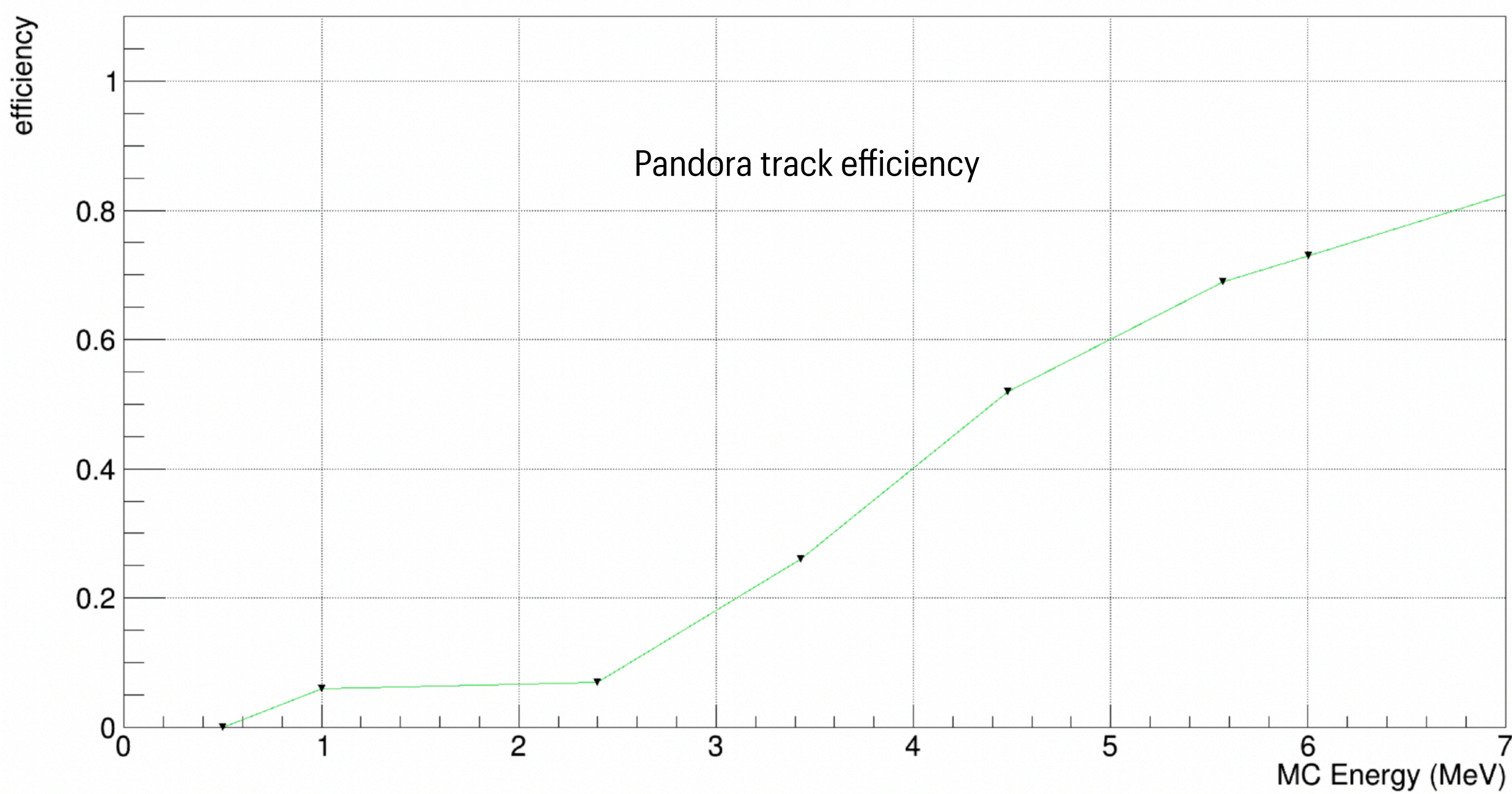
$N_{cluster}$ = Number of clusters with ($d < 25$ cm)

d = distance to True MC position [cm]

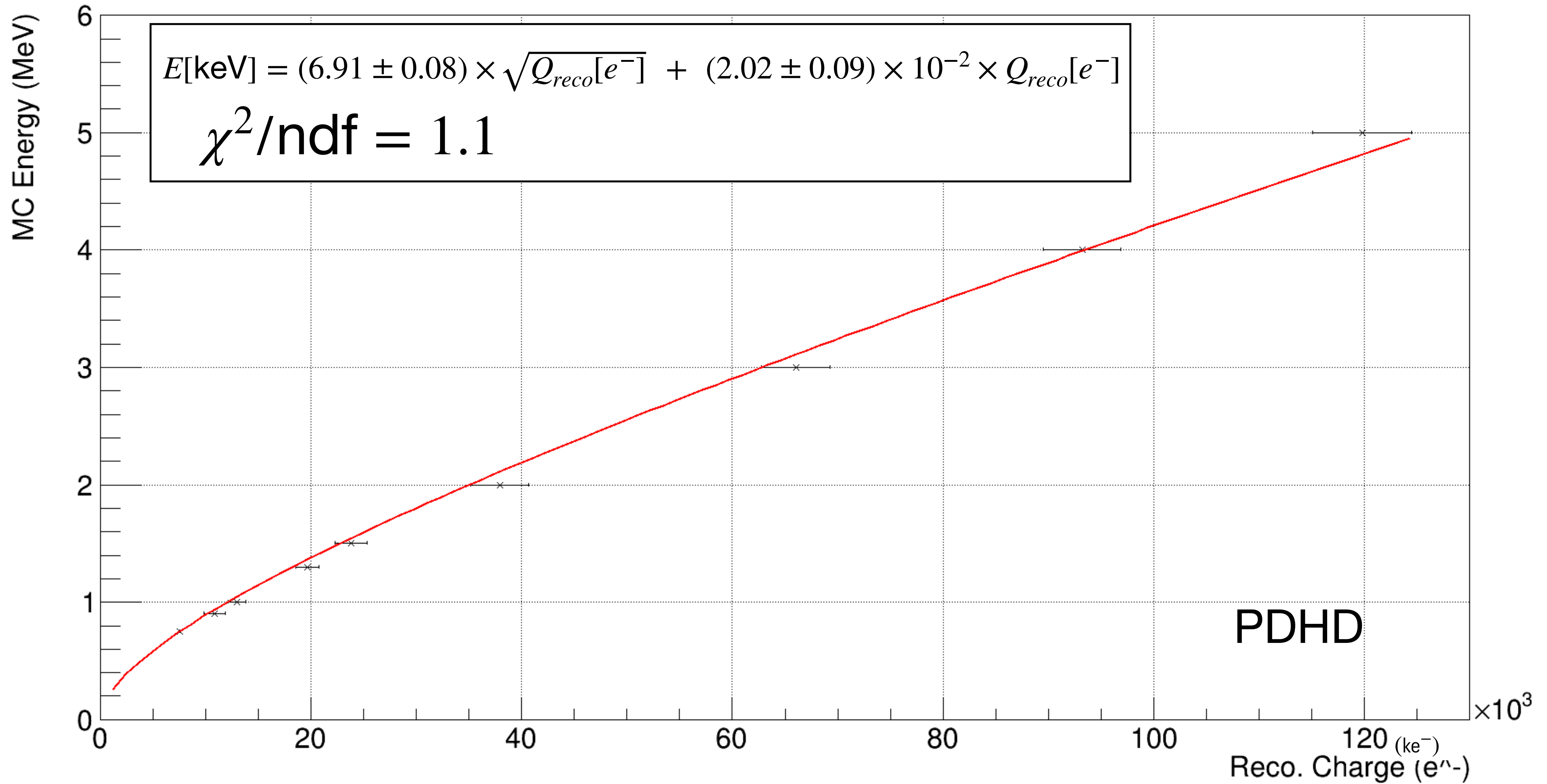


- No hit reconstructed with $E_{e^-} \leq 750$ keV (gaushit)
- Reconstruct 99% of e^- if. $1.3 \text{ MeV} \leq E_{e^-} \leq 5 \text{ MeV}$ (SingleHit module)

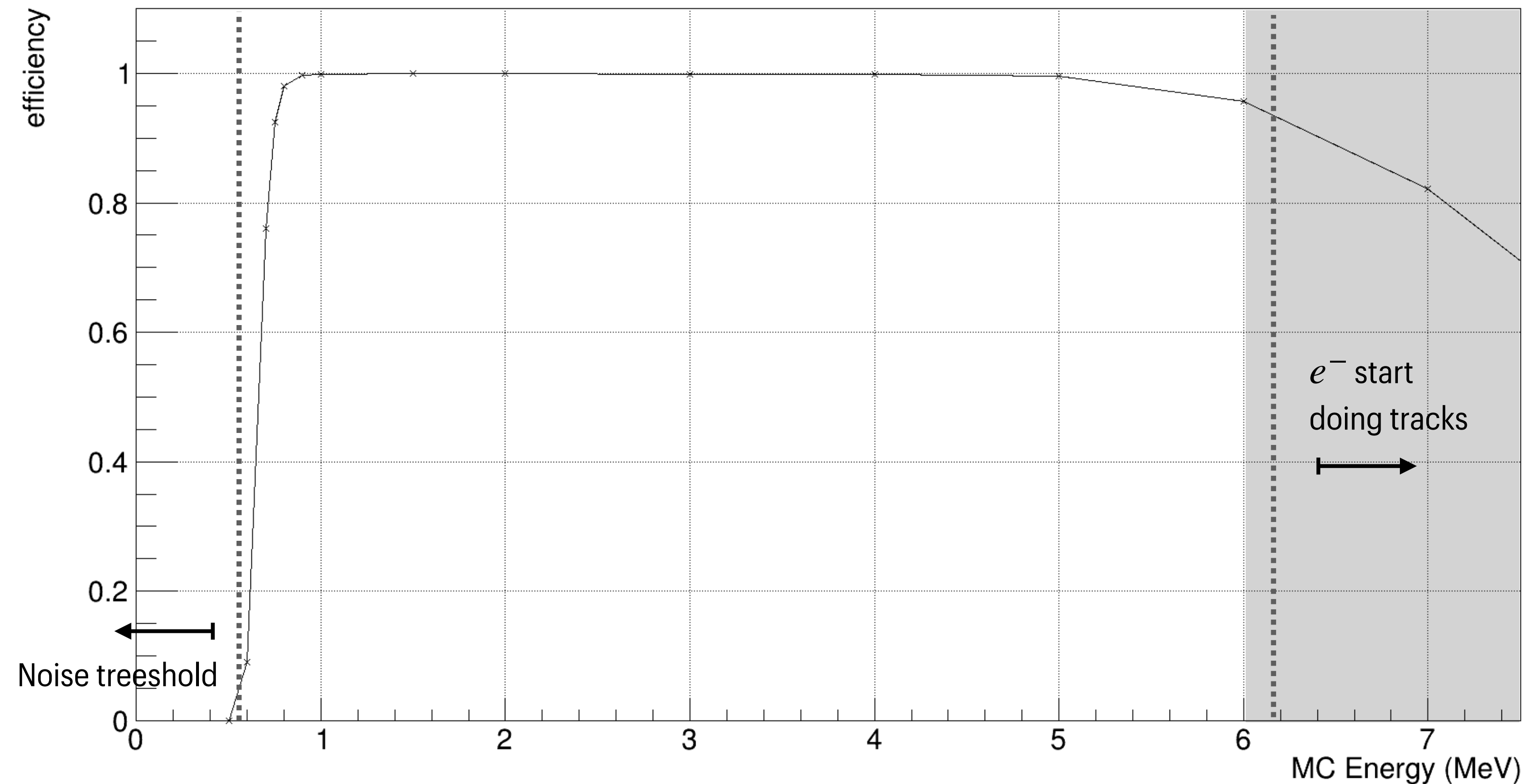
In comparison



- Calibration curve on simulation

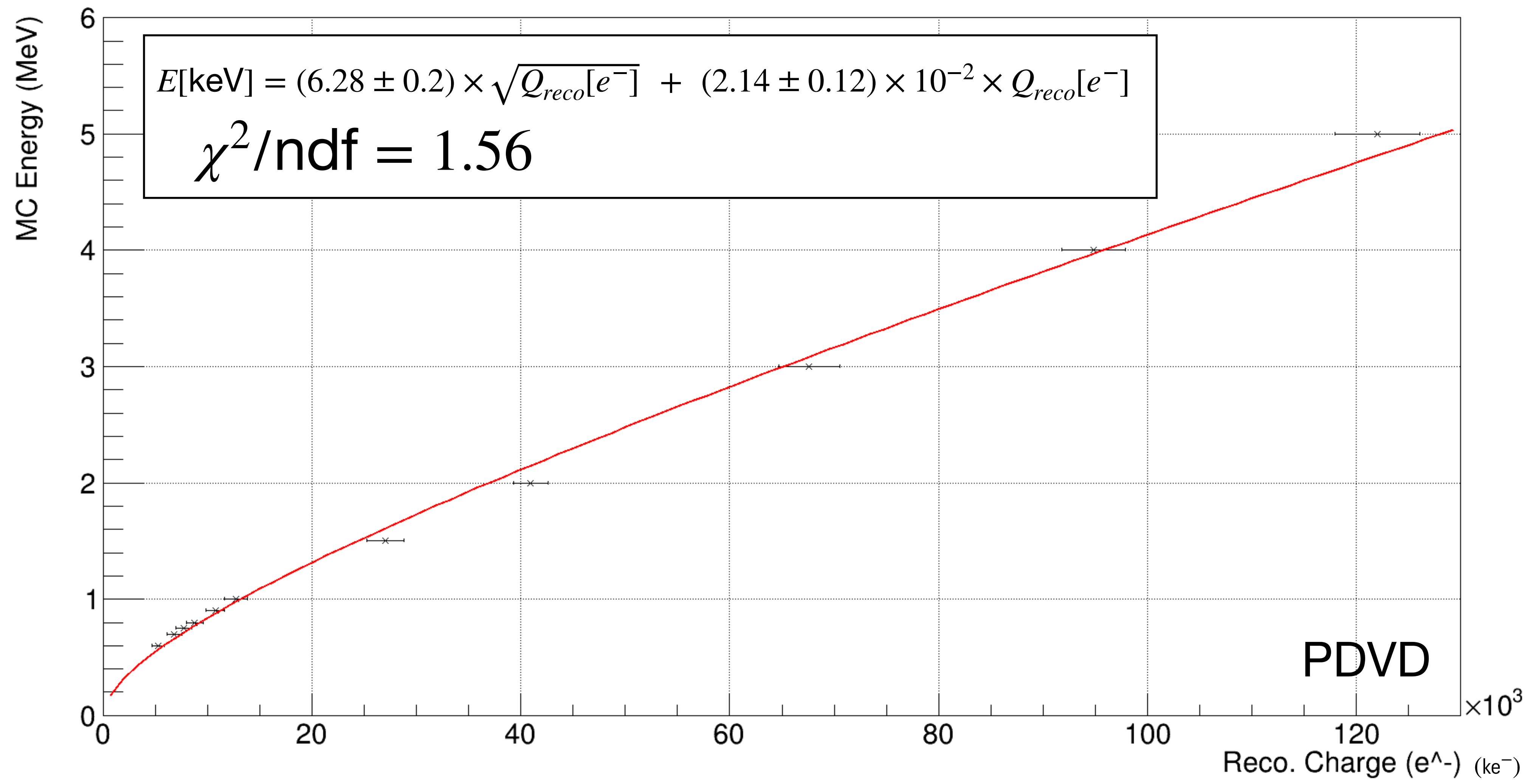


- $\sim 2500 e^-$ for a given energy E_{e^-} from 0.5 MeV to 10 MeV

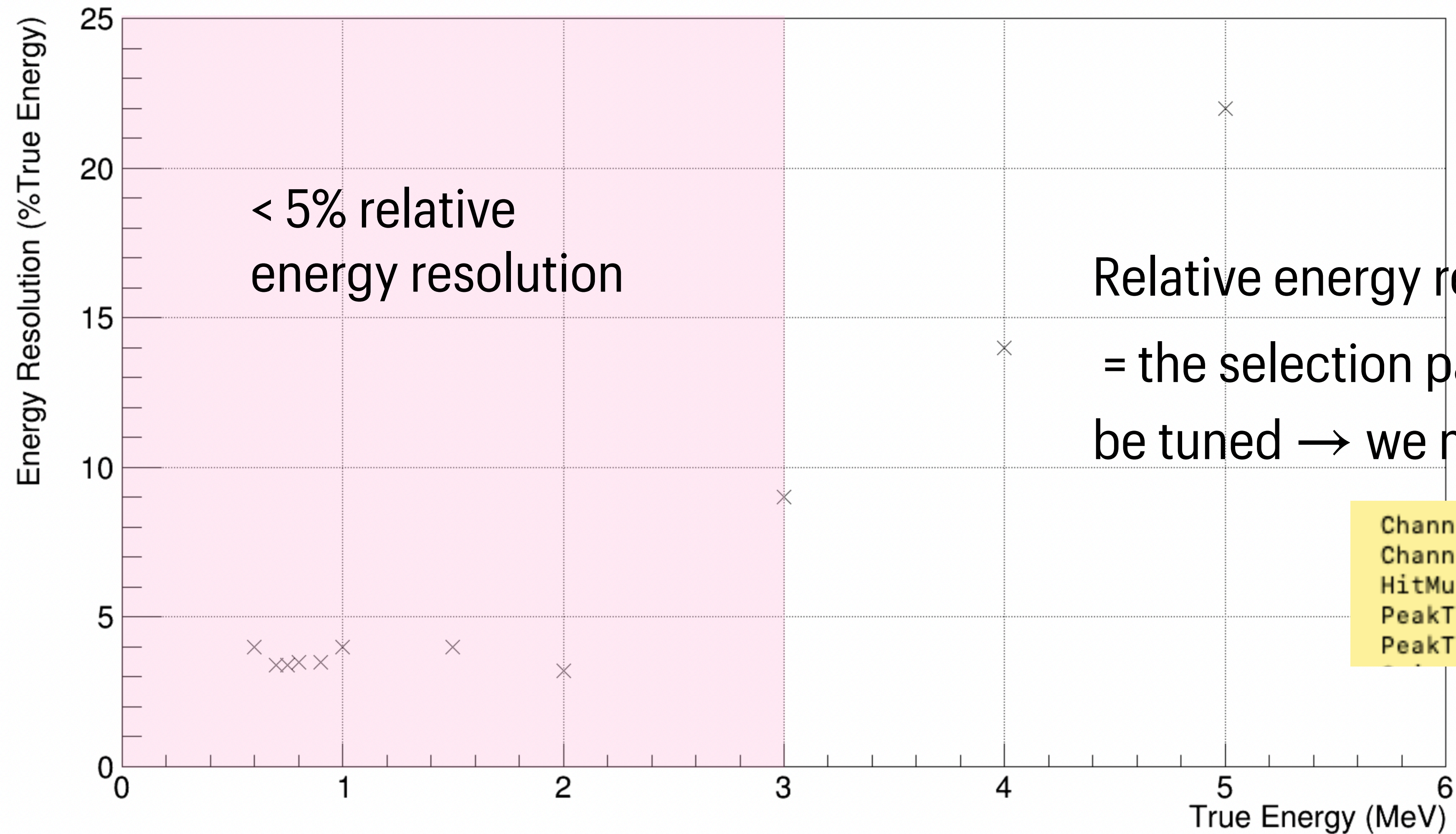


- No hit reconstructed with $E_{e^-} \leq 600$ keV (gaushit)
- Reconstruct 99% of e^- if. $800 \text{ keV} \leq E_{e^-} \leq 5 \text{ MeV}$ (SingleHit module)

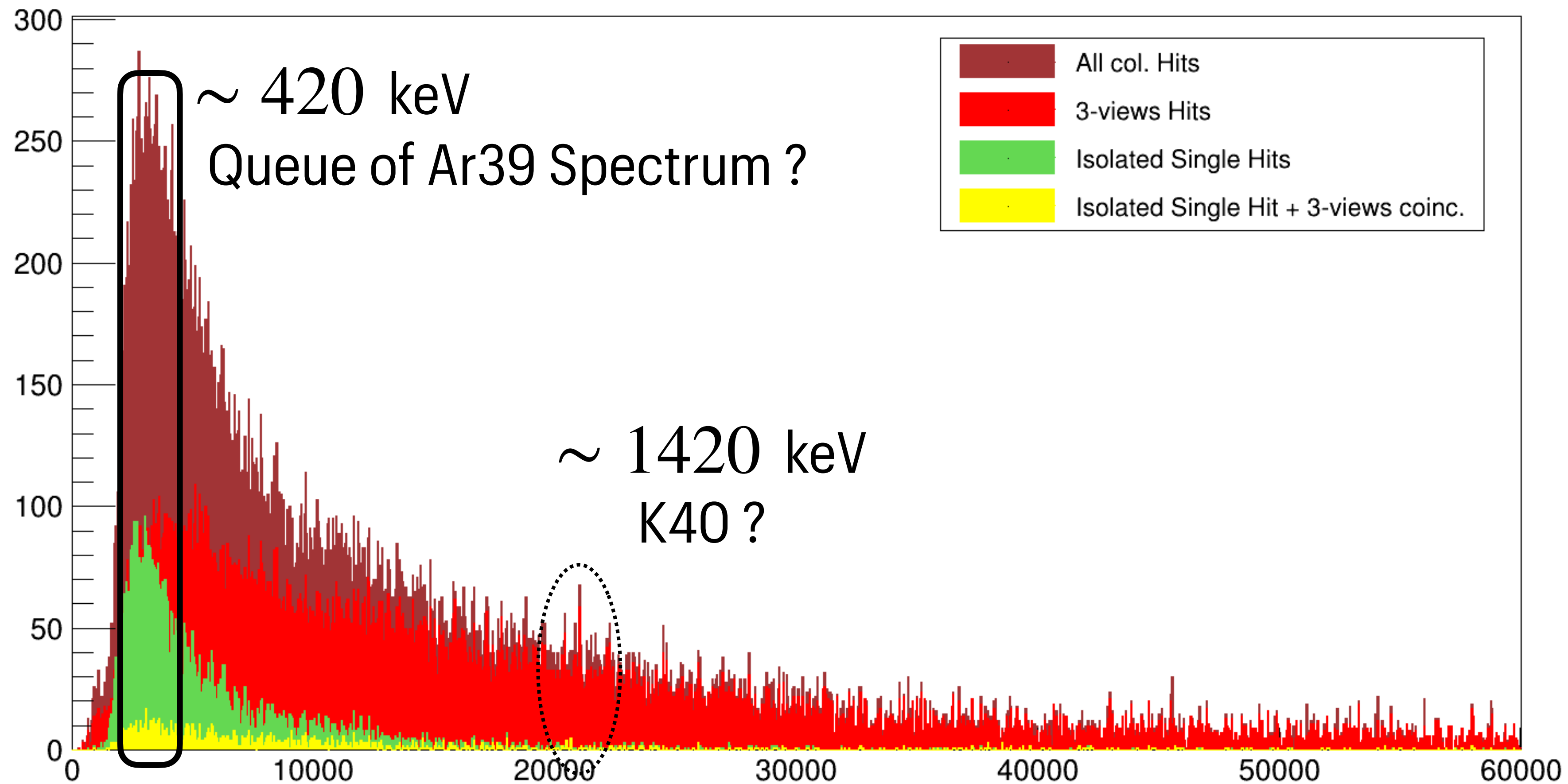
- Calibration curve on simulation



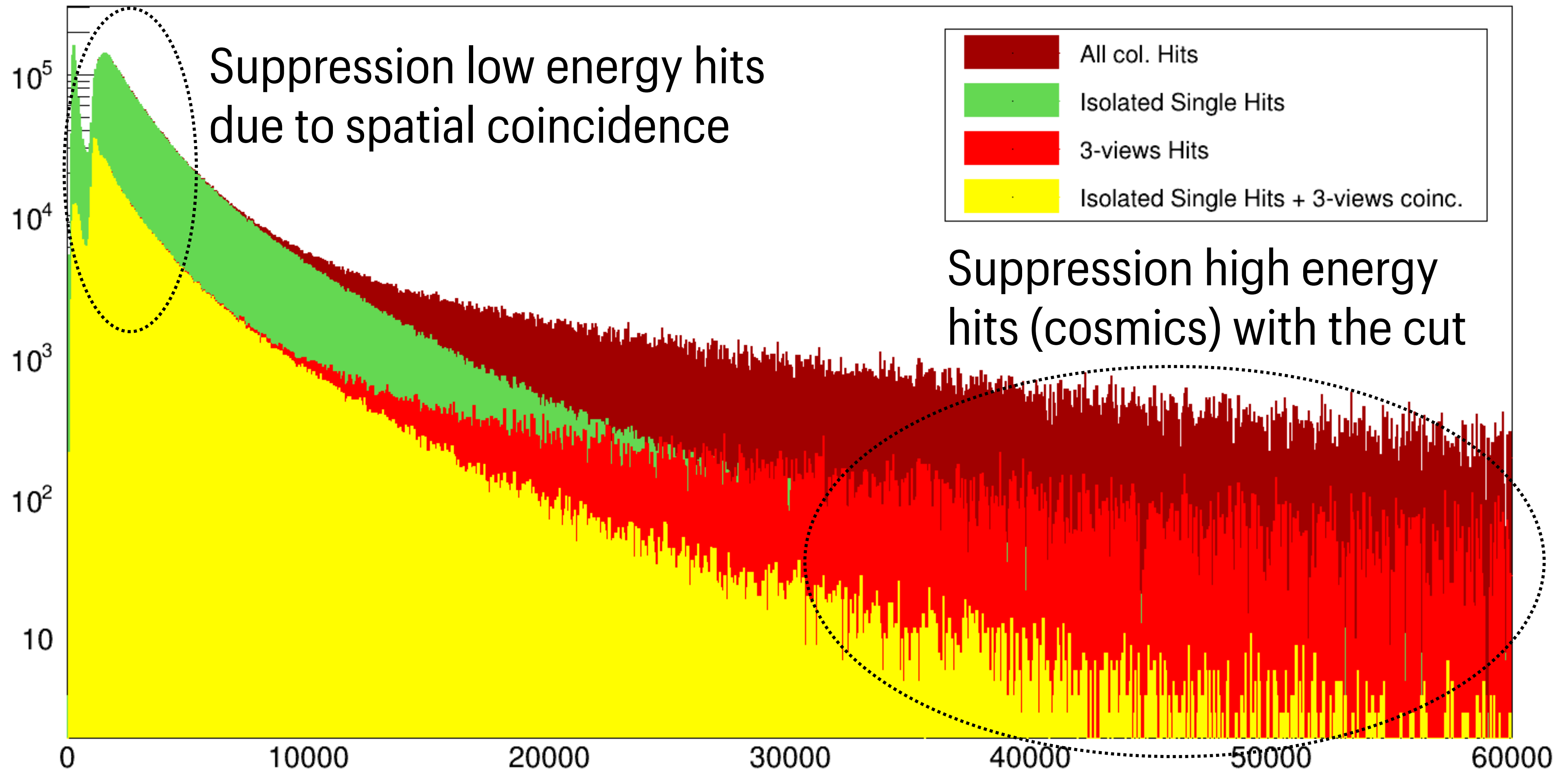
- Energy Resolution → preliminary



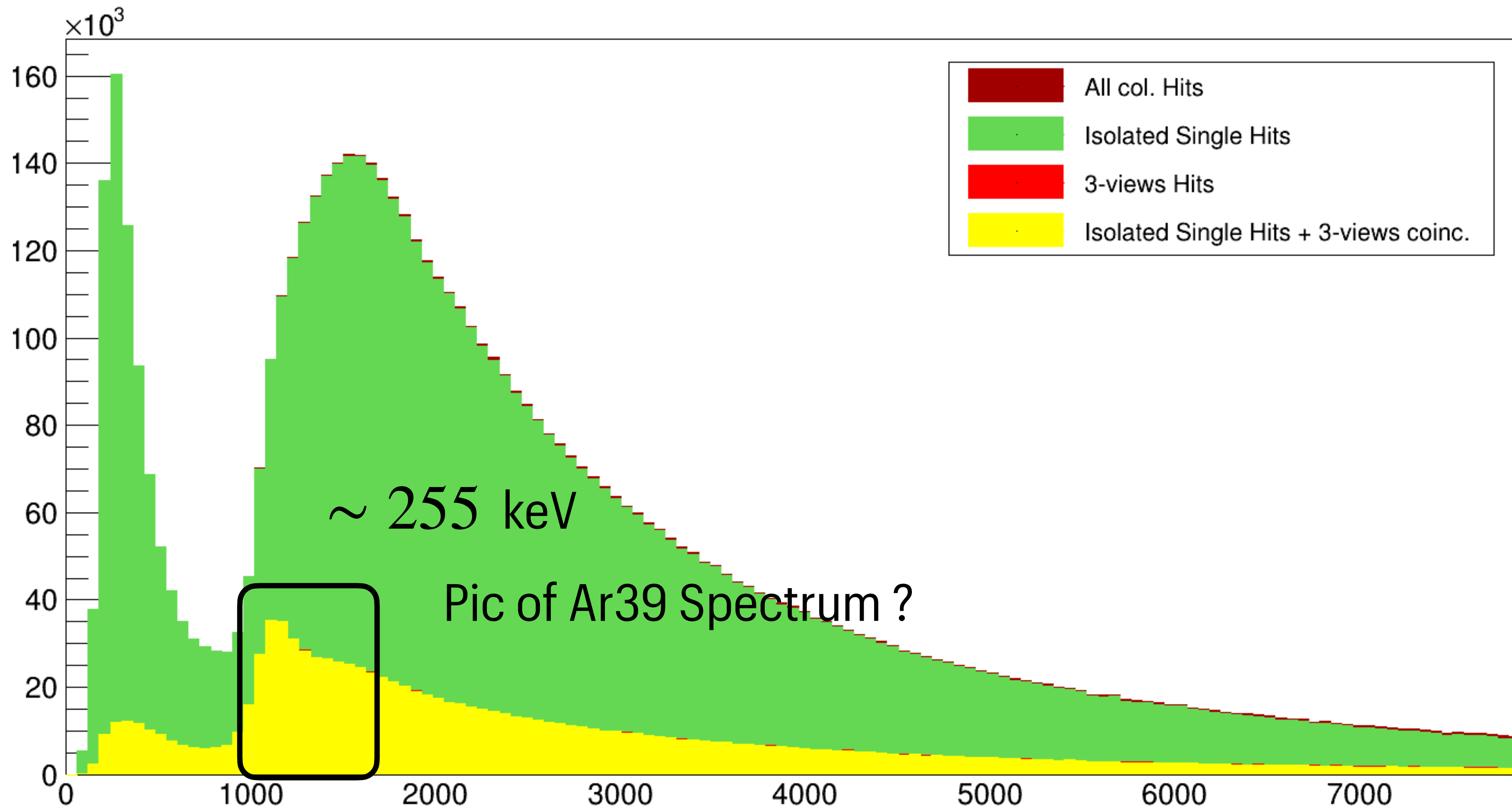
- On 22 events of 4ms : expected rate of Ar39 \rightarrow 8000 decays
- We have at the end **1200 decays**



- Run 5809



- Zoom in



Conclusion

- Identification efficiency on PDVD/HD simulation : **~99% of e- in the 1-5 MeV region**
- Capable of calibrating both detector at low energy
- Sharp threshold (limited by HitFinder)
- Calibration constant are compatible within the statistical errors
- Understand PDHD data → need **more statistics**
- Next :
 - Incorporation of SingleHit module in duneana/calib
 - Apply the analysis on PDHD data in the coming months
 - Look at more realistic simulation with continuous spectrum (radiologicals + cosmics) and CALCI systems (PNS and laser data)
 - Simulation with different noise levels