

Analysis meeting

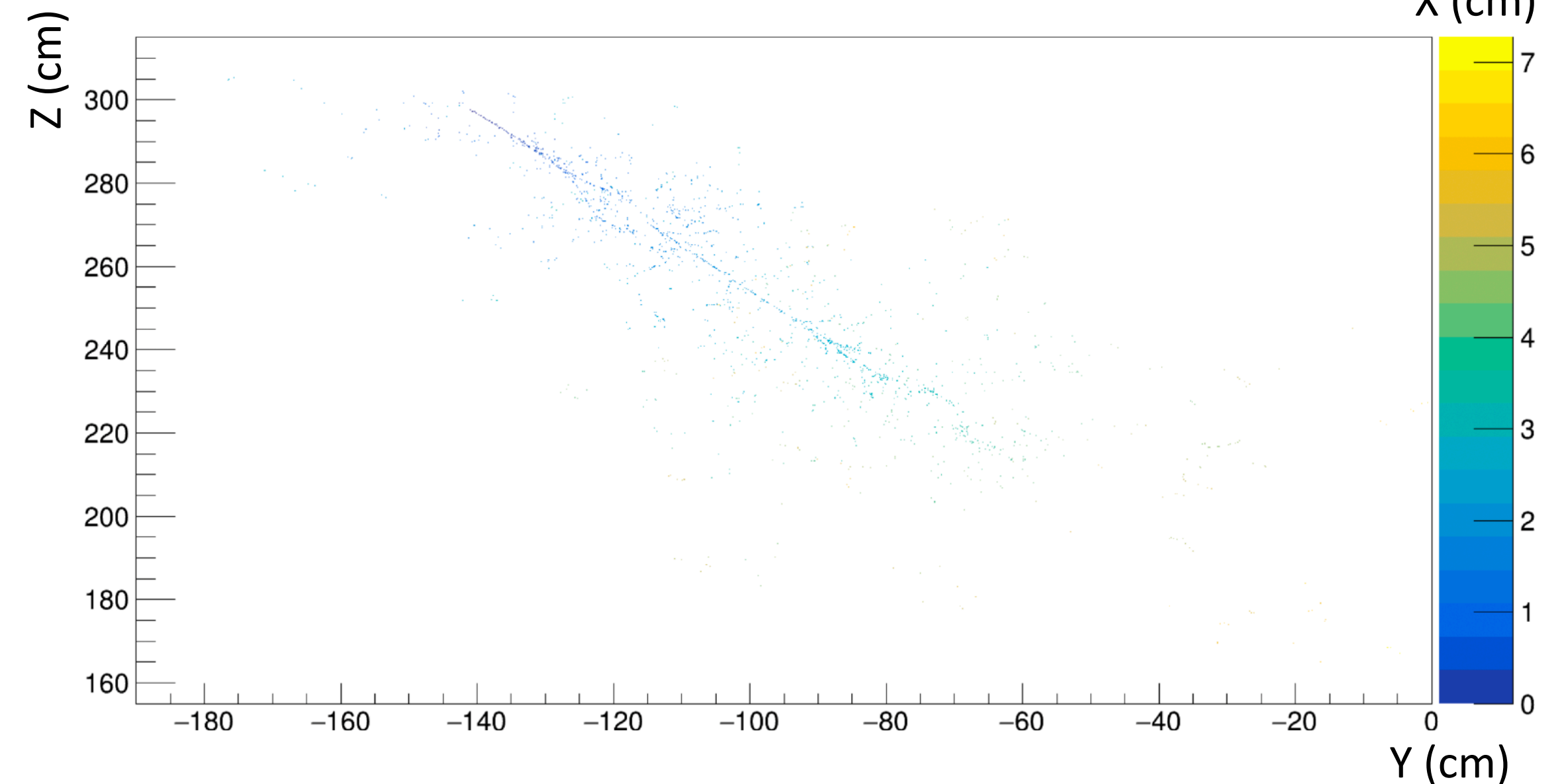
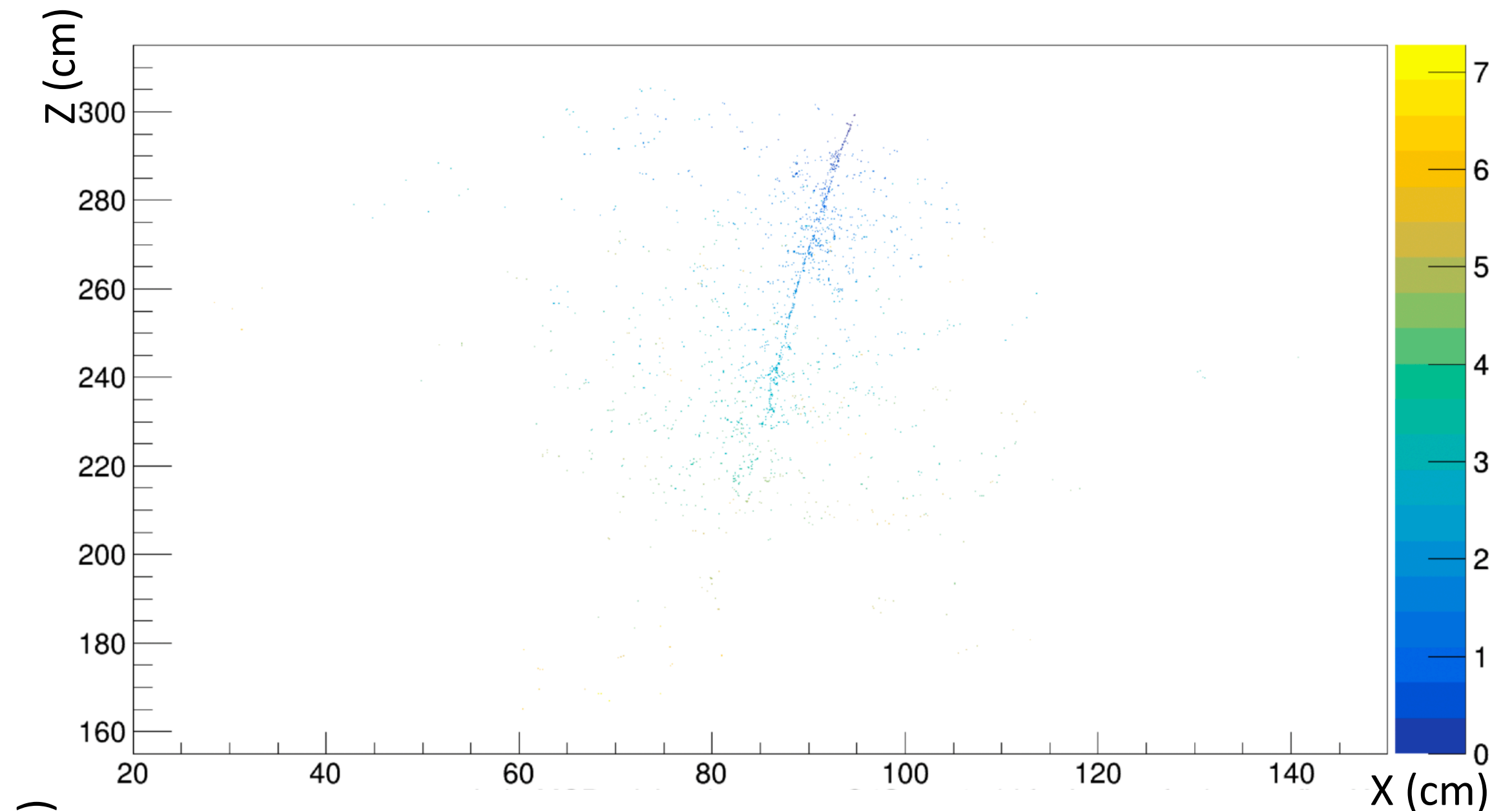
DUNE France



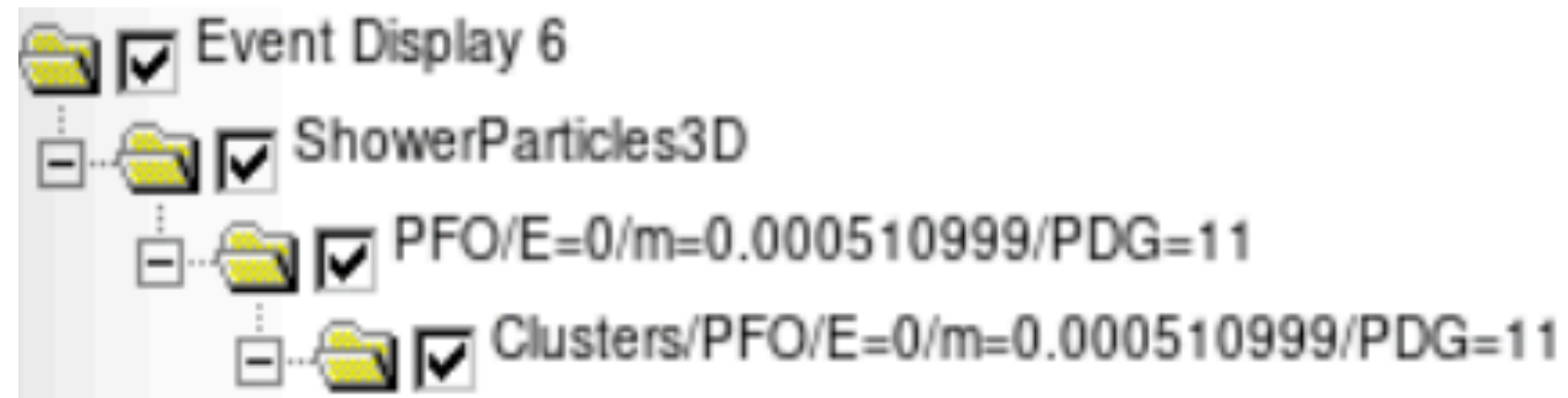
Summary

- Electromagnetic shower reconstruction analysis for PDVD (Y. Kermaidic)
- Michel electron analysis -identification of stopping tracks- for PDVD (J. Quelin Lechevranton, T. Houdy)
- Calibration at low energy
 - Ar39/radiologicals reconstruction/identification for PDHD and PDVD (E. Lavaut)
 - PNS (Pulse Neutron Source) analysis for CBVD and PDHD (?) (Y. Kermaidic E. Lavaut)

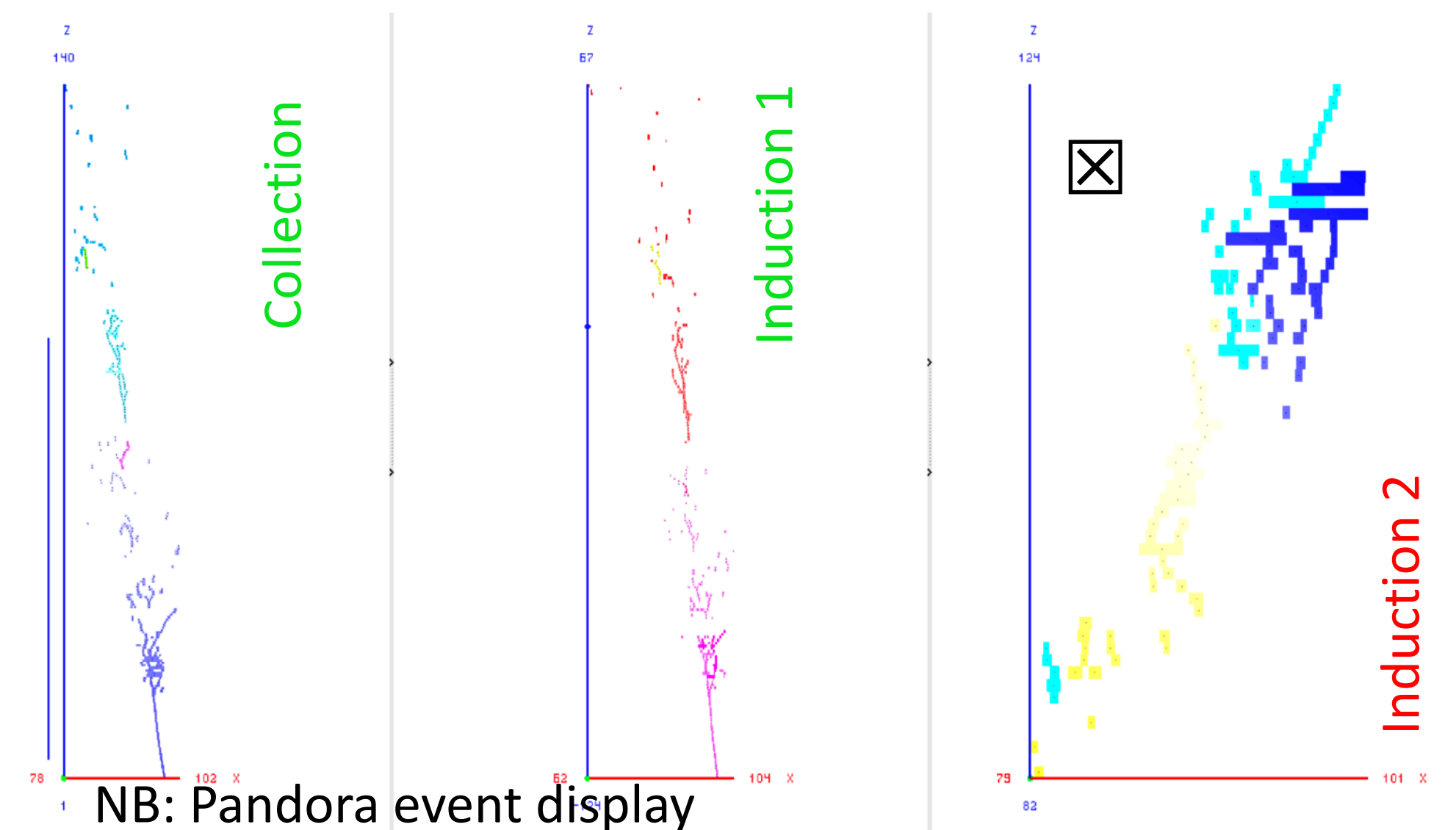
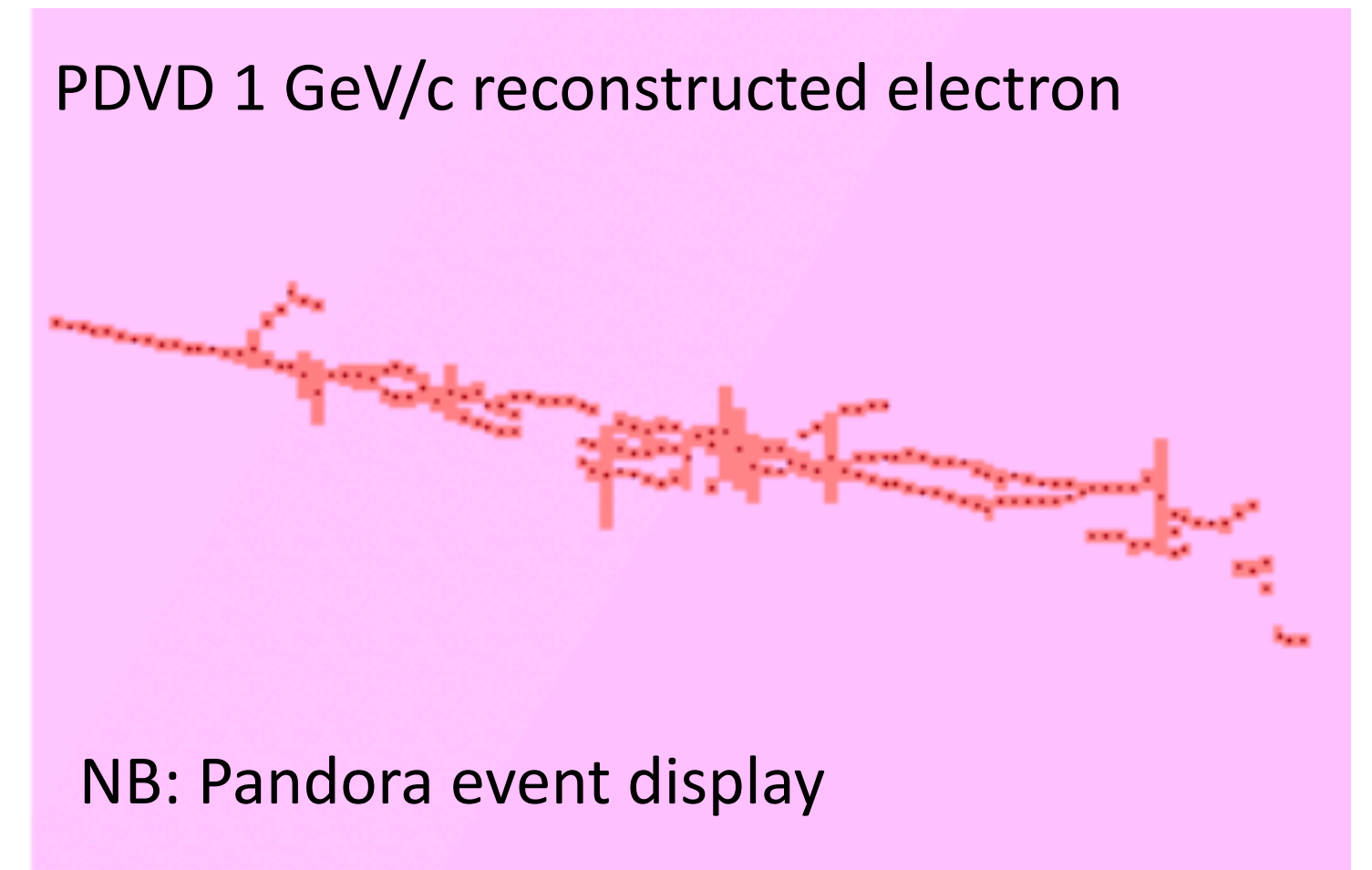
- Particle gun starting at the beam entrance
« Ideal case »
- **Dataset:**
 - 10000 electrons available
 - [vd-protodune:vd-protodune_full-reconstructed_v09_88_00d00_protodunevd_reco_gen_protodunevd_electron_1GeV_out1_e1gev_validation](https://github.com/DUNE/dunesw/blob/develop/fcl/protodunevd/gen/gen_protodunevd_singlelep.fcl)
- **Goal:**
 - validate the pandora shower identification
 - perform the calorimetry and estimate the energy reconstruction performance
- **FHICL:**
 - https://github.com/DUNE/dunesw/blob/develop/fcl/protodunevd/gen/gen_protodunevd_singlelep.fcl
 - https://github.com/DUNE/dunesw/blob/develop/fcl/protodunevd/reco/protodunevd_reco.fcl
- **Using:**
pandora: @local::protodune_pandora
- **Bug:** Start at the wrong position – PR opened



- **Upgrading the Pandora configuration:** PandoraSettings_Master_ProtoDUNE_VD.xml to include beam entrance position and direction (à la HD config.)
- **Testing the Pandora shower reconstruction & particle identification**

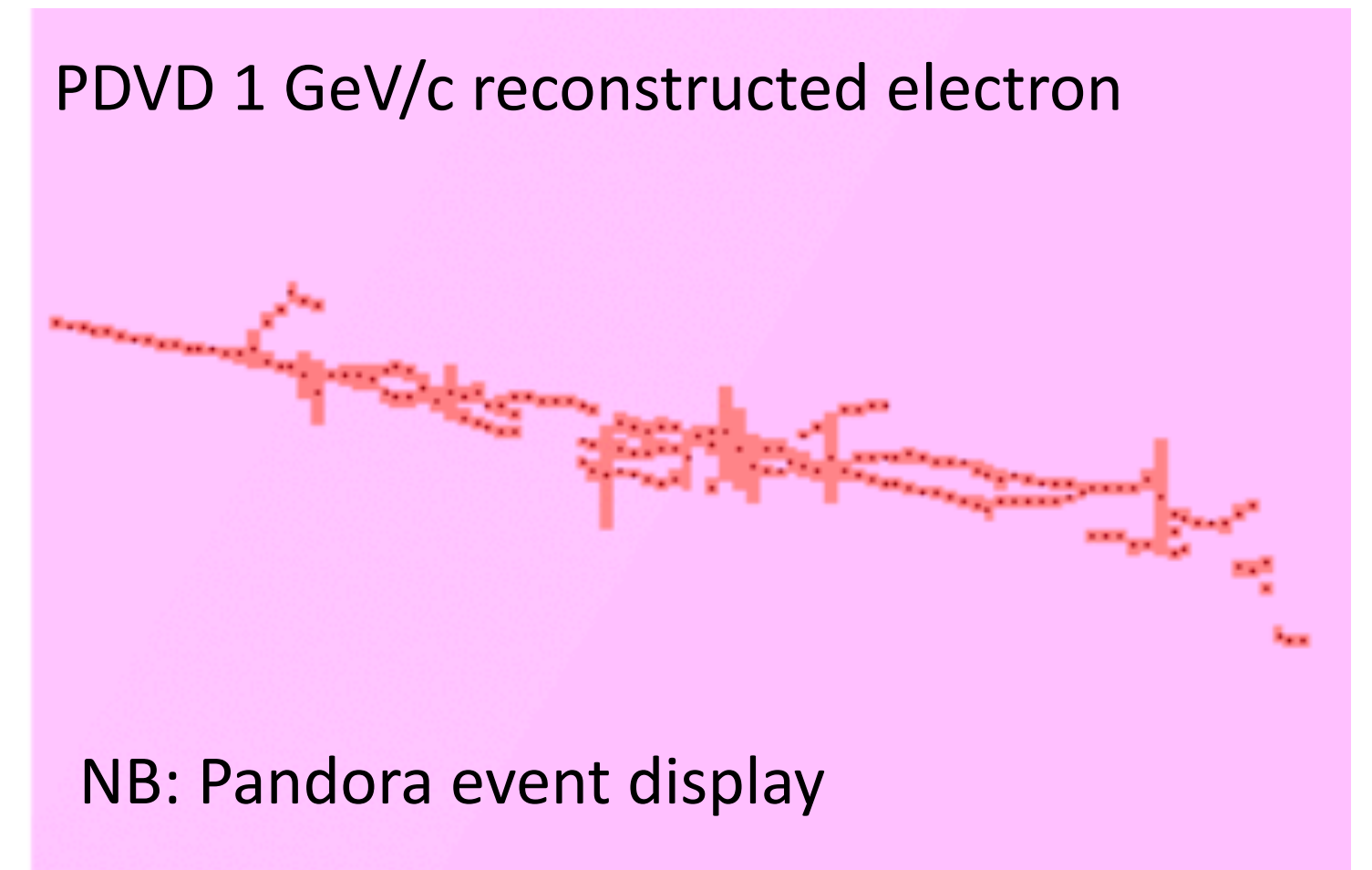
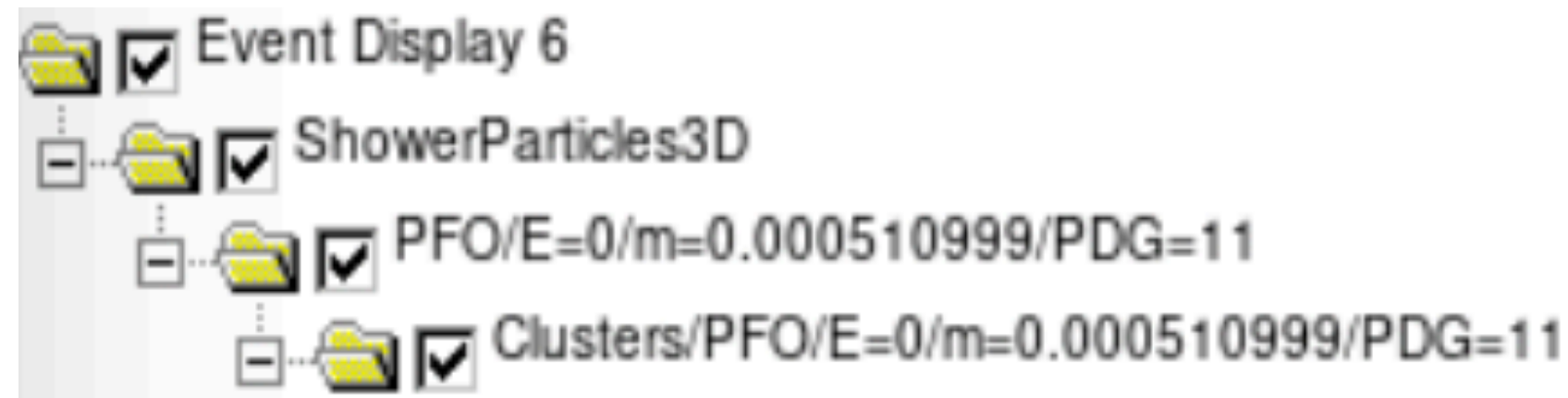


- **Two issues to be noticed:**
 - As of now, 8 times out of 10, pandora would reconstruct an electron shower as a pion.
 - What's popping-up for beam matters is its direction w.r.t. to one of the induction plane : 45 deg. vs 30 deg
One of the three views has poor information



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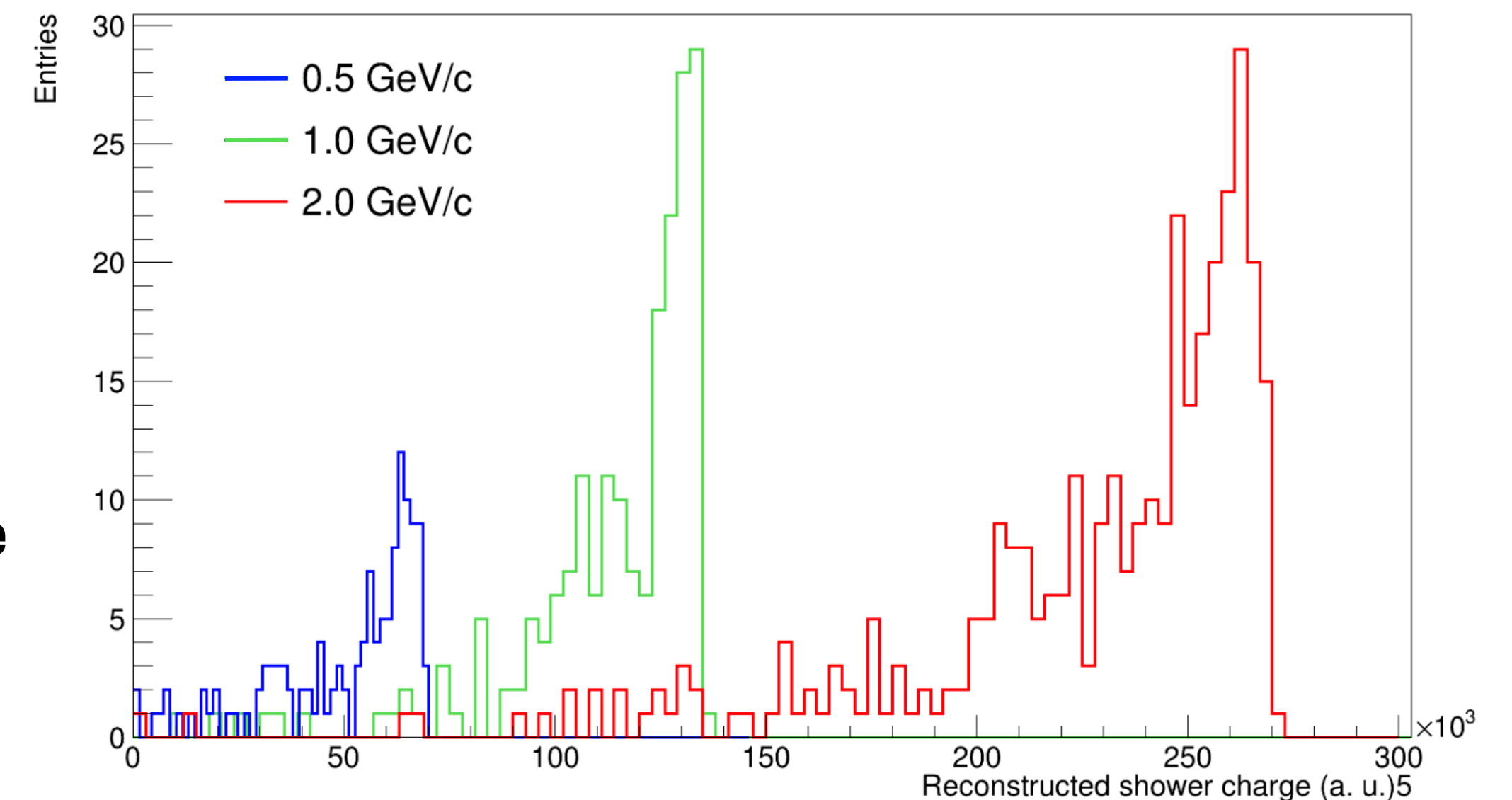
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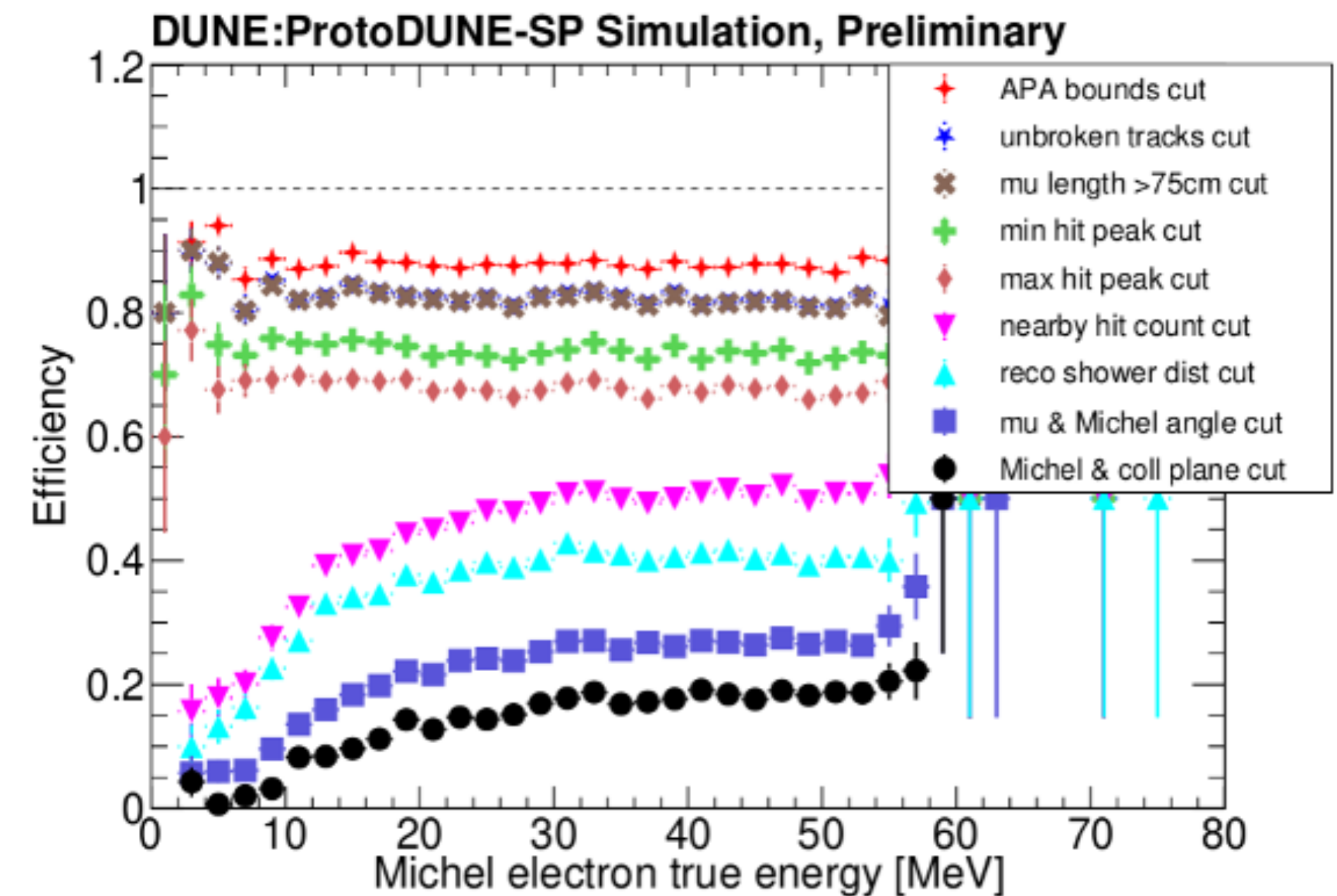
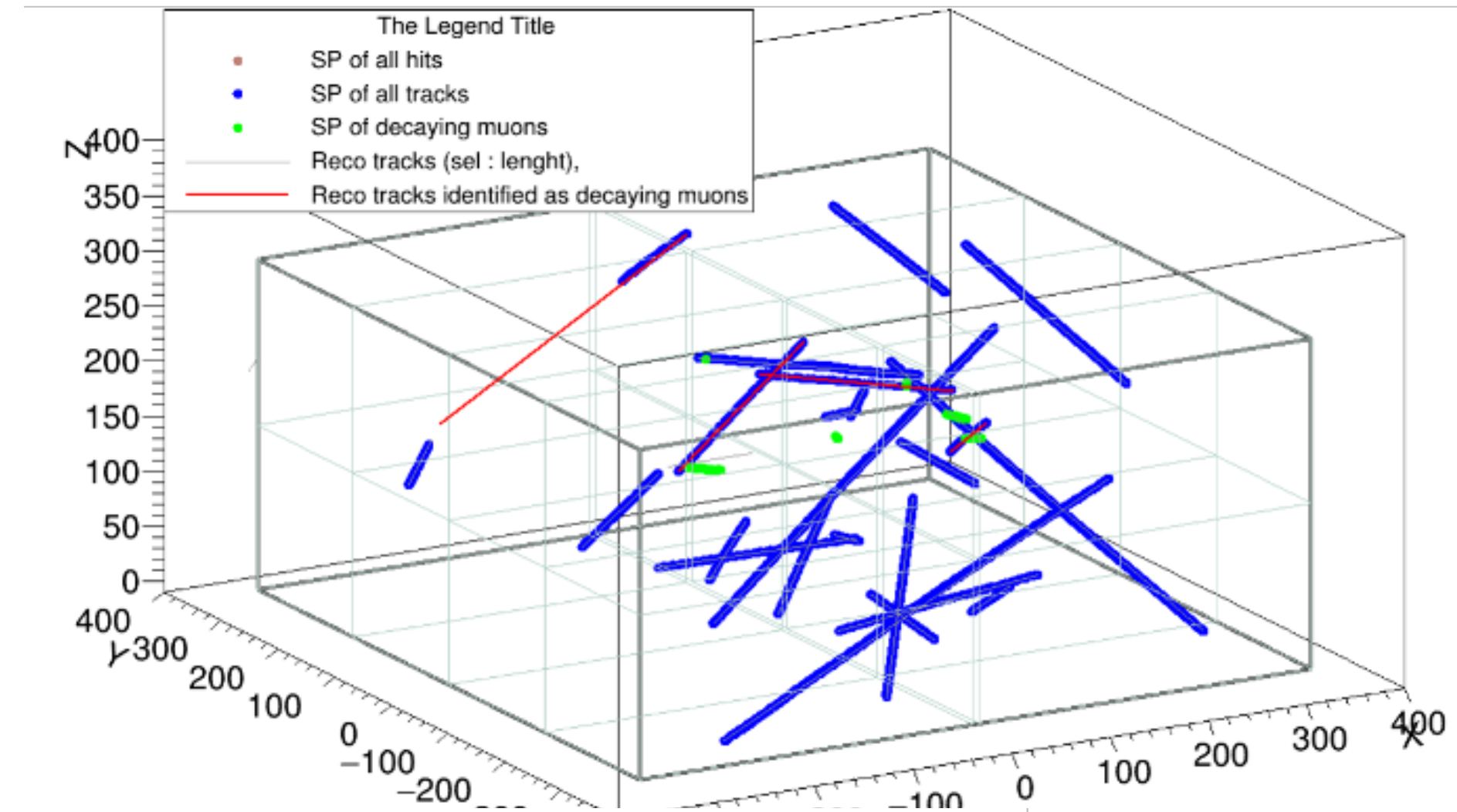
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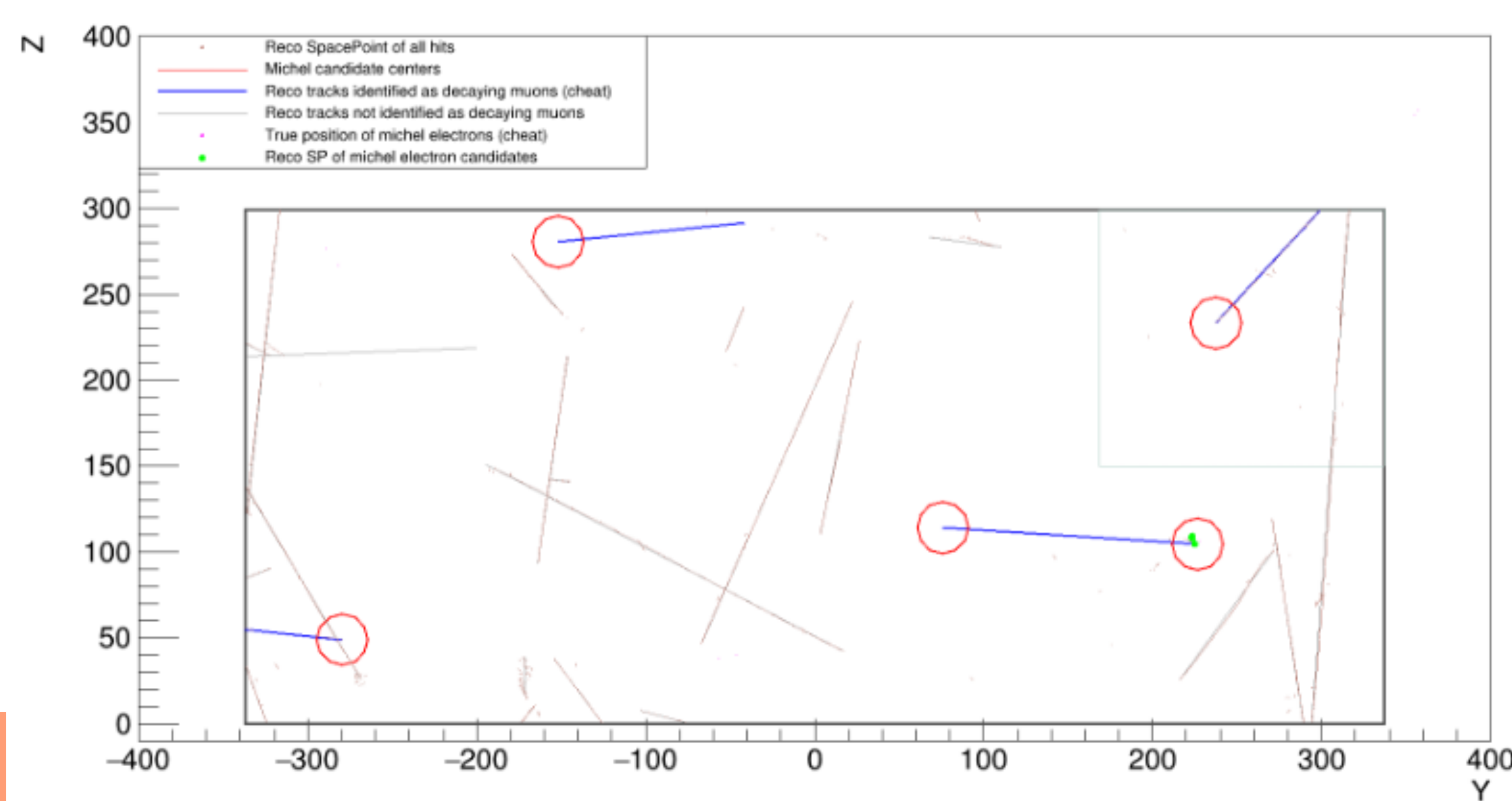
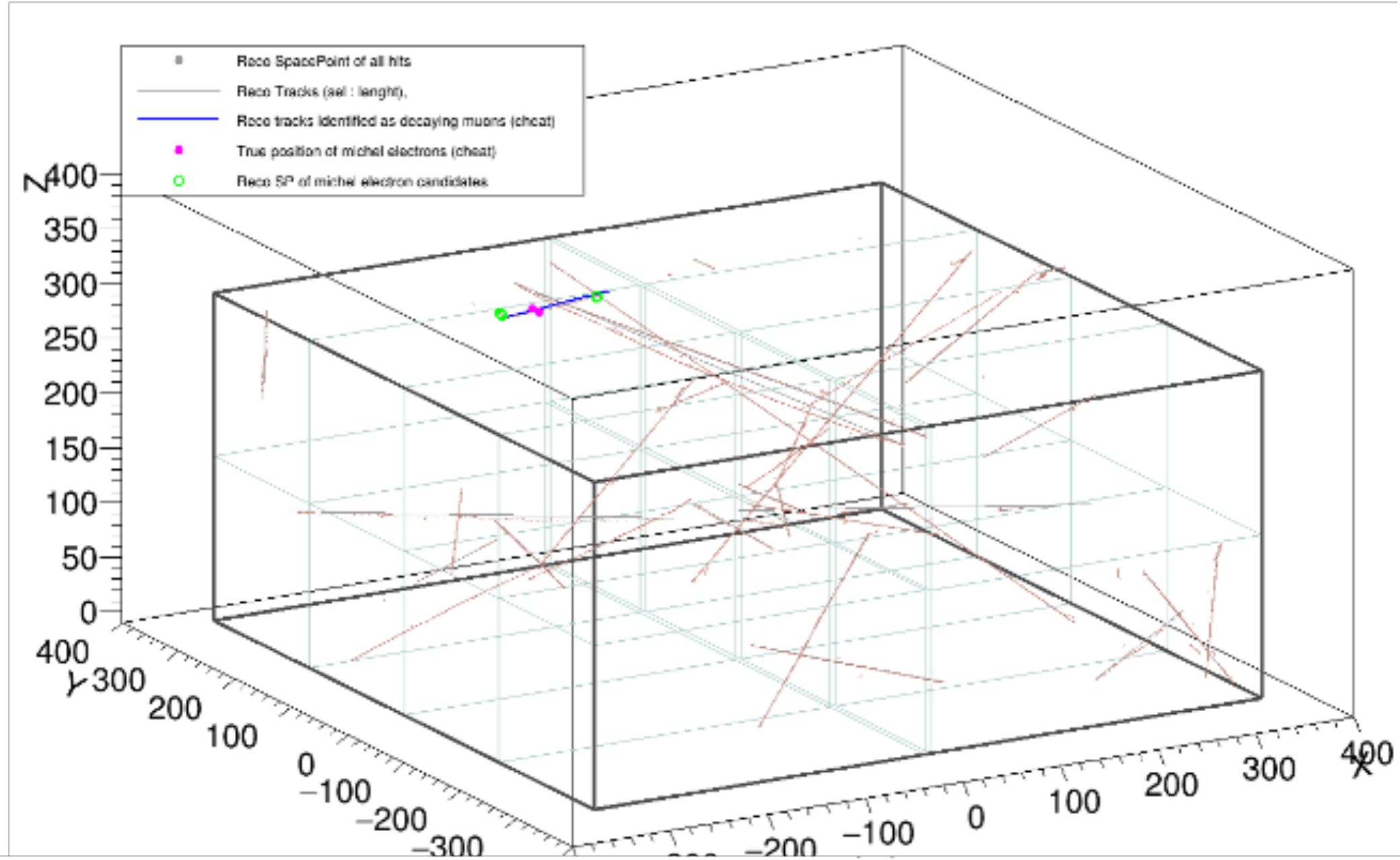
- As of now, 8 times out of 10, pandora would reconstruct an electron shower as a pion.
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- **Energy scan working to first order when looking at the reconstructed charge of summed wires**



- Using existing data set of cosmics in ProtoDUNE-VD
- **Objectives :**
 - validate the **ProtoDUNE-VD cosmics** preproduction and reconstruction (track efficiency, track/single hit)
 - build a `LArSoft` module to select the decaying muon and reconstruct the Michel electron energy
 - gain efficiency (particularly at low energy) wrt **last analysis** (Aleena Rafique cf plot) through the Bragg peak to clearly tag the end point of a muon ($dE/dX > MIP$)
 - **Jeremy Quelin Lechevranton** started his PhD 2 weeks ago on this very topic!





- 1st investigations :

- Muon well reconstructed. 1 event = 1 cosmic → 50 reco tracks, 27 muons decay, 5 within the detector
- The drift reconstruction is wrong for single hits → transformation of (x,y,z) plan into (time, y, z) for selecting events around muon decay
- Check plots for hits selection within muon decay spots.

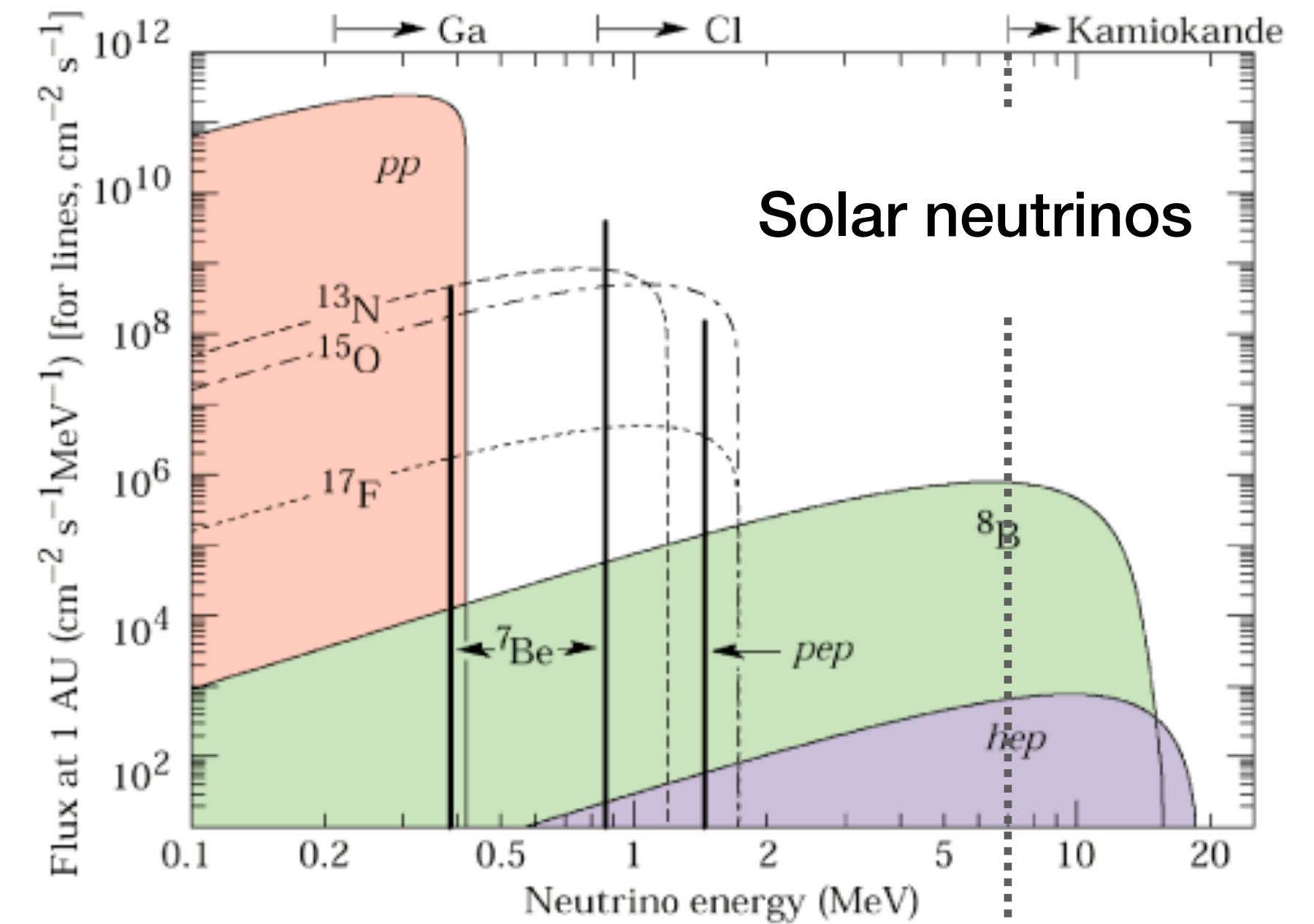
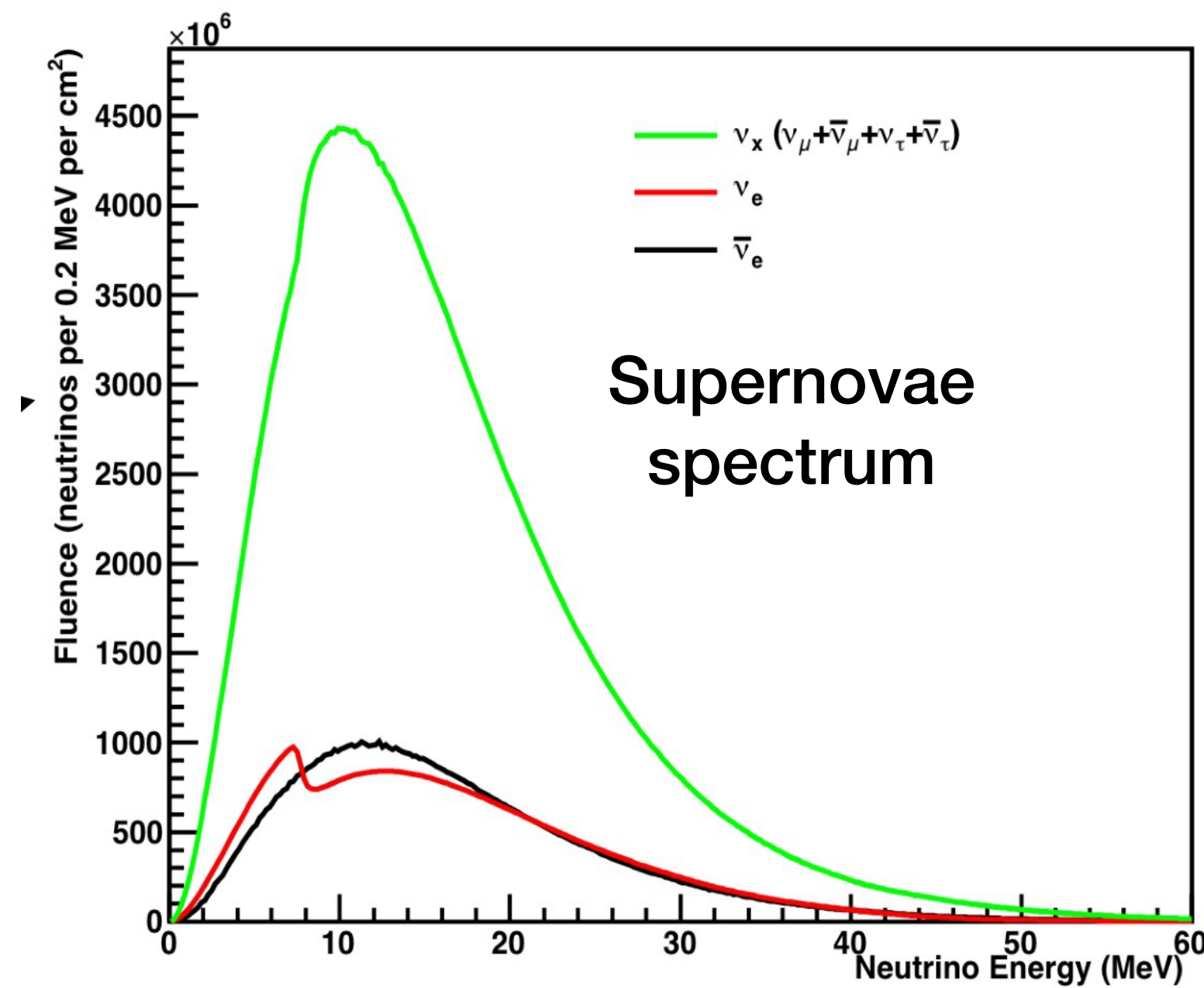
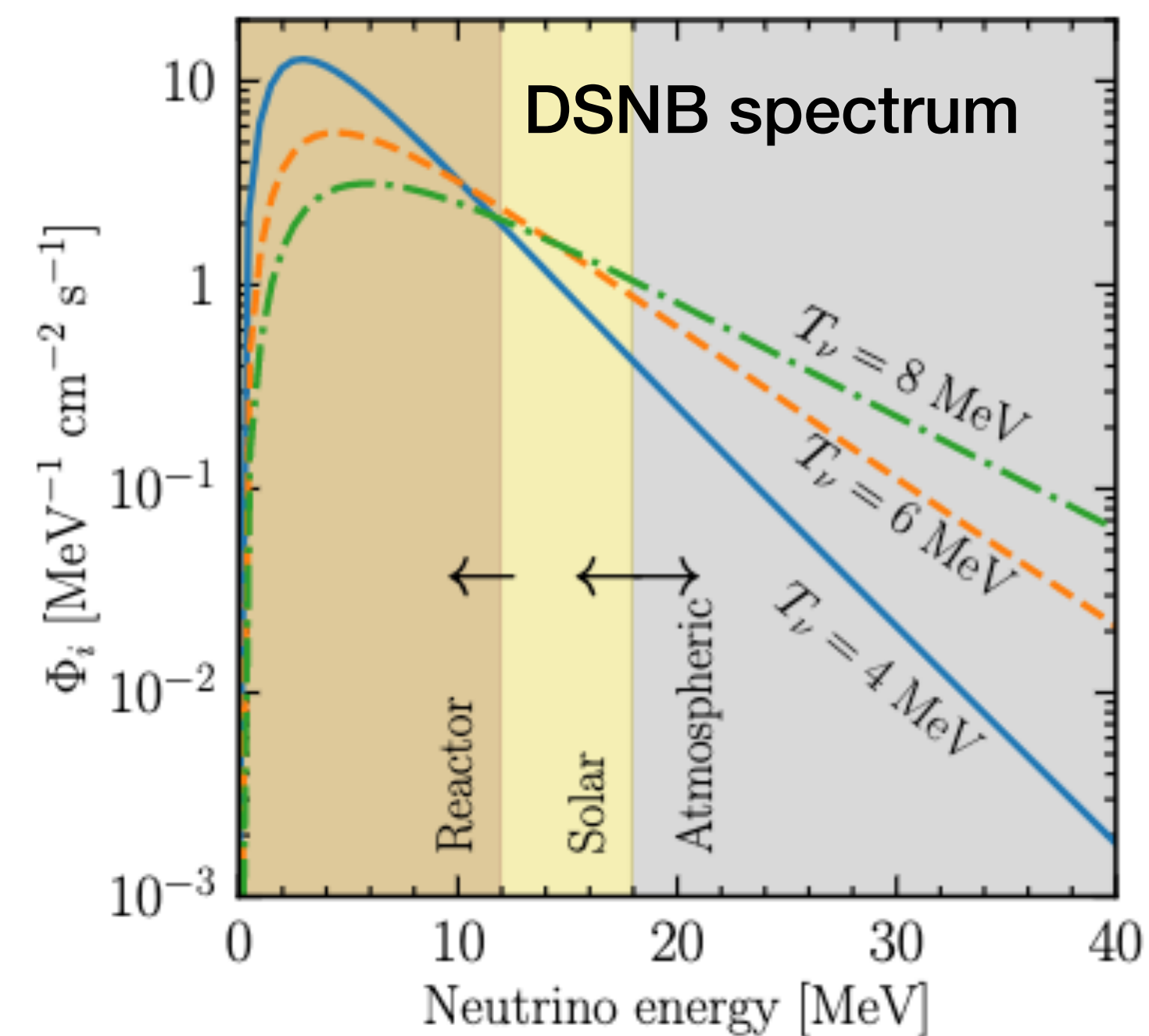
- Next phases :

- Go to wire/time check plot
- Increase statistics by using the full preproduction
- Evaluate efficiency of muon decay spot selection

- **Low energy physics context :**

- Energy range : [0 , ~20 MeV]
- Solar, SuperNovae,

Diffuse SuperNova Background neutrinos



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]

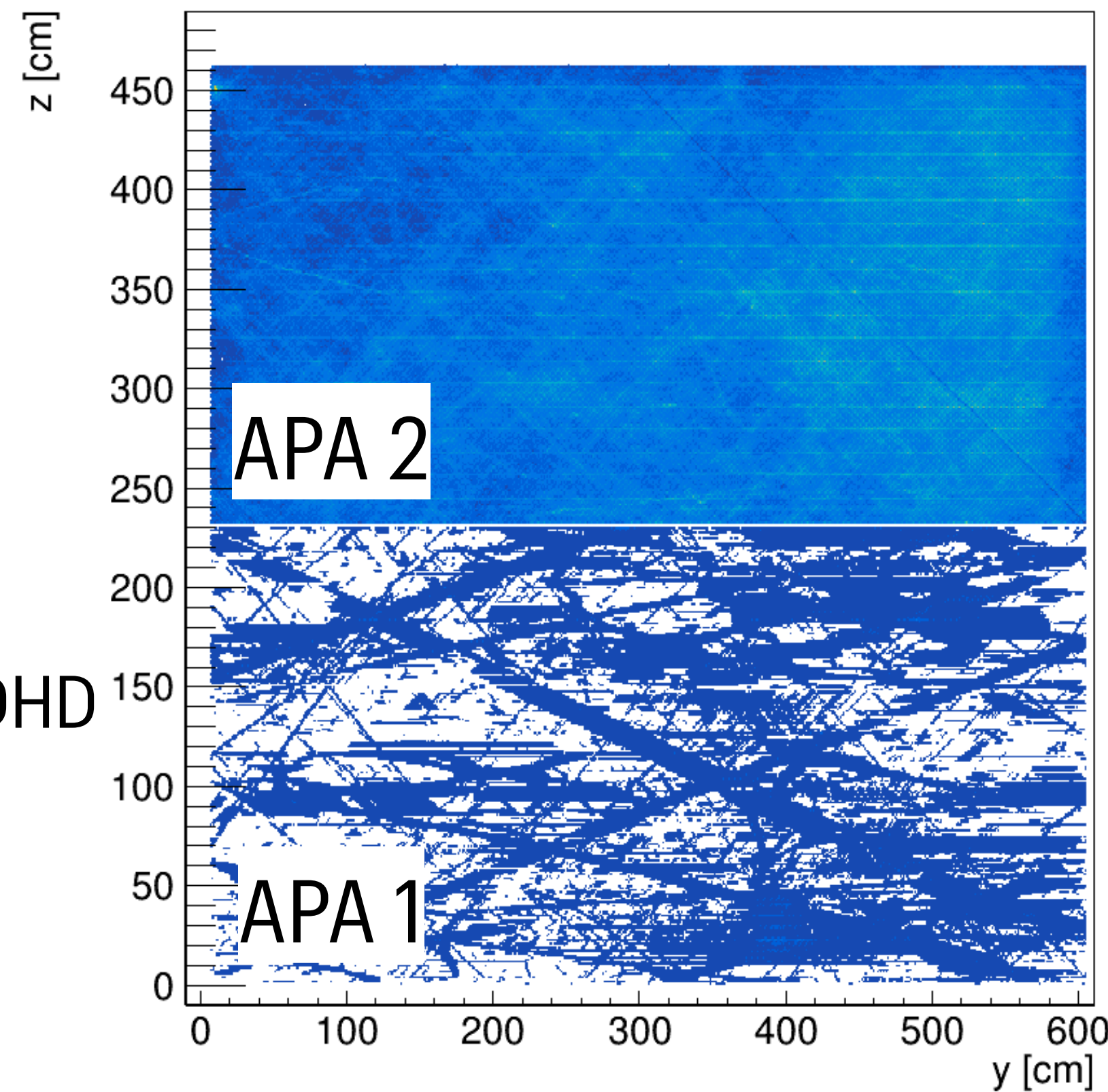
arXiv:2207.09632 [astro-ph.HE]

- **Low energy physics** context :
 - Energy range : [0 , ~20 MeV]
 - Solar, SuperNovae, Diffuse SuperNova Background neutrinos

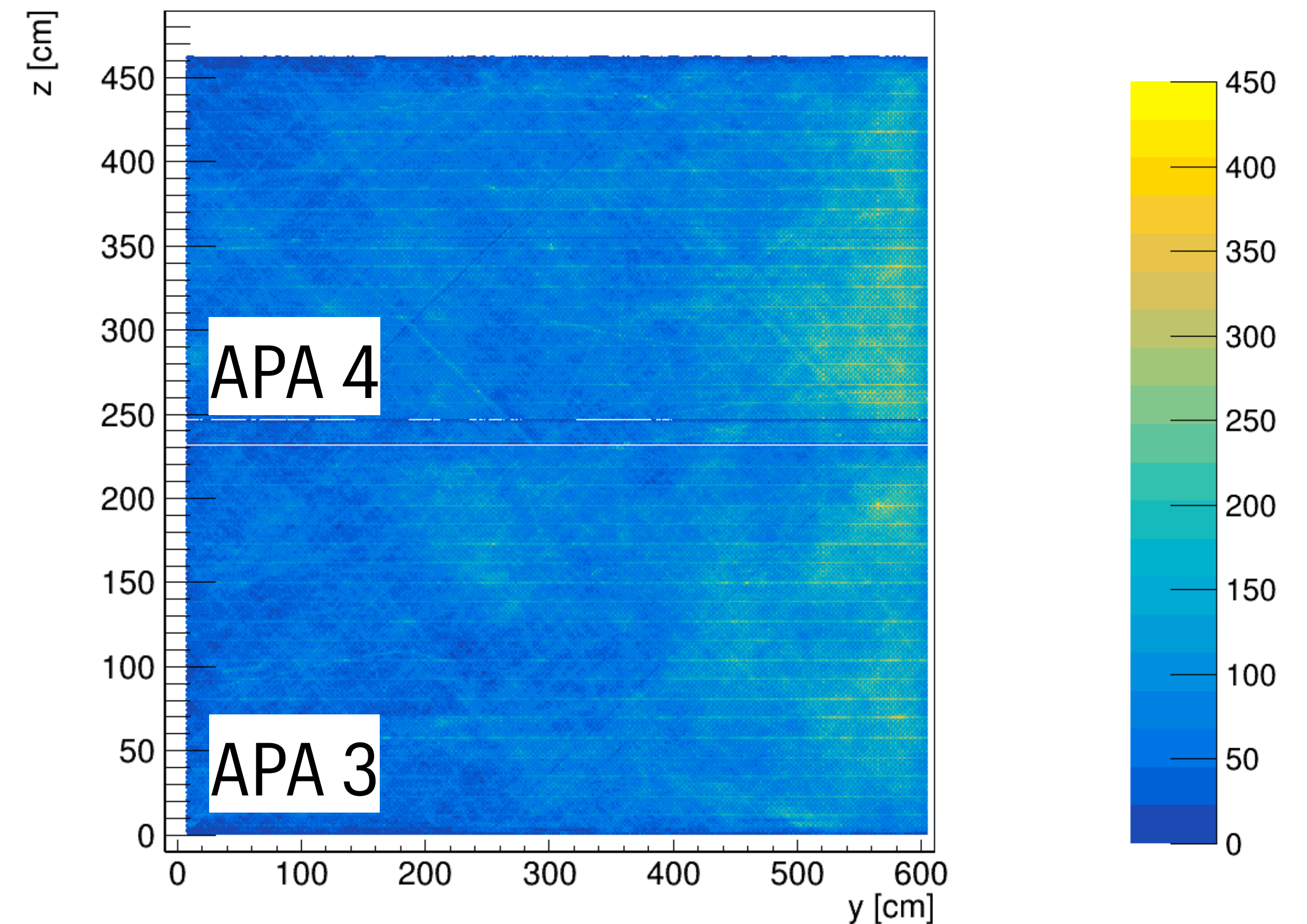
- Needs for :
 - **Calibration sources** :
 - Natural : **Ar39** (FD : ~ 10^7 decays/s PD : ~ 10^5 decays/s), **radiological**, Michel- e^-
 - Extern : Pulse Neutron Source (**PNS**)
 - The natural sources must be characterised as they are either a **background** (neutrino analysis) or give **information on the detector** (purity, space charge effect ...)

- LArSoft analysis/reconstruction module developed for 2 years ([github here](#))
- **First: reconstruction of the position** of hit with low charge $\lesssim 500$ [ADCxticks] ≈ 10 [MeV]
 - `pandora` and `reco3d` optimised for GeV track like events
 - **crossing point** of a collection wire with 1 or 2 induction wire in **time coincidence** (2 or 3 view coincidence)

- LArSoft analysis/reconstruction module developed for 2 years ([github here](#))
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100 events
Run 28850 PDHD

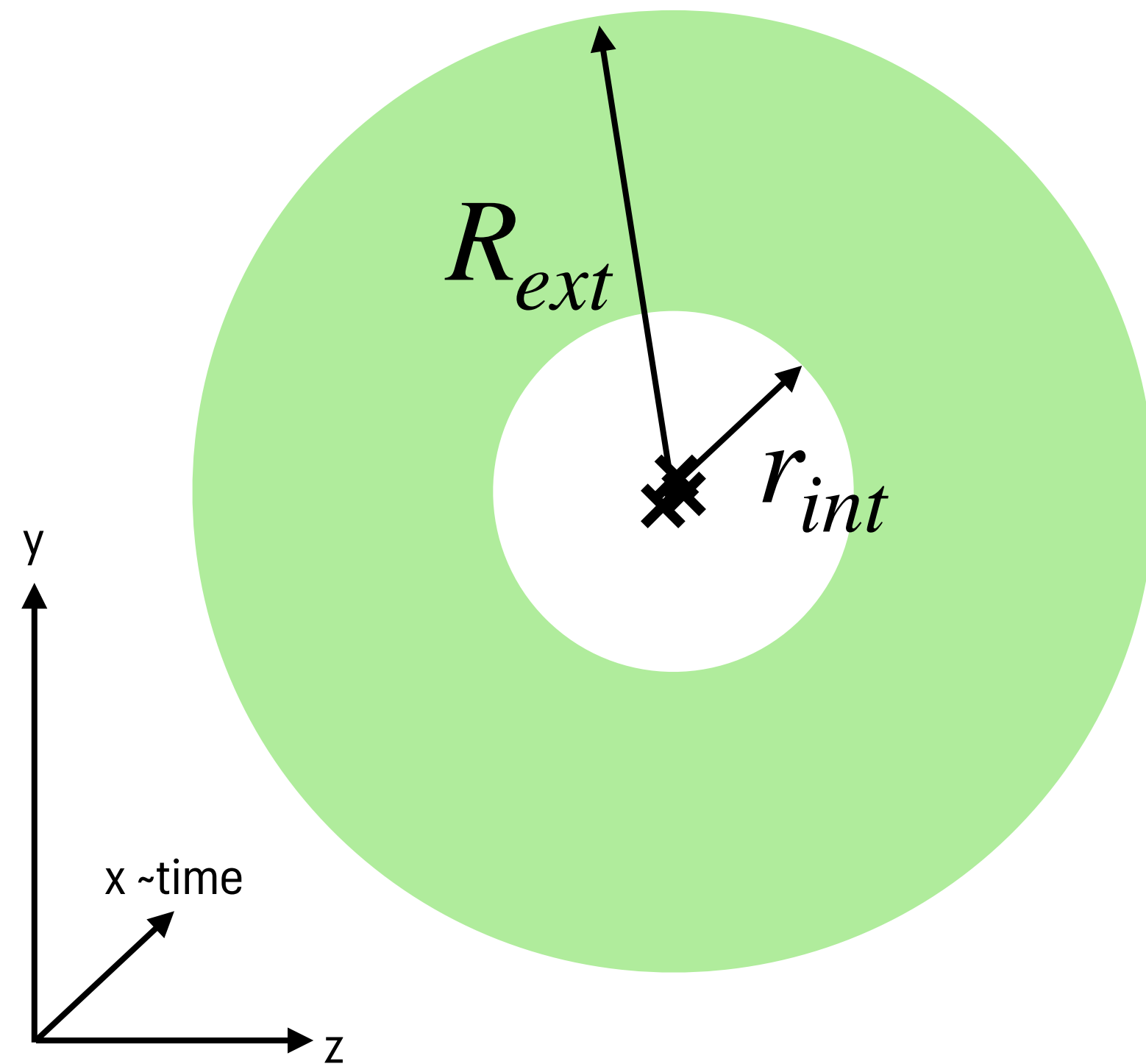


achieved precision on spatial reconstruction (test on MC) ≈ 0.5 cm \approx wire pitch

- **First:** reconstruction of the position of hit with low charge $\lesssim 500$ [ADCxticks] ≈ 10 [MeV]
- **Second:** the reconstructed space-points must be **isolated** and **localised**
 - **isolated** → important for **surface detectors** (cosmic contamination) : protoDUNE's
 - **localised** → Ar39 spread on up to 2 wires/channels
 - blip-like (PNS, higher energy radiologicals ...) spreads on few wires/channels

- **First:** reconstruction of the position of hit with low charge $\lesssim 500$ [ADCxticks] ≈ 10 [MeV]
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« Donut analysis »



$$R_{ext} > 10 \text{ cm}$$

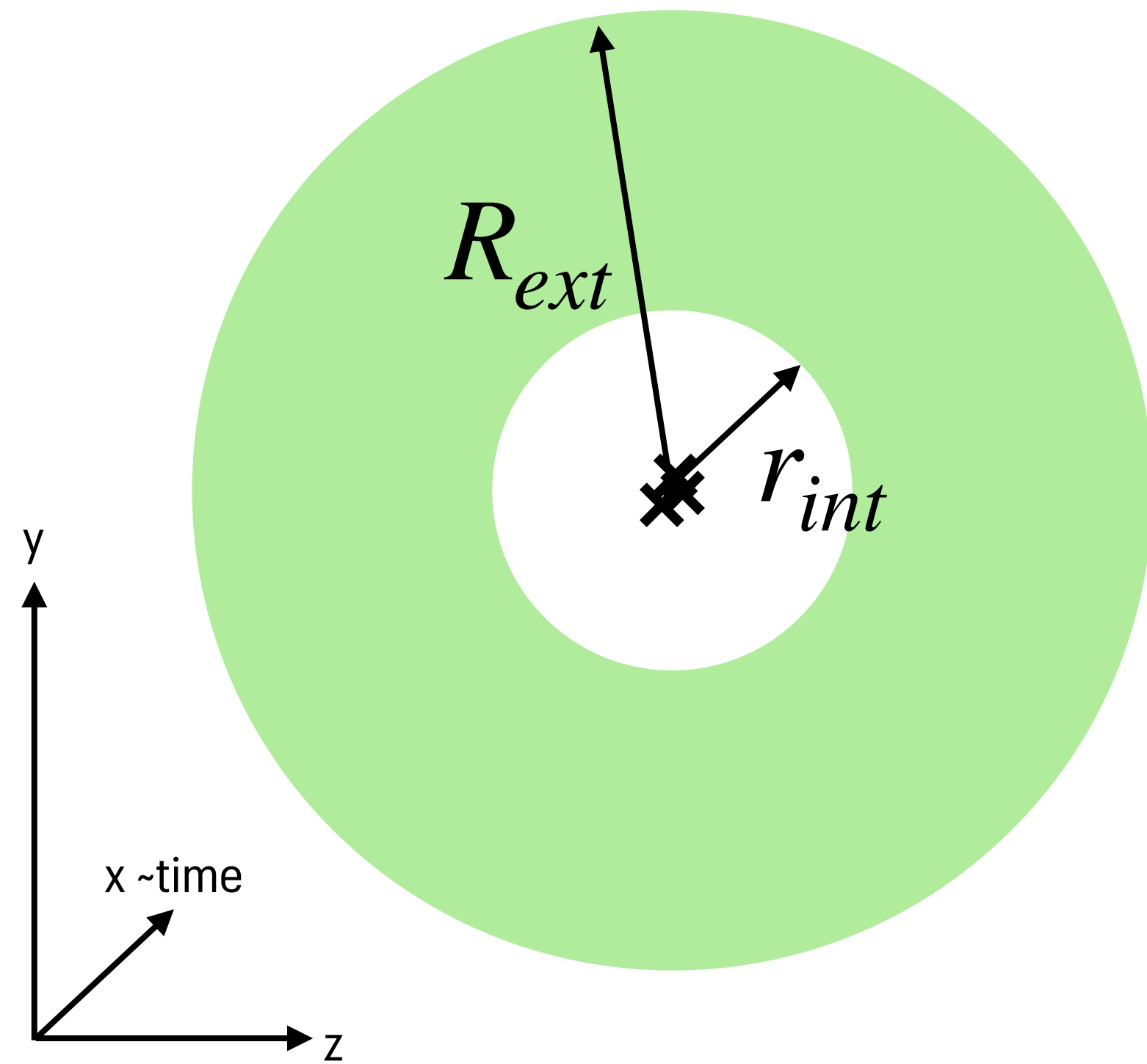
$$r_{int}^{39\text{Ar}} = 0.5 \text{ cm}$$

$$r_{int}^{\text{PNS}} = 4 \text{ cm}$$

z [cm]

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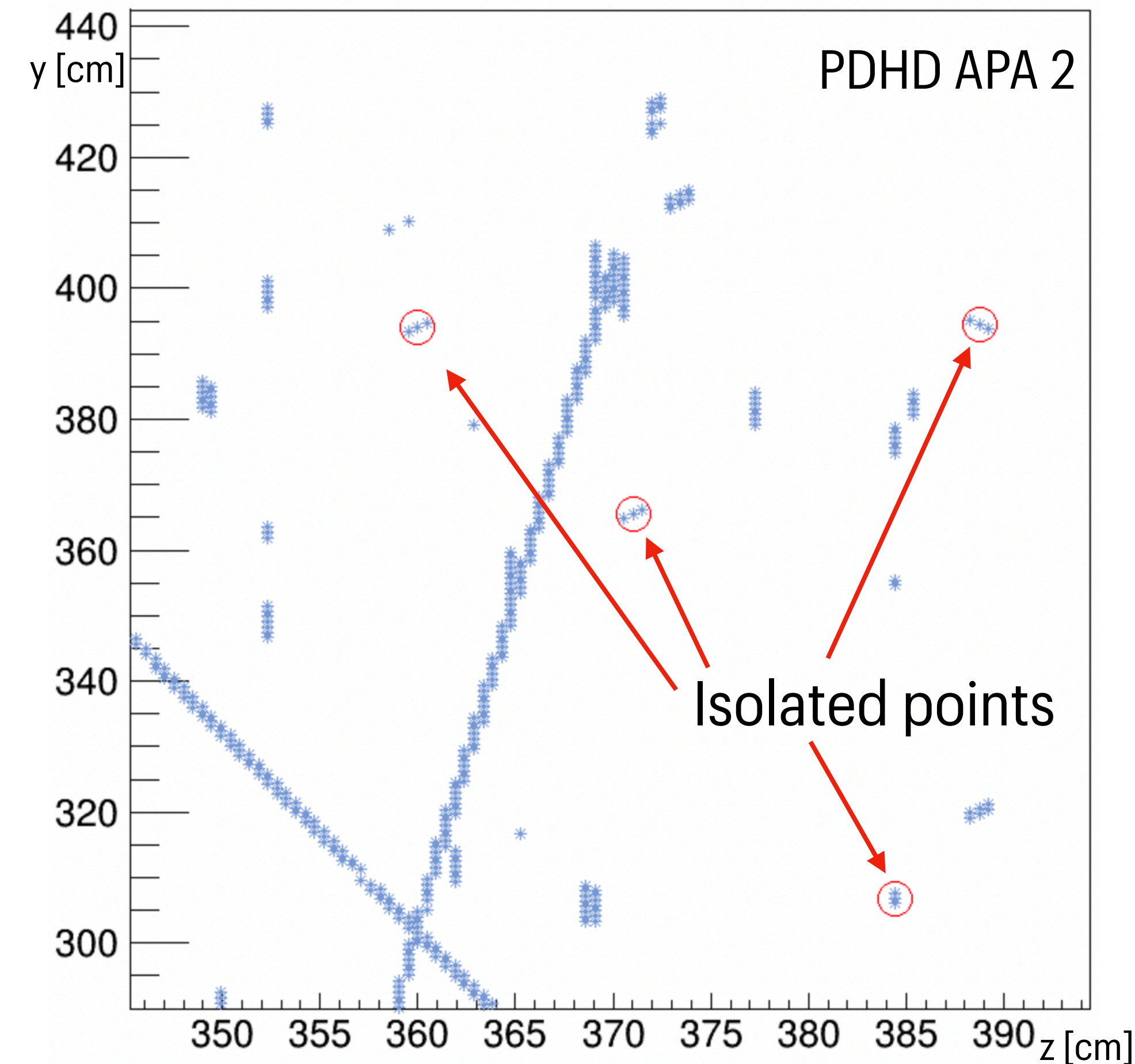
« Donut analysis »



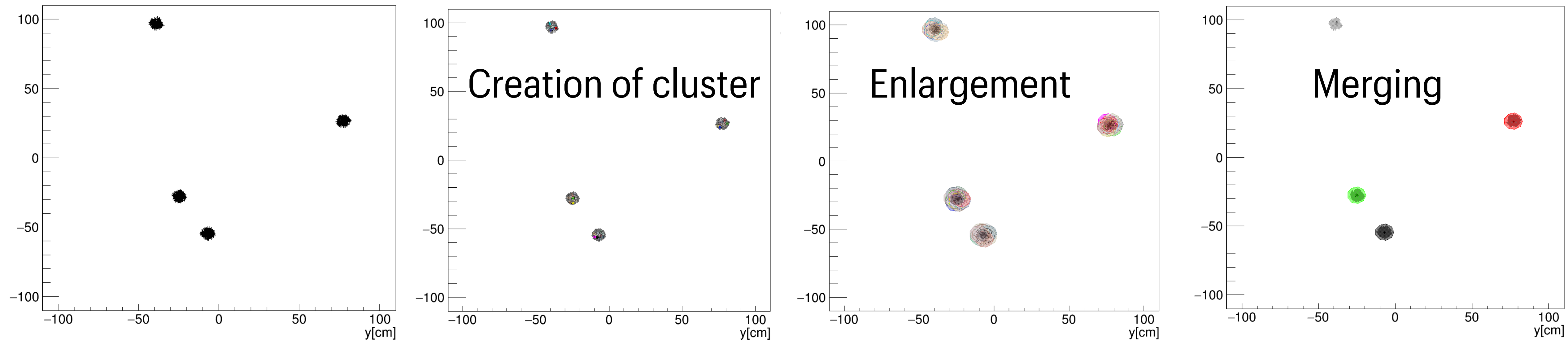
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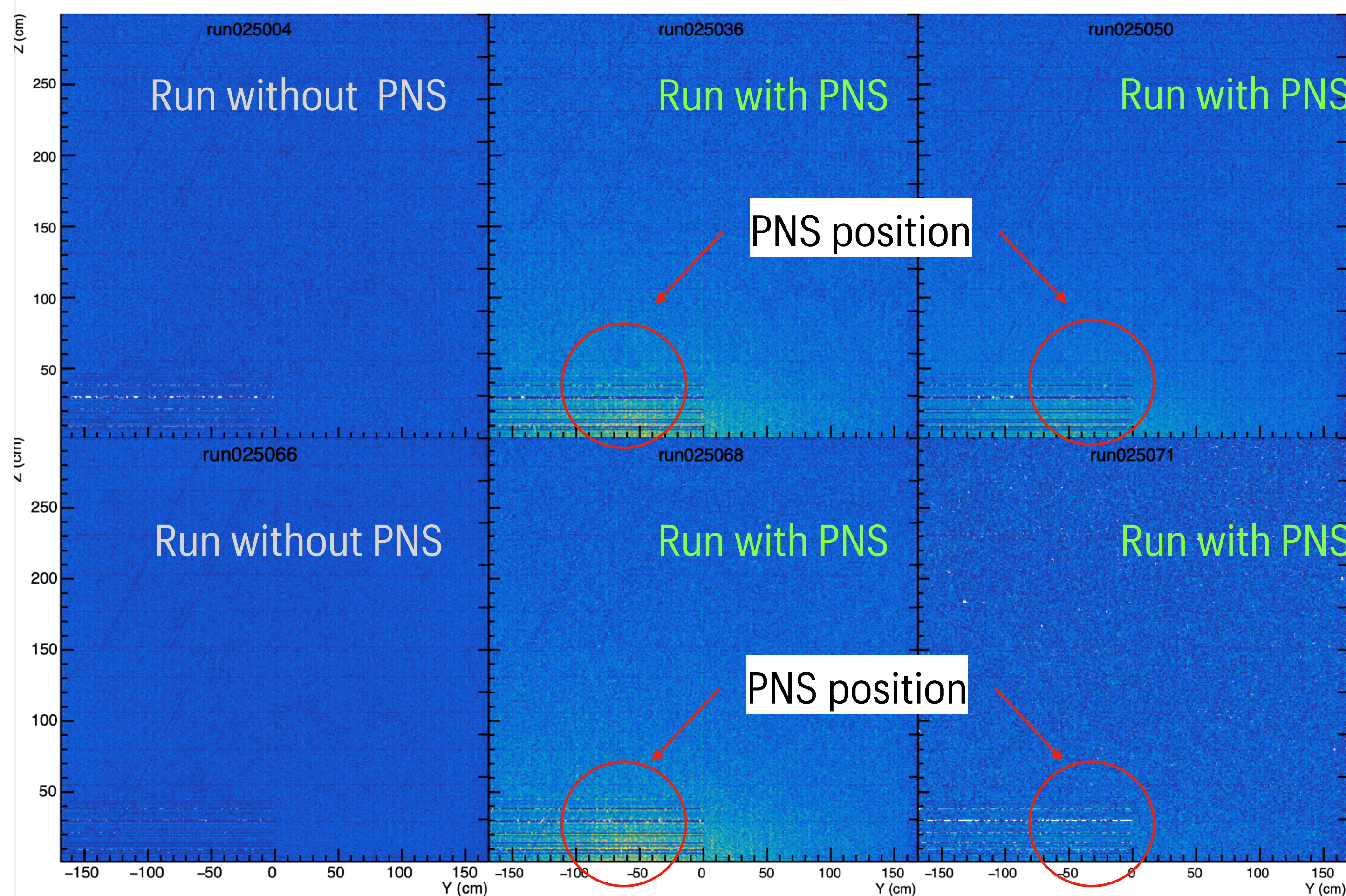


- **First:** reconstruction of the position of hit with low charge $\lesssim 500$ [ADCxticks] ≈ 10 [MeV]
- **Second:** the reconstructed space-points must be **isolated** and **localised**
- **Third:** Clustering of this space-points (lloyd-kpp algorithm) (not going to develop here if interested go [see](#))



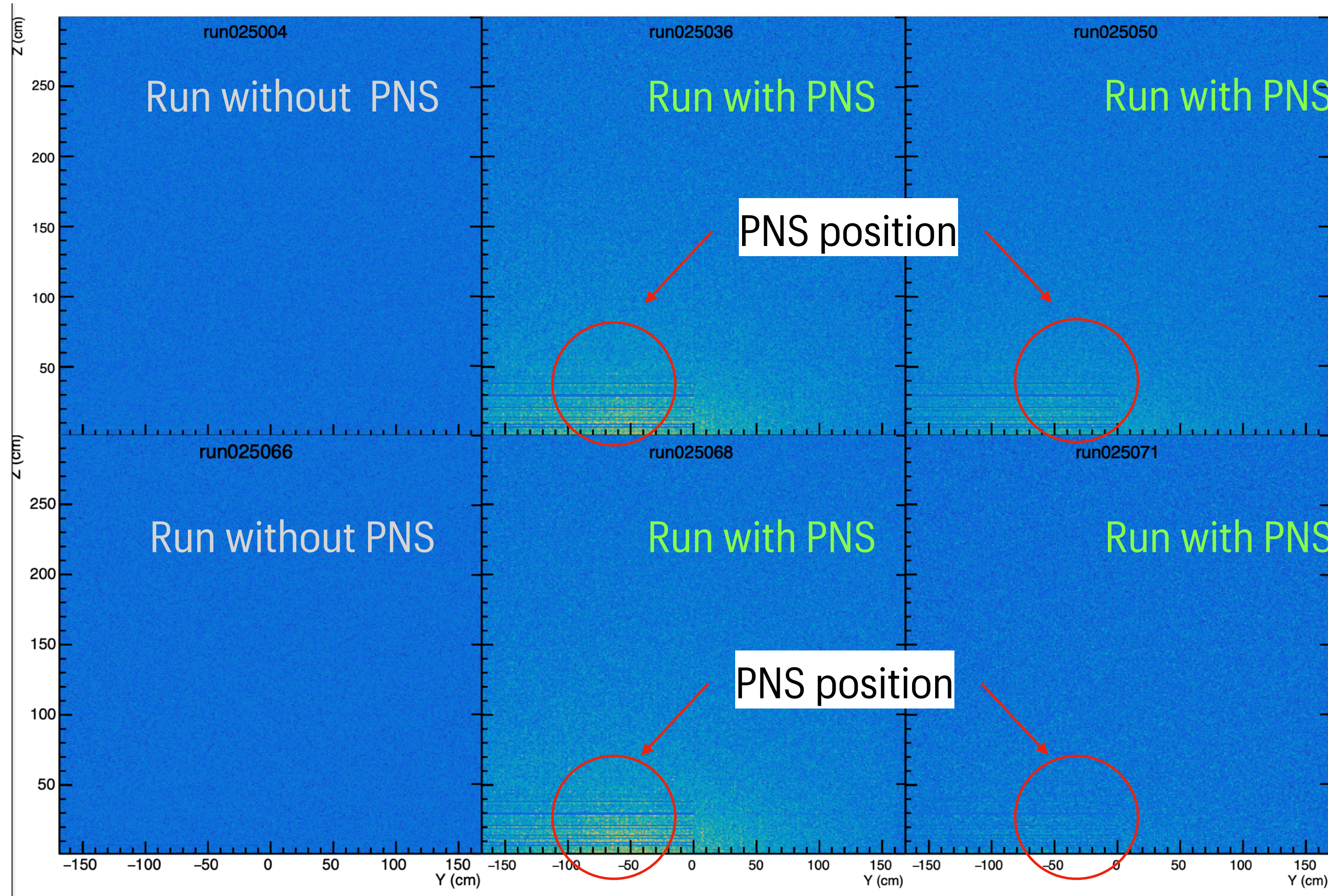
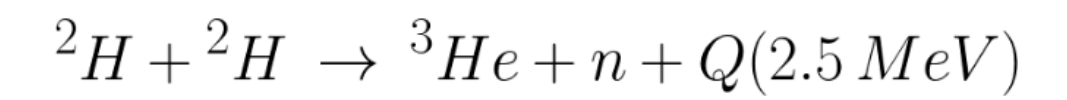
Module has been **optimised** (voxelisation search...) and is ready for large production

- Monoenergetic neutrons source placed on the side of the ColdBox-VD ${}^2\text{H} + {}^2\text{H} \rightarrow {}^3\text{He} + n + Q(2.5 \text{ MeV})$



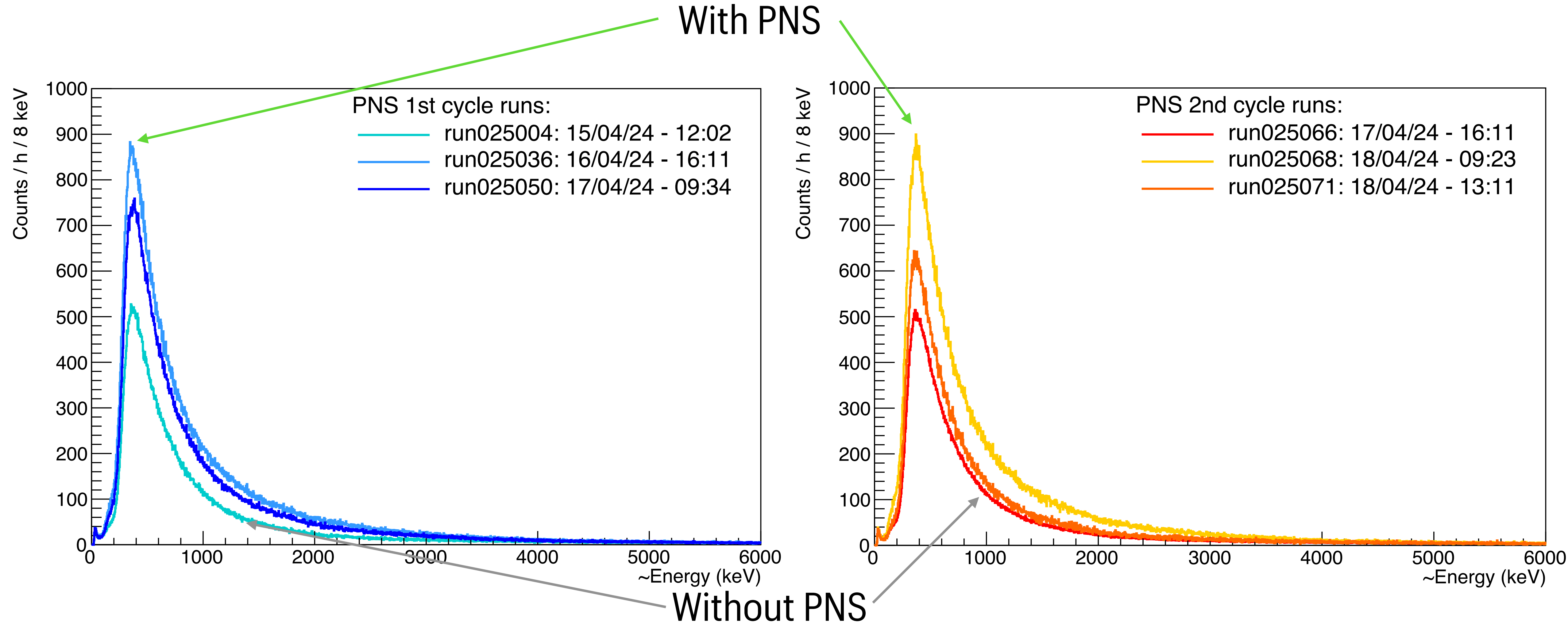
Clear identification of PNS position

- Difference between run with and without PNS



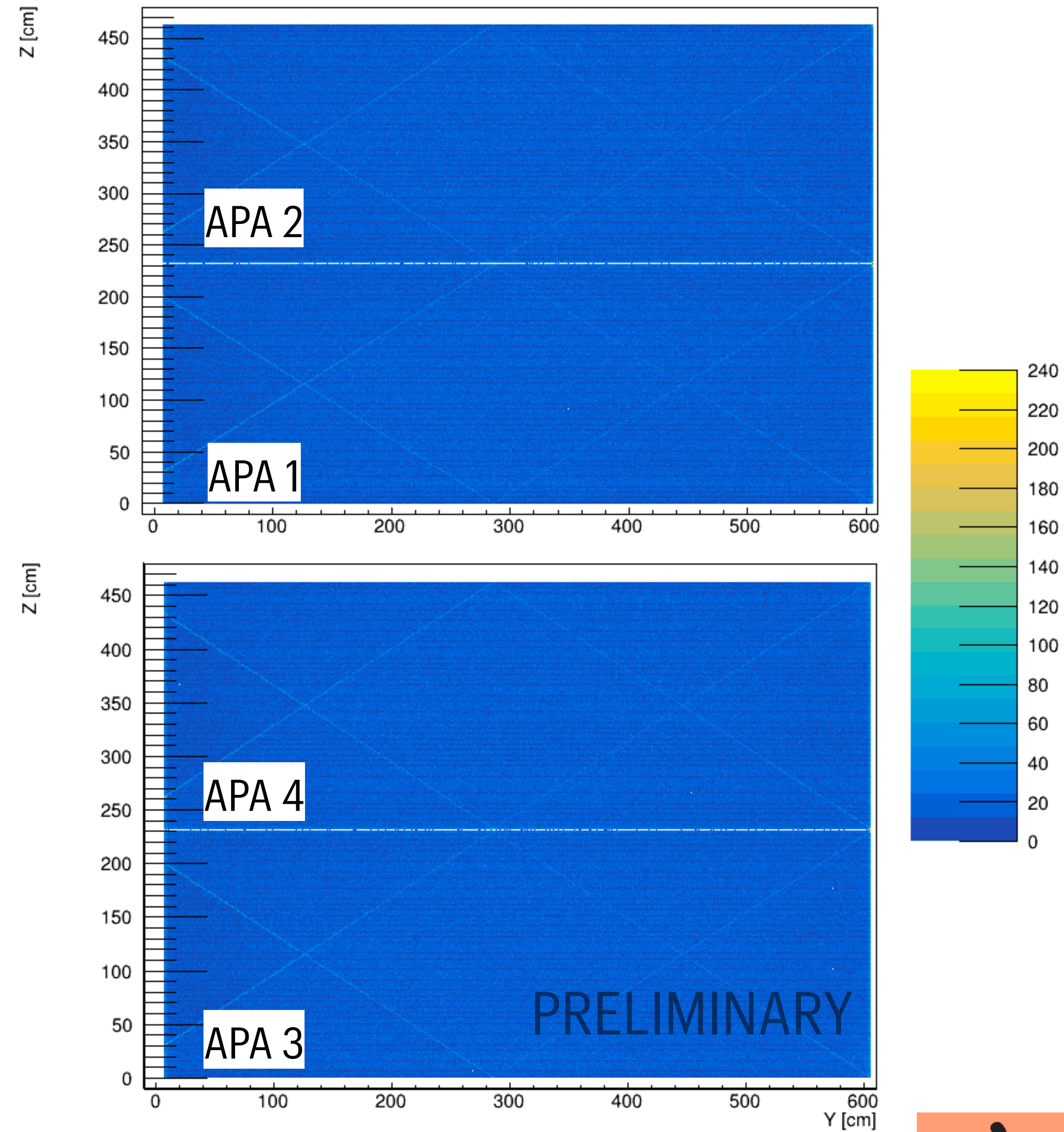
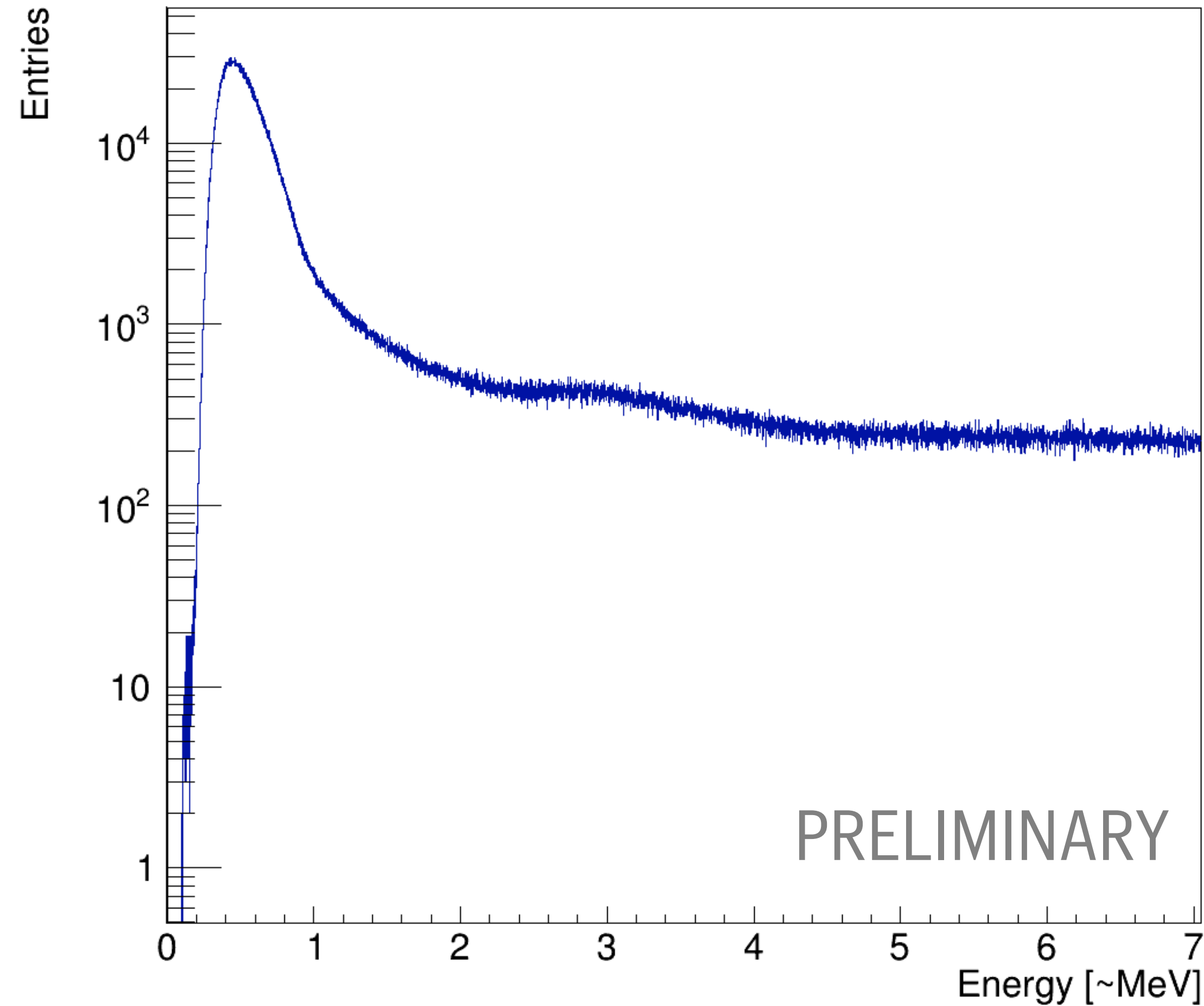
Clear identification of PNS position

- Very similar behaviour from 1 cycle to another if in the same configuration

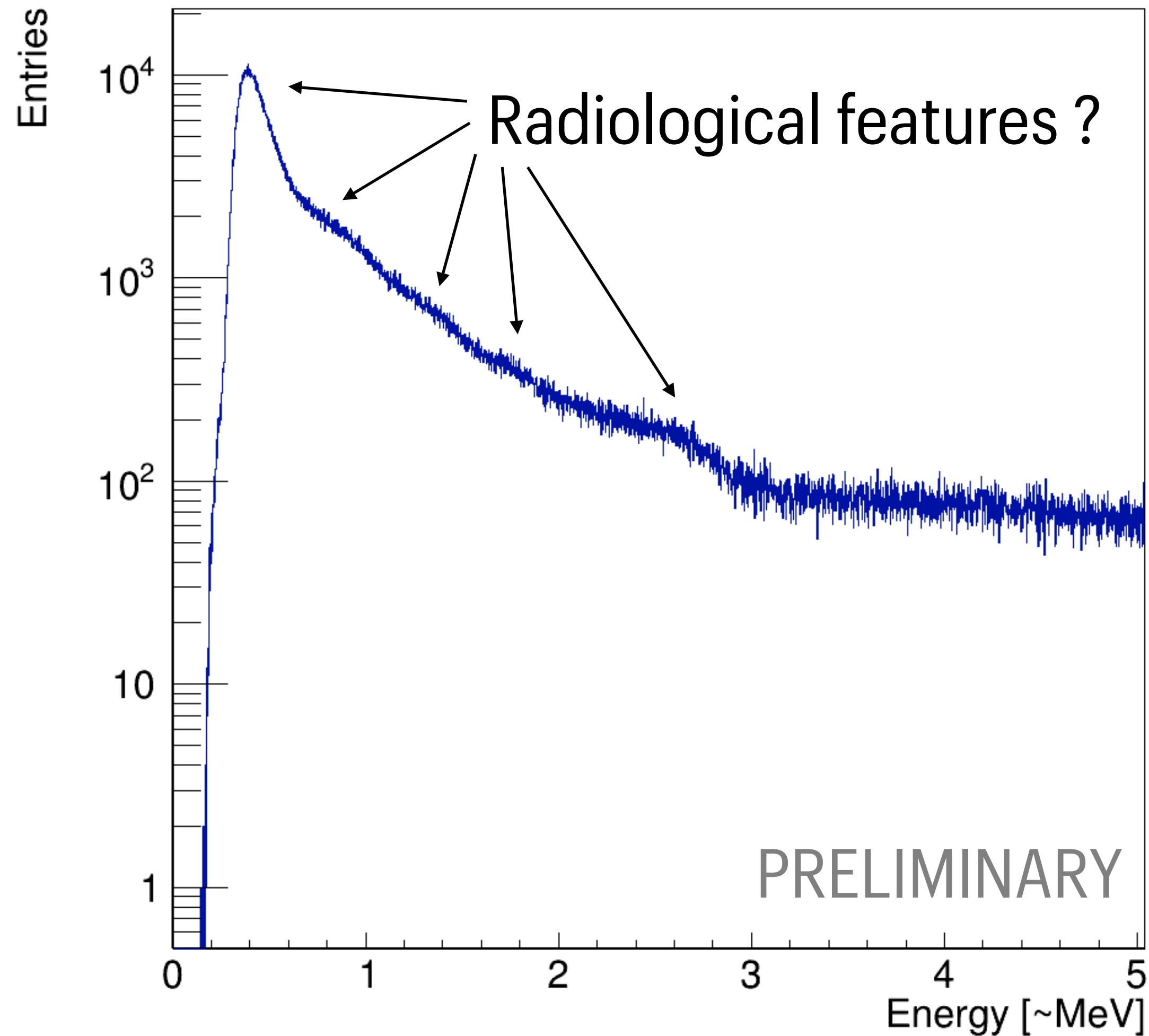


Starting discussion with PNS team for interpretation

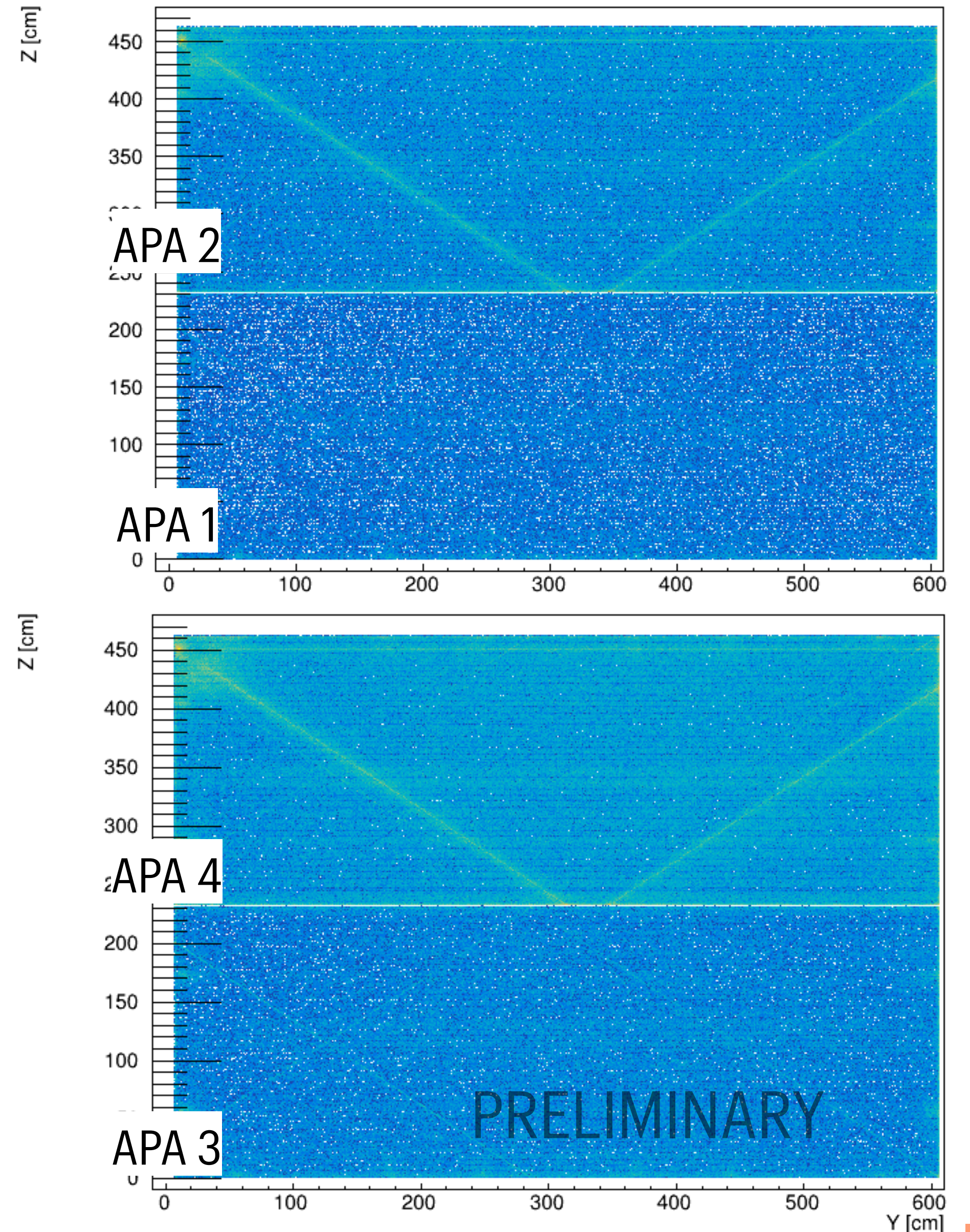
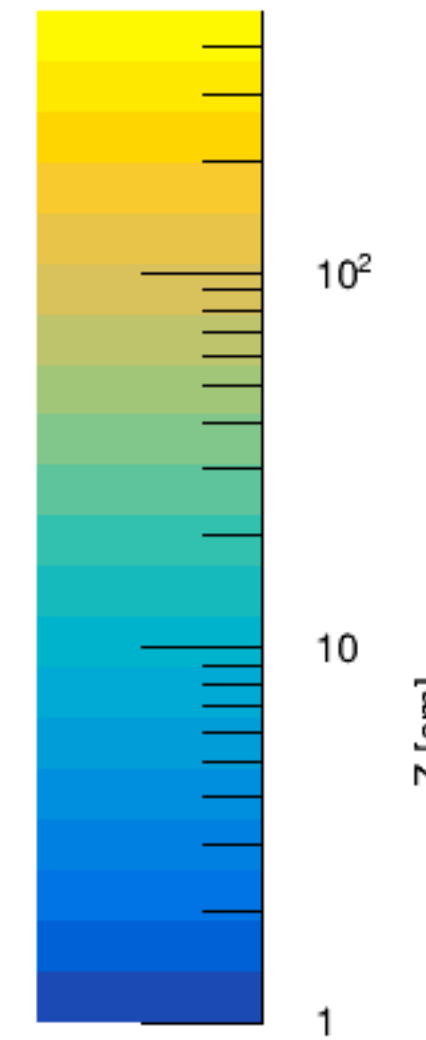
- **Prod4a** SCE OFF : 18926 events processed
- Beam (1 GeV) + cosmics + Ar39 + Kr85 + Rn222



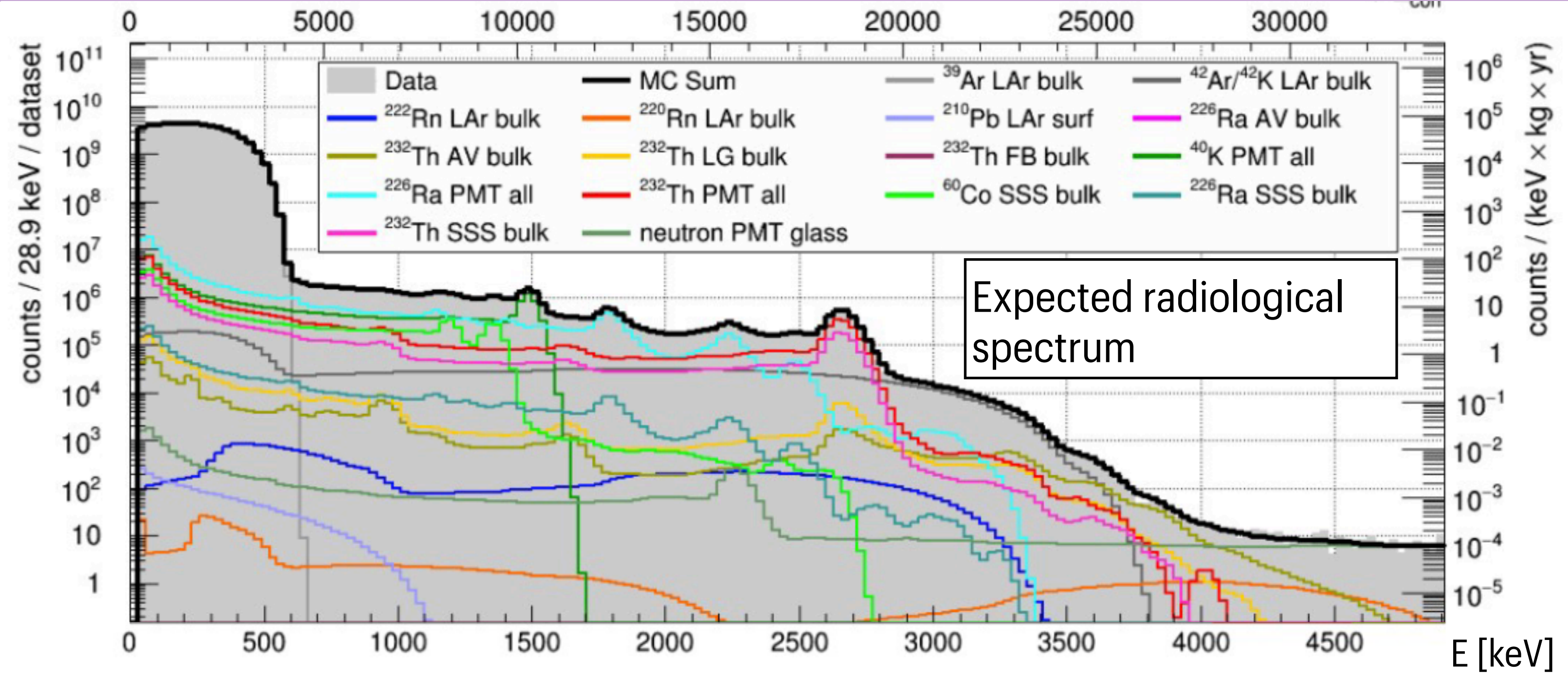
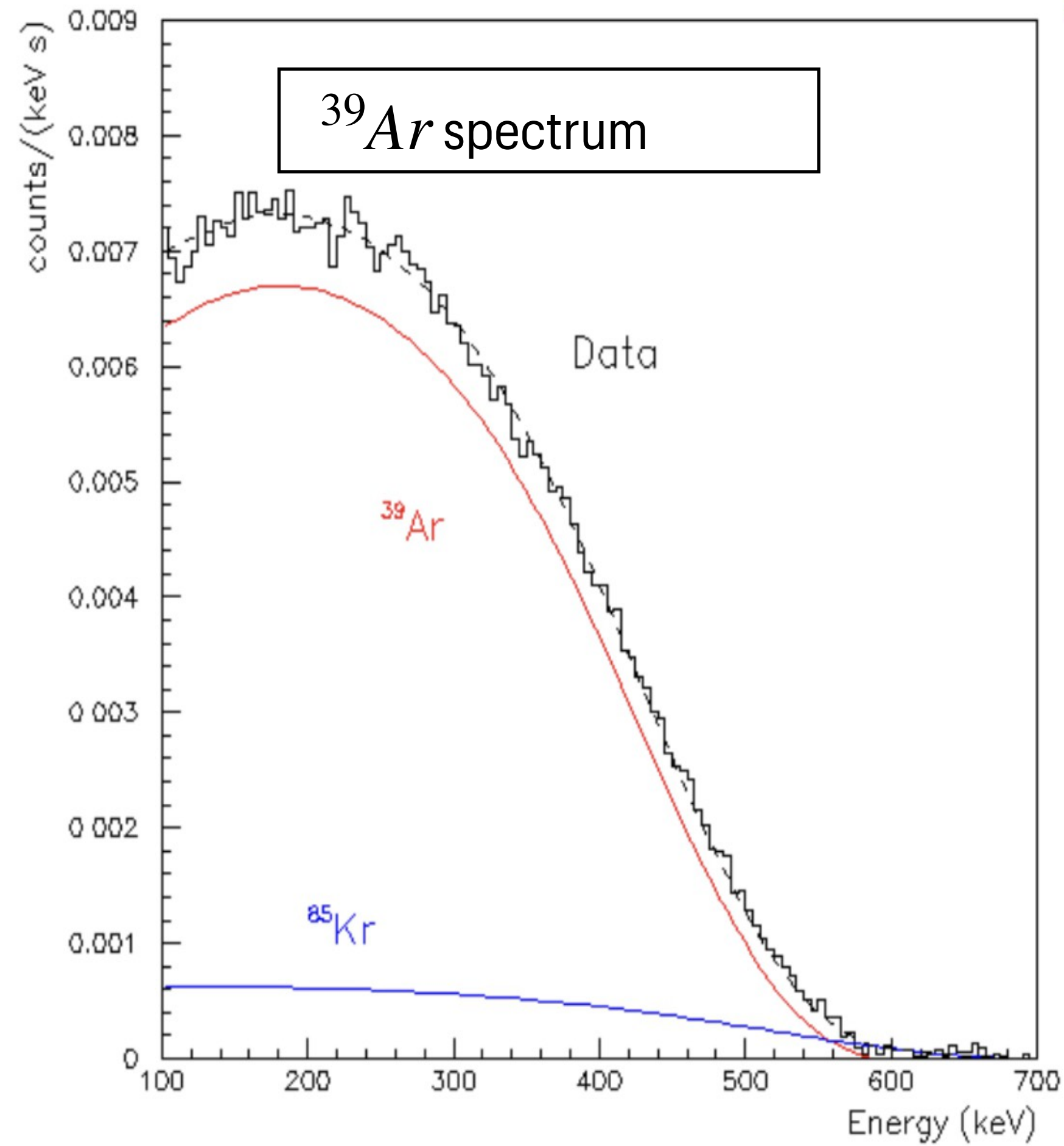
- **Run 28850** (Only cosmics) : 19530 events processed



Shape agreement with the simulation



- Lots of calibration activities at IJCLab (electromagnetic shower, michel electron, low energy but also light matching in CBVD)
- Module ready for large production phase and CAF-maker
- First analysis at low energy on **PDHD data** and comparison with MC
- Analysis in progress on PNS in ColdBox → perfect physic case to understand better the module
- Many tools developed to be ready when PDVD data taking starts



Background measurement with DEAP-3600 (3.3 tonne LAr dark matter detector at SNOLAB)

- Run 28850 : 19530 events processed

