

DUNE-IN2P3 workshop

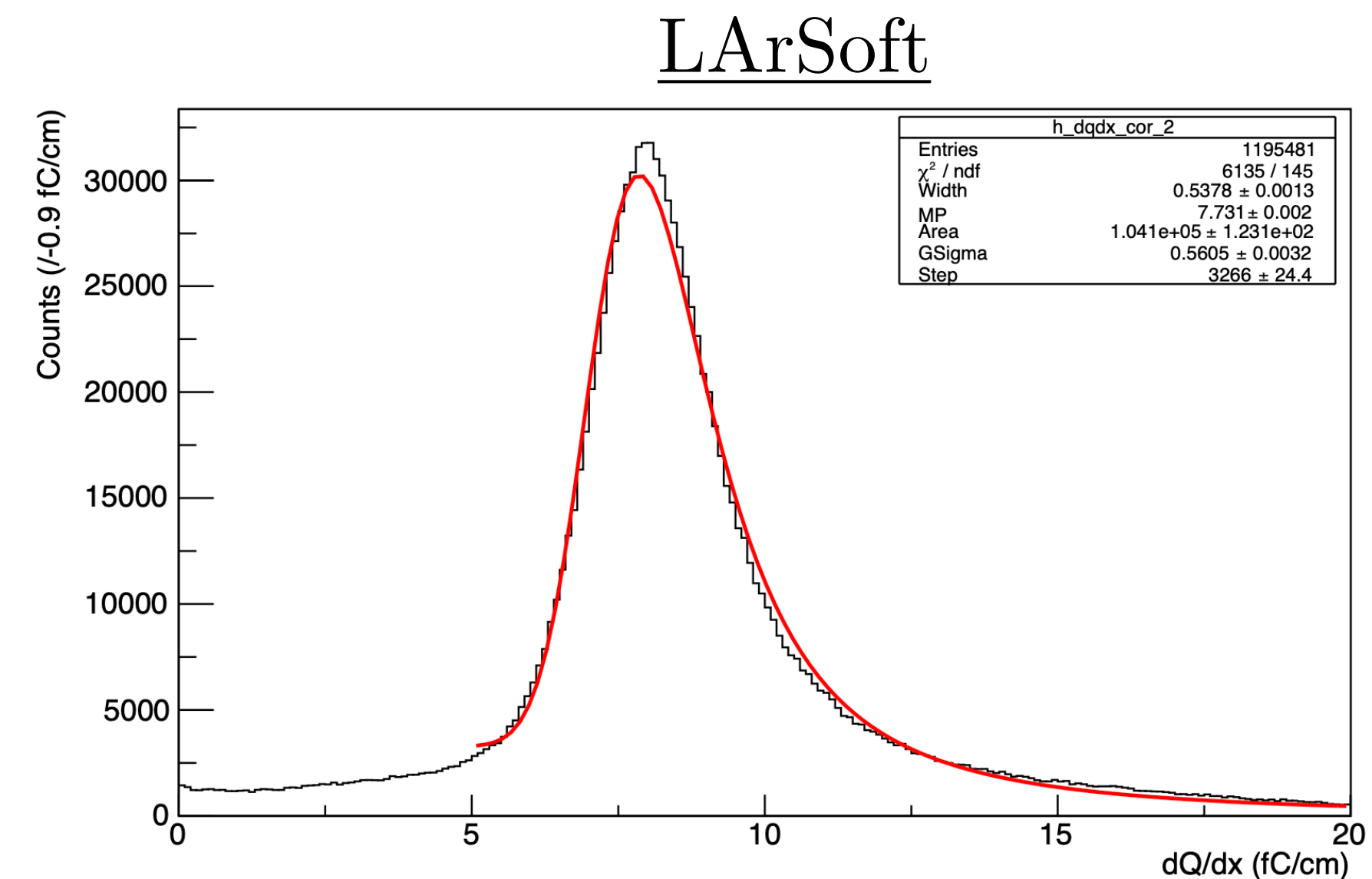
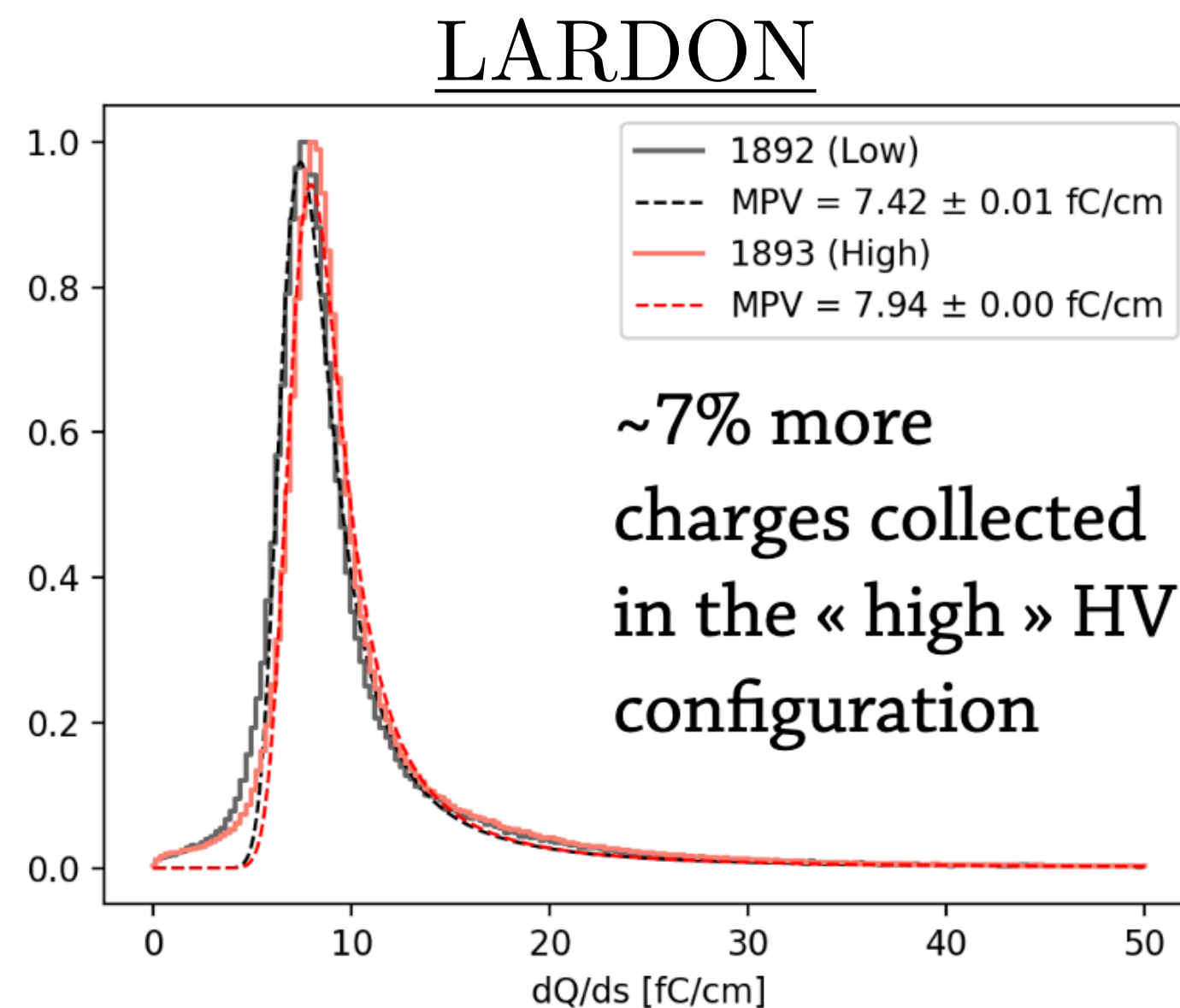
June 5, 2024

# Calorimetry in the coldbox-VD with LArSoft

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# Analysis

- **Look at calorimetry information of going-through muons in the coldbox-VD (CB-VD):**
  - Performed by LARDON (by Laura Zambelli)
  - Checked with LArSoft with hand-written calorimetry module (by Yoann Kermaidic)
  - This work: reproducing with LArSoft GnocchiCalorimetry module



# Inputs

## ○ Data

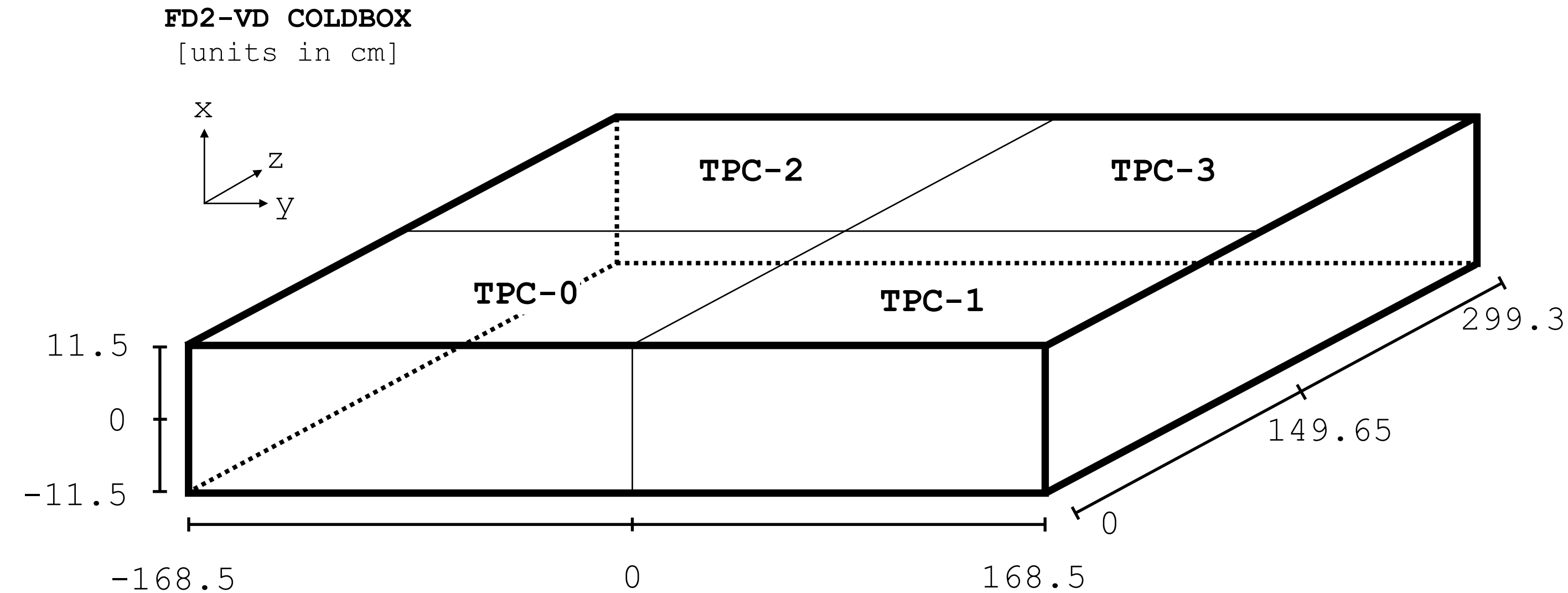
- Using run 1727  
(recorded in October 2023)
- Cosmic ray tracks
- CRP3 installed

## ○ Reconstruction

- Reconstruction with DUNE software  
v09\_72\_00d00
- More info on the [wiki](#)

## ○ Event

- defined by  $t_{\square} = 4 \text{ ms}$  read-out window
- x-coordinate:  $x_c = t_c v_{drift}$   
with  $v_{drift} = 1.6 \text{ mm}/\mu\text{s}$



### ON DUNEGPVM:

#### ▶ INPUT:

```
xroot://fndca1.fnal.gov:1094/pnfs/fnal.gov/usr/dune/tape_backed/dunepro/vd-  
coldbox-top/full-reconstructed/2023/detector/test/  
VD_coldbox_CRP2_CRP3_2022/00/00/17/27/1727_100_a_cb_reco_67284240_0_2023-04-  
-11T124909Z.root
```

#### ▶ MODULE:

```
/exp/dune/app/users/lhaegel/larsoft/v09_82_02d01/srcs/protodunearna/  
protodunearna/verticaldrift/checks/ColdboxThroughGoingTracks_module.cc
```

# Event selection

- **Selection of through-going tracks**

- track starts inside of coldbox in  $y$  and  $z$
- track  $x$ -length is between  $[0.95 L_x, 1.0 L_x]$

- **Track with unexpected  $dQ/dX$  ?**

- Reject track with  $dQ/dX < 0 e^-/cm$  for some hits  $\rightarrow$  22 tracks rejected
- Reject track with  $dQ/dX > 10^7 e^-/cm$  for some hits  $\rightarrow$  4 tracks rejected
- Reject track with  $dQ/dX = NaN$  for some hits  $\rightarrow$  2 tracks rejected

- **Track with unexpected residual range ?**

- Reject track with  $range < 0 cm$  for some hits  $\rightarrow$  5 tracks rejected
- Reject track with  $range > 450 cm$  for some hits  $\rightarrow$  4 tracks rejected
- Reject track with  $range = NaN$  for some hits  $\rightarrow$  0 tracks rejected

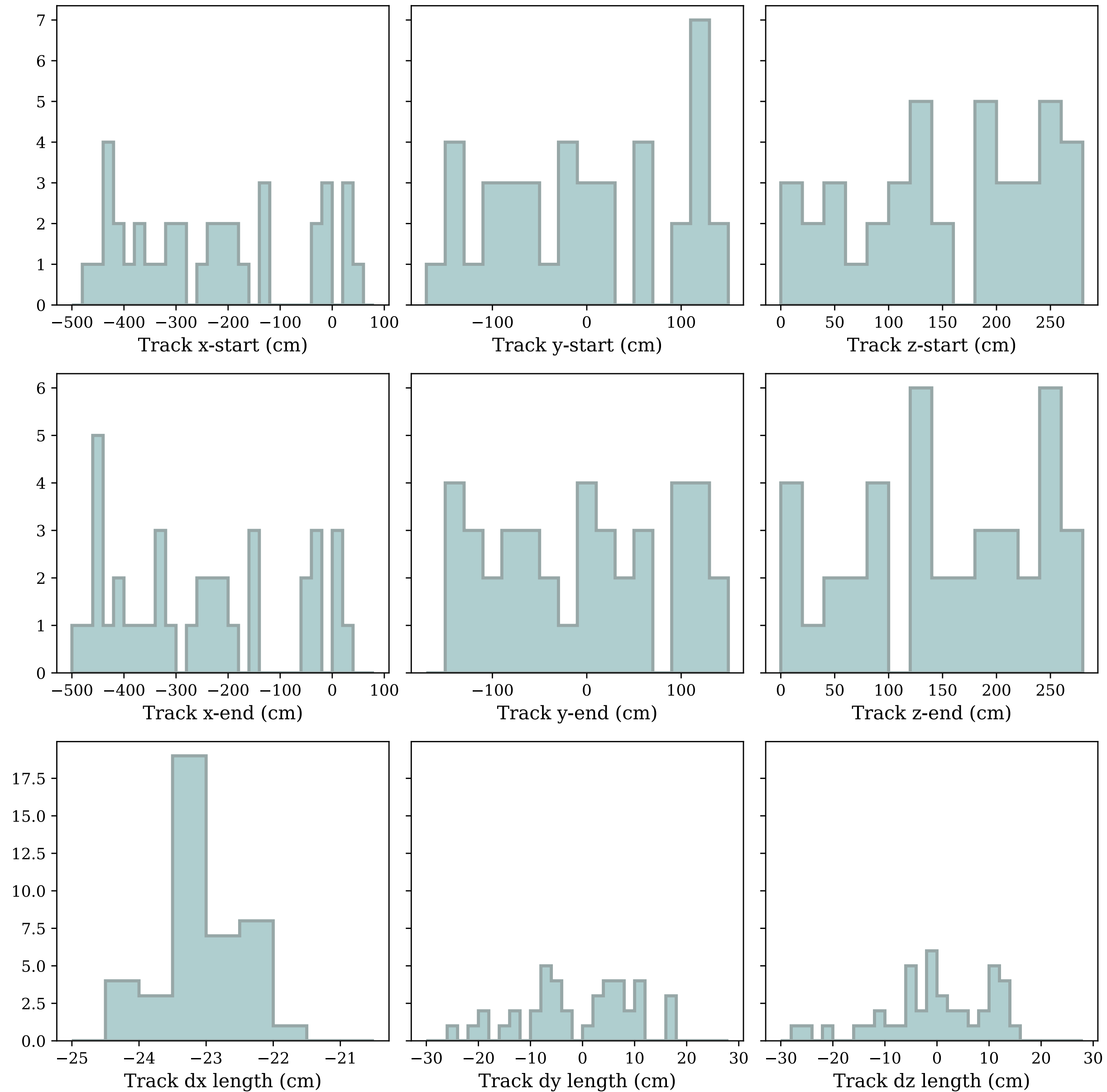
- **Calorimetric hits outside start/end of track ?  $\rightarrow$  0 track rejected**

63 through-going tracks  
selected from 25 events

26 tracks pass quality  
cuts

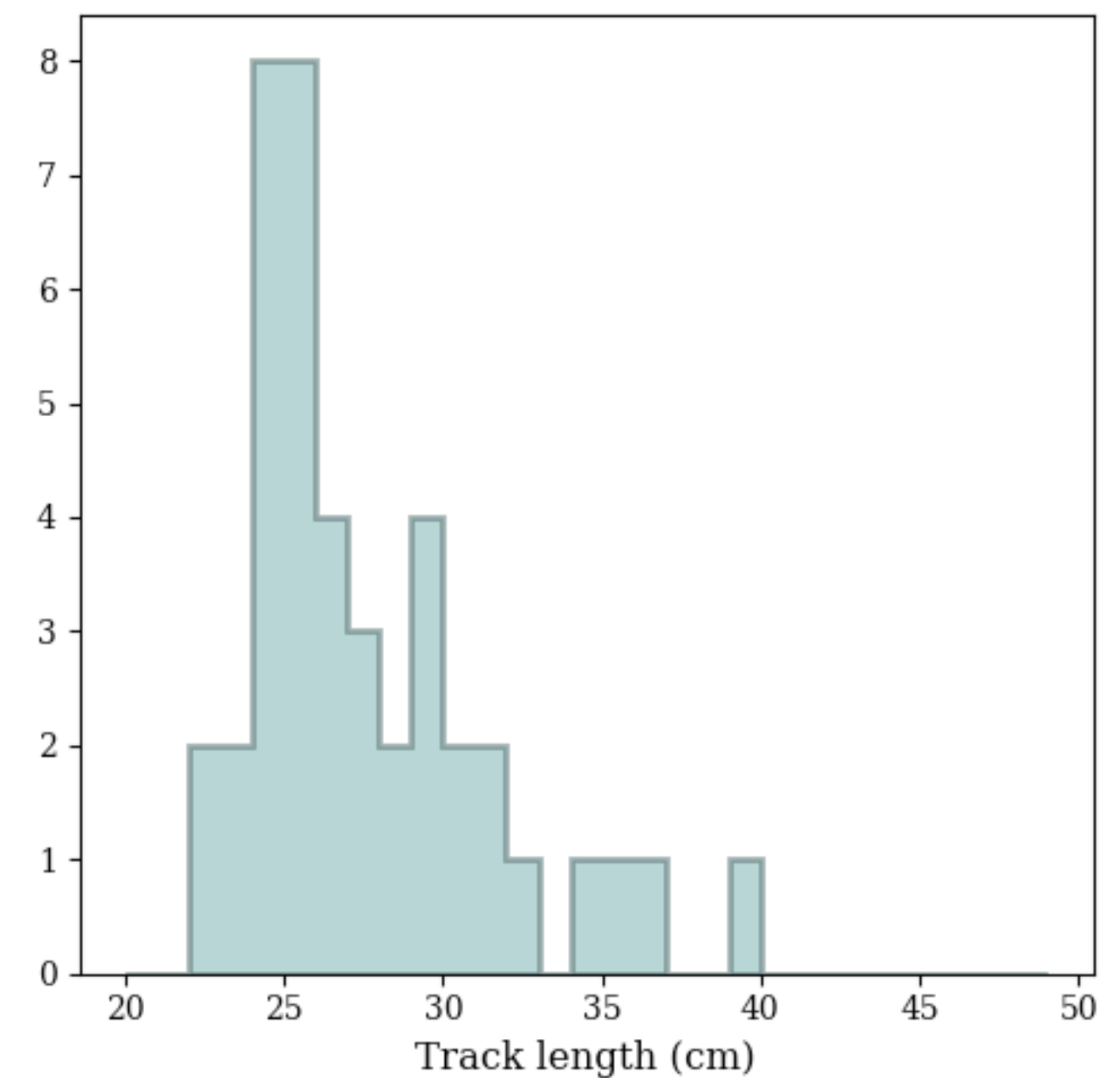
Reconstruction failures  
to investigate?

# Selected tracks: spatial distribution



## ○ Track distribution

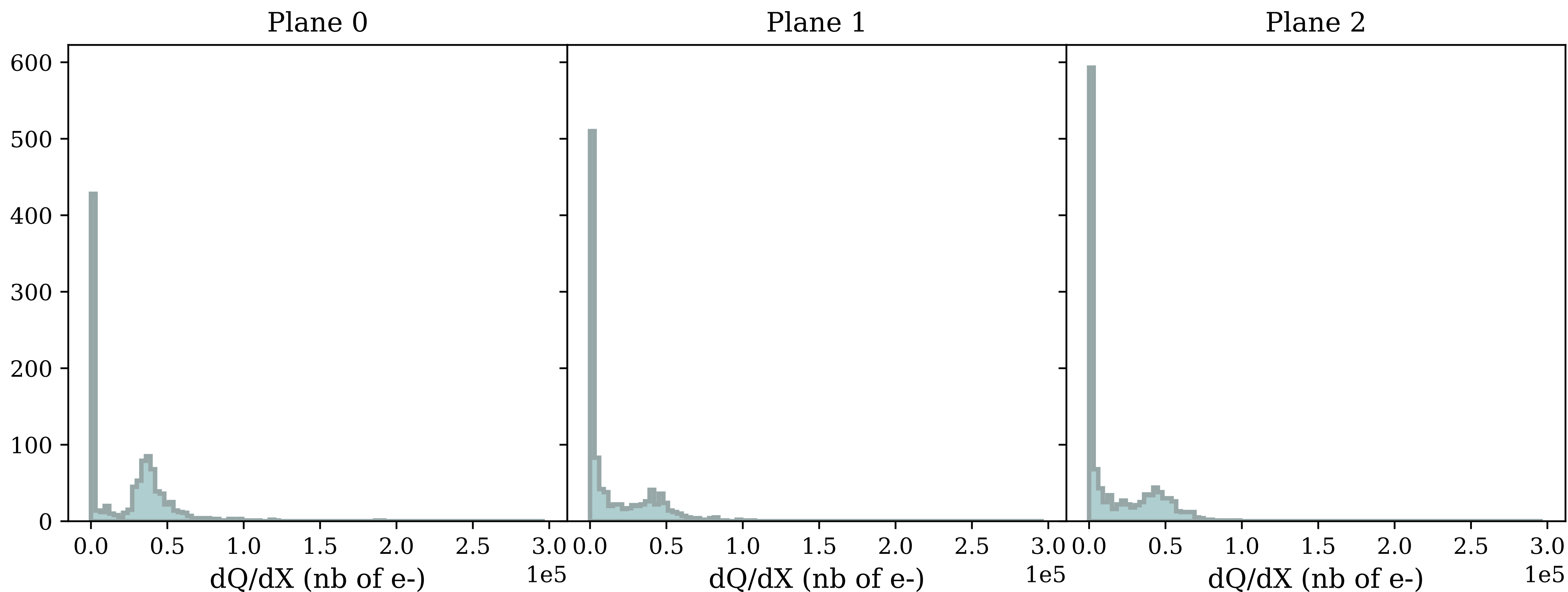
- Spatial distribution homogenous in the coldbox



# Selected tracks: $dQ/dx$

- **Calorimetry information**

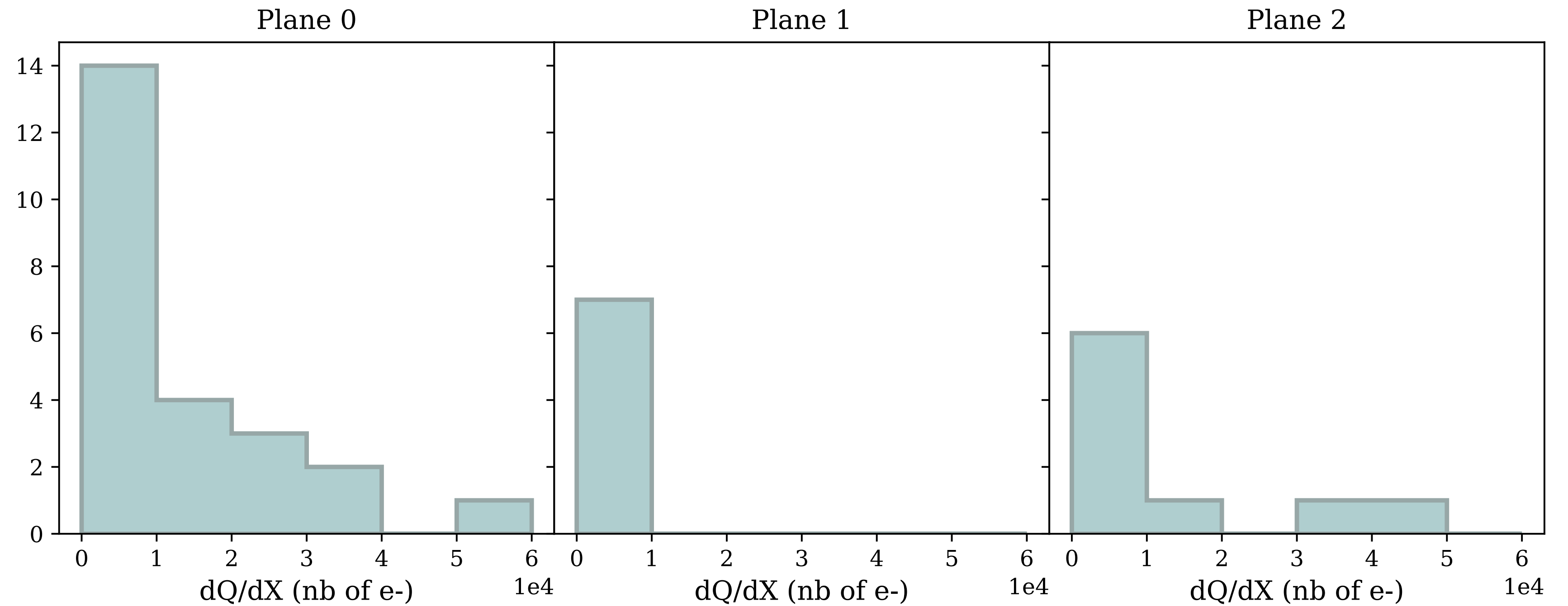
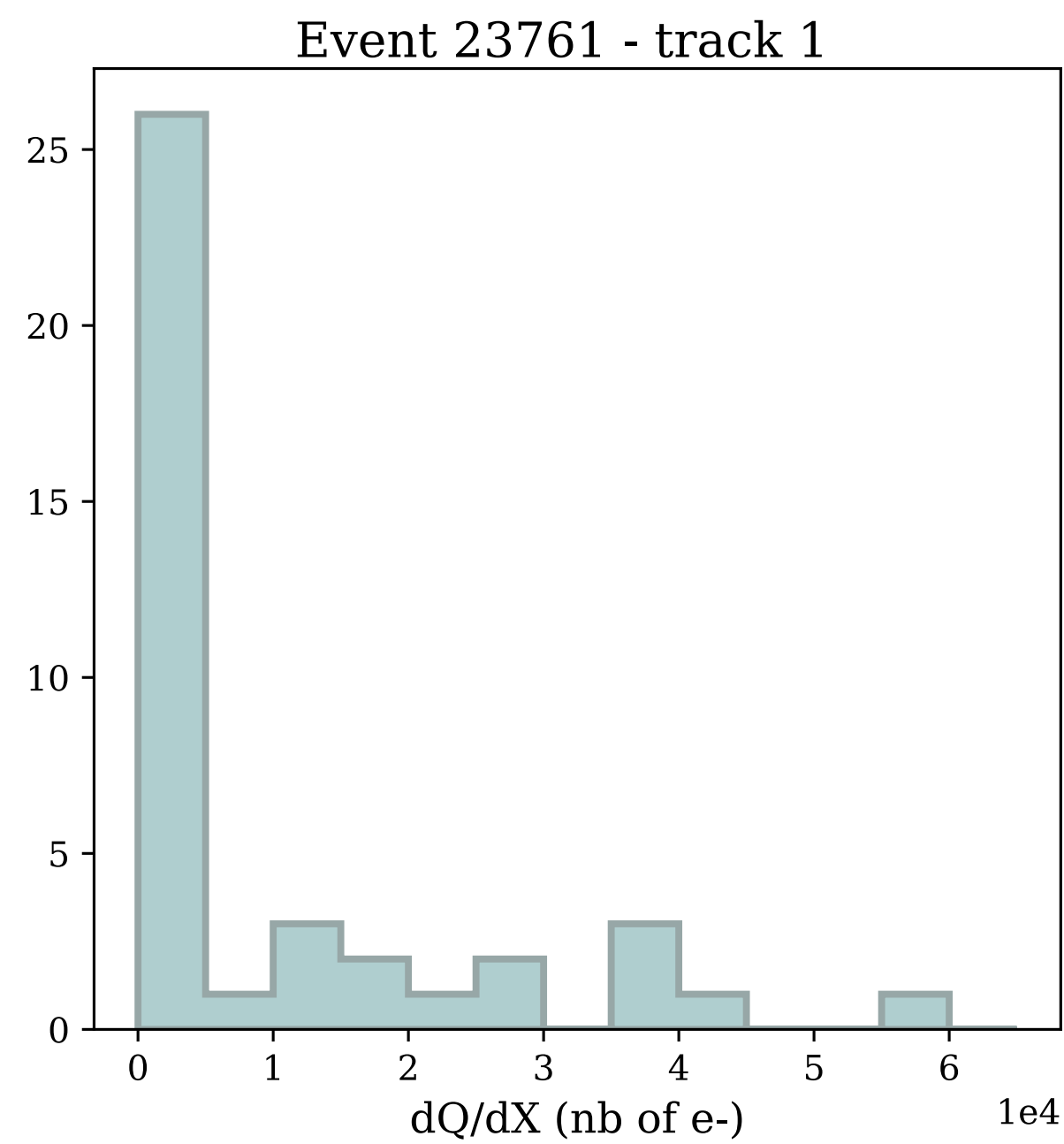
- $dQ/dX$  given by GnocchiCalorimetry module
- Large peak at low  $dQ/dX$  → why?



# Investigating low $dQ/dX$ peak

- **Event-per-event inspection**

- All events present a peak at low  $dQ/dX$
- Not a subset of pathological events





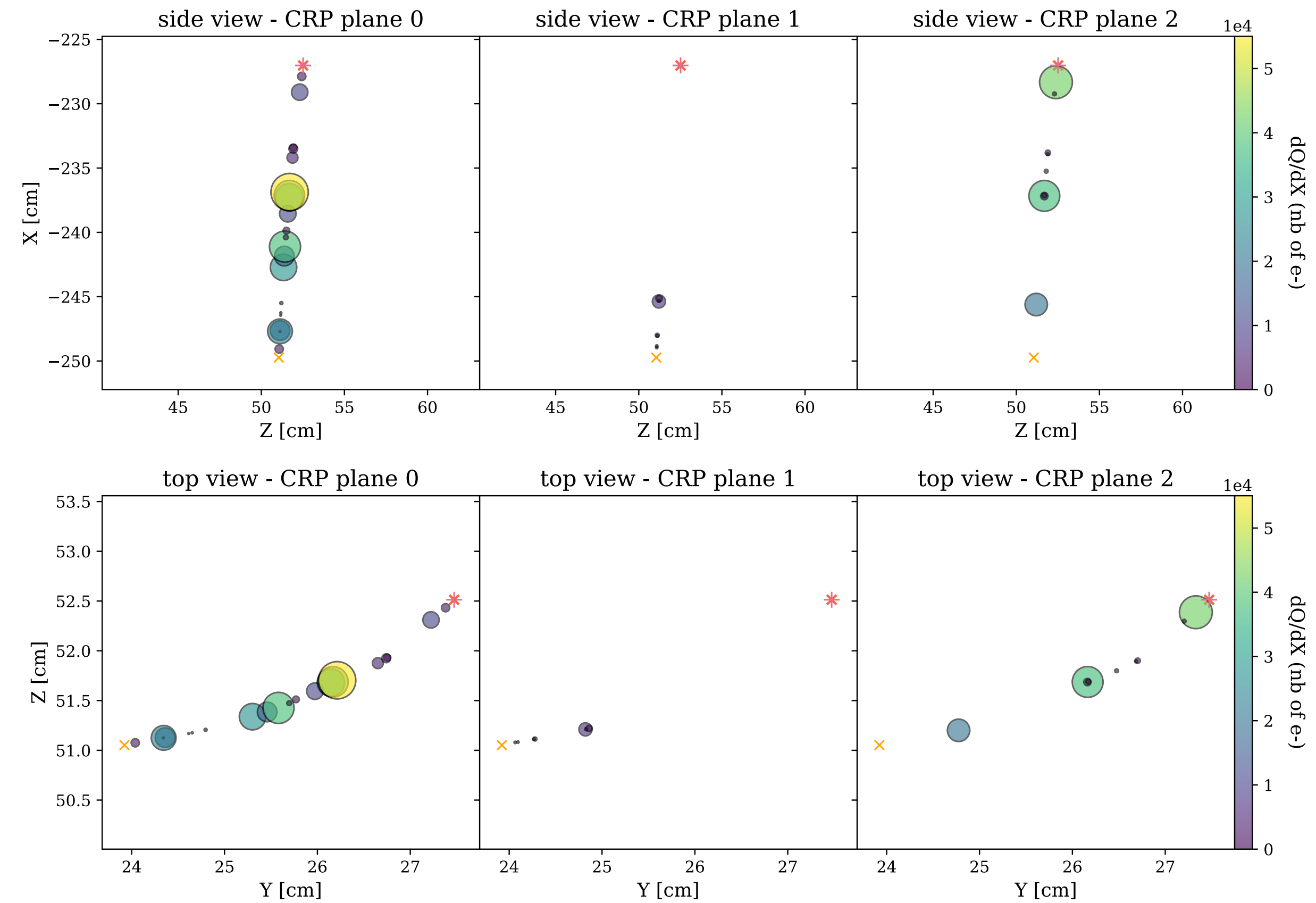
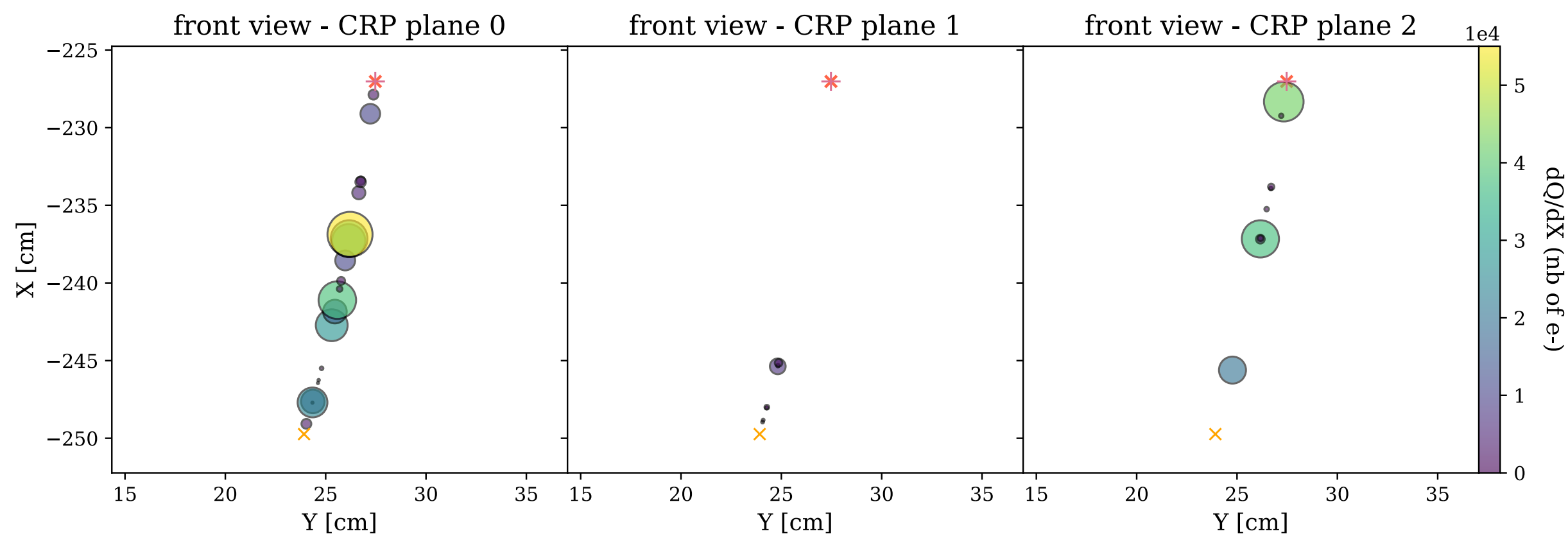
# GnocchiCalorimetry hits

## o $dQ/dX$ hits

- calorimetry hits merge several hits in « snippets »  
-> no 1-to-1 correspondency with hits / space points
- low  $dQ/dX$  hits are distributed all along the track

Event 23761 - track 1

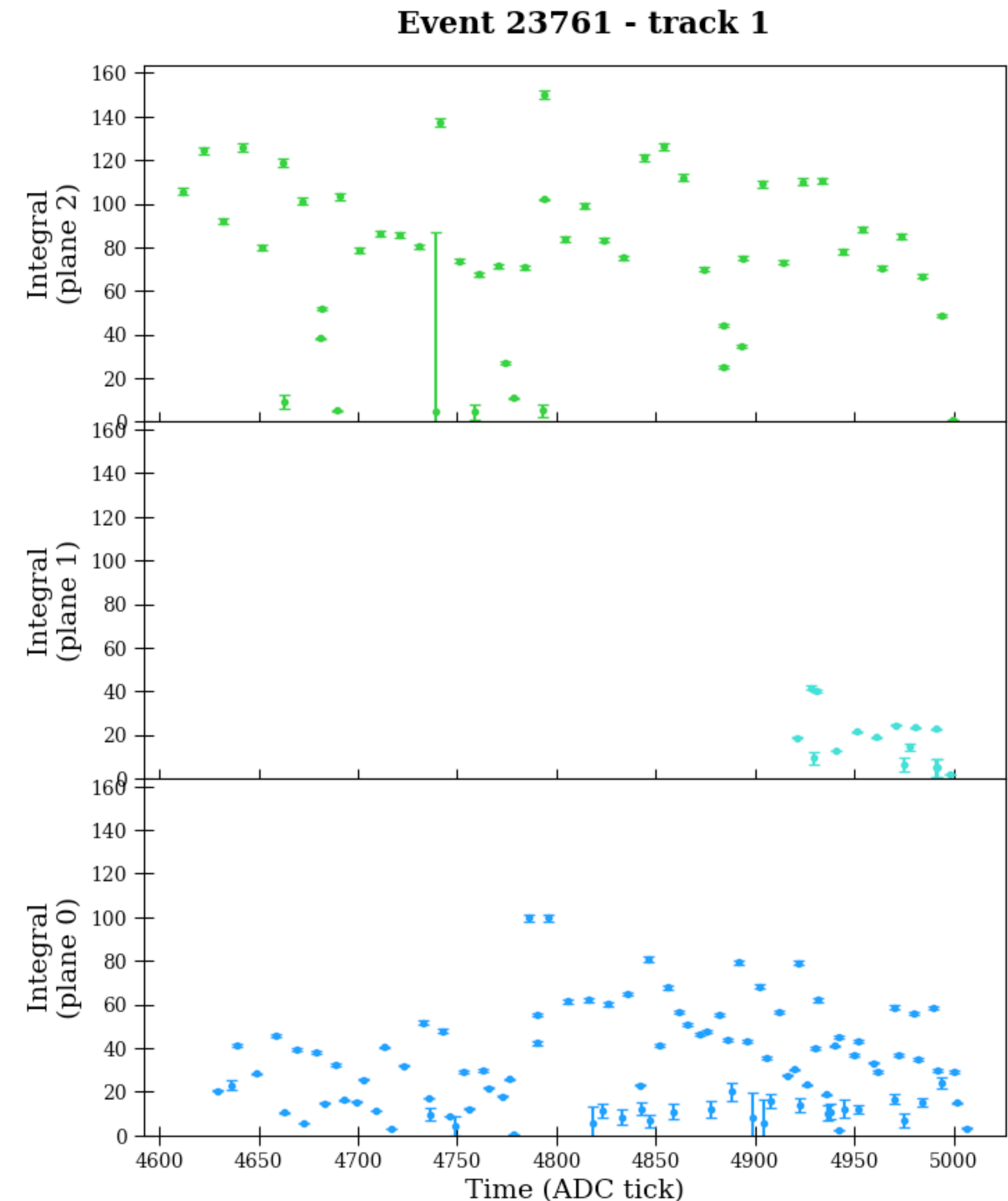
Track information: + vertex × start × end ● calorimetric hits





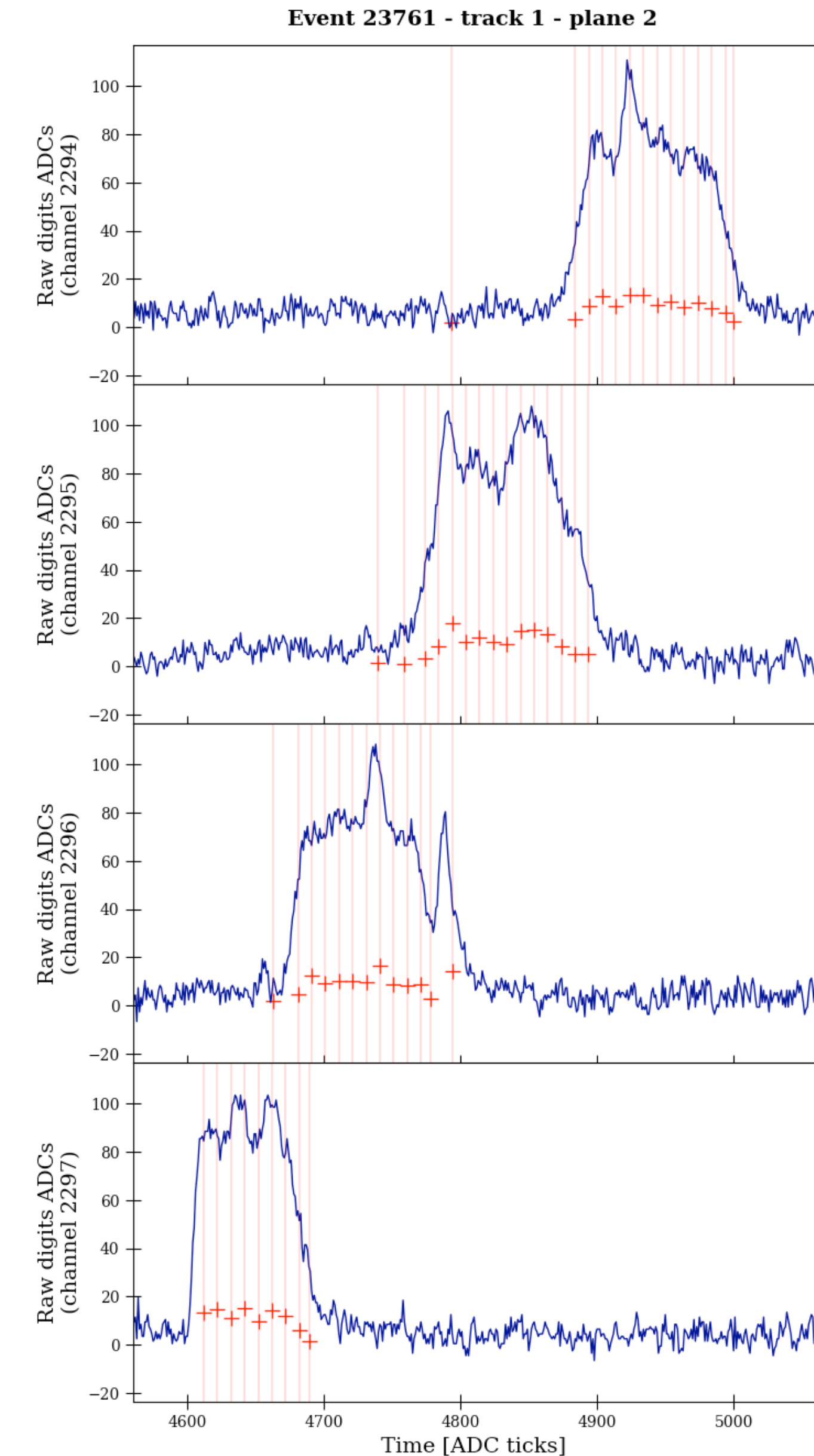
# Hit charge integral

- **Looking at hit charge information**
  - Uses recob::Hit information
  - Deconvoluted & filtered signal fitted with Gaussian
  - Plot Gaussian integral vs time → presence of low energy hits, culprit?
- **Do we peak up noise?**
  - Look at raw signals on channels corresponding to selected low & high integral hits



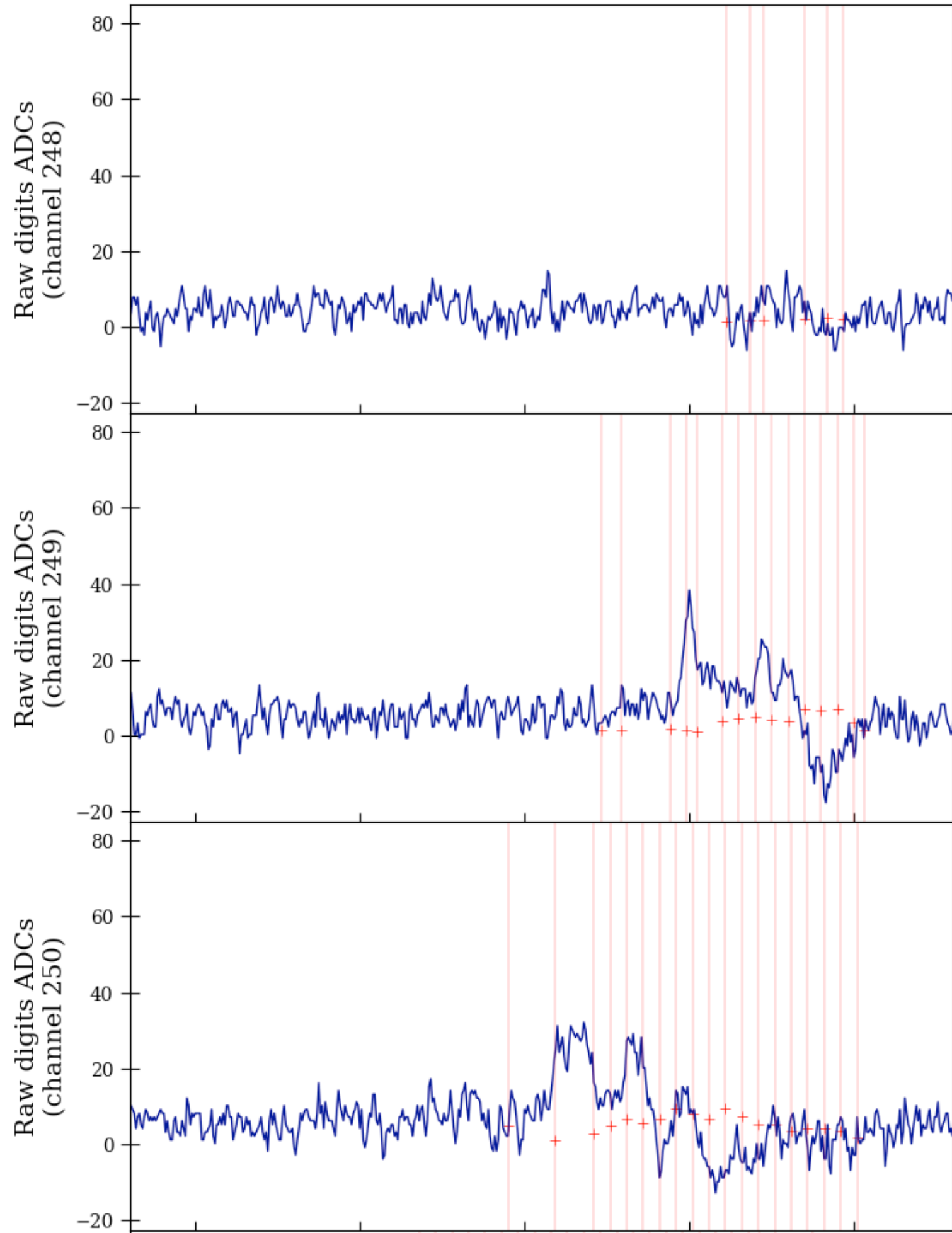
# Track hits waveforms: collection planes

- **Track hit time:** `recob::hit -> PeakTime()`
  - track hits distributed in [4612, 5006] ADC ticks
    - induction plane 1: [4629, 5006]
    - induction plane 2: [4921, 4998]
    - collection plane: [4612, 4999]
- **Track hit amplitude:** `recob::hit -> PeakAmplitude()`
  - track hits distributed in [0.56, 17.96] ADC units
    - induction plane 1: [0.6, 11.9]
    - induction plane 2: [0.6, 4.8]
    - collection plane: [1.2, 17.9]

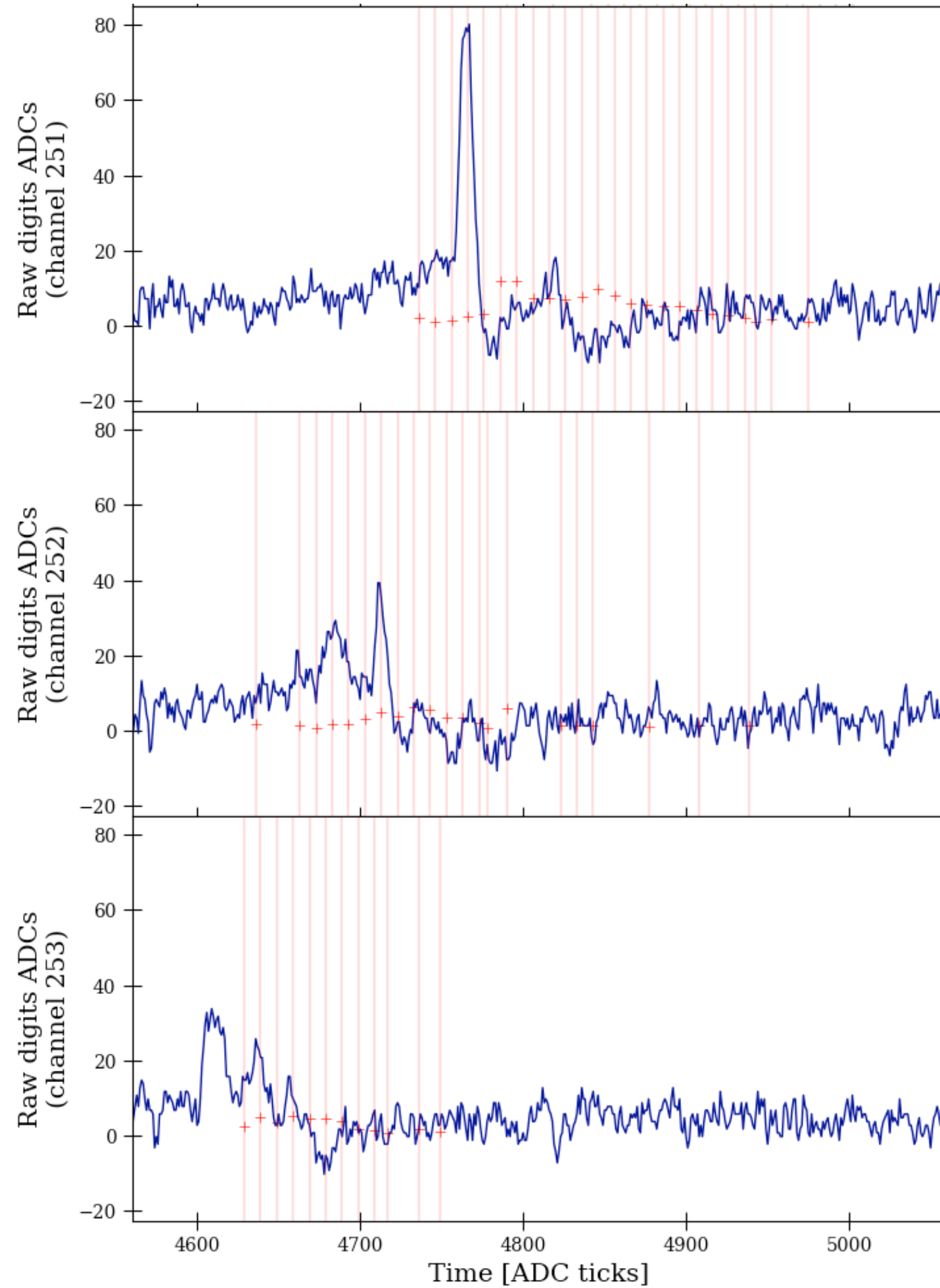


# Track hits waveforms: induction planes

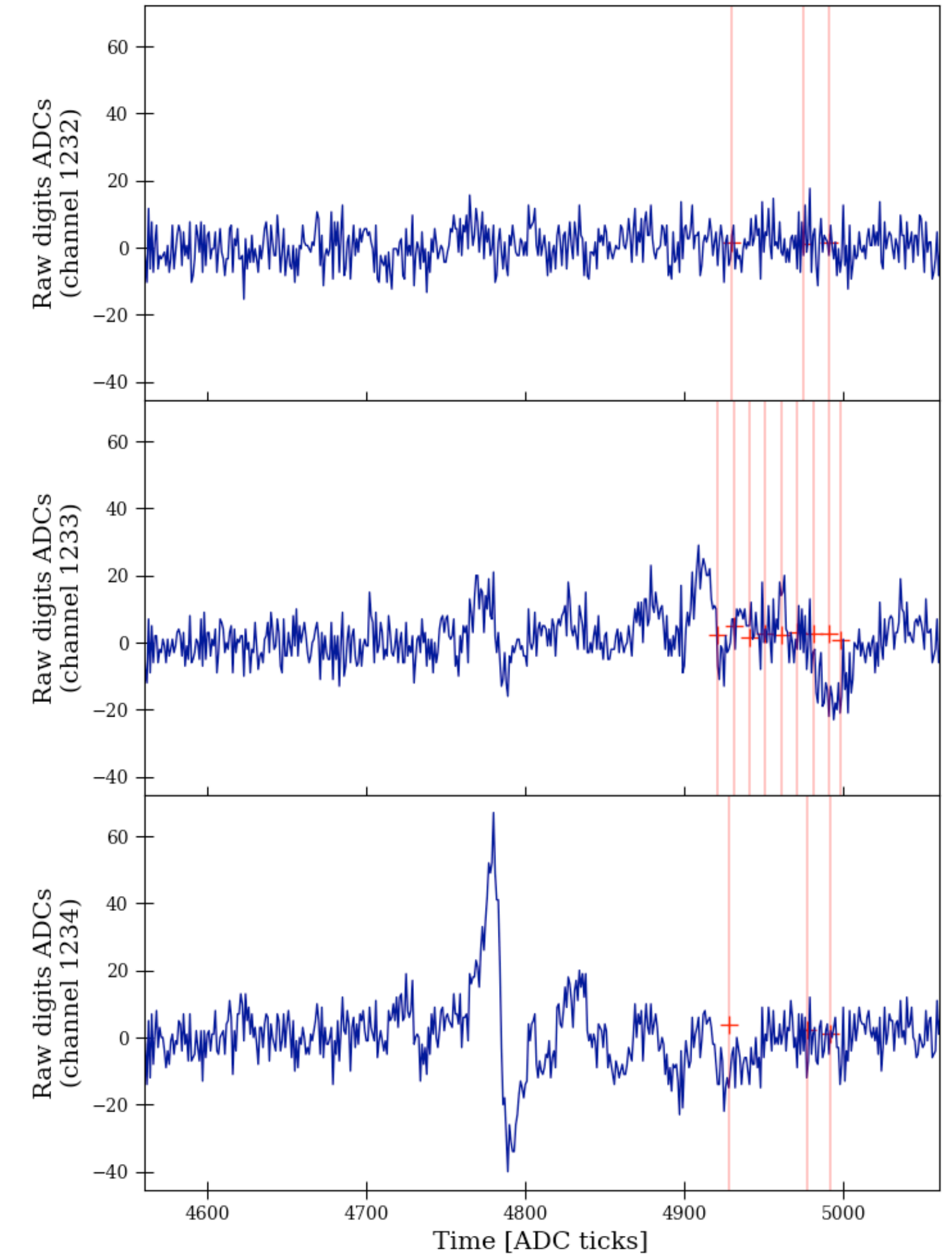
Event 23761 - track 1 - plane 0



Event 23761 - track 1 - plane 0



Event 23761 - track 1 - plane 1



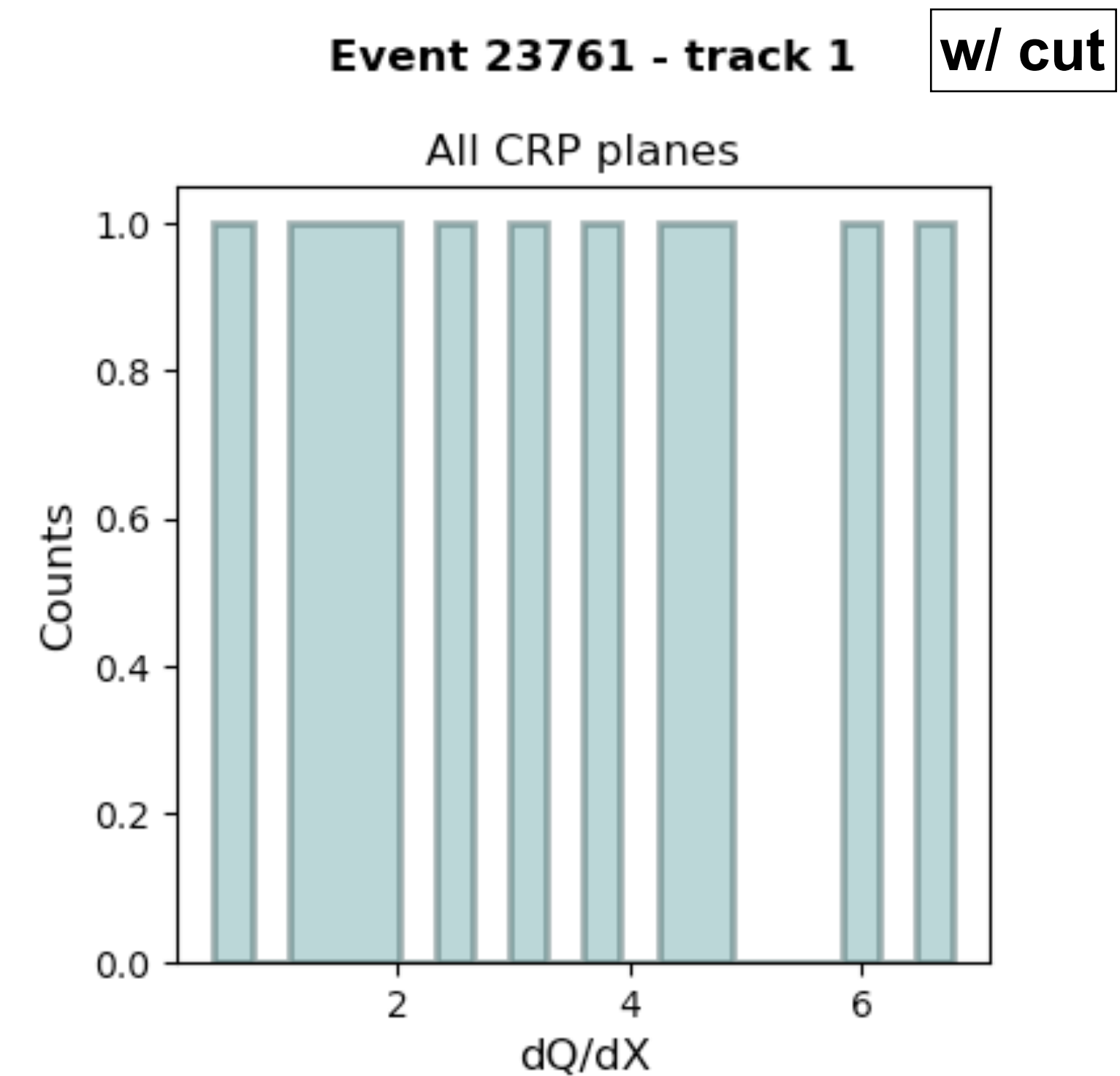
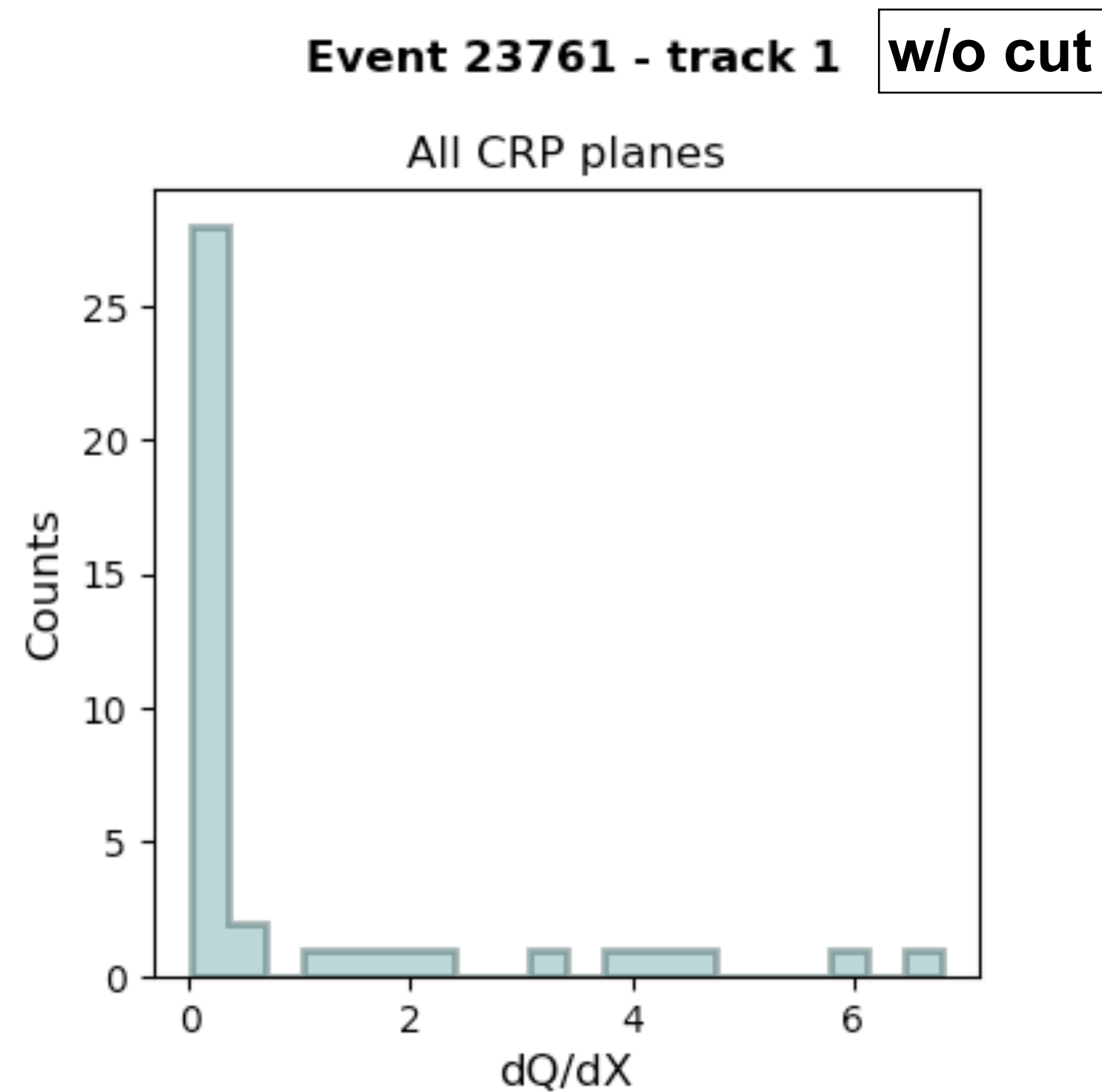


# Checking with Yoann module

## ◦ Yoann dQ/dX module

- Reproduce GnocchiCalorimetry from hit summedADC information
- Introduce a cut on hit charge:  $Q > 3 fC$
- When removing this cut, the large dQ/dx peak appear as well

```
MODULE:
${LARSOFT}/protoduneana/
verticaldrift/checks/
FitdQdx module.cc
```



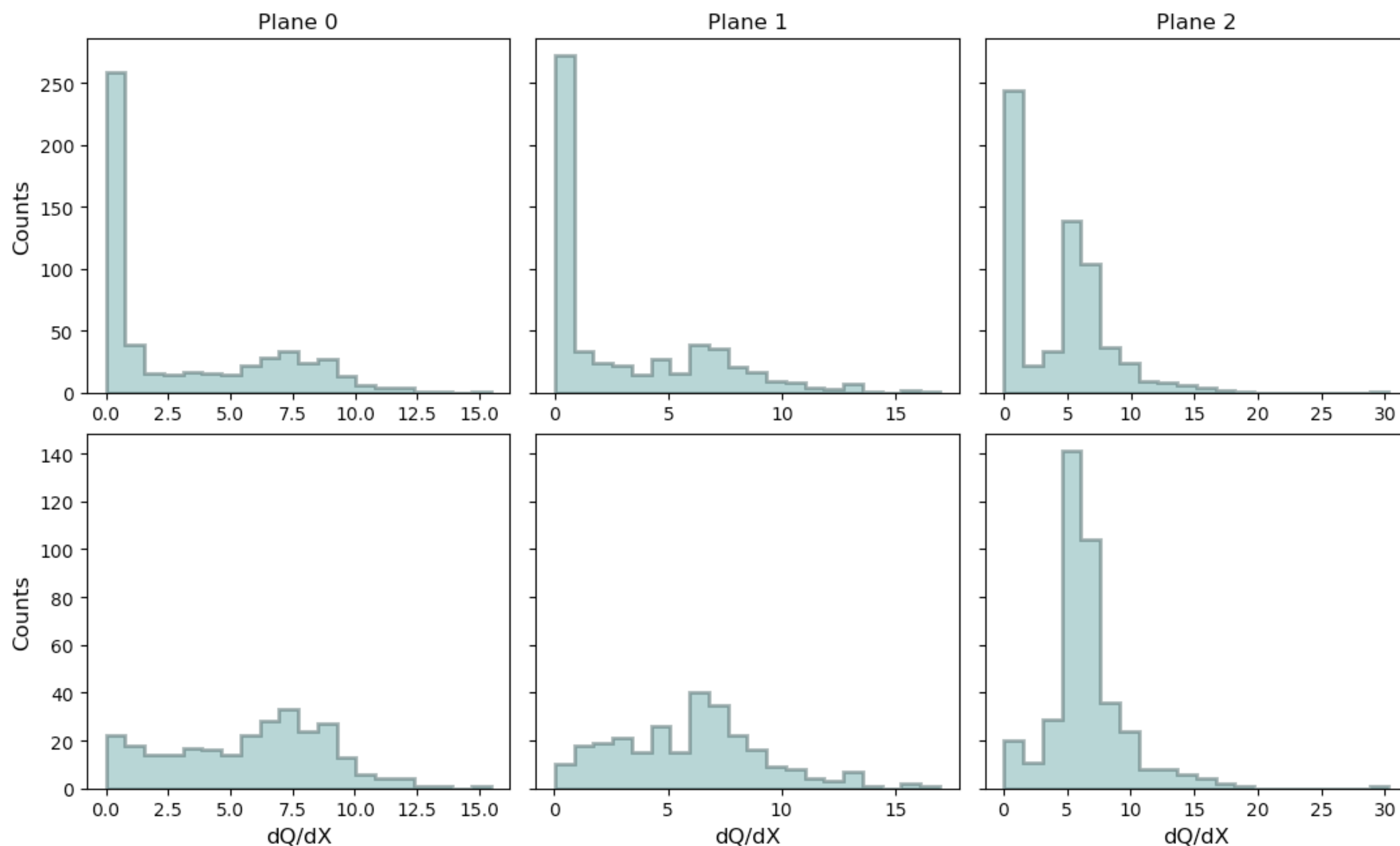
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```
MODULE :  
${LARSOFT}/protoduneana/  
verticaldrift/checks/  
FitdQdx module.cc
```

22 tracks,  
w/o cut



22 tracks,  
w/ cut

Recently, check of dQ/dX  
from GnocchiCalorimetry  
in PD-VD MC production:  
no peak at low dQ/dX !

# Reconstruction settings

- **Issue seems to be due to picking up hits in noise**

- Yoann looked at the  $dQ/dX$  from GnocchiCalorimetry in PD-VD MC production:  
no peak at low  $dQ/dX$  !
- CB-VD reconstruction uses the following Region of Interest (ROI) threshold value to find hits:

```
$ less crpcb_top_process.fcl
...
crp2_july22_prod_config.gaushit.HitFinderToolVec.CandidateHitsPlane0.RoiThreshold: 1.0
crp2_july22_prod_config.gaushit.HitFinderToolVec.CandidateHitsPlane1.RoiThreshold: 1.0
crp2_july22_prod_config.gaushit.HitFinderToolVec.CandidateHitsPlane2.RoiThreshold: 1.0
```

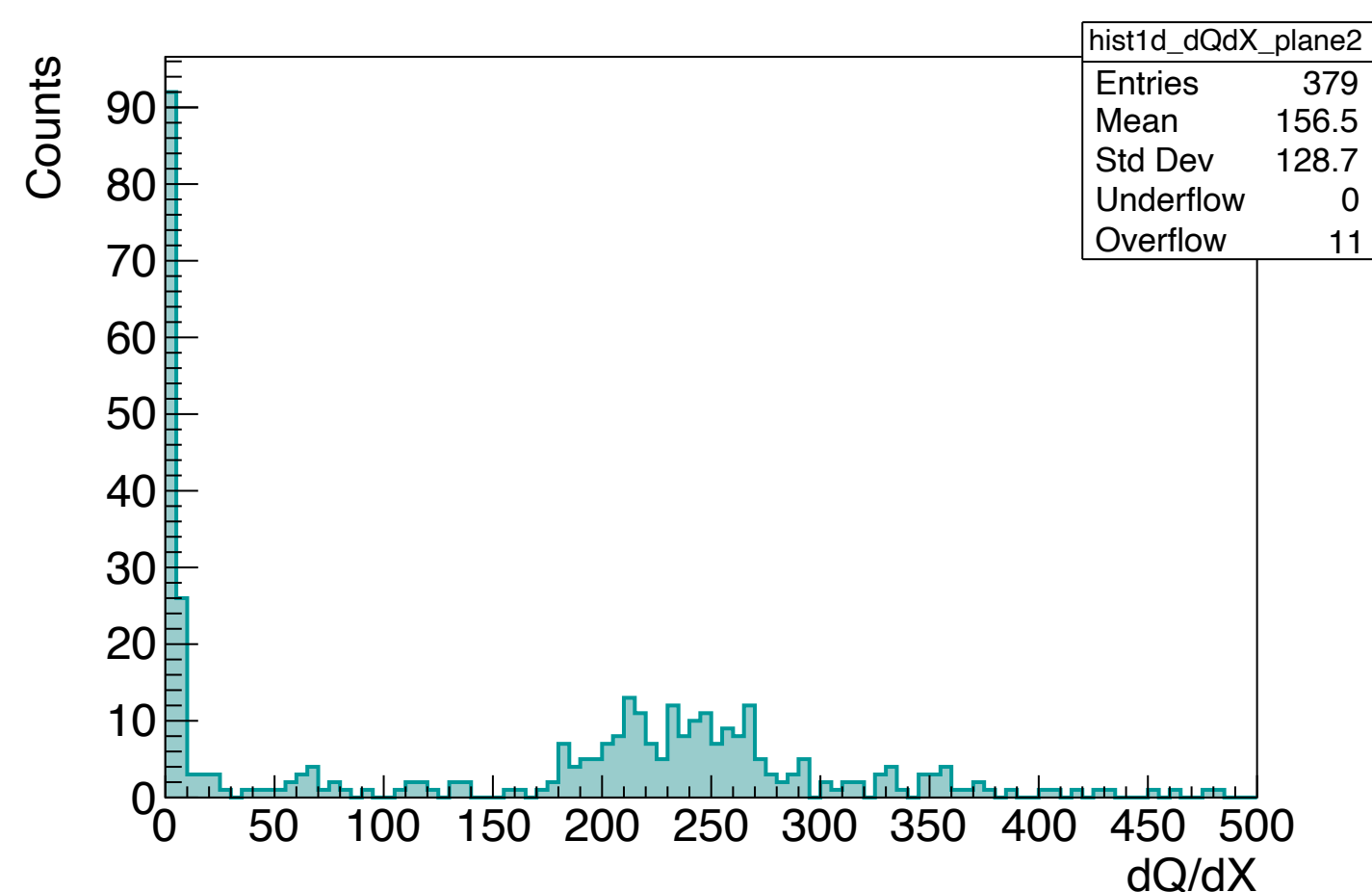
- PD-VD reconstruction set the ROI threshold to 5  
-> rerun reconstruction on CB-VD with this value of ROI threshold

# Comparison of reconstruction

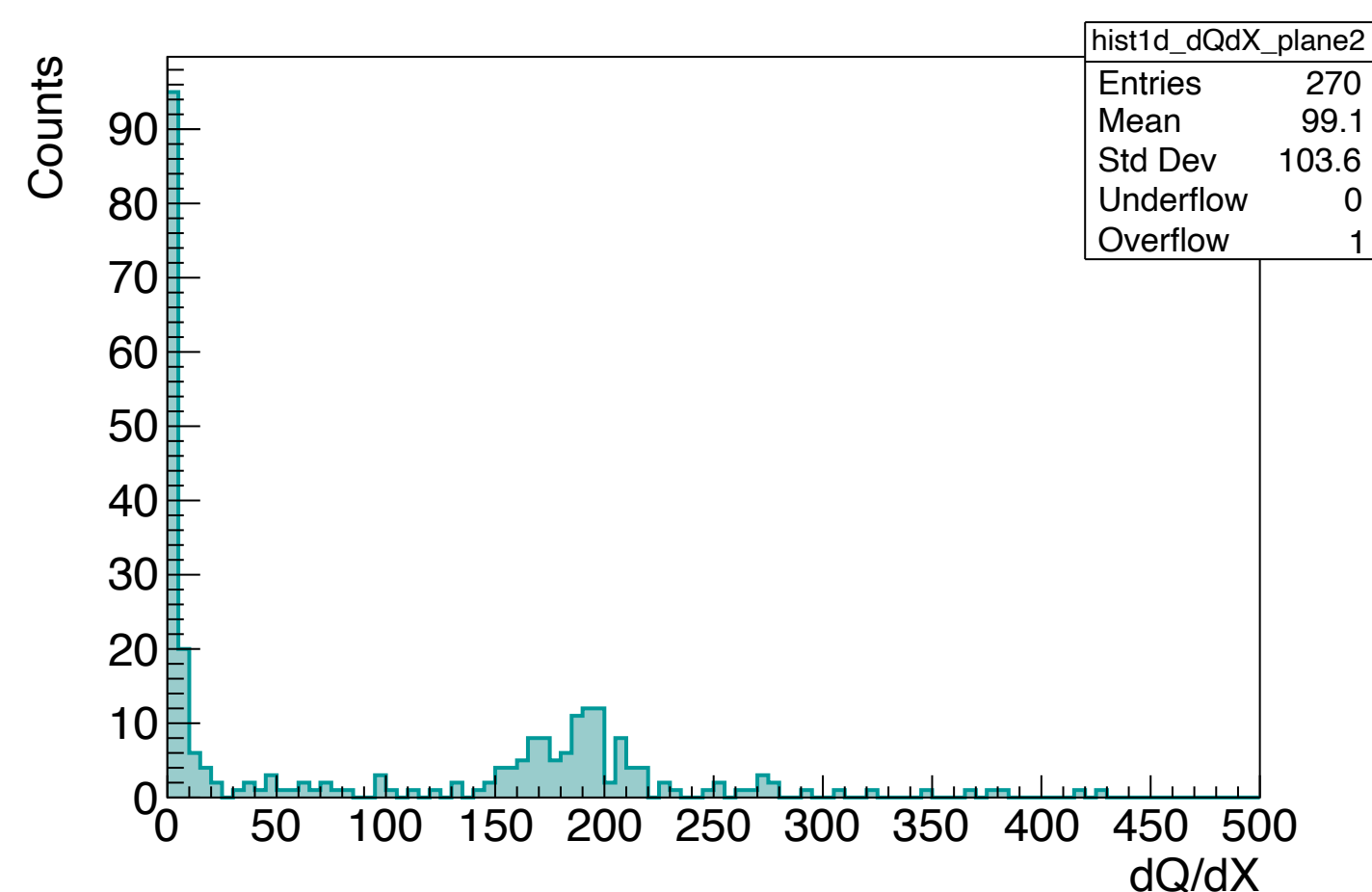
- o **dQ/dX from GnocchiCalorimetry for through-going tracks**

- Collection plane (plane 2), similar selection as slide 6
- No more low dQ/dX peak with ROI threshold set to 5
- Expected differences between DUNE software versions?

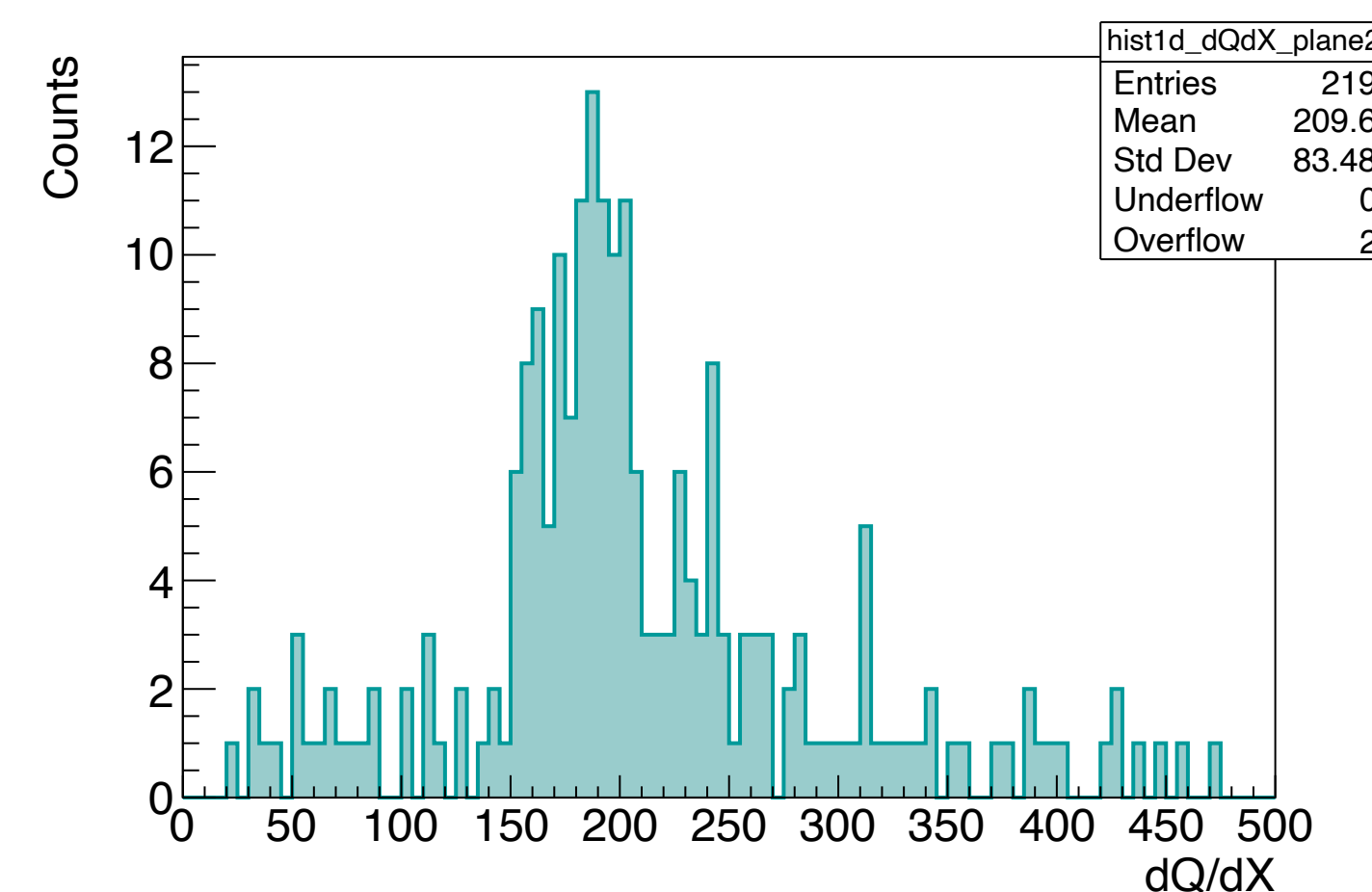
DUNE\_SW v09\_72\_00d00  
RoiThreshold: 1.0



DUNE\_SW v09\_90\_01d00  
RoiThreshold: 1.0



DUNE\_SW v09\_90\_01d00  
RoiThreshold: 5.0





# Conclusion

- **Hit ROI threshold matter**

- Study which value to set according to the desired study
  - > low ROI: good for low-energy events (Ar39, etc)
  - > high ROI: better to select high-energy hits
  - > in-between: study impact of ROI threshold on reconstruction ?

- **More calorimetry studies to perform**

- Can GnocchiCalorimetry reproduce LARDON results?
- How good is the PID for different particles & interaction?
  - > Look at PD MC to complete CB studies
- Follow-up work to come soon :)

*A big thanks to the IP2I group  
and Yoann Kermaïdic for the  
more-than-fruitful discussions !*