CRP6 Charge-Light data with LARDON

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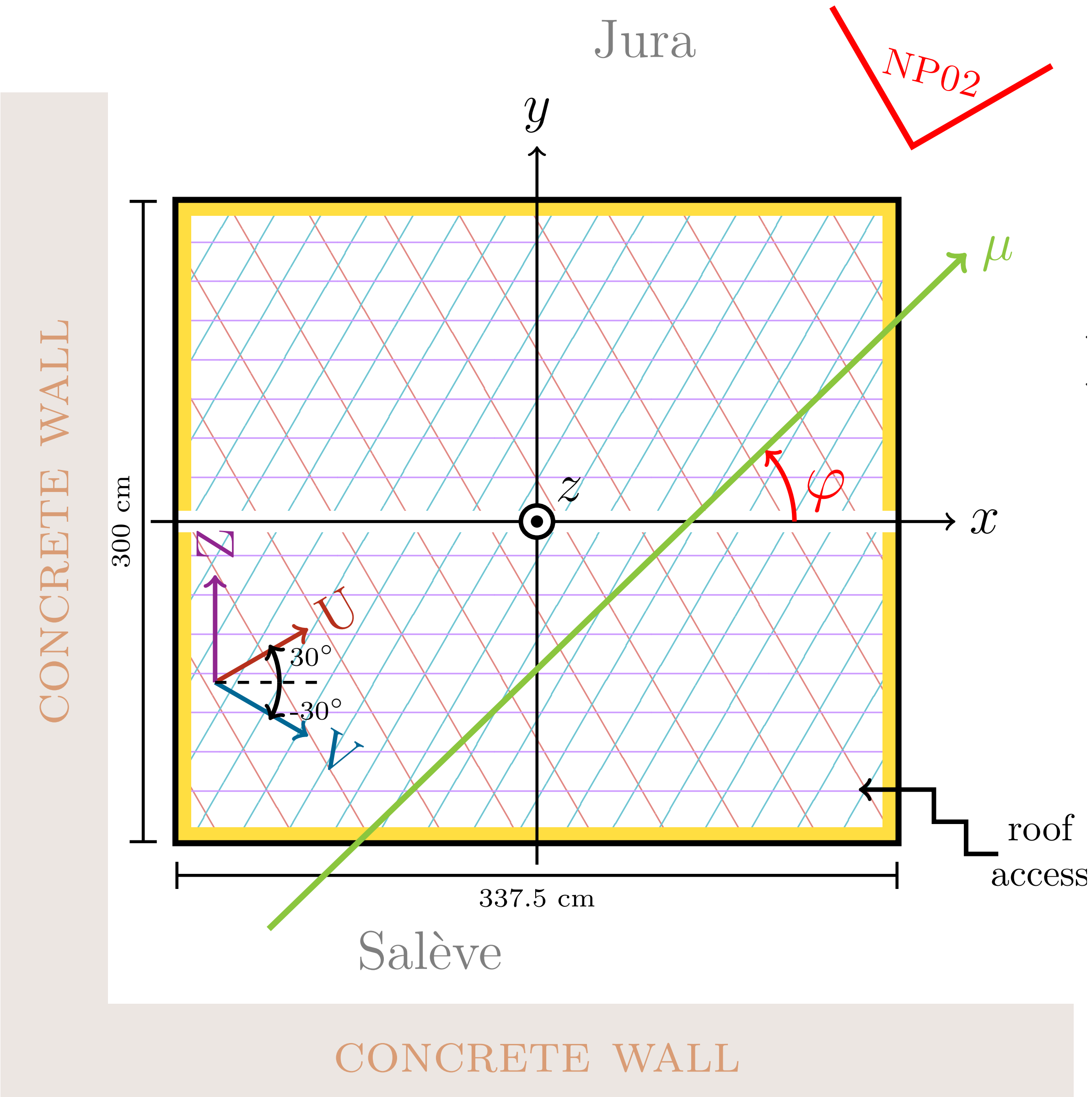
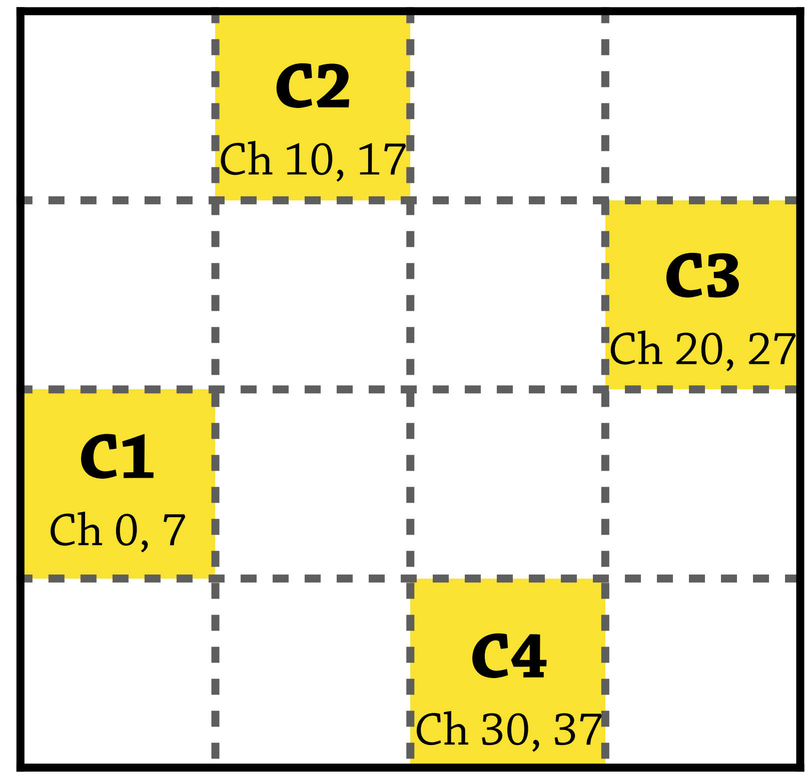
DUNE-France workshop #3

CRP6 Coldbox test

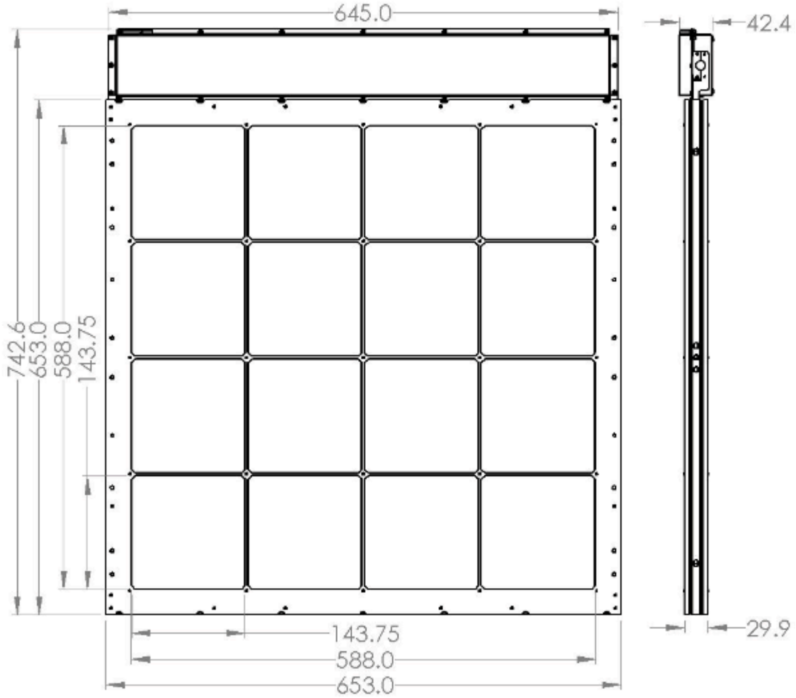


6 X-ARAPUCAS installed
4 on the cathode
2 on the membrane

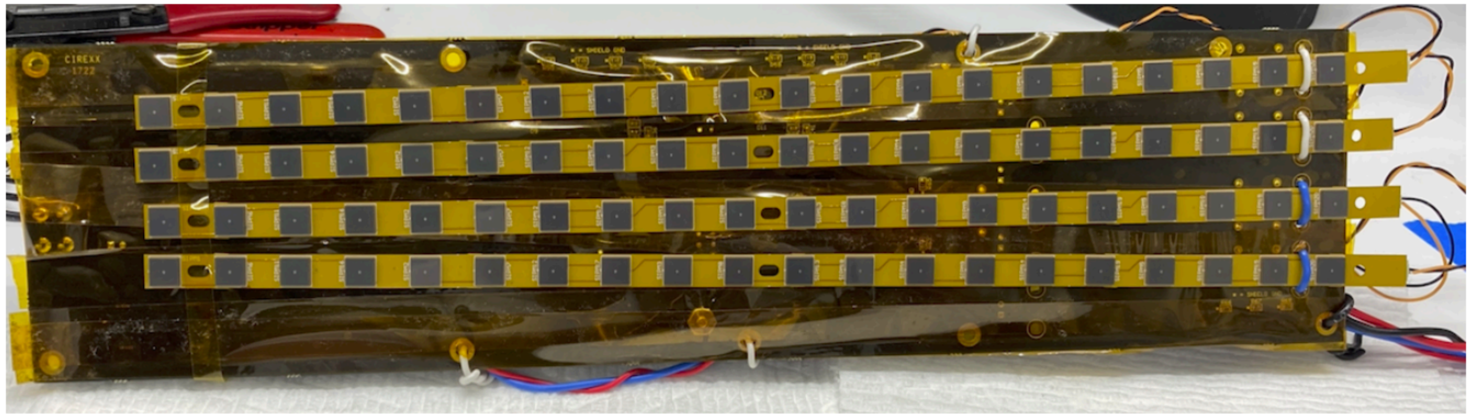


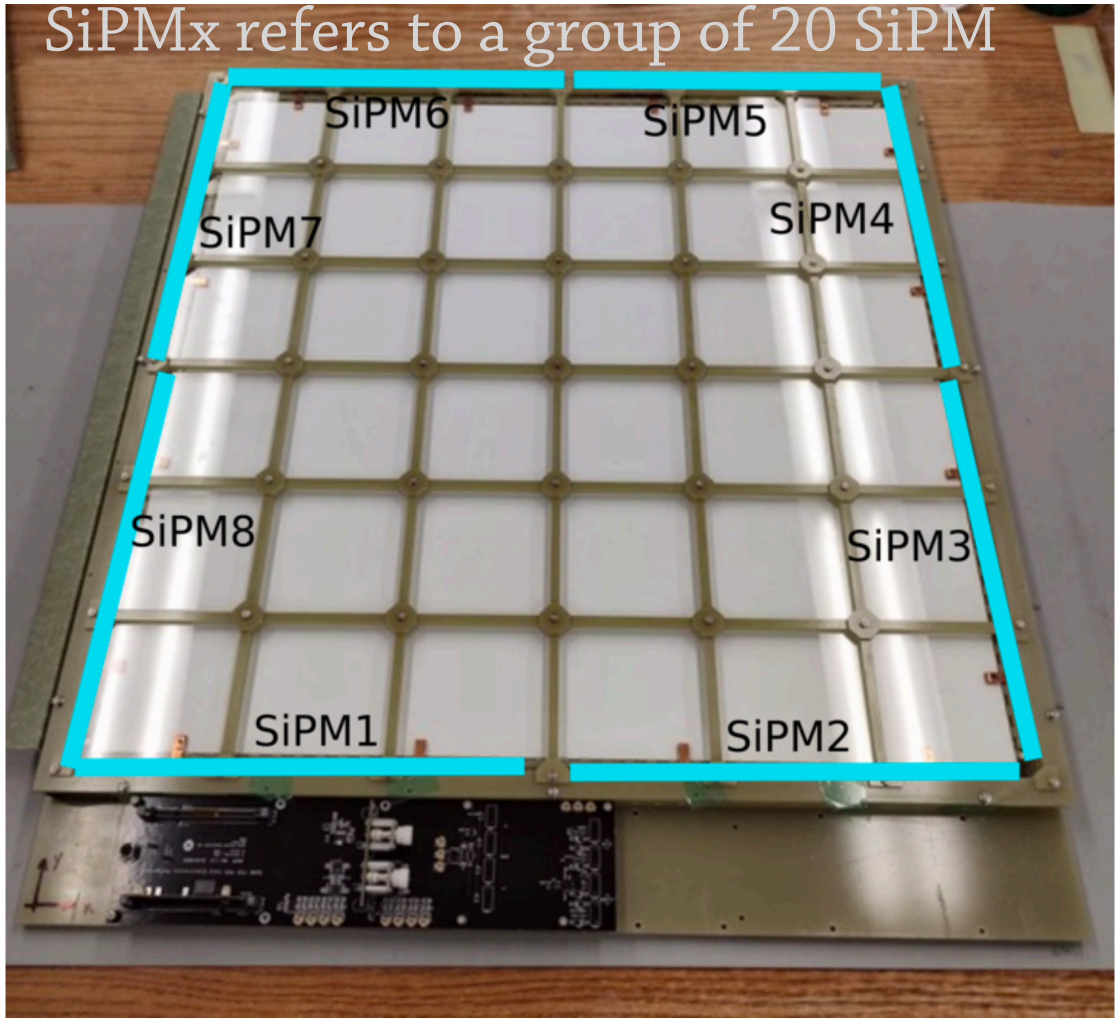
-> x-ARAPUCAs can stream their data in the hdf5 file (all cathode, sometimes membrane too)
-> Not all CRP6 runs have charge and light data collected, check my summary file
-> x-arapucas have different configurations, check CRP6-II and CRP6-III summaries from Sabrina

X-arapucas



4 strips of mounted 20 SiPM together :





X-arapuca cathode module characteristic :

- Active surface is 65.3×65.3 cm^2
- Equipped with 160 SiPM, grouped by 20
- Provides 2 read-out channels (80 SiPM/readout)
  - One channel reads SiPM 1,3,5 and 7
  - Other reads SiPM 2, 4, 6, 8
  - NB: I don't know which is which

Raw data format

Example: /TriggerRecord00001.0000/RawData/Detector_Readout_0x00000064_WIBEth (Array(928872, 1))

CHARGE DATA

Fragment Header

WIB Header

WIB data of 64 channels for 64 ticks
Ticks [0 .. 63]

WIB Header

WIB data of 64 channels for 64 ticks
Ticks [64 .. 127]

WIB Header

WIB data of 64 channels for 64 ticks
Ticks [128 .. 191]

... up to ticks [8128 .. 8191]

The Fragment Headers are the same for both data
It provides the run and event number, and a timestamp of the event (DAQ timestamp?)

E.g : /TriggerRecord00001.0000/RawData/Detector_Readout_0x00000001_DAPHNEStream (Array(1933856, 1))

LIGHT DATA

Fragment Header

DAPHNE Header

DAPHNE data of 4 channels for 64 ticks
Ticks [0 .. 63]

DAPHNE Header

DAPHNE data of 4 channels for 64 ticks
Ticks [64 .. 127]

DAPHNE Header

DAPHNE data of 4 channels for 64 ticks
Ticks [128 .. 191]

... up to ticks [262127 .. 262143]

Raw data format

Example: /TriggerRecord00001.0000/RawData/Detector_Readout_0x00000064_WIBEth (Array(928872, 1))

CHARGE DATA

Fragment Header

WIB Header

WIB data of 64 channels for 64 ticks
Ticks [0 .. 63]

WIB Header

WIB data of 64 channels for 64 ticks
Ticks [64 .. 127]

WIB Header

WIB data of 64 channels for 64 ticks
Ticks [128 .. 191]

… up to ticks [8128 .. 8191]

Each data frames (WIB, DAPHNE) contains the data of × channels for 64 ticks

- WIB <-> 32.768 µs
- DAPHNE <-> 1.024 µs

The charge data is sampled at 1.953125 MHz (1 tick = 512 ns)
The PDS data is sampled at 62.5 MHz (1 tick = 16 ns)

The WIB and DAPHNE Headers provides <u>the timestamp of each frame</u> and other information (channel, type of data, …)

E.g : /TriggerRecord00001.0000/RawData/Detector_Readout_0x00000001_DAPHNEStream (Array(1933856, 1))

LIGHT DATA

Fragment Header

DAPHNE Header

DAPHNE data of 4 channels for 64 ticks
Ticks [0 .. 63]

DAPHNE Header

DAPHNE data of 4 channels for 64 ticks
Ticks [64 .. 127]

DAPHNE Header

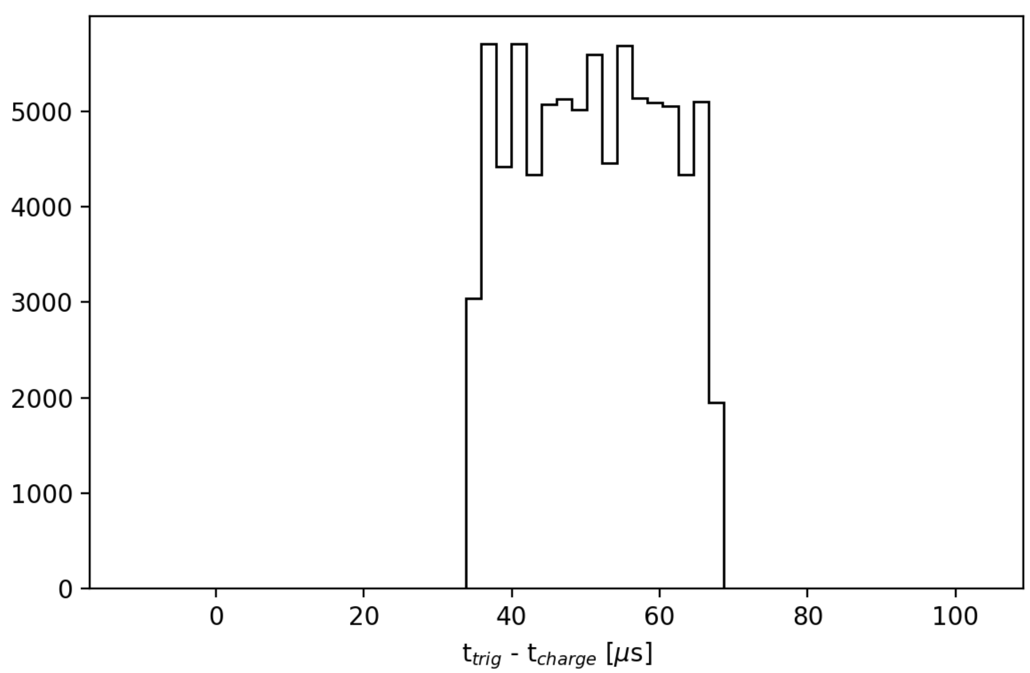
DAPHNE data of 4 channels for 64 ticks
Ticks [128 .. 191]

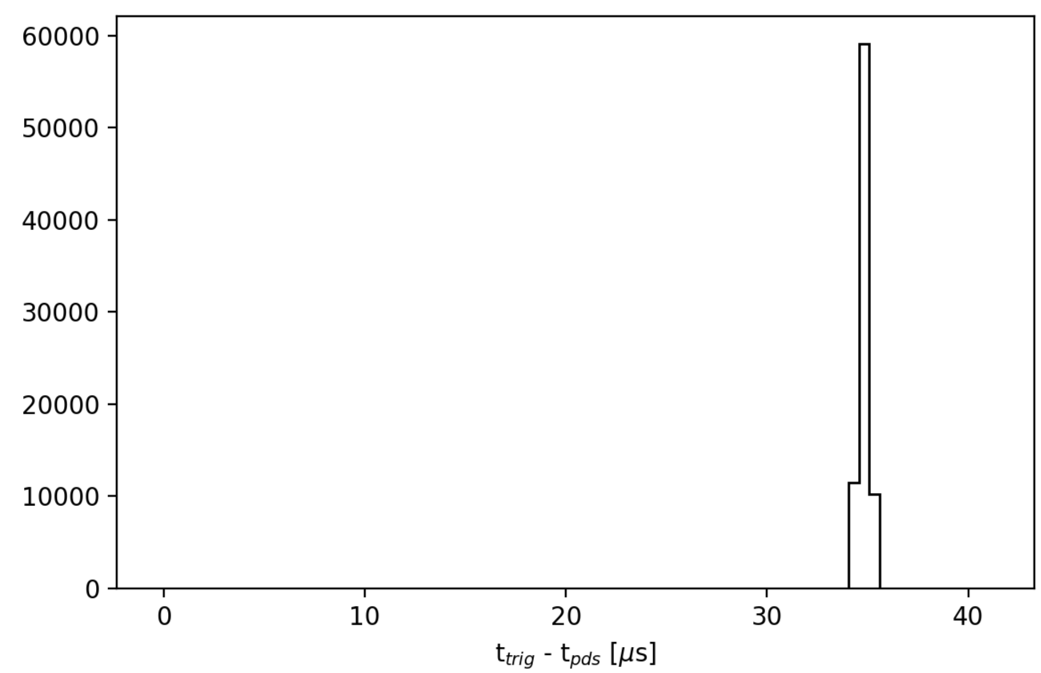
… up to ticks [262127 .. 262143]

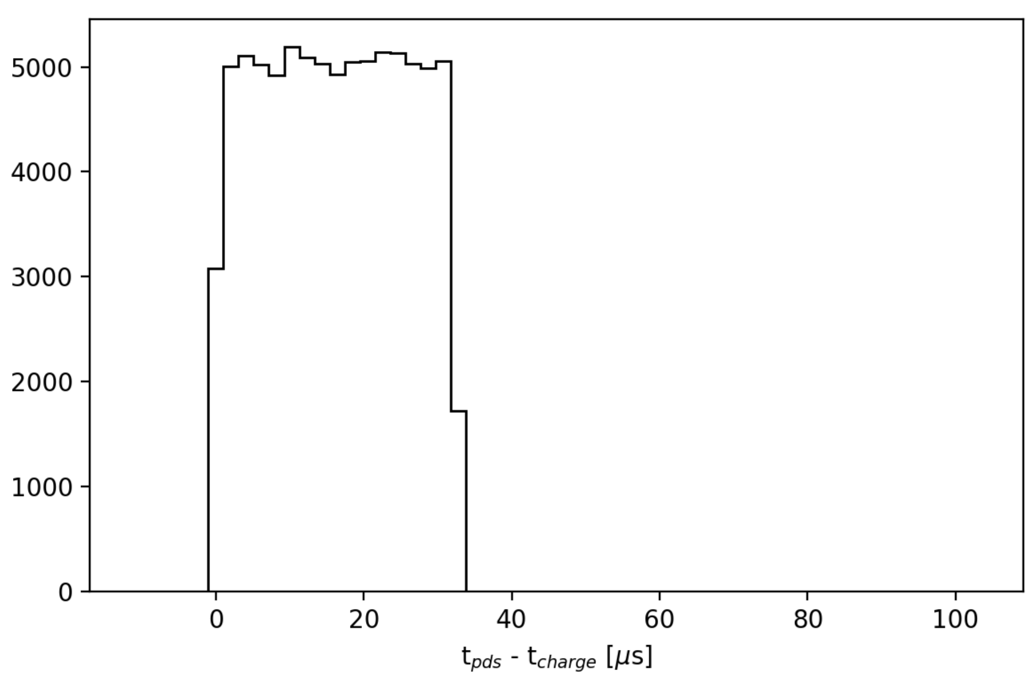
Timestamps

The 3 timestamps provided are :

- By the Fragment Header - DAQ signal ? : t_{trig}
- By the 1st WIB Frame - when the charge data starts to be recorded : t_{charge}
- By the 1st DAPHNE Frame - when the light data starts to be recorded : t_{pds}





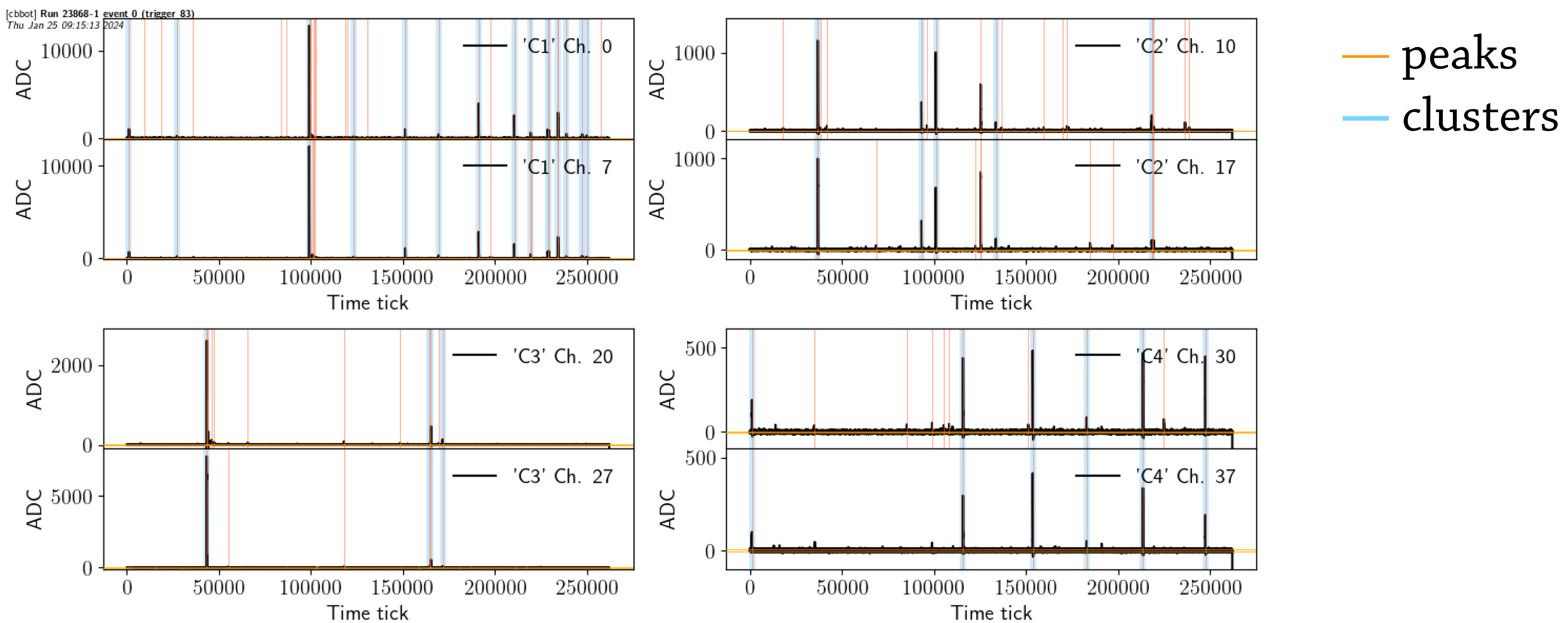


The charge and light data events can be delayed up to 1 WIB Frame duration, i.e. 32.768 μs

PDS data processing

The signal processing of the PDS waveforms is very simple:

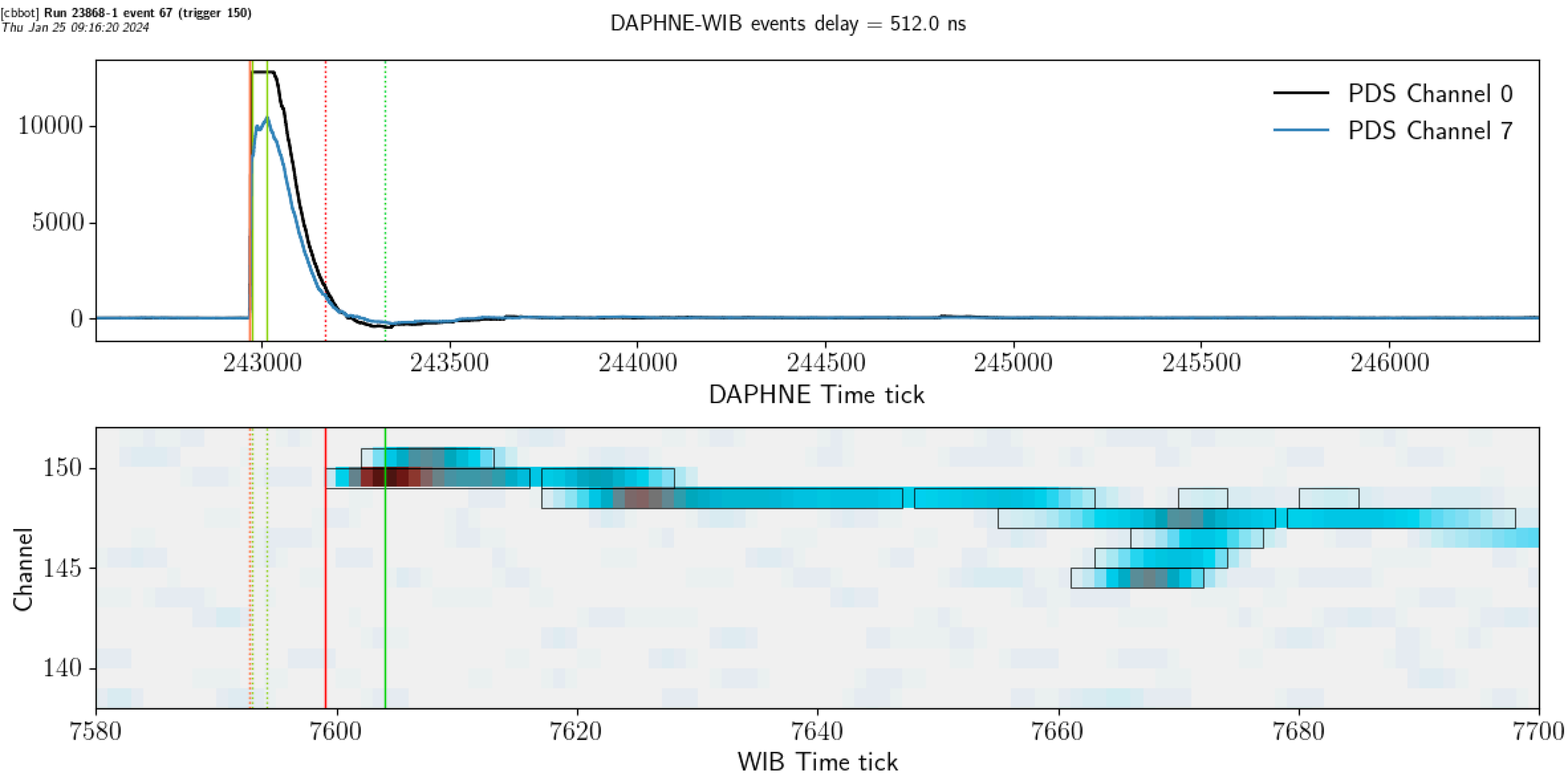
1. Pedestal alignment - *subtract the median ADC value of each waveform, compute a rough RMS using an ADC threshold (consider signal anything with ADC > 200)*
2. Recompute Pedestal RMS *with a better ROI definition: data higher than 3×RMS - done for 3 consecutive times*
3. Search for hit - *data higher than 15×RMS for at least 50 consecutive tick*
4. Build clusters with peaks seen at the same time
   - By the two ×-ARAPUCA channels : cluster of size 2
   - With other ×-ARAPUCA modules : clusters of size 4, 6 or 8



Light-Track time matching : definition

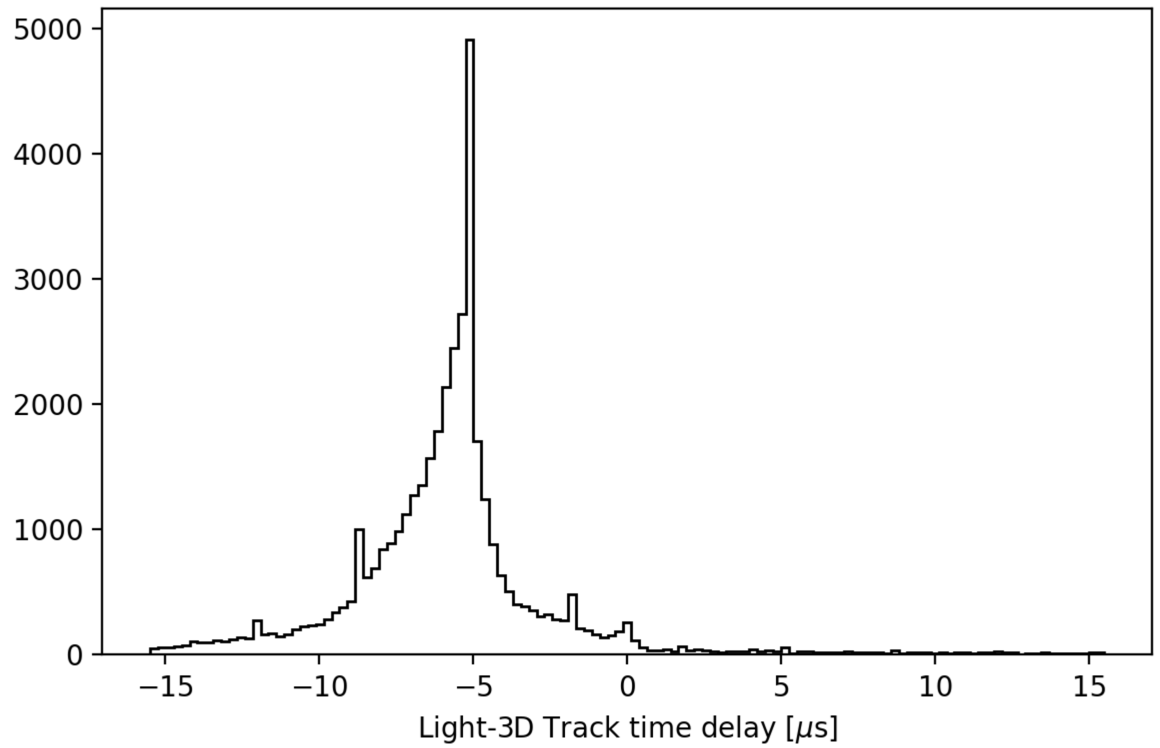
Here is zoom on a track-light event. The DAPHNE and WIB are almost aligned (512ns delay)

-> One can compute the light-track delay considering either the starting time of both signals or the peaking time of both signals (1st hit of the crossing track, at the level of the anode)

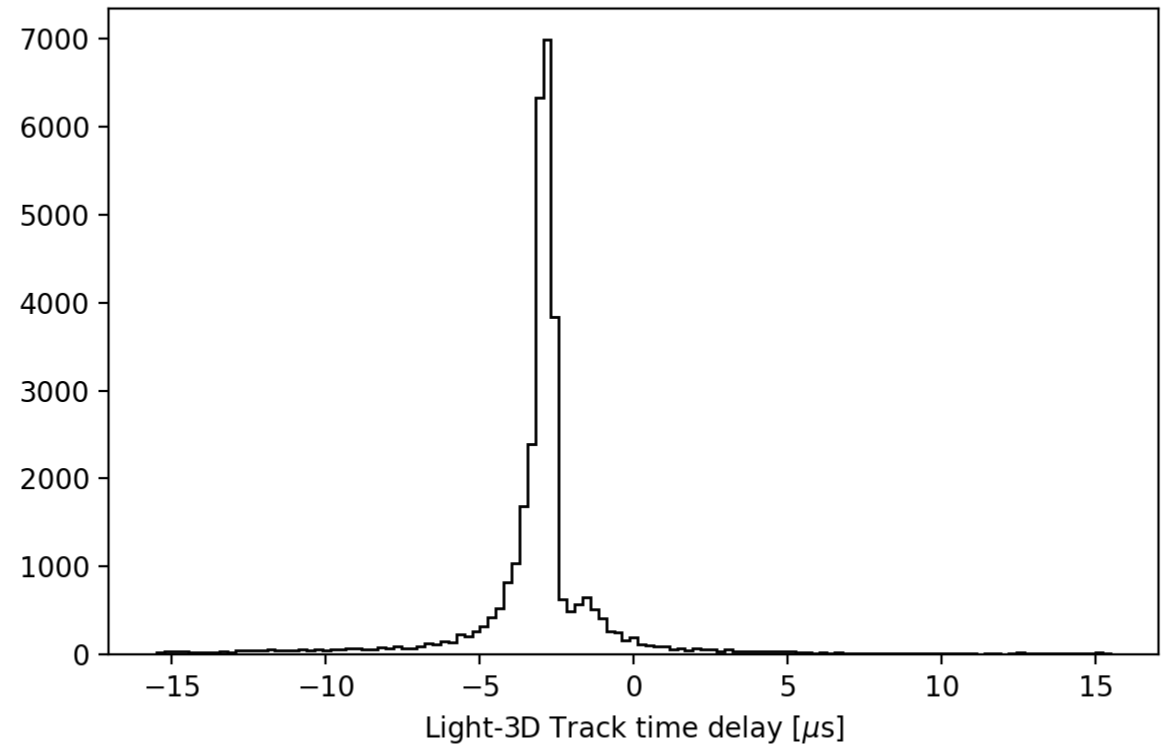


Light-Track matching time

Taking signal peaking time as reference
-> About 5 μs delay



Taking signal starting time as reference
-> About 2.7 μs delay



There are some pipeline delays in the processing chain, estimated at

PDS system : around 150~200ns

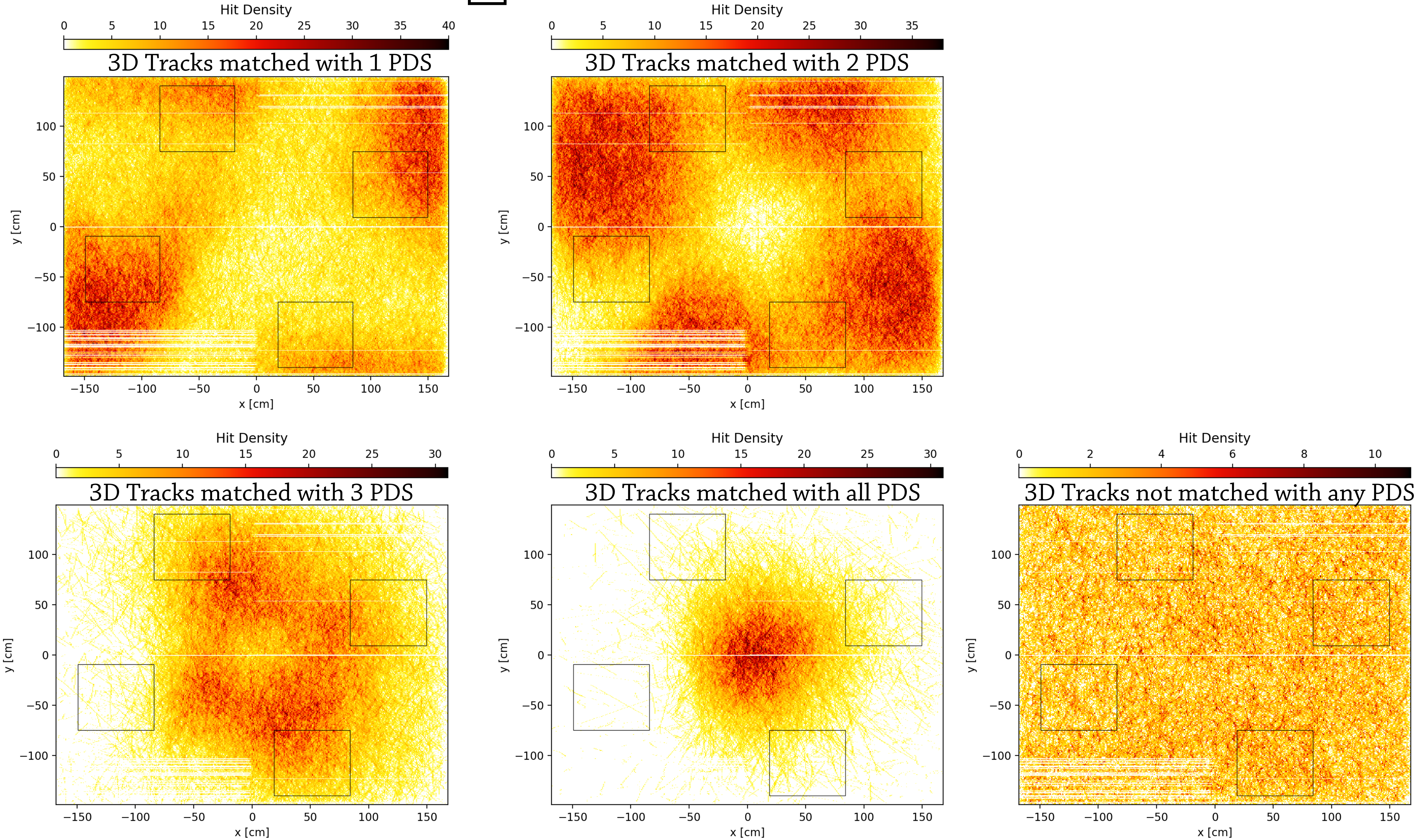
Charge system : up to 2100 ns

-> Taking the definition of the signal starting time as the best reference to when the track emitted both charge and light signal, there is still up to 0.8 μs delay to be understood

Track & Light

CRP6 - III Run 25086

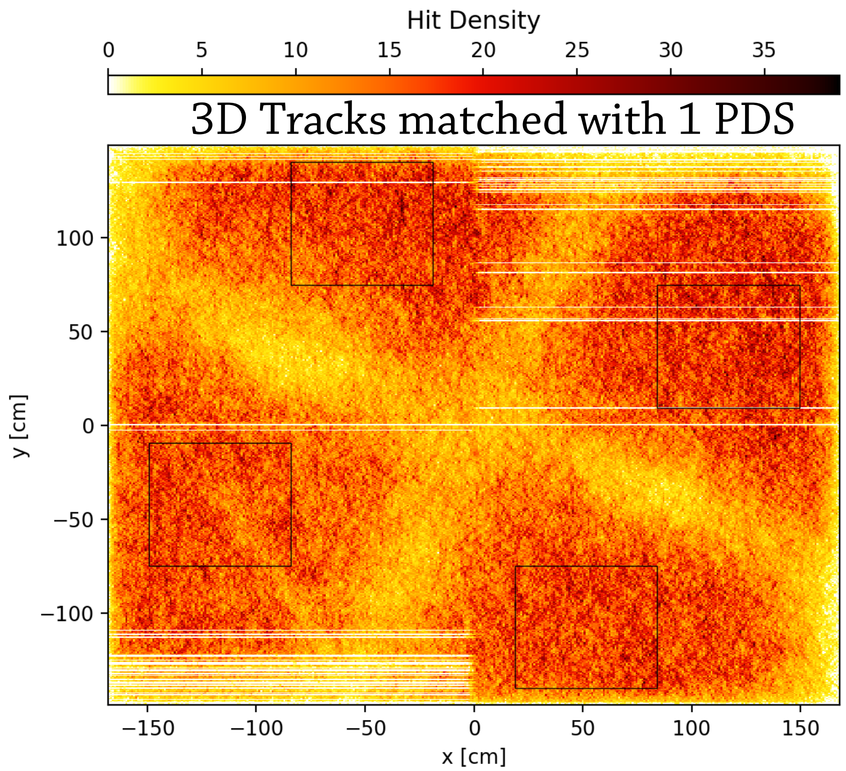
□ : ×-ARAPUCA location

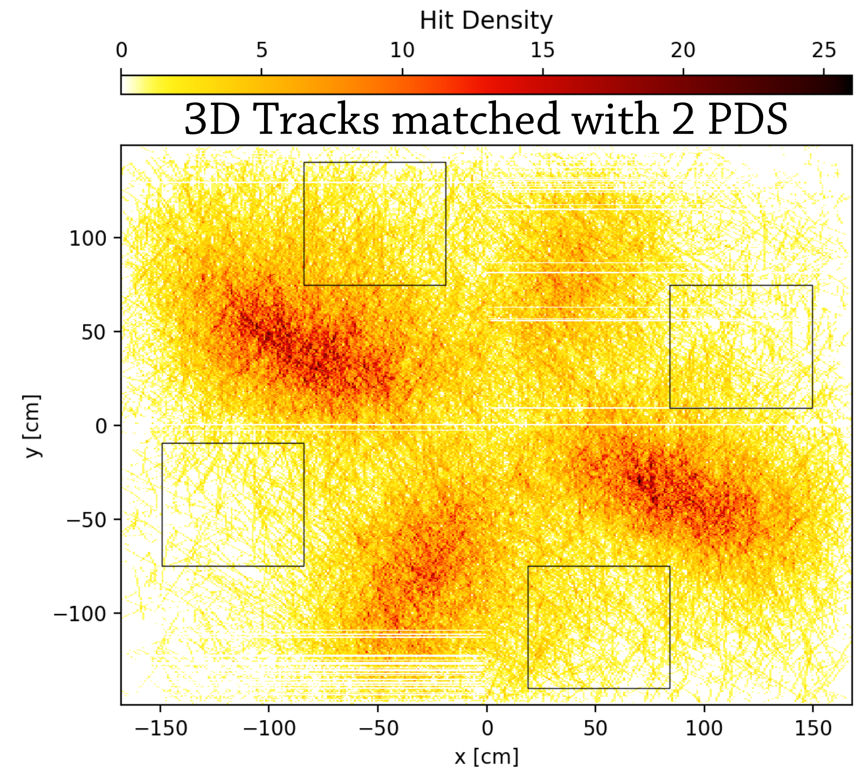


NB : Only using cathode ×-ARAPUCAs

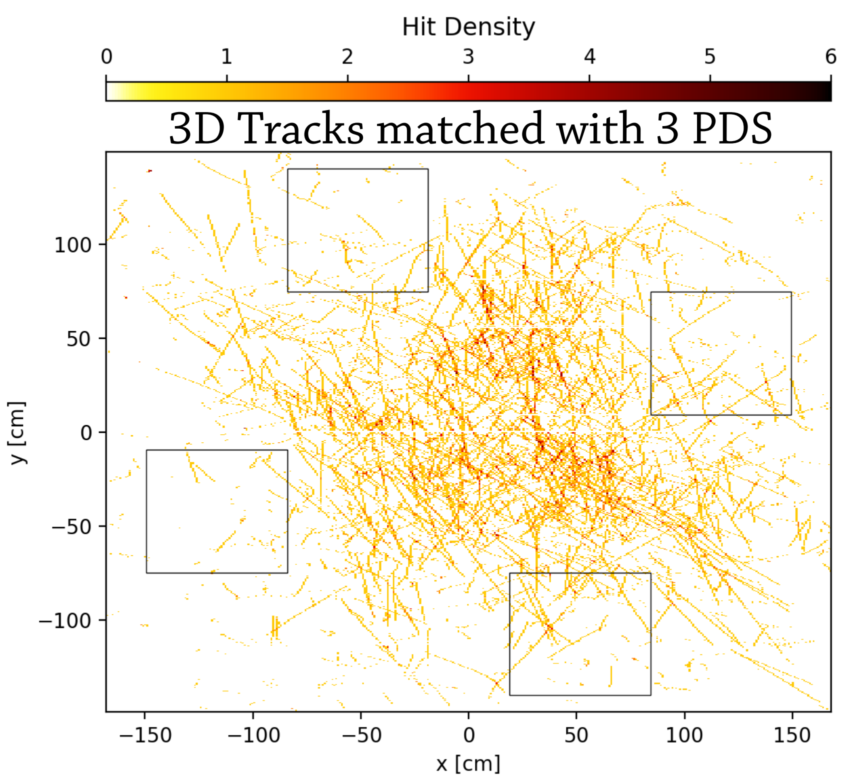
Track & Light (CRP6-II)

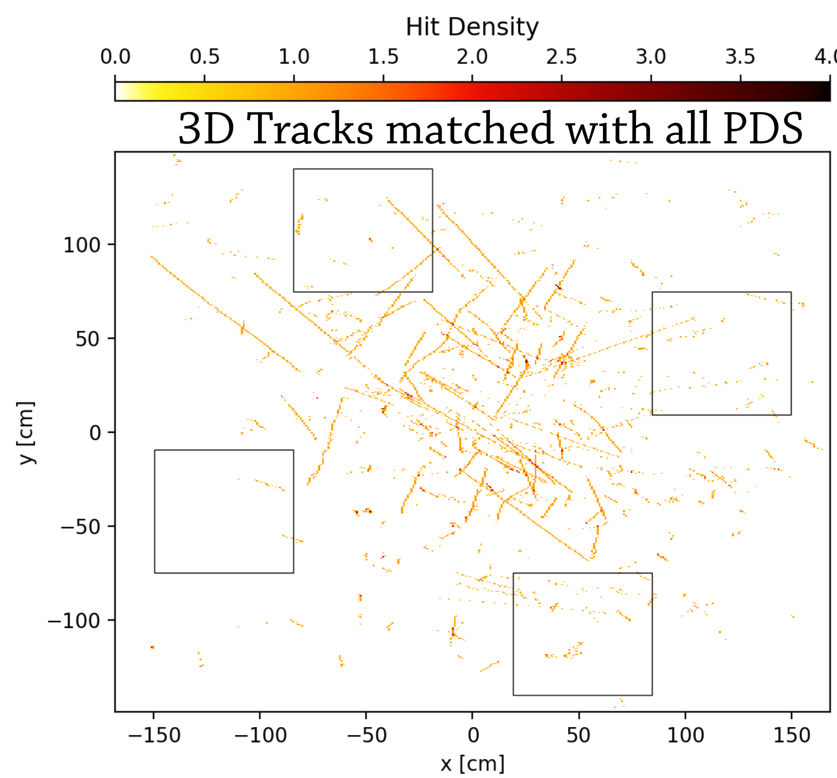
CRP6 - II Run 23868

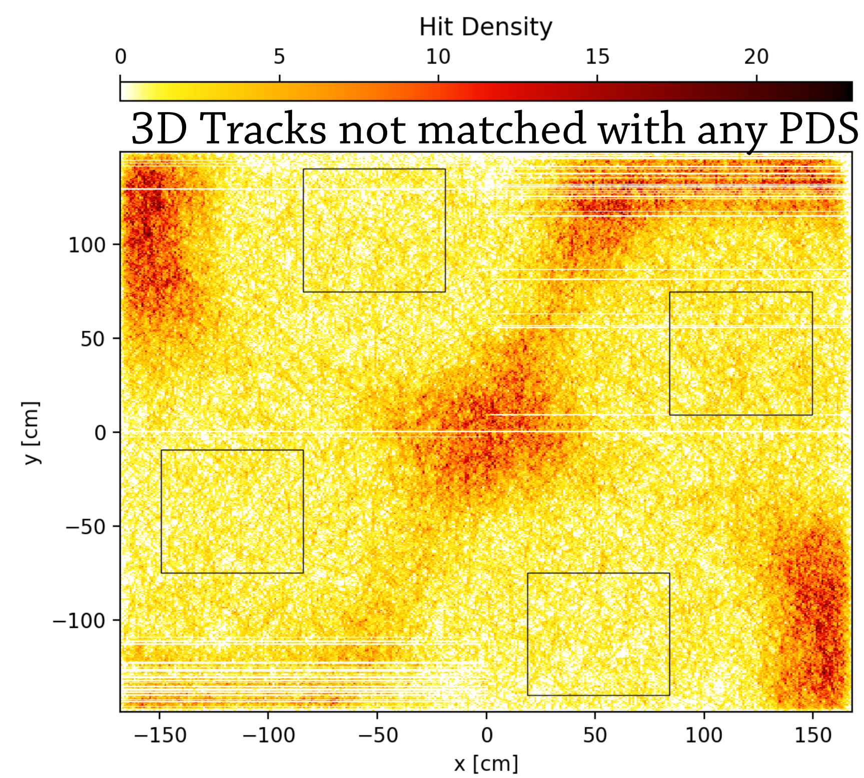




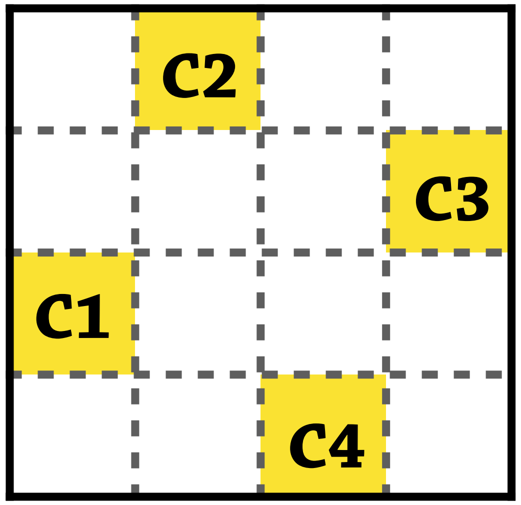
For comparison, same plots during CRP6-II operations
-> Most tracks was seen by only 1 PDS module





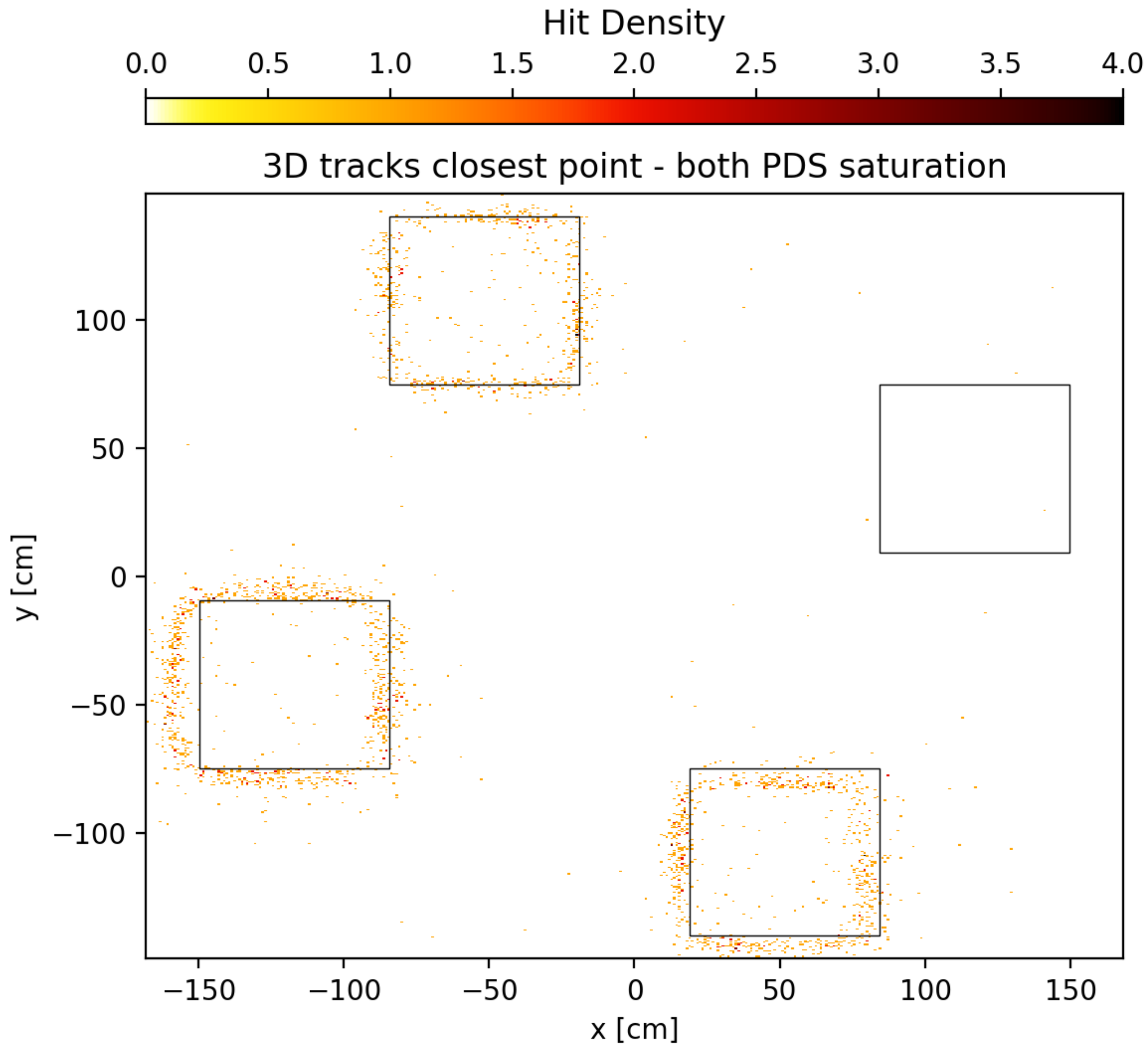


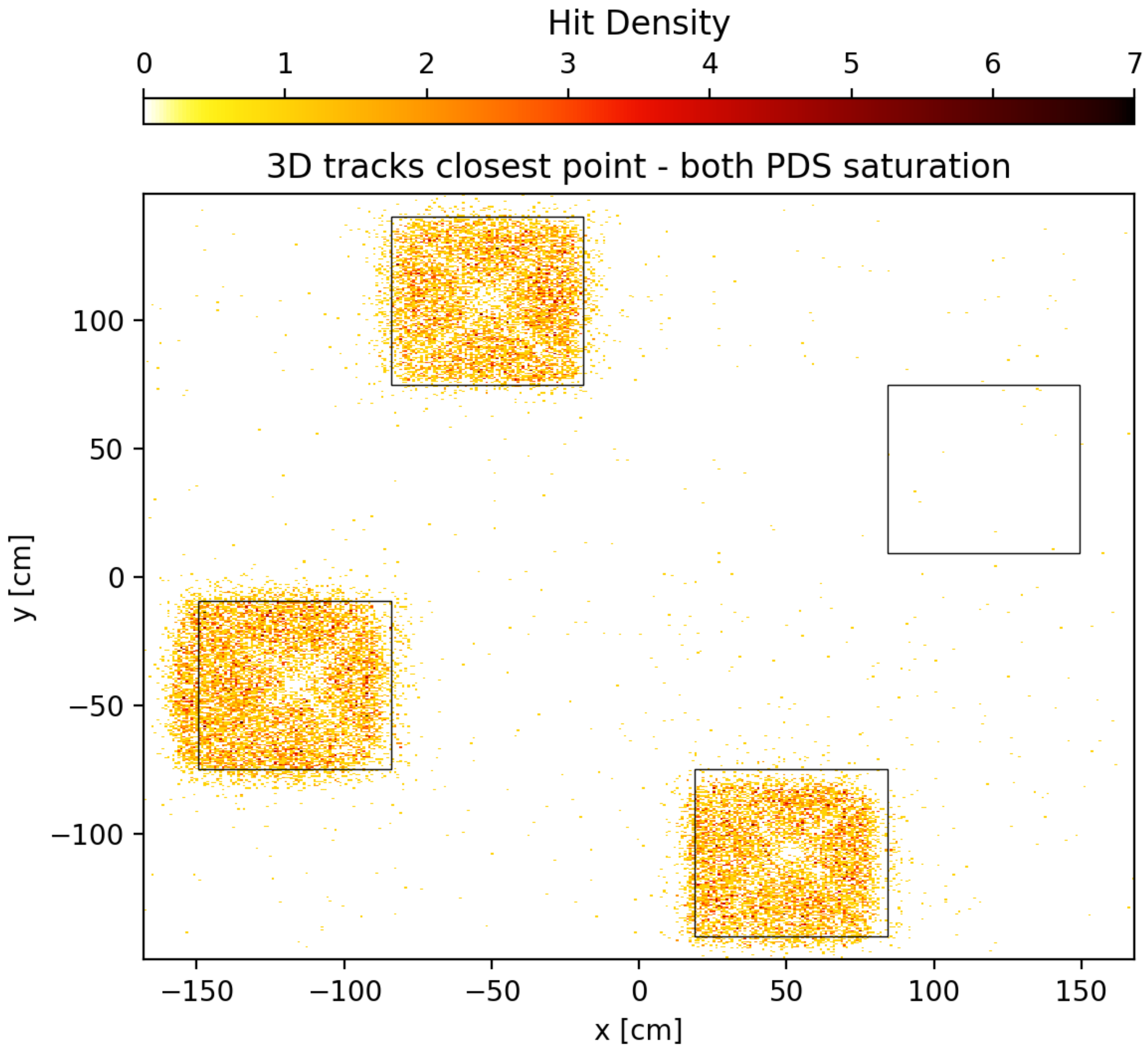
Closest track point to PDS when saturating



Look at the track-PDS closest point when the PDS system saturates
Left : When both saturates -> Get the outline of the x-arapucas
Right : Only one saturates -> Get the center and diagonals of the x-arapucas

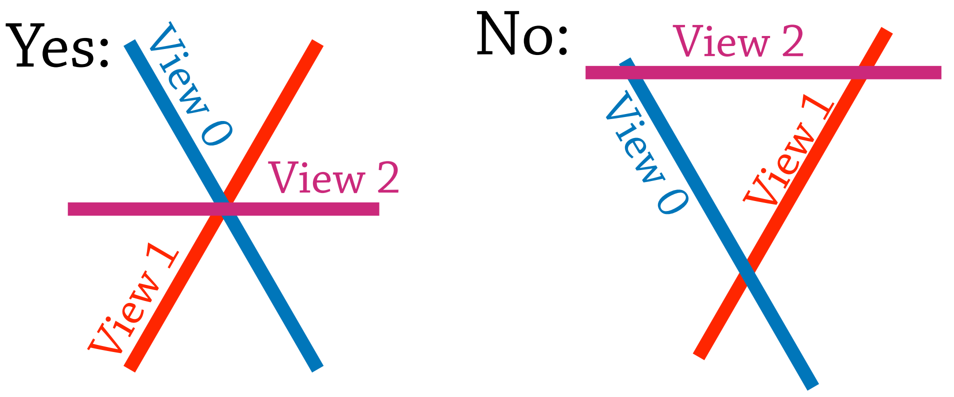
—> I obviously made a small mistake in C1 and C4 modules location
—> No C3 saturating events here (in CRP6-II run, C3 had issues)



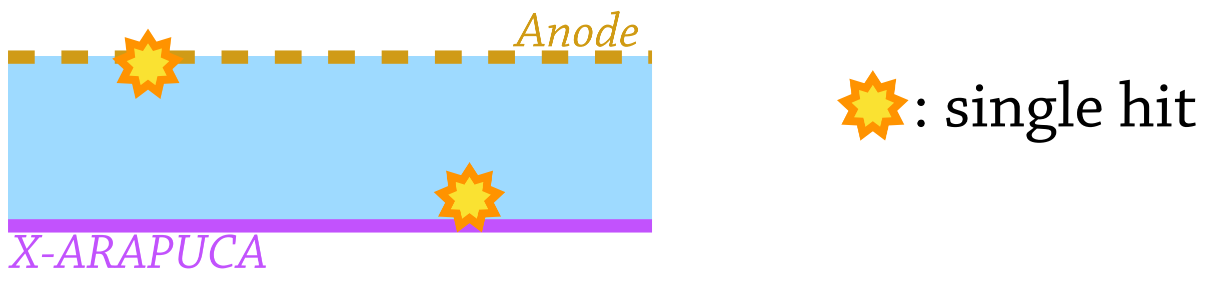


Single Hits reconstruction

Single Hits are found from the unmatched hits after track reconstruction:
- In each view, the isolated hit could be seen from 1, 2 or 3 consecutive strip
- Isolated hits from 3 views are assembled together if:
  - they are within a certain tight time tolerance
  - the reconstructed 3D position makes sense



Single-hit & light matching: two extreme cases



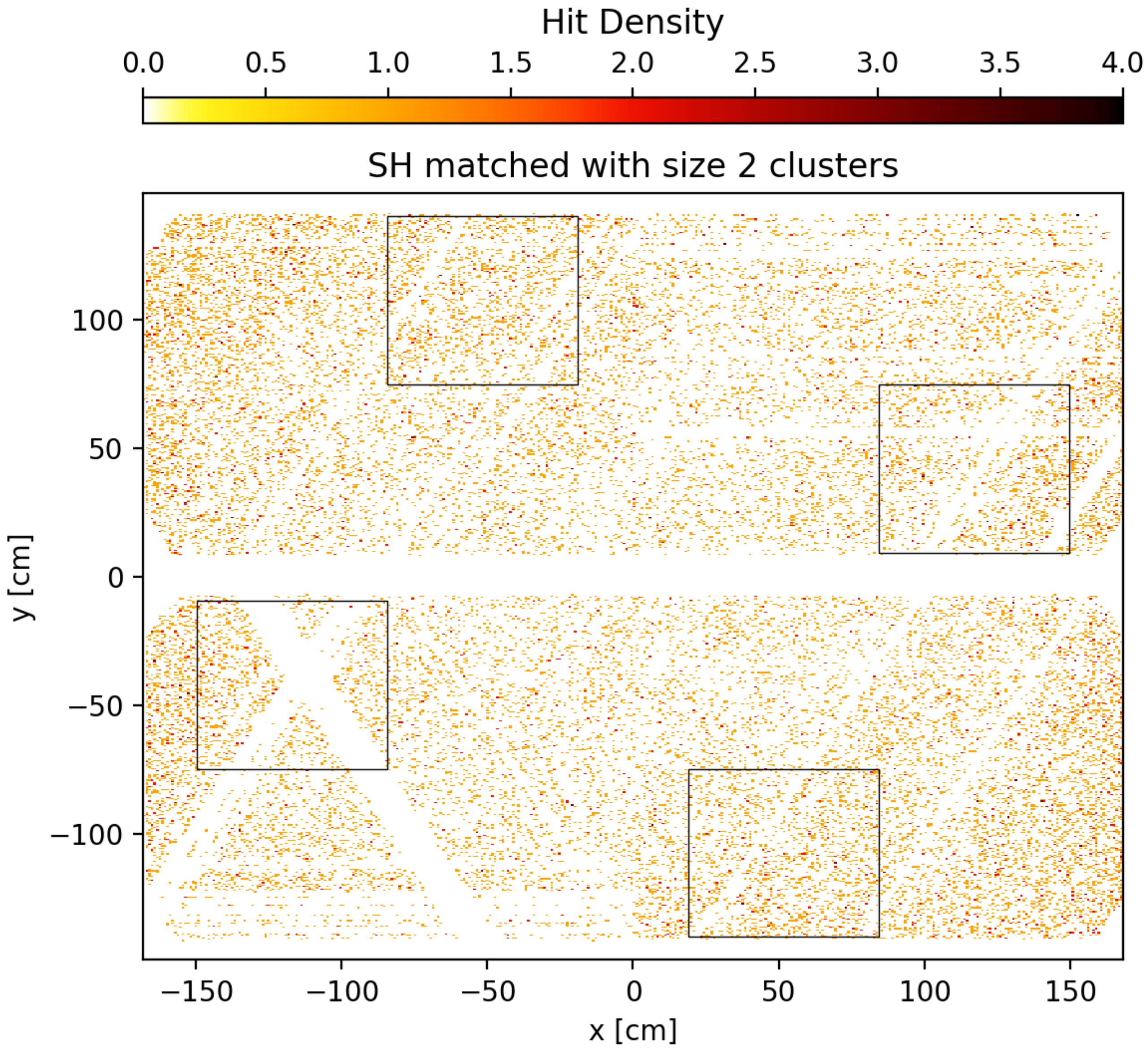
Single hit is at the level of the anode
↳ Charge and light signals are seen at the same time
-> Δt ~0μs [+ some pipeline delays]

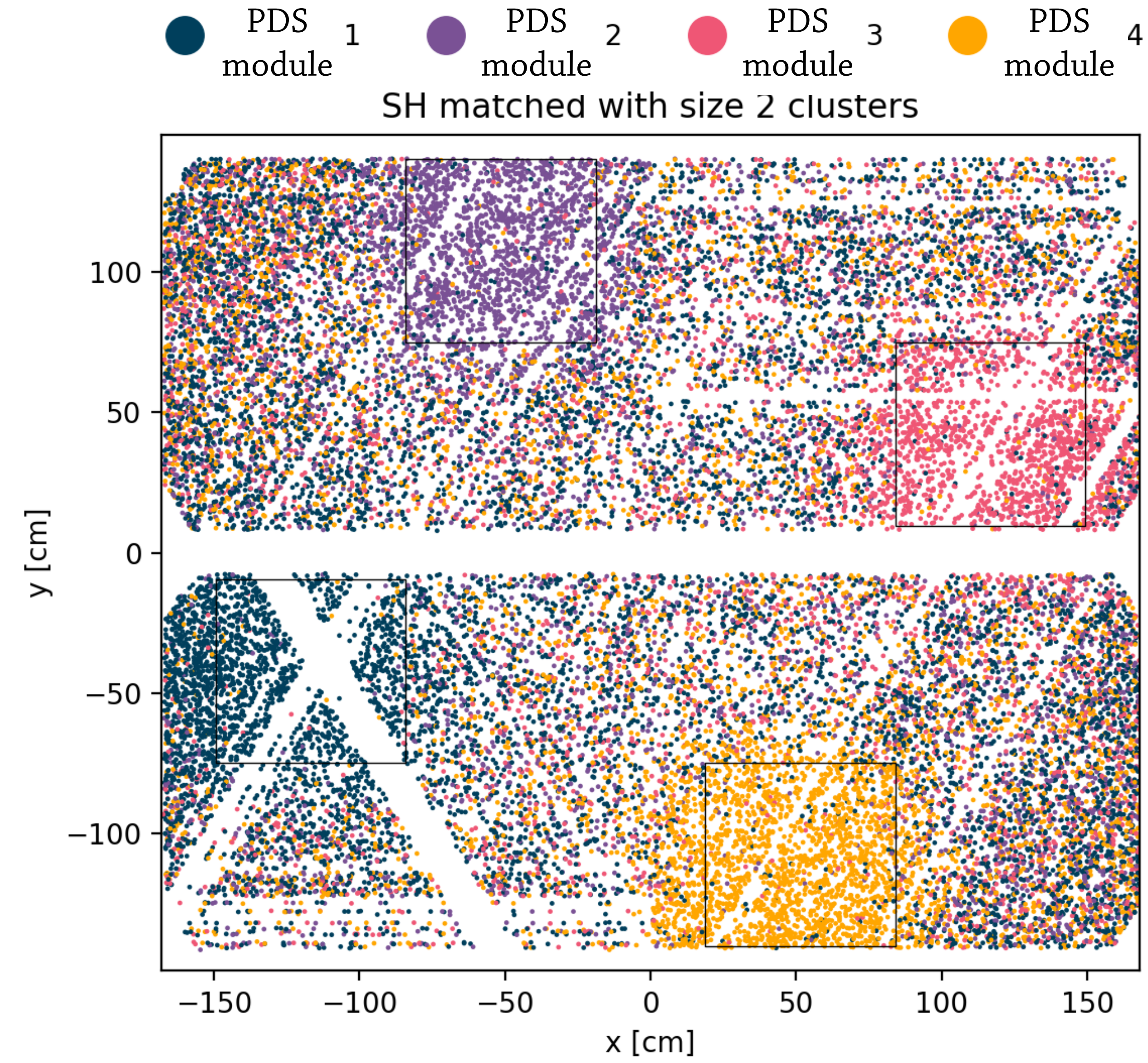
Single hit is at the level of the cathode
↳ Charge signal is seen t_{drift} after the light
-> Δt ~140μs [+ some pipeline delays]

Single hits are merged with a light cluster if there is no other light cluster in [t_{SH} ; t_{SH}+140μs]
-> From the light / charge delay, one can compute the depth of the single hit

Single Hits matched with size 2 clusters

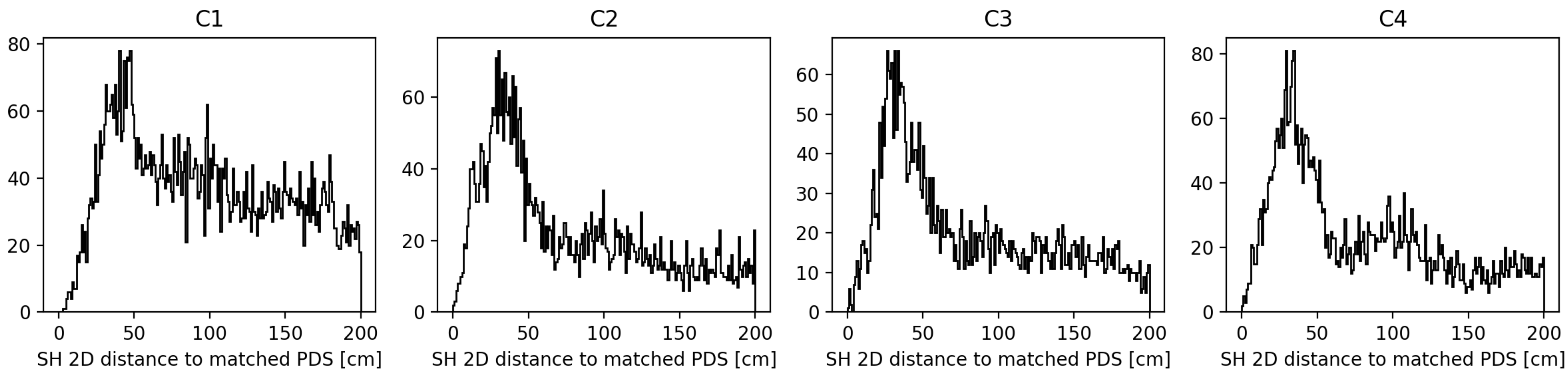
The code finds single-hit—light clusters matches irregardless of the spatial conditions
-> There are a lot of mismatches, but single-hits above the x-arapucas are mostly correctly matched





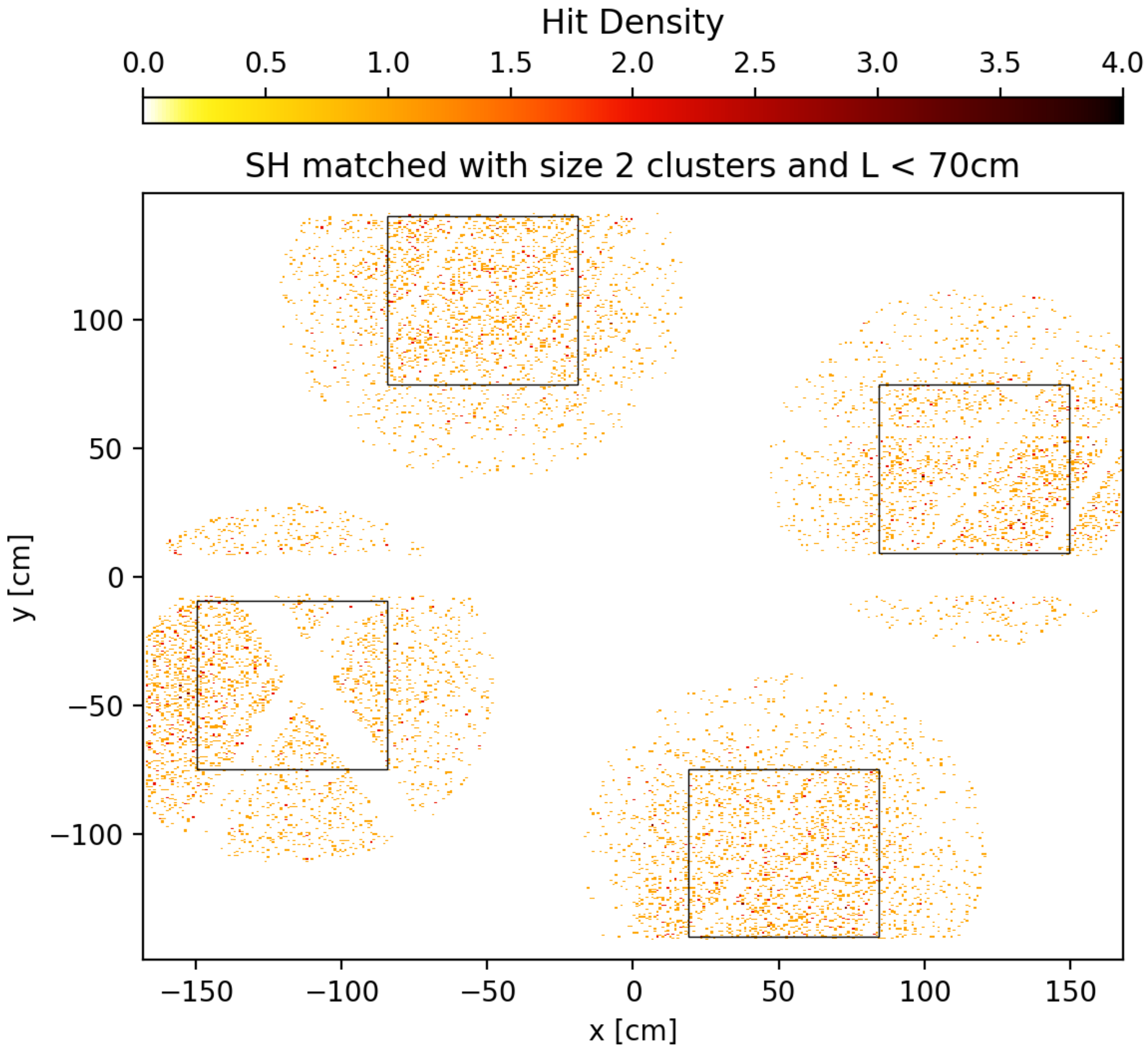
Single Hits matched with size 2 clusters

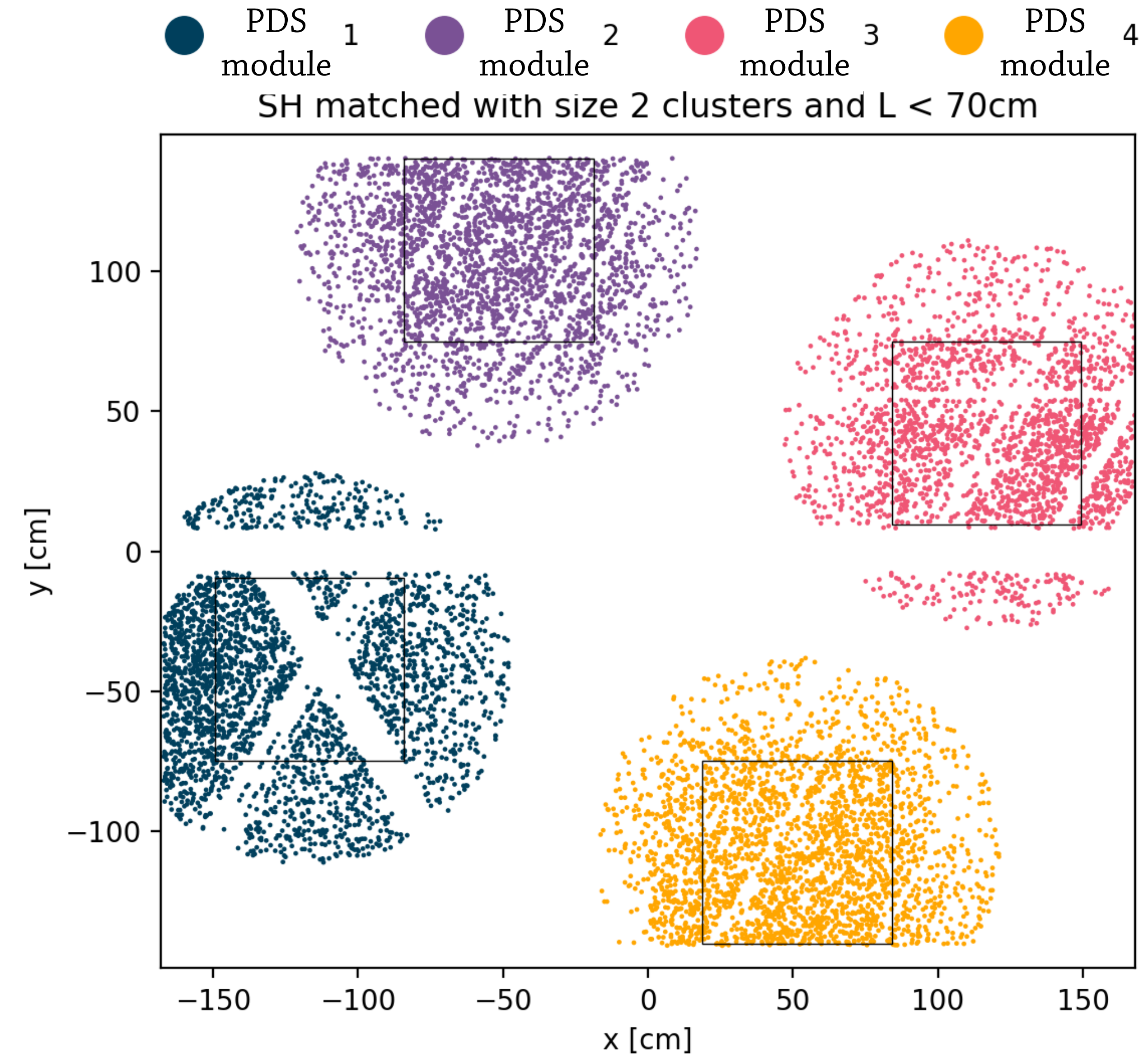
To select the 'good matches', I compute the SH—(×-arapuca center) transverse distance for all matches
-> I only select matched single-hits when that distance is <70 cm



Single Hits matched with size 2 clusters

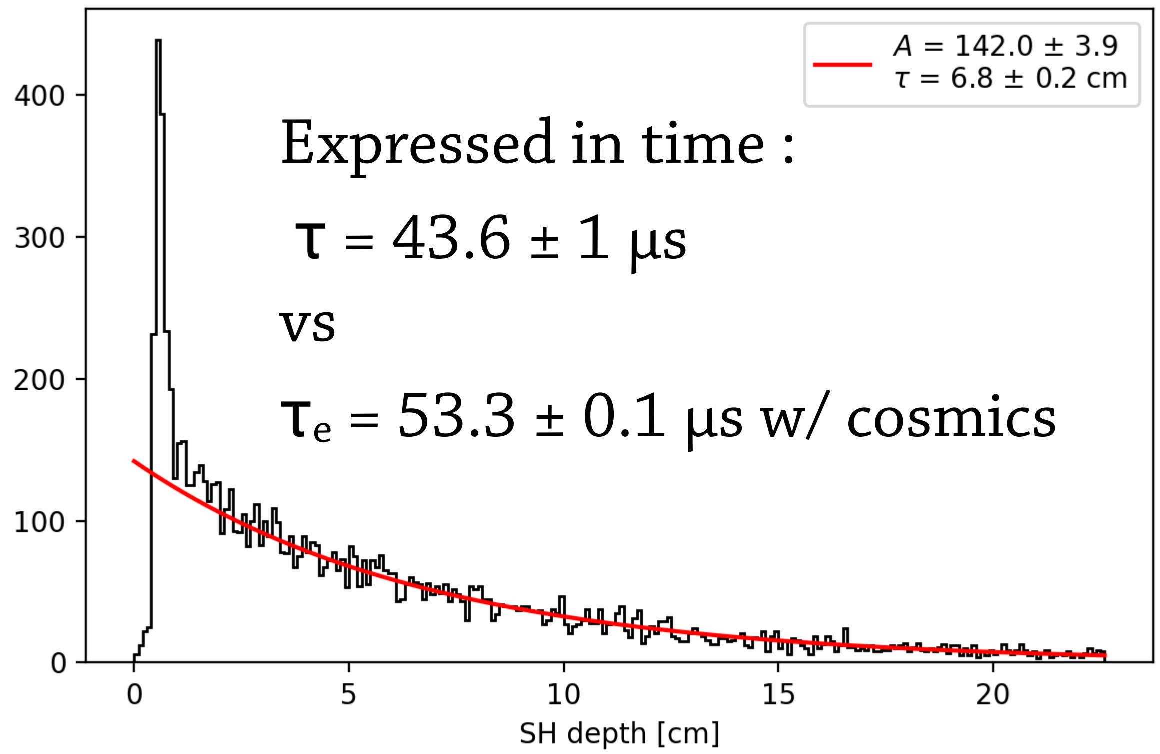
Matched single-hits— PDS clusters (size 2) when the 2D distance < 70 cm





-> There is no single hits matched with multiple x-ARAPUCAs modules

Single Hits matched & selected delay/depth

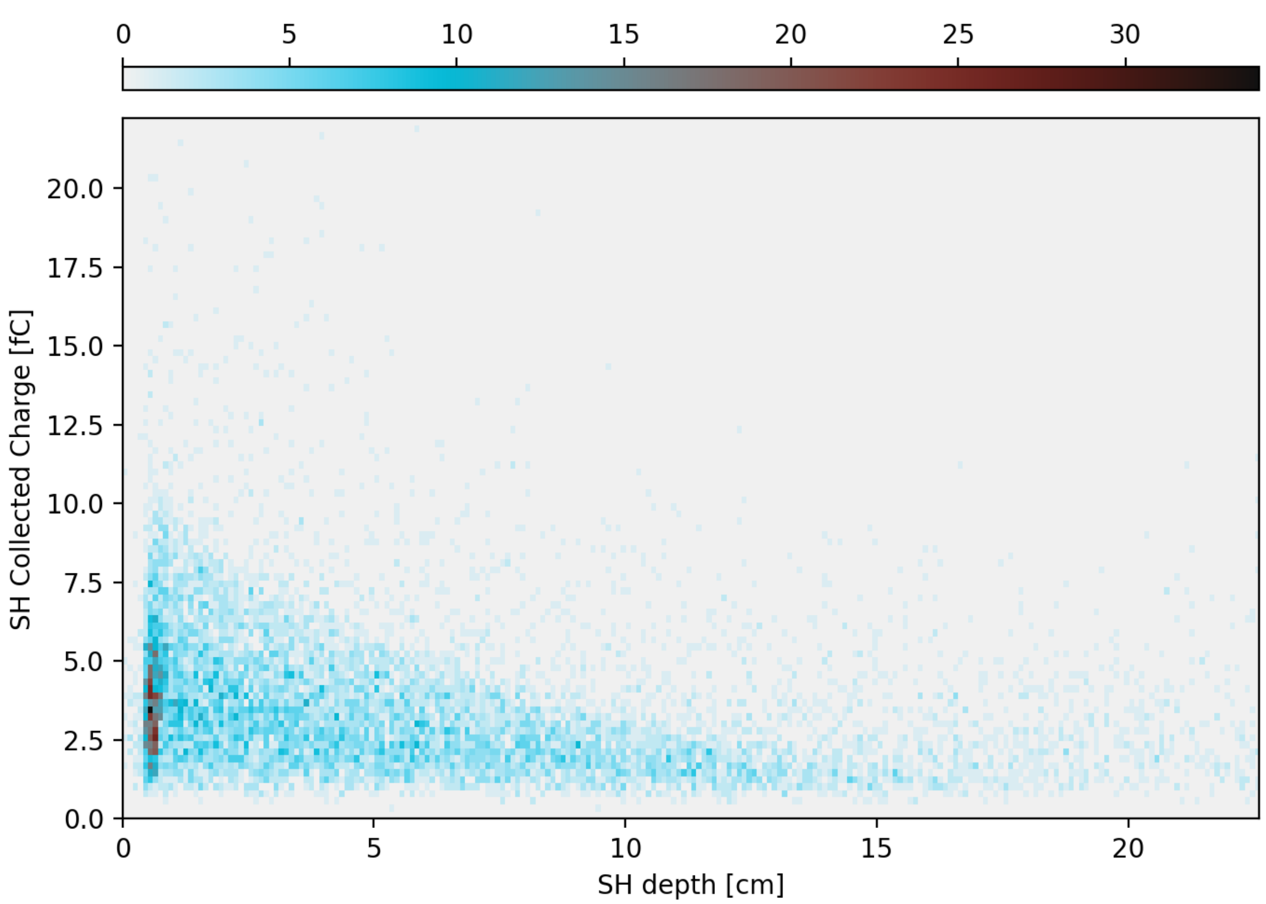


With the delay between light and charge detection, one can estimate the Z position of the matched single hit, or their depth w.r.t to the anode.

-> Excess at small depth <-> Lot of single hits at the level of the anode

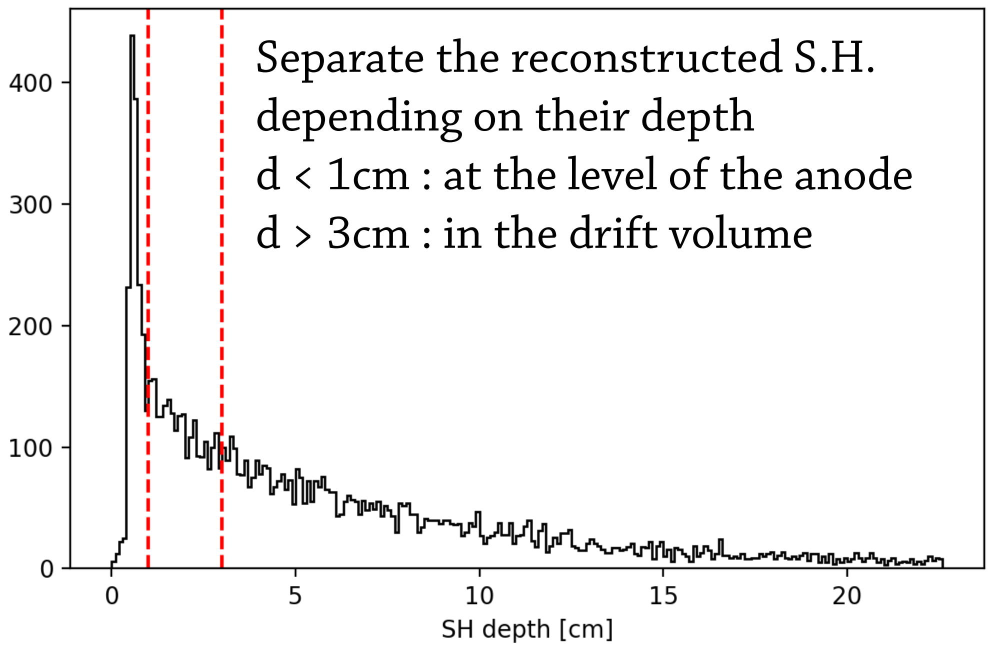
-> Amount of reconstructed single hit vs depth follows an exponential decay ;

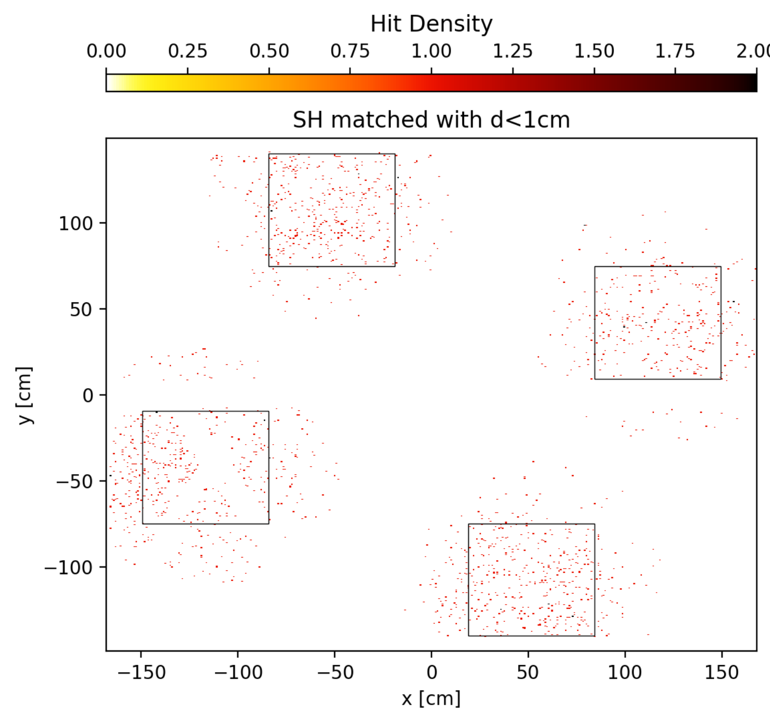
Linked to the amount of impurities, but I'm not so convinced that it provides a direct measurement of τ_e

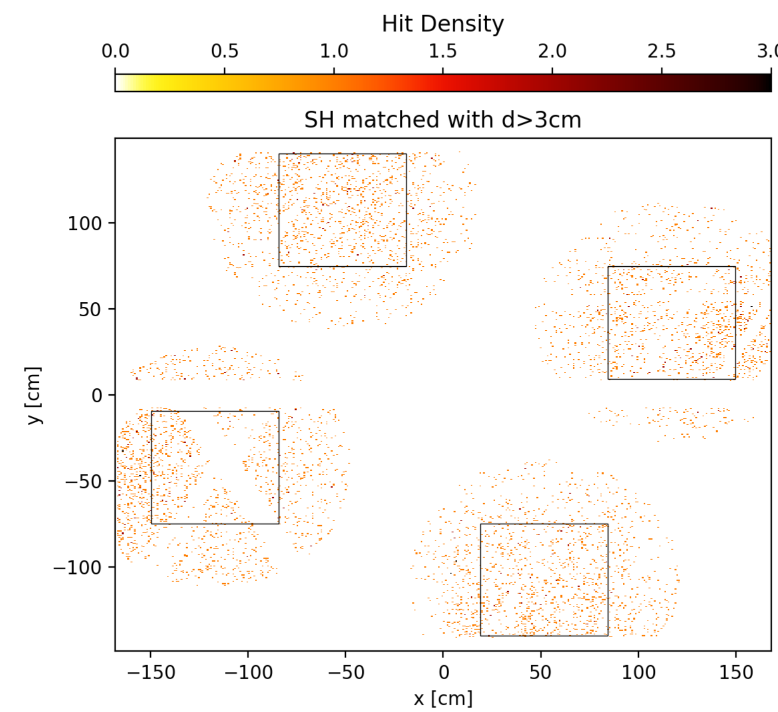


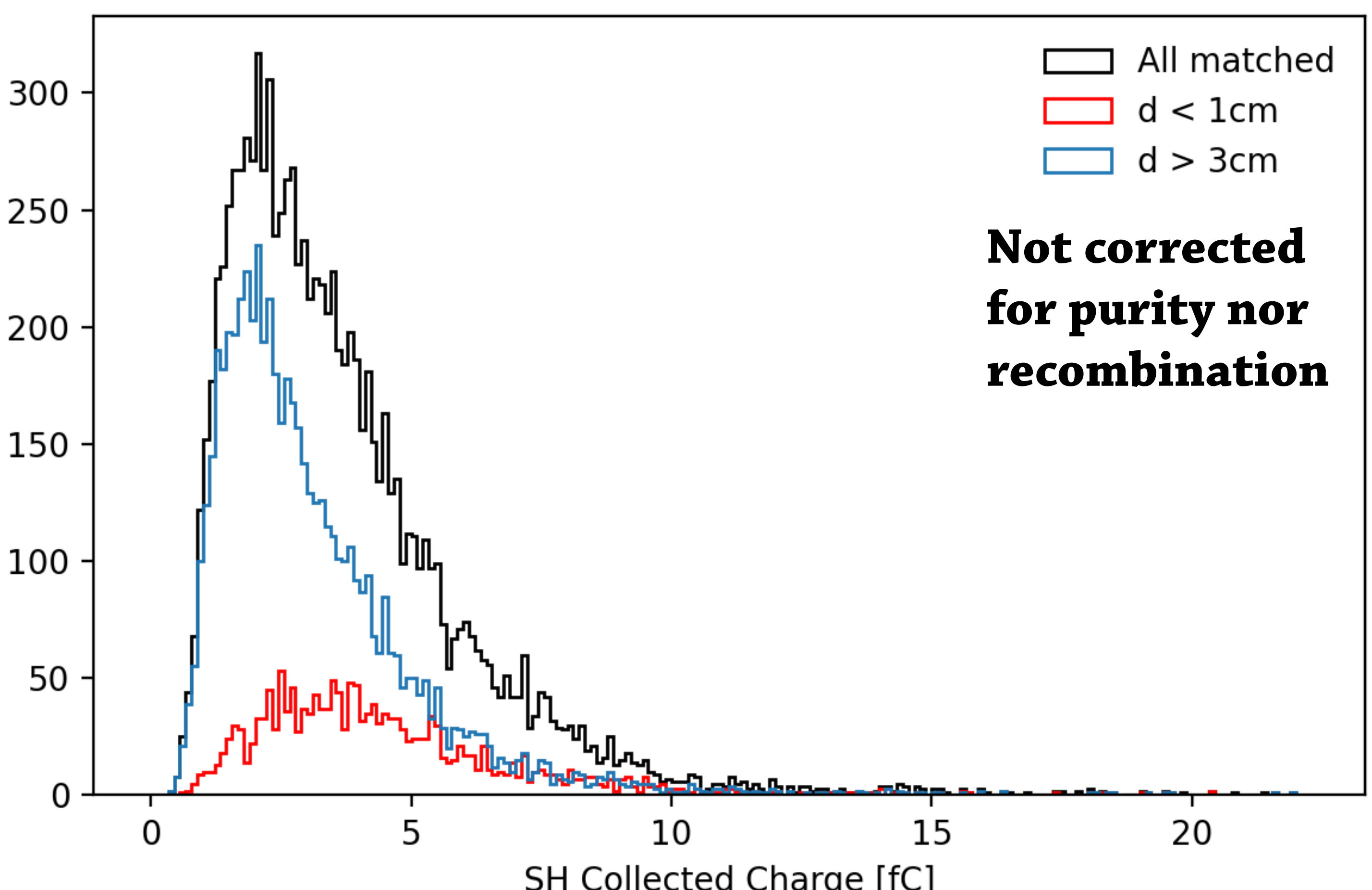
The amount of charge collected vs depth follows an exponential decay due to the impurities, which is a convincing observation that most matchings are not random association

Single Hits matched & selected at depth





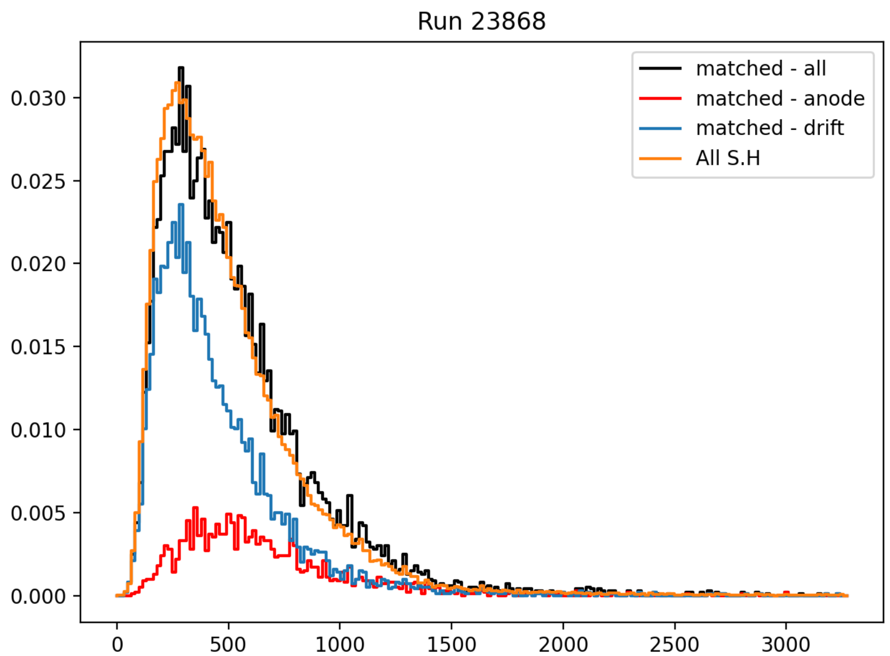




- There is no preferred location of SH reconstructed at the level of the anode and in the liquid argon
- The collected charge distribution for S.H. in the anode (d<1cm) is very different from the S.H. in the drift volume
- NO purity corrections on the spectrum as it would strongly bias the spectrum to large depositions !

Single Hits matched & selected

In terms of collected charge, all matched single hit spectrum is the same as the one from all single hits reconstructed in this run.



Looking at the K^{40} and U^{238}, and Th^{232} decay chains β emitters spectrum if located

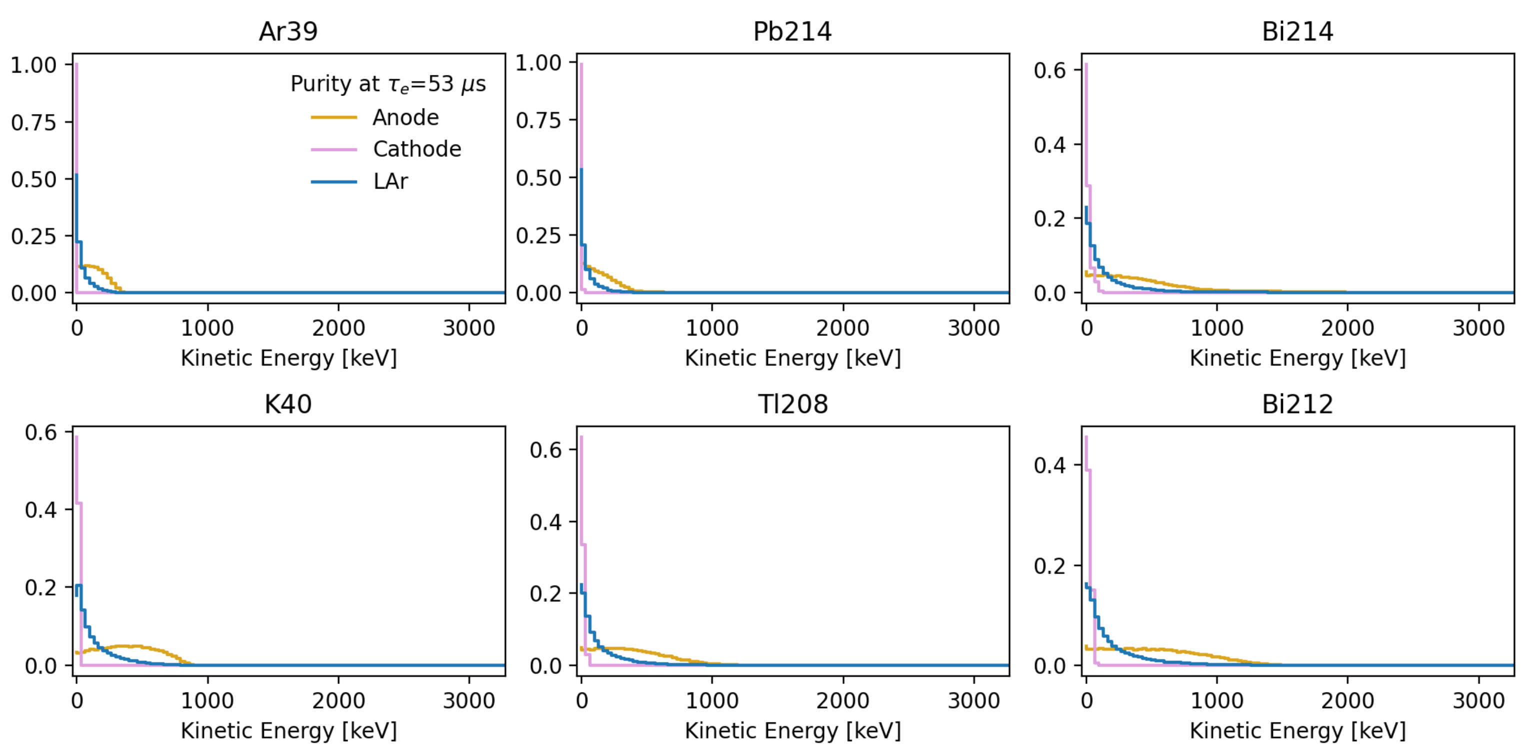
- at the anode (no purity effects)
- in LAr (integral of the purity effects along the drift
- at the cathode (maximal purity effect)

-> <u>The PCB anode radio-purity is estimated at</u>:

U^{238} : 5 Bq/kg

Th^{232} : 7 Bq/kg

K^{40} : 6.8 Bq/kg



- The 'anode' charge spectrum could be a mixture of K^{40} and Bi^{212}
- The 'drift' spectrum is little harder to understand

To investigate :

- Isotope migrations into LAr
- α emitters (different recombination)
- reconstruction efficiency & resolution

Perspectives

The single-hits & light matching algorithms could be improved
- the currently very strict 'no ambiguity' condition can be lifted up by 'no ambiguity with the closest PDS module' of the single hit to increase the statistics

If the excess at low depth is due to radio-impurities in the PCB:
- with the current reconstruction algorithm, we are only looking at decays on the shield plane
- can look at single hits only seen by two views :
View 1 + View 2 : would be decays from the upper face of the 1st PCB
View 0 + View 2 or View 0 + View 1 : would be used to estimate the false matching rate

Most of CRP6 data was taken with not so good LAr purity
- anode excess should (and does not seem to be) be affected by the impurities
- make it harder to interpret/fit the spectrum of impurities in LAr