Analysis with DPD reprocessed files

- UPDATE -

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Interesting runs

Charge runs	***Light runs***	***Trigger***	***Drift field***	***Extraction Field in liquid***	***Amplification Field***	***Induction Field***
840 *842*	*1406* *1407* *1408*	*PMT*	*0.49*	*1.85**	*28**	*1.5**
993	1671	CRT	0.48	2.14	25.5	1
996	1682	PMT	0.48	2.14	26	1
997 998 999	1683	PMT	0.48	2.15	26.5	1
1003	1685	PMT	0.49	2.1	27	1
1007 1008 1009 1011	1687	PMT	0.48	2	27	1.25
1012 1013 1014 1016 1035	1688 1689 1690	PMT	0.48	1.95	27.5	1.25

** : only for central LEMs*

Analysis Improvements

I have made several changes to the DPD reconstructed variables :

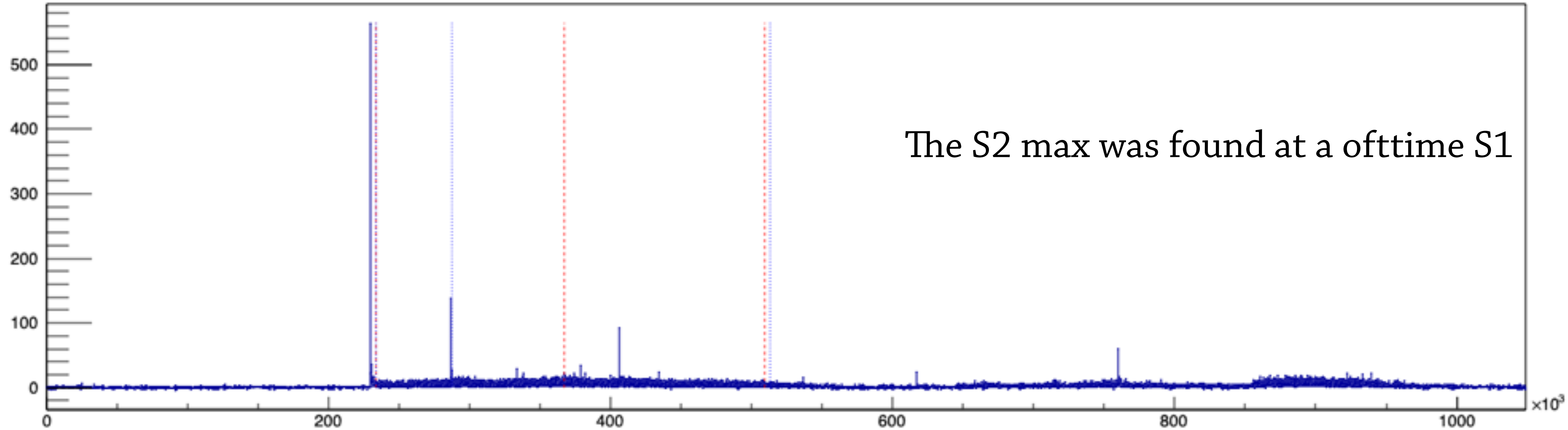
- Computation of the pedestal and standard deviation :
  Computed in several points of the waveforms - at least two measurements should agrees within standard deviation

- Search for S1 peaks (trigger and off-times):
  Don't use the TH1->Rebin(x) method, but do a smooth scan instead

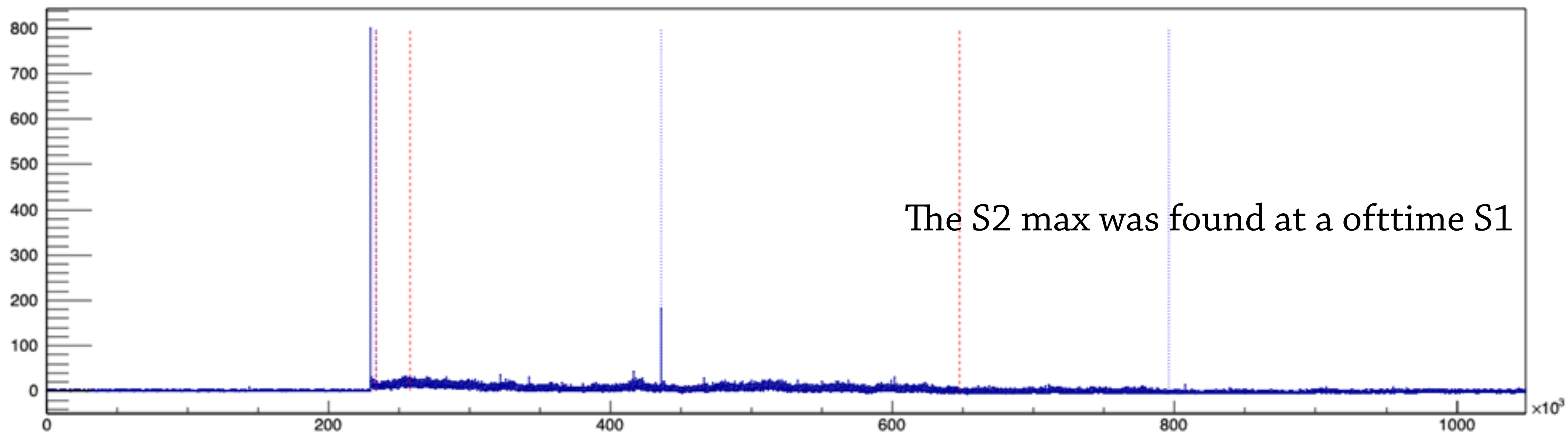
- Search for S2 signal :
  Remove the S1 peaks from the waveform [-40ns ; 1μs], replace it with an interpolation of the signal
  Search for the waveform maximum with a smooth scan (no Rebin(x))
  Search for the start and ending point of S2 (threshold being 3.5×pedestal std. dev.)

S2 reconstruction examples

start - max - end of S2 signal reconstructed in DPD and with my code



The S2 max was found at a offtime S1



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S2 reconstruction examples

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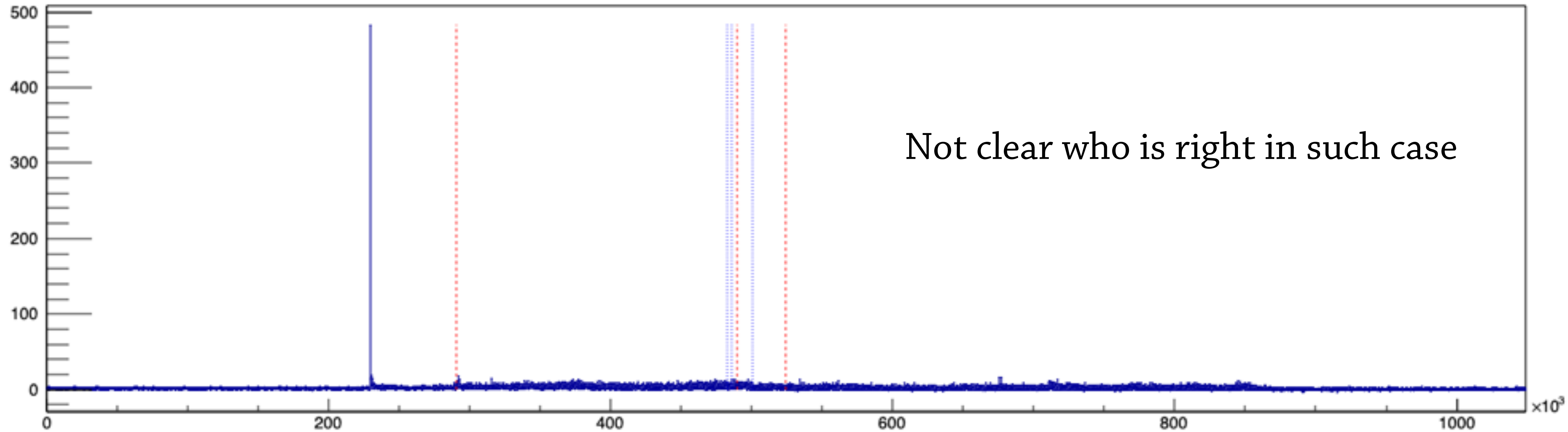
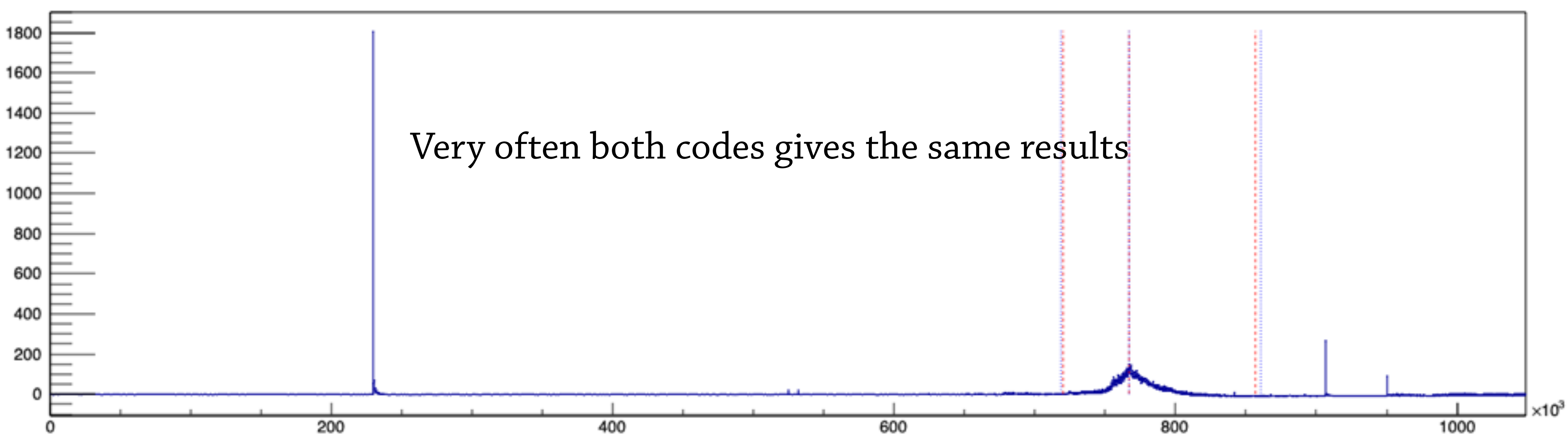




μ-like track selection [reminder]

Trigger muon-like selection :

- Track has to be longer than 25 cm
- Leading track of the event (takes the most reconstructed charge)
- Track mean CBR < 0.25 in both views
- Track has an entering and an exiting point of the field cage-anode-cathode volume

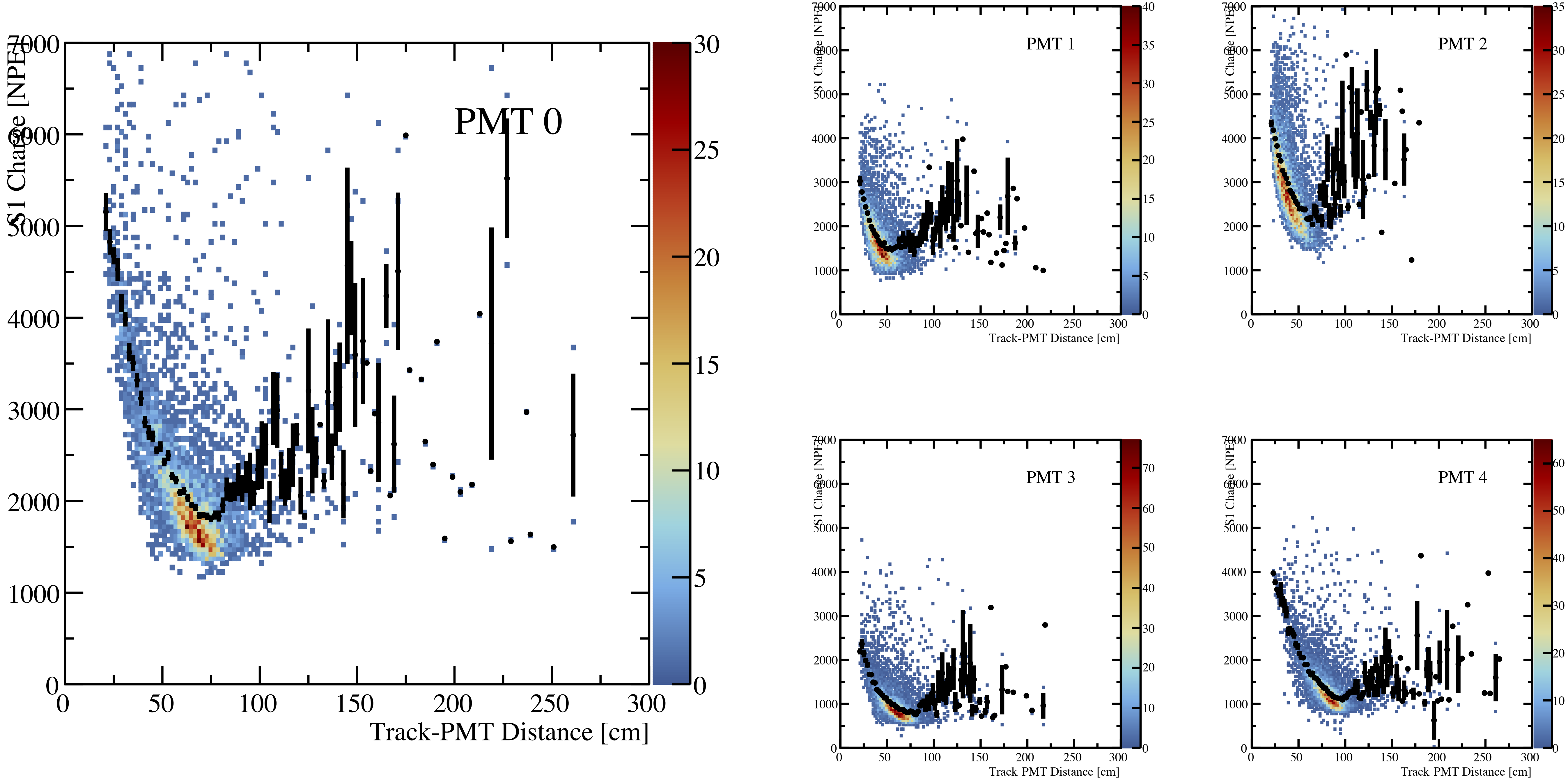
Off-time muon-like selection :

- Track is longer than 40 cm
- Not the leading track
- Mean CBR < 0.25 in both views
- If earlier than t_0 :
  Track has a reconstructed entering point at the anode, no exit point

  If later than t_0 :
  Track has no reconstructed entering point, reconstructed exit point is below the cathode

S1 charge vs track-PMT distance

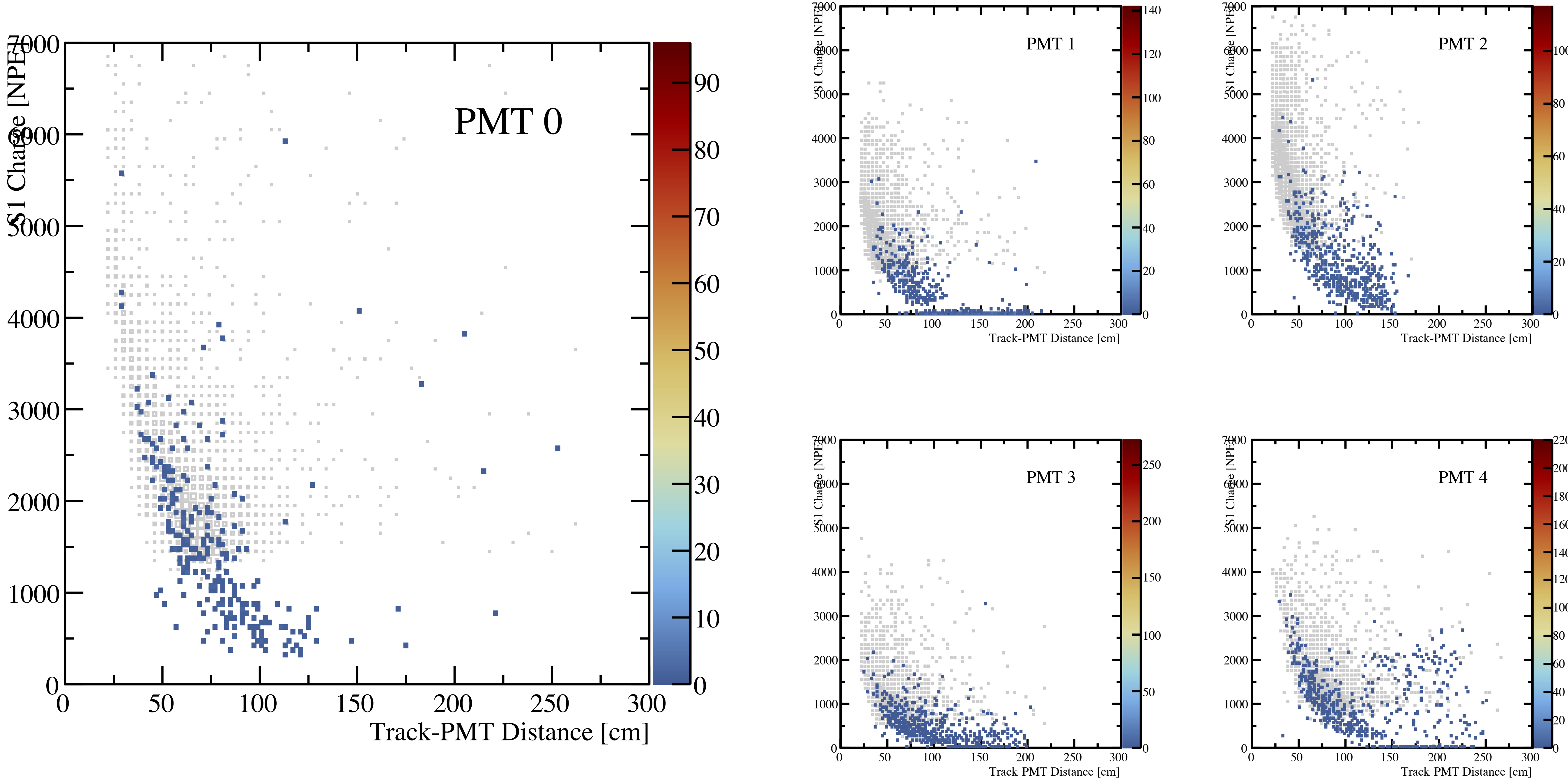
Only trigger S1 + default TProfile of ROOT



-> Should we keep using TProfile as some outliers shifts the mean value ?

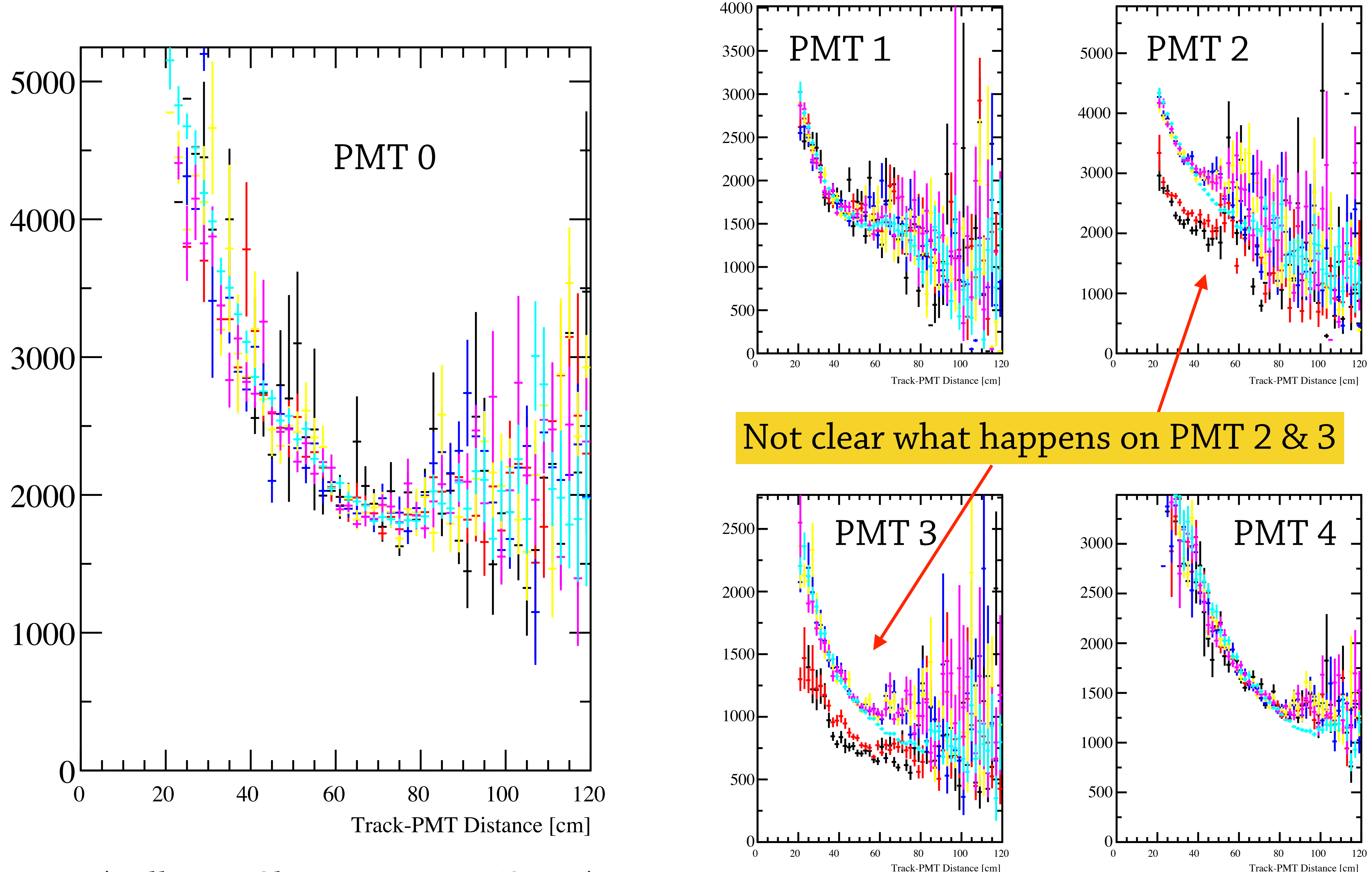
S1 charge vs track-PMT distance

Trigger S1 + ofttime tracks



S1 charge vs track-PMT distance (PMT trigger)

runs 996, 997..., 1003, 1007..., 1012..., 840...

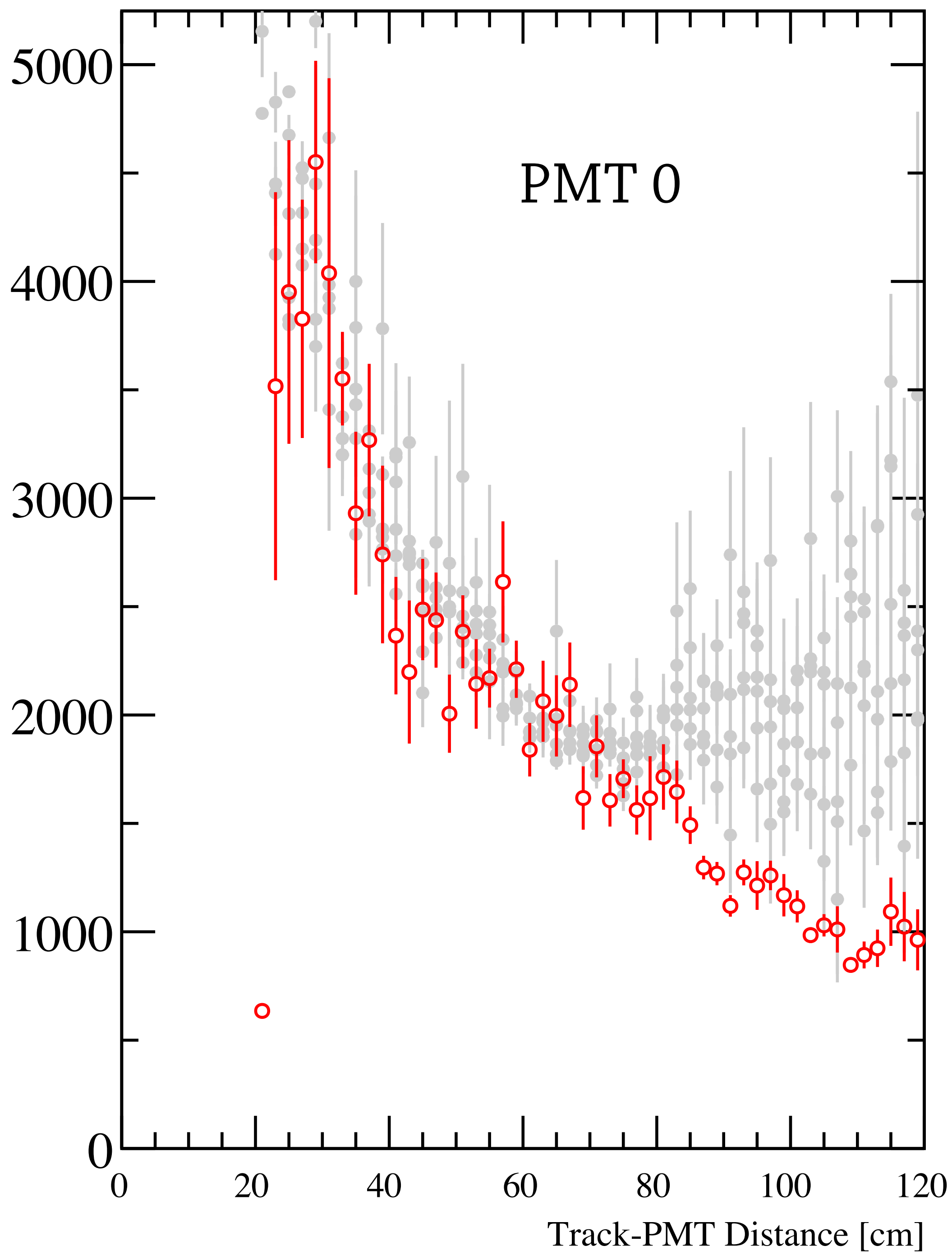


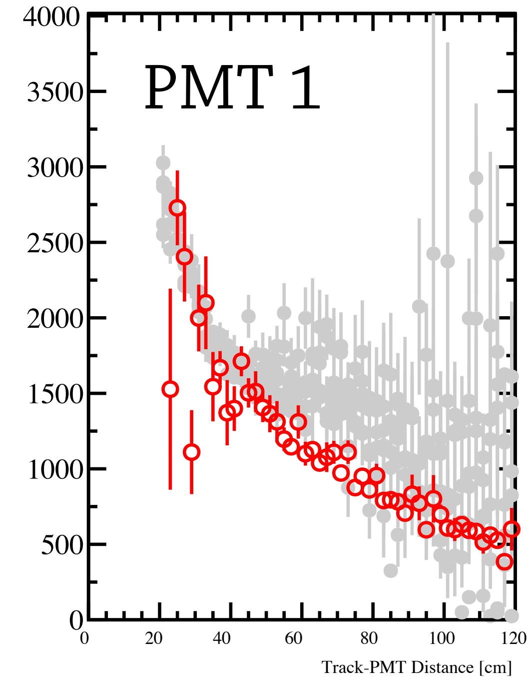
(still TProfile - trigger + offtime)

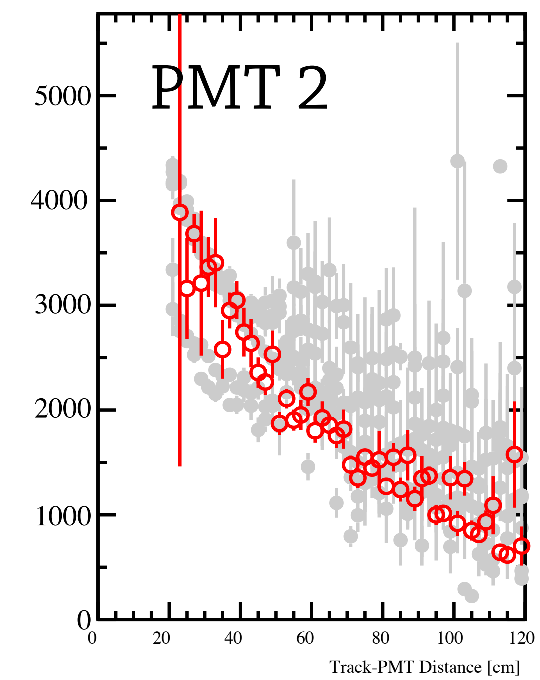
S1 charge vs track-PMT distance

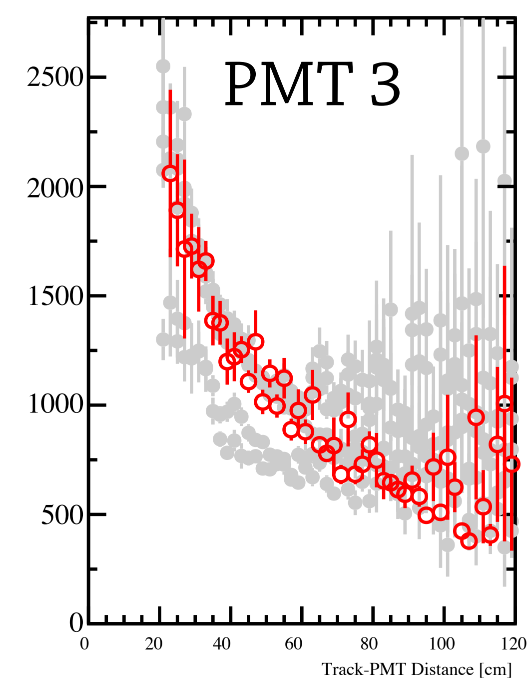
runs 996, 997..., 1003, 1007..., 1012..., 840... (pmt trigger)

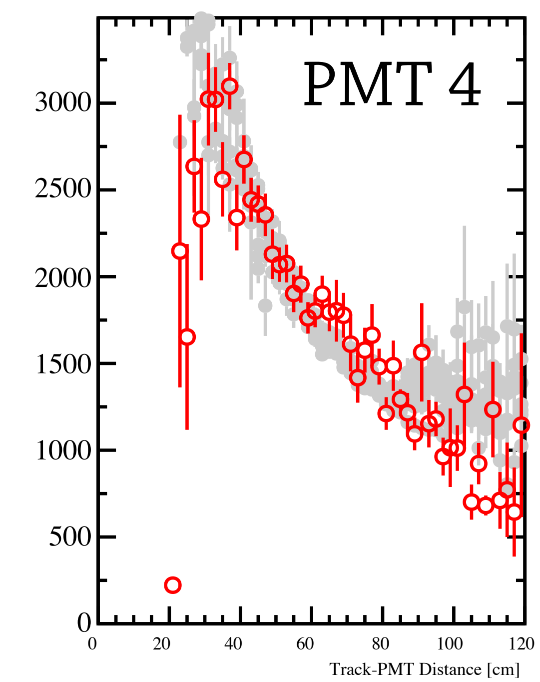
run 993 (crt trigger)









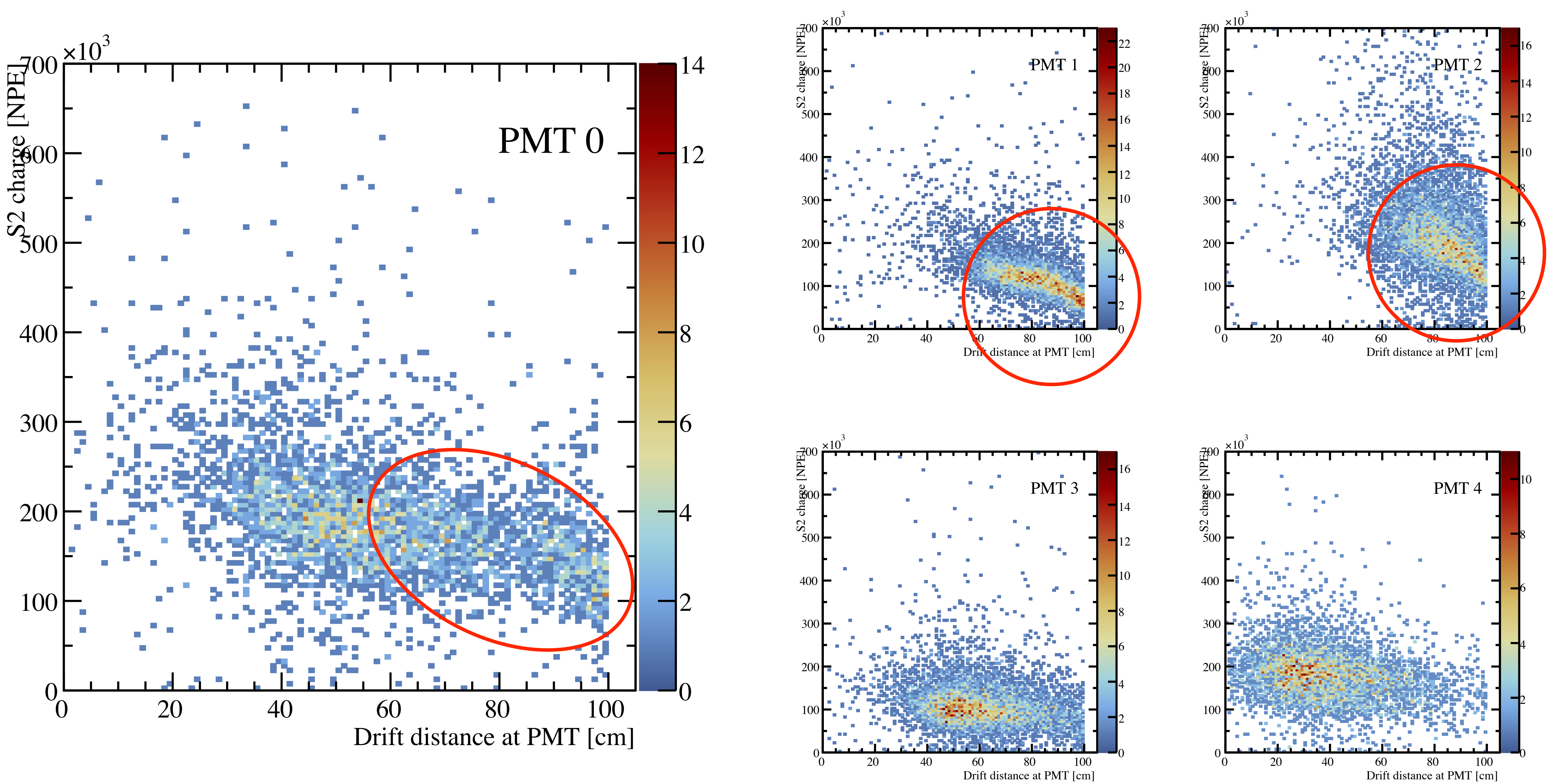


(still TProfile)

On the S2 signal - previously

From the charge analysis, we know that the electron lifetime ≥ 4ms ↔ charge reduction of ~15%

The S2 signal should reflect the good purity and be almost flat w.r.t. the e^- drift distance
↳ Not really what is measured



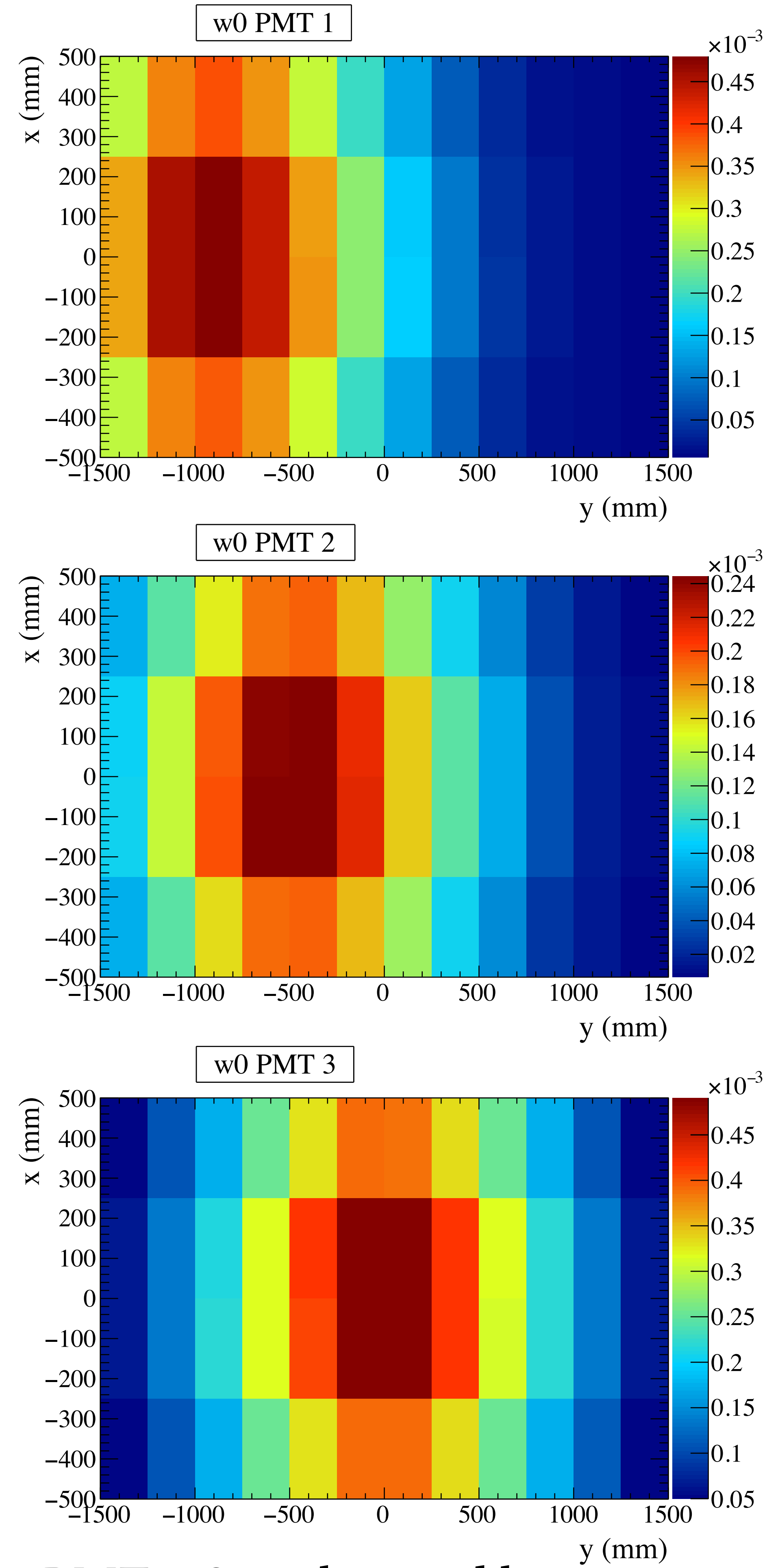
(run 840-842, same behavior in all runs)

S2 visibility

The (x-y) S2 visibility maps for each PMT are extracted from the current light maps, here with rayleigh at 55 cm.

→ The visibility difference between voxels above the PMT and voxels far away is not very huge: factor of 3-4.

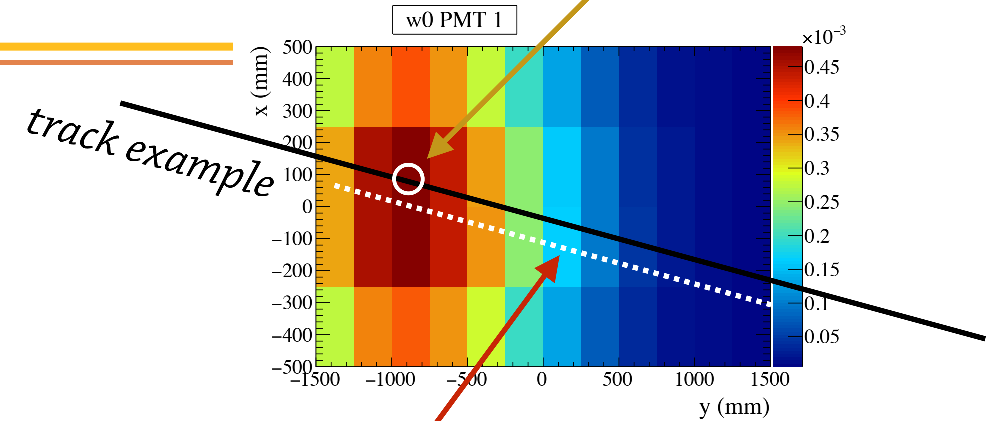
This means that the S2 signal seen by each PMTs cannot be just considered originating from the track portion above it ; there is a non-negligible amount picked up from the whole track



PMT 4 & 5 obtained by symmetry

S2 visibility test with tracks

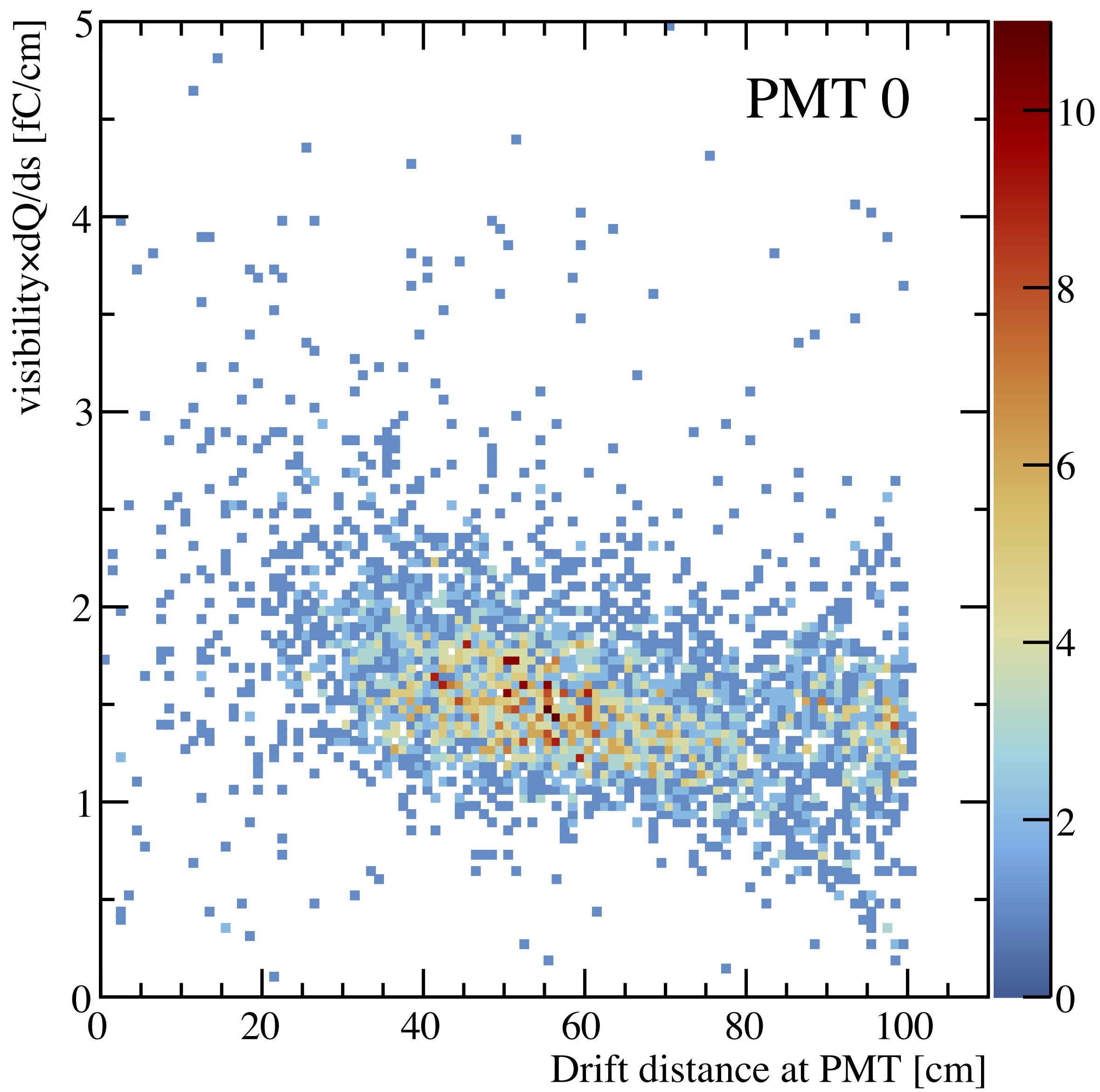
S2 for PMT 1 is not just from this part

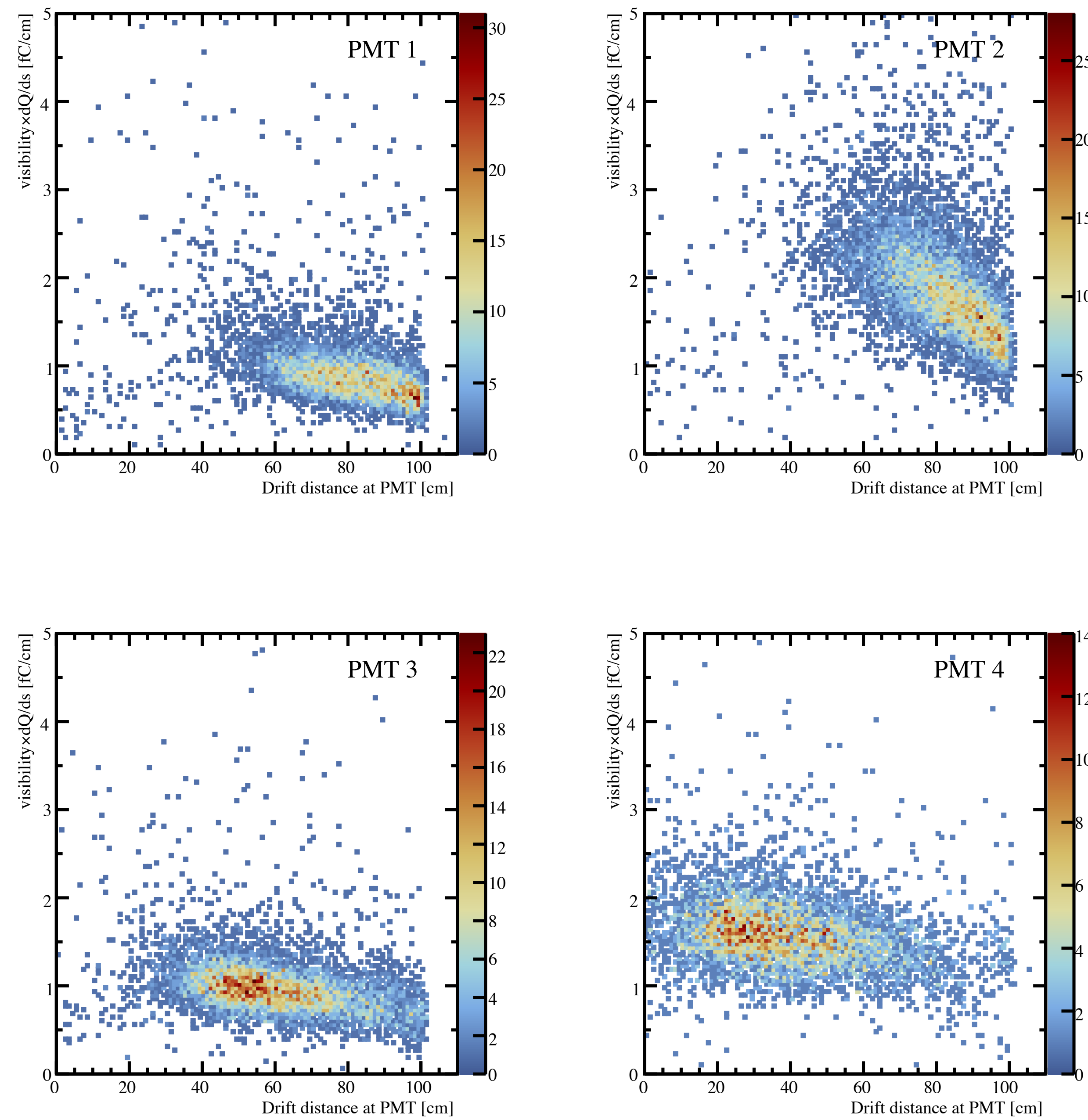


but a reweighed sum along track path

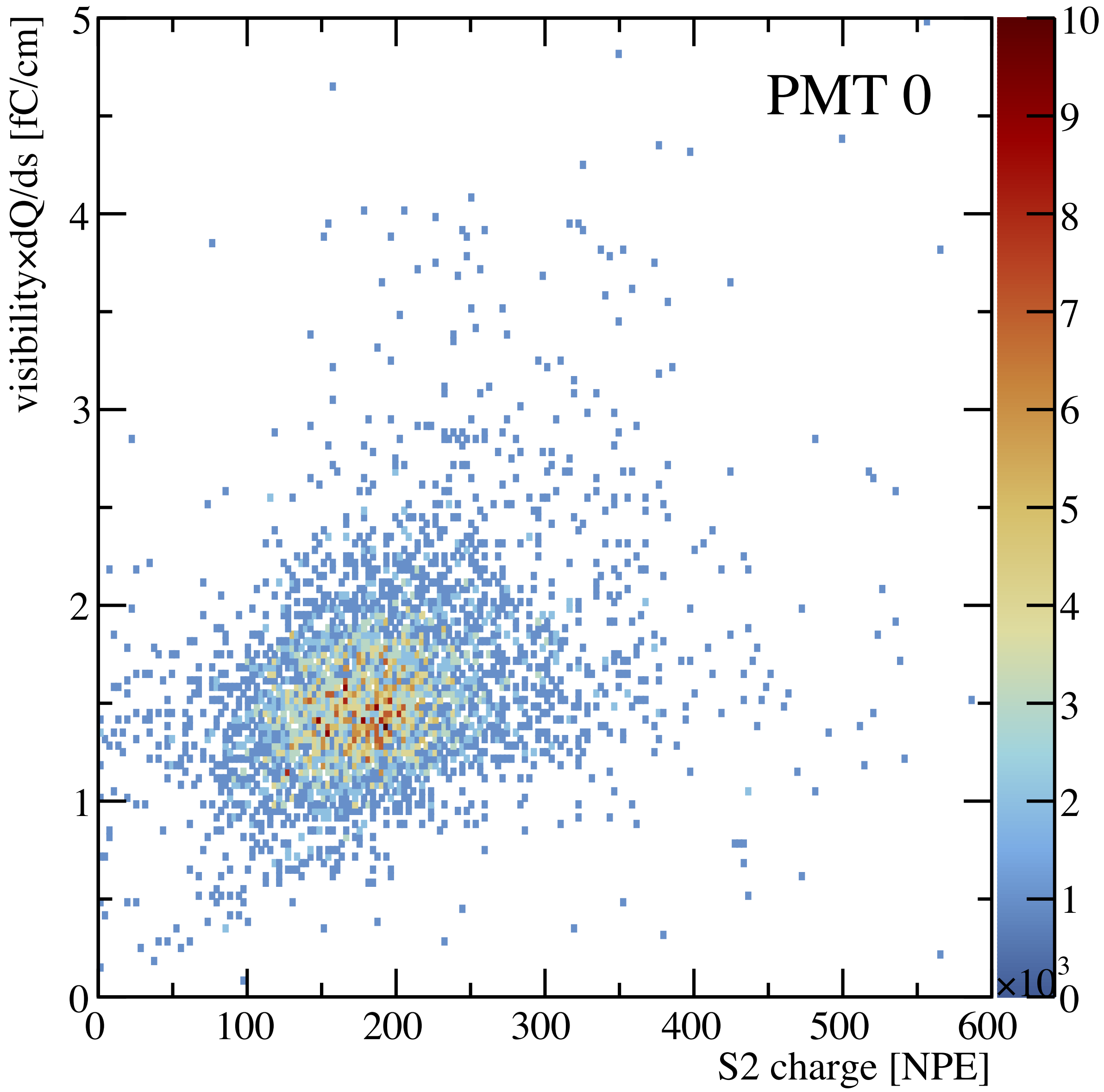
For all μ-like track selected, compute hits dQ/ds reweighed by the S2 visibility from the maps.

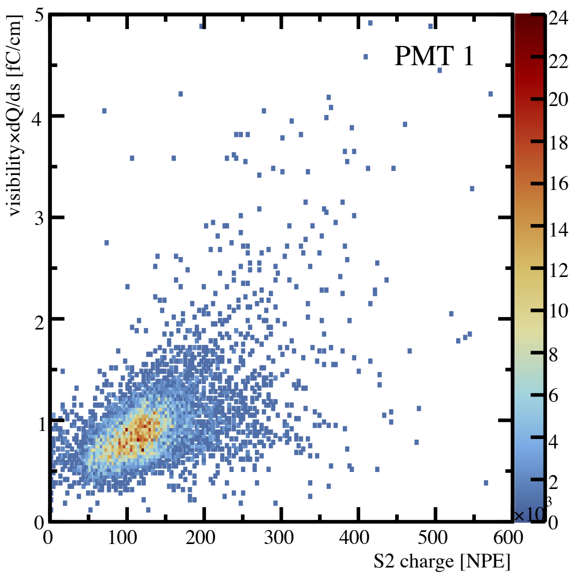
The plots are very similar !

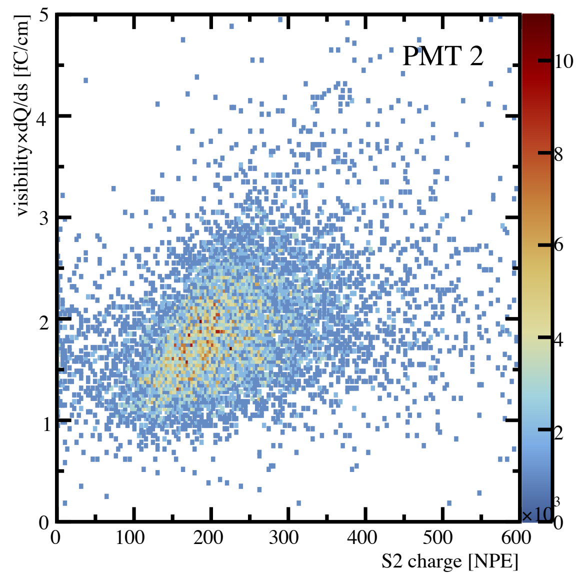


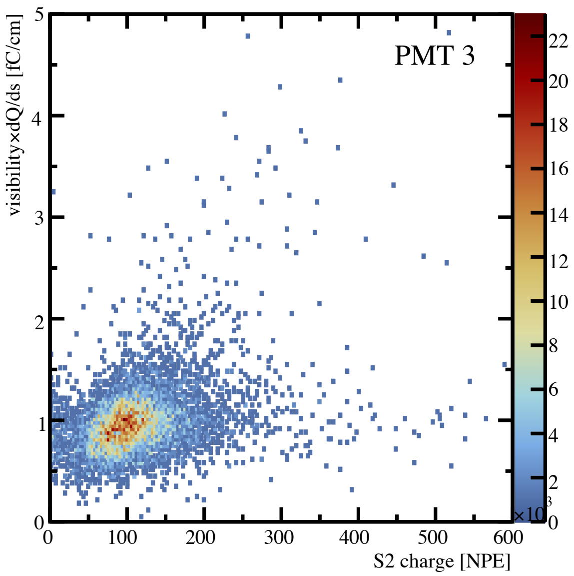


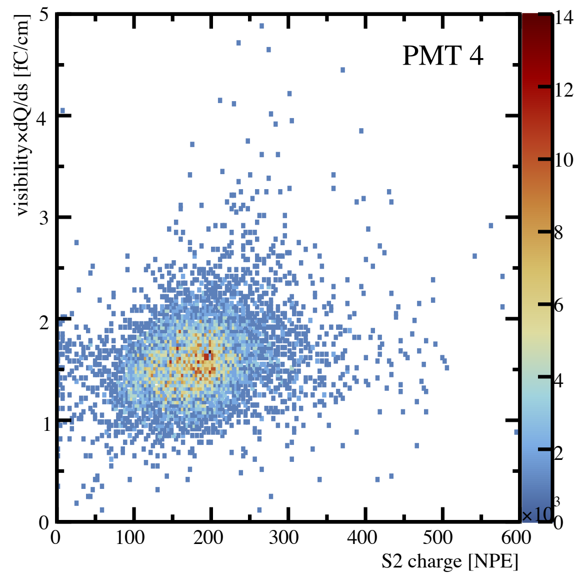
S2 visibility - cross check





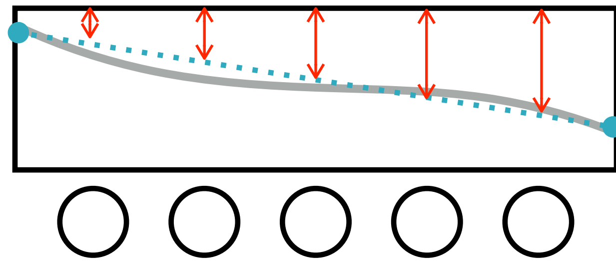


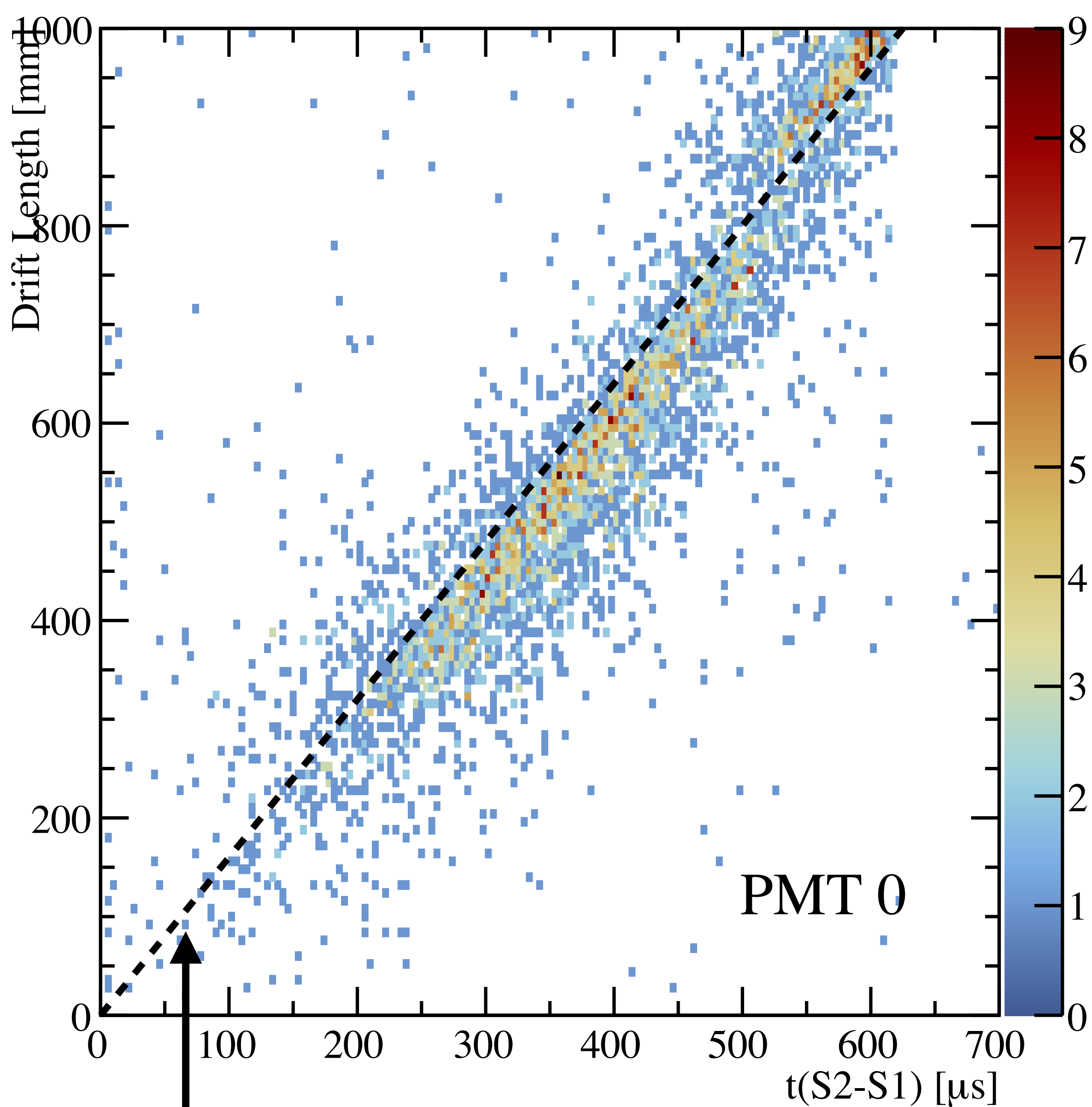




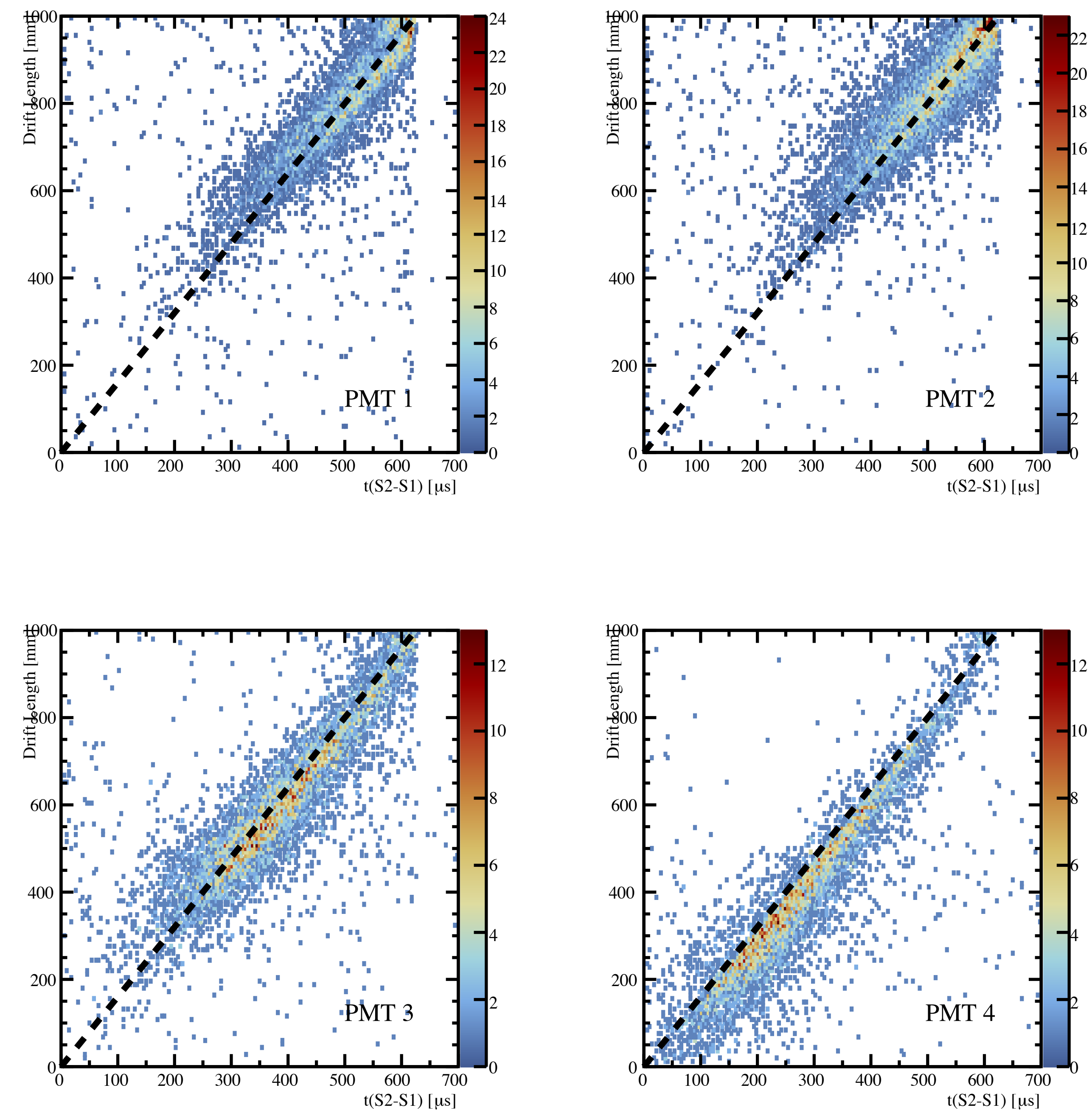
Drift velocity

Look at the track *extrapolated* drift length above each PMTs versus time from S1 to S2 maximum amplitude





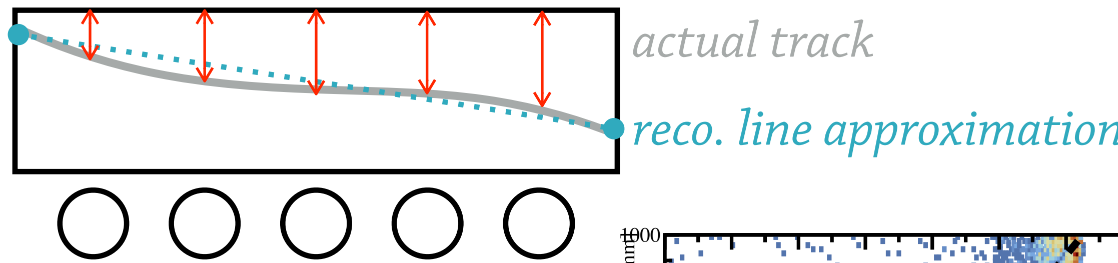
guide line with v_{drift} = 1.6 mm/μs

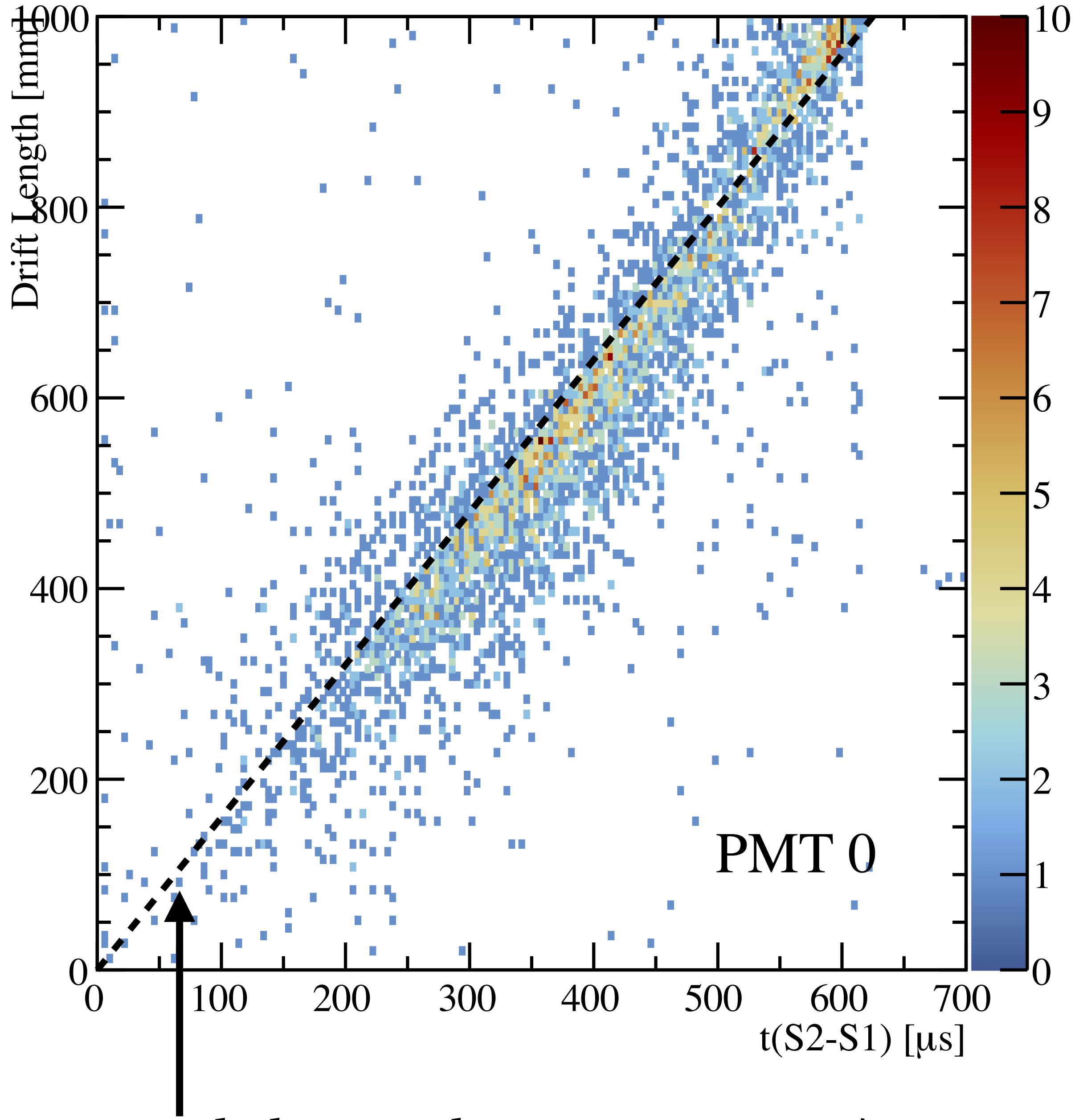


Deviations from the guide line is visible

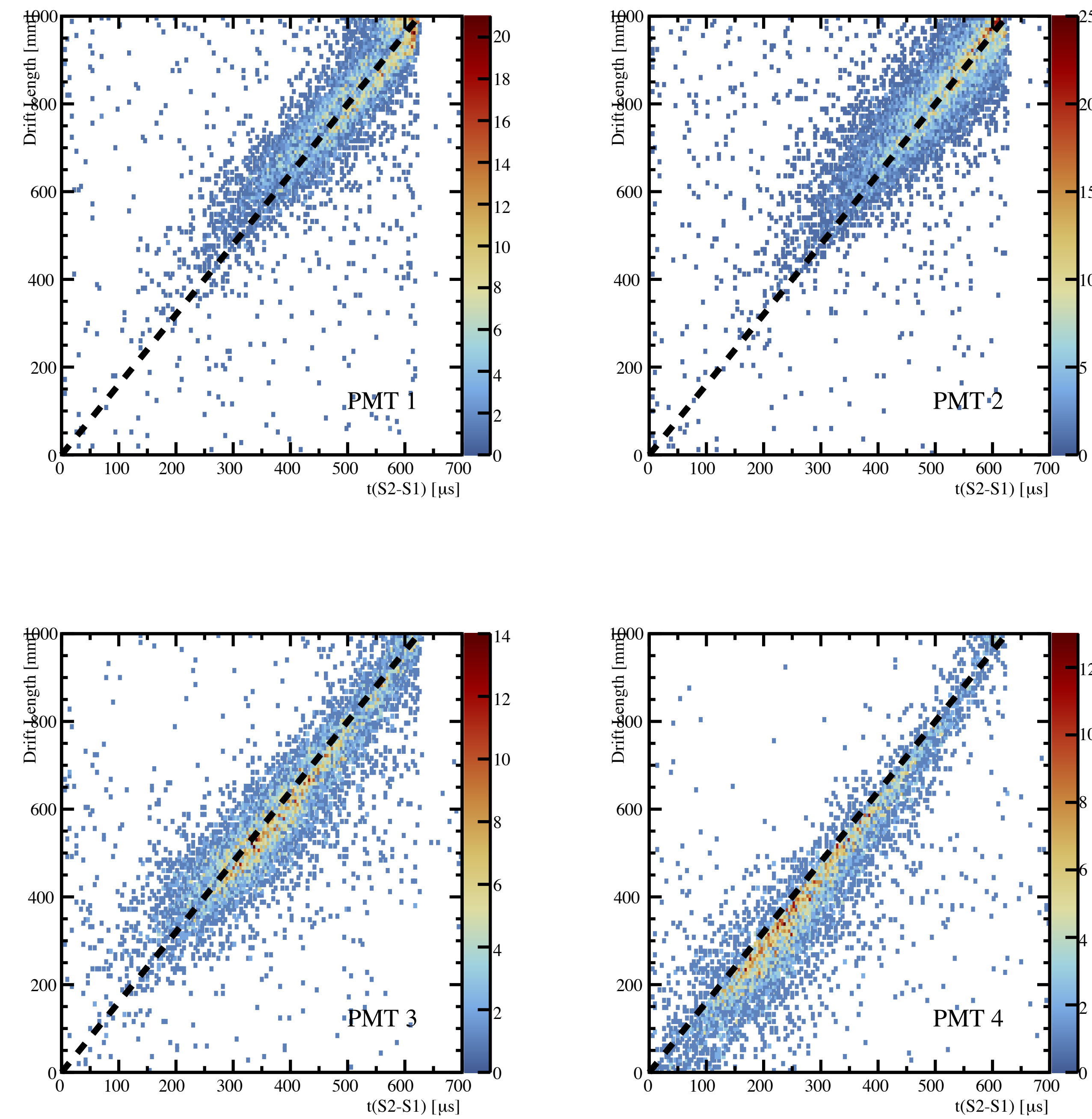
Drift velocity

Look at the track *reconstructed* drift length above each PMTs versus time from S1 to S2 maximum amplitude





guide line with v_{drift} = 1.6 mm/μs

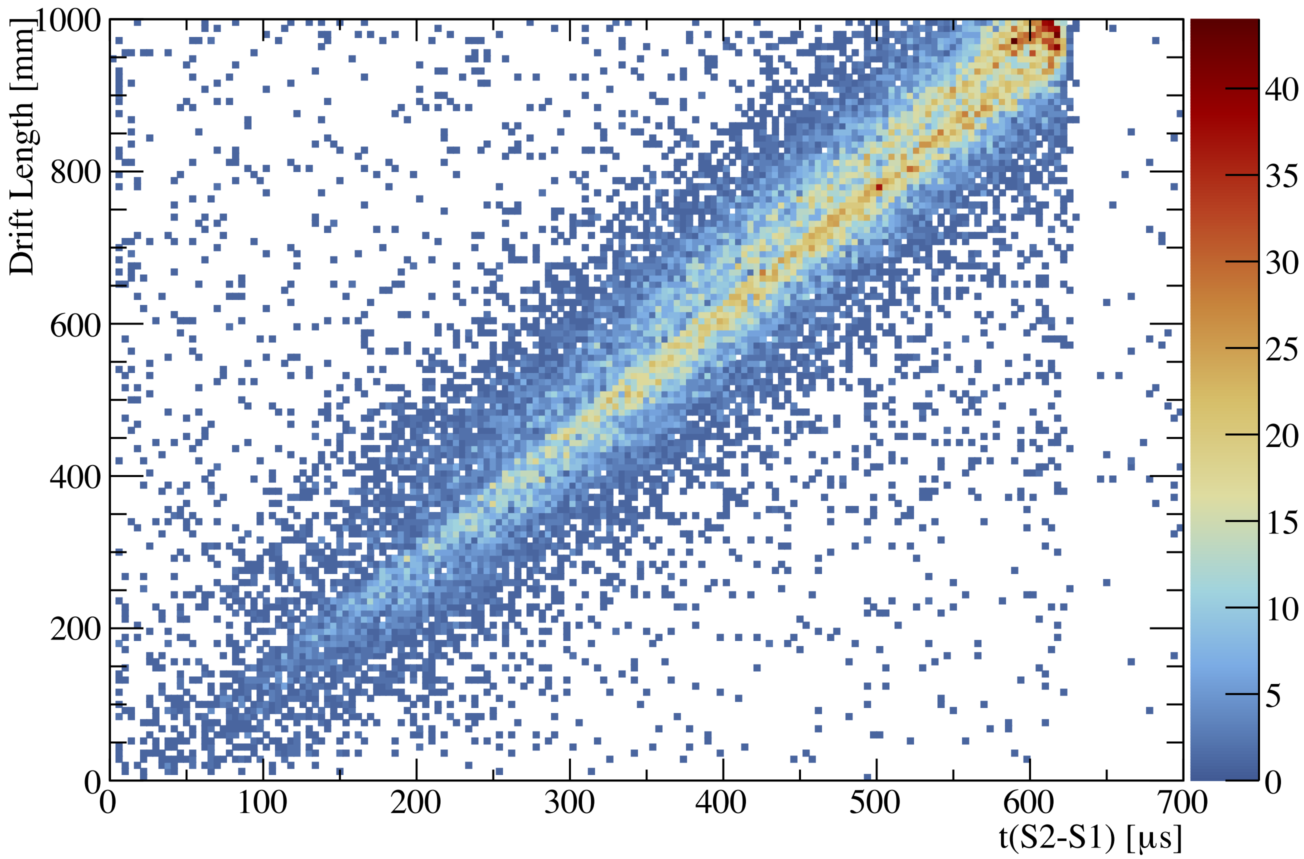


Deviations from the guide line is visible

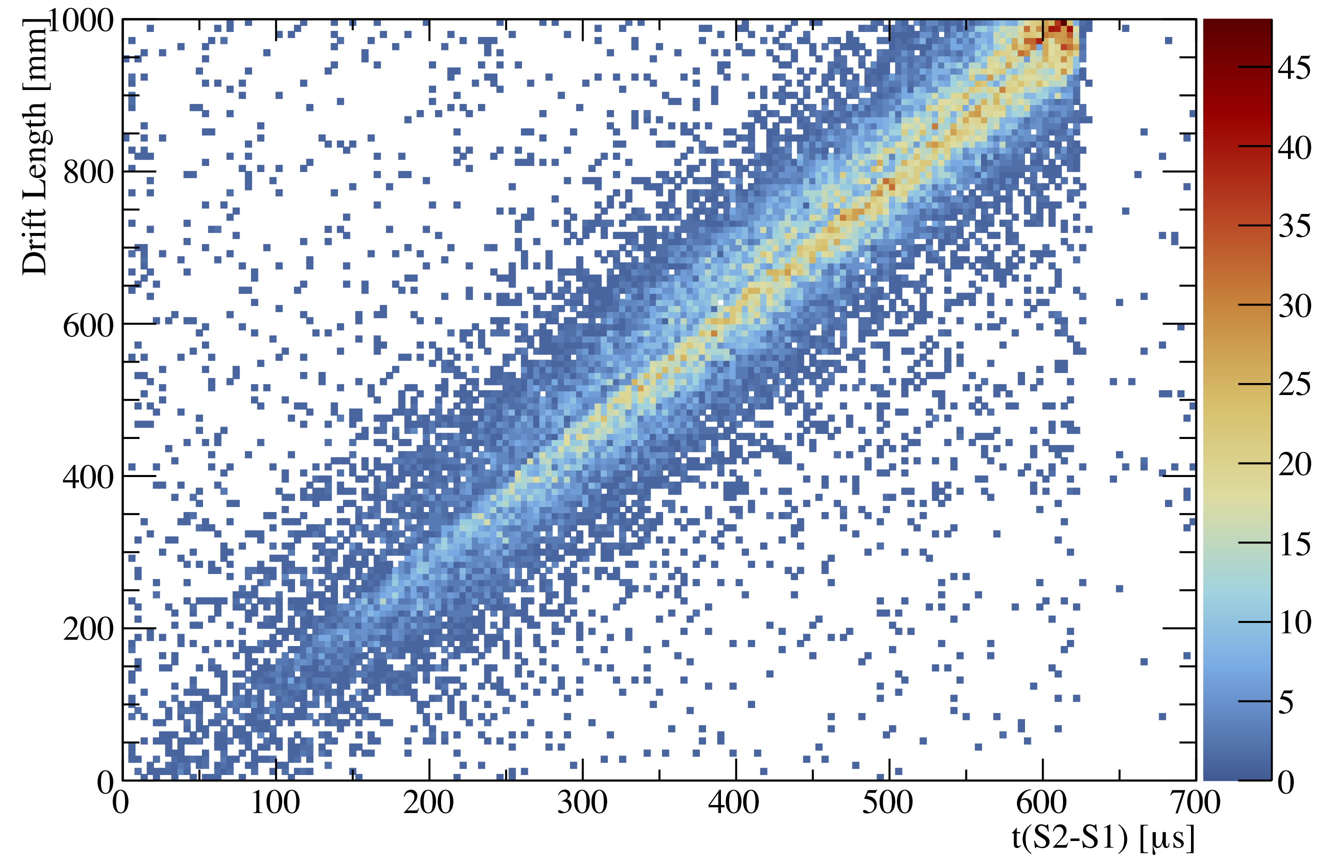
Drift velocity

Summing all PMTs, the effect is very clear - and very complex to understand !

extrapolated track position



actual track position

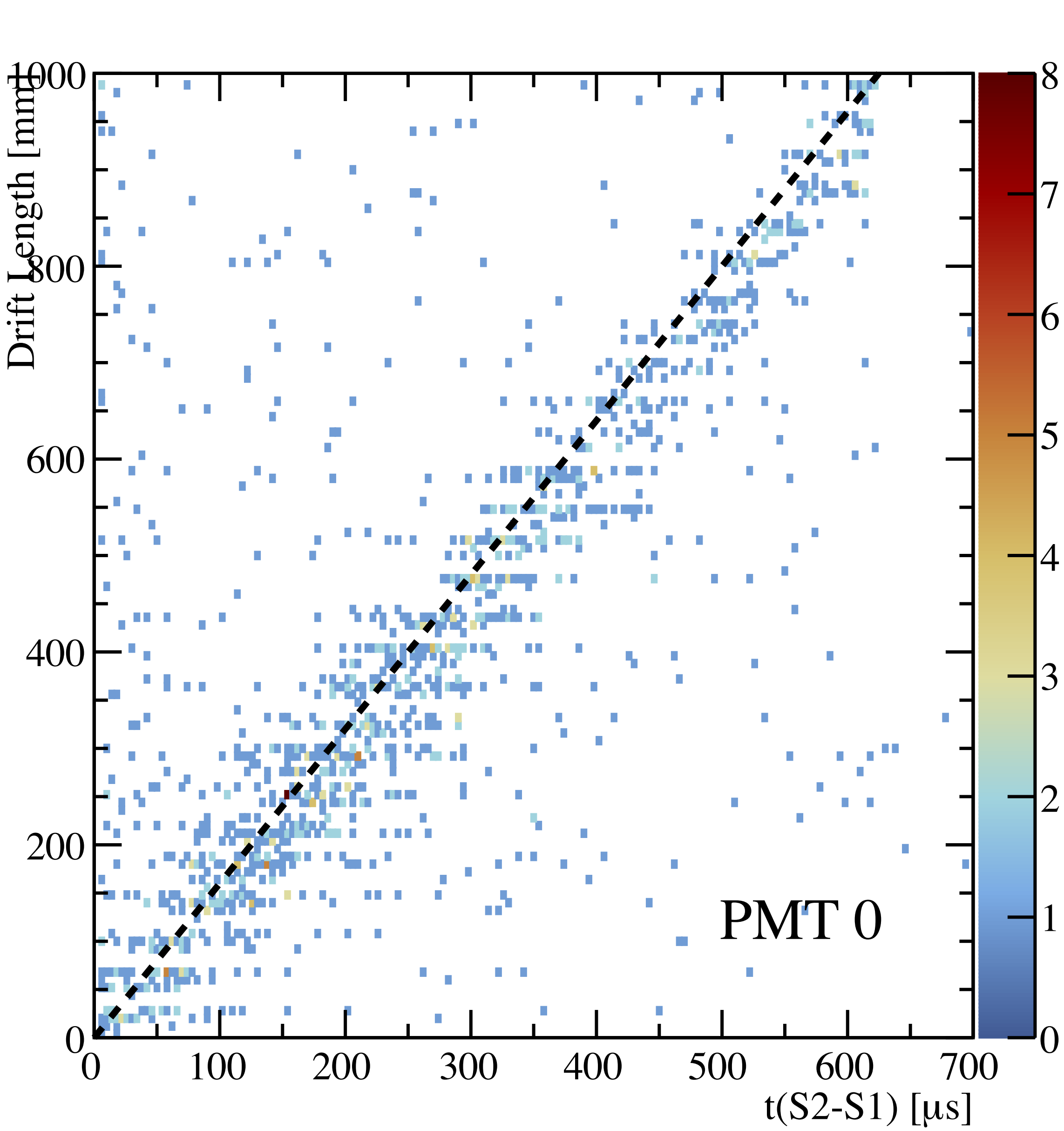


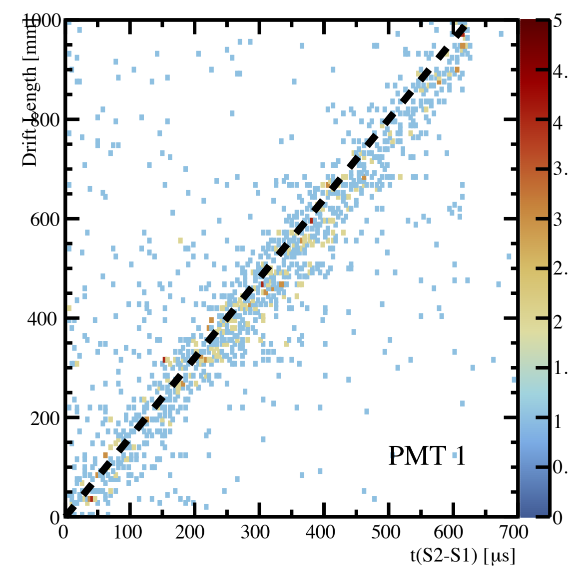
(run 840-842, same behavior in all PMT trigger runs)

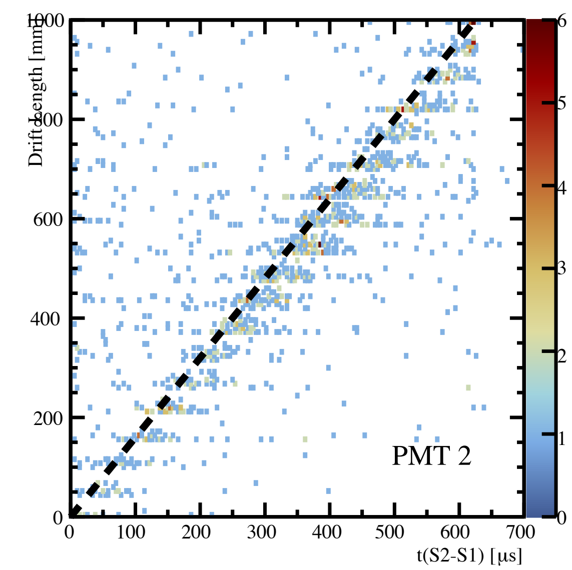
Drift velocity

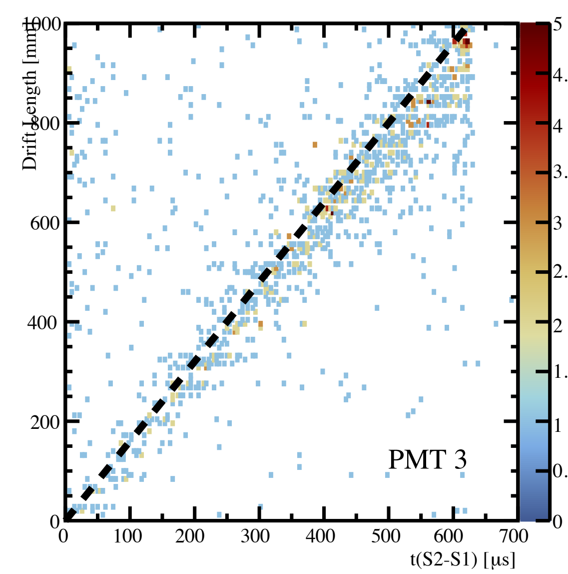
Doing the same with run 993 (CRT trigger) the effect is not so clear

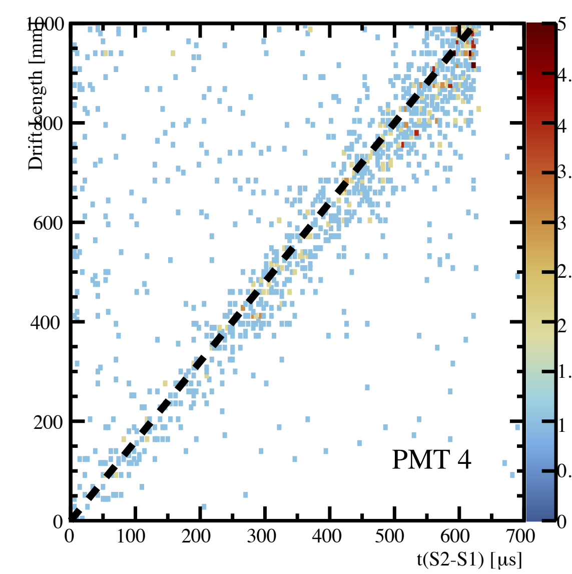
NB : I only used the CRT track information here - statistics is poor but might be increased soon







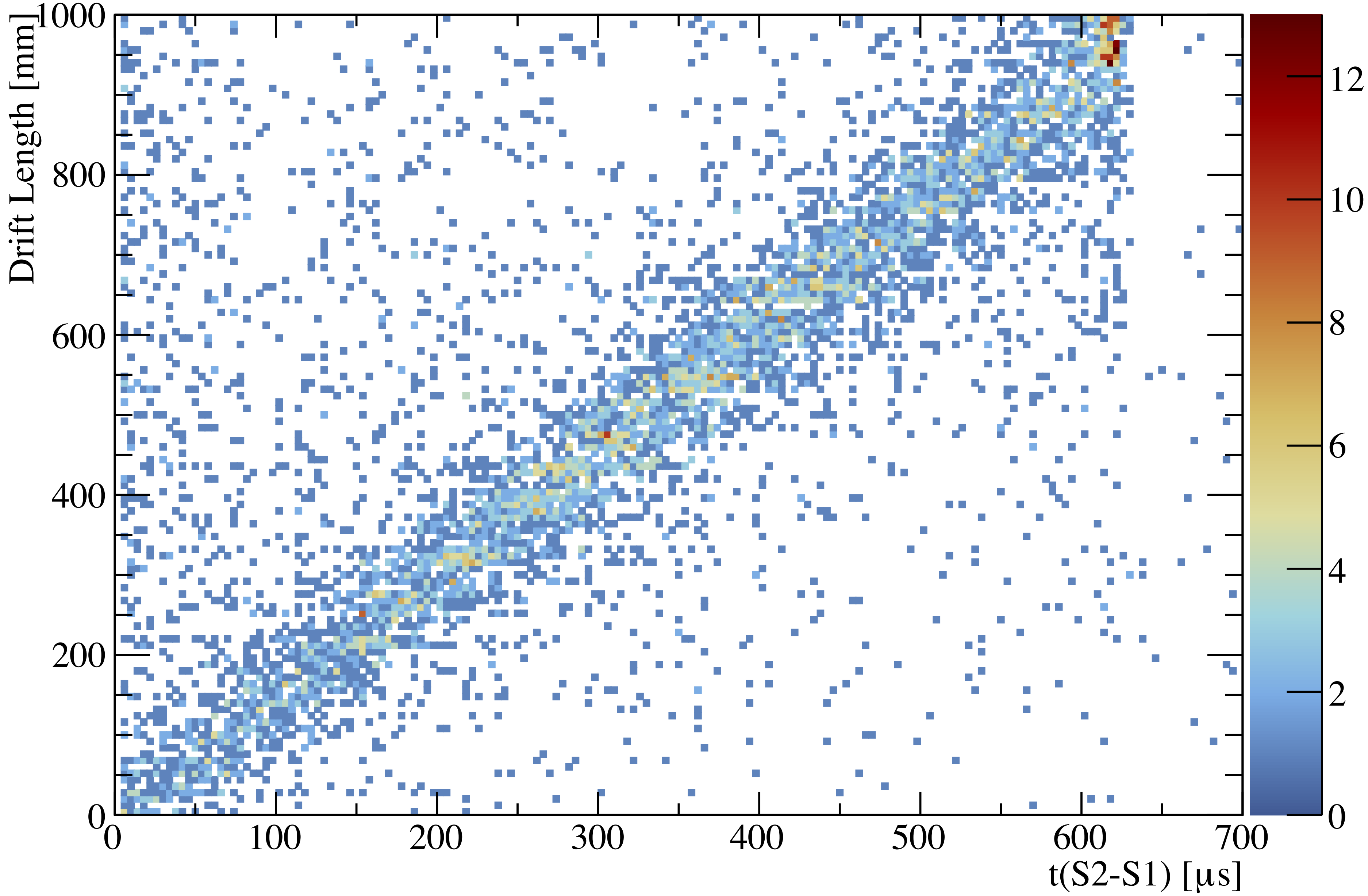




Deviations from the guide line is not so clear

Drift velocity

Doing the same with run 993 (CRT trigger) the effect is not so clear - all PMTs summed
NB : I only used the CRT track information here

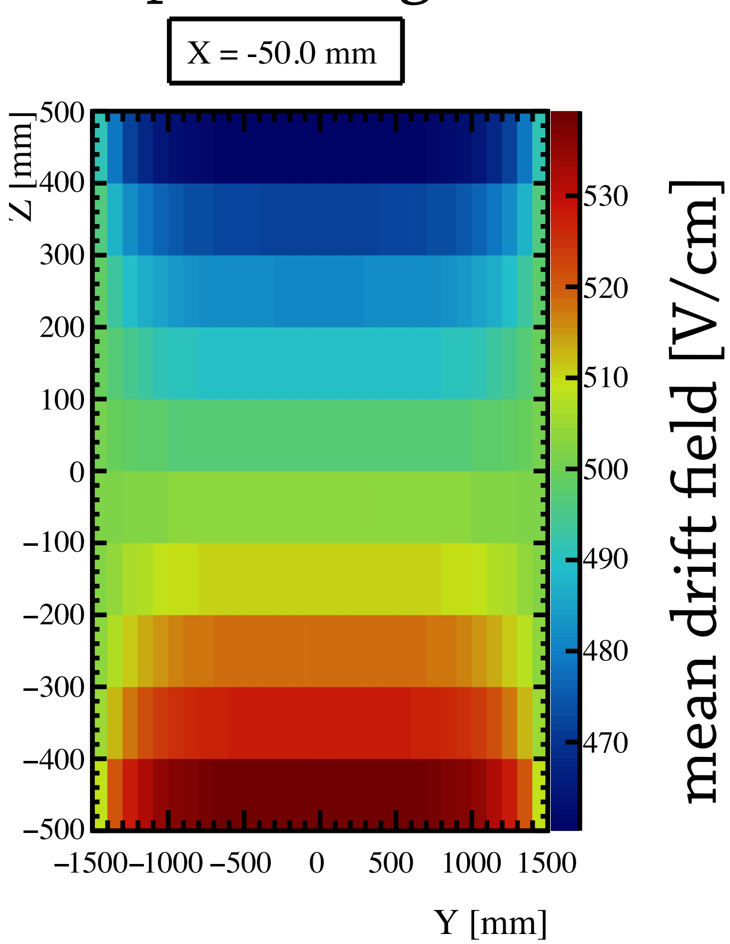


Drift velocity

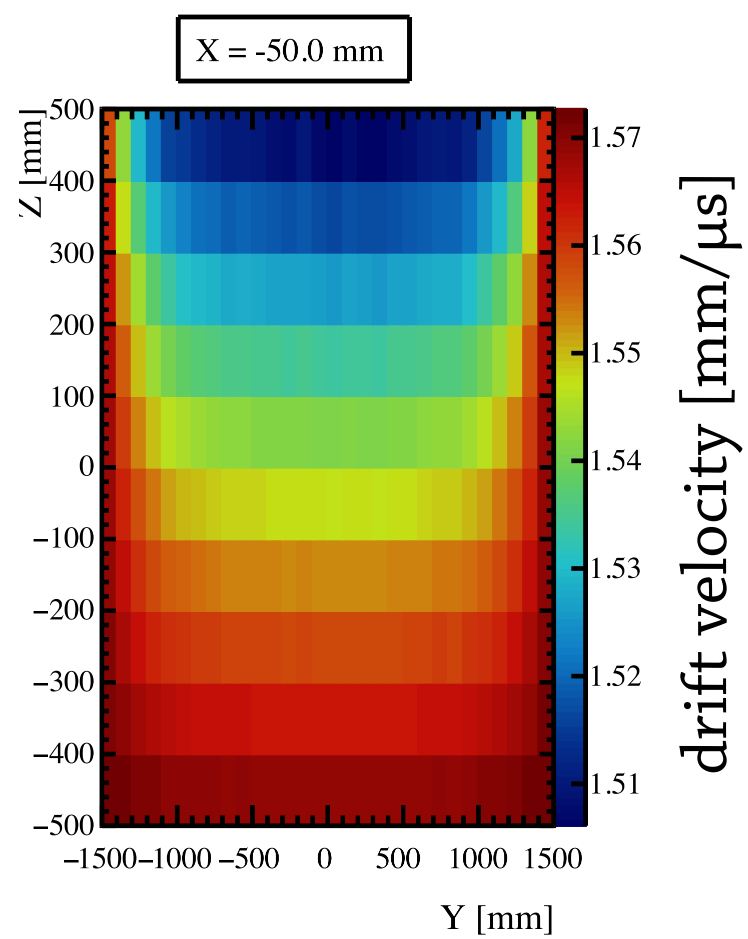
→ Given the space charge I would have naively expect the opposite trend :
deviations when using CRT information, better agreement with the reconstructed track in PMT trigger runs

→ Note that for run 993 (CRT trigger) the amplification field is the lowest at 25.5 kV/cm : if the deviations are due to the space charge, the effect might be smaller in this run anyway

From the comsol simulation :
mean drift field in voxels due to space charge (50% IBF)



From the field map generation :
effective drift velocity (50%IBF)



It's a bit hard to understand all the effects from the maps only.
I will try to make proper simulations to see if we can reproduce a similar trend with MC

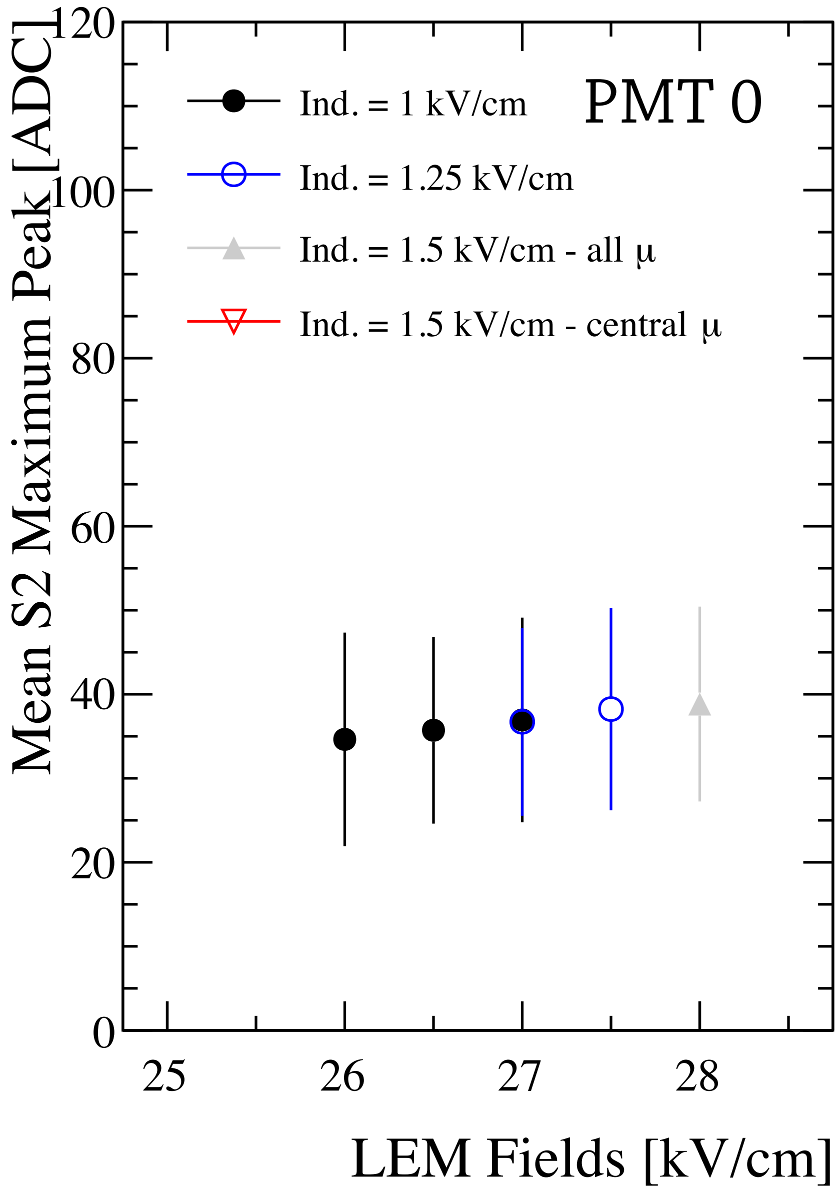
S2 max. amplitude & charge

Look at the effect of the amplification field on S2 signal

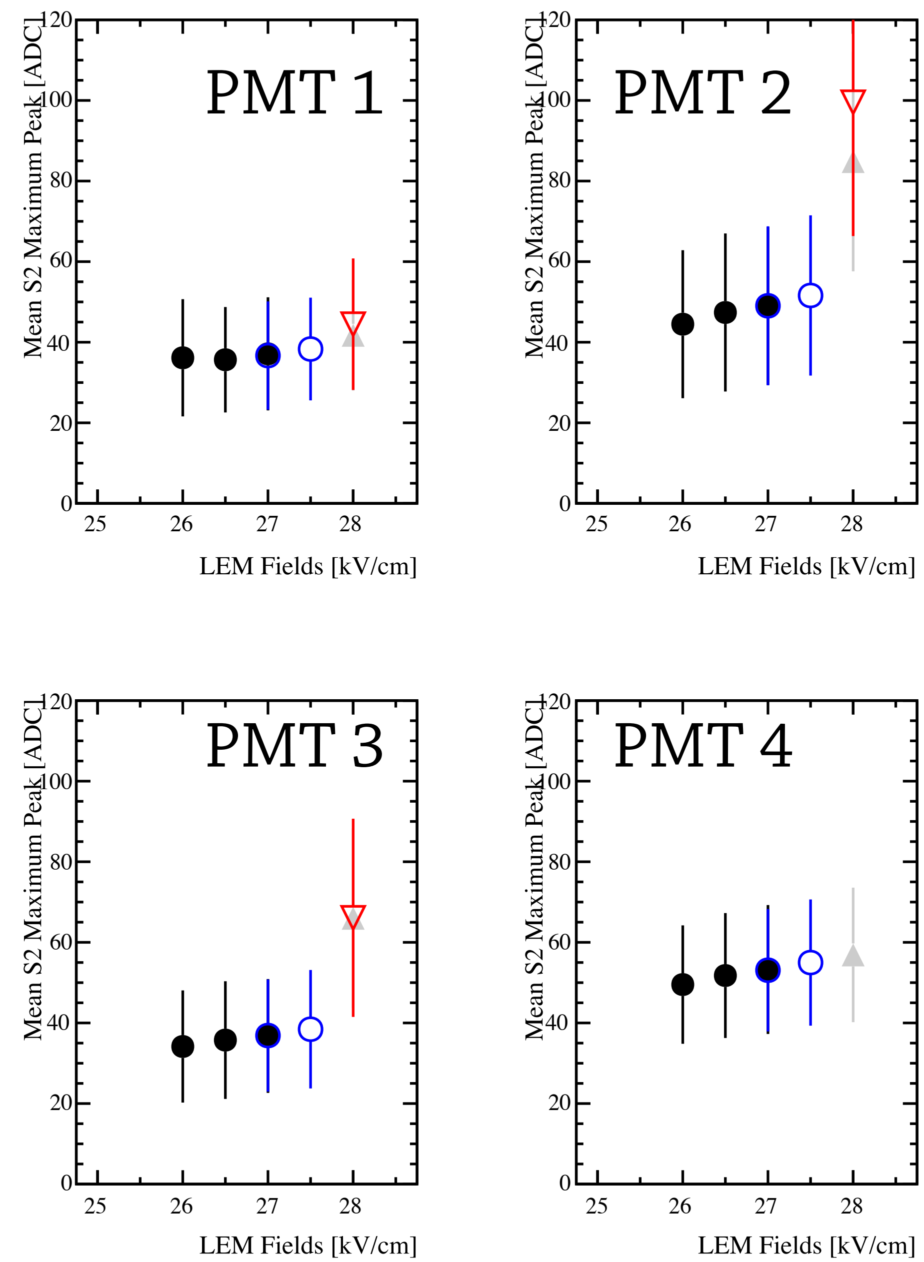
NB : for runs 840-842 (field at 28kV/cm in central LEMs) there is two analysis

- All muons taken into account : PMT 0 & 4 see two kind of S2s
- Only muons crossing the central part of the detector : much less stats, uniform S2

S2 maximum amplitude



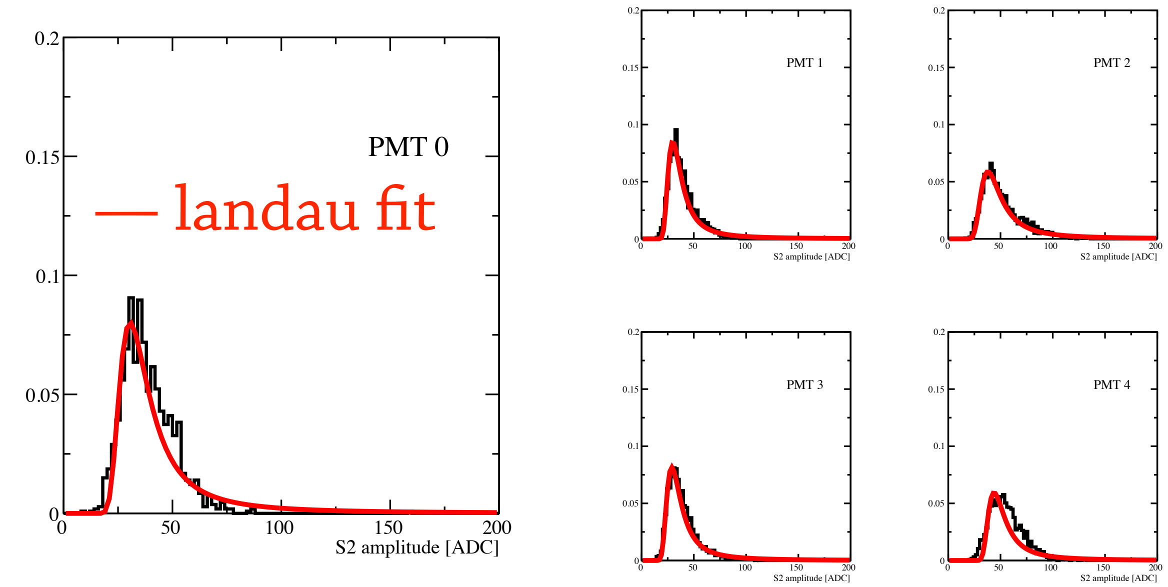
didn't add yet the point at 25.5 kV/cm



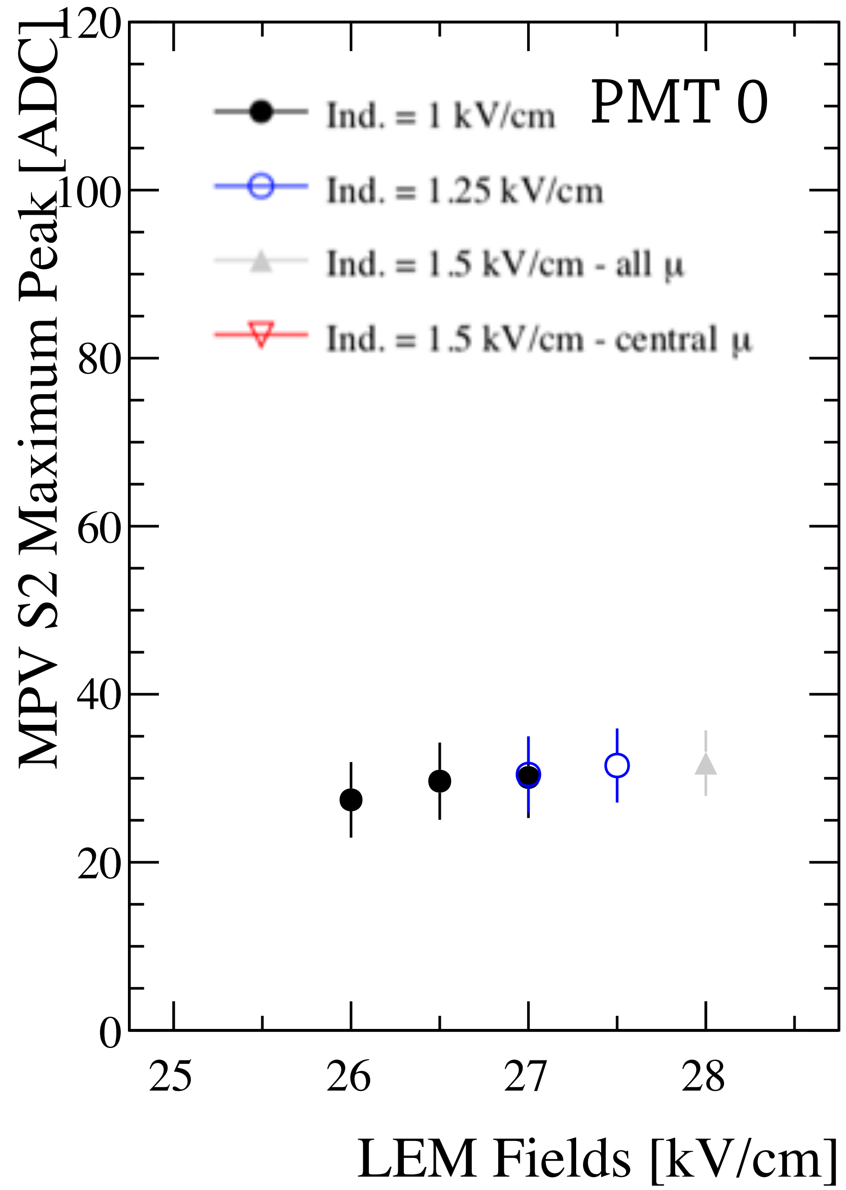
S2 max. amplitude & charge

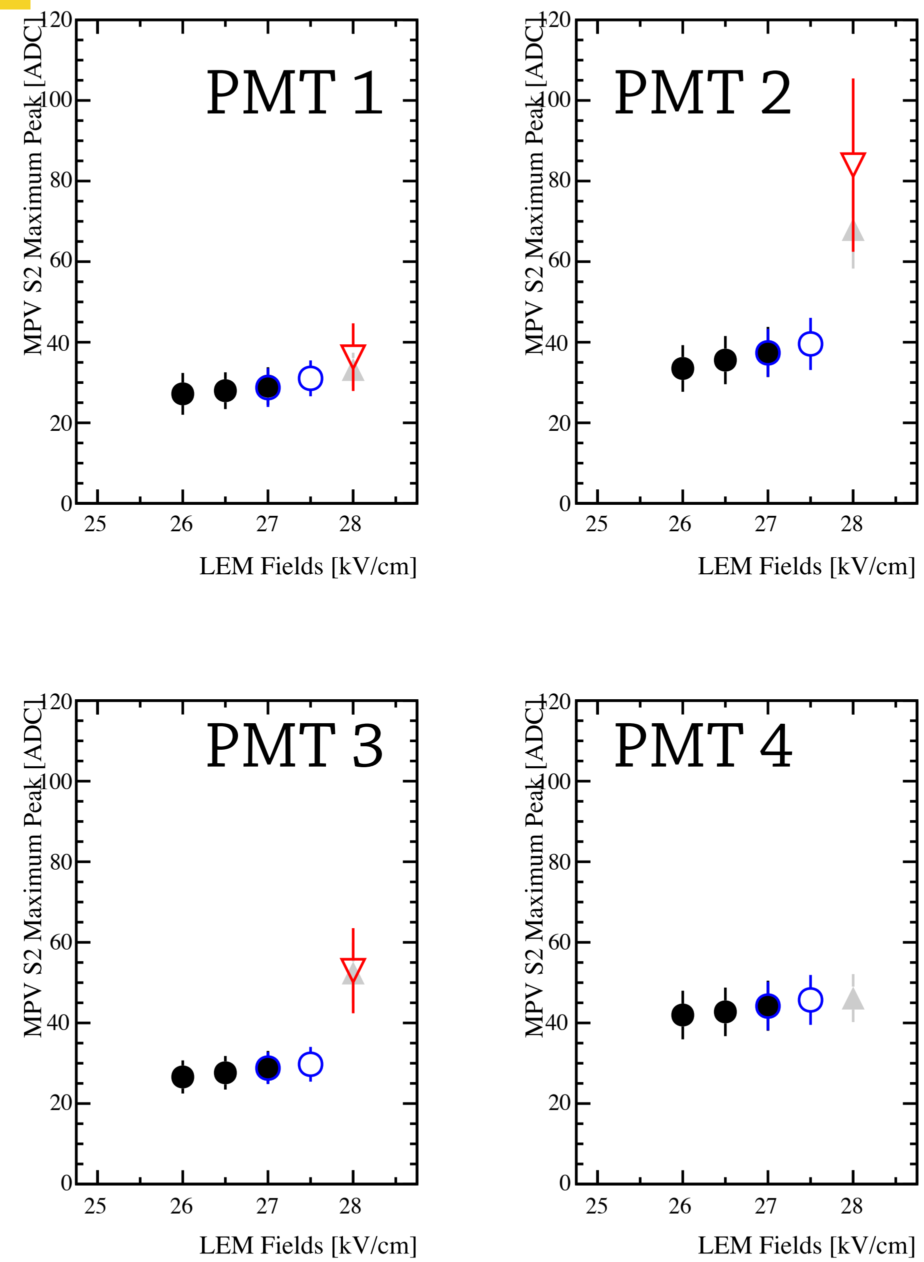
(run 1012... at 27.5 kV/cm)

Each distribution is fitted with a landau
[can be improved ?]



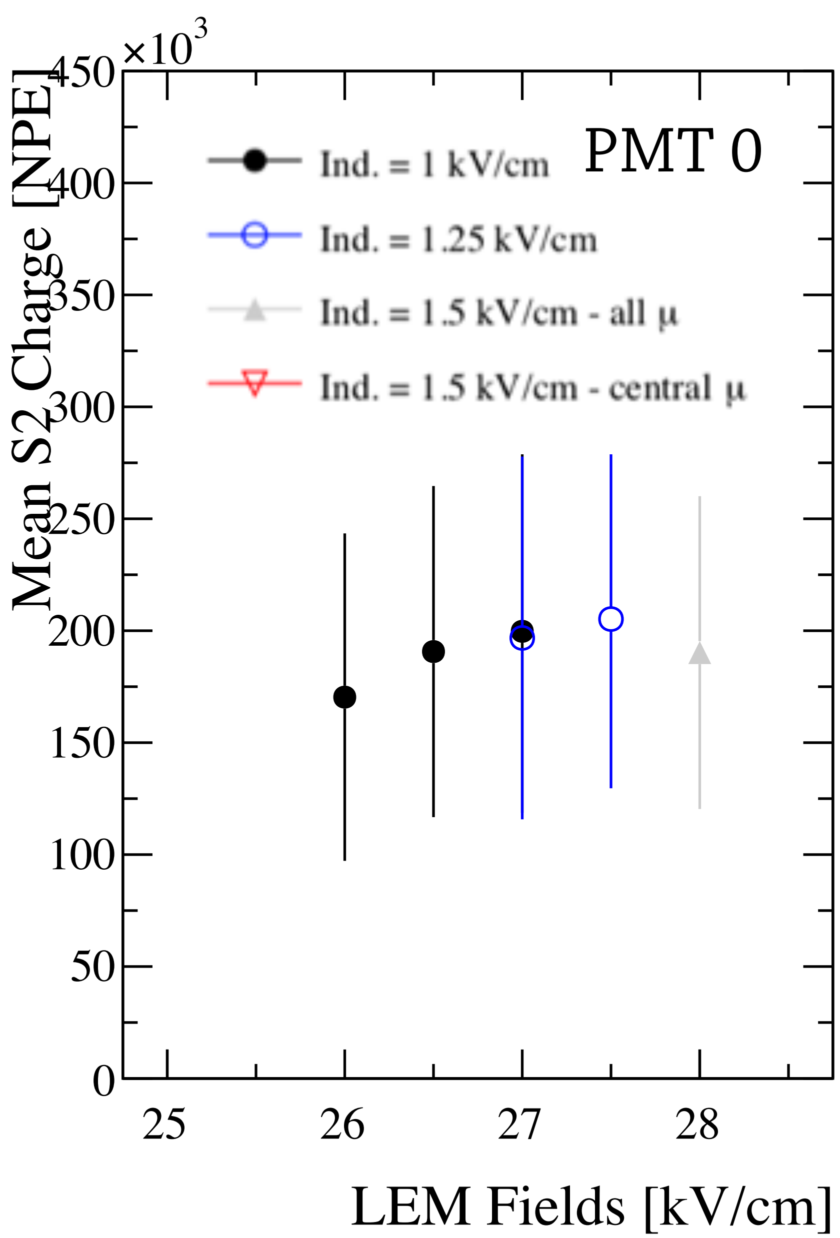
S2 maximum amplitude MPV fit

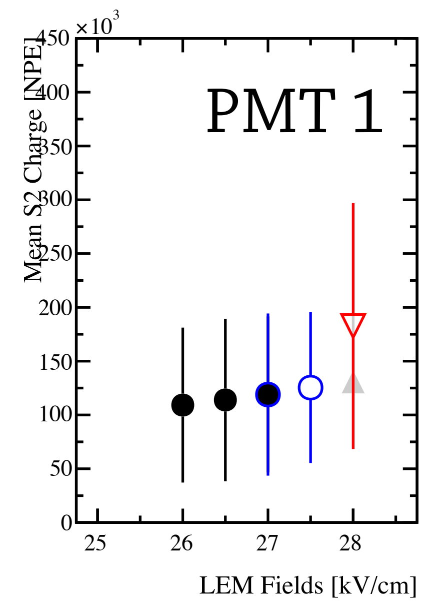


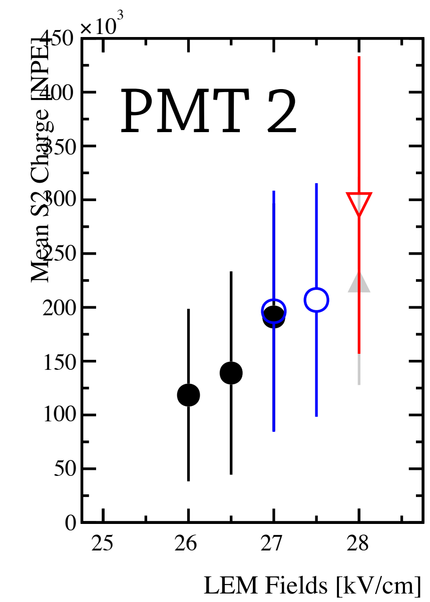


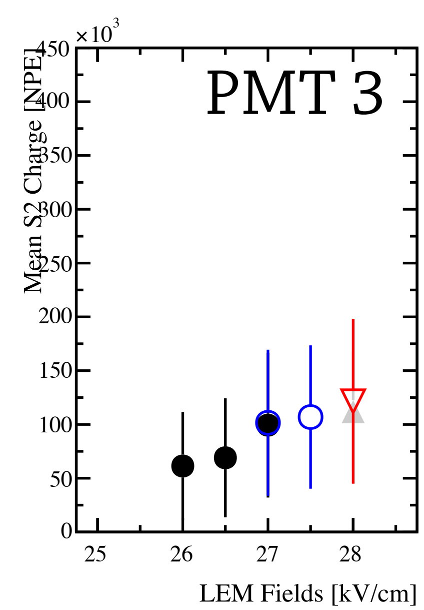
S2 max. amplitude & charge

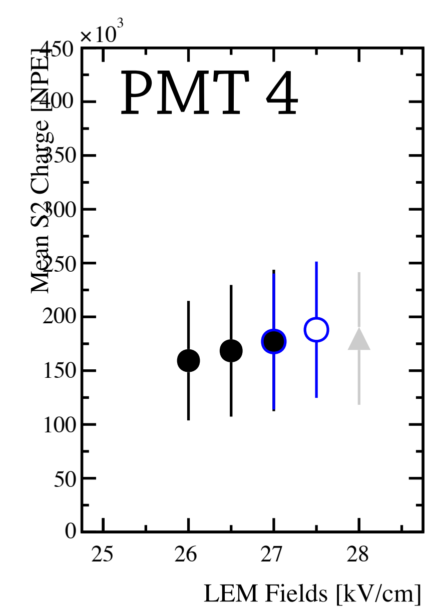
S2 total charge - Mean value







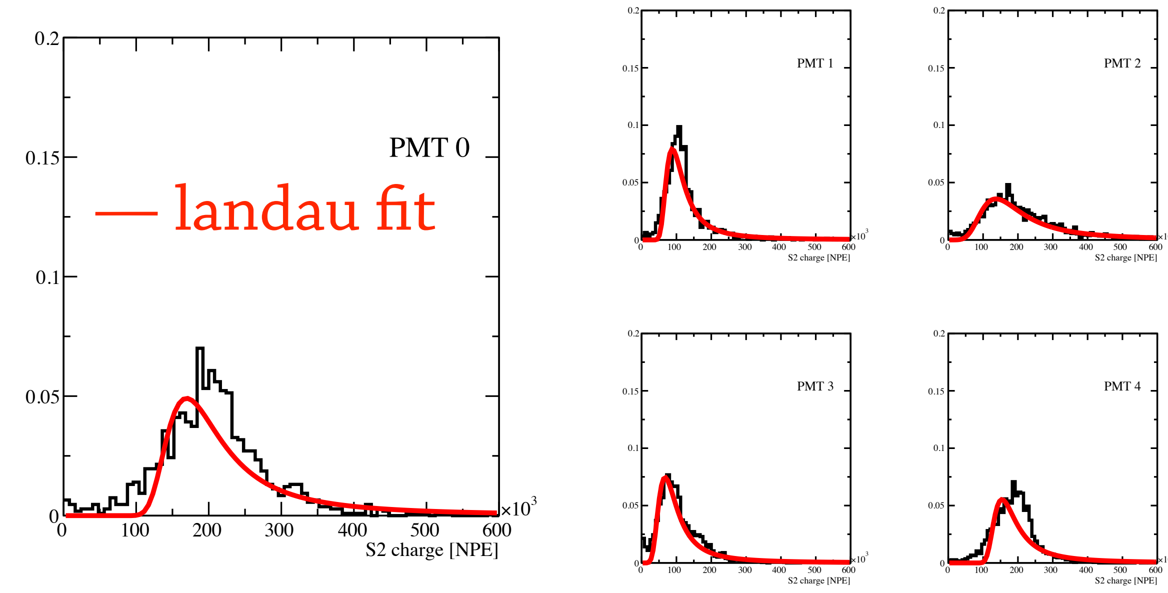




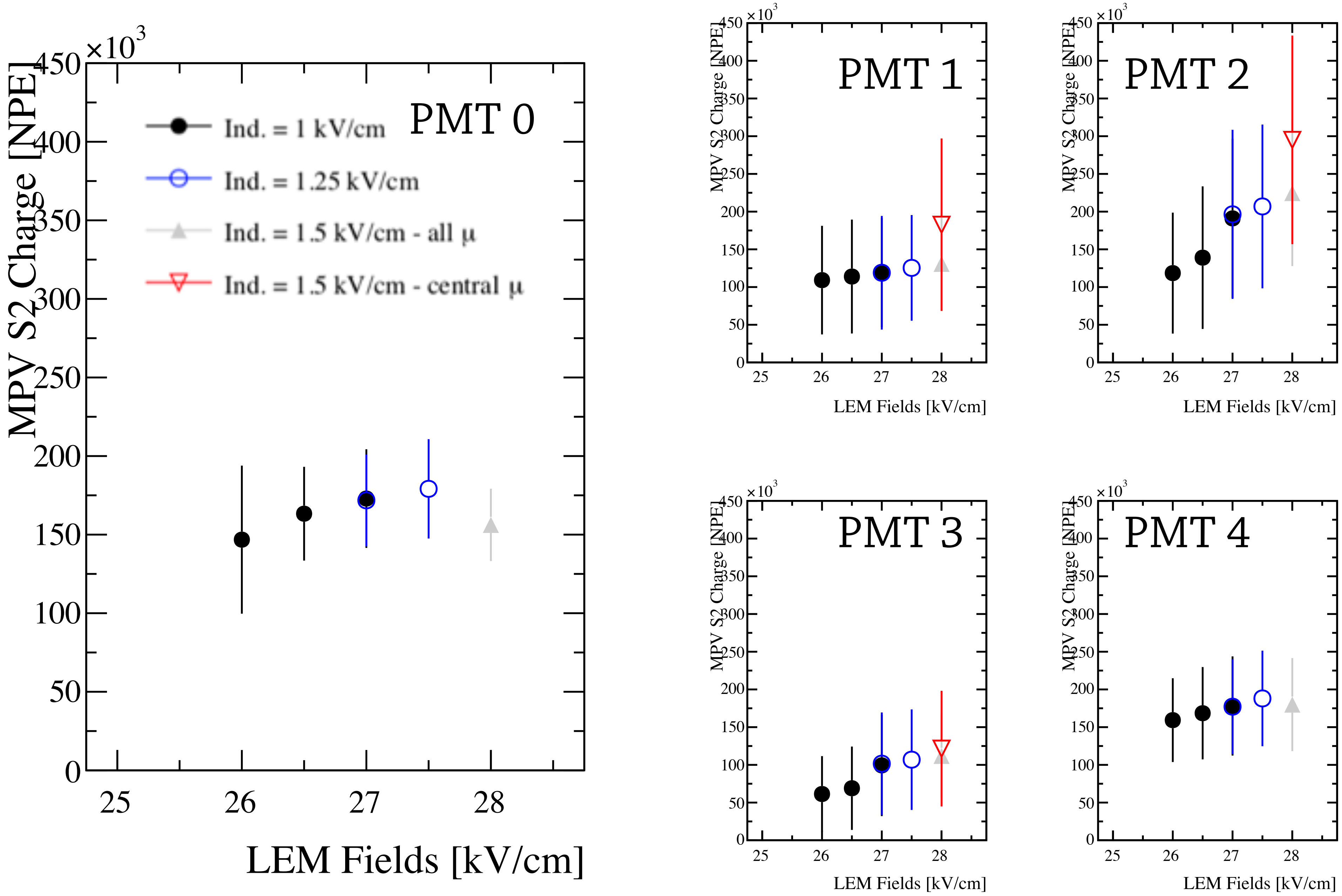
S2 max. amplitude & charge

(run 1012... at 27.5 kV/cm)

Each distribution is fitted with a landau
[can be improved ?]

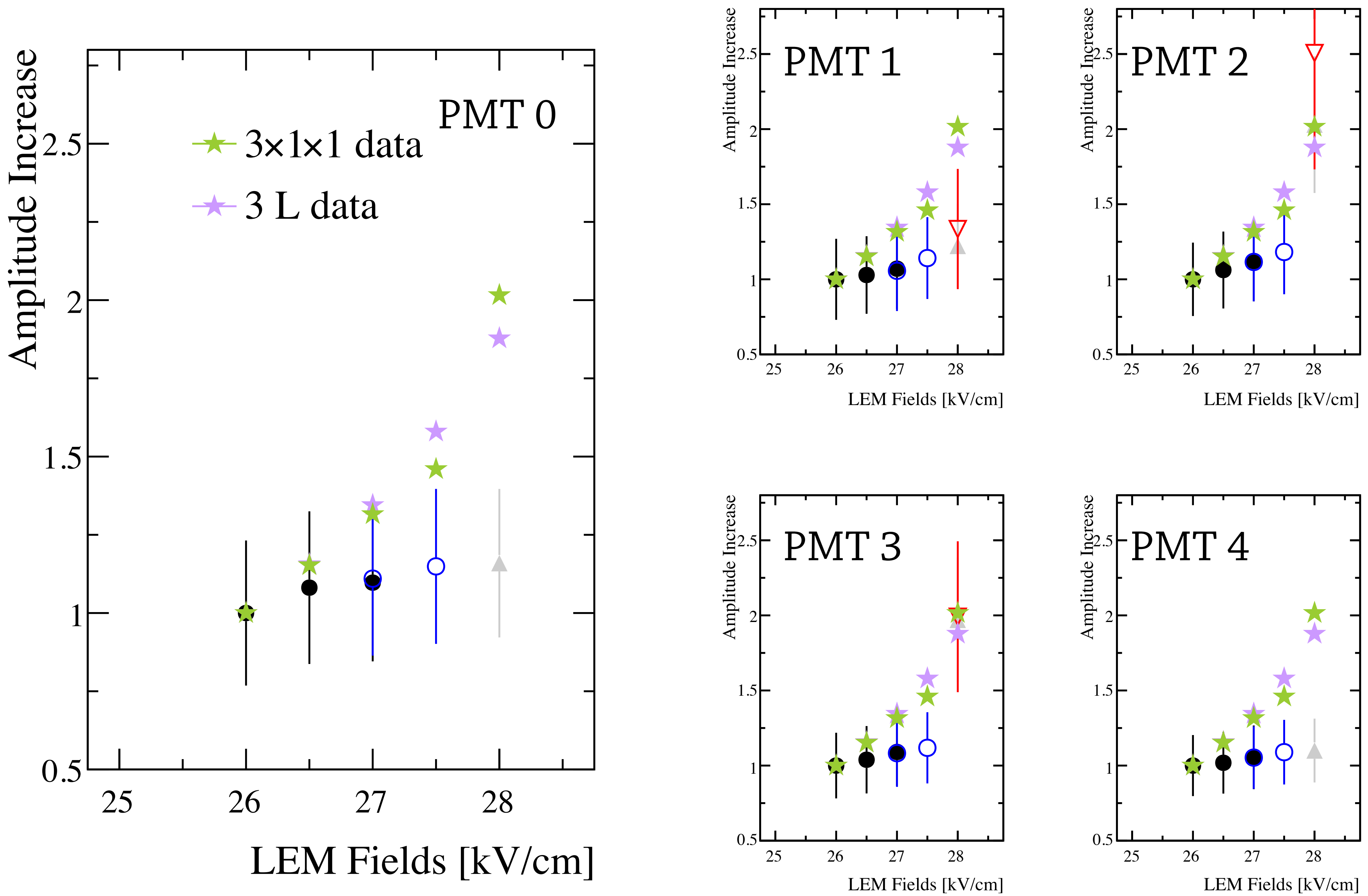


S2 total charge MPV fit



S2 (MPV) amplitude increase

Values compared with the charge analysis done by P. Cotte presented here
(Maybe not the latest values, he defended his thesis 2 weeks ago)



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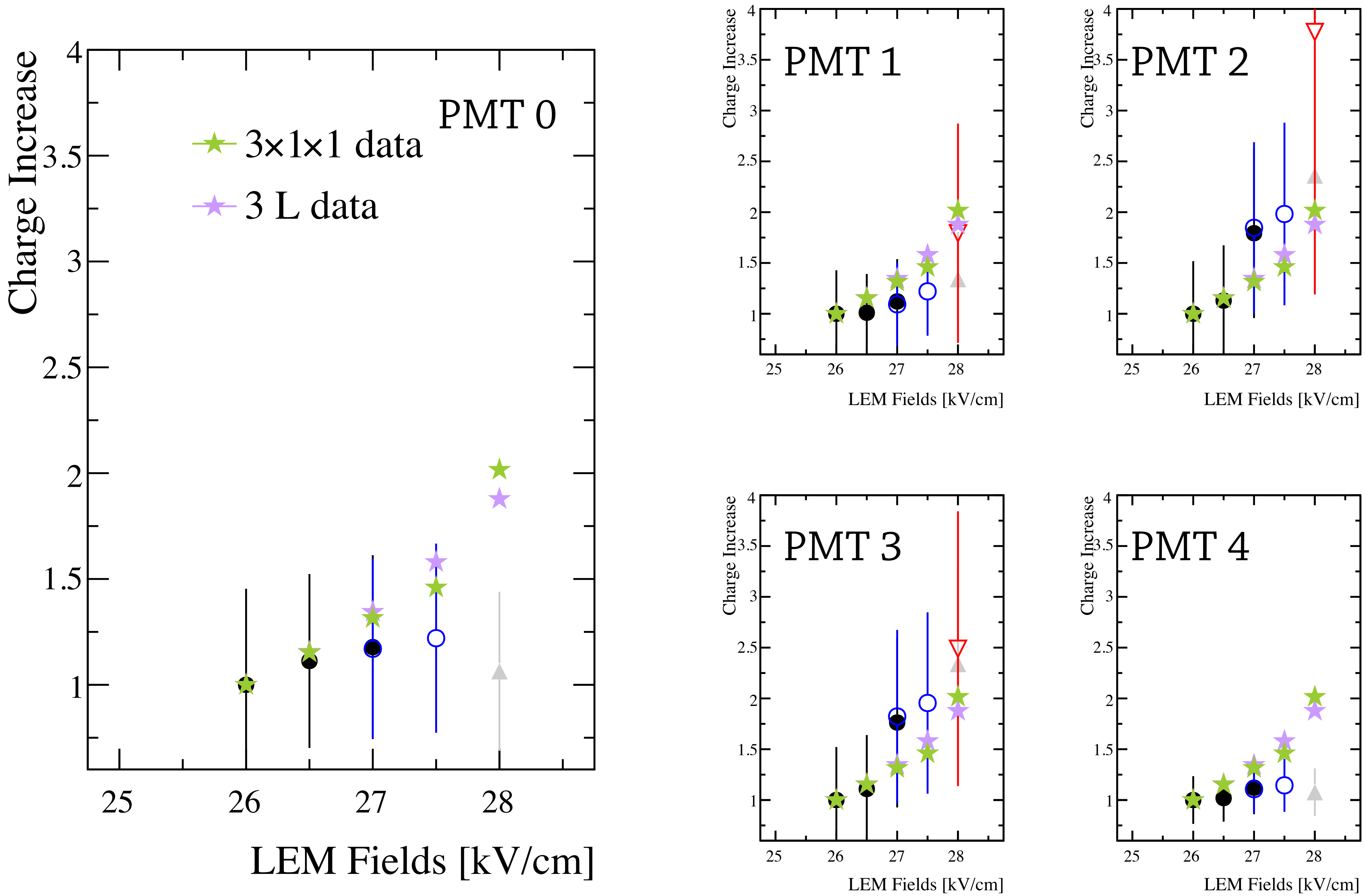


To do list

- Looking at charge & light signals combined allows many studies

- At the S1 analysis level :
  Increase the statistics on the charge vs track-PMT distance at 500 V/cm which was only performed with CRT data up to now. Can be used to improve the recombination effect measurement.
  To do : understand the shift for some runs in PMT 2 & 3 ; do not use TProfile by default ?

- At the S2 analysis level :
  - S2 charge vs drift distance behavior understood ? ***To do*** : check with MC
  - Drift velocity : is it due to space charge ? Problem with the light or charge reconstruction ?
  To do : study through MC
  - S2 increase with LEM field : interesting first results
  To do : improve the S2 fits (landau×gaussian ?) ; can do a quick MC test with different G_{el} values to make sure we can do this analysis without S2 visibility corrections ; get final effective gain values from Philippe Cotte

Preliminary MC studies

- Generated in QScan
- Using the ‘old’ light map
- Light produced outside of the charge active volume taken into account:
  - near the field cage
  - in between the cathode and the ground grid

- Some previously found bugs were corrected : 311 geometry, PMT response, recombination
- Some known bugs still here and can’t be yet corrected
  - light maps interpolation at the level of the volume between cathode & ground grid: only 1 voxel along the z-axis was simulated

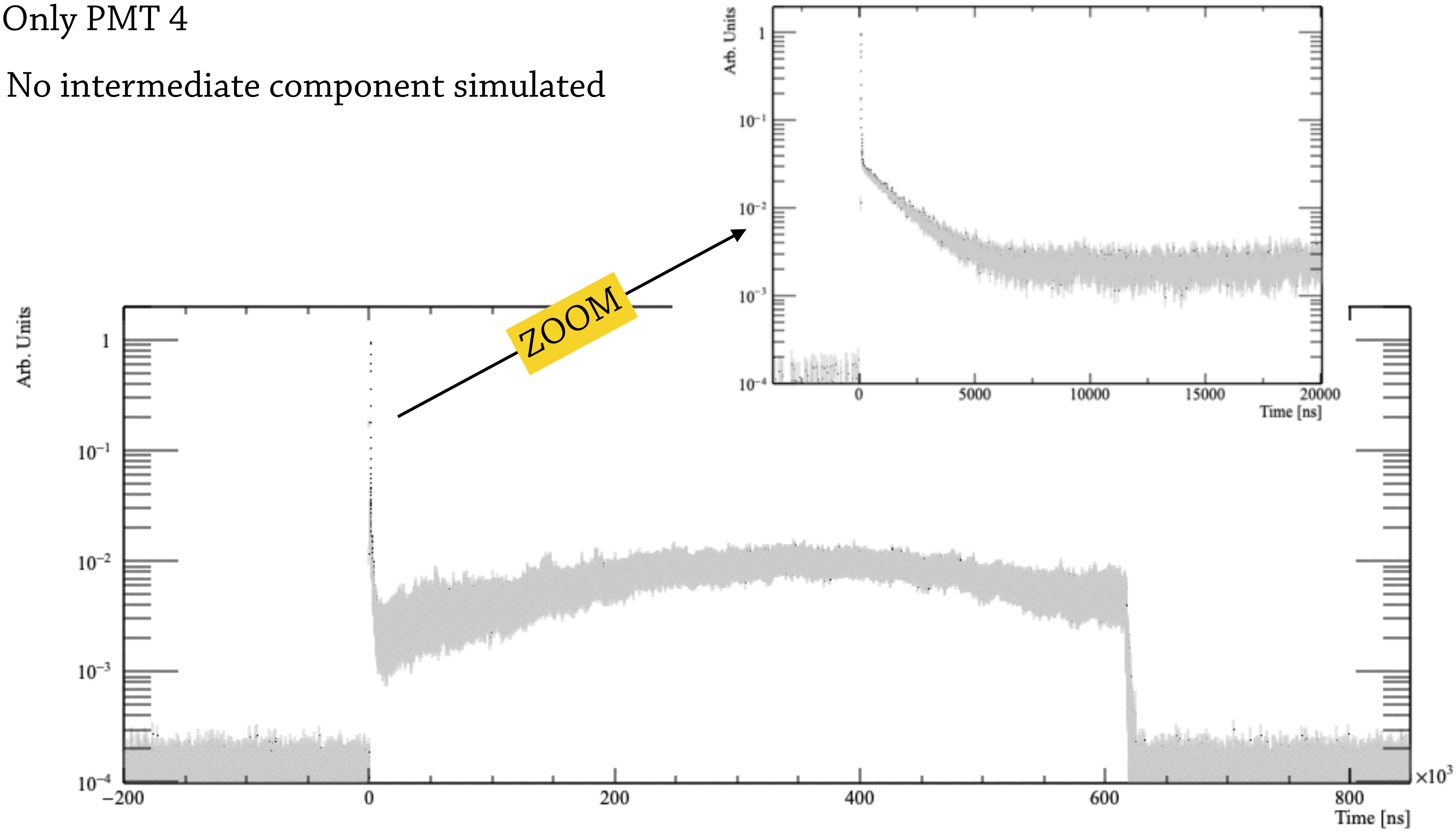
- Same light reconstruction algorithm used as in the data

- Otherwise stated, the default parameters in the following slides are :
  - Muon momentum at 4 GeV/c ; uniform drift field of 500 V/cm ; no impurities
  - Muon generated randomly from the anode to the cathode
  - Rayleigh at 55 cm
  - Absorption length at 30 m
  - G_{el} = 160 photon/extracted e^-

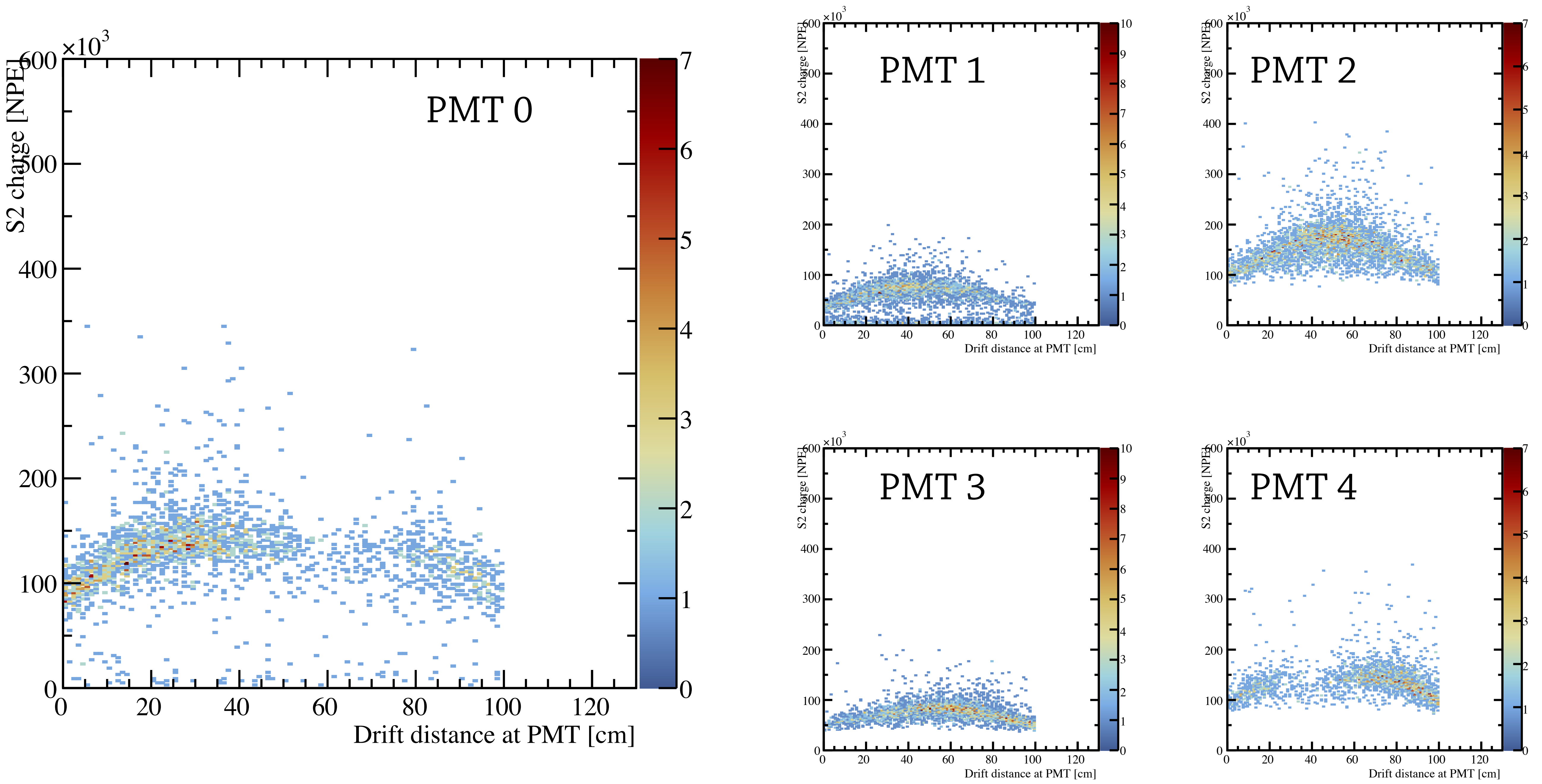
MC Average Waveforms

Only PMT 4

No intermediate component simulated

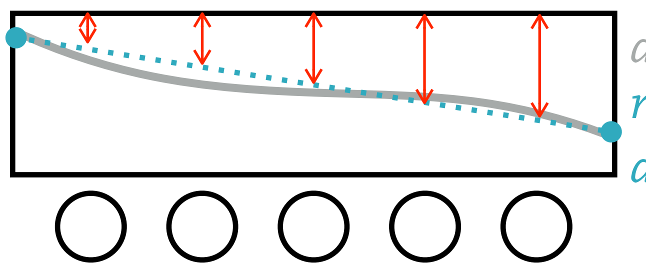


Preliminary MC studies - S2 charge vs drift



MC Drift velocity

For the drift length, the extrapolated track position is used
→ I can do the reconstructed position, but the reconstruction code will be different from the one used in the DPD (done through LArSoft)



(statistics is still low, but it seems that the deviation is not here)