STATUS OF S1 AND S2 ANALYSIS

CHIARA LASTORIA (CIEMAT)

3x1x1 Light data/MC analysis meeting

November 13th , 2019

Outline

1. update on the track selection

2. drift velocity with CRT runs
   → preliminary analysis (discussion of the method)

3. scintillation time fit:
   → fit of runs with S2
   → comparison of other studies (tau slow dependence with the drift field)

S2, DRIFT VELOCITY AND S2 ALGORITHM (PART I)

Introduction

:> data analysis (using CRT runs), two methods:

a) linear fit of the d vs ΔT_{S2-S1} (looking at the distributions of the 5PMTs together)

b) event by event, gaussian fit of the distribution of the $v_{drift,i}$ (ch) = d_i(ch) / $\Delta T_{S2-S1,i}$ (ch)

:> in both cases the event selection has been improved:

- only tracks inside the FC volume (33 mm < d_i < 950 mm)
- closest point inside the FC volume

:> no track length selection but, for comparison, the results obtained selecting only long tracks or all tracks are kept separated and the two results are compared

Event selection

Drift length definition:

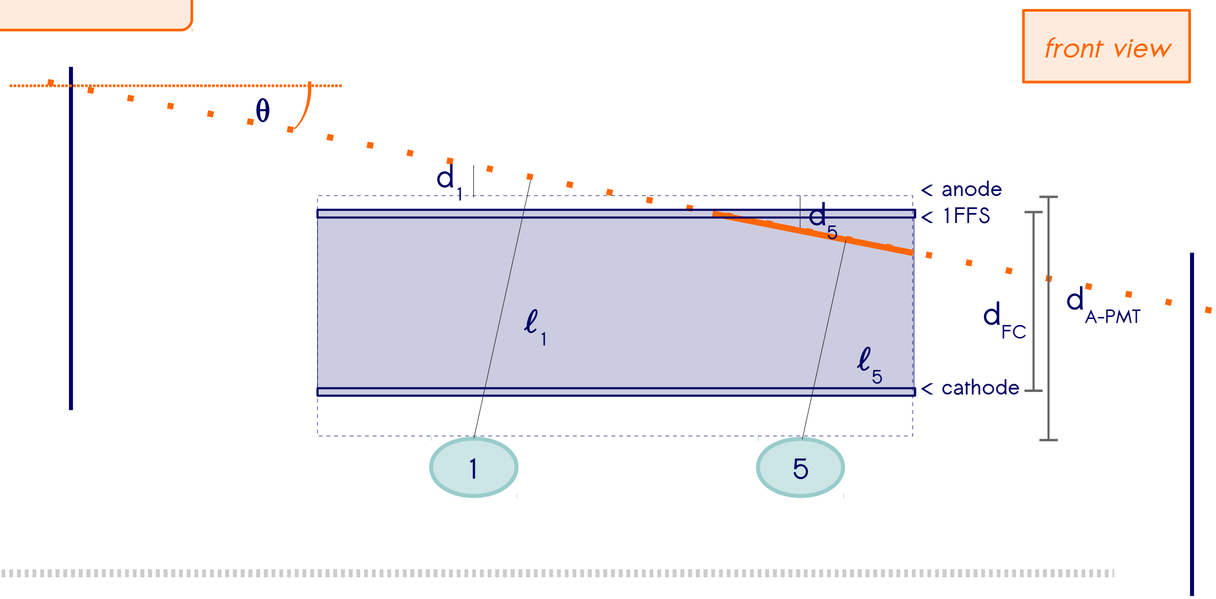
$$d_i = \text{anode} - \ell_i{}^* \cos\theta$$

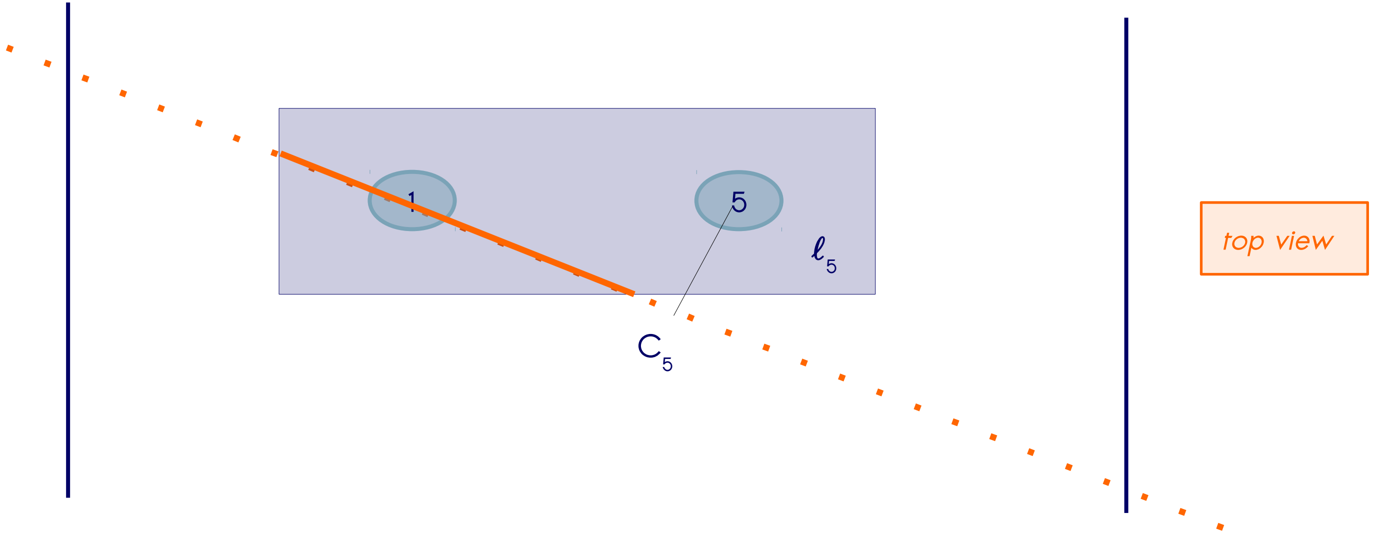
a) if d_i<33 mm || d_i>983 mm

b) if C_i is outside the FC volume

the i-PMT is detecting the S2 light produced above another PMT

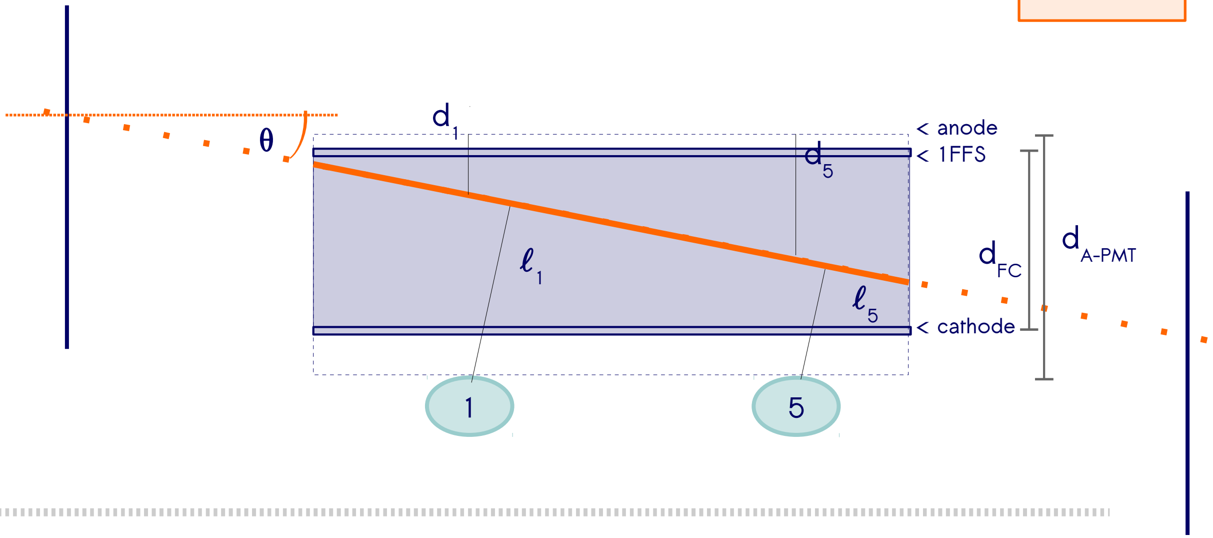
→ light not included for the i-th PMT





Event selection

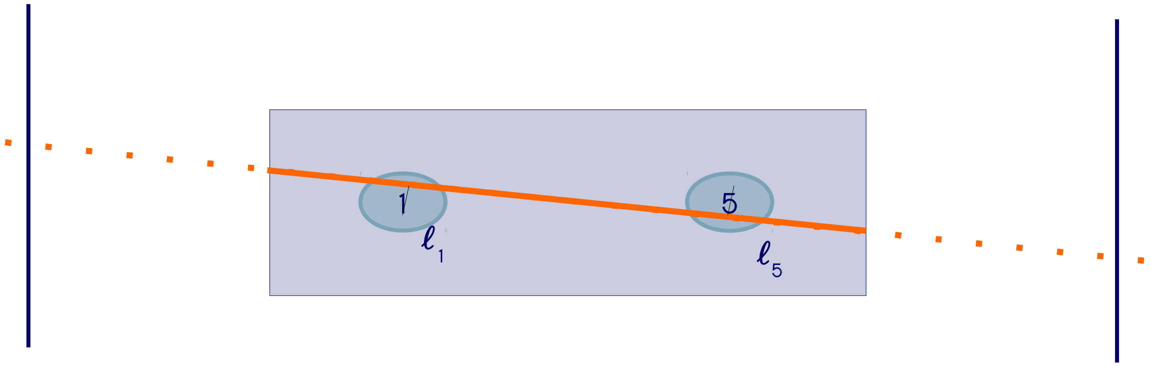
front view



If long tracks, possibility of having tracks partially outside the FC volume is mitigate By the CRT geometry selection

→ despite that, same cuts applied as before

top view



The drift length is in the vertical plain, the same as in picture above

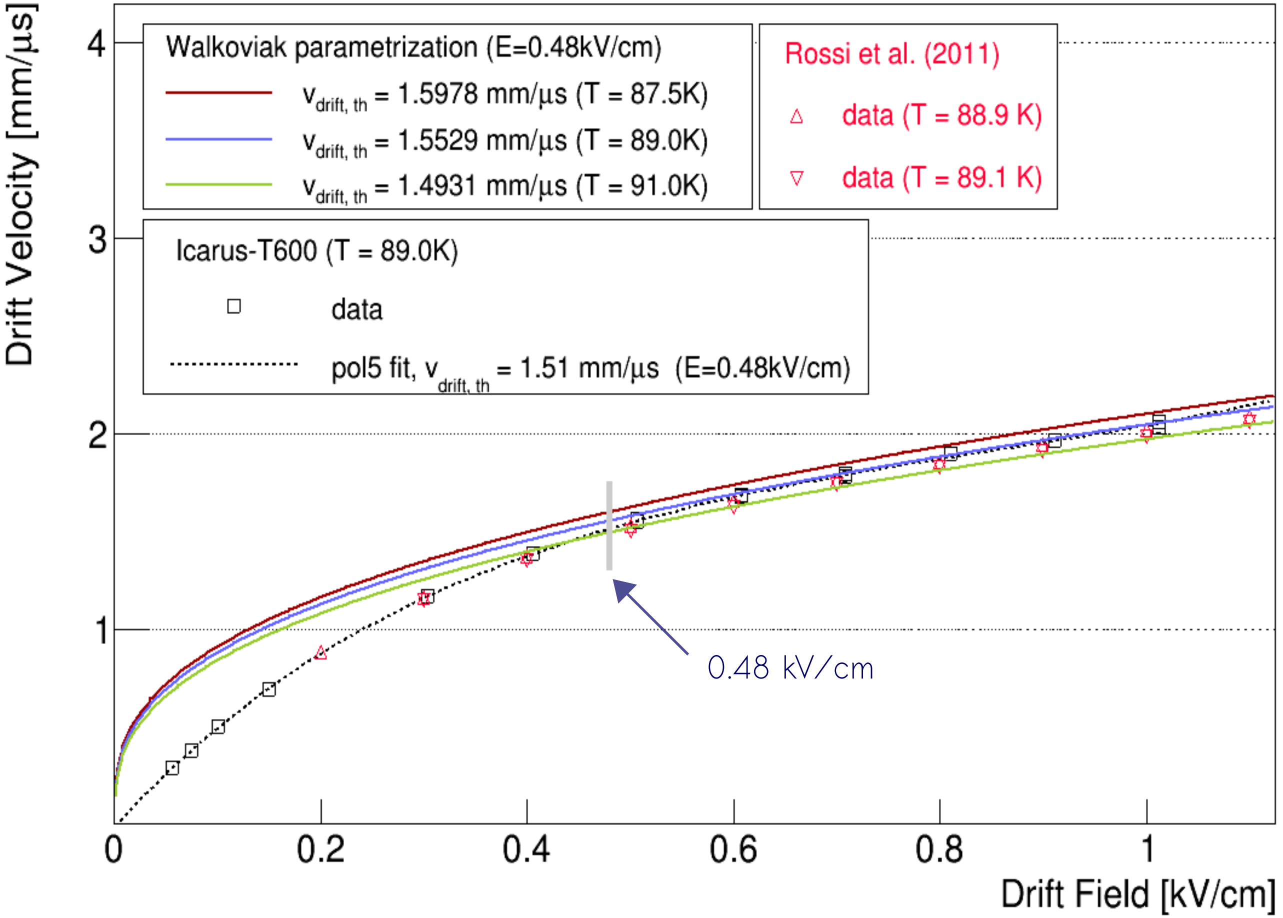
$$d_i = anode - \ell_i * \cos\theta$$

Predictions and comparisons

:> Walkoviak (2000) → v(|E|, T) parametrization using data taken in drift field range (0.5; 12.5) kV/cm and in 87 K <T< 94 K (NIM. A 449 2000 288)

:> Icarus-T600 combines results from long tracks, shower and purity monitor (at low drift field) and fit with a pol5 function (NIM. A 516 2004 68-79)

:> Rossi et al. (2011) does two measurements (T=88.9K and T=89.1K) in the drift field range (0.2; 1.2) kV/cm calculating the drift velocity from the time distance between S2 and S1 as a function of the drift length
→ in agreement with Icarus points at low drift field values
(J. of Phys.: Conf. Series 308 2011 012025)

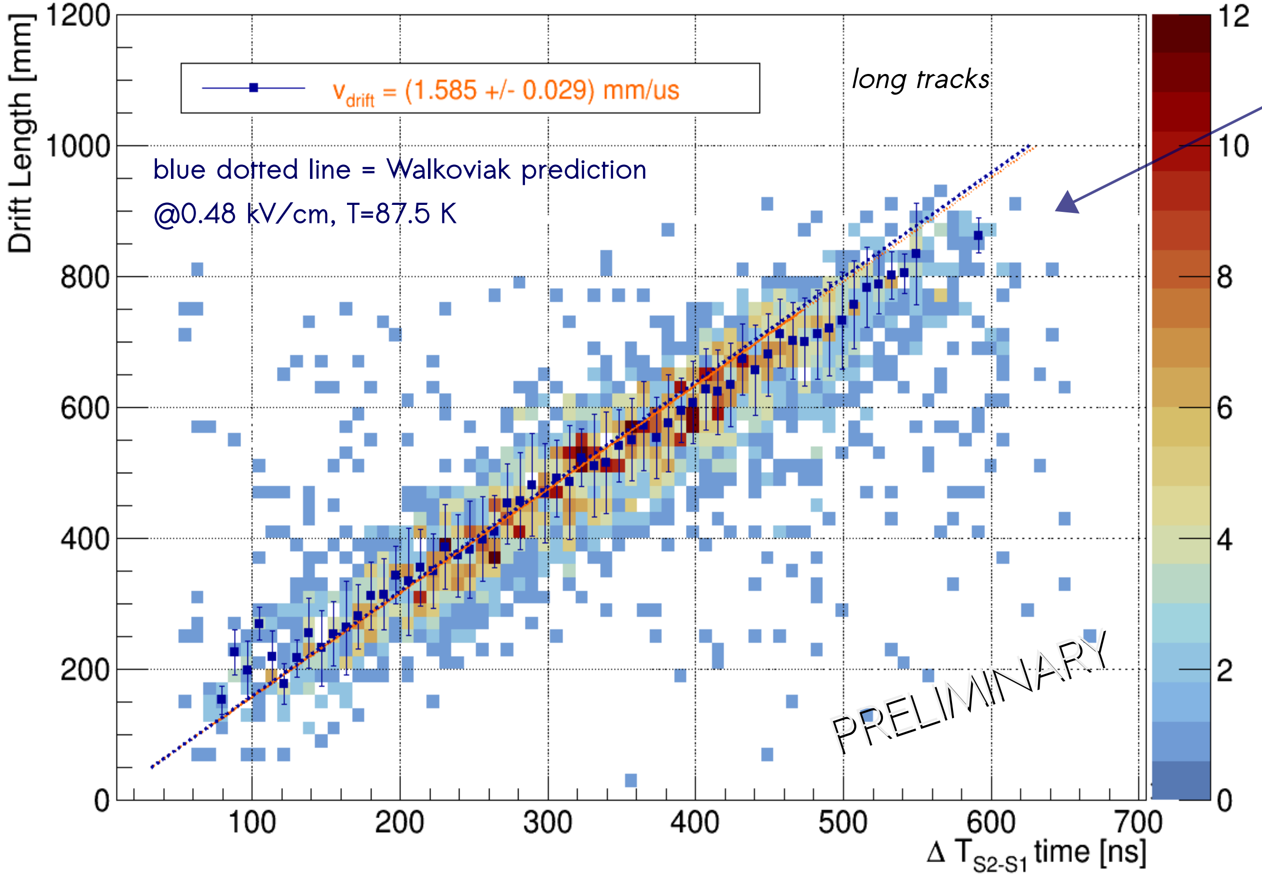


Drift velocity

RUN1670: DRIFT = 0.48KV/CM; AMPL. = 25.0 KV/CM

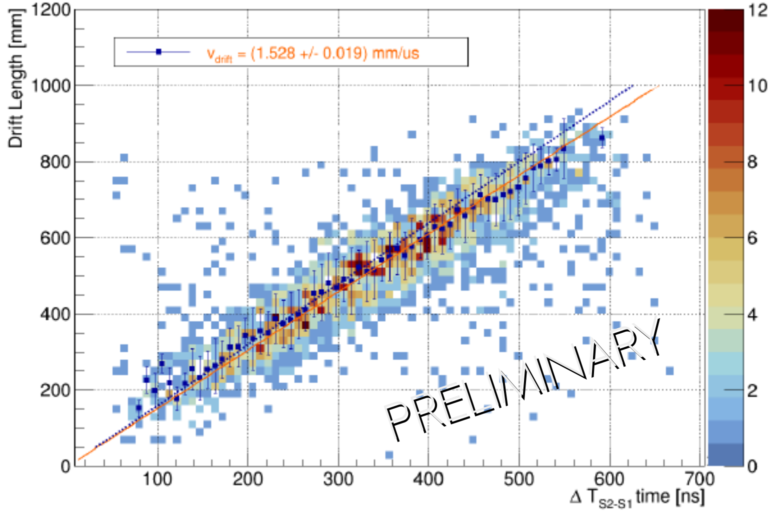
:> d vs ΔT_{S2-S1} distributions considering together the 5 PMTs - linear fit

each point is the mean of the gaussian fit of the drift length distribution in each ΔT_{S2-S1} slice, the error is the sigma of the distribution



last points can be affected by low statistics

:> fitting the points in the whole range, the central value of the drift velocity tends to decrease

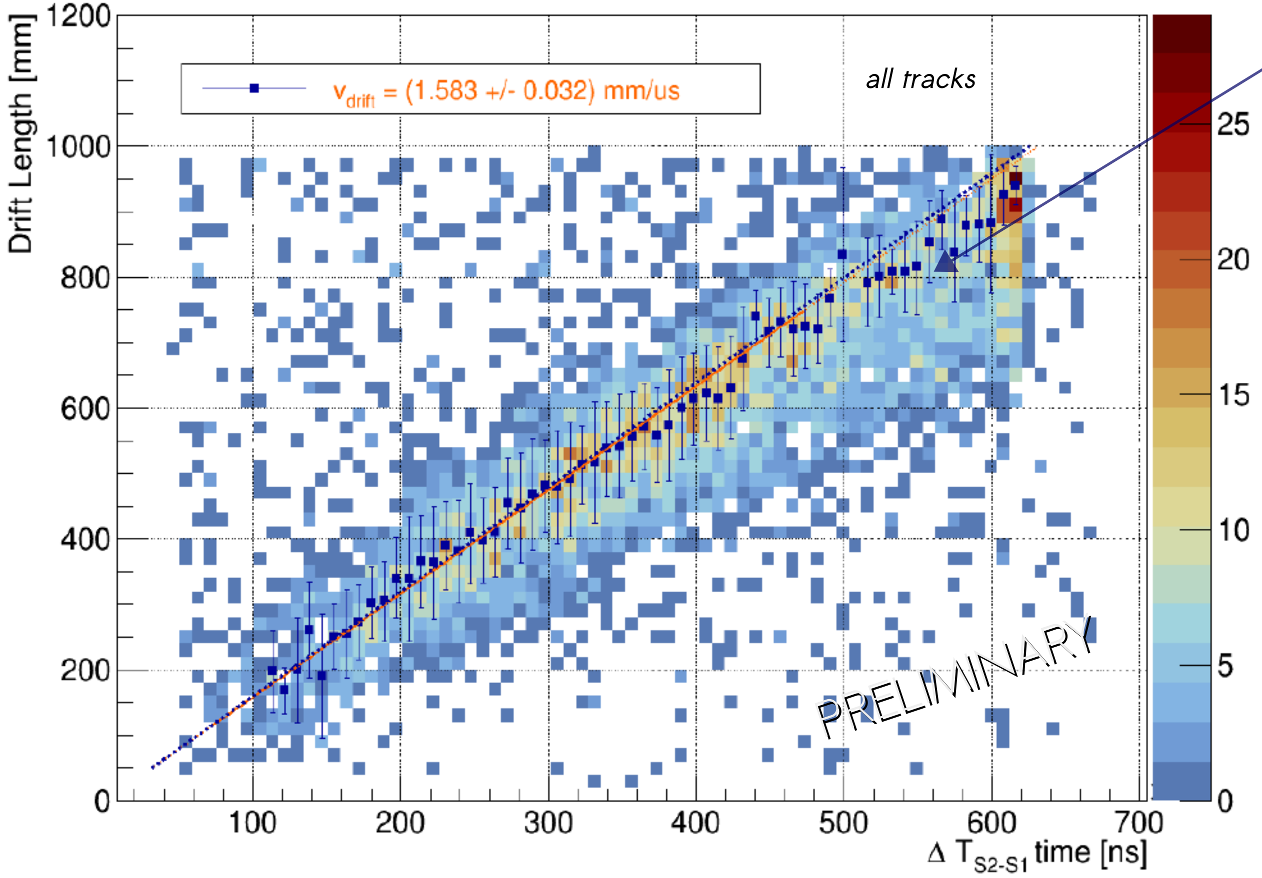


Drift velocity

Run1670: drift = 0.48kV/cm; ampl. = 25.0 kV/cm

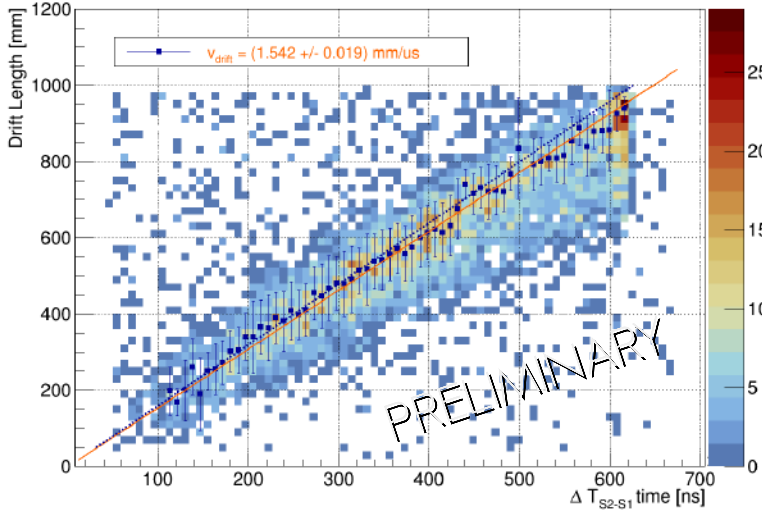
:> d vs ΔT_{S2-S1} distributions considering together the 5 PMTs - linear fit

each point is the mean of the gaussian fit of the drift length distribution in each ΔT_{S2-S1} slice, the error is the sigma of the distribution



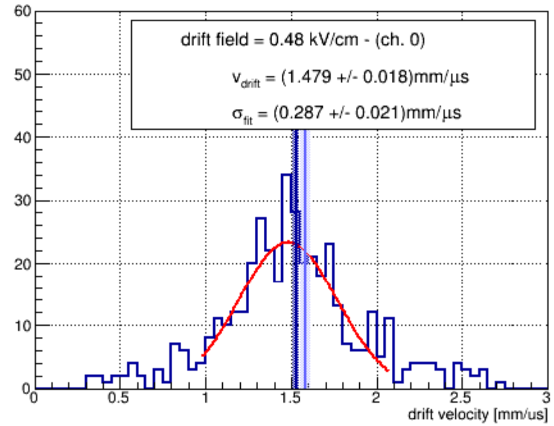
last points can be affected by low statistics

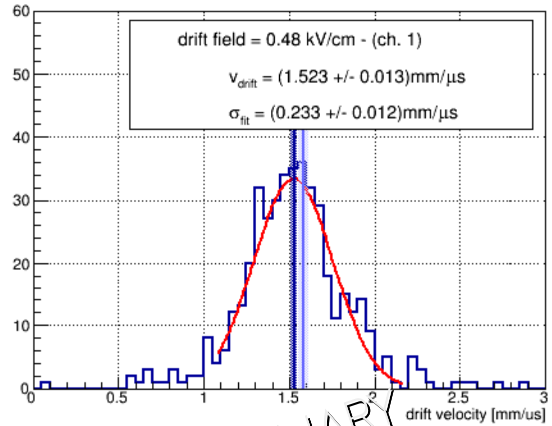
	whole range	short range
(long) v_{drift}	1.528 ± 0.019	1.585 ± 0.029
(all) v_{drift}	1.542 ± 0.019	1.583 ± 0.032

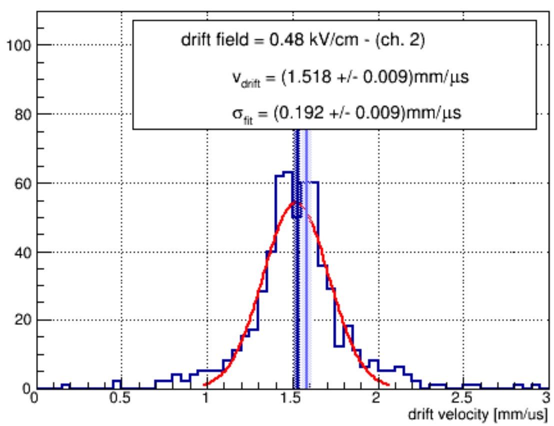


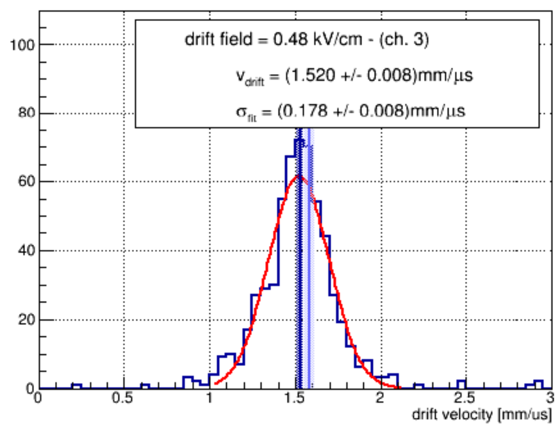
Drift velocity

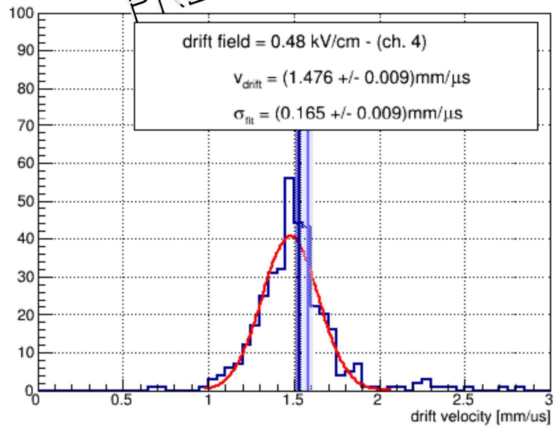
:> **(long tracks)** event by event, gaussian fit of the distribution of the $v_{drift,i}(ch) = d_i(ch) / \Delta T_{S2-S1,i}(ch)$







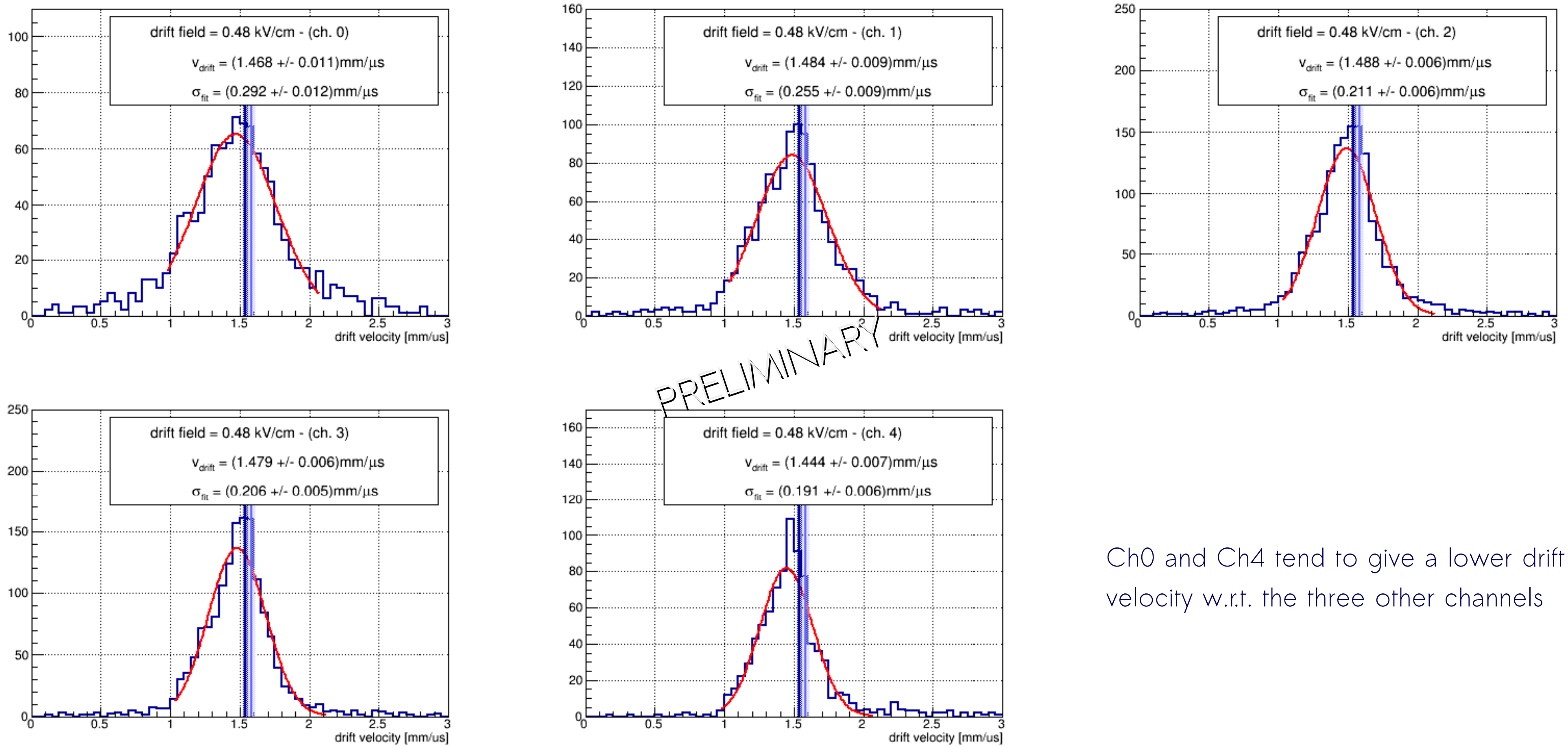




Ch0 and Ch4 tend to give a lower drift velocity w.r.t. the three other channels

Drift velocity

:> **(all tracks)** event by event, gaussian fit of the distribution of the $v_{drift,i}$ (ch) = d_i(ch) / $\Delta T_{S2-S1,i}$ (ch)



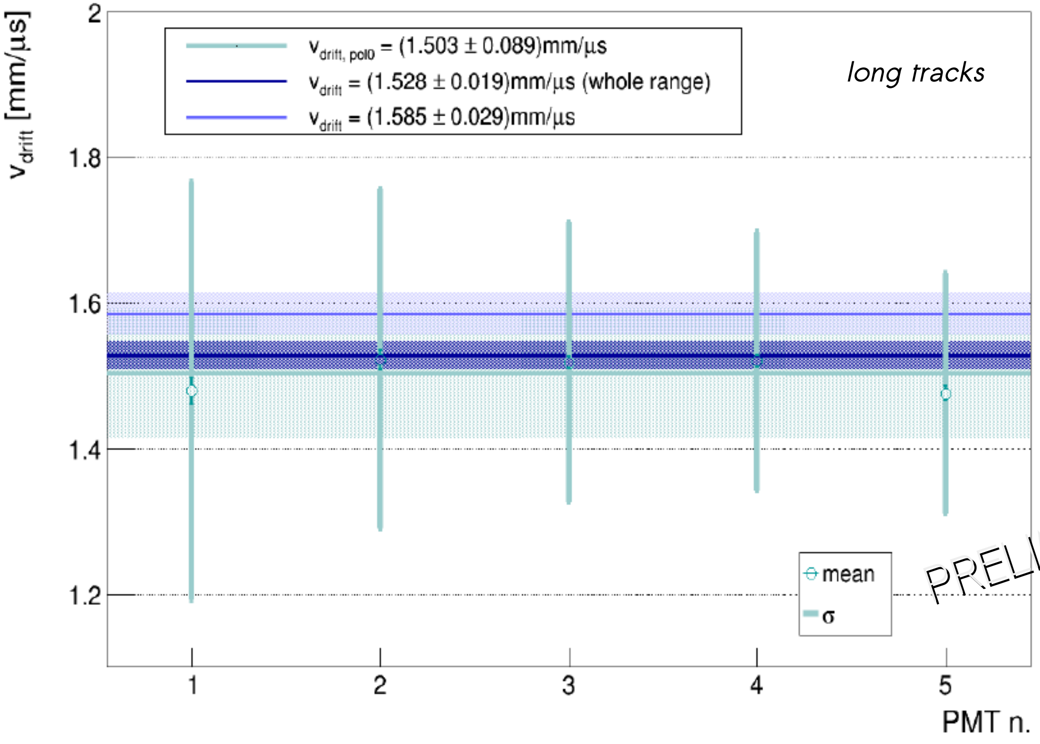
Ch0 and Ch4 tend to give a lower drift velocity w.r.t. the three other channels

Drift velocity

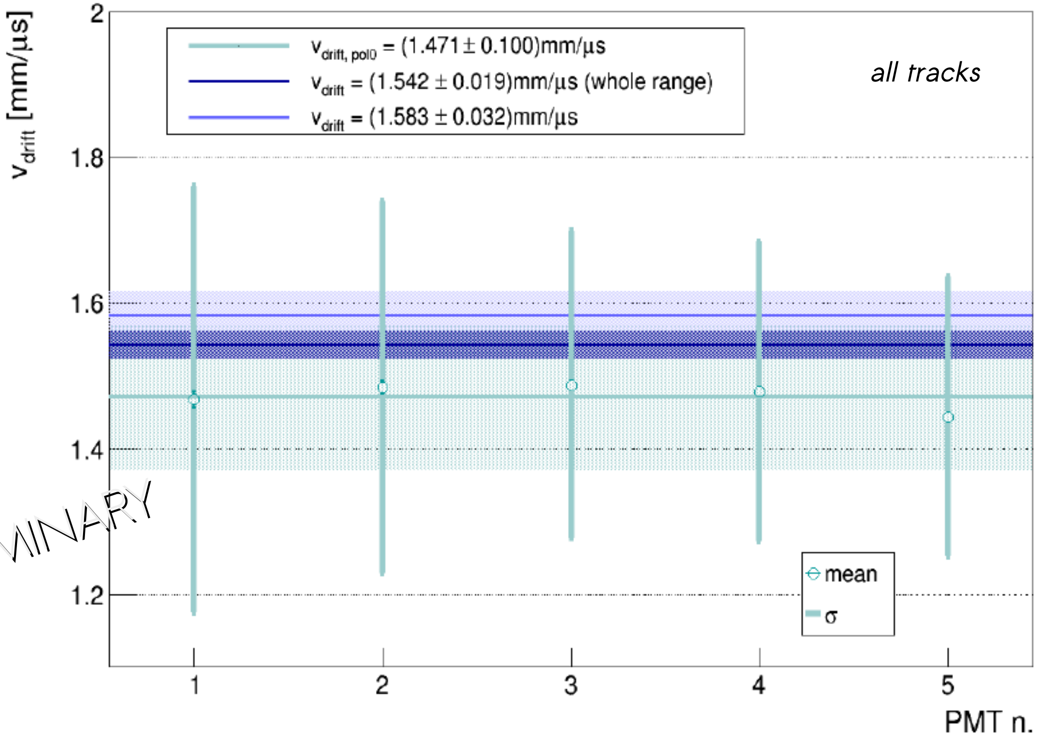
RUN1670: DRIFT = 0.48 kV/cm; AMPL. = 25.0 kV/cm

:> comparison between two methods

(the error bar in each point is the sigma of each gaussian distribution)



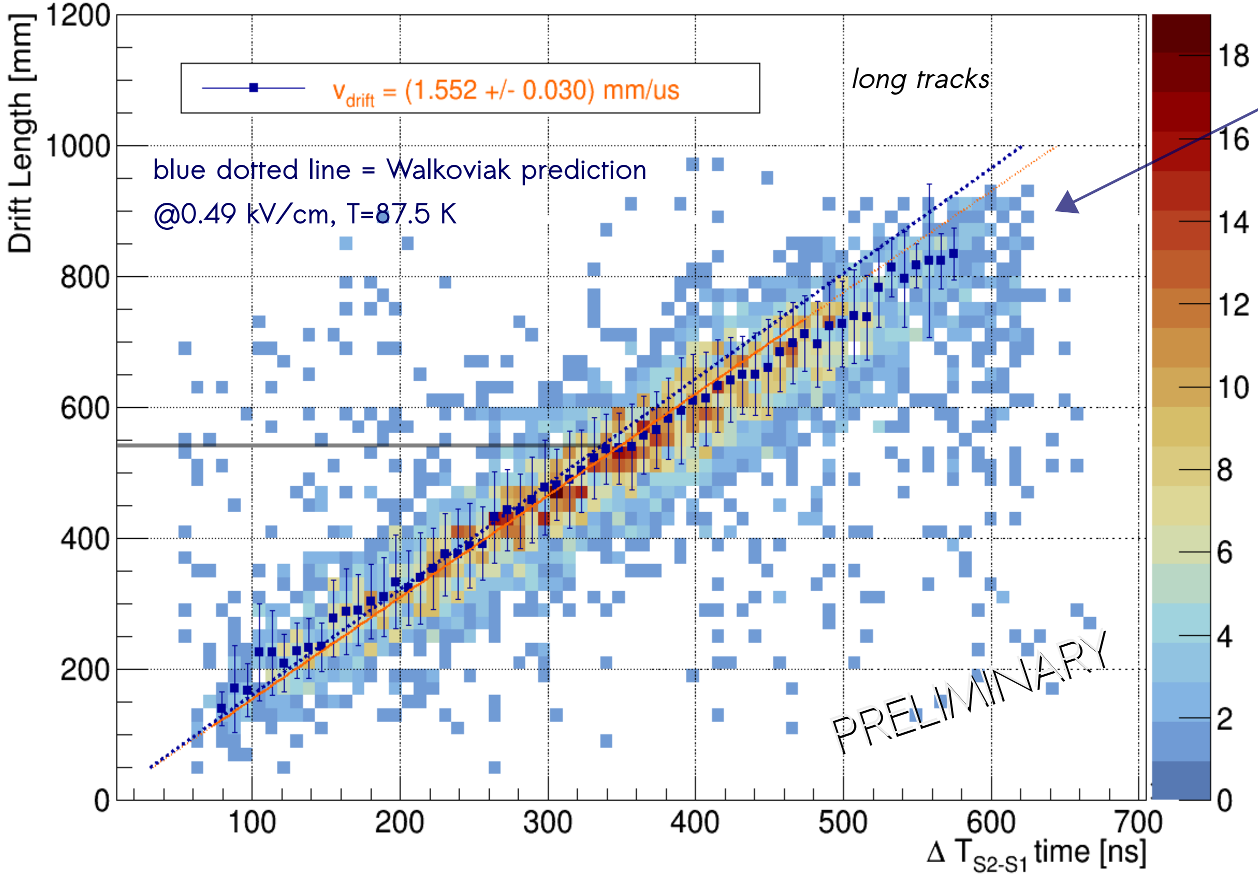
PRELIMINARY



Drift velocity

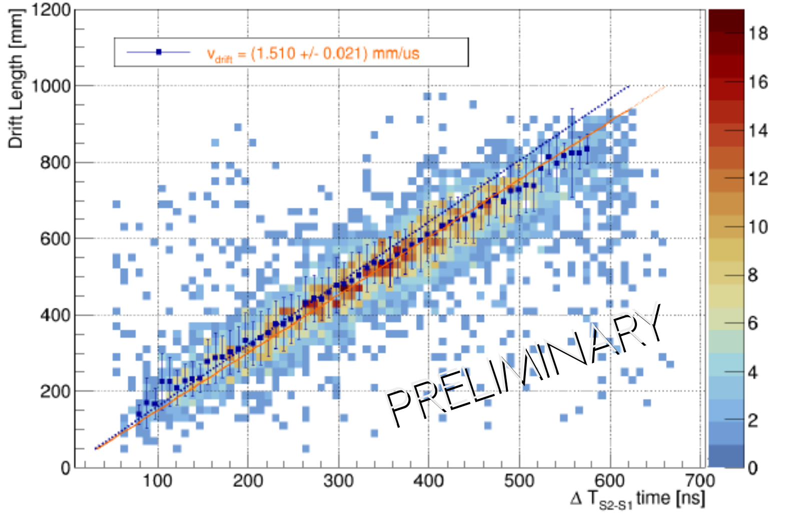
:> d vs ΔT_{S2-S1} distributions considering together the 5 PMTs - linear fit

each point is the mean of the gaussian fit of the drift length distribution in each ΔT_{S2-S1} slice, the error is the sigma of the distribution



it's hard to say if the distribution follows a straight line with a different slop or there two populations that follows different lines..

(but the statistics is quite low..)

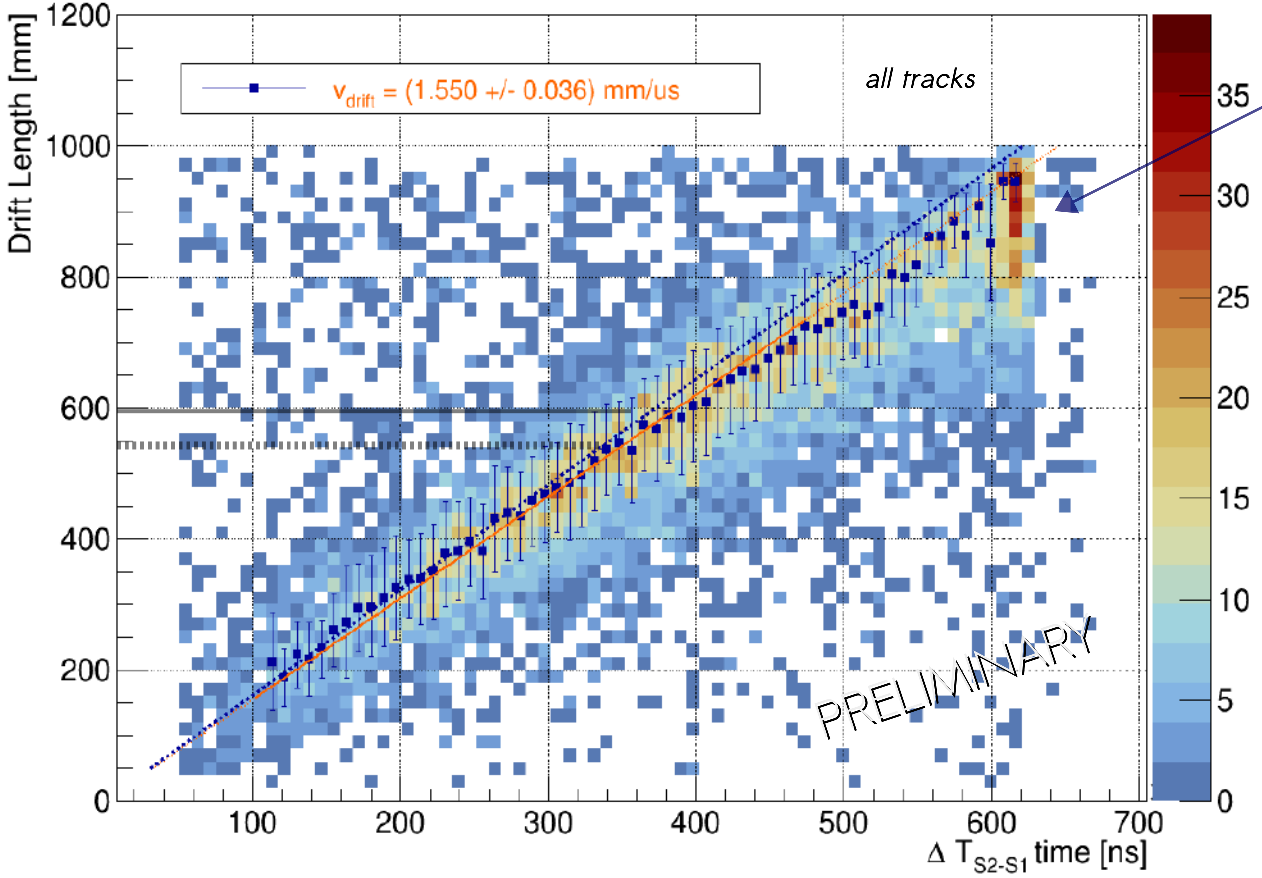


Drift velocity

RUN1671: DRIFT = 0.49KV/CM; AMPL. = 25.5 KV/CM

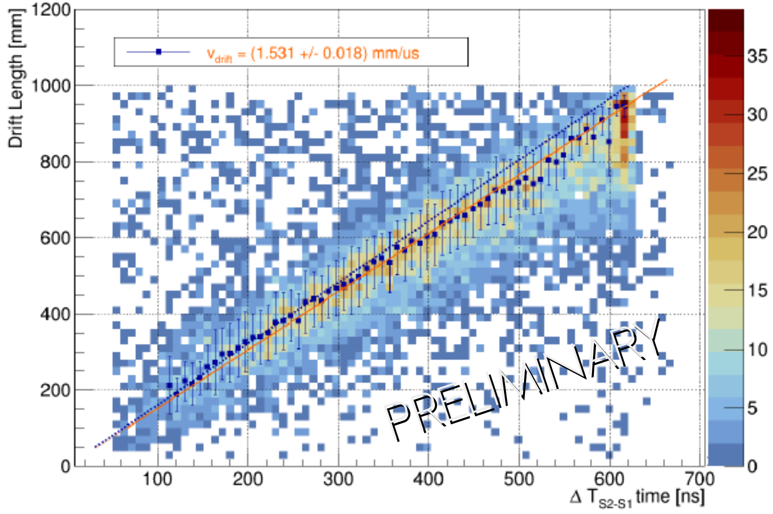
:> d vs ΔT_{S2-S1} distributions considering together the 5 PMTs - linear fit

each point is the mean of the gaussian fit of the drift length distribution in each ΔT_{S2-S1} slice, the error is the sigma of the distribution



..same trend?

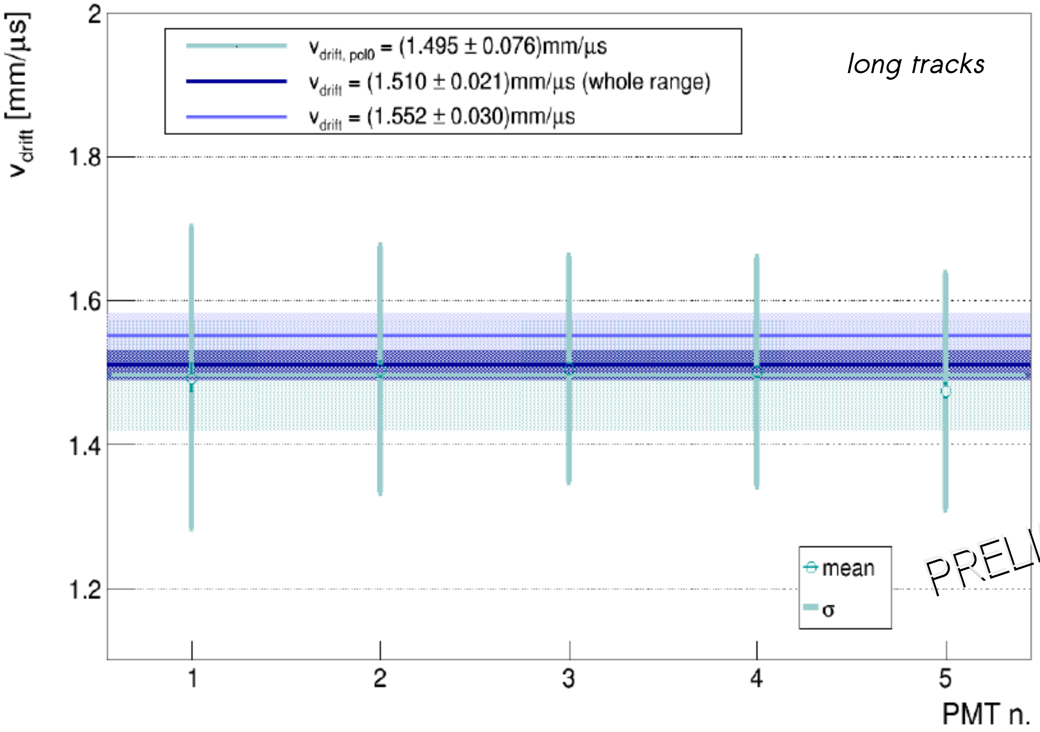
	whole range	short range
(long) v_{drift}	1.510 ± 0.021	1.552 ± 0.032
(all) v_{drift}	1.531 ± 0.018	1.550 ± 0.036

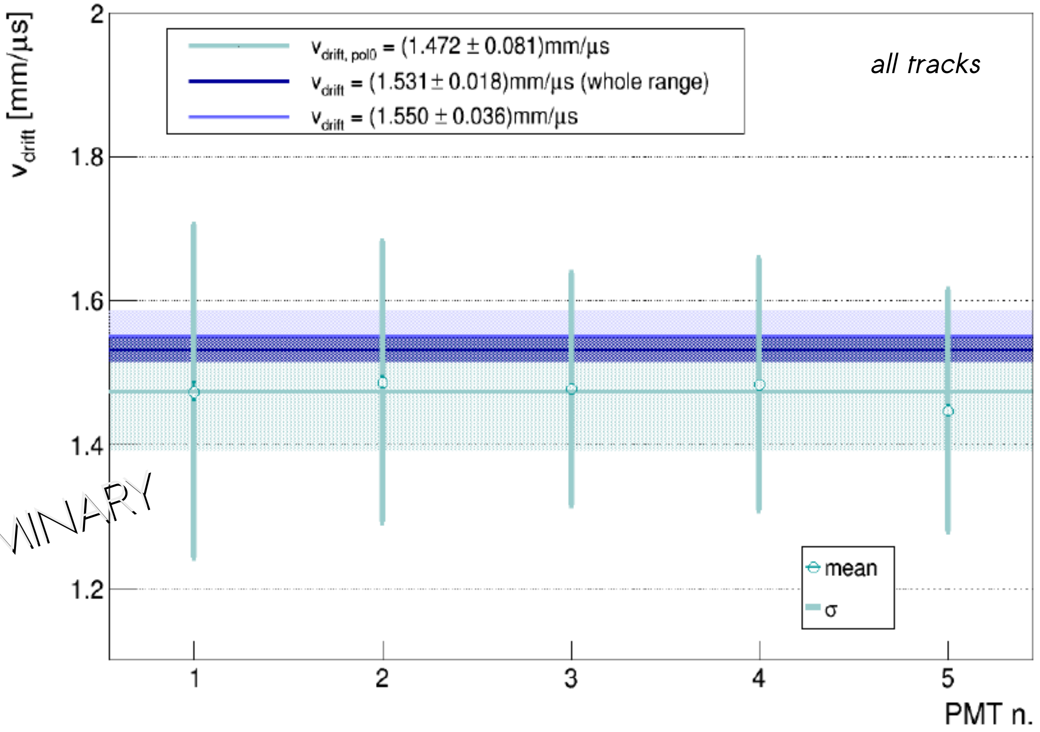


Drift velocity

RUN1671: DRIFT = 0.49KV/CM; AMPL. = 25.5 KV/CM

:> comparison between two methods, all results





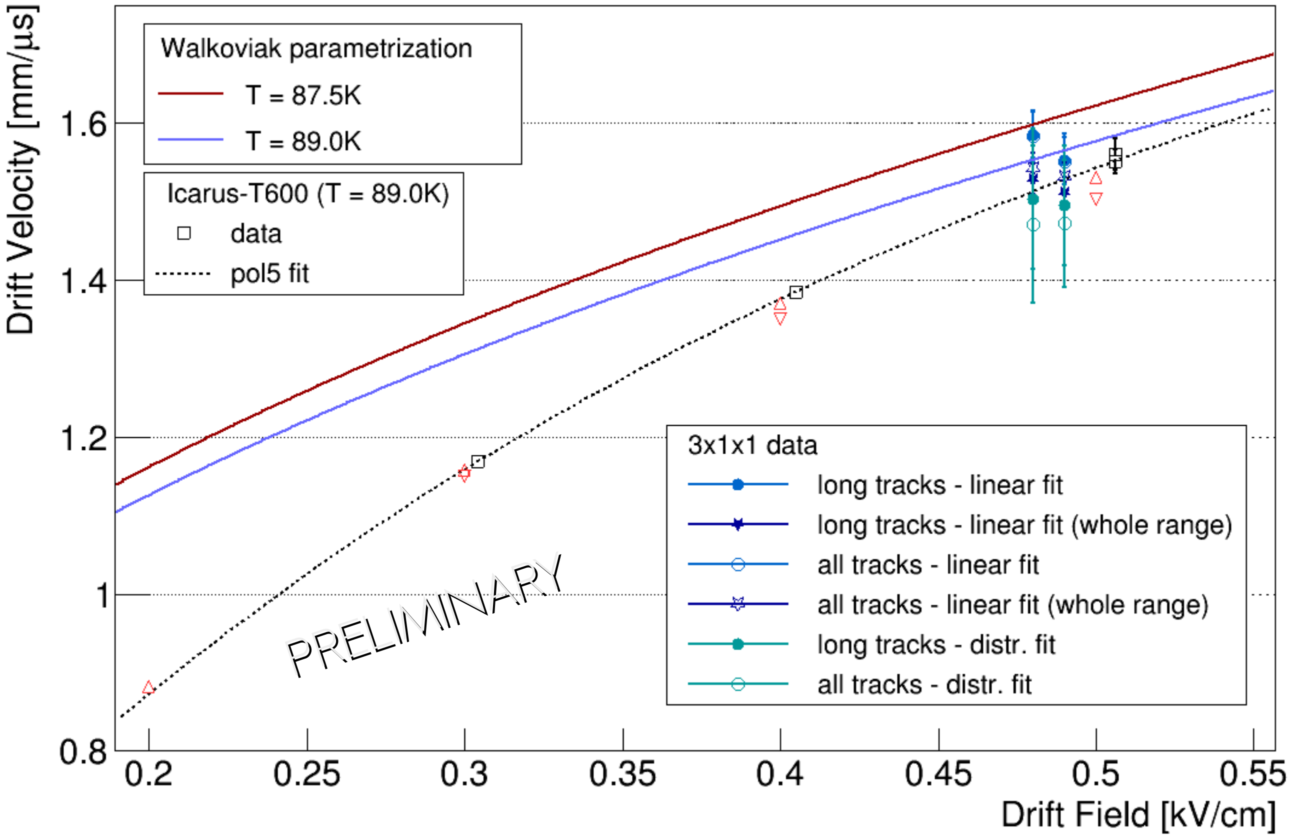
PRELIMINARY

Predictions and comparisons

:> at 0.48kV/cm, at least considering the results from the linear fit, within the error the drift velocity calculated is close to the prediction

:> but the values obtained at higher drift field gave lower value for the drift velocity

:> to check the method and possible bias introduced by the algorithm, cross check with the MC simulation



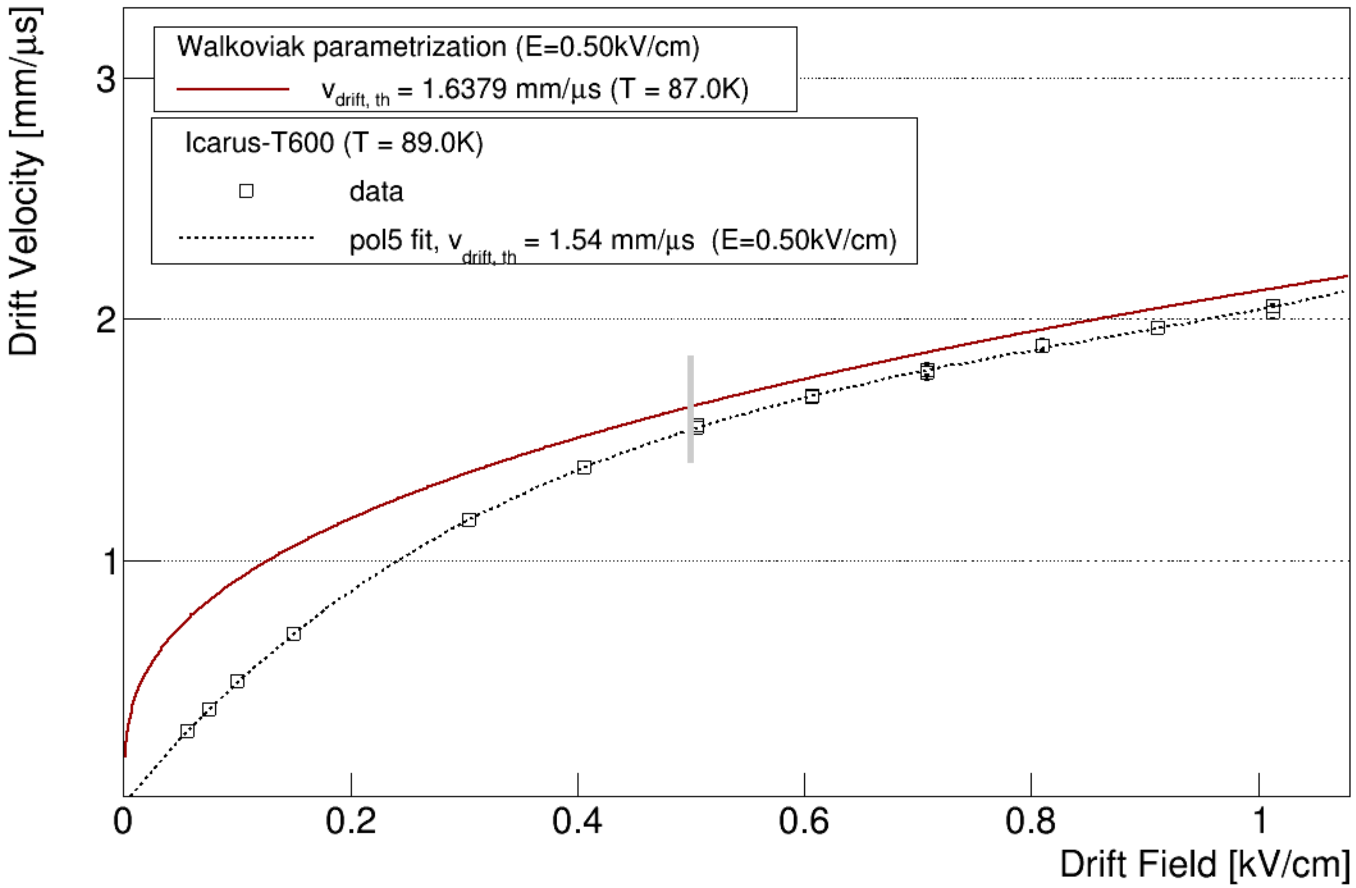
Drift velocity - MC simulation

:> comparison with MC simulation

→ the MC has been simulated @0.5 kV/cm and T=87K, the expected drift velocity is 1.62 mm/us

→ Gel = 160

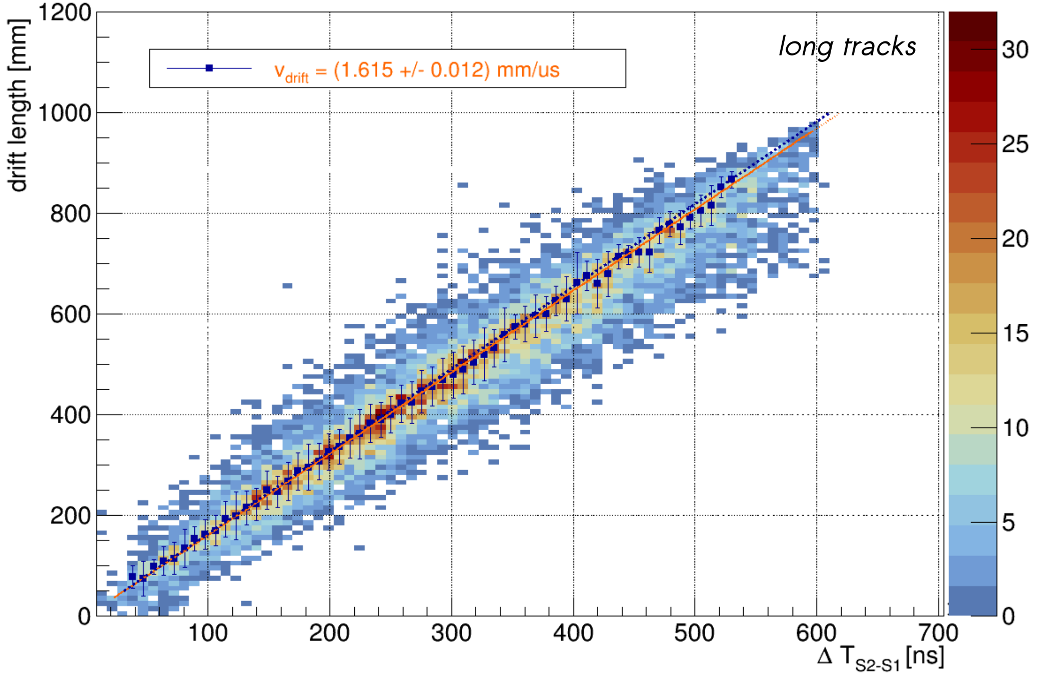
→ tracks homogeneously generated in the tantheta range (-0.3, 0.3)

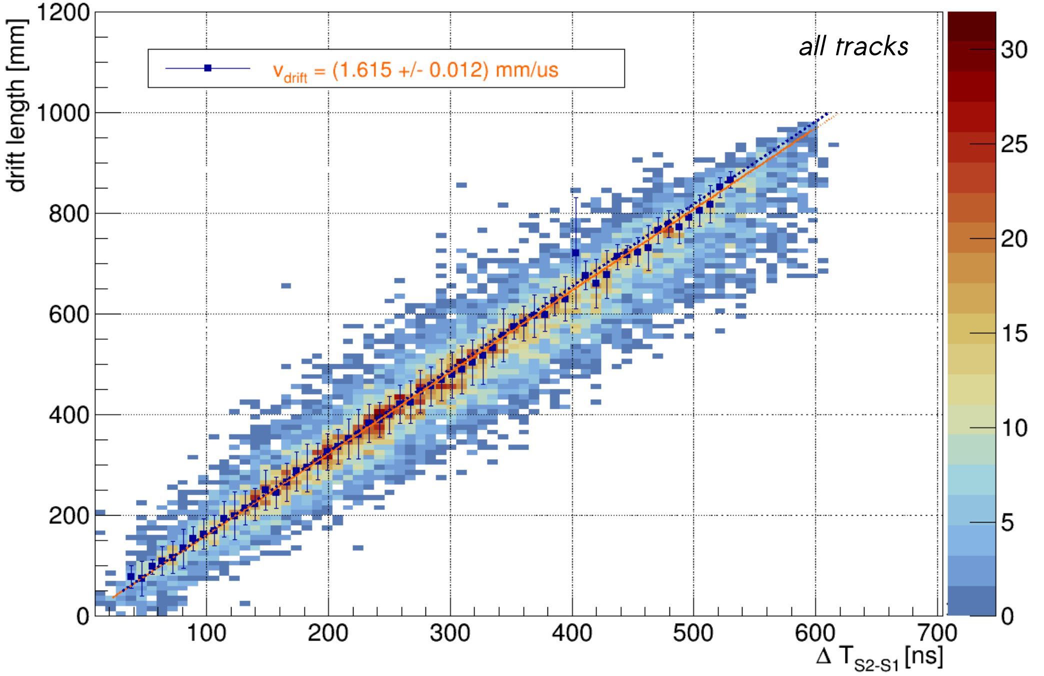


Drift velocity - MC simulation

:> comparison with MC

"Side" : homogeneous distribution in (-0.3; 0.3) tan theta range



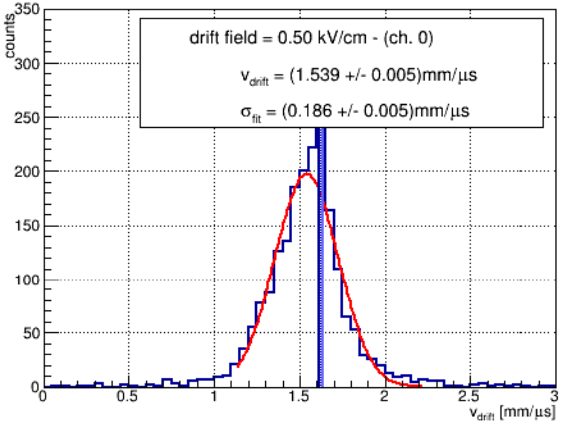


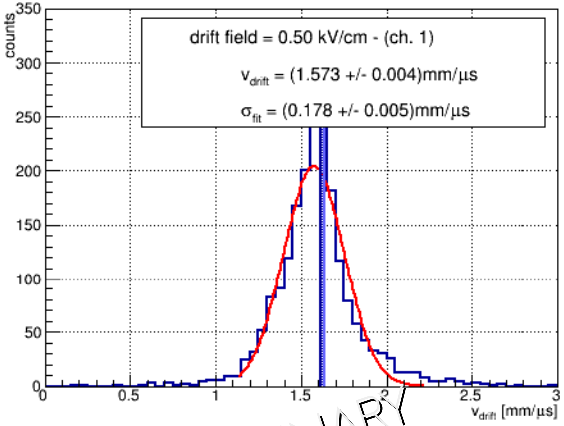
:> same result independent of the track length selection

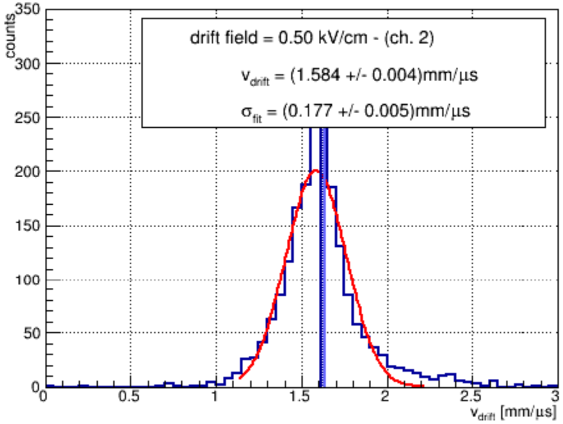
Drift velocity

MC: DRIFT = 0.5KV/CM; GEL = 160

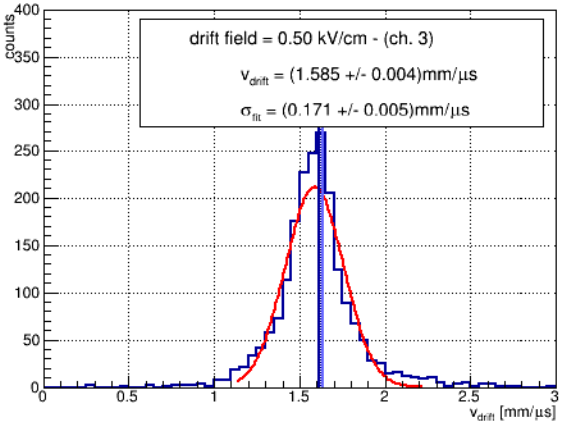
:> **(long tracks)** event by event, gaussian fit of the distribution of the $v_{drift,i}$ (ch) = d_i(ch) / $\Delta T_{S2-S1,i}$ (ch)

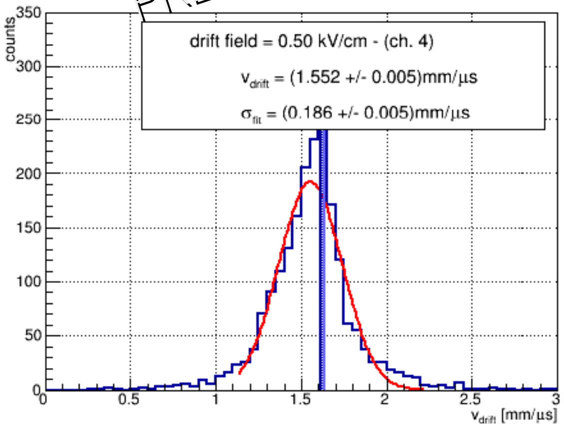






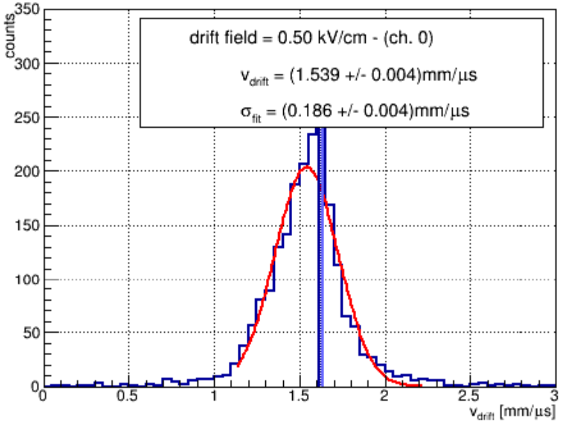
PRELIMINARY

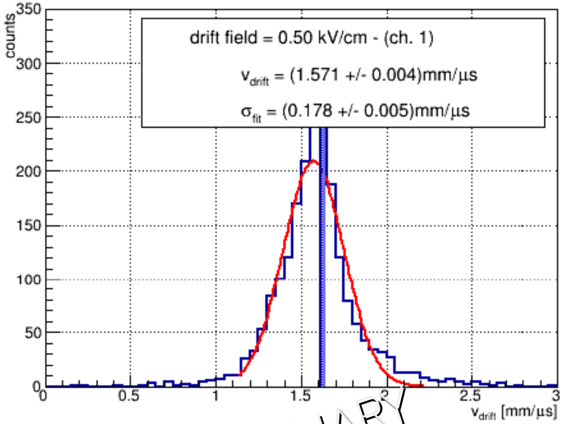


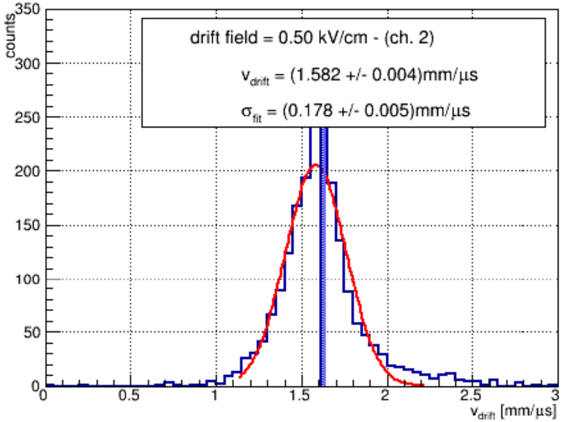


Drift velocity

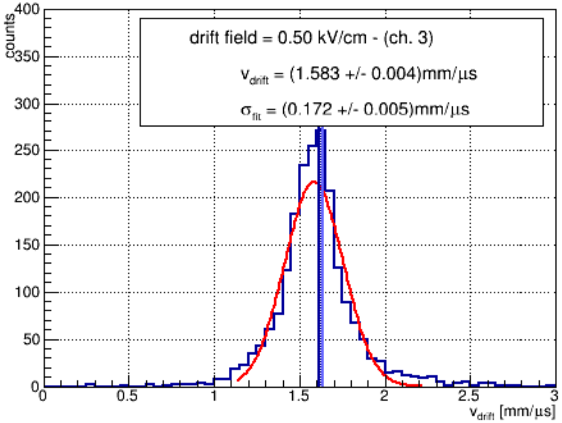
:> **(all tracks)** event by event, gaussian fit of the distribution of the $v_{drift,i}$ (ch) = d_i(ch) / $\Delta T_{S2-S1,i}$ (ch)

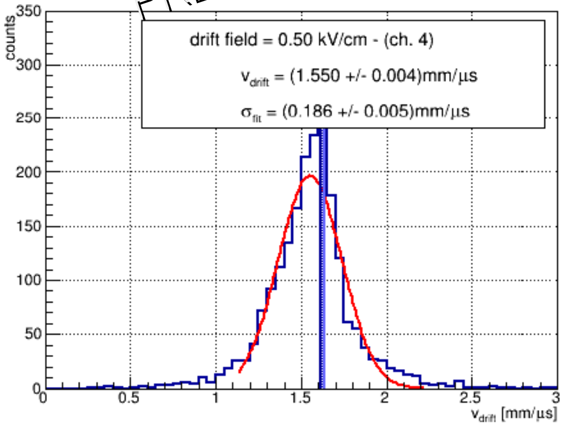






PRELIMINARY

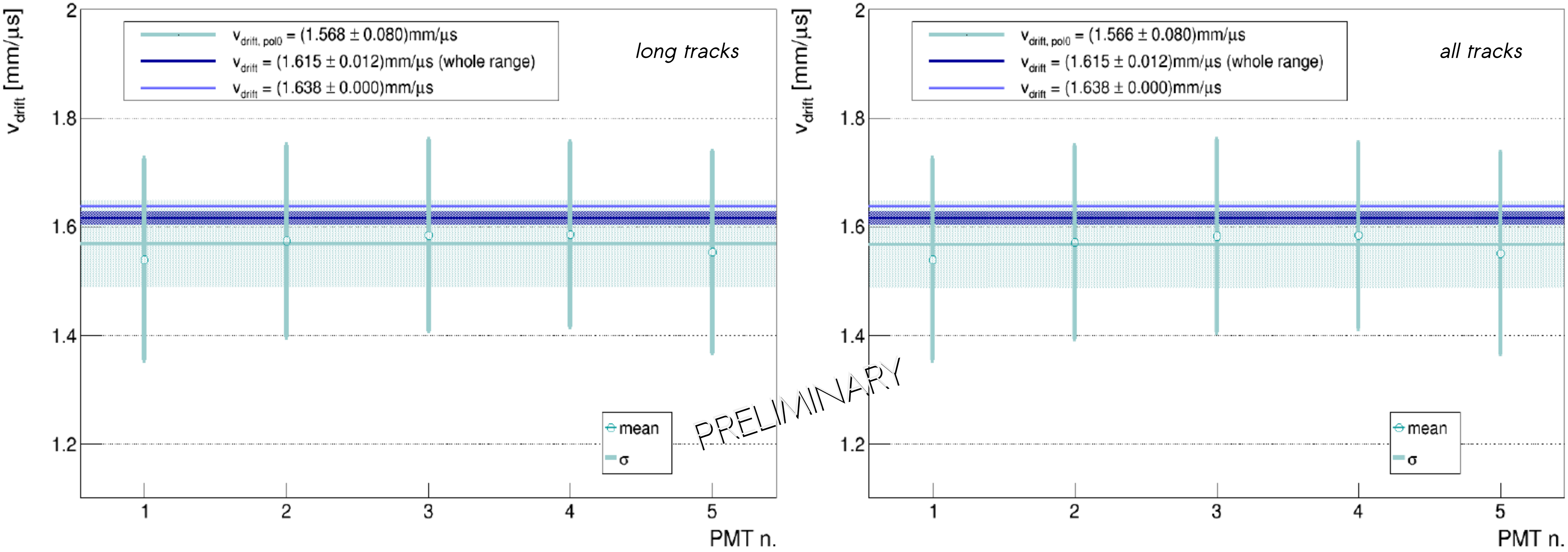




Drift velocity

MC: DRIFT = 0.5KV/CM; GEL = 160

:> comparison between two methods
(the error bar in each point is the sigma of each gaussian distribution)



:> if the linear fit of the 2d distribution gives a result very close to Walkoviak prediction, fitting the distribution of the drift velocity calculated event by event confirm the bias found in the data

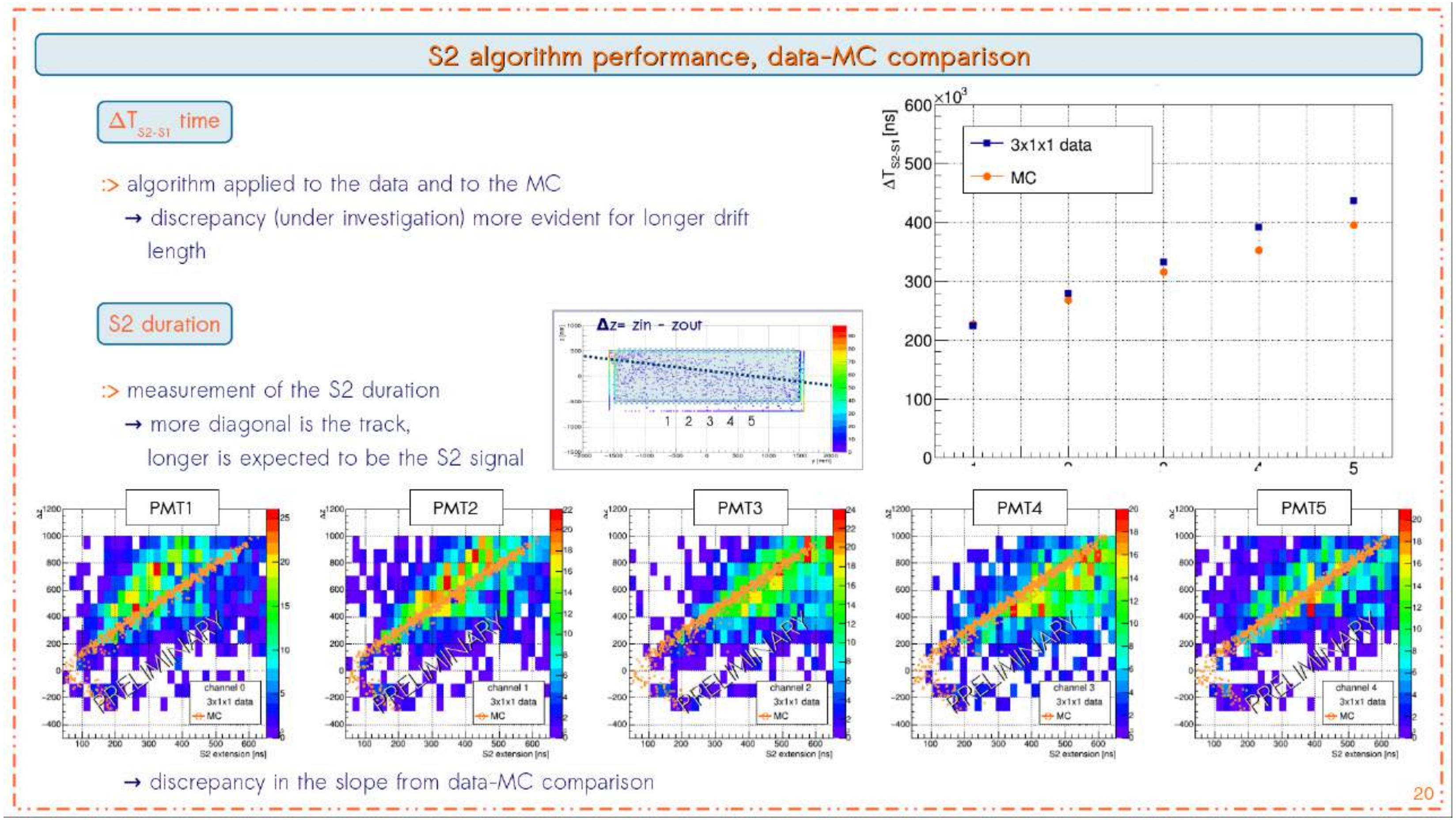
→ if compared with the linear fit, is ~3% lower because of doing a pol0 fit

→ not the same drift velocity obtained by the 5 PMTs (in Ch2, in the center, is higher, Ch0 and Ch4 lower)

Comments and next steps

:> a preliminary data-MC comparison was done with sample produced with Gel=300 but maybe to idealistic

→ some discrepancies between data and MC were already there



:> I'll update the data-MC comparison with this samples produced with Gel=160

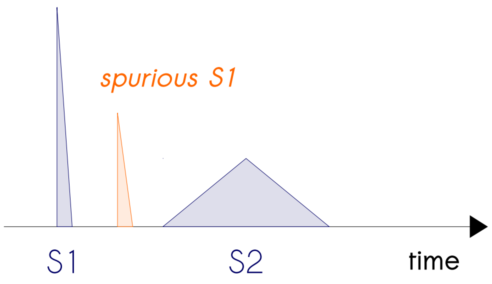
→ compare this algorithm with Laura's algorithm to understand where the two differ and optimize them

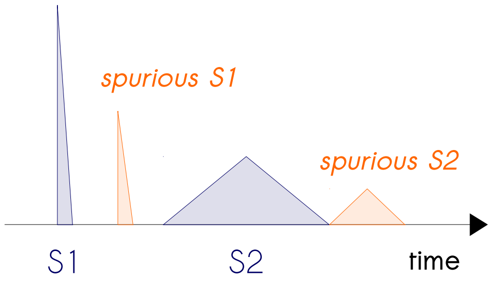
Remind on the S2-algorithm

:> so far, the algorithm is able to:

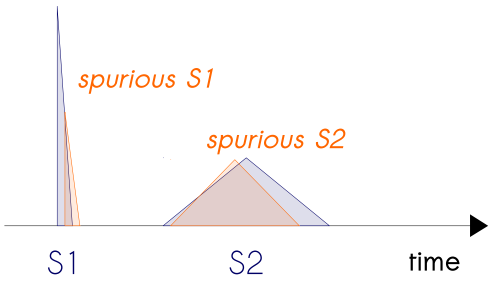
a) exclude the S1 contribution from the S2 reconstruction

b) exclude the S2 contribution coming from the spurious S1 if it starts after the mainS2 ending





:> the more complicated kind of event to be recognized are the ones where there is a spurious S2 contribution convoluted with the main S2 since there is no evident S1 spurious peak (still ongoing)



SCINTILLATION TIME PROFILE STUDIES
(PART I)

Scintillation time profile fit

Results presented so far

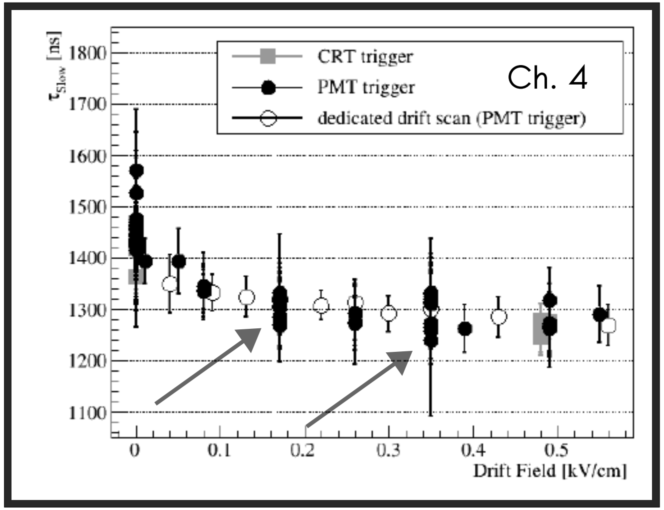
:> included all the "good" runs we have

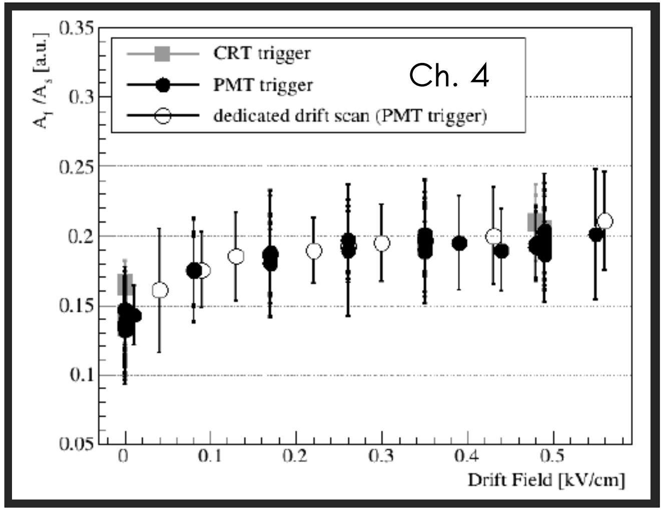
→ important to validate the results we see in the runs of the drift field scan

→ to prove the trend is not a statistical fluctuation (to make this statement even stronger, a proper study of the systematics is important - ongoing - not discussed in this presentation)

:> in runs with drift field AND amplification field, the *provisional* approach used so far, was to decrease the range of the fit and include possible effects in a systematical error (previously discussed here)

→ for high amplification, this approach was not robust enough, especially for the tau slow calculation



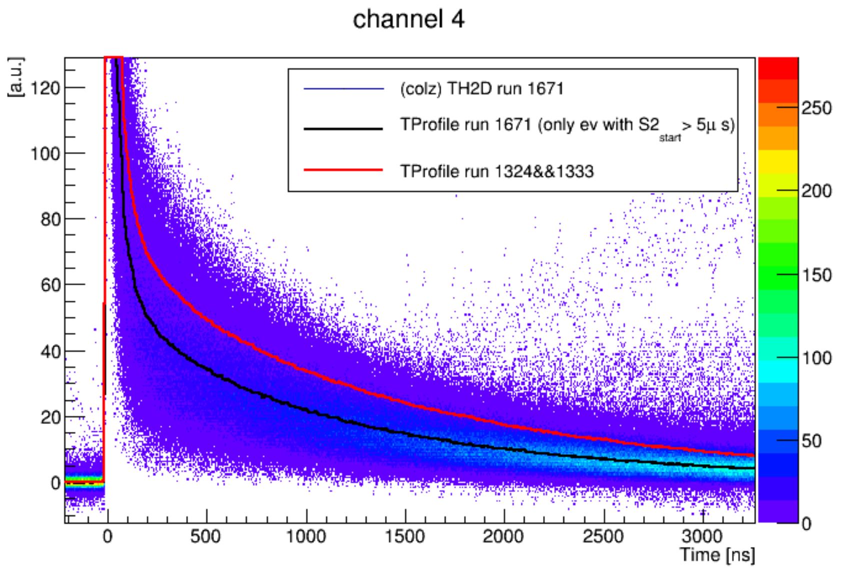


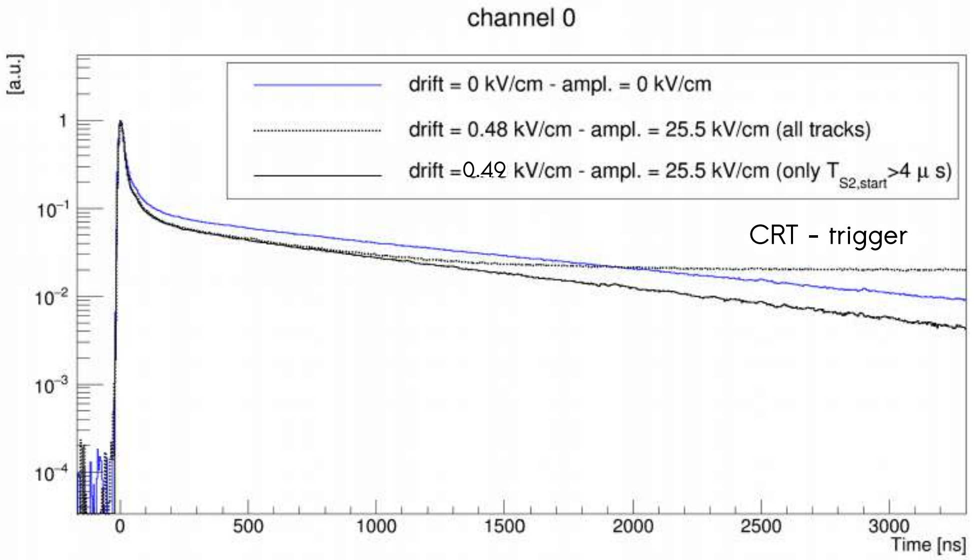
How to fit the runs with S2 contamination

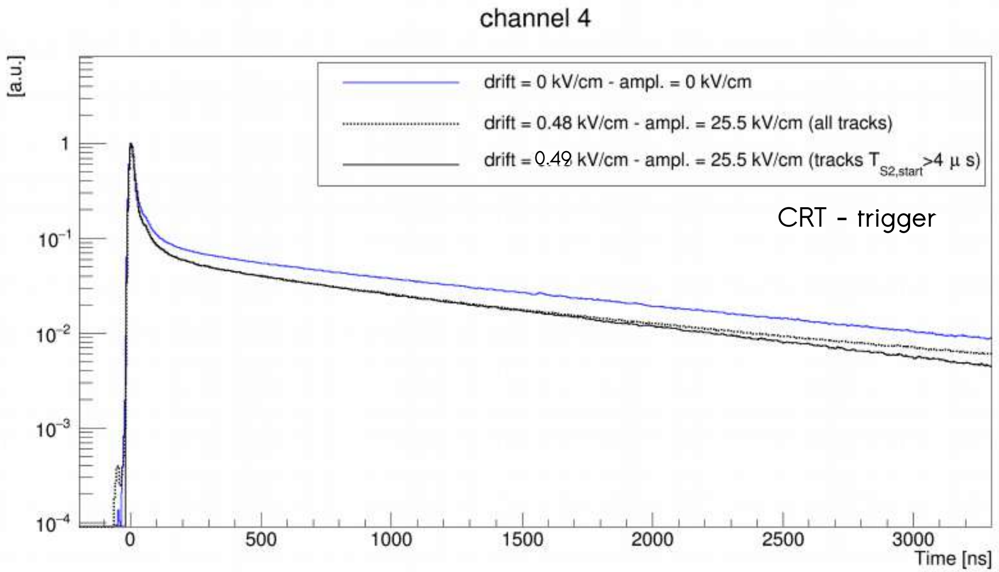
:> accept only events with S2 signal starting 4us after S1 peak

→ even using the TProfile, is clearly excluded the possible contamination of S2 charge in the scintillation time profile fit

→ the fit can be done in the same range as for runs without amplification!

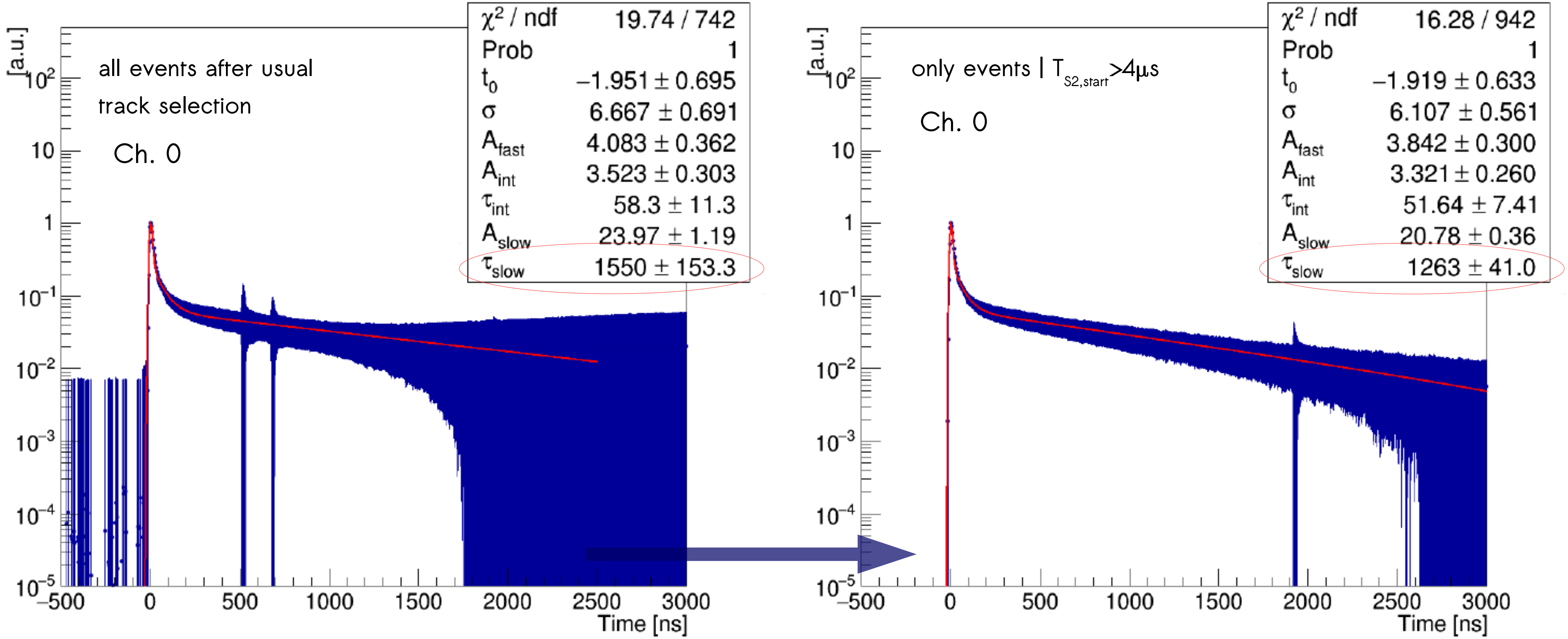






How to fit the runs with S2 contamination

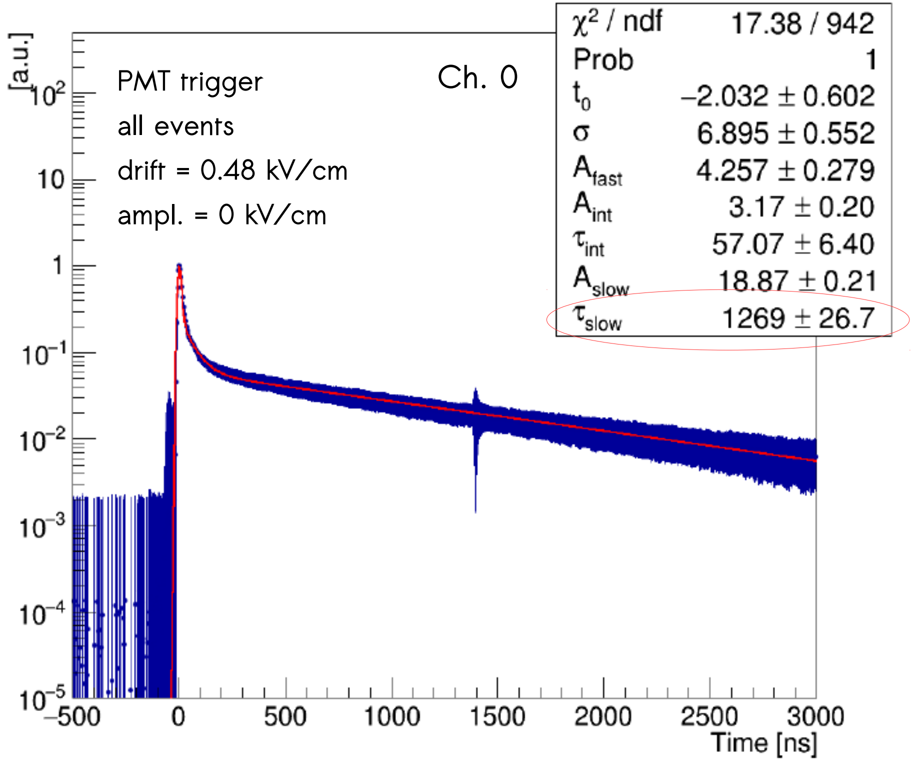
BEFORE	NOW
(fitting in a decreased range)	(including only events with $T_{S2,start} > T_{S1}$ +4us)

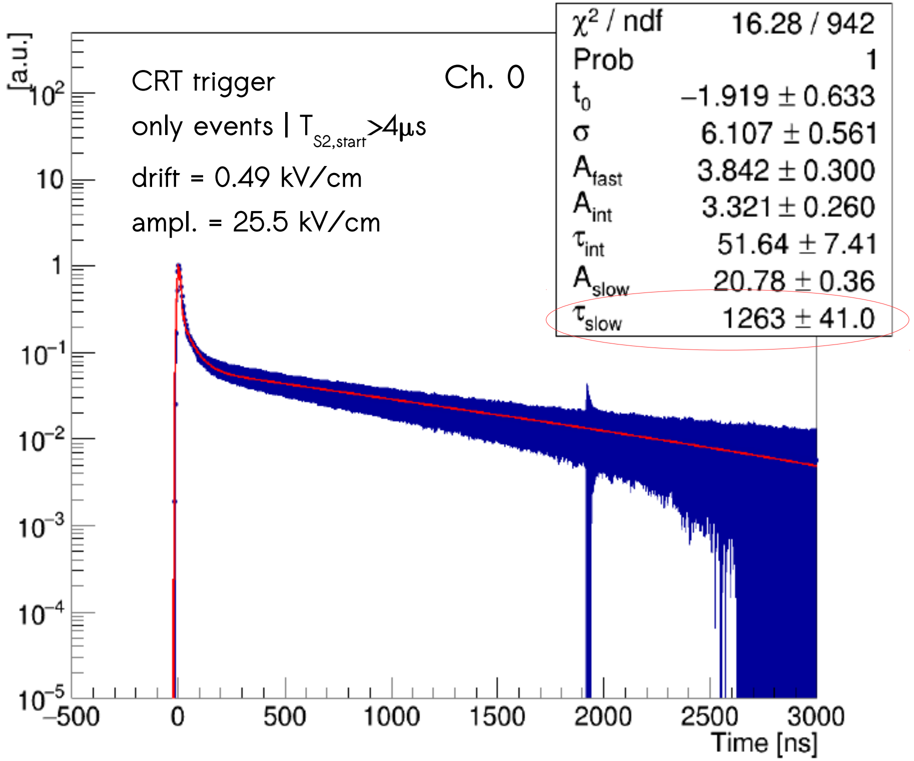


How to fit the runs with S2 contamination

:> comparison with run without S2 but same drift field

BEFORE	NOW
(fitting in a decreased range)	(including only events with $T_{S2,start} > T_{S1}$ +4us)



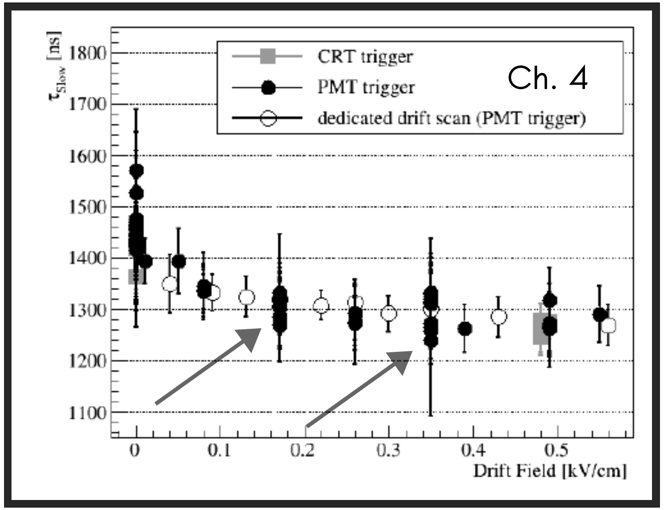


How to fit the runs with S2 contamination

:> Fit result comparison, all the parameters, that are expected to be in agreement, are in agreement within the error

	Run 1451 (PMT tr.)	Run 1671 (CRT tr.)
	drift = 0.48kV/cm ampl 0kV/cm	drift = 0.49kV/cm ampl 25.5kV/cm
t0	(-2.032 ± 0.602)	(-1.919 ± 0.631)
σ	(6.895 ± 0.562)	(6.107 ± 0.561)
A_{Fast}	(4.257 ± 0.279)	(3.842 ± 0.301)
τ_{Fast}	6 ns fixed	6 ns fixed
A_{Int}	(3.17 ± 0.20)	(3.321 ± 0.26)
τ_{Int}	(57.07 ± 6.40)	(51.64 ± 7.41)
A_{Slow}	(18.87 ± 0.21)	(20.78 ± 0.36)
τ_{Slow}	(1269 ± 26.7)	(1263 ± 41.0)

:> This method should allow to decrease an artificial spread introduced by the way of doing the fit
→ tested on CRT runs (it's working)

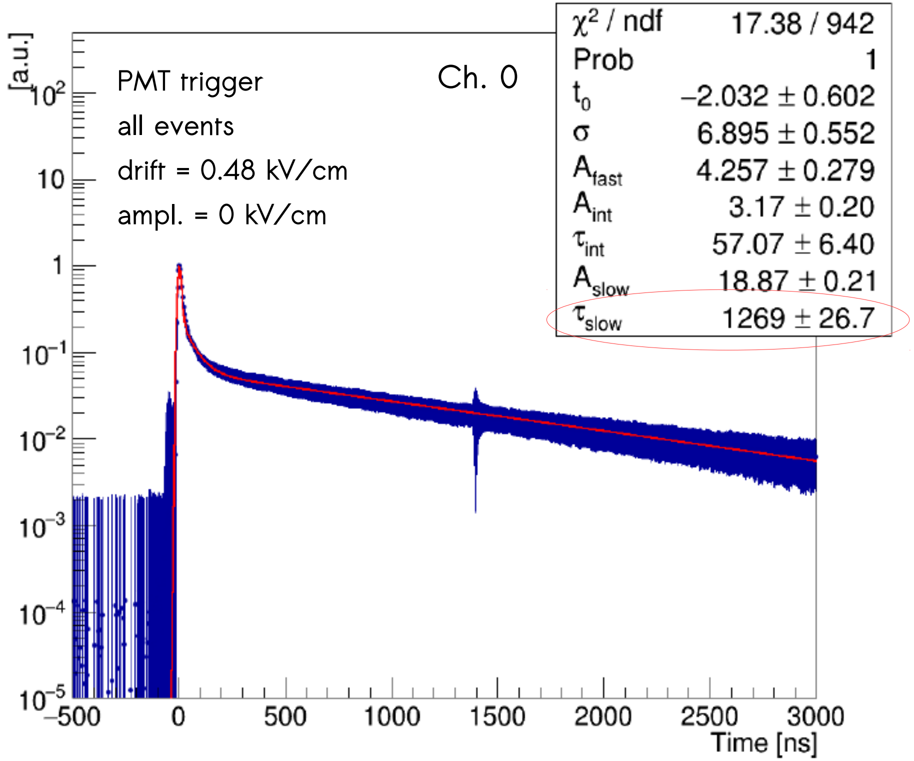


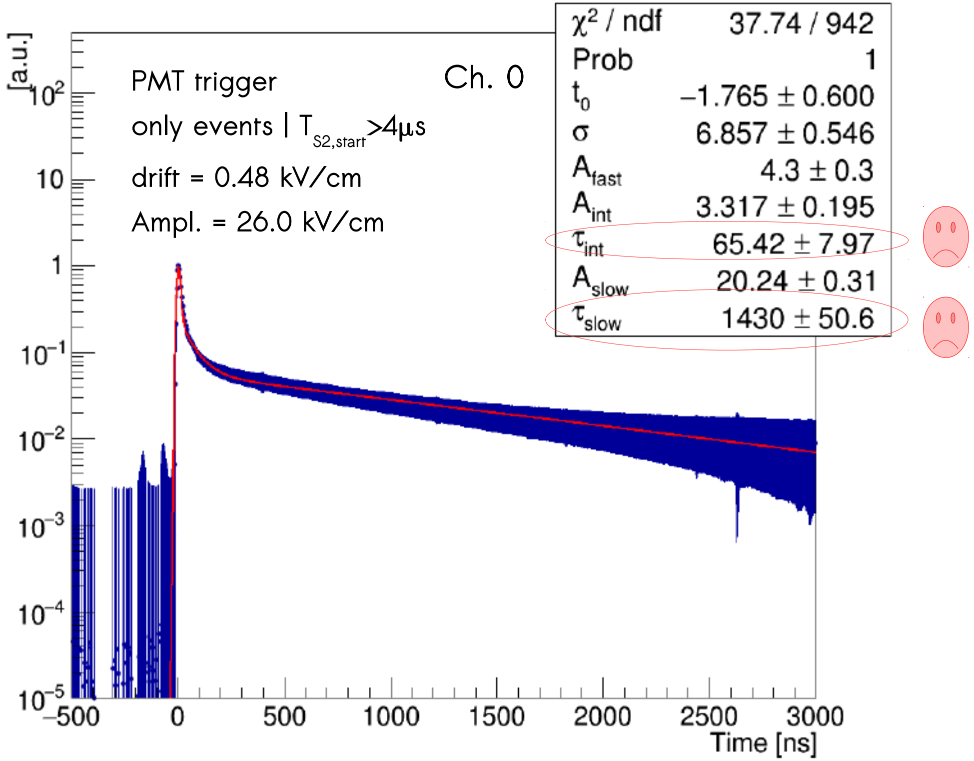
:> Another possible improvement for this plot is to use the global fit for all the runs with the same field
→ this should decrease the uncertainties in each point and take into account properly the errors

How to fit the runs with S2 contamination

:> comparison with run without S2 but same drift field

BEFORE	NOW
(fitting in a decreased range)	(including only events with $T_{S2,start}$>T_{S1}+4us)





How to fit the runs with S2 contamination

:> Fit result comparison, in the case of CRT runs all the parameters, that are expected to be in agreement, are in agreement within the error in the case of PMT runs the selection based on the starting S2 is not enough

:> my interpretation, in the case of CRT trigger, the track topology is already helping due to the CRT geometry
→ maybe add a cut based on the DeltaTS2-S1, to do a selection only in this case similar to the CRT trigger ?

	Run 1451 (PMT tr.)	Run 1671 (CRT tr.)	Run 1682 (PMT tr.)
	drift = 0.48kV/cm ampl 0kV/cm	drift = 0.49kV/cm ampl 25.5kV/cm	drift = 0.48kV/cm ampl 26.0kV/cm
t0	(-2.032 ± 0.602)	(-1.919 ± 0.631)	(-1.765 ± 0.600)
σ	(6.895 ± 0.562)	(6.107 ± 0.561)	(6.857 ± 0.546)
A_{Fast}	(4.257 ± 0.279)	(3.842 ± 0.301)	(4.3 ± 0.3)
τ_{Fast}	6 ns fixed	6 ns fixed	6 ns fixed
A_{Int}	(3.17 ± 0.20)	(3.321 ± 0.26)	(3.317 ± 0.195)
τ_{Int}	(57.07 ± 6.40)	(51.64 ± 7.41)	*(65.42 ± 7.97)*
A_{Slow}	(18.87 ± 0.21)	(20.78 ± 0.36)	(20.24 ± 0.31)
τ_{Slow}	(1269 ± 26.7)	(1263 ± 41.0)	*(1430 ± 50.6)*

SCINTILLATION TIME PROFILE STUDIES (PART II)

Comparison with other experiments

:> Even if the result is not expected from the theoretical point of view, I think we tried to *confute* this result in different ways (e.g. studying possible parameters correlations) but the trend is still there

:> On the other hand, the same trend has been seen by ArDM experiment
→ PhD thesis by Mu Wei ethz thesis (HTTPS://DOI.ORG/10.3929/ETHZ-B-000335024)
→ the explanation is found in the recombination process
→ is given a function that should describe the trend (Eq.6.3 $\tau(\mathcal{E}) = 1.18 \times e^{-\mathcal{E}/35.0} + 1120$)

As discussed in Chapter 1, the argon scintillation is from the decay of argon excimer which is formed in two processes: agon excitation and electron-ion recombination. Assuming that it takes time for electron-ion to get recombined, the recombination light might have longer delay time. This hypothesis explains why at higher drift field, the decay time of argon slow scintillation light gets shorter. This conclusion might be confirmed by the measuring the decay time variation of argon slow scintillation light from NR events in different drift fields. Since NR has higher stopping power in LAr, the recombination rate of the electron-ion pairs produced by NR is expected to be less impacted by the drift fields. This measurement requires the calibration data from neutron sources.

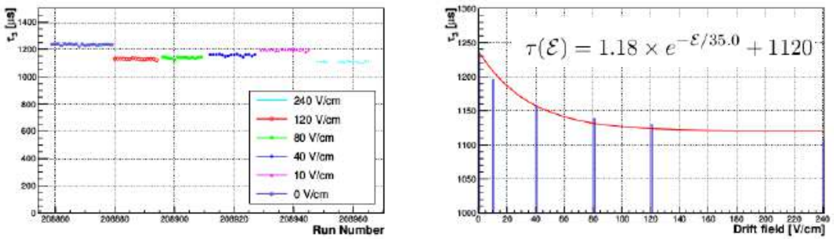


Figure 6.7: The decay time of the argon slow scintillation light under different electric drift fields. In the right plot, the decay time is fitted to an exponential function (the red curve) of the drift field $\mathcal{E}$.

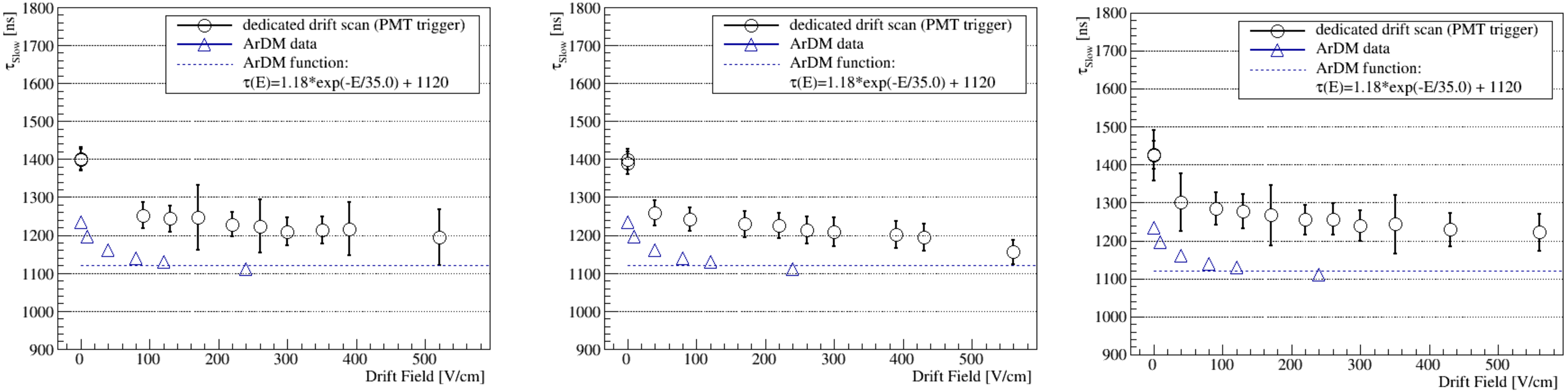
Comparison with with other experiments

:> I compared our data (so far only runs from drift scan, for simplicity) with their points - qualitative comparison since:

→ the errors are not given

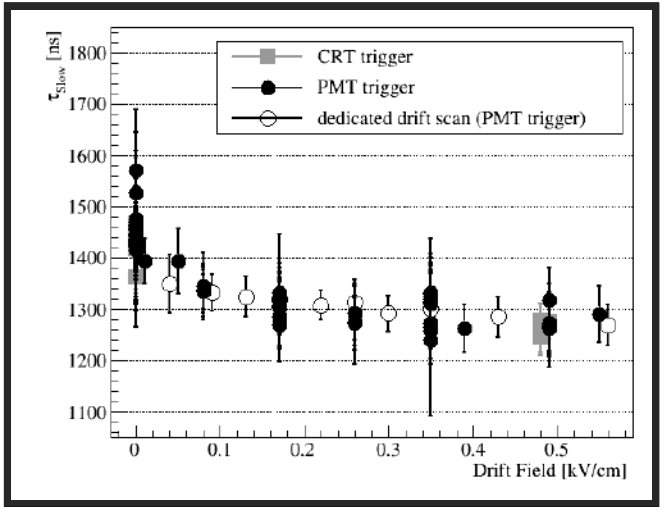
→ the function given it seems that does not reproduce the data points

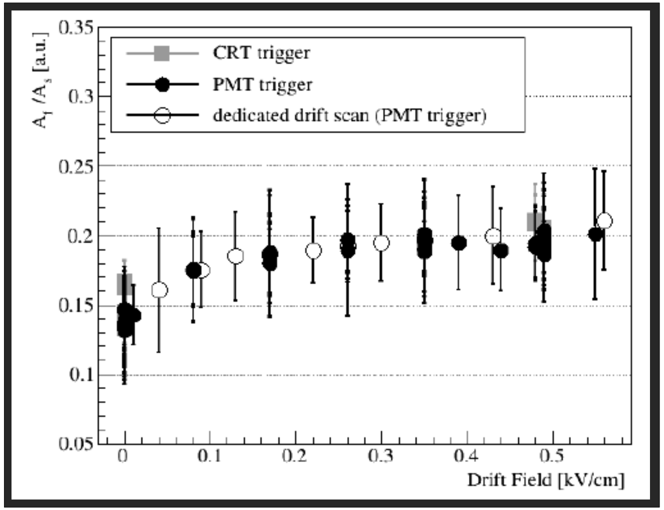
→ but the trend is quite similar to our trend but its shifted

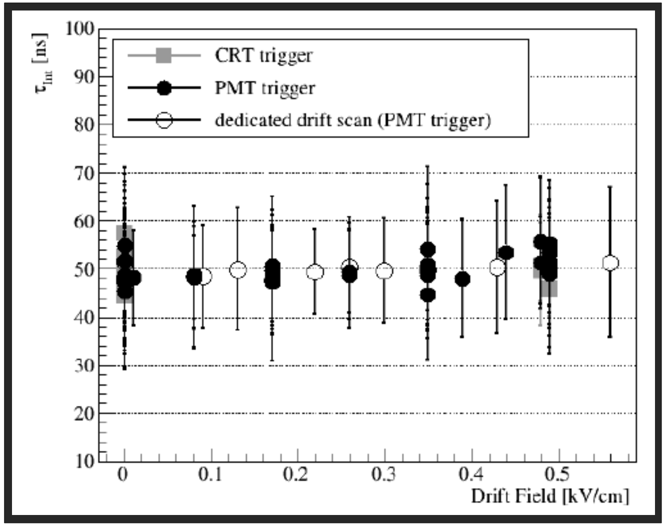


Backup slides

Scintillation time profile







How to fit the runs with S2 contamination

:> <u>accept only events with S2 signal starting 4us after S1 peak</u>

→ even using the TProfile, is clearly excluded the possible contamination of S2 charge in the scintillation time profile fit

→ the fit can be done in the same range as for runs without amplification!

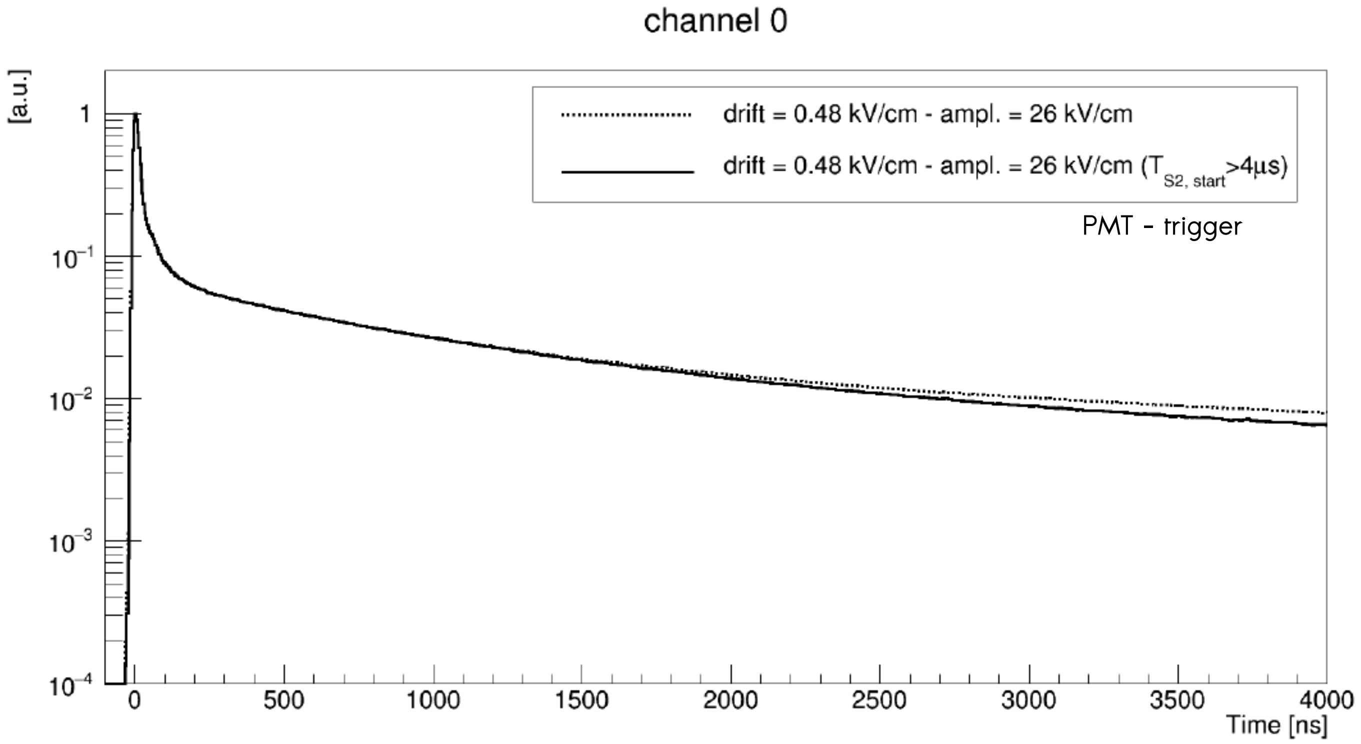
:> <u>PMT trigger</u>

→ the effect is the same in the 5 PMTs (no preferred inclination of the tracks, not expected)

→ 2 additional cuts are needed to improve S2 algorithm performance (in the case of PMT trigger since no preliminary selection on the track topology is applied):

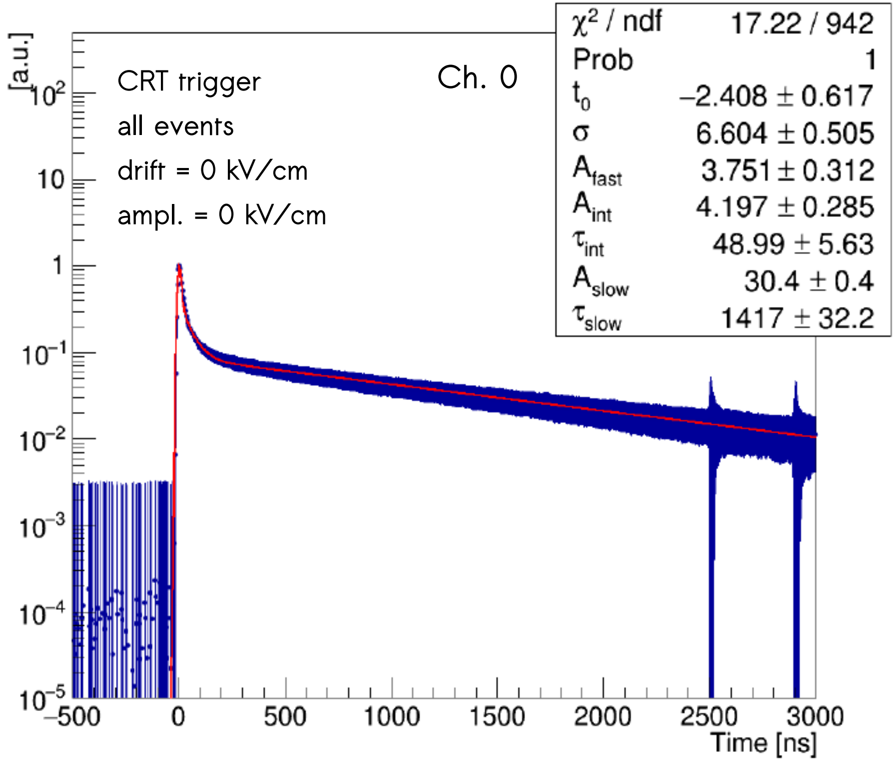
a) excluded events where the algorithm failed S2-S1Time<0 or before S2 starting time

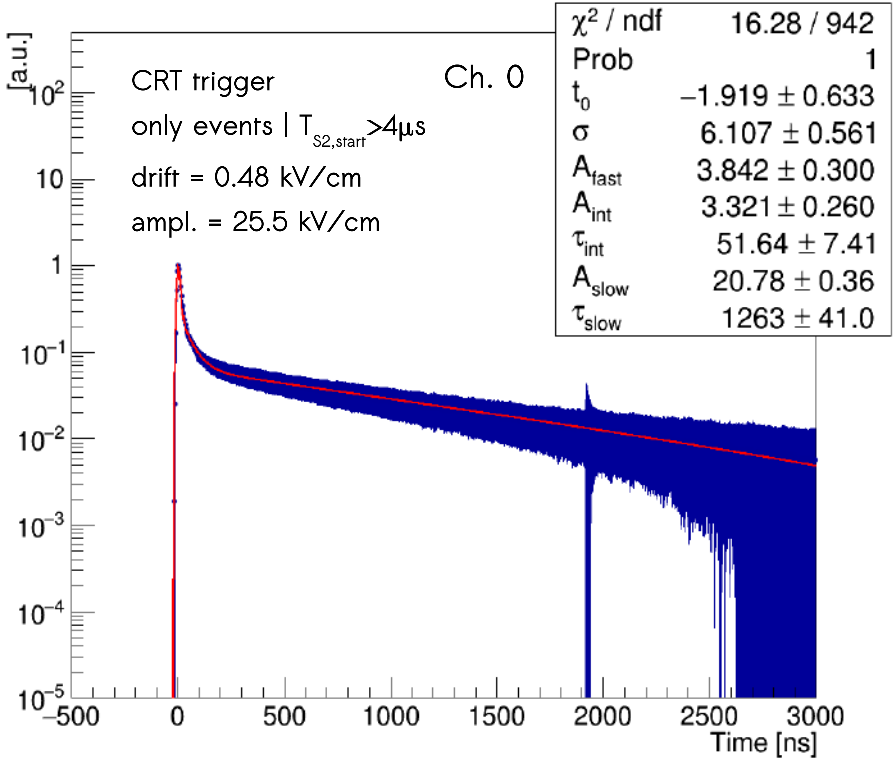
b) required a minimum S2-S1 time distance (50 us, empirical - to be tuned)



How to fit the runs with S2 contamination

:> comparison with another CRT run but different drift field





How to fit the runs with S2 contamination

Fit result comparison, all the parameters, that are expected to be in agreement, are in agreement within the error

	Run 1451 (PMT tr.)	Run 1671 (CRT tr.)	Run 1333 (CRT tr.)
	drift = 0.48kV/cm ampl 0kV/cm	drift = 0.48kV/cm ampl 25.5kV/cm	drift = 0kV/cm ampl 0kV/cm
t0	(-2.032 ± 0.602)	(-1.919 ± 0.631)	(-2.408 ± 0.617)
σ	(6.895 ± 0.562)	(6.107 ± 0.561)	(6.604 ± 0.505)
A_{Fast}	(4.257 ± 0.279)	(3.842 ± 0.301)	(3.751 ± 0.312)
τ_{Fast}	6 ns fixed	6 ns fixed	6 ns fixed
A_{Int}	(3.17 ± 0.20)	(3.321 ± 0.26)	(4.197 ± 0.285)
τ_{Int}	(57.07 ± 6.40)	(51.64 ± 7.41)	(48.99 ± 5.63)
A_{Slow}	(18.87 ± 0.21)	(20.78 ± 0.36)	(30.4 ± 0.4)
τ_{Slow}	(1269 ± 26.7)	(1263 ± 41.0)	(1417 ± 32.2)

Predictions and comparisons

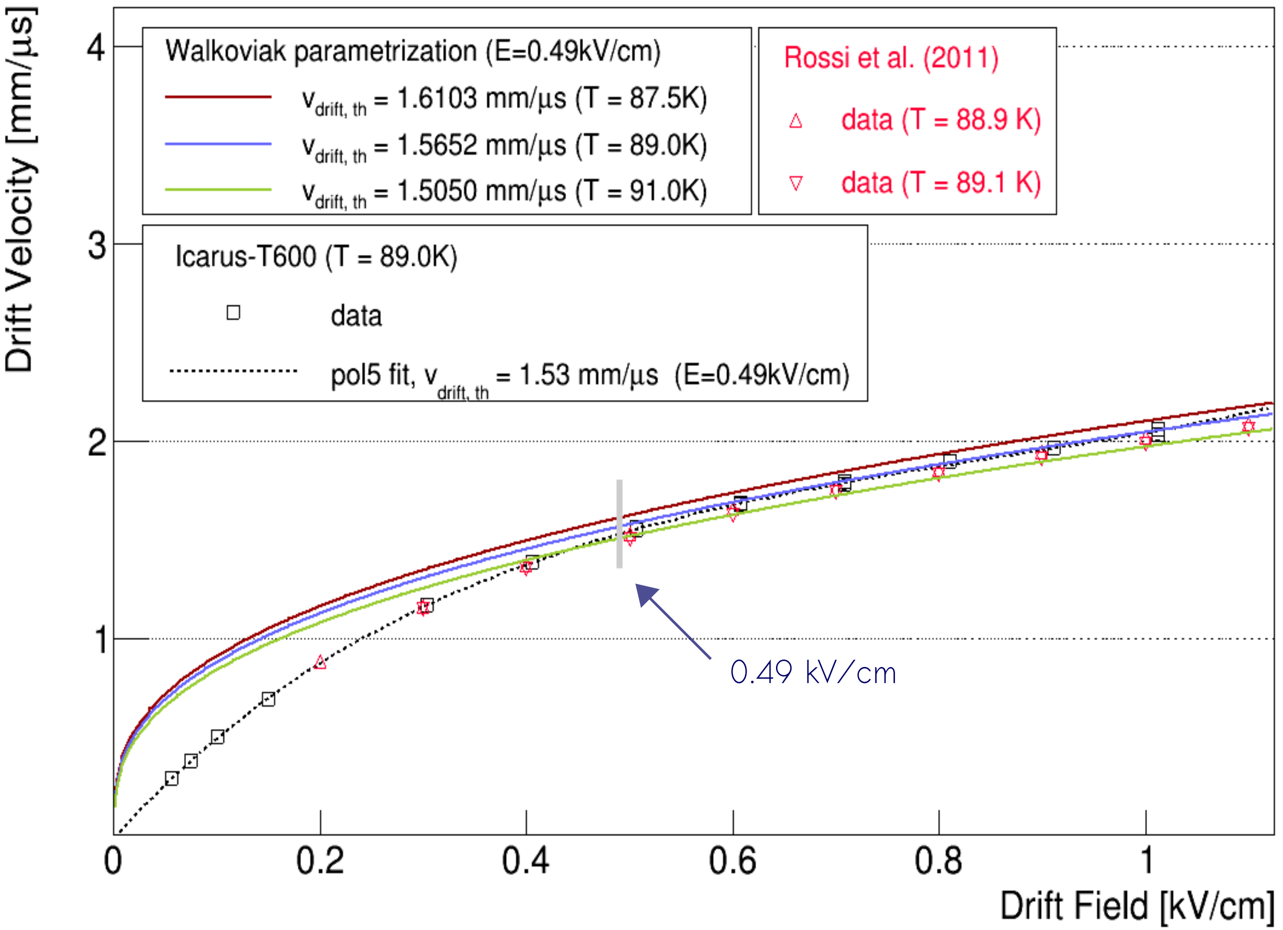
:> Walkoviak (2000) → v(|E|, T) parametrization using data taken in drift field range (0.5; 12.5) kV/cm and in 87 K <T< 94 K (NIM. A 449 2000 288)

:> Icarus-T600 combines results from long tracks, shower and purity monitor (at low drift field) and fit with a pol5 function (NIM. A 516 2004 68-79)

:> Rossi et al. (2011) does two measurements (T=88.9K and T=89.1K) in the drift field range (0.2; 1.2) kV/cm calculating the drift velocity from the time distance between S2 and S1 as a function of the drift length

→ in agreement with Icarus points at low drift field values

(J. of Phys.: Conf. Series 308 2011 012025)

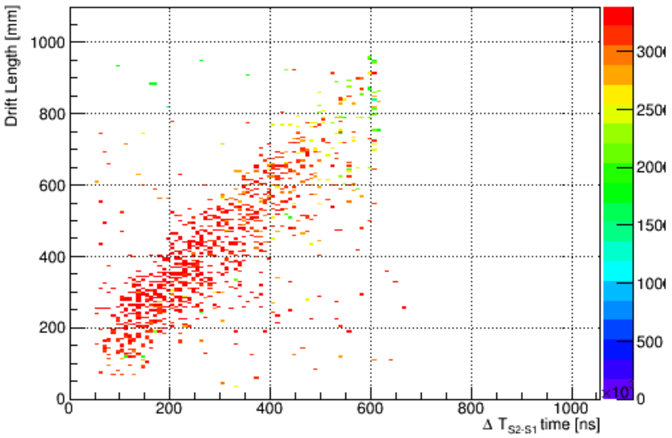


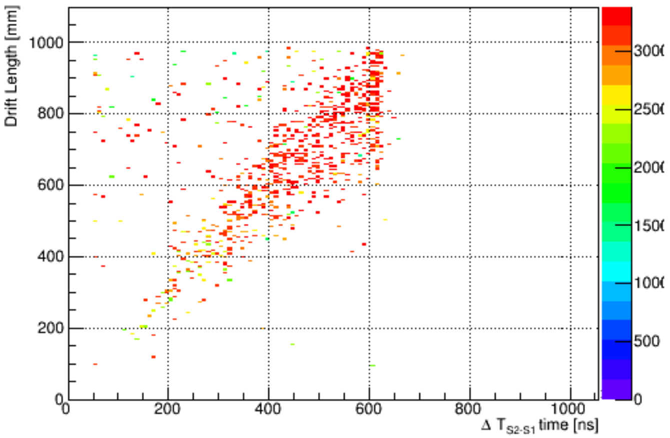
Drift velocity - qualitative description of the results

:> d vs ΔT_{S2-S1} distributions → "clear" distribution, quite good ΔT_{S2-S1} reconstruction

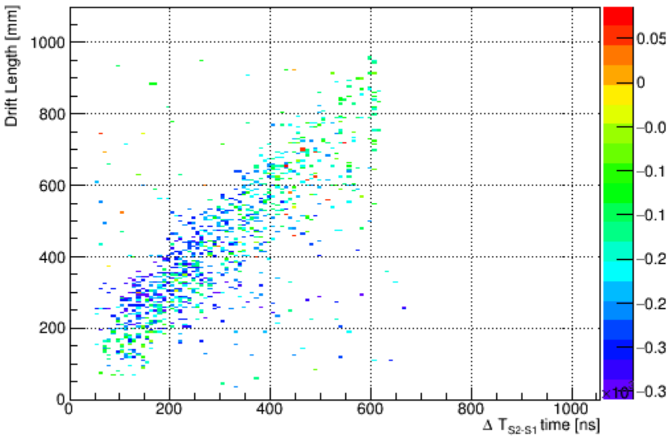
→ ΔT_{S2-S1} reconstruction becomes harder in the case of short tracks

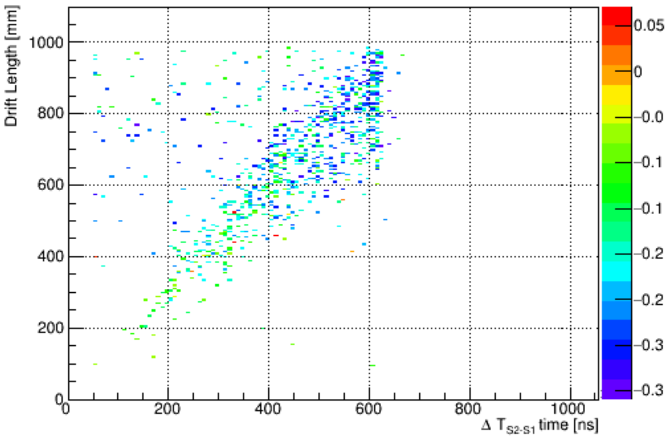
track length in the scale





tantheta in the scale





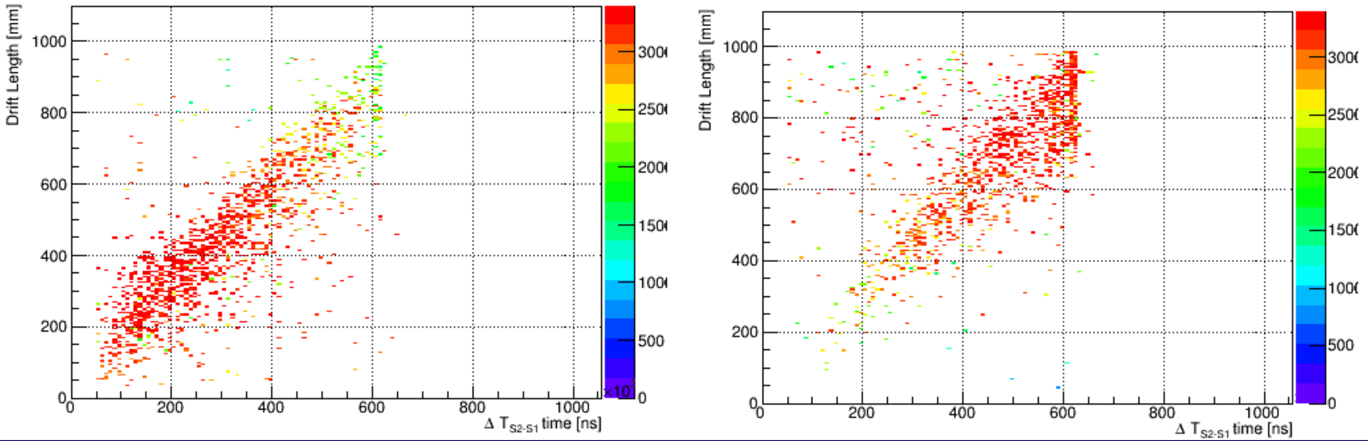
Drift velocity - qualitative description of the results

RUN1671: DRIFT = 0.49KV/CM; AMPL. = 25.5 KV/CM

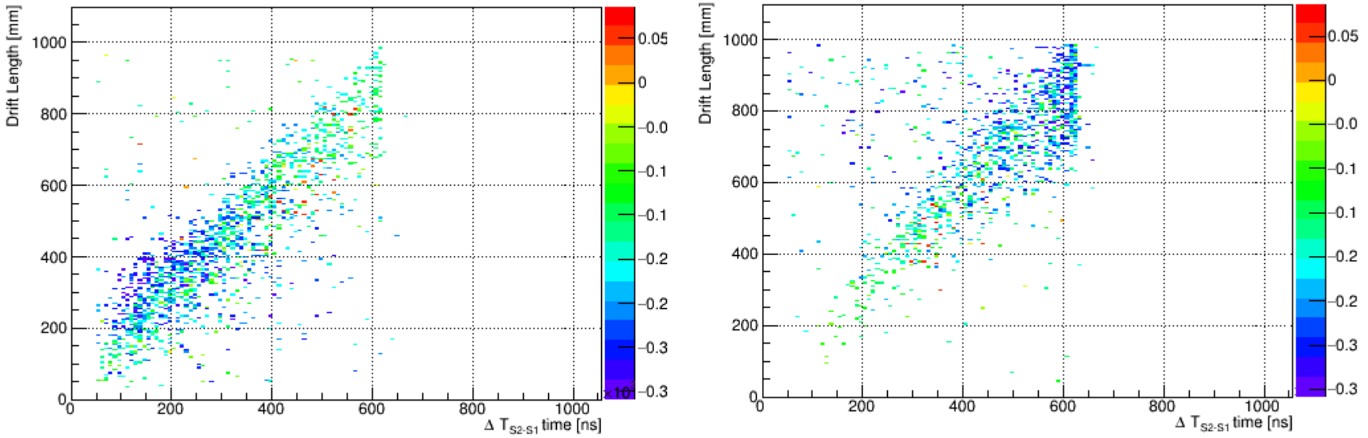
:> d vs ΔT_{S2-S1} distributions → "clear" distribution, quite good ΔT_{S2-S1} reconstruction

→ ΔT_{S2-S1} reconstruction becomes harder in the case of short tracks

track length in the scale



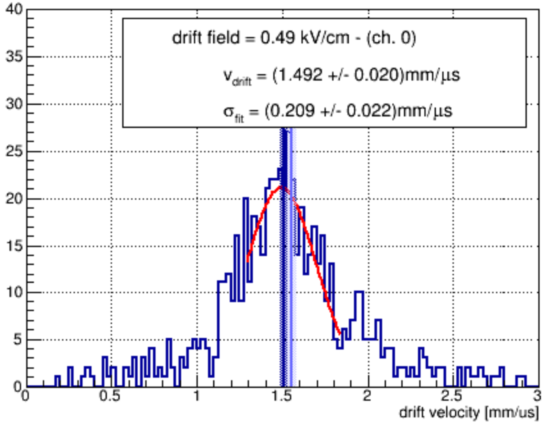
tantheta in the scale

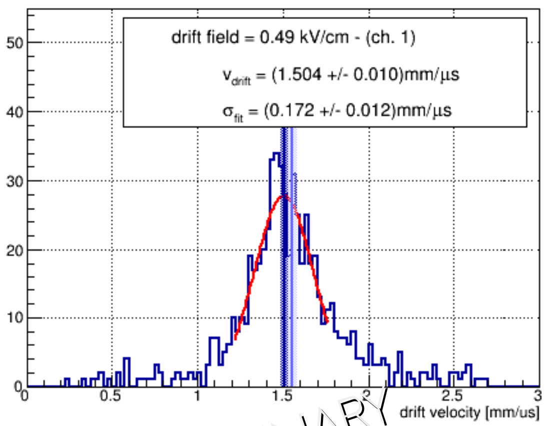


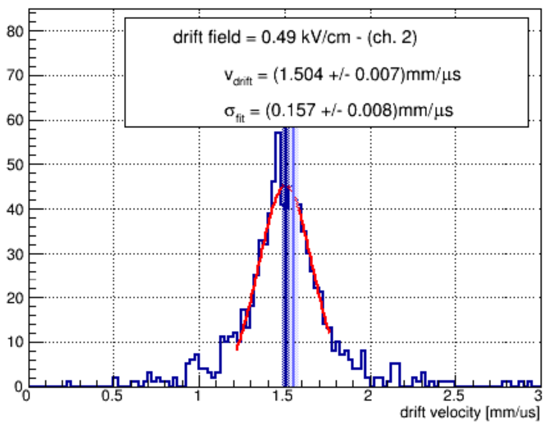
Drift velocity

Run1671: drift = 0.49kV/cm; ampl. = 25.5 kV/cm

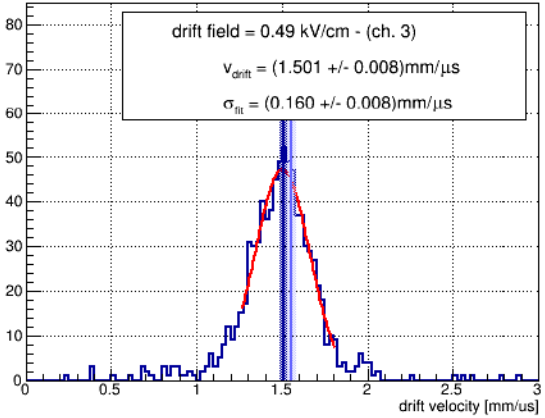
:> **(long tracks)** event by event, gaussian fit of the distribution of the $v_{drift,i}$ (ch) = d_i(ch) / $\Delta T_{S2-S1,i}$ (ch)

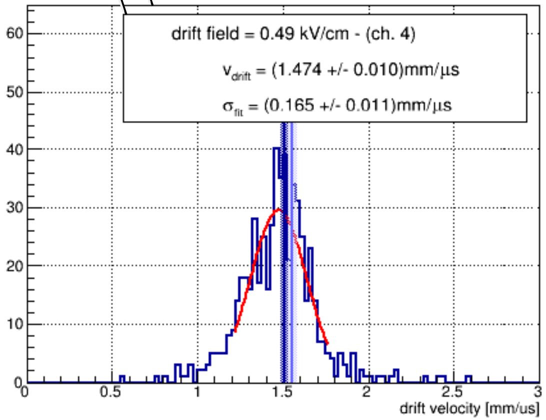






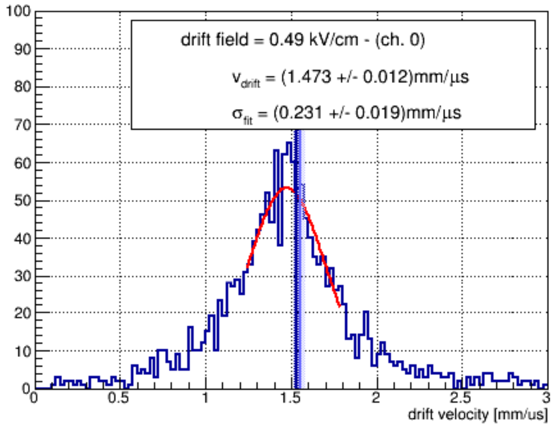
PRELIMINARY

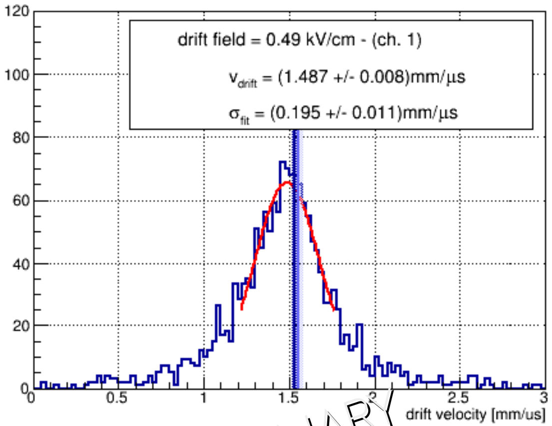


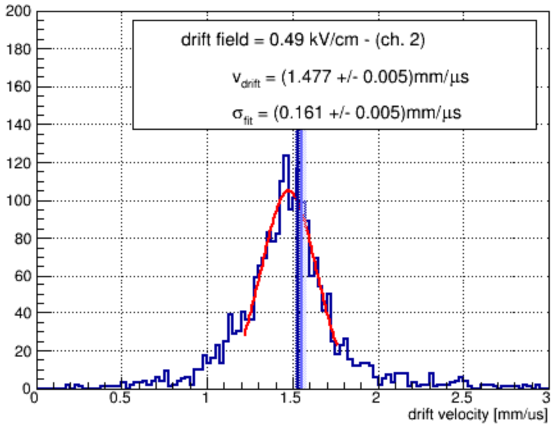


Drift velocity

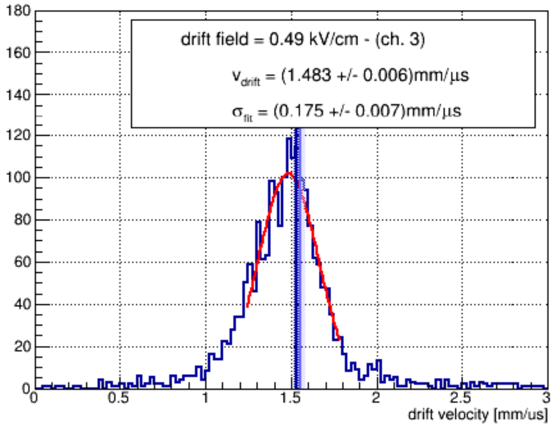
:> **(all tracks)** event by event, gaussian fit of the distribution of the $v_{drift,i}$ (ch) = d_i(ch) / $\Delta T_{S2-S1,i}$ (ch)

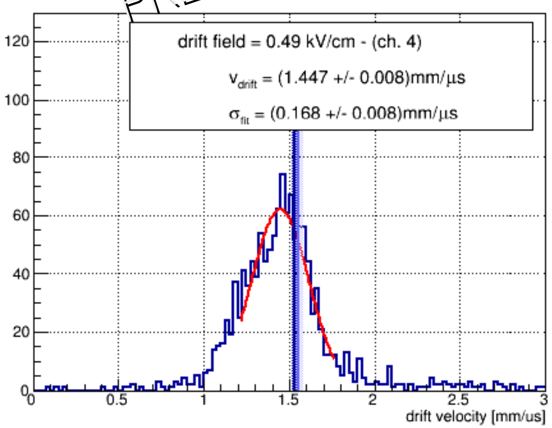






PRELIMINARY





Predictions and comparisons

:> Walkoviak (2000) → v(|E|, T) parametrization using data taken in drift field range (0.5; 12.5) kV/cm and in 87 K <T< 94 K (NIM. A 449 2000 288)

:> Icarus-T600 combines results from long tracks, shower and purity monitor (at low drift field) and fit with a pol5 function (NIM. A 516 2004 68-79)

:> Rossi et al. (2011) does two measurements (T=88.9K and T=89.1K) in the drift field range (0.2; 1.2) kV/cm calculating the drift velocity from the time distance between S2 and S1 as a function of the drift length
→ in agreement with Icarus points at low drift field values
(J. of Phys.: Conf. Series 308 2011 012025)