Summary of previous PMT studies

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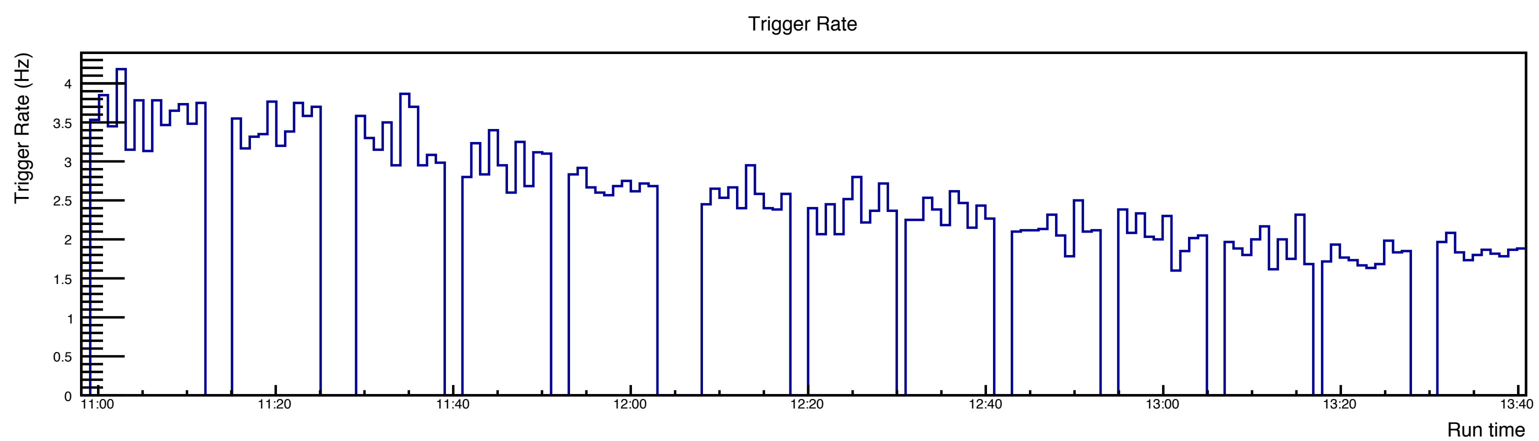
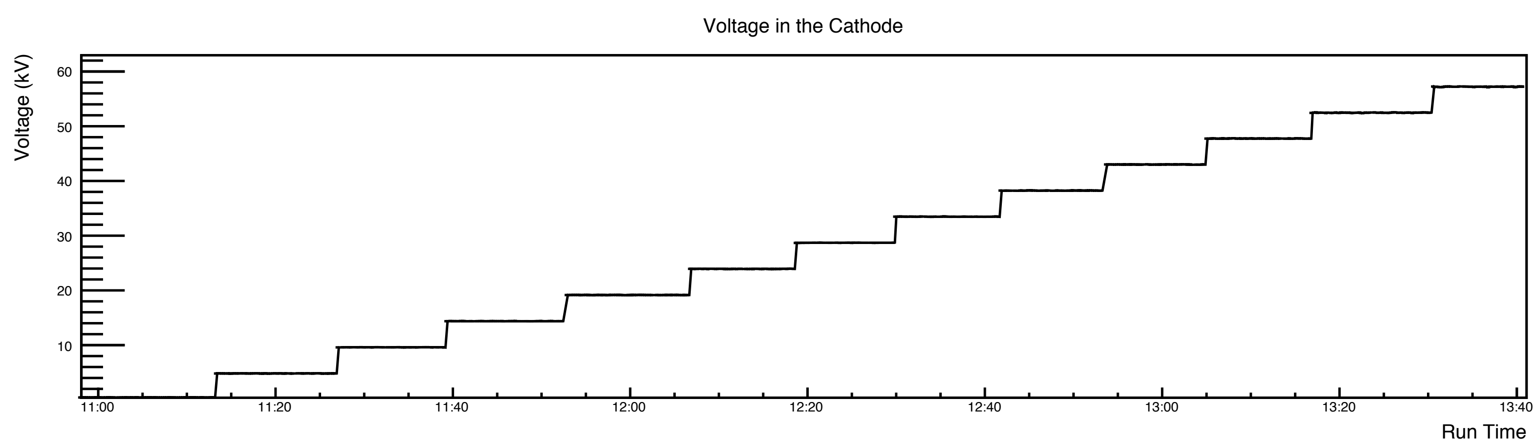
Previous Studies

- PMT Trigger Rate dependence on the voltage in the cathode

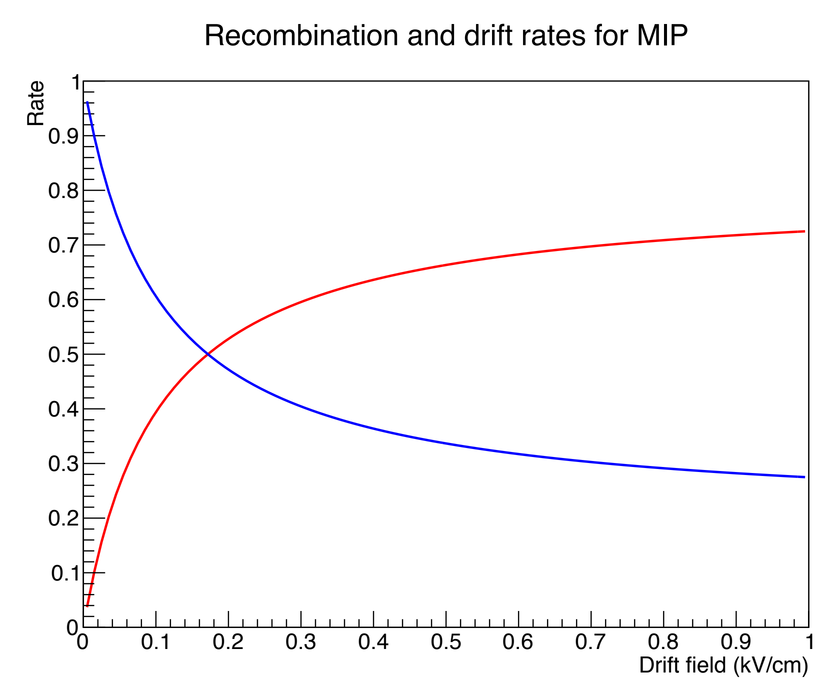




- As the drift effect of the electric field increases, there is less light coming from recombination of electrons and ions
- Decrease in the trigger rate with the voltage, due to a smaller number of events giving signals above the set threshold

- Charge measured by the PMTs for different drift fields (S1 only)

The decrease in the amount of light coming from recombination is given by Birks' law. With it, we can obtain a first approximation to the total amount of charge that depends on the drift field.



Heinzinger Voltage Input

Run Number	HV (kV)	Length (s)	Num. Events
1440	0	836	3008
1441	5	616	2140
1442	10	610	2015
1443	15	632	1893
1444	20	611	1656
1445	25	607	1548
1446	30	605	1447
1447	35	604	1416
1448	40	606	1287
1449	45	605	1246
1450	50	603	1154
1451	55	603	1067
1452	60	605	1127

- Increase the voltage in 5 kV each run
- Runs of ~10 min length
- Significant decrease in the number of events as the voltage is increased

- Voltages in the PMTs

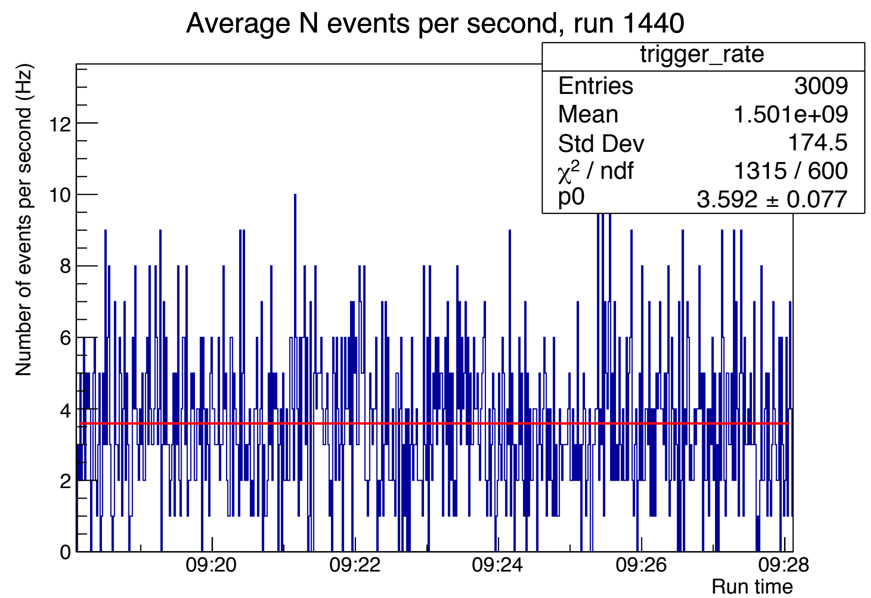
(See Jose's work on the gains of the PMTs)

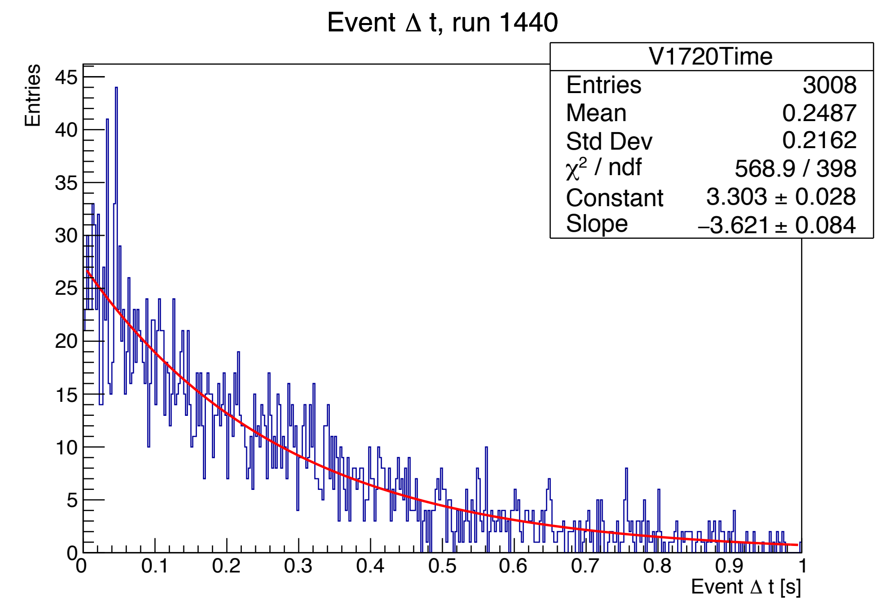
PMT	Voltage (V)
1	1200
2	1200
3	1150
4	1150
5	1200

PMT Trigger Rate

- Two different ways of computing the trigger rate

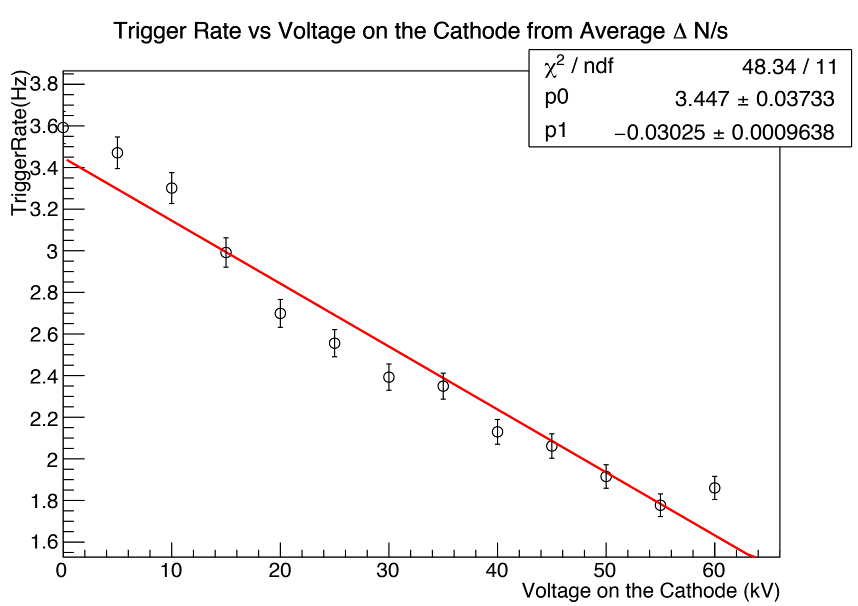
Plot the number of events per second and fit it with a straight line…

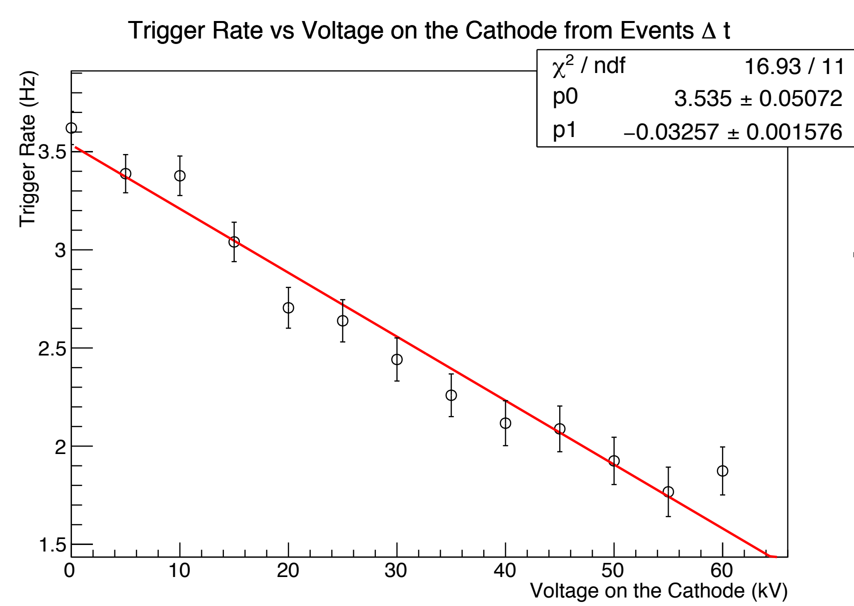




…or compute the histogram of the time difference between consecutive events and fit it with an exponential.

- Both methods provide compatible results





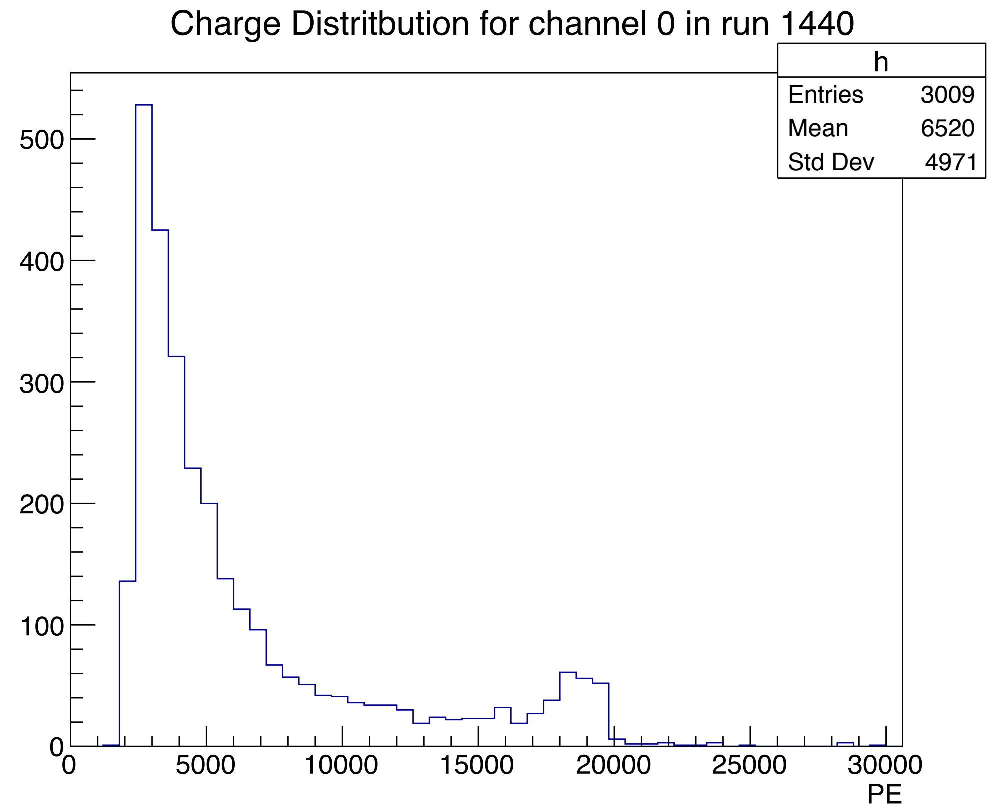
The PMT Trigger rate decreases Δ r~0.03 Hz/kV

Measured Charge

- Compute the charge of one event for each channel as the integral of the waveform (just taking S1), convert from ADC counts to charge and divide by the gain of the PMT to get the number of PE.

- Gain for all the PMTs at the voltages used. Higher gains in PMTs 3 and 4 often lead to saturation.

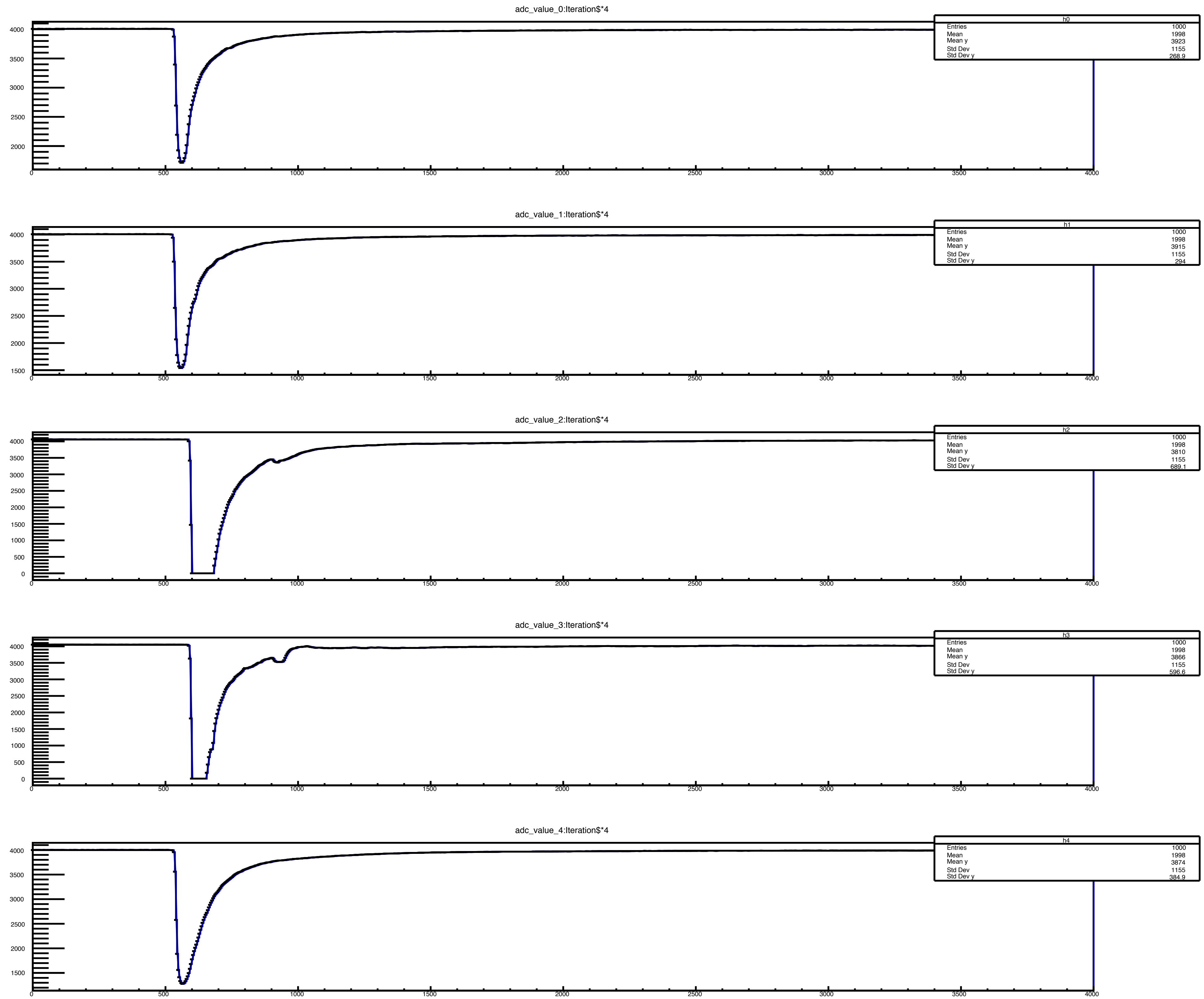
PMT	Gain (10^6/e)
1	1.10±0.14
2	1.54±0.20
3	2.27±0.17
4	3.01±0.20
5	1.57±0.26



- The tail of the charge distribution exhibits a strange behavior. Looking at the events in the tail we find they are different from the “normal” ones.

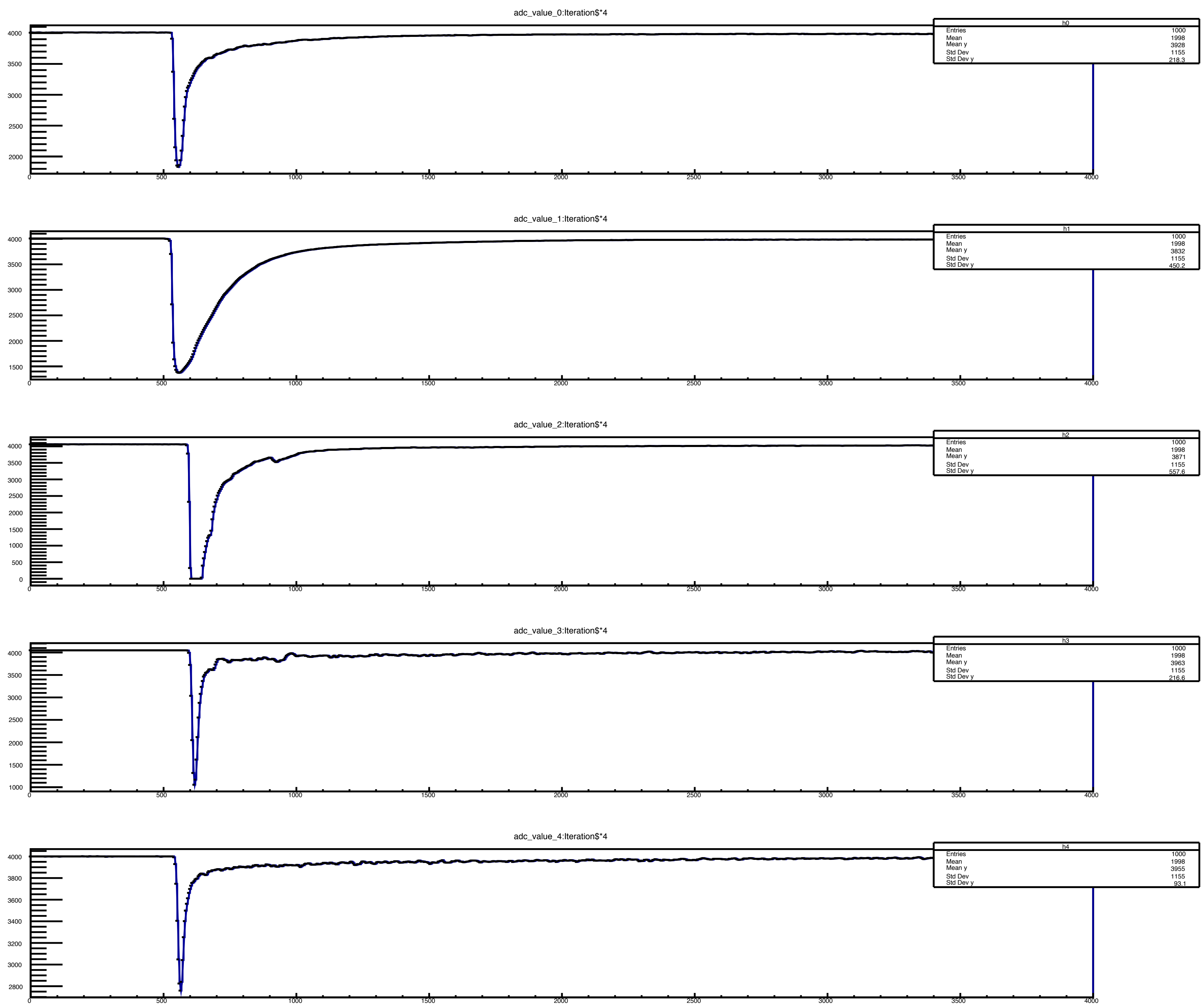
Unusual events

- They show significant differences in their waveforms to normal scintillation events.
- They have greater charge and the time profile does not fit well the scintillation profile expected for LAr.
- It is not something related to a single PMT: sometimes you can see this in all of them.



Unusual events

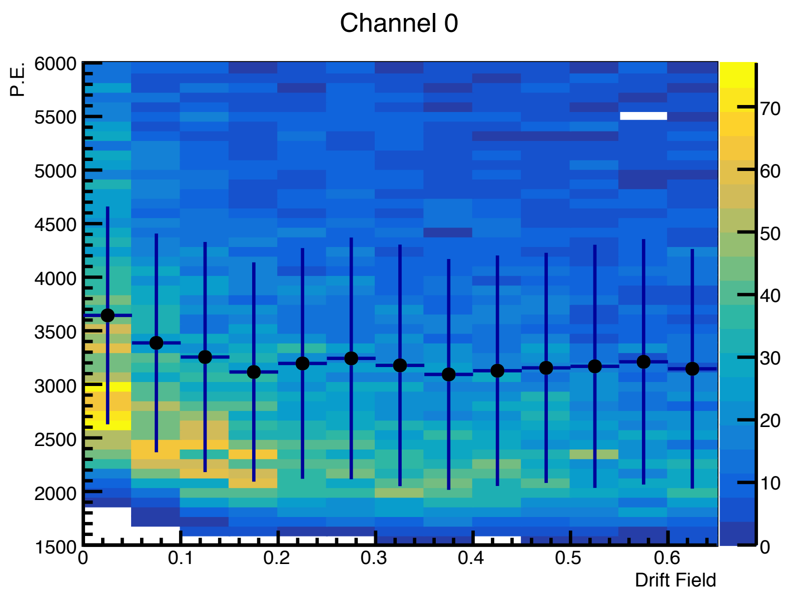
- However, most of the times you see this effect only in one or two channels simultaneously, along with a normal scintillation waveform in the other channels.

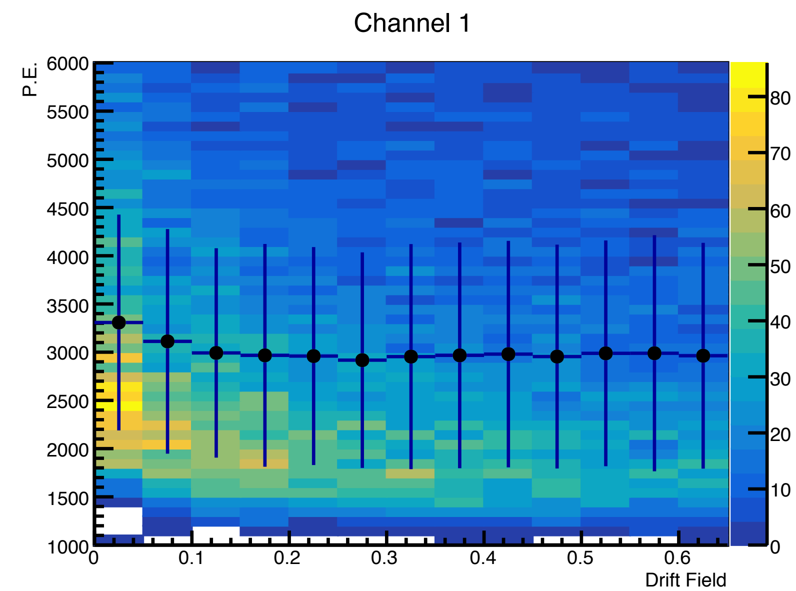


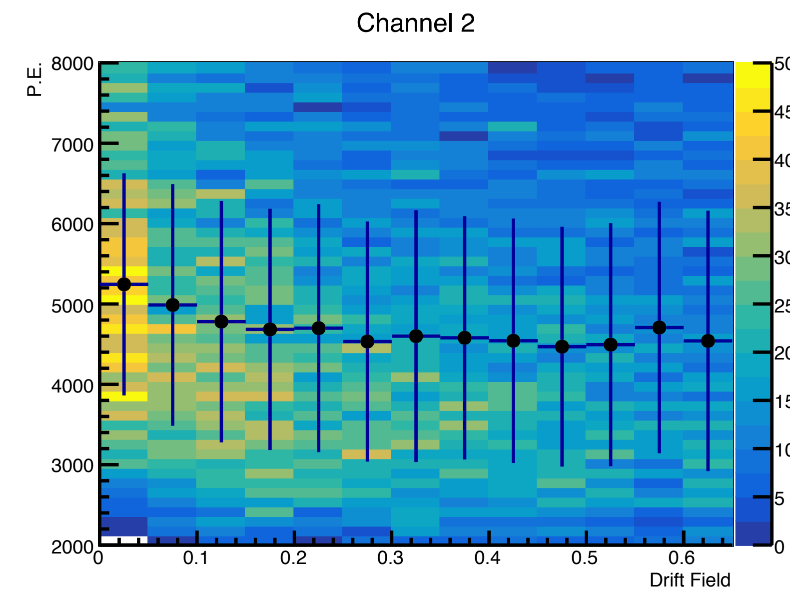
- These signals appear in at least one channel with a rate of 20-30% in all runs.
- We do not understand them yet.

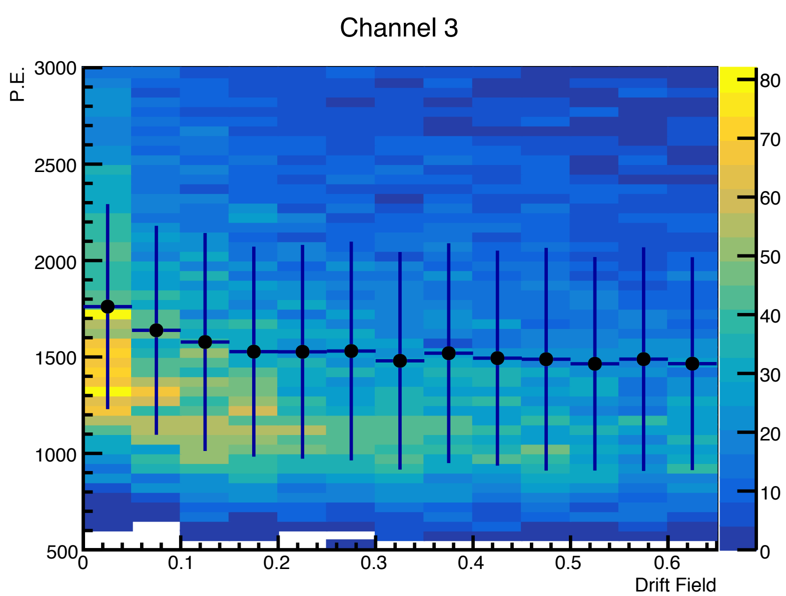
Measured Charge

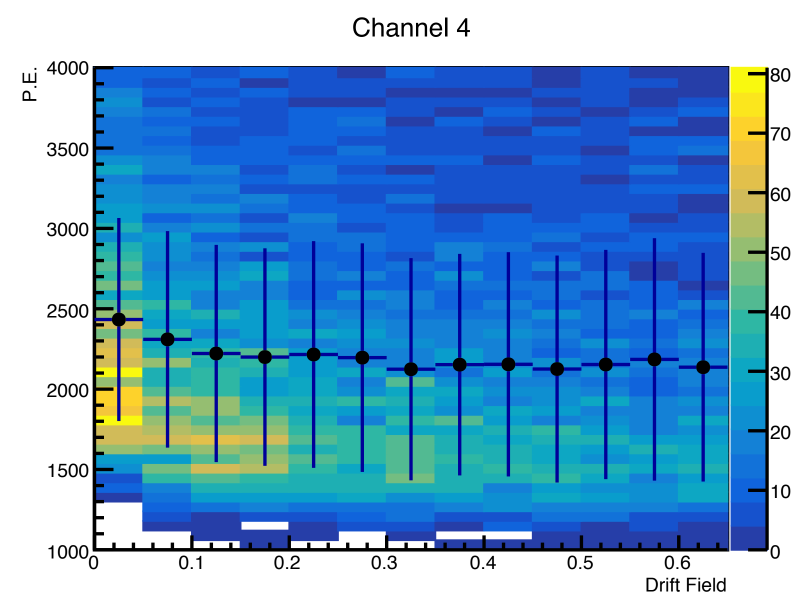
- We remove these events that behave differently. Plotting all the histograms for the different runs we see a decrease in the charge as the drift field is increased.





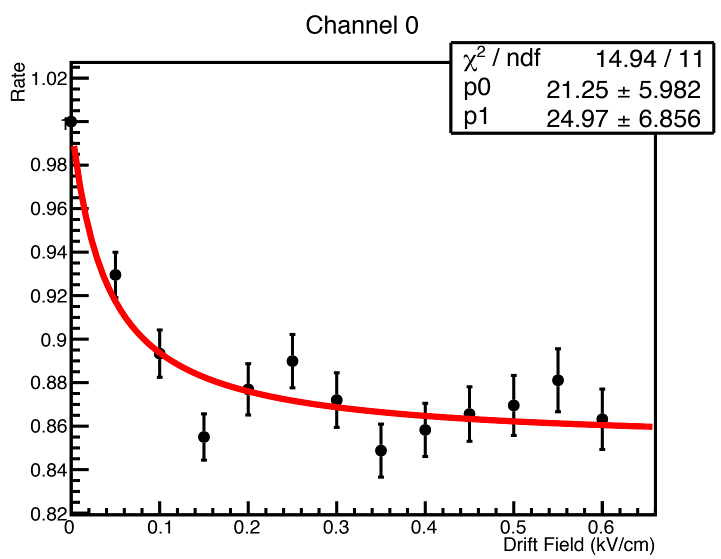


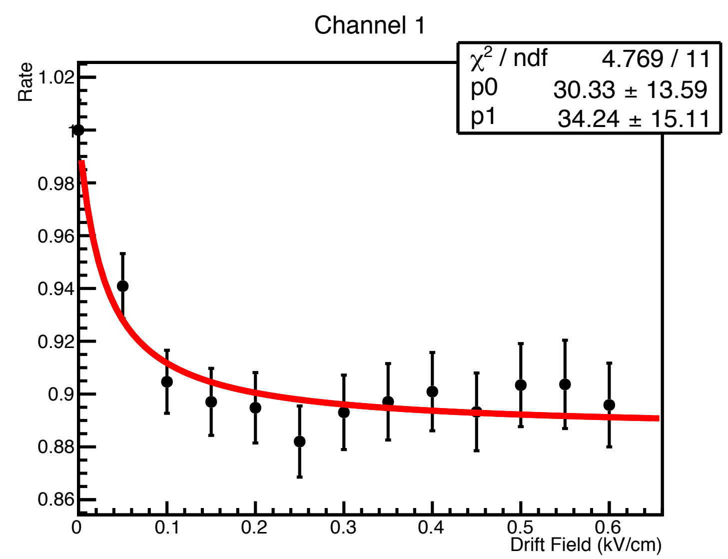


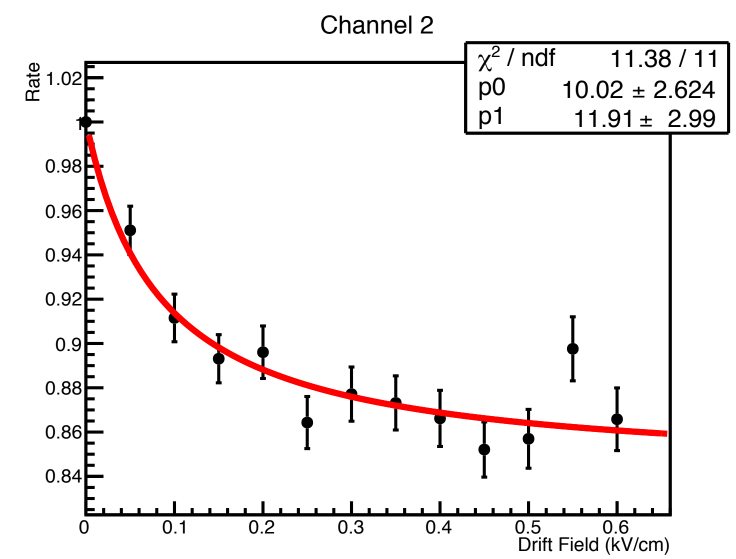


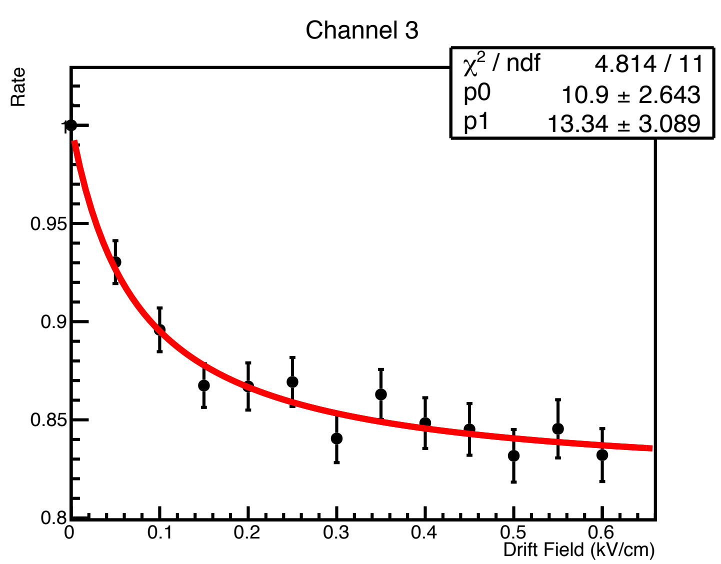
Charge and Birks' Law

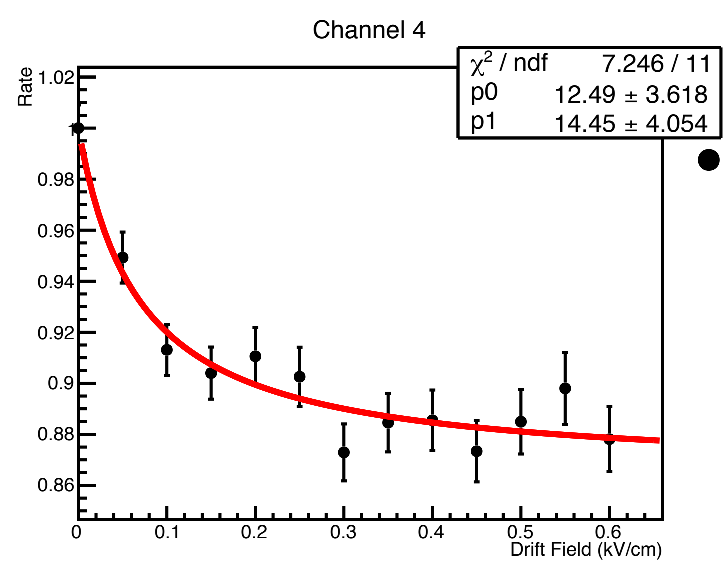
- Comparison of the average charge for each run to the first one (no drift field) should exhibit a similar behavior to Birks' law.











- It can be fitted with the Birks' curve, as expected. We can obtain from the fit the "residual" constant light that does not change with the drift field

S1 dependence on the drift field

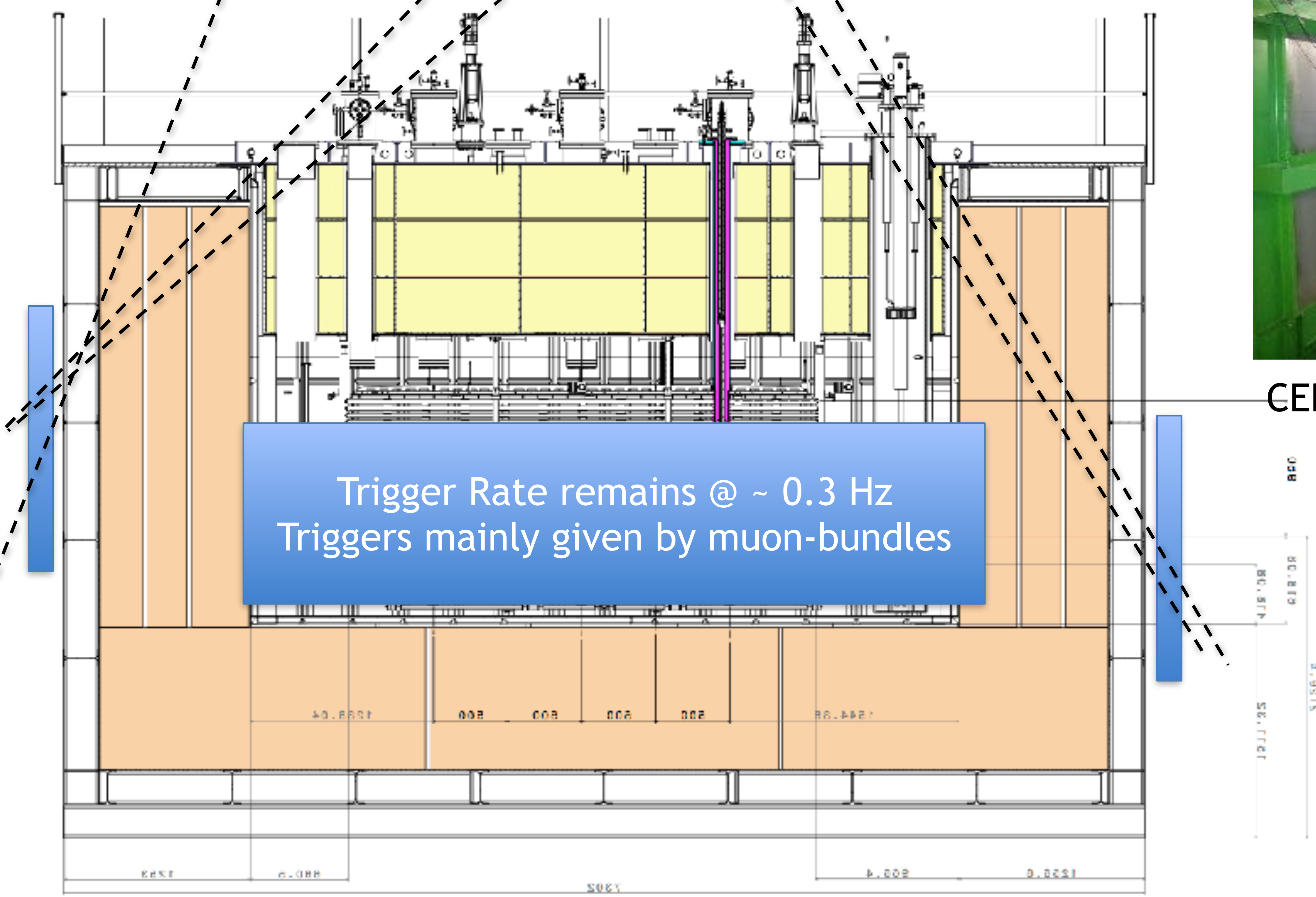
- This can be useful to put an upper limit in the amount of light that depends on the drift field.

$$R = \frac{A\epsilon + 1}{B\epsilon + 1} \Rightarrow \lim_{\epsilon \to \infty} R = \frac{A}{B} = C \equiv \text{Residual light}$$

PMT	1-C
1	~15%
2	~12%
3	~16%
4	~19%
5	~14%

CRT Detector

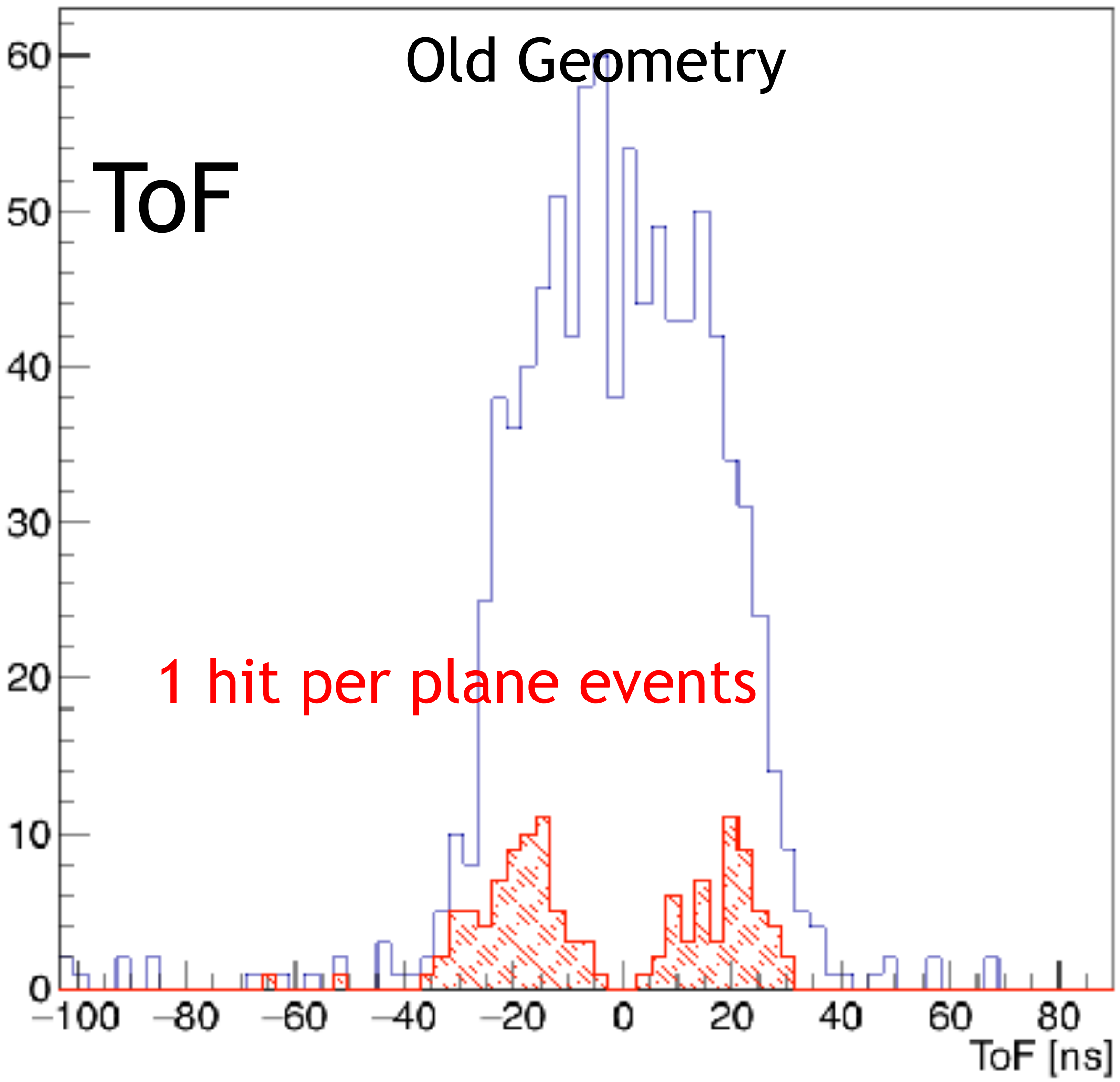
- Geometry changed in order to:
  - Understand main source of trigger events.
  - Increase trigger purity.
  - Ideally panel “asimmetry” should be larger.

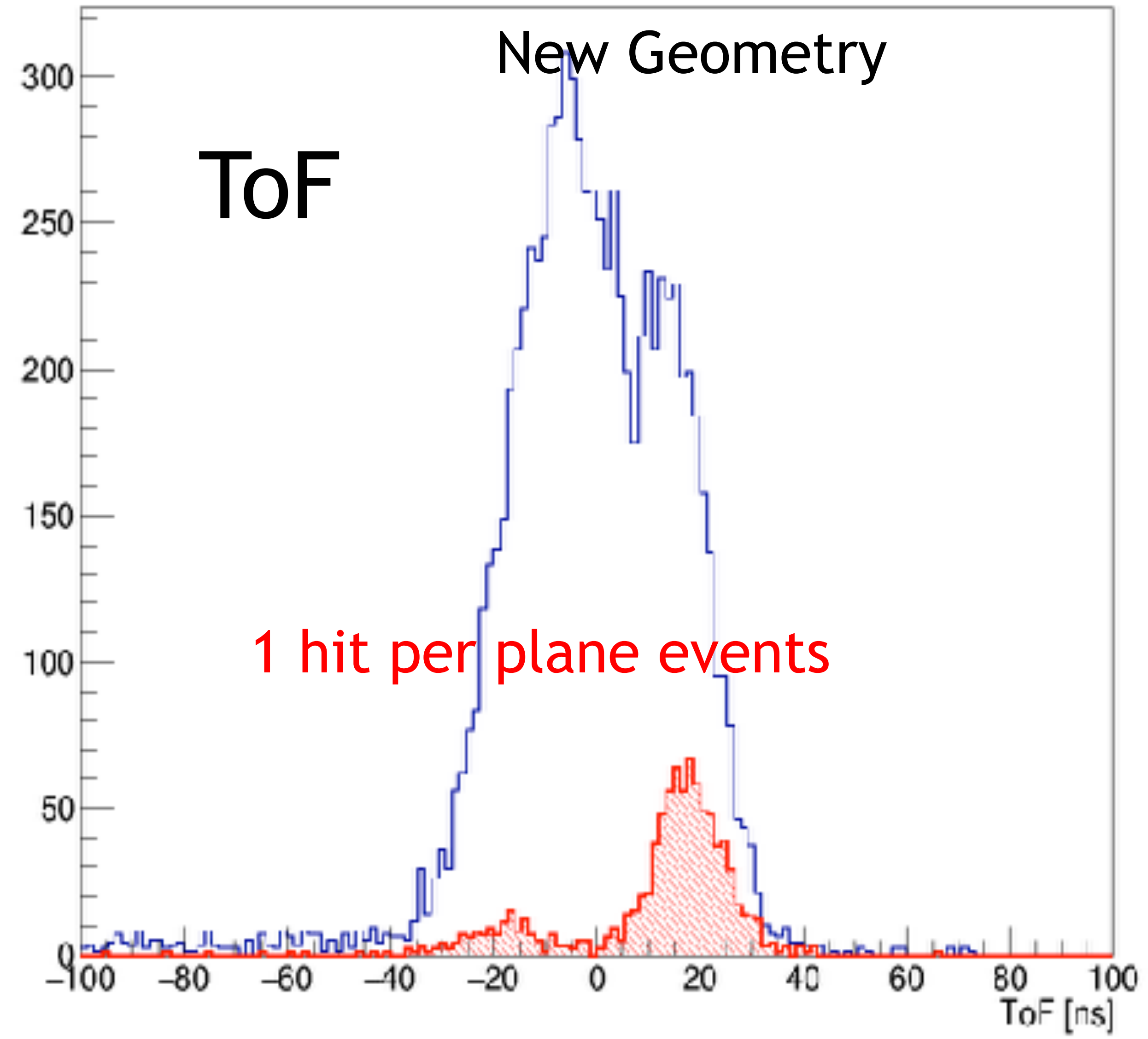


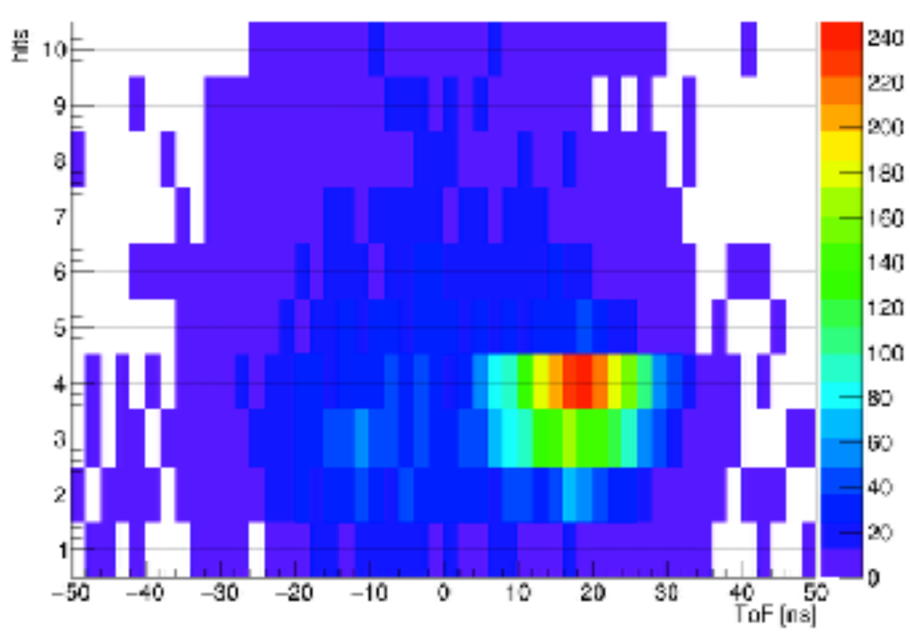
Trigger Rate remains @ ~ 0.3 Hz
Triggers mainly given by muon-bundles

CERN+Bern groups

CRT Detector







The time of flight for events with 1 hit per plane has a peak around ~20 ns.

This criteria might help to distinguish muons actually crossing the detector from other events registered in the CRT.

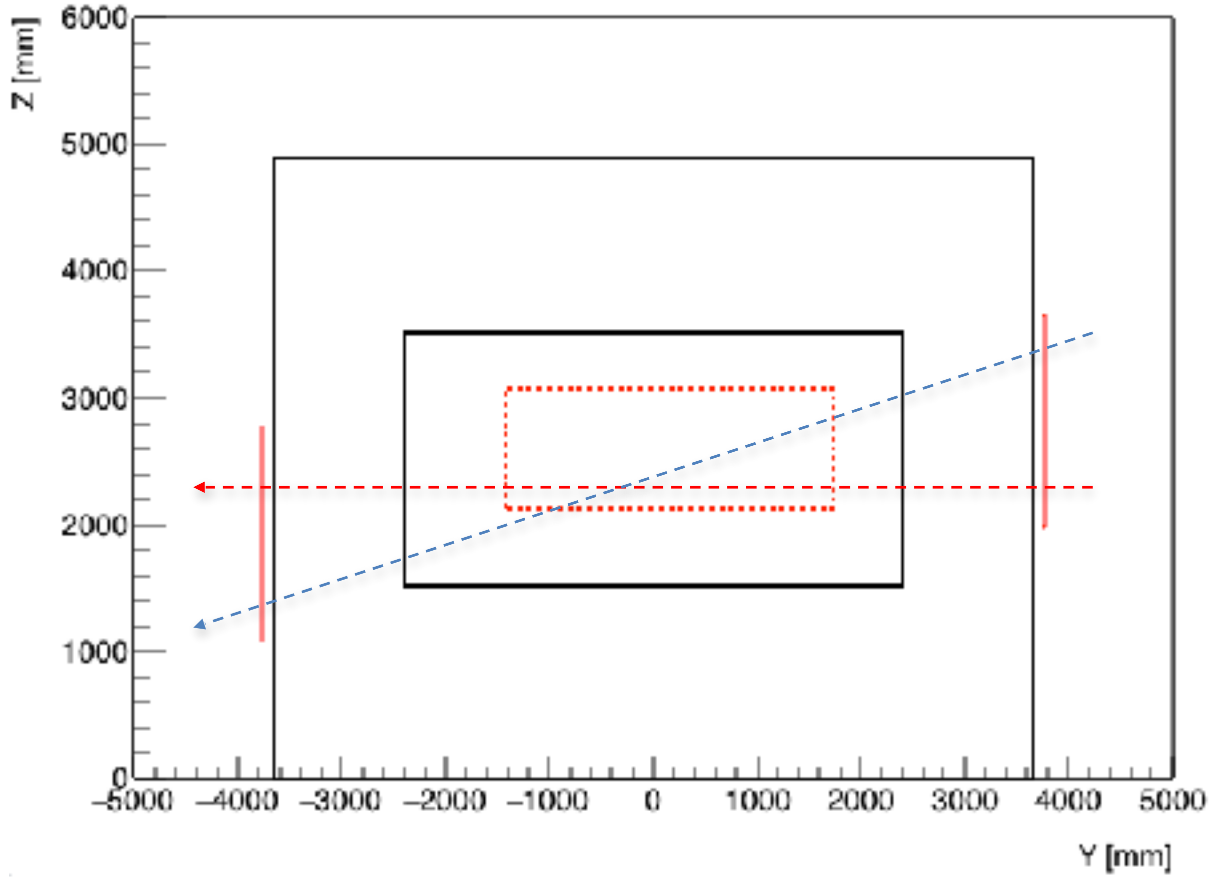
Studies ongoing

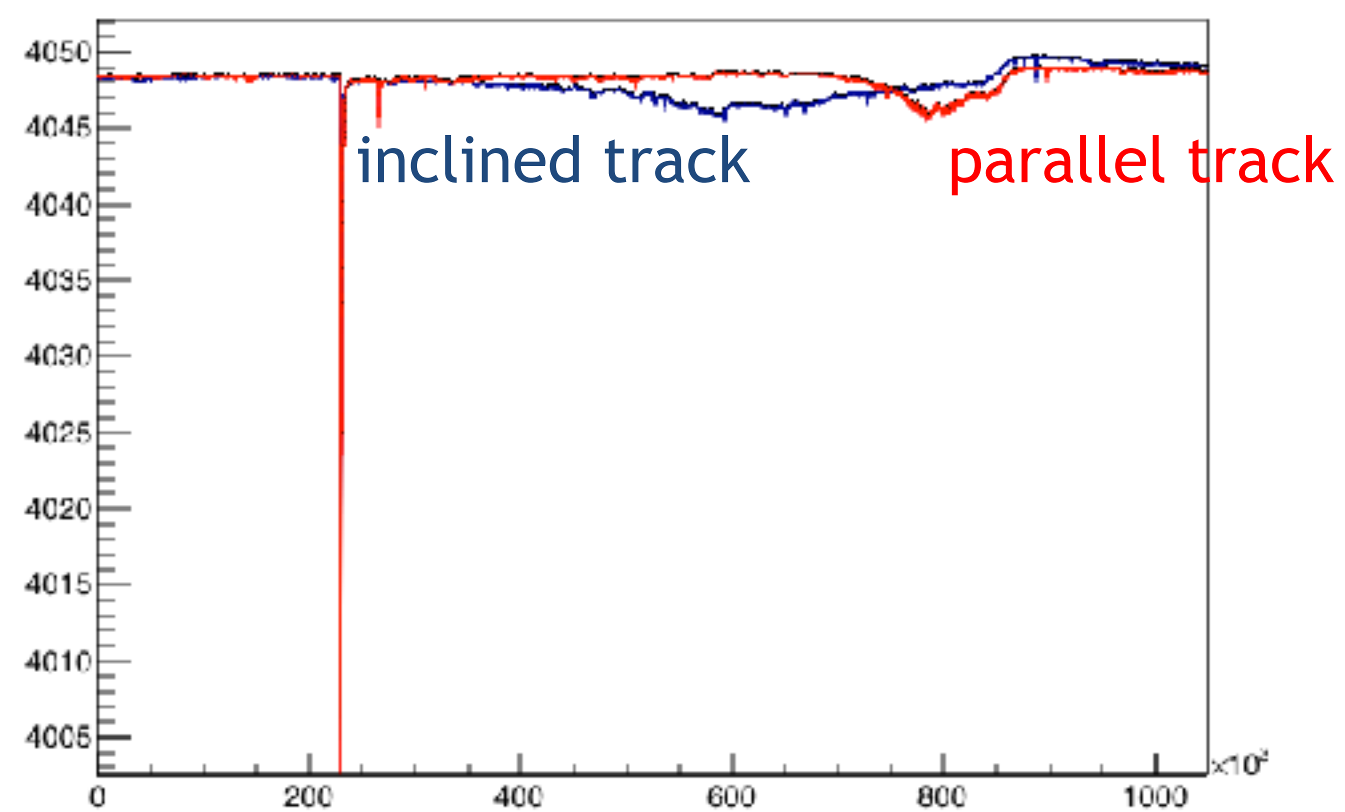
- Study of S1 with HV on the grid and the LEMs. Changes in the PMT Trigger (we still need more data).

- Study of S2 with different voltages in the grid and the LEMs.

S2 Studies

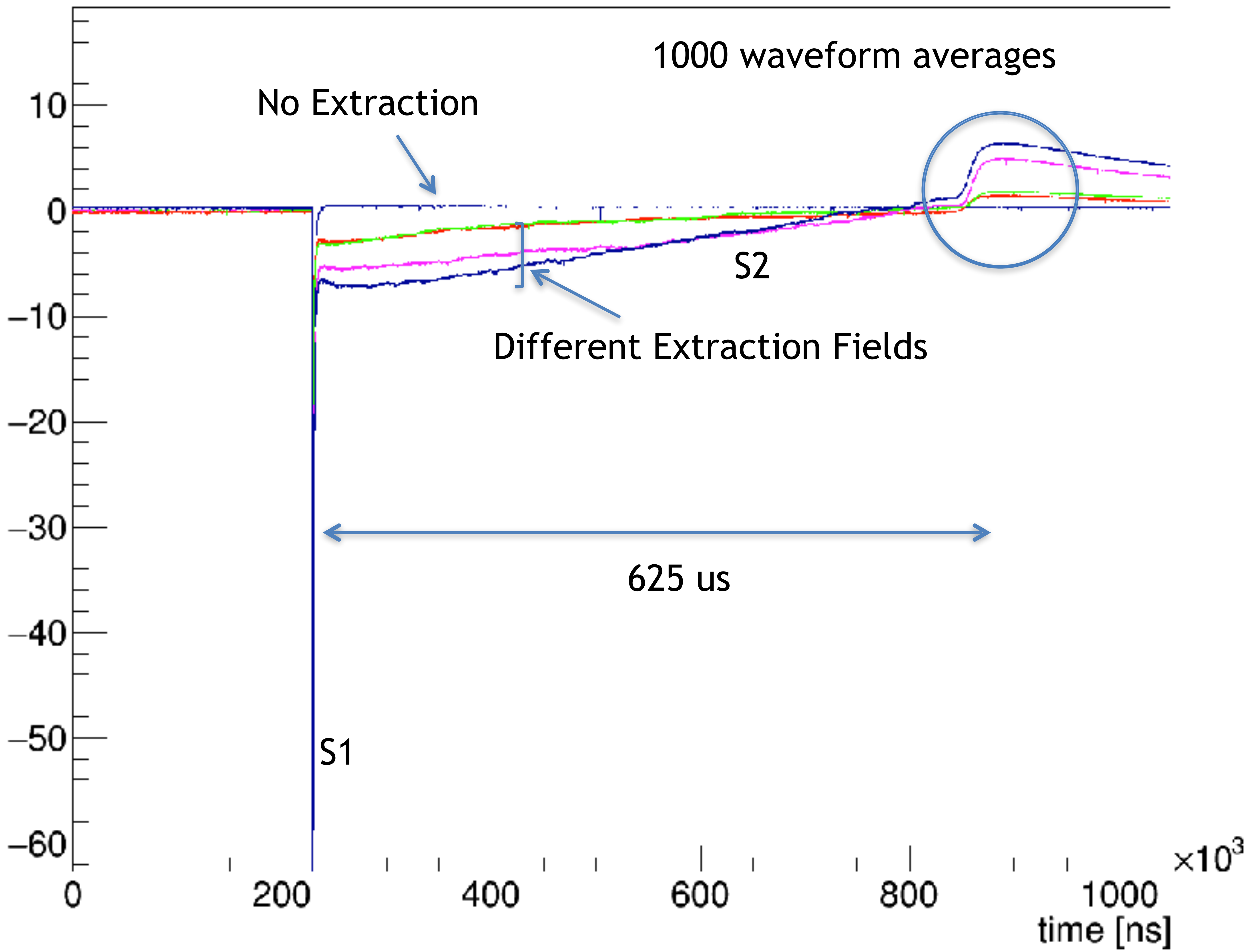
- The drift time needed by an electron to get to the anode depends on where it is created. It can be studied with S2 and compared to the reconstructed track given by the CRT.
- A parallel track crossing the bottom of the detector will show an S2 concentrated in time far from S1.
- S2 coming from an inclined track will be more spread in time.





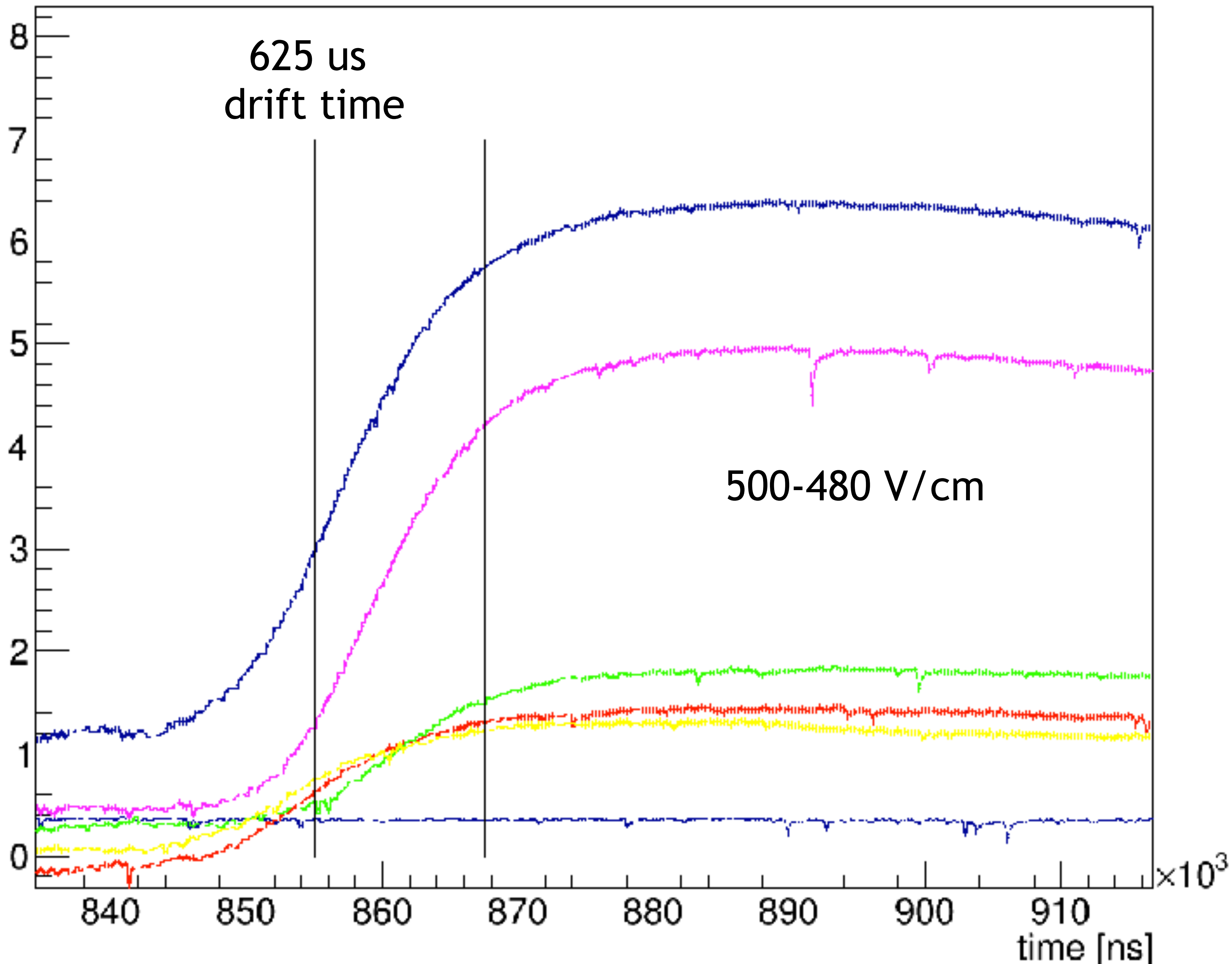
Measuring the drift time

1 m @1.6 mm/us -> 626 us drift time



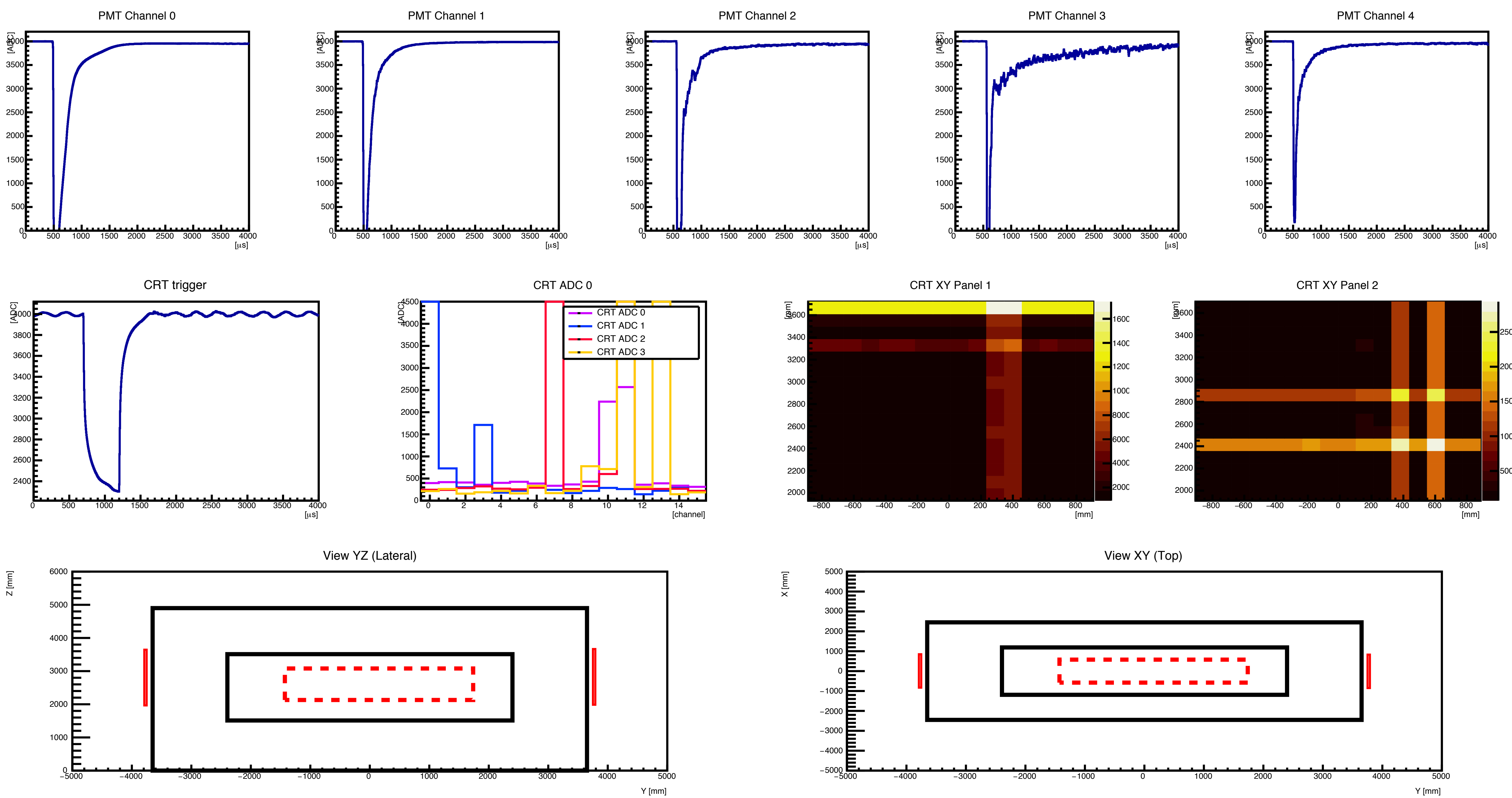
Measuring the drift time

- Fitting with a sigmoid function, the turning point changes with the drift field. We still need more data.



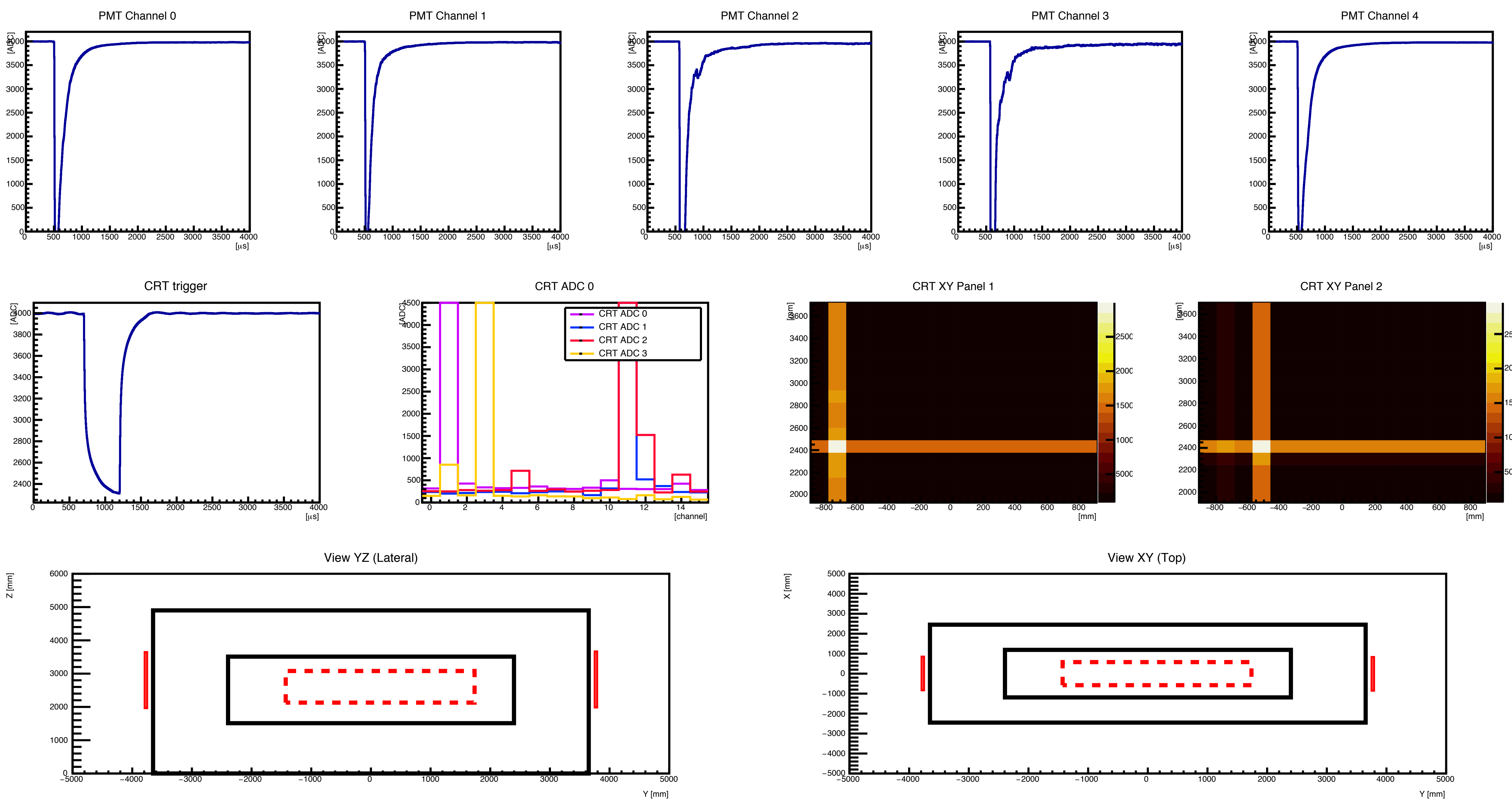
Backup slides

Unusual events with CRT Trigger



Run 837 - Event 570

Unusual events with CRT Trigger



Run 837 - Event 1169

Rate of unusual events

Run	Rate
1440	24,76 %
1441	25,17 %
1442	26,54 %
1443	26,98 %
1444	29,87 %
1445	29,57 %
1446	26,24 %
1447	28,16 %
1448	24,15 %
1449	22,77 %
1450	29,78 %
1451	30,62 %
1452	28,90 %

Events that differ from the average values of charge, amplitude, width and pedestal in more than 2σ