

# Status and plan for the 3x1x1 PMT data analysis

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on behalf of the CIEMAT and IFAE groups

- Plans for light studies after commissioning
- Available software
- Commissioning data taken so far

# Plans for light studies

1. PMT gain calibration, PMT system long term stability (monitoring).
2. Compare positive/negative basis PMT to optimise splitter-box design for the 6x6x6
3. Compare cathode/plate coated PMT response w.r.t. light simulation
4. Study S1 level vs drift field, extraction field and amplification
5. Study S2 level vs drift field, extraction field and amplification
6. Study evolution of LAr purity and light attenuation using S2 signals
7. Measure light propagation speed in LAr with CRT triggered muons
8. Combine charge/light data: study purity, attenuation, etc.

# Software available

- **Event display:** show raw waveforms, CRT information, muon tracks
- **Waveform fitter:** fit fast, intermediate and slow scintillation components
- **Charge reconstruction:** peaks finder and charge reconstruction
- **Event loop:** compiled code to loop over run file and access information event-by-event
- Some dedicated analysis/study performed with simple ROOT macro
- Available on personal repositories. To be moved on collaboration svn/git repositories. To be coordinated with Elisabetta.

# Data available so far

- Run information available on the [ELOG](#) and summarised in a google docs available [here](#)
- CAVEAT: these are COMMISSIONING run! **Data quality is not granted...**
- Run classified by DAQ configuration:
  1. **Early commissioning data:** dry run with PMT off, CRT trigger test
  2. **PMT self-trigger scans:** self-trigger run with w.r.t. trigger threshold
  3. **PMT HV scans:** external random trigger w.r.t. PMT HV
  4. **CRT trigger:** muon showers and muons crossing the field cage
  5. **HV scan with external random trigger:** HV on cathode, grid and lem
  6. **HV scan with CRT trigger and 1ms readout window**
  7. **PMT self trigger:** to provide trigger to the CRP

# Possible data taking scenario during stable operation

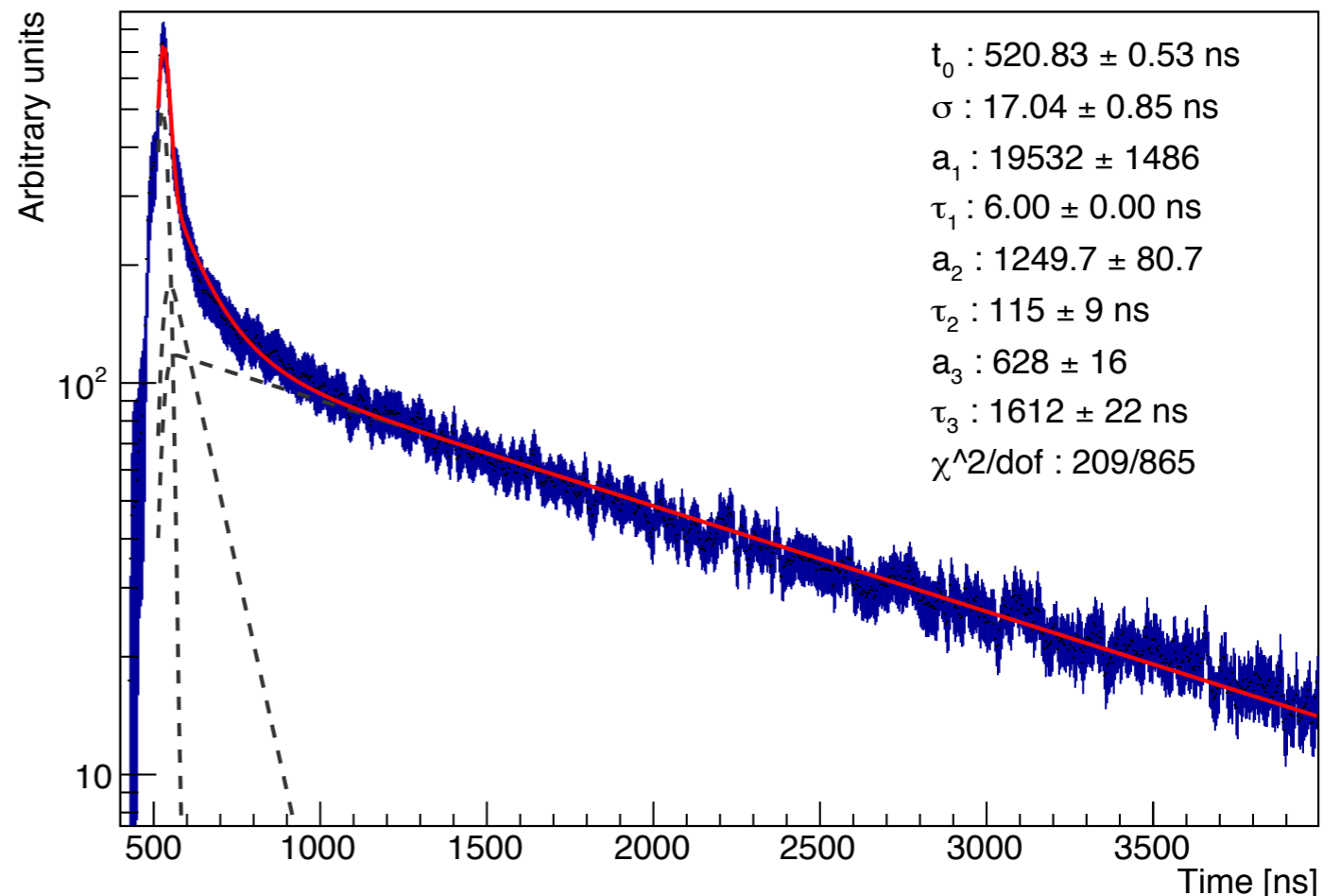
- PMT self-trigger with 4us (1ms) readout window for S1 (S2) studies and charge+light correlation:
  - During cathode HV scan only (6h or more @ ~3 Hz)
  - During grid HV scan only (6h or more @ ~3 Hz)
  - During LEM HV scan at constant drift fields (6h or more @ ~3 Hz)
  - **At operation condition (12h/day @ ~3 Hz) in parallel with charge readout**
- CRT trigger with 4us (1ms) readout window for S1 (S2) light propagation measurement
  - **At operation condition (12h/day @ ~0.3 Hz)**
- **To be discussed and fine tuned within the operation group**

# Studies ongoing with commissioning data

1. Measurement of LAr scintillation light (Alberto)
2. PMT gain measurement (Jose)
3. Positive/Negative base PMT comparison (Jose/Chiara)
4. PMT self-trigger studies (Silvestro)
5. CRT event characterisation (Chiara/Silvestro)
6. Preliminary S2 studies (Alberto/Jose)
7. S1 level during HV tests (Alberto)

# LAr scintillation light

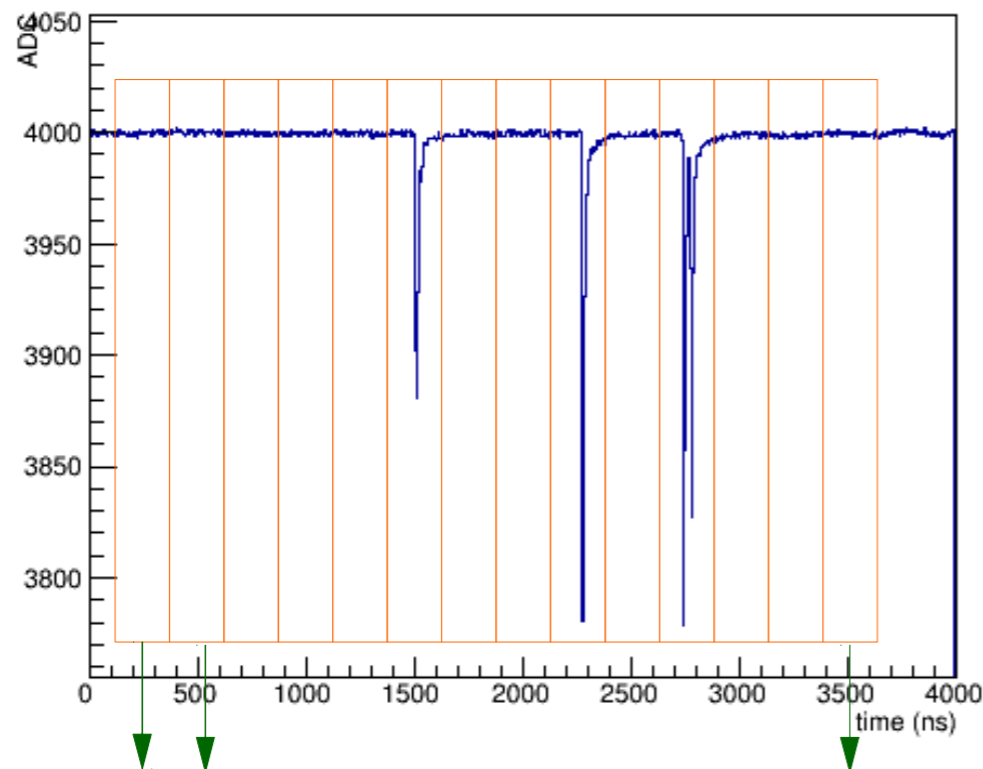
- Average the non saturated waveforms upon baseline subtraction
- Fit with 3 exponential convolved with a gaussian function
- Performed at very early stage of PMT operation and during detector filling
- **Should be performed consistently** as is a good indicator of the LAr purity at PPM level



$$\begin{aligned}
 f(t) &= G(t - t_0, \sigma) \otimes \left[ \sum_{i=1}^3 \left( \frac{a_i}{\tau_i} \times e^{-\frac{t-t_0}{\tau_i}} \right) \right] \\
 &= \sum_{i=1}^3 \left\{ \frac{a_i}{\sqrt{2\pi\sigma}} e^{\left( \frac{\sigma^2}{2\tau_i^2} - \frac{t-t_0}{\tau_i} \right)} \times \left[ 1 - \text{Erf} \left( \frac{\sigma^2 - \tau_i (t - t_0)}{\sqrt{2} \sigma \tau_i} \right) \right] \right\}
 \end{aligned}$$

# PMT gain measurements

- PMTs in the 3x1x1 characterised in warm GAr in 2016 at CERN.
- Dedicated run taken in the 3x1x1 at cold with different HV setting.
- Trigger performed with an external pulser @ 10 Hz. Random light taken with a read-out window of 4 us.
- Charge integrated within a 60 ns sliding window.

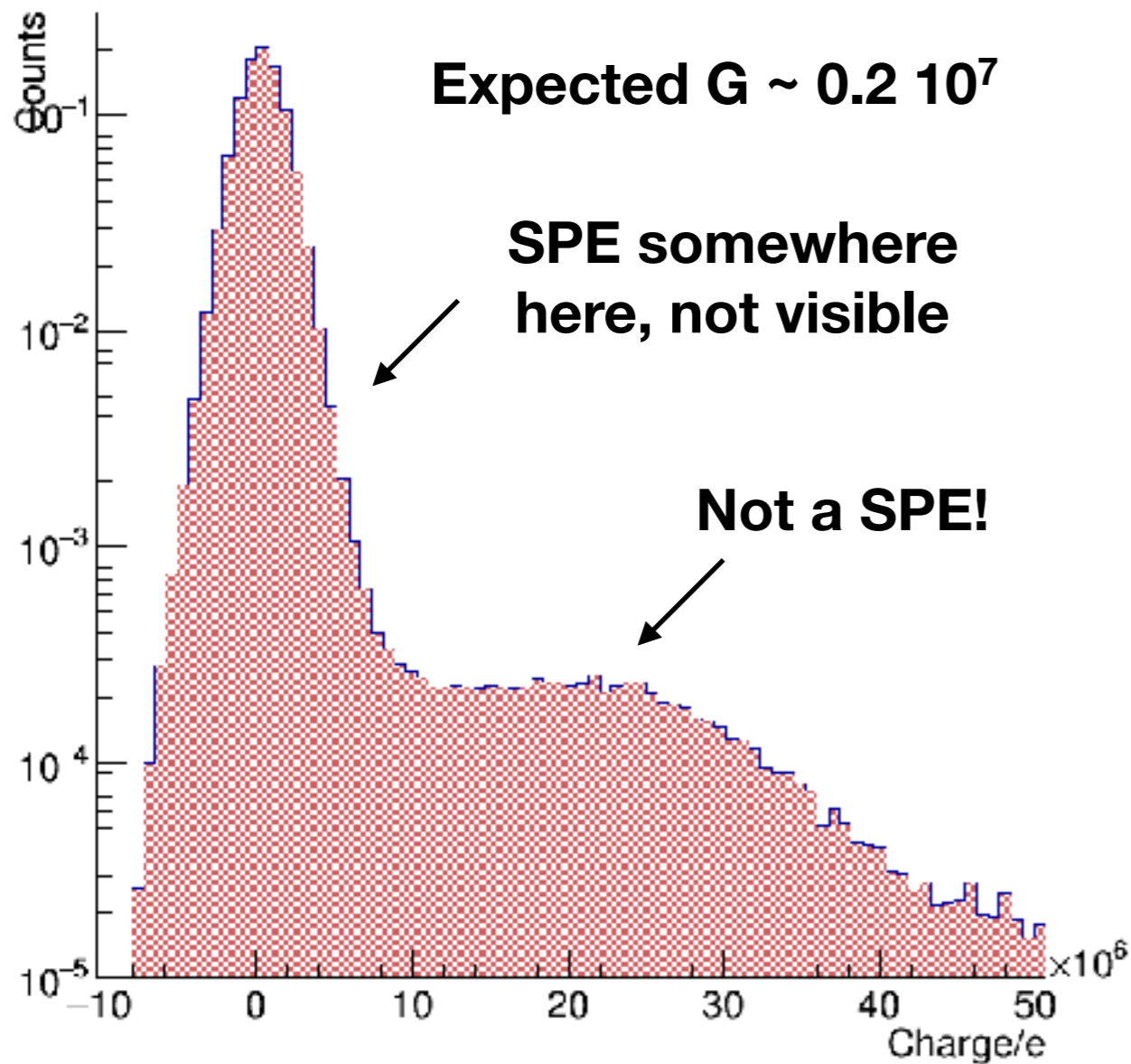


PMT Ch	High Voltage [V]			
0	1500	1600	1700	1800
1	1500	1600	1700	1800
2	1320	1450	1600	1750
3	1300	1450	1600	1750
4	1400	1550	1700	1850
Run	914	919	920	921

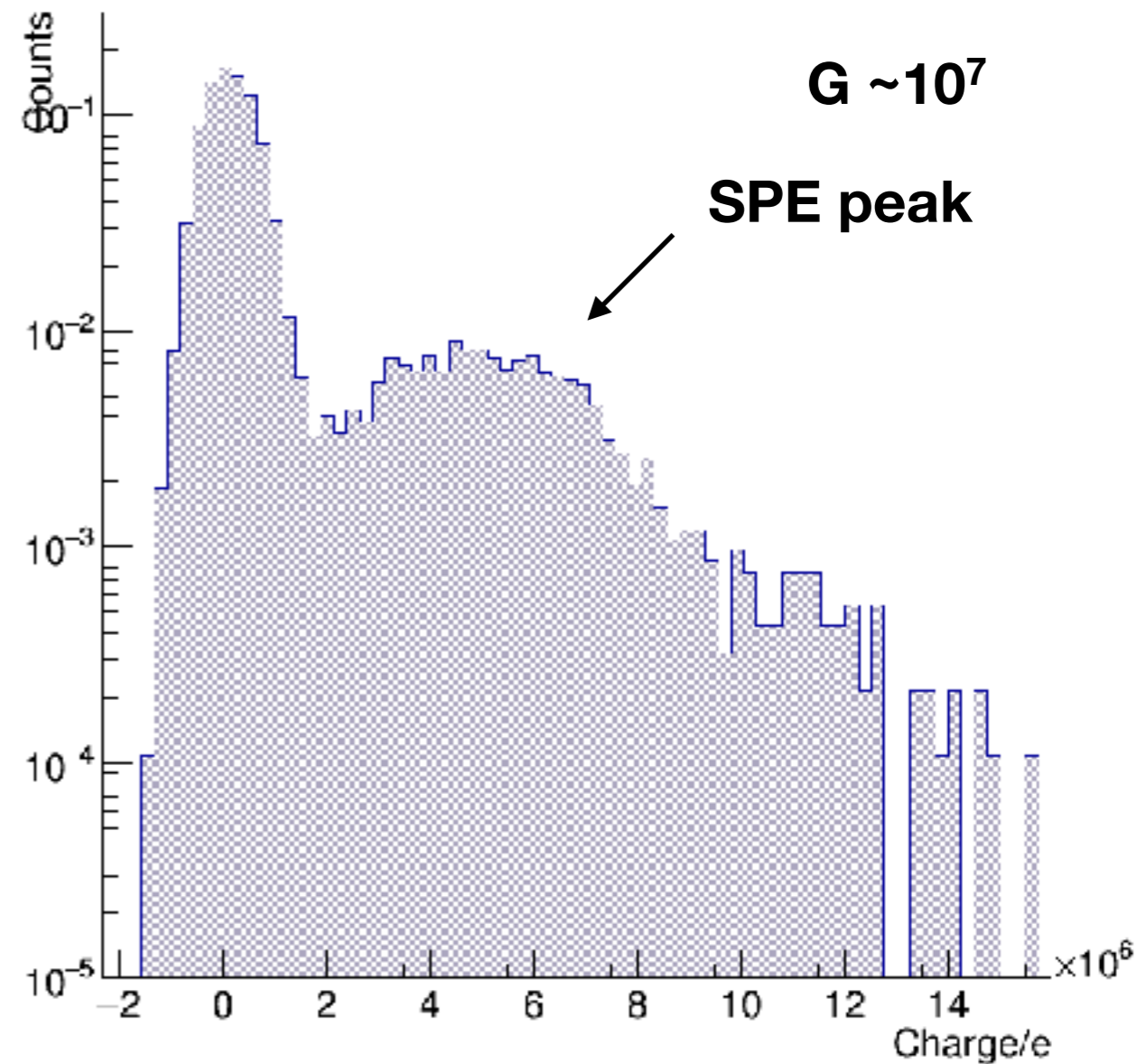


# PMT gain measurements

Light Spectrum in LAr at 1600V - channel 0



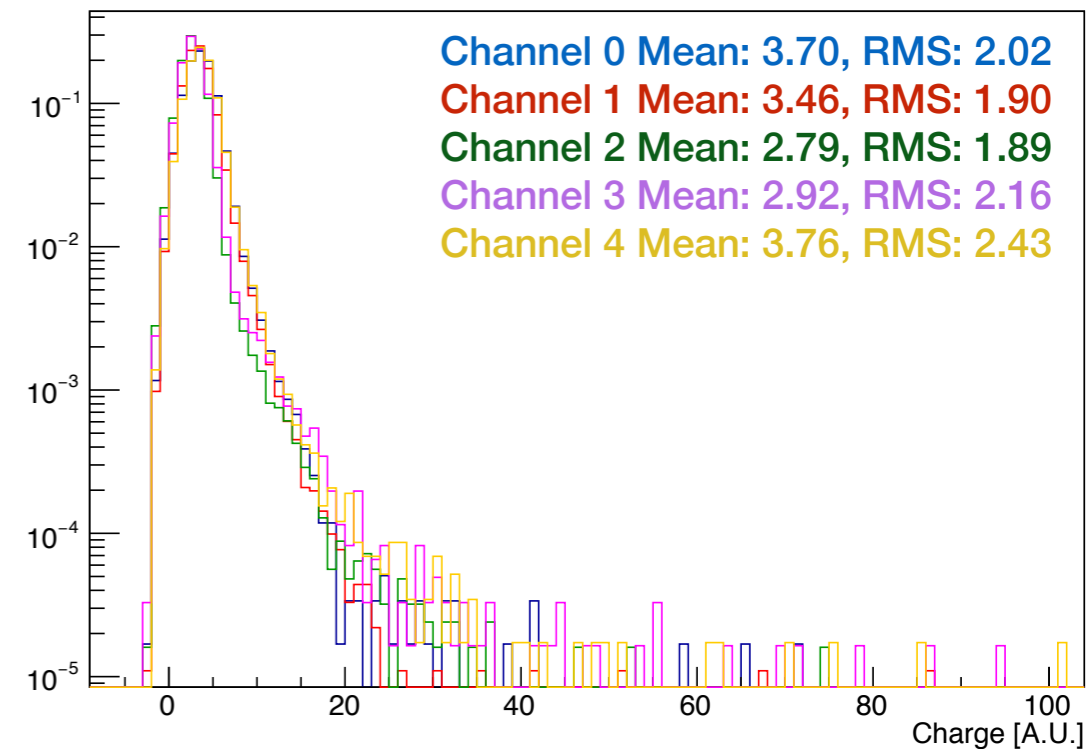
SPE Spectrum in GAr at 1600V - channel 0



# PMT gain measurements

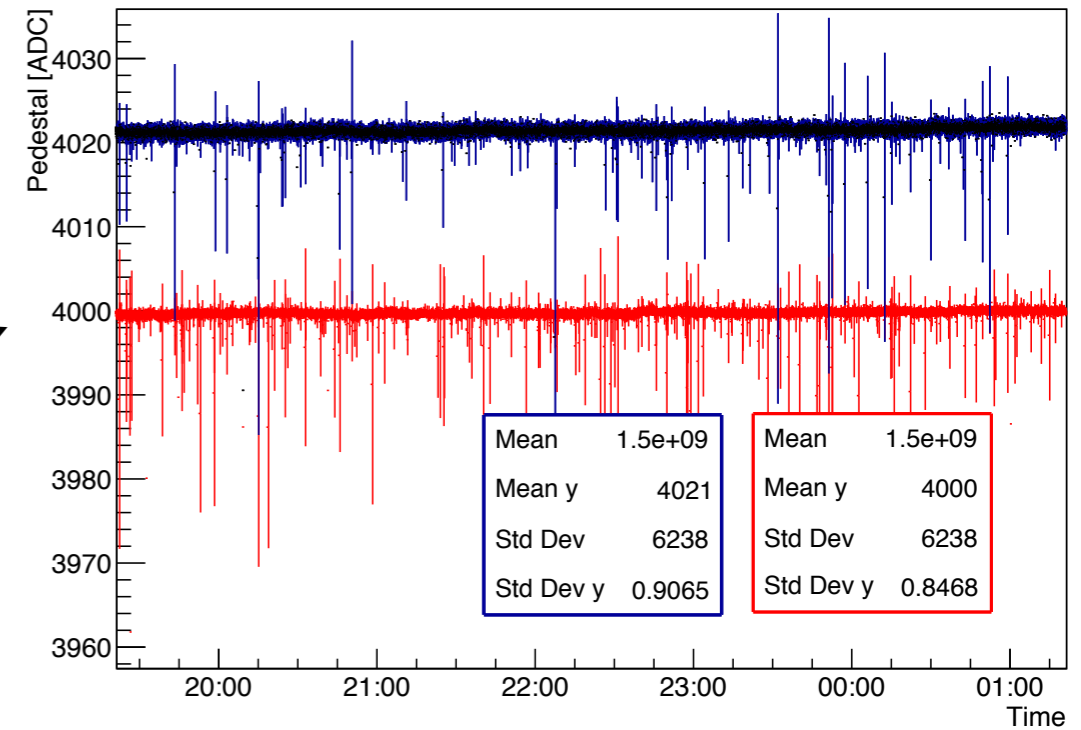
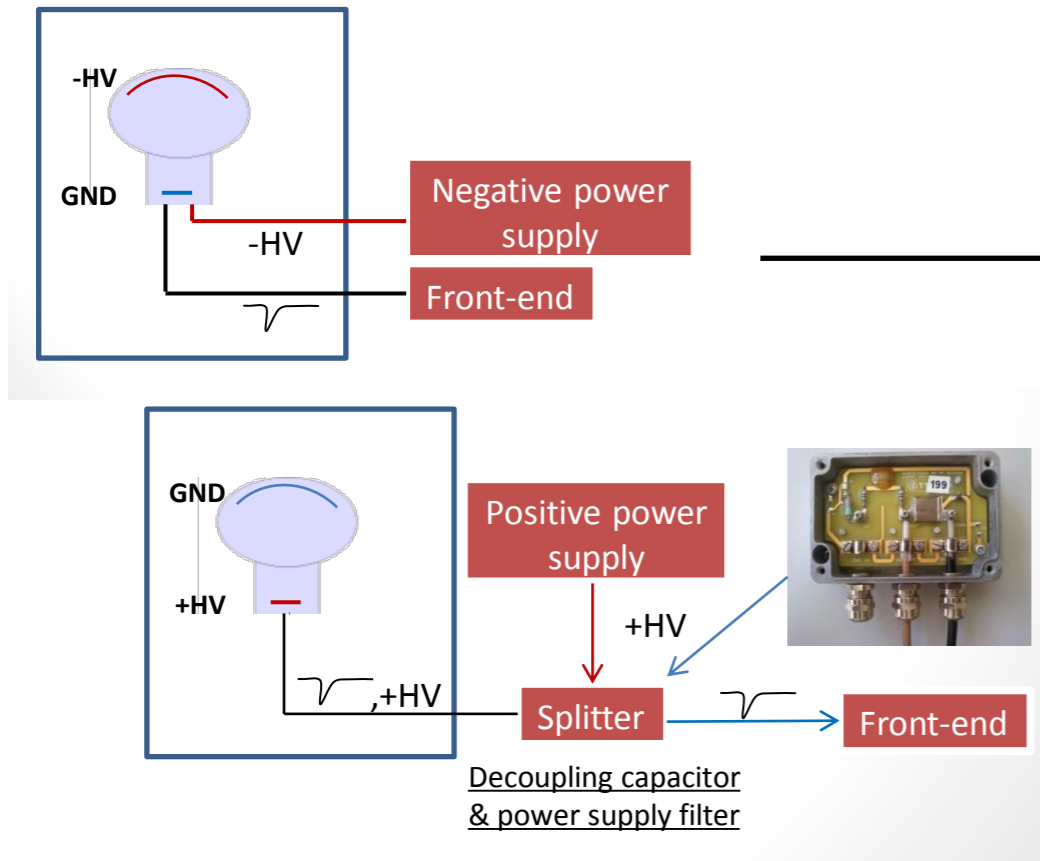
- The amount of light present in the 3x1x1 does not allow to see SPE pulses
- We are not able to calibrate the gain of the PMTs with precision in the 3x1x1
- We can only equalise the PMTs response and rely on the extrapolation of the measurement being performed at CIEMAT

**Current PMT HV settings:  $G \sim 10^6$**

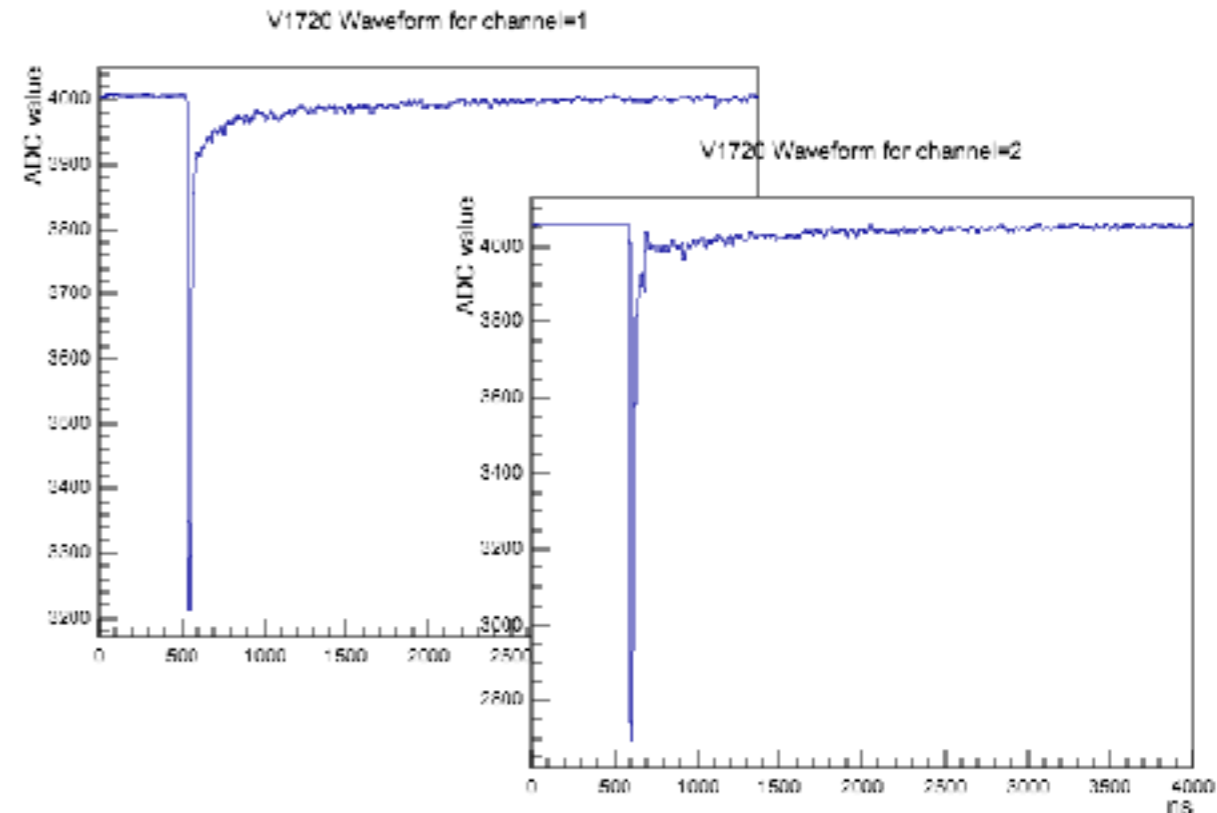


# Positive/Negative PMT

## basis

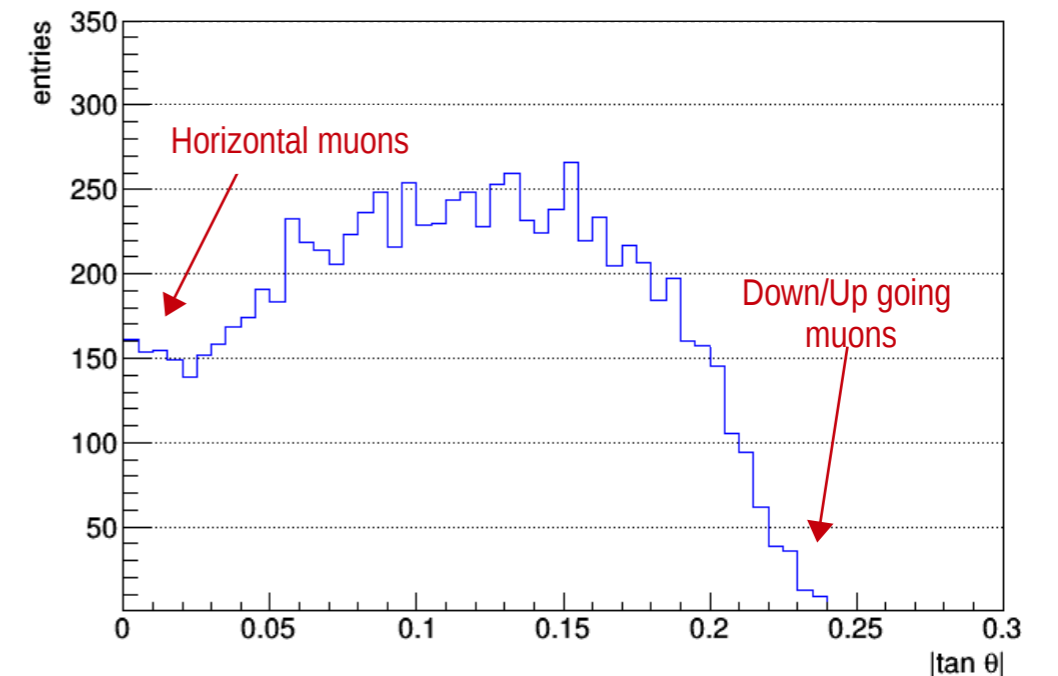
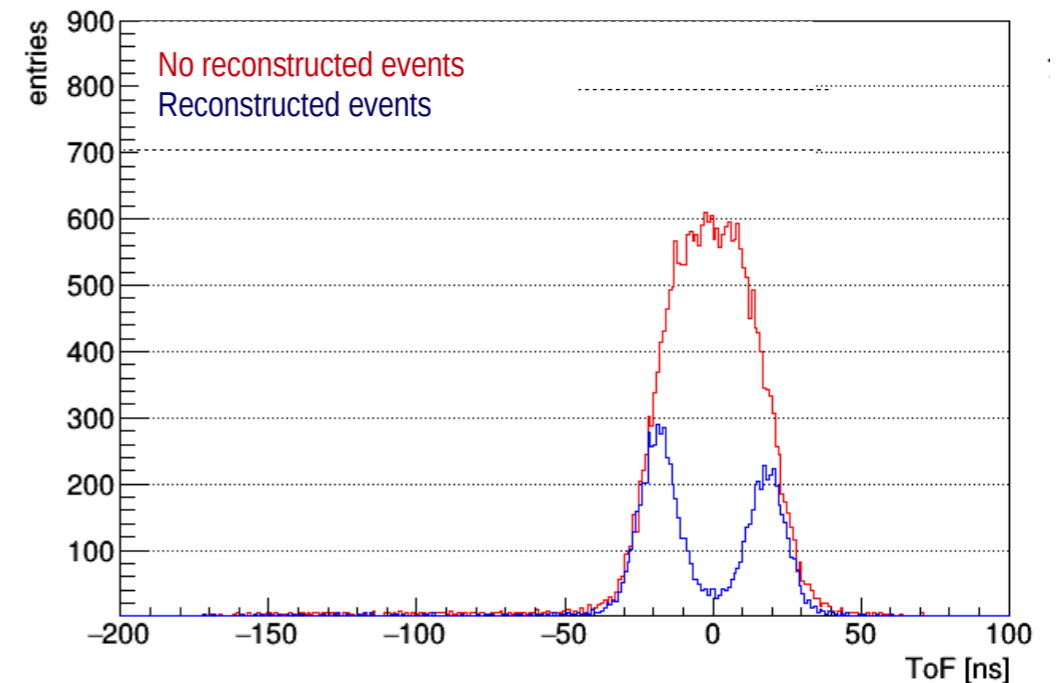


- Positive biased PMT show reduced pedestal fluctuation without drift field
- Impedance mismatch on the feedthrough create a reflection of the signal at a constant position



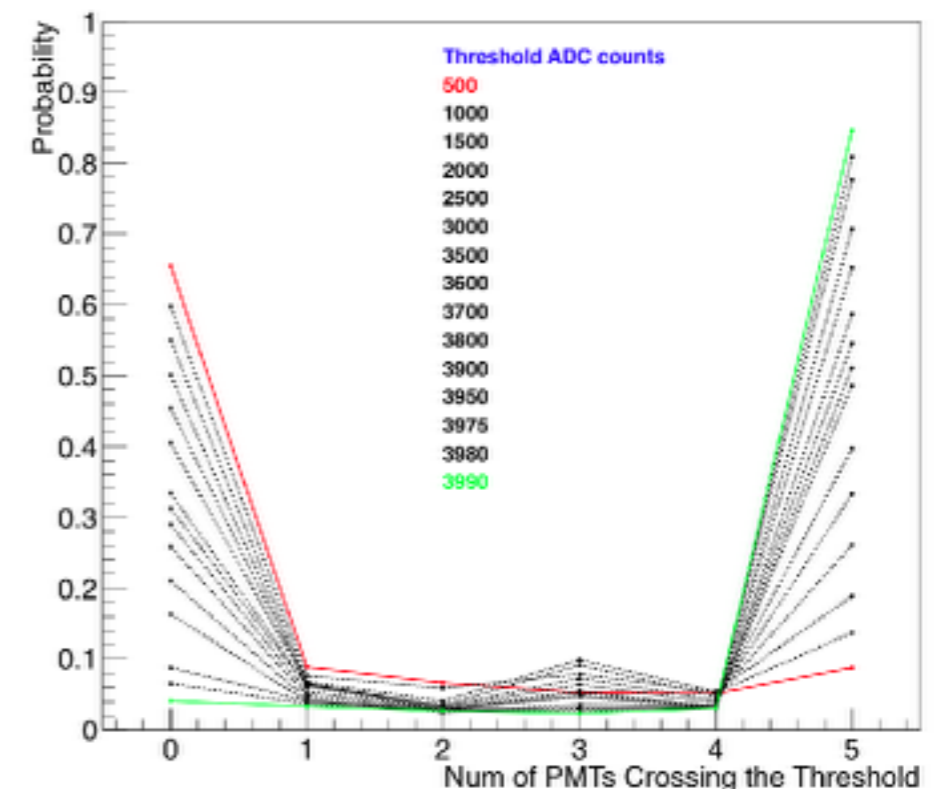
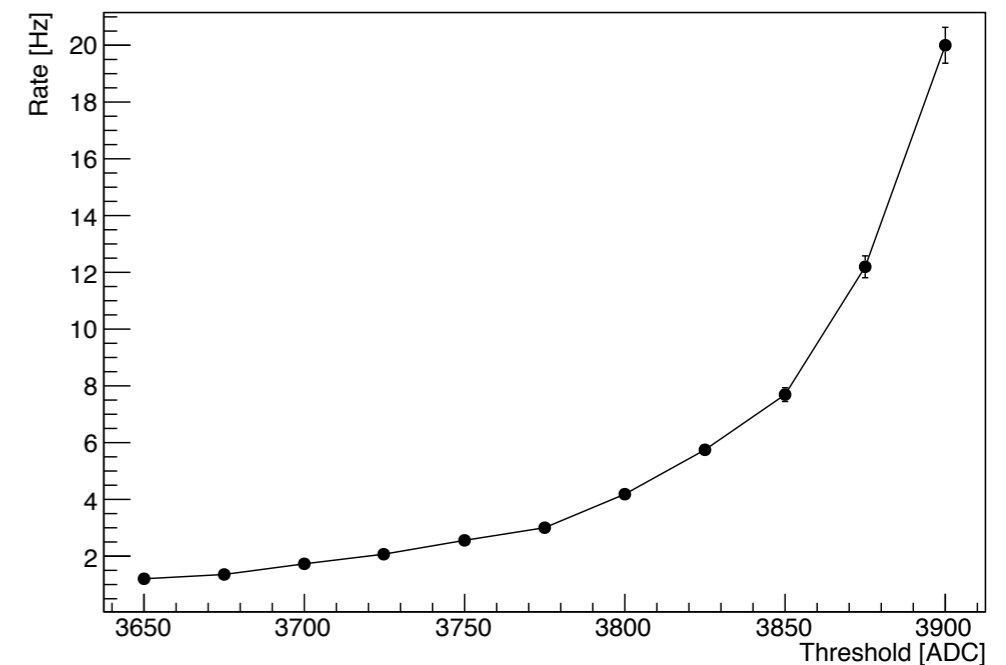
# CRT studies

- CRT event characterisation for selecting crossing muon tracks
- Study cut definition, purity and efficiency
- Only ~30% of the CRT trigger are matched online with the PMT events
- **Offline matching might improve the situation, study ongoing**
- About ~26% of recorded CRT events are muons crossing the field cage



# PMT self-trigger studies

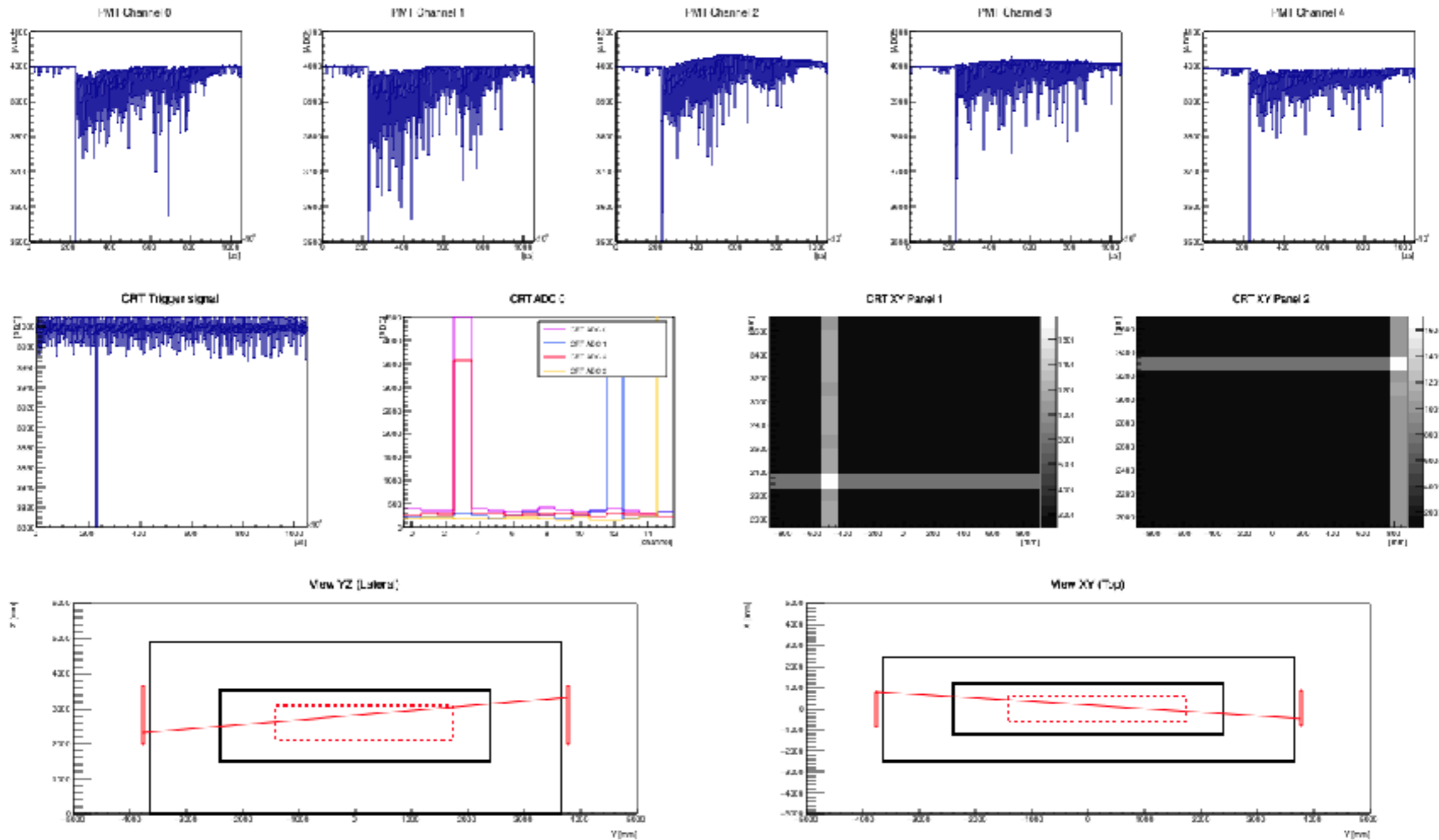
- Study of self-trigger condition on S1 signals
- Trigger scan to study S1 level w.r.t trigger threshold
- PMT Multiplicity study w.r.t. trigger threshold



# Preliminary S2 studies

- HV on the cathode, extraction grid and bottom LEMs
- PMT readout at 250 MHz in 1ms window with CRT trigger
- S1 and S2 are easy to disentangle by eye
- Most of the events are consistent with multiple tracks crossing the field cage (multiple S1 signals)
- More data in this configuration is required for dedicated studies

# Preliminary S2 studies

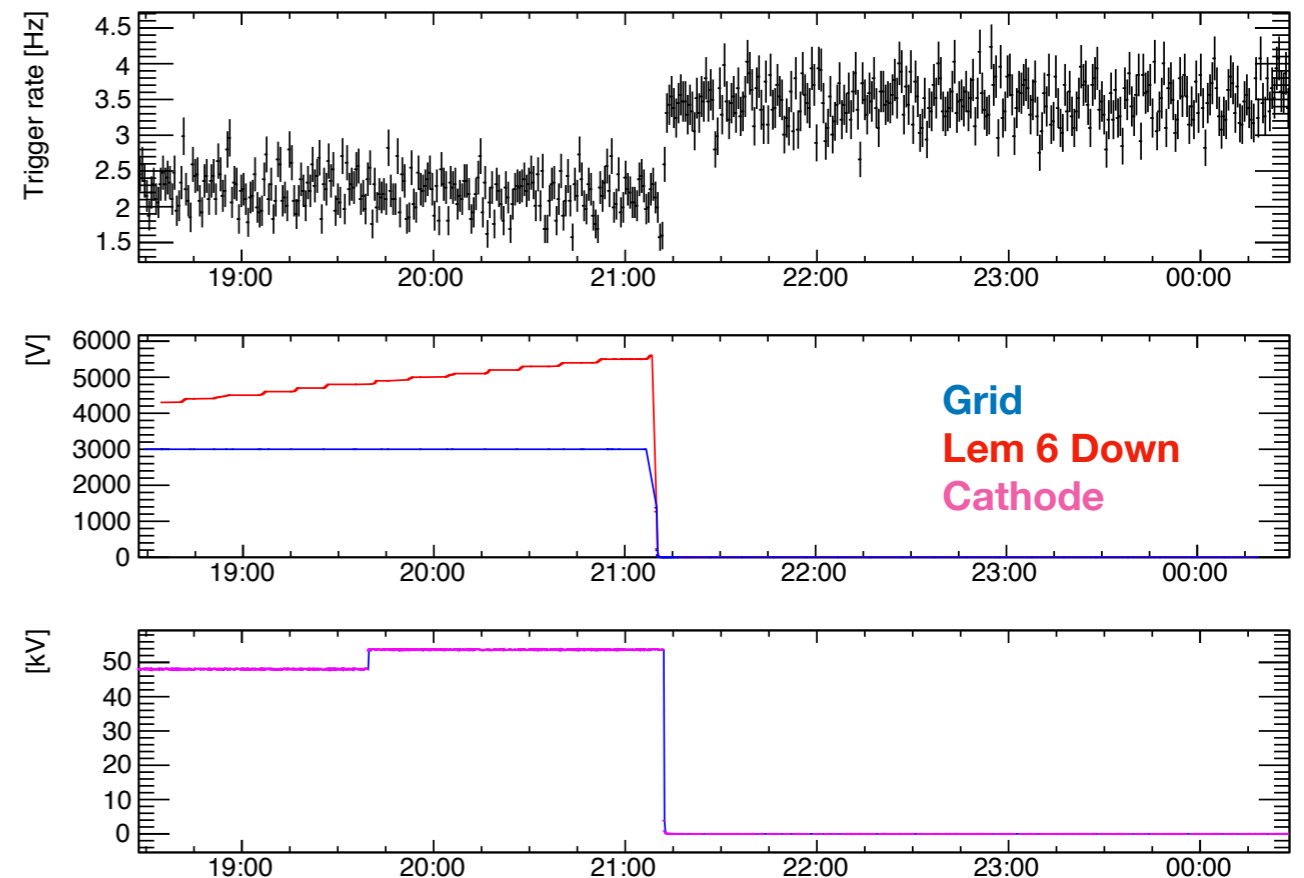


**Event no.1610, Time Stamp Thu, 15 Jun 2017 21:04:22 CEST**

# S1 level during HV tests

- PMT self-trigger rate as a function of the drift field, the extraction field and amplification
- Study the light quenching induced by the drift field
- Study the effect of the LEM amplification on the light signals

Run 1295: self-trigger th. 3750 ADC





# Conclusions

- Light system is working well and taking data regularly.
- The system is flexible enough to be adapted to different scenario (as already demonstrated!)
- Some studies to understand the detector from the light point of view are ongoing with the commissioning data
- The analysis plan presented here is based on what is considered relevant by the PMT group, also w.r.t. the extrapolation of the light system to the 6x6x6
- Some data are already available but more needs to be taken to complete the proposed analysis plans: to be coordinated with the operation group
- We are of course open to suggestion, measurements or data taking configuration that people might success or being interested to test