Summary of PMT behavior at cryogenic temperatures and observed light characteristics @ 3x1x1 prototype

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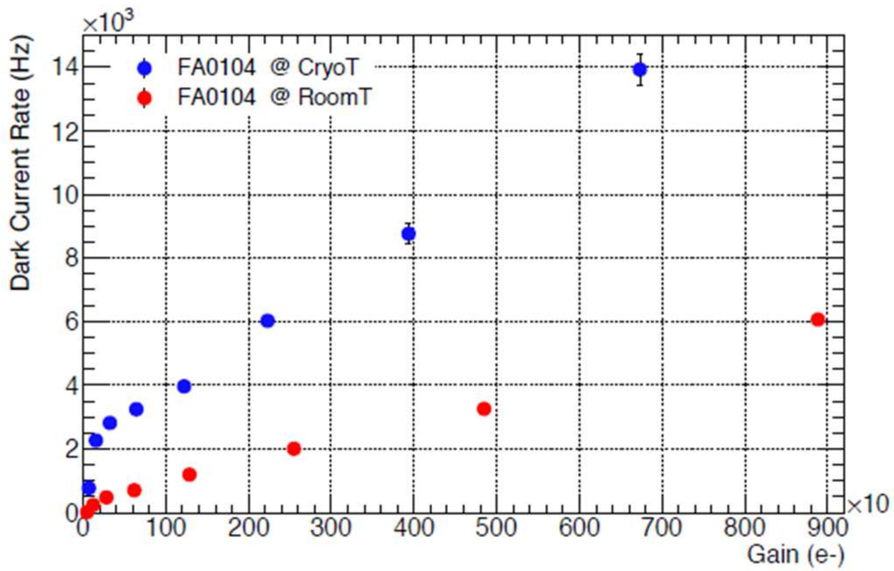
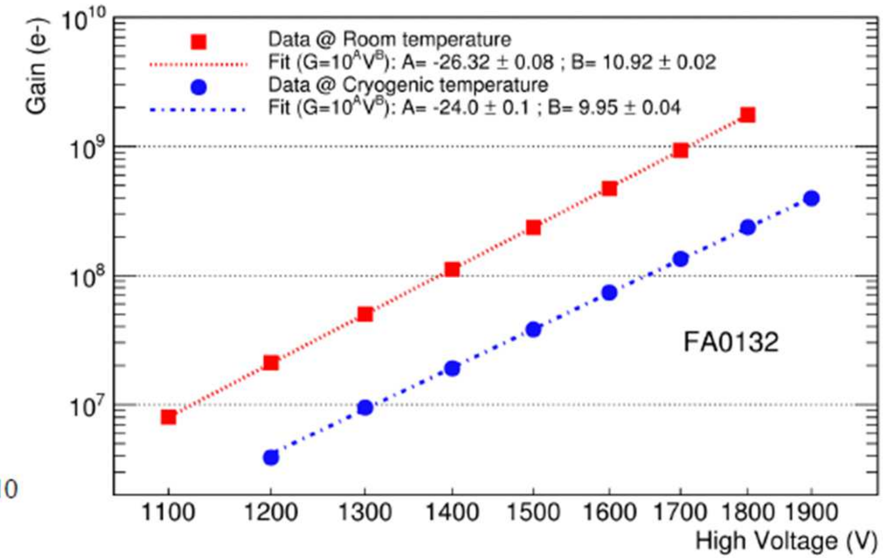
PMTs behavior at cryogenic temperatures

- **Dark rate is larger** than at room temperature
- **Gain decreases** for the same applied voltage

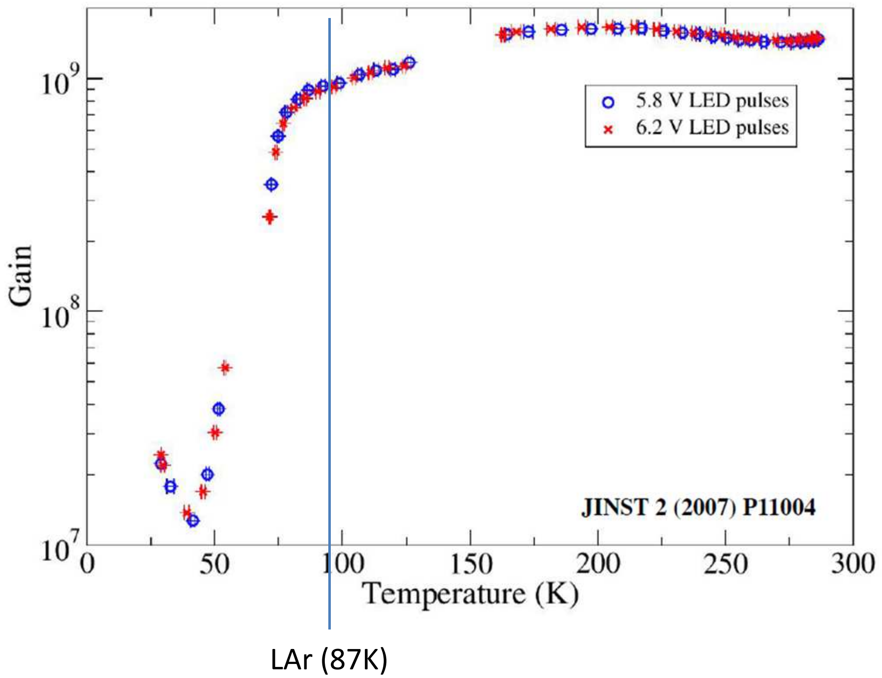


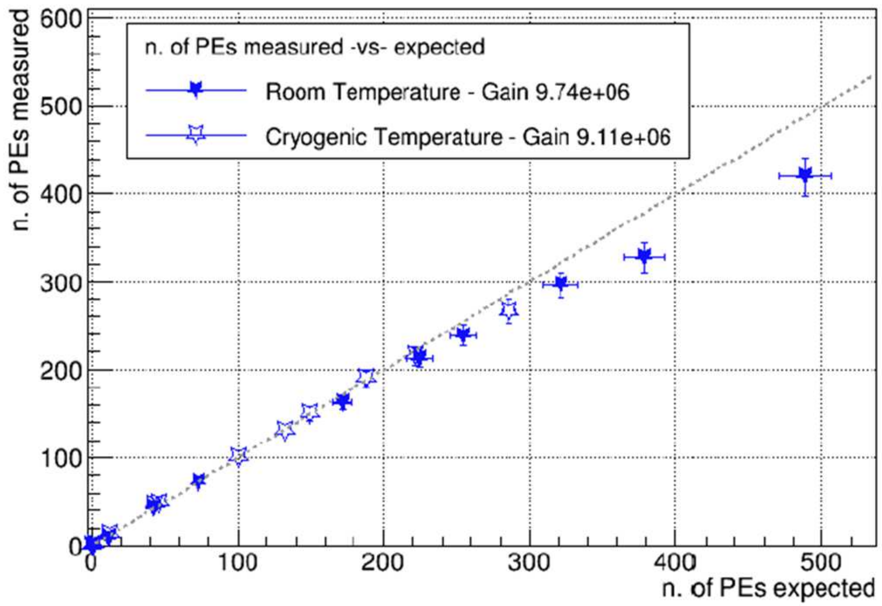


PMTs behavior at cryogenic temperatures

- Small **temperature variations** can affect the PMT **gain**:
  ~20% variation observed in our setup between 77K (LN2) and 83K (LN2@ 1Bar overpressure)

- Linearity vs amount of incident light is the same as at room temperature

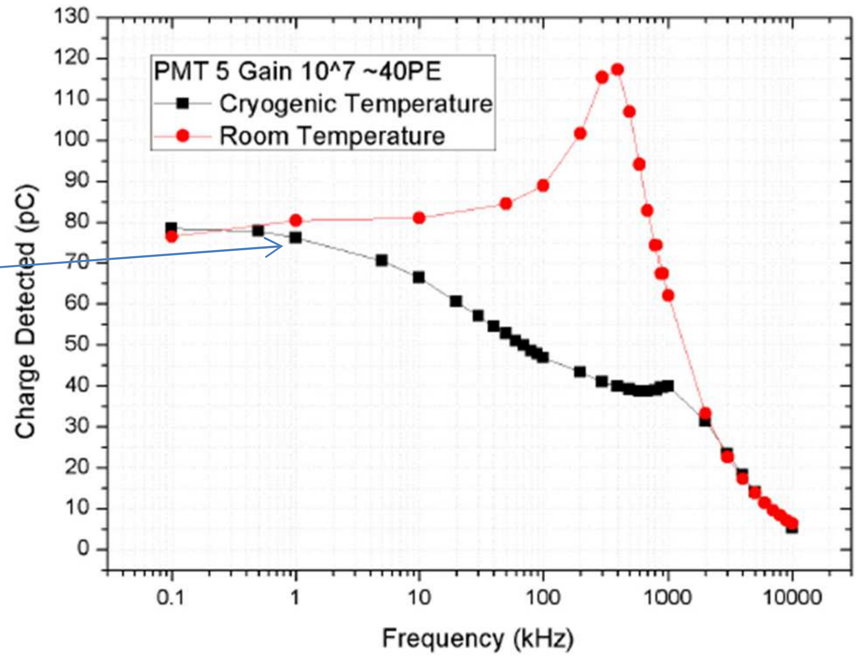




PMTs behavior at cryogenic temperatures

- **Linearity vs light pulses rate** gets worse at cryogenic temperatures.
- In addition **the PMT gain is affected** (decreases) when PMT is exposed to light pulses with high repetition rate (>~ 1KHz) and **the effect remains** after the excitation has disappeared. The PMT requires time to recover the initial gain. Depending on the frequency and intensity of the excitation the recovery time goes from minutes to several days.

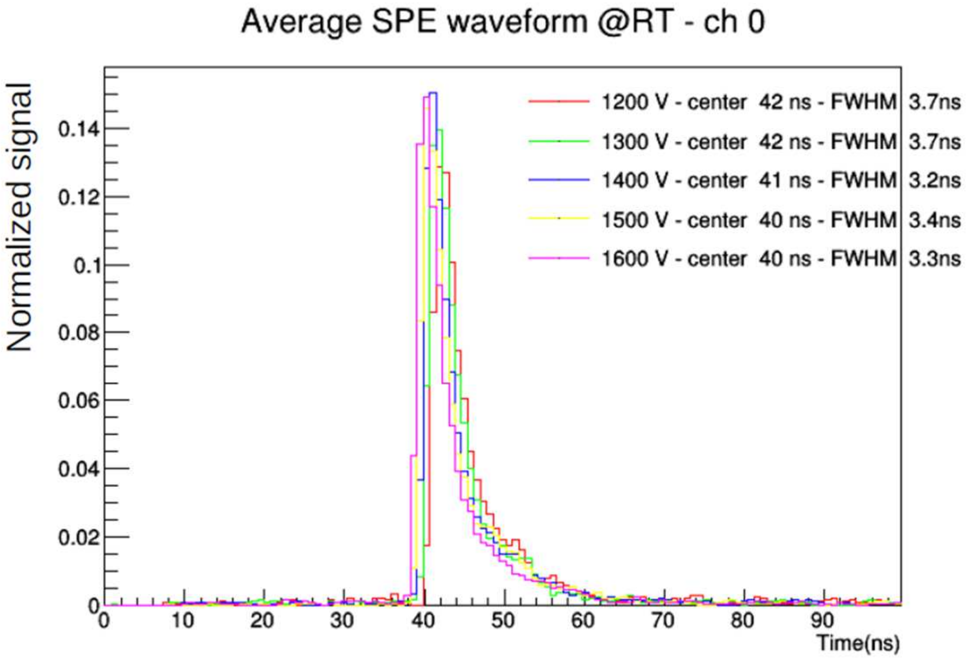
Events of 40 Pes @ 1KHz affects the PMT response (gain)



The described **effects** of the temperature over the different PMT characteristics **varies from PMT to PMT**. Some are more affected than others.

Summary of 3x1x1 observed light characteristics

SPE waveform shape

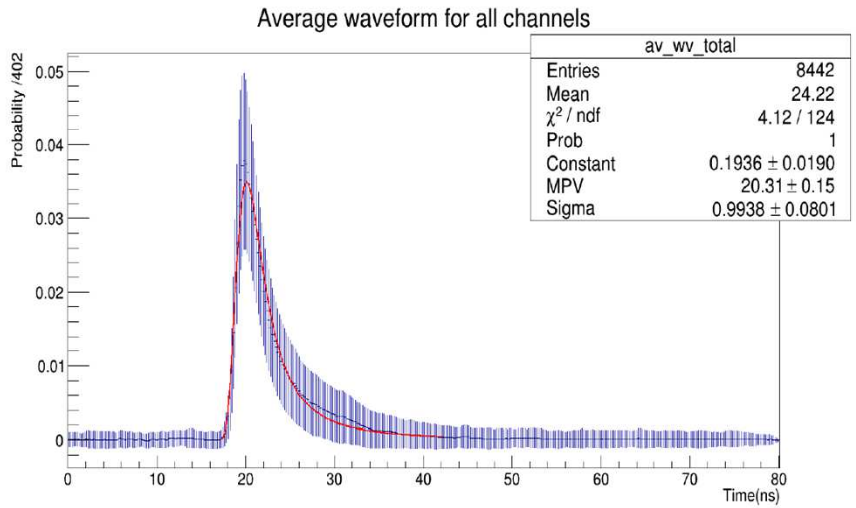


SPE waveforms obtained at different voltages normalized for comparison.

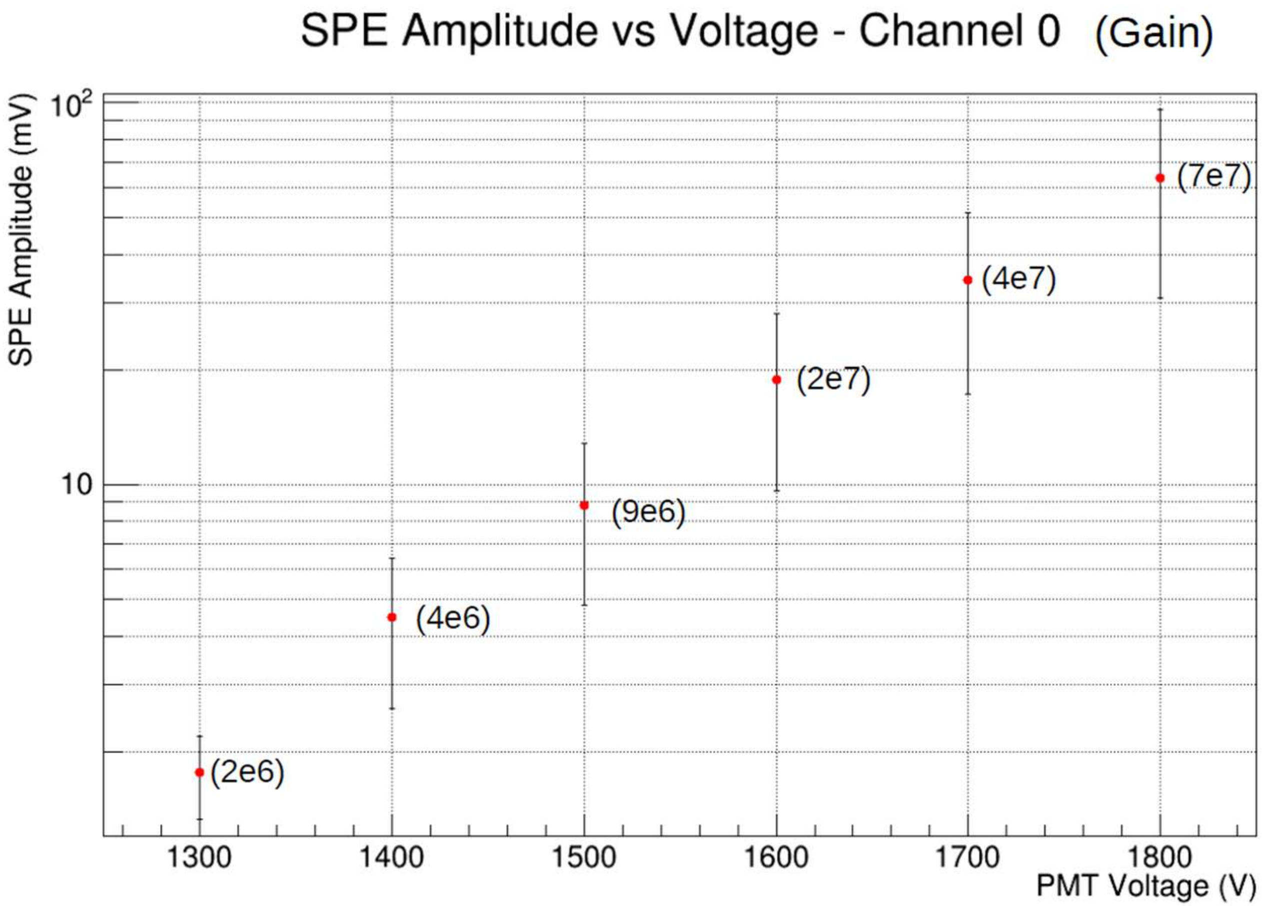
As the voltage increase the SPE shape increases in amplitude but not in time length.

SPE width at half maximum is about 3.5ns

The behaviour is similar for all the PMTs

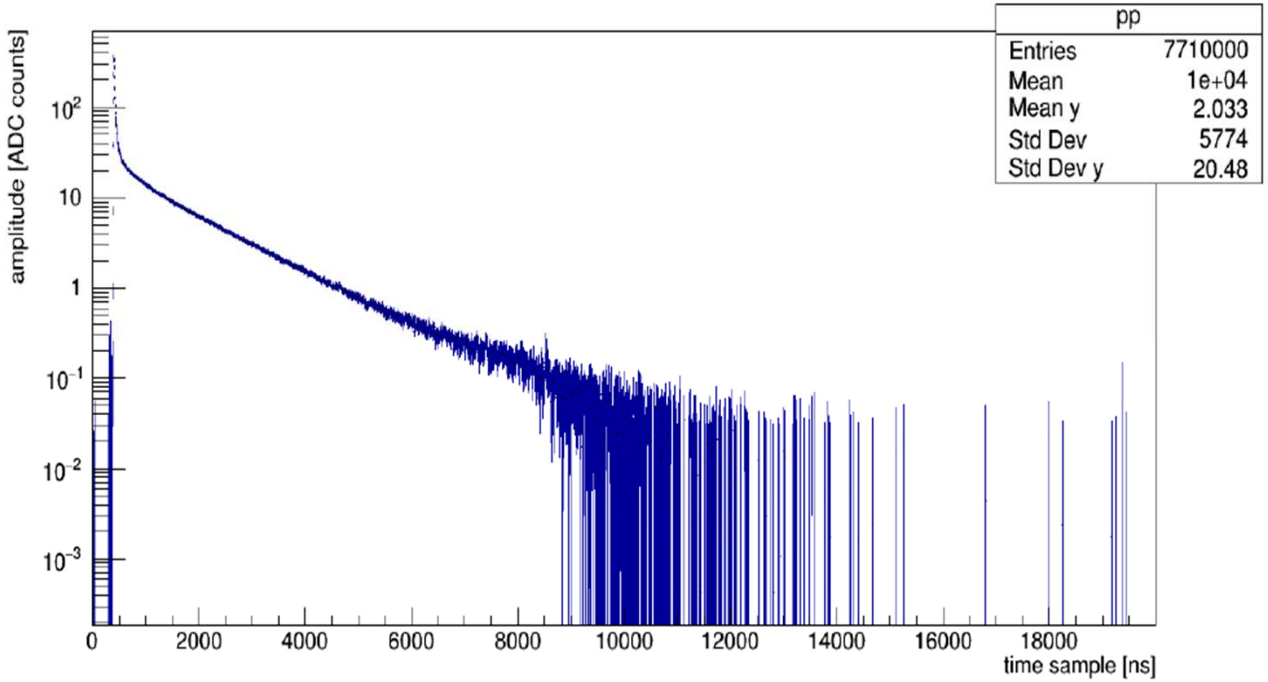


SPE waveform amplitude



- SPE amplitude varies from the mV level to hundreds of mV
- To distinguish SPE from the noise background PMT gain must be 10^6 or higher

Event waveforms without drift field (only S1)

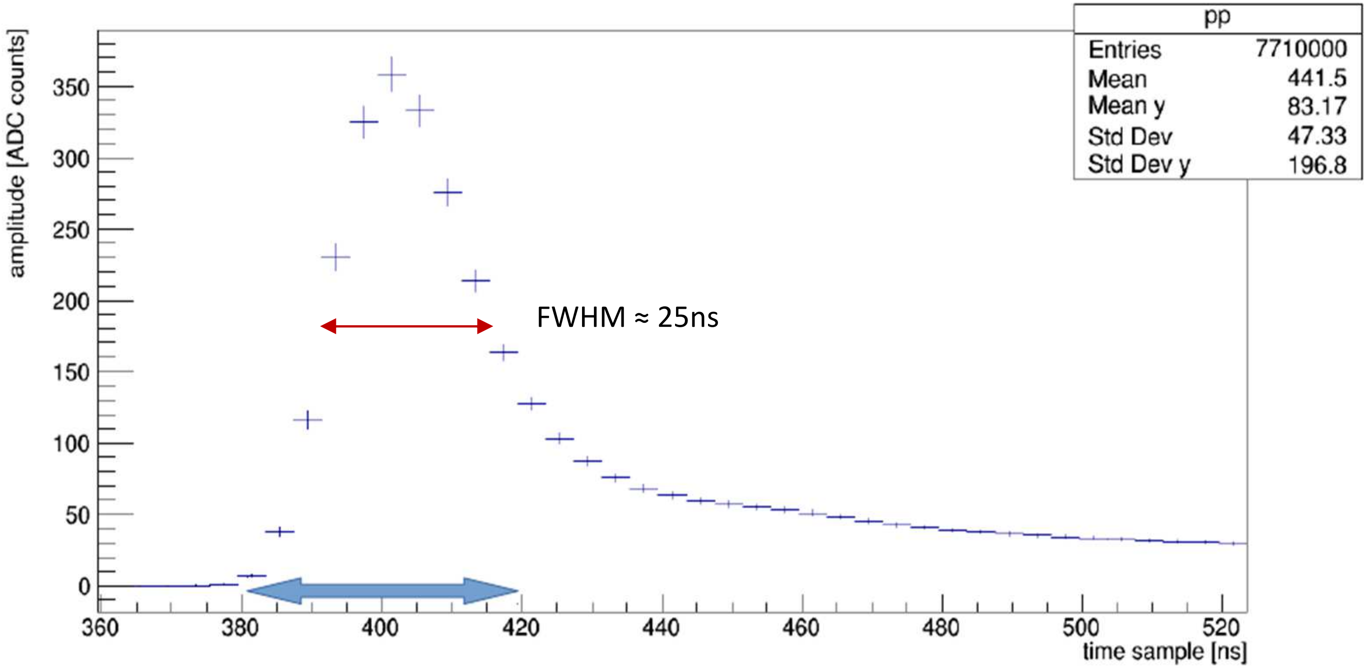


Averaged events on run 1618 ch0 (1200V , G= 1.1x10^6) CRT Trigger

Total charge on the 18us : 2300 PE

Event waveforms without drift field

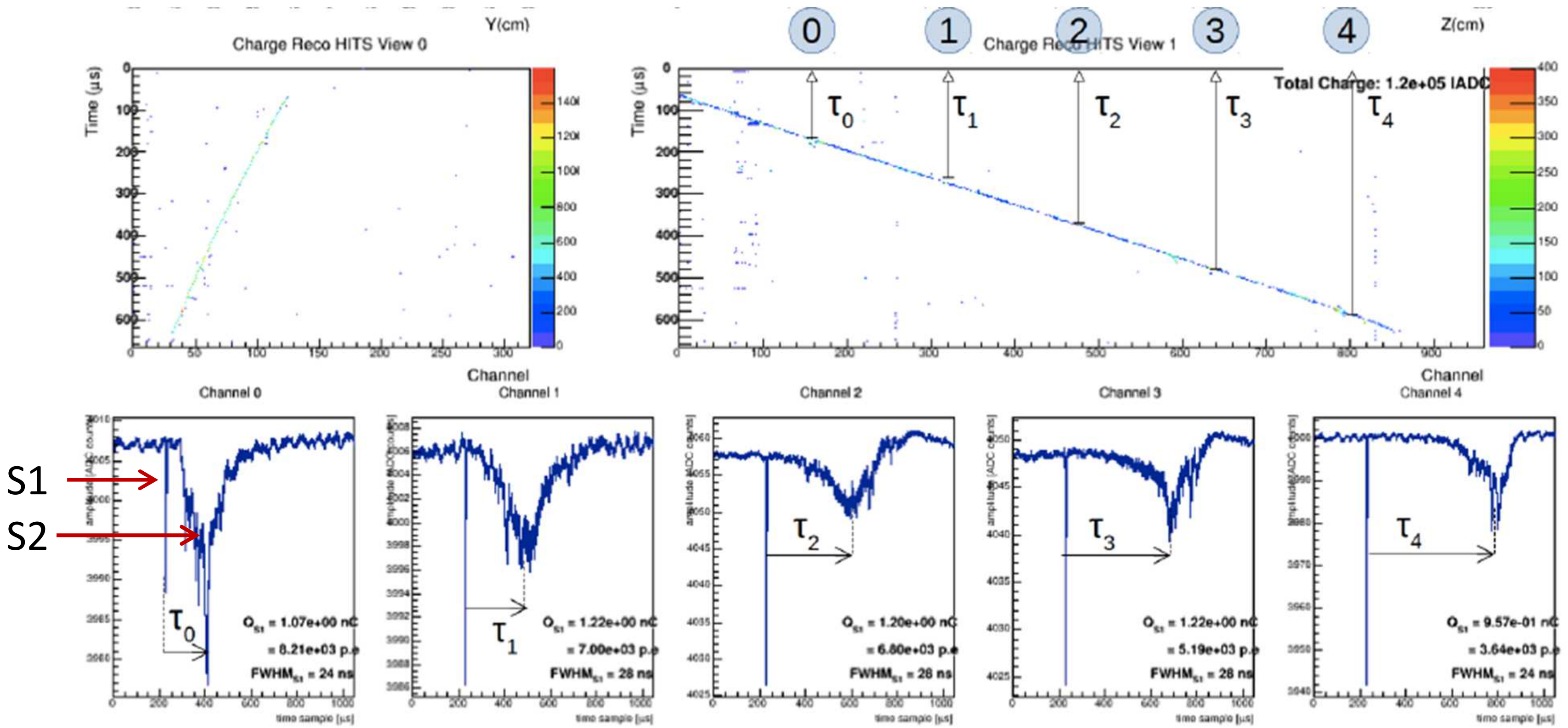
Zoom over S1 fast component



Averaged events on 1618 ch0 (1200V , G= 1.1x10^6) CRT Trigger

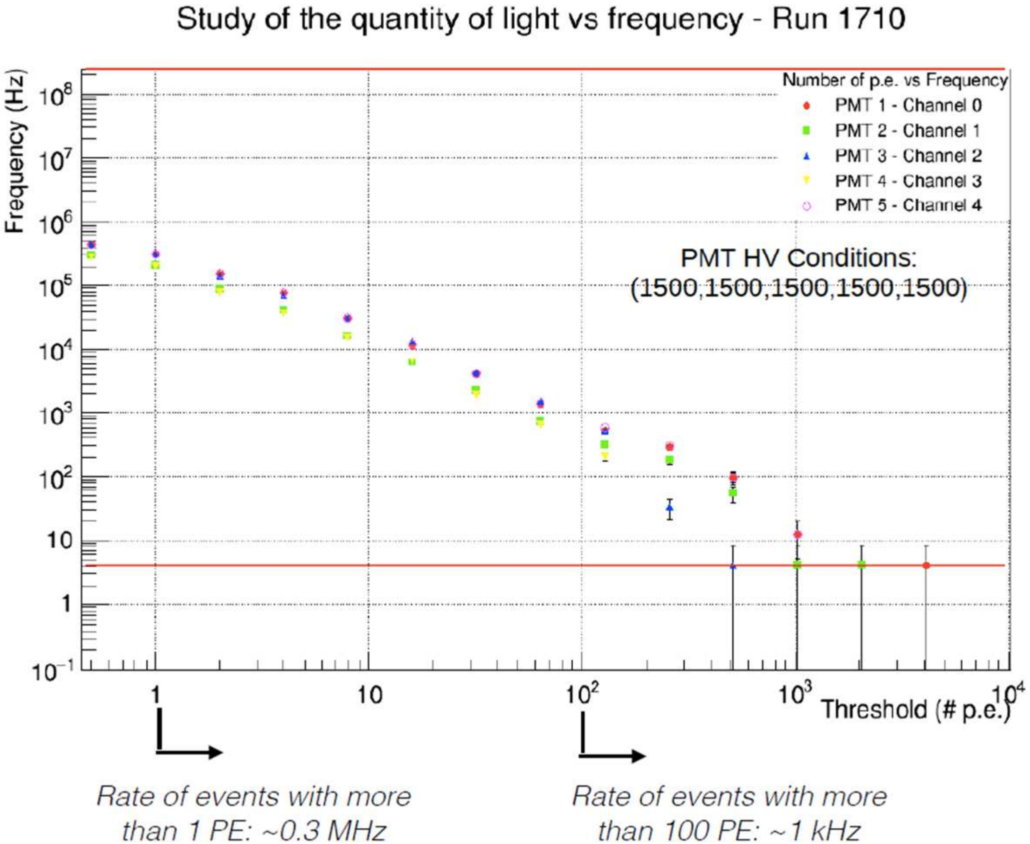
- Maximum amplitude 357 ADC counts (~140 SPE)
- Total charge on fast component (380 to 420ns): 490 PE
- ➢ This is about **20% of the total charge in 0.2% of the time**

Waveforms with drift field



- When drift field is connected each interaction produces two light events: S1 and S2
- The time difference between these two light events can be used to calculate the drift speed

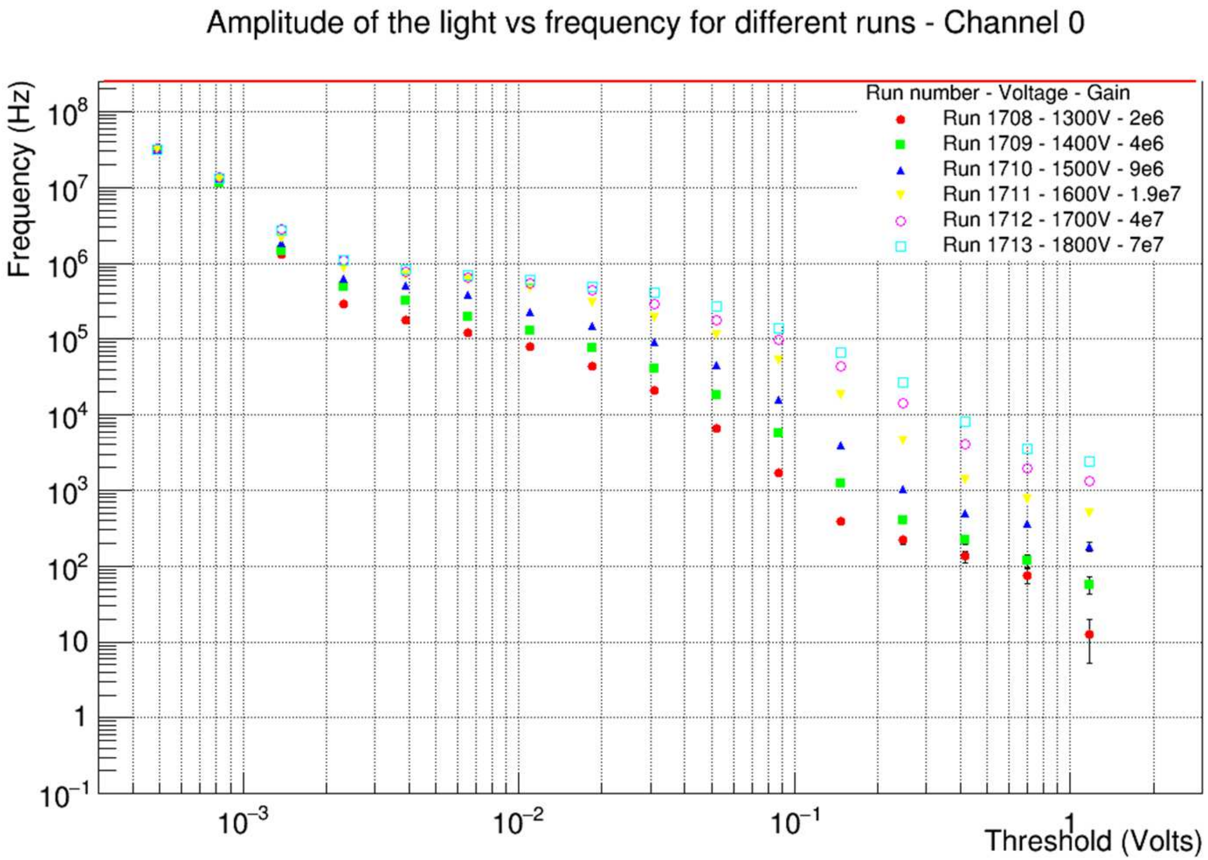
3x1x1 Amount of light vs frequency



As we know from our lab tests that the background light affects the PMT gain we have studied the frequency of the light events over different thresholds on the 3x1x1.

- There are events at 1KHz with more than 100PEs probably the PMT gain is affected.
- We also see events (at few Hz) up to around 1000 PEs in a single pulse that corresponds to the 2V limit of the ADC.

3x1x1 PMTs output signal amplitude



This plot shows the dynamic range of the PMT output signals for several gains

- Even for gains of the order of 10^6 there are signals over the 2V ADC limit

Summary and general considerations

We will have **long cables** (~40m) on the 6x6x6 from the PMTs to the FE, they will attenuate the PMT signal and increase the pick-up noise. So, on one hand, the PMTs gain should be high enough to distinguish the SPE from the noise (typically around 1mV), and, on the other hand, **it shouldn't be too high to keep signals into the FE dynamic range**. For a minimum gain of 10^6 the FE dynamic range should be from 1mV or lower to 2V or higher.

For the PMTs waveform digitalization 12bits would be enough (LSB ≈ 0.5mV).

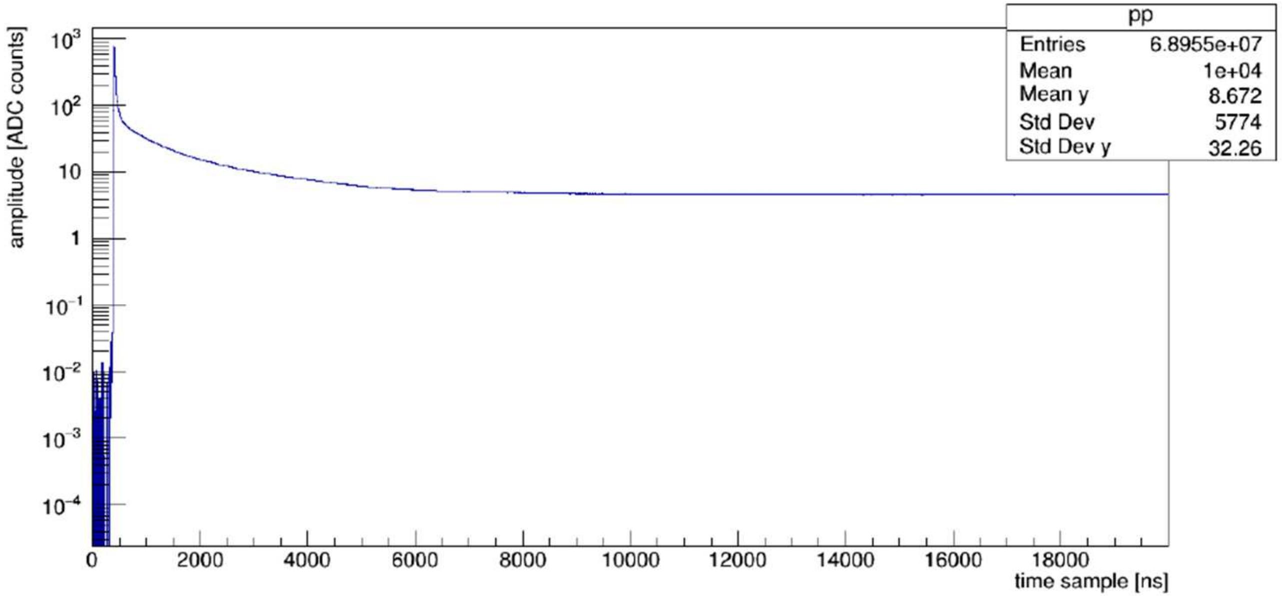
- **If we want to recover the SPE shape properly** the sampling period should be about ½ of SPE width (~3.5ns). So sampling frequency should be ~500MHz.
- **To recover the S1 fast component shape**, as the width is about 25ns a sampling period of 12.5ns (80 MHz) should be enough.

The PMT time resolution is given by the transit time spread that is around 3ns for our PMTs. As the Rayleigh scattering will dominate the time resolution limit, a **FE time resolution** of the **same order of the PMT will be OK**.

As in cold the PMT gain is affected by several factors (temperature, background light) it will be necessary, from time to time, to measure the PMTs operation gain. For that the DAQ must be able to measure the SPE charge in combination with the light calibration system. DAQ should be synchronized with calibration system and be able to measure a charge of 160fC that corresponds to the SPE charge for gain=10^6

Backup

Typical waveforms without drift field

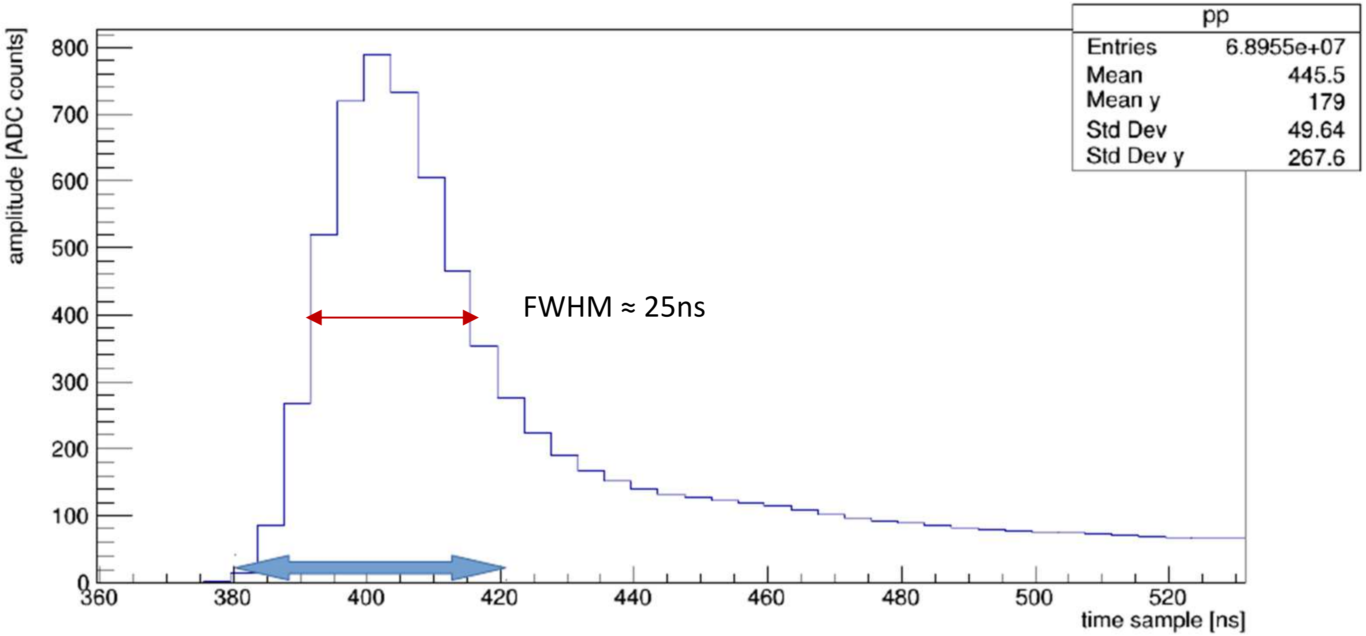


Averaged events on 1684 ch0 (1200V , G= 1.1x10^6) PMT Trigger

Total charge on the 18us : 9600 PE

Typical waveform without drift field

Zoom over fast component



Averaged events on 1618 ch0 (1200V , G= 1.1x10^6) PMT Trigger

Maximum amplitude 788 ADC counts (~315 SPE)
Total charge on fast component (380 to 420ns): 1070 SPE