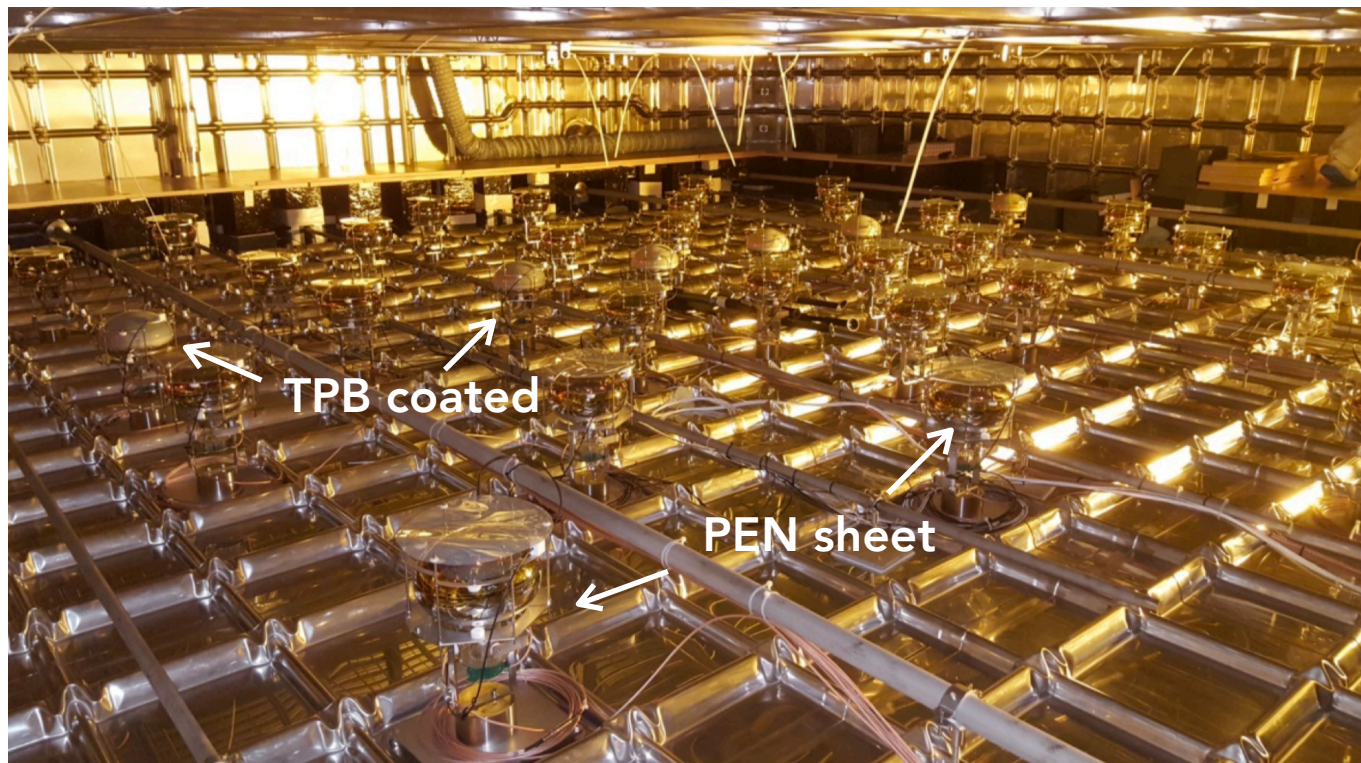
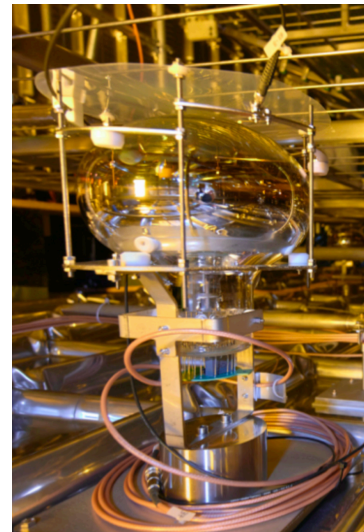


Status of the PDS in ProtoDUNE Dual Phase and Light Data Analysis

J. Soto and A. Gallego on behalf of CIEMAT & IFAE teams

DPPD Consortium Meeting
September, 10th 2019

Photon Detection System (PDS)

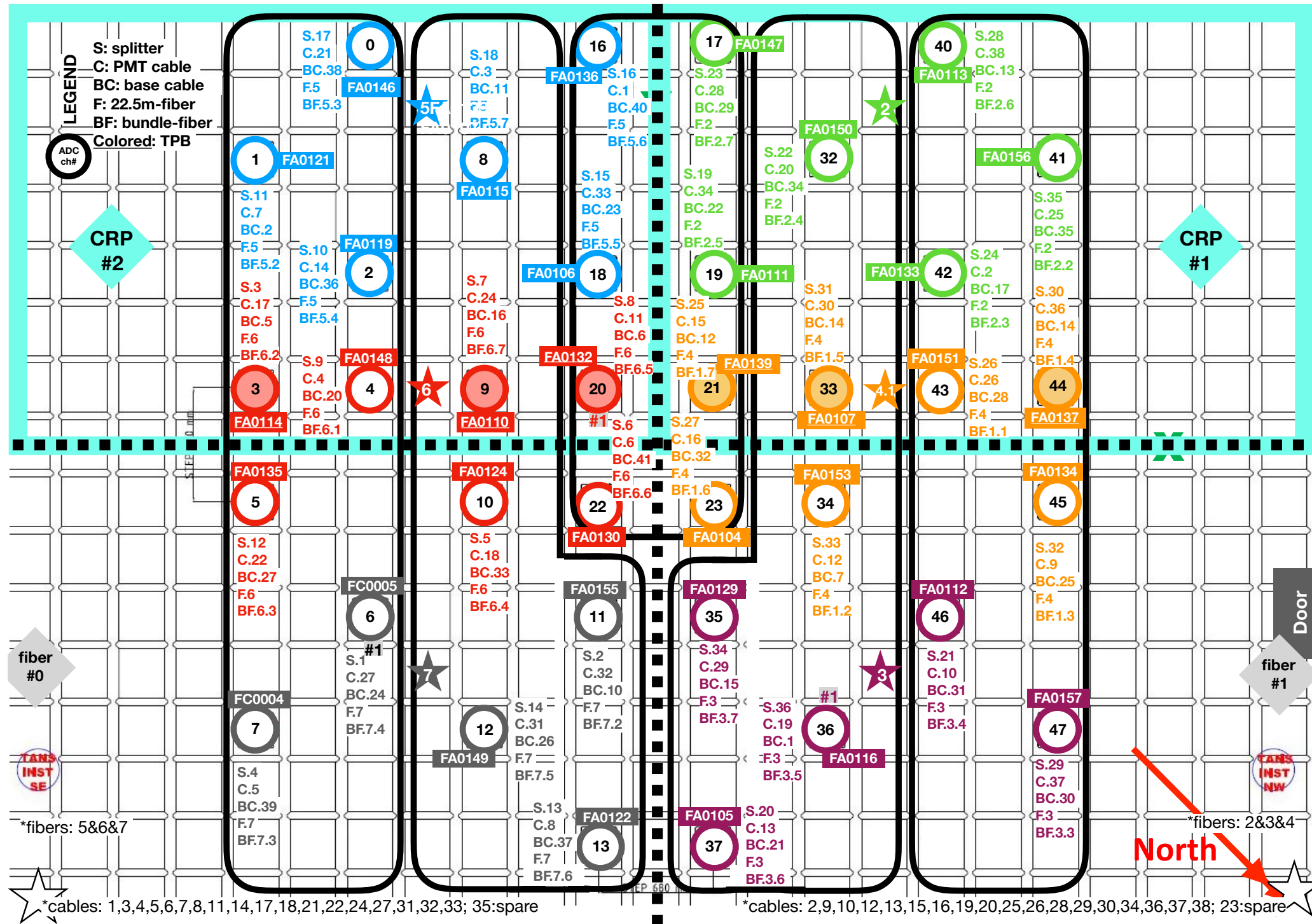


- ▶ **36 8" cryogenic PMTs**
(Hamamatsu R5912-MOD20)
fully characterized [JINST 13 \(2018\) T10006](#)
- ▶ **Wavelength-shifter: PEN / TPB coating on PMT**
- ▶ Voltage divider base + single HV-signal cable + splitter (external)
- ▶ **Light calibration system: LED & fiber based** [JINST 14 \(2019\) T04001](#)
- ▶ **DAQ system** (external)

PDS layout

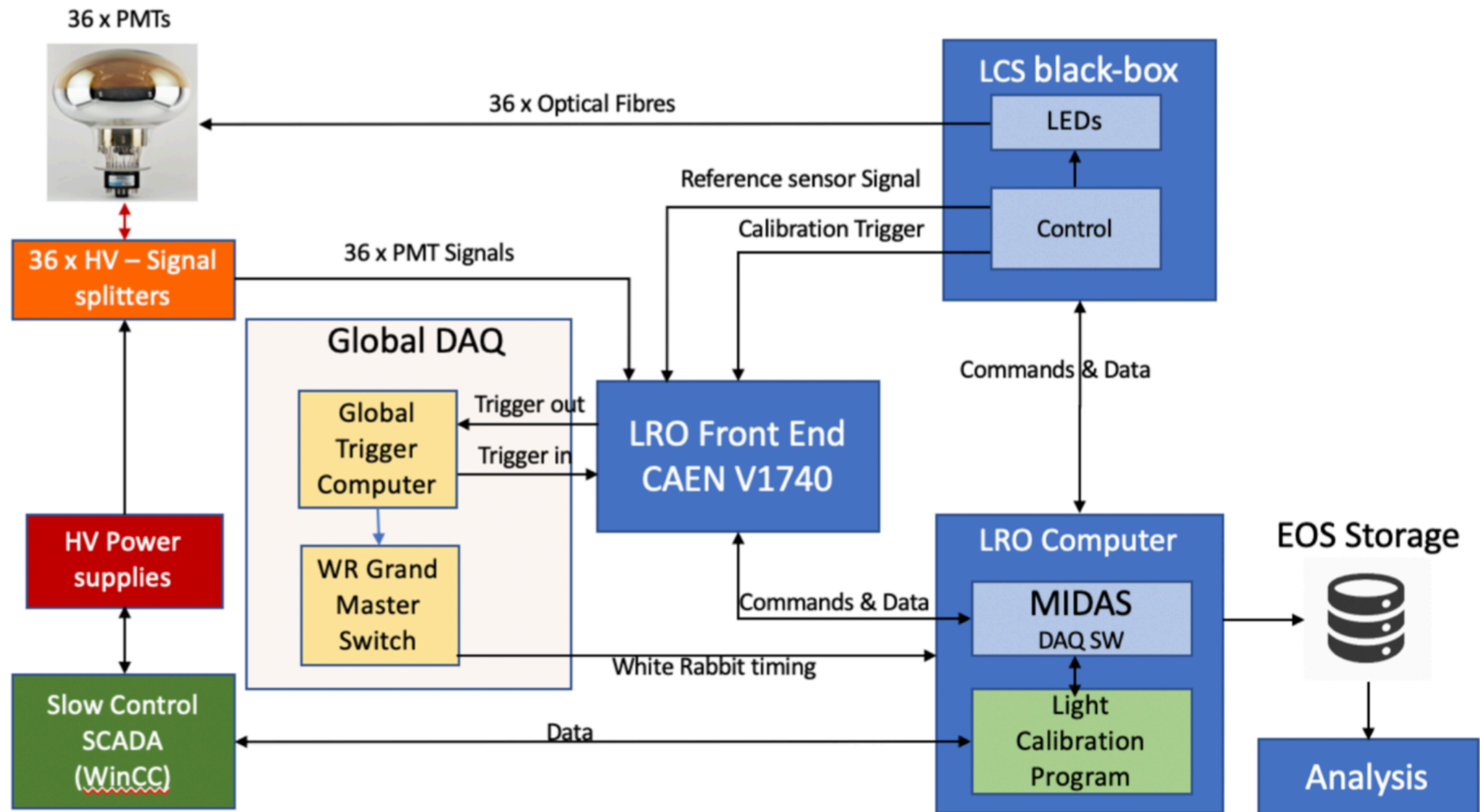
- ▶ 6x TPB coated PMTs
- ▶ 30x PEN sheet PMTs

- ▶ 5x trigger groups (preliminary)



Light DAQ

- ▶ LRO computer runs MIDAS SW as interface for control and data readout from v1740 ADC



Light DAQ

HV splitters



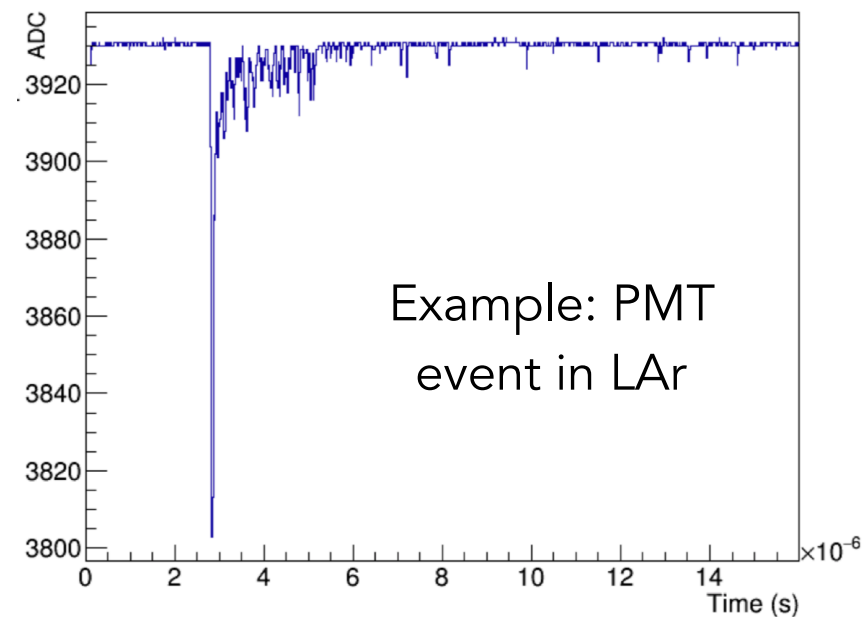
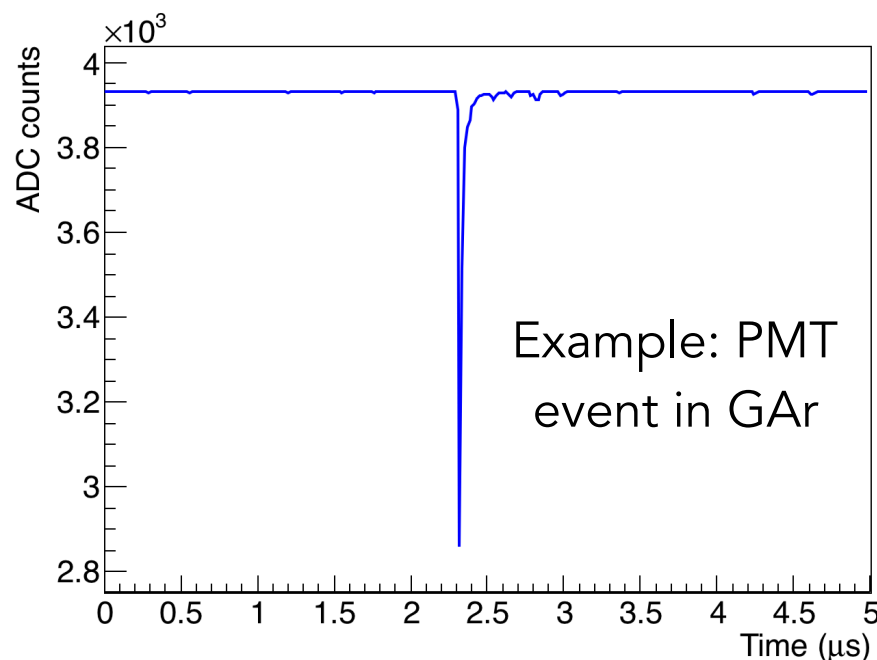
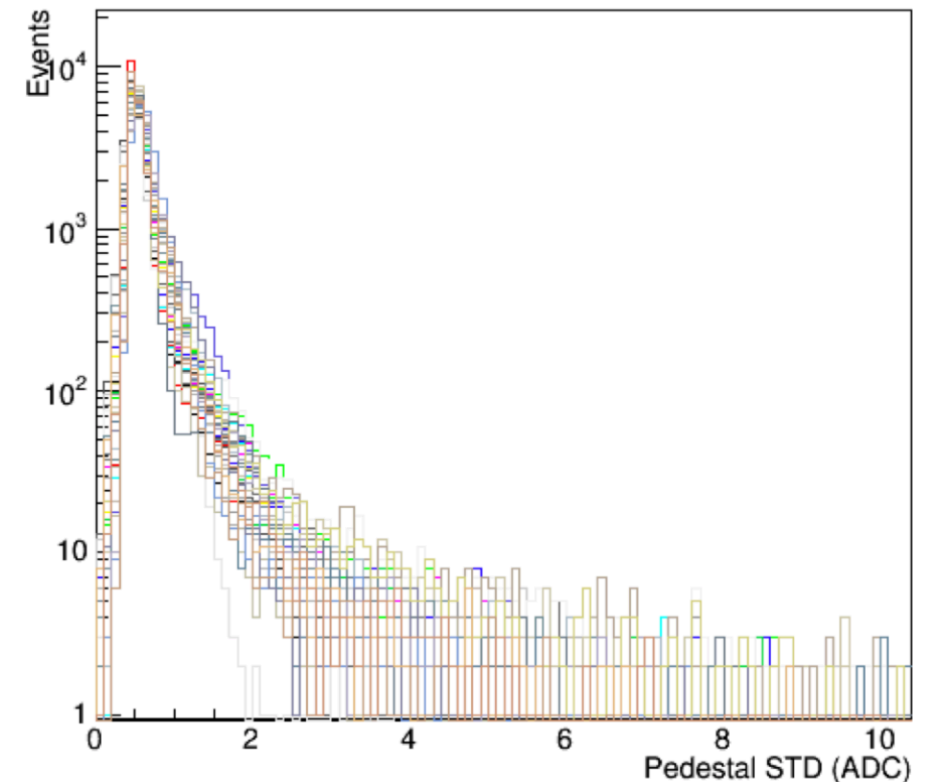
Power supply and ADC



- ✓ PMT calibration
- ✓ Acquisition with random trigger
- ✓ Acquisition with PMT trigger (coincidence of selectable PMTs signals over a threshold)
- ✓ Communication with the slow control for controlling the power supply
- Integration with global DAQ trigger & timing: to be done **this week!**

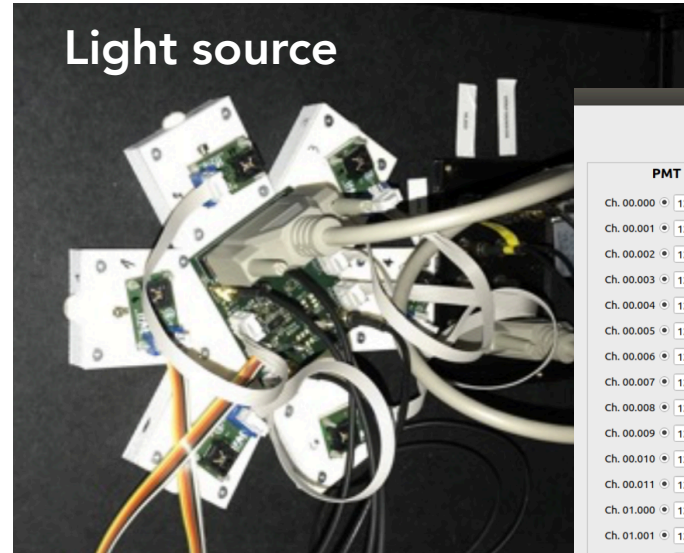
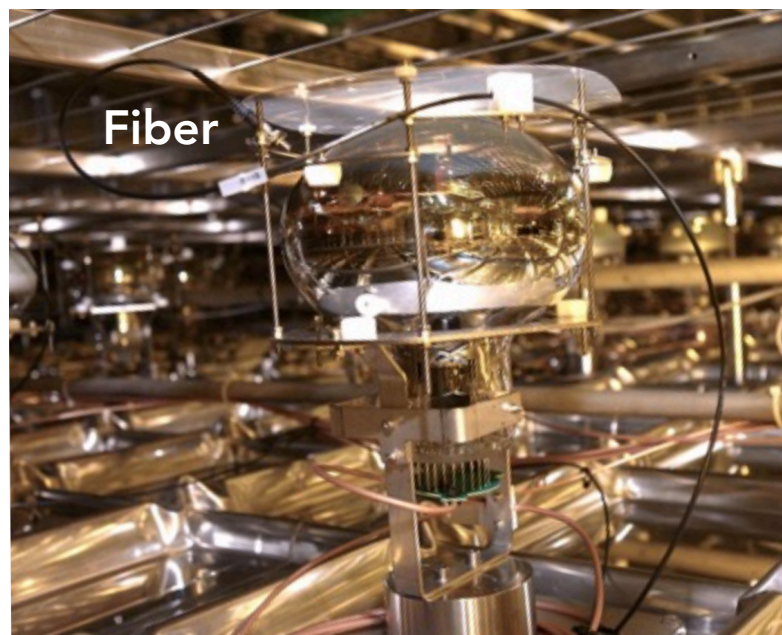
Light data taking

- ▶ Data taken:
 - **GAr**: last week of June - first week of July
 - **LAr filling**: July 5 - August 9
 - **LAr full volume**: August 9 - present - ...
- ▶ PMTs covered by LAr since July 8
- ▶ All PMTs are operative
- ▶ Low noise: <1 ADC count pedestal STD

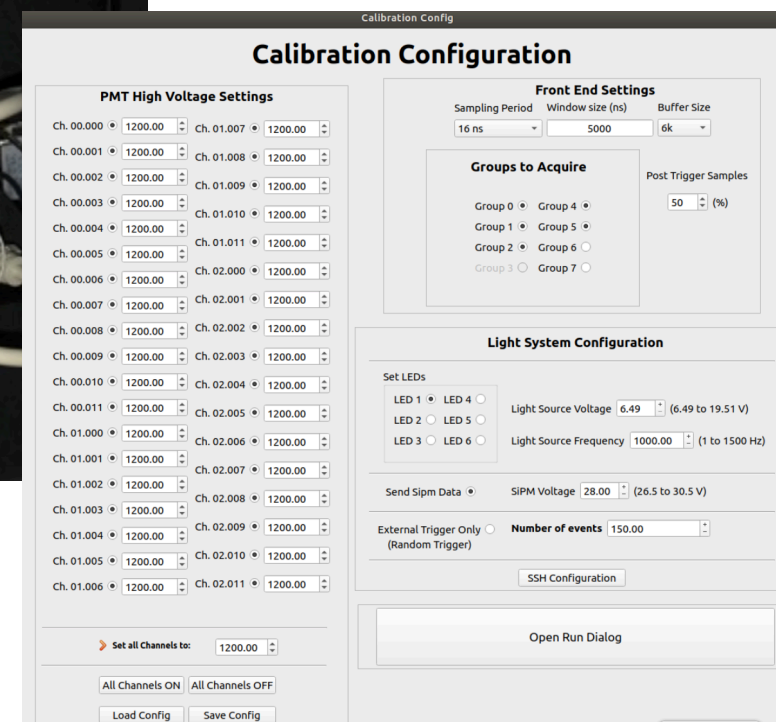


Light Calibration System (LCS)

- ▶ LED & fiber based [JINST 14 \(2019\) T04001](#)
- ▶ Calibration hardware and software running
- ▶ The system provides:
 - light to 6 PMTs at the same time
 - diffuse light from the top of the detector (alternative LCS)



Program for light calibration



LCS: gain monitoring

Complete calibration runs (G vs HV)

- ▶ **GAr (RT):**
 - 2017-2018 {CIEMAT}
 - 2019/06/26 [oscilloscope]: $G/G_{CIEMAT} \approx 1.2 \pm 0.3$
- ▶ **LAr (CT):**
 - 2017-2018 {CIEMAT}
 - 2019/07/17 [v1720]
 - 2019/07/30 [v1740]
 - 2019/09/03 [v1740]

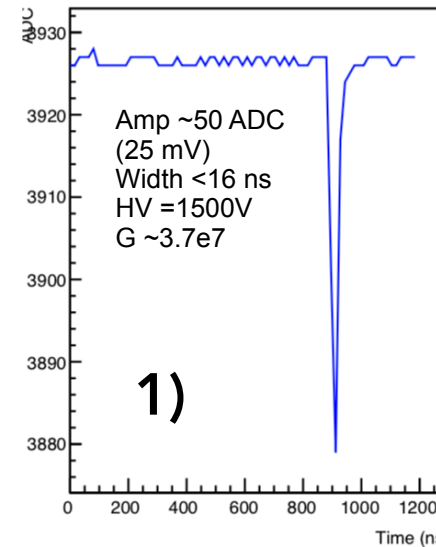
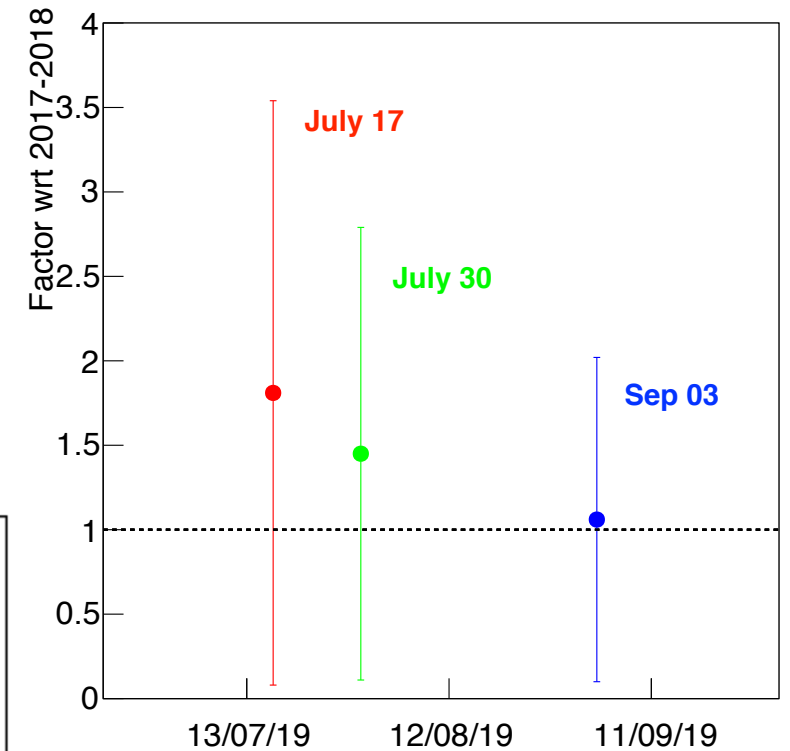
Gain stability (target gain: $1e7$)

- ▶ **GAr (RT):**
 - 2019/06/27, run9: $G/G_{CIEMAT} \approx 1.0 \pm 0.2$,
 - 2019/06/27, run14: $G/G_{CIEMAT} \approx 0.9 \pm 0.1$
- ▶ **LAr (CT):**
 - 2019/07/25 [v1740] (analysis ongoing)

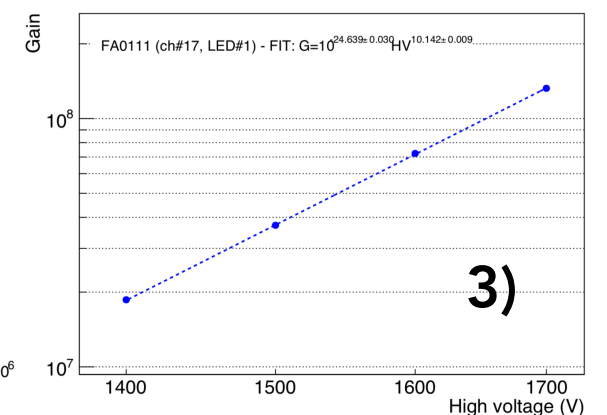
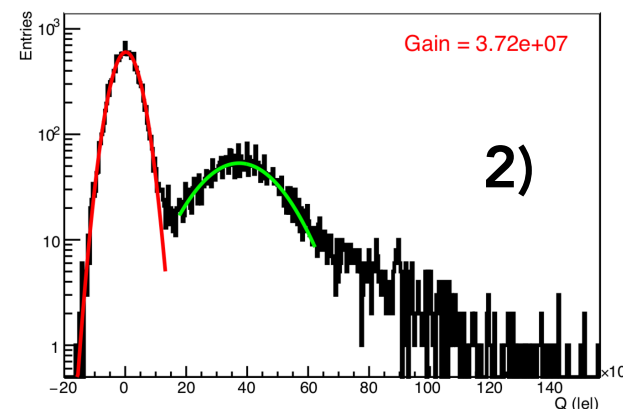
Alternative LCS

- ▶ 2019/08/02: top fibers (analysis ongoing)
- ▶ To do: complete calibration

G/G_{CIEMAT} (for HV_{CIEMAT}[1e7])



- 1) Waveform integration
- 2) Fit SPE spectrum (2 gaussians)
- 3) Gain vs HV curve

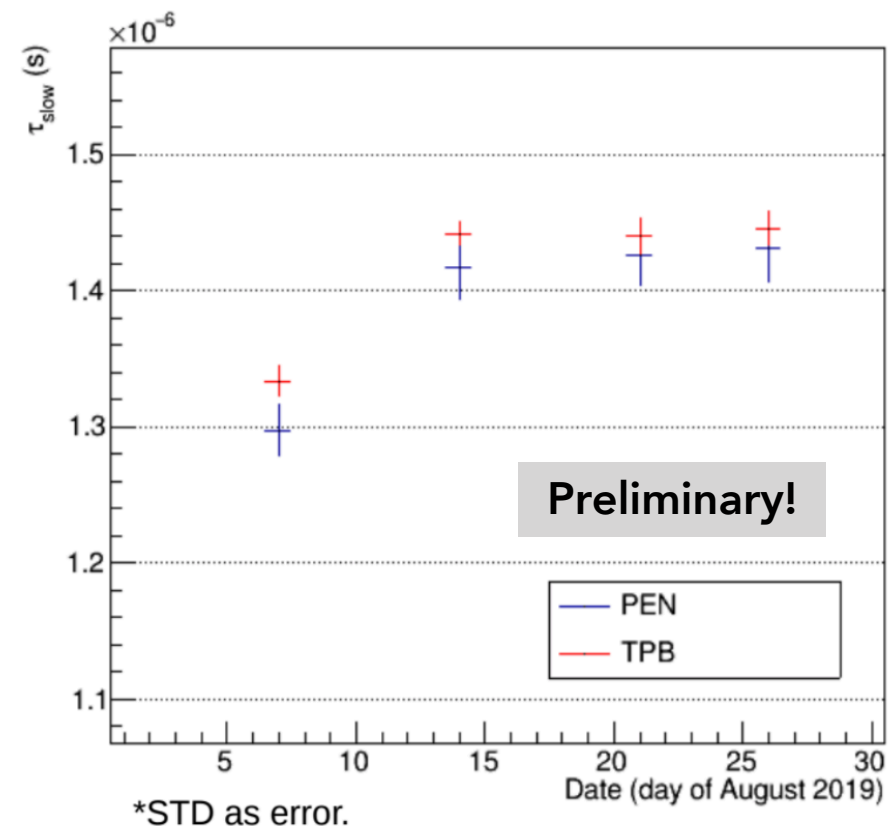
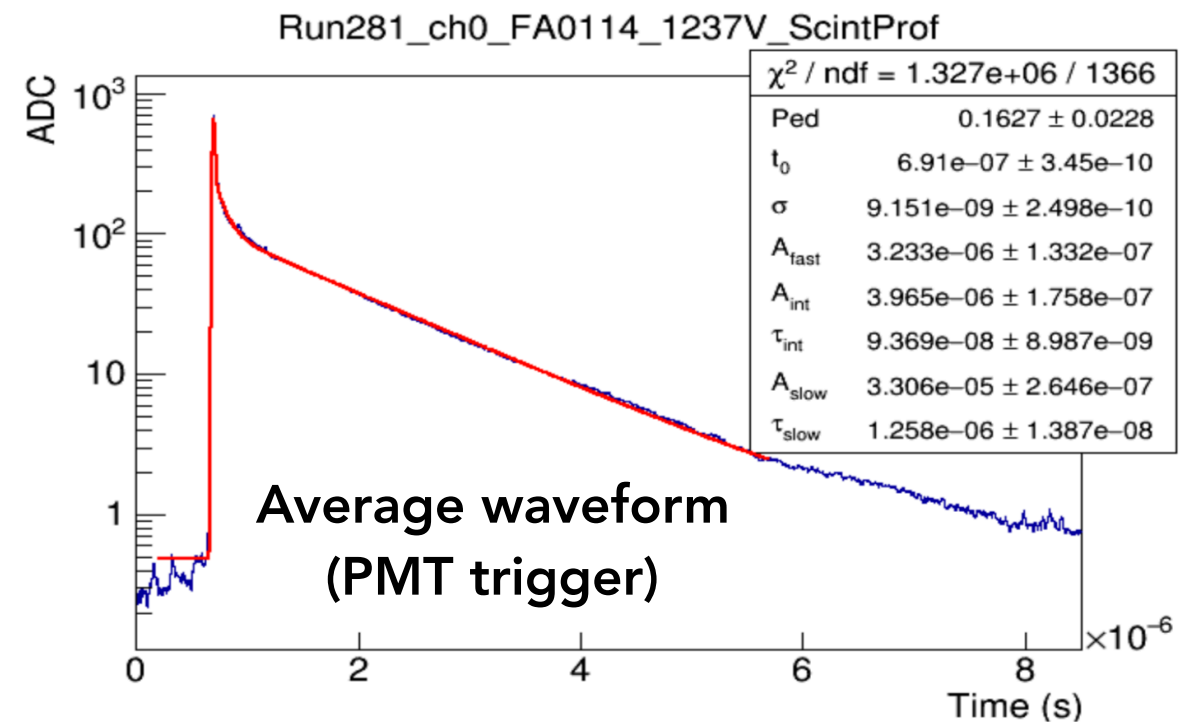


Light data - Purity

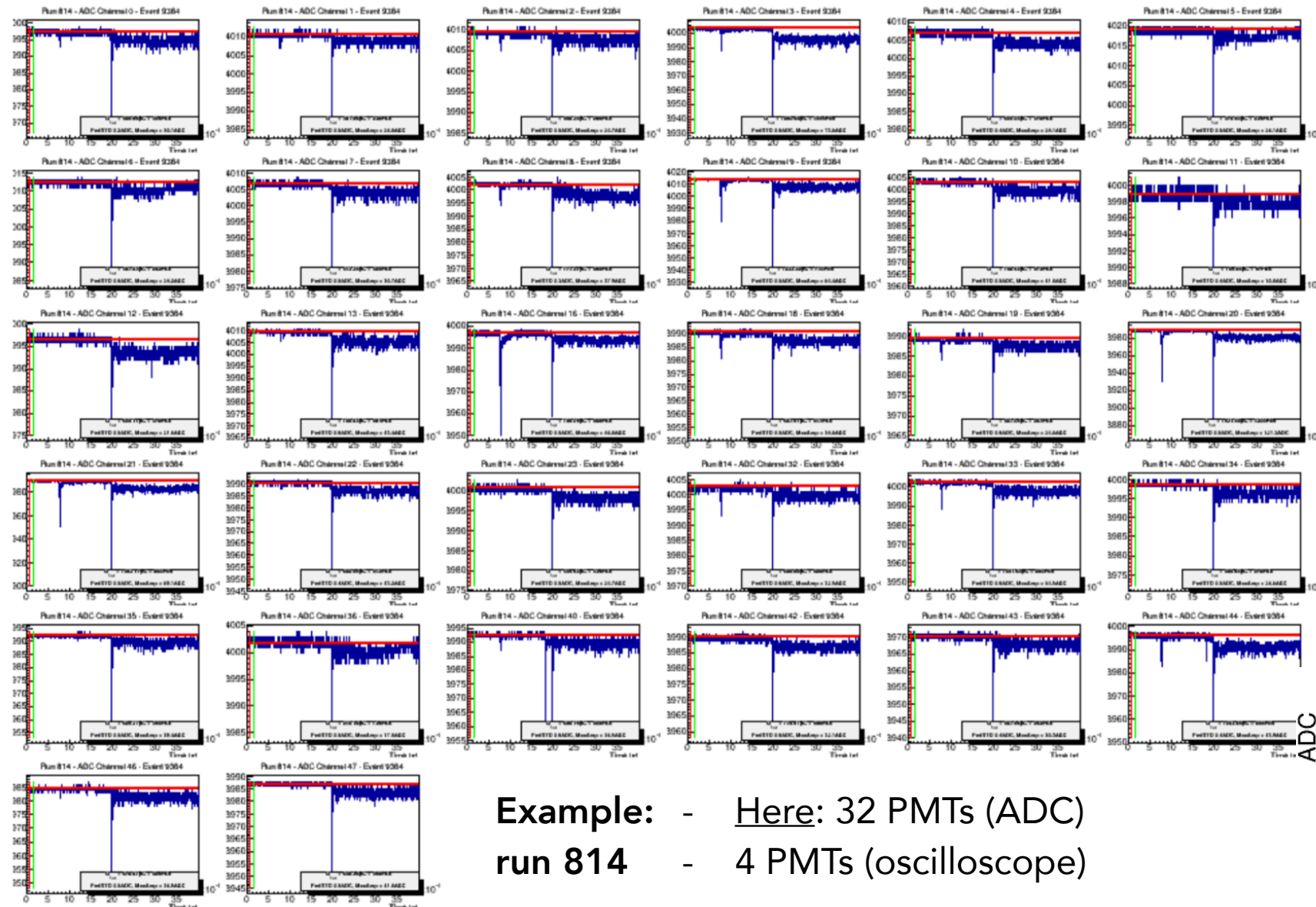
- ▶ **Goal:** τ_{slow} evolution in time
- ▶ **Event selection:**
 - cut 1: pedestal STD (88% of events)
 - cut 2: saturation (almost no saturation)
 - cut 3: threshold (2-4% of events)
- ▶ **Fit:**

$$f(t) = \sum_i \left(Ped + \frac{A_i}{2\tau_i} e^{\frac{\sigma^2}{2\tau_i} - \frac{(t-t_0)}{\tau_i}} \left(1 - \text{Erf} \left(\frac{\sigma^2 - \tau_i(t-t_0)}{\sqrt{2}\sigma\tau_i} \right) \right) \right)$$

$$I(y) = \frac{1}{2} e^{-\lambda(y - \frac{\sigma^2\lambda}{2})} \left[1 + \text{erf} \left(\frac{(y - \sigma^2\lambda)}{\sqrt{2}\sigma} \right) \right]$$



Light data - First S1+S2 signals



Example: - Here: 32 PMTs (ADC)
run 814 - 4 PMTs (oscilloscope)

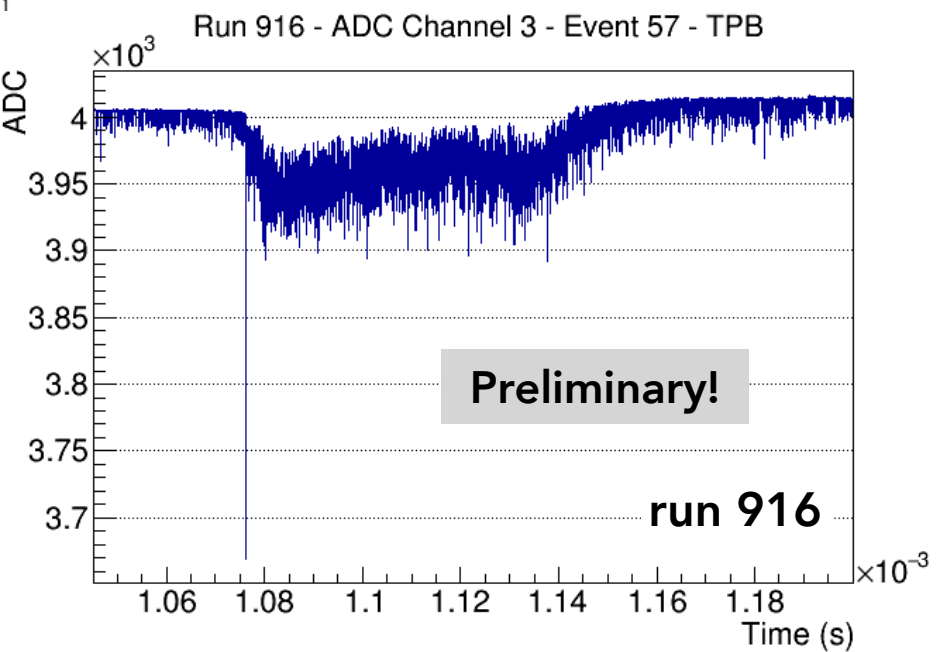
Data under different detector conditions:

- ▶ drift
- ▶ amplification
- ▶ extraction

Detector conditions of the examples:

#814: cathode 50 kV, grid 5 kV, LEMs 2.9 kV across

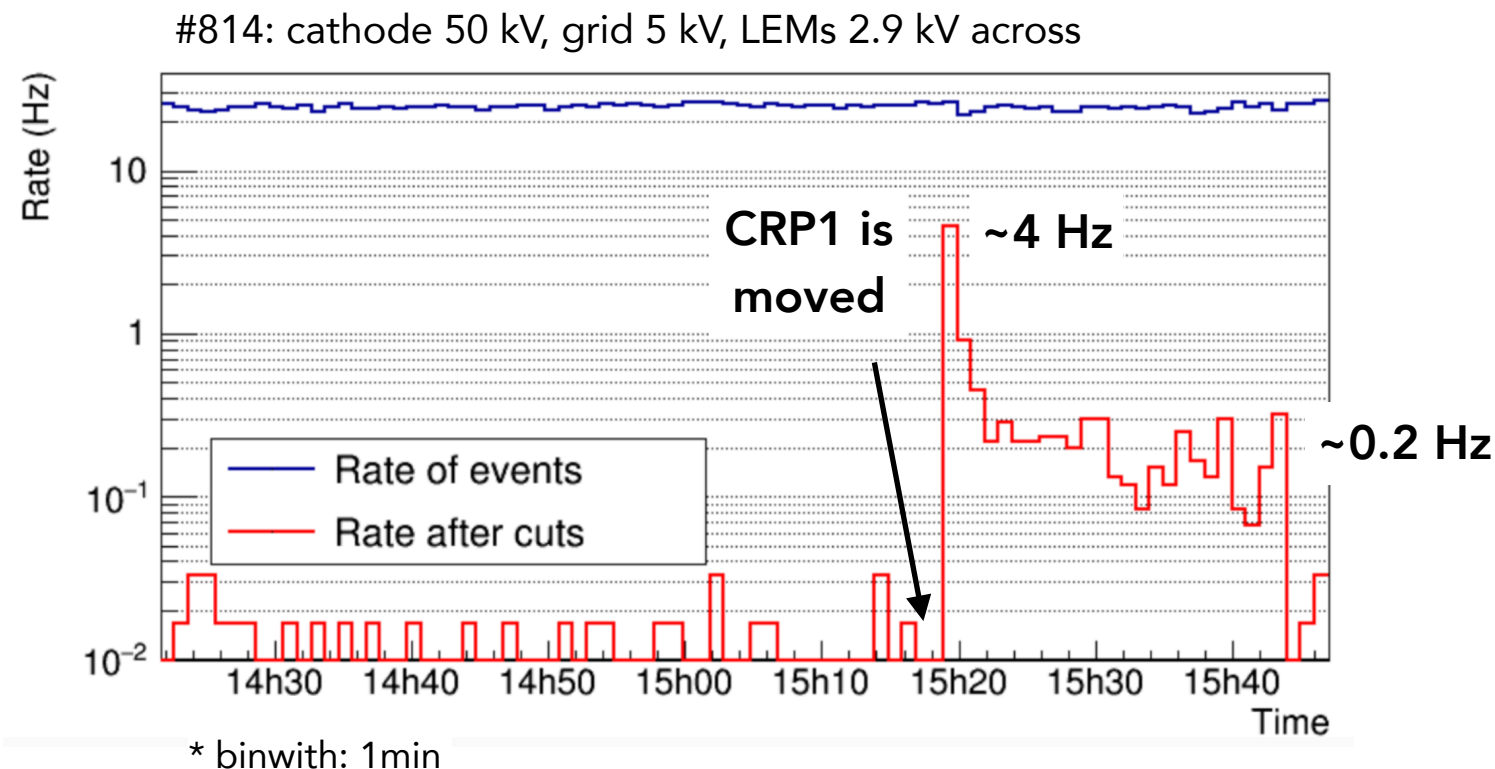
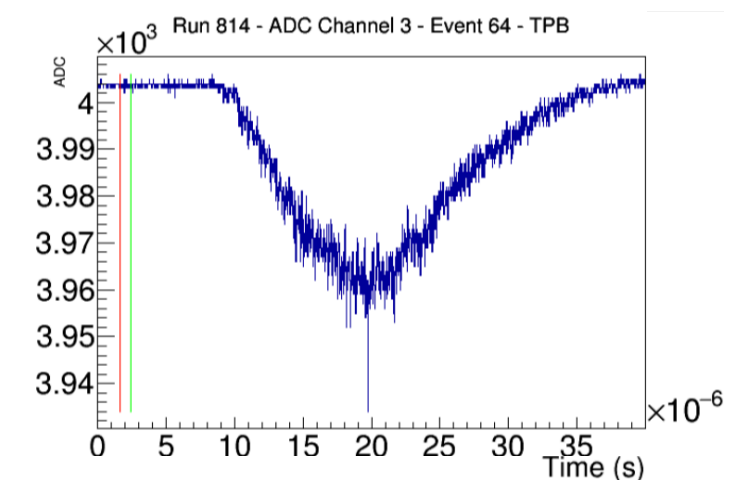
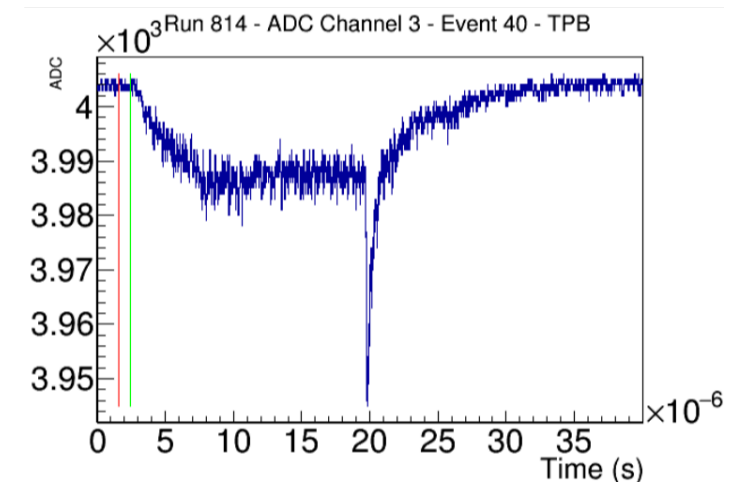
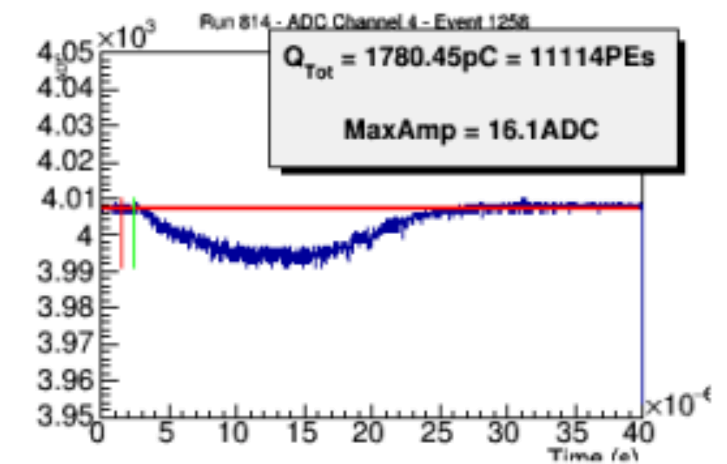
#916: cathode 50 kV, grid 5 kV, LEMs 2 kV across



Light data - "Strange" signals

Preliminary! More analysis is ongoing

- ▶ CRP1, LEMs: ON
- ▶ Strange light events appeared for the first time when CRP1 was moved (run 814): sparks?
- ▶ Strange signals have been seen under different detector conditions: **to be understood!**
- ▶ PDS is helping to monitor these events and find the origin



Summary & next steps

- ▶ The **commissioning** of the PDS of ProtoDUNE Dual Phase is **progressing well**
- ▶ The 36 PMTs are operative and have been already **calibrated several times**
- ▶ **Different measurements** (PMT trigger, random trigger) have been taken: **data available** in `/eos/experiment/neutplatform/protodune/rawdata/np02/PMT`
- ▶ **To-do list:**
 - Comparison PEN vs TPB
 - Trigger optimization: test different configurations and thresholds
 - Complete the analysis of the measurements taken so far (including new ones with drift field and LEMs)
 - Calibration with top fibers
 - Charge-light matched data
 - Charge data taking with light trigger