LIGHT DETECTION SYSTEM IN THE PROTODUNE DUAL PHASE DETECTOR

LAURA ZAMBELLI (LAPP - CNRS/IN2P3)

on behalf of the DUNE collaboration

LIDINE 2019 - August 29th 2019 - Manchester

Dual phase LArTPCs for DUNE

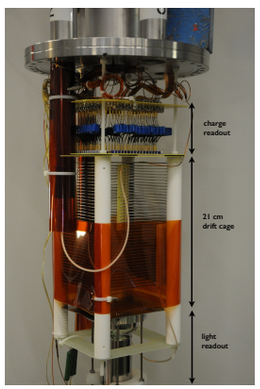
DUNE long baseline neutrino experiment foresees to measure neutrino mass hierarchy and the CP violation phase in the leptonic sector.

The DUNE far detector will consist of 4×10 kt of liquid argon TPC in single/dual phase technology.

Long R&D program to develop and optimize the liquid argon dual phase technology towards DUNE scale

R&D

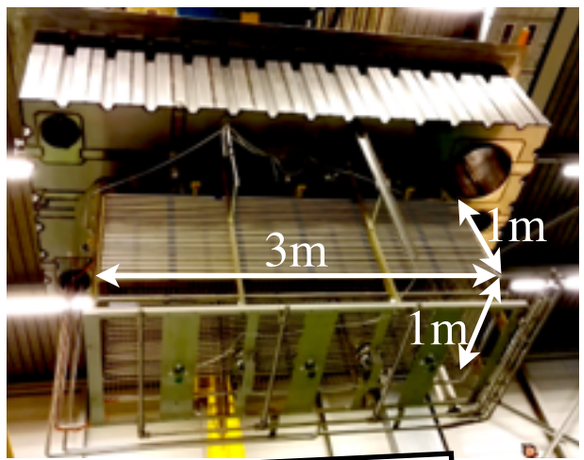
2010 ~ 2014



@CERN, KEK, …

Demonstrator

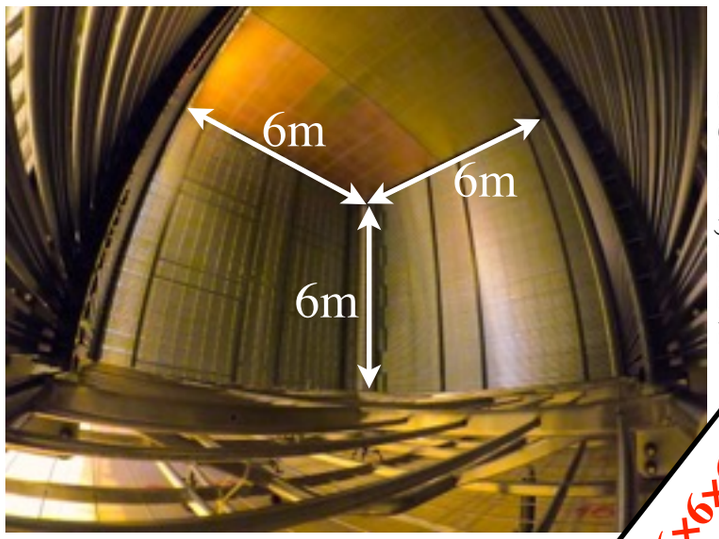
2014 ~ 2017



@CERN, Bld 182

Prototype

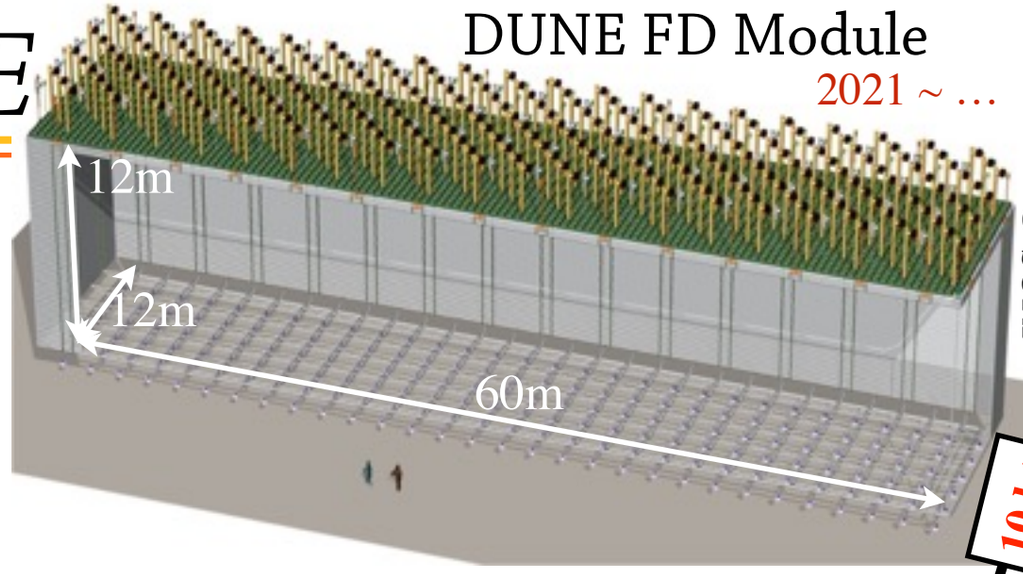
[protoDUNE-DP] 2016 ~ 2021



@CERN, EHN1

DUNE FD Module

2021 ~ …



@ SURF

3 ~ 250 L

3×1×1 m³

6×6×6 m³

10 kt

Today

DUNE IDR :

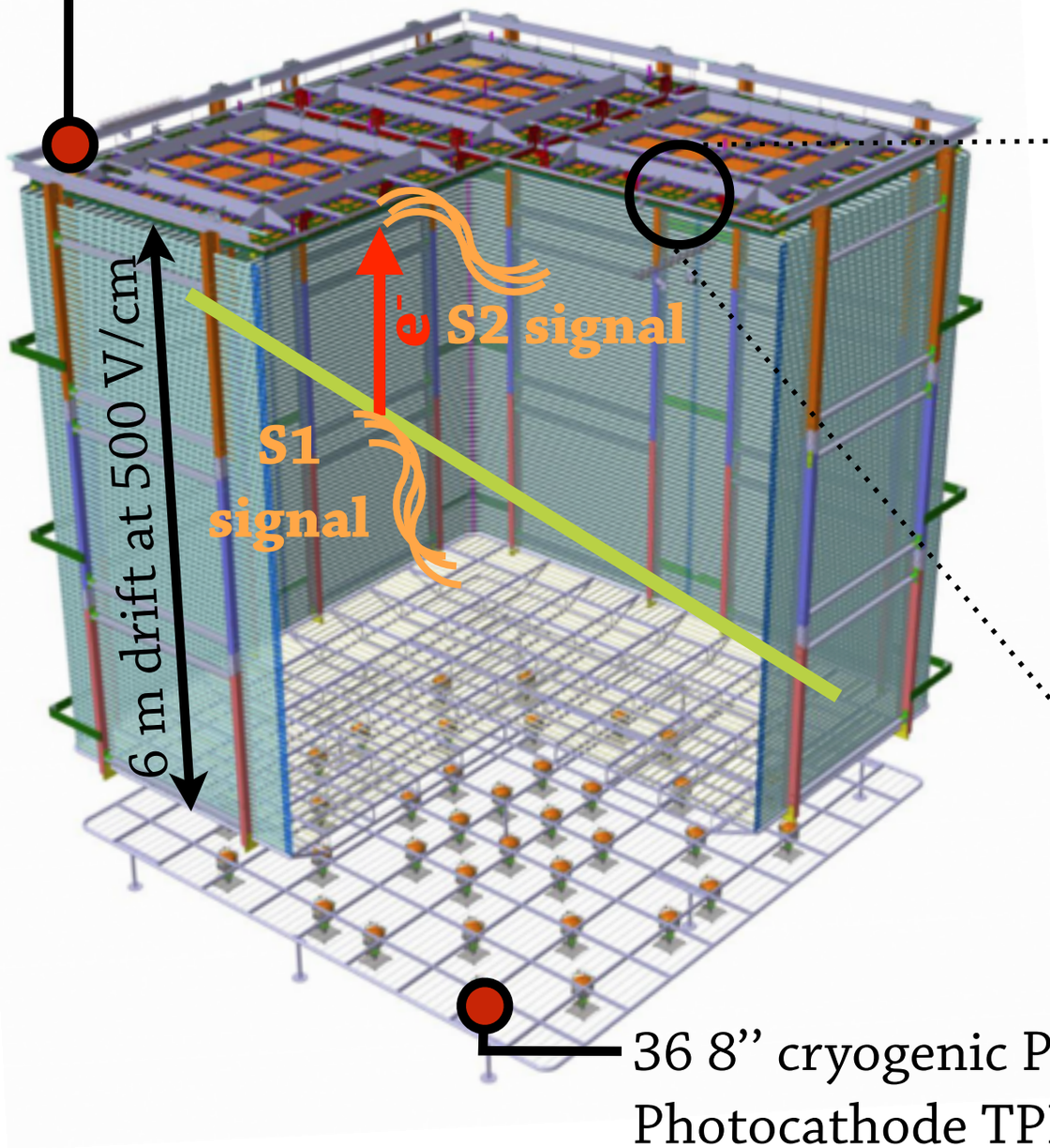
DUNE Physics - Vol. 1 [1807.10334]
DUNE SP Module - Vol. 2 [1807.10327]
DUNE DP Module - Vol. 3 [1807.10340]

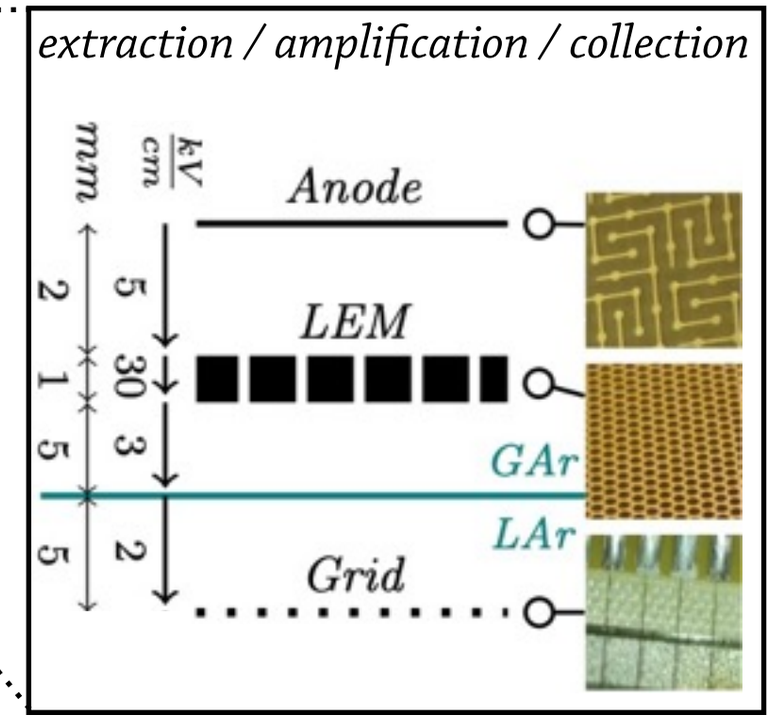
(DUNE TDR coming soon)

↳ C. Lastoria talk for more details

protoDUNE-DP initial design

6×6 m² fully instrumented area:
in 4 Charge Readout Plane (CRP) modules
144 LEM/Anode modules of 50×50 cm² each





36 8” cryogenic PMT
Photocathode TPB coated
Positive-biased readout
(single cable carrying HV + signal)

In the scope of DUNE :

- High resolution [mm³] 3D image
- High signal/noise ratio
- Low energy threshold

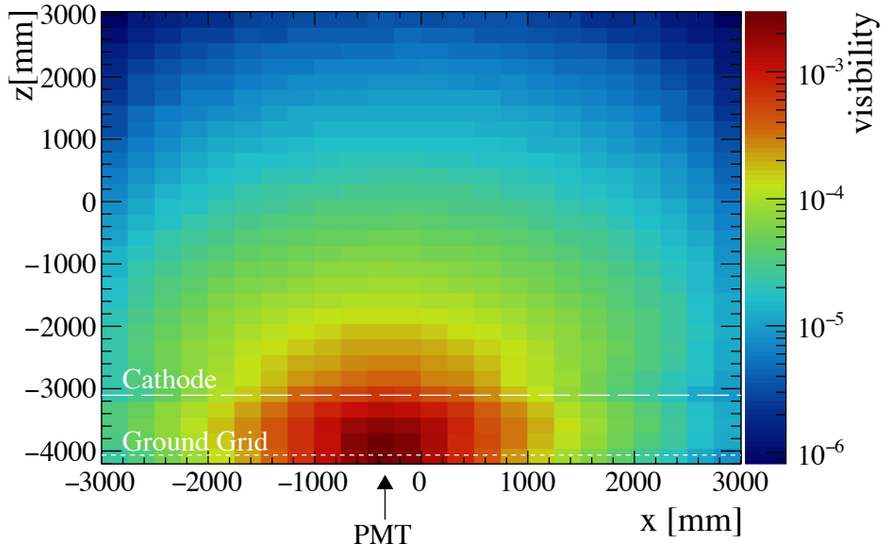
In the scope of DUNE :

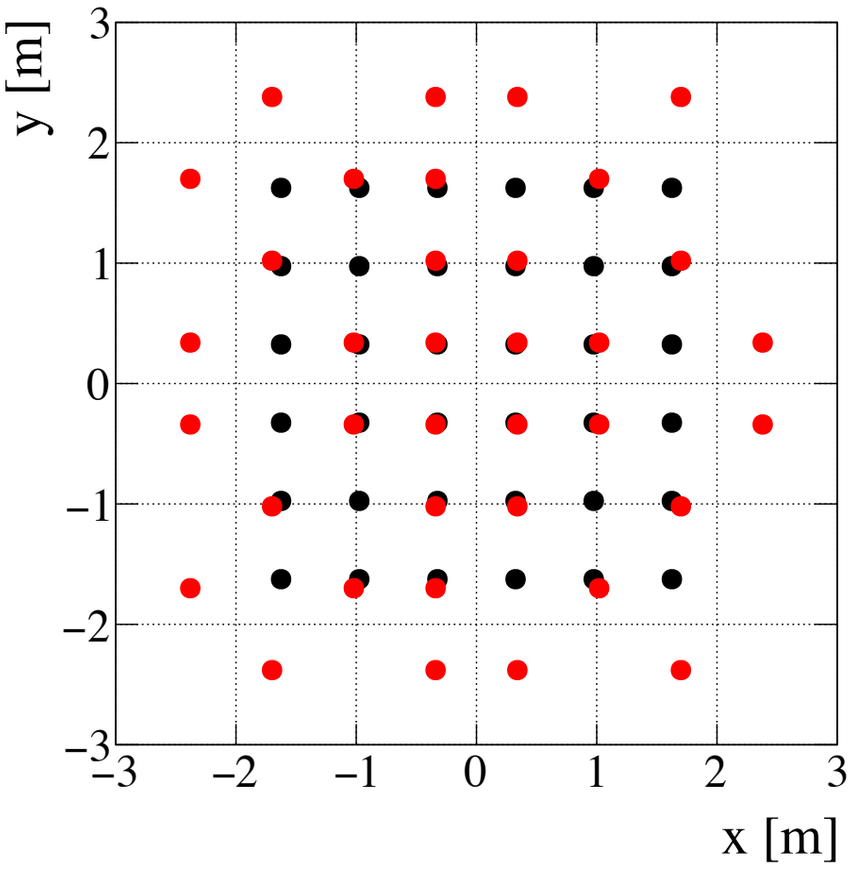
- Trigger for non-beam events
- t_0 for track reconstruction
- Calorimetry and PID

protoDUNE-DP light simulation and PMT layout

A dedicated geant4-based simulation of the light propagation was developed for protoDUNE-DP

- Production of a light map containing photon visibility and arrival time for each PMTs
- PMT layout could be optimized





The ***uniform*** layout is more efficient at collecting light produced in the center of the detector

→ Suited for calorimetry purposes

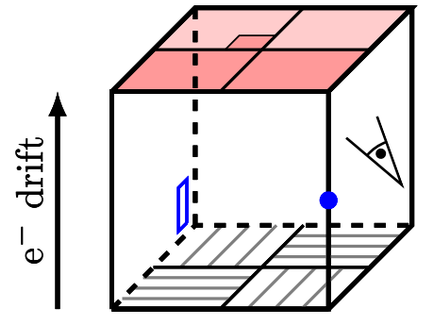
The ***non-uniform*** layout has a better coverage of the light produced on the side of the detector

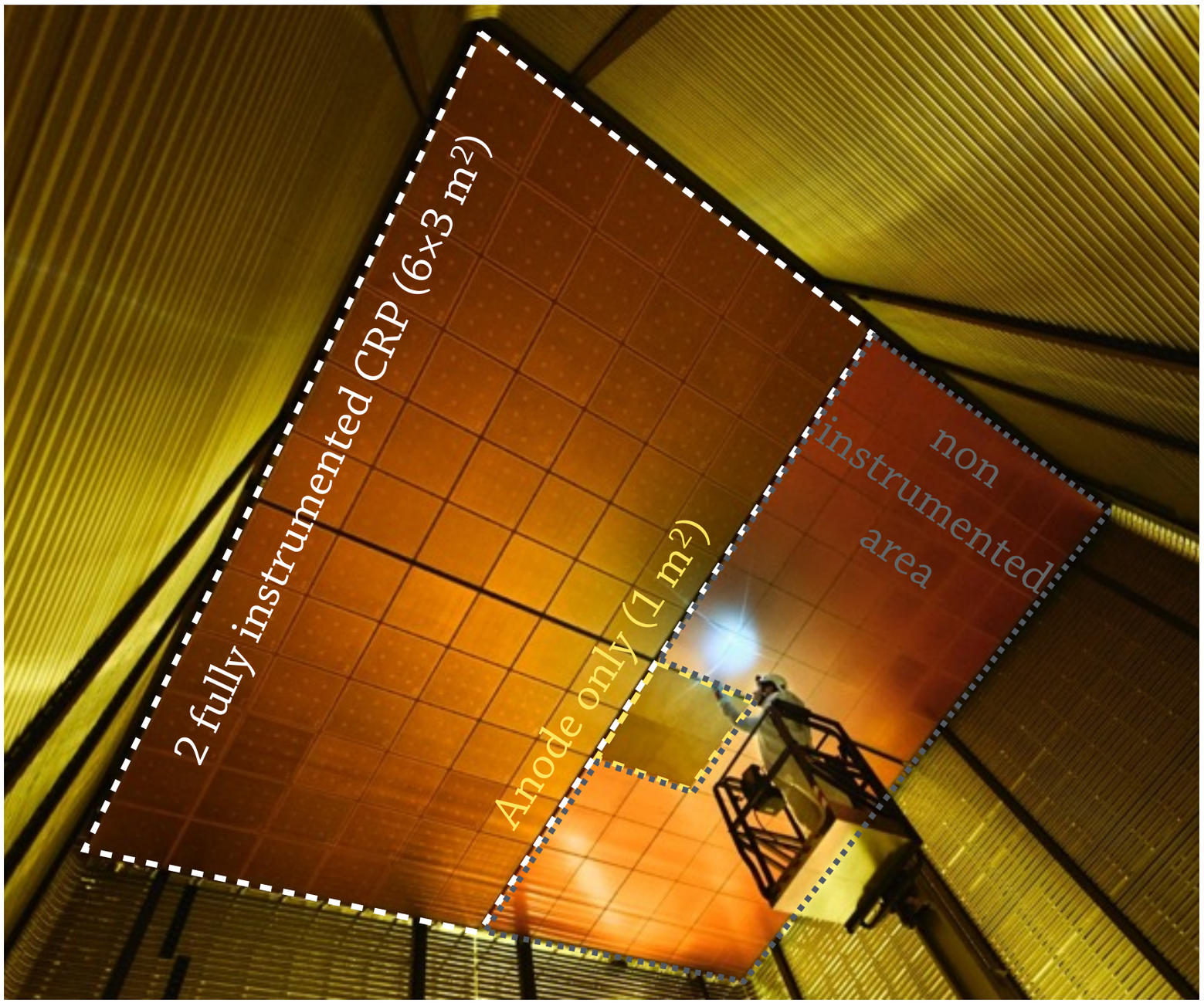
→ Suited for track t_0 tagging

As protoDUNE-DP is exposed to cosmic rays on surface, the non-uniform layout was chosen.

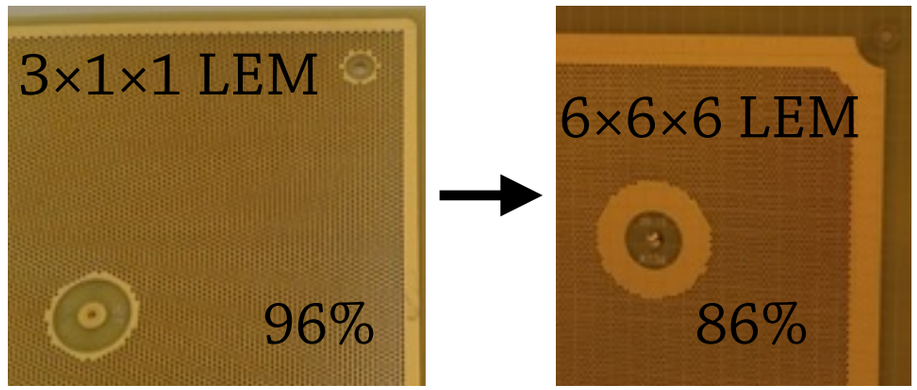
A. Chappuis PhD (2018) - Université Grenoble Alpes

protoDUNE-DP design changes (1/2)



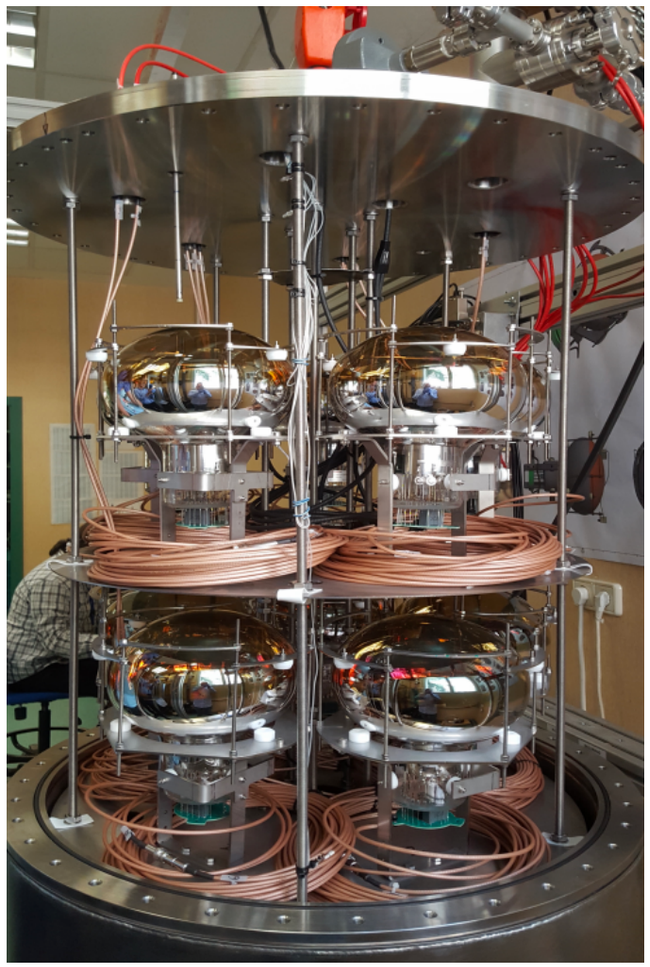


From the experience learned in the demonstrator, the LEM design had to be improved to reduce the sparking risks.



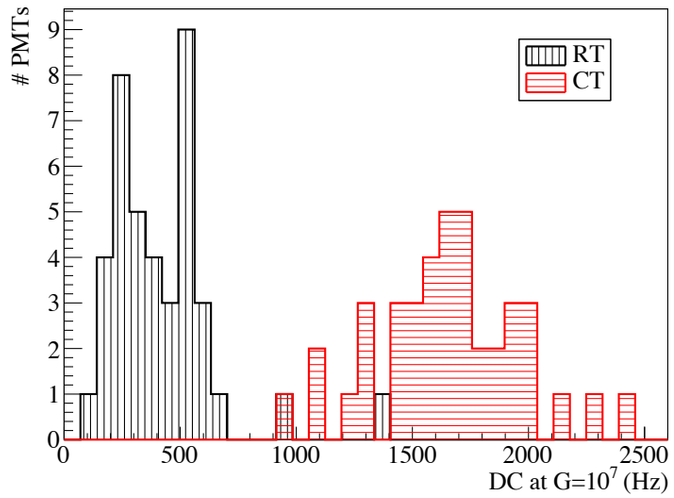
Due to time constraints, only 2 CRPs could be fully instrumented (72 LEM/Anode sandwich) + 4 spare anodes was installed (no amplification).

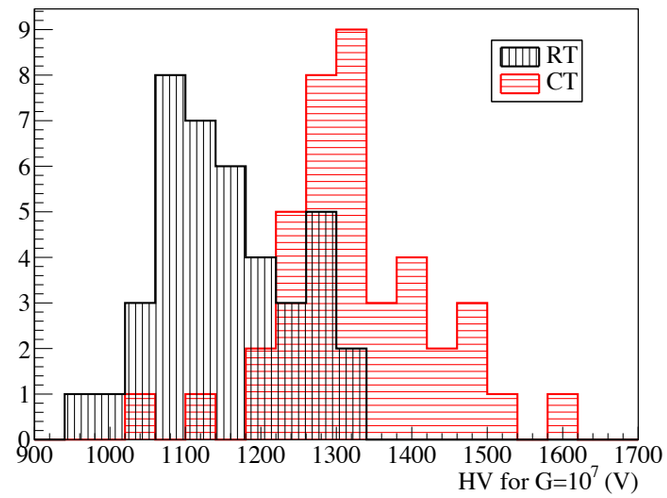
PMT preparation and installation



40 (36 + 4 spares) R5912-20MOD Hamamatsu PMTs were characterized at CIEMAT in a dedicated setup at room and cryogenic temperatures :

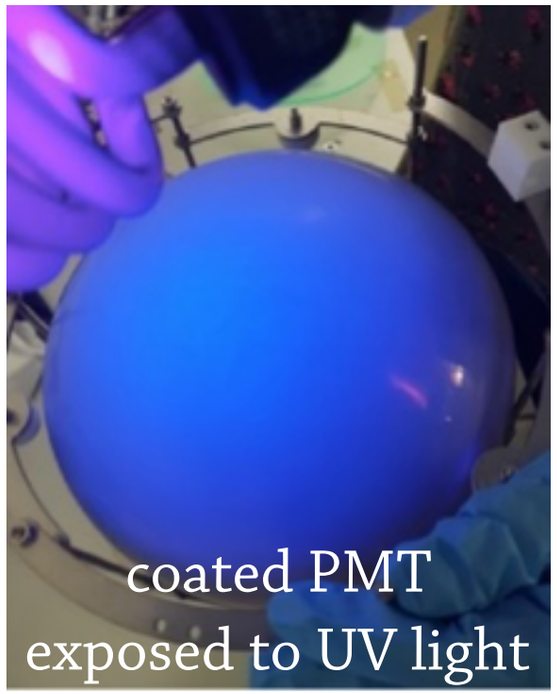
- Dark current, gain and PMT linearity measured





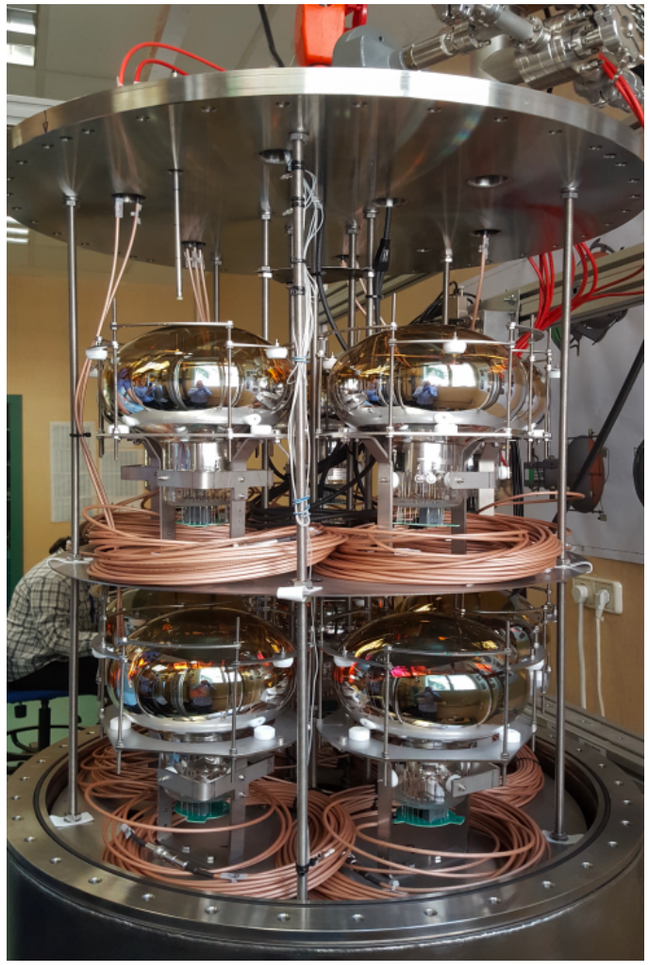
Dark Current and Gain evolution from **room** to **cryogenic** temperatures

All PMTs photocathode have been coated with TPB in summer 2018 and were safely stored since



More details in C. Cuesta talk at last LIDINE
and Belver et al. JINST 13 (2018) no.10, T10006

PMT preparation and installation



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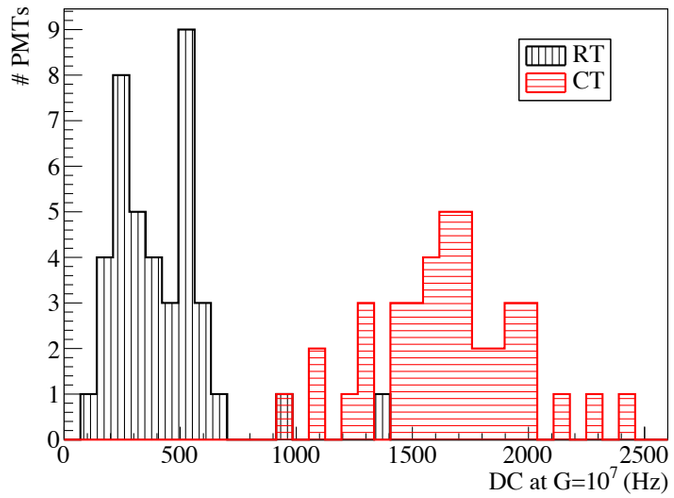
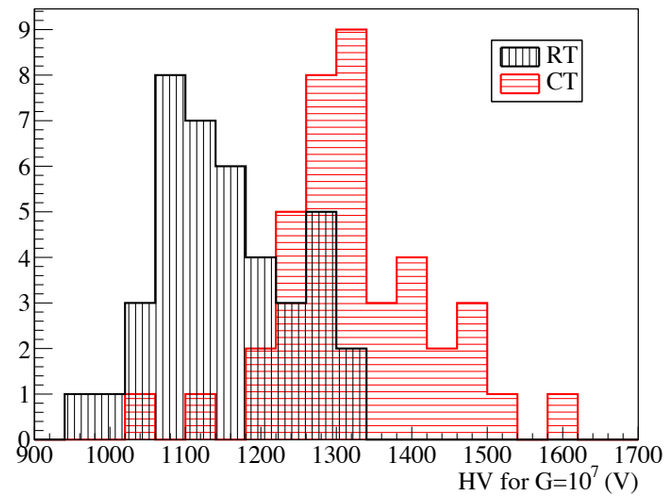
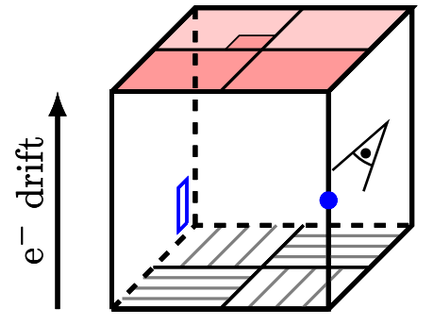




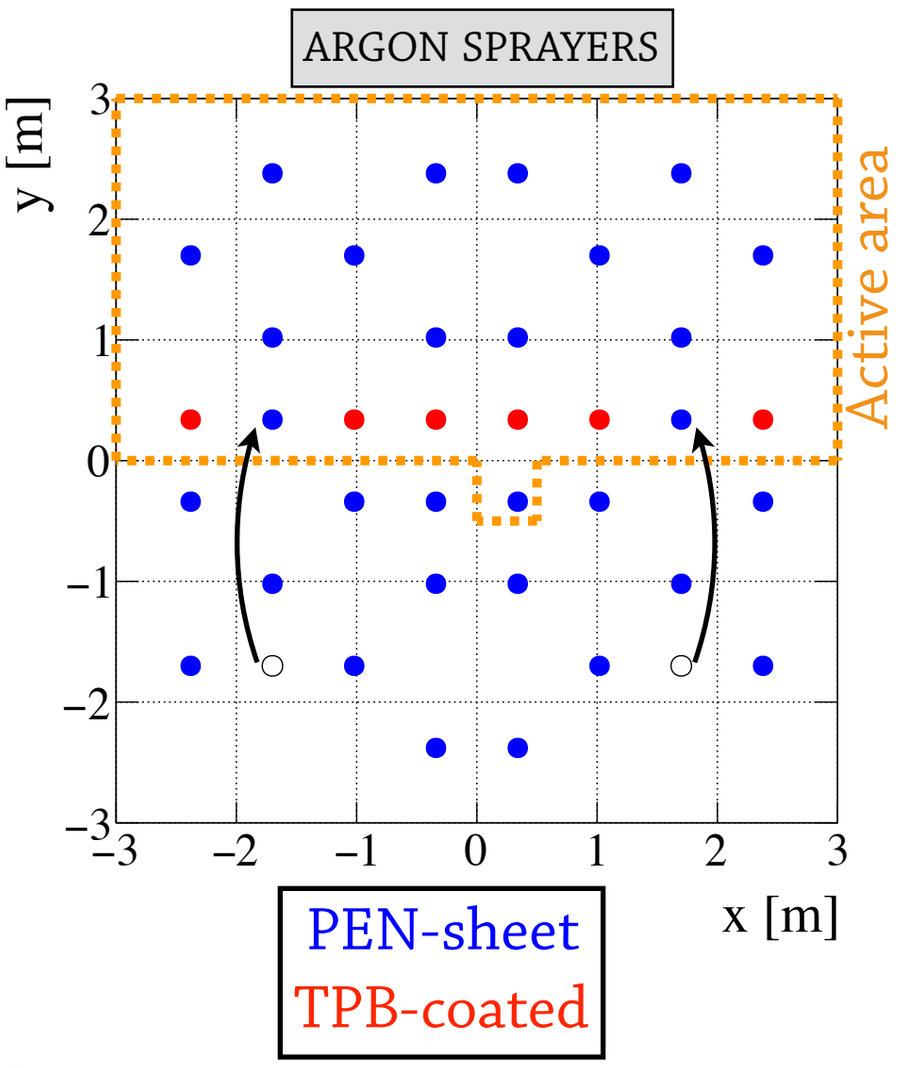
Dark Current and Gain evolution from **room** to **cryogenic** temperatures

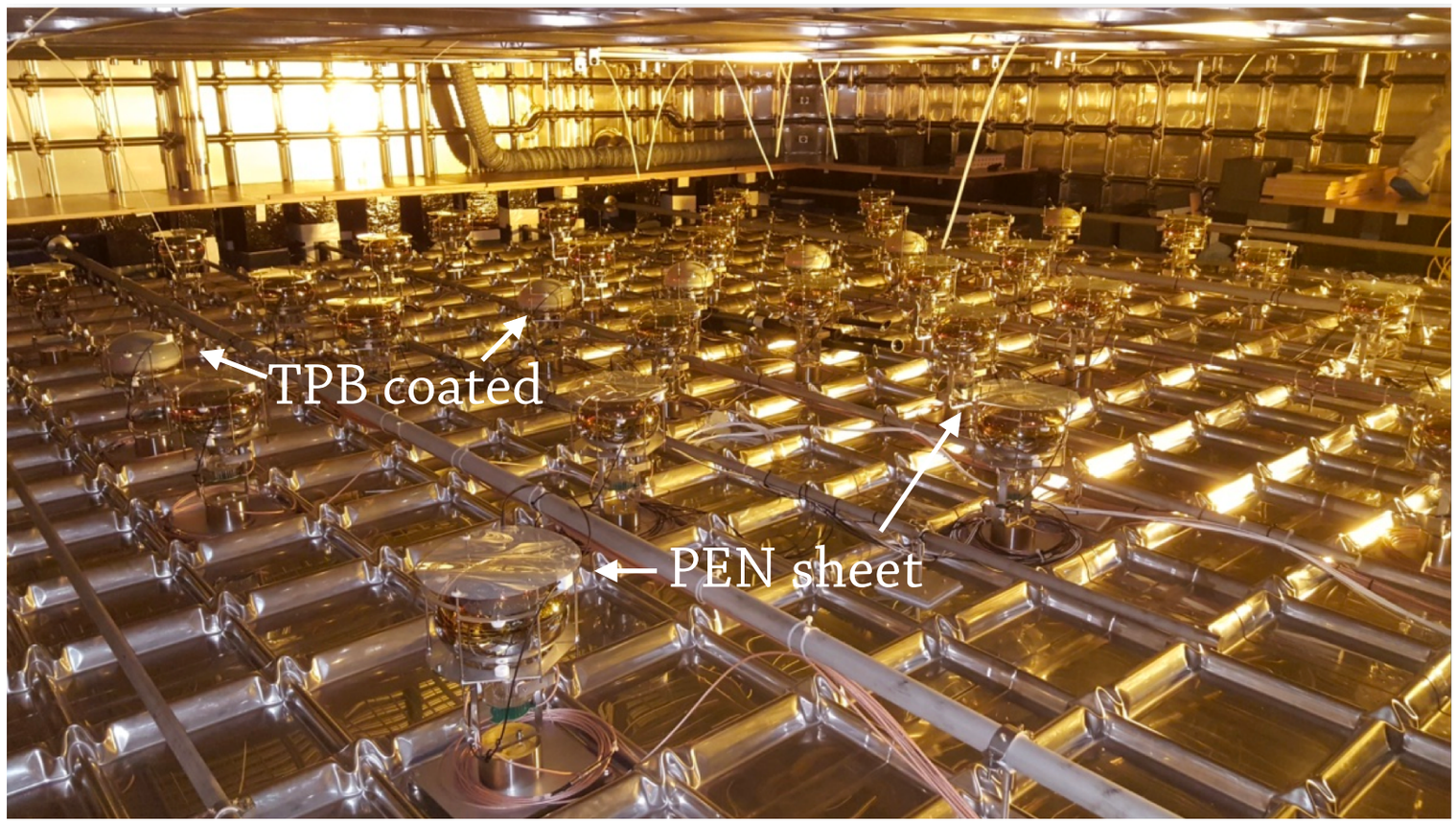
During the final test prior to PMT installation, we noticed that the TPB could be damaged by liquid argon droplet, as it could happen during cryostat cool down through argon sprayers

protoDUNE-DP design changes (2/2)

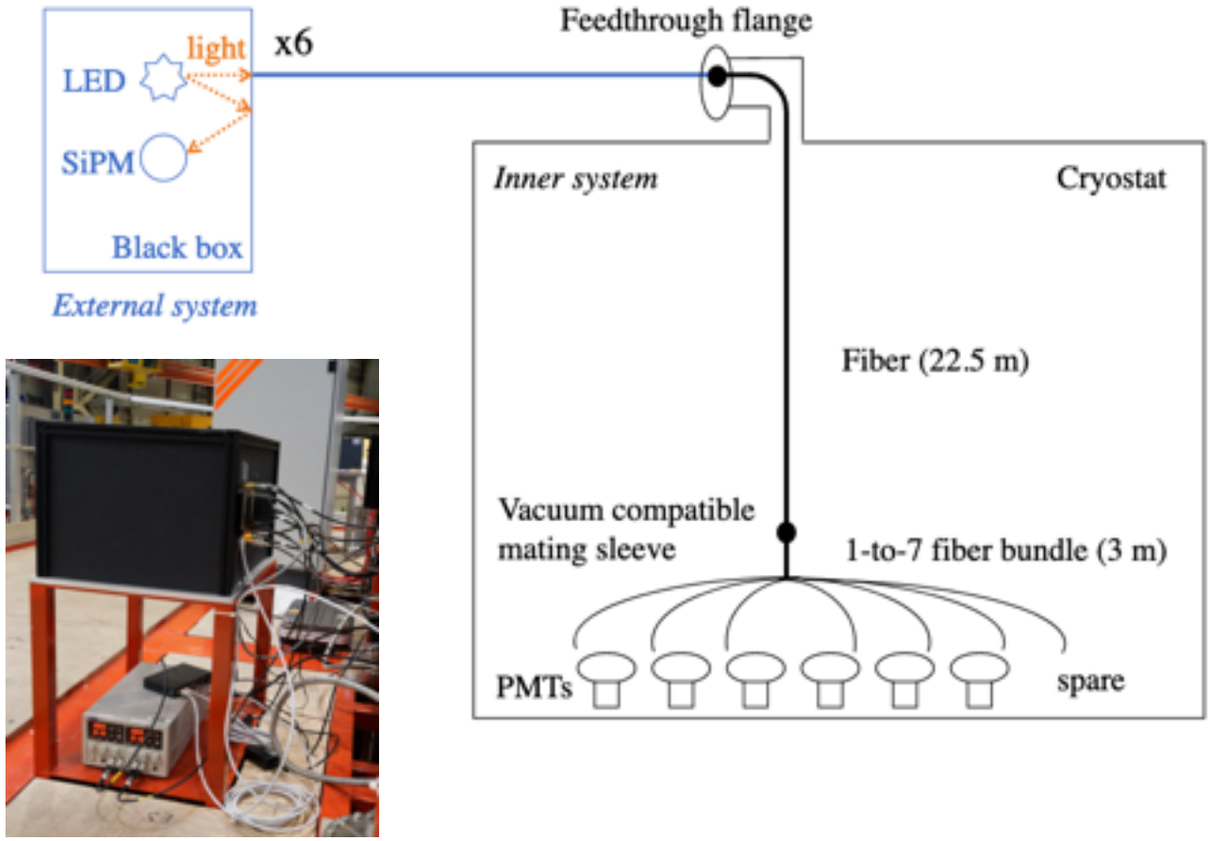


The instrumented area being too close to the argon sprayers, it has been decided to change the wavelength shifting method to a PEN sheet for 30 PMTs as a conservative option for protoDUNE-DP.
At the center of the detector, a line of 6 TPB-coated PMTs were kept, and 2 PEN-PMTs were moved to complete the line



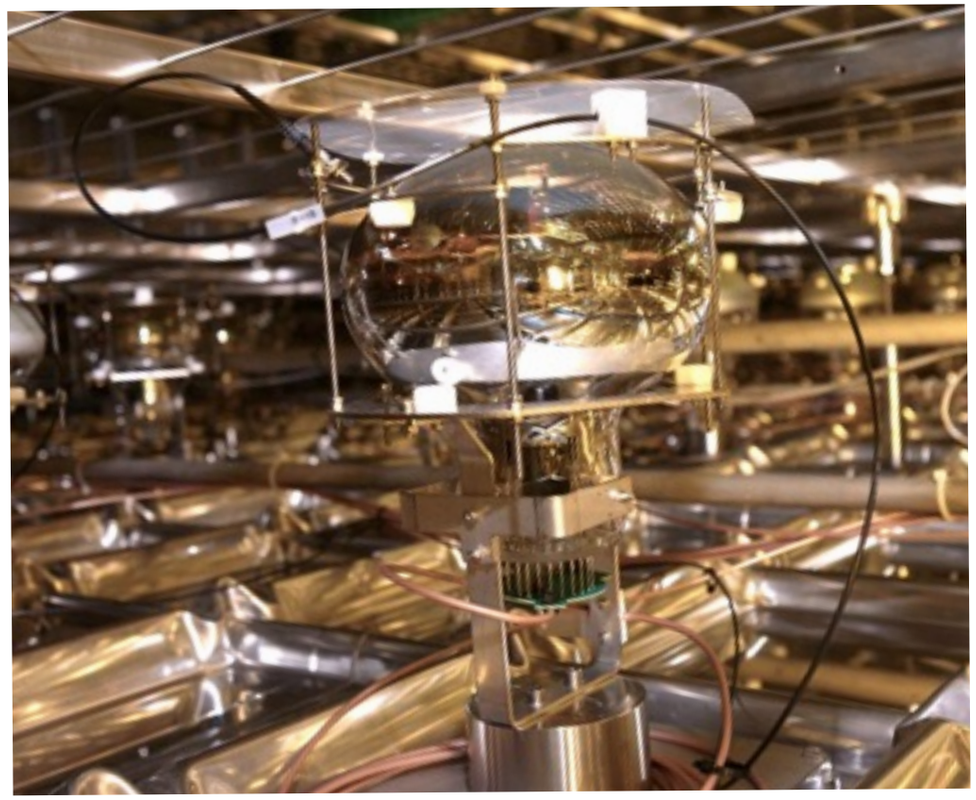


Light calibration system



Goals of the calibration system :

- PMT gain calibration curve
- PMT gain stability
- PMT quantum efficiency stability



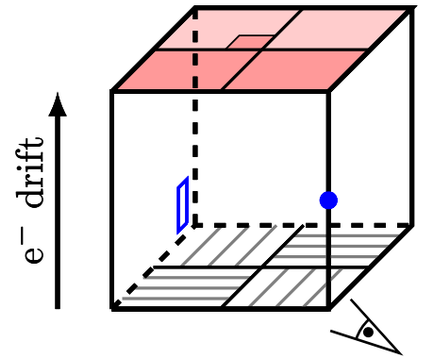
The system provides :

- calibrated amount of light to 6 PMTs simultaneously
- diffuse light from the top of the detector

More details in C. Cuesta talk at last LIDINE

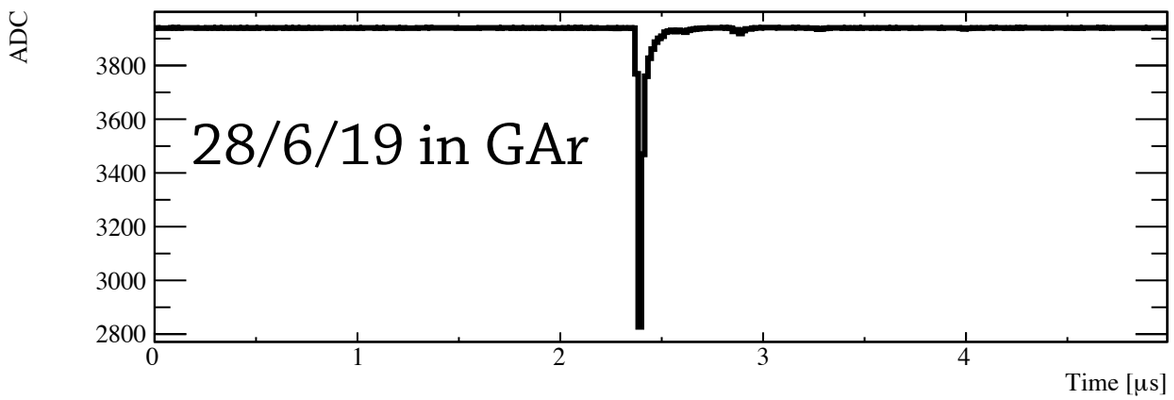
and Belver et al, JINST 14 (2019) no.04, T04001

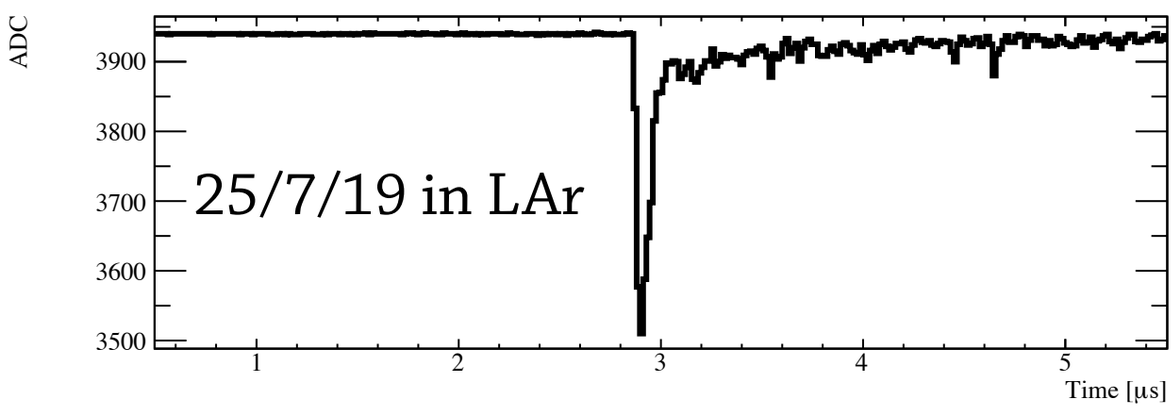
protoDUNE-DP LAr filling



- Filling started on July 4th
- Filling status could be monitored thanks to thermometers and cryo-cameras
- LAr reached its nominal level on August 9th
- HV commissioning started since
- PDS collected data since cooling down stages

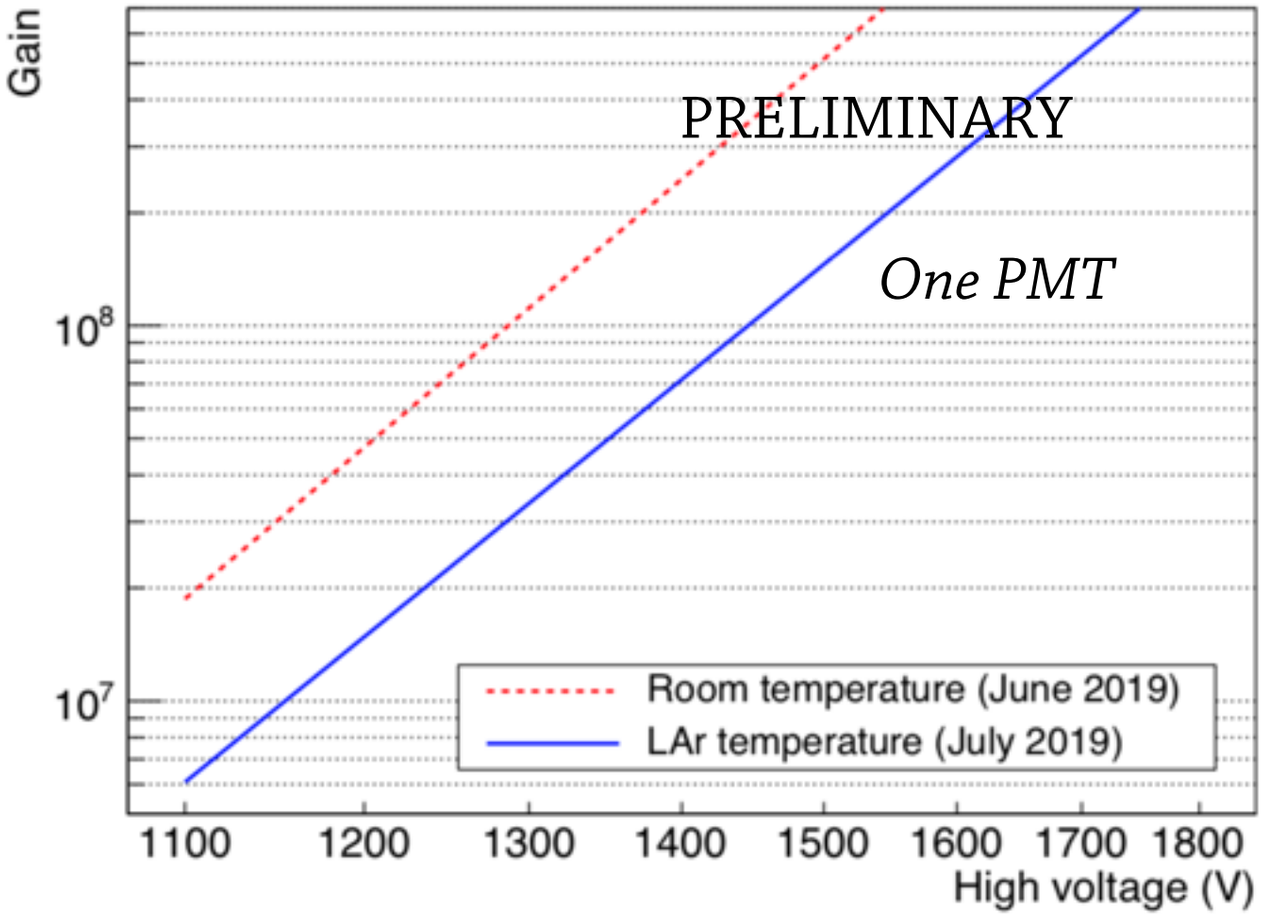
Example with same PMT and same sampling :

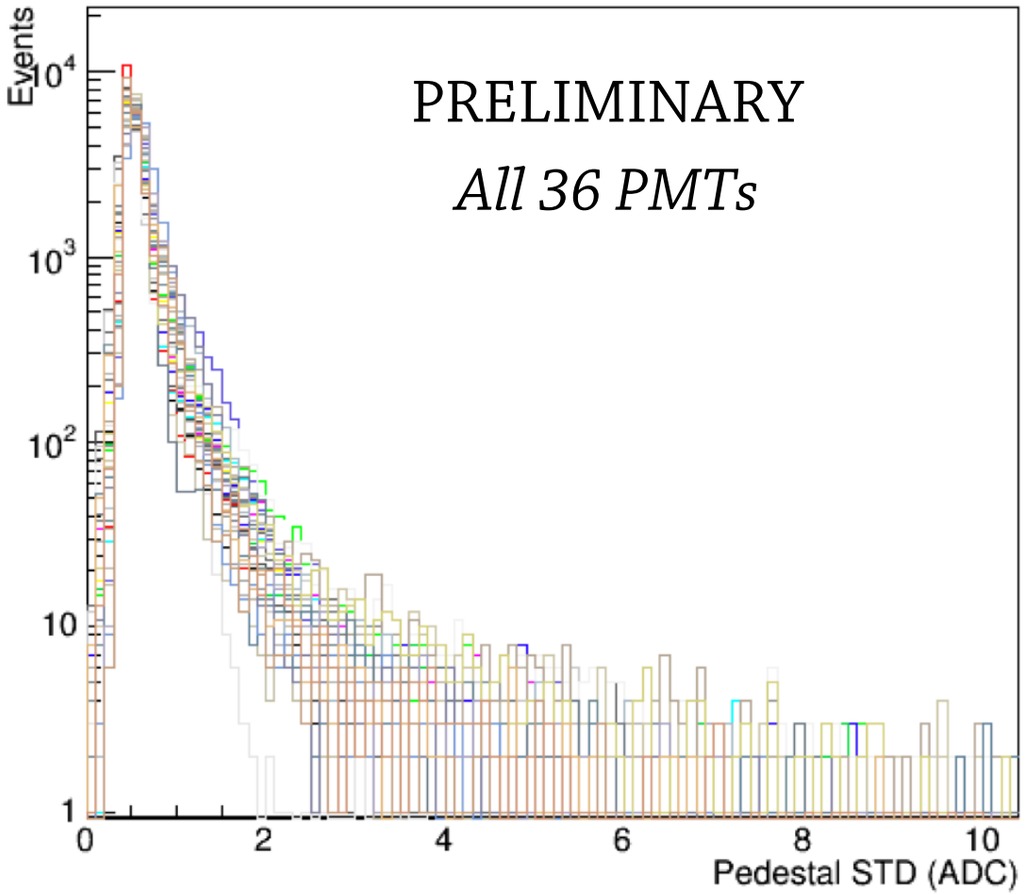




Preliminary PMT operation

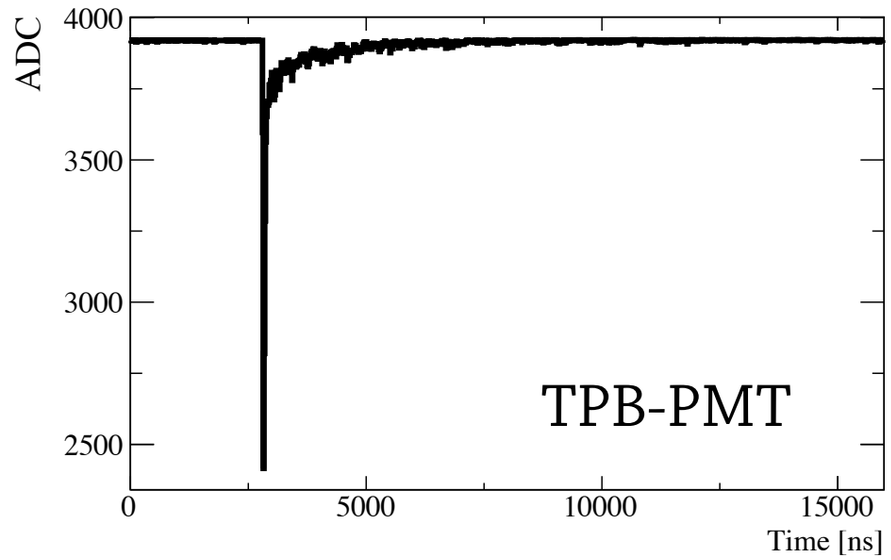
- All PMTs are operational
- Operated at a gain of 10^6 and 10^7
- Pedestal fluctuation below 1 ADC

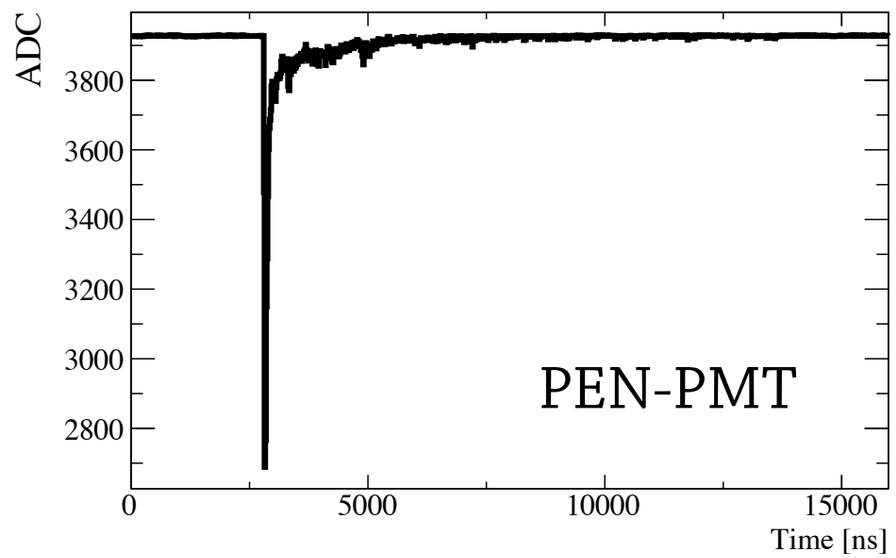


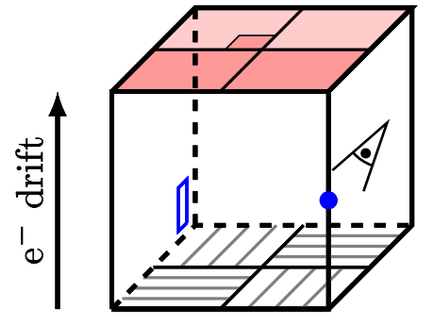


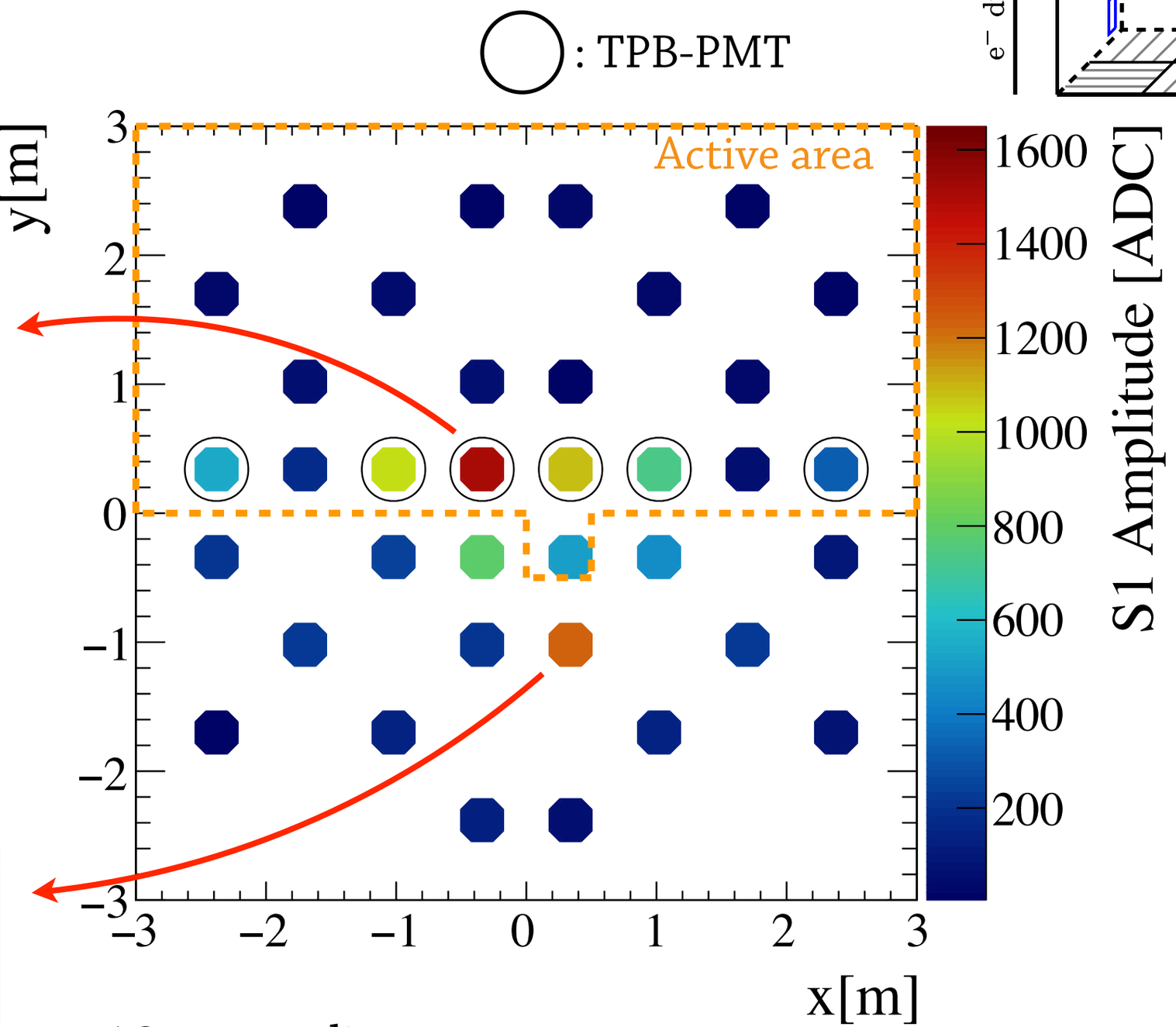
PMT gain and response are regularly monitored through the calibration system

First triggered events





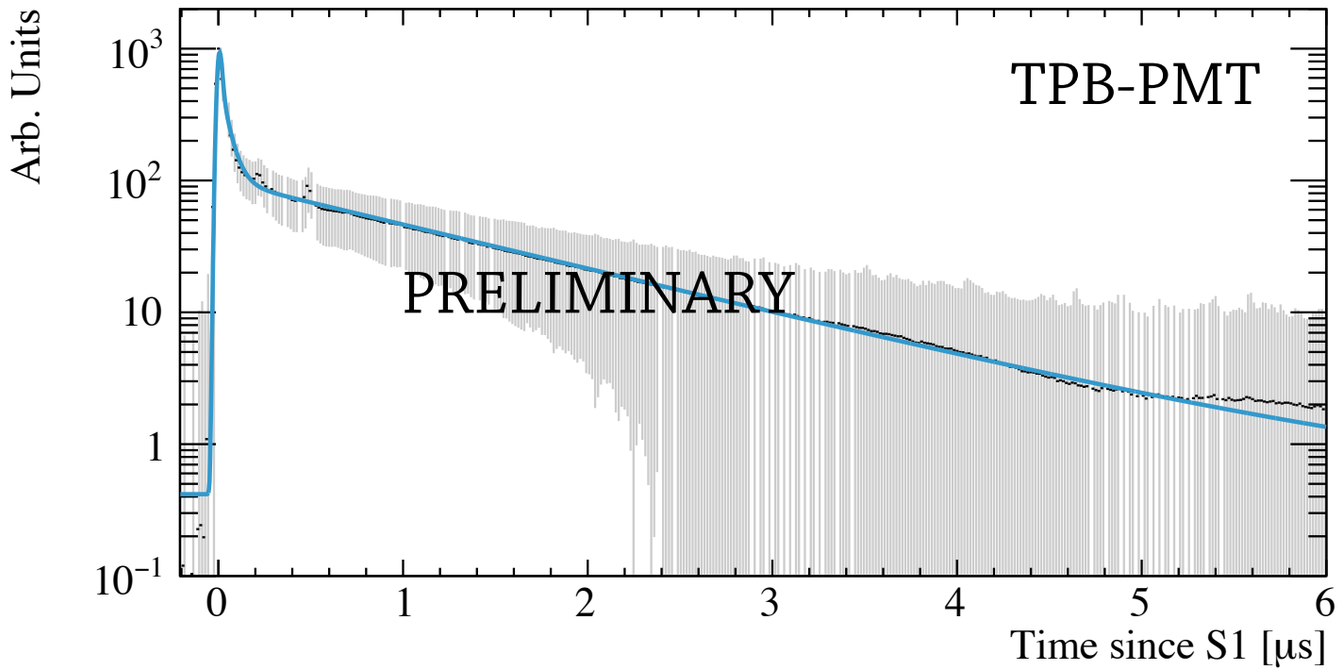




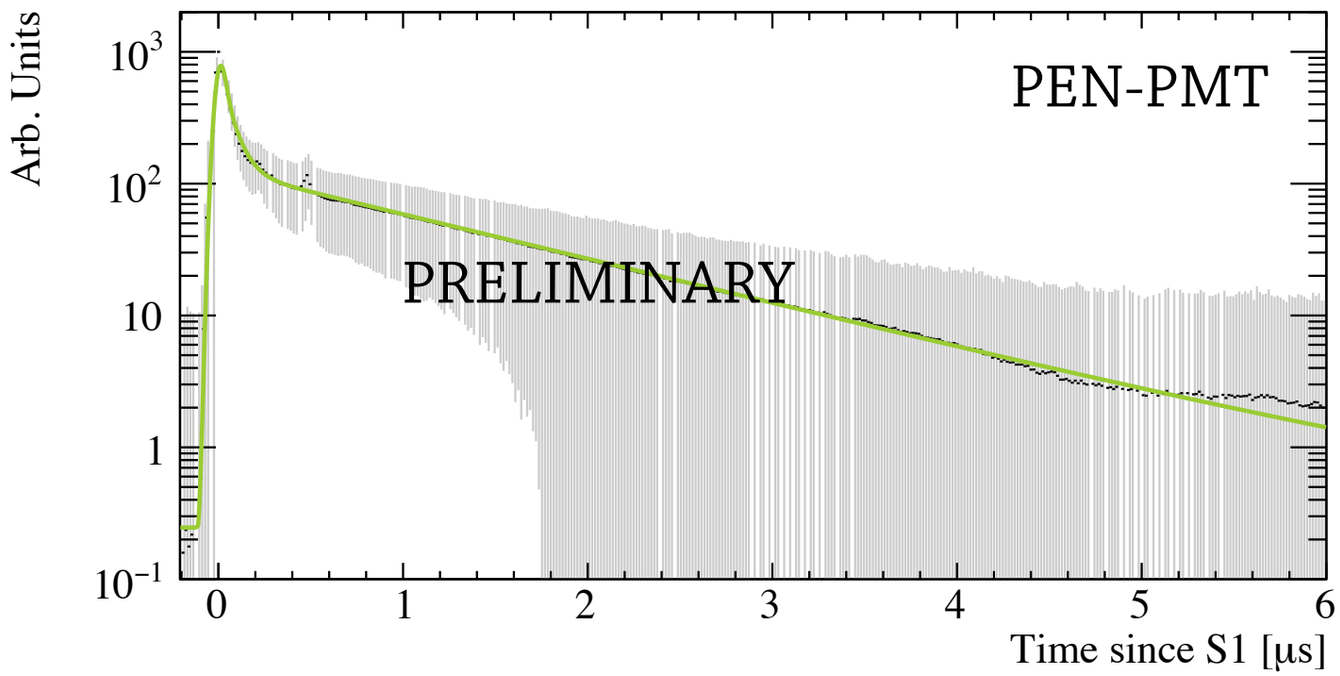
- 16 ns sampling
- Trigger done by the coincidence of 2 PMTs over threshold
- PMTs operated at a gain of 10^7
- No drift field ; LAr not yet at the nominal level

Preliminary averaged waveforms

No drift field applied



- First average waveform in LAr from PMT self trigger events
- Fitted with a gaussian convoluted with 3 exponentials [fast, intermediate and slow components]



- Preliminary fit results suggest:
  - τ_{int} ~ 50-60 ns
  - τ_{slow} ~ 1280 ns

  for both WLS technology

Data taking plans and analysis strategies

At the PMT characterization level :

- Monitor PMT gain and response at the weekly precision with the light calibration system

At the analysis level during commissioning - without drift field nor S2 signal :

- No field data is very important for future analysis : statistics is important !
- Custom PMT self trigger and random trigger configurations data is mandatory for understanding and modeling the light pattern of cosmic rays
- Optimum trigger configuration still under study

During physics run :

- Repeat analysis done in the demonstrator (which were mostly limited by the statistics)
- Compare the performances of PEN and TPB technologies
- Combine charge and light data

… Much more results at the next LIDINE !

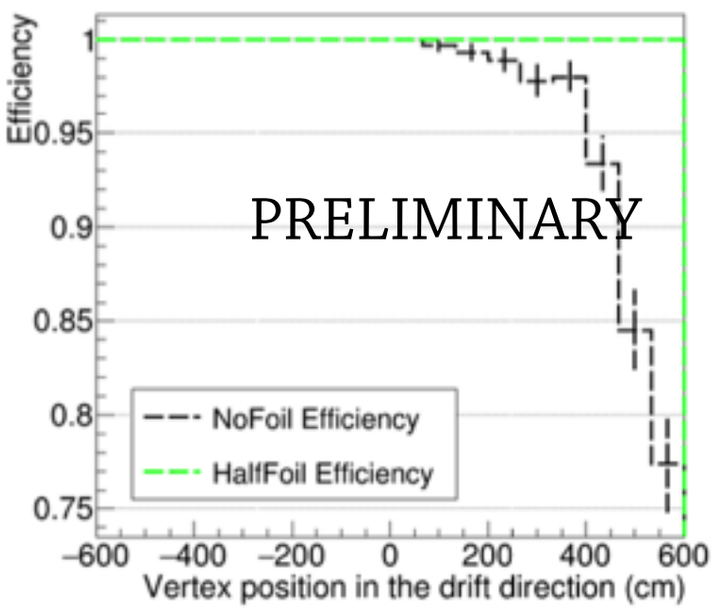
Light detection system foreseen at DUNE

The baseline photon detection system for DUNE far detector module is:

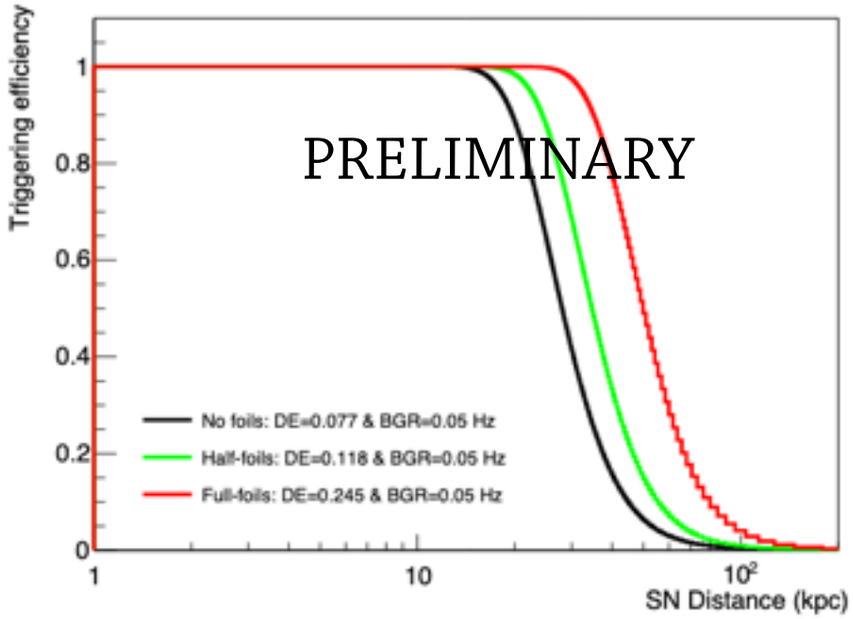
- 720 8'' PMT [hamamatsu R5912-20MOD]
- TPB coating on the PMT photocathode [0.2 mg/cm^2]
- Uniform layout at the bottom of cryostat
- TPB foils / WLS reflectors installed on the upper half of the field cage

The performances of this configuration for various physics analysis have been studied and will be included in the DUNE TDR :

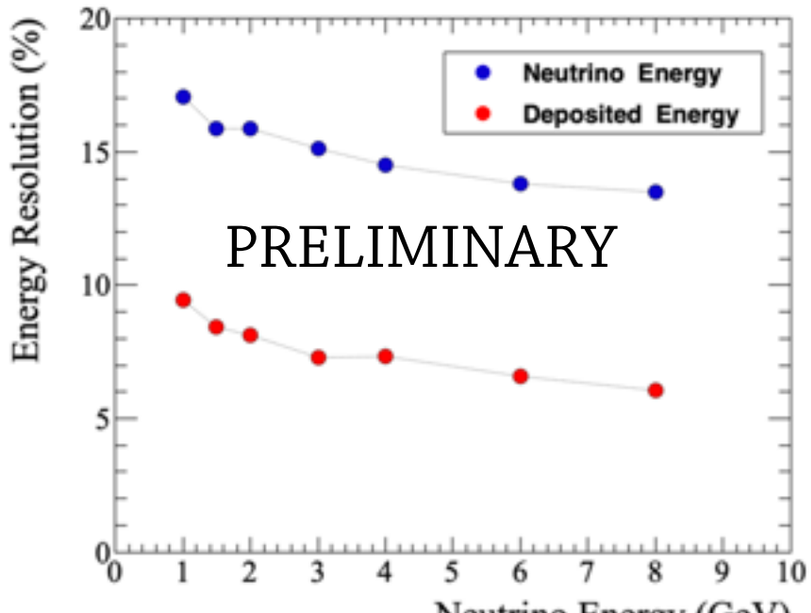
nucleon decay t_0 reconstruction efficiency



Supernova triggering efficiency



ν_e CC energy resolution with the photon detection system only



... Much more results at future LIDINEs !

First triggered events