Development of WA105/ProtoDUNE-DP detector at CERN

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ENIGMASS General Meeting

Grenoble

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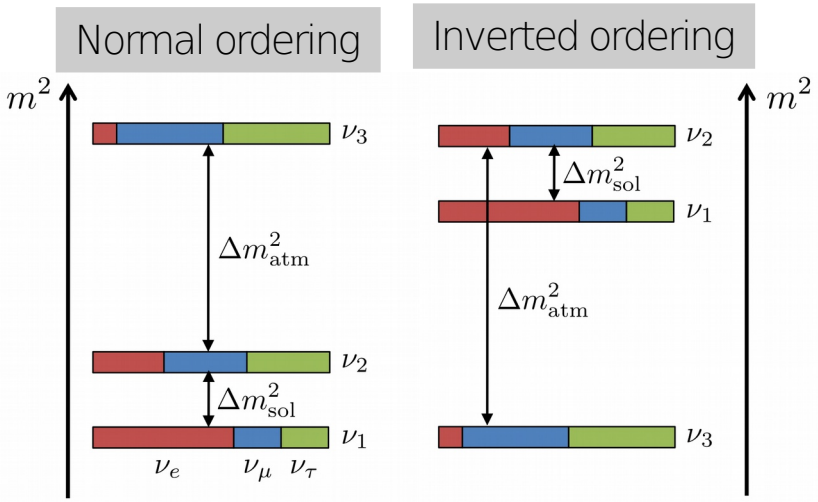
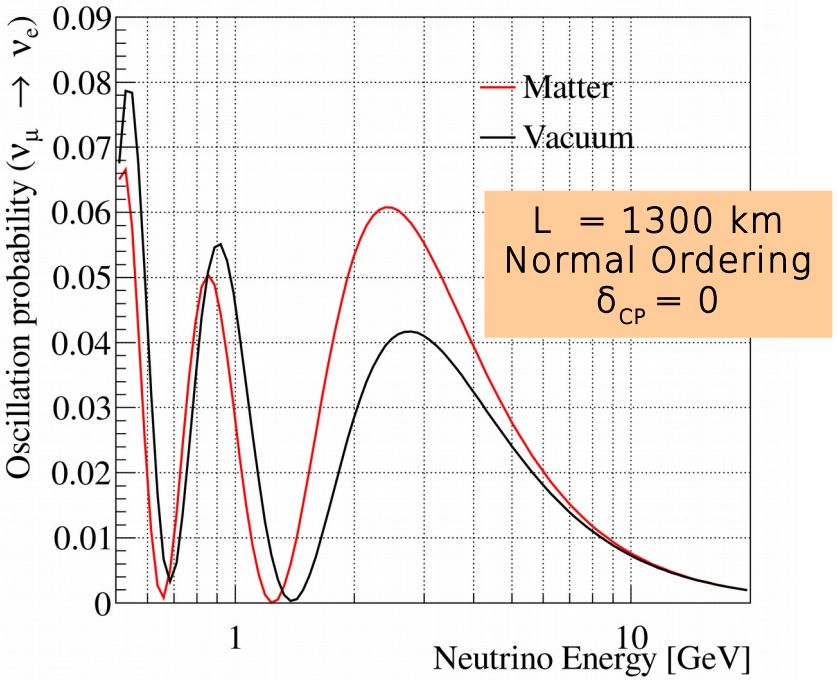
Introduction

- Long baseline (LBL) experiments:
  - High intensity neutrino beams
  - Underground detectors
  - Aiming to improve our knowledge of neutrino oscillations and oscillation parameters
    - Mass ordering
    - CP violation



- Those massive underground detectors also allow:
  - Astrophysics studies (supernovae explosion)
  - Nucleon decay searches

- Large propagation length
- Study of the neutrino oscillations in matter
- Possibility to produce neutrinos and also antineutrinos

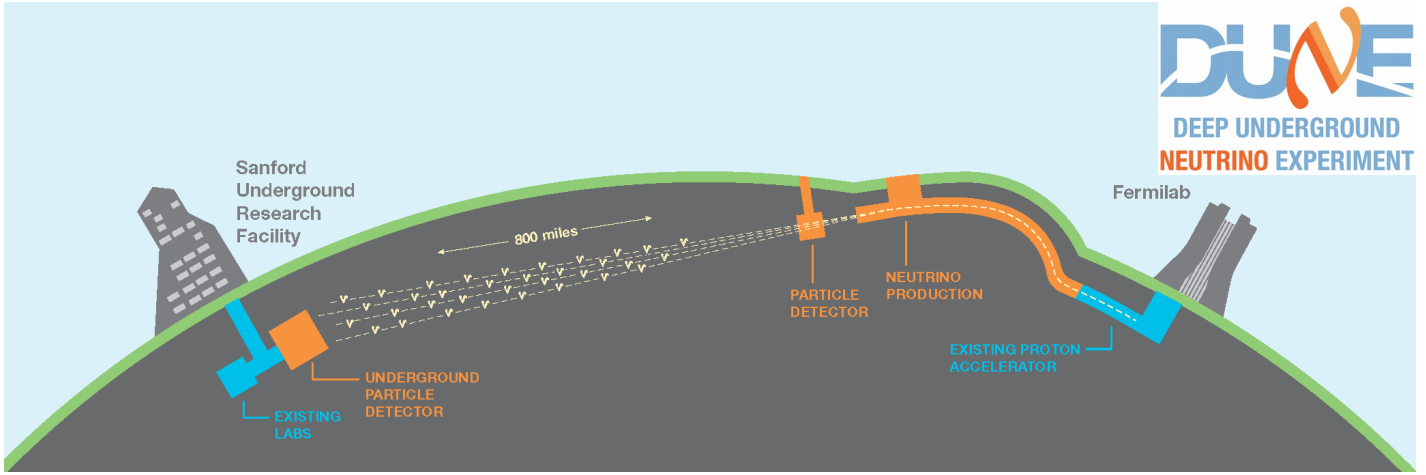


Deep Underground Neutrino Experiment - DUNE

Long baseline neutrino beam produced at Fermilab: 1300km

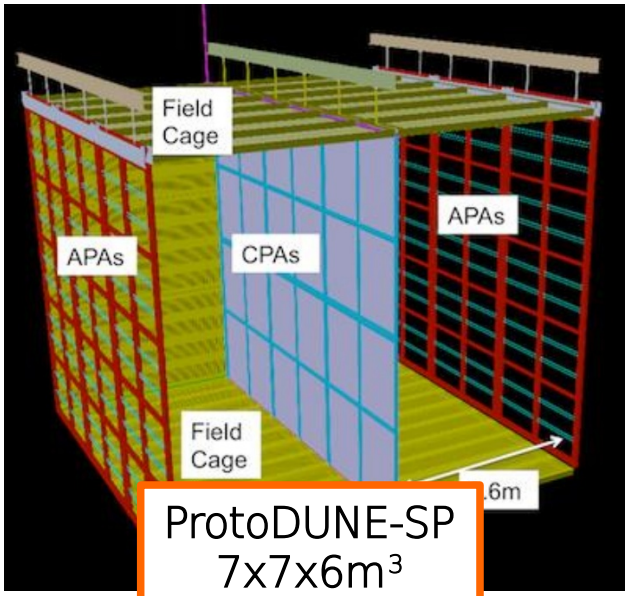
→ Large-scale far detector:

- Liquid Argon Time Projection Chamber (LArTPC)
- 40kton in 4 modules of 10kton (~60x15x15 m^3)



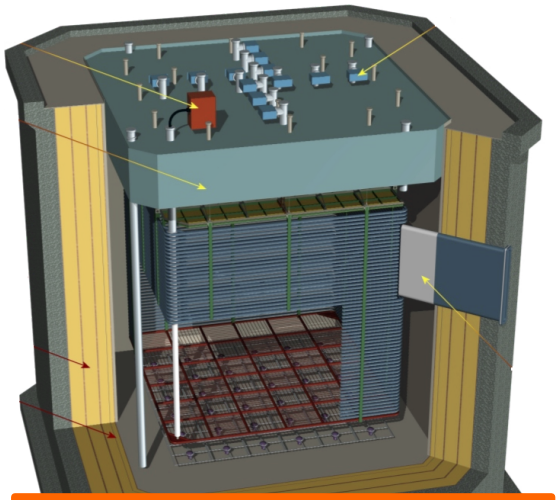
2 technologies are under consideration → development of 2 prototypes at CERN

Single-phase (liquid)



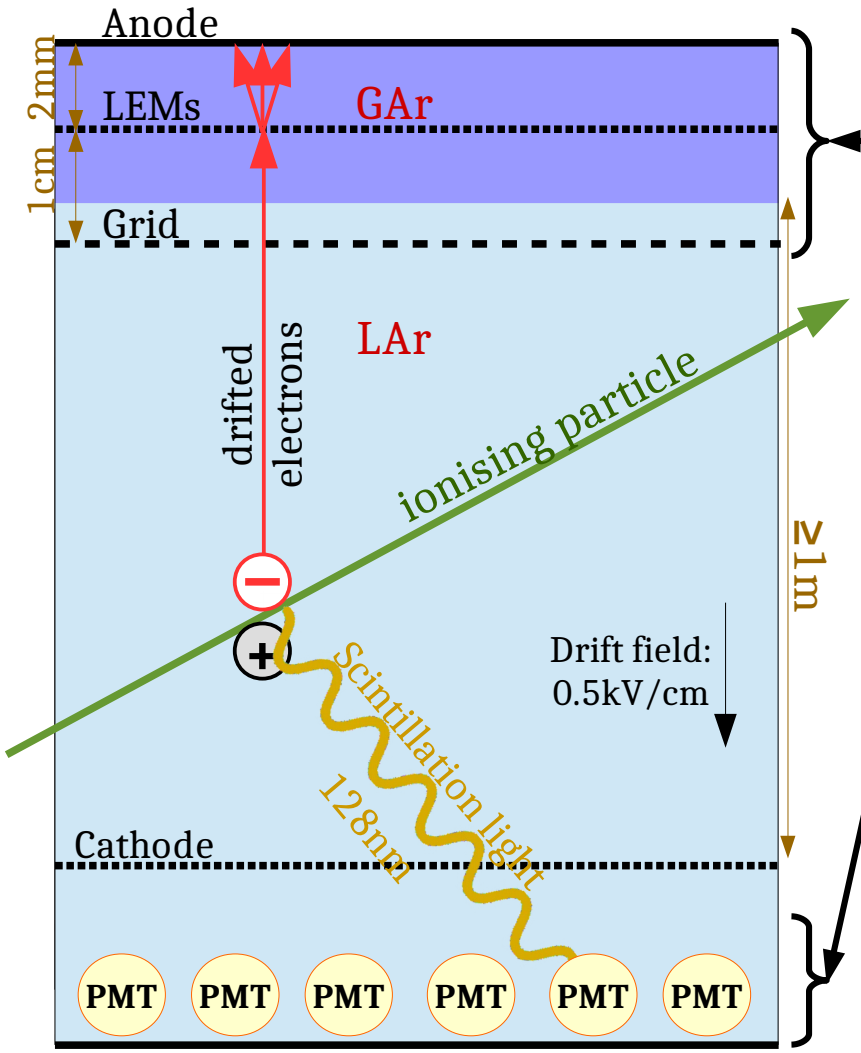
ProtoDUNE-SP
7x7x6m^3

Dual-phase (liquid + gas)



ProtoDUNE-DP (WA105)
6x6x6m^3

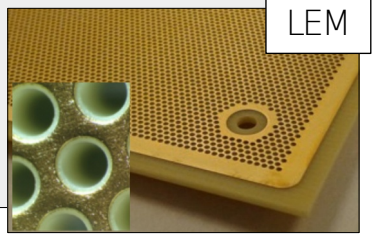
Dual phase LArTPC principle



Charge collection (Charge readout Plane – CRP)

- CRP : Extraction grid + LEM + Anode
- Must be **constantly adjusted** to keep the **LAr level** between the grid and the LEMs
- Electron **amplification** in the **LEMs**

→ 3D imaging and calorimetry



Light collection (photomultipliers)

→ DUNE: **trigger** and **calorimetry** improvement

→ ProtoDUNE-DP: cosmic muons **tagging** and **rejection** (not underground detector)

Advantages of the dual-phase technology:

- ✔ Longer drift distance allowed , thanks to the **electron amplification**
- ✔ Fewer readout channels with better resolution
- ✔ Digitization at warm
- ✔ Accessible cold front end **electronics**

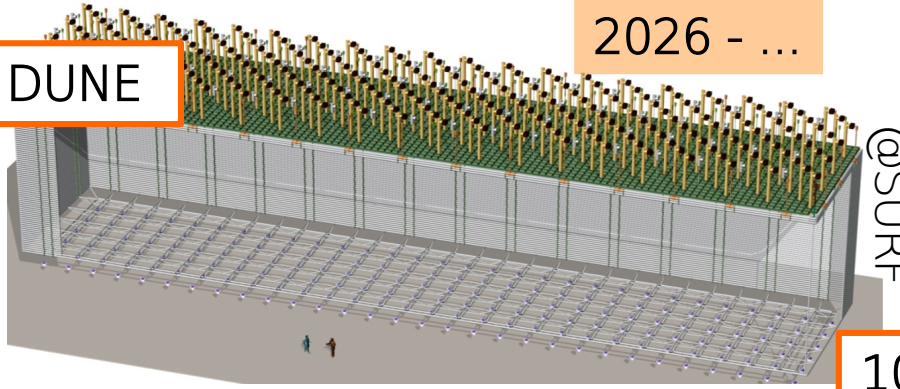
The WA105/ProtoDUNE-DP collaboration

Goal: demonstrate the capabilities of the dual phase technology for a large-scale detector

✔ A first step has been achieved with the 3x1x1 operation!

2026 - …

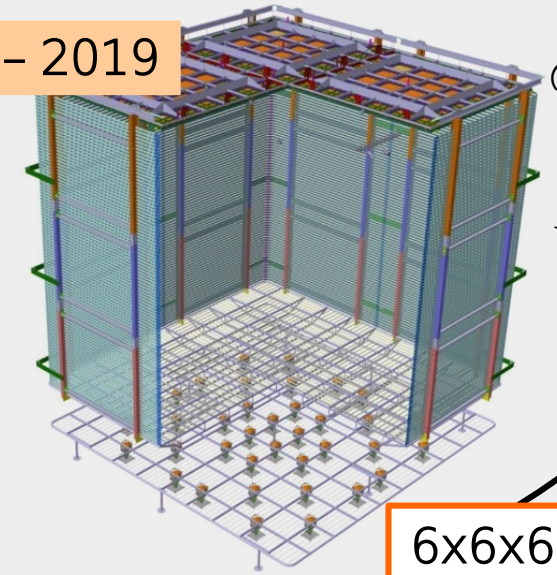
DUNE



@SURF

10kt

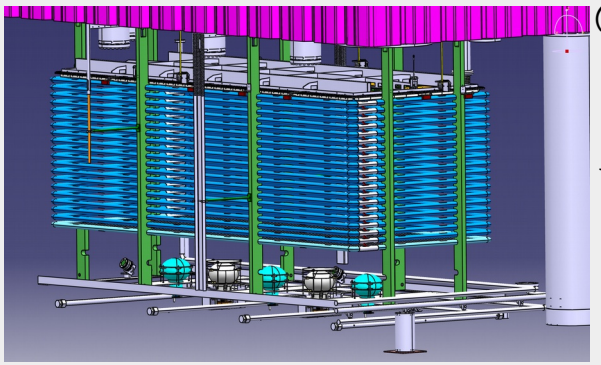
2016 – 2019



@CERN, EHN1

6x6x6 m³

2014 – 2017



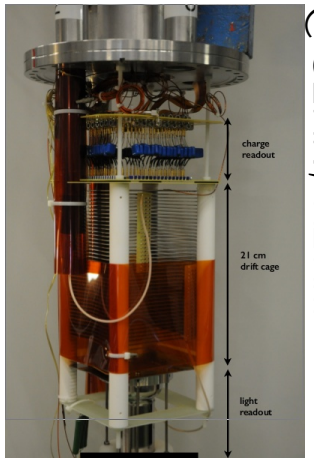
@CERN, Bld 182

Today

3x1x1 m³

ProtoDUNE-DP collaboration

2010 – 2014

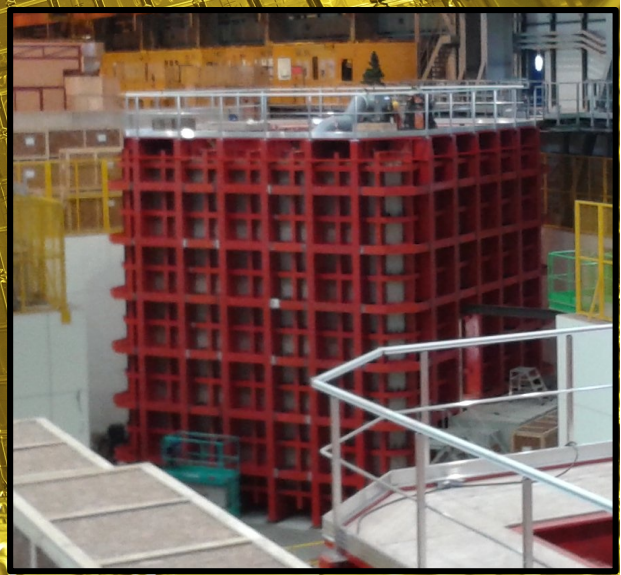


@CERN, KEK…

3L

LAPP involvement in the 6x6x6 m^3 prototype

- Light signal simulation
- Light Readout electronics
- Charge Readout Plane design



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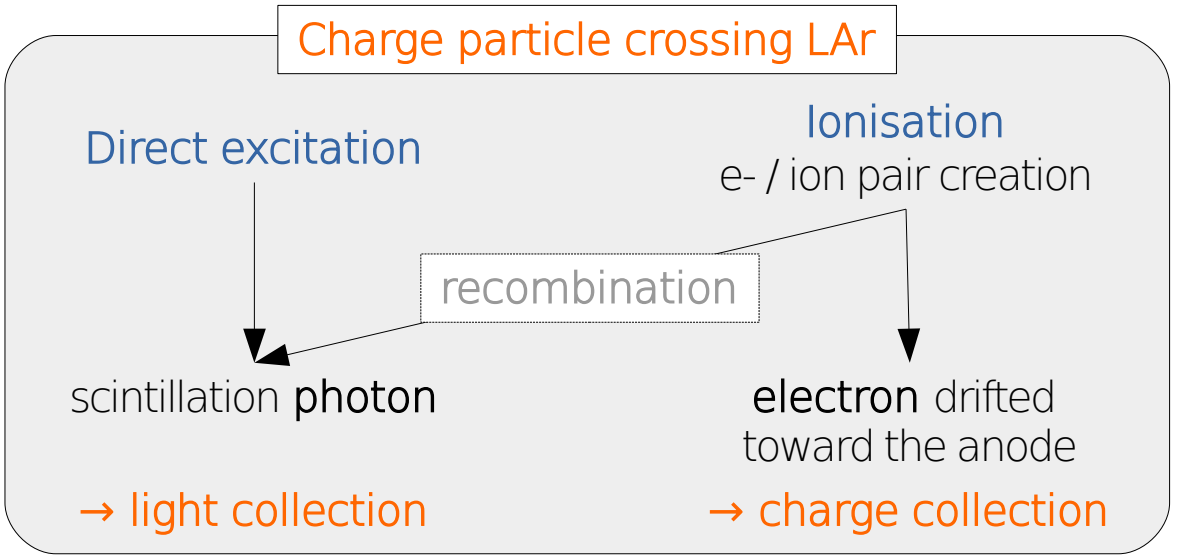
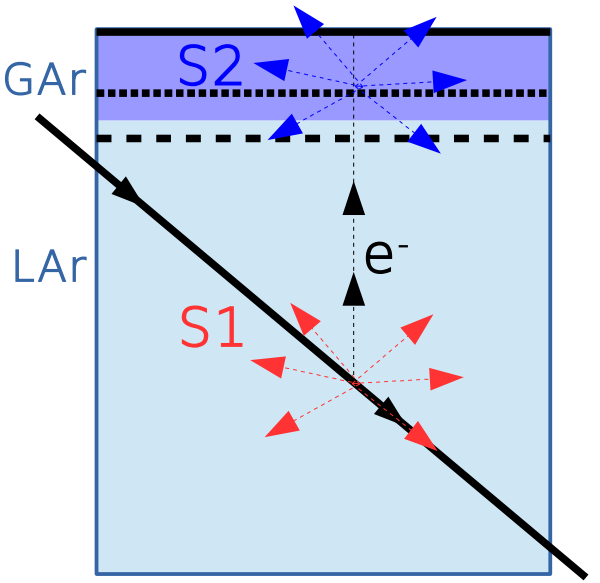
Light signal in dual phase TPC



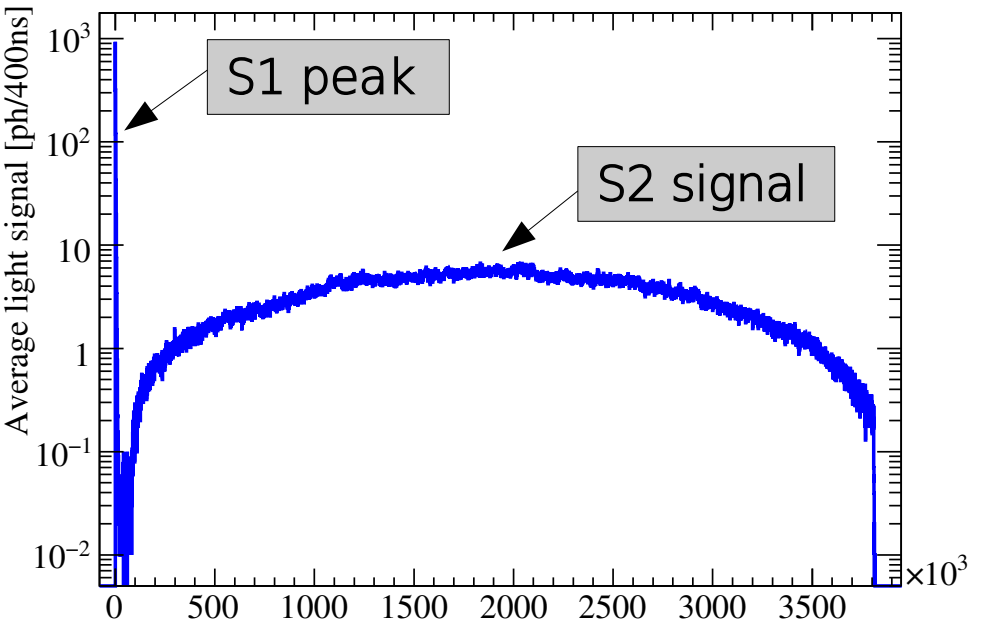


Light signal composed of 2 contributions:

- Scintillation in LAr (prompt signal – S1)
  - λ = 128 nm (9.69 eV)
- Electroluminescence in GAr (signal S2)
  - Due to the drifted electrons
  - Mainly produced during the e^- amplification
  - λ = 128 nm (9.69 eV)

Simulation based on the NEST approach (arXiv:1106.1613v1)

Signal induced by a 5-GeV muon

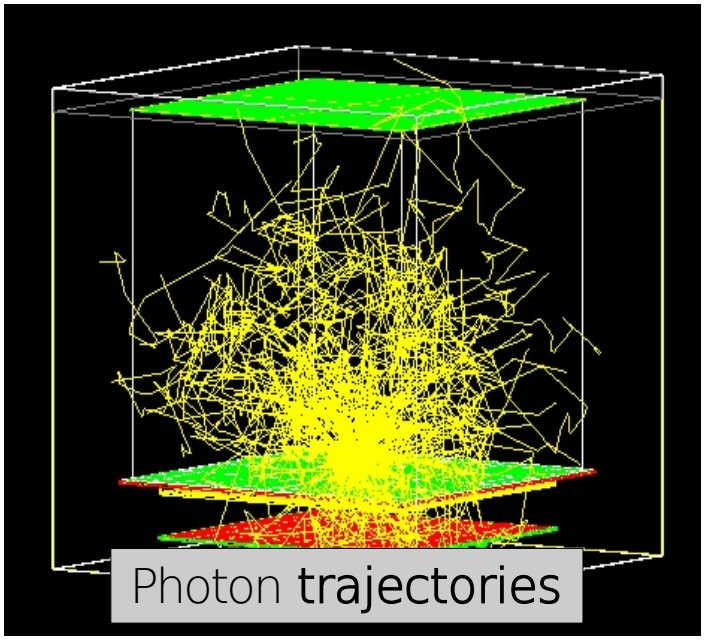


Light propagation in ProtoDUNE-DP

Propagation impacted by:

- Absorption in LAr
- Rayleigh scattering on LAr molecules
- Absorption on the detector components

Main issue: huge amount of photon due to the cosmic background, leading to very time-consuming simulations

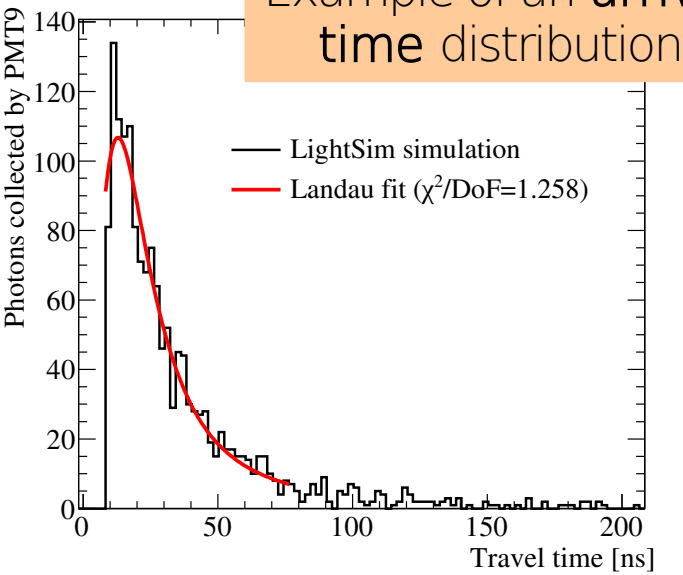


Solution: build a map that gives, for each PMT and each photon emission point in the detector:

- Probability to reach the PMT
- Parametrisation of the arrival time (Landau fit)

→ Light maps produced at LAPP in March 2017

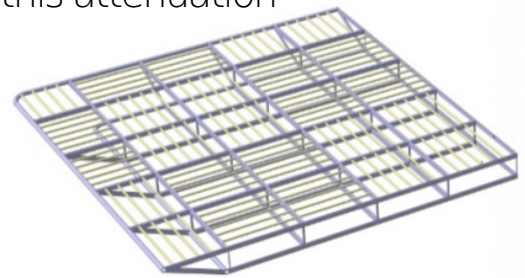
Example of an arrival time distribution

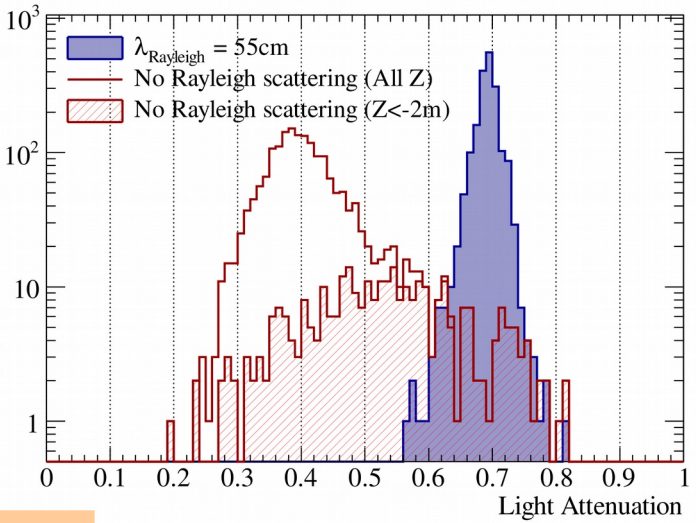


Scintillation light studies

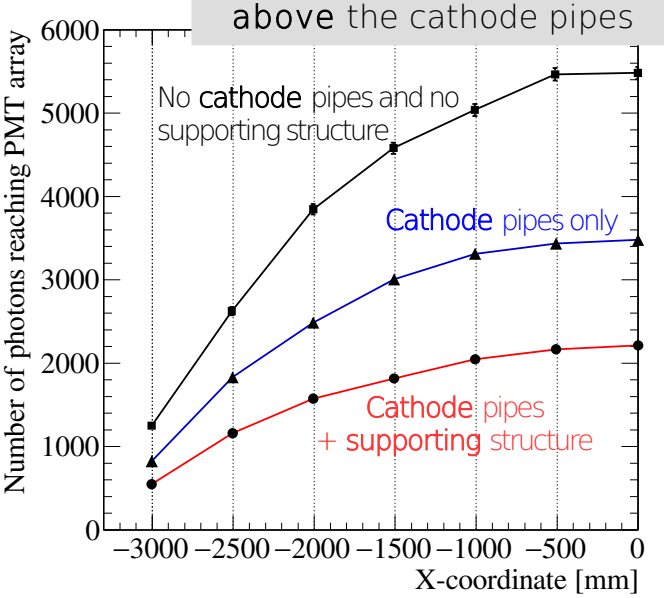
Understanding of the cathode impact on the light collection

- ✔ Light attenuation due to the cathode design
- ✔ Rayleigh scattering impact on this attenuation



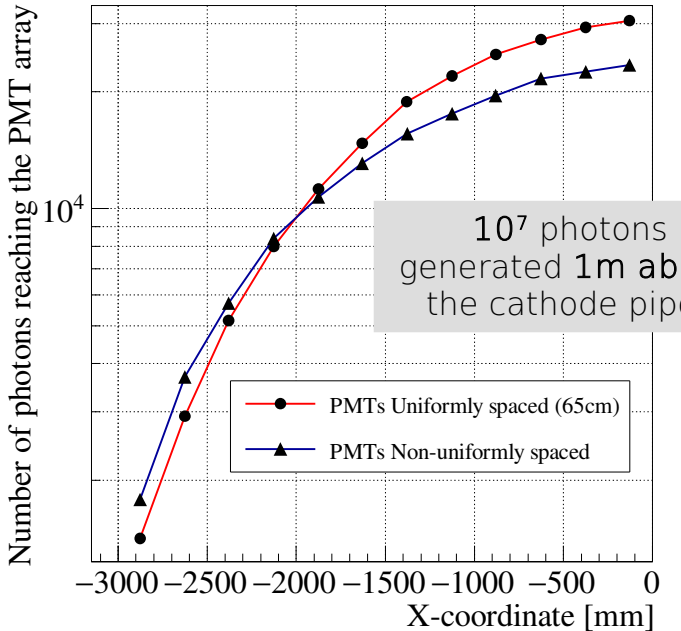


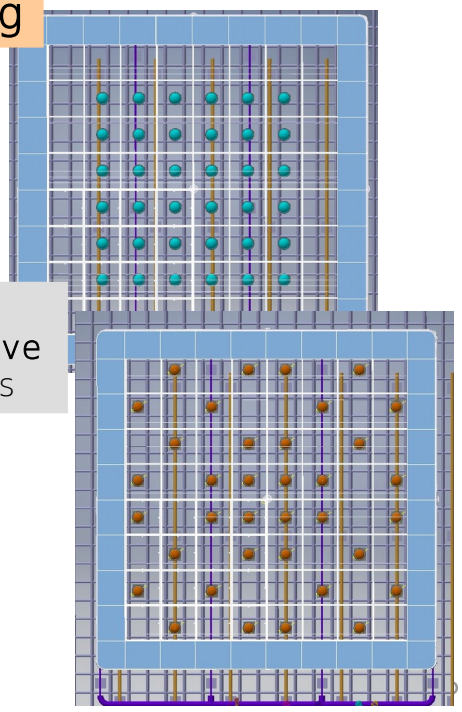
10^6 photons generated 1m above the cathode pipes



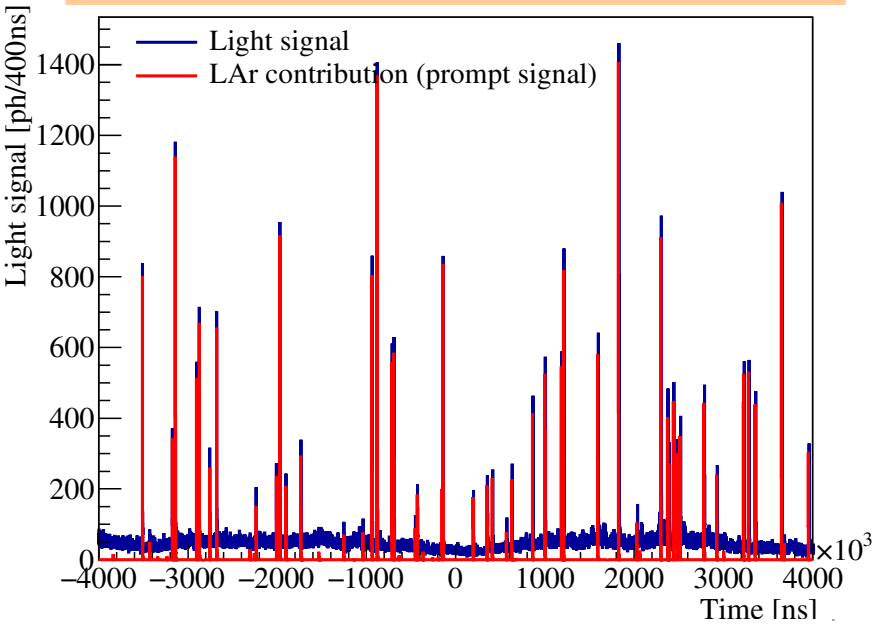
Optimization of the PMT positioning

10^7 photons generated 1m above the cathode pipes



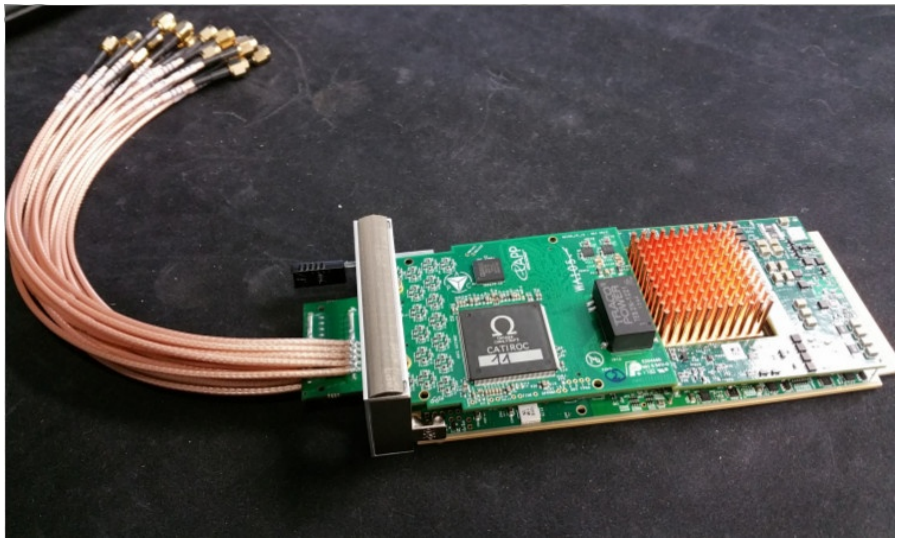


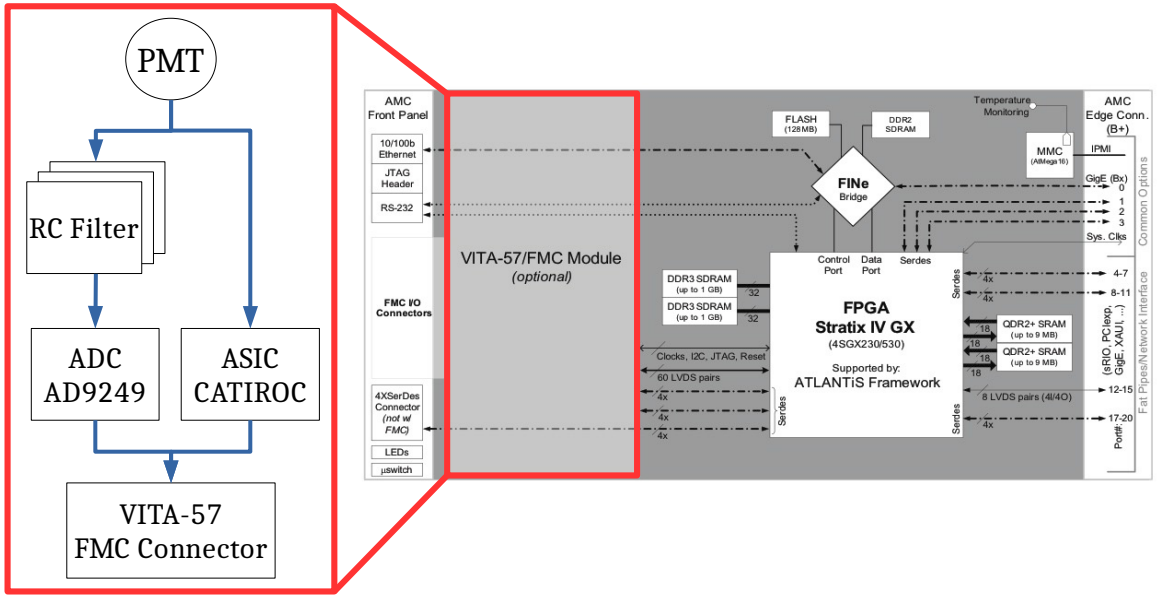
Light signal induced by cosmic muons



Light Readout electronics

Collaboration with **APC** and **OMEGA**



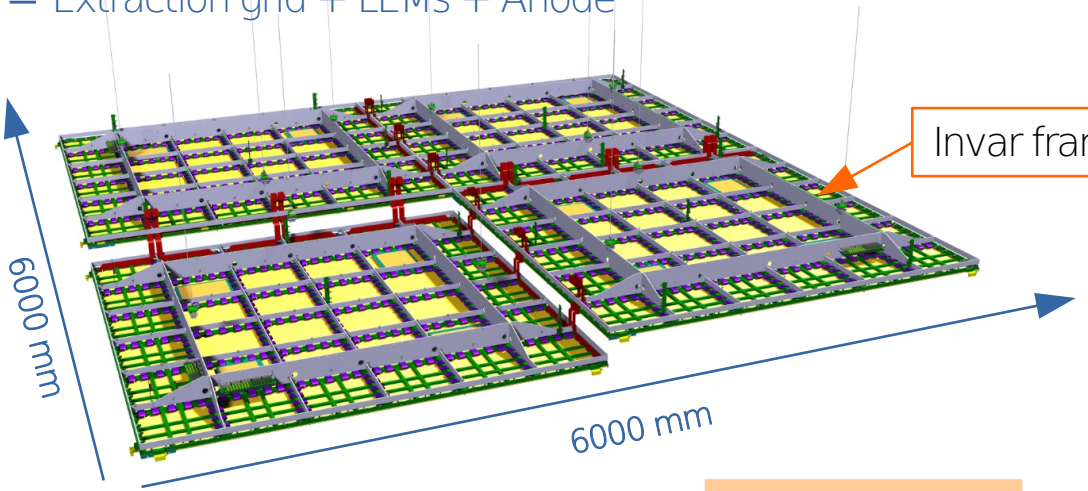


- For the **time being**: use of industrial mother boards with **home made mezzanine cards**
- 3 mezzanine cards has been **developed** in collaboration with **APC** and **OMEGA**
- Next steps:
  - **Integration** of the cards in the **DAQ** (charge and light readout)
  - For DUNE:
    - Development of **home made mother boards** at **LAPP**
    - **Test** with the **6x6x6m³**

Design of Charge Readout Plane and suspension system

CRP structure and suspension system design by LAPP

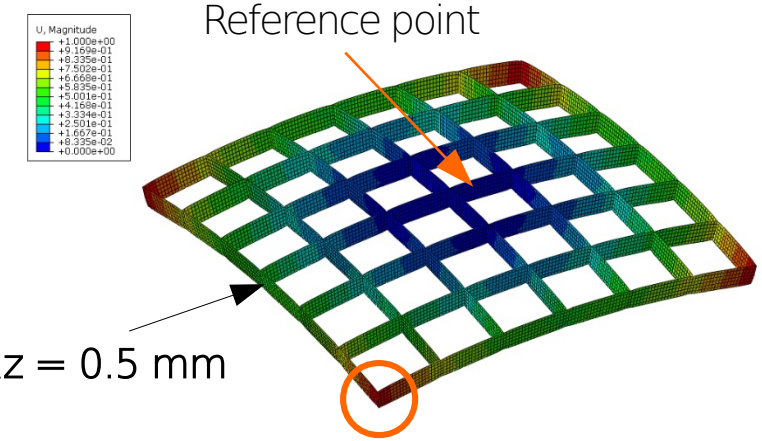
CRP = Extraction grid + LEMs + Anode



Full size engineering model of the first invar frame

The invar frames are under fabrication!

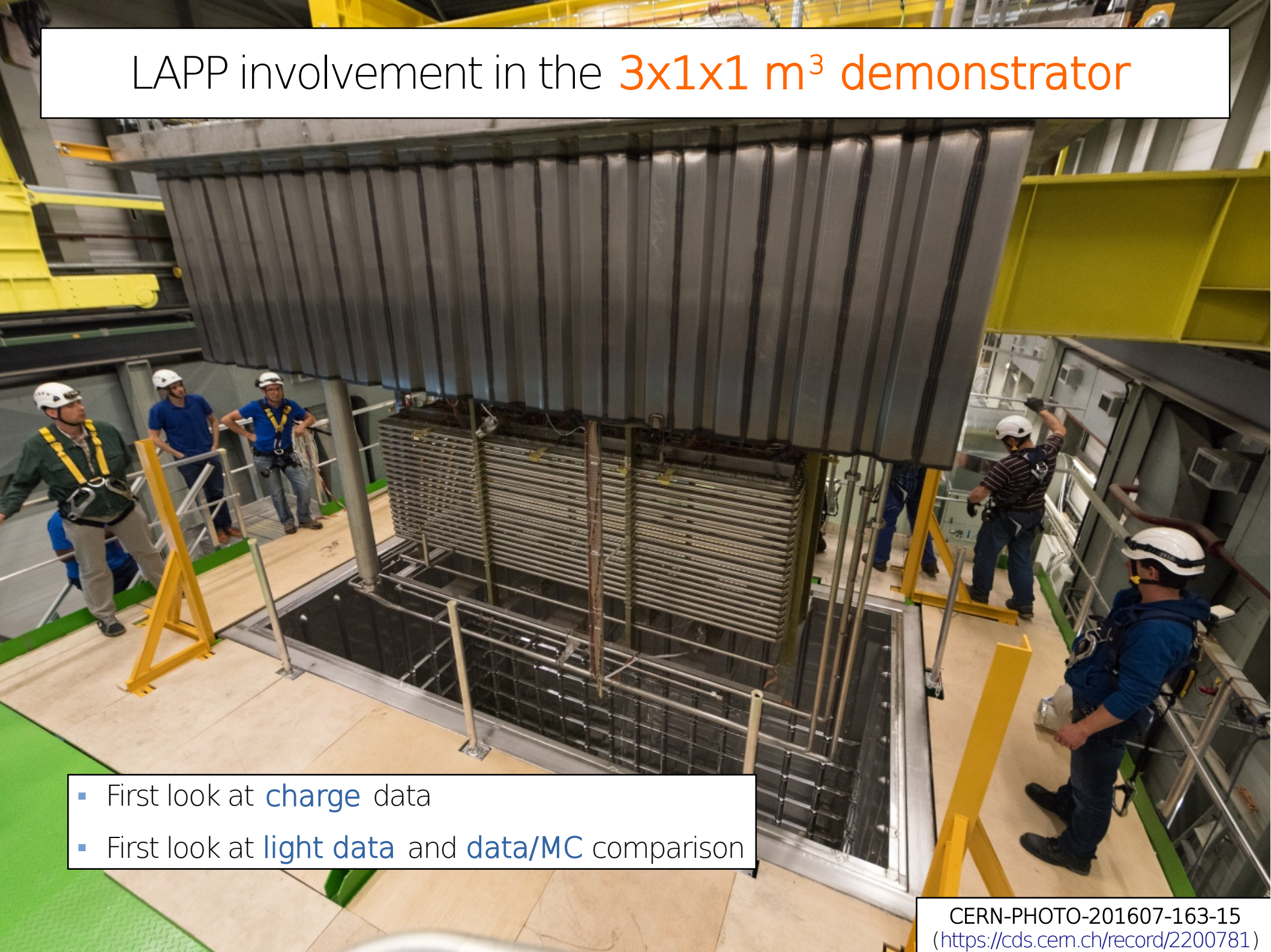
Suspension system



Maximal deformation $\Delta z_{max} = 1$ mm

LAPP also developed different assembly tooling

LAPP involvement in the 3x1x1 m^3 demonstrator



- First look at charge data
- First look at light data and data/MC comparison

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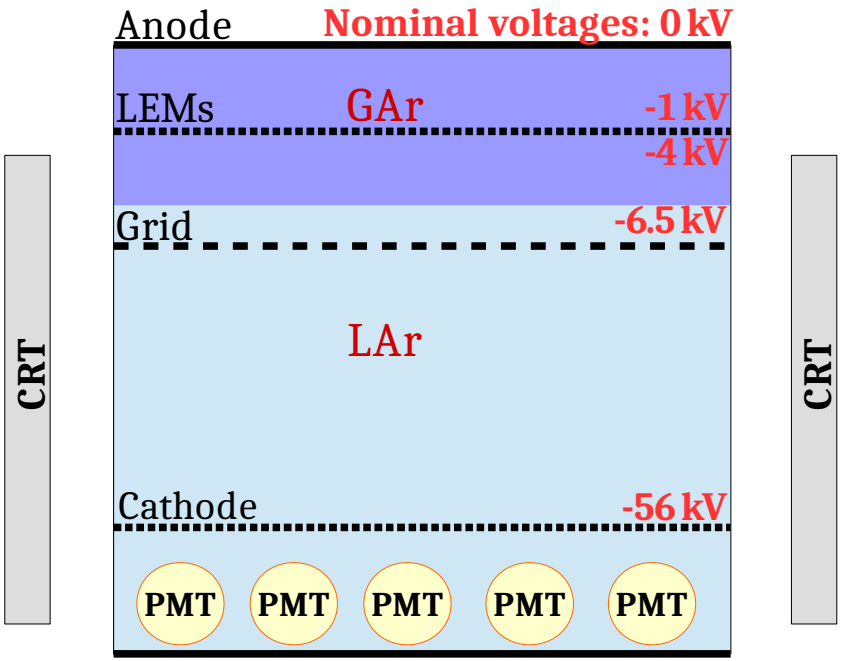
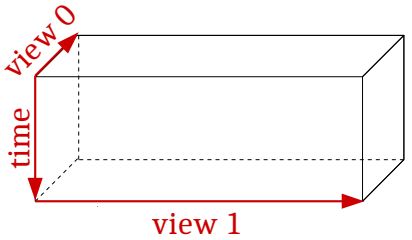
(https://cds.cern.ch/record/2200781)

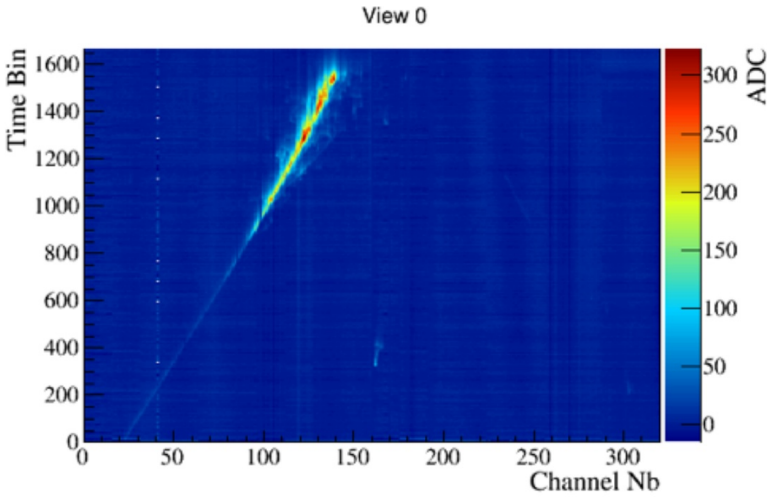
Data collected

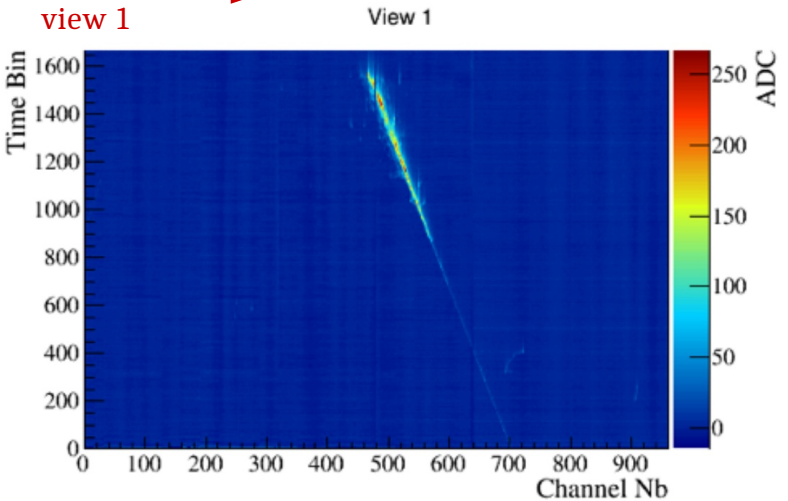
- Exposed to cosmic rays
- First light signal: June 15th
- First track: June 21st
- 2 triggers: Cosmic Ray Tagger (CRT) and PMT
- Data collected with different values of the fields
  - Drift field
  - Extraction field (between Grid and LEMs)
  - Amplification field (LEM field)
  - Induction field (between LEM and anode)



Example of event





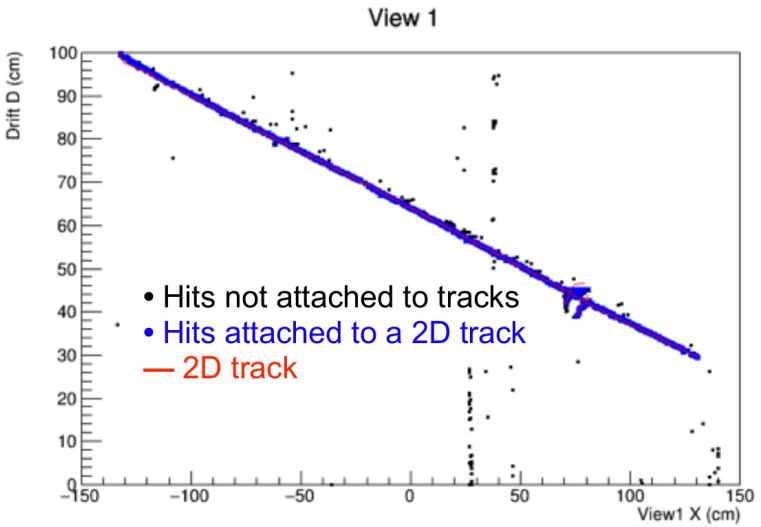


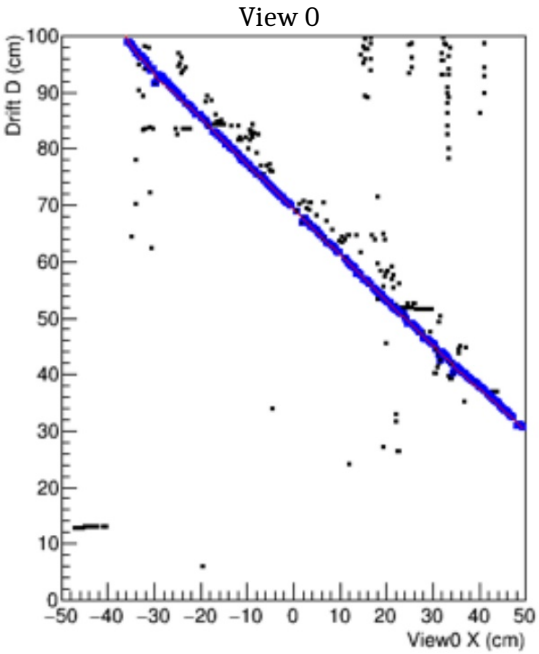
Raw data:
- 1 time bin: 0.4 µs
- 1 channel: 0.3125 cm

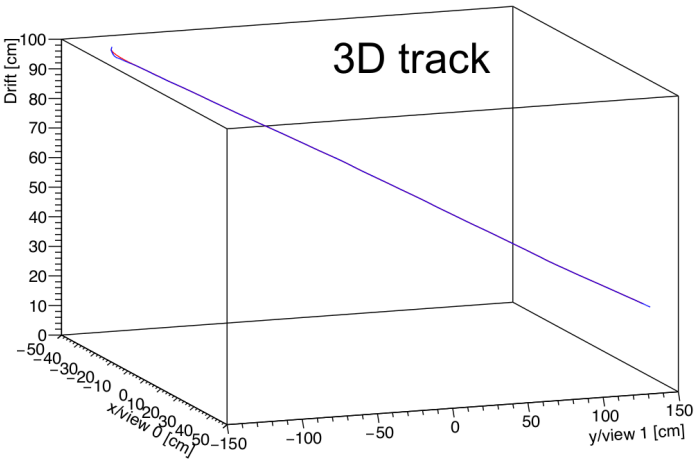
Drift Field: 500 V/cm
Extraction Field: 1.85 kV/cm
LEM Field: 28 kV/cm
Induction Field: 1.5 kV/cm

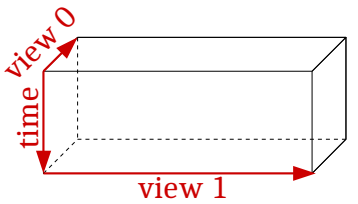
First look at charge data

Reconstruction of charge data



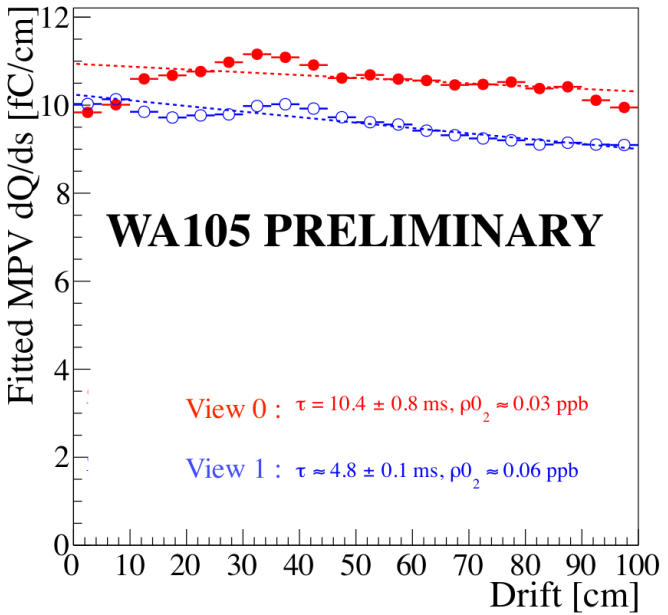






LAr purity

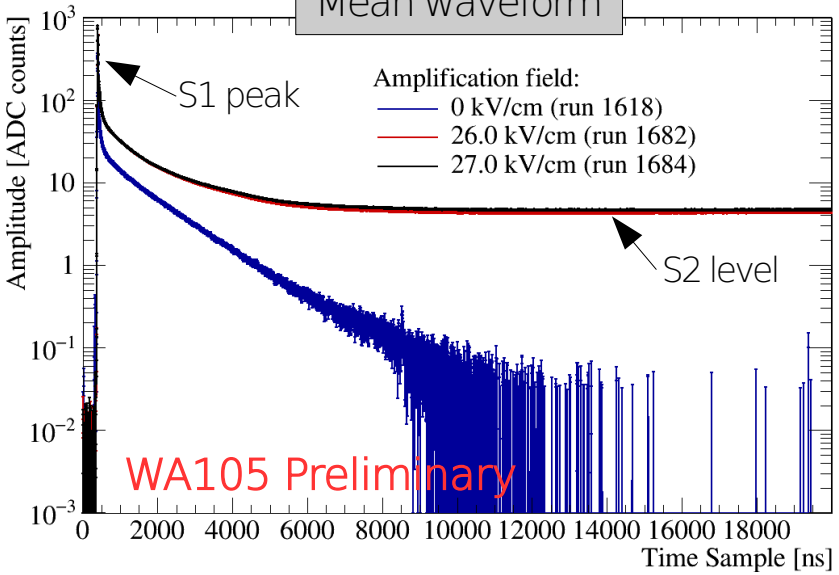
The **evolution** of the **collected charge** with the drift indicates a good LAr purity with an **electron lifetime of** ~5ms



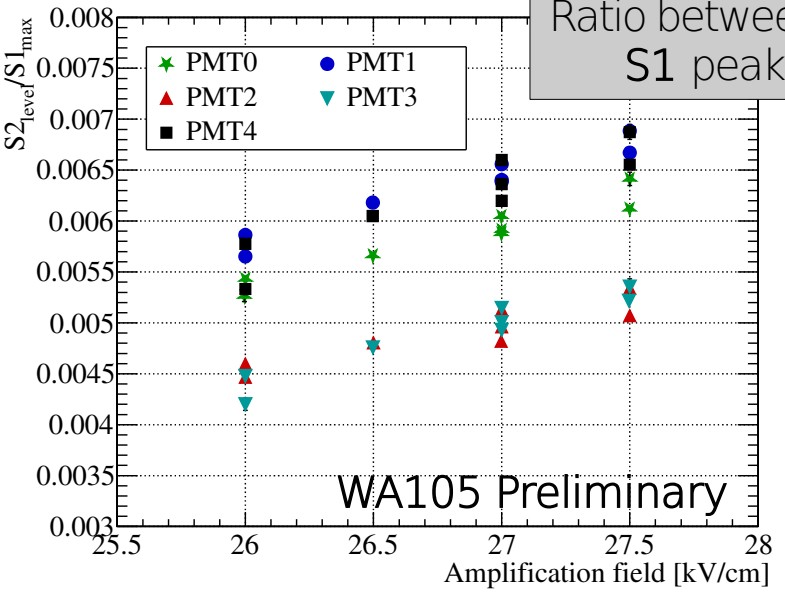
First look at light data

Dependence of the **S2 light signal** (produced in **GAr**) to the **amplification field**

Mean waveform



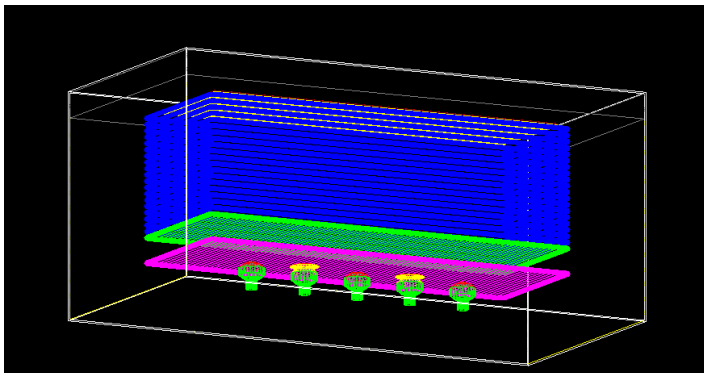
Ratio between **S2 level** and **S1** peak **amplitude**



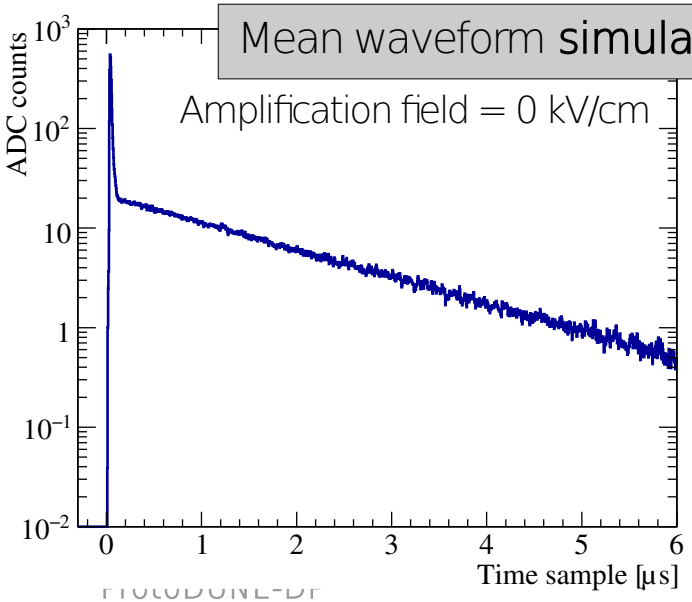
The amount of S2 light is proportional to the LEM field

→ Ongoing study

Comparison Data/MC are ongoing



Mean waveform **simulation**



- Simulation of the detailed geometry
- Production of 3x1x1 light maps
- Implementation of the PMT response ongoing

Conclusion and Prospects

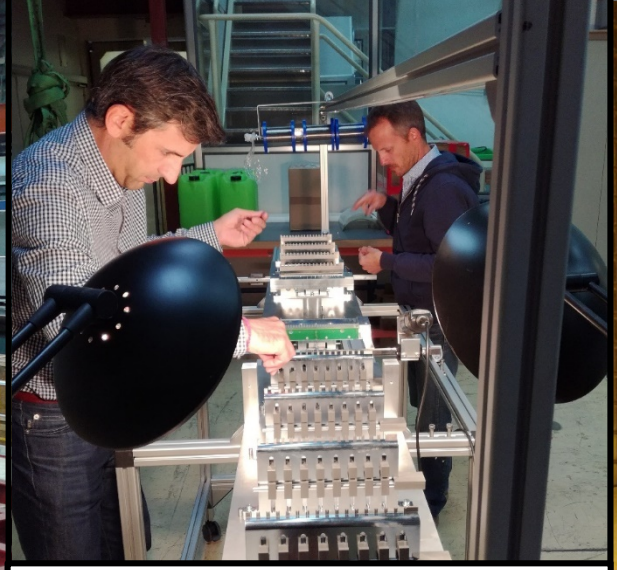
- 3x1x1 m^3 demonstrator:
  - Stopping today
  - The data analysis is ongoing

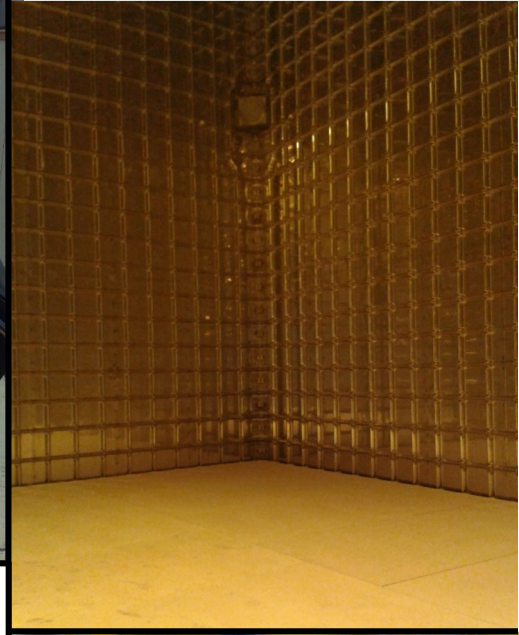
    → Technical and analysis papers are foreseen for 2018

- The construction of the 6x6x6 m^3 prototype should be completed in 2018

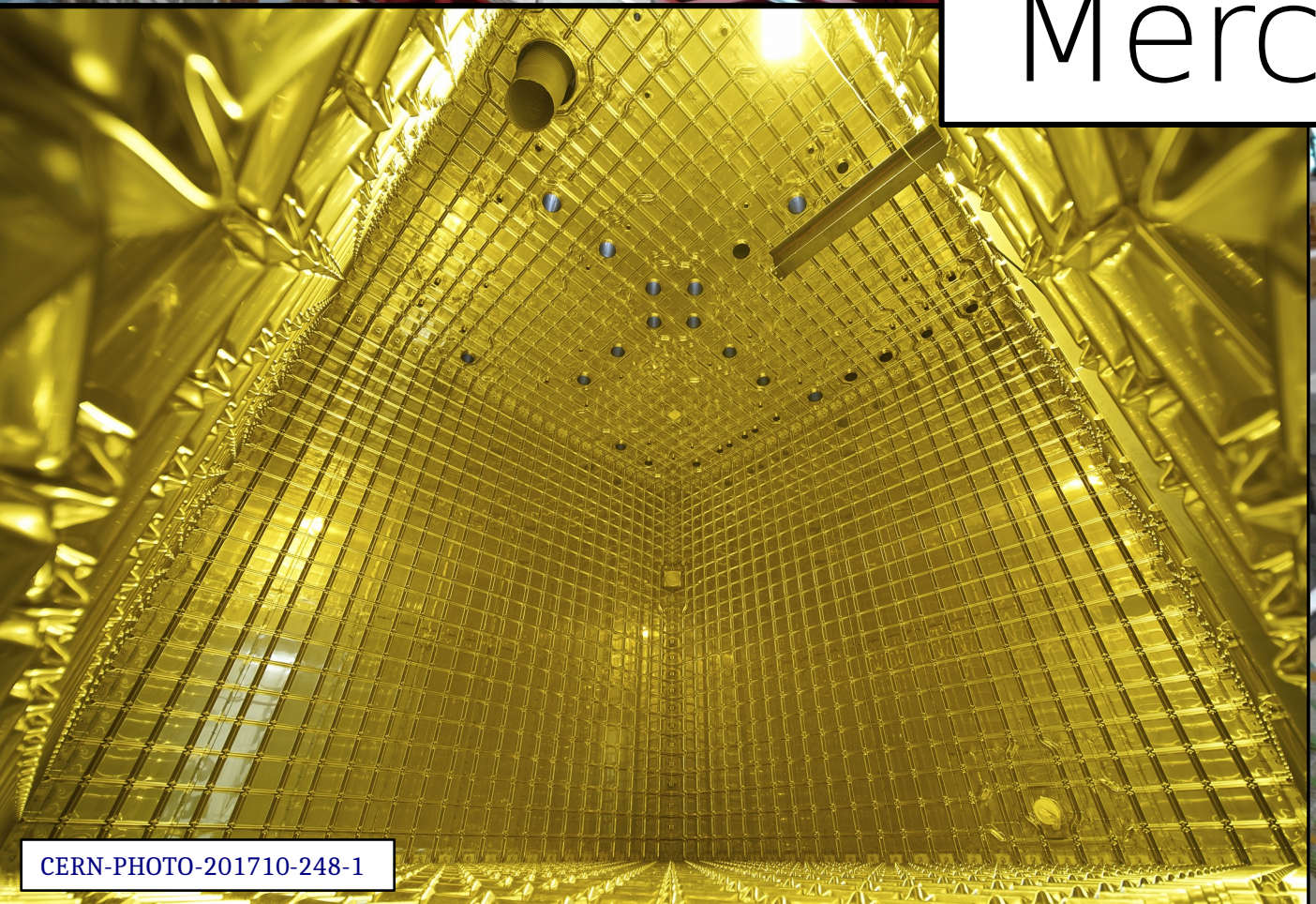
- ProtoDUNEs (single and dual phase) are key milestones towards DUNE detector
- At least one DUNE module will be a dual-phase LArTPC
- All our mechanical and electronical developments can be adapted to DUNE design
- Consortia are under developments to prepare a DUNE Technical Design Report for 2019

→ It's a good time to join and participate !





Merci !



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