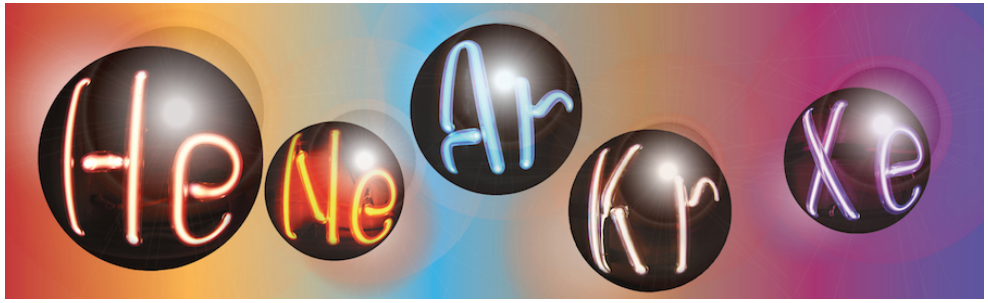
Photon detection system for ProtoDUNE dual phase

Clara Cuesta on behalf of the DUNE collaboration

LIDINE 2017: Light Detection in Nobel Elements

September, 23rd 2017



Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
EXCELENCIA MARÍA DE MAEZTU
DUNE

Content

DUNE

ProtoDUNE-DP

- Photon system
- PMT bases
- PMT characterization
- TPB coating
- Light calibration system

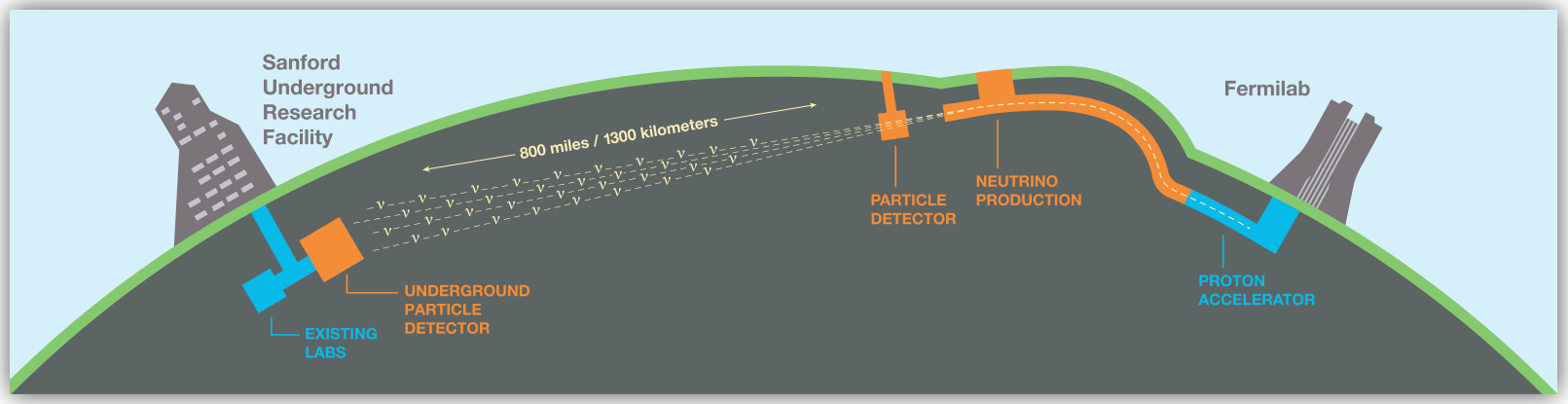
3x1x1 m^3
LAr DP TPC

- Photon system
- Preliminary results

DUNE

CDR: arXiv:1512.06148

- What is the origin of the matter-antimatter asymmetry in the Universe?
- What are the fundamental underlying symmetries of the universe?
- Is there a Grand Unified Theory of the Universe?
- How do supernovae explode? New physics from a neutrino burst?



✓ New neutrino beam facility at Fermilab

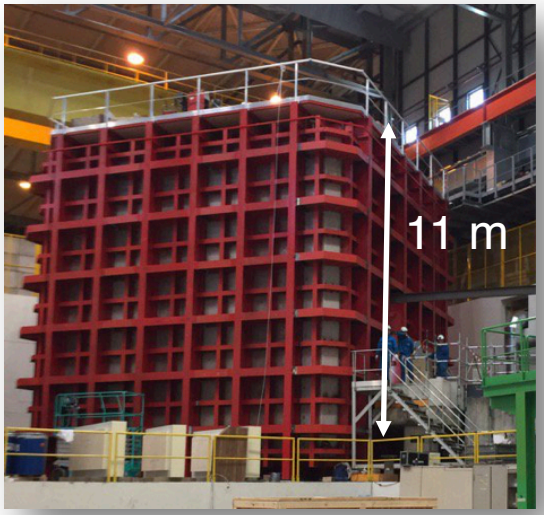
✓ A highly capable Near Detector at Fermilab to measure the unoscillated neutrino spectrum and flux constraints

✓ 4 x 10 kton (fiducial) LArTPC modules (single and/or dual-phase) deep underground at SURF (Lead, SD, 1300 km baseline) to measure oscillations, SN burst neutrinos, nucleon decay, atmospheric neutrinos… first data in 2024

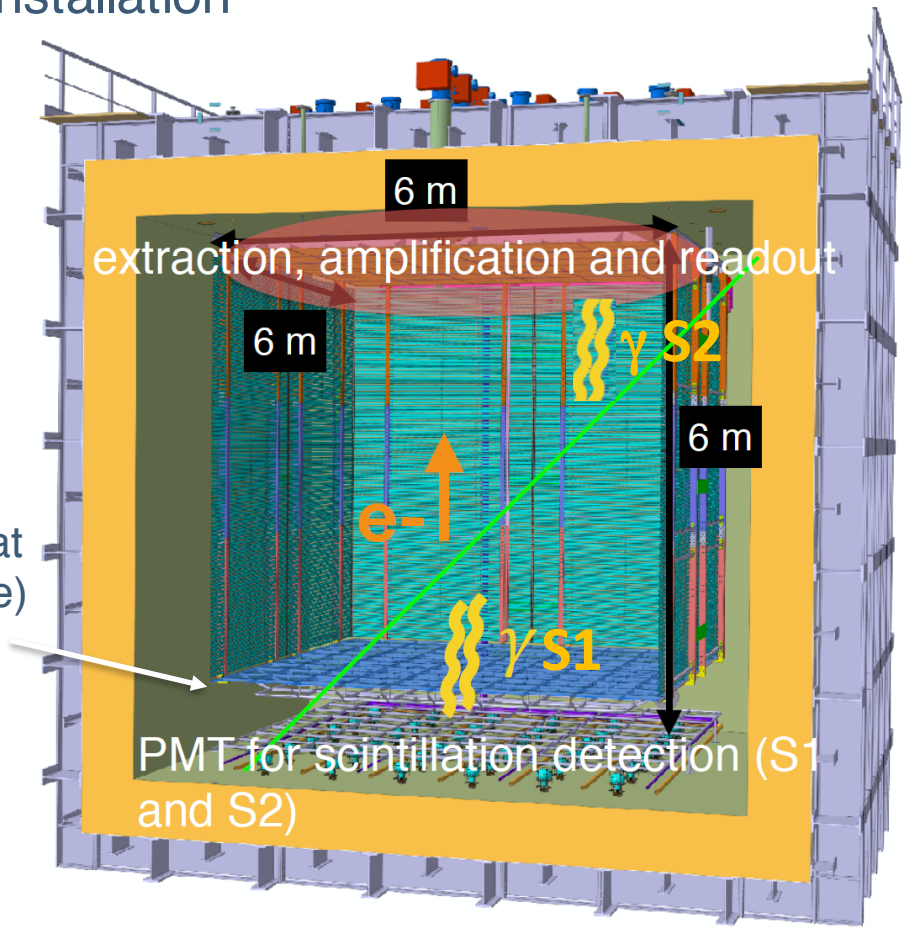
ProtoDUNE dual phase

WA105

- 6x6x6 m^3 double phase LAr TPC at CERN
- Almost all detector aspects and installation sequence identical to those foreseen for the 10 kton
- Under construction
- Cosmic muons and charge particle test beam data in 2018

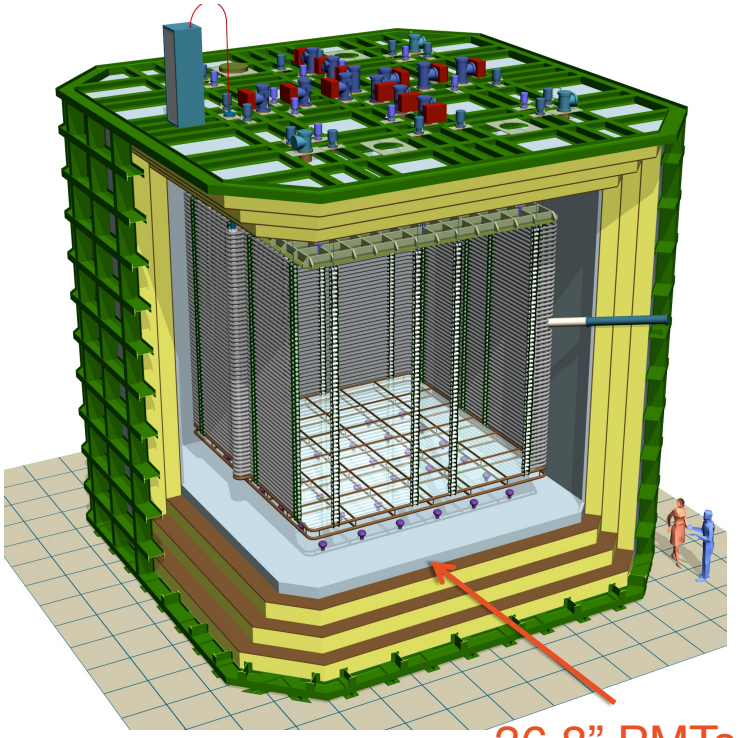


Drift = 6 m
(~ 300 kV at the cathode)



ProtoDUNE-DP Photon System

6x6x6 m^3 (fid.) DLAr TPC @CERN



TDR: arXiv:1409.4405

Basic configuration:

- 36 8” cryogenic photomultipliers
- Wavelength-shifter: TPB coating on PMT
- Voltage divider base + single HV-signal cable + splitter (external)
- Light calibration system
- DAQ system (external)

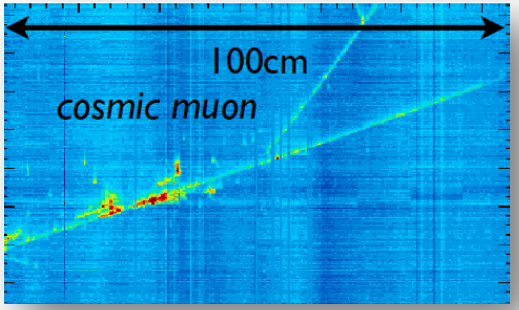
Goals of the light detection system:

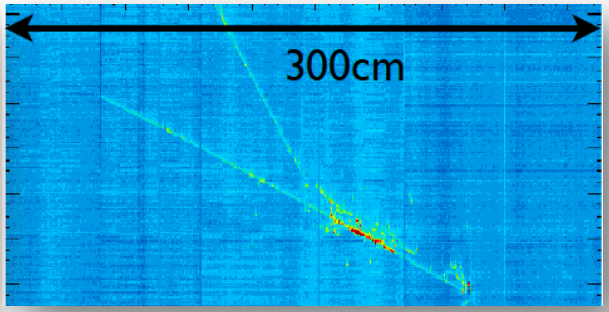
- Trigger for non-beam events
- t_0 for both beam and non-beam events (cosmic background rejection)
- Possibility to perform calorimetric measurements and particle identification

3x1x1 DP LAr TPC

- 5 ton demonstrator constructed - being operated at CERN 2015 – 2017
- Same technology as ProtoDUNE-DP 6x6x6 m^3
- One of the goals of the 3x1x1 m^3 prototype is to validate the system in real conditions
- Taking cosmic ray data!

5 PMTs: *Different configurations being tested*



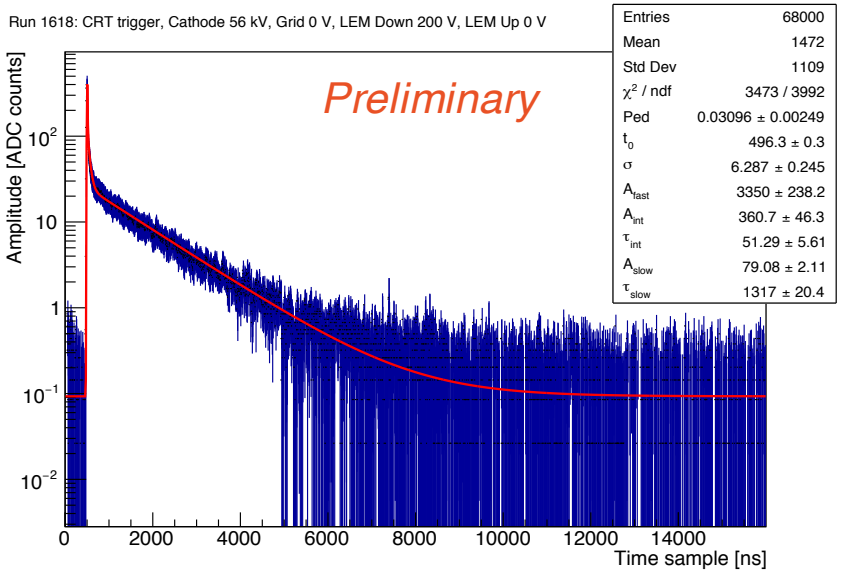


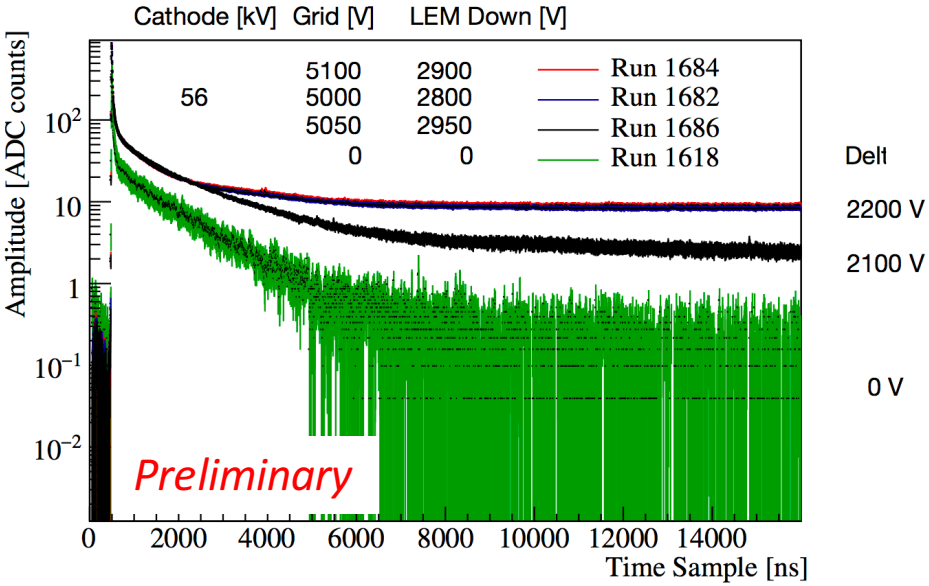
Charge data (no noise filtering)

Light data

3x1x1 Preliminary Results

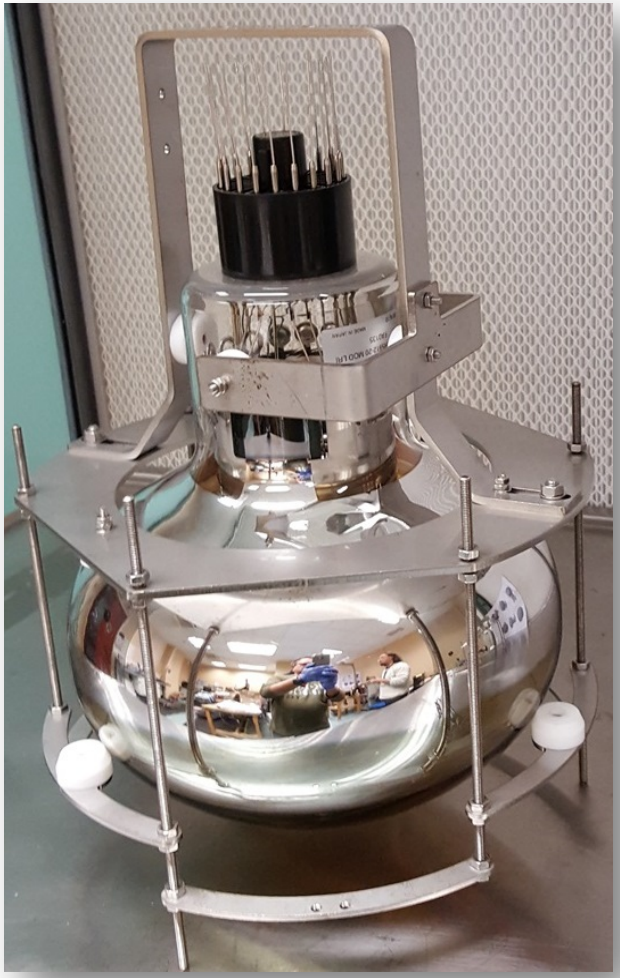
- **Commissioning preliminary results:**
  - **LAr purity studies**: The slow scintillation component can be monitored run by run on every PMT
  - **S1 and S2 studies**: determination of best operating conditions





- **Light analysis signals on-going**:
  - Response to muon interactions
  - Light & charge correlation
  - Data to simulations comparison (adding photon detection system)

PMT testing at CIEMAT



1. **Validation** of PMT base and detailed characterization of PMT response at warm and cold

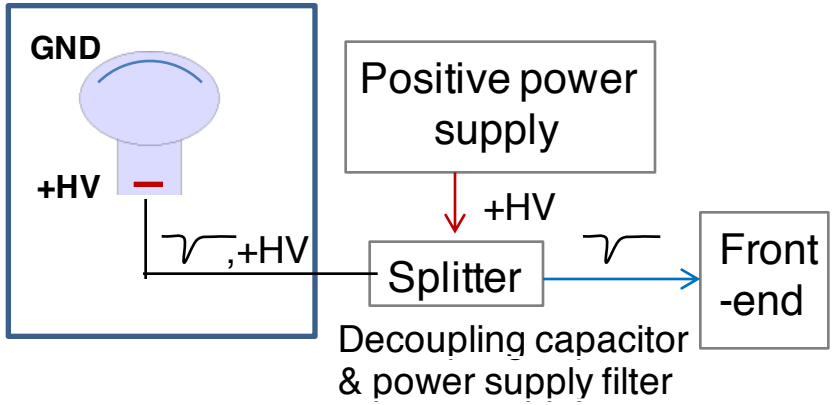
2. **Characterization** of the 40 PMTs before their installation in the 6x6x6 m^3 detector

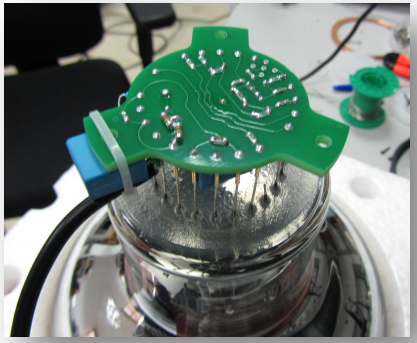
Measurements:

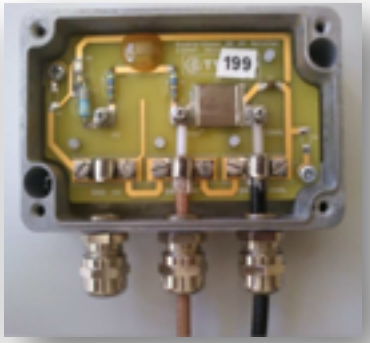
- Gain - operating HV
- Dark current rate - rejection of noisy PMTs
- Light frequency linearity - saturation range
- Light linearity - range for linear response

PMT base circuit

- Design: 1 cable base (positive HV) + ext. Splitter



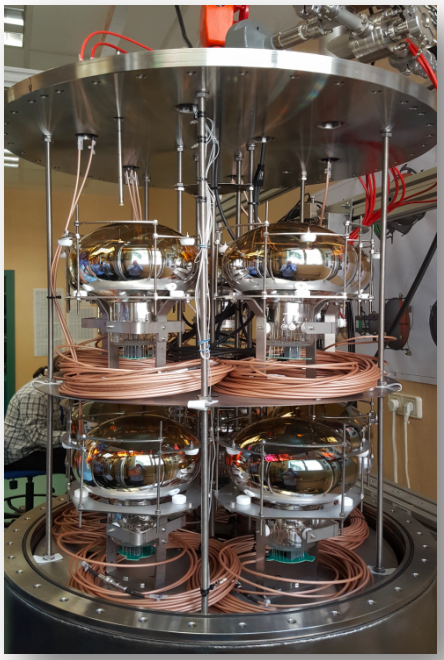




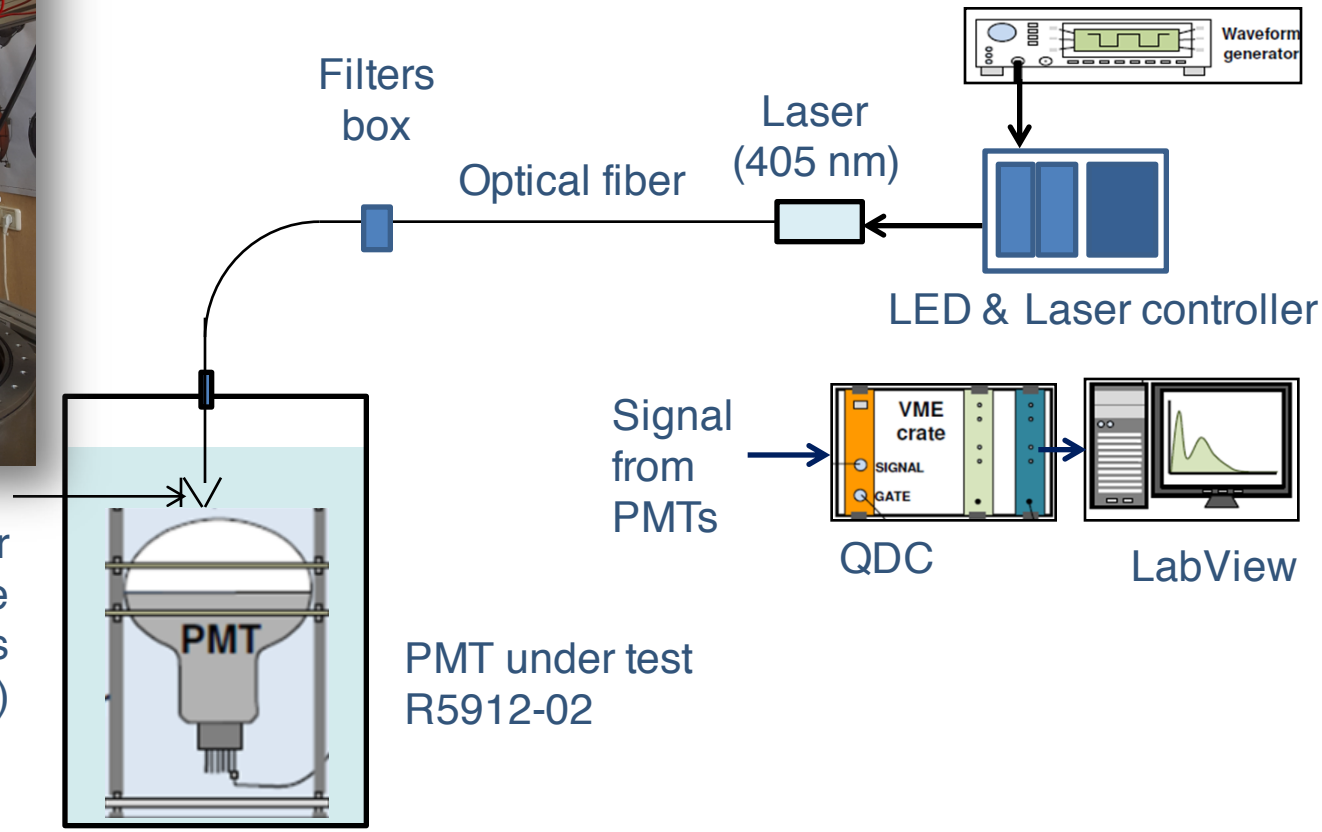
The splitter decreases the effective voltage by a small per cent, but reduces the number of cables.

- All the PMT bases have already been mounted, cleaned and tested at CIEMAT
- The PMT bases have been soldered to the PMTs

PMT characterization - setup

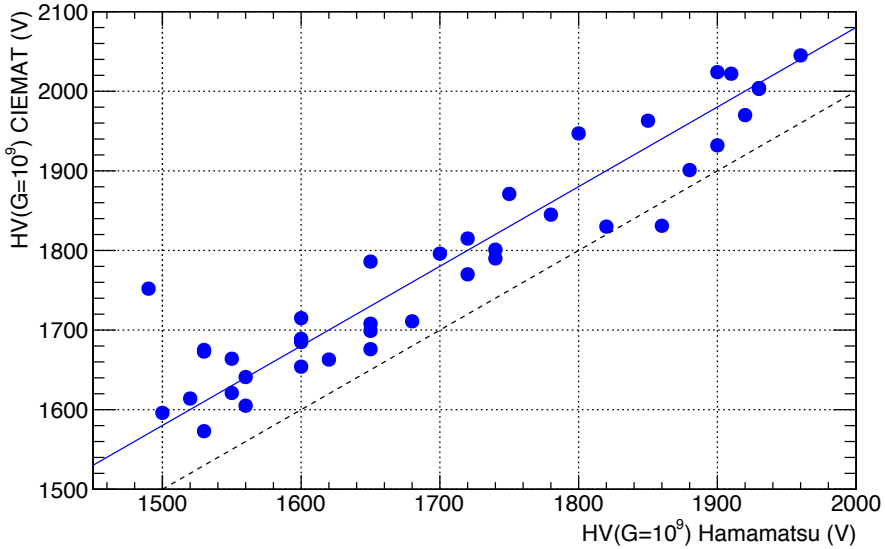


Designed to test PMTs immersed in LN2 with a configurable amount of light



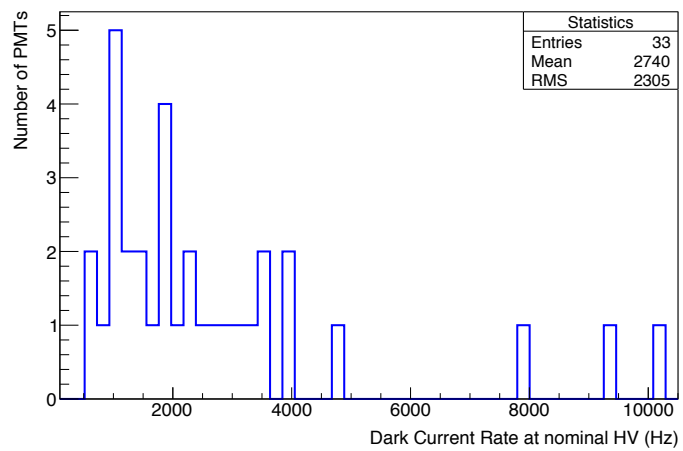
Room temperature results

- **Gain:**



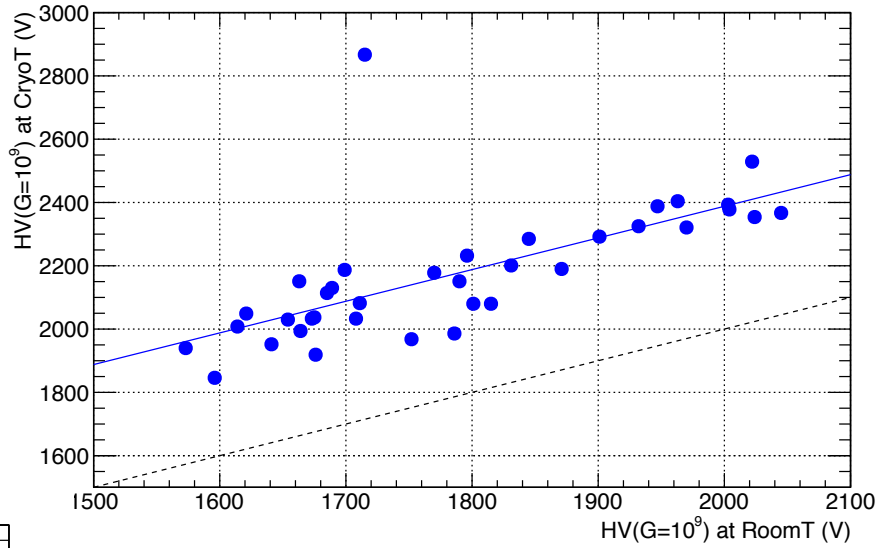
Blue solid line:
CIEMAT voltages are 80 V above the Hamamatsu values, expected by splitter configuration

- **Dark current:**
  expected rates, some PMTs under investigation

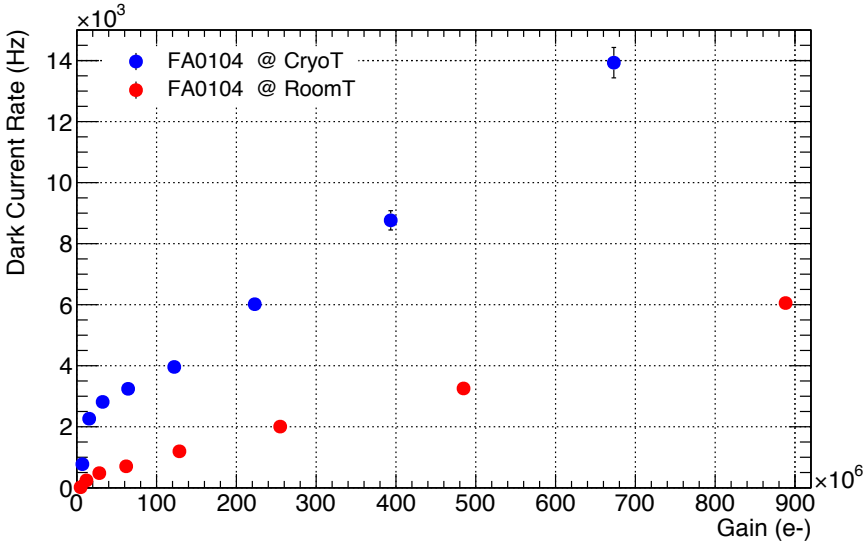


Cryogenic temperature results

- **Gain:** The voltages for the nominal gain (10^9 e^-) at cryogenic temperature are 388 V higher (22% higher on average) than the values obtained at room temperature



Blue solid line:
388 V above the RT voltage

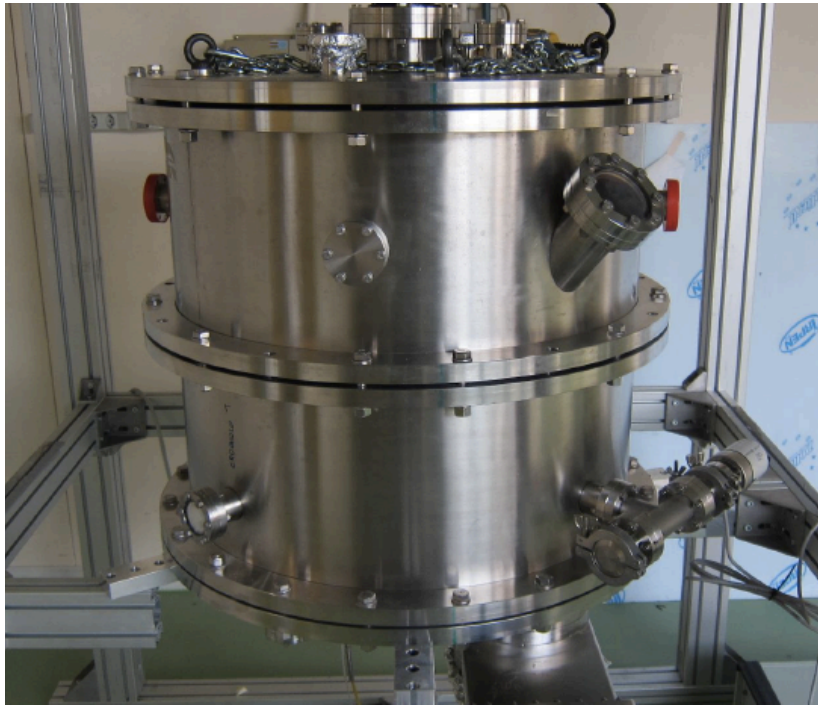


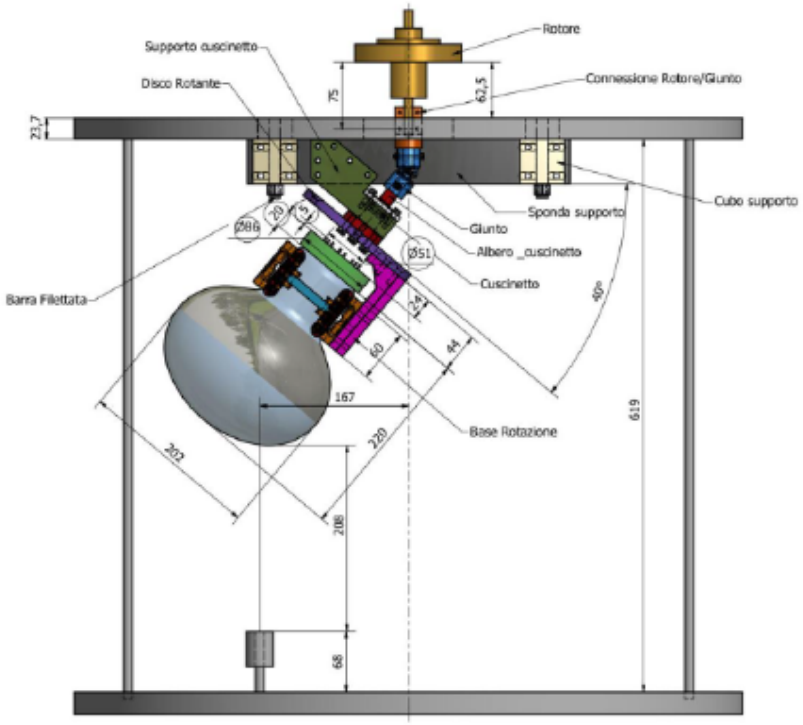
- **Dark Current:** For a given gain, DC is typically higher at CT thant at RT.

On-going data taking
- Light frequency linearity
- Light linearity

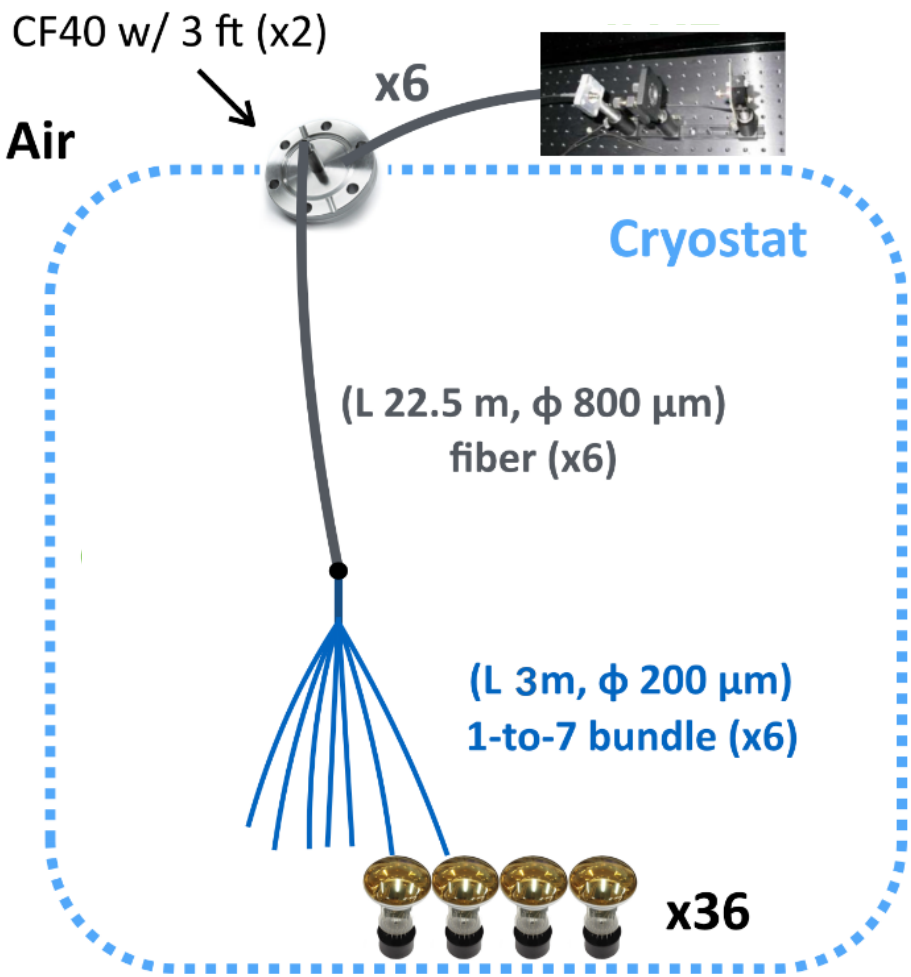
TPB coating

- Reuse the setup available at CERN for the PMTs of the ICARUS experiment
- Evaporator + vacuum pumps + quality assessment of coating





Light Calibration System



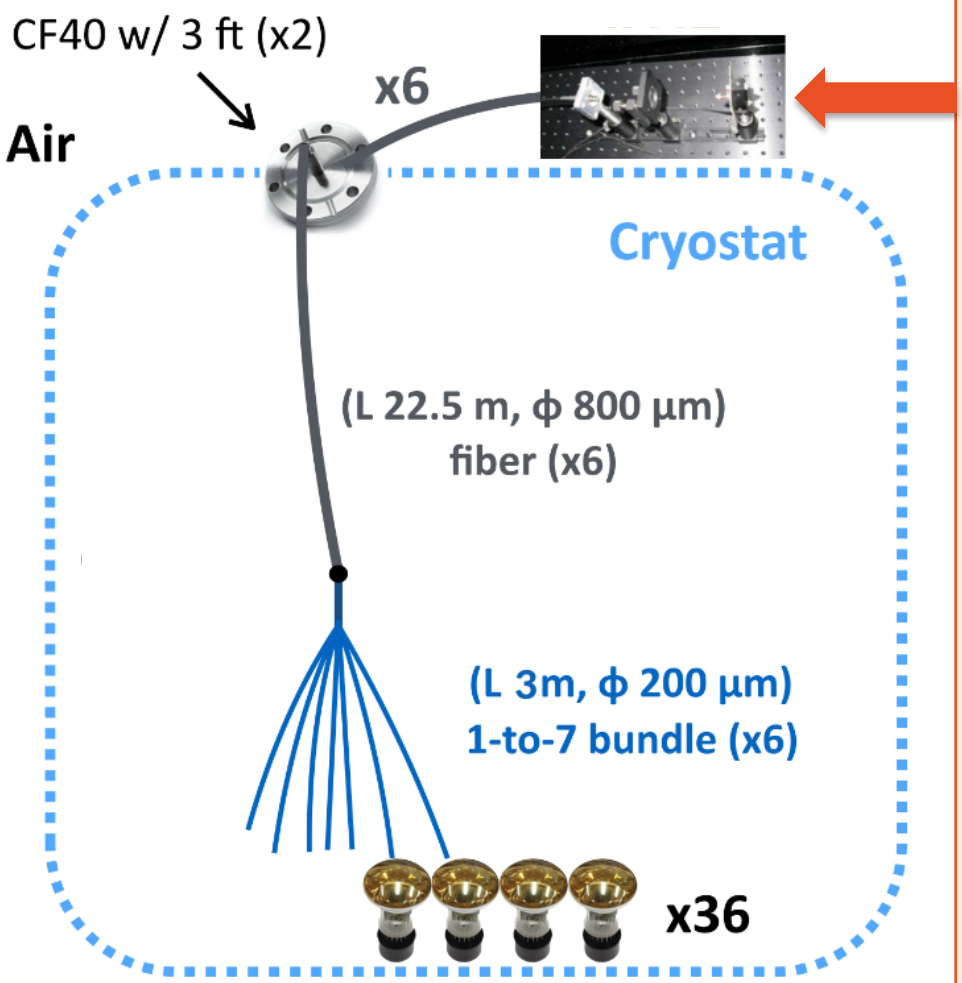
Goal:

- Determine PMT gain (SPE)
- Study PMT stability

Components:

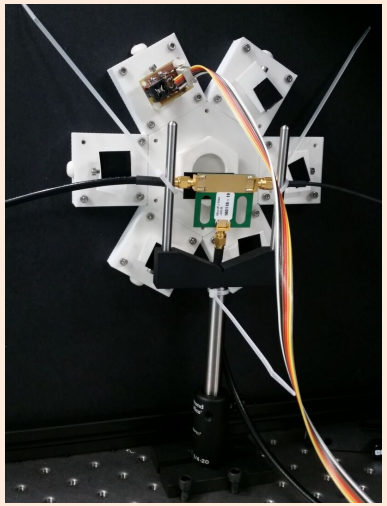
- Black box with light source (Kaputschinsky LEDs) outside of cryostat
- 6 fibers going to cryostat
- 2 CF40, each with 3 optical feedthroughs
- Inside the cryostat (6x):
  - 22.5 m fiber
  - 3 m 1-to-7 bundle

Light Calibration System



SOURCE

- Blue LED of 470 nm
- Kapuschinski circuit as LED driver
- 1 LED connected to 1 fiber going to one optical feedthrough
- 6 LEDs in total placed in an hexagonal geometry
- Direct light to fiber, stray light to reference sensor
- 1 reference sensor in center: Sensl SiPM



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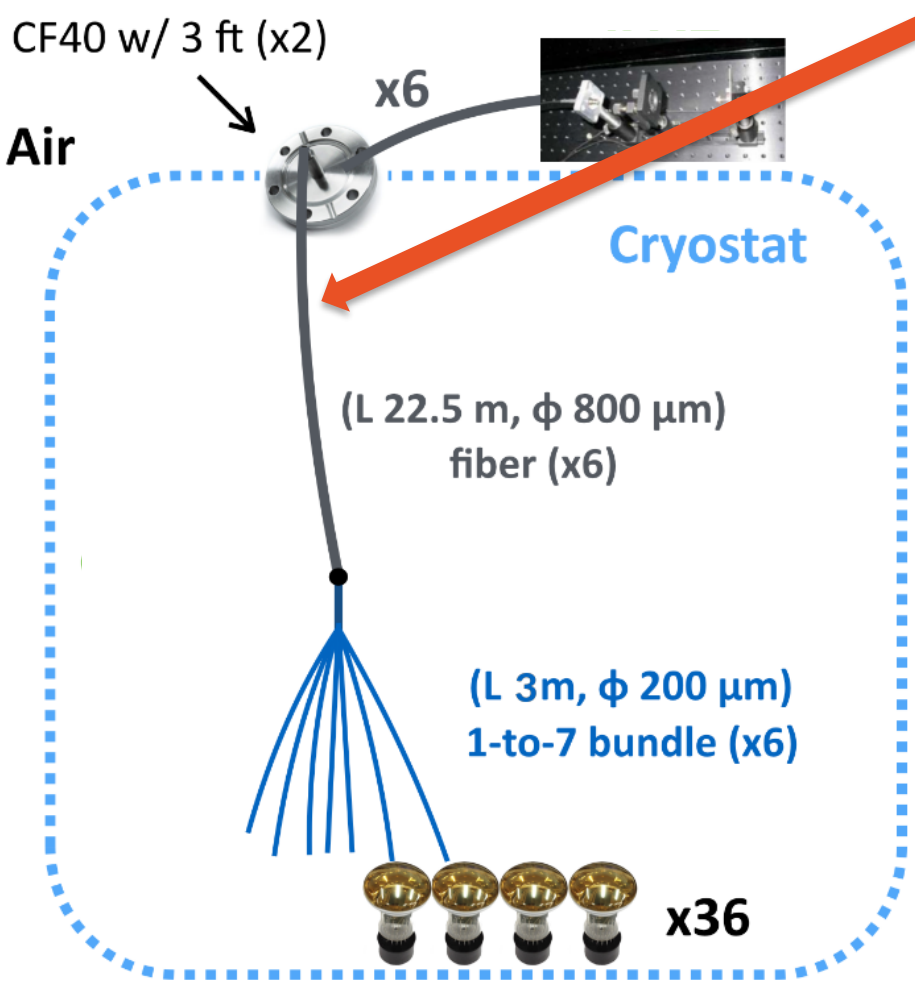

INNER FIBERS

- Selected to minimi-ze light loss (0.2% light transmission, losses dominated by surface reduction)
- Full system tested at CT to study mechanical performance and light output.
- Input power measured with a power meter compared to PMT response.

Conclusions

- The first WA105 results (from the 3x1x1 m^3 detector) the cosmic muons are available: the performance of the first prototype is being successful and we are obtaining valuable experience for the upcoming projects.
- The construction of ProtoDUNE-DP (the 6x6x6 m3 detector) is in progress and it is expected to start taking data with cosmic rays and the charged-particle beam before CERN LS2.
- The 40 PMTs characterization at CIEMAT for ProtoDUNE-DP is almost finished and the final configuration for the light calibration system is being tested.
- We will learn a lot about neutrinos in the next decades and DUNE will be a crucial experiment as well as an enormous challenge.