Dual-Phase
Photon Detector Calibration

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DUNE FD Calibration Workshop

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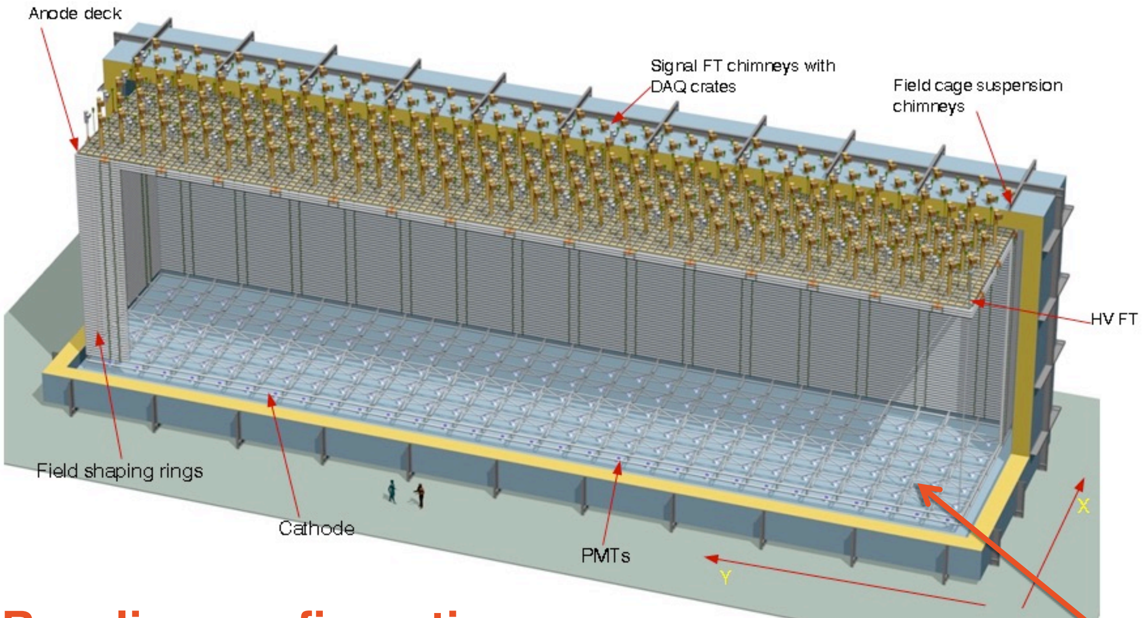
Outline

1. DUNE FD DP Photon Detection System
2. Light Calibration System (LCS)
3. ProtoDUNE-DP LCS
4. R&D measurements
5. Validation tests
6. LCS requirements

1. DUNE FP DP Photon System



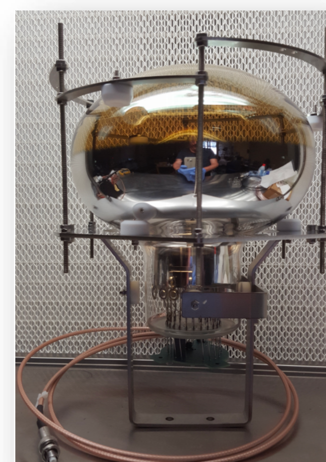
Goals

- t_0 for both beam and non-beam events
- Trigger for non-beam events

Baseline configuration

- **8" Hamamatsu R5912-02mod PMTs**
- 1 PMT/m^2 (720 total) fixed at the membrane floor
- Wavelength-shifter: TPB coating on PMT
- Voltage divider base + single HV-signal cable + splitter
- Light calibration system
- DAQ system (external)

PMTs



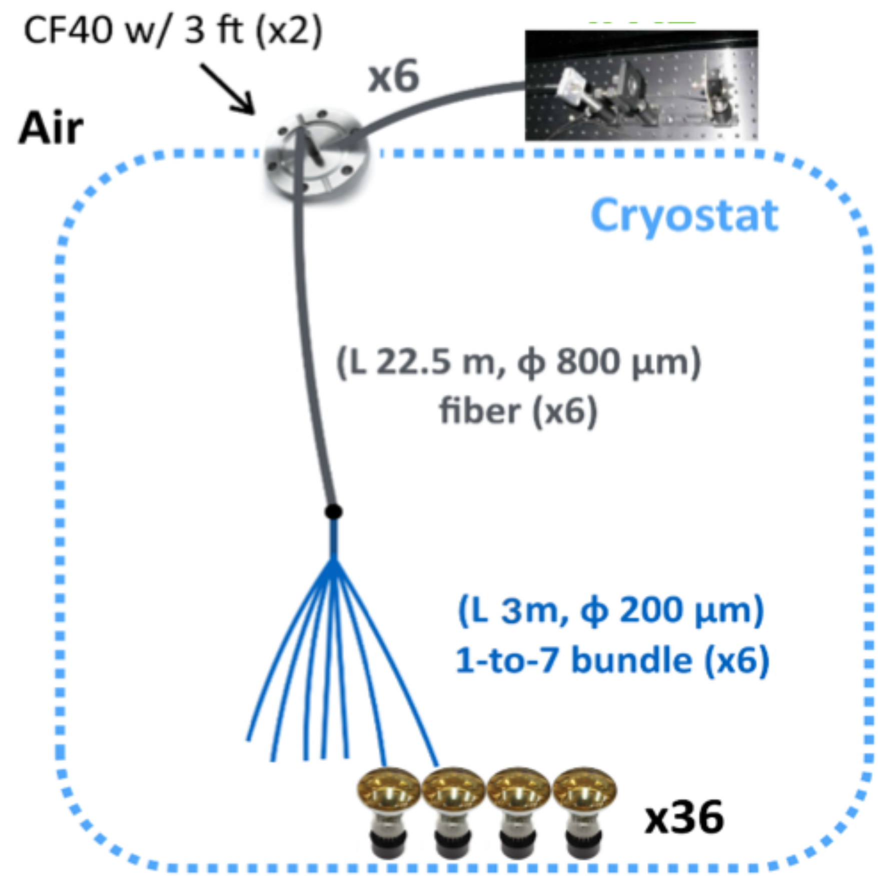
2. Light Calibration System (LCS)

Goals
- Determine PMT gain
  (record single-photoelectron spectrum)
- Study PMT stability to identify and correct for gain shifts
  (PMTs are biased independently)

Main components
- External light source (LED)
- Optical fibers (external and internal)
- Flange feedthroughs
- Diffusers (to be studied)

Design
- Baseline design: same as ProtoDUNE
- R&D to reduce the number of fibers

3. ProtoDUNE-DP LCS



C. Cuesta et al. Photon detection system for ProtoDUNE dual phase [JINST12 (2017) C12048]

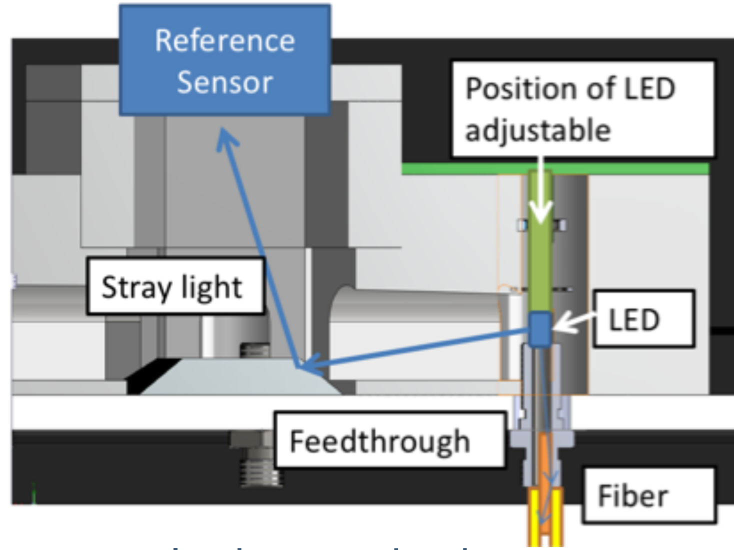
Goal
- Determine PMT gain (SPE)
- Study PMT stability

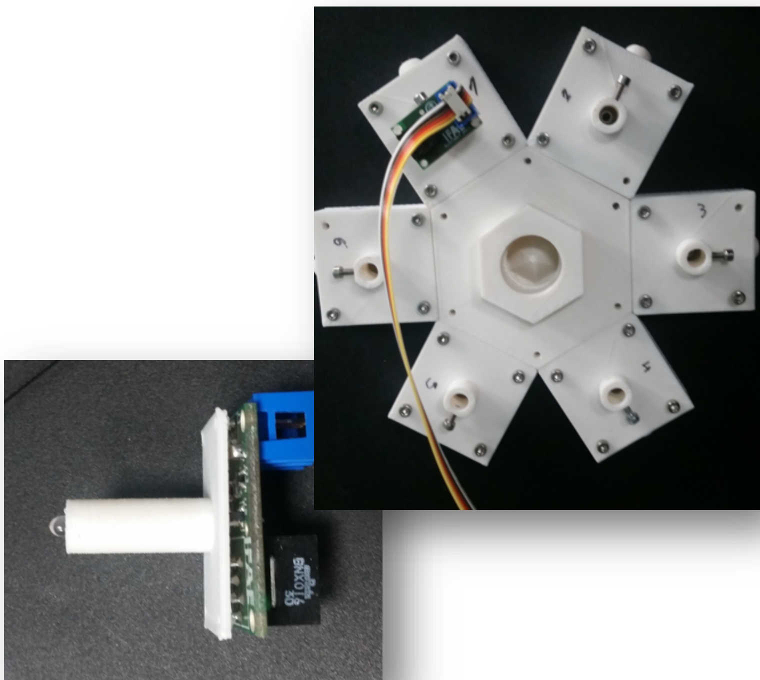
- Black box with **light source** (6 Kaputschinsky LED drivers) and reference sensor
- Out of the cryostat: 6 fibers to cryostat *Thorlabs, ϕ 1000-μm, M59L01*
- 2 **CF40**, each with 3 optical FT *Allectra*
- Inside the cryostat (6x):
  - **22.5-m fiber** *Thorlabs ϕ 800-μm, FT800UMT, SS jacket*
  - Matting sleeve *- vacuum compatible*
  - **3-m 1-to-7 bundle** → 1 fiber per PMT *Thorlabs ϕ 200-μm, FT200UMT, SS jacket common end, black jacket at split ends*

  All fibers with SMA connectors

3. ProtoDUNE-DP LCS: Light Source

- Central **reference sensor (SiPM)**
- 6 **Kaputschinsky PCBs** around each LED (460 nm) with light cavity to guide light to reference sensor
- Material: 3D printed plastic

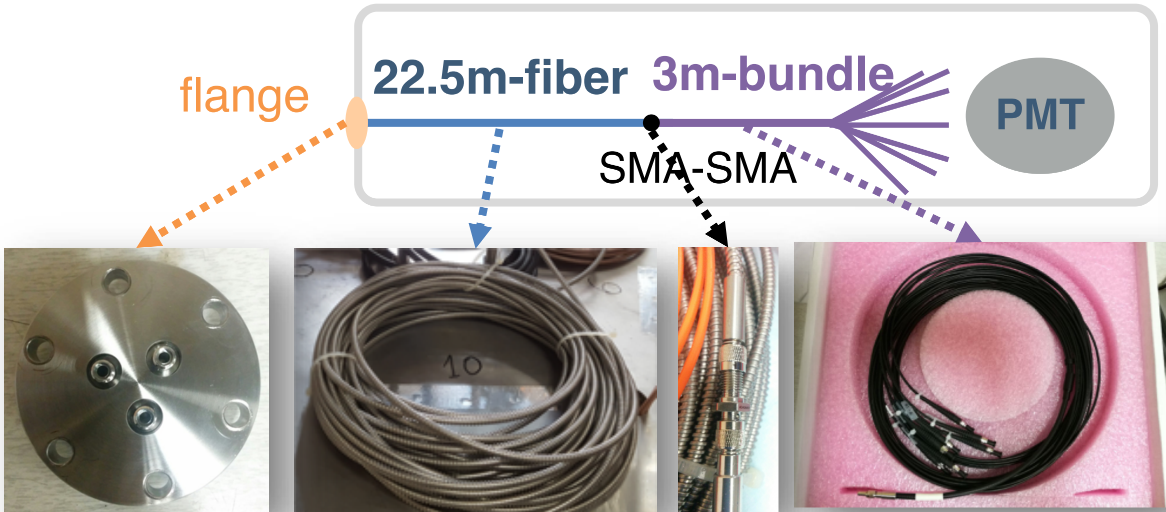




PCBS:
- 12 PCBs currently characterized
- Tested and system characterized preliminary
- Differences between PCBs much larger than positioning issues
- Reduction methods tested to get SPE

Reference sensor
- Full system probe of concept is done
- Reference sensor board design finished and characterization ongoing
- Developing software

3. ProtoDUNE-DP LCS: Inner System



All components available and tested at CIEMAT

- PMT orientation not relevant
- SPE spectrum does not show anomalous events

Attenuation measurements

- **Source:** LED with Kaputsinsky driver, and laser
- **Sensor:** power meter and PMT
- Conditions: **RT and CT**

Expected and measured light attenuation of the inner system ~20 dB (~1% light transmission)

Full system to be tested at CIEMAT in April

4. R&D measurements

- **Reducing the amount of fibers** (1 fiber/PMT) would simplify the installation and reduce the cost
- To reduce the number of fibers, **light diffusers or reflectors** will be investigated.
  For example, one fiber could illuminate 4 PMTs placing a diffuser at the ground grid. For this, ground grid dimensions and R&D measurements are needed.
- In case Kaputschinsky LED drivers present issues in ProtoDUNE-DP or a higher light intensity is required, **a laser** could be used

R&D measurements and light simulations will be performed to investigate the different options

5. Validation tests

- The final design will be **validated at RT and at CT** (LN_2) at the institutions labs with PMTs and power-meters.
- **Basic characterization measurements** will be performed on the fibers upon receiving them. Light will be provided with a known source and the output measured with a power-meter.
- **During the installation**, each fiber and source will be re-tested. A dedicated procedure will be designed.

6. LCS Requirements

Dedicated calibration runs with a dedicated software

- **Trigger:** TTL signal provided by the light source
- **Digitization:** single-photoelectron spectrum needs to be recorded. For PMT stability studies a configurable higher amount of light is possible
- **Software:** on-line visualization and automated gain calculation
- **Data:** 10^3 events per PMT per calibration run
- **Calibration runs** to be performed regularly and every time PMTs are biased
  If light is not completely homogeneous among PMTs, different runs for PMT-sets will be needed.

Summary

- **FP DP photon detector calibration goals:**
  - Determine PMT gain
  - Study PMT stability to identify and correct for gain shifts
- **ProtoDUNE-DP** design validated:
  - Black box with 6 LEDs (+1 SiPM) outside the cryostat
  - 6 fibers into the cryostat divided at the end in 7 fibers arriving to each PMT)
- ProtoDUNE-DP design as baseline, improvements to be determined with **R&D measurements**.