Characterization of FD2-VD X-ARAPUCA modules at CIEMAT

CIEMAT Neutrino Group

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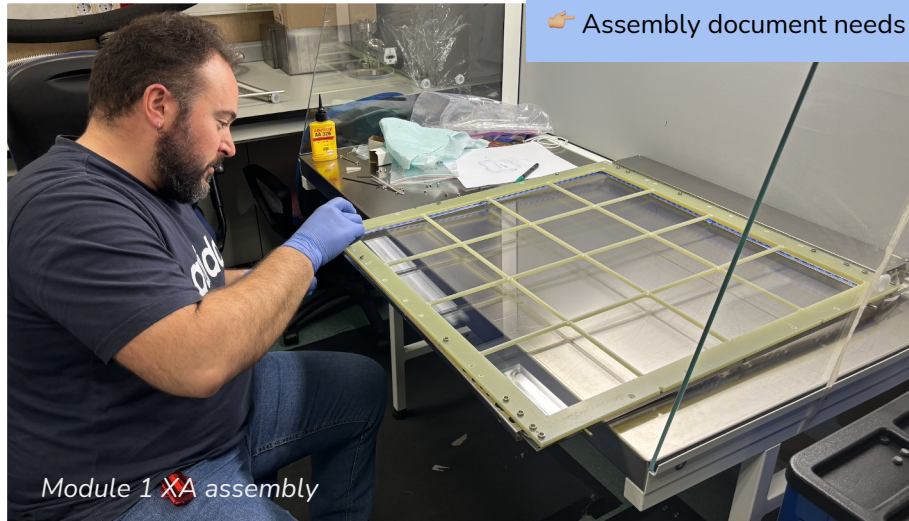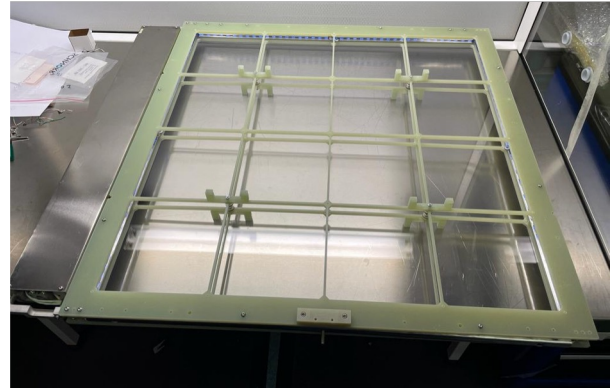
13th December 2023

Mounting FD2-VD X-ARAPUCA modules

- July 2023 membrane XA assembled for PDE measurement following the procedure of document *V5 Module Assembly Procedures.*
  Configuration:
    - 160 FBK-TT SiPMs
    - G2P 60x60 cm bar w/o dimples
    - ZAOT filters

- November 2023 2x cathode XAs assembled for Module 1 following *VD PDS Assembly Guide* and shipped to CERN

👉 Assembly document needs update

Module 1 XA assembly
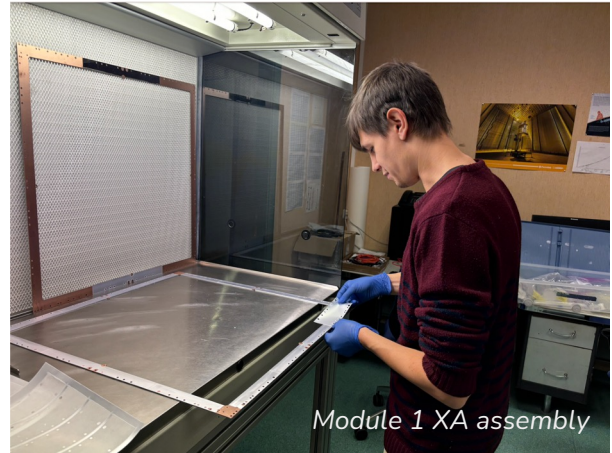
Module 1 XA assembly

# New setup for characterization of FD2-VD X-ARAPUCA modules at CIEMAT

- PDE measurement in 3 positions of the X-ARAPUCA module covering hte area of one filter with new-designed calibration boxes (α-source + VUV SiPM reference sensors + laser)
- Same methodology, same cryogenics system, bigger vessels to allocate larger X-ARAPUCA modules

LAr

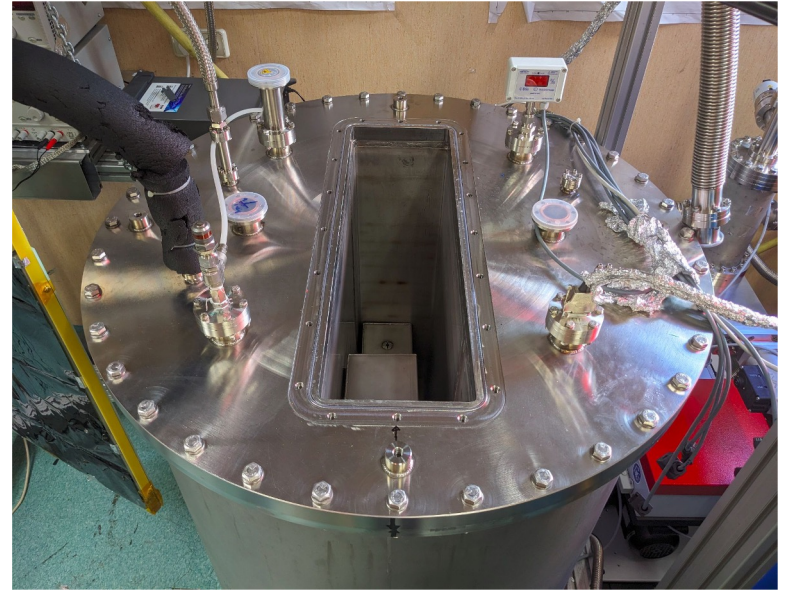80 L

LN2

Dewar wall

1231

800
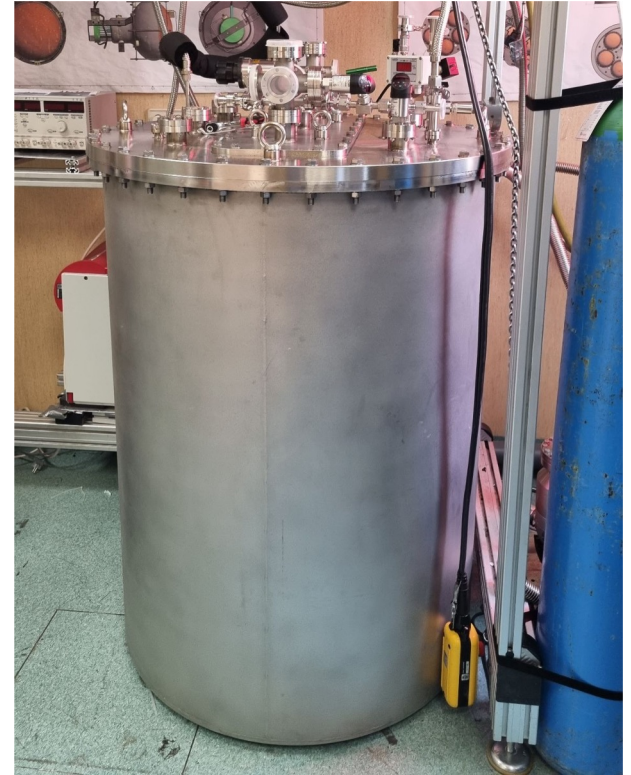
1000

1170

⌀905

500 L

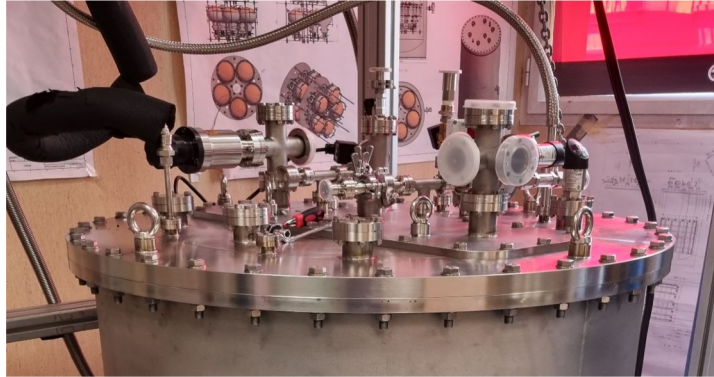Calibration boxes
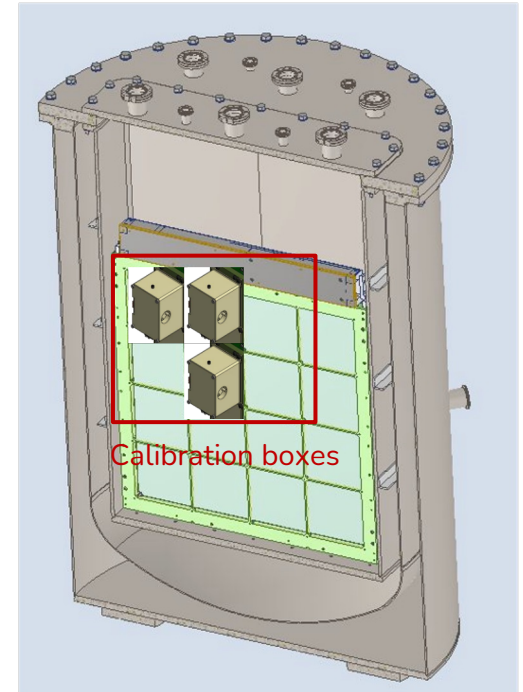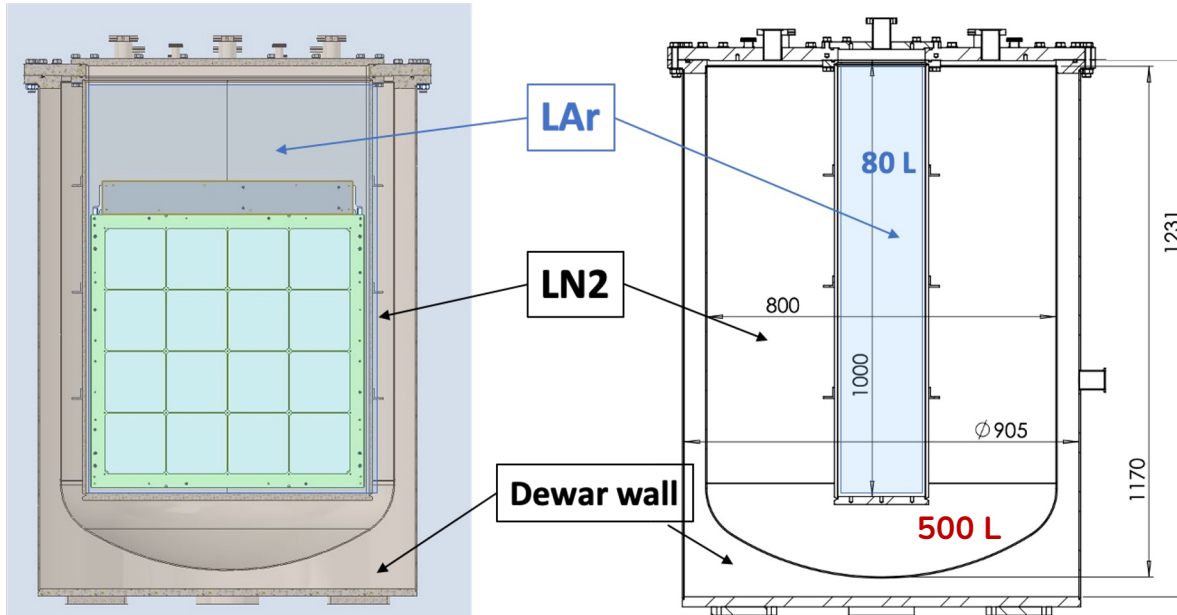
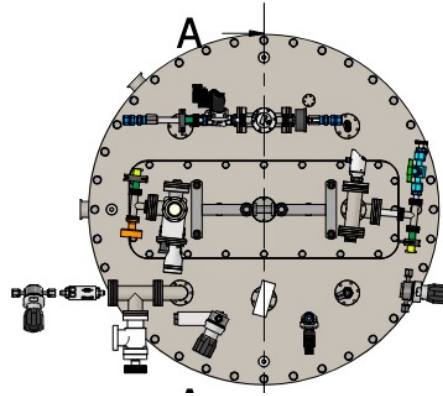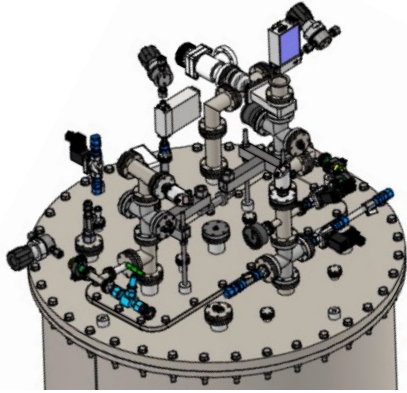# FD2-VD XA PDE setup: internal volume

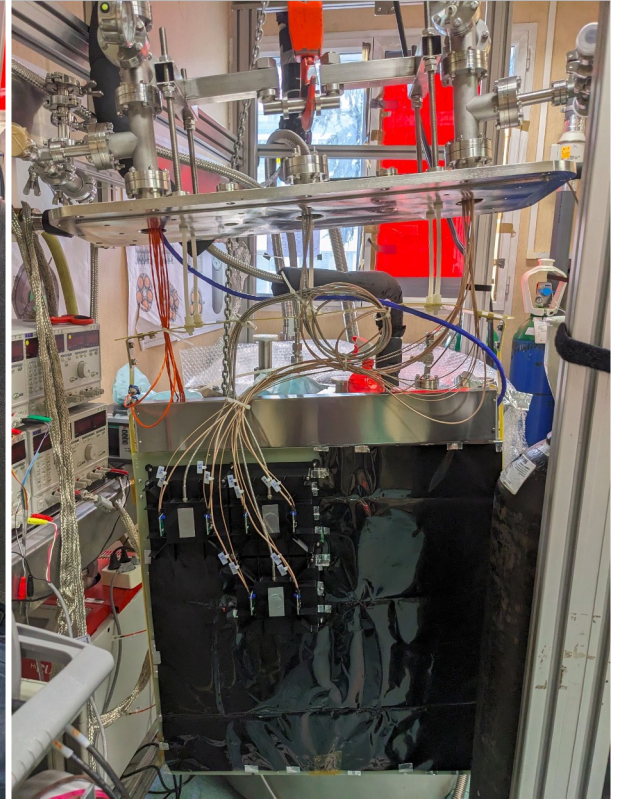# FD2-VD XA PDE setup: floats
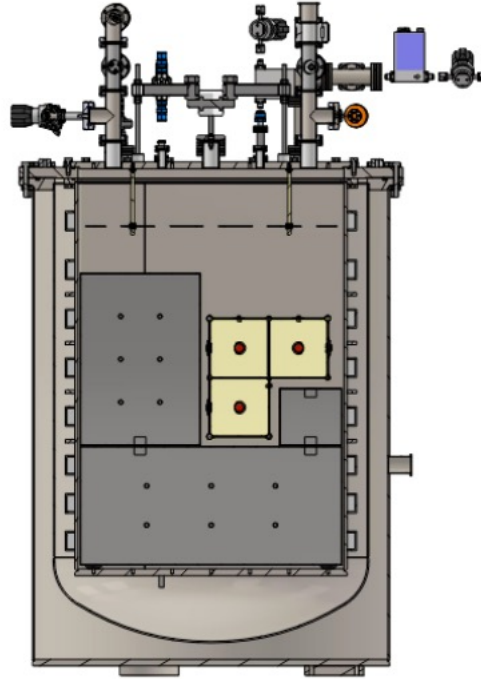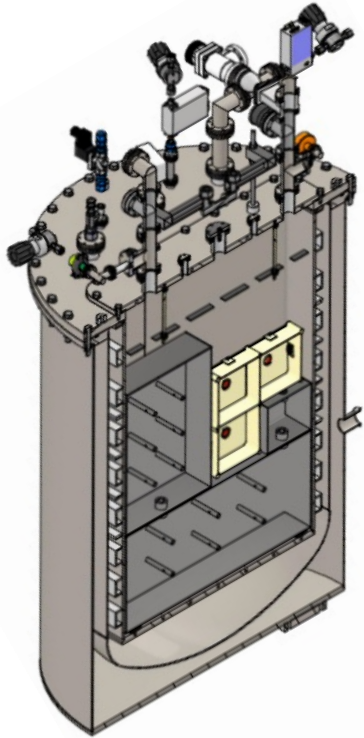
To reduce LAr volume

FD2-VD XA PDE setup: external volume

FD2-VD XA PDE setup: XA insert

Commissioning of setup for FD2-VD XA PDE measurement

- August 2023: LAr setup commissioning

- September 2023: gain calibration and noise characterization in LN_2

- Fall 2023: Setup improvements:
  - LAr vessel gasket
  - New design of black boxes
  - SiPMs boards and cables
  - Low-mass cables for temperature sensors
  - Solid-state relay
  - Vacuum system: pressure regulator, flux meter

August data taking campaign
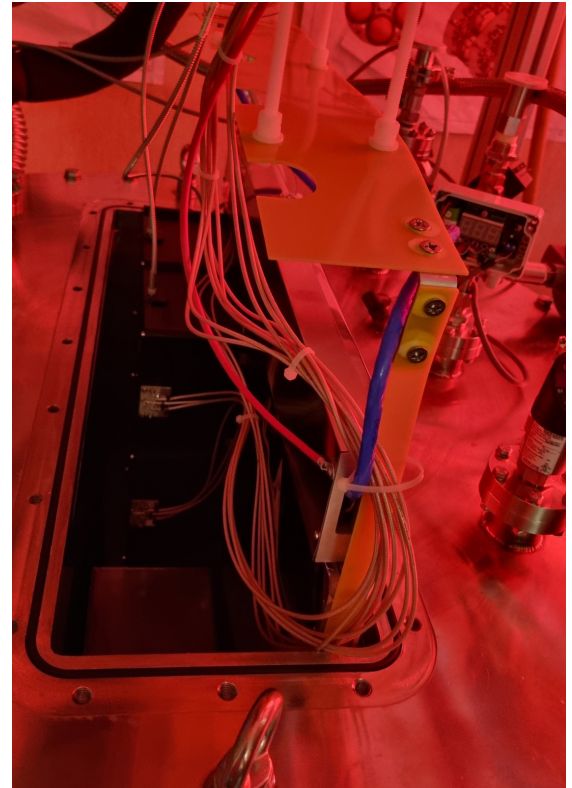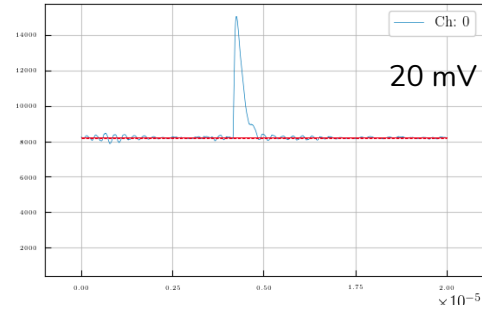
FD2-VD X-ARAPUCA calibration in LN$_2$

Calculation of the amplification factor (gain) of the new electronics with a controlled input from a pulse generator:

$$\frac{Q_{out} \left[(ADC \cdot ticks) \cdot (2V/2^{14}ADC) \cdot 4ns\right]}{Q_{in} \left[InputV (mV) \cdot 1nF\right]}$$
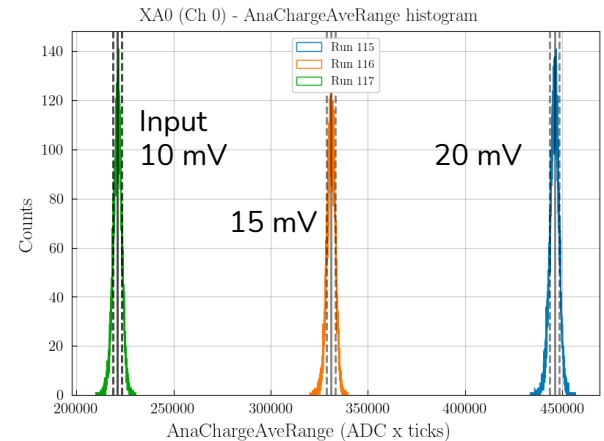
Input V (mV)	Area (ADC/ticks)	Gain
10	221 000	10 780
15	331 000	10 770
20	446 000	10 890

Electronics amplification factor = 10813

Input

20 mV

XA output area

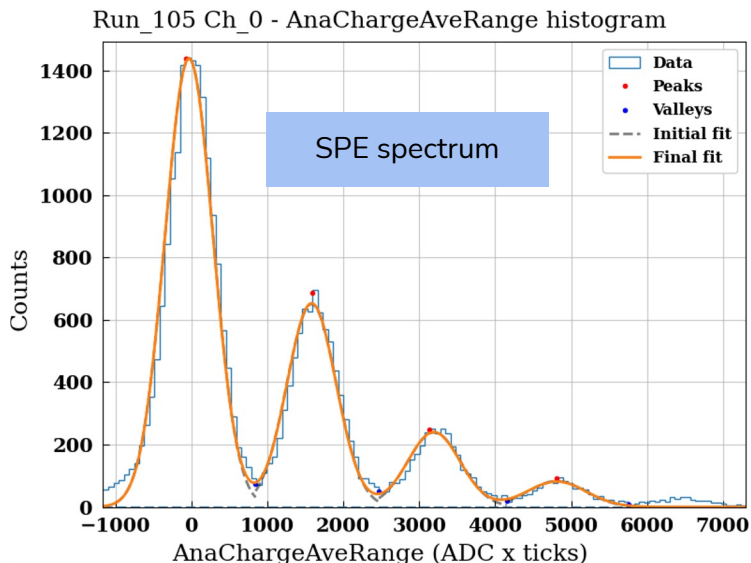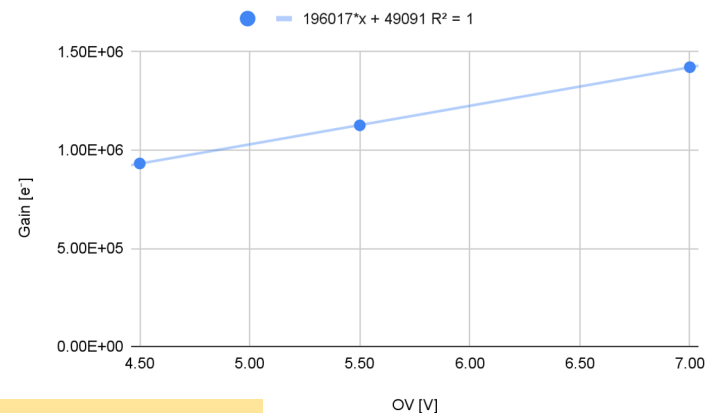XA0 (Ch 0) - AnaChargeAveRange histogram

Input 10 mV

15 mV

20 mV

FD2-VD X-ARAPUCA calibration in LN$_2$

First measurement of FD2-VD X-ARAPUCA gain and S/N at cryogenic temperature in September 2023

Run_105 Ch_0 - AnaChargeAveRange histogram

SPE spectrum

Gain vs OV

Gain & S/N vs OV for the 2 channels

OV	Channel 0		Channel 1	
	Gain (e-)	S/N	Gain (e-)	S/N
7.00	$(1.42 \pm 0.08) \times 10^6$	6.76	$(1.43 \pm 0.16) \times 10^6$	6.46
5.50	$(1.13 \pm 0.08) \times 10^6$	5.67	$(1.12 \pm 0.08) \times 10^6$	4.99
4.50	$(9.32 \pm 0.67) \times 10^5$	5.03	$(9.45 \pm 0.15) \times 10^5$	4.02

Simulation of new calibration box design

Design update based on simulations considering:

- Alpha source pointing towards filter
- Box covering filter and reduced height to increase number of PEs reaching XA.
- SiPMs on the sides of the box, closer than the size of the filter to increase the amount of light reaching them
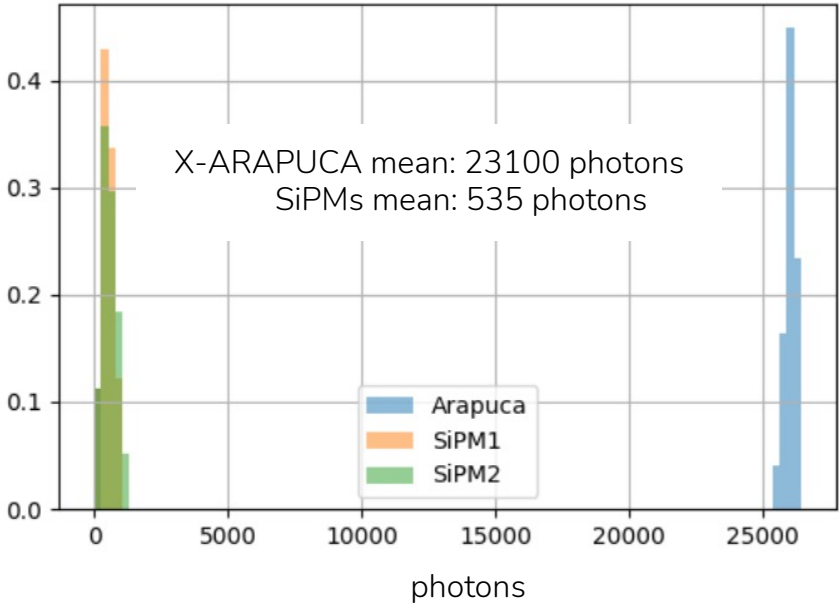- Avoiding shadowing effects.

Alpha source

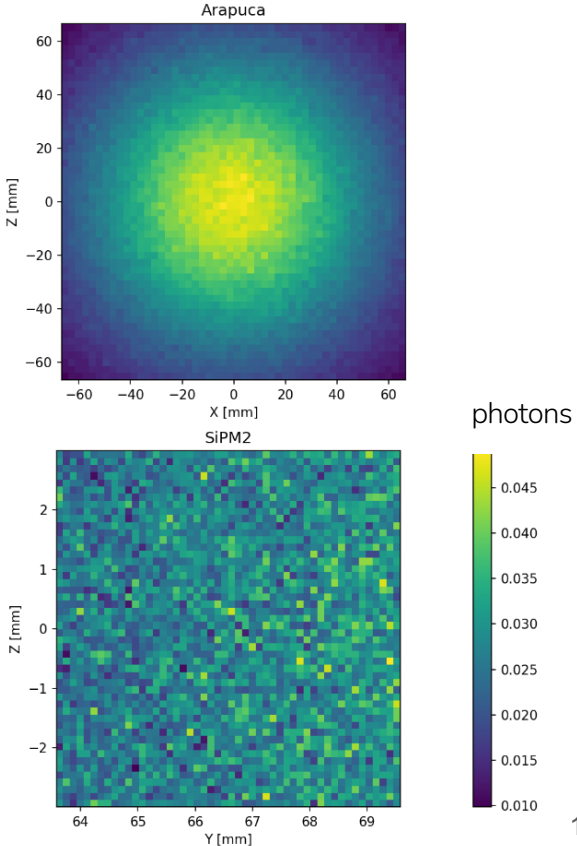SiPM1   SiPM2

XA

Photon incidence angle

megacell_v3_prod_short_tower
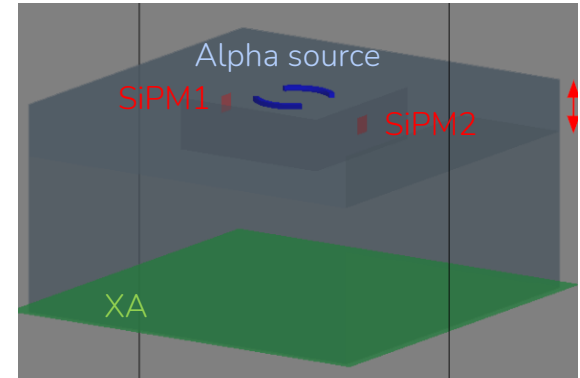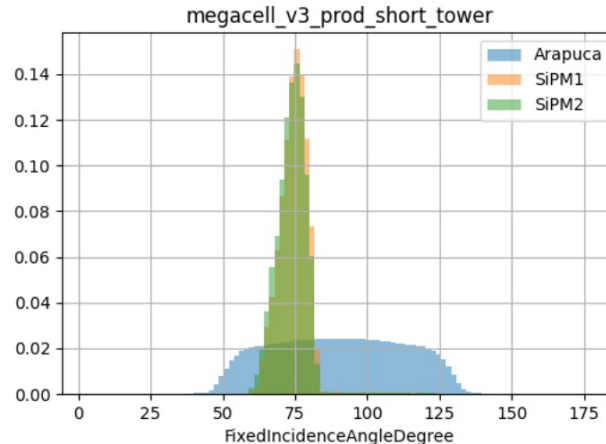
90° = Perpendicular to detector surface

Simulation of New calibration box design

Expected number of photons

Photon distribution in photosensor

X-ARAPUCA mean: 23100 photons
SiPMs mean: 535 photons

New setup design for LAr measurements

Lab pictures of the current setup and components

TOP VIEW
optical fiber

— X-ARAPUCA
— SiPMs
— Alpha Source
— Optical Fiber
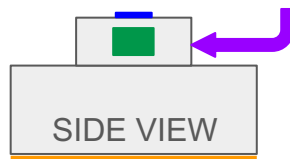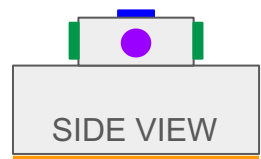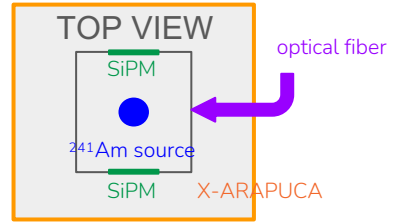
SiPM
^{241}Am source
SiPM
X-ARAPUCA

SIDE VIEW

SIDE VIEW

Calibration Boxes

Optical Fibers

Alpha Sources

SiPM

Characterization Setup

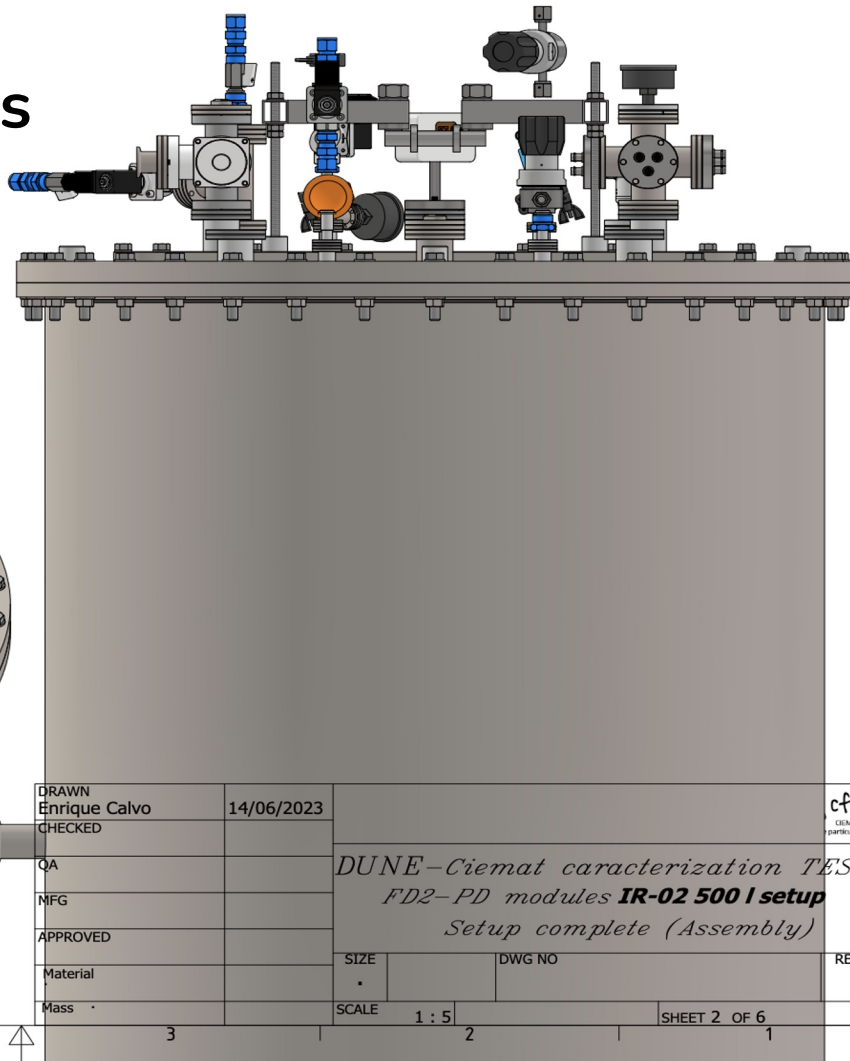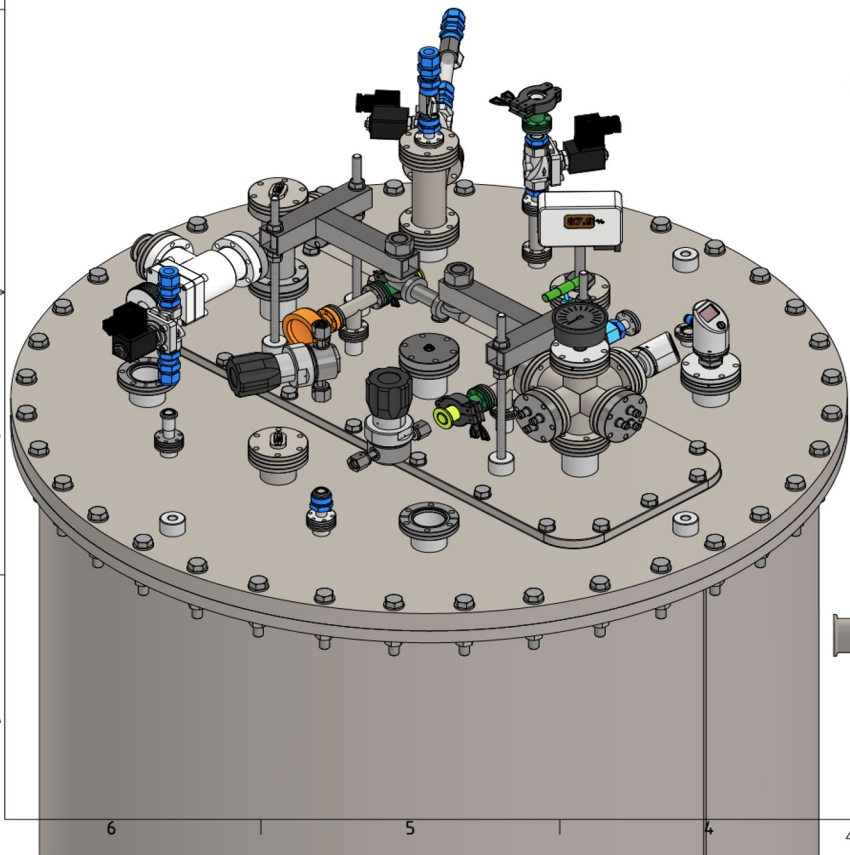**Cryogenic Vessel**

New setup design for LAr measurements
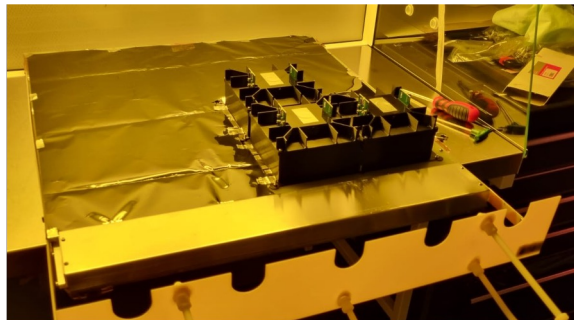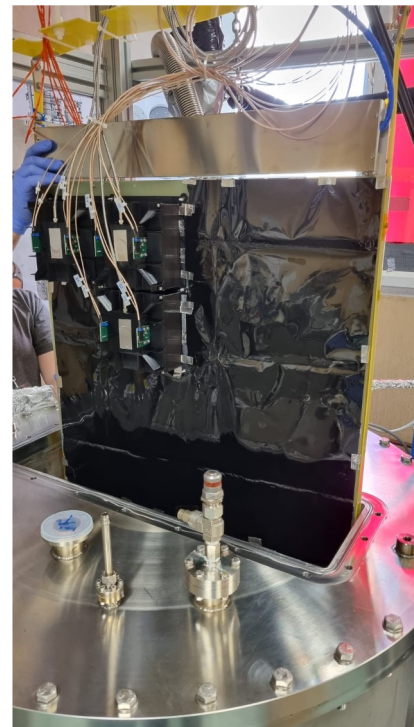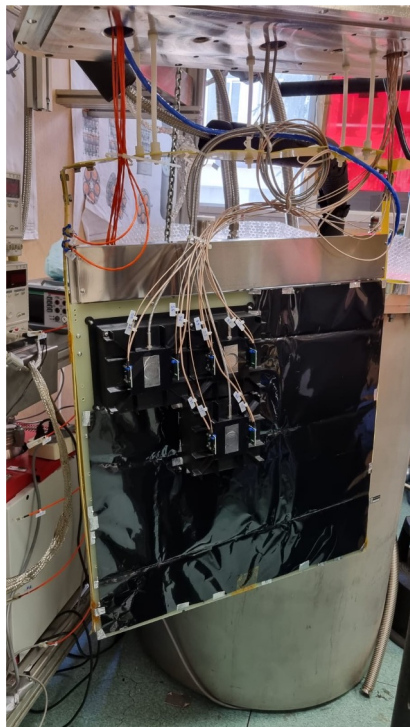
Plans for FD2-VD X-ARAPUCAs PDE measurement

- December 1-12, 2023: vacuum in LAr region with XA and all components installed (reached 1.2 e-4 bar)

- December 12-14: PDE data taking campaign

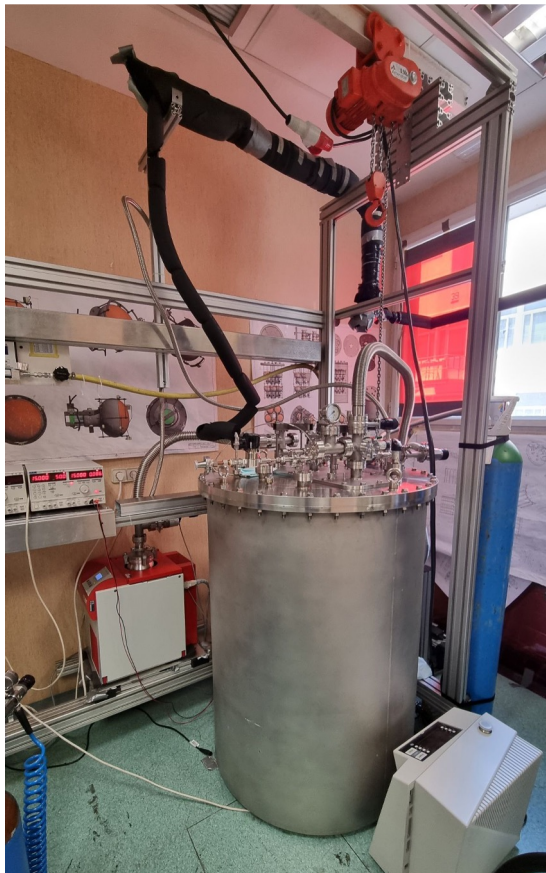- Expect to present FD2-VD X-ARAPUCAs PDE measurement results at CERN collaboration meeting
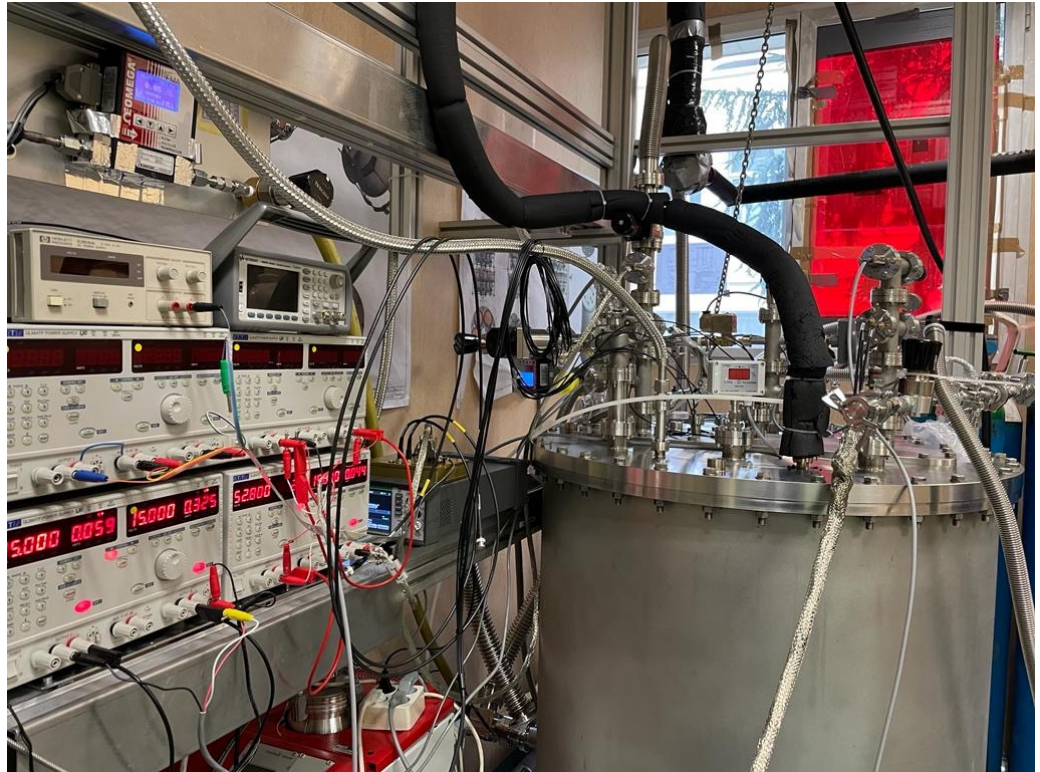
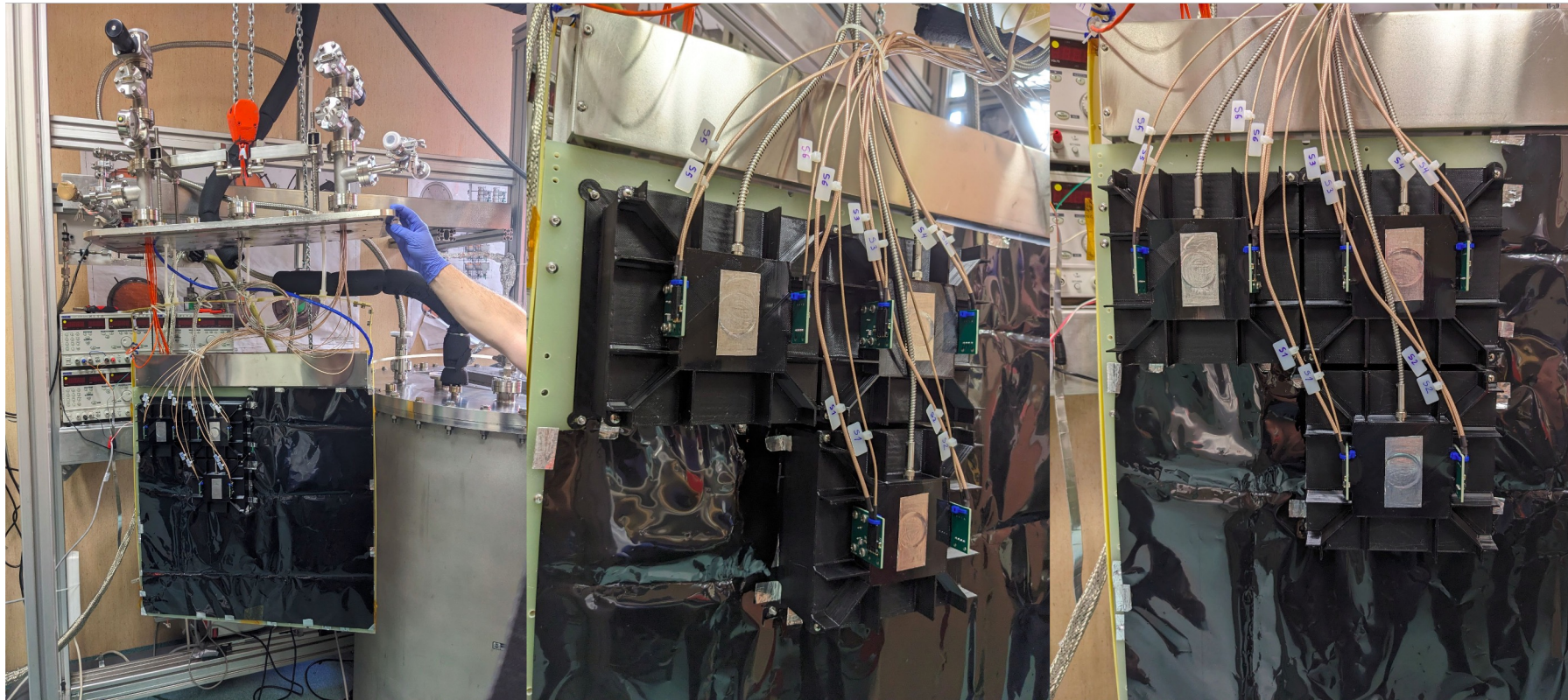# Backup

PDE VD setup preparations

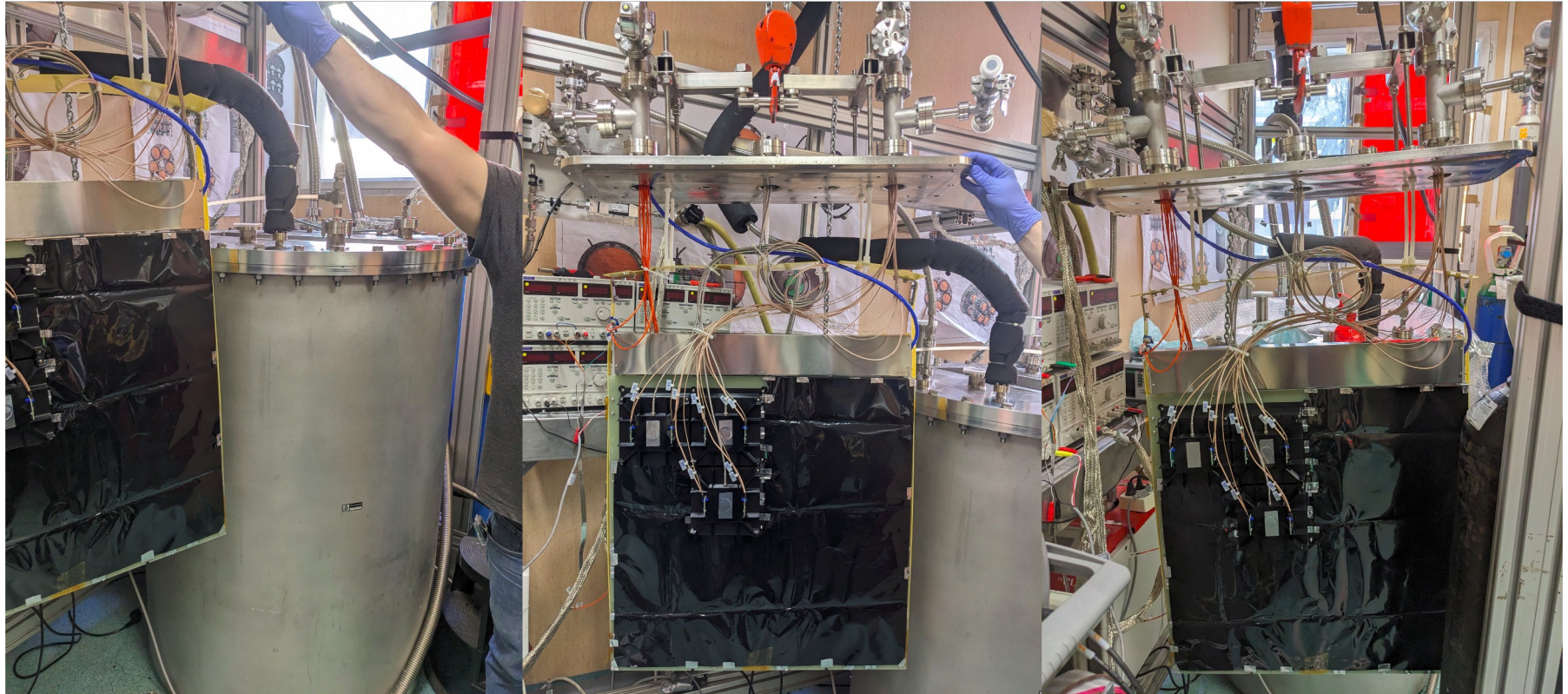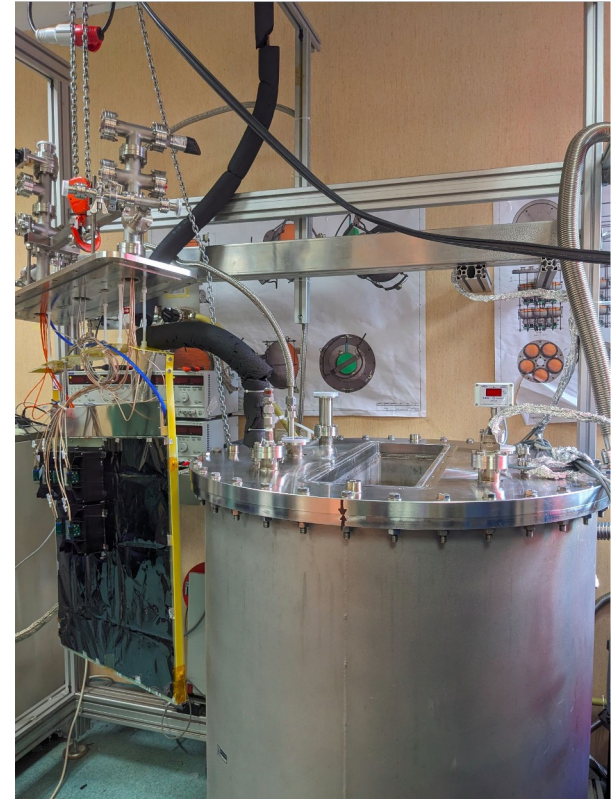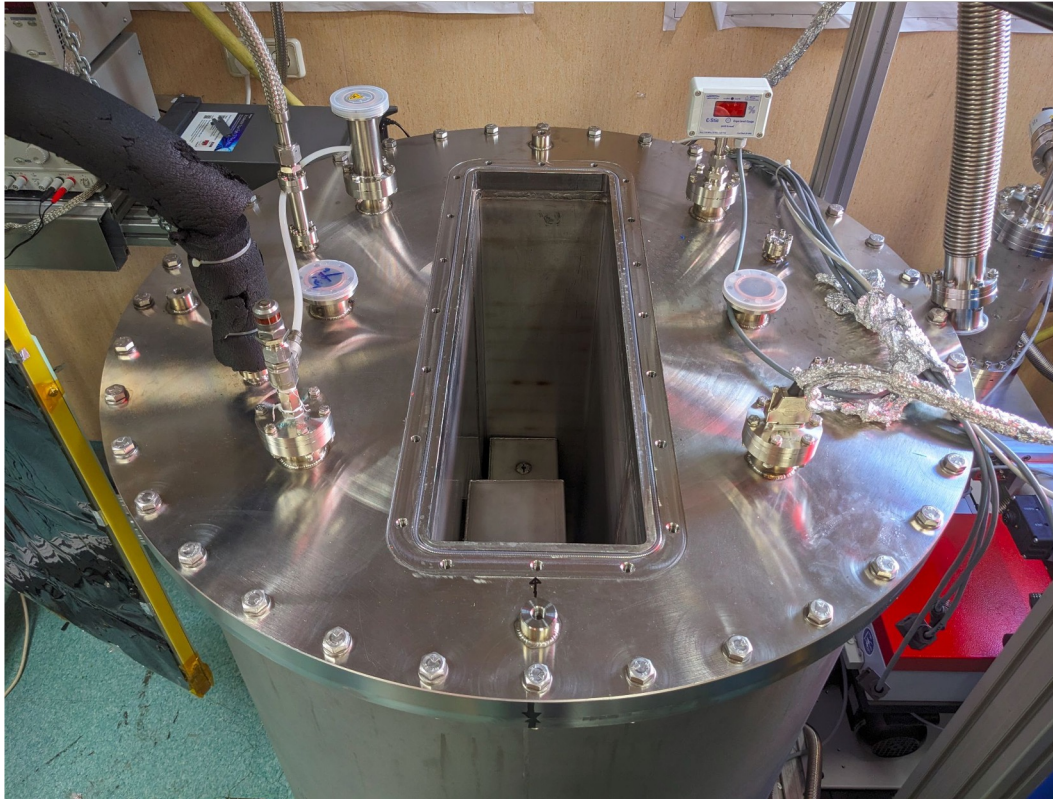| DRAWN Enrique Calvo	14/06/2023		cfp CIEMAT partículas
CHECKED		DUNE−Ciemat caracterization TEST FD2−PD modules **IR-02 500 l setup** Setup complete (Assembly)	
QA			
MFG			
APPROVED			
Material		SIZE ·	DWG NO		REV
Mass ·		SCALE 1 : 5		SHEET 2 OF 6

17

PDE VD setup preparations
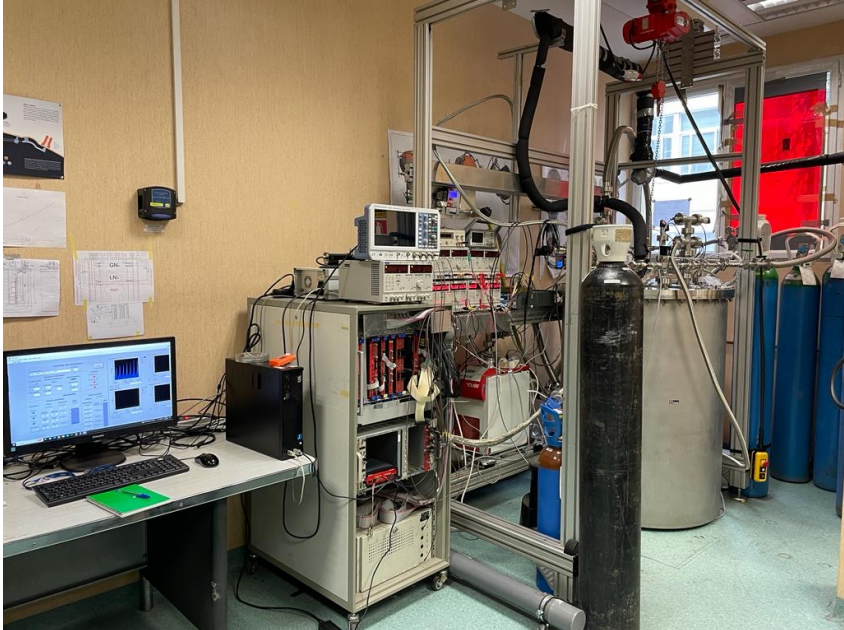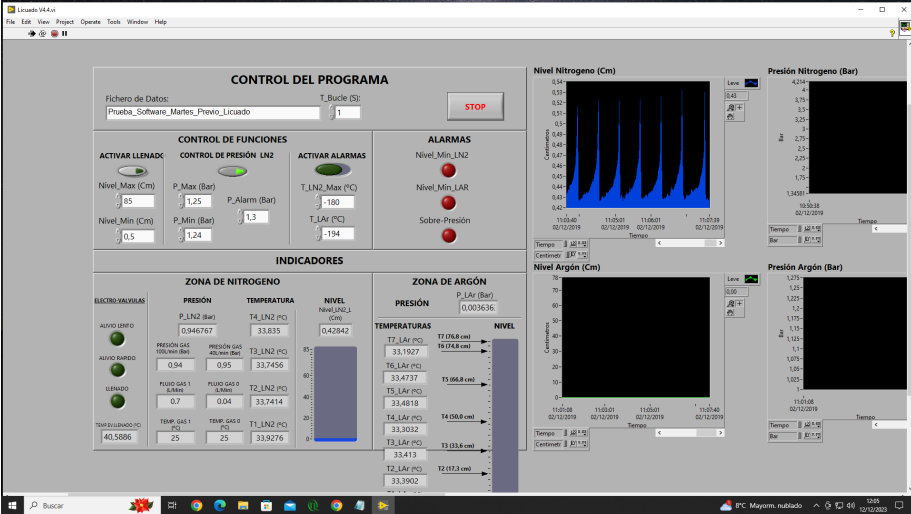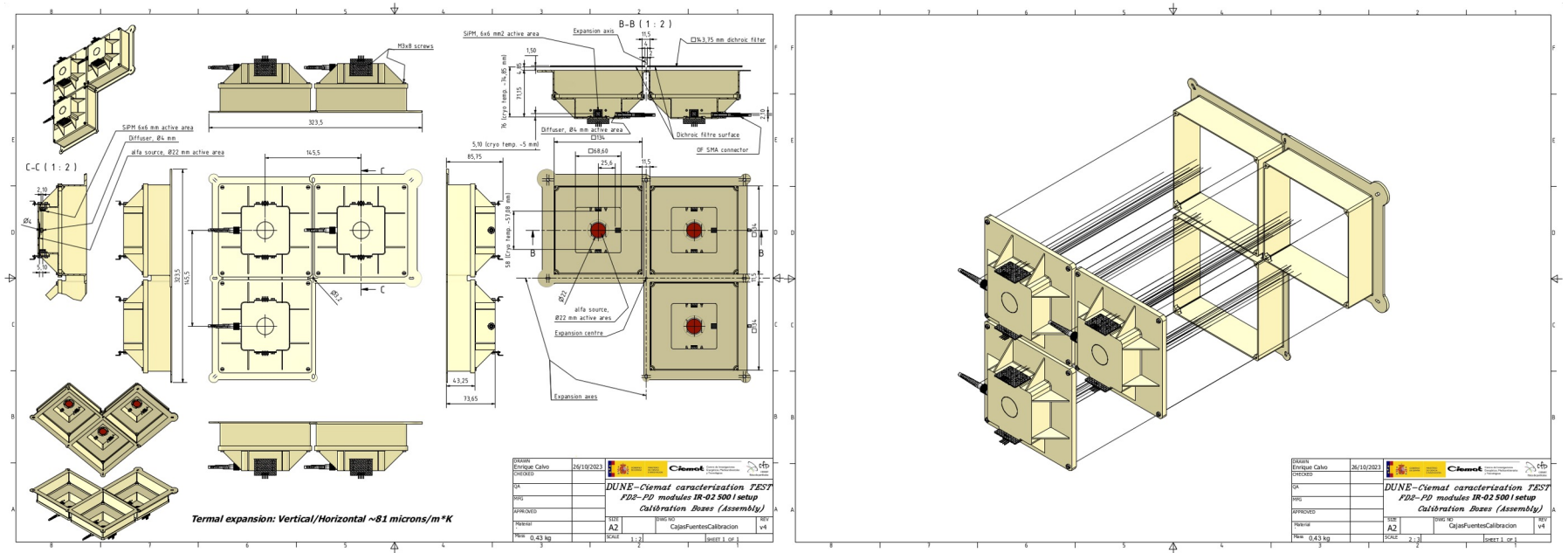
PDE VD setup preparations

PDE VD setup: Megacell preparations

PDE VD setup: Megacell insert

PDE VD setup: Vacuum in LAr region

New designs for LAr measurements

FD2-VD X-ARAPUCA calibration in LN$_2$

- Event examples for XA (0,1) and SiPM (6,7)
- Average waveforms