

Design Validation II: protoDUNE-VD Module-0 Experience

A. Cervera (IFIC-Valencia)
on behalf of **PDS consortium**



Introduction

<https://edms.cern.ch/document/2875448/1>

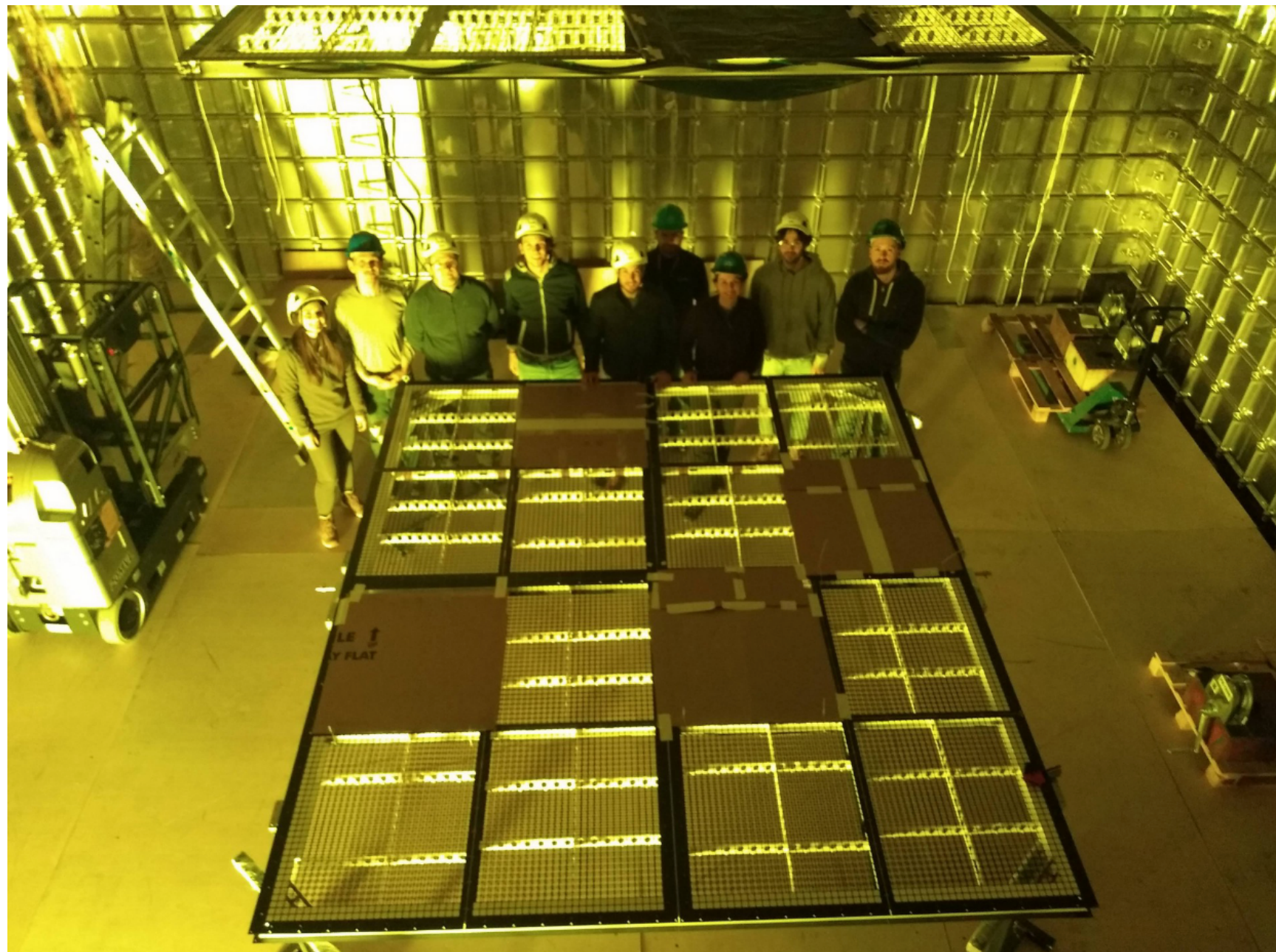
- ProtoDUNE-VD is a crucial step towards FD2
- The document describing pre-testing assembly, testing and installation is posted in EDMS:
 - Complicated logistics (production of components in more than 10 sites around the world)
 - All operations done at CERN and the plans for finalizing the installation
 - Lessons learned are detailed for each step in the process

Production and installation (initially foreseen for late 2023) was timely achieved, with not a single delay to other systems

Introduction	3
Description of ProtoDUNE-VD PDS	3
Description of X-ARAPUCA components.....	5
Configuration for each module.....	8
Pre-assembly at production sites	9
Delivery of components to CERN	9
Assembly of X-ARAPUCAs at CERN	10
Assembly procedure.....	11
Lessons learned.....	11
Cold Electronics with Signal-over-Fiber.....	15
Lessons learned.....	18
Cold Electronics with Signal-over-Copper.....	19
X-ARAPUCA tests before installation	22
Description and operation of testing setup.....	22
Membrane module tests.....	24
Cathode module tests.....	25
Lessons learned.....	29
Installation of membrane modules	29
Installation of suspension lines.....	29
Preparation in clean room.....	32
Installation of X-ARAPUCAS.....	33
Cable routing.....	36
Lessons learned.....	36
Installation of cathode modules	37
Cathode preparation.....	37
Preparation in clean room.....	38
Installation of X-ARAPUCAS.....	38
Protection of modules.....	40
Routing and distribution of optical fibers in cathode frame.....	41
Lessons learned.....	45
Installation of response monitoring system	46
Plans for installation of warm components.....	49
Lessons learned.....	51
Plans for flange installation	51
Plans for warm electronics (DAPHNE)	53
Installation of warm components.....	54
Plans for full chain validation	54
Schedule	54
Bookkeeping	55
APPENDIX 1: Testing sequence	58
APPENDIX 2: Electronics configuration for each module	59
APPENDIX 3: Detailed analysis of membrane XA tests	62

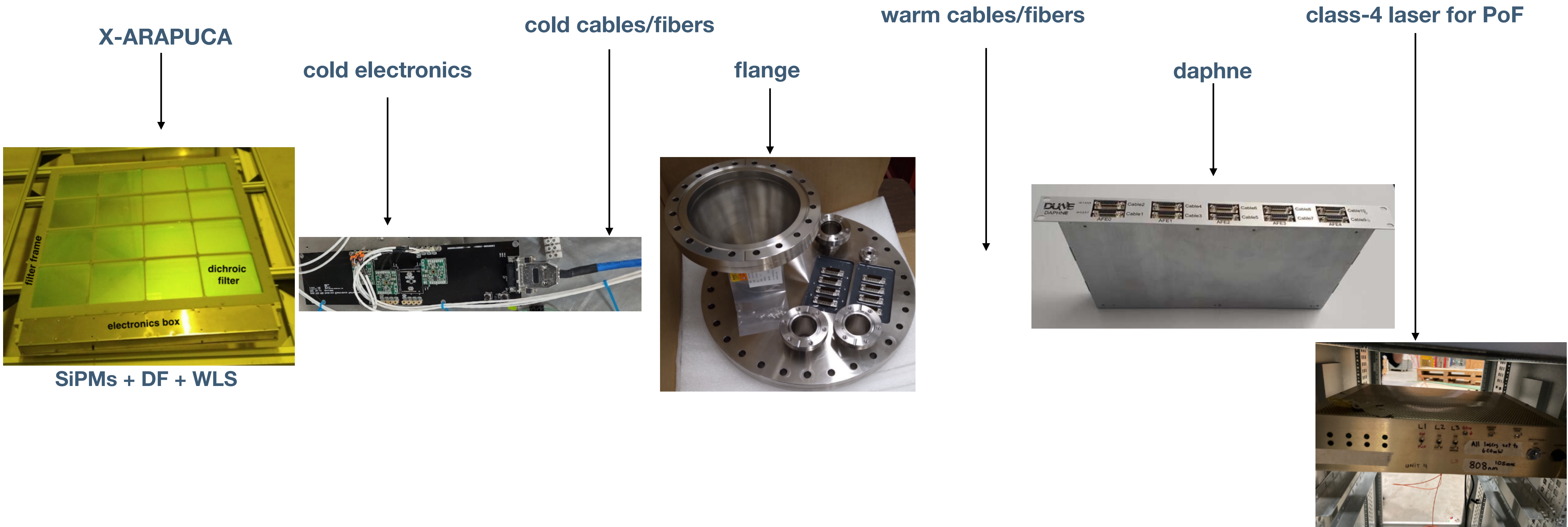
A great team

- So far a successful campaign, thanks to a great team, with more than 30 people contributing at CERN, with avg. of 6 and peaks of almost 15
- Of course, many more abroad, timely producing and testing components, and giving useful advice



The full chain

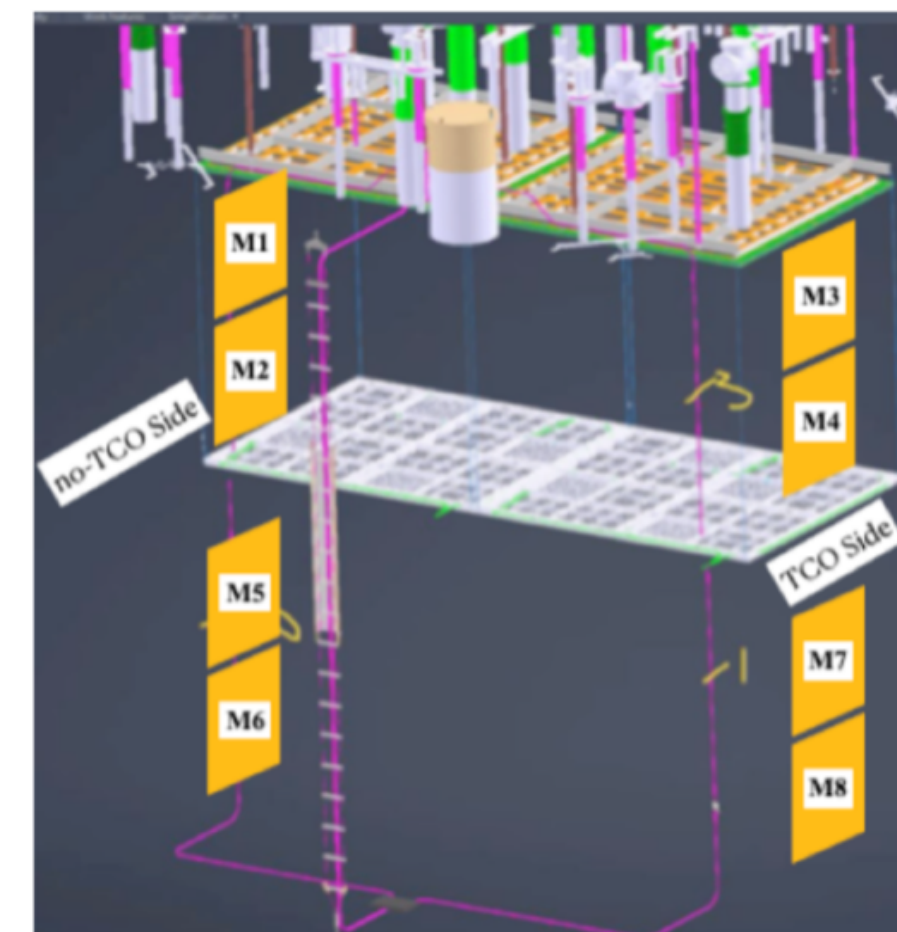
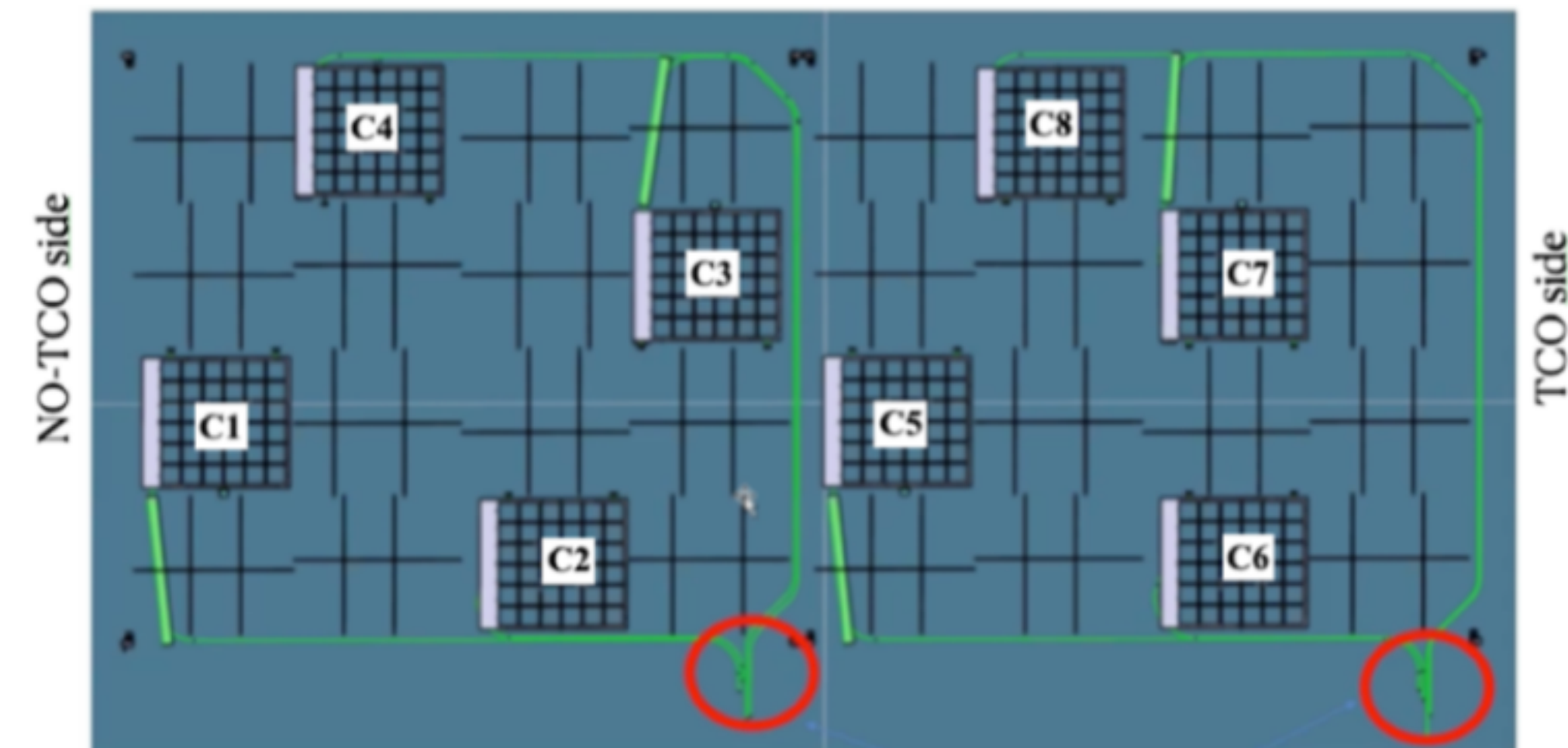
- The full chain is being exercised in ProtoDUNE-VD
- Gained expertise and lessons learned will be crucial for PRR and beyond



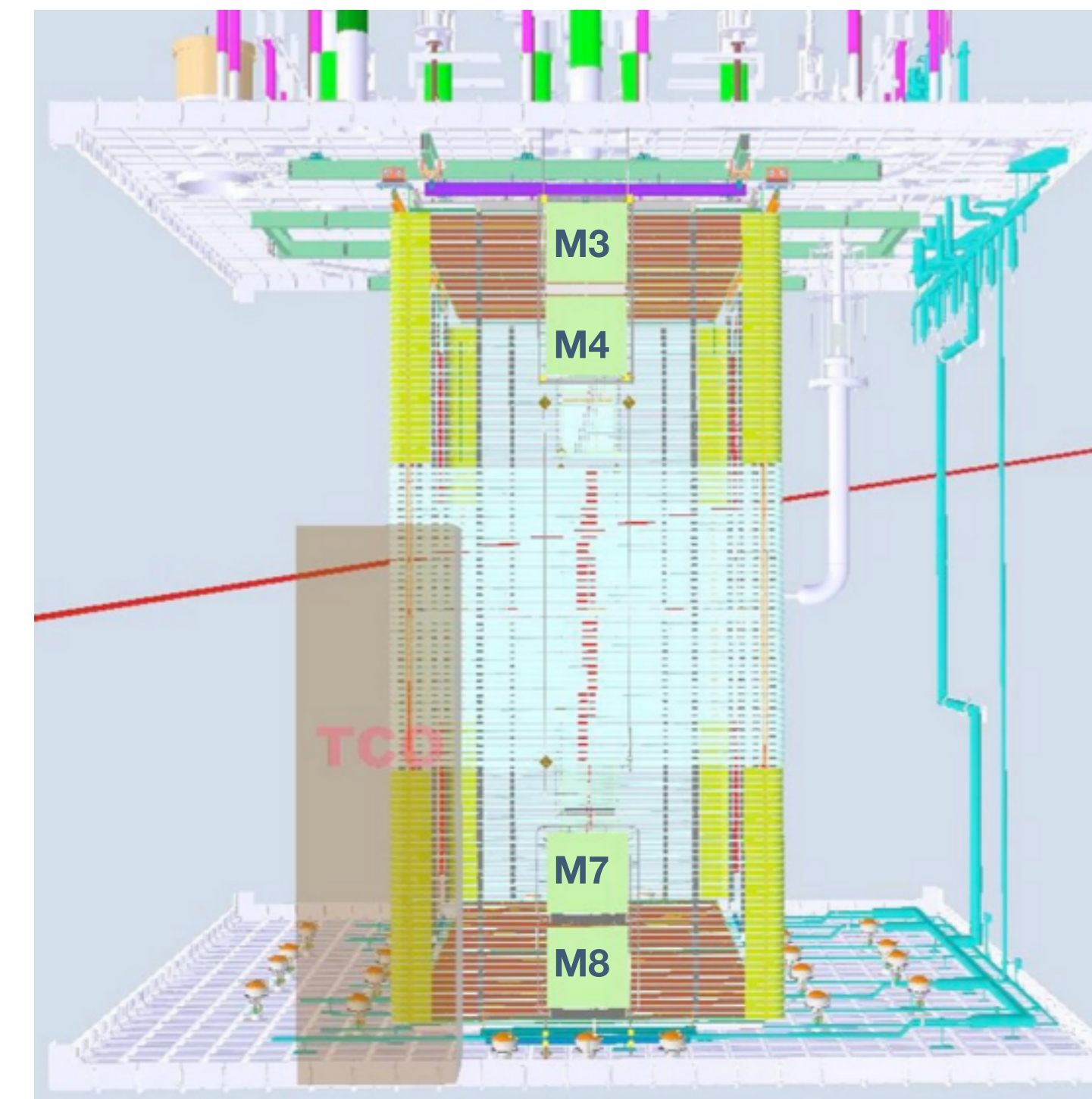
PDS in ProtoDUNE-VD

- 16 photon collectors (X-ARAPUCA), 8 in the central cathode and 8 near the cryostat membrane
- All modules assembled and tested at CERN
- A Response and Monitoring System (RMS) is also being installed

Cathode distribution as in FD2



Membrane module pairs (quartets in FD2)



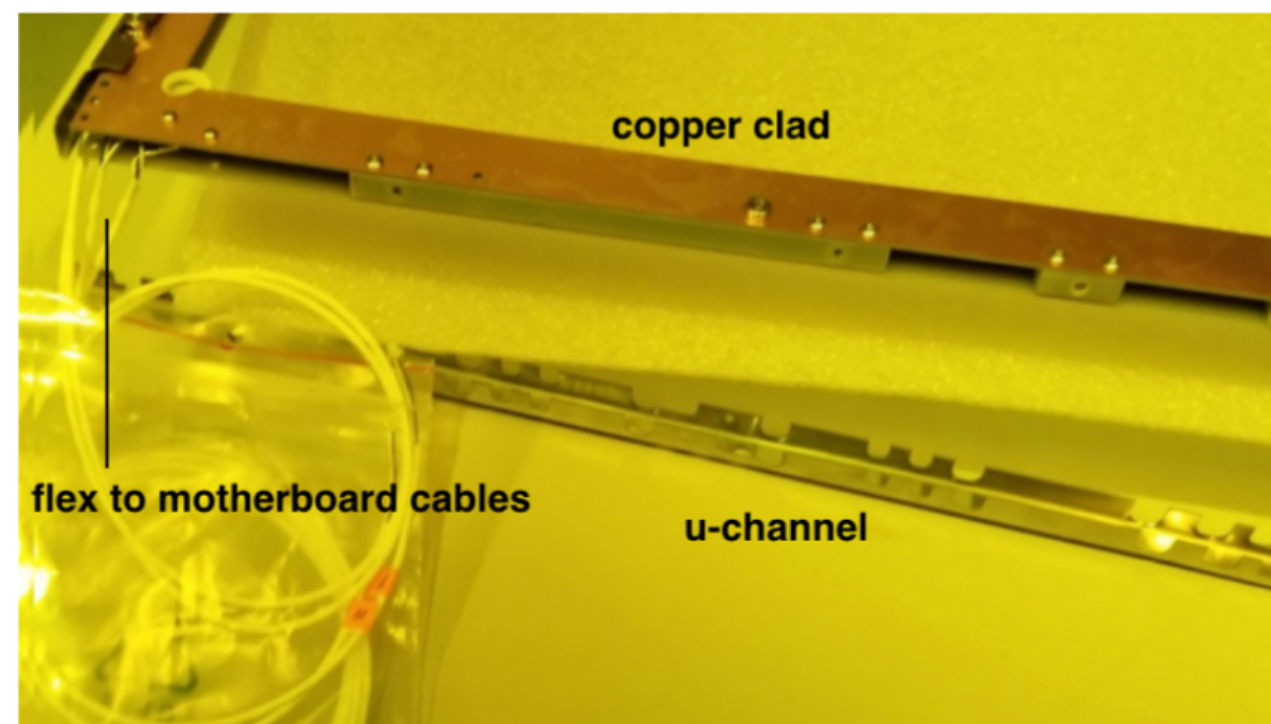
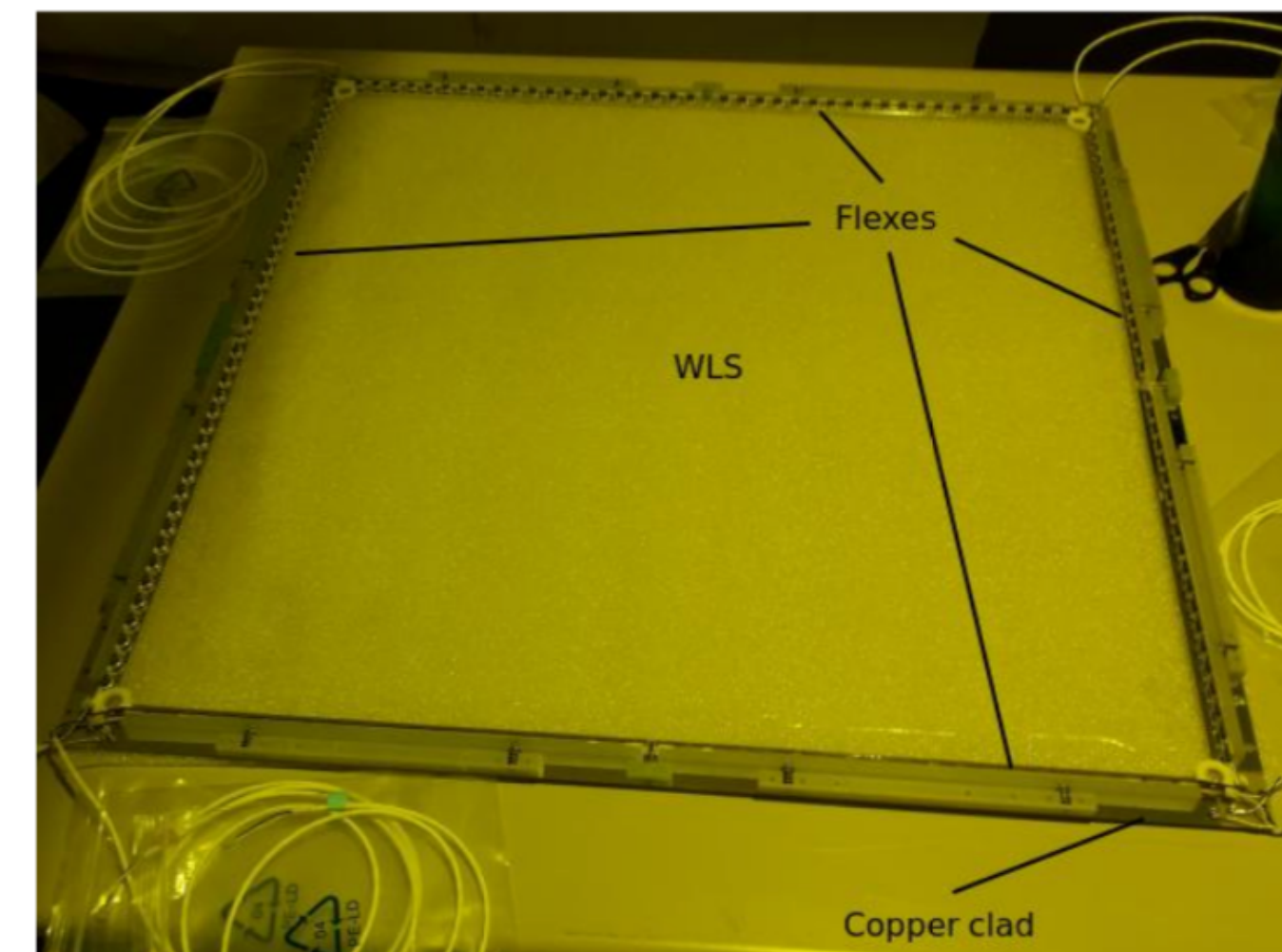
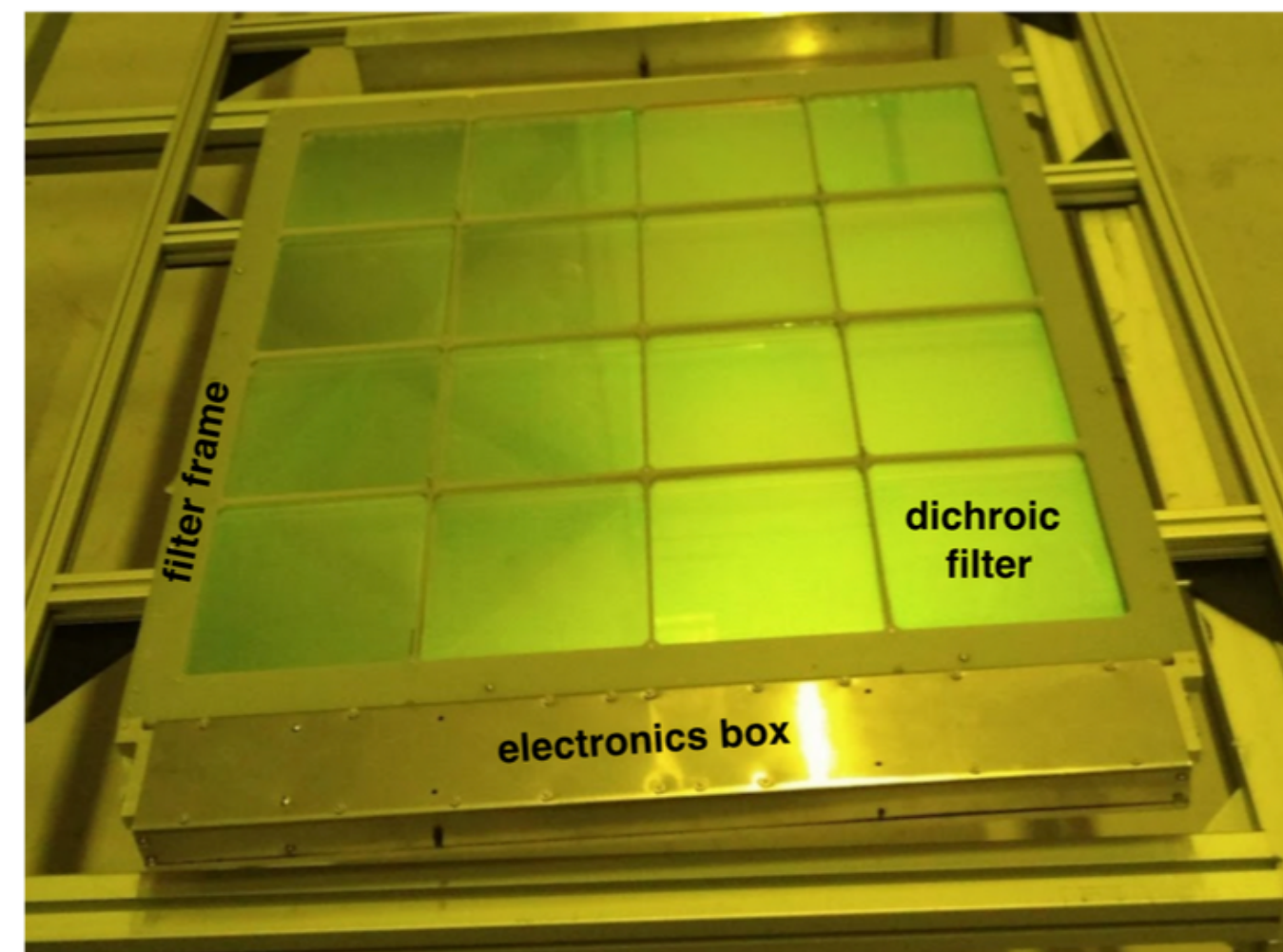
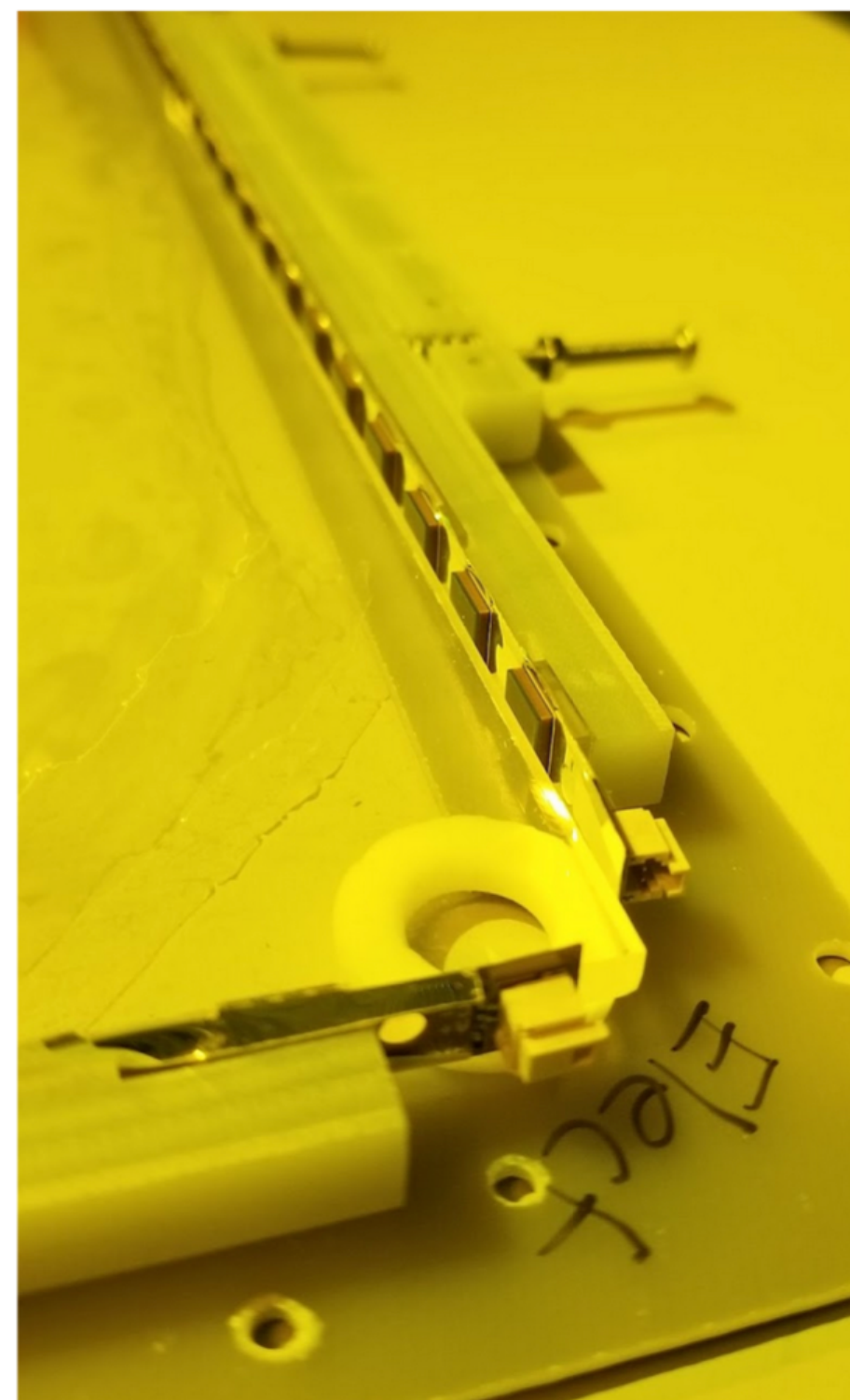
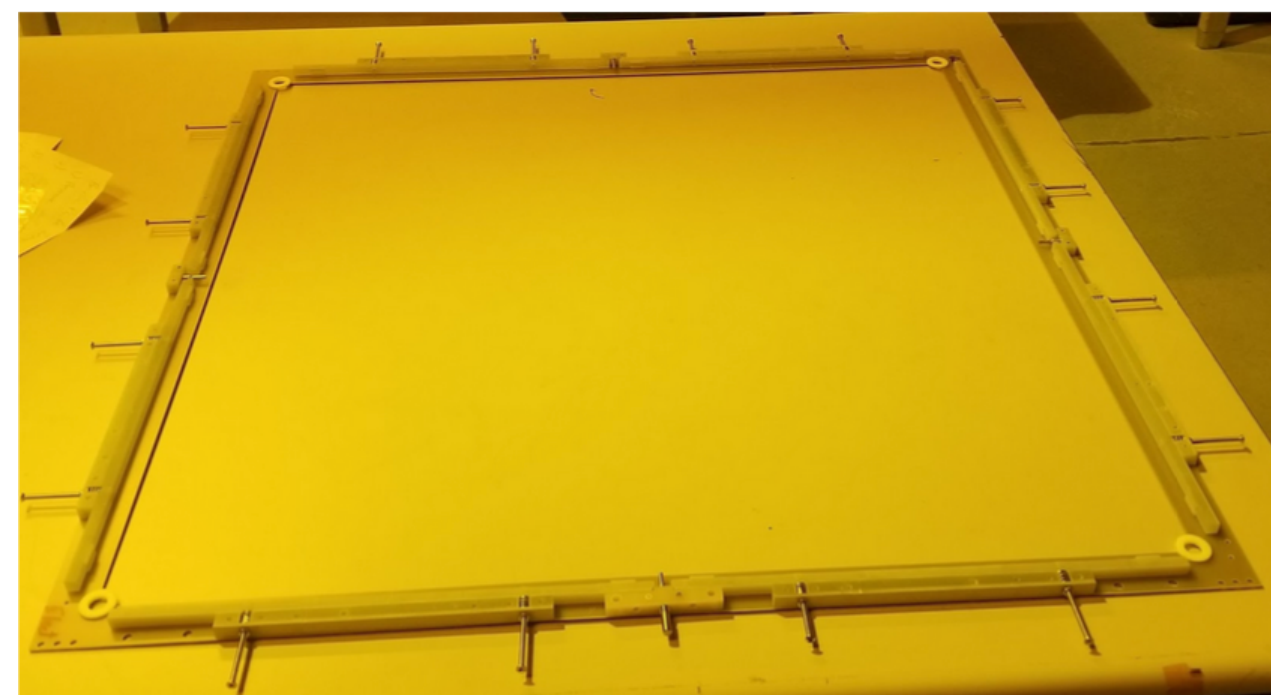
Assembly: photon collectors

X-ARAPUCA, the PDS basic unit

- XAs have many components ensuring good optical coupling in a cryogenic environment (differential shrinkage between components)

Assembling the first module took almost 2 days

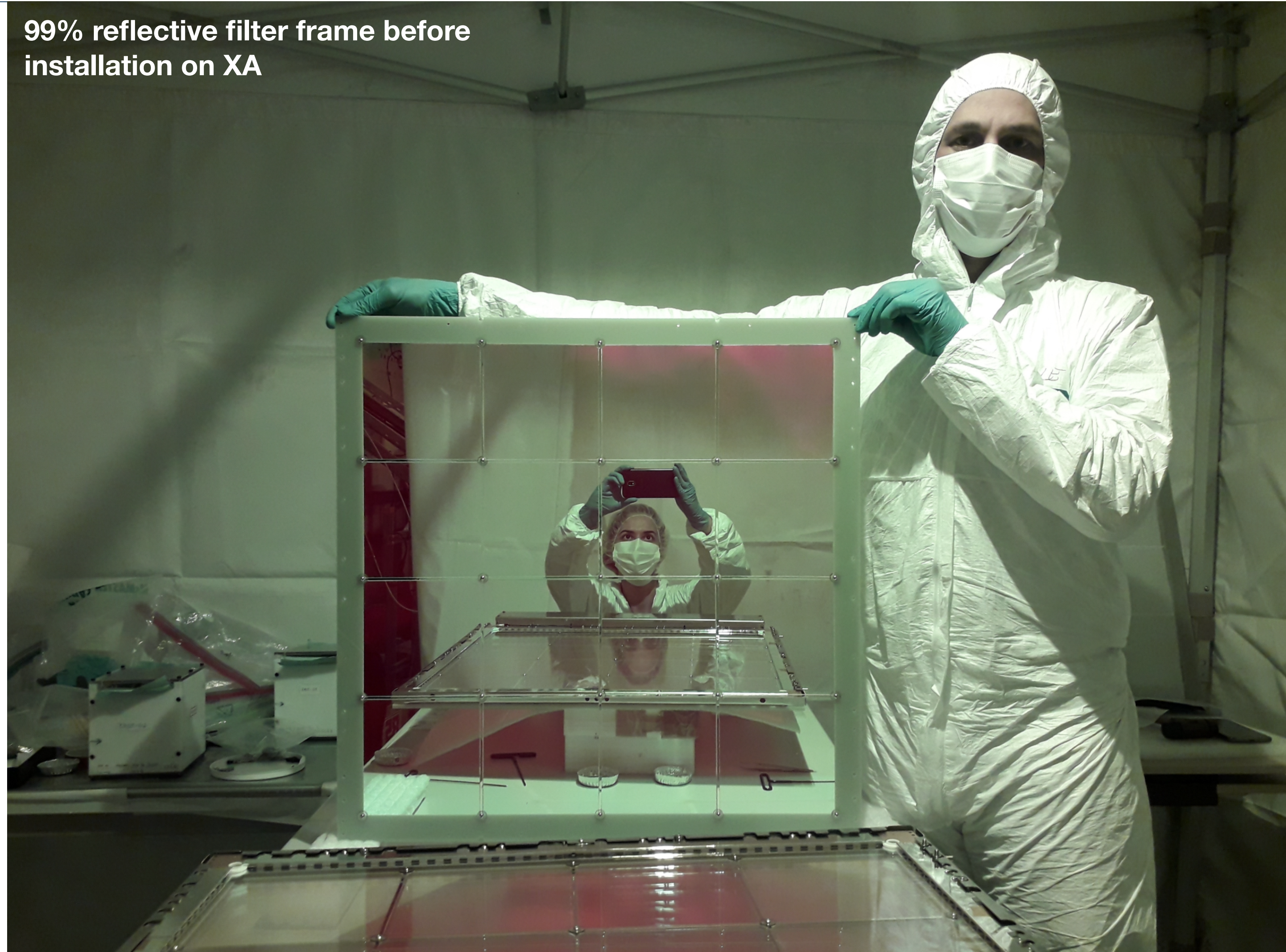
Last module was assembled in half a day



The clean tent

- A clean tent with air filter was setup inside the PDS room
- Two persons were necessary for most operations

99% reflective filter frame before installation on XA



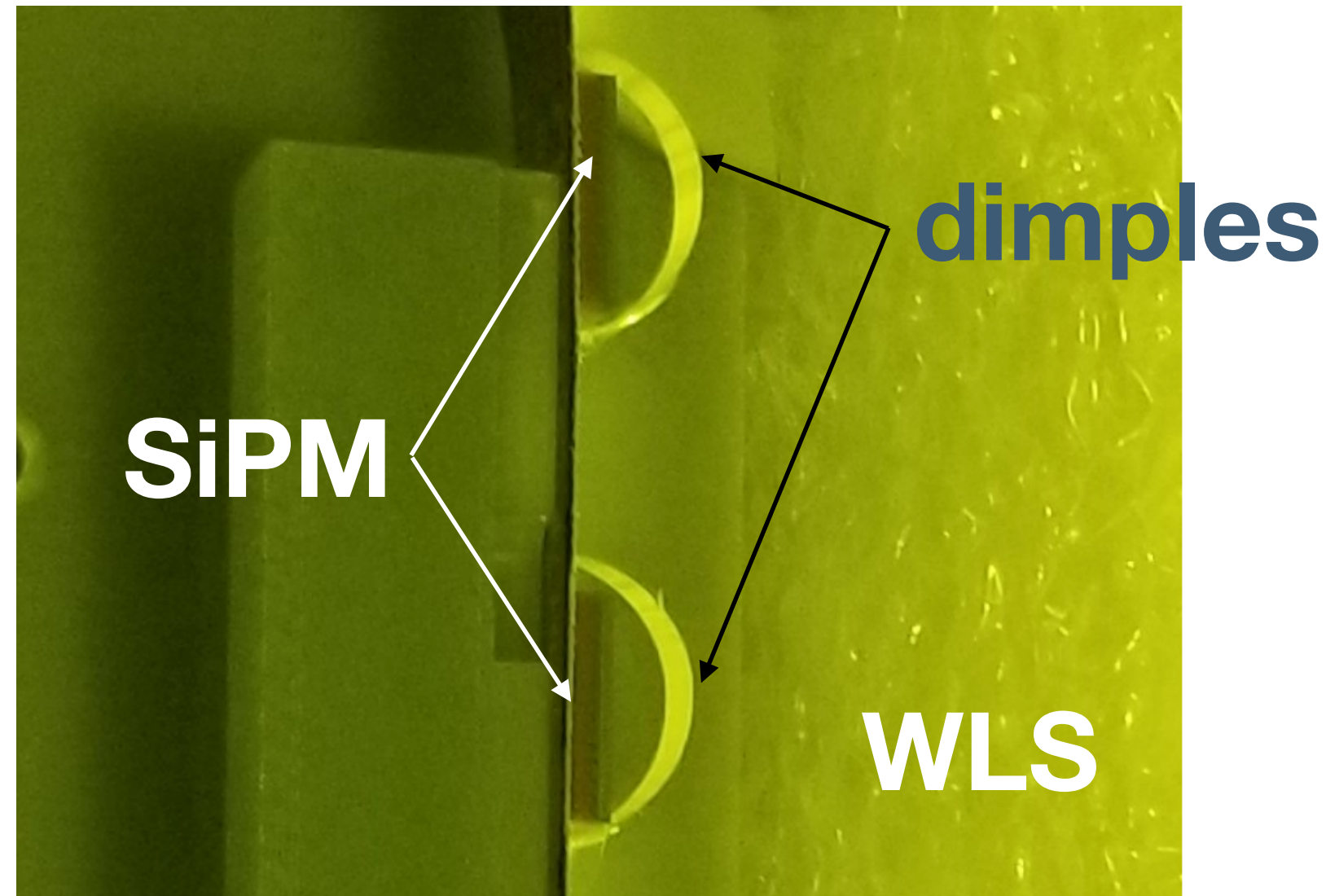
Different XA configurations

- Optical fibers for power (PoF) and signal (SoF) are mandatory in the cathode
- SoF implemented for one membrane module
- Final DF size is 150x150 mm²

2 DF & SiPM vendors

	WLS dimples	DF size (mm ²)	DF	SiPM	PoF	SoF	shared elec. box
M1		100x200	ZAOT	HPK			x
M2		100x200	ZAOT	HPK			x
M3	x	100x200	ZAOT	HPK			x
M4	x	100x200	ZAOT	HPK			x
M5	x	150x150	PE	FBK		x	
M6	x	150x150	PE	HPK			
M7	x	150x150	PE	HPK			
M8	x	150x150	PE	FBK			
C1		100x200	ZAOT	HPK	x	x	
C2		100x200	ZAOT	HPK	x	x	
C3		150x150	PE	FBK	x	x	
C4	x	150x150	PE	HPK	x	x	
C5	x	150x150	ZAOT	HPK	x	x	
C6	x	150x150	ZAOT	HPK	x	x	
C7	x	150x150	ZAOT	FBK	x	x	
C8	x	150x150	ZAOT	HPK	x	x	

Dimples act as lens focusing light into SiPM



Many lessons learned

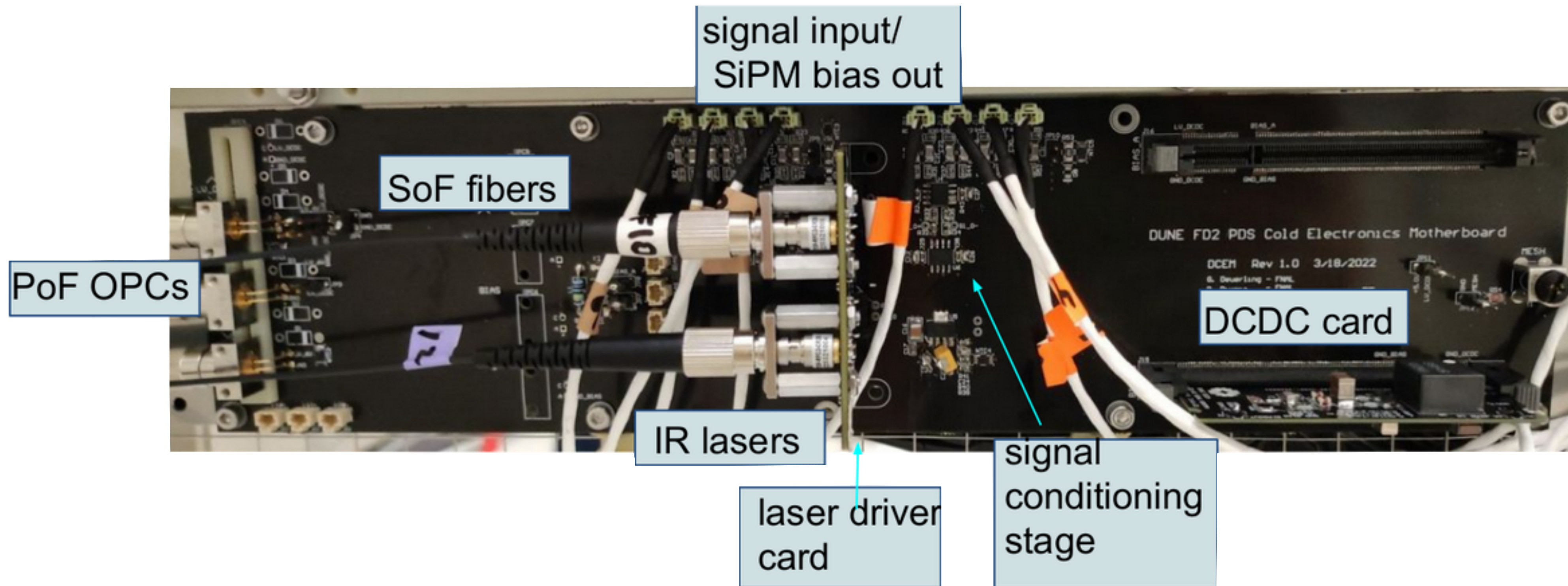
- Those are detailed in EDMS 2875448 documents
- Some of them are related to minor changes in the X-ARAPUCA design
- Many of them related with Vikuiti:
 - This is a adhesive 99% reflector used to cover all inactive inner surfaces of the X-ARAPUCA, to minimize absorption of trapped photons
 - Vikuiti on the backplane for membrane modules sometimes detached during cold testing. Problem was partially mitigated but needs further investigation (better lamination process, cleaning, bubbles, ...)



Assembly: cold electronics

Cold electronics

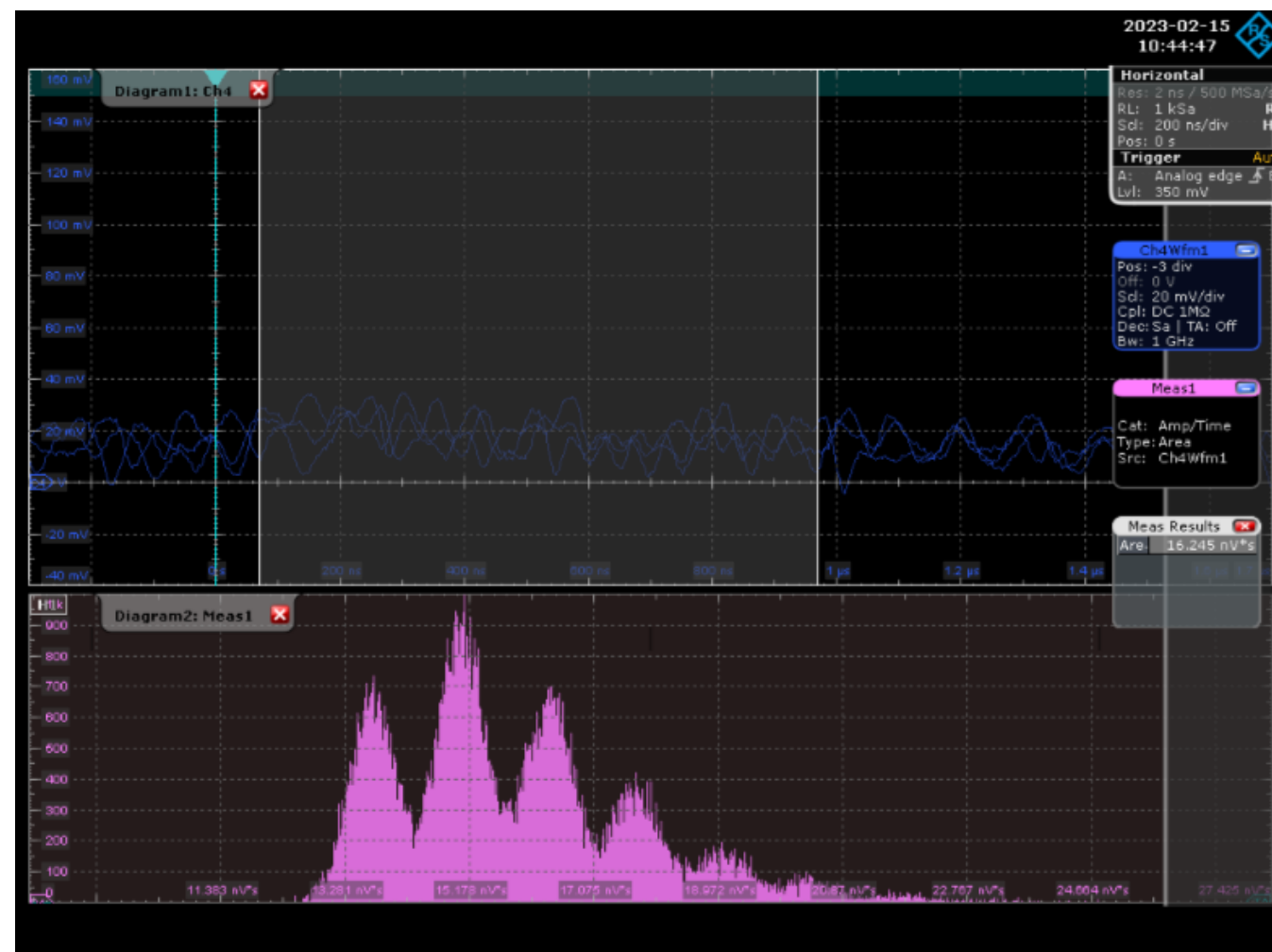
- Cold electronics, in the latest stages of development, underwent several modifications and extensive testing, both at production sites and at CERN (given time constraints)



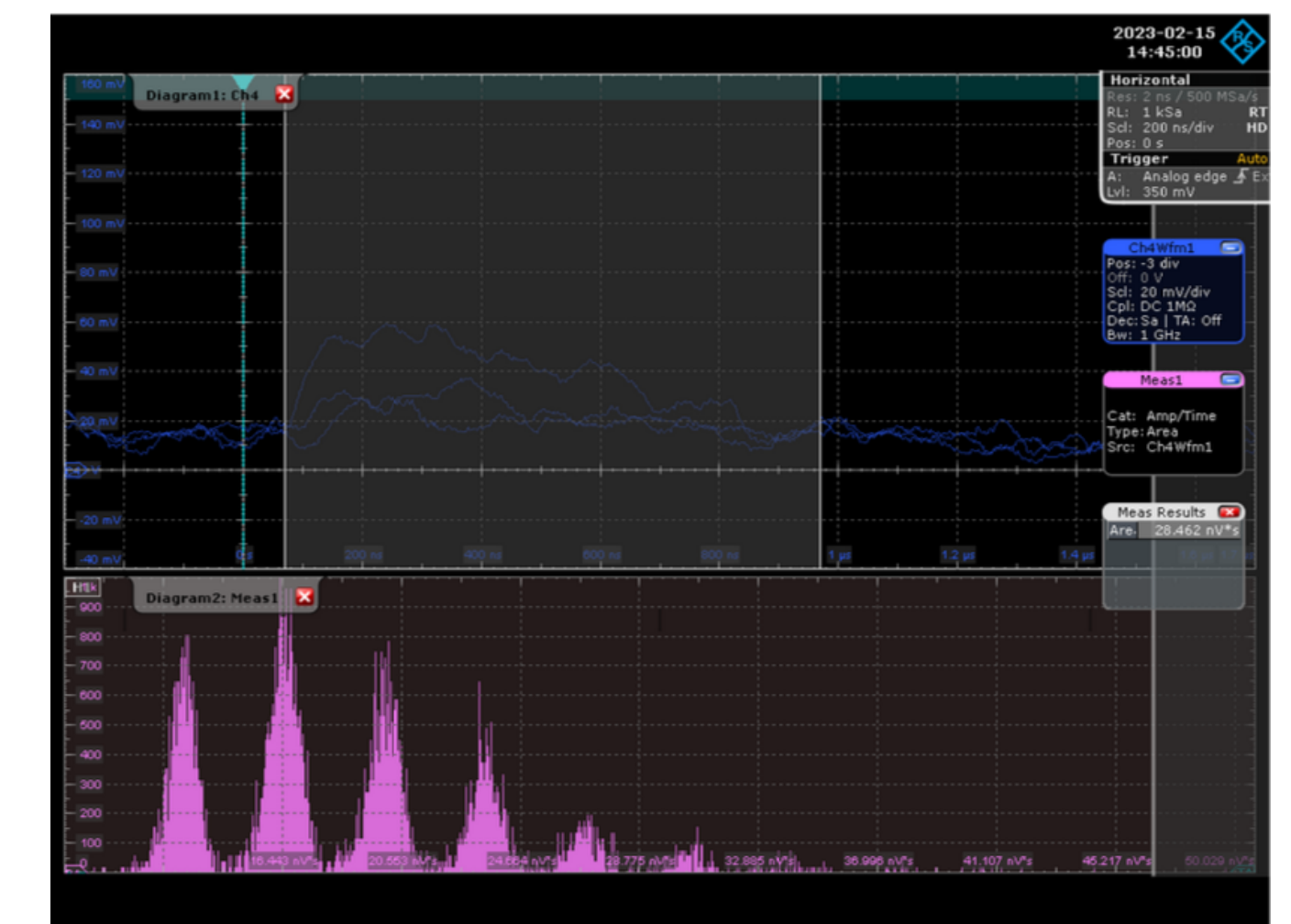
Copper cable based electronics

- Due to stringent time constraints, most of the testing was done at CERN during installation, while more detailed tests on a smaller setup were done in parallel in Milano Bicocca.
- Although already well tested for FD1, the HD-style amplifier needed additional work to be ready for FD2 due to the different SiPM ganging configuration and other boundary conditions

M1-M2



M3-M4



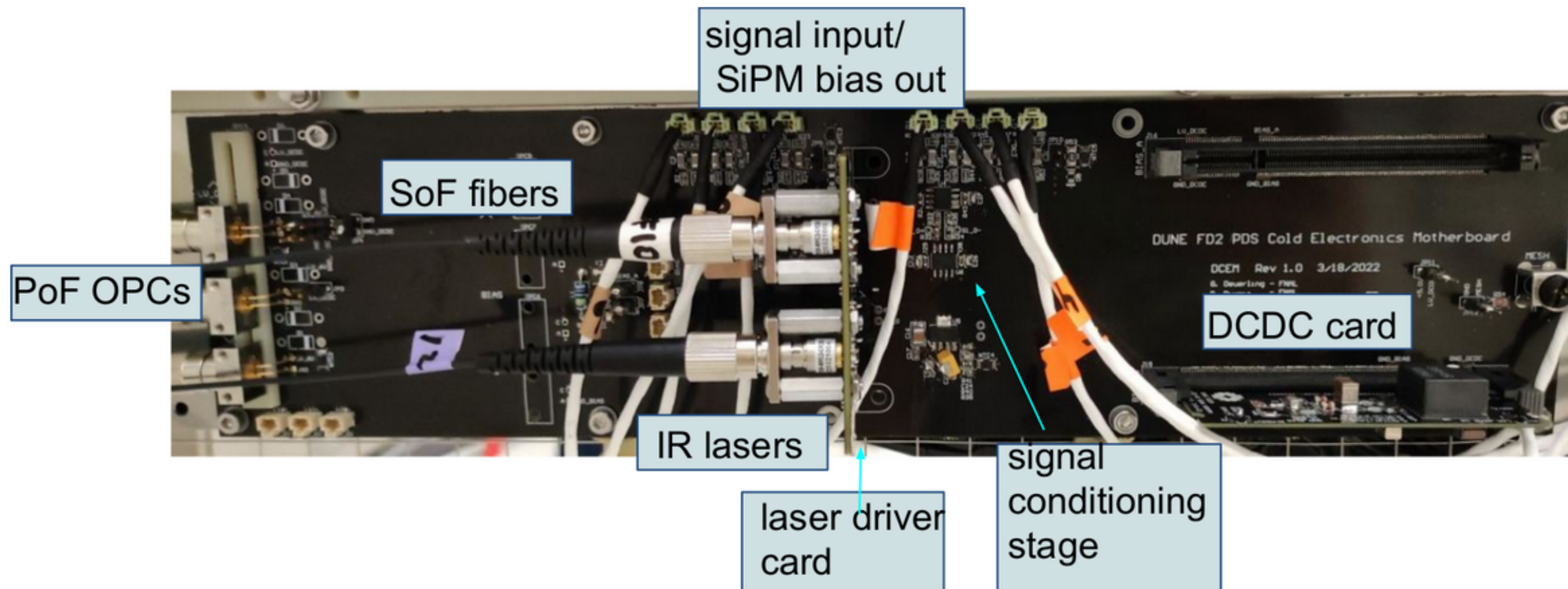
changes in amplifier feedback resistors



Optical Fiber based electronics

Work in progress !!!

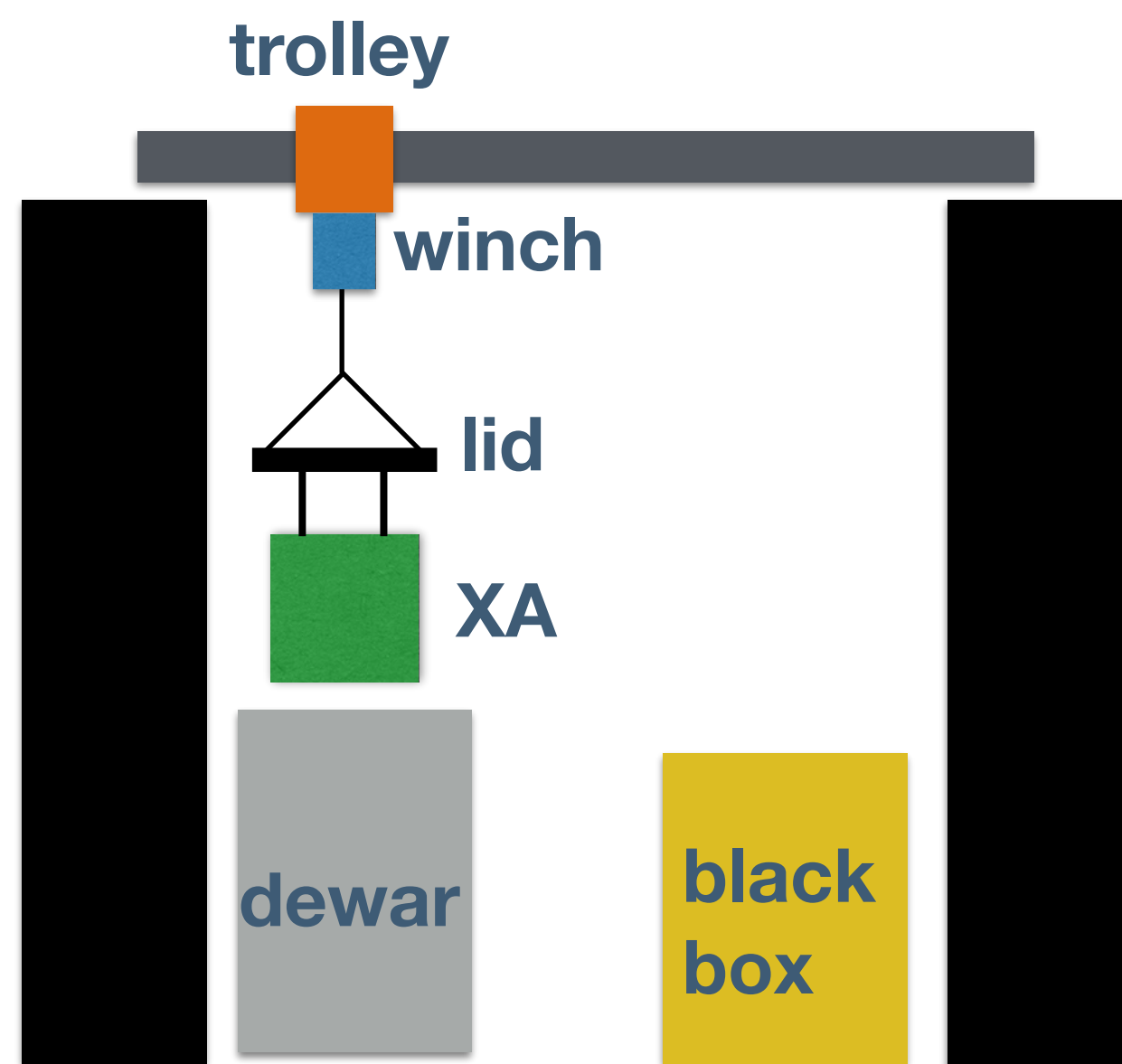
- Given the time constraints some hand population was necessary
 - Increase in amplification stage gain:
 - Replace some of the ferro-ceramic capacitors by other suitable for cryogenic conditions.



Cold tests: X-ARAPUCA

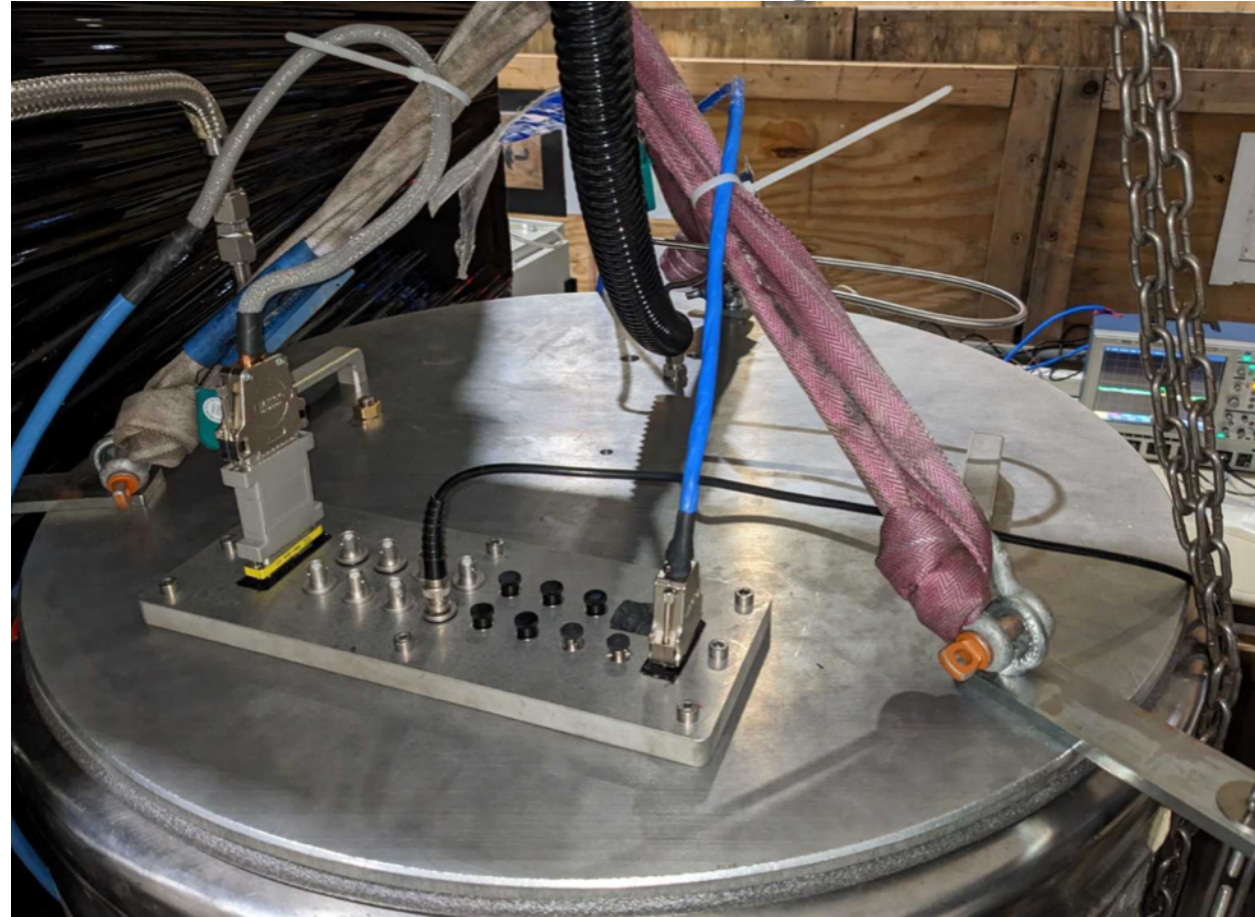
Test stand at CERN

- For FD2, there will be dedicated assembly and testing facilities decoupled from installation. This was not possible for ProtoDUNE-VD and testing had to be done at CERN
- A test stand was setup in December in front of the PDS room, below the 3rd barrack

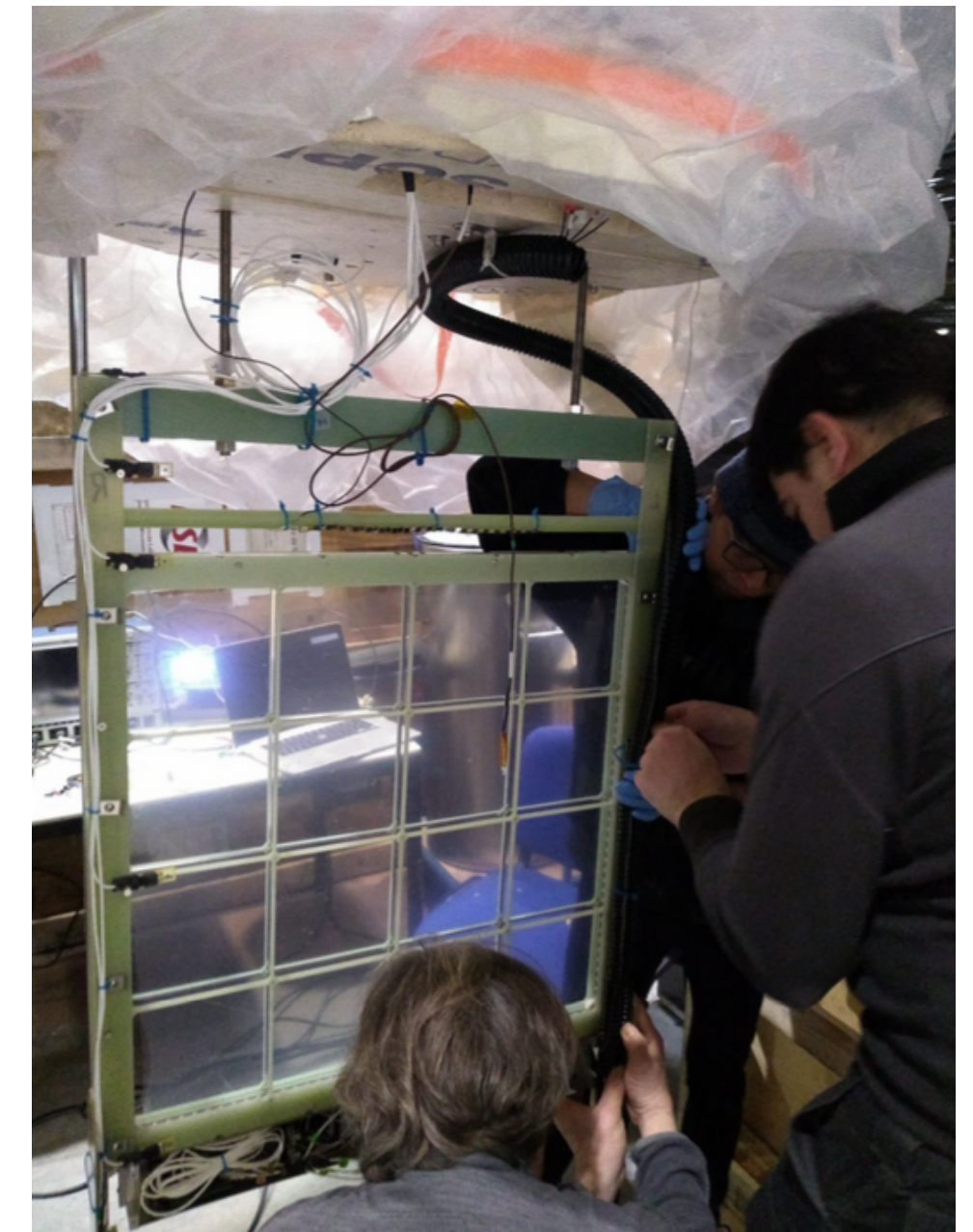


Mechanics and cryogenics

lid with feedthrough panel



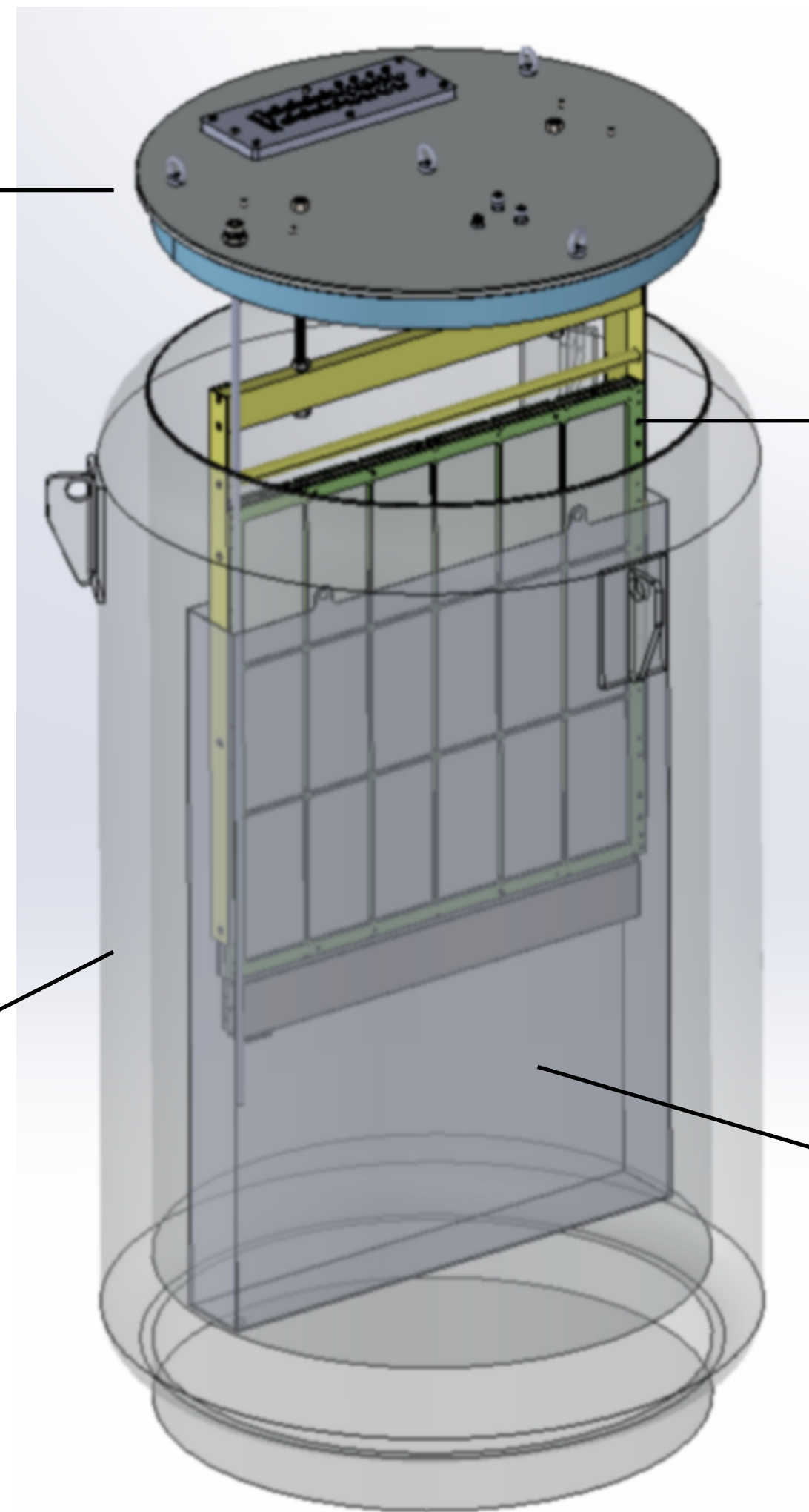
XA hanging from lid



500 l LAr dewar



450 l open dewar



inner box

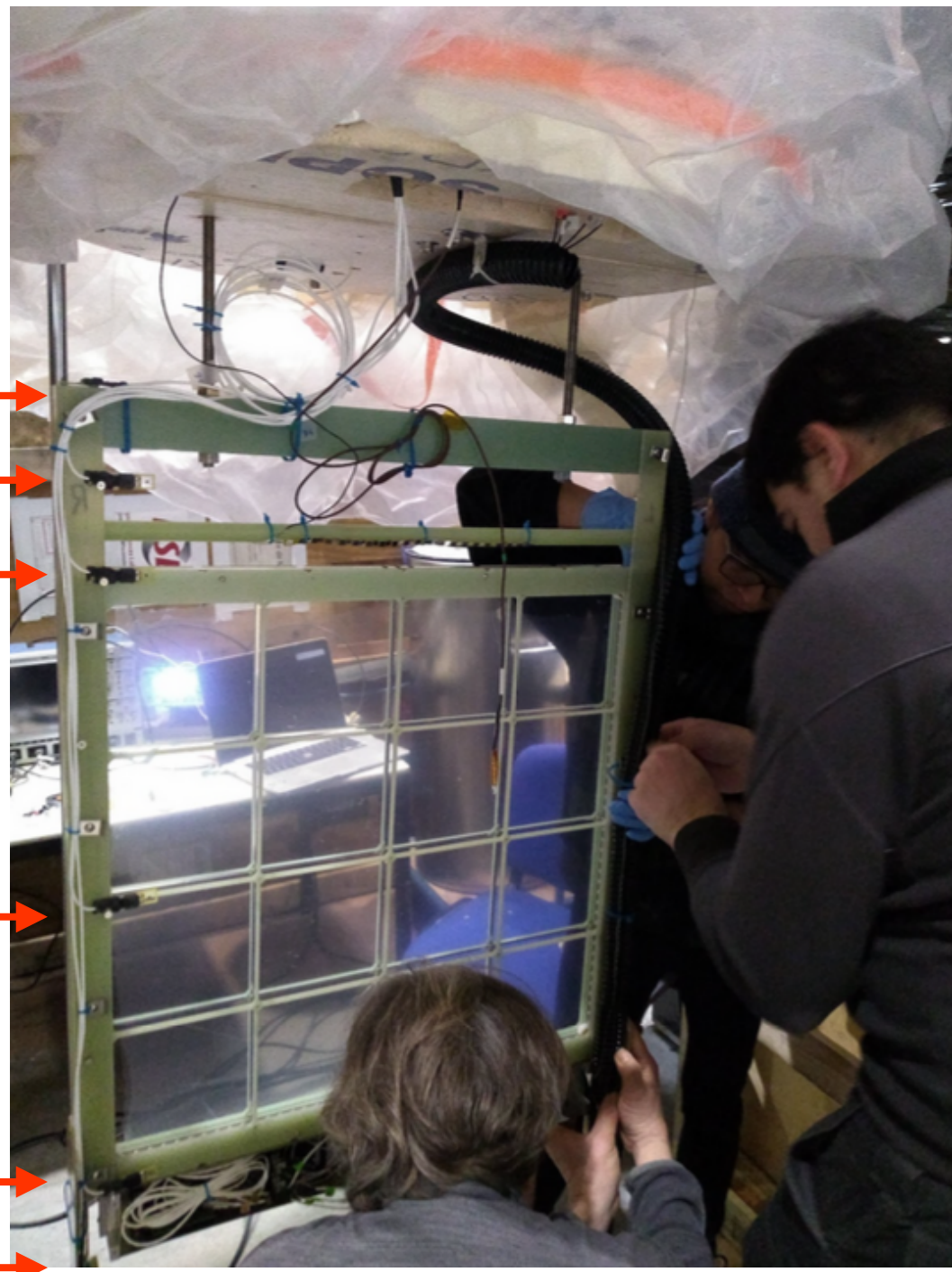


Procedure

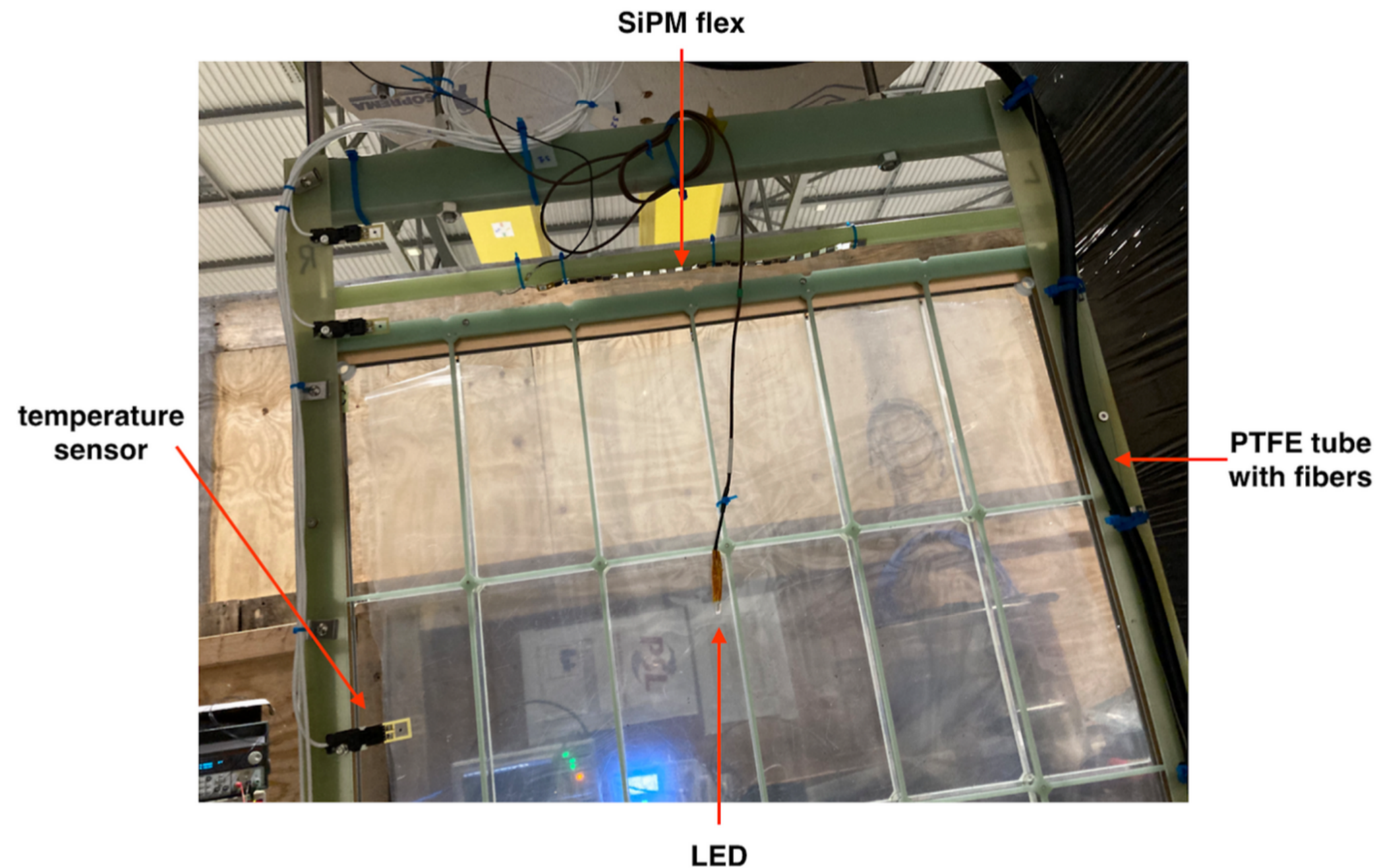
- LAr injected in dewar (bottom) through dedicated port in lid
- Slow cool-down (90') and warmup (30') phases

**Tests done
without
dichroic filters**

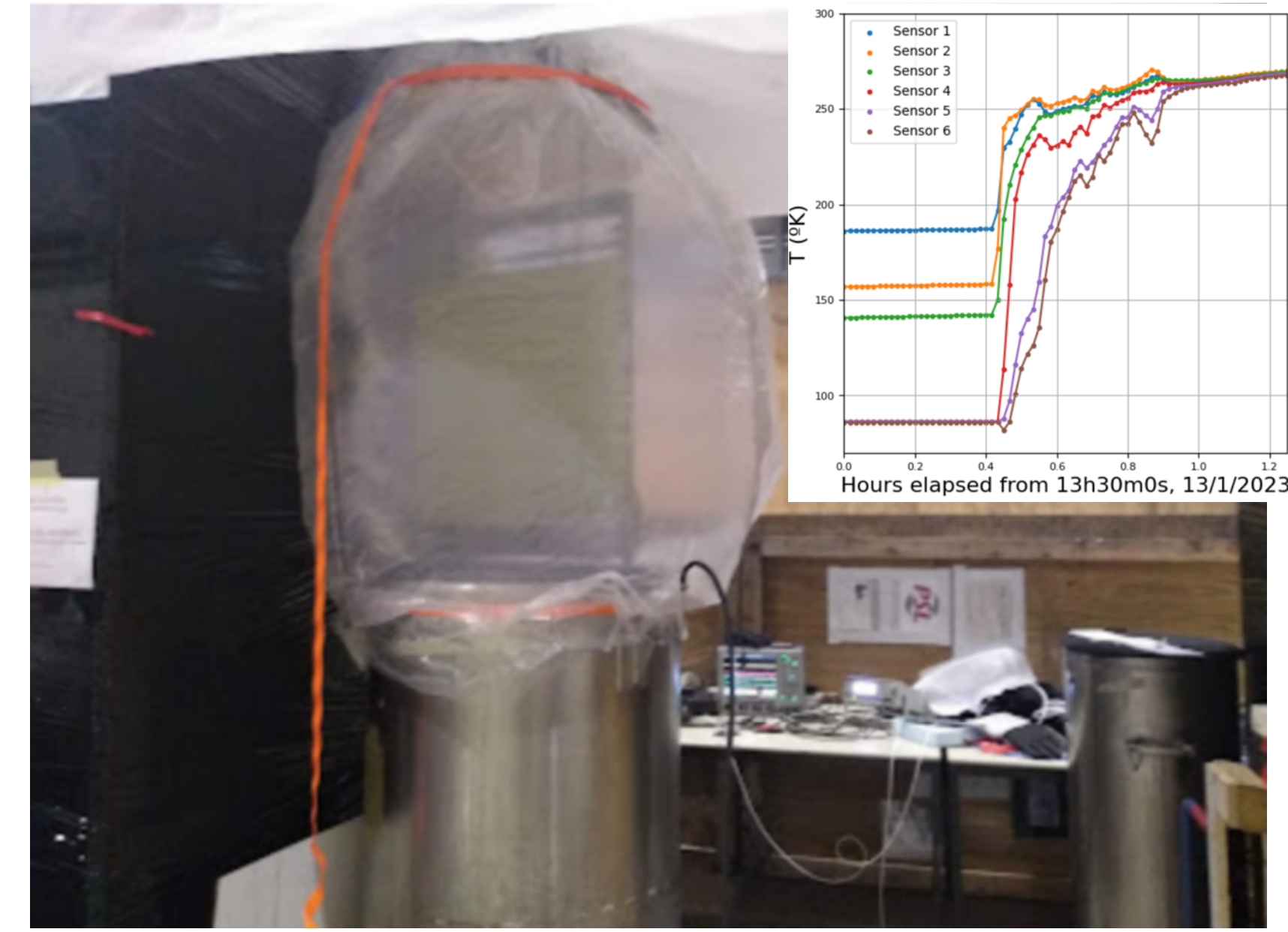
LAr level and XA temperature monitored with 6 RTDs



Pulsed led to produce light
SiPM flex to monitor PoF light leakage



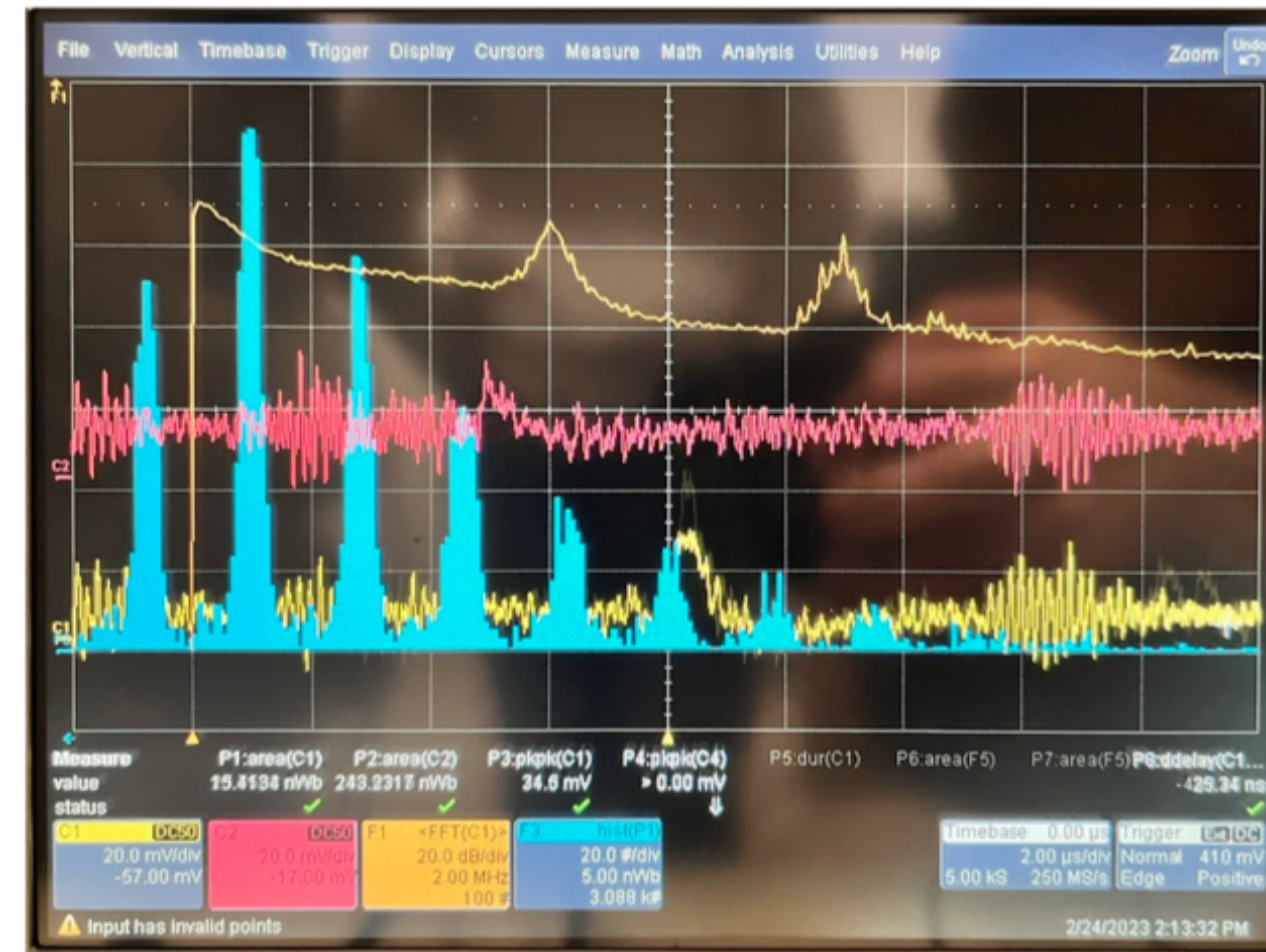
plastic tent flushed with
warm GN2 during warm up
essential to avoid condensation



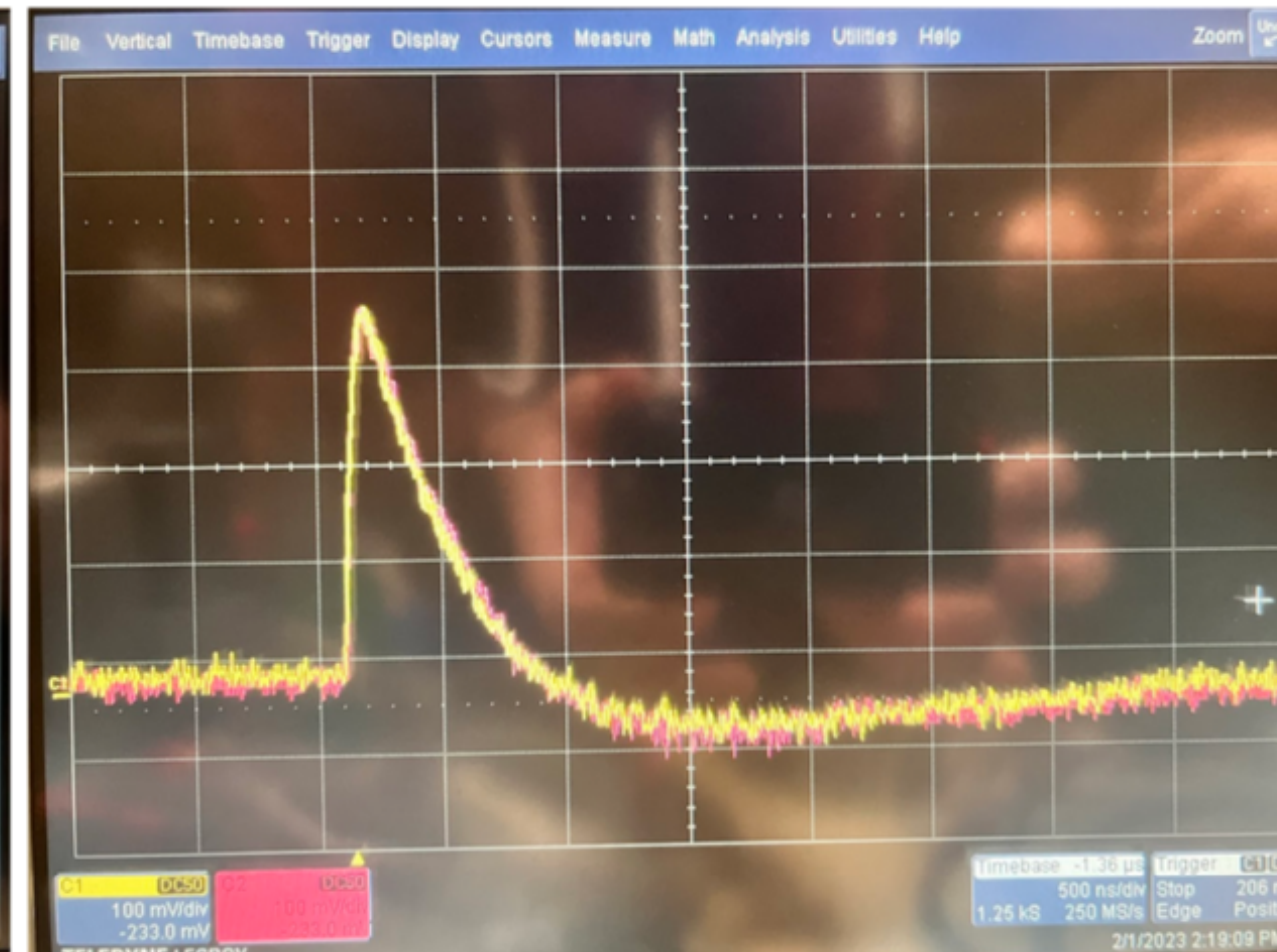
Membrane modules

SNR well within requirements

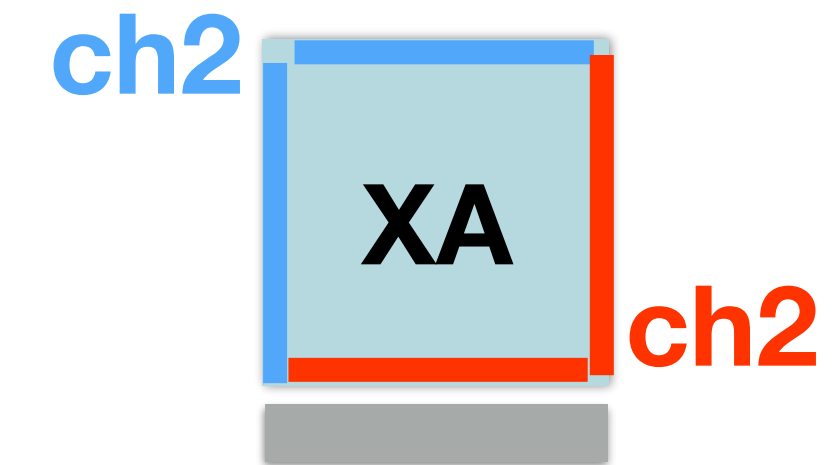
Charge histogram for LED



Waveform for cosmics



Same gain for both channels



Detailed studies for M3 and M4

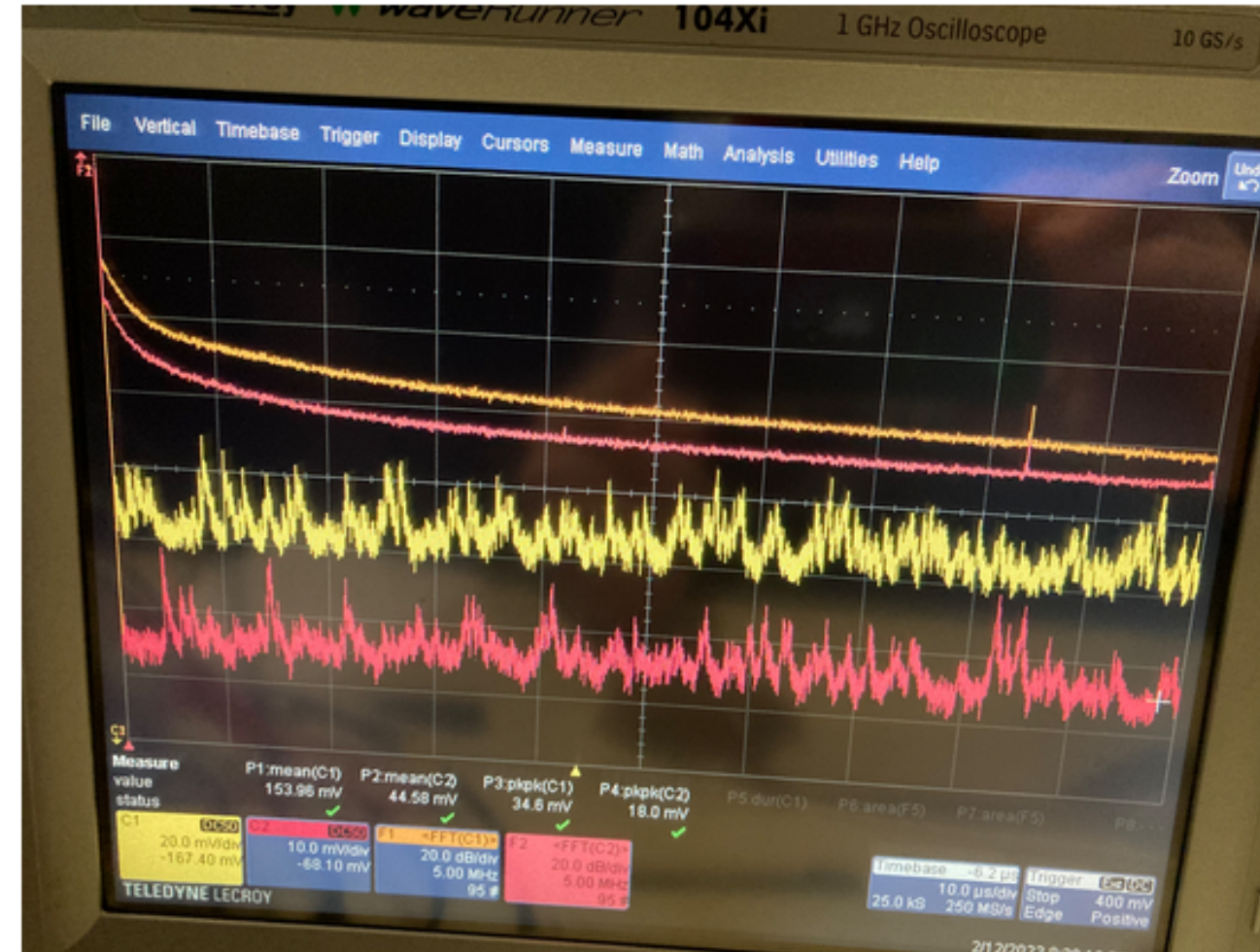
	SNR for 44 V (40% PDE)	SNR for 45 V (45% PDE)	SNR for 46 V (50% PDE)	Gain ratio between channels (cosmics)
M3	4.3	5.6	//	1.1
M4	//	6.1	7.6	0.97

Cathode modules

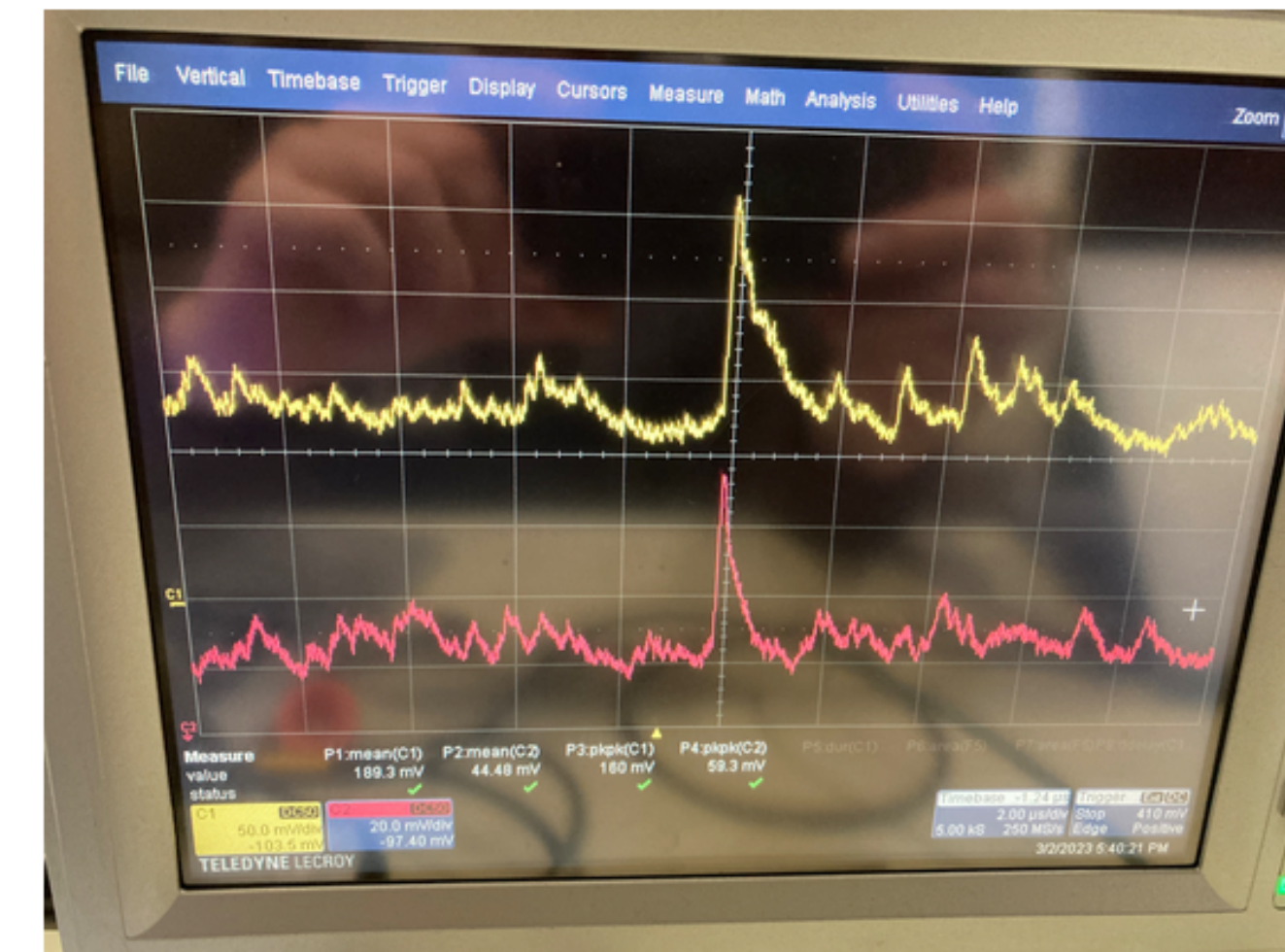
Work in progress !!!

- Studies about single photoelectrons could not be performed because of the light leakage on the dewar. The offset and power consumption are measured, registered, and compared to the previous tests with the electronic boards.

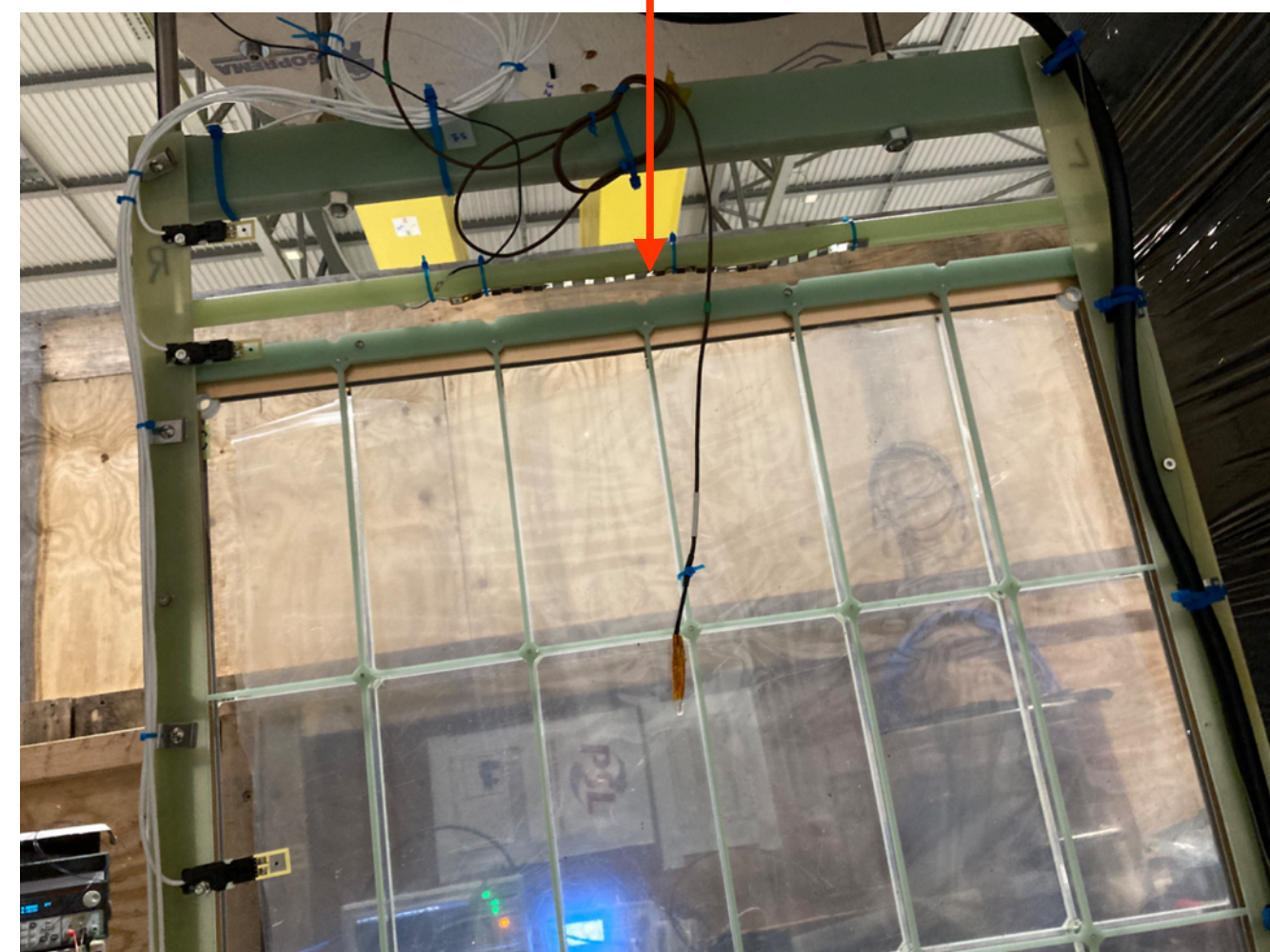
Typical FFT



LED response for 2 channels



SiPM flex to check PoF leak with LED off



fiber protection box



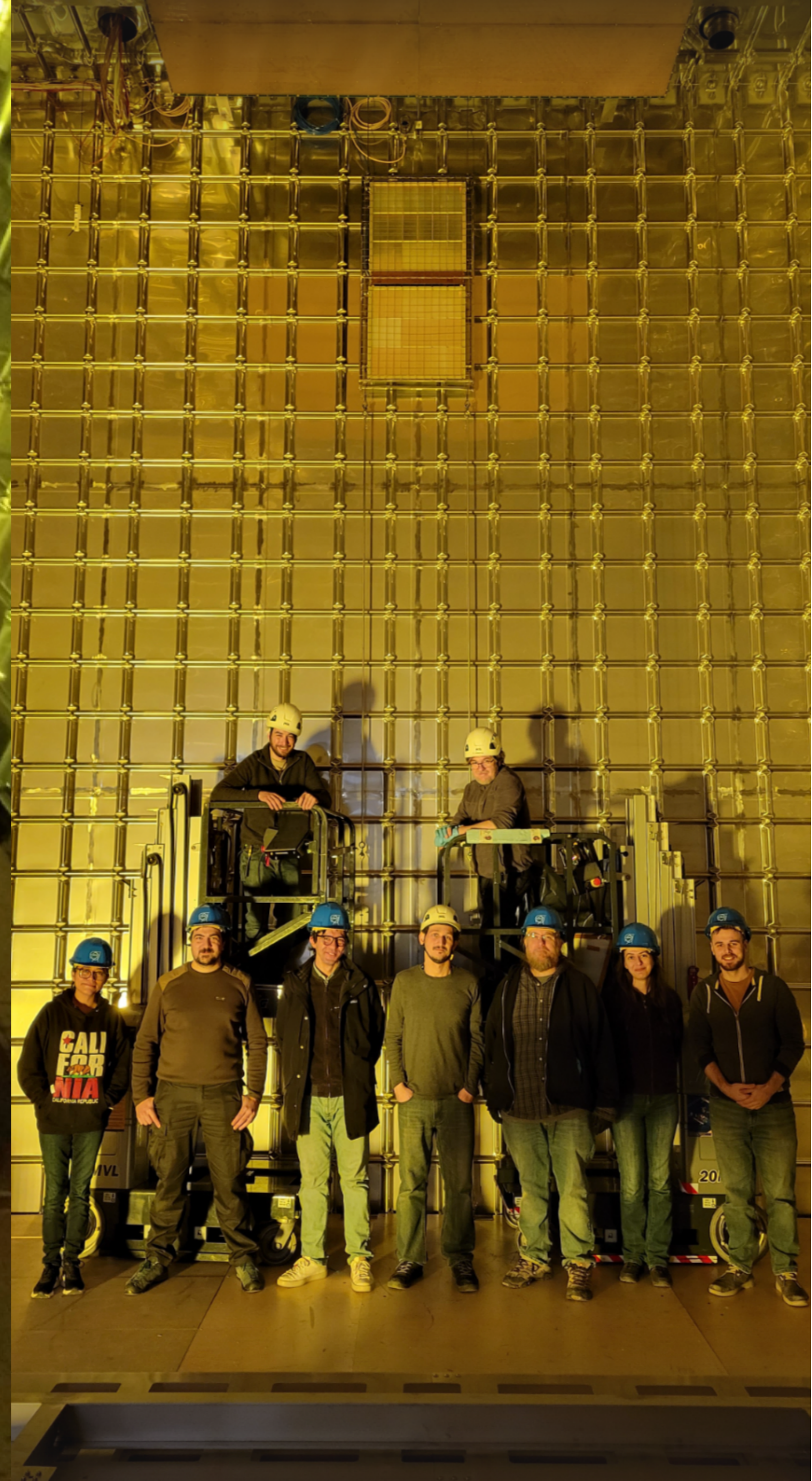
corrugated back tube from dewar to mini-rack



class-4 laser inside mini-rack

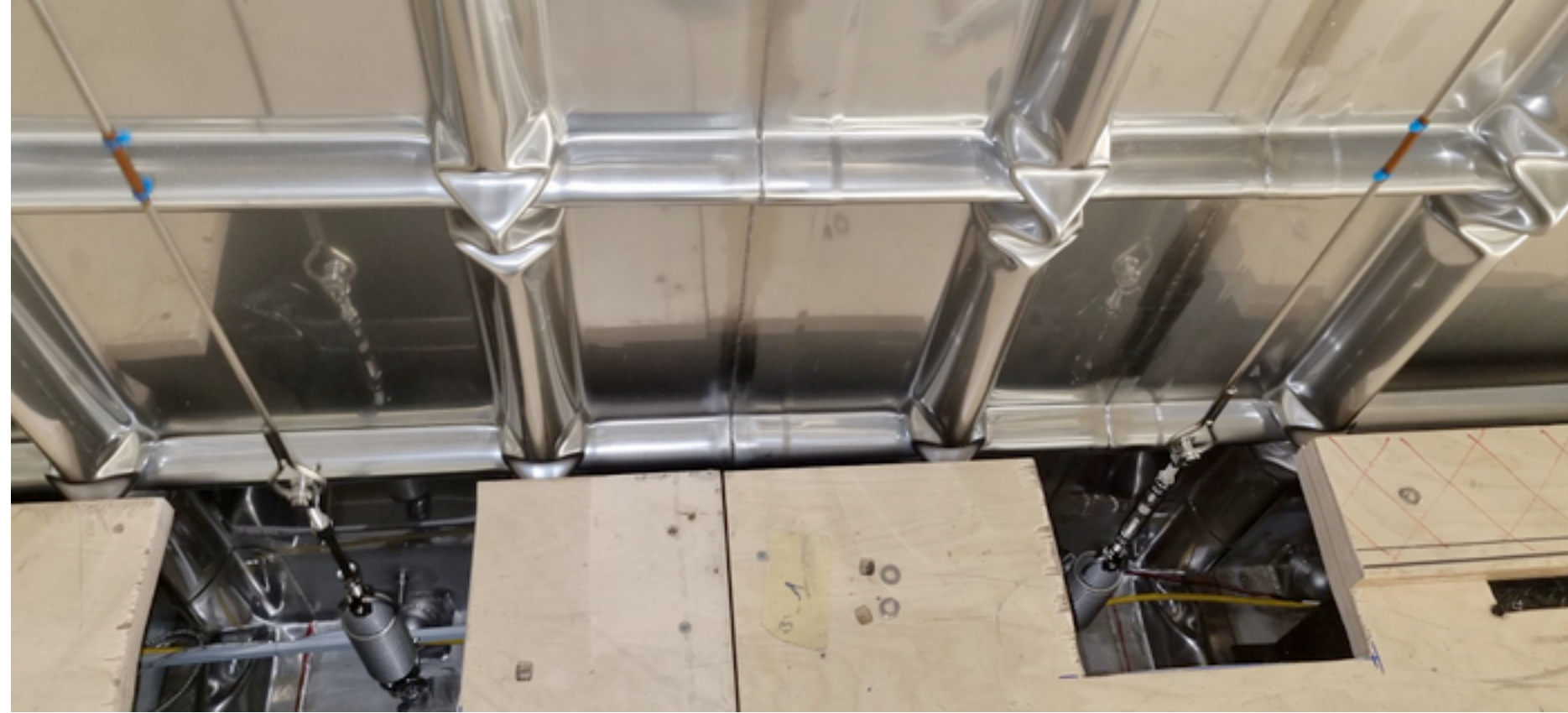


Installation

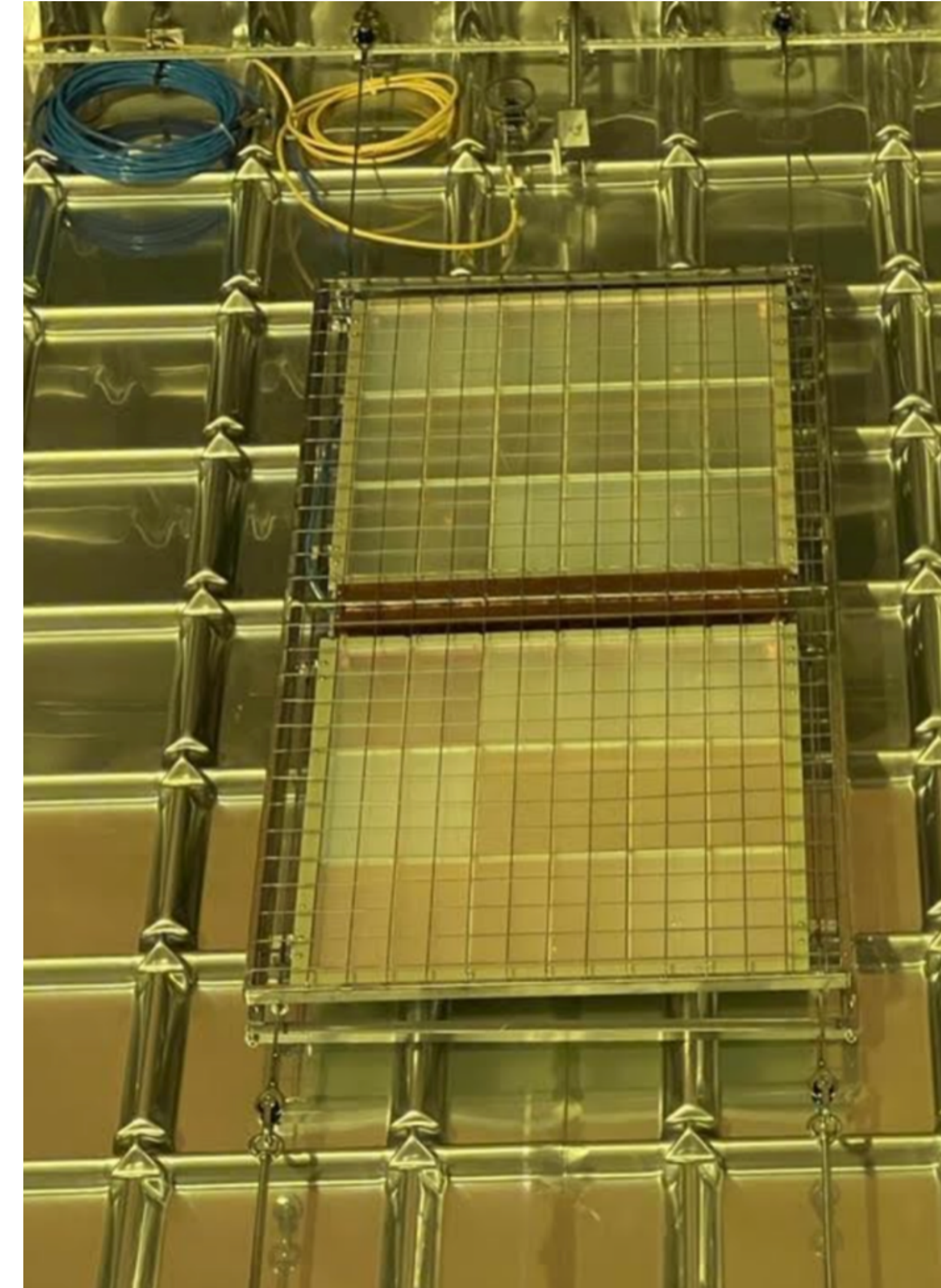


Installation of membrane modules

suspension lines



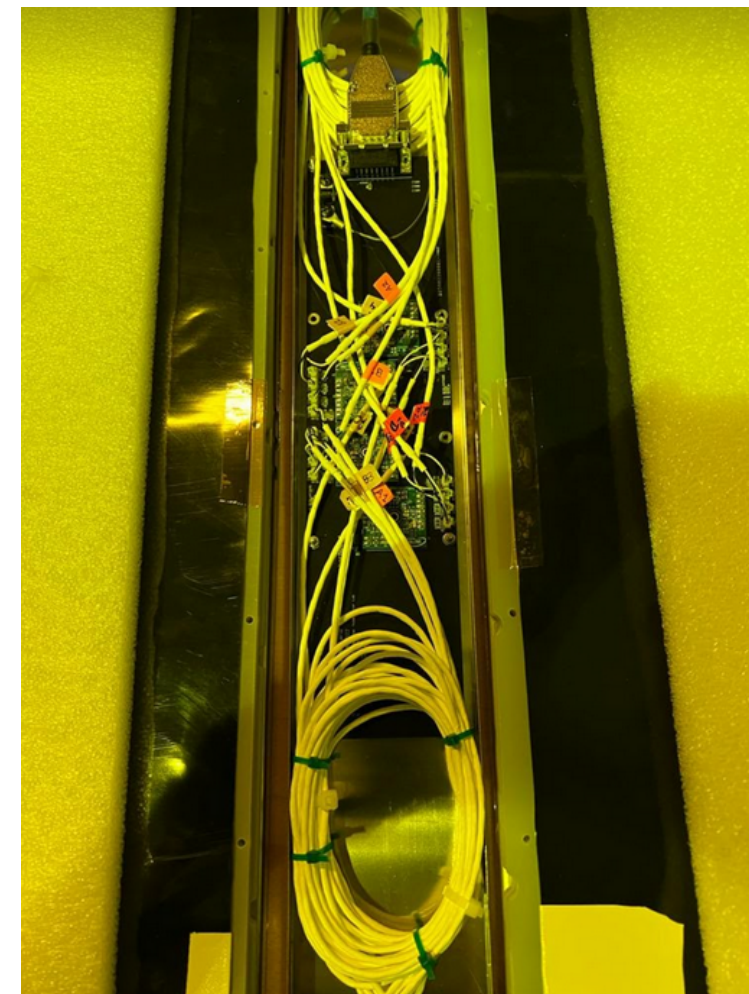
XA support



Two persons in two scissor lifts



Elec. box between two modules



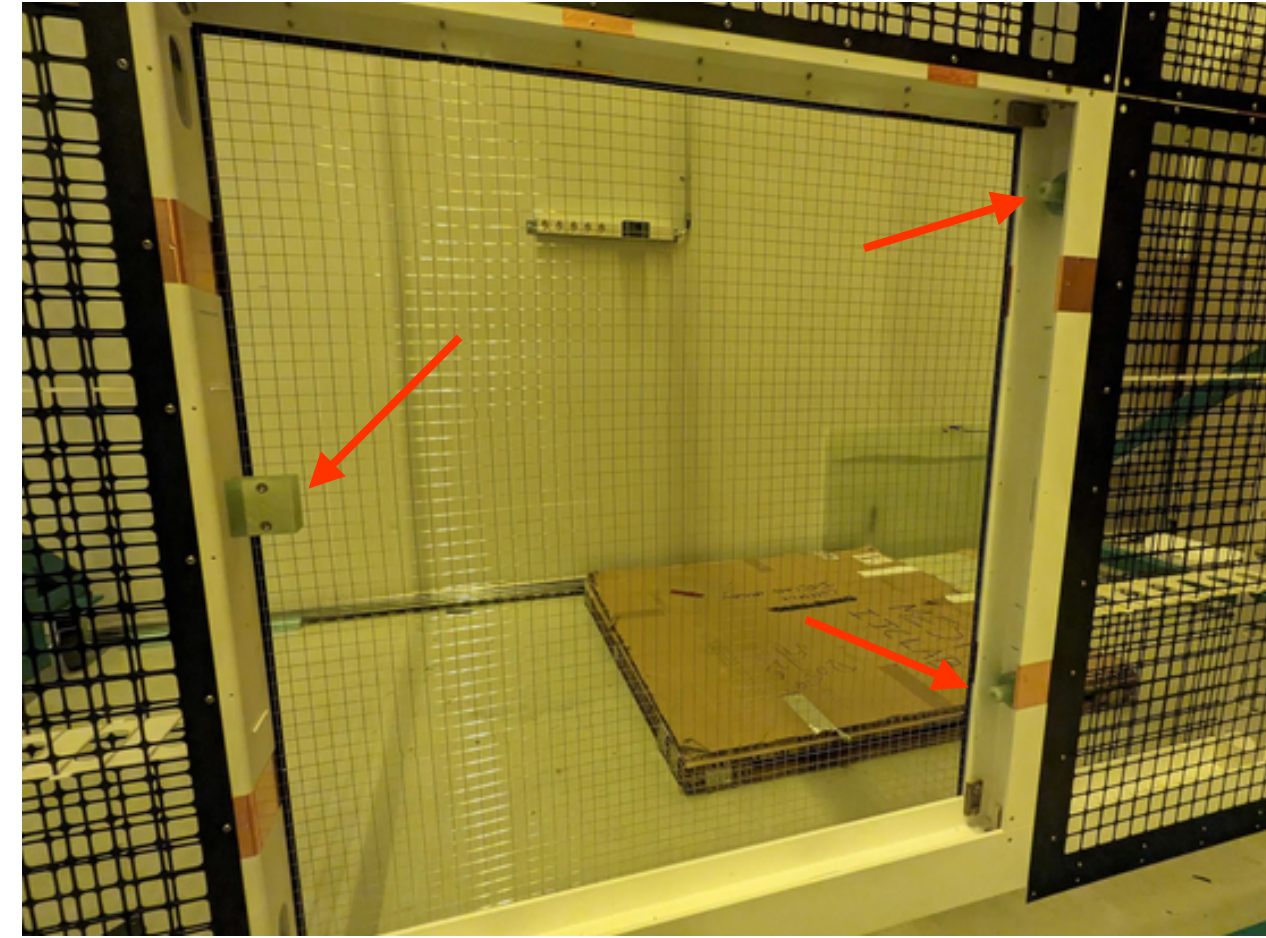
Manipulation of module pairs is delicate. Lower modules will be independent:

- One elec. box and one shielding mesh per module
- This also allows independent testing wo elec. manipulation after testing

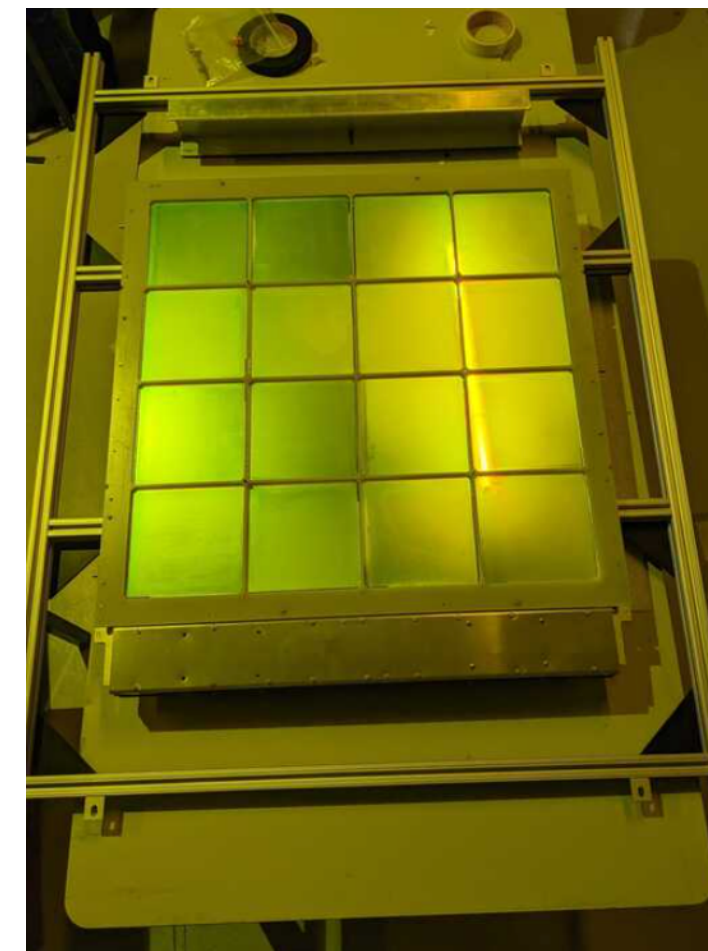
Installation of cathode modules

Quite straight forward operation except for one of the four slots: modifications in either electronics box or cathode frame required for FD2

1. G10 supports on frame



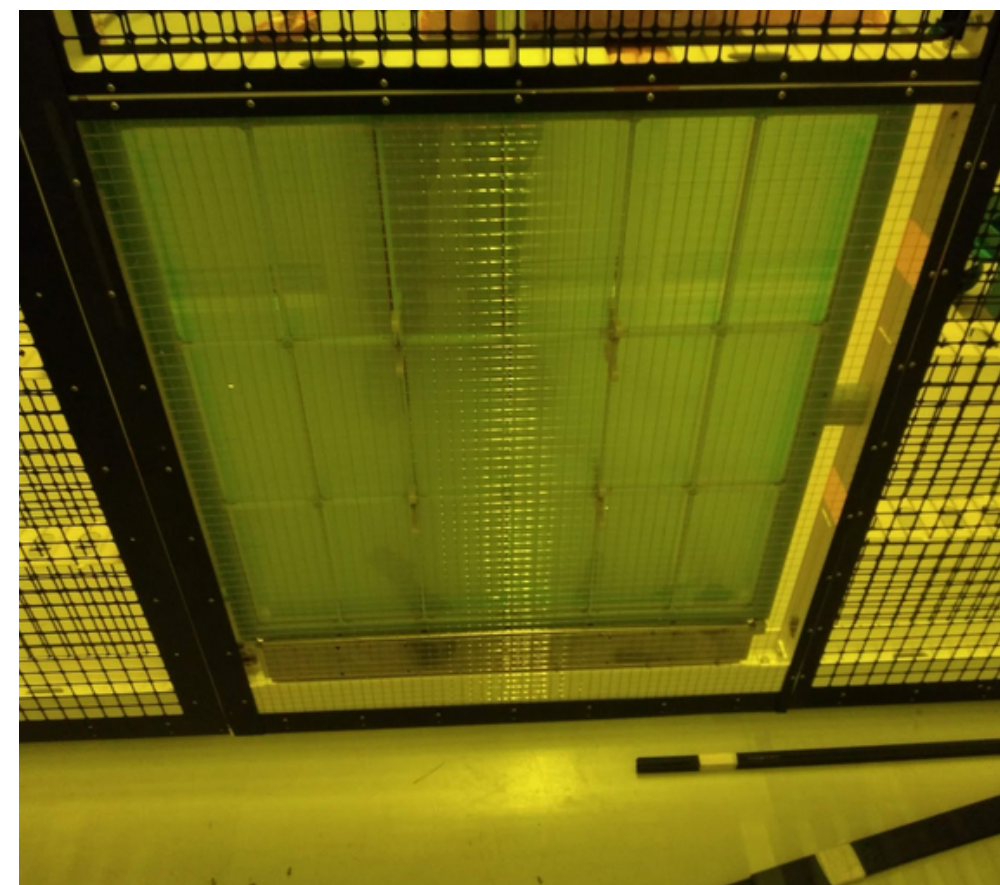
2. XA on transport frame



3. XA installation



4. shielding mesh



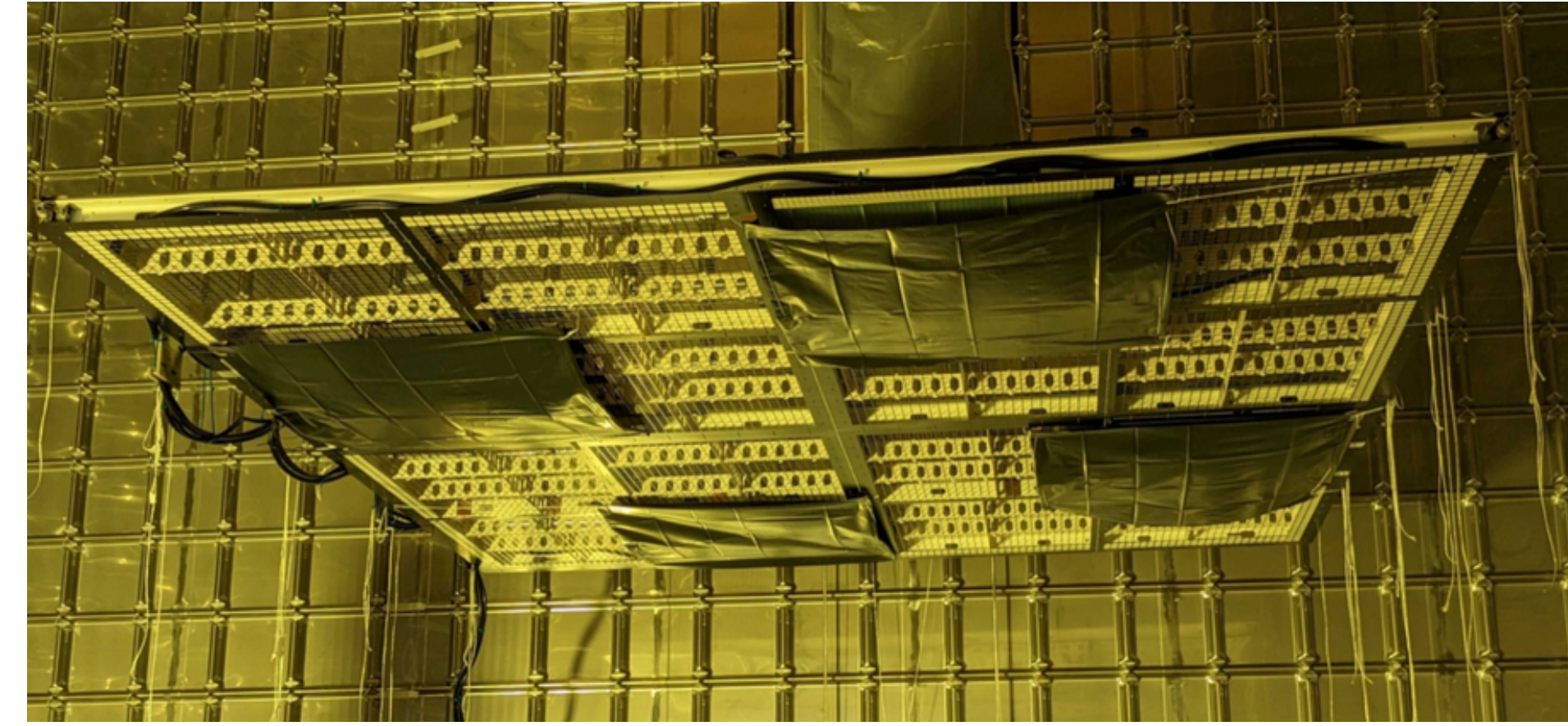
5. protection



6. to cryostat

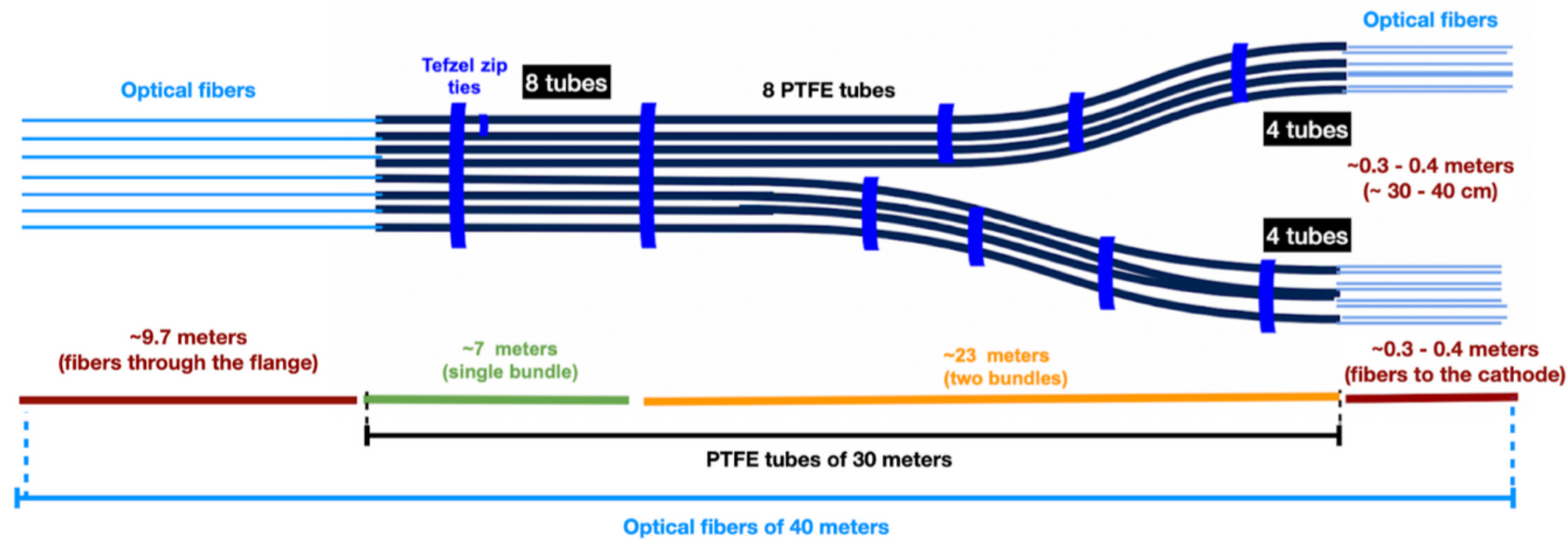


7. plastic covers



PoF and SoF fiber installation on cathode

- 64 fibers distributed in 8 PTFE tubes

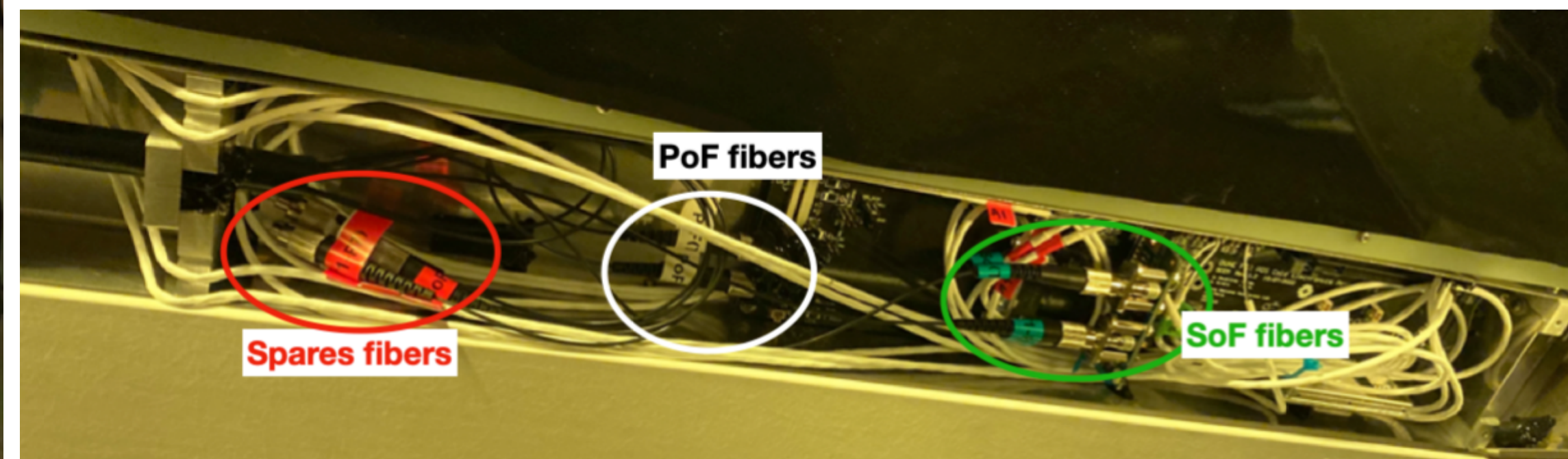


For FD2

- Need dedicated anchoring points in cathode frame
- To avoid helix shape:
 - Transport in larger boxes
 - Straighten them with heating gun



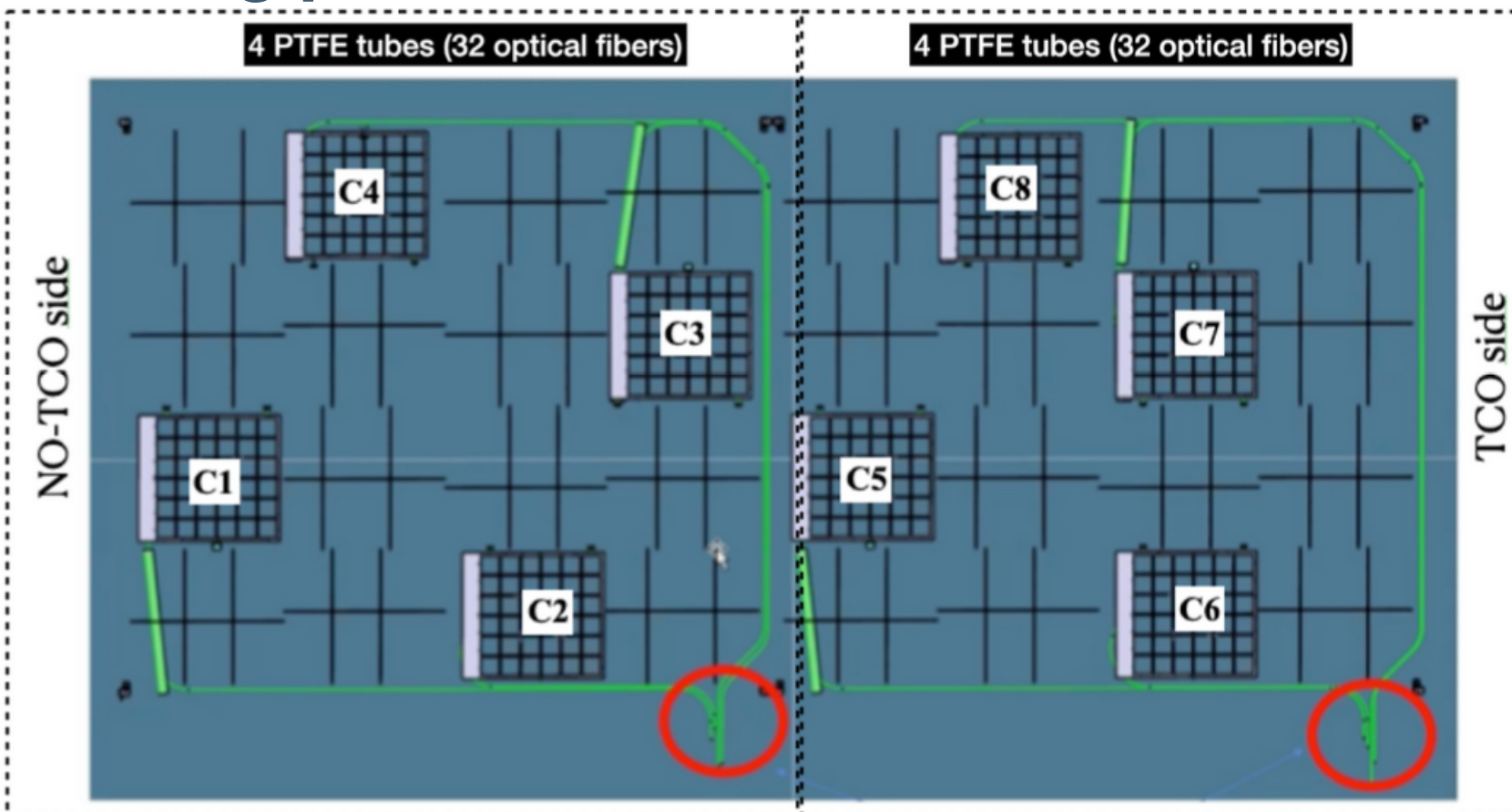
Connections in elec. box



installation



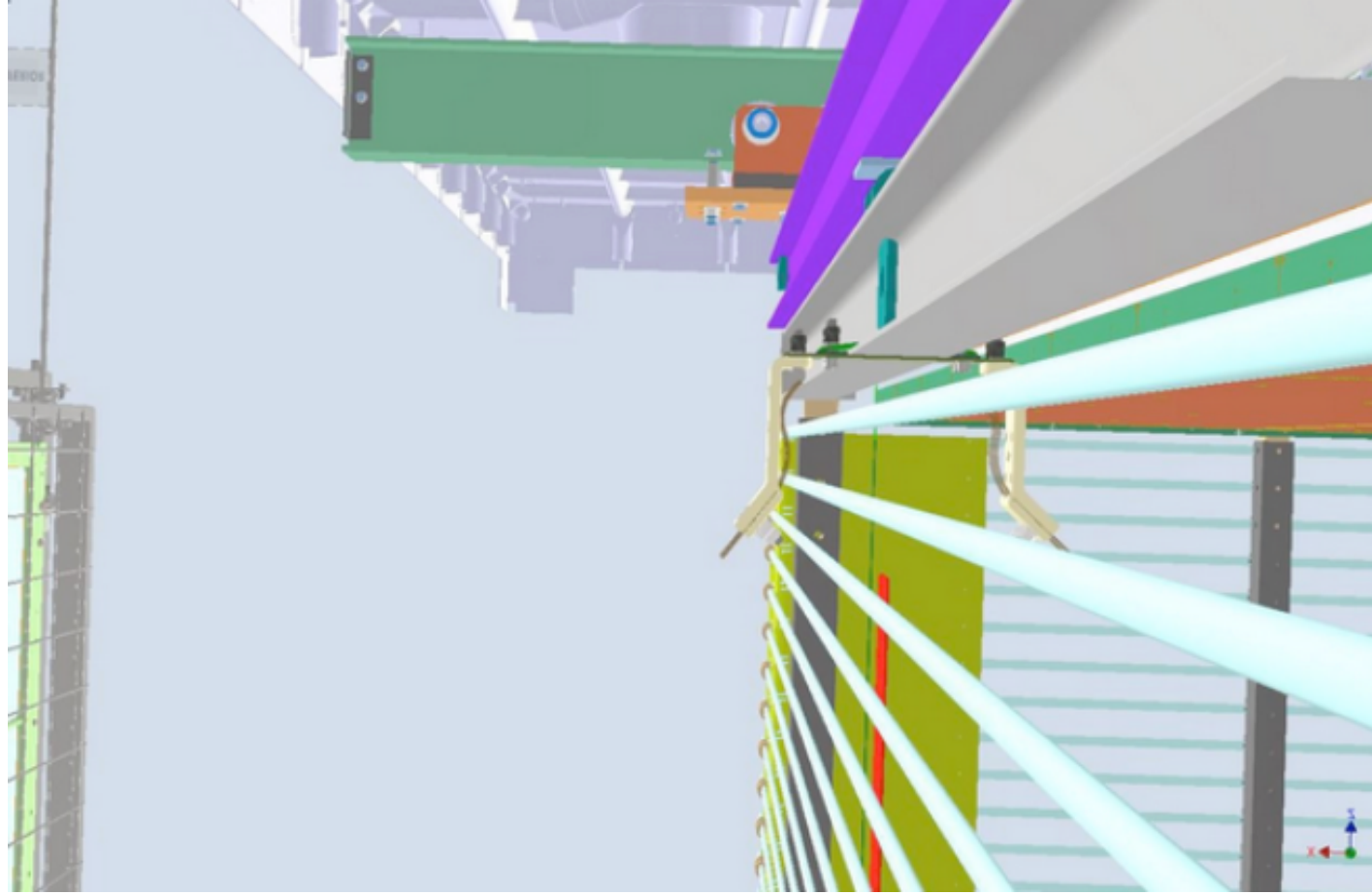
routing path




Response and Monitoring System

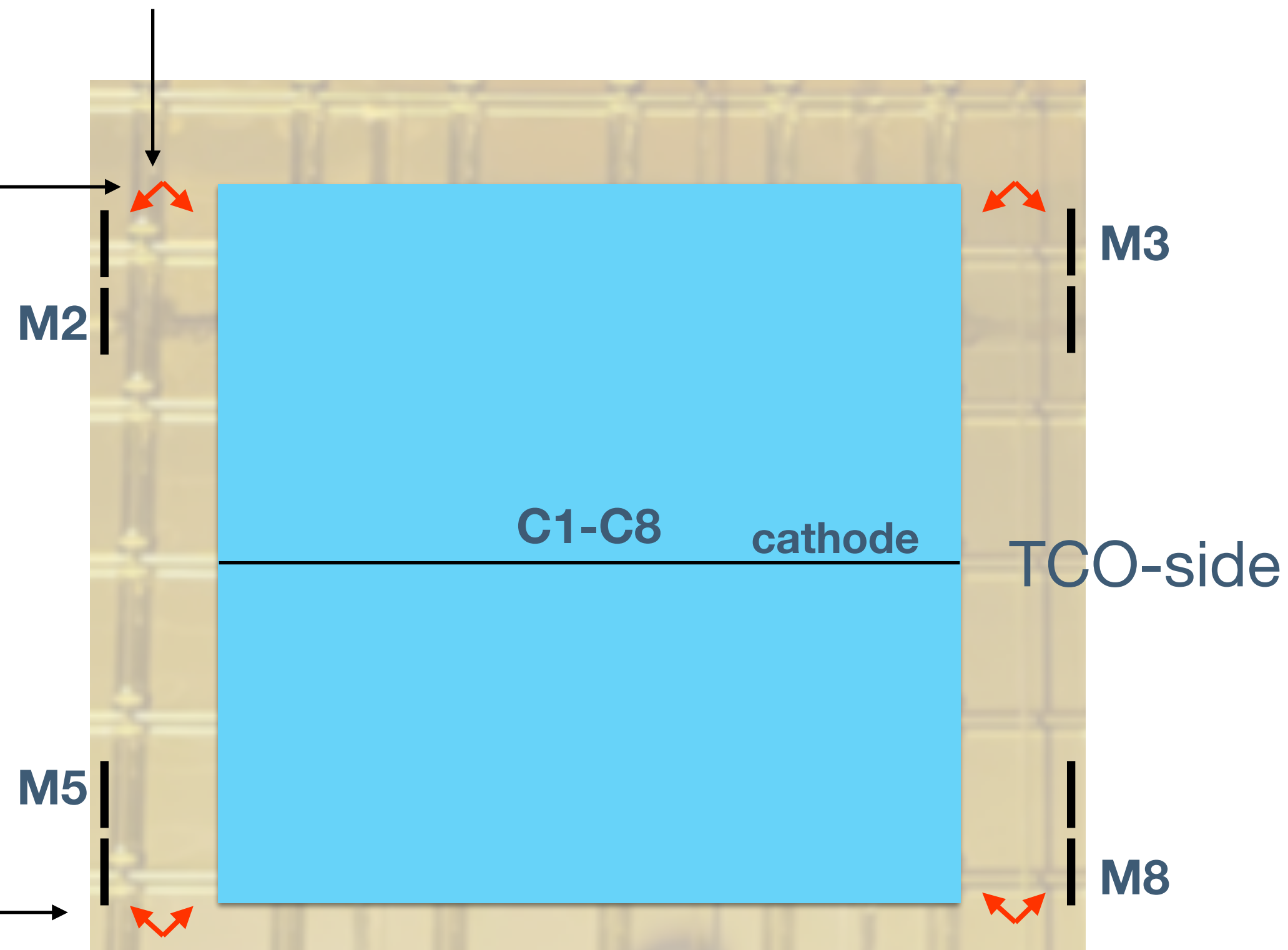
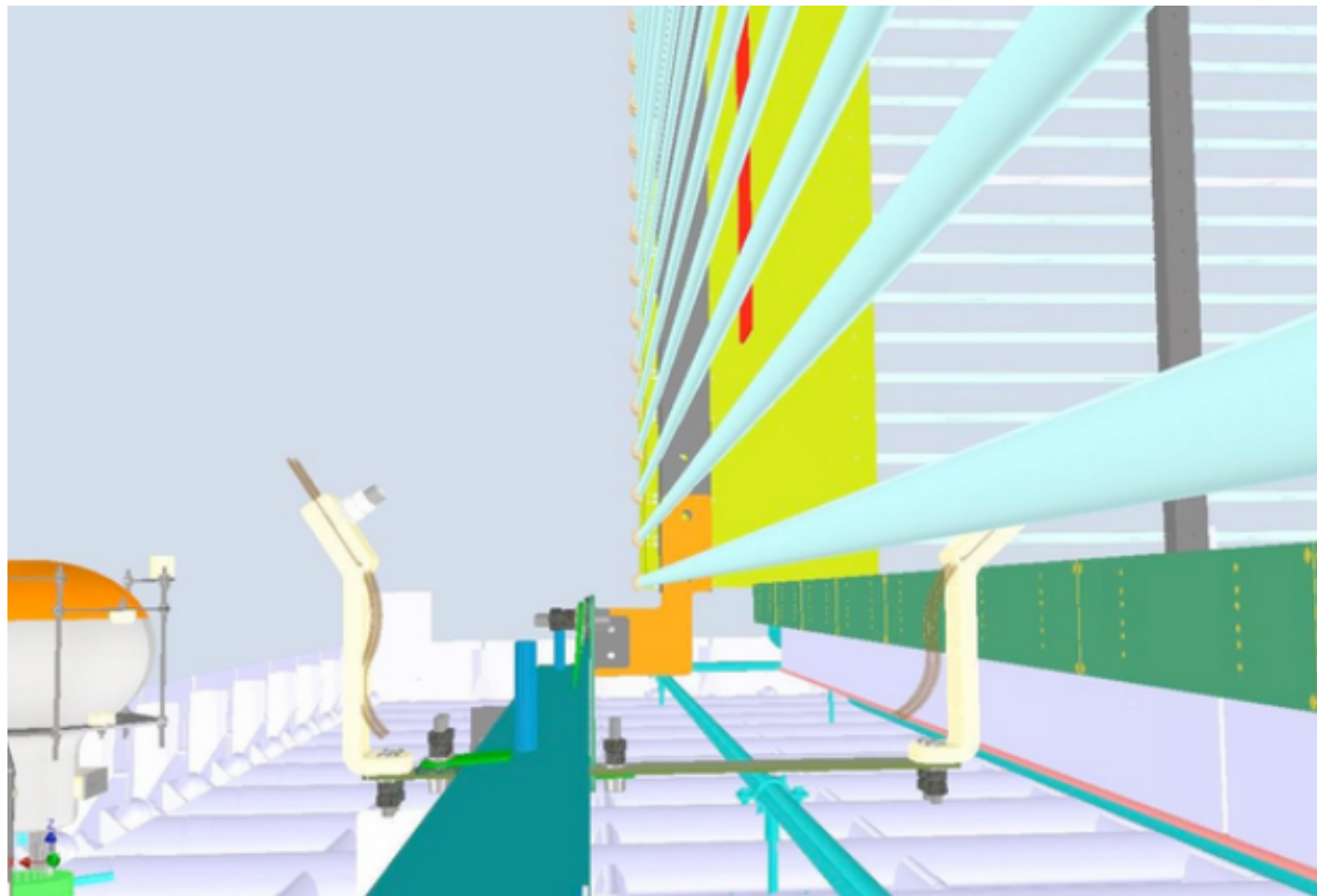
Beam with RMS kit before lifting

upper non-TCO kit



- Four kits () to be installed
- Only one installed so far

lower non-TCO kit

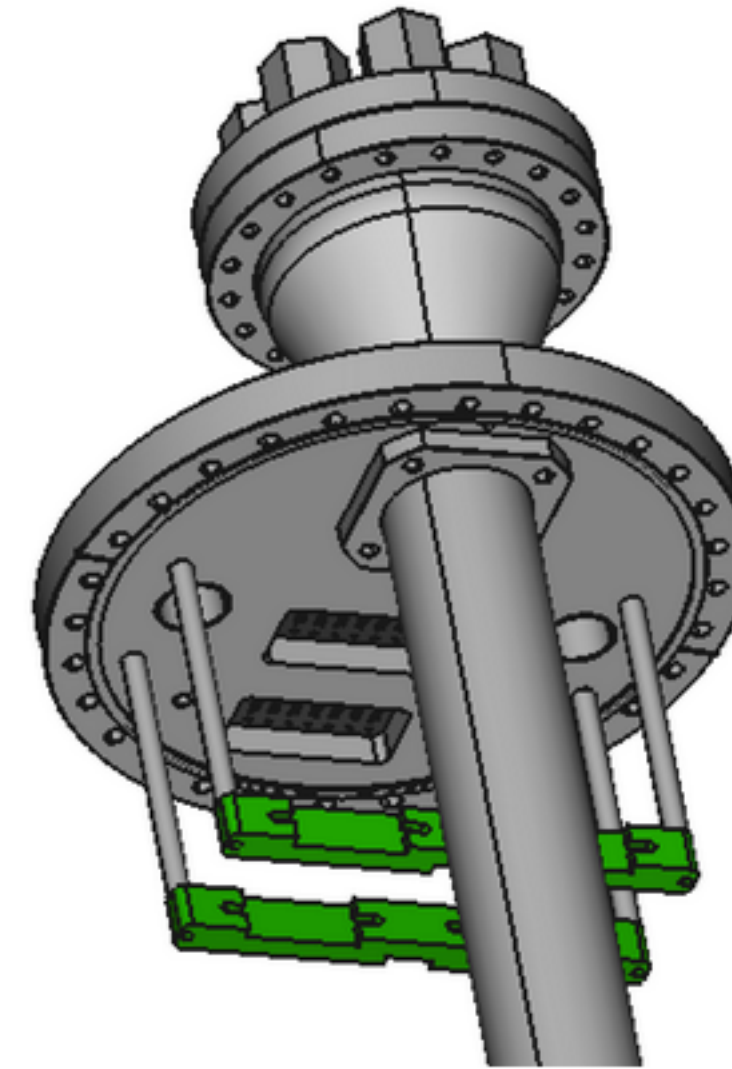
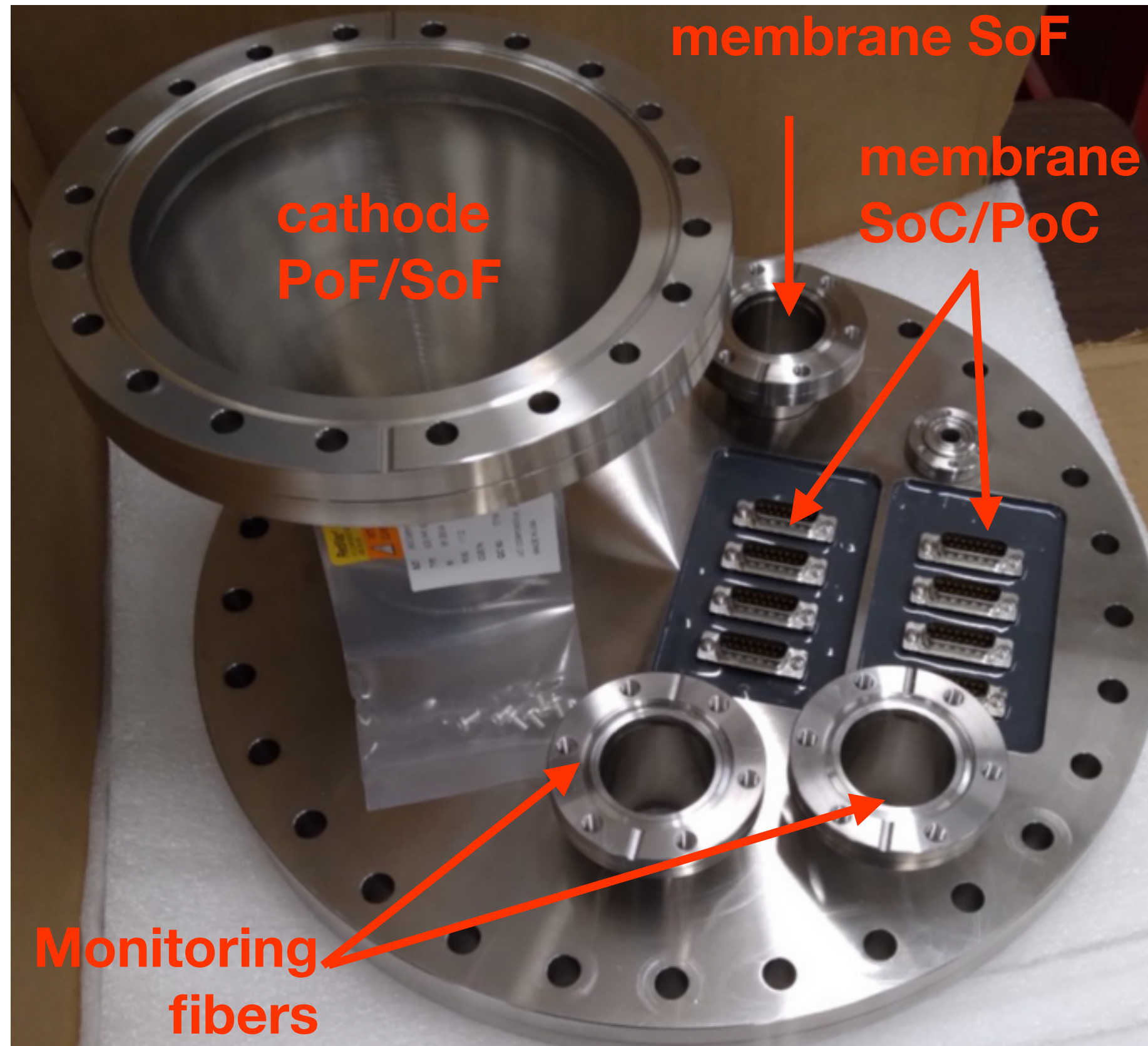


PD-HD RMS rack

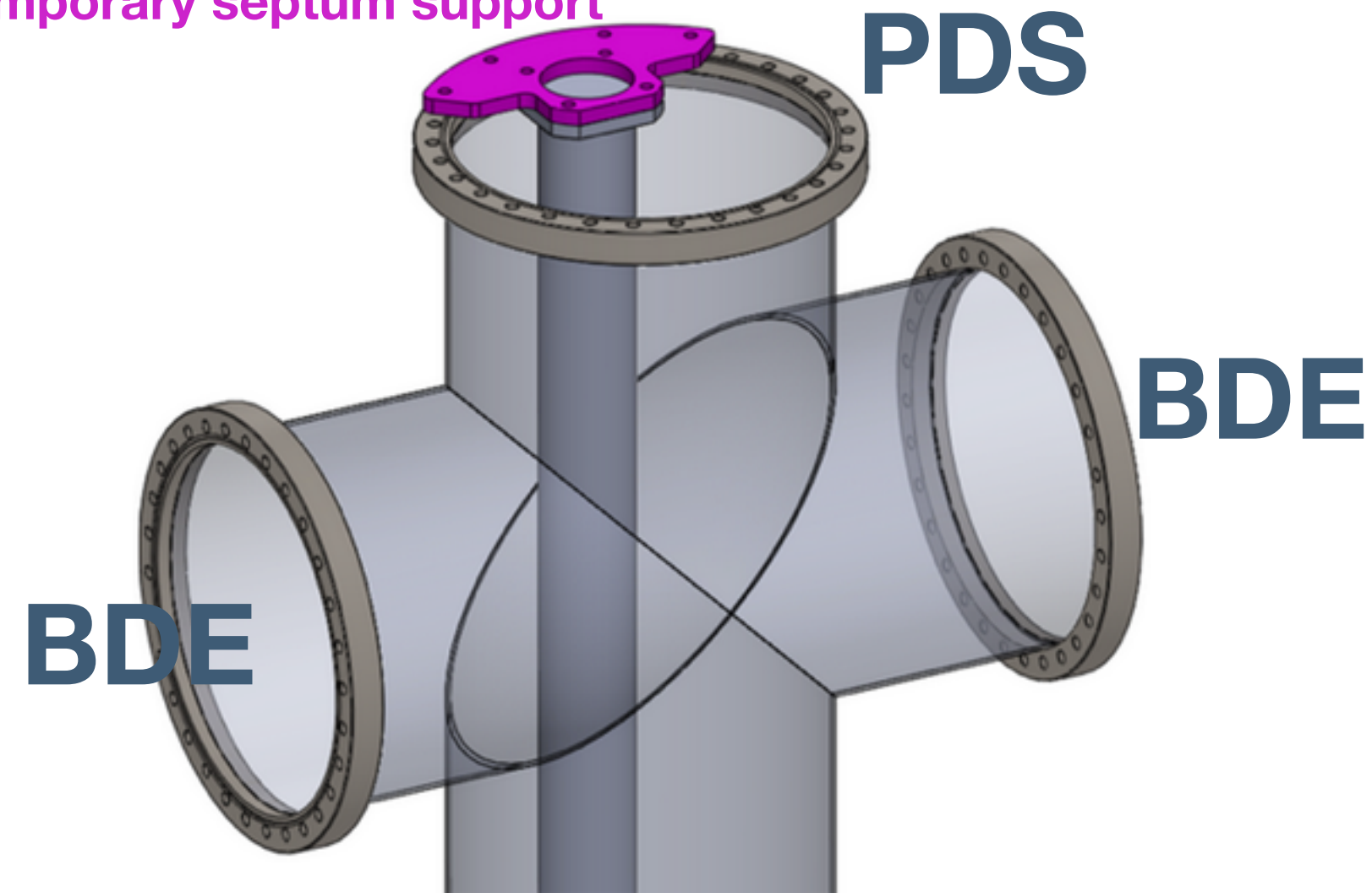


Plans for flange

- Will be installed mid May
- Needs coordination with BDE



temporary septum support



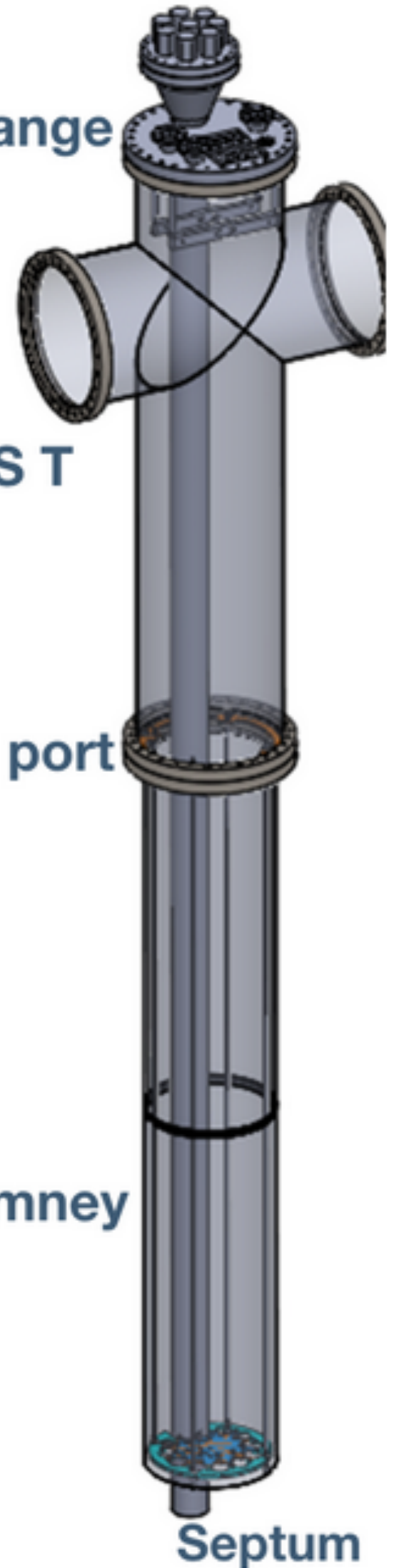
PDS flange

BDE-PDS T

cryostat port

cryostat chimney

Septum



A great team

- So far a successful campaign, thanks to a great team, with more than 30 people contributing at CERN, with avg. of 6 and peaks of almost 15
- Of course, many more abroad, timely producing and testing components, and giving useful advice.

