DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

Design Validation II: protoDUNE-VD Module-0 Experience

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on behalf of PDS consortium


900 KG
JLG

Introduction

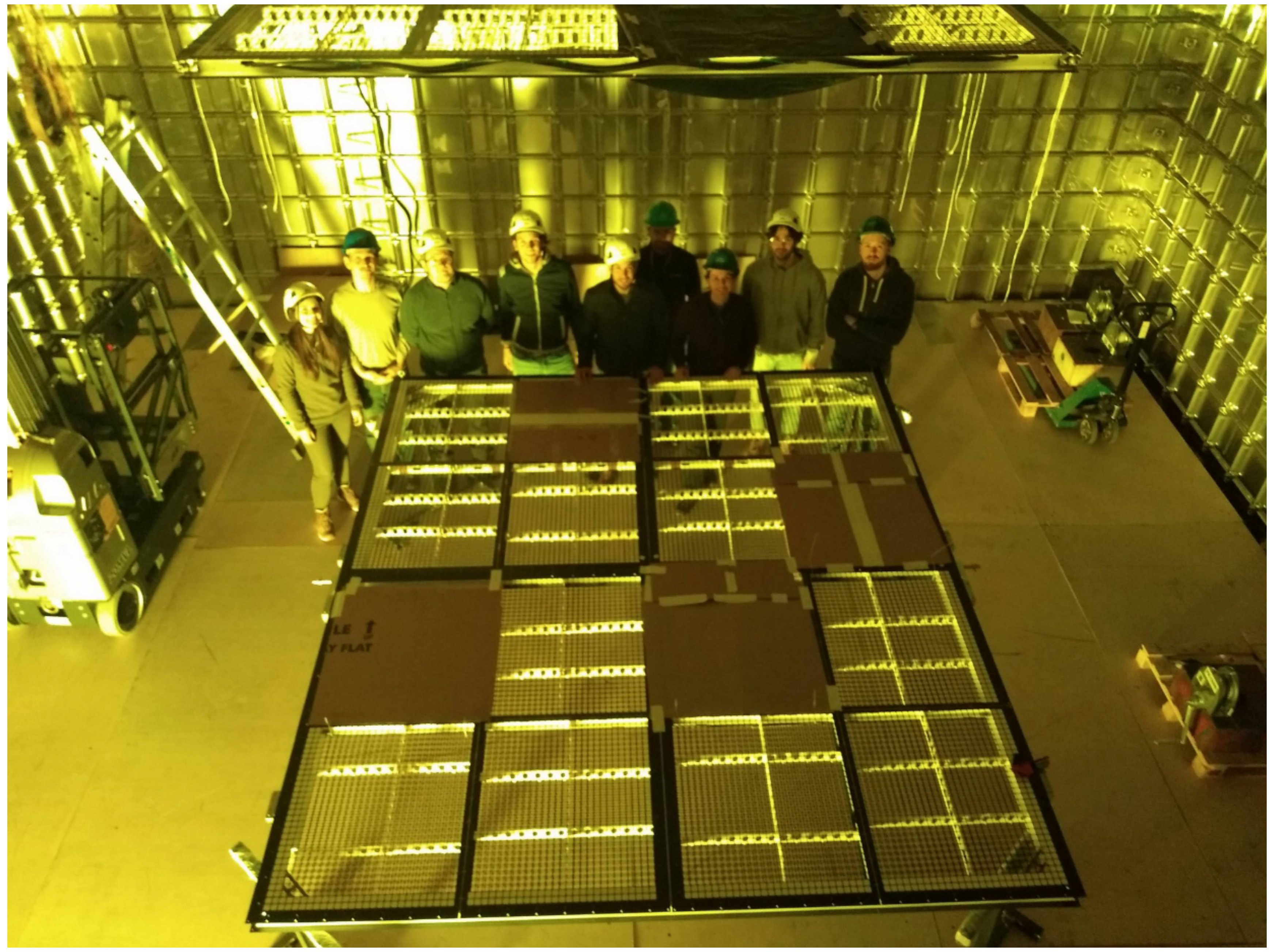
https://edms.cern.ch/document/2875448/1

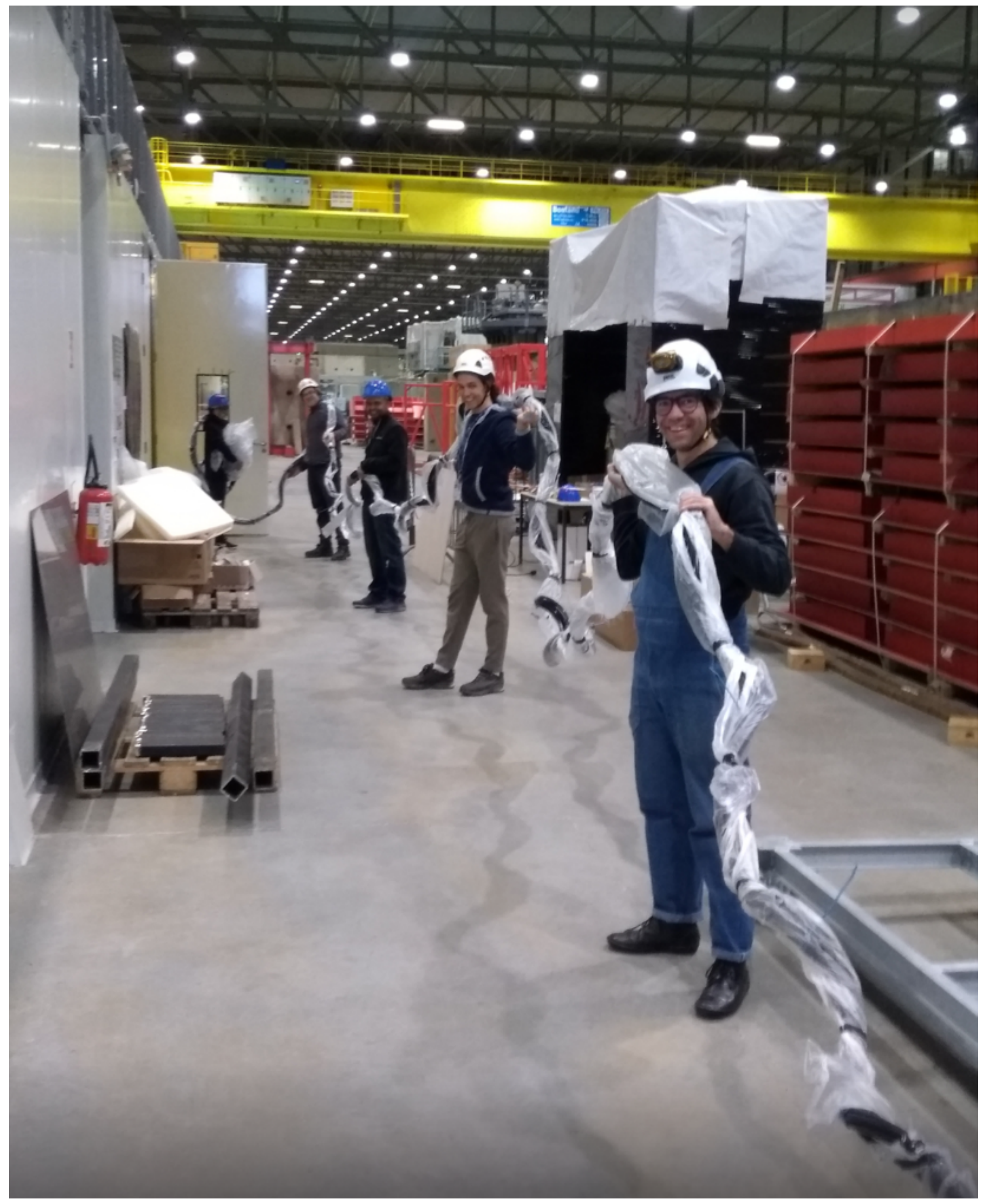
- ProtoDUNE-VD is a crucial step towards FD2
- The document describing pre-testing assembly, testing and installation is posted in EDMS:
  - Complicated logistics (production of components in more than 10 sites around the world)
  - All operations done at CERN and the plans for finalizing the installation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

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

X-ARAPUCA

cold electronics

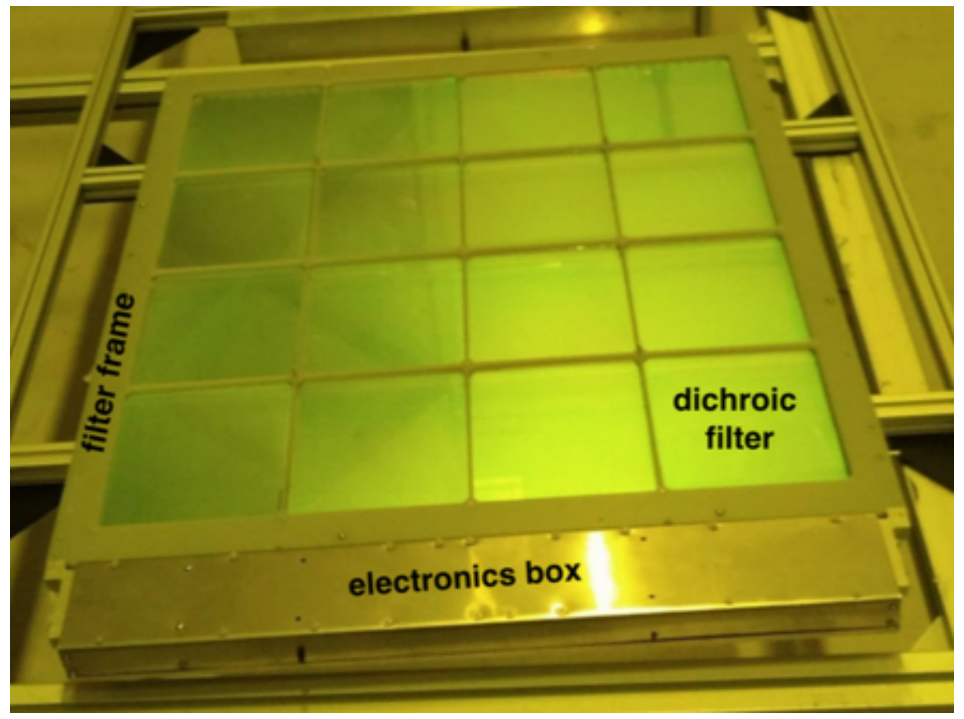
cold cables/fibers

flange

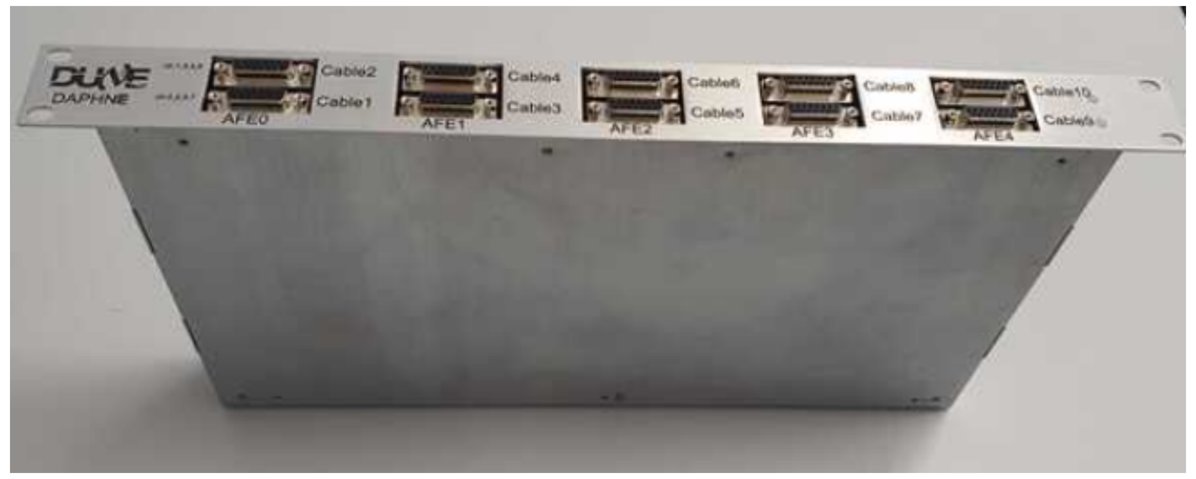
warm cables/fibers

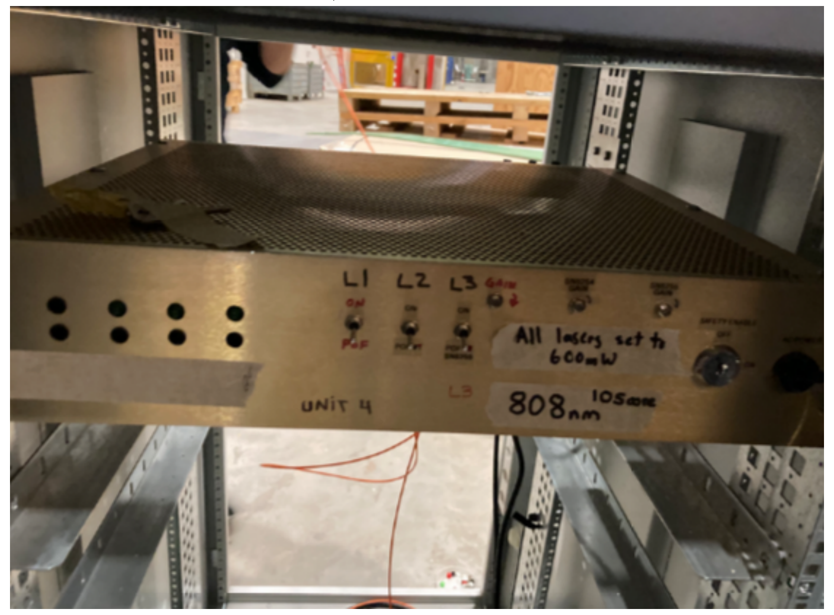
daphne

class-4 laser for PoF



SiPMs + DF + WLS

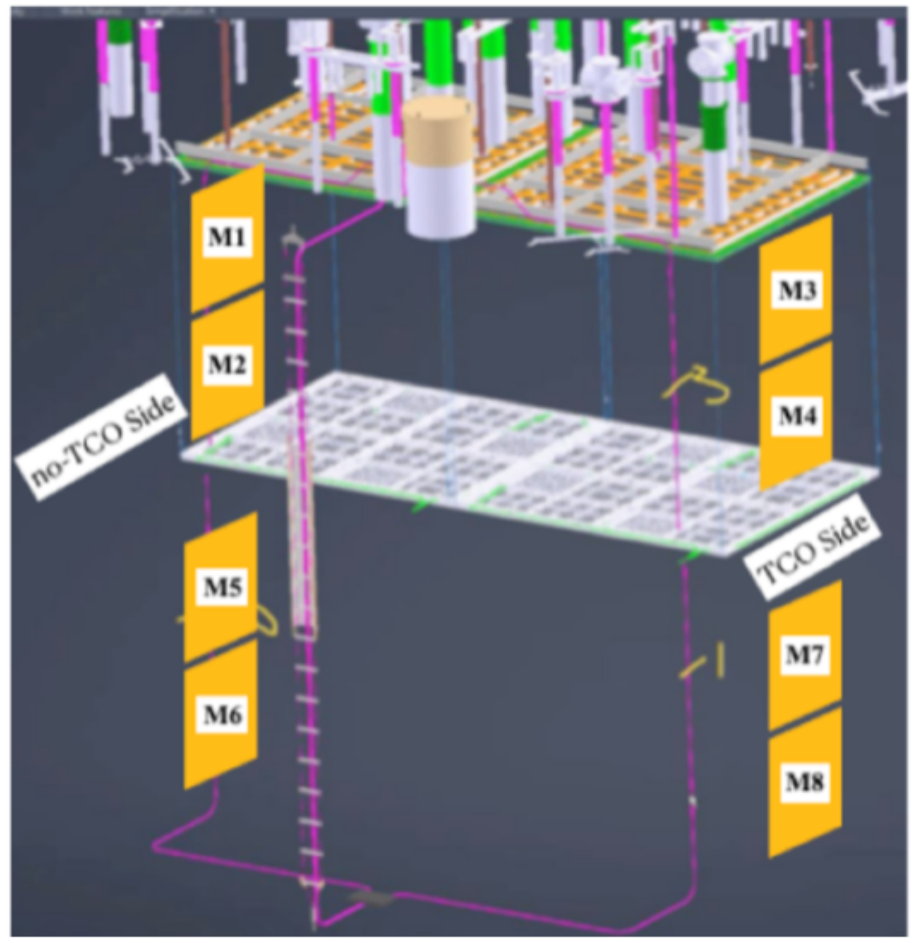


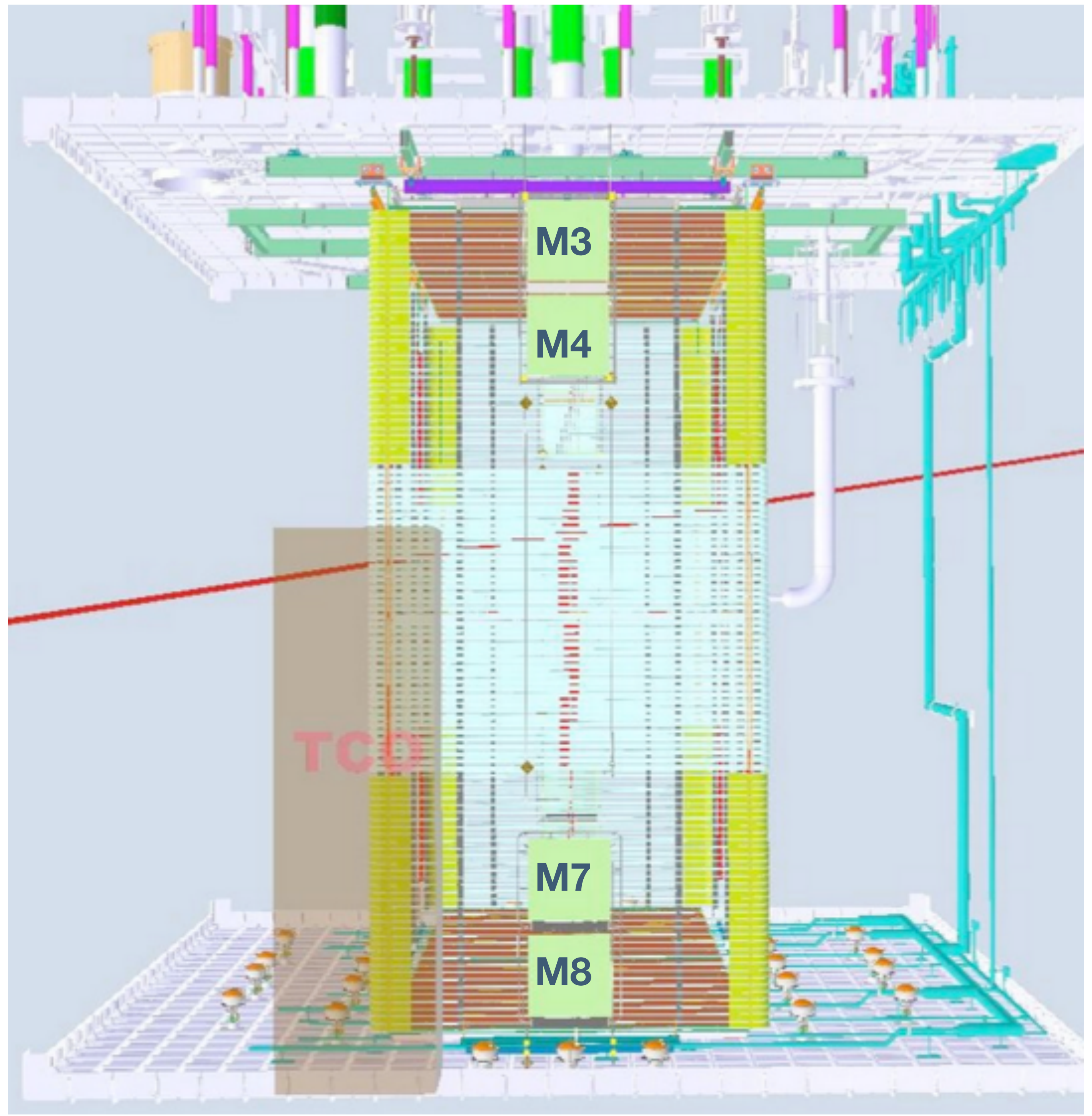


PDS in ProtoDUNE-VD

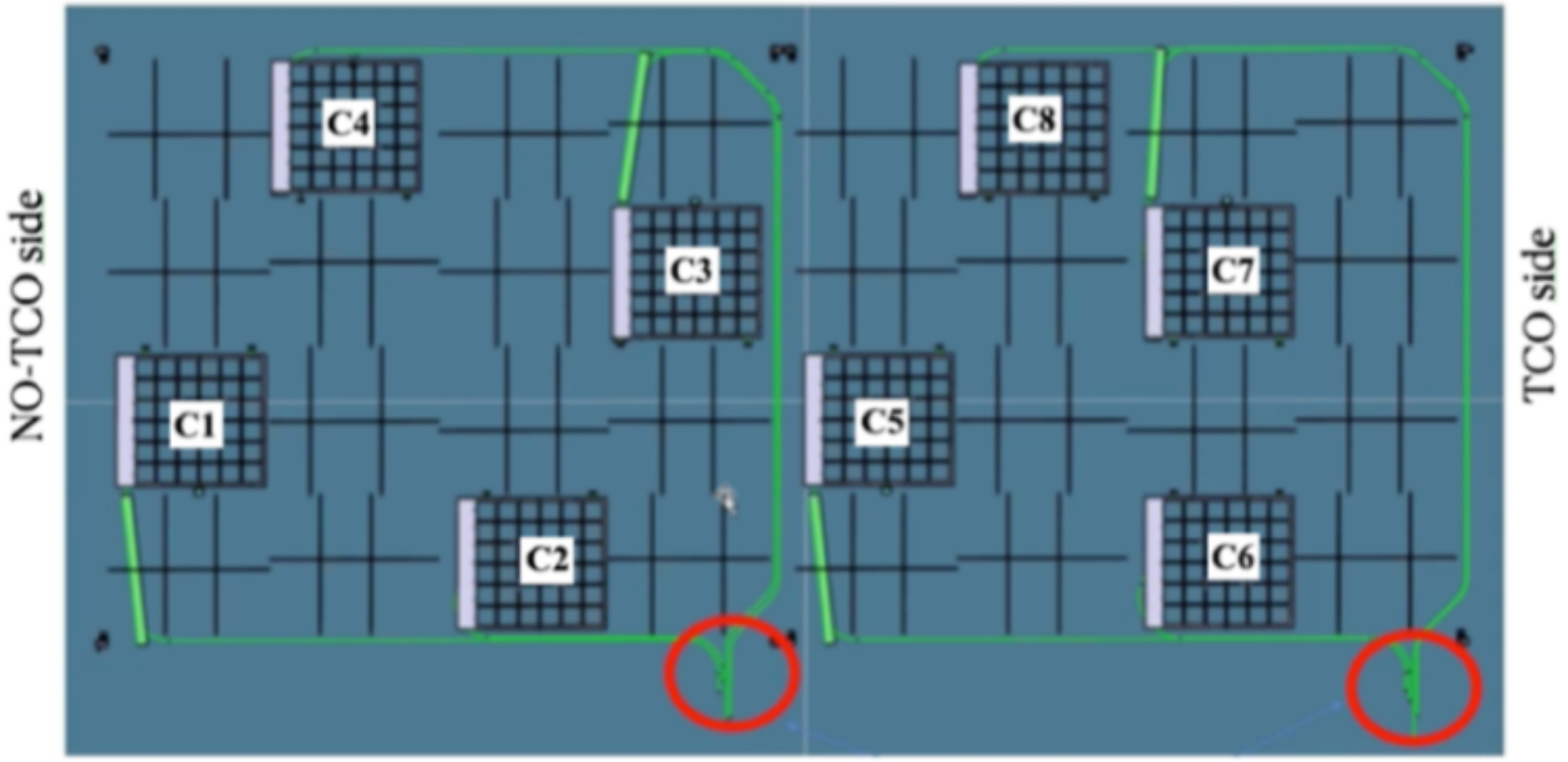
- 16 photon collectors (X-ARAPUCA), 8 in the central cathode and 8 near the cryostat membrane
- All modules assembled and tested at CERN
- A Response and Monitoring System (RMS) is also being installed

Membrane module pairs (quartets in FD2)





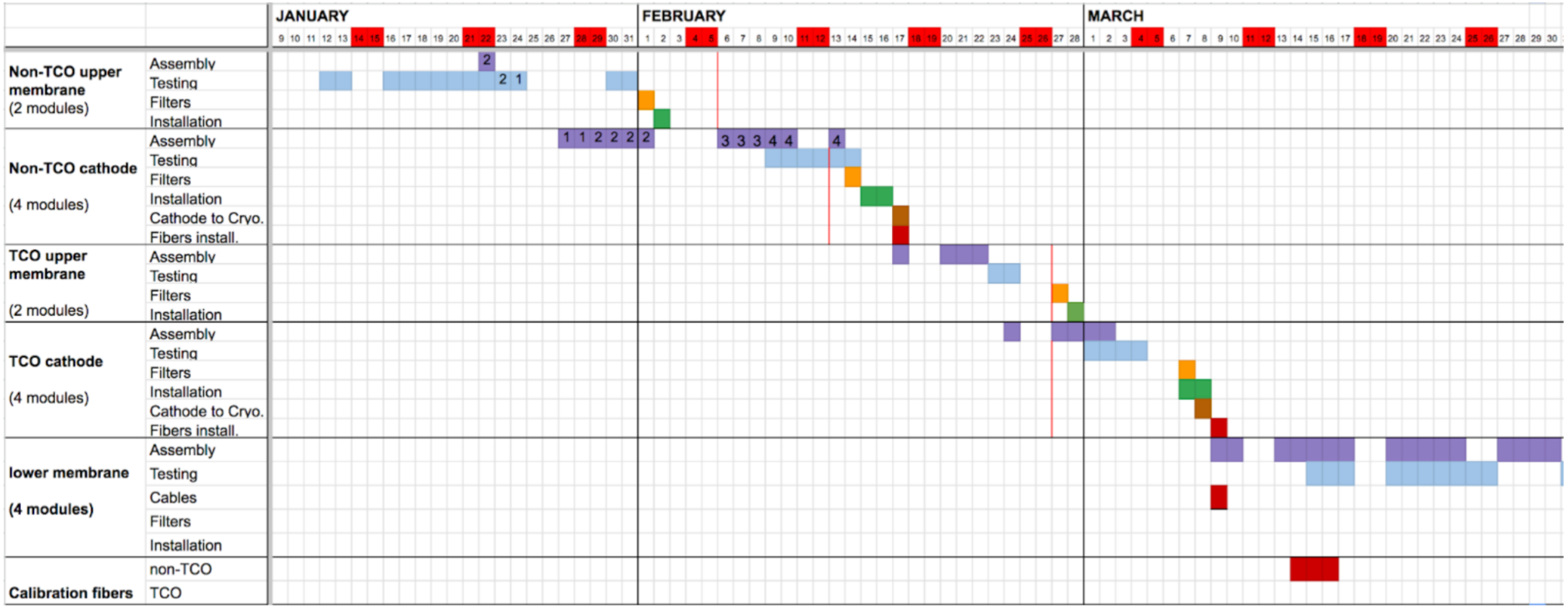
Cathode distribution as in FD2



Schedule and status

- 12 modules have been installed
- The last 4 modules (lower membrane XAs) will be installed next week
- Ongoing cold tests for the last three modules this week

test stand commissioning **massive production & testing**



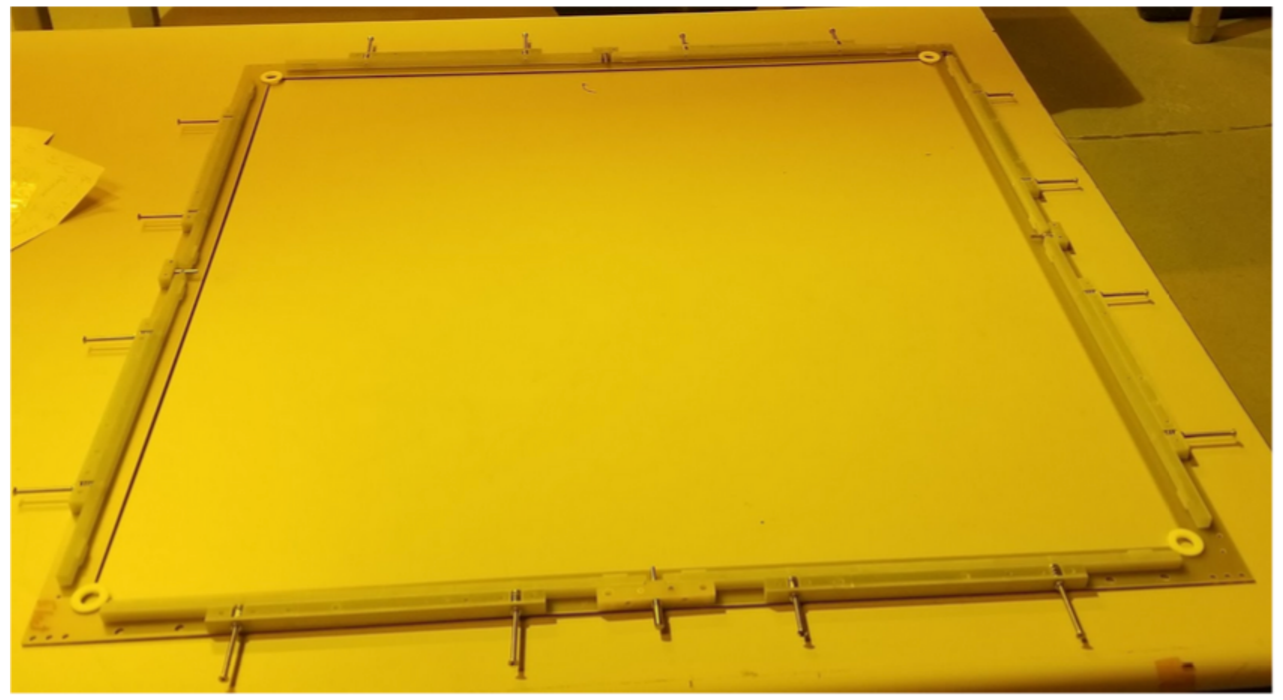
DEEP UNDERGROUND NEUTRINO EXPERIMENT

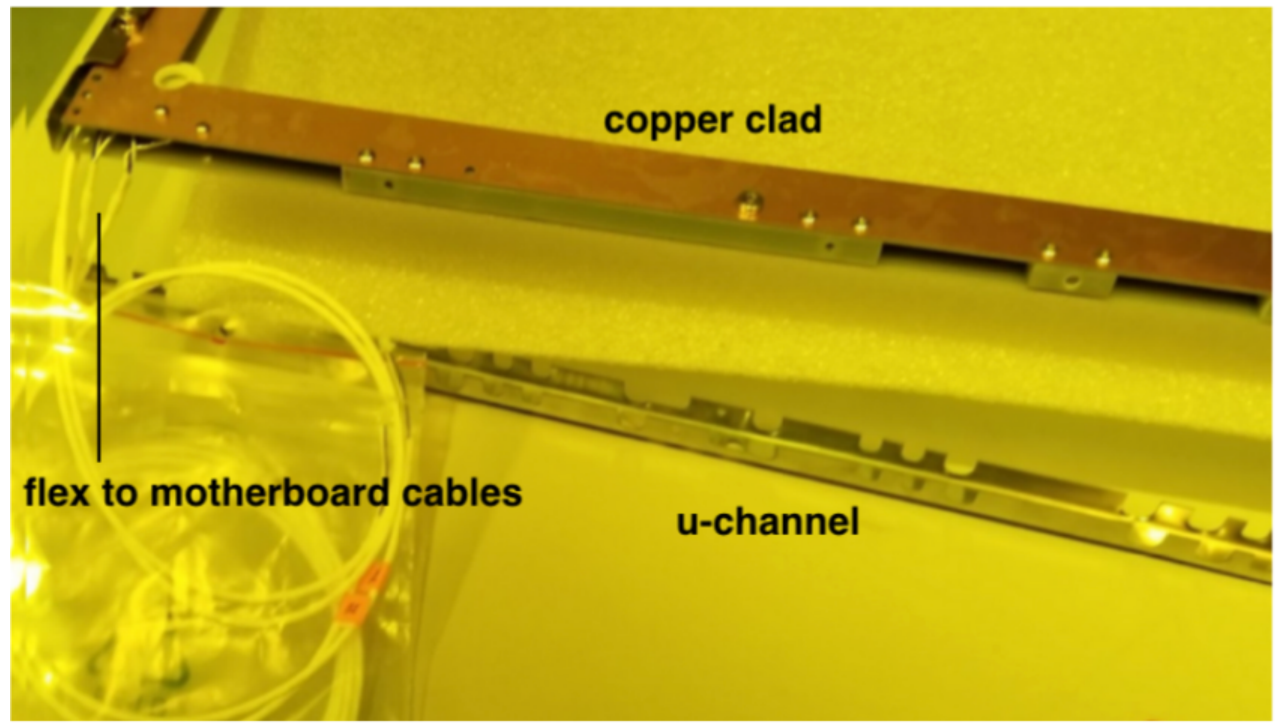
Assembly: photon collectors

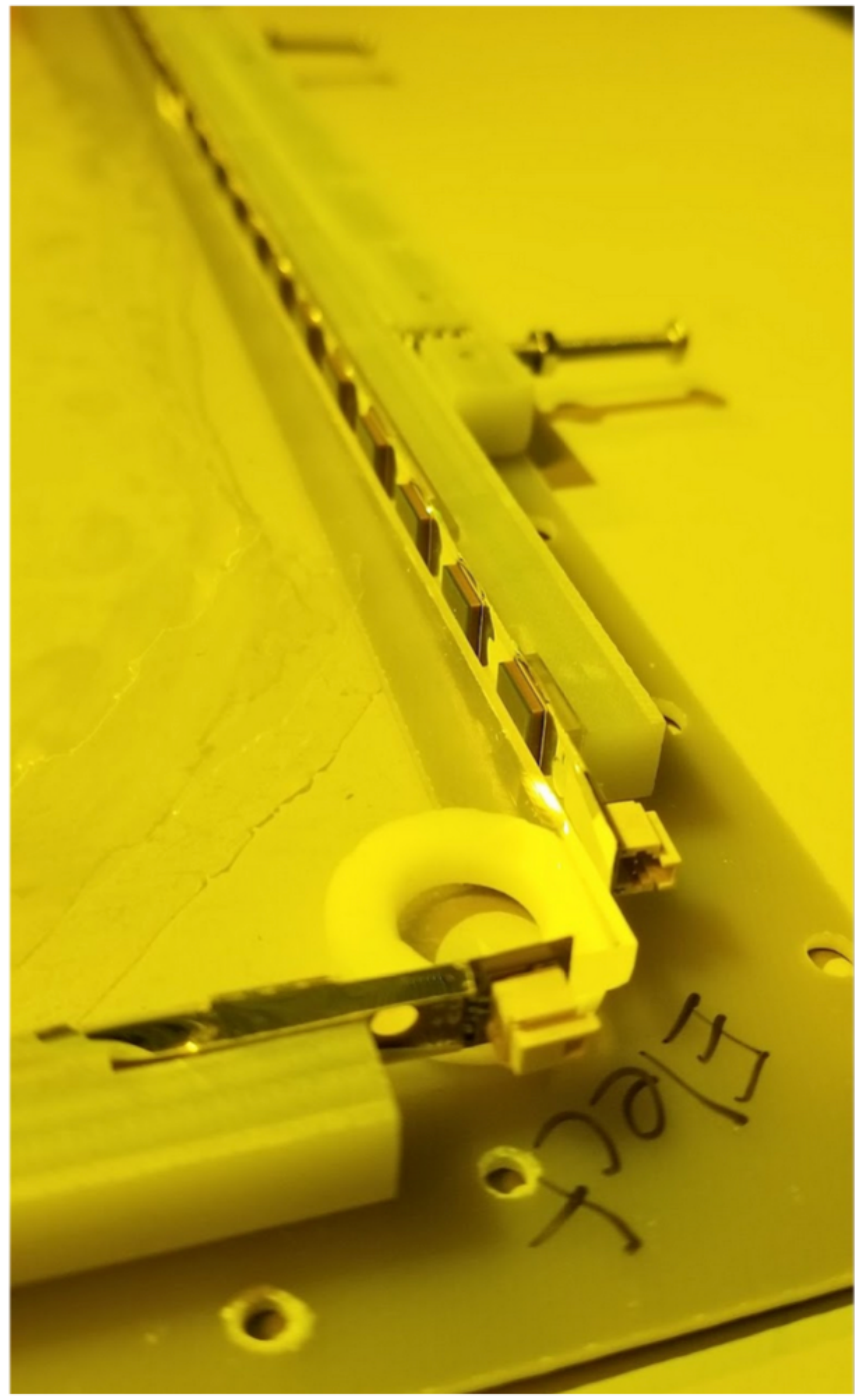
X-ARAPUCA, the PDS basic unit

See D. Warner's talk

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

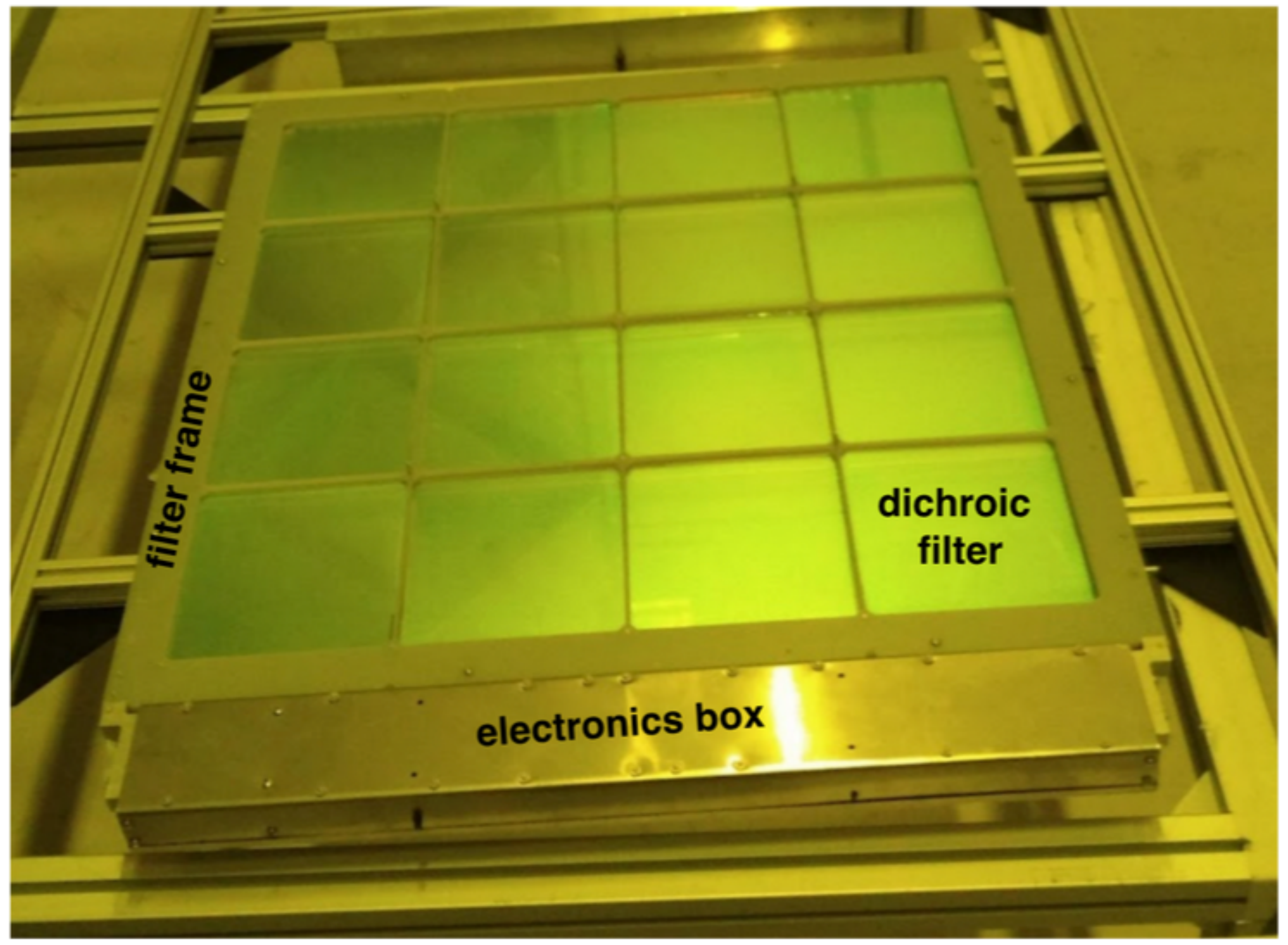


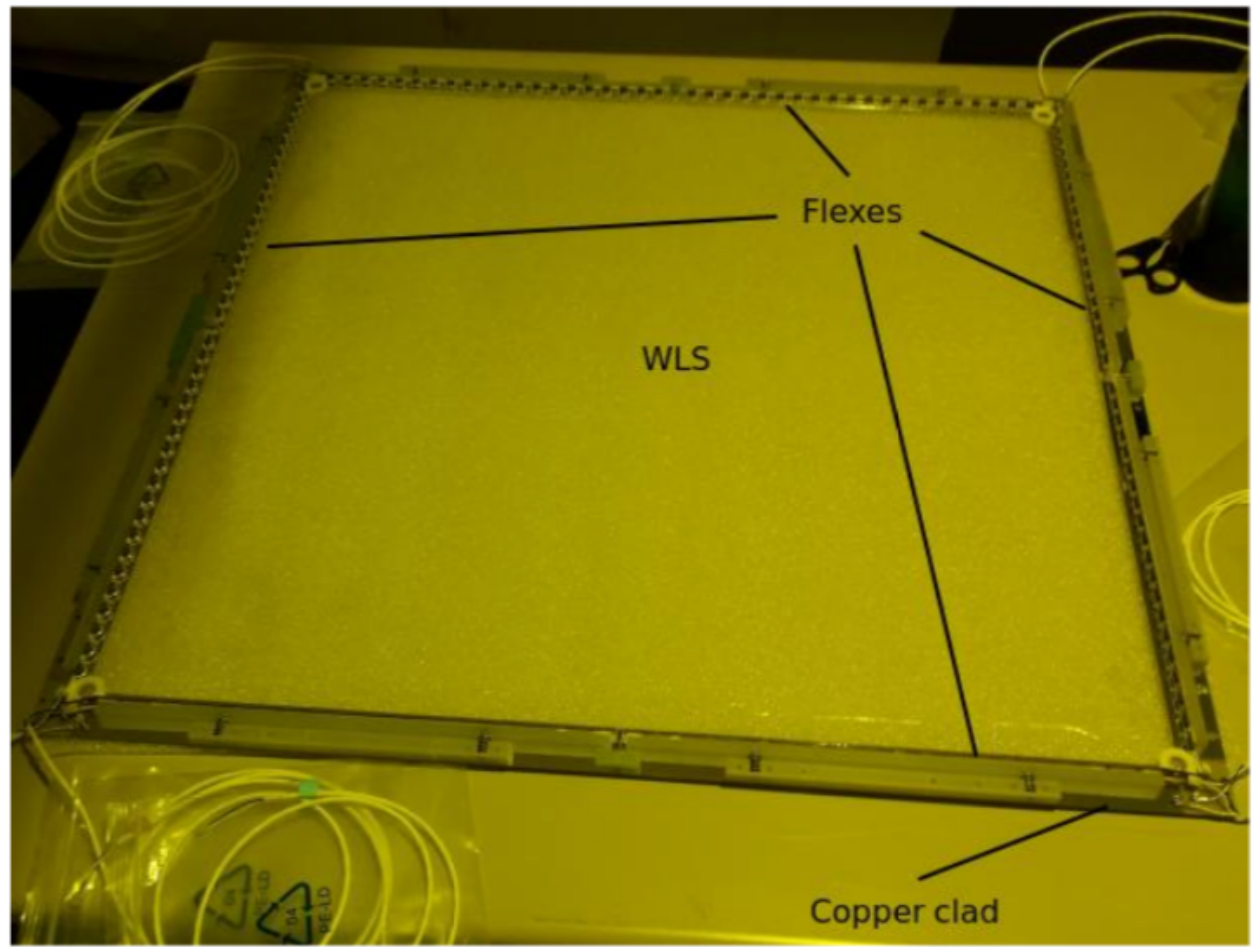




Assembling the first module took almost 2 days

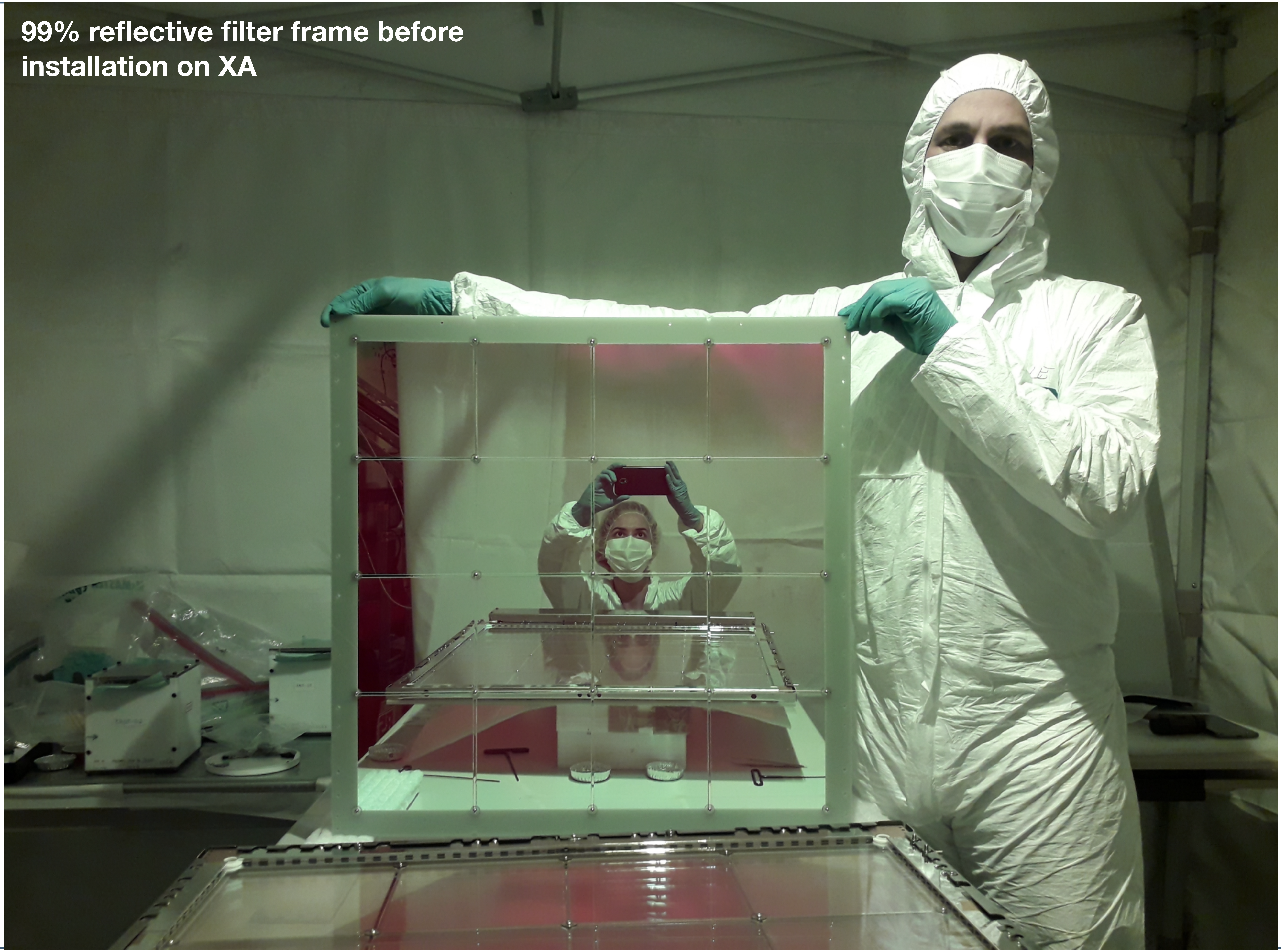
Last module was assembled in half a day





The clean tent

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



Different XA configurations

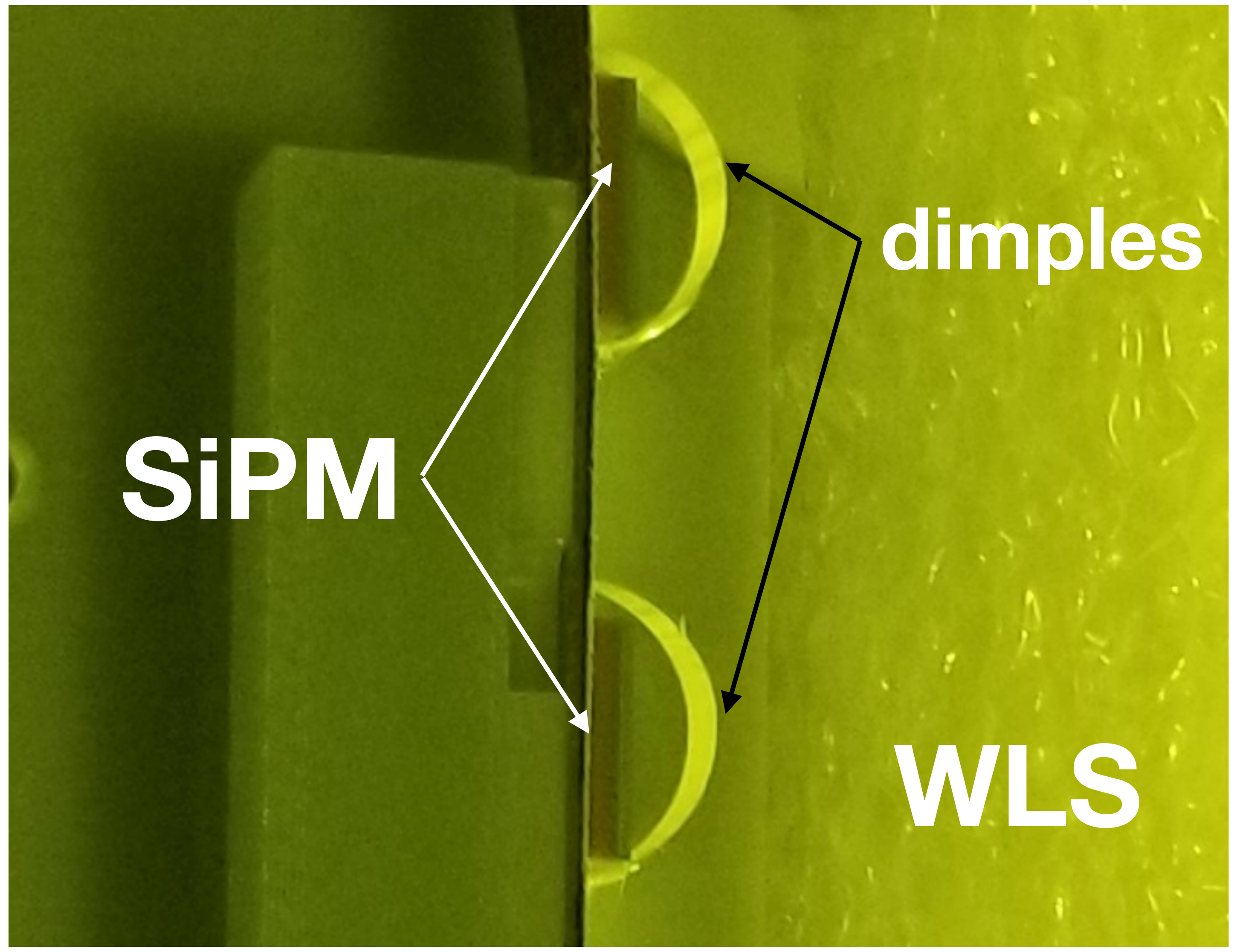
See Carla’s & Francesco’s talks

- Optical fibers for power (PoF) and signal (SoF) are mandatory in the cathode
- SoF implemented for one membrane module
- Final DF size is 150x150 mm^2

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	

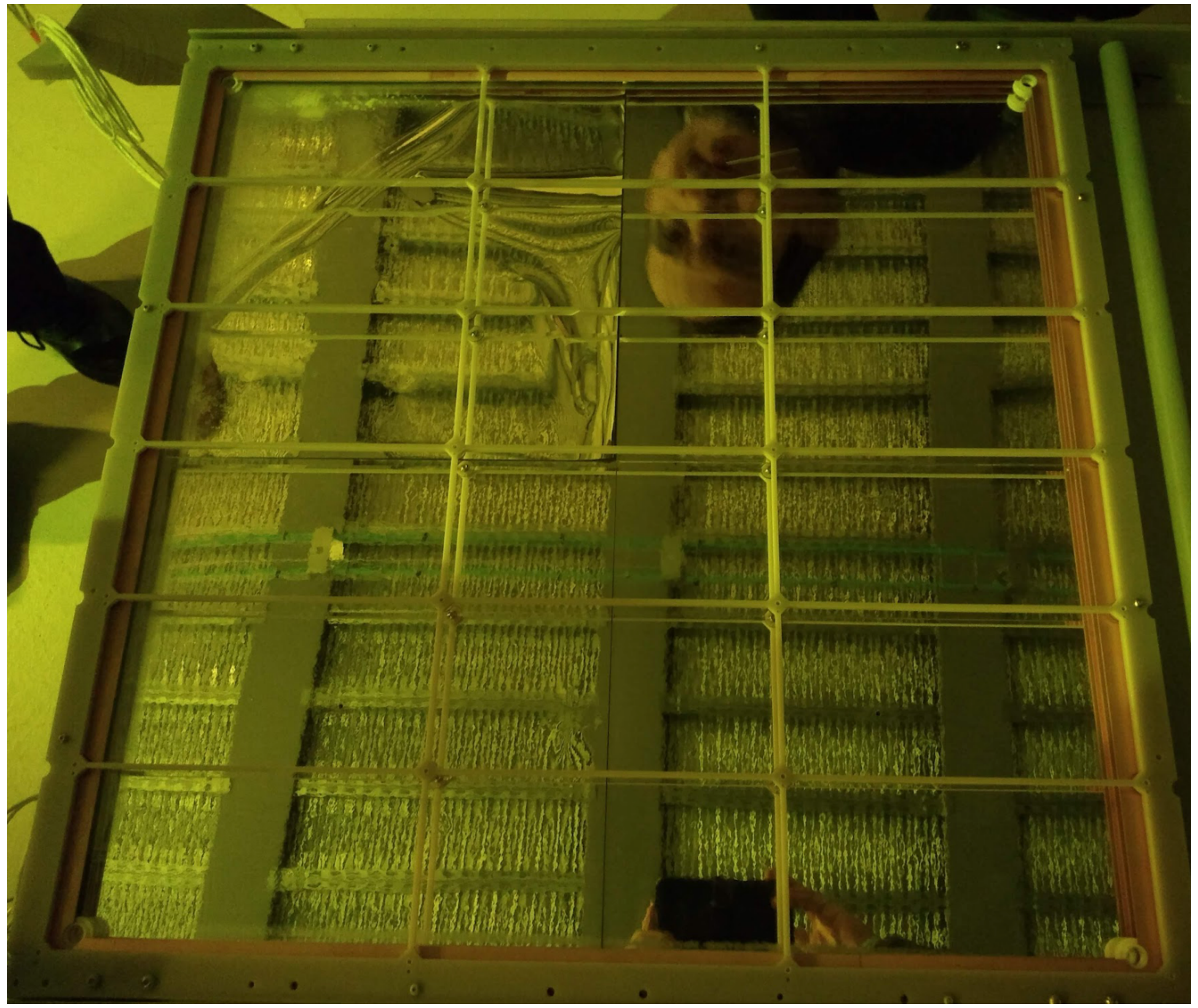
Dimples act as lens focusing light into SiPM



Many lessons learned

See Kurt's talk

- 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, …)



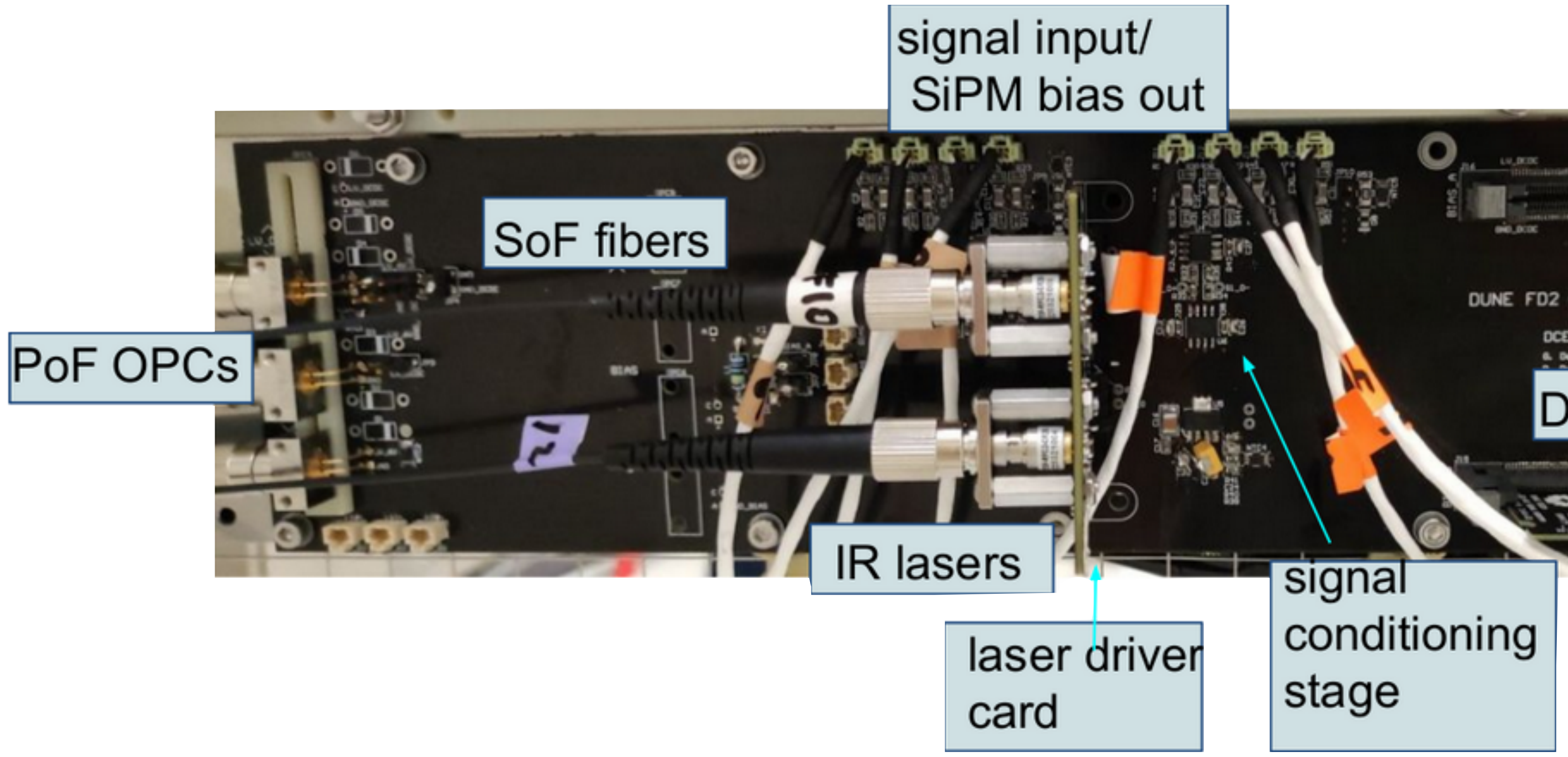
Assembly: cold electronics

Cold electronics

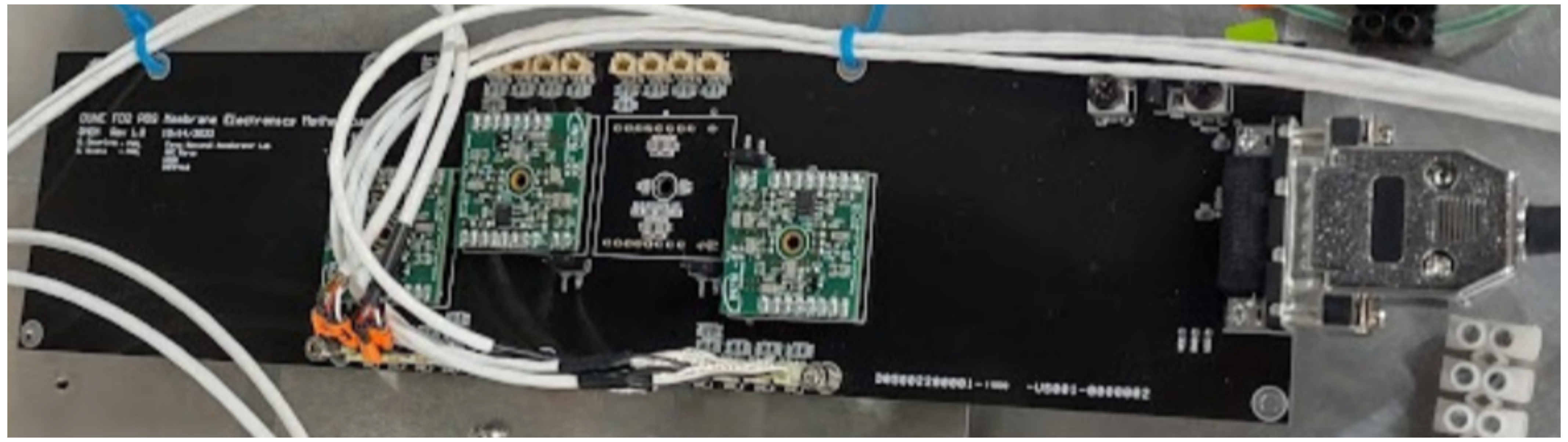
See D. Christian's and Sabrina's talks

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

Fiber



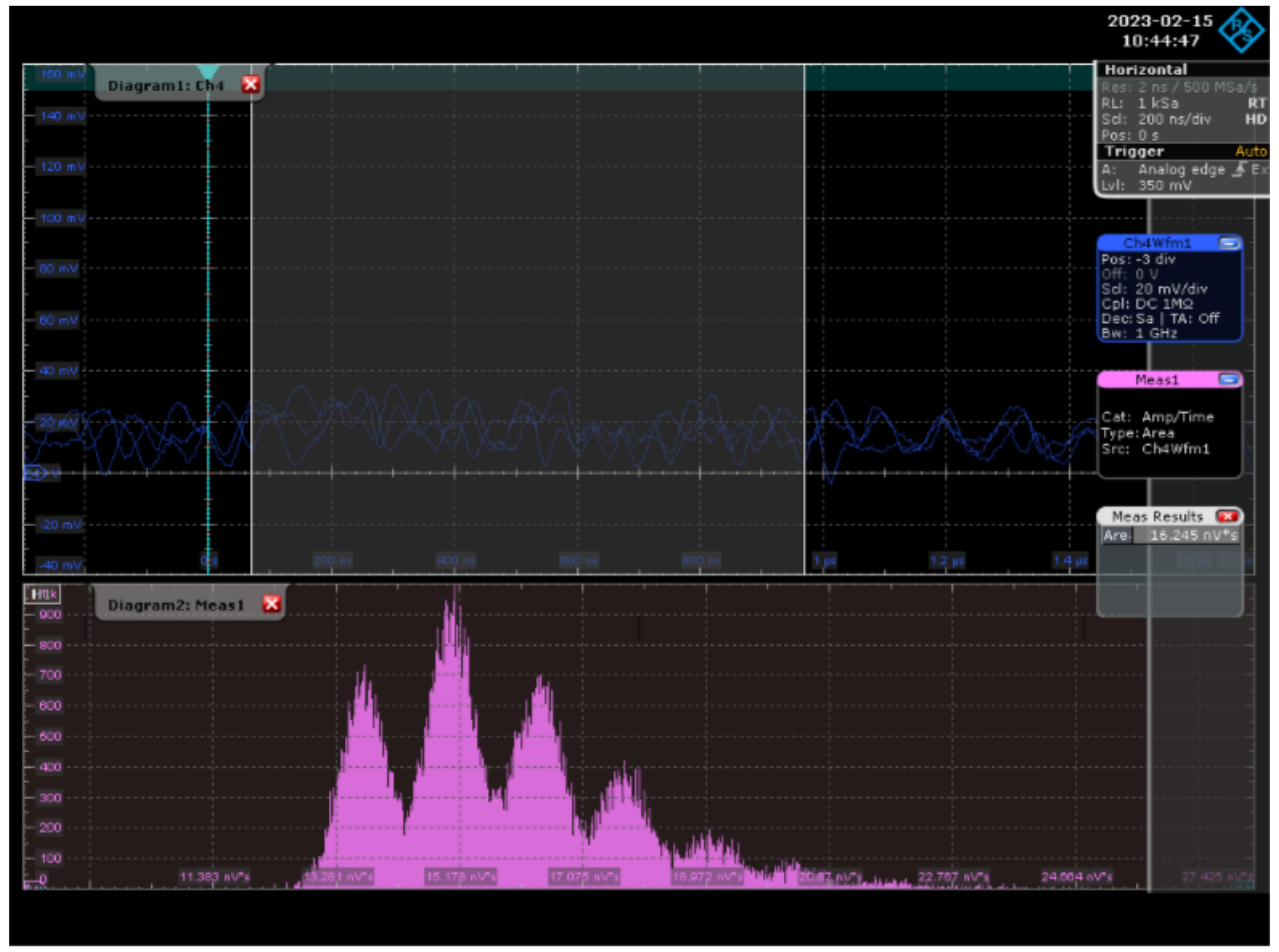
Copper

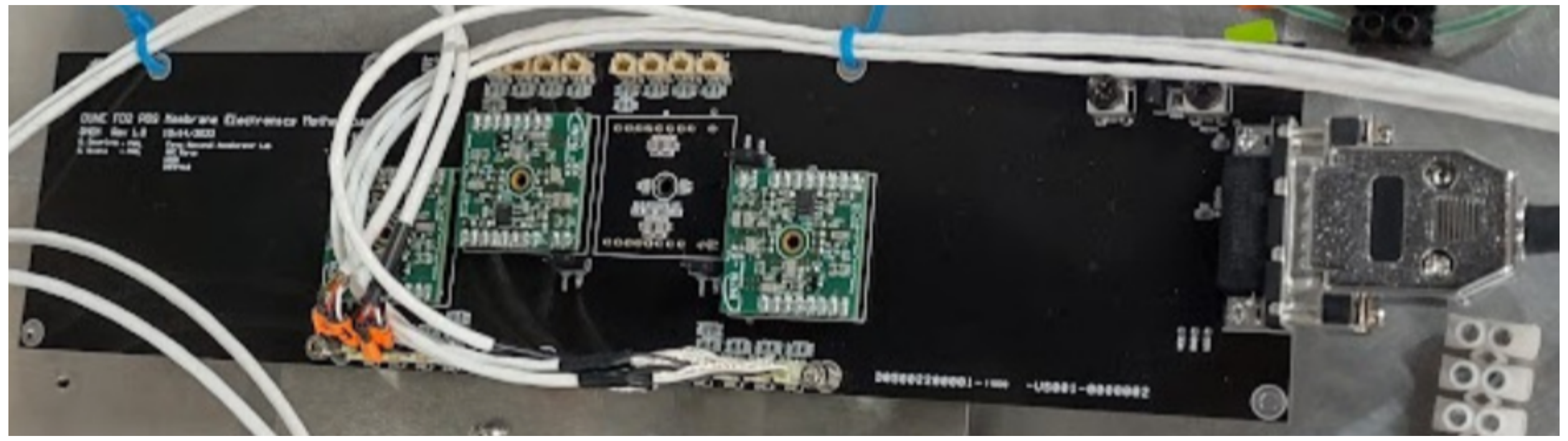


Copper cable based electronics

- 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

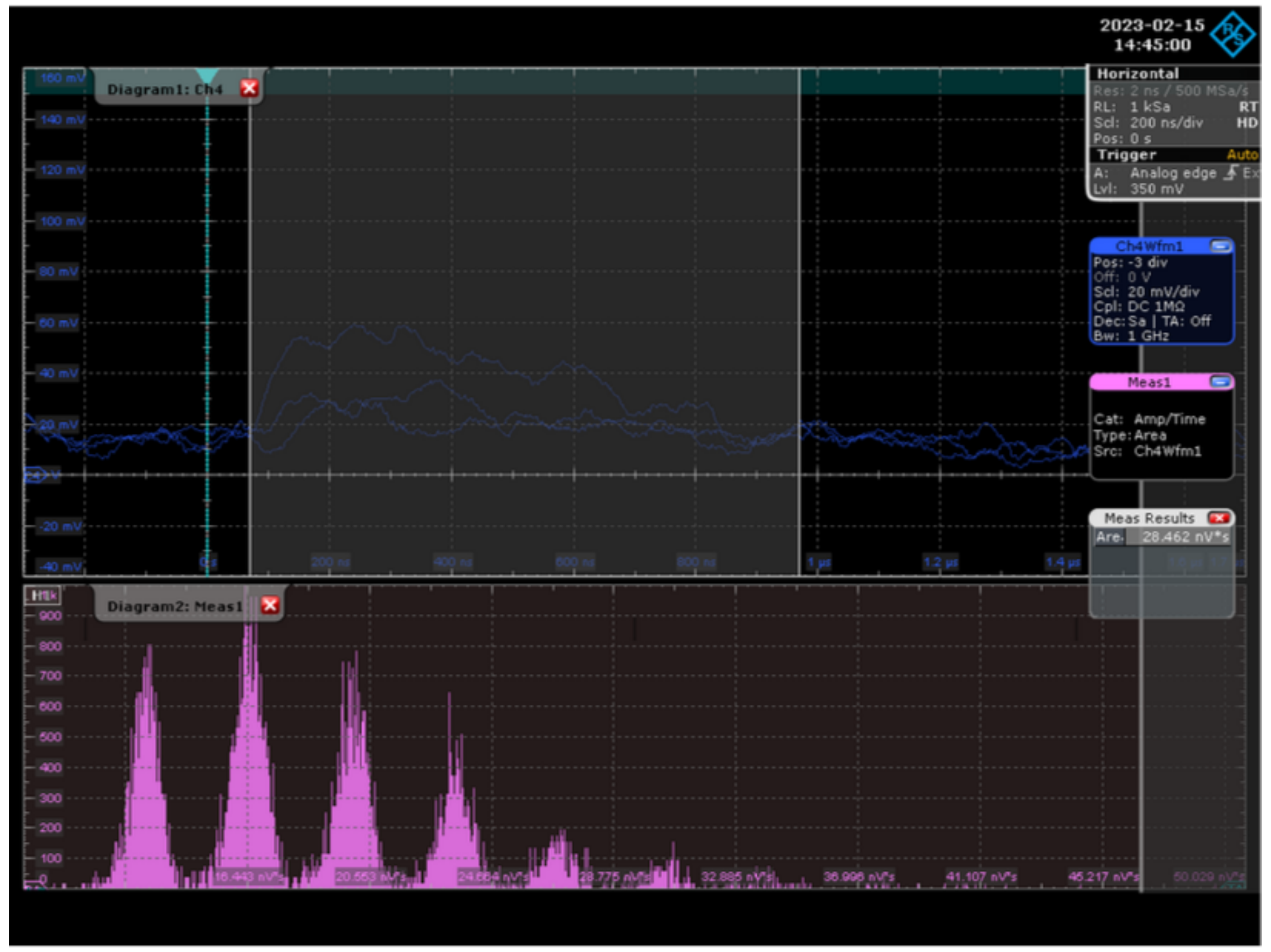
M1-M2





changes in amplifier feedback resistors →

M3-M4



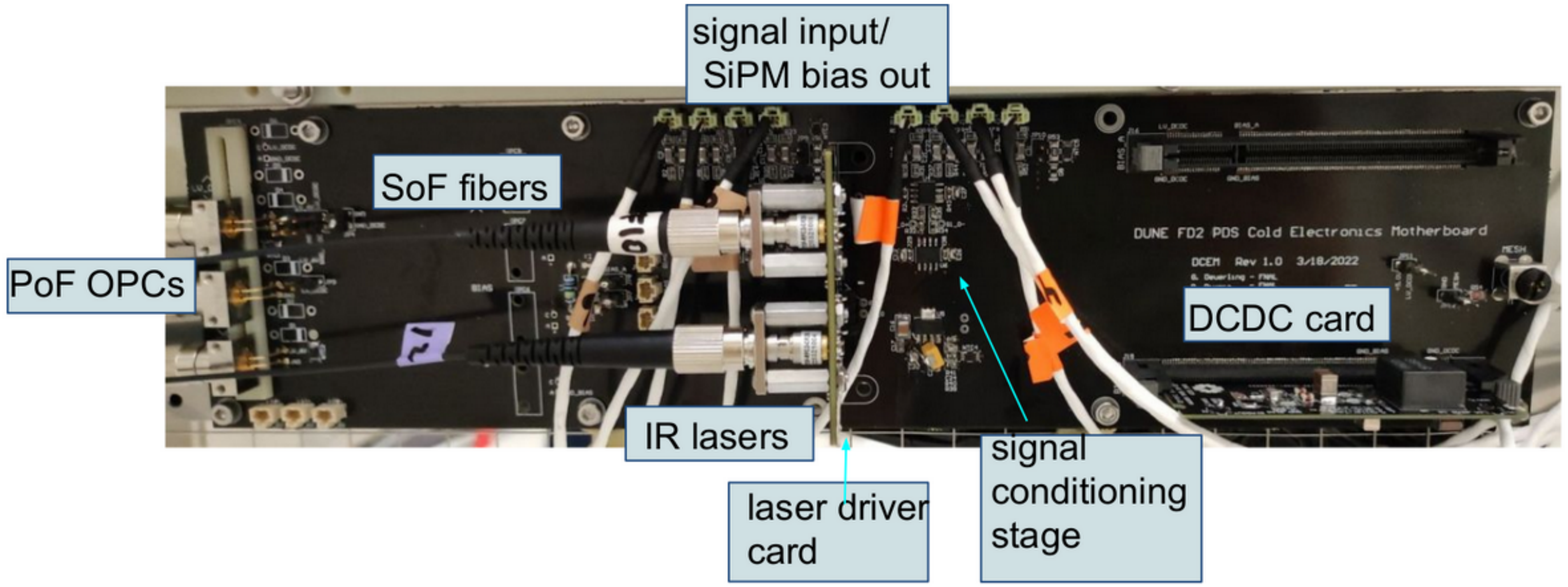
Optical Fiber based electronics

See W. Pellico's talk

- The final configuration of the electronics board was implemented at CERN, where the following was changed: gain, laser offset, capacitors, and LDO configuration
- Some important lessons learned:
  - Importance of industry fabrication and correct electronics handling
  - Several test points were identified as key to determining the correct functioning of the boards: add connector or set of pins

testing protocol

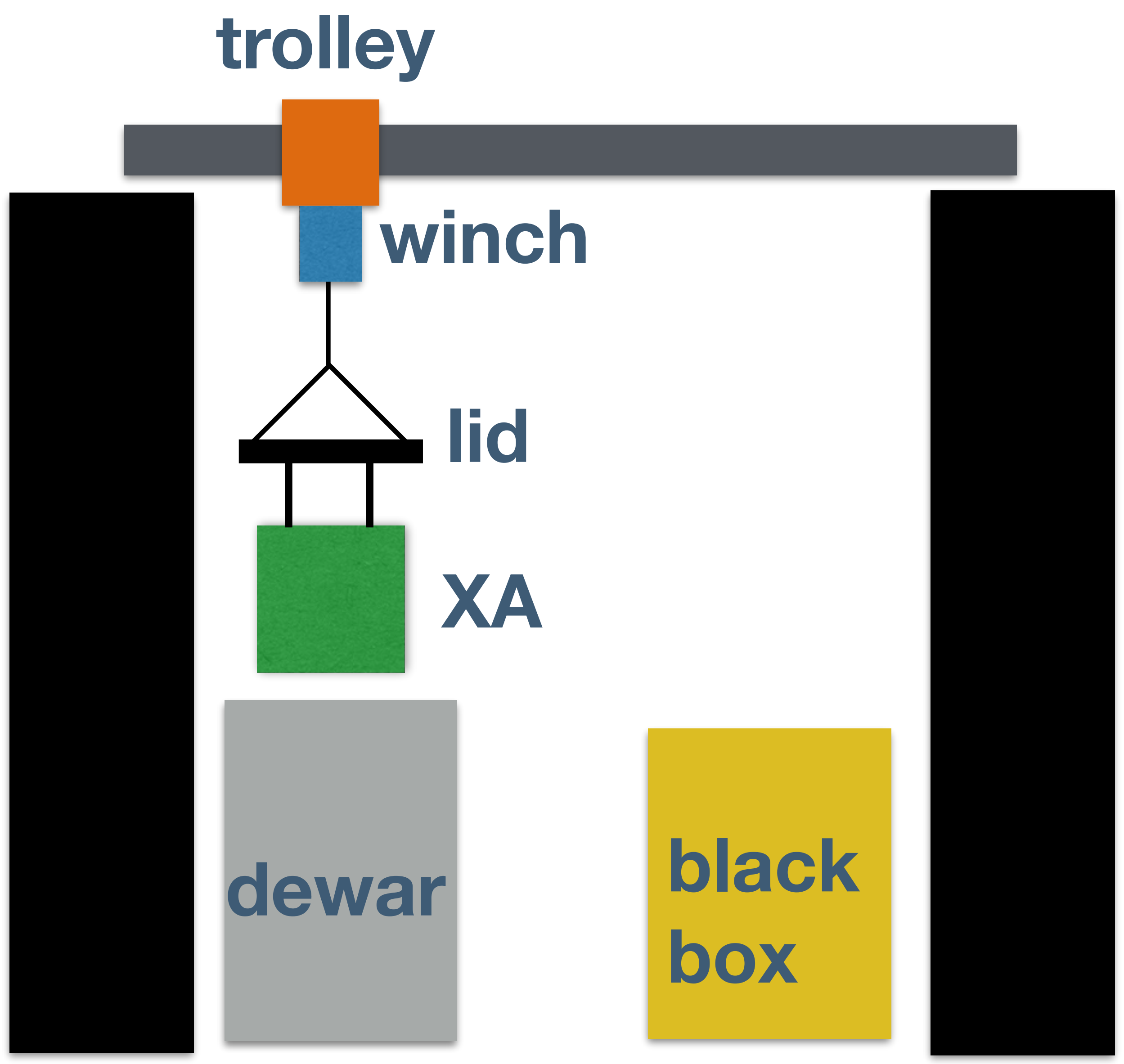
1. powered with copper at room temperature.
2. powered with copper in LAr.
3. powered with PoF at room temperature.
4. powered with PoF in LAr.



Cold tests: X-ARAPUCA

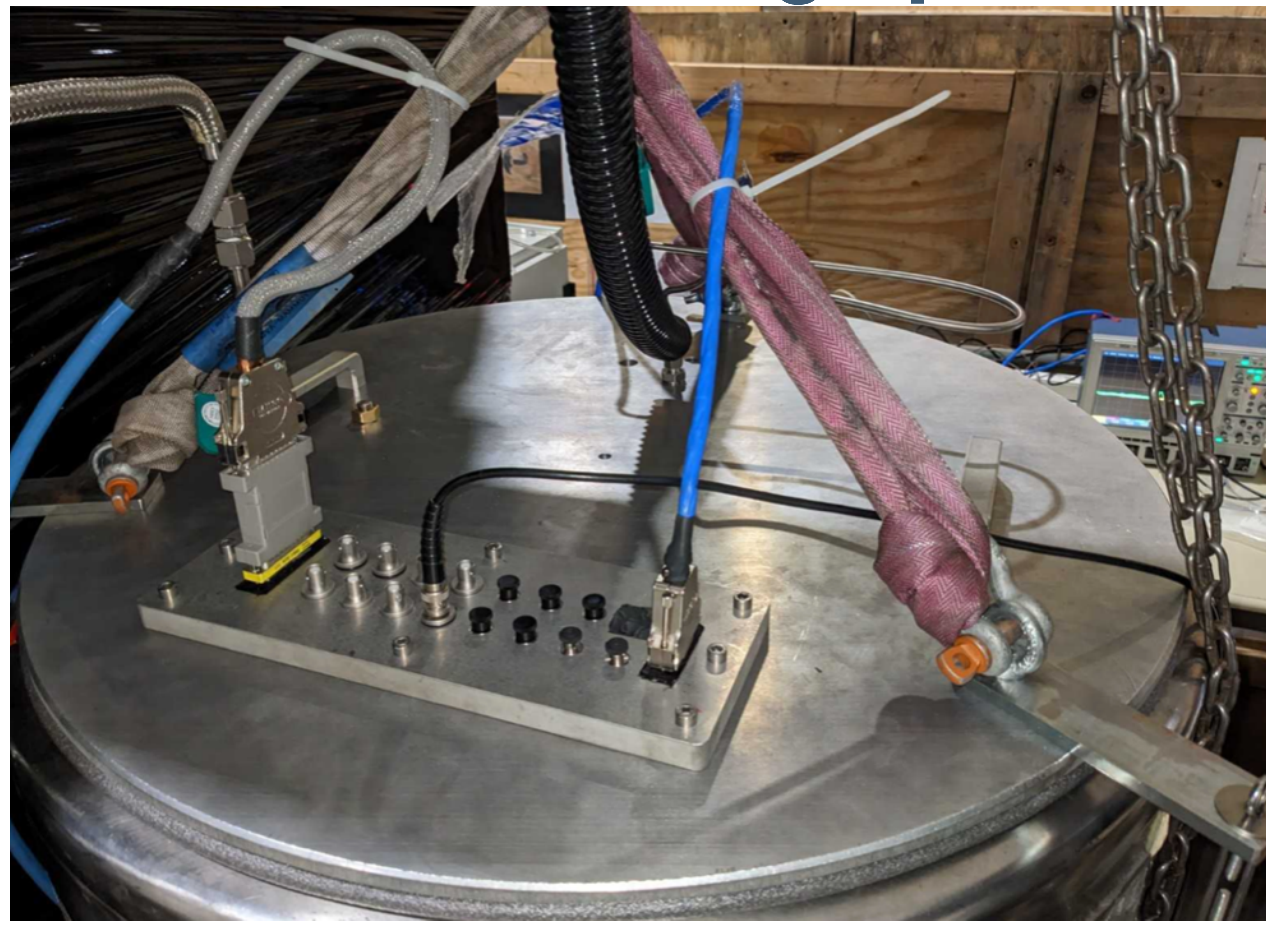
Test stand at CERN

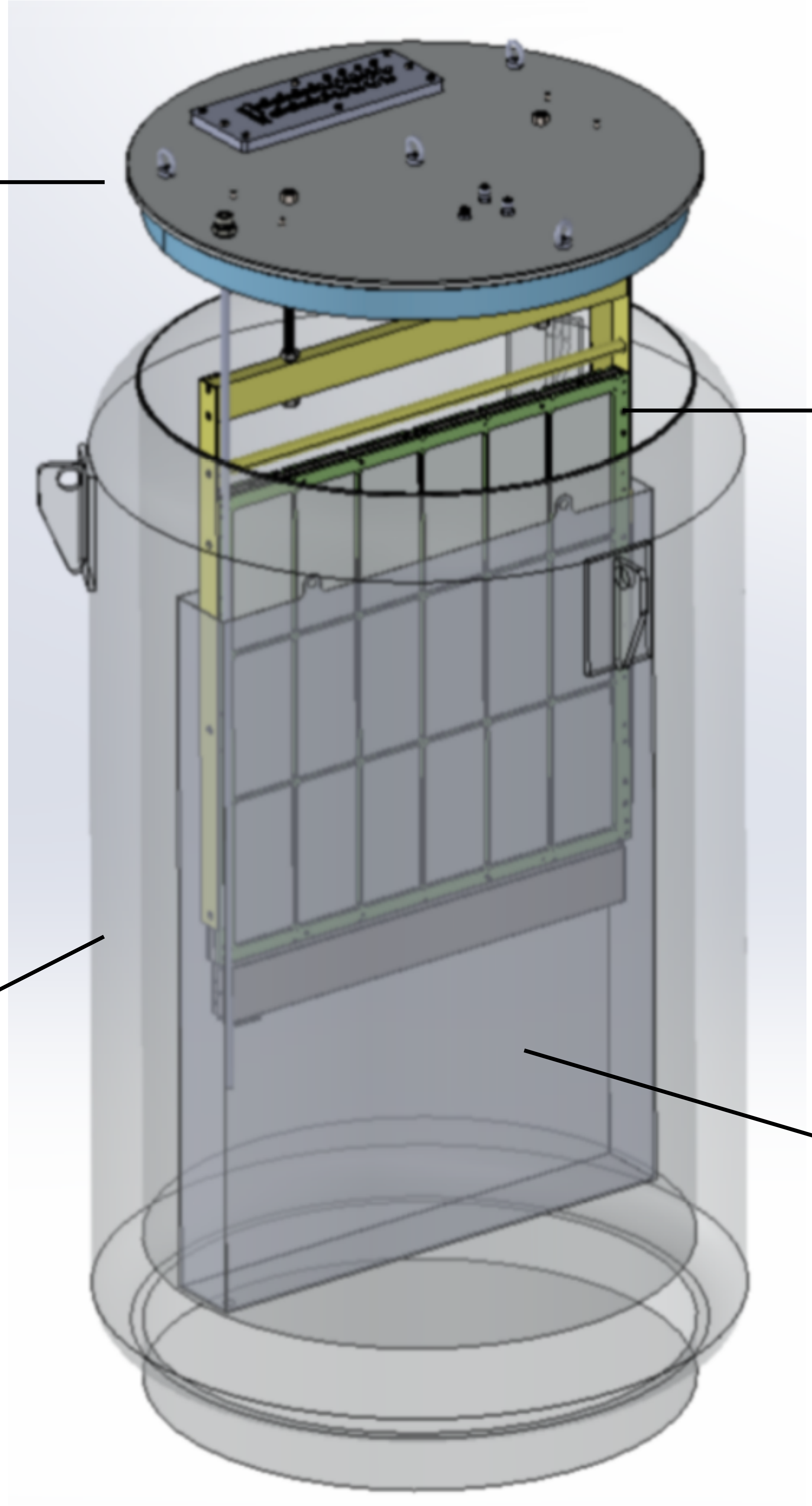
- For FD2, there will be dedicated assembly and testing facilities decoupled from installation. This was not possible for ProtoDUNE-VD and testing had to be done at CERN
- A test stand was setup in December in front of the PDS room, below the 3rd barrack



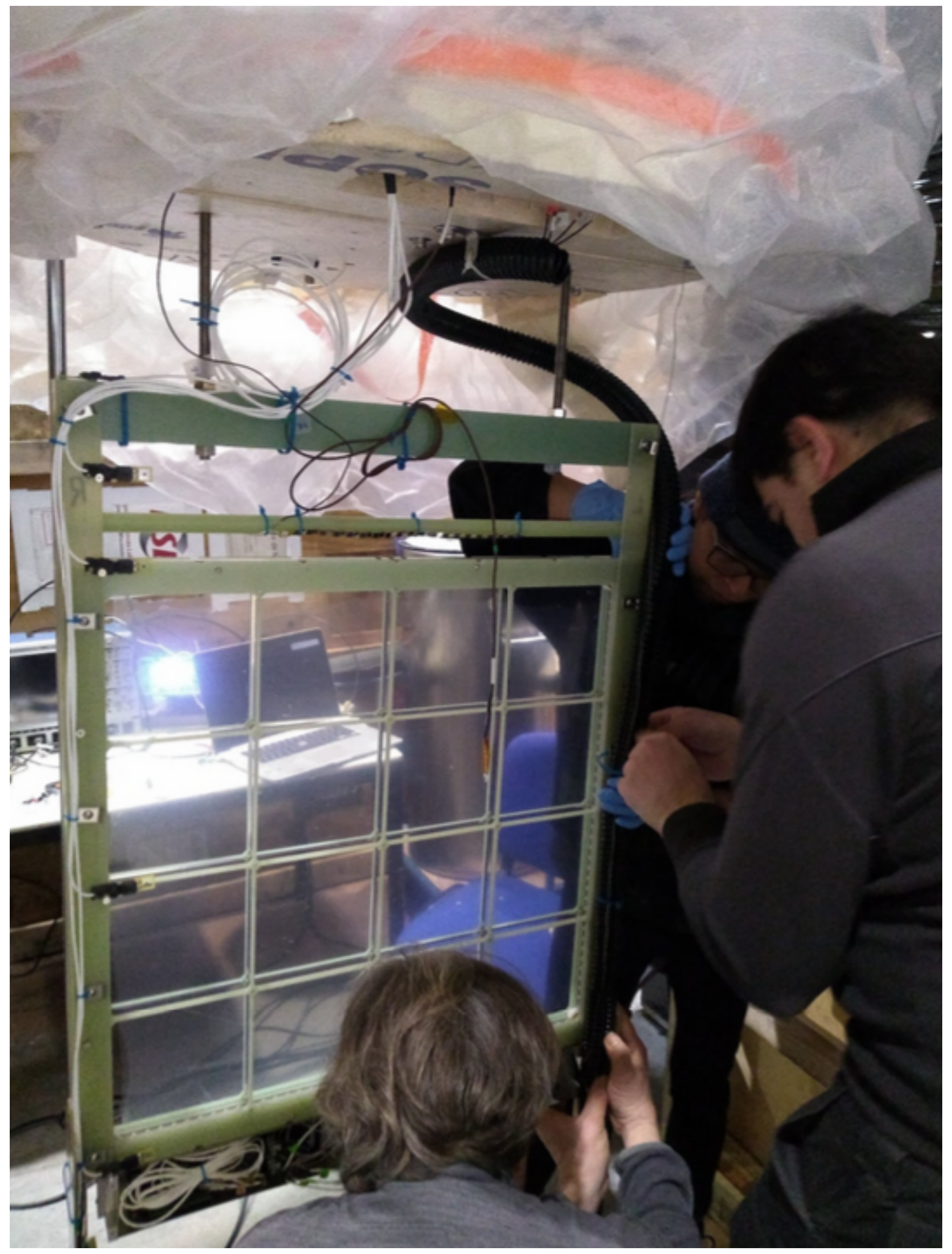
Mechanics and cryogenics

lid with feedthrough panel





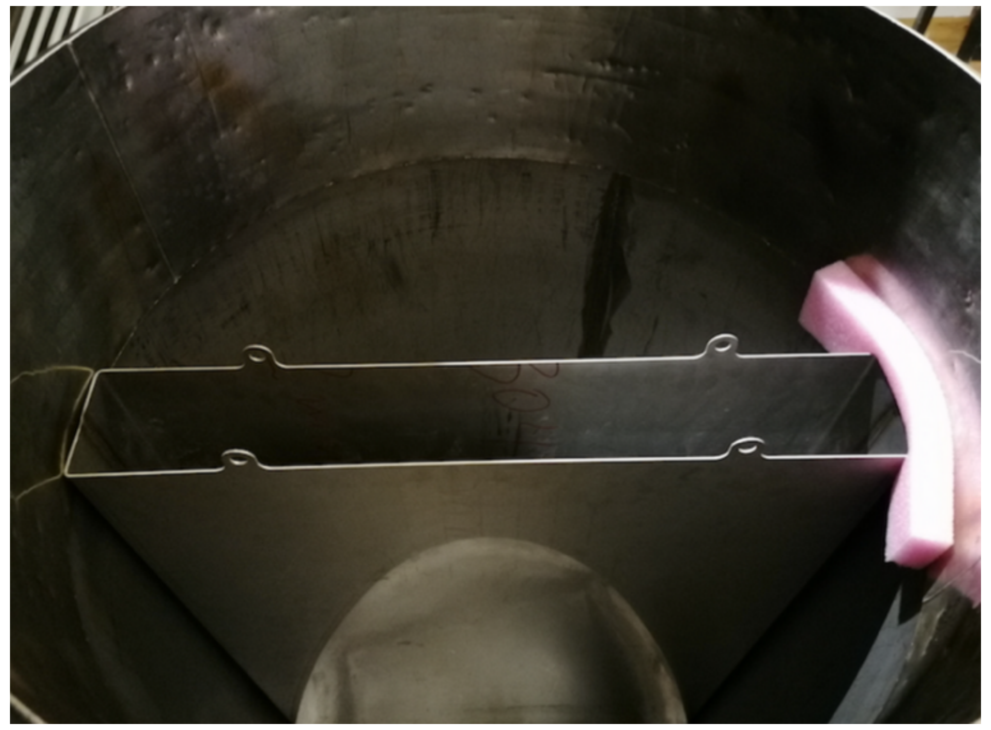
XA hanging from lid



500 l LAr dewar

450 l open dewar

inner box

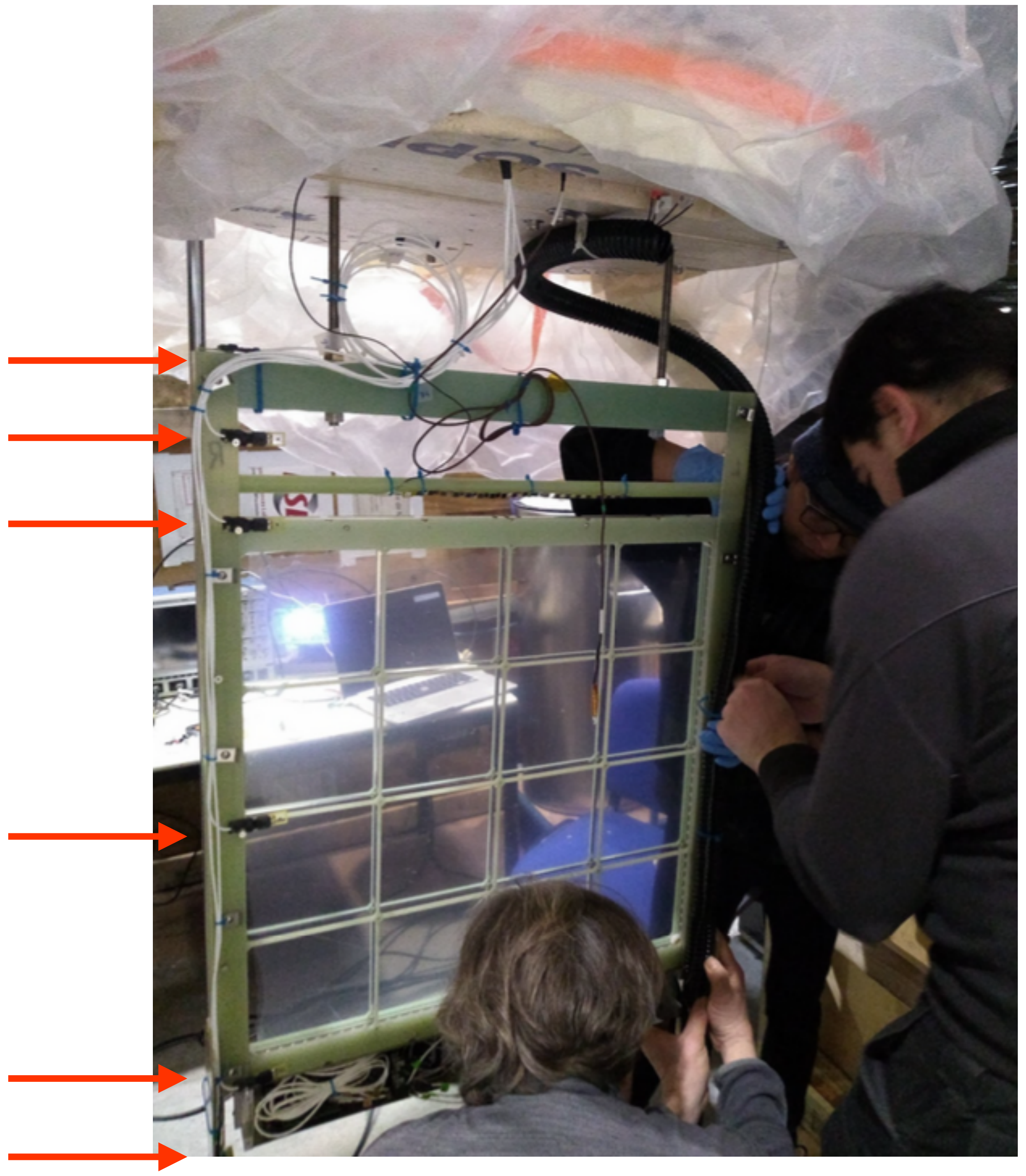


Procedure

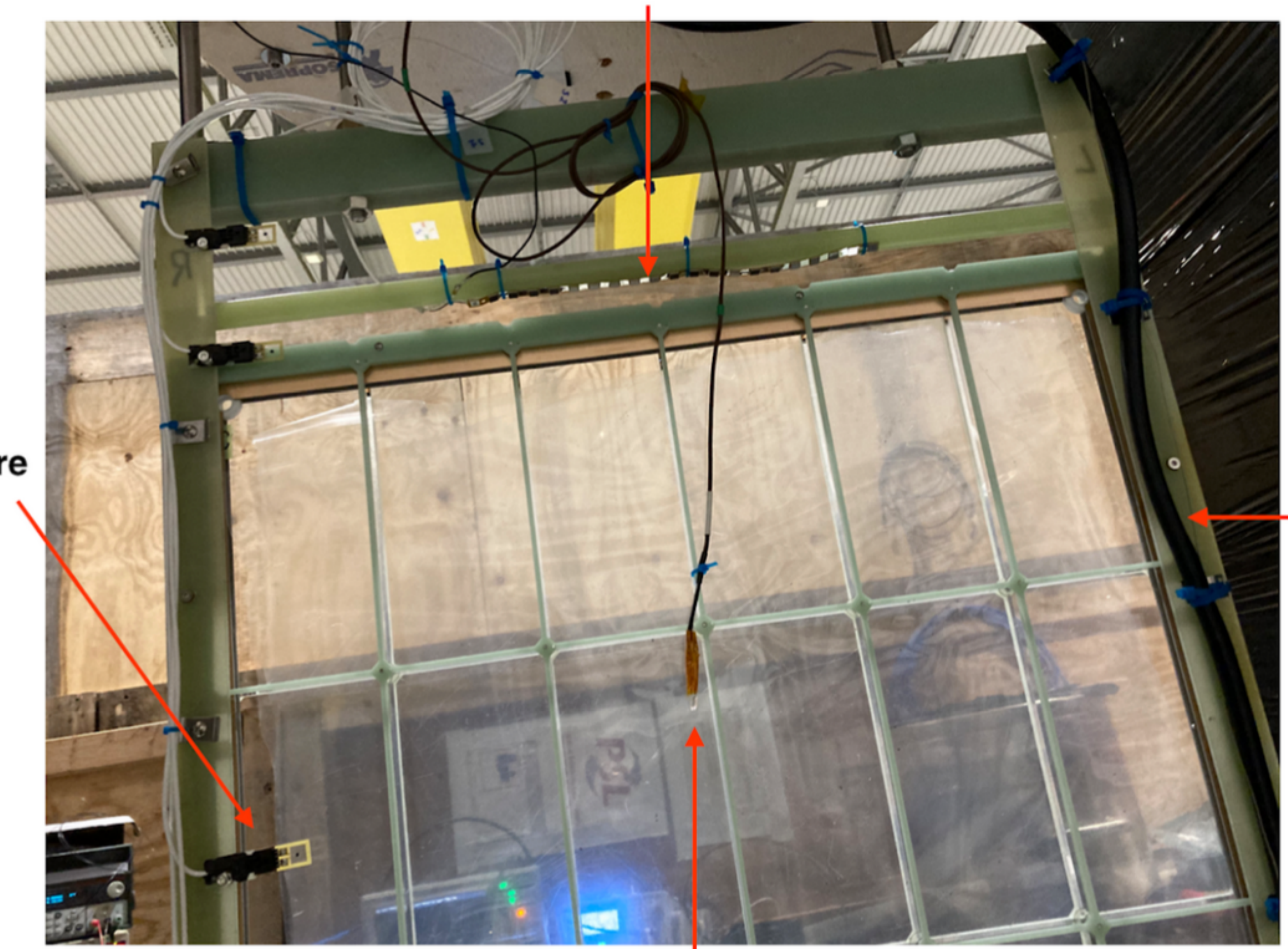
- LAr injected in dewar (bottom) through dedicated port in lid
- Slow cool-down (90’) and warmup (30’) phases

Tests done without dichroic filters

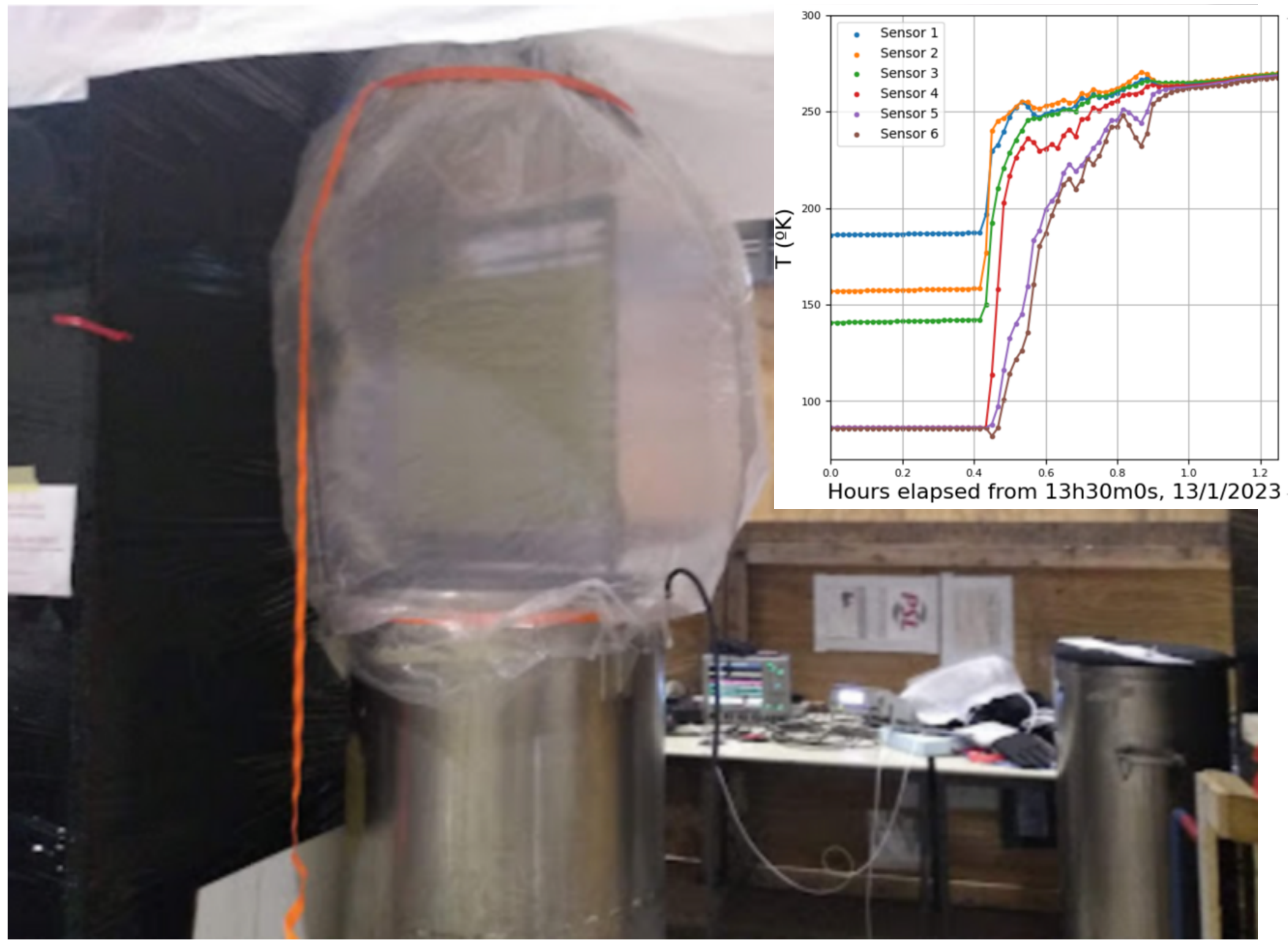
LAr level and XA temperature monitored with 6 RTDs



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



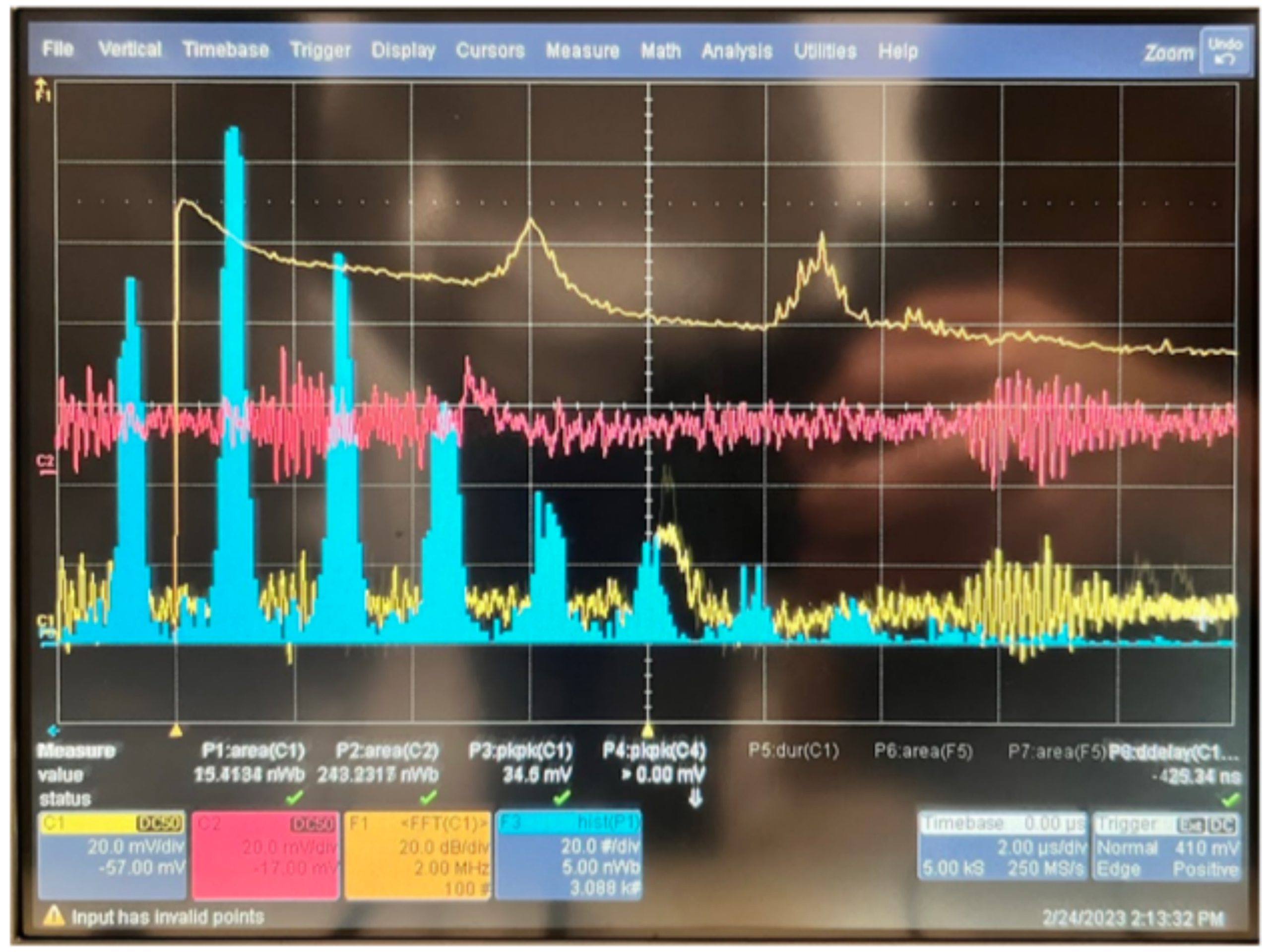
plastic tent flushed with warm GN2 during warm up essential to avoid condensation



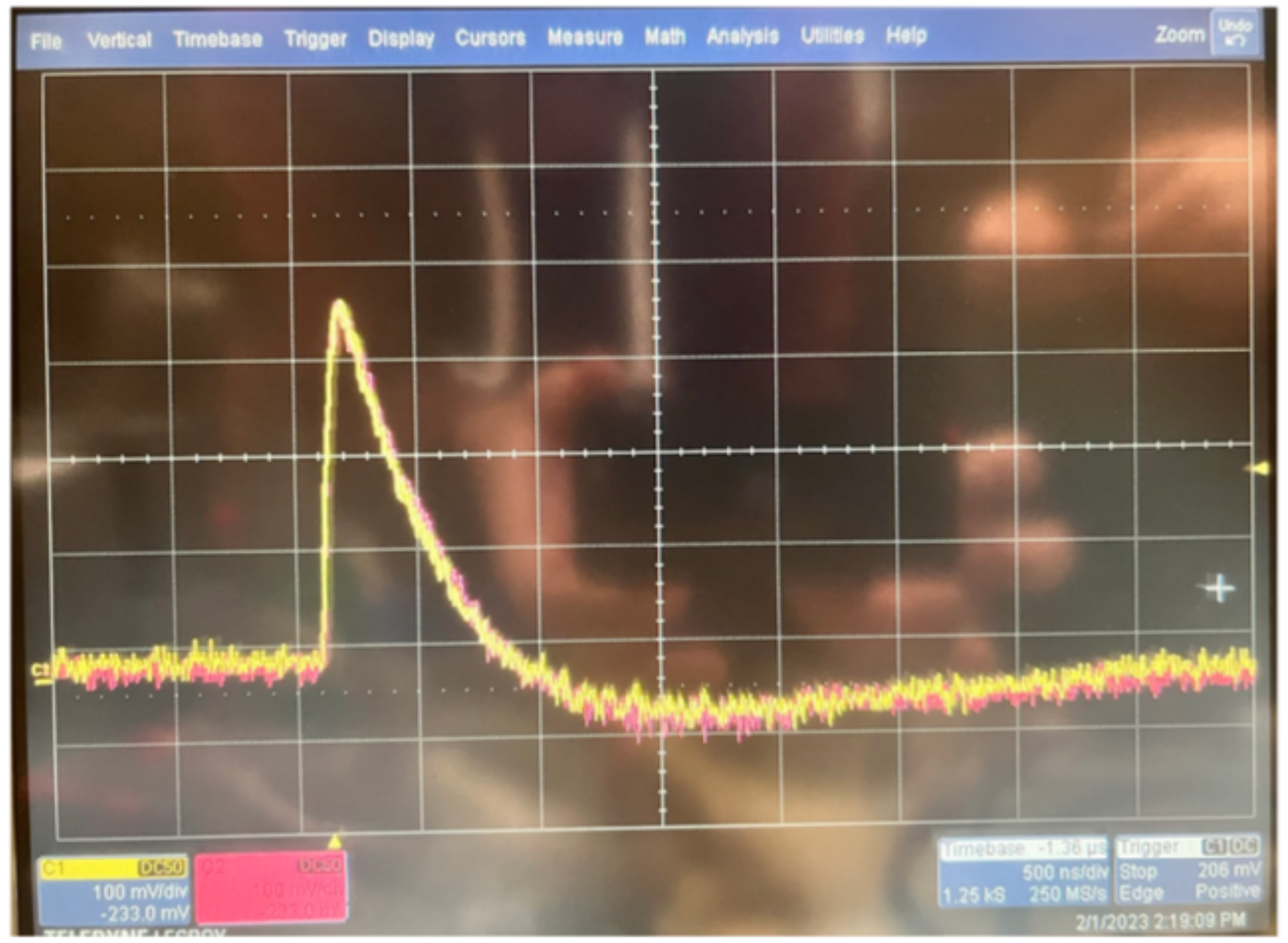
Membrane modules

SNR well within requirements

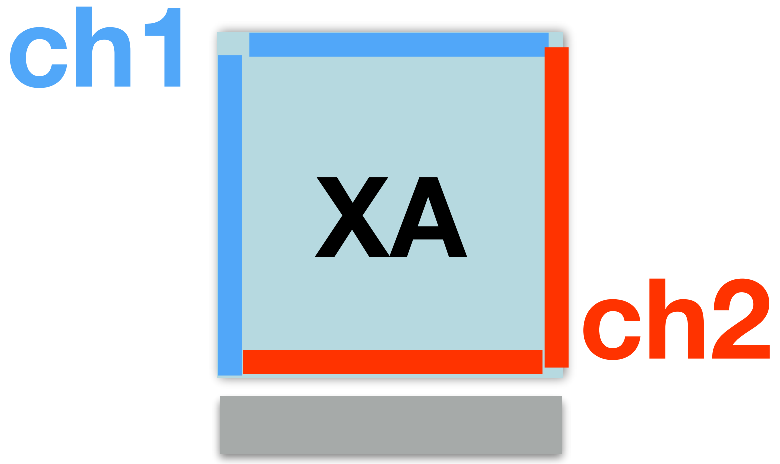
Charge histogram for LED



Waveform for cosmics



Same gain for both channels



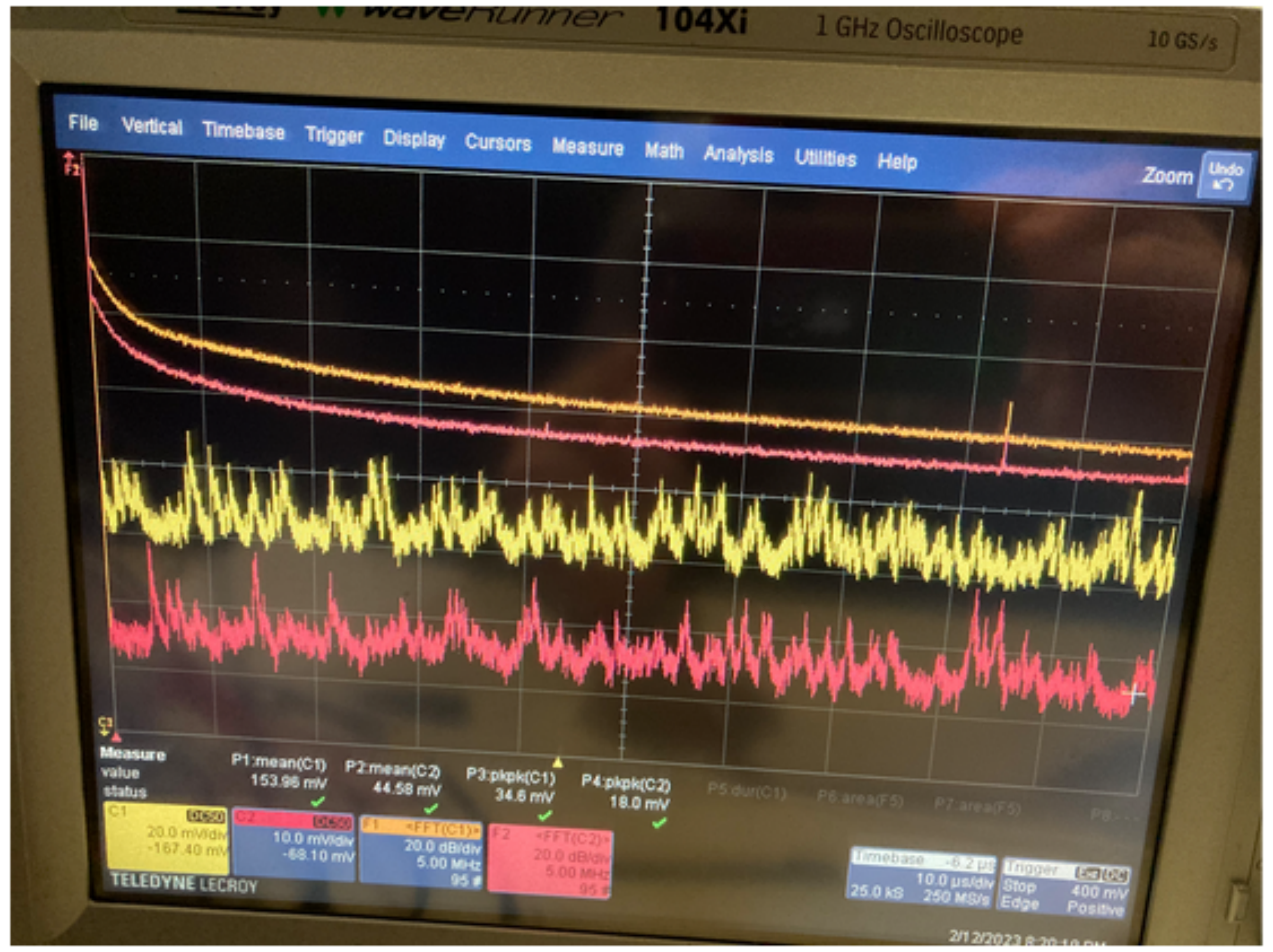
Detailed studies for M3 and M4

	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

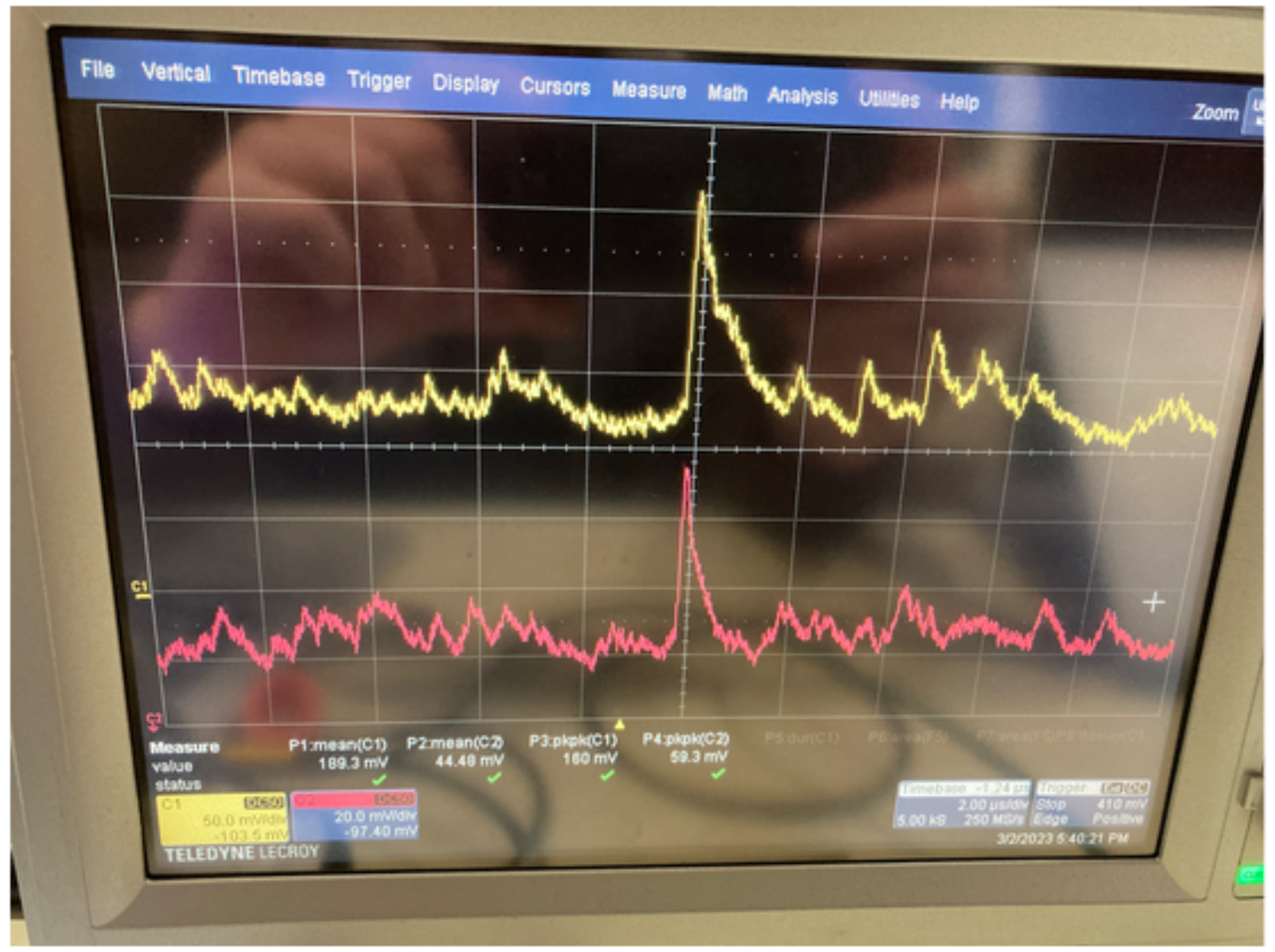
Cathode modules

- Studies about single pe could not be performed because PoF light leakage, with huge impact inside the small dewar.
- The offset and power consumption are measured, registered, and compared to the previous tests with the electronic boards.

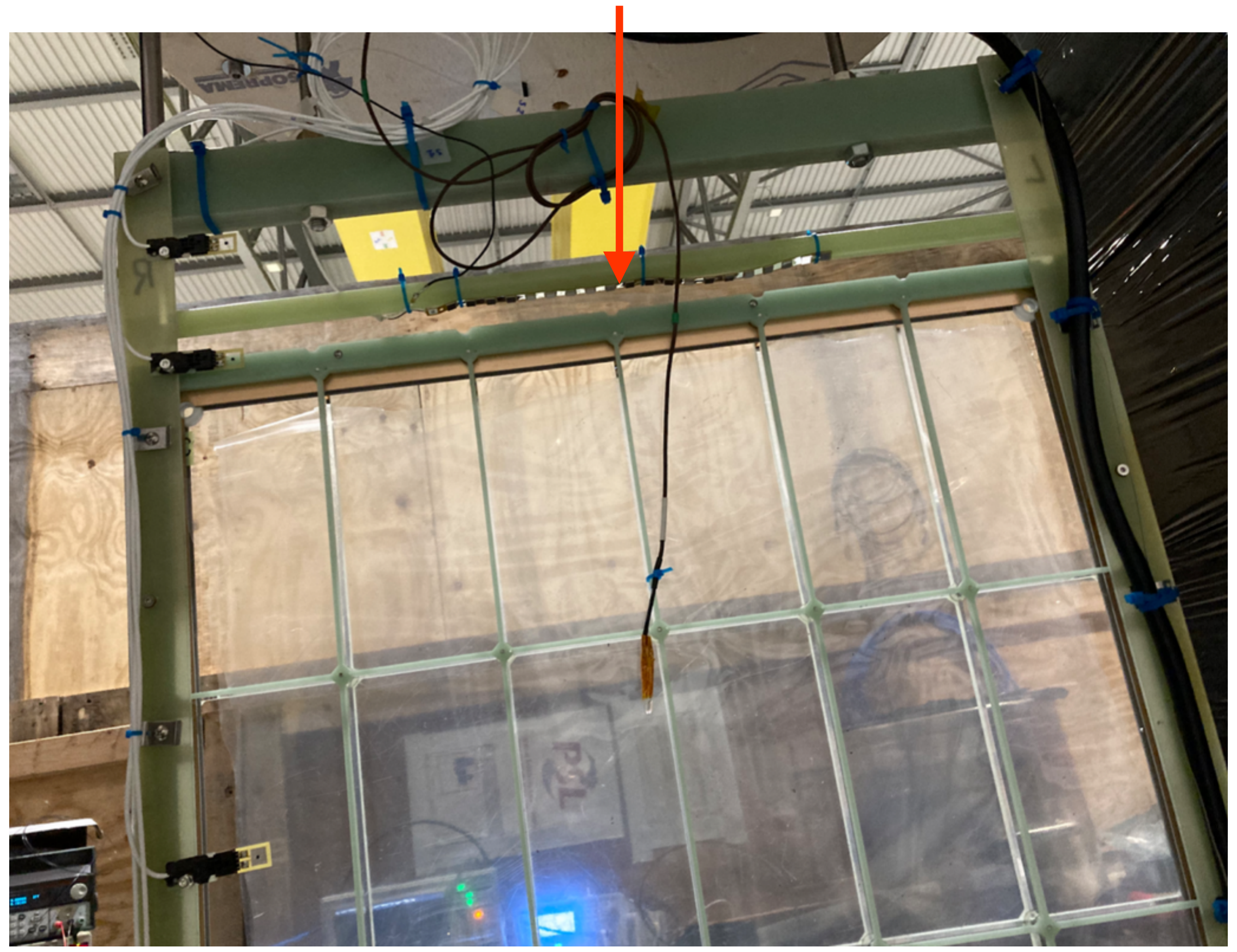
Typical FFT



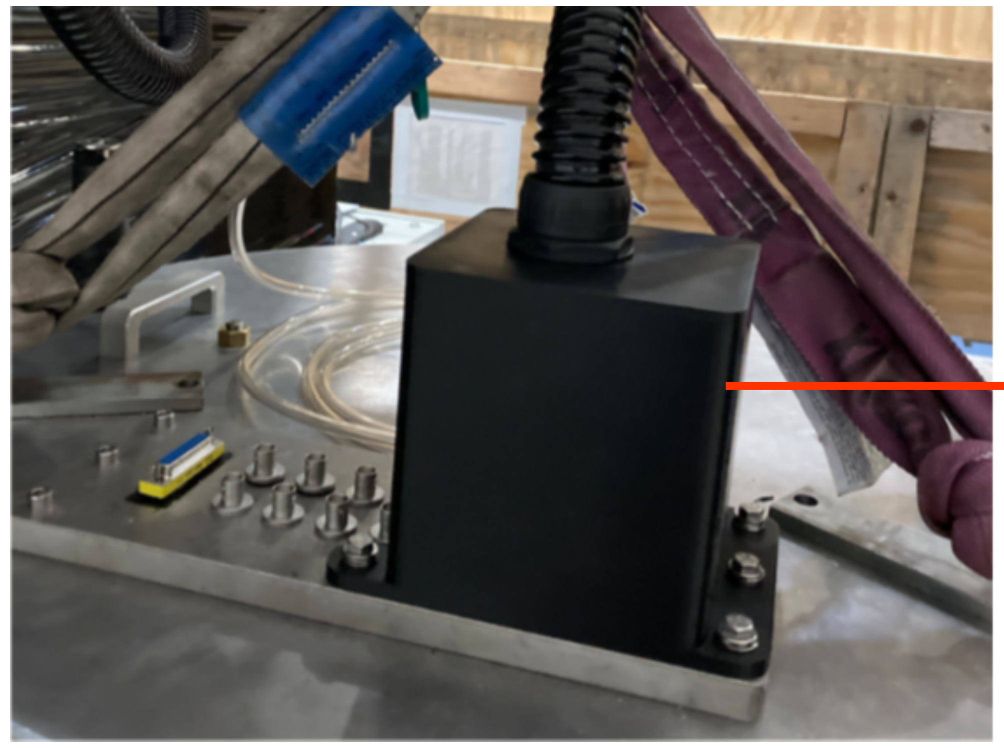
LED response for 2 channels



SiPM flex to check PoF leak with LED off



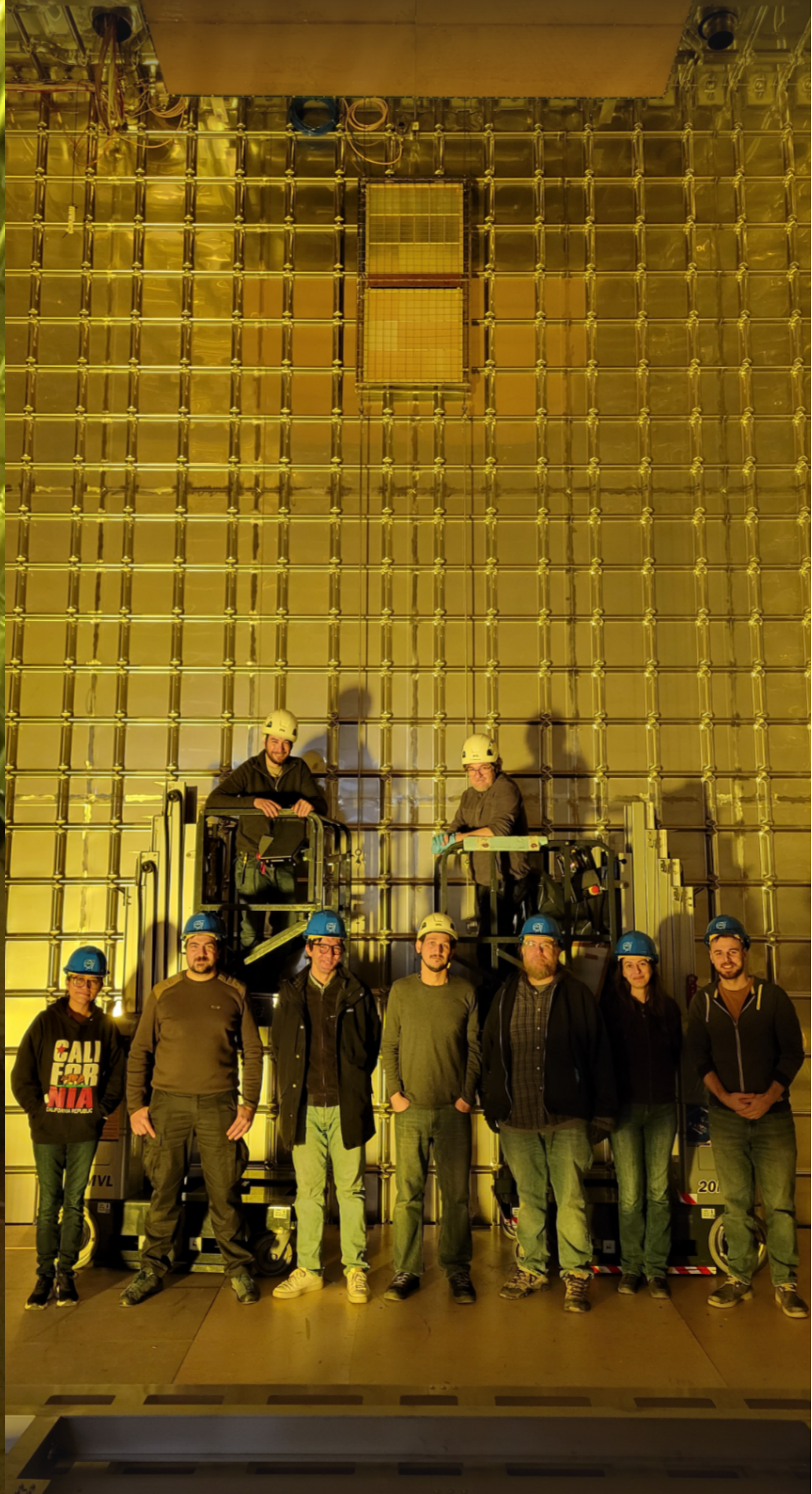
fiber protection box



corrugated back tube from dewar to mini-rack

class-4 laser inside mini-rack

Installation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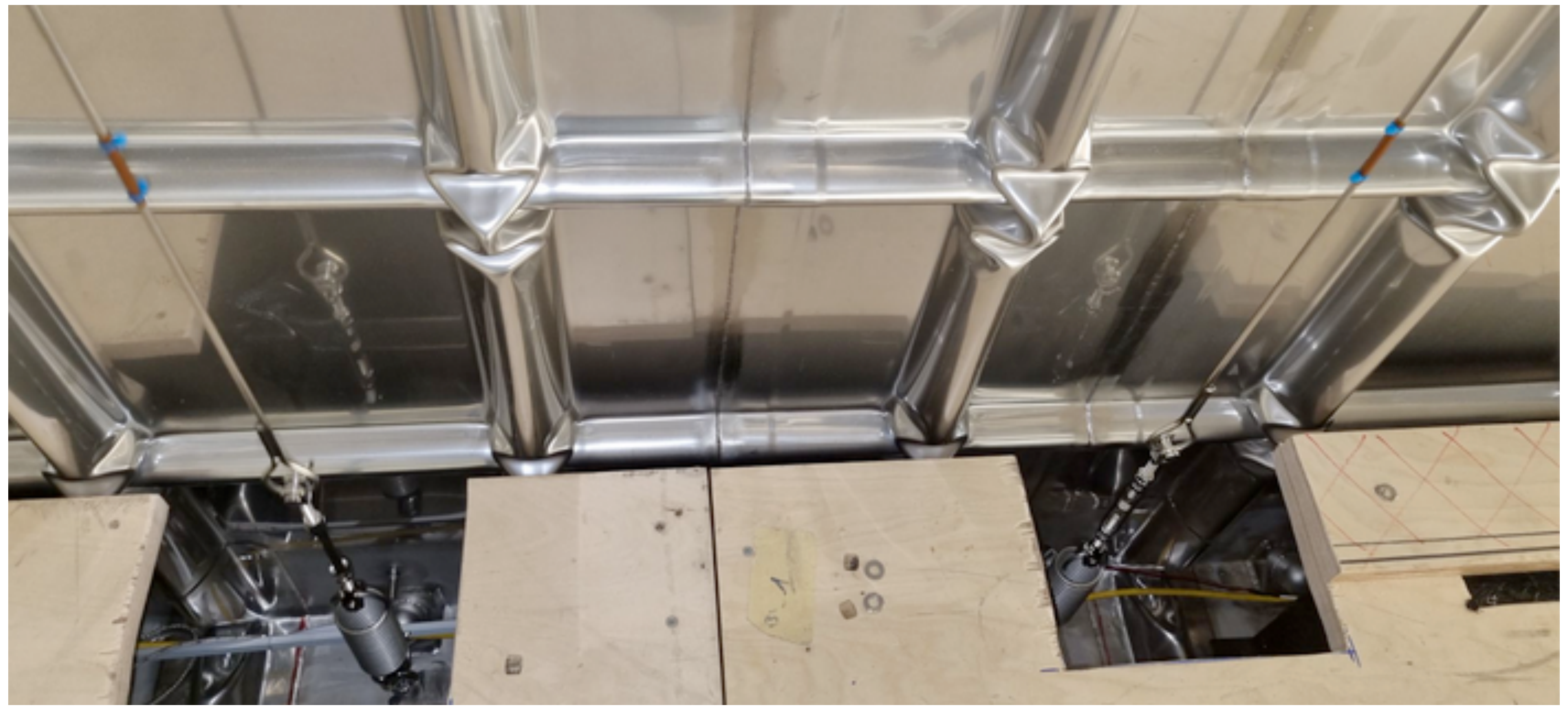
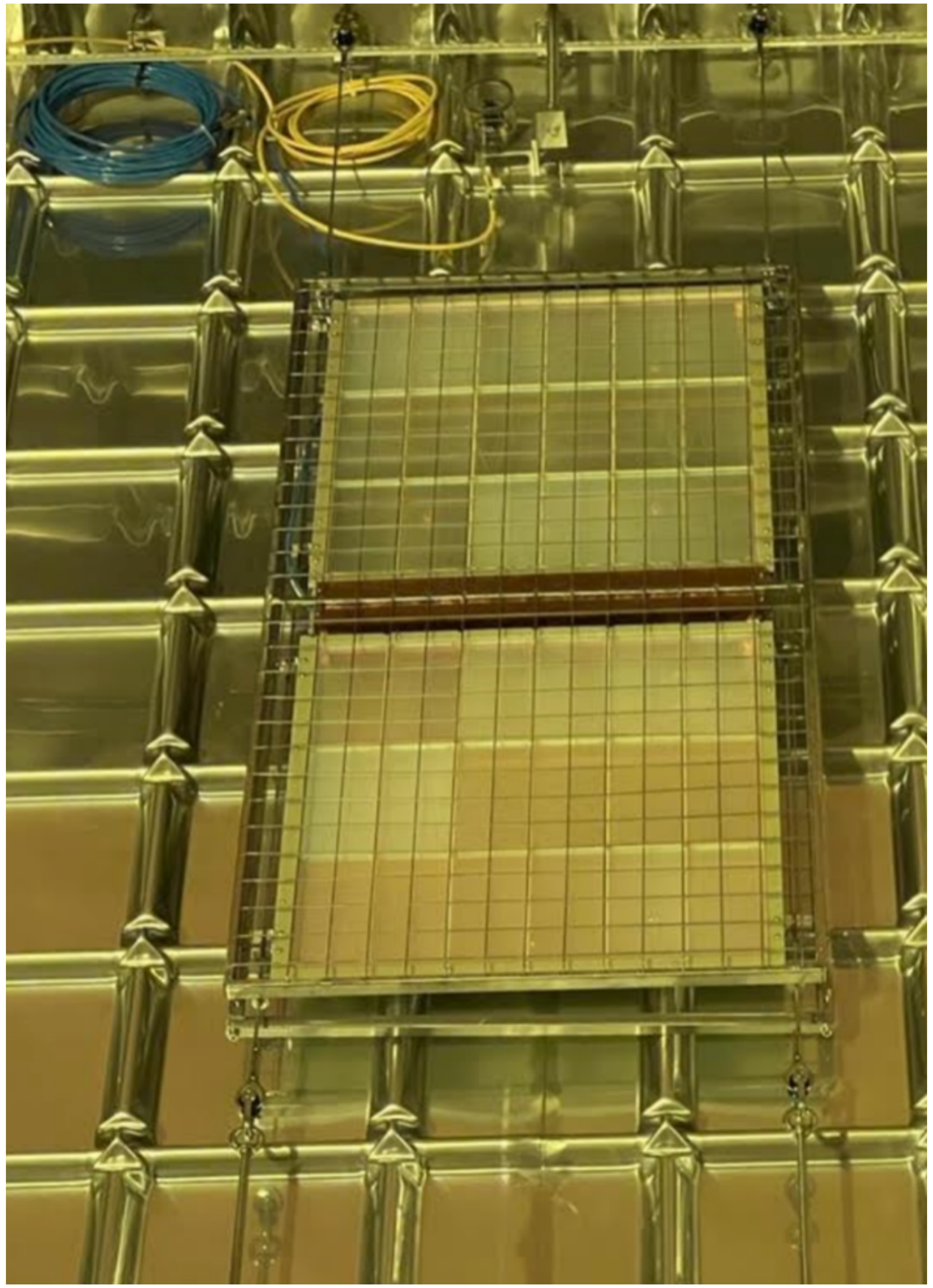
Installation of membrane modules

suspension lines



XA support



Two persons in two scissor lifts

Elec. box between two modules

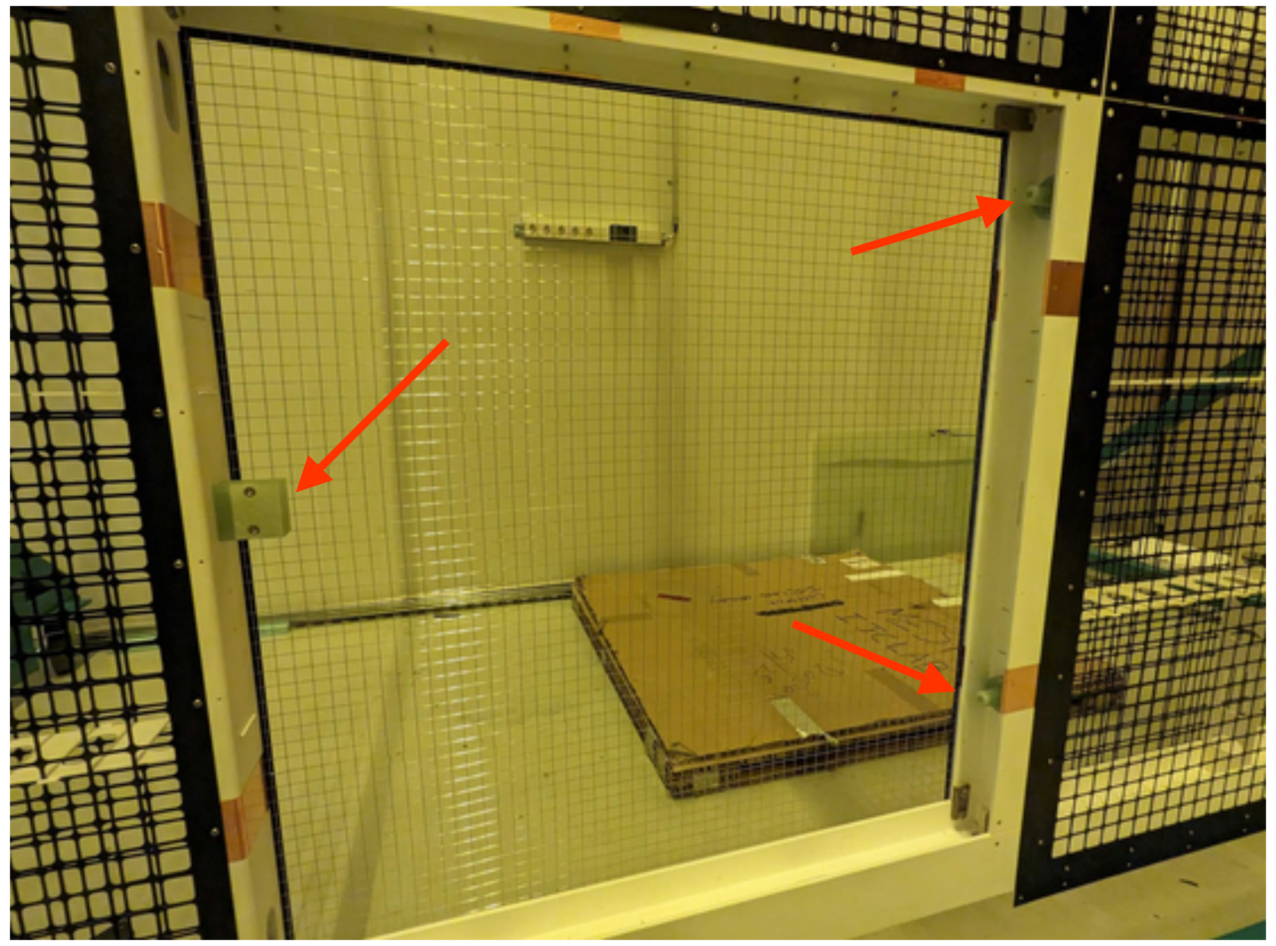
The option of fully independent modules will be tested in lower position:

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

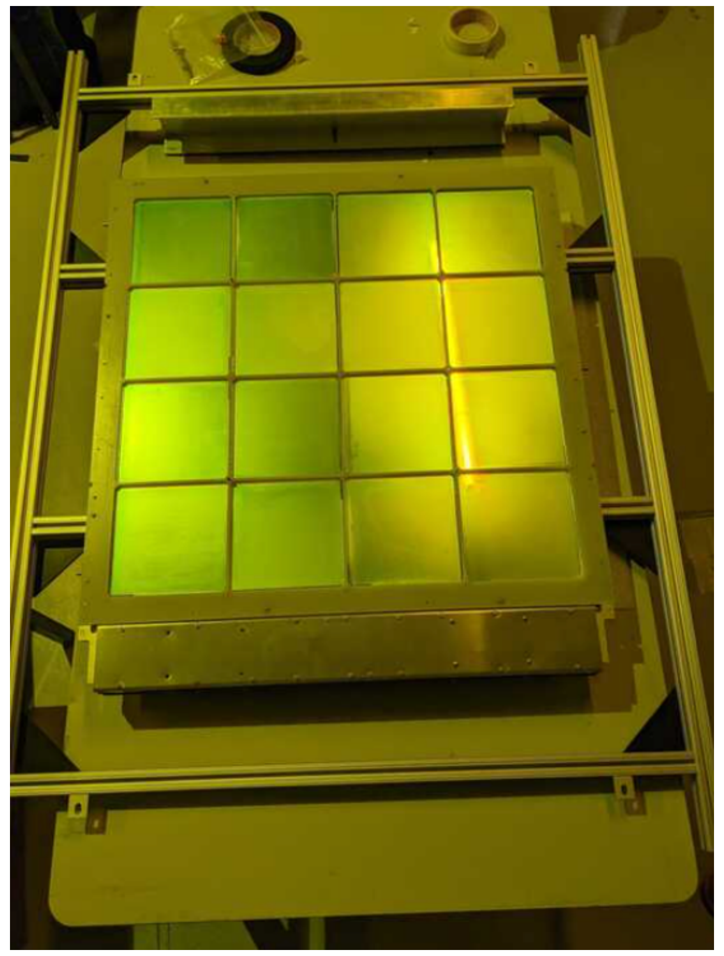
Installation of cathode modules

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

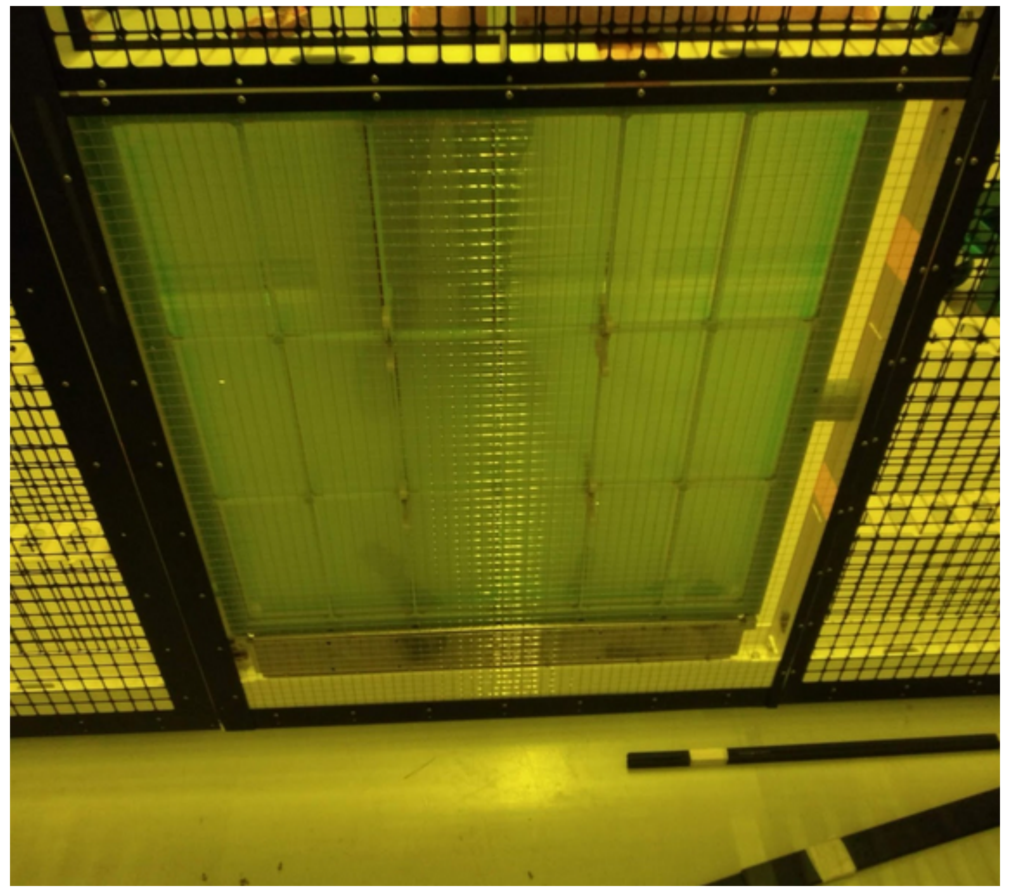


2. XA on transport frame



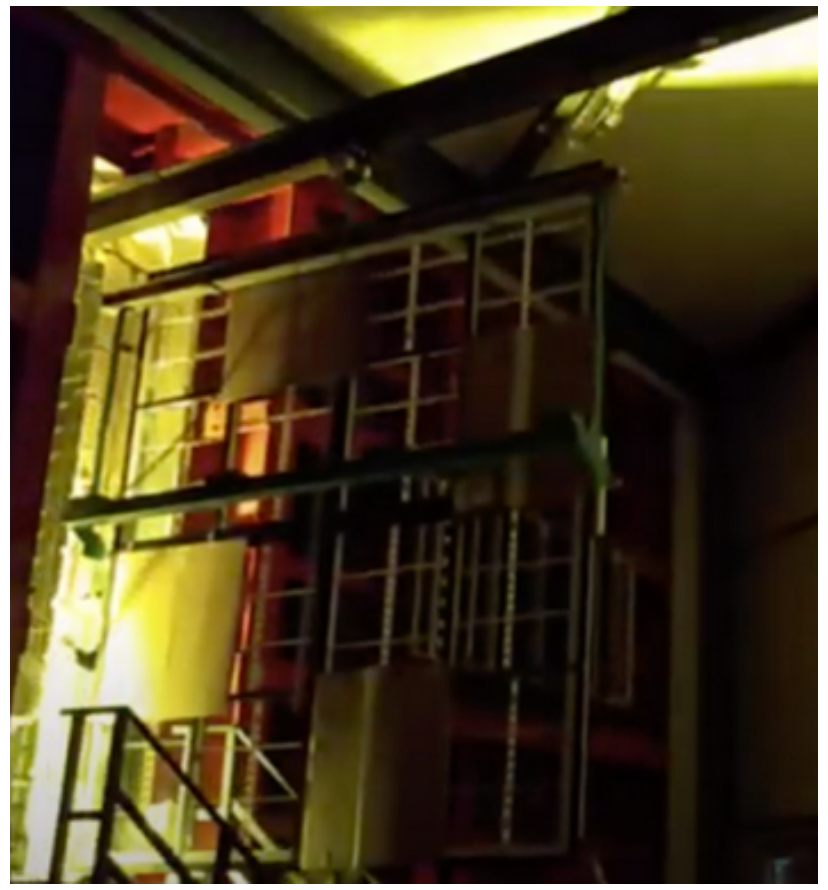
3. XA installation

4. shielding mesh

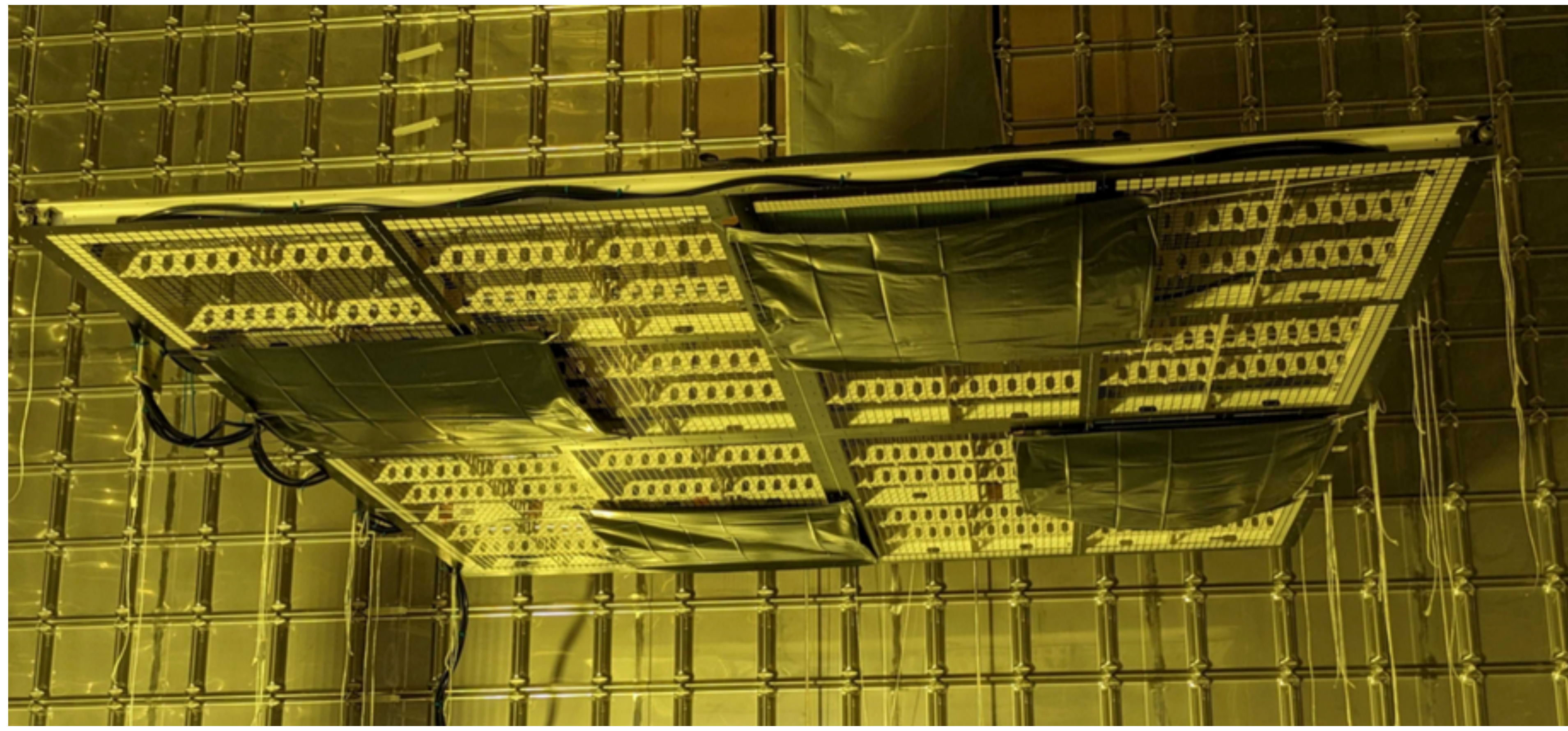


5. protection

6. to cryostat



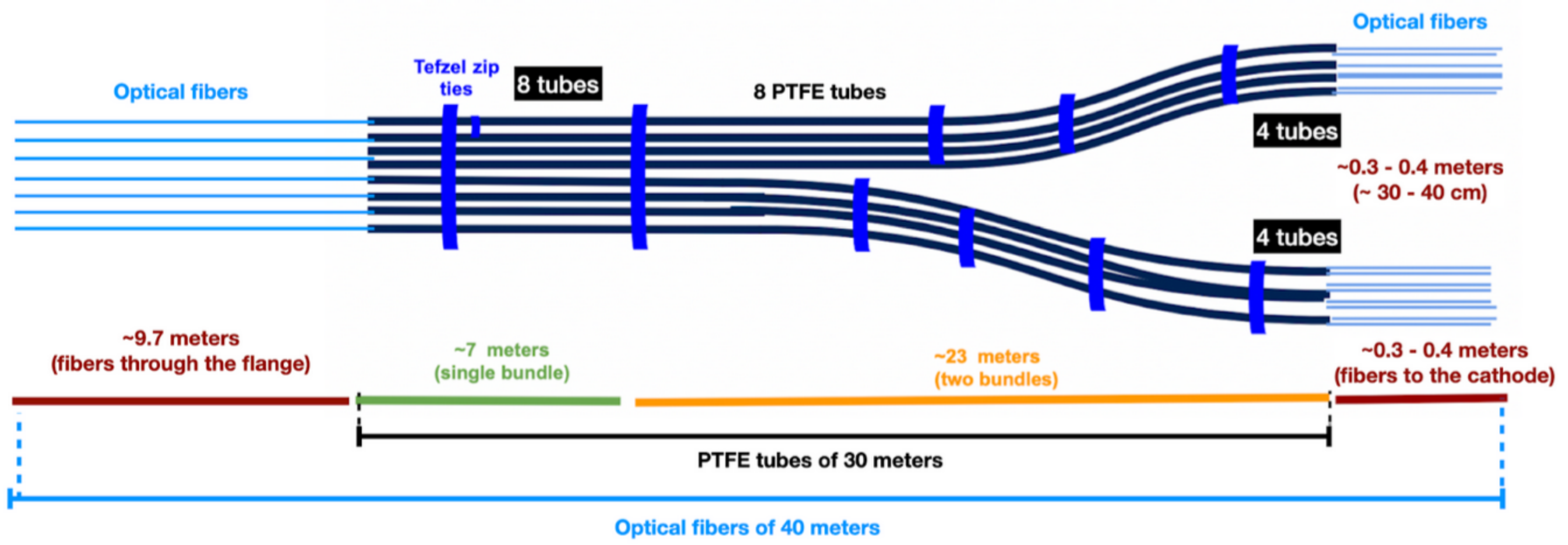
7. plastic covers



PoF and SoF fiber installation on cathode

Diana's talk

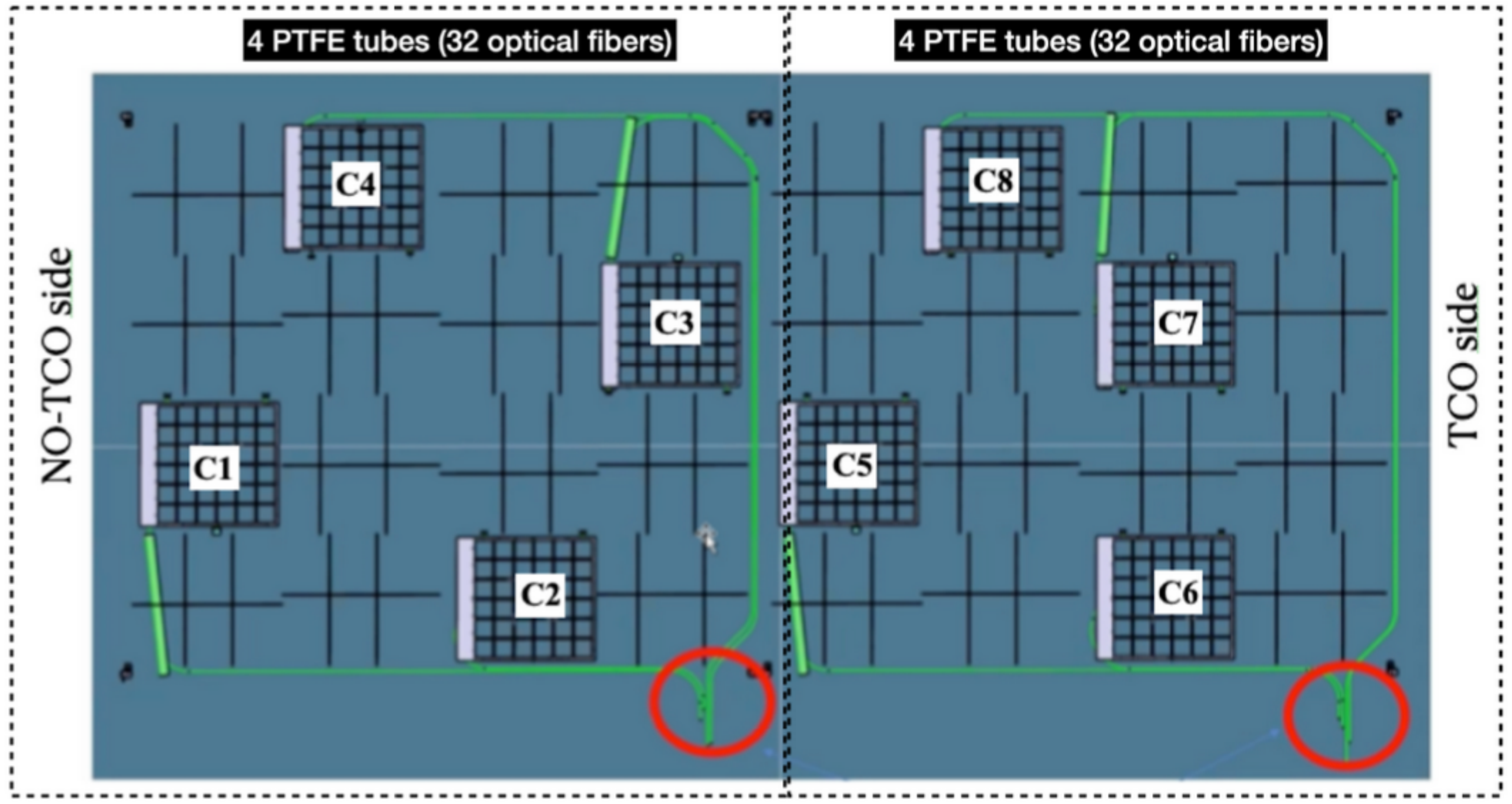
- 64 fibers distributed in 8 PTFE tubes



For FD2

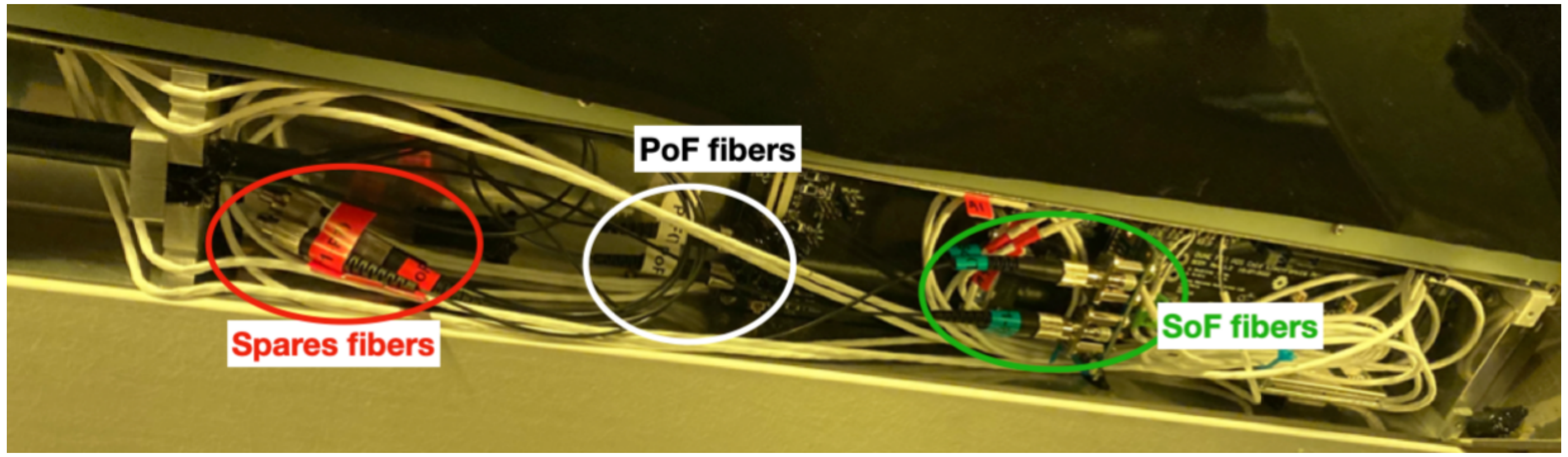
- Need dedicated anchoring points in cathode frame
- To avoid helix shape:
  - Transport in larger boxes
  - Straighten them with heating gun

routing path



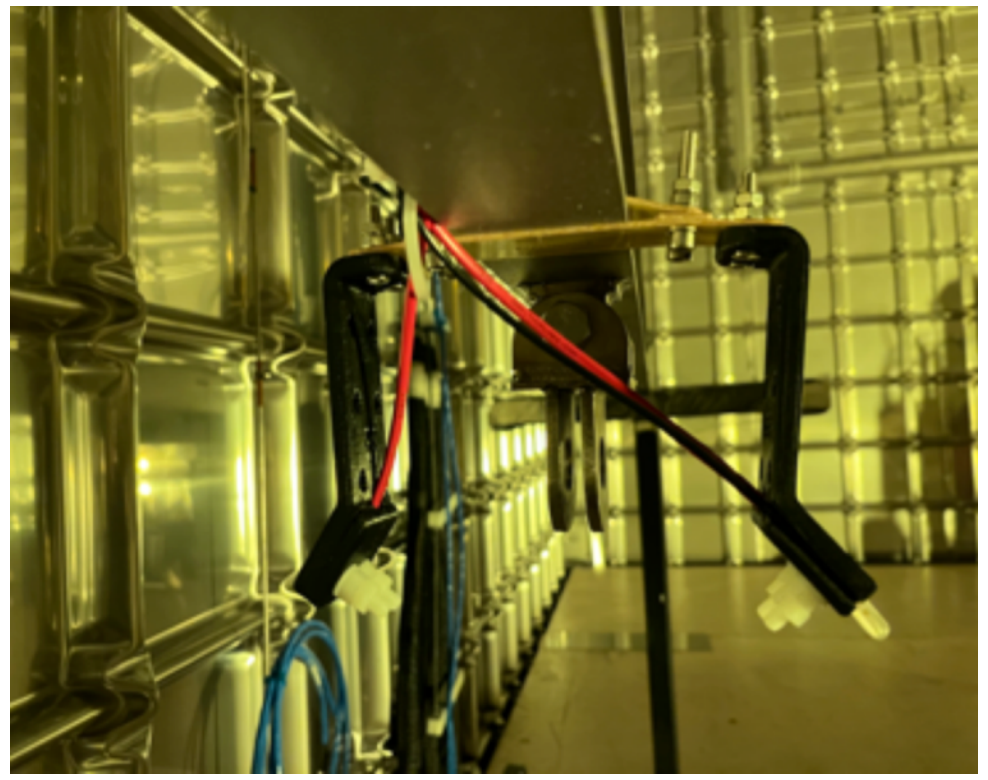
installation

Connections in elec. box



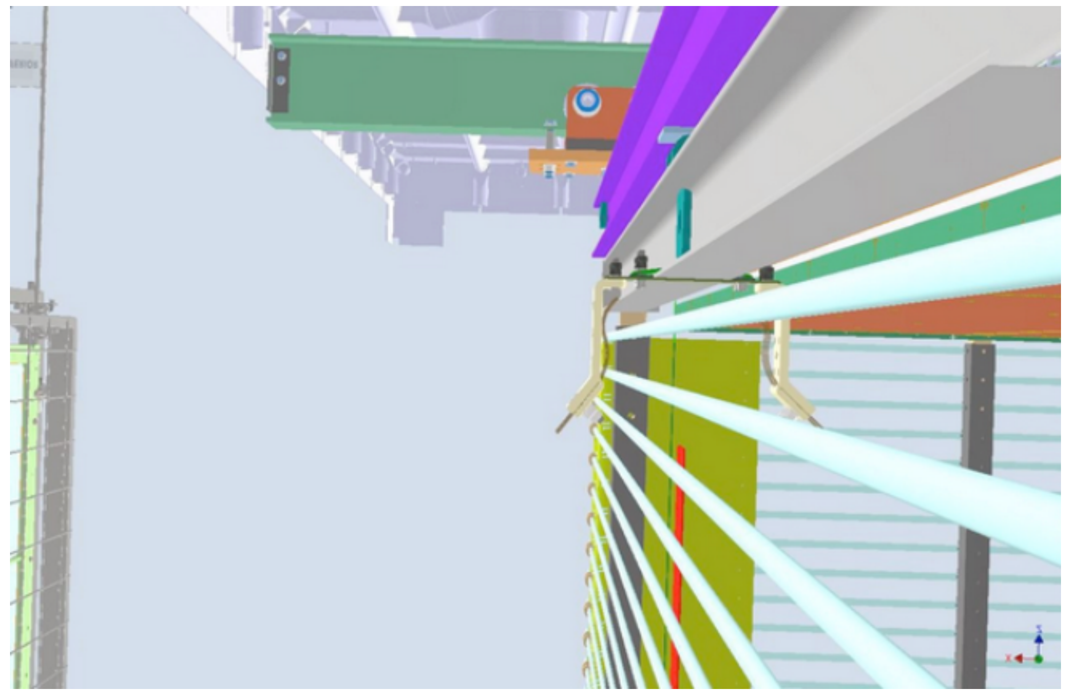
Response and Monitoring System

Beam with RMS kit before lifting

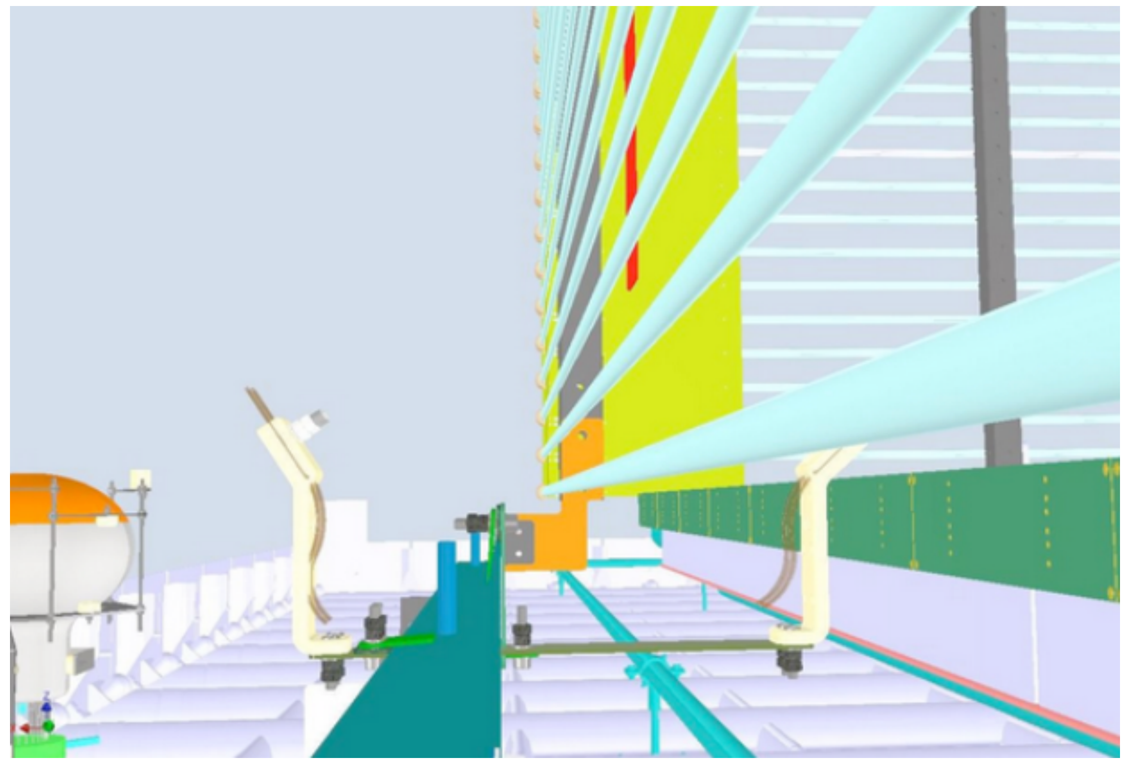


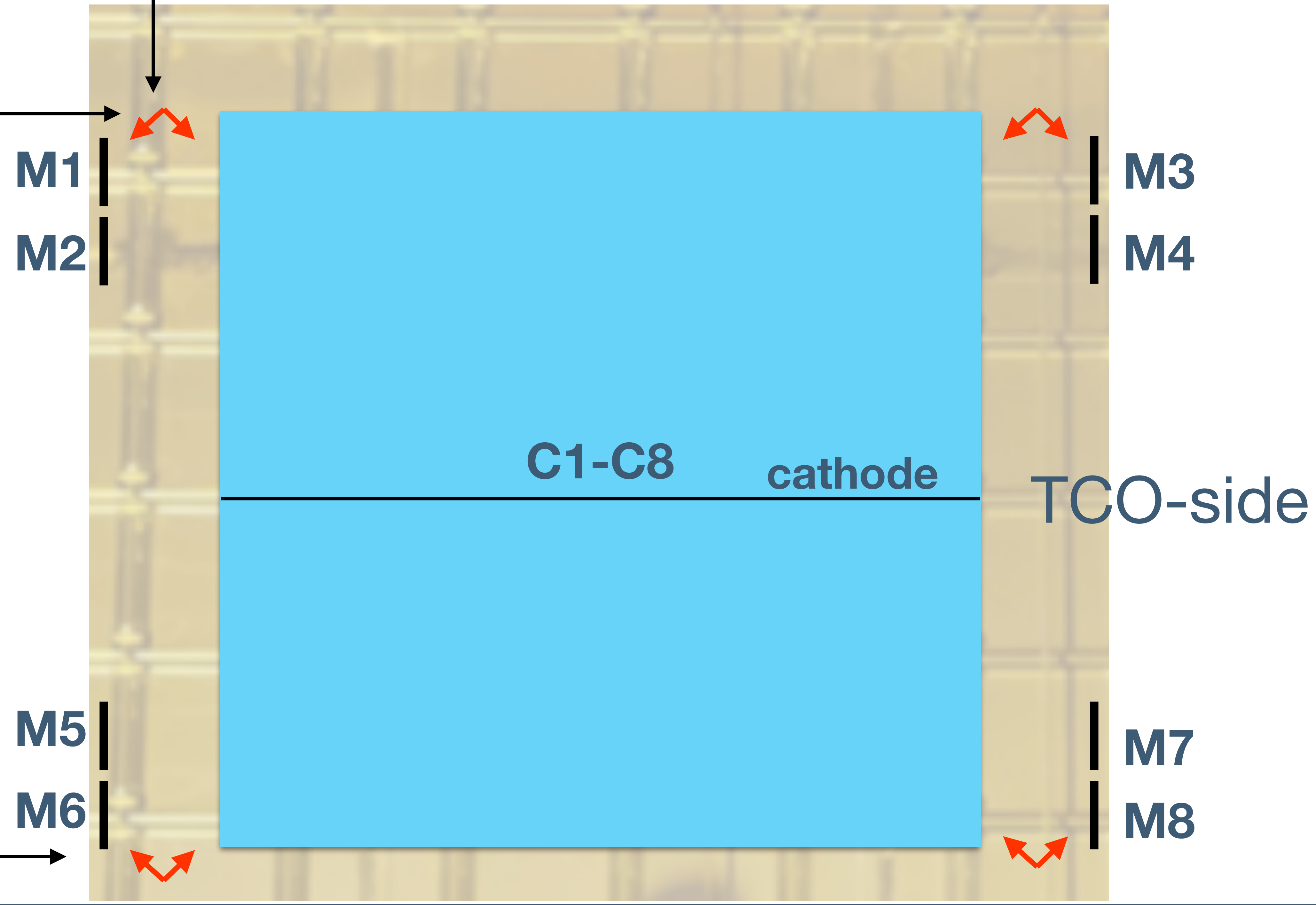
- Four kits ( ) to be installed
- Only one installed so far

upper non-TCO kit



lower non-TCO kit

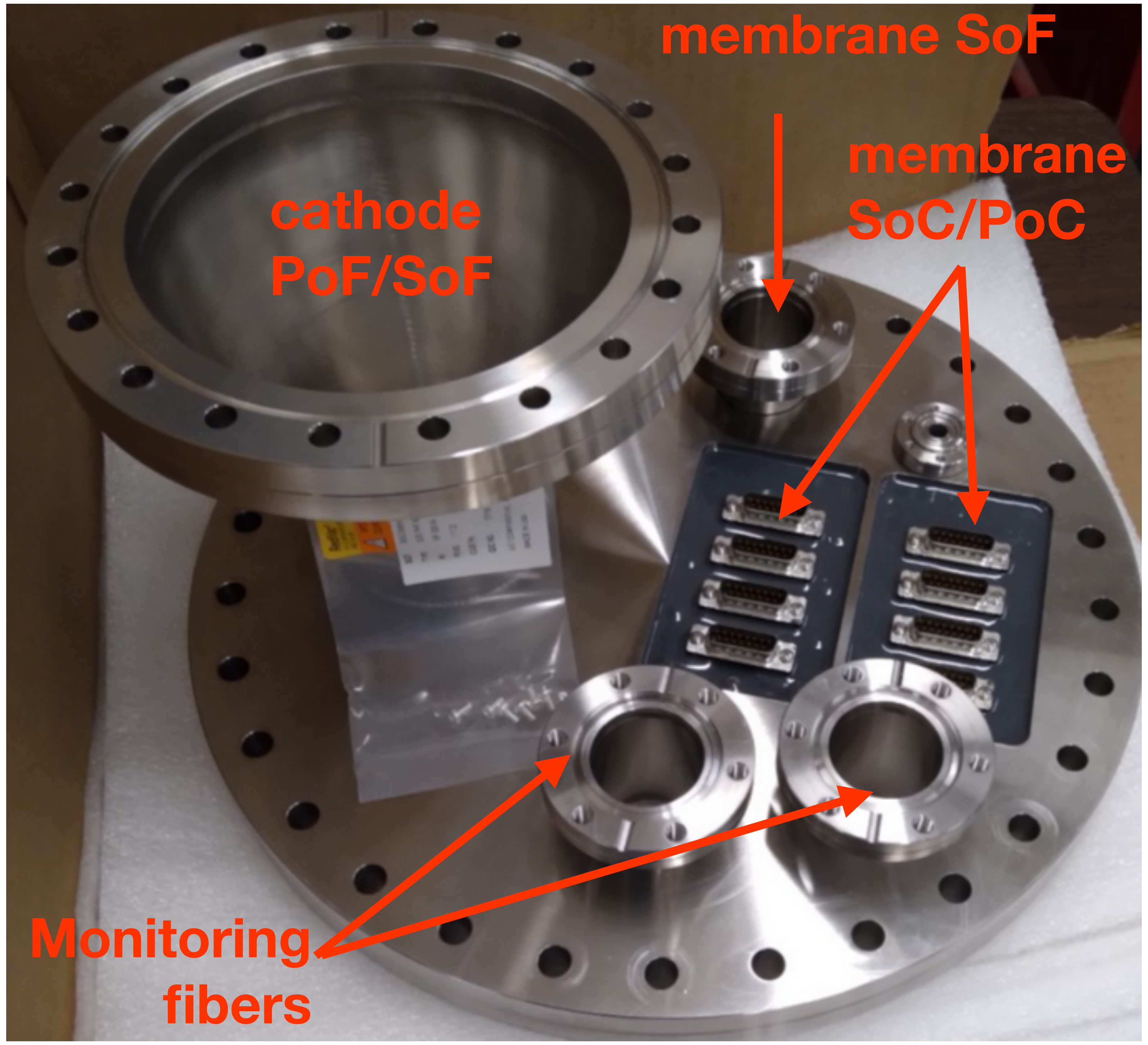


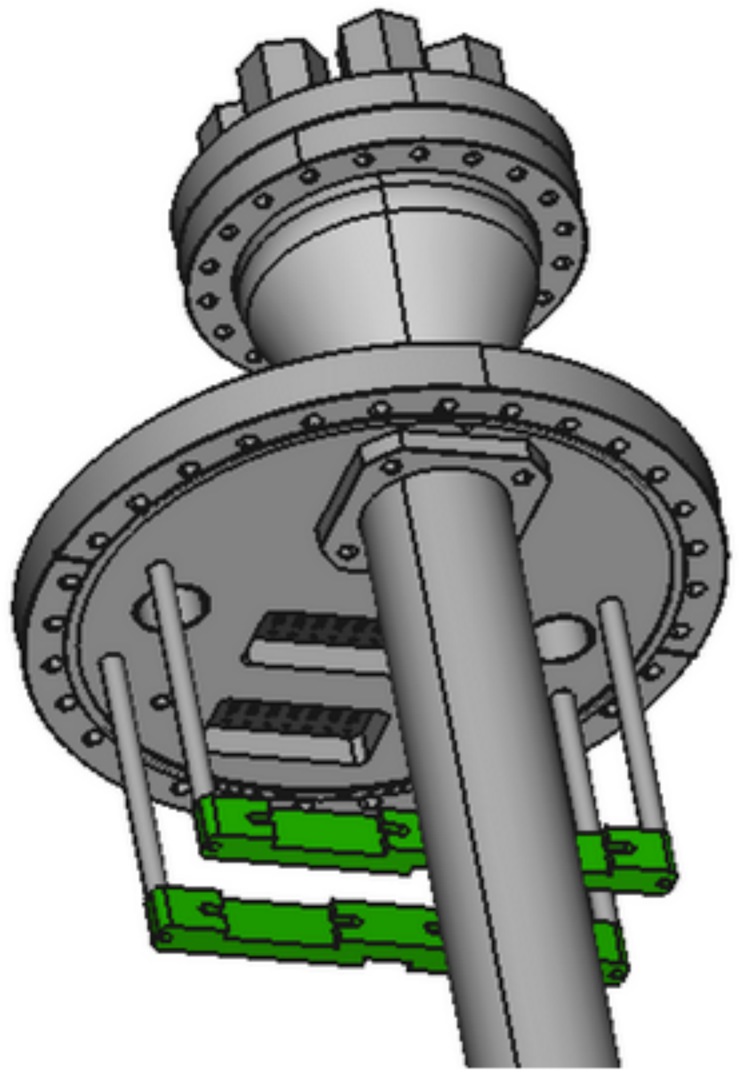


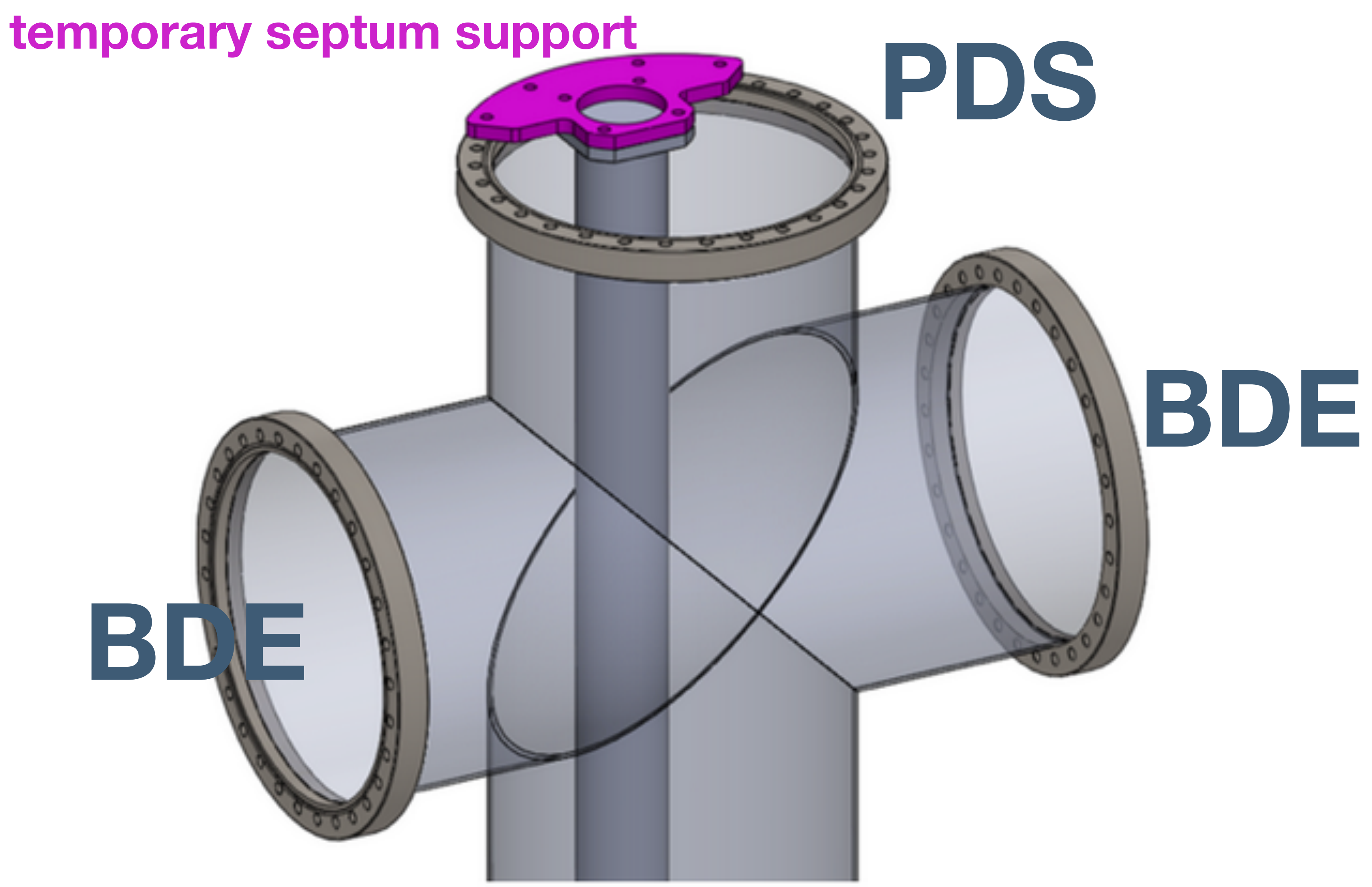
PD-HD RMS rack

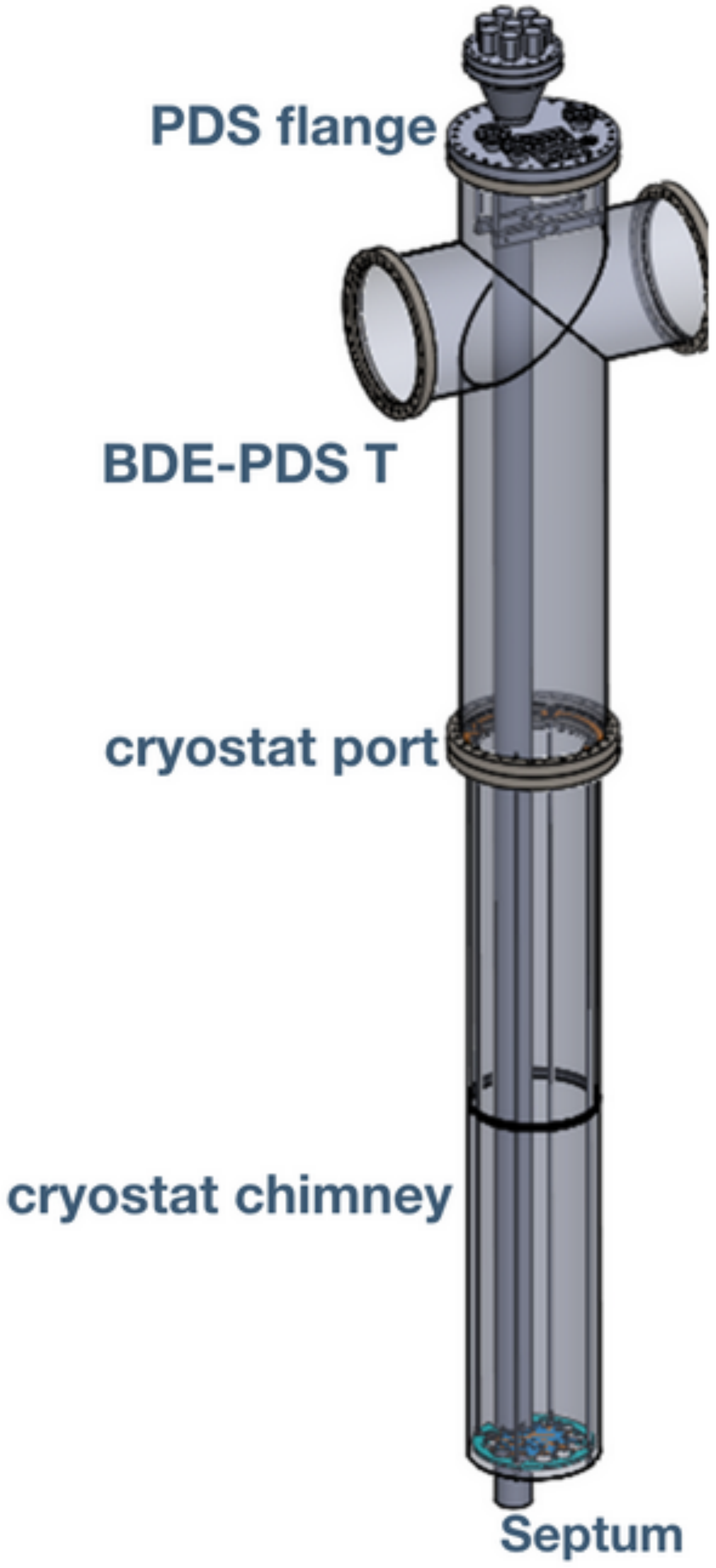
Plans for flange

- Will be installed mid May
- Needs coordination with BDE



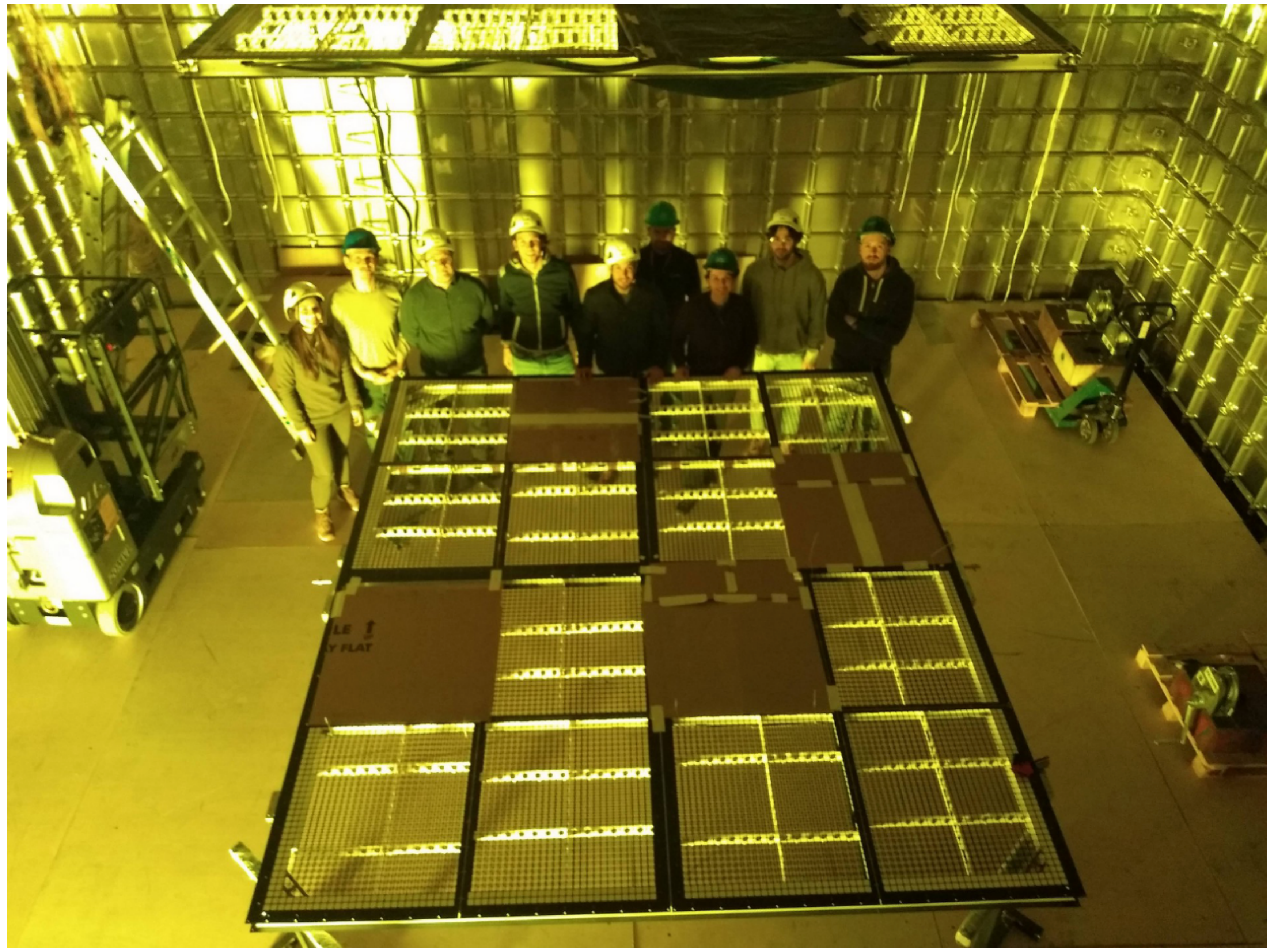


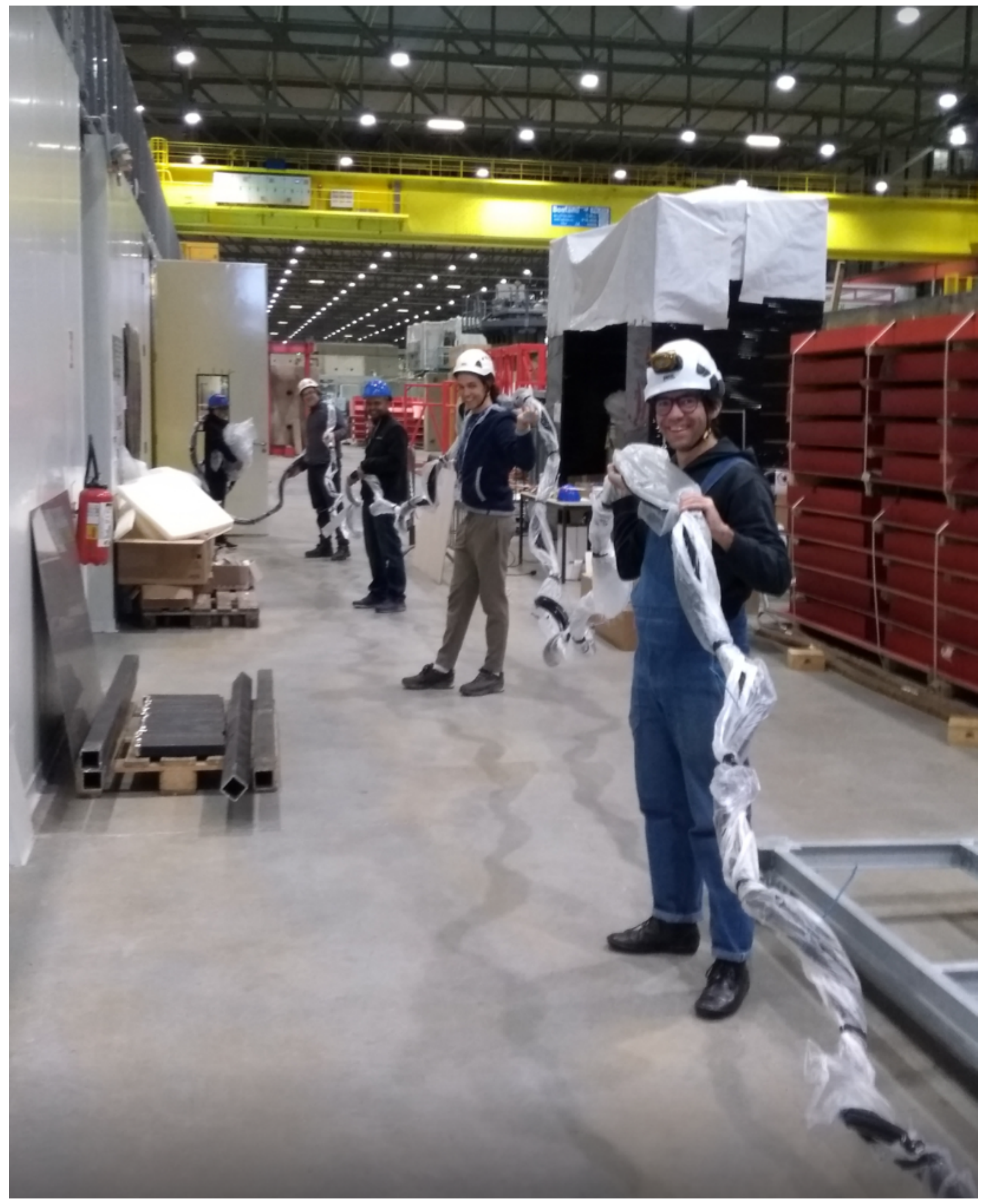


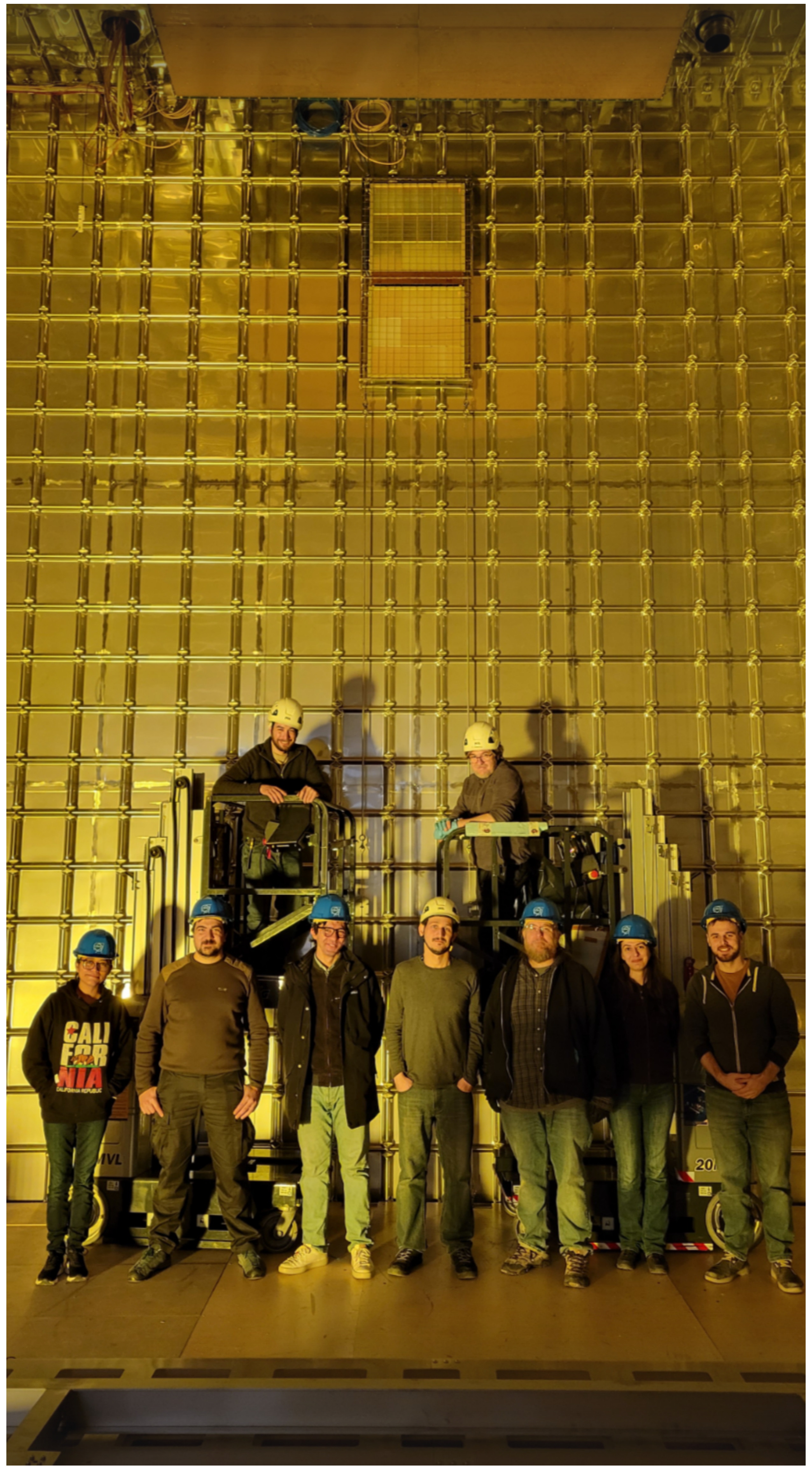


A great team

- 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.







backup