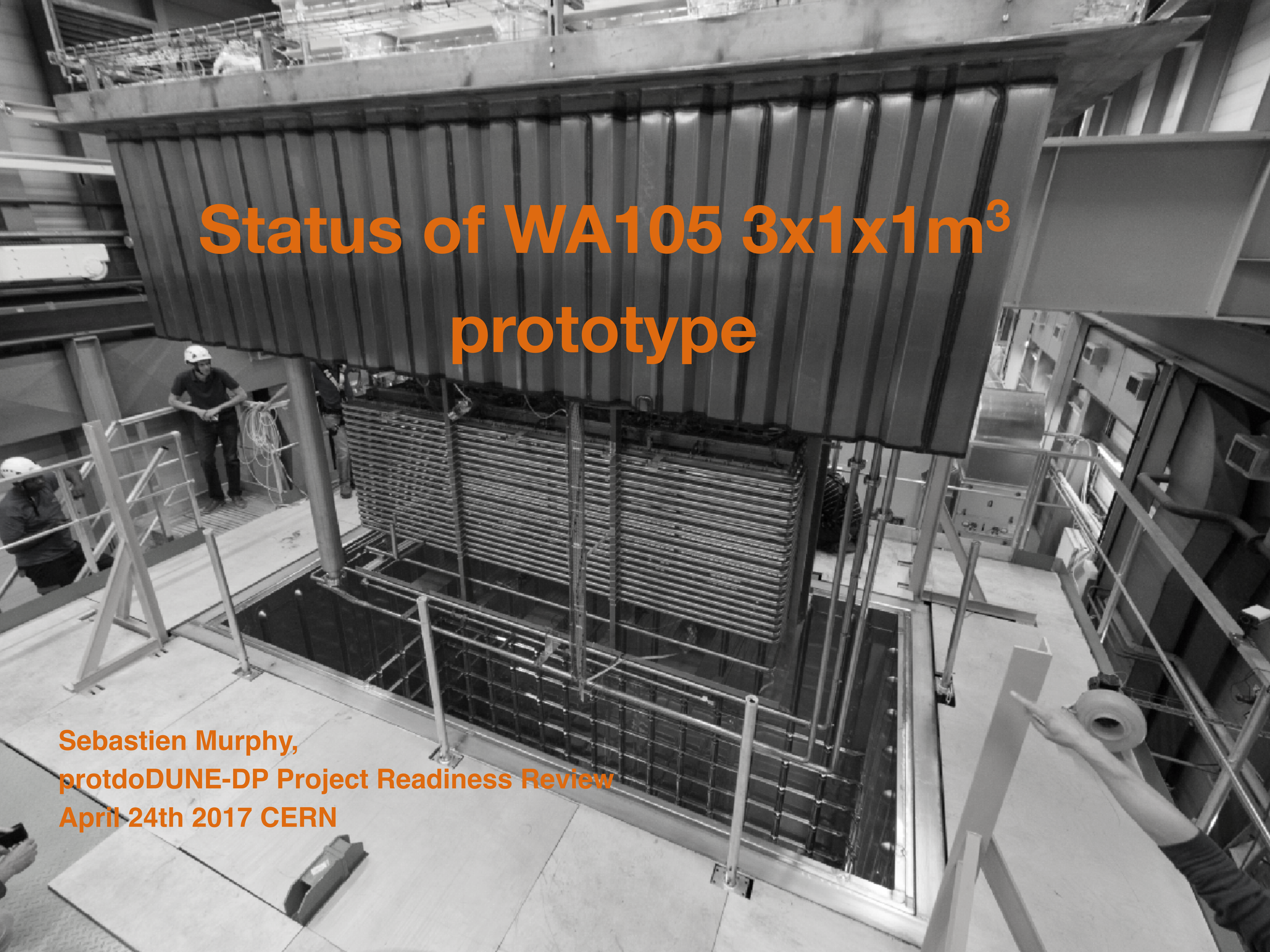


Status of WA105 3x1x1m^3 prototype

Sebastien Murphy,
protdoDUNE-DP Project Readiness Review
April 24th 2017 CERN

The WA105 collaboration

demonstrate the capabilities of the dual phase technology at the kton scale

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

UNIVERSITY OF JYVÄSKYLÄ

UCL

APC

Fermilab

LPNHE PARIS

IPNL

lapp

CERN

KEK
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

LABORATORIUM FÜR HOCHENERGIEPHYSIK
LHEP
UNIVERSITÄT BERN

IFIN-HH

UBR

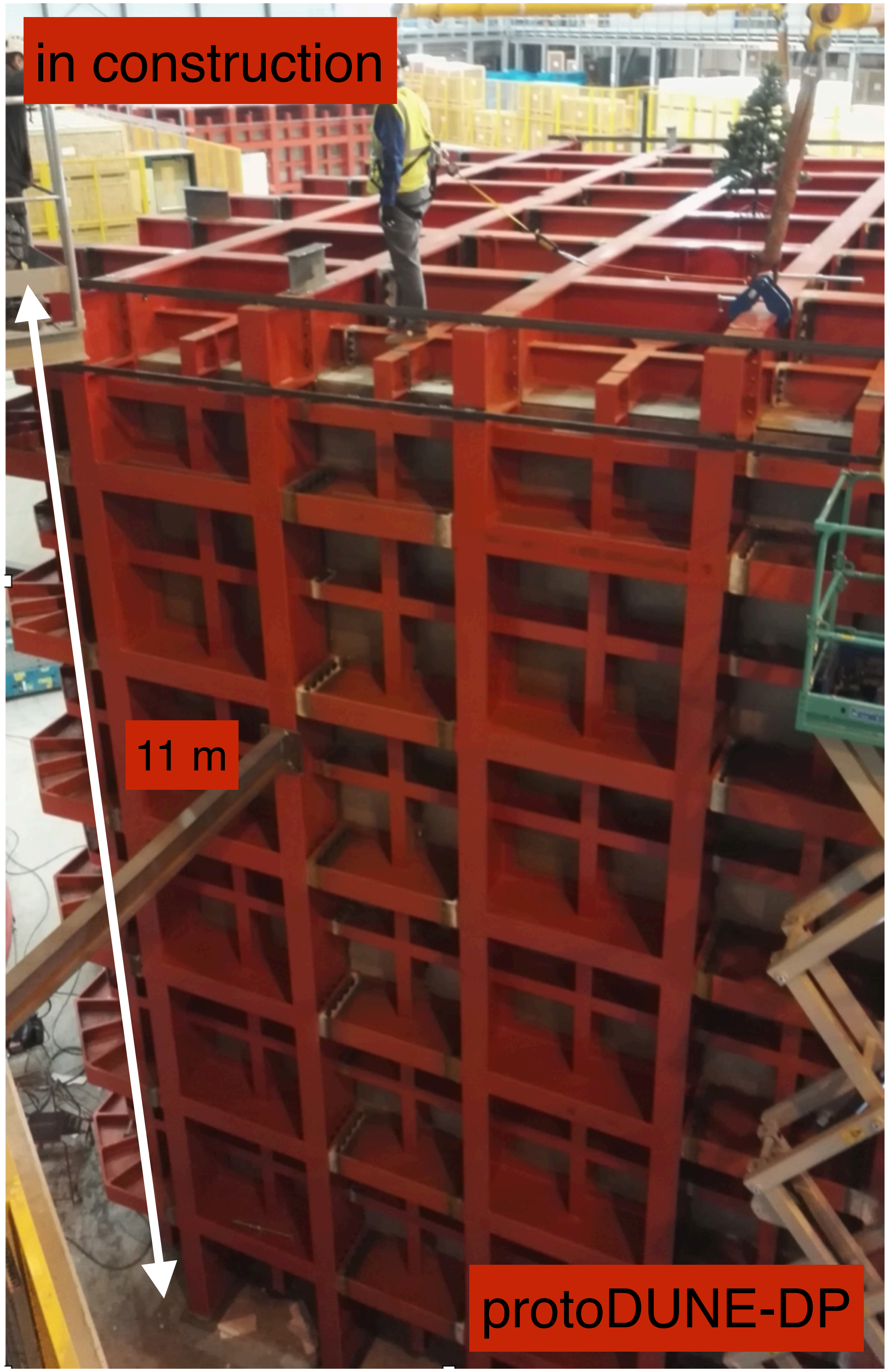
Institut de Física d'Altes Energies IFAE

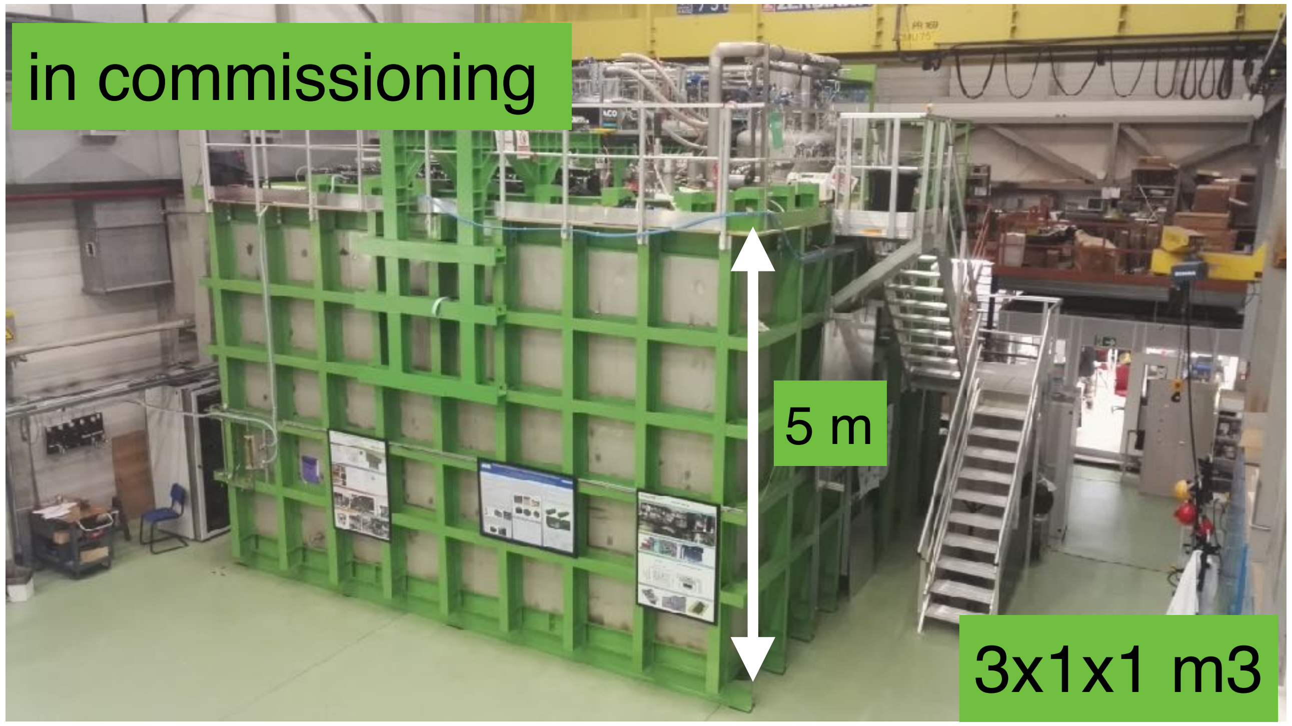
IN2P3
Institut National de Physique Nucléaire et de Physique des Particules

cea SACLAY

Two dual phase liquid argon detectors

same technology, two scales, different goals





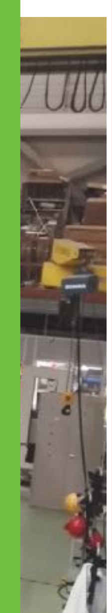
Two dual phase liquid argon detectors

Common aspects

- ✓ LEMs and anode: design, purchase, cleaning and QA
- ✓ chimneys, FT and slow control sensors
- ✓ membrane tank technology
- ✓ Accessible cold front-end electronics and DAQ system
- ✓ amplification in pure Ar vapour on large areas

3x1x1 m3

- ✓ **First GTT constructed cryostat for LAr**
- ✓ **Fully engineered versions of many detector components** with pre-production and direct implementation (installation details and ancillary services)
- ✓ **First overview of the complete system integration**: set up full chains for Quality Assessment, construction, installation and commissioning
- ✓ **Anticipate legal and practical aspects** related to procurement, costs and schedule verification
- ✓ short term data taking with cosmics



1 m

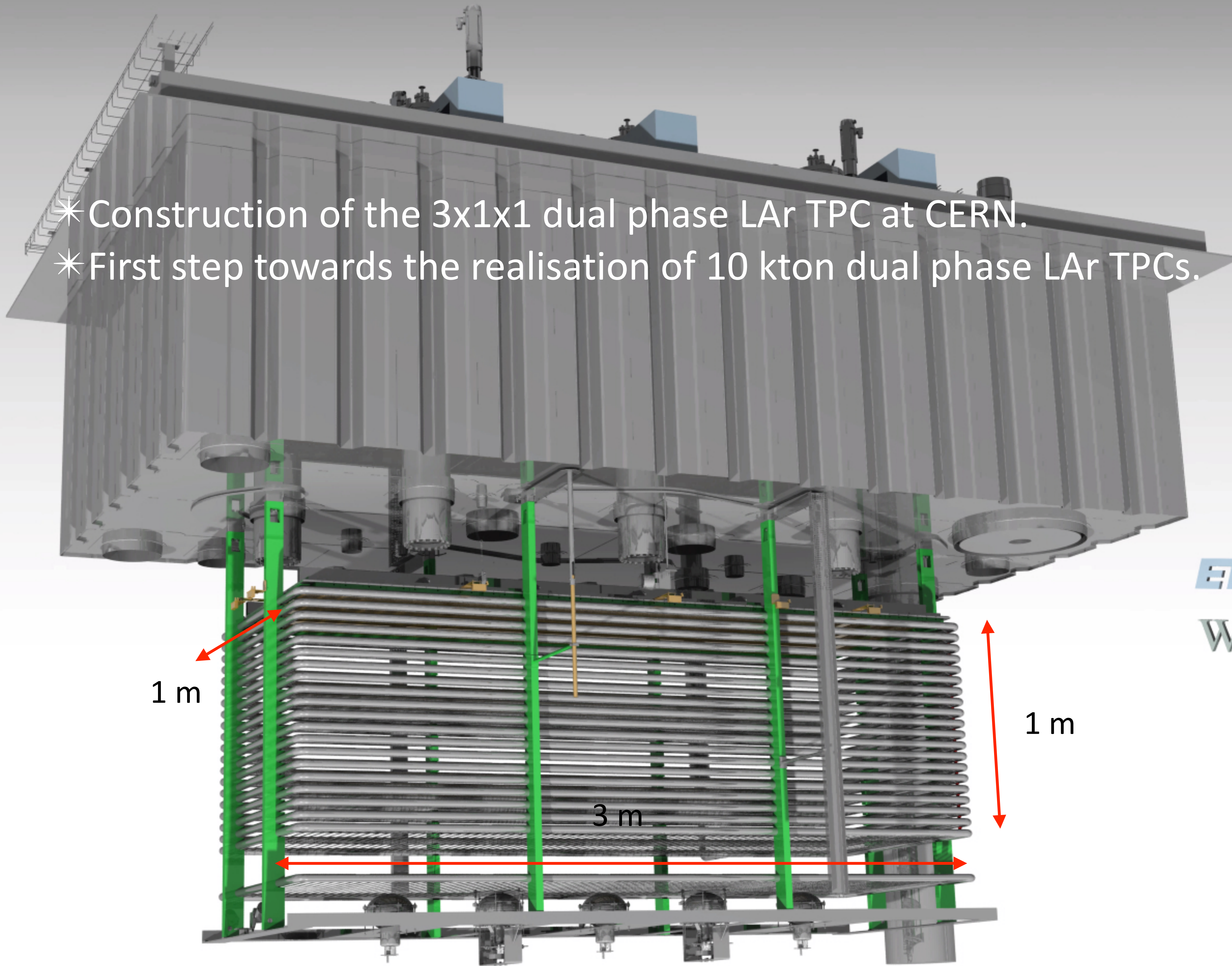
protoDUNE-DP

- ✓ Large hanging field cage structure
- ✓ Very high voltage generation and guiding
- ✓ Large area charge readouts
- ✓ long drift (e- diffusion, purity, etc..)
- ✓ test beam data (calibration, reconstruction, fully contained events, x-sections, etc…)
- ✓ Long term stability of UV scintillation light readout
- ✓ underground construction method

3m3 Dual phase LAr TPC

✳ Construction of the 3x1x1 dual phase LAr TPC at CERN.

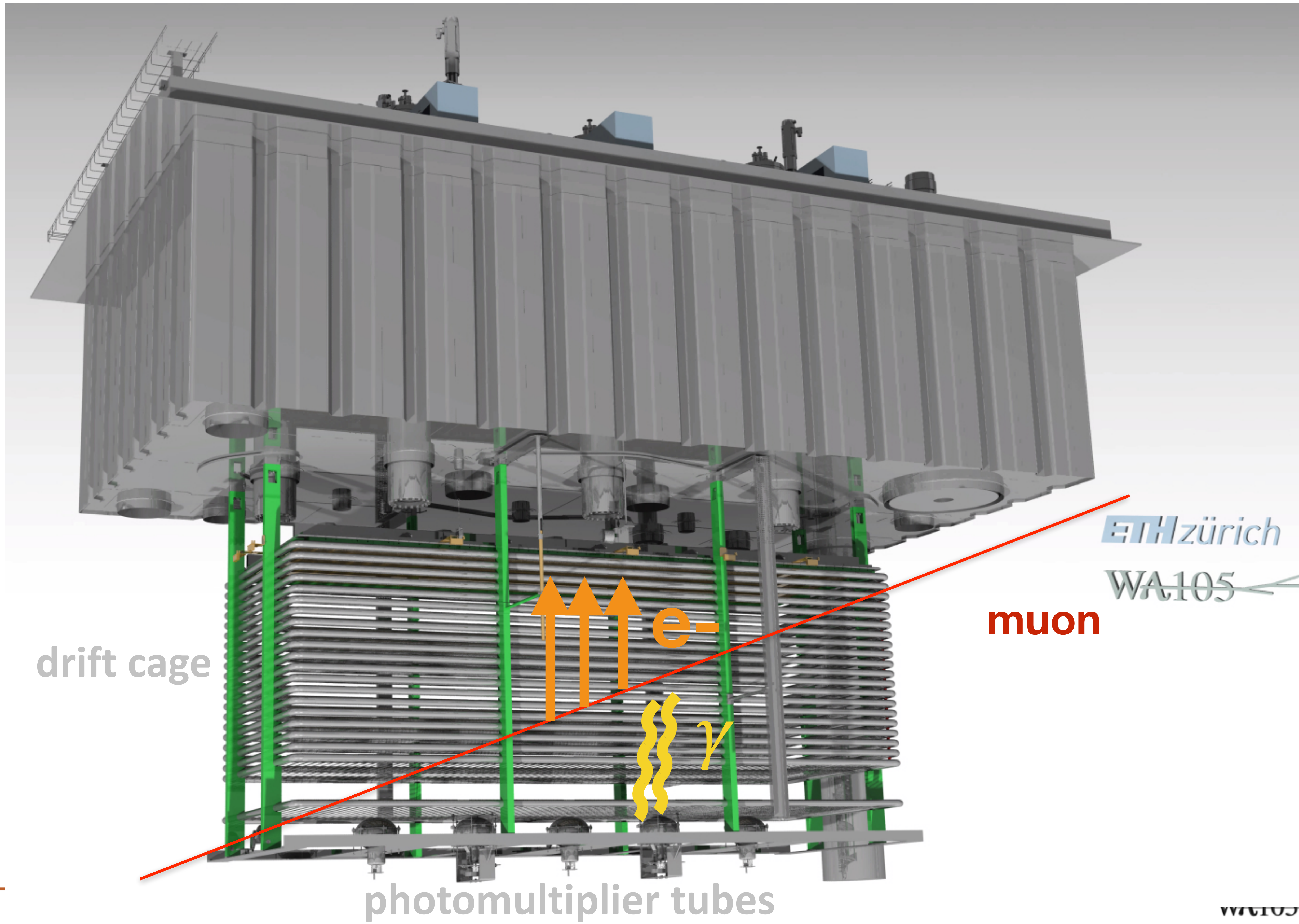
✳ First step towards the realisation of 10 kton dual phase LAr TPCs.



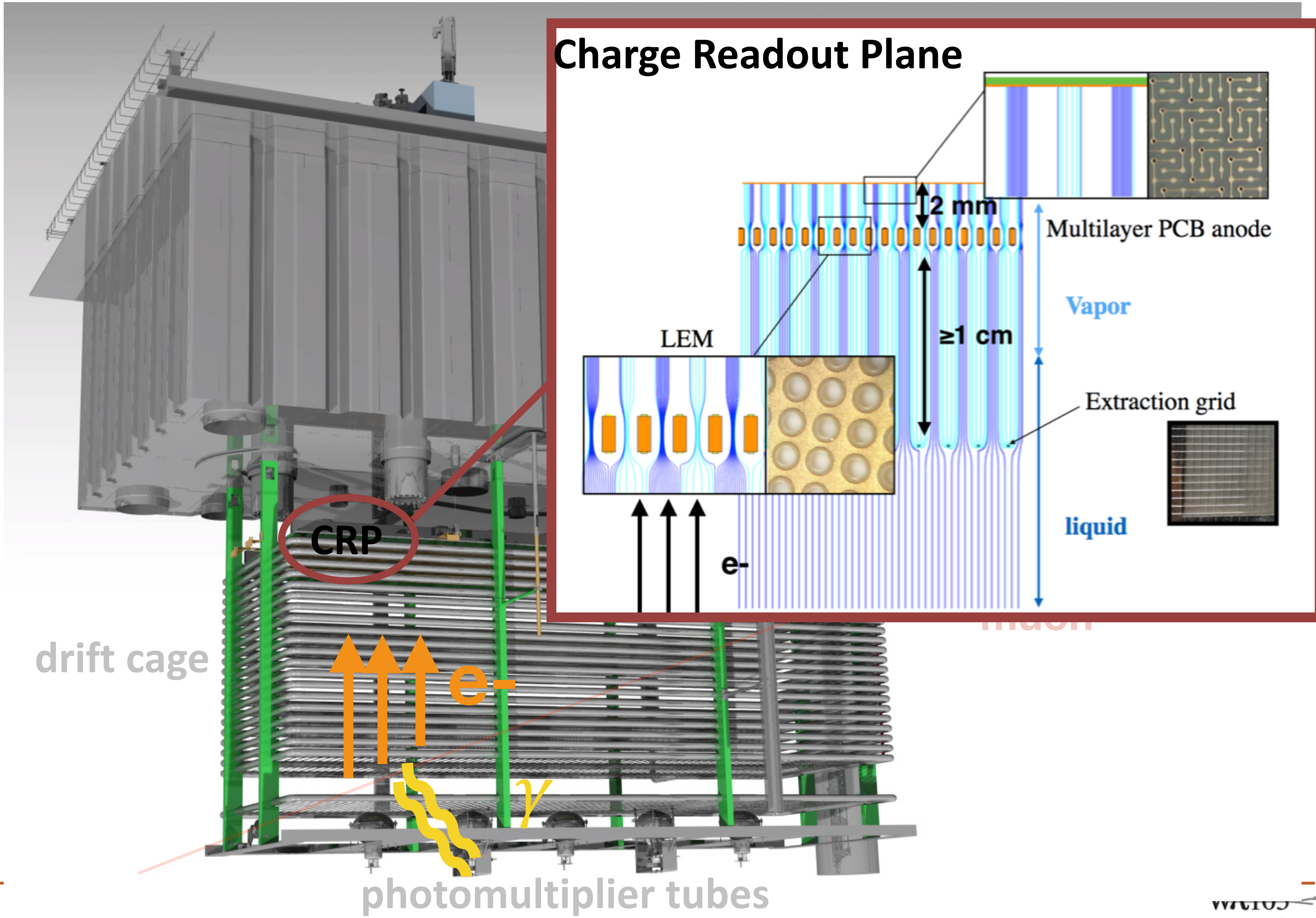
ETH zürich

WA105

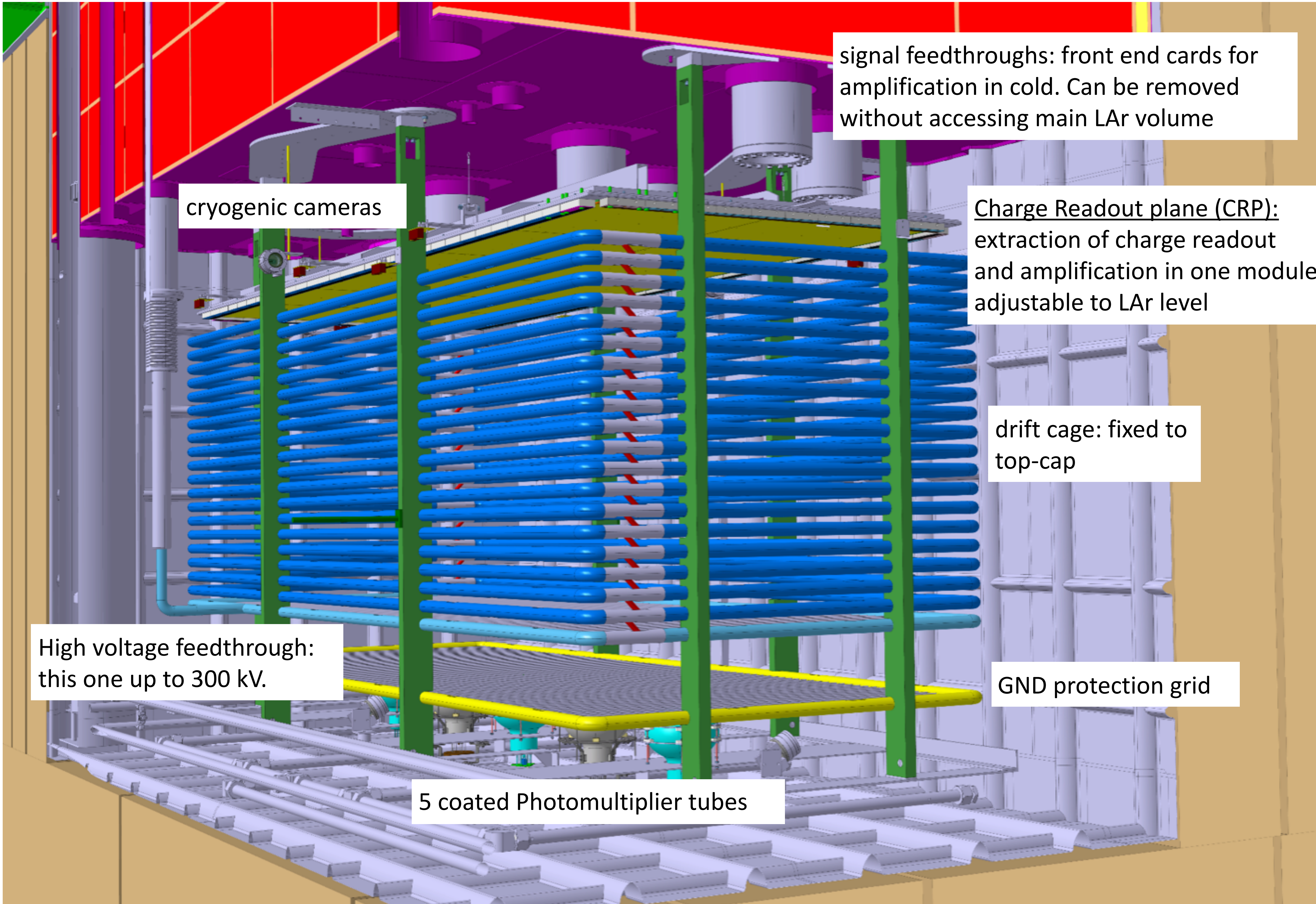
3m3 Dual phase LAr TPC



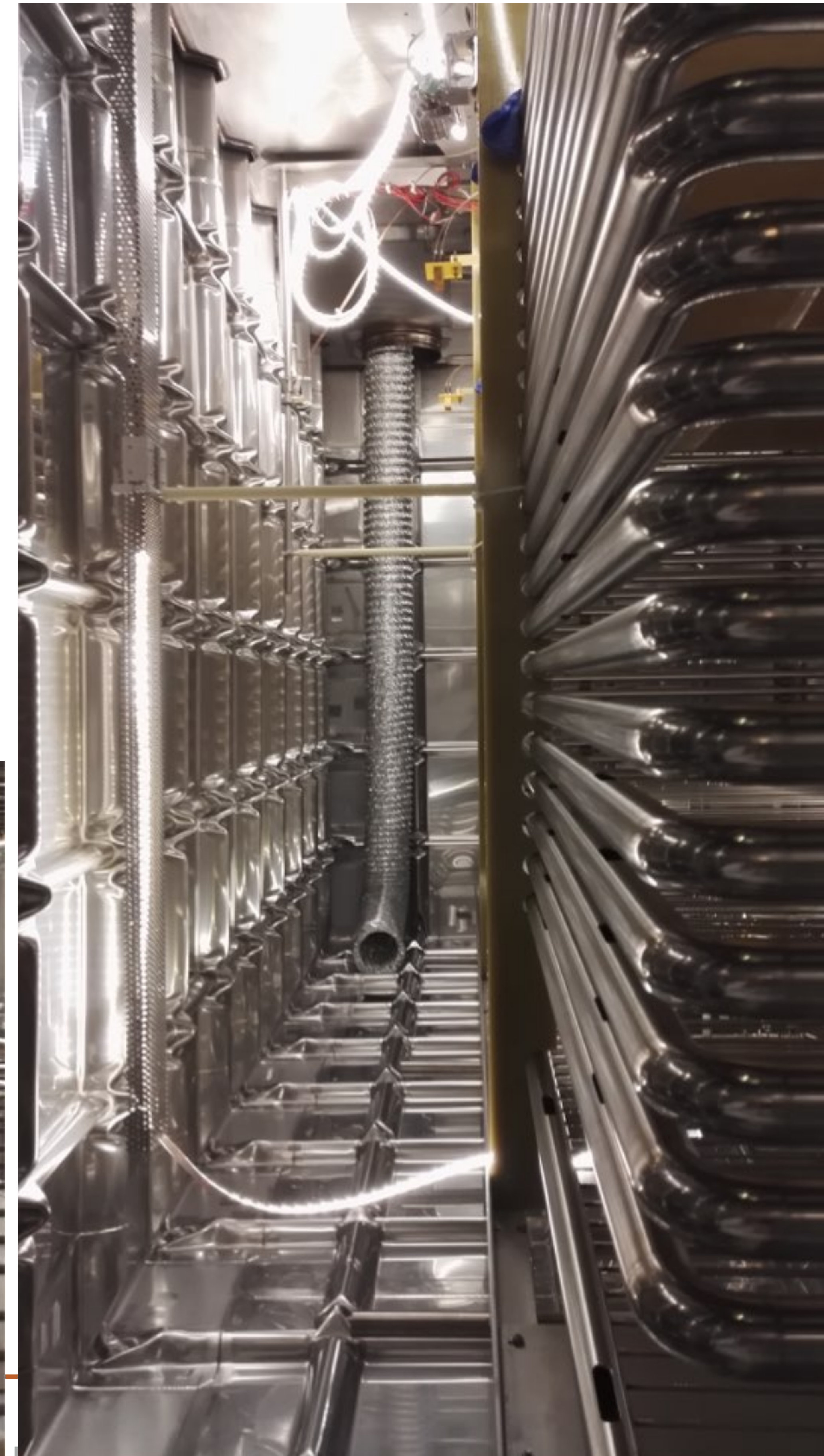
3m3 Dual phase LAr TPC



3x1x1 detector



pictures from inside the cryostat



PART 1 DETECTOR INSTALLATION

MARCH-JULY 2016

Detector construction

WA105 3x1x1 prototype

ENTIRE DETECTOR CONSTRUCTED IN 2016

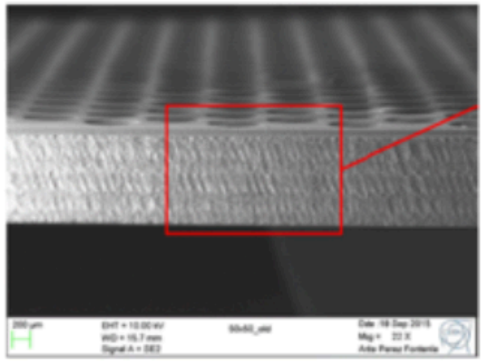
FE electronics inserted + tested

top-cap delivered

full detector installed under top-cap

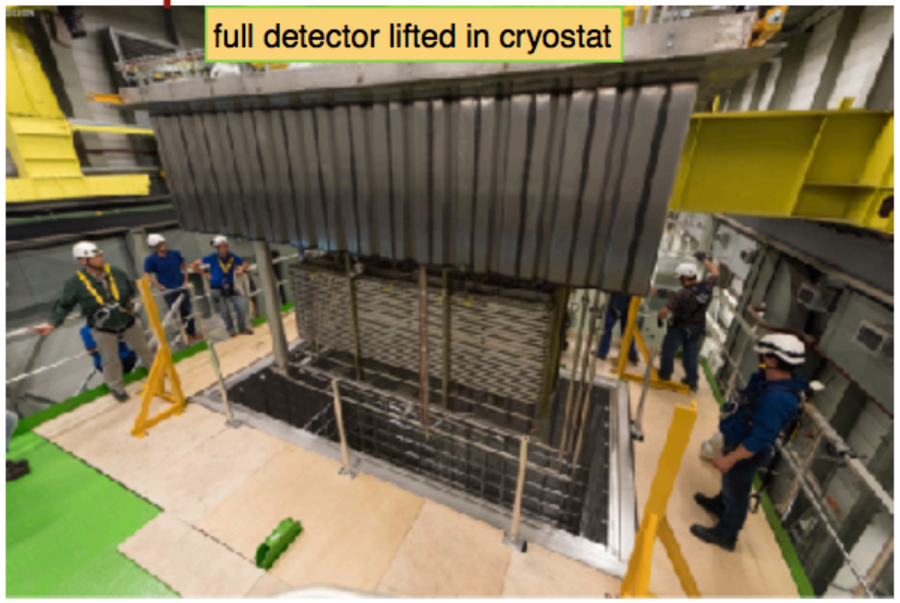
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

LEMs & anode delivered +QA/QC



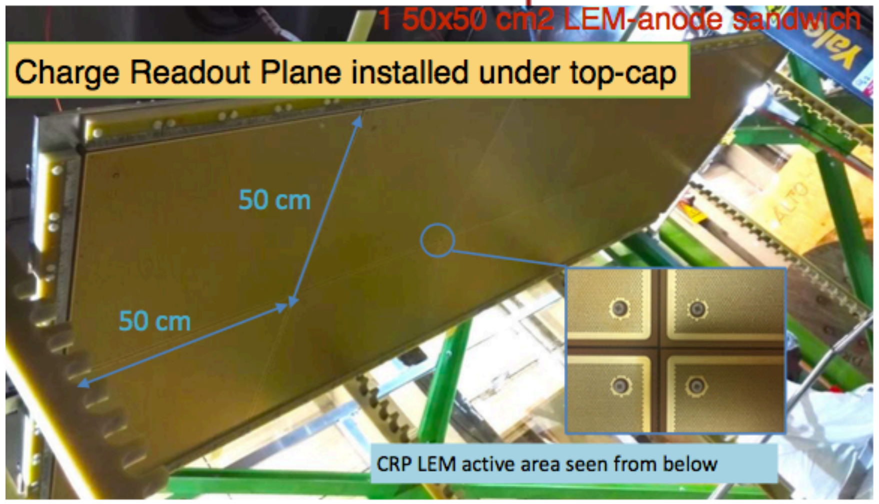
CRP cryogenic bath test

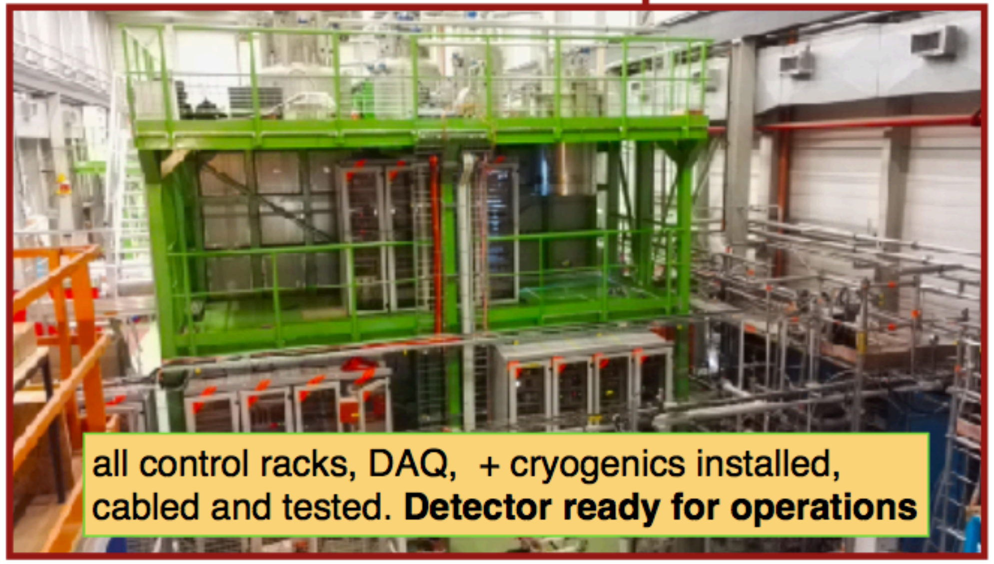
full detector lifted in cryostat



successful test and insertion of 300 kV high voltage feedthrough

Charge Readout Plane installed under top-cap

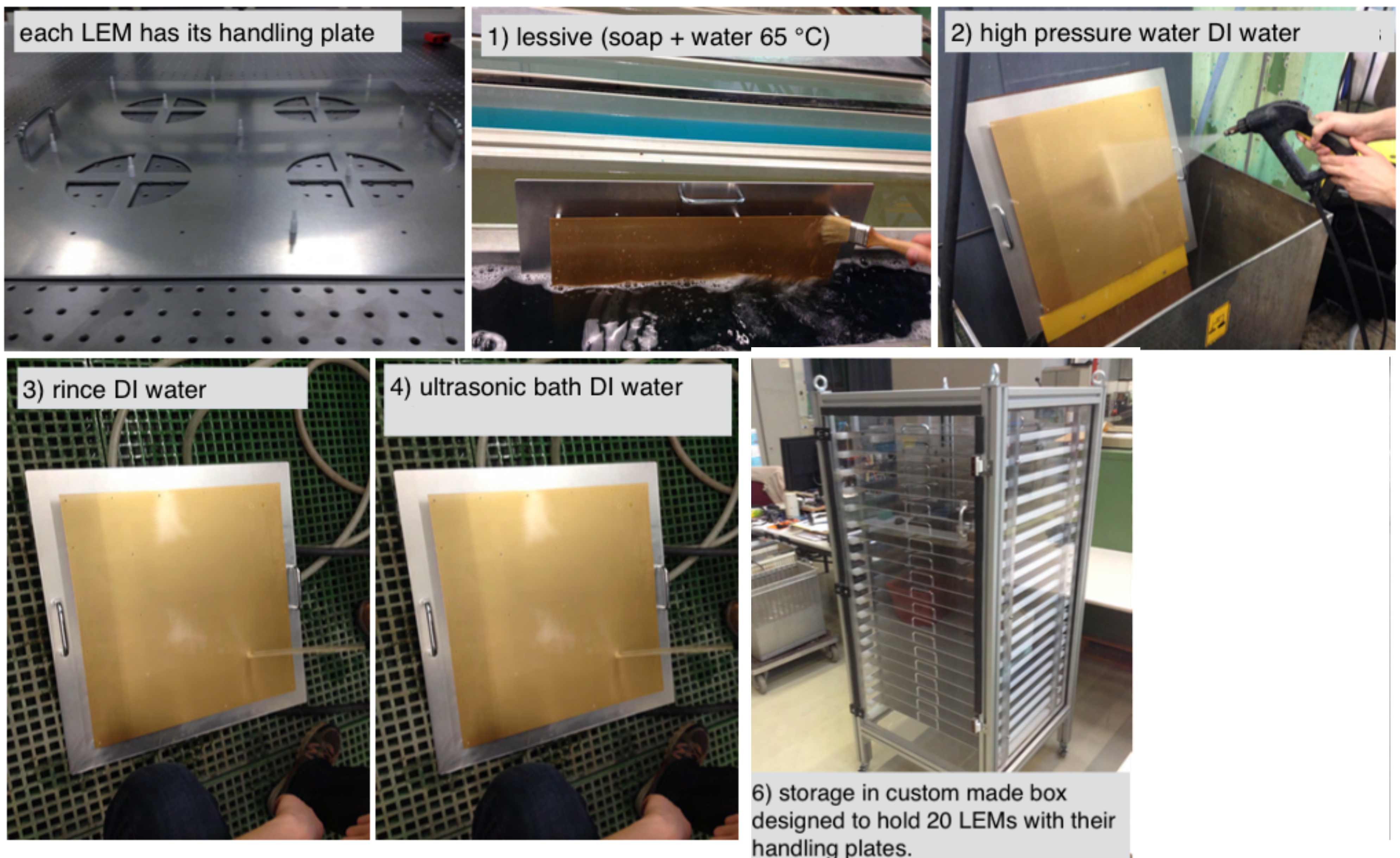




all control racks, DAQ, + cryogenics installed, cabled and tested. **Detector ready for operations**

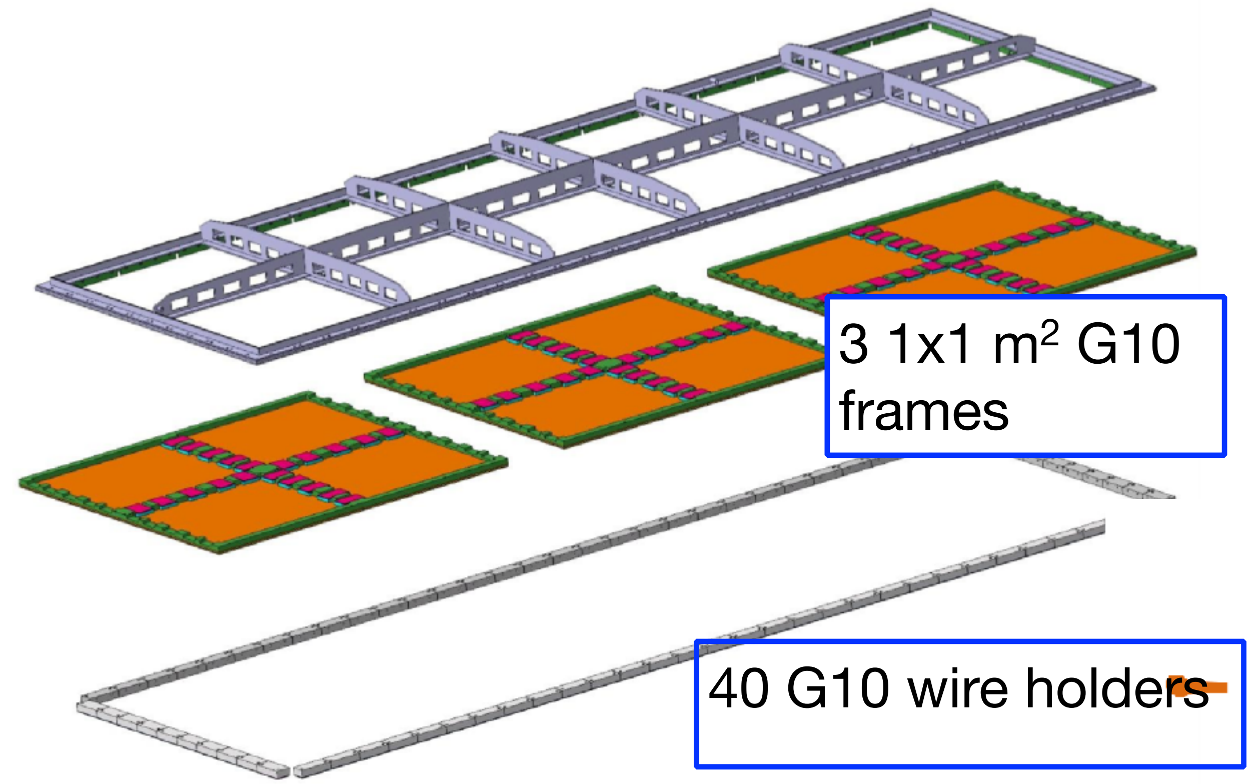
LEM cleaning

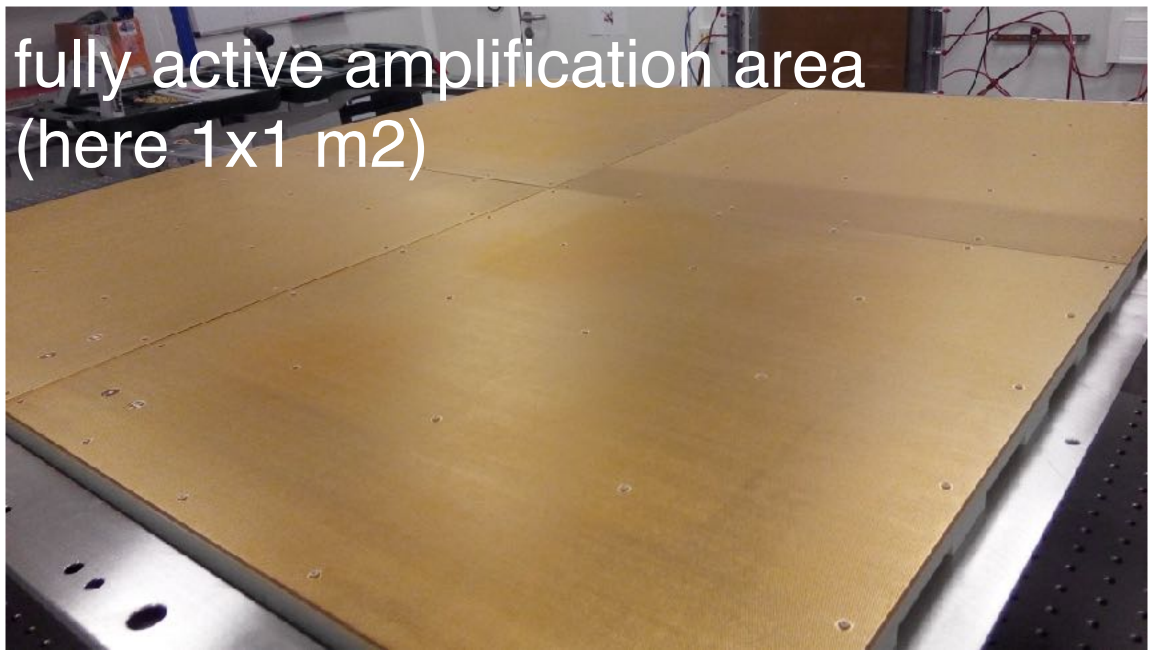
- Cleaning procedure is rather **simple and straightforward**. ~10 mins per LEM. Doesn't need specific facility.
- HV testing should be done in **controlled environment** (T,P and RH)
- **no stringent requirements on storage**, should be in a controlled environment that's about it.



Validated for protoDUNE DP

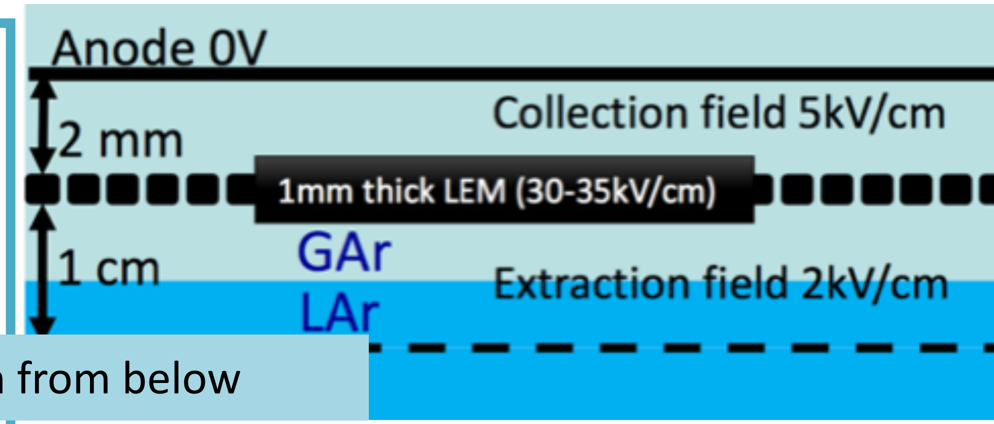
Assembly of the CRP: example of the 3x1 m^2



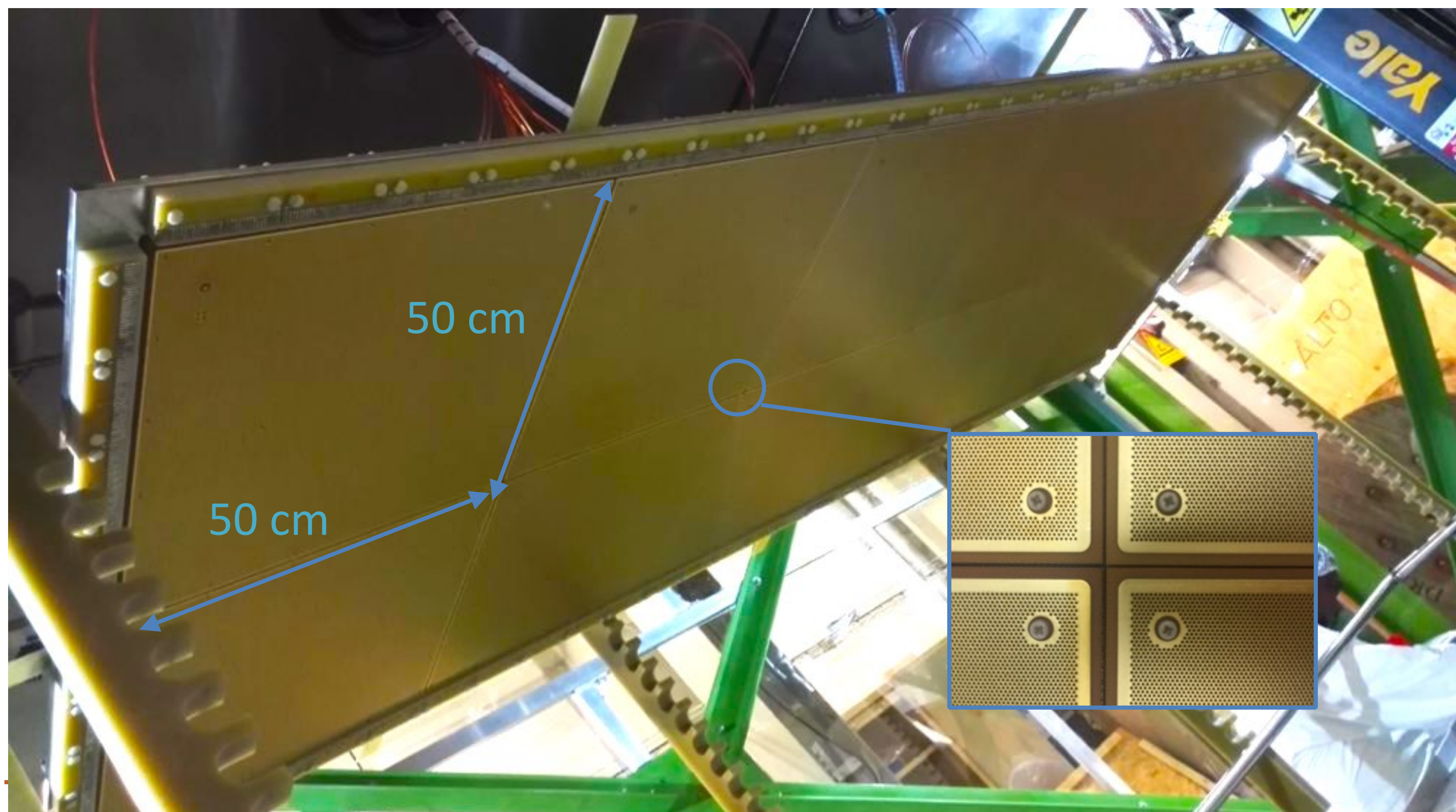


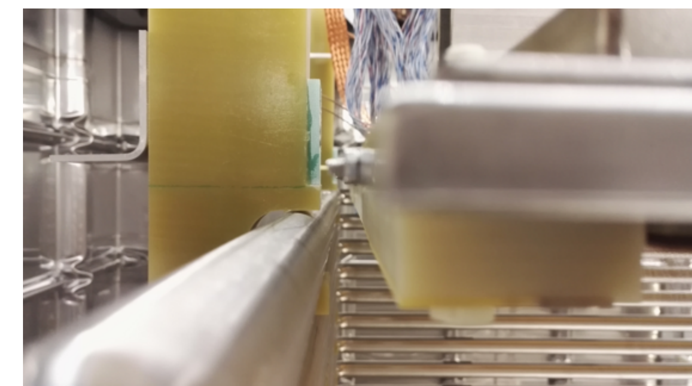
Charge Readout Plane

- fully active 3x1 m2 amplification and readout adjustable to LAr level.
- All components industrially fabricated with most of the QA/QC performed by the companies.
- mechanical tolerances validated in warm temperature in open cryogenic baths.
- Assembly is straightforward and quick (~2 people, 2 days)

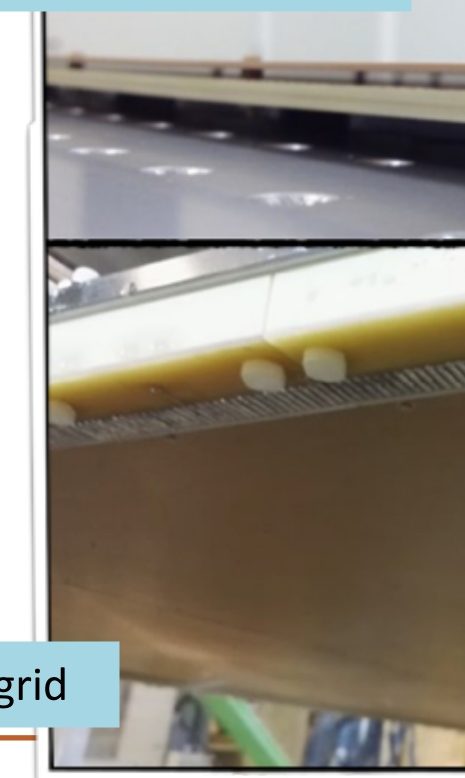


CRP LEM active area seen from below



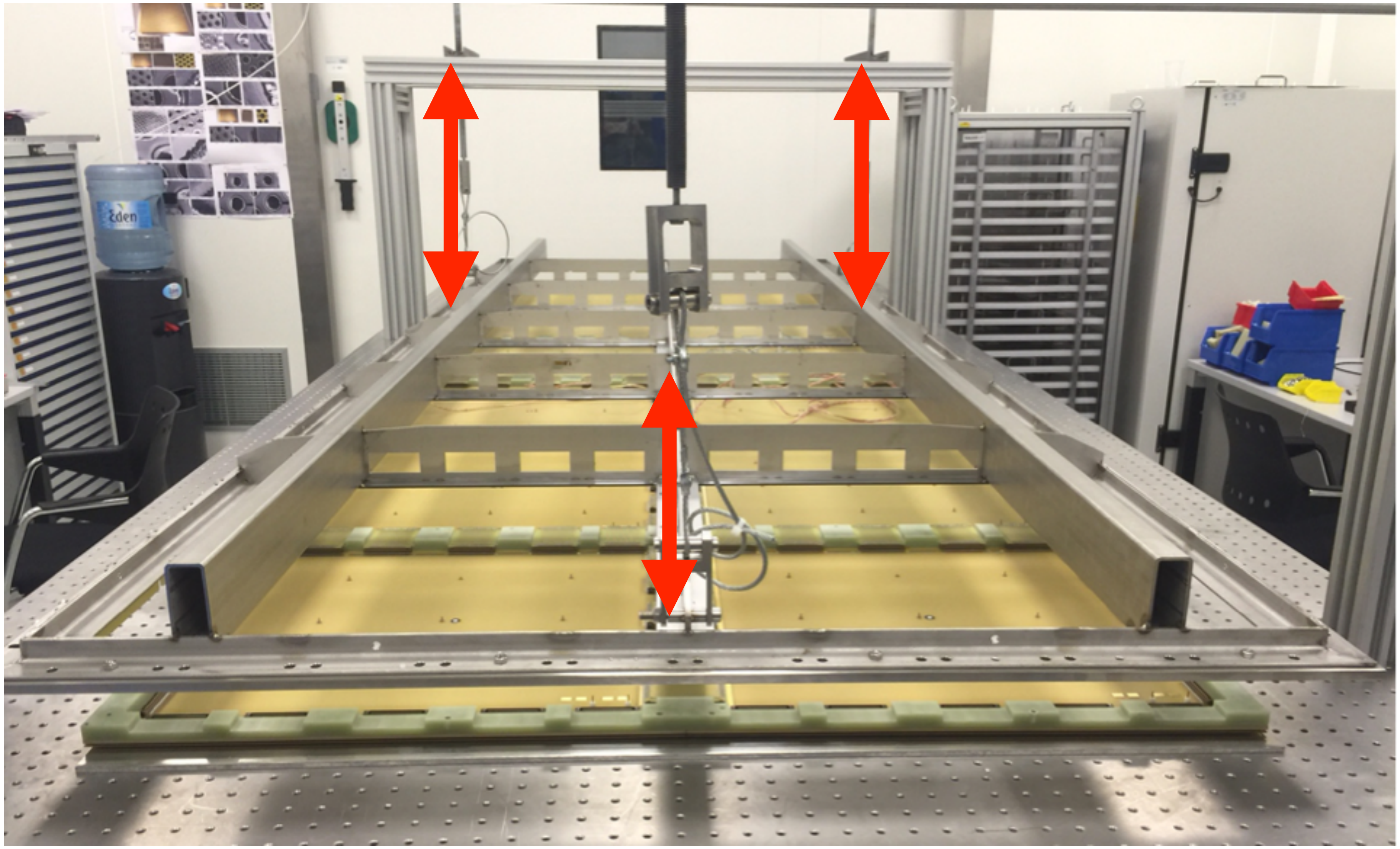


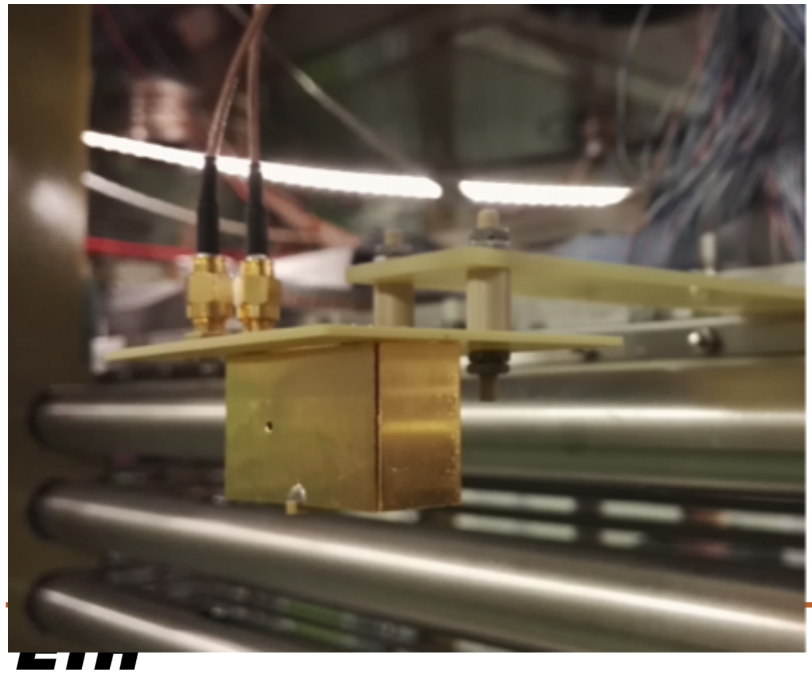
LEM + anode sandwich

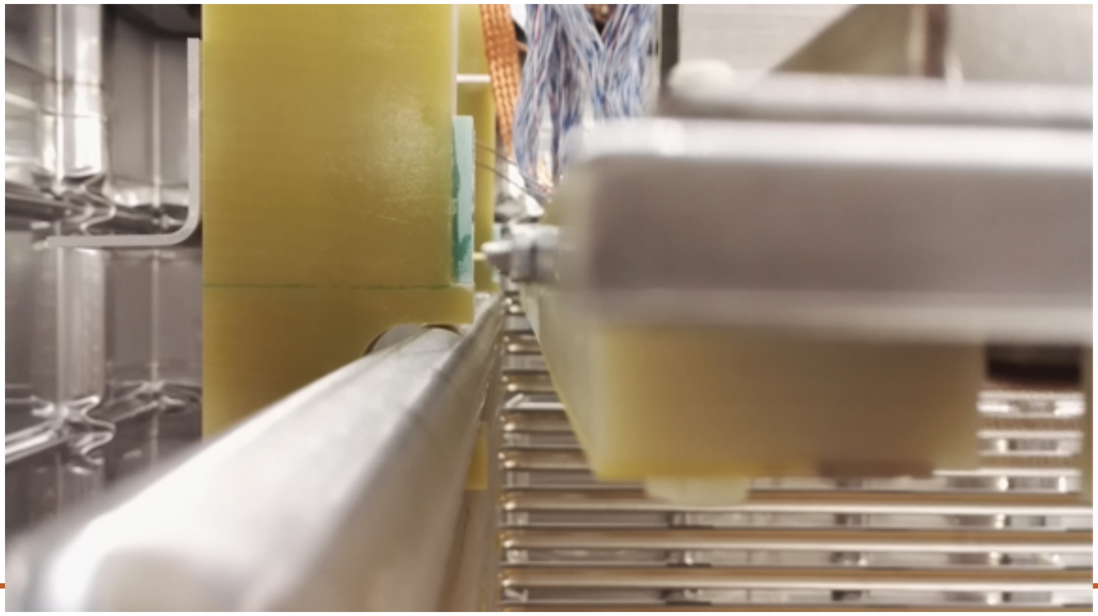


extraction grid

CRP suspension: adjust to LAr level

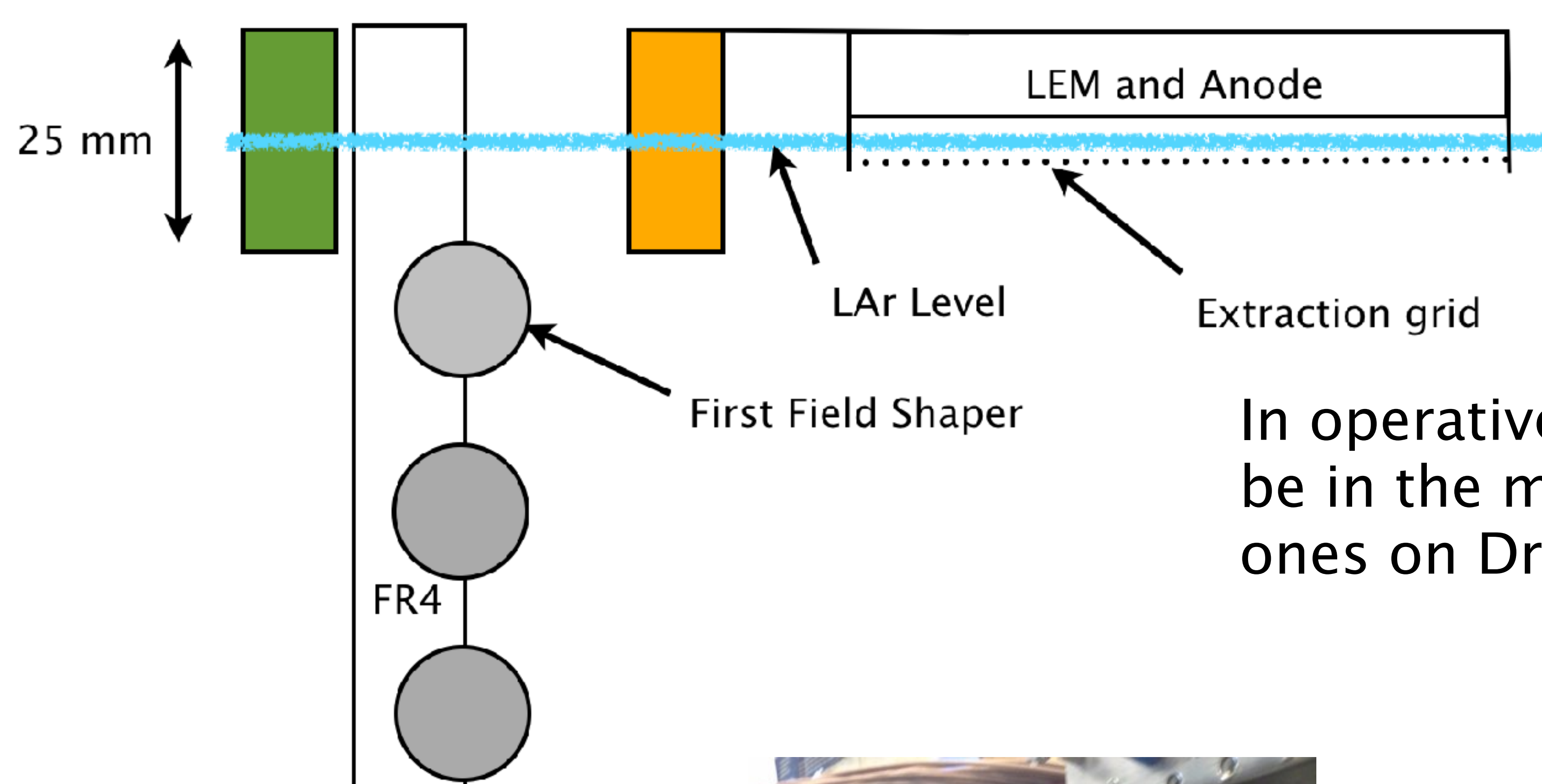


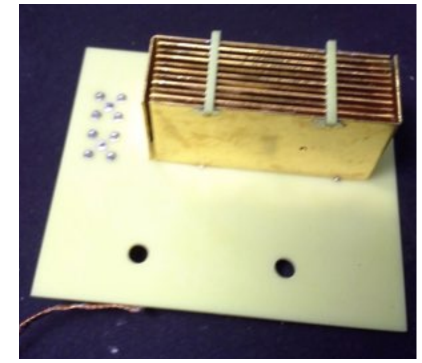




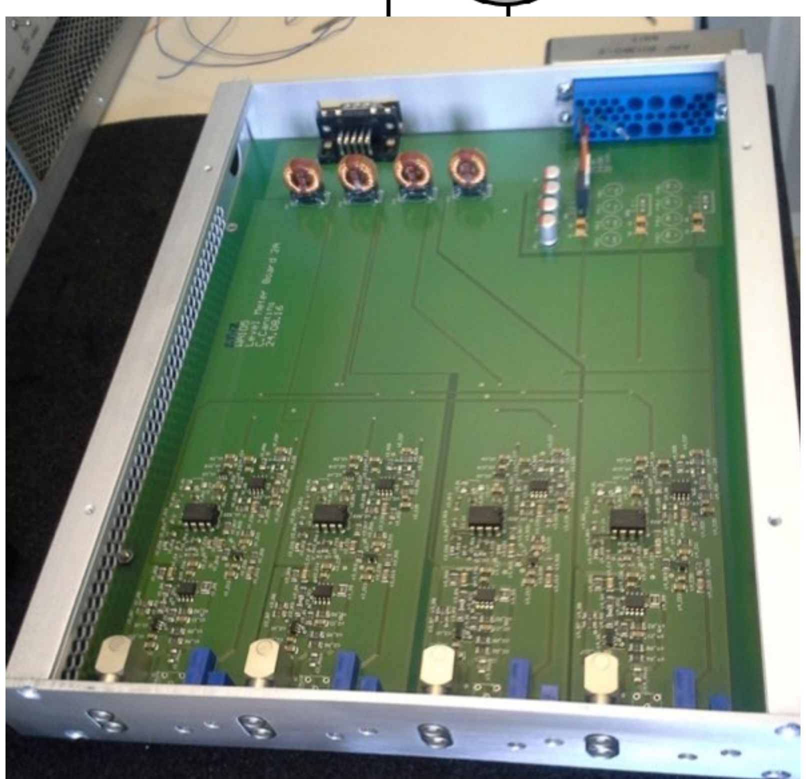
suspended by 3 ropes coupled to motors on top-cap. Precision of motors <u>100 um over 4 cm</u>.
8 capacitive level meters readout the LAr level with similar precision

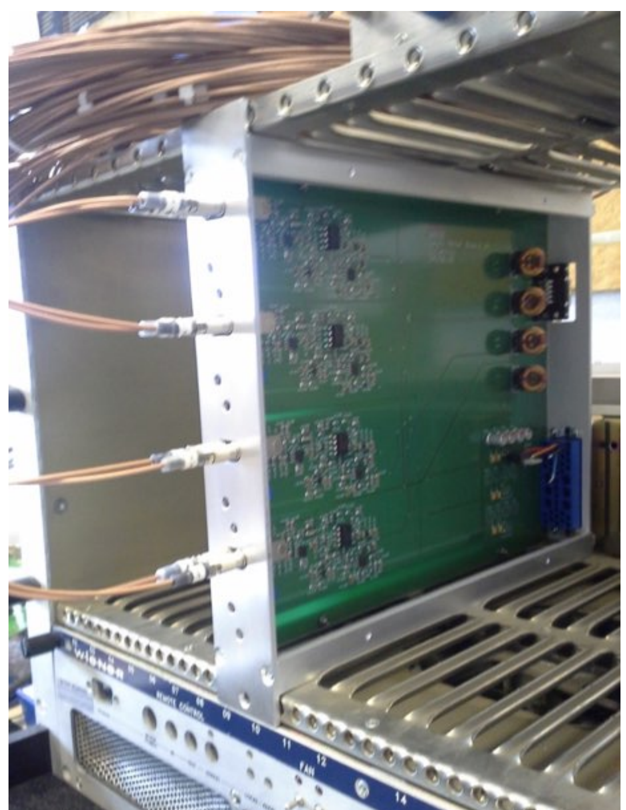
Slow control: level meters and pulser





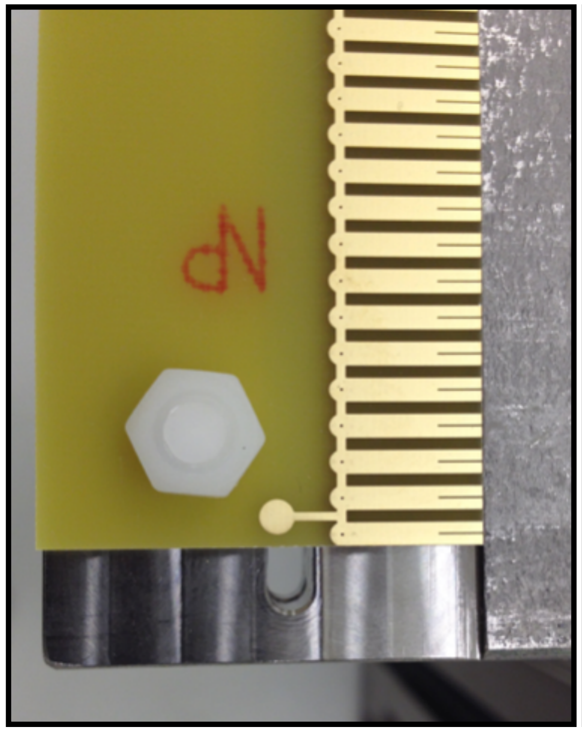
In operative condition the LAr level will be in the middle of both level meters, the ones on Drift Cage and the ones on CRP.

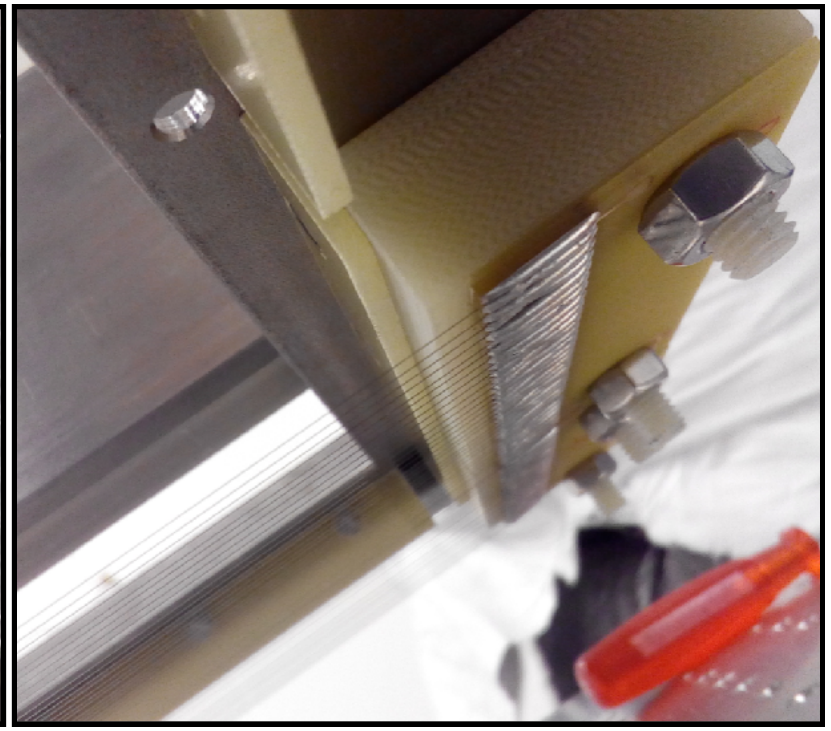




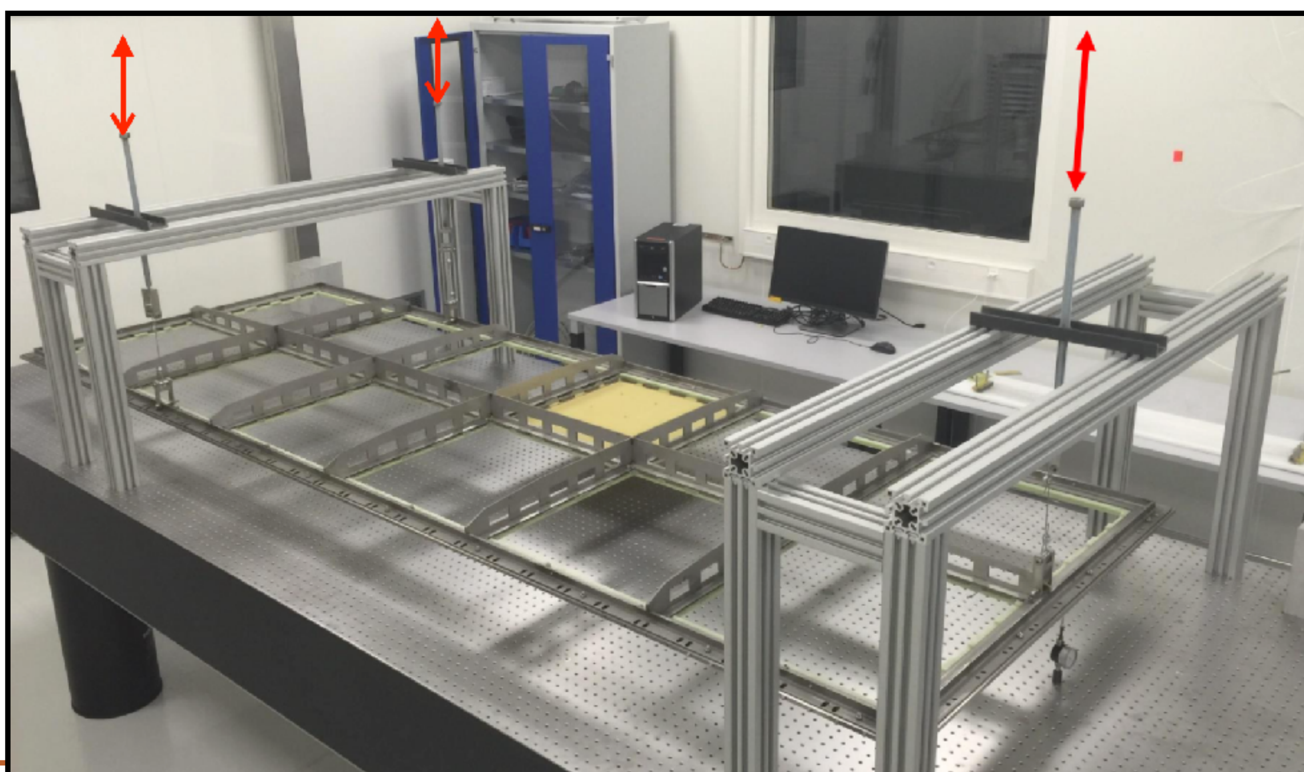
- A new NIM design has been done with:
  - 4 Channels
  - improved 0–10 V interface to NI Racks
  - improved filters on voltage rails and output
- 5 Boards NIM size are in production
- The assembly of the entire system will take place in the next 2 weeks, including calibration.
- **Aso be a test bench for the 6x6x6 Level meter system**

Extraction grid mounting and planarity check





wire spacing.
wire: SS 100 micron diameter.
spacing between each wire 3.125 mm.
Each wire is precisely positioned on soldering PCBs in 220 um grooves.
Precision obtained on wire spacing: <100 micron.



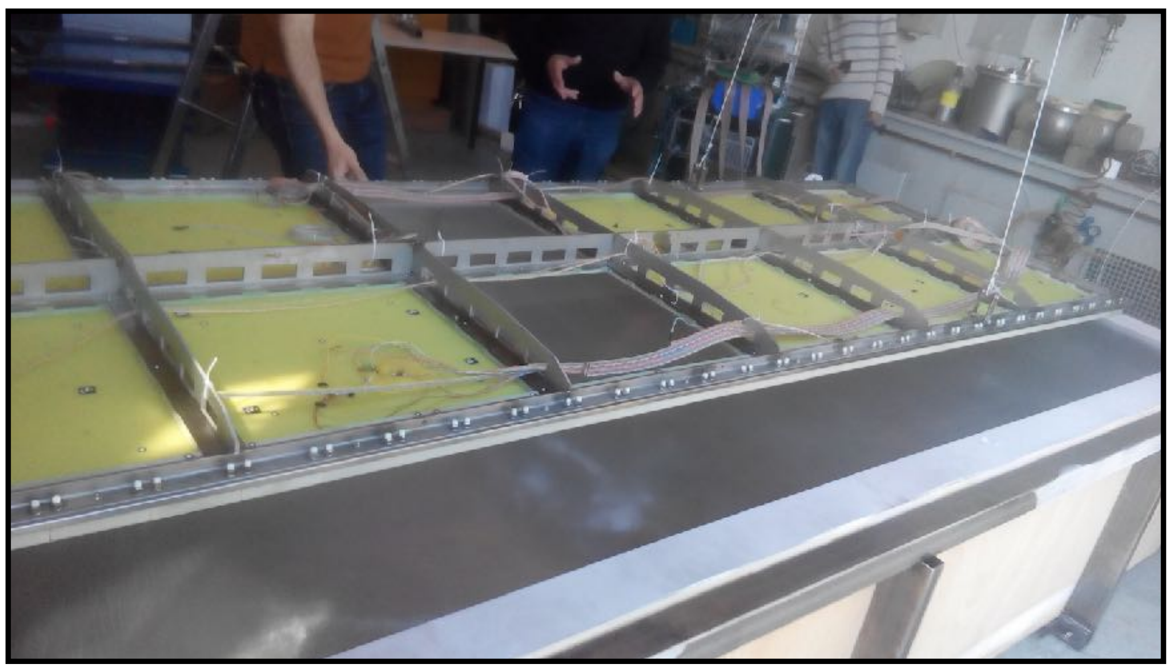
planarity.
LEM-LAr 5 mm distance.
Check that the mounted frame is within tolerance (planarity ±1 mm)

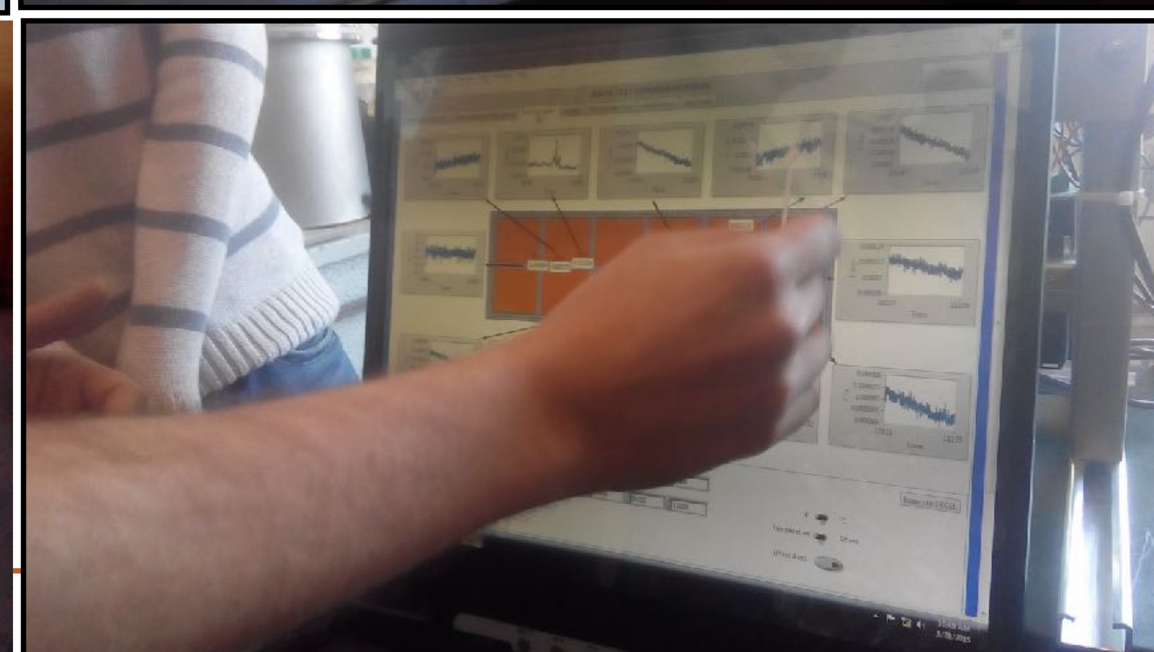
Resistance to thermal shock

The horizontal geometry of the 3x§ m² CRP allows to perform **cryogenic test in open bath**. Already demonstrated for the 3x1x1.

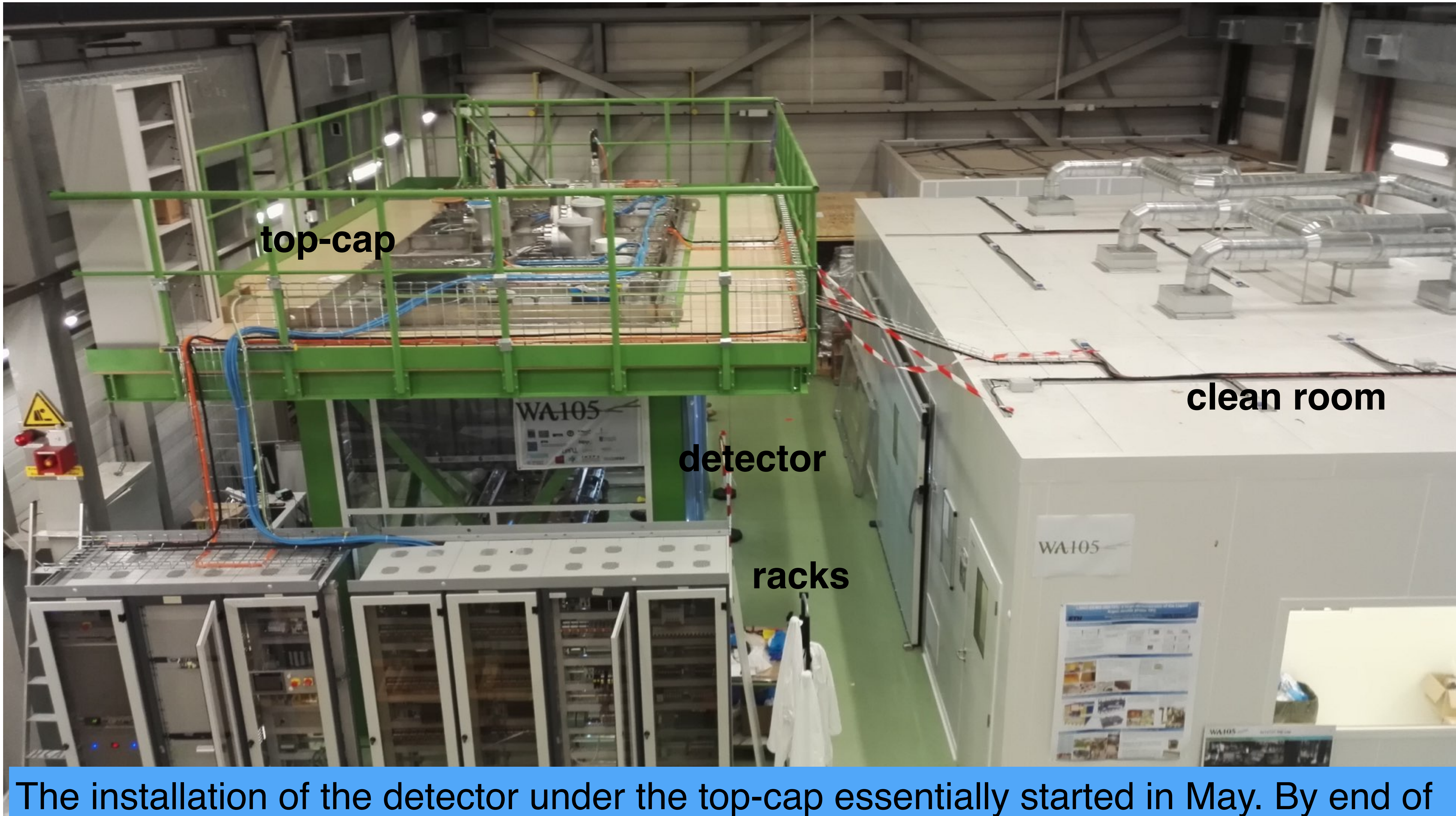
What we checked:

- monitor expected shrinkage with photogrammetric measurements.
- extraction grid robustness.





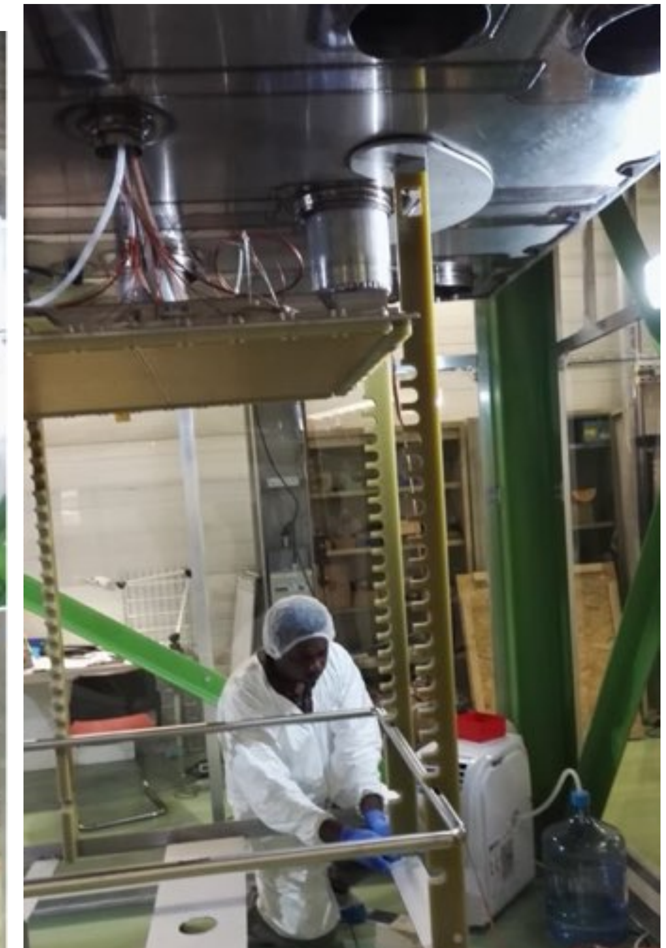
Detector installation



The installation of the detector under the top-cap essentially started in May. By end of June it was complete and most parts were tested.
Thanks to the large collaboration effort during those 2 months

Detector installation

Detector installation



Drift cage

Feedthroughs

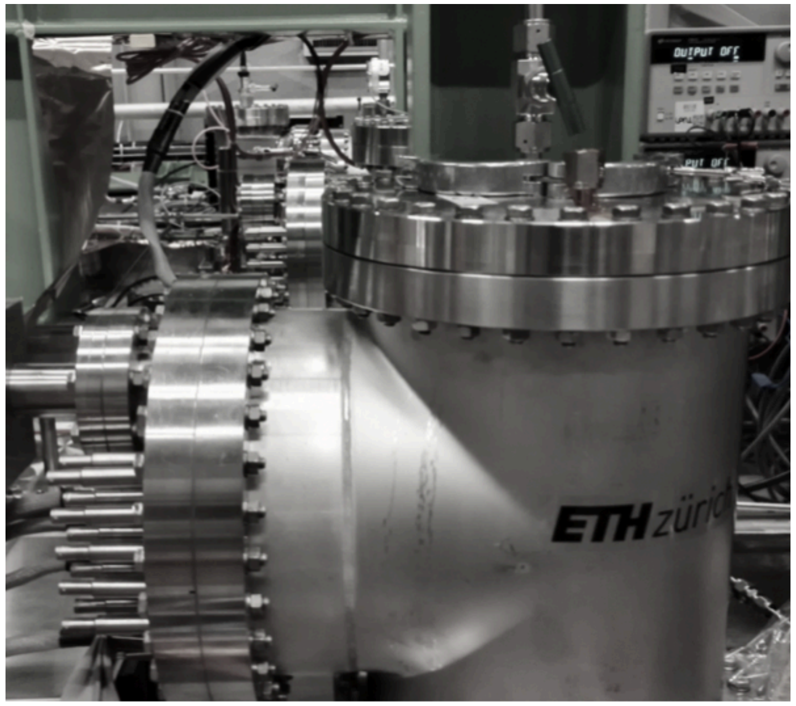
All feedthroughs operational and tested over the past year. Same to be installed in pDUNE-DP

<u>4 signal chimneys</u>

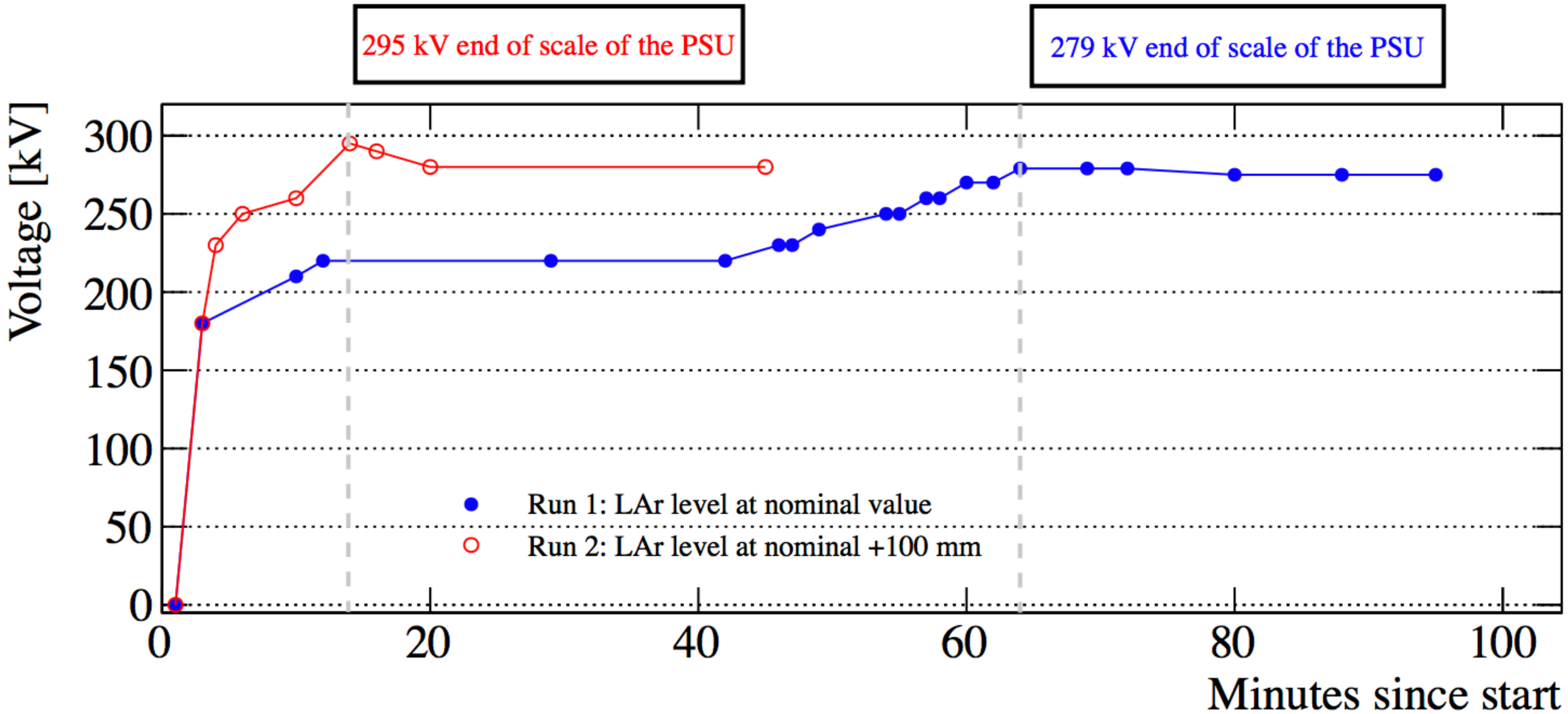
<u>3 slow control and medium voltage</u>

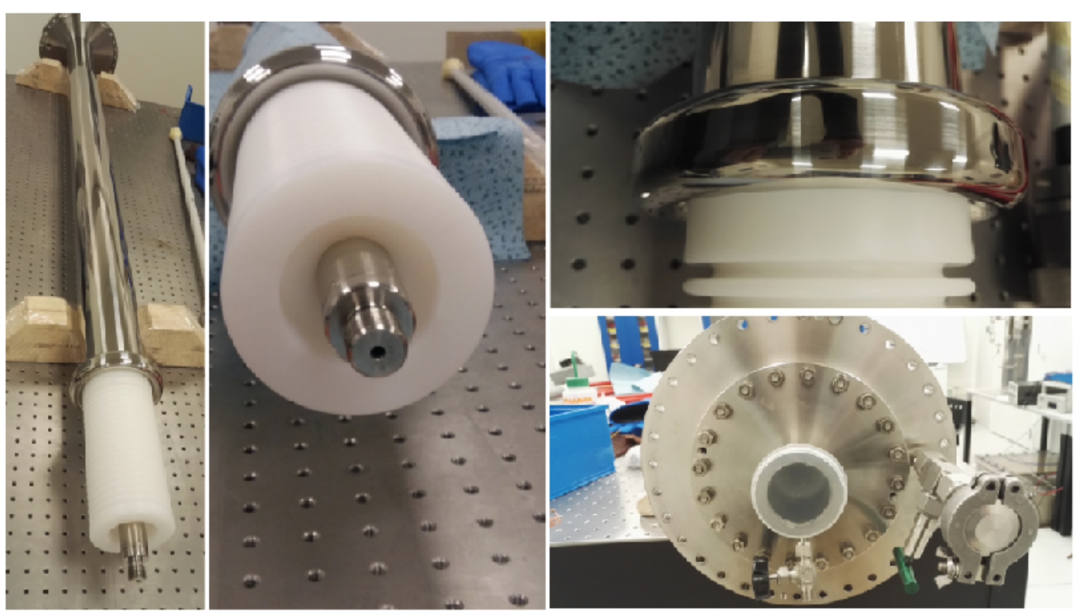
<u>3 CRP suspension</u>

<u>1 High voltage</u> tested at 300 kV, operated at ~50 kV



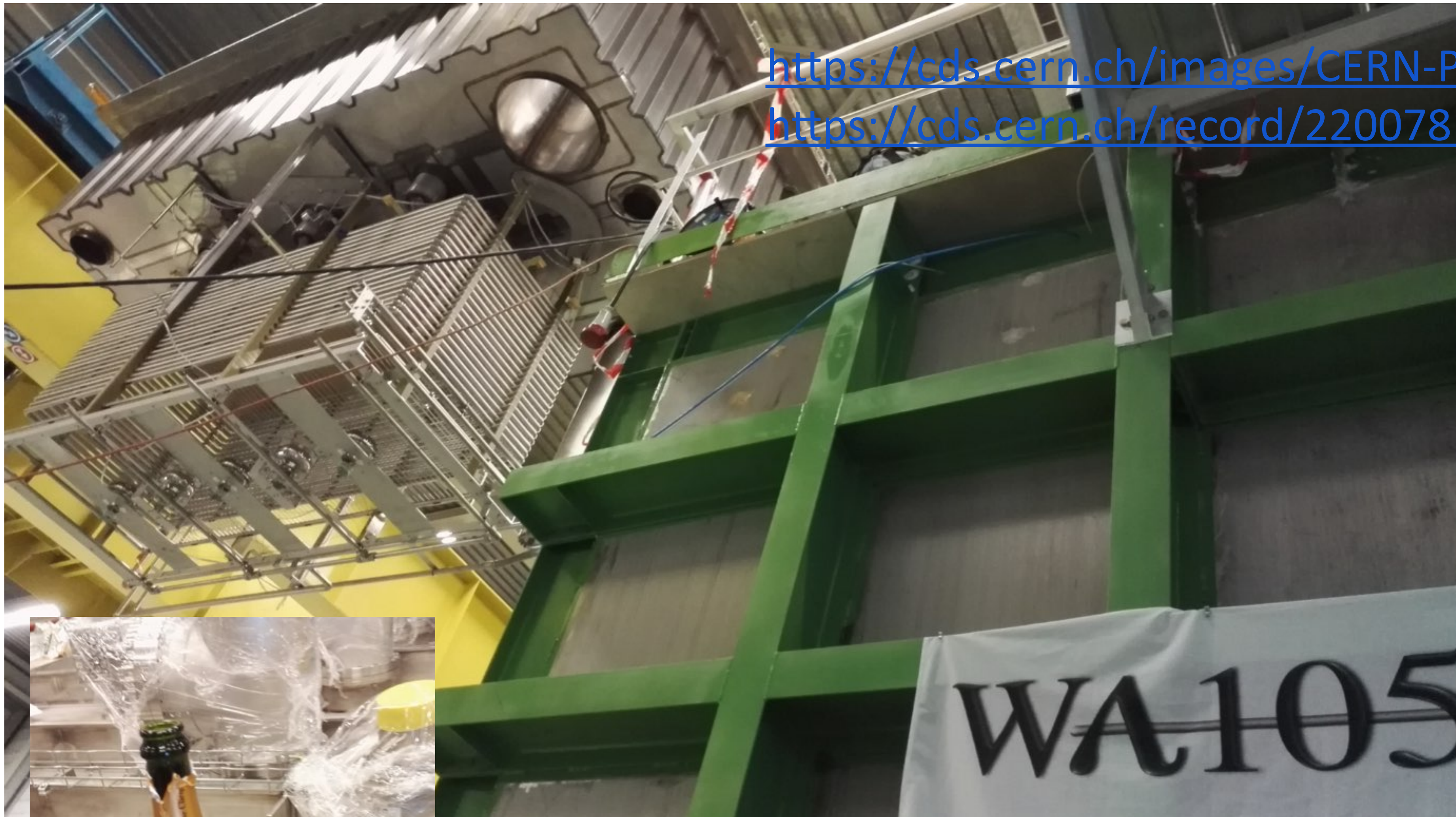
Very high voltage



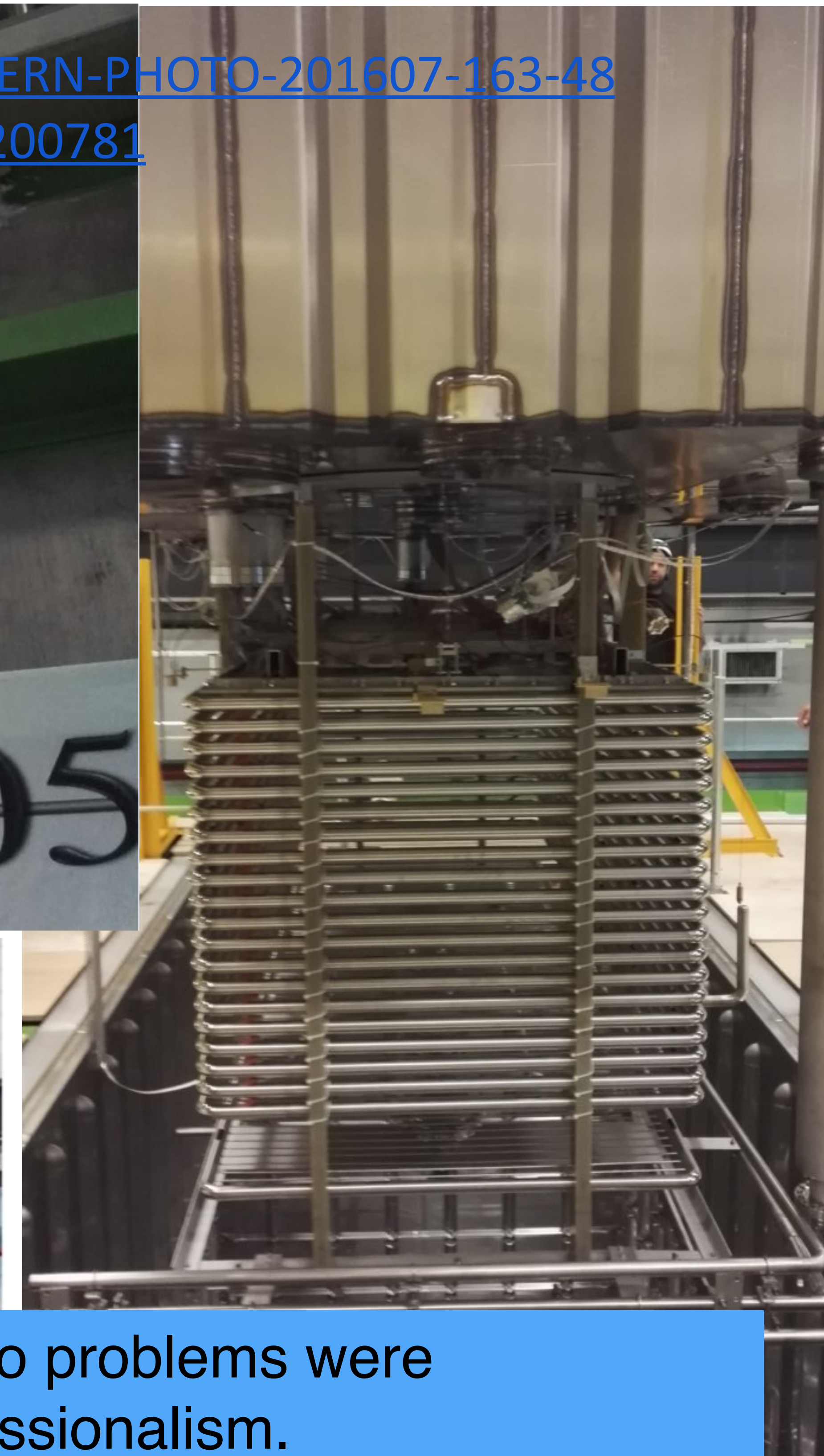


Design successfully tested in dedicated setup up to the end of the scale of the Heinzinger PSU. <u>About 295 kV.</u> JINST 12 P03021 arXiv:1611.02085

4th of July

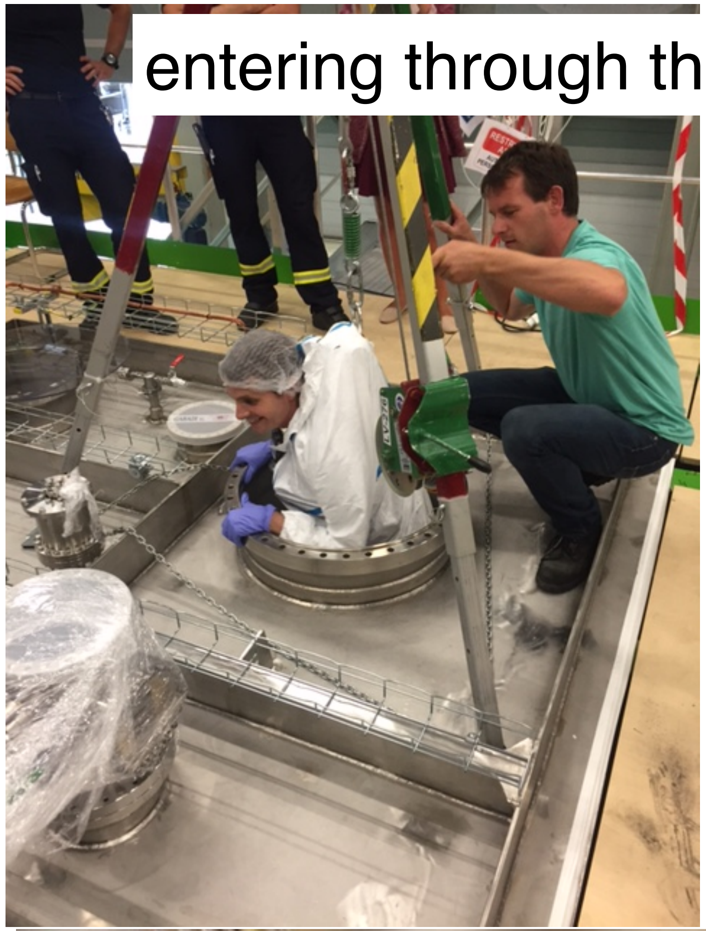


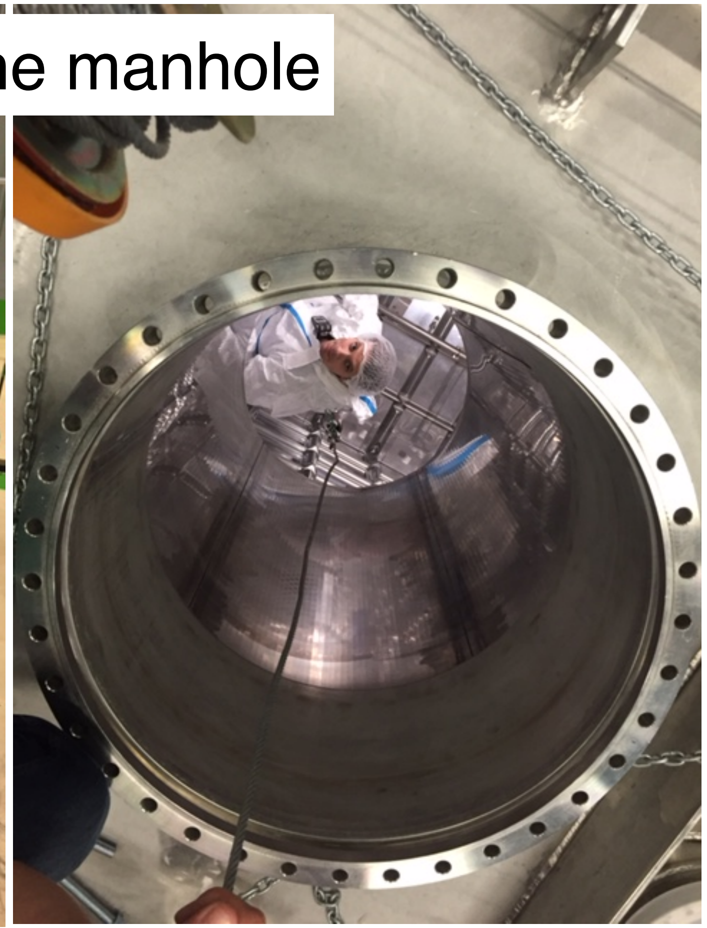
https://cds.cern.ch/images/CERN-PHOTO-201607-163-48
https://cds.cern.ch/record/2200781

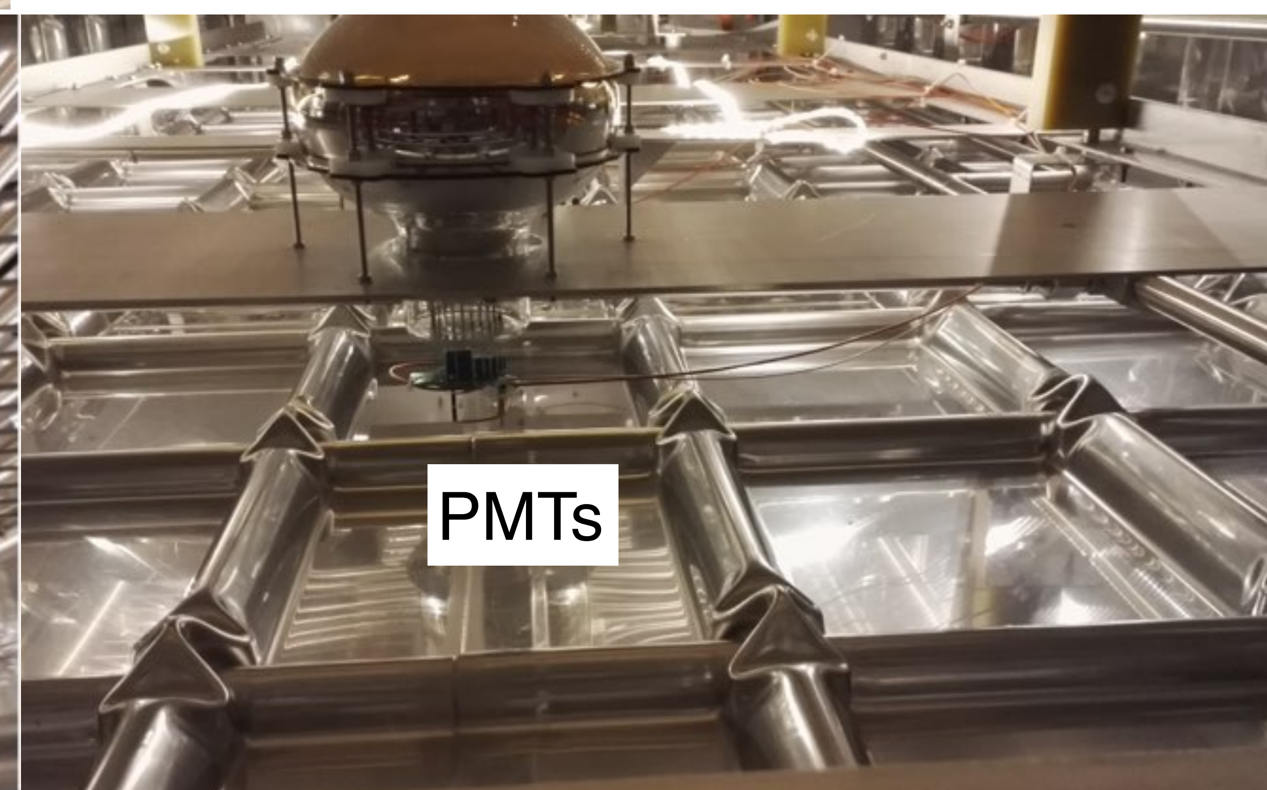


The insertion of the detector was fast about 2 hours and no problems were encountered. This was thanks to CERN support and professionalism.

Inspection and measurements inside cryostat



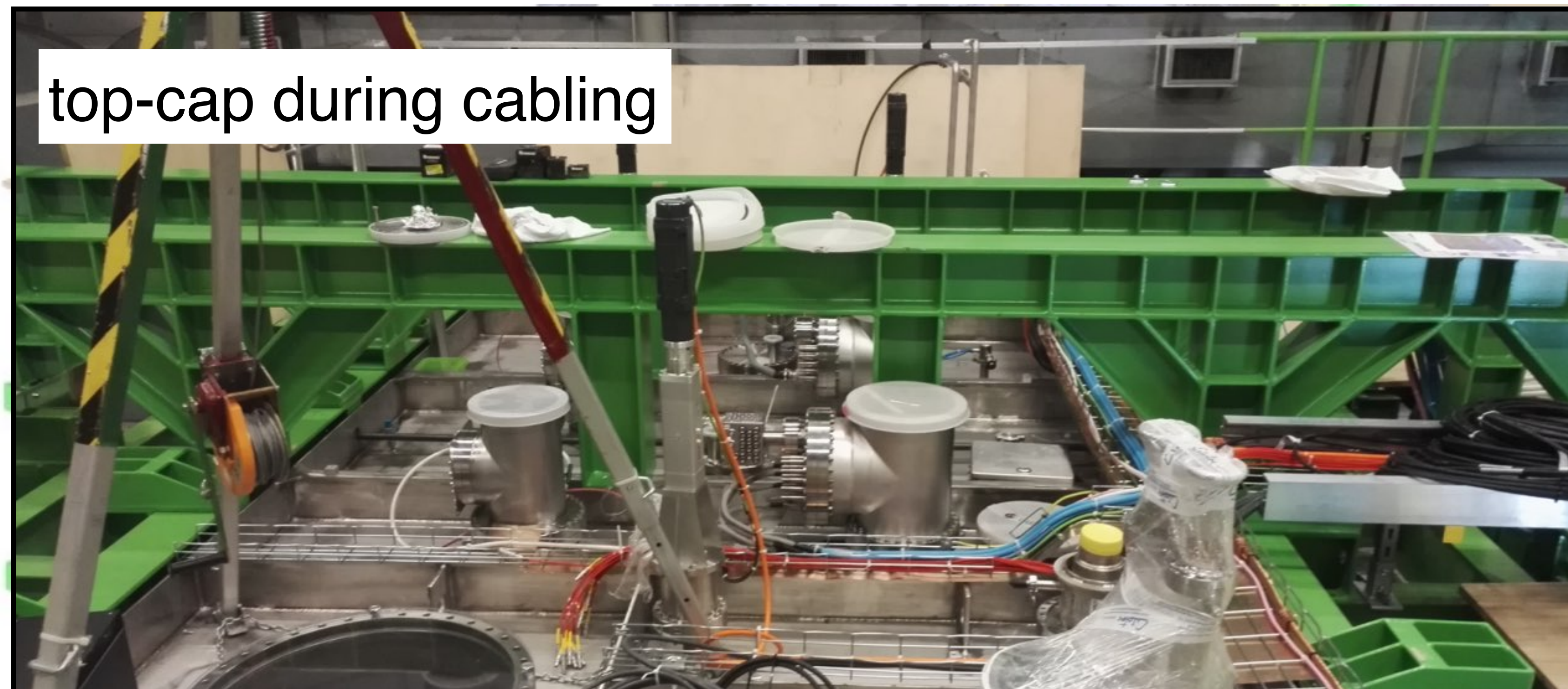


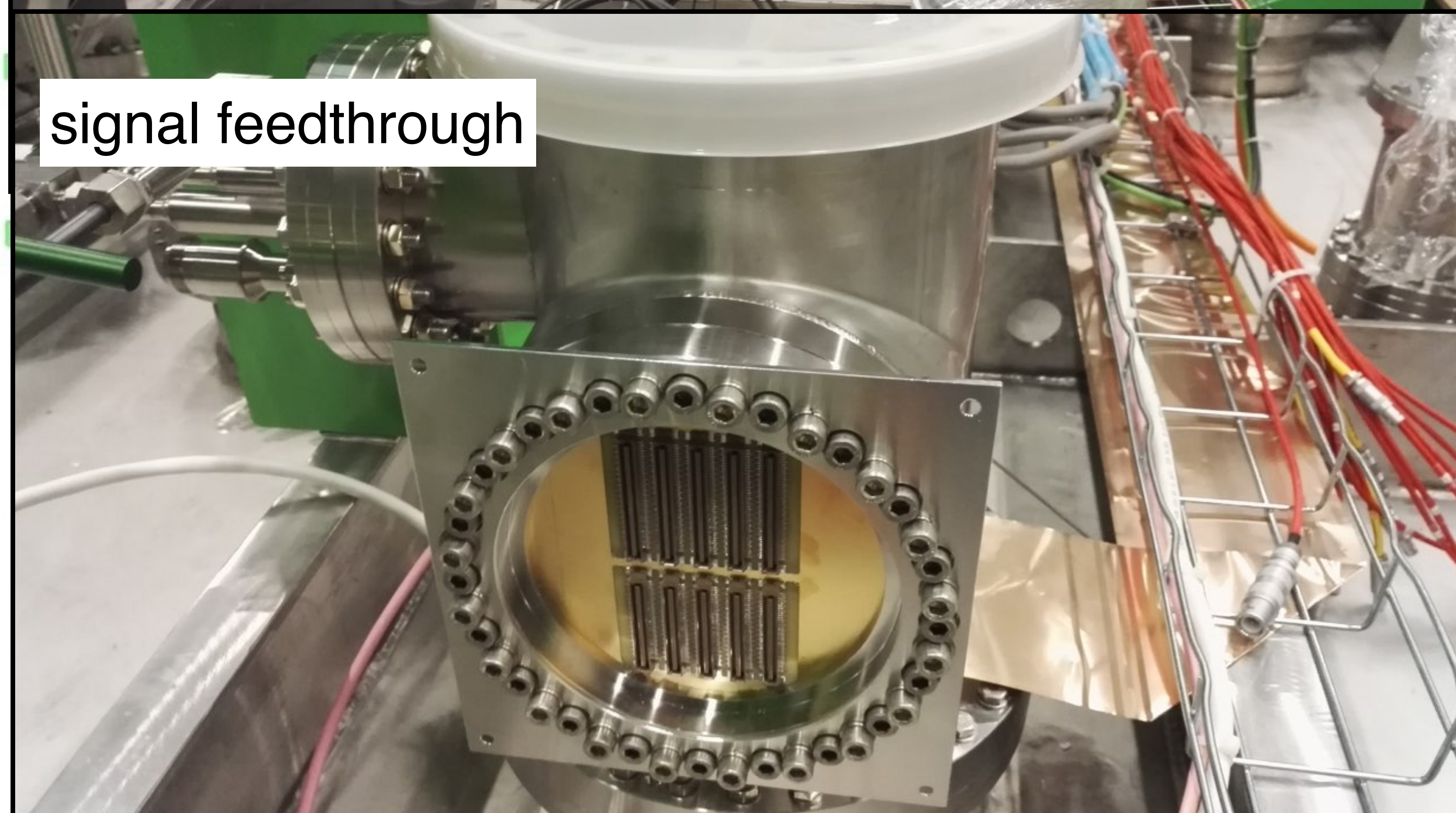


PART 2 CRYOGENICS & COMMISSIONING

AUG 2016 - APRIL 2017

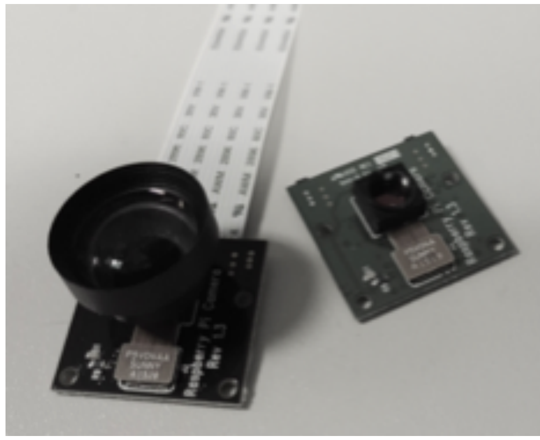
Experimental layout in final configuration


top-cap during cabling


signal feedthrough


all racks installed

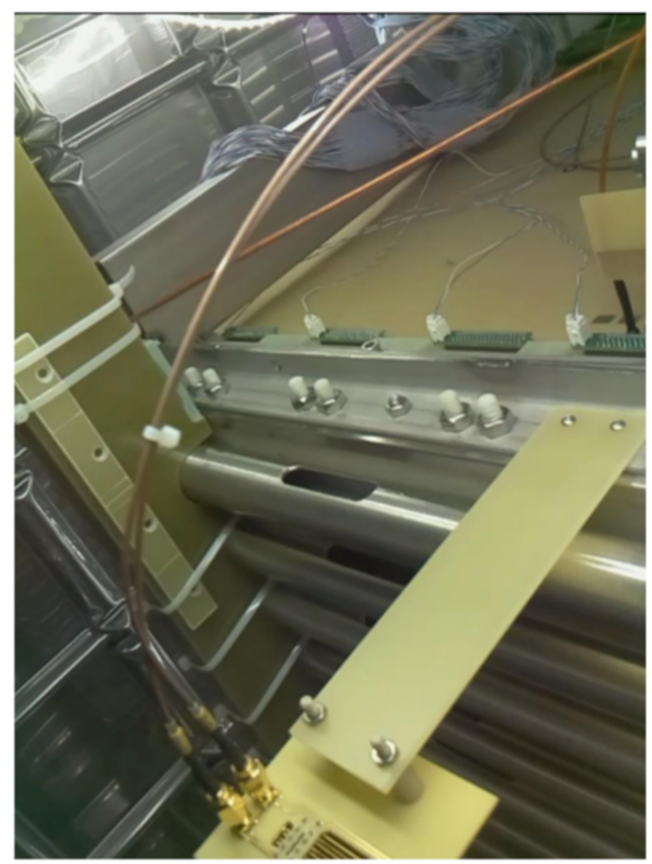
Slow control: cameras



5 cameras placed in different strategic areas of the detector. Main purpose to have visual check of the LAr level.

cameras tested in LAr for many days without degradation of image.

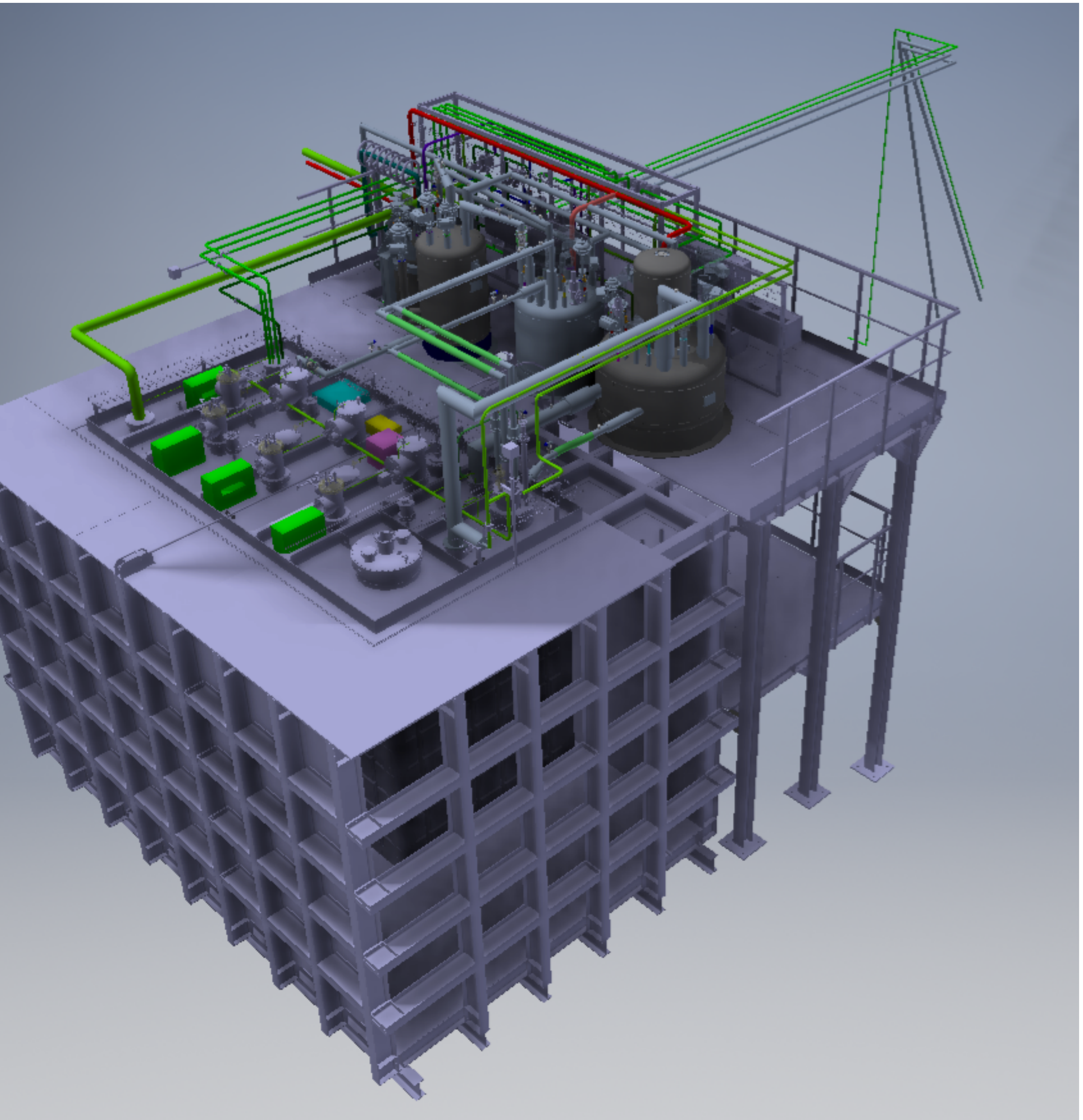
Wa105cam0:
- On top
- HV feedhrougth



Wa105cam1:
- On top
- Ar level

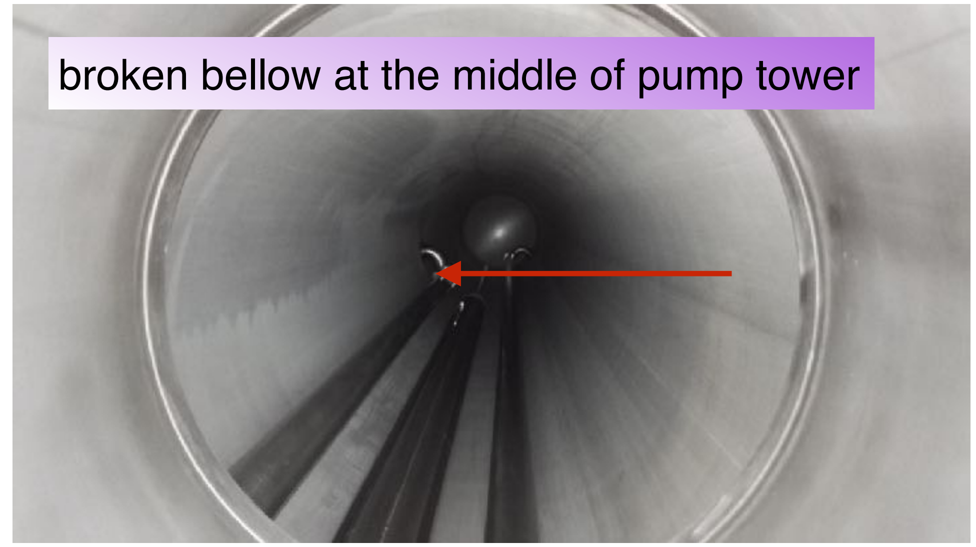
Wa105cam2:
- On top
- Ar level

Cryogenic installation and commissioning

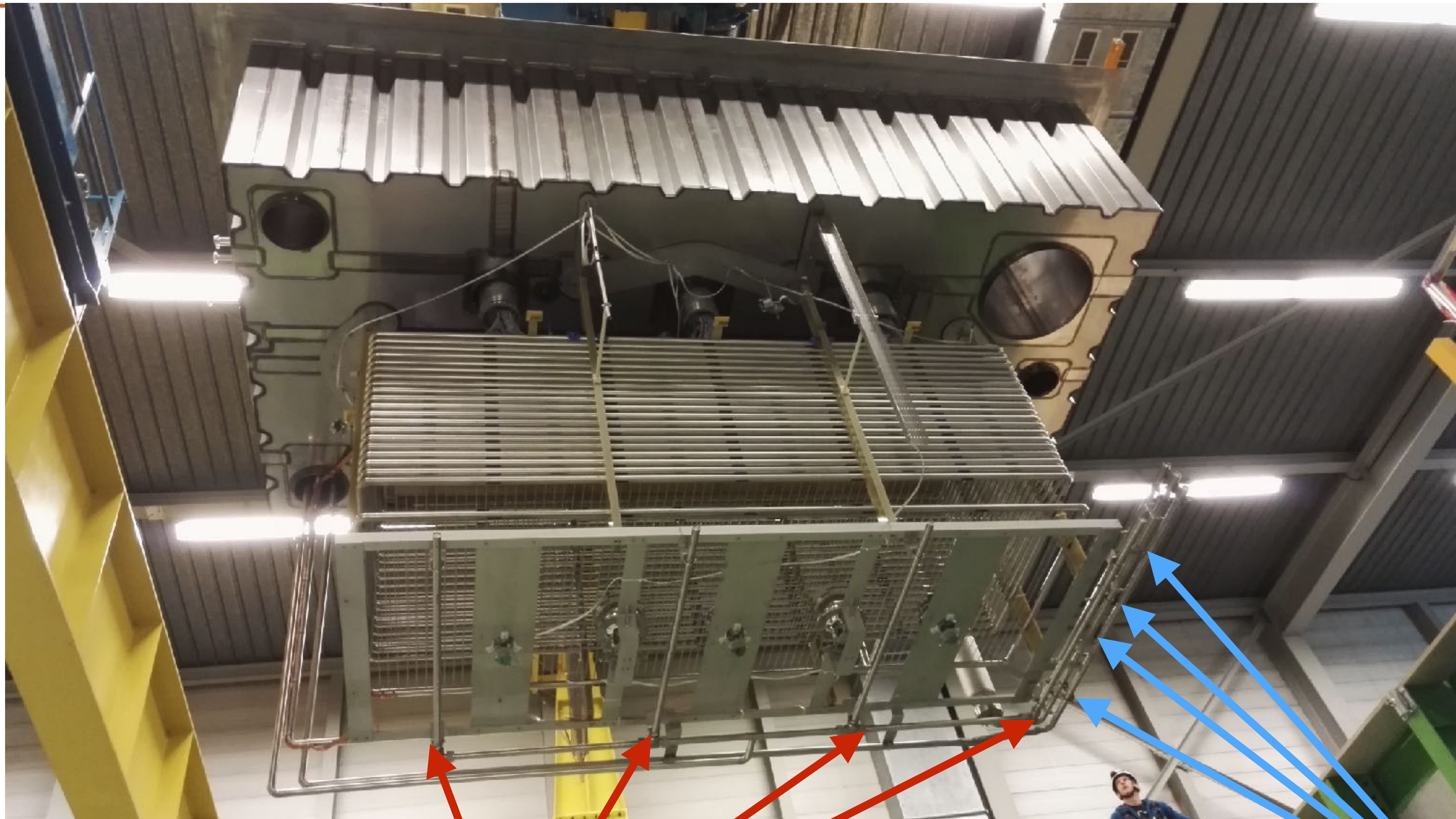


- Cold piping (LAr+ LN2 lines, valve boxes, liquid purification,..) Sept 19th- Oct 13th
- Warm piping (gas argon purification system, chimney purges, ..) Oct-Nov
- Control system Sept-Nov
- Start of gas argon piston purge Jan 24th
- Start of cool down Feb 27th

difficulties encountered during commissioning



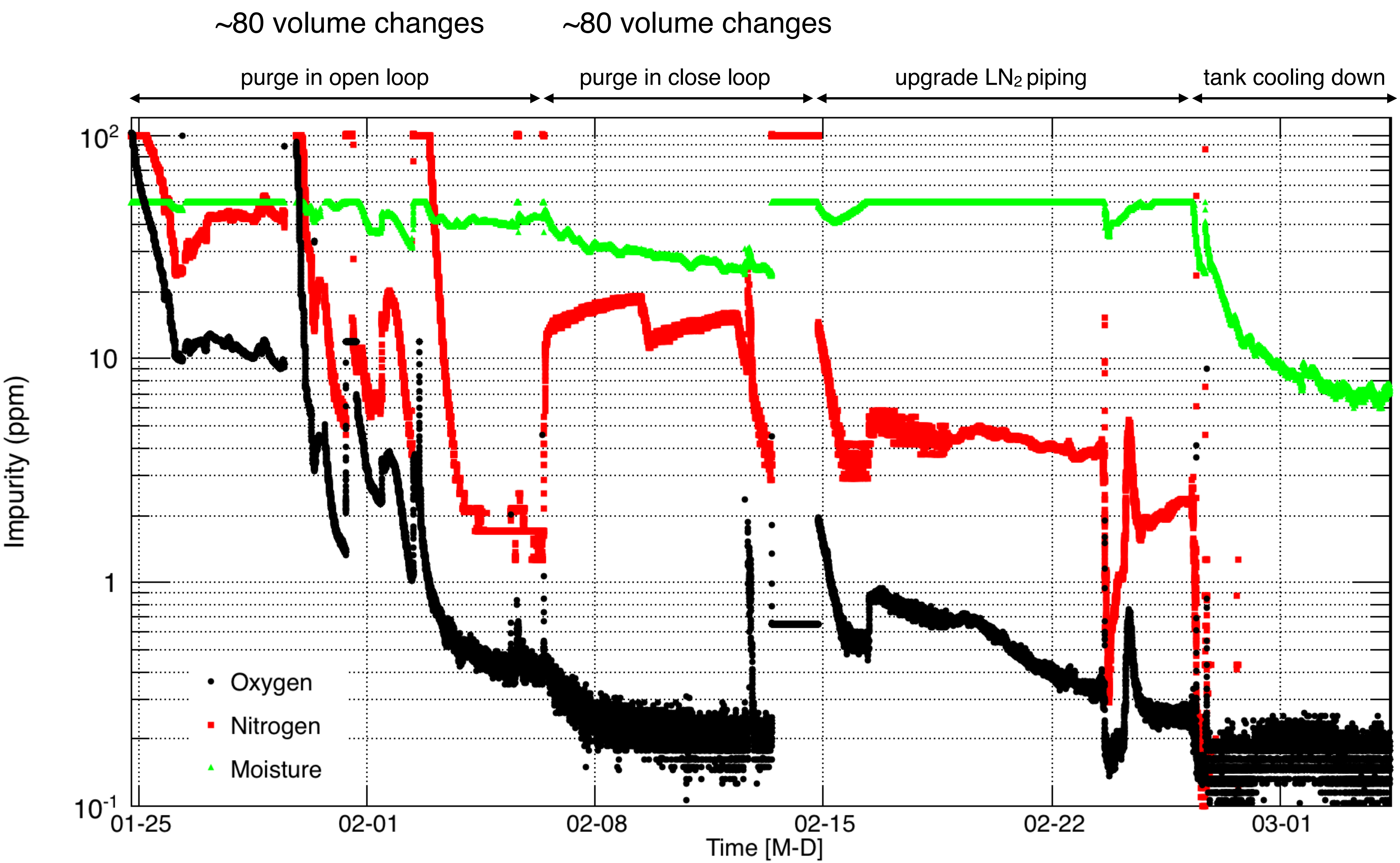
Purging and cooling down



Piston purge
4 warm gas lines each with 3 openings of 12 mm ø.
total flow rate during piston purge ~4 l/s

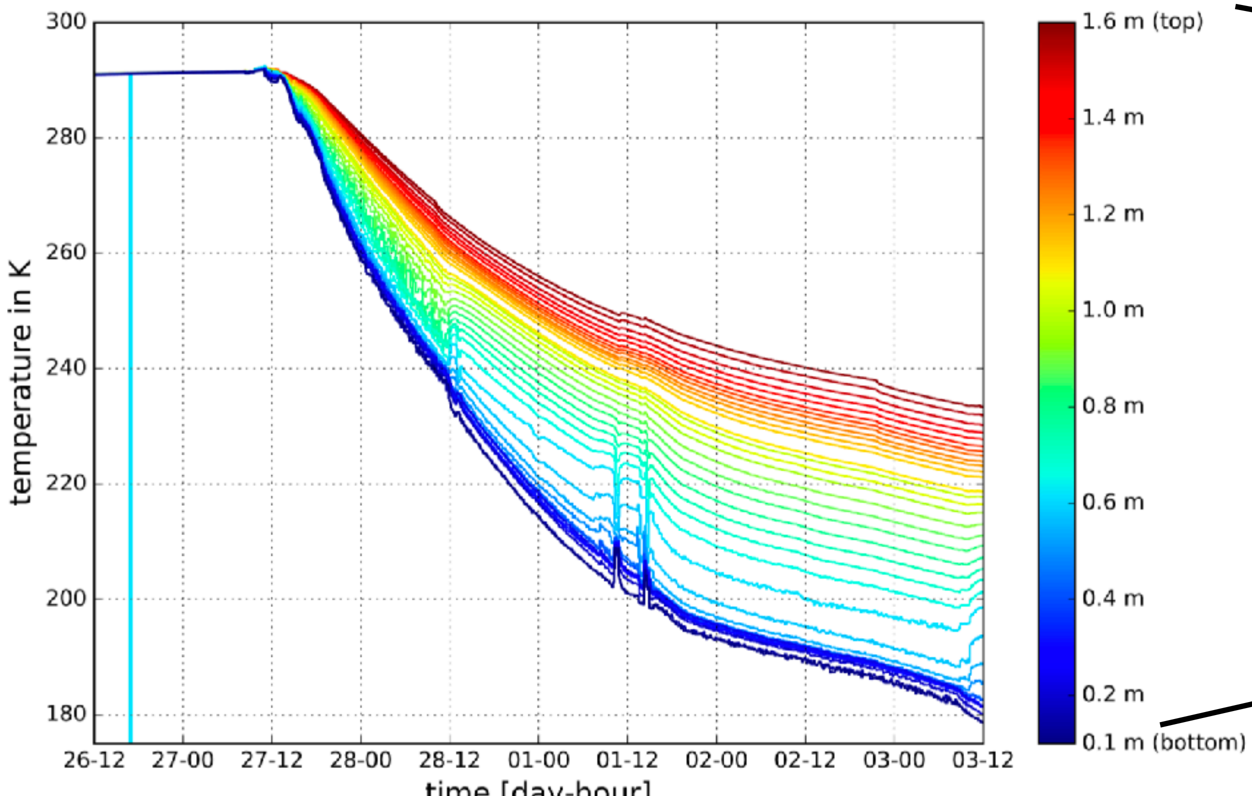
Cool down: 4 sprays mixture of LAr and GAr for slow and uniform cool down. Nominal flows:
300 K GAr 500 l/m
87 K LAr 21 l/h

Piston purge & evolution of impurities

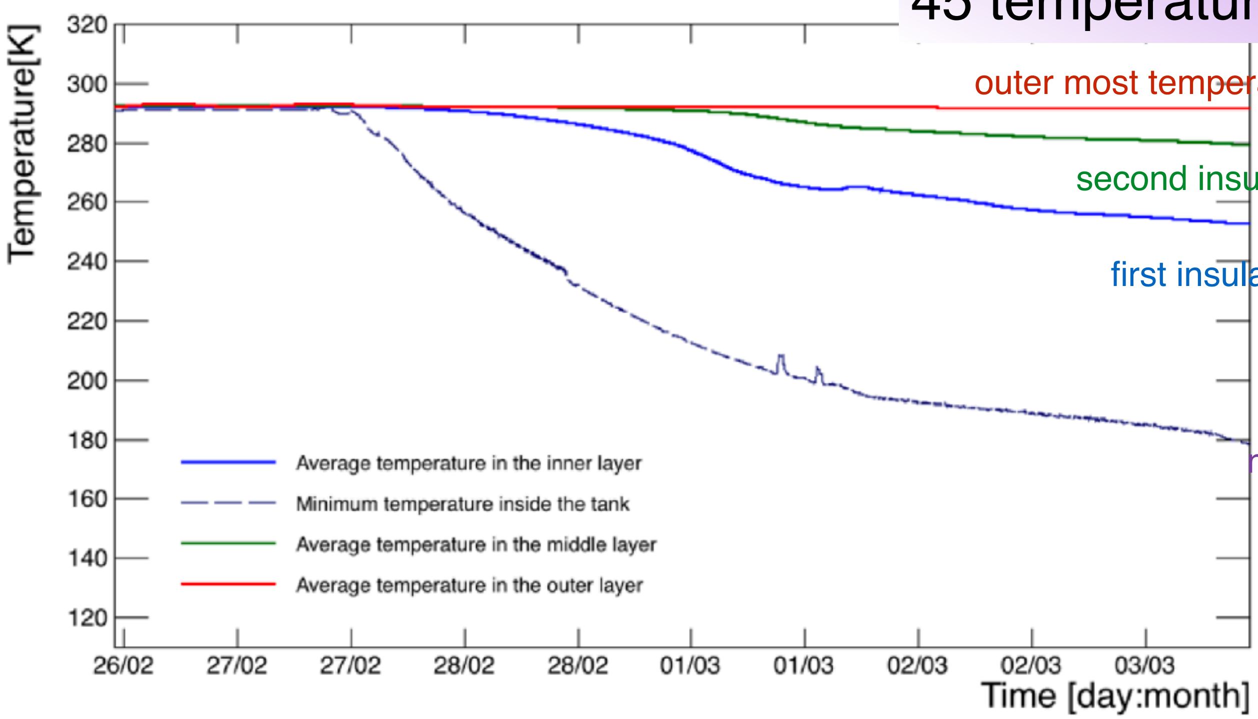


All sensors operational - some data during cool down

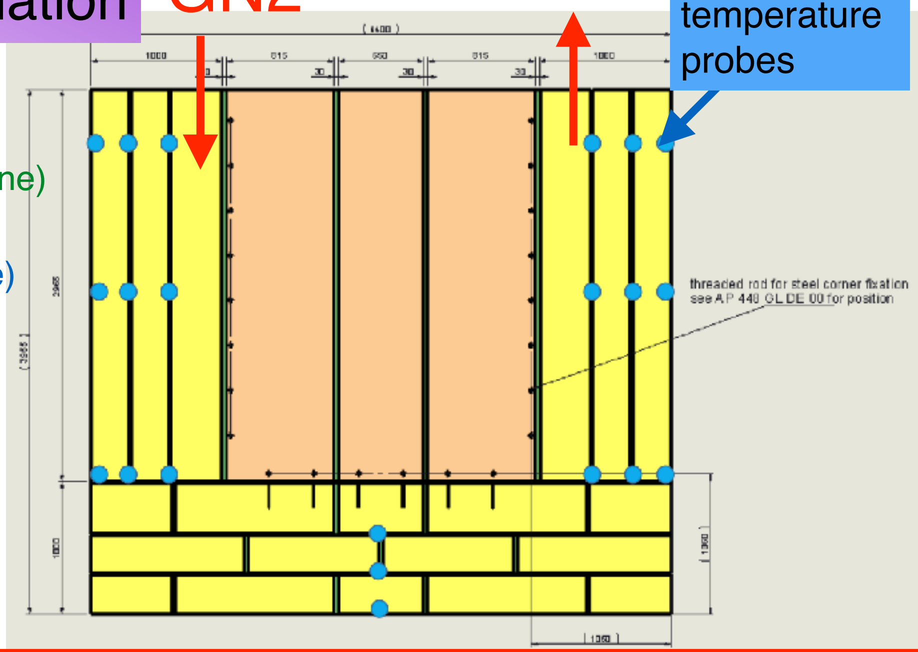
chain of temperature probes along drift cage



45 temperature probes inside insulation



GN2

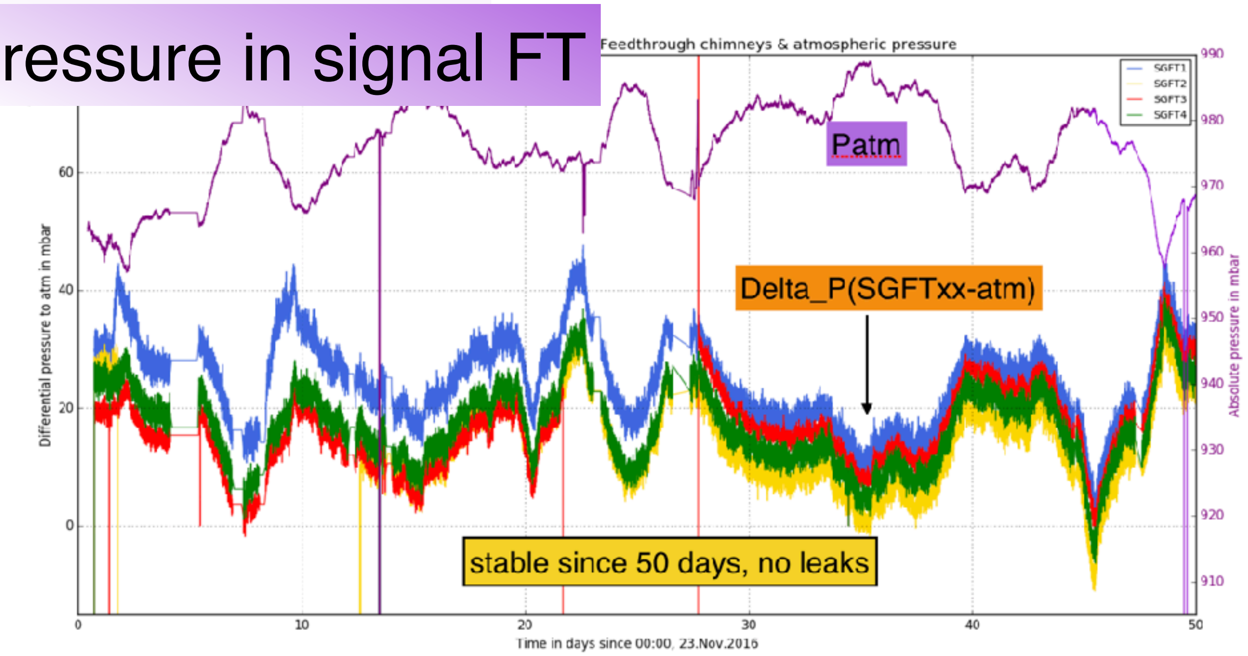


the insulation space is constantly flushed with N2 gas.
A bubbler at the output garanties a few mbar overpressure w/respect to the atmosphere

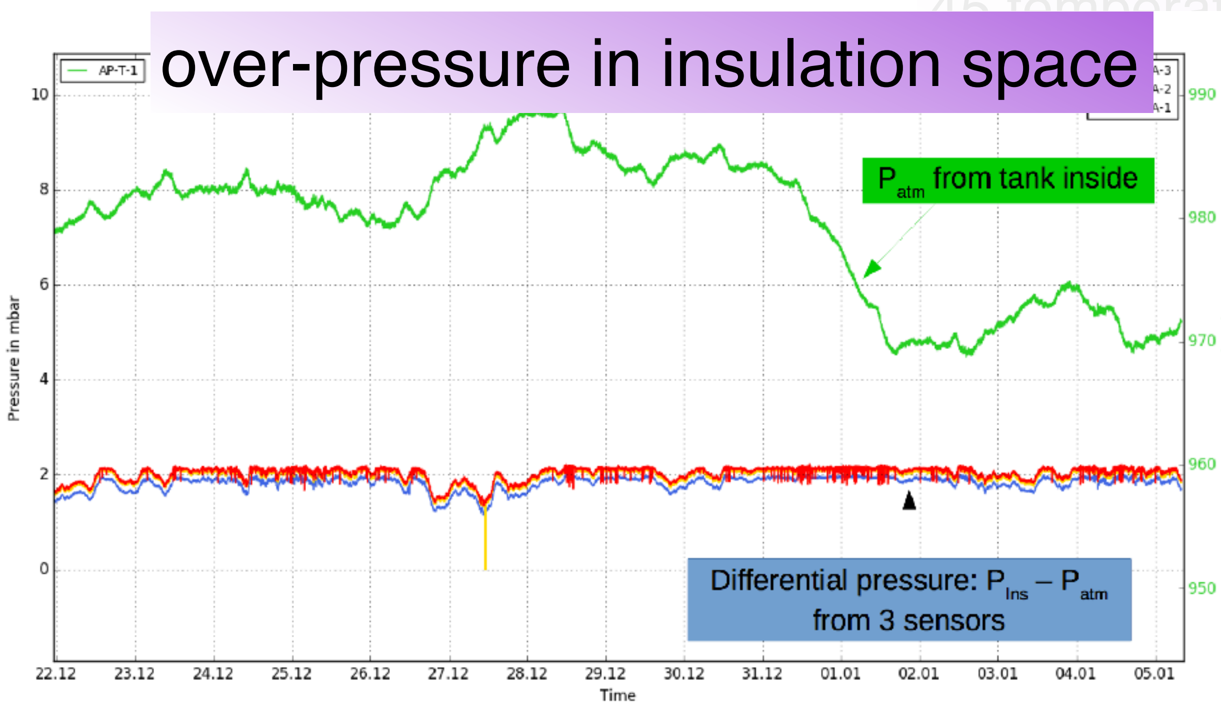
All sensors operational - monitoring over the past months

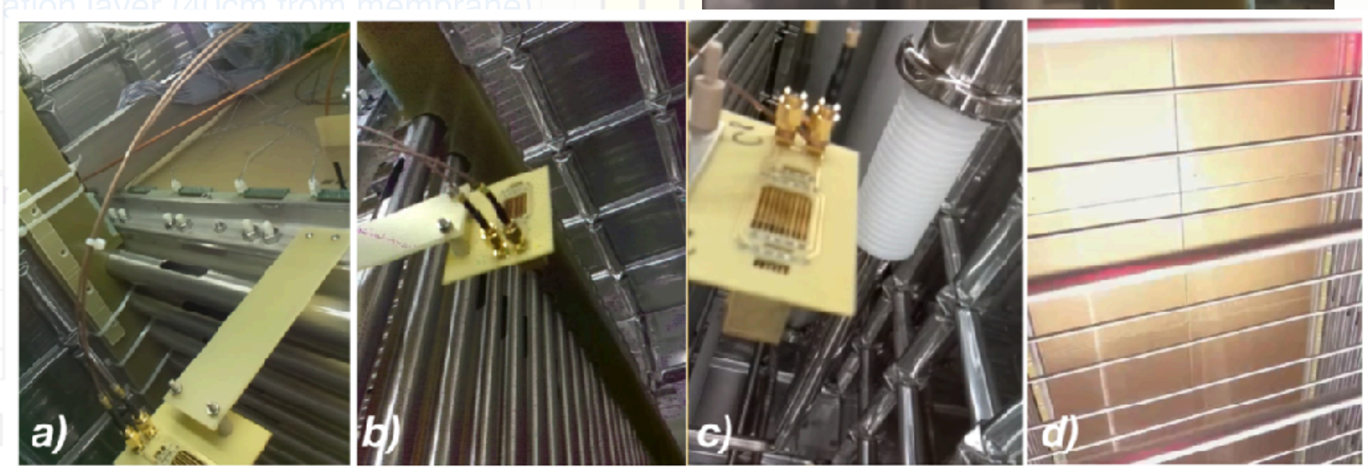
Detector monitoring:

- >150 temperature probes
- 20 pressure probes
- 30 HV channels
- 1 300 kV HV channel
- Purity monitors (Gas + liquid)
- 15 level meters
- 5 cryogenic cameras

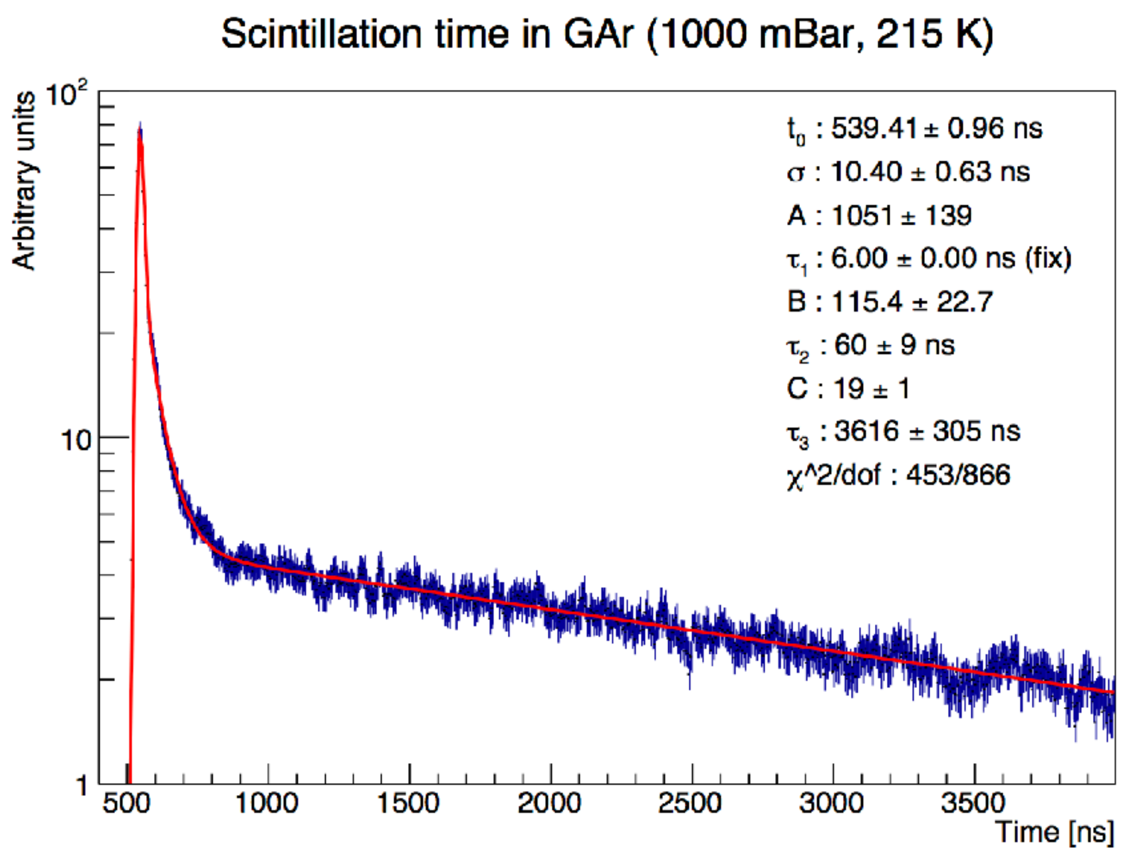


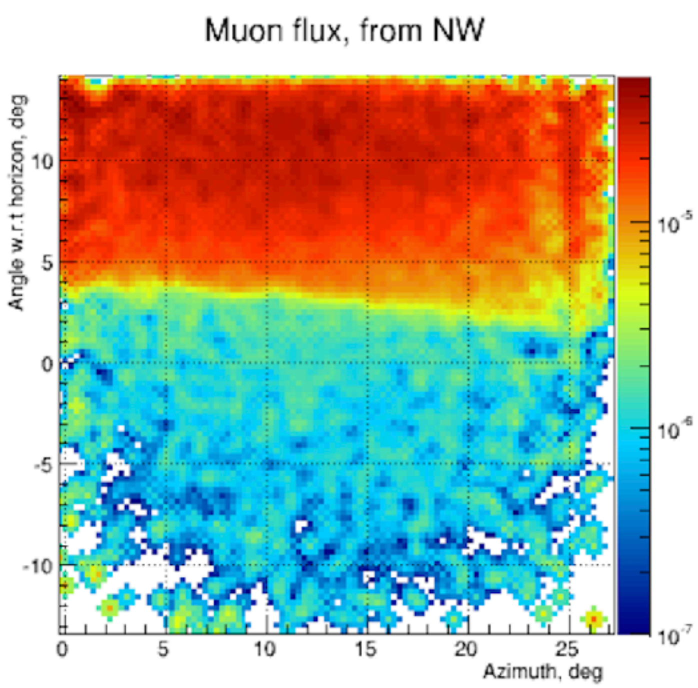
ALL OPERATIONAL

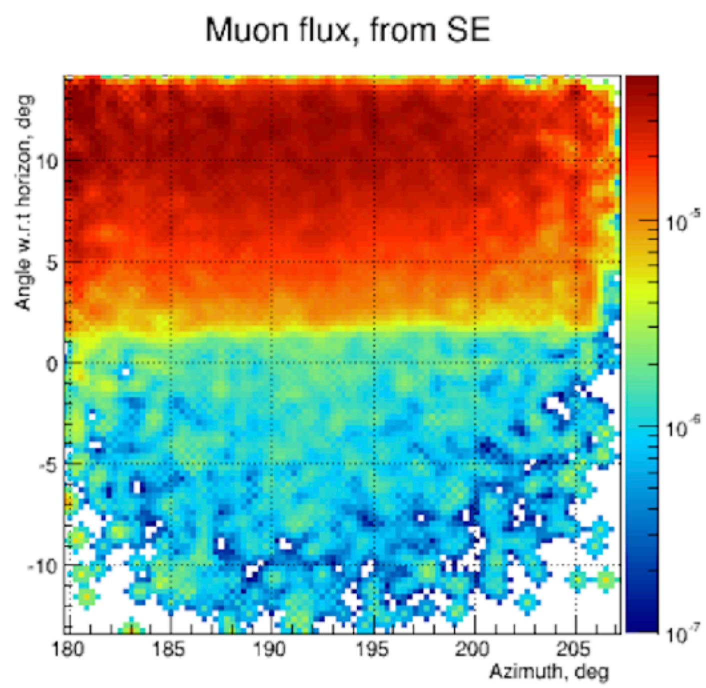




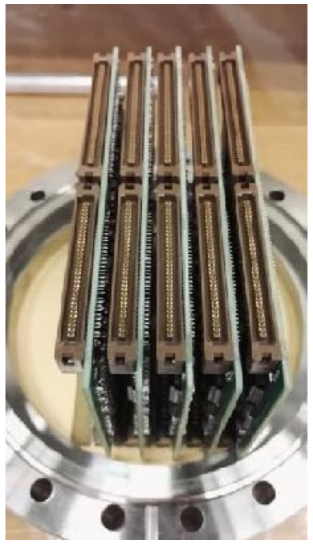
First results from commissioning - light and trigger

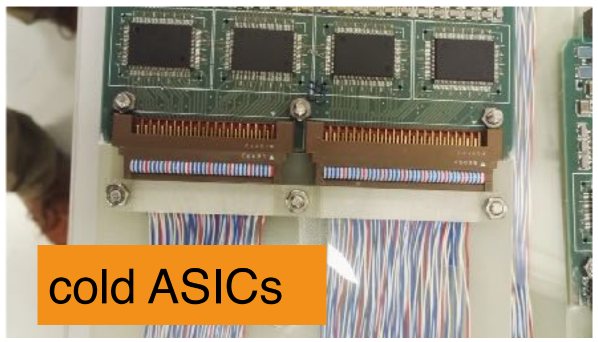


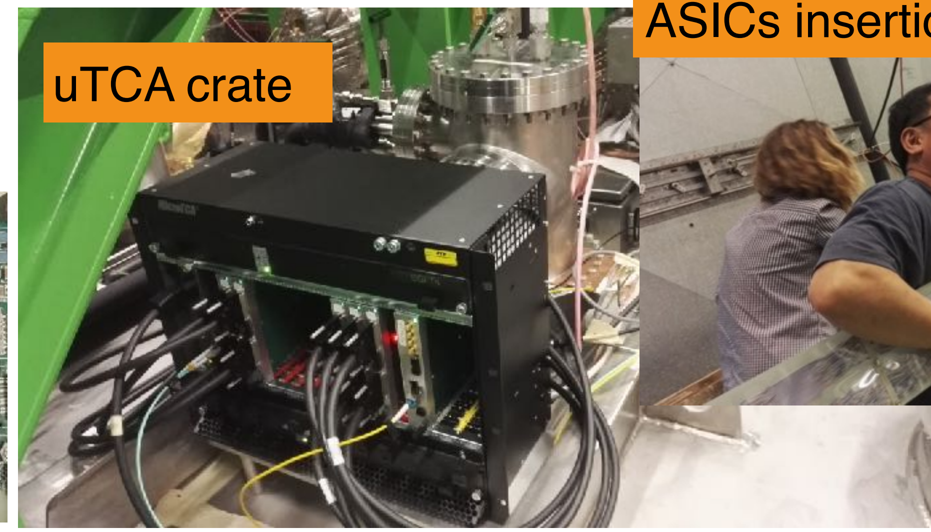


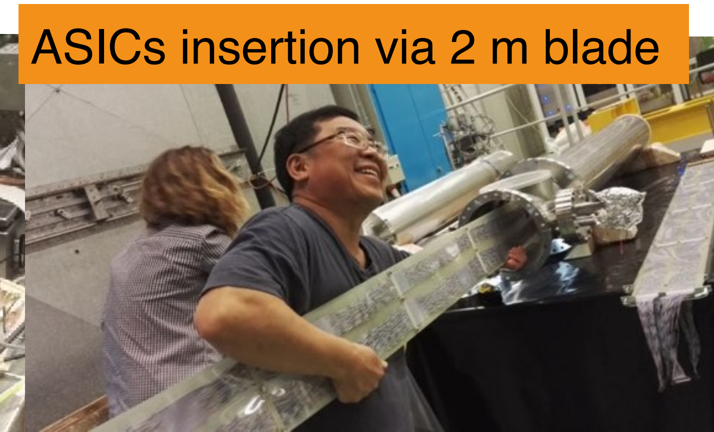


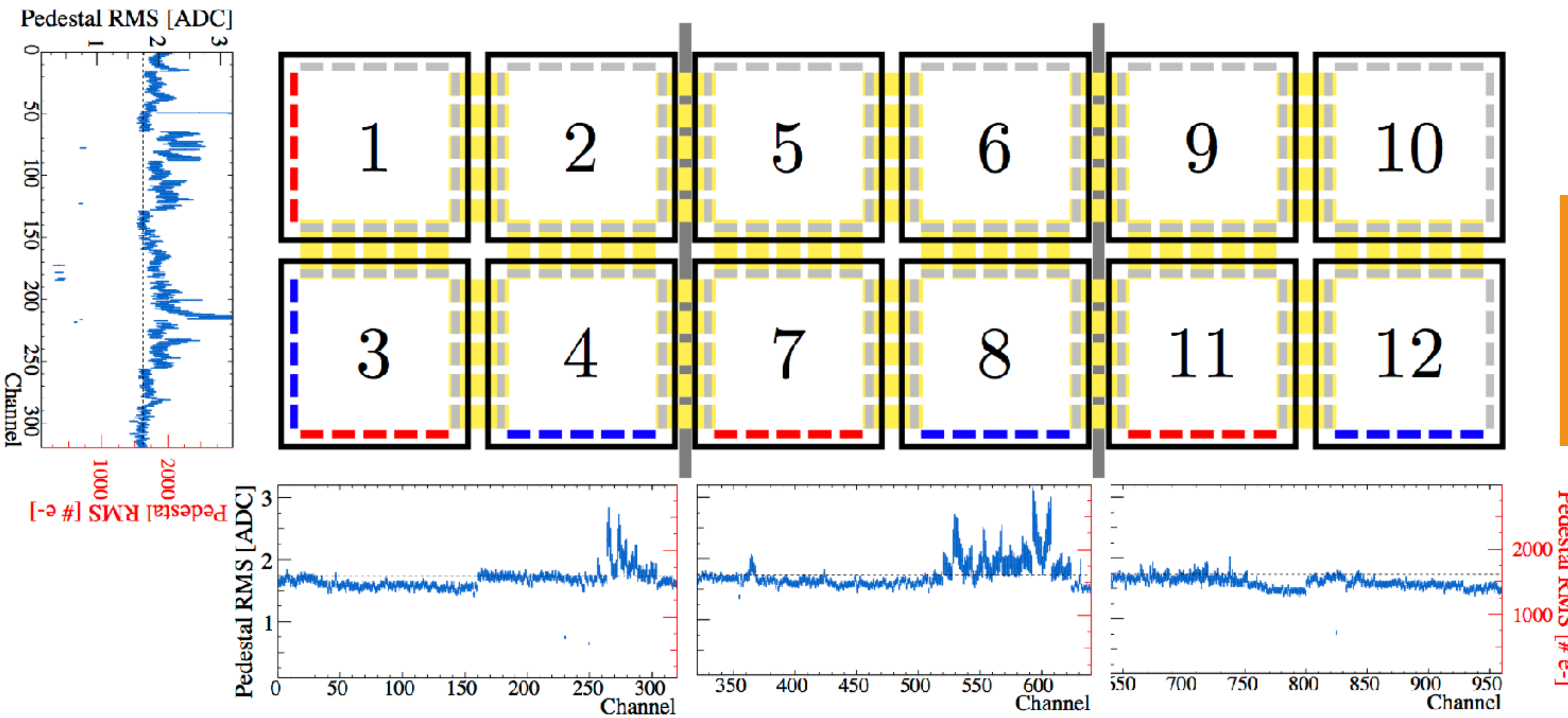
First results from commissioning - Charge readout









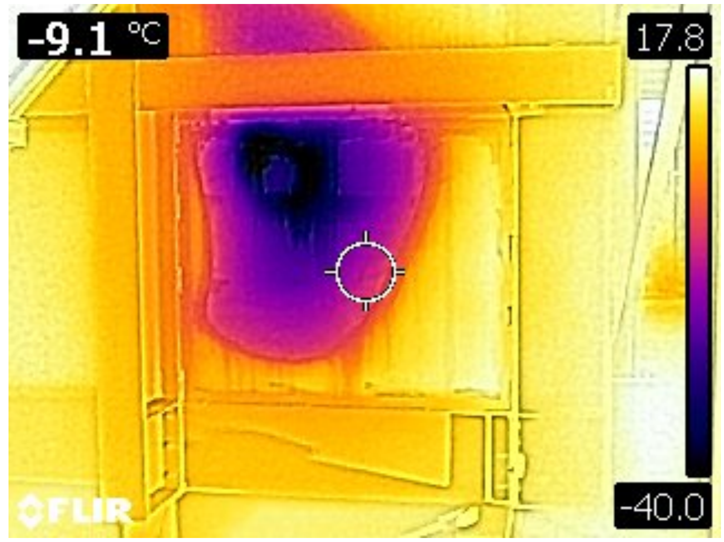


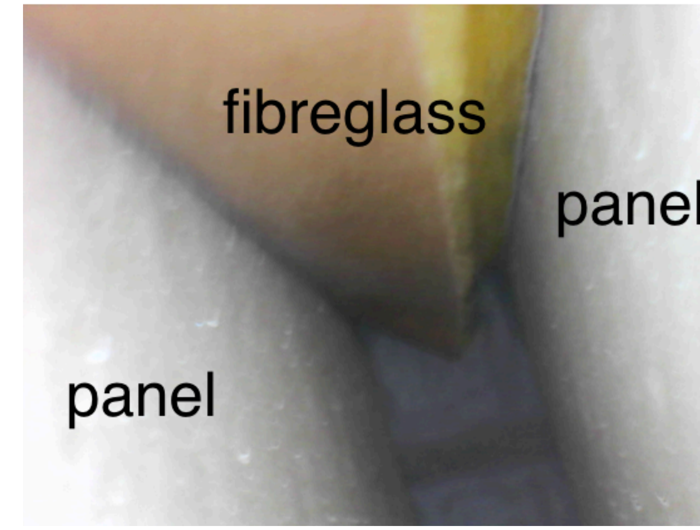
accessible cold amplifiers at 110 K. Sealed in chimney separate from main argon volume

DAQ and computing farm fully commissioned

noise at room temperature stable at about 1’500~ electrons

Cryostat- issues during cool down





- Since Feb. 28th two attempts at cooling down the cryostat have been made. Both have been interrupted due to the presence of multiple cold spots (some <-40°C) on the outer structure.
- The exact source of the cold spots as well as the solution to fix the issue is currently under investigation by CERN and GTT. So far the following has been understood:
  - A cold leak from the inner membrane has been excluded.
  - In some locations the outer structure was drilled and missing layers of fibreglass sheets were found. Those holes have been filled with expandable foam which cures the problem locally.
  - Next week a GTT team is coming to CERN and should be in position to solve the general issue based on results from a full simulation of the gas convection arising from the free spaces between the insulation blocks.

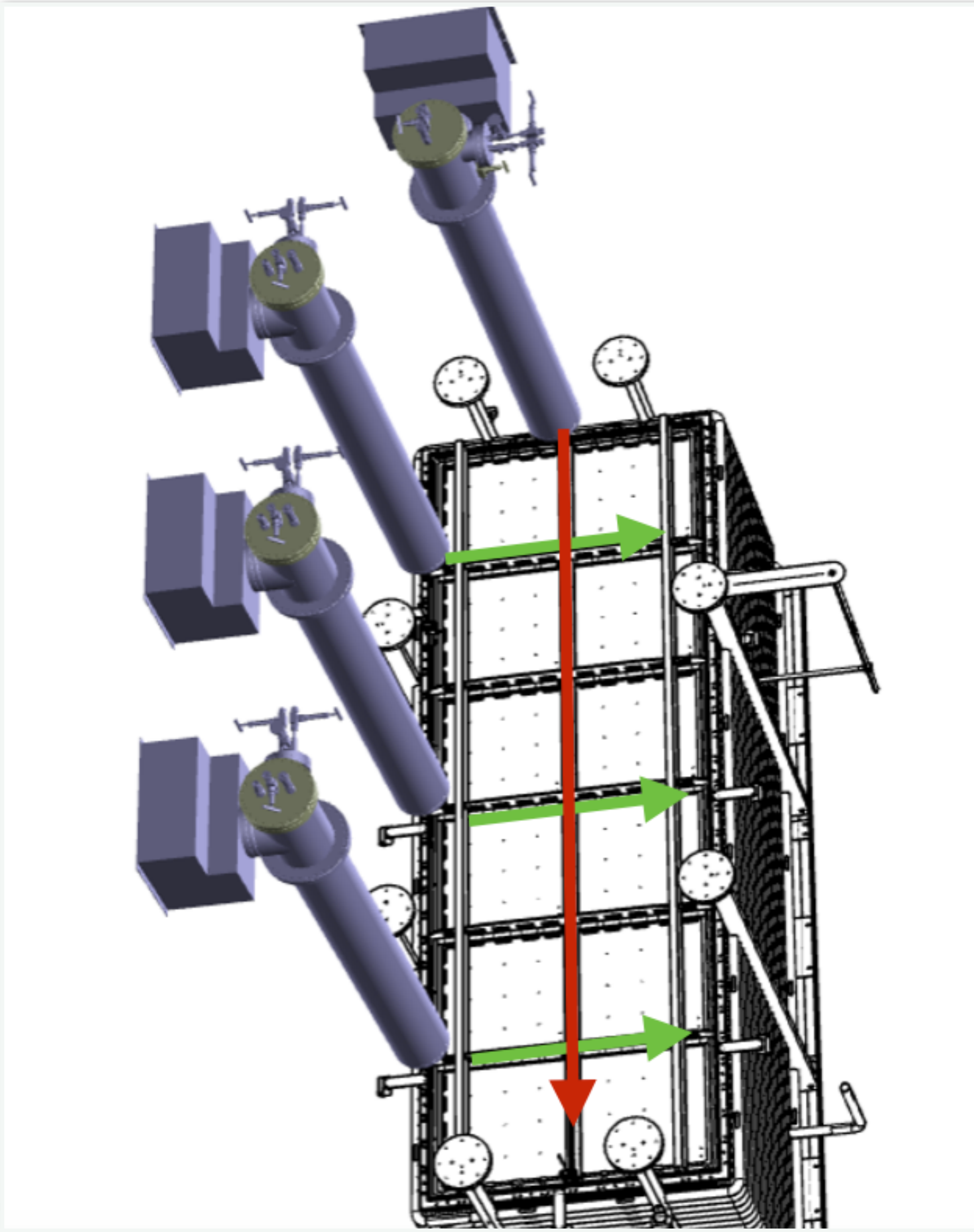
Conclusion

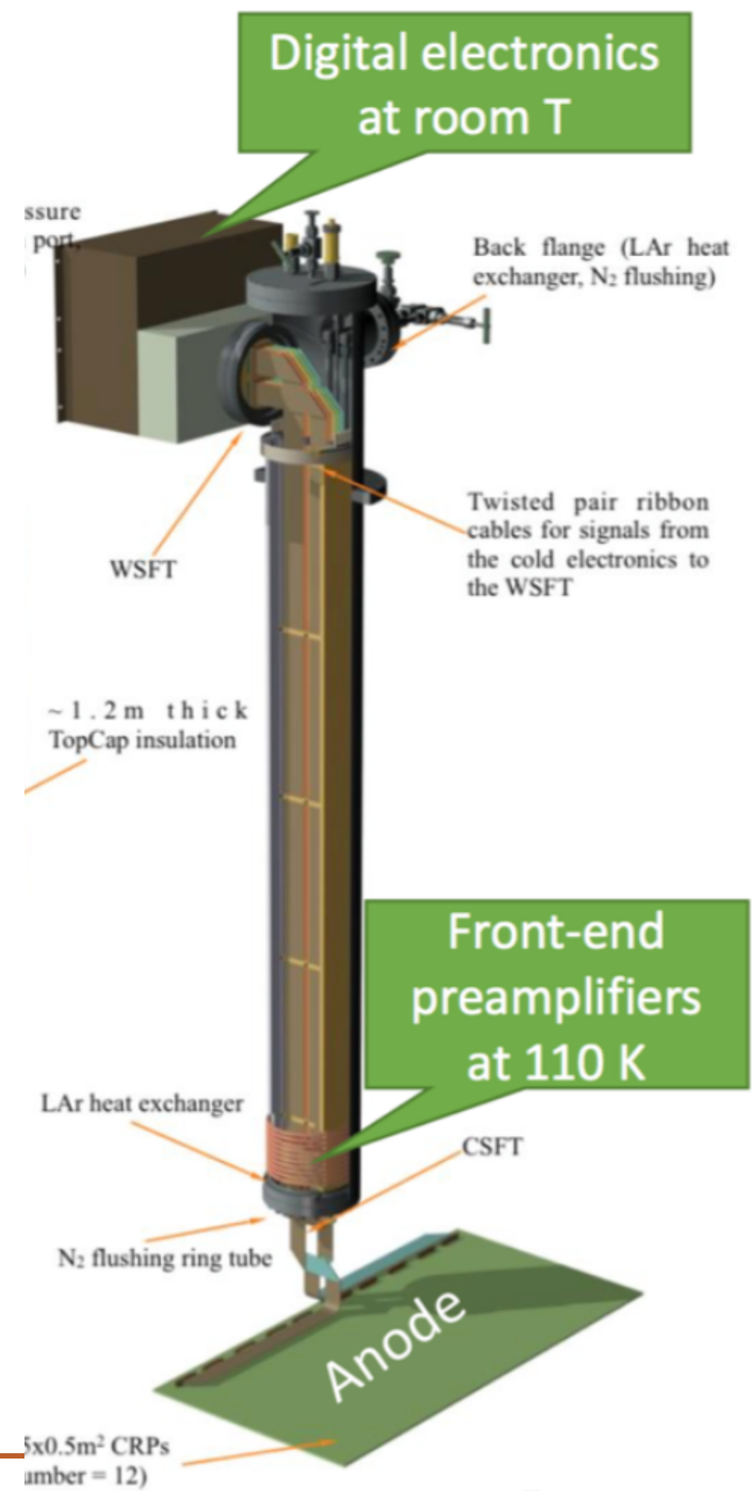
- Most of what has been shown in the slides has been **designed to match the scale of protoDUNE**. From that perspective, the installation and commissioning steps of the 3x1x1 **has provided many valuable inputs**
- The complete assembly of the 3x1x1 detector including cabling and DAQ commissioning took about 6 months.
- Some delay on the operation has been accumulated during cryogenic installation and commissioning phase and more recently due to the defect in the insulation which resulted in an abort of the cool down. The reason seems now understood and repaired. **We are currently filling the cryostat.**
- Although cosmic tracks have not yet been acquired, large experience has been gained for protoDUNE-DP design, installation and commissioning.

THANK YOU

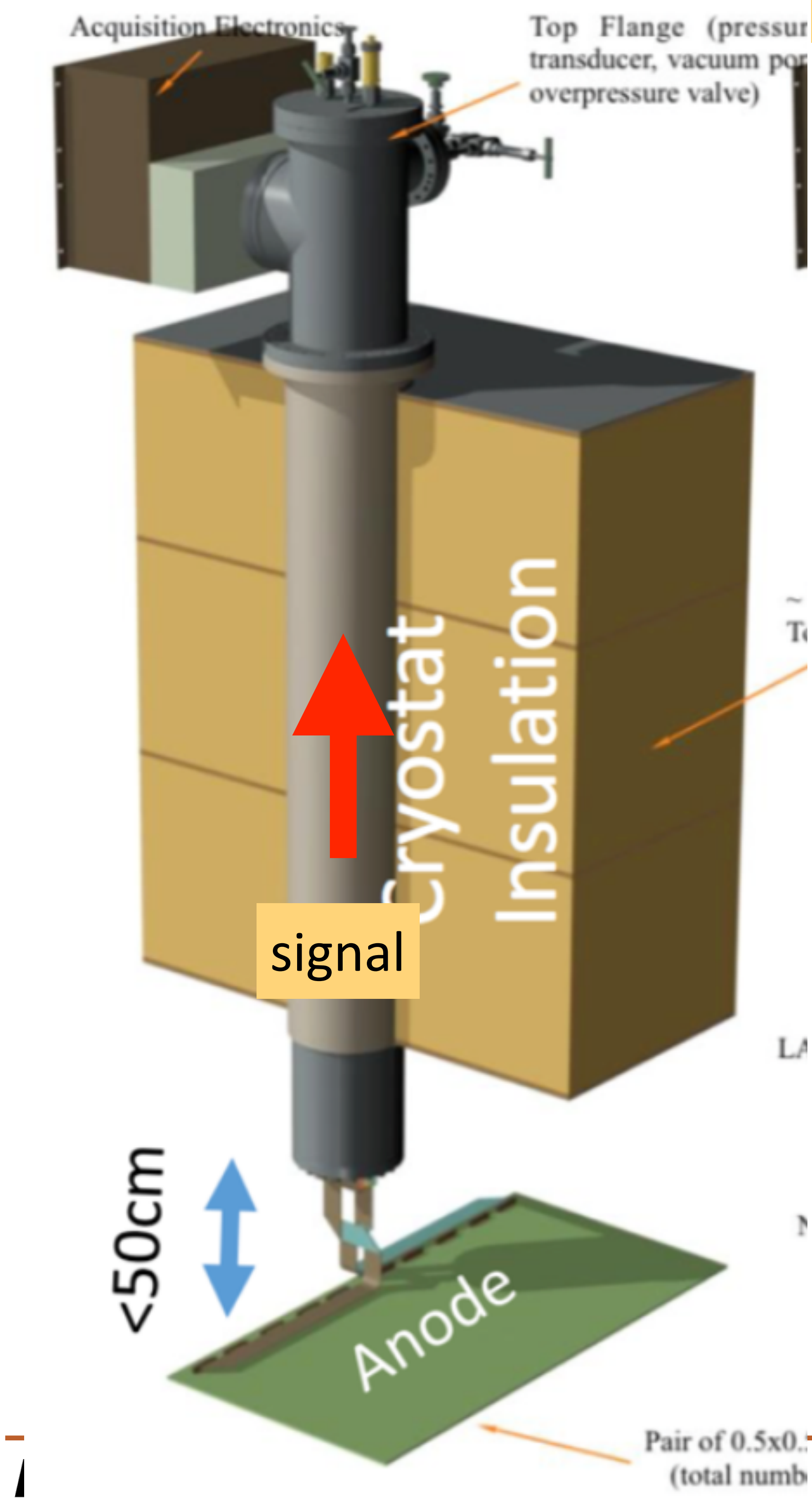
Signal feedthrough

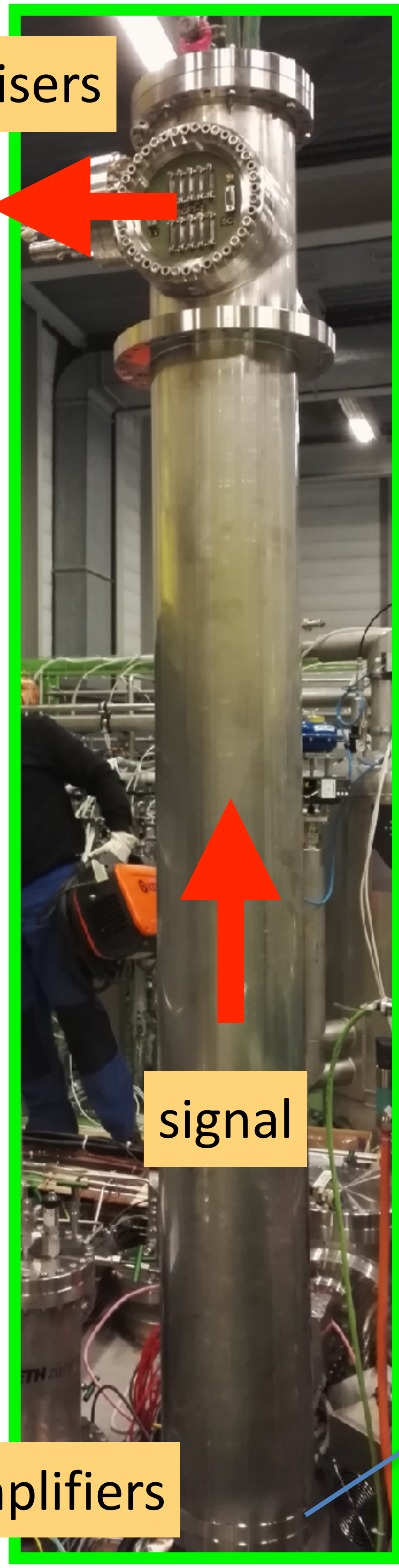
2 view readout 3 chimneys for the 1 m strips. 1 chimney for the 3m long view.





Signal feedthrough





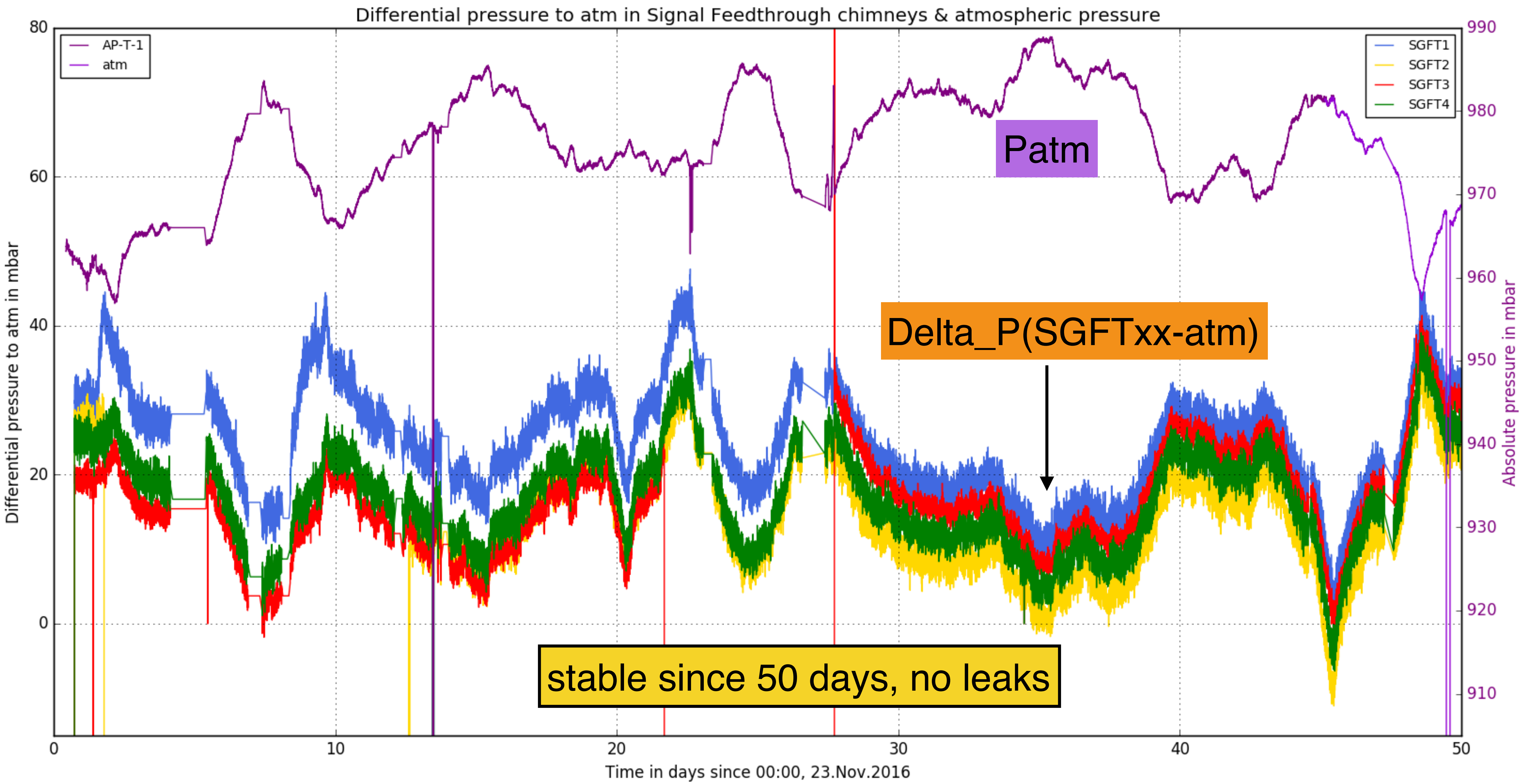
amplifiers accessible during operations

amplifiers inside closed volume. Close to anodes, ~110 K

4 ASICs per board

Signal chimneys

Independent volumes (to allow replacement of preamps). Pumped to remove air and sealed under GN2 with ~20 mbar overpressure W/ respect to Patm.



Charge Readout

1. charge signal multiplied and collected on low capacitance anode strips

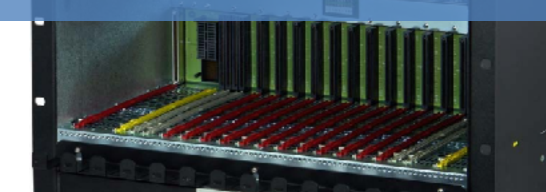
2. signal guided to cold amplifiers by group of 32 channels

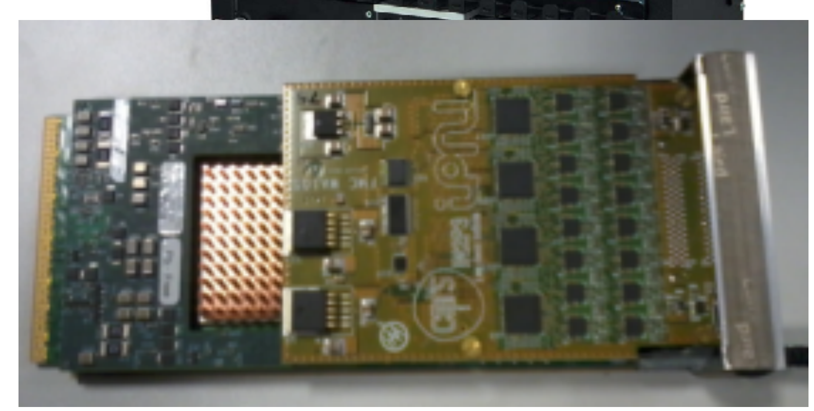
inside detector (not accessible)

3. signal amplified by ASICS in cold

4. signal brought outside by vacuum tight custom designs PCB flanges

5. signal digitised by 12it in AMC arms in uTCA crates





signal feedthrough (accessible)

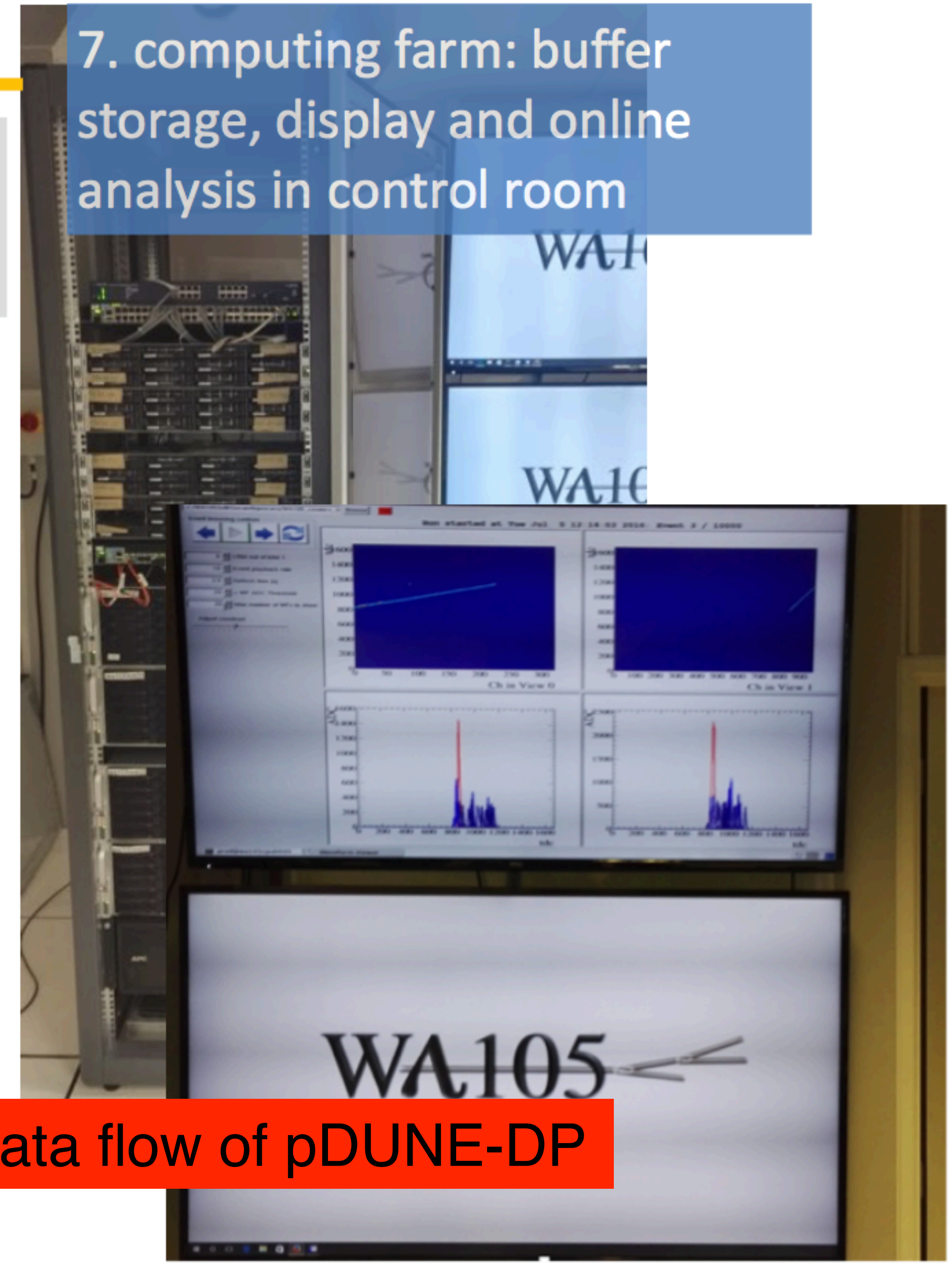
Top of cryostat

from uTCA crate

6. event building & triggering

Fiber connection :
- 2 x 10Gb rate : link aggregation in between 2 optical switches

7. computing farm: buffer storage, display and online analysis in control room

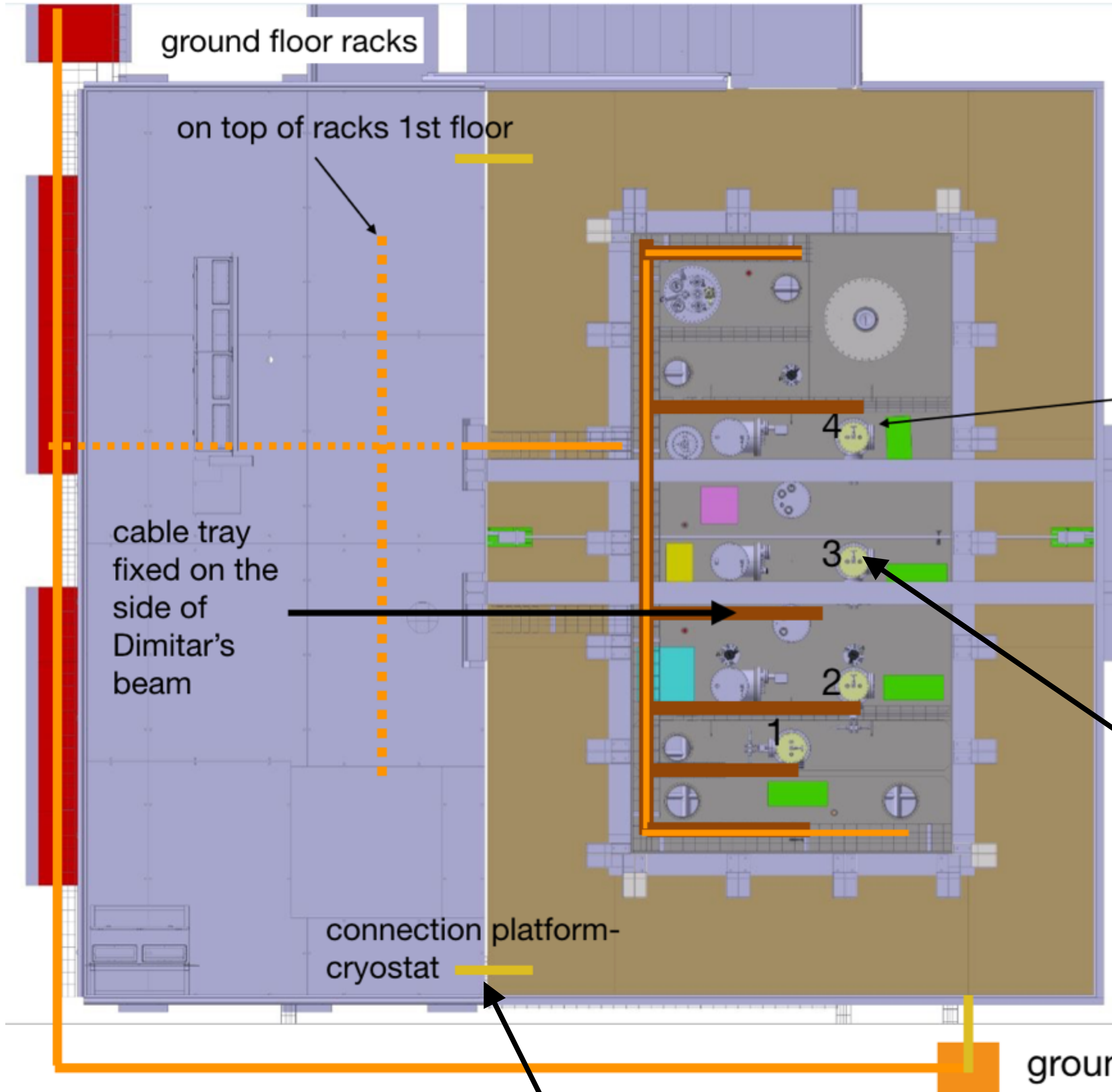


Designed for number of channels and data flow of pDUNE-DP

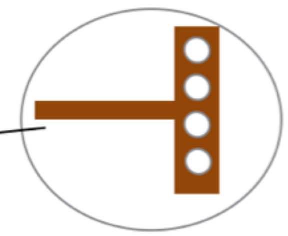
D. Autierio (IPNL) pDUNE-DP plenary

8. Send via 10 Gb CERN Network to computing center (EOS, etc ..)

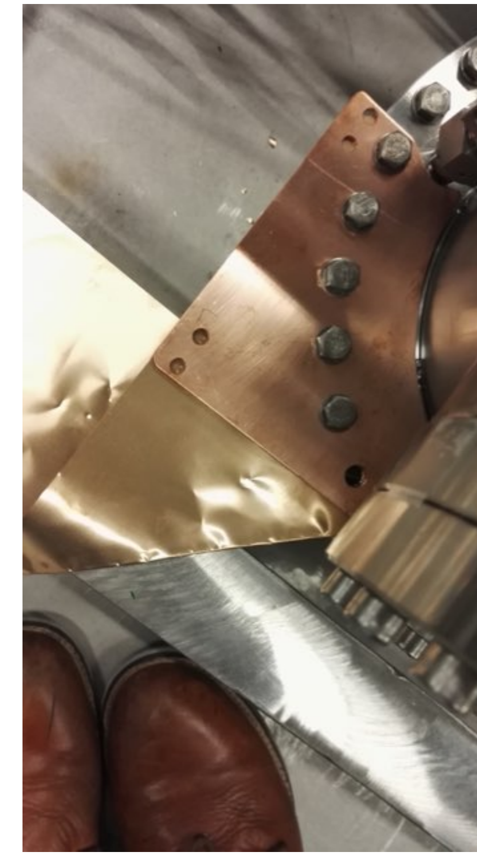
Grounding



ground pillar (approx location)



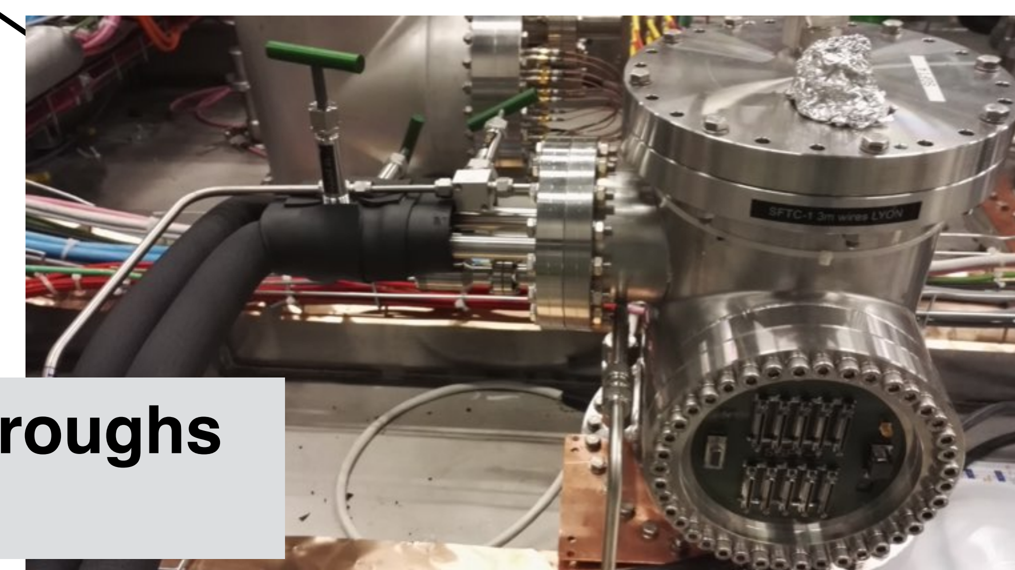
termination near SGFT: a clip with about 4 holes that will be screwed on the flange.



copper cable 95 mm2

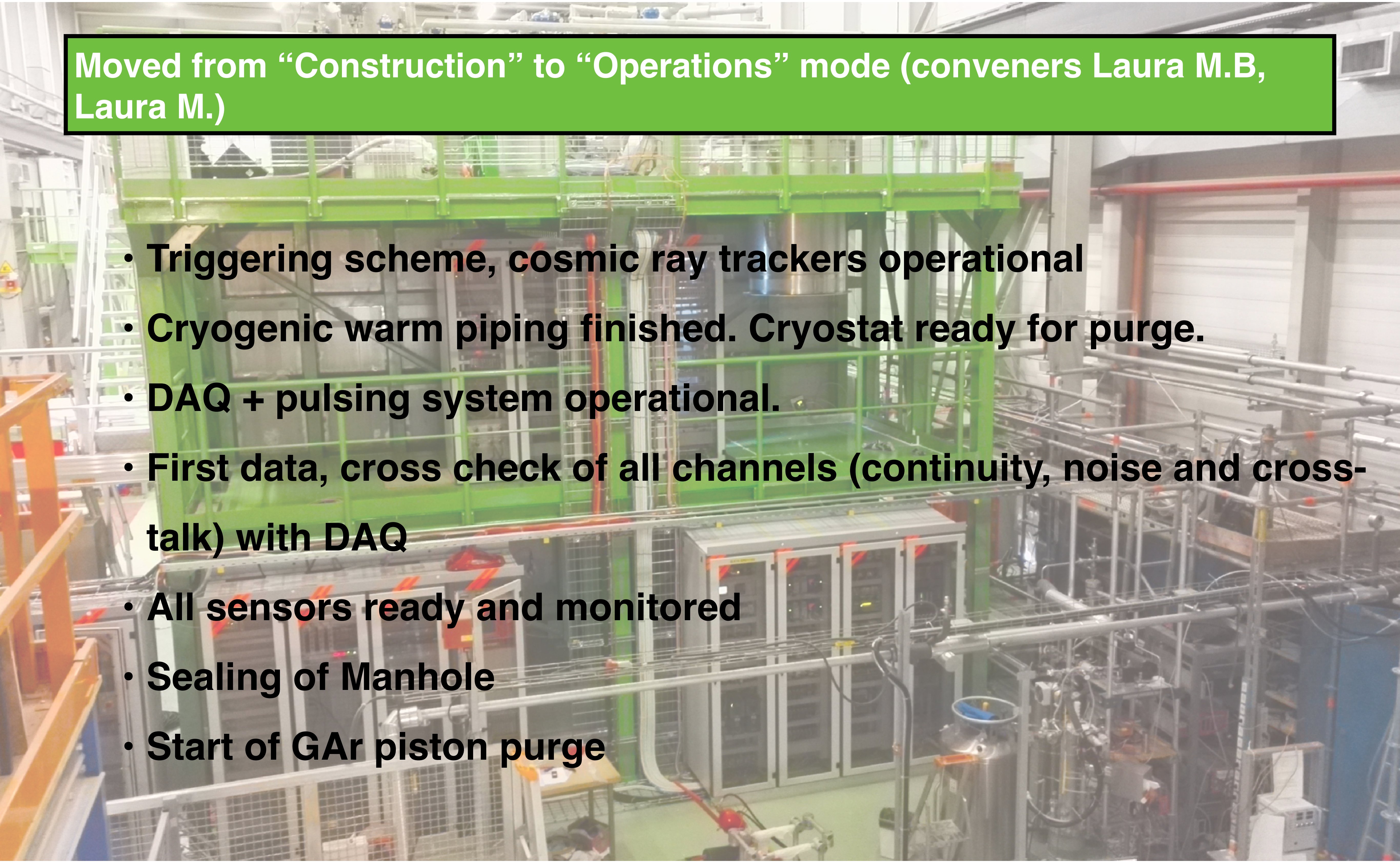
copper cable smaller section

copper foil



signal feedthroughs (1,2,3,4)

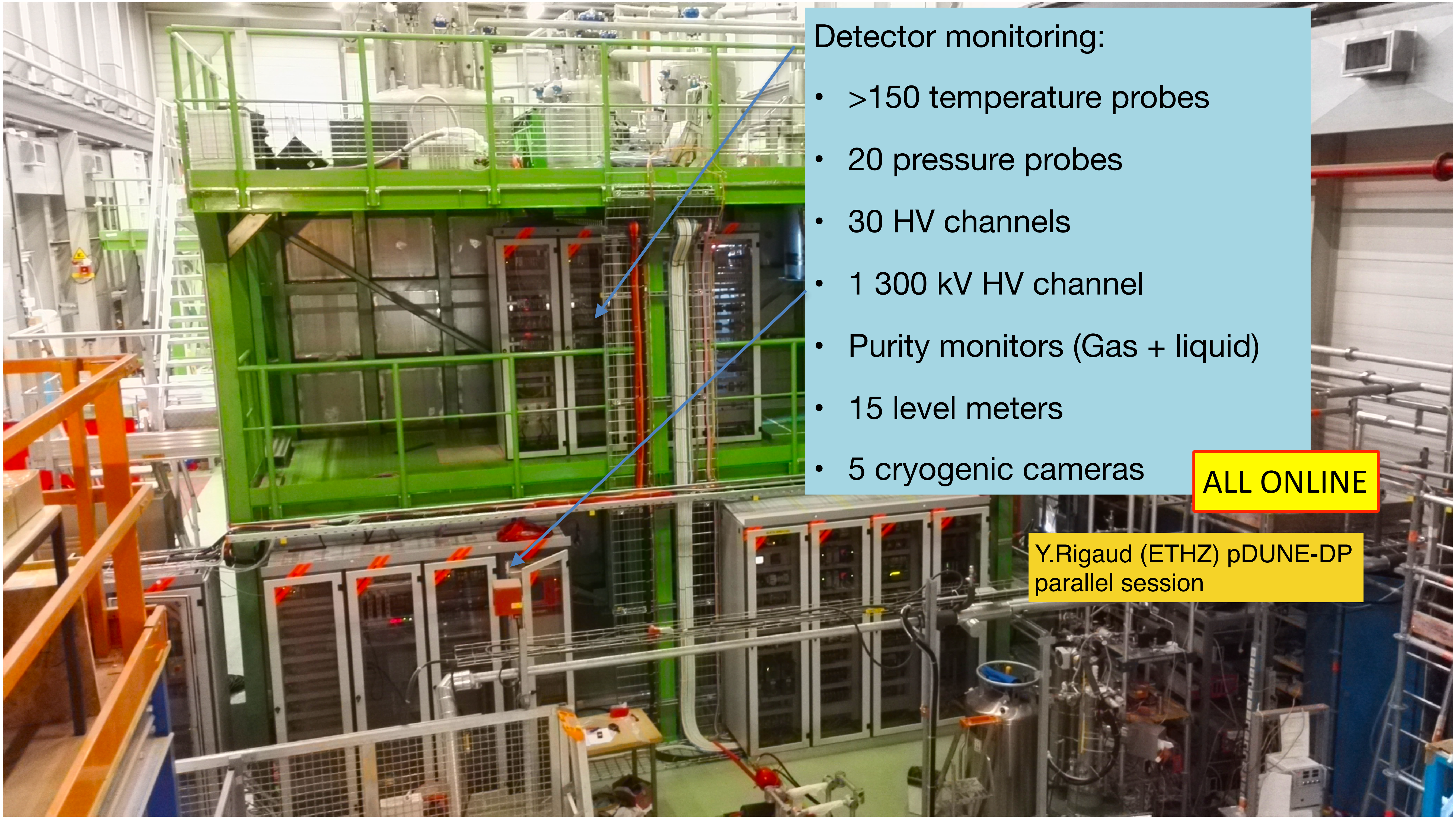
Status part 2 November-December



Moved from “Construction” to “Operations” mode (conveners Laura M.B, Laura M.)

- Triggering scheme, cosmic ray trackers operational
- Cryogenic warm piping finished. Cryostat ready for purge.
- DAQ + pulsing system operational.
- First data, cross check of all channels (continuity, noise and cross-talk) with DAQ
- All sensors ready and monitored
- Sealing of Manhole
- Start of GAr piston purge

Ready for detector operation



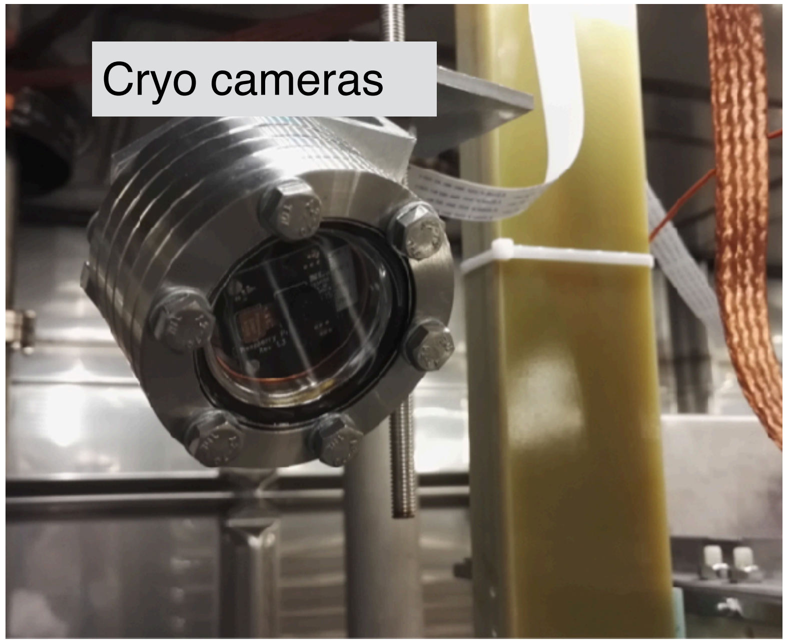
Detector monitoring:

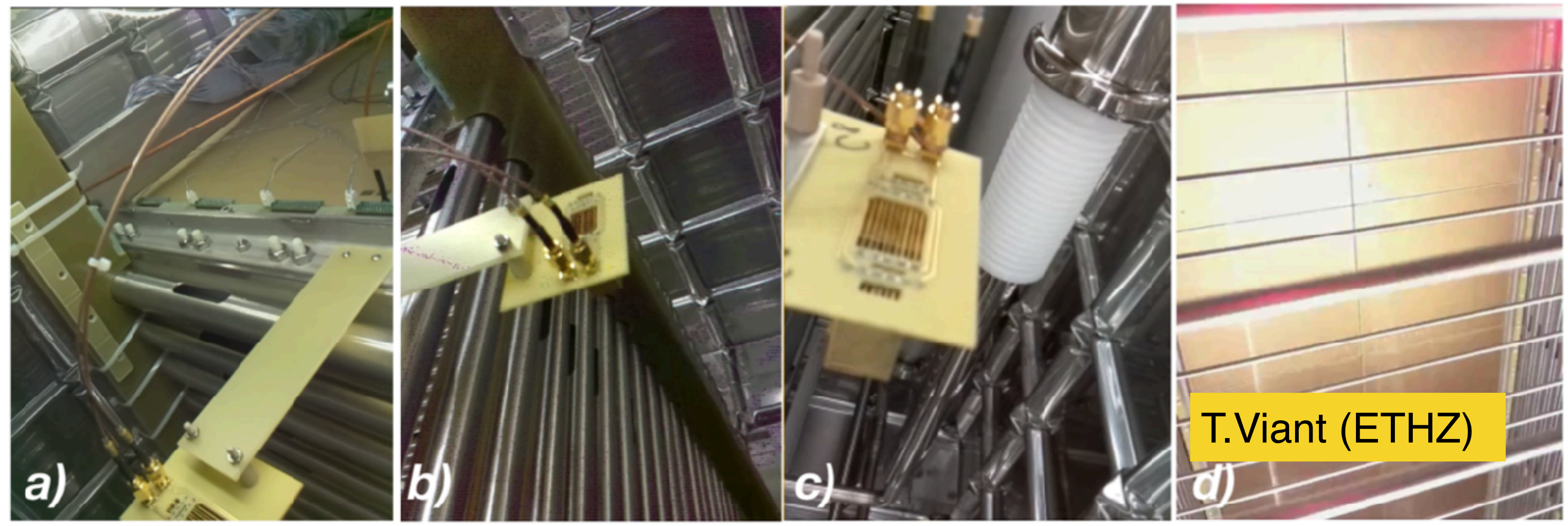
- >150 temperature probes
- 20 pressure probes
- 30 HV channels
- 1 300 kV HV channel
- Purity monitors (Gas + liquid)
- 15 level meters
- 5 cryogenic cameras

ALL ONLINE

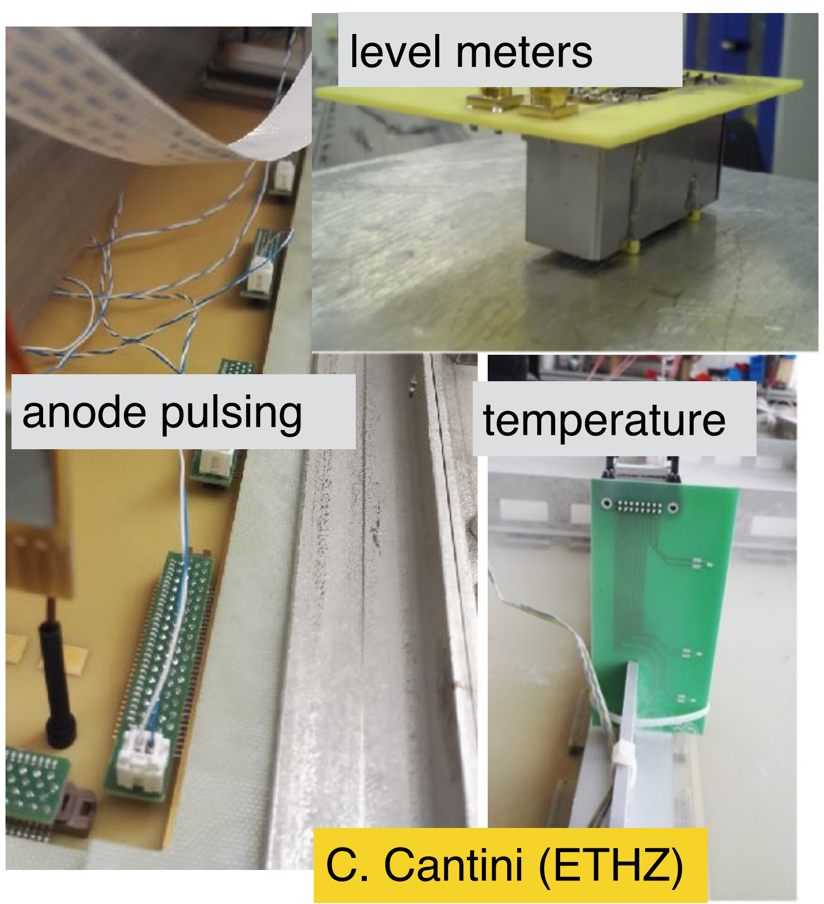
Y.Rigaud (ETHZ) pDUNE-DP parallel session

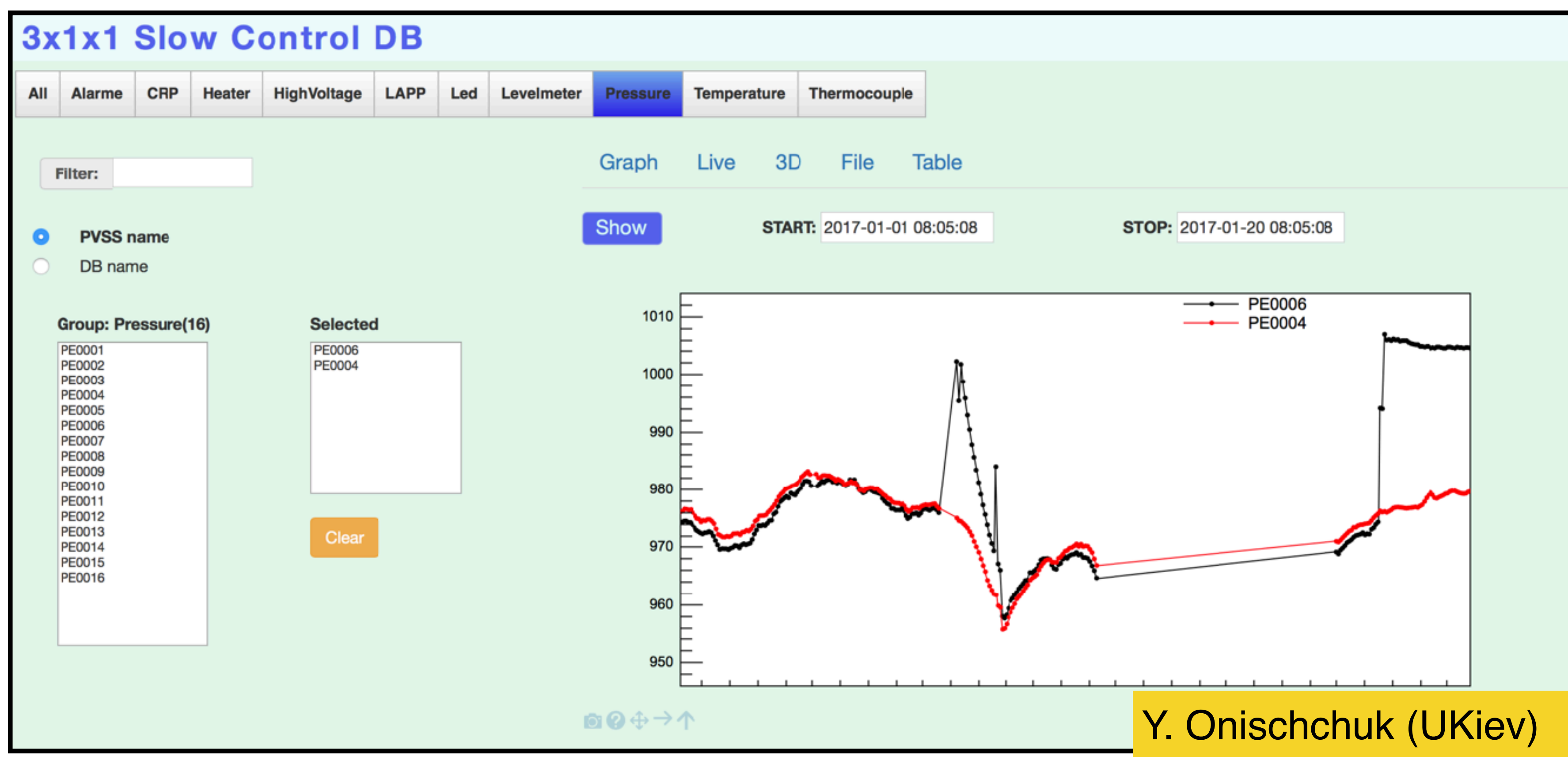
Monitoring





ALL RUNNING





Control room

Control desk:

- Linux screen : DAQ / Data management
- Windows screen : Slow control

Slow control screens:

- 2 x 55” monitors
- Windows computer screen

Conference equipment :

- Computer
- 2 x 55” monitors

Farm rack :

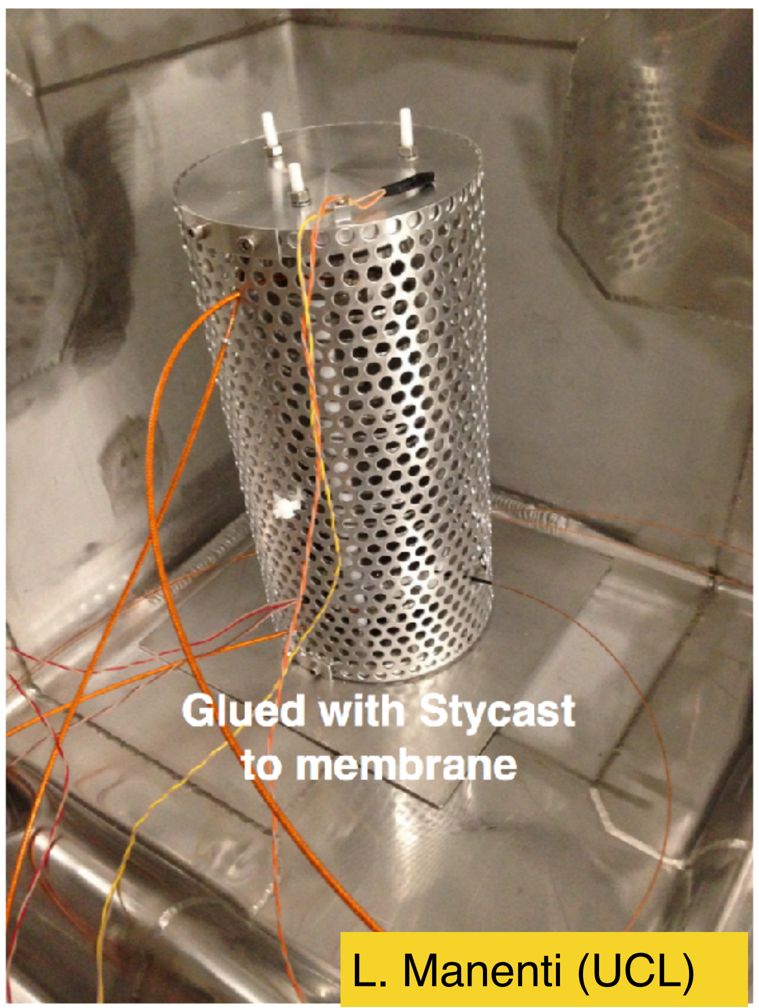
- 10 CPU computers
- 4 storage servers
- Switches

EventDisplay :

- Working with Qscan
- Connected to wa105cpu0000
- Managed from the control desk

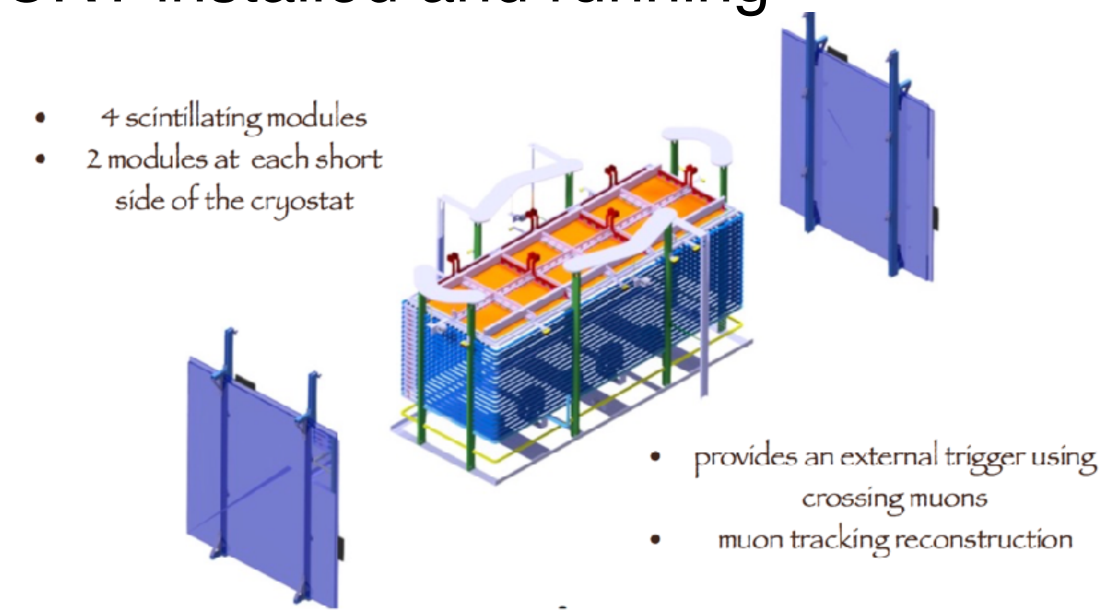
Cosmic Ray Trigger & Purtiy monitor

Purity monitor Installed



L. Manenti (UCL)

CRT installed and running

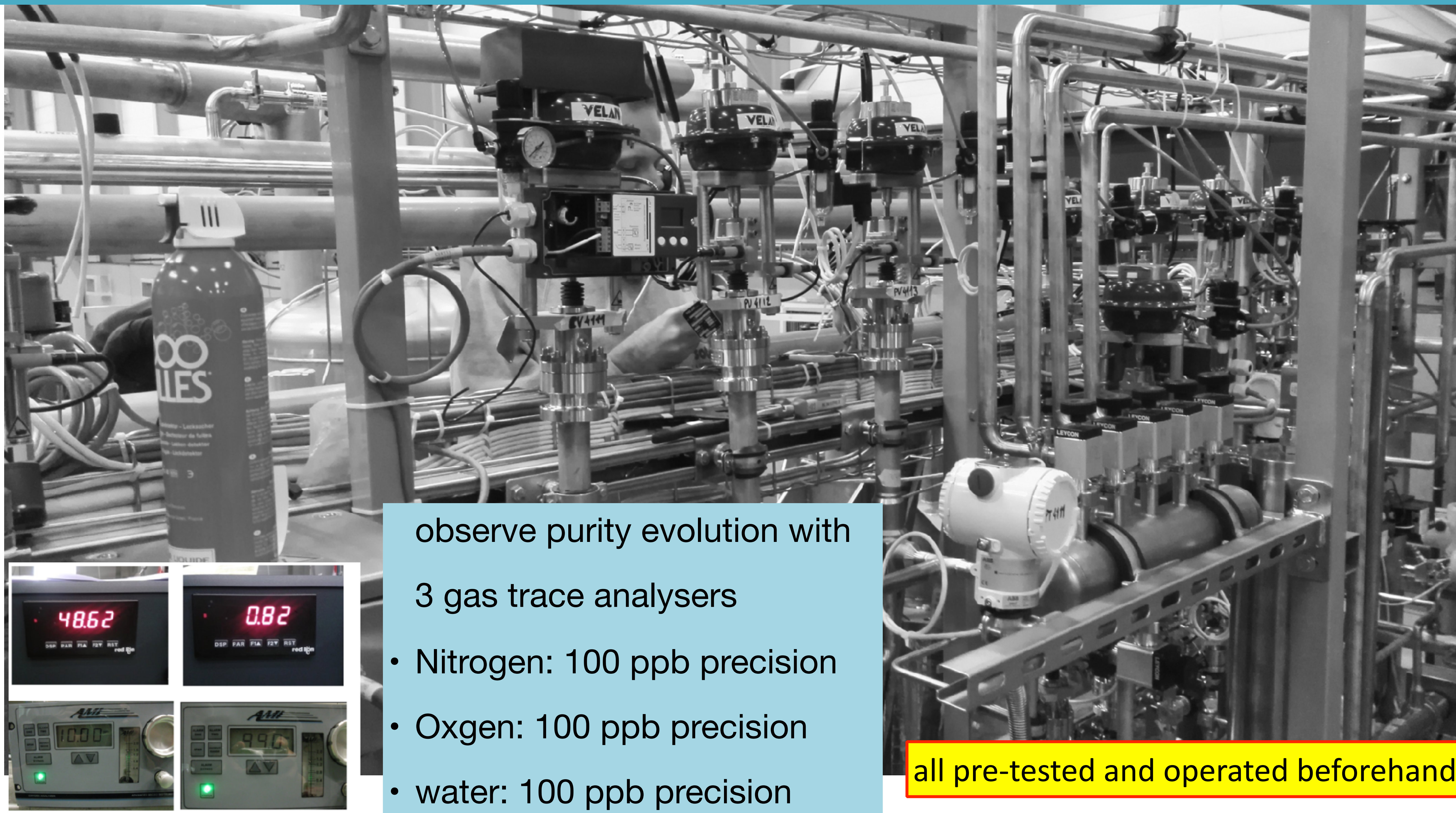


I. Kreslo D. Iorca (LHEP, Bern)

pulsing and noise data

December-ready for purge

Remove contaminants by flushing gas argon and recirculating and filtering in closed loop.



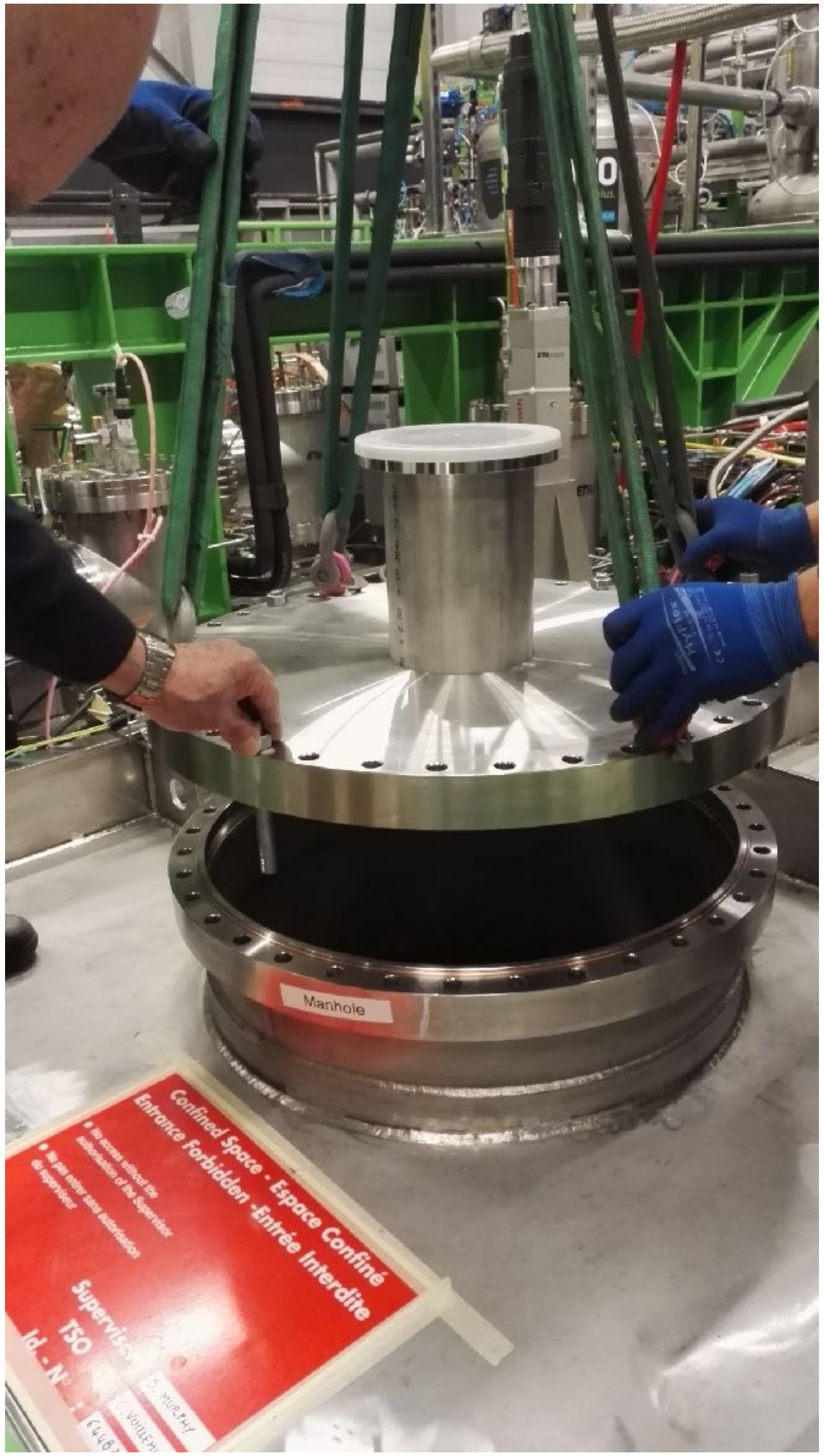
observe purity evolution with

3 gas trace analysers

- Nitrogen: 100 ppb precision
- Oxgen: 100 ppb precision
- water: 100 ppb precision

all pre-tested and operated beforehand

pressurisation of tank



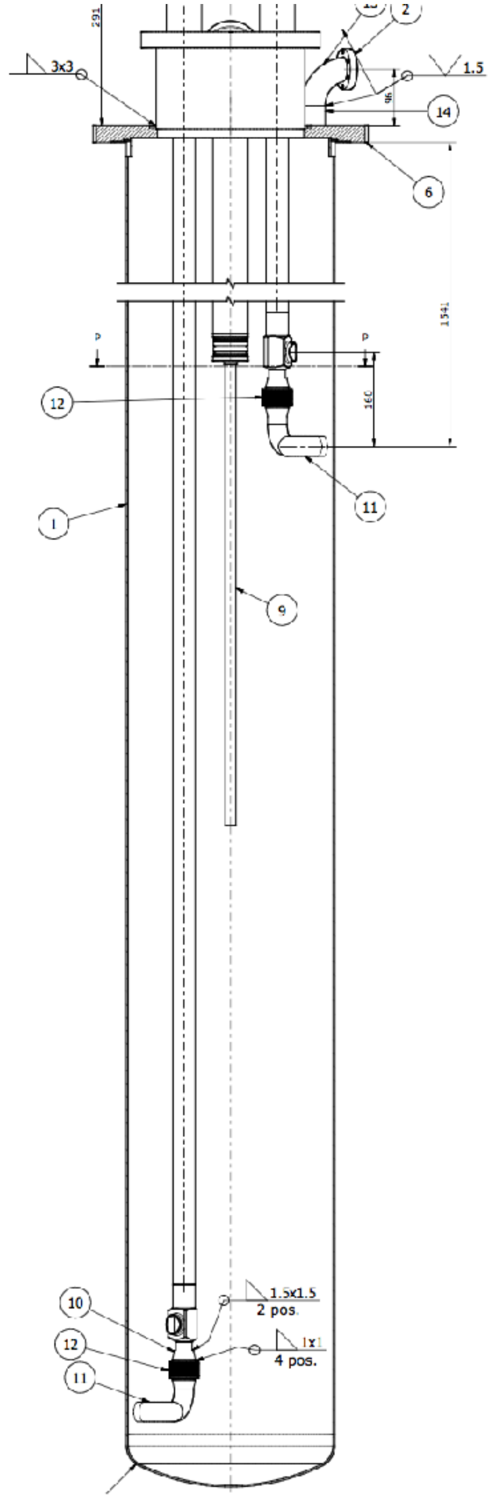
On December 19th the Manhole was sealed and GAr was flushed to pressurise the tank…

pressurisation of tank

Large leaks we found on both flanges of the pump tower

about 30 flanges on top-cap (+ piping)

pump tower



Looking back 2016

WA105 3x1x1 prototype

ENTIRE DETECTOR CONSTRUCTED IN 2016

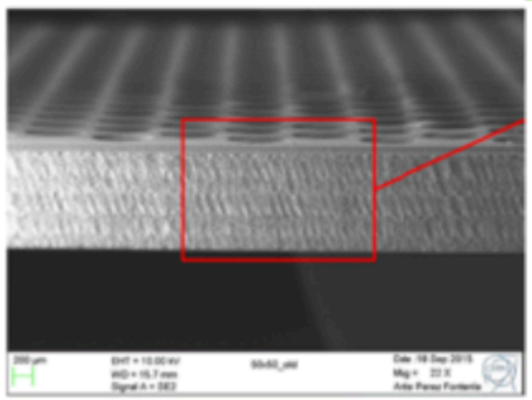
FE electronics inserted + tested

top-cap delivered

full detector installed under top-cap

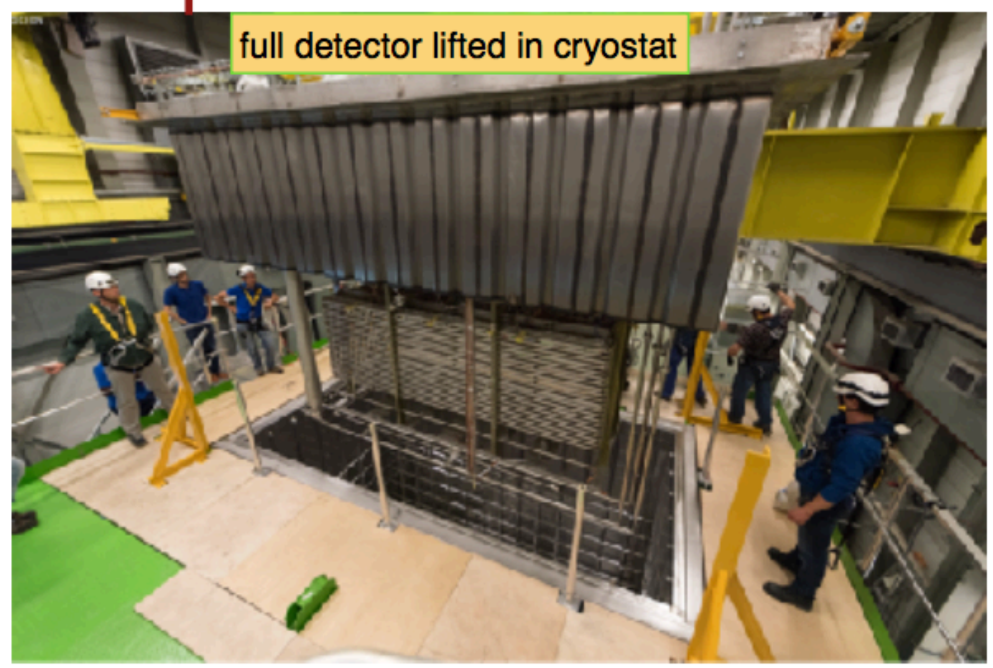
Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec

LEMs & anode delivered +QA/QC



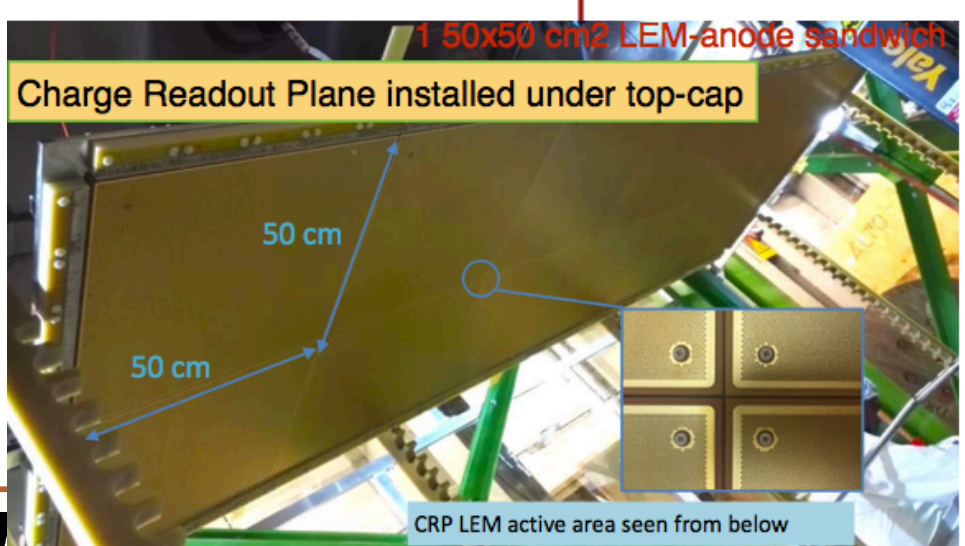
CRP cryogenic bath test

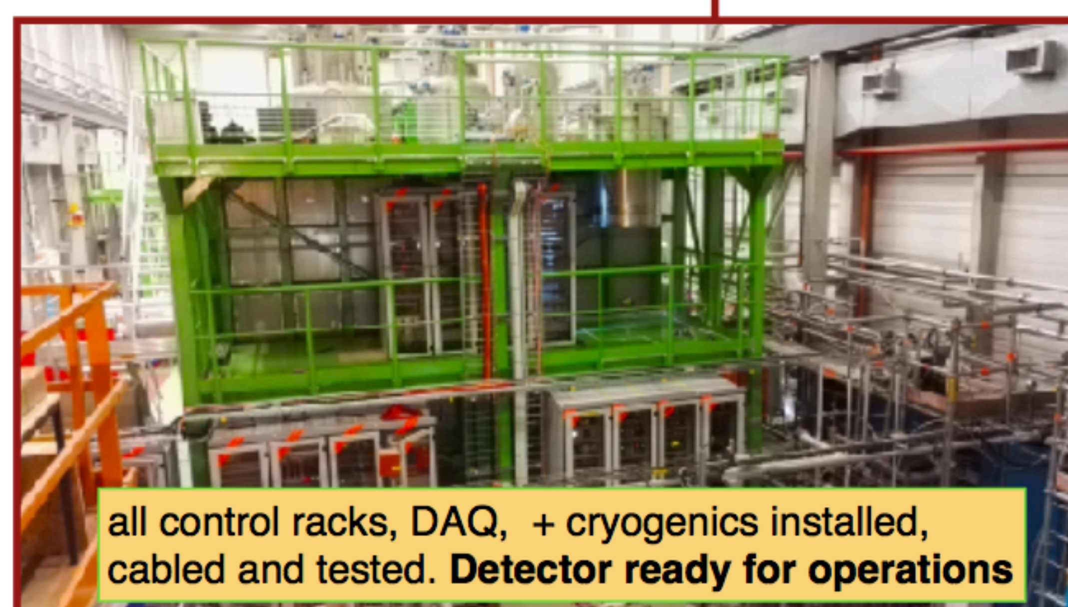
full detector lifted in cryostat



successful test and insertion of 300 kV high voltage feedthrough

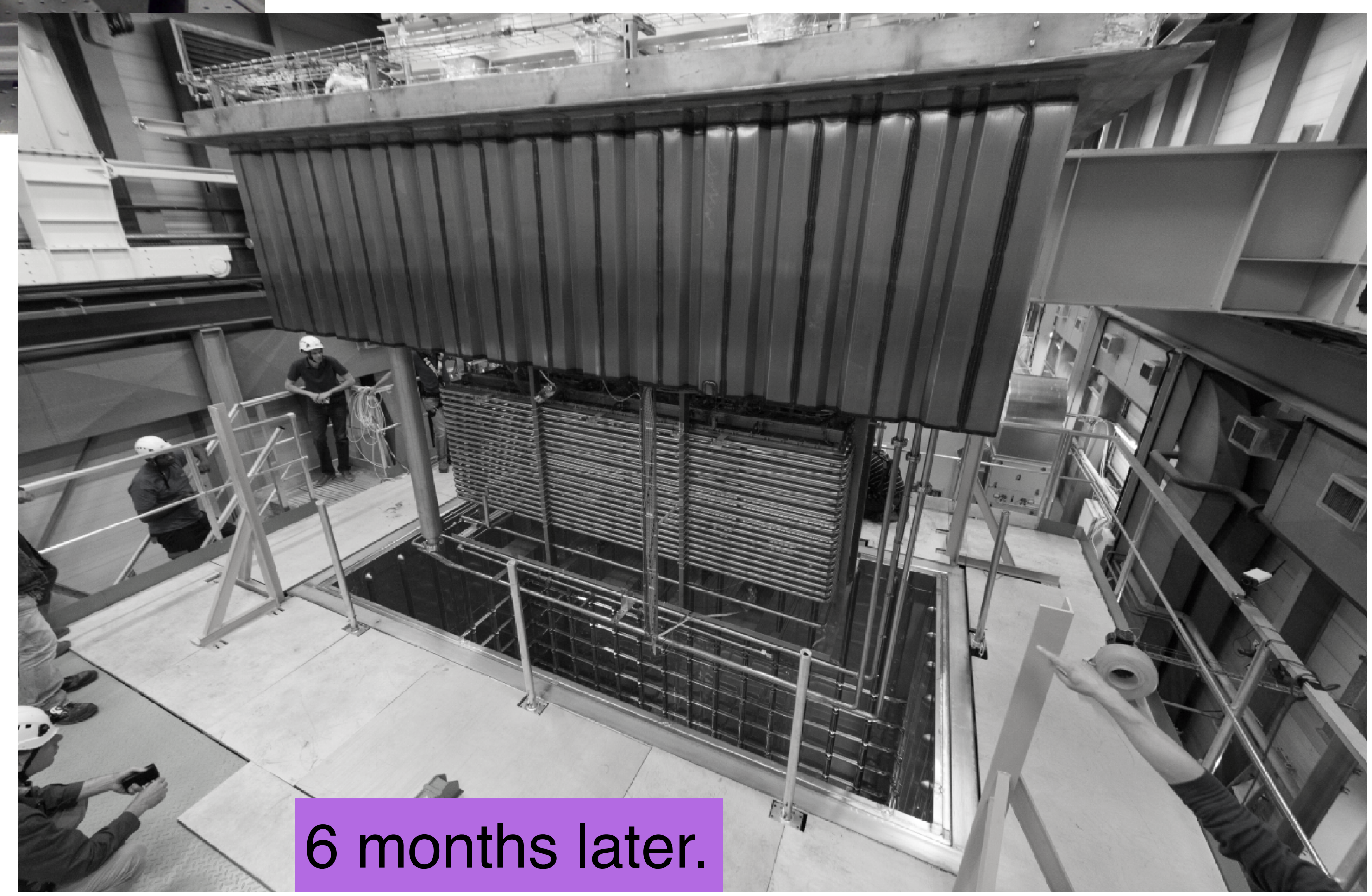
Charge Readout Plane installed under top-cap





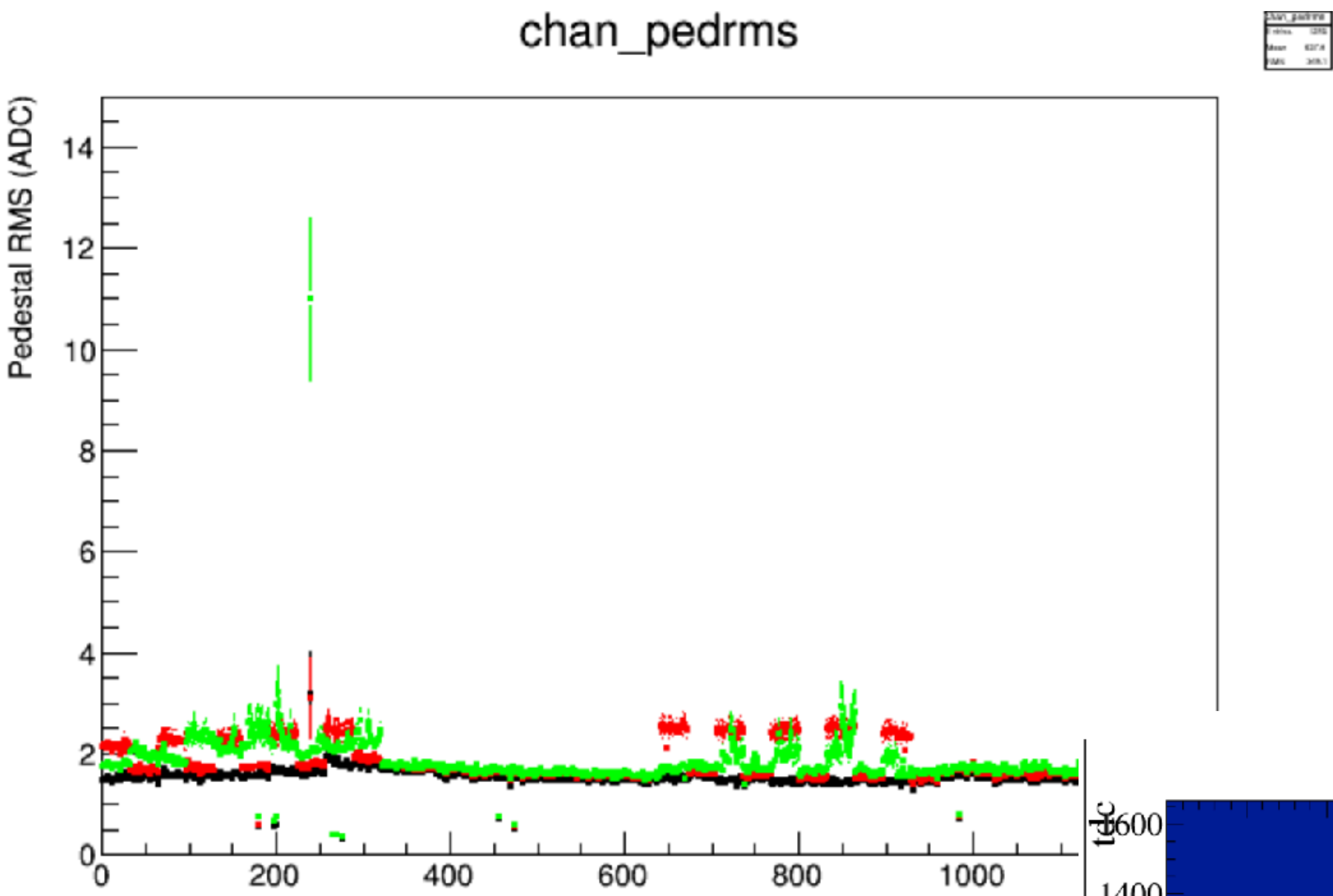
all control racks, DAQ, + cryogenics installed, cabled and tested. **Detector ready for operations**

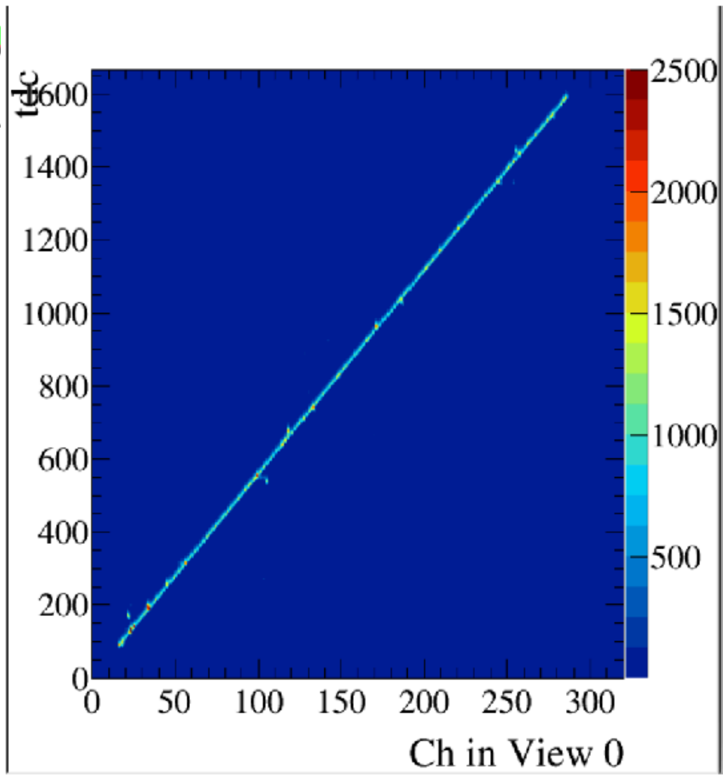
The “3x1x1” in February 2016



6 months later.

2017


chan_pedrms
Pedestal RMS (ADC)
0
2
4
6
8
10
12
14
0
200
400
600
800
1000


tdc
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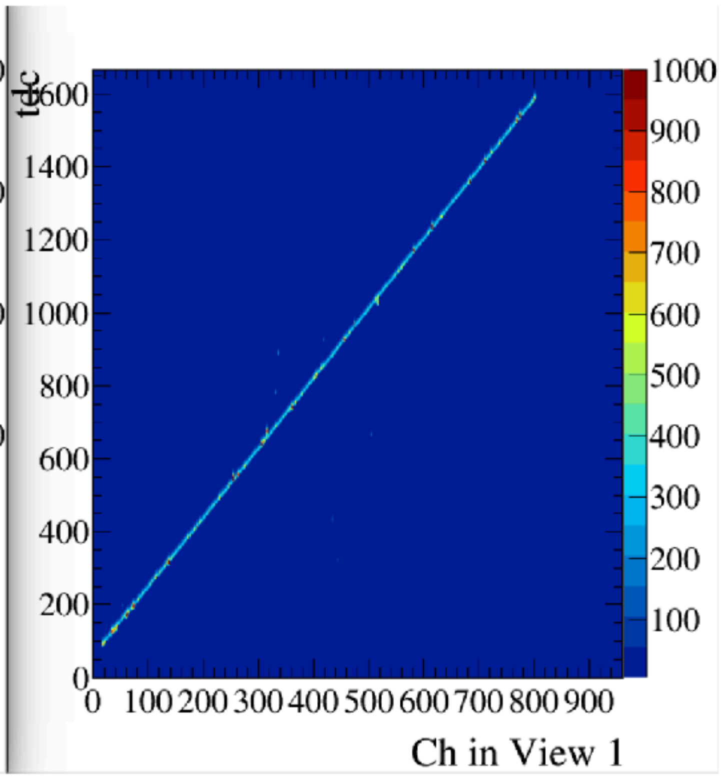
2500


tdc
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800
900
Ch in View 1
100
200
300
400
500
600
700
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900
1000

2017

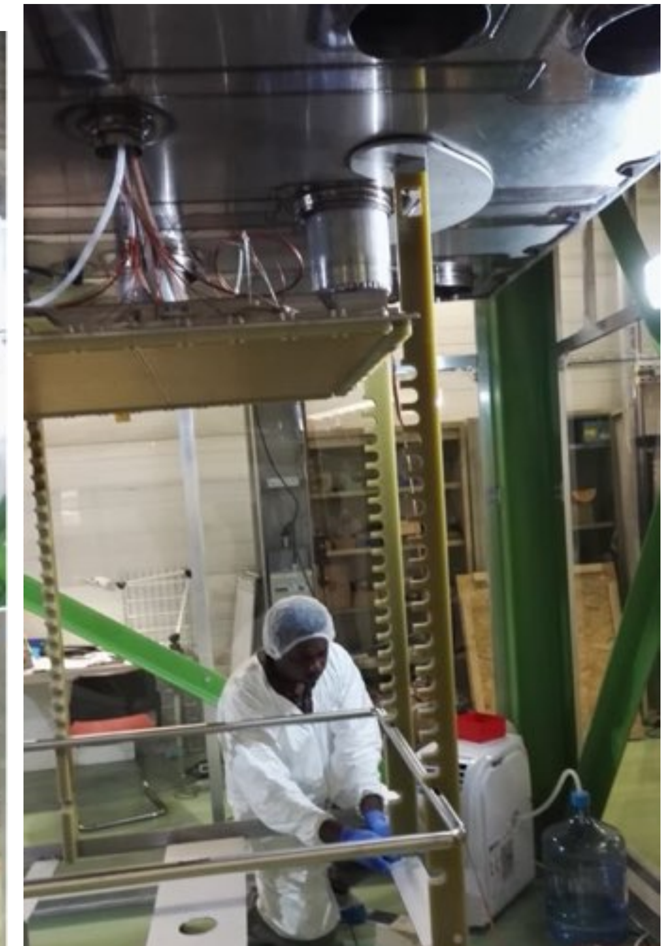
AND THE SAME FOR PROTODUNE-DP!

See D. Autiero plenary + parallel session Wednesday


THANK YOU
WA105

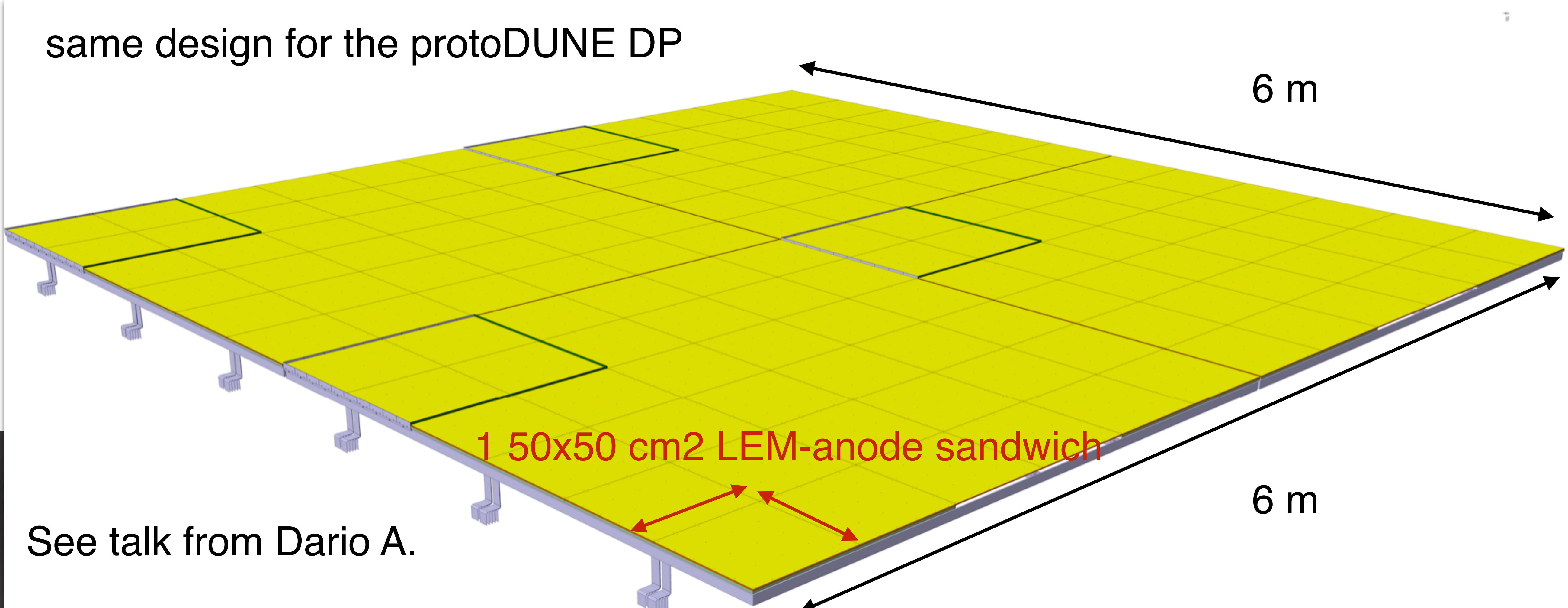
Detector installation

Detector installation

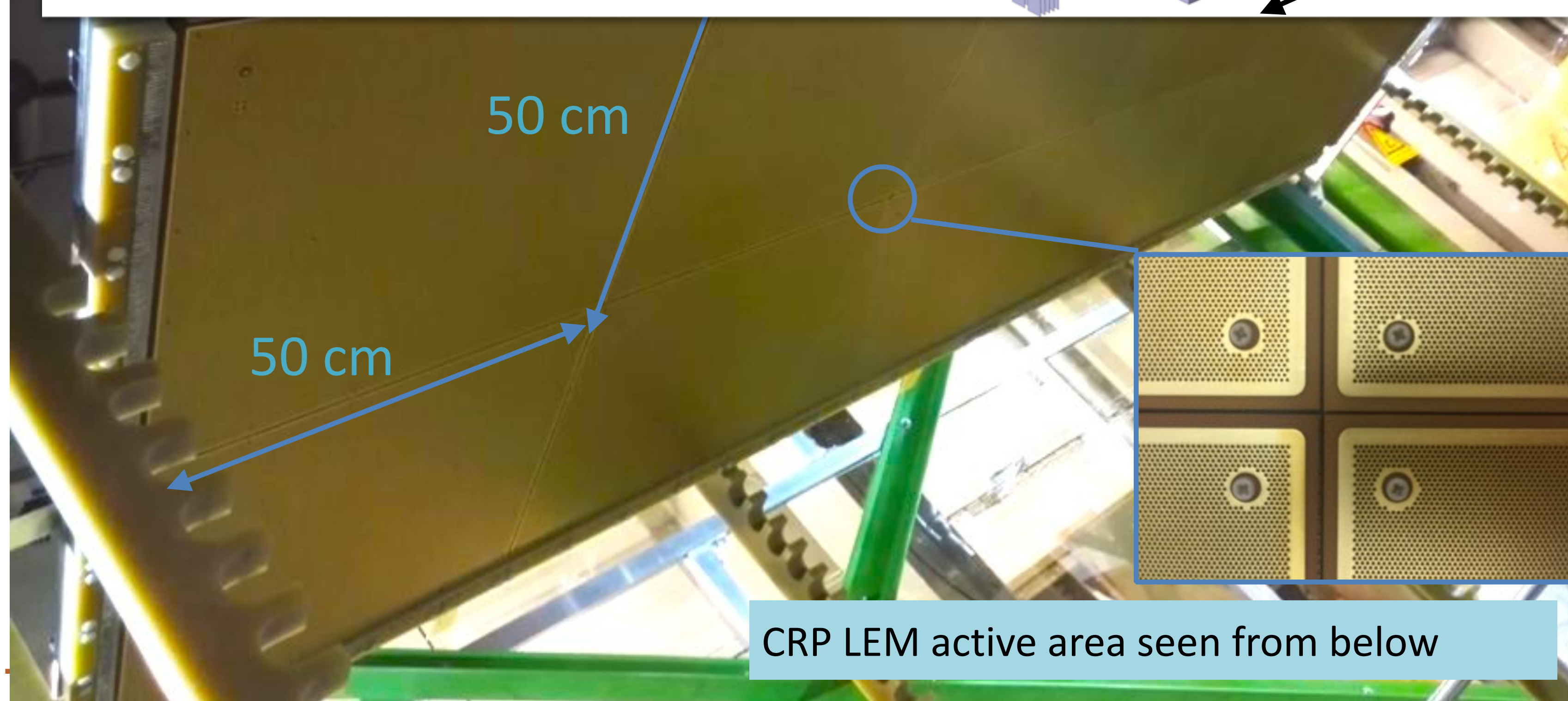


CRP 3x1 m2 -> 3x3 m2

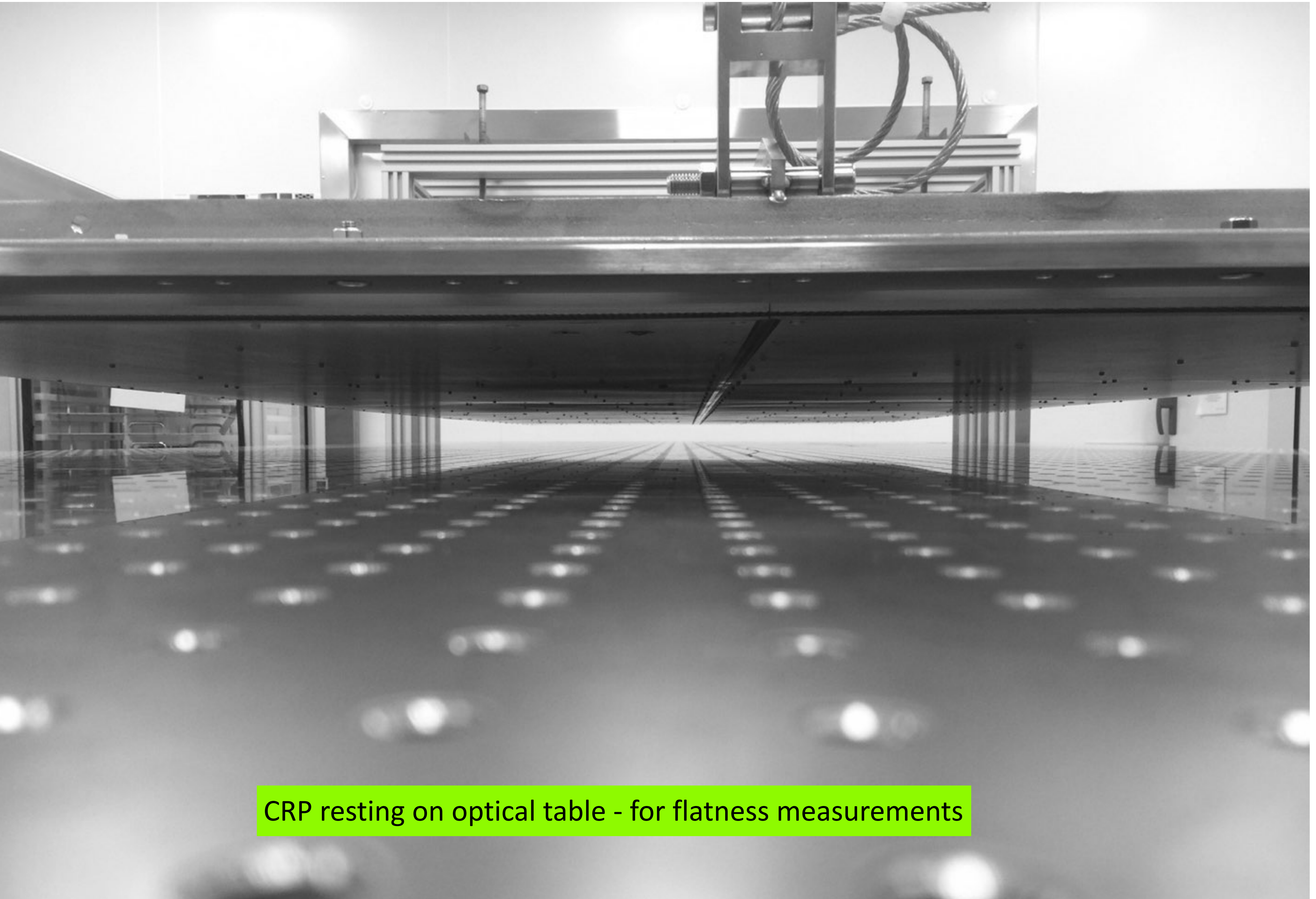
same design for the protoDUNE DP



See talk from Dario A.

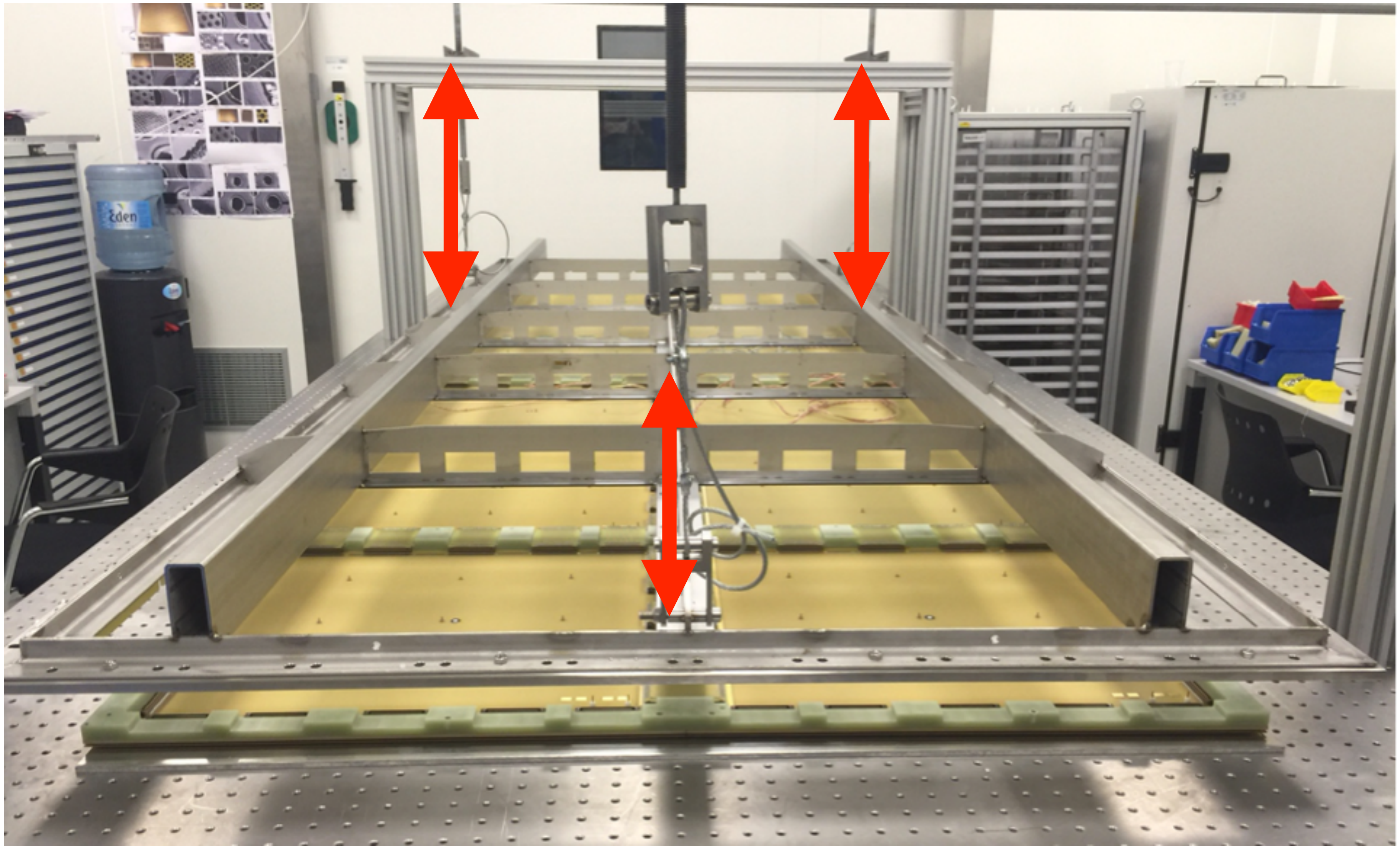


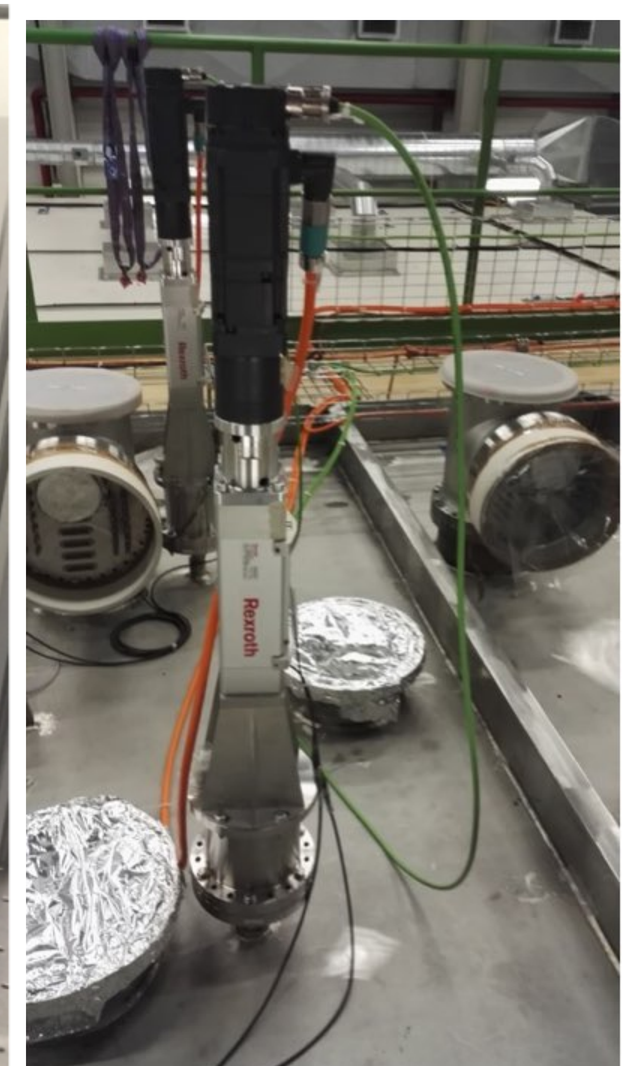
Charge Readout Plane



CRP resting on optical table - for flatness measurements

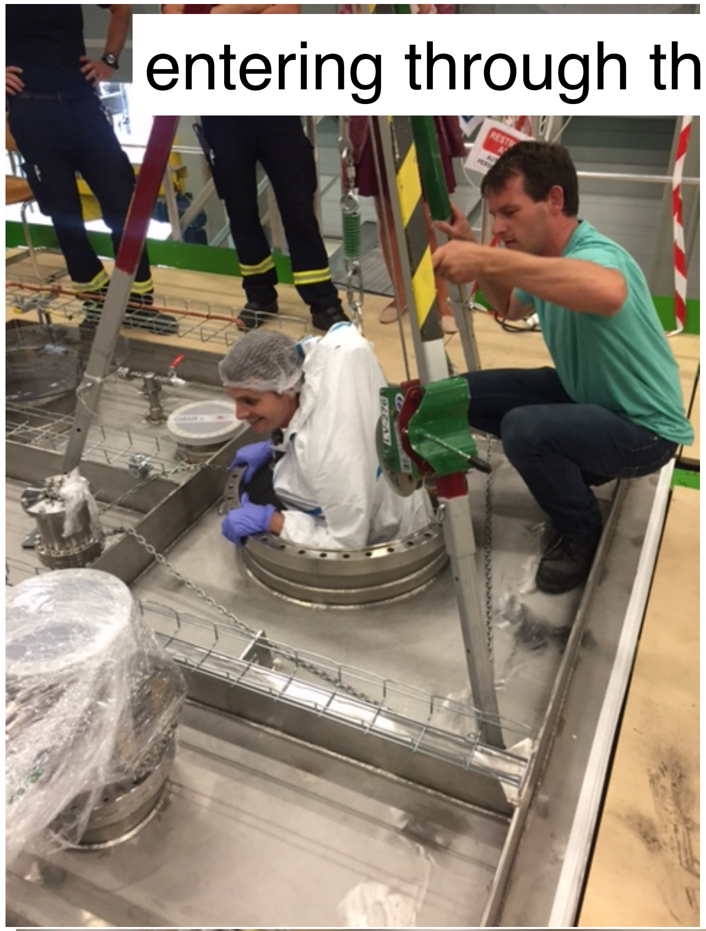
CRP: adjustable to LAr level

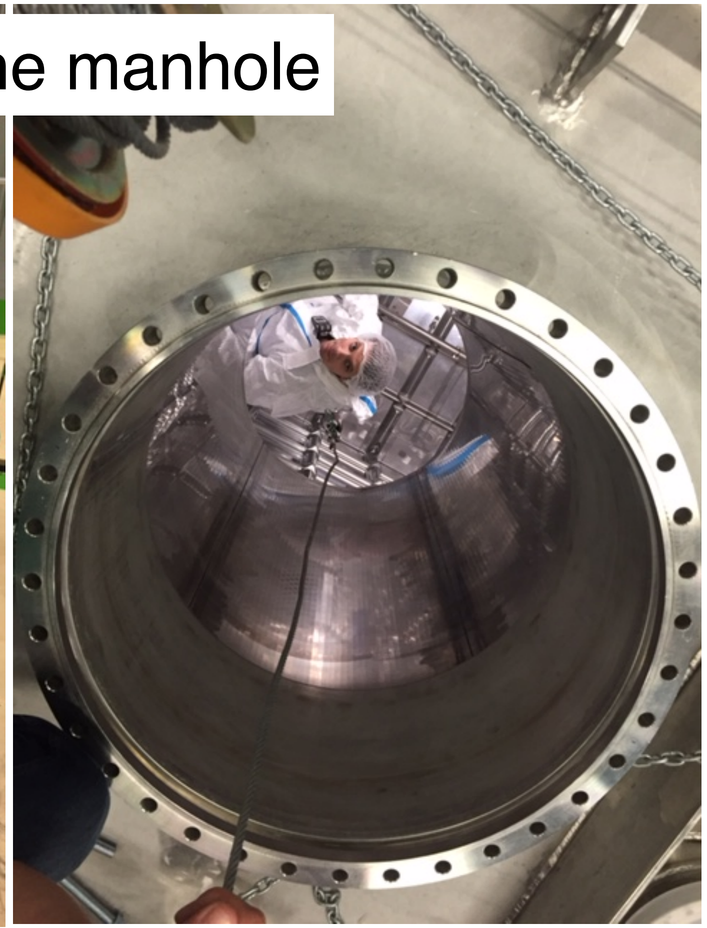


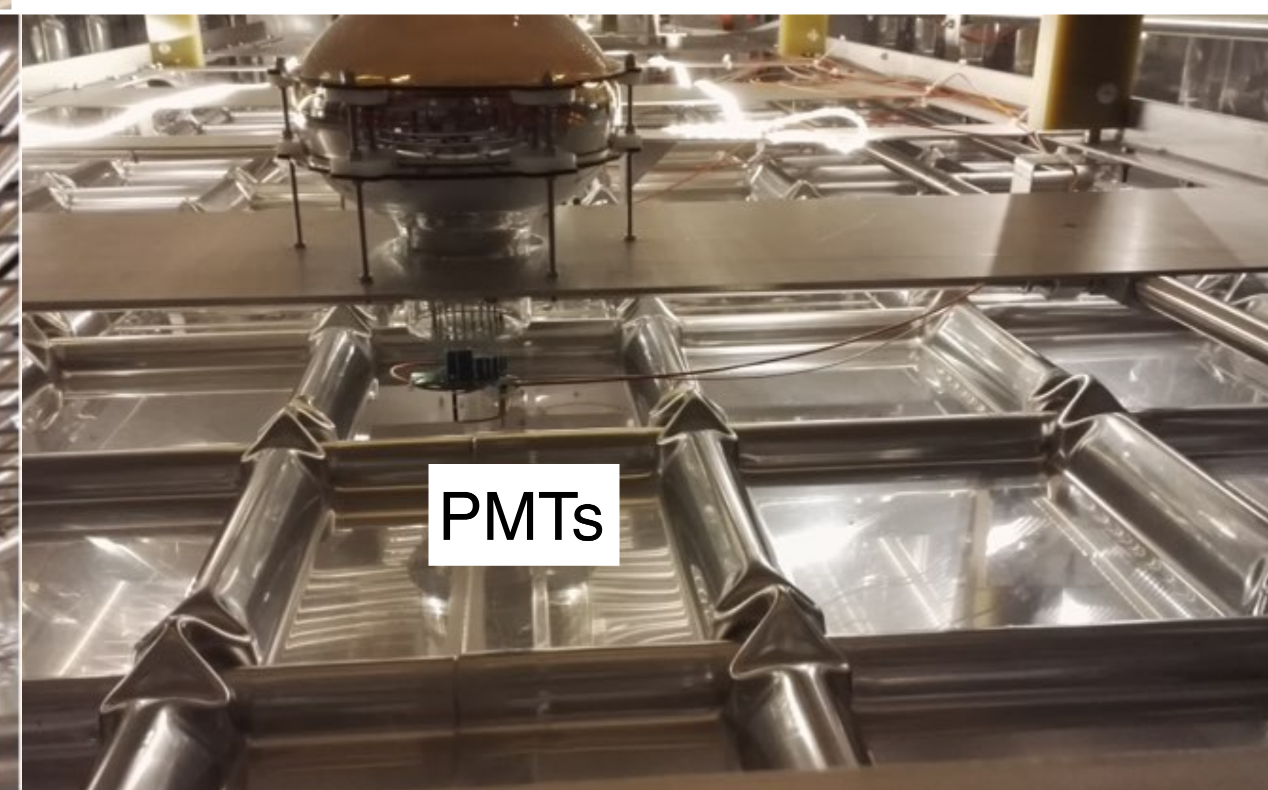


suspended by 3 ropes coupled to motors on top-cap. Precision of motors <u>100 um over 4 cm</u>.
8 capacitive level meters readout the LAr level with similar precision

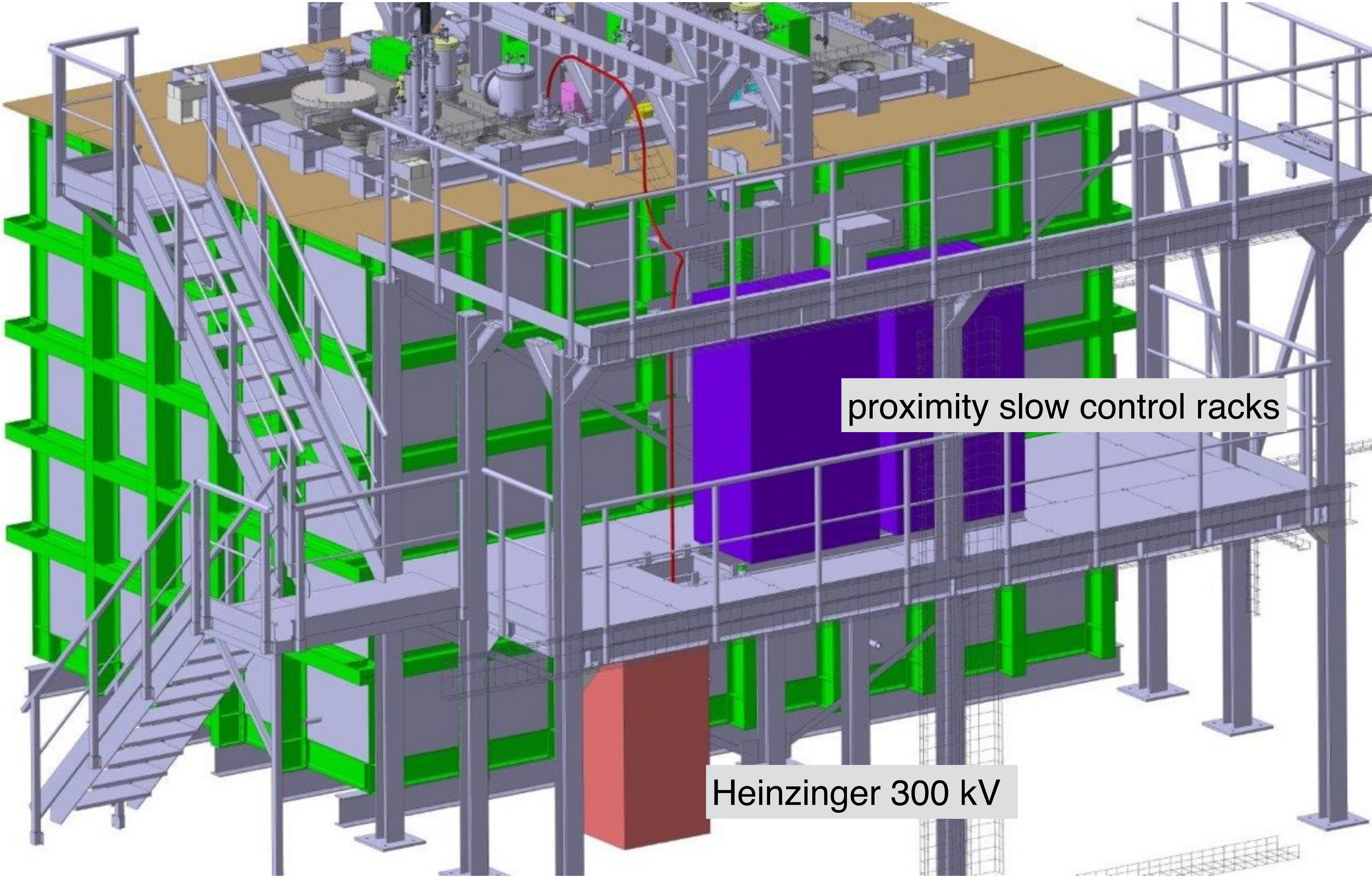
Inspection and measurements inside cryostat







Experimental layout in final configuration

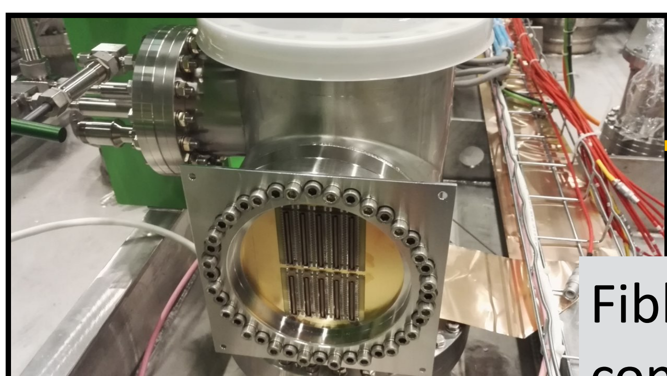


DAQ and computing farm

10 Gb CERN Network for computing center (EOS, etc ..)

~10 m

~30 m



digitised signal from uTCA on signal feedthroughs

Fibber connection from uCTA to proximity rack

proximity DAQ rack

Fibber connection :
- 2 x 10Gb rate : link aggregation in between 2 optical switches

computing farm

DAQ and computing farm

Proximity rack composed of :

- event-builder (46 TB storage server)
- 1 switch HP Procurve 6600 24xg → 2x10Gb
- White rabbit unit
- Cosmic counters crate/computer
- 4 x microTCA crate linked by fibber channel

10 Gb CERN Network for computing center (EOS, etc ..)

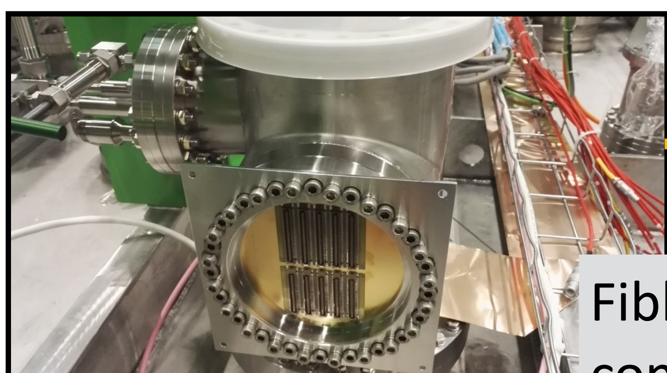
~30 m

Fibber connection :
- 2 x 10Gb rate : link aggregation in betwee
switche

Farm rack composed of :

- 16 cpu modules with 16 cores inside
- 4 storages servers : total space 192TB
- 1 switch HP Procurve 6600 24xg → 2 x 10 Gb
- 1 switch HP Procurve 6600 48g 4 xg

computing farm



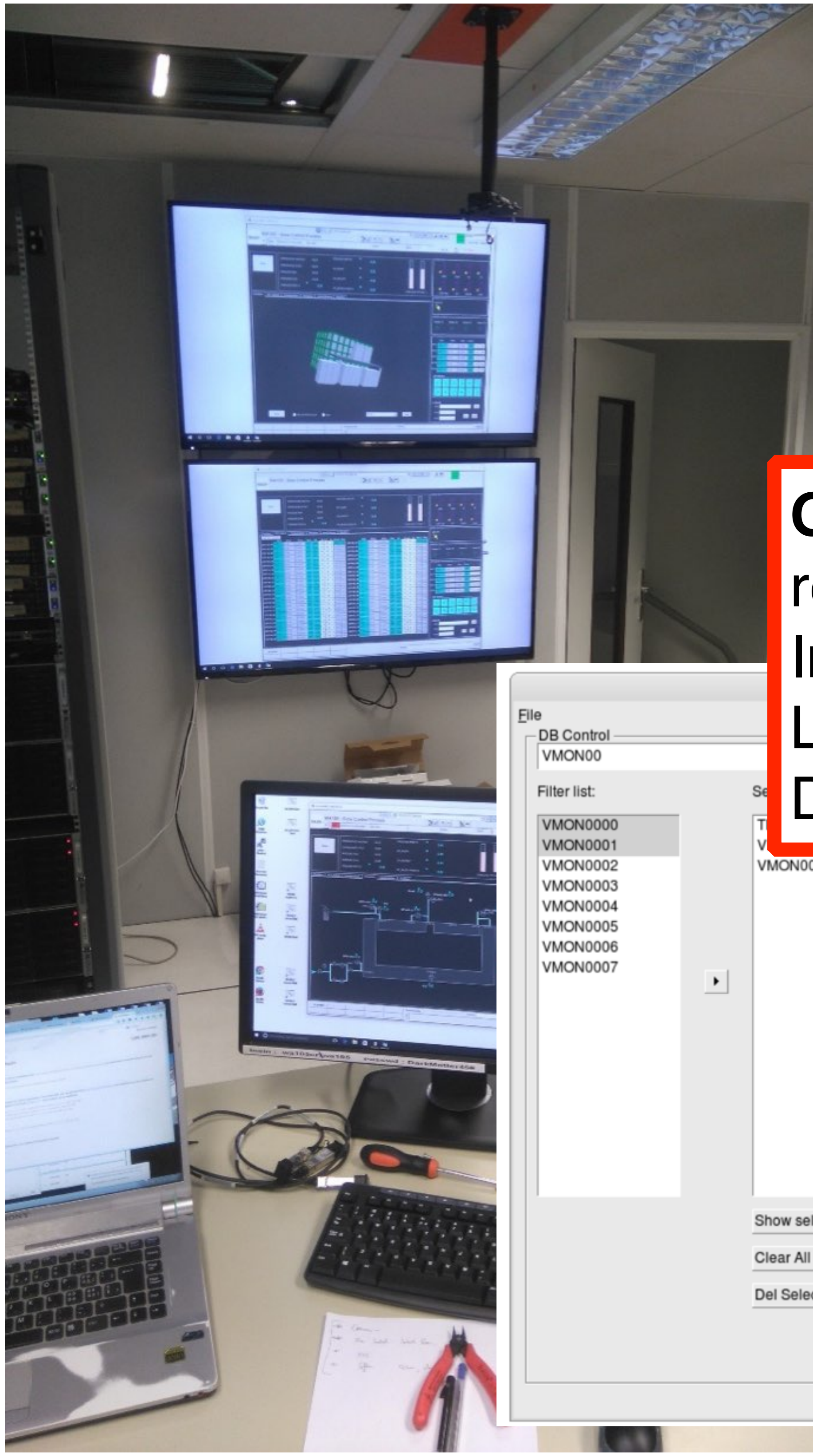
digitised signal fr
uTCA on signal
feedthroughs

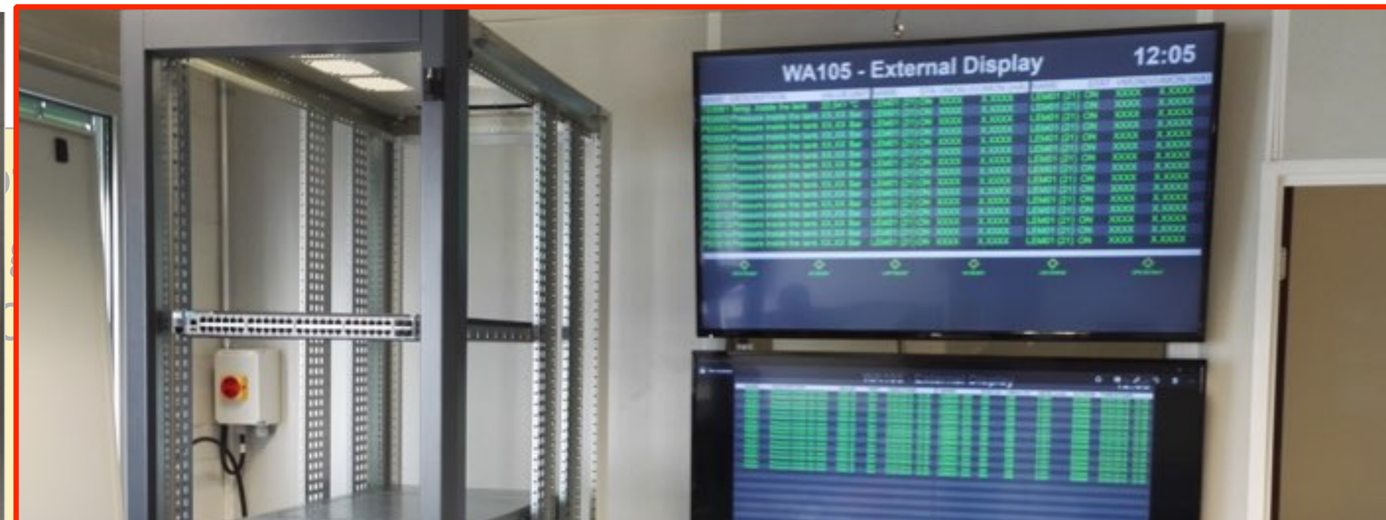
~10 m

Fibber connection from uCTA to proximity rack

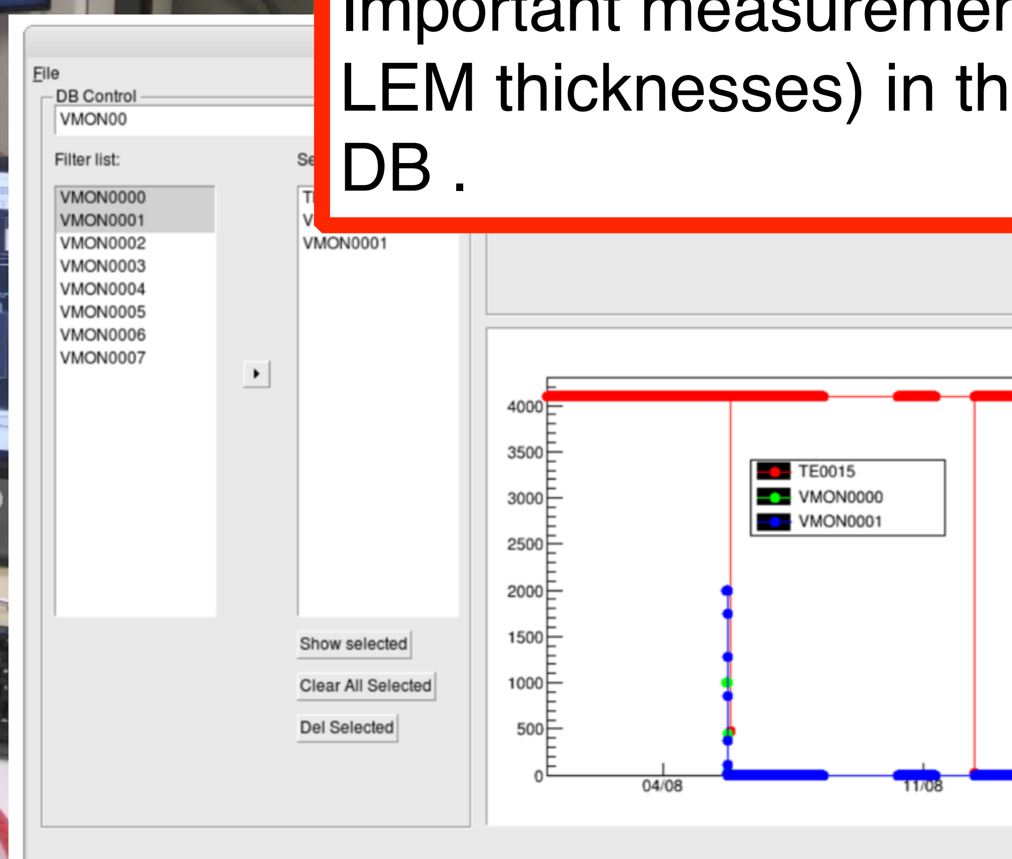
proximity DAQ rack

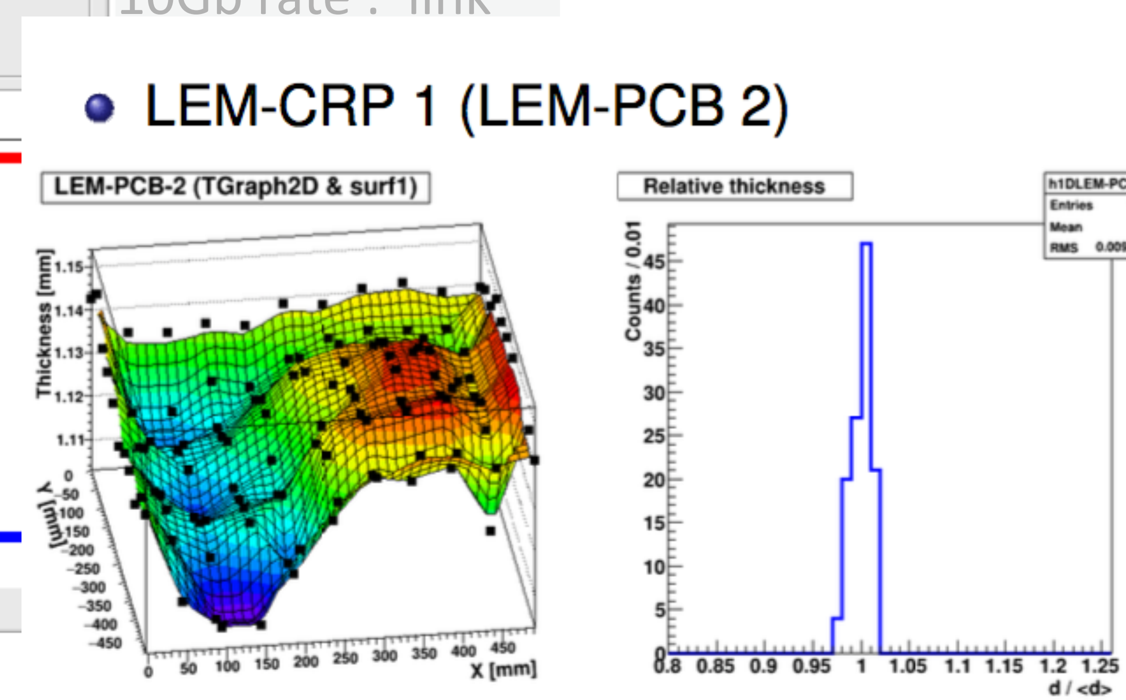
Control room, data base and monitoring



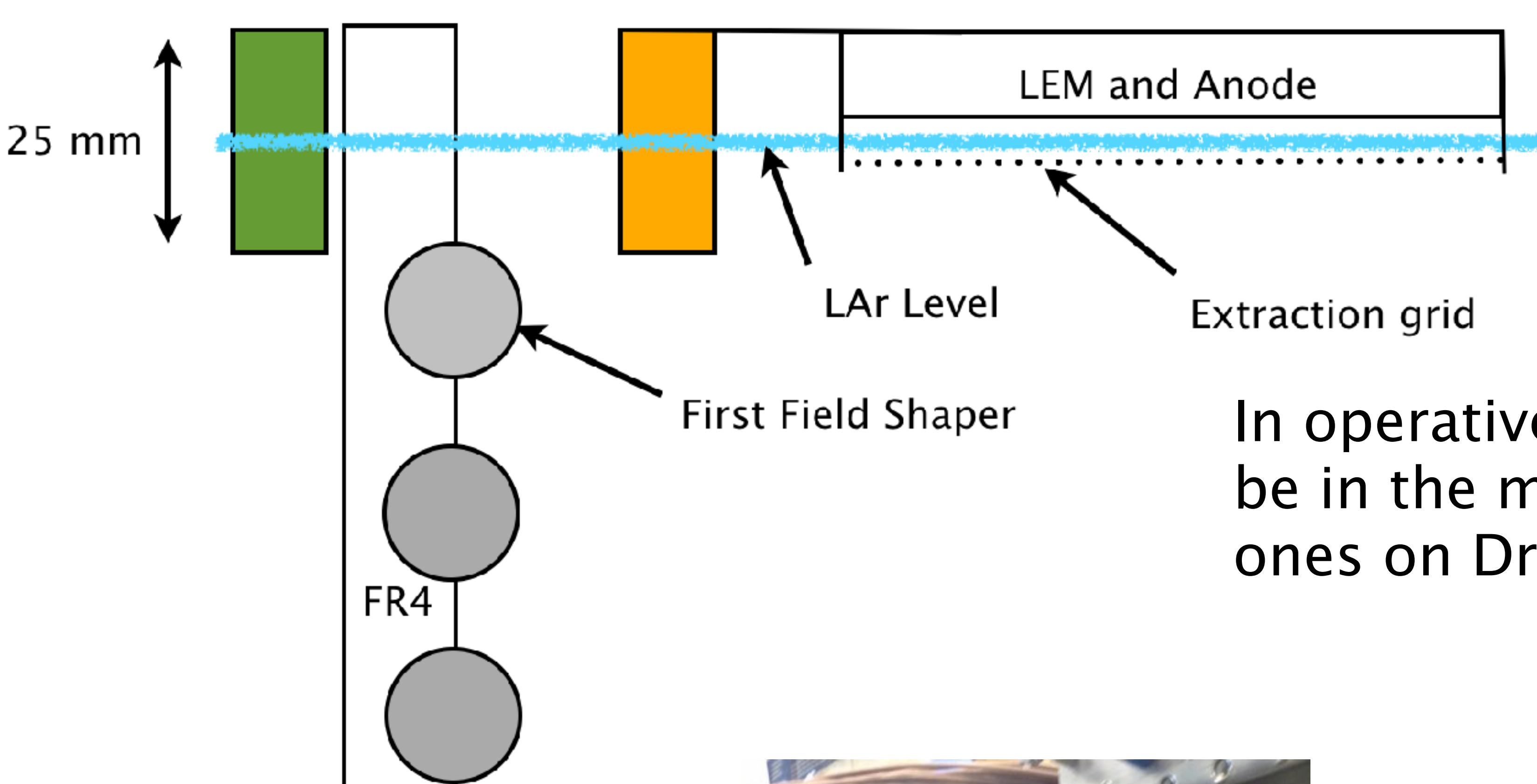


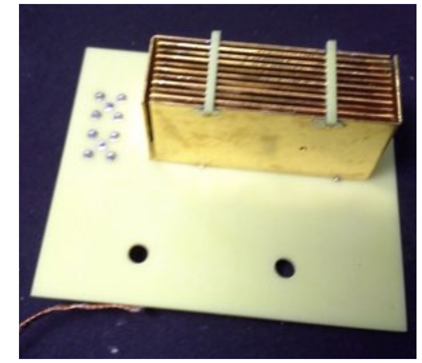
Getting prepared for data taking. Data base is setup, recording values of e.g temperatures and high voltages. Important measurements taken during assembly (such as LEM thicknesses) in the process of being incorporated in DB .



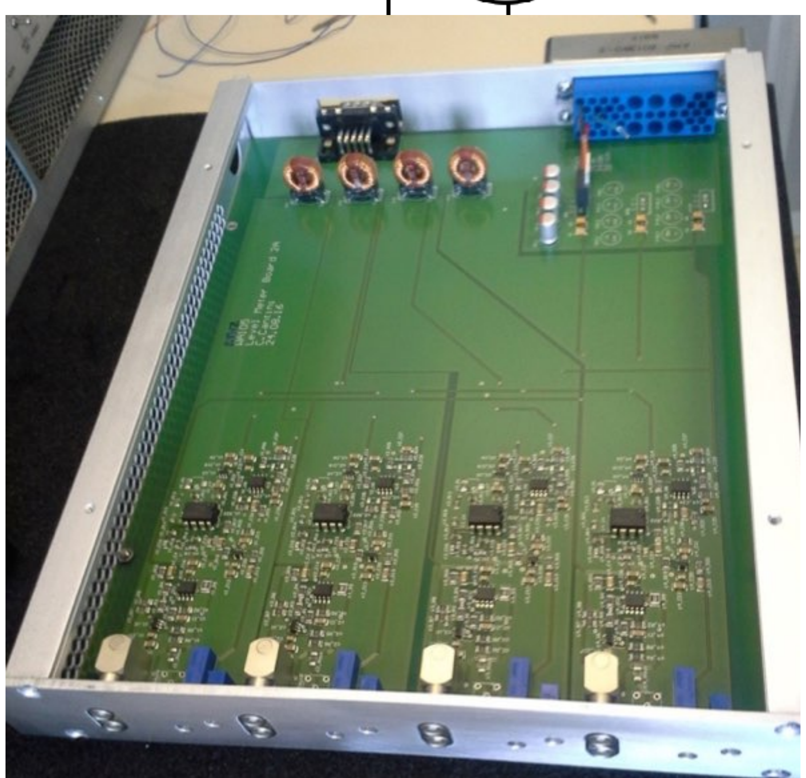


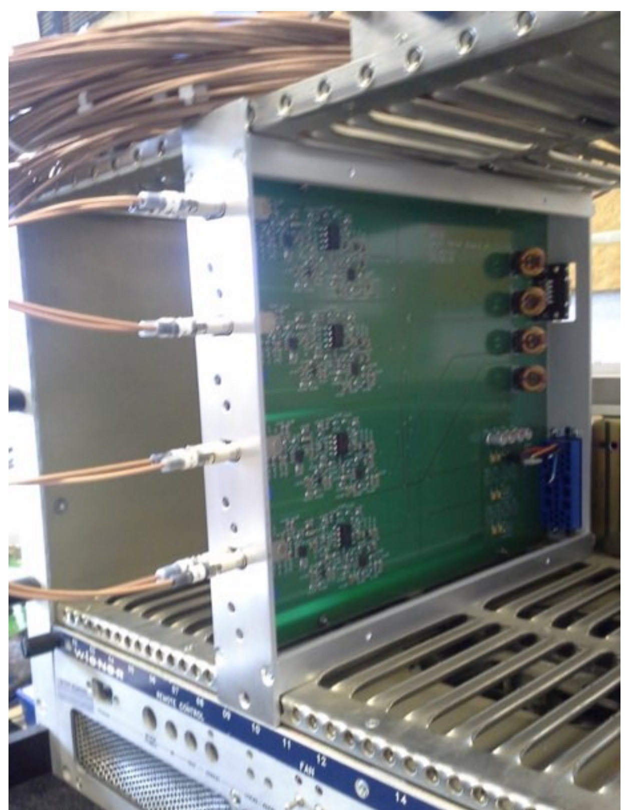
Slow control: level meters and pulser





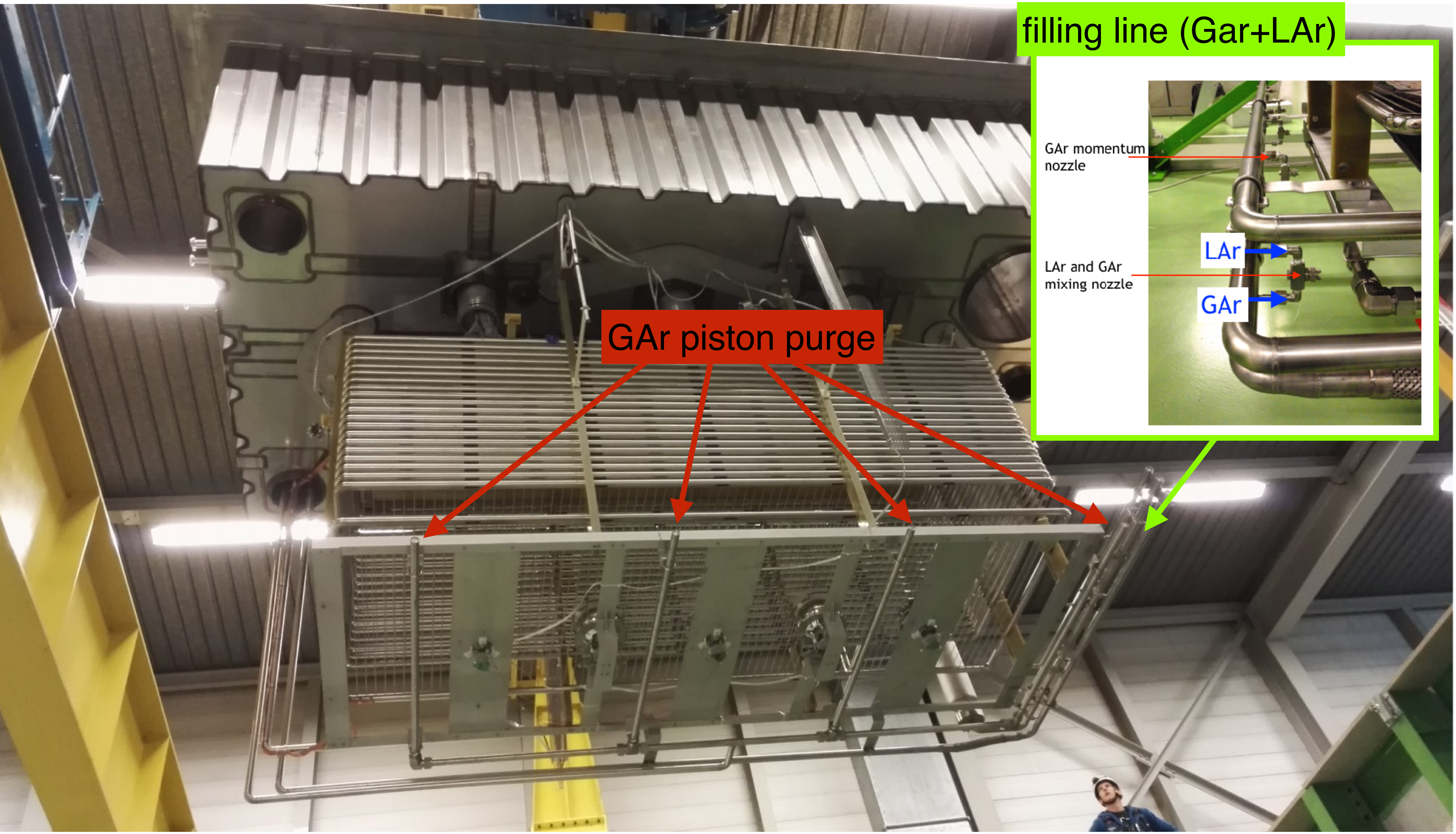
In operative condition the LAr level will be in the middle of both level meters, the ones on Drift Cage and the ones on CRP.



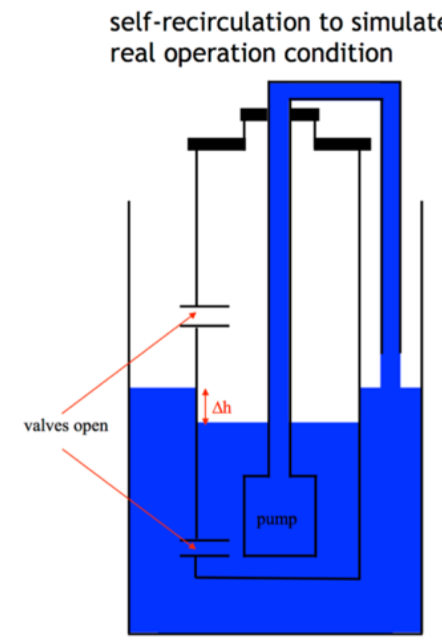


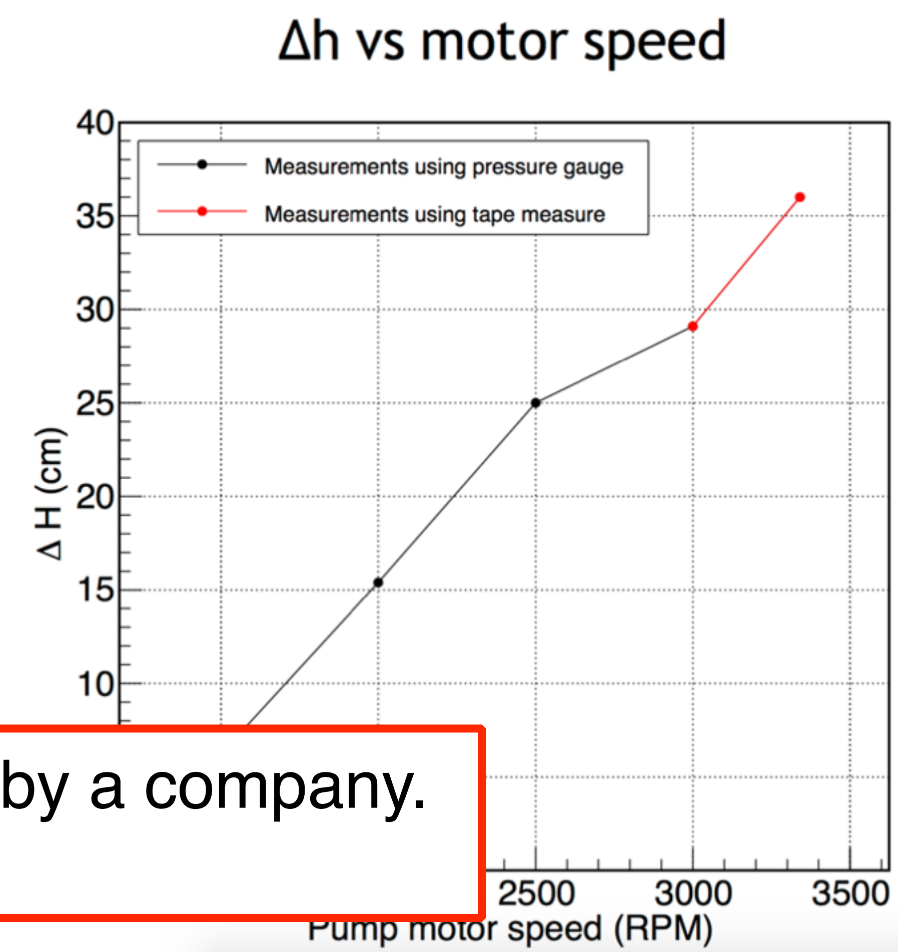
- A new NIM design has been done with:
  - 4 Channels
  - improved 0-10 V interface to NI Racks
  - improved filters on voltage rails and output
- 5 Boards NIM size are in production
- The assembly of the entire system will take place in the next 2 weeks, including calibration.
- **Aso be a test bench for the 6x6x6 Level meter system**

Cryogenics-internal piping



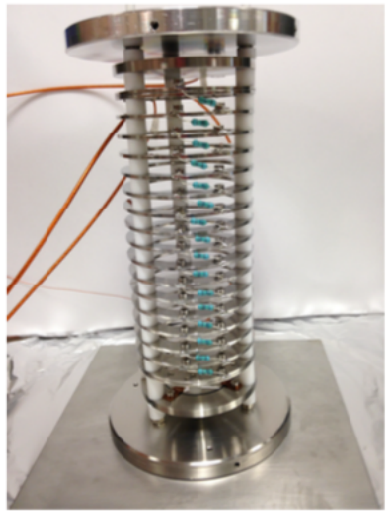
Cryogenics-pump tower



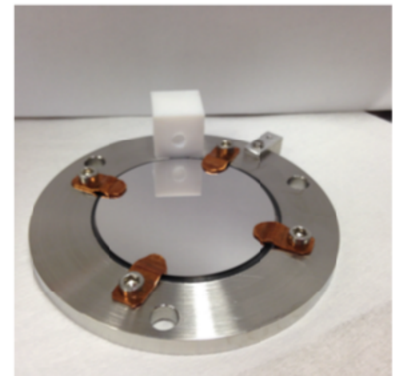


successful test of the entire pump tower was performed by a company.
The pump tower is now installed in the croystat.

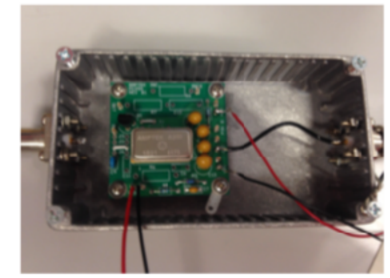
Purity monitor

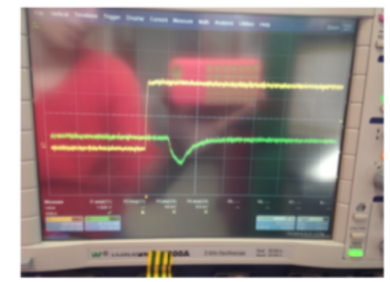


1 Purity Monitor built, tested HV at room temperature

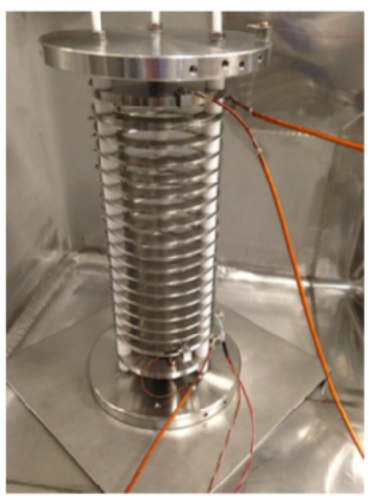


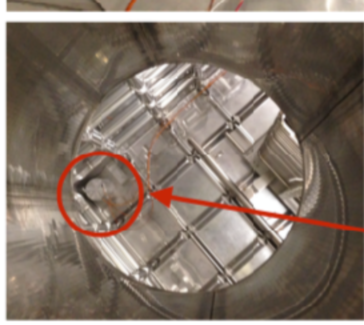
2 Tested PHC for no peeling in LAr

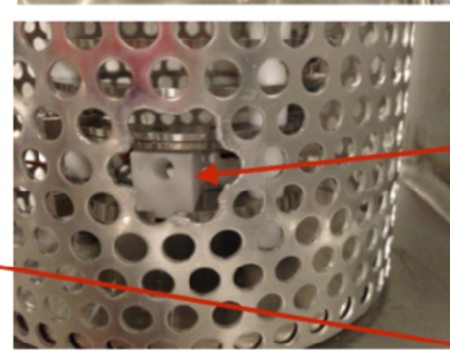




3 Charge amplifier tested







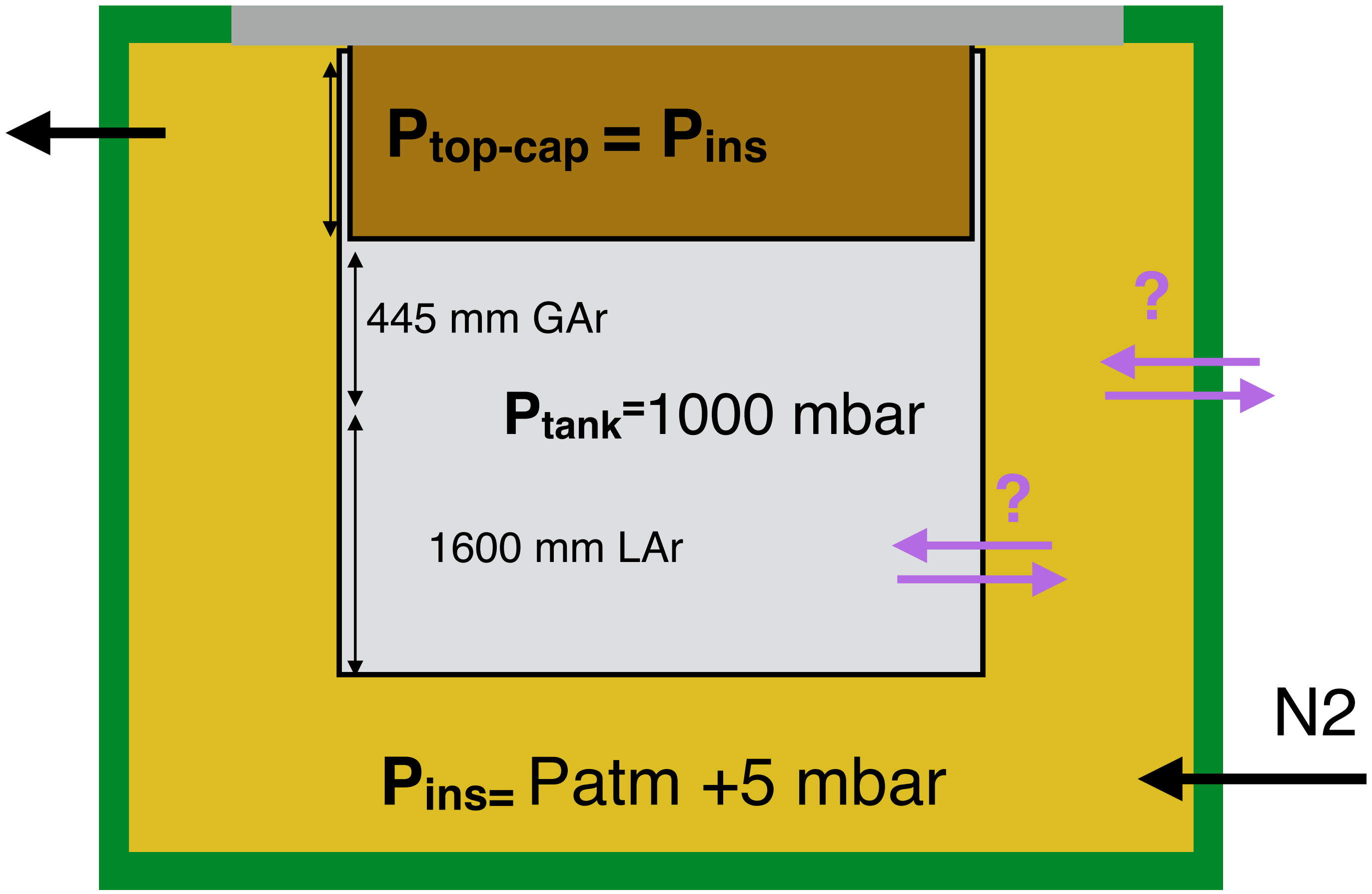
Optical fiber to install

PrM, view from top of manhole

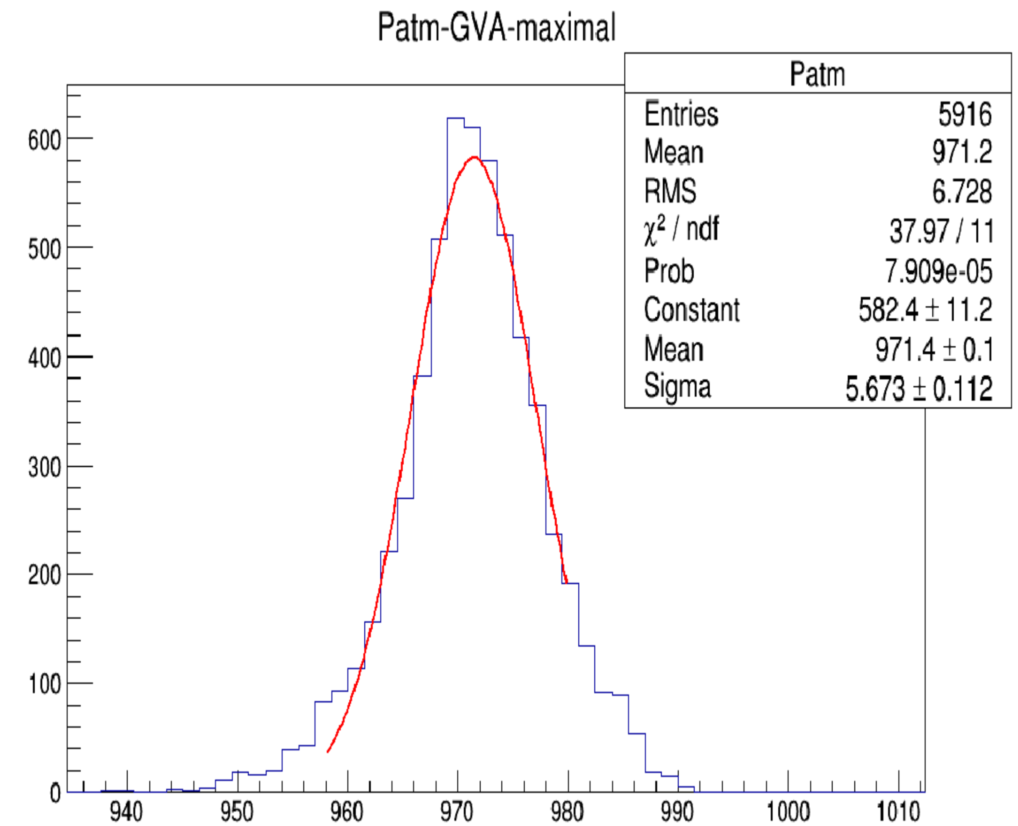
4

- PrM successfully installed in WA105
- Still to install optical fibre (1st week of October)
- Test planned when filling starts

The cryostat - leak checking



940<P_{atm}<990 mbar.



Want to keep Ptank constant at 1000 mbar independent from atmospheric pressure variations. Important to check tightness of the entire cryostat:

1. No leak from insulation space to inner tank above 1e-9 mbar l/s (to guaranty Ar purity)
2. leak-rate from atm to insulation space low enough to keep Pins= Patm +5 mbar