The WA105-3x1x1 m3 dual phase LAr-TPC demonstrator

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on behalf of WA105

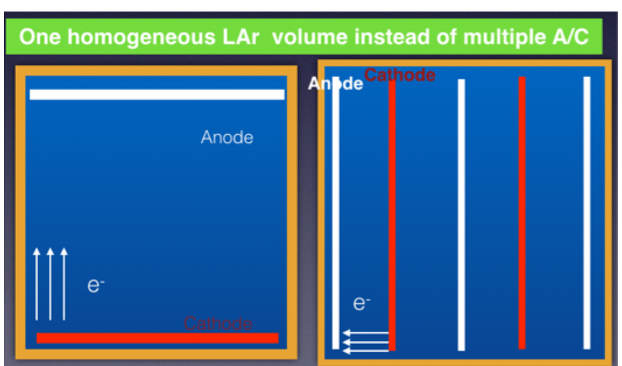
ETH

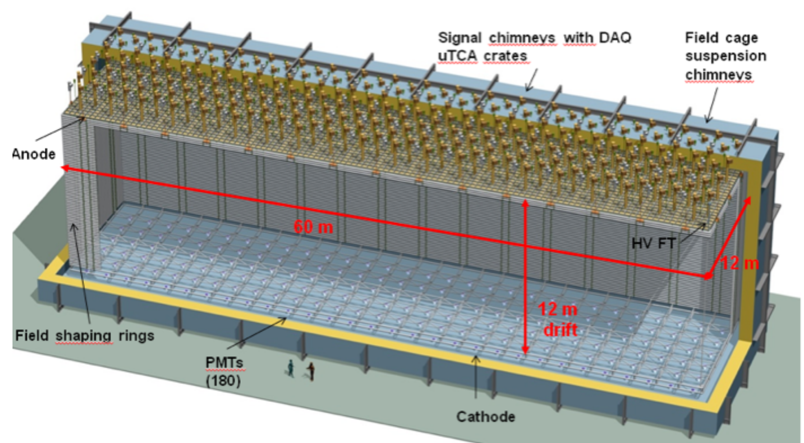
ICHEP2016CHICAGO

DUNE Far detector R&D

Large scale LAr TPC for LB neutrino oscillation physics, astrophysics, and nucleon decay search (GUT physics). (See talk Elizabeth Worcester).

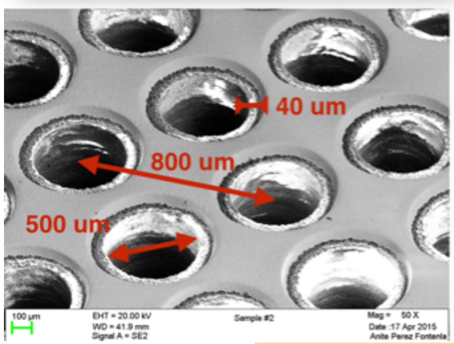
- Single cryo-tank based on industrial LNG solution to house O(10) kton of LAr mass. Envisaged options for single and dual phase TPCs. (See talk Alexander Himmel).
- R&D for double-phase for charge readout with amplification yields
  - **<u>One drift distance</u> (bottom to top) for cost effective large scale detectors**
  - **<u>Low energy detection thresholds</u> as needed for physics**
  - **High reconstruction efficiency thanks to <u>collection only readouts</u> planes. Maximise active LAr volume whilst minimising the number of channels.**
  - **<u>Robustness of signal-</u>to-noise with respect to environmental sources thanks to tunable amplification.**
  - **3x3 m2 PCB based modular charge readout plane (no extensive wiring) allow for easy industrial procurement, off site assembly and shipping.**

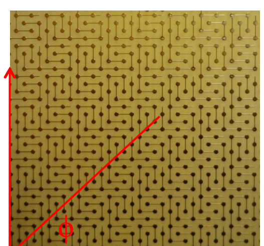




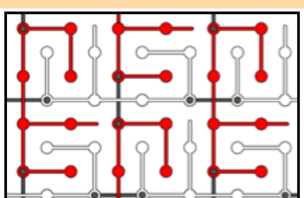
Outcome of 10 years of R&D

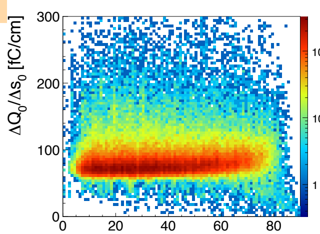
10x10cm^2: LEM/anode R&D



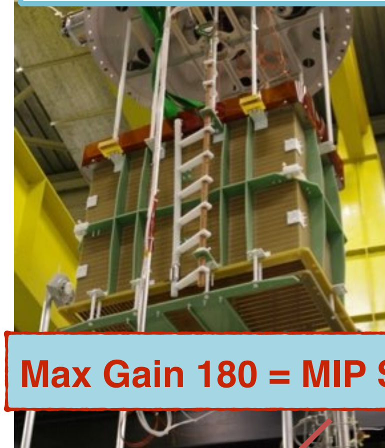


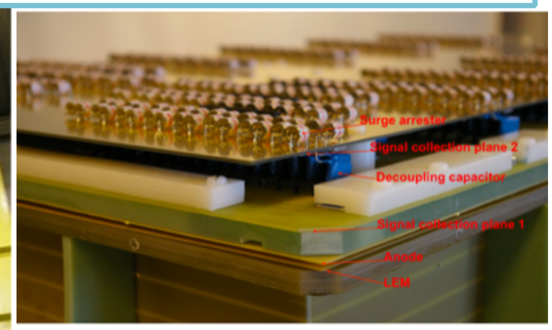
dC/dl ~ 120 pF/m



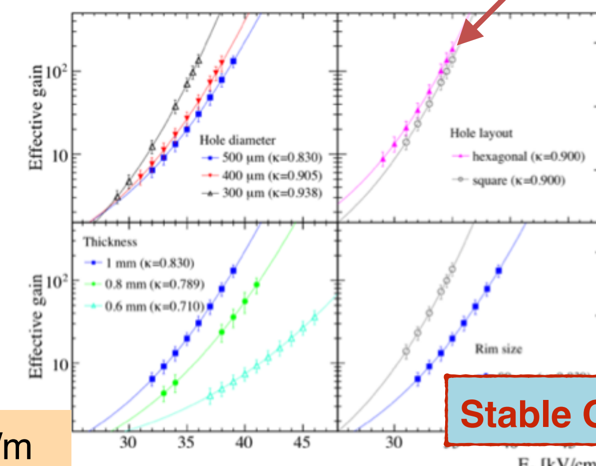


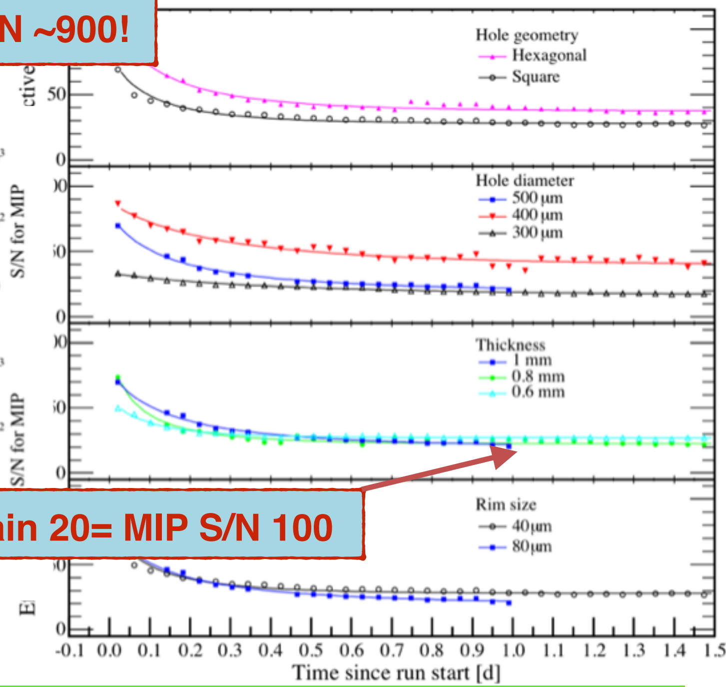
40x80cm^2: stable operation of large area readouts





Max Gain 180 = MIP S/N ~900!



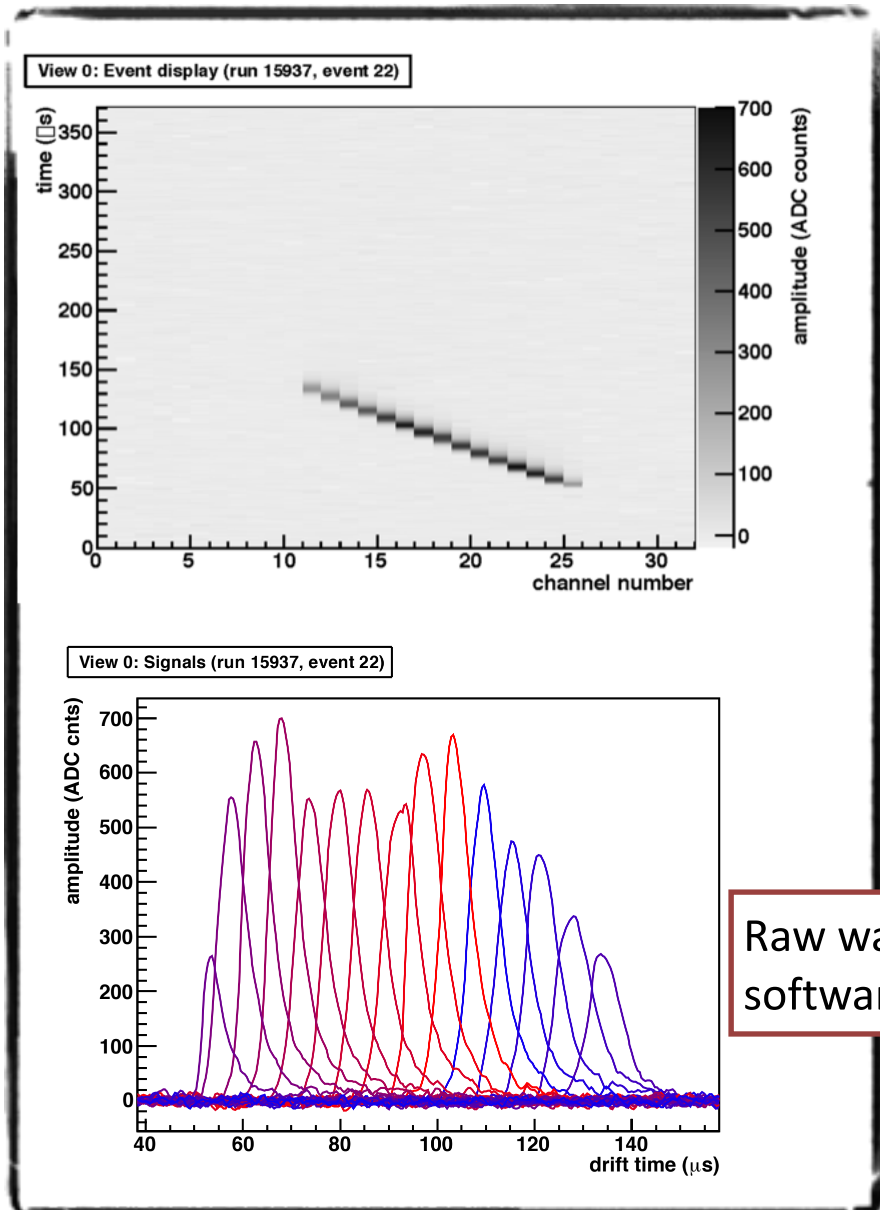


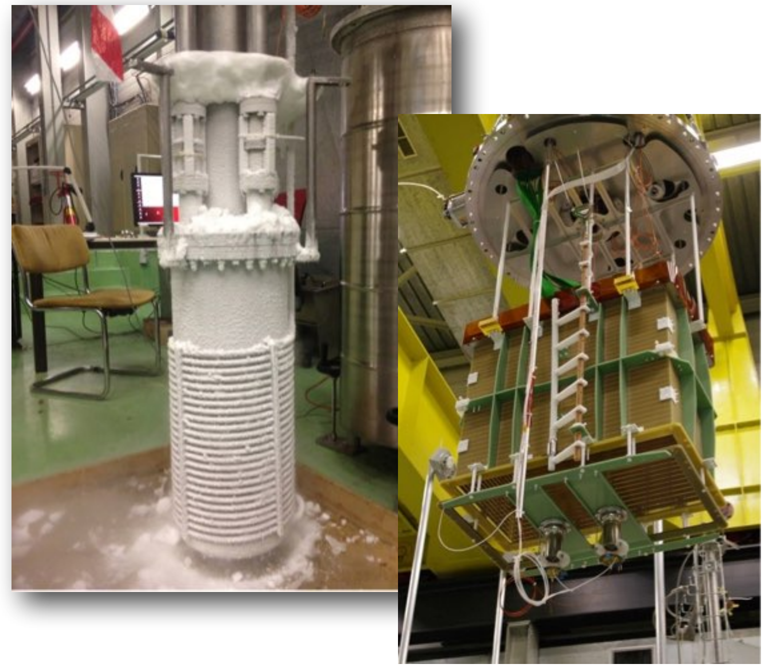
Stable Gain 20= MIP S/N 100

Operating with amplification of about a factor 20

Dual phase readout

WA105





Raw waveform no software filtering

real events on 250 liter LAr dual phase TPC

literature

NIM A617 (2010) p188-192

NIM A641 (2011) p 48-57

JINST 7 (2012) P08026

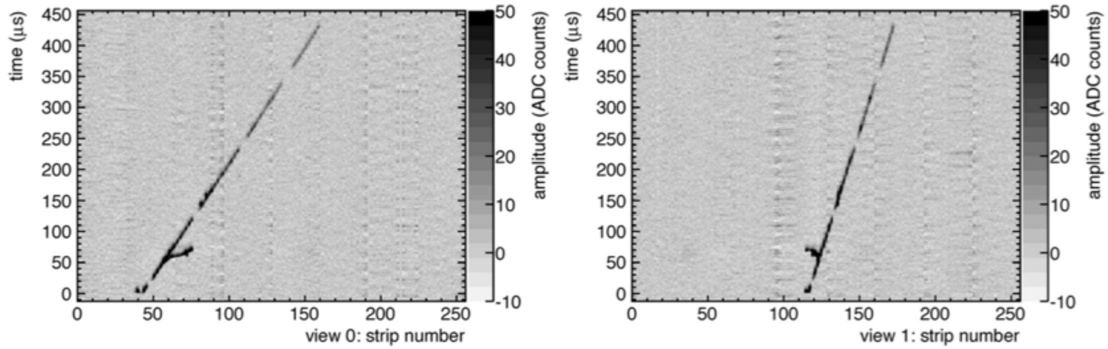
JINST 8 (2013) P04012

JINST 9 (2014) P03017

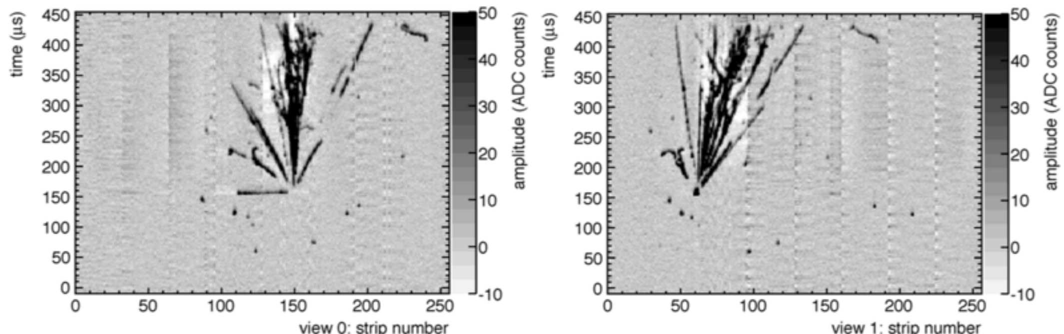
JINST 10 (2015) P03017

More events

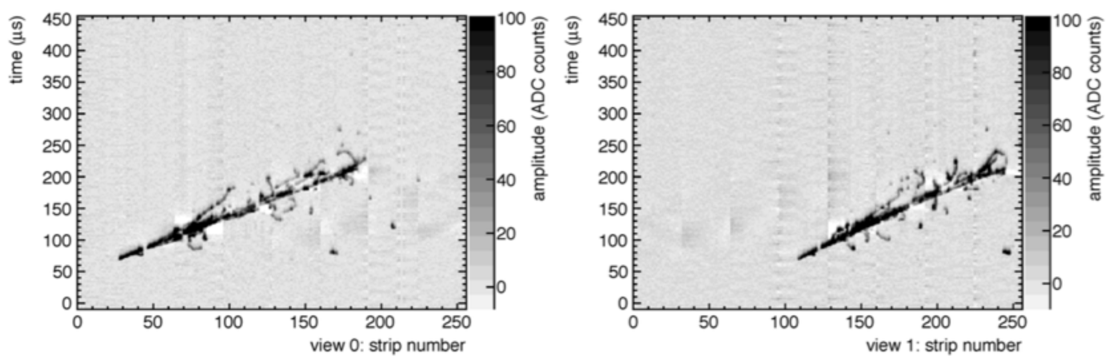
cosmic muon



HADR shower



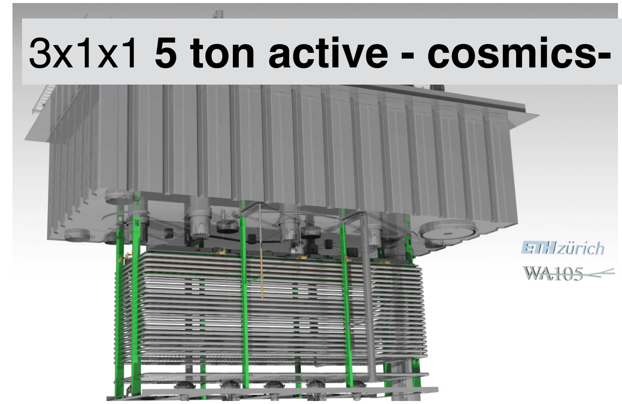
EM shower

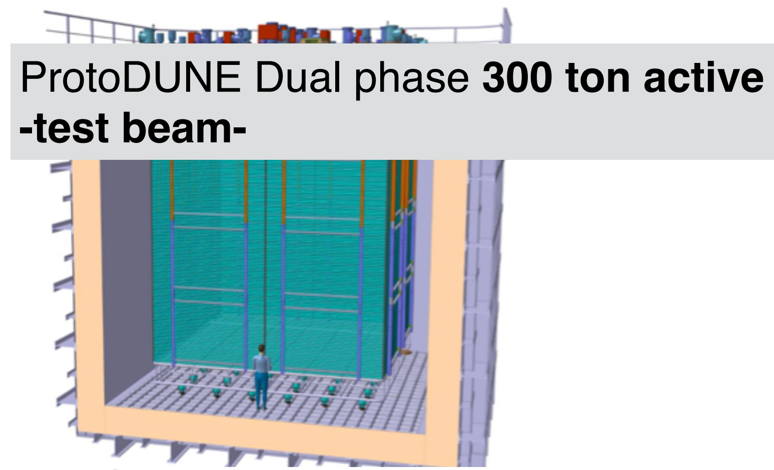


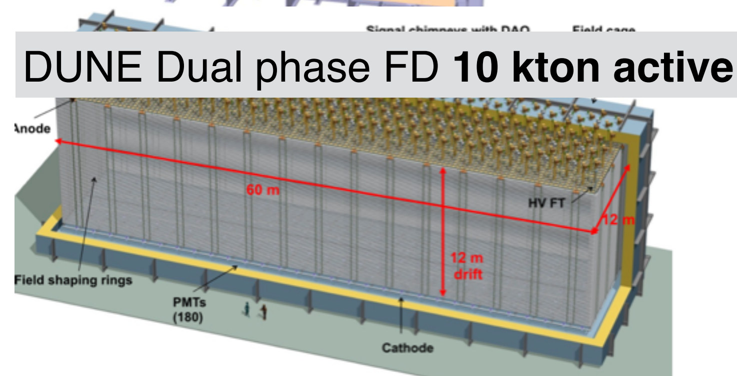
From R&D to large scale

size

time



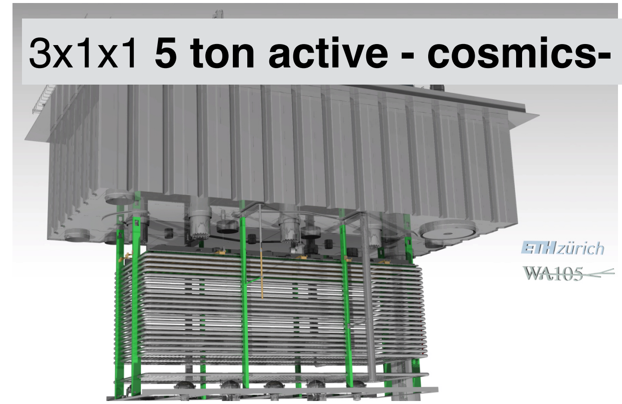




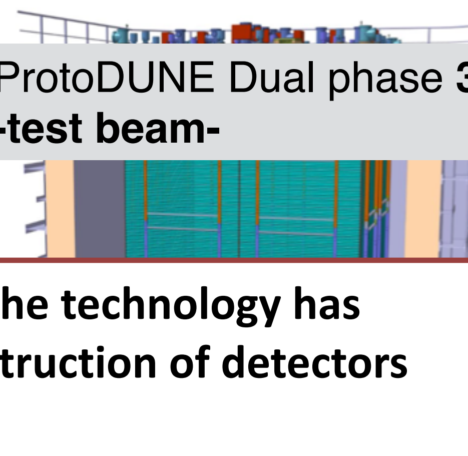
From R&D to large scale

size
time


CERN b. 182

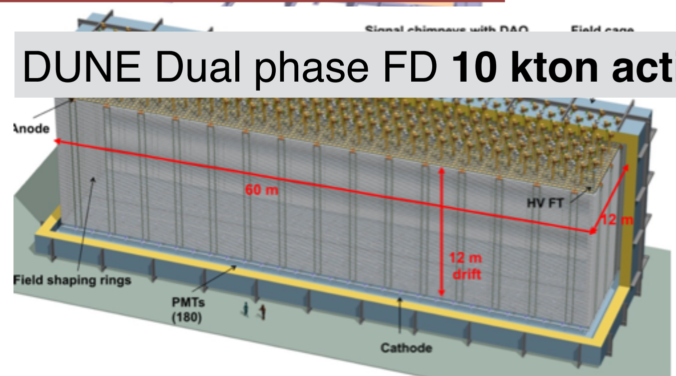

3x1x1 **5 ton active - cosmics-**


CERN EHN1


ProtoDUNE Dual phase **300 ton active -test beam-**

Thanks to the CERN Neutrino platform the technology has evolved from the R&D stage to the construction of detectors with relevant size for neutrino physics.


SURF SD



DUNE Dual phase FD **10 kton active**

ETH

The WA105 collaboration

WA105

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

DUNE

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

UNIVERSITY OF JYVÄSKYLÄ

UCL

Fermilab

LPNHE PARIS

ipnl

CERN

KEK
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

APC

IN2P3
INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE ET DE PHYSIQUE DES PARTICULES

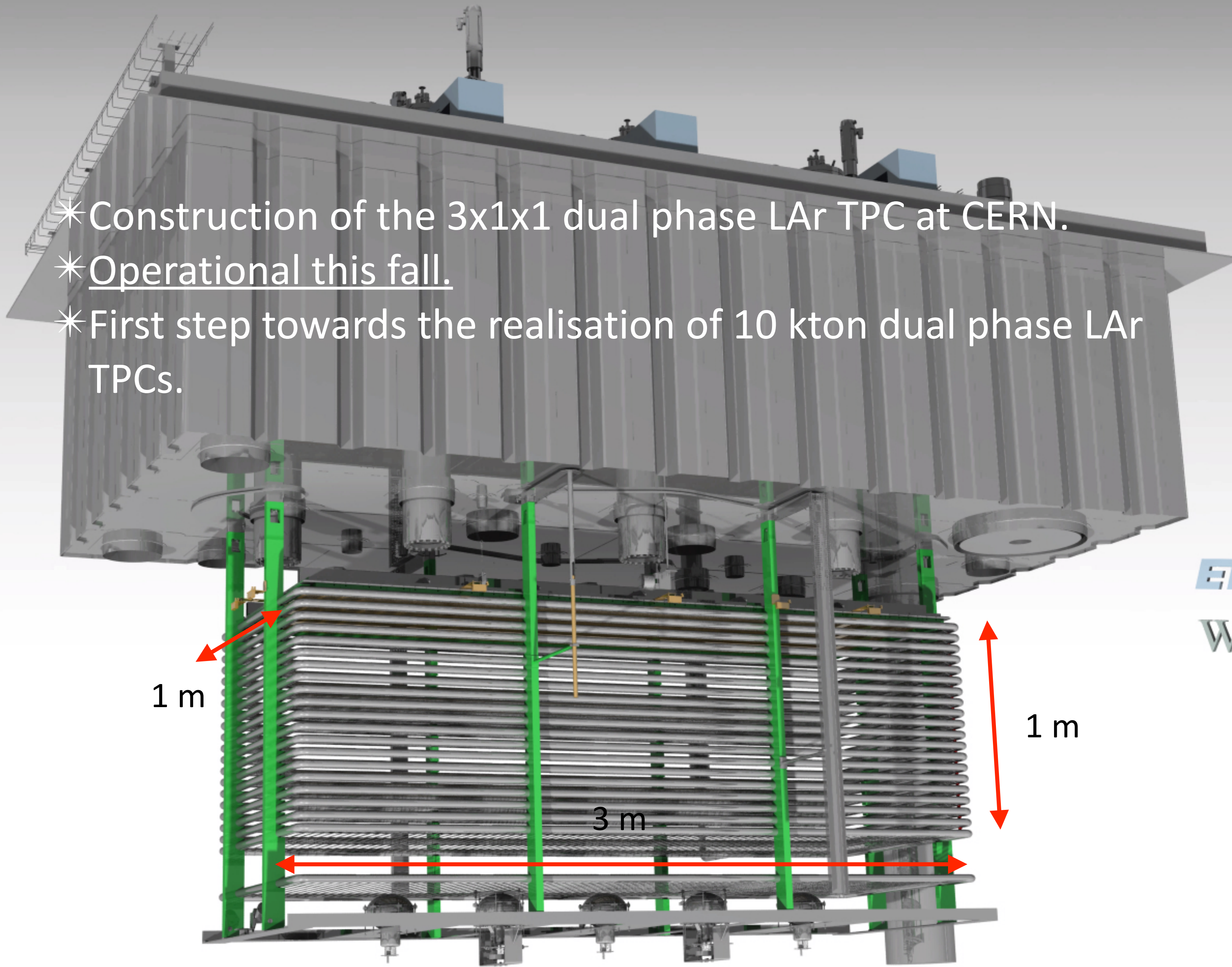
cea SACLAY

IFIN-HH

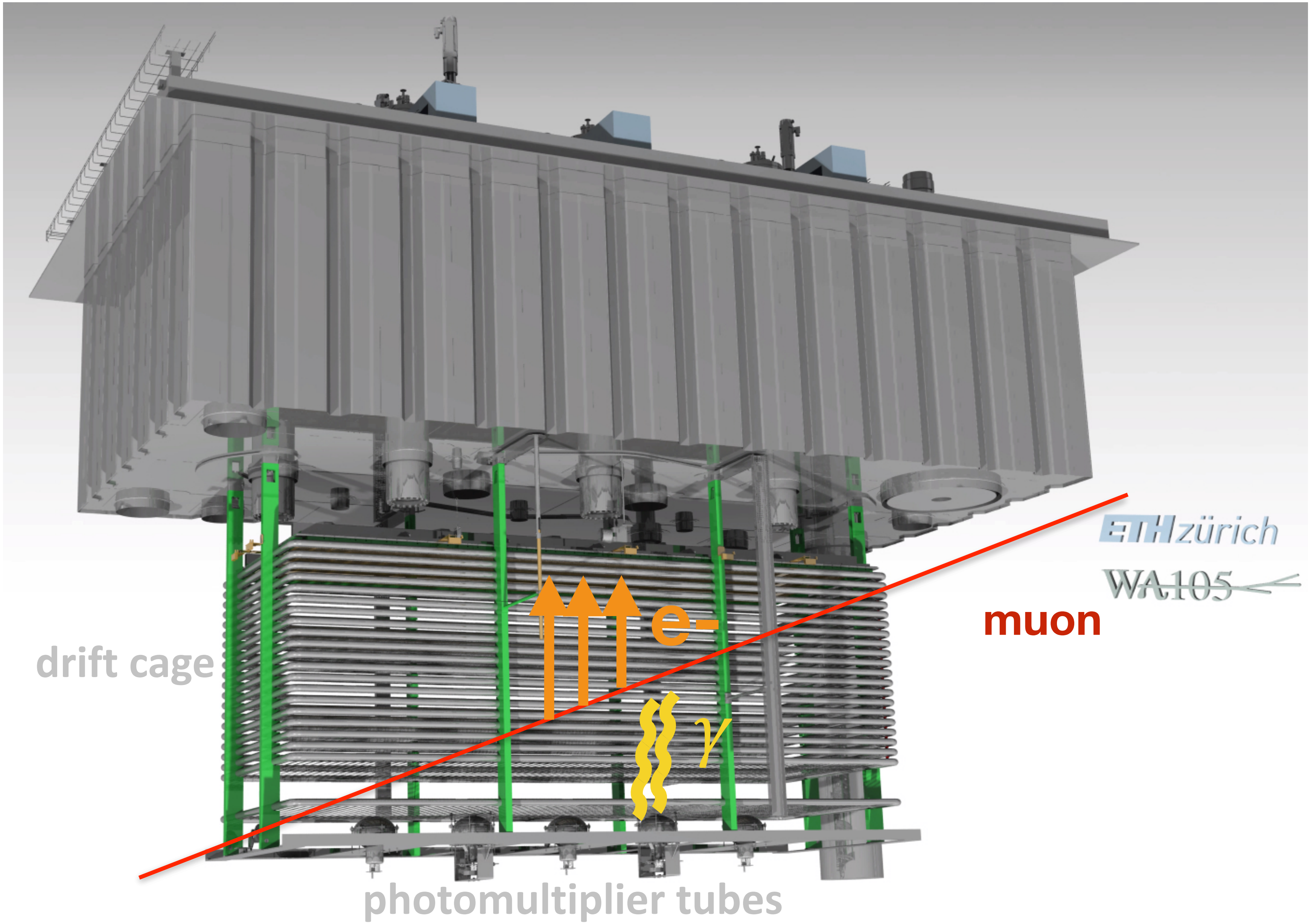
UBR

3m3 Dual phase LAr TPC

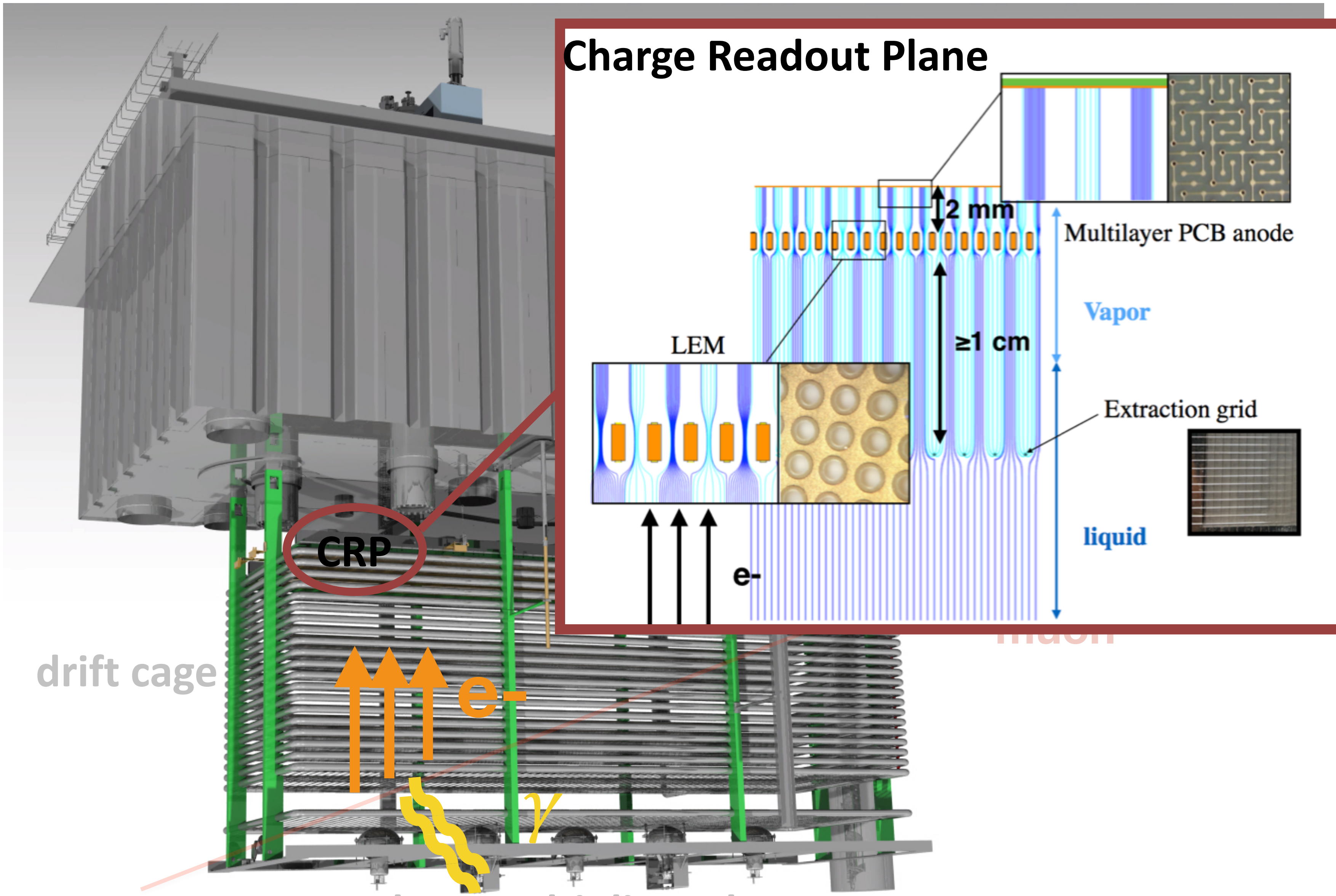
- Construction of the 3x1x1 dual phase LAr TPC at CERN.
- <u>Operational this fall.</u>
- First step towards the realisation of 10 kton dual phase LAr TPCs.



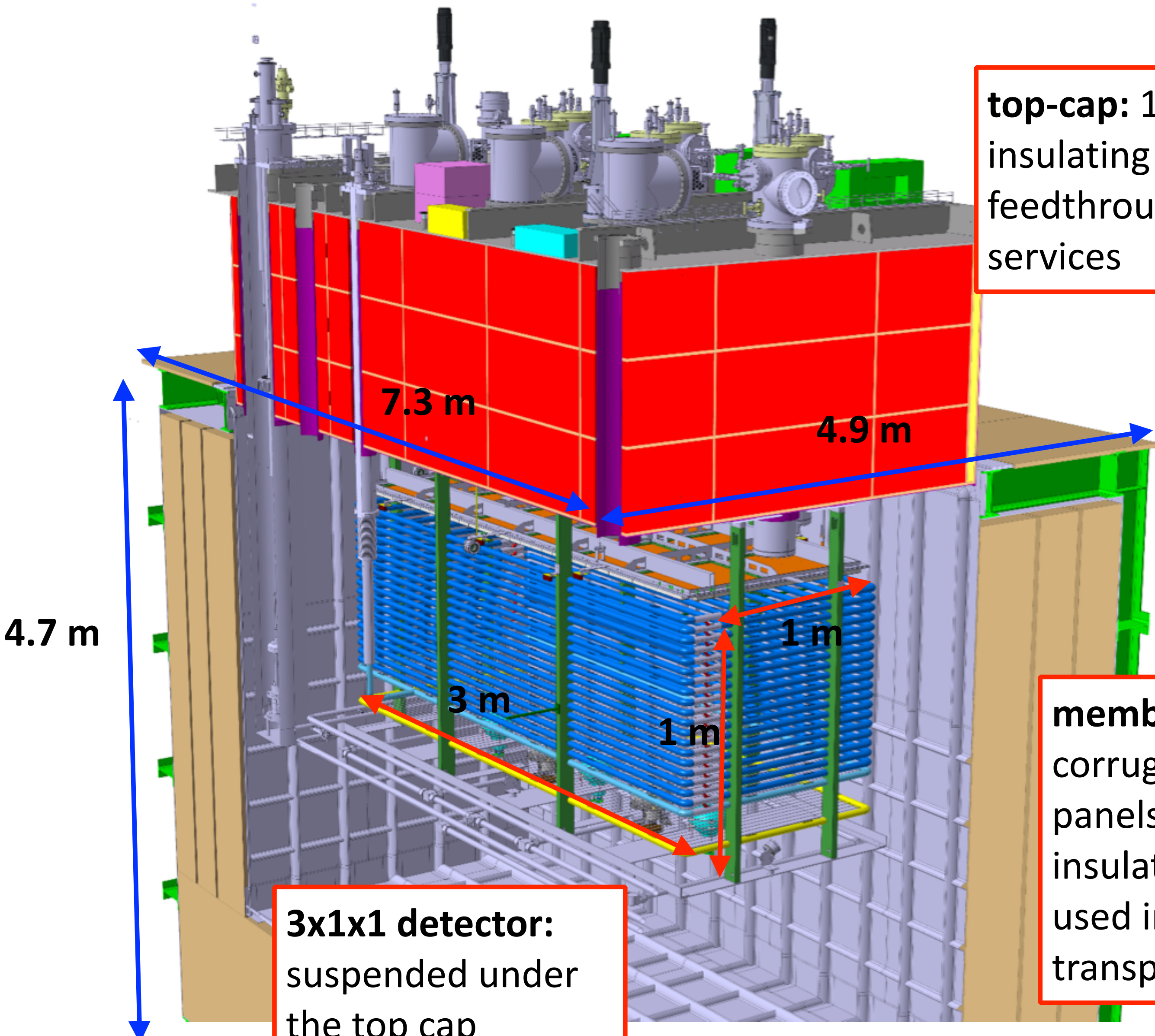
3m3 Dual phase LAr TPC



3m3 Dual phase LAr TPC



3x1x1 detector and cryostat

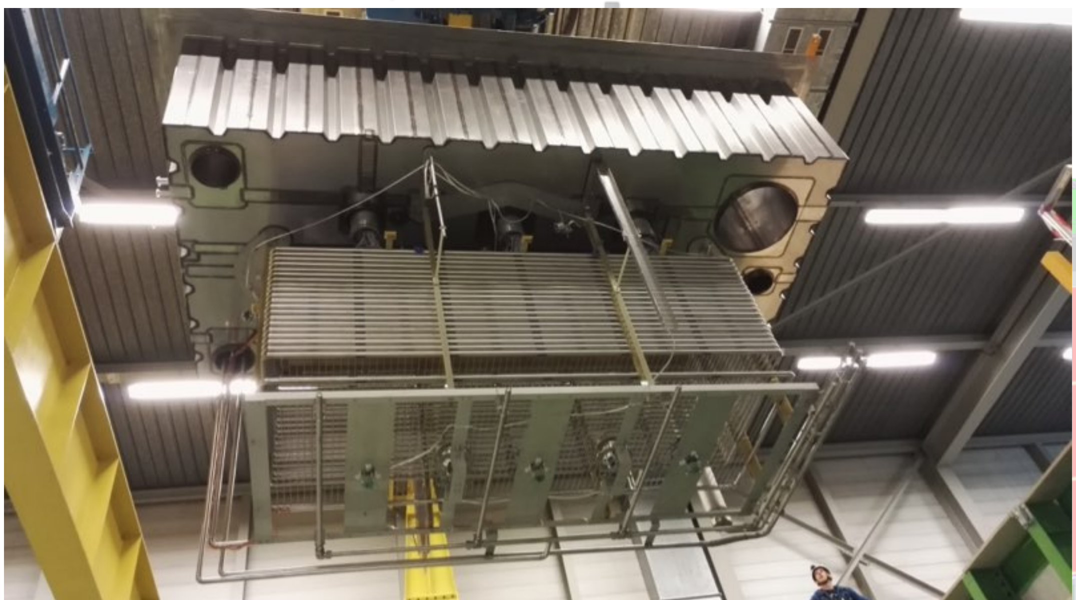


top-cap: 1.2 m passive insulating lid with all feedthroughs and services

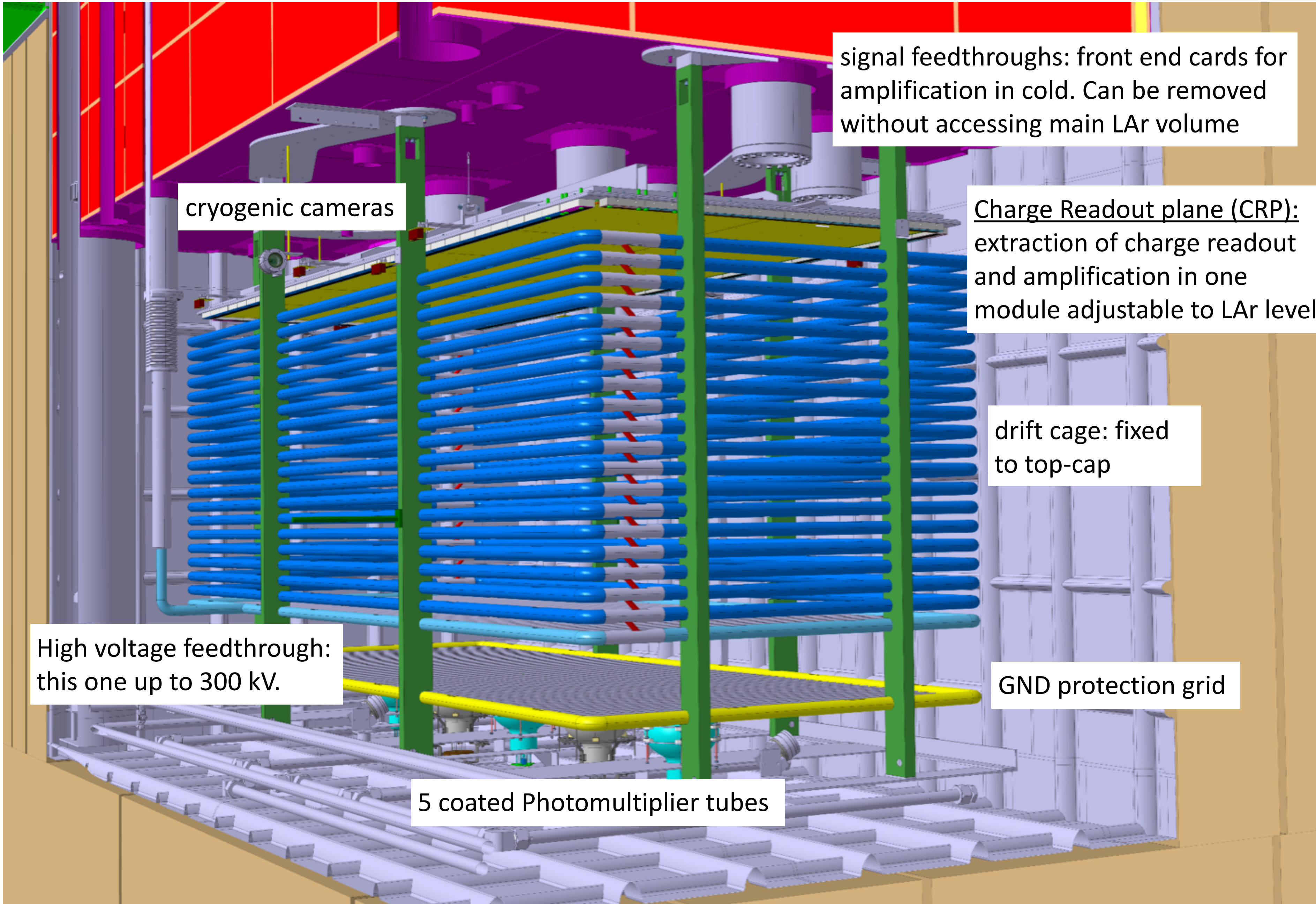
membrane cryostat: corrugated stainless steel panels and 1 m passive insulation. Technology used in LNG transportation.

3x1x1 detector: suspended under the top cap

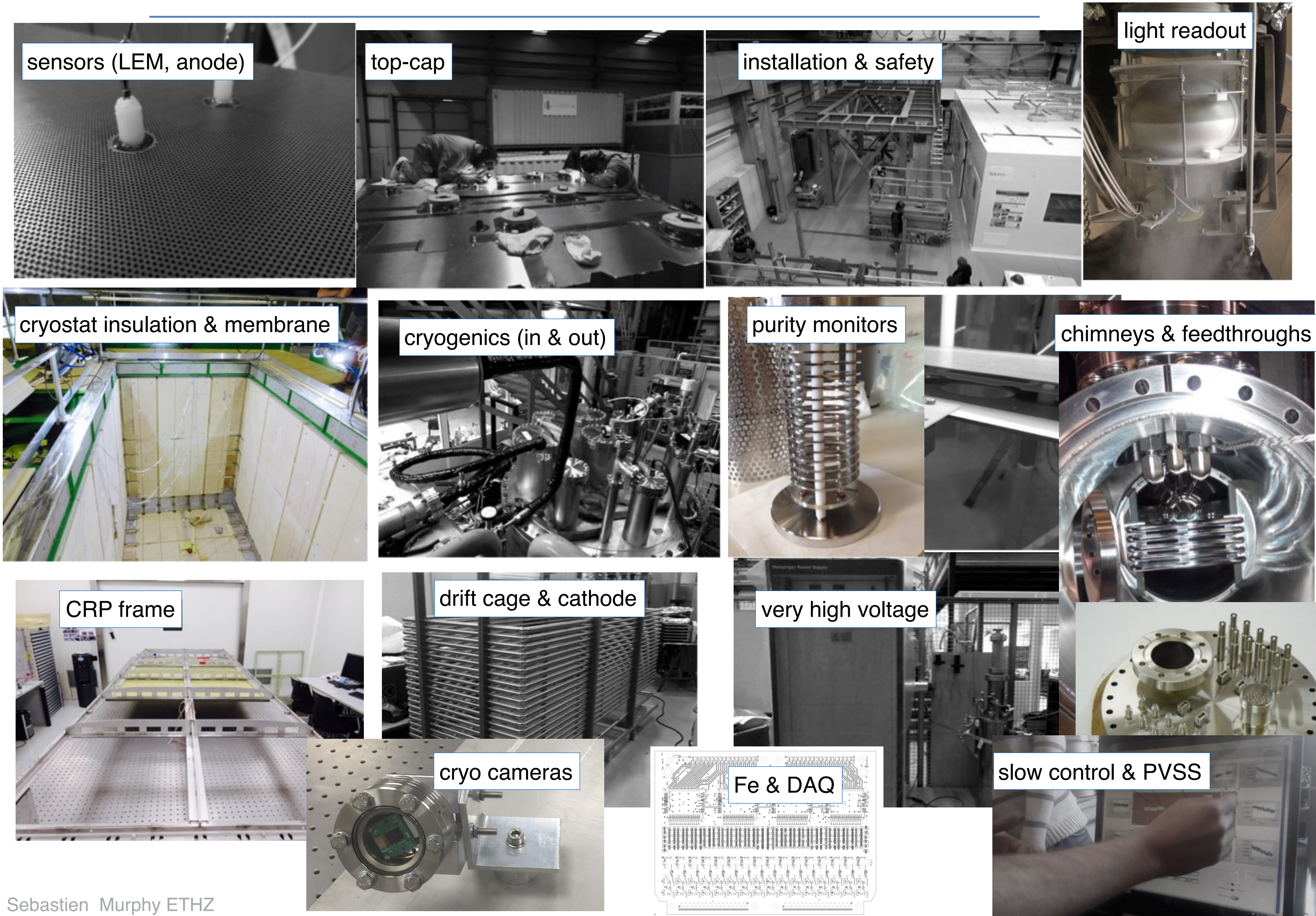
3x1x1 detector and cryostat



3x1x1 detector



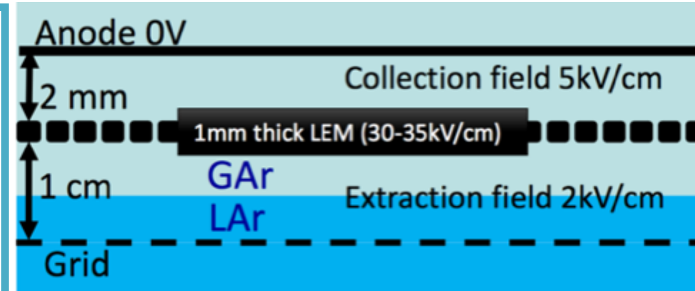
3x1x1 detector

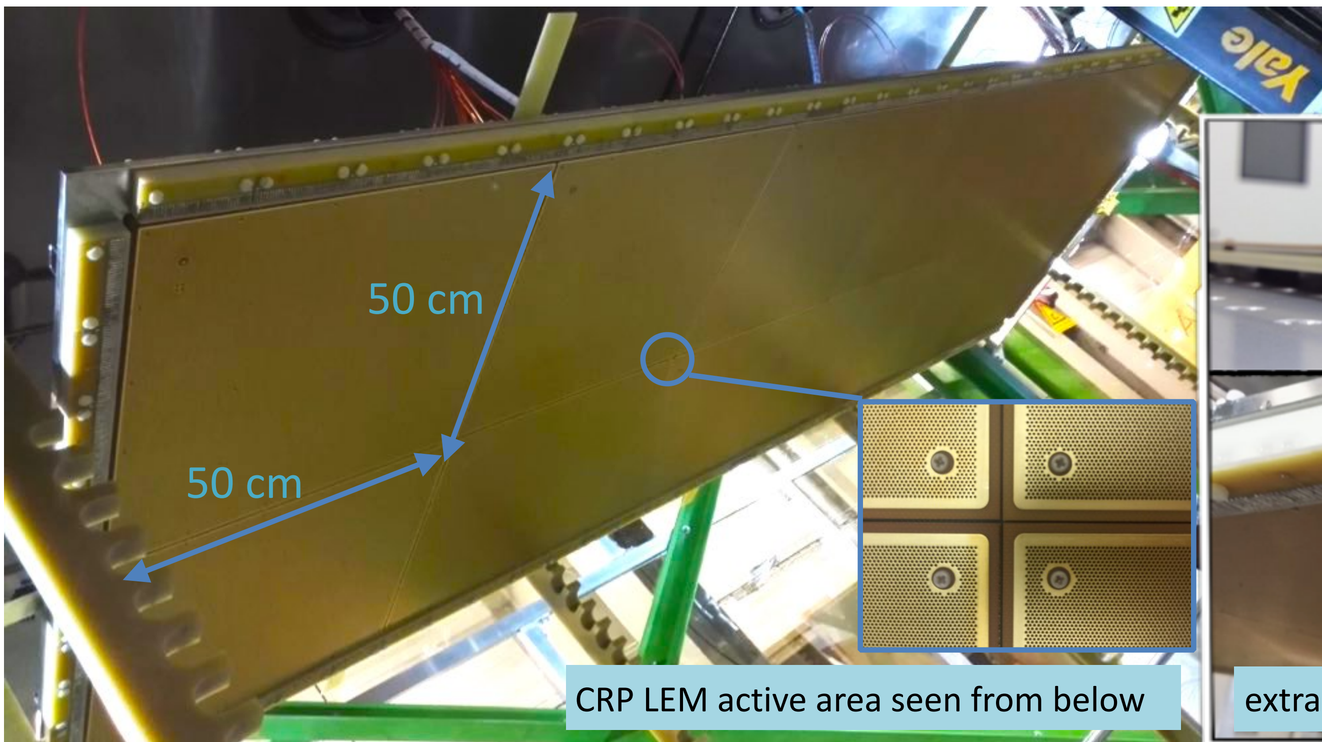


CRP for large area readouts

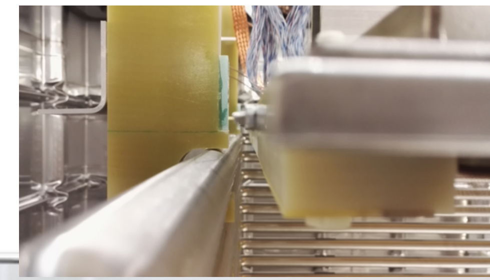
WA105

- 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 but also at LAr temperature in open cryogenic baths.
- Assembly is straightforward and quick (~2 people, 2 days)

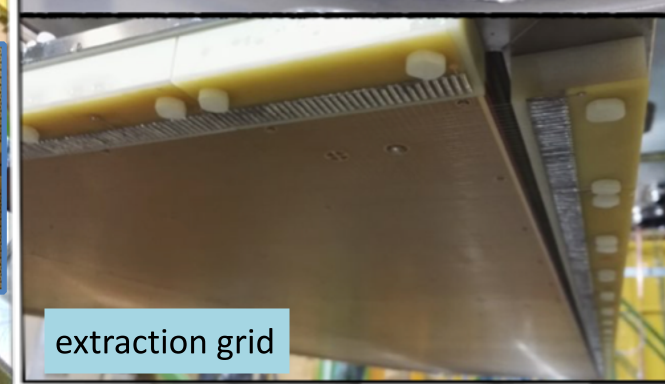




CRP LEM active area seen from below



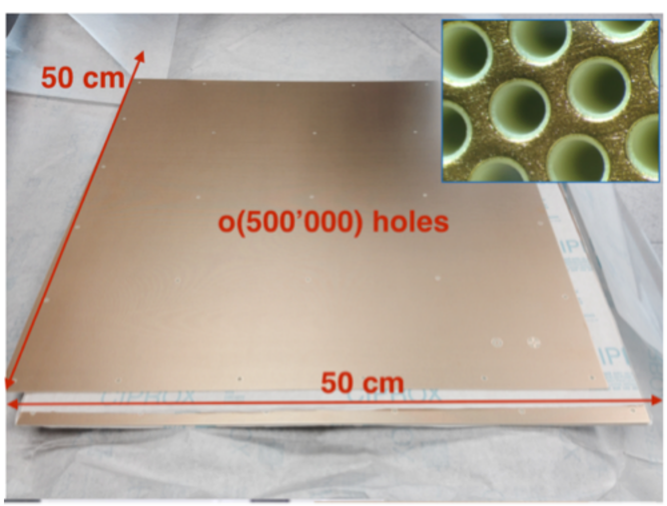

LEM + anode sandwich


extraction grid

LEMs and Anodes

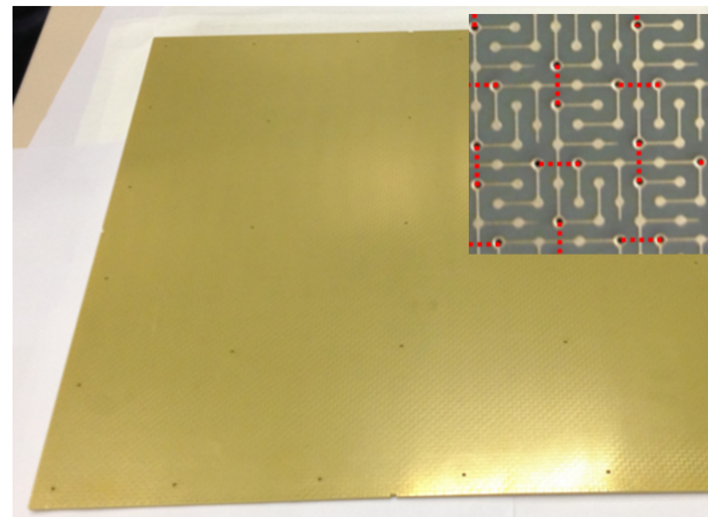
purchasing and QA/QC aspects for both are now well under control. The construction of the 311 has been fundamental in defining this.

LEMs



extensive experience on handling, cleaning, testing based on series of 20 (pilot)+ 20 (final design) LEMs.

Anodes



- 4-layer 3.4 mm thick PCB
- Rather standard to manufacture
- electrical continuity tested by company
- Minimal QC needed on our side.

Years of R&D devoted to design and testing of those crucial components.

C. Cantini et al 2015 JINST 10 P03017

C Cantini et al 2014 JINST 9 P03017

LEMs and Anodes

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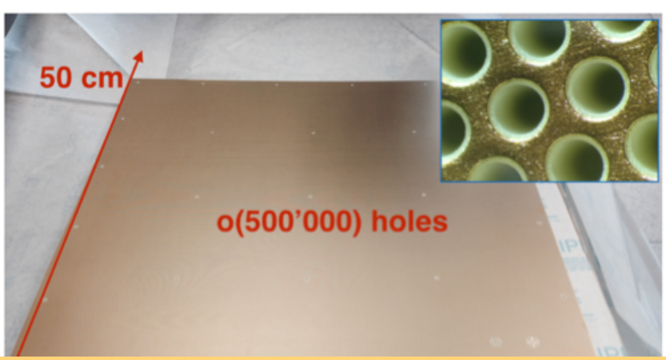
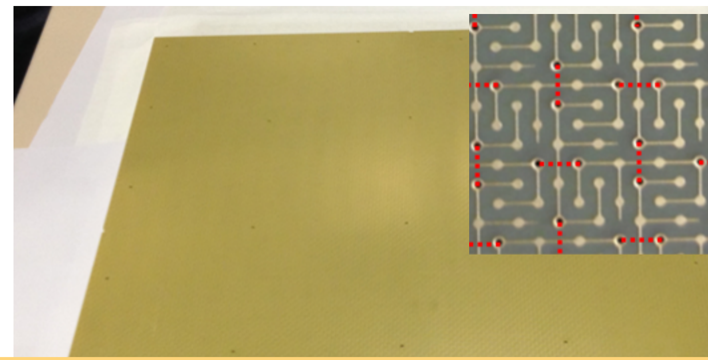
LEMs

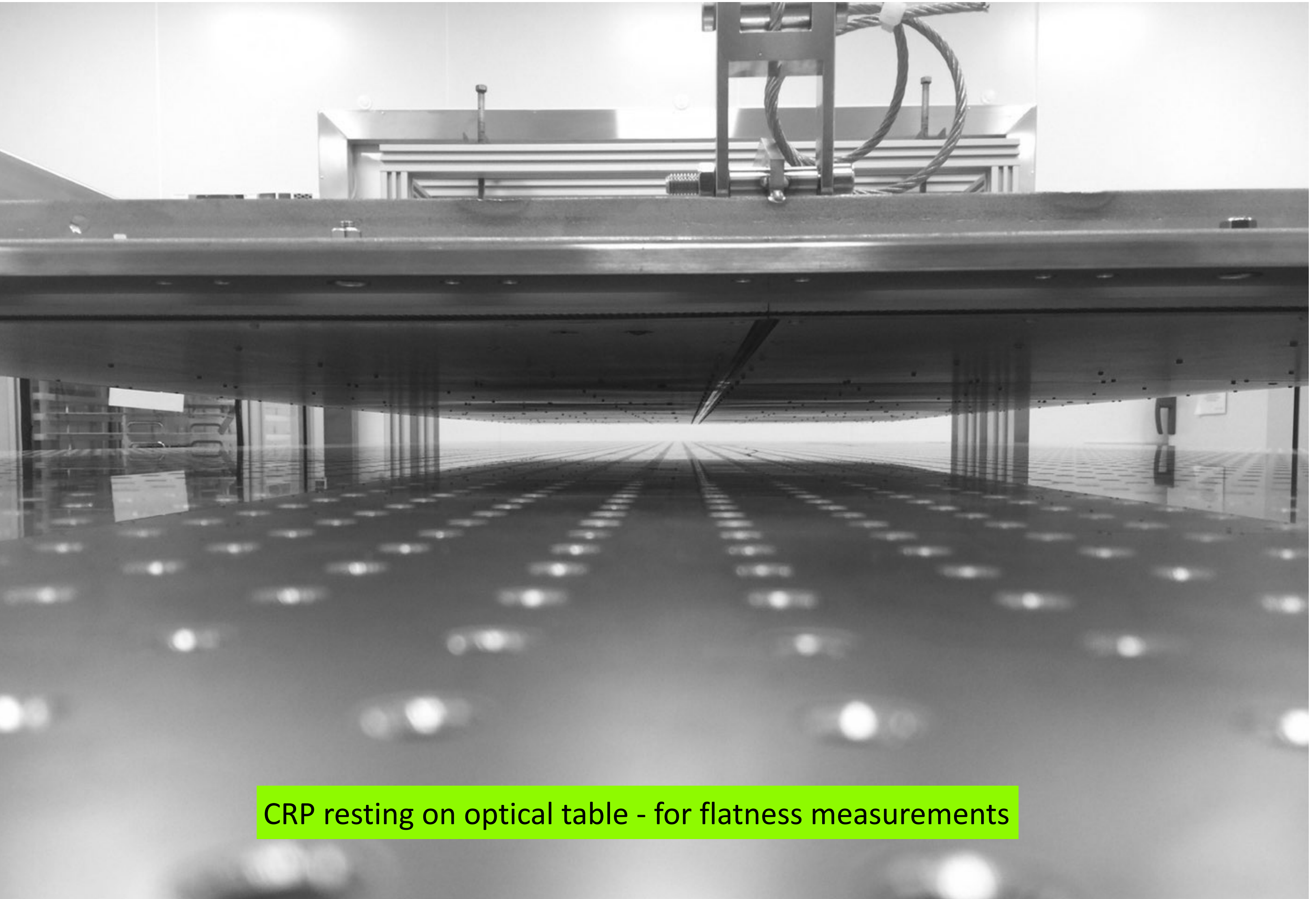


Anodes



- They are **standard industry components**. A large part of the QA is done by the companies.
- Anode & LEM Modularity of 50x50 cm2 allows for
  - ➡ practical shipping to assembly point.
  - ➡ easy and rapid check of the individual components
- the assembly is **straightforward and quick** (~2 people, 2 days for the 3x1m2).
- The entire frame can be **dipped in LAr to check mechanical integrity** and fulfilment of tolerances in cold.

Charge Readout Plane



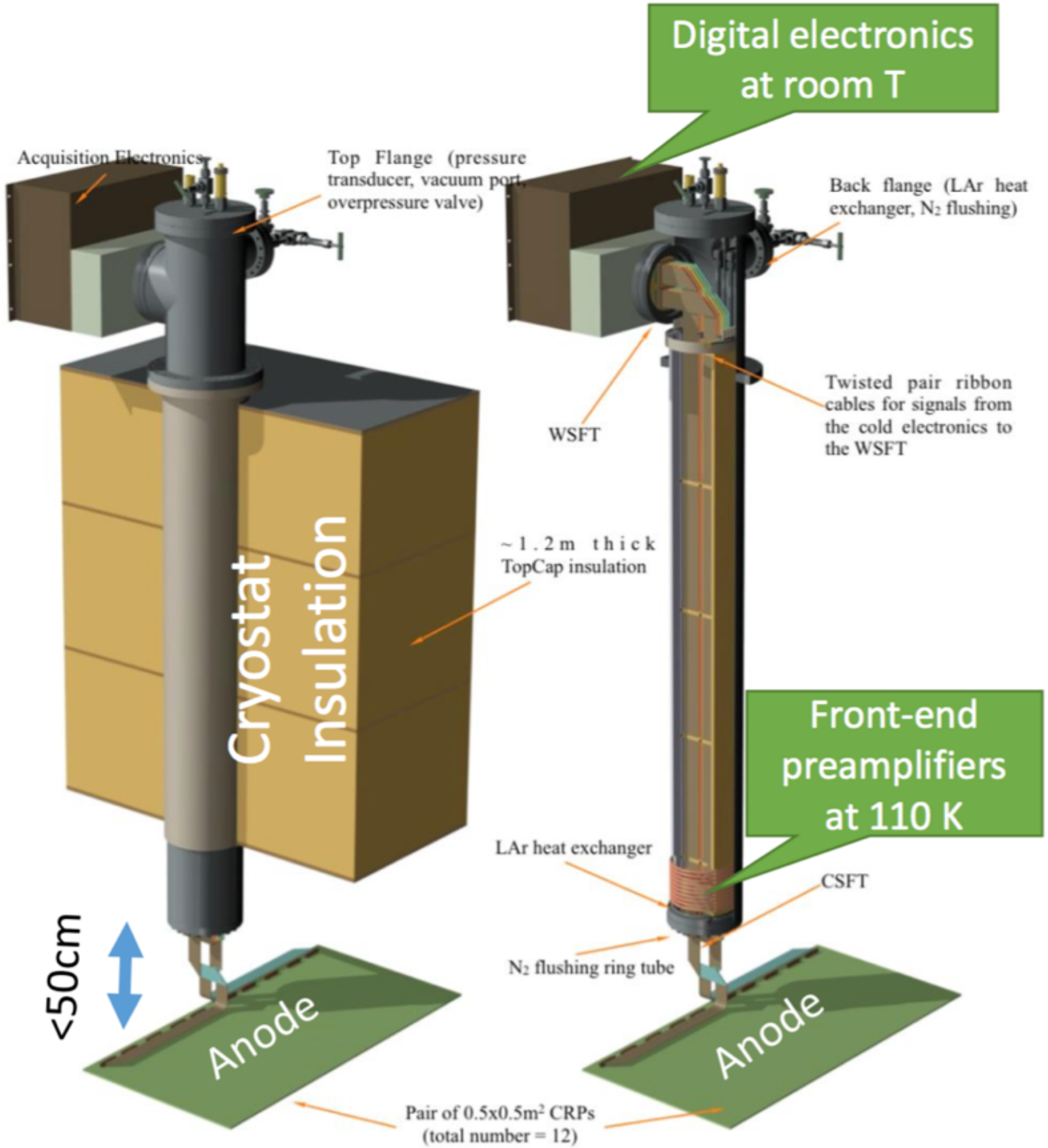
CRP resting on optical table - for flatness measurements

Charge Readout Plane

- Fully assembled CRP, partly instrumented and dipped in LAr with photogrammetric targets
- -><u>check resistance to thermal shock and planarity at cold as well as signal continuity.</u>


3x1 m2 CRP suspended in an LN2 bath- for flatness measurements (photogrammetry) and contacts in cold

Signal feedthrough



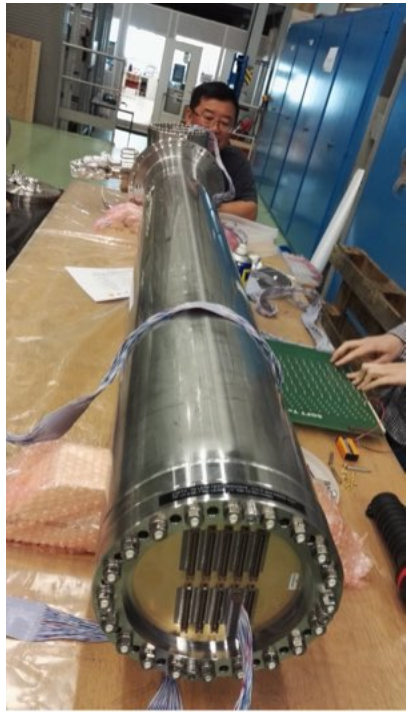
The access to electronics without emptying/contaminating inner detector volume is critical for long term operation

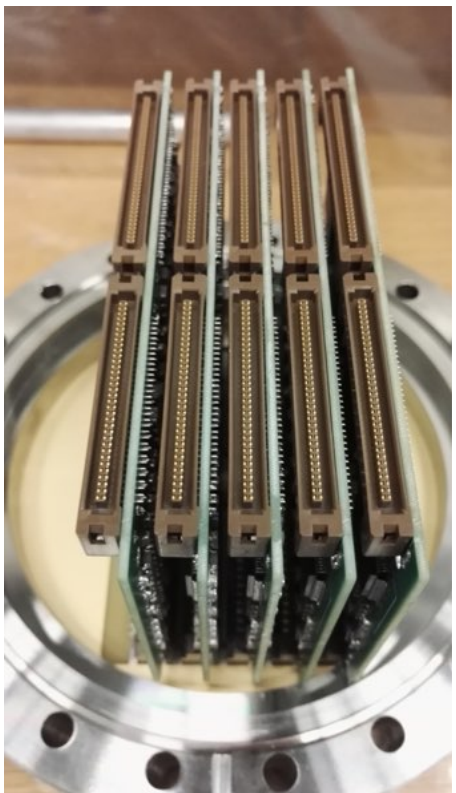
Proximity of pre-amplifiers to the readout is also an important aspect
➔ Limit noise due to cable capacitance

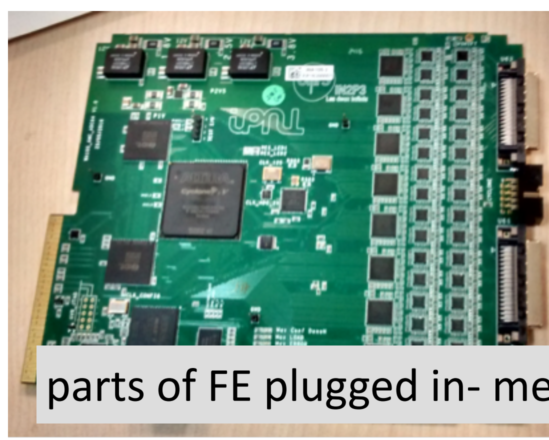
Front-end electronics is housed in "chimneys" which are physically isolated from cryostat / ambient environment with vacuum tight feedthroughs
Could be accessed/replaced without opening cryostat

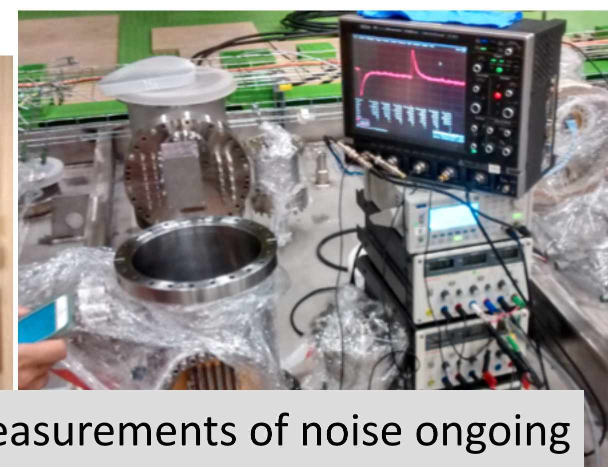
6

Signal feedthrough





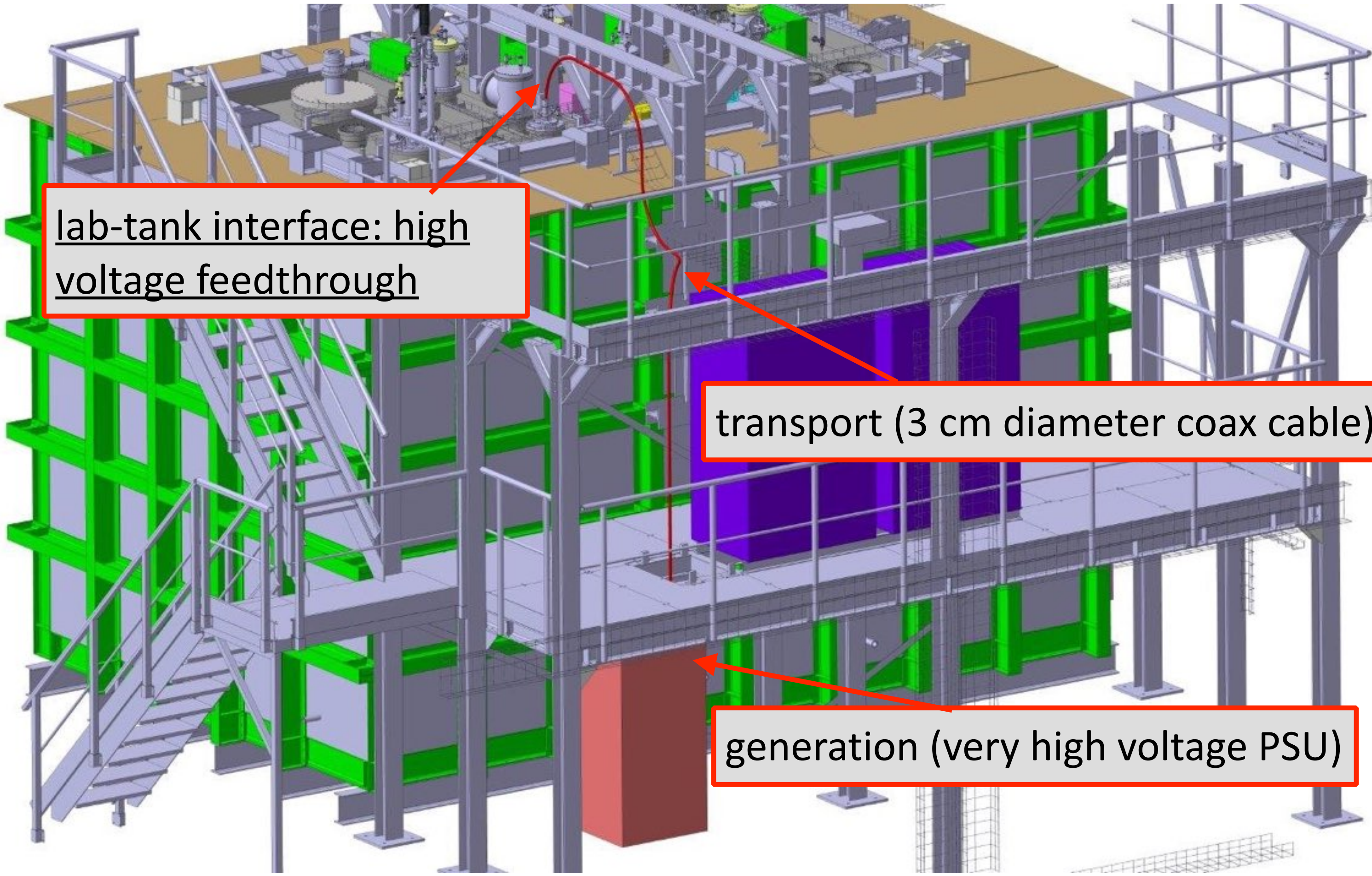




parts of FE plugged in- measurements of noise ongoing

High voltage Feedthrough

As detectors get larger so does the required HV. Developing feedthroughs that can transport several hundreds of kV through gas and liquid argon. Very important topic for the field. Lot's of ongoing R&D.



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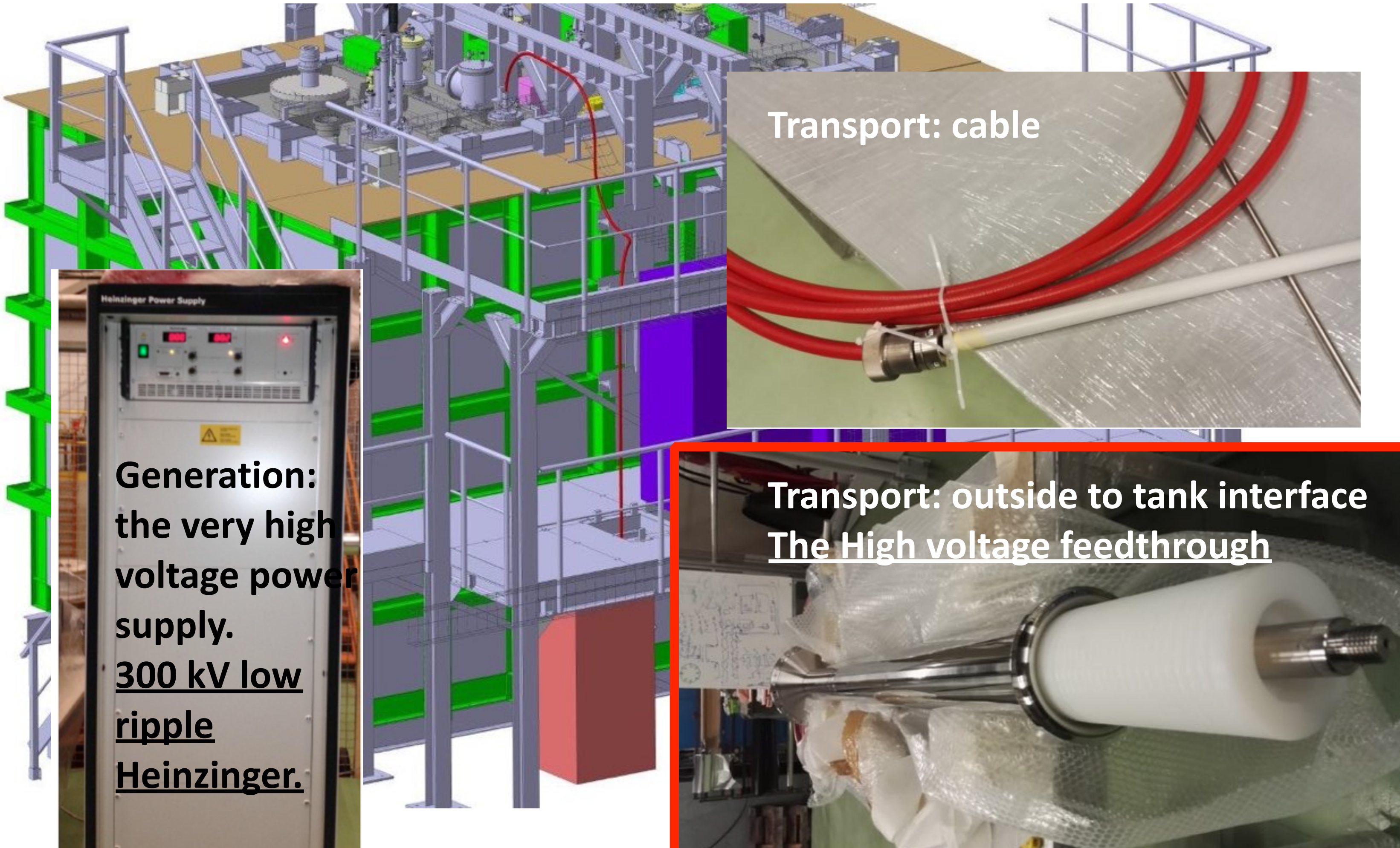
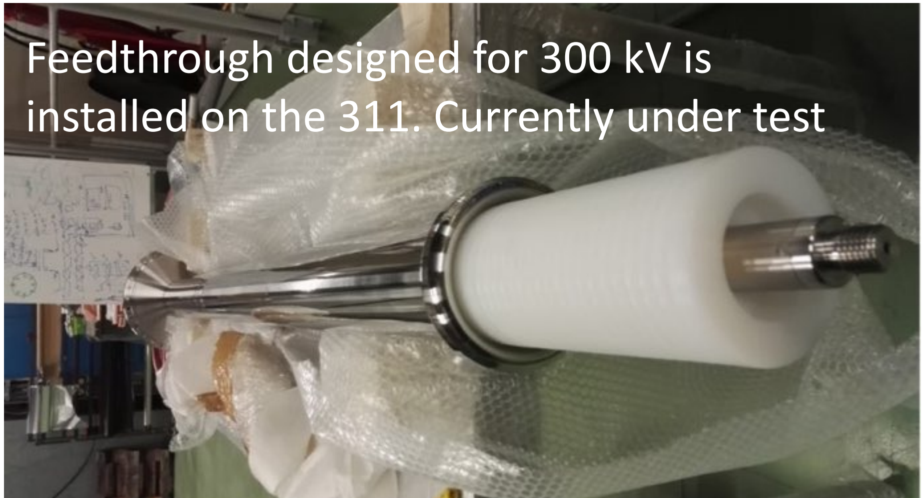
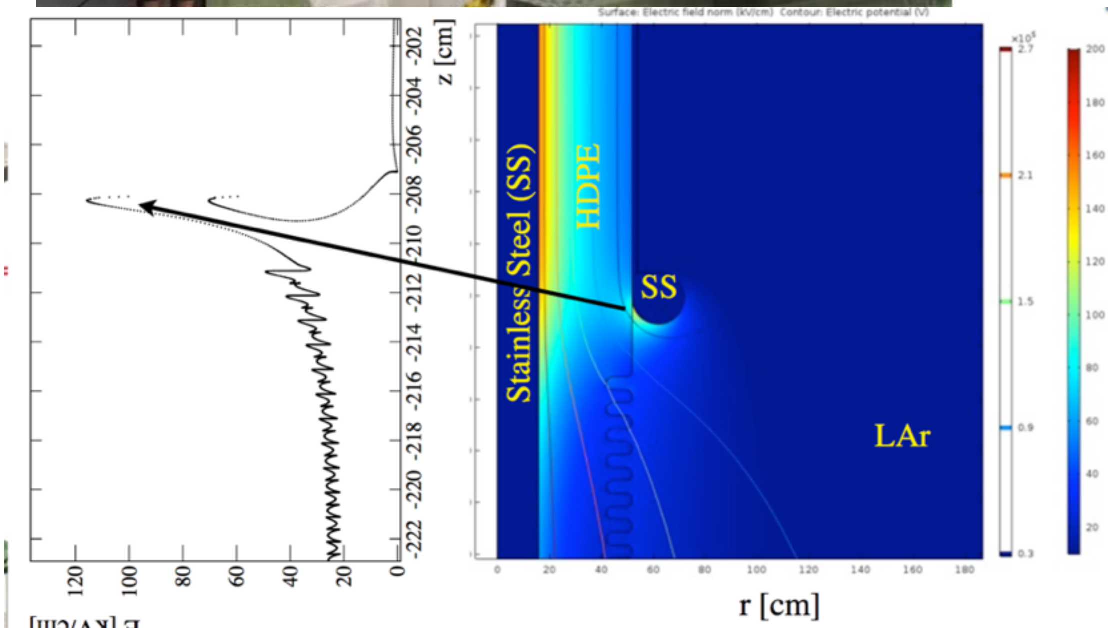


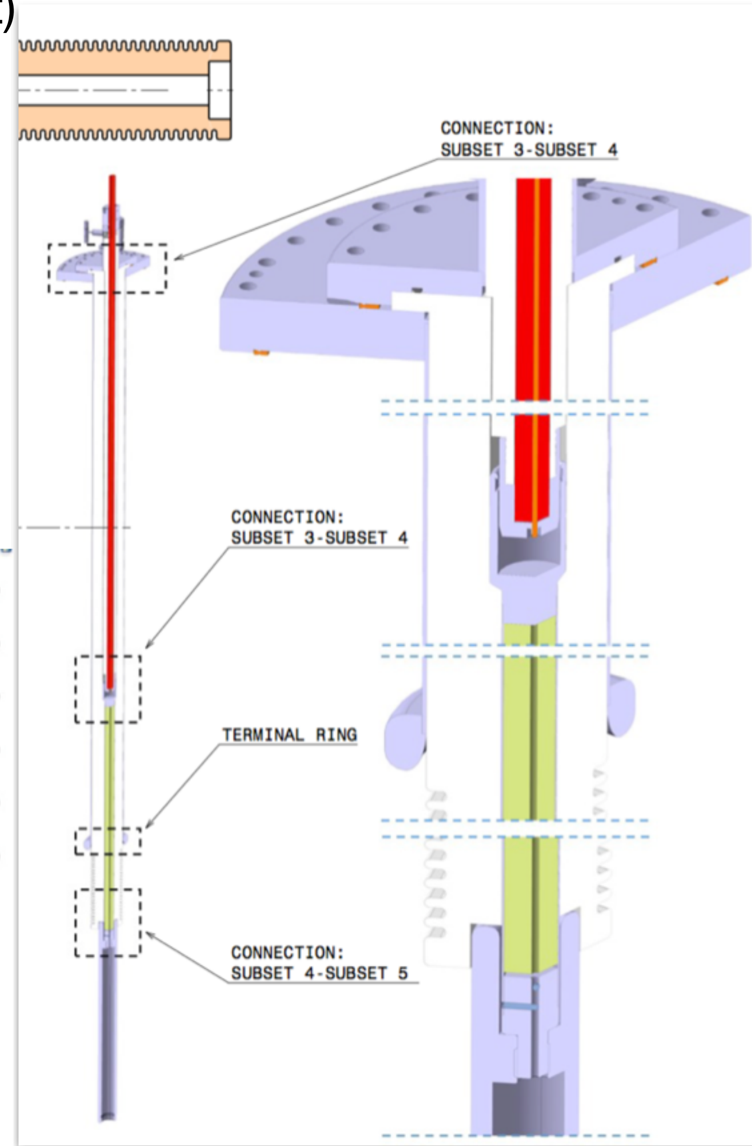
Feedthrough designed for 300 kV

High voltage Feedthrough

Successful design of ICARUS 150 kV Feedthrough has been scaled up to 300 kV.
designed for the protoDUNE dual phase (6 m drift)

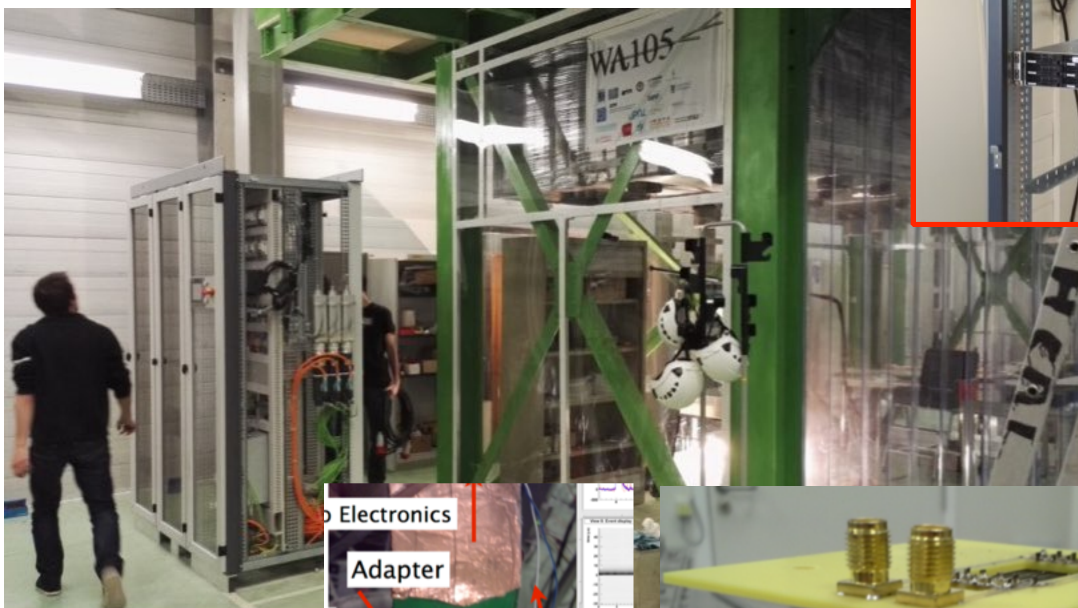


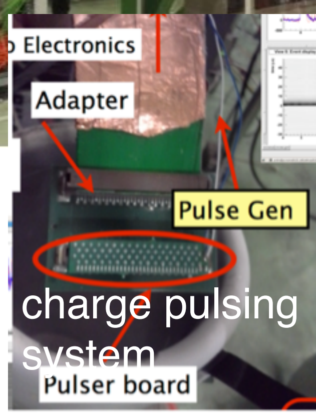




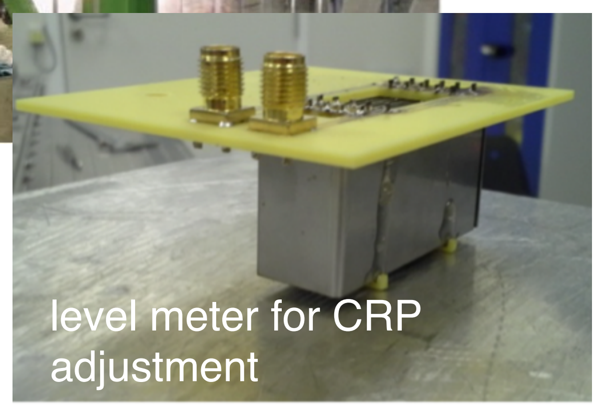
Slow control & instrumentation

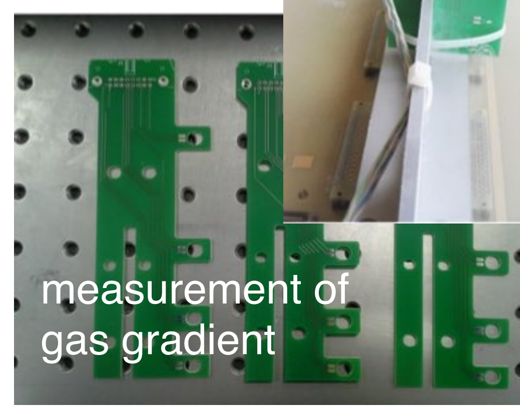
Crucial part of the experiment is all the slow control. Large development and new types of sensors and acquisition system has been developed. ->same system will be used on protoDUNE & DUNE Dual Phase.



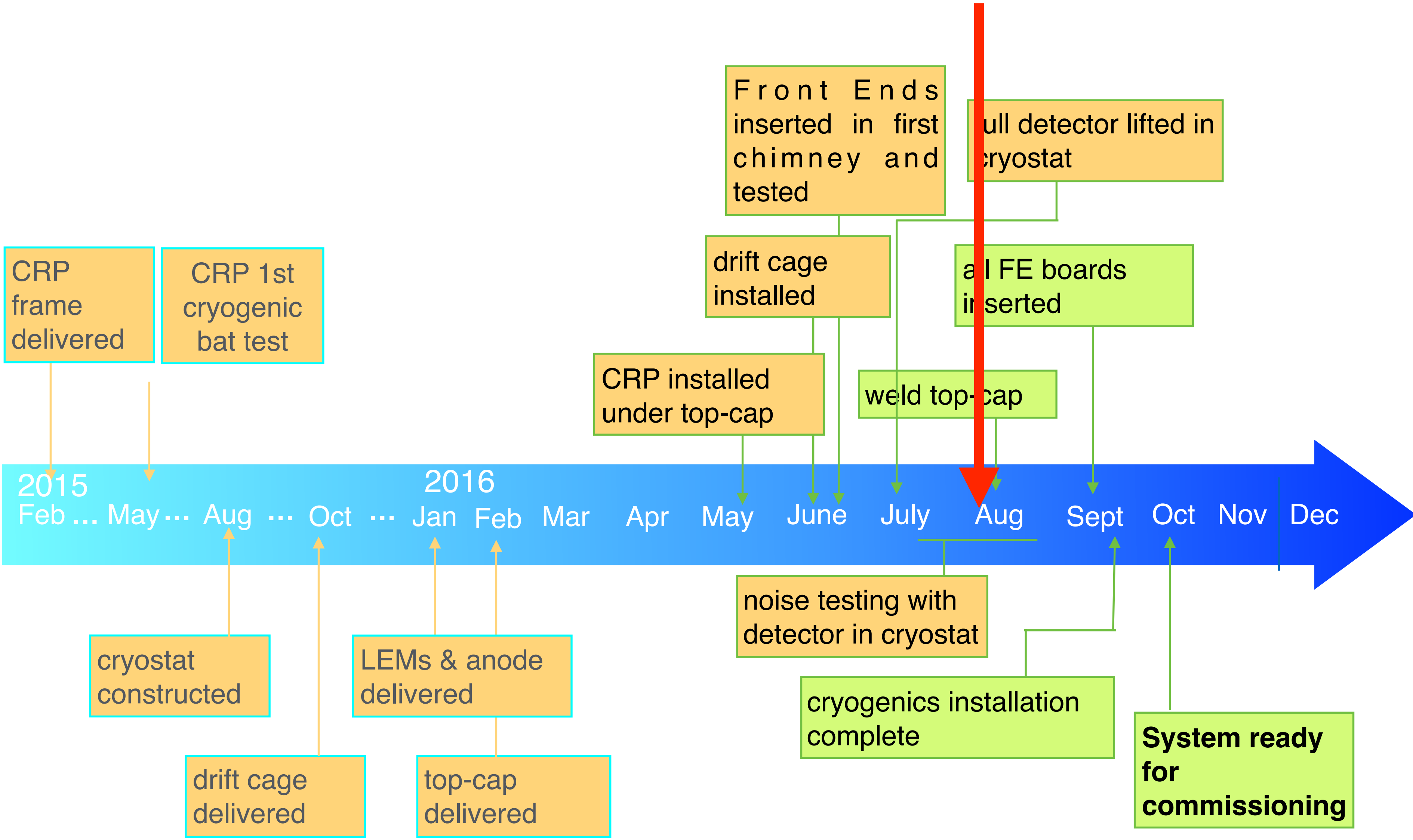


charge pulsing system


level meter for CRP adjustment


measurement of gas gradient

The plan



Front Ends inserted in first chimney and tested
ull detector lifted in
ryostat
drift cage installed
a l FE boards
i serted
CRP frame delivered
CRP 1st cryogenic bat test
CRP installed under top-cap
weld top-cap
2015
2016
Feb … May … Aug … Oct … Jan Feb Mar Apr May June July Aug Sept Oct Nov Dec
noise testing with detector in cryostat
cryostat constructed
LEMs & anode delivered
cryogenics installation complete
drift cage delivered
top-cap delivered
System ready for commissioning

Insertion in the cryostat

The detector was fully assembled and tested outside the cryostat suspended from the top cap. On July 4th 2016 the detector was lifted and inserted inside the cryostat.

Detector inside the cryostat

Conclusion

- After a decade of R&D on smaller prototypes, **the first large scale dual phase detector is now constructed.** Data taking is about to begin.

- This milestone is a **first step towards the cost effective realisation of giant liquid argon TPCs.**

- The dual phase design is considered for the second and subsequent modules of the DUNE far detector, providing several benefits compared to the baseline design.

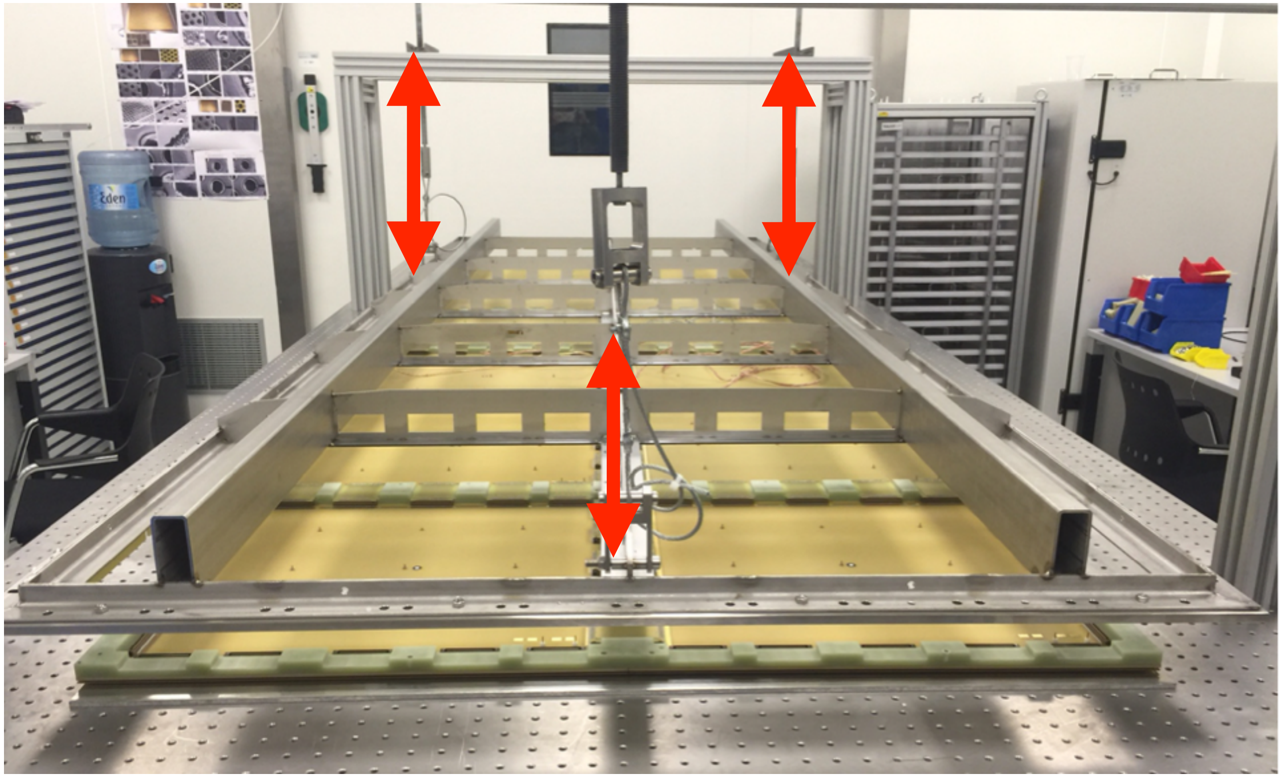
- Although of much larger volumes the protoDUNE 6x6x6 m^3 and DUNE 12x12x60 m^3 dual phase TPCs are constructed **following a modular approach.** Most of those components are identical to those already successfully installed in the 3x1x1.

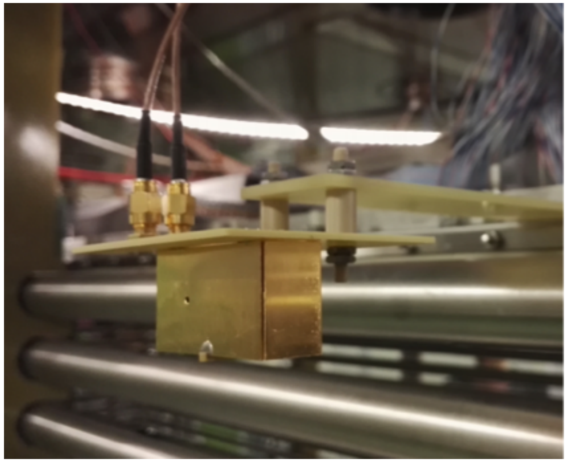
- **First results from the 3x1x1 expected by the end of the year.**

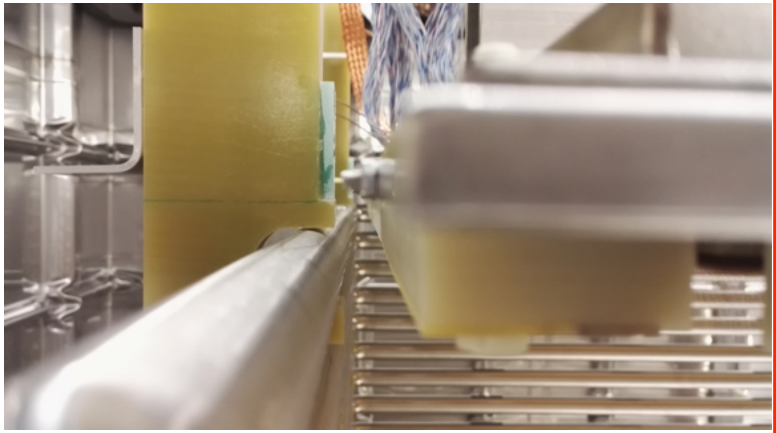
THANK YOU

EXTRA SLIDES

CRP: adjustable to LAr level

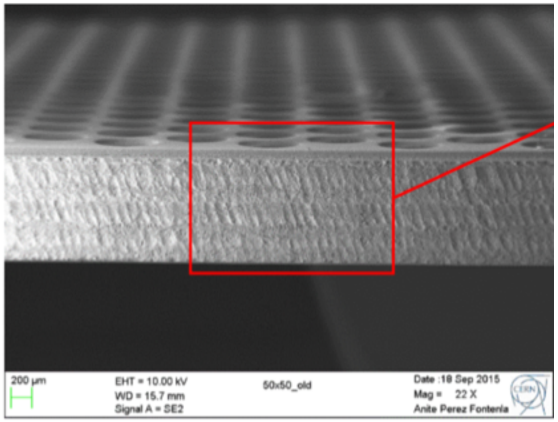


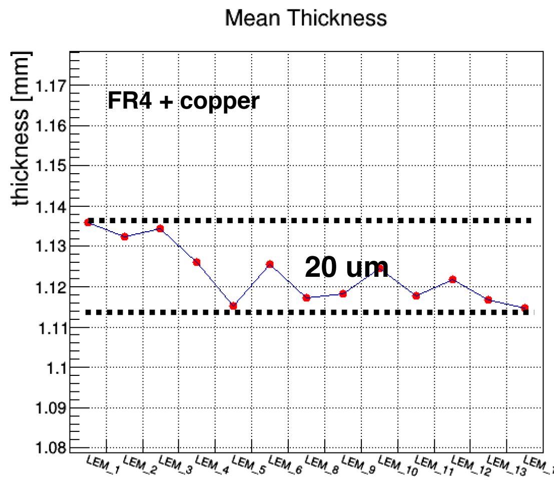


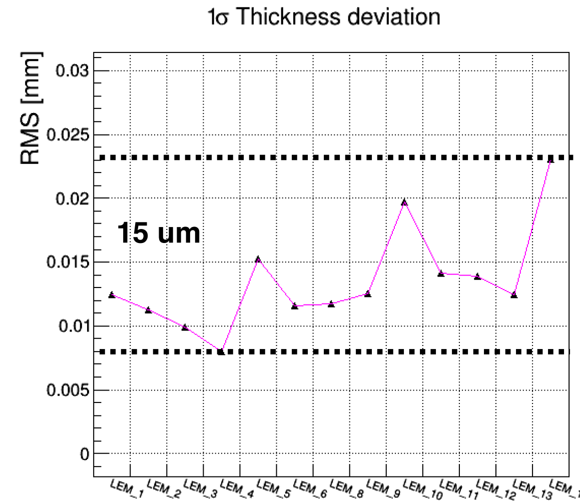


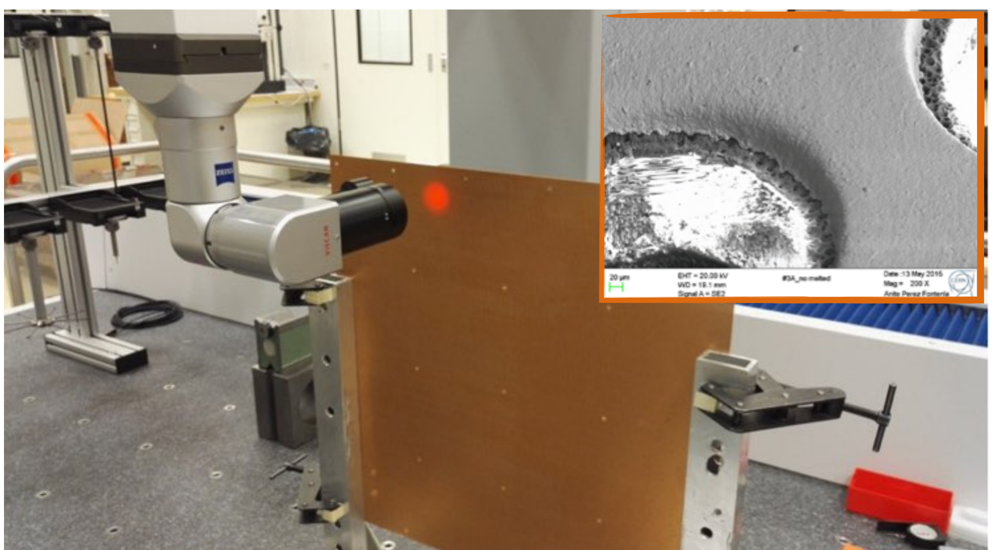
suspended by 3 ropes coupled to motors on top-cap. Precision of motors <u>100 um over 4 cm</u>.
8 capacitive level meters readout the LAr level with similar precision

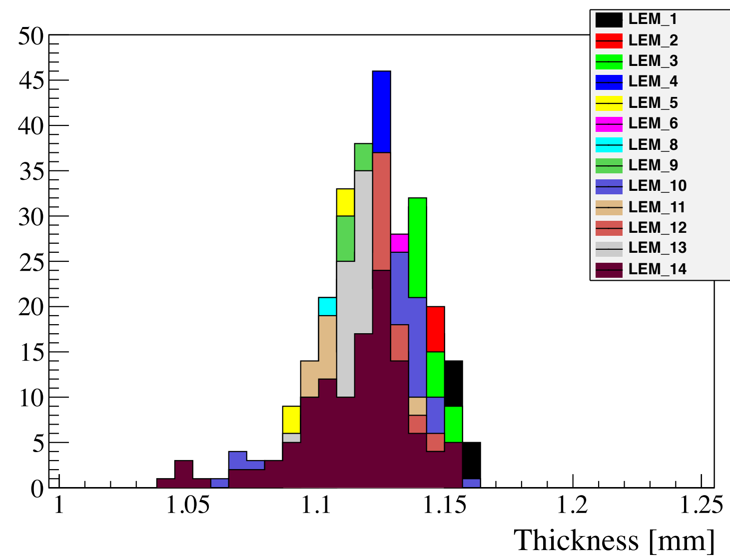
LEM thickness measurements





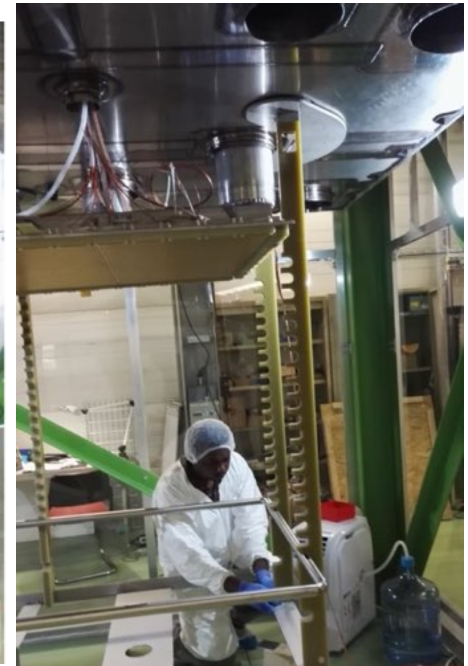






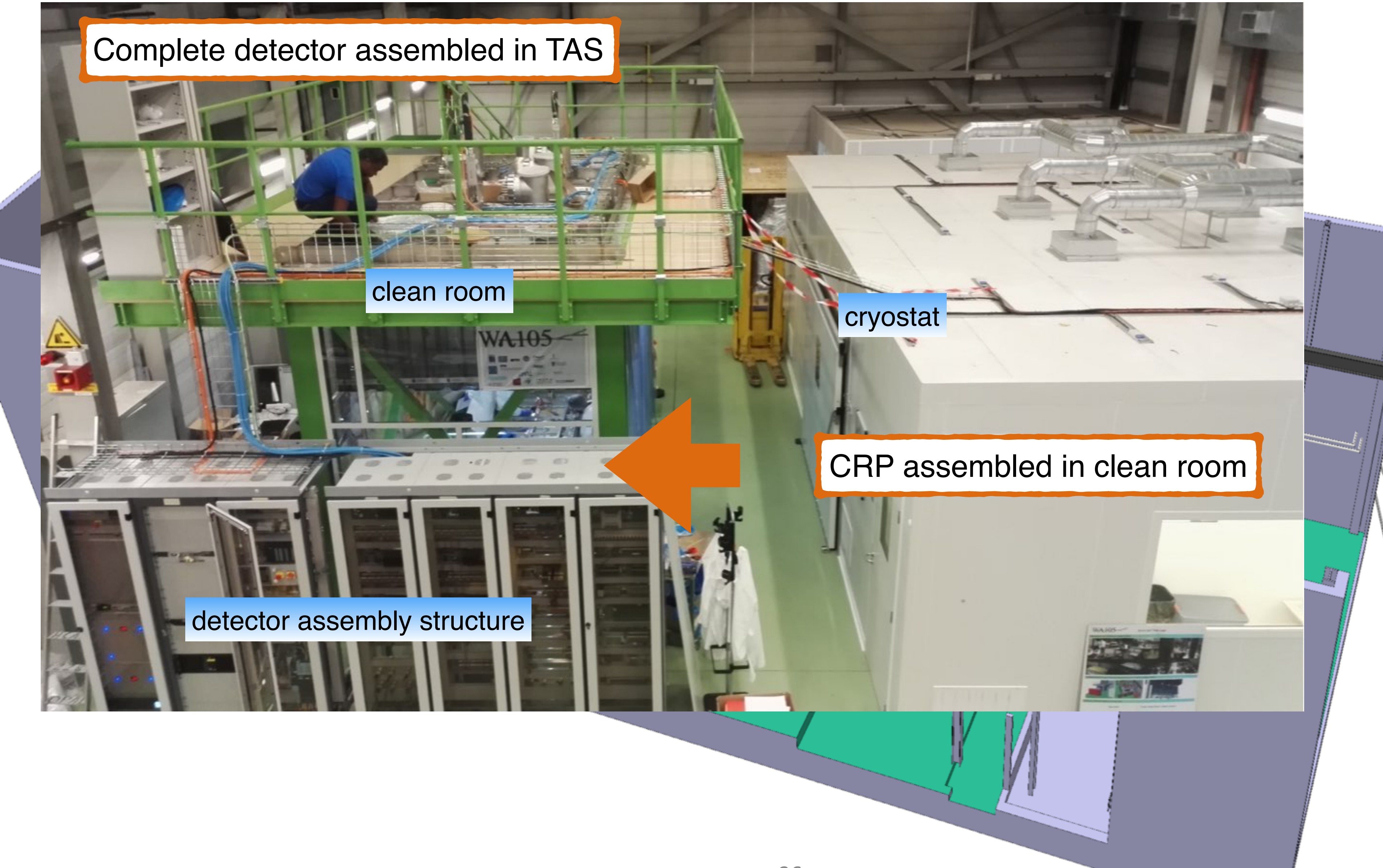
Detector installation

Detector installation



Layout in building 182

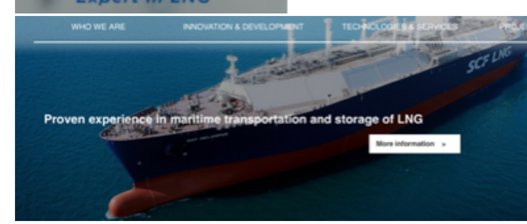
WA105 3x1x1



Layout in building 182

The cryostat itself is an important part of the R&D.
GTT (France) licence. Corrugated membrane steel panels used for storage and transport of Liquified Natural Gas.

GTT
Expert in LNG



Purification monitor

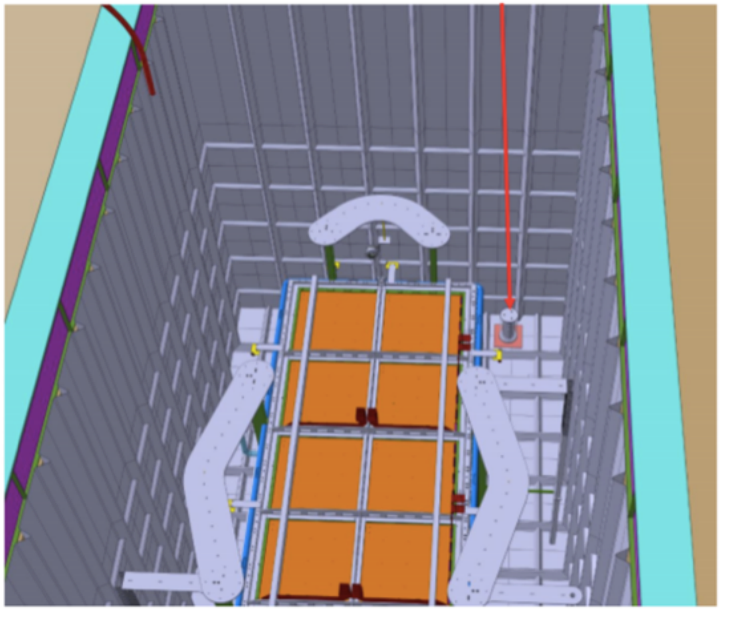
- Design follows ICARUS PrM design
- Hamamatsu Xenon lamp
- Photocathode:

  - fused silica window (λ/4 quality surface at 632 nm, i.e. < 0.1 μm surface irregularities)

  - 500 nm Al coating (at London Centre of Nanotechnology)

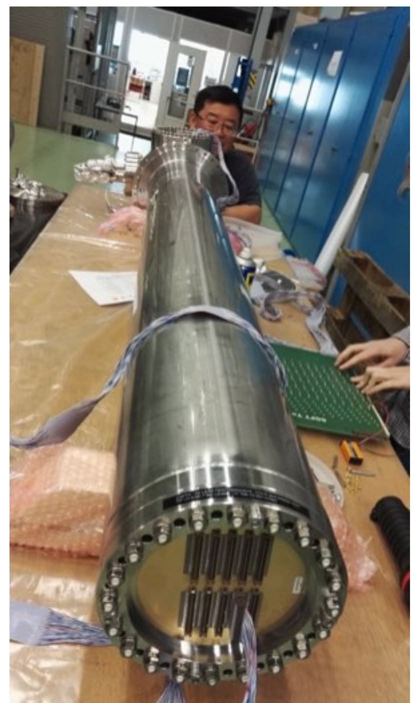
  - photoelectric effect: Al work function 4.08 eV (~300 nm)
- 600 μm Cu cladded UV fibre guides the light onto the PHC
- SS fields shaping rings
- Nickel mesh
- Al Faraday cage
- Amptek charge amplifier

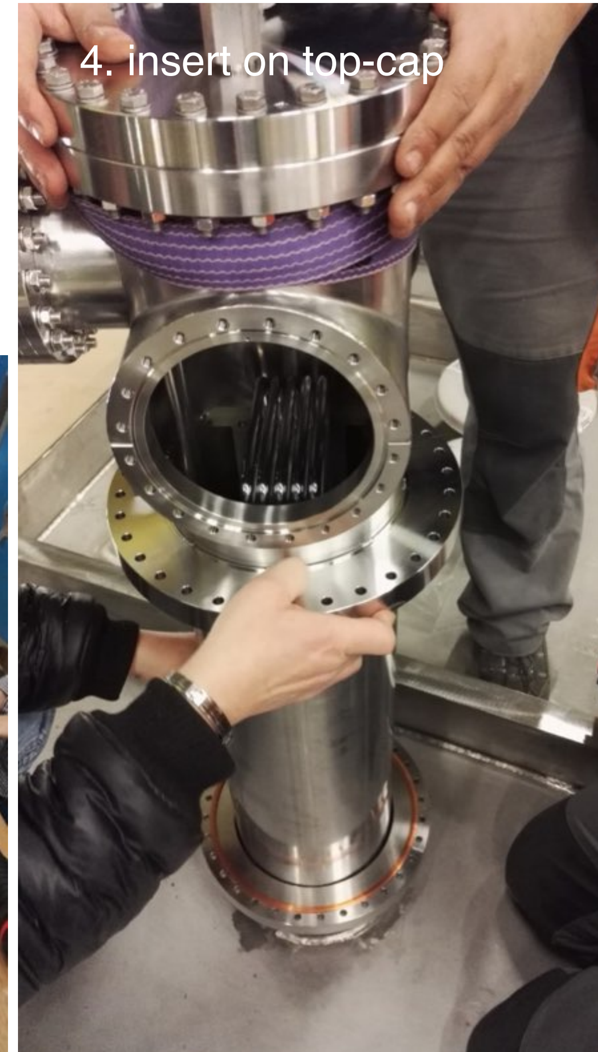
PrM in WA105



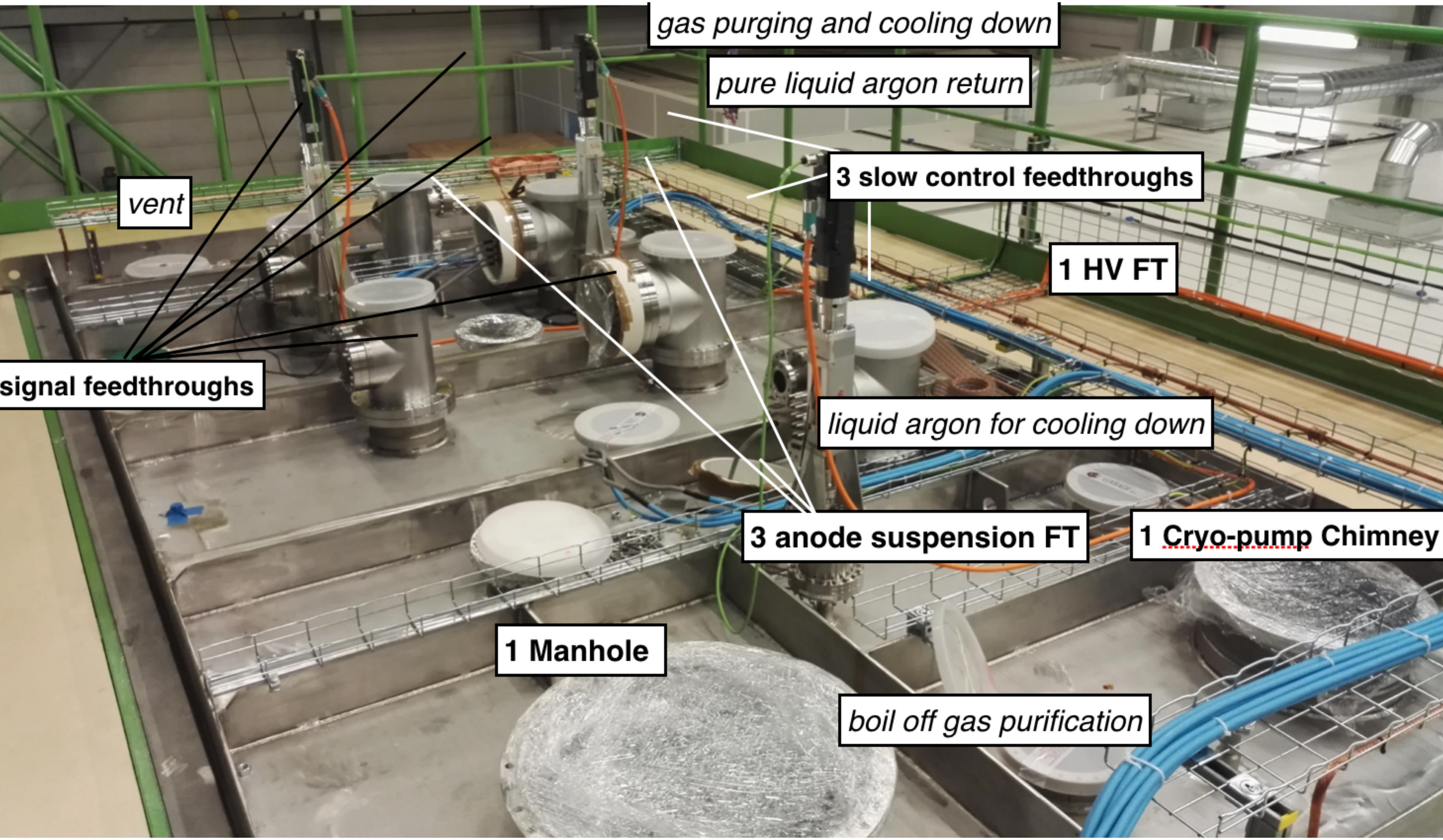
Installed in the 311 in July

Wiring and testing the chimneys





Top-cap



gas purging and cooling down
pure liquid argon return
vent
3 slow control feedthroughs
1 HV FT
signal feedthroughs
liquid argon for cooling down
3 anode suspension FT
1 Cryo-pump Chimney
1 Manhole
boil off gas purification