Yearly progress report on WA105/ProtoDUNE dual-phase

CERN-SPSC meeting April 4th 2017

Sebastien Murphy
on behalf of WA105

Dual-phase LAr TPC prototype at CERN

WA105

Demonstrate technical feasibility for O(10kton) detectors

- Large surface charge readout in dual-phase scalable to O(10kton) scale detectors
- Charge readout with 3mm pitch in two collection views
- Long drift distances
- High voltage to generate drift field
- Production and QA/QC chains for all detector elements
- Validation of installation sequence in view of underground detector assembly

Conceptual design for **DUNE dual-phase 10kton LAr TPC** is described in DUNE CDR Vol. 4 *arXiv:1601.02984*

Operation and measured performance of the prototype at CERN informs DUNE TDR (CD2 review in 2019)

Dual-phase LAr TPC prototype at CERN

WA105

- Characterize the detector with well defined particle beams
  - Study PID performance
  - Evaluate e/π_0 rejection capabilities
  - Calibrate energy scale and evaluate resolution for electronic and hadronic showers
  - Validate reconstruction tools

  ➔ Systematics for future neutrino oscillation program
  - Measure hadron shower development with exceptional granularity 3x3 mm^2

Requires:

- **Pions/protons**: reconstruction of secondaries in hadronic interactions, measurements of hadronic shower development, study compensation and energy resolution
- **Electrons**: calibrate energy scale and resolution

WA105 dual-phase LAr TPC

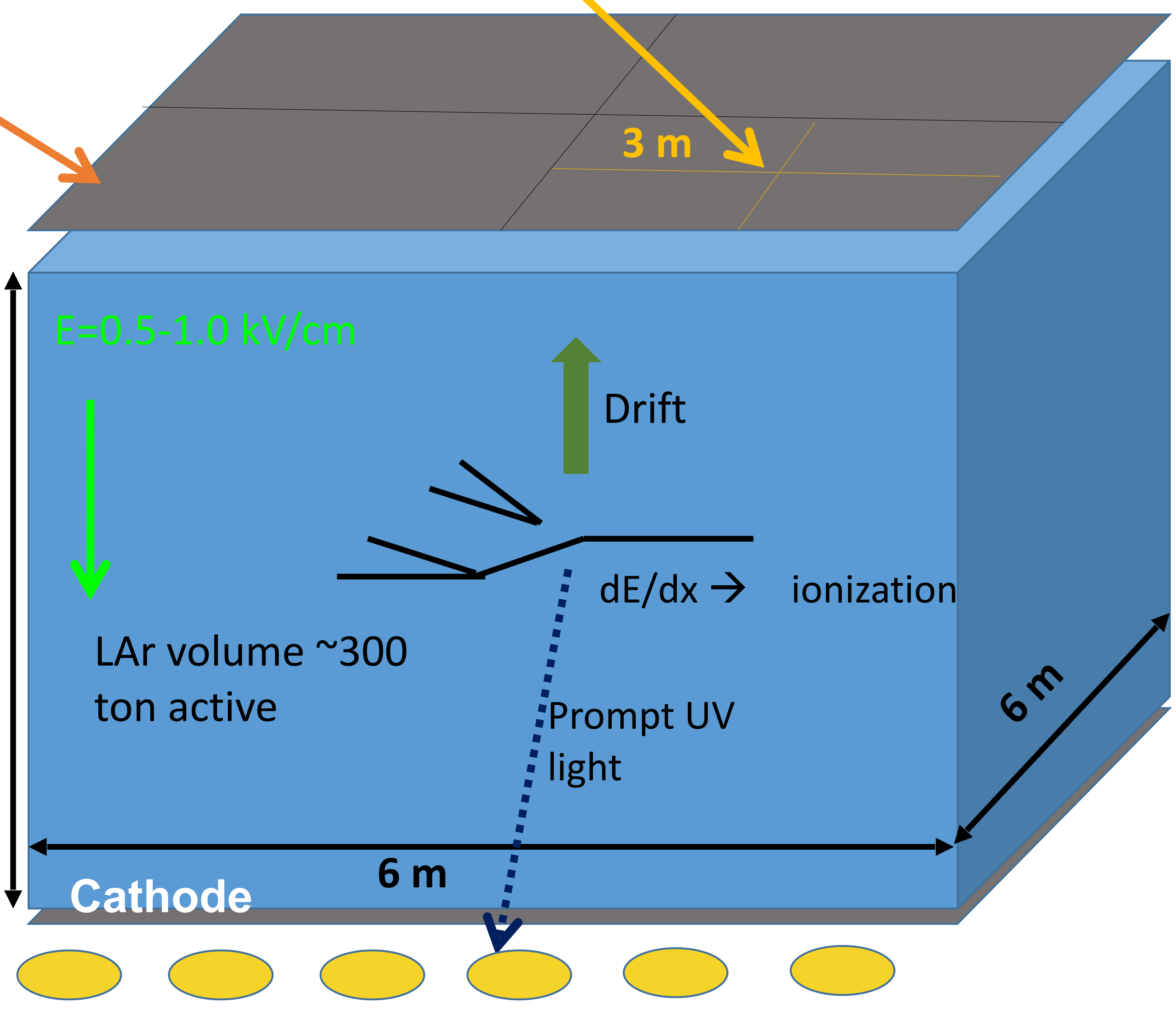
Readout in gas phase: charge is amplified and collected on a 2D anode

Drift coordinate 6 m = 4 ms sampling 2.5 MHz (400 ns), 12 bits → 10000 samples per drift window

Total event size 148MB
Data rate 15GB/s (at 100 Hz trigger)
→ DAQ bandwidth on 20 GB/s scale

Detector is built from 4 independent 3x3 m^2 units. (The same as for multi kiloton detectors)

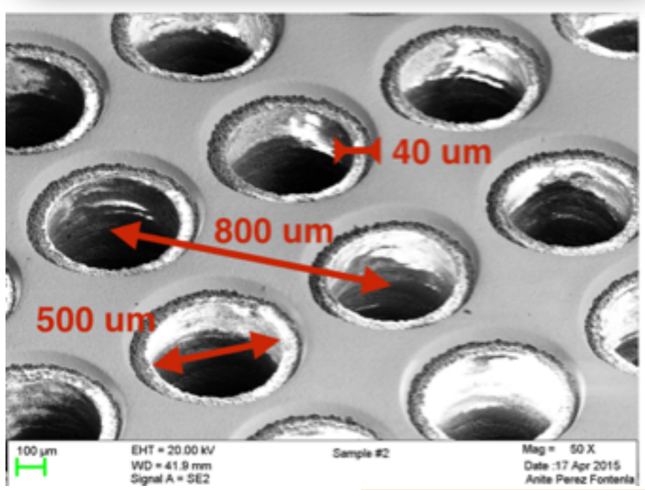
Charge Readout Plane (CRP) X and Y charge collection strips 3.125 mm pitch, 3 m long →7680 readout channels

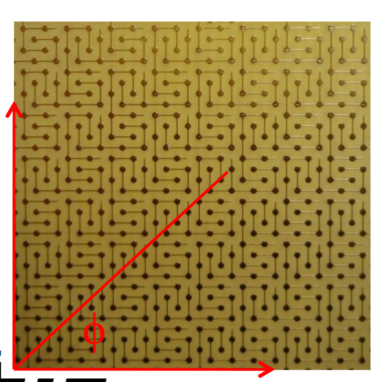


Outcome of 10 years of R&D

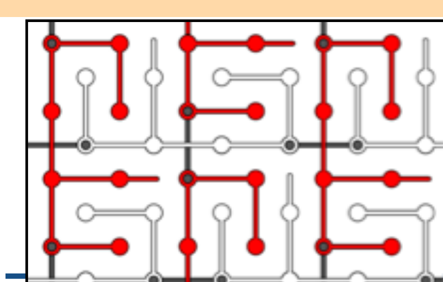
WA105

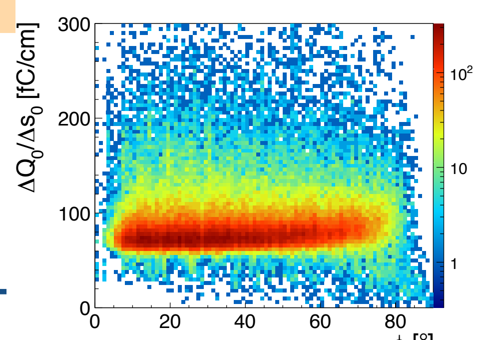
10x10cm^2: LEM/anode R&D



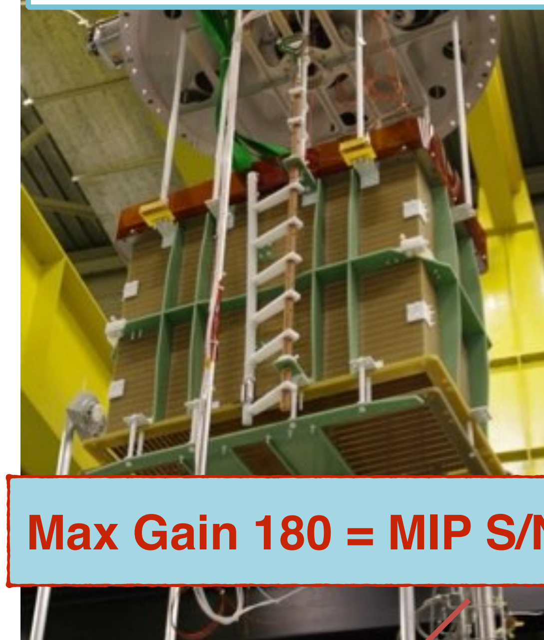


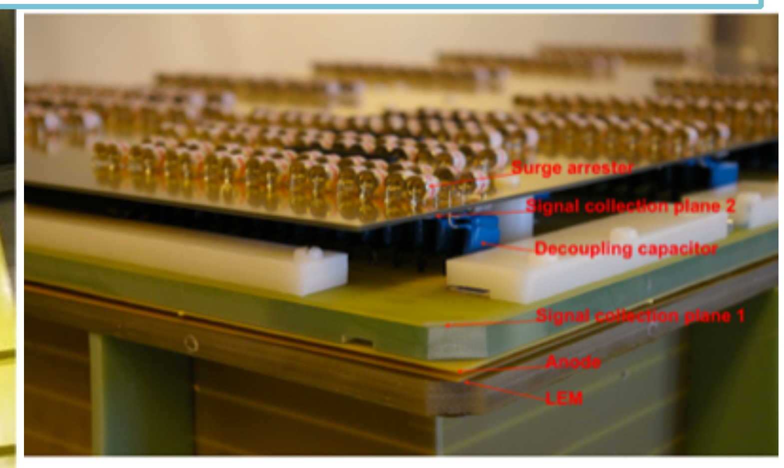
dC/dl ~ 120 pF/m



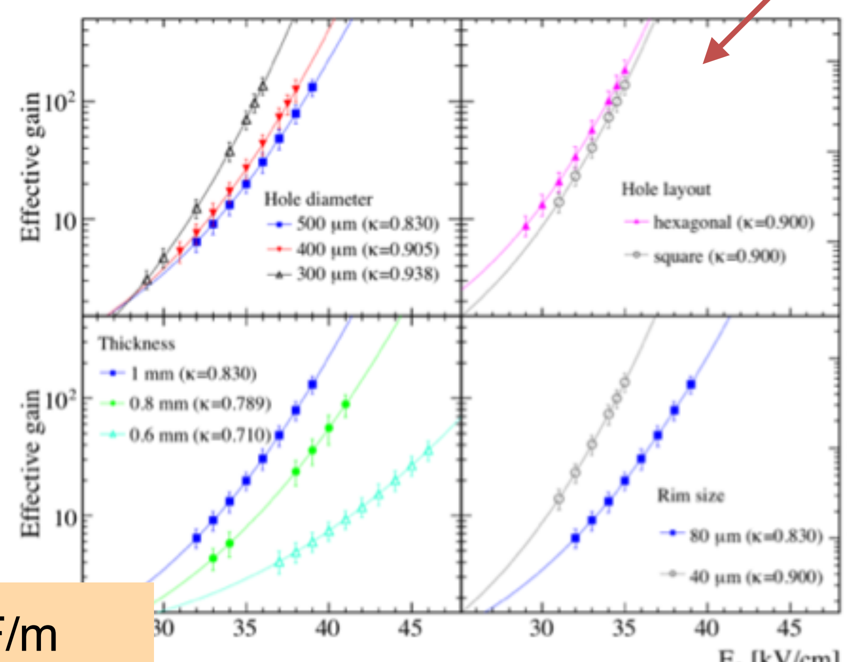


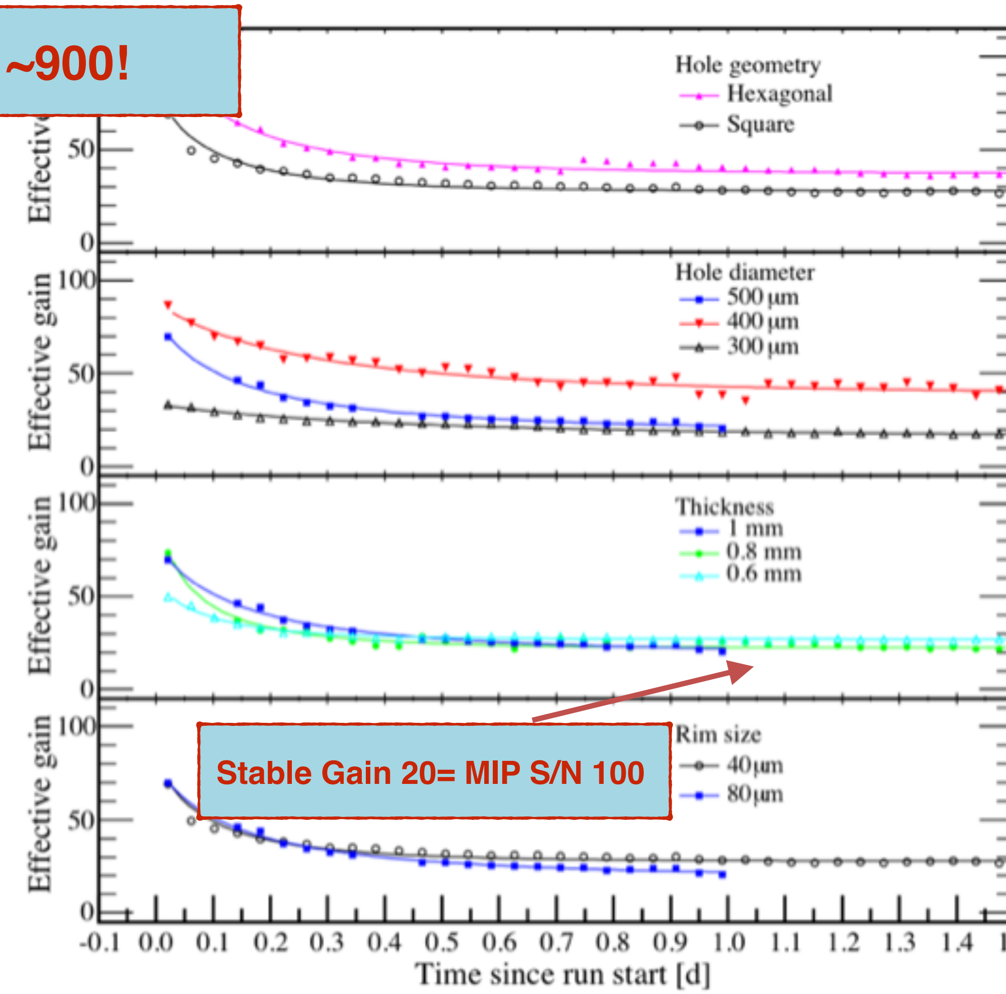
40x80cm^2: stable operation of large area readouts





Max Gain 180 = MIP S/N ~900!



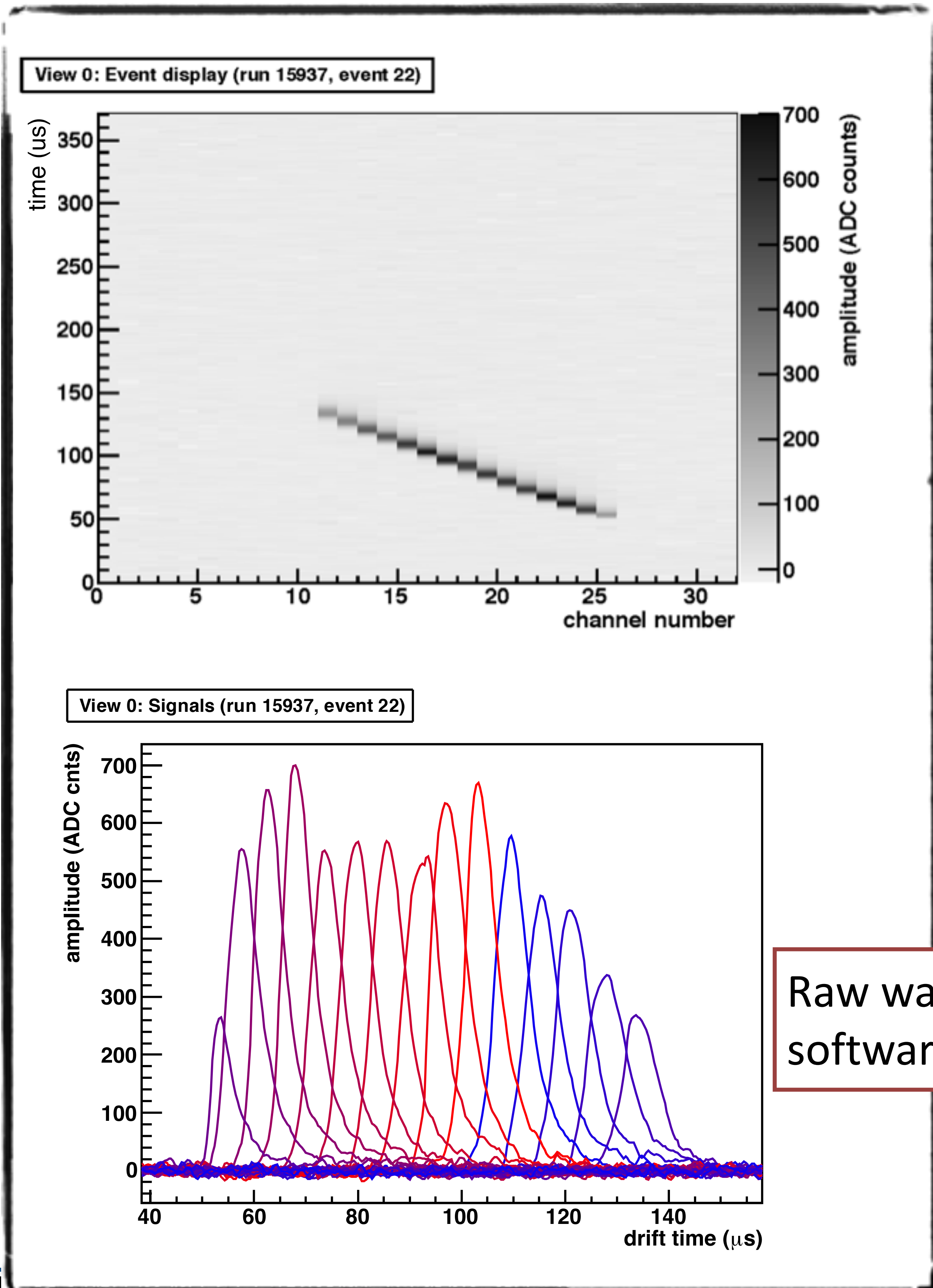


Stable Gain 20= MIP S/N 100

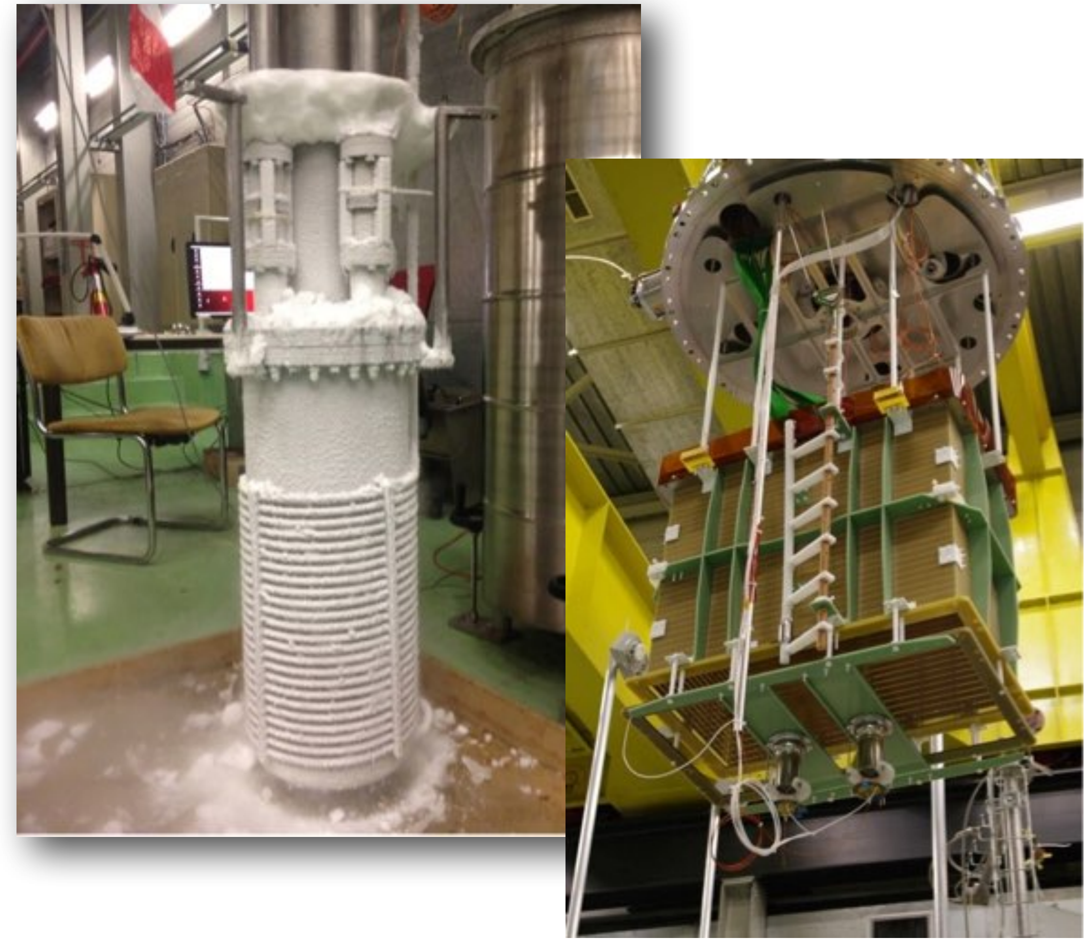
Operating with amplification of about a factor 20

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

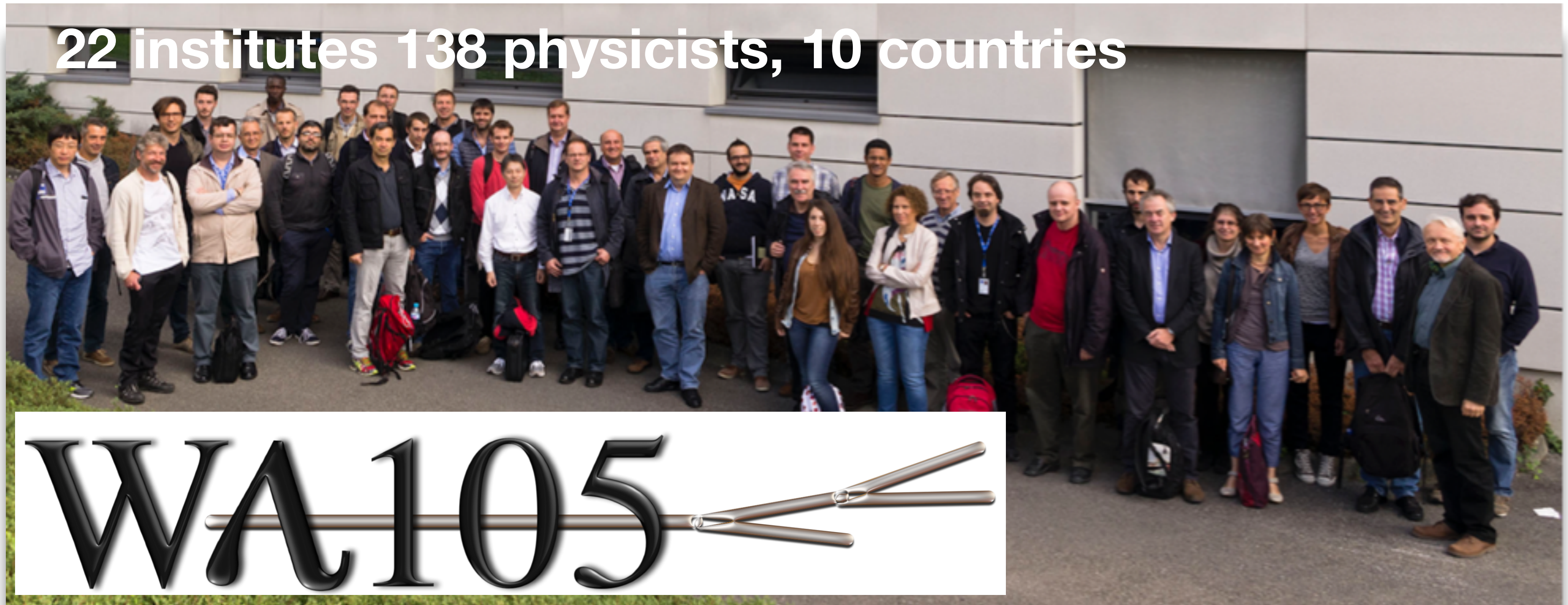
JINST 9 (2014) P03017

JINST 10 (2015) P03017

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

APC

Fermilab

LPNHE PARIS

iPNL

lapp

CERN

KEK
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION

LABORATORIUM FÜR HOCHENERGIEPHYSIK
LHEP
UNIVERSITÄT BERN

IFIN-HH

Institut de Física d'Altes Energies IFAE

I N 2 P 3
Institut National de Physique Nucléaire et de Physique des Particules

cea SACLAY

U B R

1834

Long roadmap, well established collaboration

WA105

2008-2014

- LAGUNA-LBNO FP7 design study (budget 17 M€). **Competitive and solid conceptual design developed in close partnership with specialised industries** for a > 10 kt underground dual phase LAr TPC.
- Pursuing R&D on small scale dual has TPCs towards large area readouts.

2015

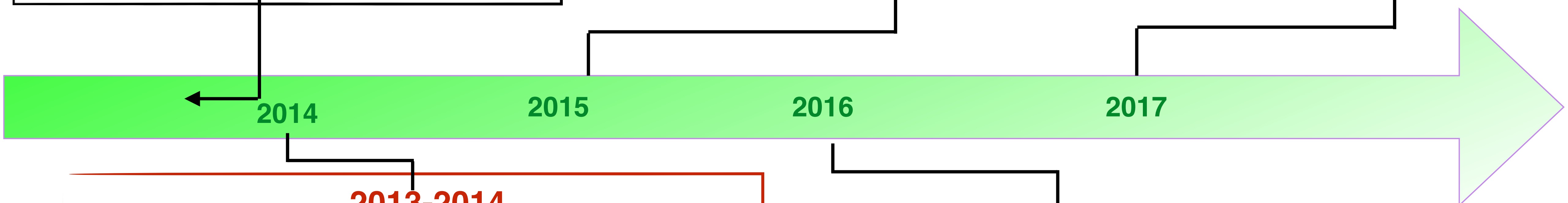
- **Formation of DUNE**. CDR submitted in June with conceptual design of a 10kt dual phase module.
- August: construction of the 3x1x1 cryostat. **First membrane cryostat constructed at CERN.**
- December. Integration of the 6x6x6 in DUNE project as ProtoDUNE-DP

2017

gas purge and cool down of the 3x1x1 TPC

June: EHN1 DP cryostat complete

Summer: start protoDUNE-DP detector assembly



2013-2014

- **2013: Creation of the WA105 collaboration.**
- Goal to demonstrate the dual phase technology at the relevant scale with a 6x6x6 m3 (300 tons) prototype located in the CERN north area.
- 2014: TDR submitted on 31st March *CERN-SPSC-2014-013*
- **Creation of the CERN Neutrino Platform**

2016

- **Construction** and start of commissioning of the **3x1x1 dual phase LArTPC.**
- **civil engineering of EHN1 complete**, start construction of protoDUNE cryostats
- Finalise design of protoDUNE-DP

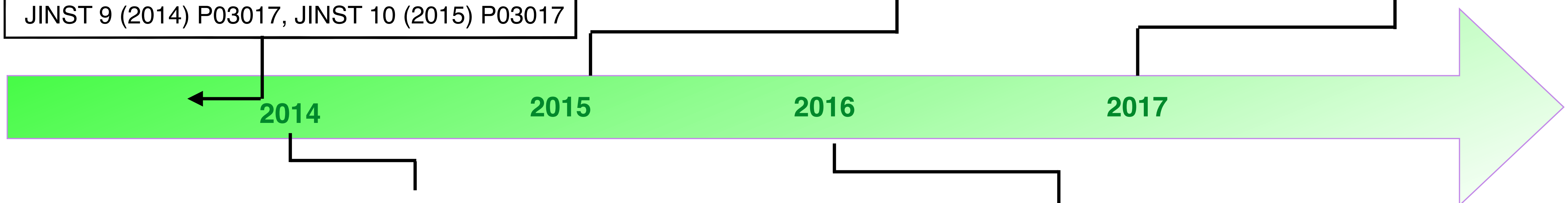
Long roadmap, well documented

WA105

2008-2014
- Expression of Interest for a very long baseline neutrino oscillation experiment (LBNO) CERN-SPSC-2012-021, SPSC-EOI-007.
- Feasibility of constructing GLACIER 20kt and 50 kt underground at reasonable cost 4000 pages 8 deliverables (delivered 31 Aug. 2014 to EC)
- Sensitivity papers
- aXiv/1412.0804
- arXiv/1412.0593
- Detector R&D (selected):
- 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

2015
- Annual SPSC progress report 31st March 2015 SPSC-SR-158
- short status update on WA105 SPSC-SR-166
- DUNE CDR, July 2015: Dual-phase 10 kton design

2017
- Annual SPSC progress report, 7th April 2016 CERN -SPSC-2016-017 SPSC-SR-206



2013-2014
- **August 2013 :WA105 approval by CERN RB**
- 31st March 2014: WA105 TDR submitted on *CERN-SPSC-2014-013 arXiv:1409.4405*
- CERN Neutrino platform MoU https://edms.cern.ch/document/1353815/2

2016
- short status update on WA105 SPSC-SR-179
- Annual SPSC progress report, 7th April 2016 CERN -SPSC-2016-017 SPSC-SR-184

Long roadmap, well documented

WA105

From past SPSC recommendations: *"encouraged CERN and the WA105 collaboration to (...) undertake all efforts to be ready with DLAr in the EHN1 extension for first beam before the start of the Long Shutdown 2."*

2014

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

March 31st, 2014
CERN-SPSC-2014-013
SPSC-TDR-004

Technical Design Report
for large-scale neutrino detectors prototyping
and phased performance assessment
in view of a long-baseline oscillation experiment

The LBNO-DEMO (WA105) Collaboration

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-SR-XXX
March 31, 2015

Progress report on LBNO-DEMO/WA105 (2015)

The WA105 Collaboration

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CERN-SR-XXX
June 22, 2015

Short Status Update on LBNO-DEMO/WA105 (2015)

The WA105 Collaboration

Bucharest - CERN - CIEMAT - ETHZ - Geneva - Glasgow - Helsinki - IFAE - IFIN-HH - IN2P3/APC - IN2P3/IPNL - IN2P3/LAPP - IN2P3/LPNHE - IN2P3/OMEGA - INR - IRFU/CEA - Jyvaskyla - KEK - Oulu - Sofia - UCL

1 Introduction

The double (or dual) phase liquid Argon TPC represents a novel concept for liquid argon detectors. This concept, developed during several years within the EC FP7 LAGUNA-LBNO design study, has been shown to provide a cost-effective solution for implementing very large deep underground liquid argon detectors with very fine imaging performance and low detection thresholds, such as those needed in next-generation long-baseline experiments.

The Deep Underground Neutrino Experiment (DUNE) [1] aims at constructing four large liquid argon detectors of 10-kt fiducial mass each, to be located underground at the 4850L level of the ...

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-SR-XXX
January 18, 2016

Short Status Update on the WA105 experiment (2016)
at the Neutrino Platform

The WA105 Collaboration

1 Introduction

The double (or dual) phase liquid Argon TPC represents a novel concept for liquid argon detectors. This concept, developed during several years within the EC FP7 LAGUNA-LBNO design study, has been shown to provide a cost-effective solution for implementing very large deep underground liquid argon detectors with very fine imaging performance and low detection thresholds, such as those needed in next-generation long-baseline experiments.

The Deep Underground Neutrino Experiment (DUNE) [1] aims at constructing four large liquid argon detectors of 10-kt fiducial mass each, to be located underground at the 4850L level of the Sanford Underground Research Facility (SURF) in South Dakota. DUNE considers both single- and dual-phase designs for the far detectors. There is recognition that the staged approach with the deployment of consecutive modules will enable an initial science programme to begin early, while allowing implementation of improvements and developments of the far detector technology during the lifetime of the experiment. Compared to the single-phase, the dual-phase design will provide a fully active volume without dead material with a smaller number of readout channels, a finer readout pitch, a more robust signal-to-noise ratio with tunable gain, a lower detection energy threshold, and a better pattern reconstruction of the events. These will allow to best exploit the "bubble chamber"-like features of the liquid argon TPC at the 10-kt scale.

The aim of the WA105 experiment at the CERN Neutrino Platform is to fully demonstrate the concept developed in LAGUNA-LBNO for the DUNE Far Detector, by constructing and testing full-scale detector components, assessing their installation procedures in the 6×6×6m³ DLAr demonstrator

CERN-SPSC-2016-009 / SPSC-SR-179
18/01/2016

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-SR-XXX
April 7, 2016

Yearly progress report on WA105/ProtoDUNE dual phase (2016)

The ProtoDUNE Dual Phase Collaboration

Abstract

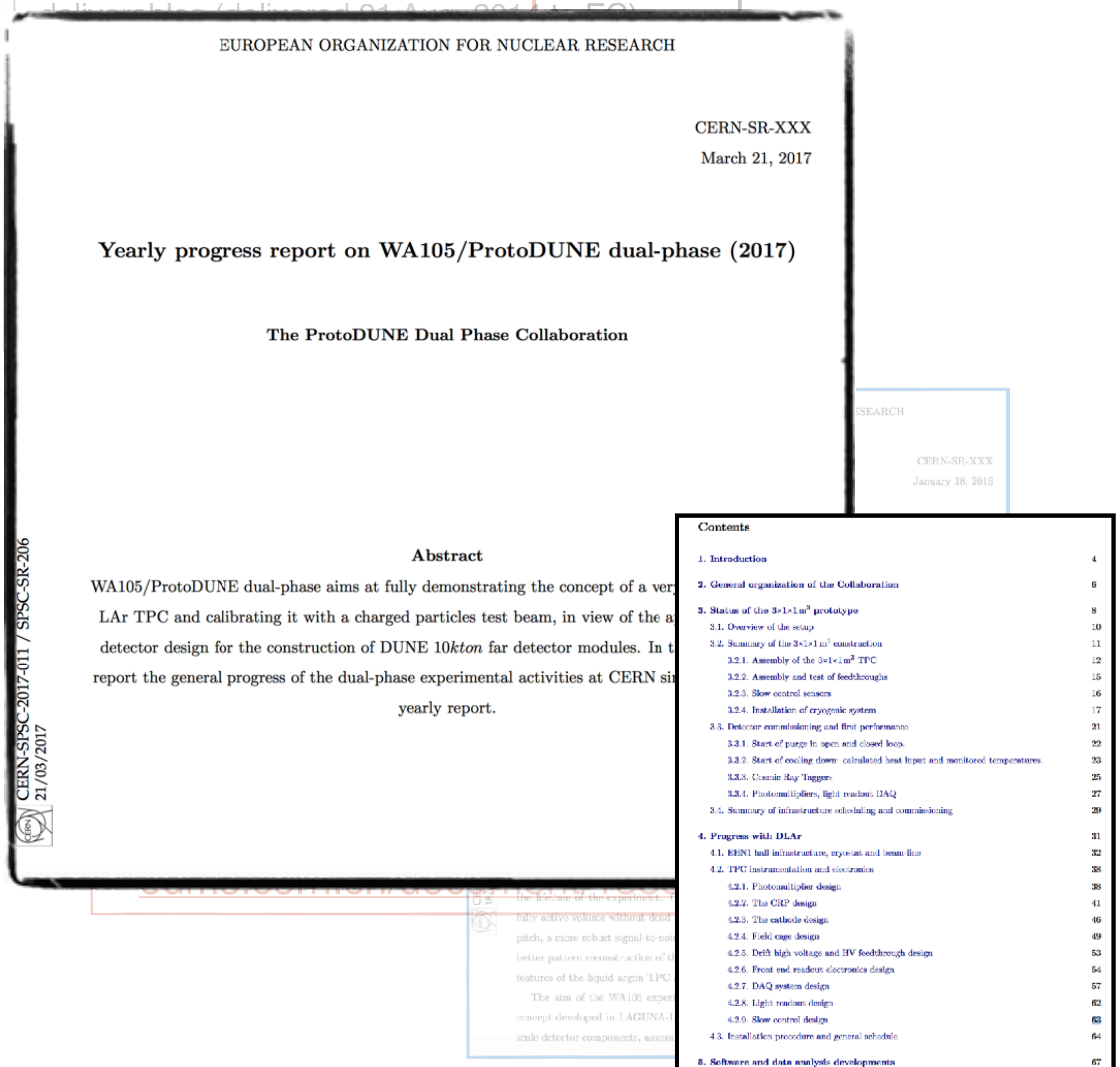
WA105 aims at fully demonstrating the concept of a very large dual phase LAr TPC and calibrating it with a charged particles test beam. In this document we report the status of the construction and the general progress of the experiment.

CERN-SPSC-2016-017 / SPSC-SR-184
07/04/2016

2017 SPSC Status Report (#206)

WA105

From past SPSC recommendations: *"encouraged CERN and the WA105 collaboration to (...) undertake all efforts to be ready with DLAr in the EHN1 extension for first beam before the start of the Long Shutdown 2."*



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-SR-XXX
March 21, 2017

Yearly progress report on WA105/ProtoDUNE dual-phase (2017)

The ProtoDUNE Dual Phase Collaboration

Abstract

WA105/ProtoDUNE dual-phase aims at fully demonstrating the concept of a ver[y] LAr TPC and calibrating it with a charged particles test beam, in view of the a[…] detector design for the construction of DUNE 10*kton* far detector modules. In t[…] report the general progress of the dual-phase experimental activities at CERN si[…] yearly report.

CERN-SPSC-2017-011 / SPSC-SR-206
21/03/2017

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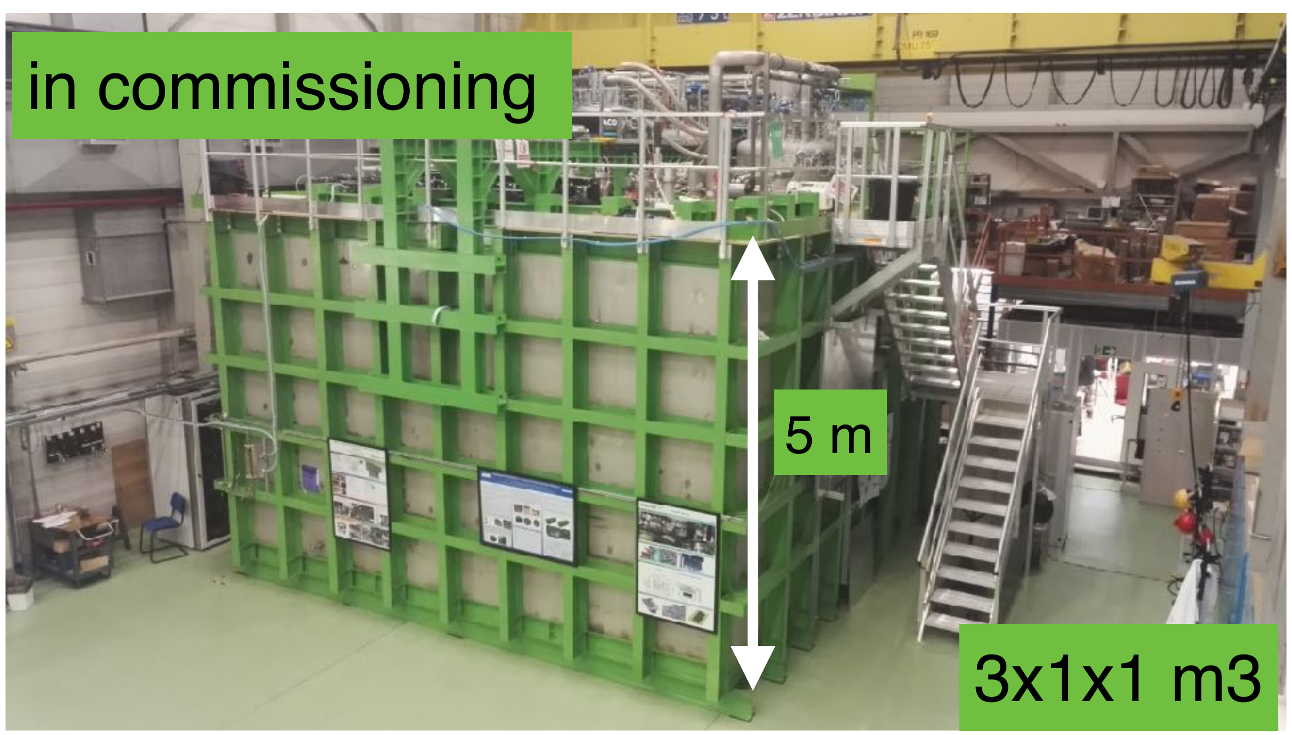
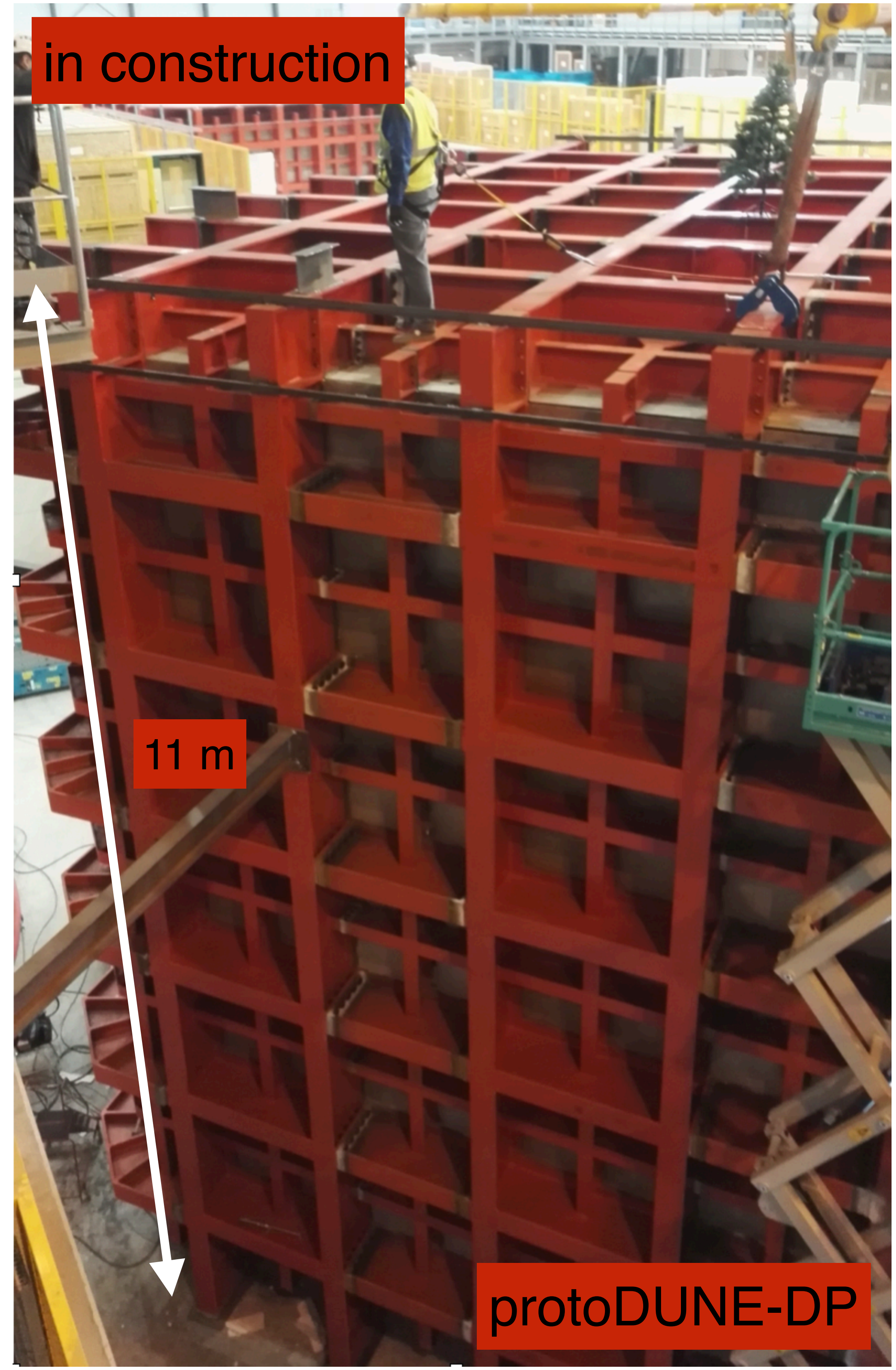
Significant progress since last year's SR. **Comprehensive summary of 80+ pages,** 3 main sections:

- The 3x1x1 m3 detector was fully assembled in 2016 and is being commissioned.
- ProtoDUNE-DP is designed, the integration phases are well defined, the updated schedule has been provided
- Software: progress includes LEM simulation, electric and light field map, benchmarking, event viewing, DP integration in LArSoft

Two dual phase liquid argon detectors

same technology, two scales, different goals





Two dual phase liquid argon detectors

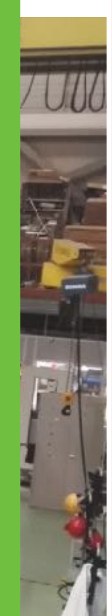
WA105

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

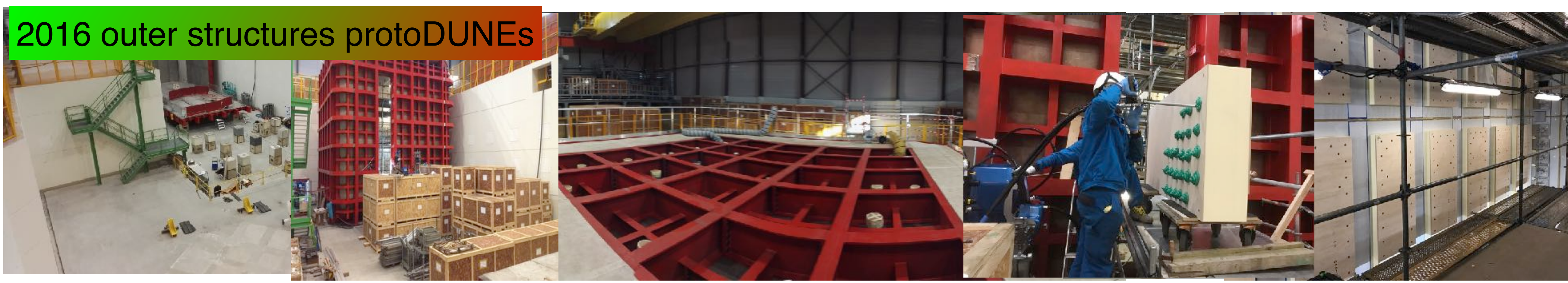


1 m

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

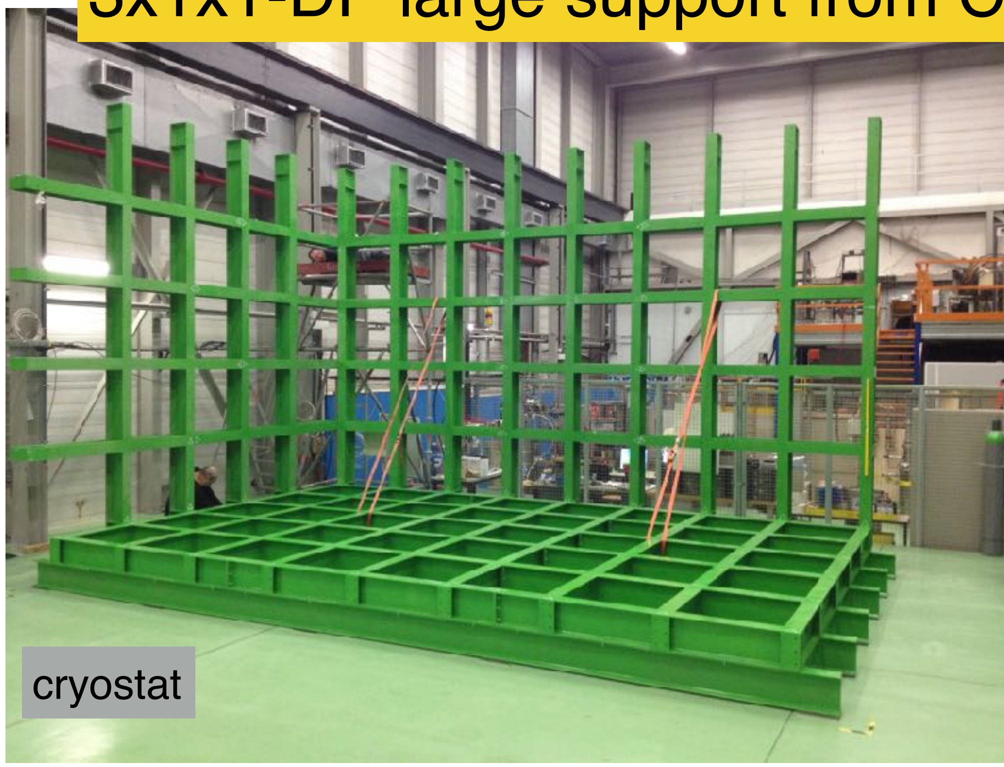
The cryostats



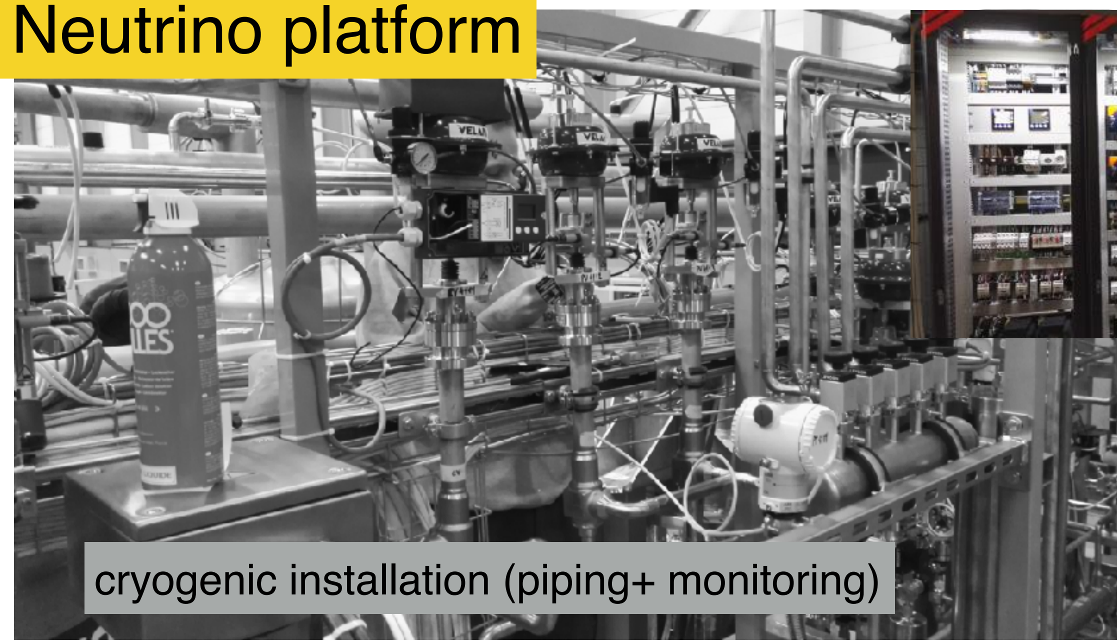
The role of CERN: Neutrino Platform

WA105

3x1x1-DP large support from CERN Neutrino platform



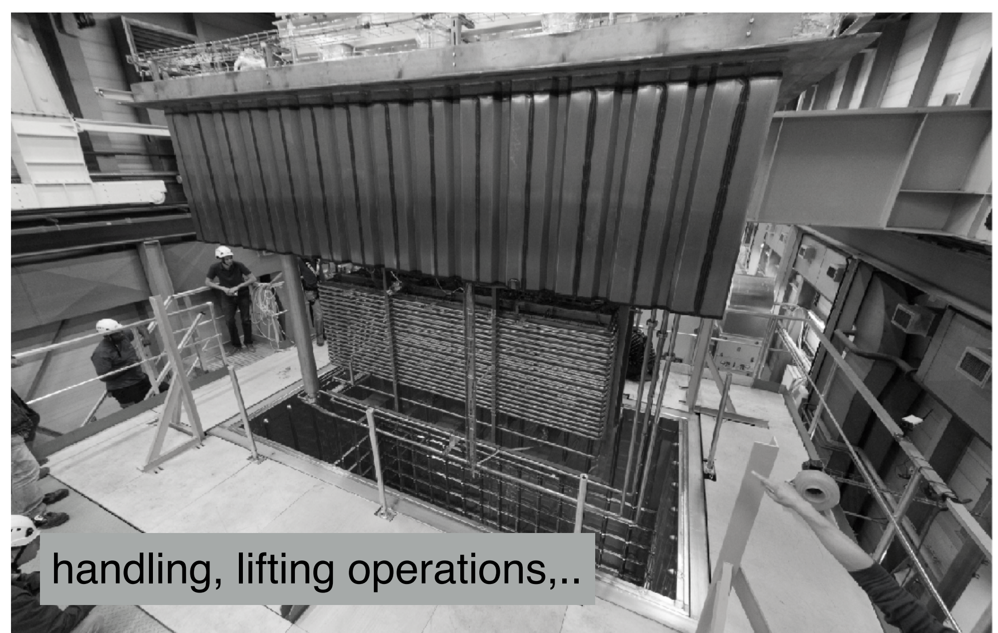
cryostat



cryogenic installation (piping+ monitoring)

DCS

infrastructure (clean room, structures,..) & safety



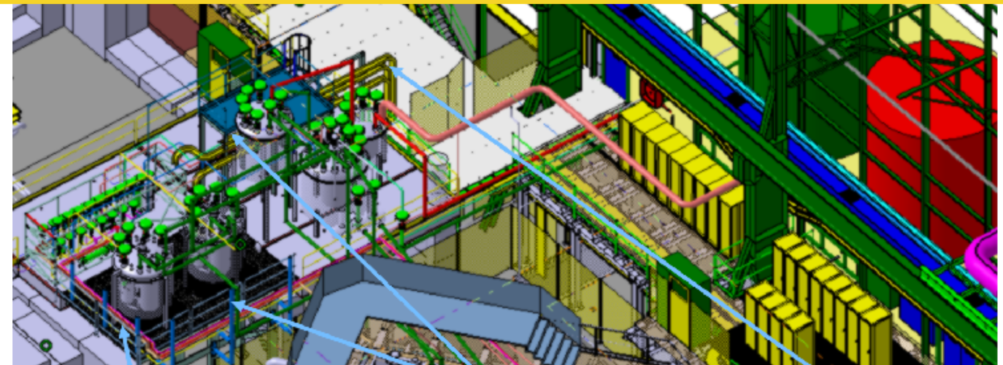
handling, lifting operations,..

The role of CERN: Neutrino Platform

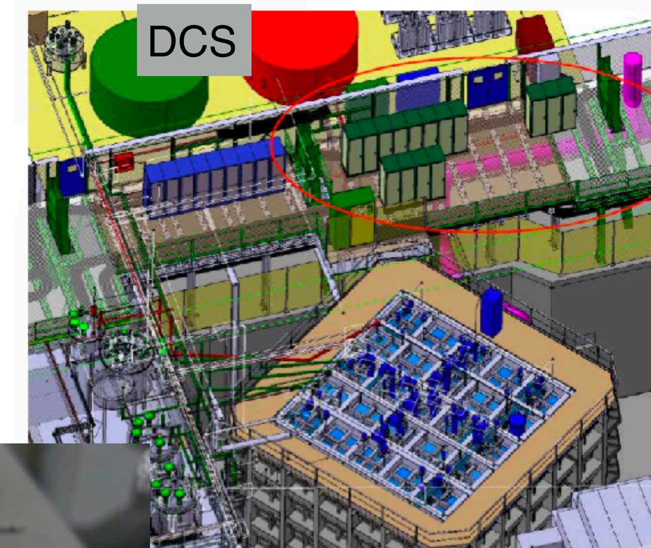
WA105

protoDUNE-DP: fundamental support of CERN NP on cryostat, cryogenic system, infrastructure and detector

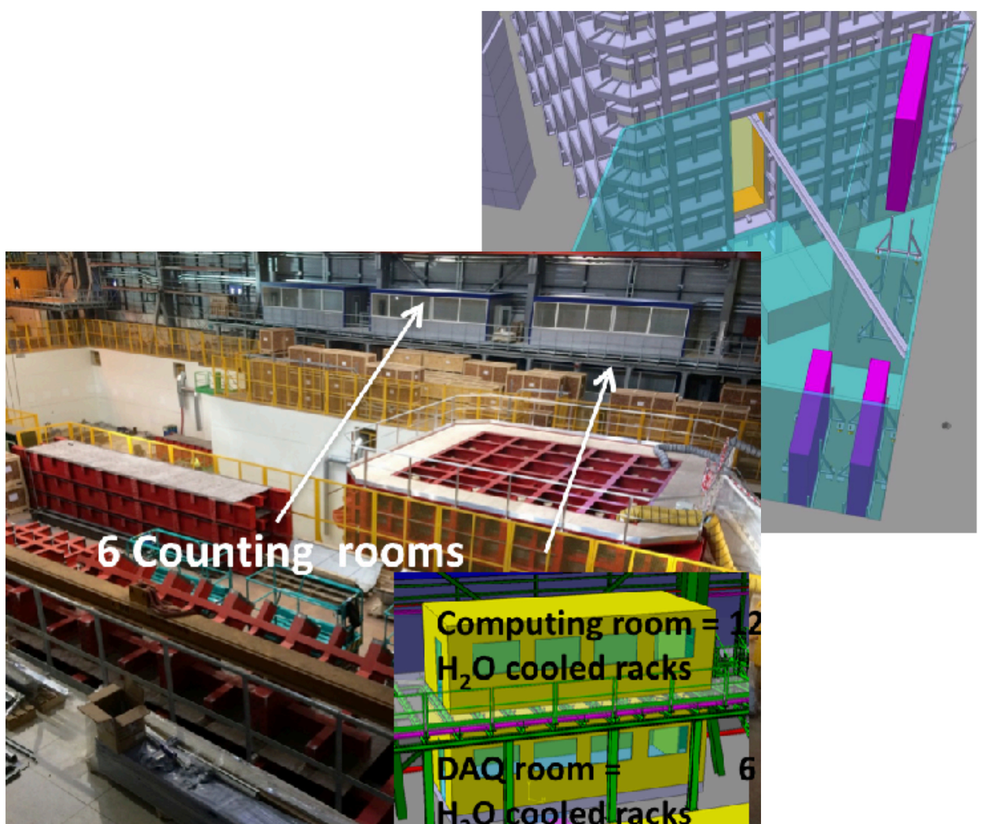
cryostat



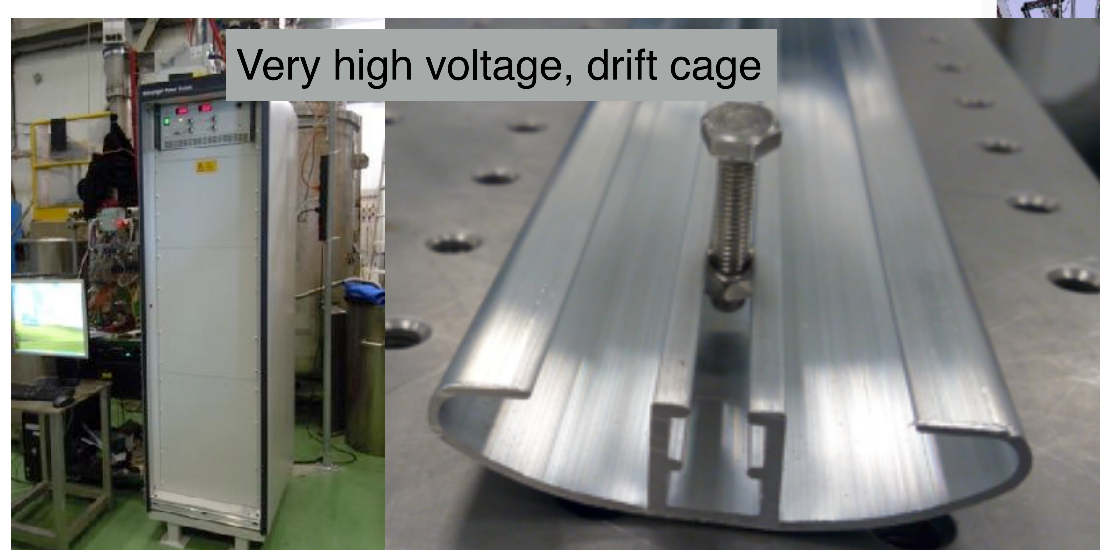
cryogenic installation (piping+ monitoring)



DCS



infrastructure (clean rooms, counting house, network,..) & safety

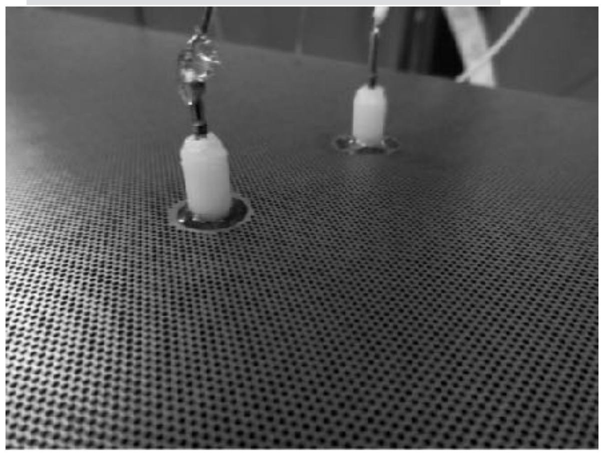


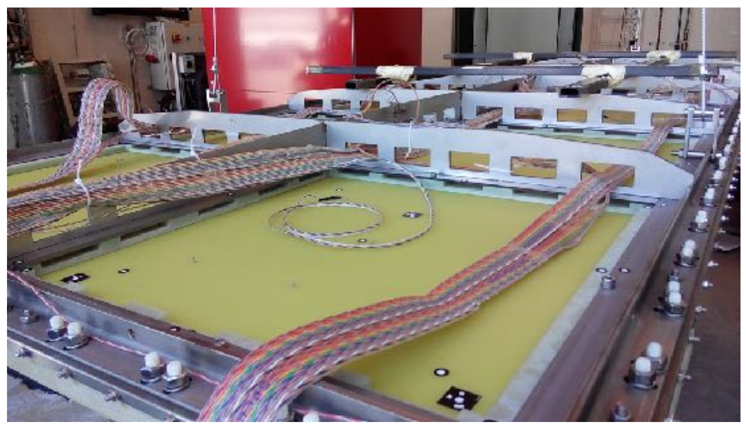
Very high voltage, drift cage

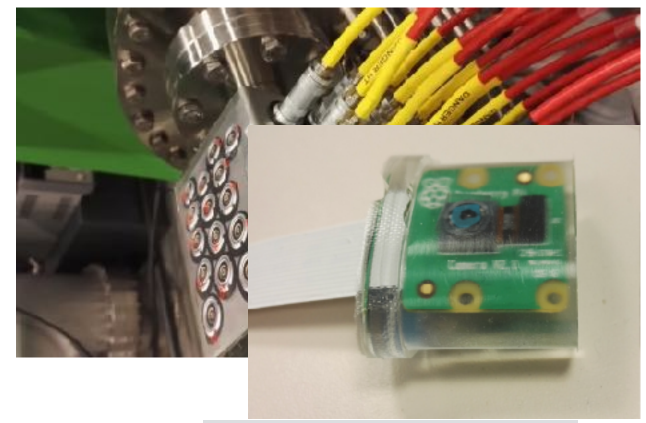
The role of CERN

WA105

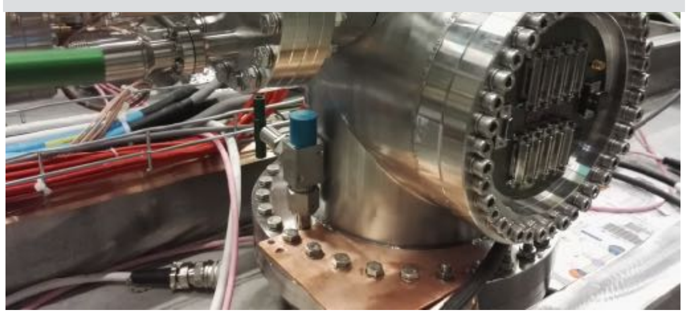
in addition to the support from Neutrino Platform, important assistance from many CERN groups and labs

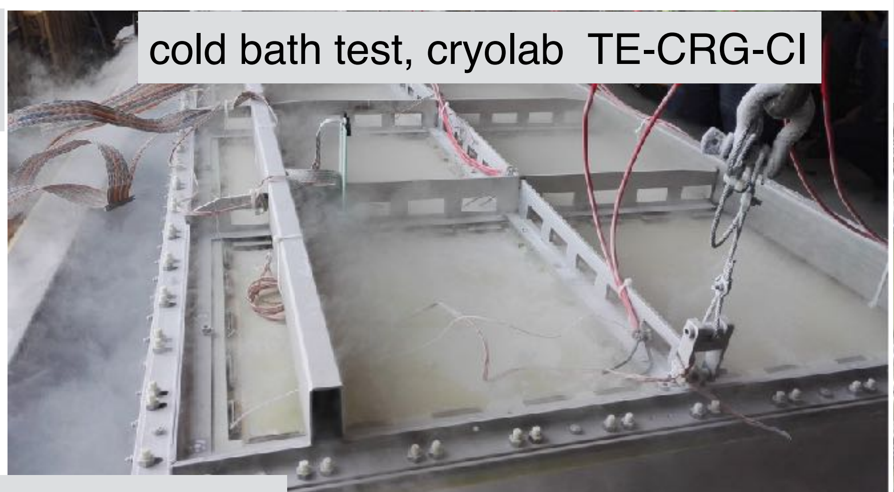

anode+LEM: EP-DT-EF

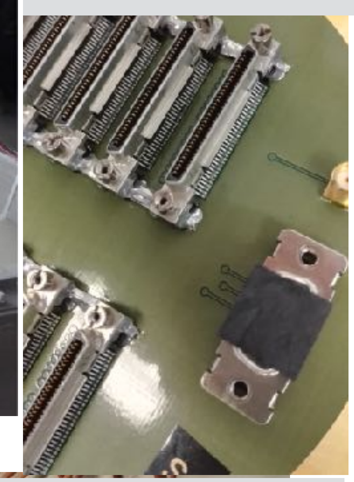

photogrammetry + survey EN-ACE-SU

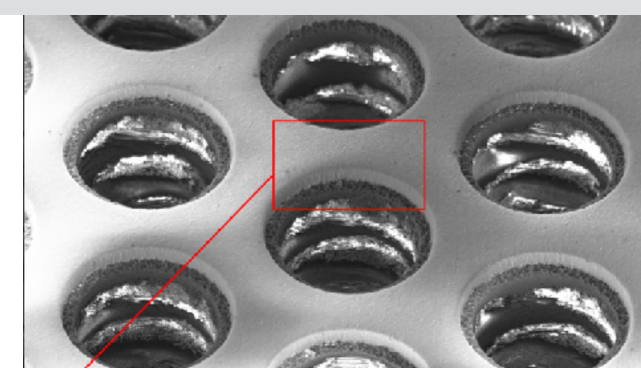

polymers: TE-MSC-MDT

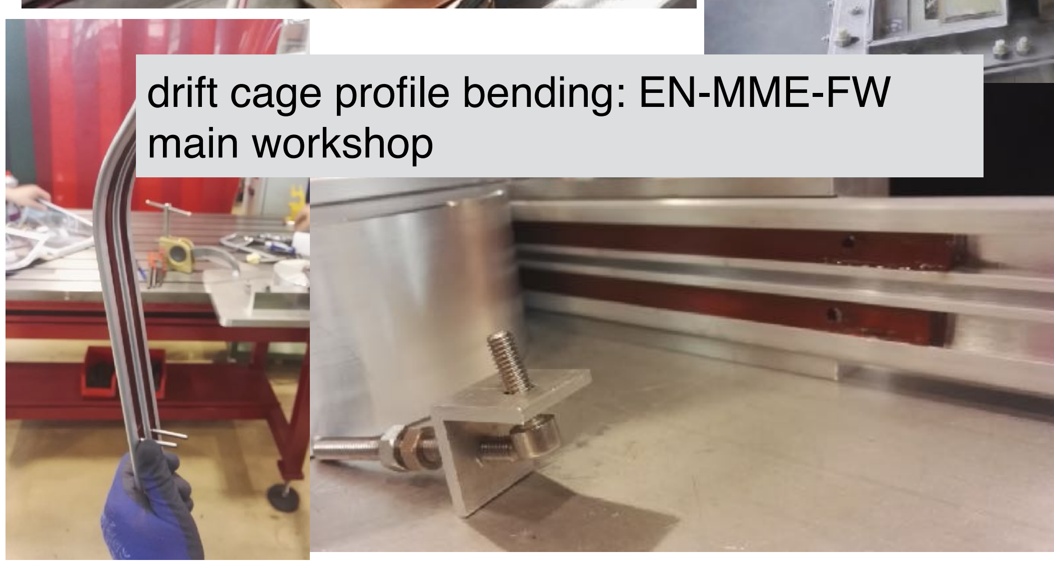

PMT coating and qualification EP-DT-EF


cabling and grounding installation EP-DT-DI

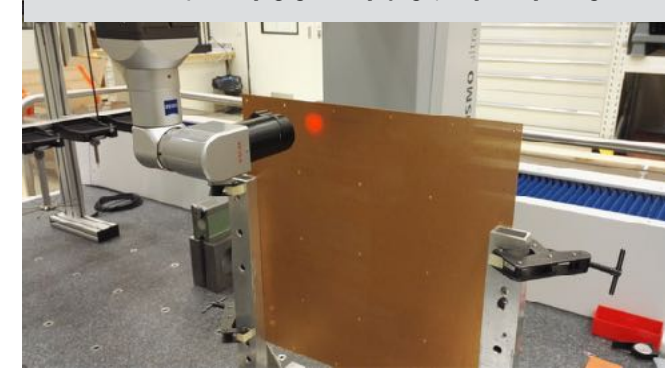

cold bath test, cryolab TE-CRG-CI


SMD soldering TE-MPE-EM


SEM observations: EN-MME-MM

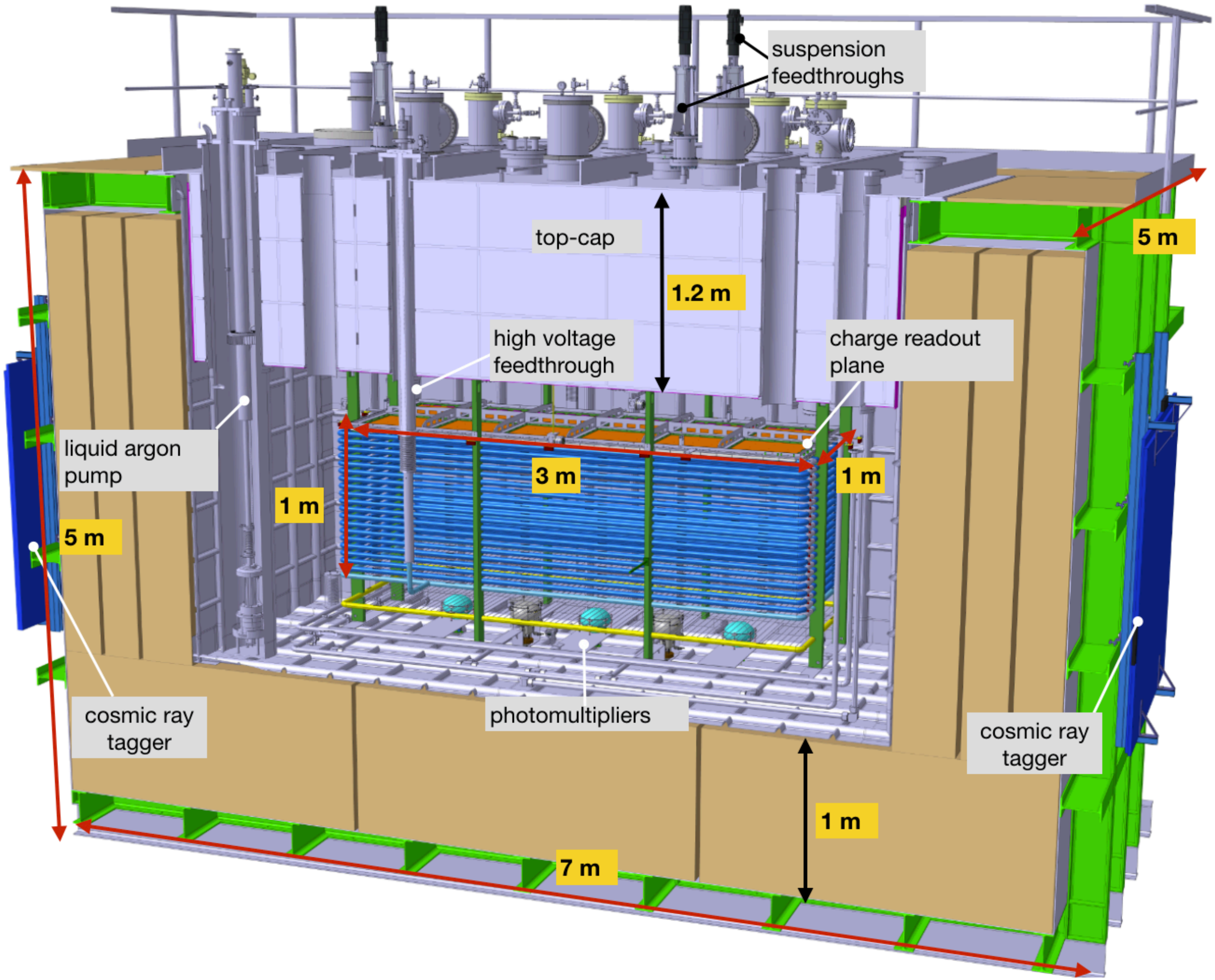

drift cage profile bending: EN-MME-FW main workshop


cabling manufacturing EN-EA-CT


LEM thickness measurements EP-UAT

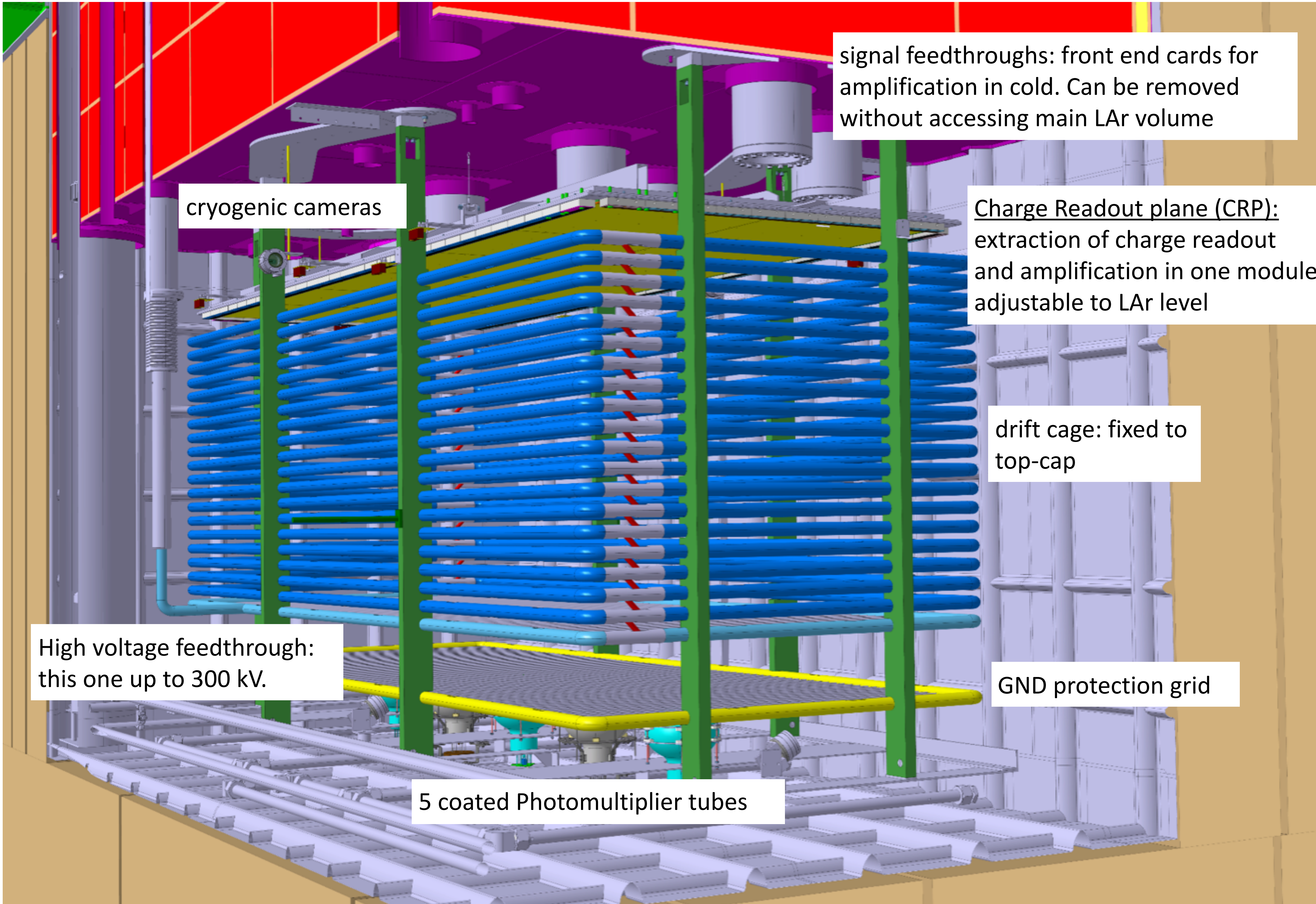
The 3x1x1 m3 dual phase LAr TPC

WA105



3x1x1 detector

WA105

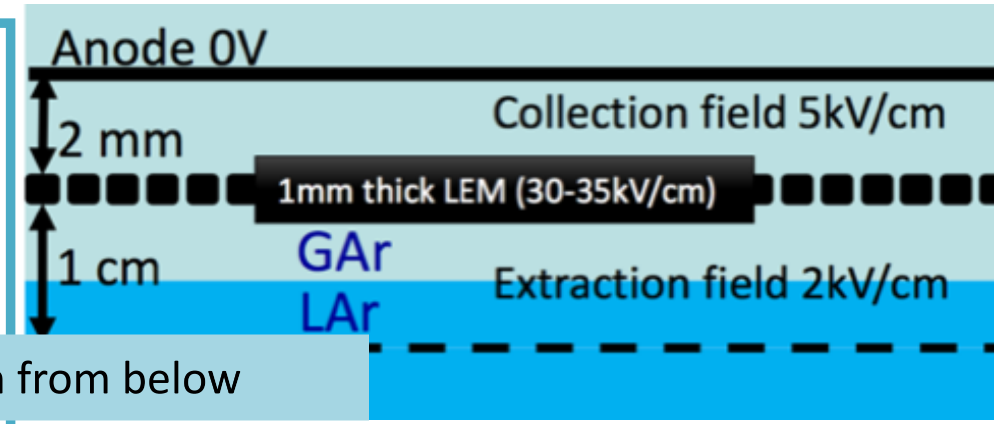


pictures from inside the cryostat

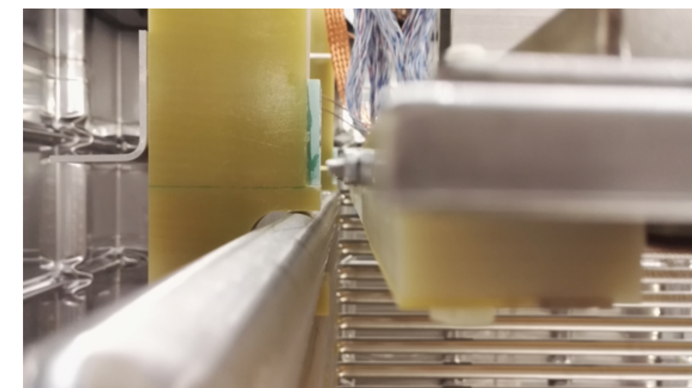
WA105

Charge Readout Plane

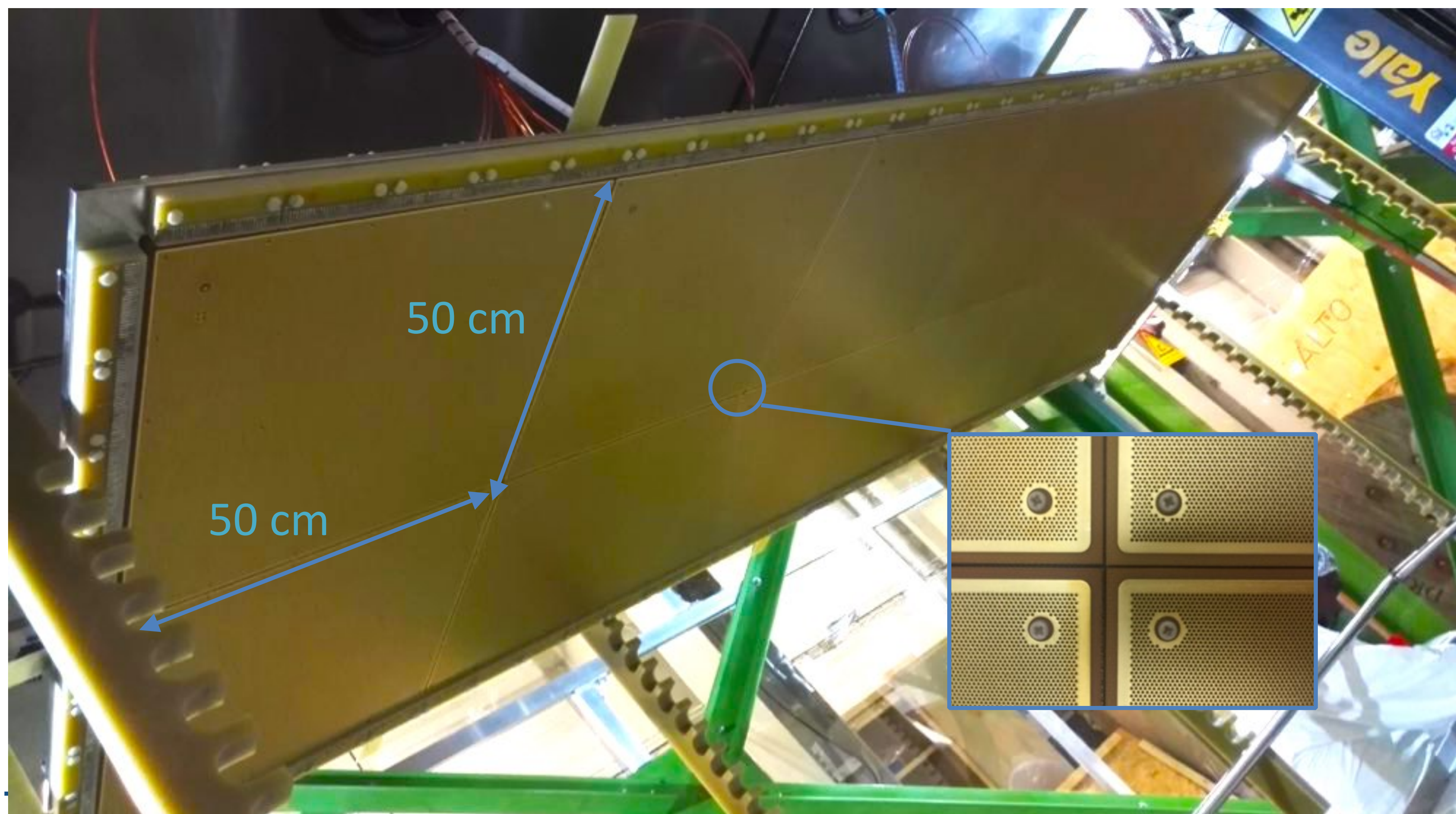
- fully active 3x1 m2 amplification and readout adjustable to LAr level.
- All components industrially fabricated with most of the QA/QC performed by the companies.
- mechanical tolerances validated in warm temperature in open cryogenic baths.
- Assembly is straightforward (~2 people, 2 days)

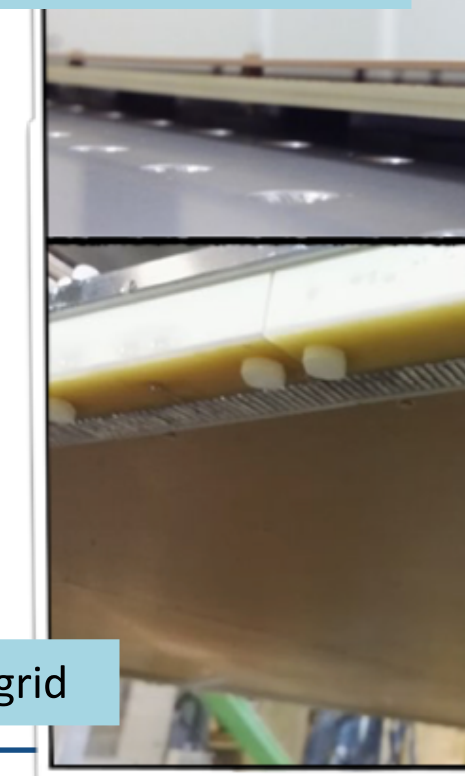


CRP LEM active area seen from below



LEM + anode sandwich





extraction grid

CRP 3x1 m2 -> 3x3 m2

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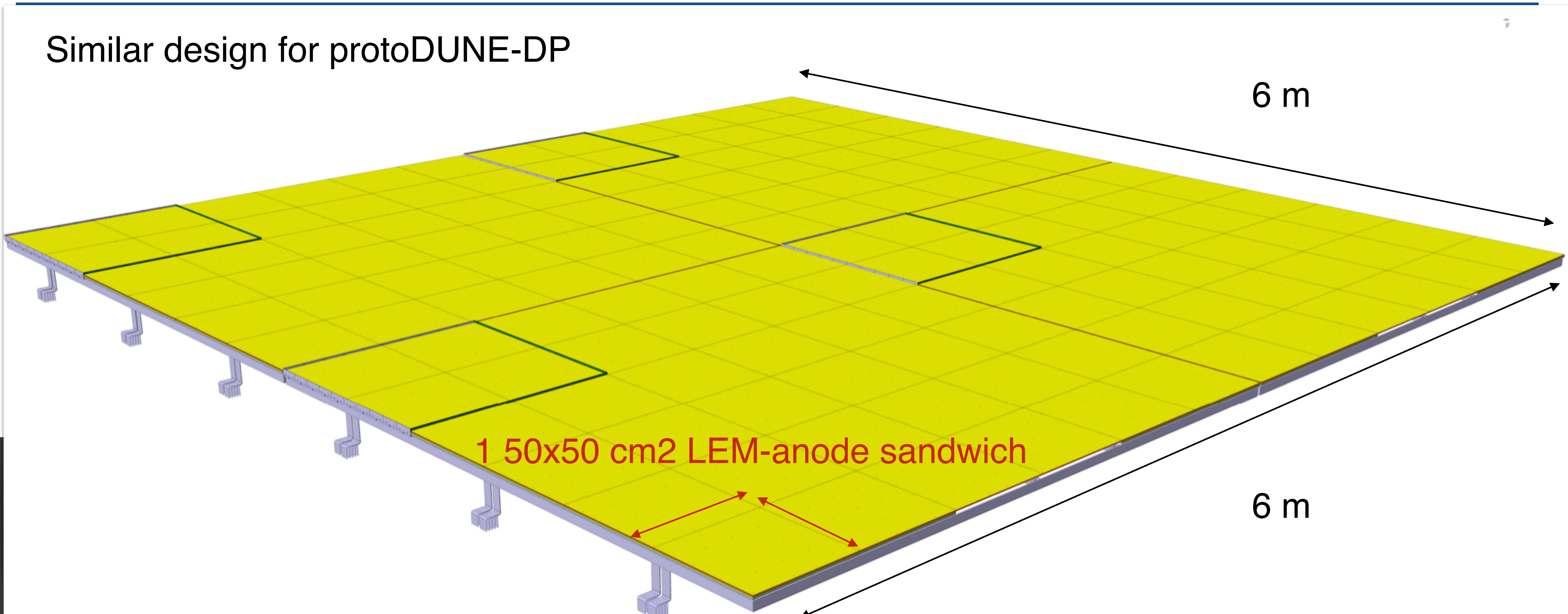
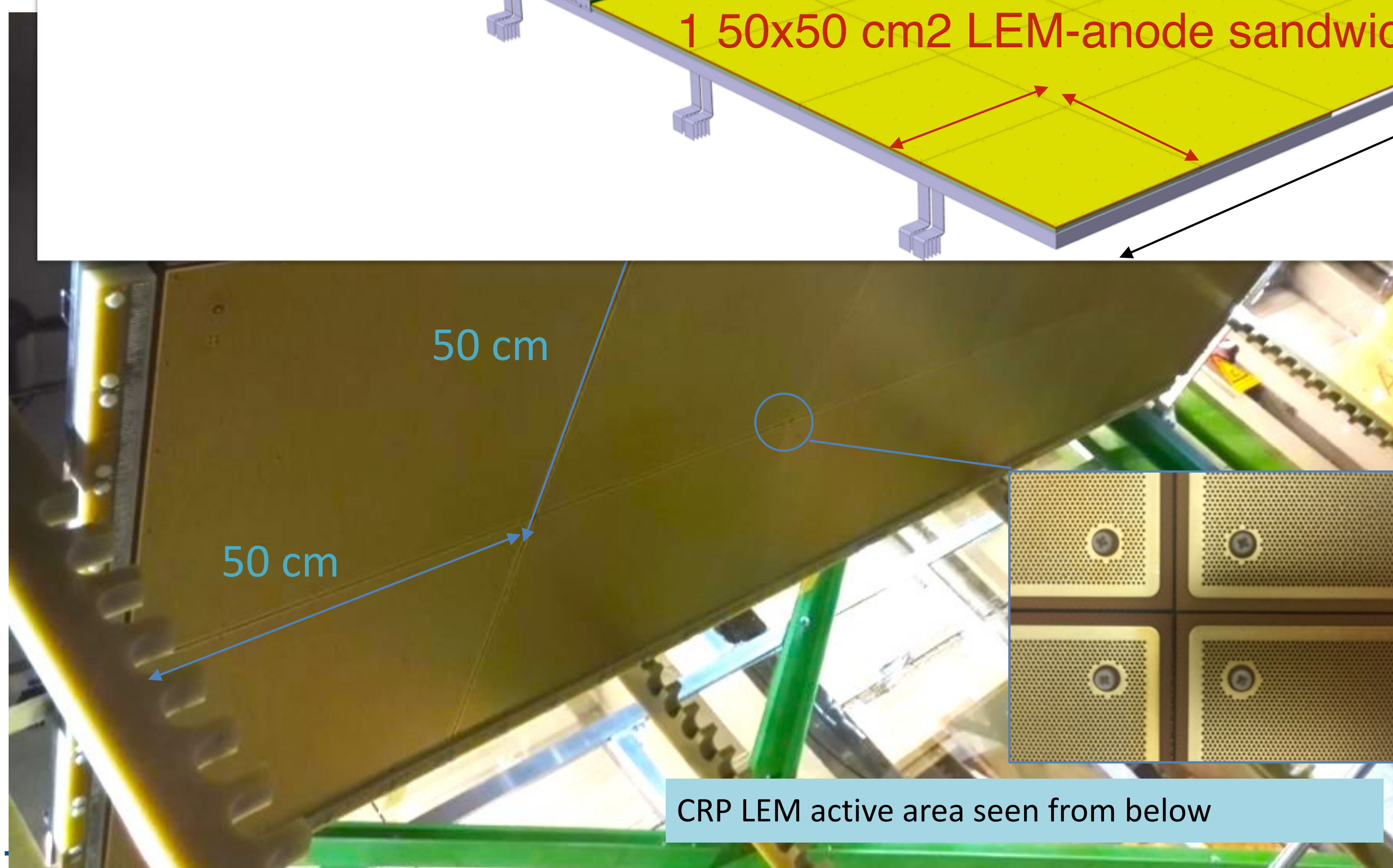
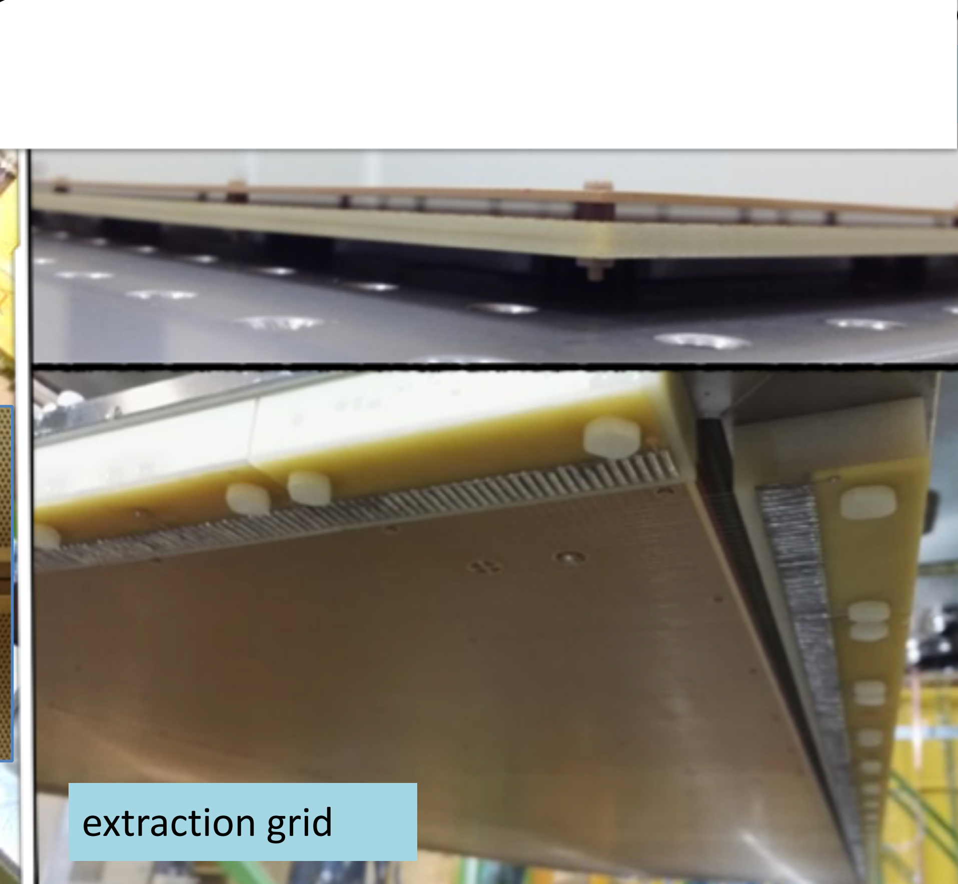






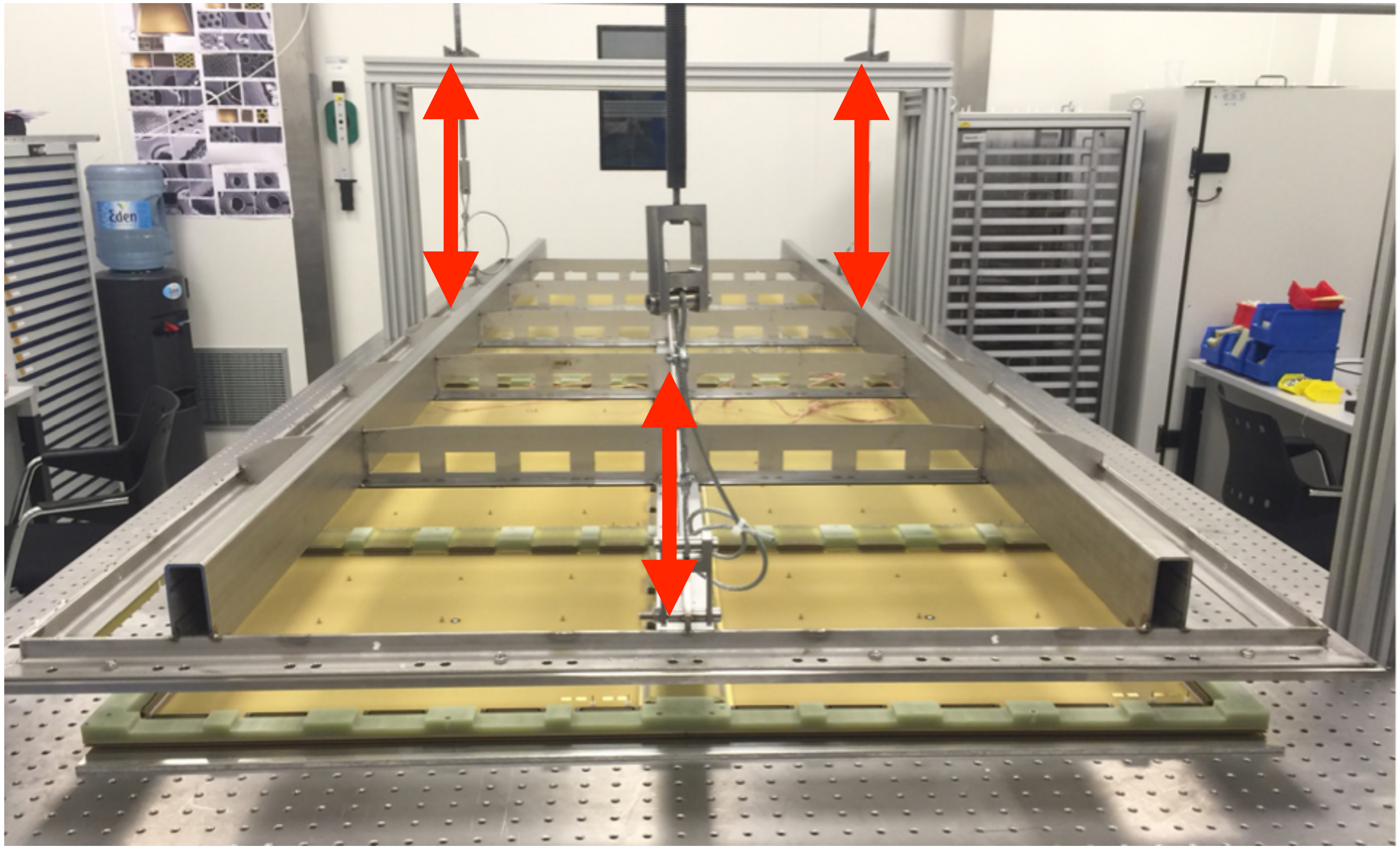
Charge Readout Plane

WA105

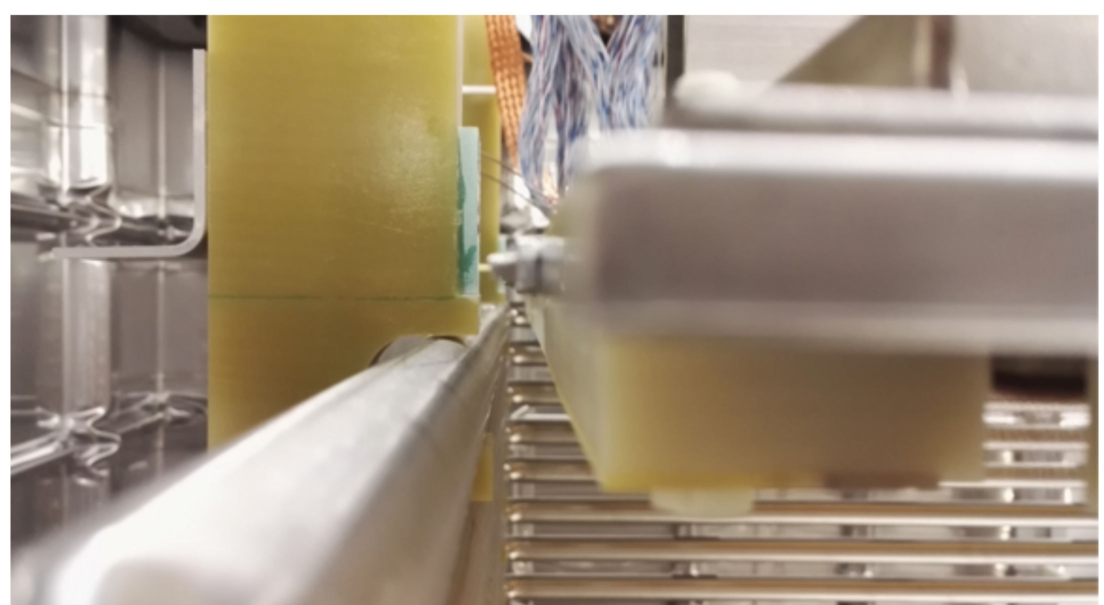
- Fully assembled CRP, partly instrumented and dipped in LAr with photogrammetric targets
- -><u>check resistance to thermal shock and planarity at cold as well as signal continuity.</u>

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

CRP: adjustable to LAr level



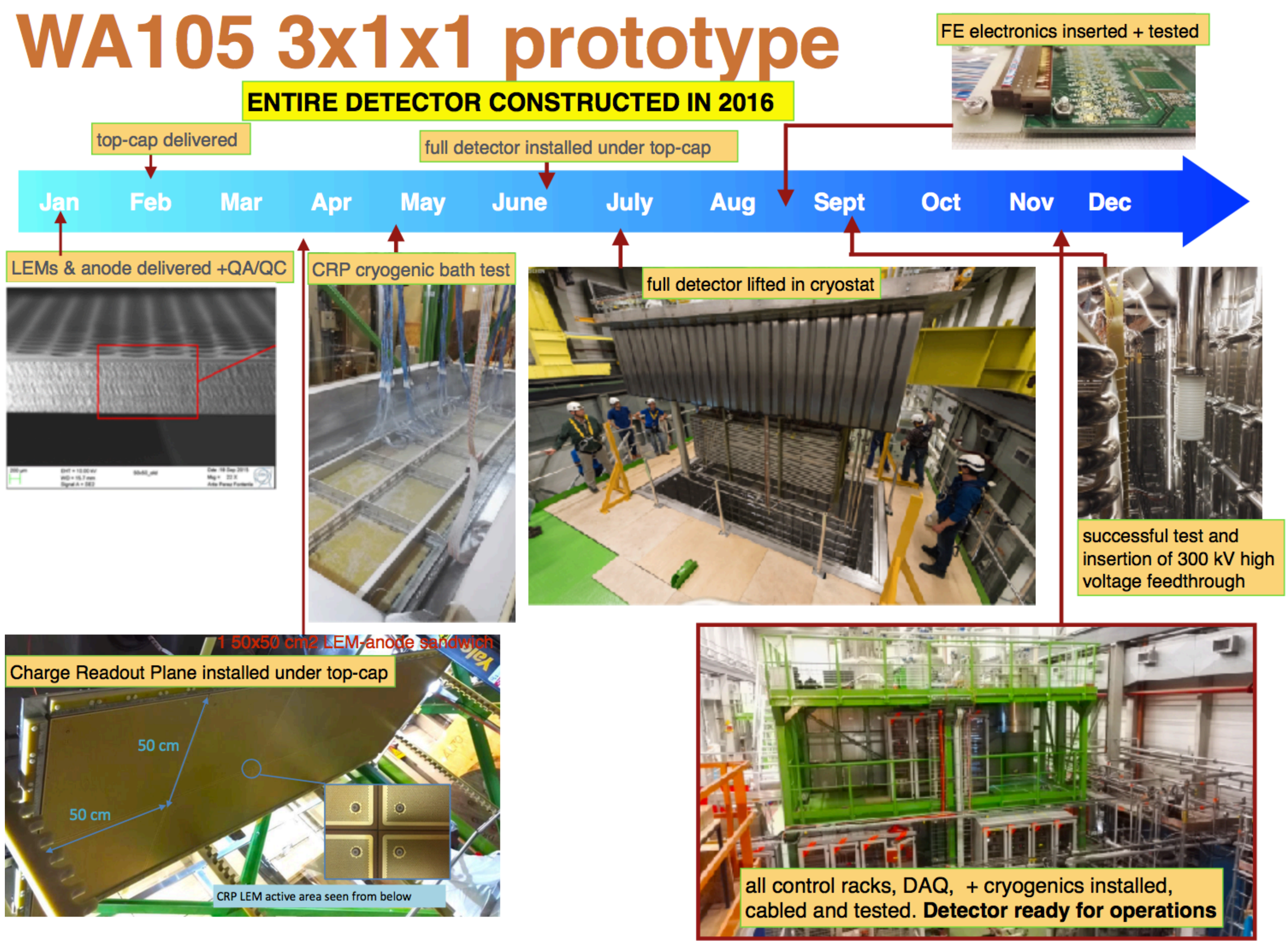
tested and validated for protoDUNE-DP



- suspended by 3 ropes coupled to motors on top-cap.
- Place the CRP so that the liquid level is in between the LEM and grid
- 8 capacitive level meters readout the LAr level with similar precision

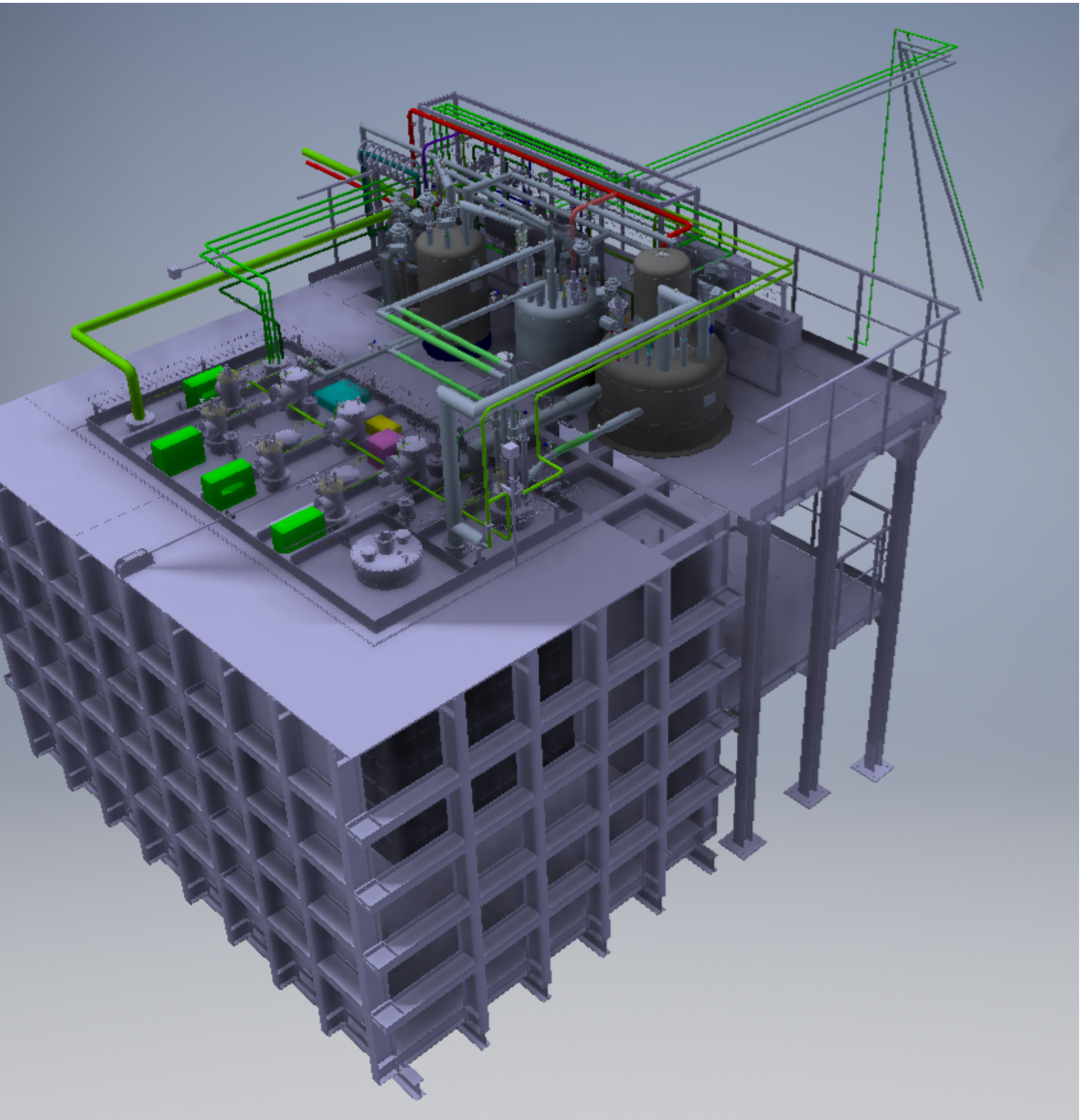
Detector installation- on schedule

WA105



Cryogenic installation and commissioning

WA105

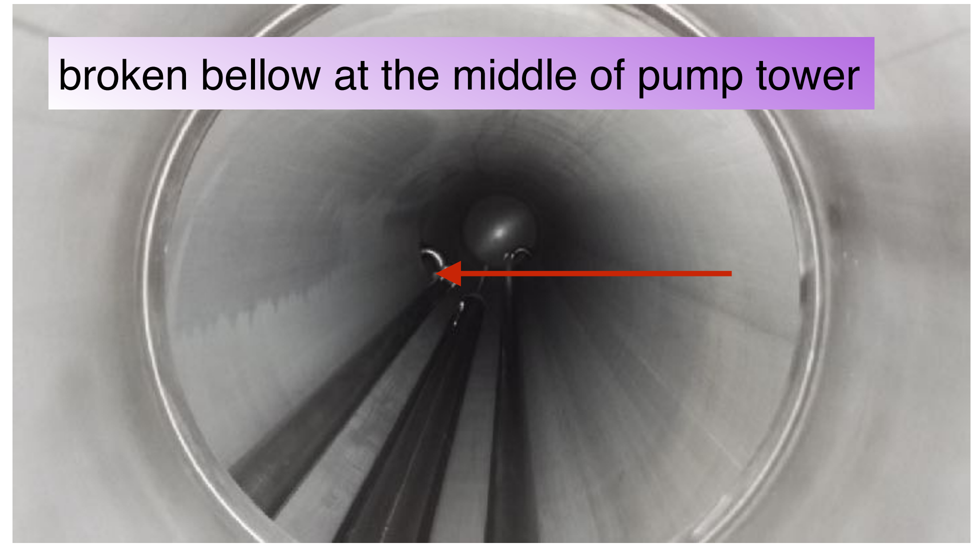


- Cold piping (LAr+ LN2 lines, valve boxes, liquid purification,..) Sept 19th- Oct 13th
- Warm piping (gas argon purification system, chimney purges, ..) Oct-Nov
- Control system Sept-Nov
- Start of gas argon piston purge Jan 24th
- Start of cool down Feb 27th

difficulties encountered during commissioning

WA105

longer than anticipated installation of warm piping



broken bellow at the middle of pump tower

manhole sealing

some leaks on pump tower flanges

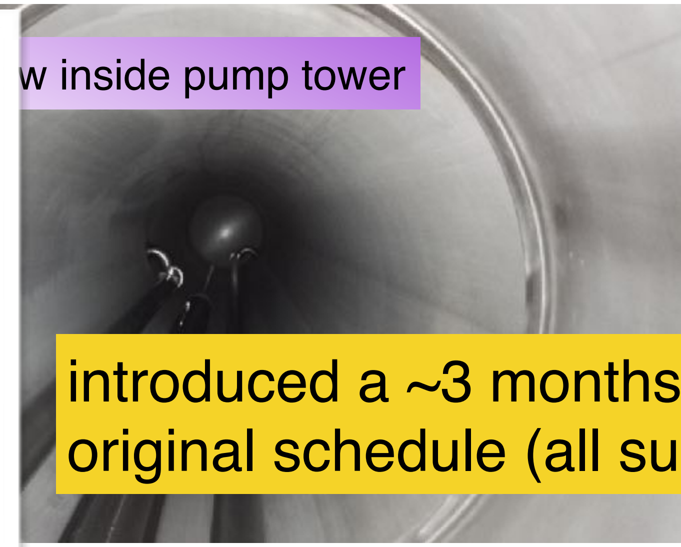
difficulties in regulating LN2 flow in condenser.
leak searched and identified in warm piping

difficulties encountered during commissioning

WA105

Activity	start date	end date	observations
cold piping installation	Sept 19th	Oct 13th	duration of on-site installation according to schedule. 1.5 month delay on start date.
warm piping installation	Oct 13th	Nov 25th	one month longer than foreseen due to late arrival of some material. As a consequence it was not possible to fill before CERN annual closure
cryogenic functional tests	Nov 25th	Dec 9th	testing of remote valve operations, verification of P&ID, pressure test of piping
closing of manhole and first pressurisation of the tank	Dec 19th	Dec 21st	leaks identified at the pump tower
repairing pump tower leaks	Jan 5th	Jan 24th	leaks on the pump tower flanges + internal leak inside the tower due to a broken bellow. 3 weeks delay introduced.
piston purge in open loop	Jan 24th	Feb 7th	stable at about 2 liters per second, roughly 80 volume changes
gas argon closed loop recirculation	Feb 8th	Feb 15th	stable at ~4 liters per second corresponding to ~80 volume changes
safety clearance for liquid filling	Feb 3rd	Feb 3rd	
first cool down trial	Feb 15th	Feb 16th	
fixing LN2 piping	Feb 16th	Feb 26th	formation of gas pockets preventing stable liquid nitrogen flow inside the condenser. This would have a direct consequence on the stability of the gas argon pressure inside during operation. Fixed by adding a purging valve at the entrance of the condenser. Introduced about 1.5 weeks of delay.
cooling down	Feb 27th	March 3rd	cooling down with spraying nozzles mixture of GAr at 500 l/min and LAr 21.2 l/h. Cooling down interrupted due to presence of ice on the south east corner of the cryostat outer structure.
warming up + dry air flushing	Marchrd	March 12th	in view of a visual inspection inside the tank
visits inside tank by GTT + and membrane inspection	March 13th	ongoing	visual inspections followed by sniffer tests performed by injecting Helium inside the insulation space and sniffing on the south side of the membrane surface and the bottom corners. Where accessible the sniffing was also performed with specifically designed vacuum plug enhancing the sensitivity of the leak check from 1e-5 mbar.l/s to 1e-8 mbar.l/s. No evidence of leak found so far. Discussion on next steps ongoing.

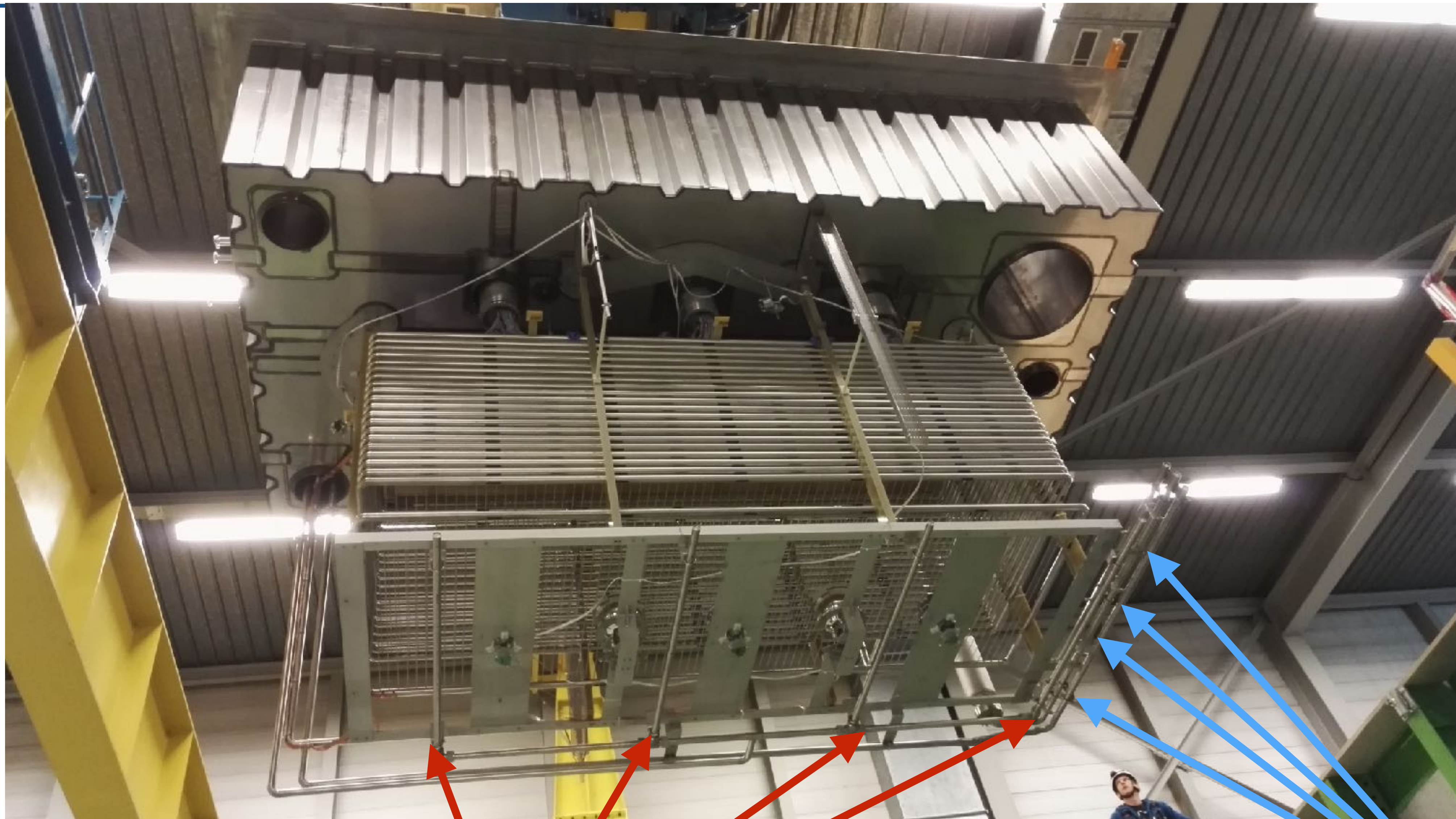
TABLE III: Main dates of the cryogenic system installation and commissioning during 2016-2017.



introduced a ~3 months delay from the original schedule (all summarised in SR-206)

Valuable input for protoDUNEs

Purging and cooling down



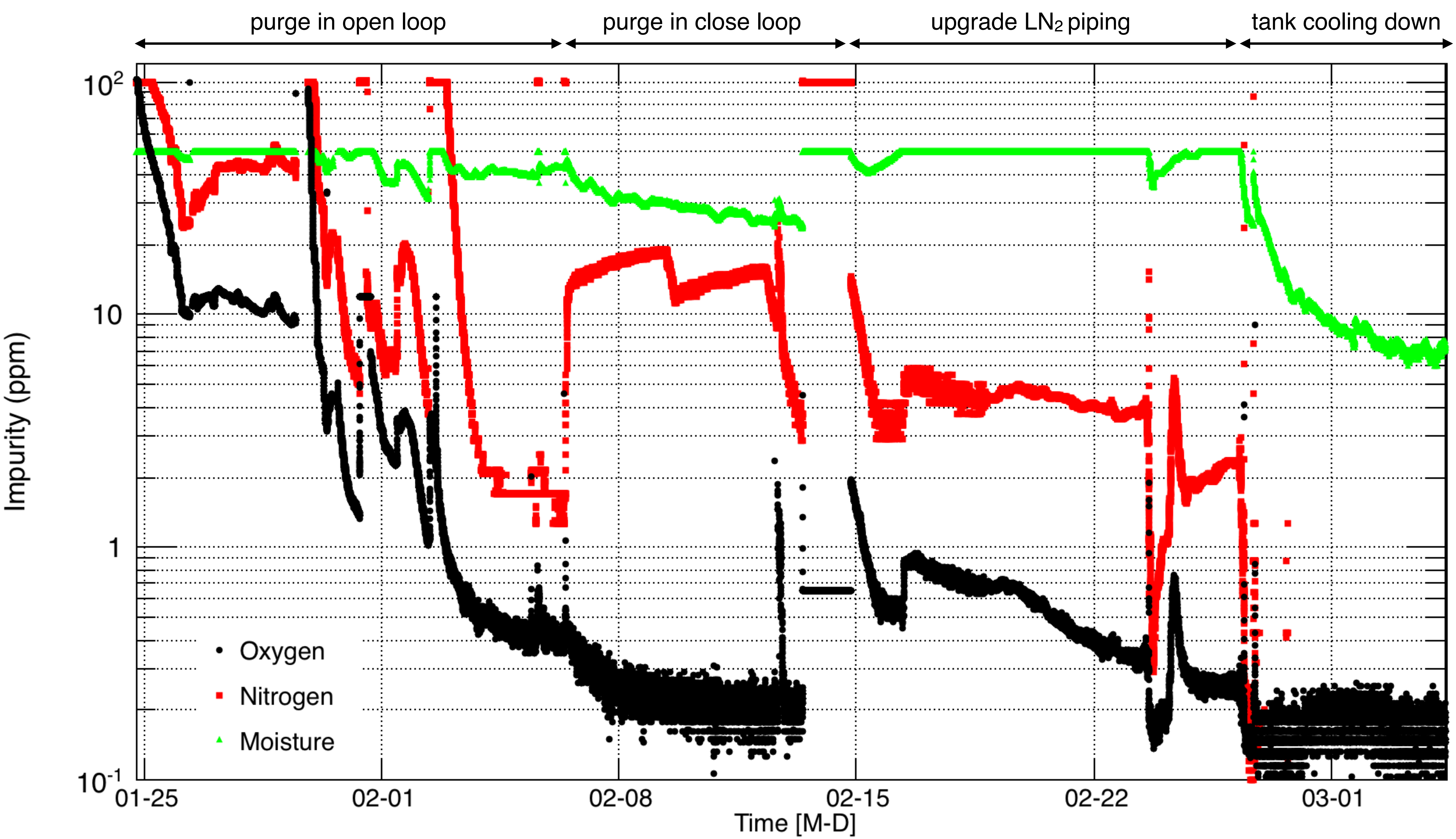
Piston purge
4 warm gas lines each with 3 openings of 12 mm ø.
total flow rate during piston purge ~4 l/s

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

WA105

~80 volume changes ~80 volume changes



All sensors operational - some data during cool down

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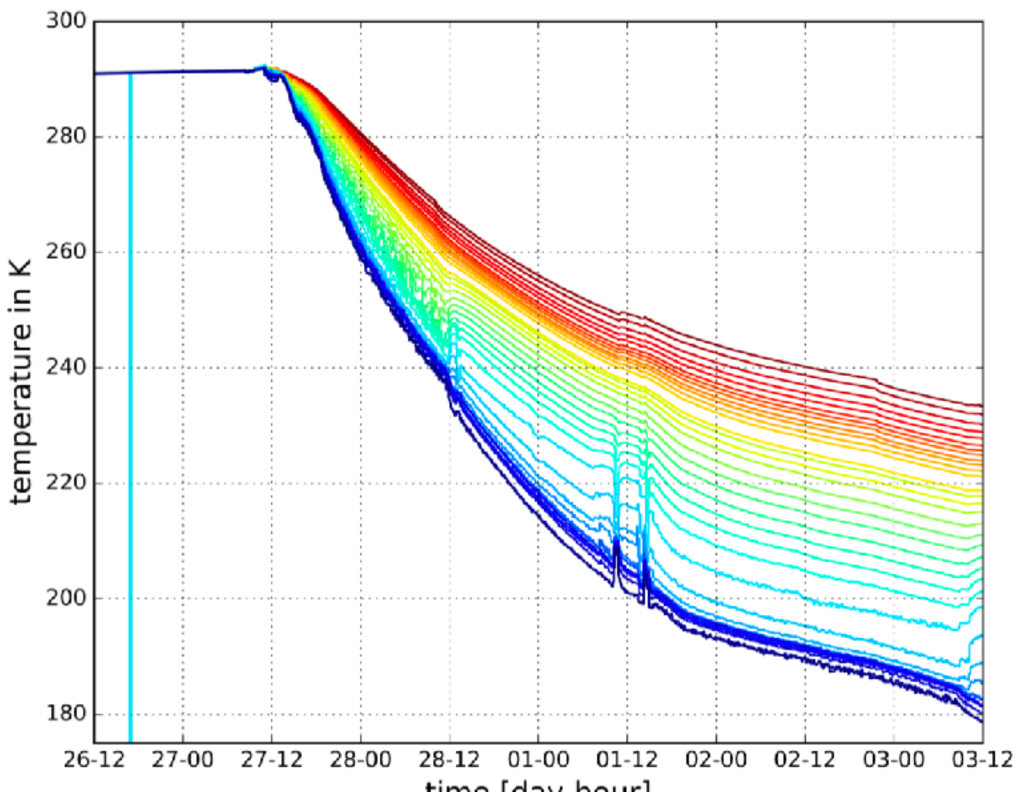
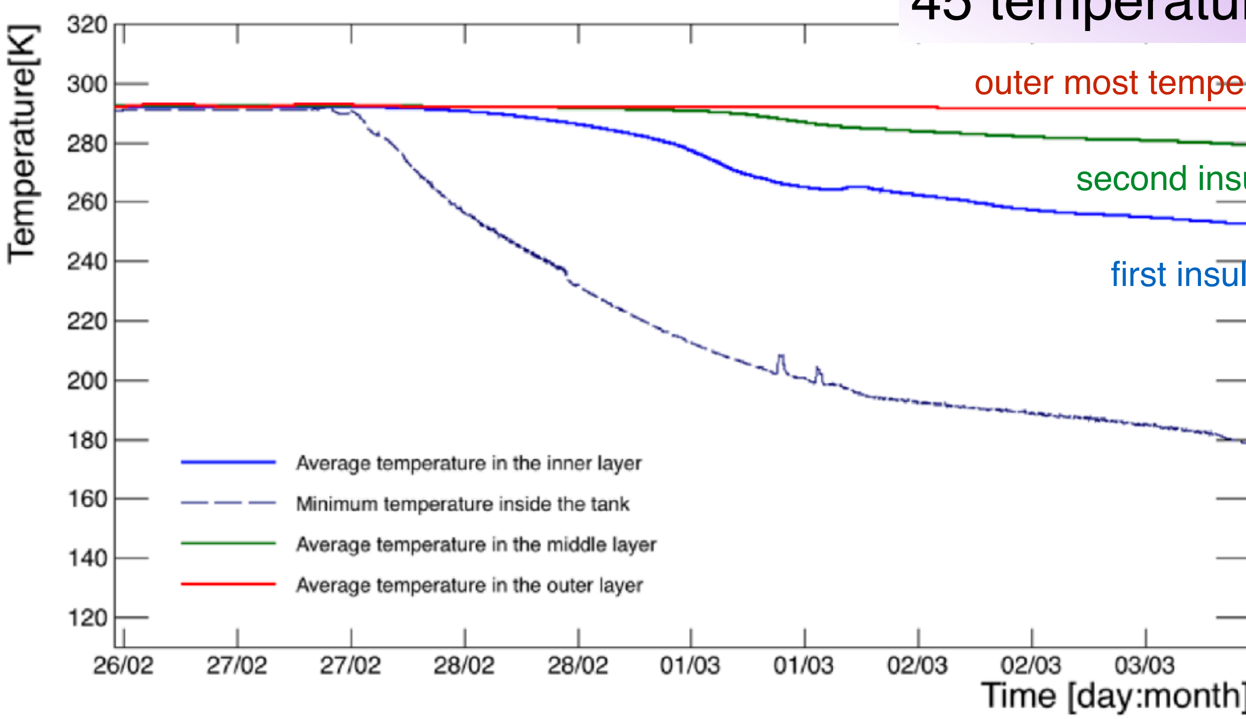
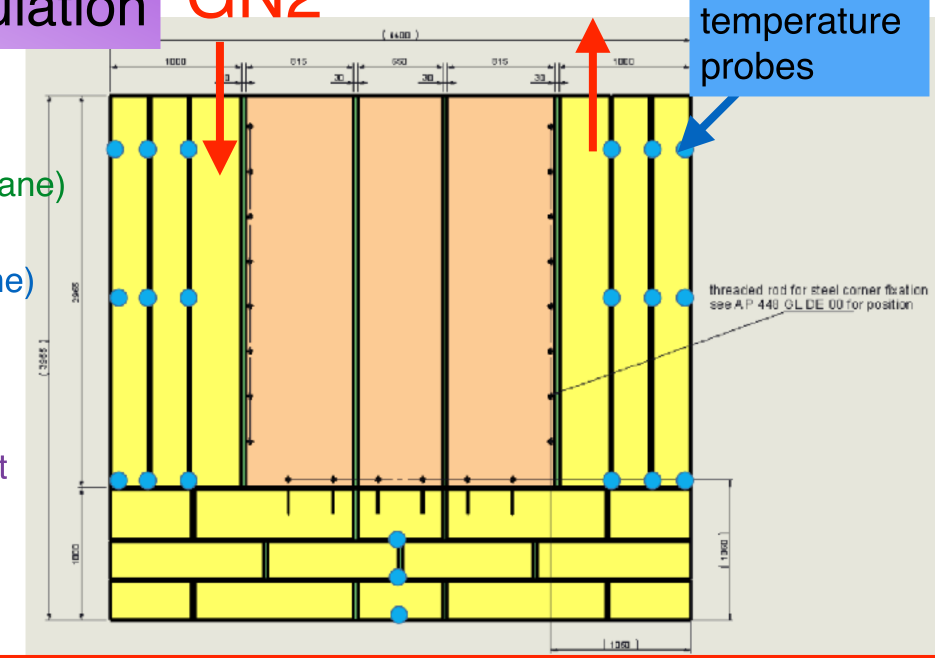
chain of temperature probes along drift cage



45 temperature probes inside insulation





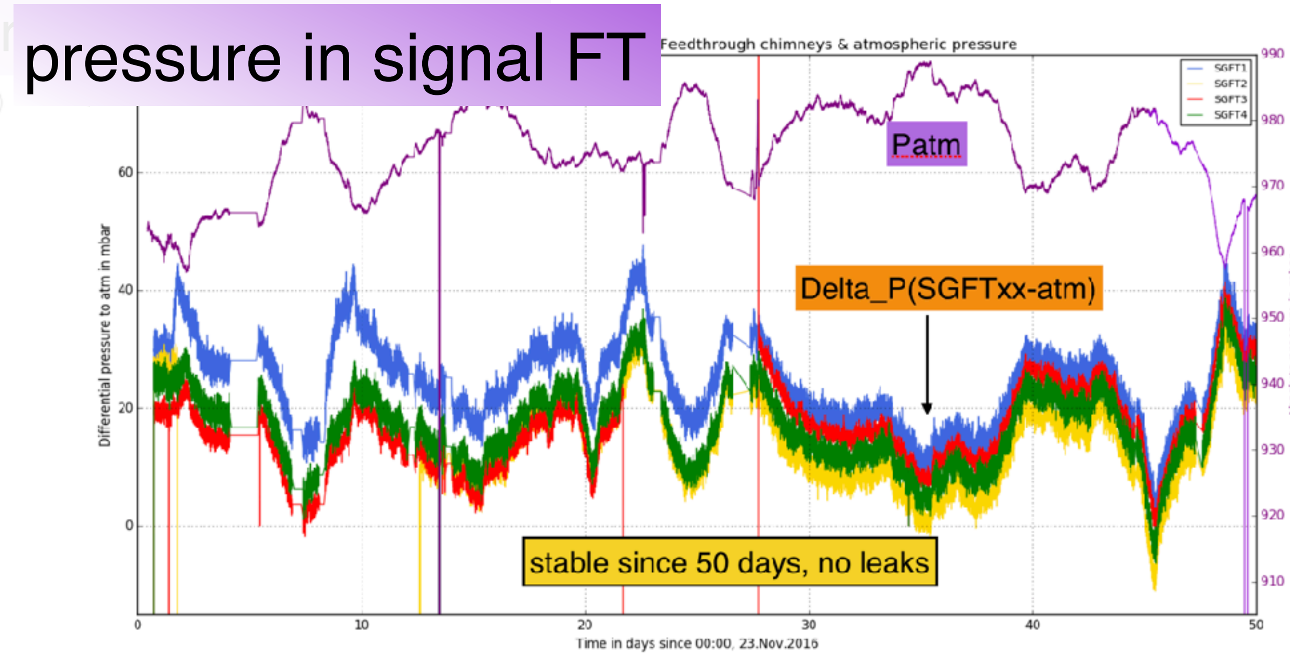
the insulation space is constantly flushed with N2 gas.
A bubbler at the output garanties a few mbar overpressure w/respect to the atmosphere

All sensors operational - monitoring over the pas months

WA105

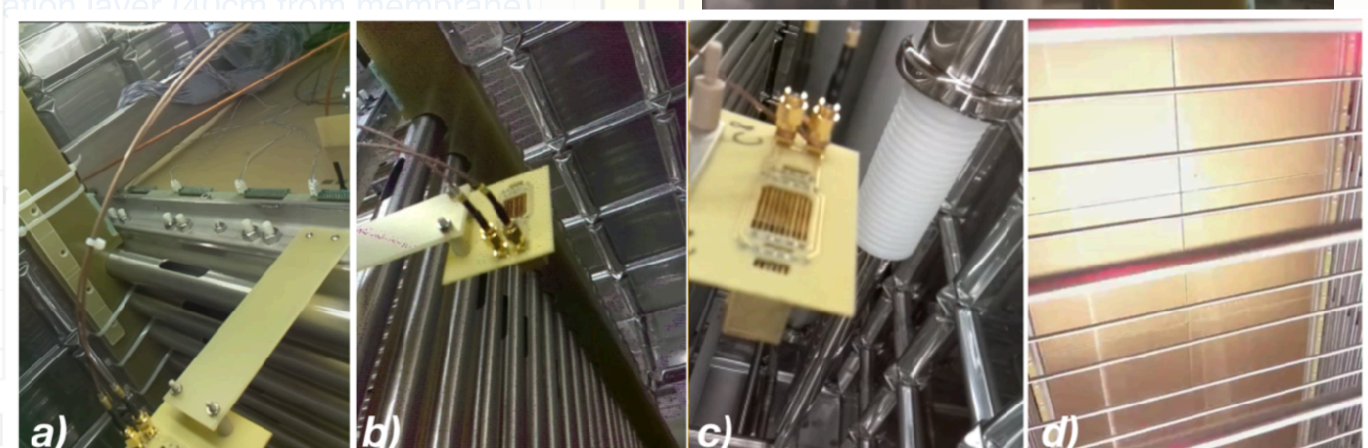
Detector monitoring:

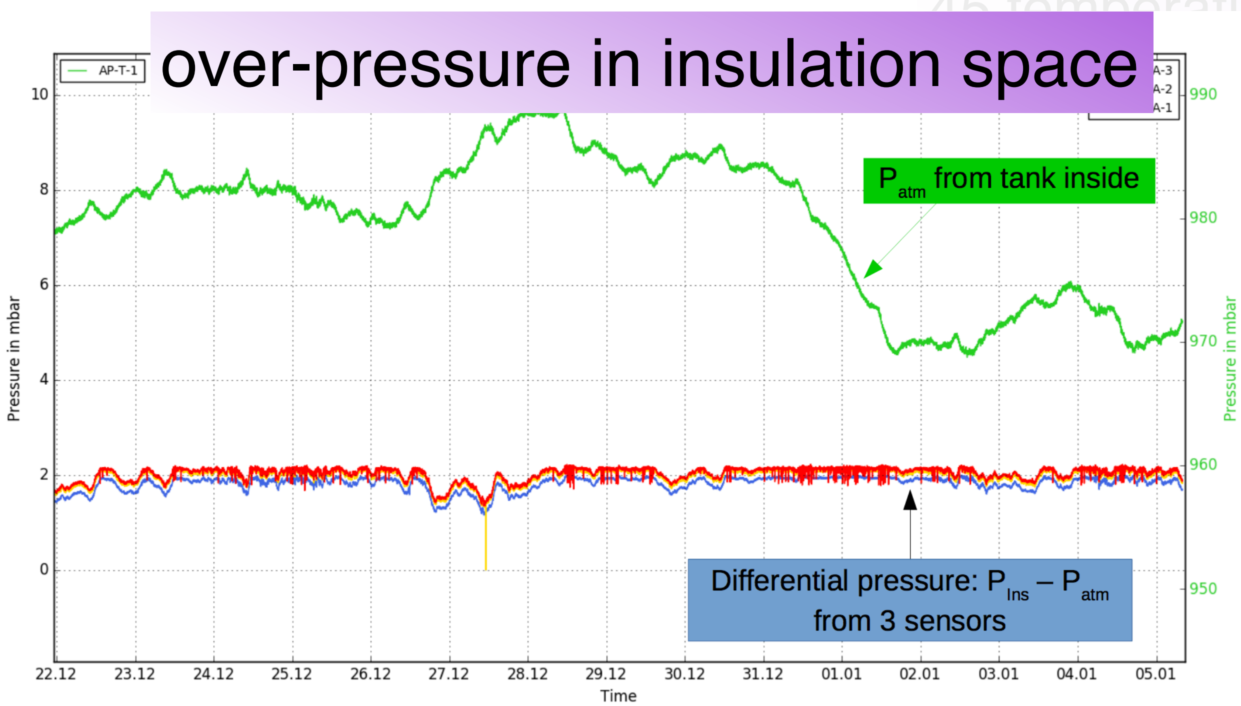
- >150 temperature probes
- 20 pressure probes
- 30 HV channels
- 1 300 kV HV channel
- Purity monitors (Gas + liquid)
- 15 level meters
- 5 cryogenic cameras



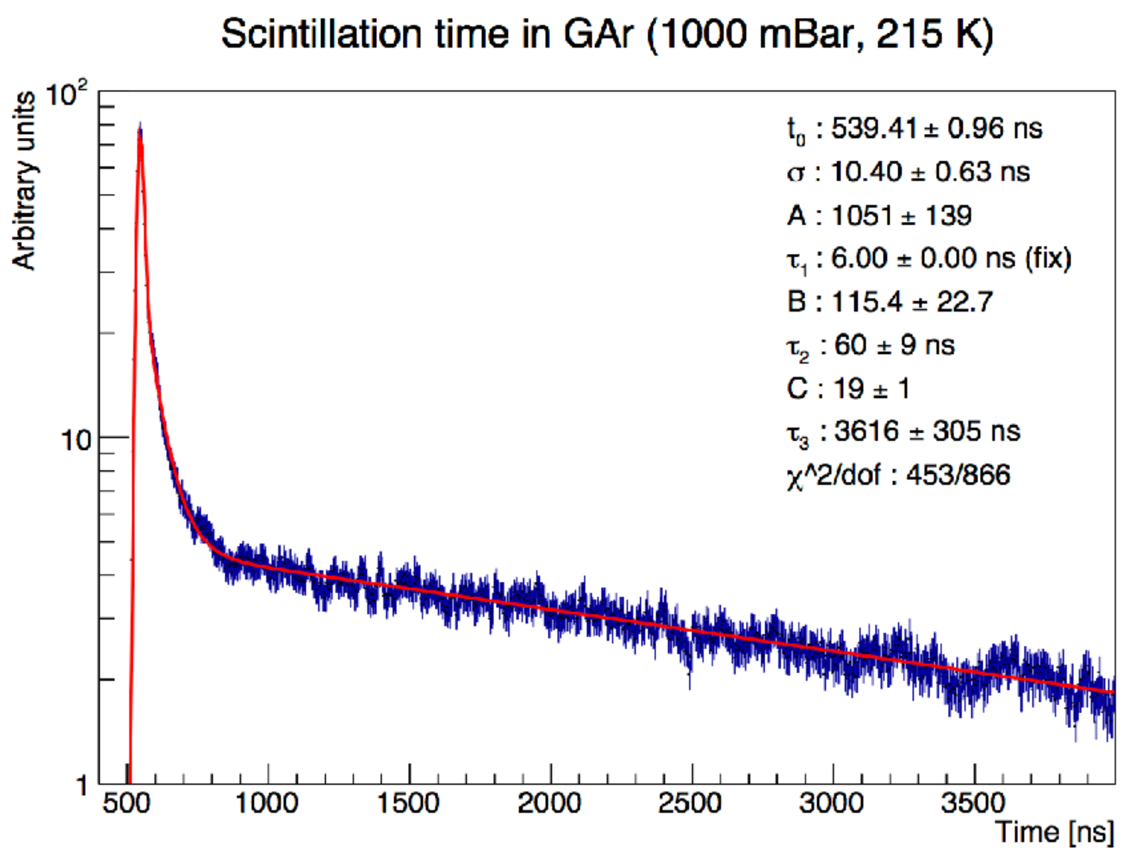
ALL OPERATIONAL

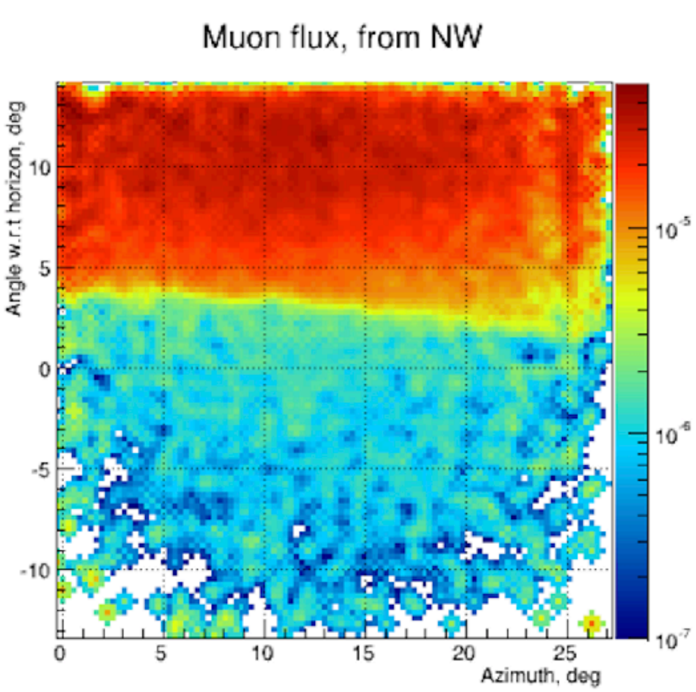
cryo-cameras

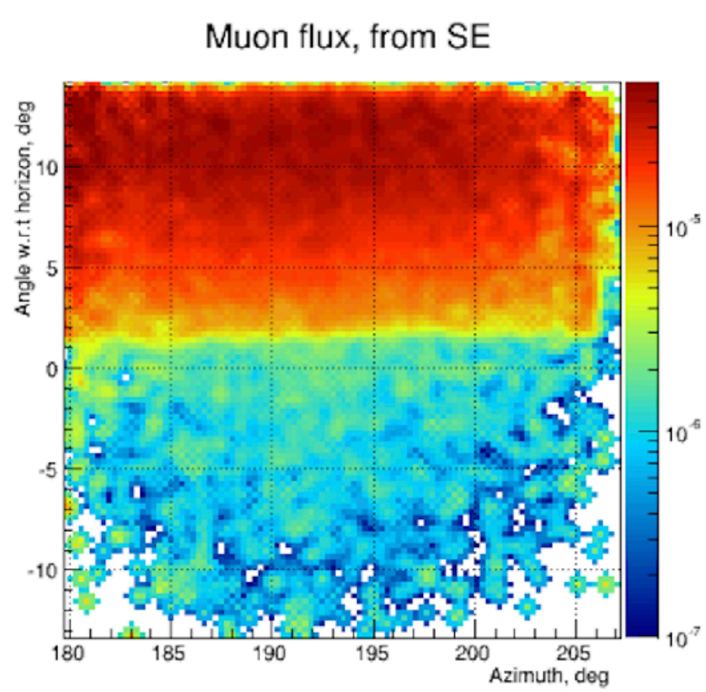




First results from commissioning - light and trigger

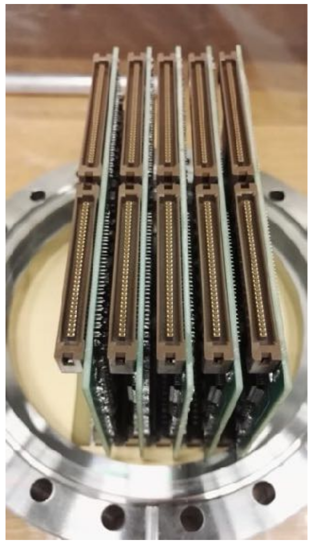


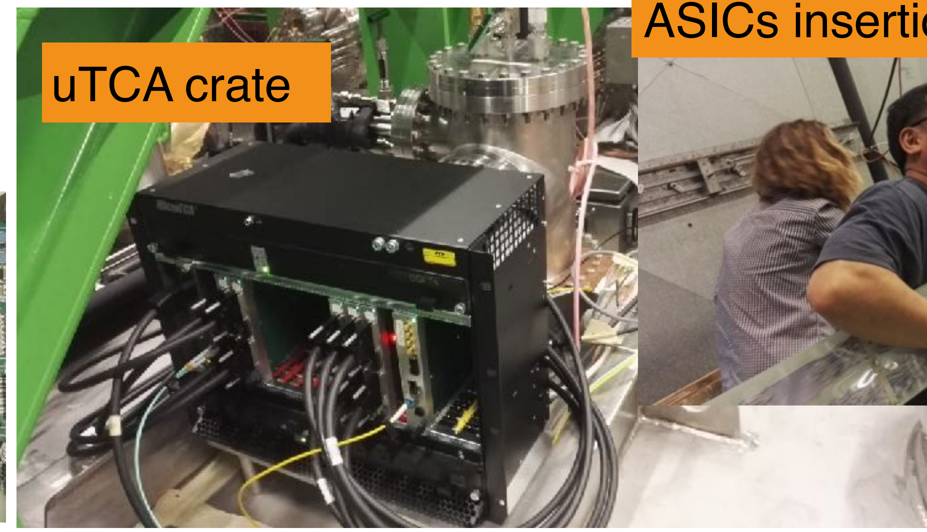


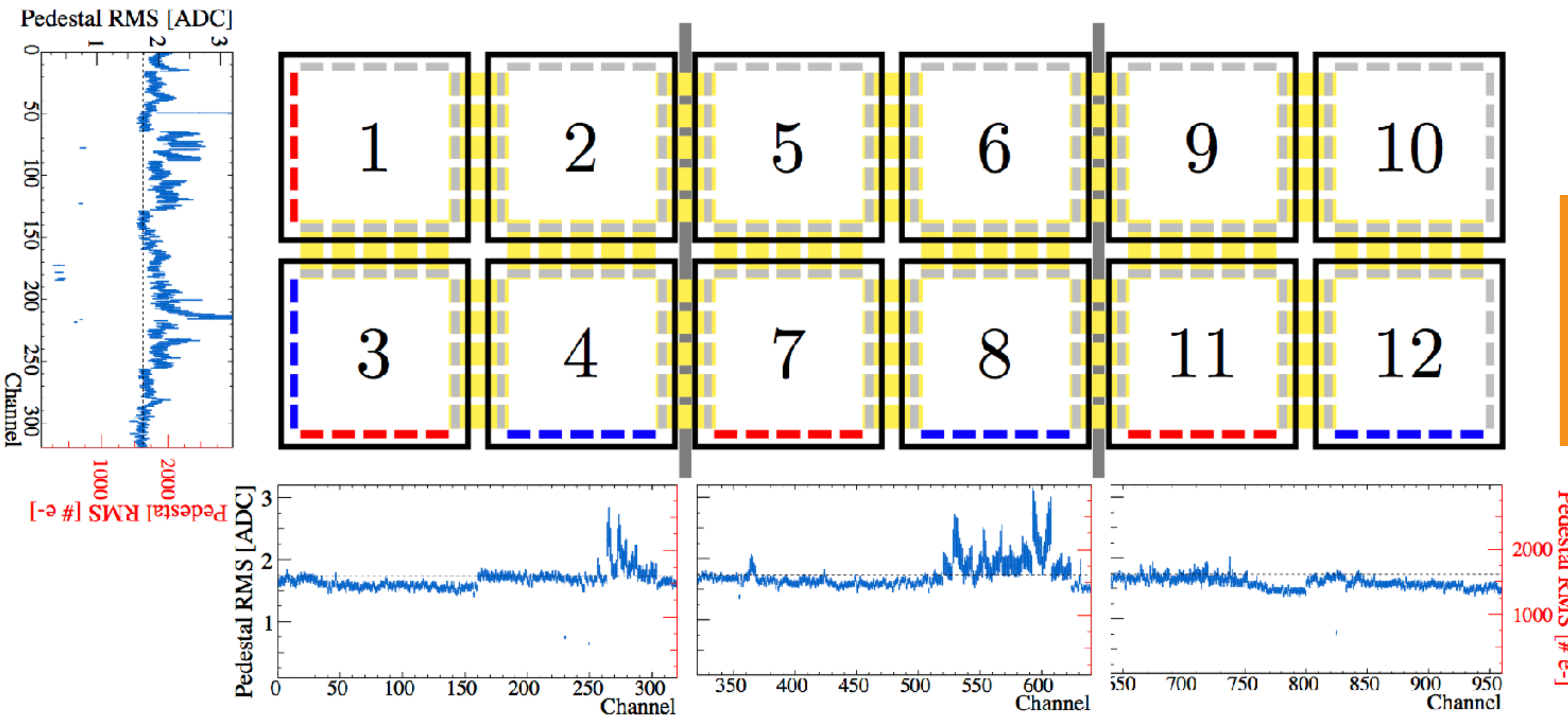


First results from commissioning - Charge readout

WA105



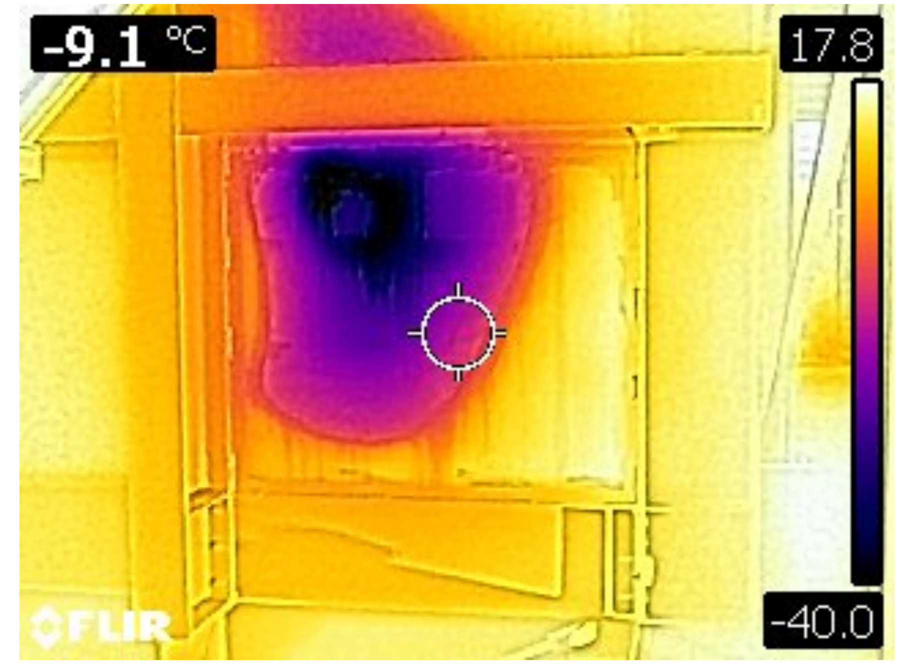




accessible cold amplifiers at 110 K. Sealed in chimney separate from main argon volume

DAQ and computing farm fully commissioned, about 1% dead or problematic channels
<u>noise at room temperature stable at about 1’500~ electrons</u>

Cryostat- issues during cool down



- On March 3rd, one week into cool down, a formation of ice was noticed on the bottom south east corner of the cryostat outer structure. The minimum temperature inside the tank was about 160K. Thermal images indicated other cold spots near this corner.
- The most probable cause was a leak from the membrane, decision was taken with Neutrino Platform and GTT experts on site to warm up the tank and flush dry air for visual inspection inside.
- Week of March 13th several descents performed, visual inspection, high res pictures, He leak testing, ultrasound checks. No leaks detected on the membrane.
- Week of March 20th holes drilled in the stainless plates of the outer structure at the precise location of the cold spots.

Cryostat- issues during cool down

SE corner

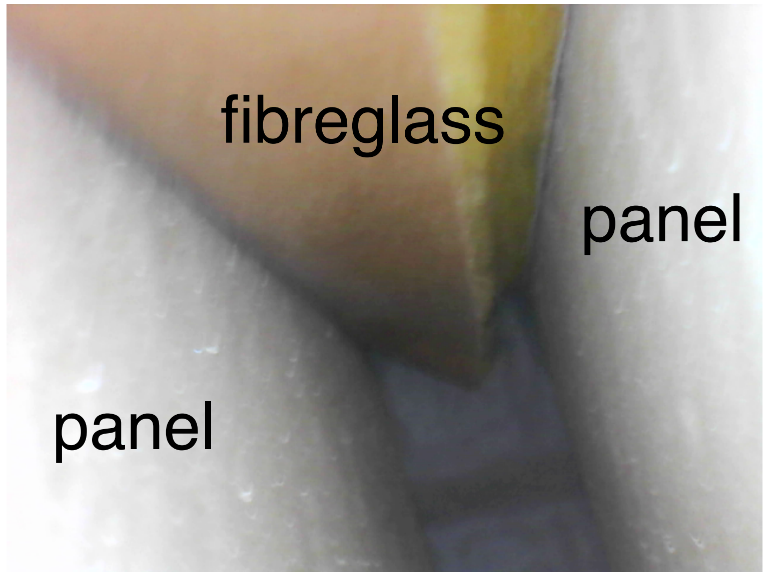
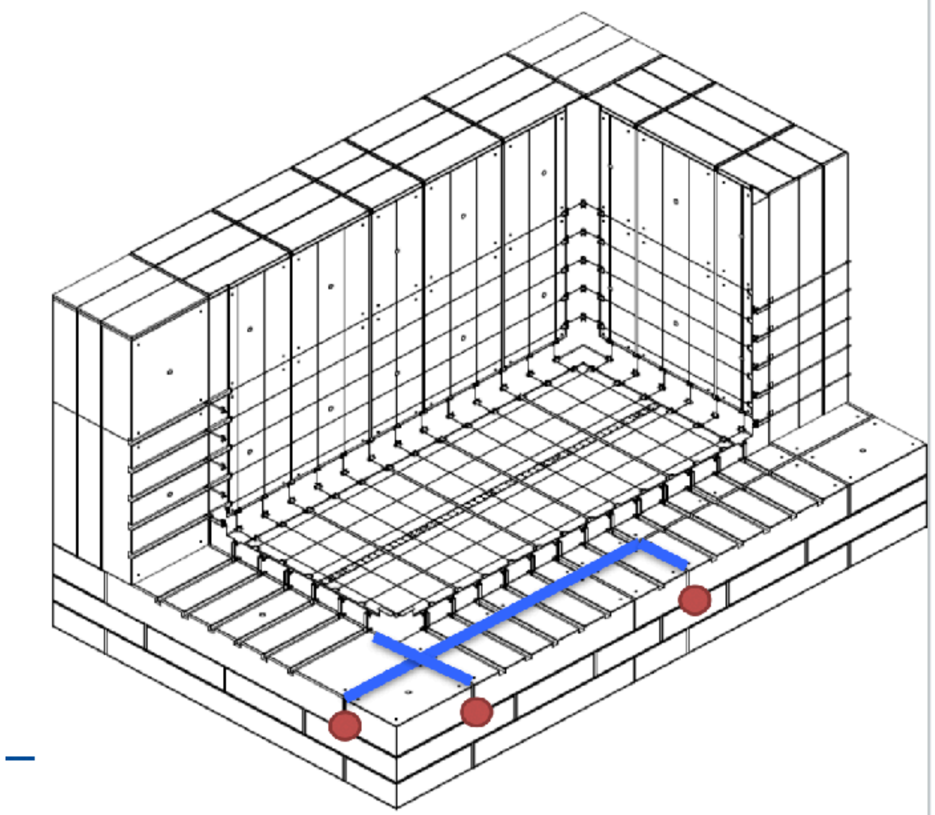


image with endoscope

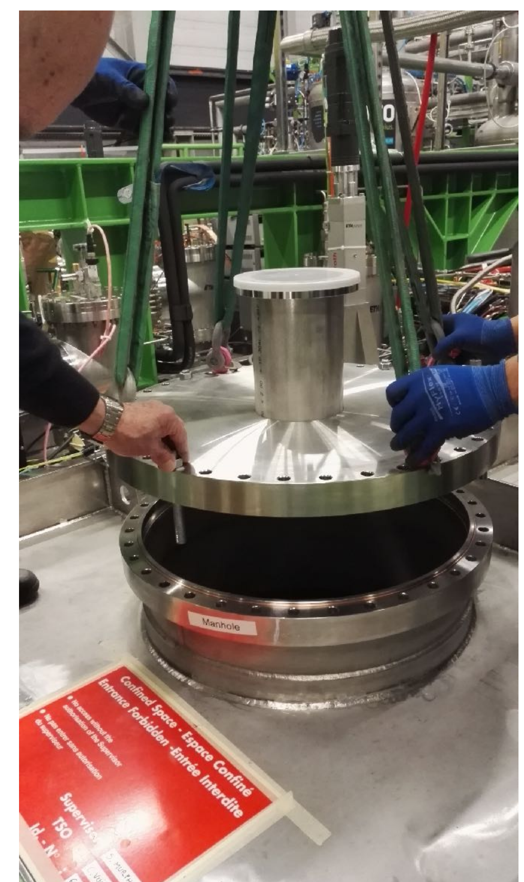


- On the SE corner hole, immediately noticed a missing layer of fibreglass sheet, approx 10x2 cm^2 and 95 cm deep.
- GTT filled the gap with expandable Polyurethane foam.
- Another 5 holes we drilled at either the cold spots observed during cool-down or potential places were a similar cold channel could be created.
- Out of the other 5 holes drilled, 3 had a gap in the insulation, although much smaller (< 1 cm2). They were also filled with PU foam.

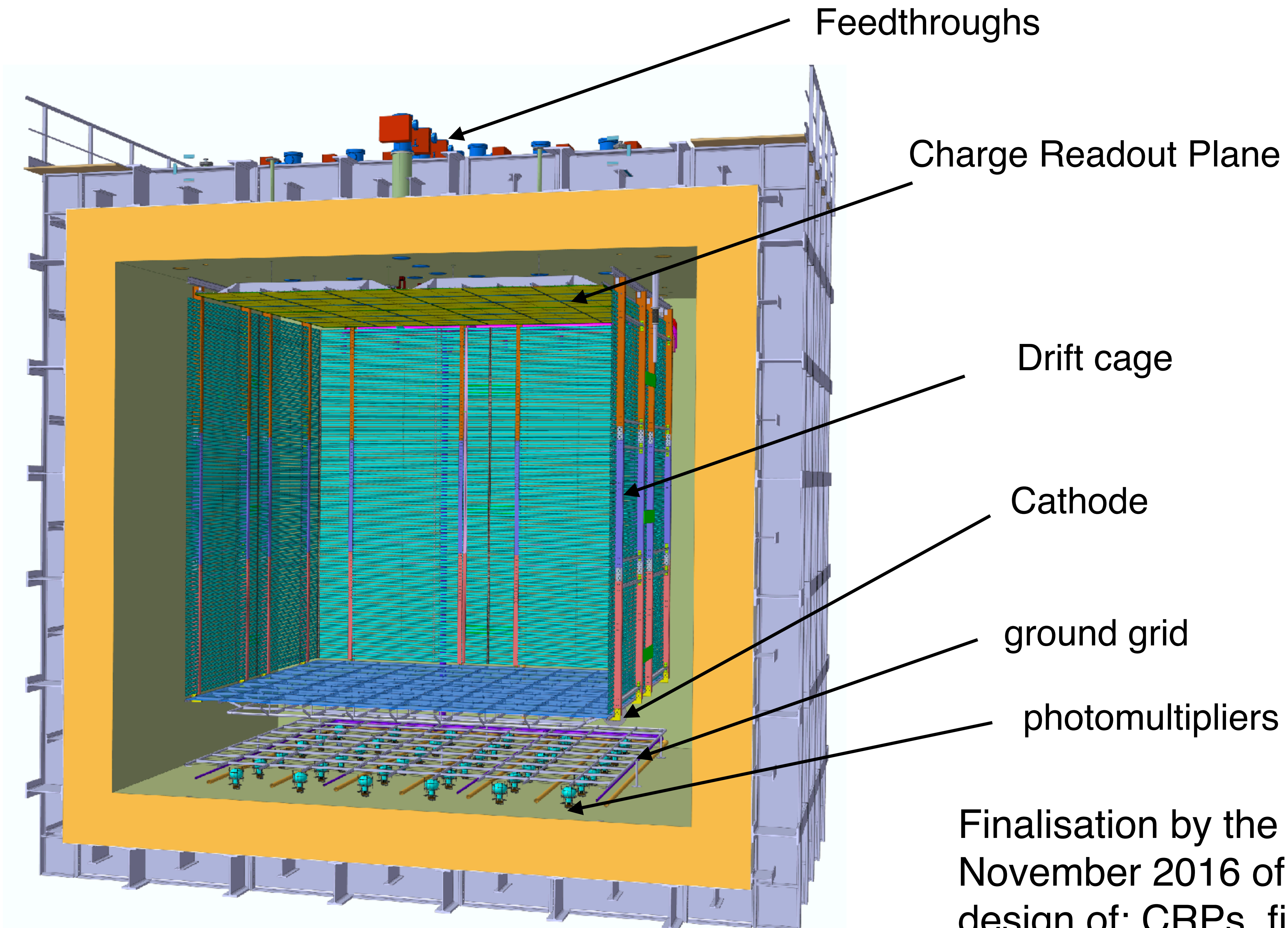
Plans

On Tuesday March 28th the GAr piston purge was started again, cooling down should follow in a few weeks depending on purity evolution.

- Added extra temperature probes inside the tank on the membrane floor and near the SE corner
- the gap in insulation of SE corner has been instrumented with 4 temperatures probes before filling with the foam
- constant monitoring of the outer structure with IR cameras.
- constant monitoring of the insulation space gas content with spectrometer. Sudden peak in argon would indicate leak from membrane.



protoDUNE-DP

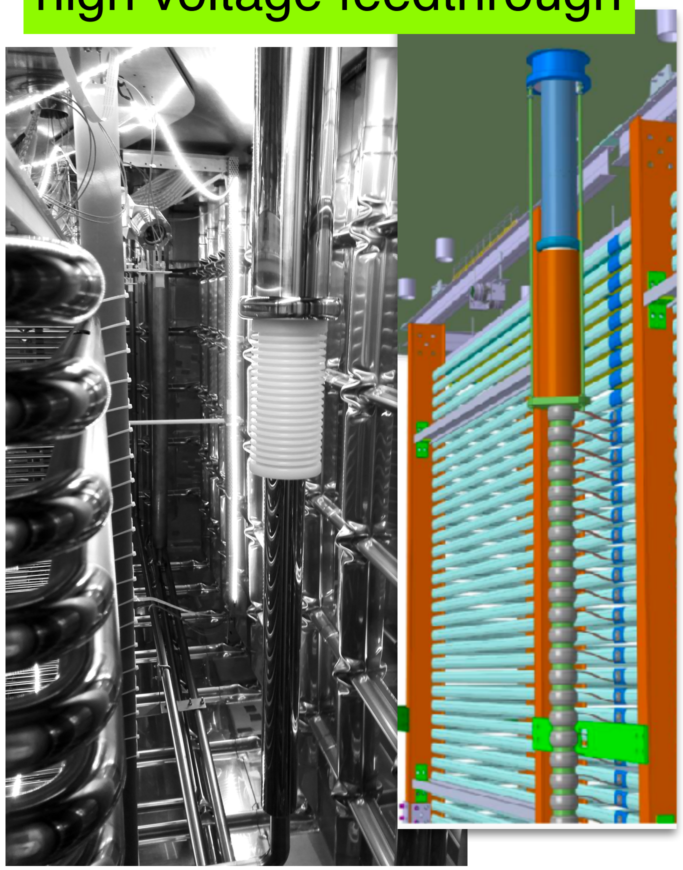


Finalisation by the end of November 2016 of executive design of: CRPs, field-cage and cathode

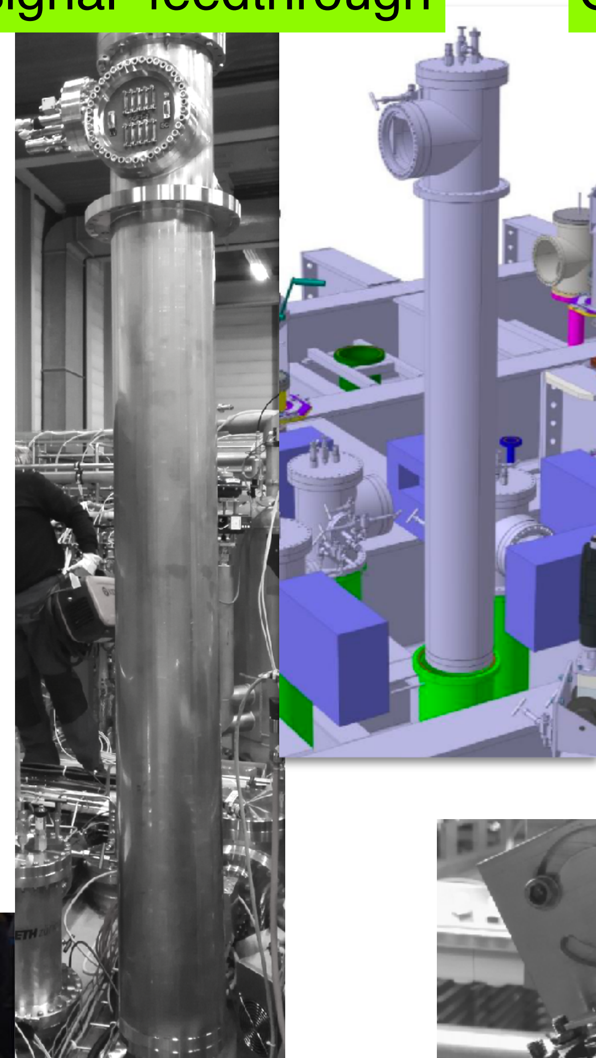
Role of the 3x1x1 pilot - some examples

WA105

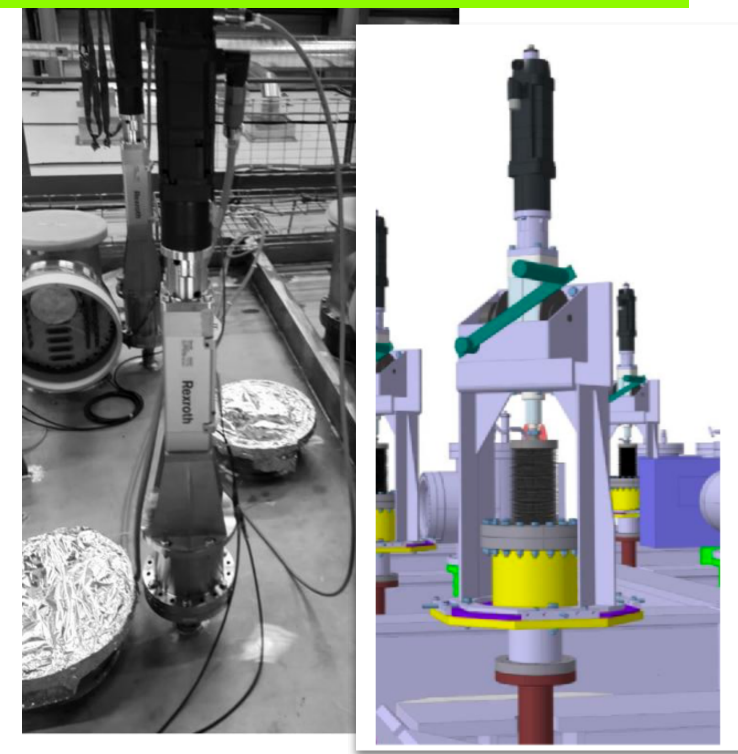
high voltage feedthrough



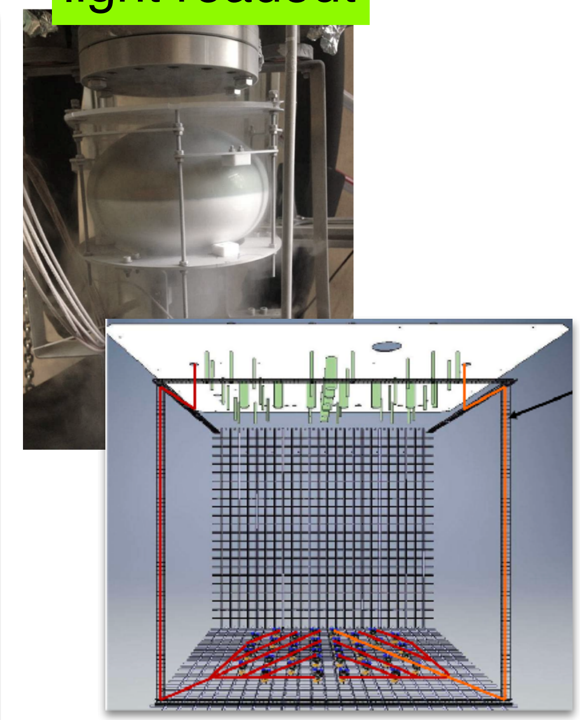
signal feedthrough

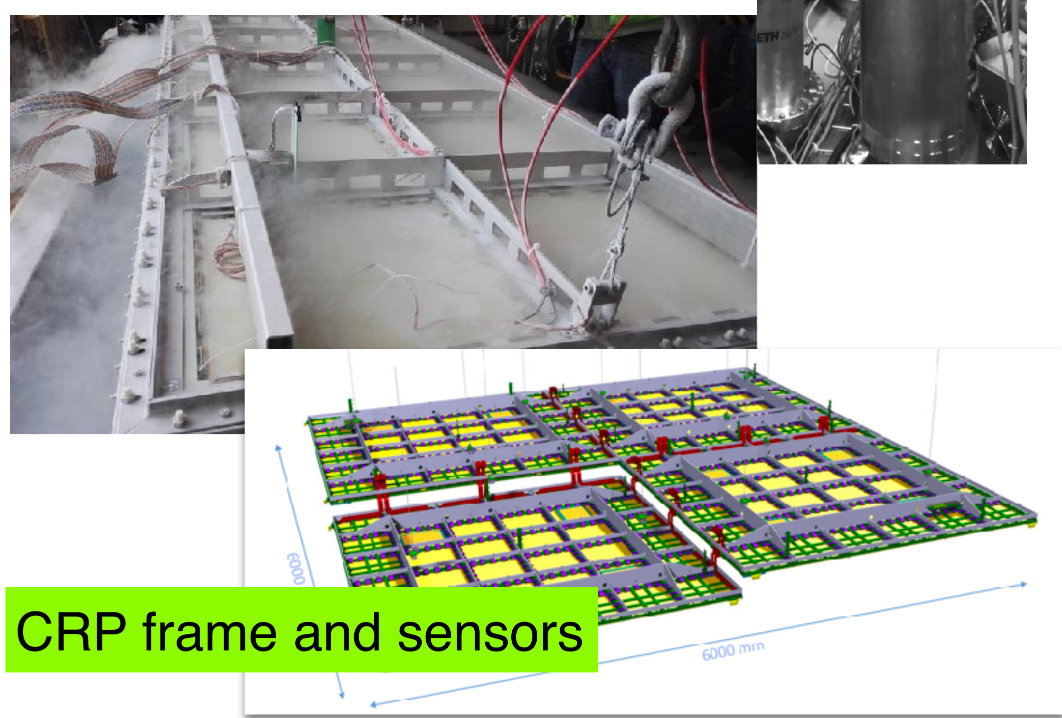


CRP suspension feedthrough

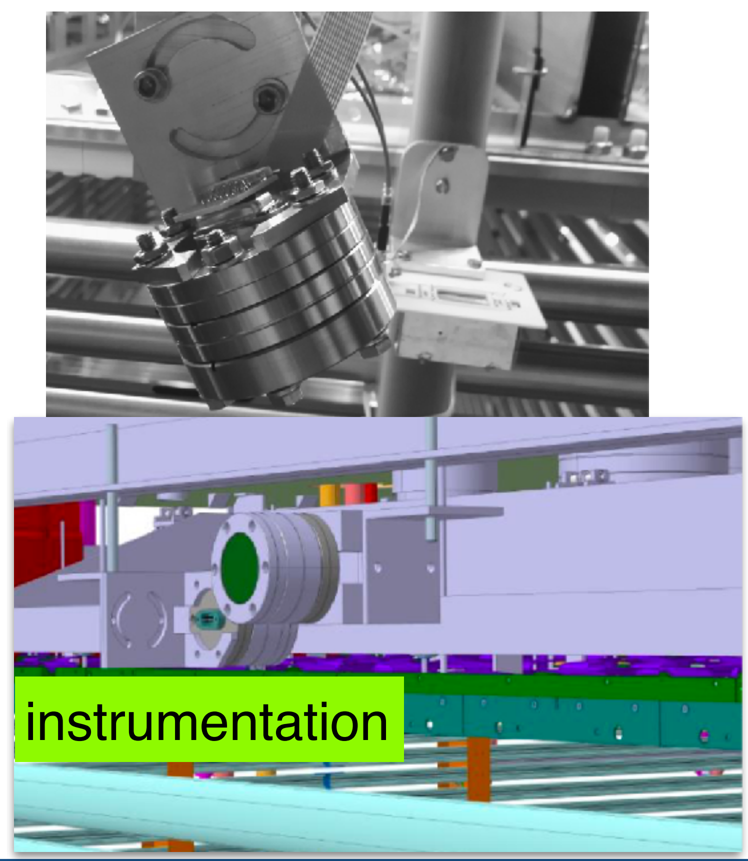


light readout

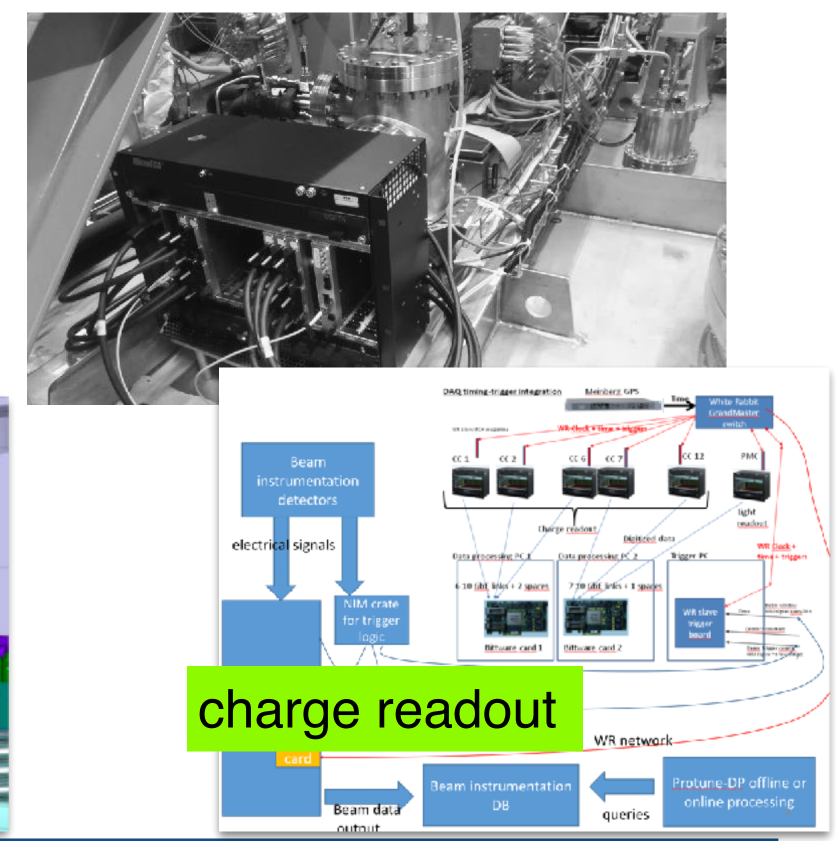




CRP frame and sensors



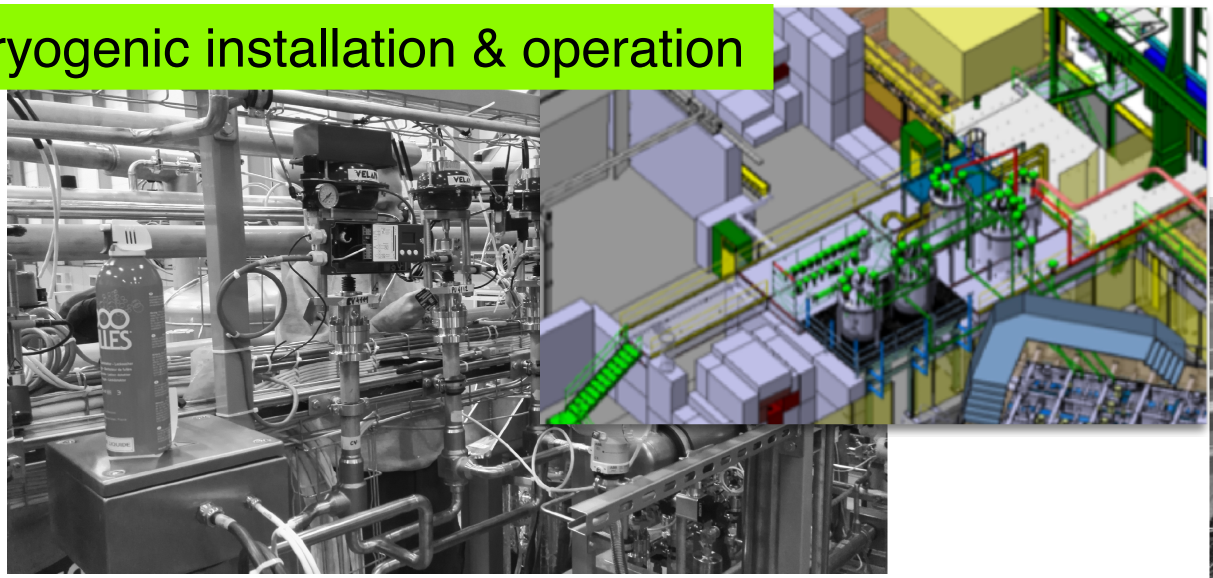
instrumentation



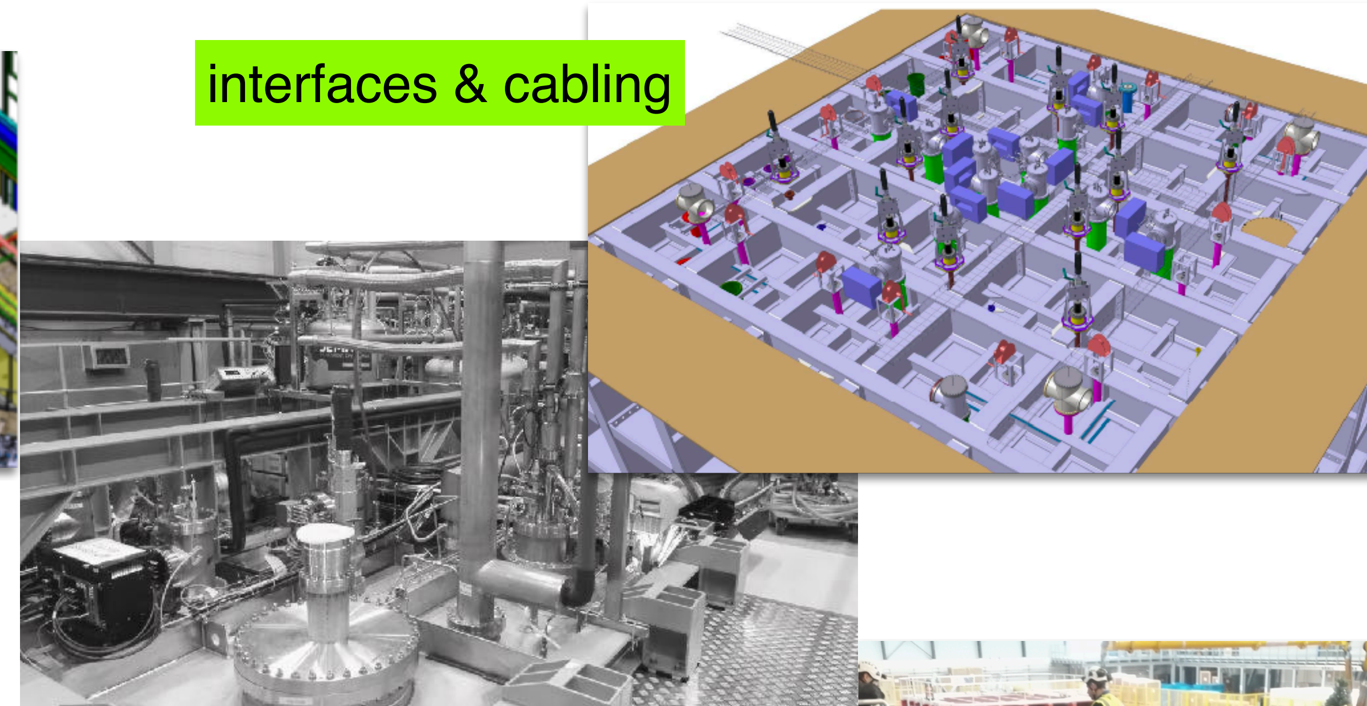
charge readout

Role of the 3x1x1 pilot - some examples

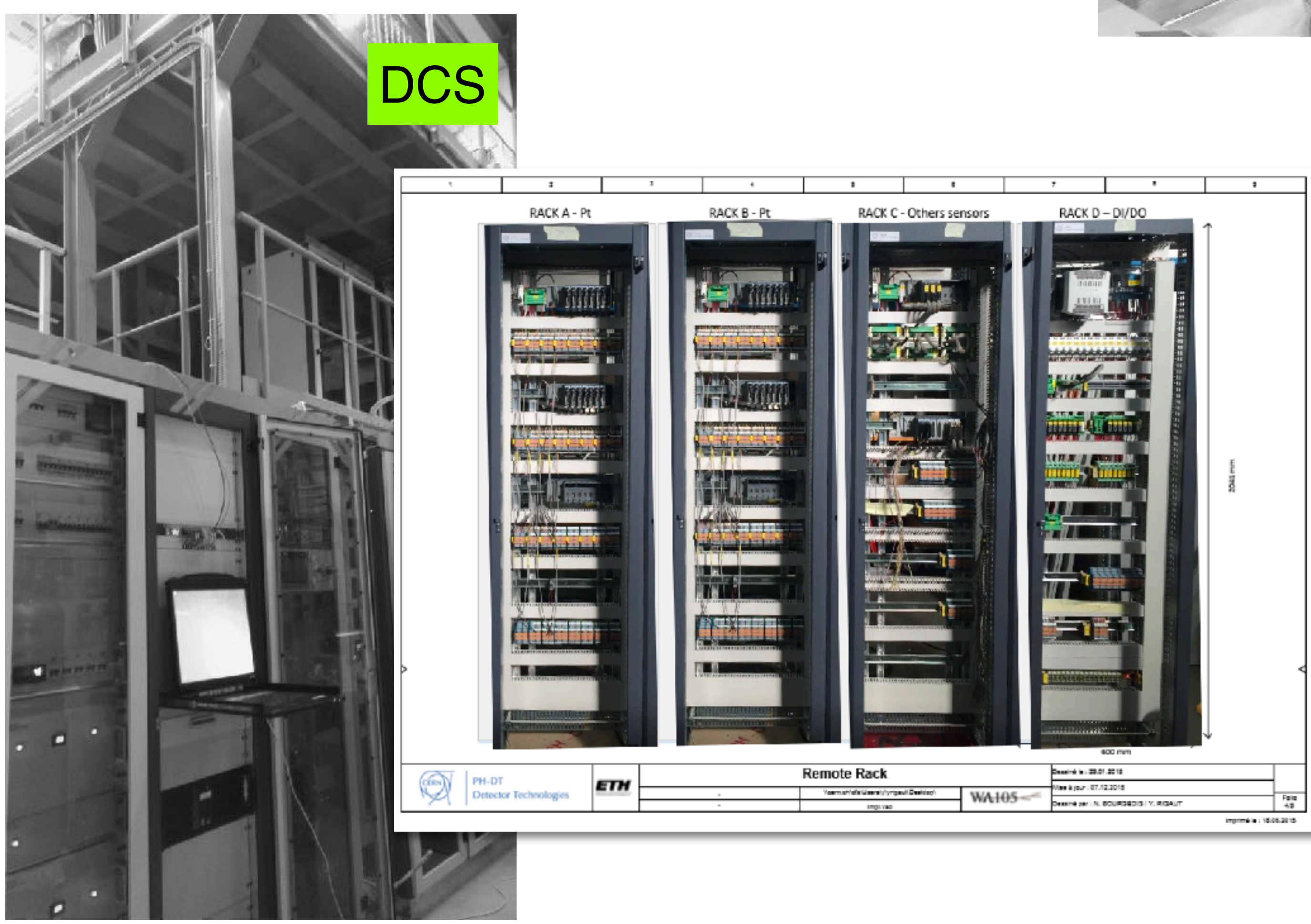
cryogenic installation & operation



interfaces & cabling



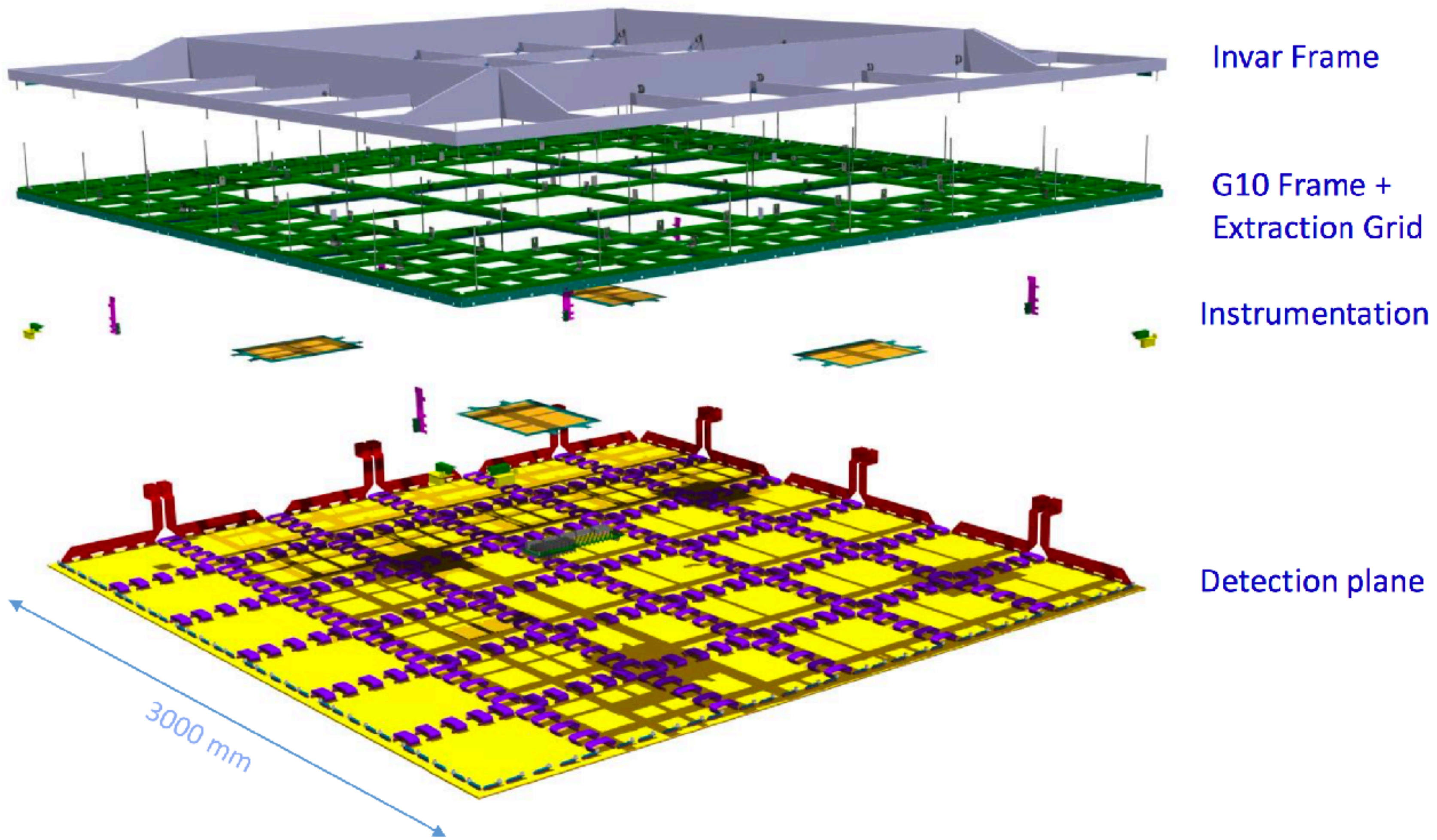
DCS

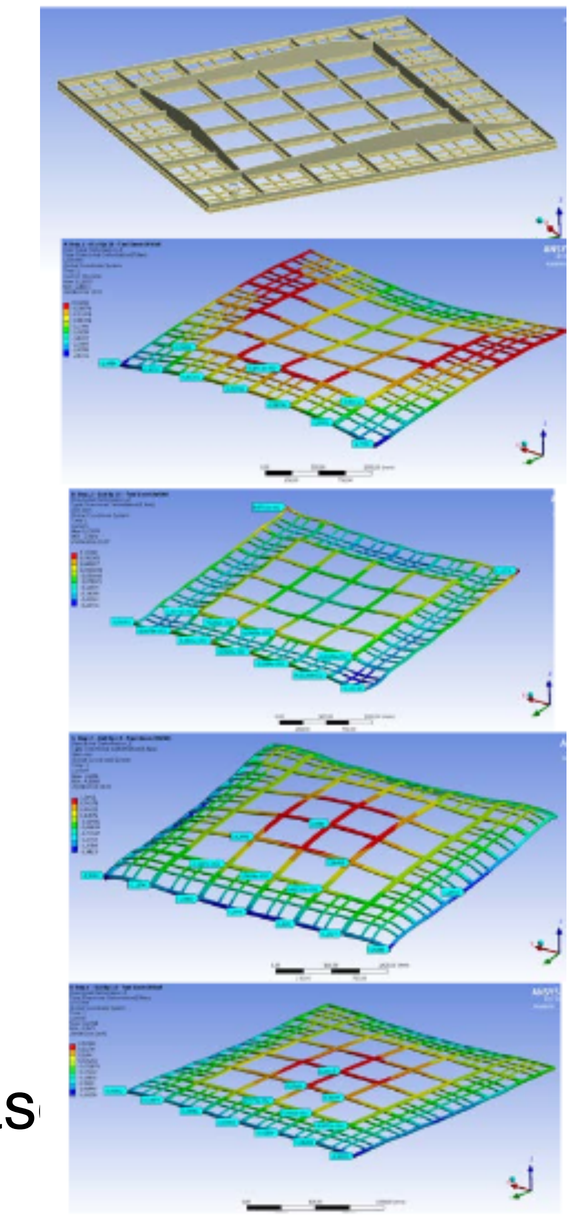


cryostat

Charge Readout plane

WA105





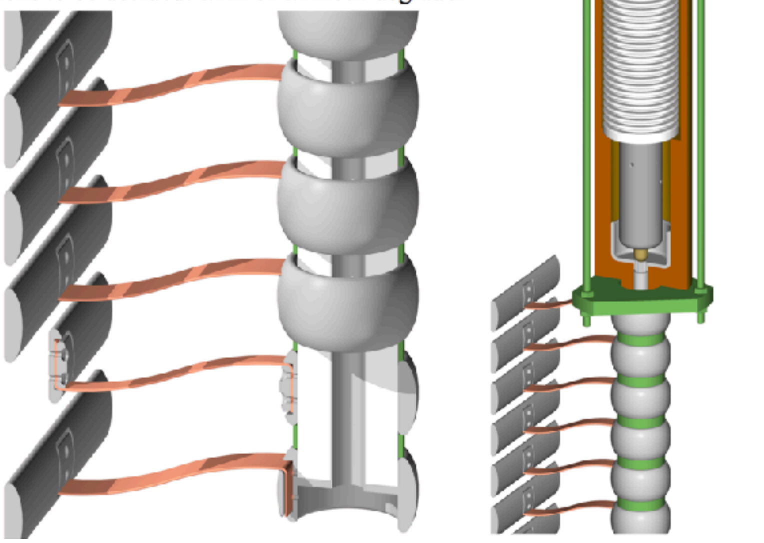
- Four 3x3 m2 CRPs integrating the LEM-anode sandwiches (50x50 cm2) and their suspension feedthroughs (CRP specific to dual-phas technology: critical item)
- Invar frame + decoupling mechanisms in assembly in order to ensure planarity conditions +-0.5 mm (gravity, temperature gradient) over the 3x3 m2 surface which incorporates composite materials and ensure minimal dead space in between CRPs

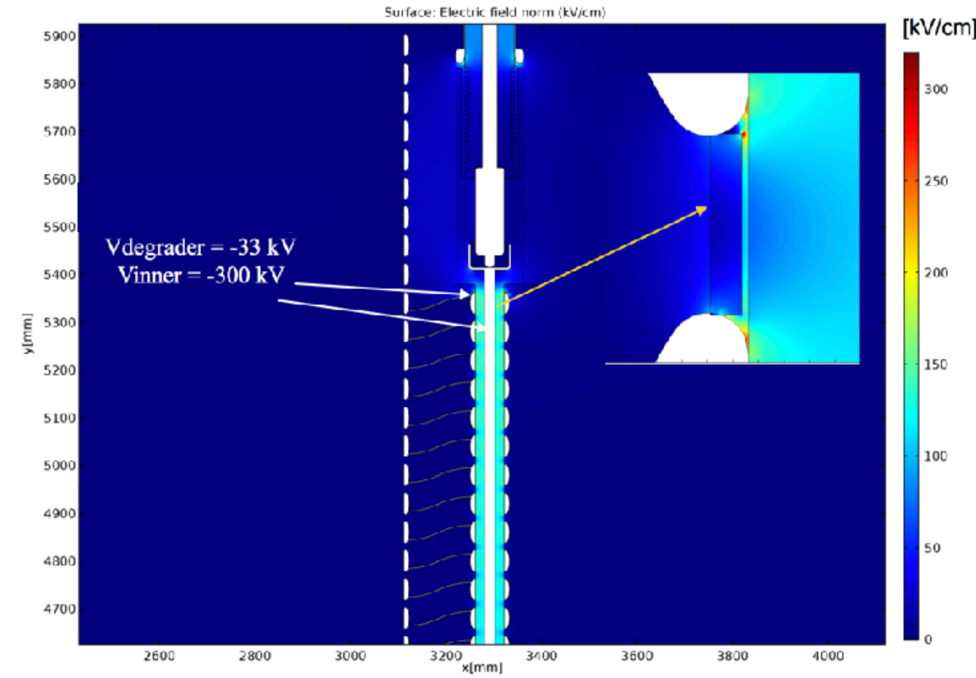
Very high voltage

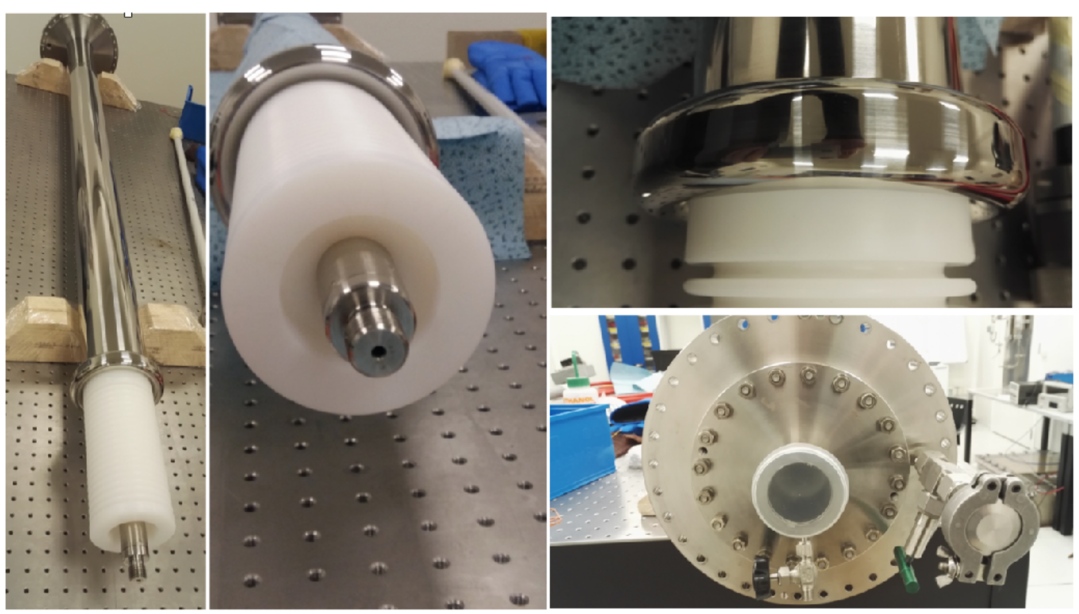
WA105

High voltage transmission from the HVFT to the cathode

- Preliminary design done by **Franco.**
- Options to be decided: **with** or **without** degrader





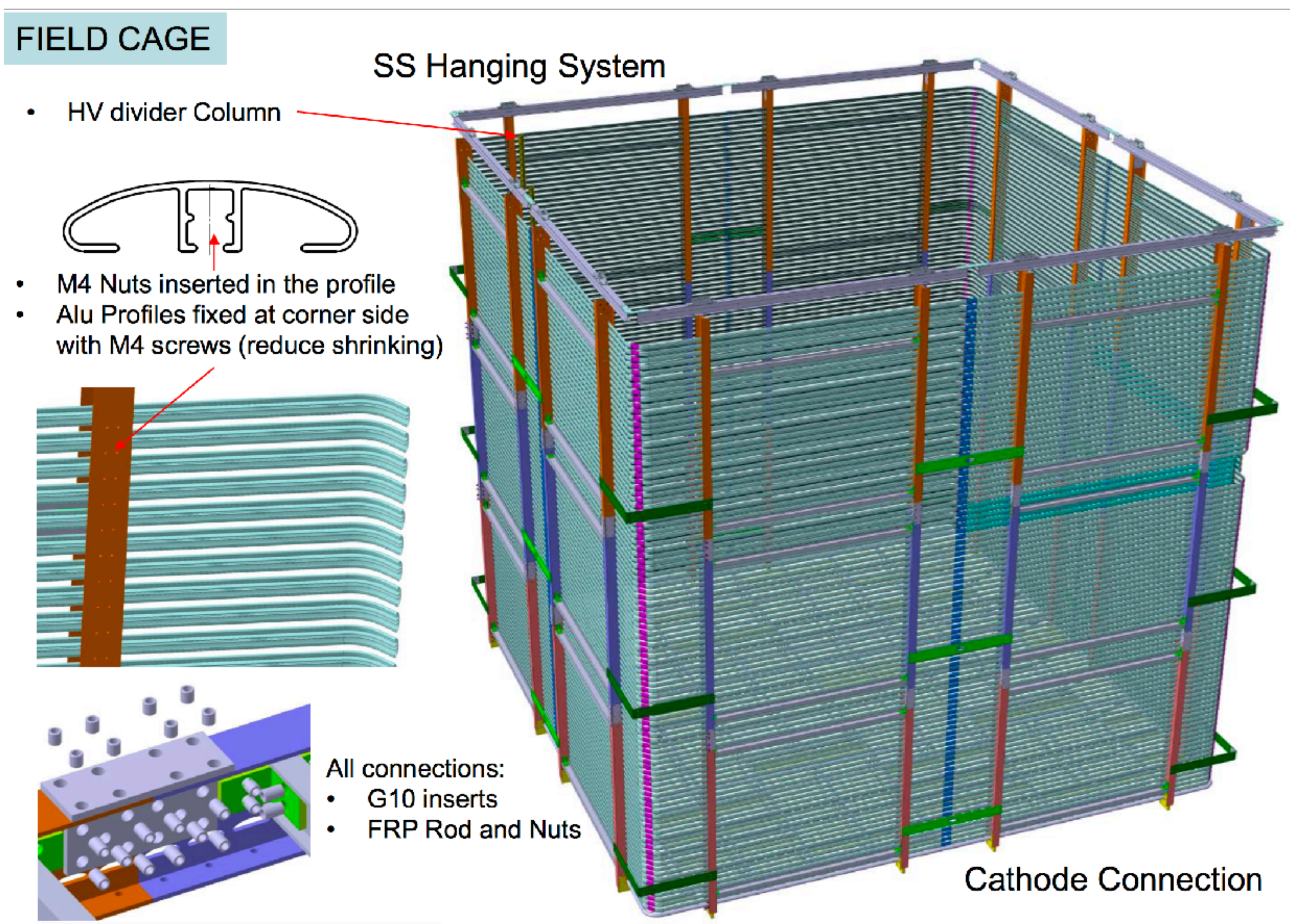


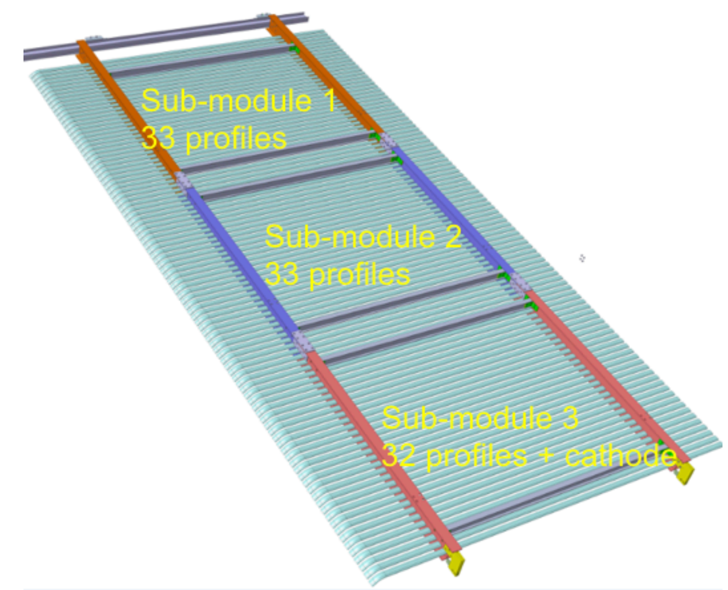
Design successfully tested in dedicated setup up to the end of the scale of the Heinzinger PSU. <u>About 295 kV.</u> **JINST 12 P03021 arXiv:1611.02085**

Drift cage

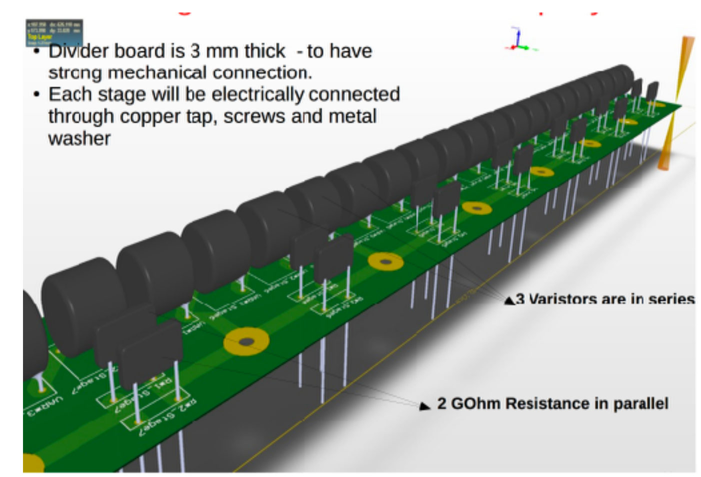
Field cage shares common basic structural elements (extruded profiles and FRP beams) with the single-phase ProtoDUNE

Assembled in 8 vertical modules of 6238x3017 mm (2 modules per detector face). Each module is assembled out of 3 sub-modules





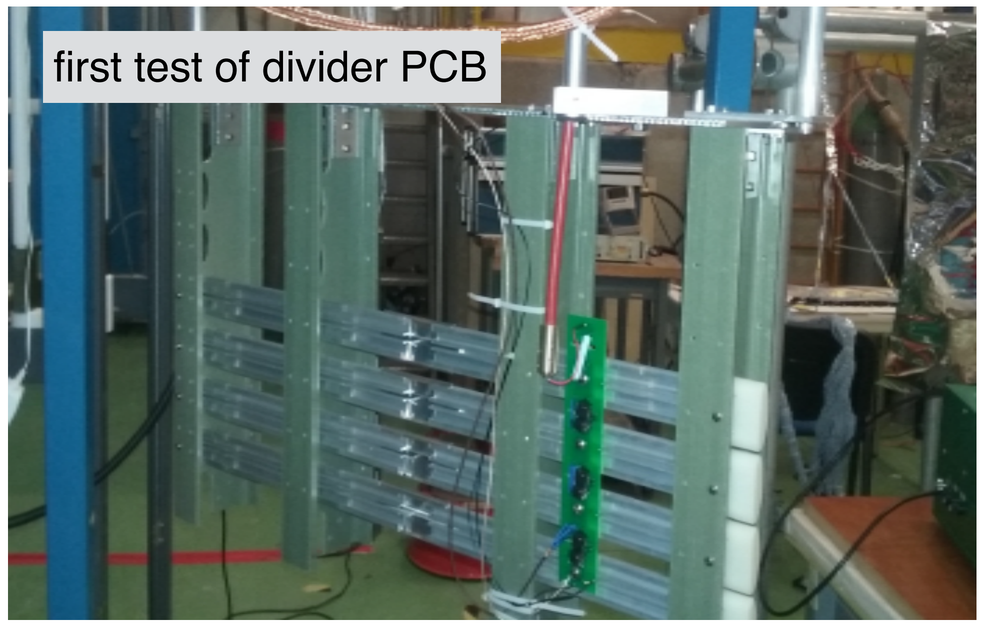
PCB divider board



Drift cage- prototyping

WA105

Joint effort with protoDUNE-SP and CERN Neutrino platform

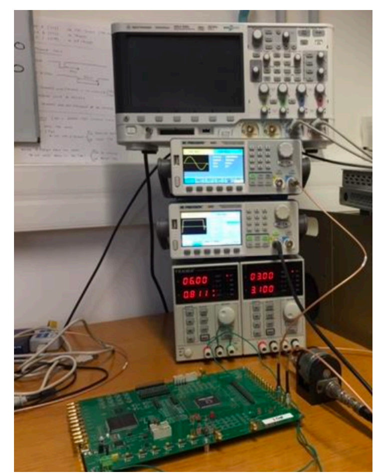


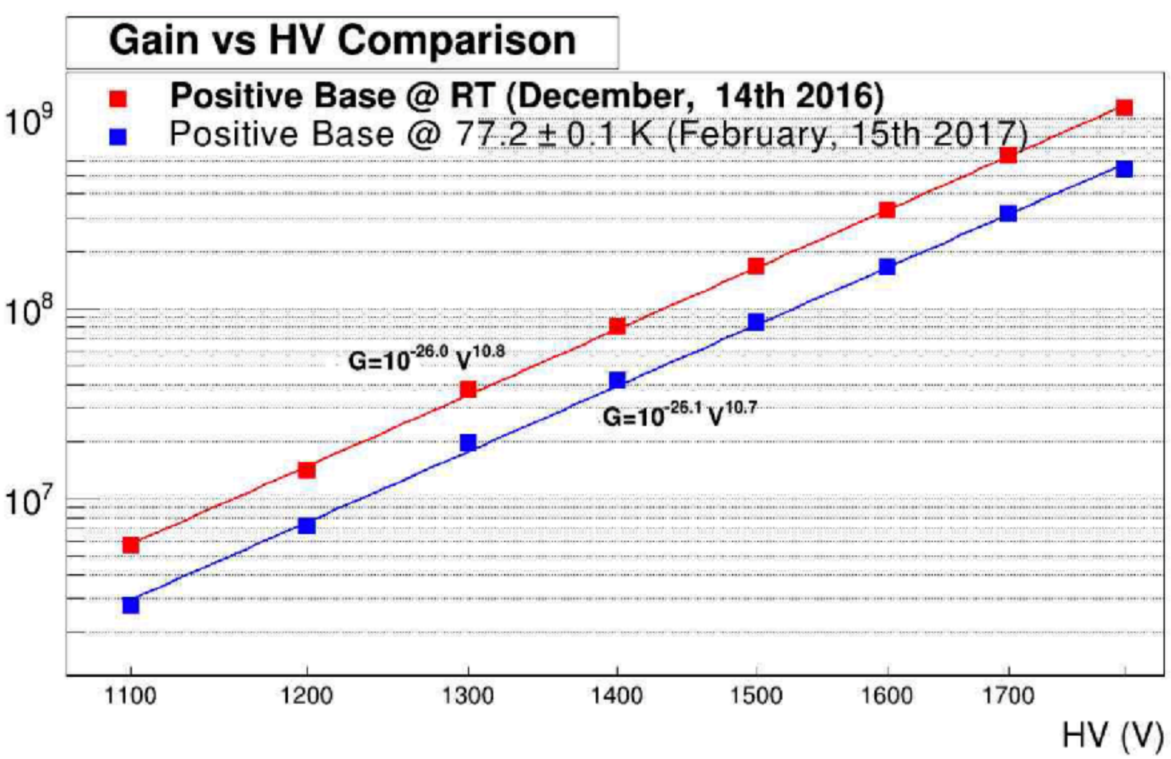
Light readout

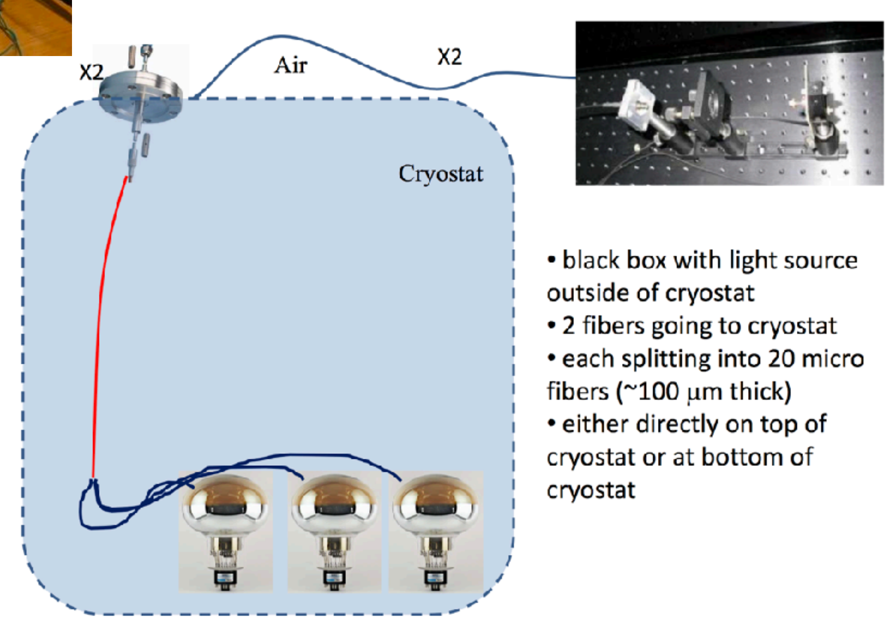
WA105

	TIME
PMTs mounting into the support (clean room). Steps: • Support and PMT assembly • PMT base and cable soldering • PMT transport box modification to accommodate PMT+ support • PMT storage into the box with double black bag	2 weeks (on-going)
Tests at RT (GAr to test the PMT bases). Measurements: • Gain vs HV • Dark current vs HV • PMT Pulse shape (with the scope) for G = 10^7	2 weeks (10 x 2,5 d)
Cryogenic tests (LN2). Measurements: • - Gain vs HV • - Dark current vs HV • - PMT Pulse shape (with the scope) for G = 10^7	4 weeks (10 x week, sequence to be repeated Firday to Friday)

- 40 PMTs delivered, testing ongoing.
- TPB coating planned at CERN (same setup as for ICARUS) September/October
- Readout electronics provide sampling of the analog PMT signal at high frequency (160 MHz). CatiROC





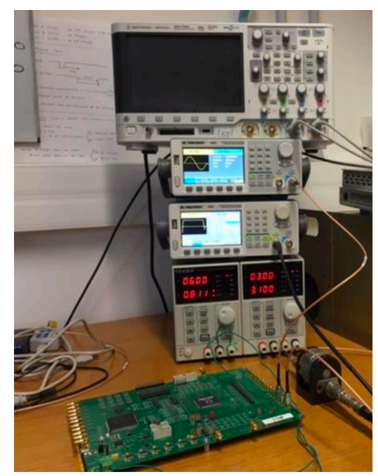


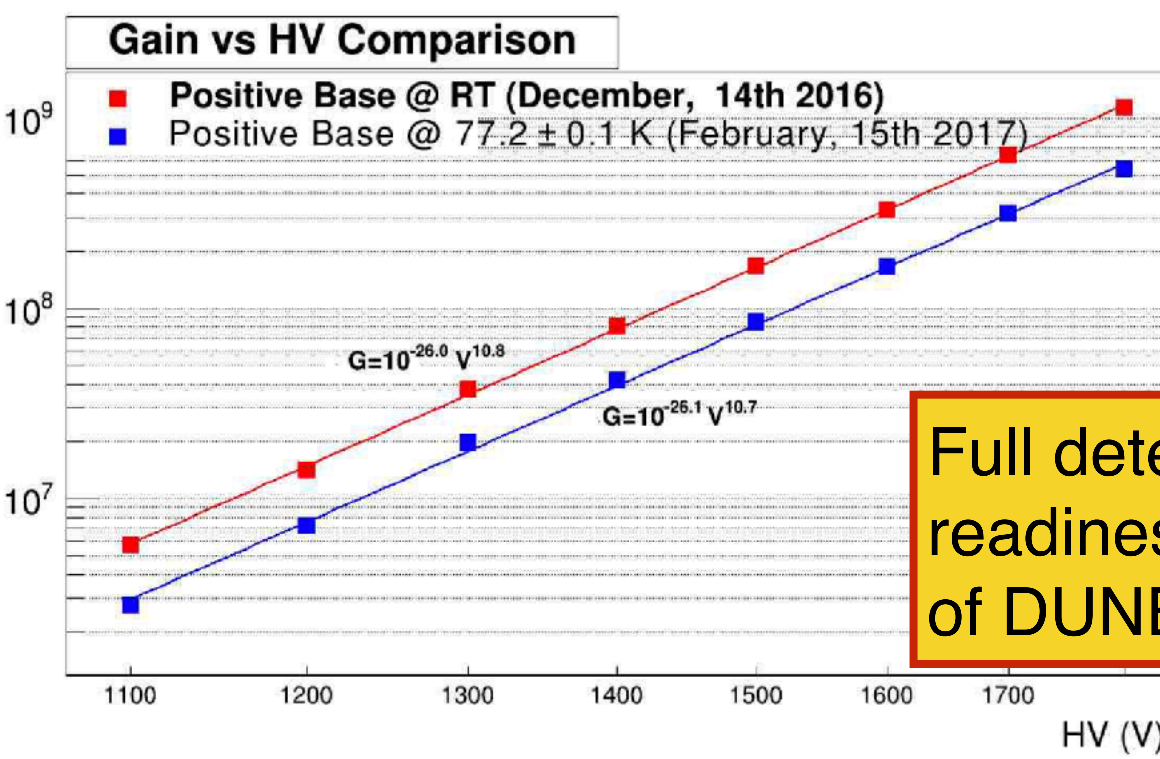
- black box with light source outside of cryostat
- 2 fibers going to cryostat
- each splitting into 20 micro fibers (~100 μm thick)
- either directly on top of cryostat or at bottom of cryostat

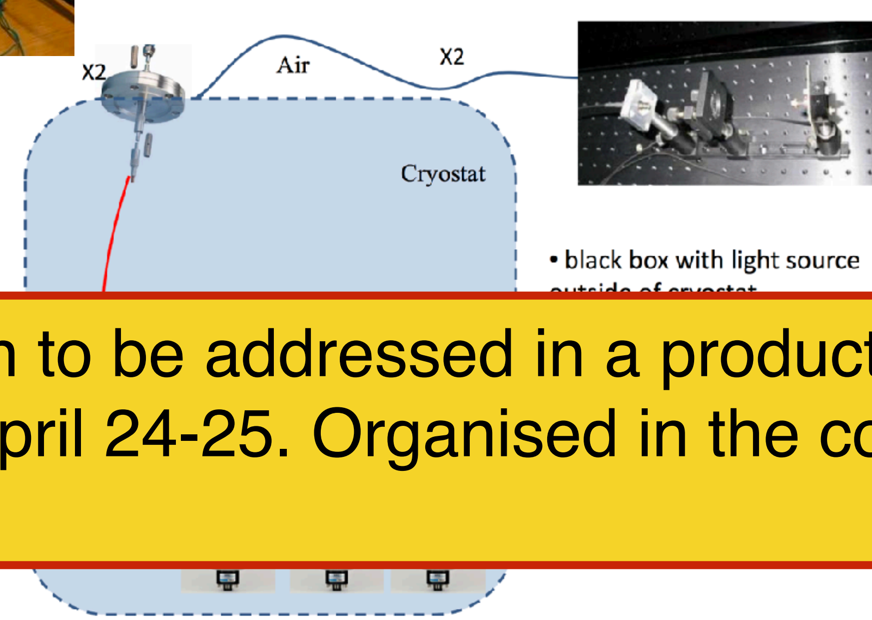
Light readout

	TIME
PMTs mounting into the support (clean room). Steps: • Support and PMT assembly • PMT base and cable soldering • PMT transport box modification to accommodate PMT+ support • PMT storage into the box with double black bag	2 weeks (on-going)
Tests at RT (GAr to test the PMT bases). Measurements: • Gain vs HV • Dark current vs HV • PMT Pulse shape (with the scope) for $G = 10^7$	2 weeks (10 x 2,5 d)
Cryogenic tests (LN2). Measurements: • - Gain vs HV • - Dark current vs HV • - PMT Pulse shape (with the scope) for $G = 10^7$	4 weeks (10 x week, sequence to be repeated Firday to Friday)

- 40 PMTs delivered, testing ongoing.
- TPB coating planned at CERN (same setup as for ICARUS) September/October
- Readout electronics provide sampling of the analog PMT signal at high frequency (160 MHz). CatiROC





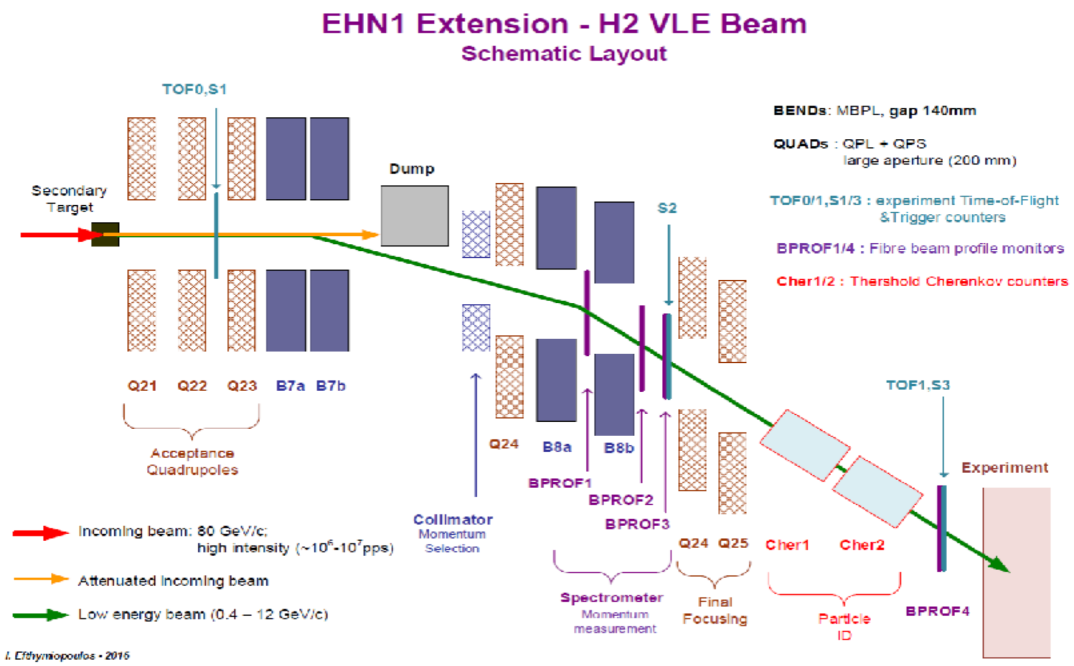


Full detector design to be addressed in a production readiness review April 24-25. Organised in the context of DUNE

H2 Beam line

WA105

Beam studies jointly by WA105/CERN

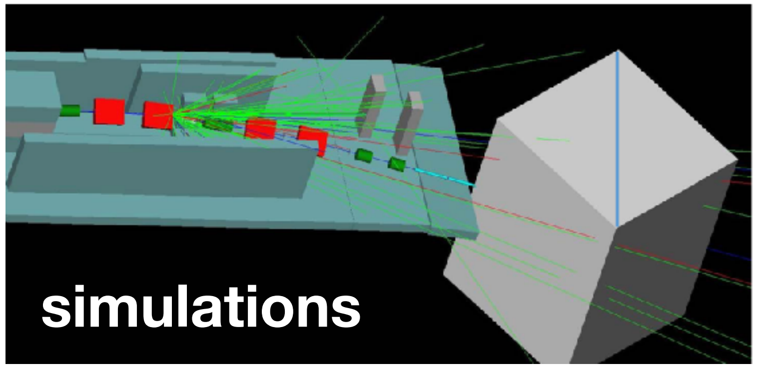


H2-VLE beam line

Tertiary beam on H2 beamline:
1-12 GeV/c, momentum bite 5% (can be reduced to 1% with integrated spectrometer measurements)

- Mixed hadrons beam 1-12 GeV/c: pions, kaons, proton electrons contamination at low energies
- Pure electron beams
- Parasitic muon halo

→O(100 M beam triggers to be acquired in 2018 in 120 days of beam operation)



Beam instrumentation well defined by B.I. WG (beam profile monitors and trigger tiles TOF, 2 Cerenkov)

Beam line with all instrumentation integrated

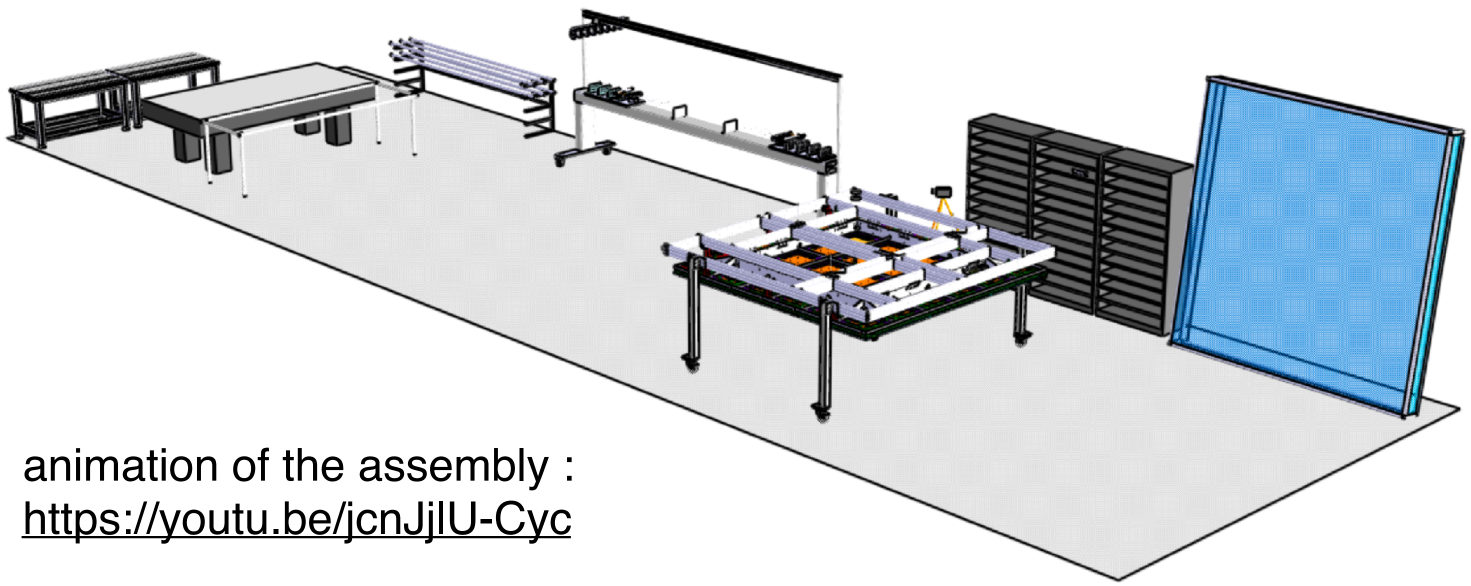
Detector construction and integration

Integration group was created within the collaboration. To role is to cover and supervise the construction, installation, cabling, etc.. of the ProtoDUNE-DP detector.

The activities, that have already started, include:

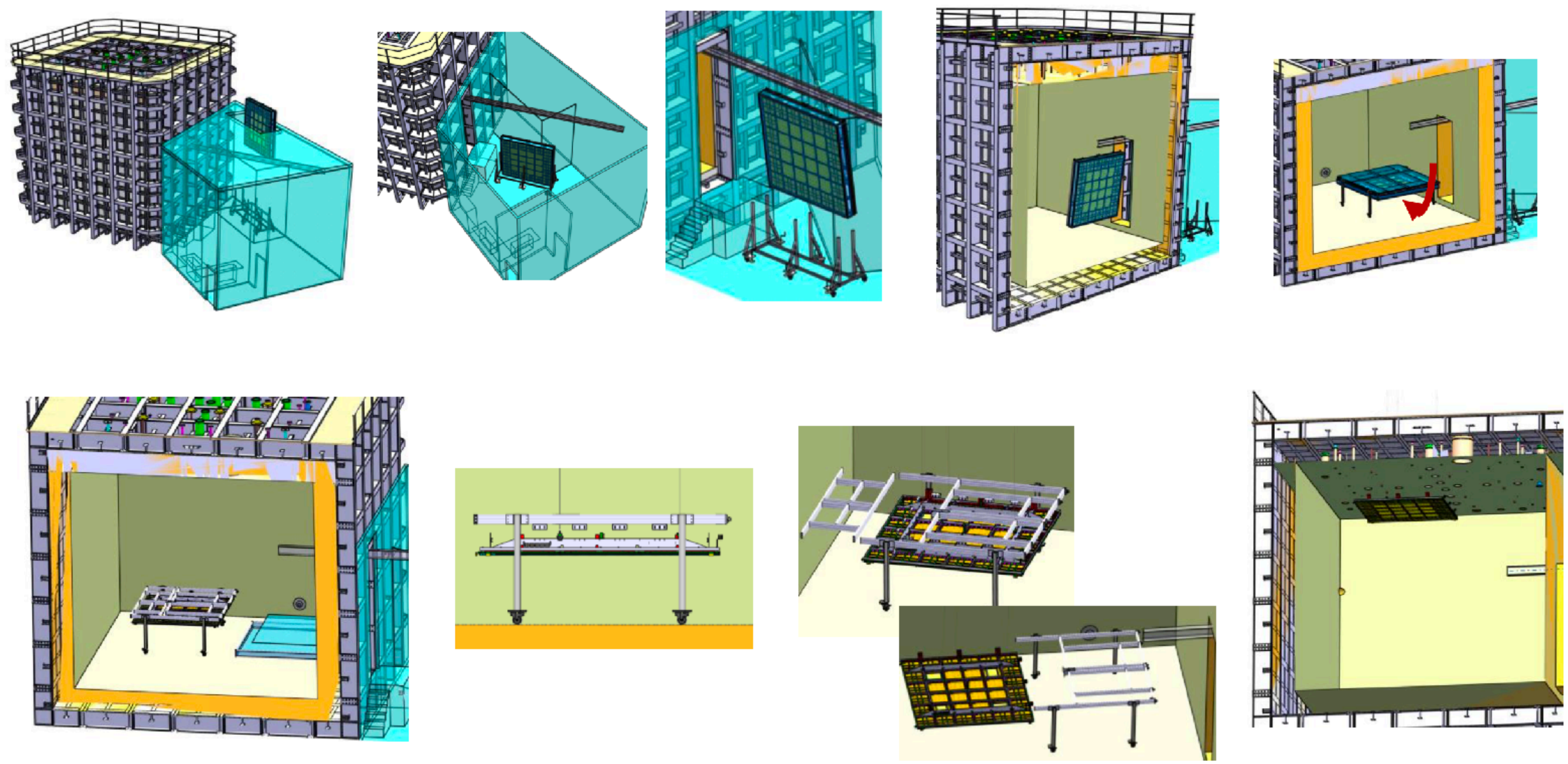
- The definition of the work, HR requirements, material, safety issues related to each of those areas
- The organisation the sequencing of the various activities
- The review and update of the planning for the detector preparation and construction. Detailed planning was provided with the SPSC SR-206
- Regular meetings with CERN Neutrino platform
- Check availability of key infrastructure
- Continuous communication with HSE (CERN safety dept).

Assembly of CRP



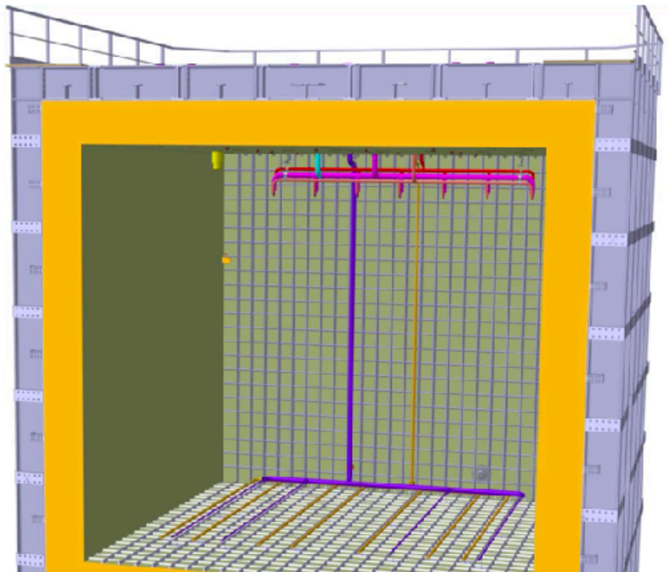
animation of the assembly :
https://youtu.be/jcnJjlU-Cyc

The individual CRPs are assembled in the clean room of building 182 and shipped one by one to the cryostat via the clean room buffer.

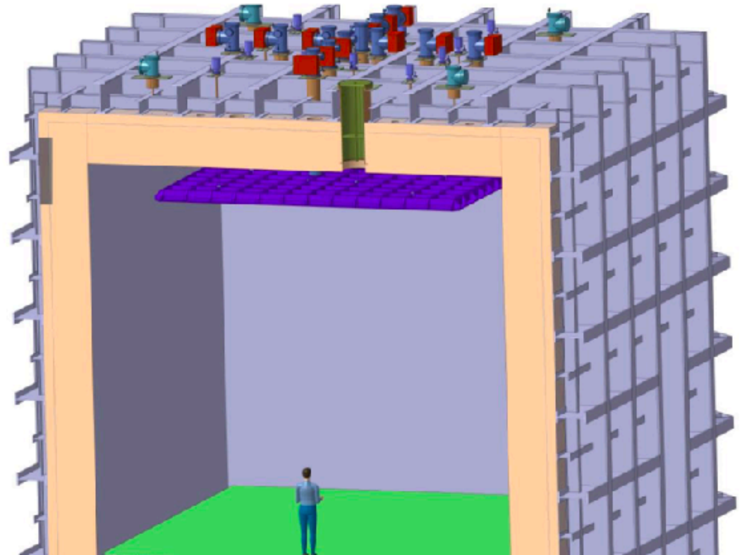


Detector construction and integration

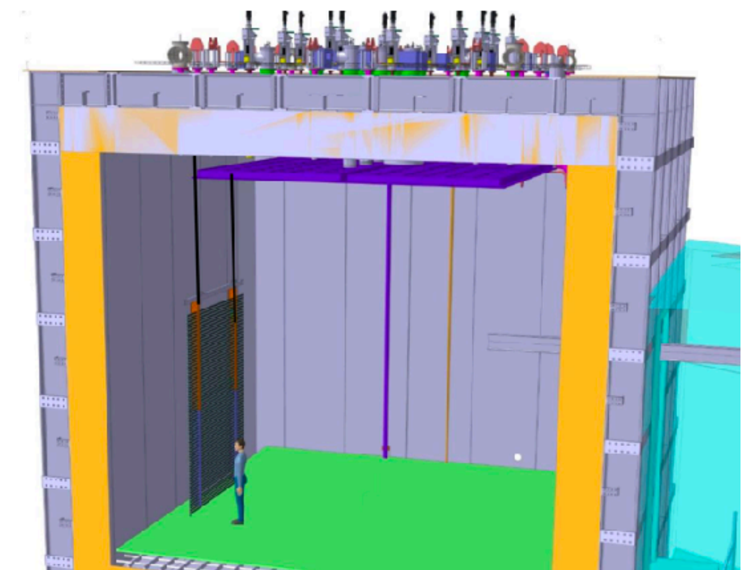
WA105



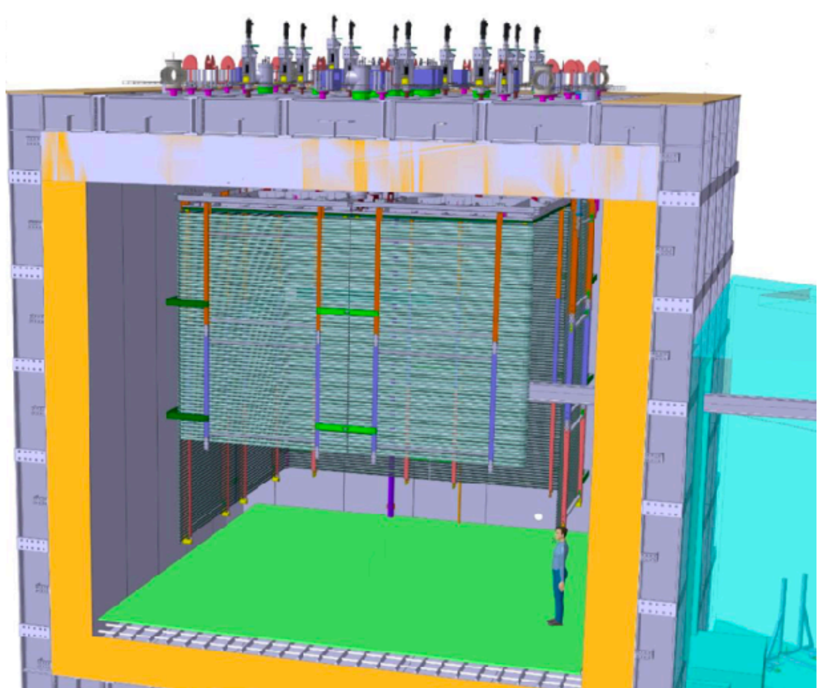
1. install internal piping & temporary floor



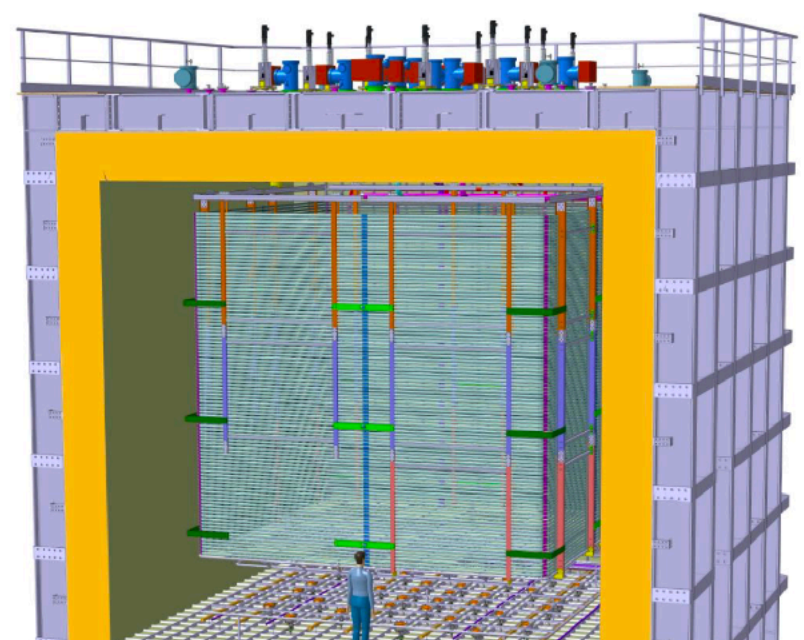
2. install the 4 CRP frames



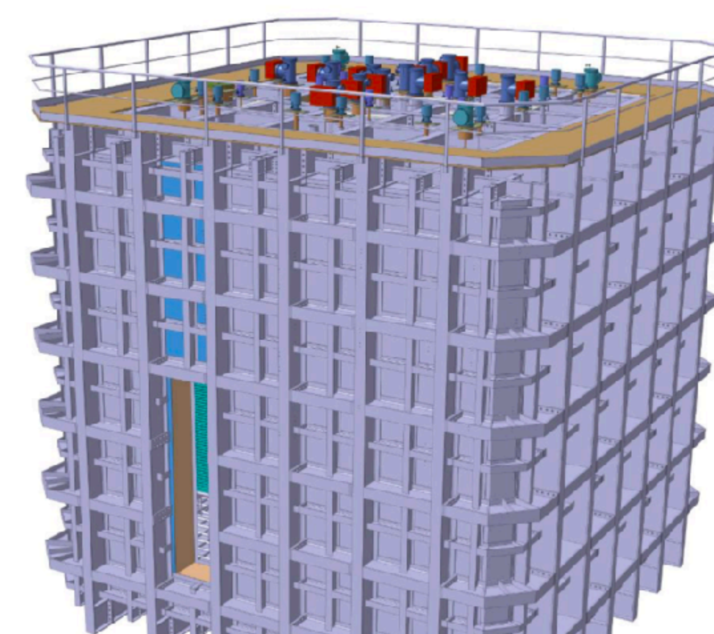
3. install the first drift cage modules



4. all drift cage modules installed



5. remove temporary floor and install photomultipliers



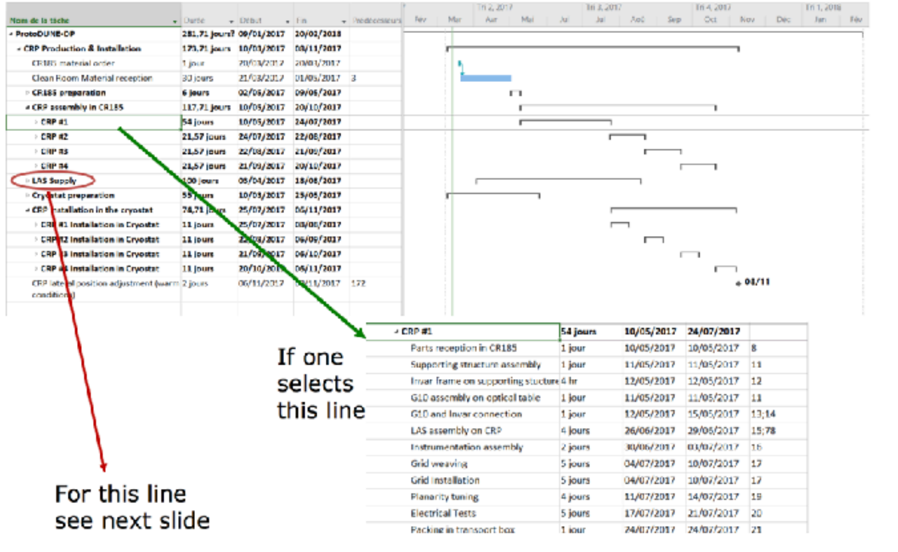
6. seal TCO

Detector construction and integration- schedule

WA105

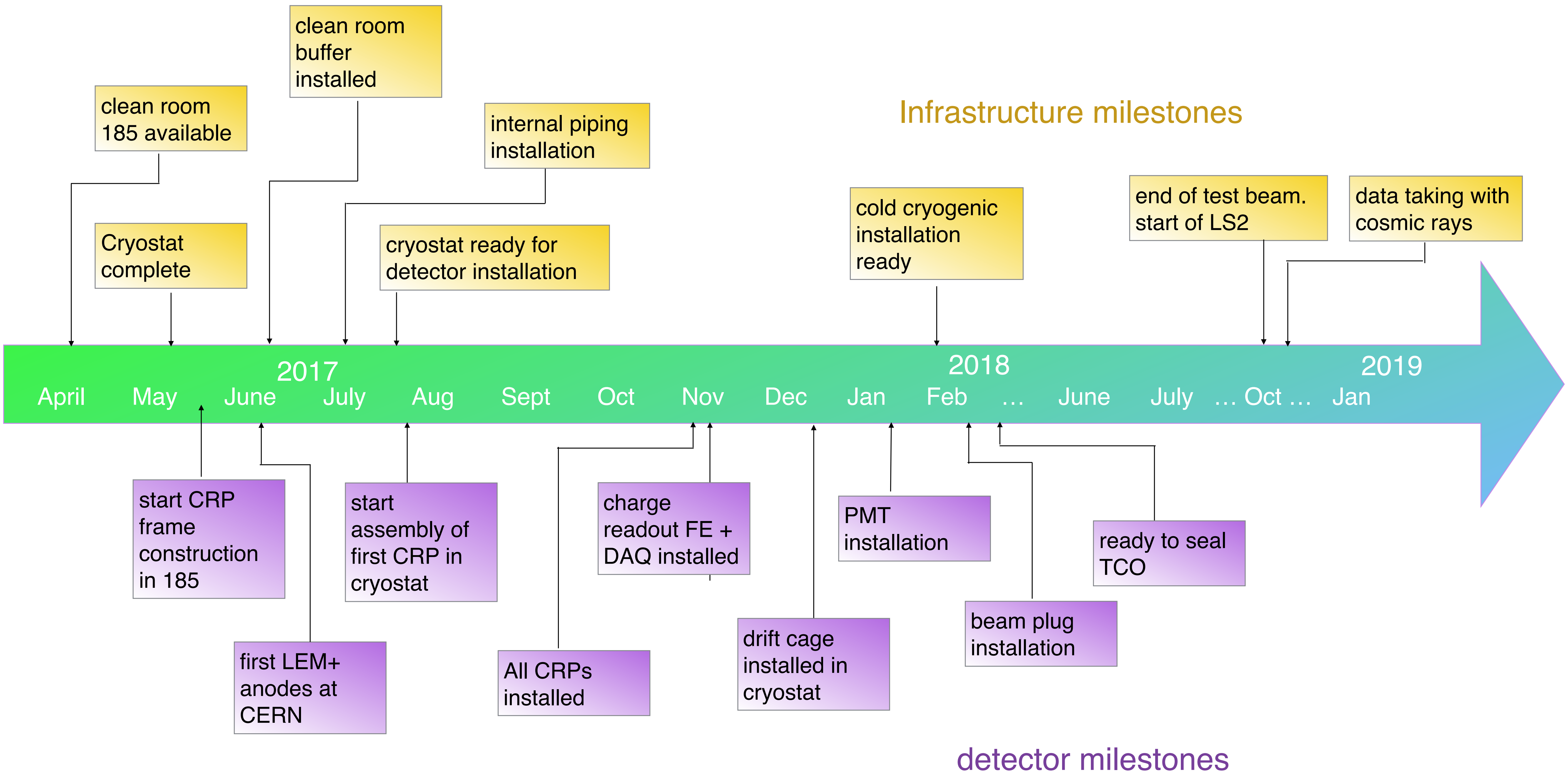
Tasks	start date	end date
ProtoDUNE-DP	**09/01/2017**	**20/02/2018**
CRP Production & Installation	**10/03/2017**	**08/11/2017**
Drift Cage Production and Installation	**01/05/2017**	**15/01/2018**
HV system	**27/11/2017**	**11/12/2017**
PMT and Light Read Out System	**09/01/2017**	**05/02/2018**
Chimneys and feedthroughs	**24/04/2017**	**04/08/2017**
Front End electonics	**11/09/2017**	**01/12/2017**
Slow control	**04/12/2017**	**26/01/2018**
Ground grid installation	05/02/2018	07/02/2018
Purity monitor	**08/01/2018**	**19/02/2018**
Beam plug installation	07/02/2018	14/02/2018
Ready to seal TCO & cryostat	19/02/2018	20/02/2018
Large Area Trigger Counters	**13/11/2017**	**22/12/2017**

The new date for TCO ready to seal: Feb 20th 2018



Detector construction and integration- schedule

WA105

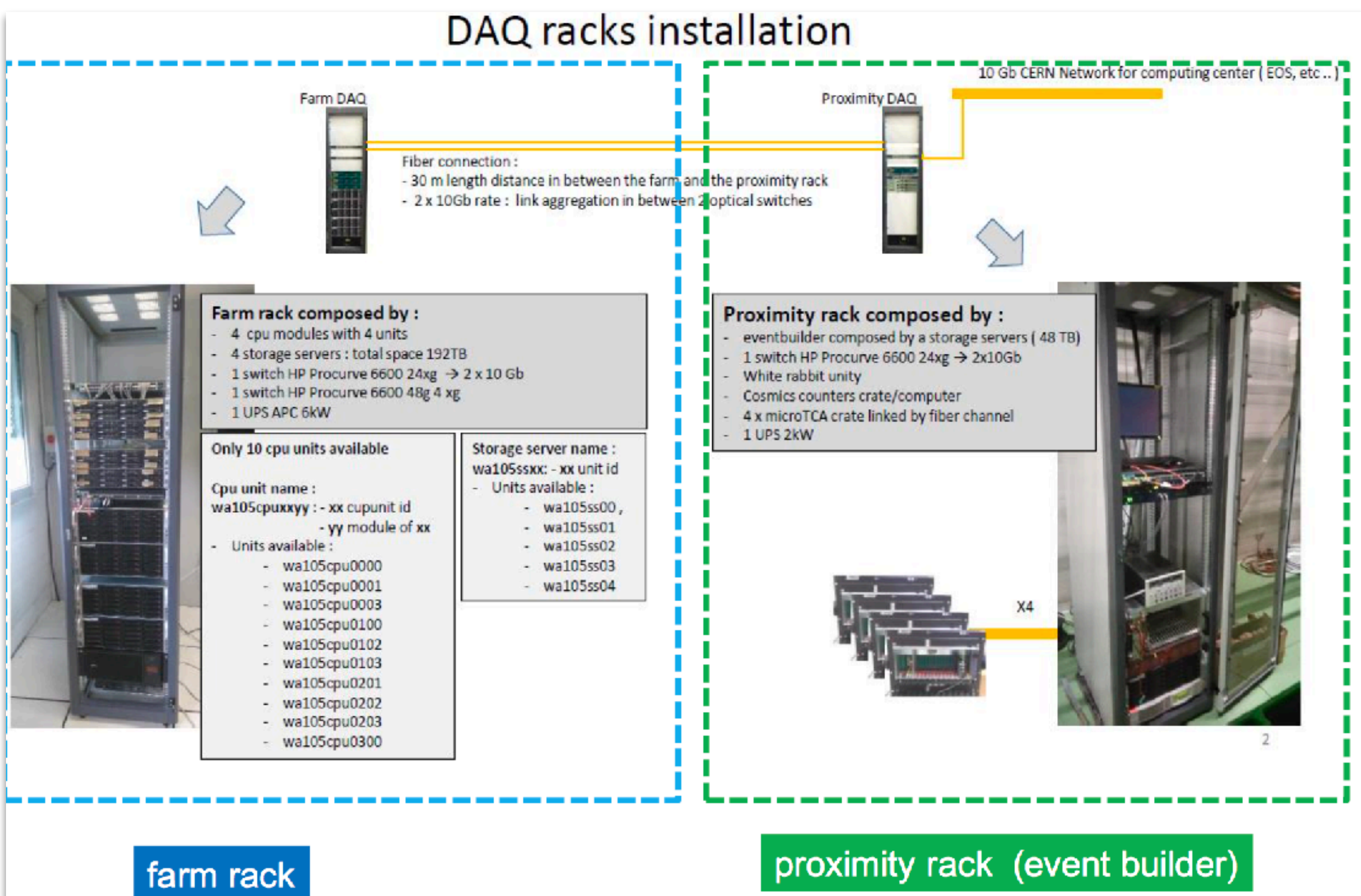


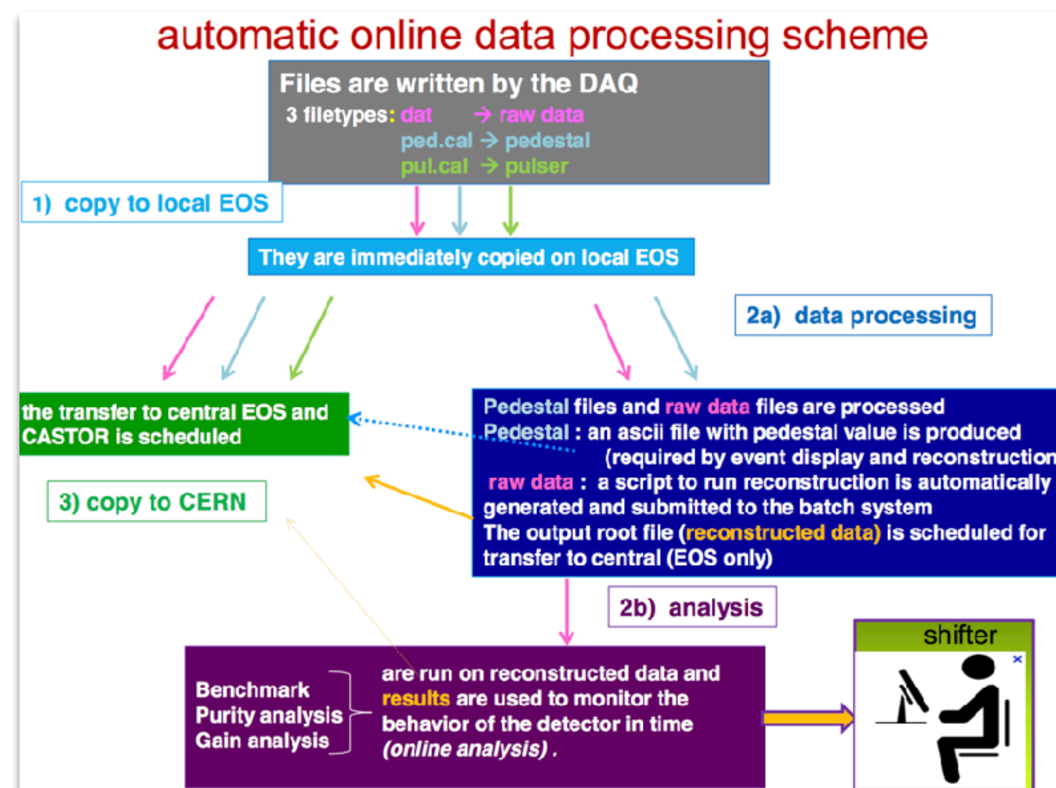
Software activities - online processing and storage

online storage and processing for protoDUNE-DP. Being tested on the 3x1x1.

The online processing has been tested during the different campaigns of noise measurement in the 3x1x1: files transferred to a local EOS and then moved to the CERN computing center.

So far up to ~ 400GB have been transferred from event builder to local EOS : transfer time ~4sec for 1GB file

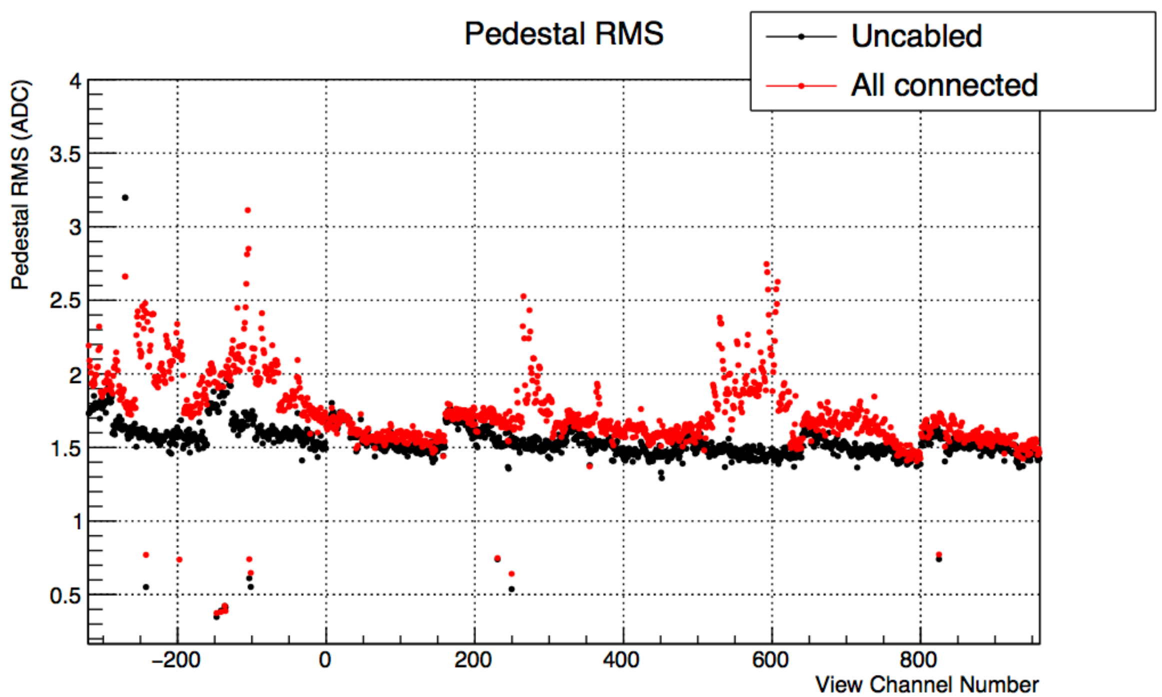




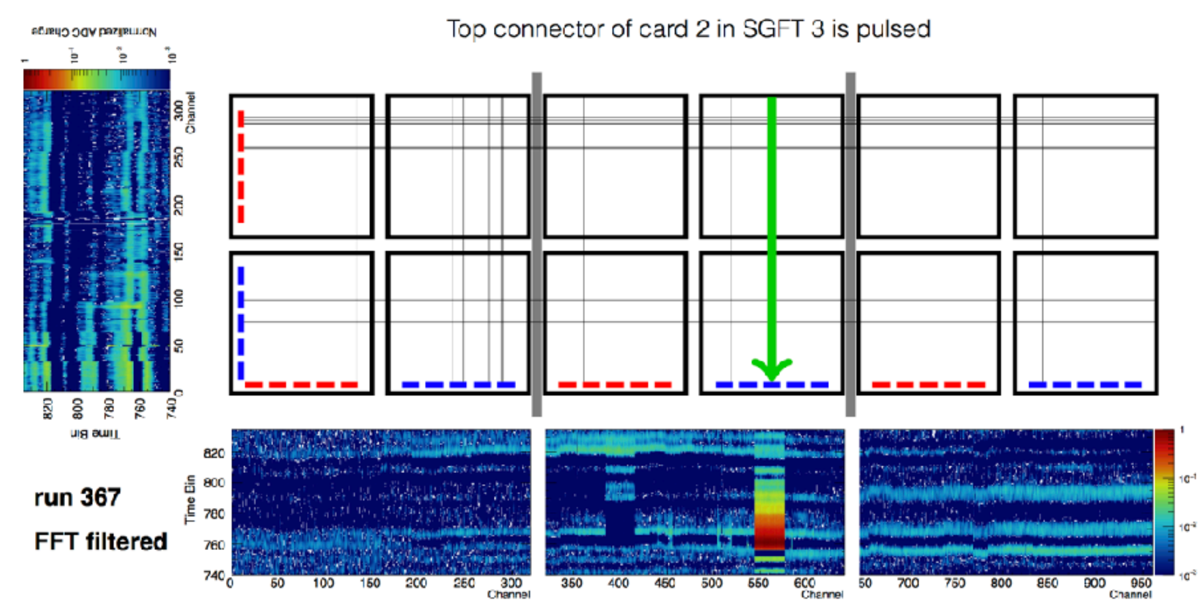
Tools in operation for the 3x1x1

WA105

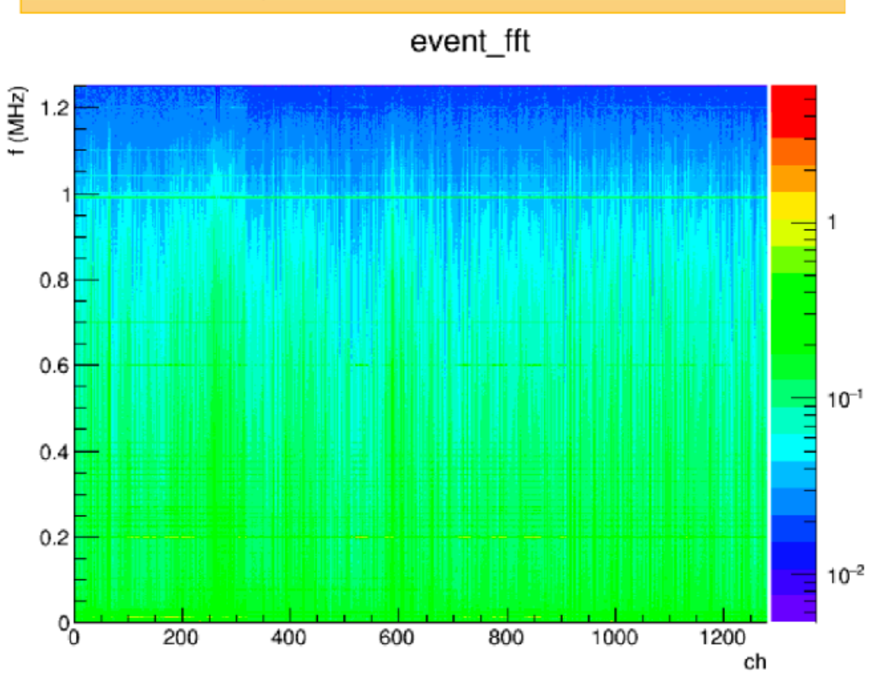
systematic check of noise

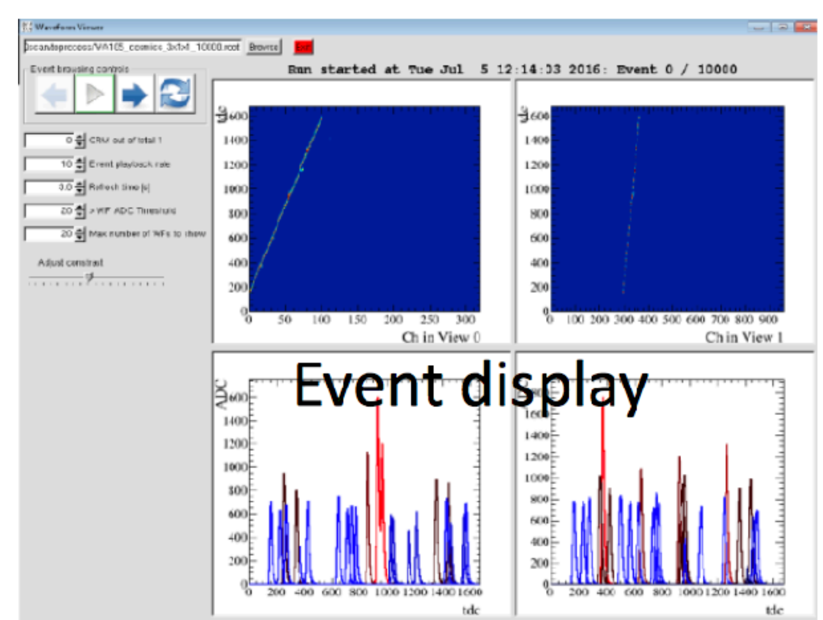


pulsing to check detector response



src/dofft.cc performs FFT on the raw data

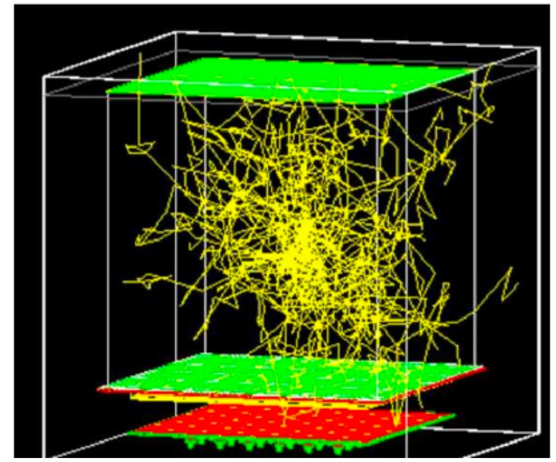




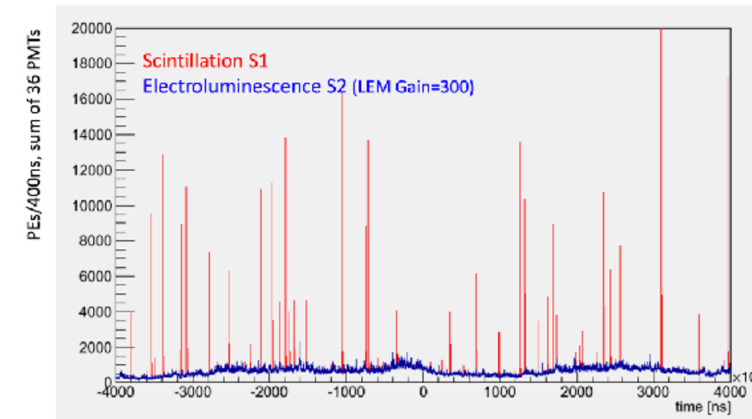
protoDUNE-DP simulations

WA105

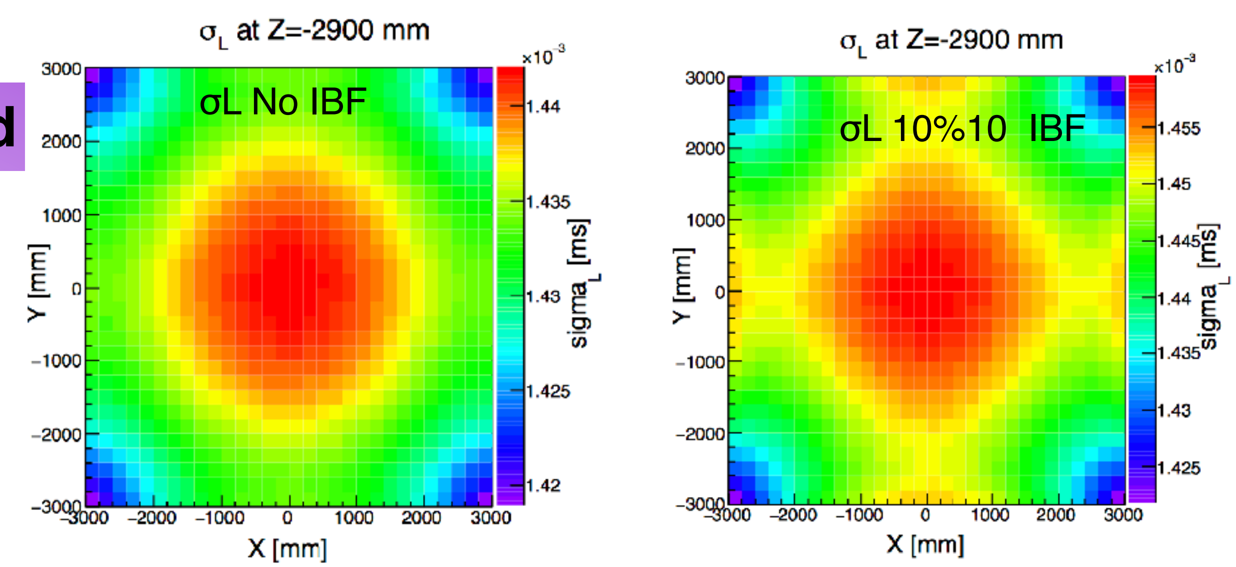
Light simulation:
-light yield and accurate positioning of PMT
-impact of electroluminescence (S2)
-cosmic ray tagging
-Absorption in LAr



Cosmic muons' light signal in 8 ms window

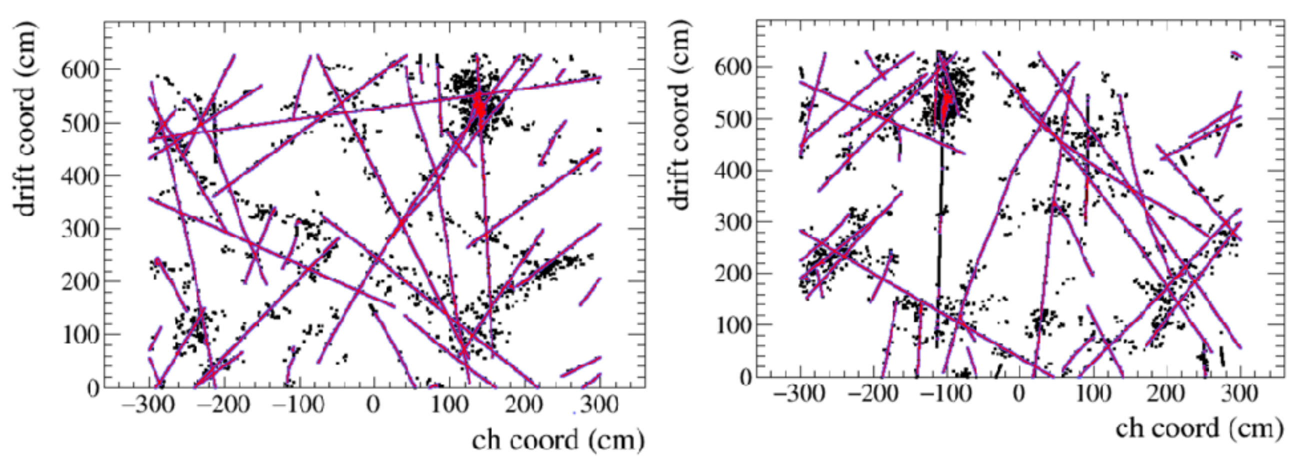


Study of space charge and effect on electric field

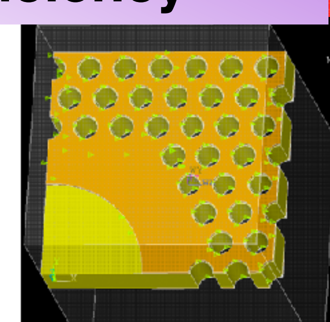


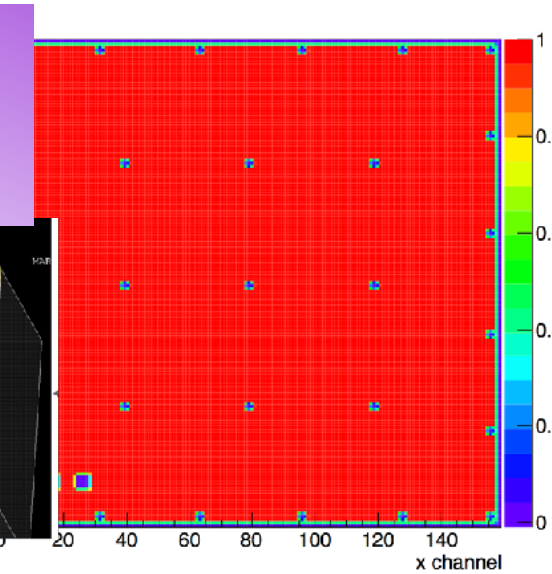
cosmic muon reconstruction

Black points show the reconstructed hits
Magenta points show hits associated to some track
Red lines indicate track paths



Study of LEM borders, effect on charge collection efficiency





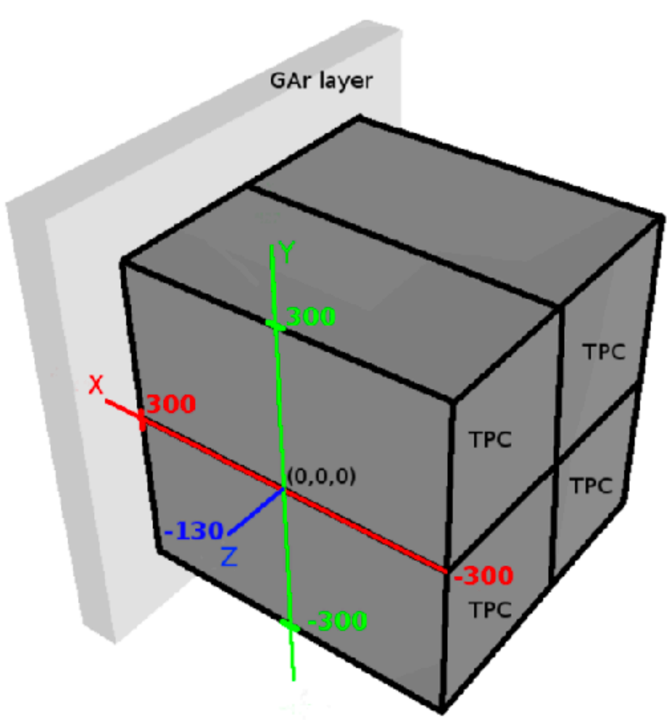
LArSoft activities

WA105

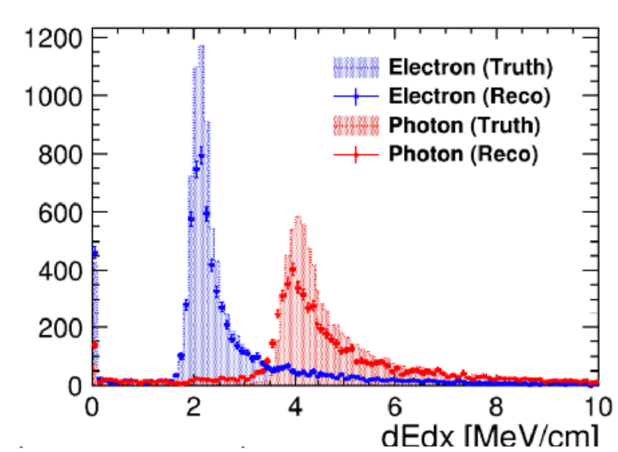
Large effort underway to integrate the dual phase detectors into LArSoft framework:

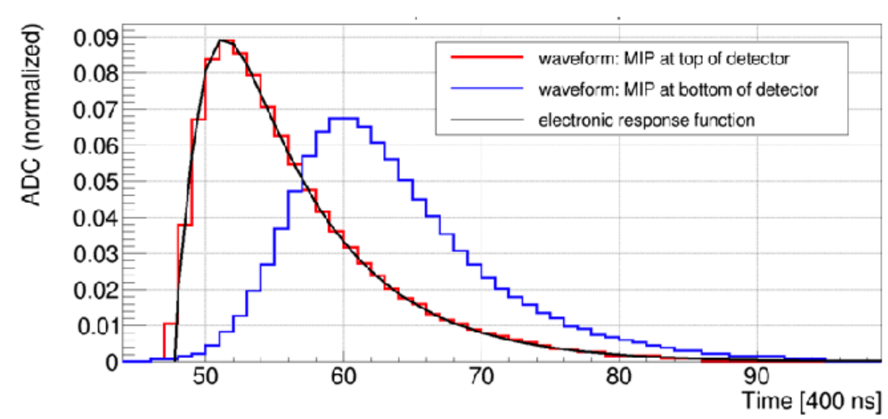
- Implementation of DUNE 10 kt DP in LArSoft
- Profit from reconstruction tools developed by world-wide community for analysis of beam data.
- Once available, compare SP and DP data with same framework

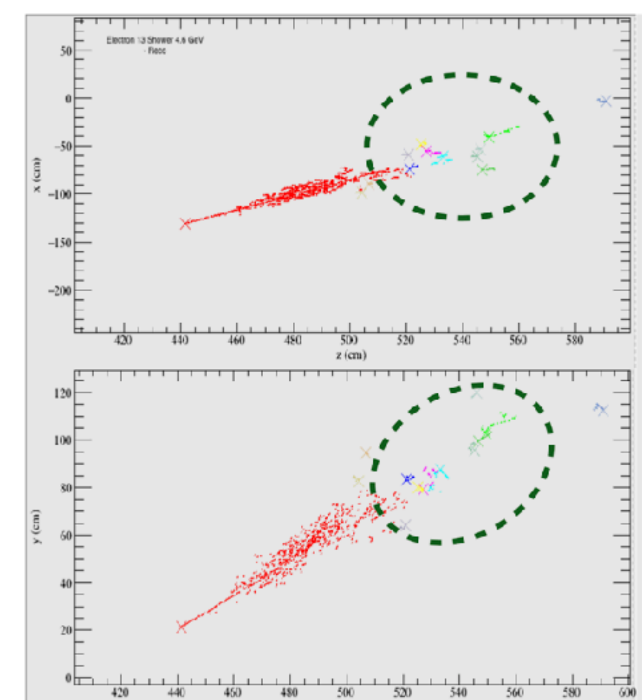
Started implementation of protoDUNE-DP geometry.



Shower reconstruction and muon reconstruction efficiency DUNE 10kt







Conclusion

Significant progress has been made since last year as reflected and described in detail in the SR-206.

- The **complete assembly of the 3x1x1** detector in about 6 months.
- The **installation of cryogenics, DAQ and start of commissioning**.
- 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 presently in GAr purging phase.
- Although cosmic tracks have not yet been acquired, **large experience has been gained for protoDUNE-DP design, installation and commissioning**.

- The **finalisation of main protoDUNE-DP design last year**
- Extensive testing of many aspects in the context of the 3x1x1 (slow control, high voltage, feedthroughs, suspension system, instrumentation, DAQ and computing farm,…)
- **Purchase of material for assembly has started**
- **Integration group setup:** detailed installation scheme, updated resource loaded schedule and regular meetings with CERN-NP ongoing in order to define interfaces, follow availability of infrastructure.

Software and simulation have also made considerable advancement:

- **Full infrastructure for data transfer** has been set up and tested in the 3x1x1
- Detailed simulations of protoDUNE-DP have been implemented and have helped guide the design.
- **Integration of dual phase geometries into LArSoft** and studies ongoing


THANK YOU
WA105

EXTRA SLIDES

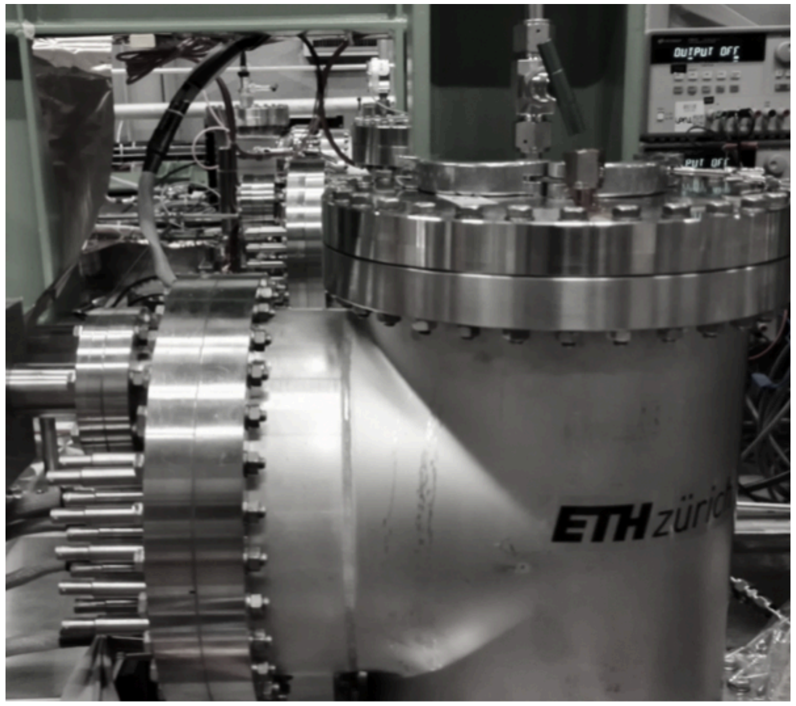
Feedthroughs

WA105

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

4 signal chimneys

3 slow control and medium voltage

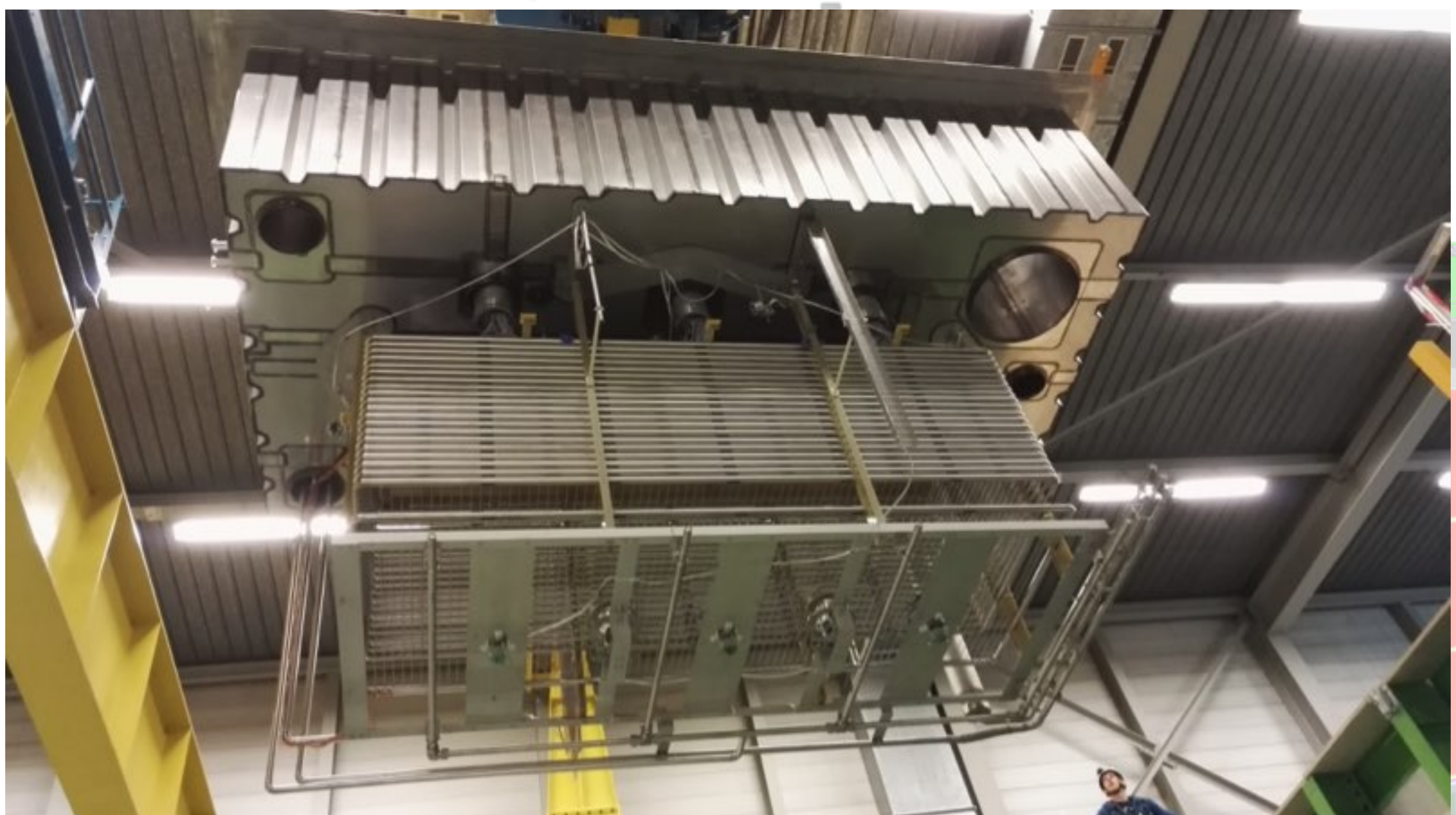


3 CRP suspension

1 High voltage
tested at 300 kV, operated at ~50 kV

3x1x1 detector and cryostat

WA105



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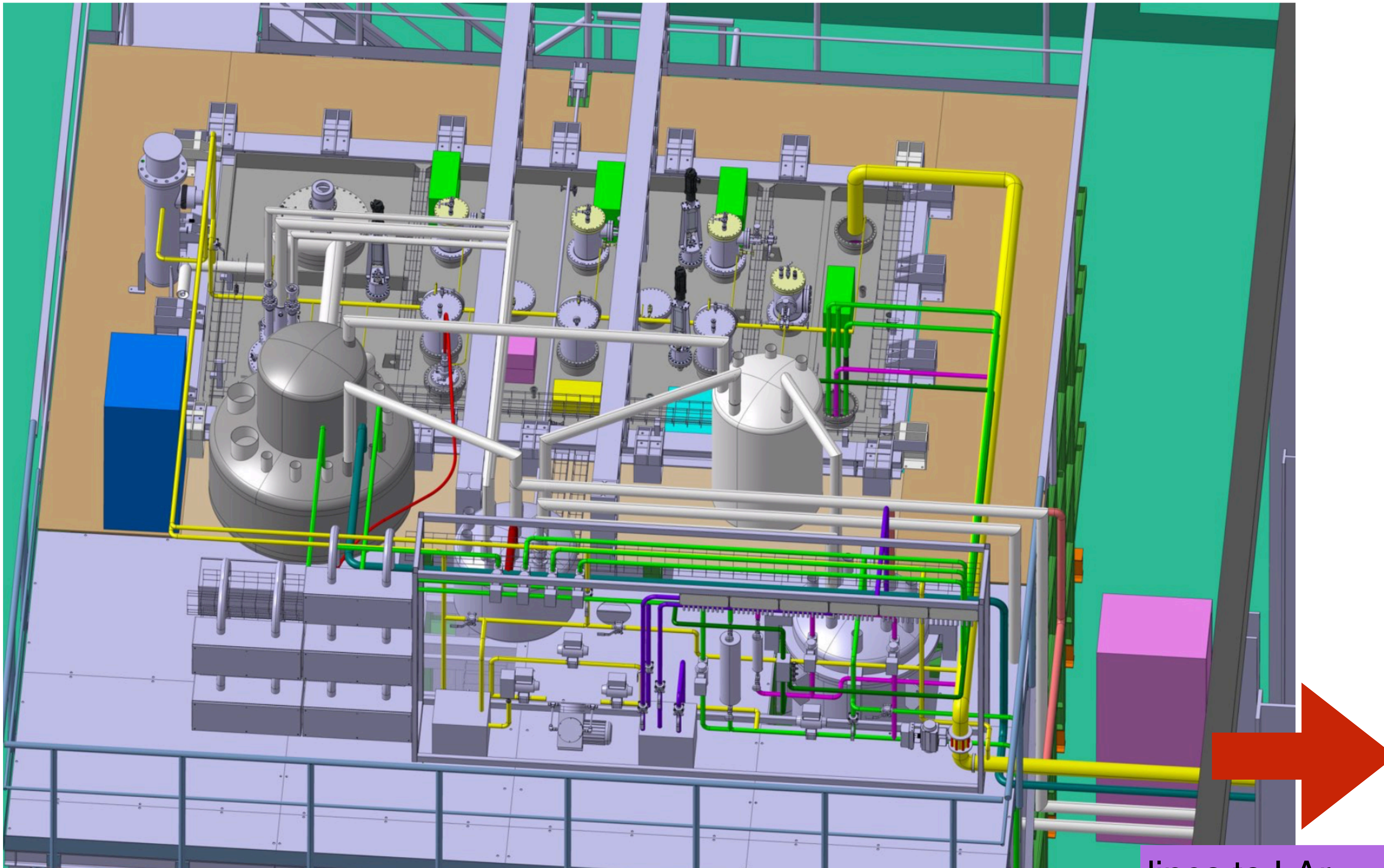
Cryogenics



lines to LAr +
LN2 tanks

Cryogenics

WA105

WARM piping

- gas argon purification
- system
- installation of pump, getter, gas trace analysers
- installation of gas piping to some of the chimneys
- collection of all purge valves to the gas recirculation system

=> Local company

COLD piping

- installation of all liquid argon and nitrogen vacuum insulated lines
- liquid purification cartridge
- condenser valve box
- phase separator valve box

=> Demaco (from invitation to tender sent January 2016)

control

- control of remote valves
- installation of all racks
- cabling and electrical connections
- supervision software

=> CERN TE-CRG

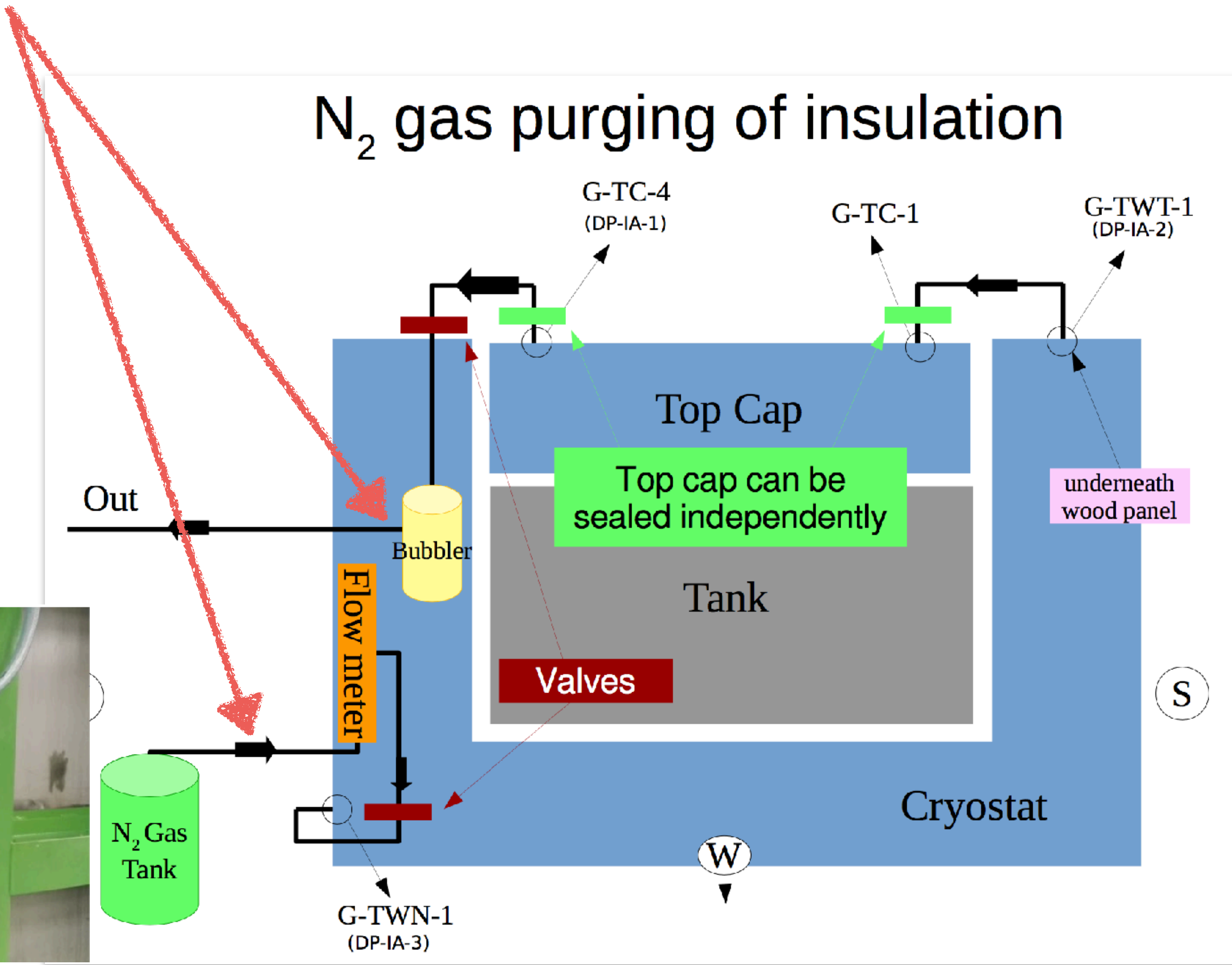
interfaces

- mainly inside cryostat
- internal piping (warm & cold)
- chimneys with gas inputs
- liquid pump tower
- cryostat rupture disks

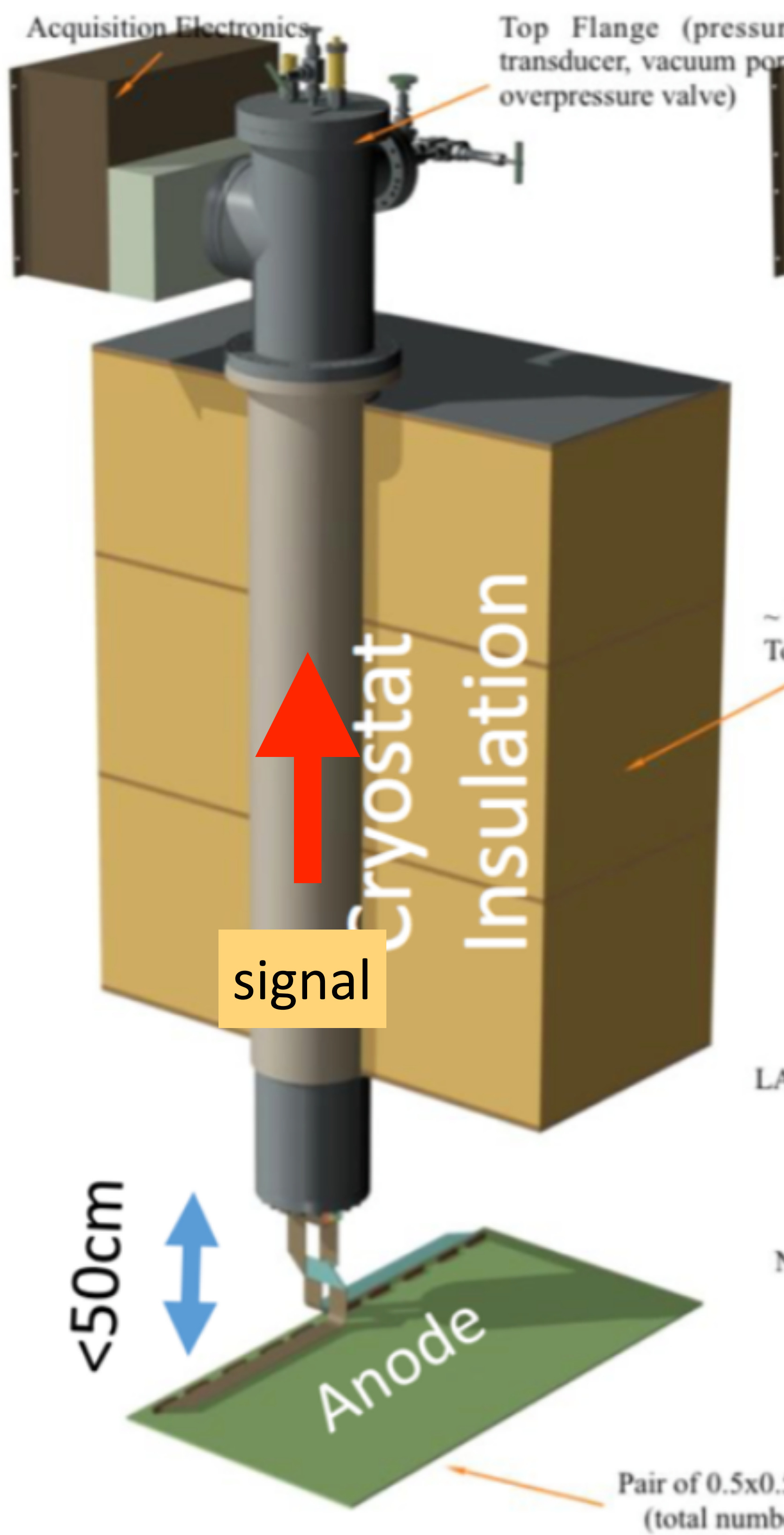
=> WA105

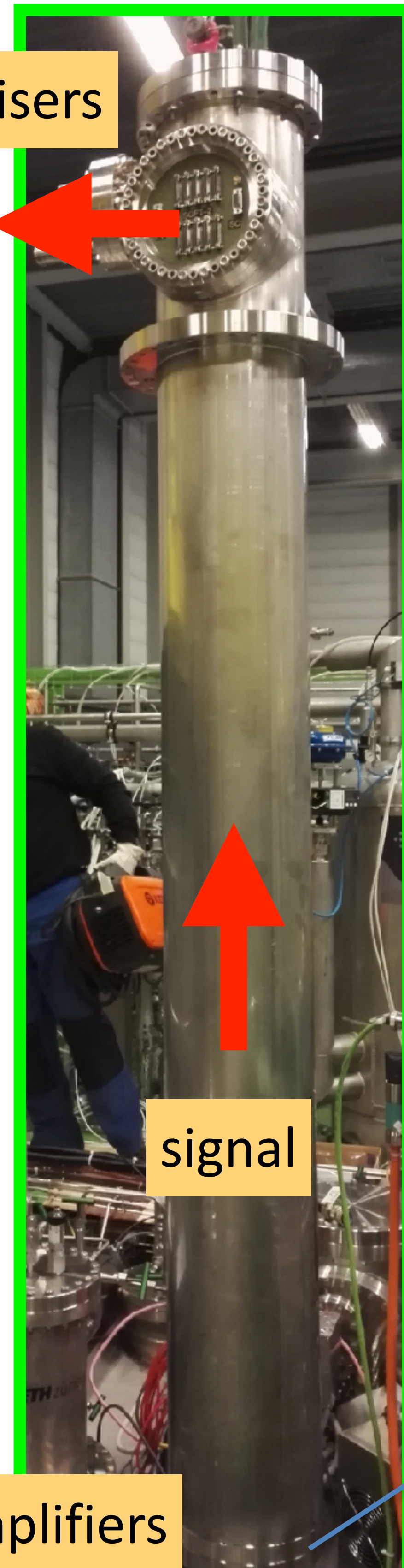
Gas nitrogen flushing of insulation space

The insulation space is continuously flushed with gas Nitrogen. A bubbler at the output maintains constant overpressure inside the insulation.



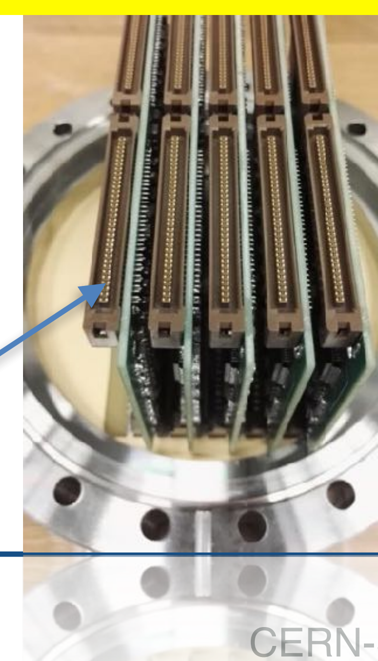
Signal feedthrough





amplifiers accessible during operations

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



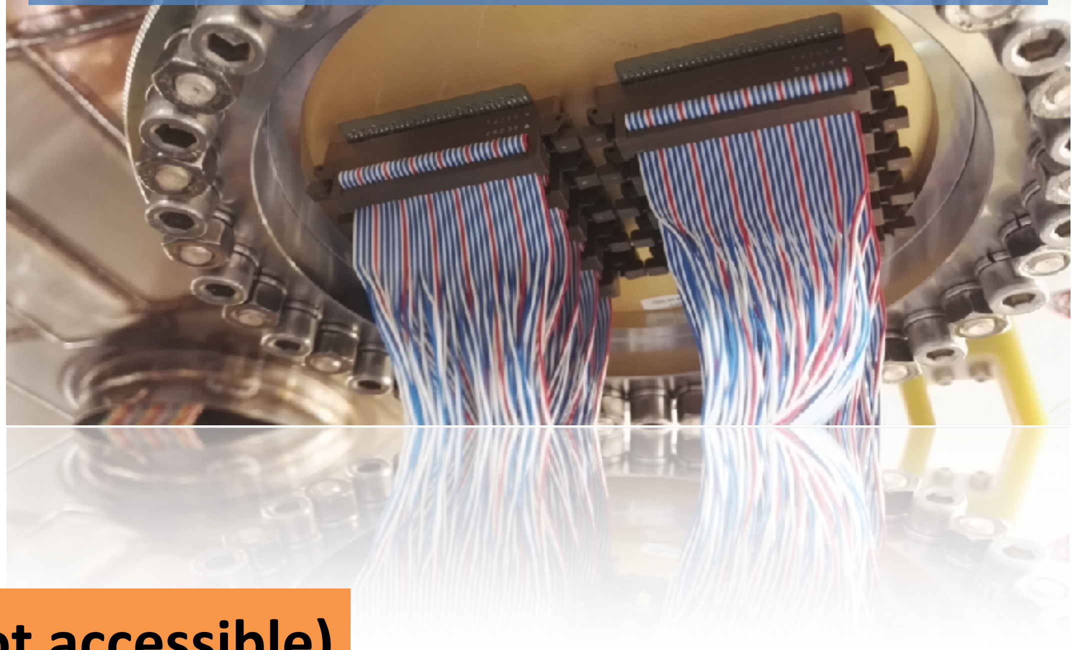
4 ASICs per board

Charge Readout

WA105

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

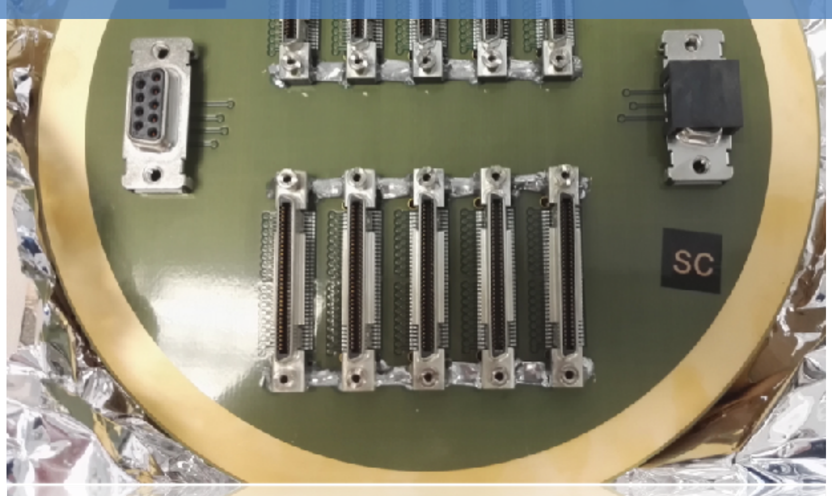
2. signal guided to cold amplifiers by group of 32 channels



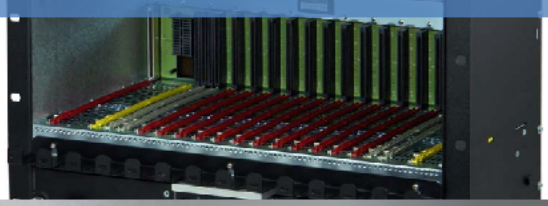
inside detector (not accessible)

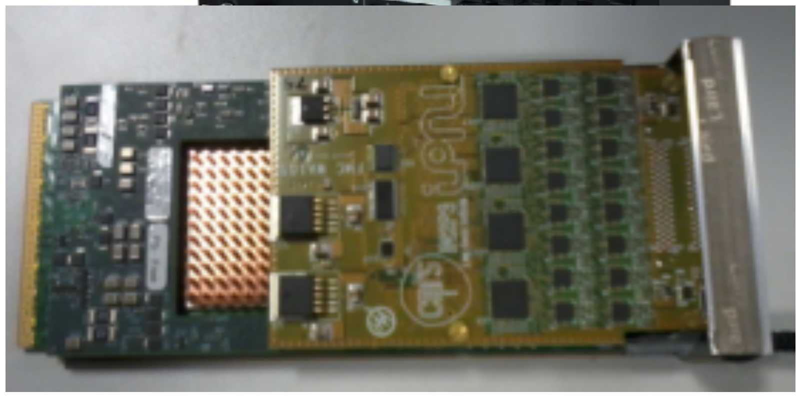
3. signal amplified by ASICS in cold

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)

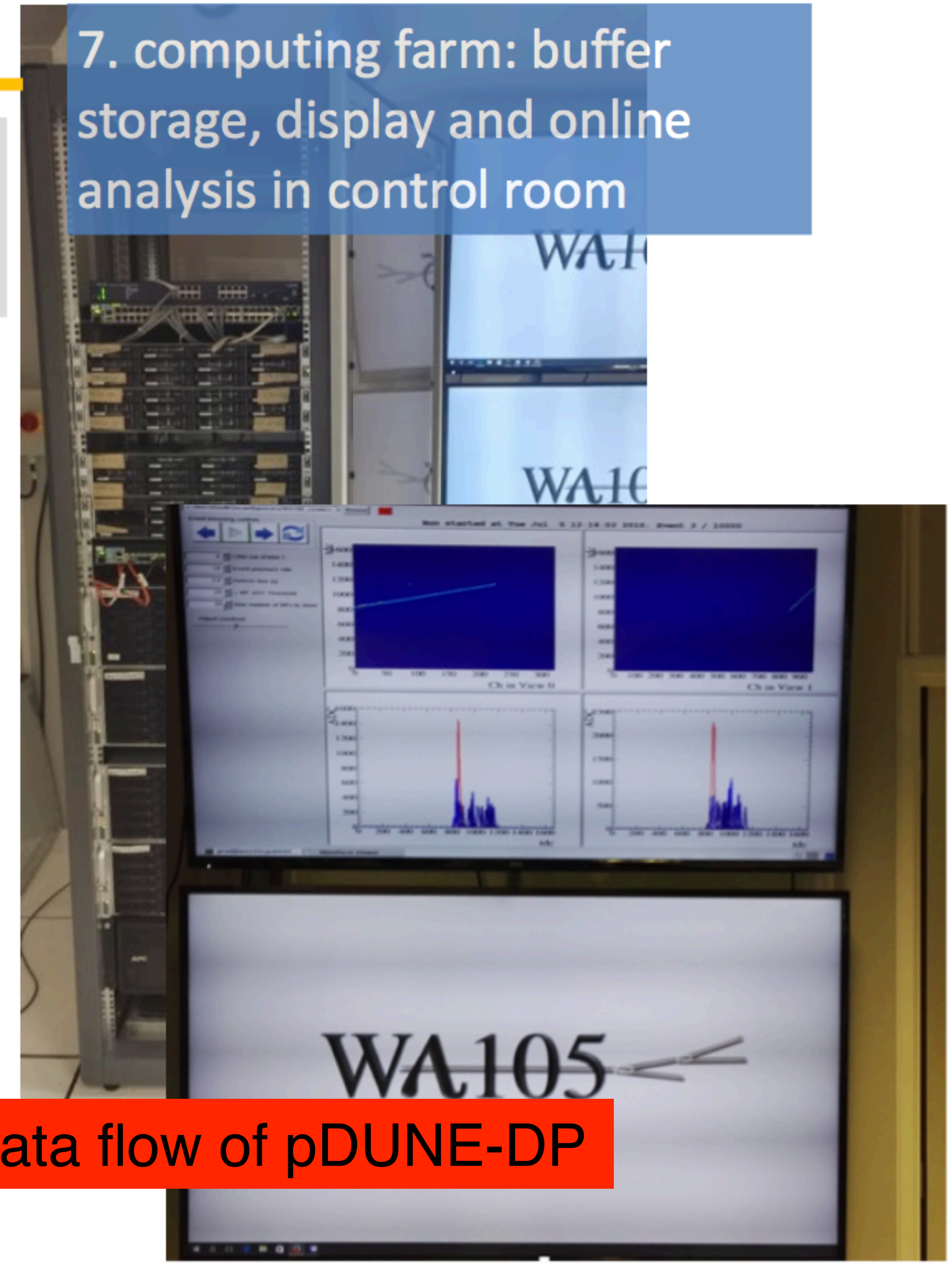
Top of cryostat

WA105

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

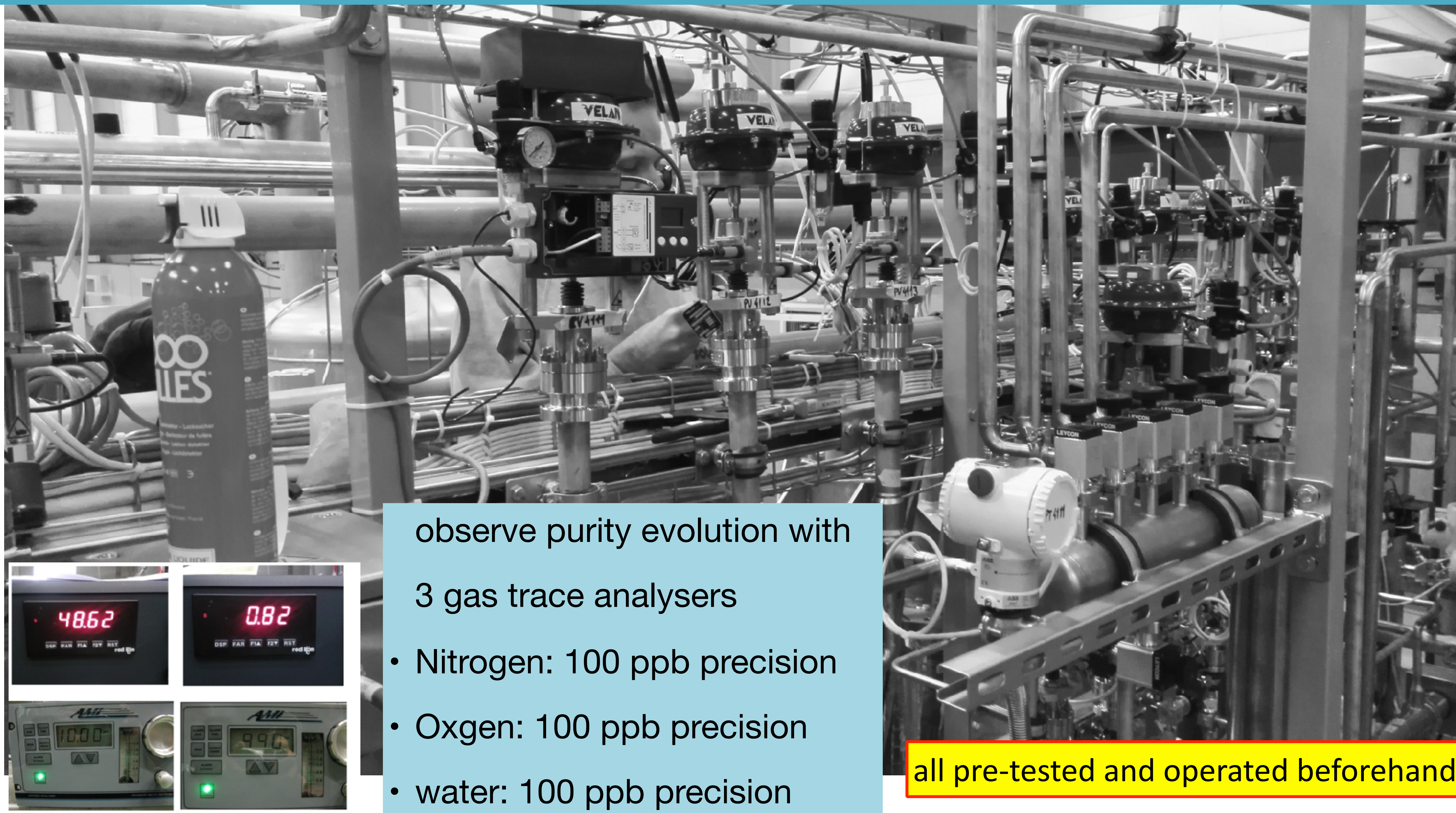
Designed for number of channels and data flow of pDUNE-DP

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

December-ready for purge

WA105

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



observe purity evolution with

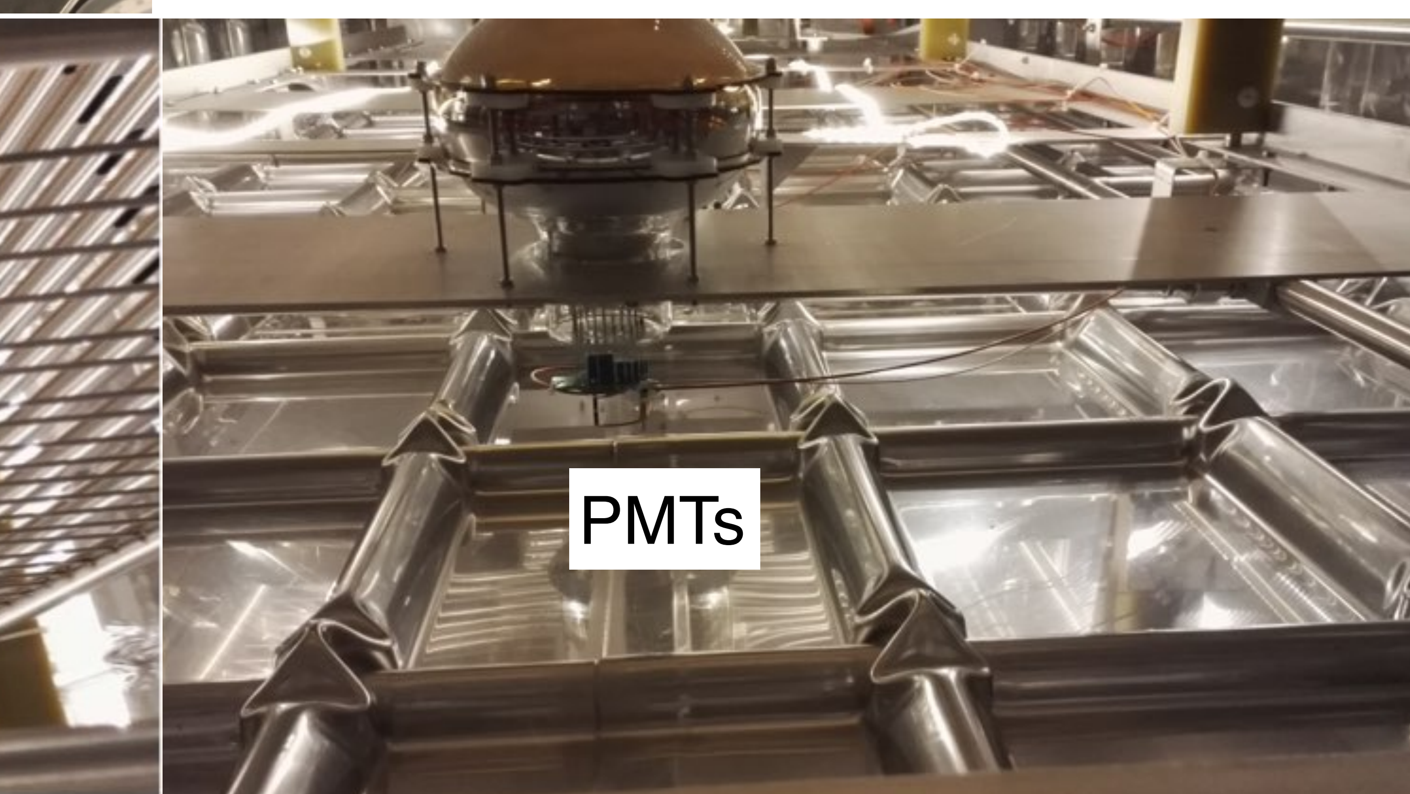
3 gas trace analysers

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

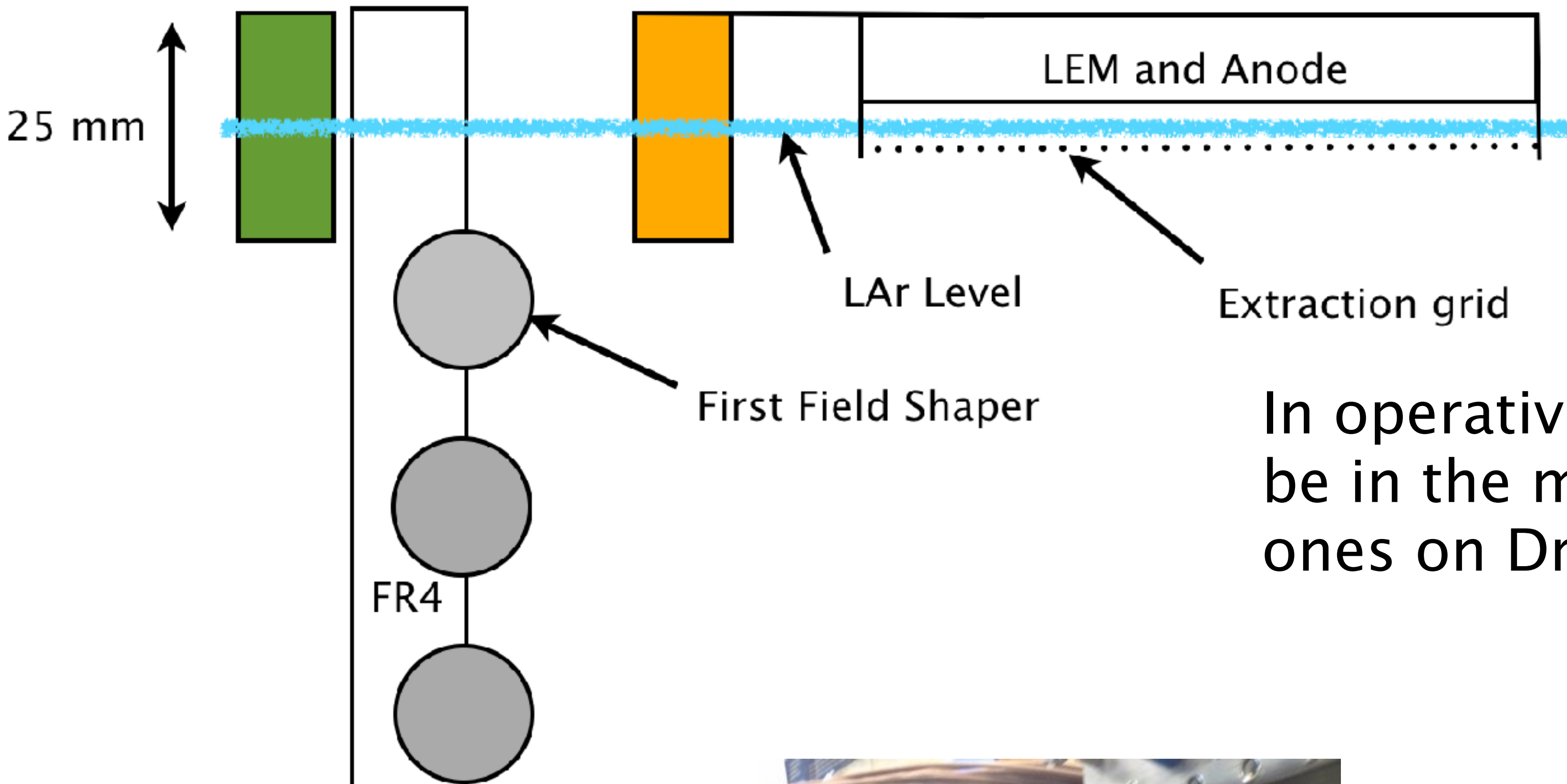
all pre-tested and operated beforehand

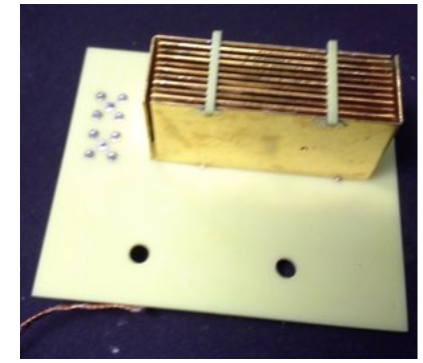
Inspection and measurements inside cryostat

WA105

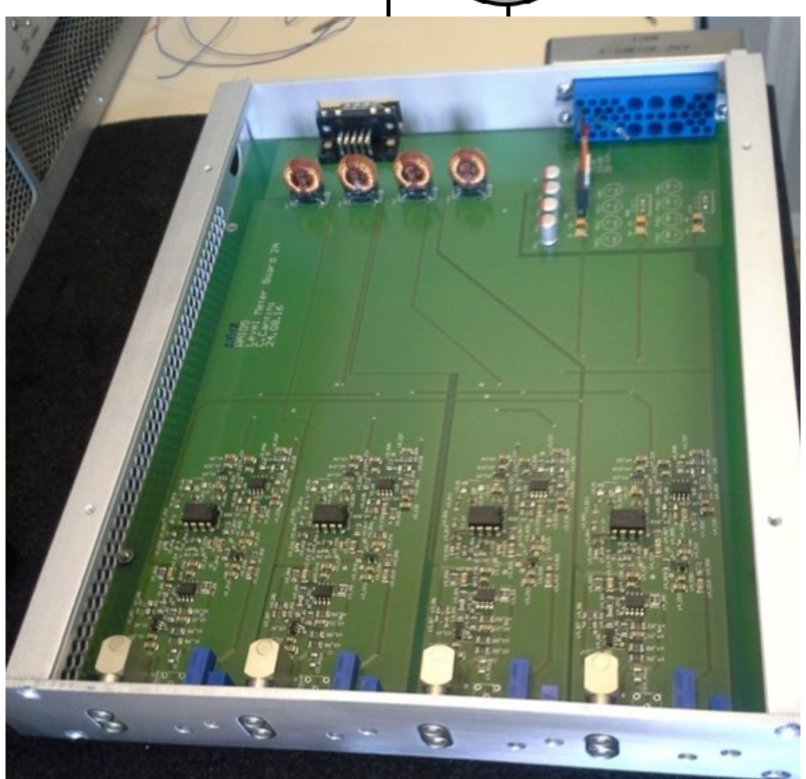


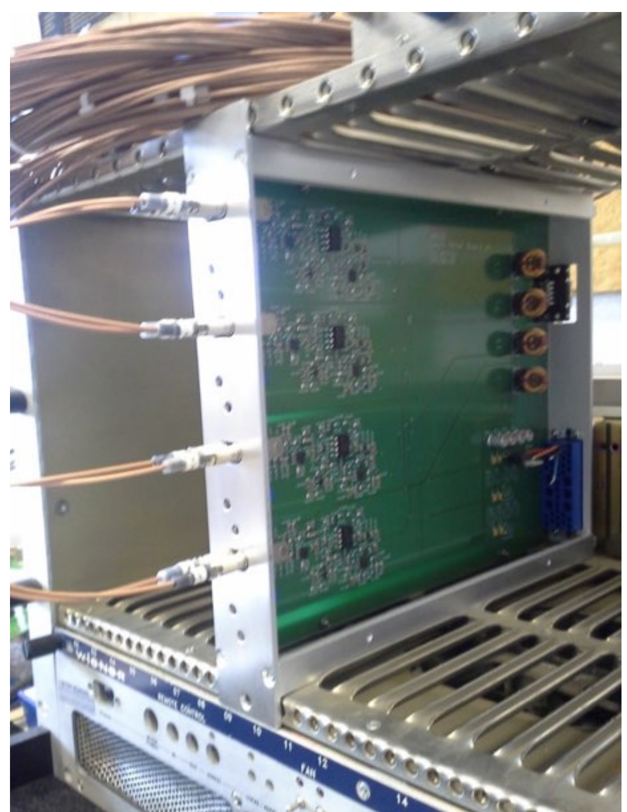
Slow control: level meters and pulser





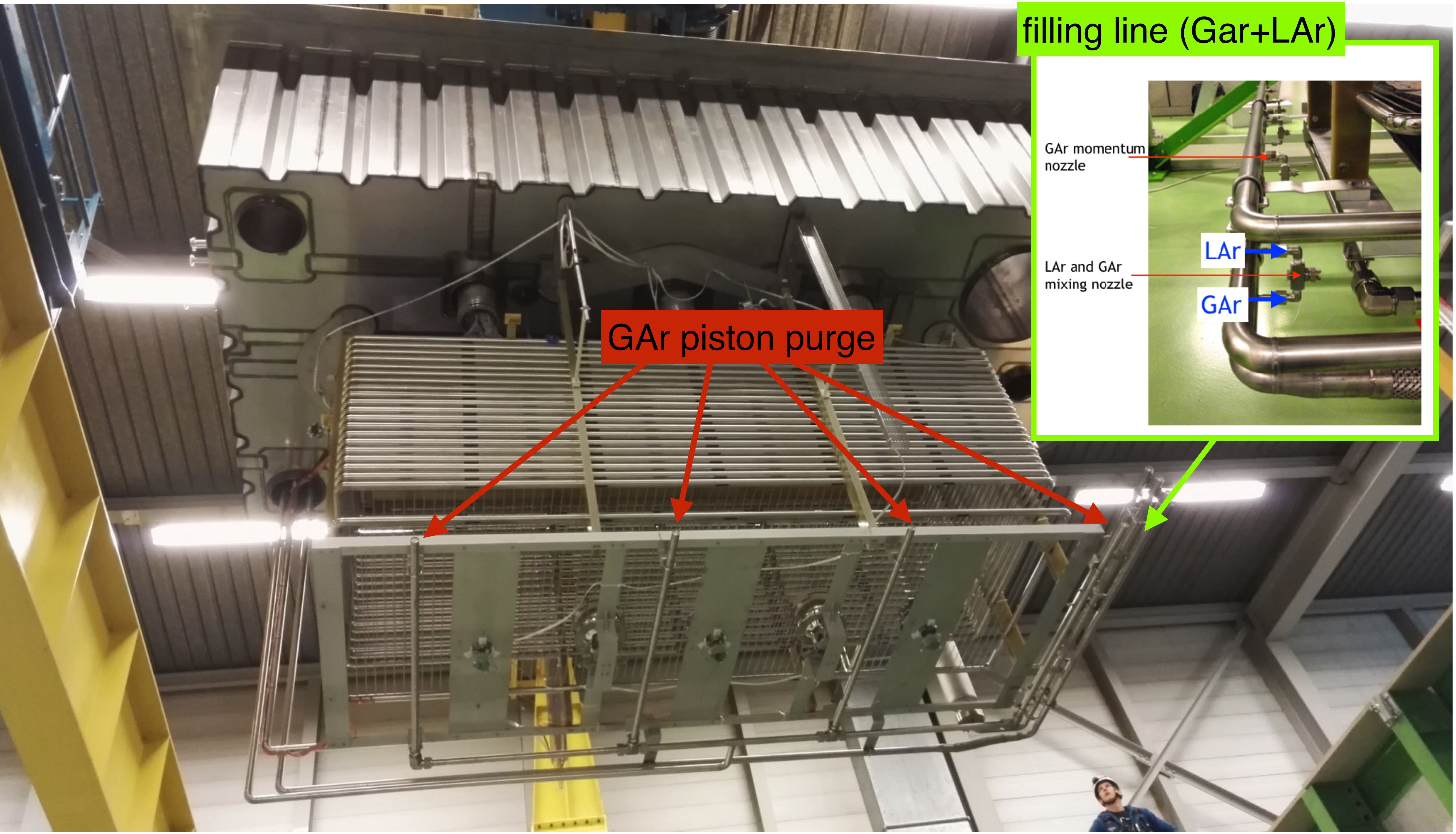
In operative condition the LAr level will be in the middle of both level meters, the ones on Drift Cage and the ones on CRP.





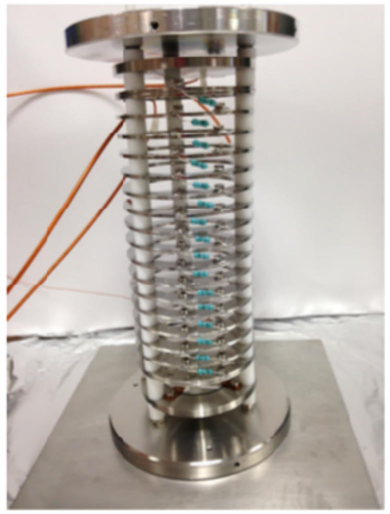
- A new NIM design has been done with:
  - 4 Channels
  - improved 0-10 V interface to NI Racks
  - improved filters on voltage rails and output
- 5 Boards NIM size are in production
- The assembly of the entire system will take place in the next 2 weeks, including calibration.
- **Aso be a test bench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

Cryogenics-internal piping

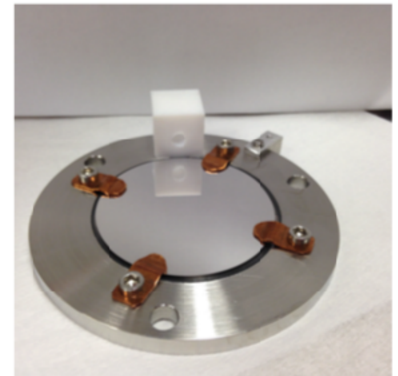


Purity monitor

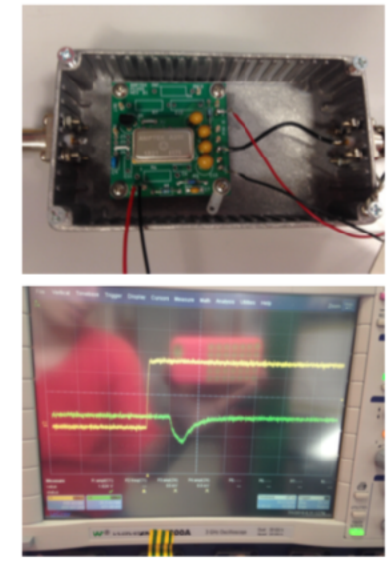
WA105



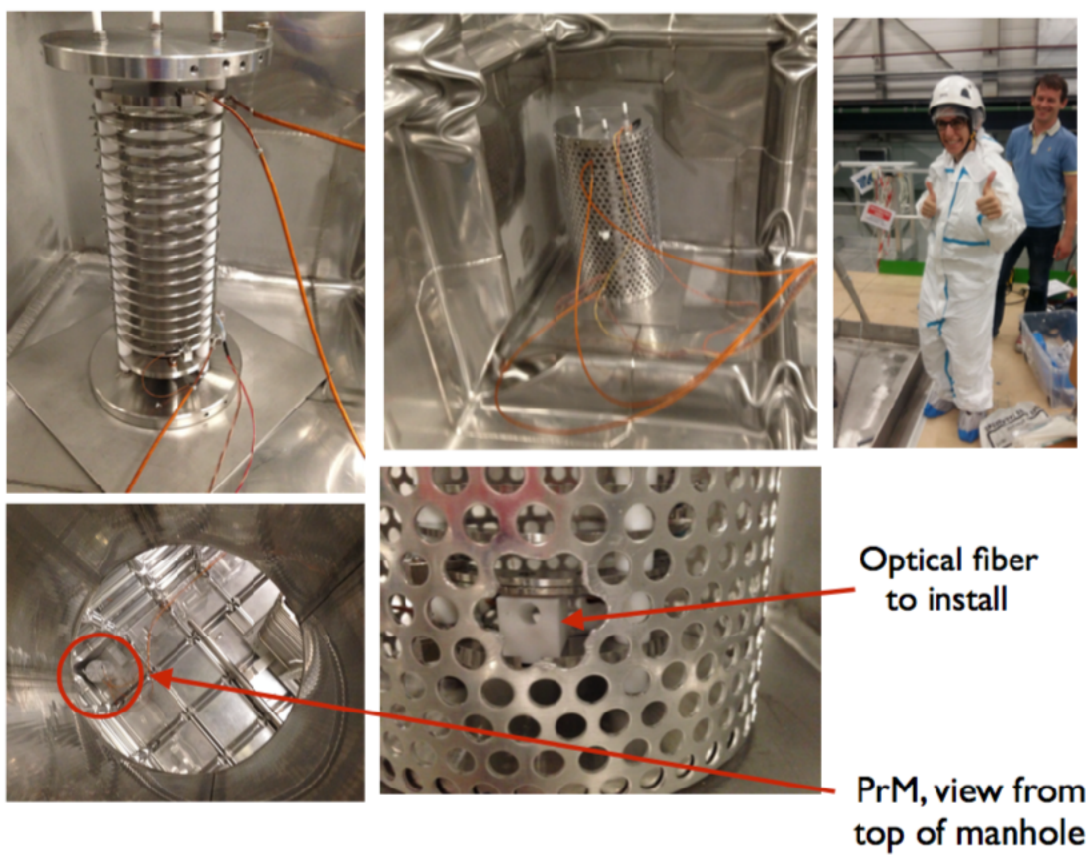
1 Purity Monitor built, tested HV at room temperature



2 Tested PHC for no peeling in LAr



3 Charge amplifier tested



4

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