Charge readout and double phase

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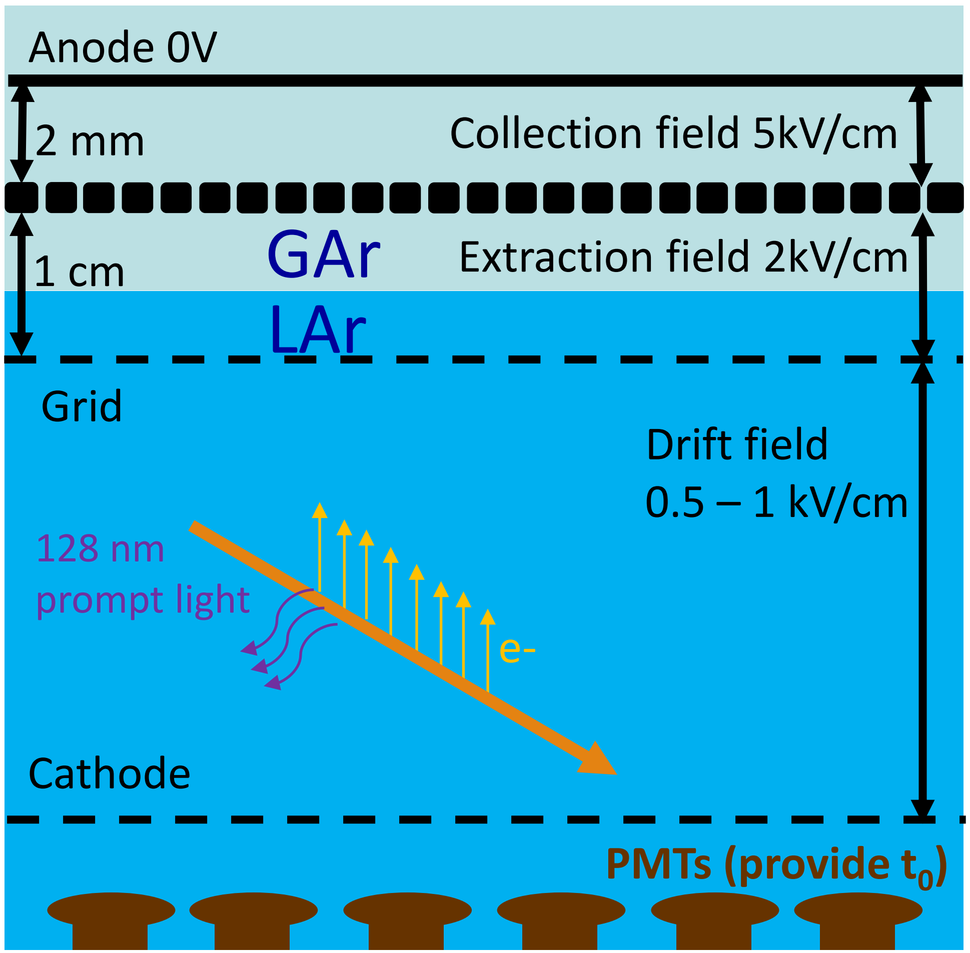
IPN Lyon

1st annual meeting AIDA-2020

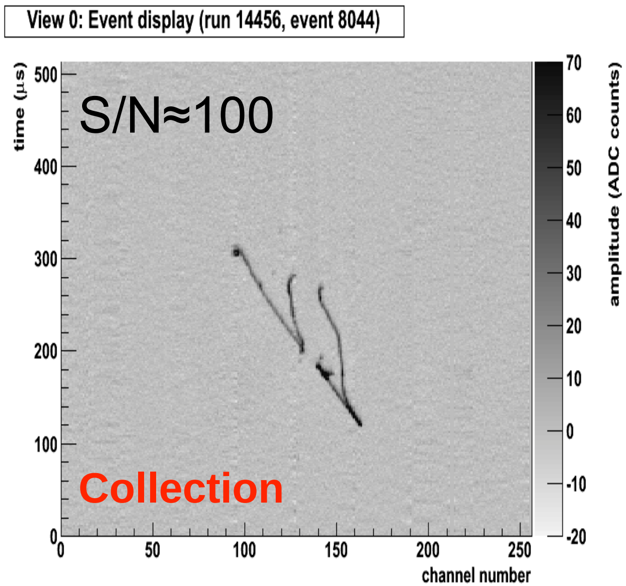
Liquid argon double-phase TPC

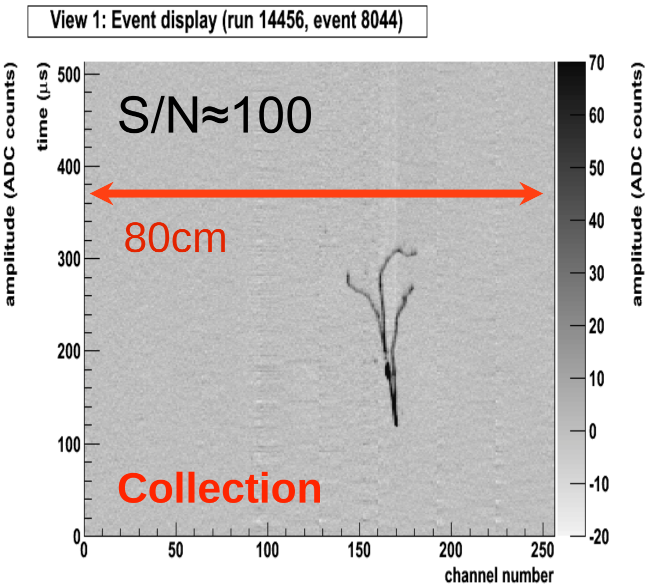
Concept of double-phase LAr TPC (Not to scale)



Large scale LAr TPC for LBL neutrino oscillation physics, astrophysics, and nucleon decay search (GUT physics)

- Double-phase for charge readout to achieve electron amplification:
  - Long drift distances
  - Low energy detection thresholds
  - Improved S/N ratio

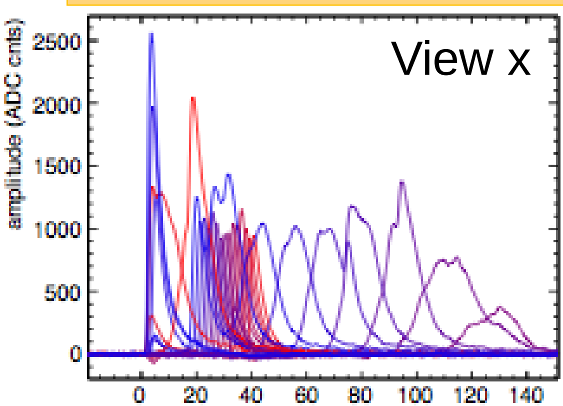


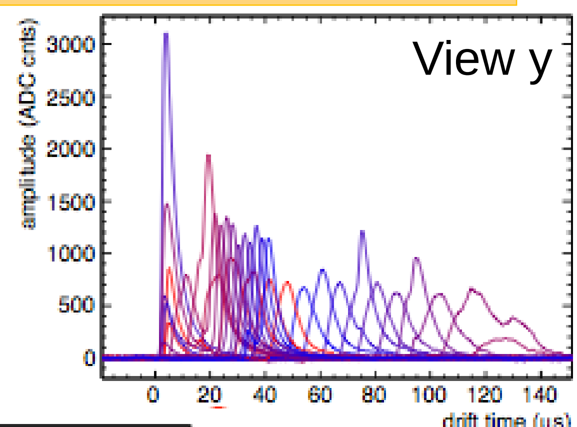


Double-phase prototypes measuring real data events since 6 years with active volumes from 3 to 250 liters

> 15 millions of cosmic events collected in stable conditions
S/N~100 for m.i.p. achieved starting from gain ~15

Raw data: no noise subtraction nor post-filtering

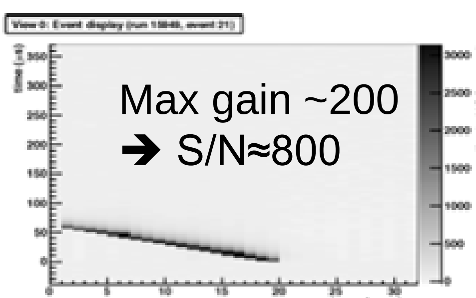


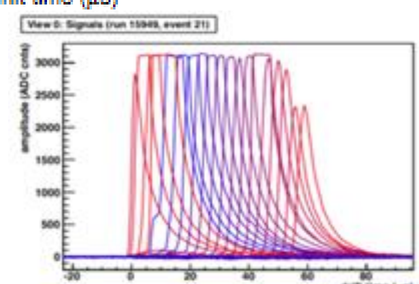


Dual-phase concept advantages:

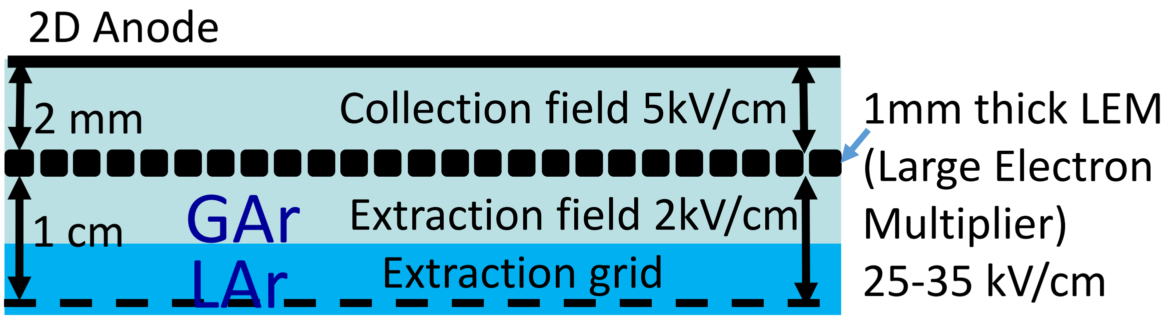
- 3mm pitch
- Robust S/N with tunable gain
- Only charge collection (no induction planes)
- Can cope with electron diffusion & charge attachment for long drift
- Insensitive to microphonic noise

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





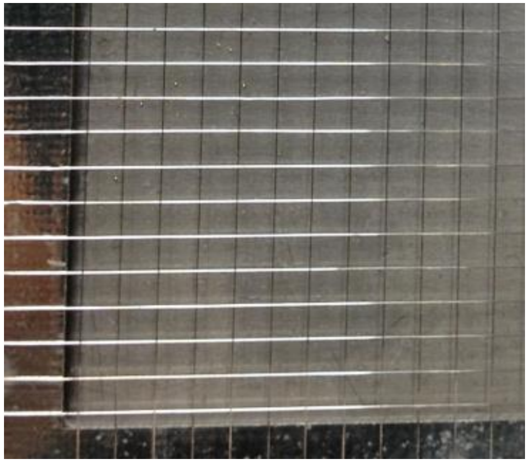
Elements of charge readout plane

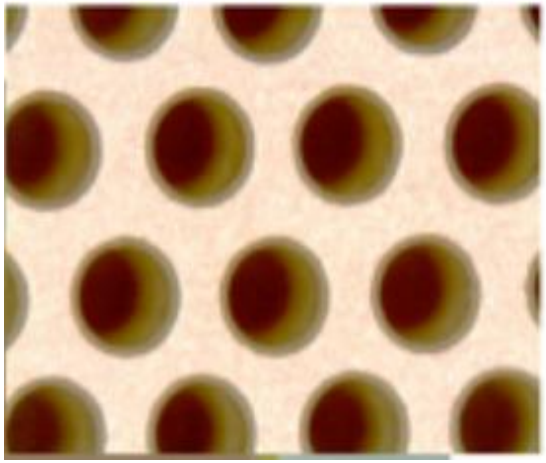


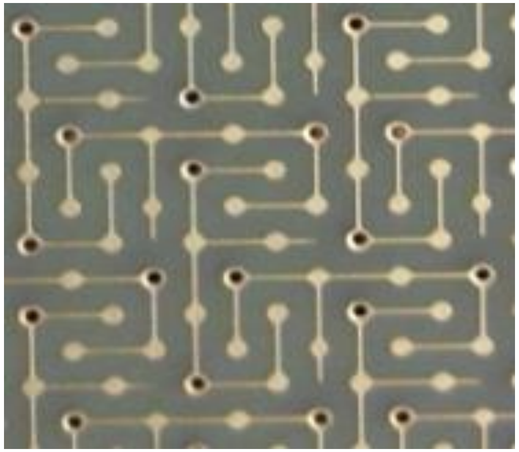
Extraction grid: 100 μm stainless still wires 3mm pitch in x and y

LEM: 500 μm holes, 800 μm pitch, 1mm thick FR4

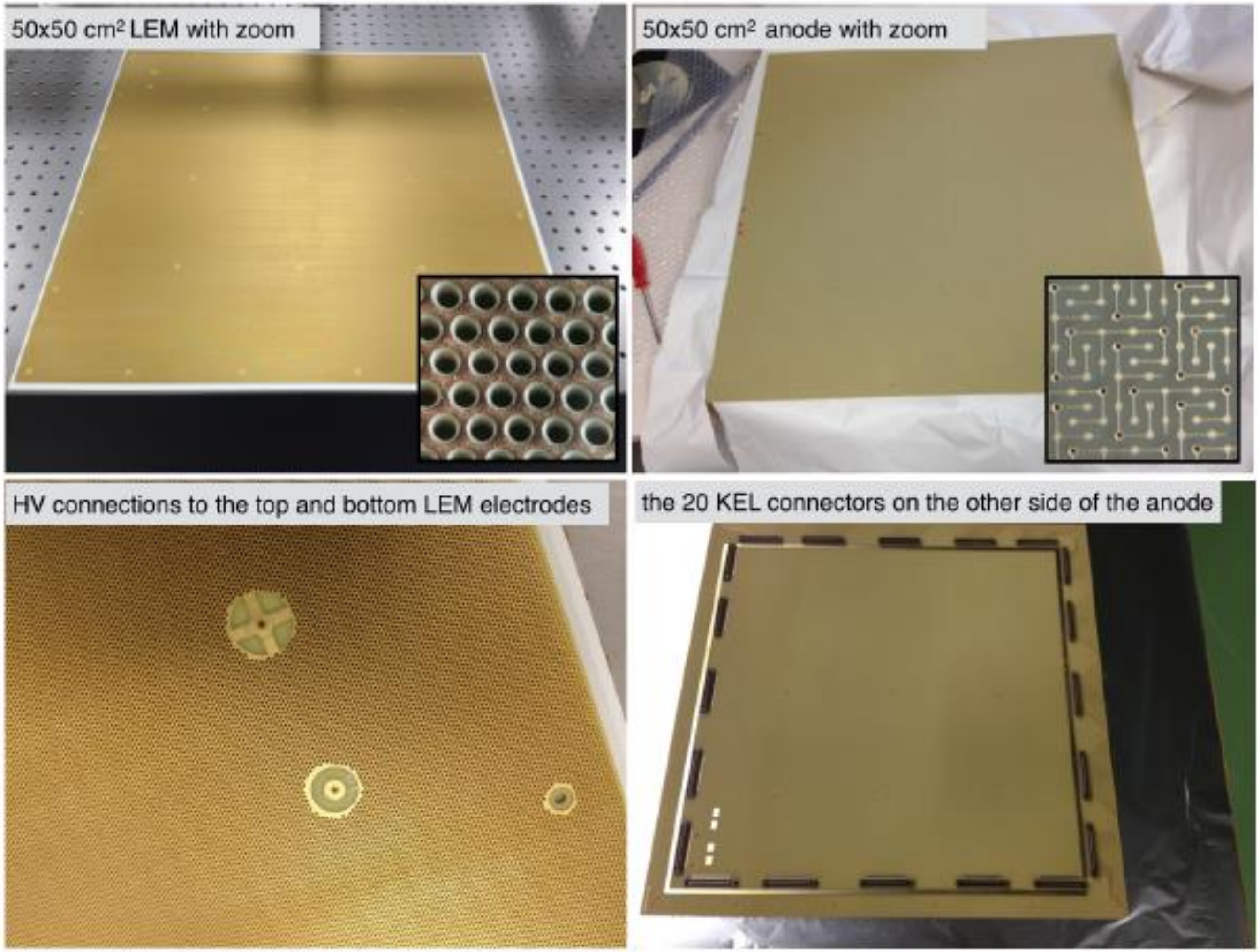
Multilayer PCB anode. 3.125 mm pitch provides 2D coordinate information (3rd coordinate comes from drift time)





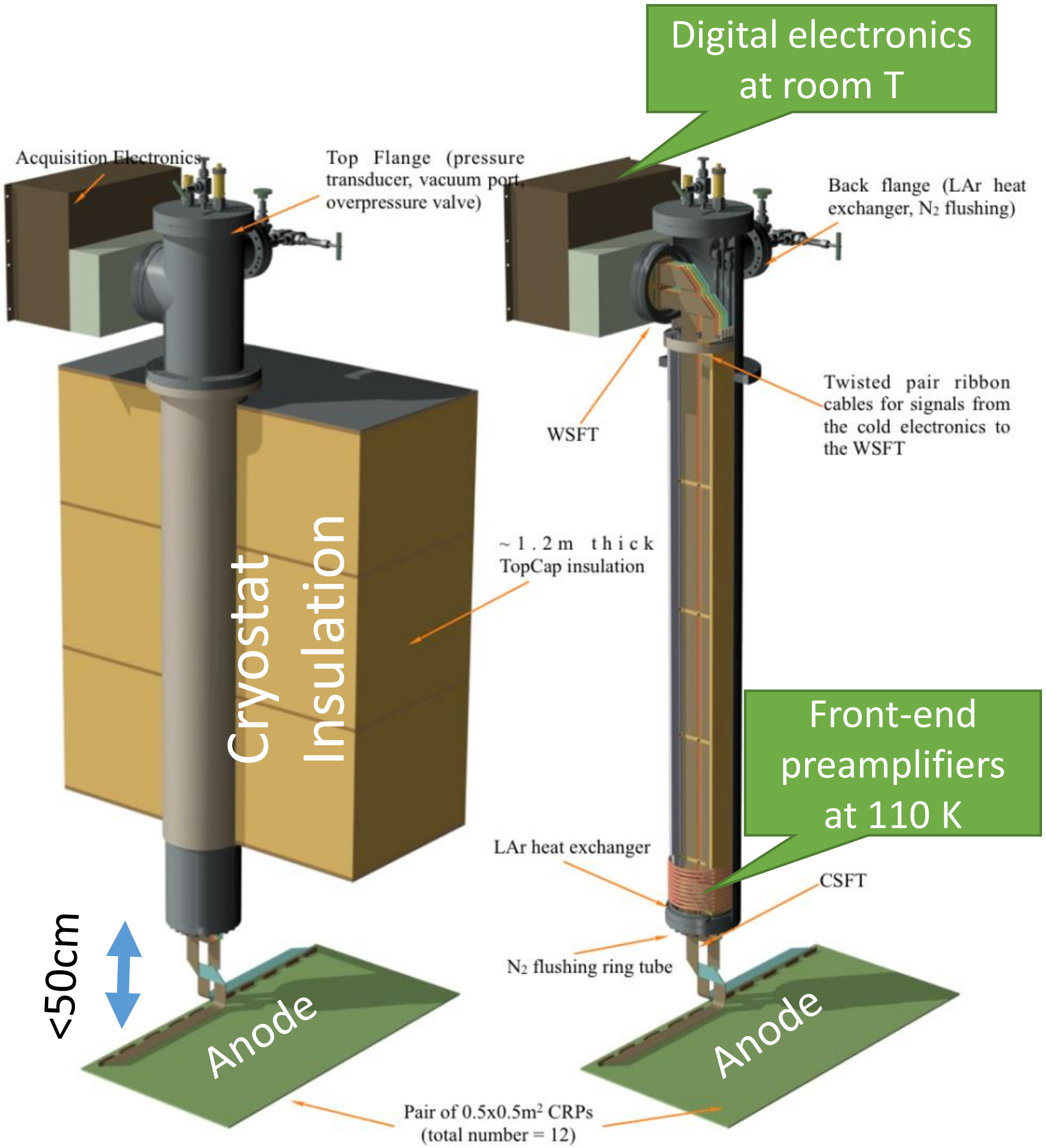


Large area LEM and Anode



The large area charge readout is built from 50x50cm^2 LEMs and anode PCBs tiles
The signal lines of the anodes are daisy-chained to form “strips” of up to 3m

Charge signal readout



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

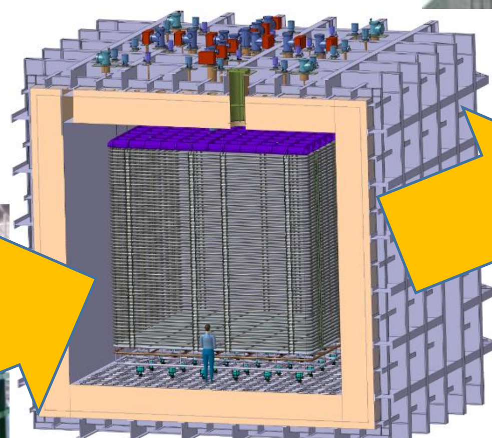
Proximity of pre-amplifiers to the readout is also an important aspect
➔ Limit noise due to cable capacitance

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

Towards large DP detectors

LArProto $3x1x1m^3$ 25ton DP LAr TPC at CERN

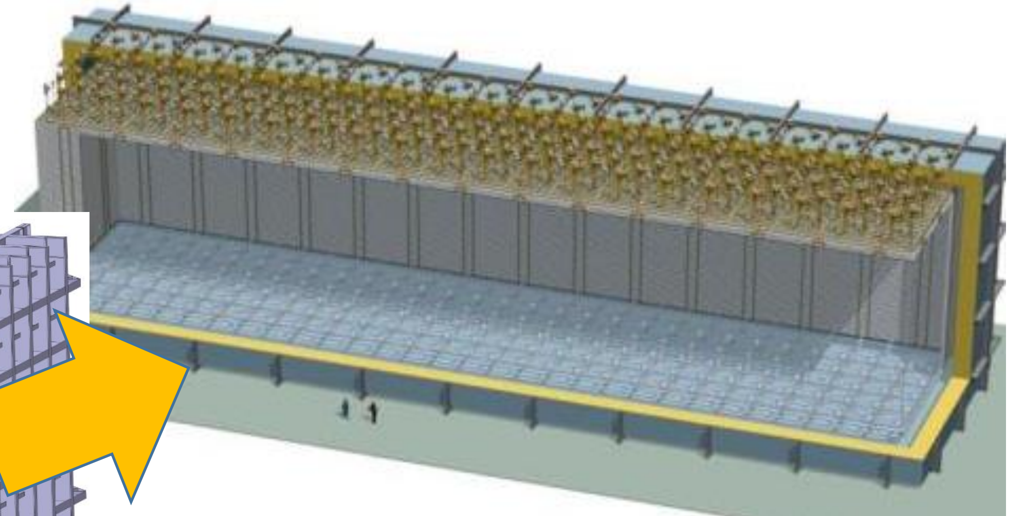
Cryo installation, feedthroughs, tank, detector integration



WA105/ProtoDUNE DP

$6x6x6m^3$ 300ton DP LAr TPC at CERN

Large surface charge readout, long drift, high voltage for drift field, physics / performance with test beam …



DUNE DP $60x12x12m^3$

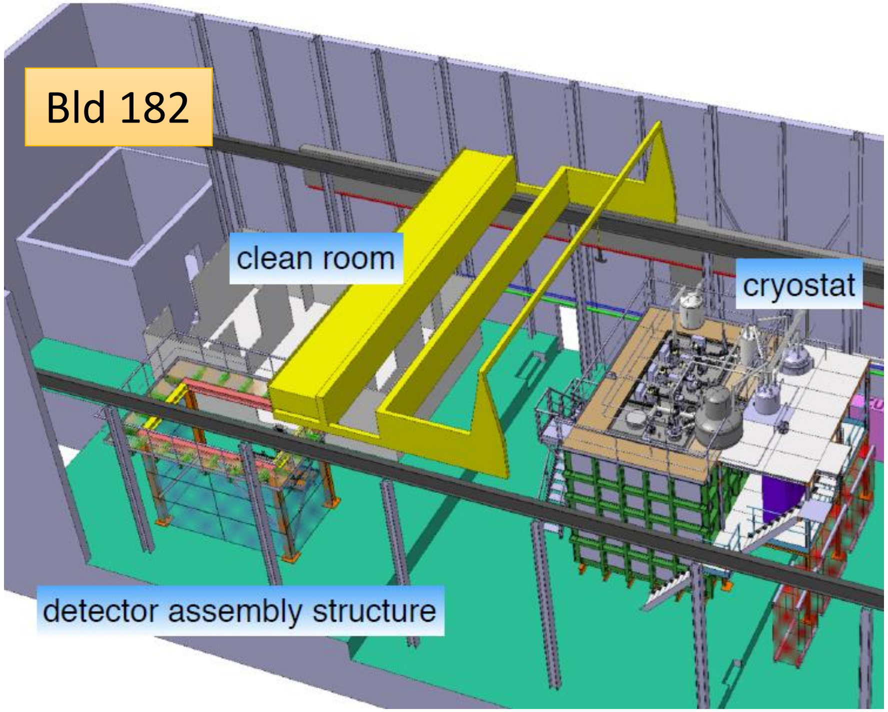
10kton DP LAr TPC underground at Sanford, SD

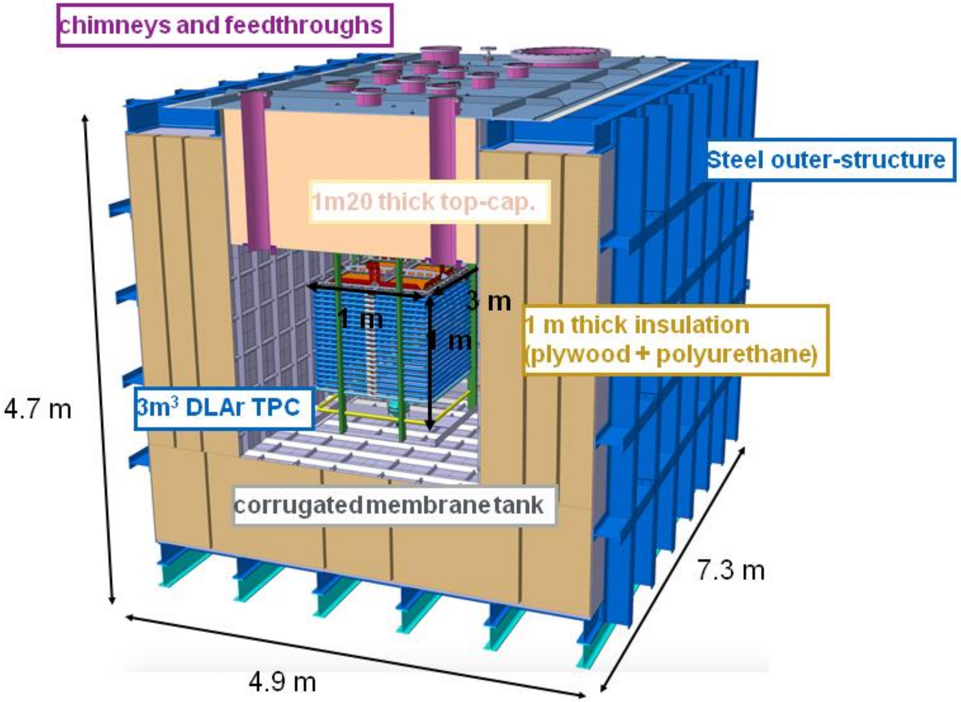
LBL neutrino physics (CP violation, MH hierarchy), supernova, nucleon decay, neutrino astrophysics

3x1x1 m^3 LArProto

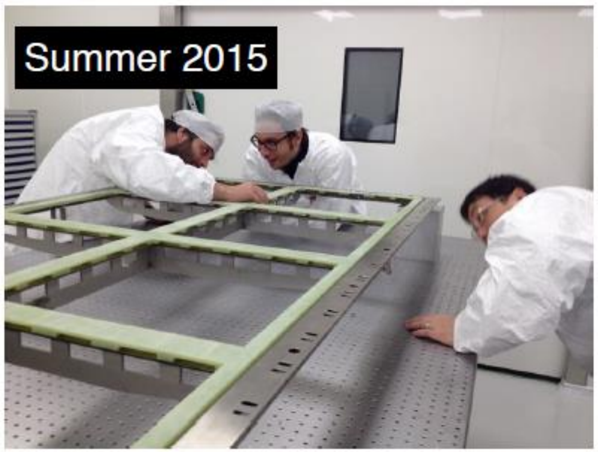
- 25 ton dual-phase LAr TPC pilot prototype at CERN Bld 182
- Charge readout area = 3x1 m^2, Drift = 1 m
- Significant progress on the pilot in the last year to construct the detector

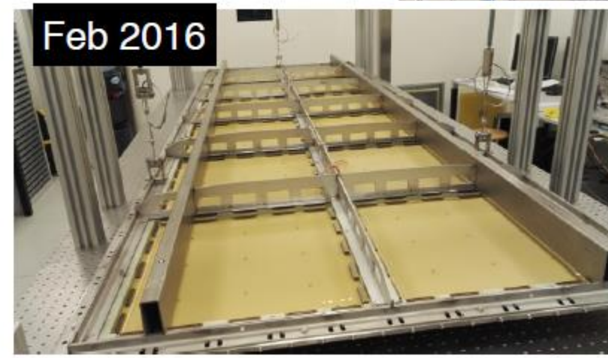
Starts taking cosmics in Fall 2016





3x1x1 m^3 LArProto





Feedthrough installations in top cap

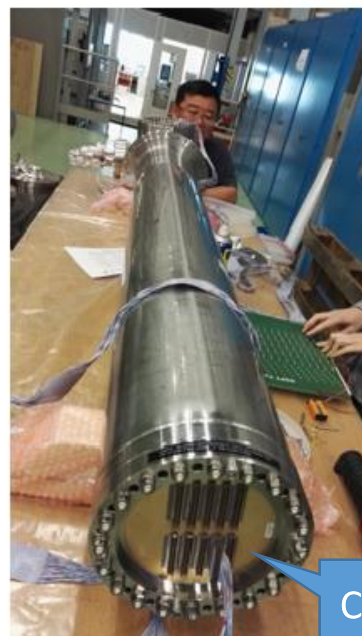
Chimneys for accessible cold FE

coated PMTs

slow control flanges

CRP suspensions

Chimney wiring

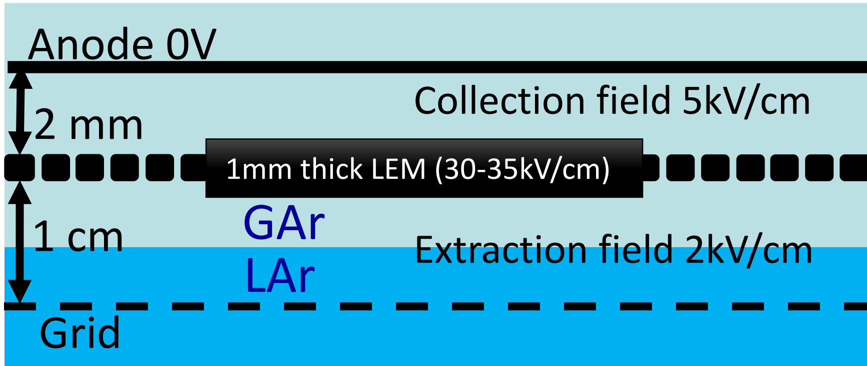


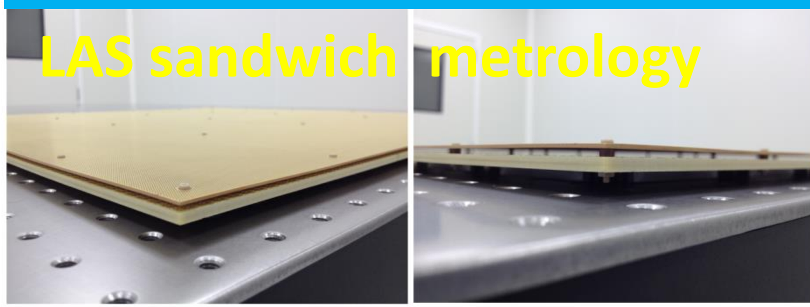
Mounting point for warm feedthrough

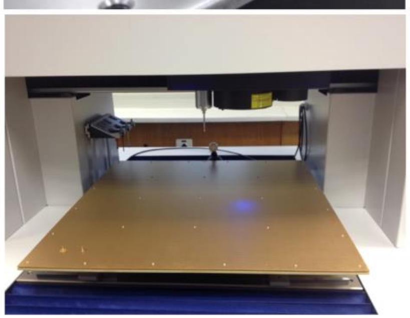
Cold feedthrough

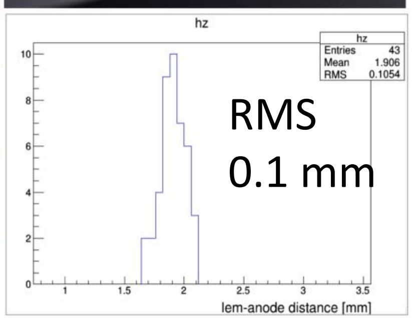
LEM-anode sandwich

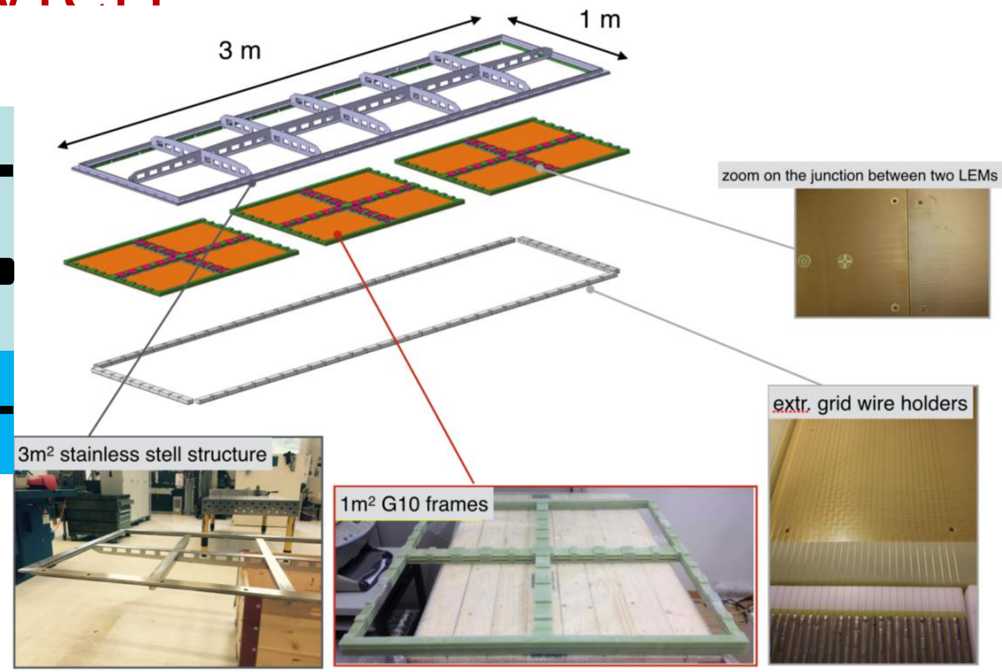
50x50 cm^2 LEM / anodes mounted on a frame



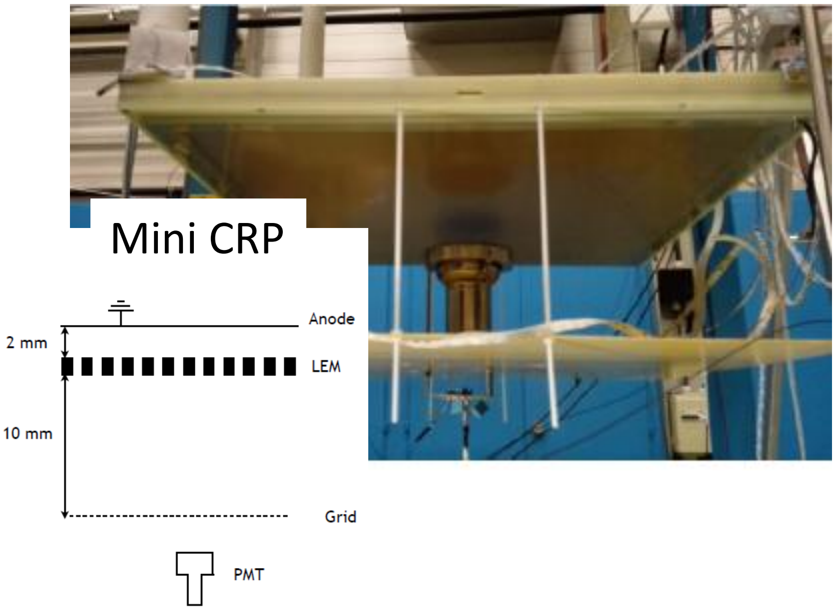


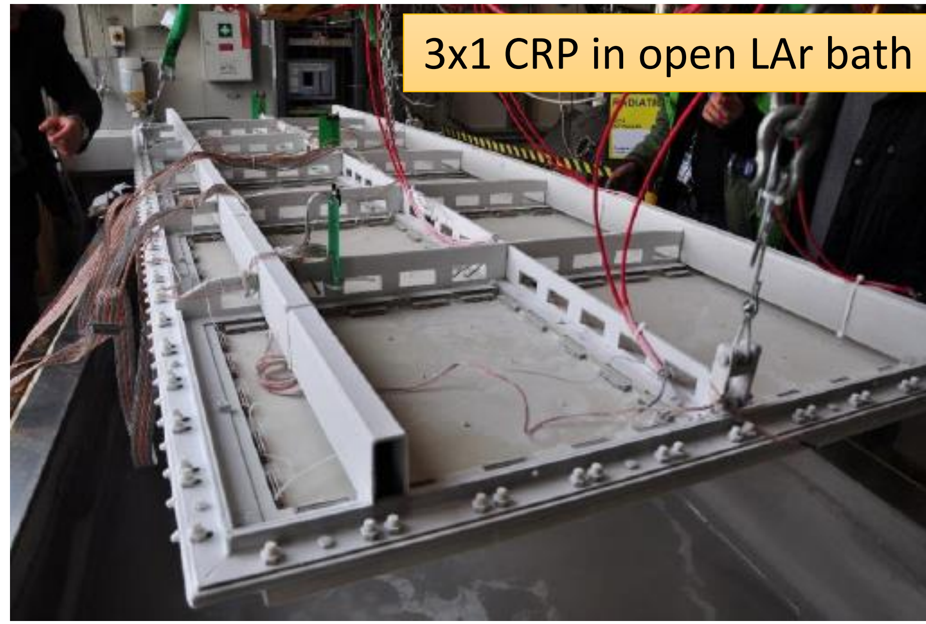






LArProto CRP cryogenic tests





- 50x50 cm^2 LEMs have been successfully tested in pure gas argon at 87K
- The fully assembled CRP mechanical structure has been tested in open LAr bath

Dual phase protoDUNE - WA105 6x6x6m^3

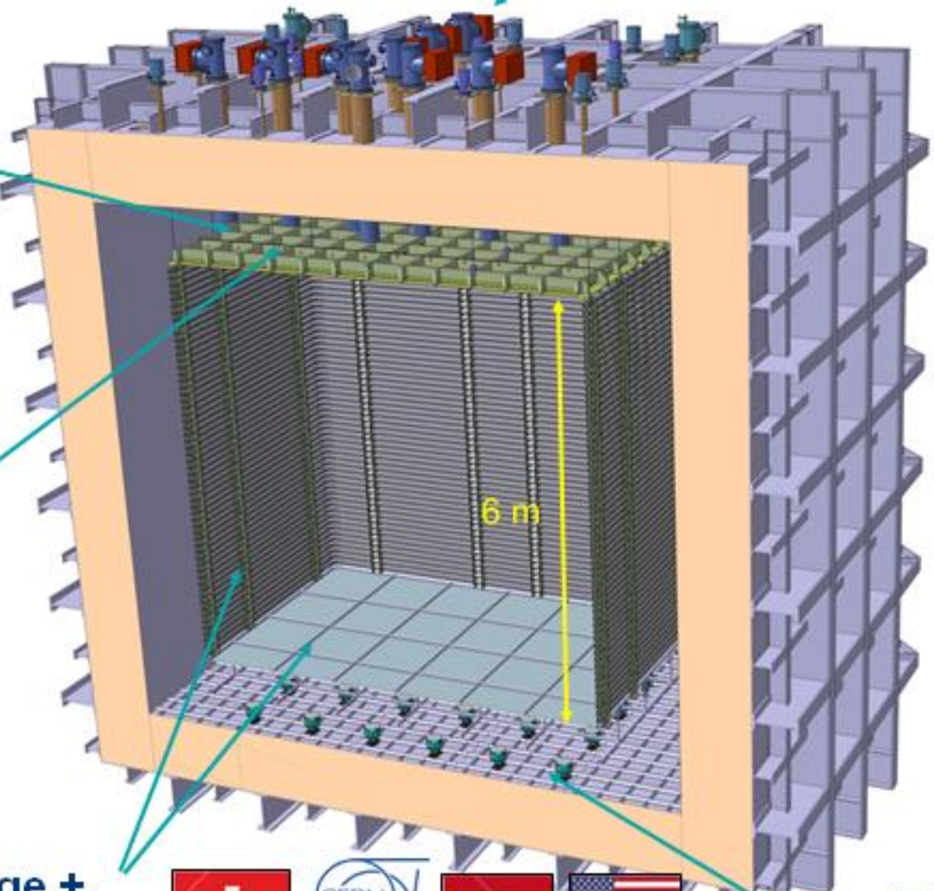
(US contributions under discussion)

Drift HV system

Signal feed-throughs

CRP frame + hanging system

CRP readout planes



Drift cage + cathode plane

Photon Electronics

Cold readout electronics

DAQ

Online computing

Purity monitor

Slow control

Cosmic tracker

Photon Detectors

WA105 dual-phase LAr TPC

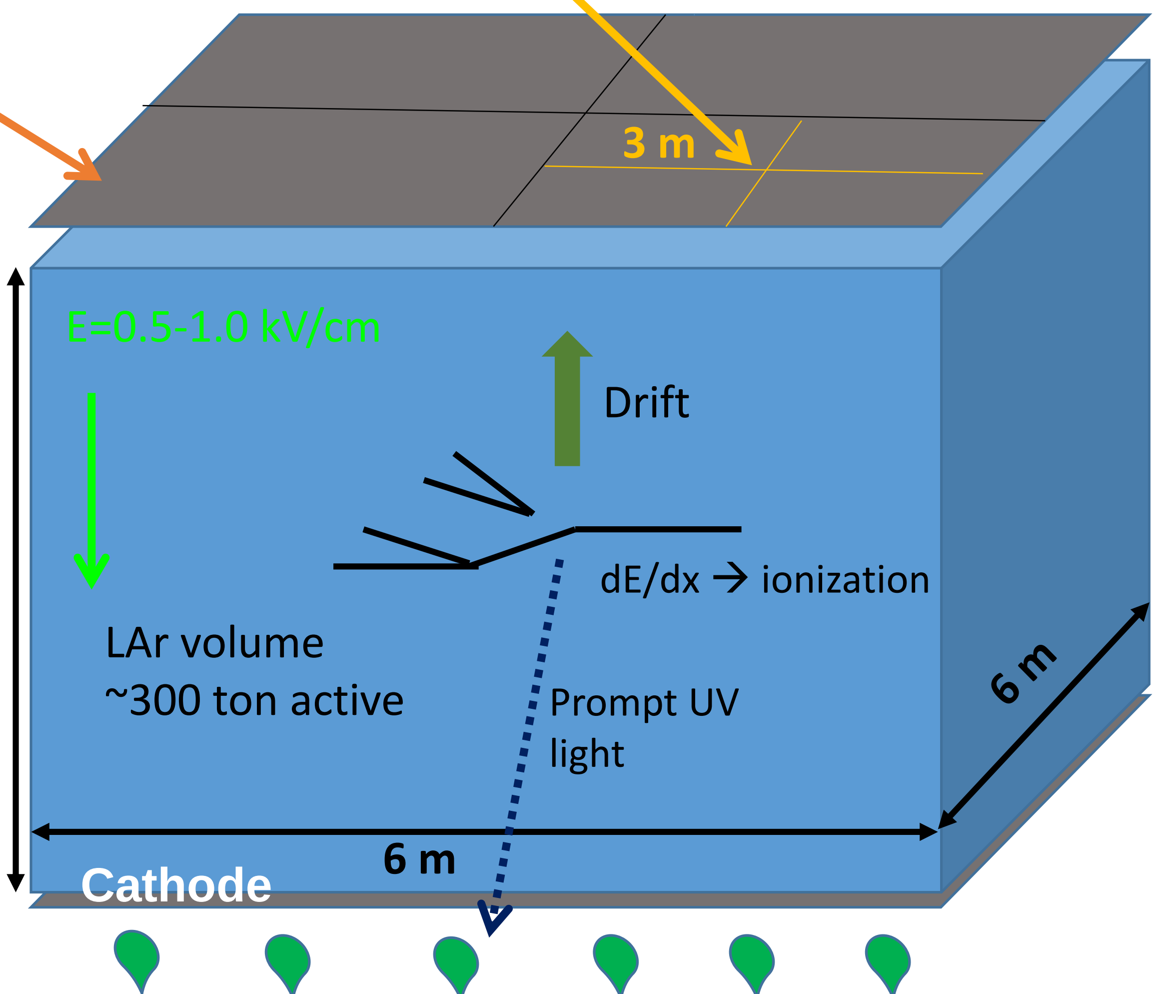
Readout in gas phase: charge is amplified and collected on a 2D anode

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

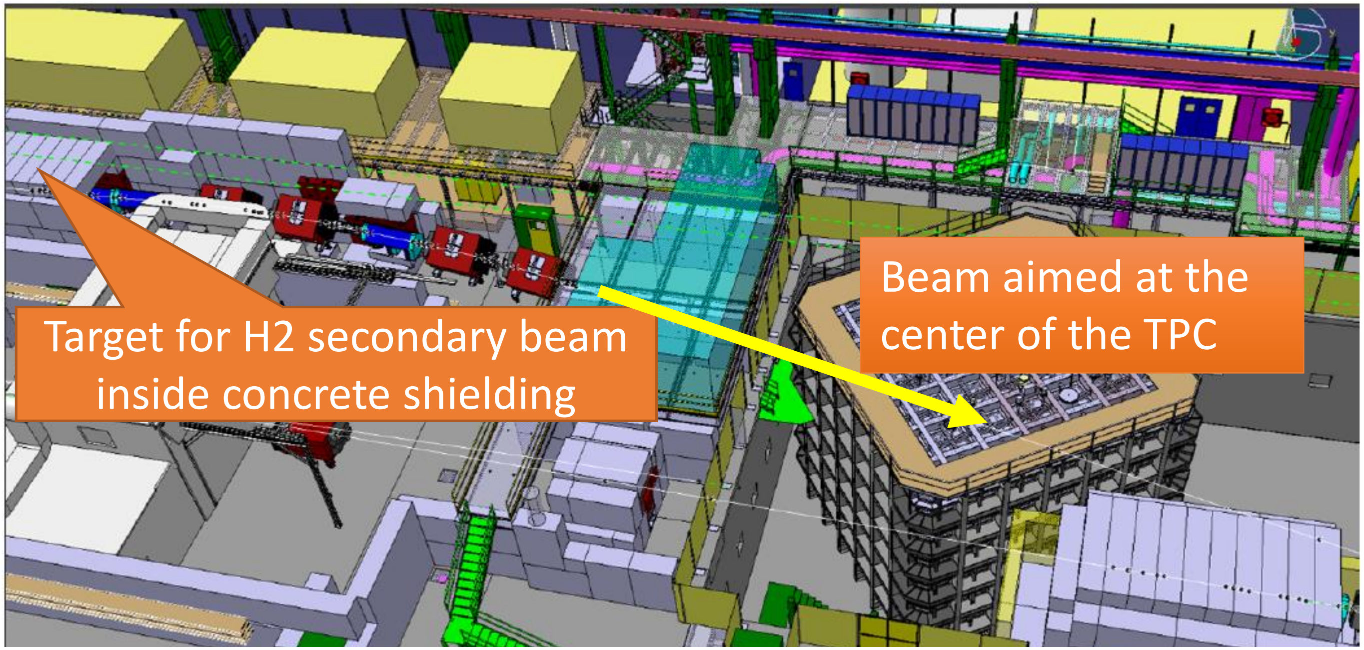
Drift coordinate 6 m = 4 ms sampling 2.5 MHz (400 ns), 12 bits
→ 10000 samples per drift window

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
For multi-kton detector, simply increase the number of CRPs



WA105 DLAr using test beam in EHN1

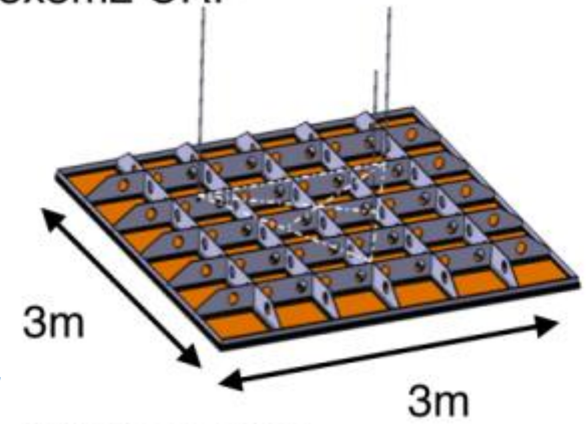


- Characterize the detector performance with well defined charged particle beams in CERN EHN1 test beam:
  - Beamline will provide particle ID system for π/p/K over beam all momenta of interest (1.0 – 12 GeV/c)
- Study PID performance
- Evaluate e/π_0 rejection capabilities
- Calibrate energy scale and evaluate resolution for electronic and hadronic showers
- Validate reconstruction tools
- Measure hadron shower development with exceptional granularity 3x3 mm^2

Modular CRP

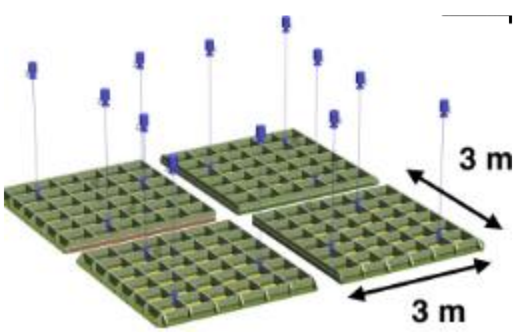
- CRP is composed of 4 3x3 m^2 readout units built from 50x50 cm^2 LEM and anodes
- Each unit has its own suspension system
- Charge is collected on 3m "strips"
- Identical structure is envisioned for DUNE 10kt

3x3m2 CRP



1920 channels/CRP
Accessible cold electronics in chimney

WA105: 4 CRPs

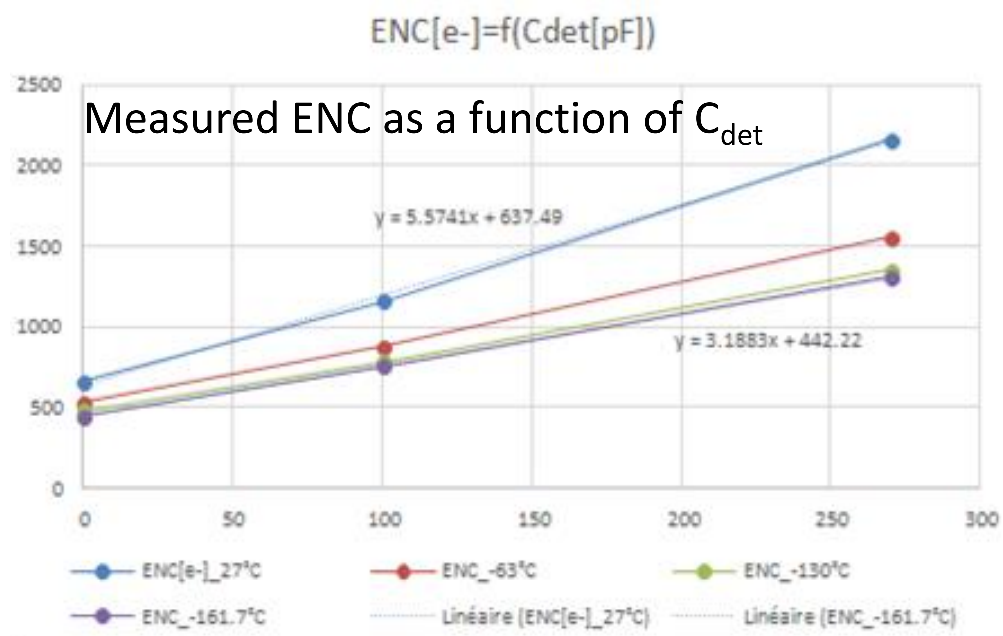


DUNE 10kt: 80 CRPs

DEEP UNDERGROUND NEUTRINO EXPERIMENT

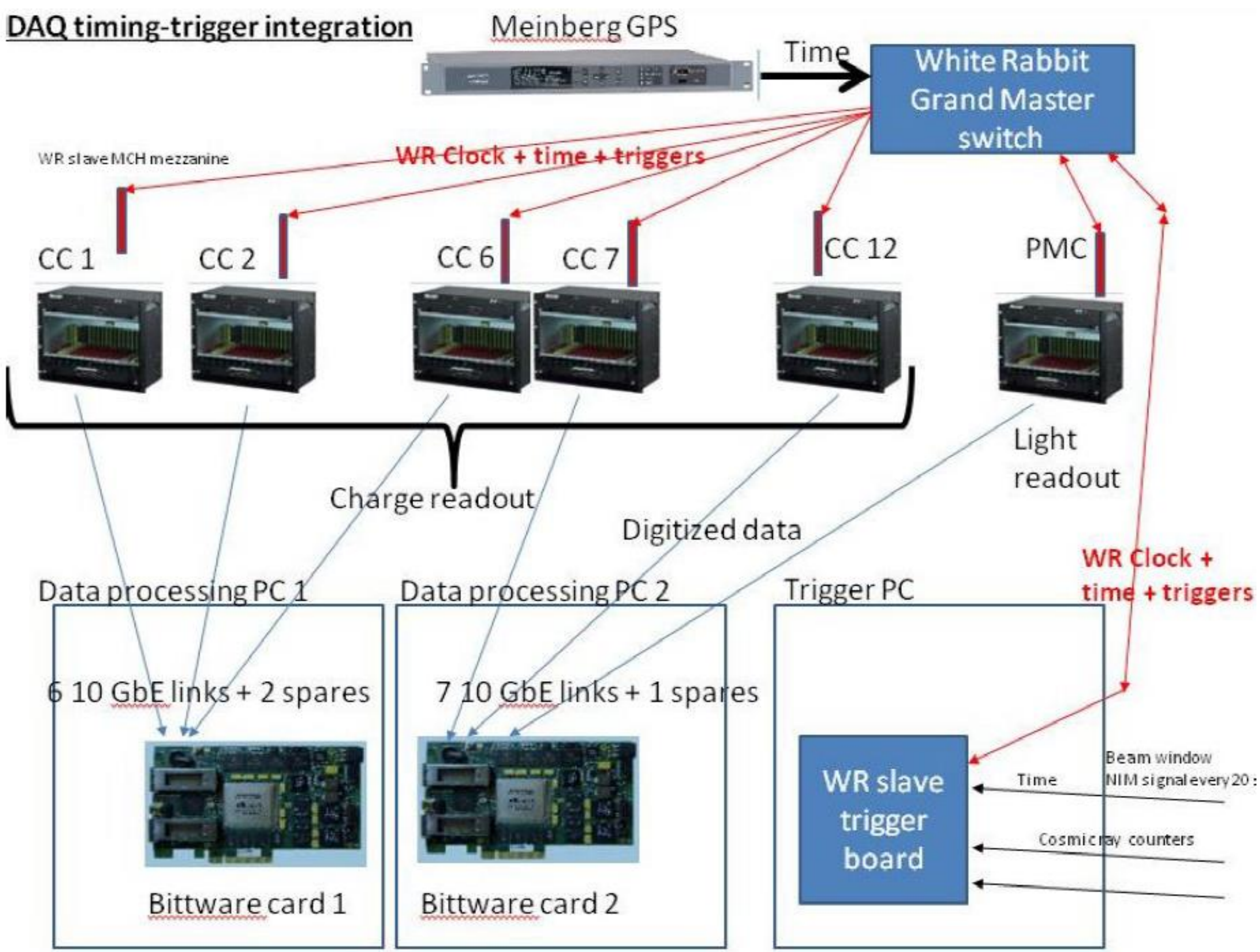
Cold front-end electronics

- Accessible via chimneys (without opening of the TPC cryostat)
- Shielded from digital electronics
- Preamplifier ASIC:
  - 16 channels
  - Double slope gain with “kink” at 400 fC
  - 1200 fC dynamic range



Anode capacitance is 150 pF/m ➔ 450 pF for a 3x3m^2 module: expected noise = 1600 ENC
For LEM equivalent gain of 20 (10 per each view)
S/N ~ 100 for 1MIP signal

Digital electronics for charge readout



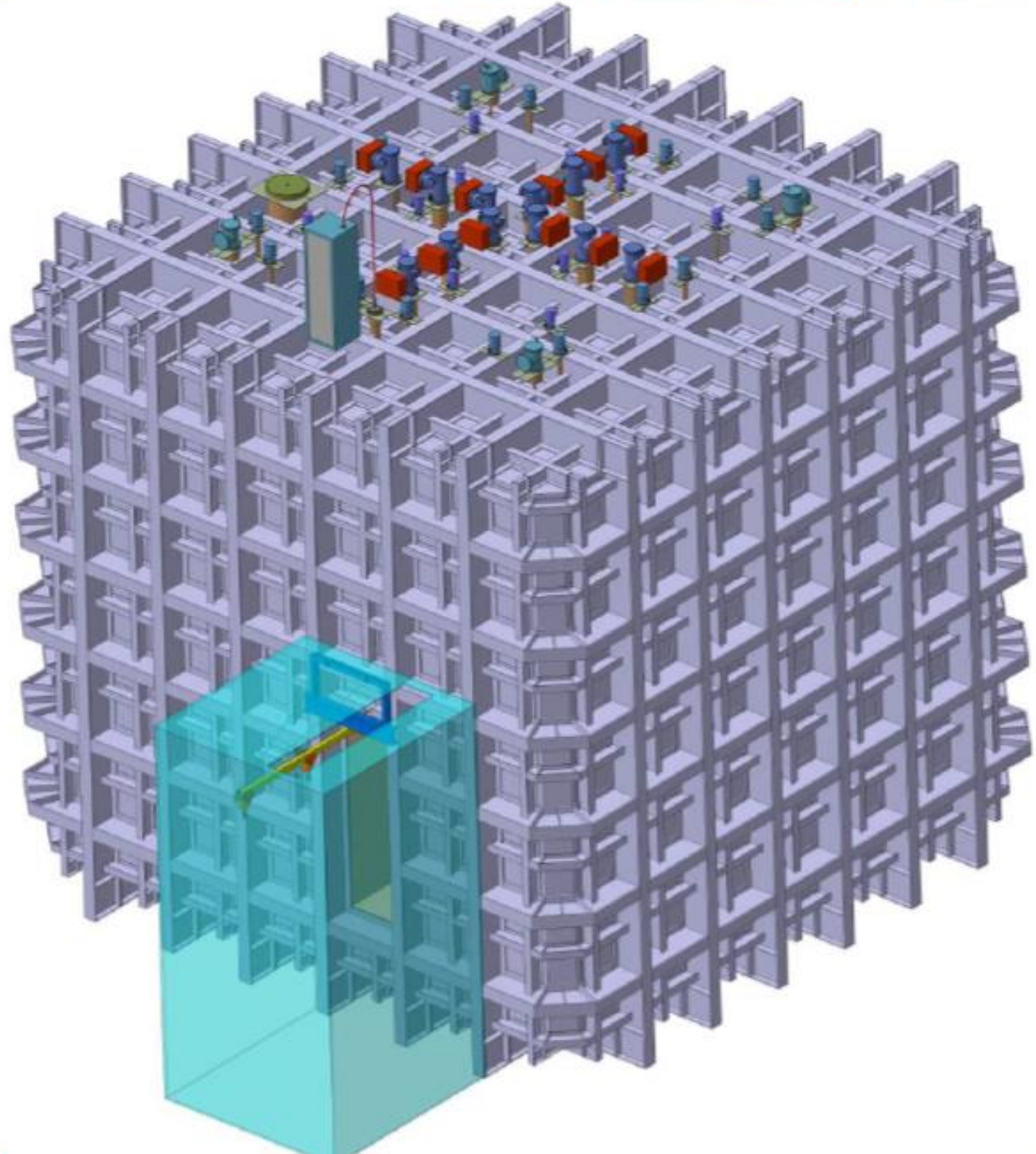
Digital electronics for charge readout

- microTCA standard
- 10 cards per crate
- 64 ch per card
- 12bit resolution
- 2.5 MHz rate

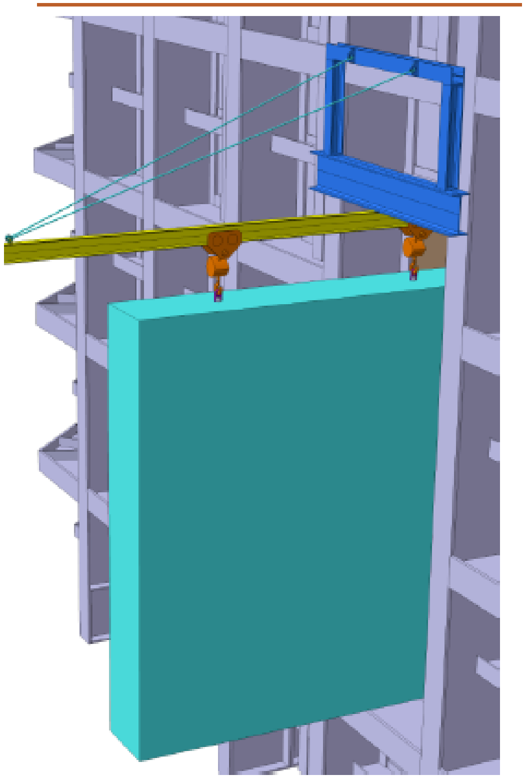
Installation of charge readout planes and TPC structure

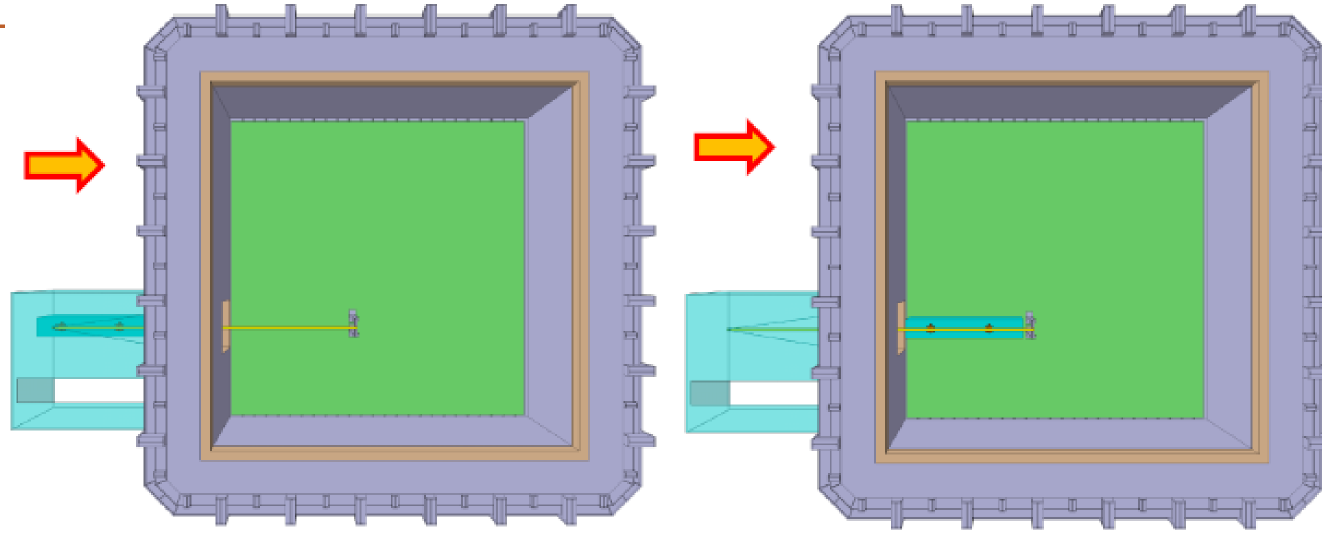
5) Temporary Clean Room for Detector installation

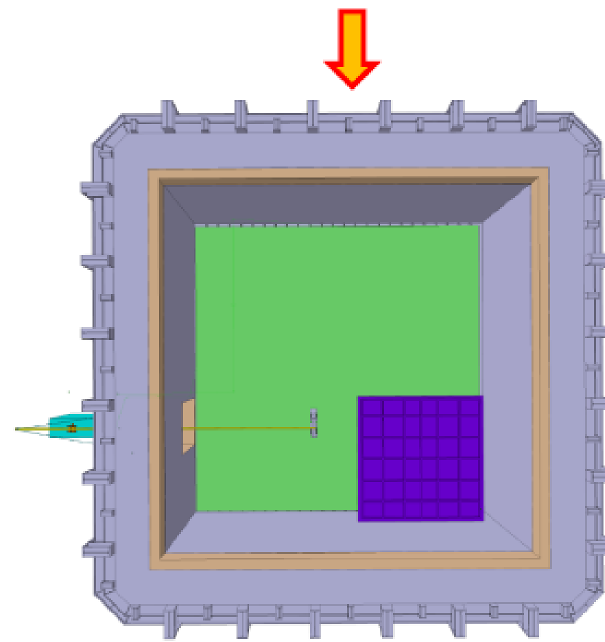
- Opening at the Top for lowering the CRP Boxes inside (3,1x3,1x0.5 m)
- Clean air from Manhole keeping the cryostat in overpressure
  → prevent dirty air to go inside the Cryostat
- Size of the Clean Room need to be defined.
  → New Field Cage design



6) CRP 3X3 m²







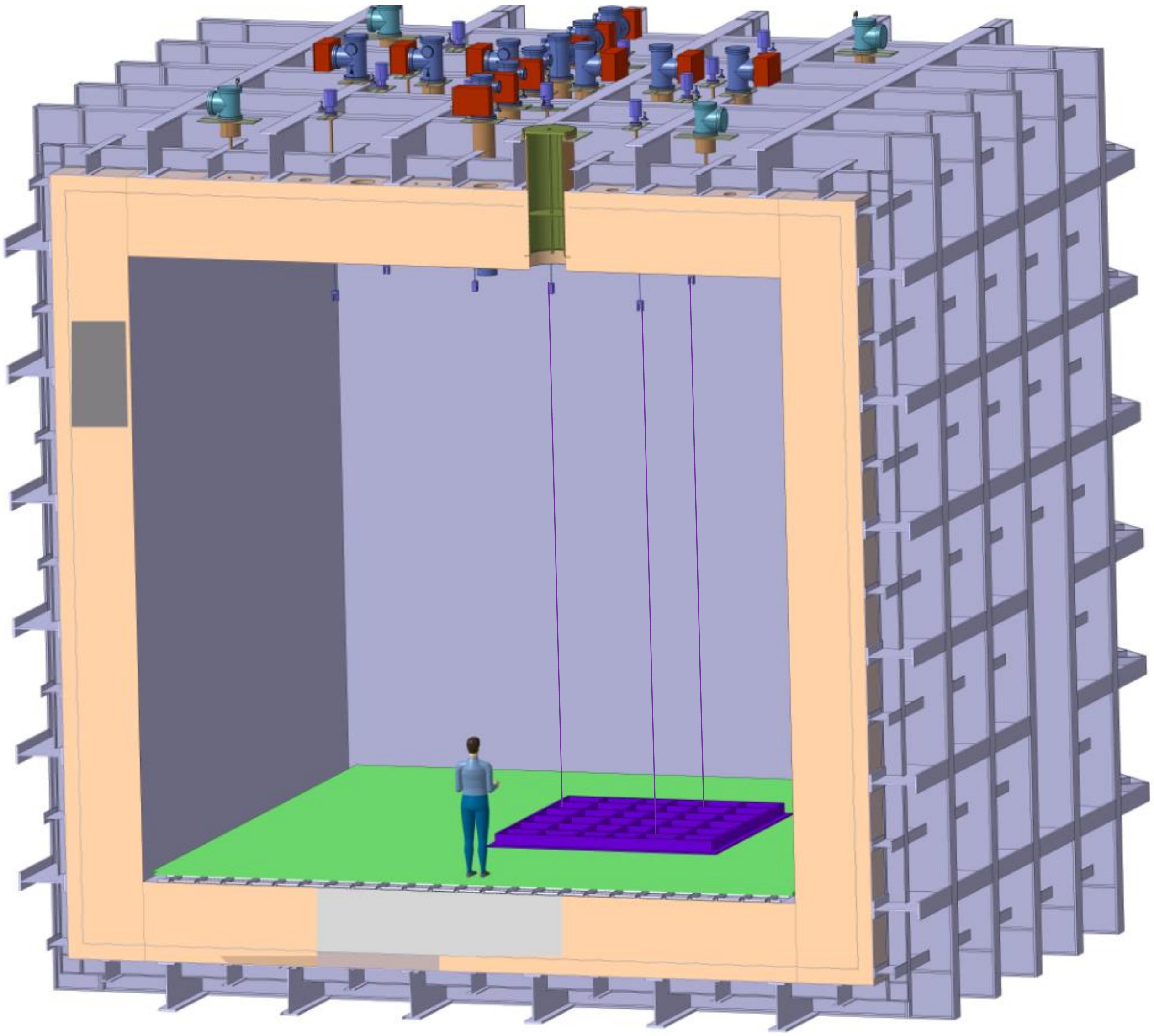
CRP INSTALLATION

1. CRP Box inside hung on the rail
2. Lowered, rotated and unpacked inside the cryostat
3. Placed in Position ready to be lifted
4. CRP Lifted in order to have all the space free on the floor

CRP 3X3 m²

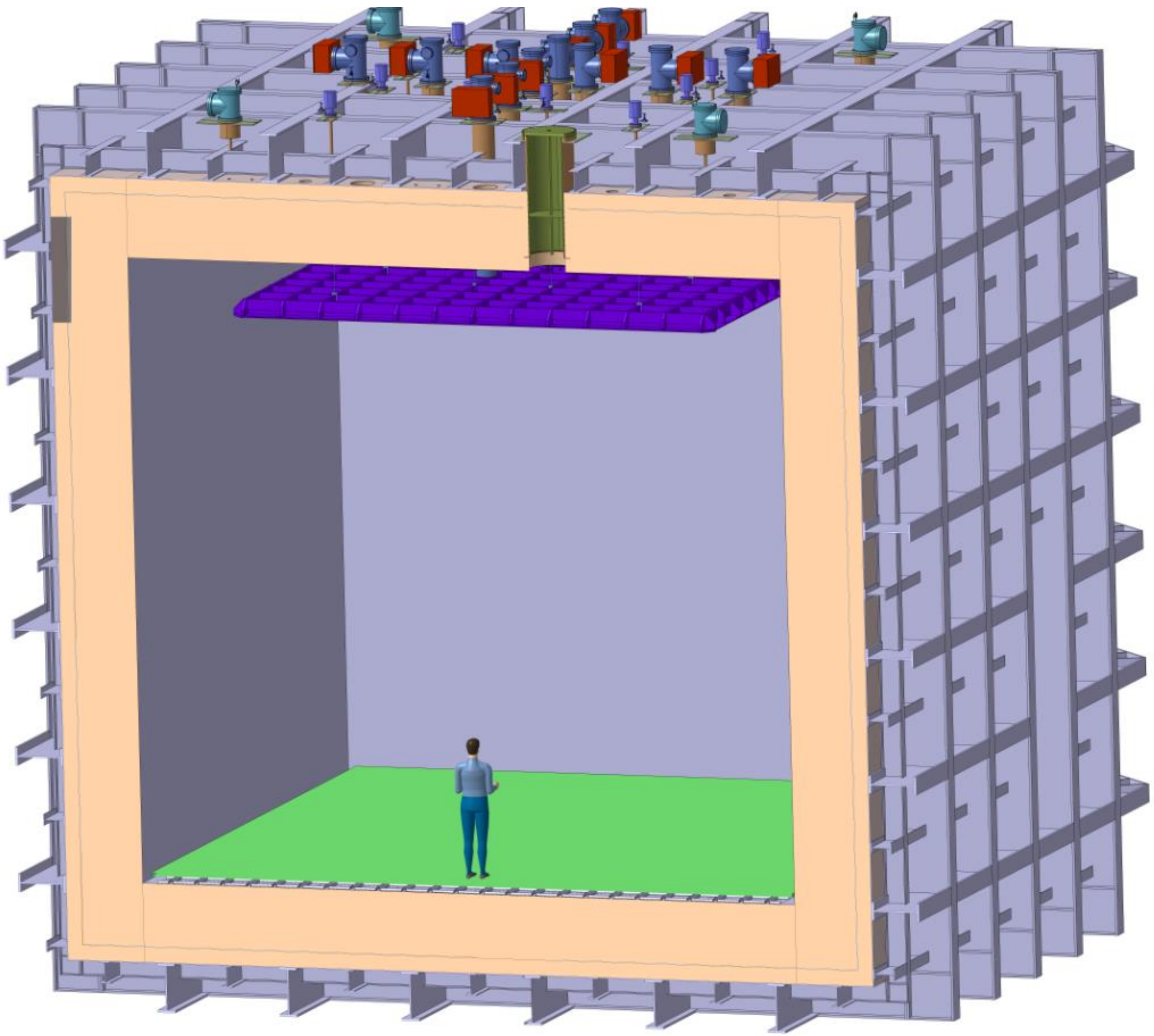
A sequence of frames showing a cut view inside the cryostat will illustrate the assembly procedure

- First CRP assembled and in position



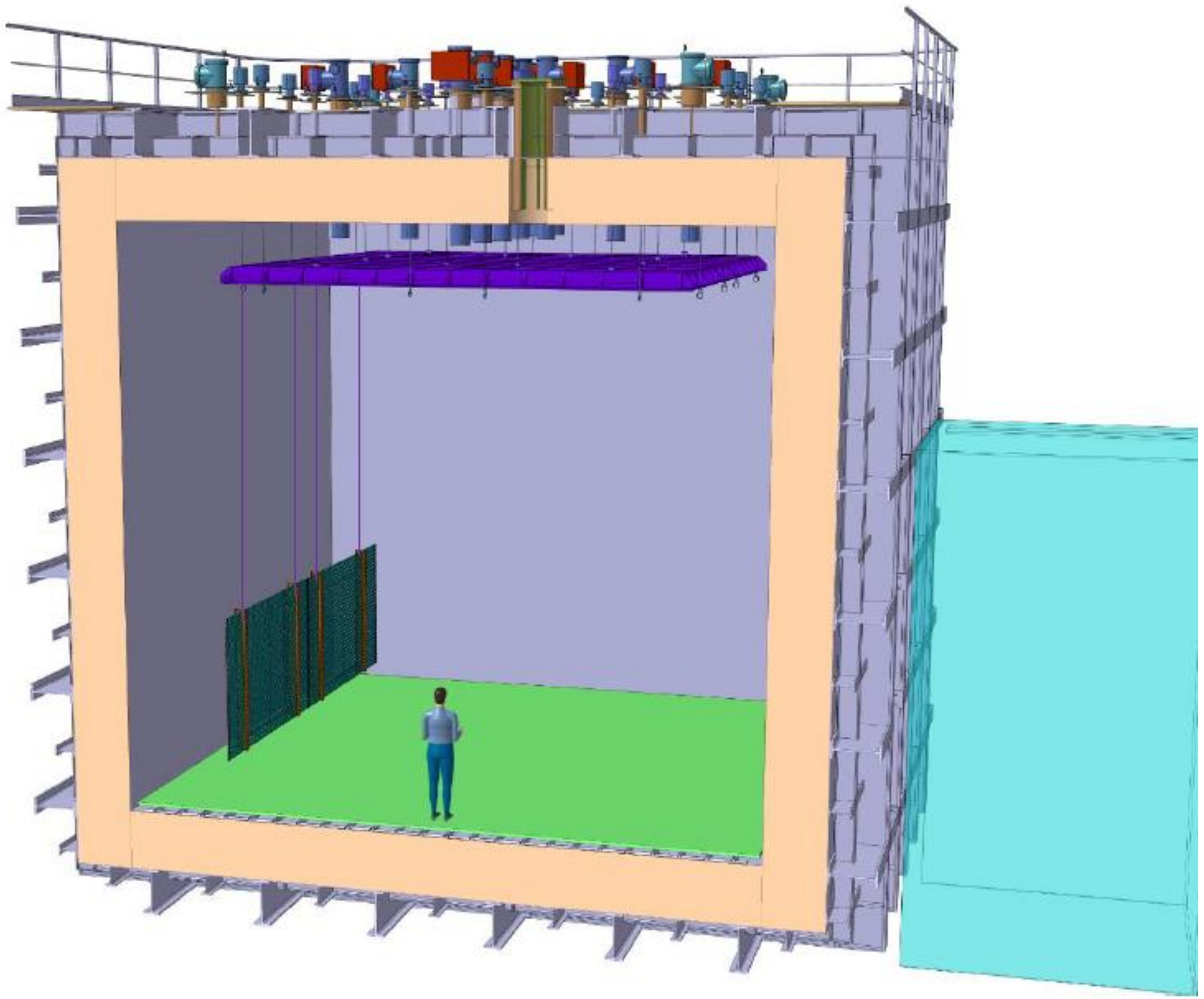
CRP 3X3 m²

- All CRPs fixed on nominal Position



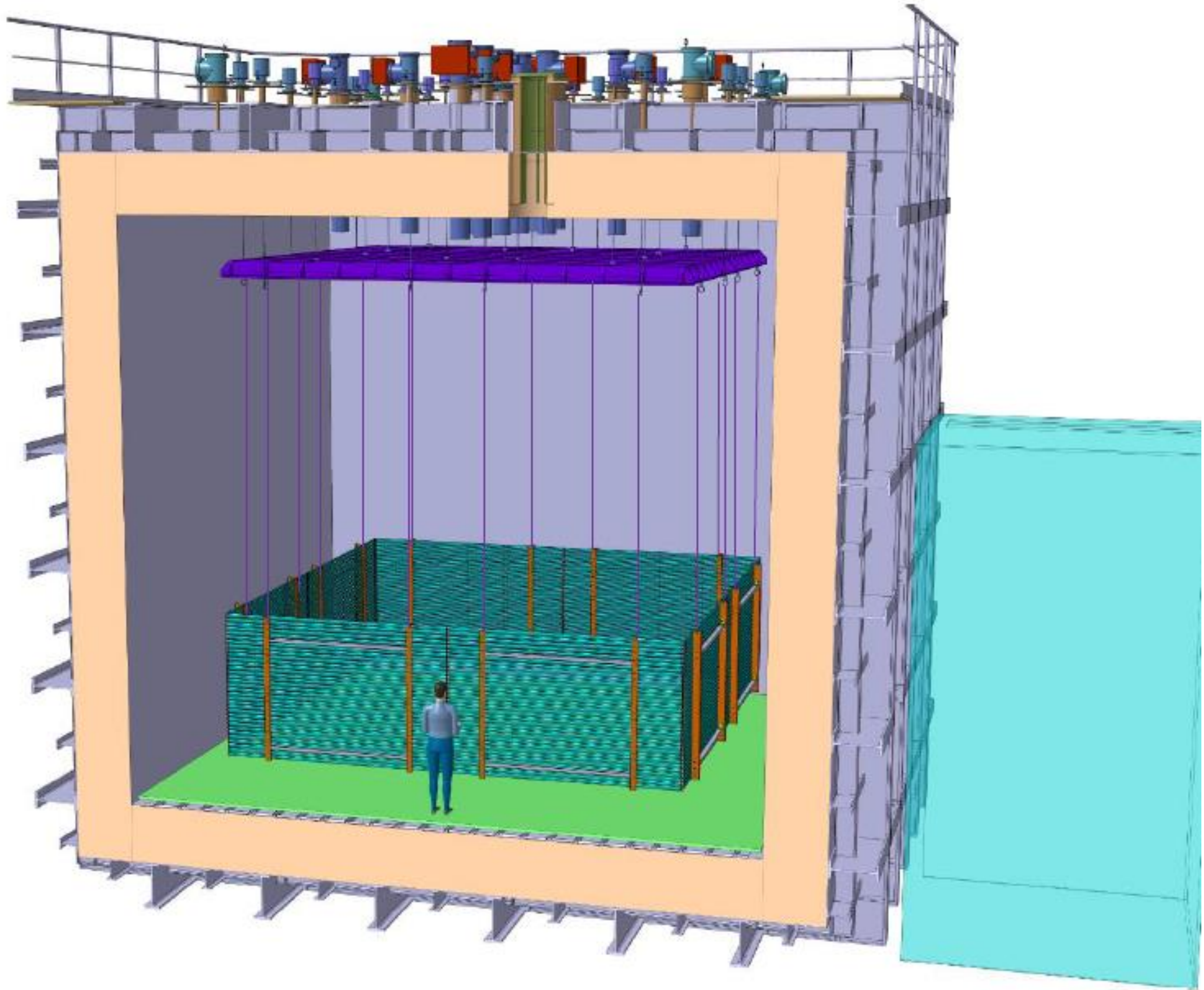
7) Field Cage

- First Field Cage Modules



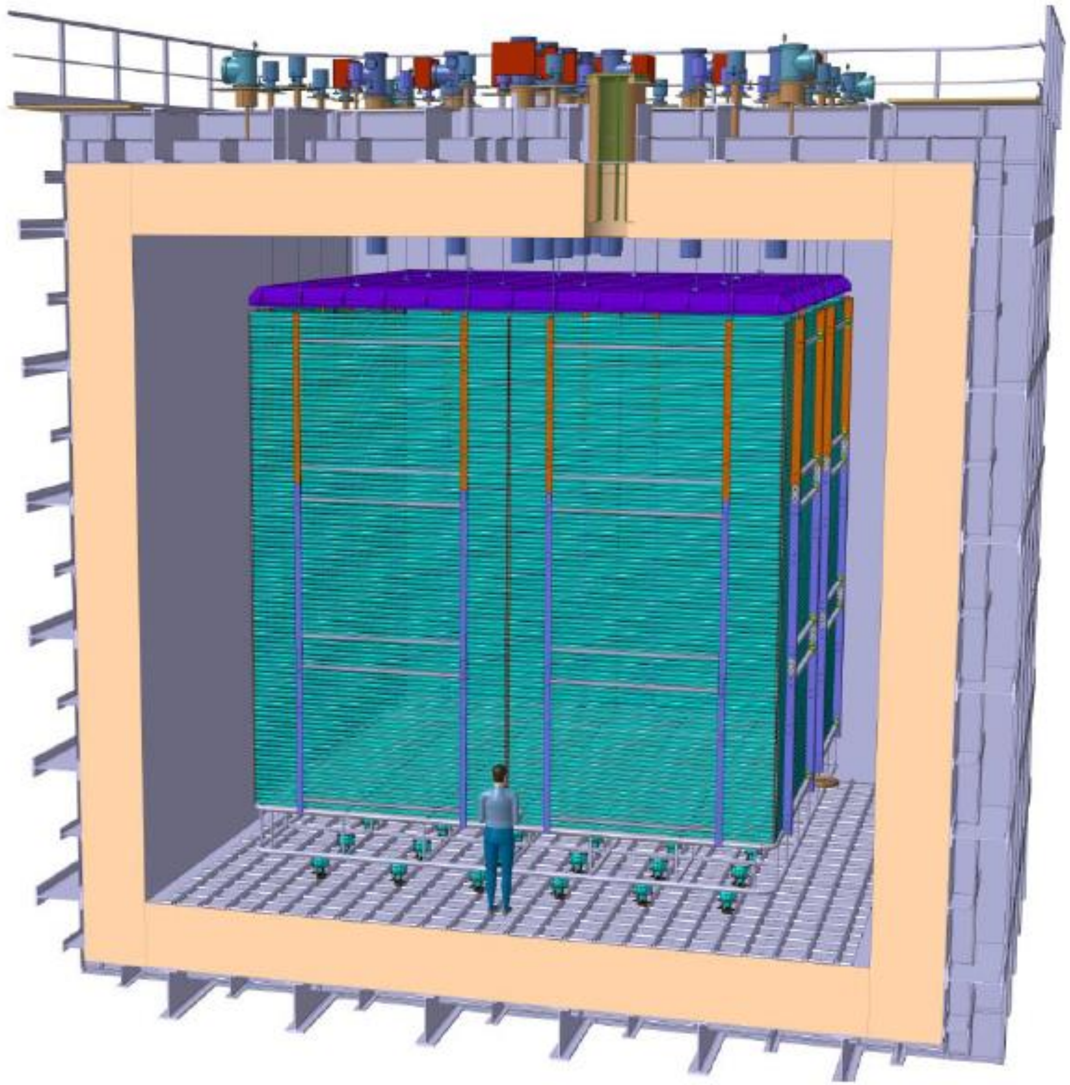
7) Field Cage

- 8 Field Cage Modules



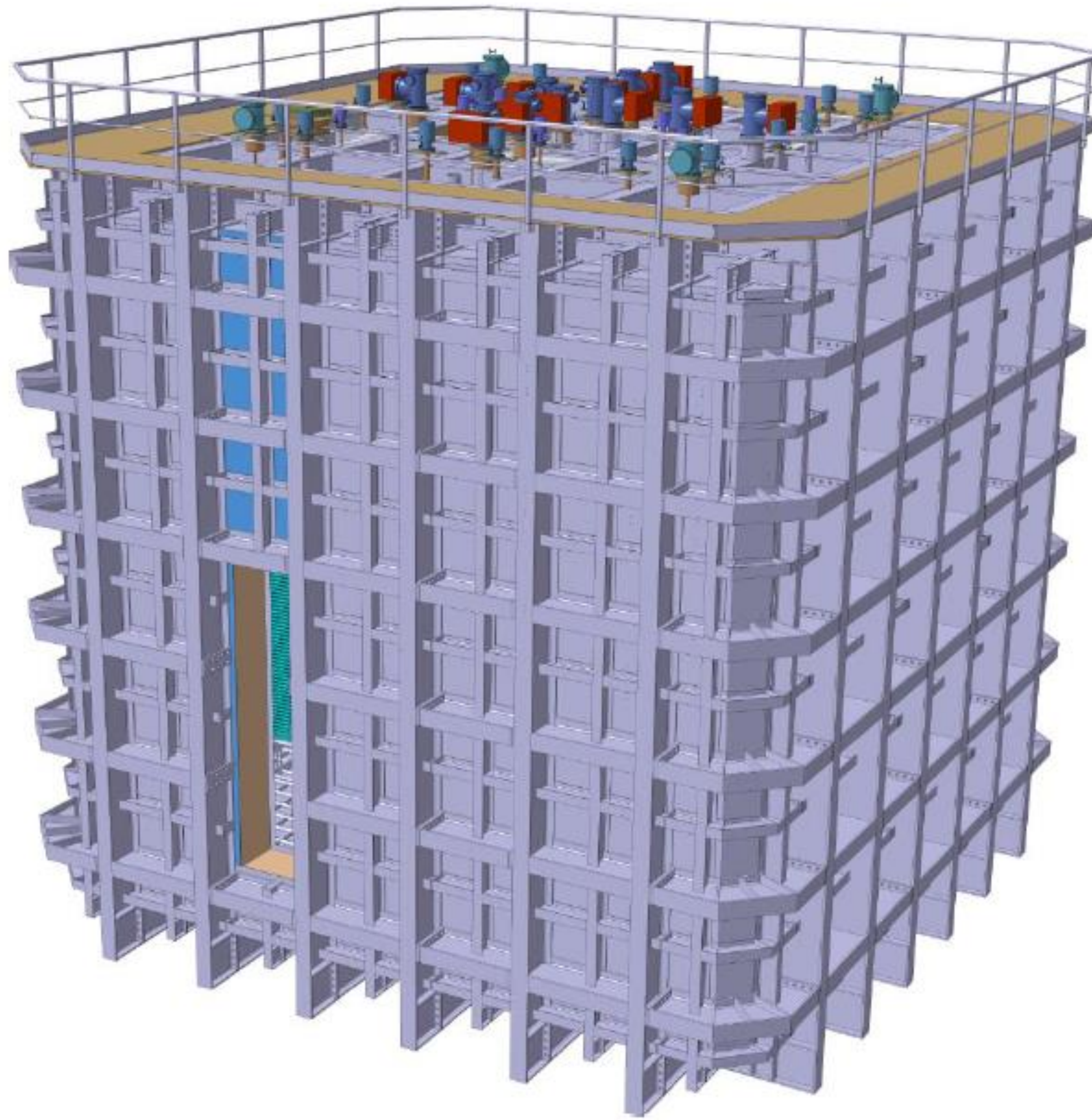
9) Removal of Temporary Assembly Floor

- Temporary Assembly floor removed



10) Closure of the TCO

- TCO closed



Conclusions

- LAr TPC with dual-phase charge readout offers many appealing advantages from detector performance to reduction of construction costs
- Significant efforts over last 10 years to bring this technology to maturity
- A pilot detector, LArProto 3x1x1m^3, will take data this Fall
- A large scale 6x6x6m^3 prototype will start taking data in April 2018
    - Test all the necessary components for O(10kt) detectors
    - Perform measurements with charged particle test beams
- Construction and operation of the 6x6x6 m^3 prototype will pave way towards 10kt scale underground detector for neutrino, astroparticle, and GUT scale physics