# Vertical drift TPC design overview

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LAPP

Outline:

- General layout and dimensions
- Anodes and CRP
- Cathode, Field cage and HV
- Photon detection system
- Summary

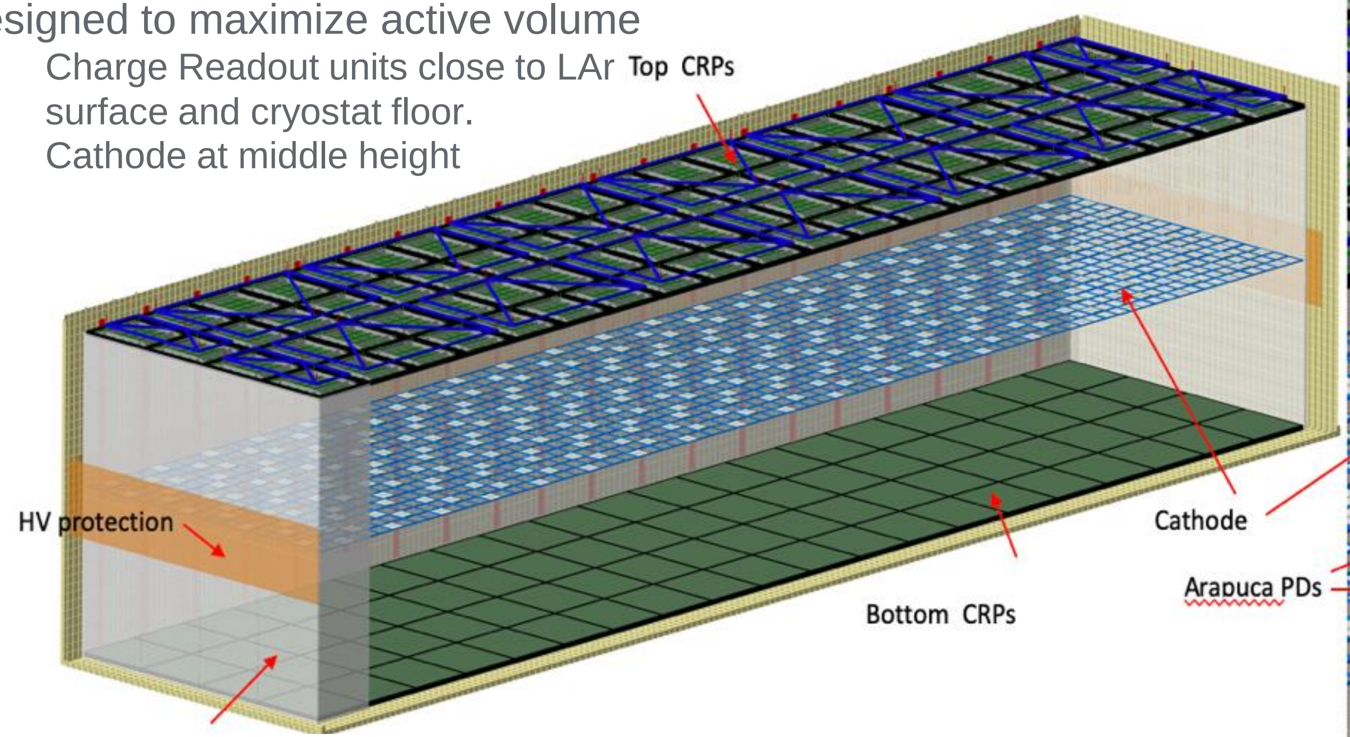
# Vertical Drift Detector components

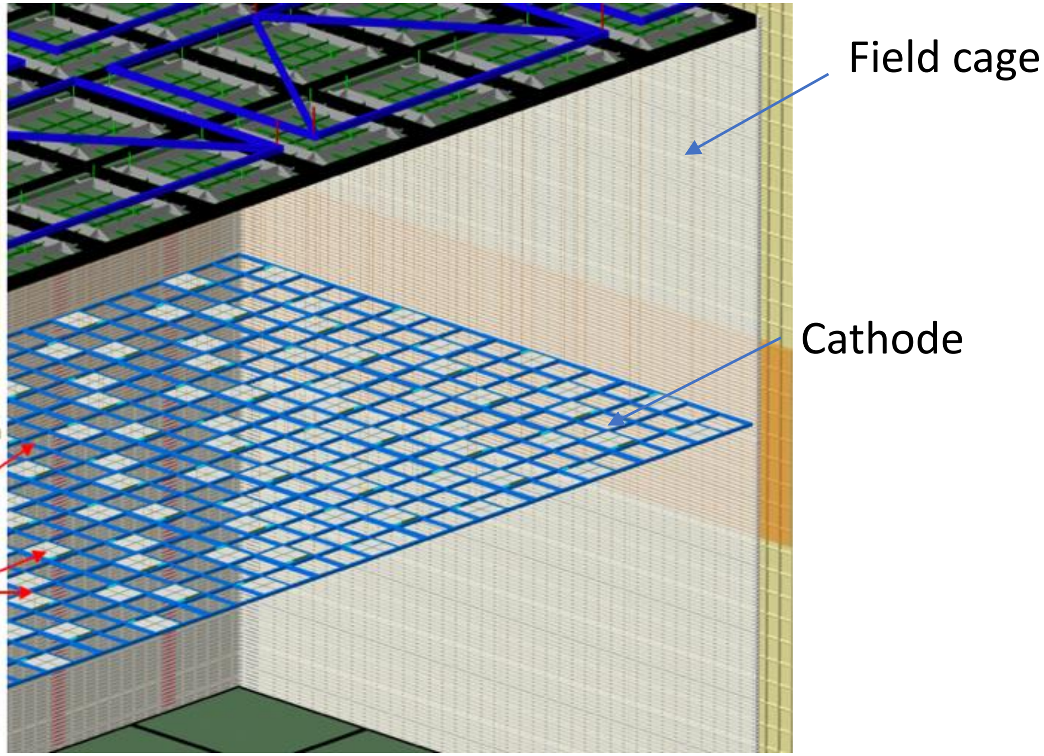
Liquid Argon TPC:

- To detect ionisation charge and scintillation light

- Single field cage surrounding entire active volume
  - derived from DUNE-DP design

- Designed to maximize active volume
  - Charge Readout units close to LAr surface and cryostat floor.
  - Cathode at middle height



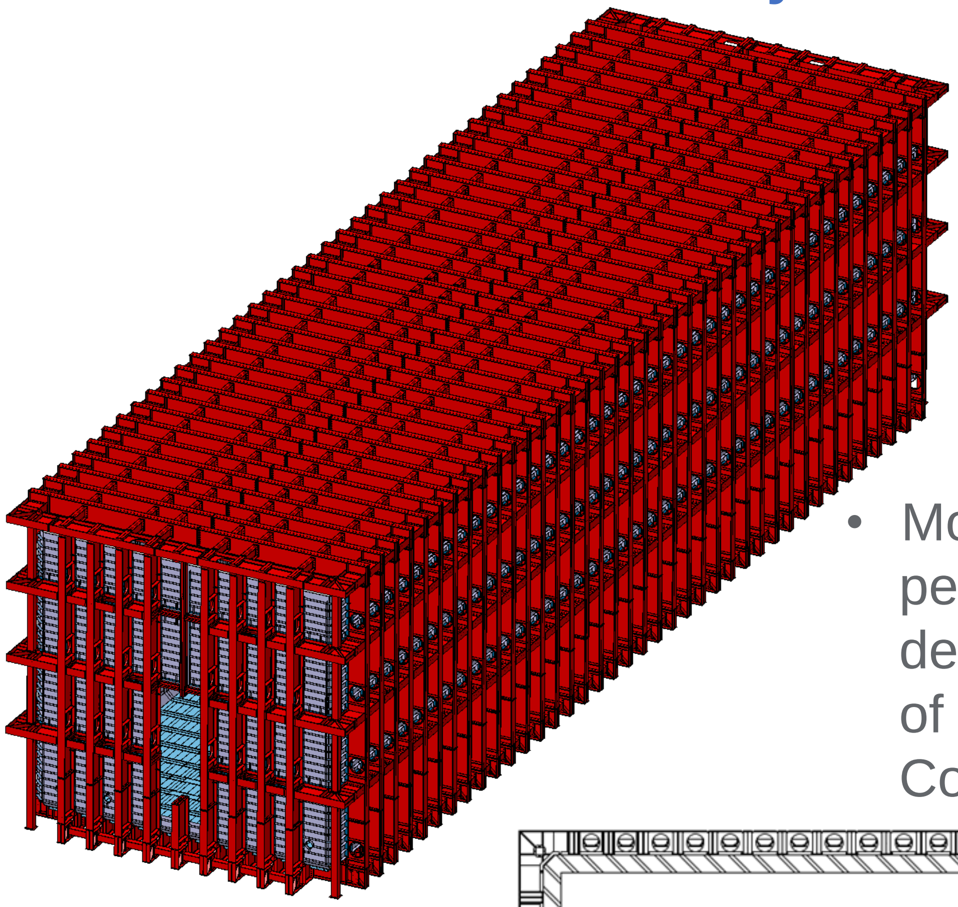




- Perforated PCB's with segmented electrodes (strips) as readout units with integrated electronic interfaces
  - 2 or 3 view using 2 perforated PCB layers
  - Optimizable strip orientation, pitch, length and PCB modularity

- Modular supporting structures for readout planes
  - Derived from CRP design of DP Incorporates cathode hanging system

- Photon detectors based on X-ARAPUCA technology (same as DUNE-HD)
  - integrated on cathode plane and on the cryostat walls.
  - decoupling from HV, achieved with optical fibers for signal and power transmission.

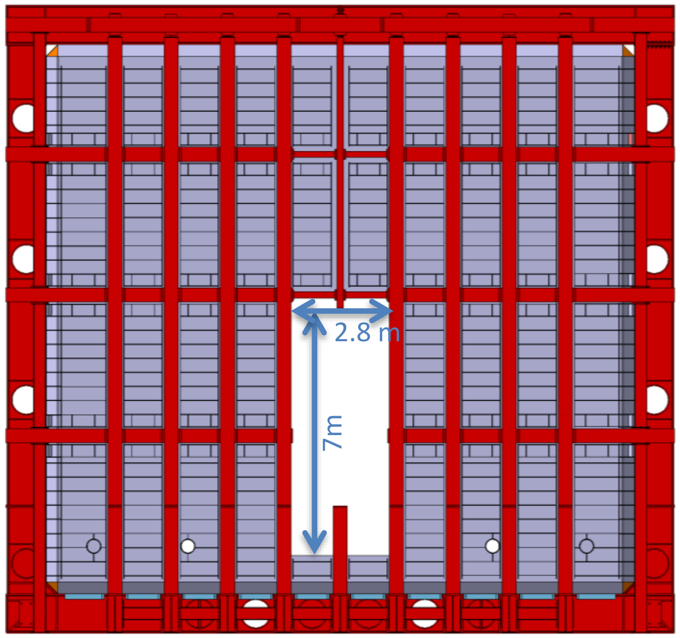
# General dimensions and cryostat for the Vertical Drift detector

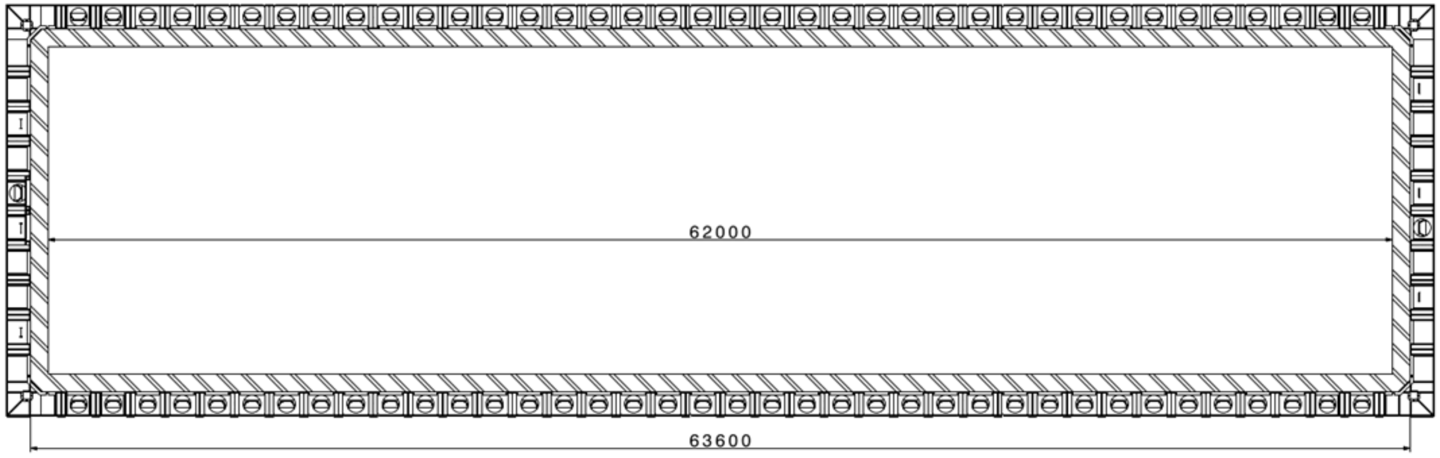


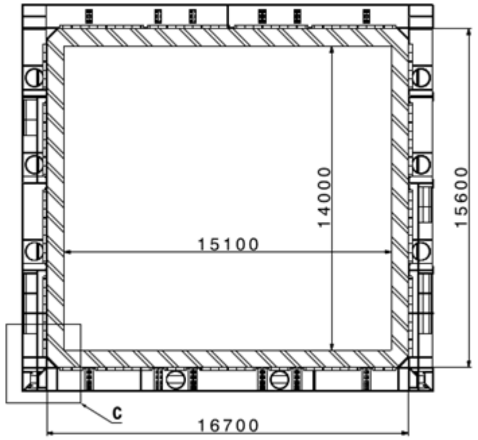
- The Cryostat layout will mostly remain the same as the one foreseen for the horizontal drift DUNE detector with internal dimension: 62m x 15m x 14m

- Modified will be the roof penetrations (signal and detector support) and the size of the TCO (Temporary Construction Opening)

## Cryostat - TCO

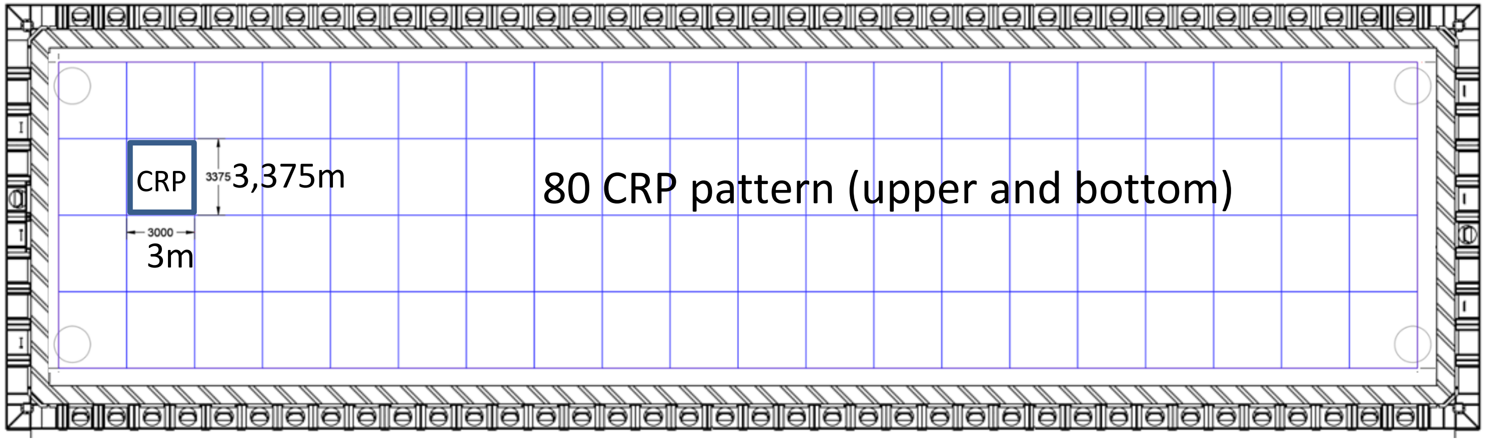


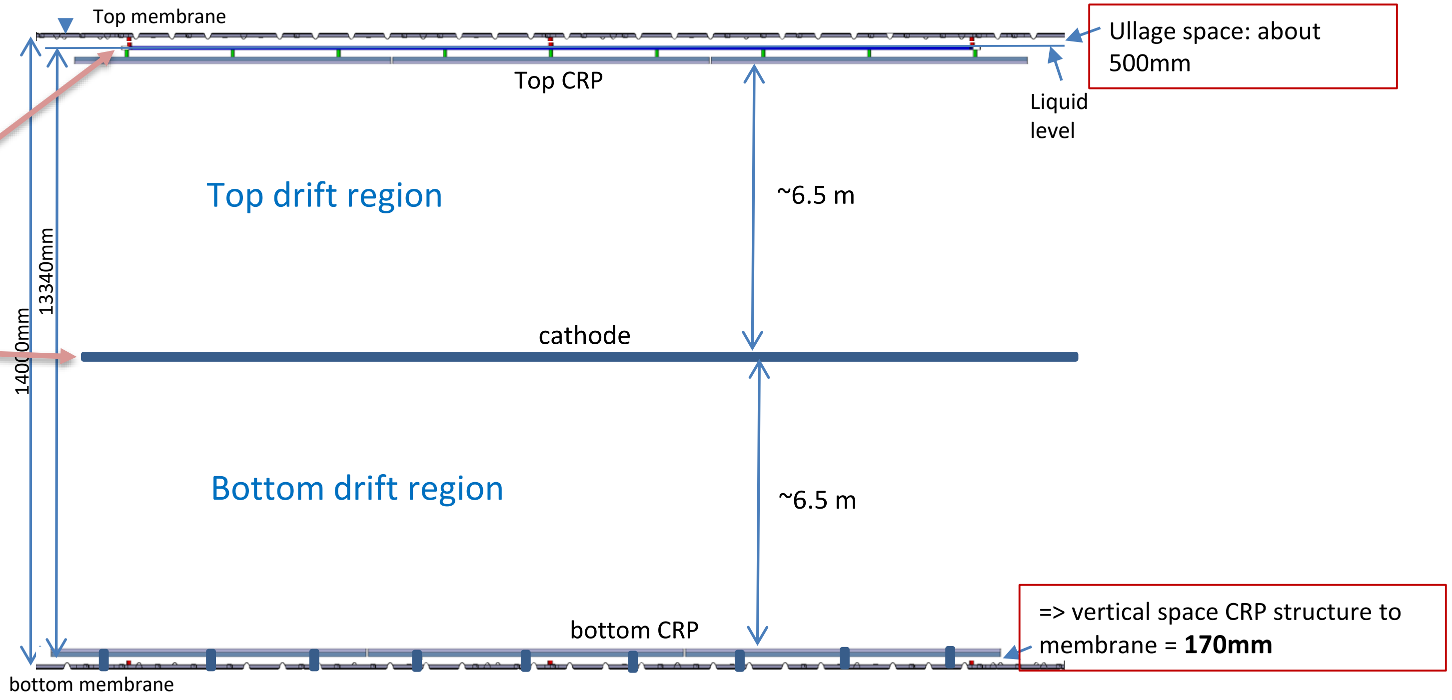



# General detector geometry arrangement

Top view:




Side view :



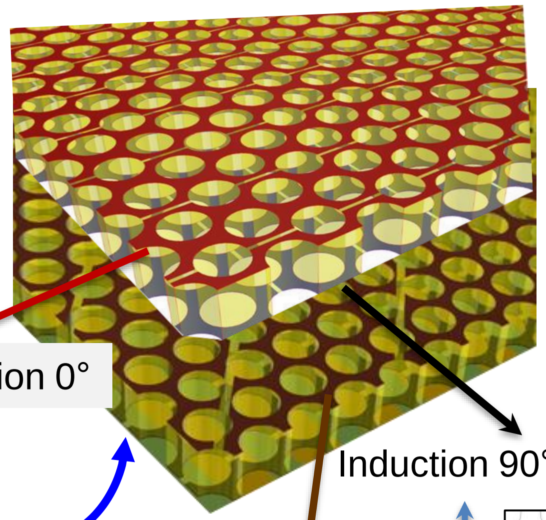

Cathode is suspended to the general CRP top support structures

6 cathode units suspended to SuperCRP by 12 points with dyneema (Kevlar) wires

# Perforated PCB Anode :

Principles: Strips on perforated PCB 3.2mm thick

**Three view** (48°, 0°, 90°)



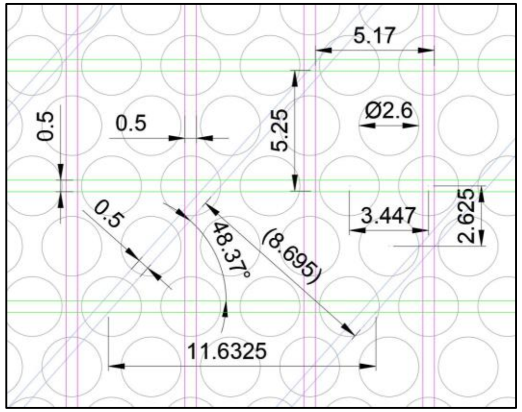

- ✓ 2.5 mm holes
- ✓ Collection strips in the transverse direction, 5.2mm width
- ✓ Induction2 strips along beam, 5.2mm width

- ✓ Adding 3$^{rd}$ view at ~48$^{o}$
- ✓ Induction1 strip pitch: 8.7mm

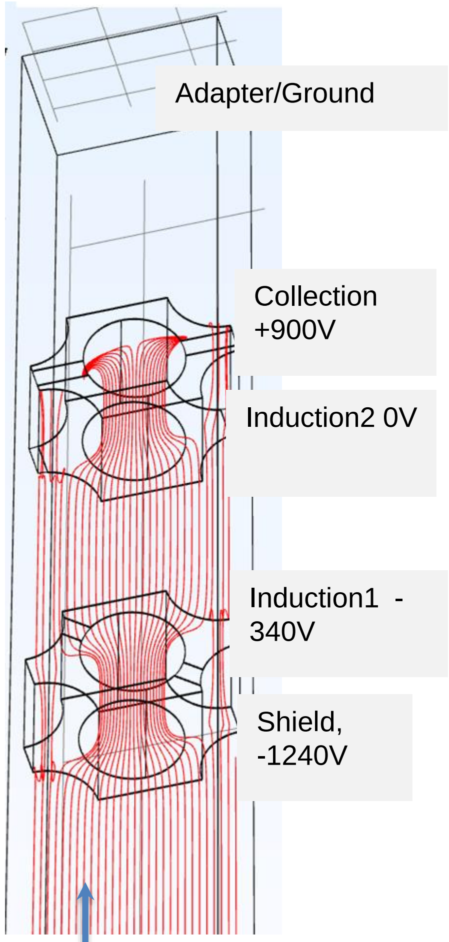
- ✓ 8.5 mm PCB spacing

adding a 'shield' layer facing the cathode to reduce the risk of charge injection to the FEE

e-

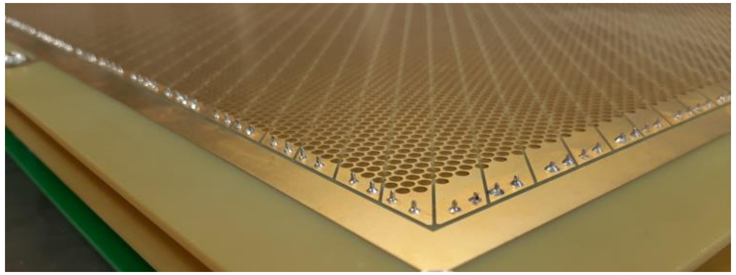


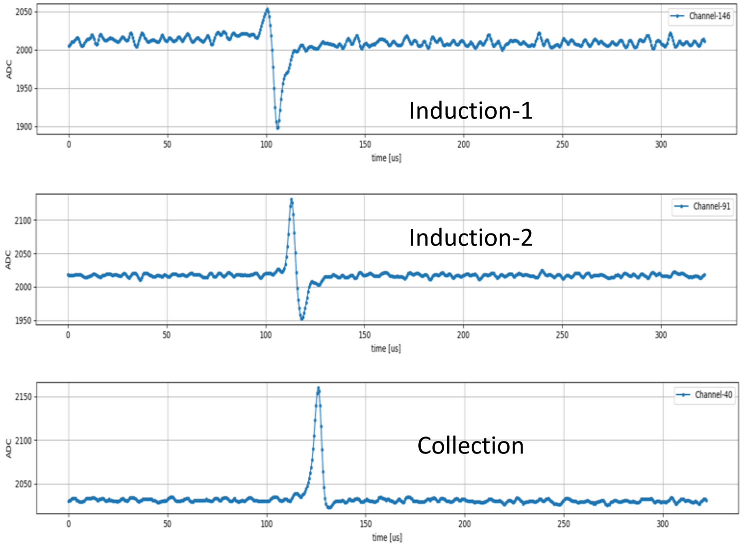

**Design for the 1st CRP and cold box test in 2021**

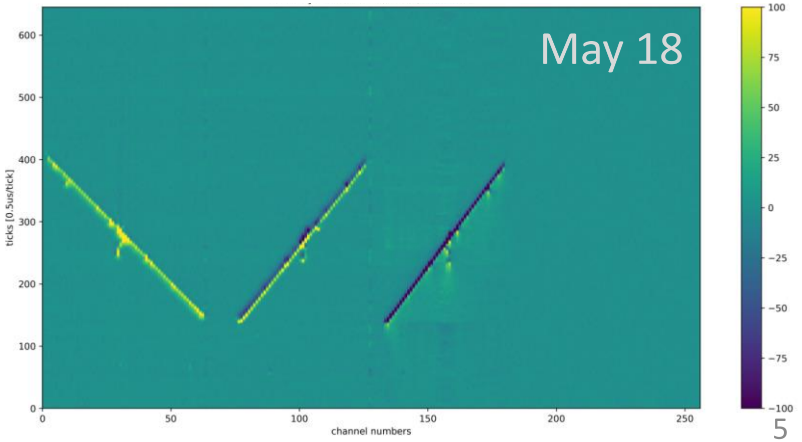



All drift electrons are passing through the holes in the 2 layers before being collected

3 View anode setup tested at CERN in 50L cryostat



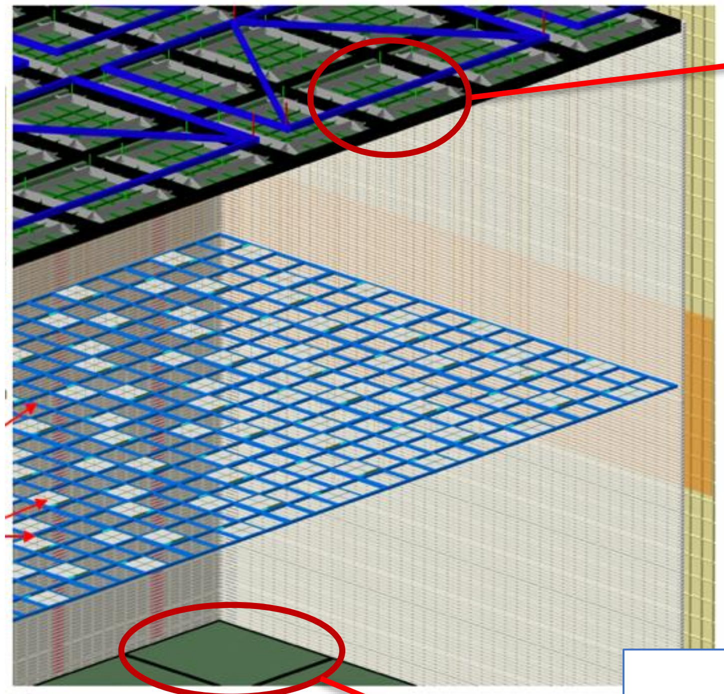


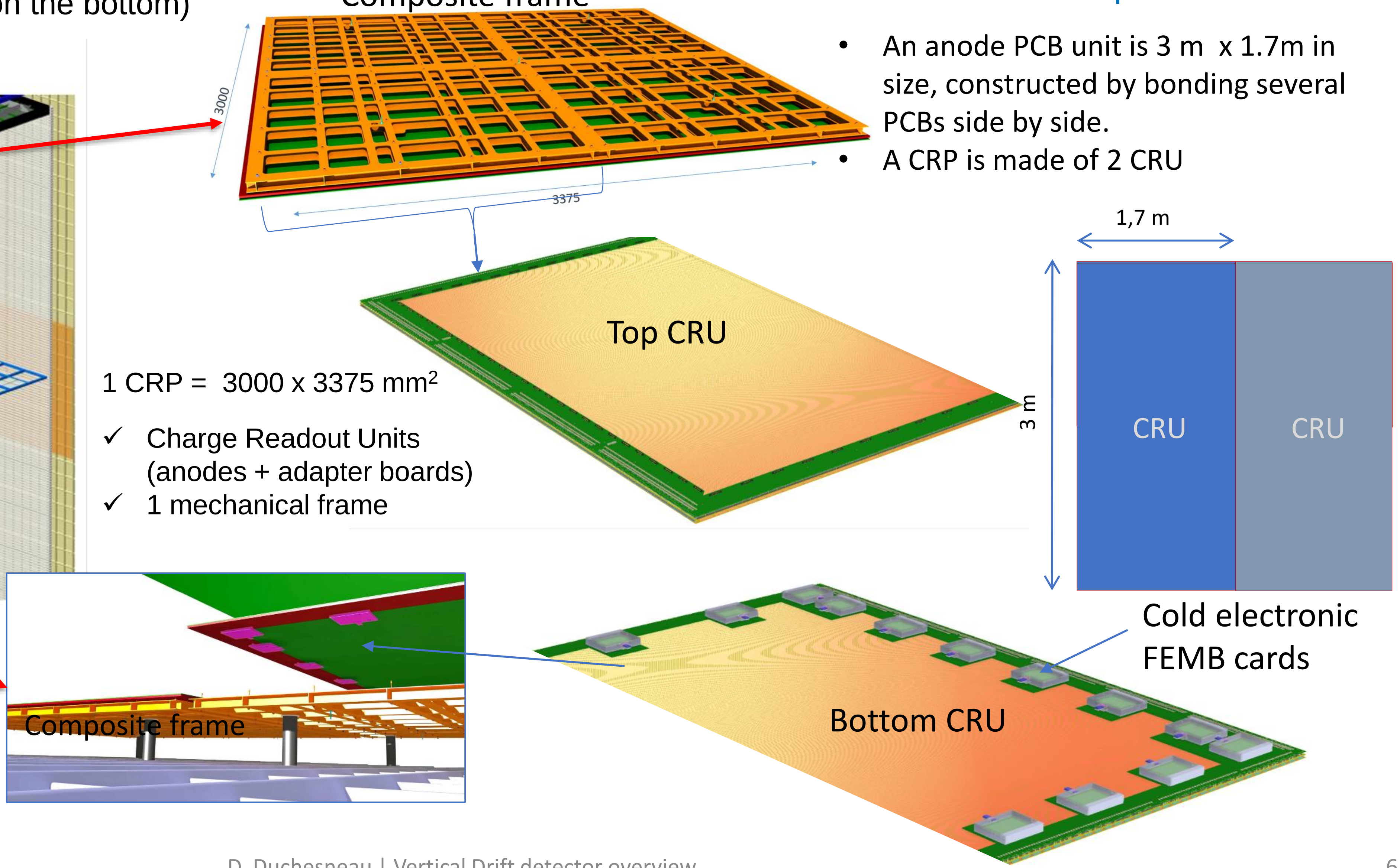
# Charge Readout Plane and anode assembly

✓ 160 CRP units (80 on top, 80 on the bottom)

Readout by DP electronics



Readout by CE



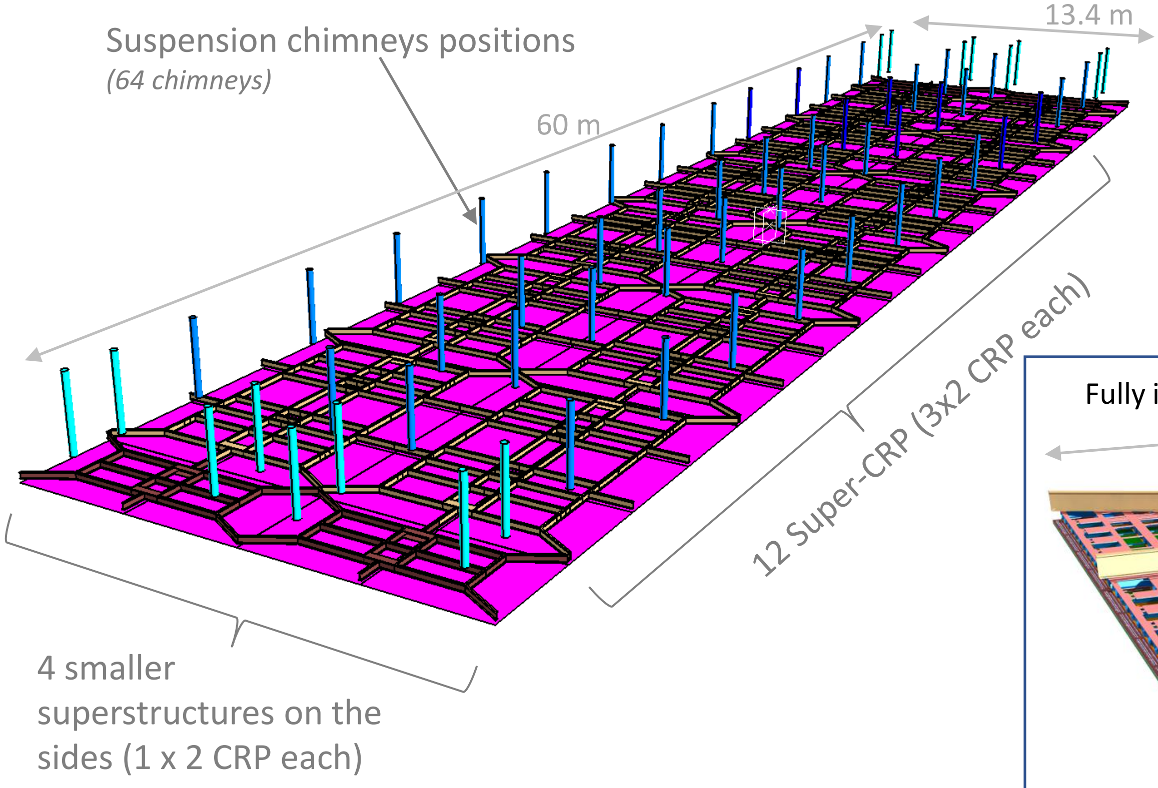

1 CRP = 3000 x 3375 $mm^2$

✓ Charge Readout Units (anodes + adapter boards)
✓ 1 mechanical frame

Readout geometry foreseen: Identical for top and bottom:

- An anode PCB unit is 3 m x 1.7m in size, constructed by bonding several PCBs side by side.
- A CRP is made of 2 CRU

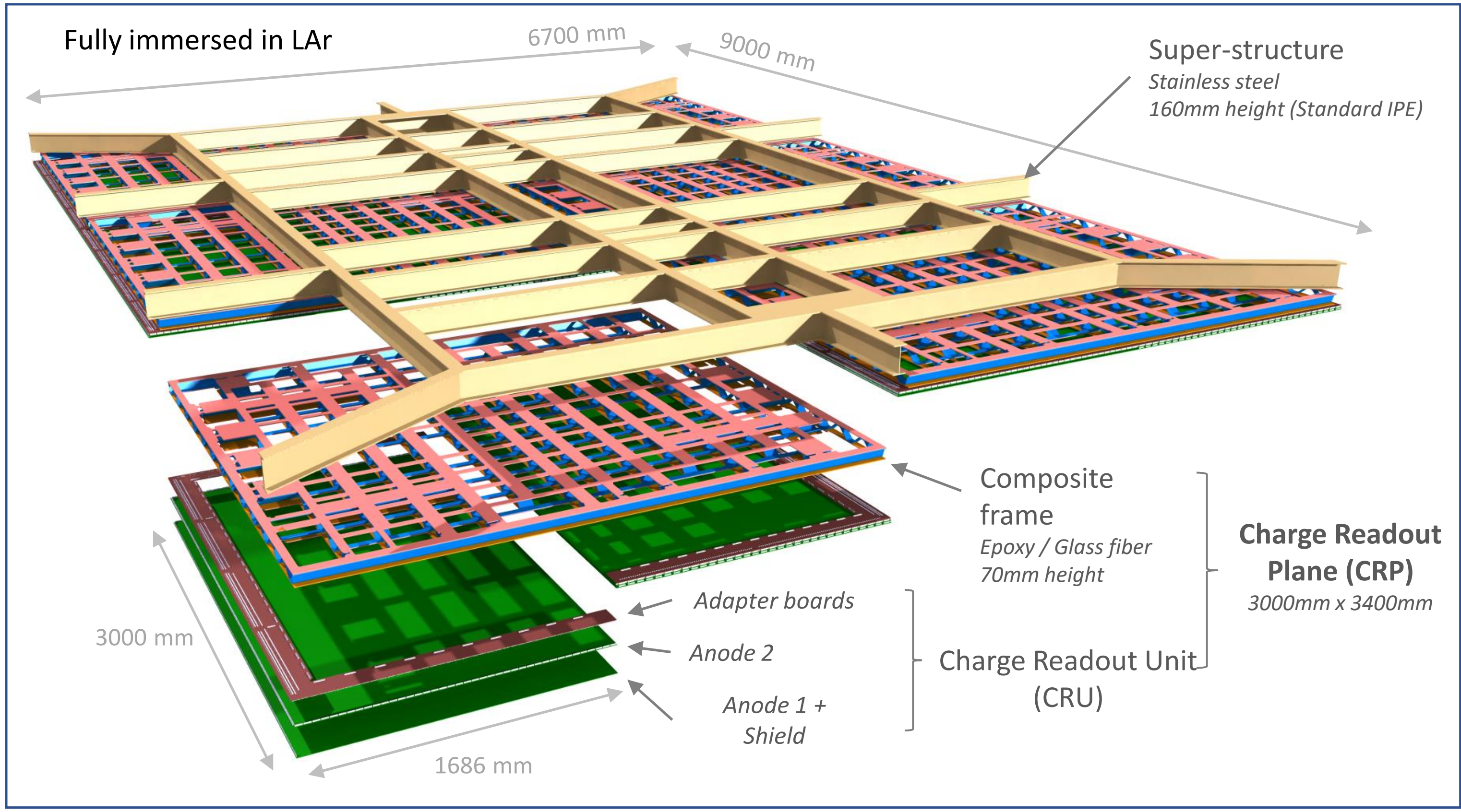
# Top CRP plane layout



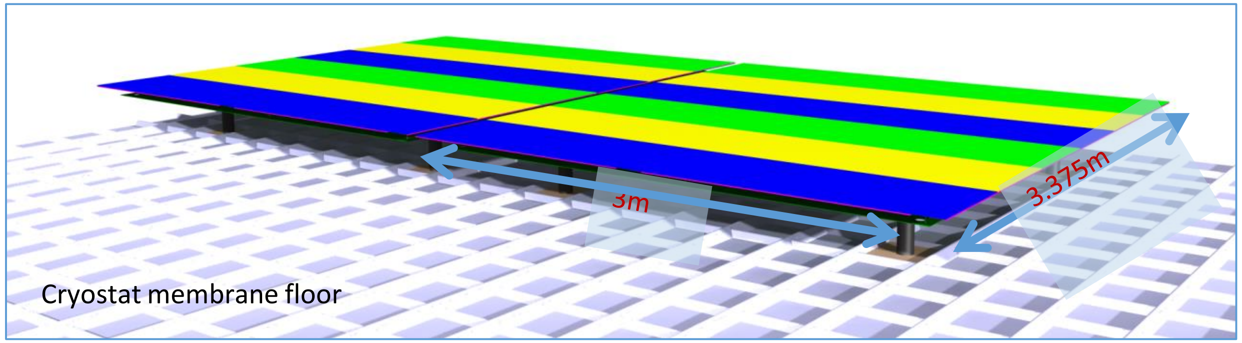

Top plane: 80 CRPs

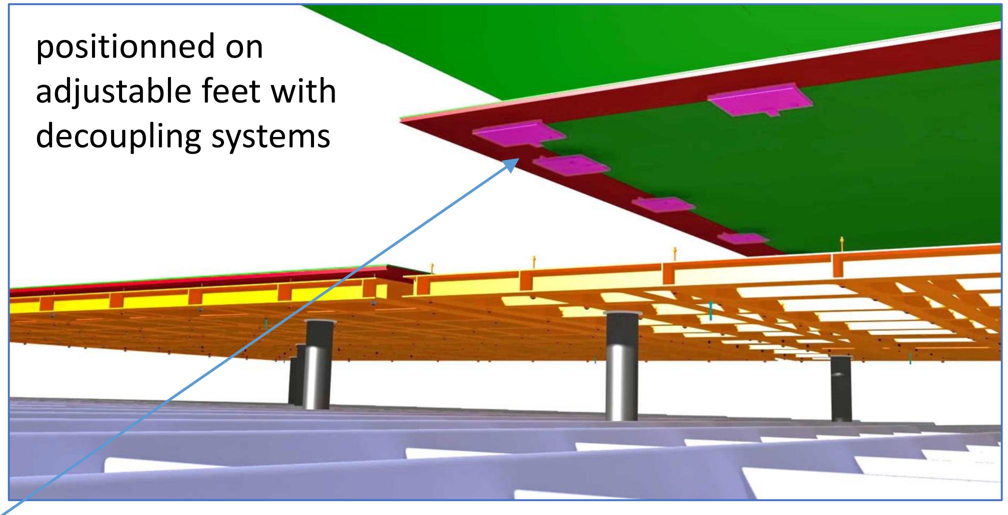
Anode planarity specification : <10 mm @ cold

Each superstructure suspended by 4 cables and position controlled from the top of the cryostat like for Dual Phase



# Bottom CRP Plane Layout



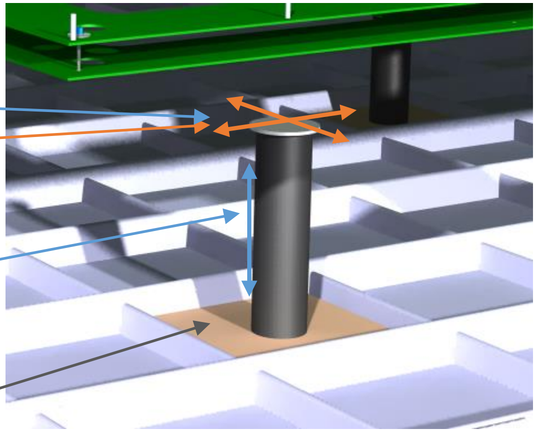




<u>Design of the bottom CRP frame</u>:
No metallic frame, only composite frame

With the bottom CE boxes attached below the anode plane +
planarity can be controlled by the supporting feet to keep each anode plane within the 5 mm deformation range

⇒ Bottom frame can be made more transparent than top frame and
⇒ Lighter thanks to the adaptable supporting feet distribution

The bottom CRPs will be positioned on adjustable feet

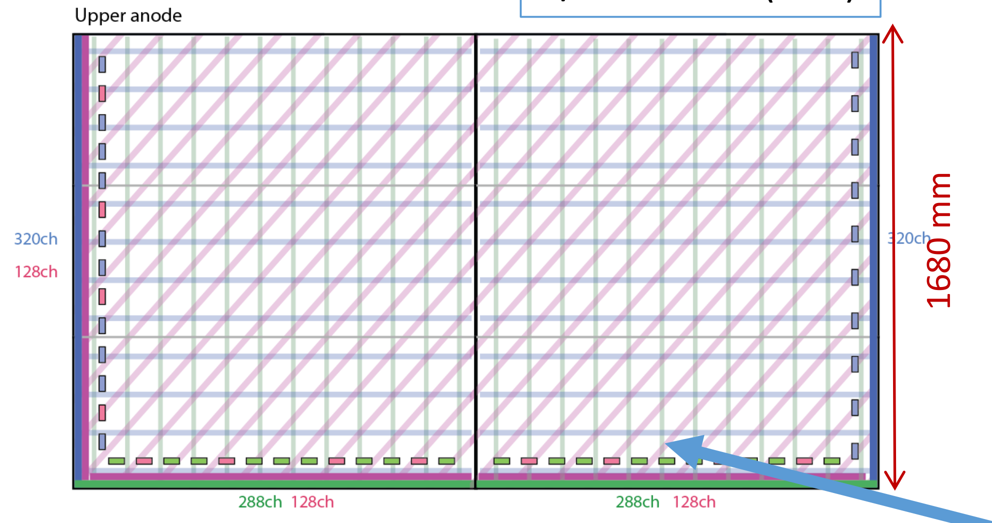


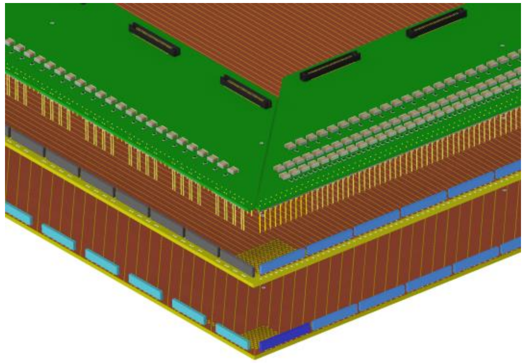
# Anode electronics and Adapter Board interface

For the (48°, 0°, 90°) => 3200 channels / CRP

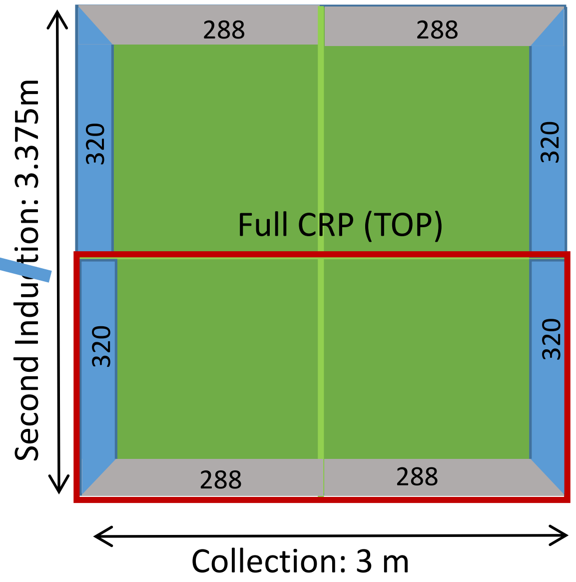
Top CRP: Readout electronic identical to Dual Phase completely accessible from cryostat roof

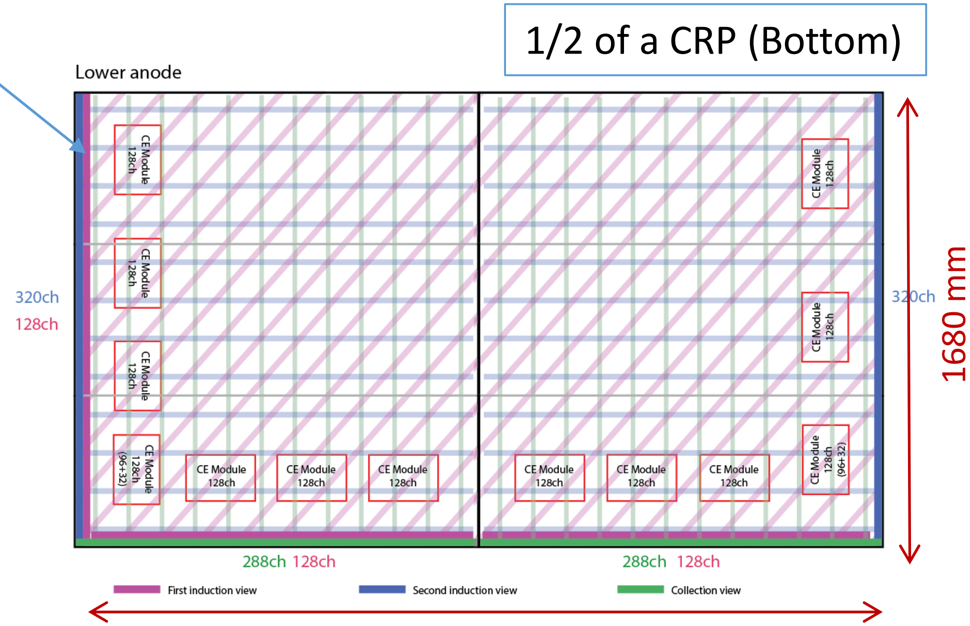
Bottom CRP: Cold electronic like for Horizontal Drift

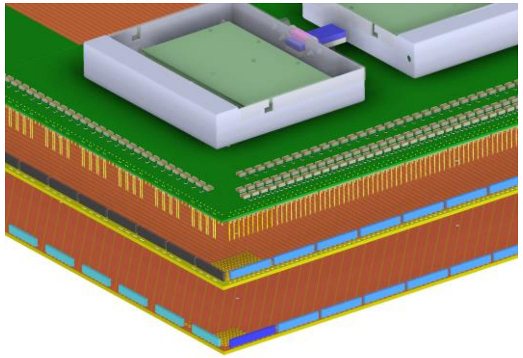


Channel count per ½ CRP
1st induction: 384
2nd induction: 640
collection: 576



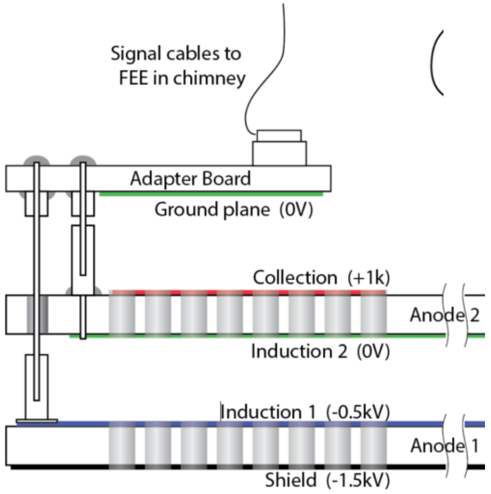



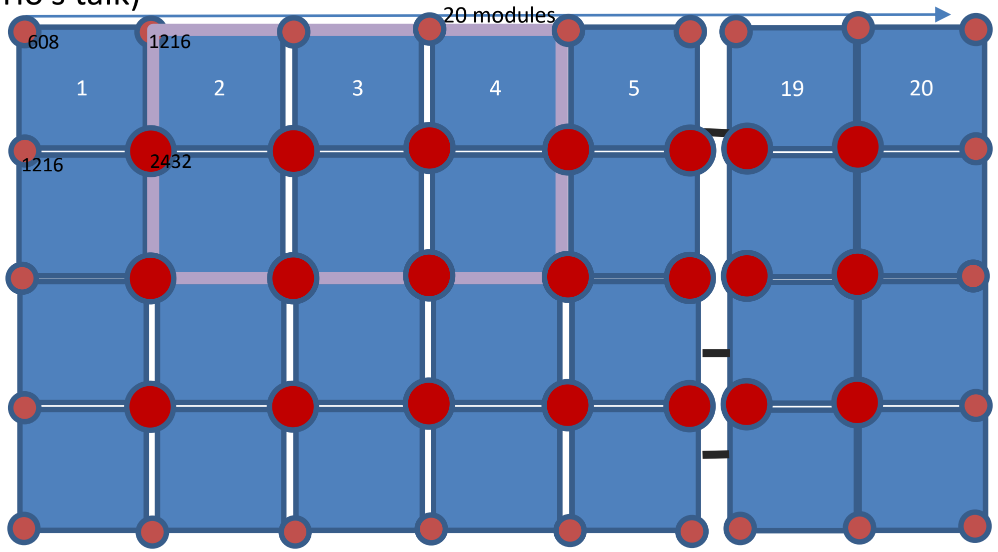
# Readout electronics

## Top Electronic (use same design as for DP)

- Analog cryogenic FE cards accessible in the chimneys
- AMC digitization cards in uTCA crates (cf: Dario's talk)

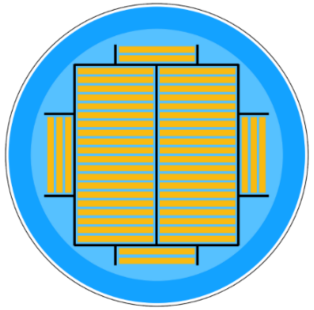



Top chimney topology:
connexion at each CRP corner



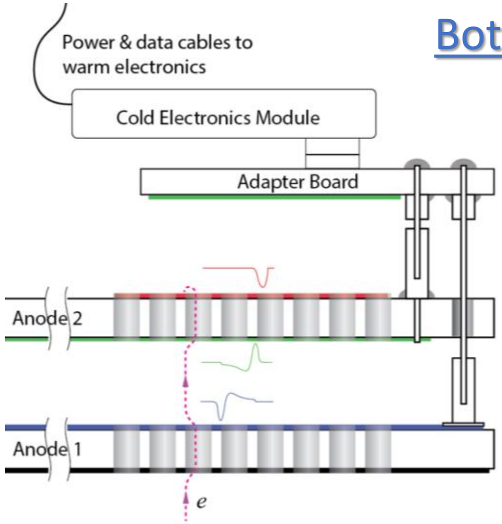

Connexion similar to DP CRP

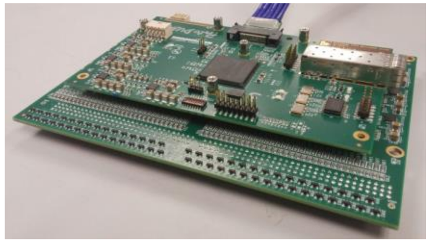
Total 105 feedthroughs
The peripherical ones can be of smaller radius



Pipe internal diameter : 48 cm

## Bottom Electronic



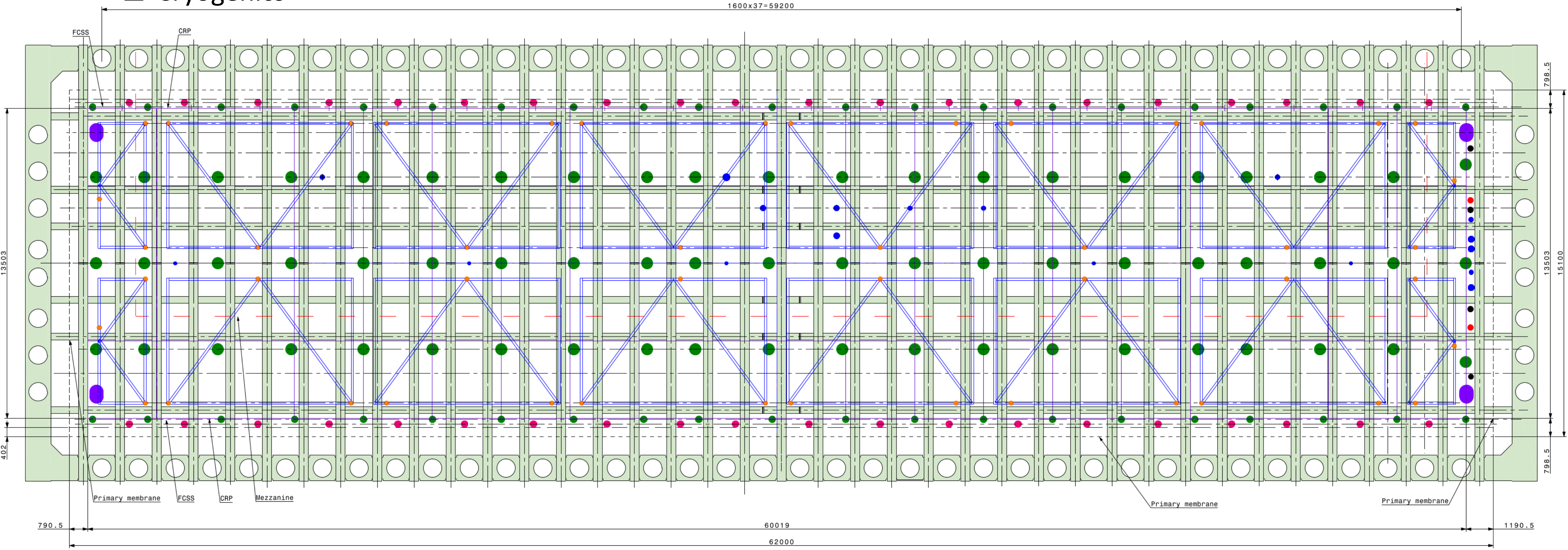
- ✓ 1 chimney for 2 bottom CRPs = 5120 ch/chimney
- ✓ Chimney runs along the long side of the detector, might use these chimneys also to support the field cage
- ✓ Cables run vertically on trays attached to the primary membrane
- ✓ 20 cable trays per side, total 40 chimneys

Use same FEMB cards and Warm Interface Board design than the Horizontal Drift detector

# Topology of the feedthroughs

- ❑ Top electronic
- ❑ Bottom electronic
- ❑ Field cage support
- ❑ CRP suspension (DSS)
- ❑ High voltage
- ❑ Cryogenics

| Pos. | Diameter [mm] | Quantity | Description |
|---|---|---|---|
| 1 | Ø200 | 48 | DSS |
| 2 | Ø500 | 63 | Top Center CRP Cables |
| 3 | Ø300 | 42 | Top Side CRP Cables & FCSS |
| 4 | Ø300 | 40 | Bottom CRP Cables |
| 5 | Ø250 | 2 | High voltage |
| 6 | Ø250 | 4 | Instrumentation |
| 7 | Ø800 | 4 | Manholes |



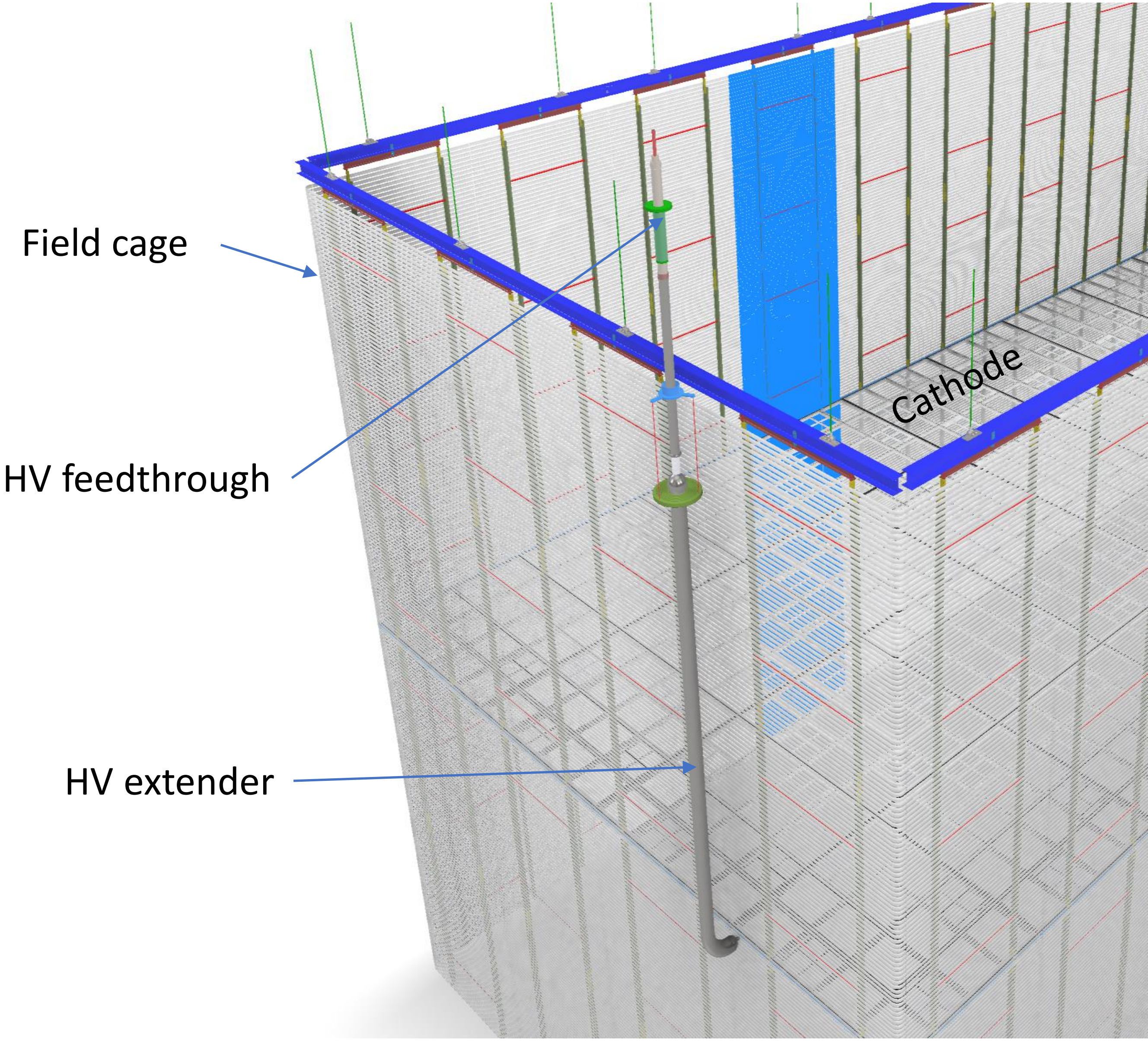
# Field cage and HV distribution

The HV system consists of:

- ❑ The HV delivery system
  - HV power supply (>300 kV)
  - PS monitoring system, HV cable, ripple filters,
  - HV Feedthrough, and
  - HV extender

- ❑ The field cage
  - 192 field cage modules, with FC aluminium profiles

- ❑ The cathode



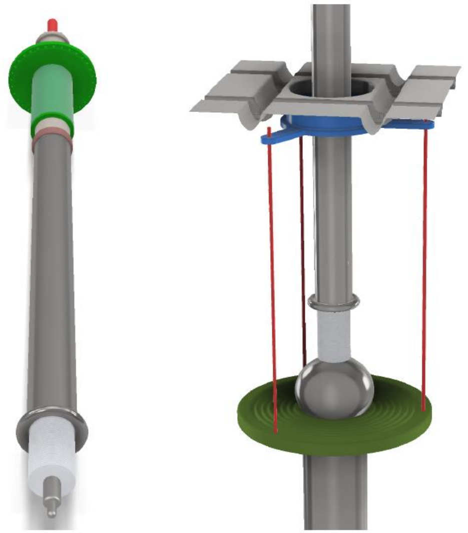
# HV Feedthrough and extender

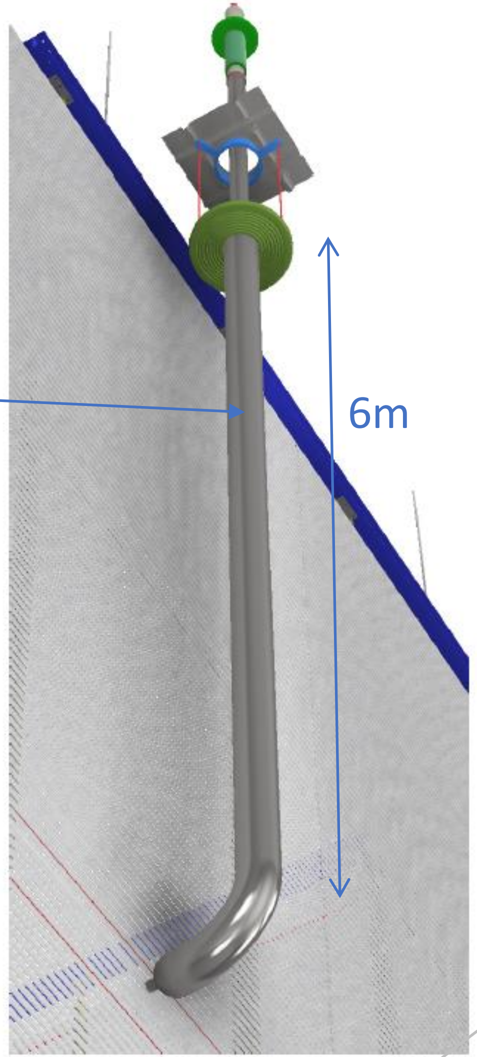
→ HV of -325 kV entering with a vertical penetration at one extremity of the cryostat in the region where FC and the cryostat wall distance is larger than a meter

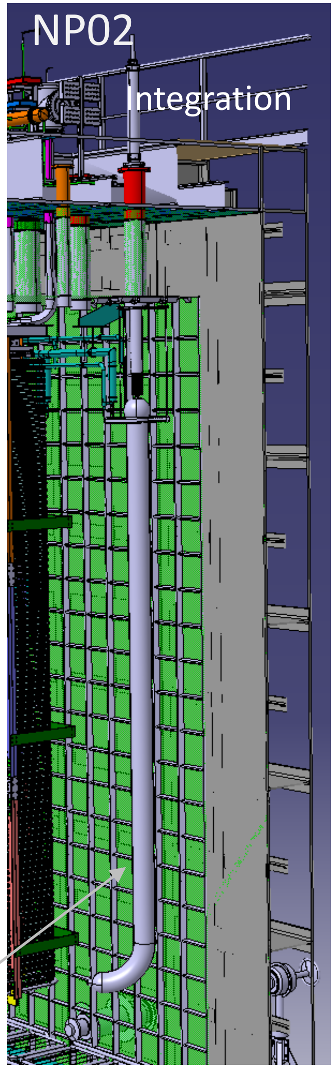
→ Max drift field over 6.5m ~500V/cm

→ Extender has a simplified technology compared to NP02: based on a highly electropolished metallic pipe of 20 cm in diameter.

→ Feedthrough and the contact part are being built and tested at Fermilab and CERN






→ The whole HV distribution chain will be integrated and tested at full scale in the NP02 cryostat this year

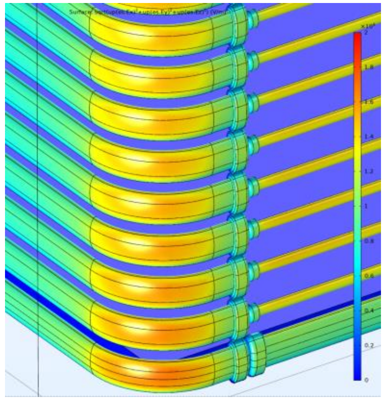
# Field cage



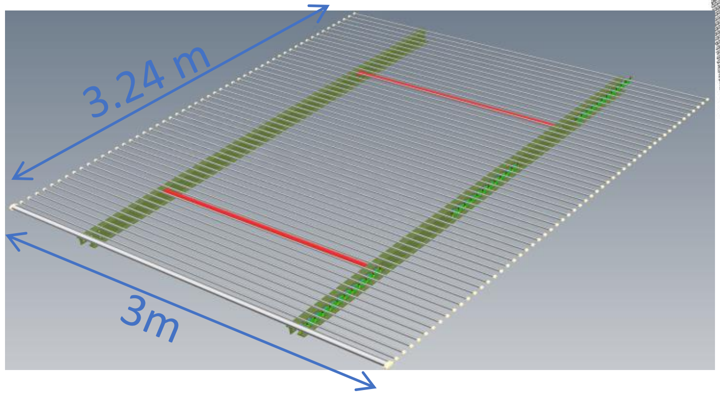
- Field cage surrounds the two active volumes (60mx13mx6.5m each) and provides a uniform electric field to LAr for ionization electrons to drift

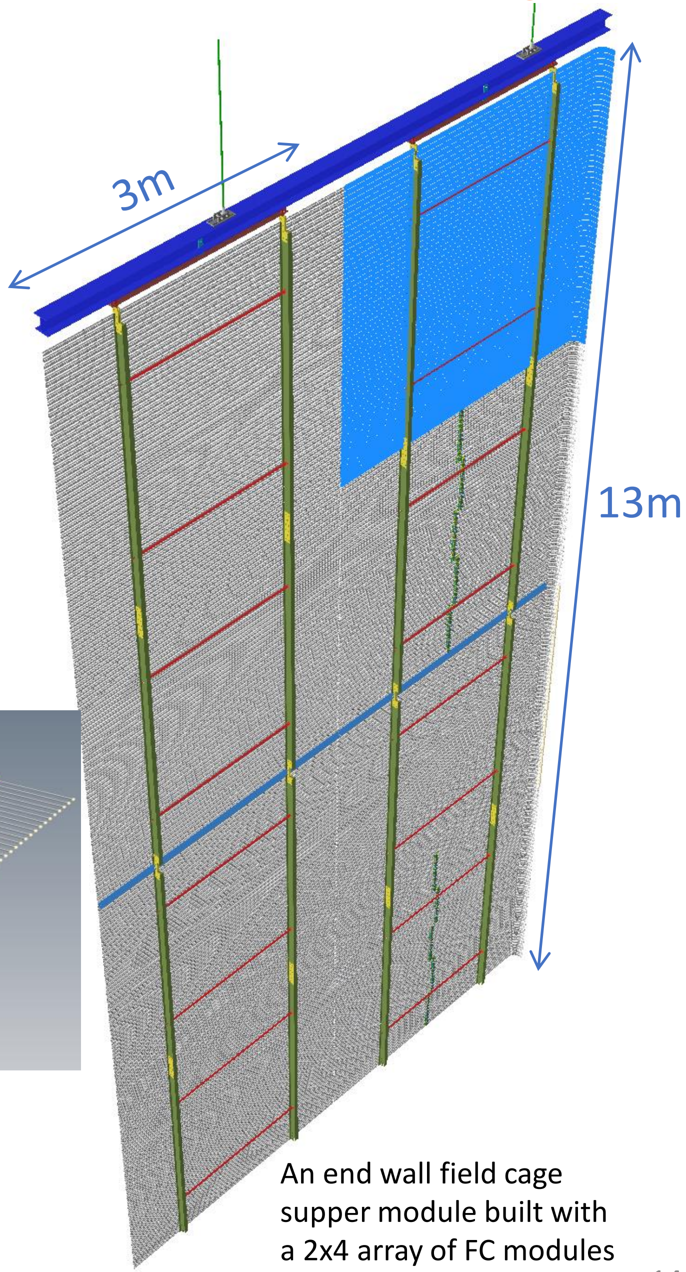
- Modular construction with two 5cm wide, 10cm tall, 3.25m long FRP I-beam frames and 55 extruded aluminum profiles in 6cm pitch
  - FC along the long wall : 3.0m (W) x 3.24m (H)
  - FC along the end wall : 3.38m (W) x 3.24m (H)
  - Profiles mounted on outside toward the cryostat wall, minimizing charge-up in insulator

- Along the 4 vertical edges of the field cage, the profiles are bent at 90° to provide smooth conductive surfaces to reduce field enhancement



A study on improving the optical transparency of the FC modules is being conducted, providing more flexible placement for the arapucas on the cryostat walls




An end wall field cage supper module built with a 2x4 array of FC modules

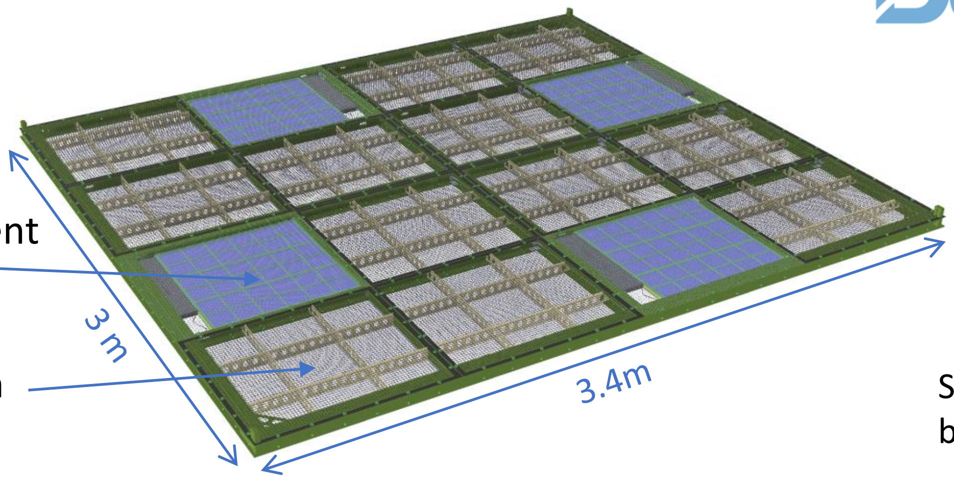
- The vertical installation scheme established and validated at NP02 PDDP
  - Further optimization ongoing

# Cathode structure and interface with CRP superstructure

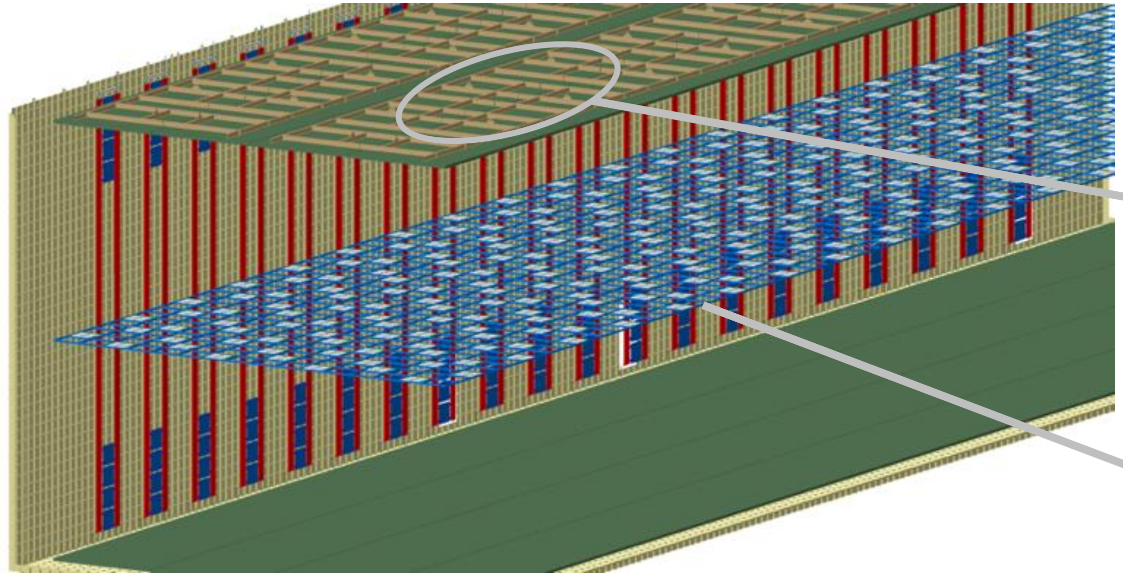
Cathode specifications:

- Planarity of the cathode plane: <20mm
- Weight: less than 10kg/m2
- Width: 50 mm
- Field distortion: < 1%

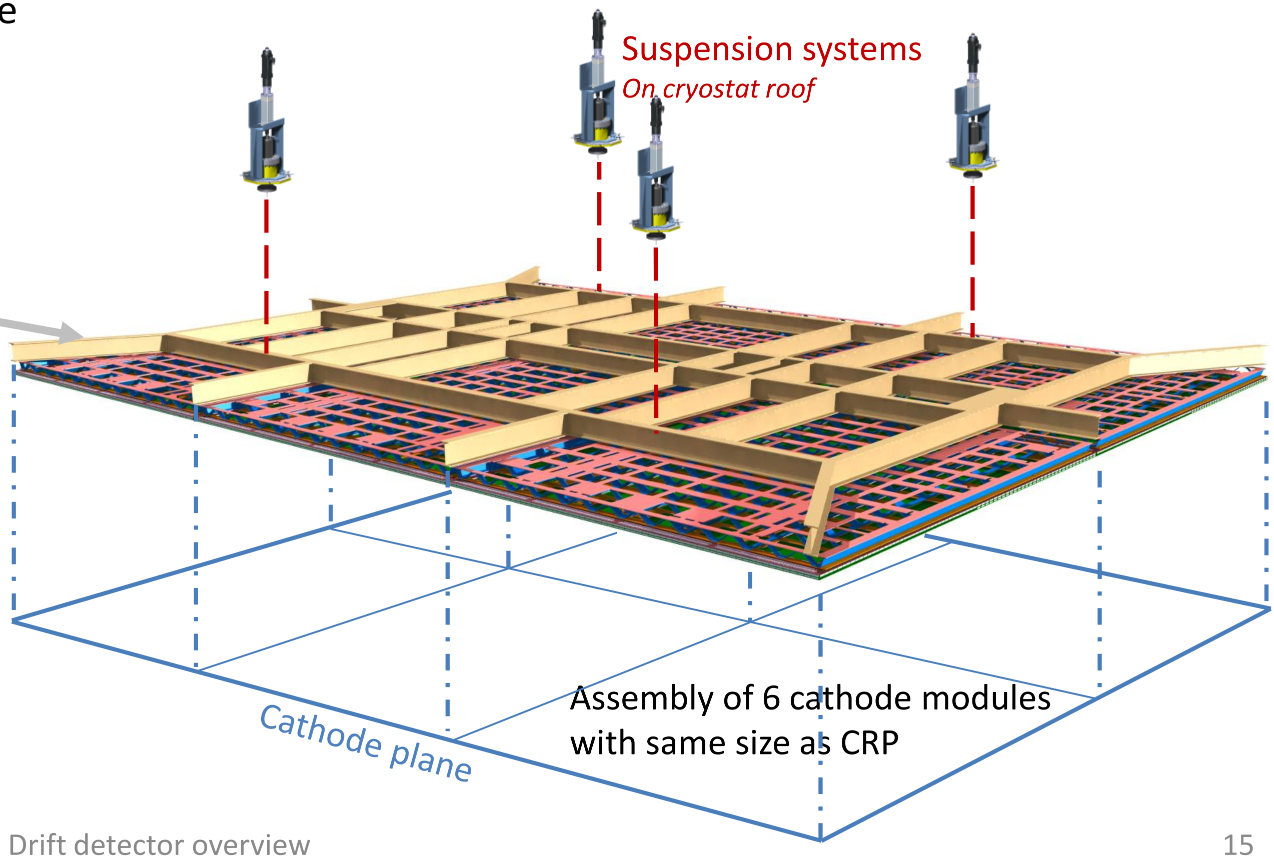
- Arapucas encased by highly transparent (~80%) metal wire mesh panels
- + perforated resistive panels to form two highly resistive surfaces with sufficiently slow discharge RC time




Structure: FRP beams



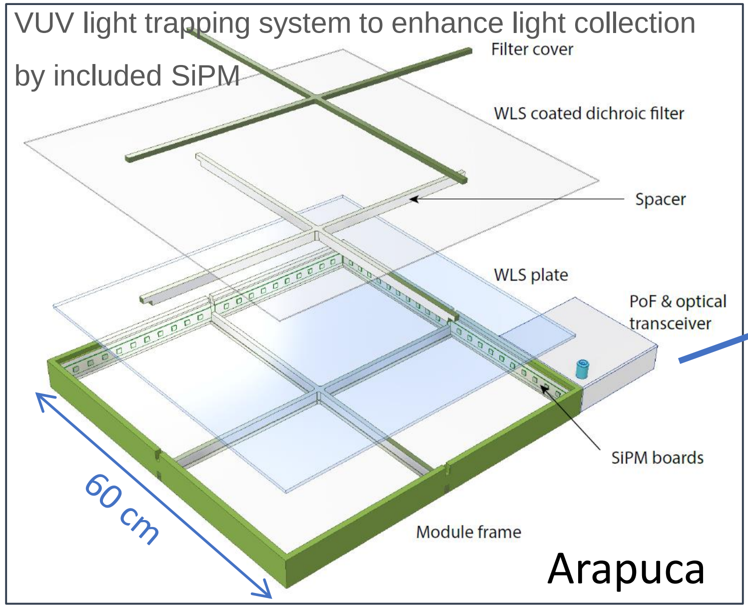
dyneema insulating ropes

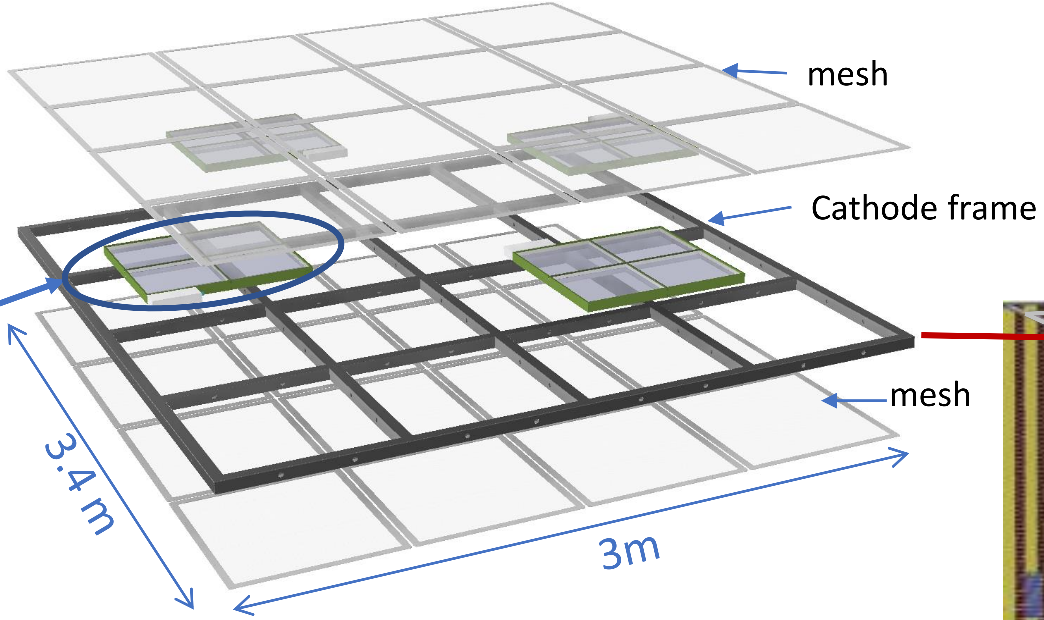


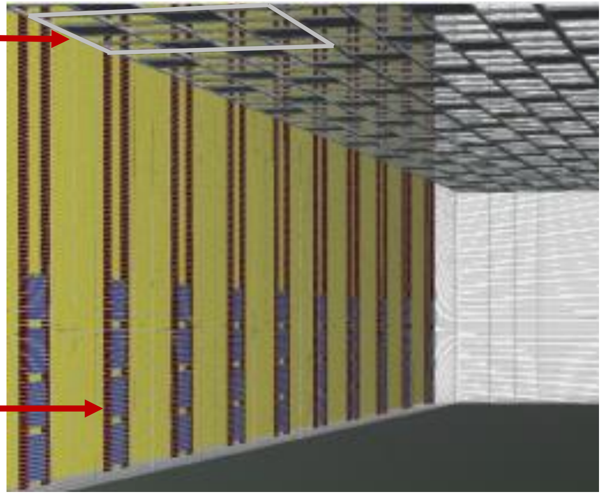
# Photon detector system

- Based on X-Arapuca tiles (like in Horizontal Single Phase detector)
- Arapucas are embedded in the cathode frame at -300 kV (4*80= 320 double sided tiles. Total surface 230 $m^2$)
- Challenging situation => power distribution over fiber for the SiPM boards and fiber readout; R&D in progress to demonstrate connectivity in presence of HV
- Reflector on the anode surface (material to be identified)
- X-Arapuca optimized for 10 ppm of Xenon

Requirements:
- Average Light yield > 20pe/MeV
- Minimum LY > 0.5 > pe/MeV
- Time resol < 1us



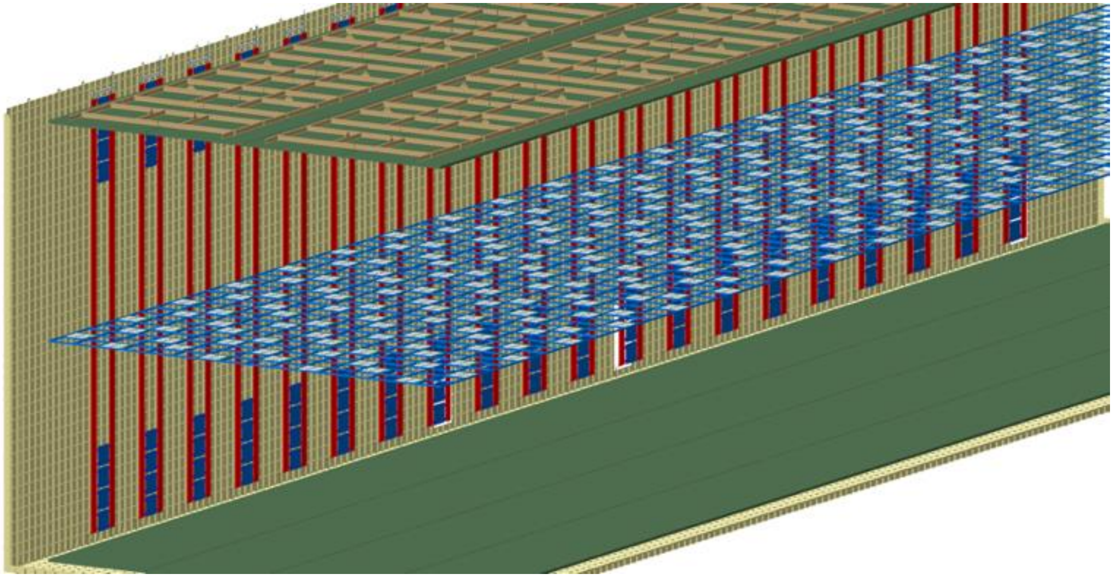



The reference design: to equip also the top and bottom cryostat walls with Arapucas

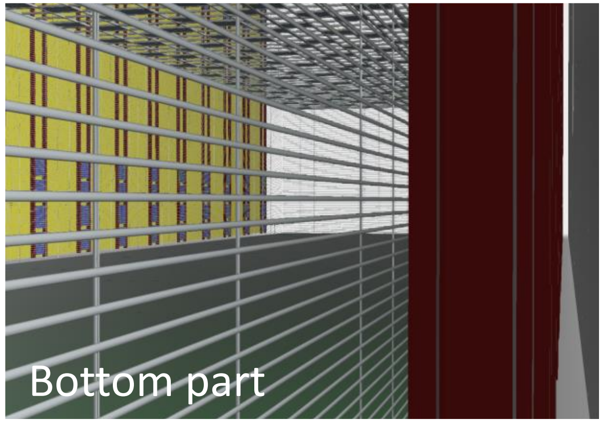
Readout: SiPM signal is transmitted over fiber (both analog and digital transmission is under evaluation)

# Photon detector system

**Photon Detection System reference design (4π):**

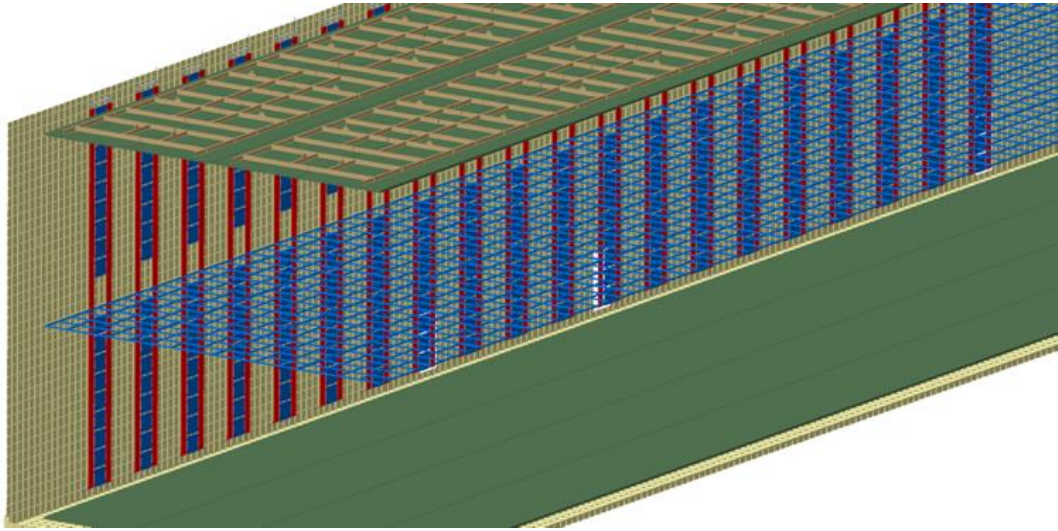


- 320 xArapuca (60x60cm$^2$) on cathode (2x115m$^2$) with analog readout
- 320 xArapuca (60x60cm$^2$) on cryostat membrane (115m$^2$) at 3m from cathode and standard FD1 readout
- 70% transparent field cage


**Backup design : All arapucas on cryostat walls (no HV)**

- 720 x-Arapuca (60x60cm$^2$) on cryostat membrane (260m$^2$). Standard FD1 readout with no PDS at 300kV.
- Xe doping, 70% transparent field cage



# Summary:

Vertical Drift detector advantages:

- Extended drift distance, profiting from excellent LAr purity, allows to maximize the fiducial mass by reducing dead material in the active volume
- Highly modular concept of each detector component
- Simplified installation and QA/QC procedures, not requiring large in situ infrastructures
- Simplified anode structure based on standard industrial techniques
- Field cage structure completely independent from the other detector components
- R&D on photon detection system at high voltage in progress
- Possibility for a Photon detection system with improved light detection coverage and trigger efficiency wrt Horizontal Drift; equivalent to HD if only cryostat wall instrumented