ProtoDUNE at CERN

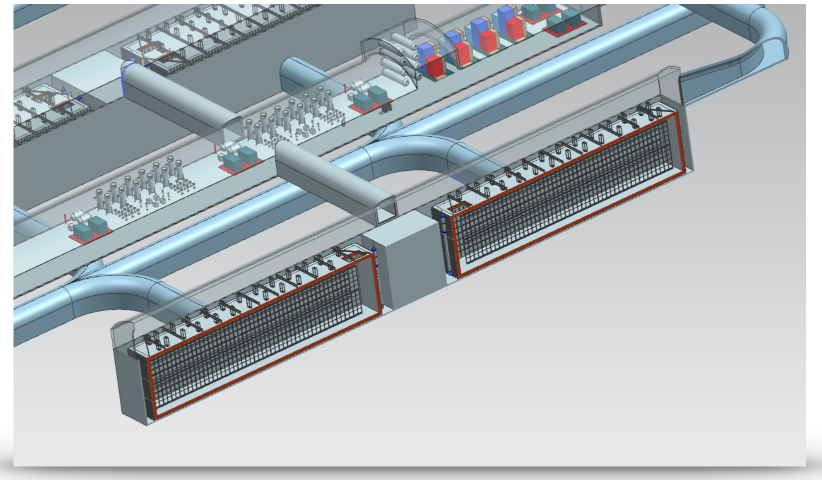
F. Cavanna

Neutrino - Latin America Workshop

April 27-28, 2016

ProtoDUNE at CERN:

DUNE Highest-Level Strategic Goals



commitment to delivering:

- Two 10-kt Far Detector modules operating by 2025

- *First 10-kt FD module based on Single-Phase design*
- *Second 10-kt FD module not necessarily the same design*

↰ **- DUNE Technical Design Report (TDR) for CD-2 Review in 2019**

↰ **- Two DUNE prototype detectors operational at the CERN Neutrino Platform in 2018:**

- **ProtoDUNE Single Phase (SP)**
- **ProtoDUNE Dual Phase (DP)**

The construction and operation of large-scale prototypes at CERN is critical for demonstrating the ability of the DUNE Collaboration to implement a major construction activity

DUNE Far Detector Prototyping

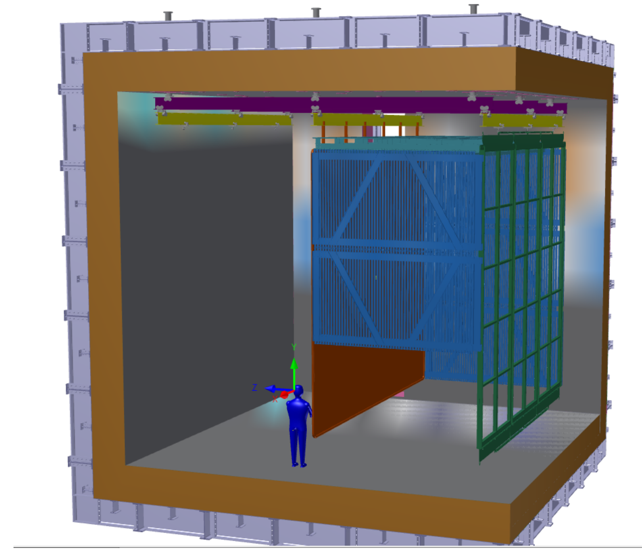
DUNE has well-developed plans for a series of detector prototypes that will provide input to the process leading to the final design(s) for the DUNE far detector modules

Single-Phase

35-TON

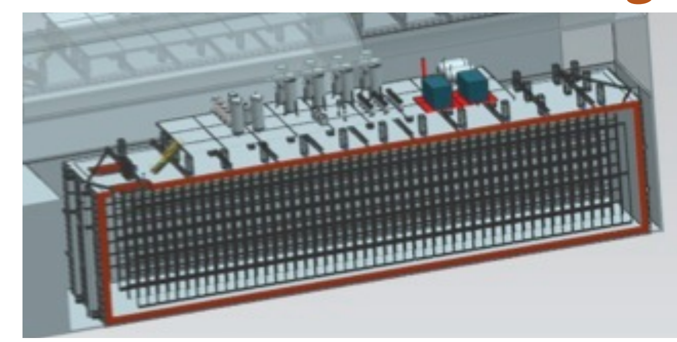
2015

NP-104 (6x6x6 m³)



2018

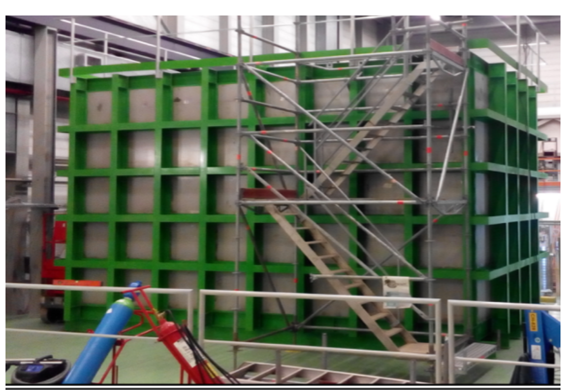
DUNE 10 kT Module
SP - Reference Design



2021

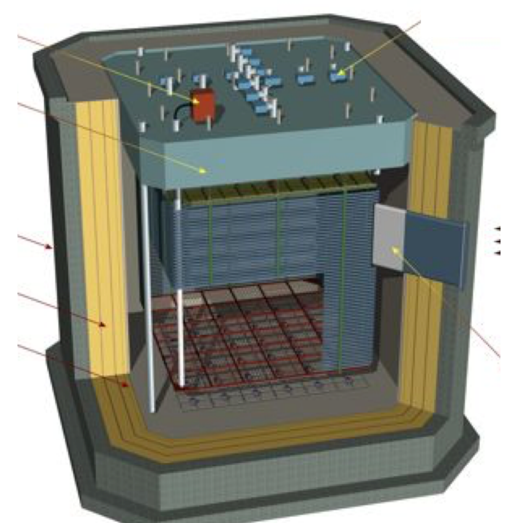
Dual-Phase

WA105 (1x1x3 m³)



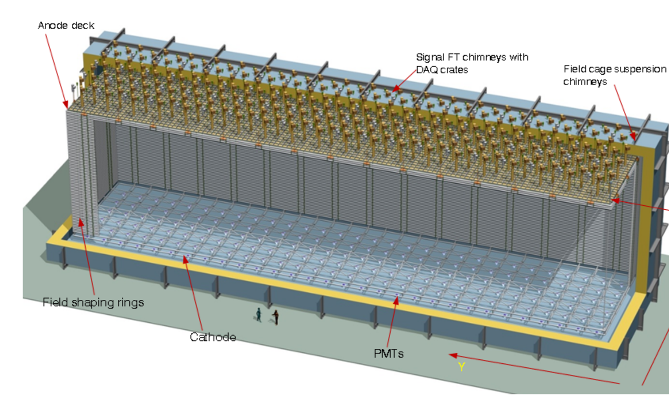
2016

WA105 (6x6x6 m³)



2018

DUNE 10 kT Module
DP - Alternative Design



ProtoDUNEs at CERN:

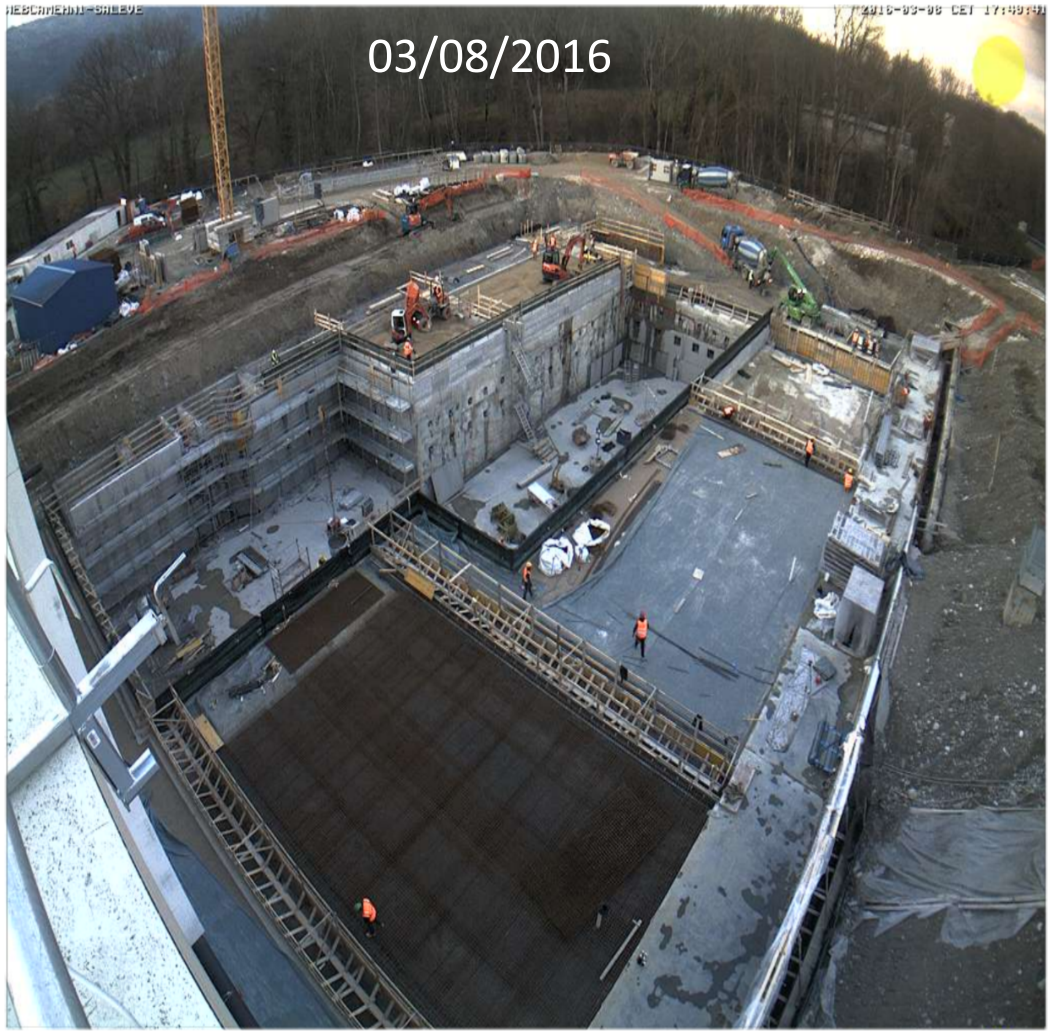
ProtoDUNE Strategy and Objectives

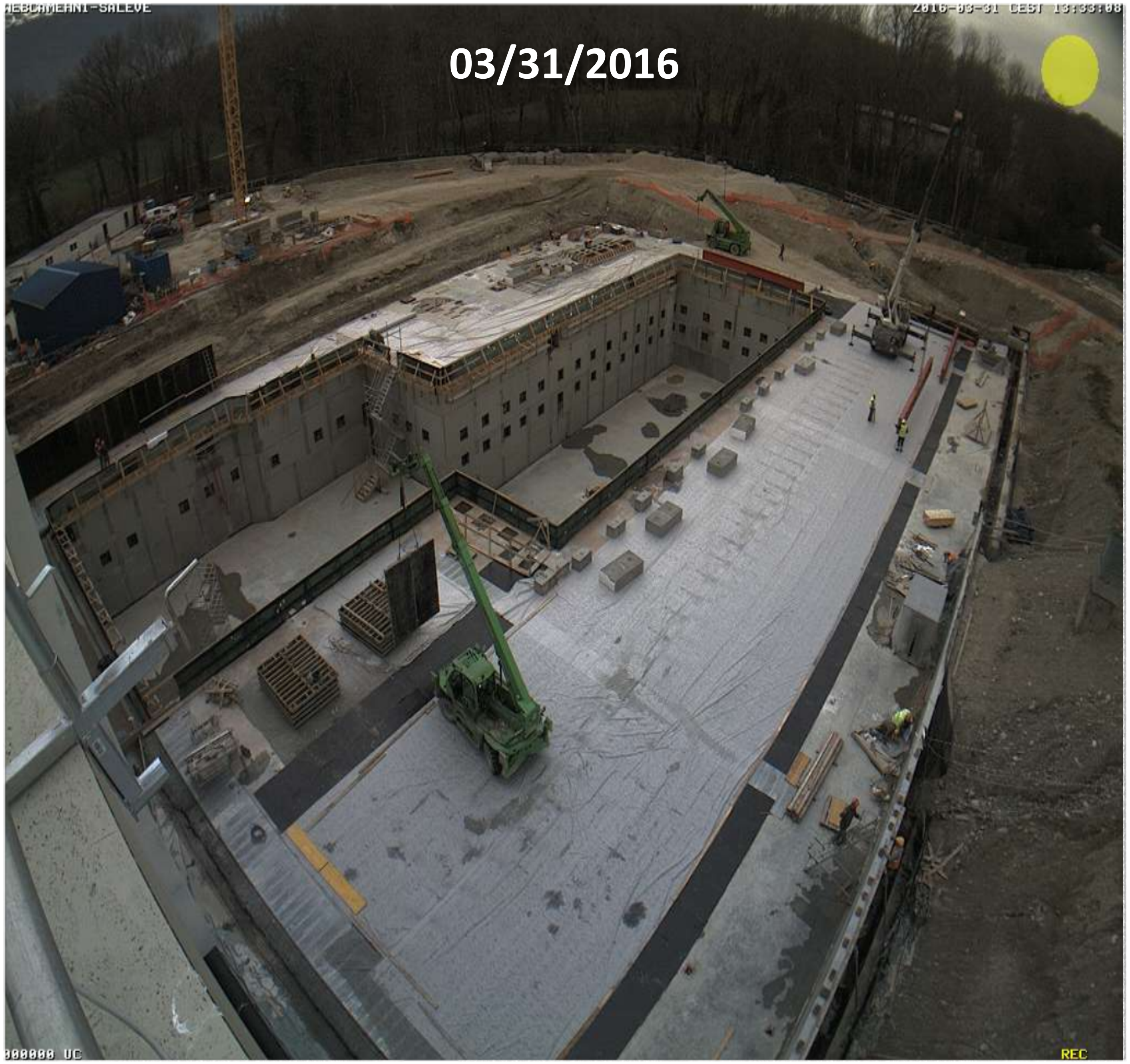
- Operation of **two ProtoDUNE** detectors using **full-scale components** to validate DUNE FD designs and to mitigate risks associated with the FD construction
- Strategic goal of **charged-particle Test Beam** data in both ProtoDUNE detectors prior to the LHC LS2 (Oct. 2018) recognized as being essential for scientific program
- **CERN Neutrino Platform** - *part of the CERN contribution to DUNE* - is a key element toward the evolution of the LArTPC technology

ProtoDUNEs at CERN:
the Neutrino-Platform - update

EHN1 extension status

M. Nessi - NP Report, 7-4-2016





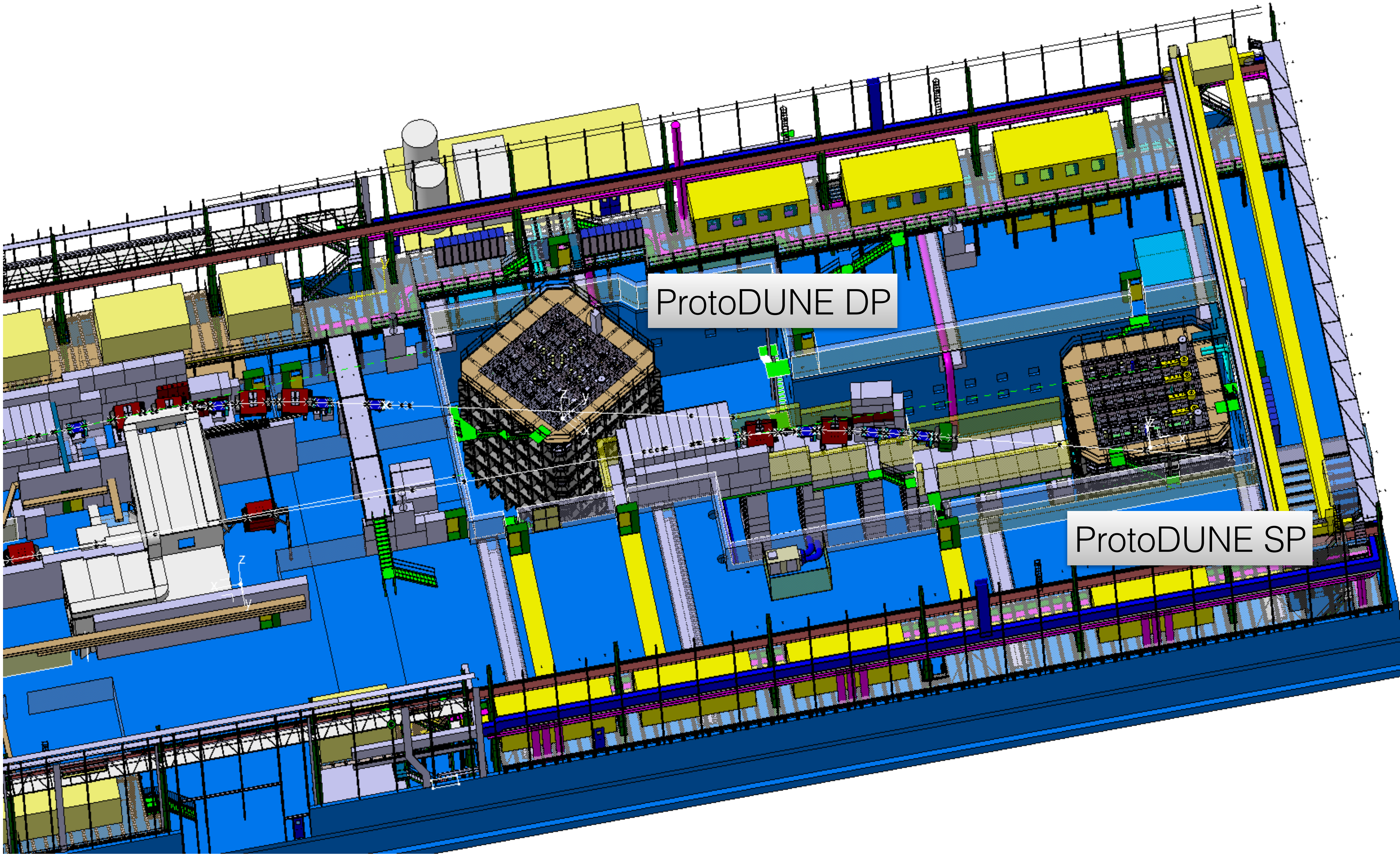
ProtoDUNEs at CERN:

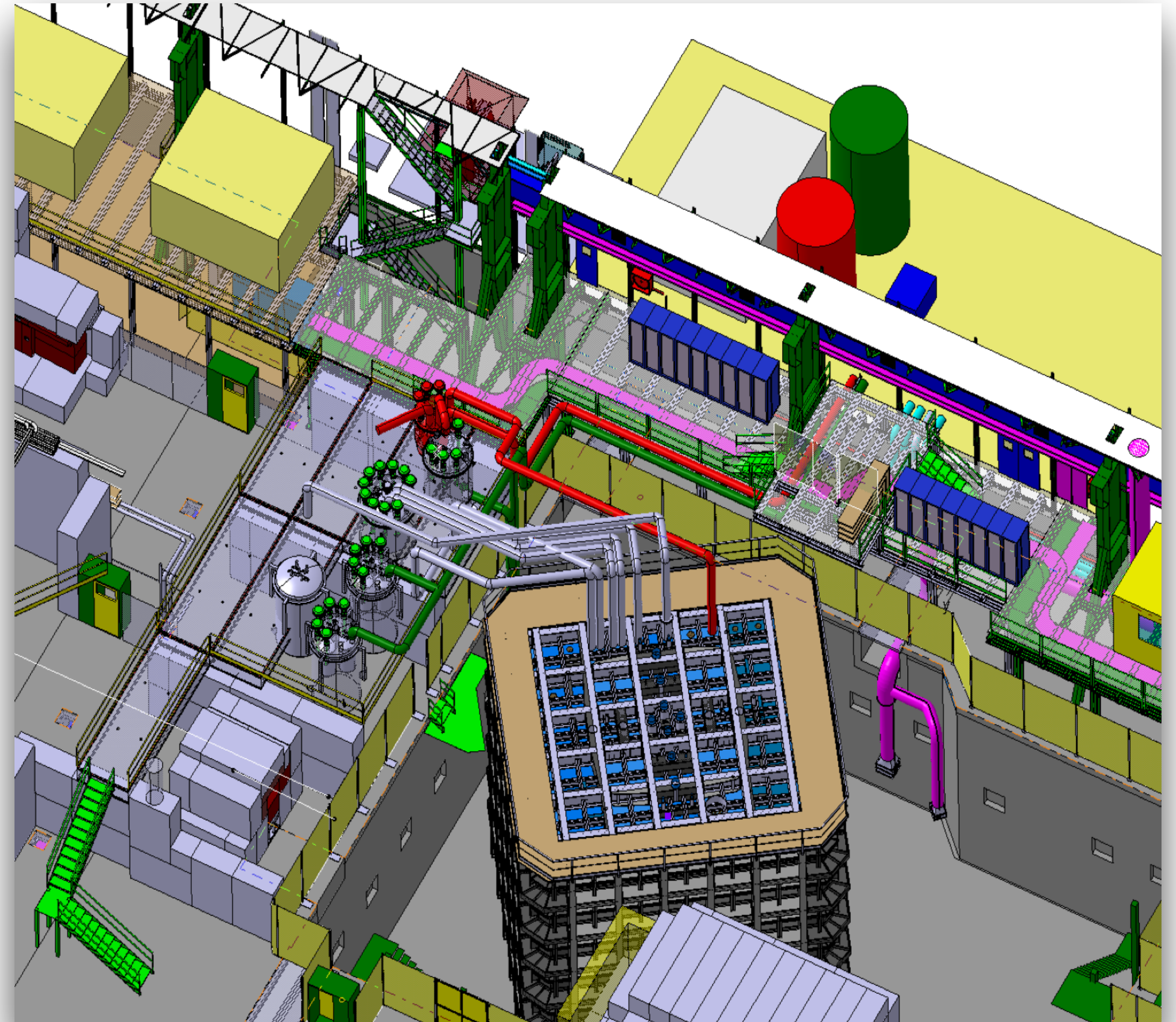
the Neutrino-Platform - update

M. Nessi - NP Report, 7-4-2016

- Extension of the north area EHN1 building
- Most of the civil engineering work done
- Infrastructure (services, safety, logistics, counting rooms, …) organized by the CERN infrastructure team. All components are under procurement or installation.
- EHN extension beneficial occupancy for September 2016
- 2 beam lines in preparations, commissioning in late 2017

Large prototyping activities for LBNF/DUNE

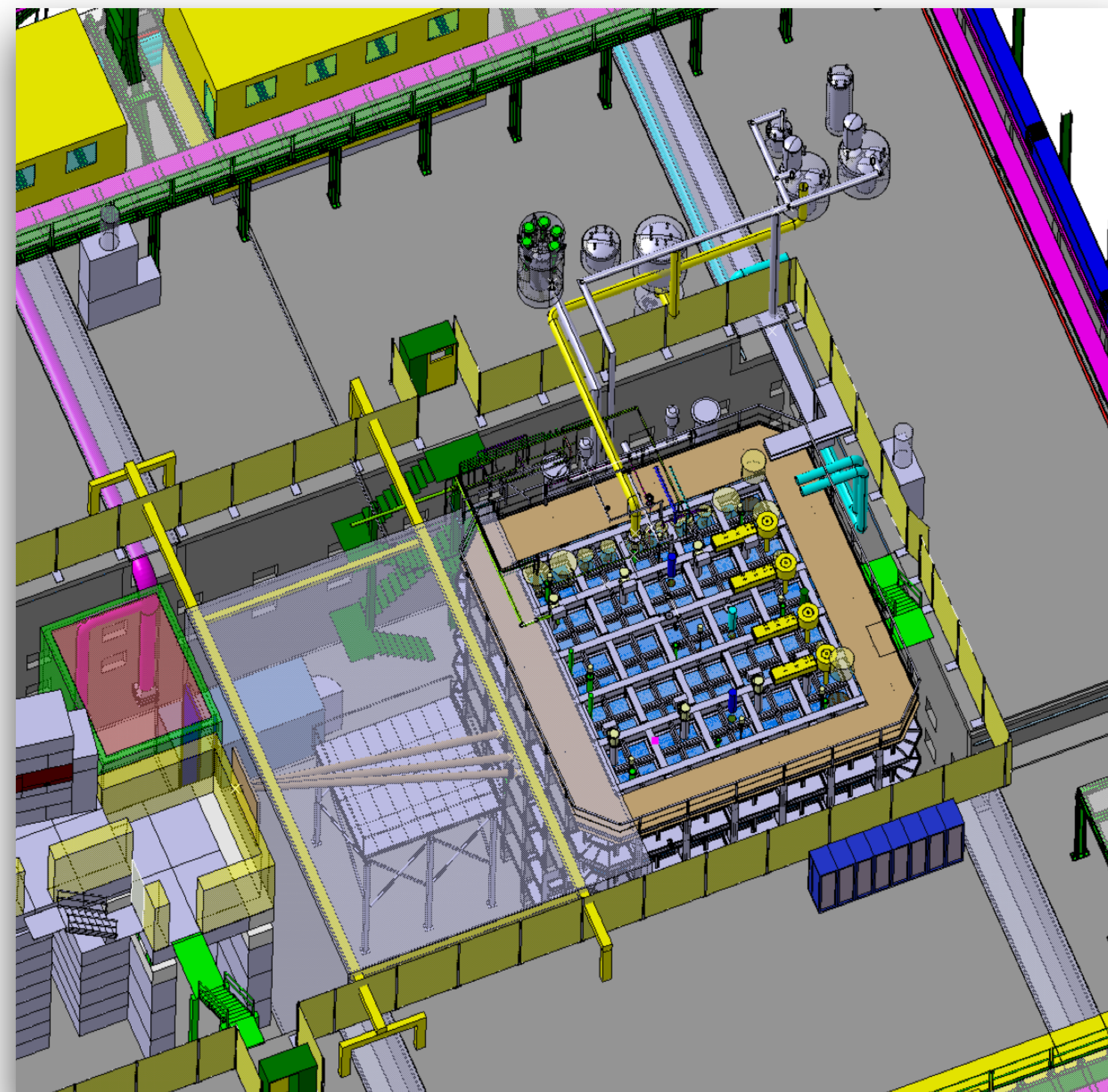




ProtoDUNE
 Dual Phase (WA105/NP02)
CRYOGENIC AREA

ProtoDUNE
 Single Phase (NP04)

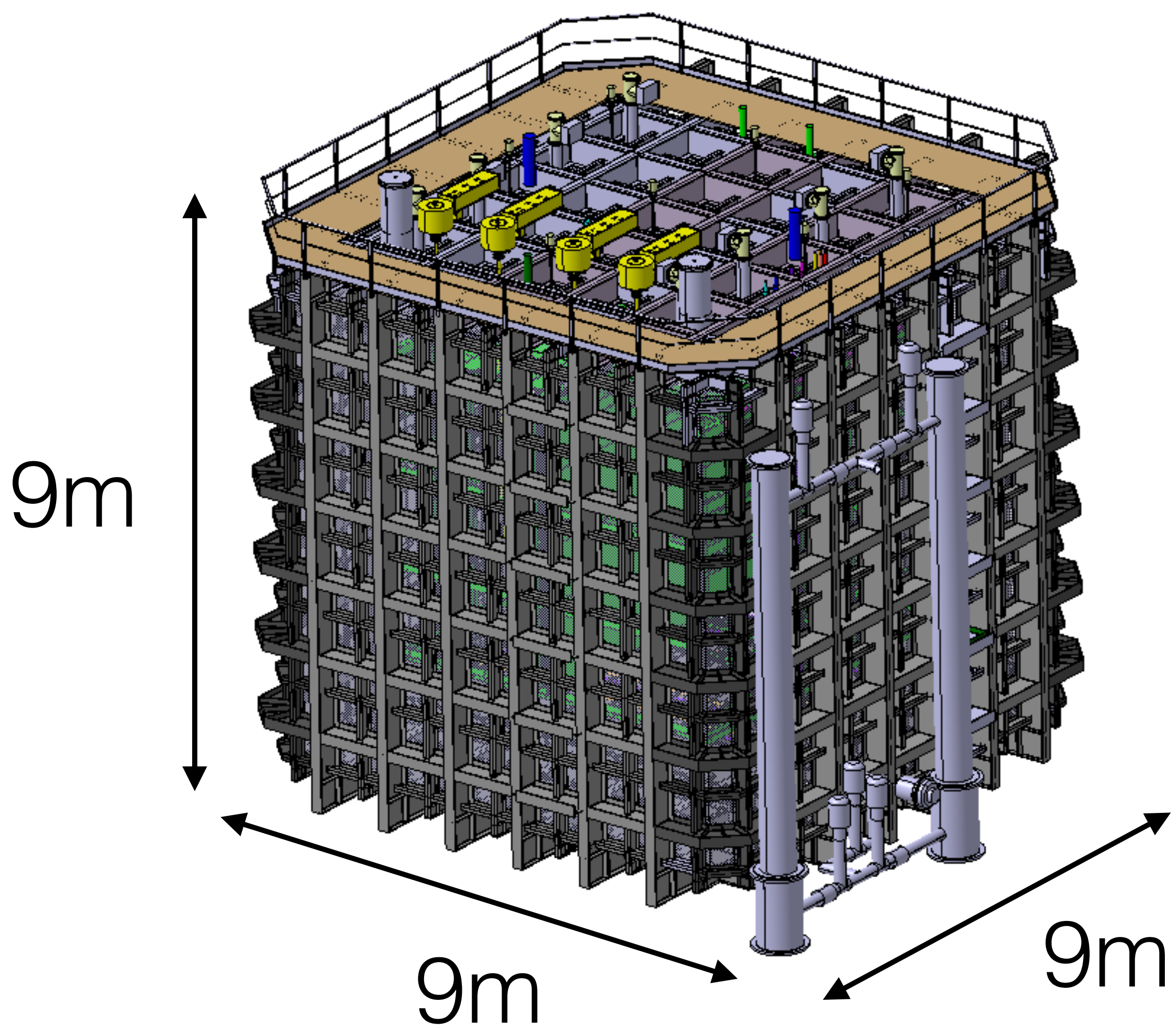
Cryogenics area +
installation clean room



Material shown below from
ProtoDUNE Cryostat Review - FNAL 17-Dec-2015

Cryostat vessels construction

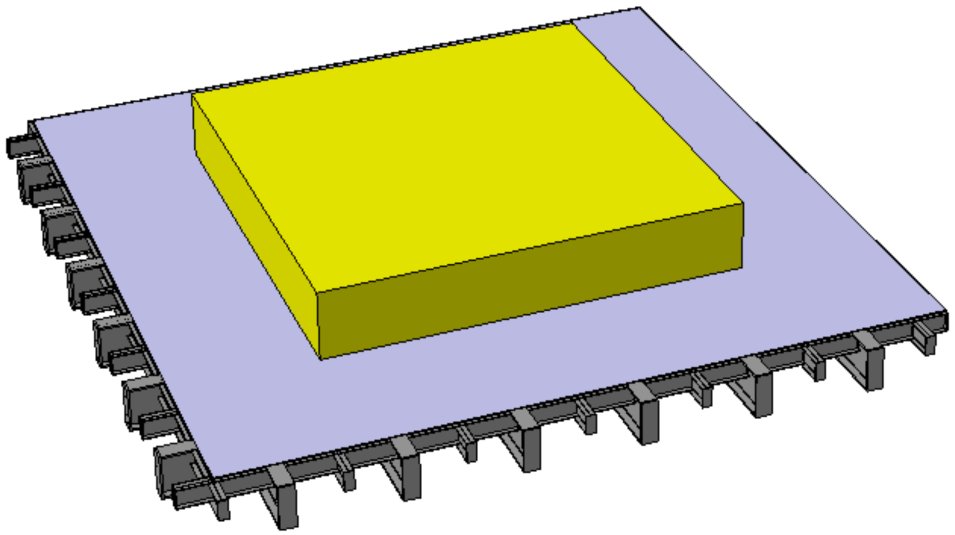
CRYOSTAT EXOSKELETON
FINAL ASSEMBLY



D.Smargianaki

Cryostat vessel construction

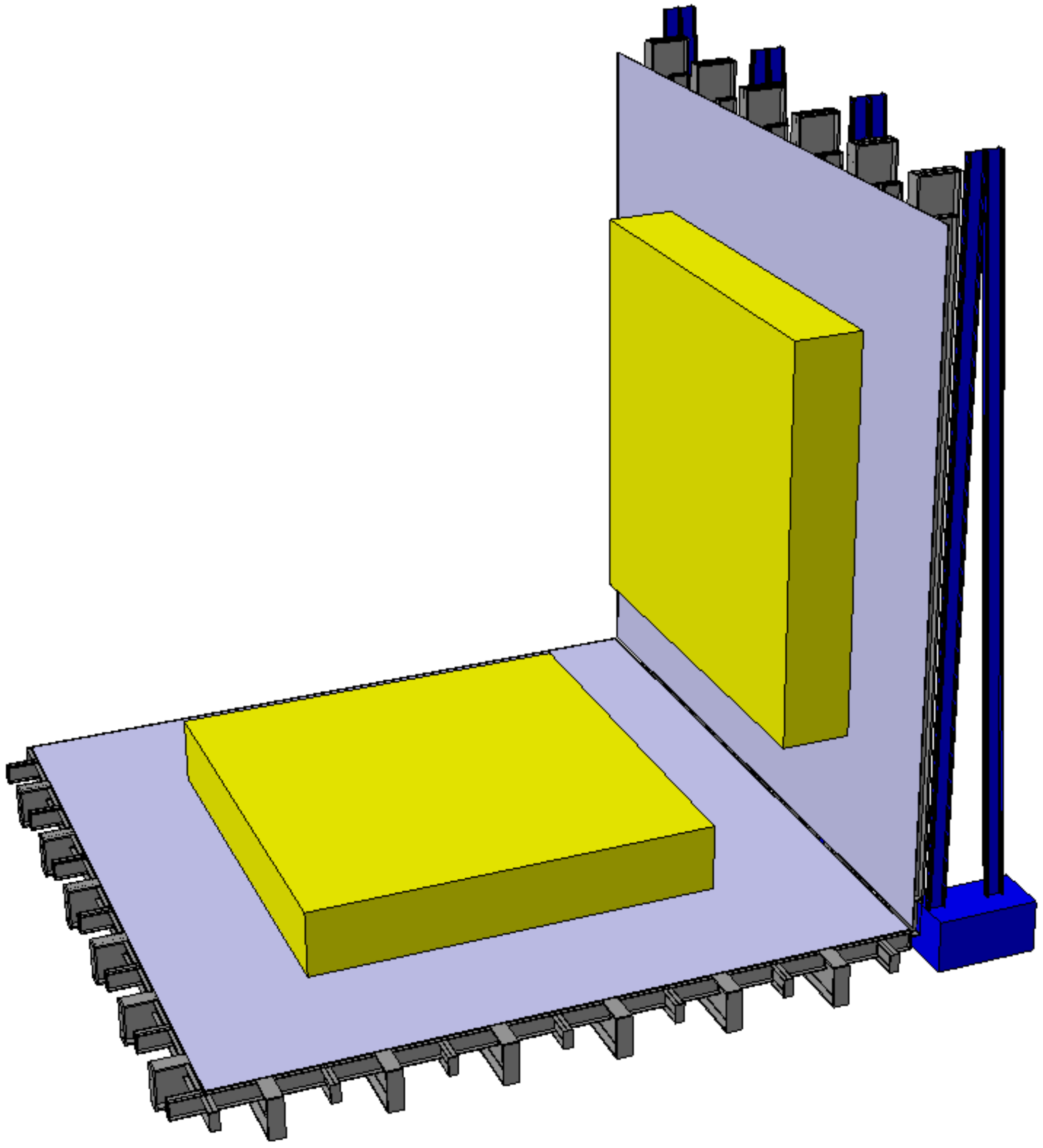
INSTALLATION



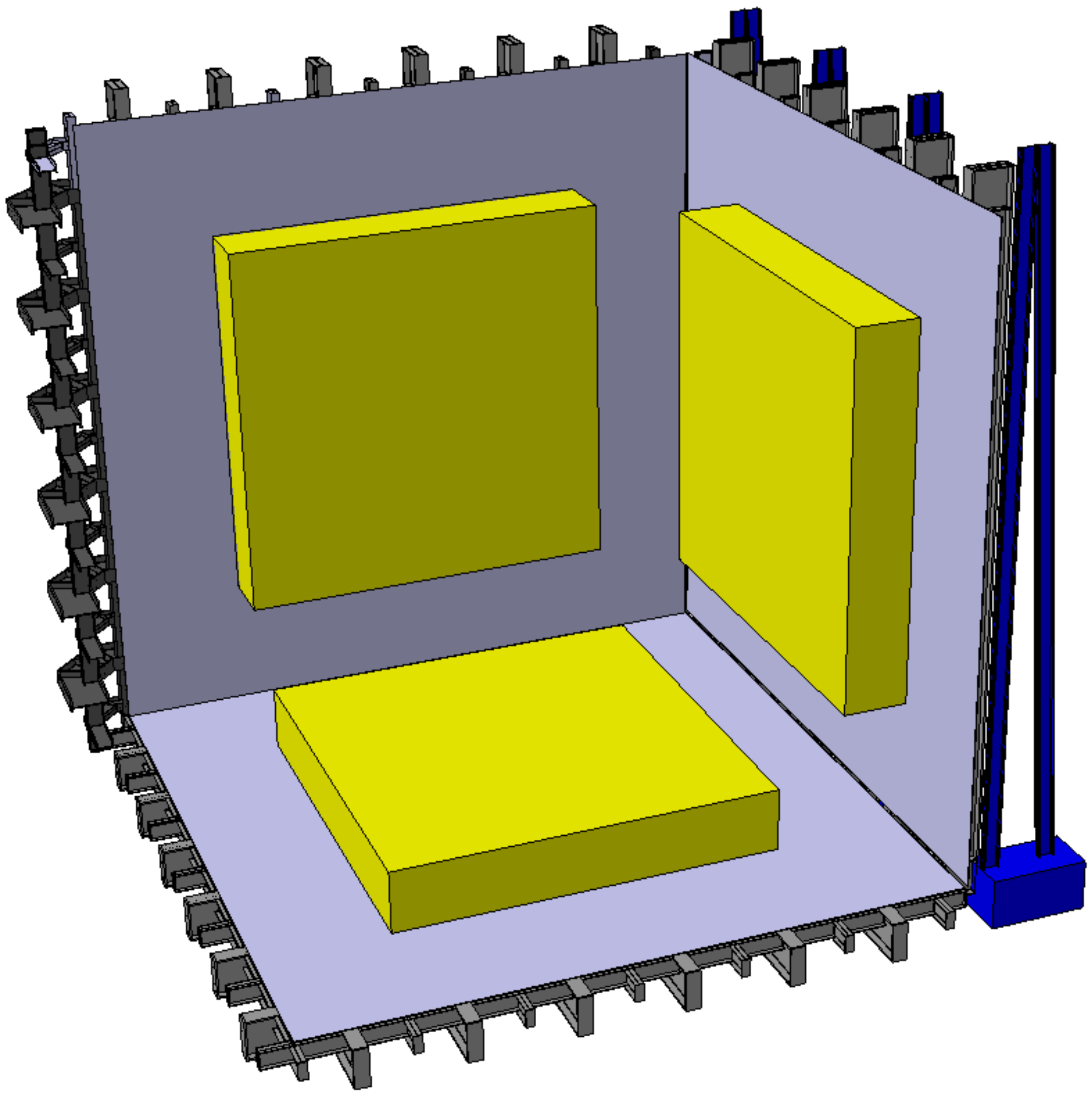
D.Smargianaki

Material shown below from
ProtoDUNE Cryostat Review - FNAL 17-Dec-2015

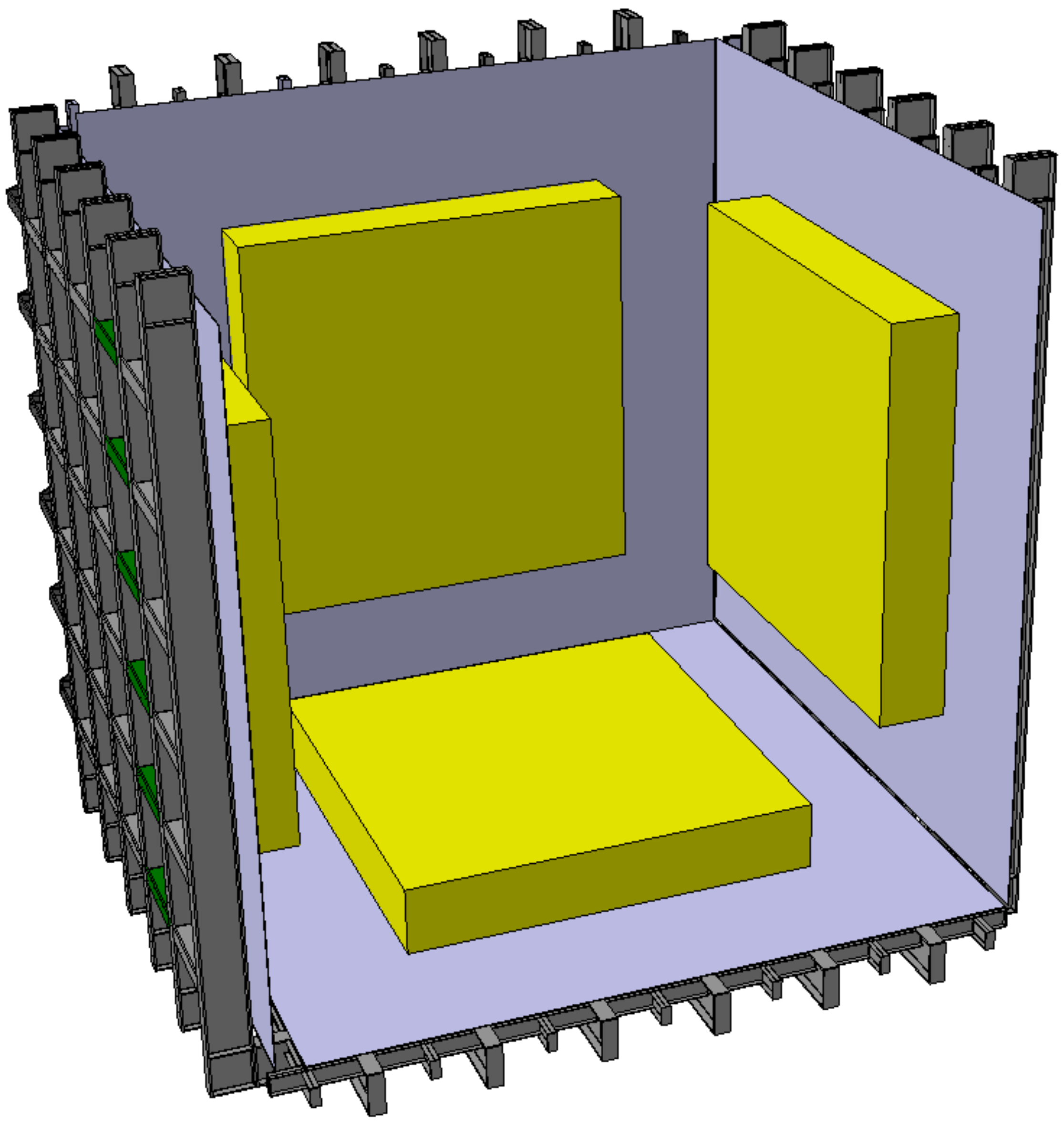
INSTALLATION



INSTALLATION

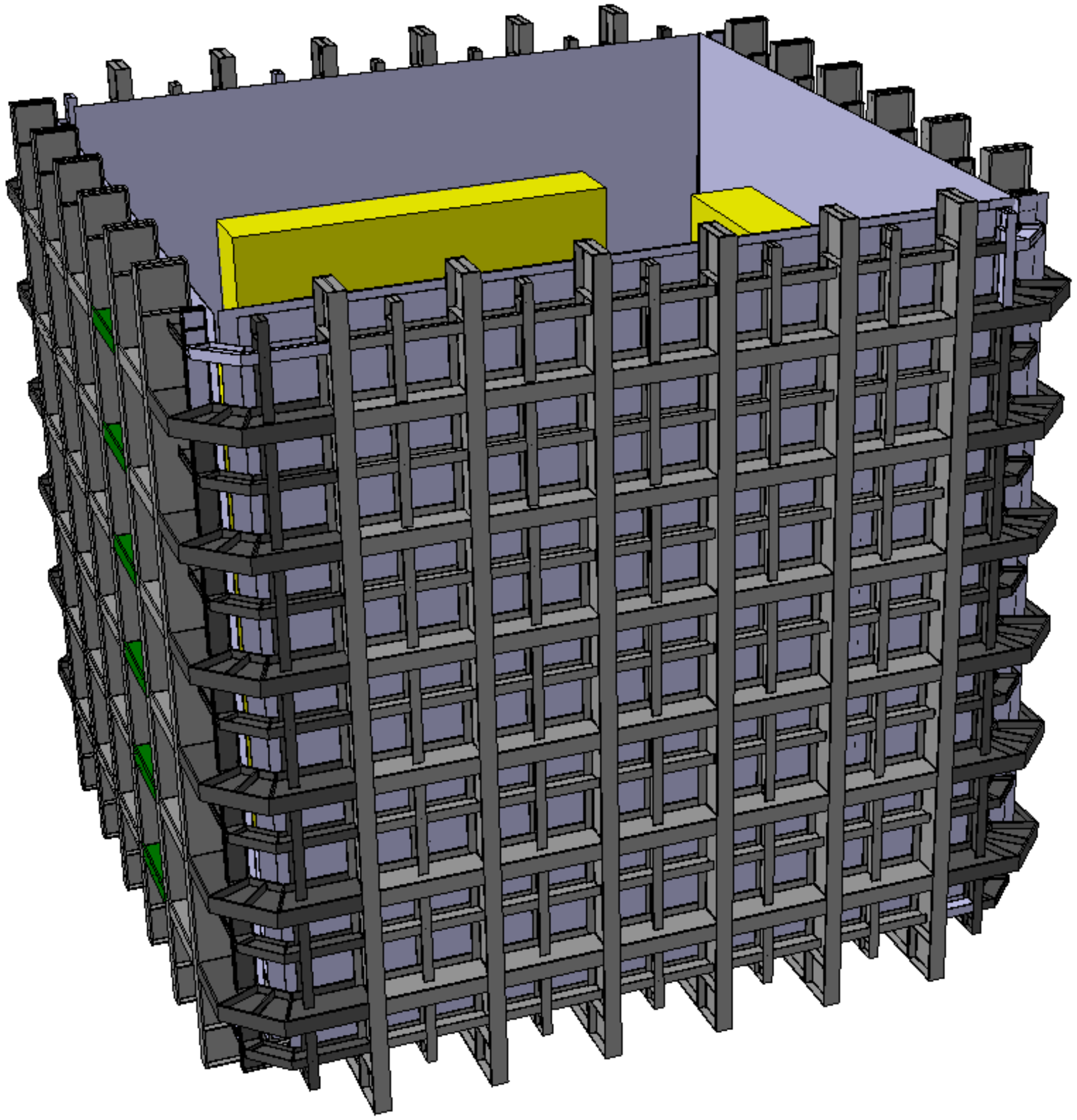


INSTALLATION

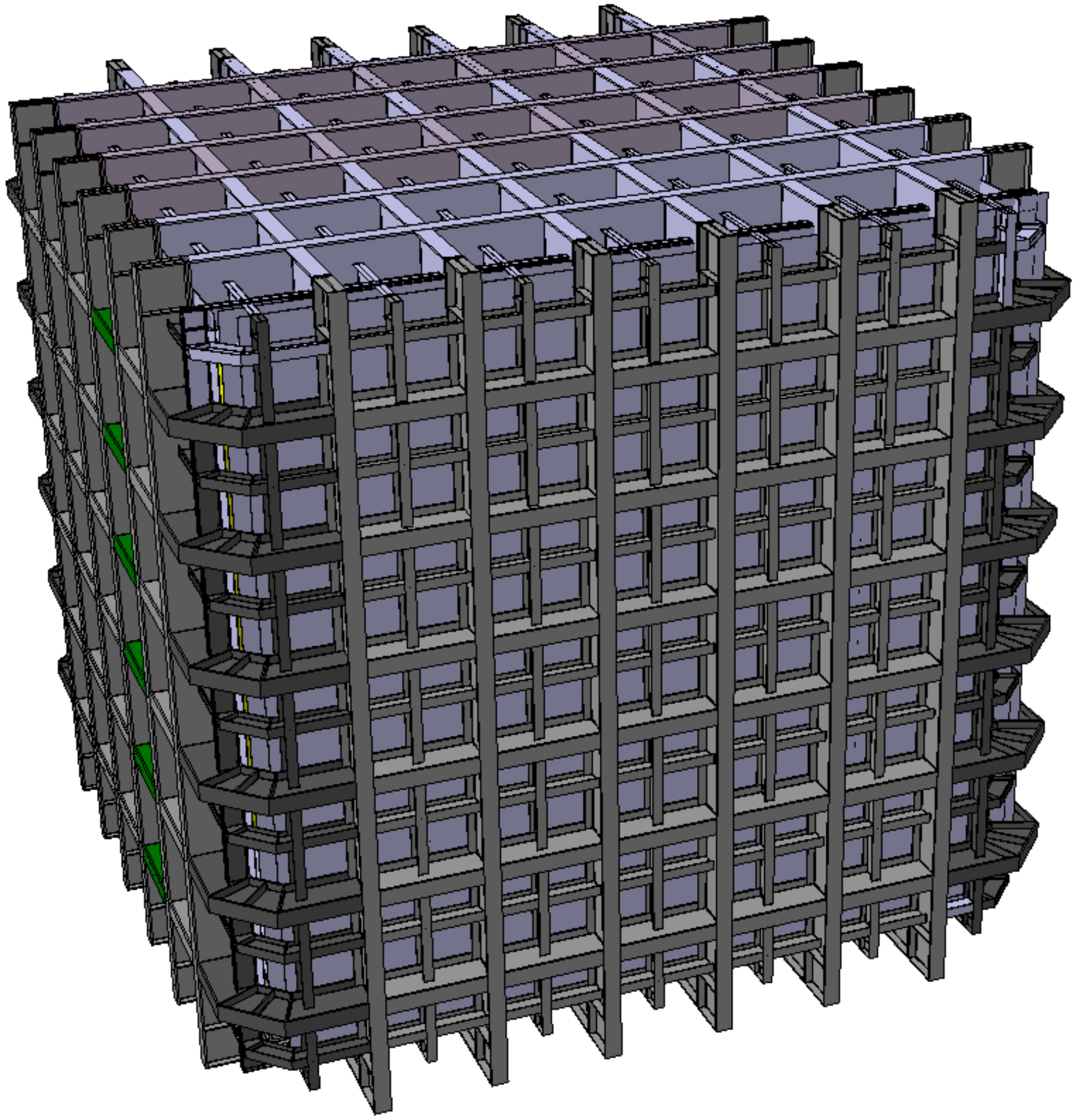


D.Smargianaki

INSTALLATION



INSTALLATION

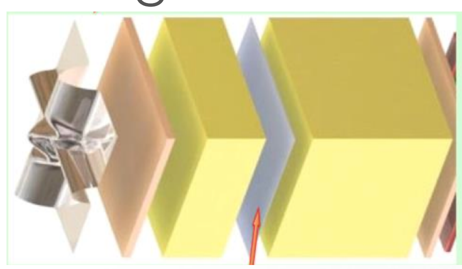


Two similar cryostats

TEMPORARY CONSTRUCTION OPENING

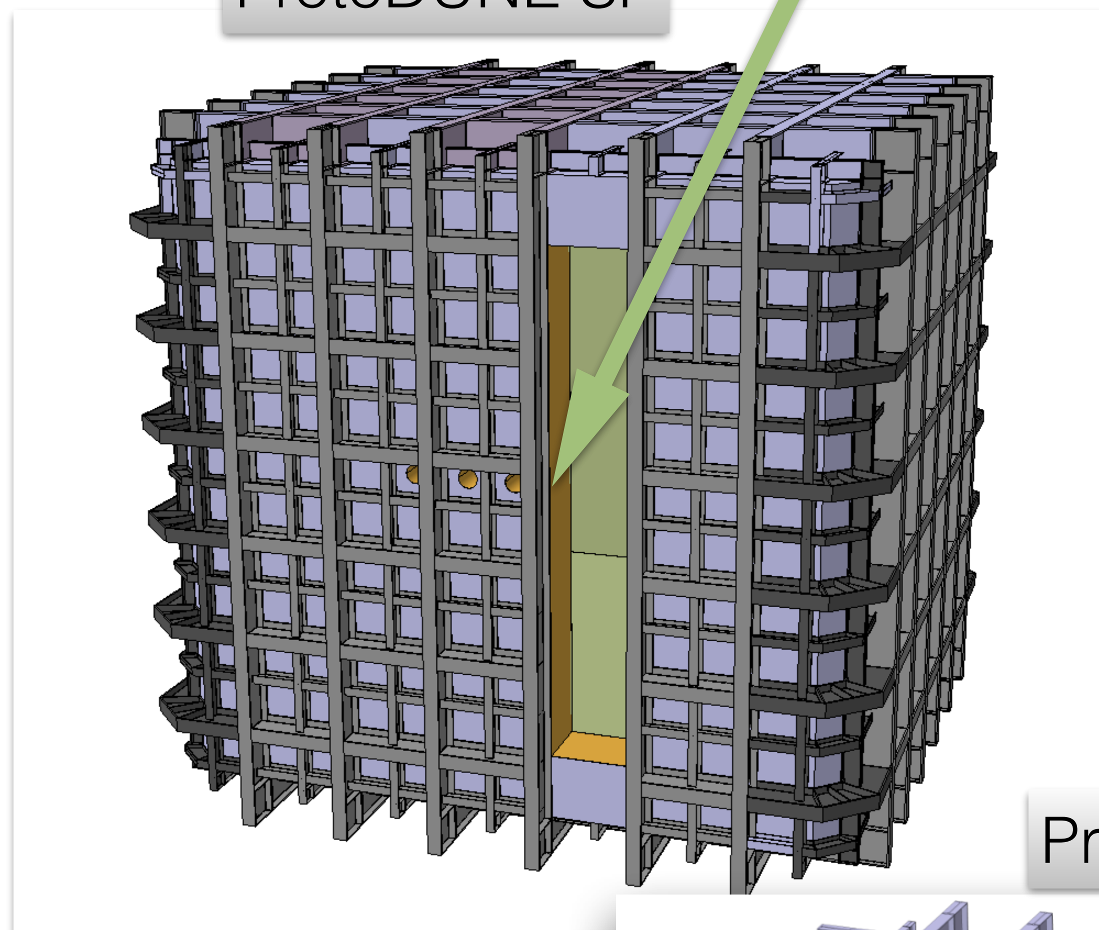
***TCO:** opening of 1372mm x 7900 mm on a side wall for inner detector installation*

- Installation of the remaining insulation
- Install membrane
- Leak test cold vessel

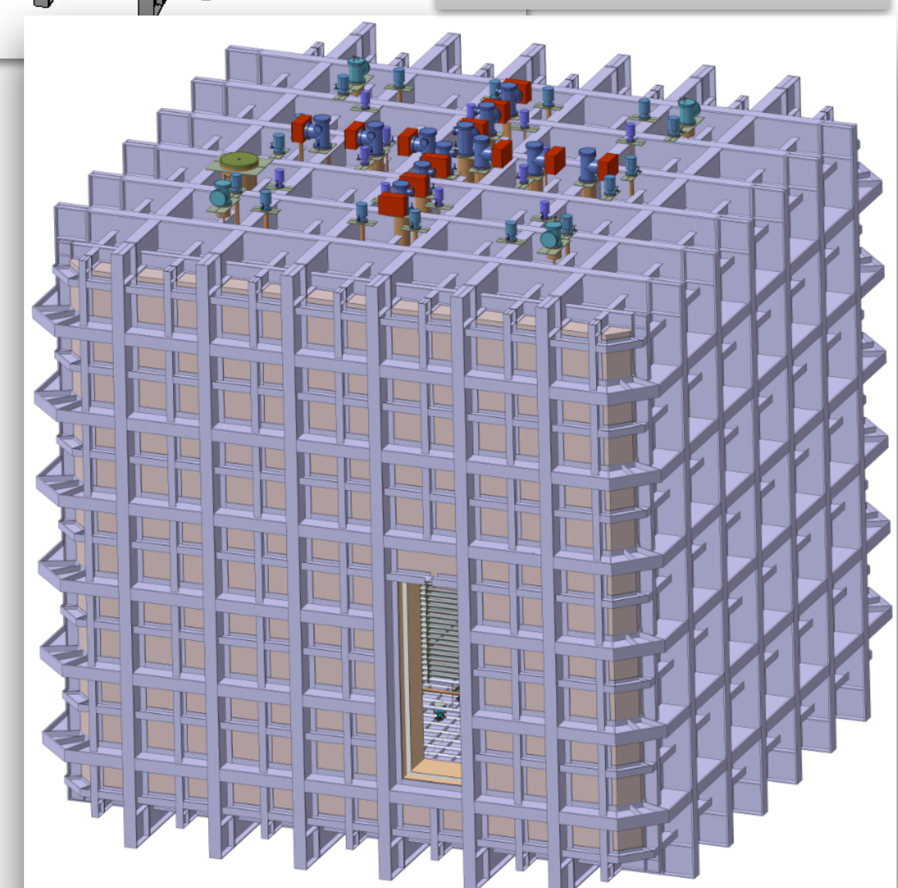


- Installation of the TPC detector
- Close TCO

ProtoDUNE SP

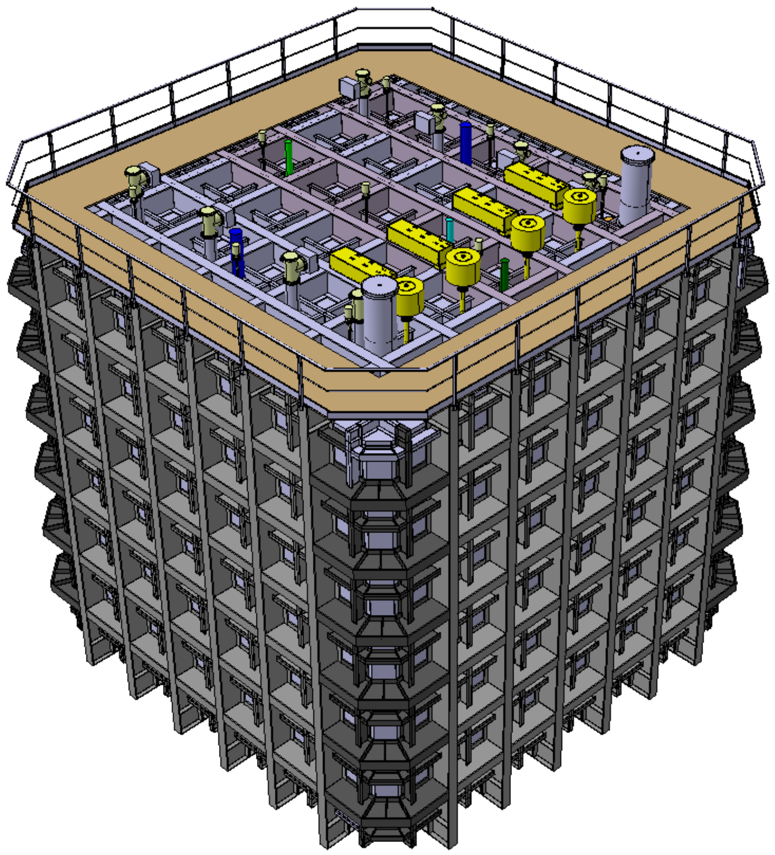


ProtoDUNE DP

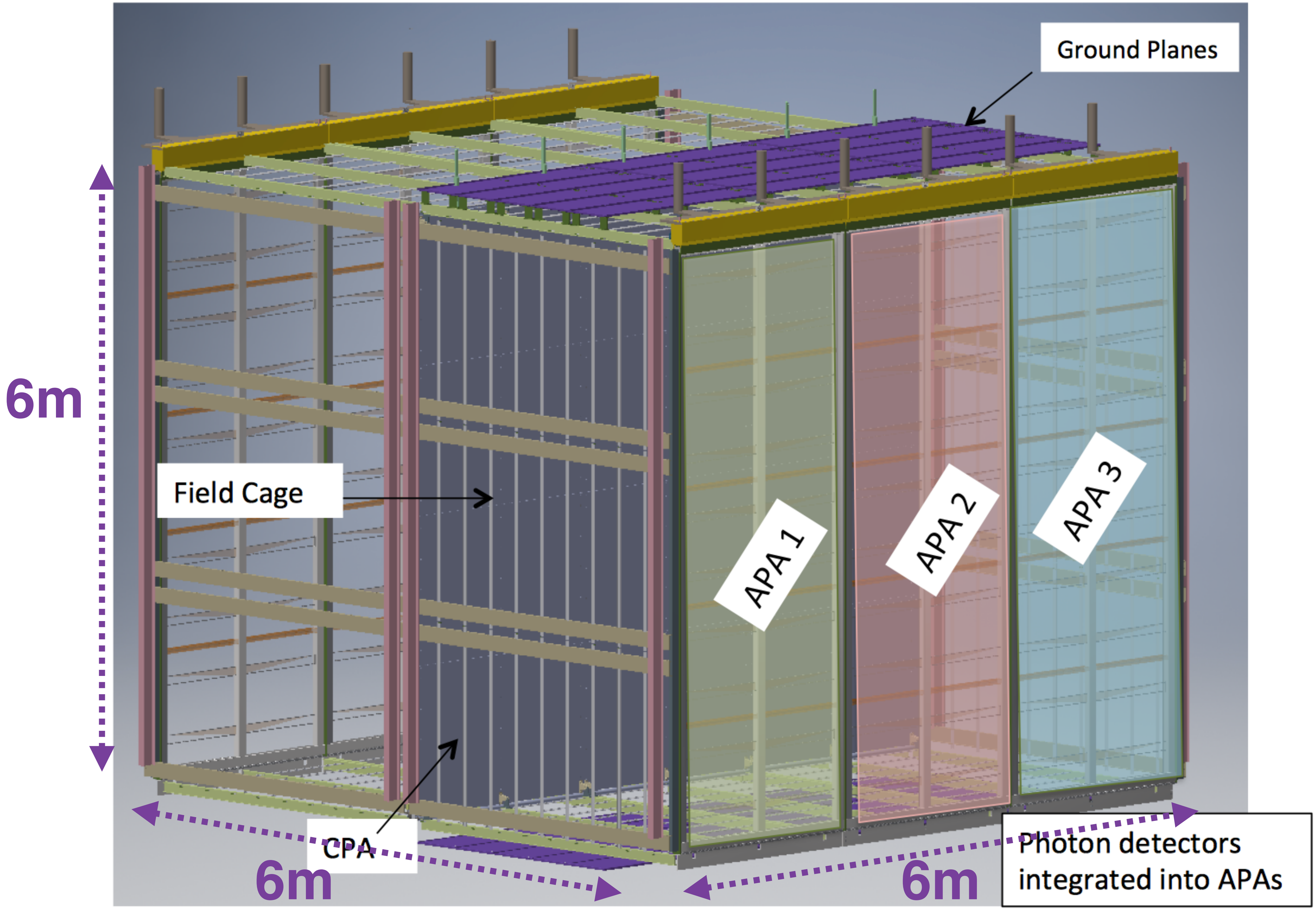


the ProtoDUNE(s) cryostats at the Neutrino-Platform - update

- Membrane cryostats + outer structures
- Outer structure CERN design done
- Membrane cryostat engineering contracted to the firm GTT in Paris
- Requirement documents approved (dimensions, thermal properties, penetration layouts, beam penetrations, internal cryogenics, …)
- Construction contract for the outer structure in place, delivery in summer 2016
- Tendering for the membrane material ongoing, goal for delivery: end September
- Tendering for membrane + insulation installation in preparation. Work should start in October
- Costs covered by CERN for both cryostats
- **Goal, cryostats ready for spring 2017**



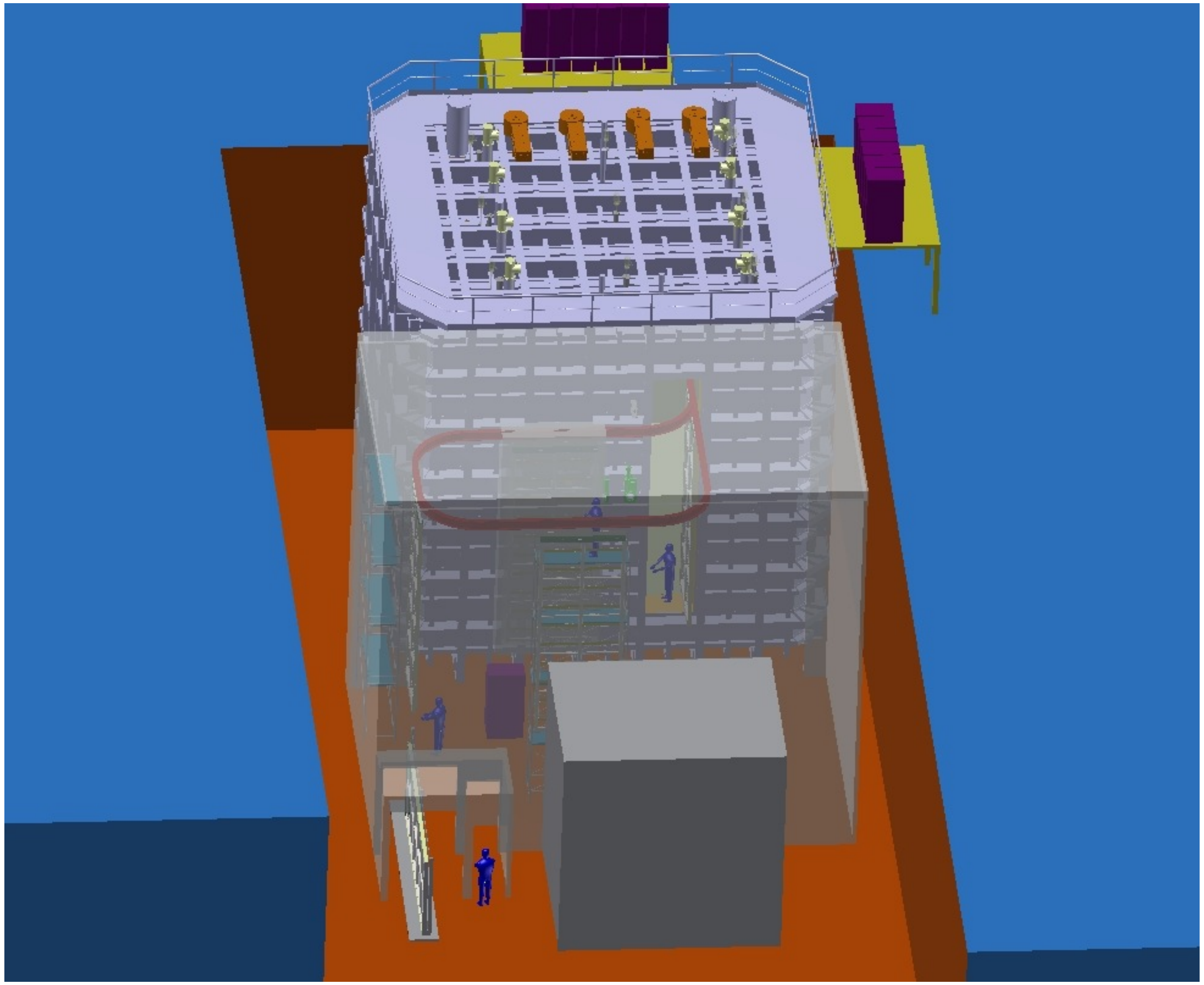
ProtoDUNE SP The LAr-TPC detector



ProtoDUNE SP at CERN:

Detector integration and installation - update

Conceptual view of installation area in Pit B EHN1

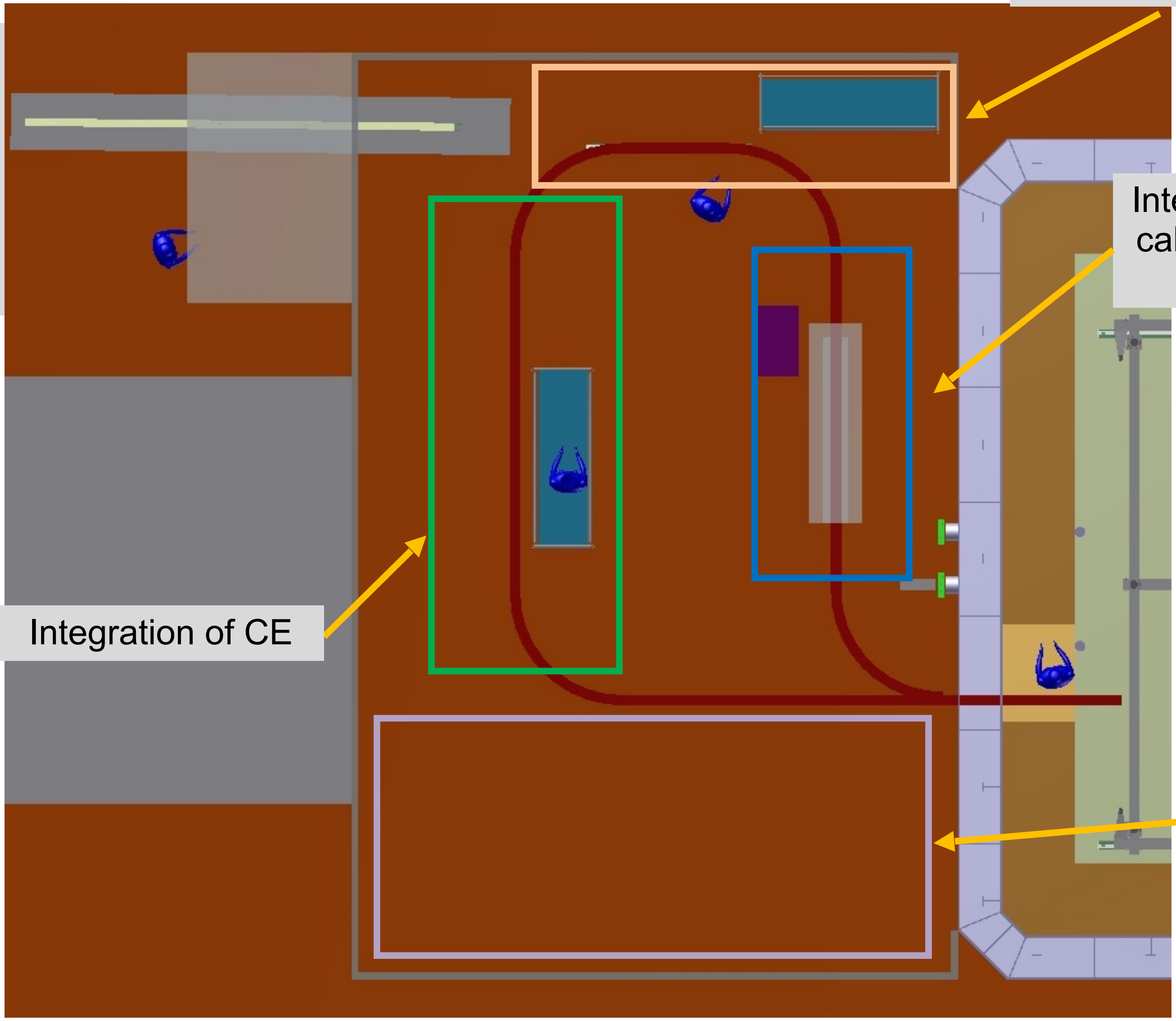


ProtoDUNE SP

ProtoDUNE SP at CERN:
Detector integration and installation - update

Conceptual layout of clean space in EHN1

- SAS comments
- Small parts and tools can arrive via the personnel SAS.
- Large components will be lowered through a vertical SAS to enter inside the clean space.



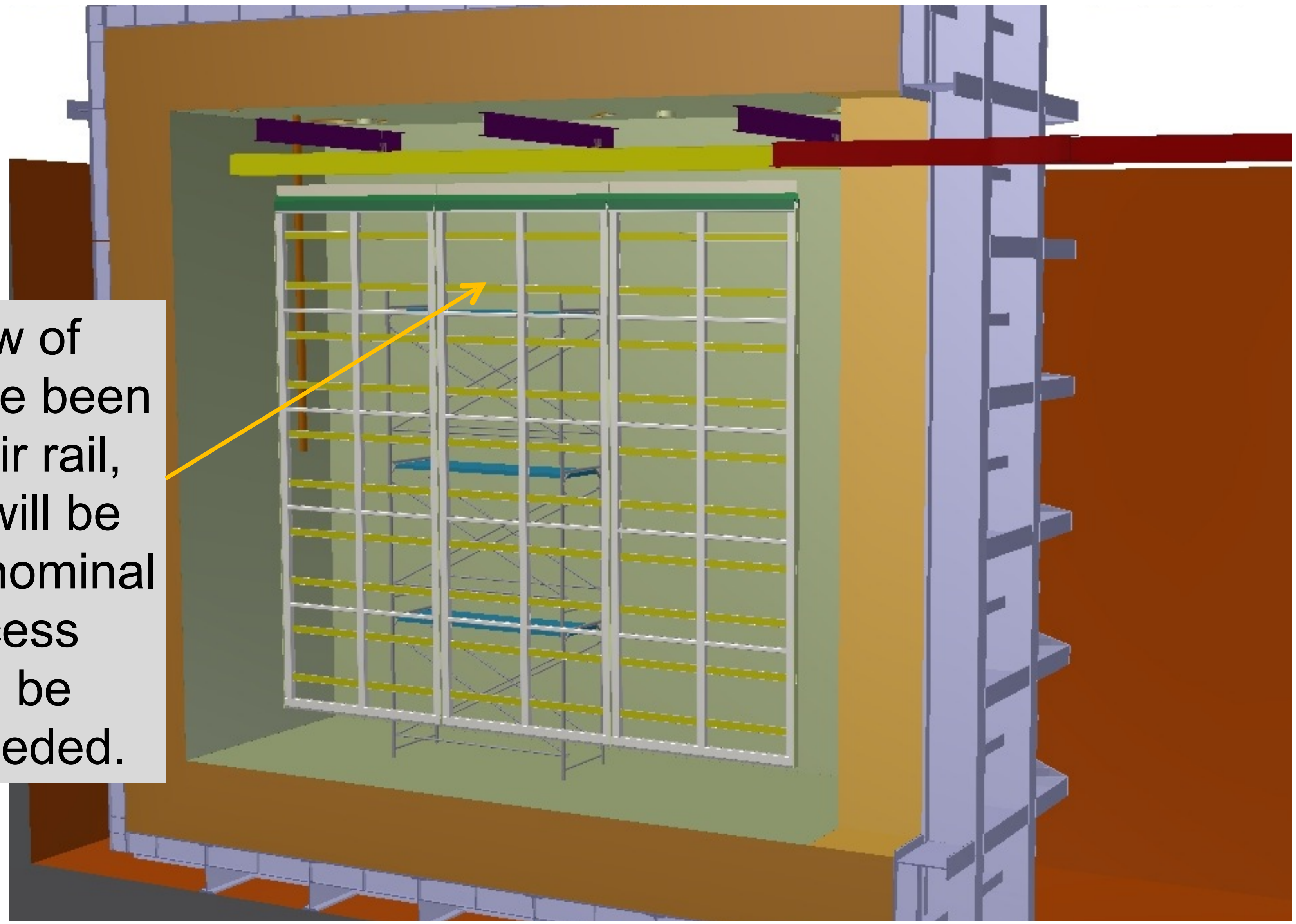
Integrate PD

Integrated cold test box (could be cabled to full chain electronics on top of cryostat)

Integration of CE

CPA, FC, ground plane integration area (~4 x 8.5 m). Leaving this space available allows for APA integration and installation inside the cryostat to happen in parallel.

Complete rows of APAs /CPAs will be translated into position

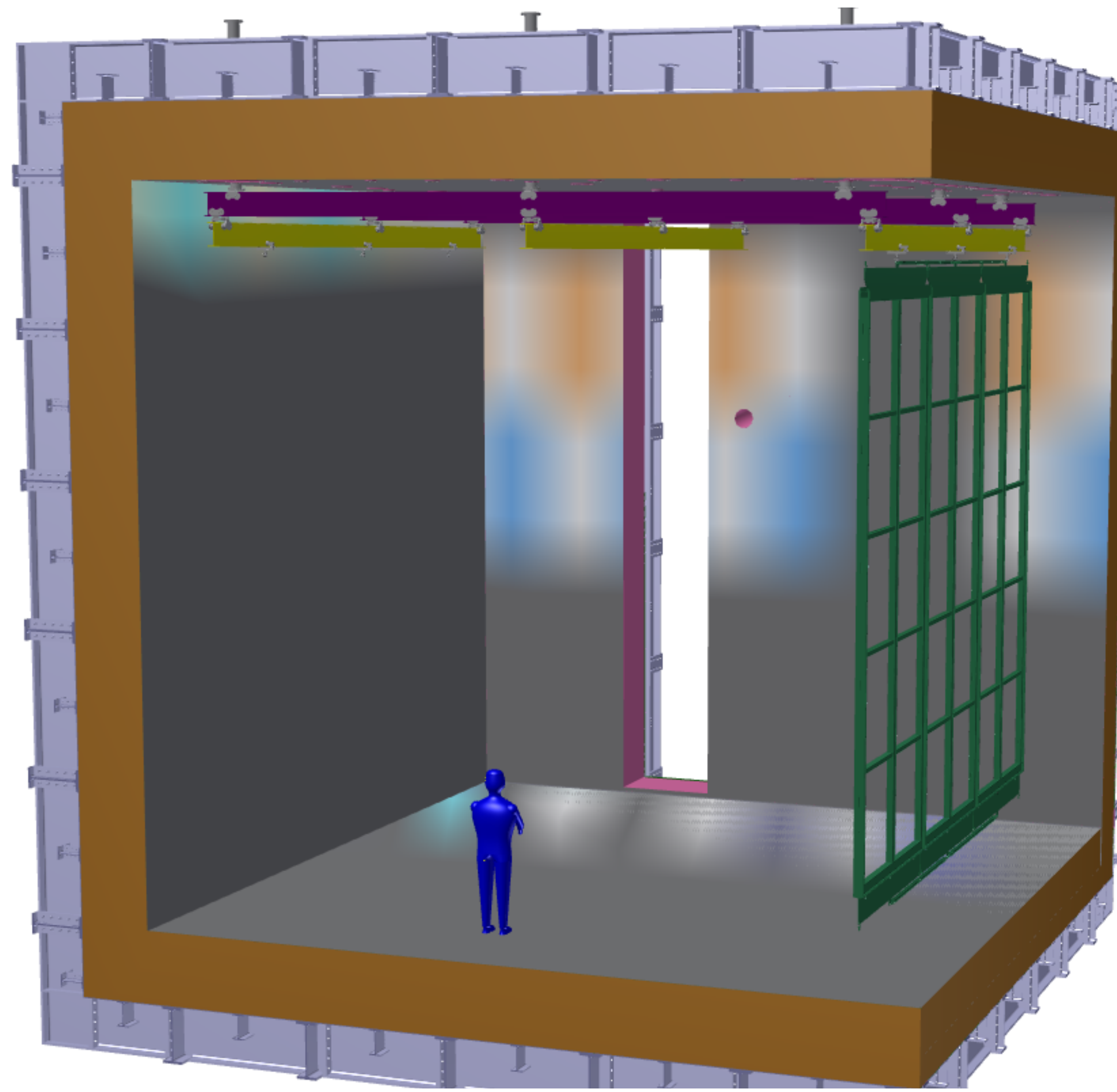


After a full row of components have been installed on their rail, the entire row will be translated to its nominal position. Access platforms will be relocated as needed.

ProtoDUNE SP at CERN:
Detector integration and installation - update

Detector installation #1

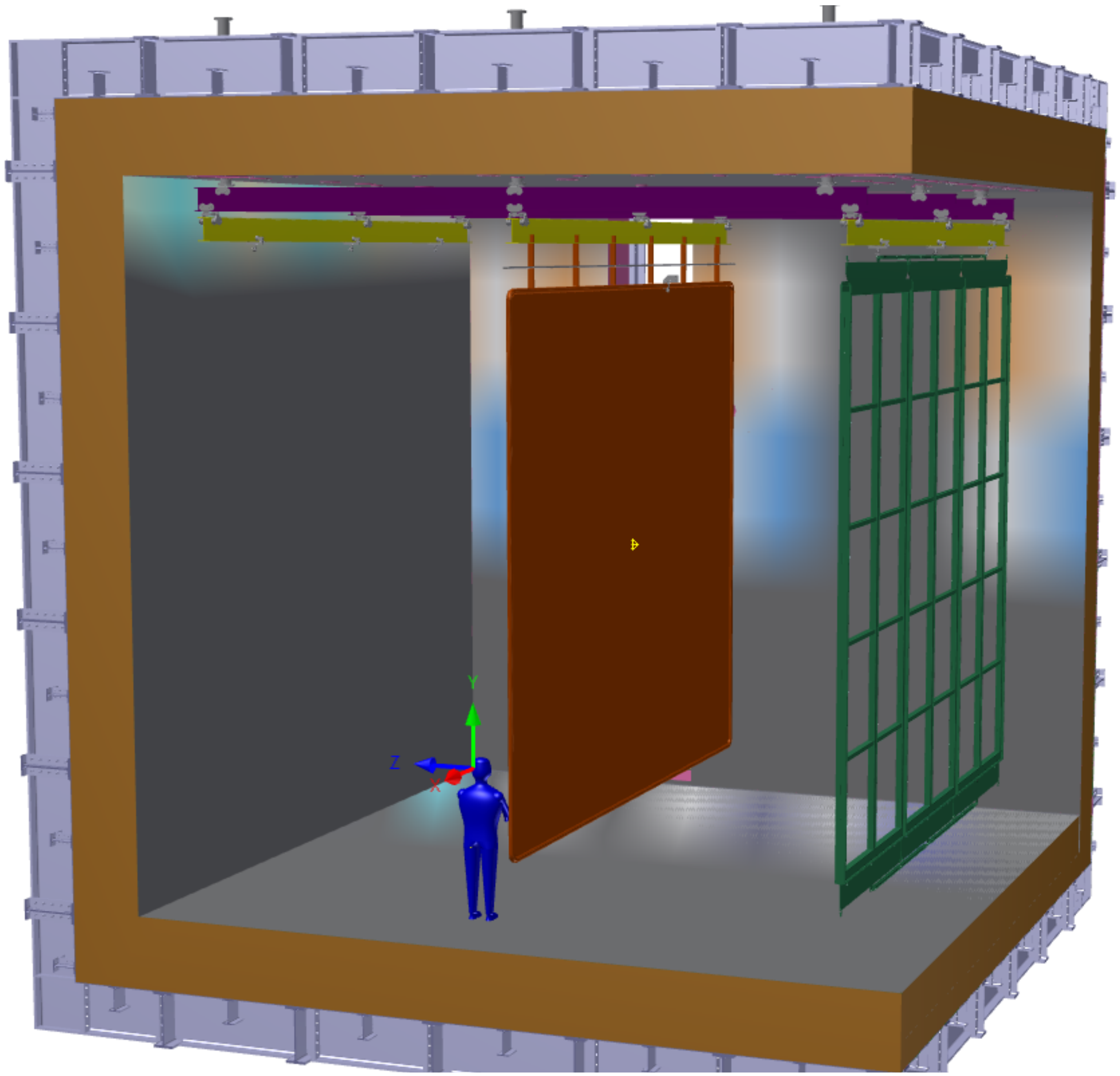
- After full row is complete, the APAs will be un-cabled and translated to the Jura position and cabled to Jura FT for continued testing.
- New rail will be moved into the "install position." The installation of the CPAs can begin.



ProtoDUNE SP at CERN

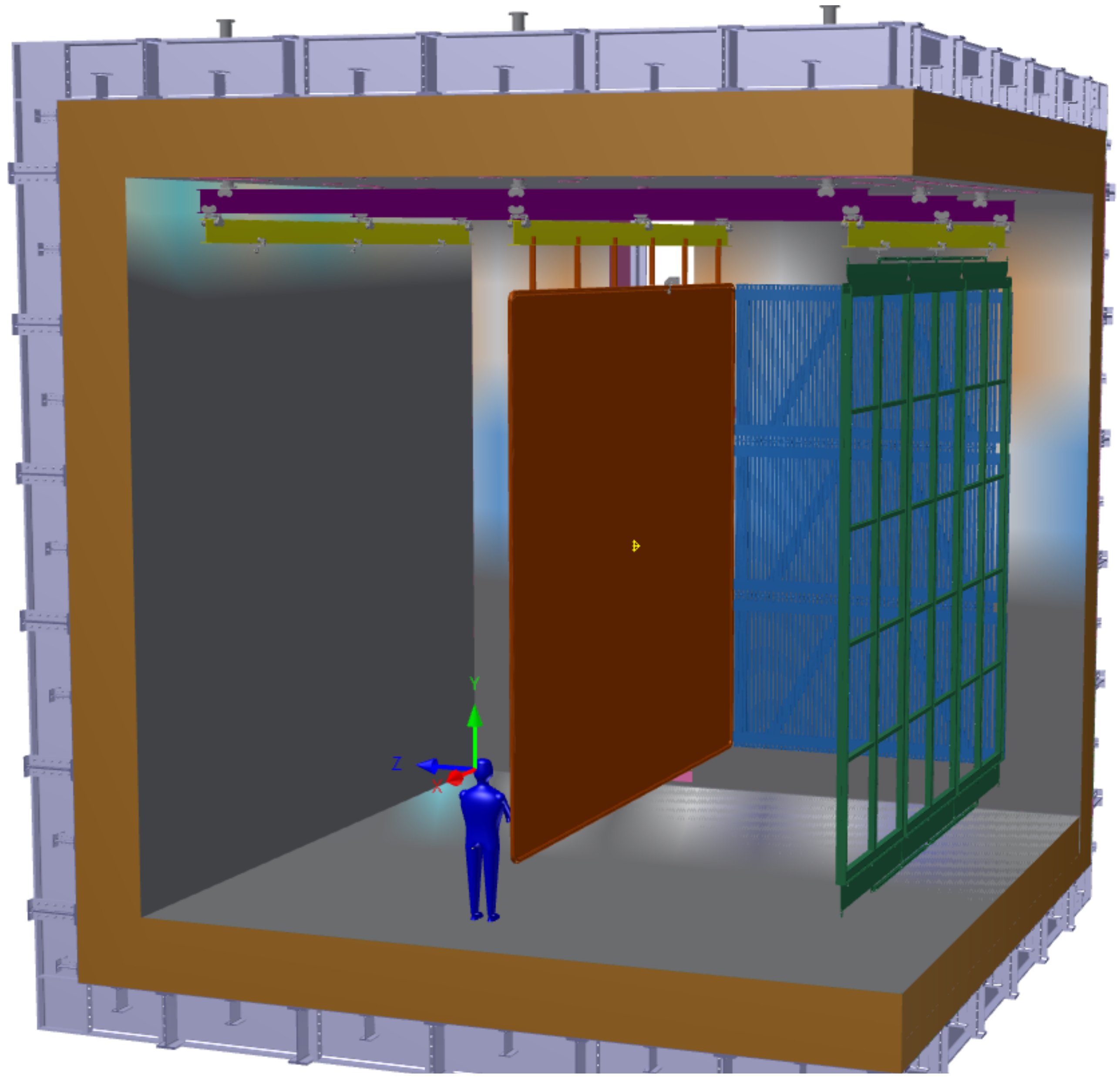
Detector installation #2

- After the CPA row is complete, it will be translated to the nominal position.
- Work can now begin on the installation of the Jura side FC.
- This order of installation is done to allow more time for APAs 4, 5 and 6 to be integrated and tested outside of the cryostat.
- Scaffolding or other access equipment will be available in the drift region between the APAs and CPAs.



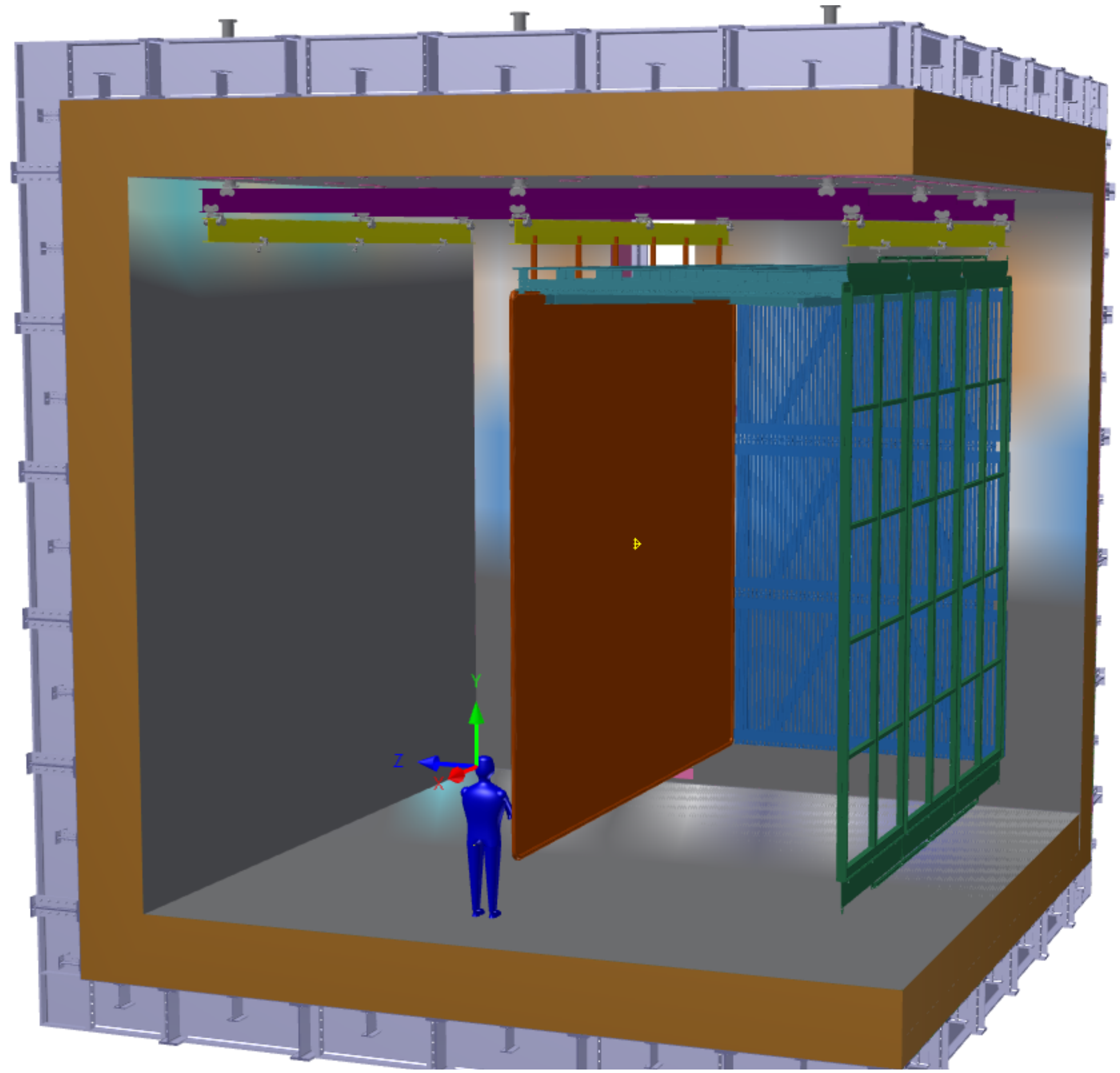
Detector installation #3

- The beam side end wall FC will be installed.
- The beam plugs for this drift volume will be installed on the end wall panels.



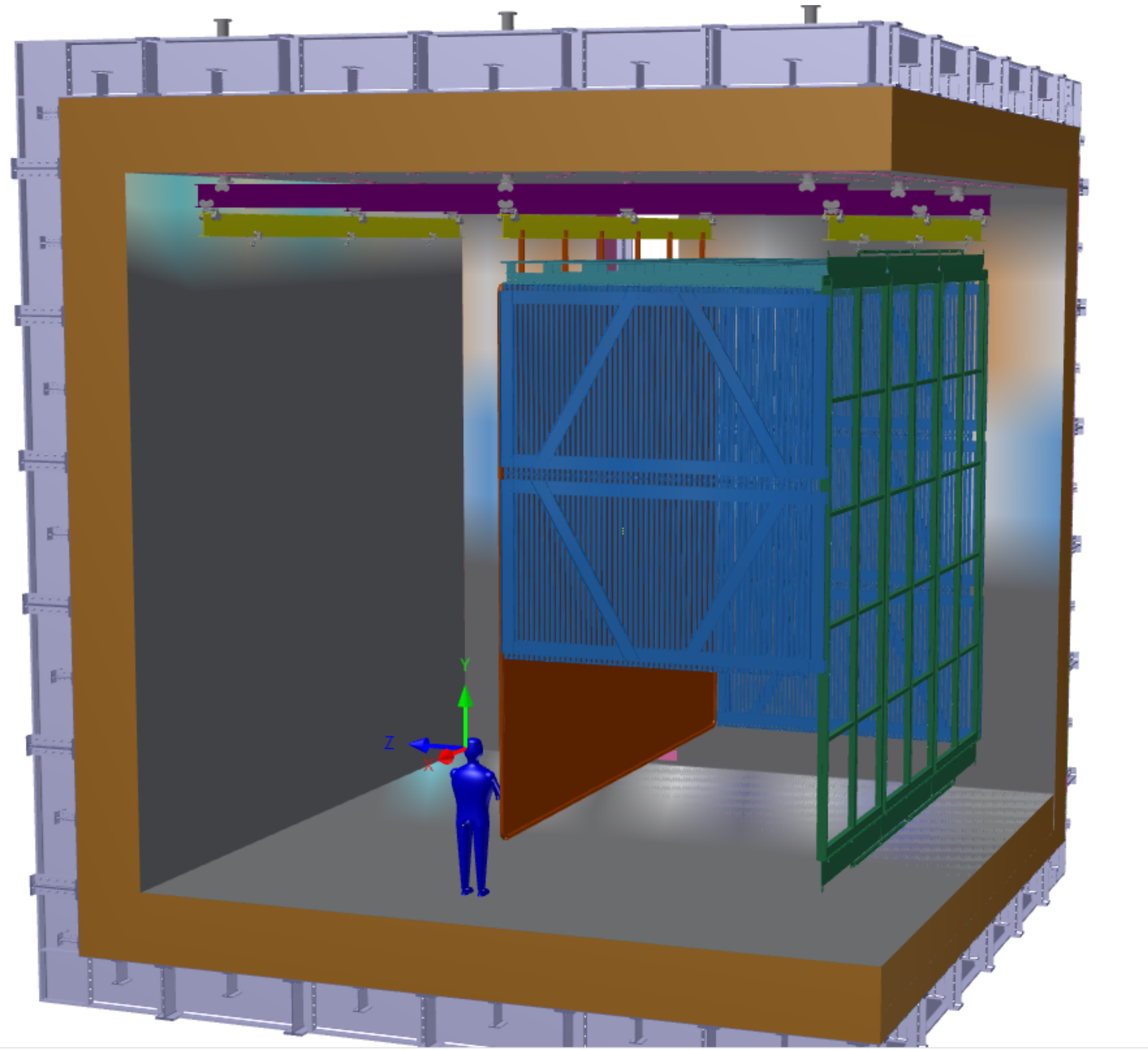
Detector installation #4

- The 3 upper field cage panels will be installed. This will be done starting from the beam window side.
- Note: Access to the CE on APAs 1, 2 and 3 is now not possible.



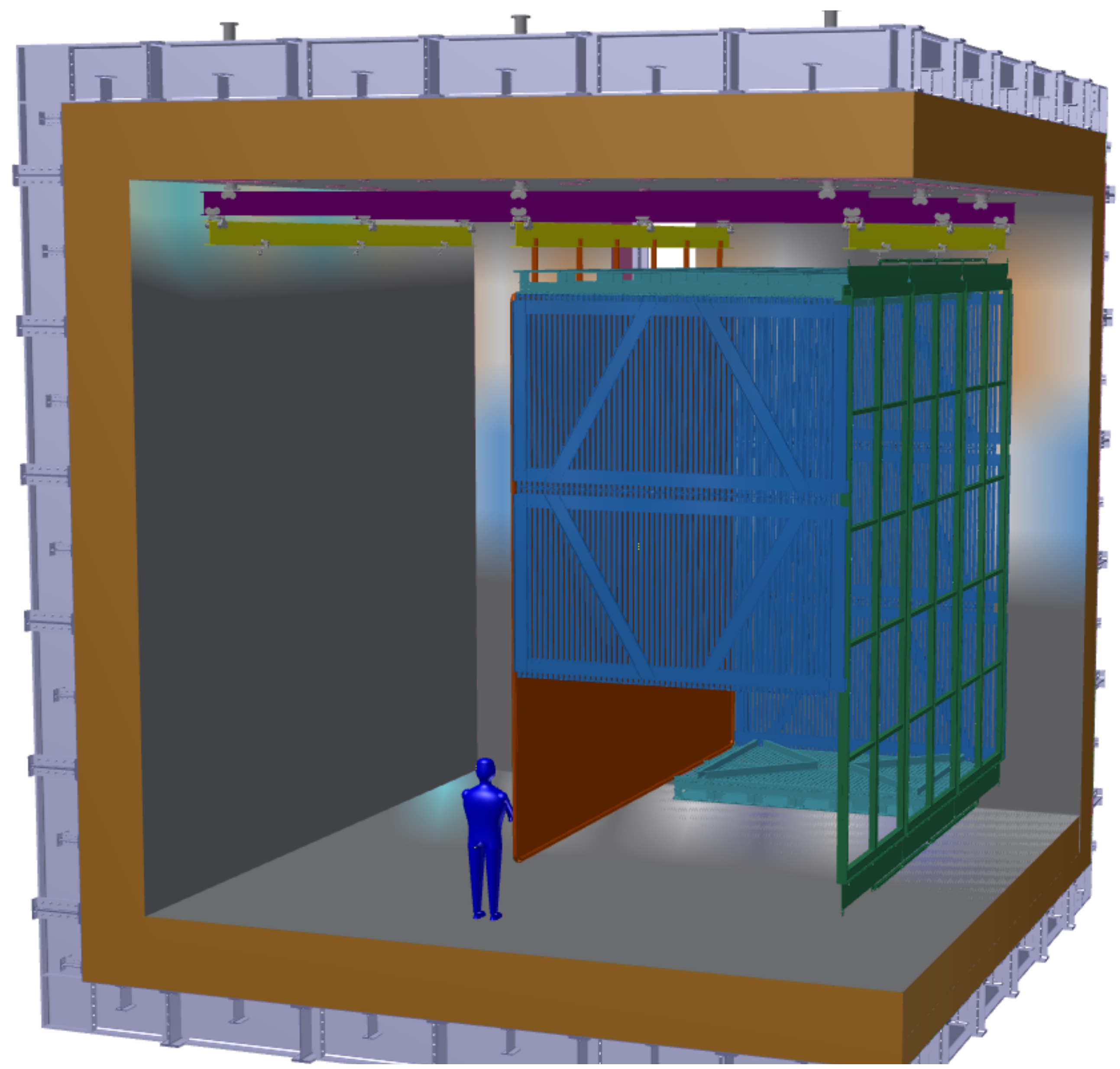
Detector installation #5

- Install the upper half of the north FC wall.
- Disassemble and remove scaffolding/ access equipment in this drift area.



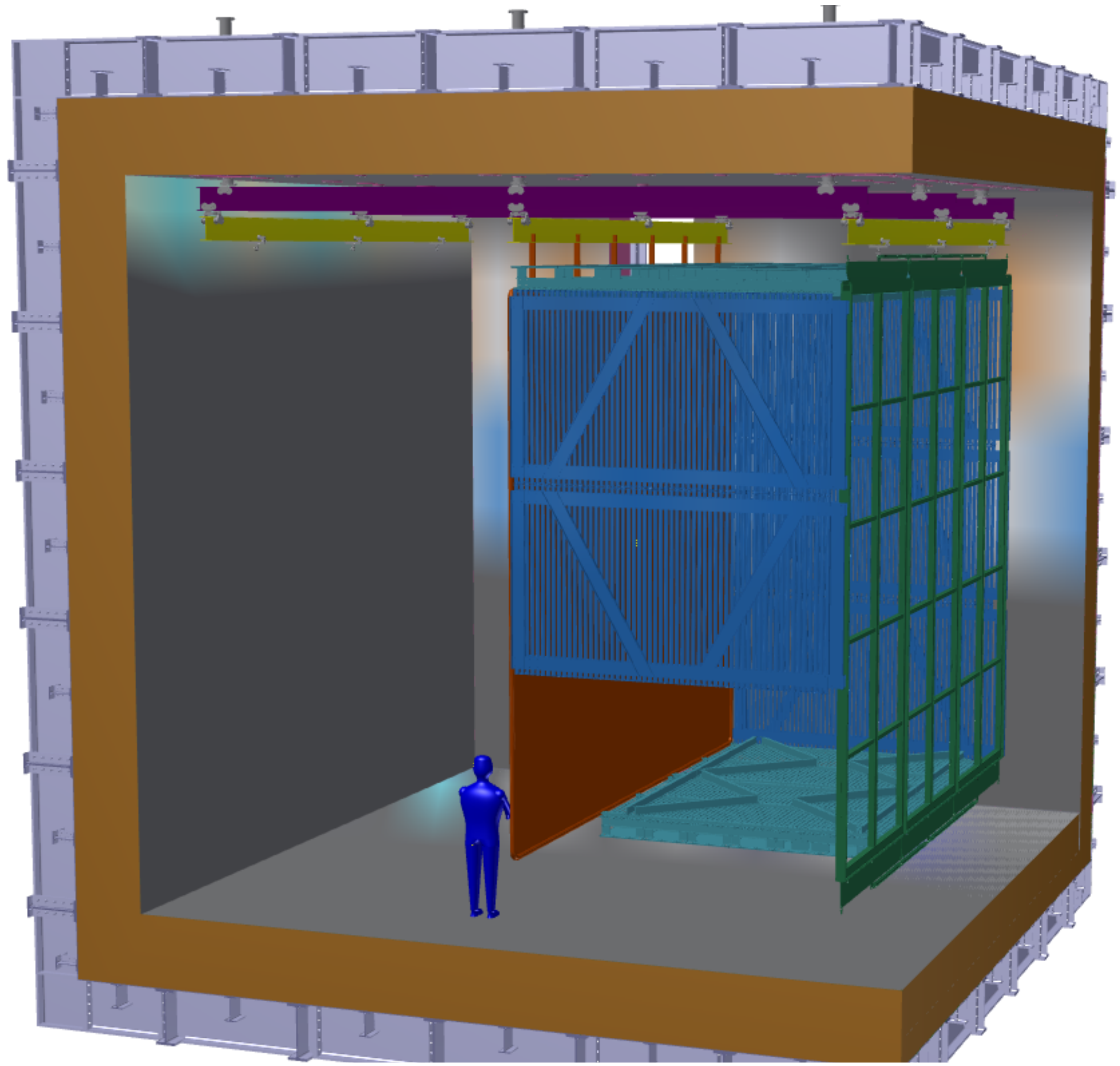
Detector installation #6

- Install the lower FC panels from beam window side to downstream.
- Removal of floor protective panels will be completed as this work progresses.
- Any work under this portion of the TPC must be completed at this point.
- One possible iteration on this, is to install the far top FC and then the bottom, indexing the scaffolding downstream away from the beam window side. This would require delaying the downstream end wall until after all three upper FC are in place but before the final lower FC is installed. This will be evaluated as the designs progress.



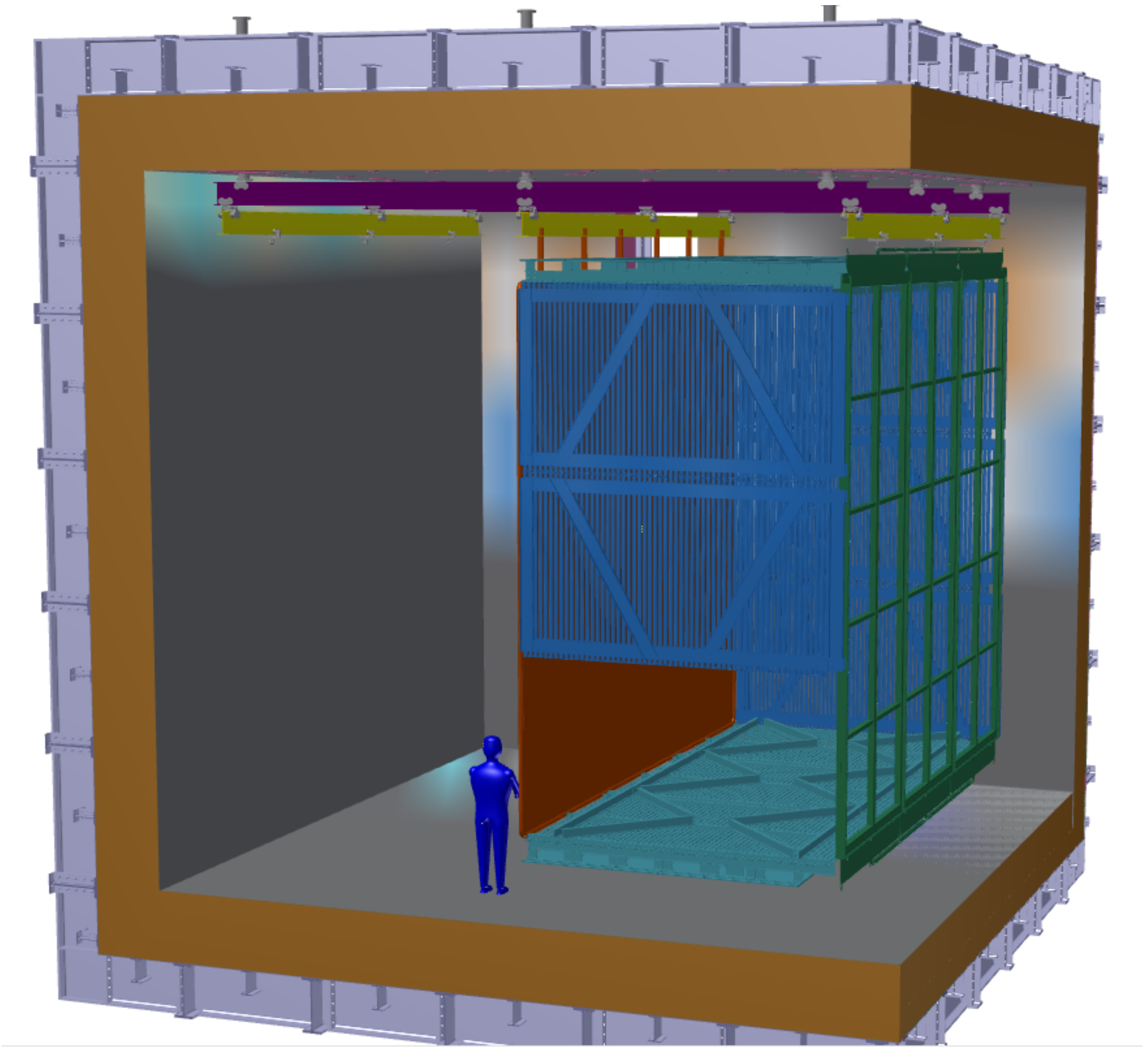
Detector installation #7

- Continuation of the lower FC panels.
- Note for all upper and lower FC panel : the cross bracing and support structure will need to be removed at they are installed. For the lower FC panels, this will require access to the top surfaces. We are in the process of determining what the minimum access required will be and how this will be done. It is likely that a temporary walking platform on top of the FC will be needed. Can the design support this or will temporary blocking be needed under the panels for support?



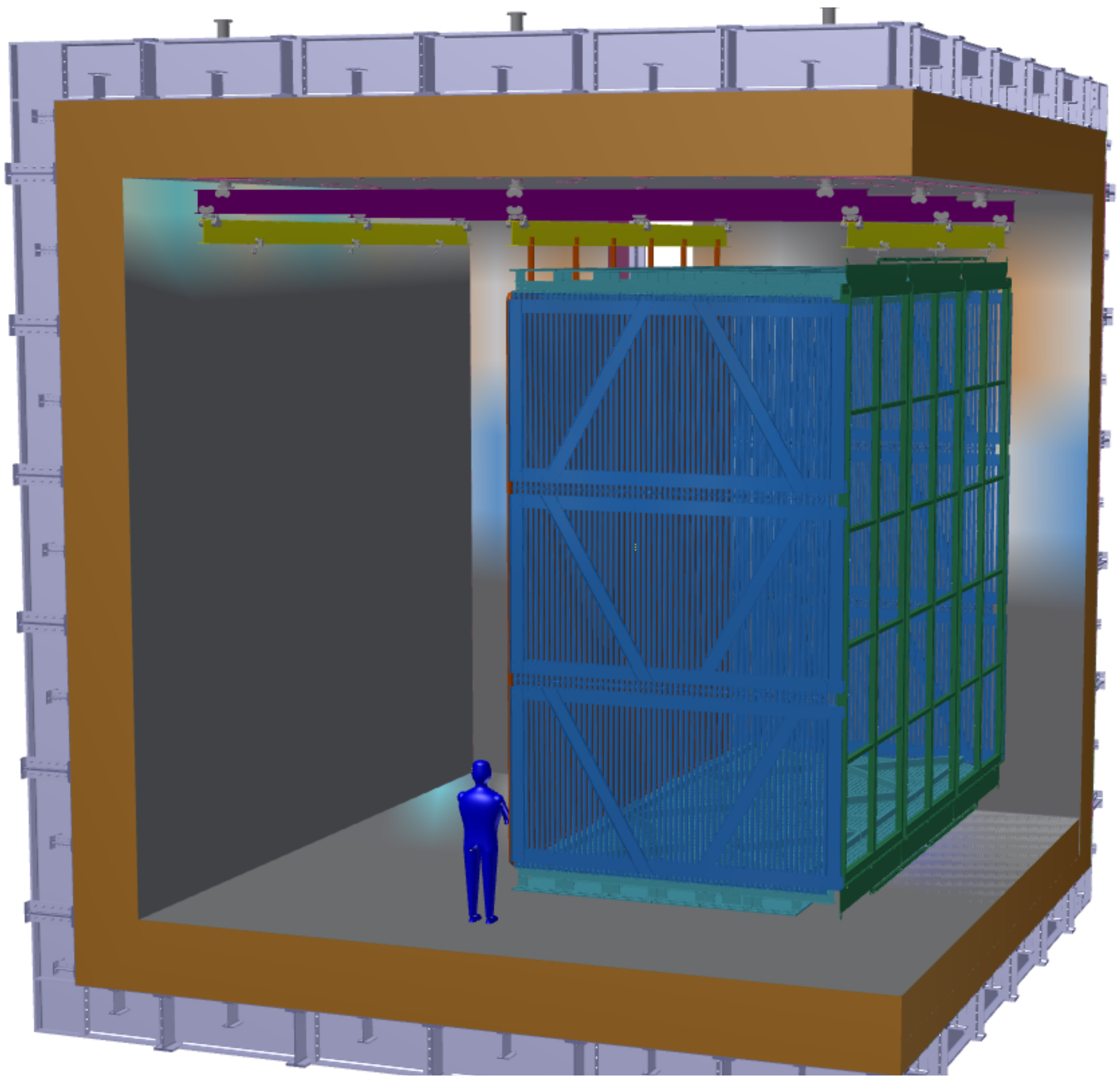
Detector installation #8

- Complete the lower FC panels.



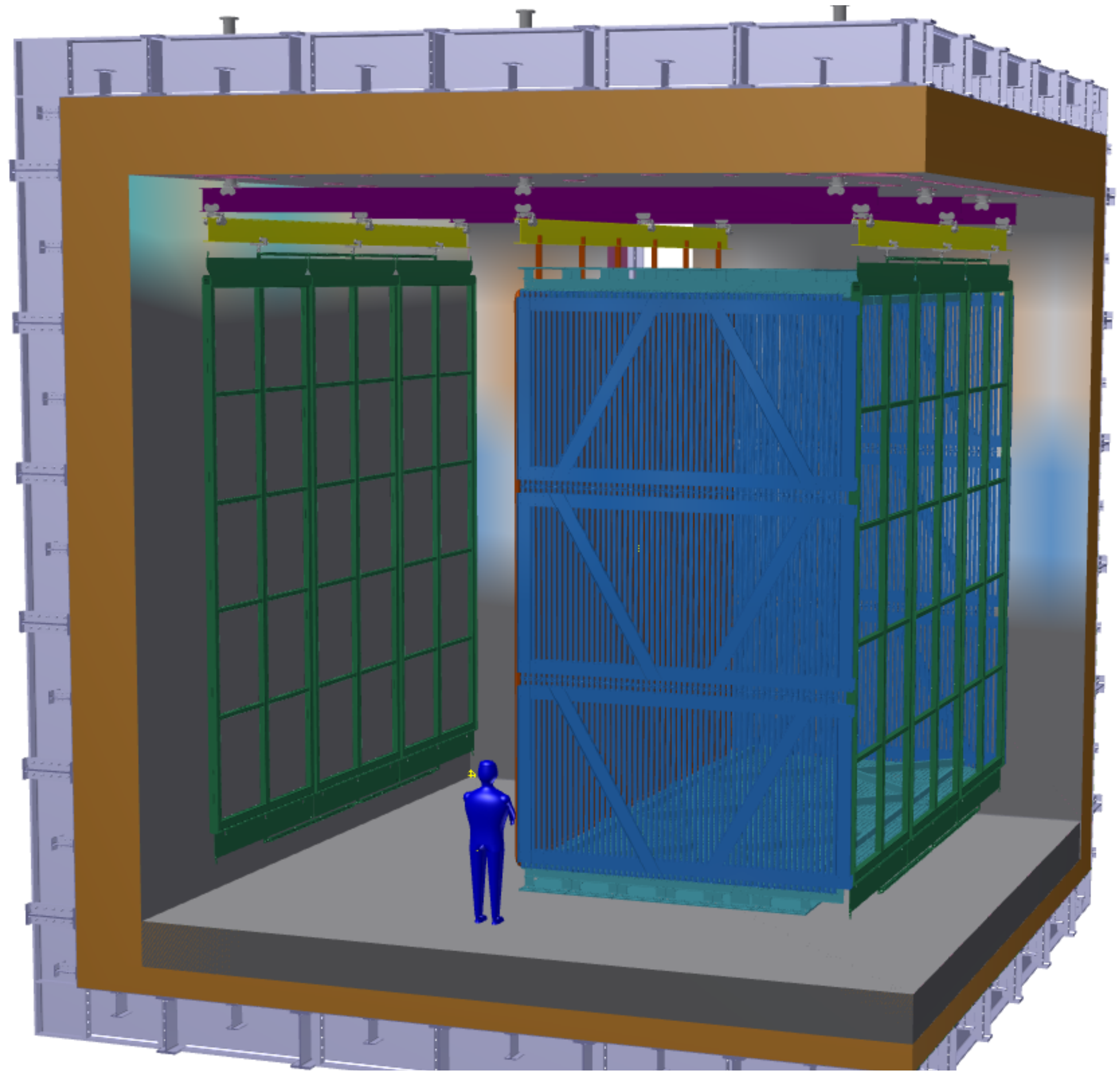
Detector installation #9

- Install the lower end wall FC panel.
- The installation in this drift volume is complete.
- Can the calibration system (fibers on the CPA) be designed and installed from one side of the CPA?
- The HV feed thru and donut can be installed at this point.
- Laser installation for this drift?



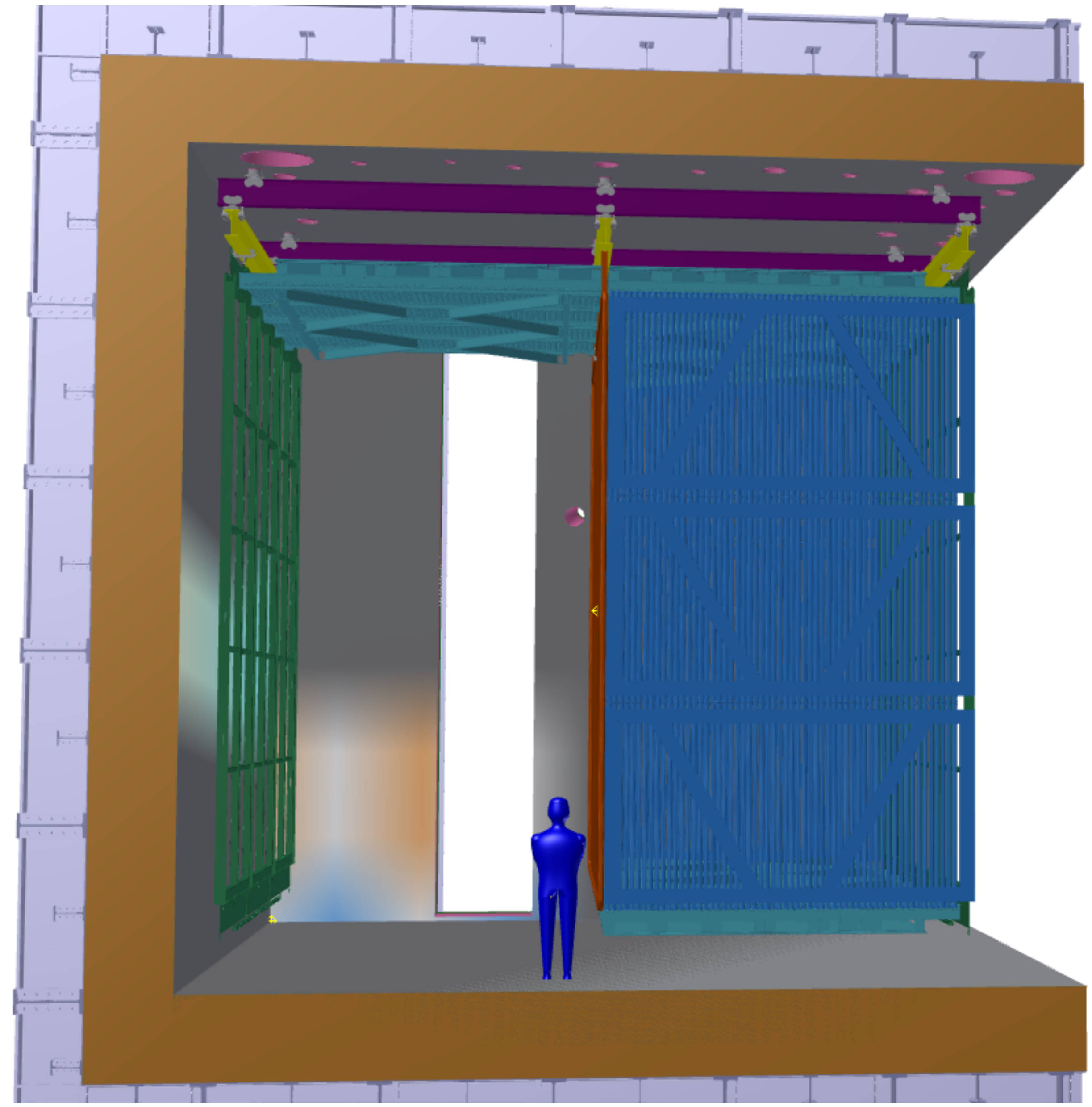
Detector installation #10

- APAs 4, 5 and 6 will be installed and translated into position.
- Scaffolding/access equipment will be in this drift region.



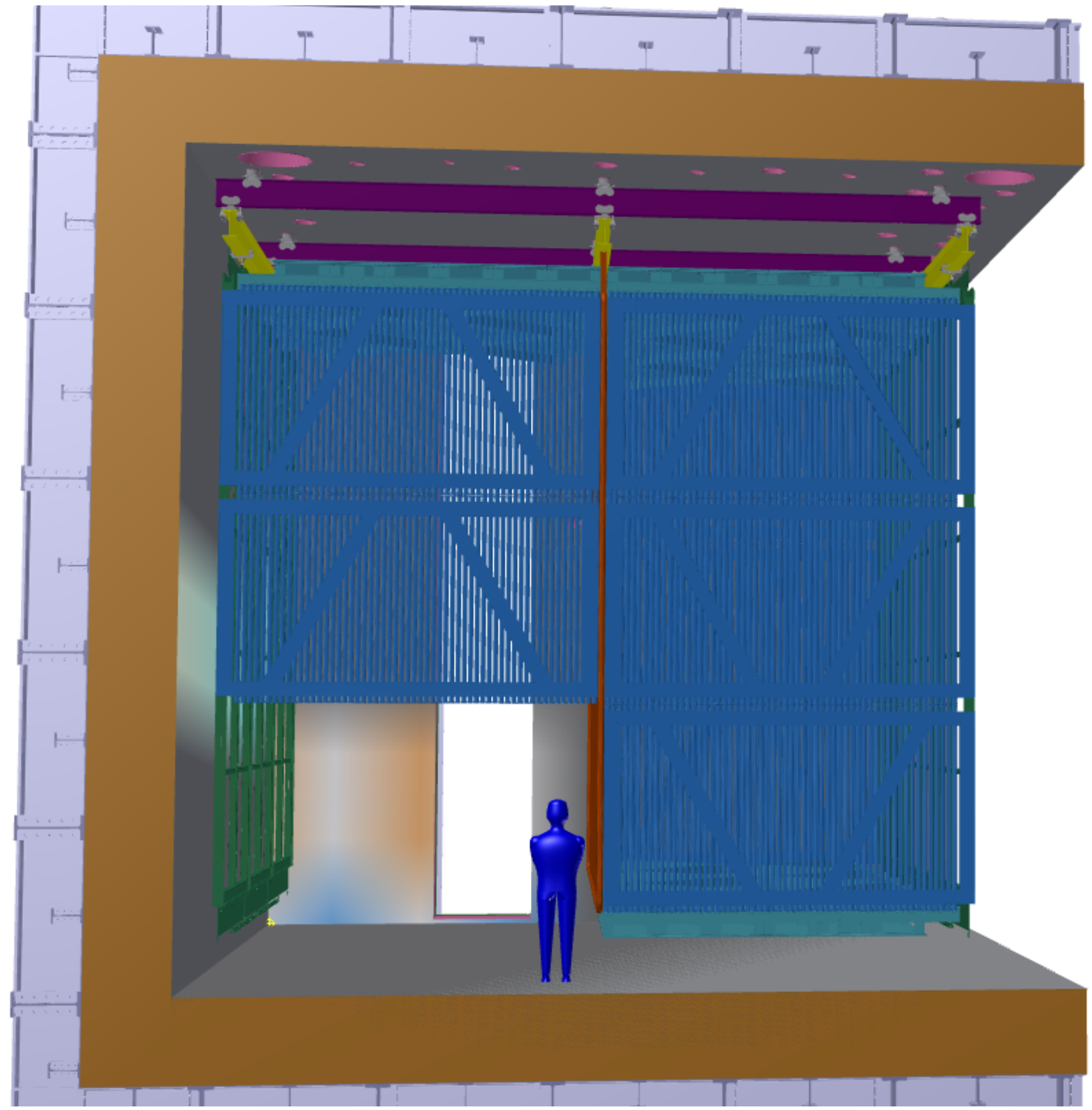
Detector installation #11

- Two of the upper FC panels can be installed (downstream and center).
- This will block access to the CE on these two APAs.



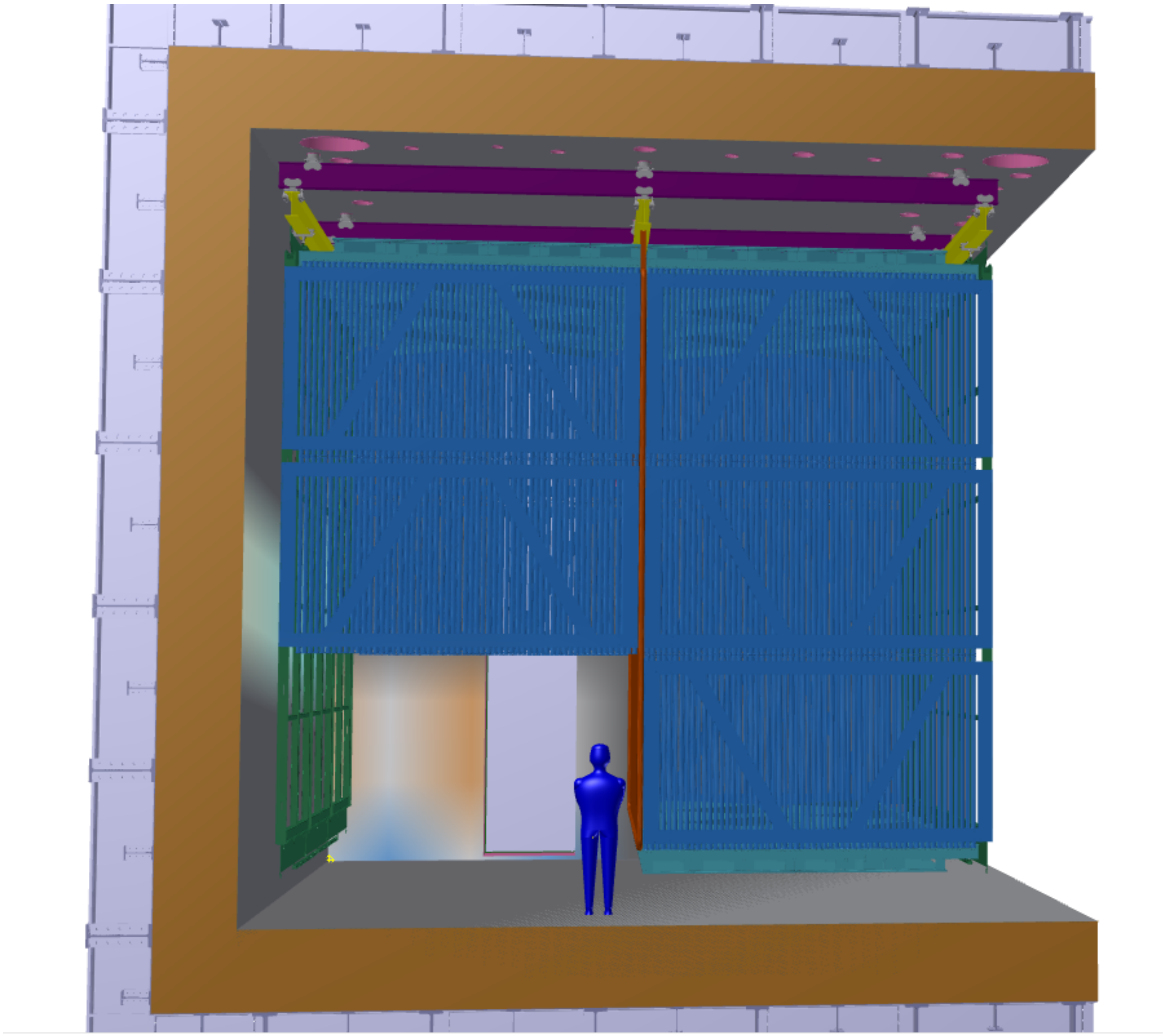
Detector installation #12

- The upper end wall FC panels will be installed on the downstream end of the TPC.
- Lasers?
- This completes the installation of all of the panels that can be installed before the closing of the TCO begins. This allows access to the full height of the TCO and the floor space in this drift.
- At this point there are still 8 FC panels to be installed. If the full TCO is closed all of these components must be in the cryostat along with all materials for closing of the TCO. Is there enough space?



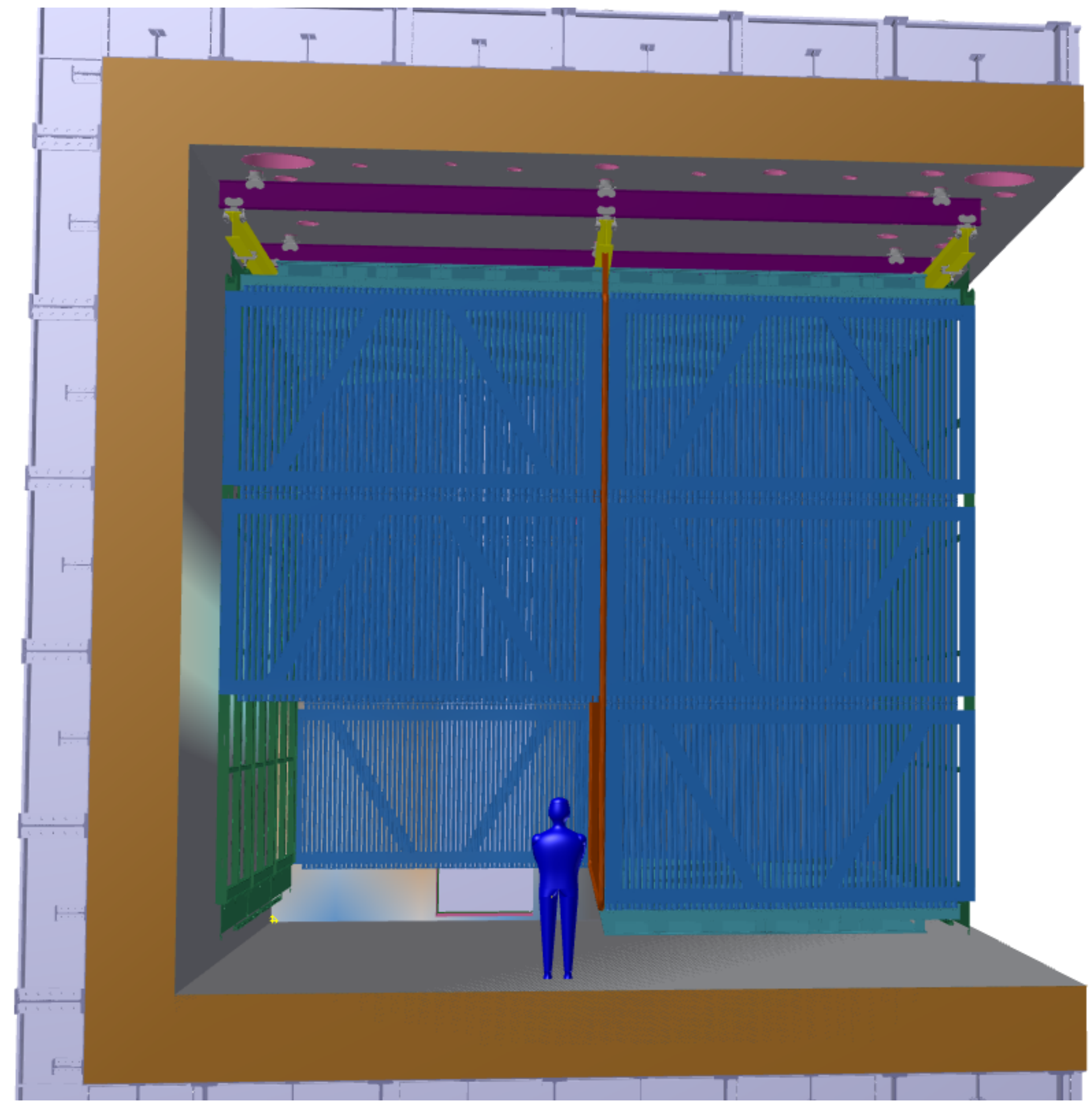
Detector installation #13

- If it is possible to close only the upper 2/3rds of the TCO:
- The final upper FC panel will be installed.
- The two upper FC panels will be installed on the beam window end.
- There is no longer the need for scaffolding/access equipment in this drift region and it can be removed through the lower portion of the TCO.
- The remaining 5 FC panels must now be in the cryostat along with the materials to complete the closing of the TCO.



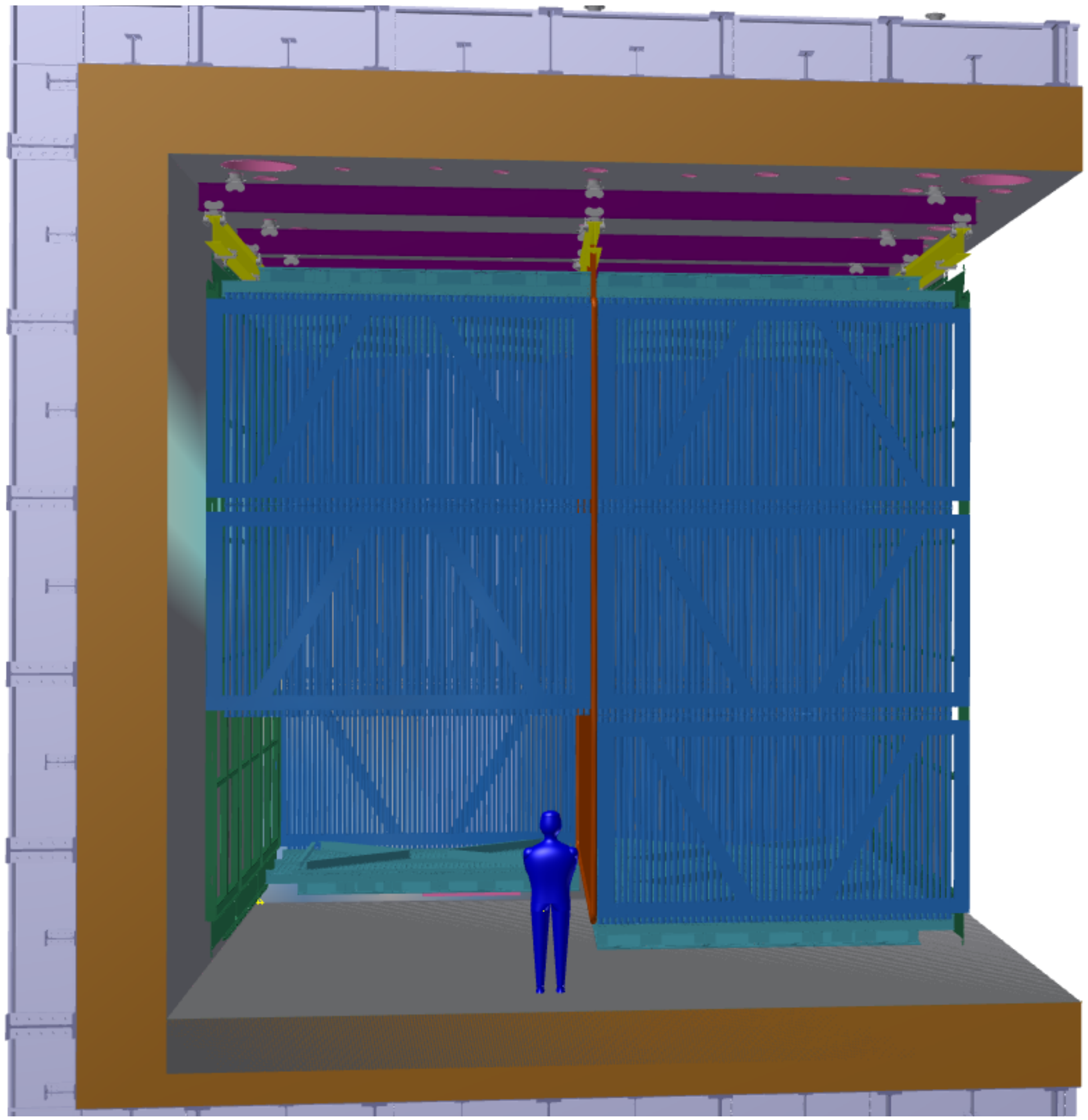
Detector installation #14

- After the closing of the lower portion of the TCO, access to the cryostat will only be available through the 710 mm diameter manholes.
- The bottom end wall FC will be installed on the beam window side.



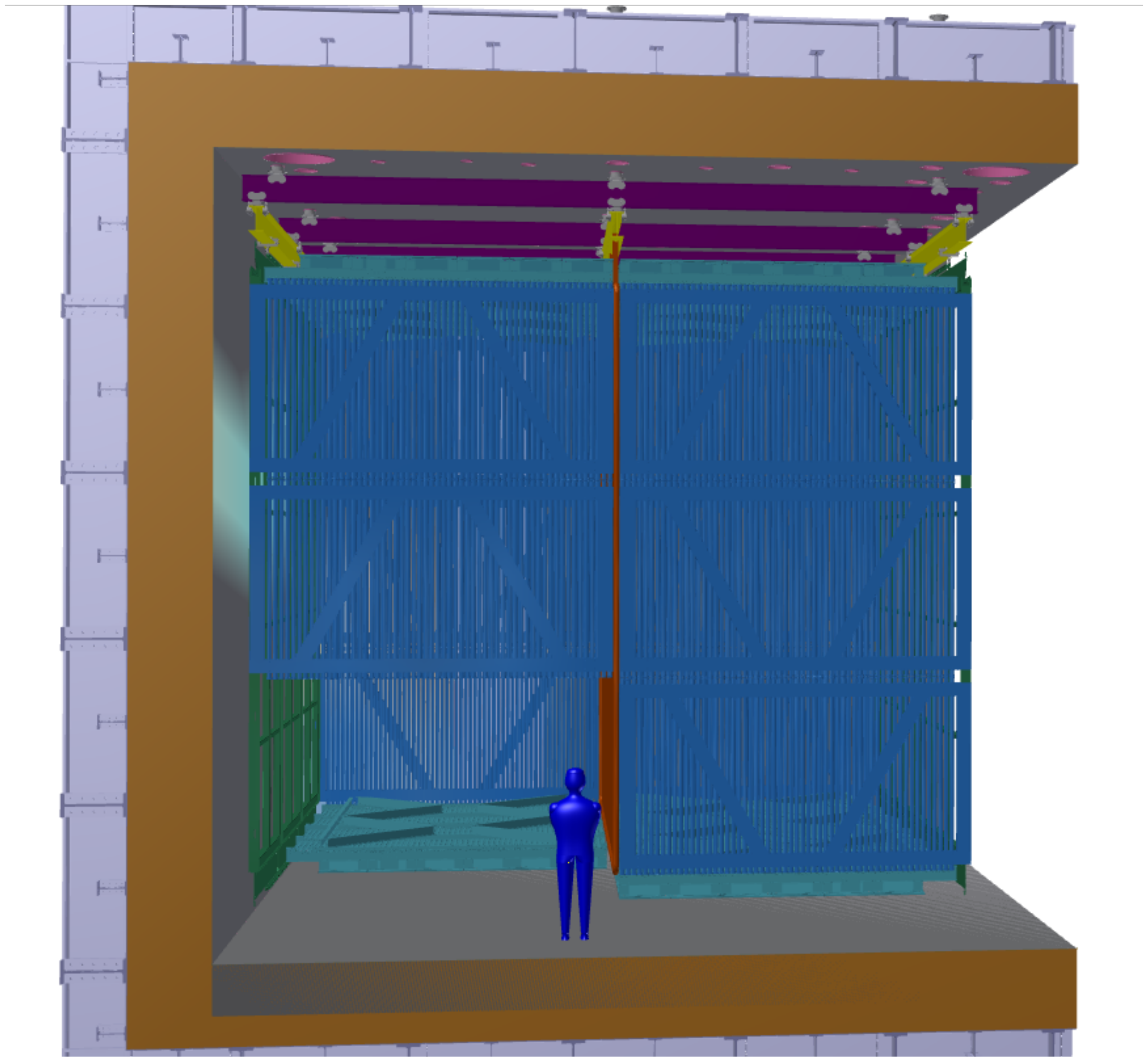
Detector installation #15

- The lower FC panels will be installed beginning at the beam window side of the cryostat.
- Protective flooring must be removed as this progresses.
- All items planned under the TPC must be in place as this progresses.
- Remove the structural bracing of the lower FC panels and remove through the manhole.



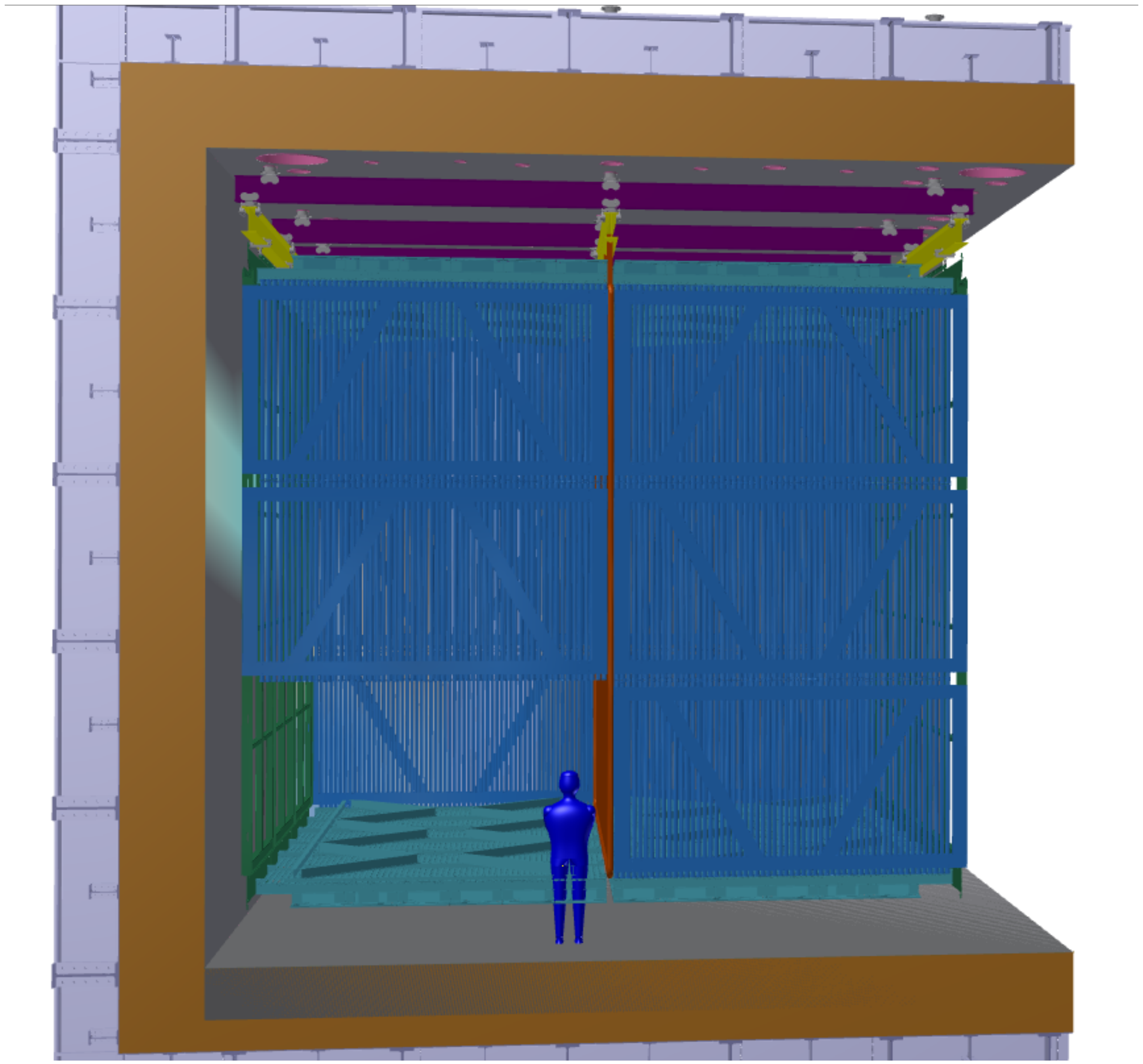
Detector installation #16

- Install the lower center FC panel.



Detector installation #17

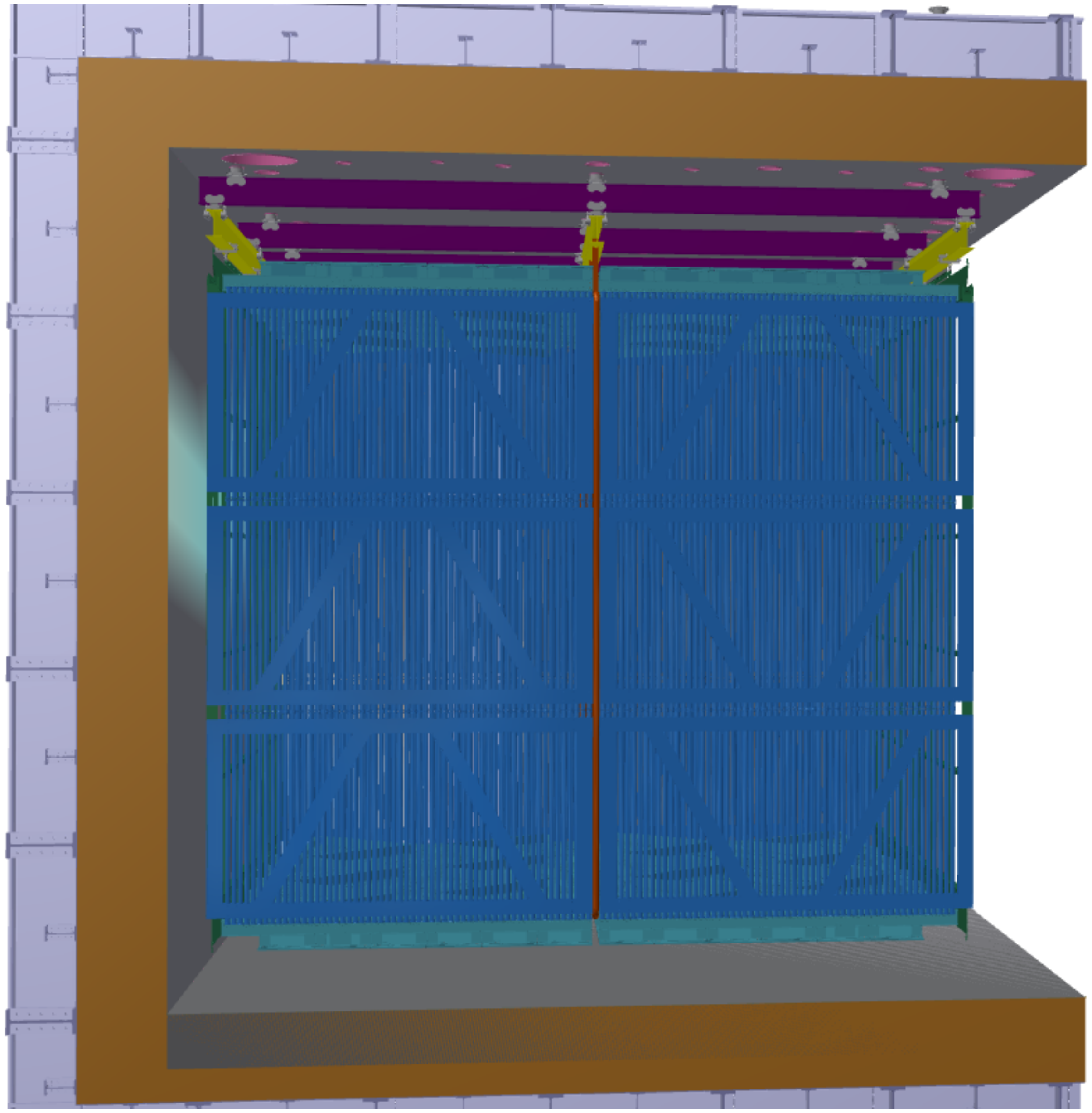
- Install the final lower FC panel.



ProtoDUNE SP at CERN

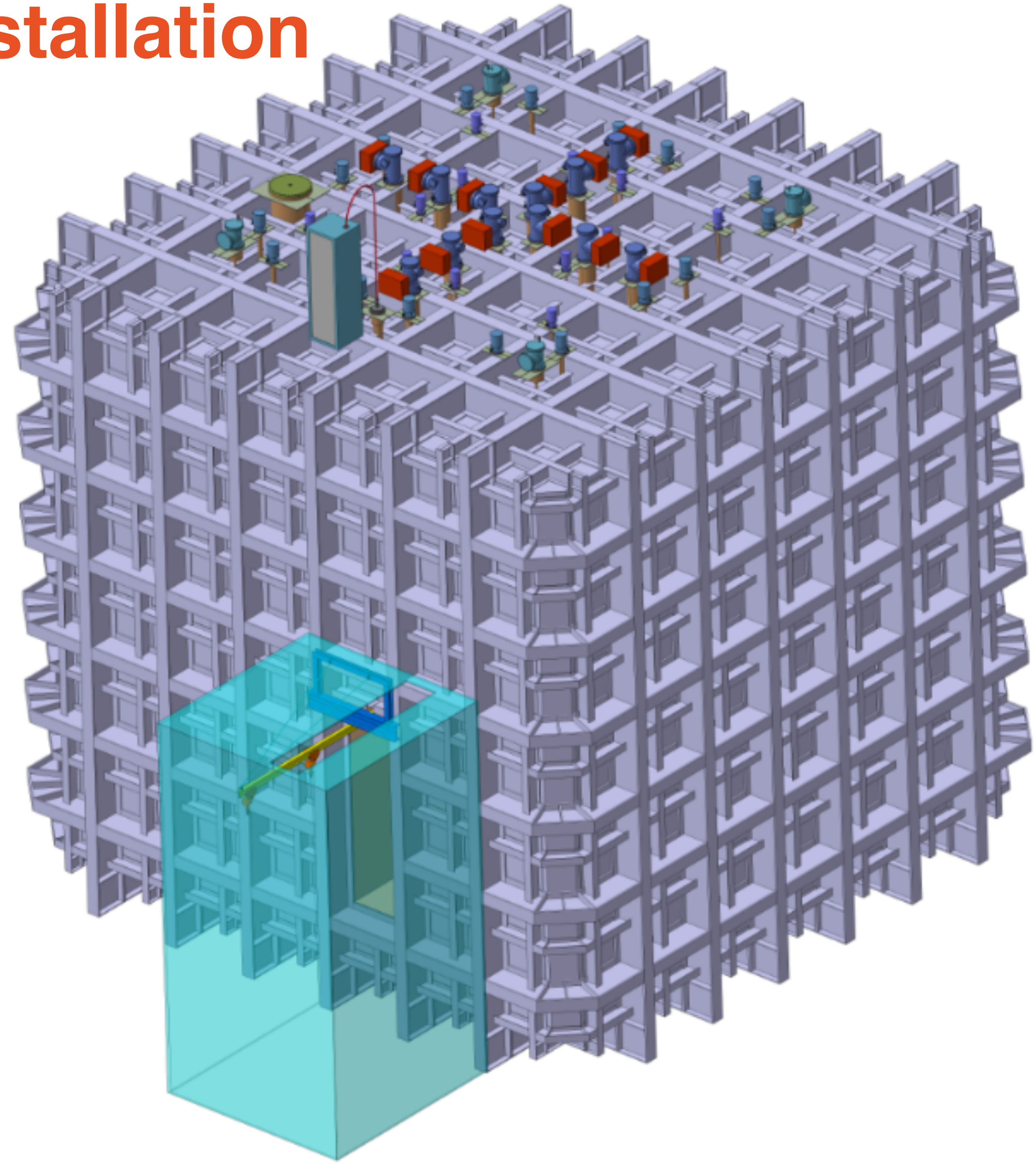
Detector installation #18

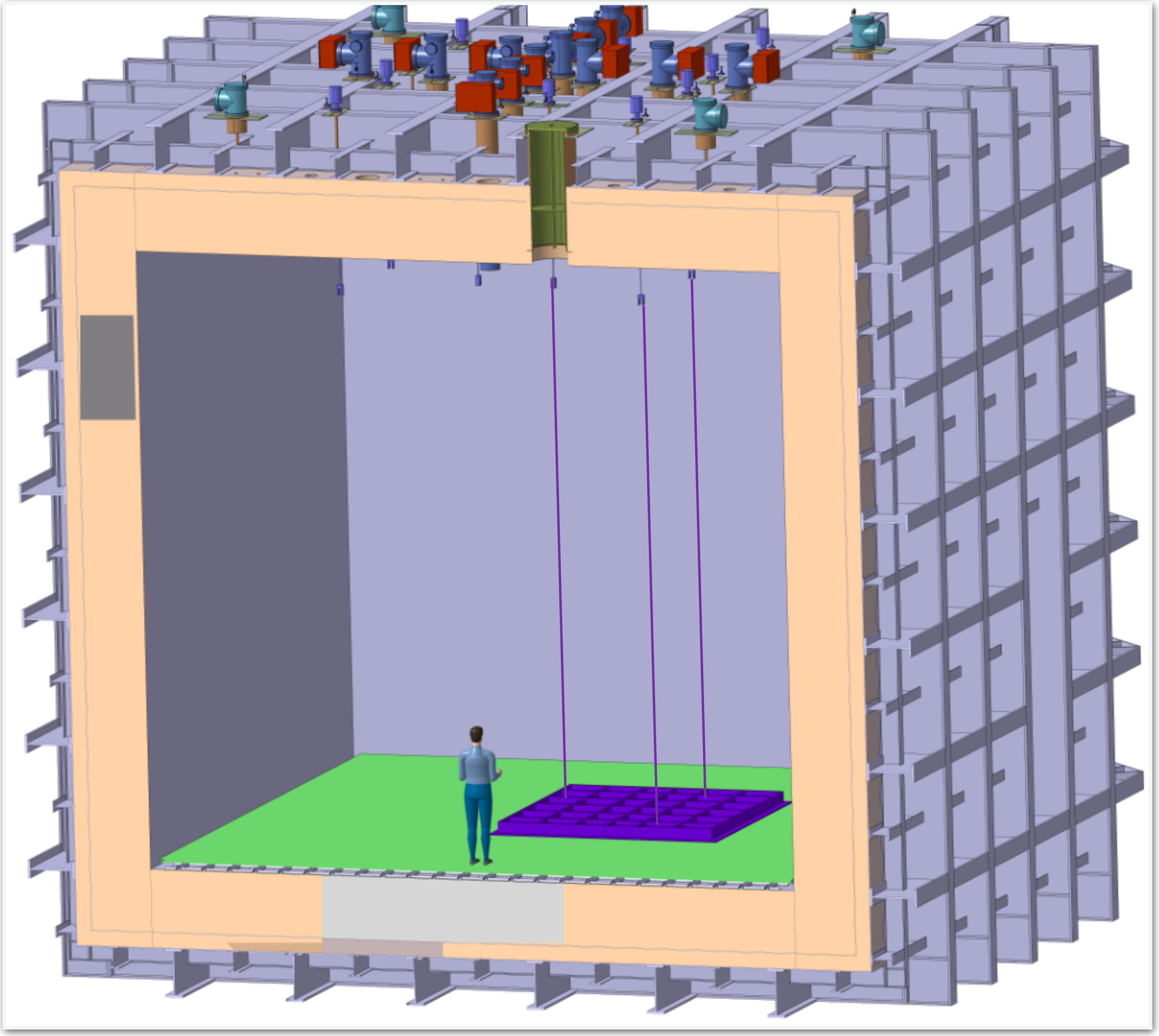
- Complete the installation of the downstream end wall FC.

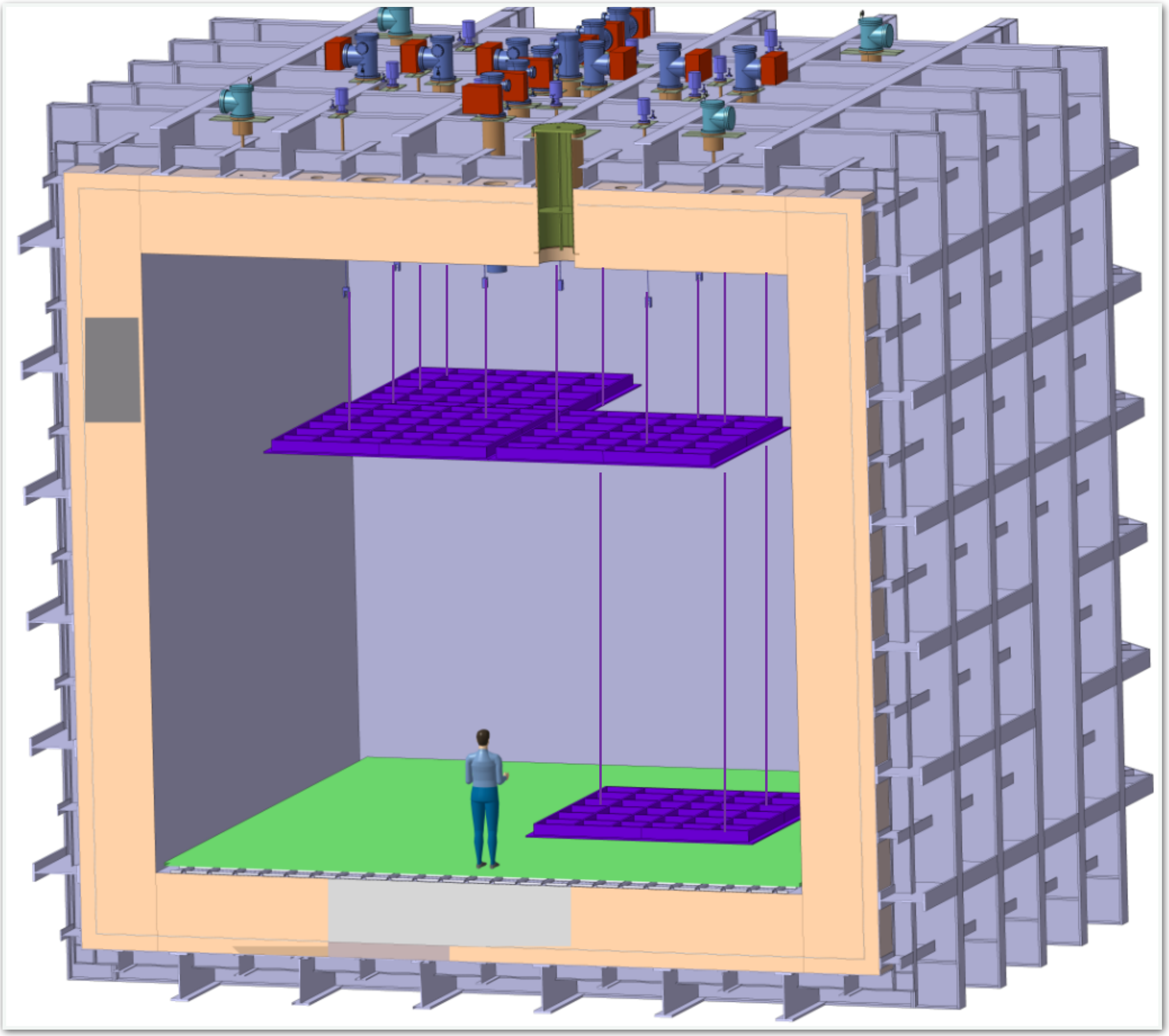


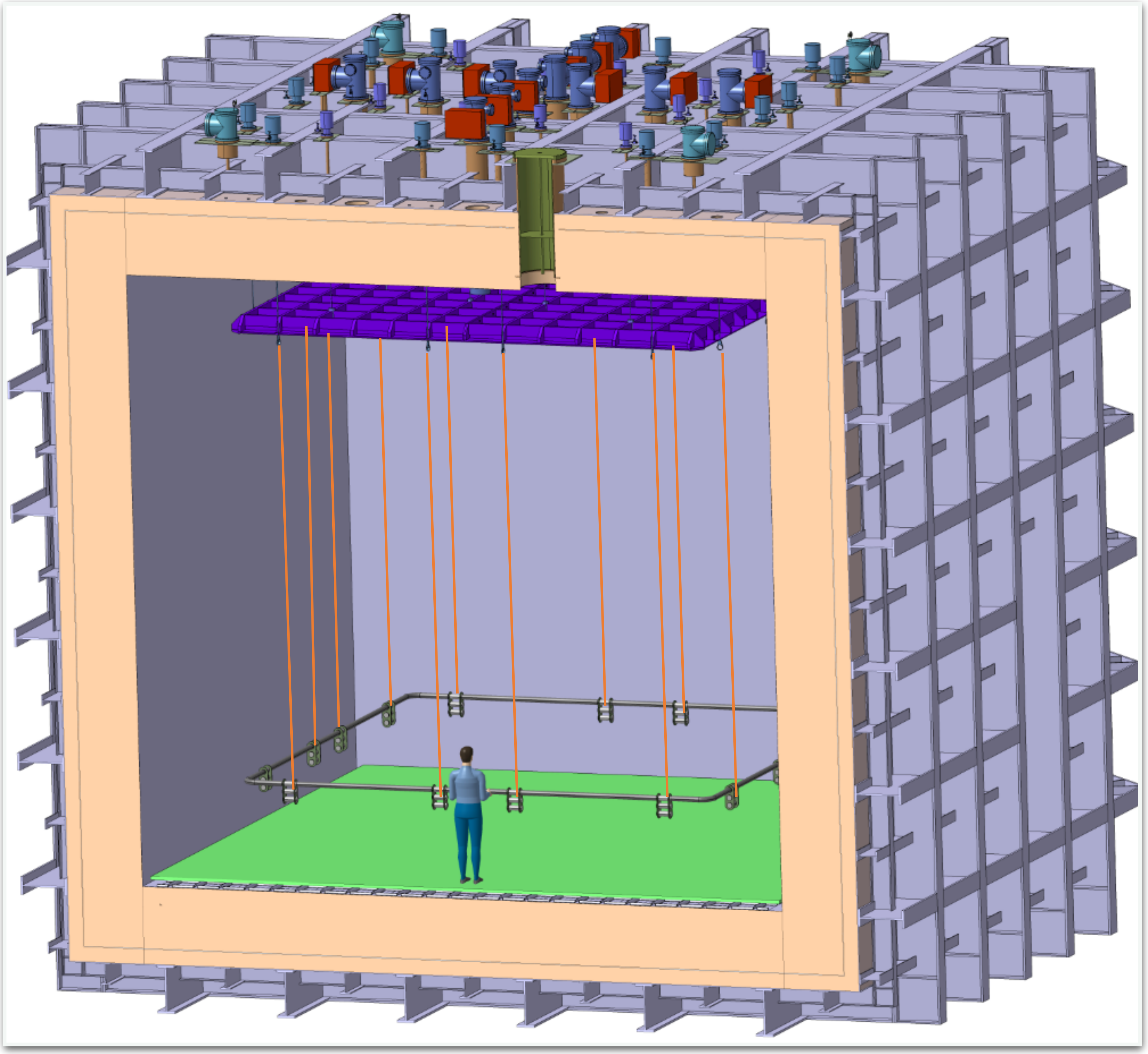
ProtoDUNE Dual Phase installation

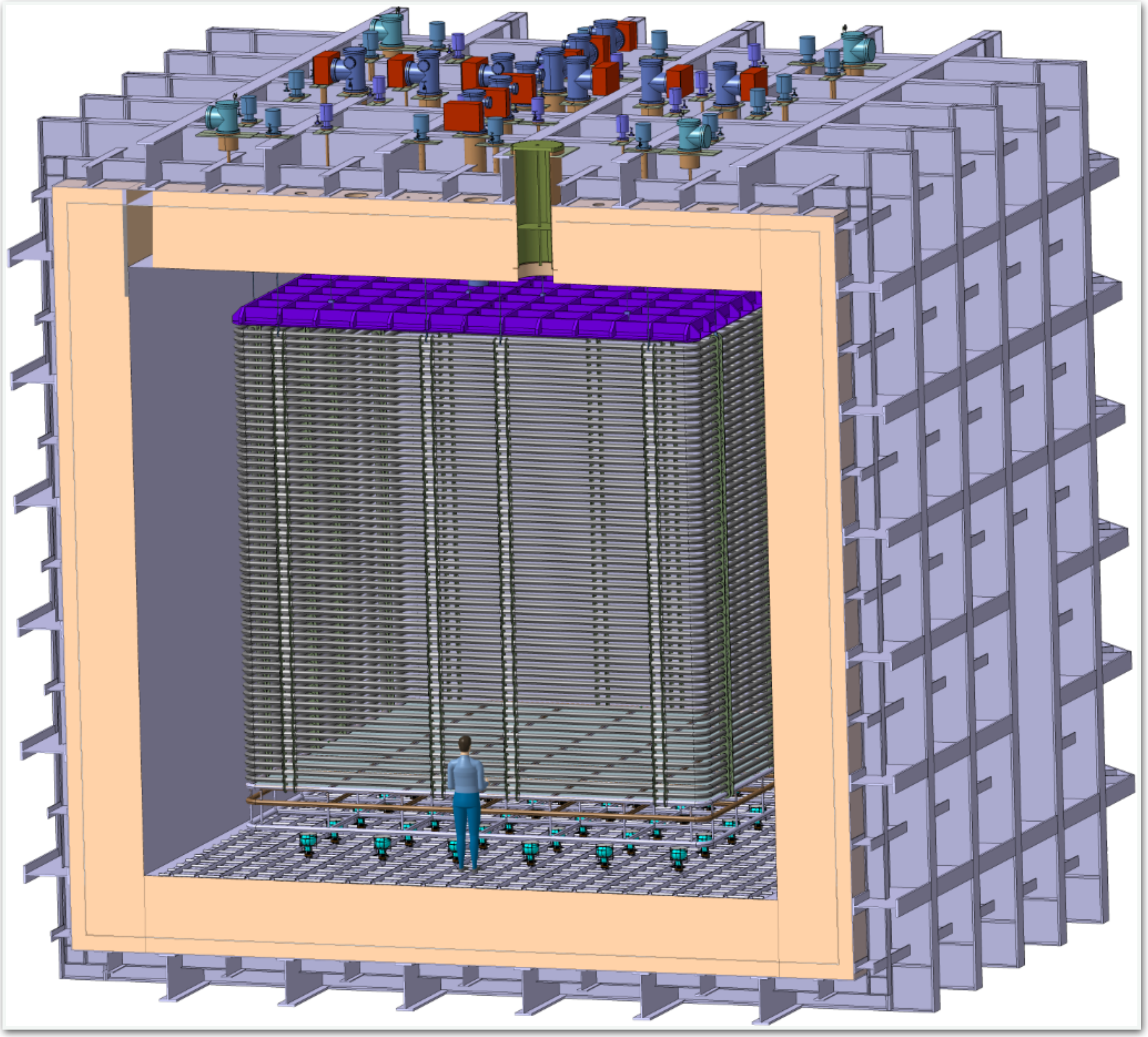
Assembly at CERN sequence same as for 10kt DUNE -> proof of principle for DUNE FD











DUNE

protoDUNE-SP: status of construction and tasks

- LAr detectors (TPC and PhotonDet + r/o Electronics) fabrication: *started or about starting (fall '16)*
- LAr detectors integration, test, installation at CERN: *plan under development (critical task) -*
- DAQ (LAr detectors): *dedicated team being formed*
- ★ Beam Line detectors (and Trigger): *need for a suite of detectors (ToF, MPWC, Cherenkov) for beam particle Id and Momentum measurement - dedicated team(s) for detectors' procurement/fabrication and installation, operation at CERN to be formed*
- ★ Calibration system for LAr Detectors: *dedicated teams being or to be formed*
- External muon tagger: *dedicated team being formed*
- ★ Software development for Event reconstruction, Off-line Analysis & MC: *common sw platform for all LArTPC experiments in place (LArSoft, serving current experiments) - lot has been done but still lot^2 should be done(see L.Fields talk).*

Organizational Structure: synergies between SP and DP efforts, and with SBND

- Both protoDUNE projects - SP and DP - are taking place at the CERN Neutrino Platform on the same timescale. Close coordination is crucial to exploit the numerous potential synergies, optimize the resources available, and coordinate the timing of key inter-dependent activities. ★ This coordination is already in place, including the organization of joint teams on specific aspects and deliverables (see ★ in previous Slide)
- ProtoDUNE (SP) detector is similar in design and timeline to the SBND detector for the ShortBaseline Neutrino Program at FERMILAB: the development of effective synergies, the exploitation of common detector solutions, of common test tooling, and the optimal use of resources (human and financial) are also goals of the on-going DUNE and SBN management effort

Opportunities for Involvement in ProtoDUNEs

- The DUNE collaboration considers the development of both the single-phase and dual-phase efforts as critical components of the DUNE program ***and places a high-value on the contributions of participating groups to these efforts***

- **Additional resources are needed to fully maximize the scientific impact of the prototyping program**

- **Relatively modest contributions to this program can have a big impact on the final designs for the far detector modules**

ProtoDUNEs at CERN:

Strategy and Objectives

To encourage broad participation in ProtoDUNE, either through construction or scientific effort:

- Use EoI process (started Jan.- ***open until Jun.'16***) to:
  - ✳ *Provide unique opportunities for all collaborating institutes to participate in ProtoDUNEs*
  - ✳ *Define the institutional responsibilities* (major tasks assigned by Jun.16)
  - ✳ *Create of Consortia (now open for signing-in and negotiation with FA for securing funding)*
- Organization of Workshops *with particular focus on internationalization:*
  - ⋆ Neutrino Latin American WS at FNAL - April 27-28, 2016
  - ⋆ Neutrino European WS at CERN - April 7-8, 2016

protoDUNE-SP membership & responsibilities

From DUNE member institutes:

- Call for EOIs Jan 2016
- 54 EOIs received
- All identified subsystems covered
- New institutes joined protoDUNE-SP

Outreach:

- Event for European institutes, CERN 7-8 April
- 70 attendants, from 13 countries
- Event for Latin American institutes, Fermilab 27-28 April

Goal is to assign responsibilities, confirm leadership of teams by June

EOI results

Description	QTY Institute EOIs
NP04-A APA Planes	12
NP04-B CPA Planes	8
NP04-C HV Distribution	5
NP04-D Field Cages	8
NP04-E Ground Planes	5
NP04-F Cold ASIC chips	6
NP04-G Cold Motherboards	9
NP04-H APA Readout Cables	2
NP04-I Photon Detectors	16
NP04-J PD Readout Cables	3
NP04-K Cryostat Flanges	3
NP04-L Warm APA readout electronics	7
NP04-M PD readout electronics	9
NP04-N Rack Infrastructure	2
NP04-O Back-end DAQ computing	10
NP04-P Run Control Software	2
NP04-Q Slow Controls & Monitoring	5
NP04-R Cryogenic Interfaces & Purity Monitors	2
NP04-S Beam Windows & Beam Interfaces	3
NP04-T TPC Calibration System	9
NP04-U PD Calibration System	4
NP04-V Cosmic Veto System	8
NP04-W Computing Infrastructure	6
NP04-X Detector Installation	9
NP04-Y Detector Integration	9

identified tasks
for group's contribution

ProtoDUNE DP EoI

Integration in DUNE project as DP-ProtoDUNE December 2015; EOI call for ProtoDUNEs, January 2016
Positive response (21 institutions submitted EOIs)
- Covering all identified DP-ProtoDUNE subsystems
- In process of bringing together interested institutions

NP02
- CERN
- ETHZ
- IFAE and CIEMAT
- IFIN - HH
- IN2P3 (APC, ipnl, lapp, omega)
- IRFU/CEA
- KEK
- University College of London
- University Jyväskylä

NP02-C CRP hanging system/movement
- Czech Republic Institutes

NP02-E Purity Monitoring
- The DUNE-UK Collaboration

NP02-I Charge readout cold analog ASIC
- Institut de Physique Nucleaire de Lyon (IPNL)
- University of Texas Arlington

NP02-J Charge readout digital FE and timing distribution system
- Institut de Physique Nucleaire de Lyon (IPNL)

NP02-L Photomultipliers, WLS coating, and mechanical integration
- CIEMAT-Madrid and IFAEBarcelona (Spain)
- Czech Republic Institutes
- Kyiv National University
- University of Wisconsin

NP02-M Light readout cabling
- CIEMAT-Madrid and IFAEBarcelona (Spain)

NP02-N Light readout digitization system
- University of Texas Arlington

NP02-Q DAQ and Online Data Processing and Storage Facility
- Fermilab Scientific Computing Division
- Institut de Physique Nucleaire de Lyon (IPNL)

NP02-R Run control software
- Institut de Physique Nucleaire de Lyon (IPNL)
- Maryland

NP02-S Slow control system, sensors, and cabling
- Maryland

NP02-V Large area trigger counters
- Czech Republic Institutes

NP02-W Computing Infrastructure
- Argonne National Laboratory
- Fermilab Scientific Computing Division
- University of Texas Arlington

NP02-X Detector Integration
- Kyiv National University

NP02-Y Engineering and Management
- University of Texas Arlington

Levels of Involvement

The timescale for the DUNE prototyping efforts is very short and not everyone interested in participating to this effort can be able to make significant capital contributions to the detectors construction on this timescale

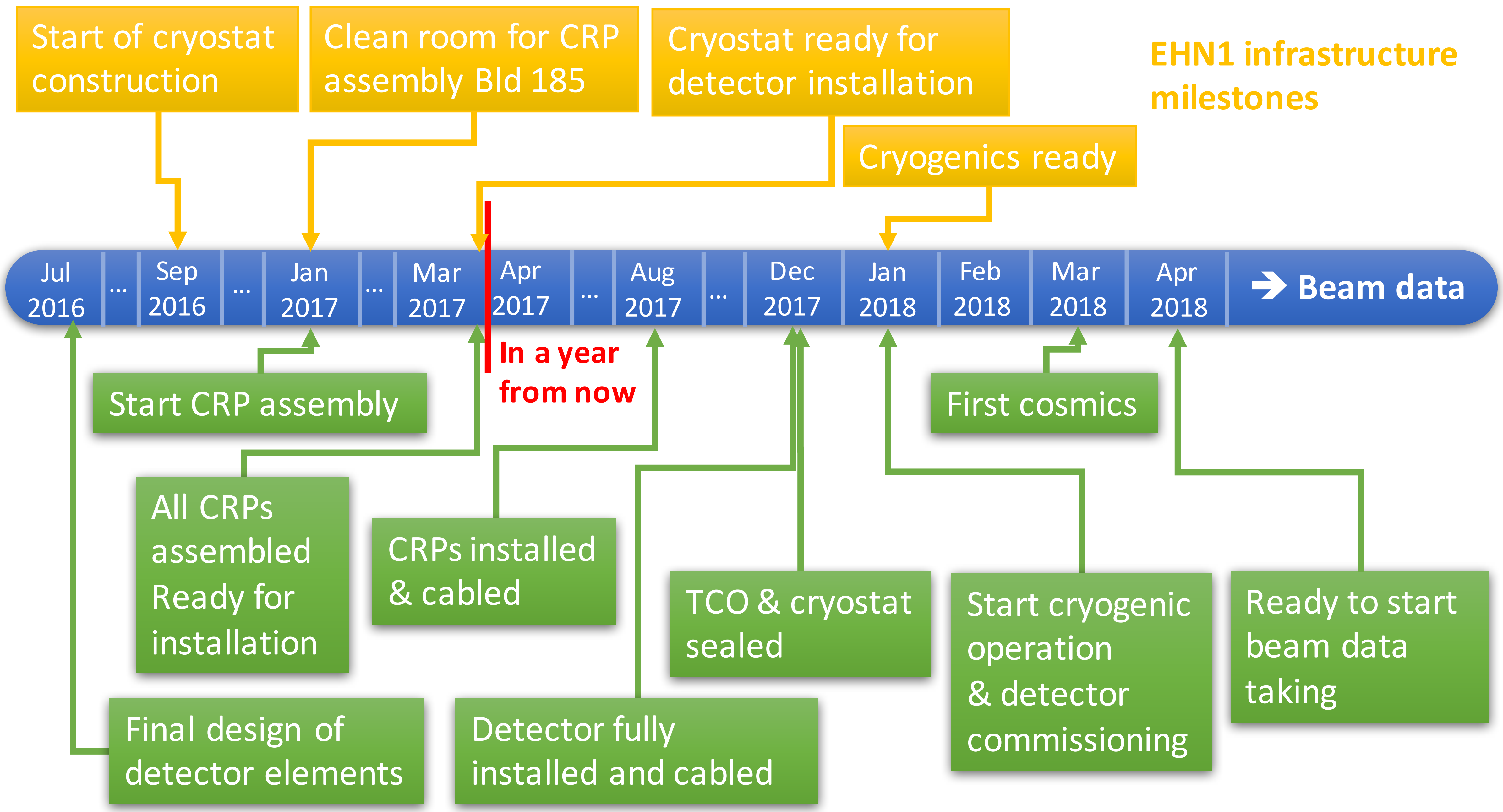
However,

- **contributions of scientific and engineering resources to these efforts are invaluable and create a path towards opportunities for future, more-significant involvement in far detector construction**
  - Represents an investment in leading-edge technology development
  - Allows for intellectual participation in the detector designs at the earliest stages
- There are plenty of opportunities for involvement in the development of sw tools (on-line, off-line) and Physics studies
- There are also opportunities for additional direct contributions to the construction of other components of the experimental set-up

Levels of Involvement:

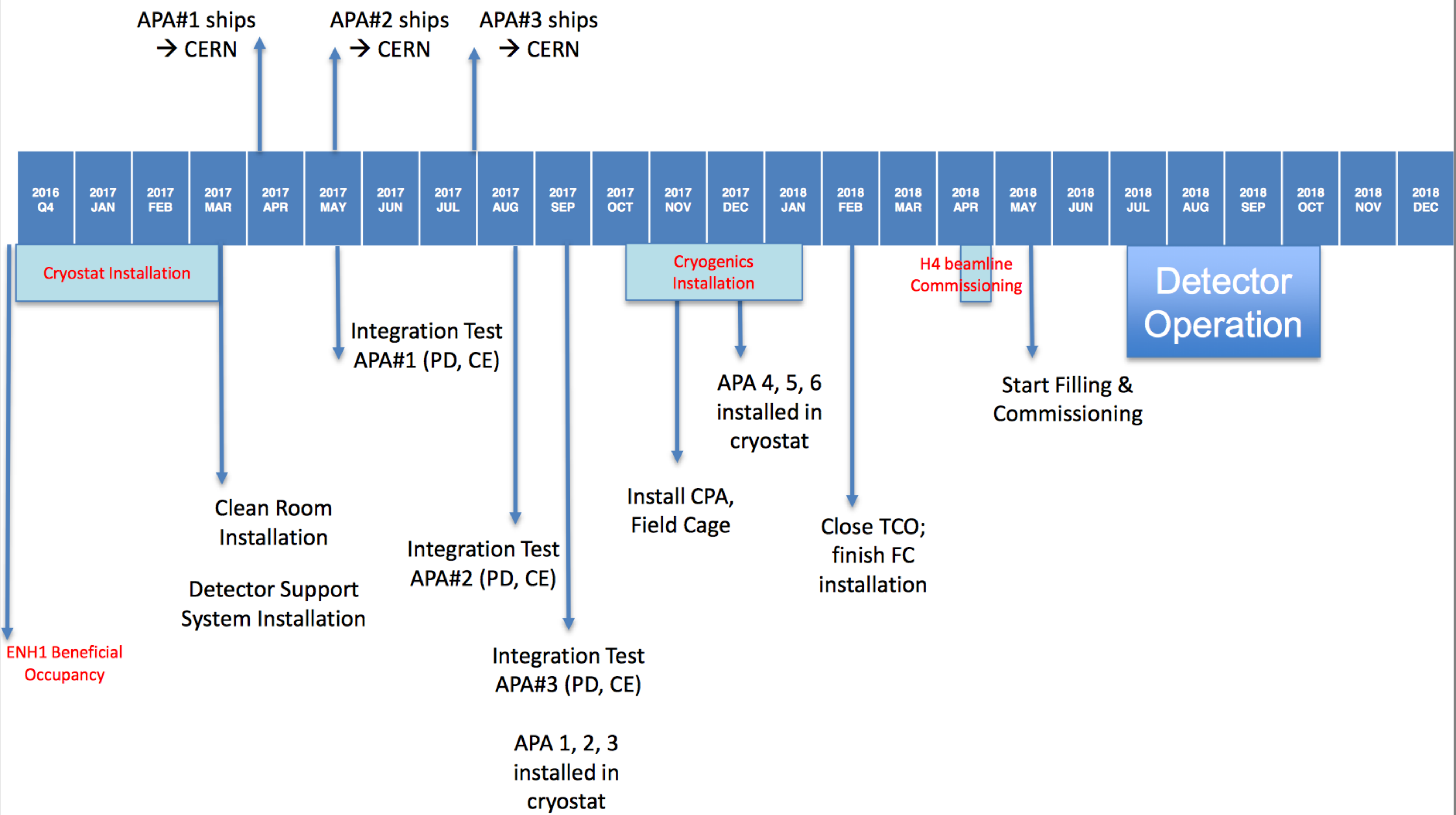
ProtoDUNEs at CERN provide possibilities NOW for an in-depth experience with LAr detector construction and operation - an invaluable opportunity for students, postdoc's and young researchers to create a robust background of skills and expertise in view of their leading role in the next decade with DUNE

ProtoDUNE DP planning



WA105 6x6x6 plans are integrated in the official EHN1 schedule
The critical path is defined by availability of infrastructure (clean room in Bld 185, cryostat, cryogenics) provided by Neutrino Platform

ProtoDUNE-SP Integrated Schedule



Summary

- DUNE collaboration views the CERN prototyping program as an essential step in the development of the far detector
  - Includes setting up the infrastructure for constructing the full-scale detector components
- Additional contributions to this ongoing effort (at all levels) are essential for maximizing the impacts of the program
- Involvement in the prototyping program is an opportunity for creating a pathway to future participation in the far detector construction project

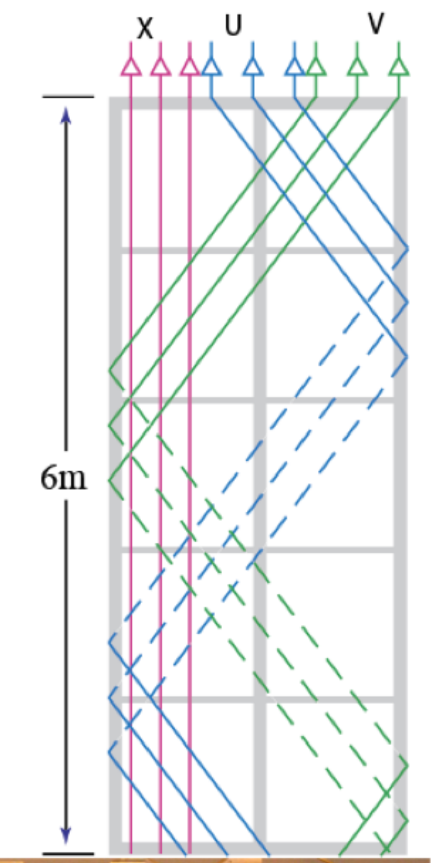
BackUp

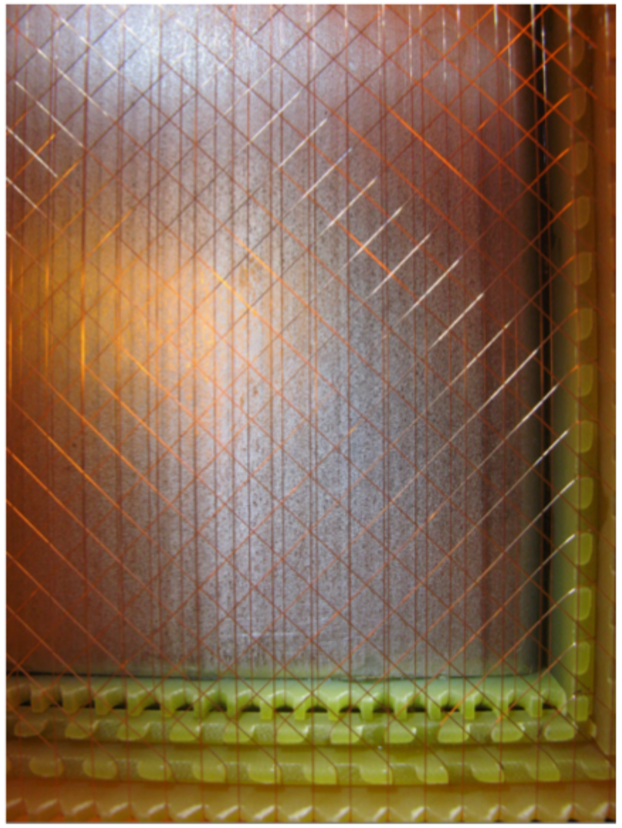
APAs

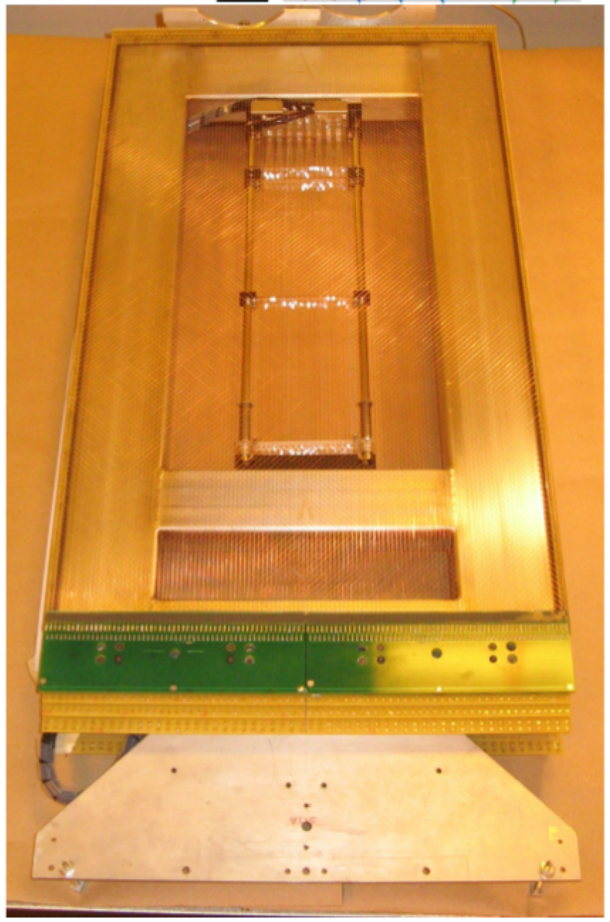
4 wire planes: Grid plane, collection, U-V induction (wrapped)

960 X wires @ 4.79mm pitch, vertical
800 V wires @ 4.67mm pitch, 35.71° from vertical
800 U wires @ 4.67mm pitch, 35.71° from vertical
960 Grid wires @ 4.5mm pitch, vertical
Wire plane spacing: 4.8mm (3/16")
2560 sense wires, 3520 wires total
Electronics on one end of the frame

- Construction of 3 APAs at PSL, U.Wisconsin
- Wire winding machine nearing completion
- Construction of 3 APAs at Daresbury, UK (funding confirmation next month) U.Liverpool, U.Manchester







Prototyping Program Goals

- Engineering Prototype Run
  - Measure and benchmark detector performance using full-scale detector components
  - Develop manufacturing capabilities at multiple sites
  - Test installation procedures and operation
- Test Beam Run
  - Assess detector systematic uncertainties
  - Validate and tune MC simulation to data
  - Test reconstruction tools and particle ID algorithms
  - Study particle interactions

ProtoDUNE SP at CERN:

the Physics program - 2018 Test Beam Run

The primary goal of the ProtoDUNE-SP test beam program is to perform the measurements needed to control and understand the systematic uncertainties that will be present in the DUNE oscillation measurements.

The use of a well defined charged-particle test beam will significantly enhance the understanding of the detector performance and boost the optimization of particle identification (PID) algorithms.

A cumulative test beam run period for ProtoDUNE-SP of four to eight weeks is assumed, depending on the extent of beamline sharing with other users at EHN1. This will take place prior to the long shutdown of the LHC in October 2018. Data will allow the development of identification criteria and energy measurements for the charged particles produced by neutrino interactions with argon in the energy range relevant for the DUNE long baseline neutrino program, from hundreds of MeV to several GeV.

- ***Pions and protons*** in the energy range expected in DUNE beam neutrino interactions - from a few hundred MeV to few GeV - primarily used to study hadronic interaction mechanisms, secondary particle production and, at higher energies, hadronic shower reconstruction and energy calibration.
- ***Electrons*** used to benchmark and tune electron/photon separation algorithms, to study electromagnetic cascade processes and to calibrate electromagnetic showers at higher energies.
- ***Charged kaons***, even if collected at low statistics, extremely useful to characterize kaon PID efficiency for proton decay sensitivity.

ProtoDUNE SP at CERN:

the Physics program - 2019-20 Cosmic Ray Run (and beyond)

An additional period of data taking with cosmic rays during the long beam shutdown is also necessary. A dedicated external trigger system consisting of arrays of scintillator paddles, suitably positioned and arranged in a proper coincidence trigger logic, will be set up to select specific classes of cosmic muon events and enable the DAQ to record them.

- long muon tracks crossing the detector at large zenith angles (horizontal muons) along its longest dimension for an overall test of the detector performance, in particular for checking the DAQ system and its capability to correctly re-build the event topology from different APAs and for a precise characterization of the detector response;
- vertical muons crossing the LArTPC from top to bottom for a precise channel-to-channel equalization; and
- stopping muons inside the LAr detector volume for accurate Michel electron spectra accumulation and energy calibration in the low-energy range.

A further test beam run, after the CERN accelerator complex is reactivated in 2021, is currently under consideration to provide a more complete calibration of the detector.