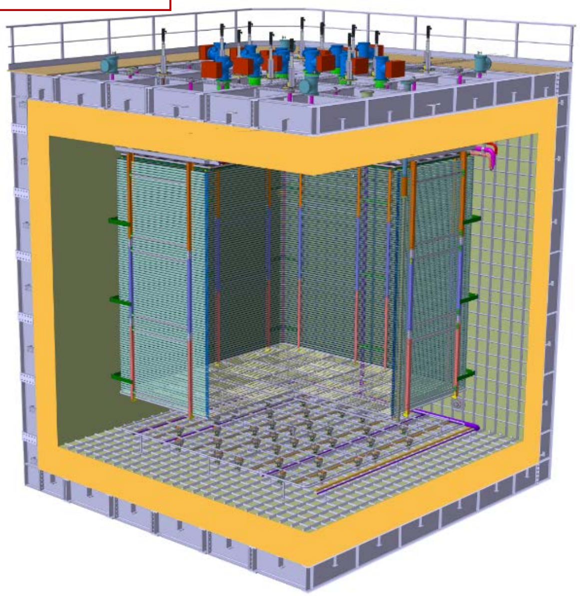
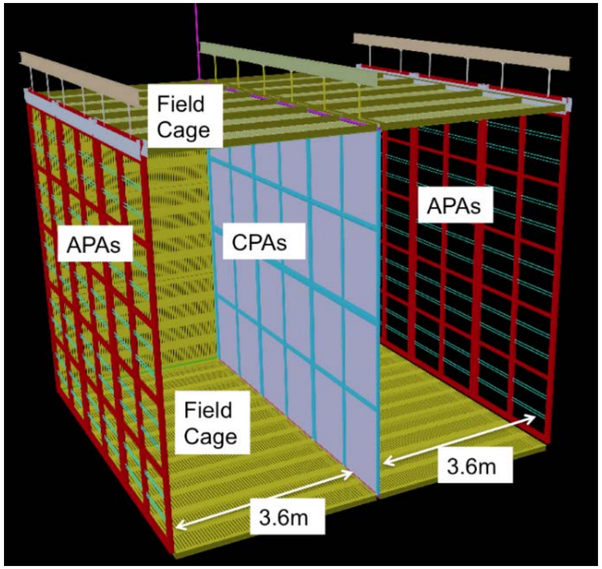
ProtoDUNE programme at CERN

D. Duchesneau



- Experiment context
- Single Phase status
- Dual Phase status



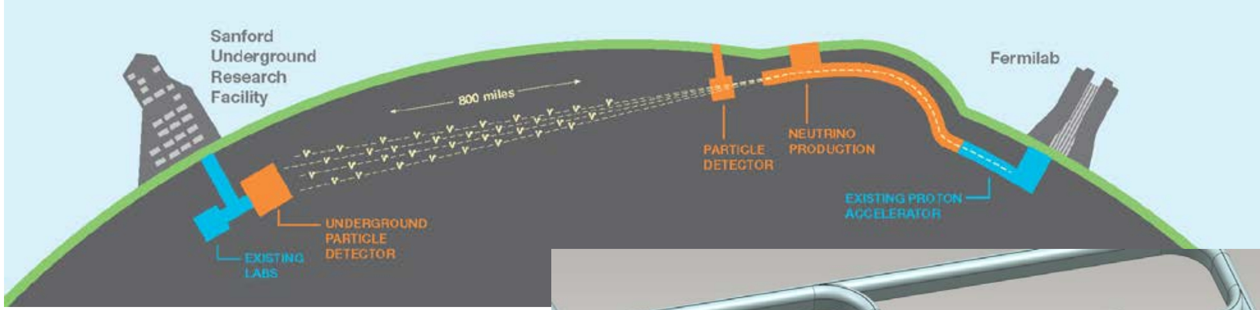
GDR meeting 29/05/2017

Context

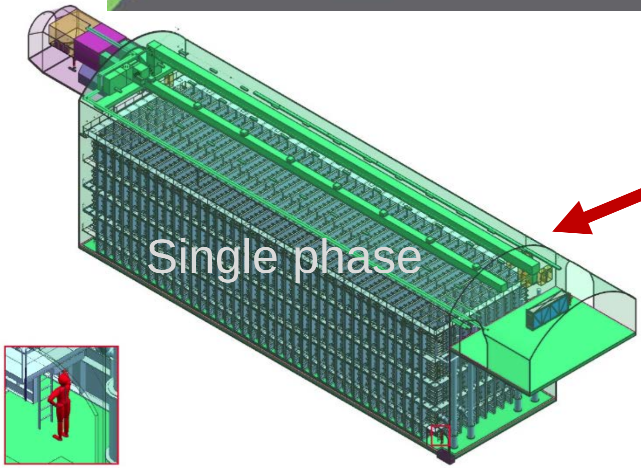
DUNE/LBNF

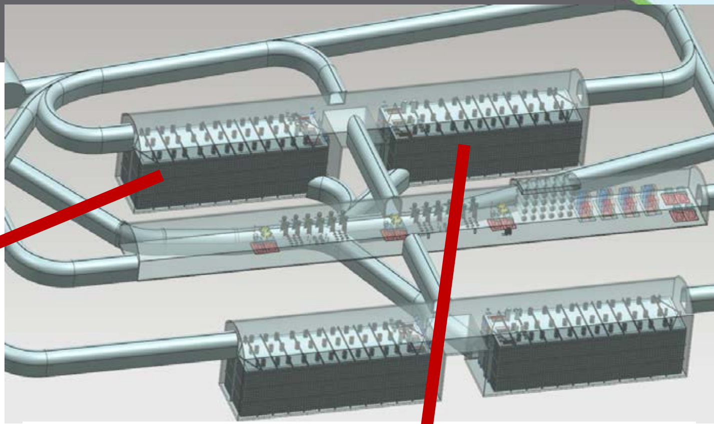
946 collaborators from 161 institutions in 30 nations

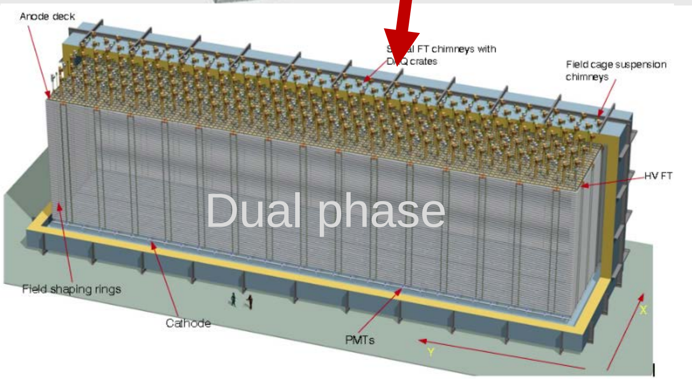
New beam at Fermilab (1.2 MW@120 GeV protons, upgradeable to 2.4 MW), 1300 km baseline

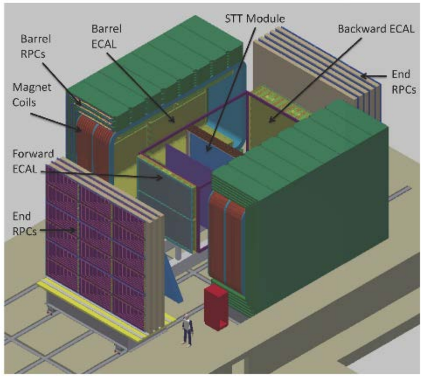


10^{21} protons on target per year.









Highly-capable near detector at Fermilab

- On-Axis 4 x10 kton Liquid Argon Time Projection Chamber (LArTPC) Far Detector at Sanford Underground Research Facility, South Dakota, 1.5 km underground

- ν_e appearance and ν_μ disappearance => Measure MH, CPV and mixing angles
- Large detector, deep underground => Nucleon decay and supernova burst neutrinos

DUNE/LBNF

Timeline

DEEP UNDERGROUND NEUTRINO EXPERIMENT

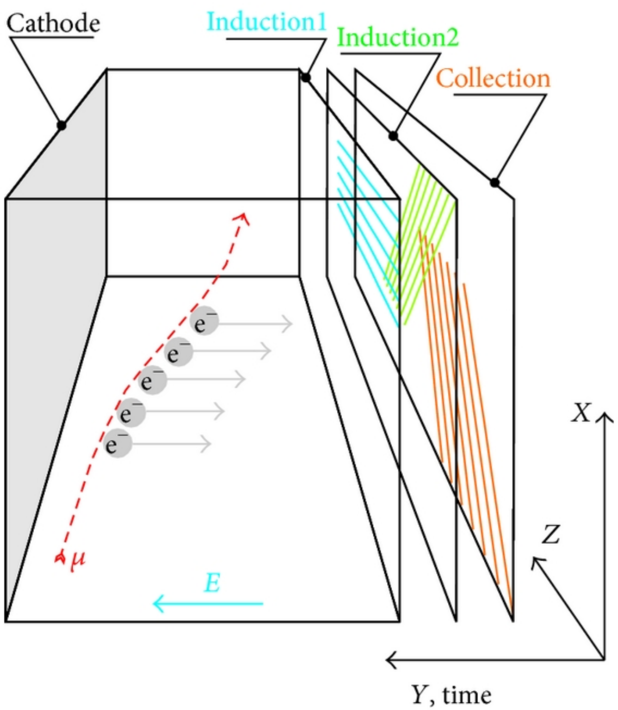
- 2020: Far Detector fabrication facilities ready
- 2021: Start to install 1st FD module
- 2023: Start to install 2nd FD module
- 2024: 20kt Far Detector operational
- 2026: Deliver neutrino beam at 1.2 MW

Far detector Technology

2 variants of giant Liquid Argon TPC

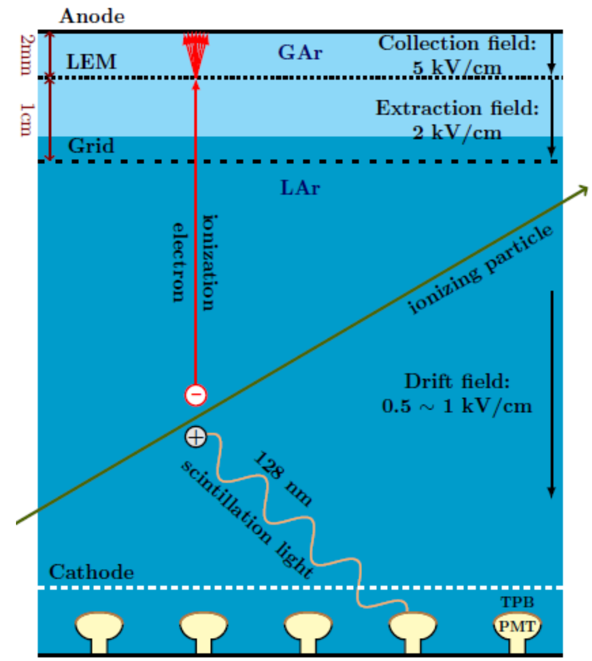
Main Liquid Argon TPC technological differences:

single Phase



The collection and induction wire planes are in the liquid

Dual Phase



The charge collection anode planes are positioned above the liquid in the Argon gas volume

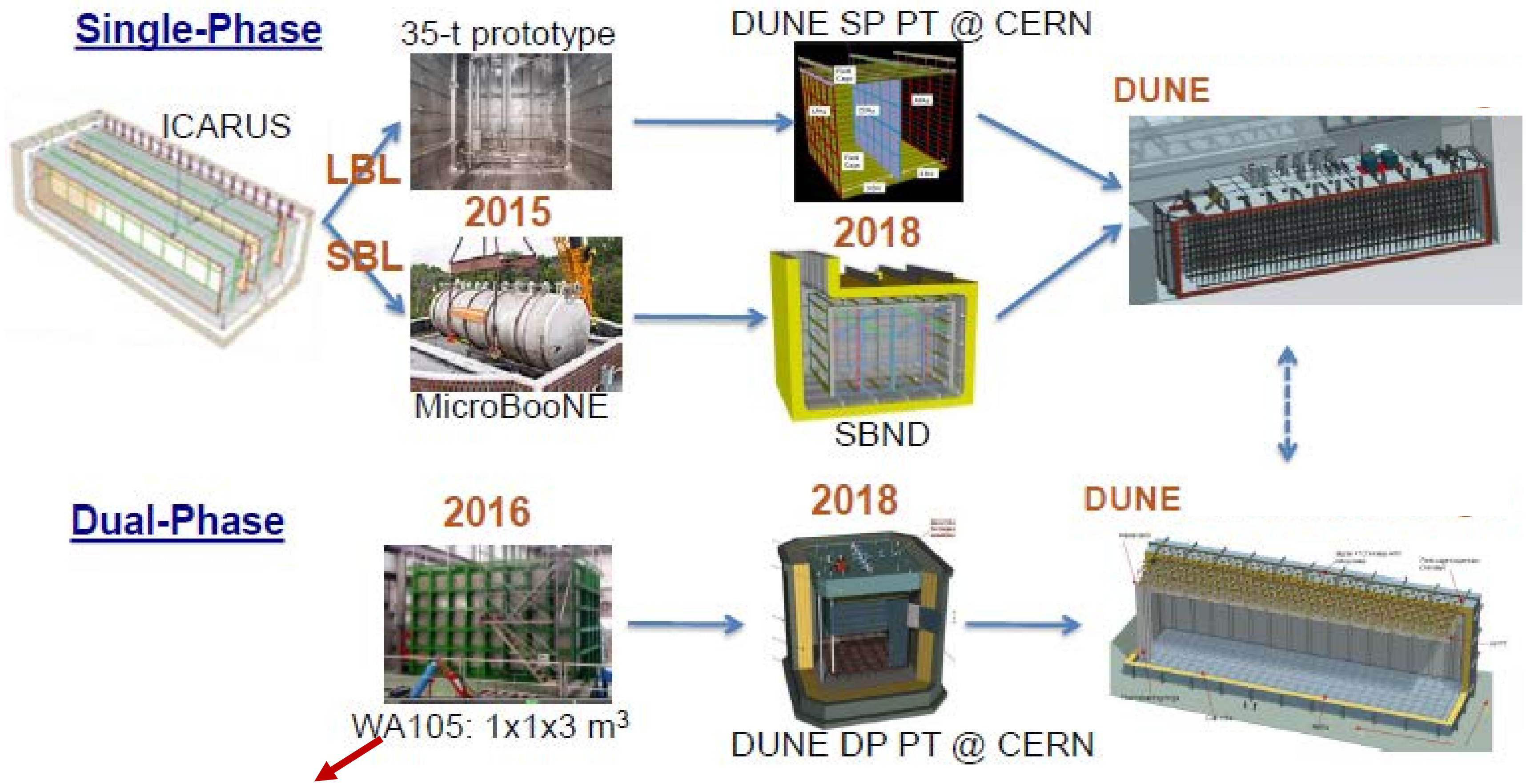
Some characteristics of Dual phase:

- Larger drift distance
- Improved S/B
- Less readout channels for same fiducial volume
- Electronics can be accessible from the top of cryostat at any time

DUNE

R&D Schedule for LAr TPC : international effort

- 35-ton single-phase TPC test at FNAL (completed)
- 3x1x1 m^3 dual-phase TPC at CERN (WA105/NP02), operating in 2017
- Associated dual & single phase ProtoDUNE's @ CERN (NP02,04), 2018



First large scale dual-phase LArTPC

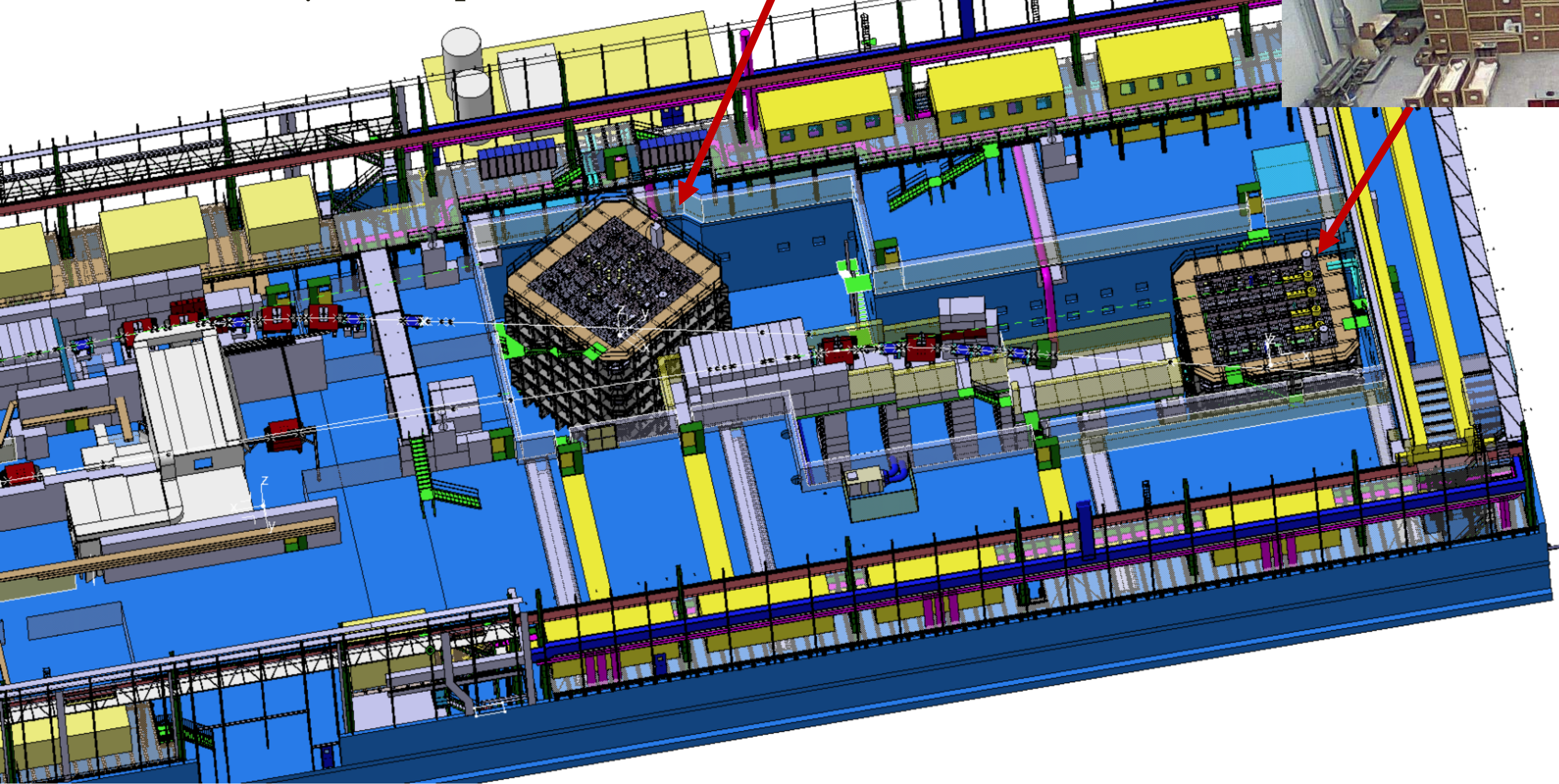
- Assembled in Bldg 182 @ CERN
- Data taking is about to begin and results expected in 2017

ProtoDUNE at the CERN Neutrino platform

Two Far Detector prototypes being built at CERN (one for each FD design) – in test beam
=> Detectors operational in 2018

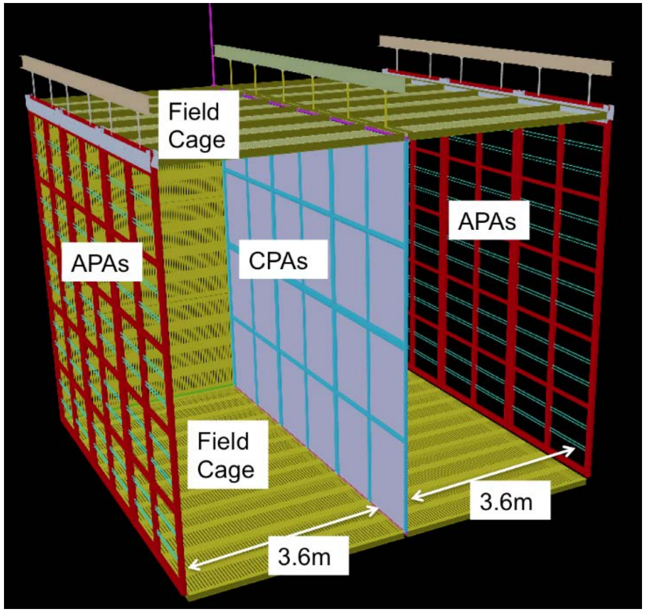
EHN1 Extension built
- Beneficial Occupancy in Sept. ’16
- Cryostats complete in July ’17
- Test-Beam Operations in 2018
- H2/H4 tertiary beam lines:

0.5-5 GeV/c e, μ, π, K, p +/- beams



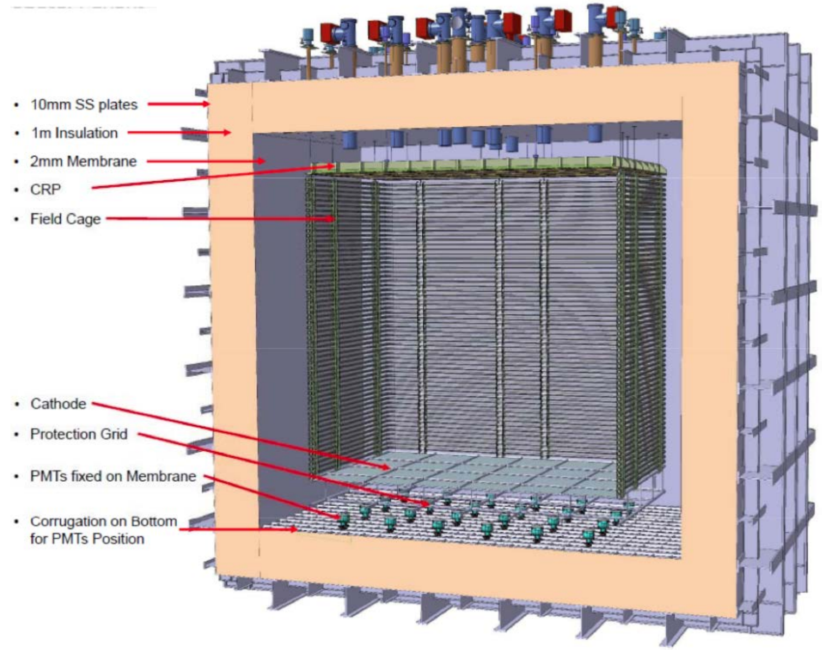
ProtoDUNE **Full-scale** engineering prototypes for far detectors

Test of component installation, commissioning, and performance
Also important for tests of FD calibration and reconstruction software tools



ProtoDUNE-SP: 7x7x6 m^3

Single phase: full-sized APAs and CPAs, full drift distance and E field



ProtoDUNE-DP: 6x6x6 m^3

Dual phase: full-sized readout/cathodes, half drift distance, operating at full and double E field

- ✓ Learning how to built, maintain and operation the large-scale prototypes are important ingredients of the DUNE program
- ✓ Understand production as well as operational issues
- ✓ Provides training and opportunities for Test Beam data analyses

ProtoDUNE-SP

Material from presentation given at the last DUNE collaboration meeting by C. Touramanis and R. Rameika

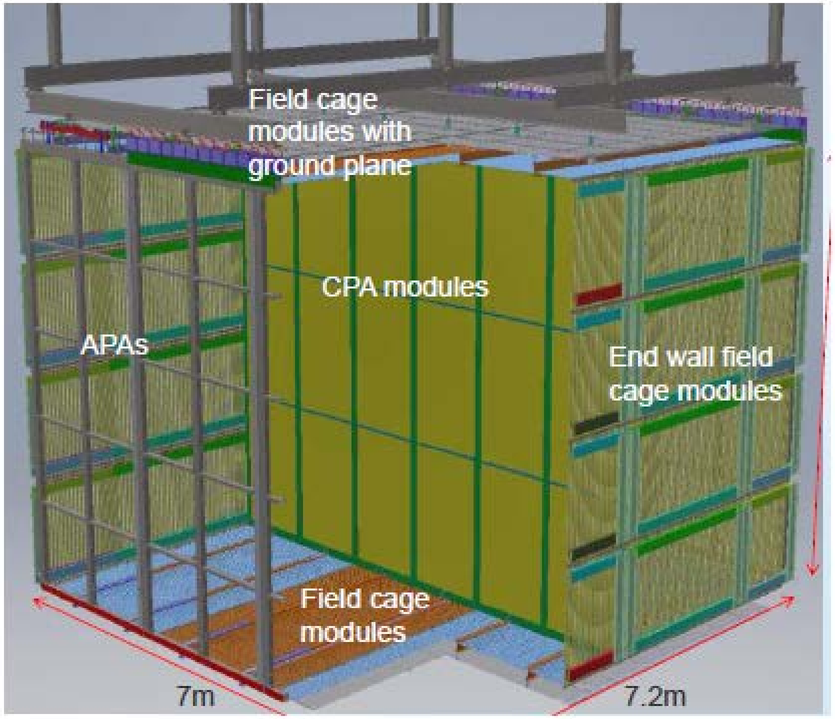
PD-SP Detector Overview

Main Detector Elements include :
Time Projection Chamber (TPC) ,
Front-end and digitizing electronics, a Photon Detector System (PDS) and Data Acquisition (DAQ)

Prototype of the single phase DUNE far detector. Full scale modules, but only half height of DUNE FD (single layer of APAs).

TPC has 6 units of anode wire planes (APAs), a high voltage cathode plane (18 "units"), 28 field cage modules, 15K readout channels

Dimensions - W: 3.6m (x2), H: 6m, L (along beam direction) : 7m ; 300 ton active mass



ProtoDUNE-SP

Cryostat & Clean Room Frame

ProtoDUNE-SP

Process outline and areas in the Clean Room

1) APA lowered into the SAS and inspected
2) APA PD Installation
3) APA CE Installation

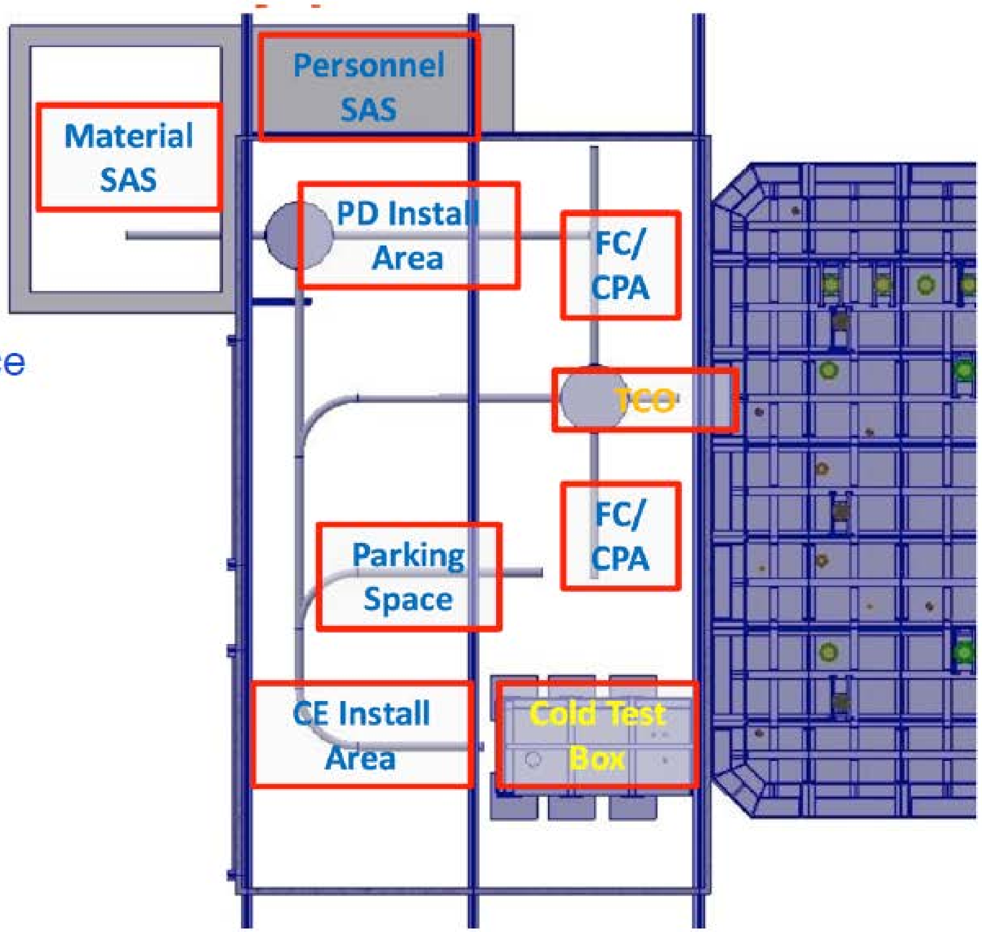
- Testing with small test station

4) APA Cold Test

- Connected to DAQ vertical slice in the Control Room

5) (APA parked)
6) APA in cryostat, cabling, testing

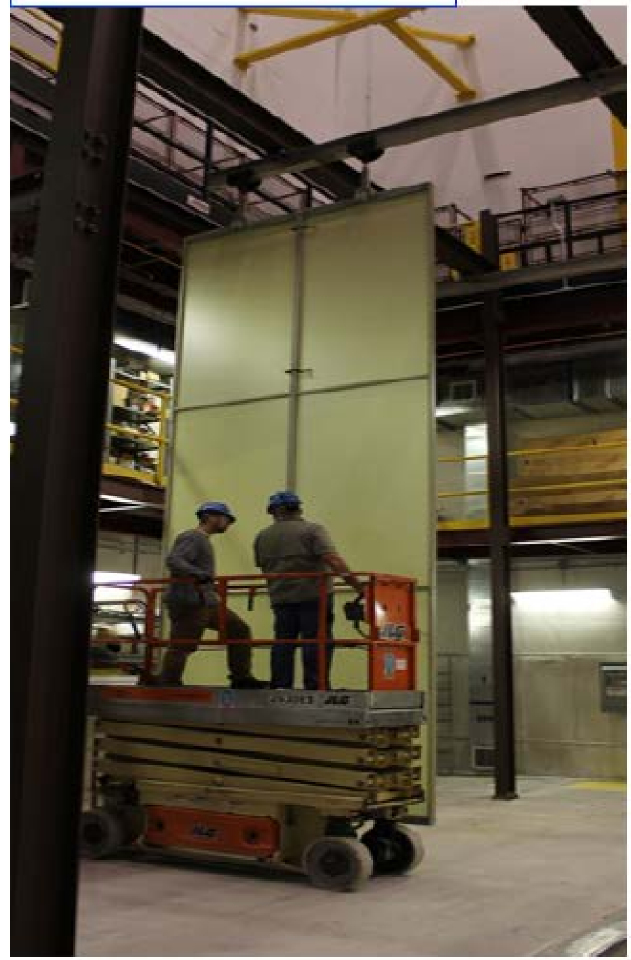
- <u>Can handle 3 APAs in the Clean Room at any time</u>
- CPA/FC assembly and installation



ProtoDUNE-SP

Cathode Plane (CPA)

Argonne National Lab, BNL, CERN



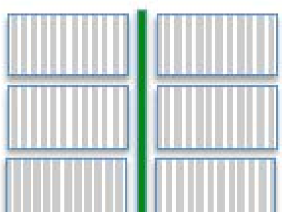
18 individual "panels" assembled into units of 3 and assemblies of 2 panels; 3 total panels needed

Field Cage Module Construction

Top and Bottom

Stony Brook University

Need 12 of these
6-top, 6-bottom



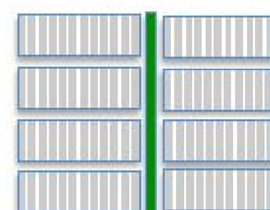
58 profiles in each module;
Profiles being procured by CERN and will be installed at CERN in the summer;

CERN, William & Mary

Endwalls

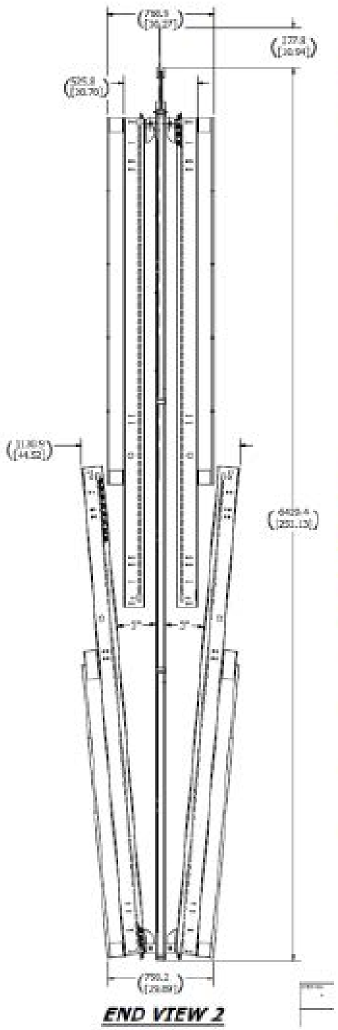
Louisiana State University

Need 16 of these
8 upstream
8 downstream
(1 us has the beam plug)



ProtoDUNE-SP

CPA-FC Assemblies



Each composed of a

- CPA (2 columns, 6 units)
- 4 Field Cage Modules (w Ground Planes)
  - Beam Right
    - Top and Bottom
  - Beam Left
    - Top and Bottom

Units are assemble outside of the cryostat and moved into the cryostat through the TCO

Need 3 Assembled Units :

- Upstream
- Midstream
- Downstream

ProtoDUNE-SP main schedule (may 2017)

Expected status on some key dates

(not a concise milestones list)

End June:

Clean Room operational

APA 1 in Clean Room

End July:

APA 1 PDS & CE integrated

August-September:

APA 1 warm & cold testing in Cold Box

End September:

APA installed inside cryostat

End November:

3 APAs inside cryostat in final position

End March 2018:

ready to close TCO

Mid-May 2018:

Installation inside cryostat completed

July 2018:

protoDUNE-SP cold & filled, start commissioning

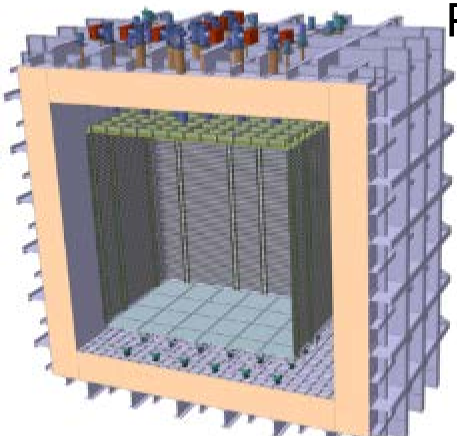
Mid August 18: Start taking cosmics & beam data

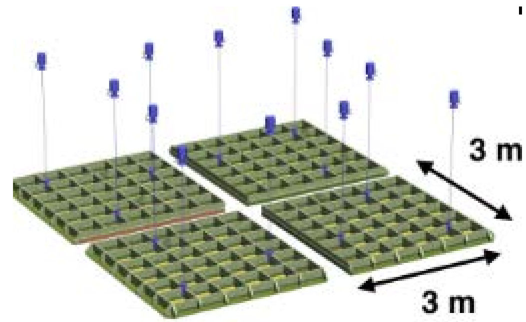
EHN1 Hall

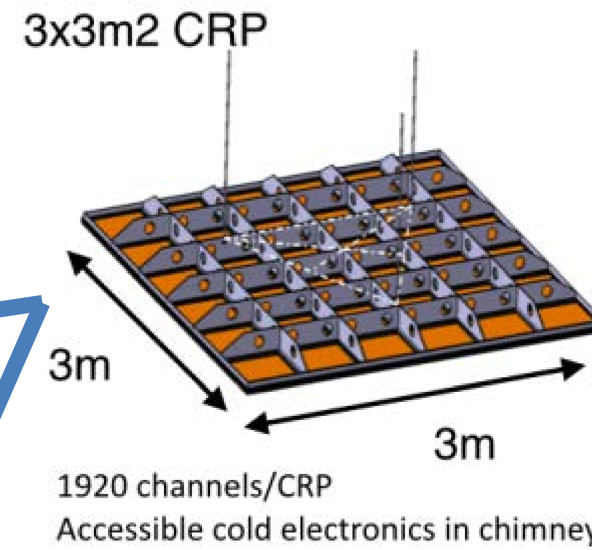
Control & computing rooms, offices

ProtoDUNE-DP

The Dual-Phase ProtoDUNE/WA105 6x6x6 m³ detector is built out of the same **3x3m² Charge Readout Plane units (CRP)** foreseen for the 10 kton Dual-Phase DUNE Far Detector (same QA/QC and installation chains)

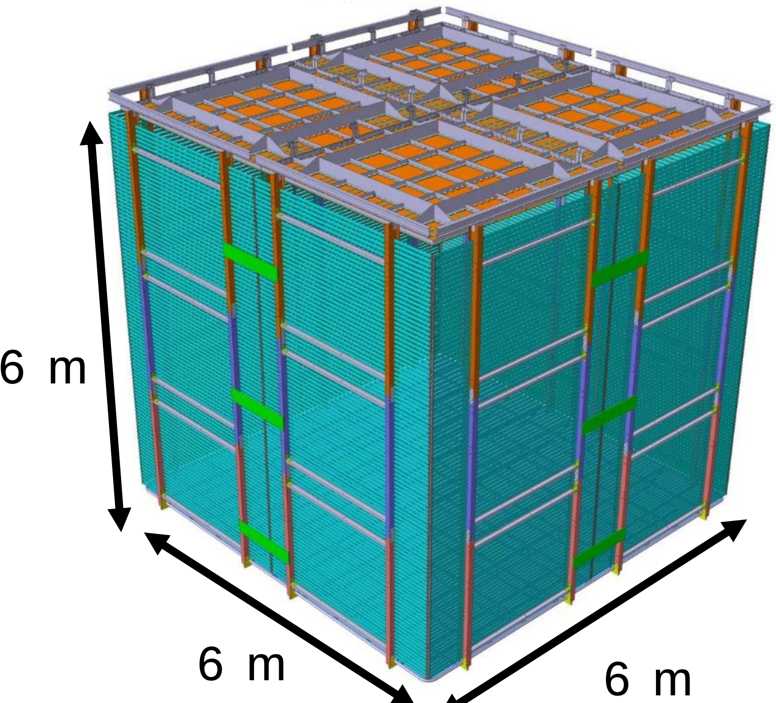


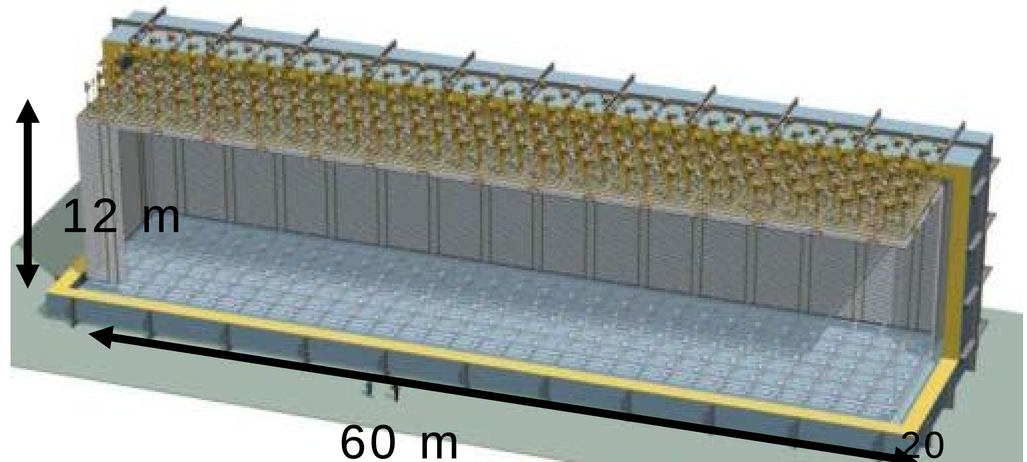




WA105: 4 CRP

10 kton: 80 CRP





ProtoDUNE-DP

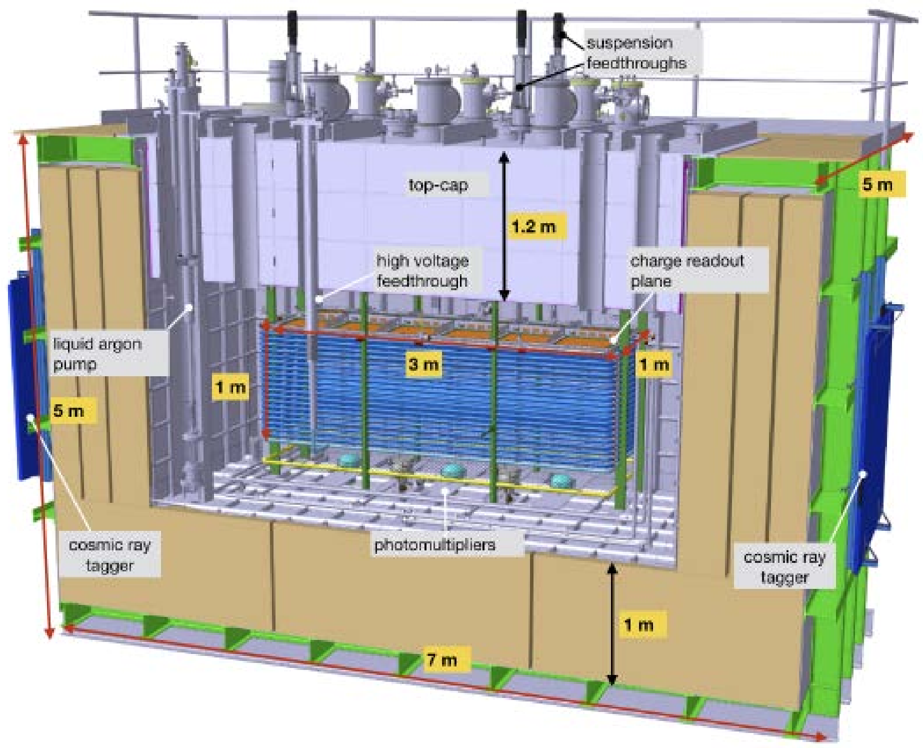
3x1x1 catalyzing progress on 6x6x6 m^3:

- Membrane vessel design and procurement
- Cryogenics
- Charge Readout Plane (CRP) detectors
- CRP structure and hanging system
- Feedthroughs
- HV and field cage
- Charge readout FE electronics + digital electronics
- Light readout system + electronics
- DAQ and online processing
- Slow Control

Advanced state of design, prototyping and production preparation

For many items huge benefit from immediate application of a smaller 3x1 prototype LAr-proto

- ✓ **Fully engineered versions of many detector components** First overview of th complete system integration: **set up full chains** for QA, construction, installation, commissioning
- ✓ **Anticipate legal and practical aspects** related to procurement, **costs and schedule verification**
- ✓ **Retirement of several risks for PD-DP thanks to (1) identification of critical components (2) early detection of potential problems**



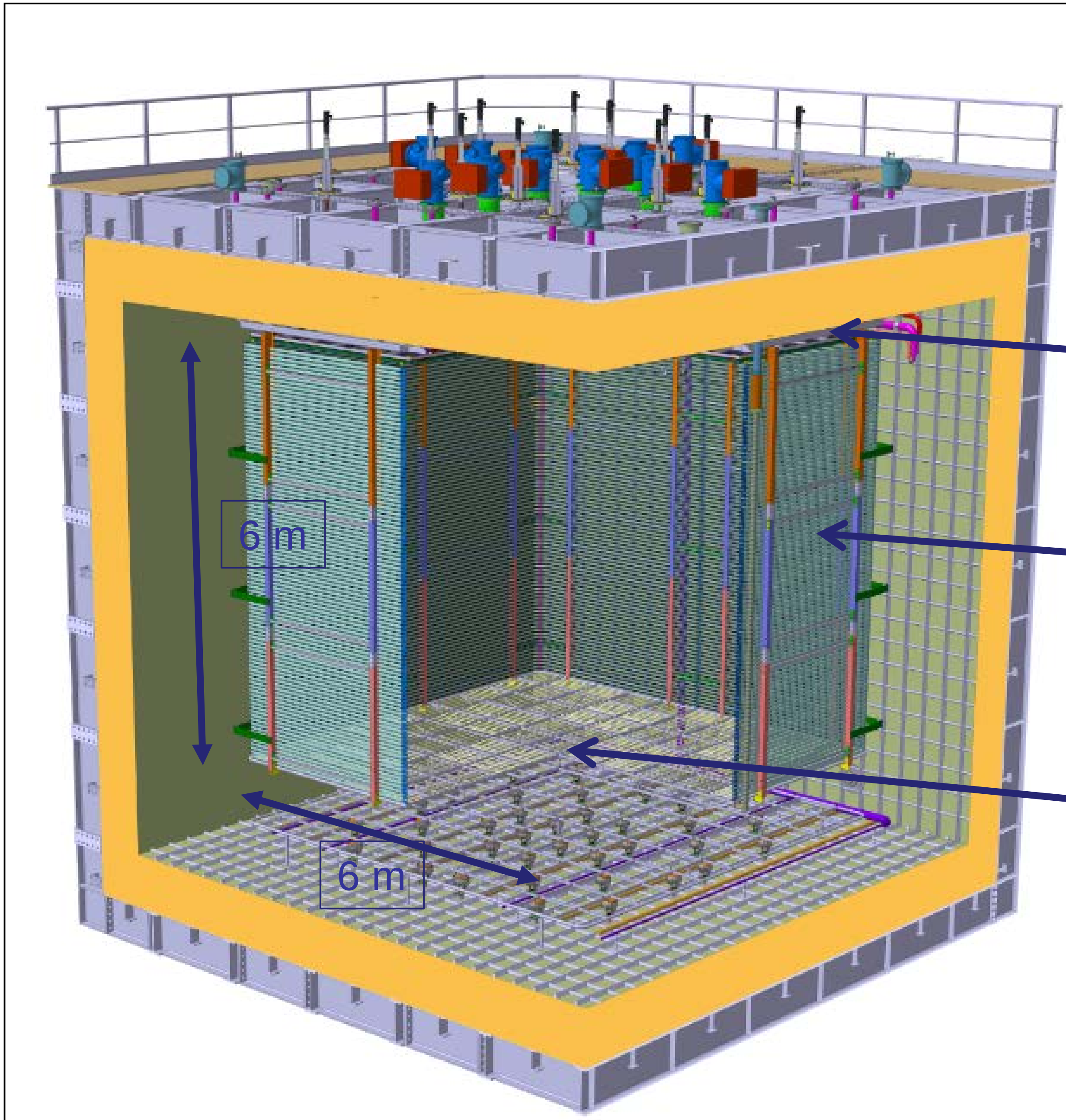
Detector Installation completed in Fall 2016

- **Delay in the cryogenic system installation and of its commissioning**
- **The cryostat purge with pure argon was successfully performed by middle of February.**
- **Problems with formation of cold spots of ice on the exoskeleton since March 3rd → under investigation**

ProtoDUNE-DP

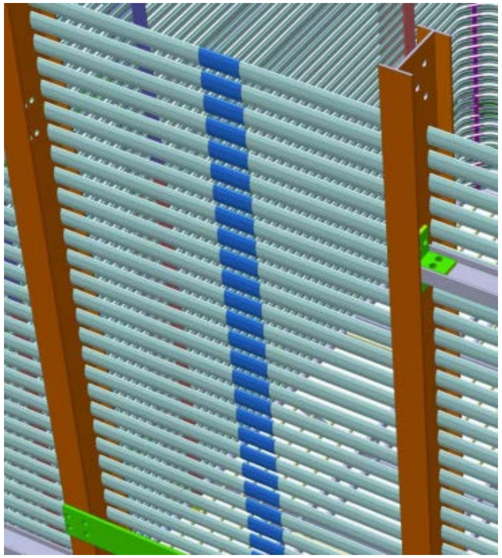
Detector–Cryostat integration

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



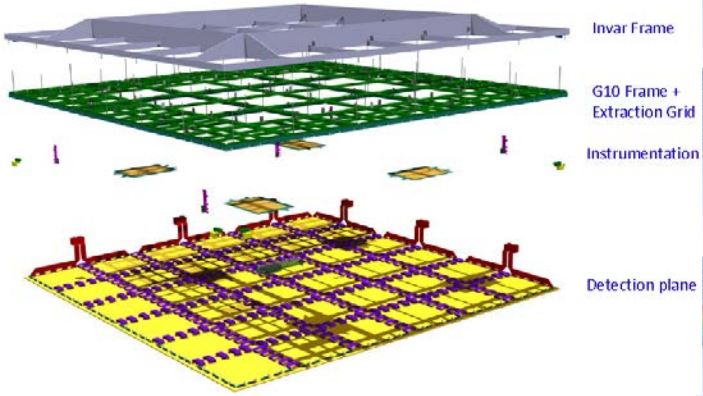
Test and validation of components

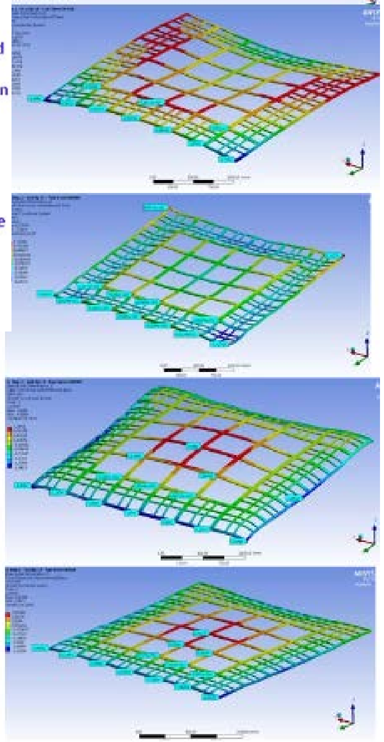
Field Cage and profile structure



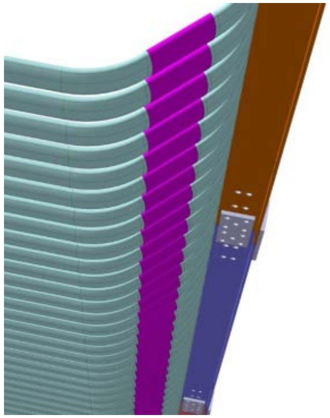
Sub-module zero built at at UTA to qualify FRP vendors

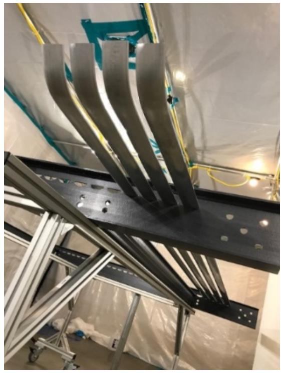
Charge Readout Plane

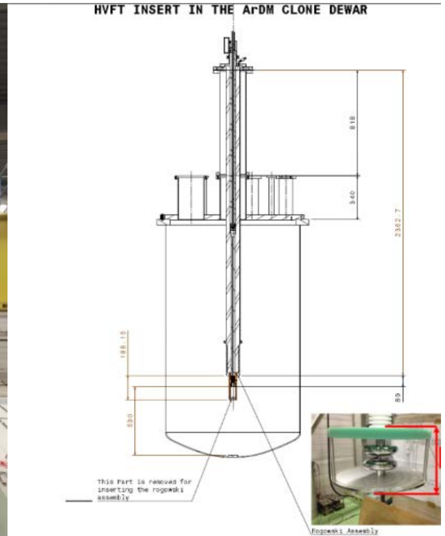





Cold bath to test T gradient behaviour of material

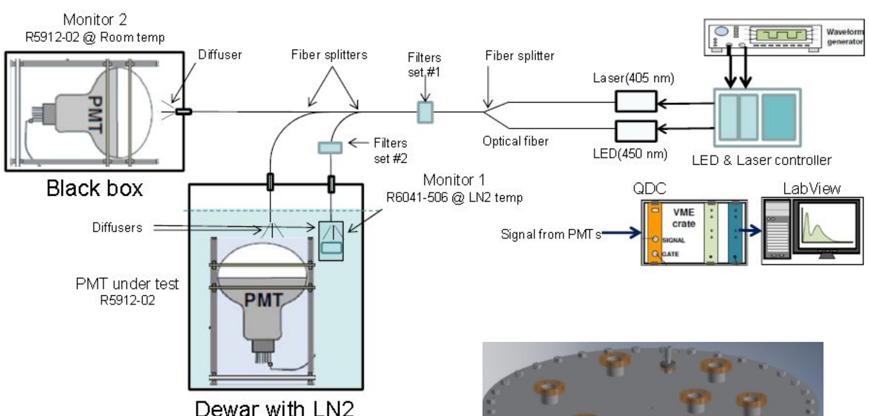






Cathode HV system:

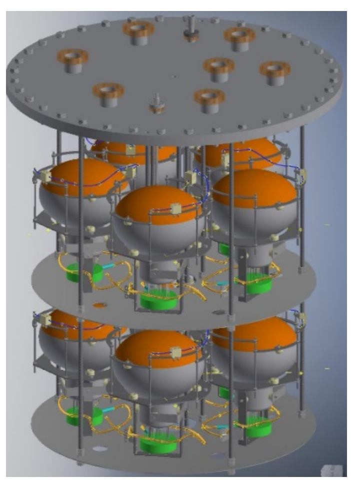
- HV power supply for 300 kV already available Heinzinger
- HV feedthrough deployed on 3x1x1 but designed to work up to 300 kV (300 kV milestone achieved in September in dedicated test setup, article: C. Cantini et al 2017 JINST 12 P03021.)

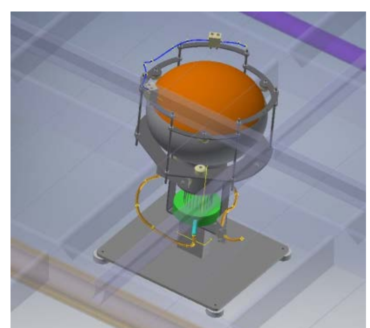


Preparation for PMTs installation:

- 40 PMTs procured in December 2016
- Calibration/characterization system at warm/cold
- TPB coating at CERN (Icarus facility)

Cryostat for test in batches of 10 PMTs (April 2017)



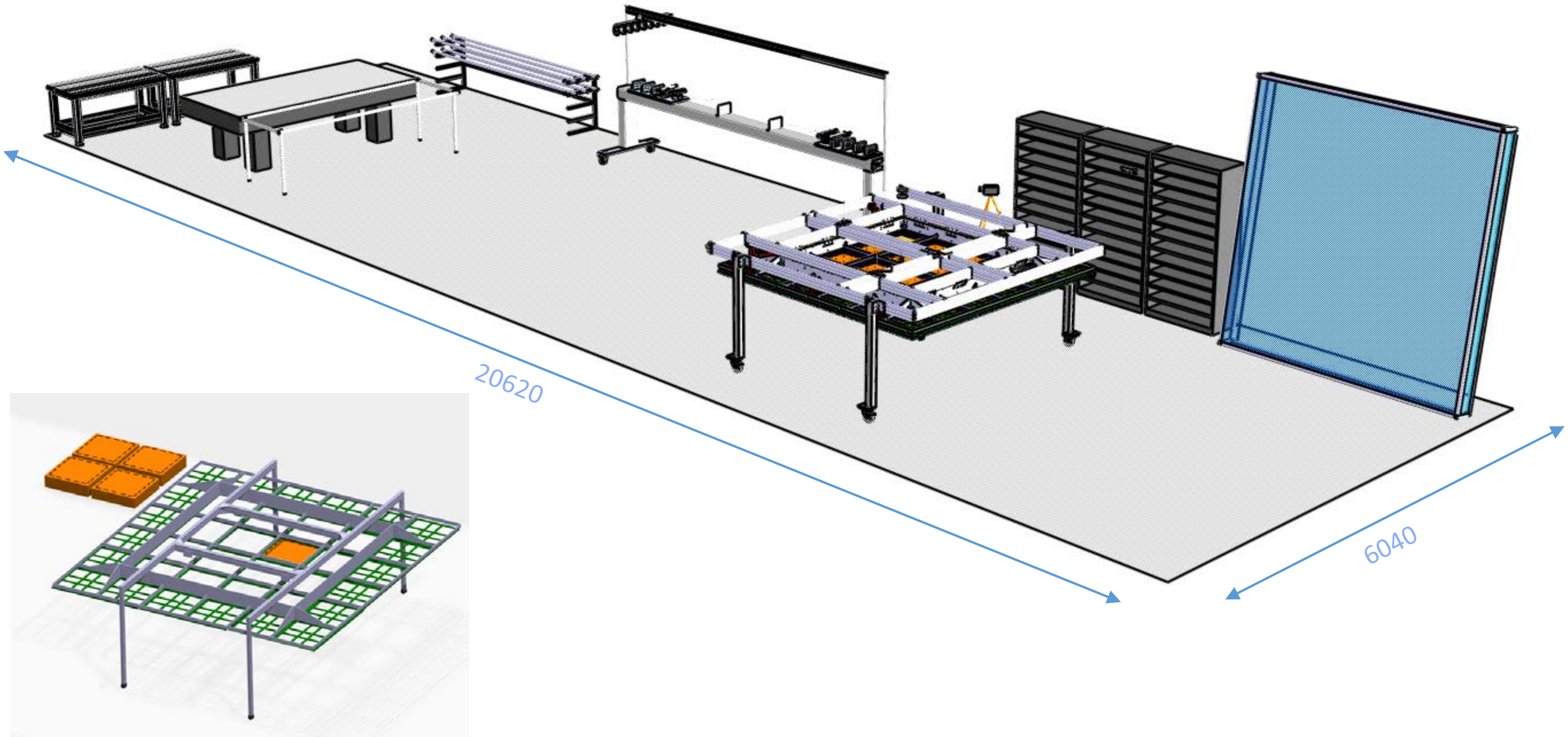


Mechanical supports for installation on the cryostat floor in between corrugations (arrangement compatible with cryo-piping)

CRP assembly in Clean Room 185

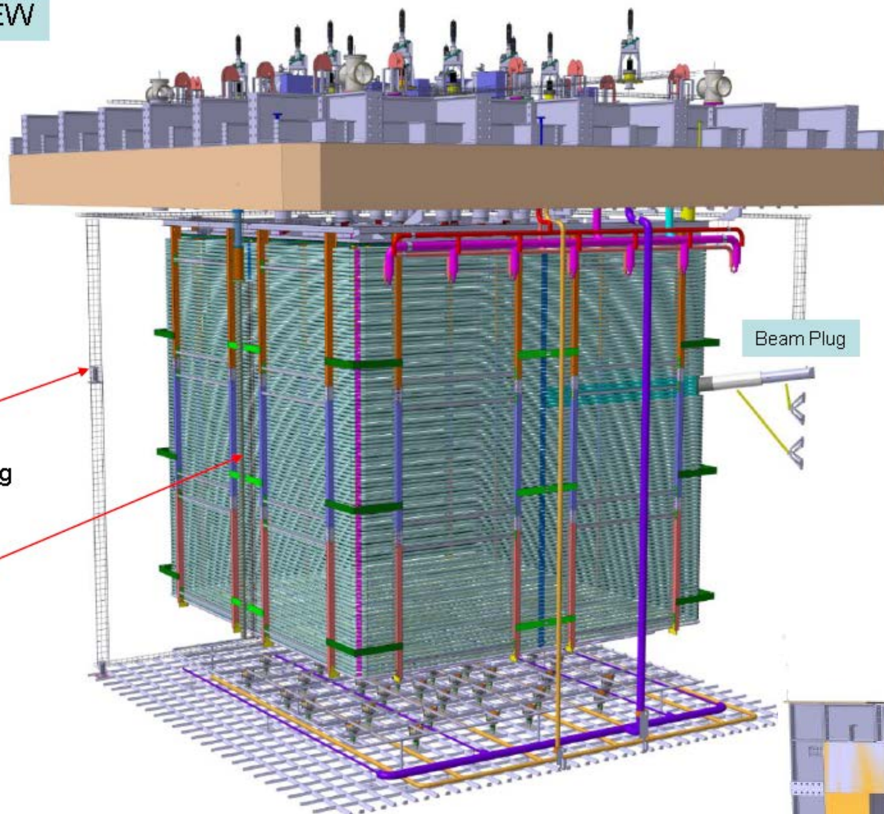
See the animation of the assembly : https://youtu.be/jcnJjlU-Cyc

- **Clean Room in hall 185, used so far by Icarus, freed in April in order to host the CRP assembly activities**

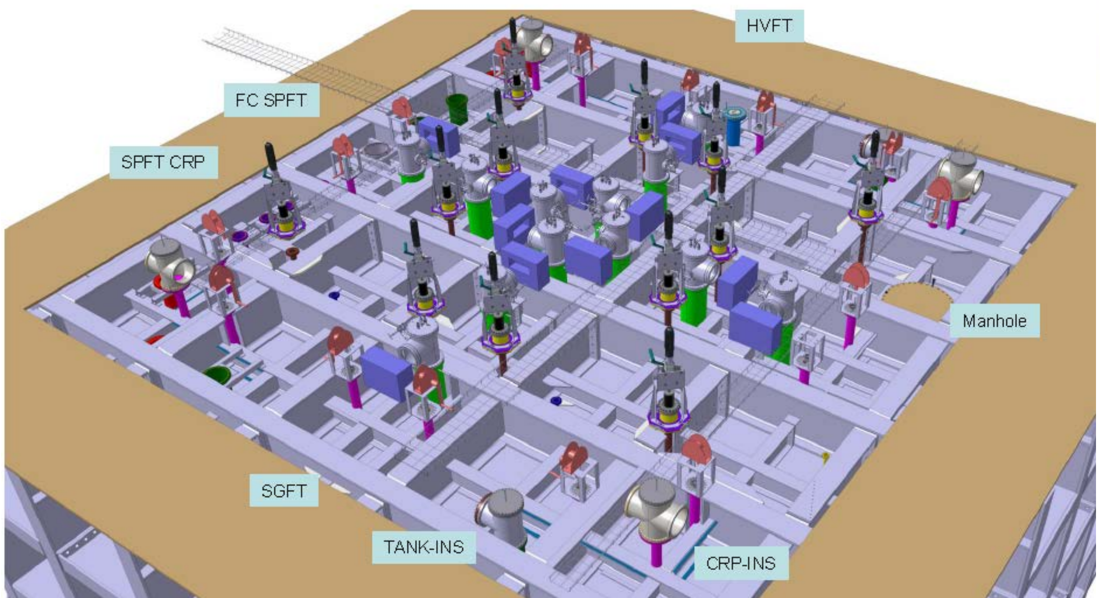


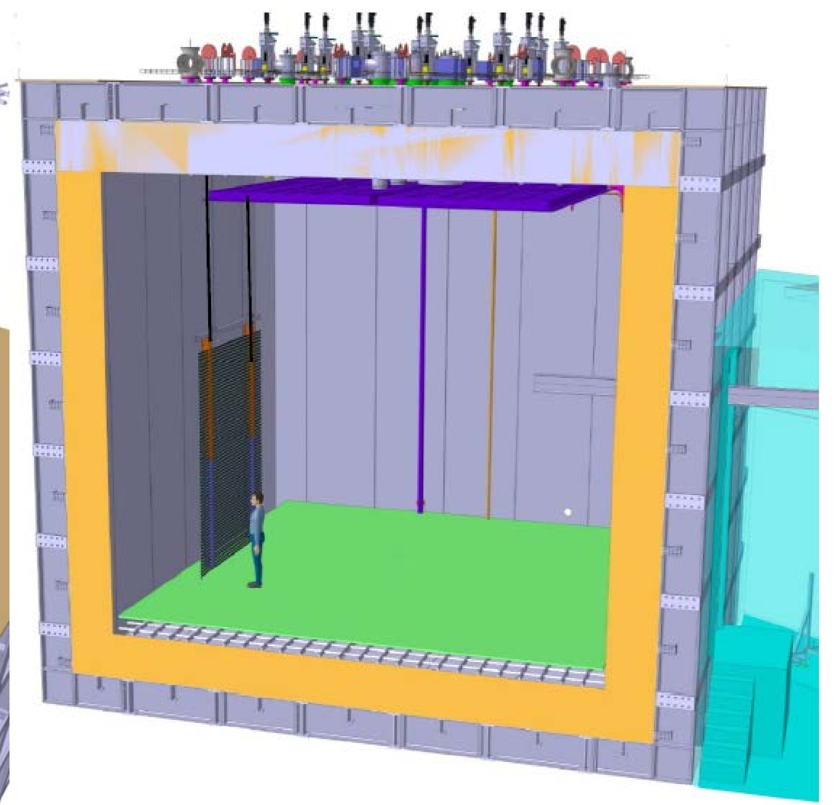
DETECTOR OVERVIEW

- Top FTs
- Internal Cable Trays
- 4 x Purity Monitor
- Internal Cryogenic piping
- Beam Plug
- HVFT degrader

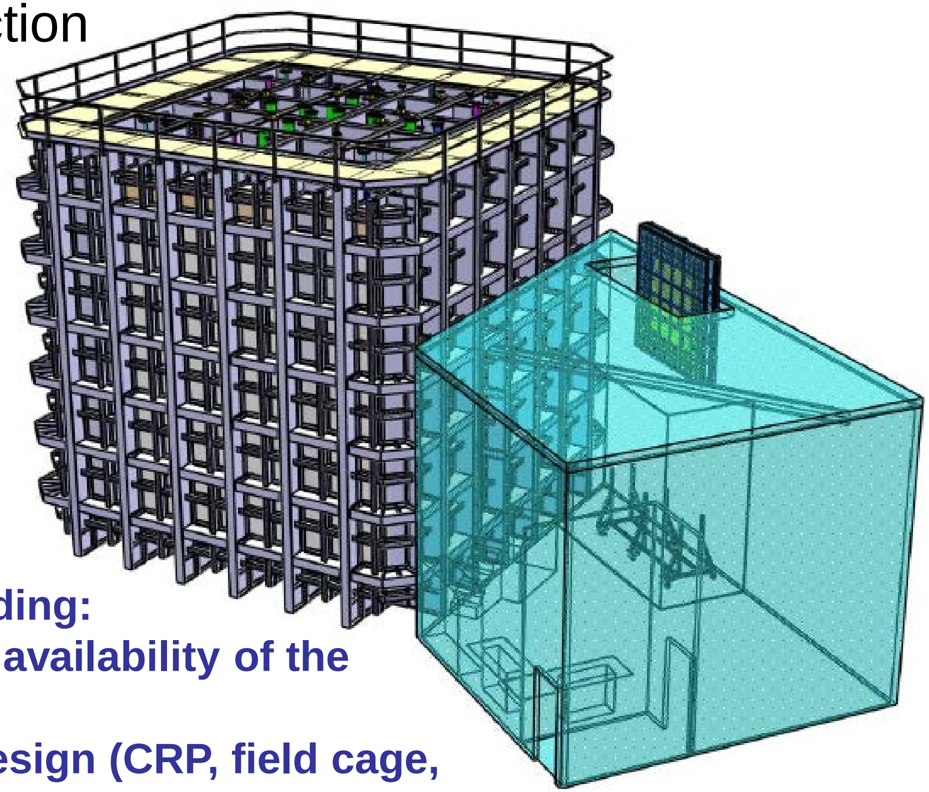


- **Global detector integration performed as well as precise definition of mounting operations**
- **Assembly procedures and transportation boxes defined to be compatible with 10 kton assembly at LBNF**





ProtoDUNE-DP Integration and construction



- **Cryostat + clean room buffer should become available in June to start the detector installation activities**
- **Assembly/procurement activities started**

Schedule revision including:

- **information from the availability of the infrastructure**
- **detector executive design (CRP, field cage, cathode) related to a more precise definition of the construction and assembly procedures**
- **refinements related to experience from the 3x1x1**
- **Procurement/tendering follow-up**

→ end of detector installation 6 April 2018

Dedicated assembly/installation WG with neutrino platform people

Overall close coordination among EHN1 and two ProtoDUNES needed during assembly (as recommended by SPSC)

ProtoDUNE-DP main schedule (may 2017)

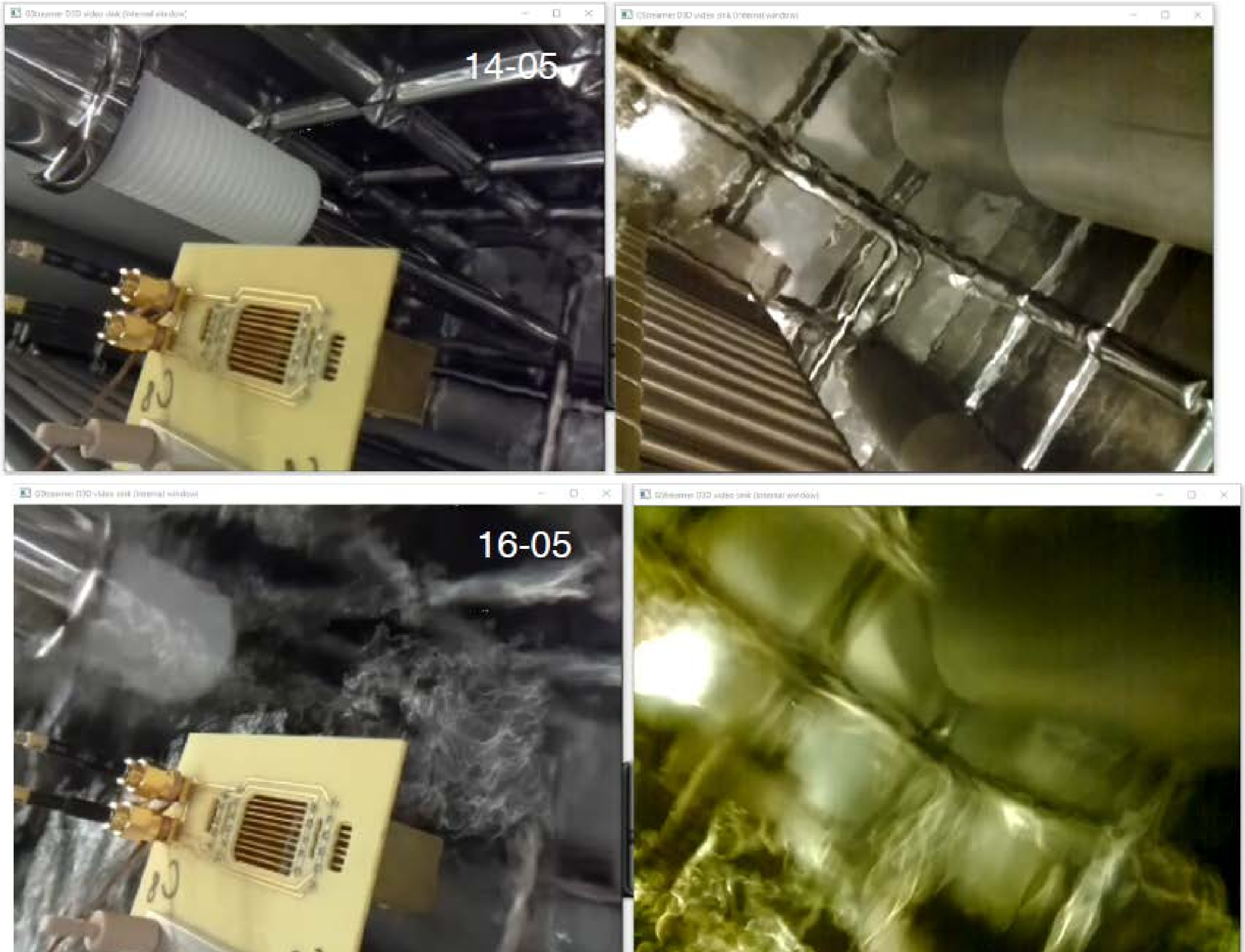
- **Access to clean room in Hall 185 11/4/2017**
- **Access to cryostat/clean room buffer in EHN1 to start the detector installation 1/6/2017**
- **First CRP installed 3/10/2017**
- **All CRPs installed and cabled 17/1/2018**
- **End of readout electronics installation 9/2/2018**
- **End of drift cage and cathode installation**
- **End of beam-plug installation 5/3/2018**
- **End of PMTs installation 4/4/2018**
- **Detector fully installed/cabled , ready to seal TCO 6/4/2018**

Similar timing as the Single Phase:

- July 2018: cold and filled, start commissioning
- August 2018: start data taking (cosmics & beam data)

The End

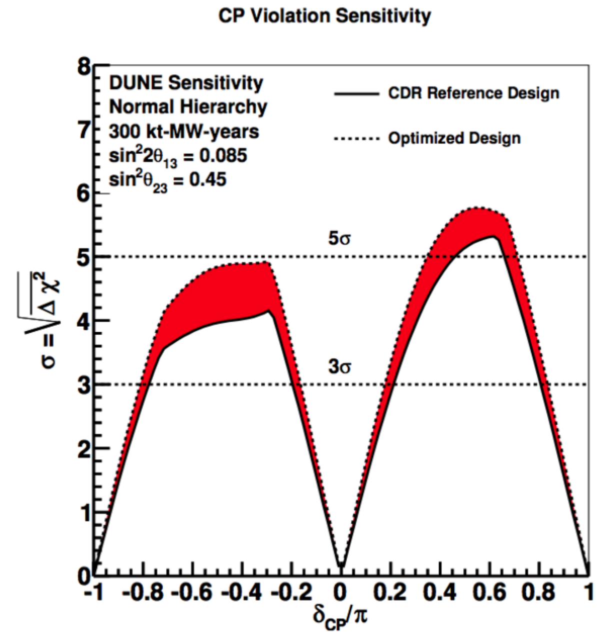
Cryostat filling



DUNE physics performance

300 kt-MW-yrs = 3.5+3.5 years x 40kt @ 1.08 MW, 80GeV protons

Physics milestone	Exposure kt · MW · year (optimized beam)	
1° θ_{23} resolution ($\theta_{23} = 42°$)	45	1 year
CPV at 3σ ($\delta_{CP} = +\pi/2$)	60	
CPV at 3σ ($\delta_{CP} = -\pi/2$)	100	2 years
CPV at 5σ ($\delta_{CP} = +\pi/2$)	210	
MH at 5σ (worst point)	230	5 years
10° resolution ($\delta_{CP} = 0$)	290	
CPV at 5σ ($\delta_{CP} = -\pi/2$)	320	7 years
CPV at 5σ 50% of δ_{CP}	550	
Reactor θ_{13} resolution ($\sin^2 2\theta_{13} = 0.084 \pm 0.003$)	850	
CPV at 3σ 75% of δ_{CP}	850	



CDR, arXiv: 1512.06148