DUNE

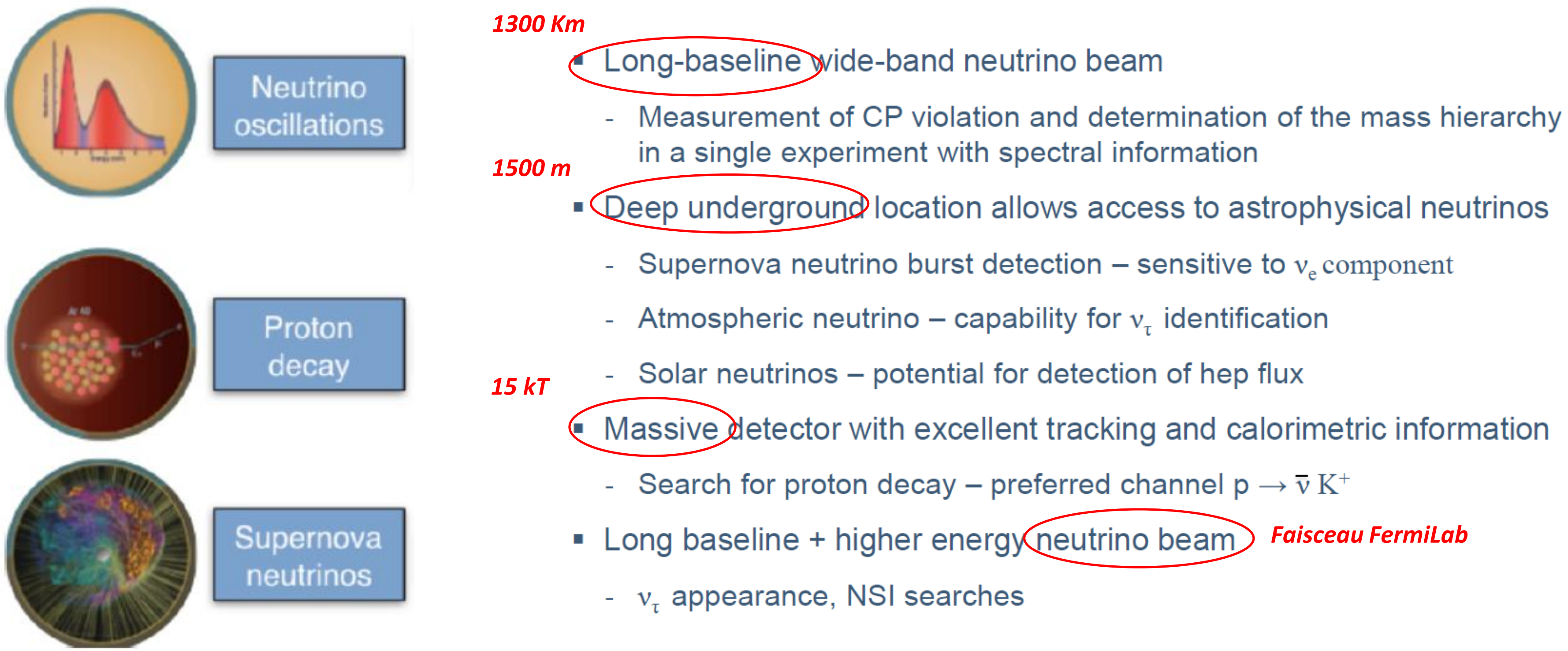
- Présentation du projet DUNE
- « Focalisation » sur la contribution IN2P3

But scientifique
Le site SURF et LBNF
Principe de détection
Historique R&D Dune
Organisation DUNE et IN2P3
Contributions IN2P3
Présentation de la construction des détecteurs
Organisation projet et gestion
I&I engineering et installation

https://www.ijclab.in2p3.fr/

philippe.rosier@ijclab.in2p3.fr
Bureau études mécaniques

Le programme physique de DUNE



1300 Km

- Long-baseline wide-band neutrino beam
  - Measurement of CP violation and determination of the mass hierarchy in a single experiment with spectral information

1500 m

- Deep underground location allows access to astrophysical neutrinos
  - Supernova neutrino burst detection – sensitive to ν_e component
  - Atmospheric neutrino – capability for ν_τ identification
  - Solar neutrinos – potential for detection of hep flux

15 kT

- Massive detector with excellent tracking and calorimetric information
  - Search for proton decay – preferred channel $p \rightarrow \bar{\nu} K^+$
- Long baseline + higher energy neutrino beam

  Faisceau FermiLab
  - ν_τ appearance, NSI searches

Besoin de detecteurs sophistiqués massifs (>10 kton) dans le but d’étudier des effets minuscules:

- Identification précise des flaveurs de neutrinos à partir de l’état final des leptons (muon, electron, tau)
- Mesure precise de l’energie des neutrinos

=> les TPC Argon Liquide

Technologie Argon Liquide

- Use of LAr for the detection of high energy particles first suggested by L.W. Alvarez (1968)

- LAr TPCs proposed by C. Rubbia (1977) and H.H. Chen (1978)
  - Thanks to the high mobility and low diffusion of electrons in LAr, large LAr volumes can be operated as TPCs, providing high-quality imaging and high-resolution energy measurements from the detection of the ionization charge
  - The abundant scintillation light emitted by excited argon diatomic molecules can be used to determine the absolute event time (~10 ns resolution), to provide a self-trigger with no bias on the charge detection, and for calorimetry
  - High readout granularity, can sample electromagnetic showers down to a few % of a radiation length (as Gargamelle with Freon & NOMAD)
  - LAr TPCs overcome the deficiencies of both bubble chambers (limited in size and sensitive for short times) and large-size calorimetric detectors (coarser granularity)
  - **Ideal detectors for physics in the MeV to GeV range**

- Many LArTPC detectors operating in the last ~15 years: ICARUS, ArgoNEUT, MicroBooNE, LARiAT, CAPTAIN, protoDUNE_SP, 3x1x1 m^3, protoDUNE_DP

Exemples de TPC

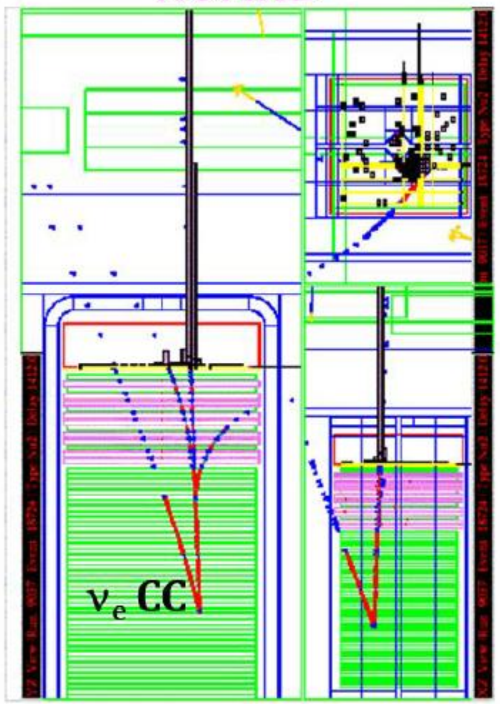
Gargamelle Bubble Chamber

3 ton sensitive mass

Heavy Freon

Bubble ∅ (mm)	3
Density (g/cm^{3})	1.5
X_0 (cm)	11.0
λ_T (cm)	49.5
dE/dx (MeV/cm)	2.3

NOMAD



2.7 tons drift chambers target

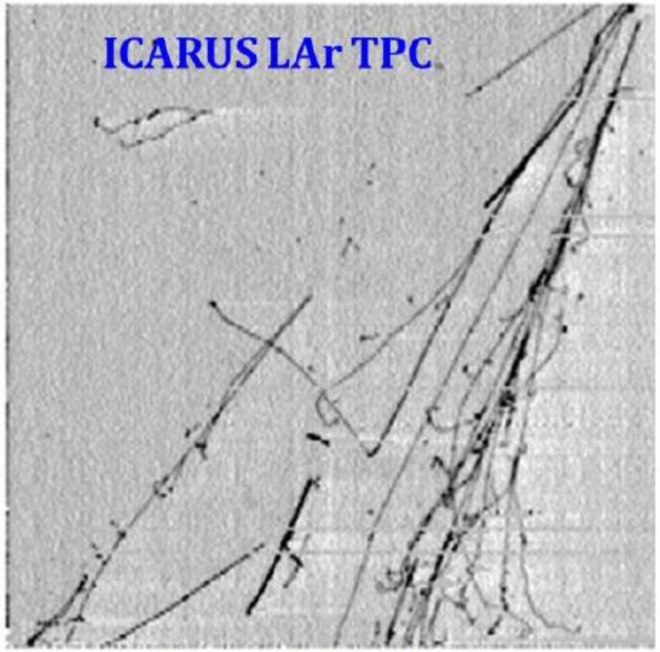
Density (g/cm3) 0.1

2% X_0/chamber

0.4 T magnetic field

TRD detector

Lead glass calorimeter

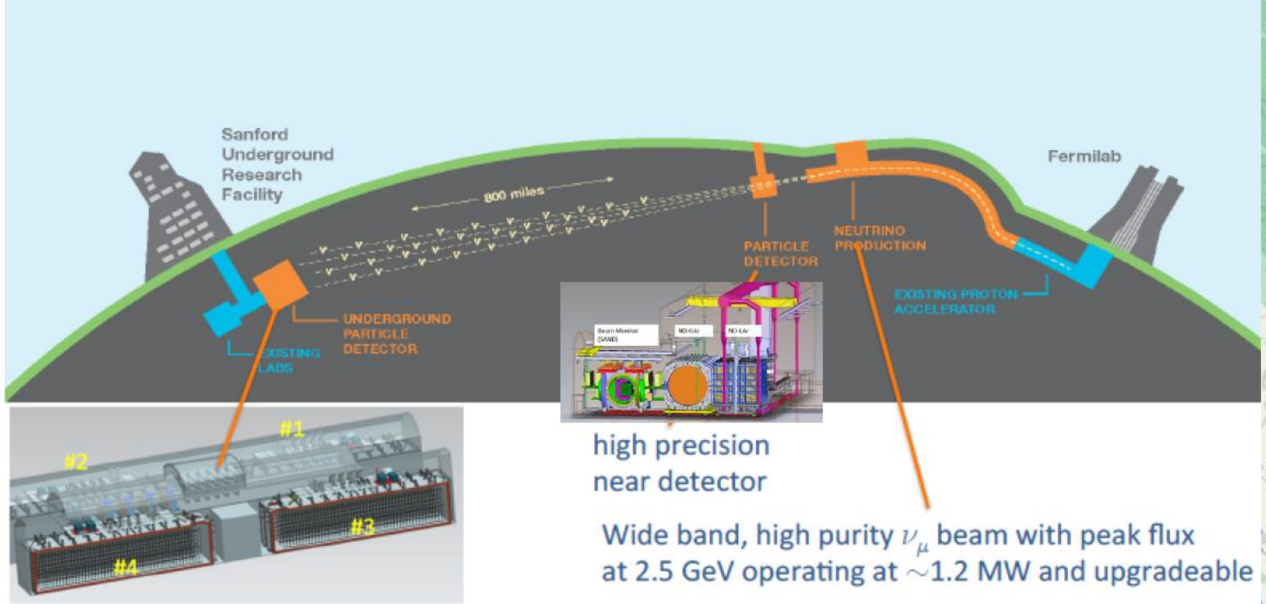


ICARUS LAr TPC

Resolution (mm^3)	3×3×0.2
Density (g/cm^{3})	1.4
X_0 (cm)	14.0
λ_T (cm)	54.8
dE/dx (MeV/cm)	2.1

C. Rubbia,
CERN Report 77-8,
May 1977

The Deep Underground Neutrino Experiment (DUNE) supported by the Long Baseline Neutrino Facility (LBNF)



high precision near detector

Wide band, high purity ν_μ beam with peak flux at 2.5 GeV operating at $\sim$1.2 MW and upgradeable

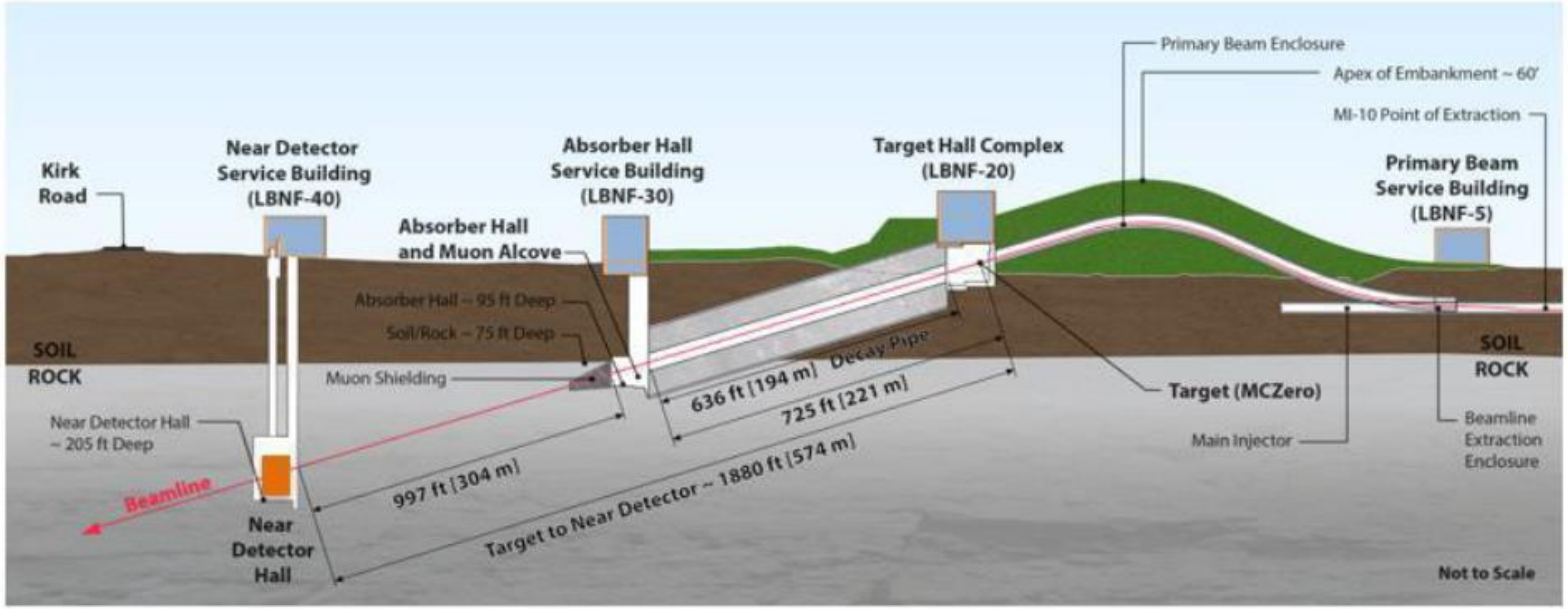
- Four Far Detector modules at 1500m depth
- Staged approach Phase-I, Phase-II for FD modules, beam and ND configuration

Beam 1.2 – 2.4 MW
40 kton Far Detector mass

La distance de 1300 km……..

- The 1300 km baseline enables unambiguous measurement of the neutrino mass ordering
- The detector’s on-axis location provides for a wide-band energy spectrum of neutrinos enabling detailed fitting of the oscillation parameters, including δ_{CP}
- The liquid argon technology for the Far Detector, at a depth of 1480 m, fully exploits the wide-band neutrino beam
- The Near Detector complex provides control of systematic uncertainties

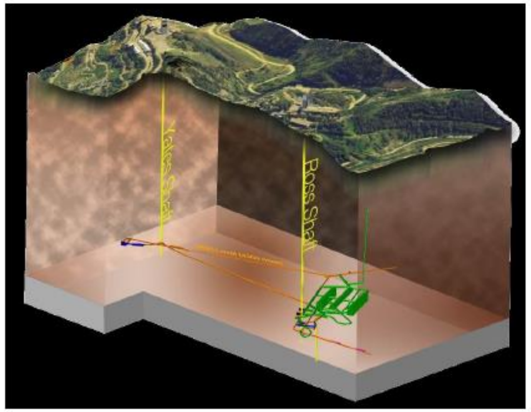
La Near Site Facility



Basé entre autres sur les cavités PIP II (participation IJCLAB)

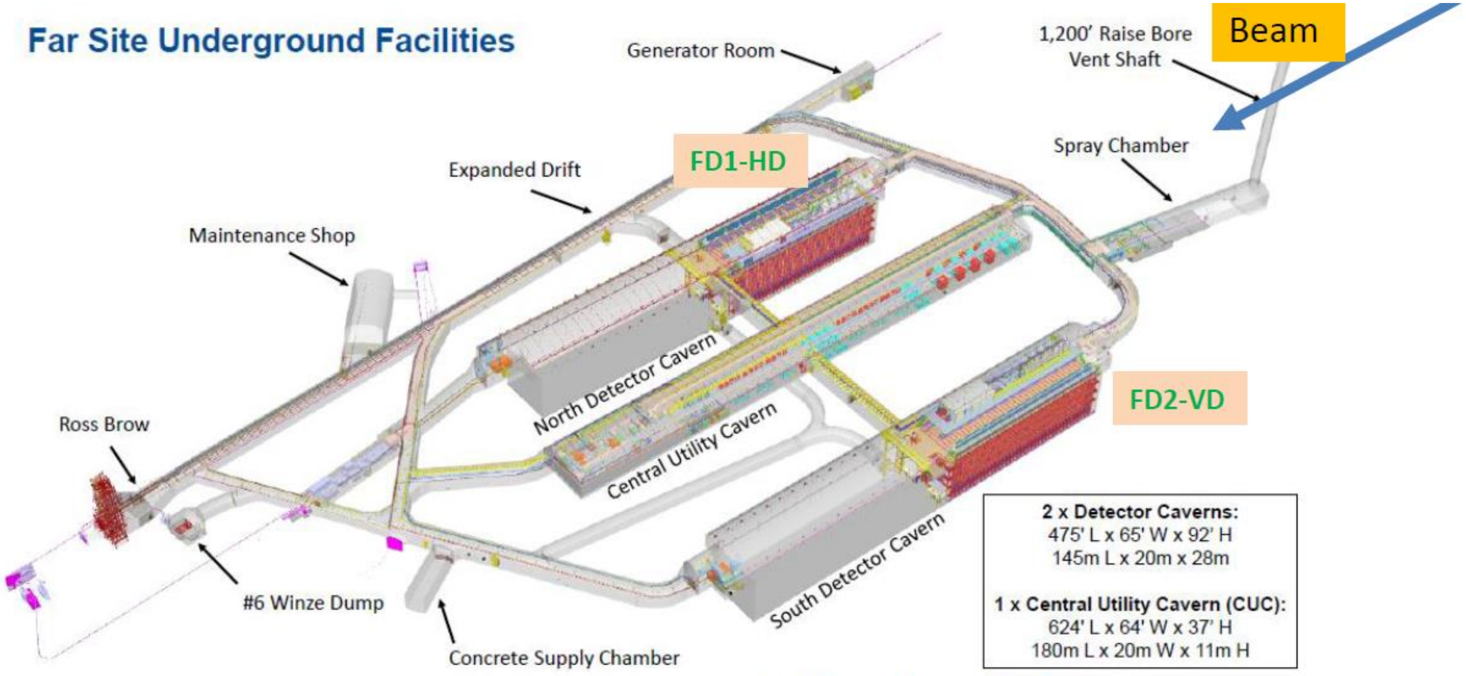
- High intensity primary protons (60 - 120 GeV energy range) on a graphite target
- Designed for 1.2 MW initial proton beam power, upgradeable to 2.4 MW
- PIP II upgrade of the current LINAC necessary to reach 1.2 MW (with participation of IN2P3 and CEA)
- Presently achieved record beam power of 803 kW in March 2021 (no PIP II)

Le LBNF Far Site Facility



2 x Detector caverns:
145m L x 20m W x 28m H
to house four 17.5 kt total mass modules

1 x Central utility cavern:
180m L x 20m W x 11m H



2 x Detector Caverns:
475' L x 65' W x 92' H
145m L x 20m x 28m

1 x Central Utility Cavern (CUC):
624' L x 64' W x 37' H
180m L x 20m W x 11m H

DUNE Phase-I :

- Beam 1.2 MW
- ND initial configuration
- **Two FD LAr TPC modules: FD1-HD, FD2-VD**

52% of LBNF underground infrastructure already excavated in January 2023

North Detector Cavern – West End

Drilling holes for blast charges for bench C (left) and removing muck (right) in North Detector Cavern (4850-33)

Excavation terminée en fevrier 2024

- ✓ Reliability Project upgrades completed
  - significant improvements, including new hoist system and refurbished shaft
- ✓ Pre excavation work completed
  - work to move excavated rock from one mile underground to the surface and deposit in the Open Cut
- Excavation work construction of three DUNE caverns underway
  - Work stated in April 2021; will finish April 2024

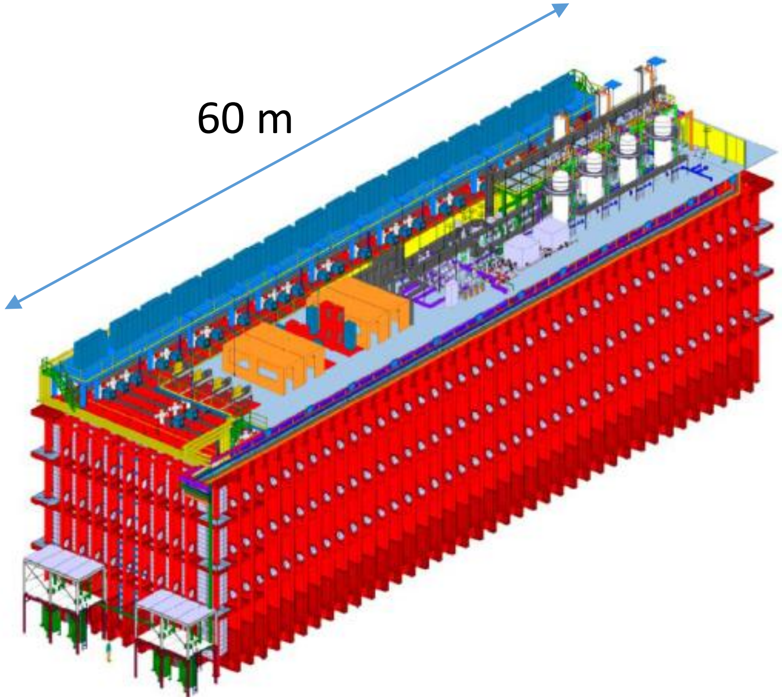
Rock conveyor in operation

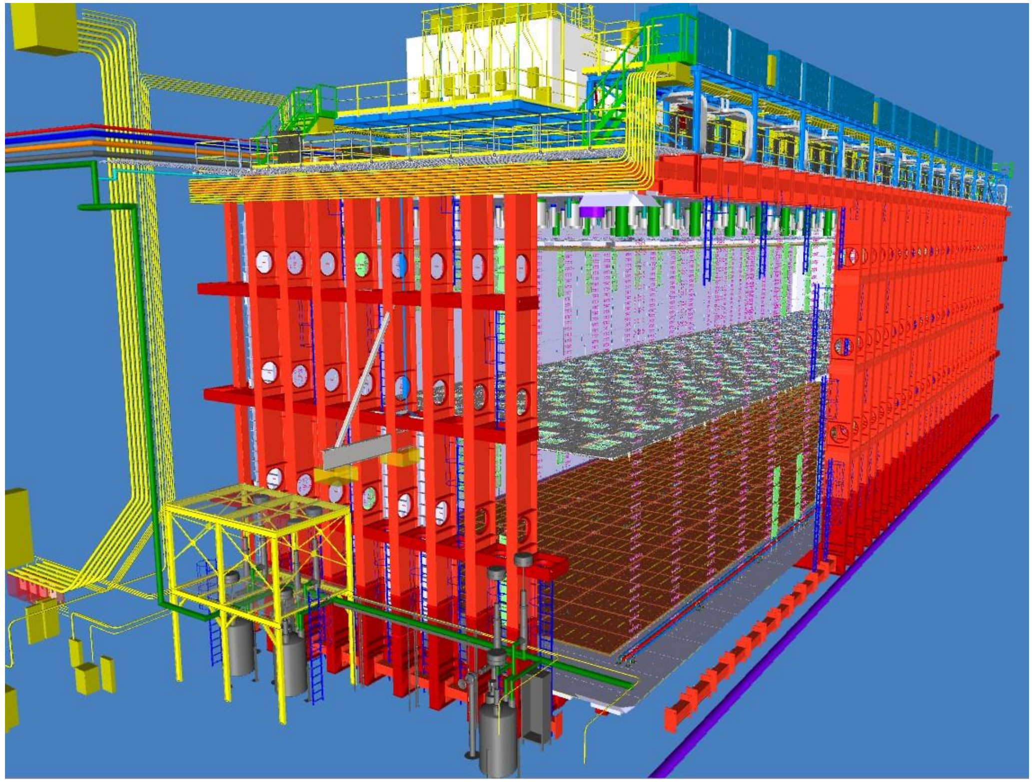
Drilling charge holes

Drilling holes for blast charges for bench C (left) and removing muck (right) in North Detector Cavern (4850-33)

Far site cryogenique infrastructure

- In addition to the 1st cryostat, CERN Council agreed to provide 2nd cryostat module at June 2021 meeting
- Nitrogen system acquired via commercial contract (in initial award process)
- Argon system (receiving facility on surface, purification, recirculation and condensing systems, internal cryo systems) with in-kind contributions from international partners

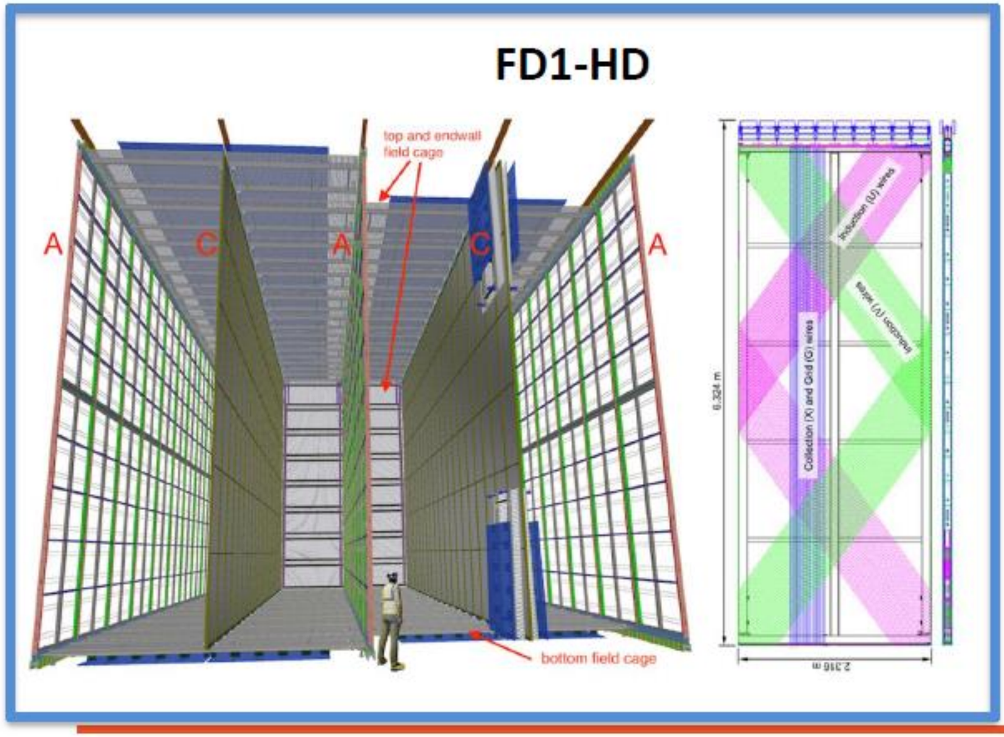


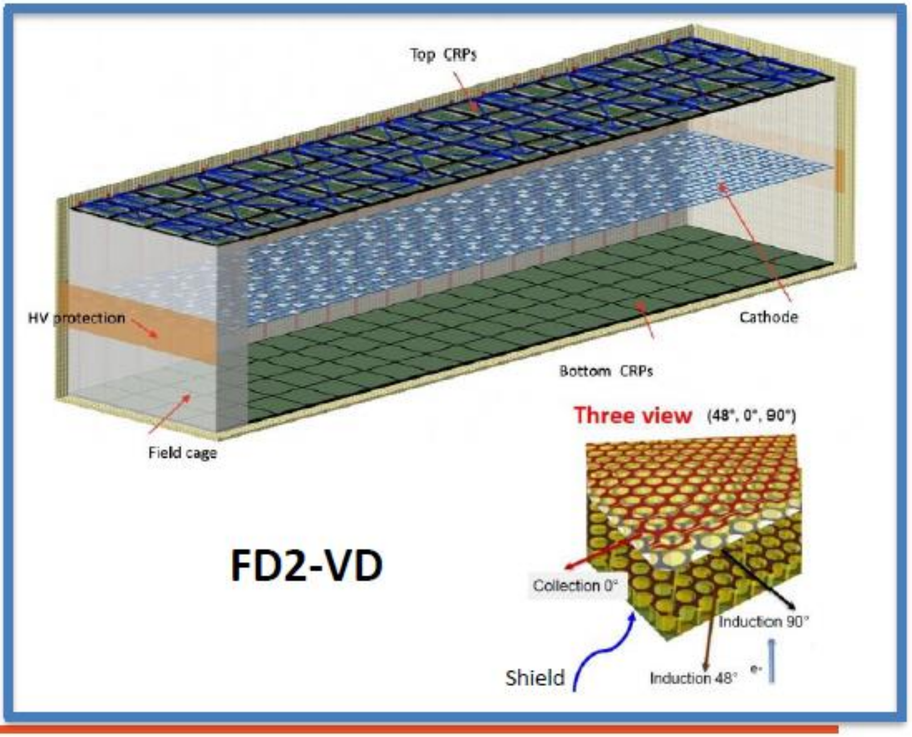


Température de LAr = 88 K
Temps de remplissage = 1 an

Les détecteurs du FarSite

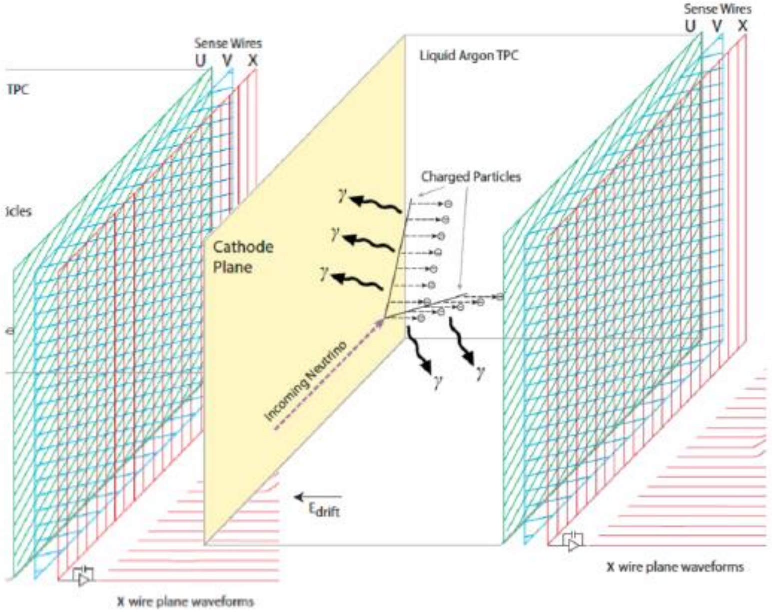
- The ultimate DUNE detector will comprise 4 Far Detector (FD) modules
- The Collaboration currently focuses on delivering 2 FD modules by 2029
  - FD1-HD: single-phase horizontal drift detector with anode wire planes (APA) readout
  - FD2-VD: single-phase vertical drift detector with perforated PCB's with segmented electrodes (strips) as Charge Readout Planes (CRP)



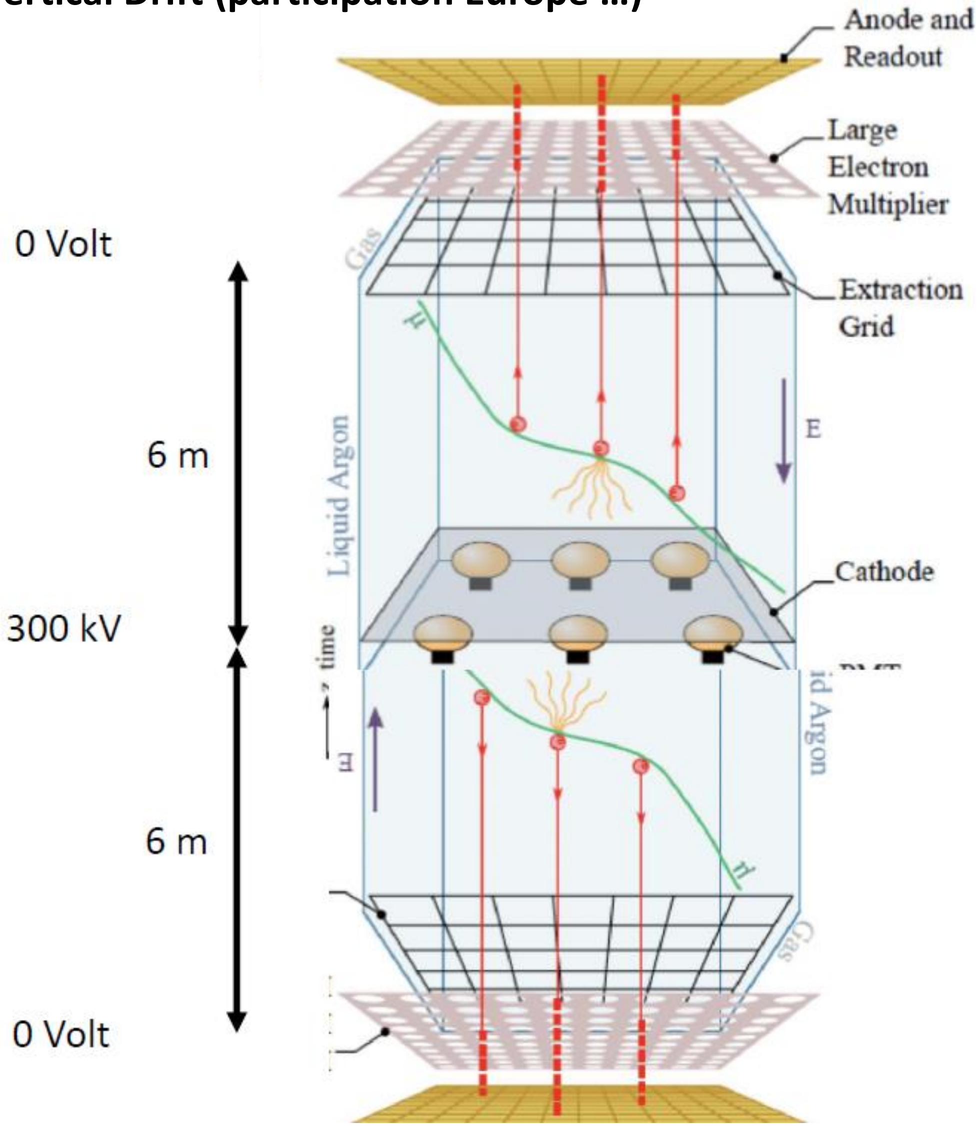


Principe de detection: e+ / γ

Cryostat 1: USA = horizontal drift



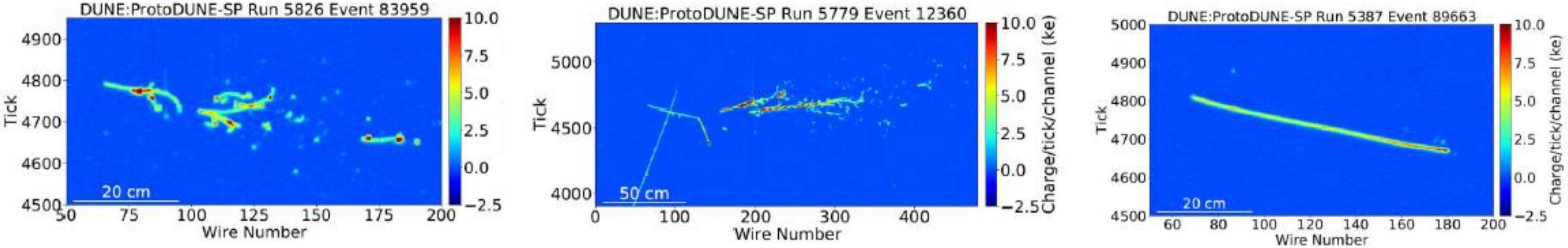
Cryostat 2 = Vertical Drift (participation Europe …)



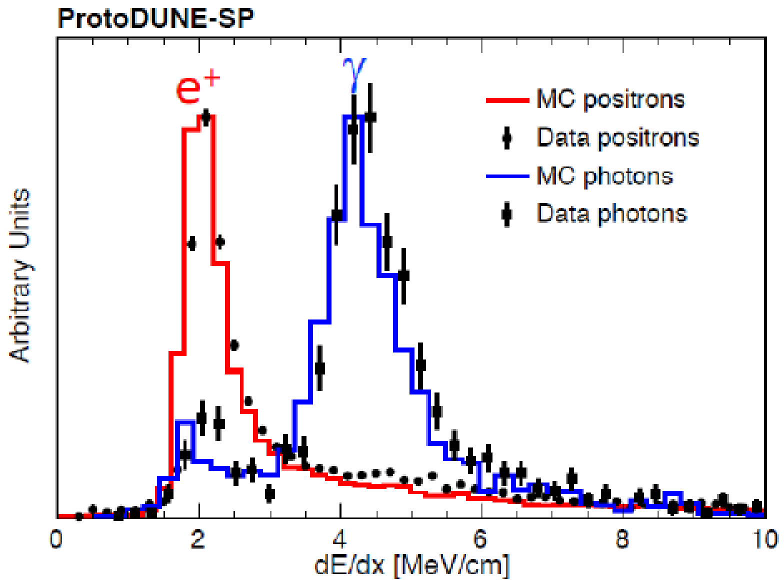
Evenements provenant de la TPC LAr protoDune-SP

Résultats Proto DUNE

ProtoDUNE-SP, single phase

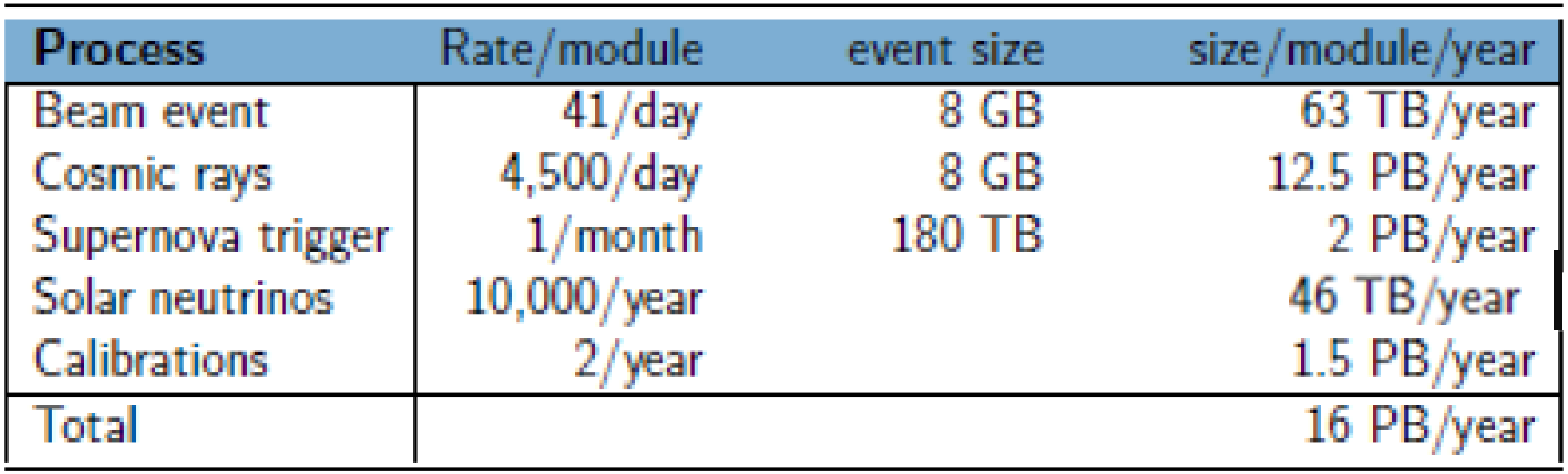


(a) A 0.5 GeV/*c* electron candidate. (f) A 2 GeV/*c* pion charge exchange candidate. (e) A 1 GeV/*c* stopping proton candidate.



Good e/γ separation crucial for electron neutrino ID

Type d'evenements détectés et estimations des ressources informatiques

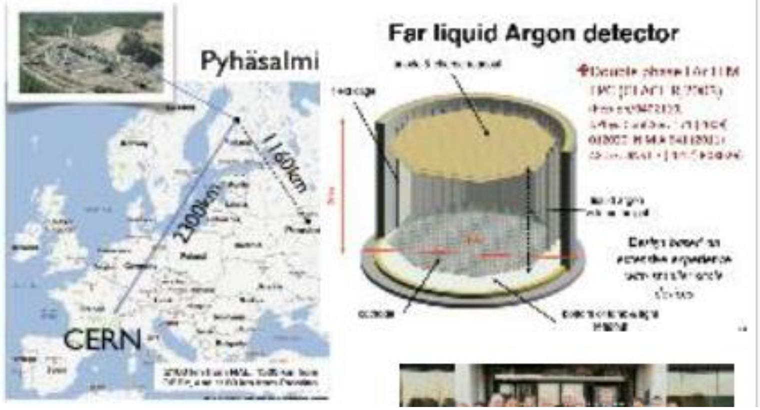


Process	Rate/module	event size	size/module/year
Beam event	41/day	8 GB	63 TB/year
Cosmic rays	4,500/day	8 GB	12.5 PB/year
Supernova trigger	1/month	180 TB	2 PB/year
Solar neutrinos	10,000/year		46 TB/year
Calibrations	2/year		1.5 PB/year
Total			16 PB/year

The raw data volume is dominated by cosmic events

*: C'est quand on pense avoir vu une supernova (en pratique, on attend une/30 ans au mieux donc c'est souvent du déclenchement sur du bruit). C'est pour cela qu'on dit "supernova trigger" et pas "supernova"

Birth of DUNE, a large IN2P3 contribution and objective



Lar R&D started in 2006 first for charge readout electronics, and after in 2008-2014 with LAGUNA-LBNO program where R&D developed DP technology (2013 starting IN2P3 contribution the CERN R&D for the DP project)
IN2P3 groups contributed in 2014 to the fusion of EU and US efforts an to the birth of DUNE

1347 Collaborators, 204 institutions in 33 countries

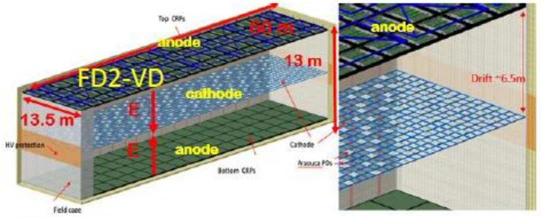
Project : Funding Agency
DUNE-US : DOE
DUNE-UK :UKRI/STFC
DUNE-Italy : INFN
DUNE-France: IN2P3, CEA
DUNE-Spain
DUNE-Brazil : FAPESP
DUNE-Swiss : Bern, SNF
DUNE-CERN
+ ....

Construction@CERN of a 3x1x1 demonstrator in 2015-2017
Construction NP02 DP proto DUNE 2018-2022

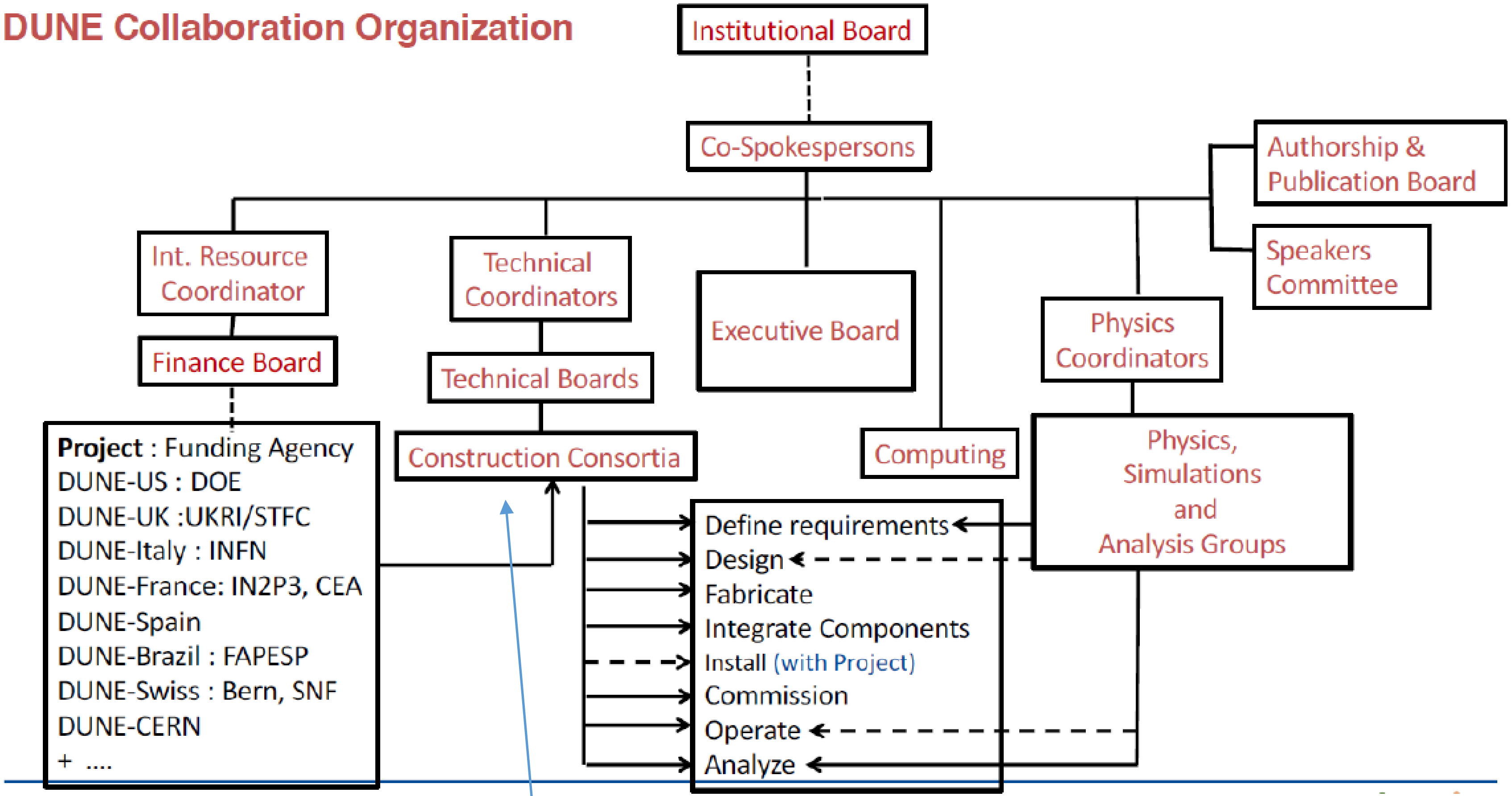
IN2P3 TGIR 2020

Check 300kV and 6 m drift in NP02 in 2022
Module 0 integration 2022-2023

Installation in 2027 of FD2



La collaboration DUNE et son organisation



DUNE Collaboration Organization

Institutional Board

Co-Spokespersons

Authorship & Publication Board

Speakers Committee

Int. Resource Coordinator

Finance Board

Technical Coordinators

Technical Boards

Construction Consortia

Executive Board

Computing

Physics Coordinators

Physics, Simulations and Analysis Groups

Project : Funding Agency
DUNE-US : DOE
DUNE-UK :UKRI/STFC
DUNE-Italy : INFN
DUNE-France: IN2P3, CEA
DUNE-Spain
DUNE-Brazil : FAPESP
DUNE-Swiss : Bern, SNF
DUNE-CERN
+ ....

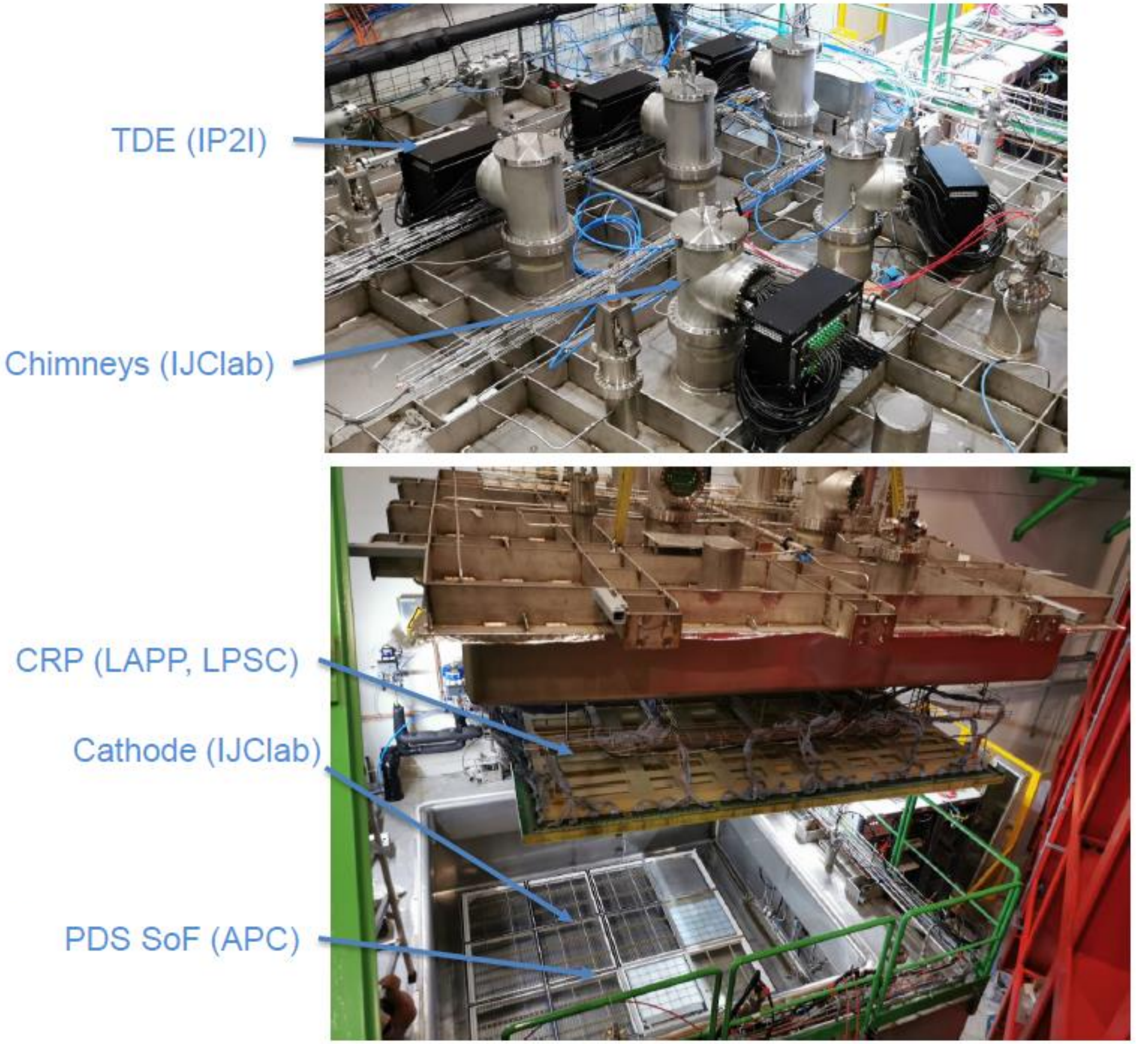
Define requirements
Design
Fabricate
Integrate Components
Install (with Project)
Commission
Operate
Analyze

1347 Collaborators, 204 institutions in 33 countries

Regroupement et pilotage des activites techniques

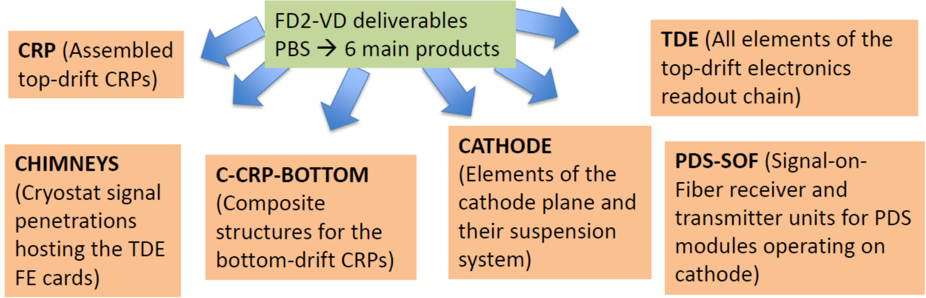
Répartition des taches et responsabilites des laboratoires IN2P3

Cold box test of CRP3 in July 2022



- APC: Cryogenic Optical Transmitter, Optical Receiver
- IJCLab
  - Cathode: frame, rope, Top Adjusting Device, Length Adjusting Device, Resistive and metallic meshes, module assembly, tests and quality monitoring, integration tests with CRP, shipping, installation tooling, installation
  - Chimneys: Steel tank V24 and V48, Guiding system V24 and V48, Blades, Cables, Assembly and tests, PCB flanges (Cold (V24 and V48) and Warm), tests and quality monitoring, shipping, installation
- IP2I: LARZIC ASIC, Front-End boards, uTCA digitization cards, uTCA crates, WR Switches, uTCA WR end-nodes, ancillary systems, cables to DAQ, tests and QC, shipping, installation
- LP2I: tests and QC, shipping, installation of TDE electronics (list above)
- LAPP: Anode support structure frame top, Anode support structure frame bottom, Connections frame-CRU, Super CRP metallic structure 2x3 top + integration test with cathode, Super CRP metallic structure 1x2 top ,Coupling systems of CRP to superstructures, CRP Suspension Feedthroughs, CRP Superstructure automatisation, Top signal cables to feedthroughs, Tooling and cable trays for Top CRPs in DUNE, Top CRP installation in DUNE,Top CRP assembly site at CERN
- LPSC: integration test with cathode, Top CRP assembly site at Grenoble, CRP Transport Box, level-meters

DUNE-IN2P3 Product Breakdown Structure (Development Plan ATRIUM-800055)



FD2-VD deliverables
PBS → 6 main products

CRP (Assembled top-drift CRPs)

TDE (All elements of the top-drift electronics readout chain)

CHIMNEYS (Cryostat signal penetrations hosting the TDE FE cards)

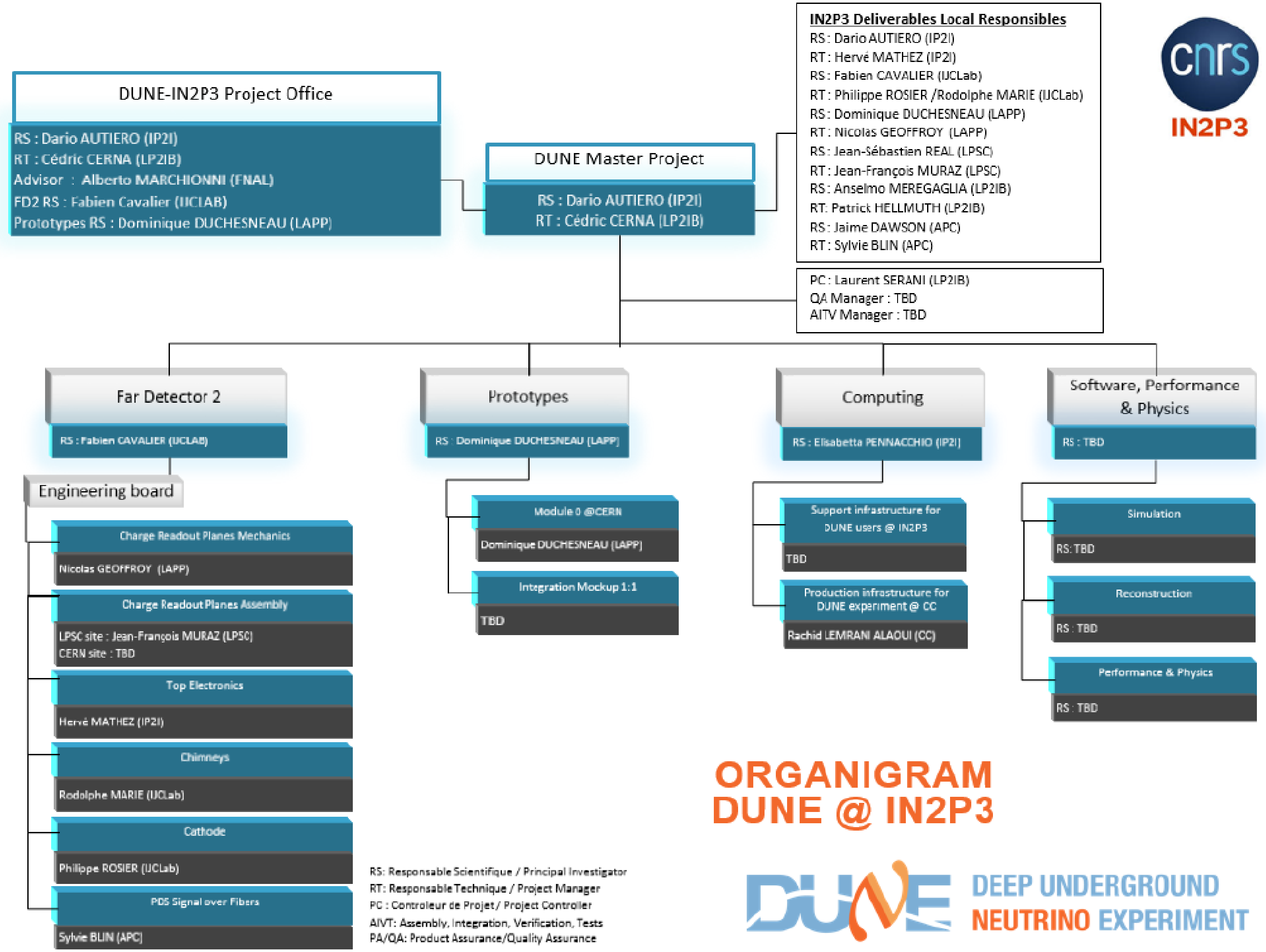
C-CRP-BOTTOM (Composite structures for the bottom-drift CRPs)

CATHODE (Elements of the cathode plane and their suspension system)

PDS-SOF (Signal-on-Fiber receiver and transmitter units for PDS modules operating on cathode)

Organigramme IN2P3

En parallèle de l'organisation DUNE Consortia, il y a celle de l'IN2P3



DUNE-IN2P3 Project Office
RS : Dario AUTIERO (IP2I)
RT : Cédric CERNA (LP2IB)
Advisor : Alberto MARCHIONNI (FNAL)
FD2 RS : Fabien Cavalier (IJCLAB)
Prototypes RS : Dominique DUCHESNEAU (LAPP)

DUNE Master Project
RS : Dario AUTIERO (IP2I)
RT : Cédric CERNA (LP2IB)

IN2P3 Deliverables Local Responsibles
RS : Dario AUTIERO (IP2I)
RT : Hervé MATHEZ (IP2I)
RS : Fabien CAVALIER (IJCLab)
RT : Philippe ROSIER /Rodolphe MARIE (IJCLab)
RS : Dominique DUCHESNEAU (LAPP)
RT : Nicolas GEOFFROY (LAPP)
RS : Jean-Sébastien REAL (LPSC)
RT : Jean-François MURAZ (LPSC)
RS : Anselmo MEREGAGLIA (LP2IB)
RT: Patrick HELLMUTH (LP2IB)
RS : Jaime DAWSON (APC)
RT : Sylvie BLIN (APC)

PC : Laurent SERANI (LP2IB)
QA Manager : TBD
AITV Manager : TBD

Far Detector 2
RS : Fabien CAVALIER (IJCLAB)

Engineering board
- Charge Readout Planes Mechanics: Nicolas GEOFFROY (LAPP)
- Charge Readout Planes Assembly: LPSC site : Jean-François MURAZ (LPSC), CERN site : TBD
- Top Electronics: Hervé MATHEZ (IP2I)
- Chimneys: Rodolphe MARIE (IJCLab)
- Cathode: Philippe ROSIER (IJCLab)
- PDS Signal over Fibers: Sylvie BLIN (APC)

Prototypes
RS : Dominique DUCHESNEAU (LAPP)
- Module 0 @CERN: Dominique DUCHESNEAU (LAPP)
- Integration Mockup 1:1: TBD

Computing
RS : Elisabetta PENNACCHIO (IP2I)
- Support infrastructure for DUNE users @ IN2P3: TBD
- Production infrastructure for DUNE experiment @ CC: Rachid LEMRANI ALAOUI (CC)

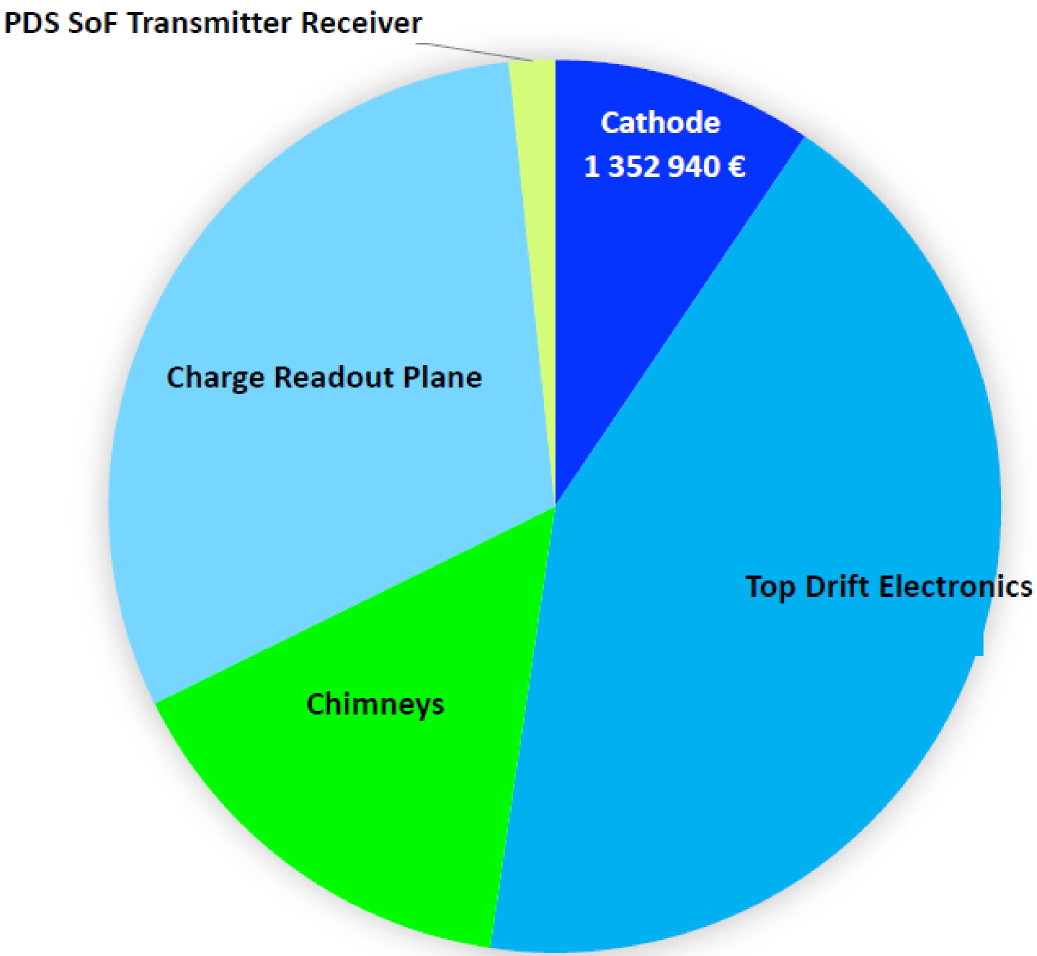
Software, Performance & Physics
RS : TBD
- Simulation: RS: TBD
- Reconstruction: RS : TBD
- Performance & Physics: RS : TBD

RS: Responsable Scientifique / Principal Investigator
RT: Responsable Technique / Project Manager
PC : Controleur de Projet / Project Controller
AIVT: Assembly, Integration, Verification, Tests
PA/QA: Product Assurance/Quality Assurance

ORGANIGRAM DUNE @ IN2P3

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Bilan financier pour le matériel sur budget IN2P3

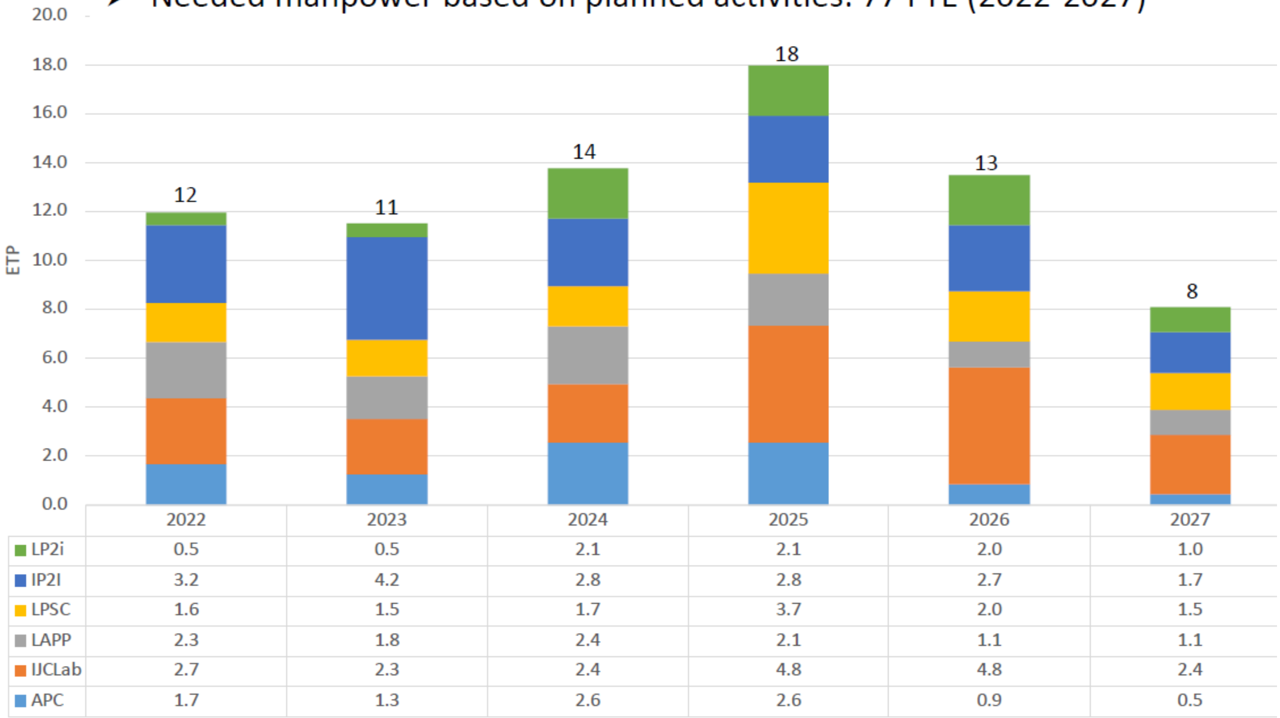


- **18 M€ total including**
  - **Deliverables production and shipping**
  - **Past and futures expenses for qualifications**
  - **Tests & Verification systems**

- **On all future expenses we anticipate 20% of contingencies**

Ressources humaines ITA IN2P3 estimées en 2022

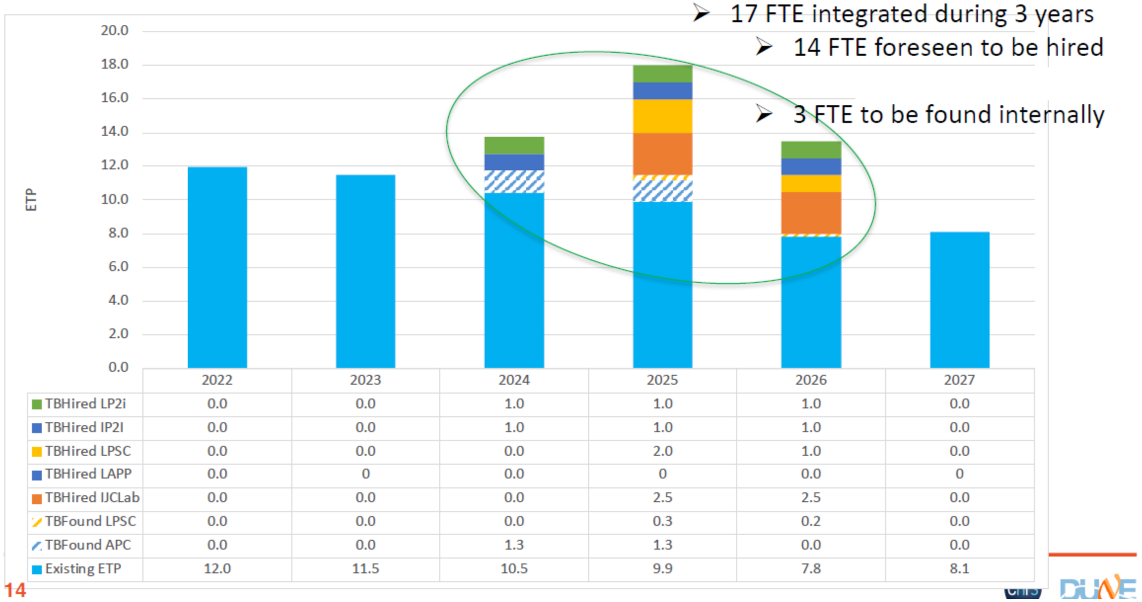
- Needed manpower based on planned activities: 77 FTE (2022-2027)



	2022	2023	2024	2025	2026	2027
🟩 LP2i	0.5	0.5	2.1	2.1	2.0	1.0
🟦 IP2I	3.2	4.2	2.8	2.8	2.7	1.7
🟨 LPSC	1.6	1.5	1.7	3.7	2.0	1.5
⬜ LAPP	2.3	1.8	2.4	2.1	1.1	1.1
🟧 IJCLab	2.7	2.3	2.4	4.8	4.8	2.4
🟦 APC	1.7	1.3	2.6	2.6	0.9	0.5

- **Existing manpower**: 60 FTE (2022-2027) → [8-12] FTE/y average

- **Additional technical mpw during production**
  - 17 FTE integrated during 3 years
    - 14 FTE foreseen to be hired
    - 3 FTE to be found internally



	2022	2023	2024	2025	2026	2027
🟩 TBHired LP2i	0.0	0.0	1.0	1.0	1.0	0.0
🟦 TBHired IP2I	0.0	0.0	1.0	1.0	1.0	0.0
🟨 TBHired LPSC	0.0	0.0	0.0	2.0	1.0	0.0
🟦 TBHired LAPP	0.0	0	0.0	0	0.0	0
🟧 TBHired IJCLab	0.0	0.0	0.0	2.5	2.5	0.0
▨ TBFound LPSC	0.0	0.0	0.0	0.3	0.2	0.0
▨ TBFound APC	0.0	0.0	1.3	1.3	0.0	0.0
🟦 Existing ETP	12.0	11.5	10.5	9.9	7.8	8.1

Besoin en RH pour construire, préassembler et contrôler

Hors Installation à SURF

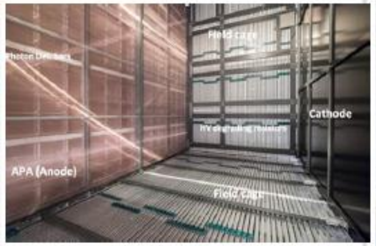
Estimation des permanents et besoin des embauches

La plateforme Neutrino du CERN => phase prototype et tests

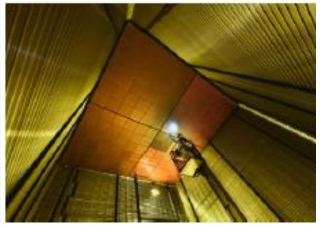
- **Provide** to the ν community a **test beam infrastructure** (charged particles)
- Bring **R&D** at the level of **technology demonstrators** in view of major technical decisions
- **Support** the short & long baseline **activities** (infrastructure & detectors)

TPC Prototypes at the scale 1:20, with **modules at the DUNE scale**
Two technologies originally investigated **(LAr single phase (NP04), LAr double phase (NP02))**

NP04 :
Single Phase
Horizontal Drift

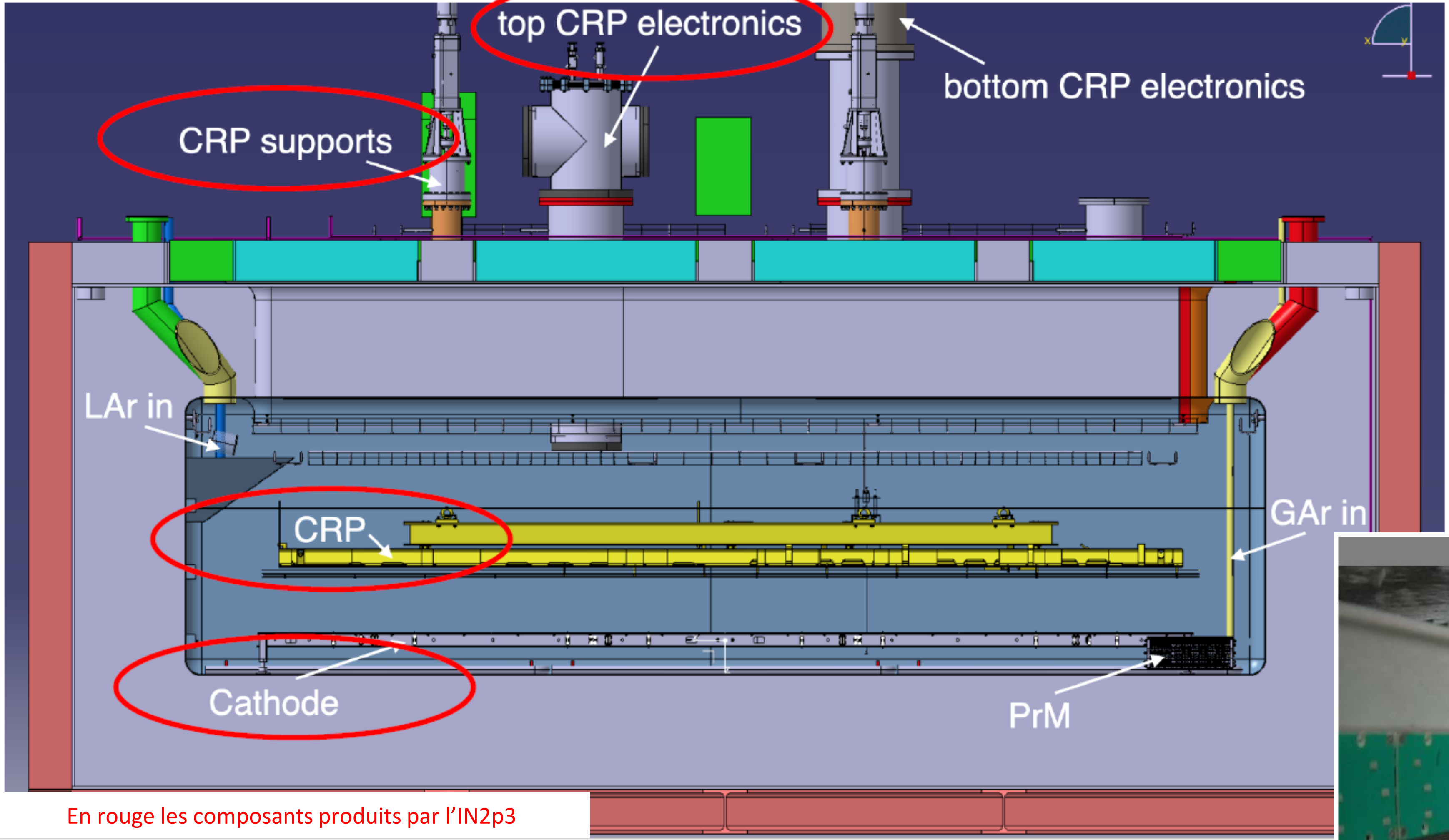


NP02 :
Double Phase
→ Single Phase
Vertical Drift

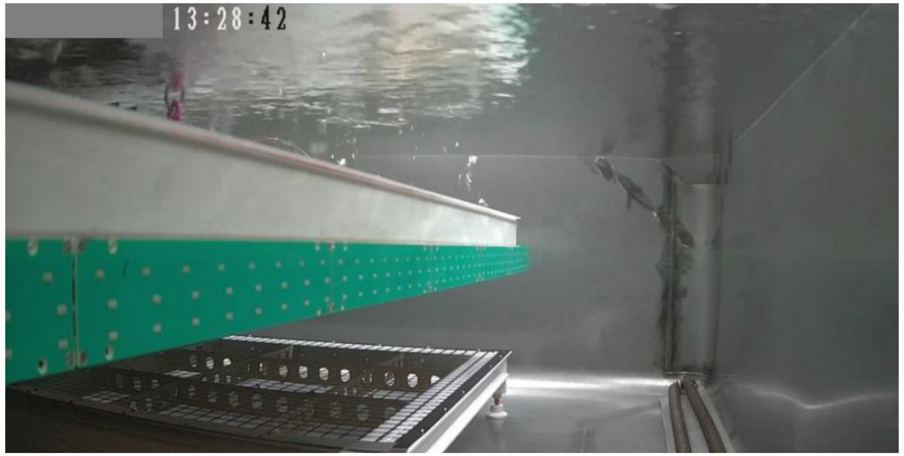


Et la cold box

Prototype: Le contenu de la cold Box



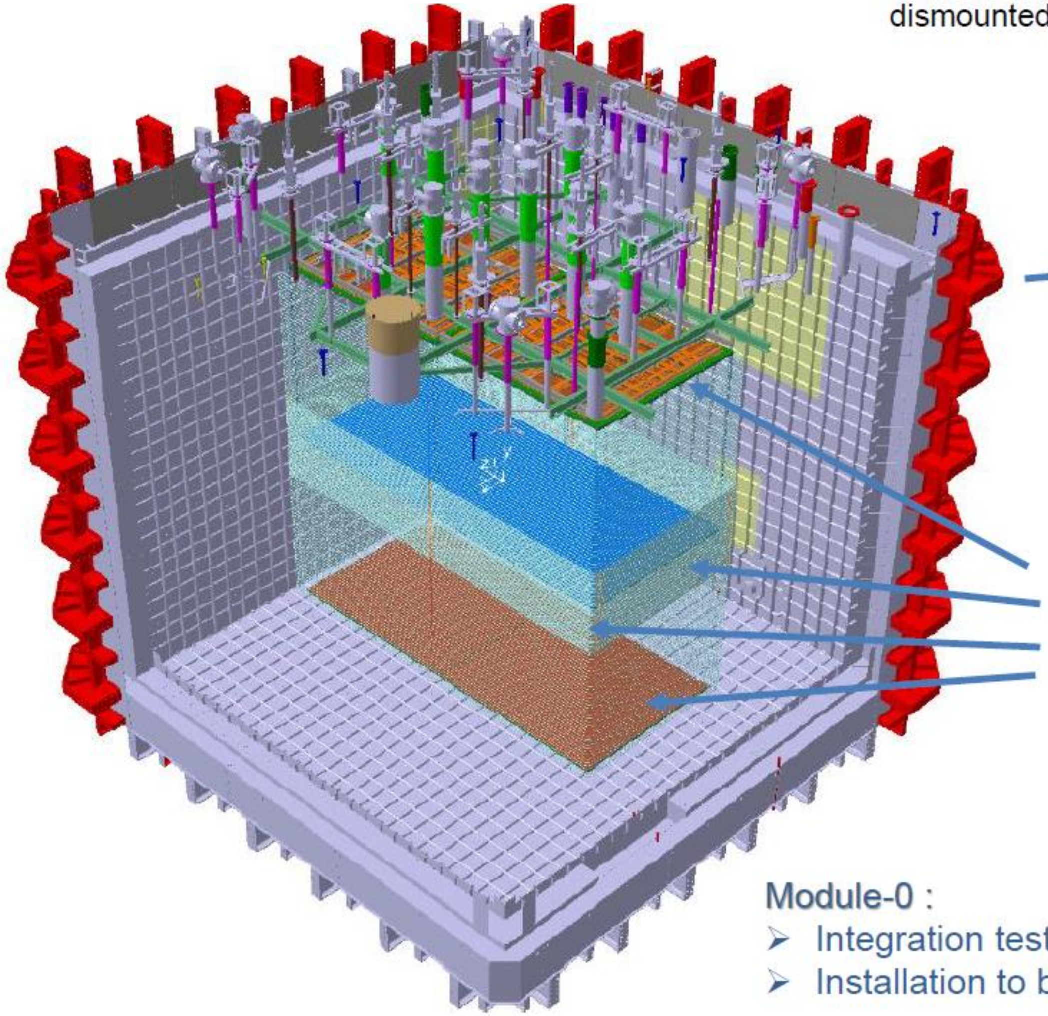
En rouge les composants produits par l'IN2p3



Depuis le 10 janvier 2023, la coldbox est rempli d'argon liquide

Prototype Module-0

NP02 Cryostat: used for ProtoDUNE Dual Phase detector which was dismounted end of 2022



- 2 top CRPs
- 2 cathode modules in the middle hanging from the top CRPs
- Field cage modules hanging independently from the new DSS
- 2 bottom CRPs

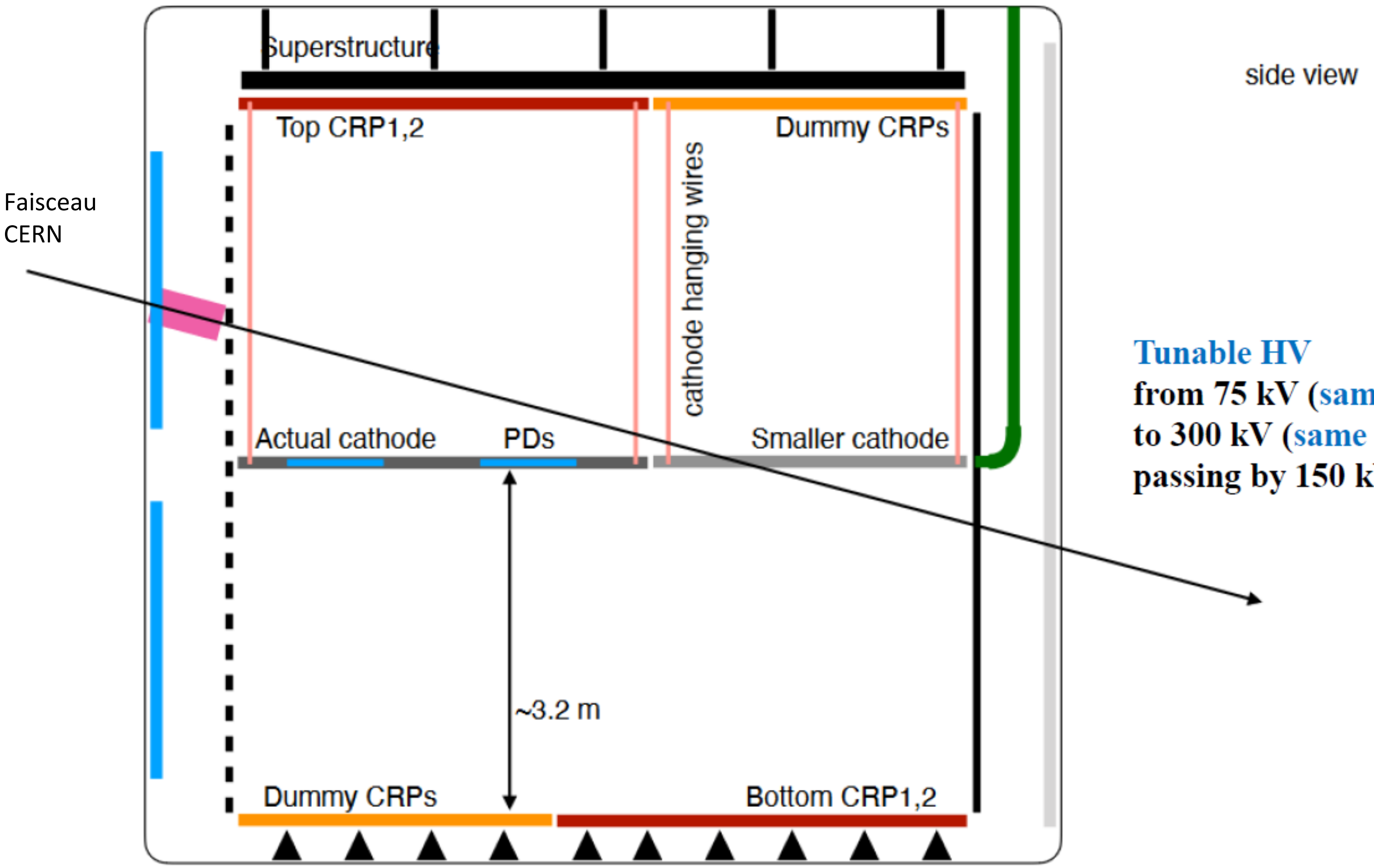
- ~3.2 m long drift, 300 kV capable HV system (tested in ProtoDUNE-DP)
- PDs on the cathode and on the walls
- 4.3 m long beam plug NP04 style

Module-0 :

- ➢ Integration test with final detector elements before starting massive production
- ➢ Installation to be completed before May 2023

Principe TPC du test en module 0 – NP02

Module-0 in NP02

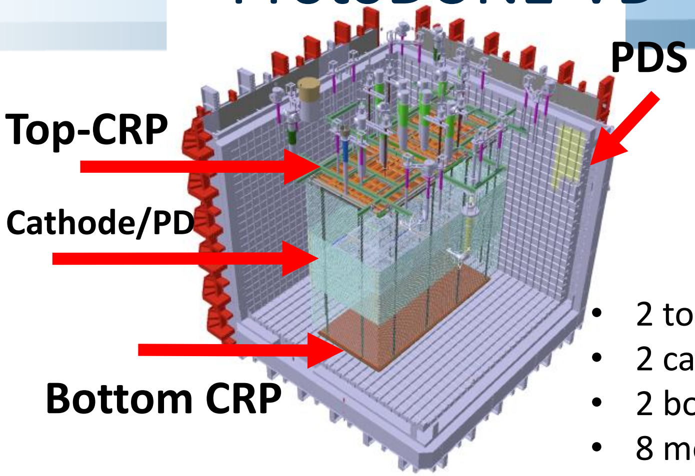


Tunable HV
from 75 kV (same drift time)
to 300 kV (same max HV)
passing by 150 kV (same drift field)

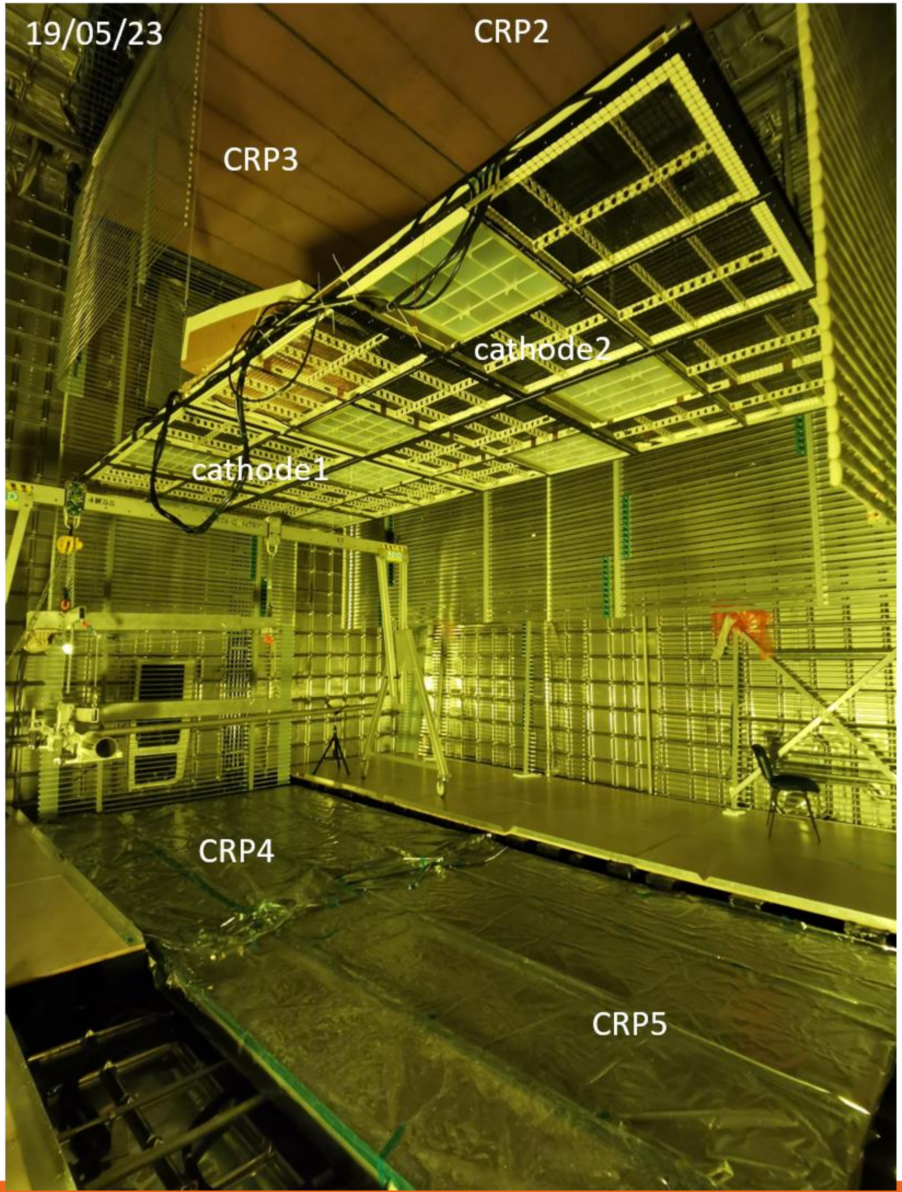
Remplissage de LAr prévu fin 2024…

ProtoDUNE-VD

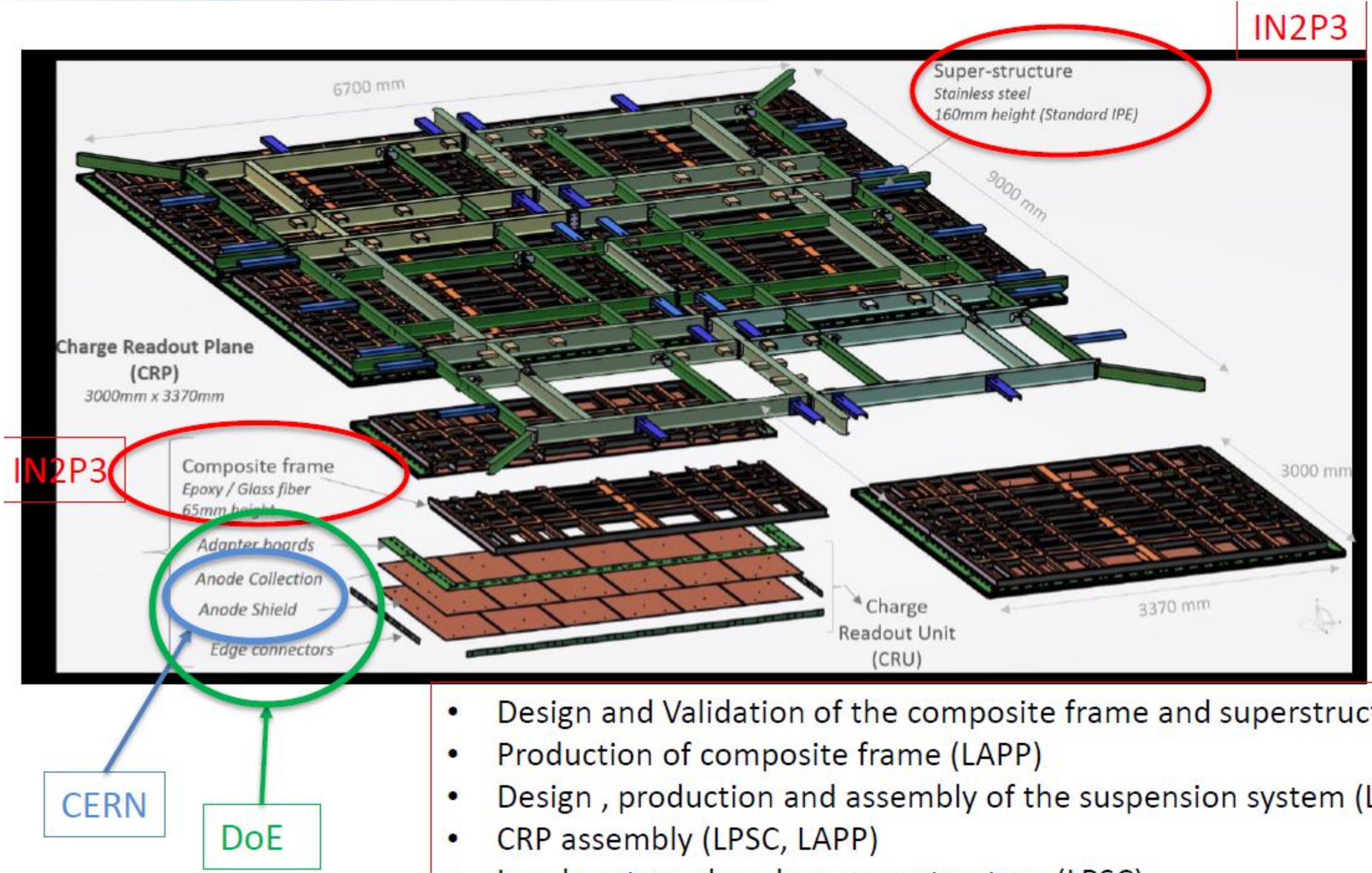
This full installation experience done by IN2P3 teams tested main features of FD2 integration scheme



- 2 top CRP (#2-3)
- 2 cathodes (8 x-Arapuca)
- 2 bottom CRP (#4-5)
- 8 membrane x-Arapuca
- 70% Field cage

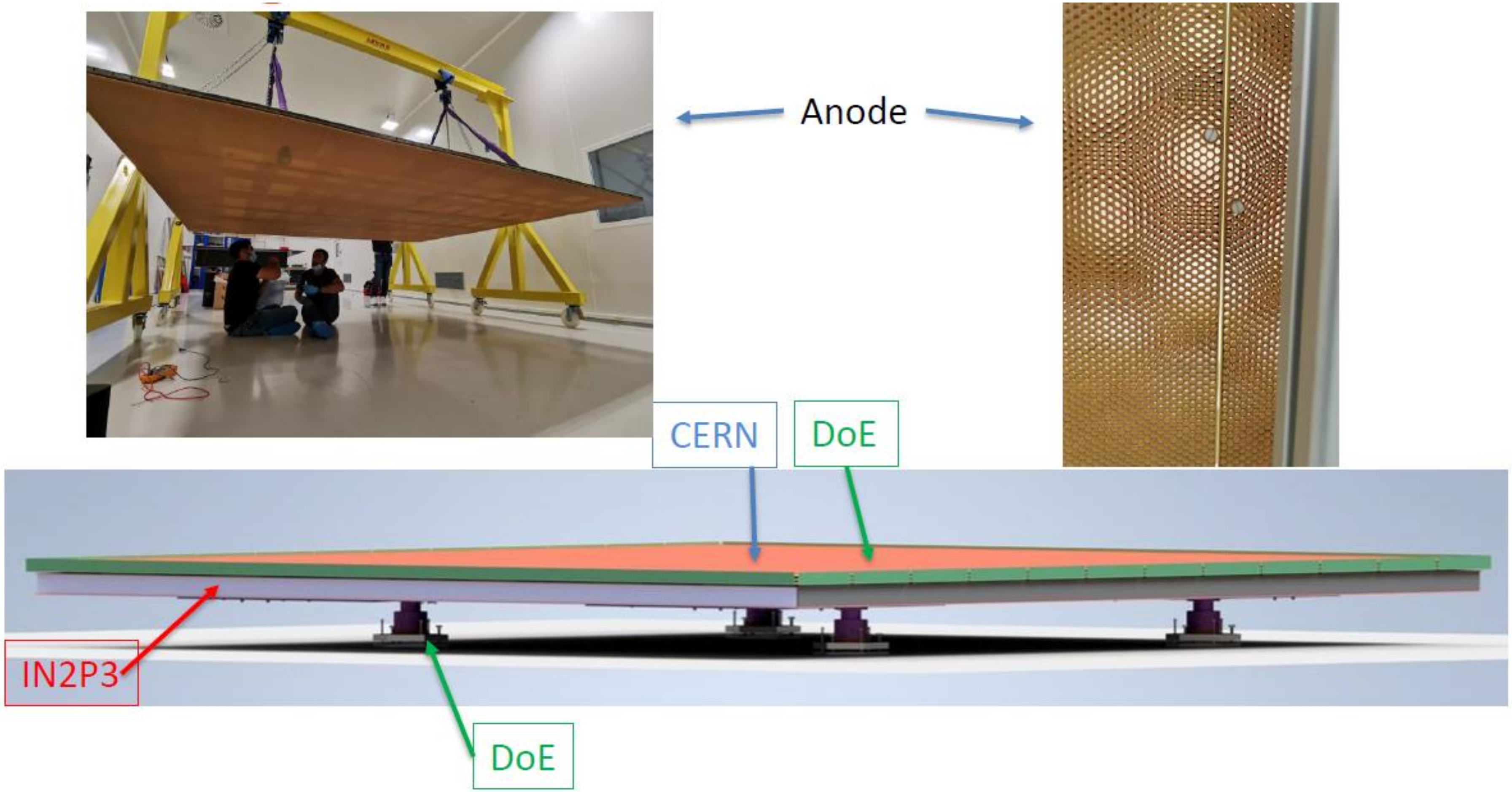


Charge Readout Plane (CRP) (TOP)



- Design and Validation of the composite frame and superstructure (LAPP)
- Production of composite frame (LAPP)
- Design , production and assembly of the suspension system (LAPP)
- CRP assembly (LPSC, LAPP)
- Level-meters placed on superstructure (LPSC)

Charge Readout Plane (CRP) (Bottom)

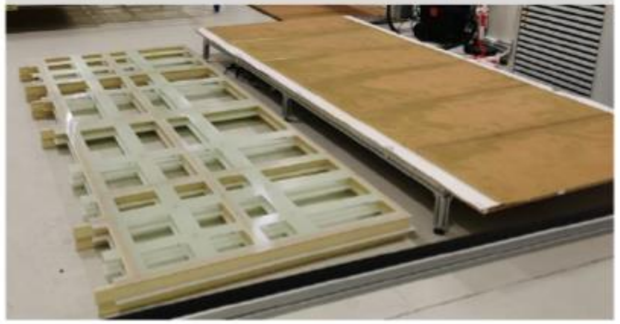


- Design and Validation of composite frame (LAPP)
- Production of composite frame (LAPP)

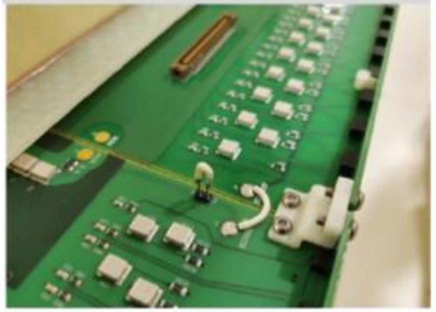
CRP Sites d’assemblage et de controle qualité

- Two assembly sites in Europe :
  - LPSC
  - CERN (supervised by LAPP)

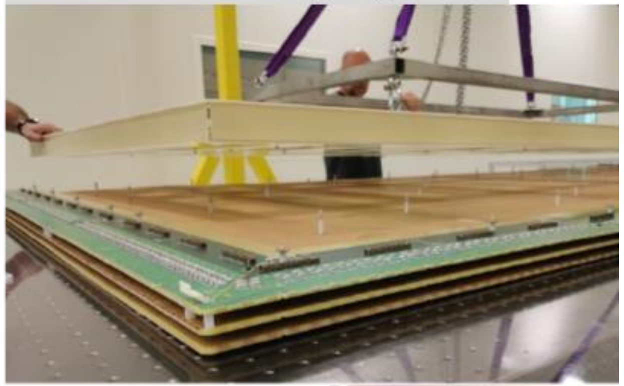
Composite frame and anode planarity



Adapter board and HV bias jonction control



Mechanical assembly alignment

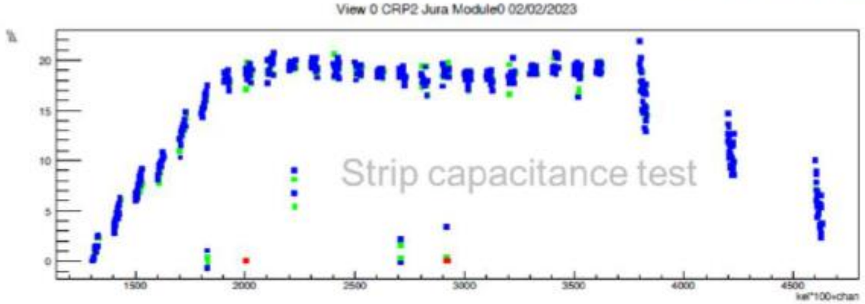


Warm and Cold electrical test bench

- Strip continuity
- Strip to strip insulation
- HV

strip capacitance measurement with a dedicated system developed at LPSC

Capacitance test is foreseen to be done at different steps:
- at warm after assembly,
- at cold in liquid nitrogen
- after warm-up before packing for storage and shipment



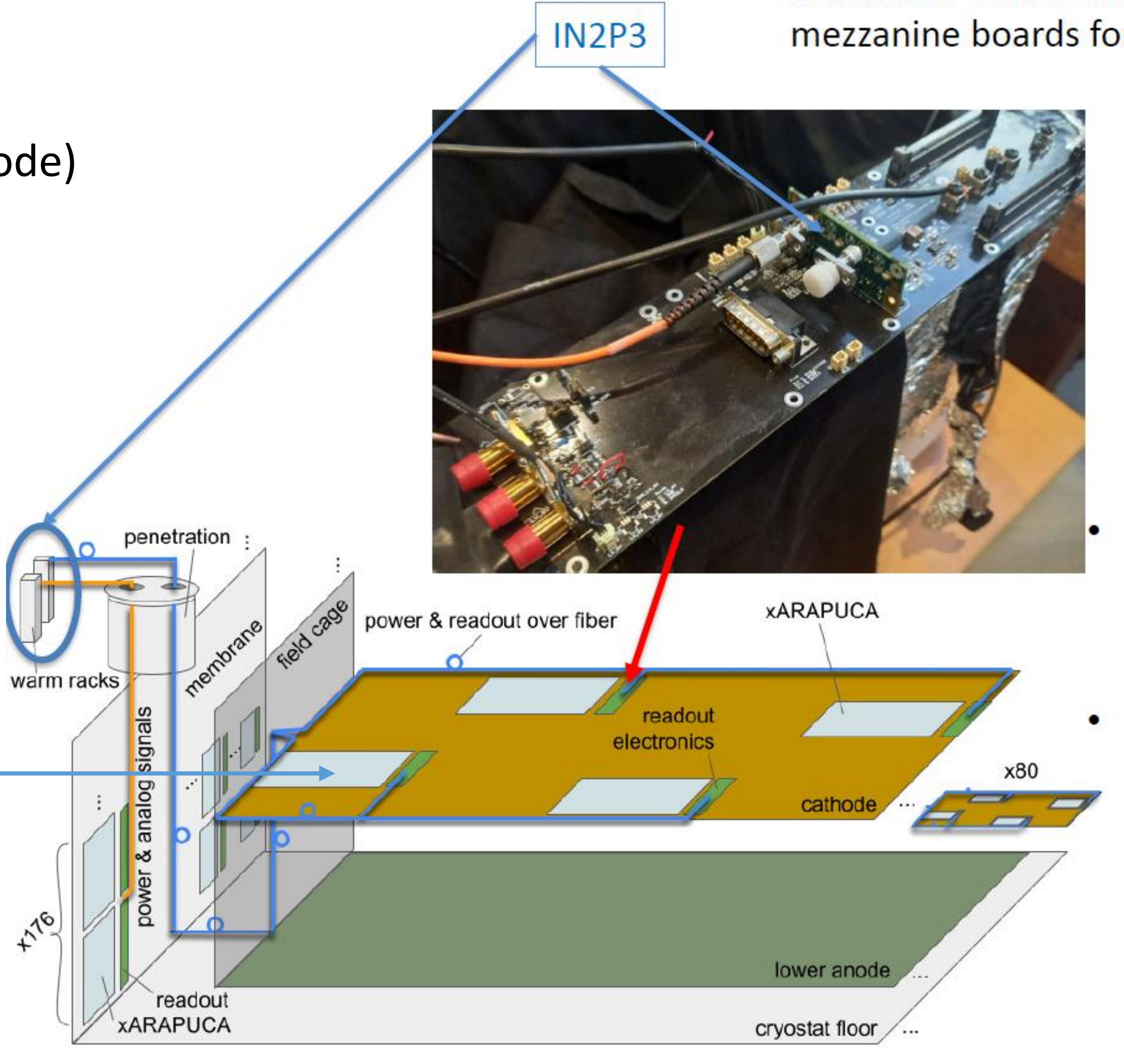
Strip capacitance test

Photon Detector System (PDS)

Technologie “Power over Fiber”
(Isolation HV)

Module Arapuca Xar (mural et cathode)
Lecture par SiPm

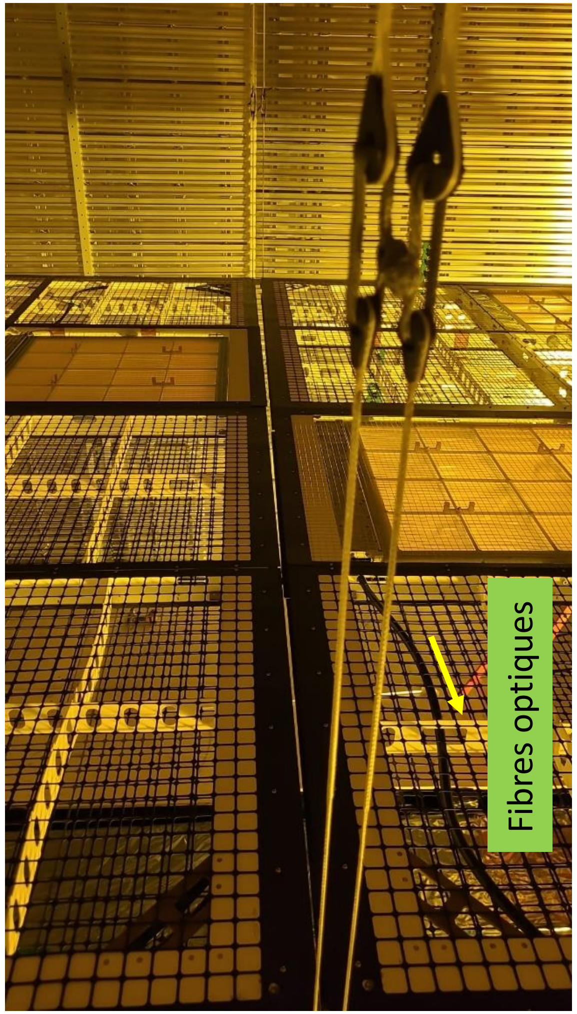
Interface avec Cathode
Intégration en cooperation avec US



- Warm and Cold transmitters and receivers mezzanine boards for signals (APC)

- Consortium with a large number of contributors (INFN, US, Spain, Brazil …)
- Interactions with FNAL and UCSB (Cold Board), FNAL and INFN (Warm Board)

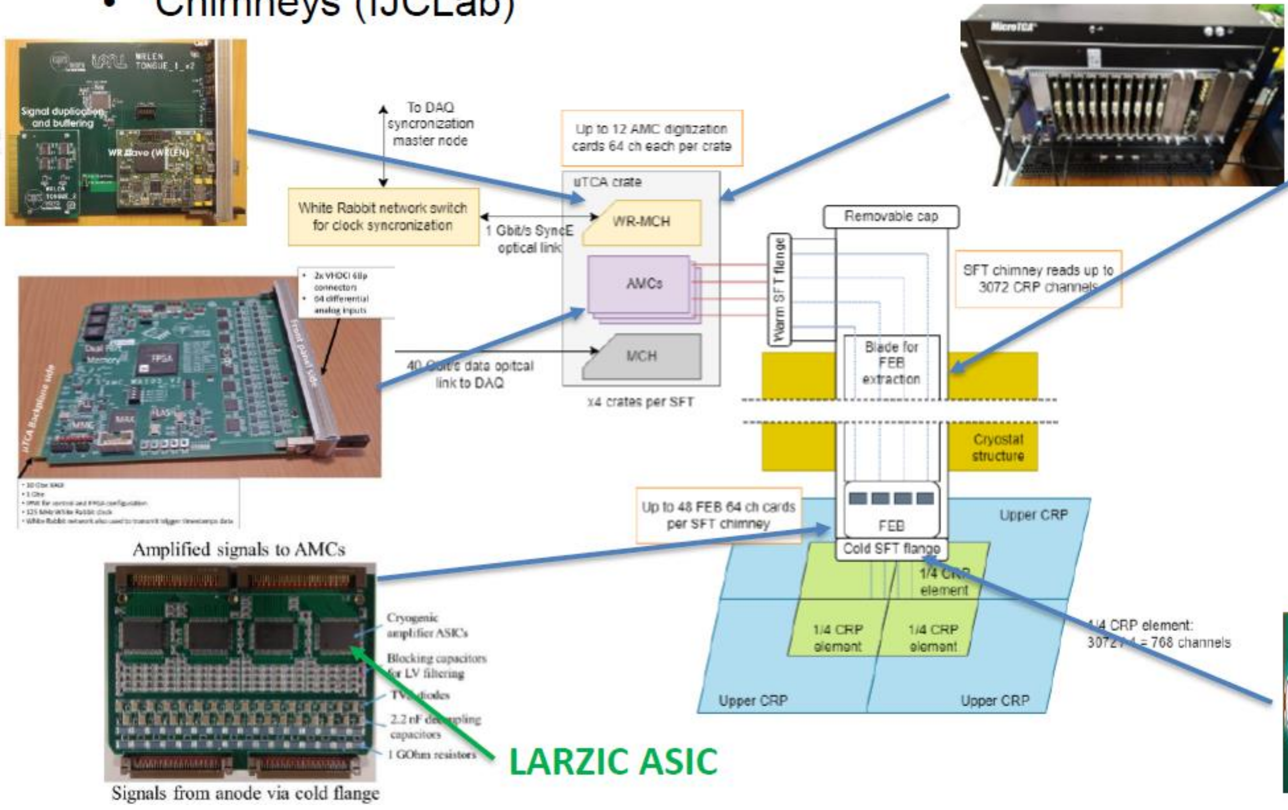
Module 0 installé au CERN

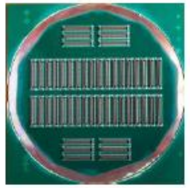


Electronique de derive TOP (TDE)

All components under IN2P3 responsibility

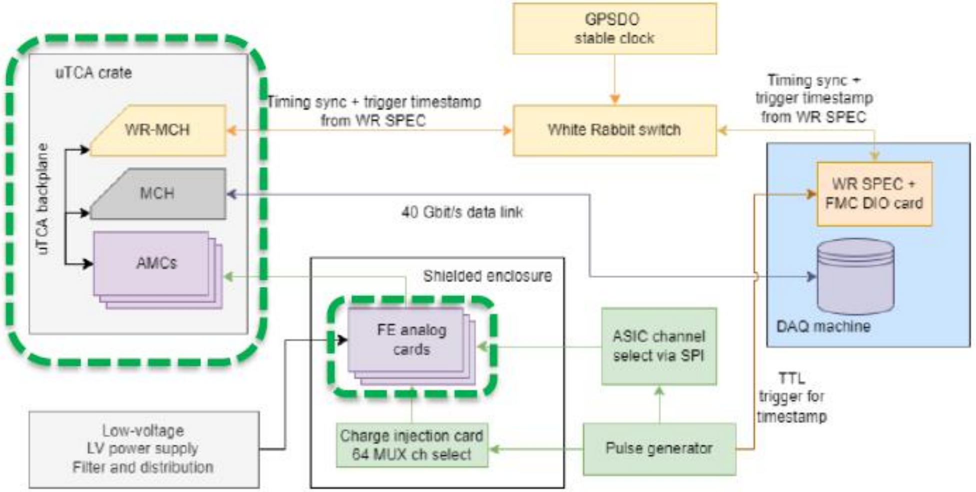
- Design and validation of electronics (IP2I)
- Production and tests of electronics (IP2I, LP2I)
- Chimneys (IJCLab)

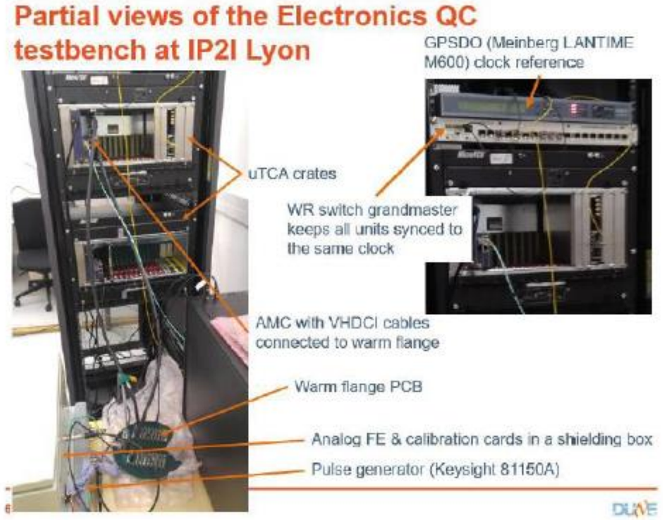




TDE Electronique et controle qualité

- Details in Development Plan and in the DUNE FDR TDE QA Plan → fully integrated in DUNE QA, HWBD
- Sharing of load among two QC centres IP2I and LP2I with same QC chain, involving conservatively 2 FTE per site (including IR* CDDs).
- Long-term experience in checking all productions made by the industry for all DUNE prototypes at CERN since 2015→ proven achievement of zero-defective channels, high yield and long-term reliability
- Full functional and response tests of all elements (**FE cards, AMCs, Timing and uTCA chain elements**) with dedicated setup developed and experienced through many years, accurate response qualification (1%)




Partial views of the Electronics QC testbench at IP2I Lyon

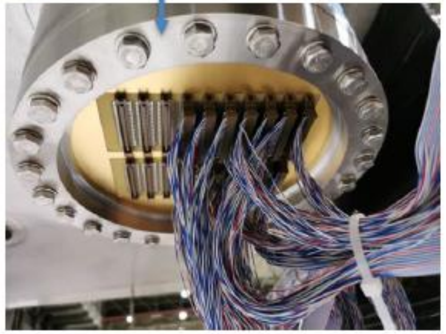
- QC strictly pipelined with productions (monthly batches) allowing interactions with producers and quick identification/prevention/fixing of issues. Productions and QC spread up comfortably over 3 years. Large time float. Execution of tests requiring a few days per month (large time margins for each monthly produced batch).

Chimney @ IJCLAB

Chimneys

Coldbox version

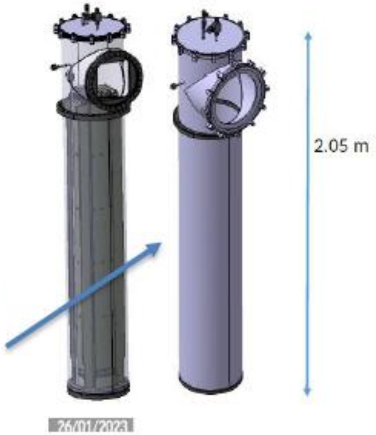
- ❑ Design and construction in 2021 of five short 10-cards chimney (similar to the DualPhase chimneys used in NP02 for 3 years) to be integrated in the Cold-Box roof for the CRP tests.
- ❑ Successful operation of the chimneys in 2021-2022 together the CRPs and the associated readout electronics.
- ❑ Demonstration of all functionalities including the operation of the FE cards and their insertion/extraction.

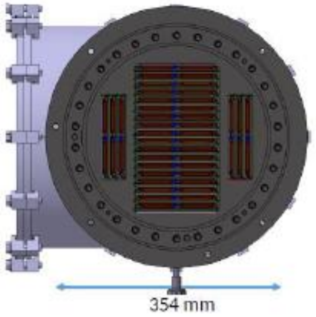


FD2 version

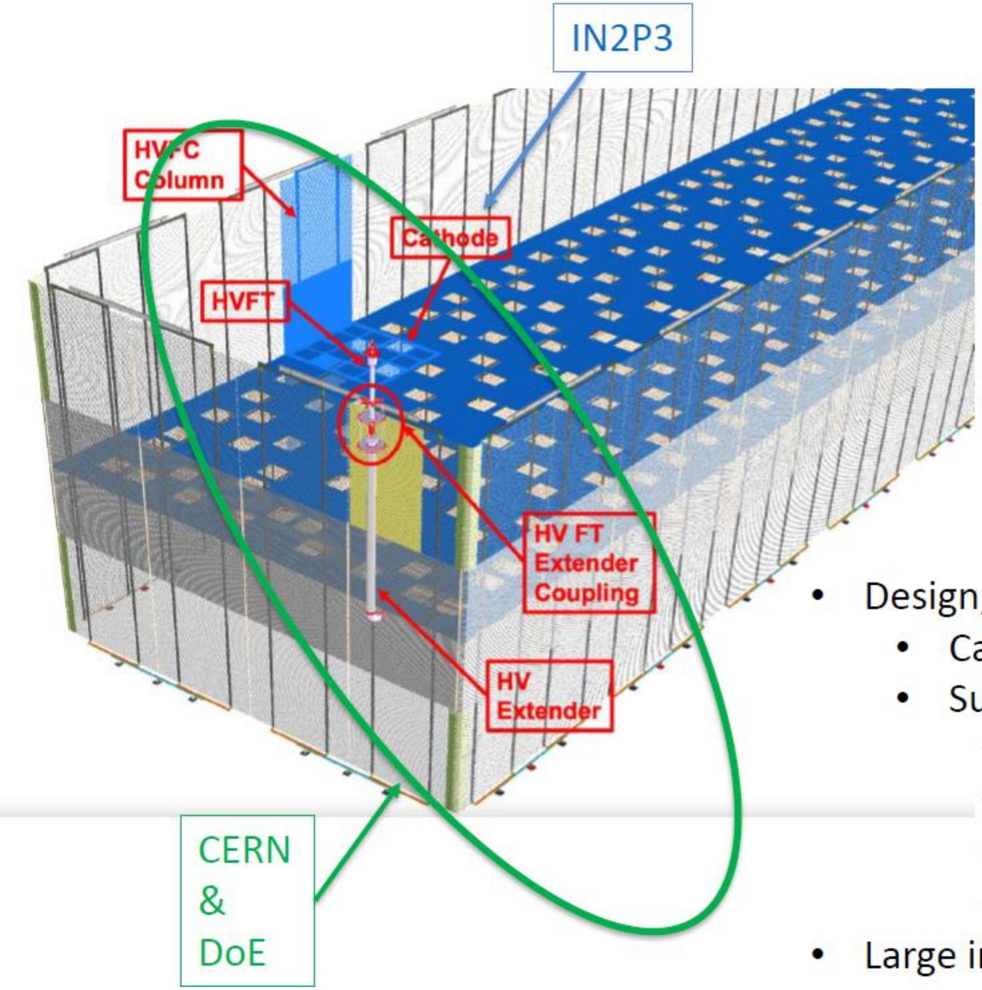
The VD-FD2 chimneys : extension of the already established 10-cards design to larger radii to cope with the final CRP strips layout leading to up to 48 FE cards

- ❑ Design development and optimization of the chimneys for FD2 following the experience accumulated with the Cold-Box in order to exploit larger chimneys capable of containing all the 48 cards
- ❑ Prototyping activities launched in 2022, starting first with the 24 cards chimney
- ❑ The 24 cards prototype tests and characterization are foreseen to be completed in 2023 when also the 48 cards model is foreseen to be built and tested.

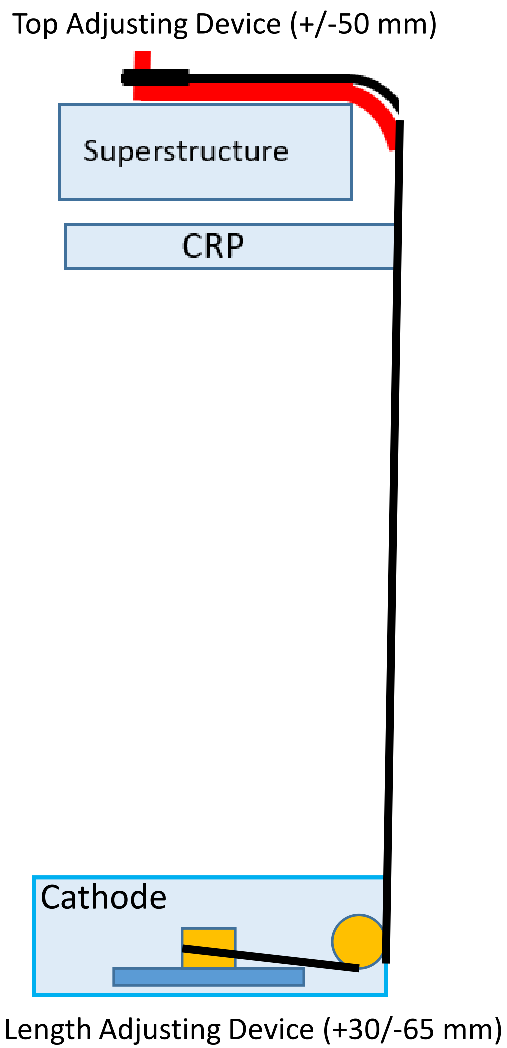




La cathode au sein du consortium HV



- Design, validation and production (IJCLab) :
  - Cathode module
  - Suspension system
    - TAD
    - Ropes
    - Shackle
    - LAD
- Large interface with PDS



Spécifications pour la cathode

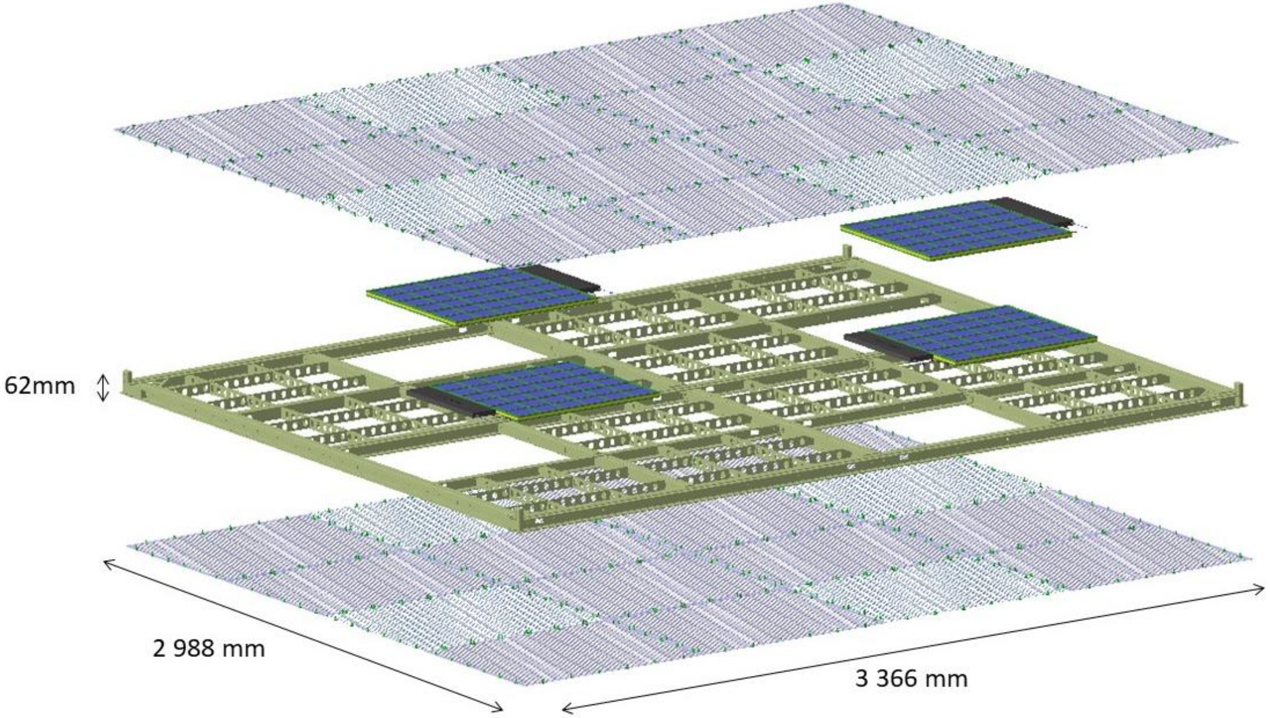
- Nominal Drift Field: **450 V/cm** => Cathode at **-290 kV**
- Drift Field **uniformity < ±1%** [in 99.8% volume]
- **Local** electric field **< 30 kV/cm**

- **Cathode Resistivity (**to slow down possible discharges**)** : **~ 1 GΩ/sq**. (lower limit 1 MΩ/sq., upper limit 10 TΩ/sq.)

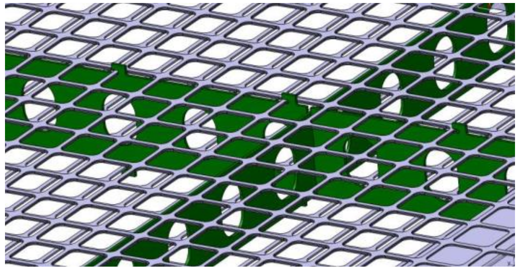
- **Dimension : 2988 mm x 3366 mm x 62 mm** (footprint of **CRP**)
- **Weight < 150 kg in air** (including **Photon Detector** to minimize deformation of **CRP**)
- **Bending < 20 mm in Lar**
- **Position stable en hauteur** (pas de fluage des cables de suspension)

- Mesh **transparency > 85%** over **Photon Detector** and **60%** elsewhere for LAr flow

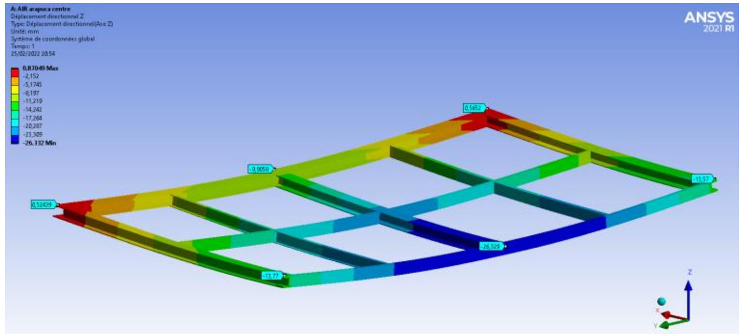
- Mesh **pitch < 30 mm** for field uniformity



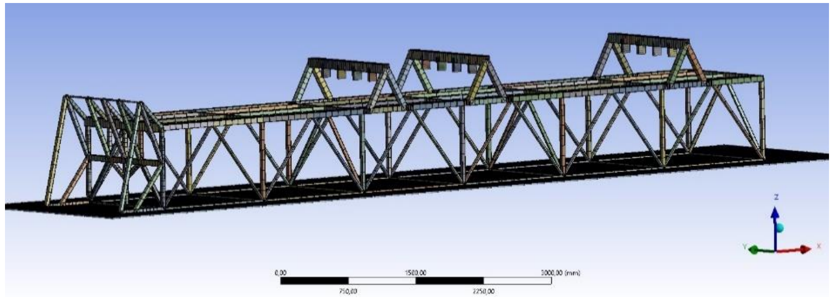
Plan de développement mécanique pour la cathode



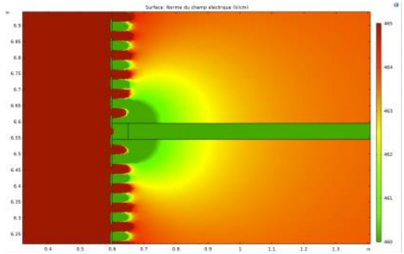
CAO de détail



Dimensionnement



Construction de bancs specifiques

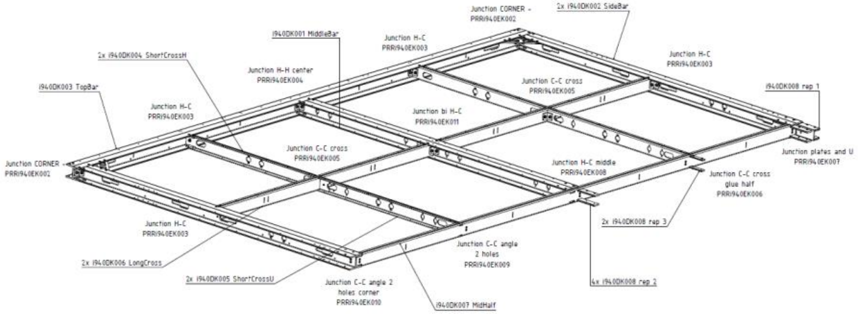


Etudes multiphysiques

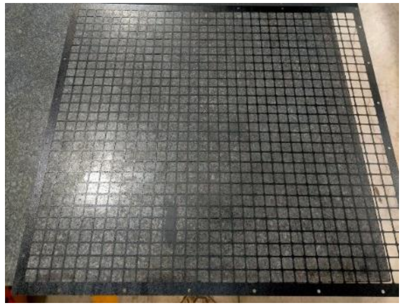
Recherche de fournisseurs
(gros projet mais dans longtemps)

Recherche de matériau

Définition des outillages d'assemblage



CAO d'assemblage

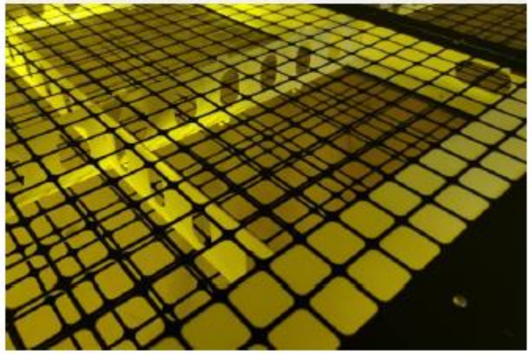


Grilles résistives

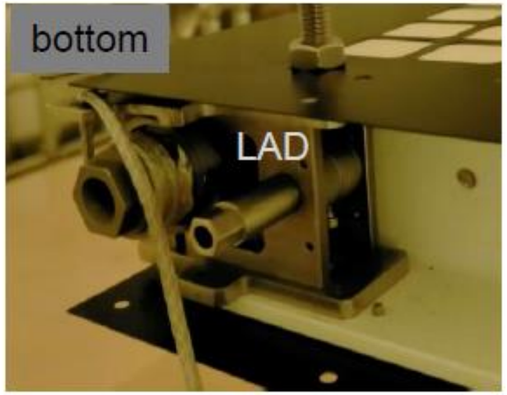
Cathode deliverables

- A cathode module, following the FD2 design, was successfully built in 2021 by IJCLab and it has been used in all cold-box tests, where it was sitting on feet at the bottom of the cryostat.

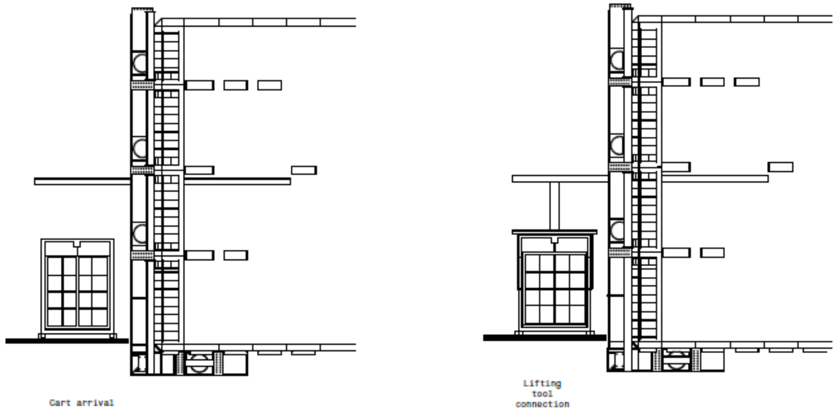
Latest version of resistive mesh on Module-0 cathode



- The behavior of the Dyneema ropes used to suspend the modules characterized in a dedicated setup at IJCLab, also at cold.

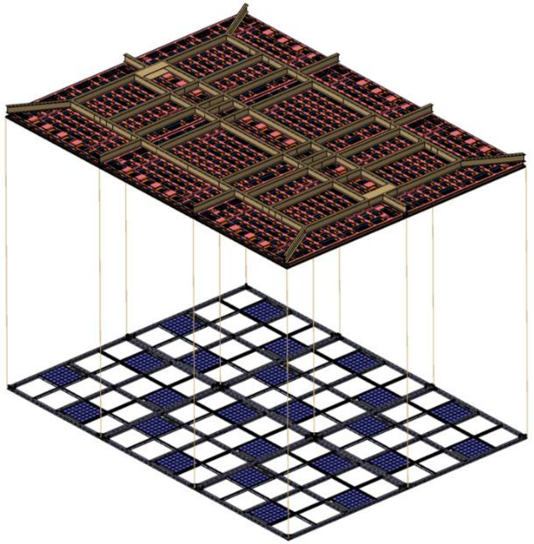


Installation de la cathode : etude de principe très en amont du projet

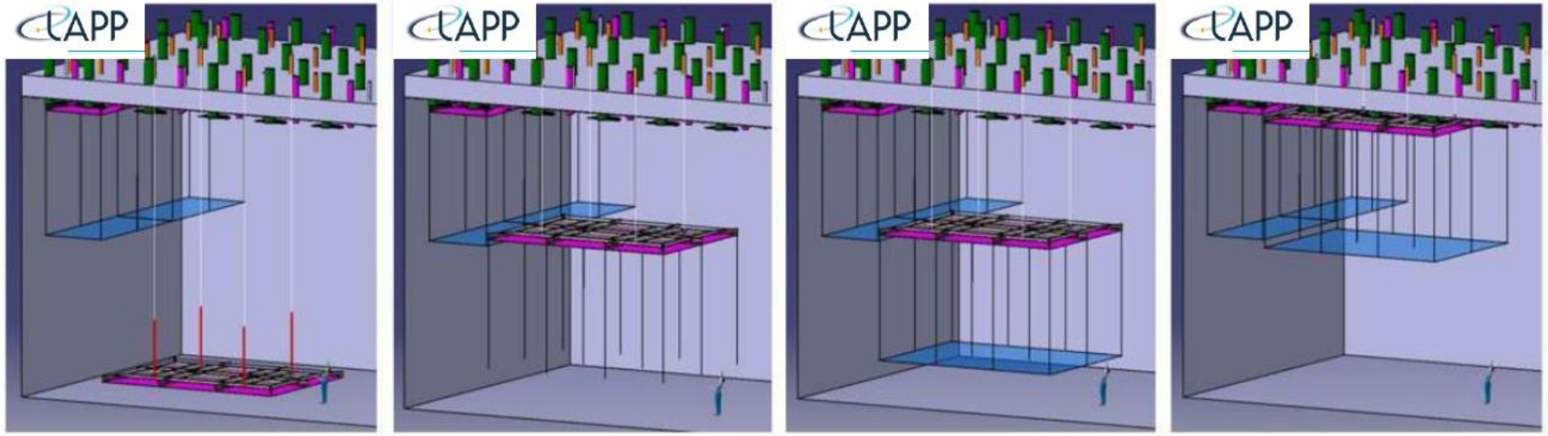


Insertion dans le cryostat par la TCO

Insertion des fibres PDS dans la cathode



Accrochage à la superstructure


Super structure in place

Super structure mid-elevation

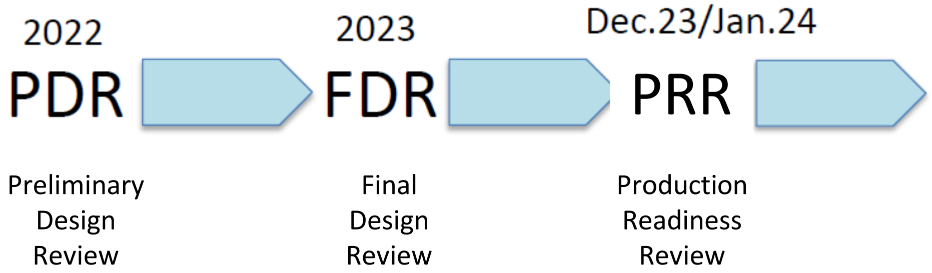
Super cathode assembly on tables and attachment to the ropes

Lifting of the supercathode and final survey

Revues de projet et documentation

Revues IN2P3, DUNE (DOE)

Advisor : Compliance Office



2022
PDR
Preliminary Design Review

2023
FDR
Final Design Review

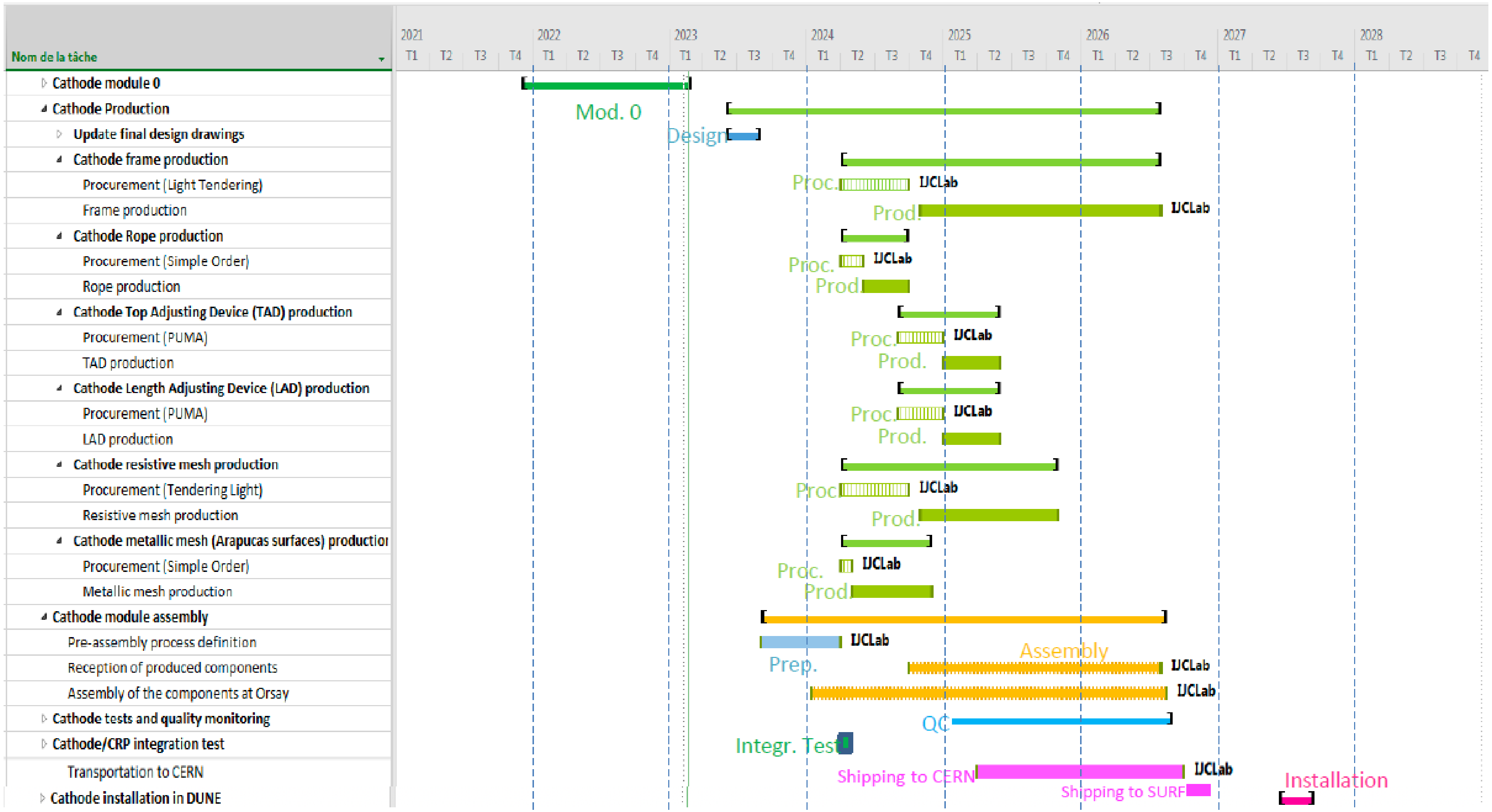
Dec.23/Jan.24
PRR
Production Readiness Review

Archivage des données DUNE sur EDMS (CERN)
Archivage IN2P3 sur ATRIUM

Documentation produite :

PBS / WBS / Planning
Note de design et de calcul
Analyse de risques projet
Technical Readiness Level (TRL) status
CAO en STEP (NAVIS / Soliworks / Catia V5 / 3Dexperience)
Plans de fabrication des pieces
Plans d’assemblages et procédures de montages (estimations RH et temps, besoin outillage et infra)
Plans d’interface
Procédure d’installation
Plan Assurance produit et controle qualité
Sécurité
Purchasing management plan (fournisseurs, procedures, budget estimé et planning)

Planning de préassemblage à IJCLAB de la cathode

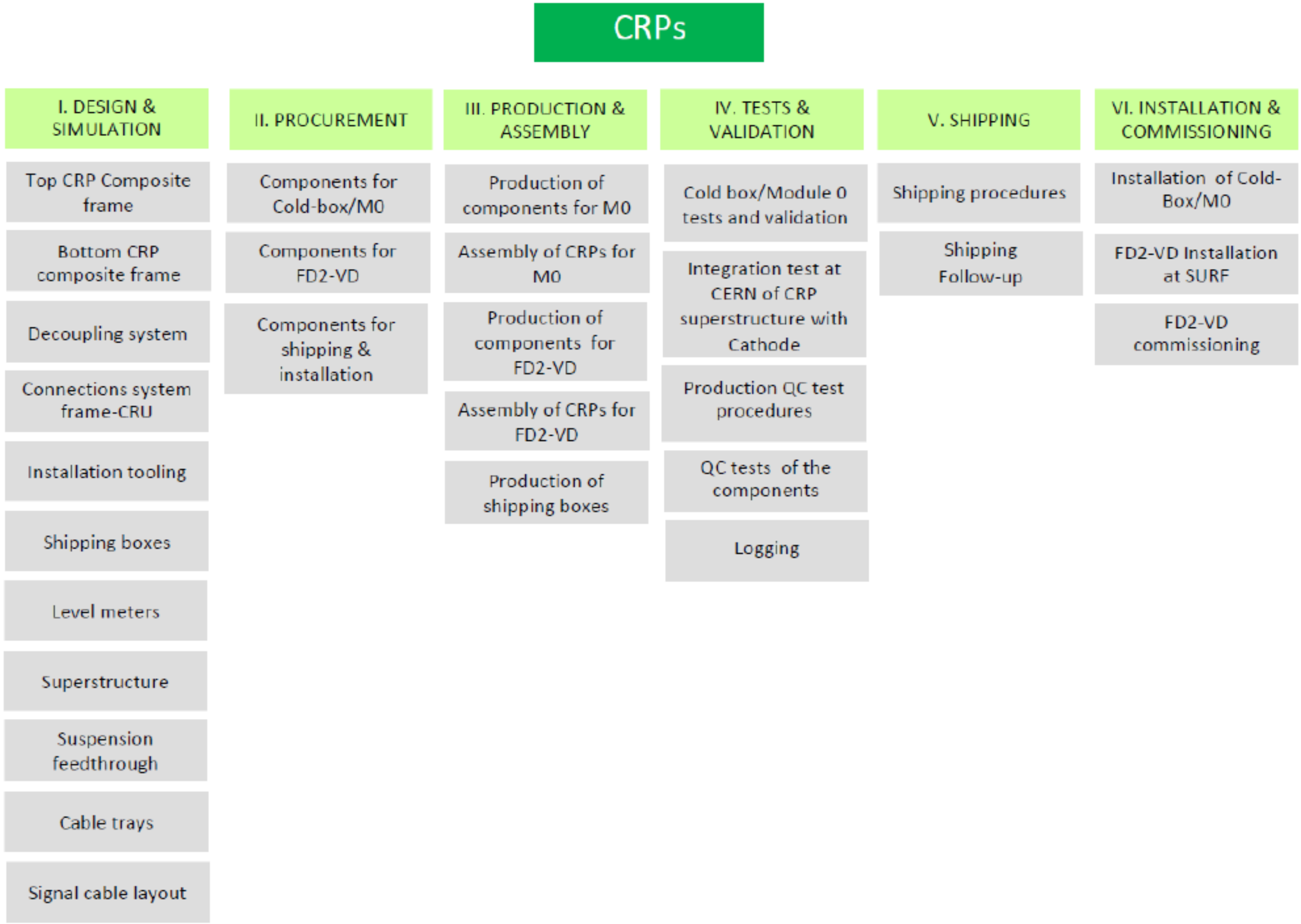


Nom de la tâche

- Cathode module 0
- Cathode Production
  - Update final design drawings
  - Cathode frame production
    - Procurement (Light Tendering)
    - Frame production
  - Cathode Rope production
    - Procurement (Simple Order)
    - Rope production
  - Cathode Top Adjusting Device (TAD) production
    - Procurement (PUMA)
    - TAD production
  - Cathode Length Adjusting Device (LAD) production
    - Procurement (PUMA)
    - LAD production
  - Cathode resistive mesh production
    - Procurement (Tendering Light)
    - Resistive mesh production
  - Cathode metallic mesh (Arapucas surfaces) productior
    - Procurement (Simple Order)
    - Metallic mesh production
- Cathode module assembly
  - Pre-assembly process definition
  - Reception of produced components
  - Assembly of the components at Orsay
- Cathode tests and quality monitoring
- Cathode/CRP integration test
  - Transportation to CERN
- Cathode installation in DUNE

Exemple de PBS (CRP)

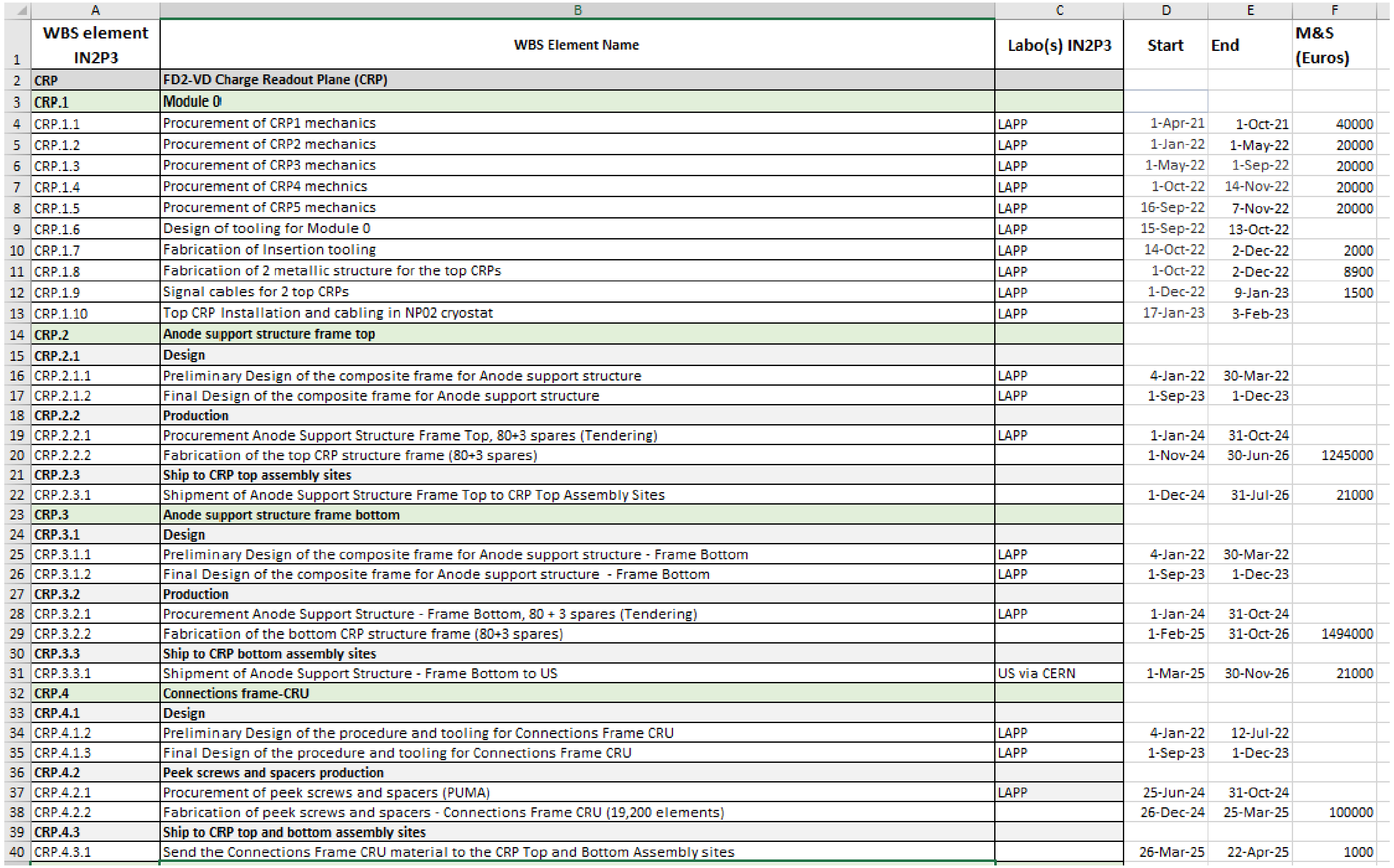
Example (CRP) of product associated WPs (Work Packages ATRIUM-800052)
→ Details on responsibilities, cost and schedule in the WBS document ATRIUM-800053)



- CRPs
  - I. DESIGN & SIMULATION
    - Top CRP Composite frame
    - Bottom CRP composite frame
    - Decoupling system
    - Connections system frame-CRU
    - Installation tooling
    - Shipping boxes
    - Level meters
    - Superstructure
    - Suspension feedthrough
    - Cable trays
    - Signal cable layout
  - II. PROCUREMENT
    - Components for Cold-box/M0
    - Components for FD2-VD
    - Components for shipping & installation
  - III. PRODUCTION & ASSEMBLY
    - Production of components for M0
    - Assembly of CRPs for M0
    - Production of components for FD2-VD
    - Assembly of CRPs for FD2-VD
    - Production of shipping boxes
  - IV. TESTS & VALIDATION
    - Cold box/Module 0 tests and validation
    - Integration test at CERN of CRP superstructure with Cathode
    - Production QC test procedures
    - QC tests of the components
    - Logging
  - V. SHIPPING
    - Shipping procedures
    - Shipping Follow-up
  - VI. INSTALLATION & COMMISSIONING
    - Installation of Cold-Box/M0
    - FD2-VD Installation at SURF
    - FD2-VD commissioning

Exemple de WBS (CRP)

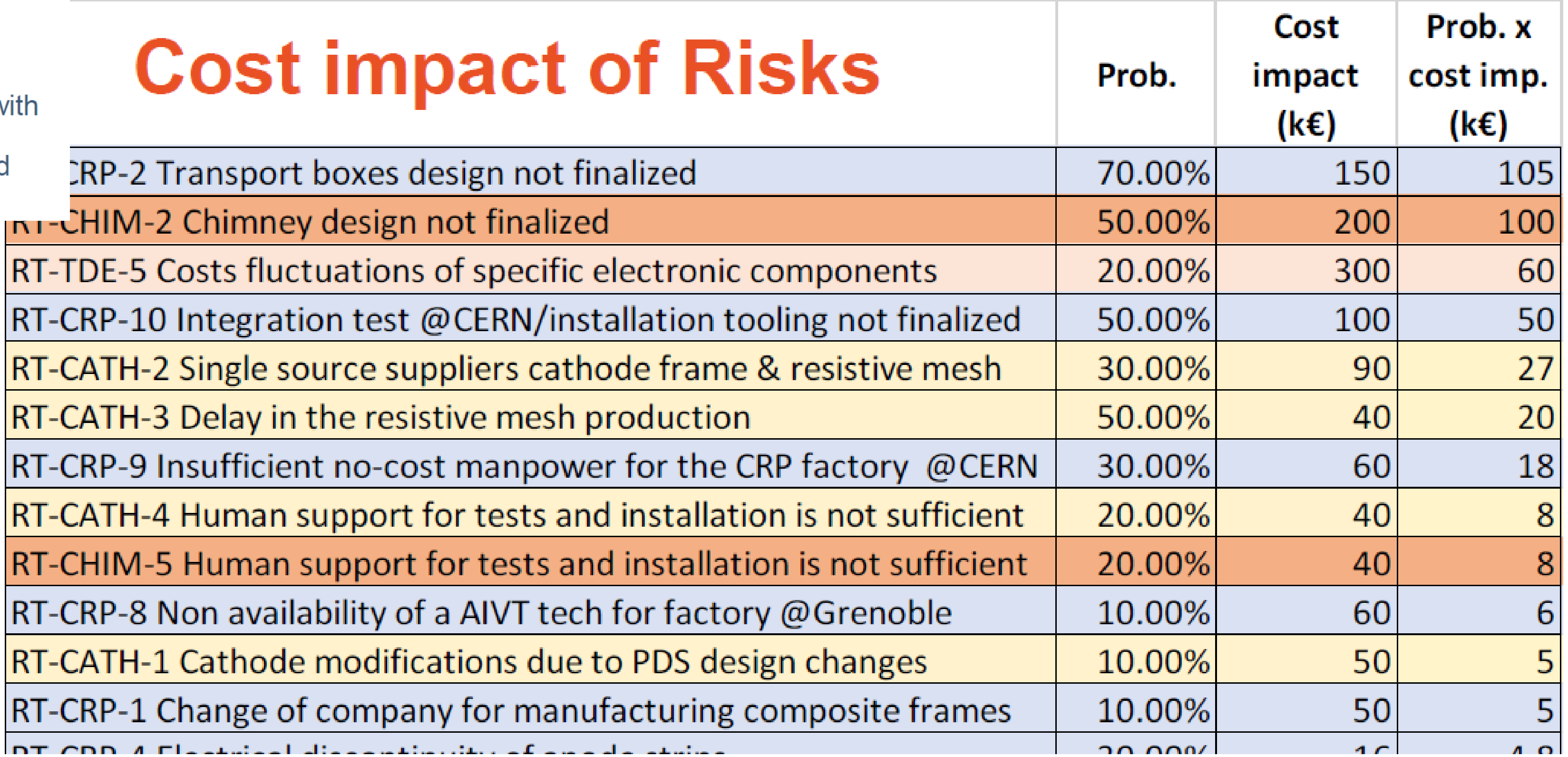
Work Breakdown Structure (WBS ATRIUM-800053, Excel Document with 5 tabs. C-CRP-BOTTOM embedded in CRP tab, 185 lines, more details on WBS in next presentation)



	A	B	C	D	E	F
1	**WBS element IN2P3**	**WBS Element Name**	**Labo(s) IN2P3**	**Start**	**End**	**M&S (Euros)**
2	**CRP**	**FD2-VD Charge Readout Plane (CRP)**				
3	**CRP.1**	**Module 0**				
4	CRP.1.1	Procurement of CRP1 mechanics	LAPP	1-Apr-21	1-Oct-21	40000
5	CRP.1.2	Procurement of CRP2 mechanics	LAPP	1-Jan-22	1-May-22	20000
6	CRP.1.3	Procurement of CRP3 mechanics	LAPP	1-May-22	1-Sep-22	20000
7	CRP.1.4	Procurement of CRP4 mechnics	LAPP	1-Oct-22	14-Nov-22	20000
8	CRP.1.5	Procurement of CRP5 mechanics	LAPP	16-Sep-22	7-Nov-22	20000
9	CRP.1.6	Design of tooling for Module 0	LAPP	15-Sep-22	13-Oct-22	
10	CRP.1.7	Fabrication of Insertion tooling	LAPP	14-Oct-22	2-Dec-22	2000
11	CRP.1.8	Fabrication of 2 metallic structure for the top CRPs	LAPP	1-Oct-22	2-Dec-22	8900
12	CRP.1.9	Signal cables for 2 top CRPs	LAPP	1-Dec-22	9-Jan-23	1500
13	CRP.1.10	Top CRP Installation and cabling in NP02 cryostat	LAPP	17-Jan-23	3-Feb-23	
14	**CRP.2**	**Anode support structure frame top**				
15	**CRP.2.1**	**Design**				
16	CRP.2.1.1	Preliminary Design of the composite frame for Anode support structure	LAPP	4-Jan-22	30-Mar-22	
17	CRP.2.1.2	Final Design of the composite frame for Anode support structure	LAPP	1-Sep-23	1-Dec-23	
18	**CRP.2.2**	**Production**				
19	CRP.2.2.1	Procurement Anode Support Structure Frame Top, 80+3 spares (Tendering)	LAPP	1-Jan-24	31-Oct-24	
20	CRP.2.2.2	Fabrication of the top CRP structure frame (80+3 spares)		1-Nov-24	30-Jun-26	1245000
21	**CRP.2.3**	**Ship to CRP top assembly sites**				
22	CRP.2.3.1	Shipment of Anode Support Structure Frame Top to CRP Top Assembly Sites		1-Dec-24	31-Jul-26	21000
23	**CRP.3**	**Anode support structure frame bottom**				
24	**CRP.3.1**	**Design**				
25	CRP.3.1.1	Preliminary Design of the composite frame for Anode support structure - Frame Bottom	LAPP	4-Jan-22	30-Mar-22	
26	CRP.3.1.2	Final Design of the composite frame for Anode support structure - Frame Bottom	LAPP	1-Sep-23	1-Dec-23	
27	**CRP.3.2**	**Production**				
28	CRP.3.2.1	Procurement Anode Support Structure - Frame Bottom, 80 + 3 spares (Tendering)	LAPP	1-Jan-24	31-Oct-24	
29	CRP.3.2.2	Fabrication of the bottom CRP structure frame (80+3 spares)		1-Feb-25	31-Oct-26	1494000
30	**CRP.3.3**	**Ship to CRP bottom assembly sites**				
31	CRP.3.3.1	Shipment of Anode Support Structure - Frame Bottom to US	US via CERN	1-Mar-25	30-Nov-26	21000
32	**CRP.4**	**Connections frame-CRU**				
33	**CRP.4.1**	**Design**				
34	CRP.4.1.2	Preliminary Design of the procedure and tooling for Connections Frame CRU	LAPP	4-Jan-22	12-Jul-22	
35	CRP.4.1.3	Final Design of the procedure and tooling for Connections Frame CRU	LAPP	1-Sep-23	1-Dec-23	
36	**CRP.4.2**	**Peek screws and spacers production**				
37	CRP.4.2.1	Procurement of peek screws and spacers (PUMA)	LAPP	25-Jun-24	31-Oct-24	
38	CRP.4.2.2	Fabrication of peek screws and spacers - Connections Frame CRU (19,200 elements)		26-Dec-24	25-Mar-25	100000
39	**CRP.4.3**	**Ship to CRP top and bottom assembly sites**				
40	CRP.4.3.1	Send the Connections Frame CRU material to the CRP Top and Bottom Assembly sites		26-Mar-25	22-Apr-25	1000

Analyse de risques: definition des impacts et des priorités

- We have considered 3 main risk categories:
  - Management and external risks
  - Technical risks, related to the state of advancement of the design, quality of deliverables during production, nonconformities during installation and operational risks
  - Logistics risks, related to procurement, assembly facilities, availability of human resources, and transportation
- Each risk has been evaluated for the impact on cost and/or schedule with respect to the project constraints
  - a cumulative risk analysis of the cost has been performed and compared to the available contingency
  - schedule delays have been assessed by comparing the delay with the available float in the schedule (in addition delays of the installation dates by a few months are currently being discussed within LBNF/DUNE)

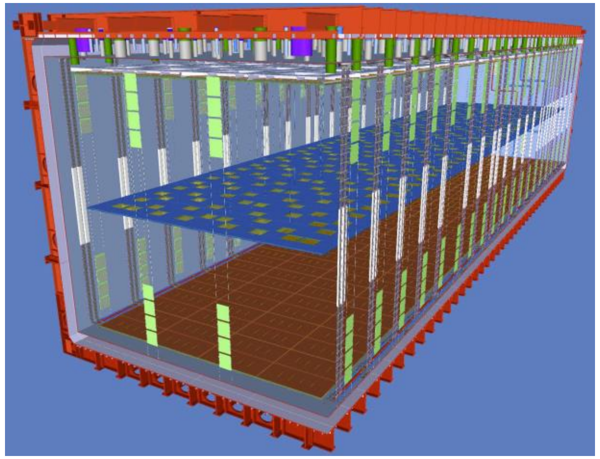


Cost impact of Risks	Prob.	Cost impact (k€)	Prob. x cost imp. (k€)
CRP-2 Transport boxes design not finalized	70.00%	150	105
RT-CHIM-2 Chimney design not finalized	50.00%	200	100
RT-TDE-5 Costs fluctuations of specific electronic components	20.00%	300	60
RT-CRP-10 Integration test @CERN/installation tooling not finalized	50.00%	100	50
RT-CATH-2 Single source suppliers cathode frame & resistive mesh	30.00%	90	27
RT-CATH-3 Delay in the resistive mesh production	50.00%	40	20
RT-CRP-9 Insufficient no-cost manpower for the CRP factory @CERN	30.00%	60	18
RT-CATH-4 Human support for tests and installation is not sufficient	20.00%	40	8
RT-CHIM-5 Human support for tests and installation is not sufficient	20.00%	40	8
RT-CRP-8 Non availability of a AIVT tech for factory @Grenoble	10.00%	60	6
RT-CATH-1 Cathode modifications due to PDS design changes	10.00%	50	5
RT-CRP-1 Change of company for manufacturing composite frames	10.00%	50	5

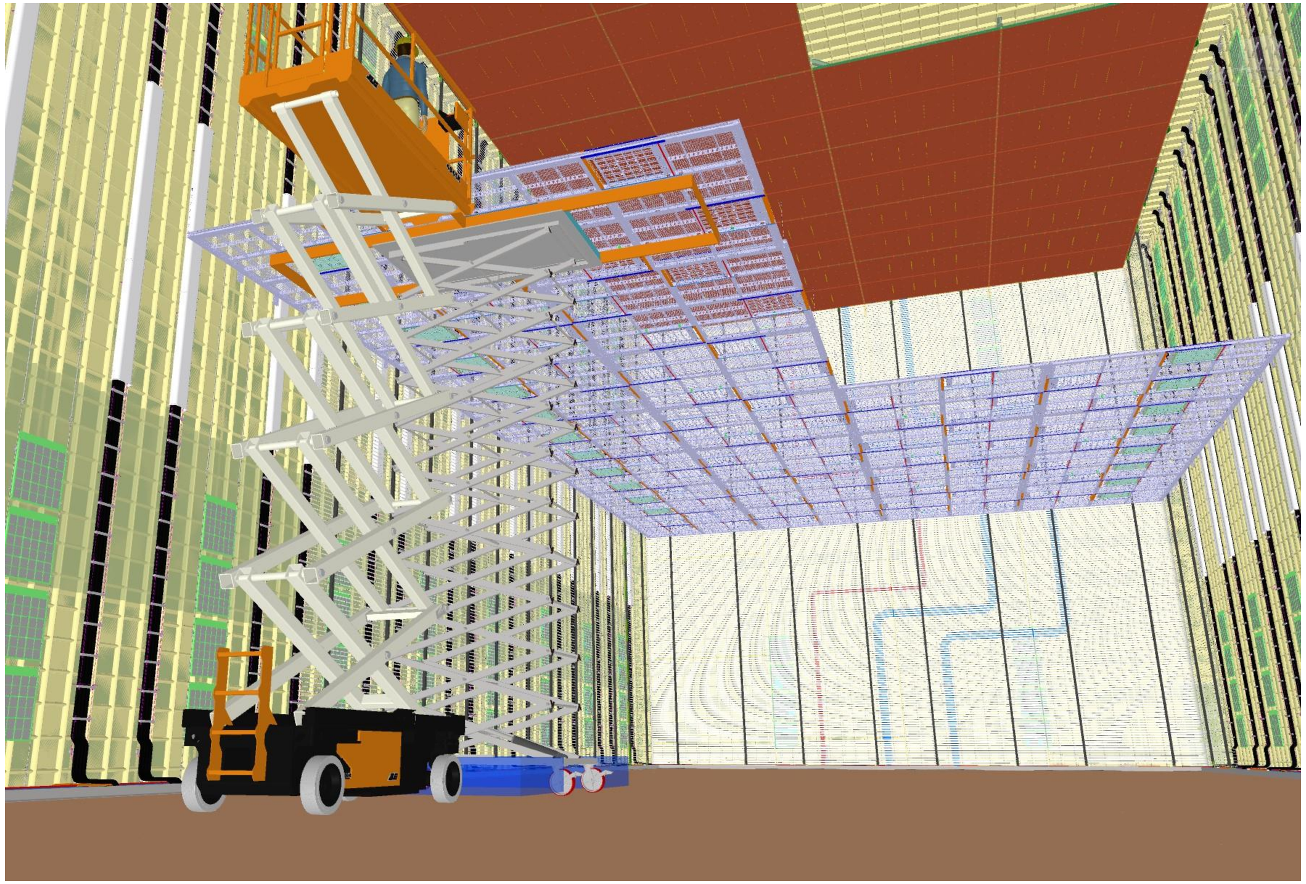
Coordination and I&I engineering group

Coordination des USA et CERN sur
les Interfaces and Infrastructure Engineering :
- Installation (planning, RH, logistique, design)
- Infrastructure
- Global CAD

I&I engineering group (SURF) :
- Habilitation travail en hauteur sur nacelle
- Habilitation manipulation pont roulant
- Organisation et logistique
- Contrôle accès mines et ascenseur



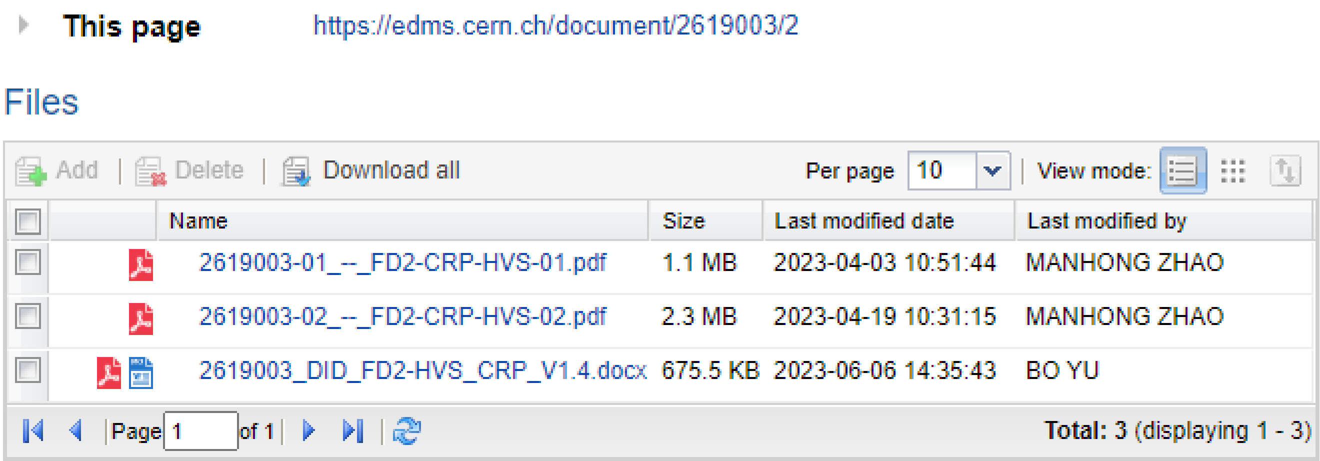
Global CAD



View of Cathode plane being installed with X-Y table

Interface studies by FermiLab

HVS – CRP: https://edms.cern.ch/document/2619003/2



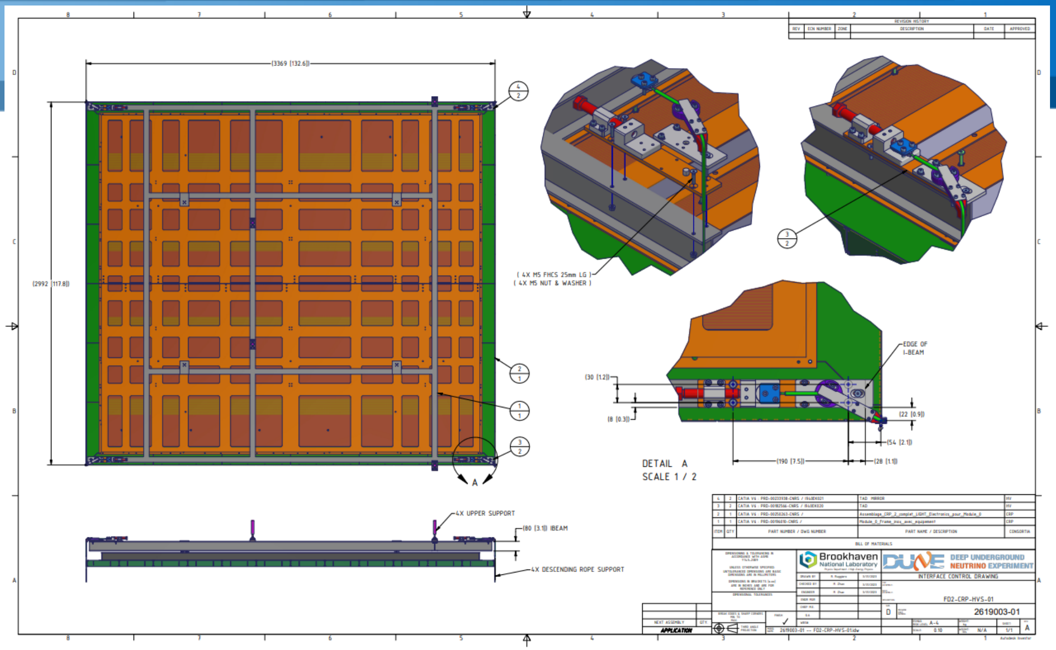
This page https://edms.cern.ch/document/2619003/2

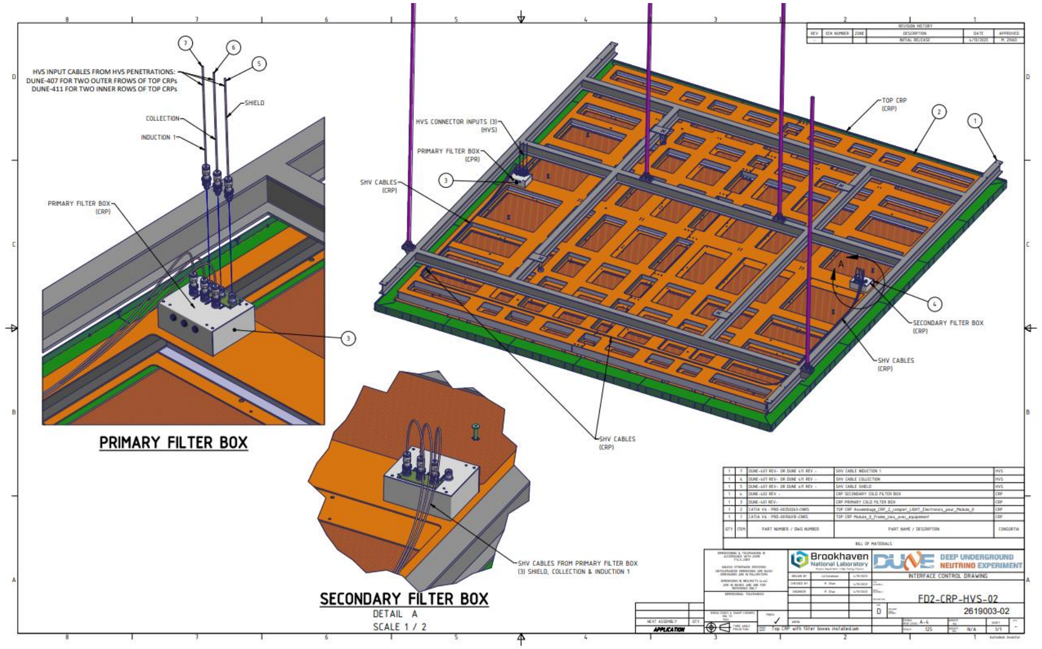
Files

☐	Name	Size	Last modified date	Last modified by
☐	2619003-01_--_FD2-CRP-HVS-01.pdf	1.1 MB	2023-04-03 10:51:44	MANHONG ZHAO
☐	2619003-02_--_FD2-CRP-HVS-02.pdf	2.3 MB	2023-04-19 10:31:15	MANHONG ZHAO
☐	2619003_DID_FD2-HVS_CRP_V1.4.docx	675.5 KB	2023-06-06 14:35:43	BO YU

Page 1 of 1

Total: 3 (displaying 1 - 3)

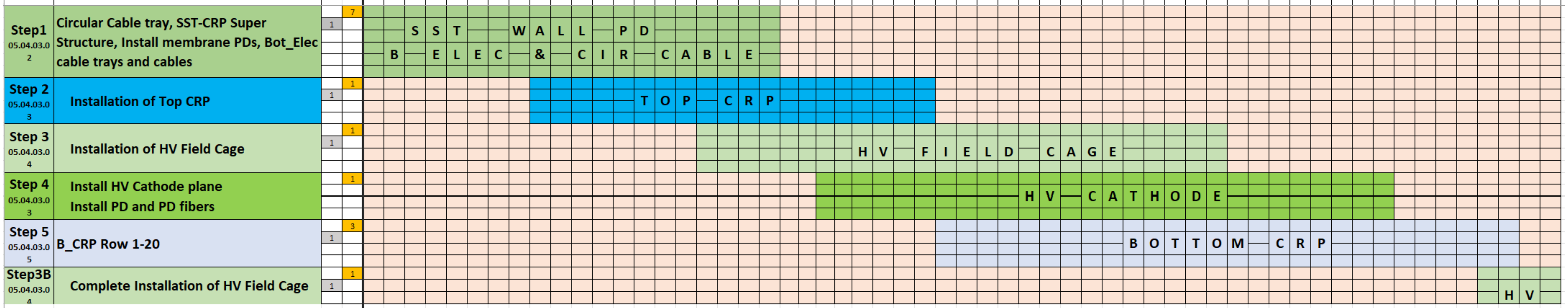




Planning en vue simplifiée pour l'installation des détecteurs dans FD2 en 2027

Activity	Month																													
	Month			41						42								43										44		
	Week			13-Feb-28		20-Feb-28		27-Feb-28		5-Mar-28		12-Mar		19-Mar		26-Mar		2-Apr		9-Apr		16-Apr		23-Apr		30-Apr		7-May		14-May
	Day	SrMT	MT	13-Feb		20-Feb		27-Feb		5-Mar		12-Mar		19-Mar		26-Mar		2-Apr		9-Apr		16-Apr		23-Apr		30-Apr		7-May		14-May
	Schedule dates based of P6 output June, 2023 output	# FTE	# FTE	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM

Month							45								46										47					
Week	14-May	21-May		28-May		4-Jun		11-Jun		18-Jun		25-Jun		2-Jul		9-Jul		16-Jul		23-Jul		30-Jul		6-Aug		13-Aug		20-Aug		20-Aug	
Day	14-May	21-May		28-May		4-Jun		11-Jun		18-Jun		25-Jun		2-Jul		9-Jul		16-Jul		23-Jul		30-Jul		6-Aug		13-Aug		20-Aug		20-Aug	
	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM



Activity		SrMT # FTE	MT # FTE
Step1 05.04.03.02	**Circular Cable tray, SST-CRP Super Structure, Install membrane PDs, Bot_Elec cable trays and cables**	1	7
Step 2 05.04.03.03	**Installation of Top CRP**	1	1
Step 3 05.04.03.04	**Installation of HV Field Cage**	1	1
Step 4 05.04.03.03	**Install HV Cathode plane** **Install PD and fibers**		1
Step 5 05.04.03.05	**B_CRP Row 1-20**	1	3
Step3B 05.04.03.04	**Complete Installation of HV Field Cage**	1	1

	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7		Week 8		Week 9		Week 10		Week 11		Week 12		Week 13		Week 14	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Mechanical Tech - Total FTE shifts /week	68	68	72	72	78	78	91	91	102	102	84	84	84	78	78	72	92	78	102	71	68	36	92	60	92	60	80	48
Sr Mechanical Tech - Total FTE shifts/week	12	17	24	18	18	18	21	21	24	30	18	24	20	20	17	17	18	18	20	16	16	12	15	11	16	12	12	8
CRP Consortia - Total FTE shifts/week	12	0	12	0	18	18	24	24	60	36	42	18	24	24	15	15	18	18	15	15	30	18	27	15	30	18	18	6
HV Consortia - Total FTE Total FTE shifts/week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	24	31	24	32	24	44	36	44	36	44	36
PD Consortia - Total FTE Total FTE shifts/week	24	0	28	0	12	0	38	18	42	18	42	18	42	18	42	18	42	18	28	12	6	0	18	12	18	12	18	12
TDE Consortia - Total FTE Total FTE shifts/week	0	0	0	0	0	0	0	0	12	0	12	0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	3	3
B_Elec Consortia - Total FTE Total FTE shifts/week	12	0	12	0	12	12	26	18	30	18	30	18	30	18	30	18	30	18	24	12	0	0	0	0	0	0	0	0
Average I&I and Consortia FTE in cryostat/shift	21.3	14.2	24.7	15	23	21	33.3	28.7	45	34	38	27	34.3	27.3	31.3	24.3	39.7	30	37.6	26	26	16	34	23	34.3	24	29.2	18.8

	Week 15		Week 16		Week 17		Week 18		Week 19		Week 20		Week 21		Week 22		Week 23		Week 24		Week 25		Week 26		Week 27		Week 27		Week 28	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
Mechanical Tech - Total FTE shifts /week	56	30	62	36	68	42	77	51	74	48	74	48	58	48	48	48	48	48	48	48	44	44	24	24	24	24	24	24	30	30
Sr Mechanical Tech - Total FTE shifts/week	4	0	10	3	16	6	13	5	10	4	10	4	8	4	6	4	6	4	6	4	6	4	6	4	6	4	6	4	6	6
CRP Consortia - Total FTE shifts/week	0	0	6	0	12	0	15	9	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	0	0
HV Consortia - Total FTE Total FTE shifts/week	44	36	44	36	44	36	44	36	20	12	20	12	15	12	12	12	12	12	12	12	6	6	0	0	0	0	0	0	12	12
PD Consortia - Total FTE Total FTE shifts/week	18	12	18	12	18	12	18	12	18	12	18	12	12	12	12	12	12	12	12	12	6	6	0	0	0	0	0	0	0	0
TDE Consortia - Total FTE Total FTE shifts/week	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B_Elec Consortia - Total FTE Total FTE shifts/week	0	0	6	0	12	0	12	6	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	0	0
Average I&I and Consortia FTE in cryostat/shift	20.3	13	24.3	14.5	28.3	16	29.8	19.8	25.3	17.7	25.3	17.7	20.5	17.7	18	17.7	18	17.7	18	17.7	15.3	15	10	9.67	10	9.67	10	9.67	8	8

End of PRR first quarter 2024

Start of production April 2024 => Material at SURF in Septembre 2026

Start of IN2P3 Installations spring-summer 2027

Detector closure beginning 2028

Start filling mid-2028

<u>Exemple d'une contrainte:</u>

Débit de l'ascenseur pour acheminer le matériel et le manpower dans la mine à 1500 m de profondeur

Temps d'accès et de presence limité (1+8+1h)

Remerciements

Références :
Mes sources
Et celles de Fabien Cavalier, Alberto Marchionni, Dario Autiero, Cedric Cerna, Dominique Duchesneau,
Et tous mes autres collaborateurs DUNE …

MERCI DE VOTRE ATTENTION