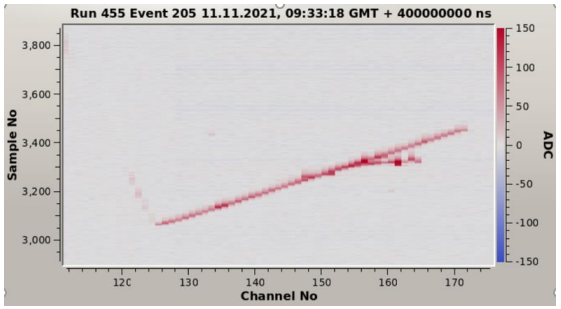
TDE Consortium Meeting
14/4/2022

D. Autiero, T. Hasegawa

Preparation for TDE PDR



The TDE PDR will take place on May 17-18

Unfortunately the schedule is subject to many constraints such as the tests activities at CERN and other PDRs. It overlaps with the DUNE collaboration week but for the second and third day of parallel sessions

TDE PDR indico page (under construction) :
https://indico.fnal.gov/event/53543/

Previous TDE CDR (4/6/2021):
https://indico.cern.ch/event/1038740/
https://edms.cern.ch/file/2580460/1/DUNE-FD2-VD_TDE_CDR_Report_v2.docx

TDE design quite mature since several years, developments since CDR:

- Adjustment on CRP layout and channel counting
- Successful application of all what described in the CDR and prepared in 2021 in the cold-box tests campaign (on top of previous massive production/exploitation in 3x1x1, NP02/protoDUNE-DP)
- Further progress on interfaces definition CRP/DAQ (also treated in CRP and DAQ PDRs)
- Progress on large chimneys design 24/48 cards and on their installation procedure
- General progress on installation procedures/cryostat roof layout; LV system, cabling, 48V power supplies for uTCA

In-line with CDR:

- Production schedules/QA (already large experience from past productions) unchanged to CDR plans
- Requirements (in common with BDE) unchanged, some more details on internal specifications
- Progress on continuation of VD deployment 2022 CB tests, Module-0

Other PDRs:

PDRs which already happened:
DAQ:
https://indico.fnal.gov/event/52094/ (important interface aspects with TDE)

CRP:
https://indico.fnal.gov/event/53111/ (important interface aspects with TDE)

PDRs to be done:
HV:
https://indico.fnal.gov/event/53541/

BDE:
https://indico.fnal.gov/event/53544/

PDS:
https://indico.fnal.gov/event/53542/

Installation:
https://indico.fnal.gov/event/53545/ (important common documents with TDE)

Charge letter (similar to other PDRs): https://edms.cern.ch/ui/#!master/navigator/document?D:101011547:101011547:subDocs

DEEP UNDERGROUND NEUTRINO EXPERIMENT

DUNE Preliminary Design Review

Charge

Top Drift Electronics

May 17-18, 2022

The committee is requested to review the DUNE FD2 Top Drift Electronics (TDE) design and determine if it meets the requirements of preliminary design as outlined in the LBNF/DUNE Review Plan (edms-2173197) and the DUNE Far Detector PDR deliverables in (edms-2374096). The committee should provide answers to the following questions:

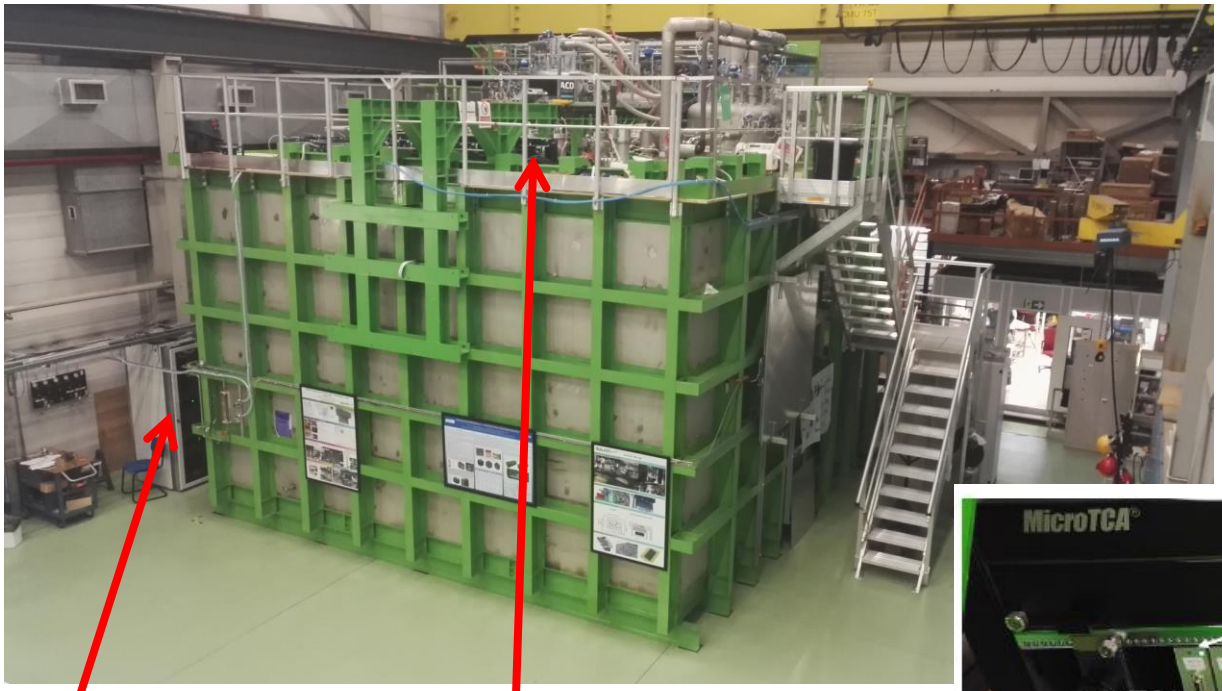
1. Are the full specifications of the TDE system and components available in EDMS?
2. Have interfaces with other detector components been addressed and documented? Do risks of design changes in other systems have appropriate mitigation strategies?
3. Does the proposed system design address detector requirements: performance, installation, testing, commissioning, operation and maintenance? Have design choices been fully identified and do they meet detector requirements?
4. Have lessons learned from ProtoDUNE been implemented both for the overall system design and design of the individual components?
5. Are plans for prototyping reasonable and sufficient?
6. What is the status of the procurement strategy and of the manufacturing and testing plan?
7. Are quality assurance and testing plans sufficiently developed to proceed to final design?
8. Have appropriate cost estimates and schedule been determined? Are plans for required technical resources consistent with scope of remaining work?

Review Findings:

The committee should present its findings, comments and recommendations in a final written report by June 17.

ProtoDUNE dual-phase 6x6x6: 12 uTCA crates (120 AMCs, 7680 readout channels)

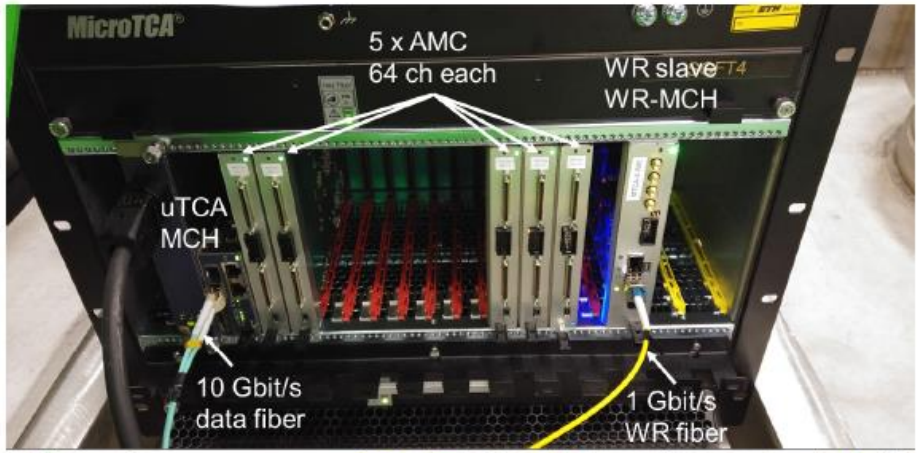
→ 3x1x1: 4 uTCA crates (20 AMCs, 1280 readout channels)



Signal Chimneys and uTCA crates

Event builder, network, GPS/White Rabbit GM, WR Trigger PC

Electronics/DAQ system operational on the 3x1x1 in the period November 2016-March 2018

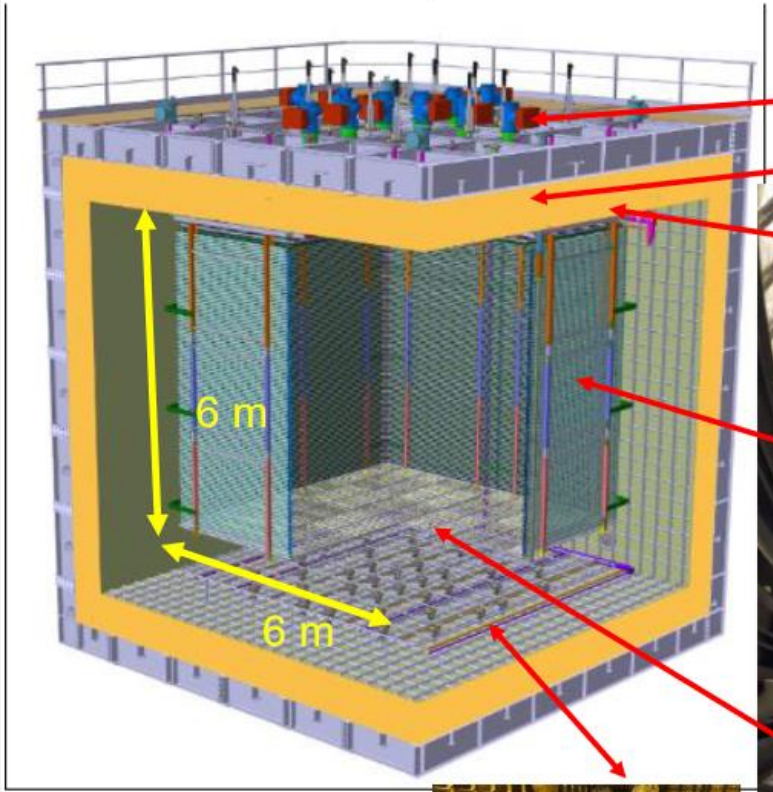


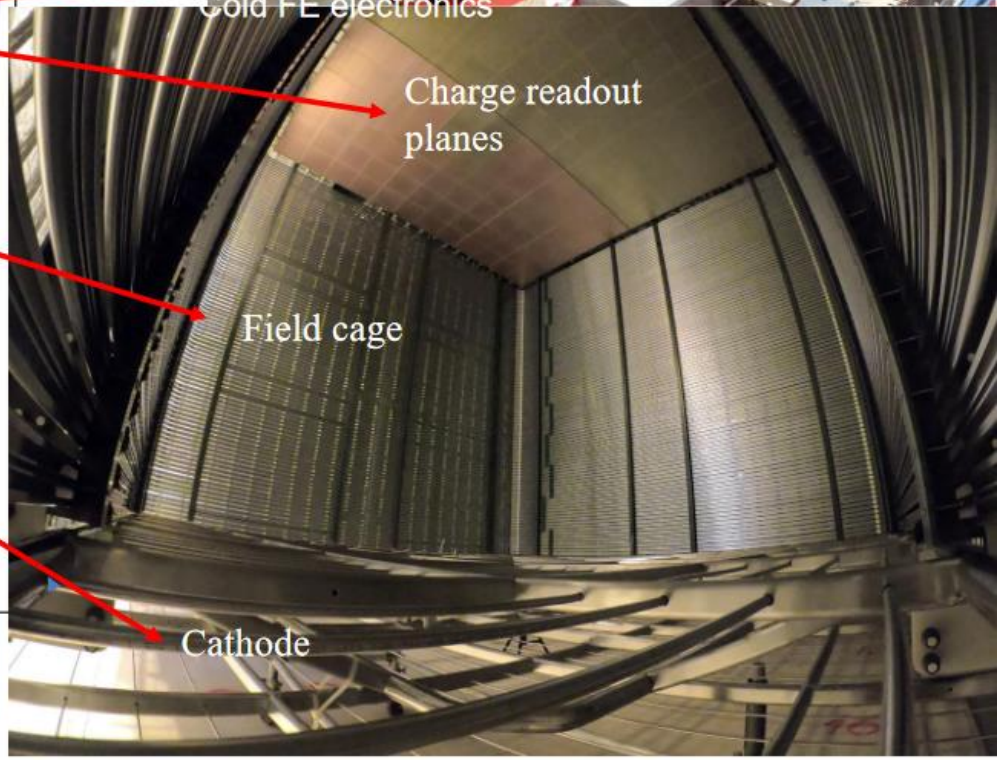
NP02/protoDUNE dual-phase

dual-phase FD design based on NP02:

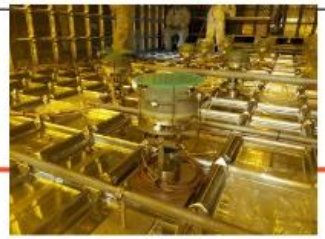
- 1/20 of active area of DP 10 kton
- NP02/protoDUNE DP 4 CRPs → DUNE 80 CRPs

Construction 2018-19 Operation 2019-20





36 cryogenic photomultipliers Hamamatsu R5912-02mod with TPB coating



ProtoDUNE-DP accessible cryogenic front-end electronics and uTCA FE system

Full accessibility provided by the dual-phase charge readout at the top of the detector

➢ **Digital electronics at warm on the tank roof:**

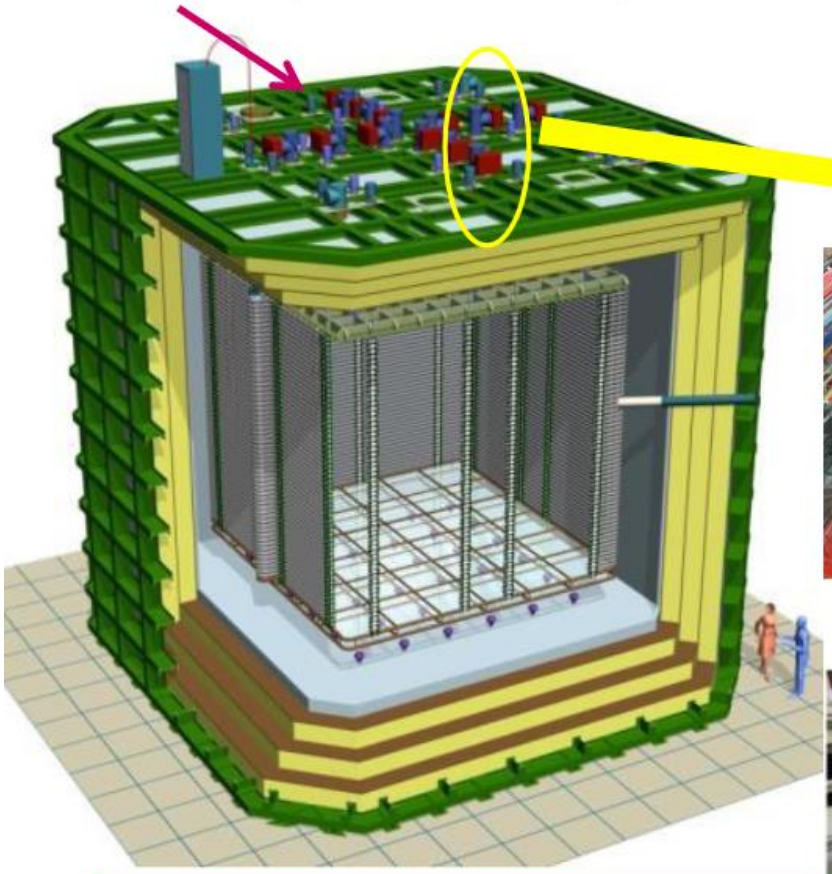
- Architecture based on uTCA standard
- 1 crate/signal chimney, 640 channels/crate

→ 12 uTCA crates, 10 AMC cards/crate, 64 ch/card

➢ **Cryogenic ASIC amplifiers (CMOS 0.35um) 16 ch externally accessible:**

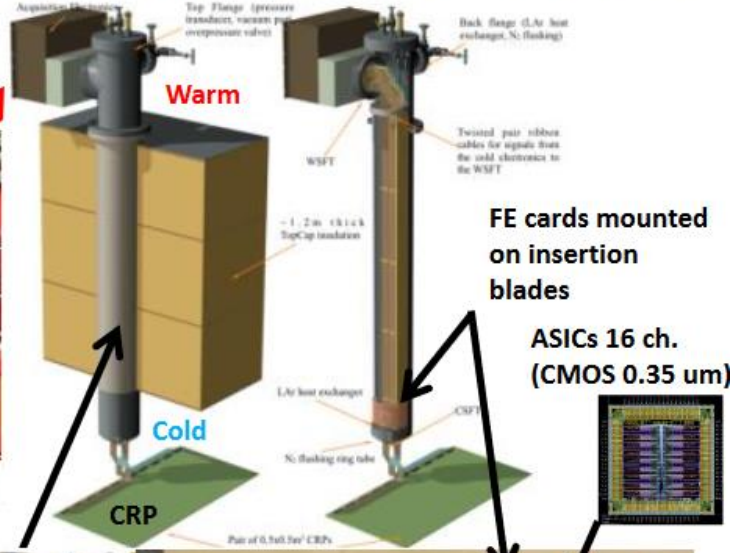
- Operating at 110K at the bottom of the signal chimneys
- Cards fixed to a plug accessible from outside

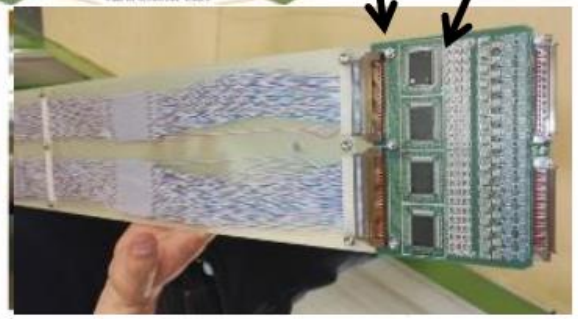
→Short cables capacitance, low noise at low T

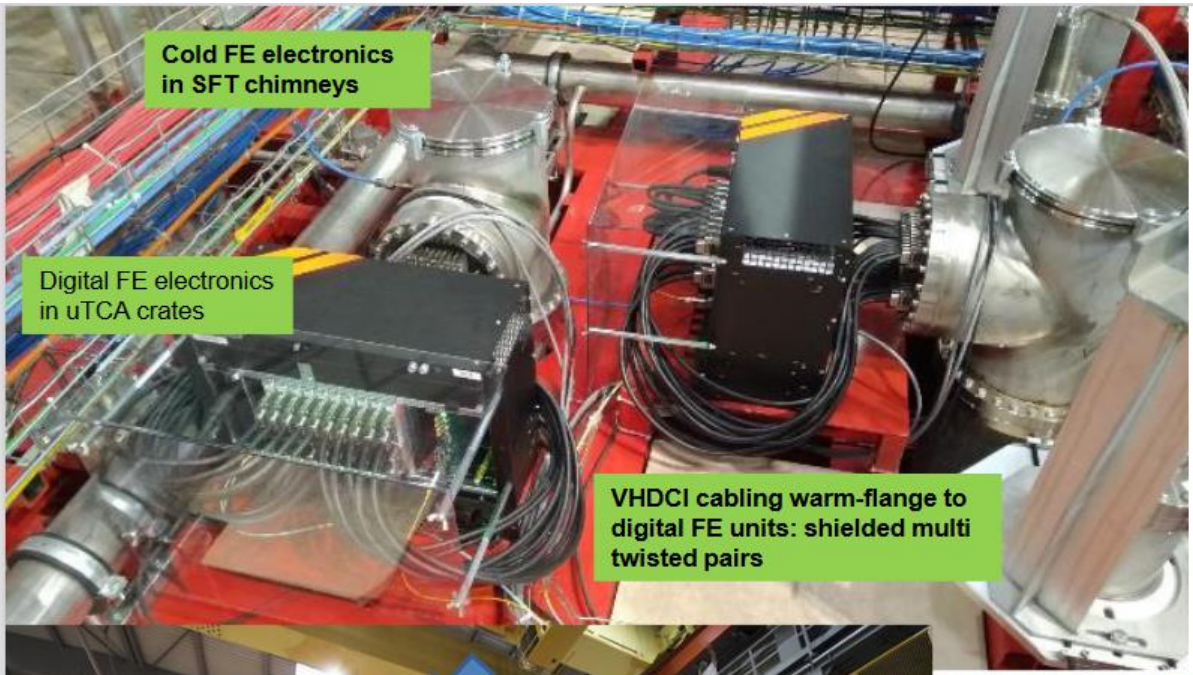


Signal chimney

<50 cm





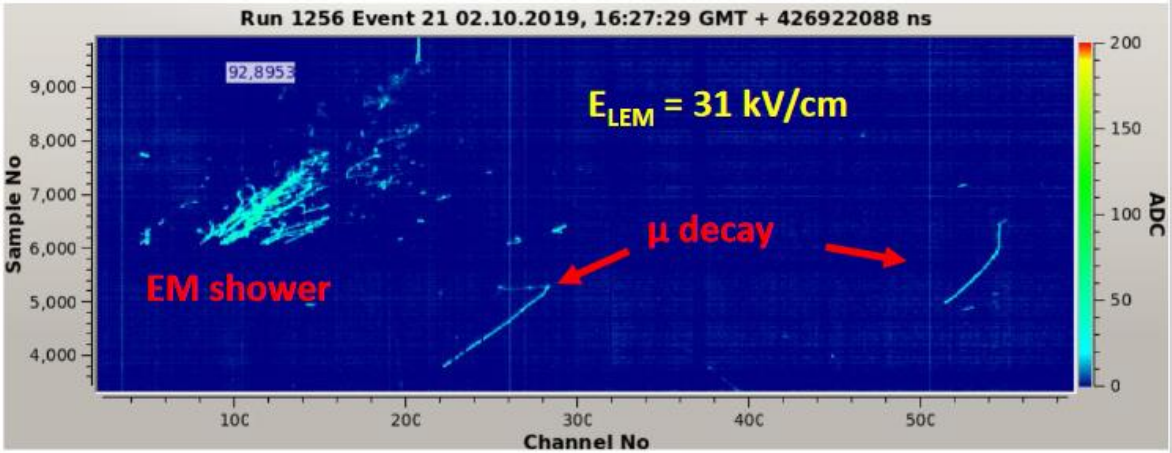


ProtoDUNE dual-phase view of the cryostat roof with:

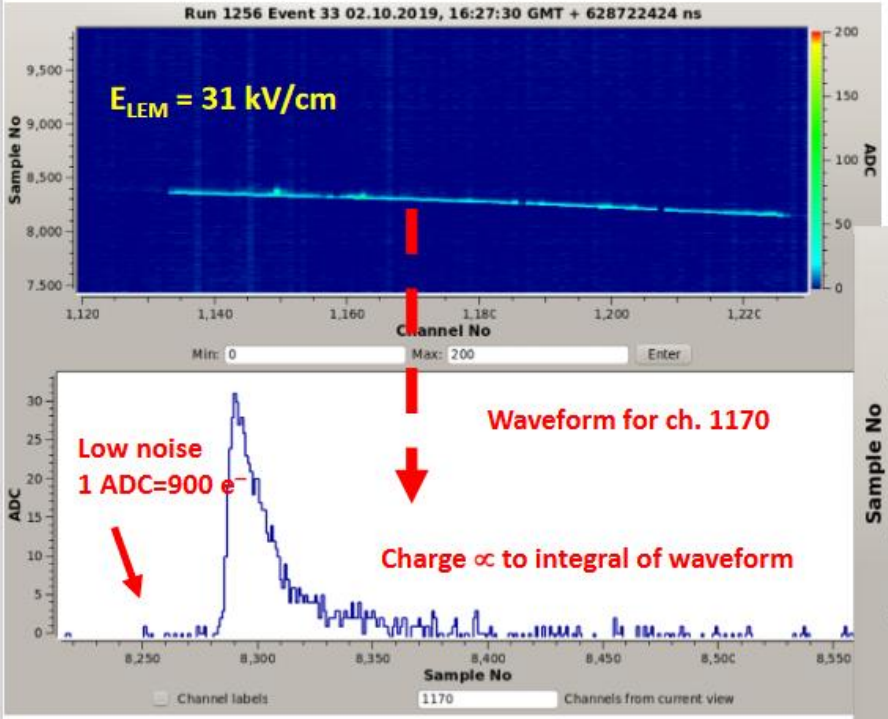
- **FE digitization electronics in the uTCA crates**
- **Signal feedthrough chimneys with cold electronics**

Cosmic ray events in protoDUNE dual-phase

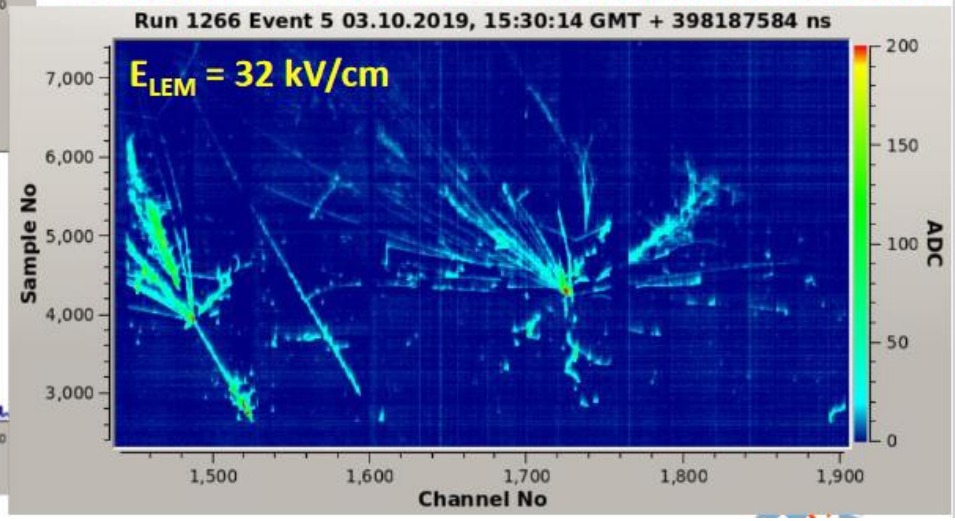
Electromagnetic shower + two muon decays



Horizontal muon track

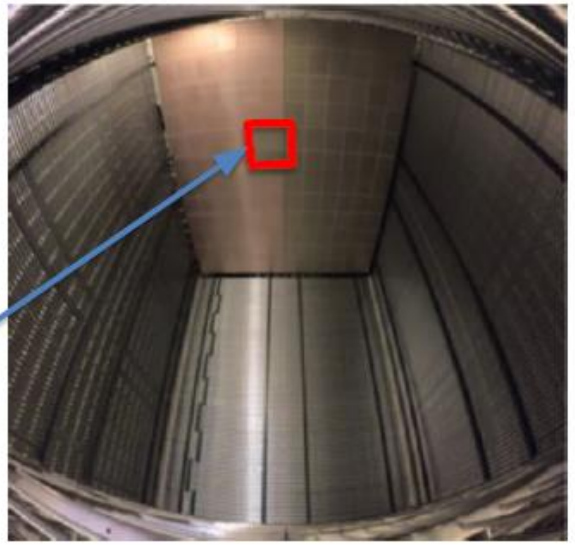


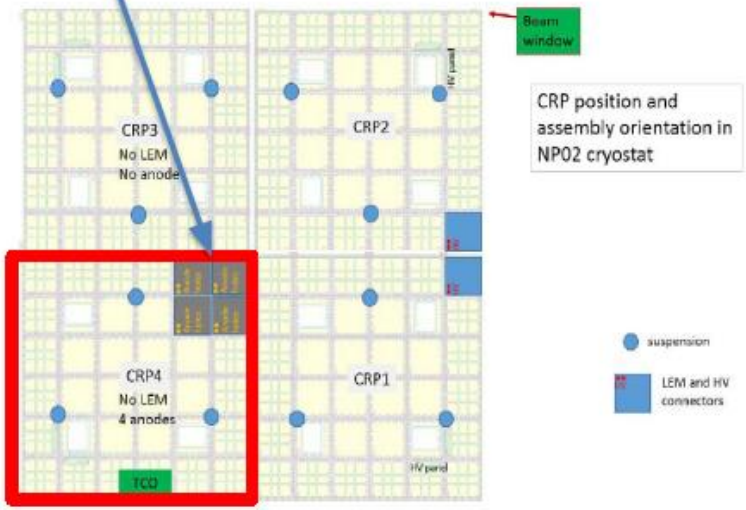
*Multiple **hadronic interactions in a shower***



Full 6m drift readout with 300 kV on cathode

- During Jan/Feb, efforts to activate dual-phase CRP1/CRP2 were not successful due to past damages (LEMs, stuff trapped in the grids, thermal excursions etc …).
- Focus on dual-phase CRP4:
  - Instrumented with 4 anode PCBs each of 50cm x 50cm with two orthogonal collection views, 3 mm pitch, 50% - 50% charge sharing, ~640 channels
  - Anodes operated in gas. Grid in LAr to extract electrons to the gas with high efficiency (DV = ~ 3kV over ~1.3 cm). Sensitive area = $1m^2$.
    Given drift distance, active volume = $6m^3$.
  - *No LEM and no dual-phase amplification.*
    Electrons simply collected by the anodes,
    as in the new Vertical Drift CRPs but signals reduced to ~1/4
  - Drift E field intensity variations due to space charge expected < 20%; thanks to central location of active CRP, E drift field direction quite uniform.





Readout activation & data taking

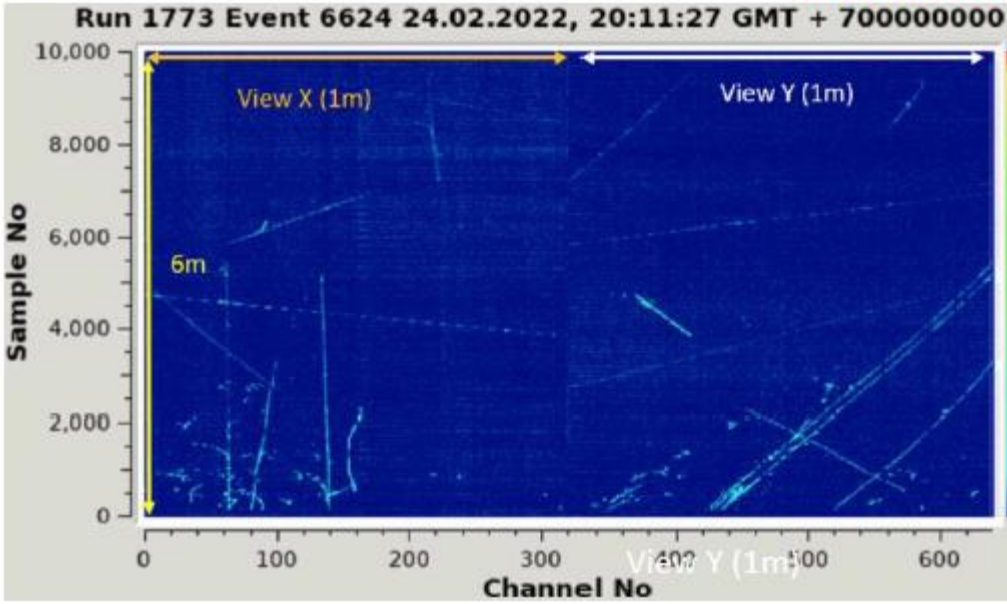
Successful activation of DP readout system (analog, digital, timing, DAQ) Feb 23 to 25, high rate data taking with random triggers / with an external trigger (ET, two scintillation counters located on top of the 4 anodes)

Long tracks immediately visible

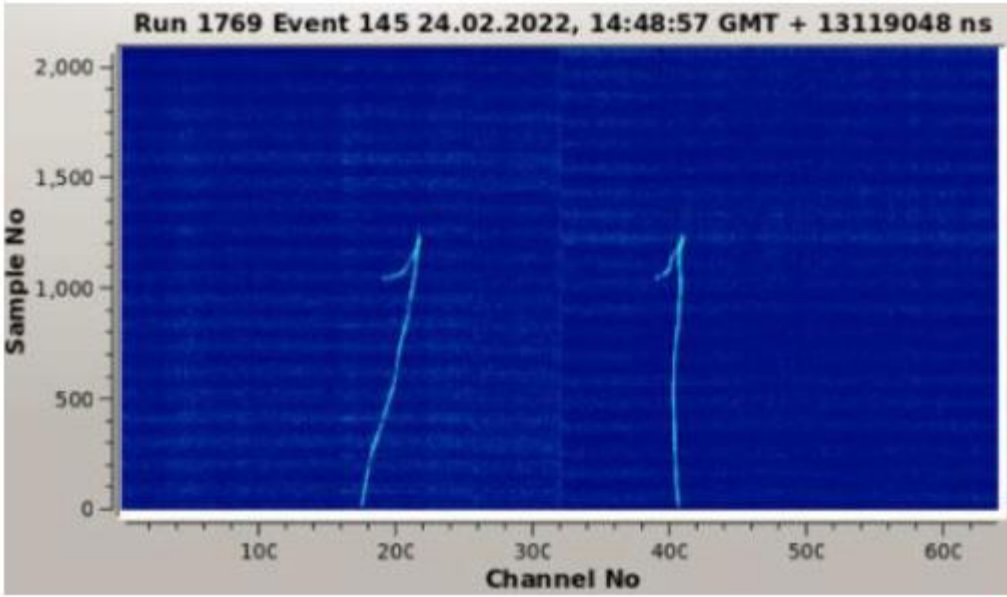
- Tracks near the cathode are visible after 6m drift and this is with only ¼ of the charge expected in the VD case, with an additional 70% attenuation due to purity, and with a signal broadening due to diffusion

These results demonstrate that 6m drift will be amply manageable in DUNE FD2 where more charge is expected, possibly with higher purity

Random tri



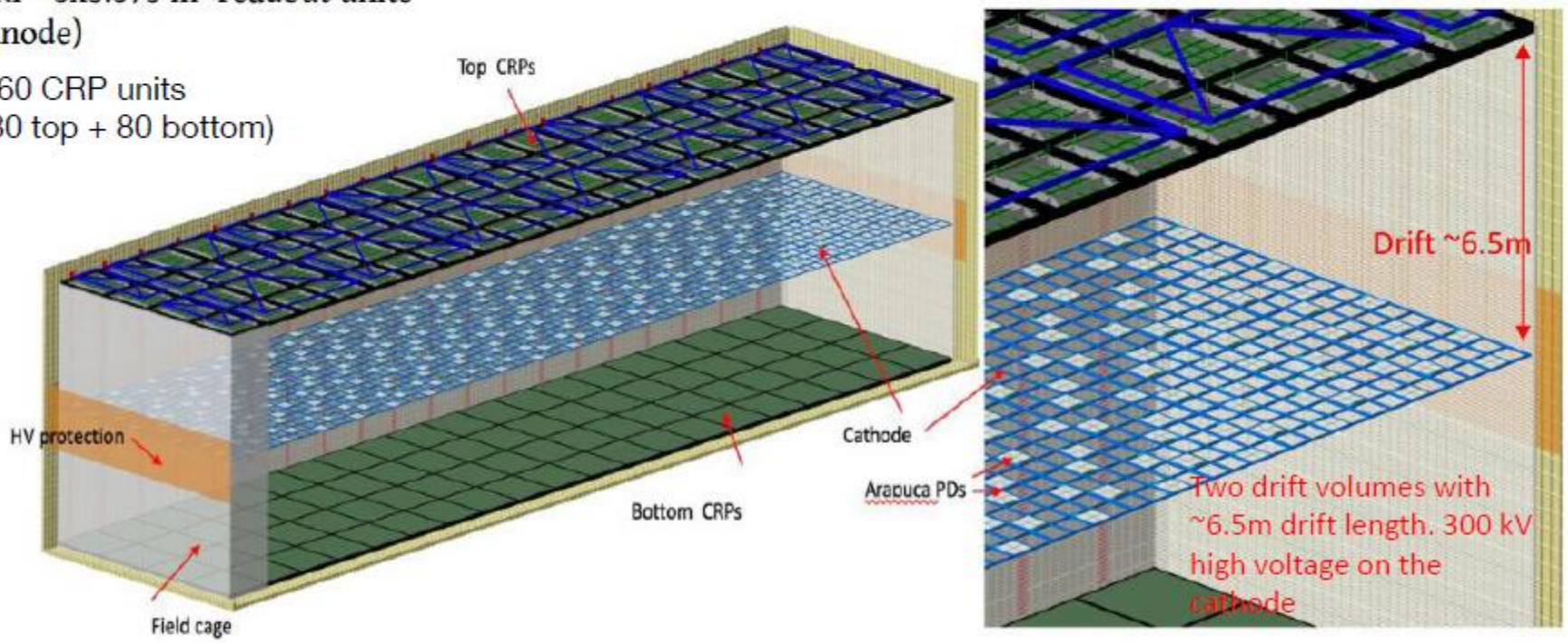
ET Muon decay candi



DUNE Vertical Drift far detector module

CRP= 3x3.375 m^2 readout units (anode)

160 CRP units
(80 top + 80 bottom)



Detector details are described in the conceptual design report
Vertical drift detector and related tests in NP02 were introduced and described in the last year's SPSC meeting
This talk covers the details of HV and CRP tests that were performed in 2021

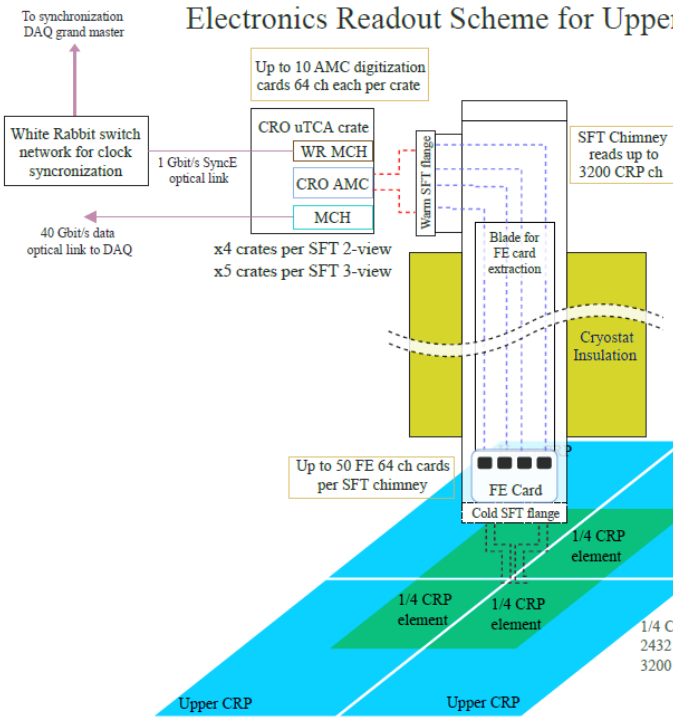
Final detector readout layout after CRP channels counting re-optimization and for final 3 views layout:

x80 Top-Drift Charge Readout Planes

Units per CRP:
x3072 Readout channels per CRP
x48 AMC digitization cards per CRP (64ch/card)
x12 AMC digitization cards per uTCA crate
x4 uTCA crates per CRP

105 chimneys of two sizes 48/24 cards:
Chimneys at detector sides have less than 48 cards/chimney

Total:
x320 uTCA crates
x3840 AMC digitization cards
x245760 readout channels



Top-drift Electronics Components

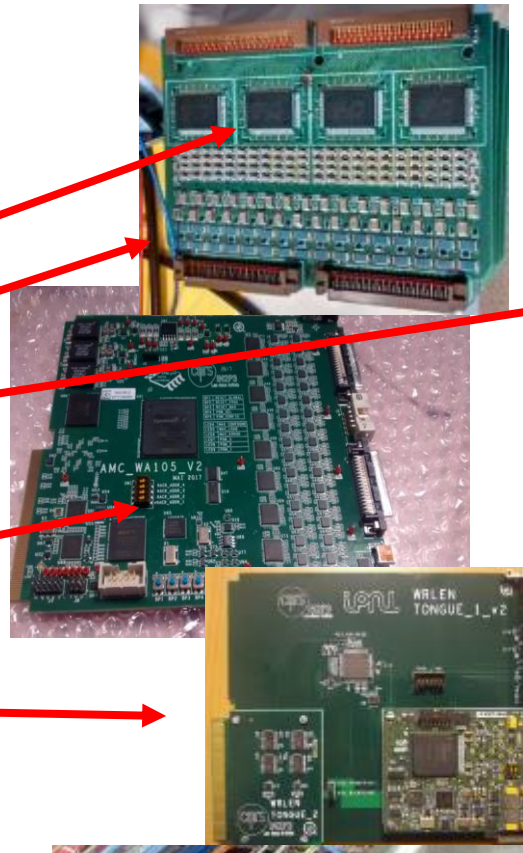
Total number of charge readout channels: **246k**

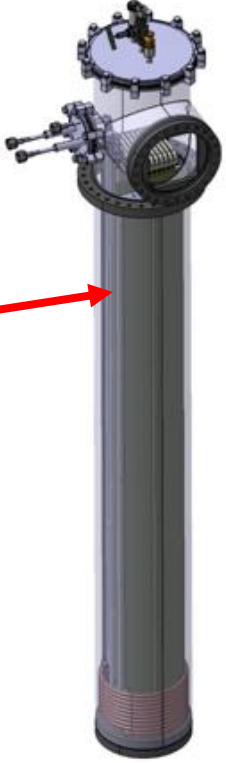
Analog:

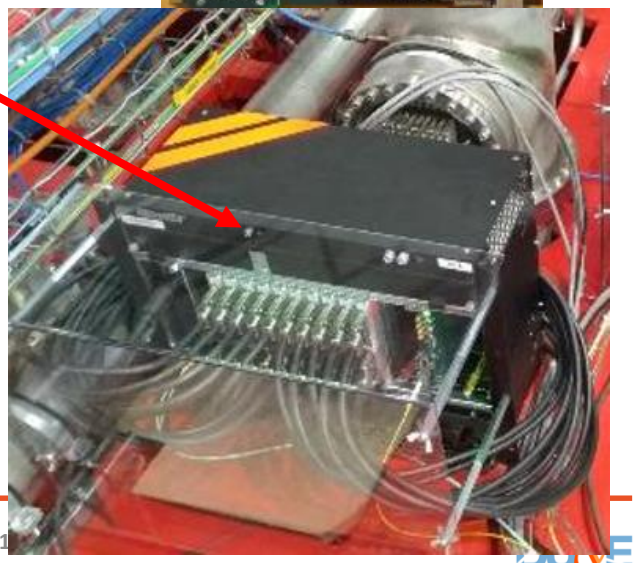
- Cryogenic ASICs (16 ch): **15360**
- Cryogenic FE cards (64 ch): **3840**
- 24/48 Cards Chimneys: **105**

Digital:

- AMC cards (64 ch): **3840**
- uTCA White Rabbit MCH: 320
- uTCA crates (including MCH,PU,FU): **320**
- 40 Gbe optical links to backend: **320**



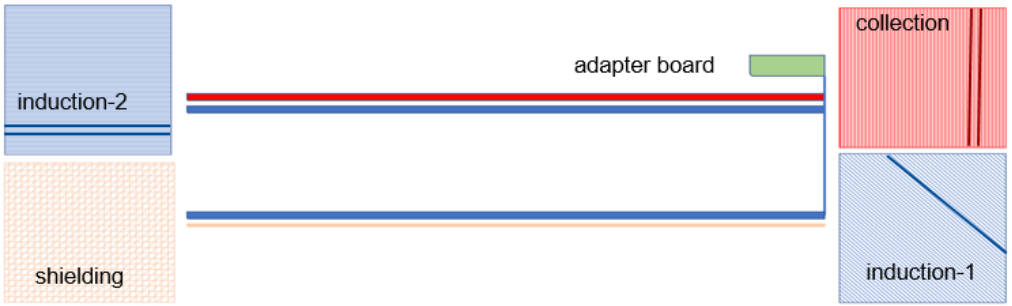




The top-drift CRPs electronics is based on **two main elements** with **64 ch modularity**:

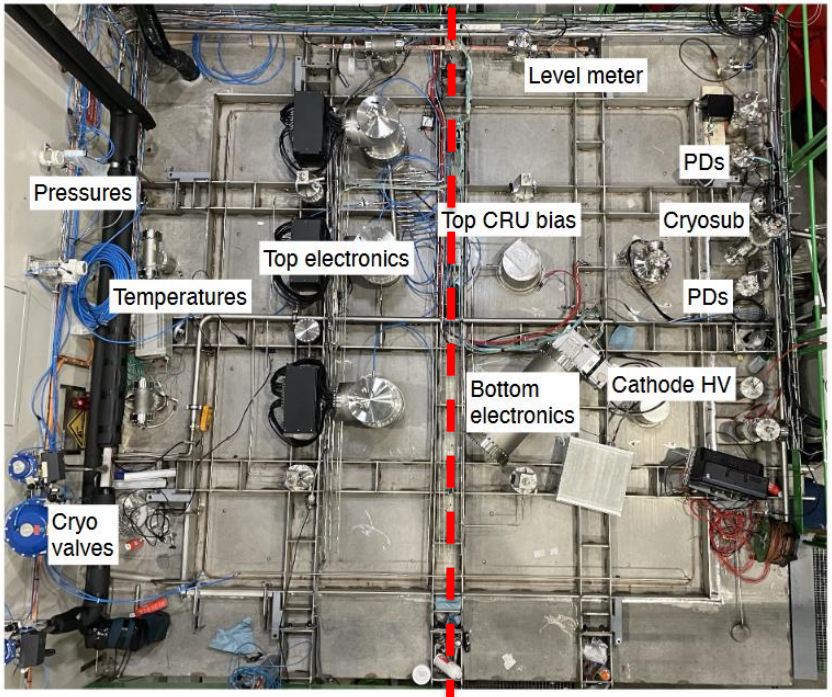
- **The analog cryogenic FE cards** accessible in the chimneys → **3840 units**
- **The AMC digitization cards** in the uTCA crates → **3840 units**

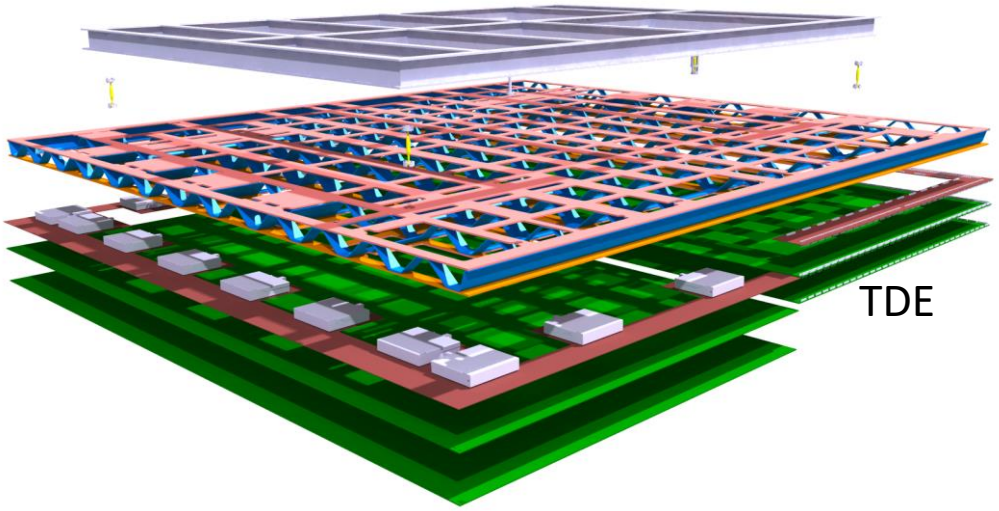
CRP for first cold-box test shared by the TDE and BDE



Jura side

TDE BDE



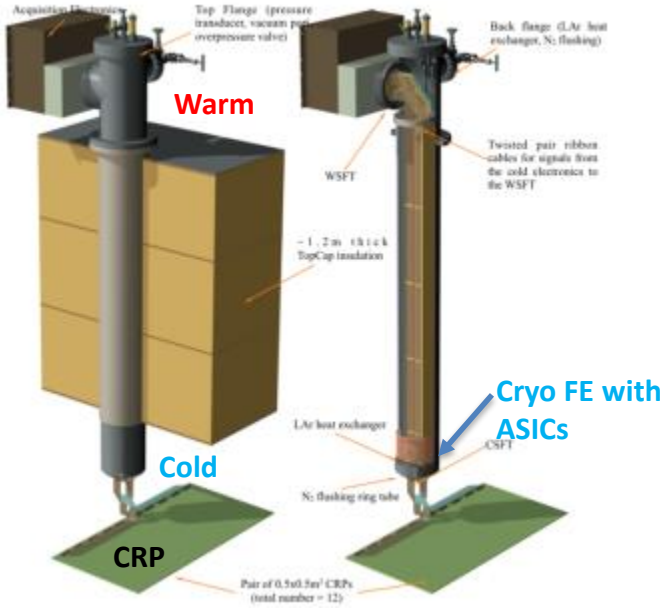


Saleve side

VD Cold-Box TDE activity

- **Top drift CRPs readout based on the completely accessible electronics:**

➢ **Cryogenic ASICs and Front-End cards at the bottom of the chimneys**
➢ **AMC digitization cards + uTCA systems**
➢ **Timing distribution system**



- **TDE (DP) electronics successfully operating on 3x1x1 and on NP02/protoDUNE dual-phase, developed at IP2I with the R&D carried on since 2006. More details in Vertical Drift CDR**

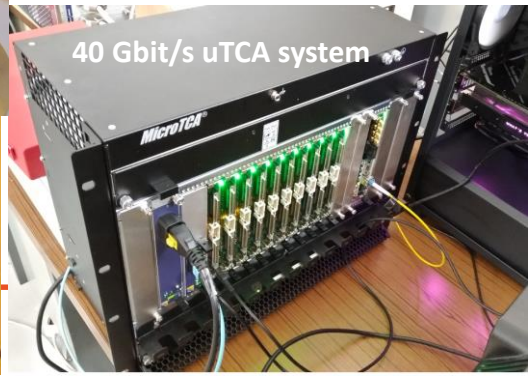
- **Adaptations and developments performed in 2021 from DP version for the Vertical Drift:**
➢ **New FE cards with decoupling components for Vertical Drift anodes**
➢ **Modification of digitization cards dynamics for bipolar signals of Vertical Drift induction views**
➢ **Development of 40 Gbit/s uTCA connectivity and associated DAQ.**

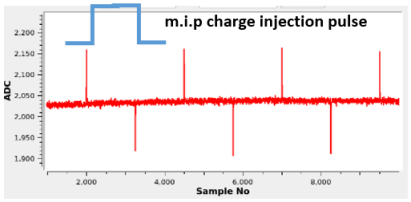
- **Needed to preserve integrity and operation of NP02/protoDUNE-DP for HV test:**
→ **New system completely independent on NP02 readout electronics, DAQ and ancillary systems**
→ **New productions and duplication of several sub-systems**
→ **Sharing of some infrastructure of NP02 DAQ back-end/storage**

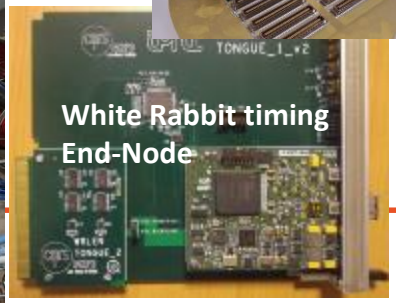
Components for the cold-box test of top-drift procured with new productions in spring 2021

→ Large efforts for production and completion of extensive tests before bringing materials to CERN by the beginning of the summer 2021.

- New ASICs production
- New front-end cards production
- Modifications to digitization cards and validation
- Production of new timing cards and new timing distribution network dedicated for cold-box
- New MCHs in uTCA crates at 40 Gbit/s developed with NAT and associated infrastructure
- New low voltage generation and distribution system independent on NP02
- New calibration system also usable for FD2
- Setting up new DAQ/network system for cold-box
- Production of new cold/warm flanges and tests
- Production of VHDCI cabling + inner chimneys cabling
- Dedicated production of 5 mini-chimneys for the cold-box tests

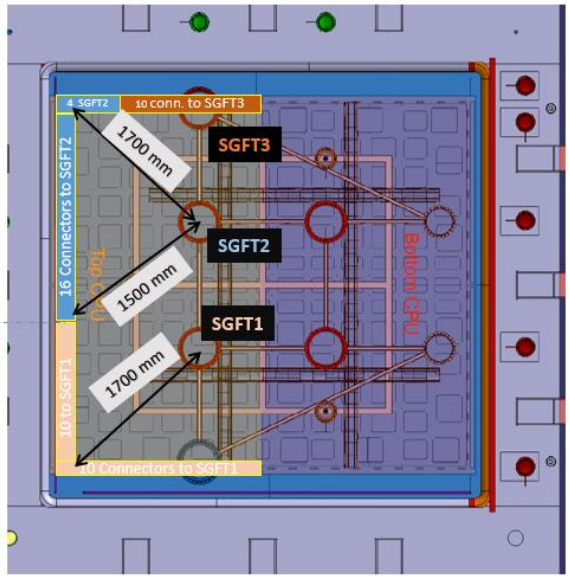


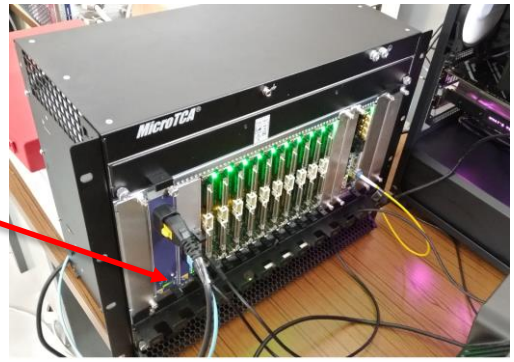




uTCA crates with MCH design with 40 Gbit connectivity

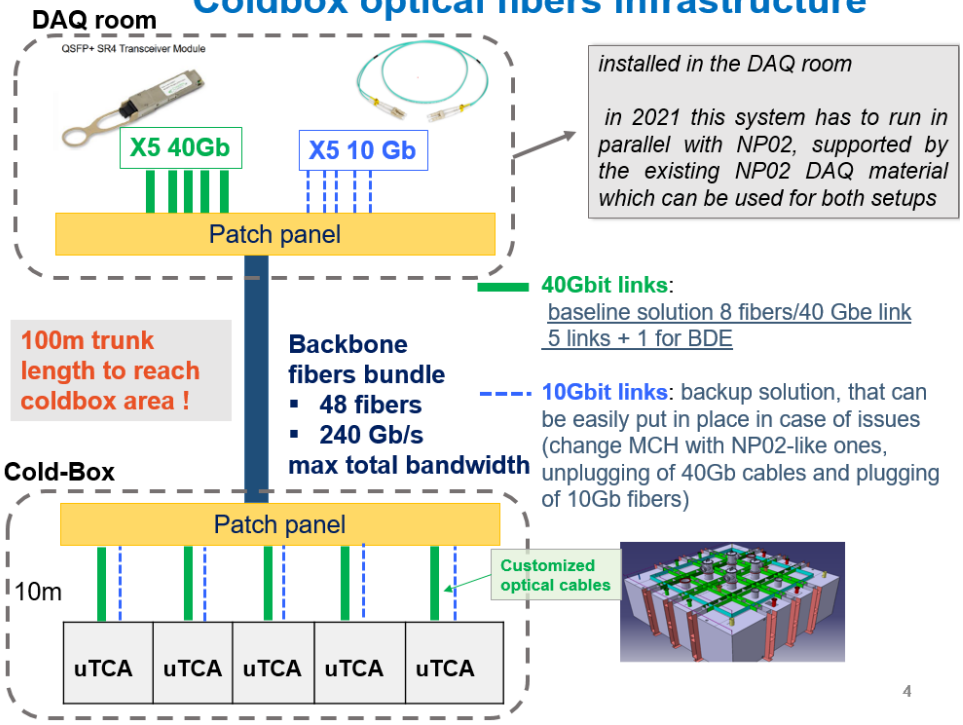
- ✓ Joint definition of the project by the TDE team with NAT since 2018
- ✓ TDE first world users in April 2021 when initial units delivered
- ✓ Extensive tests and firmware debugging April-July 2021





- ✓ First large scale system installed in the world for the DUNE cold-box tests (3 crates for 2021 CRP test)
- ✓ Dedicated fiber network infrastructure (240 Gbit/s) deployed for cold-box to support 5 crates (full top-drift CRP test in 2022)

Coldbox optical fibers infrastructure



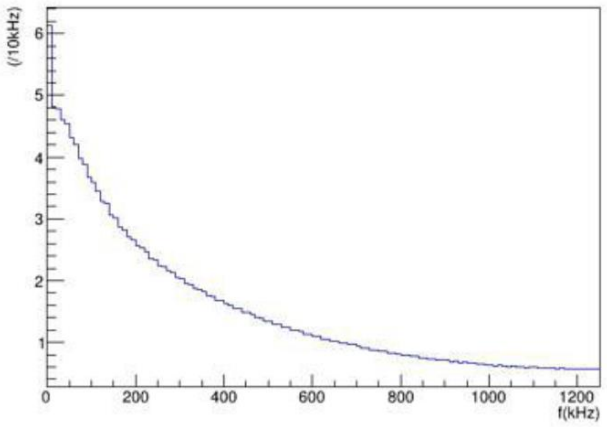
Integration test of electronics/chimneys/DAQ

- **Full integration test performed since July in a dedicated area at EHN1 for one chimney, including all elements produced for the cold-box (chimneys, low-voltage system, timing system, pulsing system, uTCA crates, DAQ, data fibers infrastructure)**

→ **Validation of all readout chain elements and noise in agreement with expectations**

- **Extension to three chimneys fully tested with DAQ in the integration setup: September-October**

- **All channels active and tested. Integration setup dismounted and needed material moved to Cold-Box area on 28/10**



EHN1 TDE Integration Test Area

FFT noise spectrum:

- **Good noise conditions at warm (2.5 ADC rms) despite temporary setup not connected to cryostat ground but to EHN1 building ground**
- **Very little coherent noise contamination present**

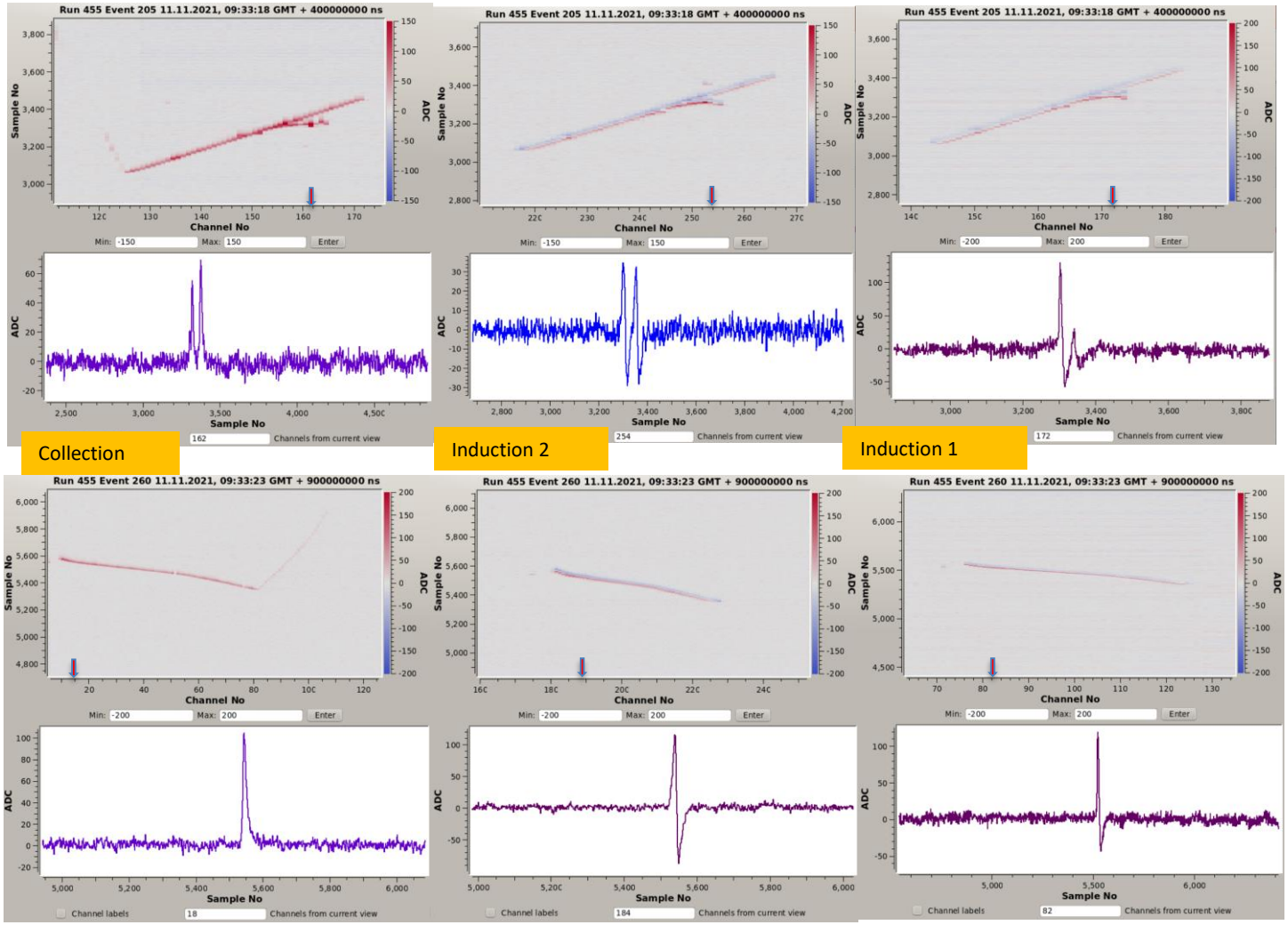
Cold-box roof integration

After closure of the cold-box roof, on 28/10 the full TDE system was moved from the integration area and remounted and re-cabled from scratch on the cold-box roof (3 crane pallets):

- Insertion of blades with the cryo-FE cards in the chimneys
- Installation and cabling of uTCA crates
- Installation and cabling of LV distribution/calibration systems
- Optical fibers connectivity to network and timing

→ The complete system was installed from scratch and became fully operational and taking data in just a few hours without issues (good example also for FD2 installation)

First data with TDE: Raw data online event display, no noise removal



Vertical drift CRPs in 2022

After the successful completion of the first tests in 2021, the cold-box testing campaign for the Vertical Drift CRPs will continue in 2022

4 more CRPs will be built and tested in 2022

- CRP2:
  Assembly in April-May. Test in the coldbox at the end of May
- CRP3:
  Assembly in Aug-Sep. Test in the coldbox in Oct.
- CRP4:
  anode and composite structure will be sent to US in September; assembly in Oct in US, ship to CERN beginning of Nov. Test in the coldbox in December
- CRP5:
  Assembly in Nov in US, ship to CERN in Dec.

TDE
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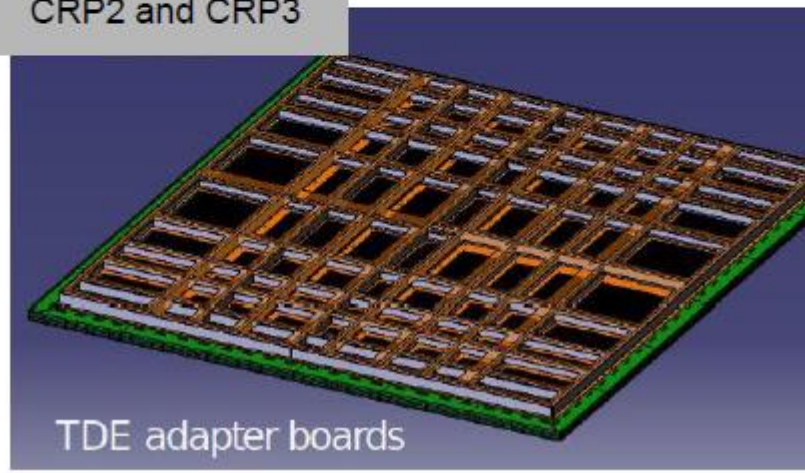
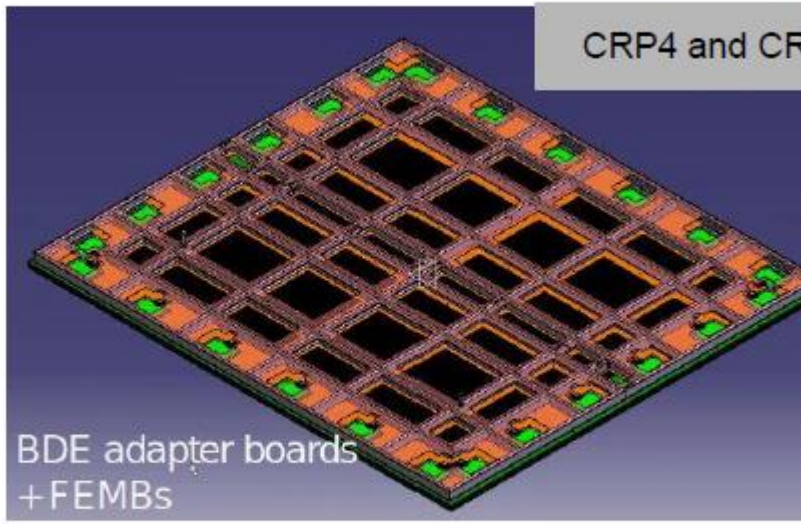
CRP2 and CRP3



CRP4 and CR



Module-0 for vertical drift

Before entering to the production phase for the DUNE far detector, the last full integration test, so called Module-0, on the basis of the final design of the detector components will be performed in NP02 cryostat in 2023

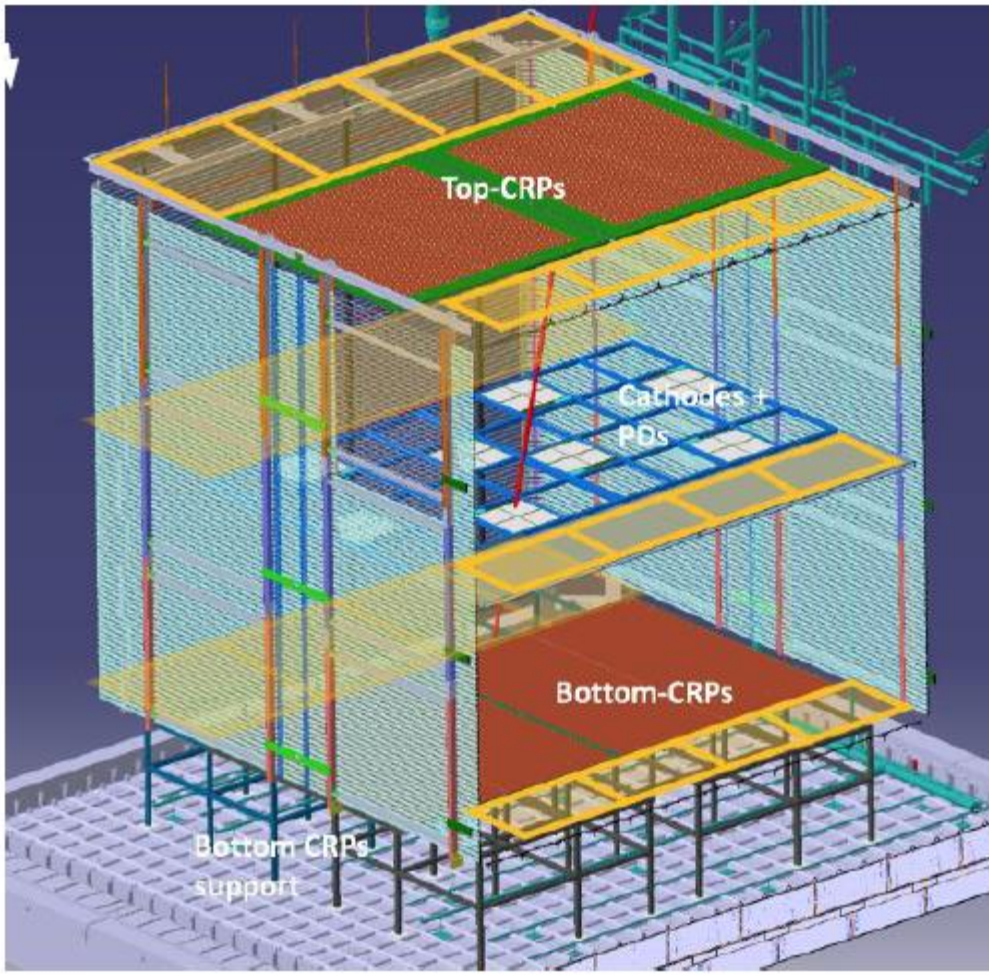
Detector configuration:

- Two top and two bottom CRPs
- Cathode in the middle at 300kV
- Photon detectors on the crystat wall and on cathode
- 70% transparent field cage on one side for the photon detectors
- 3m drift on both sides of the cathode

Schedule:

- Currently emptying the NP02 cryostat
- Starting September 2022, dismounting dual phase detector
- Module-0 installation from end of 2022 to first quarter of 2023

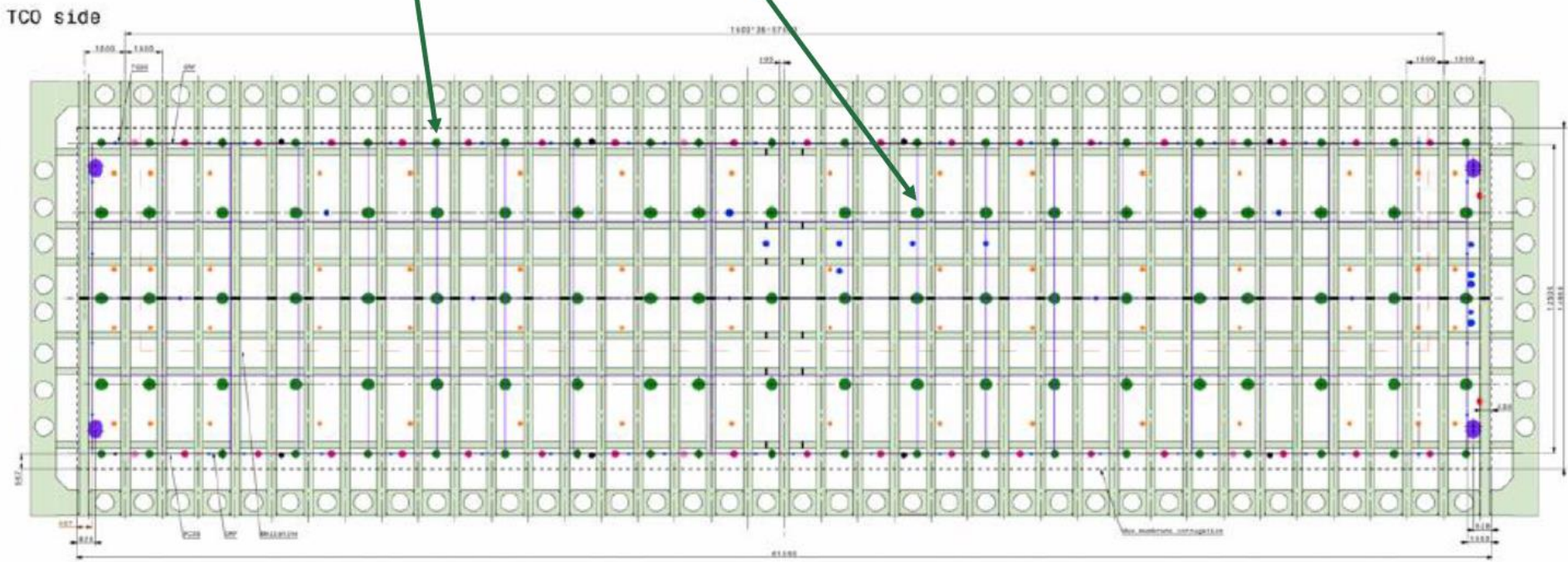
After filling, from July high intensity hadron beam at 100 GeV/c on the H2 beam line for up to total 4 weeks will be requested



Penetration Definition

Final conclusion : **2 types of chimneys** for global optimization of the CRP cabling

- **63** penetrations on the center **∅ 526 mm**
- **42** penetrations on the sides **∅ 381 mm**



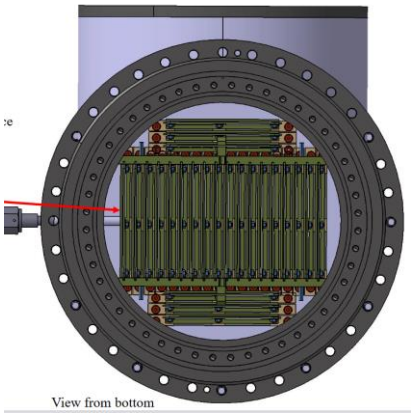
Chimneys:

- Chimneys design with smaller number of cards (5 cards for 3x1x1), 10 cards for NP02 and cold-box already successfully exploited

- CRP cabling scheme and chimneys penetrations layout already defined on FD2 cryostat

- Design for enlargement to 24/48 cards worked out at IJCLAB

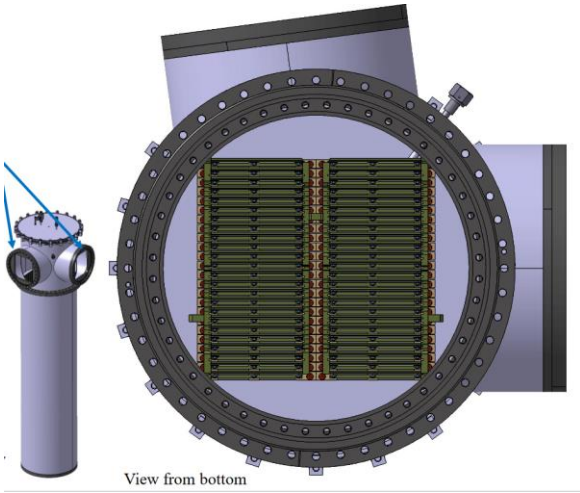
+ work in collaboration with I&I to define installation tooling



381 mm

- At the PDR we have to document the design (also with drawings on EDMS):
- Chimneys mechanical design for larger chimneys (include on EDMS also design of previous 10 cards chimneys)
- Thermal aspects
- Production
- Installation procedures/tooling
- Today update since January CM → discuss in the second part of the meeting what we can provide at the PDR in terms of drawings/status of design

- Parallel testing program to module-0 (NP02 cryostat roof has 10 cards chimneys)



526 mm

Examples of documents needed on EDMS for the TDE and installaiton PDRs

2.1 Chimney Installation interfaces

- TDE will provide the chimneys
- The hardware to connect the chimney to the cryostat flange will be provided by I&I. (drawings from Dimitar).
- TDE provides design details and drawings. Please include link to drawings. Assume plated steel nuts and bolts? Is a wire seal used? What part number or drawing number?
- I&I will provide leak testing equipment to test the chimney seal to the cryostat
- I&I will provide the gantry crane or other suitable hoisting device for the chimney installation.
    - The specification of the crane will be agreed upon with the TDE consortia.
        - Include specifications here. Load, handling, …
    - I&I provides drawings and models of the lifting equipment
- The TDE consortia will design and shepherd the approval process for any specific lifting features needed on the chimneys.
    - TDE provides drawings of the interface of the chimney to the lifting device.
    - The connection points and motion of the chimney will be agreed upon by both I&I and the TDE
- Drawings of the cryostat and chimney flanges showing the mated connection are part of this ICD
    - TDE drafts a set of interface drawings for review. Add link to As Installed Drawings.
    - This needs to show the side port locations and verify there are no cryostat conflicts.
- Drawings showing the chimney installation and interfaces to the surrounding equipment is part of this ICD
    - I&I will draft mechanical interfaces to the I&I equipment
- Drawings of the installed Chimney and the location on and inside the cryostat are part of this ICD.
    - These drawings should be provided by TDE. This is part oof the TDE-CRP interface but is included here for completeness.
- The installation plan is part of this ICD
    - I&I and TDE will work jointly on a detailed presentation for the installation. TDE will then draft a word version for the PDR review.
- The TDE is responsible for the draft installation procedures they should be linked to this ICD.
- Any chimney specific testing equipment is a TDE responsibility.
- TDE is responsible for the QC plan for the chimneys and this should be linked to this ICD here.

Documents in preparation (to be mave available on EDMS):

- Requirements (in common with BDE) + TDE specifications
- Synoptic and design documents for various electronics components, drawings for chimney mechanics
- Interface documents: DAQ/CRP (done) Installation (in progress)
- Updated risk register
- QA/QC and testing procedures document
- Production and installation plans/schedules and institutions
- Installation and integration layouts, interface drawings (several documents in common with Installation PDR)
- Installation procedures
- Tracking document (previous review)

Draft repartition of topics over the two PDR days:

Day 1:

Overview

Design reminders/descriptions:

- FE cards
- AMCs/uTCA system
- Timing
- LV distribution/calibration
- Chimneys

Interfaces

Previous experience in NP02 and 2021 Cold-box results

Day 2:

Continuation of CB/module 0 testing plans

Production plans

QA and testing procedures

General installation/integration aspects (grounding, LV distribution/power for uTCA/calibration/timing/data fibers)

Chimneys installation

Electronics installation procedures/commissioning and schedule