# Analog electronics, LV distribution

D. Autiero

IP2I Lyon

Top-Electronics CDR Review

4/6/2021

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

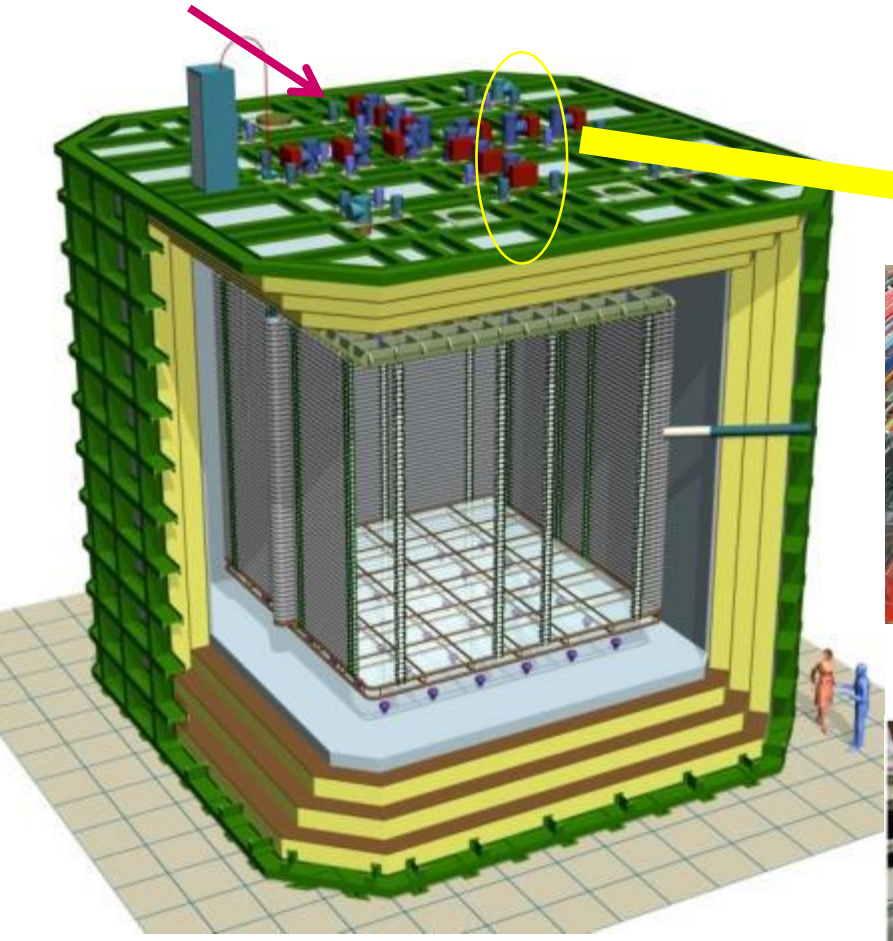
**Full accessibility provided by the dual-phase charge readout at the top of the detector**

- **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

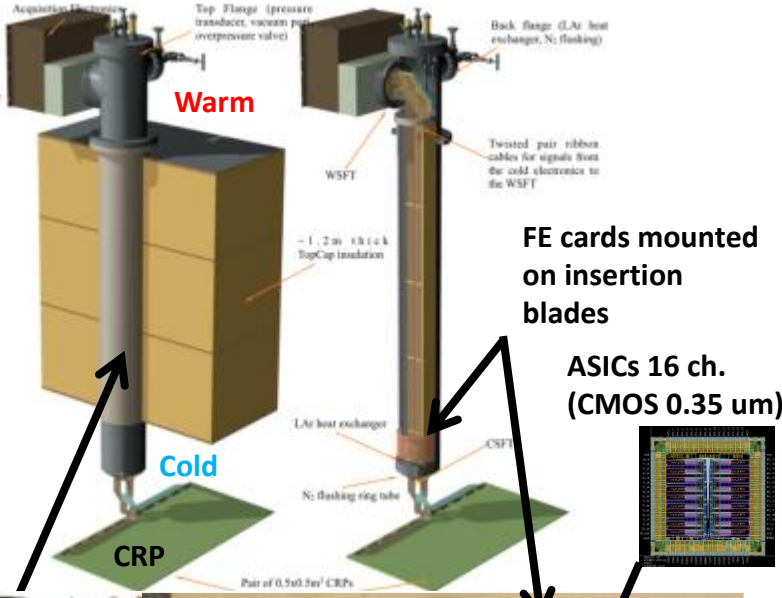
- **Cryogenic ASIC amplifiers (CMOS 0.35um) 16 ch externally accessible:**
  - Operating at 110K at the bottom of the signal chimneys
  - Cards fixed to a plug accessible from outside

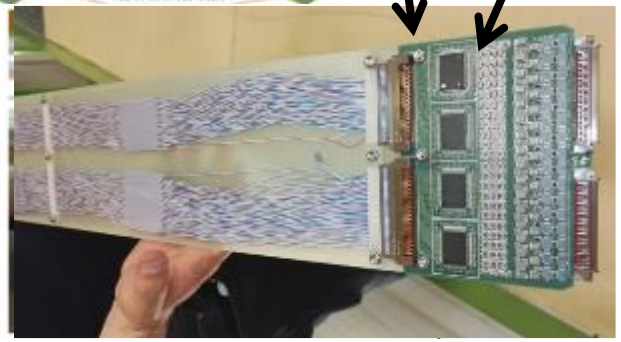
→Short cables capacitance, low noise at low T



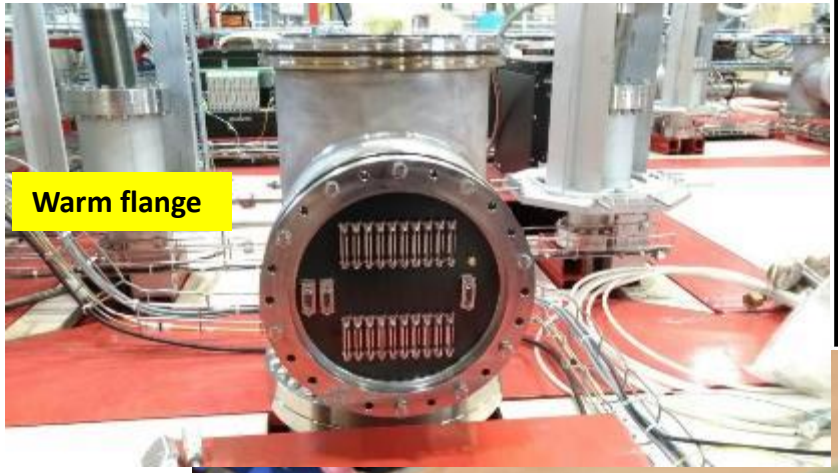
Signal chimney

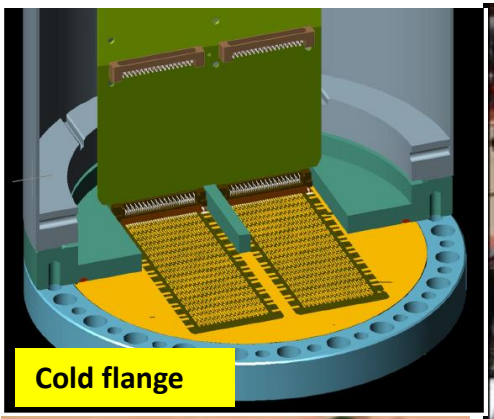

<50 cm



# ProtoDUNE-DP FE electronics



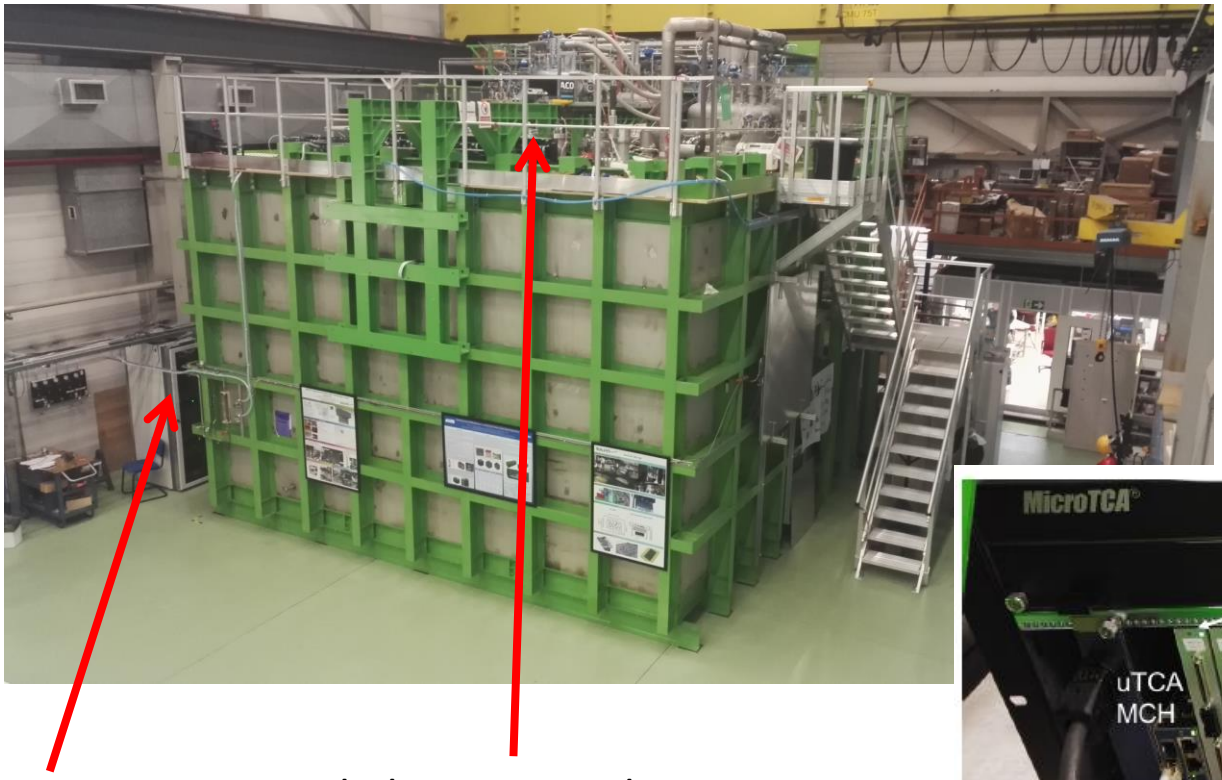


- **Signal feed-through chimneys** containing the cryogenic amplifier cards mounted on the extraction blades

- **Cryogenic amplifiers in the signal feedthrough chimneys accessible at any time** without interfering with the functioning of the rest of the detector. Simple intervention, routinely exploited during NP02 operation

  **(see also movie at: https://drive.google.com/file/d/16f2ADi4x-CpcNQltQHwR8ZUdAB4VtB1h/view )**

- **R&D on analog and digital charge readout electronics pursued since 2006 aimed at building a large system at low costs**
- **First large scale application in 2016 3x1x1 detector : 4 chimneys/uTCA crates (20 AMCs, 1280 readout channels), smaller chimneys 5 FE cards instead than 10 FE cards for protoDUNE-DP**
- **ProtoDUNE dual-phase: 12 chimneys/uTCA crates (120 AMCs, 7680 readout channels)**

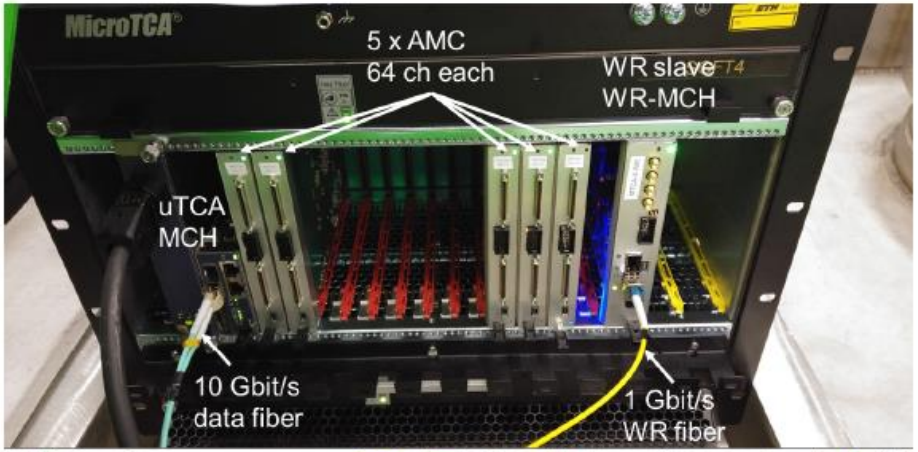


Signal Chimneys and uTCA crates

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

Electronics/DAQ system smoothly operational in the period November 2016-March 2018

3x1x1 paper on JINST:
https://arxiv.org/abs/1806.03317




# TOP drift electronics

- The **top drift electronics essentially unchanged with respect to the dual-phase design** documented in the TDR and deployed and validated in 3x1x1 and in ProtoDUNE-DP NP02.

- Foreseen to use for top drift: DP **analog FE cards with the same cryogenic ASICS**, plugged at the bottom of the **signal feedthrough chimneys** and the **digital FE electronics and associated timing distribution system located in the uTCA crates** on the cryostat roof.

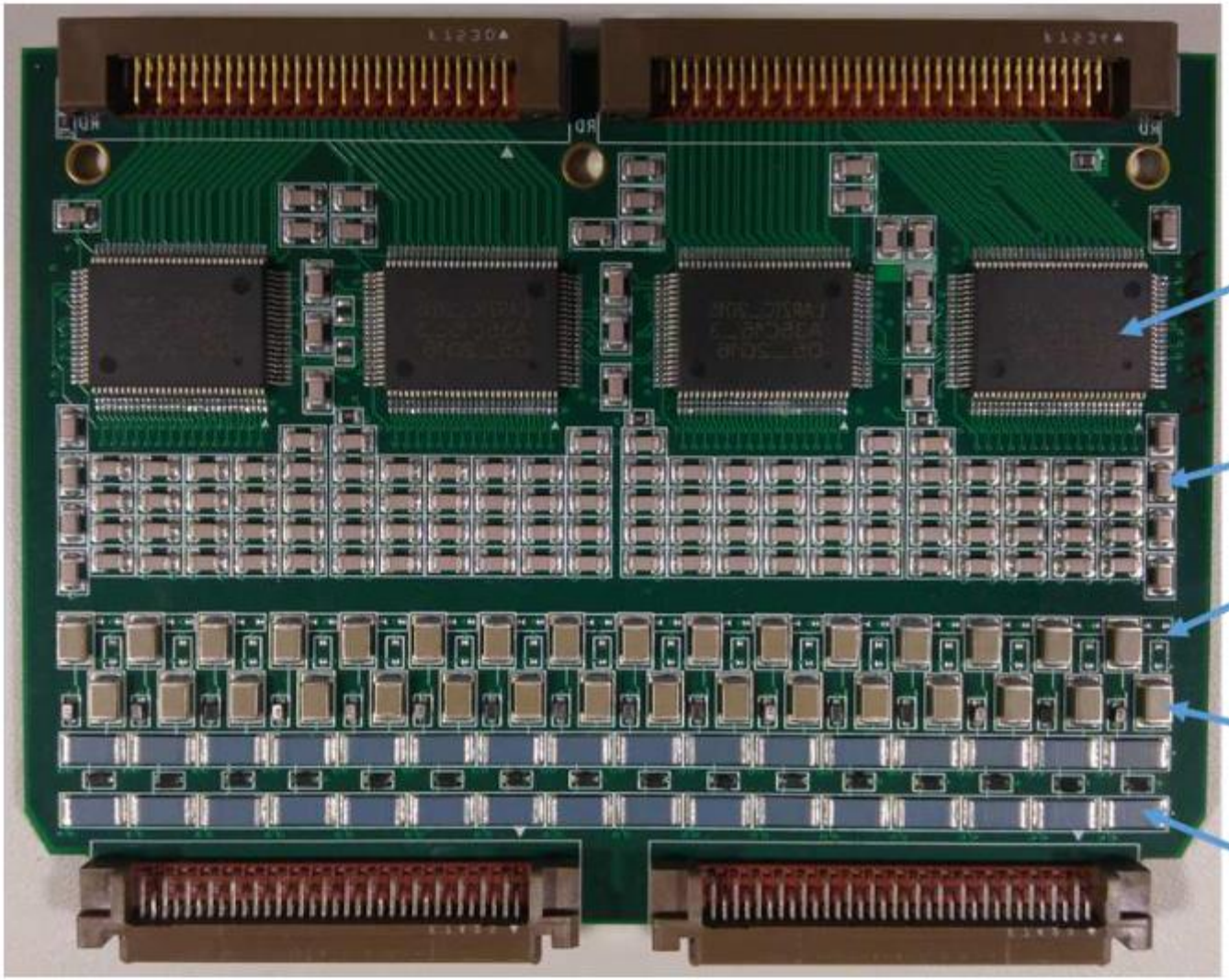
From VD proposal document:

TABLE I. Top drift charge readout electronics: units counts

| Quantity | 2-view Configuration | 3-view Configuration |
|---|---|---|
| 1.5m x 1.7m CRU in the top drift | 320 | 320 |
| Anode channels per CRP | 2432 | 3200 |
| Channels per FE card or AMC card | 64 | 64 |
| FE cards or AMC cards per CRP | 38 | 50 |
| Number of SFT | 105 | 105 |
| FE card slots per SFT | 50 | 50 |
| Installed FE cards per SFT | 38 | 50 |
| uTCA crates | 320 | 400 |
| WR-MCH | 320 | 400 |
| 40 Gb/s data links | 320 | 400 |
| Anode channels in the top drift | 194,560 | 256,000 |

- **Minor interface aspects** worked out:
  - **Signal feedthrough chimneys** which are now larger and containing more cards (see next slide)
  - **Removal of some passive components on the cryogenic Front-End cards** (few resistors and decoupling capacitors) used to bias to ground potential the DP strips These components will be directly on the VD anodes, as part of the anode biasing system
  - **ADC dynamics adjusted to bipolar mode**

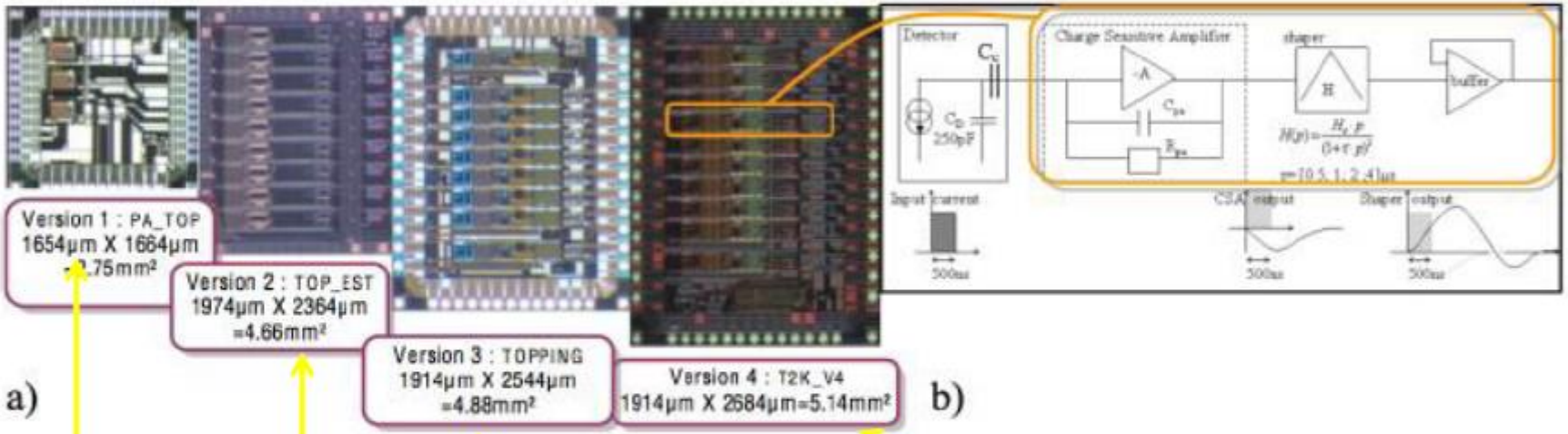
# Amplified signals to AMCs




Signals from anode via cold flange

Since 2006 6 versions of the analog ASIC (CMOS 0.35 um) at cold were developed for single-phase + 3 for dual-phase dynamics

2007 2008 2009 2010




Amplifier
+ test components

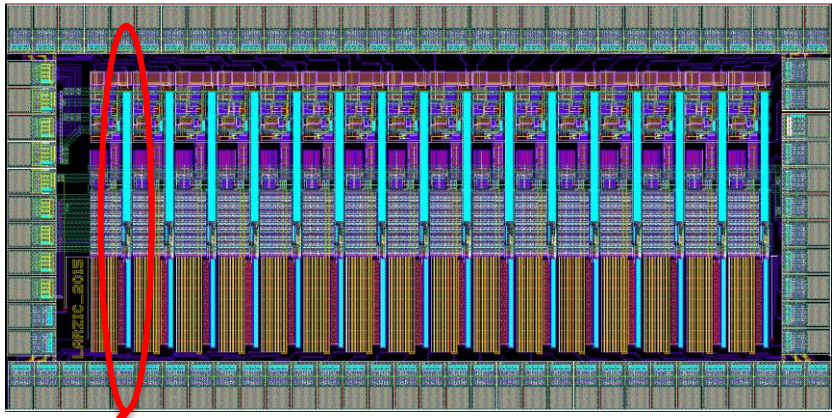
8 channels shaper + buffer, xtalk optimization

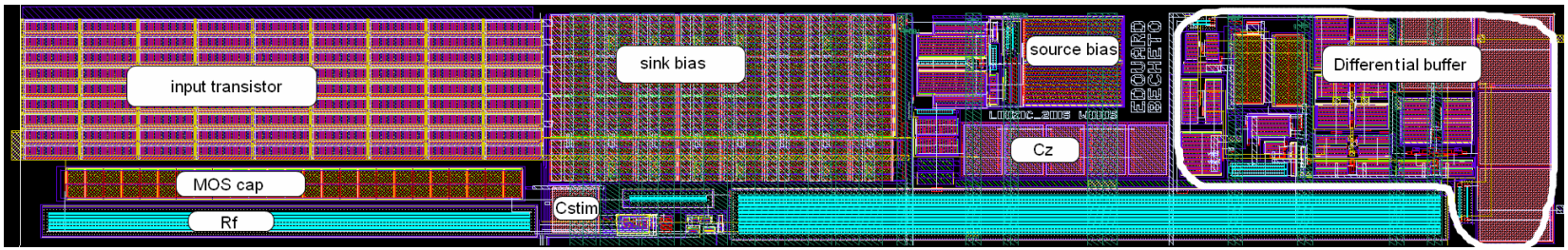
8 channels shaper + buffer, selectable configuration

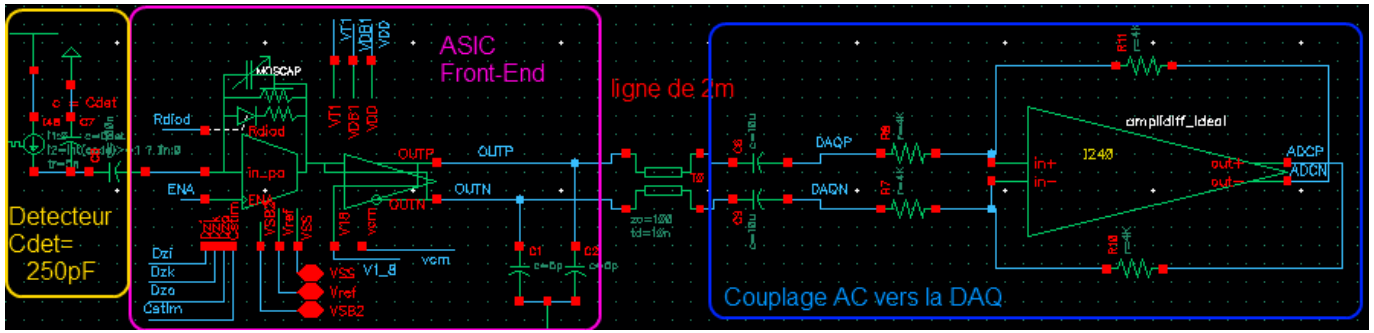
8 channels shaper + buffer
Phase margin optimization

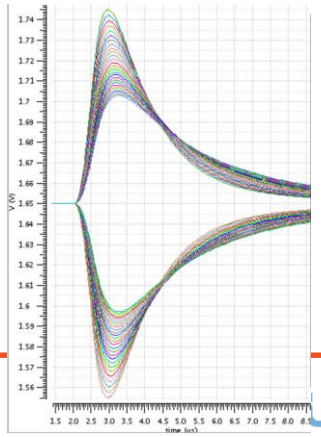
# LARZIC ASIC

- ASIC CMOS 0.35 um 16ch
- Charge Sensitive Amplifier + Differential Buffer
- Peaking time 1us
- Can operate in LN2, operation in chimneys at 110k
- Power consumption 11mW/ch
- Integrated charge injection system/capacitor
- Noise <400 electrons at cold (<600 electrons warm)
- 14 mV/fC conversion factor at cold (ASIC+ADC buffer)
- Supporting larger DP unipolar dynamics with large LEMs gain: linear 400 fC (max 1200 fC with dual slope )
- Bipolar linear dynamics +-200 fC
- Overall bipolar dynamics (including also ADC) ~+-80 fC



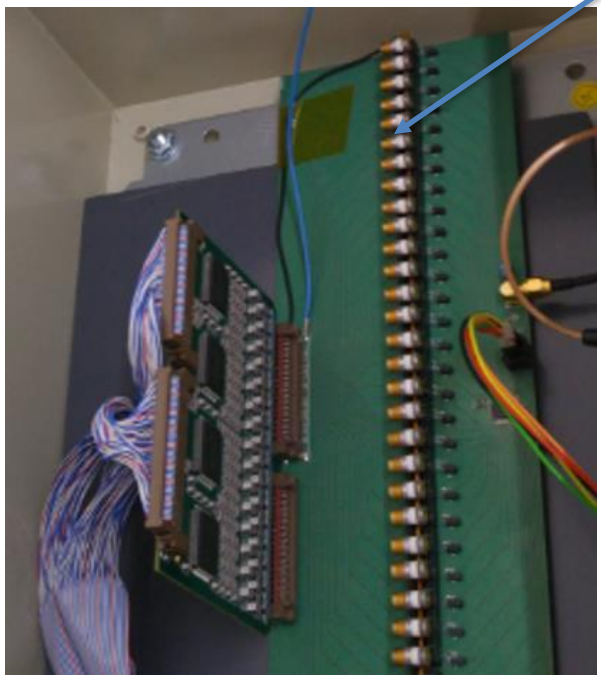


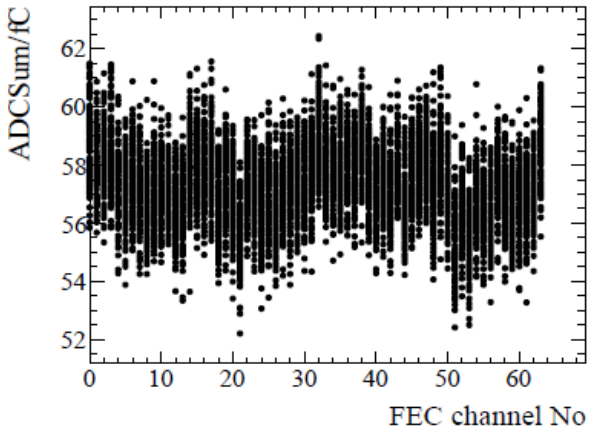
- 2016 production run for 700 chips
- 2020 production for additional 300 chips (equivalent characteristics to 2016)

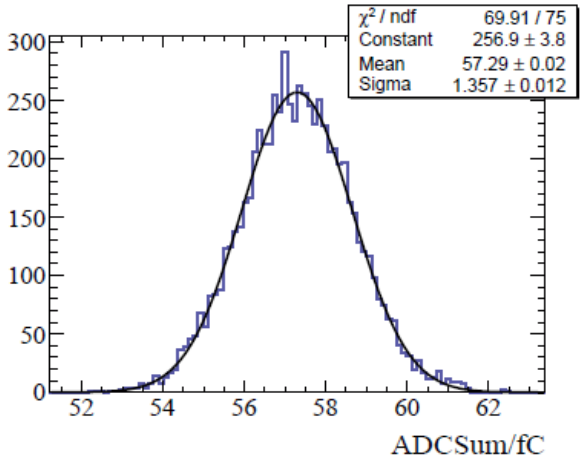
FE Cards calibration with dedicated charge injection system setup with individually mechanically trimmed and calibrated (QuadTech 7600) air varycaps at 1pF for 1% accuracy

Superimposed response patters for channels 1-64 of all cards of the production (see DP TDR 4.3.1 and QC presentation by Slavic)

→ <2% channels uniformity with some small syst. Variations related to the injection card itself

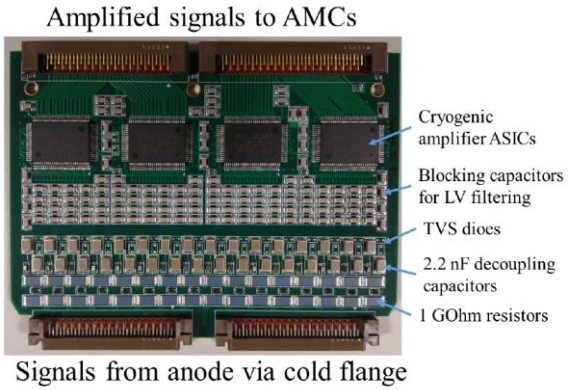


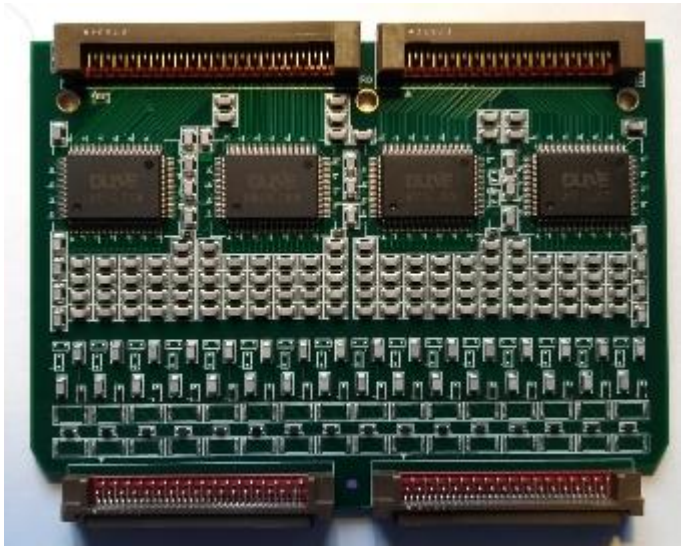
- **Cryogenic FE cards VD modifications (see also presentation by Elisabetta on CB preparation)**

Modifications : produce new cards in VD configuration with HV decoupling and biasing components not mounted (transferred to anode adapter boards).

70 new cards launched for production, **first batch of 27 new VD cards, covering 2021 cold-box tests, mounting ASIC batch produced in 2020, already delivered and underwent QC tests showing that the production is fine and the cards work well**



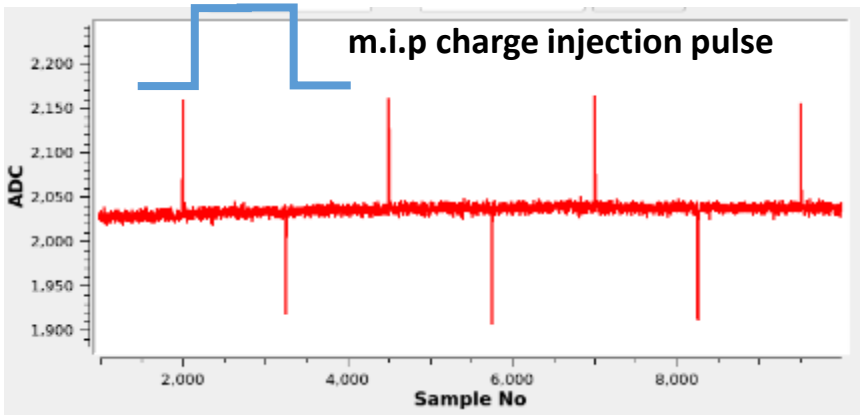

**Newly produced FE card in VD configuration →**



- **AMC digitization boards VD modifications (Slavic's presentation):**

needed ones for 2021 cold-box tests already available from NP02 spares, had ADC pedestals optimized for the unipolar signals dynamics

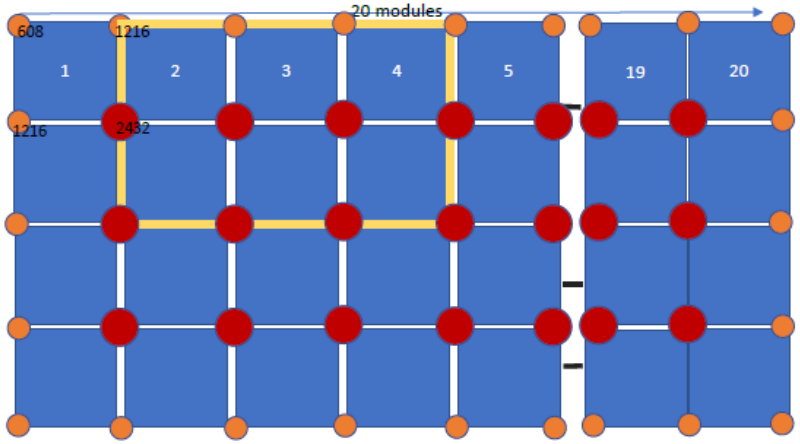
→ cards modified to **VD configuration** with a ADC reference voltage set to GND in order to match the dynamics of the bipolar signals. Well in progress and undergoing QC tests



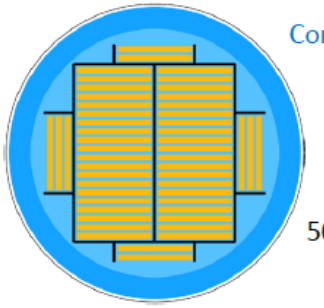
# TOP drift electronics: chimneys optimization

Upper Electronic Feedthroughs

Top chimney topology: connexion at each CRP corner




Total 105 feedthroughs
The peripherical one can be of smaller radius!



Connexion similar to DP CRP

50 cards can fit inside!

Pipe internal diameter : 48 cm

- Experience with the cryostat design has shown that **larger penetrations** are possible and desirable.

- Signal feedthrough chimneys **optimized by keeping the same design as in NP02** but by exploiting larger cryostat penetrations, each one capable of **containing up to 50 cards and serving 4 quarters** of different CRPs.

- **105 chimneys designed to accommodate a max number of cards corresponding to the 3 views readout**

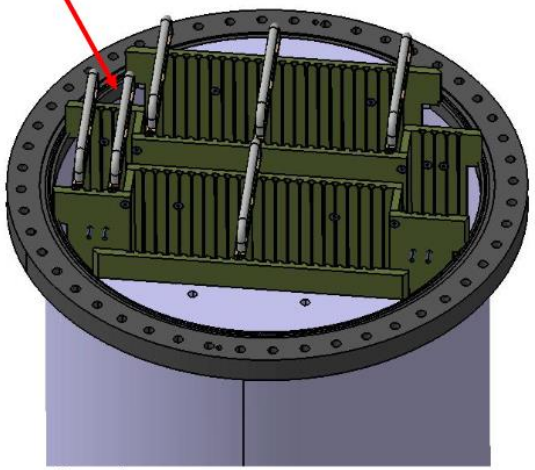
- **Cables from the CRPs to the feedthroughs may be slightly longer** with respect to what was done for the DP in between 1.5 and 2m instead of 1.5m for NP02.

- VD design activities showed the opportunity for a further optimization (still based on the same basic design) by increasing the diameter of the penetration for the pipes and hosting more cards

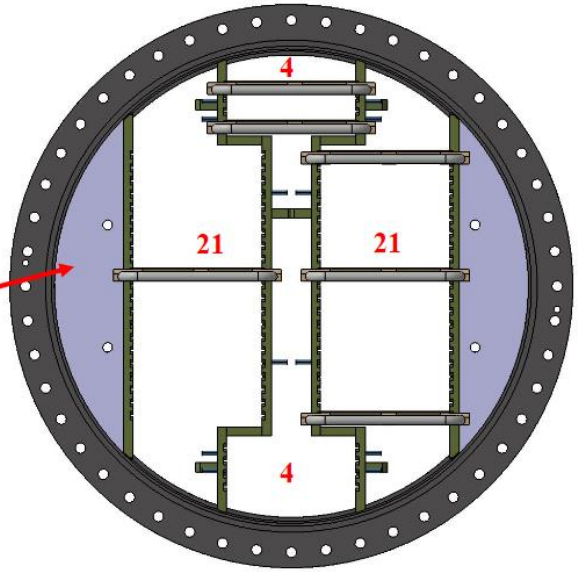
- Design of the 50 cards chimneys in progress at IJCLAB, no foreseen technical issues, aiming at prototyping in 2022

## Chimneys for Vertical Drift

- Penetration diameter **from 250 to 480 mm**
- Able to house up to **50 FE boards** instead of 10
- **105 chimneys** to be produced
- Positioning of 50 connectors on Cold flange is possible with associated guiding system
- PCB design to be done
- Heat dissipation to be simulated



Perspective View



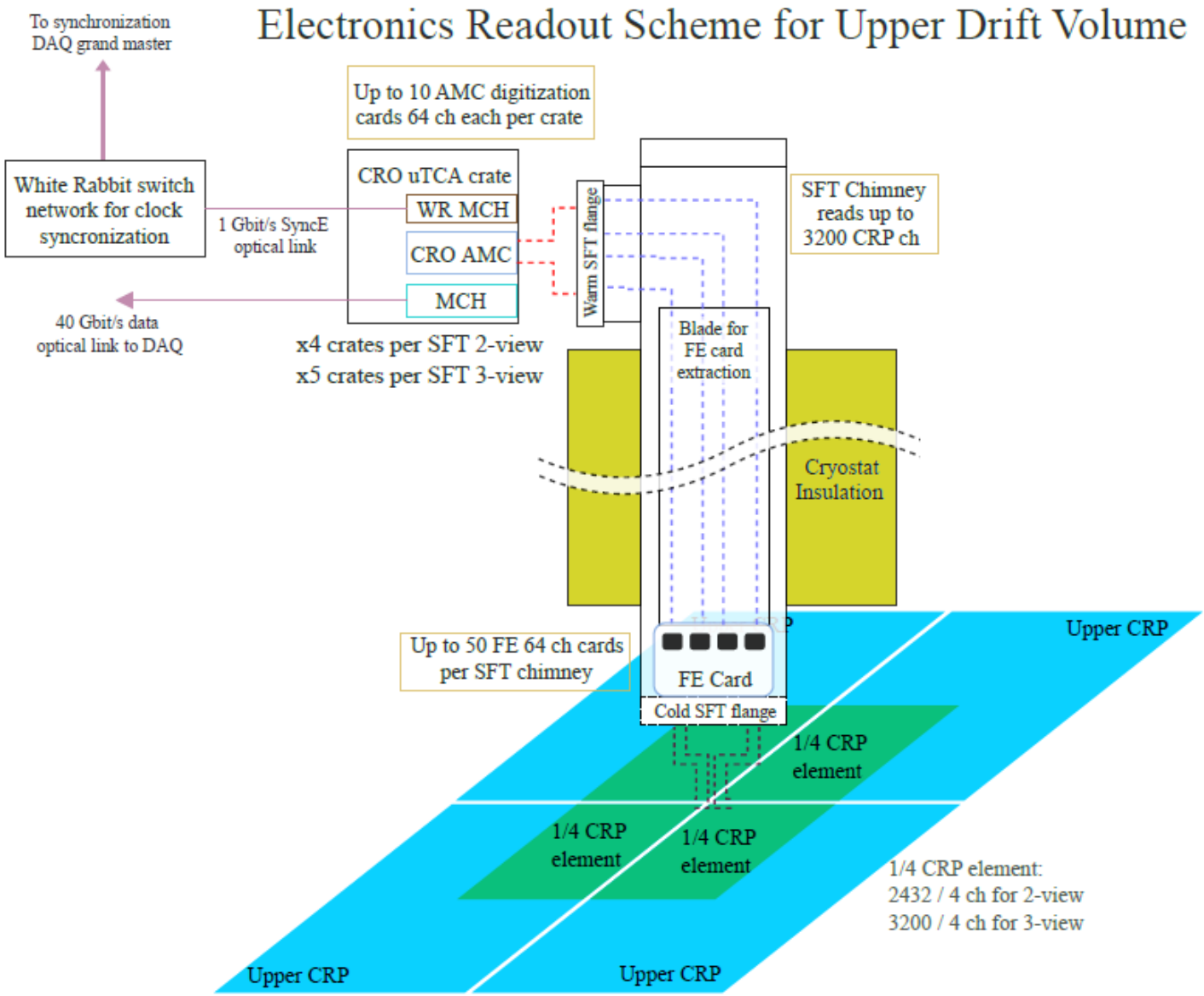

Top view

First design fitting 50 boards within defined penetration diameter



F. Cavalier
DUNE Collaboration Meeting
May 2021

# TOP drift readout: general layout

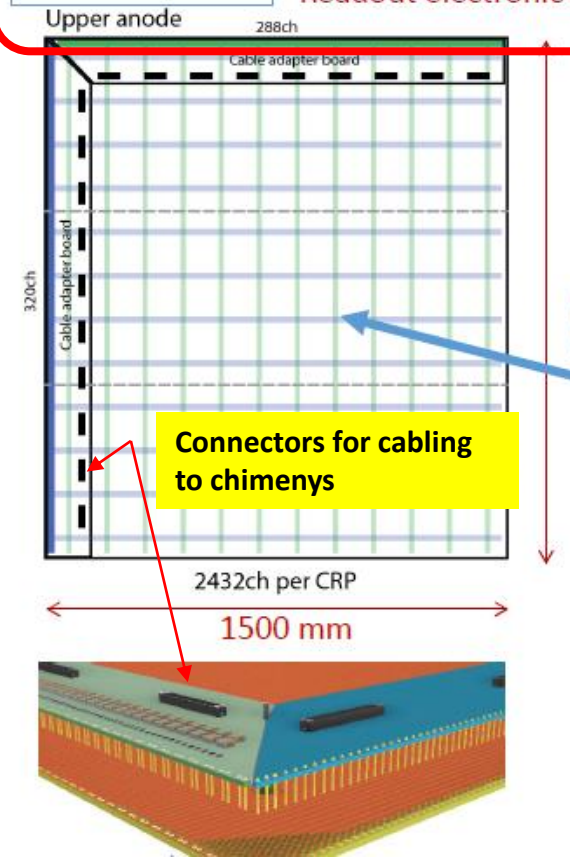


# TOP drift readout: anodes layout and connections for cabling

## Anode electronics and Adapter Boards

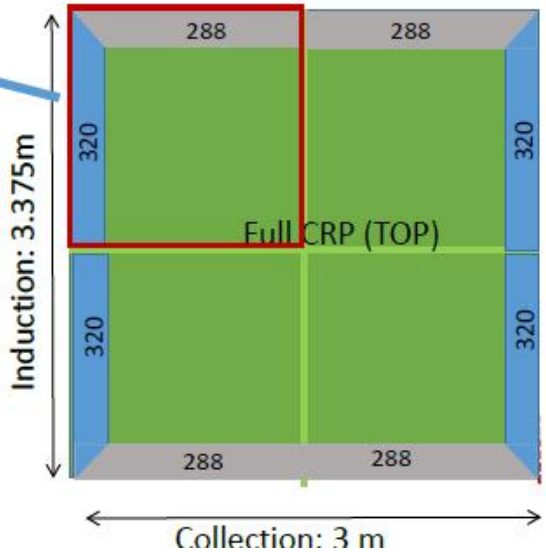
¼ of a CRP (TOP)

Readout electronic identical to Dual Phase



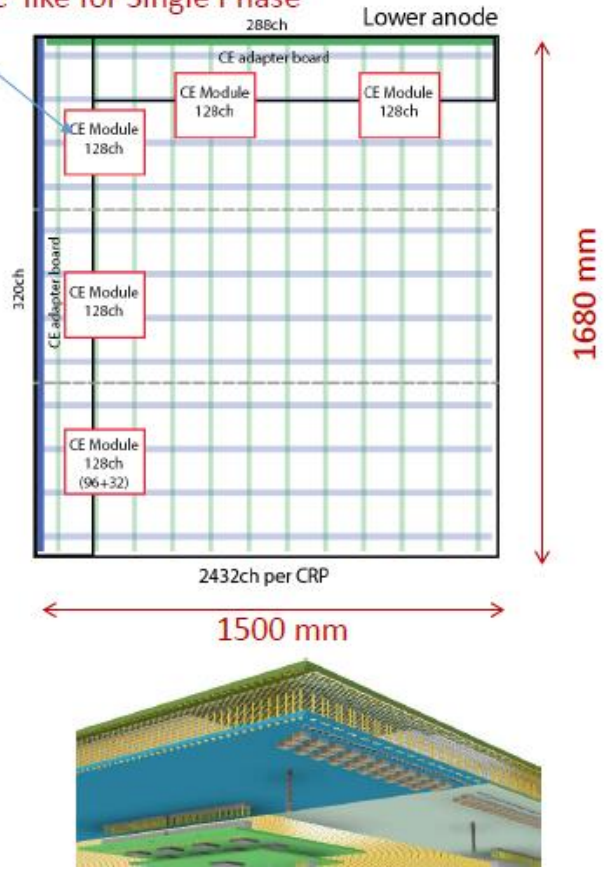

Connectors for cabling to chimenys






¼ of a CRP (Bottom)

Cold electronic like for Single Phase



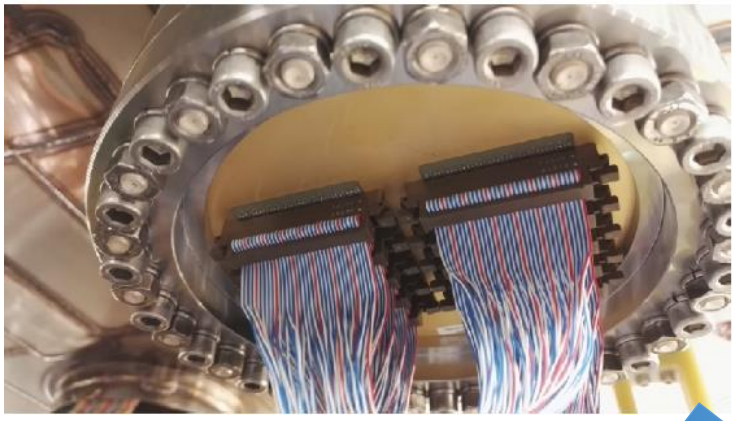
# TDE – TOP Drift CRPs interface

- The configuration is similar to the dual-phase design

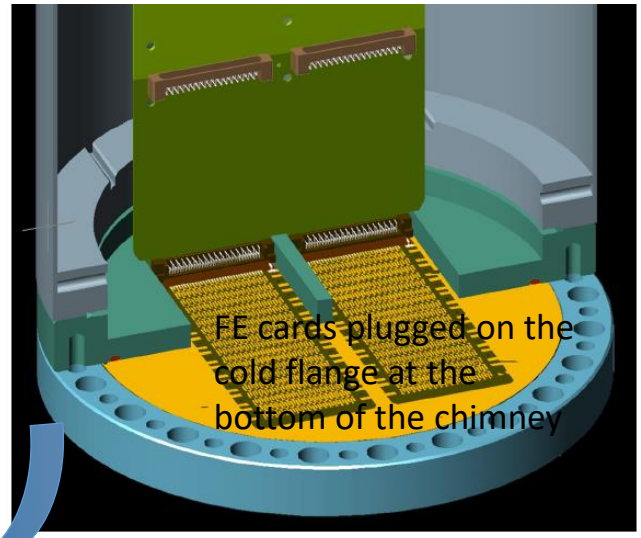
- Similarly as described in the dual-phase TDR the **interface between the electronics and the CRPs is defined at the level of the cold flanges**

TDE

CRP



Cold flange seen by the CRP




**Implications (CRP consortium):**

- **Cabling:** similar cabling with flat cables going from top drift CRP anodes to the cold flanges of the chimneys as for DP CRPs. This is integrated in the CRP installation activities which is also similar to DP It had an influence on the positioning of the KEL connectors at the CRP borders in order to guarantee accessibility to the chimneys and easiness of cabling
- **Adapter boards:** Adapter boards are very simple hosting just the flat cable connectors and the anode biasing and decoupling components. They have to:

1) Host the KEL connectors guaranteeing the correct mapping of the anodes and accessibility to chimneys via cabling, modularity of 32, views not mixed on the same KEL connector
2) Host the anode biasing and decoupling components, biasing should happen locally with AC decoupling to the electronics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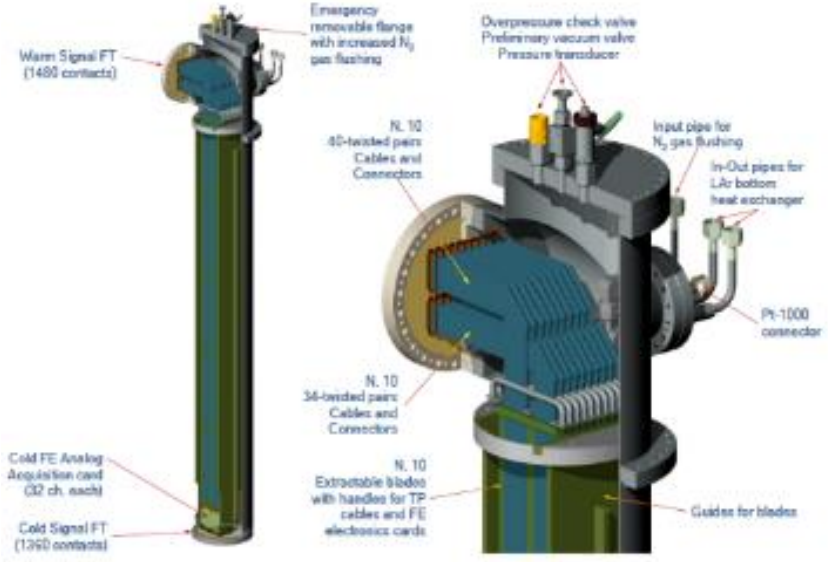
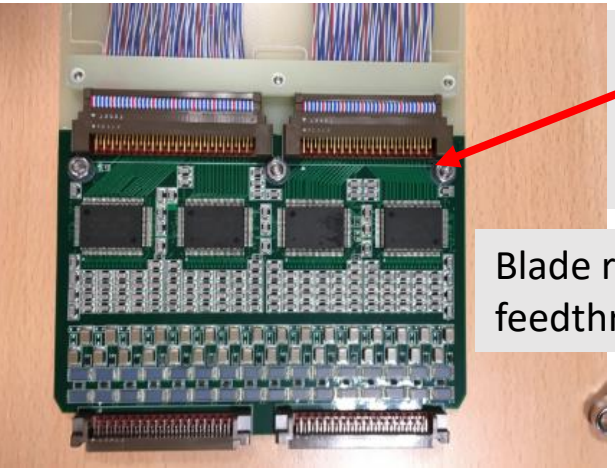
**Blades preparation and insertion in the chimneys (April 2019):**

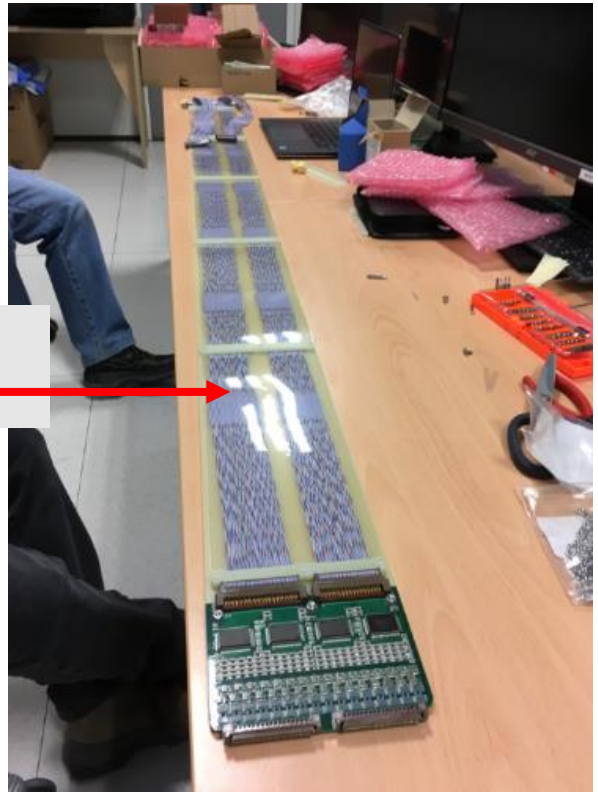
Insertion blades after assembly with flat cables, mylar protection foils and fixation mechanics



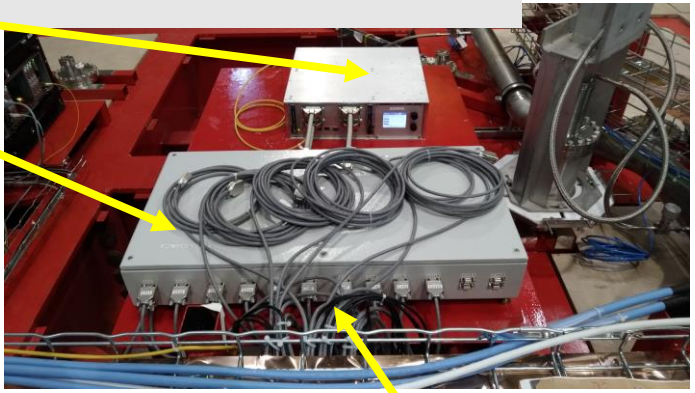
Assembly of the 64 channels cryogenic FE cards on the insertion blades and pre-insertion checks

Blade ready for its insertion in the signal feedthrough chimney



# Low voltage generation and distribution system

Low voltage power supply: Wiener MPOD Micro-2 LX 800 W with 2 modules MPV 4008I (remote control by network)



LV filtering and distribution box (5 voltages distributed per chimney + sense system)

Power supply:
generates VCC,VDD,V18,VREF,VTIN

4 shielded cables MPV Sub-D 37, 30 cm, for high currents

30 cm

Low voltage filtering and distribution box

Cabling to 10 chimneys

10 m

Multi-wire shielded cables connecting the 5 voltages, GND + sense to a FE units (Chimneys 1-6) (Chimneys 7-12)

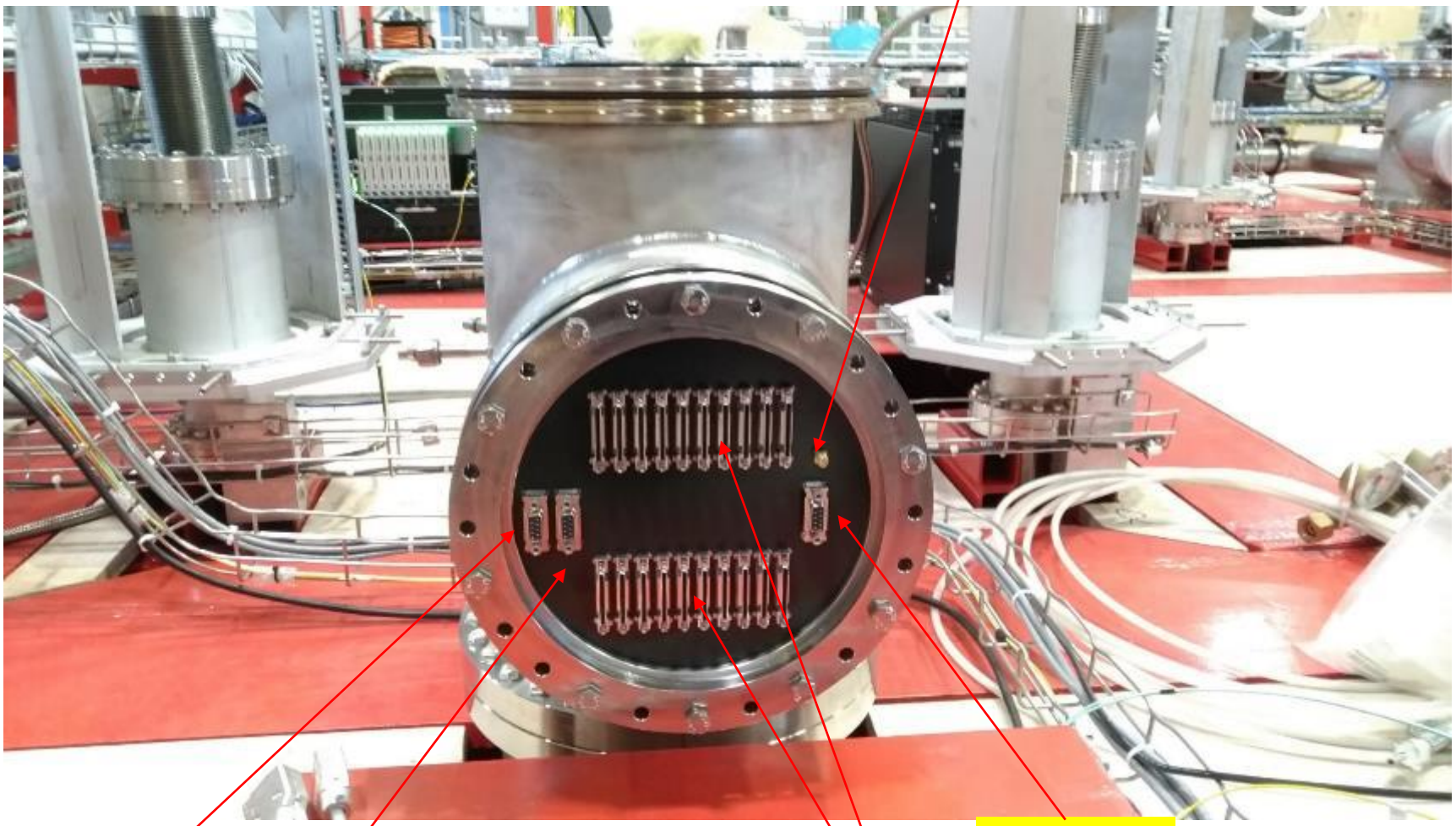
FE unit 1 | FE unit 2 | FE unit 3 | FE unit 4 | FE unit 1 | FE unit 2 | FE unit 3 | FE unit 4 | FE unit 1 | FE unit 2 | FE unit 3 | FE unit 4

Front-End Units (chimneys warm flanges) VHDCI cabling to uTCA

**Chimneys+ LV distribution system + cabling to uTCA and uTCA infrastructure**
- → **successful system for noise prevention**
- → **low intrinsic noise level of the electronics/DAQ system ~600 electrons**

Signal Feedthrough Chimney Warm Flange

Calibration



Controls

LV distribution, Sense

VHDCI signal cables to uTCA crates (shielded differential pairs)

- **Low voltage generation/distribution system:**

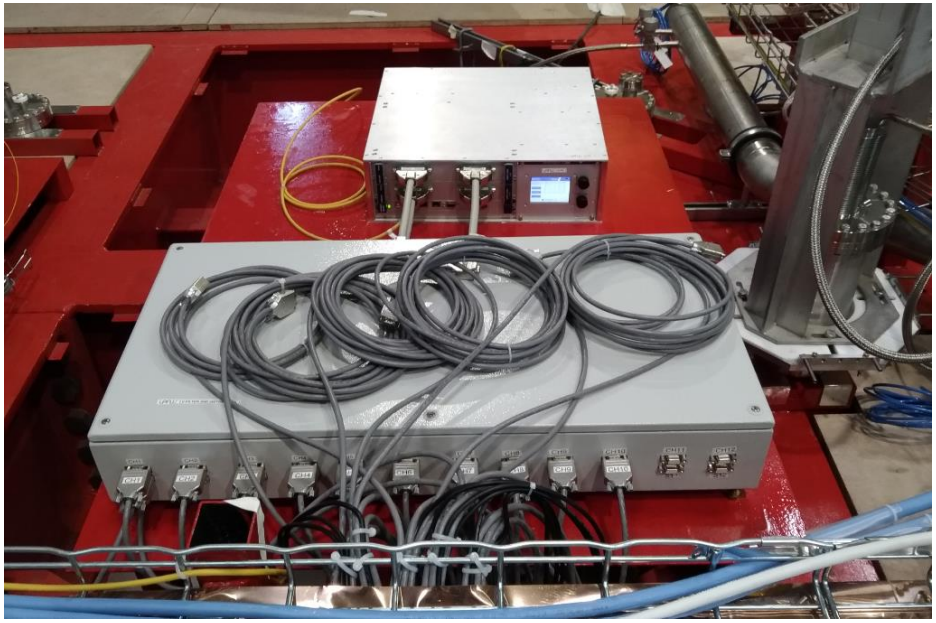
**System of NP02 serving 12 chimneys** (should stay untouched at NP02 for the HV extender test) **already completely cloned and fully tested**, at the moment **routinely in use for boards QC tests in Lyon.** Only 5 connections out of 12 really needed for CB test

**This implied:**

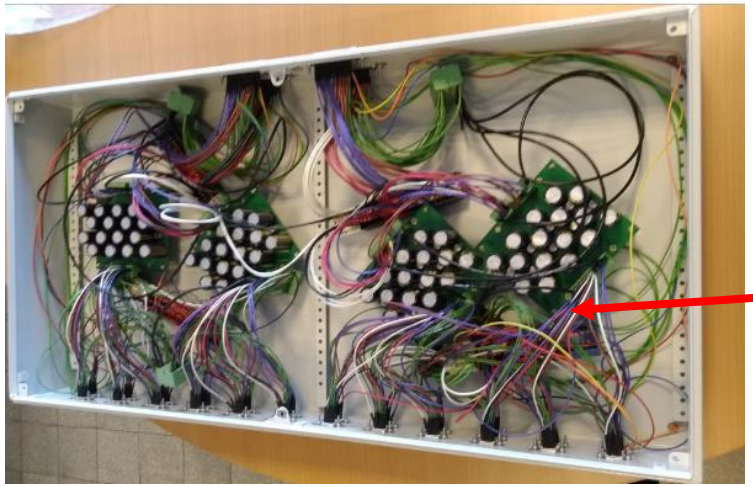
✓ procurement of a new Power Supply (Wiener MPOD Micro-2 LX 800 W + 2 modules MPV 4008I

✓ construction of a new filtering and distribution box → see next page

**NP02 LV PS and distribution system on NP02 cryostat roof**



**Undergoing design for integration of these systems Vertical Drift module roof. Filtration/distribution box in compact format integrated in the same rack as the Wiener PS**



LV Filtering and distribution box during construction

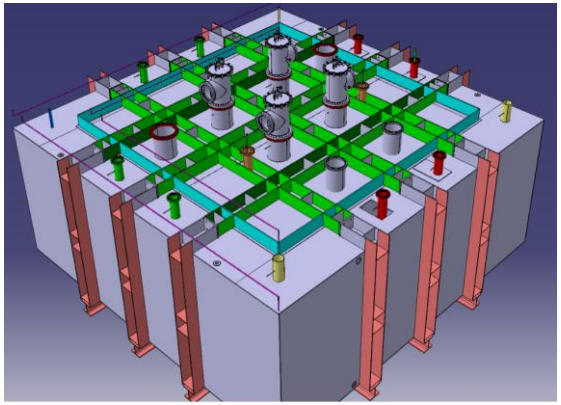
Filtering Boards (Each board serving a group of 3 chimneys)

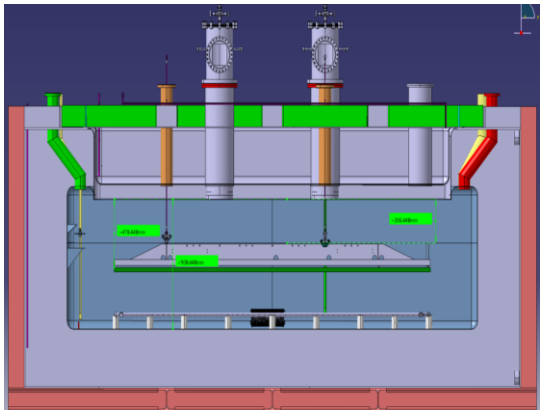
LV generation and distribution system routinely used in lab tests

PS Wiener MPOD Micro-2 LX 800 W
LV filtering and distribution box


# TDE Consortium 2021 test activities:

**Intensive activity foreseen to support and perform the top drift CRPs cold box tests (up to 50 FE cards) (see also VD proposal document)**





- **Given the layout of the cold box shorter versions of the 10 cards chimneys have been produced**

**List of TDE components (foreseen production of max quantities for full CRP top test in 2022 with 3 views)**
**Initial test in 2021 ½ CRP (CRP sharing among top and bottom drift electronics)**
**Max quantities for full top drift CRP**

- **Chimneys: 5**
- **Warm + Cold Flanges PCBs : 5+5**
- **Blades: 50**
- **Cryogenic FE Cards: 50**
- **uTCA digitization cards: 50**
- **uTCA crates: 5**
- **White Rabbit timing end nodes: 5**
- **Low voltage power supply + distribution system**
- **Associated Cabling etc …**

**Tests campaign:**

a) **Procurement and tests of additional material until June (practically completed)**
b) **Integration and preliminary tests June-August**
c) **Commissioning and operation + NP02 support September**

**→ Most of the material for 2021 CRP test is procured and being cross-checked and calibrated**

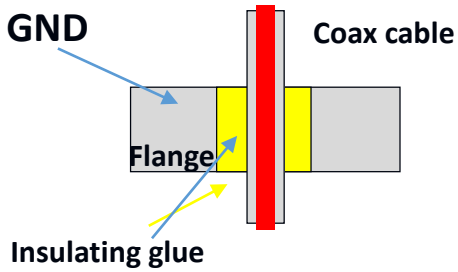
**+ Support to protoDUNE-DP electronics for the HV extender tests (this implies also keeping electronics alive, spares and maintenance)**

# General grounding aspects (valid for all flanges)

Basic prescriptions:

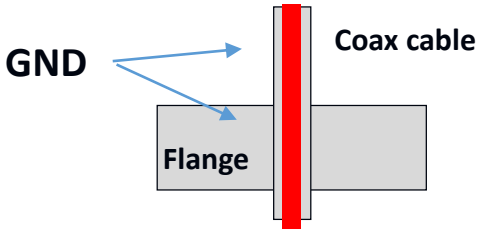
1) **Grounding of all equipments referred to cryostat**, decoupling, isolation transformer
2) Connections topology of cabling on cryostat roof to avoid ground loops
3) **Use for all connections shielded cables correctly grounded at the cryostat flanges**

→ The cryostat is a Faraday cage shielding the anode strips but if the shields of the cables are not well connected to the cryostat ground at the level of the flanges these cables will act as antennas and bring external noise inside the cryostat




NOT OK: Coax cable shield disconnected from flange GND

OK: Coax cable shield grounded to cryostat at the feedthrough flange via feedthrough connector



# Conclusions:

- **The top drift electronics for the vertical drift capitalizes on the dual-phase electronics design documented in the TDR and successfully deployed in NP02 at the 10k channels level. This is the outcome of a long R&D effort started in 2006. The main elements can be used with little modifications**

- **This scheme  preserves interesting features such as the complete external accessibility of the electronics (including the cryogenic amplifiers) guaranteeing risks minimization and perfect functioning over a very long lifetime span as well as the possibility of profiting of technological/economical evolutions**

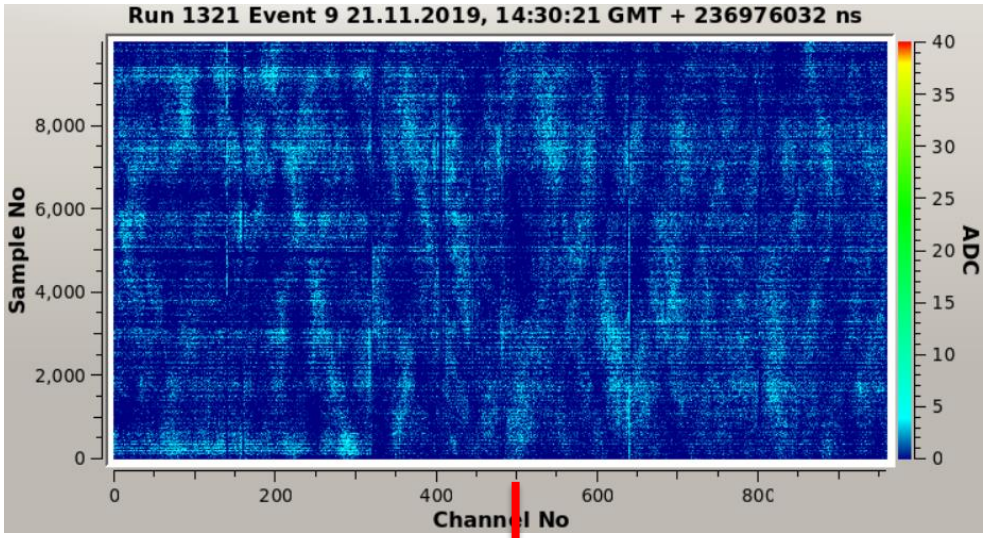
- **FE-end electronics already working in fully bipolar mode, modifications for bipolarity made at the level of the AMC cards to fully exploit the dynamic range (see Slavic's talk). Expected signals amplitudes and noise similar to bottom electronics.**

- **Modifications to FE cards for Vertical Drift version successfully performed and cards produced and tested for cold-box test. Undergoing now calibration tests (see Slavic's talk)**

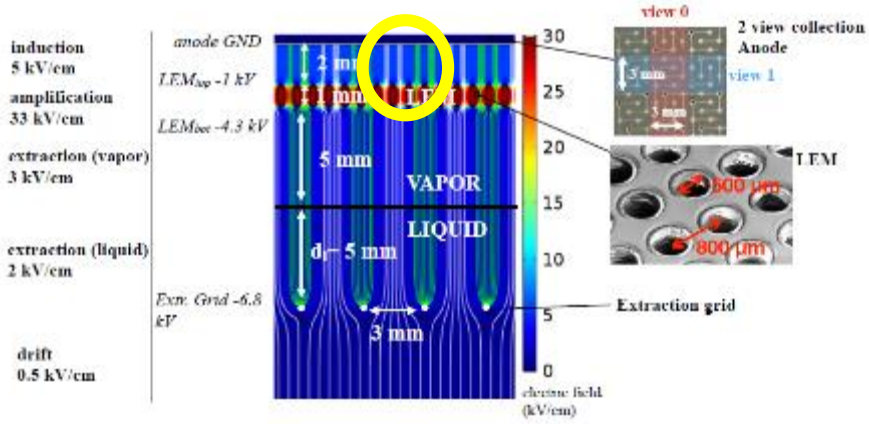
- **Low voltage distribution system (clone of the NP02 one) procured from scratch and rebuilt and tested**

# Induced signals from CRP microphonic effects

- The CRP stack grid+ 2 LEM faces is a set of capacitors.
- Capacitance variations related to changes in geometry (vibration, change in dielectrics related to waves on LAr surface) may induce tiny signals on the anodes → microphonic effects



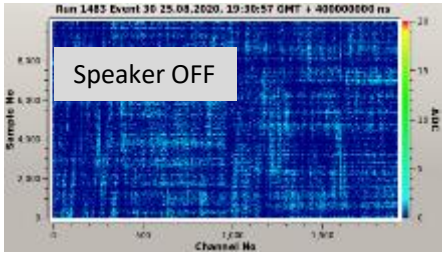

→ Tiny signals ~2-3 ADC counts are induced on anodes
→ The pattern of waves changes continuously from one event to the other
→ After an extensive campaign of investigation this microphonic effect has been localized in between the anodes and the top surface of the LEMs
→ The pattern of waves is switched on when the LEMs top are put at HV (default value 500V) and it is proportional to the HV applied



# Study of microphonic effects with acoustic excitation:

Acoustic excitation tests performed with a sinusoidal function generator and a woofer (160W) coupled to a spare cryostat penetration

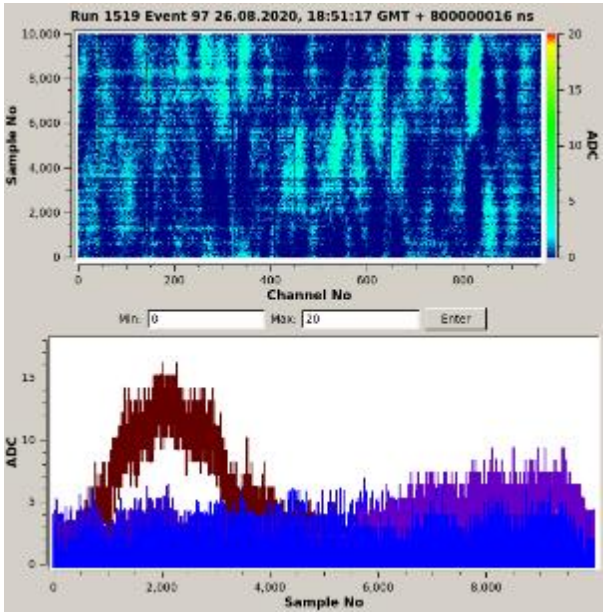
- Spectacular microphonic effects demonstrated in between 240-265 Hz
- No effects (speaker on/off) for frequencies below 200 Hz
- Stronger proximity effects on CRP1, close to the penetration pipe with a gate valve used to channel the sound in the cryostat (see pictures below for CRP1 and CRP2 in the same event taken at 250Hz)



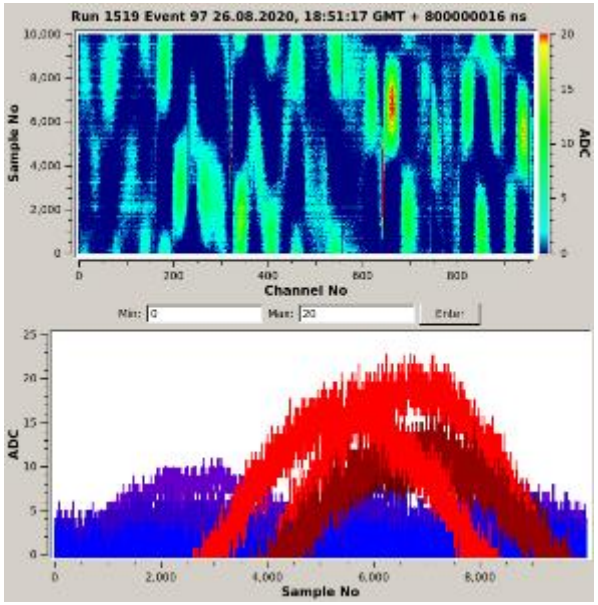

- Fine scan at 1Hz steps from 240-265 Hz performed to characterize resonances

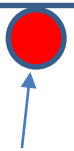
- Repetition of some measurements foreseen with the CPRs completely immersed in the liquid → stronger effects in liquid and widening of resonances

CRP2




CRP1



Sound injection pipe