Prototypes and demonstrators tests at CERN

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(CERN)

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Outlook

50 L tests, results and plans

First full scale CRP plan

Cold box status and plans

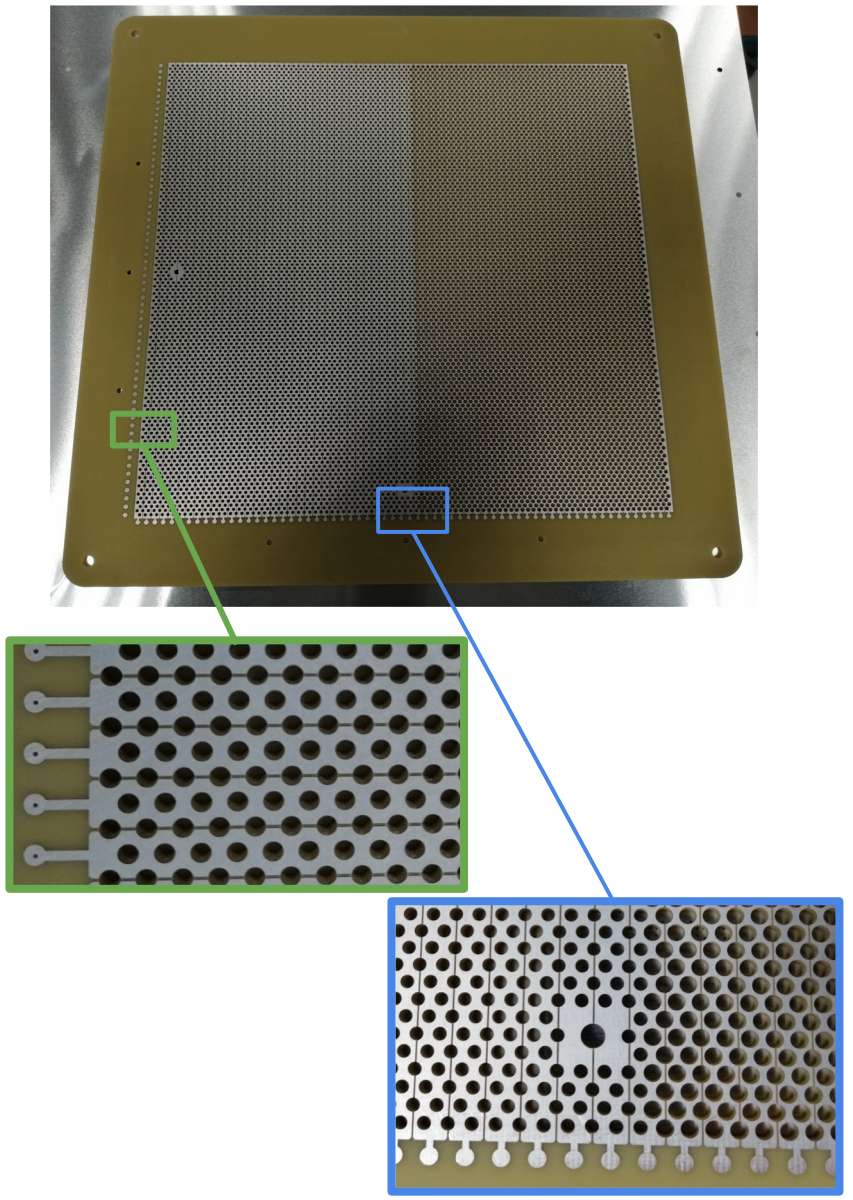
50 L

2-view PCB anode tests in 2020

- Proof of principle for the LArTPC with perforated PCB anode and integrated CEs

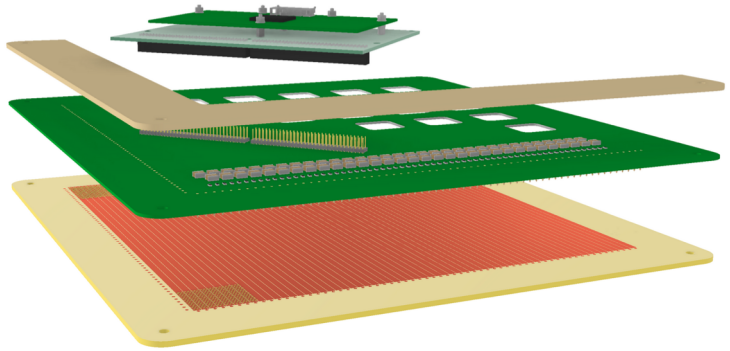
- 2-view perforated PCB
  - 64 induction and 64 collection channels orthogonal to each other on the two sides of the PCB
  - 32 cm x 32 cm active area
  - Two hole configuration: 2mm, 2.5mm diameters with 3.33mm pitch
  - Strip capacitance: ~40 pF (150-220 pF wires in LAr)

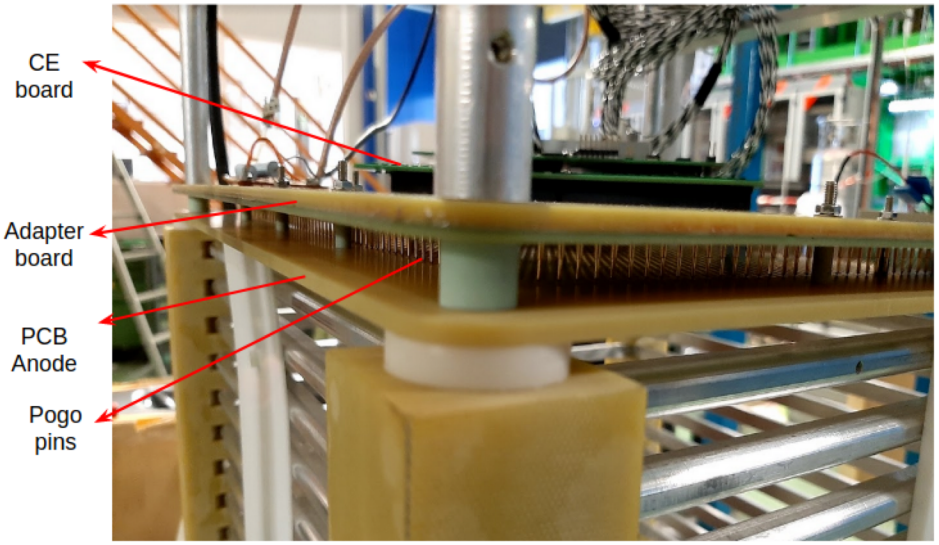
- Collect cosmic data and performed long term stability runs
  - Signal and noise characteristics of the PCB anode with CE assembly
  - Electron transparency, bias voltage, effects of hole and pitch configuration
  - Topological and calorimetric reconstruction
  - Single hit events, field response estimation

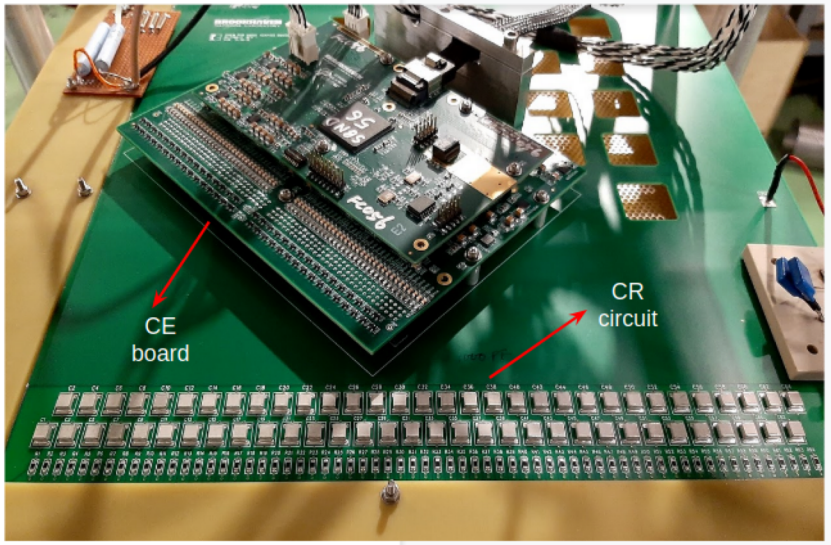


Adapter board and readout electronics

- Adapter board for support, bias and noise filtering
- SBND CEs
  - Analog motherboard with 8 x 16 channels FE ASIC
  - FPGA mezzanine
  - 128 channels of digitized readout
  - 2μs peak time, 14 mV/fC gain
- Warm Interface Board to communicate between the DAQ and FEMB

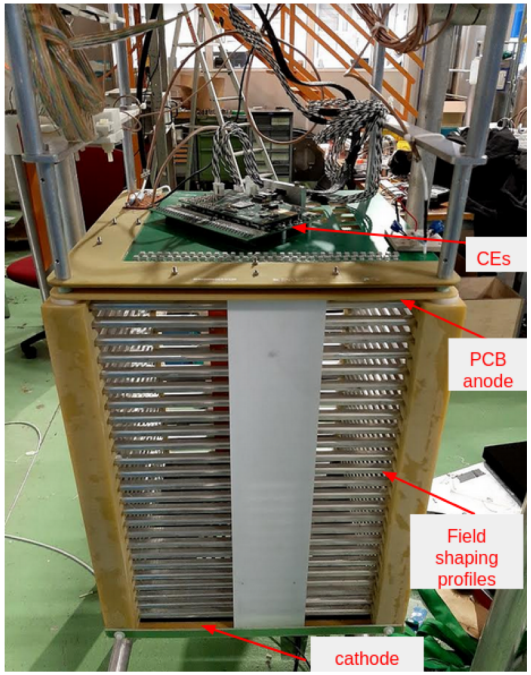


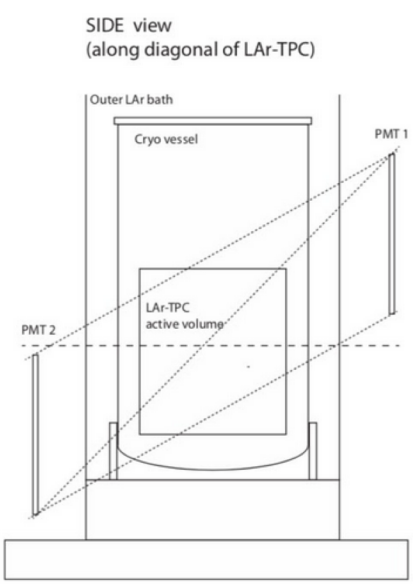


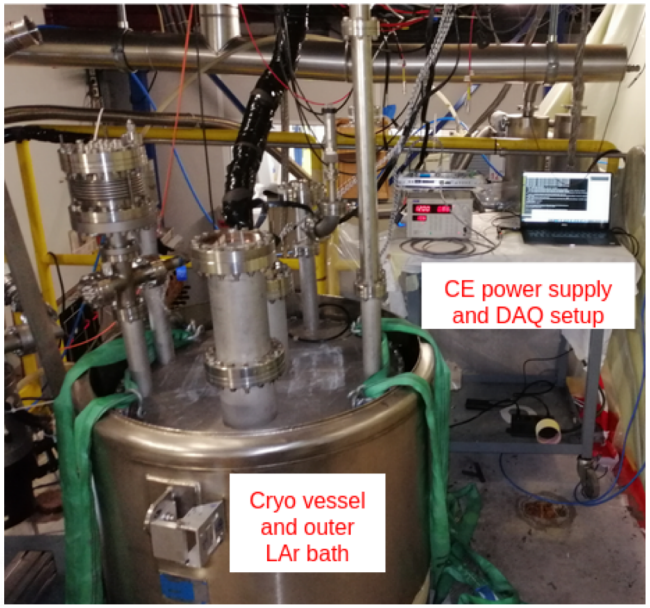


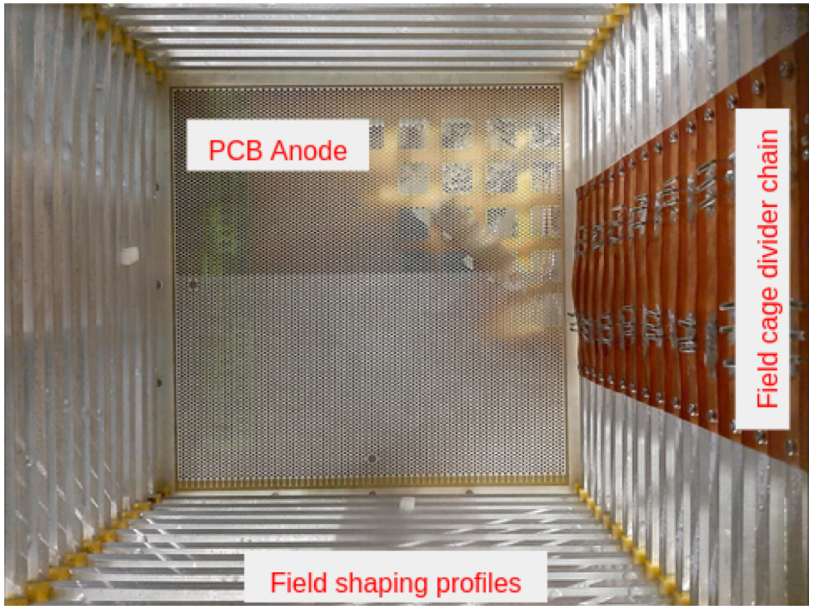
Test setup at CERN 50L

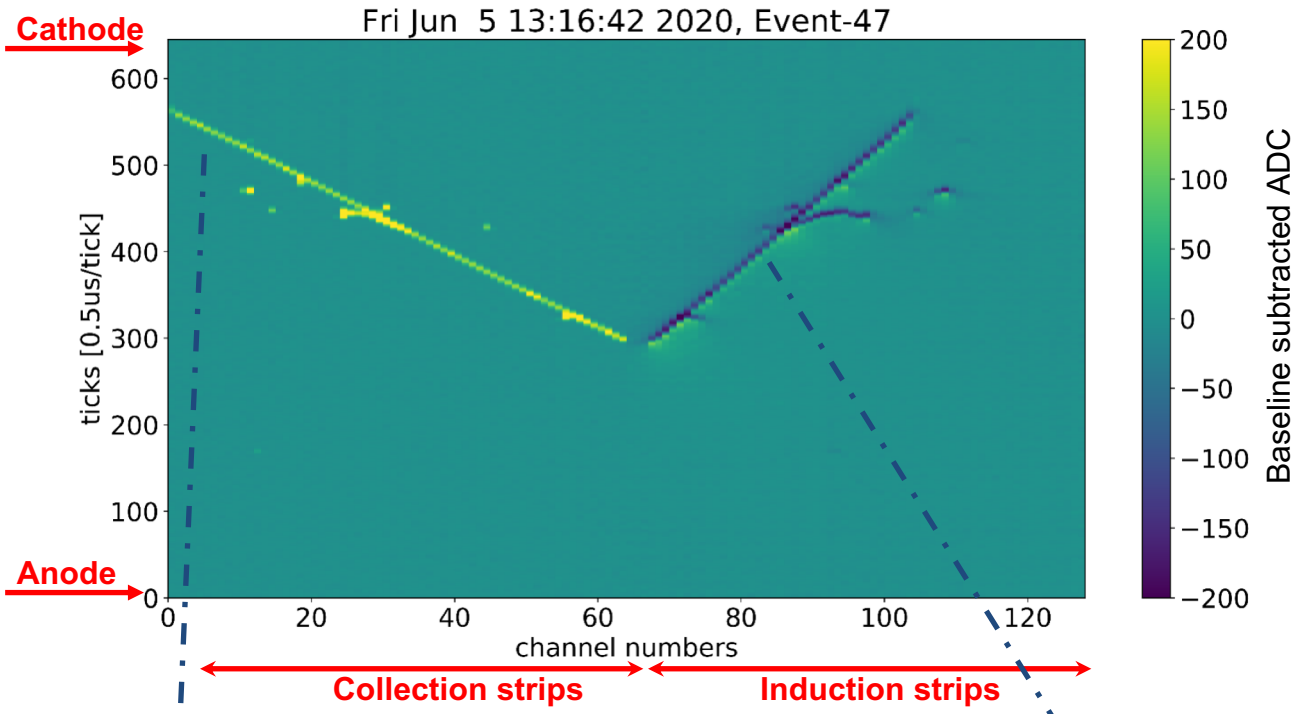
- LArTPC:
  - 2-view PCB anode with CEs, resistive cathode, 52cm drift, Al field shaping rings, 500V/cm field
- Trigger to select muon track with similar angles:
  - Coincidence from 2 scintillator paddles around the cryostat for external trigger
- Readout/data handling/analysis:
  - CE firmware, data with internal and external trigger, custom data handling and analysis tools



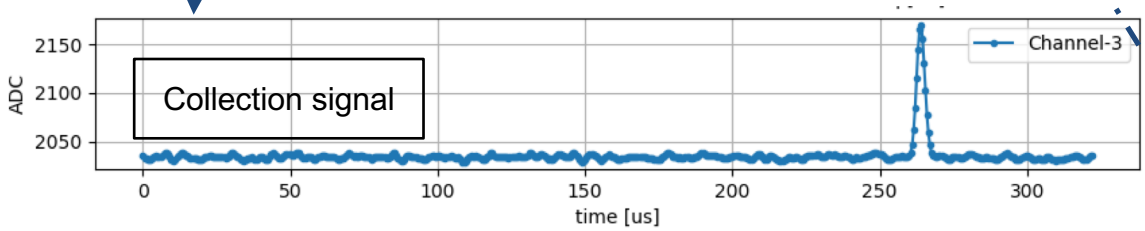


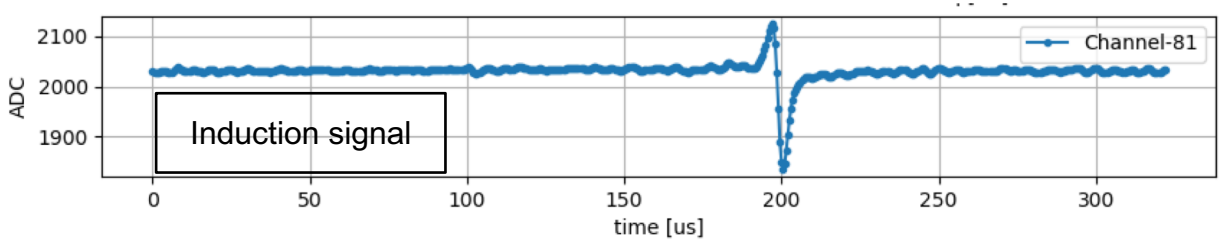


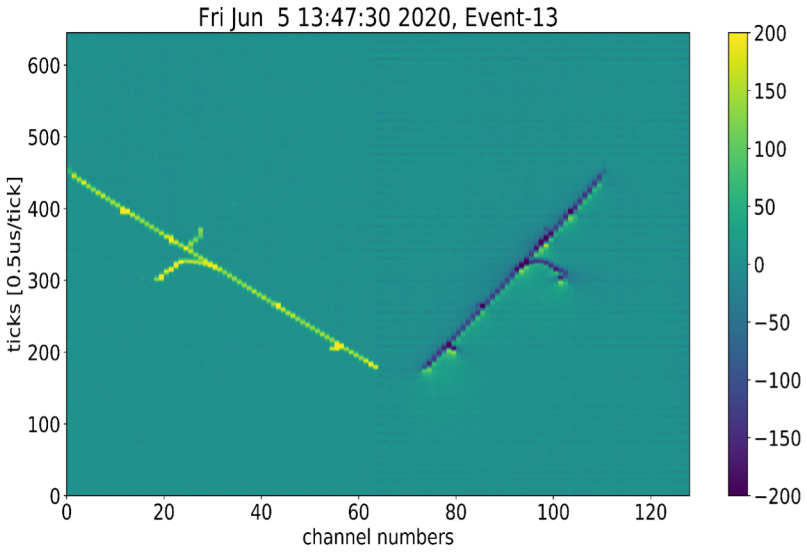


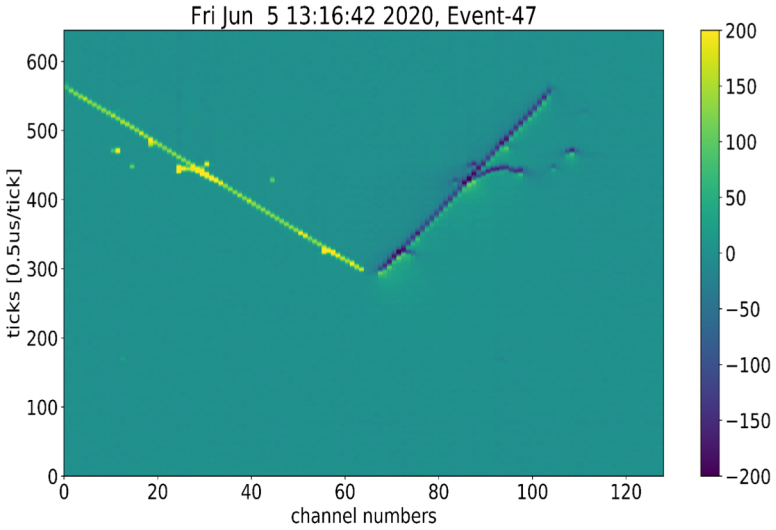


Sharp induction and collection signals! No spread of charge, no cross-talk!

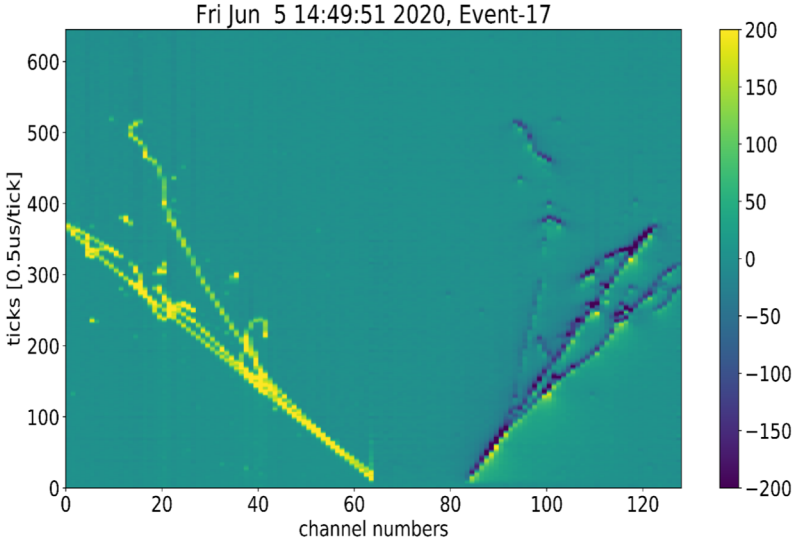


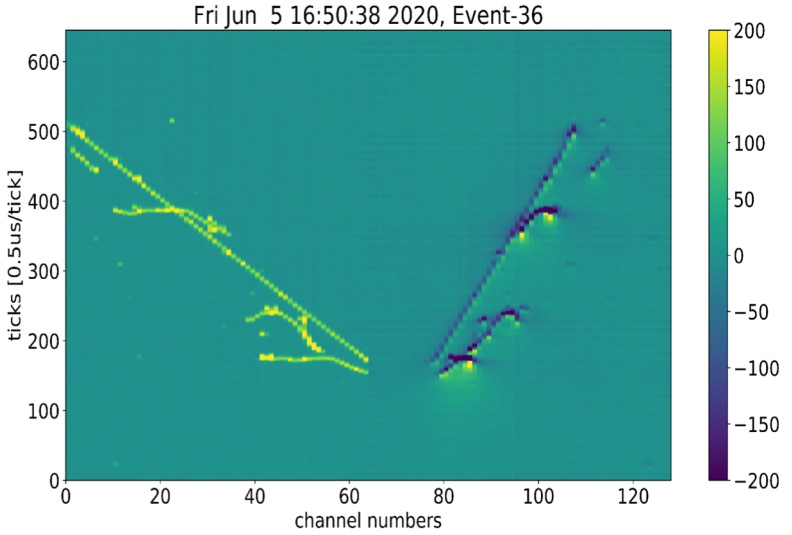






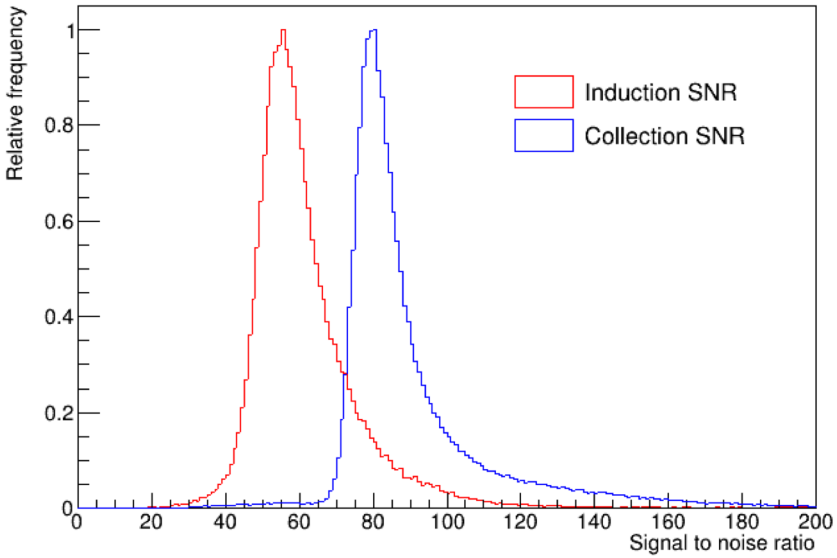
High S/N, clear mip and shower events !!

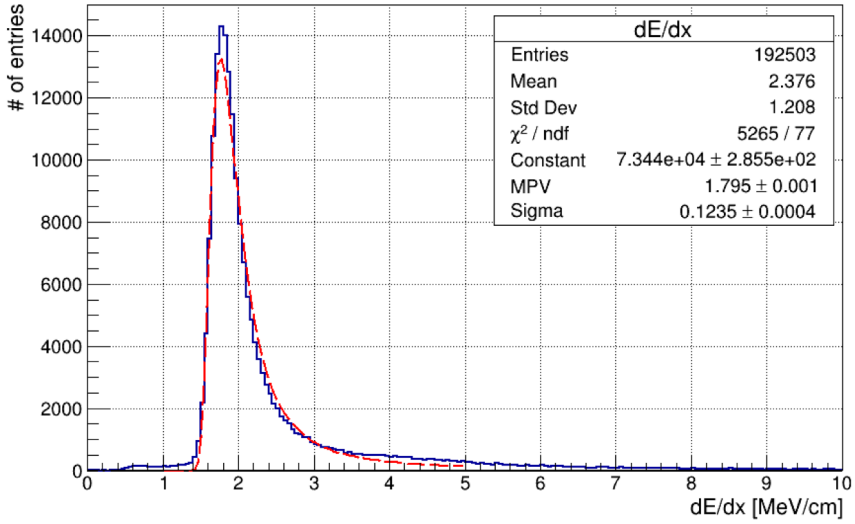




Noise level, SNR, dE/dX

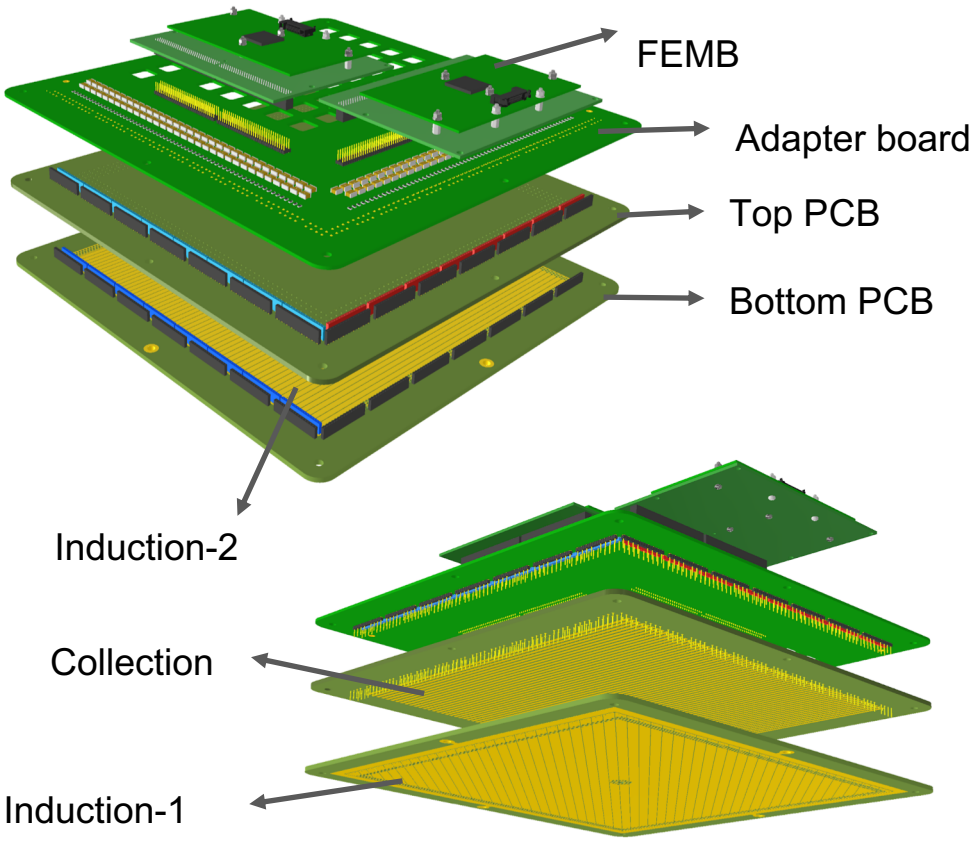
- ENC for small PCB anode at room temperature and in LAr:
  - Collection plane: ~ 900e^- at room temperature, ~ 320e^- in LAr.
  - Induction plane: ~800e^- at room temperature, ~355e^- in LAr
  - Coherent noise removal improved noise level to 300e^- for both layers
- Signal to noise ratio for 32 cm strips:
  - Signal peak height over the rms noise
  - MPV: 81 for collection and 57 for the induction (using only the negative peak)
- Extrapolating SNR to ~1.7m PCB strip:
  - Assuming 200 e^- ASIC noise at 0pF input capacitance of FE in LAr
  - SNR is 33 for the collection and 23 for the induction.
  - This is very similar to the values reported by ProtoDUNE-SP (*https://iopscience.iop.org/article/10.1088/1748-0221/15/12/P12004/pdf*)
- Very good dE/dx agreement with the theoretical expectations

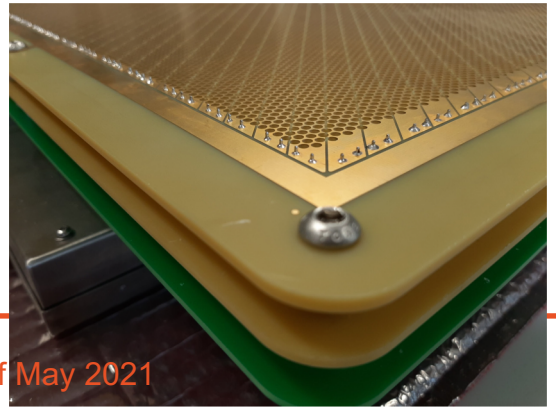




3-view anode PCB prototype tests in 2021

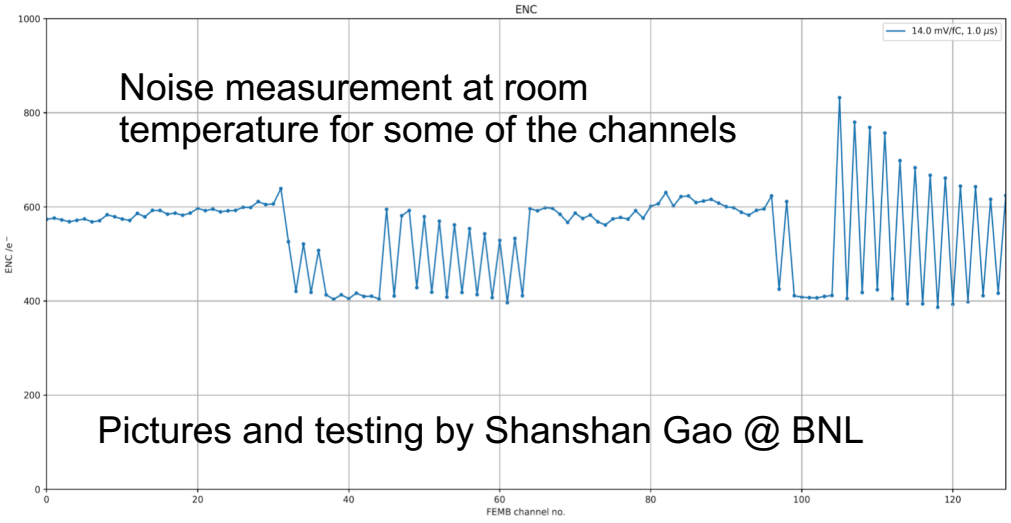
- Demonstrate principle and performance of 3-view anode PCB in 50L tests
- Two induction planes on the first PCB and a collection on the second PCB
  - (48,0,90) strip configuration
  - 8.7mm first induction, 5.2mm second induction and collection strip width
  - 182 readout strips
- Adapter board with 2 FEMBs mounted on it
- Pin and sockets between the PCBs and adapter board
- +800 V bias for induction-2 and +1400 V for the collection





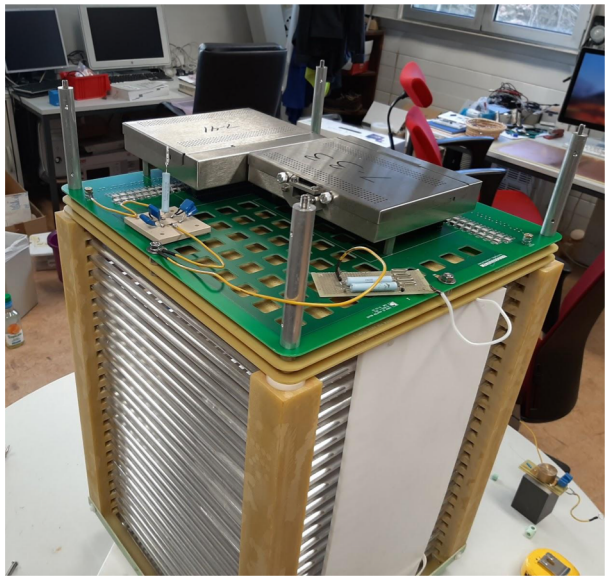
Characterization tests at BNL

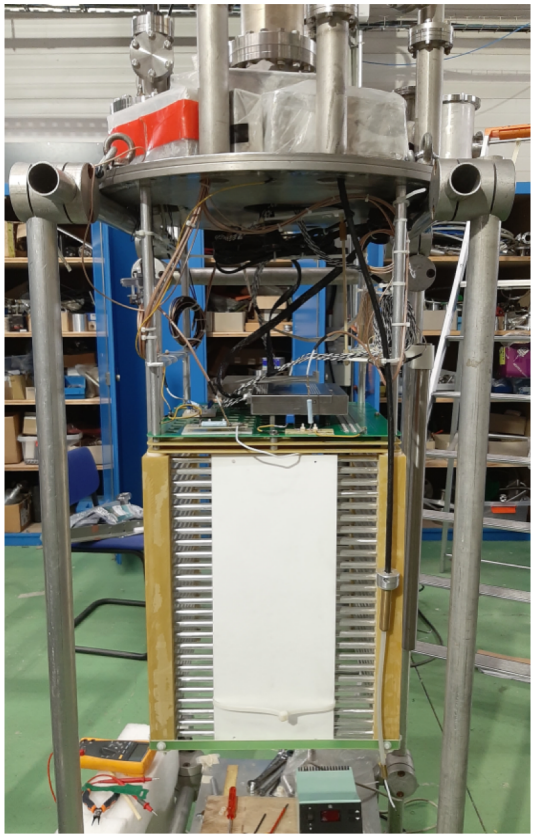
- Procurement, assembly and initial tests were performed at BNL
- Noise measurement and characterization at room and LN2 temperatures
  - Pickup noise when the FEMBs are not enclosed in the metal boxes
  - Shielding improvements were performed
  - FEMBs are placed into the CE-boxes
- 3-view anode assembly, data/power cables for FEMB and a feedthrough flange were shipped to CERN for testing at 50L TPC



Preparations for 50L tests with 3-view anode PCB

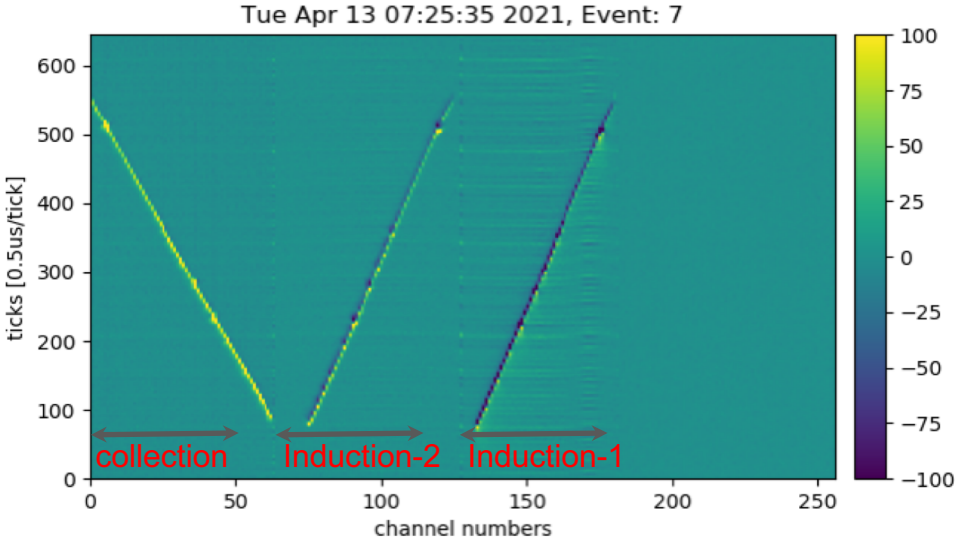
- Installed 3-view PCB anode on to the 50L TPC
- Build additional noise filters, finalized all cabling and integration
- Placed Bi-207 source on the first field cage ring, closest to the anode
- Installed auxiliary instrumentation into the cryostat for monitoring/operation of 50L

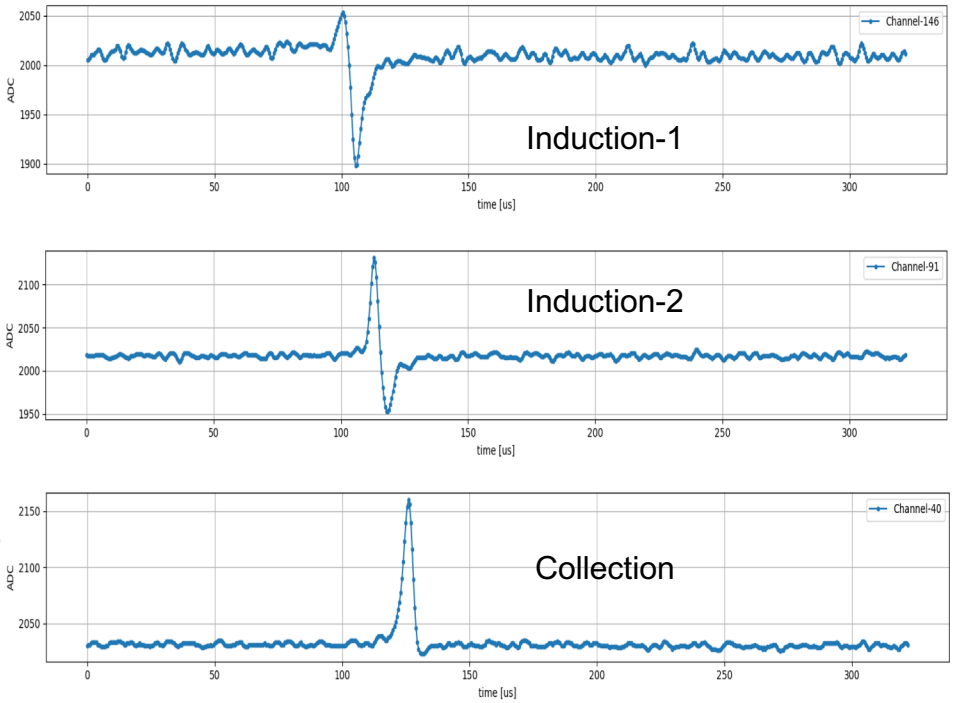




First phase of data taking and first events

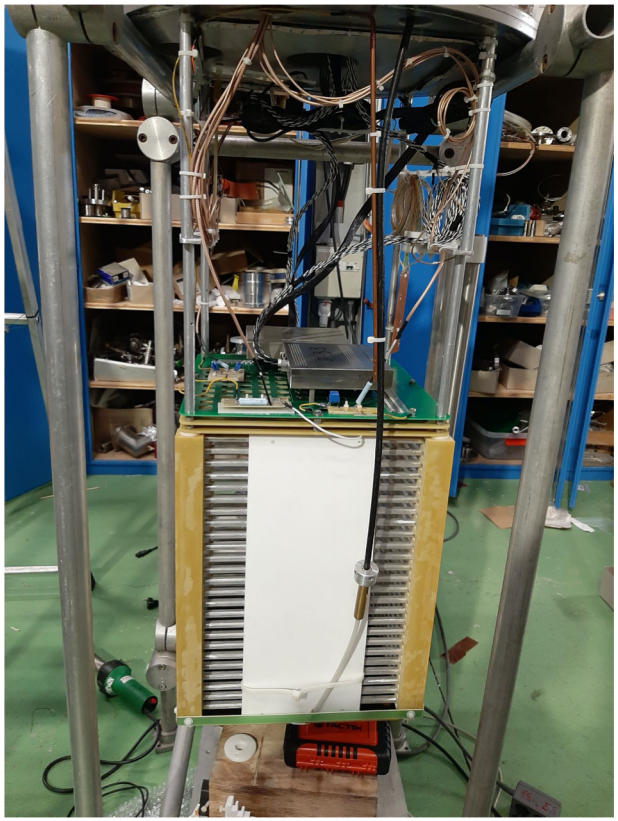
- Filled the cryostat on April 7th and took few noise runs at lower bias voltages
- Data taking with nominal bias voltages and electric field started on April 8th and stopped on April 13th
- Started data taking with lifetime <0.5ms. After 6 days of running and recirculation, lifetime improved to ~1ms.





Second phase of data taking

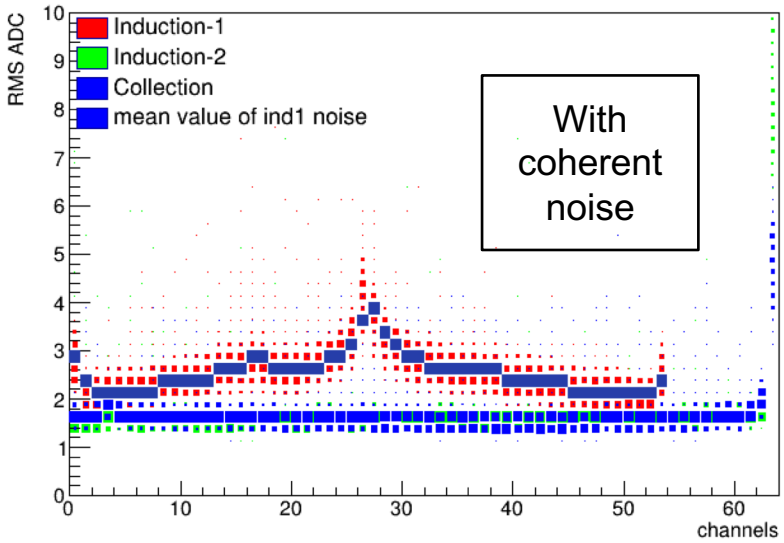
- Improvements and modifications on the setup:
  - Rearranged the cabling inside the cryostat
  - Found and fixed problem with LEDs
    - LED cables were caught under the flange → leak and possible noise source
  - New cryogenic dewar
  - New NIM crate for the external trigger formation
  - Improved overall grounding of the 50L setup
    - Cleaned up all the unused cables
    - Re-wired the grounding connections
- Second phase of data taking started on May 13 with nominal bias and HV

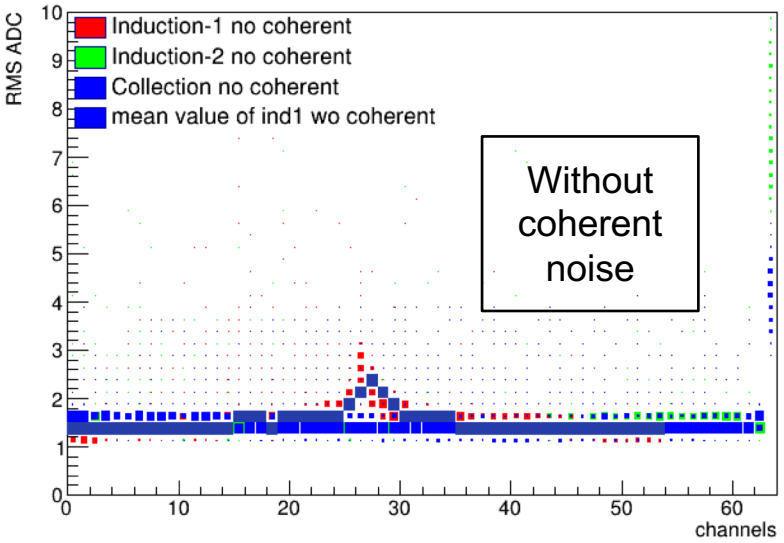


50L setup for the the new longer cryostat

Second phase of data taking noise level

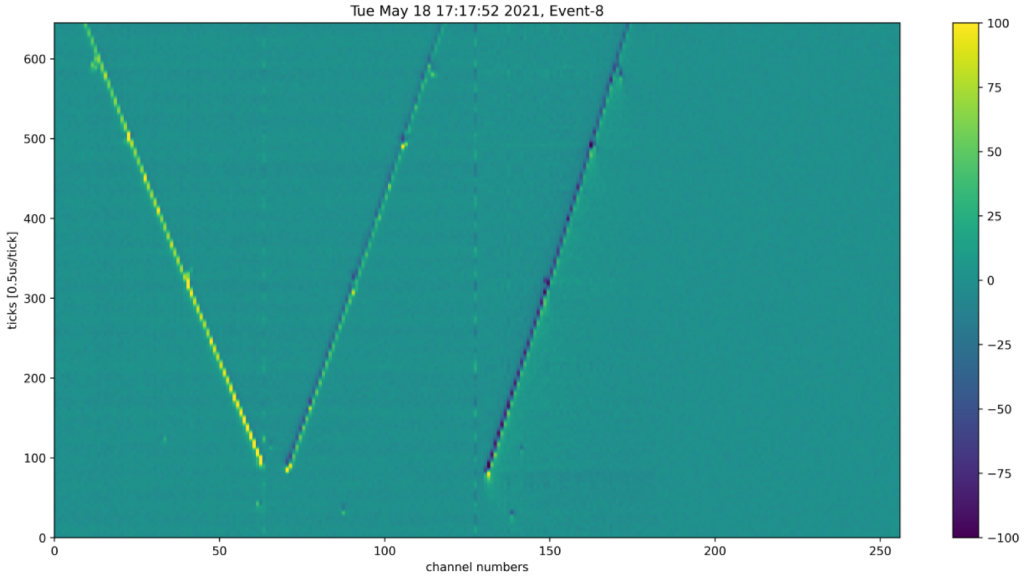
- Noise levels (MPV) with coherent noise:
  - Induction 1: ~500e
  - Induction 2: ~310e
  - Collection: ~310e
- Noise levels (MPV) after coherent noise removal
  - Induction 1: ~290e
  - Induction 2: ~280e
  - Collection: ~280e
- Continue to study noise levels, especially ind-1 long strips
  - Initial analysis indicates difficulty to access noise vs strip length relation due to short strips

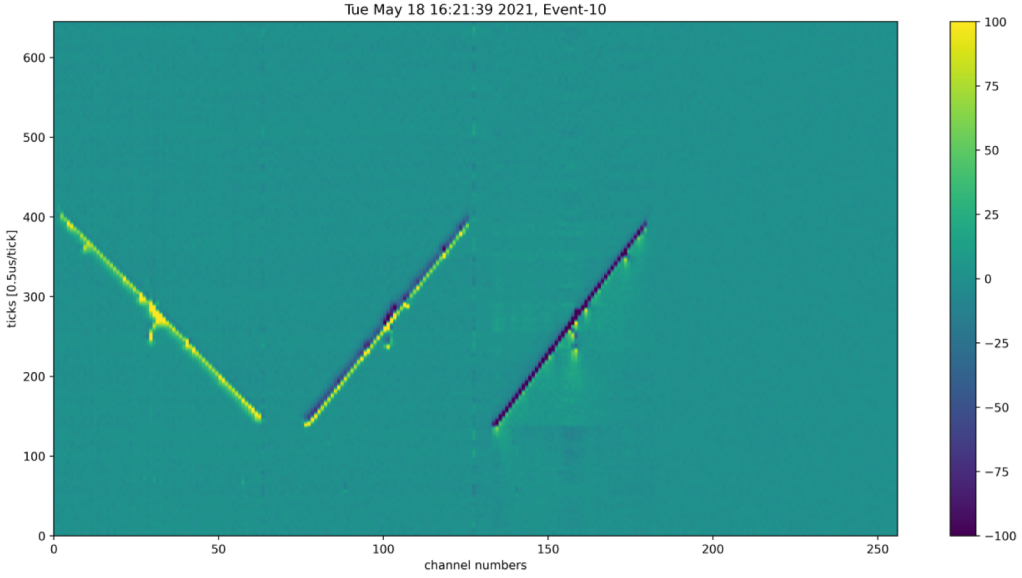




Event displays after coherent noise removal plan for next few weeks

Cosmic and source data taking is ongoing and detailed analysis will follow!!



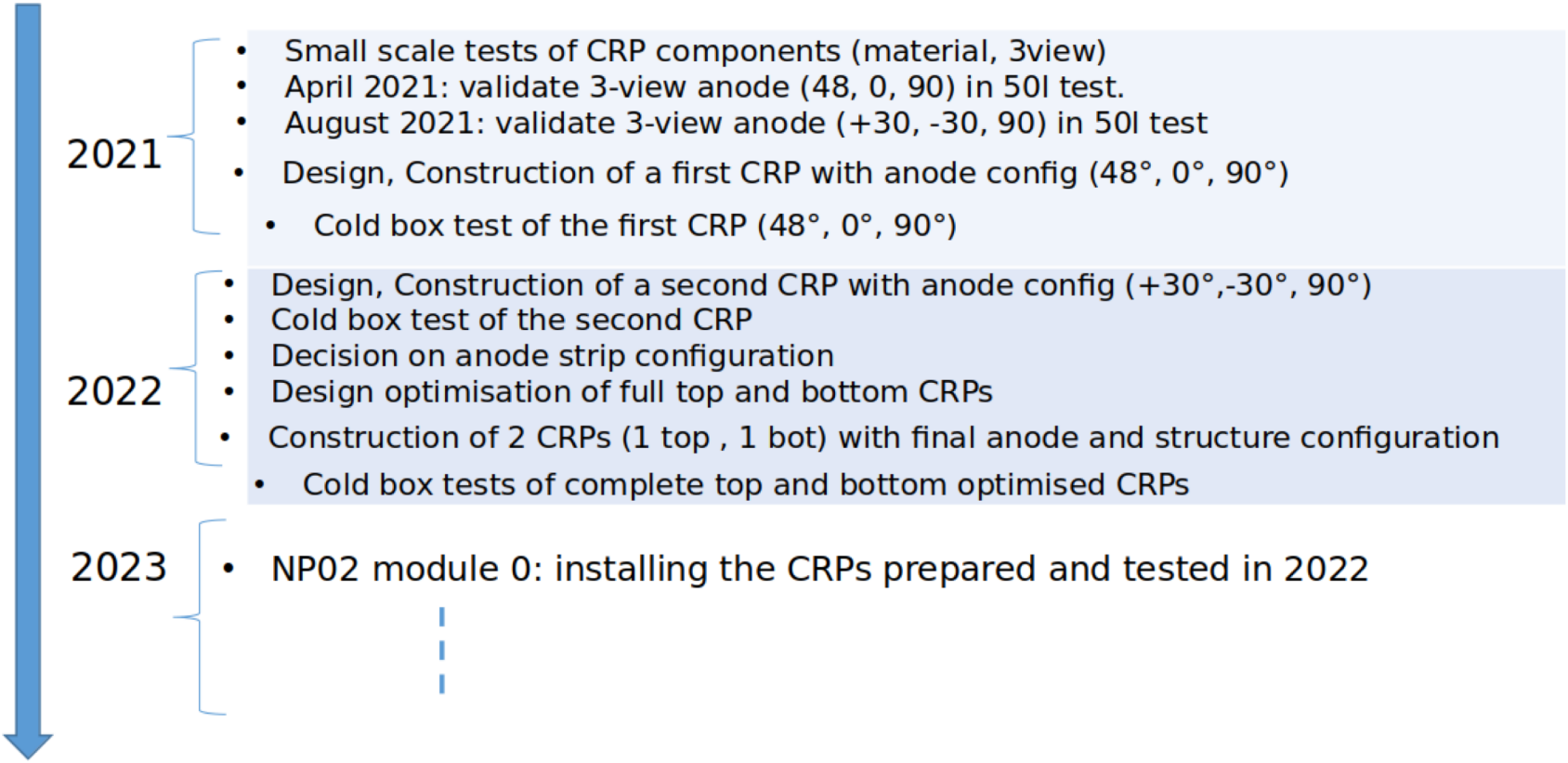


We will continue to collect various data sets as well
- different gain, peak time settings
- different HV PS
- different bias voltages

Full scale CRP

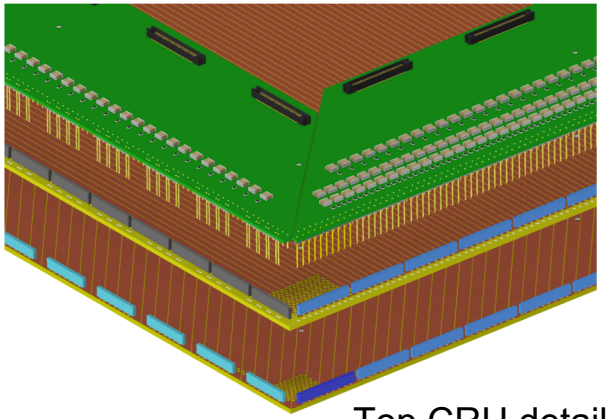
Full scale CRP tests in 2021 and beyond

- Tests with small scale demonstrators are ongoing as planned
- Meanwhile procuring, building components for the first full scale CRP test in cold-box in 2021
- Planning the details for 2022 and beyond

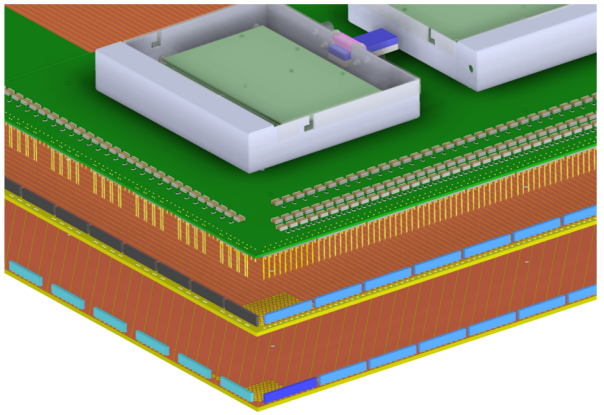


Anode PCB for the cold-box test in 2021

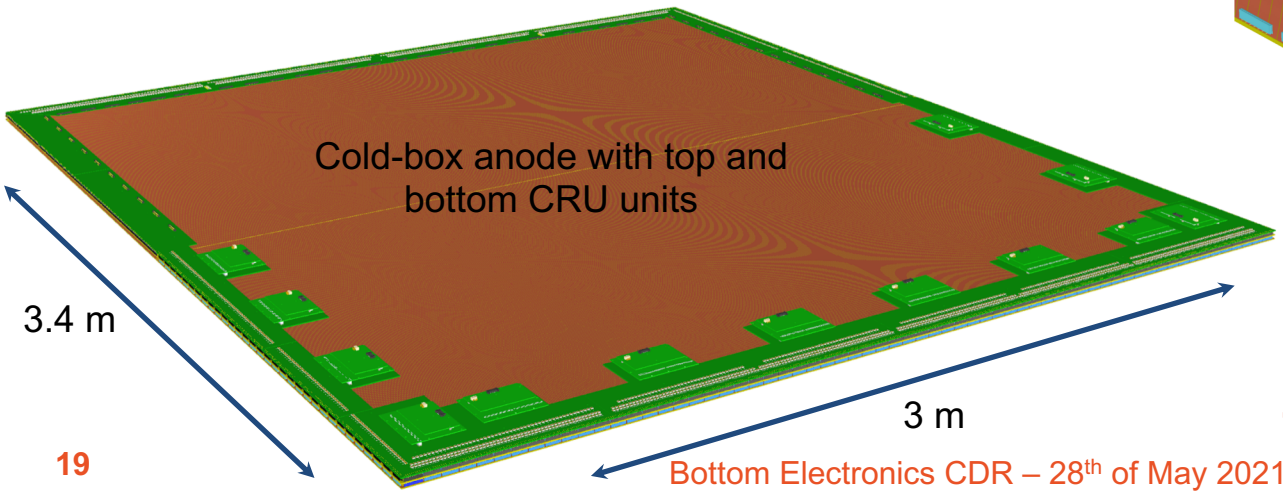
- 3m x 3.4m anode PCB composed of 2 CRU units
  - Six 1.68m x 0.5m perforated PCBs will glued together to assemble a CRU unit
    - Half lap joint technique
    - Screen printed conductive ink, that can be cured at room temperature, for the electrical continuity. This will be tested in LAr
- Hybrid readout
  - One of the CRUs will be readout by the top electronics and the other one by the bottom electronics
- Current status:
  - PCB panels are under production
  - Design of the adaptor boards is about to be finalized

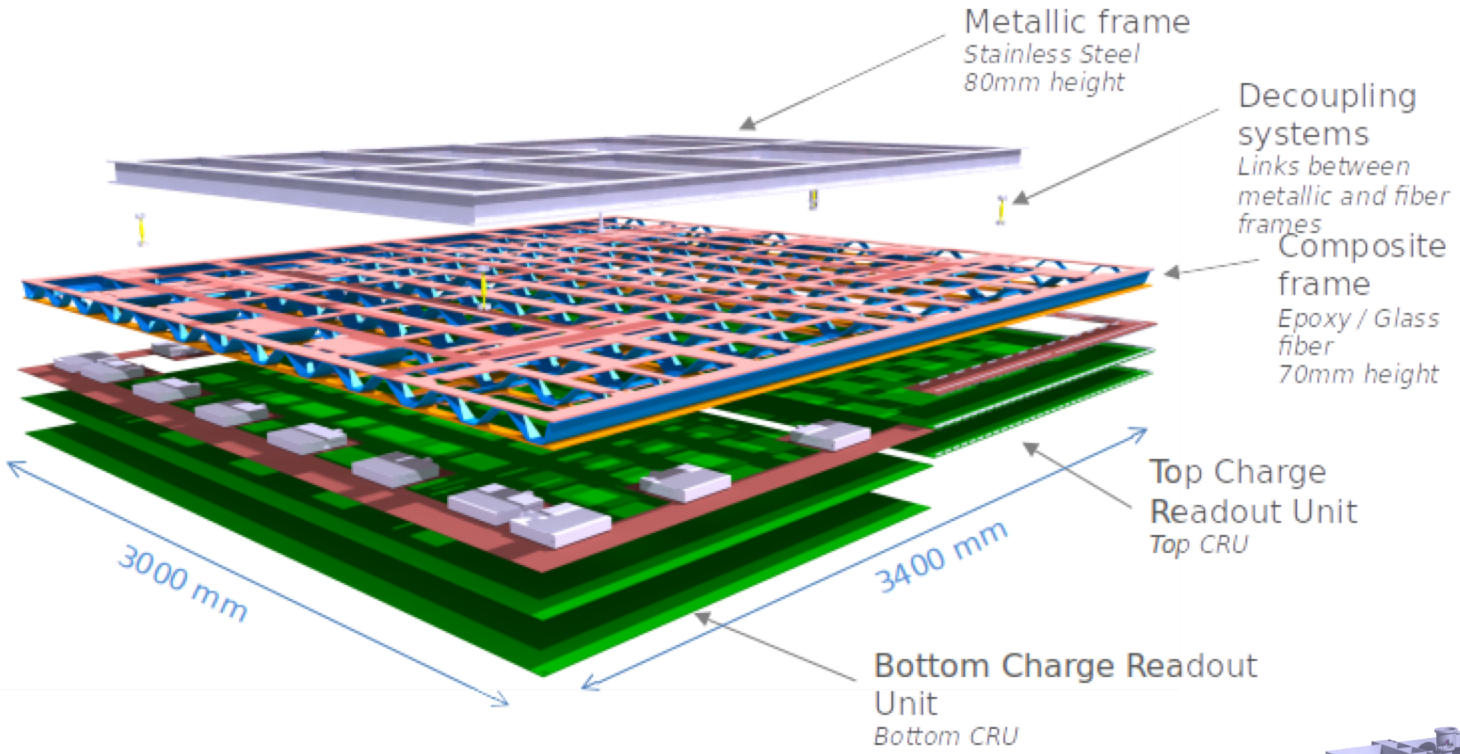


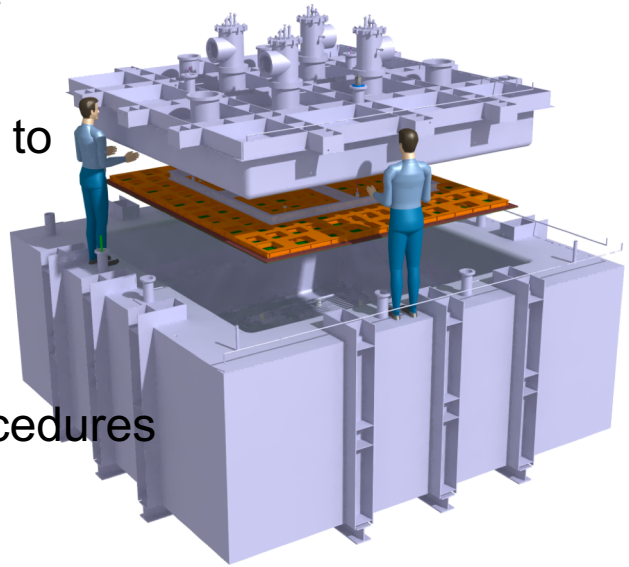
Top CRU details



Bottom CRU details







Cold-box CRP assembly is expected to happen from June to September at CERN

- Assembly details are well developed
- Preparing the assembly area in early June

Testing in cold-box at EHN1 later in 2021

- Characterize, validate the design and construction procedures of a full scale CRP equipped with electronics
- Mechanical and electrical test of the CRP in cryogenic conditions

Cold box

Goals of the Cold Box test in 2021

Characterize and validate the design and the construction procedures of a full scale charge readout module equipped with electronics.

- mechanical and electrical test of the CRP in cryogenic conditions,

- mechanical test of the cathode module in cryogenic conditions,

- characterization of the performance of the perforated anode and the full electronics chain in terms of signal to noise ratio and its stability,

- test the light readout detector concept at large scale,

- test the integrated system as a whole and evaluate the interplay between the powering scheme, the charge electronics and the light detector system.

Cold Box Requirements

- The cold box must host a CRP module of 3 x 3.375 m^2,

- The LAr level must be maintained within +/- 5 mm,

- The absolute vapour pressure must be stabilised within few mbar around the nominal value (approximately 1000 mbara),

- The liquid argon purity must be compatible with electron drift over 20 cm in typical 500 V/cm electric field,

- The drift distance must be larger than 20 cm with a drift field of 500 V/cm.

- Building and detector ground must be separated.

- Quick turnaround cycles (driven by the tests themselves).

Upgrade Required

The new requirements for the VD CRP tests imply major upgrades to the mechanics and the cryogenics system of the cold box.

The cold box will be installed at EHN1 to profit from the cryogenics and safety infrastructure already available.

A CRP equipped with both top and bottom electronics will be tested in the second half of the year.

Additional tests of CRP equipped uniquely with top and bottom electronics or different strip layout will be planned for 2022.

Changes to Mechanics

The sealing of the roof against the walls needs to be improved, straightening the interface surfaces and using a softer gasket.

Additional penetrations need to be opened on the movable part of the roof and on the fixed part of the roof (HV, PrM, …).

The roof aperture of the cold box must be increased to allow the simple installation of the CRP (3 x 3.375 m2)

The cold box structure need to be reinforced to allow higher overpressure to operate it in closed loop and reduce the air back flow from possible leaks.

Changes to Cryogenics

The absolute vapour pressure needs to be controlled, this implies a valve at the output: the cryostat cannot be considered anymore an “open bath” dewar.

The requirement on the liquid argon purity is of the order of 1 ppb O_2^{eq}. The liquid argon need to be filtered at the input via the NP02 filters.

The boil-off must purified before being re-condensed.

Use NP02 LN_2 circuit, but and independent condenser, so that operation of NP02 and cold box can be mostly independent. Simultaneous operation expected from Fall 2021.

Cold box preparation

Mechanical modification (stiffeners, fixed roof, enlarge aperture, …)
- beginning of June
- installation of the cold box in final position scheduled for the 7th of June

QC (leak test, load with water, possibly pressure test, cleaning)
- complete in June (when cold box installed in final position)

Cryogenic components procurement
- all material available ~end of May

Cryogenic installation and connection to the cold box
- 4 week from when the material is available (complete by end of June)

Instrumentation ready (temperature sensors, level meters, cameras, PrM, …)
- installation in the cold box by the second half of June

Cold box dry run
- from first half of July (at least two weeks to test stability and purity increase)
- if purity does not increase as expected, major impact on the schedule

First Cold box CRP test

First CRP test equipped with both top and bottom electronics starting at the beginning of October.

Contingency of the two months between the commissioning of the cold box and the first test of the CRP.

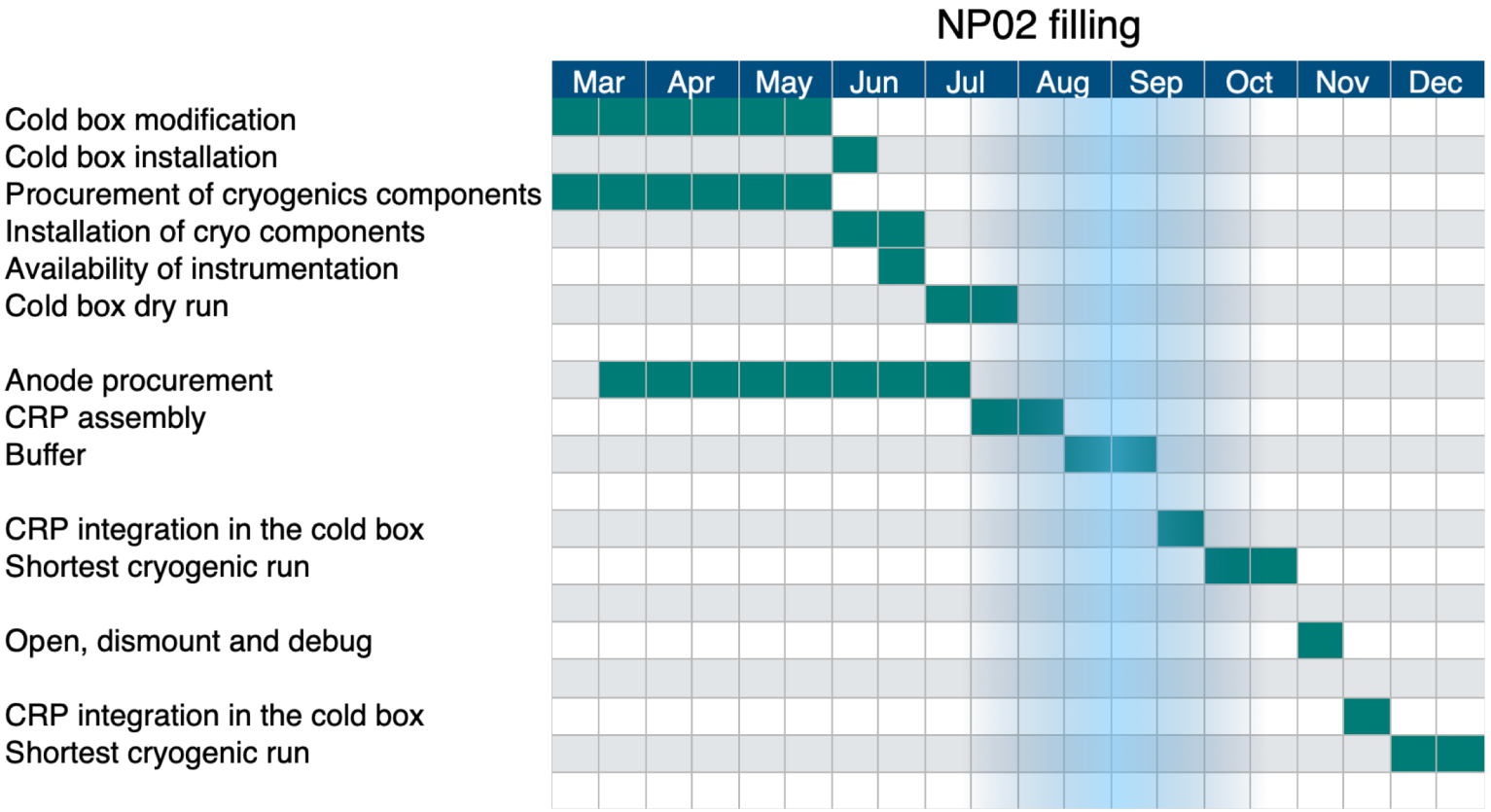
The CRP will be exposed to cosmic rays till the end of the year.

Quick turnaround of the cold box operation allow accessing to the detector.

In August, NP02 will also be filled for the full scale test of the HV.

In 2022 additional tests of different CRPs (strip layouts and electronics) are foreseen before the full scale module 0 test in NP02.

Time line


NP02 filling
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Cold box modification
Cold box installation
Procurement of cryogenics components
Installation of cryo components
Availability of instrumentation
Cold box dry run
Anode procurement
CRP assembly
Buffer
CRP integration in the cold box
Shortest cryogenic run
Open, dismount and debug
CRP integration in the cold box
Shortest cryogenic run

After the cold box tests

Open points related to bottom CRP electronics:

- CRP in *correct* position (facing upwards and sitting on the floor)
- Realistic cable length

- It is possible to envisage a test in the cold box with full cable length.
- Need to evaluate the possibility (and the need) of cold box test with CRP at the bottom and cathode at the top in 2022.
- Cold box needed for tests preparatory to installing CRPs into Module-0?

- Test the actual cable length and the correct orientation of the CRP seems necessary prior DUNE Vertical Drift Module.
- Vertical Drift module 0 will be equipped with 1 or 2 bottom CRPs hanging from the top (integration not yet started).
 -Consider the possibility to install in NP02 bottom CRPs underneath the cathode with an asymmetric drift length?

Summary

Rapid and successful small scale tests demonstrated the principle of operation.

Ongoing tests for the optimization of the perforated anode stack and strip layout.

Solutions developed in small scale tests till beginning of 2021 implemented in the design of the first full scale CRP.

First CRP equipped with both top and bottom electronics.

Demonstration test of the first CRP in the cold box from October till end of 2021.

Additional tests of optimized CRPs will be planned for 2022.

Layout of Module 0 to be tested in 2023 in NP02 will follow.