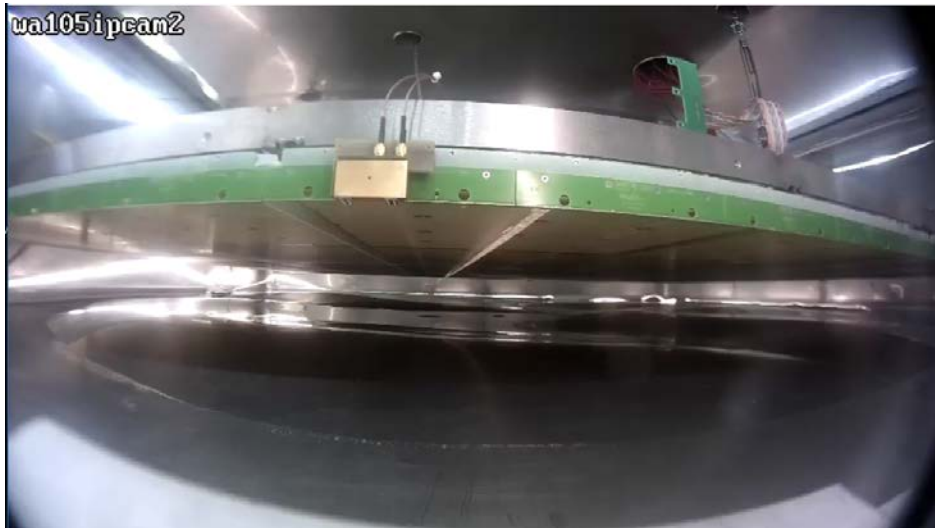


D. Duchesneau

on behalf of the ProtoDUNE-DP collaboration

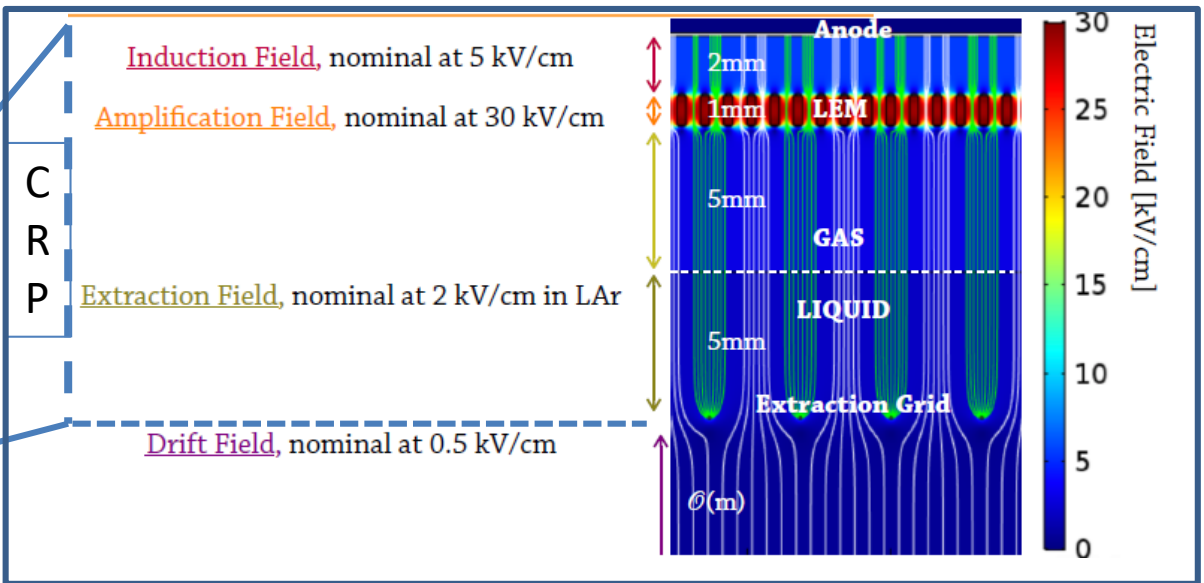
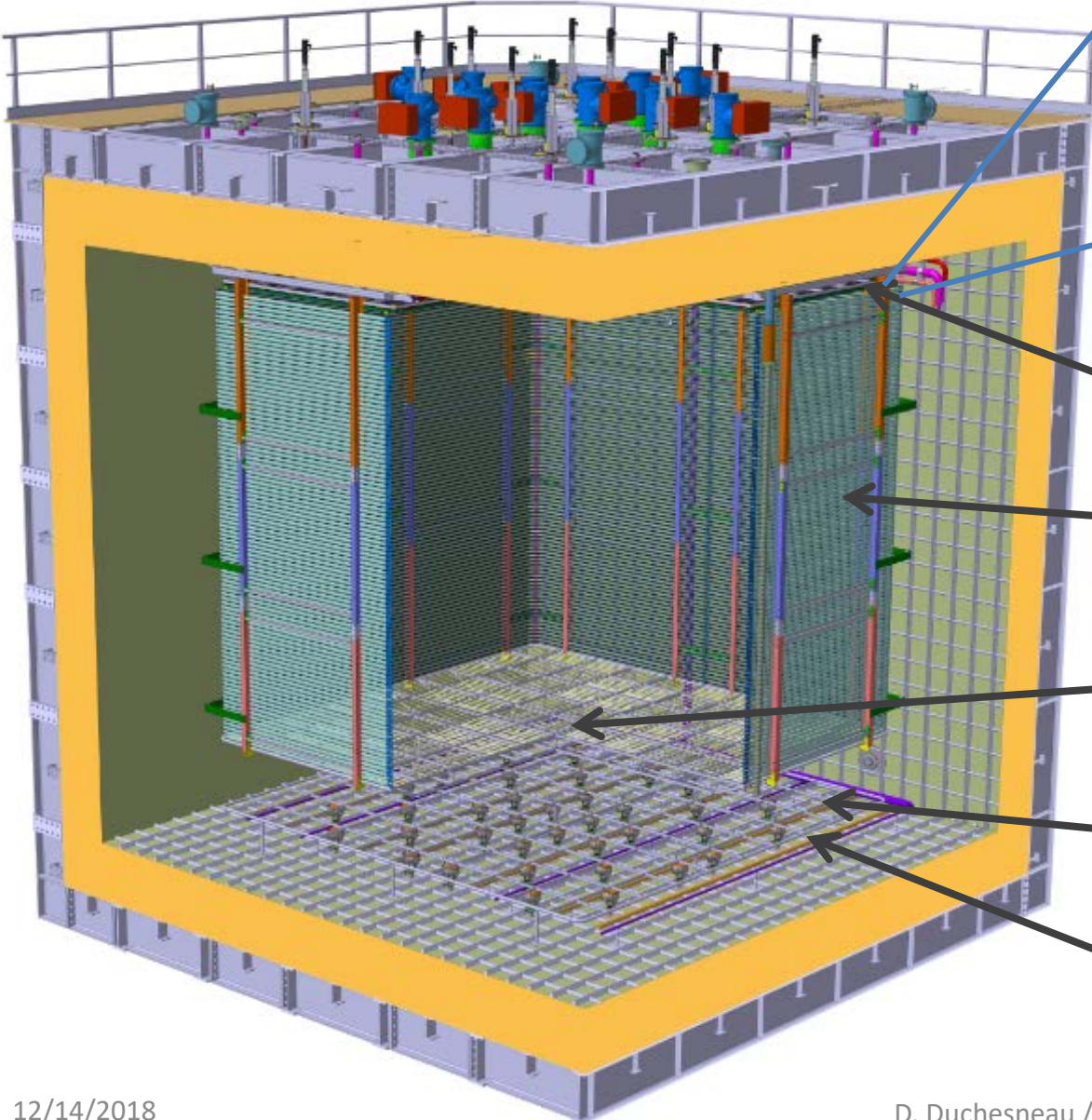
- CRP construction and tests
- Signal Feedthroughs
- Cathode and ground grid
- Summary



DUNE collaboration call
Dec. 14, 2018

ProtoDUNE-DP (NP02)

Components and operating conditions



Charge Readout Planes (CRP)

Field Cage

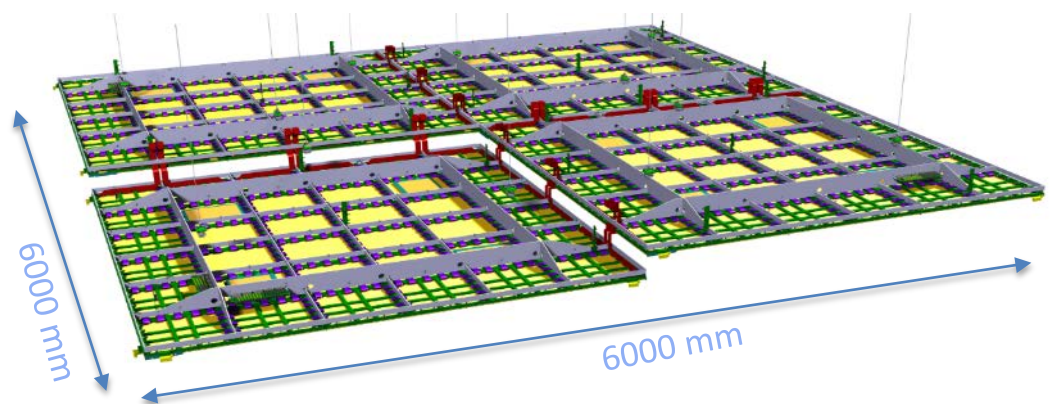
Cathode 300 kV

Ground grid

Photomultipliers

Charge Readout Plane (CRP)

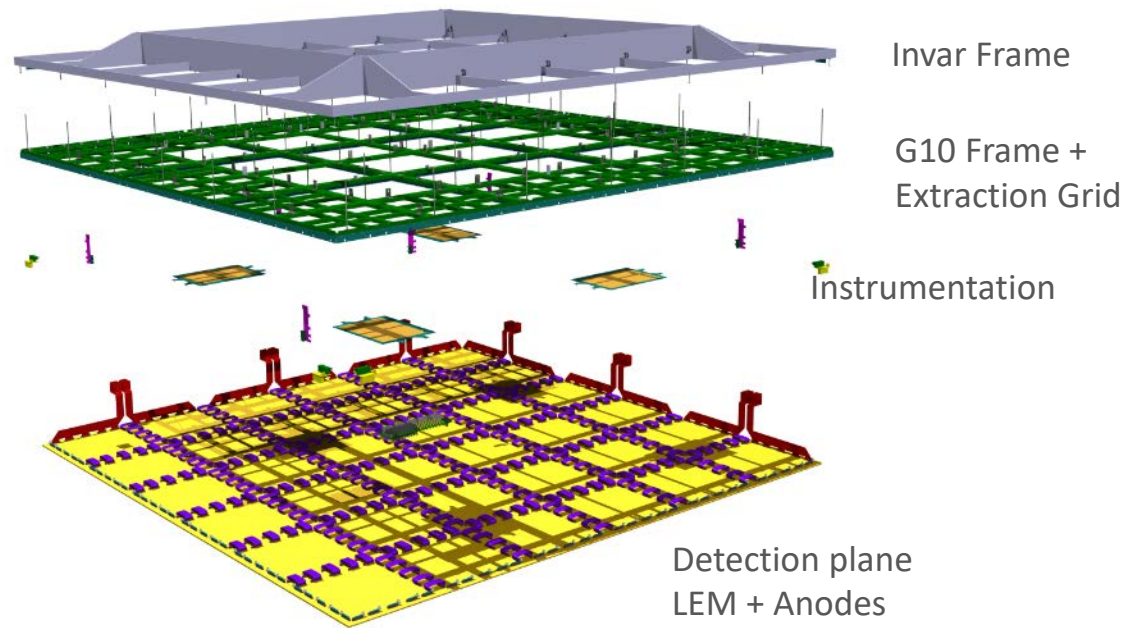
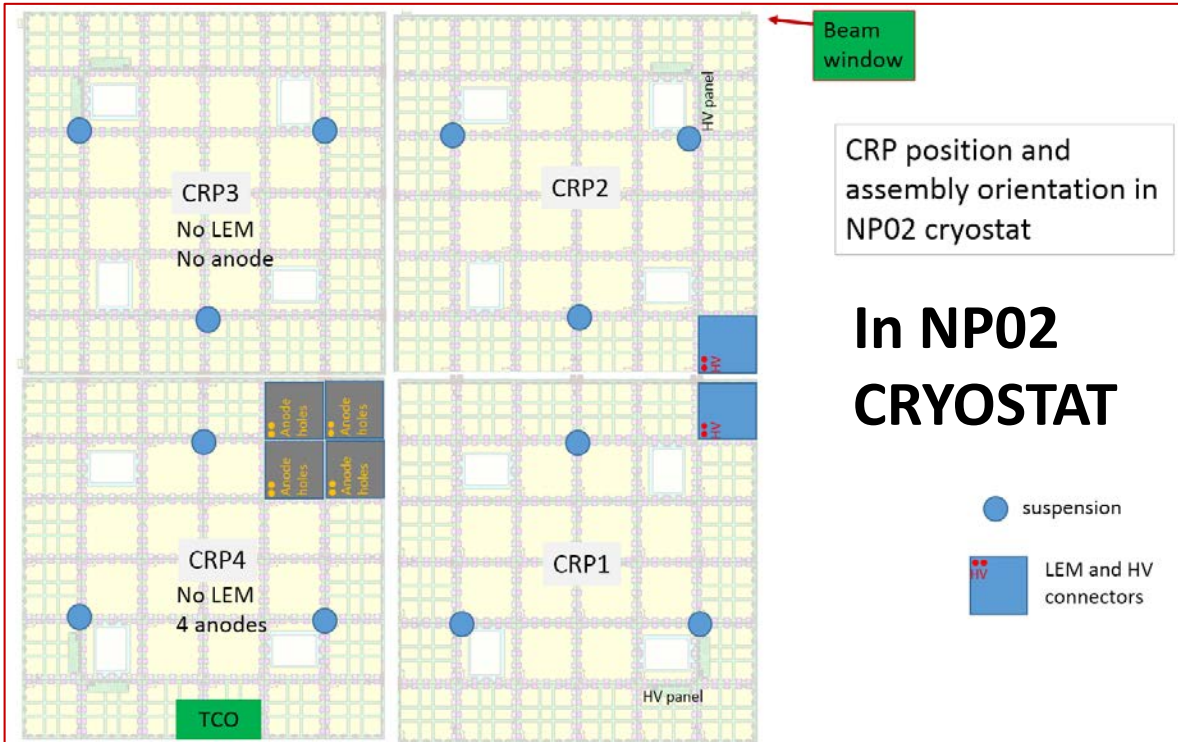
Components and operating conditions



Seen from top



4 CRPs



2 instrumented CRPs with LEMs and anodes:

- ✓ CRP#1 built in May-June 2018
- ✓ CRP#2 built in October 2018

2 'fake' CRPs without LEMs:

- ✓ CRP#3 built in September 2018
- CRP#4 to be completed by Jan. 2019

CRP3 assembly in September 2018

CRP3 and CRP4: no LEMs and anodes.
Those are replaced by 'fake anodes' with
a copper surface on one side and no strip.

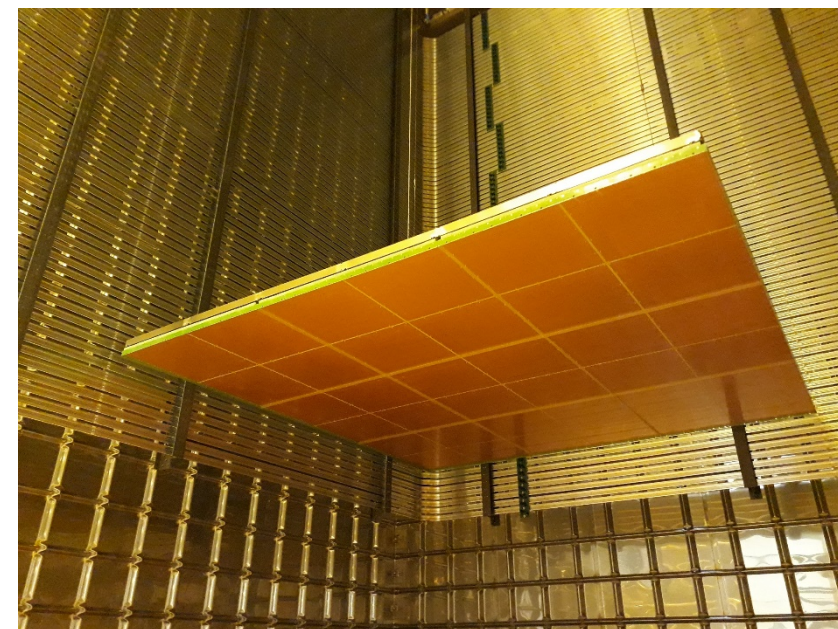
+ full grid mounted

CRP3 started while waiting CRP2 LEM
and anode production



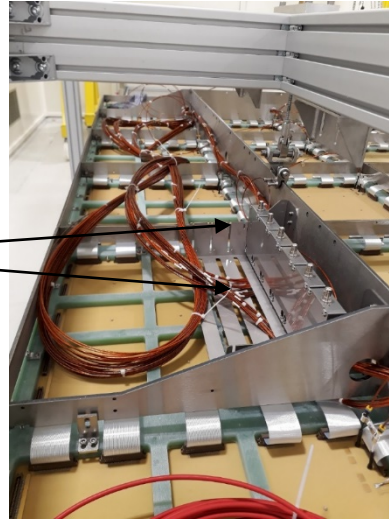
A test in cold box done beginning of
October

Installation in NP02 cryostat: Nov 19th



CRP2 assembly in October 2018

New top LEM HV DB
And Bottom LEM cabling



CRP2

CRP1

CRP4 assembly

Started in November but paused to allow modifications on CRP1 and CRP2



This CRP will
have 4 real
anodes without
LEMs put on this
corner

Will be resumed in January with grid
production and short cold test

12/14/2018

Next steps for the CRPs:

CRP#1:

- Grid reinstalled after the replacement of 4 LEMs last week
- Cold box test starting
- Bring to EHN1 beginning of January 2019

CRP#2:

- 1 LEM replaced and some grid reassembled beginning of this week
- Bring to EHN1 next week

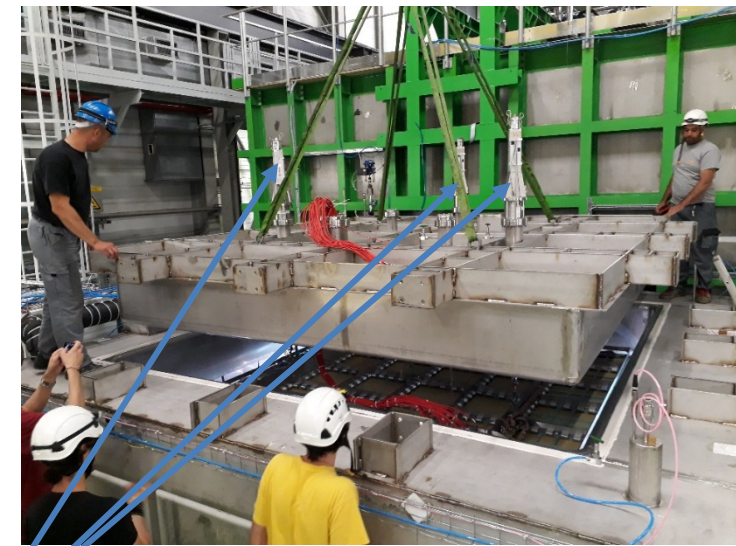
CRP#4:

- Resume the assembly and grid production mid January
- Short cold box test
- Bring to EHN1 end January

Cold box test procedure

When CRP and box closed (1 hour)

- Inject dry air during > 1 day and test the LEM HV
- Purge and flush with Gas argon for 1 day
- Cool down and fill LAr : 10 hours
- start tests of LEMs + grid



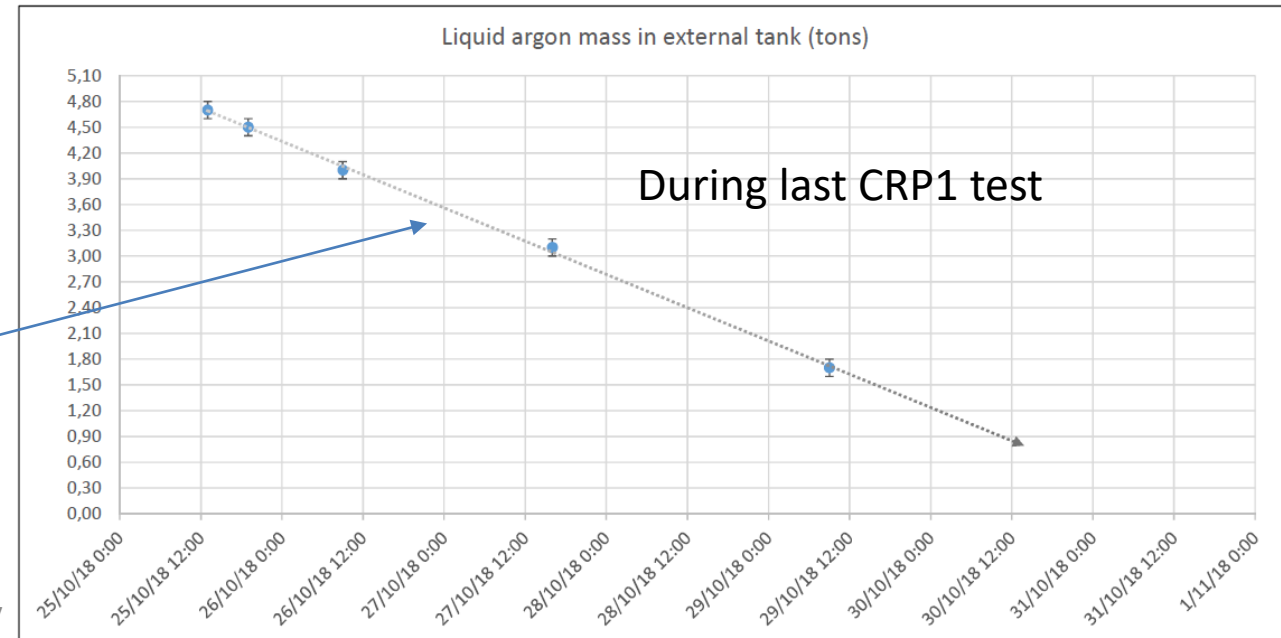
=> 3 days between closure and cold operation

To adjust horizontality the CRP wrt the liquid argon level:

The CRP is lowered or raised manually using the 3 suspension feedthroughs.

Liquid argon consumption during the various processes:

- Flushing/purge: 500Kg
- Cool-down: 750Kg
- Filling: mini 4000Kg
- Normal operation: 750Kg/24h (about 1400W)

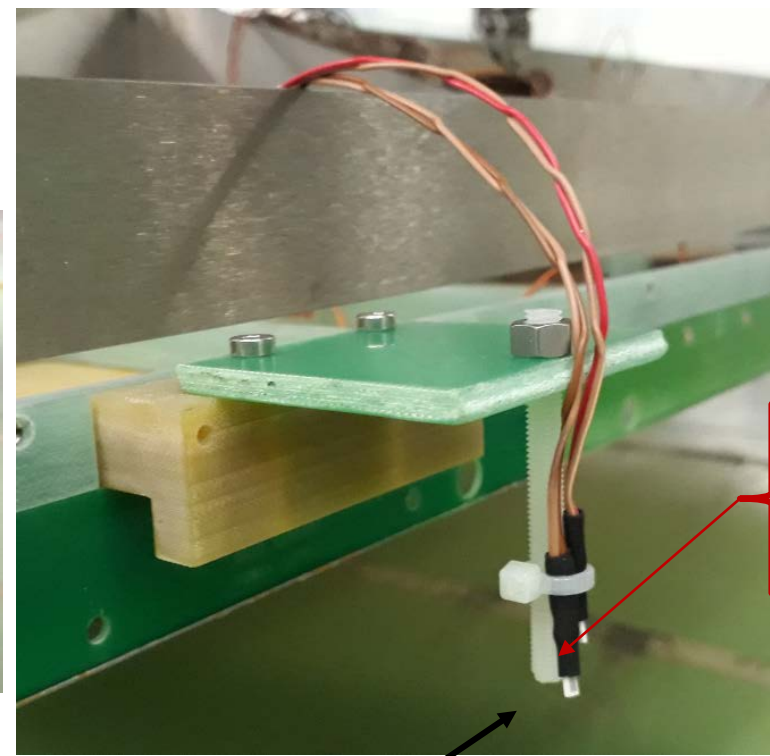
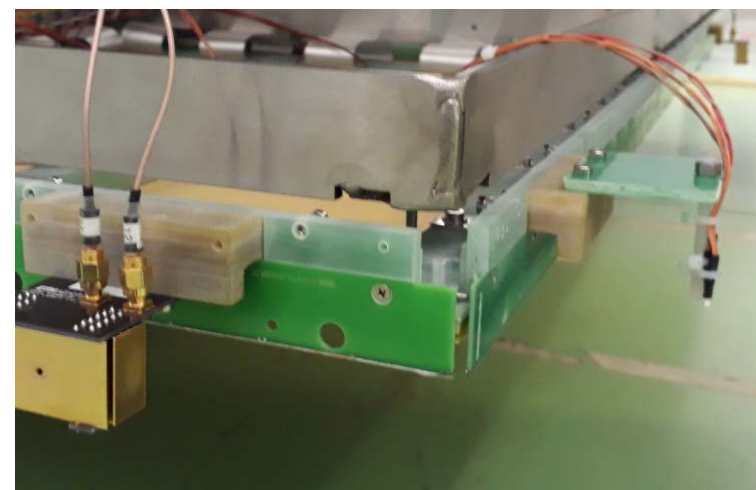


CRP instrumentation:

Level meters and Pt probes

Used after the second cold test in July

4 additional level meters have been added on the sides of the CRP => total + 8

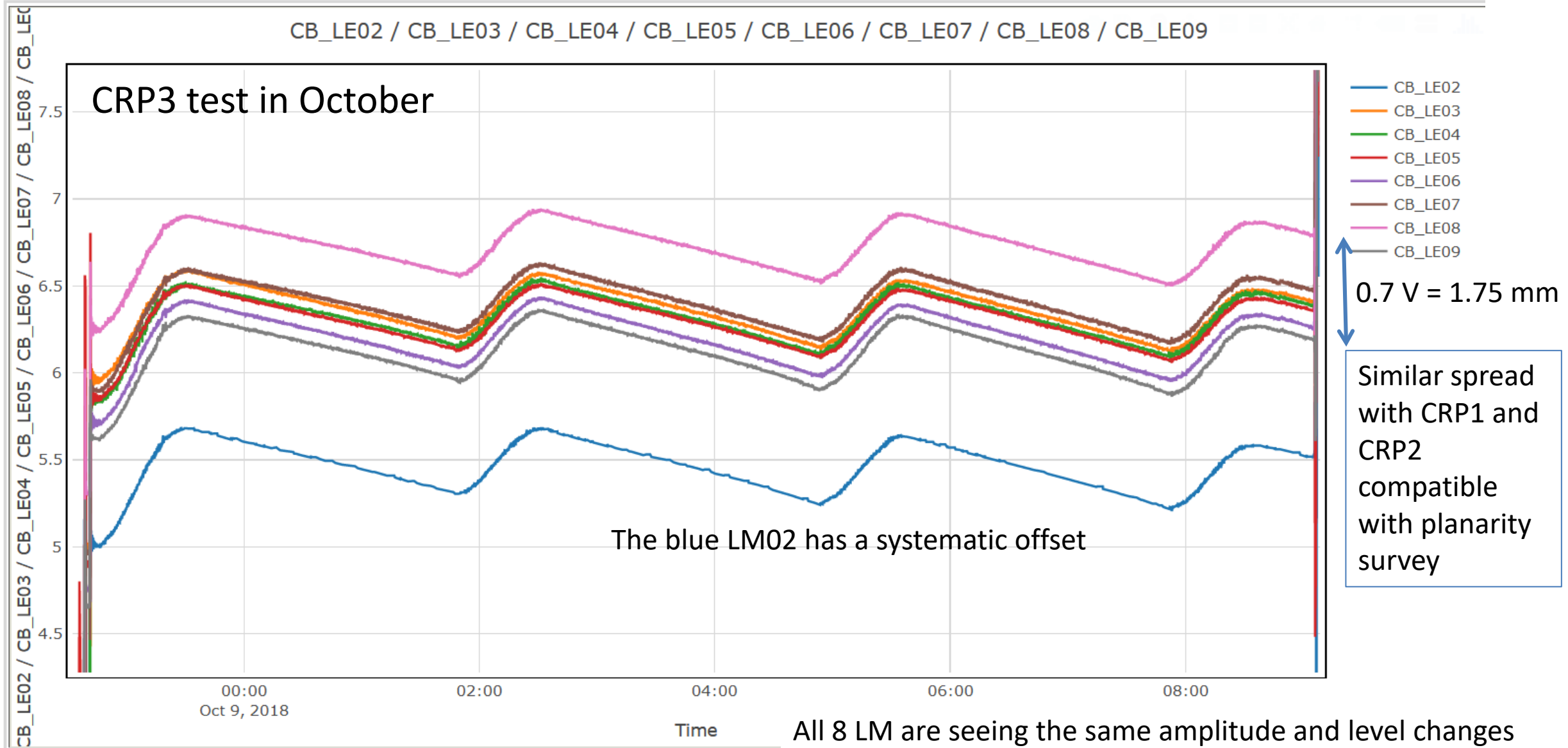


TT200	86.416 K
TT201	91.513 K
TT202	86.479 K
TT203	86.331 K
TT204	89.927 K
TT205	86.31 K
TT206	91.619 K
TT207	86.395 K
TT208	86.31 K
TT209	91.386 K



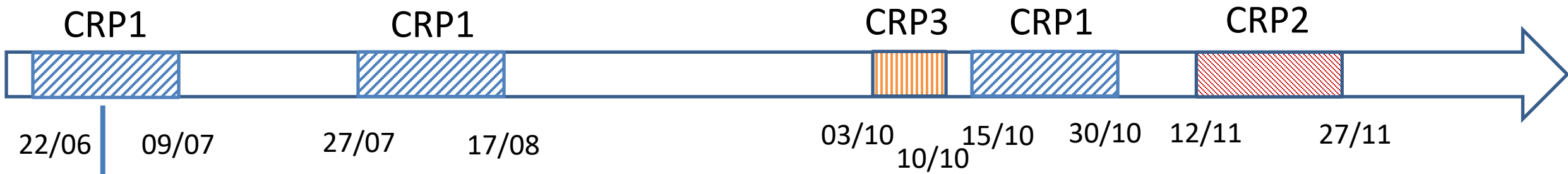
Pt sensors have been added to the 4 corners to give an indication of horizontality and if liquid is between grid and LEMs

2 per corner:
1 just above the grid and the 2nd just below the LEM



All 8 LM are seeing the same amplitude and level changes
The slopes are similar and trend is linear in this range

Cold box tests of CRP from June to November



Initial HV LEM DB
design + Grid

← Liquid argon level regulated using coaxial level meter Regulation using 1 CRP level meter →

Lessons from the cold box tests

Two Upgrades and modifications on CRP were performed after the first 2 cold box tests of CRP1

- The grid tension and HV connection (cf: talk at the September Collaboration meeting)
- The HV distribution to the LEM top and bottom layer

HV operation and operating points of the LEMs

=> 2 interventions needed after the last cold box tests of CRP1 and CRP2

- CRP1: 4 LEMs showed a problem => had to remove them
- CRP2: 1 LEM showed a problem => had to remove them

LEM HV tests in Cold box

- Final configuration of LEM HV distribution (cabling, DBs) available for both CRPs since October.
- Temporary CAEN PS system with limited number of available channels (14 out of 42 needed).
- 6 LEM_TOP HV and 6-8 LEM_BOT HV (LEM groups together).

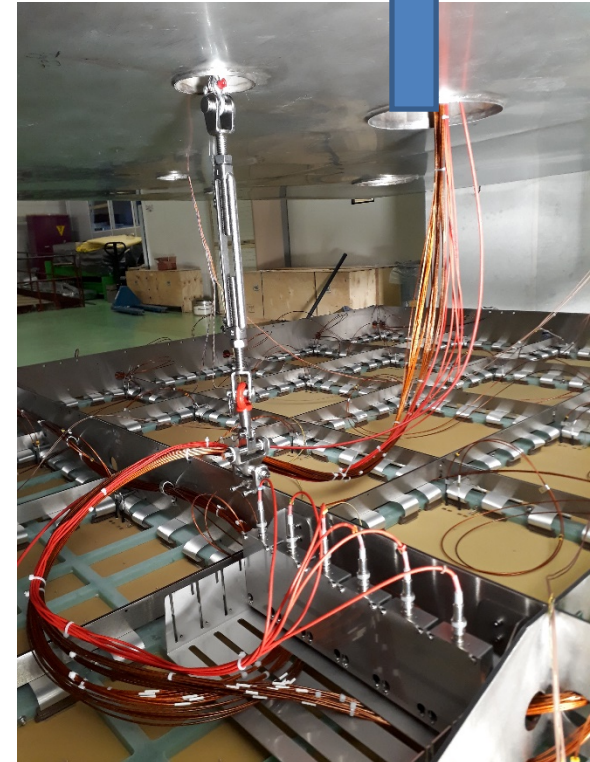
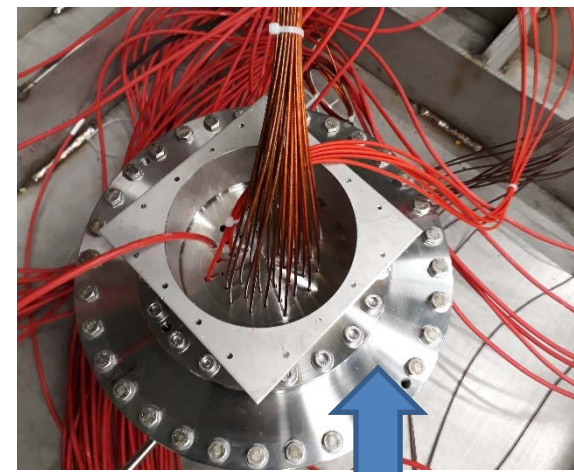
Power supply crate used for the LEMs and grid



Patch panel to distribute the 14 PS channels to the 42 LEM connexions



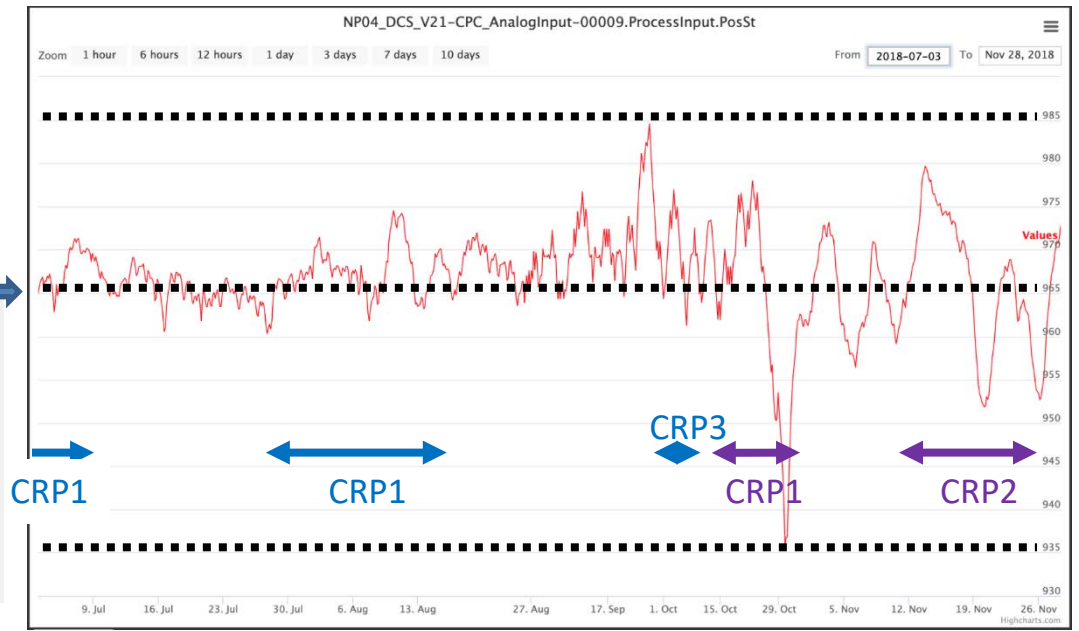
- Basic SC monitoring program (not the one for ProtoDUNE-DP).



LEM HV tests in Cold box

- Ar purity < 100 ppm
- large GAr density variations due to P_{atm} rapid changes.

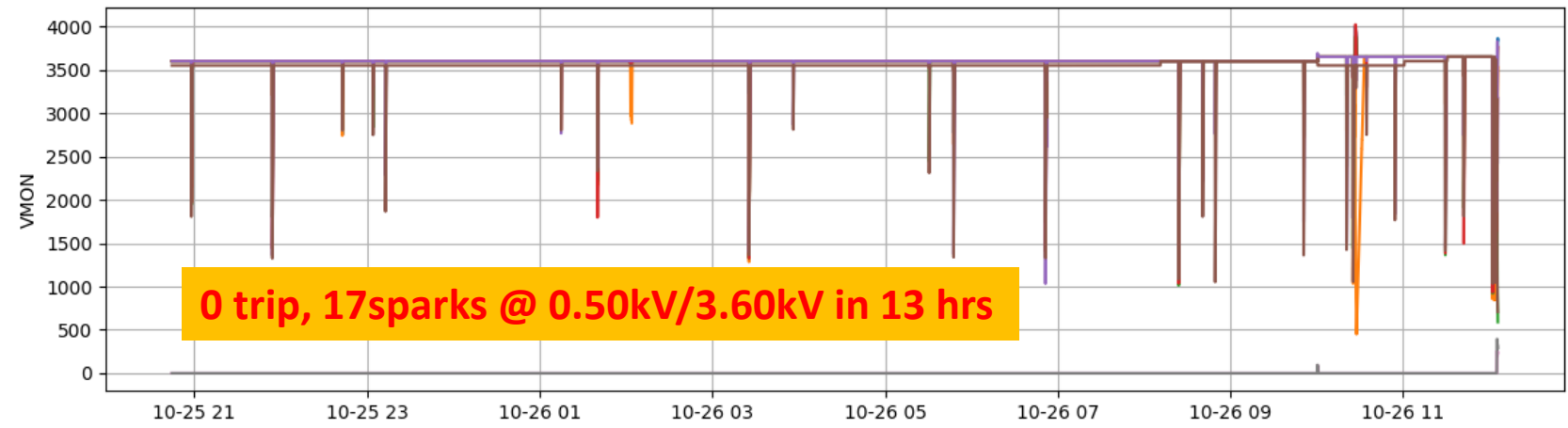
Atmospheric pressure variation during the 5 cold box tests



985 mbar
965 mbar
935 mbar

- CRP1 and CRP2 operated for « long » periods of time at different HV settings with all 36 LEMs powered.
- Exceeding by far LEM operation time with the 311.
- Stable operation conditions reached with ~1 spark/hour per CRP.

CRP1 : $V_{TOP} = 0.50kV$ and $V_{BOT} = 3.60kV$



CRP1 and CRP2 LEM HV Test Results (Oct. – Nov./2018)

- Liquid level in CB stable to within $\sim 250\mu\text{m}$; $T_{\text{LEM}} \sim 91^\circ\text{K}$; $\Delta V_{\text{LEM-GRID}} = 3\text{kV}$

CRP1

V_{TOP} (kV)	V_{BOT} (kV)	E_{LEM} (kV/cm)	Time (h)	Spark Rate (h^{-1})	P_{atm} (mbar)	Estimated G_{eff} (no ch. up)
0.25	3.35	31.0	12	1.3	968 - 972	20
0.50	3.55-3.60	30.5-31.0	13	1.3	962 - 966	24 - 31
0.75	3.70	29.5	42	0.6	943 - 953	20
1.00	3.80	28.0	18	2 trips*	970 - 976	9
1.00	3.85	28.5	12	3 trips	936 - 947	15

* PS TRIP time set too short

CRP2

V_{TOP} (kV)	V_{BOT} (kV)	E_{LEM} (kV/cm)	Time (h)	Spark Rate (h^{-1})	P_{atm} (mbar)	Estimated G_{eff} (no ch. up)
0.10	3.15 – 3.20	30.5 – 31.0	17	0.8	969 - 973	9 - 11
0.25	3.34	30.9	16	1.3	968 – 970	19
0.50	3.55	30.5	11	0.9	957 – 965	24
0.50	3.555	30.55	42	0.5	962 – 964	25

- Effective gain of 20 before charging up within range. Best HV configuration with $V_{\text{TOP}} \sim 0.5\text{kV}$. For larger V_{TOP} values, need to decrease ΔV_{LEM} to achieve stable operation. Not well understood yet.

LEM HV tests in Cold box

- Stable operation achieved over a full CRP for several days (with ~1 spark/hour per CRP (36 LEMs))
- A few LEMs (4 LEMs on CRP1 and 1 LEM on CRP2) suffered suddenly from an uninterrupted series of discharges after several days of stable operation.
- Could not work at desired voltage afterwards. => Dark spots (FR4 carbonization) were observed in some of the corners of the LEMs after CRP removal from CB. **Such discharges can be quickly detected and stopped with an « intelligent » HV monitoring program. Work in progress.**
- **Faulty CRP1 LEMs reconditioned** : FR4 carbonization successfully treated with potassium permanganate. LEMs were then cleaned and successfully tested in Ar @ 3.3 bar at CEA/Irfu.
- **CRP2 LEM replaced by a spare one.**

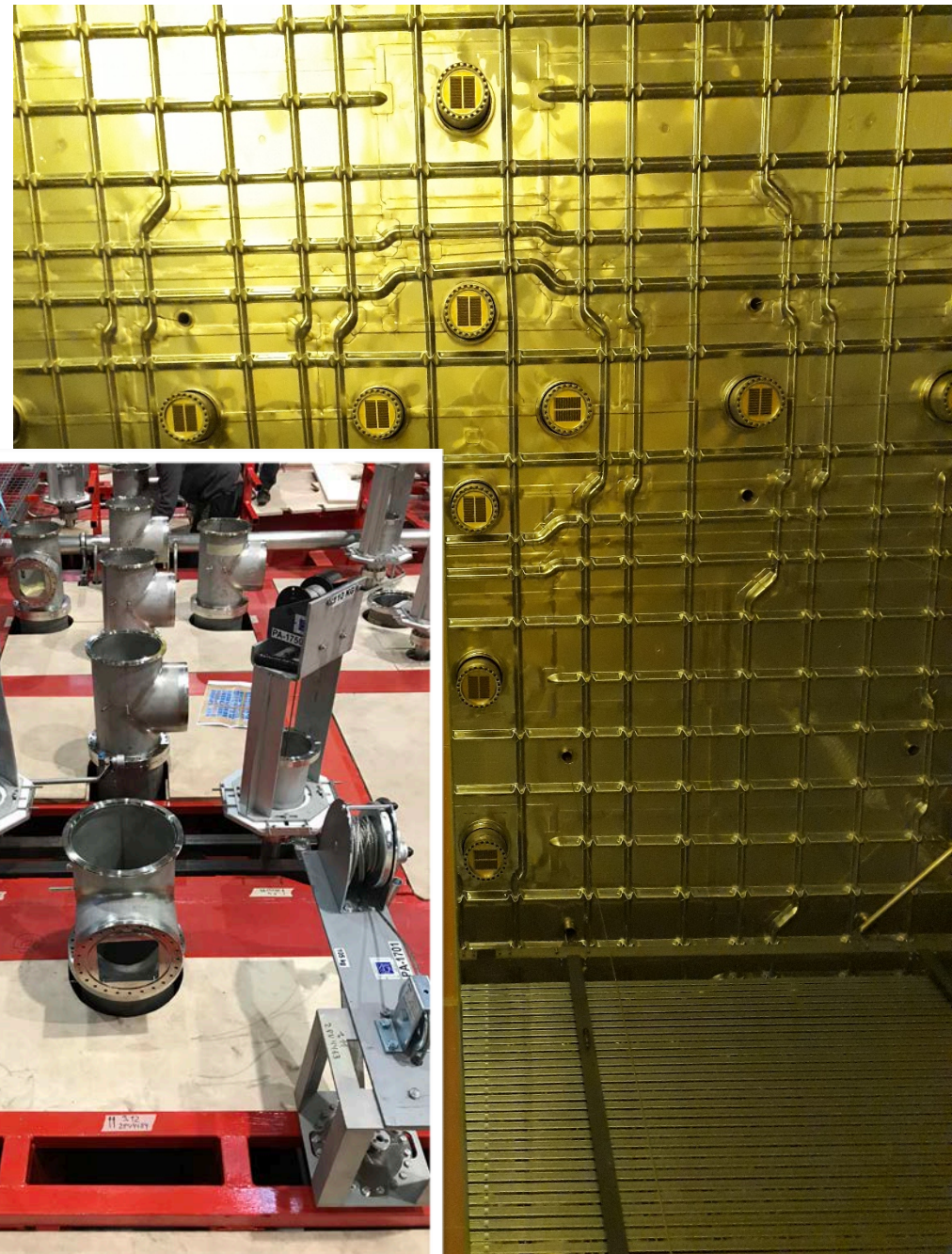
Final test of CRP1 in Cold Box with 36 LEMs is starting.

Signal chimneys

- In the double phase argon TPC all the active electronics is accessible from outside, still being at cold.
- The electronics cards are inserted in a vacuum tight chimney that crosses the cryostat insulation.

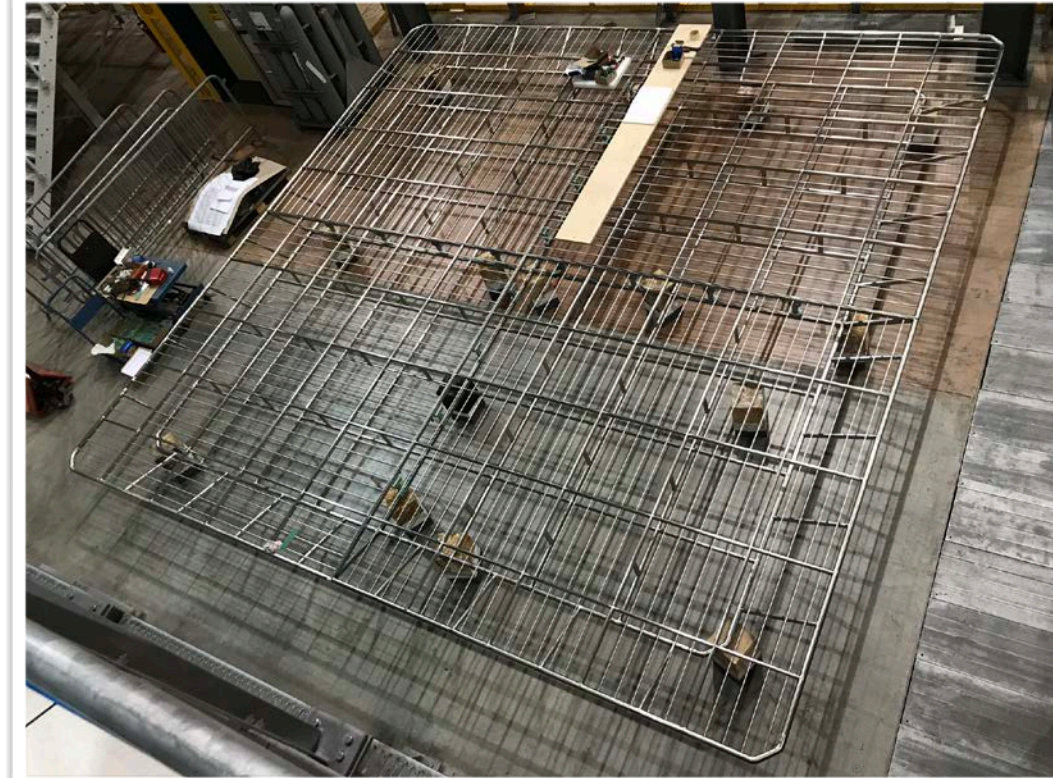
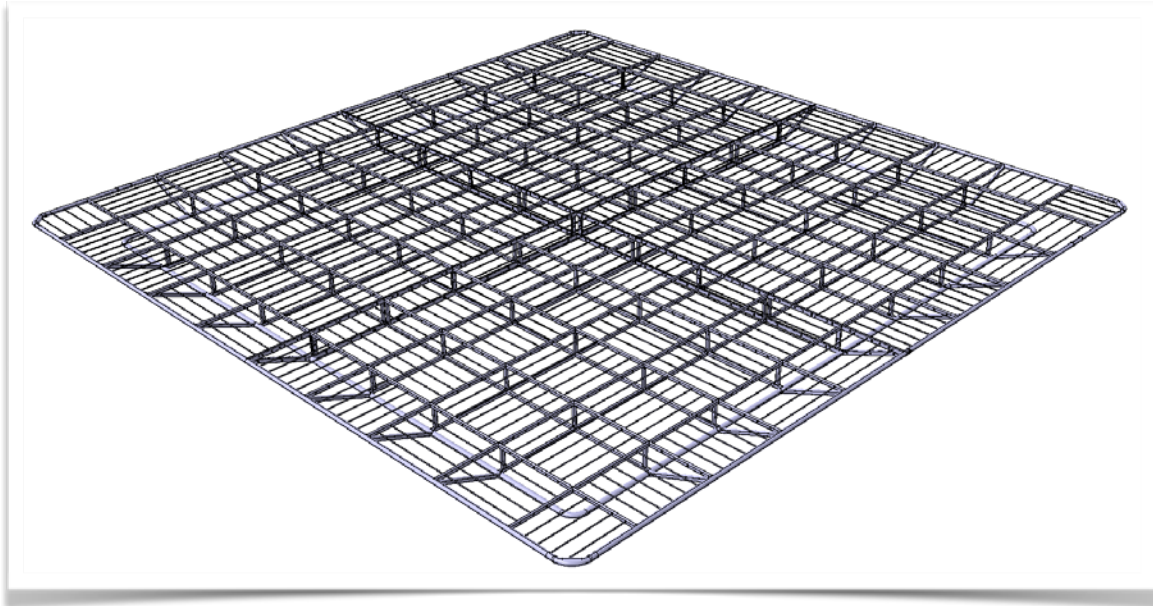
Status:

- All 12 SGFTs completed equipped with blades and cold flanges
- Mechanically and vacuum tested
- Presently installed in their penetration on the roof of NP02
- Insertion of blades and FE cards tested successfully



Cathode module assembly in EHN1

- Cathode will be powered at -300 kV.
- Composed by 4 identical sections mechanically assembled together during installation.
- Electrically the 4 parts are connected via damping resistors.
- 6 m x 6 m cathode is held only at the edges (scalable concept).



Status:

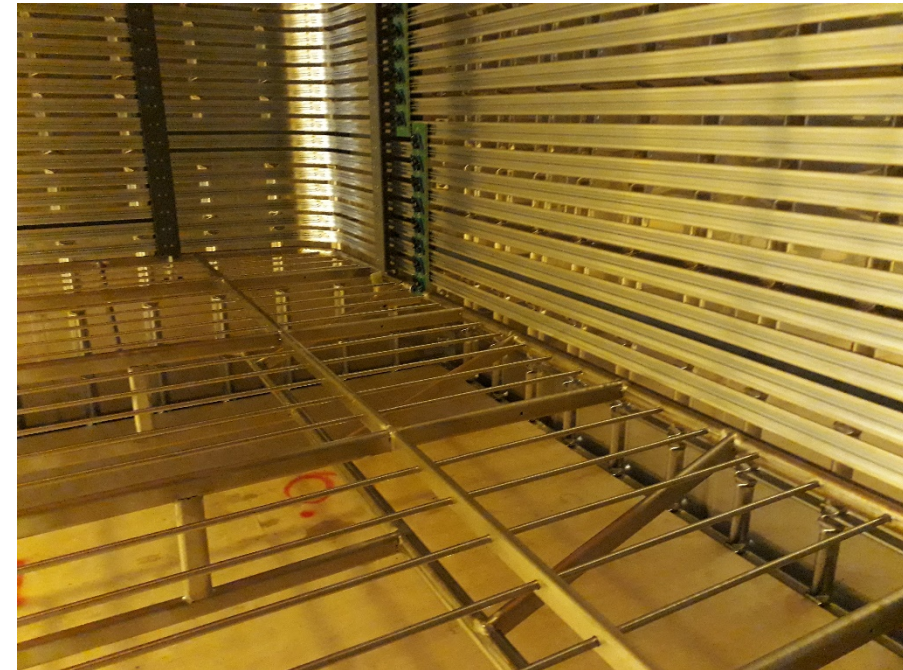
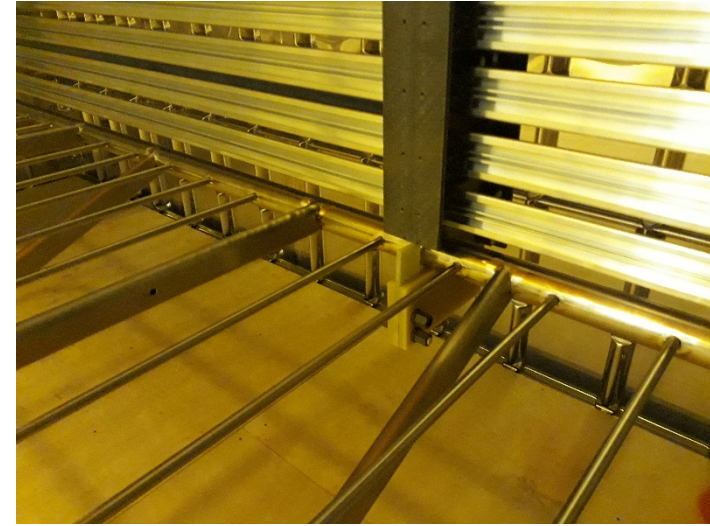
- All four modules completed
- Mechanical trial assembly completed
- Cleaned and ready to be installed

Cathode module assembly in EHN1

Test of installation and connection of 1 module to the field cage



Dec 6th 2018



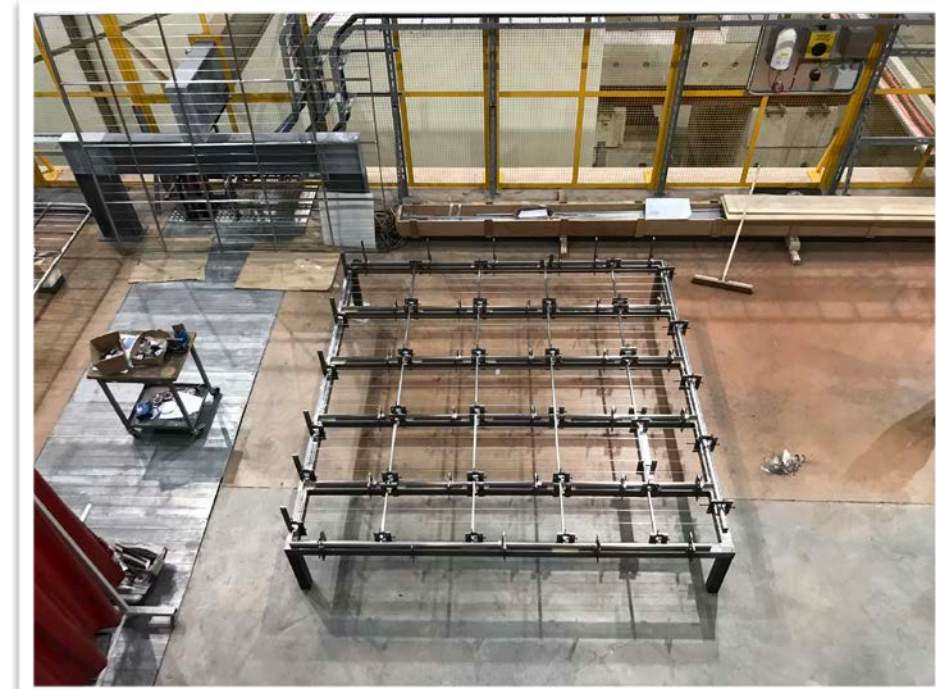
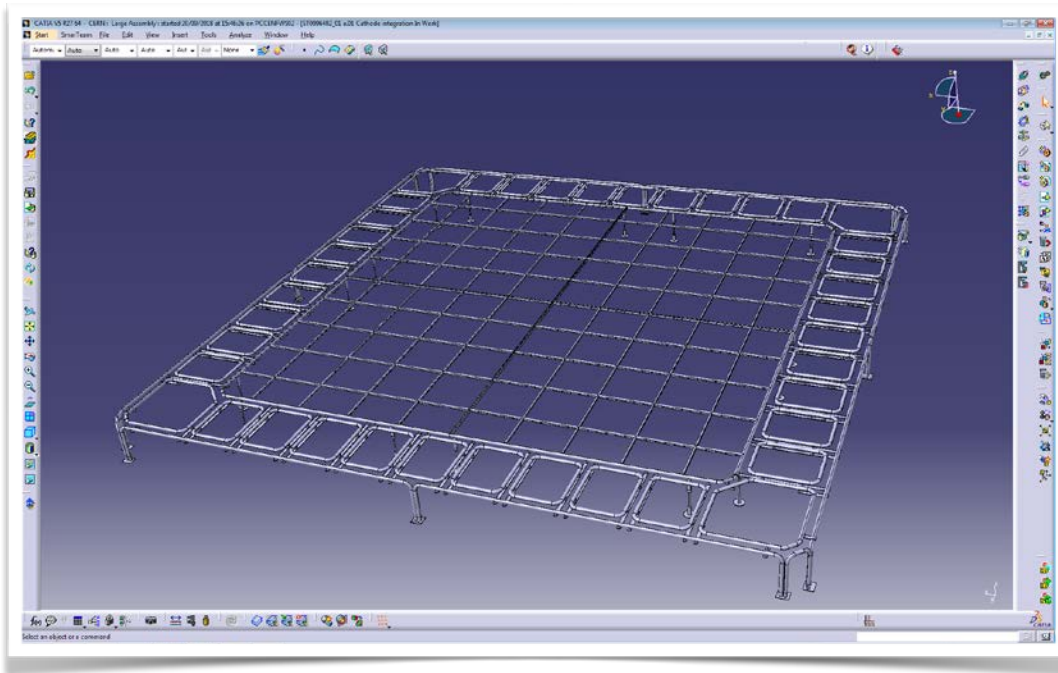
Ground grid module assembly in EHN1

Ground grid (for PMT protection) has the same construction philosophy as the cathode

It consists of:

- 4 3x3 m² identical modules put together inside the cryostat
- Additional smaller modules to protect the periphery

All is resting on the cryostat floor



Status:

- Welding ongoing at EHN1: two of the four large modules completed.
 - Complete the four large modules before the end of the year
- Last large object to be inserted into the cryostat

Summary:

- 3 CRPs are constructed and the last one will be completed in January.
- Several modifications and upgrades have been implemented on the CRP after the various cold box tests
- CRP1 and CRP2 LEM HV have been studied in details defining the operational characteristics in the cold box condition
- Grid design and nominal performance have been reached and validated for the constructed CRPs
- The cold box is operating in an efficient way with a reasonable turn around (CRP1, CRP2, CRP3); The sequence of operation is well defined and can be set up rather rapidly.
- Electronics and DAQ are ready and tested. FE installation in January (cf: September DUNE meeting)
- The foreseen goal for ProtoDUNE-DP assembly in cryostat is :
 - Install the 4 CRPs in the cryostat by the end of January
 - Install the cathode, ground grid modules, the photomultipliers in the following month
 - Start the TCO closure mid March