ProtoDUNE-DP Commissioning and Operations

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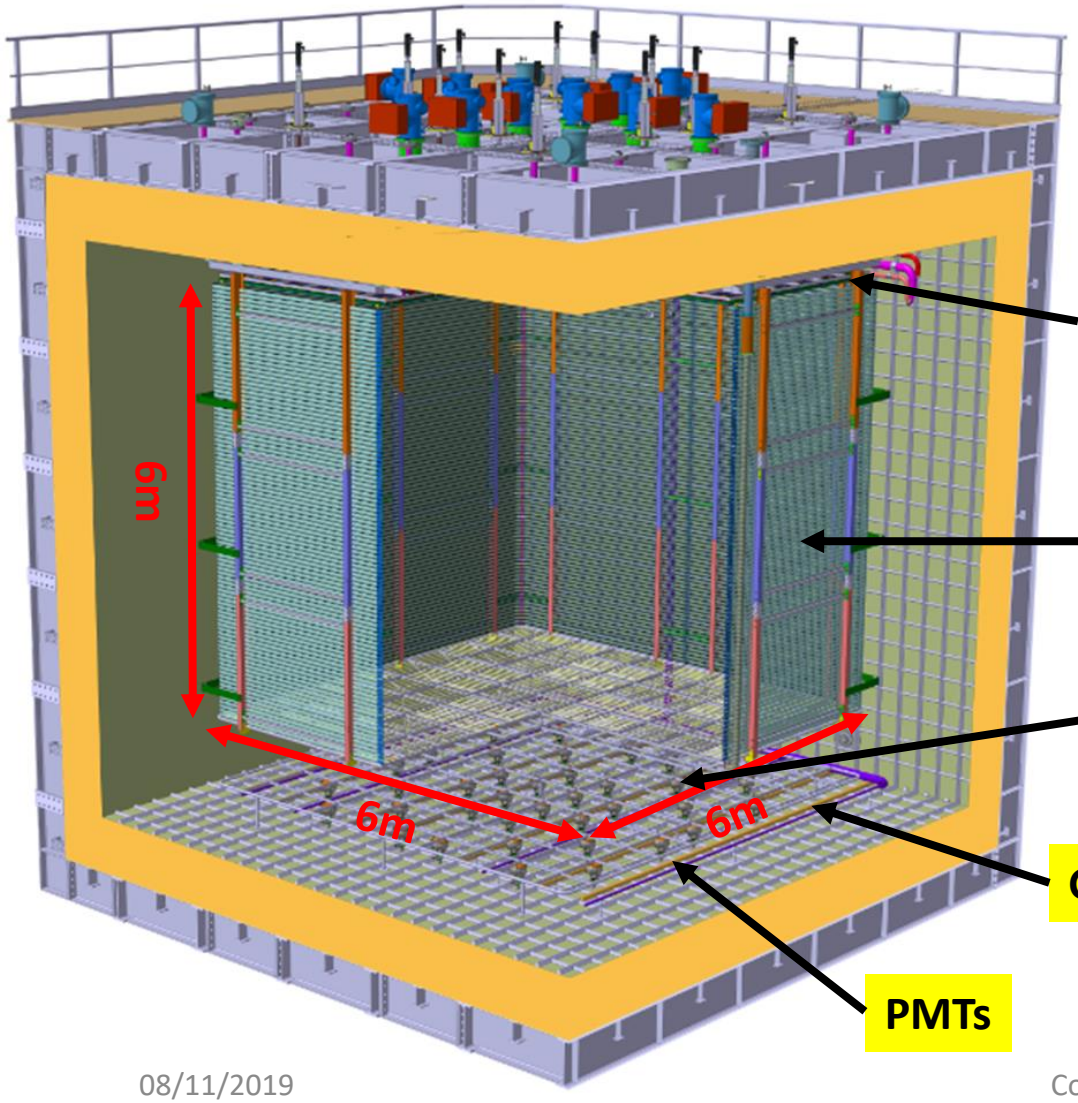
ProtoDUNE-DP



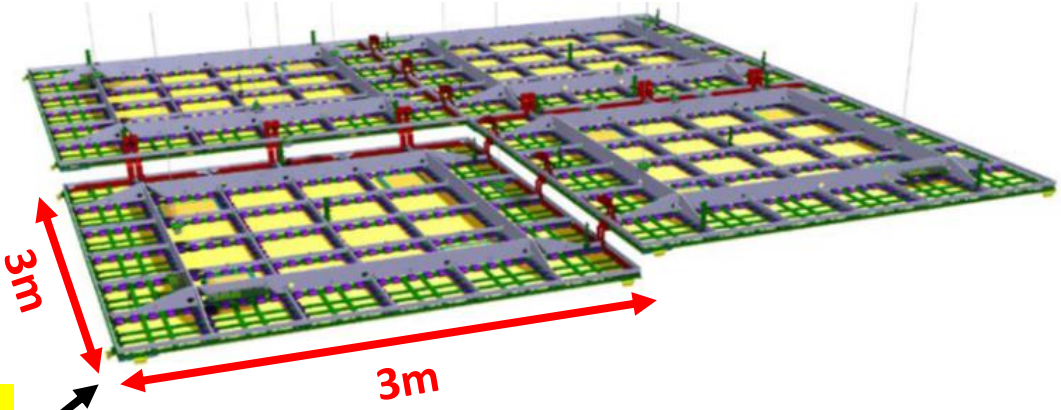
Charge Readout Planes (CRP)

Field Cage

Cathode

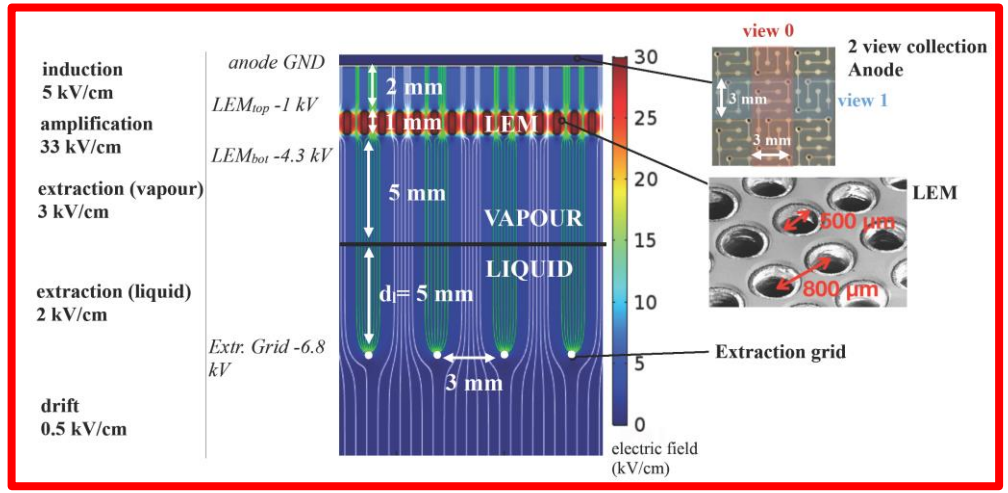
Ground Grid

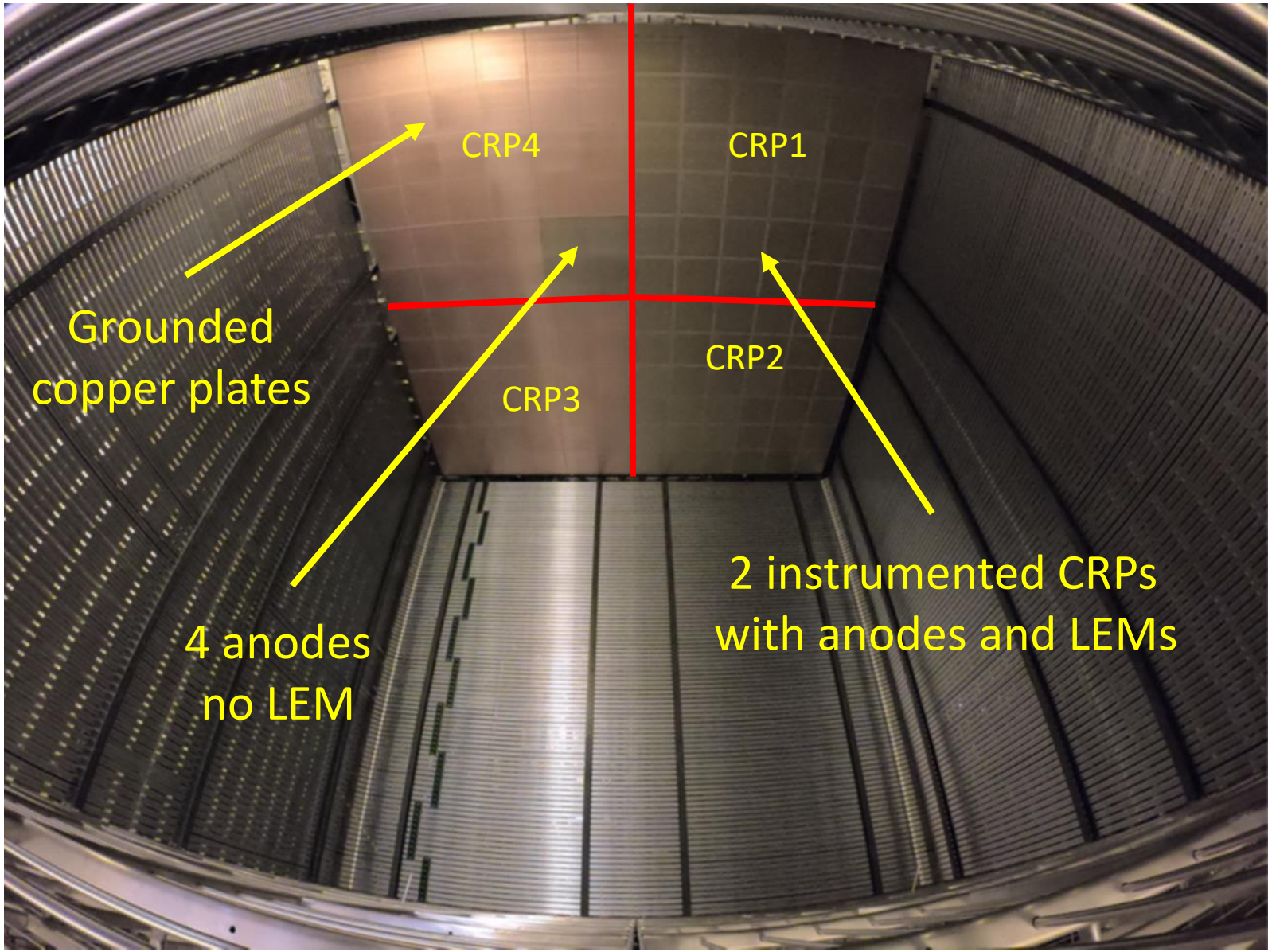
PMTs



1 CRP = 36 Anodes + 36 LEMs (50×50 cm²) + 3×3 m² Extraction Grid

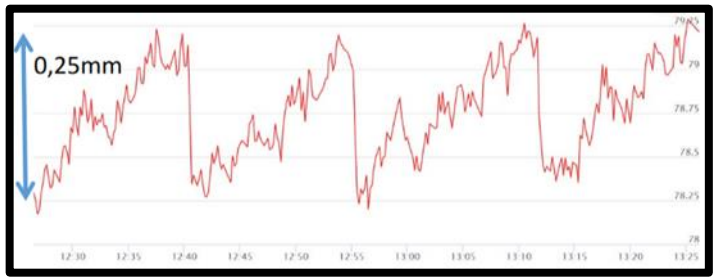
Dual phase principle




CRP4
CRP1
CRP3
CRP2
Grounded
copper plates
4 anodes
no LEM
2 instrumented CRPs
with anodes and LEMs

Activities since last DUNE Collaboration Meeting

- Data taking of cosmics until Oct. 3rd with LEM ΔV up to 3.2kV and high extraction efficiency (V_{GRID} : 5.5 – 6.5kV, tested up to 7.5kV) :
  - Use of CRP automatic tracking of LAr level.
  - Achieve low electronic noise : ~1.5 ADC, dominated by coherent noise.
  - Smooth DAQ operation: 1.2M events over 4ms drift time and ~135 TB collected since 29/08, data transferred to FNAL.



- Since October, main effort in looking for stable LAr surface conditions (no bubbles) and keeping the detector at the same pressure in order to establish long duration and stable operation conditions.

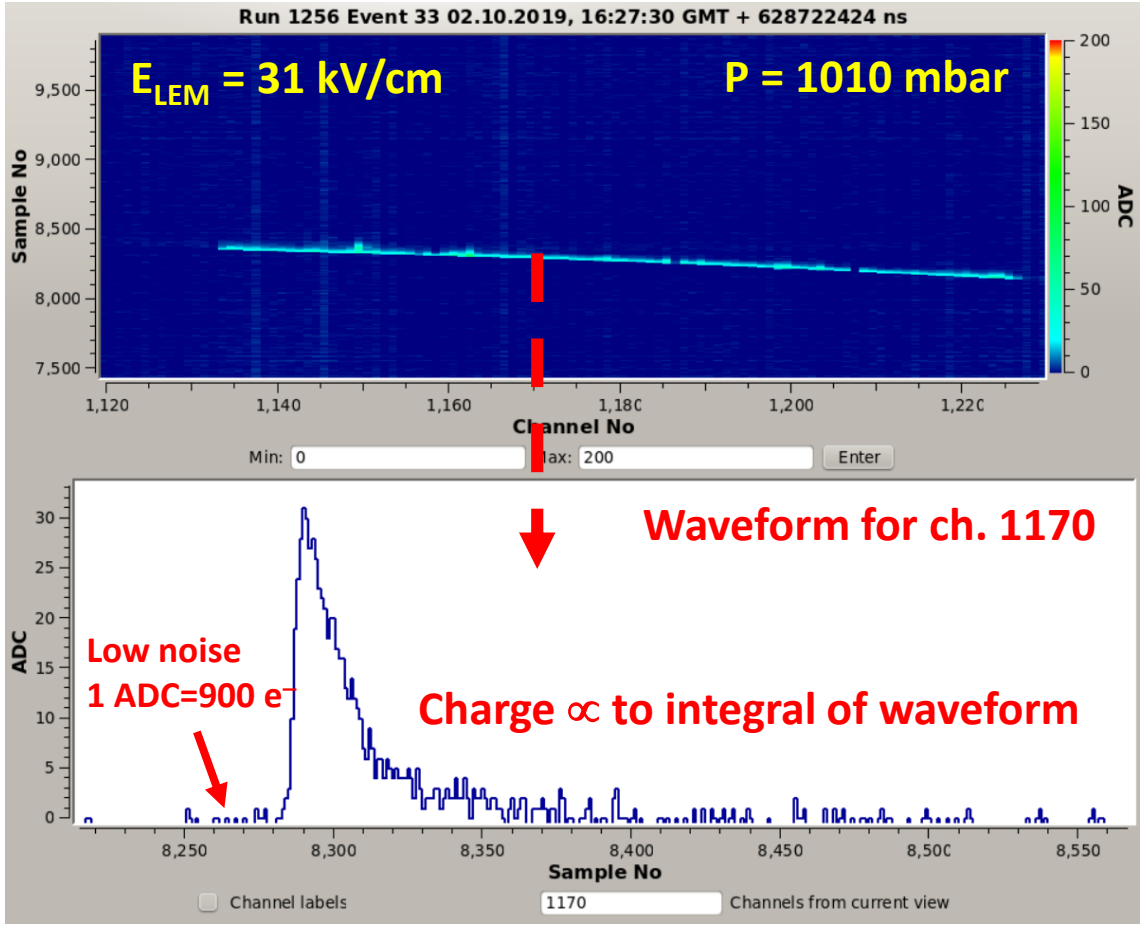
  ⇒ *Necessary condition to perform long-term HV stability tests of CRPs*

- Effort also in HV stability studies of LEMs and Grids mitigated by frequent appearance of bubbles on liquid surface and by necessary cryogenic operations to clean clogged recirculation filter.

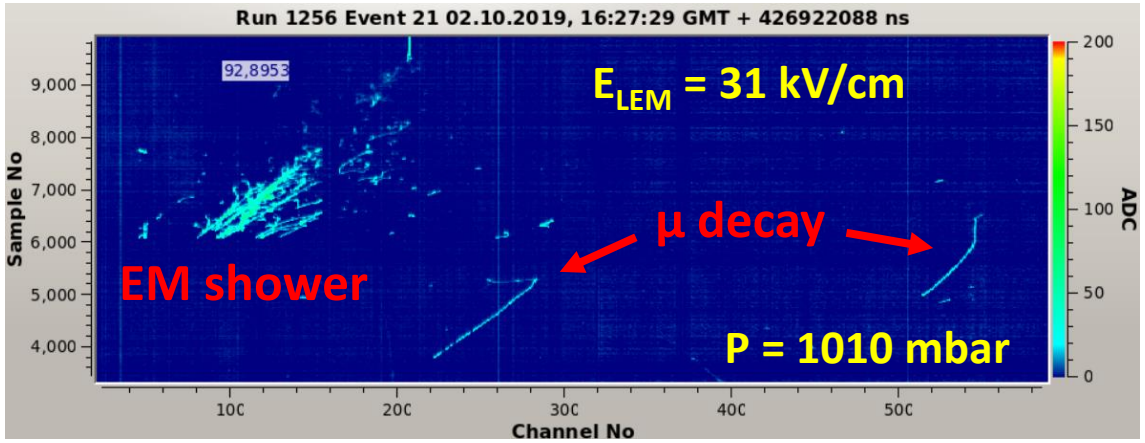
  LAr surface with ripples (no bubbles) can also affect HV operation of Grids and LEMs (sporadic sparks).

Event Gallery

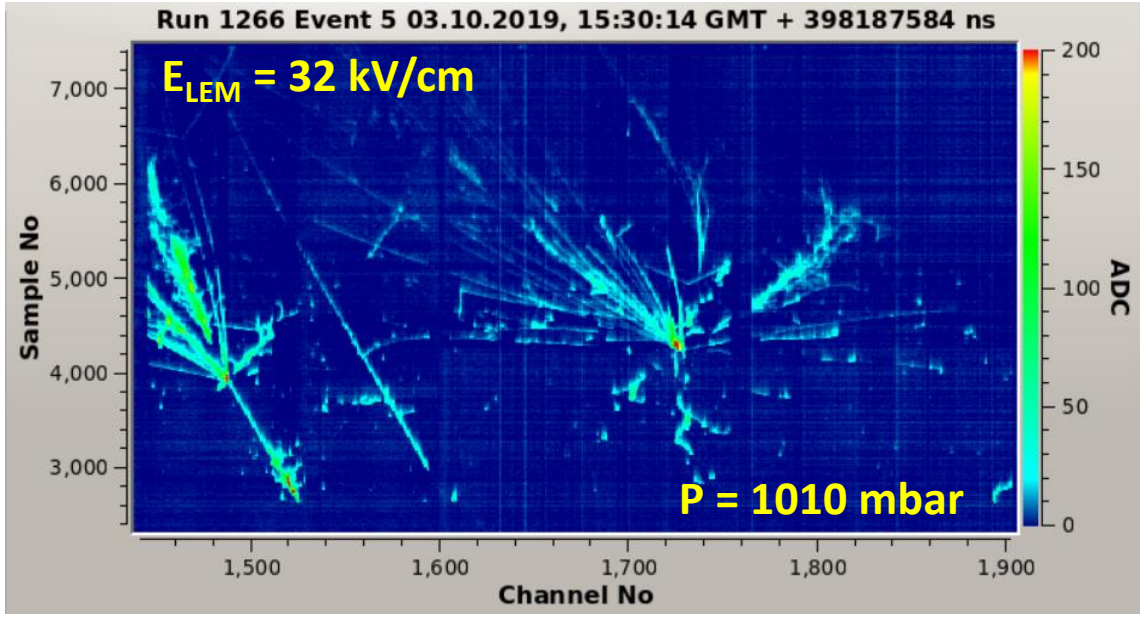
Horizontal muon track



Electromagnetic shower + two muon decays



Multiple hadronic interactions in a shower



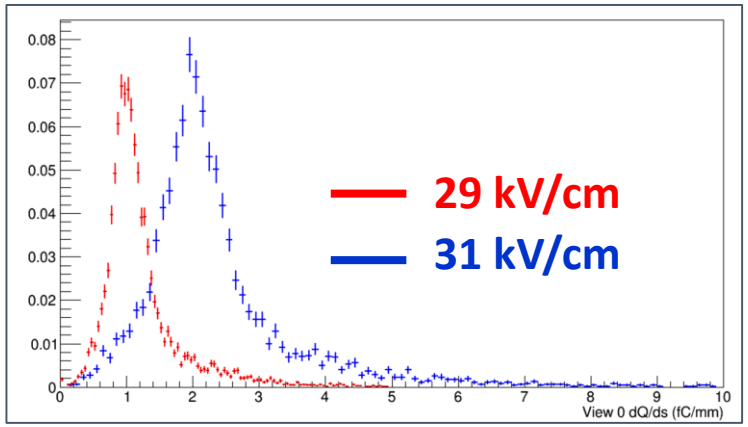
LEM + GRID operation

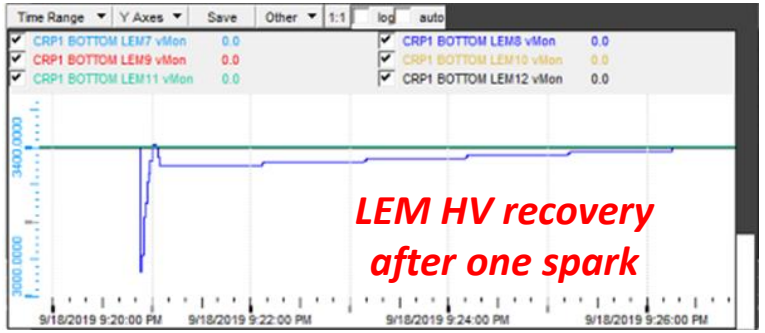
- ΔV_{LEM} @ 2.9, 3.0, 3.1, 3.2kV and 3.3kV
  - G_{eff} (2.9 kV) : ~ 2 @ 1045 mbar (V_{GRID} = 6 kV)
  - R_G (3.0 kV / 2.9 kV) = 1.4 (expected 1.3)
  - R_G (3.1 kV / 2.9 kV) = 2.0 (expected 1.8)
  - LEM gain @ ΔV_{LEM} = 3.2 kV : ~8

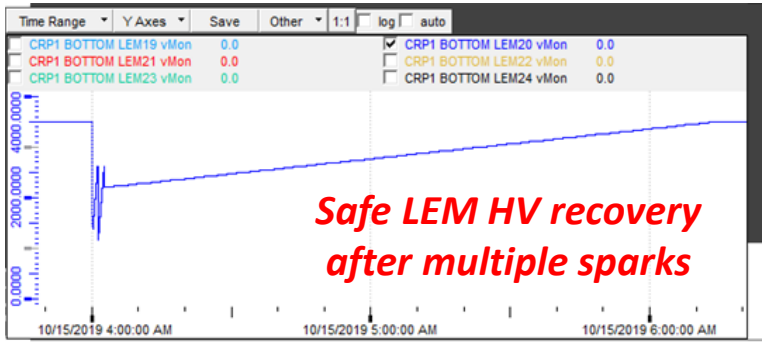
LEM charging up not complete

- Spark rates @ ΔV_{LEM} = 2.9 kV :
  - Cathode OFF : < 0.05/h per CRP
  - Cathode ON : 0.4/h per CRP
- Aim at ~ 1 spark/h per CRP at higher gain.
- Automatic recovery of LEM HV after a spark :
  - Avoid power supply trips
  - Safe operation of LEMs

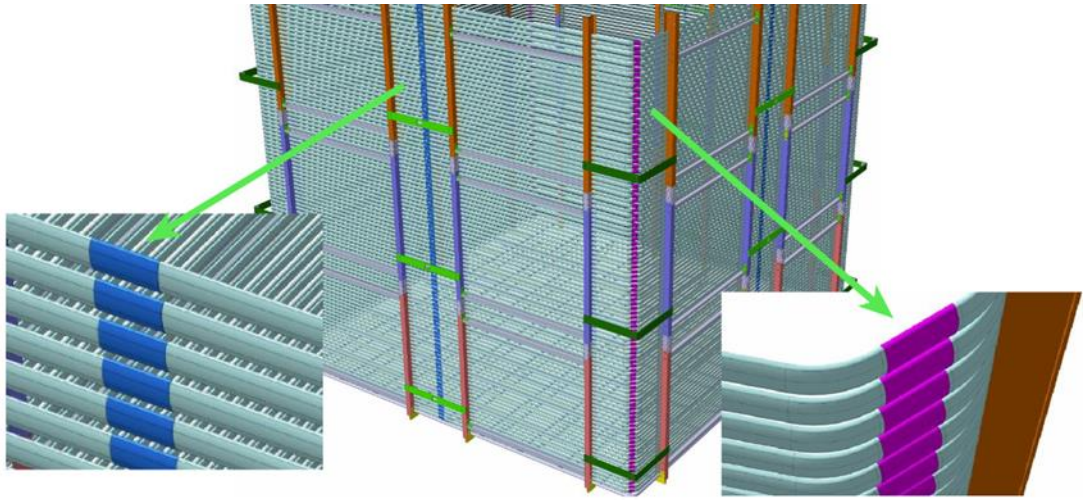
dQ/dx in one of the two collection views



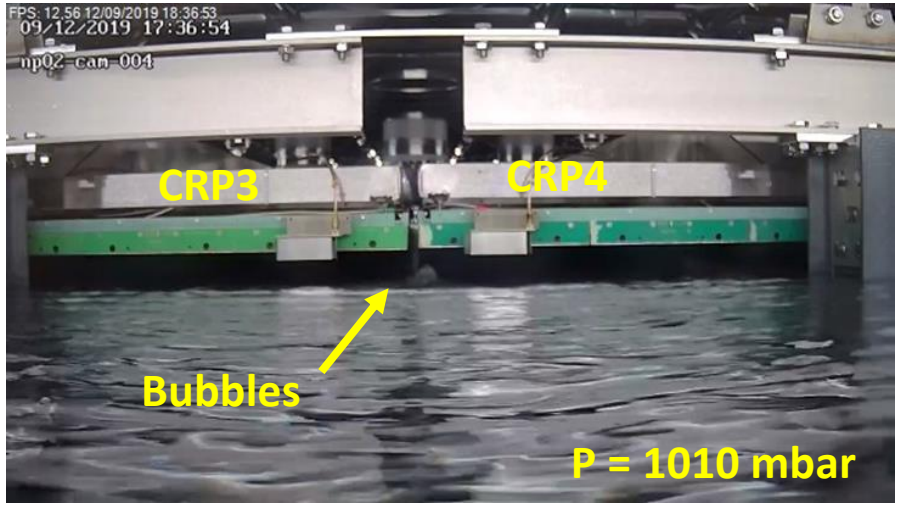


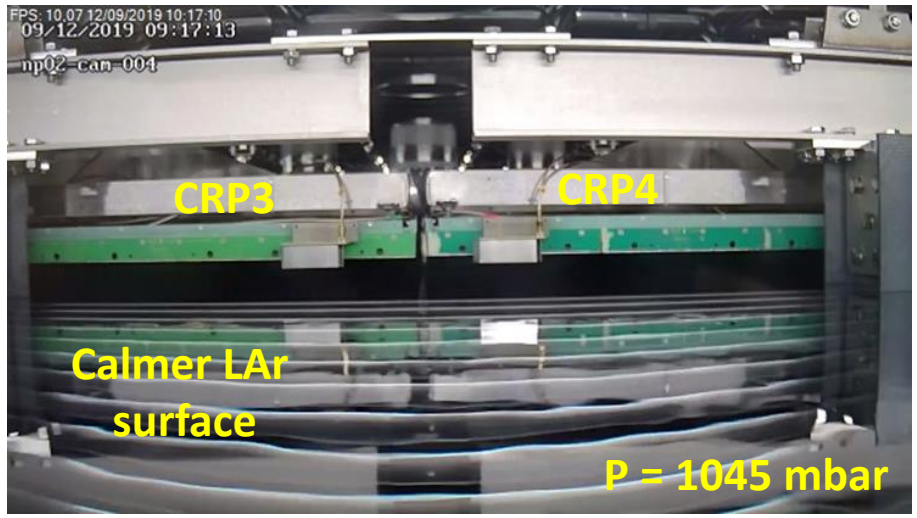


- Origin of the bubbles not well understood yet.
- Bubbles are created over a large surface inside the first profile ring(s) of the field cage.
- Bubbles are trapped inside the top part of the C-shape profile.
- Bubbles exit from the clips connecting two profiles.
- Linked to hydrostatic pressure. Increase of cryostat pressure (> 30mbar for 1/2h to a few hours) stops bubbles for some time.



Bubbles may also exit from the FC corners but no camera there.





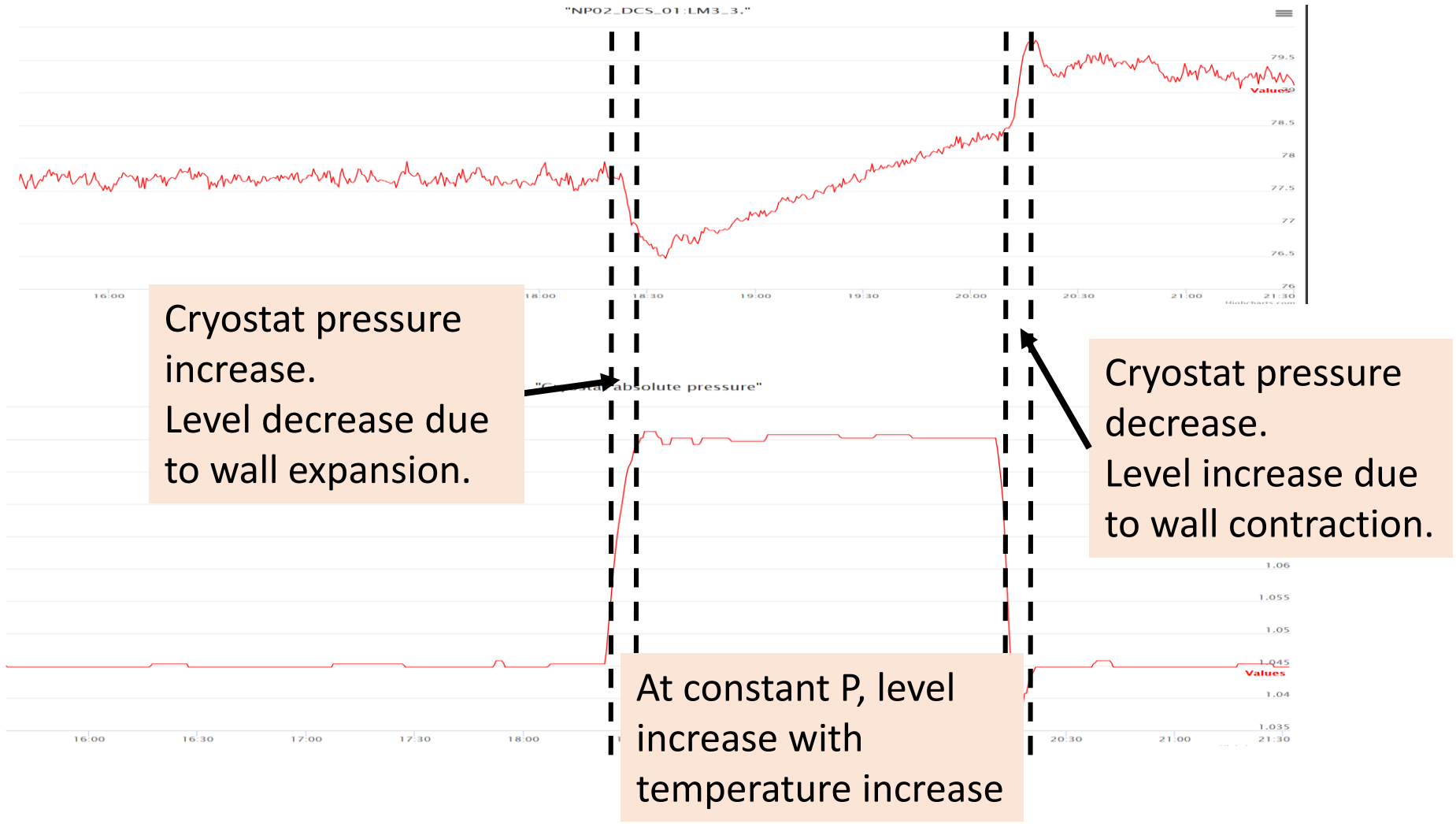
More on bubbles

- Bubbles temporarily disappear by increasing the pressure (35 mbar).
- By keeping high pressure (high pressure cycles) the quality of the surface gets worse after a few hours. Field cage bubbles reappear after two days if the pressure is kept high.
- Bubbles popping up from the middle of the field cage sides create most of the LAr surface waves or ripples. Not possible to operate the CRPs in presence of the field cage bubbles.
- Even when these bubbles from the field cage disappear, there are other bubbles present in places we see (e.g. HV feedthrough) and in places which are not in the cameras views.
- These additional bubbles create ripples and waves on the surface. They are compatible with the operation of the detector but create sporadic perturbations and grid sparks which can damage the electronics.
- On some temperature probes we see from time to time projections of LAr. On the surface we see from time to time floating residues of other bubbles which popped out at the borders of the cryostat.
- Bubbles from the HV feedthrough have practically constant production rate, independently of other conditions, of 1 bubble/2.5s corresponding to about 8W.

Short High Pressure Cycle

LAr level

Pressure

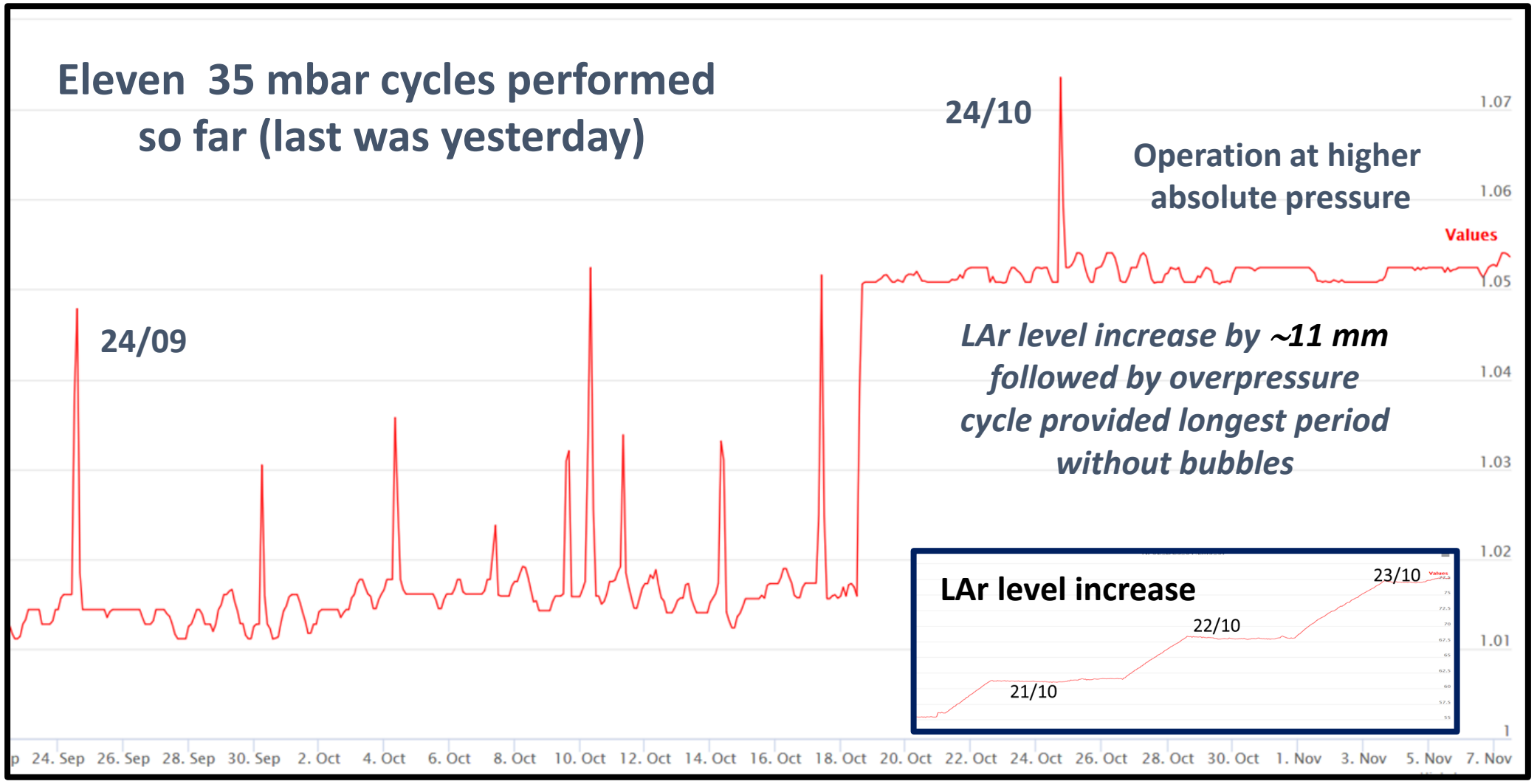


Cryostat pressure increase.
Level decrease due to wall expansion.

Cryostat pressure decrease.
Level increase due to wall contraction.

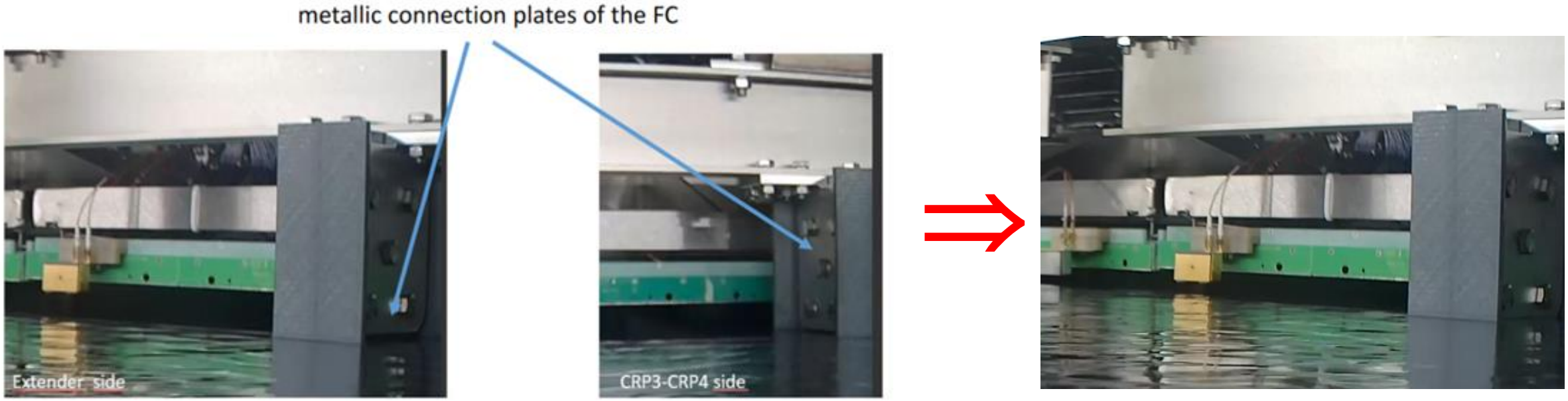
At constant P, level increase with temperature increase

Short High Pressure Cycles



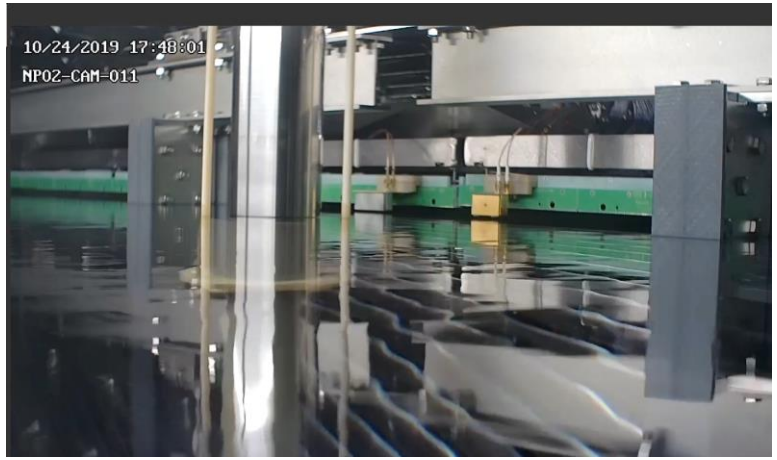
LAr level increase (21/10 – 23/10)

- Put the liquid in contact with the metallic connection plates of the FC vertical support.
- Check if bubbles disappear after some time due to reduction of temperature gradient in the gas phase and/or in the field cage supports.

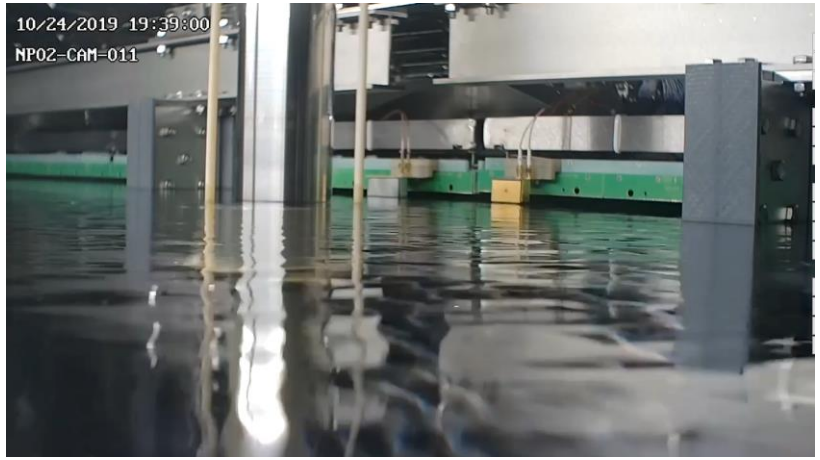


- Pressure reduction inside cryostat insulation to reduce heat input to be tested with this LAr level.

Overpressure cycle on 24/10

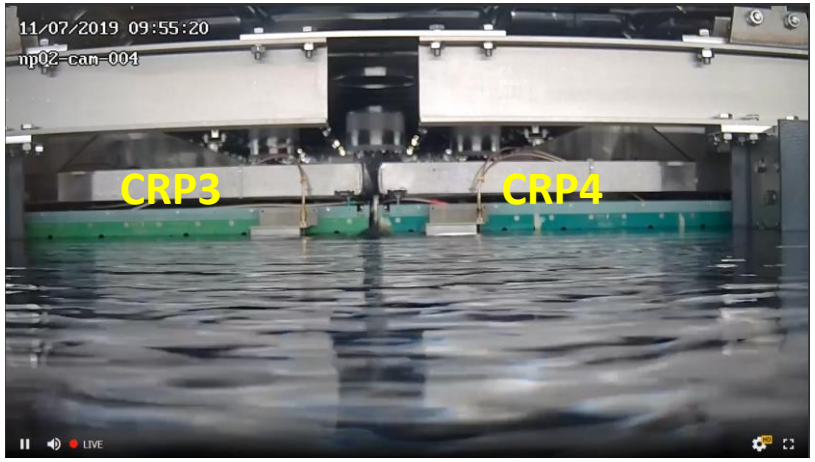


At the end of the overpressure cycle on 24/10

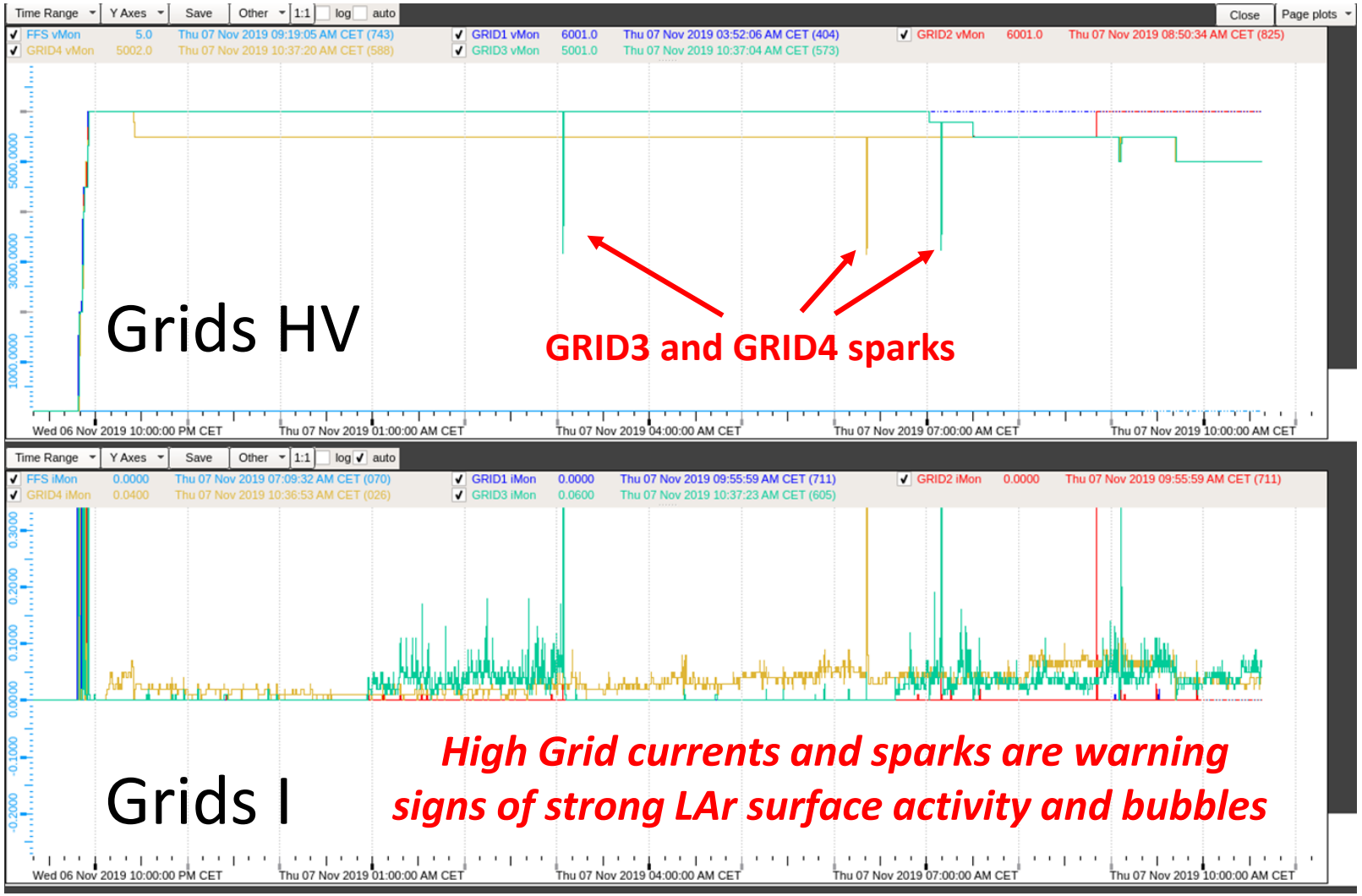


On 06/11 : still no bubbles

On 07/11 during filter bypass operation



Filter cleaning operation on Nov. 7th



LEMs and GRIDs HV stability

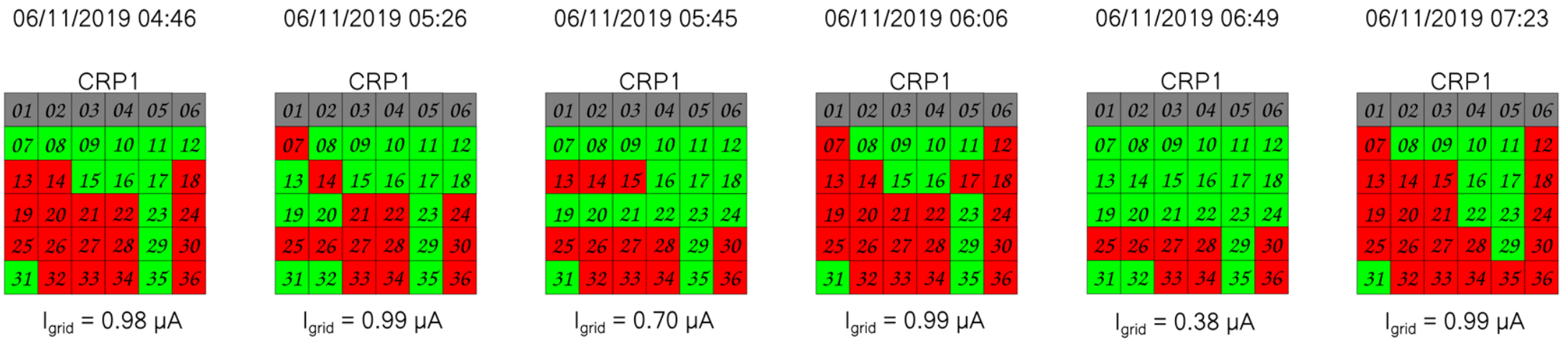
Spark

No spark

No field across LEMs

CRP1 LEM sparks @ ΔV_{LEM} = 3.2kV

Number of LEM sparking increases with Grid current

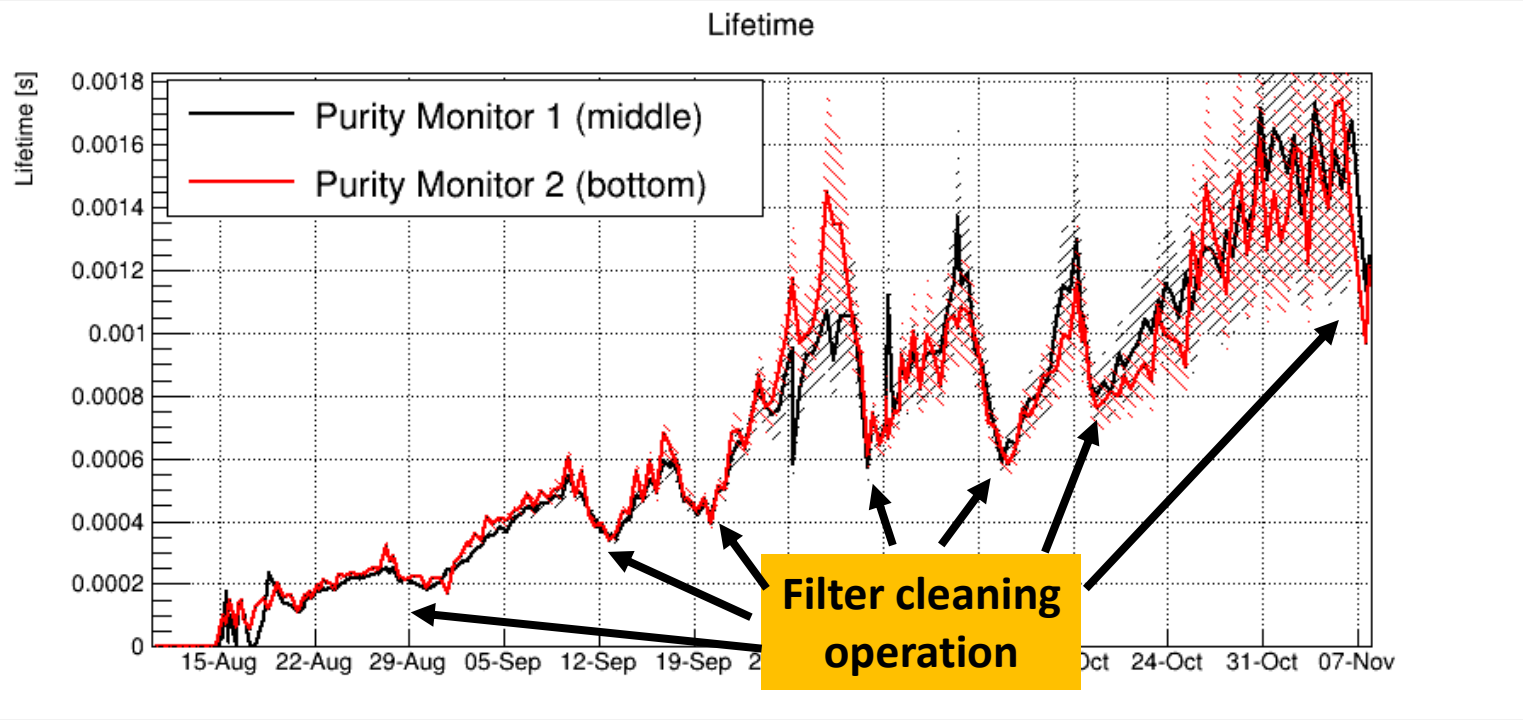


e.g. 9 Grid1 and 166 LEM sparks in 4 days (ΔV_{LEM} : 3.0 – 3.2kV) mostly associated with Grid sparks. LEM alone spark rates < 1/hr per CRP.

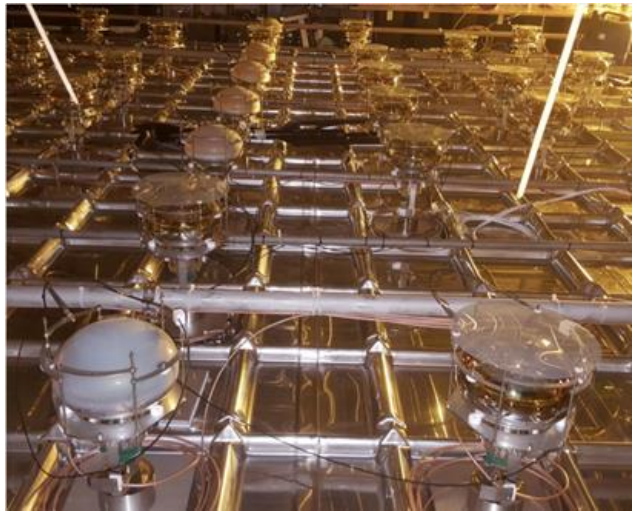
Important to disentangle contributions to sparks from LEMs, Grids and from ripples on LAr surface

Liquid Argon Purity

- LAr purity monitored so far by two 17 cm long PMs located at the bottom of the cryostat and in the middle.
- Recirculation improves e^- lifetime by factor 2.7 every ~4.5 days (1 volume recirculated).
- LAr purity limited so far to about 1.5 ms e^- lifetime by several filter clogging and cleaning operations.
- Lifetime consistent with track attenuation measurements.

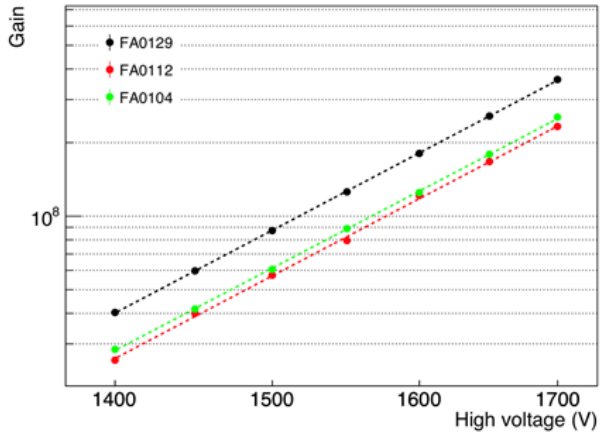


Photon Detection System (PDS)

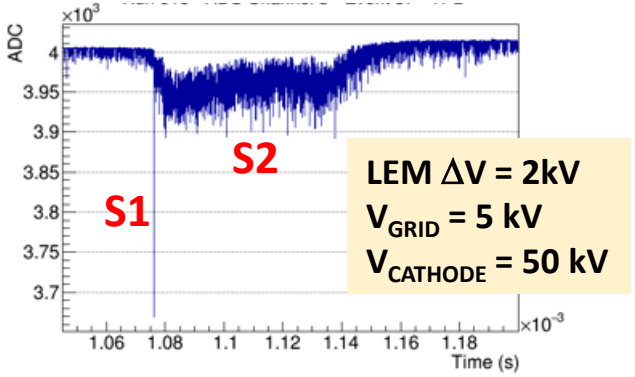


- All 36 PMTs operational. Low noise.
- Daily PDS data taking and calibrations.
- PEN/TPB : ~20-30% in S1 signal amplitude.
- All PMTs see S2 electroluminescence signal produced in gas phase.
- Fit of slow component (τ_{slow}) is a LAr purity indicator.

Gain -vs- HV calibration

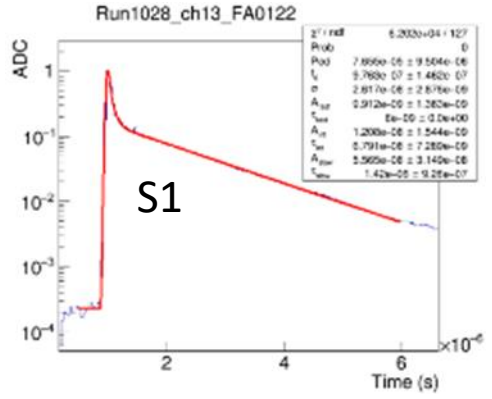


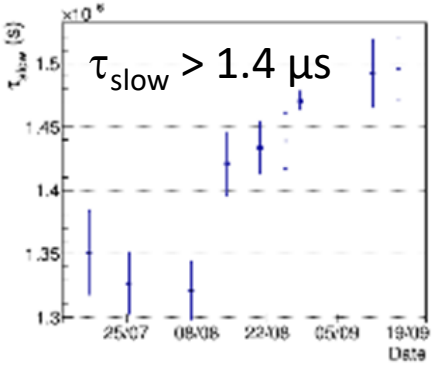
First electroluminescence signals



LEM ΔV = 2kV
V_{GRID} = 5 kV
$V_{CATHODE}$ = 50 kV

Scintillation light profiles from cosmic muons





CRTs

- CRTs installed on opposite sides of the cryostat and defining a downward angle.
- Commissioning should start in about a week.

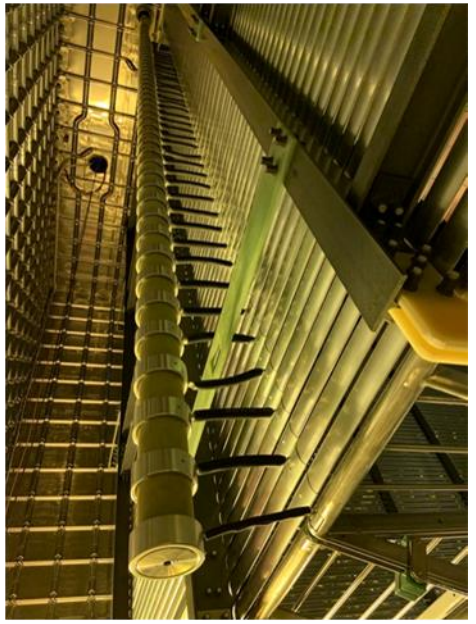
Next … until end of the year

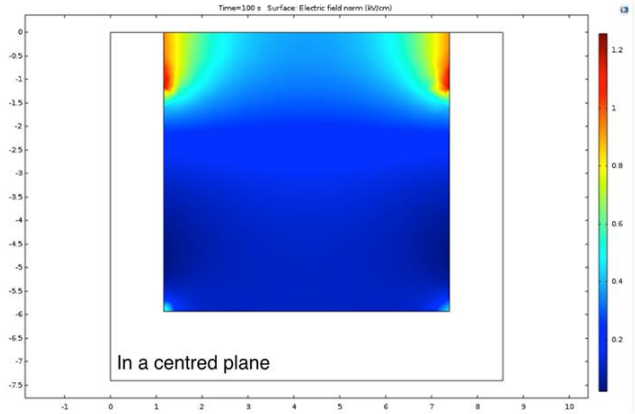
- Reduce pressure by 300 mbar inside cryostat insulation to hopefully have calmer LAr surface and for longer periods of time.
- Resume CRP HV stability tests with Cathode OFF and ON.
- Data taking with random and cosmic triggers (lifetime > 1.5 ms).
- Increase LEM amplification.
- Investigate ion feedback effects.

Backup slide(s)

VHV and Drift Field

- Cathode foreseen to operate at 300 kV.
- However on Aug. 11th, during ramping up a PS trip occured at 250 kV due to a short between the first equipotential ring connected to the FC and the extender inner conductor.
- Very likely due to a crack inside the vetronite surrounding the HV inner connector.
- Located at about 1.2 m drift distance.
- Maximum operation voltage is 150 kV.
- At 120 kV, nominal field of 500 V/cm can be obtained in the upper part of the TPC. Longer drifts are possible.
- Can possibly be repaired, but intervention is delicate.





E-field simulation