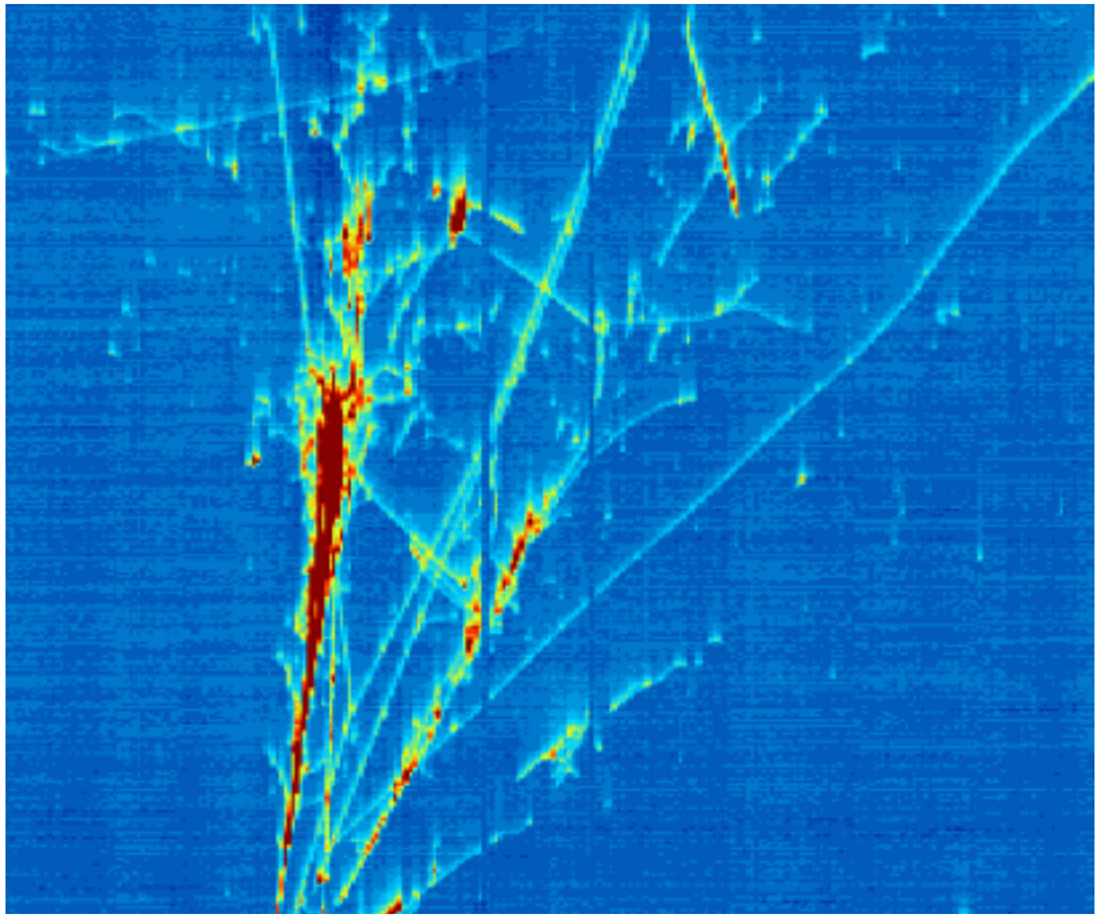


3x1x1 results obtained so far

Laura Manenti and Laura Molina Bueno

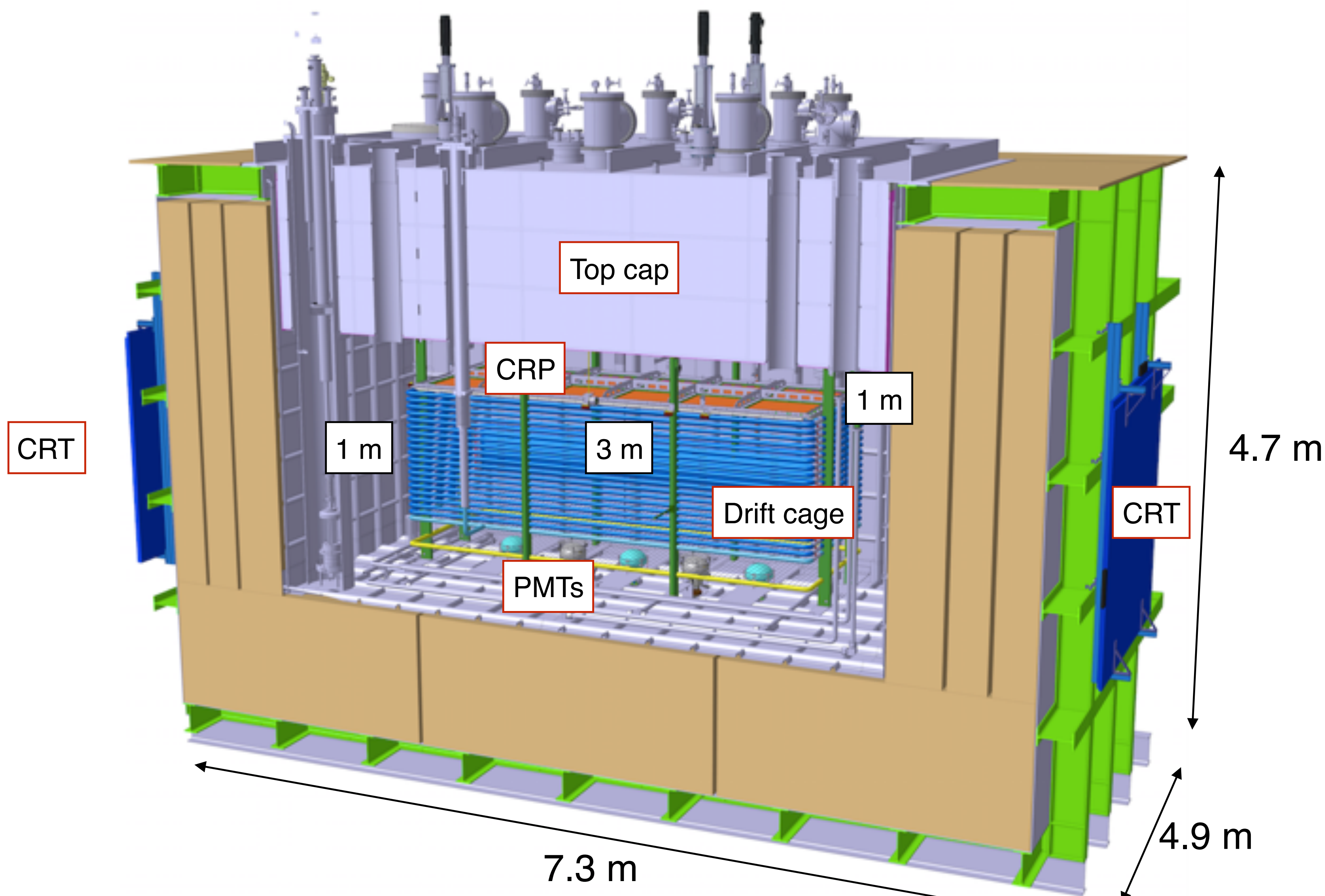
Outline

- Introduction to the WA105 3x1x1 detector
- Deliverables of the 3x1x1
- Results achieved

Goal/purpose:

DP TPC technology works at large scale

311 detector served as test bench for protoDUNE-DP



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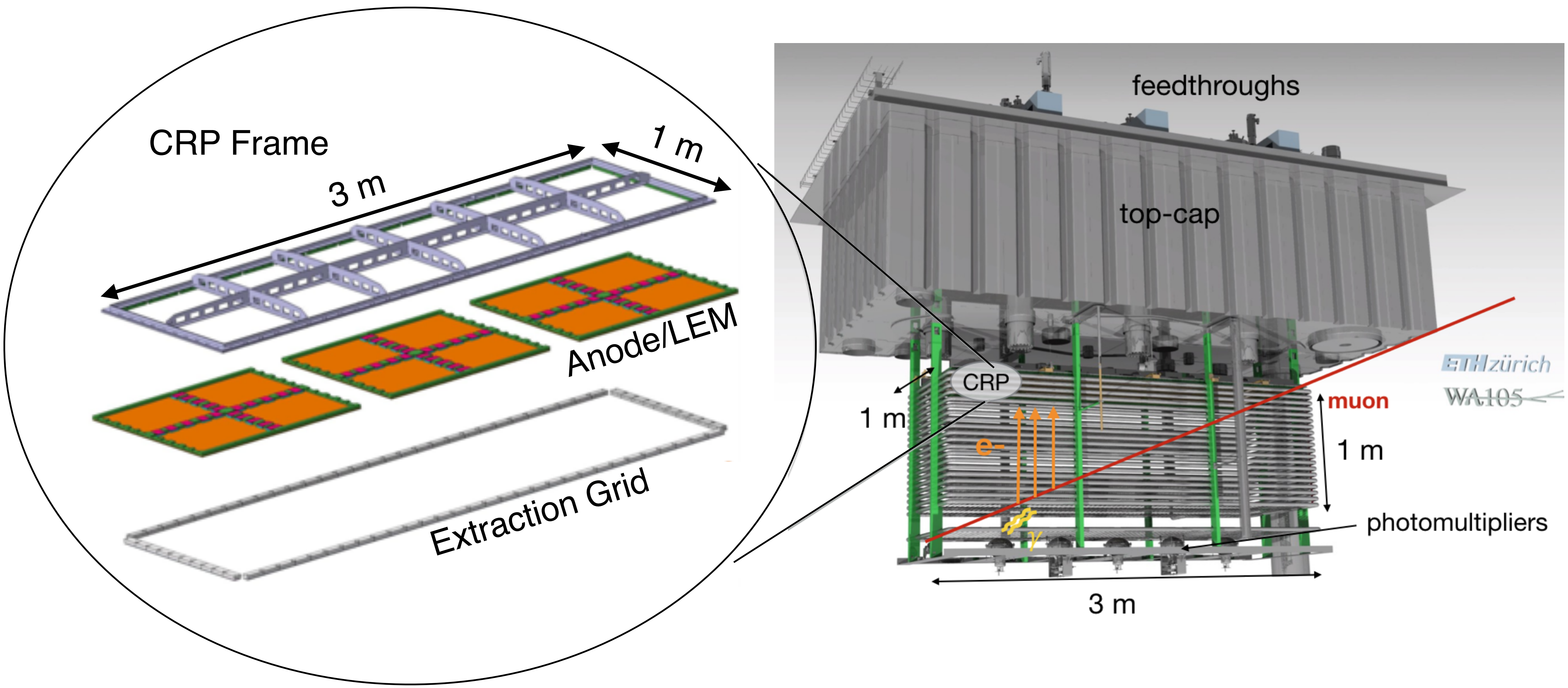
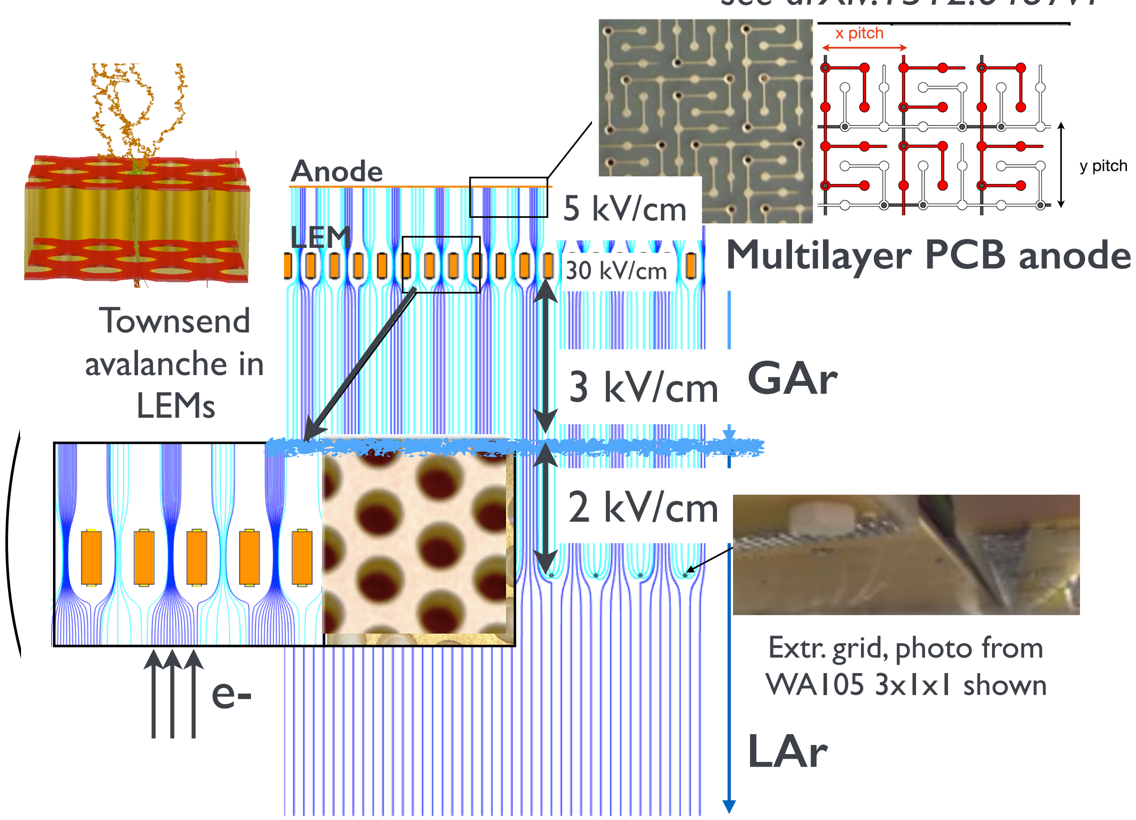


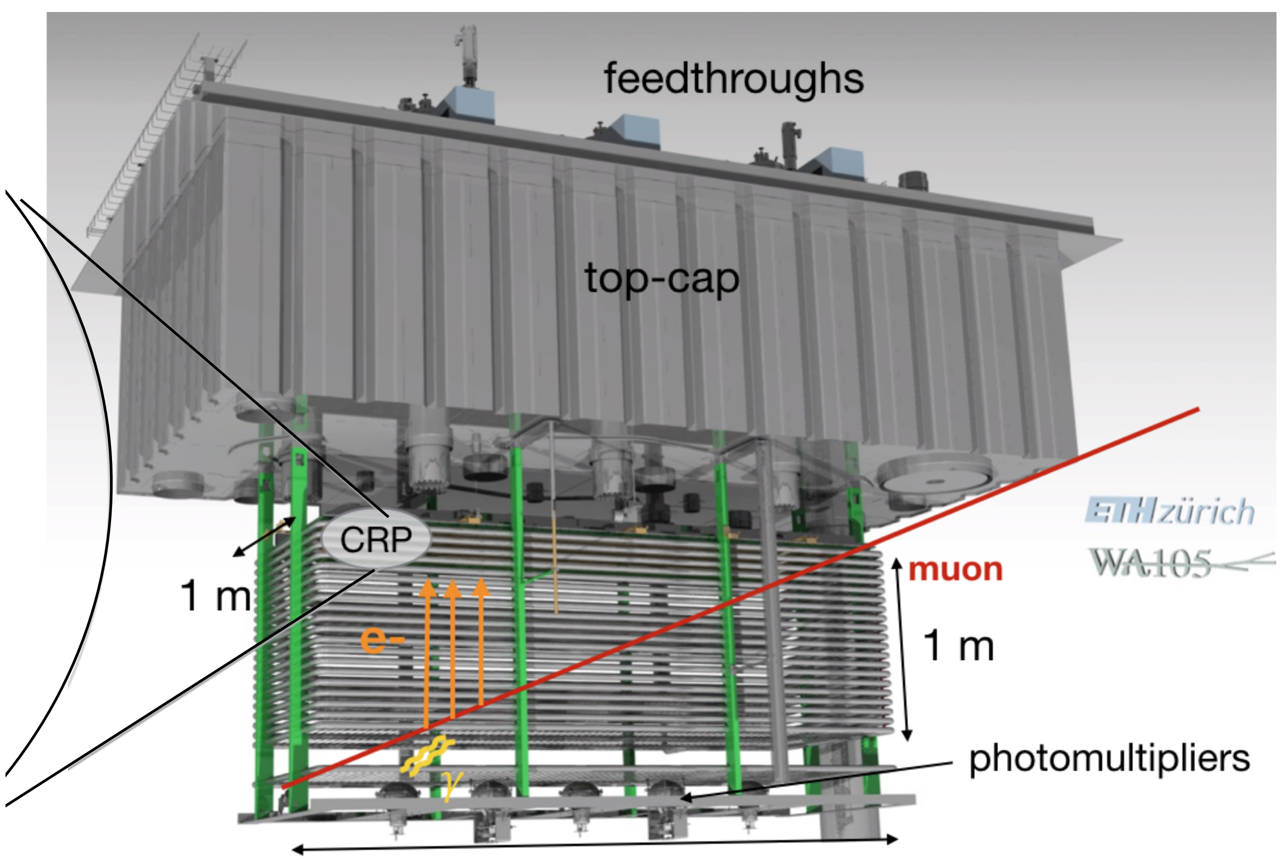
Introduction

Goal/purpose:

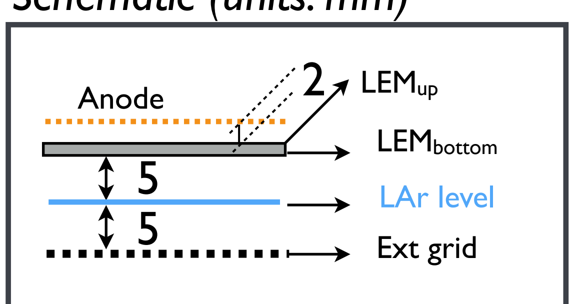
DP TPC technology works at large scale

311 detector served as test bench for protoDUNE-DP





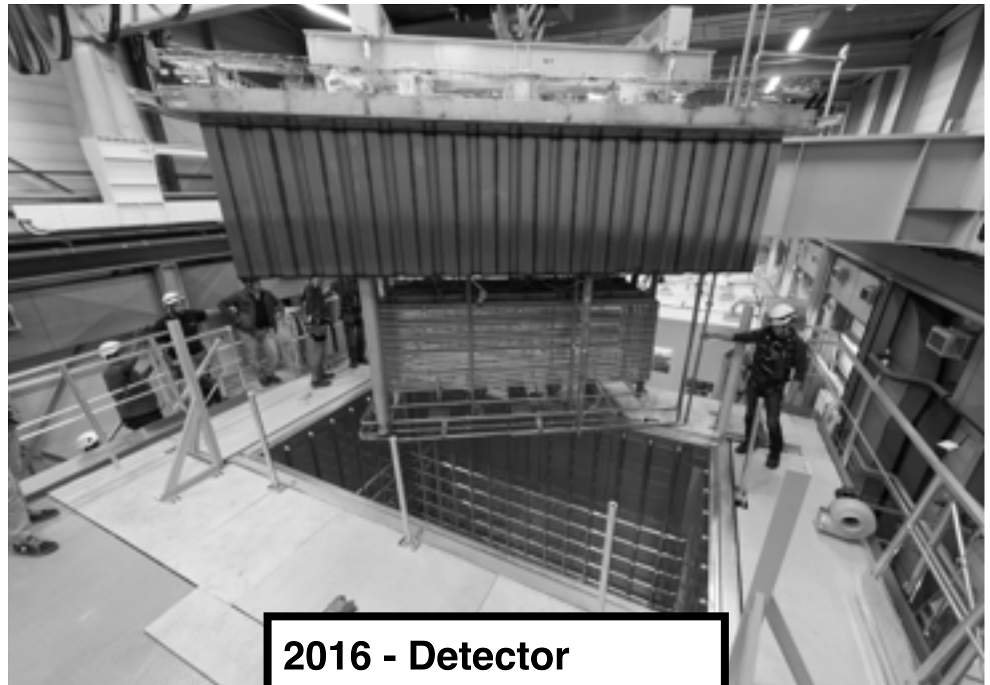
Schematic (units: mm)



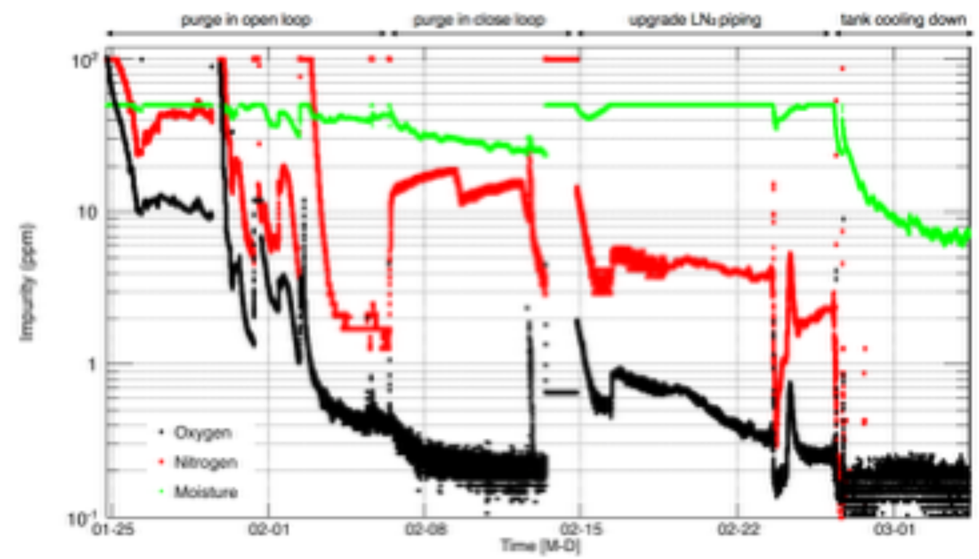
Roadmap of the 3x1x1

WA105

2015 - Cryostat constructed

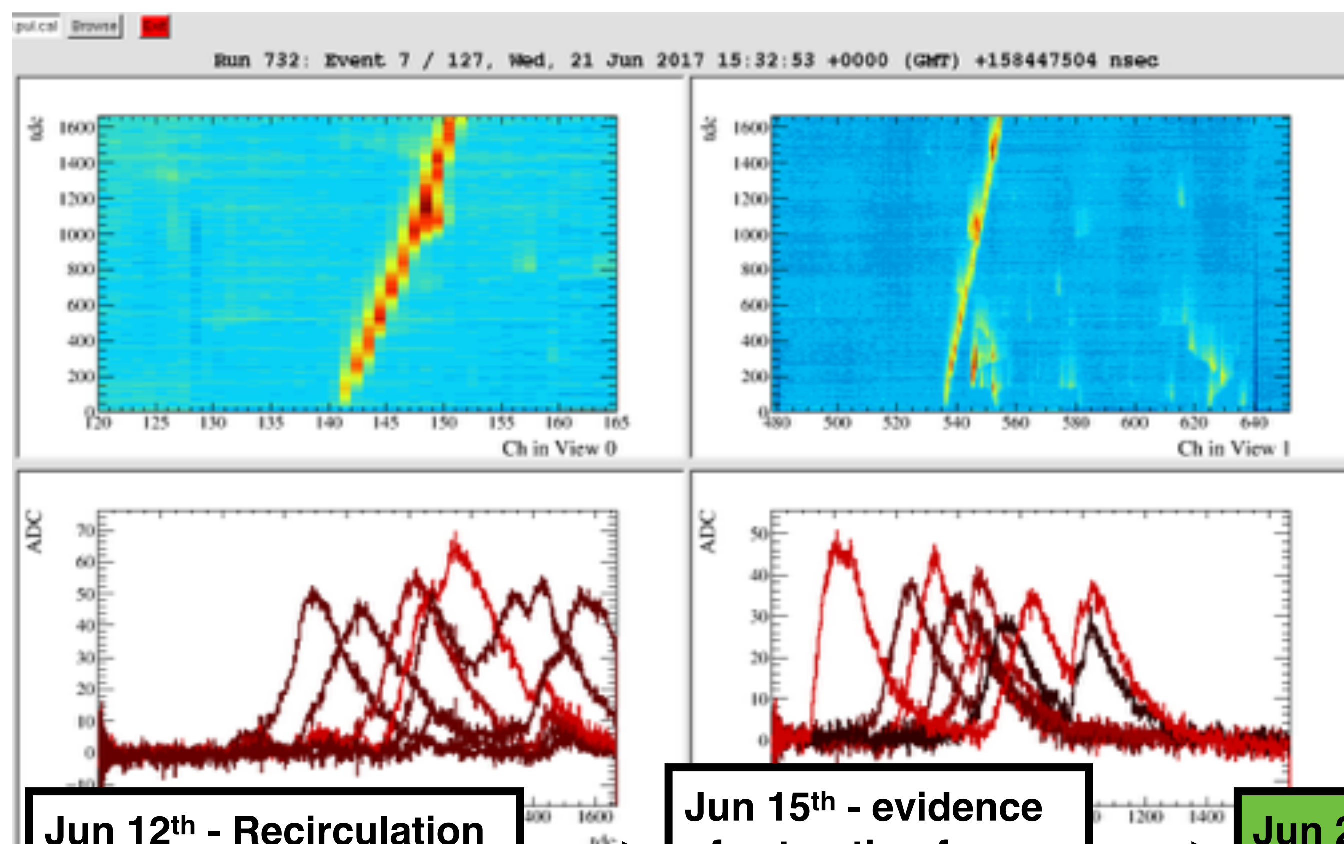


2016 - Detector installation completed



Jan 2017 - Commission started

Mar 2017 - Operation 'frozen' due to cryostat issues



Jun 12th - Recirculation started → Jun 15th - evidence of extraction from LAr to GAr → Jun 21st 2017 - First track seen!

3x1x1 derivables

WA105

Delivered
Work in progress
Issues found

1) **<u>CRP mechanical frame and suspension system:</u>**
- -Functioning of the automatic frame adjustment system: Will be tested in the following weeks.
- -Calibration procedure of level meters.
- -Resolution of level meters and their stability over time.
- -Planarity of the frame in cold conditions

2) **<u>LAr level measurement precision</u>:** long coaxial LM (next to drift cage and in pump tower), PT100s ribbon chain, plate capacitors around CRP and drift cage, level measured using cameras.
- How do they compare to each other in terms of accuracy and precision?
- Cameras: are we satisfied with the number of cameras, their location in the cryostat and their performance at cold?
- Plate capacitors around CRP: are these sufficient? Do we need more? Are we satisfied with their size, i.e. optimal shape and size of the level meters.

3) **Very High Voltage system and feedthrough:**
- -Long-term voltage sustainability of the feedthrough.
- -Stability of the voltage and the current as a function of time of the entire VHV system in general.
- -Monitoring of current and voltage: in the following weeks we will change to the 100kV
- -Fiducial volume and uniformity of the drift field.

4) **High voltage system:**

- CAEN power supply stability over time.
- Improvements foreseen: Need for a current limiting resistor for the LEMs. We are investigating if can be included in the board. Ideally one serial and one parallel resistor per LEM
- Need for filter and/or resistor to ground.
  - We observed an increase of the noise when we removed the serial resistor because was acting as filter. (Final test will be done in the following weeks)
  - We plan to do a check ground connection

5) **LEM, anode and extraction grid**

- LEM performance: maximum gain achieved and gain stability over time and position dependence of the gain.
- Extraction efficiency and position dependency,
- Charge attenuation and cross-talk.

Due to the grid performance we could not scan the induction field and the amplification field across the LEM, and therefore explore the maximum effective gain that can be achieved.

3x1x1 derivables

WA105

6) **FE electronics:**

-Low level noise and grounding optimisation at warm.
-Cryogenic operation of the front end electronics
-Insertion and extraction of the blades at warm.
-Temperature inside the SGFT: Stability of the temperature with and without electronics on.
-Operation of the DAQ and timing system.
-Setting up of the online and storage farm.
-Operation and performance of the electronics at different detector conditions.
-Signal attenuation in 3m view to the 2.2 nF decoupling capacitor.
-Card counter reaction under investigation.

7) **PMTs:**

-positive HV vs negative HV.
-self trigger vs CRT trigger mode.
-data/MC comparison through light maps: We first need to correlate with the charge events.
-gain calibration of the PMTs
-slow and fast component decay times in the liquid and in the gas.
-light dependencies on the drift field

8) **Detector slow control system:**

-Stability over time and performance: Since the beginning of operas
-Monitoring and stability of the different sensors.

9) **Performance of the muon trigger system:**

-Communication with DAQ of charge readout and light readout.
-Trigger rate and efficiency.

Results achieved

- Recirculation of LAr with cryo pump
- Detector slow control system
- Online processing and storage
- LAr level measurement/monitoring
- CRP mechanical frame and suspension system
- High voltage system
- Noise measurement FE electronics
- Performance of the muon trigger system
- PMTs
- LEM anode and extraction grid

LAr recirculation

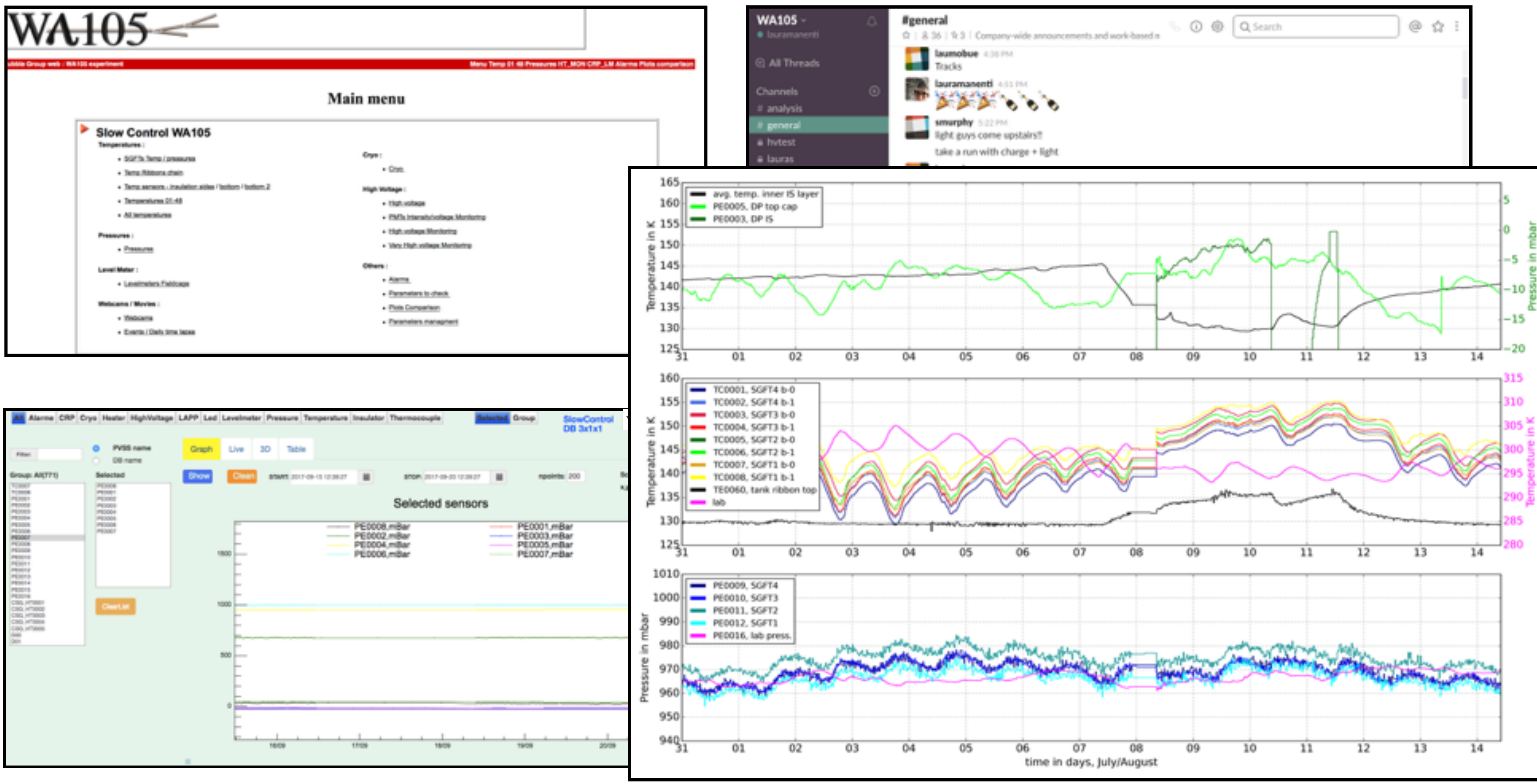
Goal: achieve a purity at the ppt level

→ from muon track studies the **purity is 10-40 ppt**

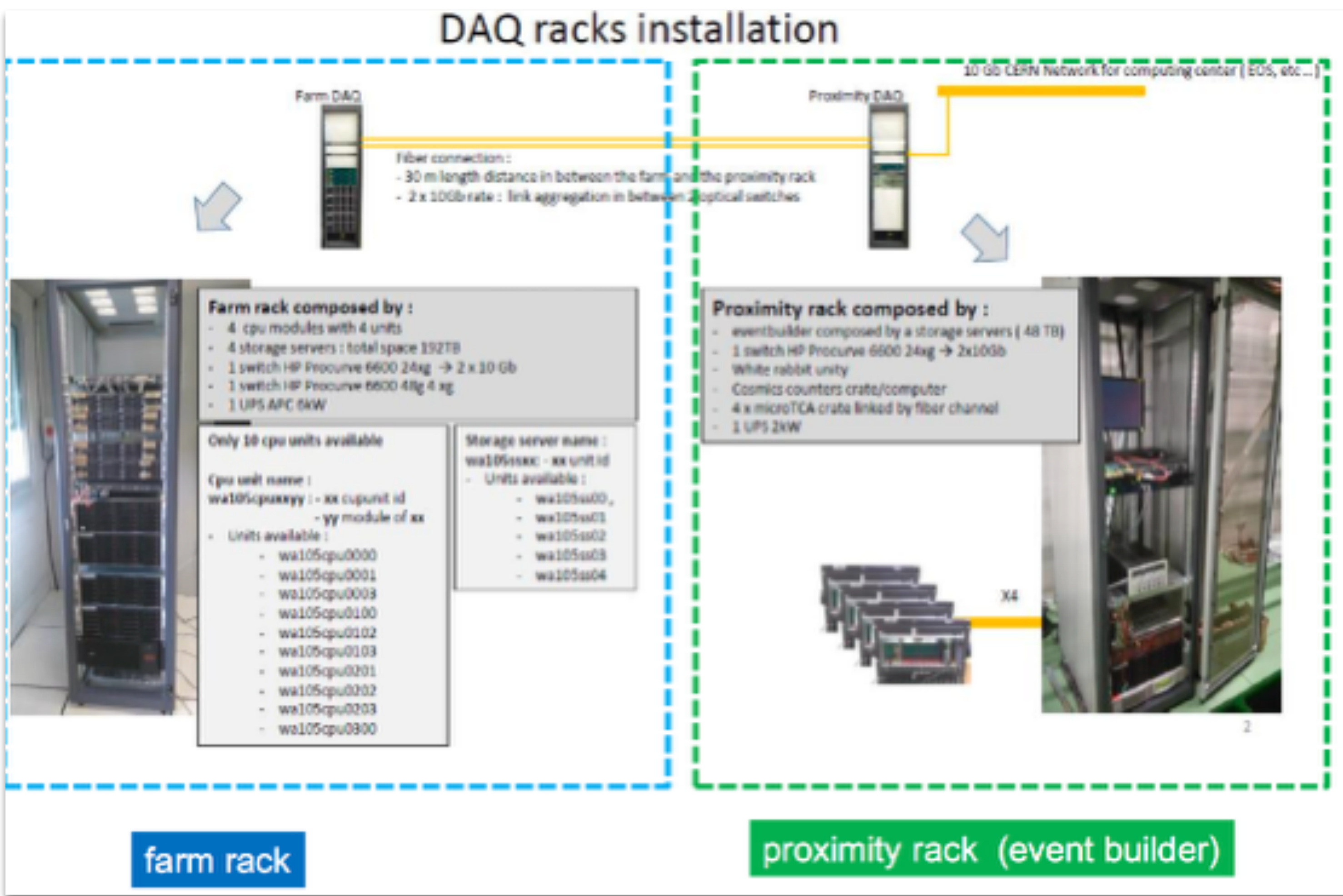
- Jun 12th: LAr recirculation started
- Jun 15th: a total of 7 volumes had been recirculated
- Pump and cartridges have been running continuously till now with no problems
- We would like to thank CERN cryogenic team for their daily support

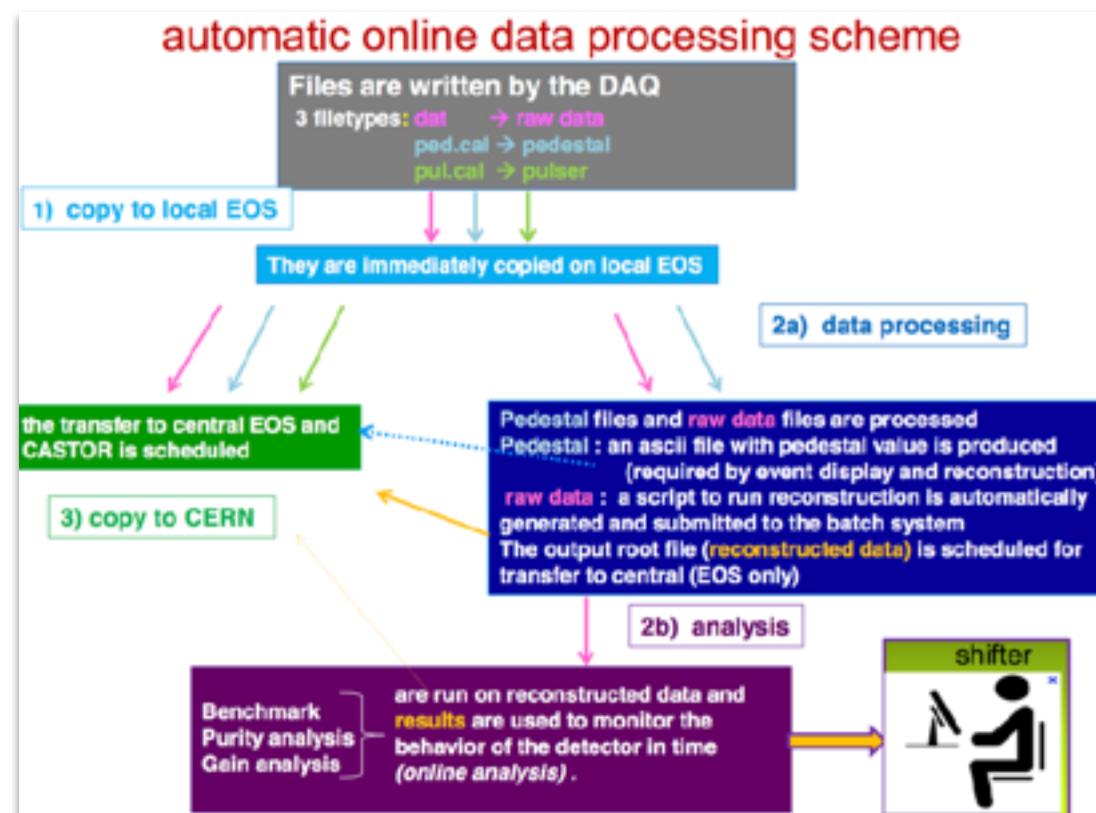
Slow control system

- **Slow control system** designed in house; similar to the one that protoDUNE-DP will use.
- **Two online displays to constantly monitor** the different pressure and temperature sensors inside the detector and inside the insulation space.
- A dedicated **ELOG** for the 3x1x1 with more than 400 entries
- A **Slack account** for the collaboration was created with different channels to report the daily activities.



* **We already have more than 140k events!**
* Summary of runs includes with main details and number of events.
* **Online storage and processing for protoDUNE-DP** b**eing tested on the 3x1x1**. Files transferred to a local EOS and then moved to the CERN computing centre.

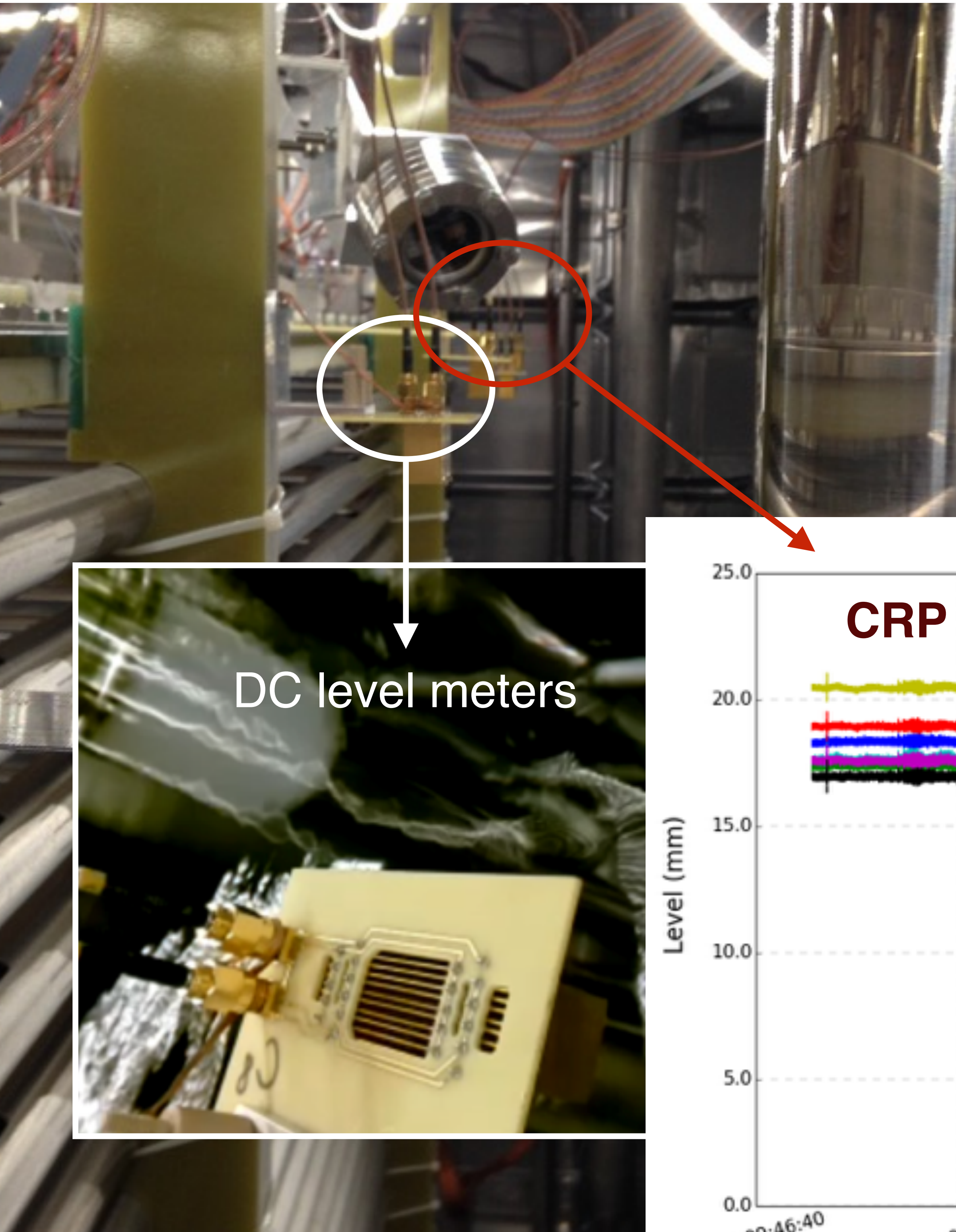


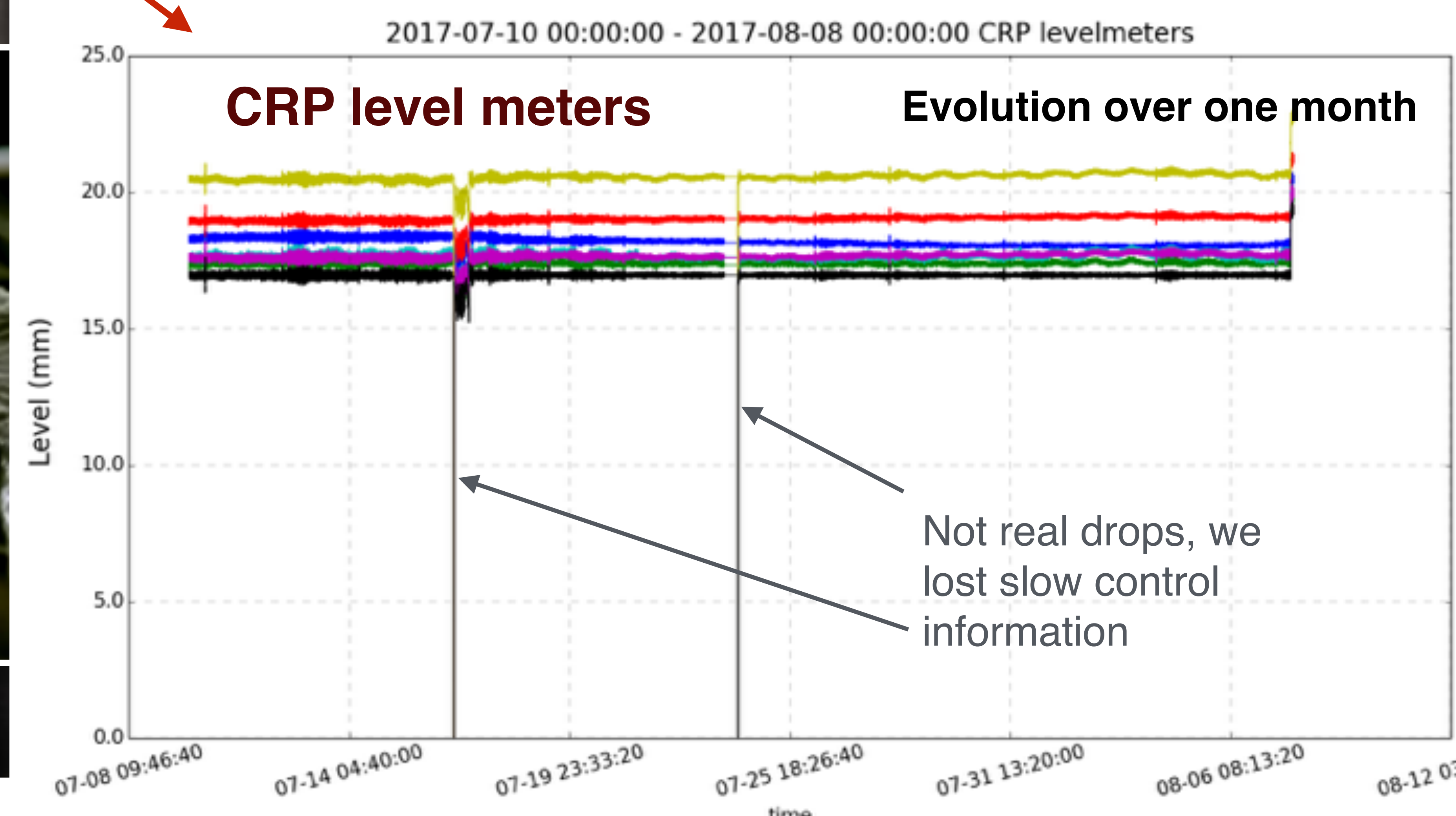


LAr level measurement

WA105

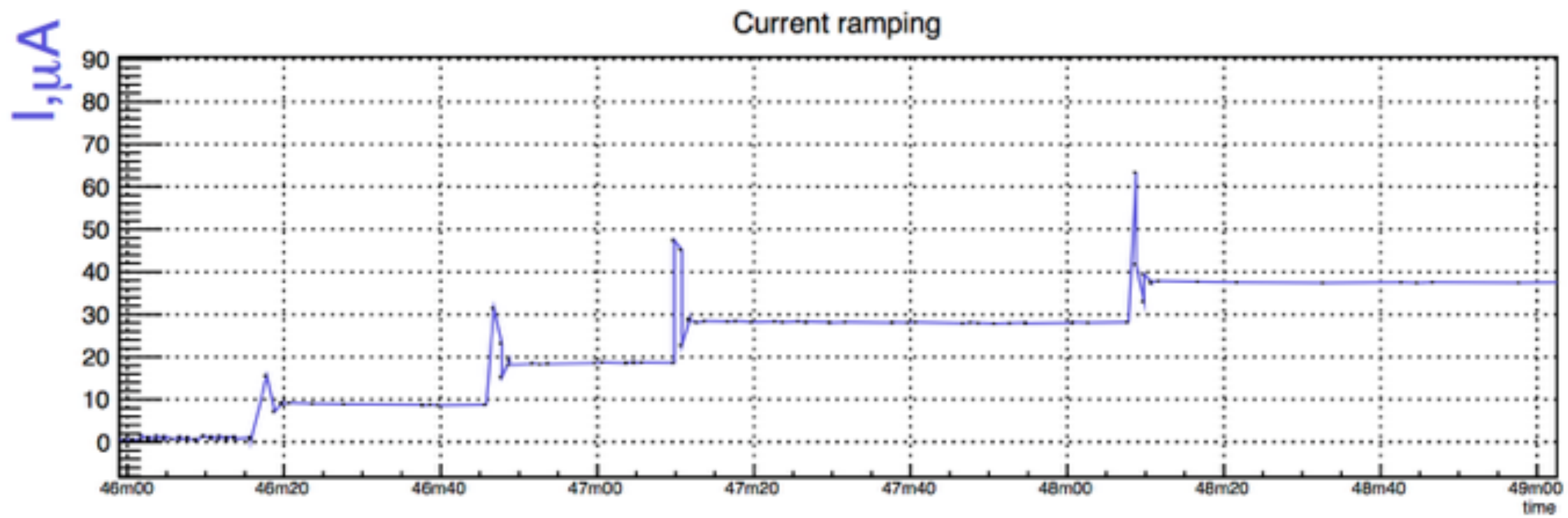
- The level is adjusted and constantly monitored using **7 capacitive level meters on the CRP**, and **5 around the drift cage**.
  Since mid June, this information is also sent to the cryogenic system to constantly regulate the system to keep the level stable.
- **Level crossed checked** also by measuring the **capacitance between grid and LEMs**
- **4 cryogenic cameras** are recording pictures continuously.

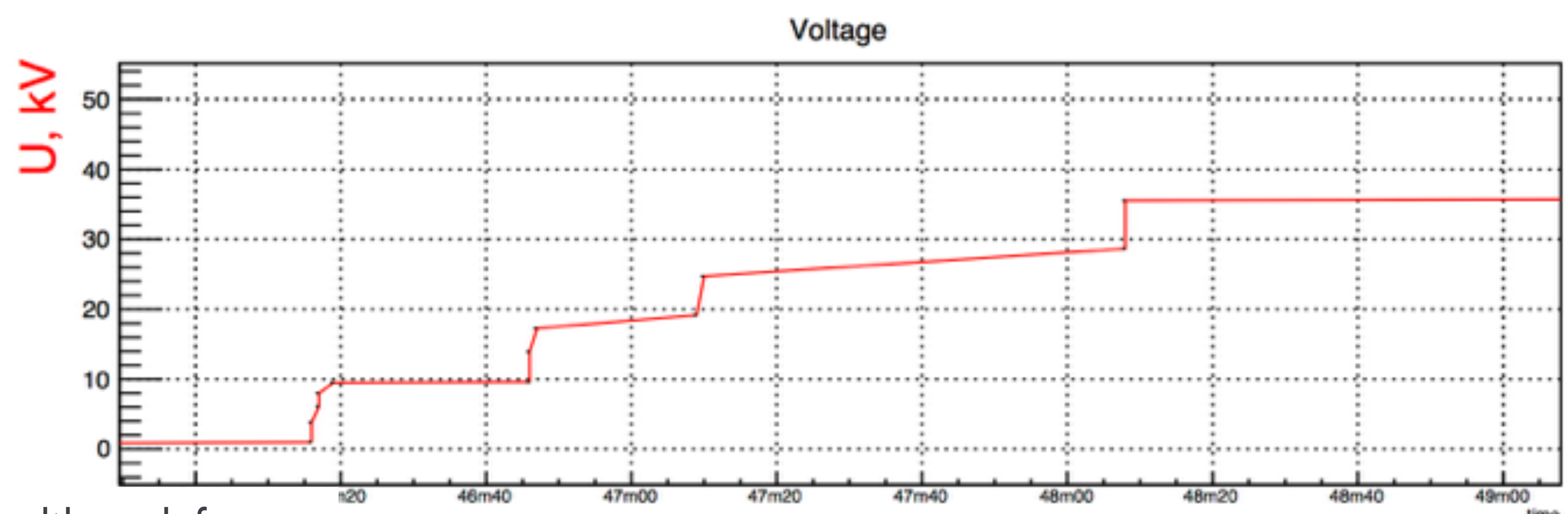




Very high voltage system

- Very high voltage tests performed in May 2017 at different LAr levels.
- Cathode and field cage powered up to 50 kV in stable conditions with the field cage terminated to ground.



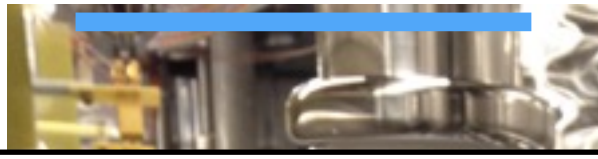


See "First test of a high voltage feedthrough for liquid Argon TPCs connected to a 300 kV power supply,"arXiv:1611.02085. Submitted to JINST.

Very high voltage system

WA105

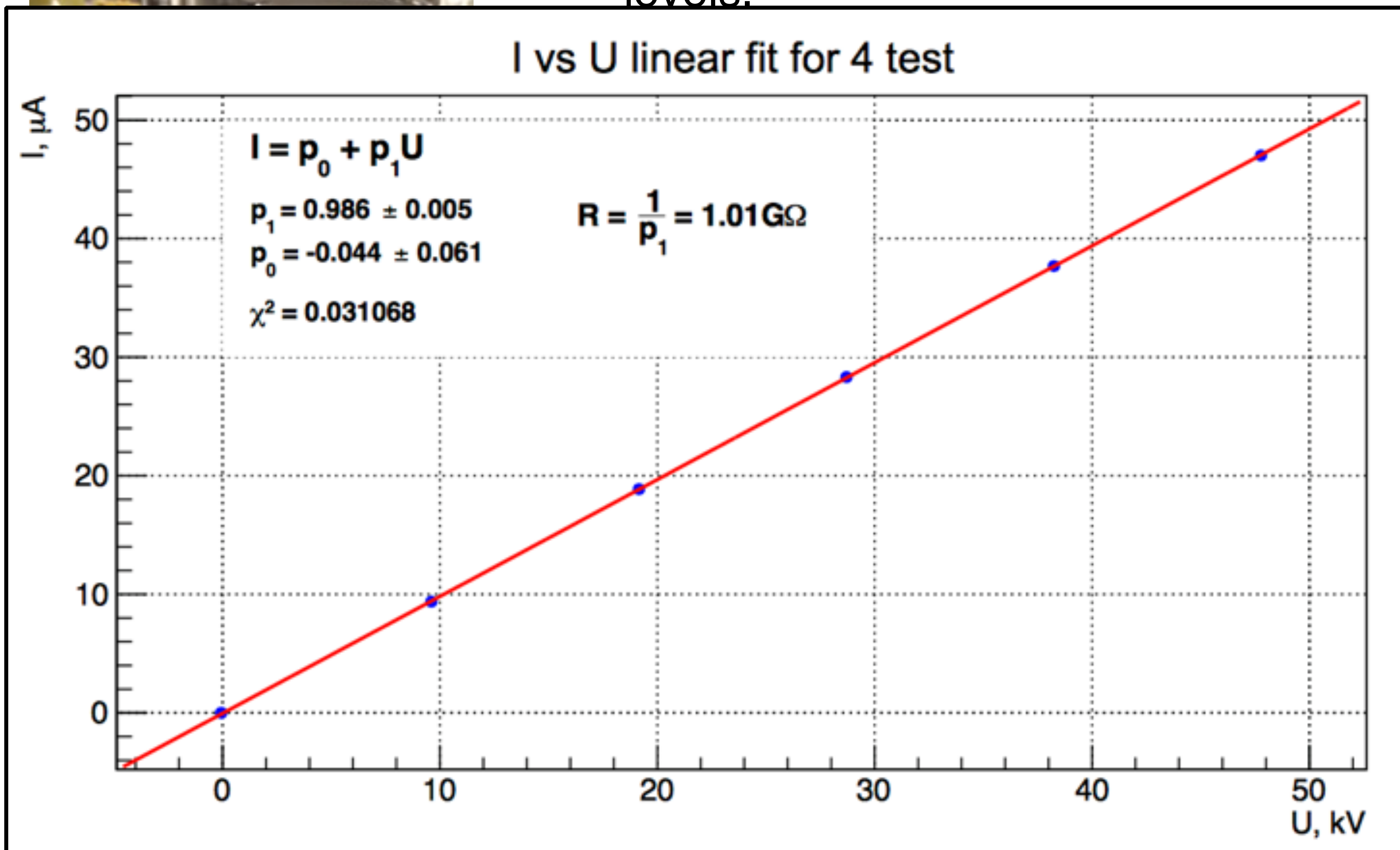
LAr level

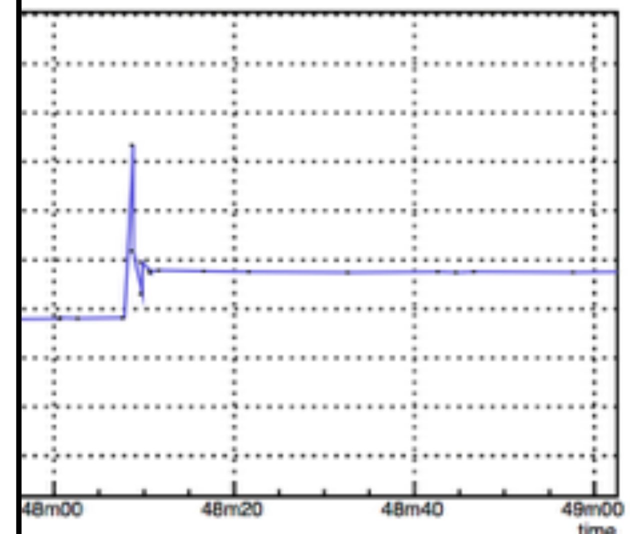


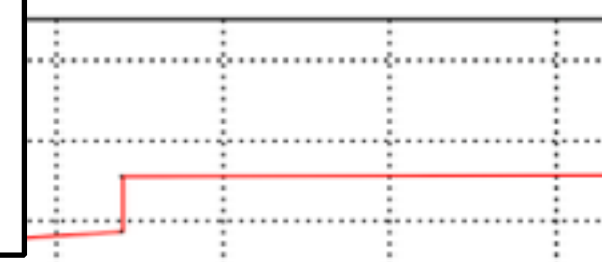
- Very high voltage tests performed in May 2017 at different LAr levels.

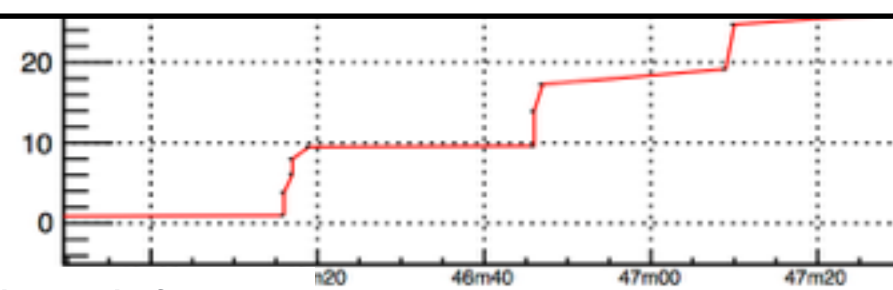
50 kV in stable

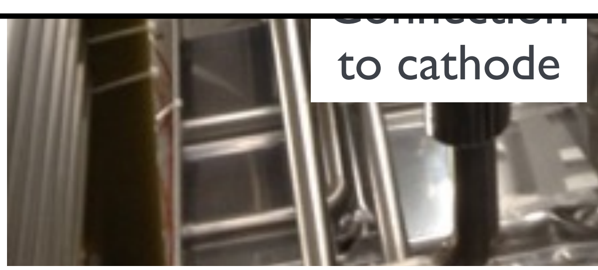
d to ground.









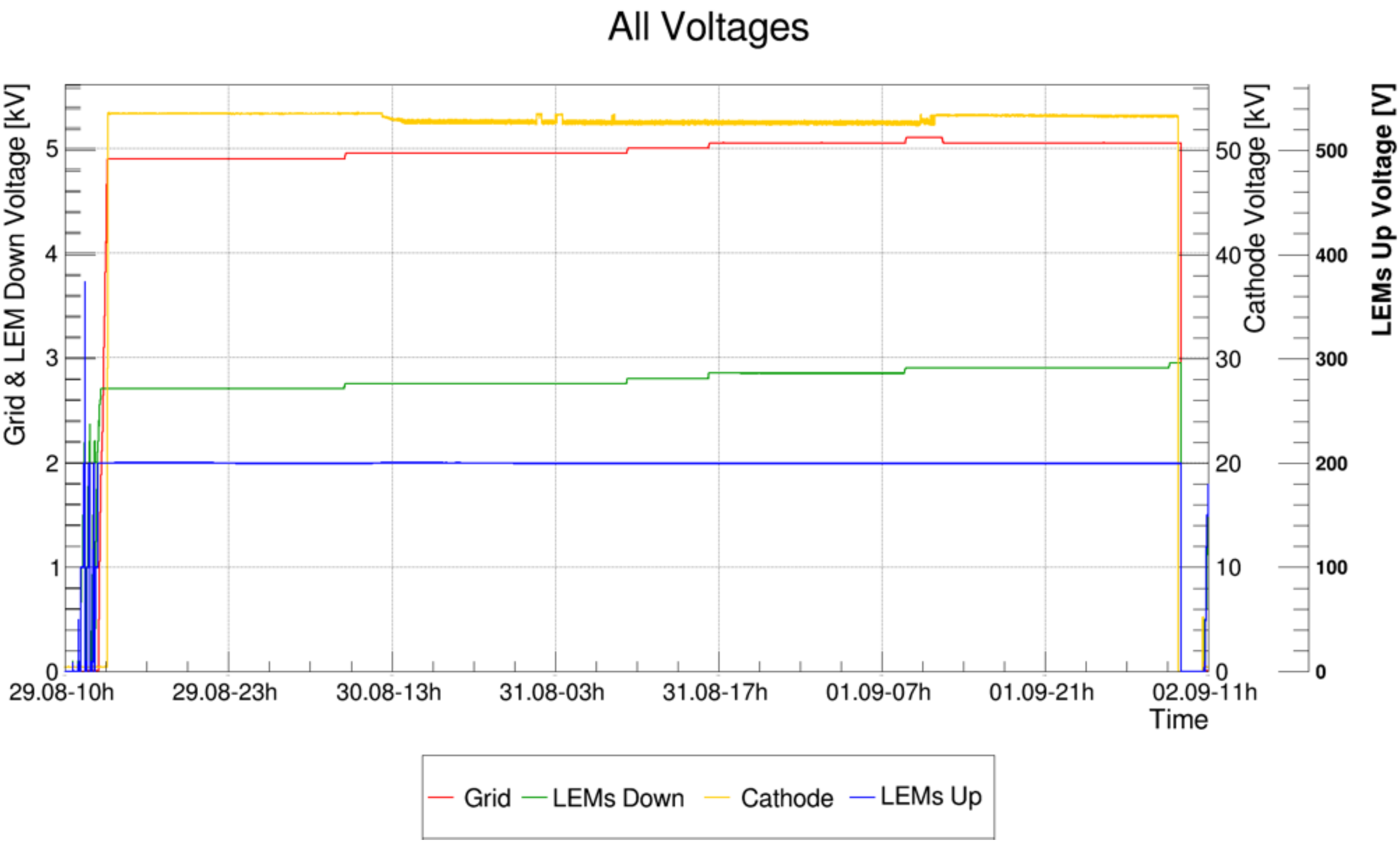


$R_{tot} = \mathbf{1.01 G\Omega}$ in liquid

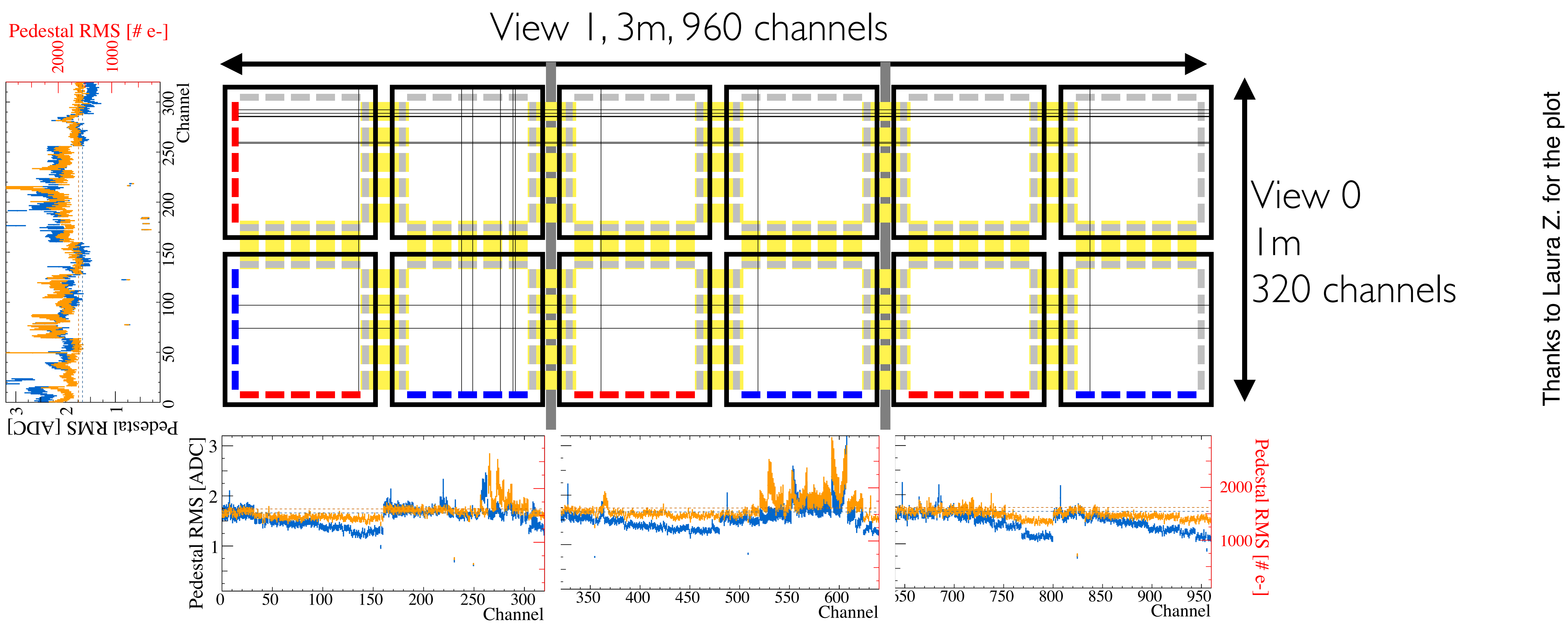
$R_{tot} = \mathbf{950 M\Omega}$ at room temperature

See "First test of a high voltage feedthrough for liquid Argon TPCs connected to a 300 kV power supply," arXiv:1611.02085. Submitted to JINST.

Very high voltage system



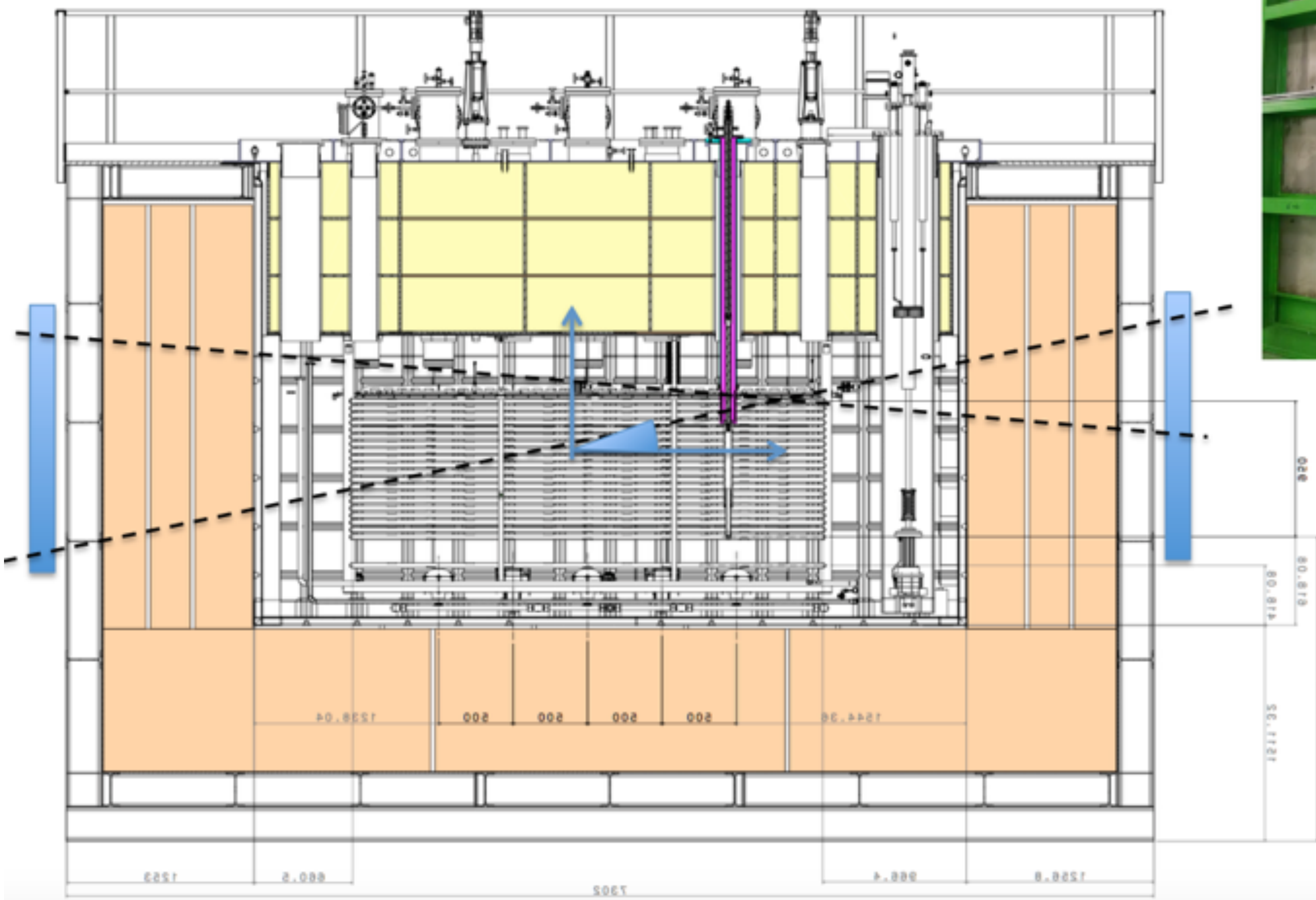
Noise evaluation at warm and cold



- Out of 1280 channels, 17 found problematic or dead (1.3%)
- Noise at room temperature stable at around 1600 e$^-$
- Noise at cryogenic temperature stable at around 1550 e$^-$
- Calibration runs with pulsed injected charge runs have shown ~ 4% of crosstalk

Trigger: CRTs

Two Cosmic Ray Tagger (CRTs) panels installed on the short sides of the cryostat providing 2D hit coordinates with a **trigger rate of 0.3 Hz**.



Trigger: PMTs

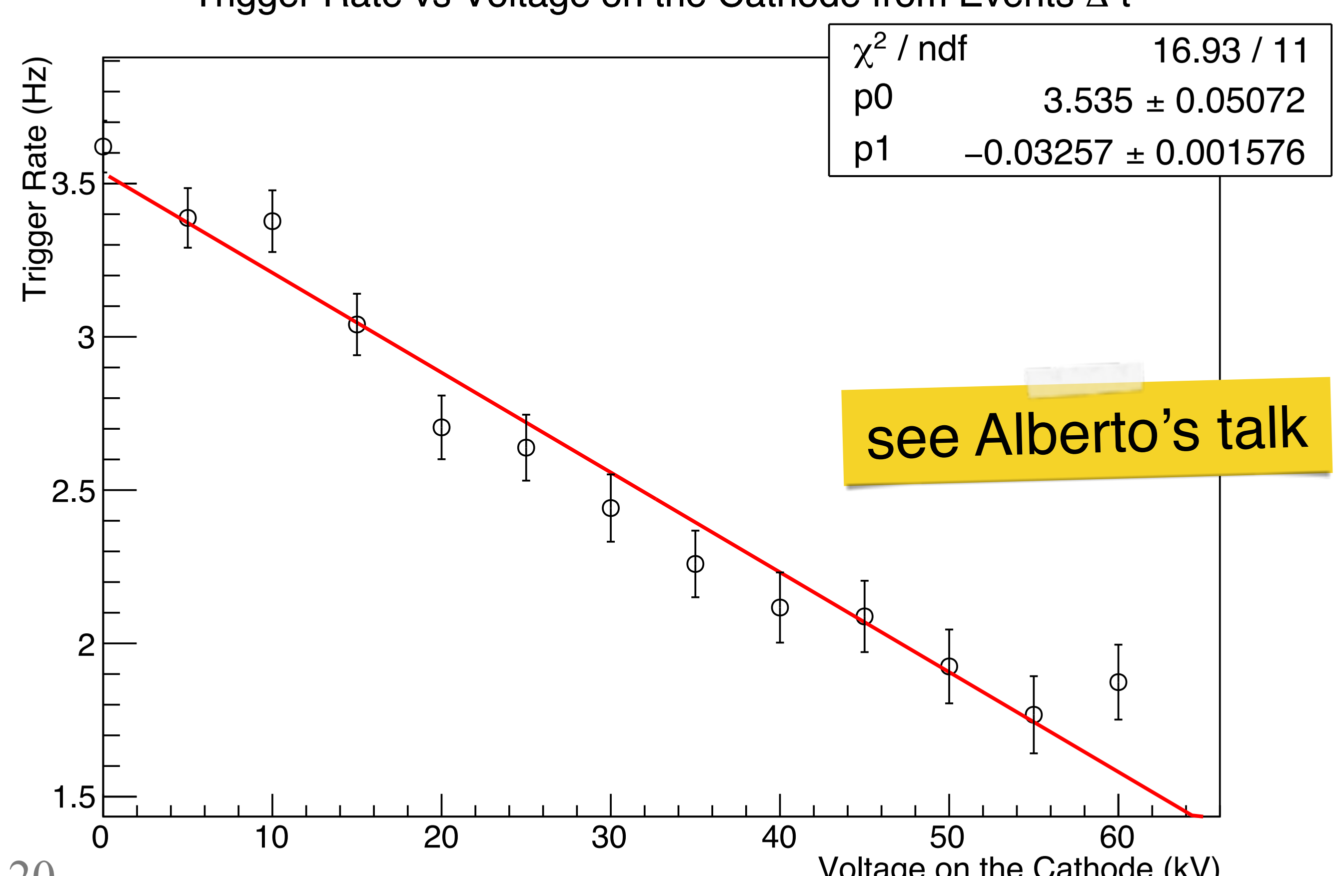
WA105

Since July, the CRP may be triggered by the PMTs.
The trigger rate is ~ 3 Hz.

From the PMT trigger, we can perform **additional measurements**:

- The rate of primary scintillation due to electron-ion recombination depends on the drift field: the higher the field the lower the S1 production (recombination component).
- We evaluated the **trigger rate as a function of the drift field** up to 60 kV on the cathode.

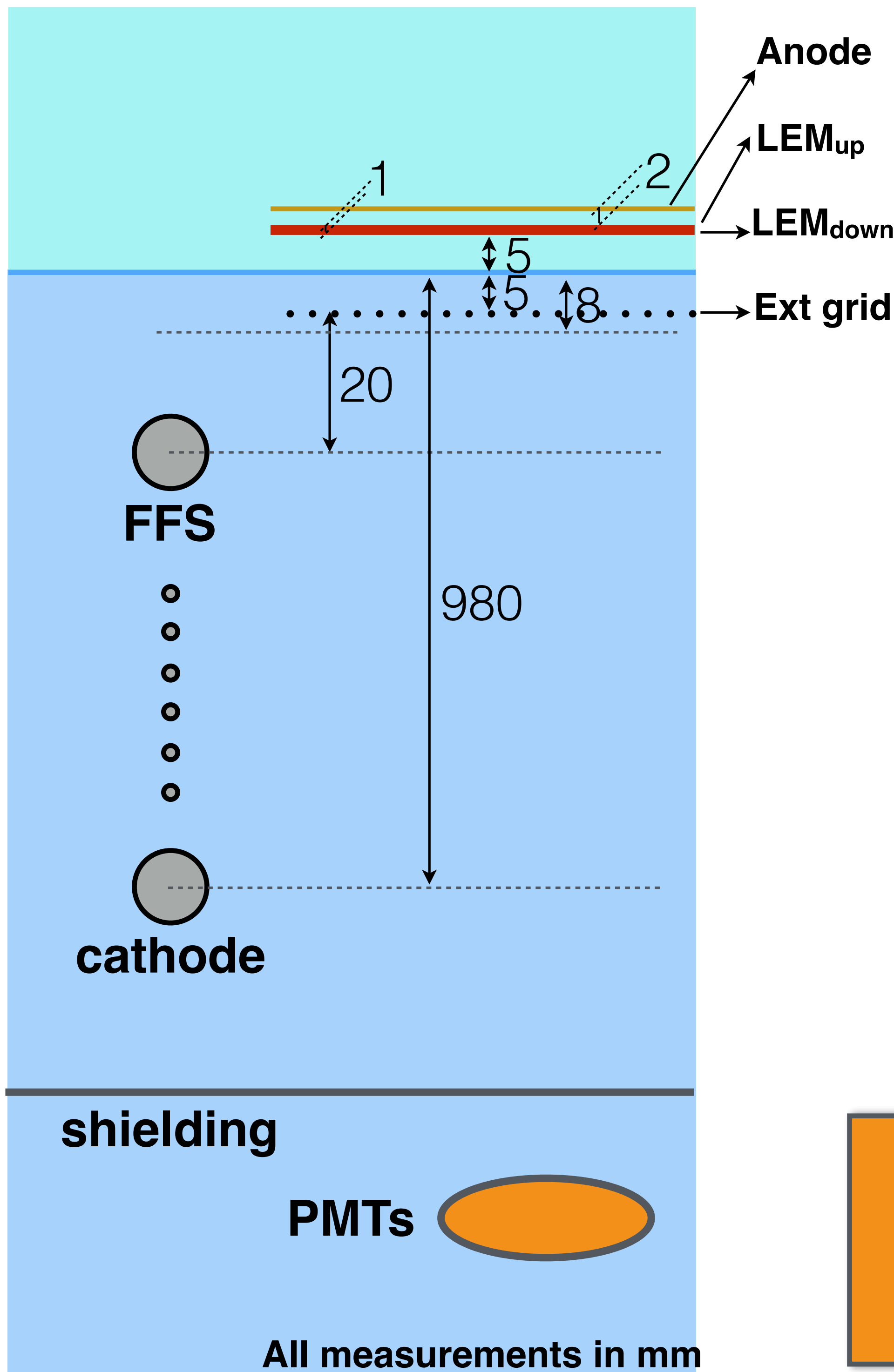
5 PMTs installed inside the 3x1x1 detector



see Alberto's talk

HV system configuration

WA105

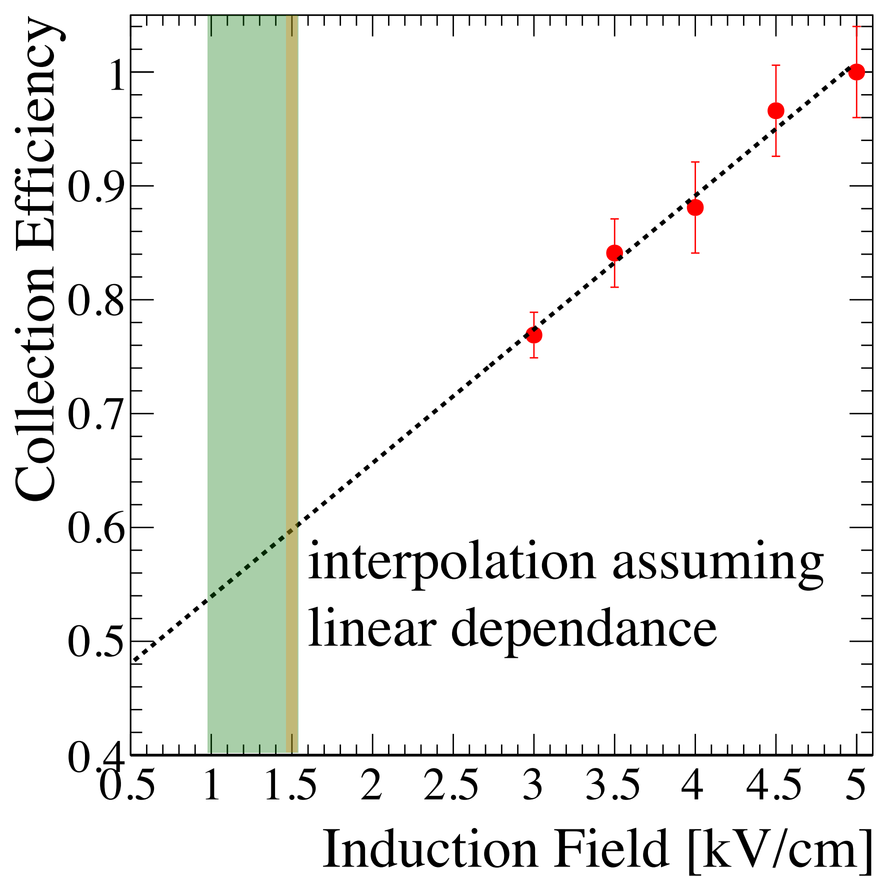


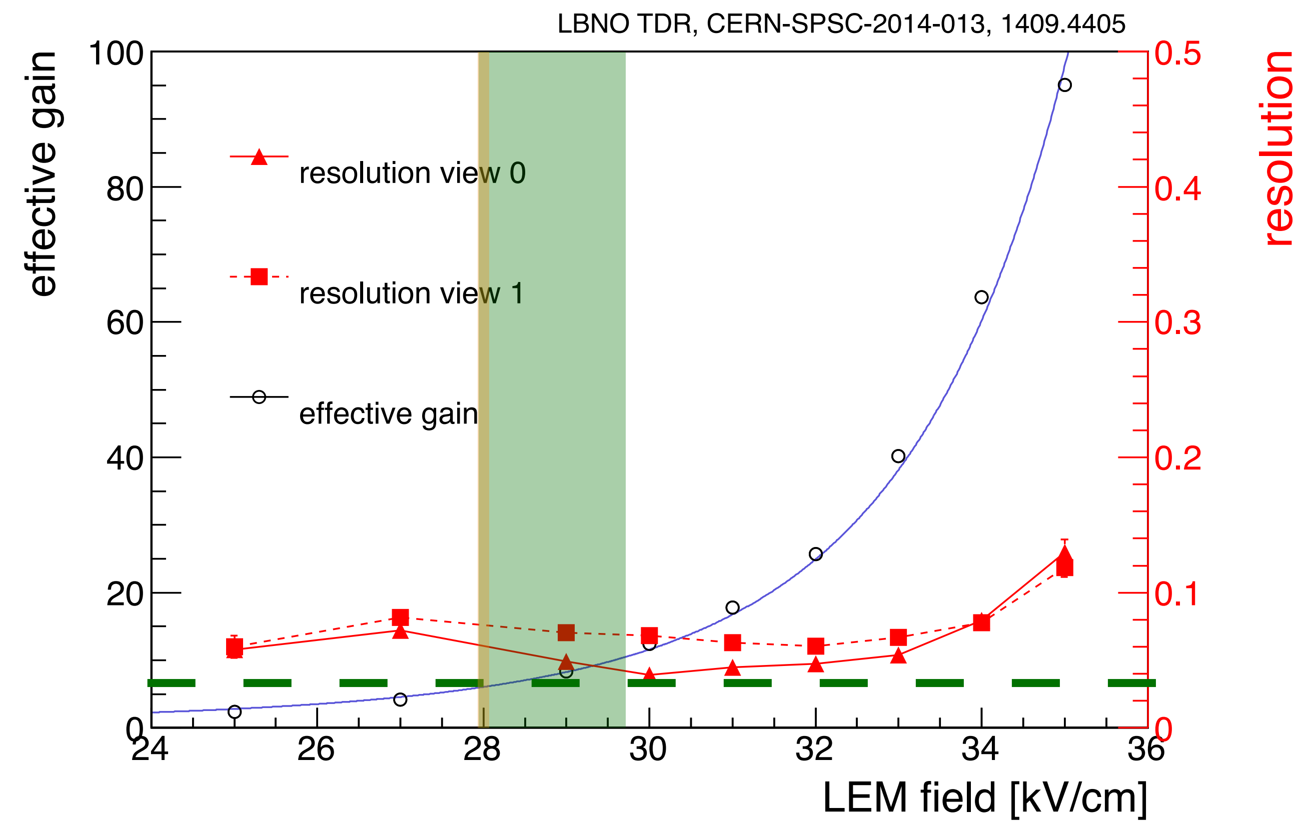
Electrode	Nominal values
Anode	0 kV
LEMup	-1.0 kV
LEMdown	-4.0 kV
Ext grid	-6.5 kV
FFS	-7.6 kV
cathode	-56 kV

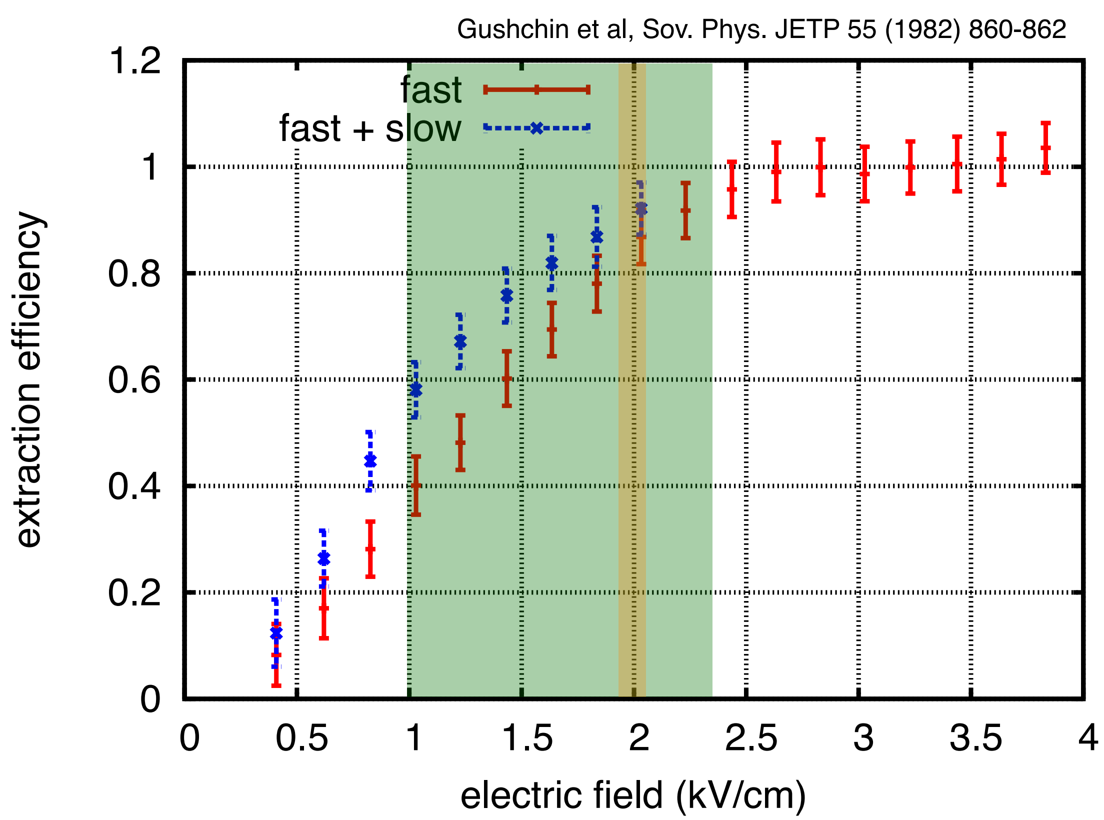
Field	Nominal values	Values reached
Induction field	5 kV/cm	1-1.5 kV/cm
LEM field	30 kV/cm	28-29 kV/cm
Extraction field	> 2 kV/cm	1-2.3 kV/cm
Drift field	500 V/cm	500-700 V/cm

During operations we have always stayed below the nominal operating voltages as the extraction grid trips before reaching its nominal value.

HV system configuration



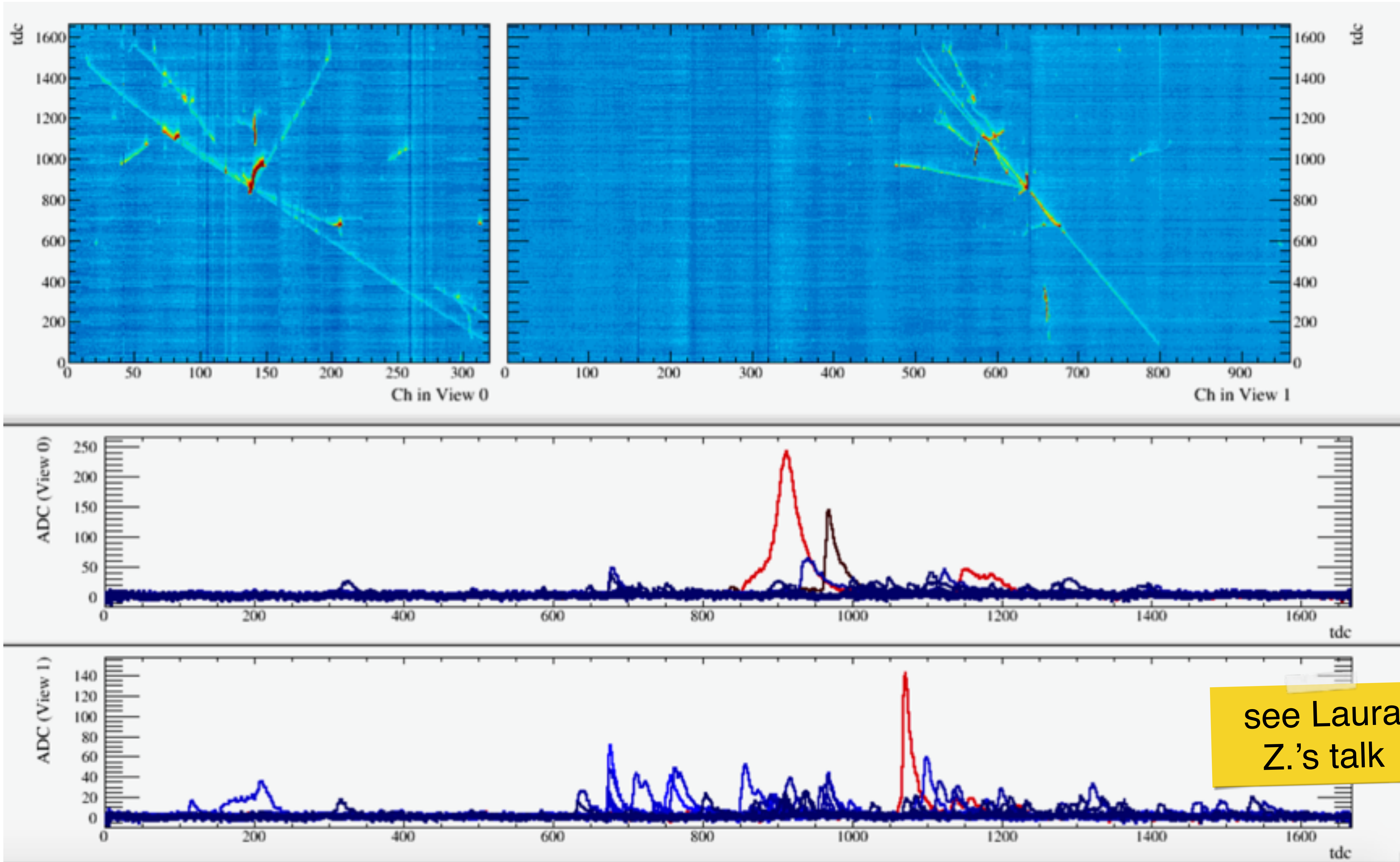




In green the field values scanned so far.
In orange the field values at most stable conditions.

$$\langle \frac{dQ}{ds} \rangle_{\text{view}} = F_{\text{share}} \times \text{Gain} \times \text{Eff}_{\text{extr}} \times \text{Eff}_{\text{ind}} \times \frac{dQ}{ds}$$

$$\langle \frac{dQ}{ds} \rangle_{\text{view}} \sim 0.5 \times 5 \times 0.9 \times 0.5 \times 10 \text{ fC/cm} = 11.5 \text{ fC/cm}$$



see Laura Z.'s talk

Conclusions

WA105

- Gained experience for ProtoDUNE-DP design, installation, and operation.
- For first time extraction over 3 m^2 area and LEM amplification over 50x50 cm^2 has been demonstrated (gain of 5 at 28 kV/cm)
- Purity in the ms electron lifetime range
- Excellent performance of the LAr pump for recirculation and the cryogenic system
- Stable operation at 500 V/cm (HVFT at -56 kV)
- Good S/N ratio for both collection views even without software noise removal
- Infrastructure for data transfer set up and tested with 140 k events recorded and being analysed so far