NP04 CALCI Performance

Technical Board Meeting

June 12, 2024

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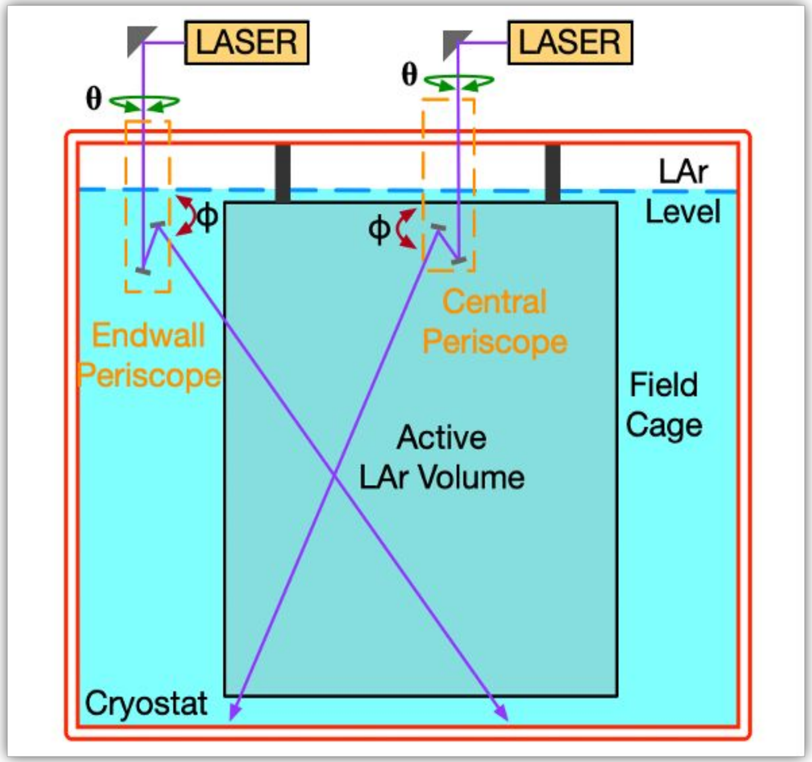
On behalf of CALCI consortium

Ionization Laser

Concept

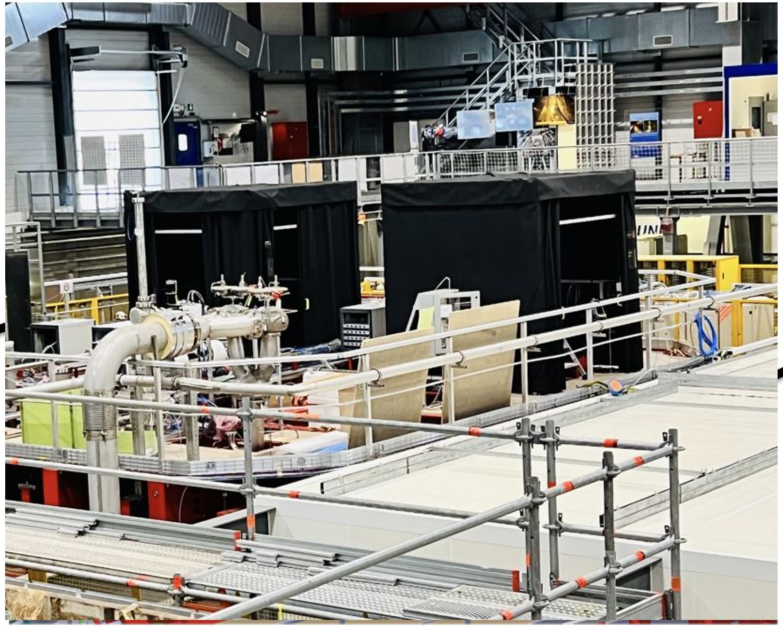


- Ionization of LAr with 266 nm laser, UV
  - 2-photon excitation + 1-photon ionization
  - Requires intense beam, ~10 mJ pulse
- Movable periscopes with cold mirror to bring beam into cryostat and steer it
  - Two designs prototyped for use in PD-HD, one penetrating the field cage, one outside
  - Automated controls integrated with DAQ
- Goals
  - Mapping space-charge distortions
  - Characterize charge collection in APAs
  - Characterize electron lifetime

Laser Periscope Feedthroughs @NP04

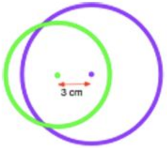
Three degrees of freedom for each periscope including rotations and retractions

Periscope 1 (P1)



ProtoDUNE laser calibration systems

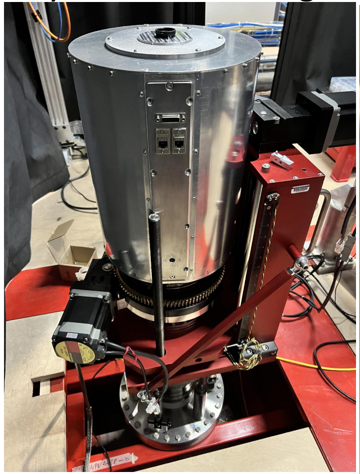
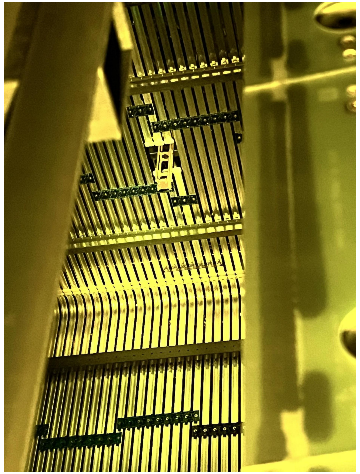
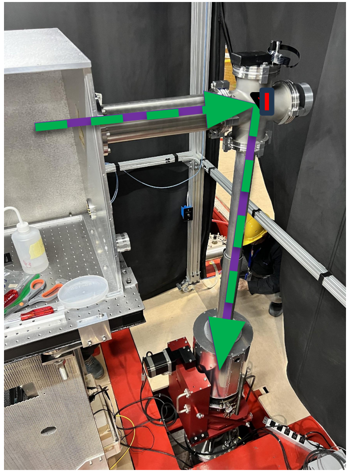
Periscope 2 (P2) / Endwall



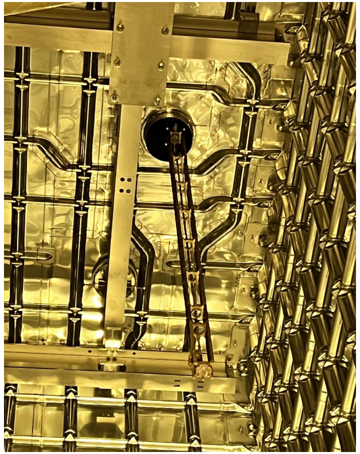
Installation @ NP04 completed

Cryostat feedthrough | Periscope | Assembly w/ laser box

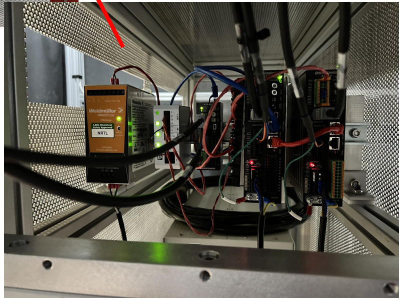
P1 penetrates top of field cage

P2 Outside field cage

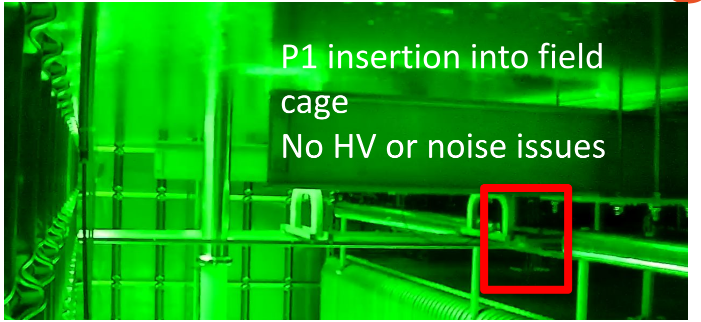





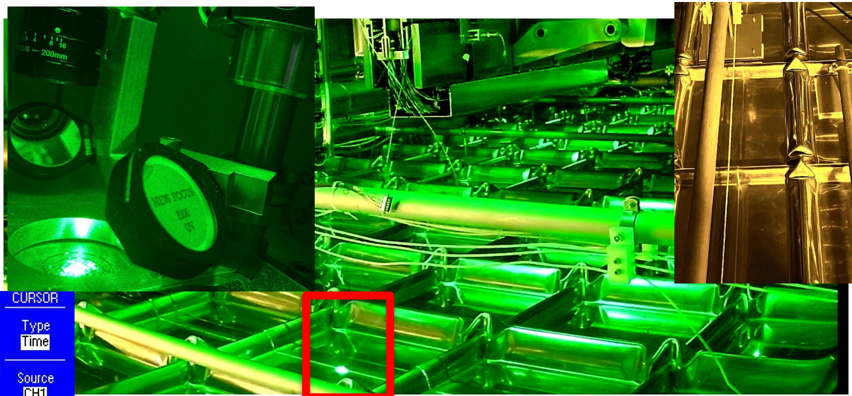
Electronics and instrumentation

Commissioning

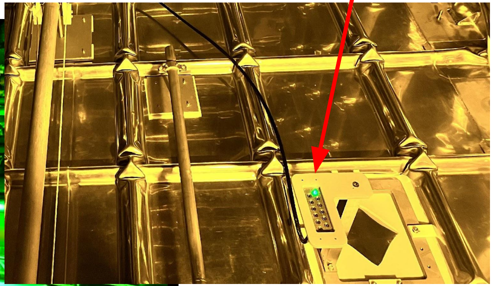


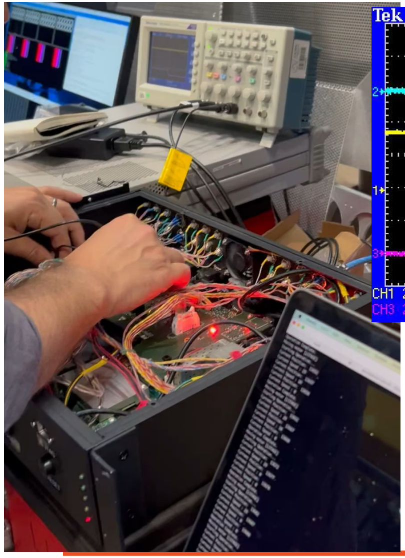
P1 insertion into field cage
No HV or noise issues

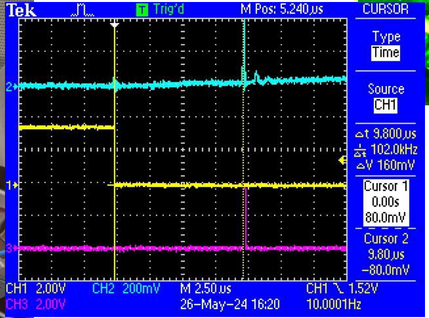
Green laser alignment, checks w/ cameras, PIN diodes



PIN diode module

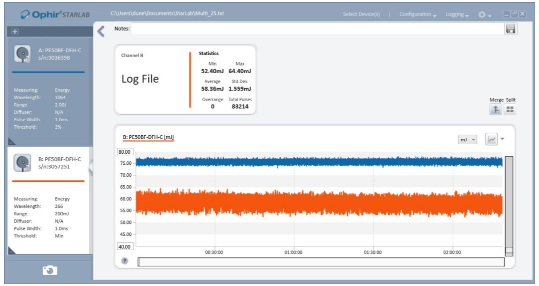




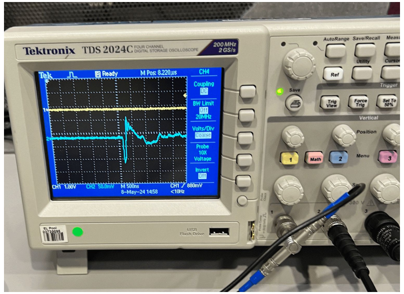


Electronics board controlling laser and reading out photodiode for trigger

UV laser safety reviews and intensity stability checks



PIN diode signal



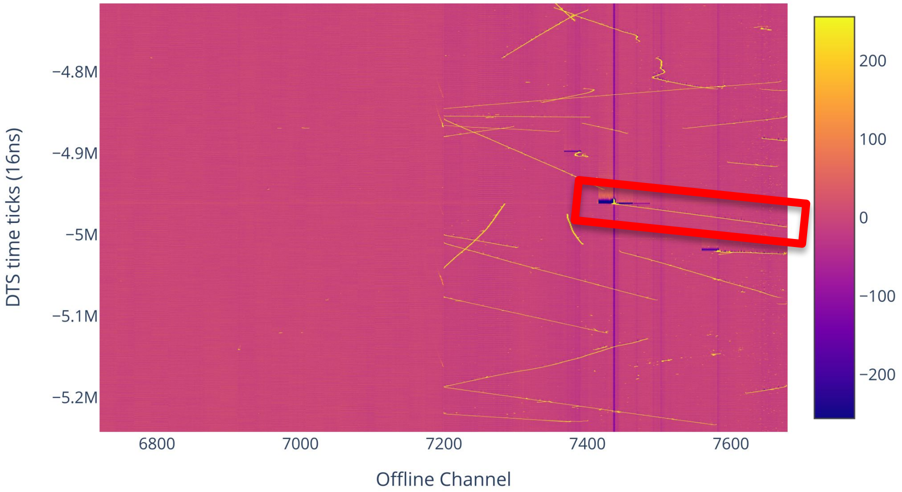
60 mJ of UV for P1.
(40 mJ for P2)

WE HAVE TRACKS!

Periscope 1 UV alignment completed first, with camera verification on the downstream end for unobstructed tracks

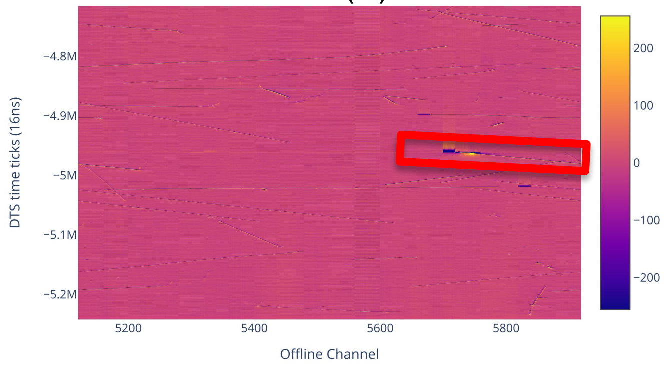
Run 26574, Trigger 3, APA2 Plane 2

Collection Plane (X)



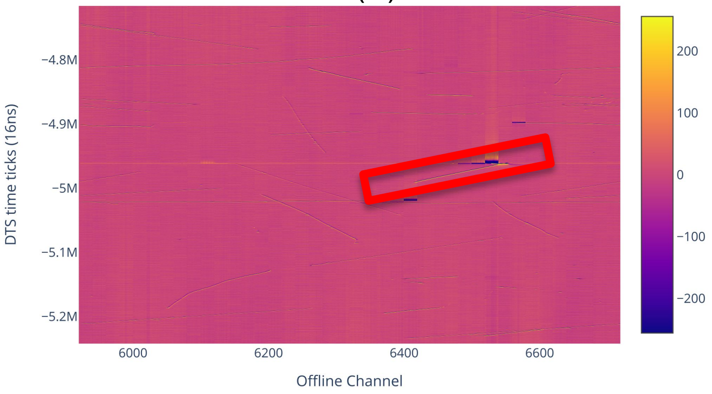
Run 26574, Trigger 3, APA2 Plane 0

Induction Plane 1 (U)



Run 26574, Trigger 3, APA2 Plane 1

Induction Plane 2 (V)



Next Steps

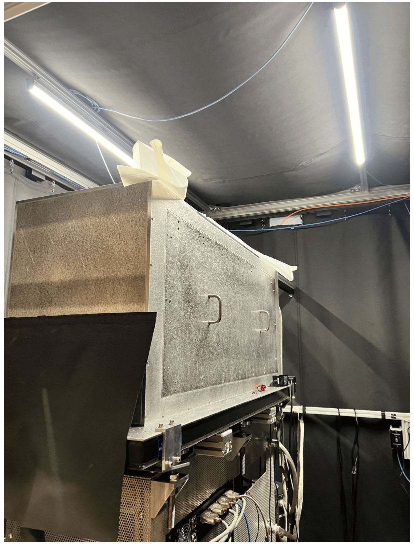
June - July 2024:

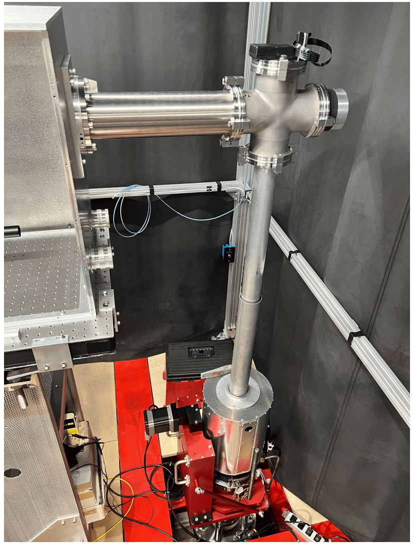
- Verify the UV alignment of P2 using the PIN diode systems & evaluate the response to UV
- Perform a safe scan crossing the entire field cage with P2 to generate tracks
- Final laser safety approval for remote operations (fully embedded)
- Commision controls/SW for full scan(s) in NP04
- Grounding studies

Before beam:

- Interest in using the laser to test the stability of the APA1 collection plane response (under discussion with the reconstruction team)

- After NP04: installation of system (single periscope) in NP02





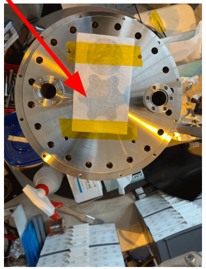
Lessons Learned (so far) - Assembly

- The quartz windows that serve as the entry point for the laser are **critical** and need to be pristine
  - NP02 design incorporates a replaceable window
- Additional restrictions during filling phase of the detector (cryo expert presence and approval)

Laser:

- Very sensitive to improper warm up and tuning
  - Dedicated window for warm up at the start of any run
- No readback of laser configuration parameters
- Internal optics easily exposed to dust, which can result in damage
  - **Immediate Mitigation:** Mount beam tubes at the output of the laser and enclose sensitive optics as much as possible
  - **DUNE FD mitigation:** identified a promising replacement laser candidate (procured)
    - Modular, modern interface, IP54 dust and moisture-proof output

Removable window



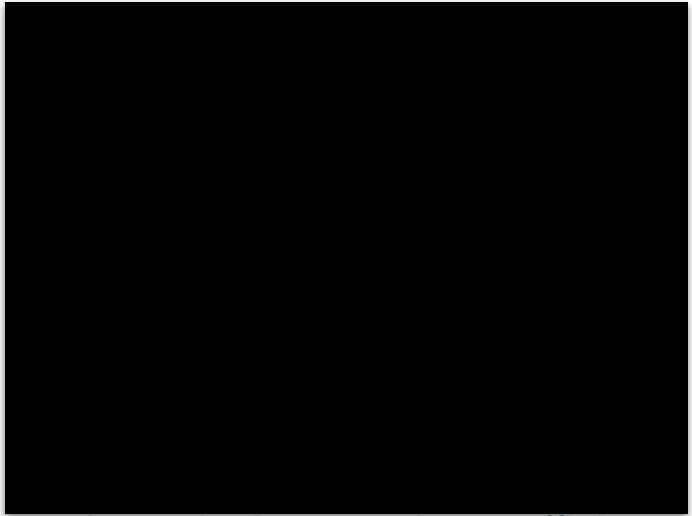
NP02 flange

New laser candidate

Lessons Learned (so far) - Commissioning

- Penetrating periscope design is **very promising**
  - No HV issues detected with the periscope inserted nor significant noise injected by the systems
- Cameras are useful verification tools
  - **Ensure that PIN diodes are visible via camera**
  - Good visibility of the field cage gaps is also useful

- Class 3B laser works reliably in air
  - 50% higher power would be ideal for use in liquid as well



- UV laser intensity is more than sufficient to generate tracks, even after losses from quartz interfaces

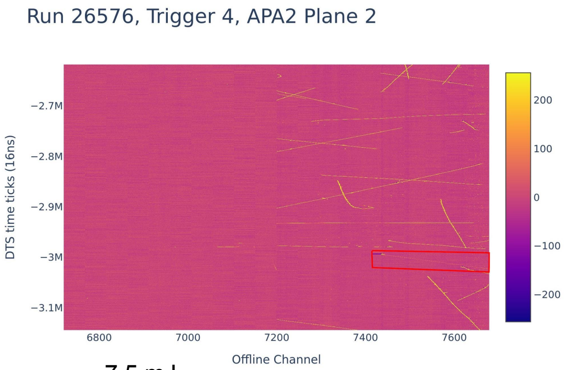
Thanks

- ProtoDUNE coordinators and safety officers at CERN!
    - Filippo Resnati, Johann Poirot, Christos Touramanis, Stephane Detraz, Letizia Di Giulio, Francesco Pietropaolo

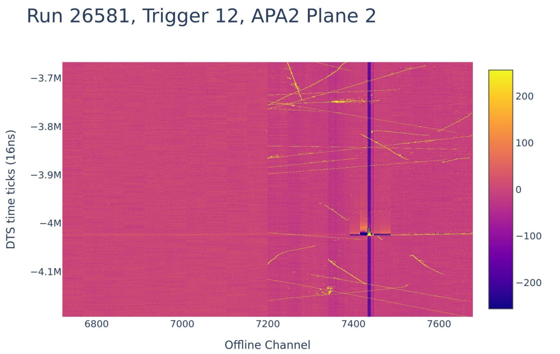
Team at CERN for this round of commissioning:

- D. Rivera (LANL), W. Campanelli (LIP), L. Tong (LANL), J. Maneira (LIP), E. Renner (LANL), N. Barros (LIP), M. Andrew (UHawaii), V. Solovov (LIP)

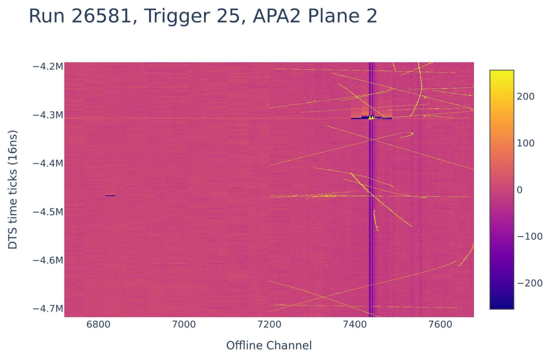
Many others offsite! (S. Gollapinni (LANL), R. Alves (LIP), D. Xing (LANL), J. Boissevain (LANL), R. Dharmapalan (UHawaii), J. Maricic (UHawaii), V. Sandberg (LANL), J. Vences (LIP), F. Neves (LIP)



7.5 mJ



15 mJ, rotating

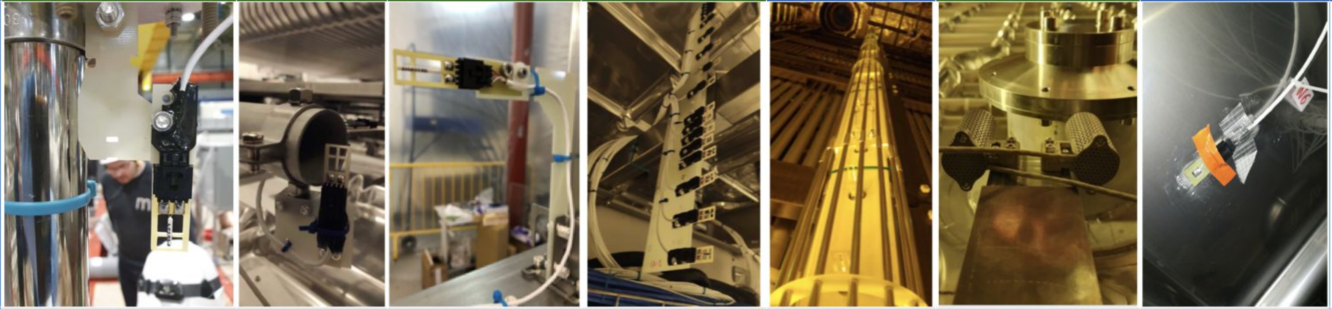


15 mJ, rotating again

Thermometers

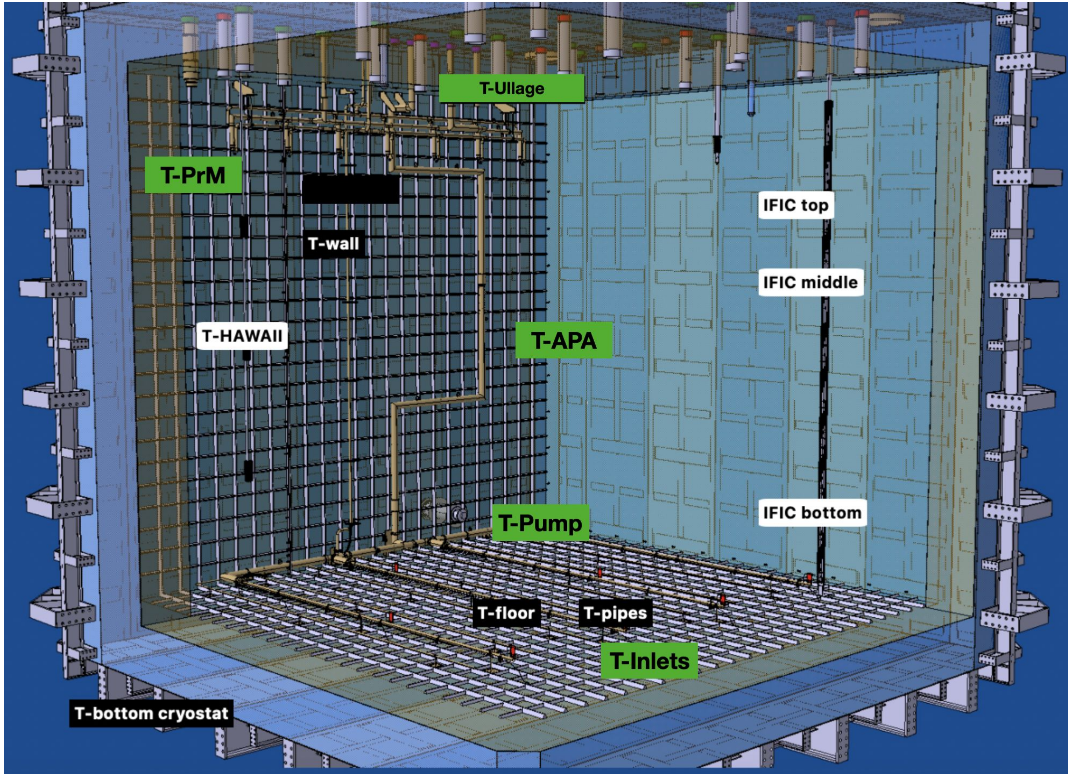
Temperature Sensors in NP04

159 sensors in NP04 monitor the LAr temperature within several subsystems. New systems in **green**.

	Purity Monitors	LAr Inlets + Pipes	APAs	ullage	T-Gradients	pumps	wall	TOTAL
								
PD-HD	6	4+8	16	36	48+24*	2	5	159
FD1	8	16	600	144	0	8	26	802

Temperature Sensors in NP04

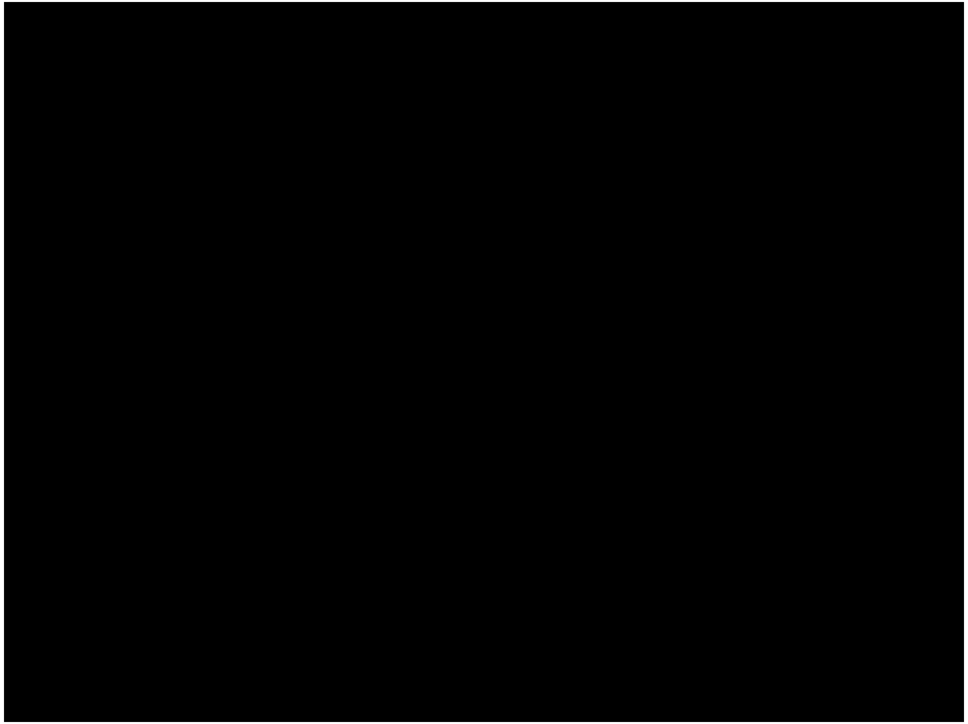
- 16 APA T-sensors are in the active volume.
- The rest map the temperature beyond the field cage.
- New systems in **green**

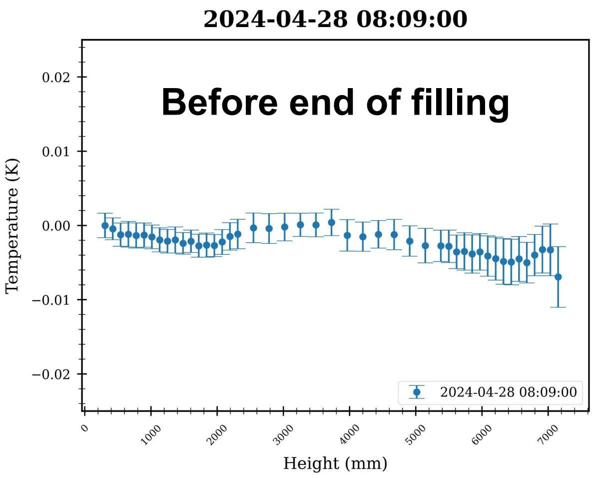


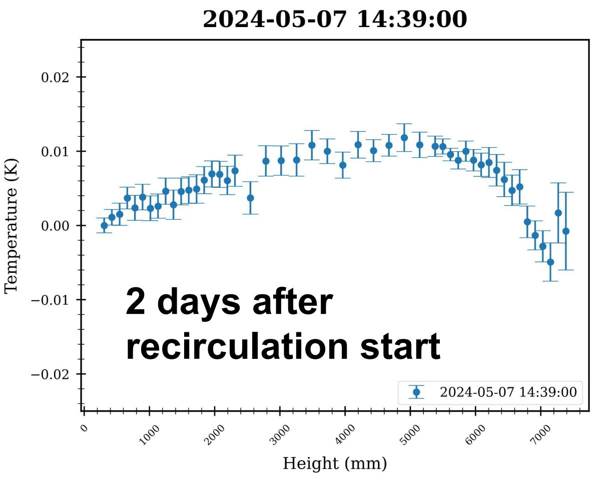
Temperature Stability in NP04

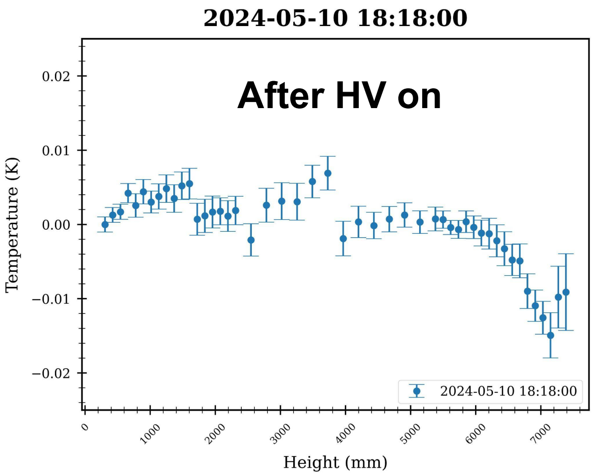
The vertical temperature profile is very stable over long-time periods.

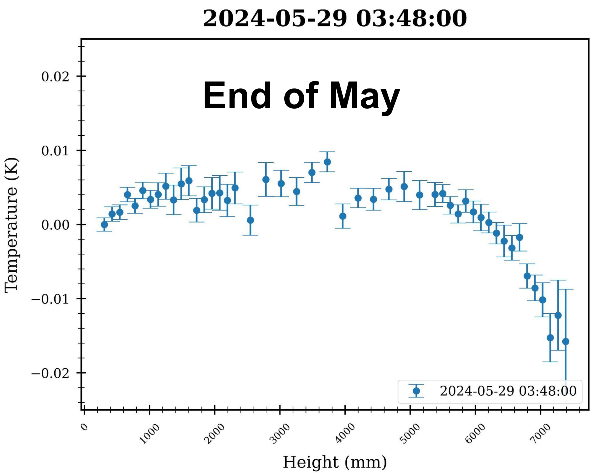
- The profile is pretty sensitive to changes on the recirculation system; i.e. LAr inlet temperature.
- It takes several days to stabilise after a major change in conditions.




2024-04-28 08:09:00
Before end of filling
Temperature (K)
Height (mm)
2024-04-28 08:09:00

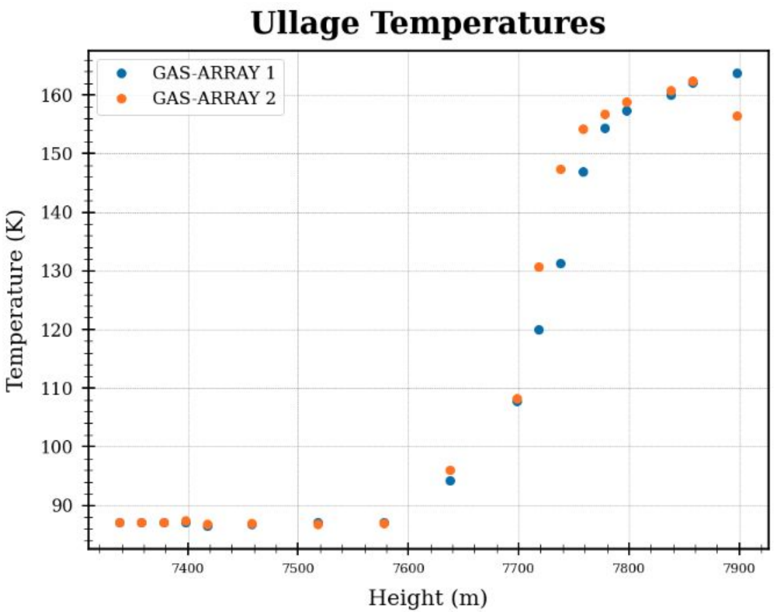

2024-05-07 14:39:00
2 days after
recirculation start
Temperature (K)
Height (mm)
2024-05-07 14:39:00

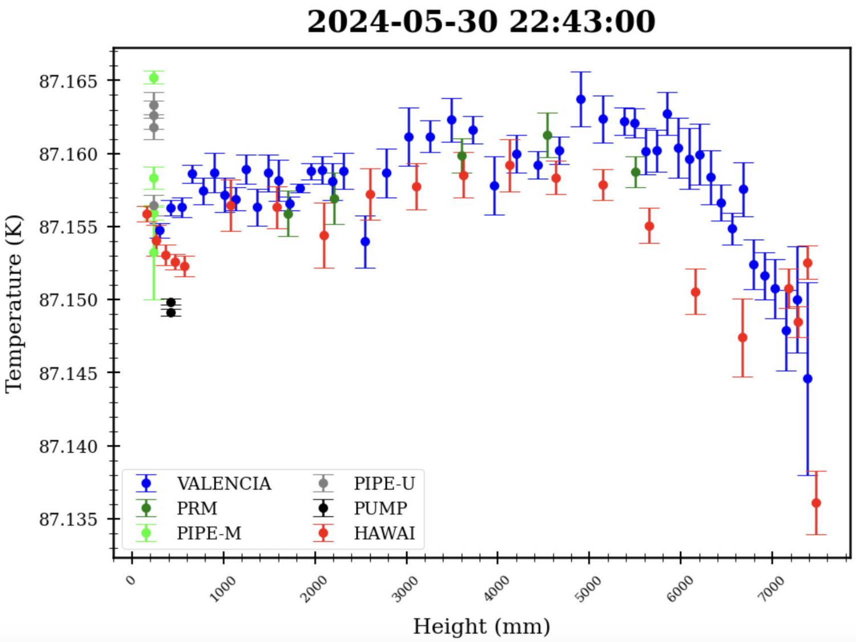

2024-05-10 18:18:00
After HV on
Temperature (K)
Height (mm)
2024-05-10 18:18:00


2024-05-29 03:48:00
End of May
Temperature (K)
Height (mm)
2024-05-29 03:48:00

Temperature maps

SDSU CFD simulations almost ready for comparisons

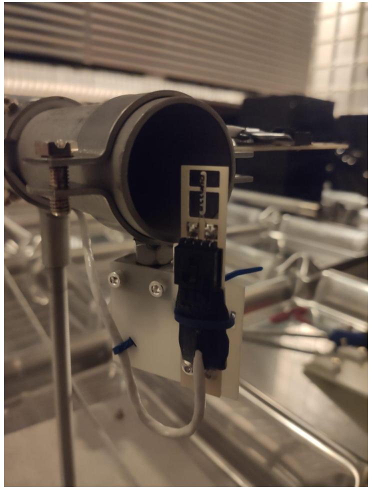




Lessons Learned (so far) from NP04

- LAr inlet sensors:
  - When filling started only one of them showed 87 K → direct exposure to LAr. X days after it stopped working
  - 3 sensors showed 87 K Y days after filling started
  - Solutions for FD1: 1) better positioning, 2) Al encapsulation

INLET



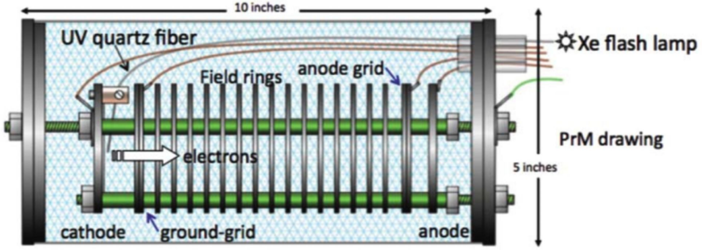
- Pumps-off calibration: equalize all sensors with no recirculation and no heat sources
  - Stabilization took almost 2 days in NP04
  - Understand needs for FD1

LakeShore Al encapsulation

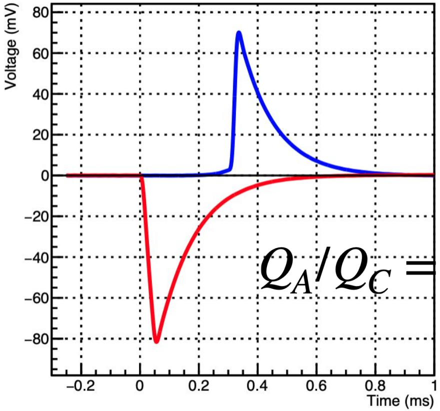
Purity Monitors

Purity Monitors at NP04

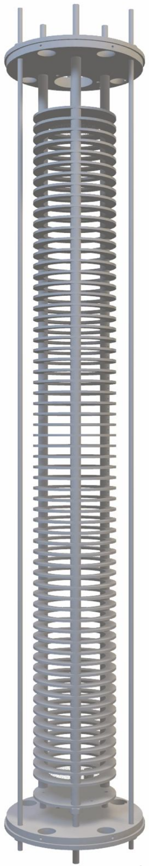
- A purity monitor is a miniature TPC, which actively generates electrons by shining light on the photocathode
  - Measuring purity by measuring the attenuation of electrons traveling from cathode to anode
- 3 PrMs were installed at NP04, at different heights
  - The middle PrM is new, with a longer drift distance (64 cm), intended to reduce the systematic uncertainty in the absolute measurement



M. Adamowski et al., JINST 9, P07005 (2014).



$$Q_A/Q_C = e^{-t_{\text{drift}}/\tau}$$

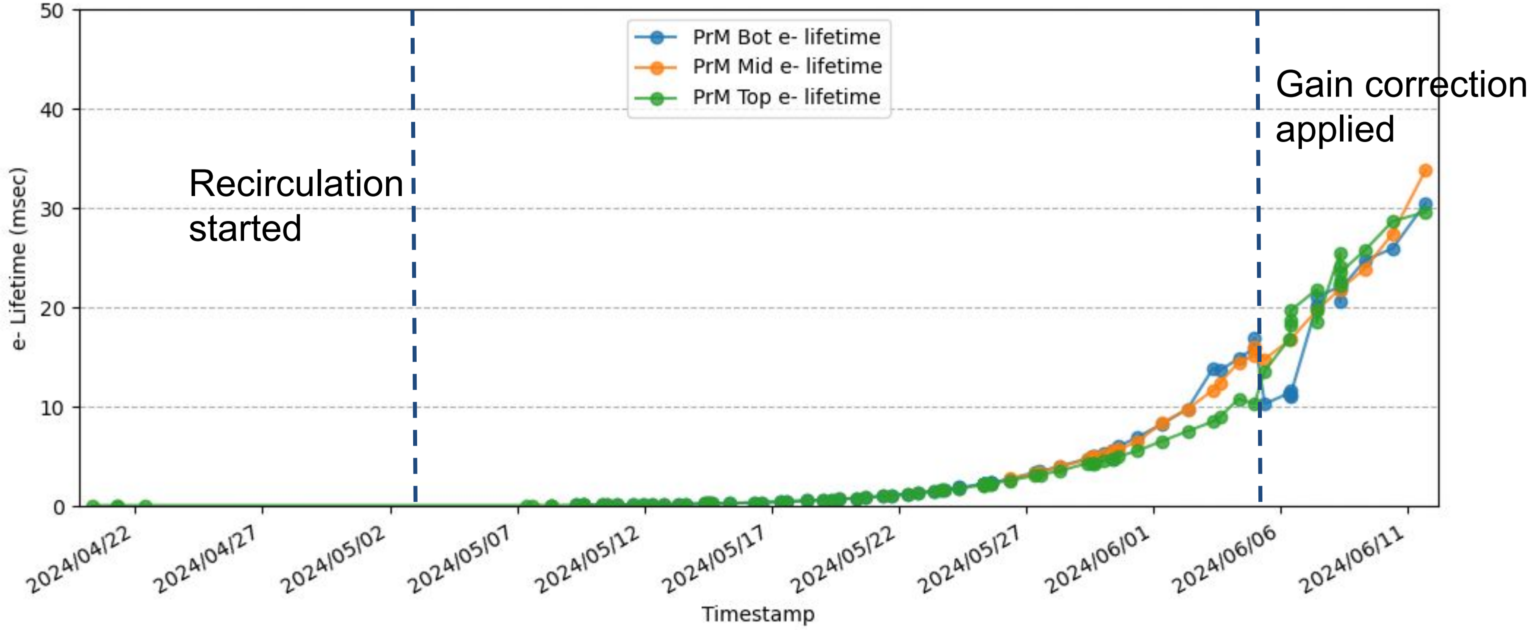


(Field Cage not shown)

Purity Monitors at NP04

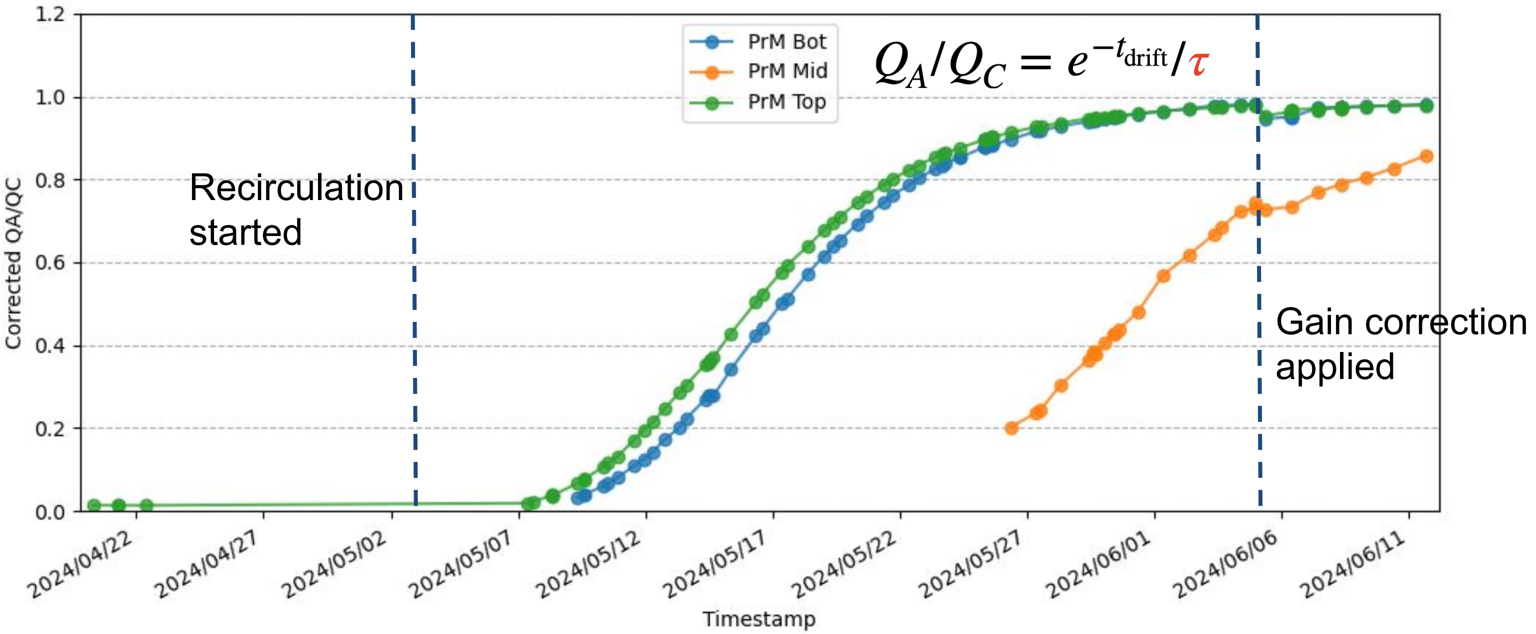
Electron lifetime monitoring

- All 3 PrMs were immersed in liquid argon since Apr. 19
- Recirculation started on May 3
- Purity is steadily improving
  - ~30 ms as of June 11 - improving at a rate of 20% per day as expected



Qa/Qc monitoring

- Top and bottom PrMs are getting saturated when the liquid is very pure
  - Qa/Qc → 1 ⇒ large uncertainty on the measured lifetime
- The long PrM has a relatively low Qa/Qc when the lifetime is ~30 ms



Next steps

- Given top and bottom PrMs are getting saturated, will tune the electric field to improve the sensitivity with a trade off of the transparency
- Systematic uncertainty estimation of the electron lifetime results

Lessons learned (so far)

- Middle PrM has smaller signals compared to the other PrMs
  - Feedthrough: lower breakdown voltage
  - Photocathode: less electrons generated
- It's important to have the PrMs tested in argon gas before installation, instead of the vacuum test only