NP04 CALCI Performance

Technical Board Meeting

August 14, 2024

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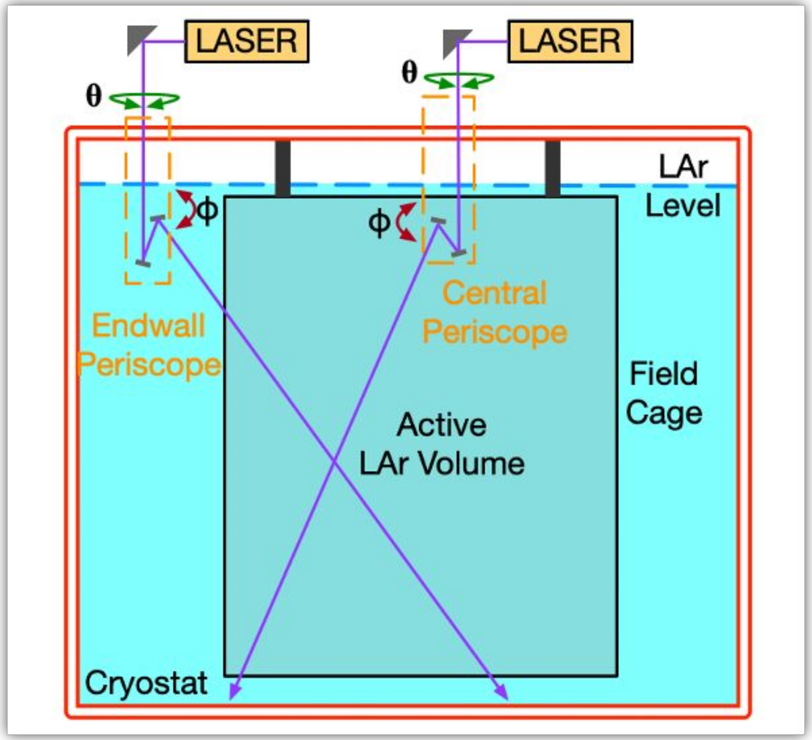
(with contributions from J. Capo and W. Wu)

On behalf of CALCI consortium

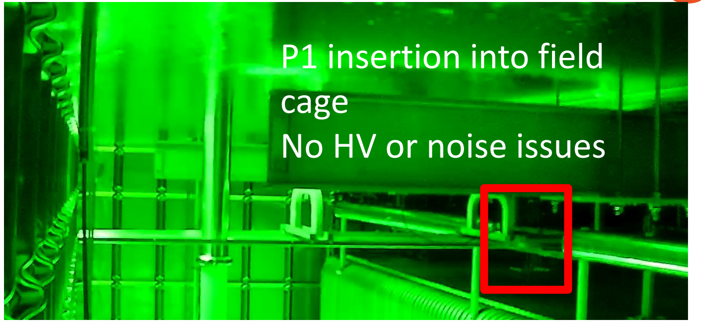
Ionization Laser

Concept



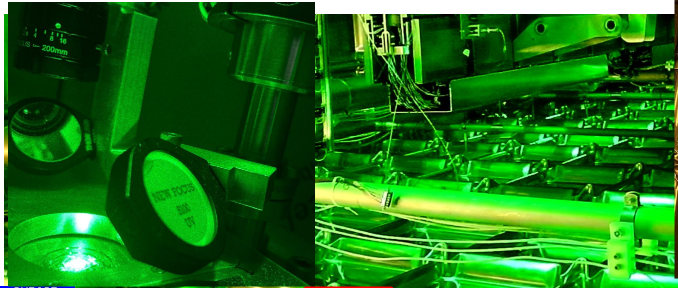
- Ionization of LAr with 266 nm laser, UV
  - 2-photon excitation + 1-photon ionization
  - Requires intense beam, ~10 mJ pulse
- Movable periscopes with cold mirror to bring beam into cryostat and steer it
  - Two designs prototyped for use in PD-HD, one penetrating the field cage, one outside
  - Automated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

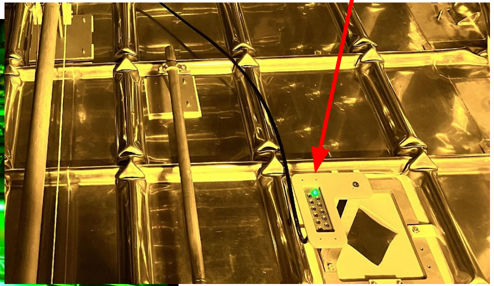
Commissioning



Green laser alignment, checks w/ cameras, PIN diodes

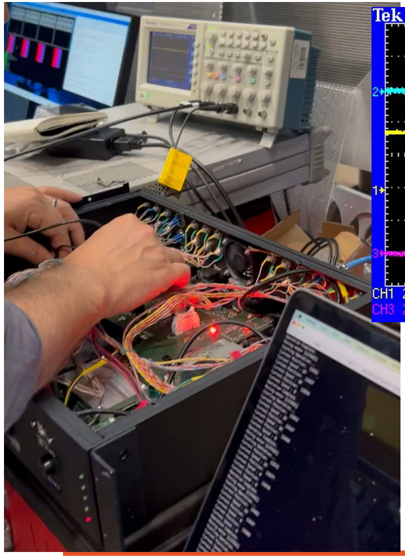
PIN diode module

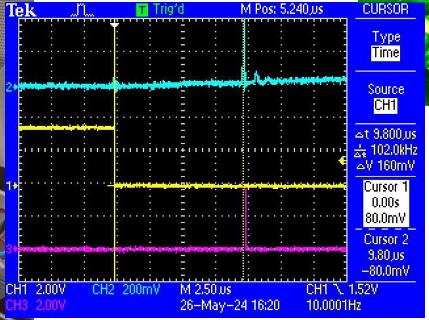




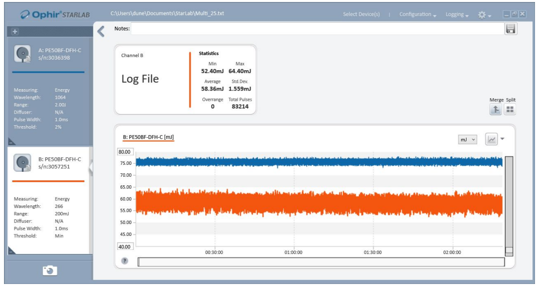
UV laser safety reviews and intensity stability checks

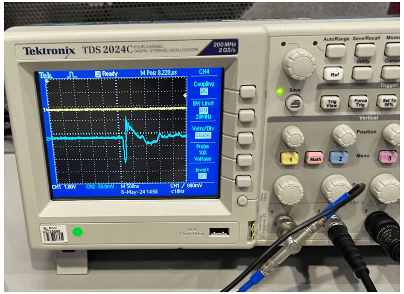
PIN diode signal





Electronics board controlling laser and reading out photodiode for trigger



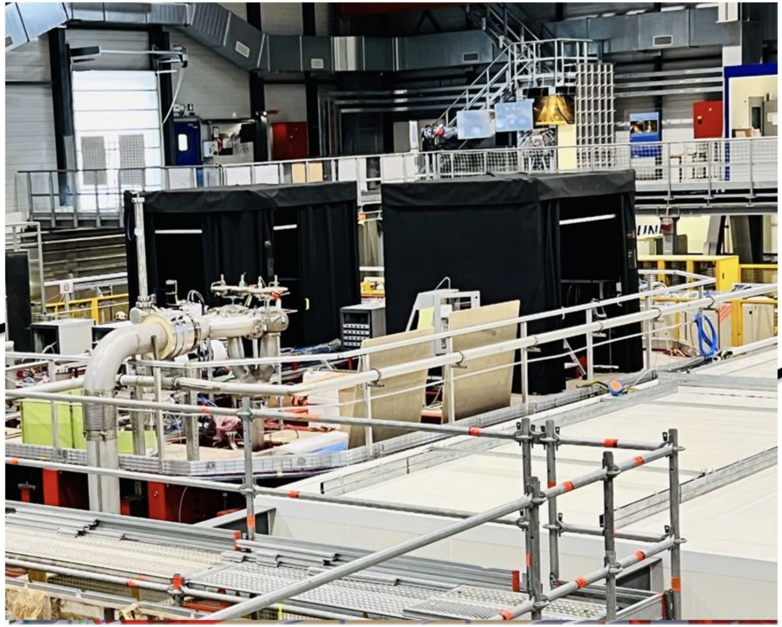


60 mJ of UV for P1.
(40 mJ for P2)

Laser Periscope Feedthroughs @NP04

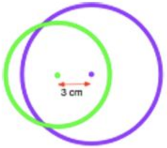
Three degrees of freedom for each periscope including rotations and retractions

Periscope 1 (P1)



ProtoDUNE laser calibration systems

Periscope 2 (P2) / Endwall

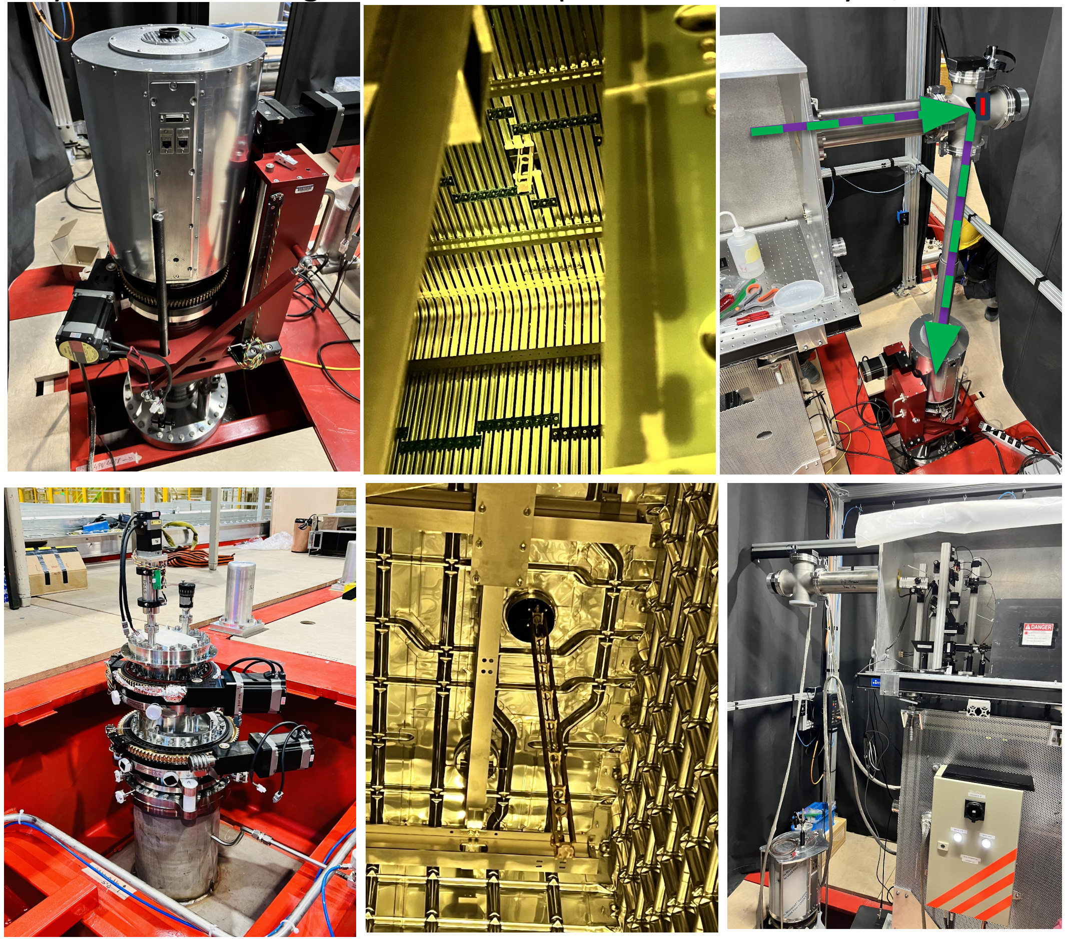


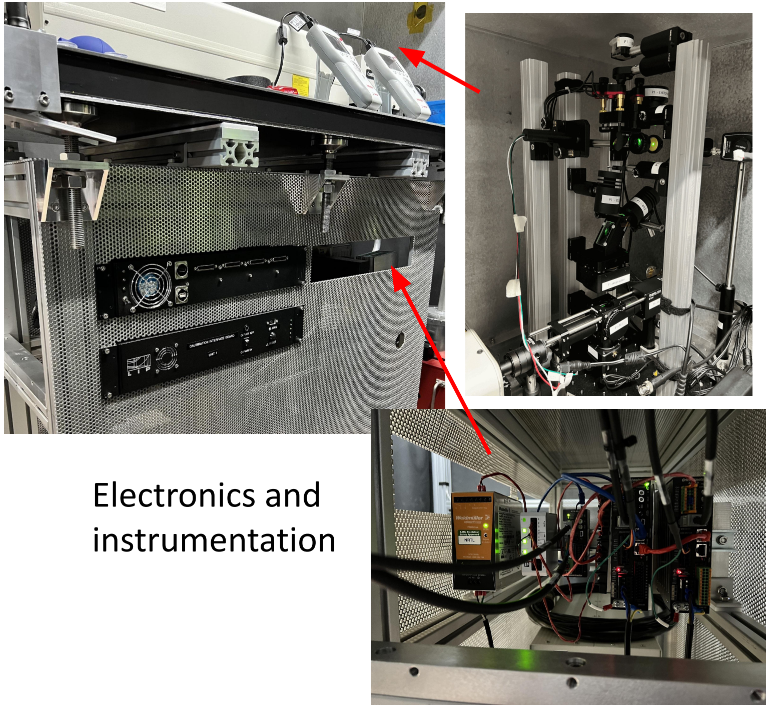
Installation @ NP04 completed

Cryostat feedthrough | Periscope | Assembly w/ laser box

P1 penetrates top of field cage

P2 Outside field cage



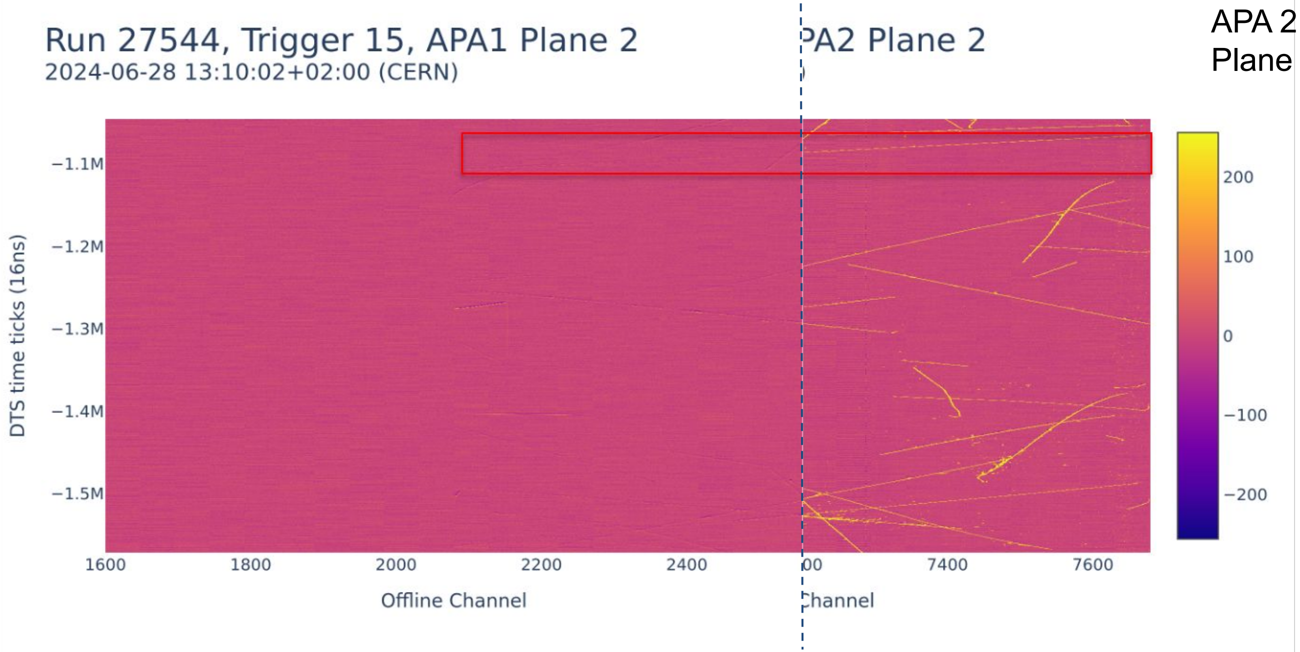


Electronics and instrumentation

Candidate tracks from P2

Periscope 2 UV alignment completed in June, with camera verification on the downstream end for unobstructed tracks. Two brief runs

APA 1 Collection Plane
(Note that this plane has the wire bias issues, but faint tracks can still be seen)

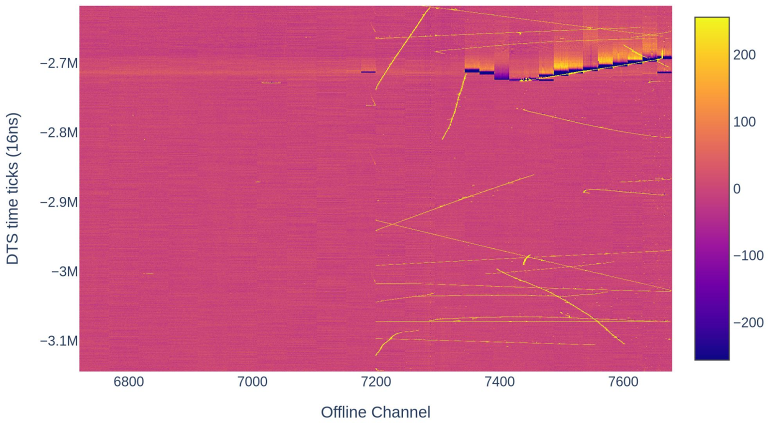


APA 2 Collection Plane

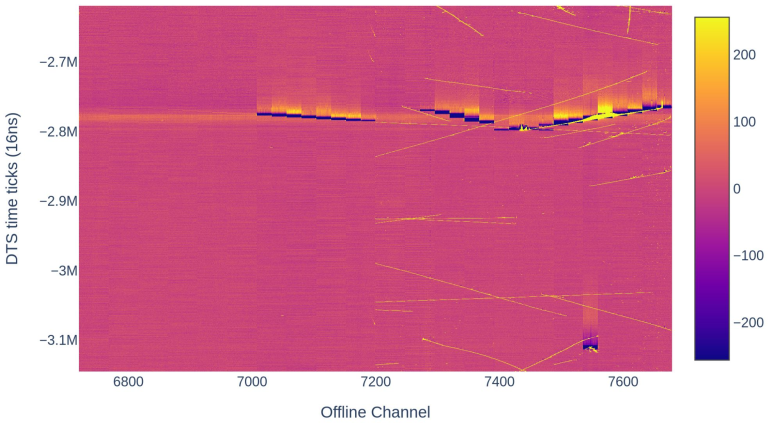
P1 Tracks

Additional P1 tracks were collected. These are from July 5th, while aiming roughly in the direction of one LBLS mirror pad

Run 27757, Trigger 3, APA2 Plane 2
Trigger Type (Timing), 2024-07-05 17:03:59+02:00 (CERN)

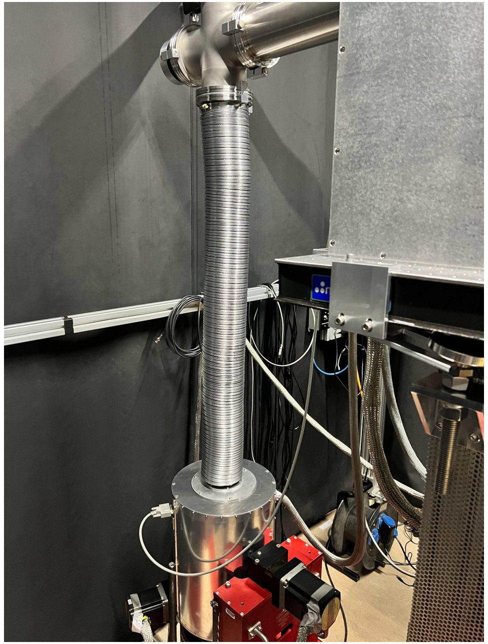


Run 27757, Trigger 10, APA2 Plane 2
Trigger Type (Timing), 2024-07-05 17:05:09+02:00 (CERN)



Successes

- Took data with both laser periscope systems
- CIB photodiode trigger validated (July)
- Initial DAQ integration completed
  - Triggered runs with fake data from both CIBs in August
- Fully embedded the laser beams for remote operations



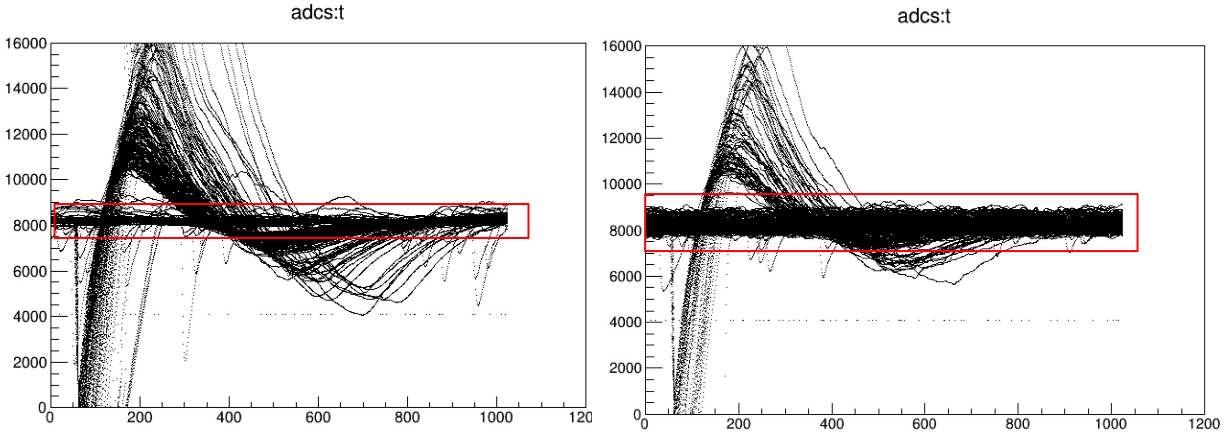
Periscope 1. Fully enclosed beam.

Periscope 2. Fully enclosed beam.

New lessons learned (so far)

- Laser systems can operate on detector ground and must therefore be well-referenced to the cryostat roof
- When running the laser and the PDS at the same time, the recovery time is significant (even when attenuating the UV to less than 1%)
- The PDS is sensitive to the class 3B green, alignment laser

(For additional lessons learned, see the backup)

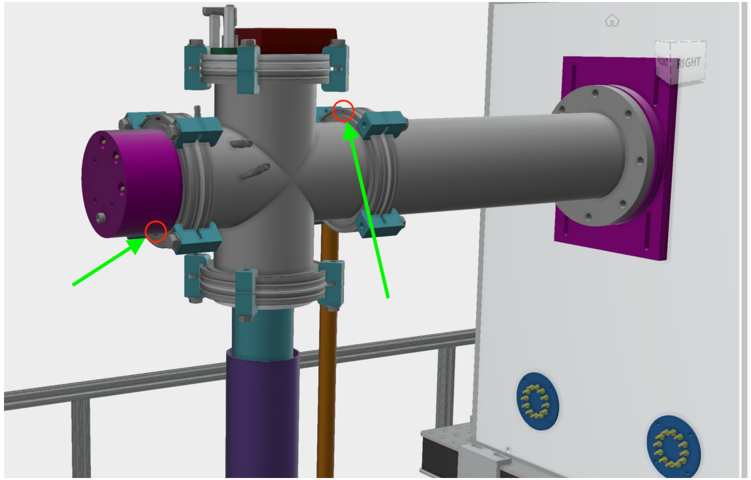


Change in the baseline with the Class 3B alignment laser OFF (left) and ON (right)

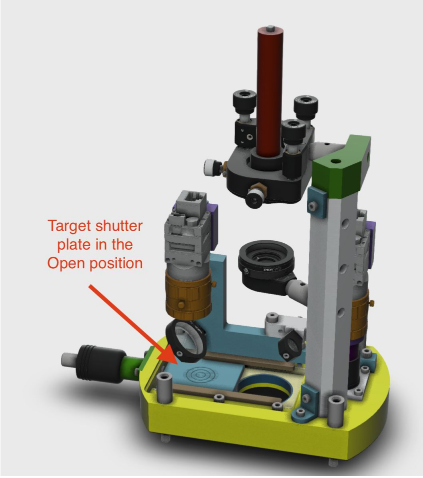
New lessons learned (so far)... continued

Updated designs that further constrain the alignment of the system for VD:

- Additional alignment pinholes added to the turret and beam tubes
- Target on the optical flange will be more tightly constrained and black anodized for safety



Additional alignment pinholes added to aid in construction



Revised shutter design for P3 optical flange

Next Steps

Now - First week of September:

- Demonstrate triggered laser runs
  - Aim P1 at a reference position
  - Run the data through the standard reconstruction
- Take weekly runs aiming at PIN diodes, LBLS mirrors, and other reference positions

Mid-September through October:

- Grounding studies
  - Measure the noise contribution from the laser systems (previously determined to be low)
- Check for bias voltage stability when running P2 after the grounding changes in July
- Aim at the PIN diodes with P2 & evaluate the response to UV
- Test the external shutter safety system for the two periscope and the interface with the CIB
- Commision controls/software for full and partial scans in NP04 with the CIB
- Filter out residual 532 and 1064 nm contamination from the UV laser beam using a beam splitter for M2 and with the PDS at a lower gain setting (if needed)
  - Check for late scintillation light

- Since we were not able to take much data with P-2 nor get P-1 and P-2 crossing tracks, full scans etc. – being able to complete the tasks following beam run in NP04 to achieve planned full datasets is critical and that being able to do this into september and possibly through mid-October (or until LAr transfer to NP02) would be very helpful

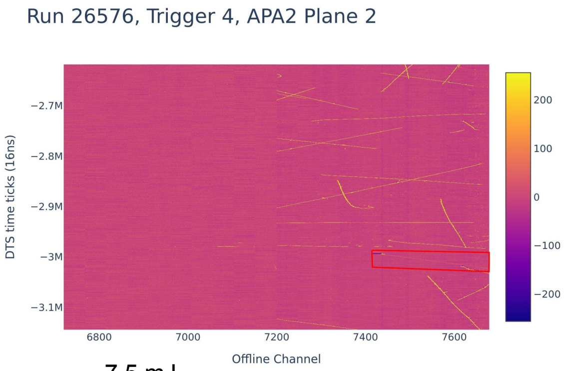
Thanks

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

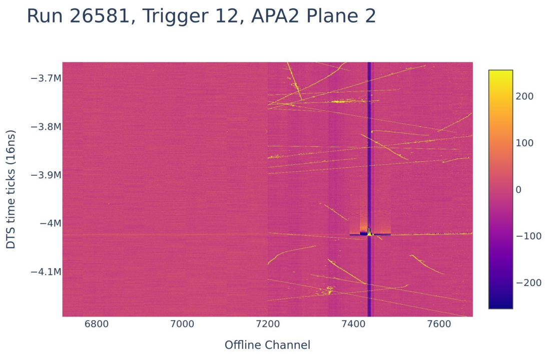
Team at CERN for this round of commissioning:

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

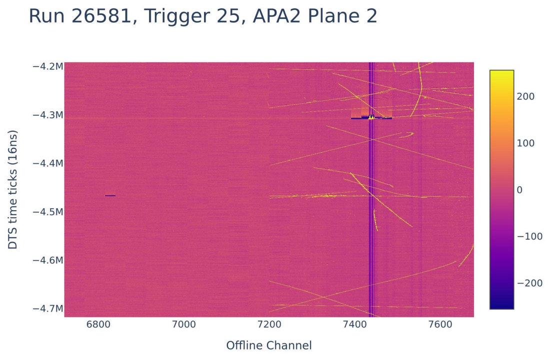
Many others offsite! (S. Gollapinni (LANL), R. Alves (LIP), D. Xing (LANL), J. Boissevain (LANL), R. Dharmapalan (UHawaii), J. Maricic (UHawaii), V. Sandberg (LANL), J. Vences (LIP), F. Neves (LIP)



7.5 mJ



15 mJ, rotating

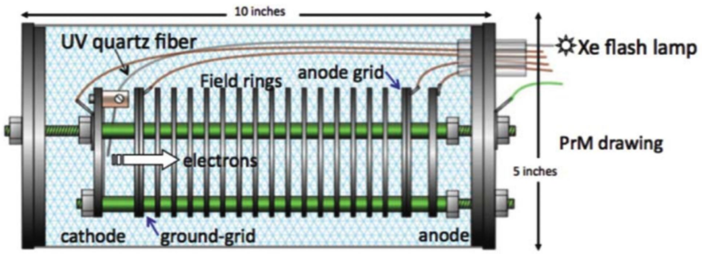


15 mJ, rotating again

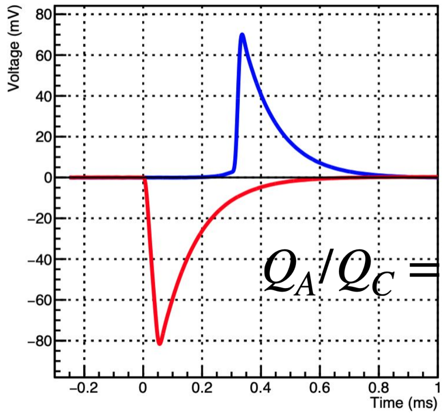
Purity Monitors

Purity Monitors at NP04

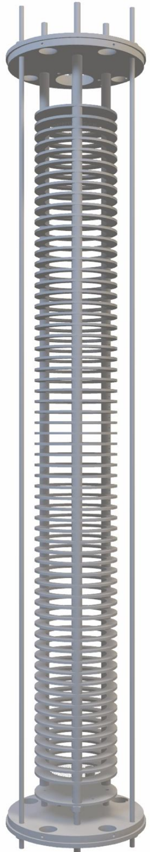
- A purity monitor is a miniature TPC, which actively generates electrons by shining light on the photocathode
  - Measuring purity by measuring the attenuation of electrons traveling from cathode to anode
- 3 PrMs were installed at NP04, at different heights
  - The middle PrM is new, with a longer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



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



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

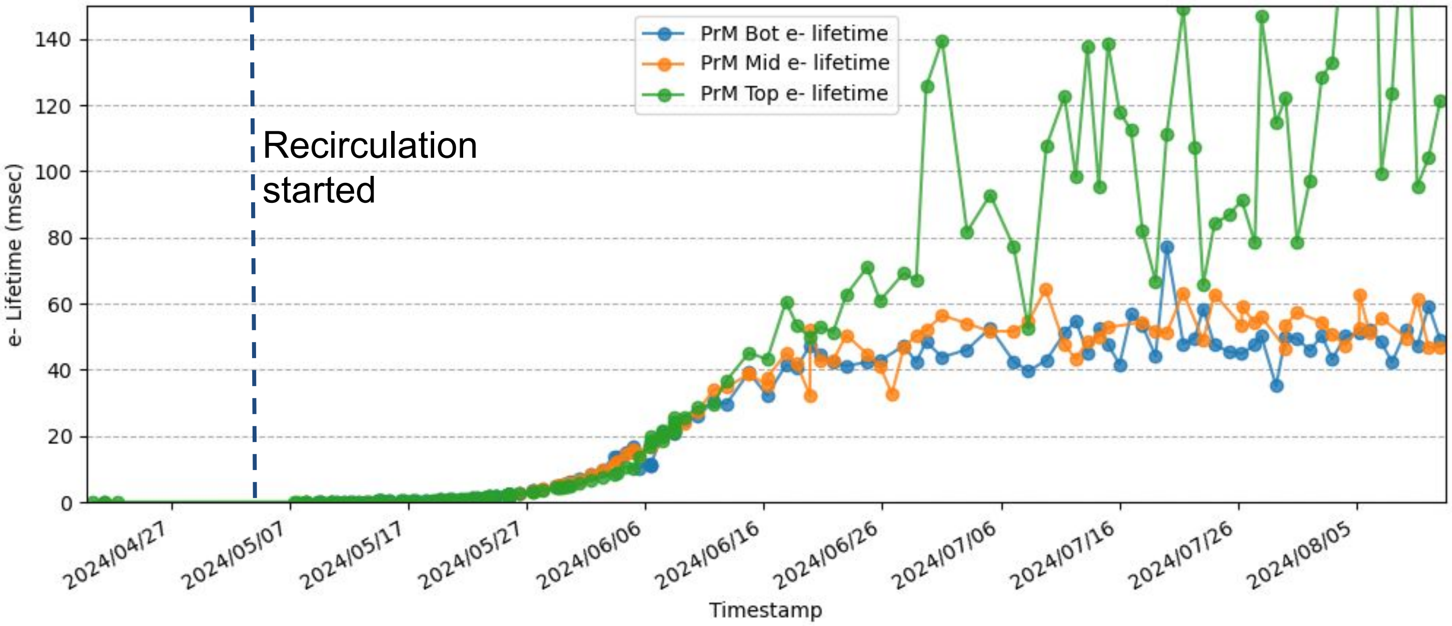


(Field Cage not shown)

Purity Monitors at NP04

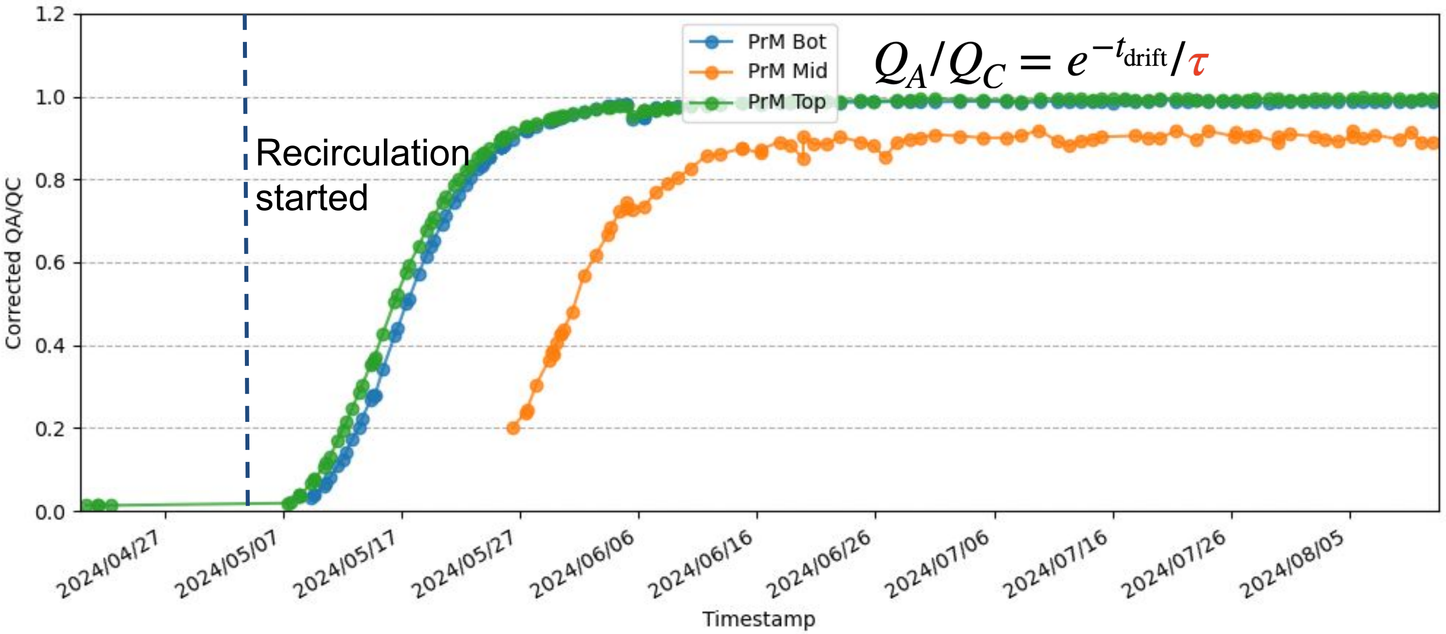
Electron lifetime monitoring

- All 3 PrMs were immersed in liquid argon since Apr. 19
- Recirculation started on May 3
- Purity is stable over the last two months, >40 ms



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

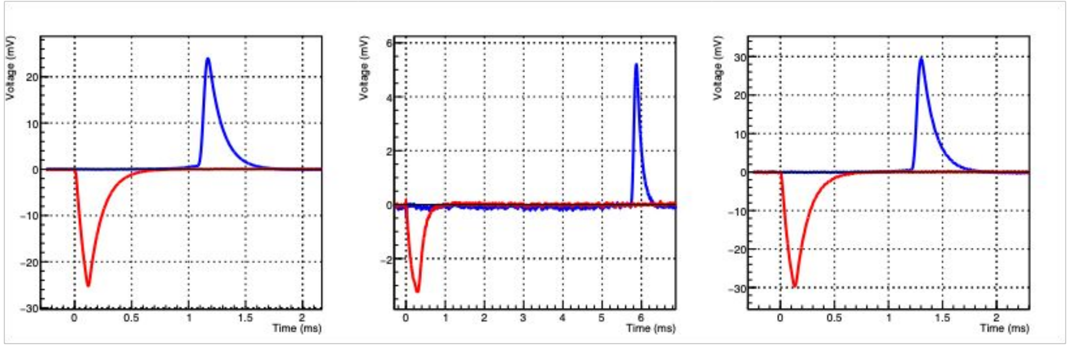


Next steps

- Middle PrM has a longer drift distance causes a difficulty to fit the waveform, will improve the model to have more stable fit results
- Systematic uncertainty estimation of the electron lifetime results

Lessons learned

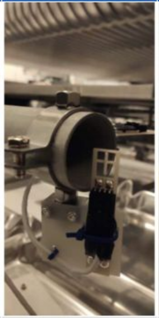
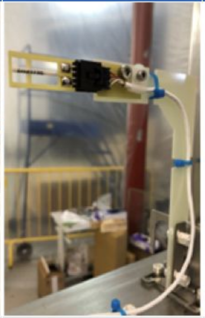
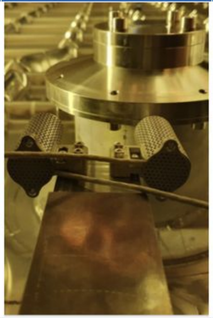
- Middle PrM has smaller signals compared to the other PrMs
  - Feedthrough: lower breakdown voltage
  - Photocathode: less electrons generated
- It's important to have the PrMs tested in argon gas before installation, instead of the vacuum test only



Thermometers

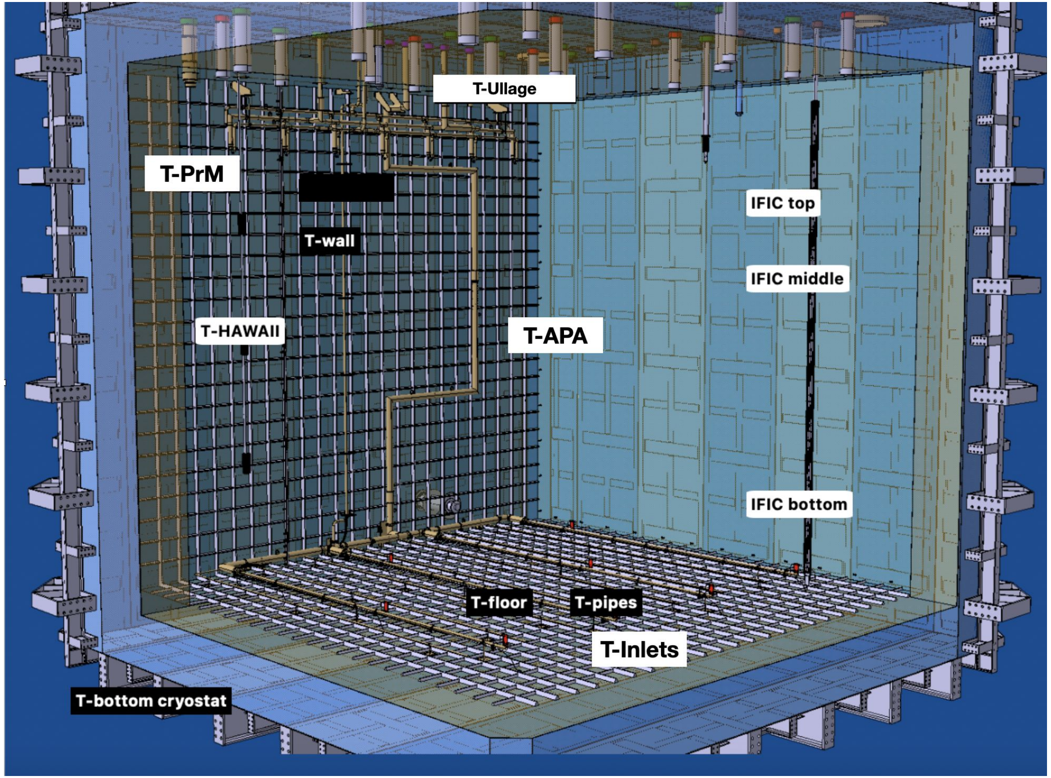
Temperature Sensors in NP04

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

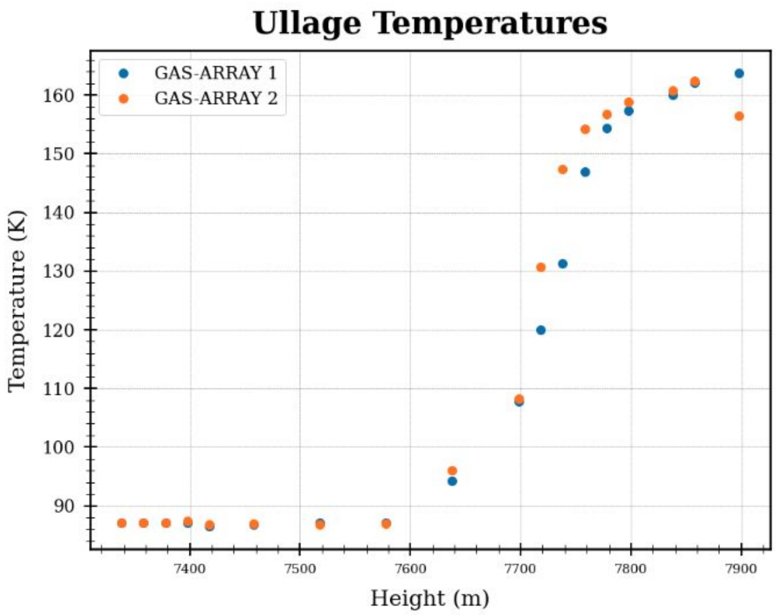
Temperature Sensors in NP04

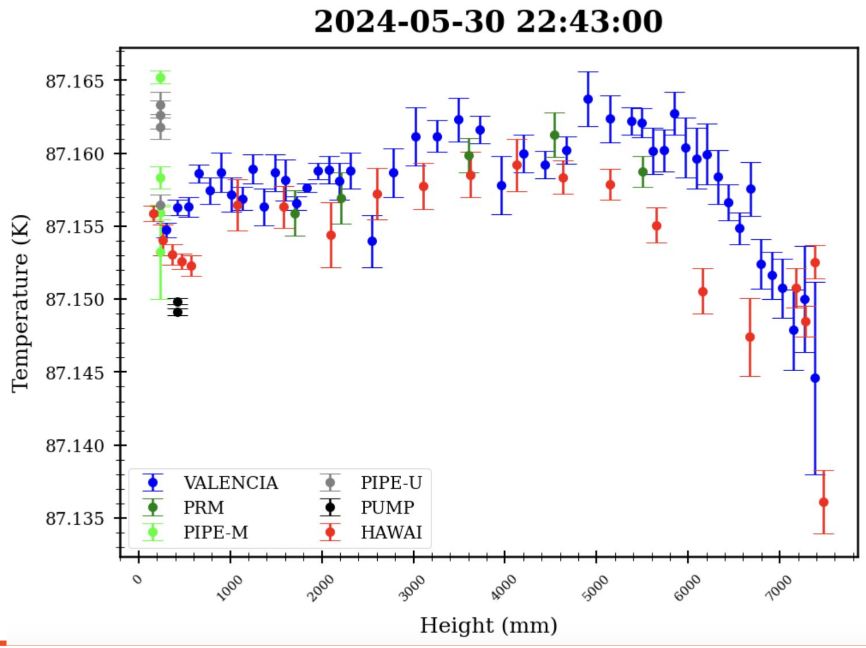
- 16 APA T-sensors are in the active volume.
- The rest map the temperature beyond the field cage.



Temperature Maps

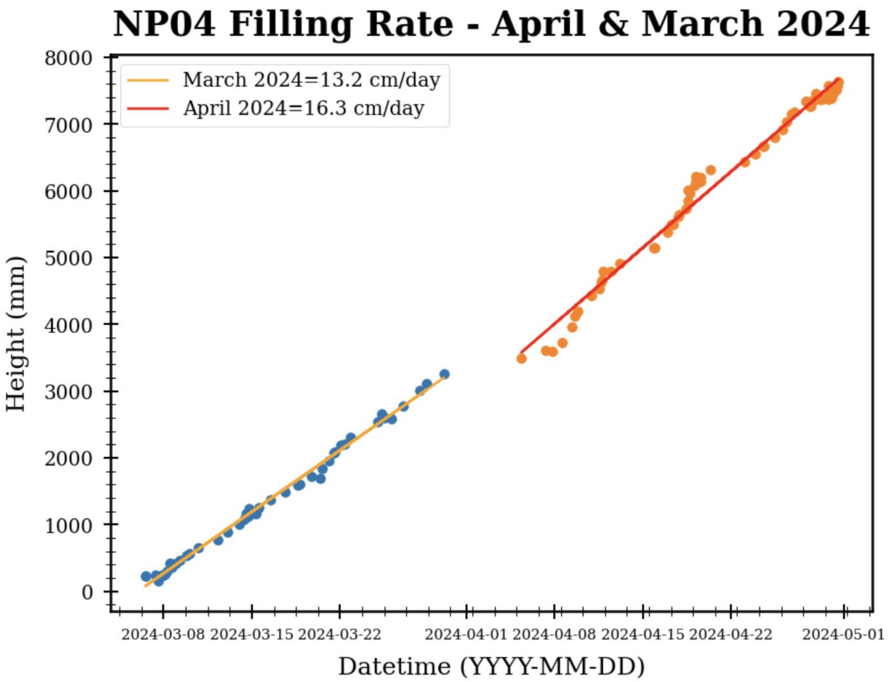
- SDSU CFD simulations expected to be ready by September for comparison with data.





NP04 Filling Rate Estimation

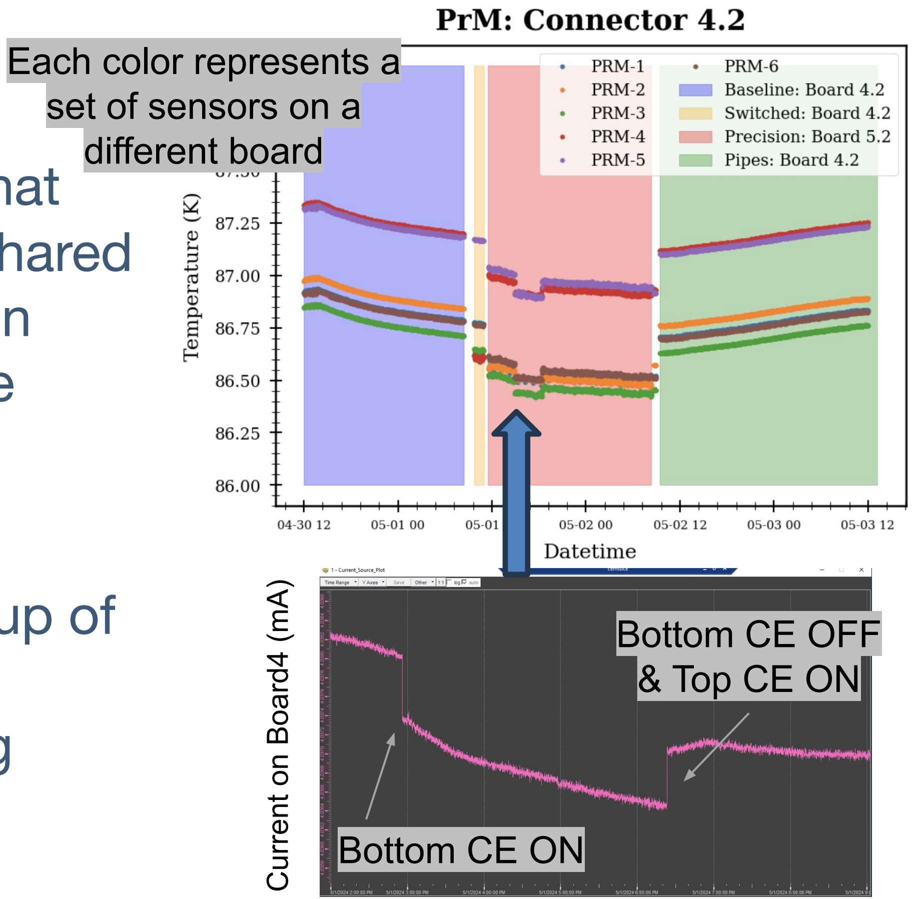
- We have looked at the immersion time of every sensor in the cryostat:
  - To check that the mapping and height assignment of each sensor is correct.
  - To extract an approximate filling rate.



Unwanted Effects

- Because the voltage supply that feeds the current sources is shared with other systems, changes in those other systems affect the readouts of the T-sensors.

- Also, there is an independent current source per board (group of 24 T-sensors) causing discrepancies when swapping T-sensors between boards.



Next Steps

- To perform additional on-site calibrations during September to characterise/understand better the unwanted effects.
- To prepare a complete report about T-sensors performance for the whole NP04 operation period.

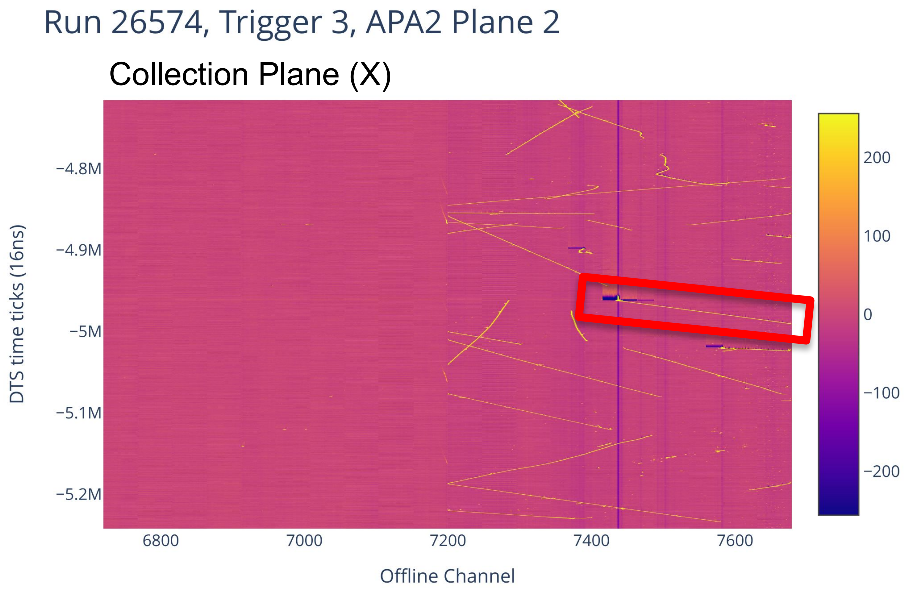
Lessons learned (so far)

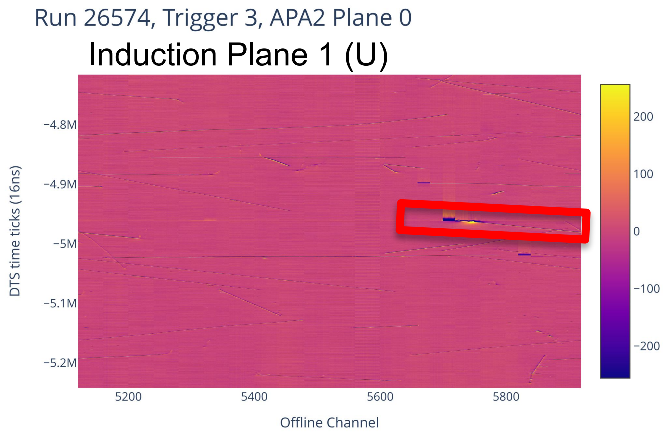
- It is not a good idea to have a shared voltage supply for the current sources that feed the T-sensors with other systems.
- Ideally, to have a unique current source feeding all boards simultaneously (in series) for FD-I.
- Stability and uniformity of temperature and gradients is excellent across the entire volume (in June 12th TB report was presented)

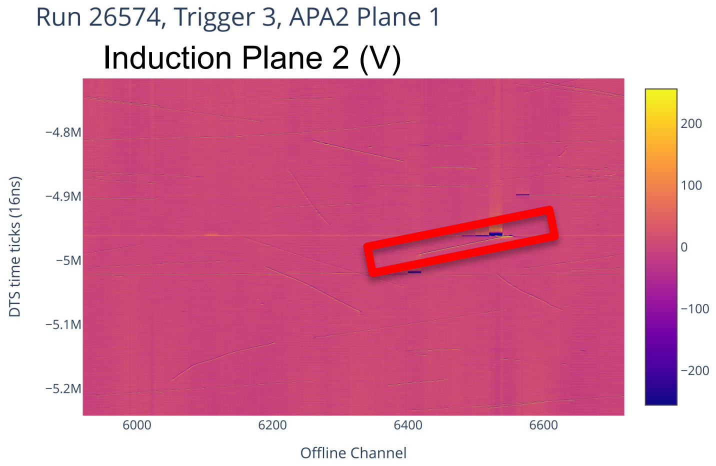
Backup

FIRST LASER TRACKS!

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







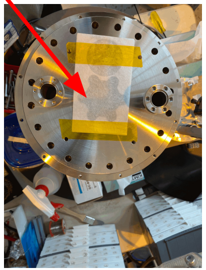
Lessons Learned (so far) - Assembly

- 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)

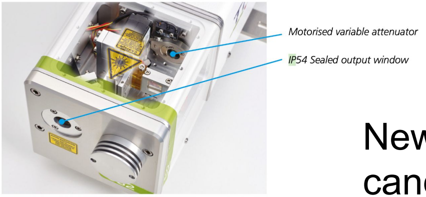
Laser:

- 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