Ton-Scale Liquid Argon Detector for Low-Energy Neutrino Processes

Se Wook Oh
Department of Physics and Astronomy
Seoul National University
COHERENT Collaboration

K-Neutrino Symposium 2026
Chung-Ang Univ. Korea
Oct. 27, 2026

Coherent Elastic Neutrino-Nucleus Scattering

- Neutrino interacts with a whole nucleus when $qR \lesssim 1$
- Precisely predicted cross section in Standard Model

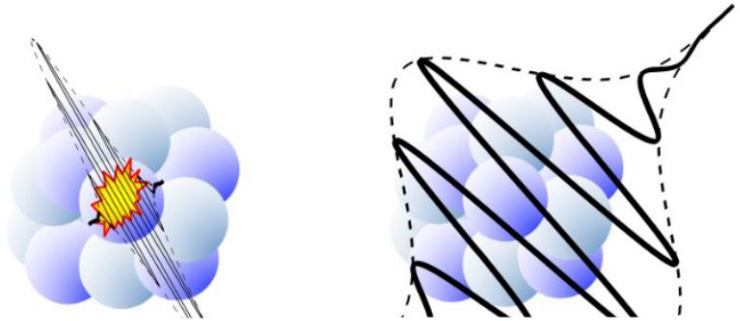
$$\frac{d\sigma}{dT} \simeq \frac{G_F^2 M}{4\pi} Q_W^2 \left(1 - \frac{MT}{2E_\nu^2}\right) F^2(Q^2)$$

- N^2-dependent cross section

$$Q_W^2 = (N - (1 - 4\sin^2\theta_W)Z)^2 \simeq N^2$$

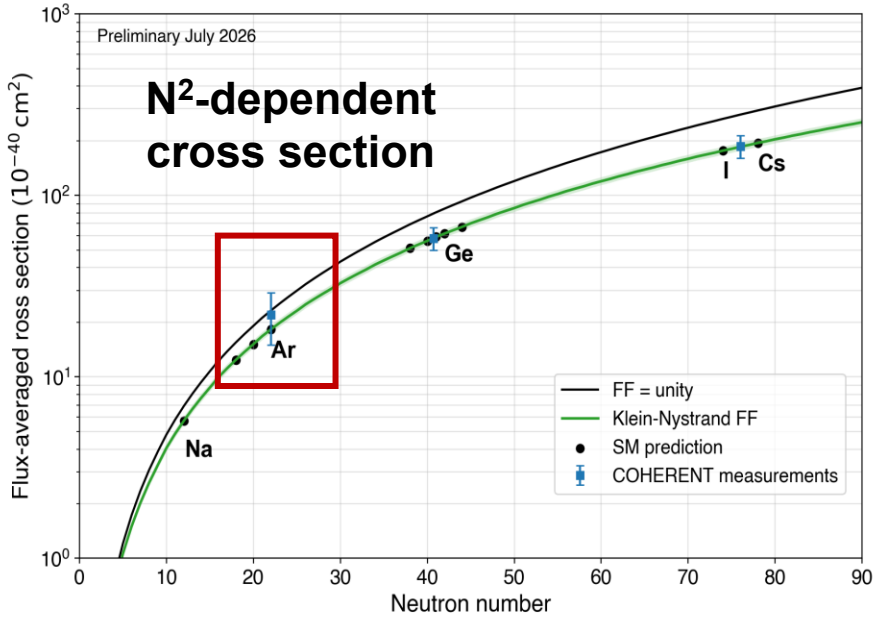
- Dominant process at low neutrino energies
- Hard to detect: $T_{\max} \simeq 2E_\nu^2/M \sim O(10 - 100\ \mathrm{keV})$

→ Need a low-threshold detector + intense neutrino source

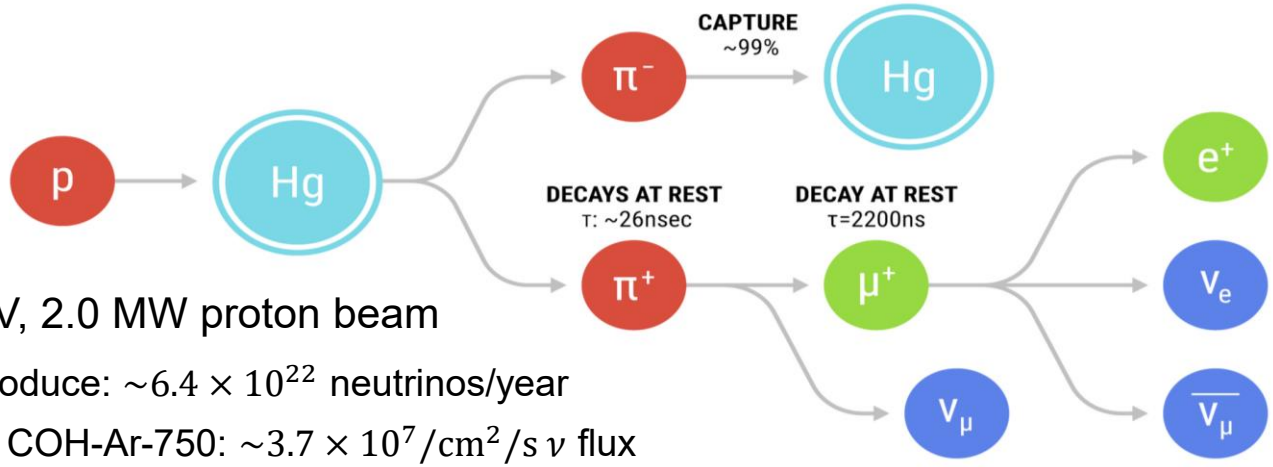


High Q = short de Broglie wavelength

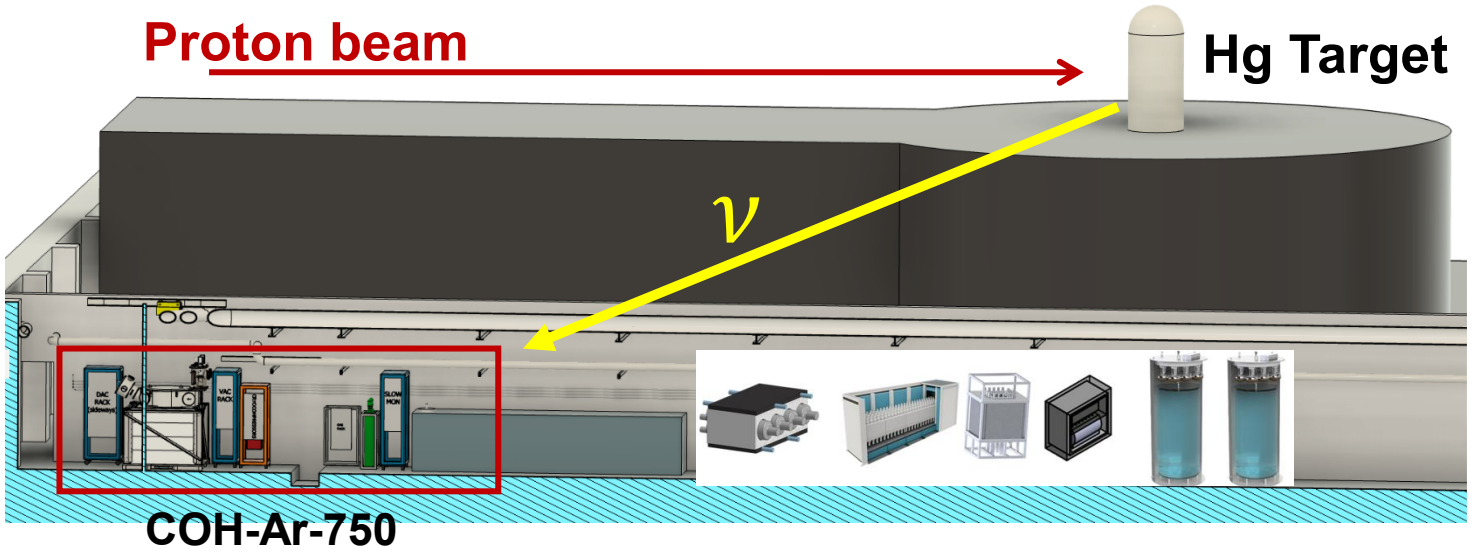
Low Q = long de Broglie wavelength

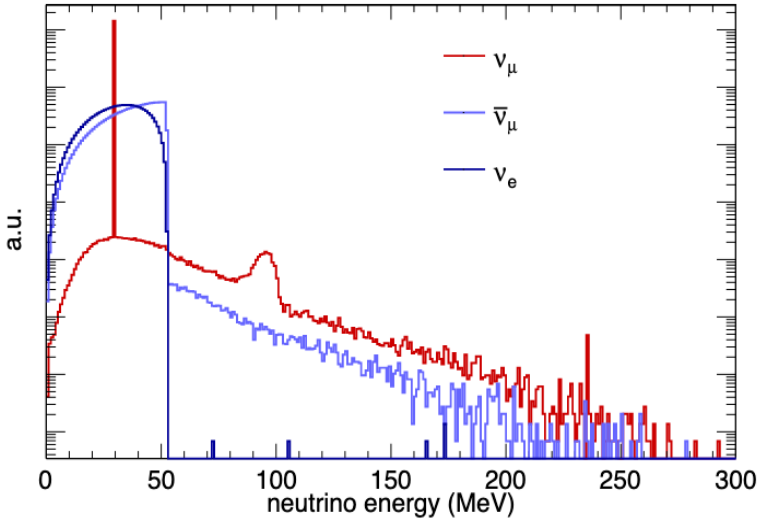


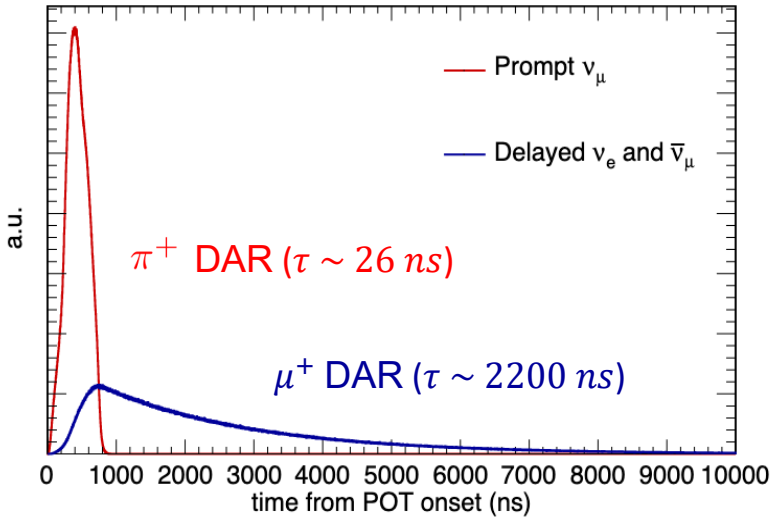
SNS at ORNL



- 1.3 GeV, 2.0 MW proton beam
  - Produce: $\sim 6.4 \times 10^{22}$ neutrinos/year
  - At COH-Ar-750: $\sim 3.7 \times 10^{7}/\mathrm{cm}^2/s\ \nu$ flux
  - Beam pluse: 60Hz, 350 ns FWHM
- Background rejection from beam duty factor $\sim 4 \times 10^{-5}$



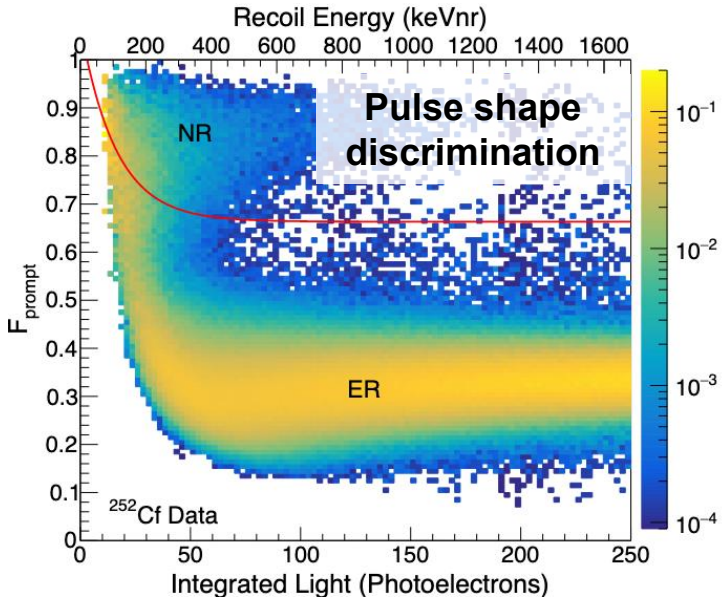


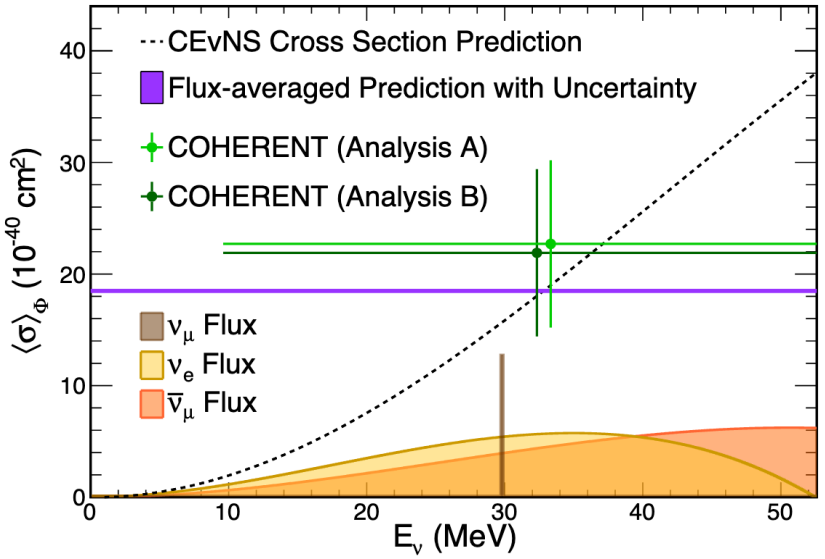


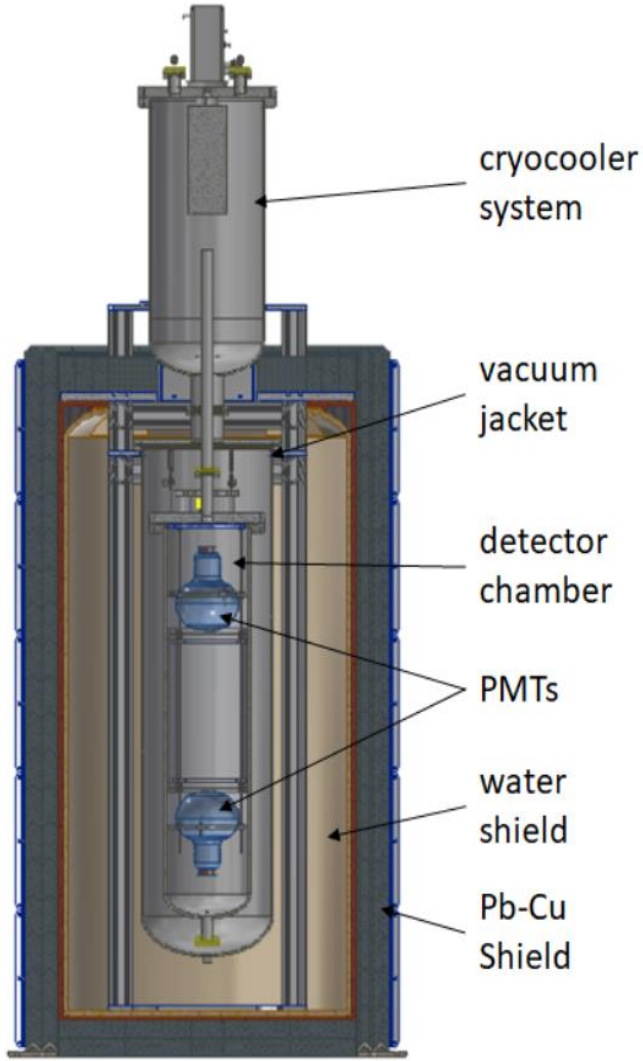
CEvNS Measurement in CENNS-10

- 24-kg single-phase LAr detector with two PMTs
- First measurement of CEvNS on Ar at 3.5σ significance
- 159 ± 43(stat.) ± 14(syst.) CEvNS (SM prediction: 128 ± 17)

  ~27% statistical uncertainty
- Haemin Jeong's previous talk for details

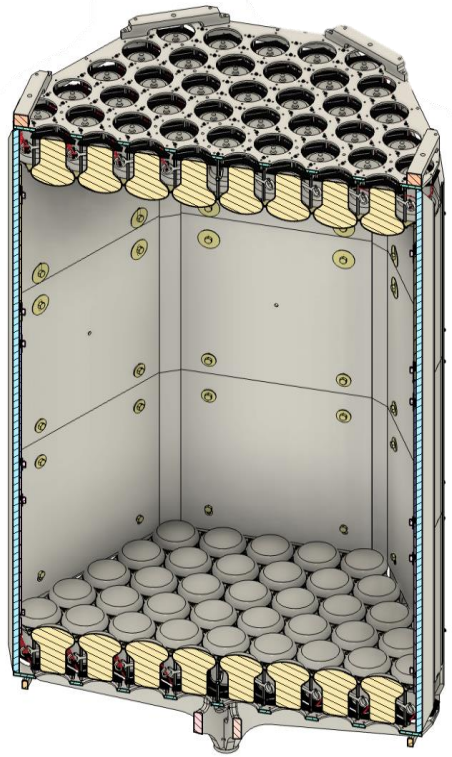






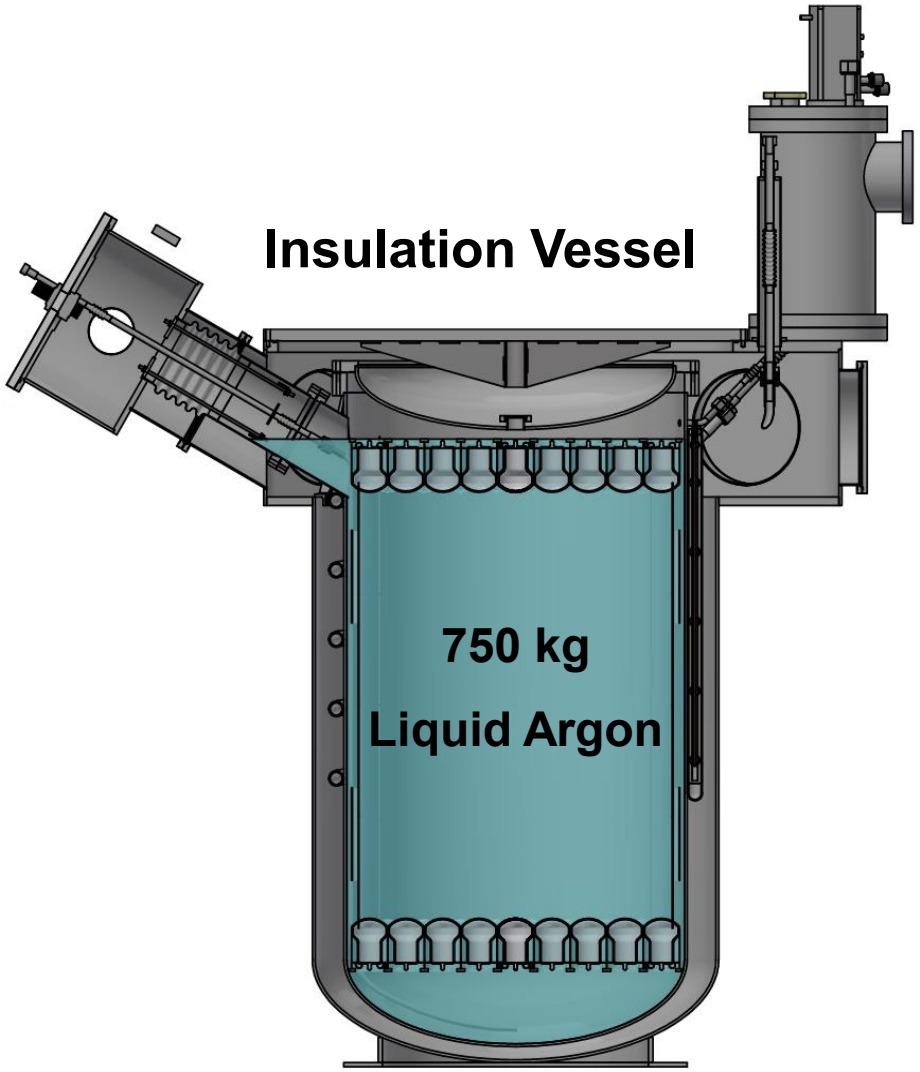
COH-Ar-750 (aka CENNS-1ton)

Optical Package
122 PMTs

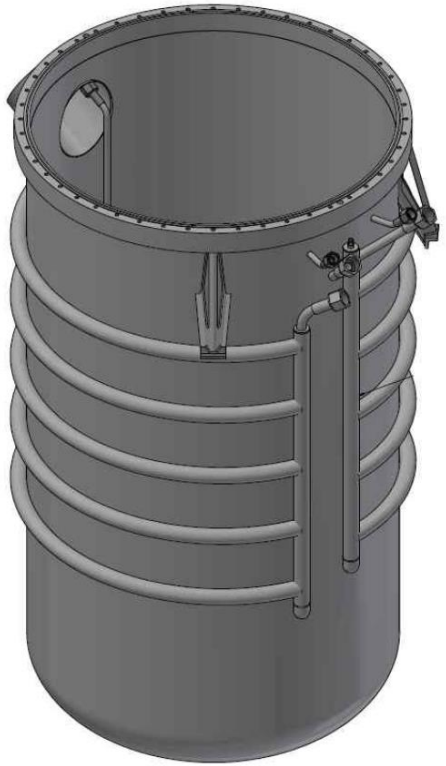


Liquefier

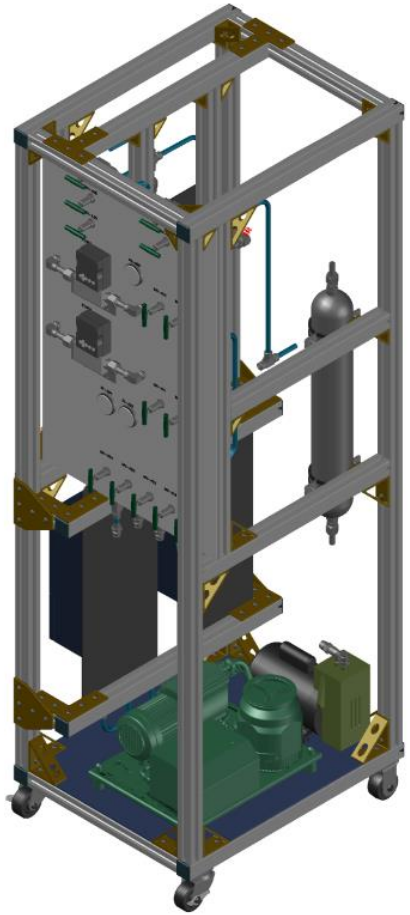
Insulation Vessel



Argon Vessel

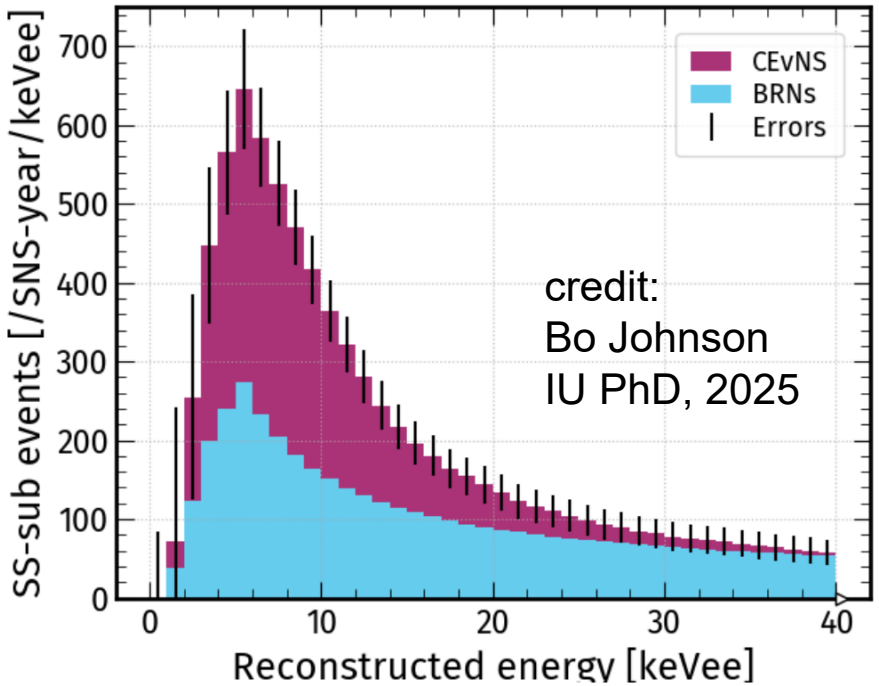


Gas Panel
Controls GAr
Three purifiers



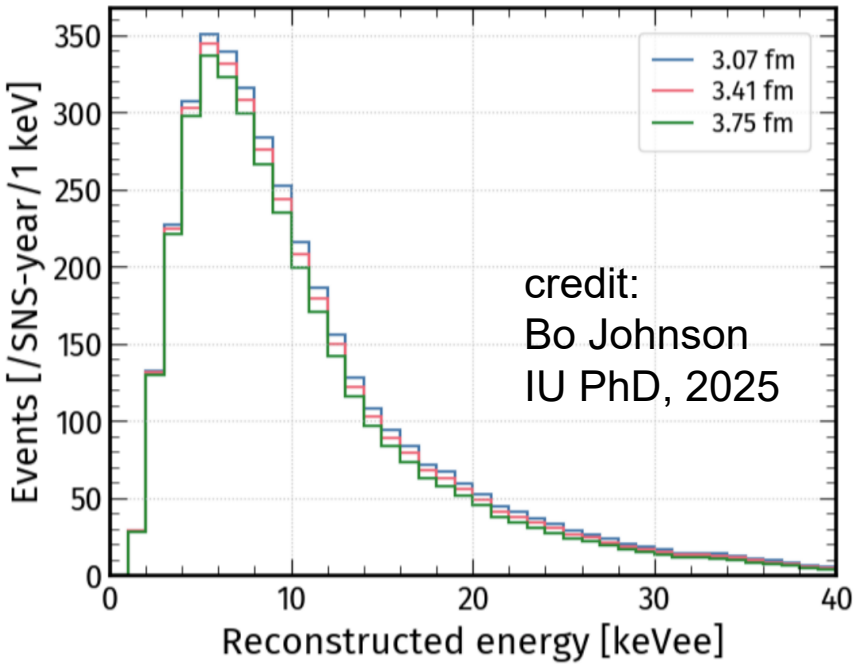
Physics Cases

Expected CEvNS signal



- ~3,400 CEvNS events/year
- ~4,000 beam-related neutron events/year
- Uncertainty: 5.3% (stat.), 10.1% (with syst.)
- Flux uncertainty will be reduced using D_2O results
- ~10,000 CEvNS events in 3 years

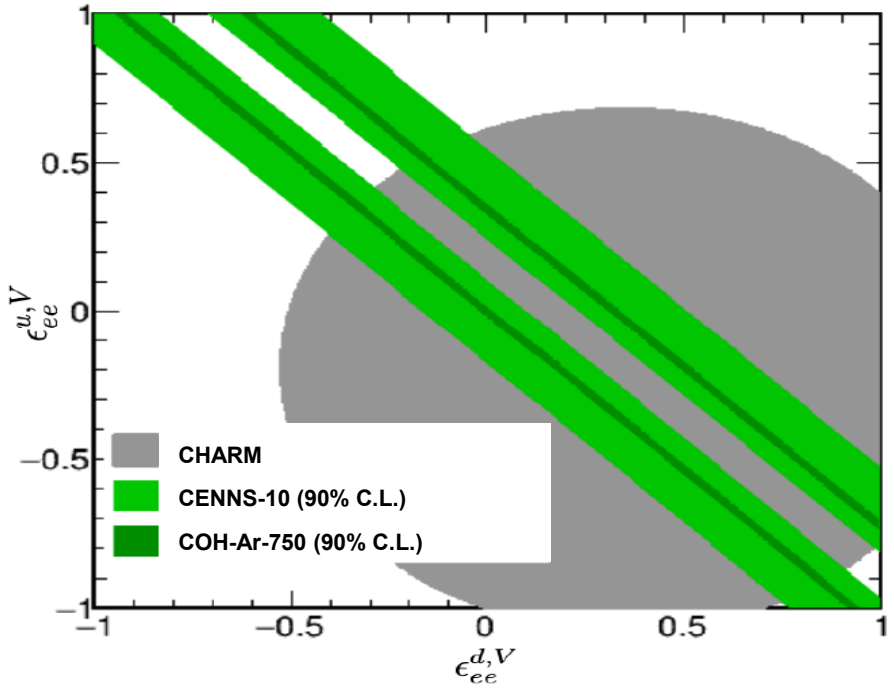
Weak Charge Radius



- $F_W(Q^2) \simeq 1 - \frac{Q^2 R_W^2}{6} + O(Q^4)$
- Sensitive to the neutron distribution in Ar
- $R_W^{\text{nominal}} = 3.41\ \text{fm}$
- $R_W^{\text{proj}} = 3.45^{+0.54}_{-0.67}\ \text{fm}$

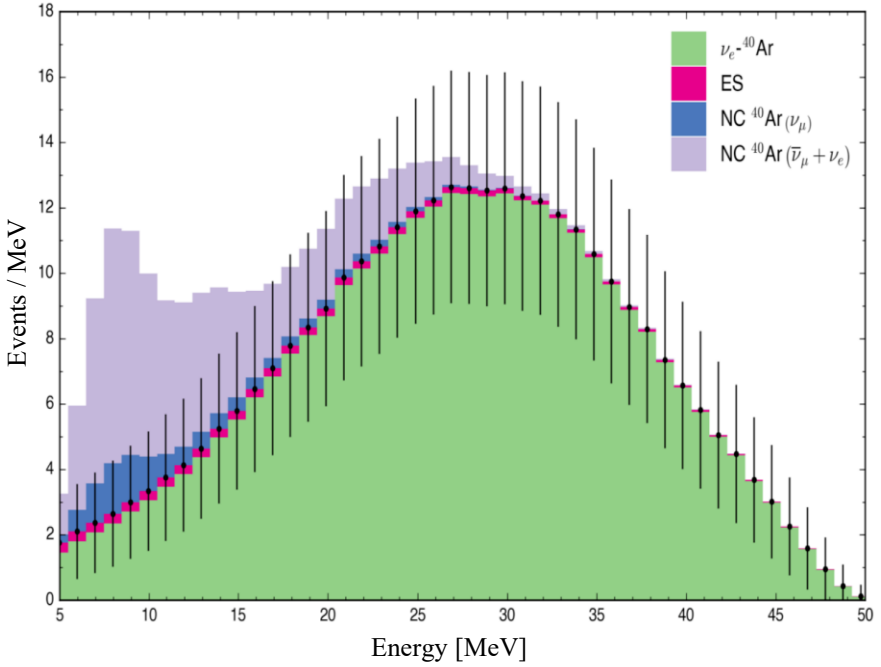
Physics Cases

Non-Standard Interactions



- $Q_W^{\mathrm{NSI}} = Q_W - 2\left[(2Z+N)\epsilon_{ee}^{uV} + (2N+Z)\epsilon_{ee}^{dV}\right]$
- NSI modify the effective weak charge
- Constraints on ϵ_{ee}^{uV} and ϵ_{ee}^{dV}
- Projected >10× improvement over CENNS-10

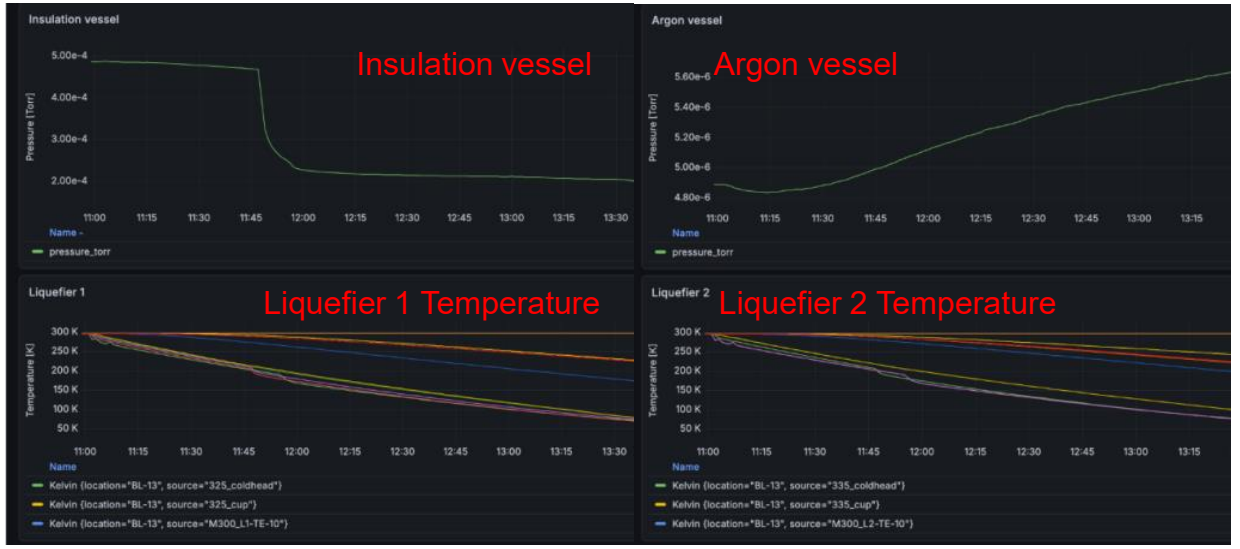
Inelastic Scattering

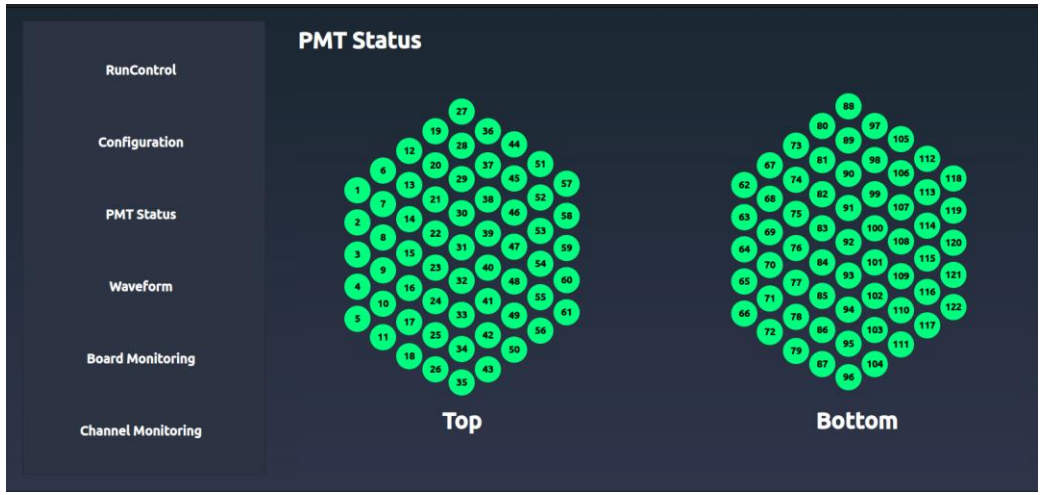


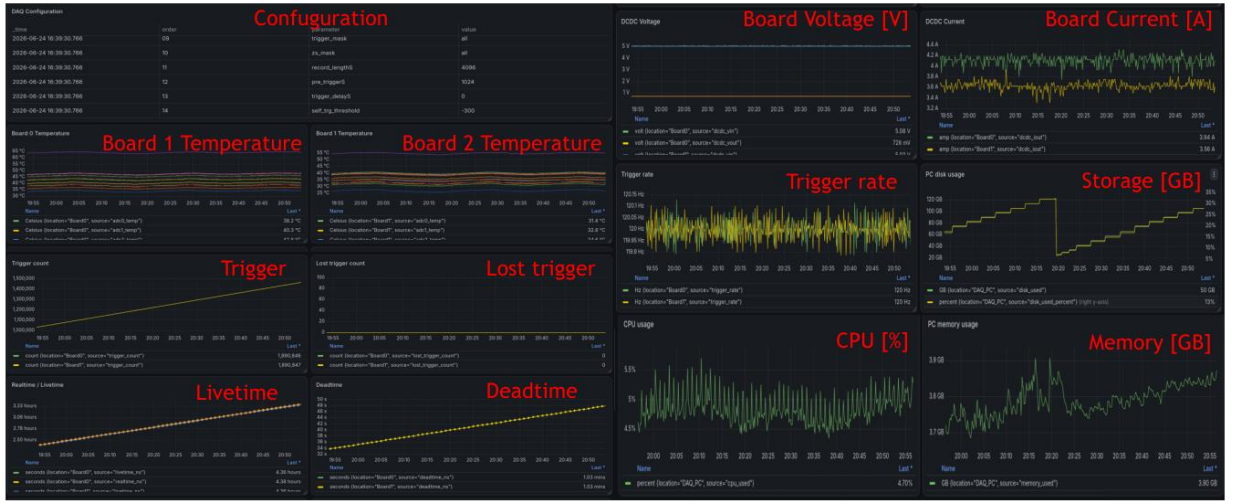
- $\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K^*$: ~1200 CC events /3 yr
- $\nu_x + {}^{40}Ar \rightarrow \nu_x + {}^{40}Ar^*$: ~300 NC events /3 yr
- Cross sections 30-100× lower than CEvNS
- MeV-scale signals (vs. keV-scale CEvNS)
- Relevant to supernova-ν detection in LAr

Slow Controls / DAQ





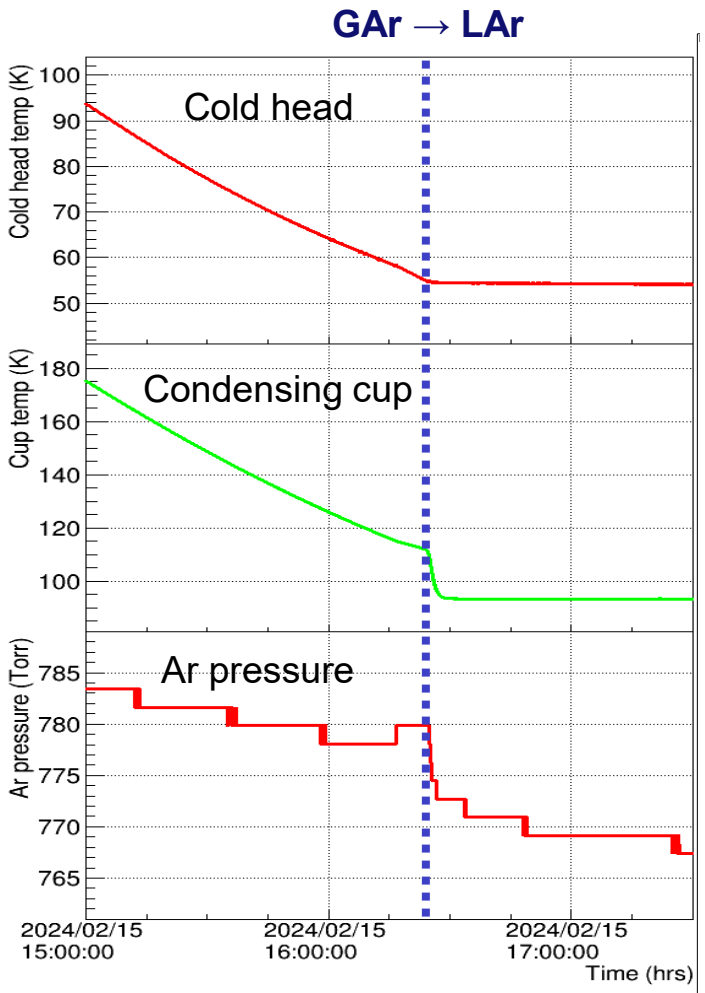


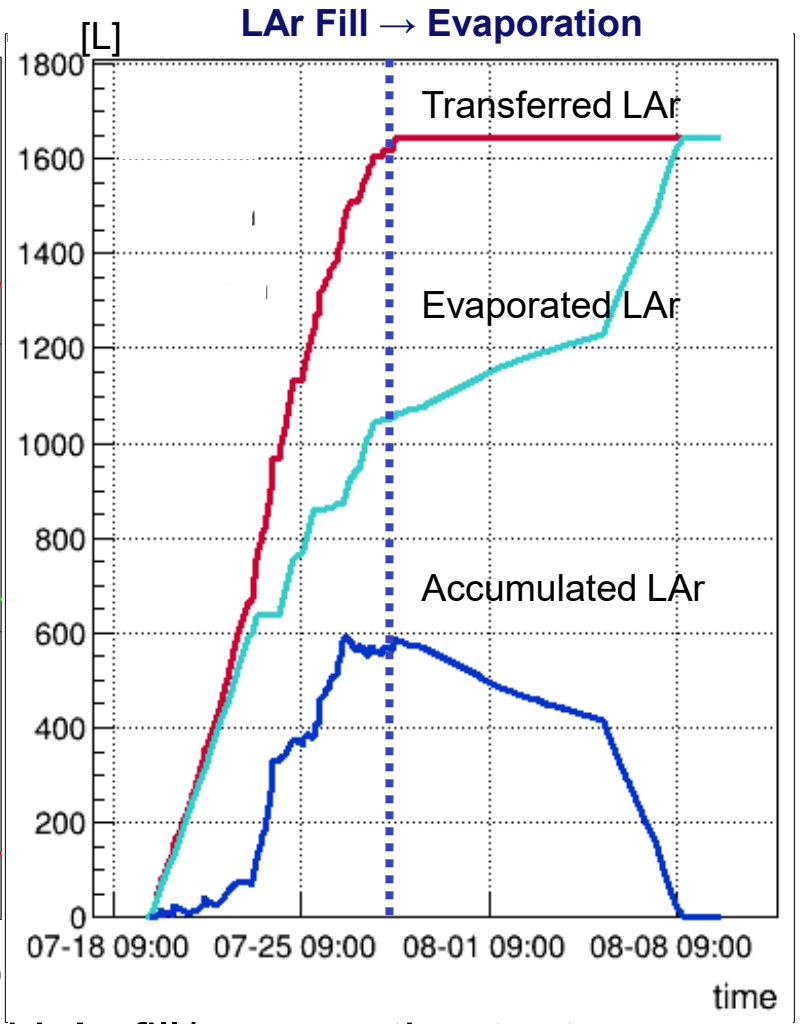


- Integrated slow controls and DAQ for detector monitoring and data acquisition

Built and Tested in Korea

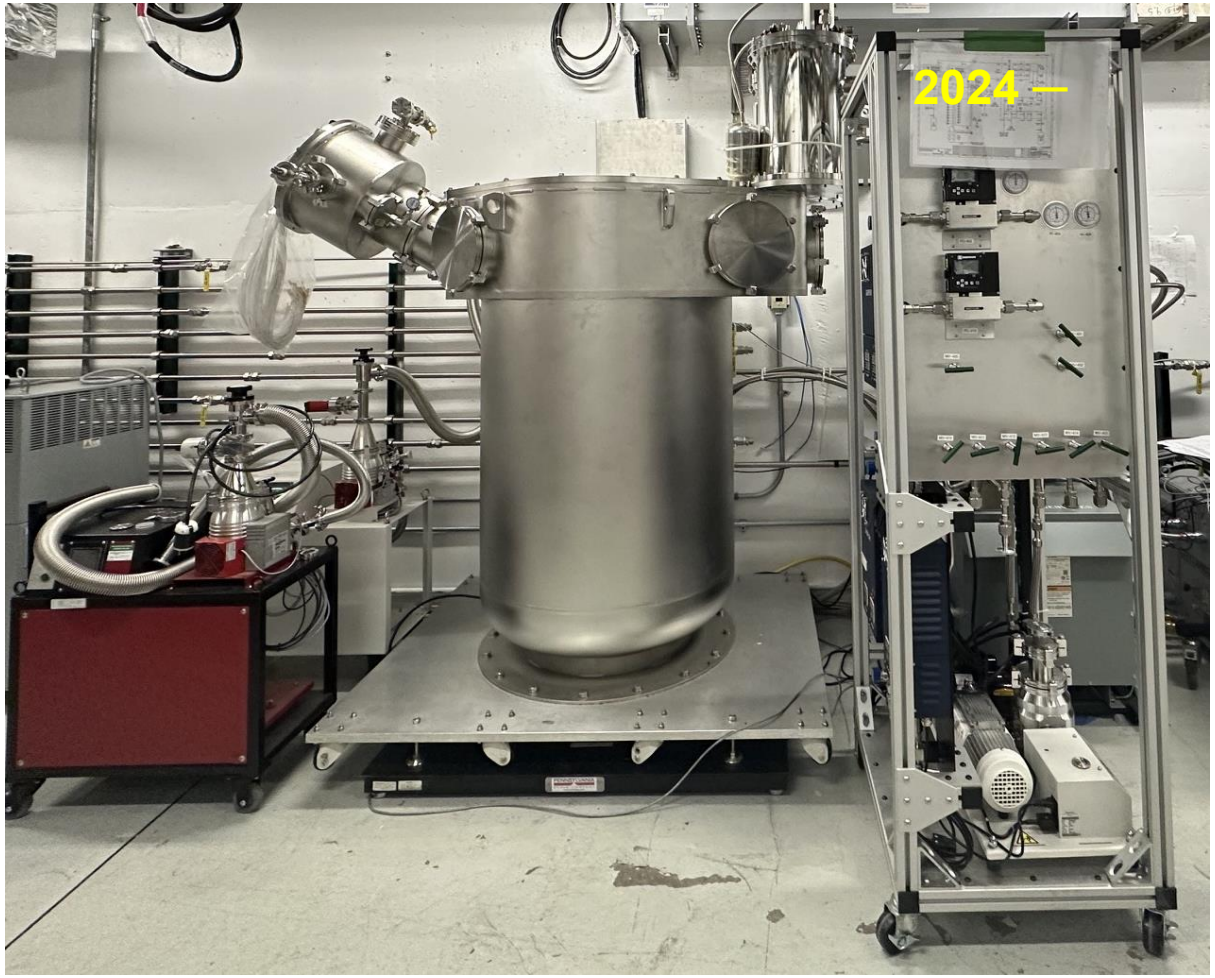


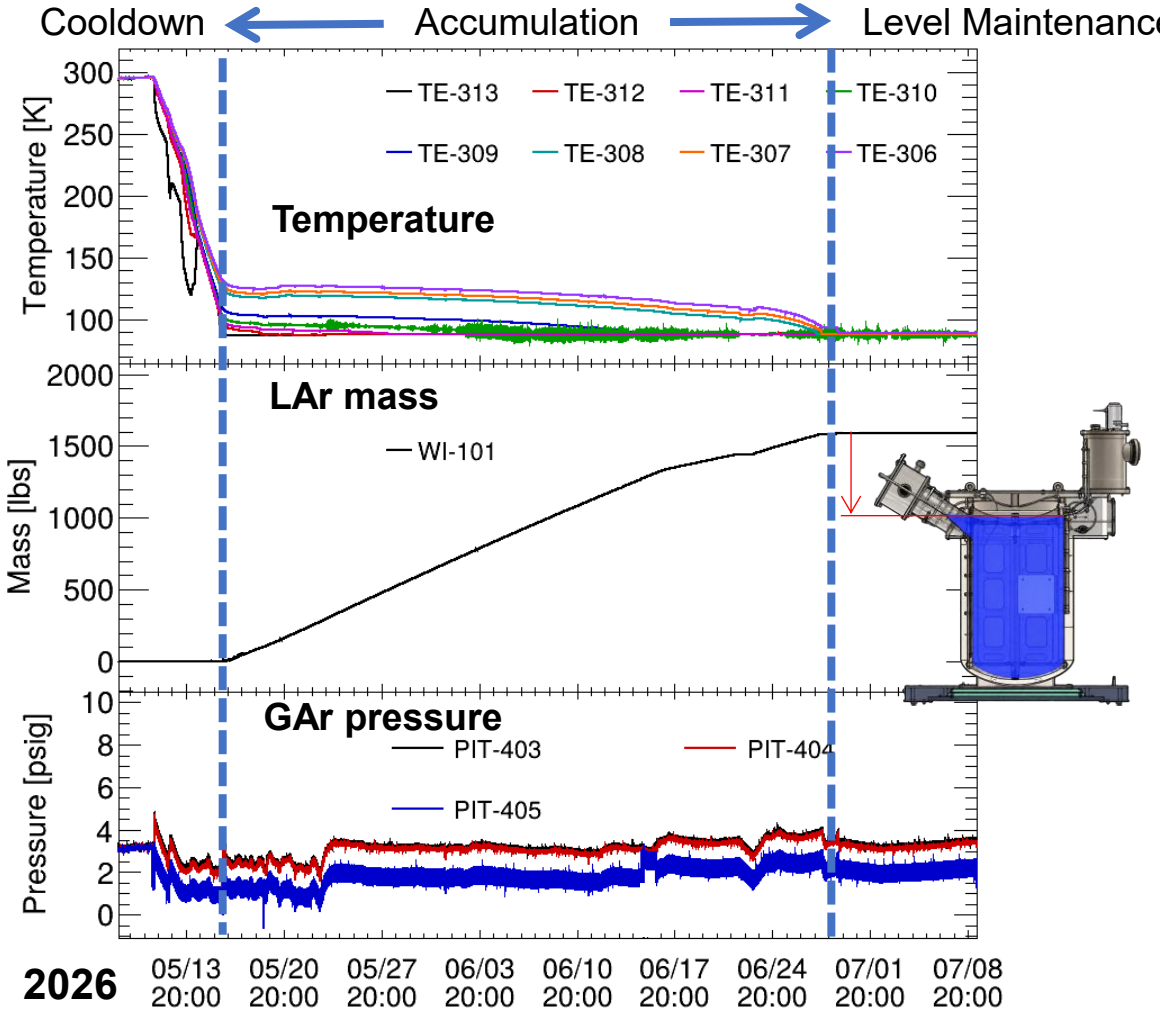




- Detector built and tested in Korea, including GAr condensation and LAr fill/evaporation tests

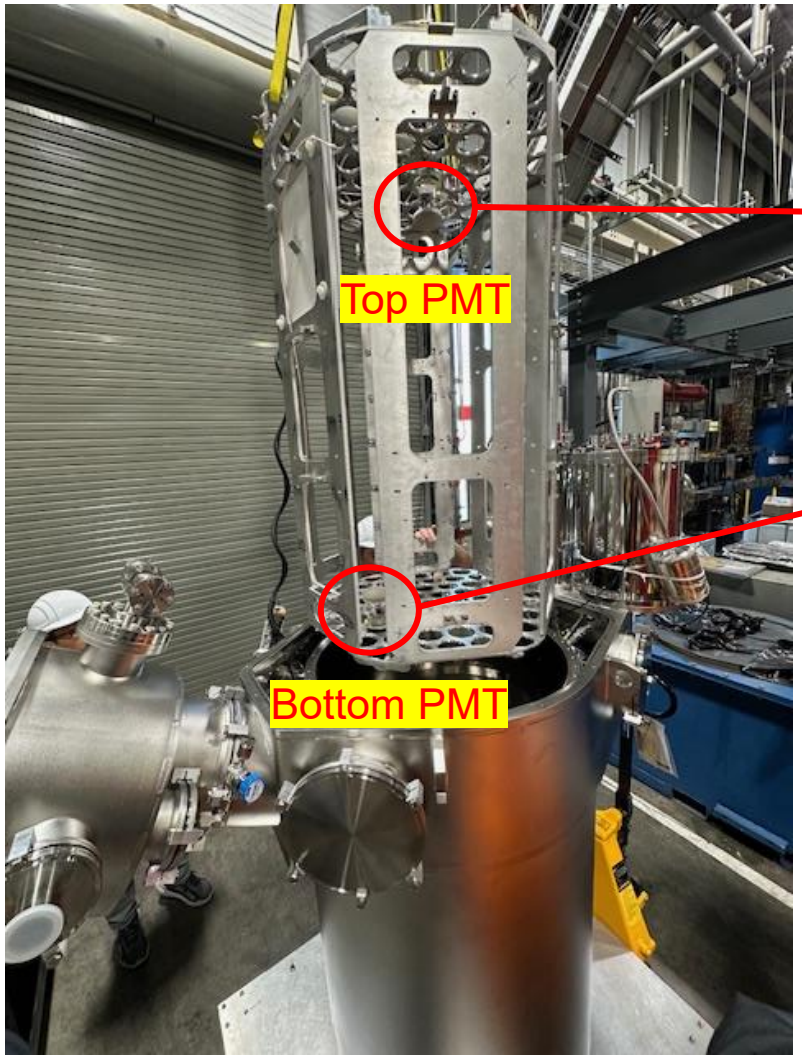
Commissioning at ORNL

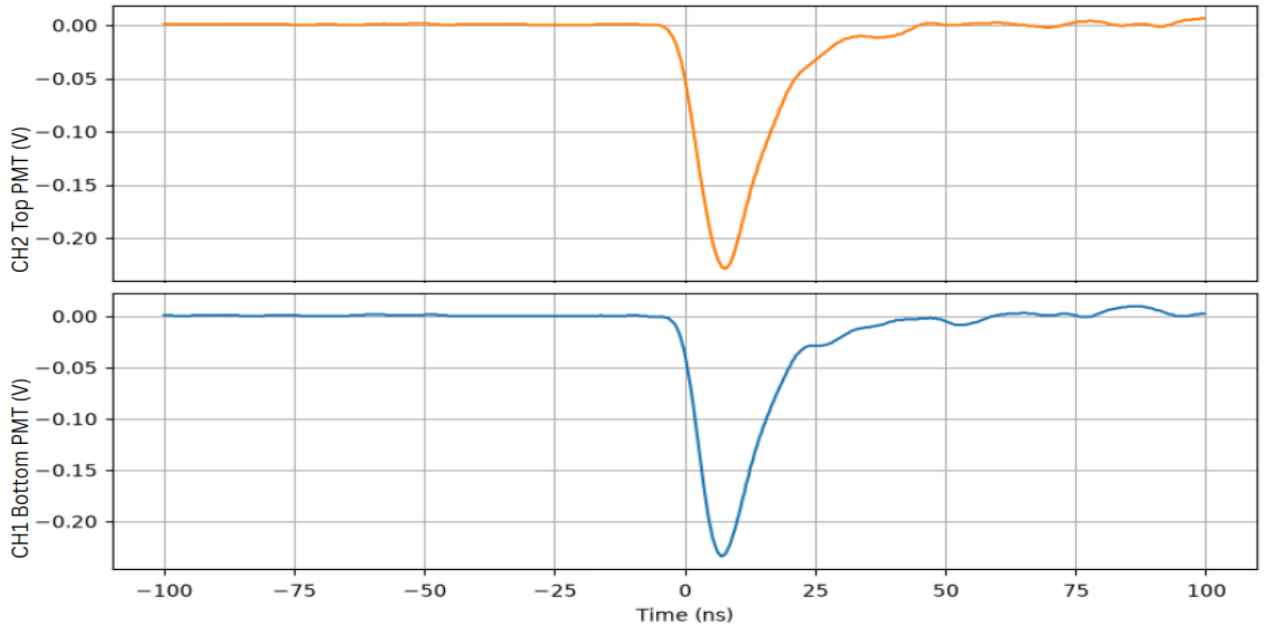




- Successful LAr filling to the operating level with stable level maintenance at ORNL

Cooldown & Muon Signal

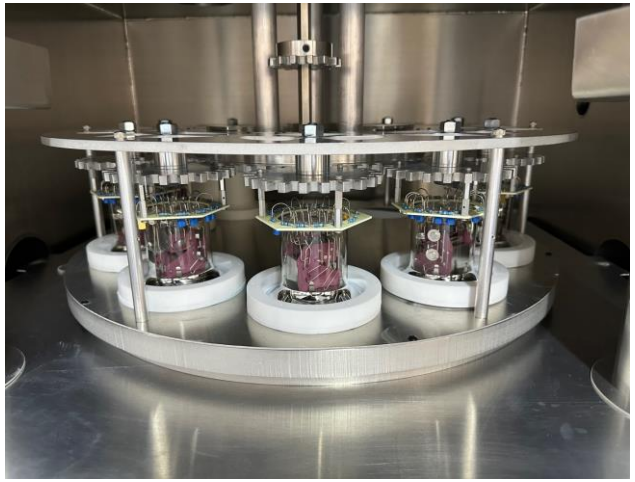




PMT Readout Test

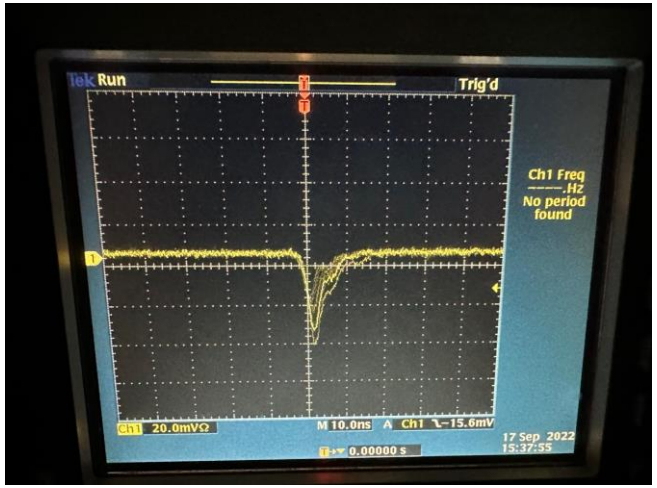
- Test conditions: 1360 V, no LAr purification
- Installed two PMTs and performed a cosmic-muon signal test after cooldown and LAr filling
- Coincident top-bottom PMT signals consistent with cosmic-muon events

TPB Coating





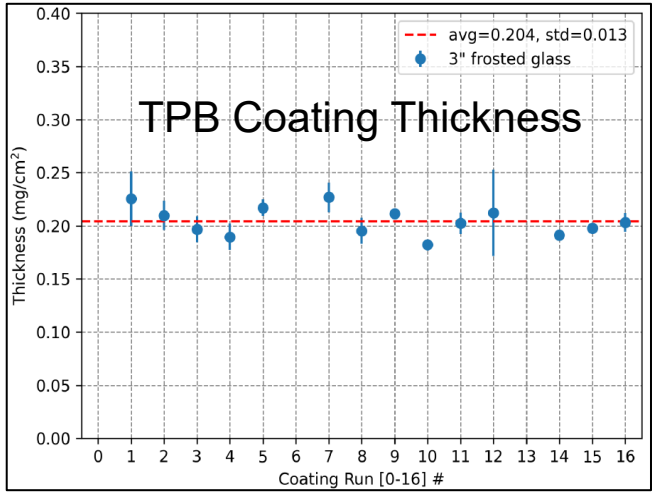






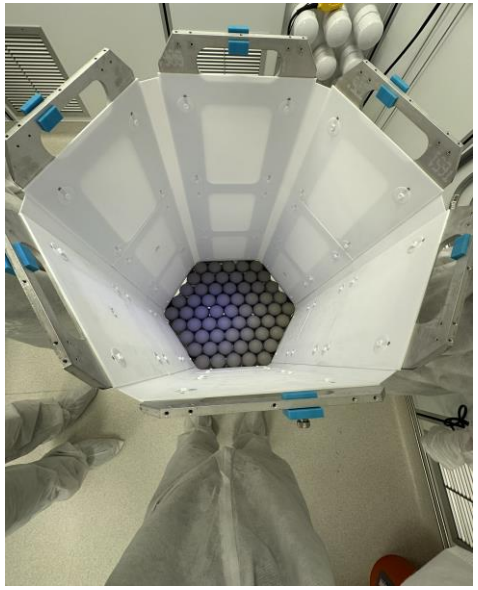




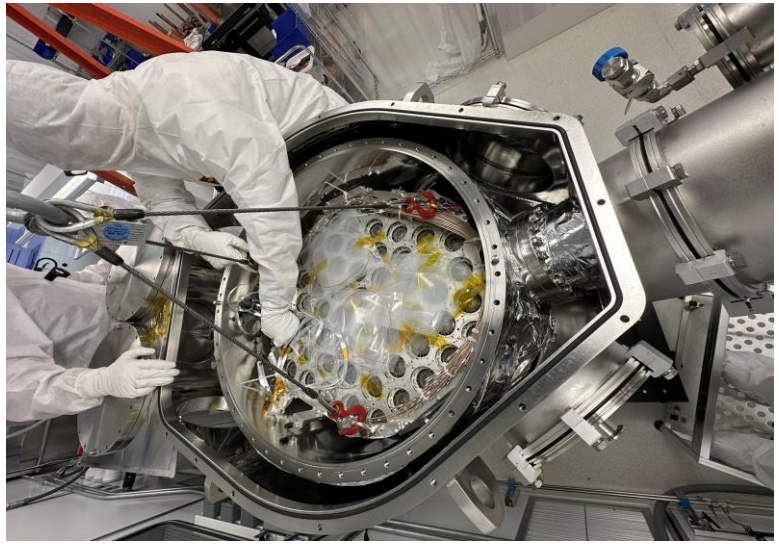
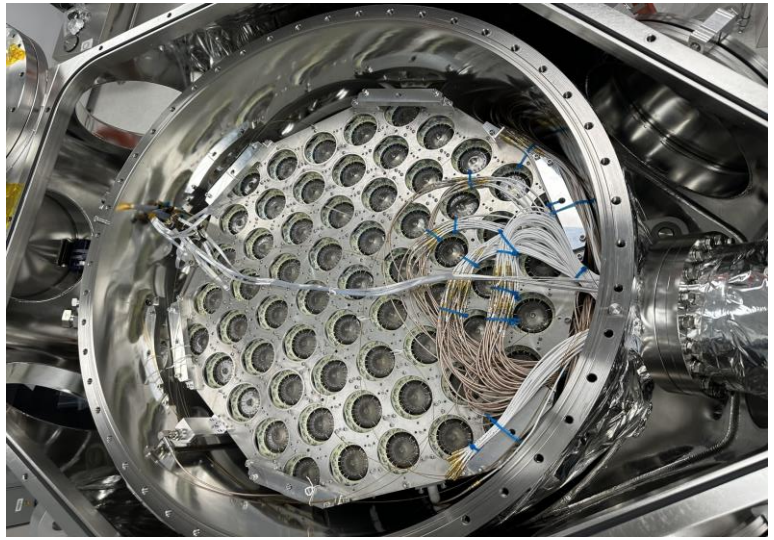


- Wavelength shifting of 128 nm Ar scintillation light to visible light (~400 nm)
- Custom-built coating chamber with demonstrated uniform coating thickness

Optical Package Installation




Commissioning

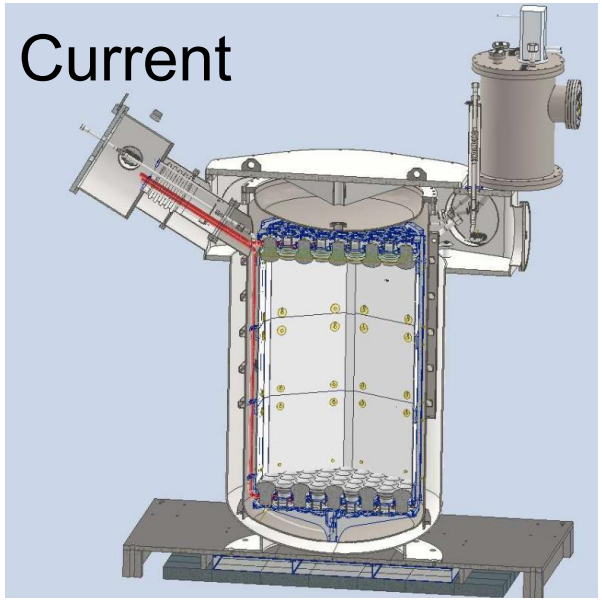




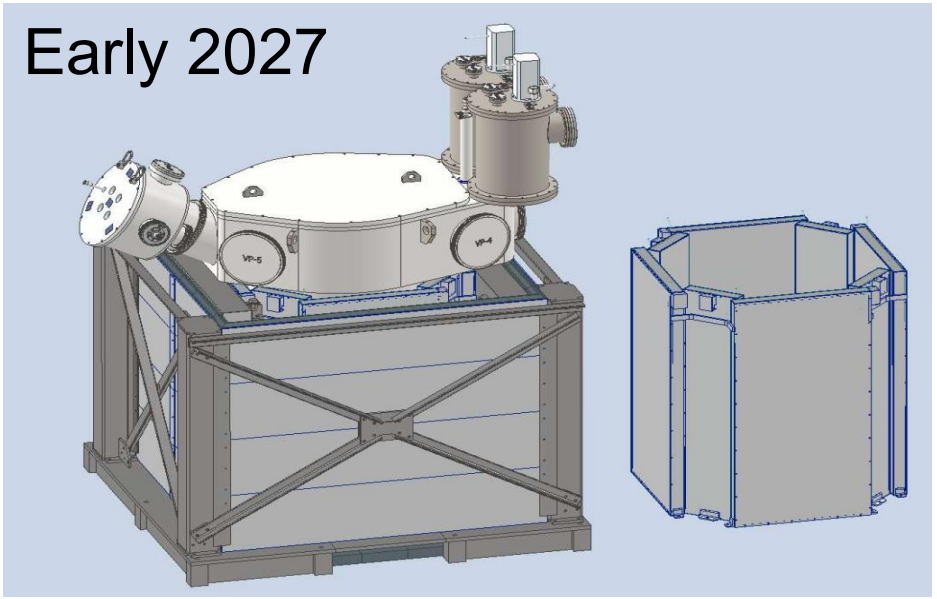
Successfully moved into Neutrino Alley !

Summary

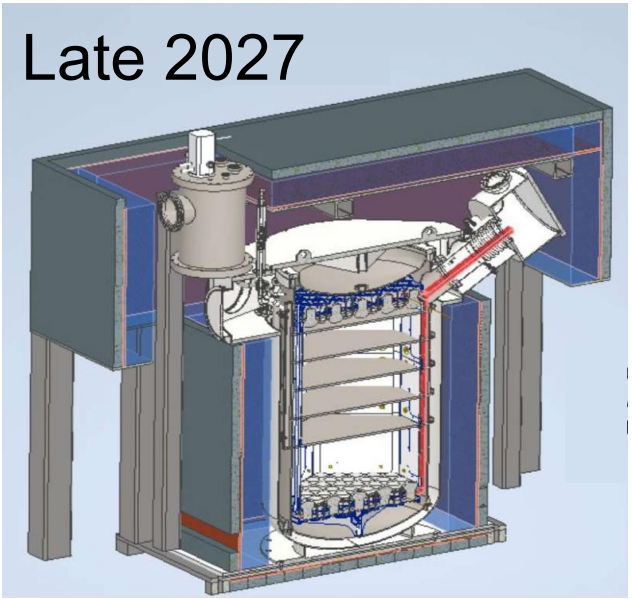
- COH-Ar-750 (aka CENNS-1ton) aims for a precision CEvNS measurement
- ~10,000 CEvNS / 3-years, enabling new physics studies
- Commissioning in Neutrino Alley is underway, with stages through 2027



Stage 0



Stage 1



Stage 2

COHERENT SNS

Thank you for your attention!



Backup

Work Progress

















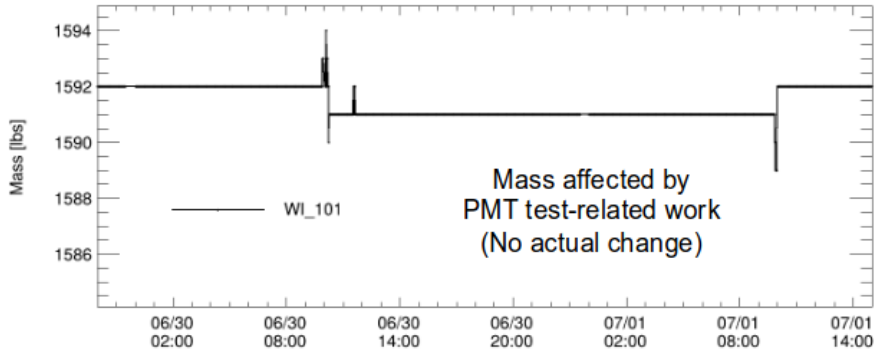


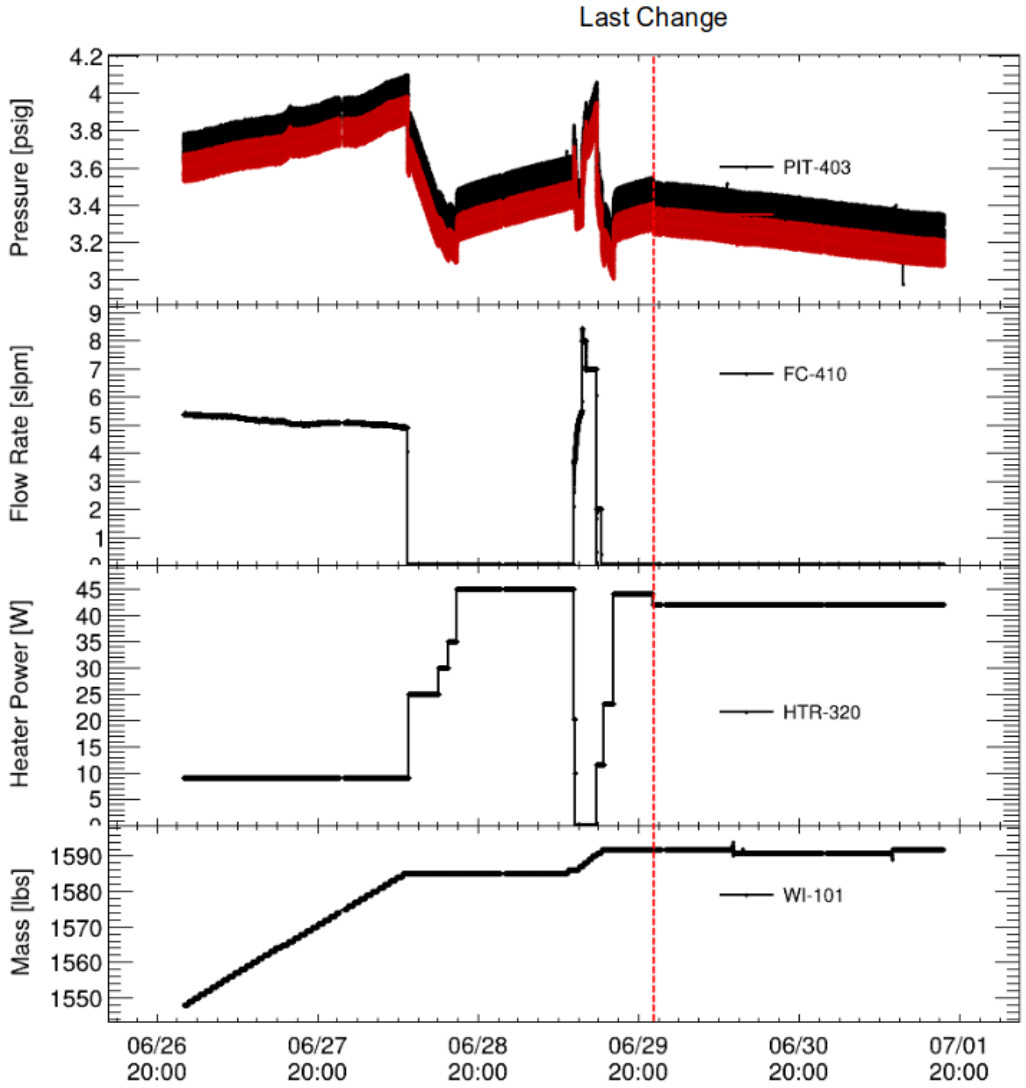


Steady State

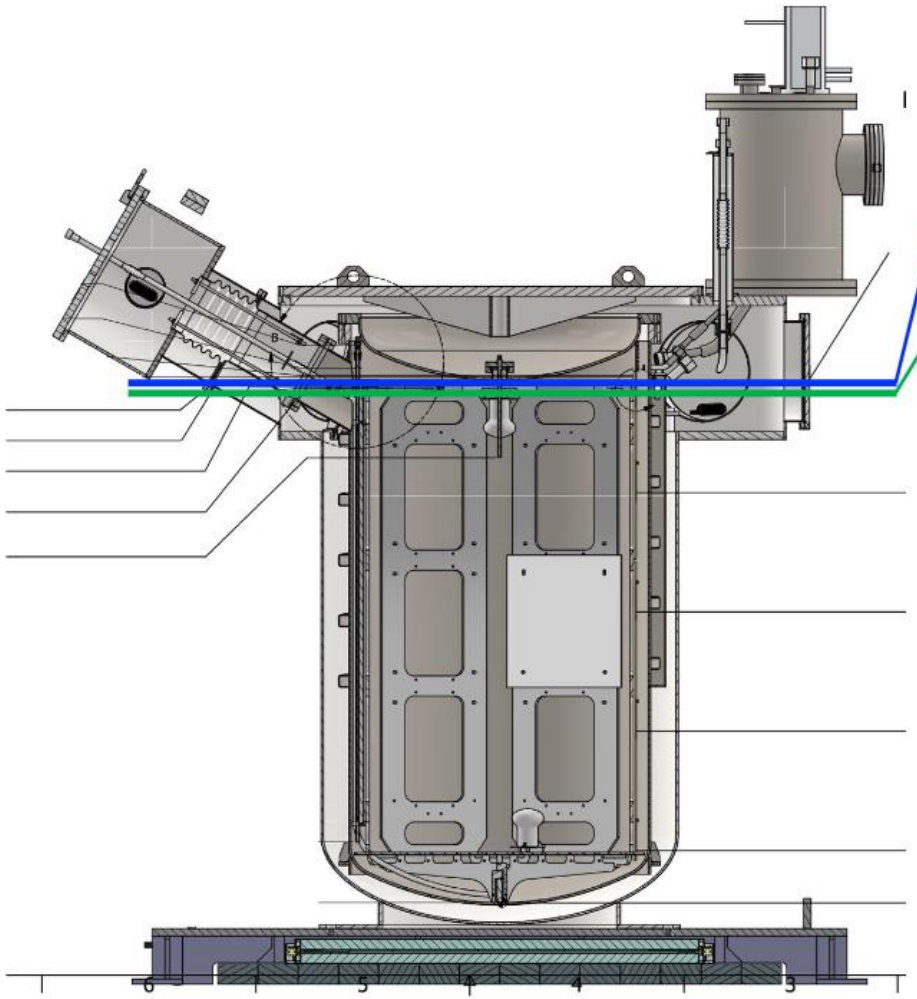
➢ **Level Maintain**

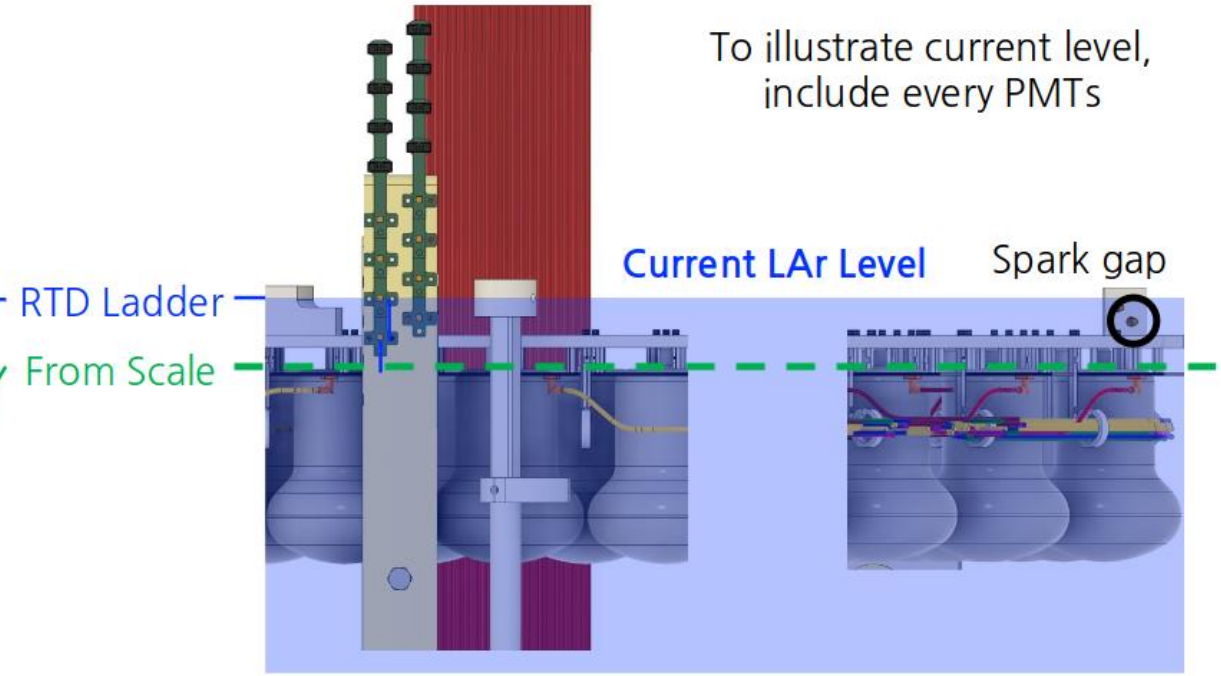
- A stable state was maintained without fine-tuning
- Setting
  - Heater Power: 40 W (on L1)
  - FC-405: 10 slpm
- Pressure is slowly decreasing (0.1 psi / day)
  - This is expected to be resolved with fine-tuning





LAr Level

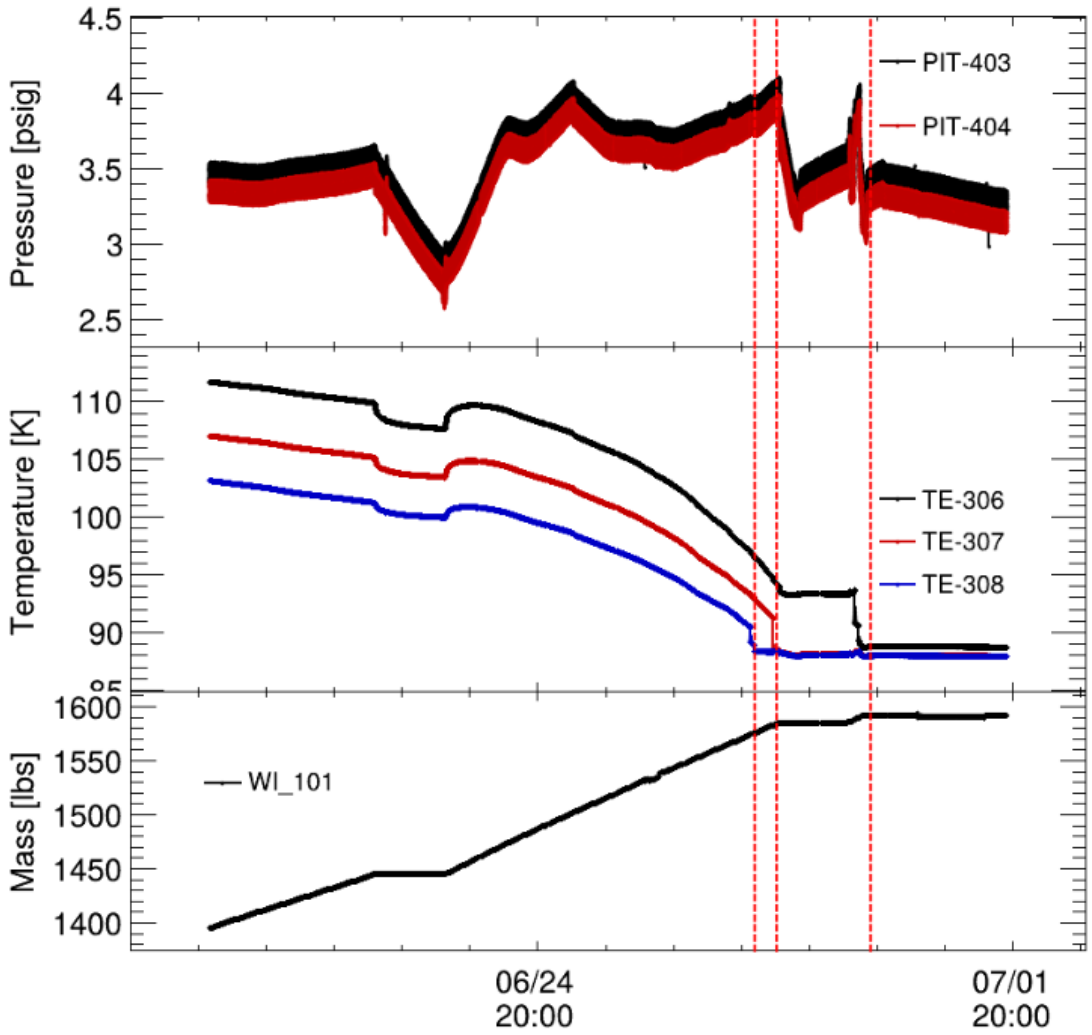




➢ **LAr Level**

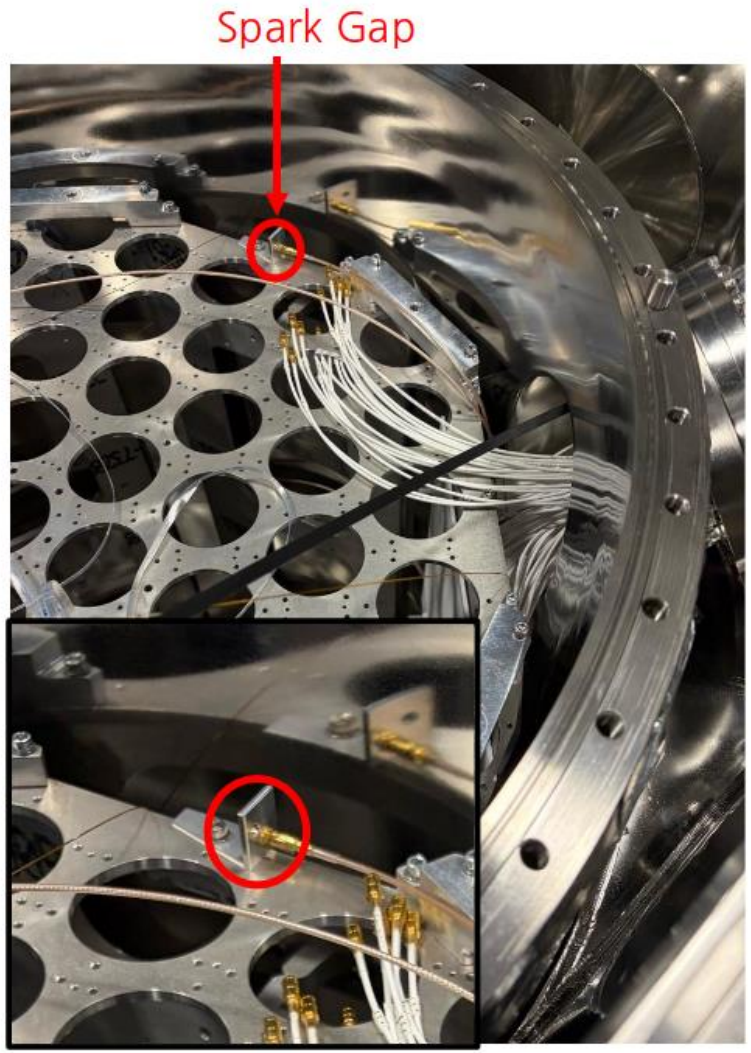
- The system is submerged in LAr 1.4 cm above the PMT base.
  - Verified by Spark gap.
- ~3% difference was observed between scale and RTD ladder.

LAr Level



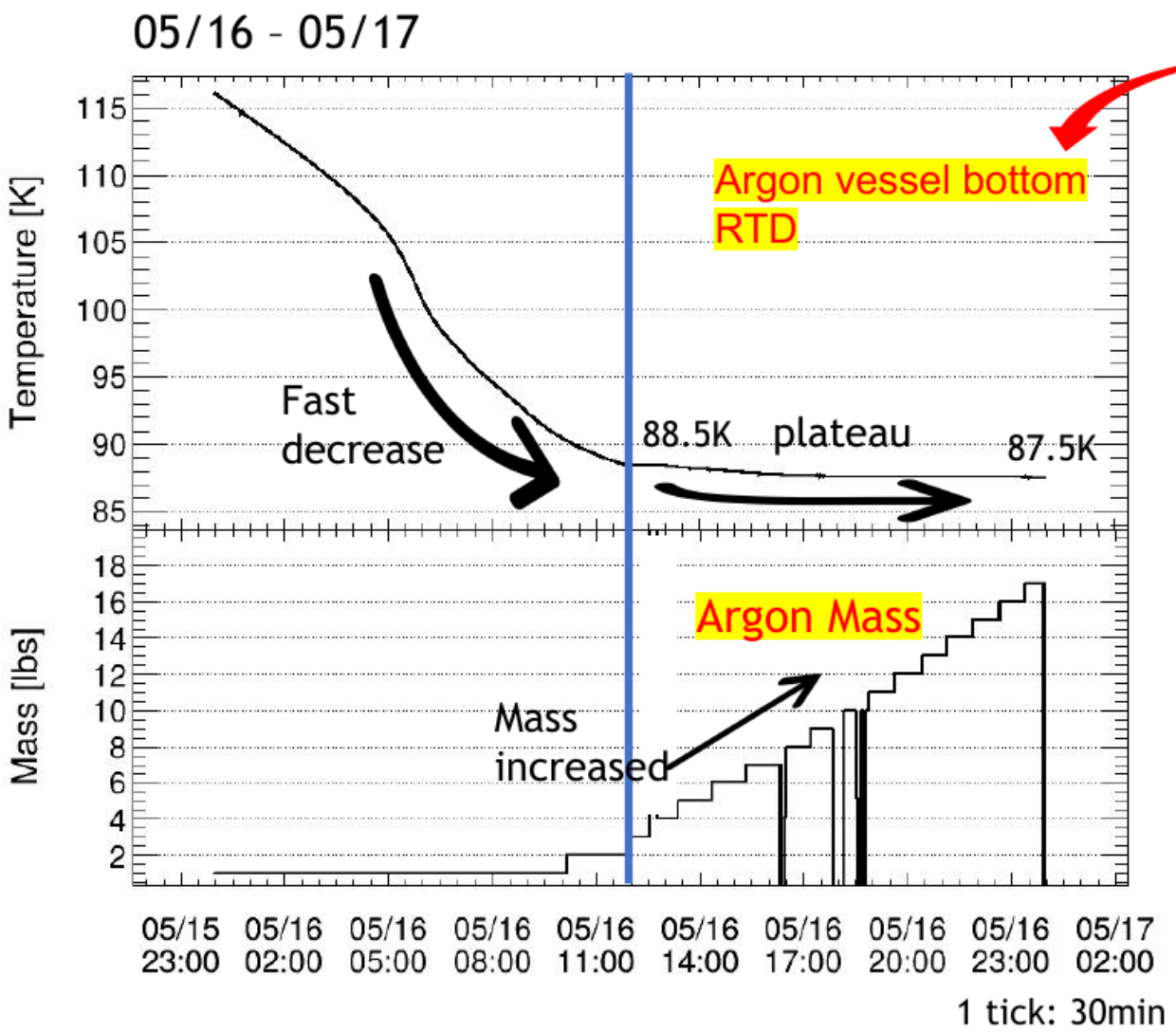
RTD	RTD Height [inch]	Weight at 88K [lbs]	Height from weight [inch]
TE-306	51.575	1592	49.68
TE-307	51.2	1583	49.42
TE-308	50.825	1576	49.21

Photos





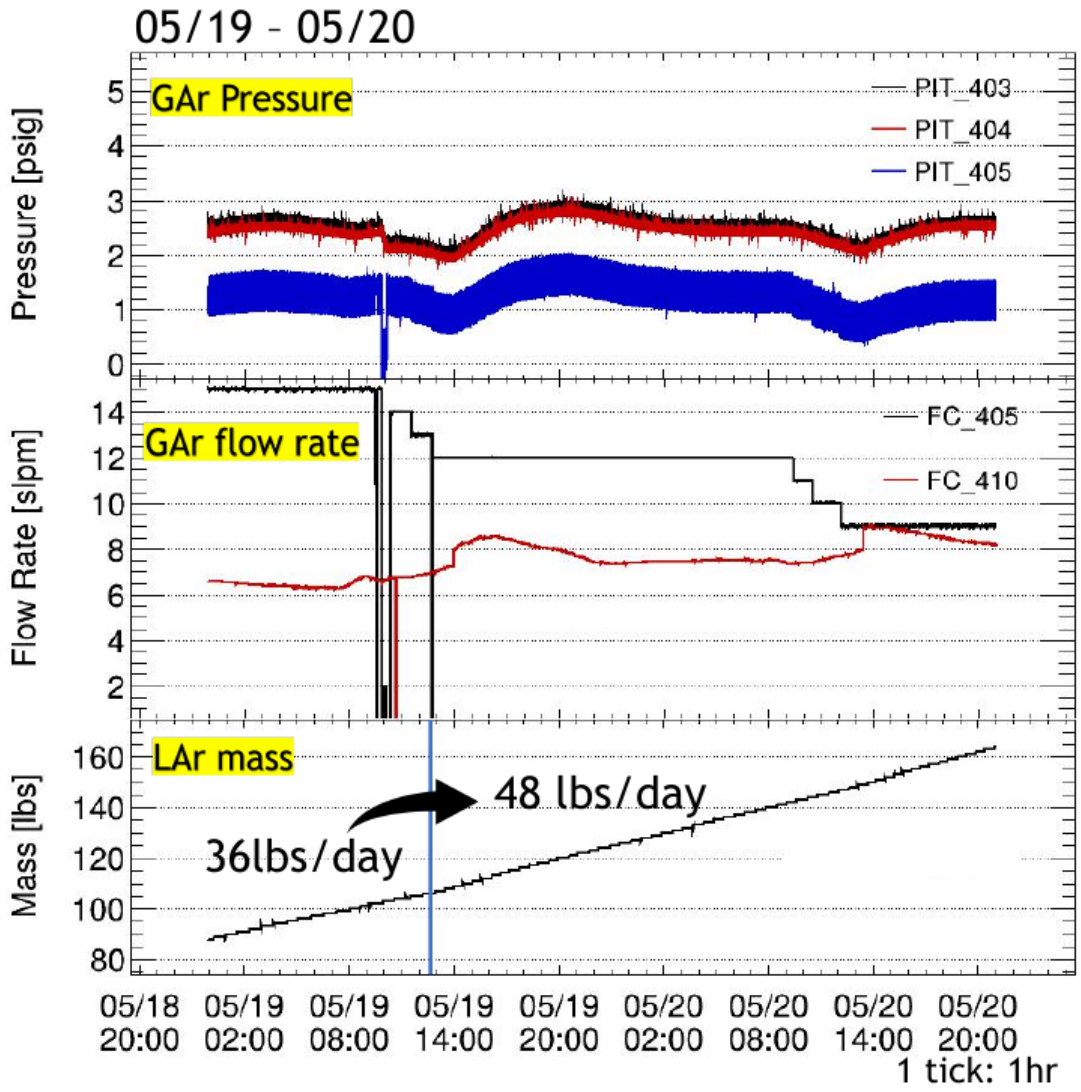
First Accumulation





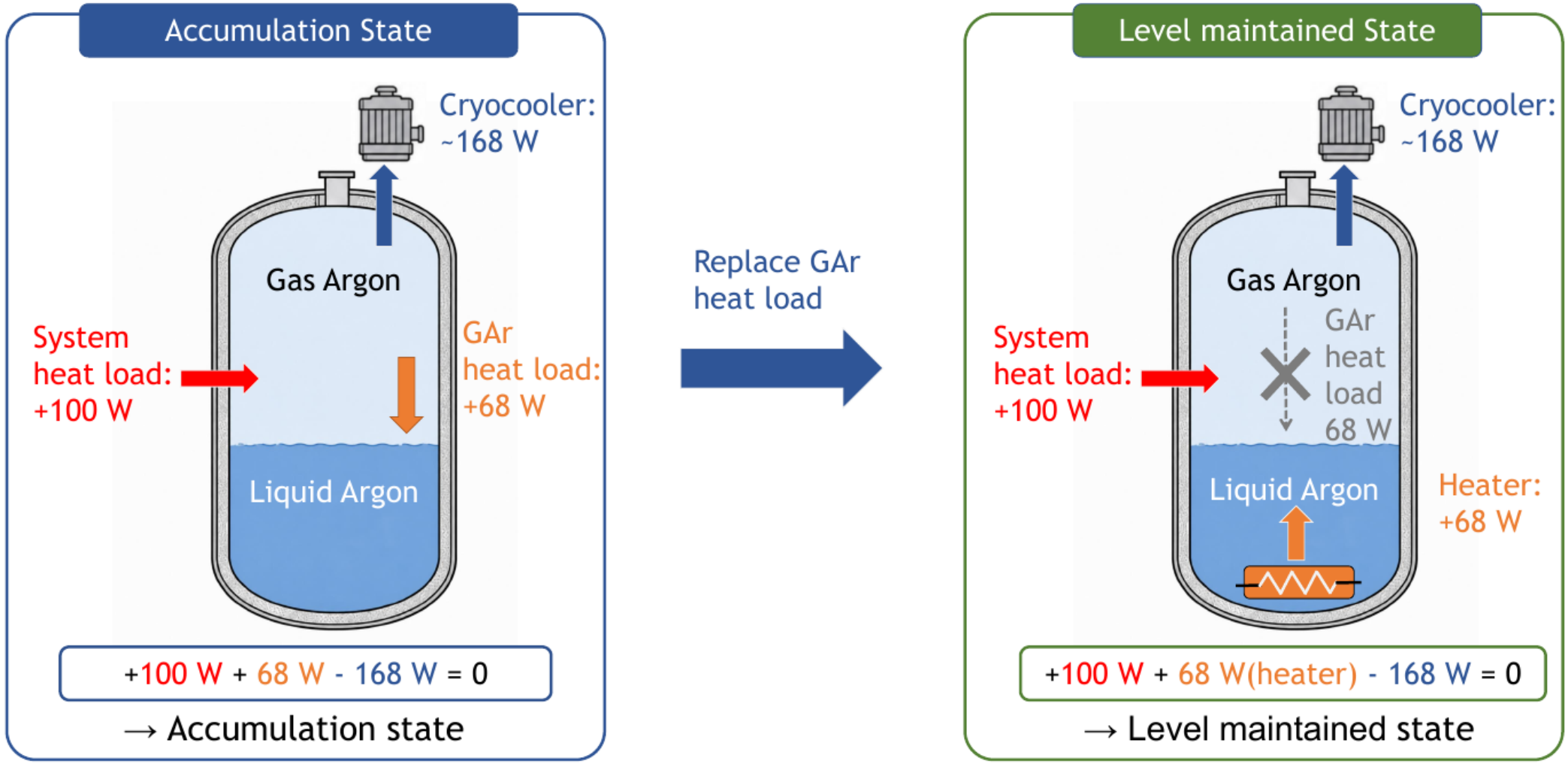
- Started cooldown on May 11
- First accumulation started on May 16
- Temperature at the bottom of the argon vessel
  - Dropped rapidly and reached a plateau
  - Argon mass started to increase
- Accumulate rate: 36 lbs/day

Accumulation Rate



- To improve the accumulation rate,
  1. Maintained GAr pressure at a stable level
  2. Reduced the GAr flow rate (FC-405)
     - FC-405: Circulation flow rate
     - FC-410: GAr supply
- Reduced the flow rate step by step:
  - 15 slpm →14 slpm → ⋯ →10 slpm
- At 12 slpm, accumulation rate increased to 48 lb/day
- Reduced to 9 slpm
  - Did not improve the accumulation rate
  - It does not seem to improve over 48 lbs/day

Matainining Level



→ Maintain thermal equilibrium using heater instead of GAr heat load

Heat Load

- GAr heatload
  - Input flow rate: $8.4\mathrm{L/min}$
  - Gas density: $1.8\mathrm{g/L}$
  - Gas input rate:
    - $8.4\mathrm{L/min} \times 1.8\mathrm{g/L} \div 60 = \mathbf{0.25g/s}$
  - $Q = C_p \Delta T + L_v$
  - $= 0.52 J/g/K \times (300 - 87) K + 160 J/g \approx 271 J/g$
  - $0.25 g/s \times 271 J/g \approx 68 W$

