

The PICO-40L Dark Matter Direct Detection Experiment

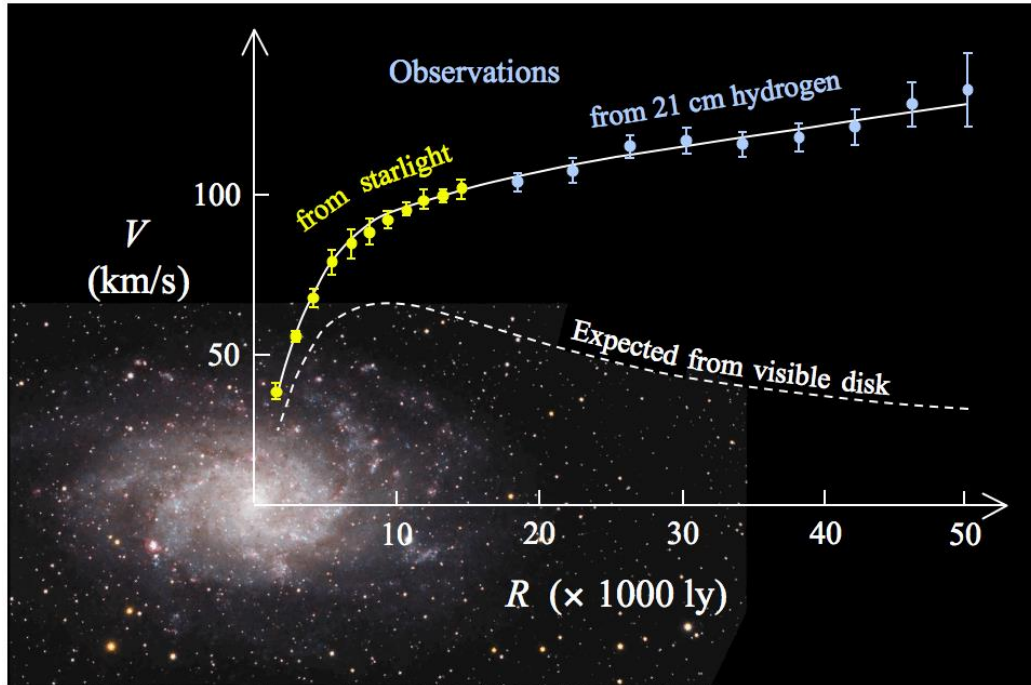
Derek Cranshaw

On behalf of the PICO collaboration

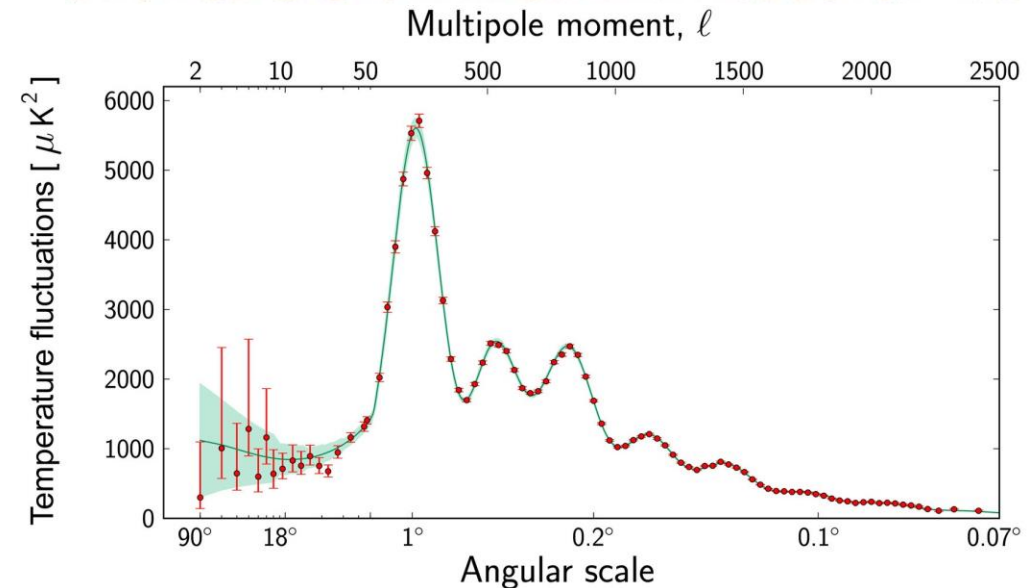
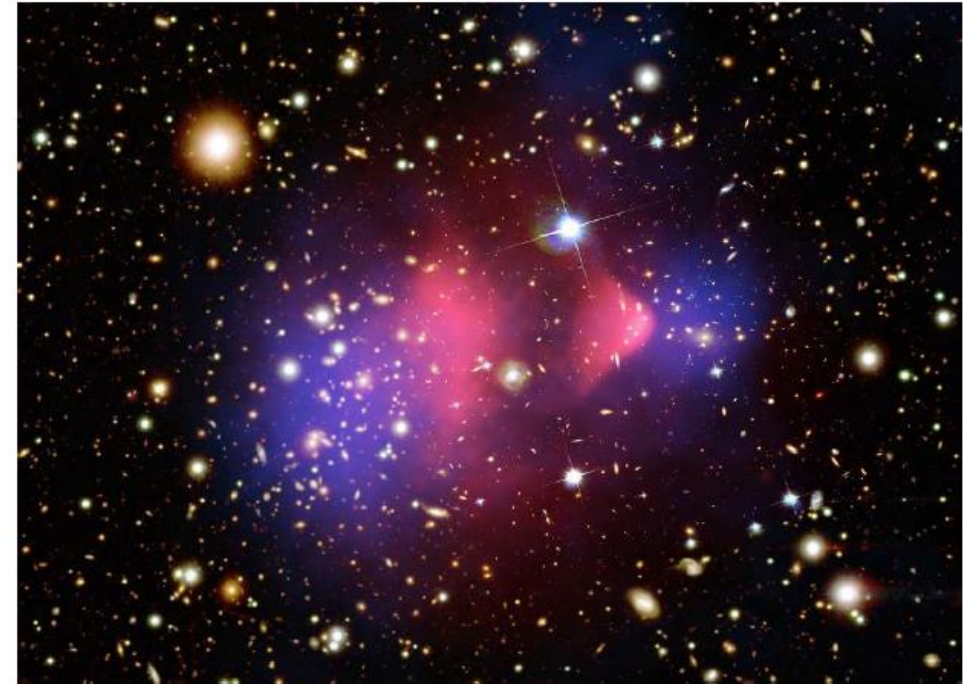
CAP Congress – University of New Brunswick

June 19, 2023

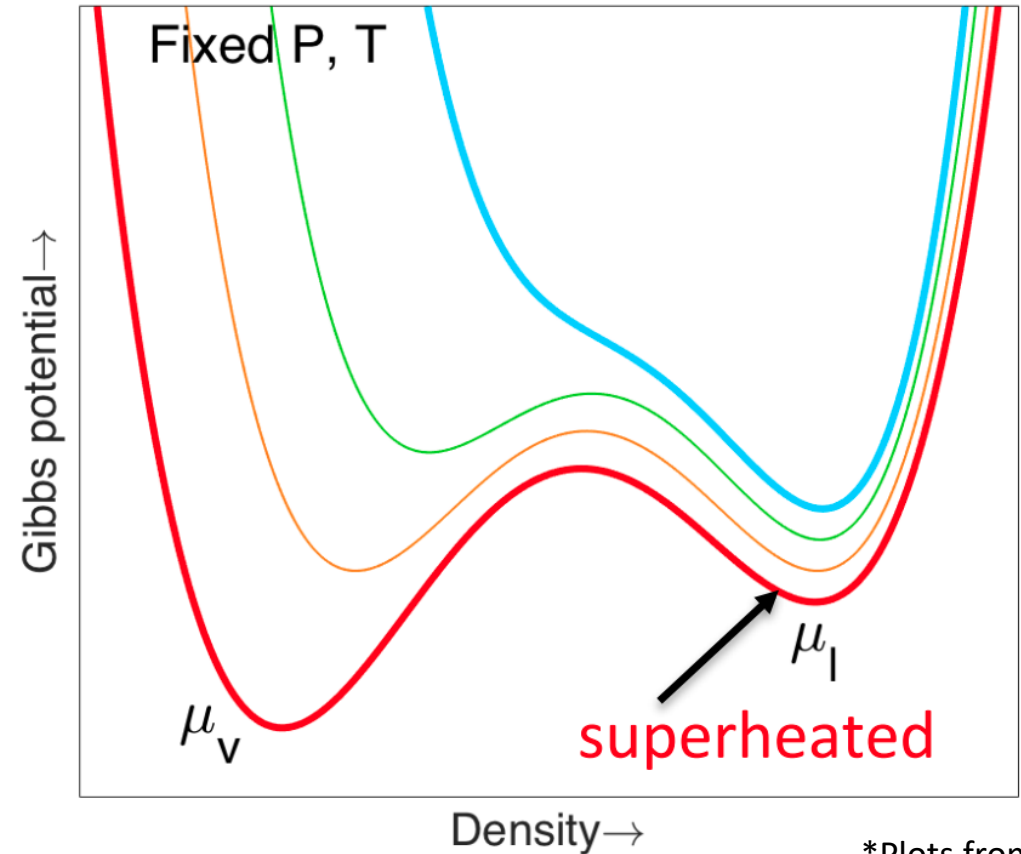
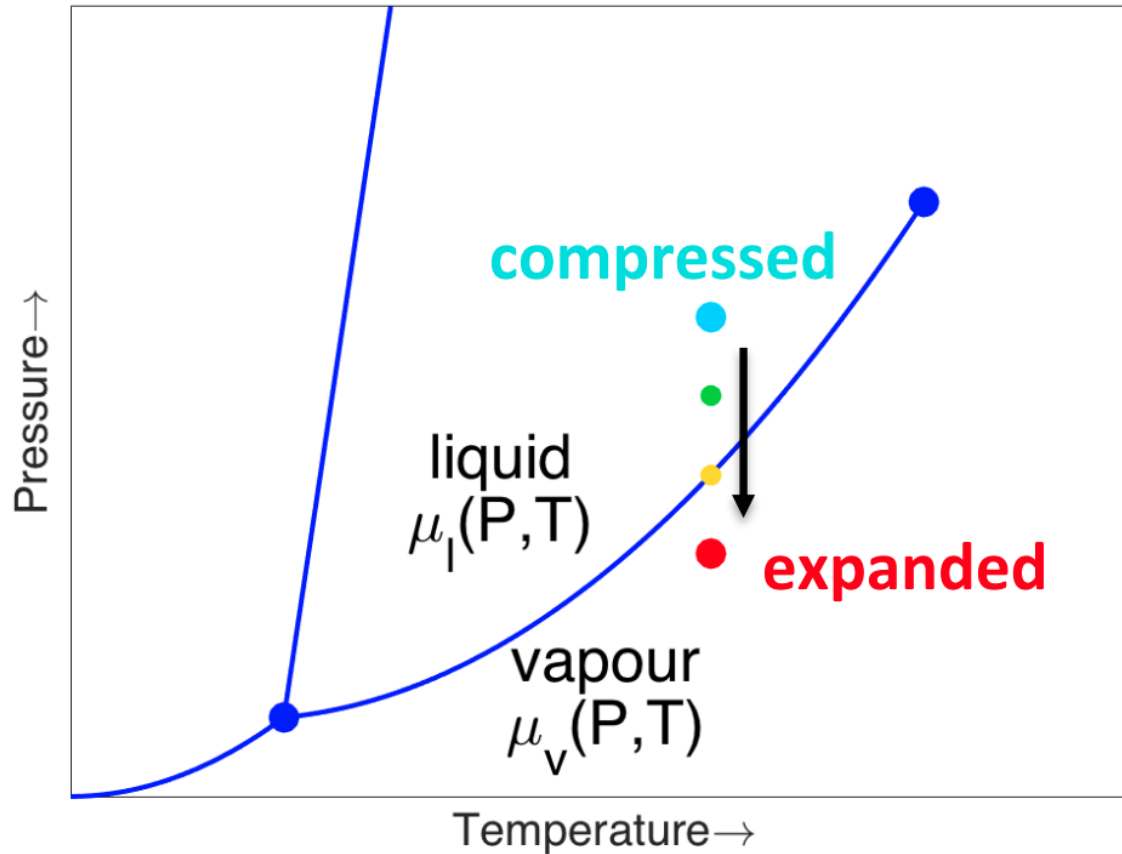
What is Dark Matter?



- Evidence for dark matter at a variety of length scales.
- Many BSM theories predict stable, neutral, weakly interacting massive particles (WIMPs).



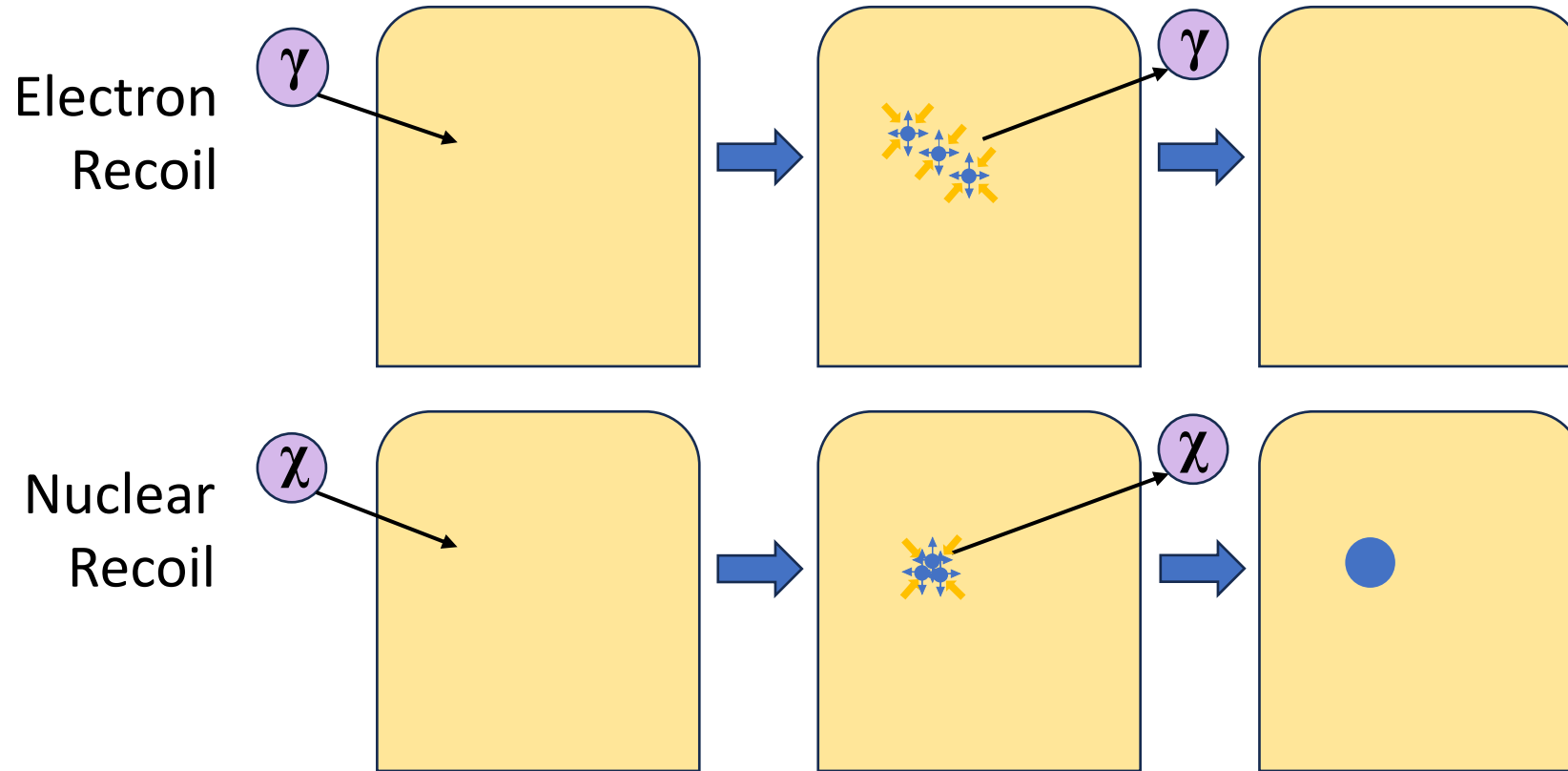
What are Bubble Chambers?



*Plots from Eric Dahl

- As pressure decreases, minimum free energy at vapor state μ_v .
 - Energy barrier keeps system at metastable liquid state μ_l – liquid is “superheated”.
- Sufficient energy deposition within a small radius can overcome the energy barrier and form a bubble.

Main Advantage – Background Rejection

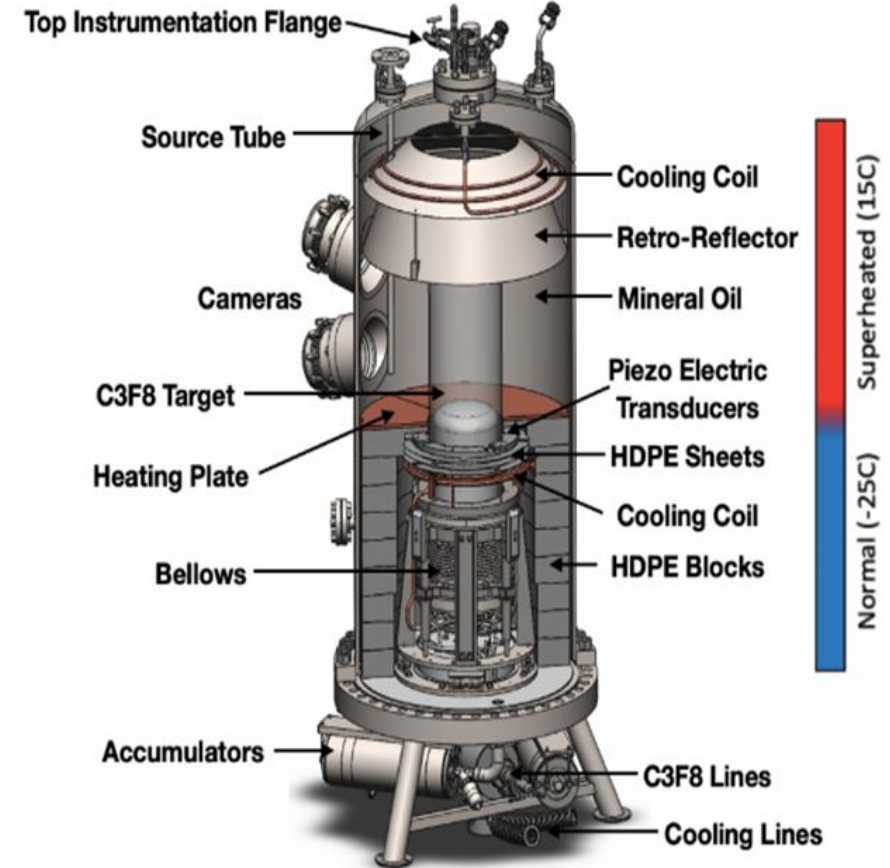
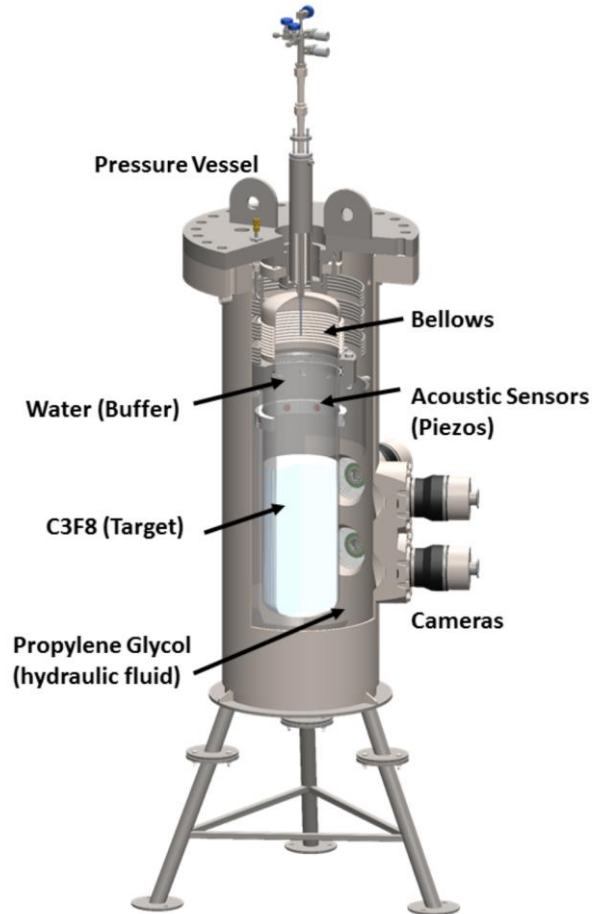


- Energy depositions from electron recoils insufficiently localized to form a bubble.
- Chamber is effectively blind to electron recoil interactions.



2023-03-05 Single Bubble Event

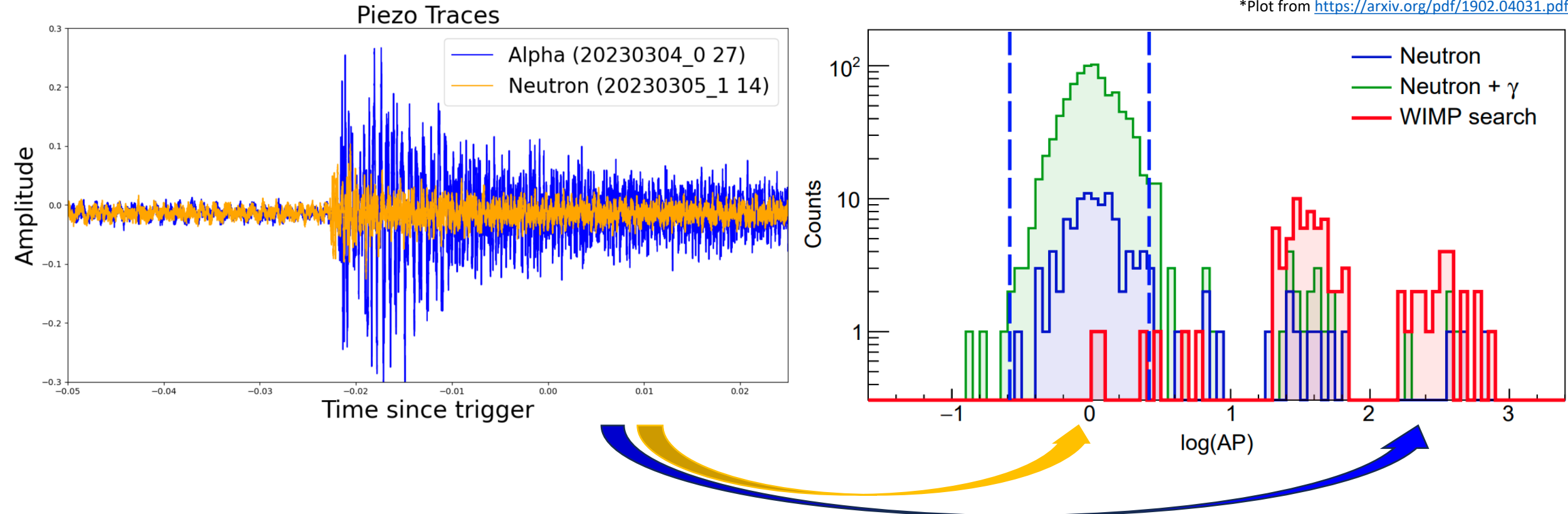
PICO-40L and the Right-Side-Up (RSU) Design



- World-leading WIMP-proton cross-section limits in 2019. (<https://arxiv.org/abs/1902.04031>)
- Bellows above the active fluid, separated by a buffer fluid (water).
- Excess of background events at buffer-target interface.
- Geometry inverted relative to PICO-60, buffer fluid removed.
- Thermal gradient suppresses bubbles near bellows.
- Additionally validates the RSU design in anticipation of larger detectors.

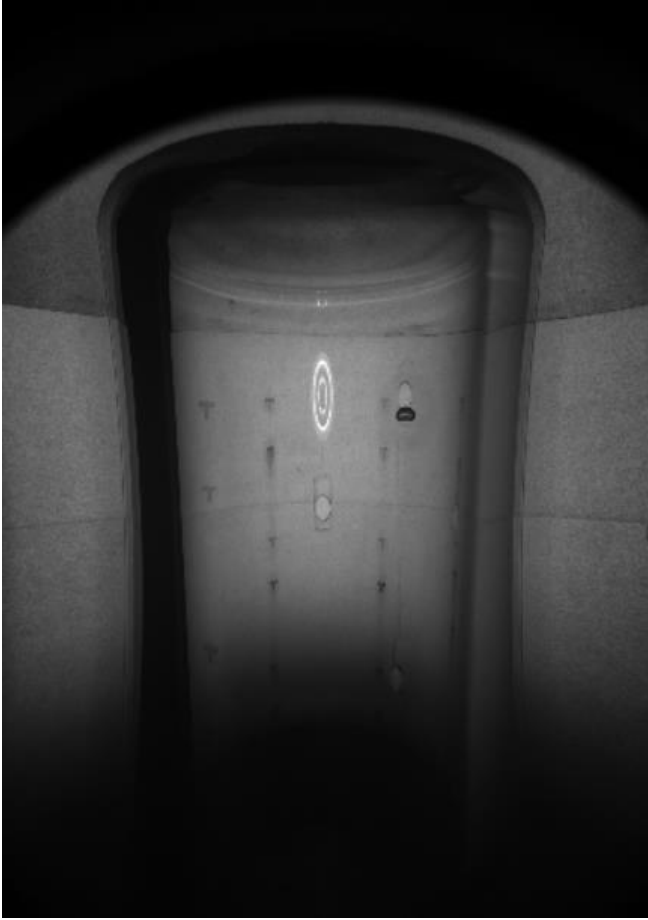
Background Rejection - Alphas

*Plot from <https://arxiv.org/pdf/1902.04031.pdf>

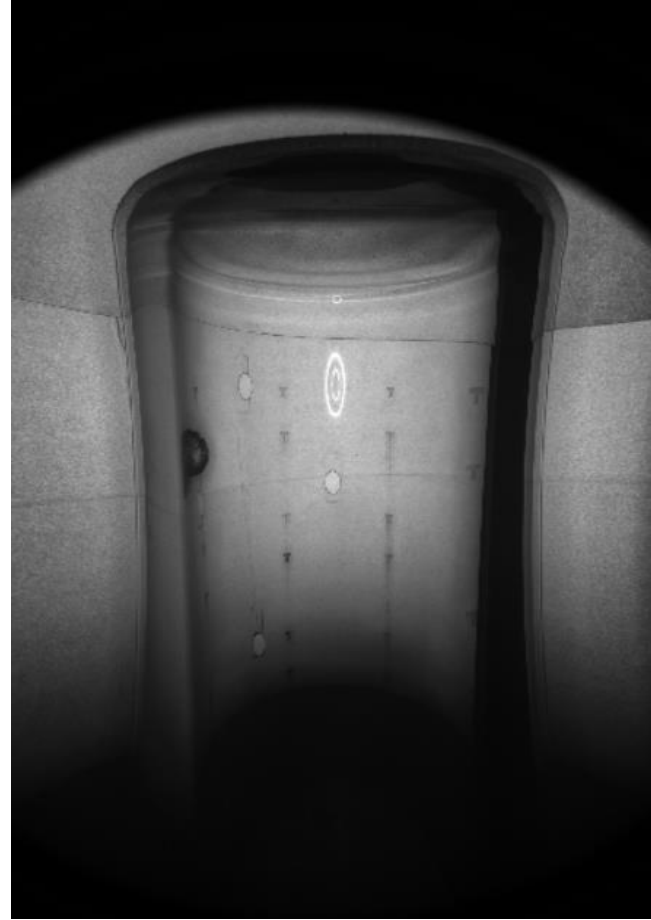
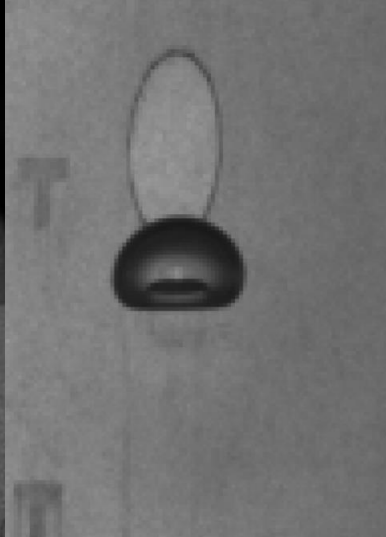


- 12 piezoelectric sensors read out during bubble formation.
- Alpha-induced bubbles several times louder than neutron-induced bubbles.
- Discrimination achieved using **Acoustic Parameter (AP)** – a measure of the acoustic power.

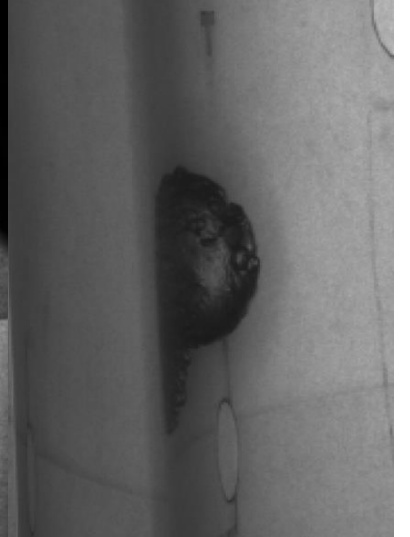
Wall Events and Bulk Events



Bulk Event
(2023-02-27)

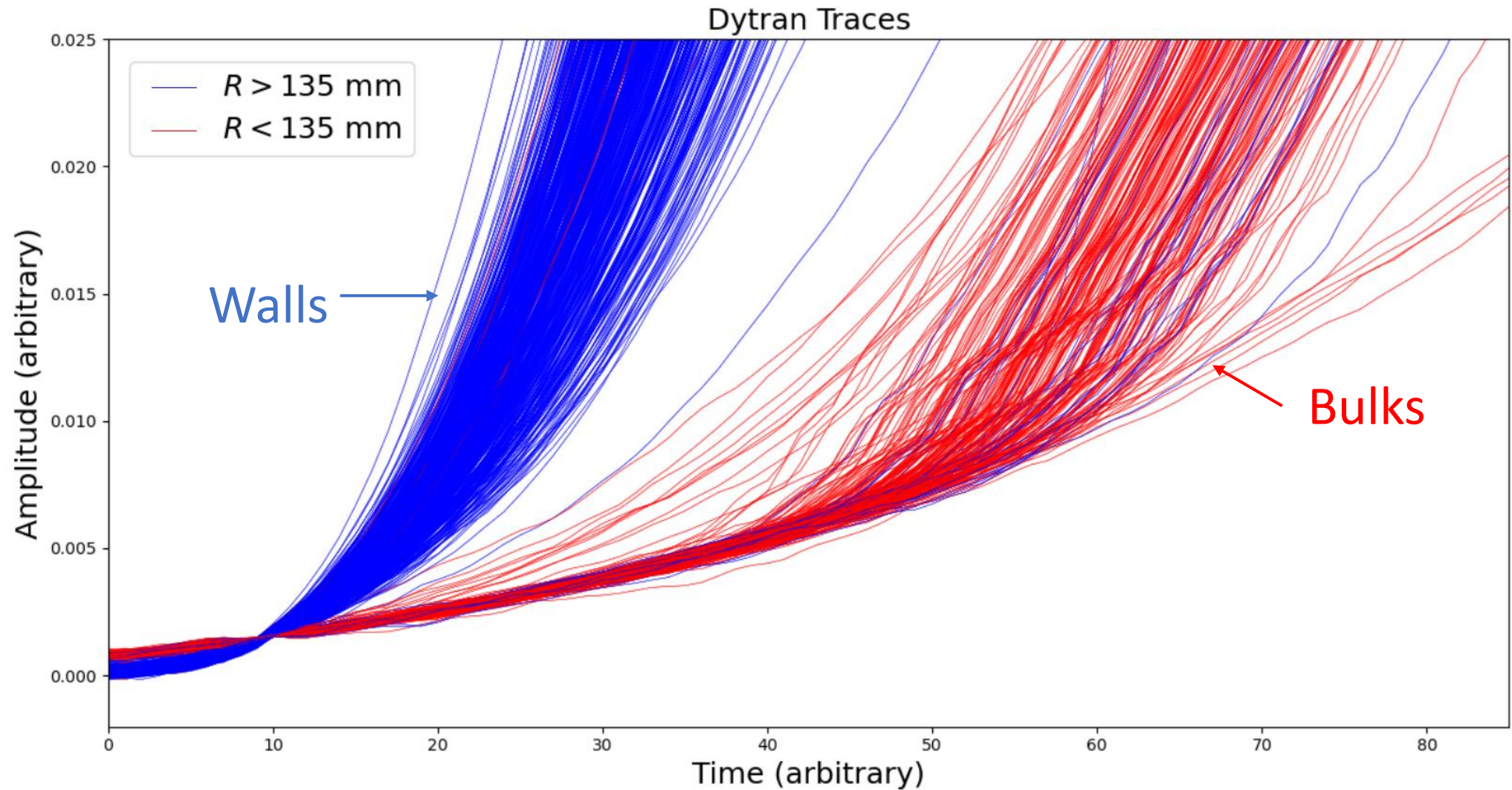


Wall Event
(2023-02-09)



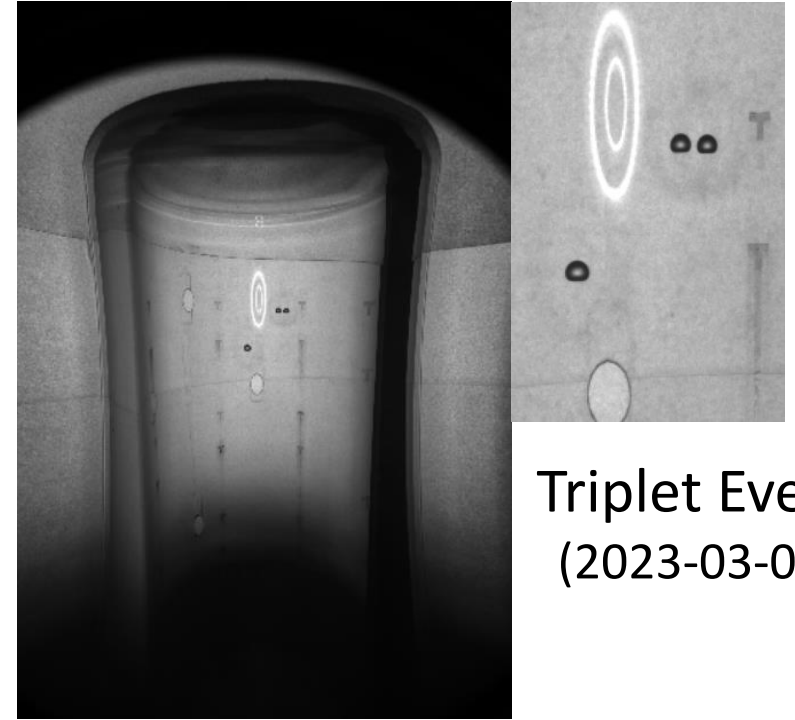
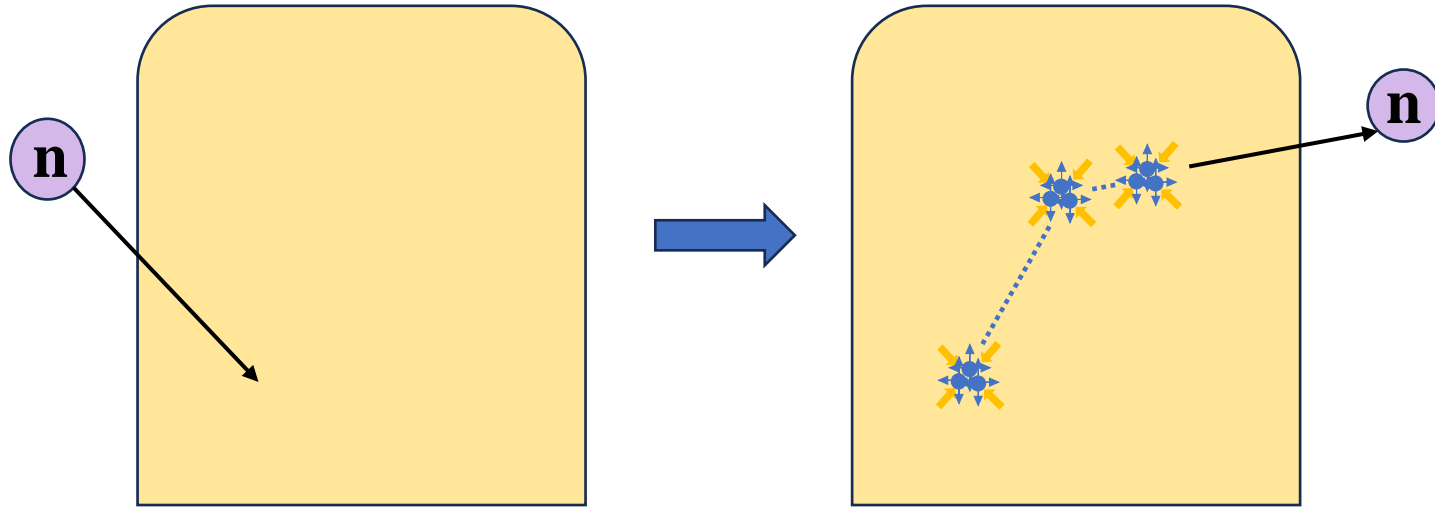
- Imperfections in vessel wall can trigger bubble nucleation.
- Distinguishable by eye from bulk events – can “handscan” to remove wall events.

Wall Events and Bulk Events



- Dytran differential pressure sensors can also distinguish wall events from bulk events.

Neutron Suppression and Rejection

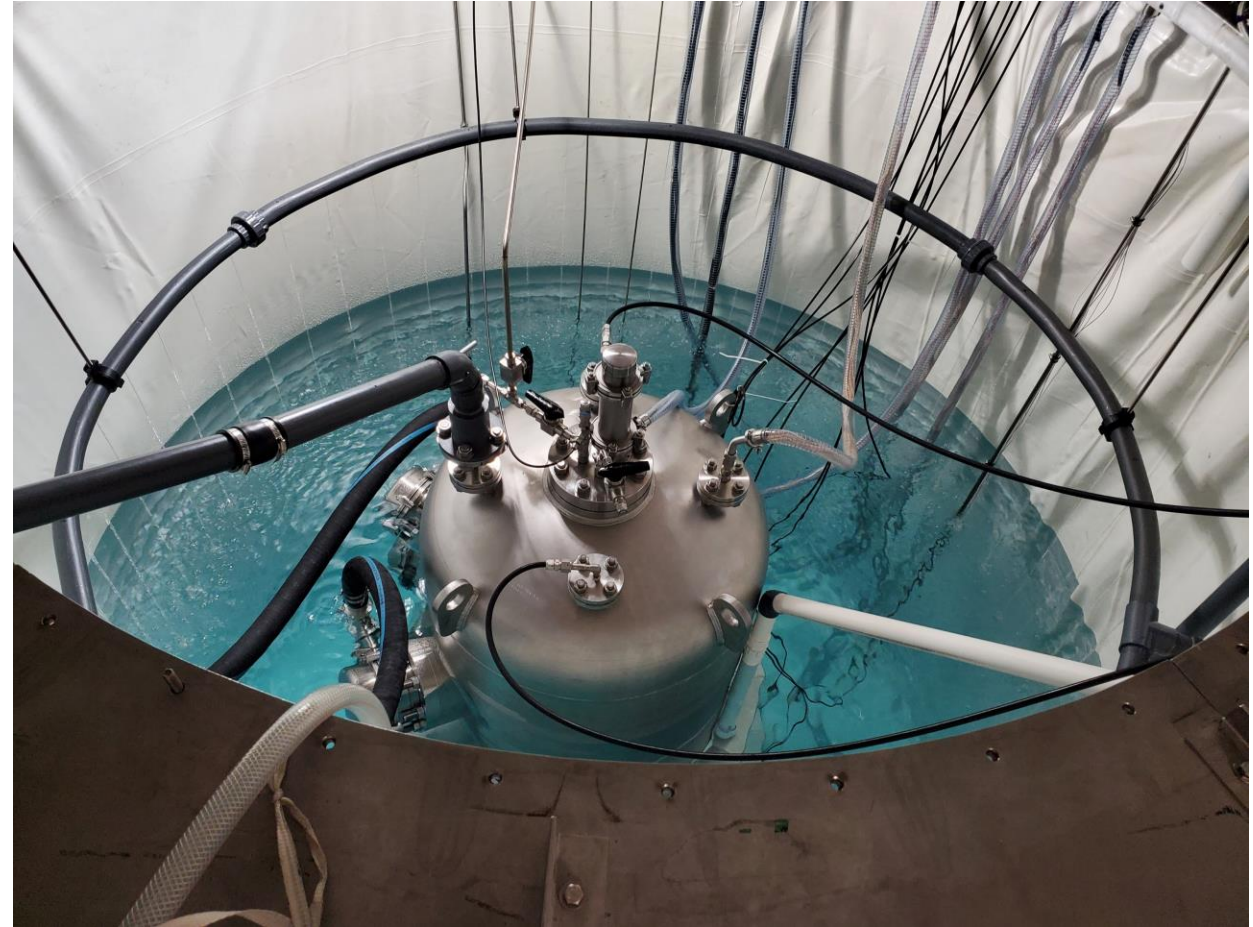


Triplet Event
(2023-03-03)

- Single scatter neutrons indistinguishable from WIMPs.
 - Large water shielding tank and careful material selection minimizes neutron background from external and internal sources, respectively.
- Neutrons likely to scatter multiple times in PICO-40L, leading to a multi-bubble event.
 - Ratio of multiples to singles (3:1) allows estimate of neutron contribution to signal.
 - Less than 1.0 single bubble event from neutrons per year expected.

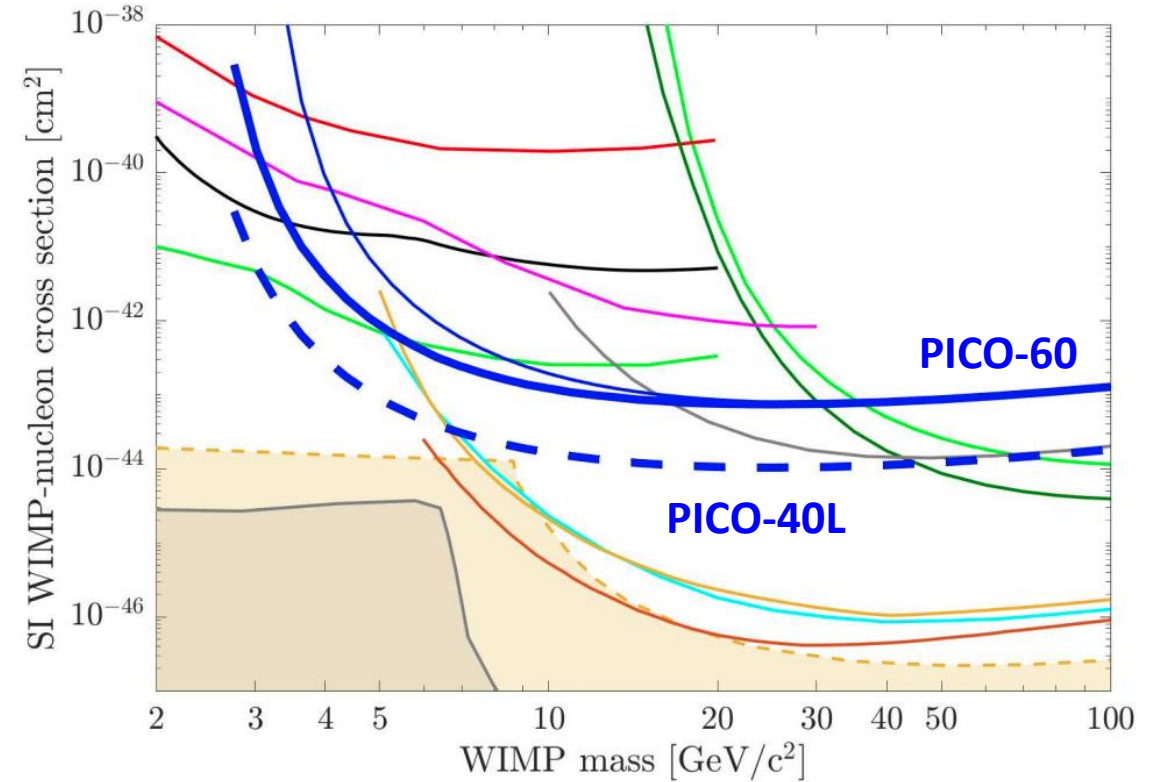
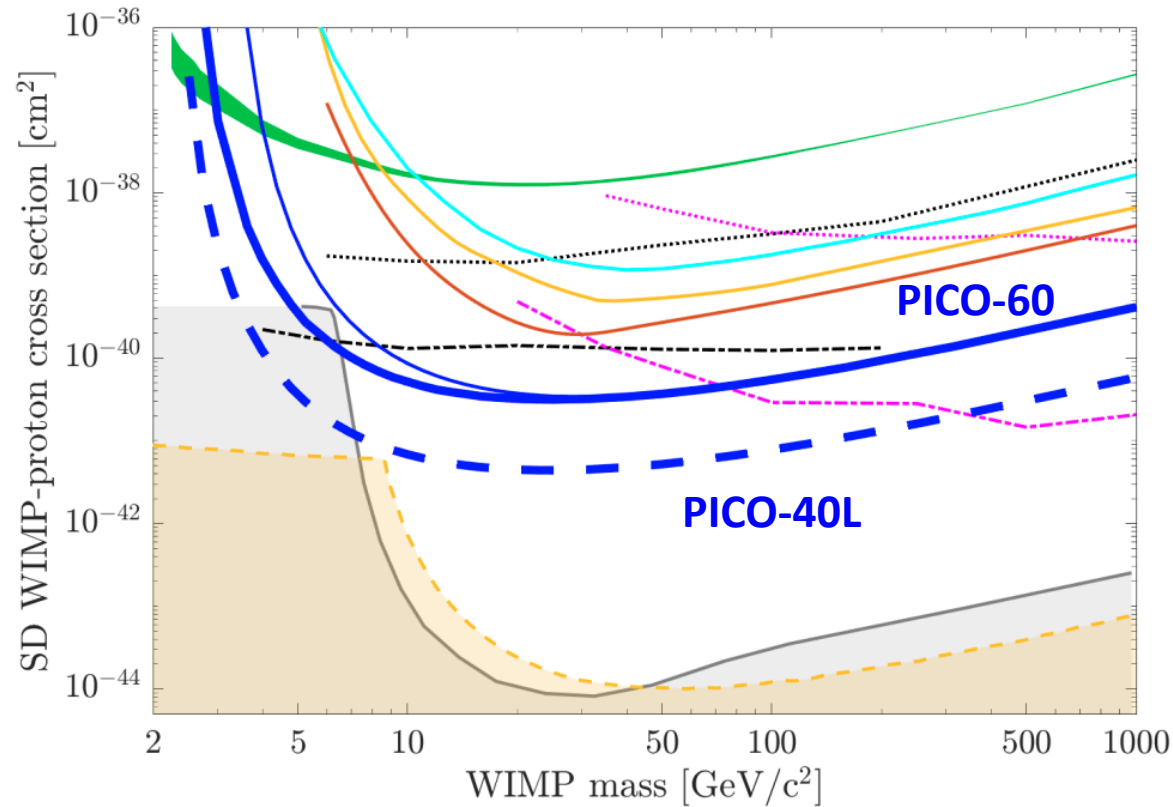
Current Status and Plans

- Detector fully assembled and operational, water tank fill in progress.
- Next steps:
 - Achieve operational stability with full water tank (1-2 weeks).
 - Neutron calibration with full water tank (2-3 weeks).
 - Blinded physics data-taking run anticipated in the next 1-2 months.



Projected Sensitivity

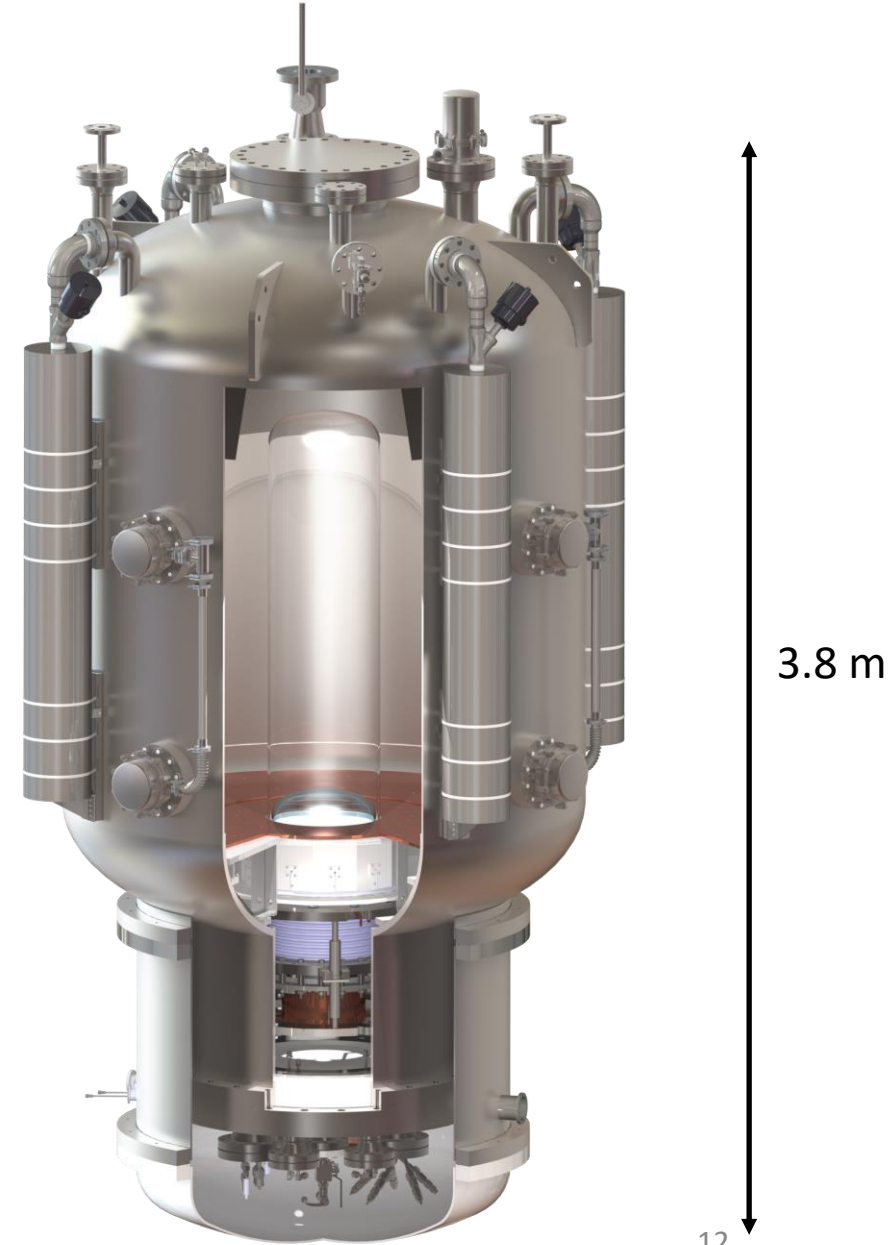
*Plots from <https://arxiv.org/abs/1905.12522>



- Factor of 5 improved sensitivity vs. PICO-60 despite similar mass, due to expected reduction in background.
 - Right-side-up design removed buffer fluid and therefore excess events at buffer-target interface.
 - Larger pressure vessel provides better neutron shielding.

The Future of PICO – PICO-500

- Tonne-scale right-side-up bubble chamber.
 - Like PICO-40L, but bigger!
- Allocated space underground in cube hall.
- Currently in procurement phase – construction to begin at the start of 2024.
- See presentation by Michaela Robert's for more details.
(Kinesiology building, Room 214,
Wednesday, June 21, 3:45 pm)



Summary

- Commissioning of the PICO-40L detector is very nearly complete - blinded physics run expected to begin in the next few months.
- In addition to its own direct dark matter search, PICO-40L validates the right-side-up design in anticipation of larger detectors (PICO-500 and beyond).
- Exciting times ahead for PICO!



