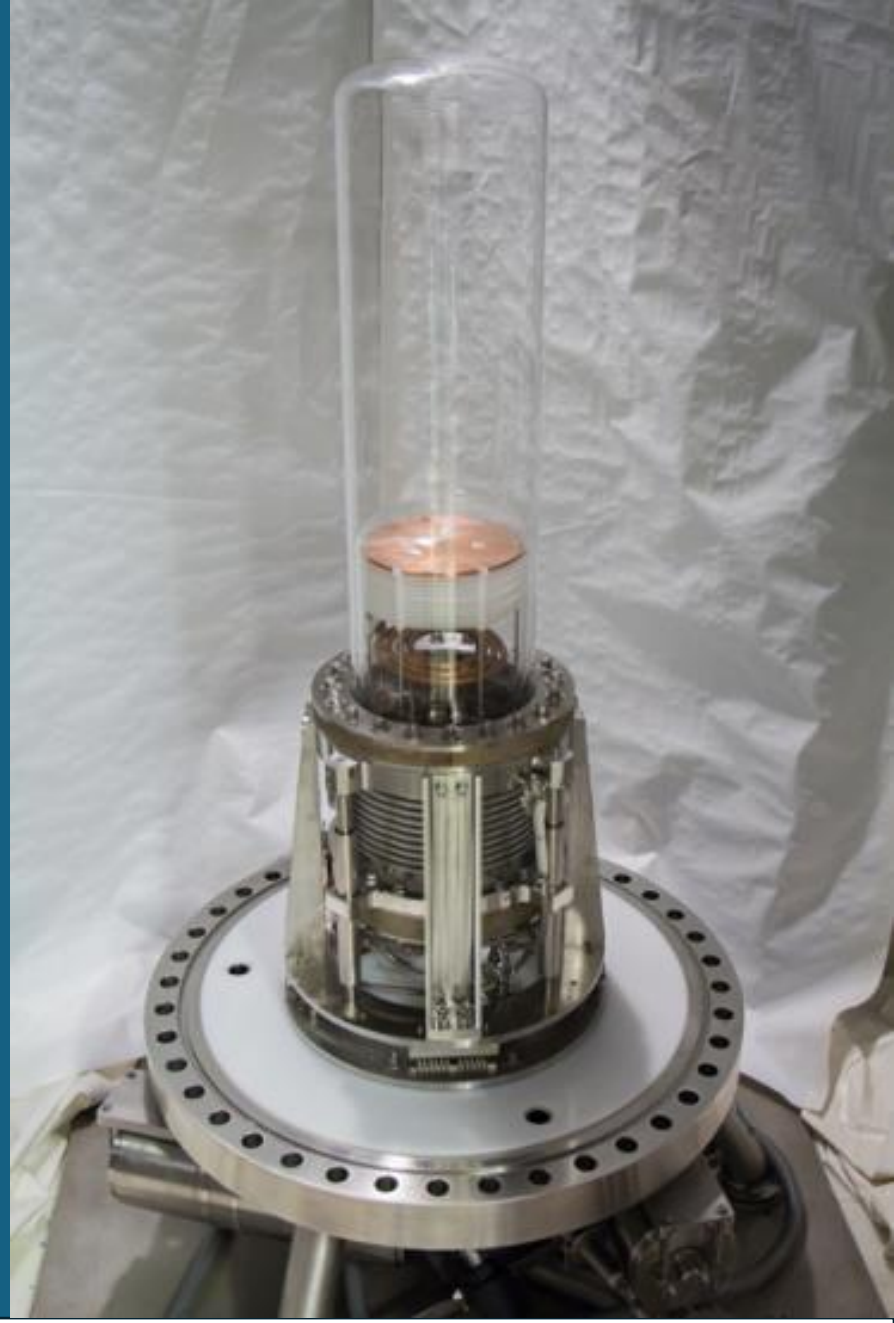
PICO

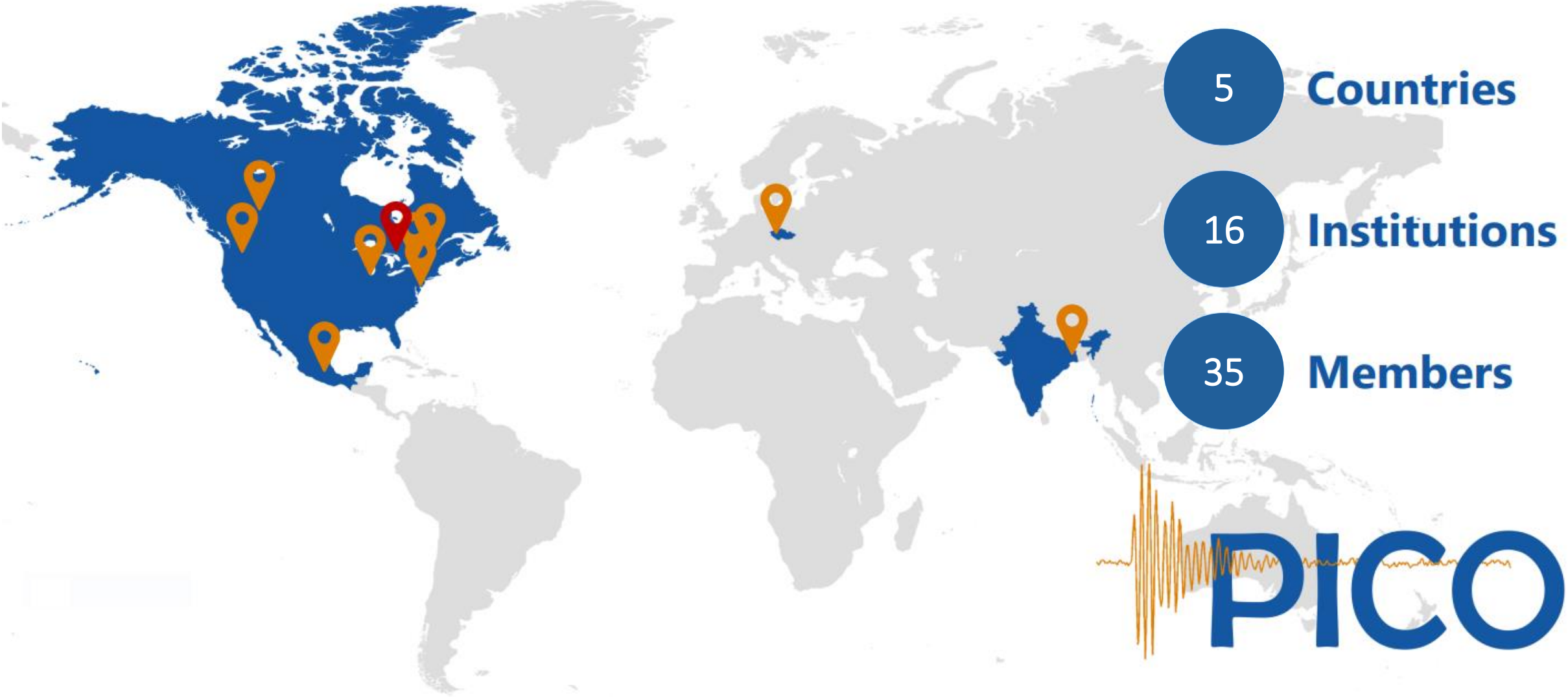
Quinn Malin, University of Alberta

On behalf of the PICO Collaboration

Lake Louise Winter Institute, March 2nd 2026



The PICO Collaboration



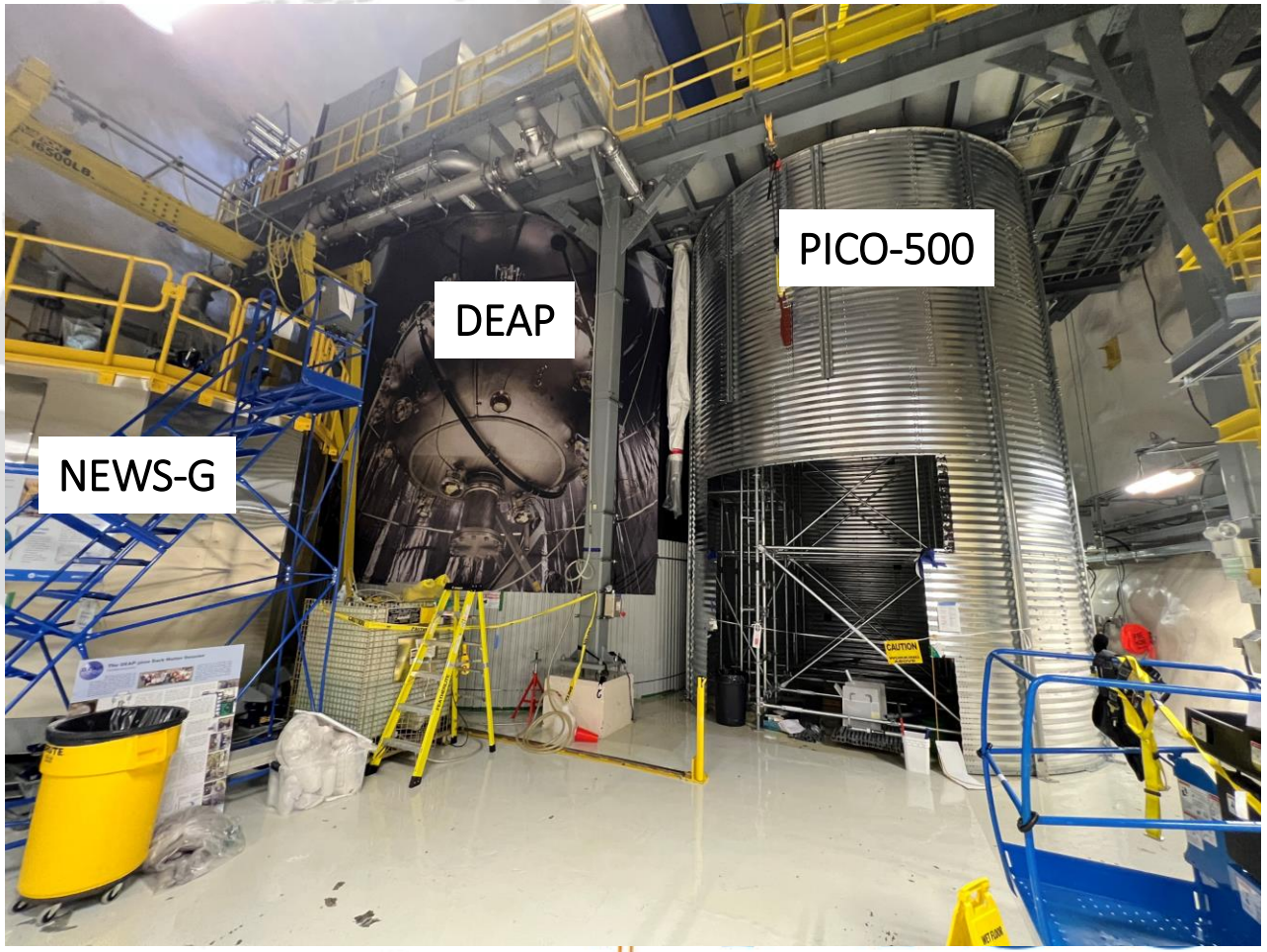
5 Countries

16 Institutions

35 Members

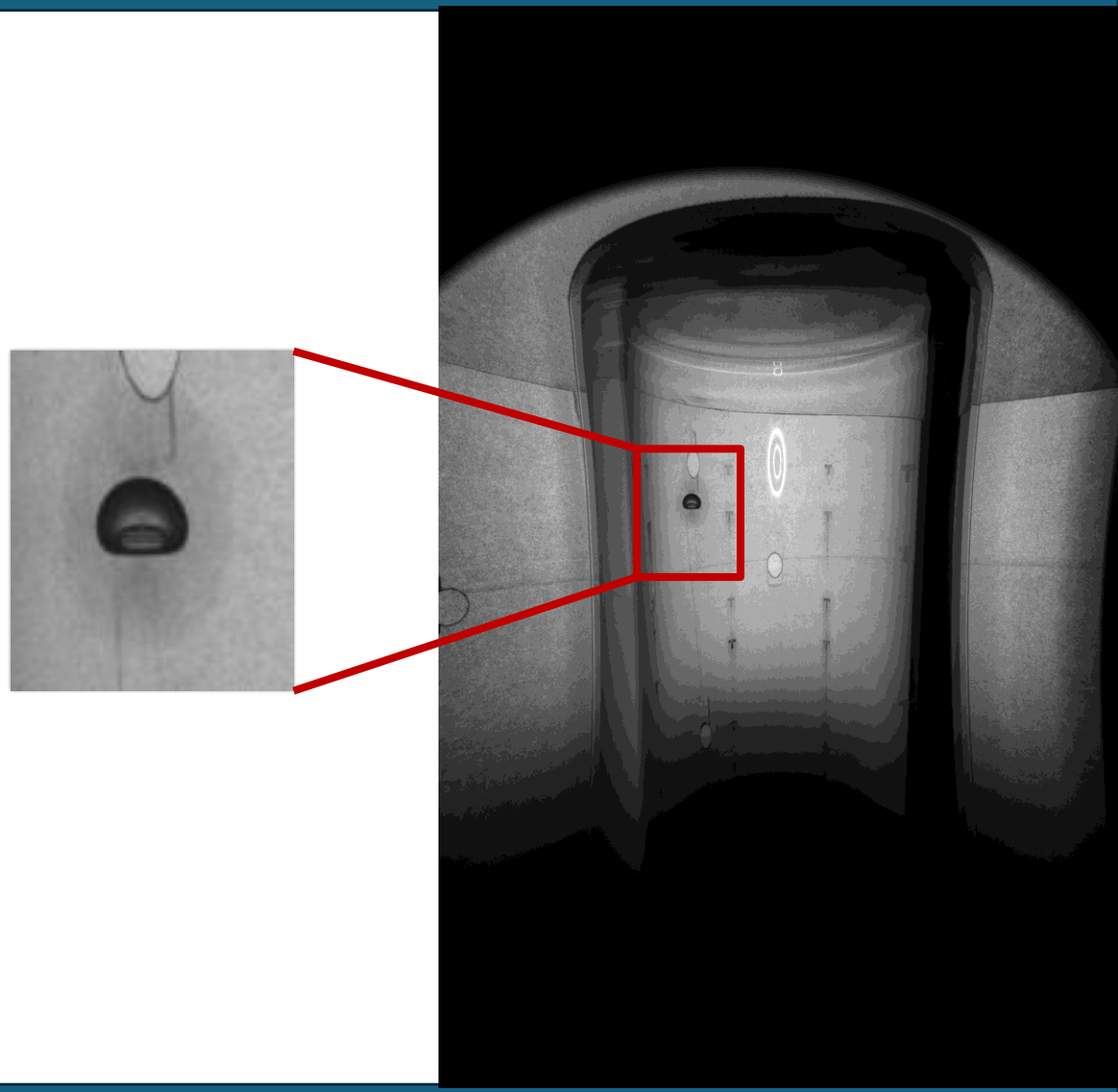
PICO

The PICO Collaboration



PICO Bubble Chambers

- Sealed synthetic silica quartz chamber filled with a superheated C_3F_8
- Particle detection in the form of bubble nucleation from ionization or nuclear recoils
- Looking for weakly interacting massive particles (WIMPs)
- Compared to old bubble chambers, we run at higher thresholds, which allows longer livetime of order of minutes and insensitive to tracks



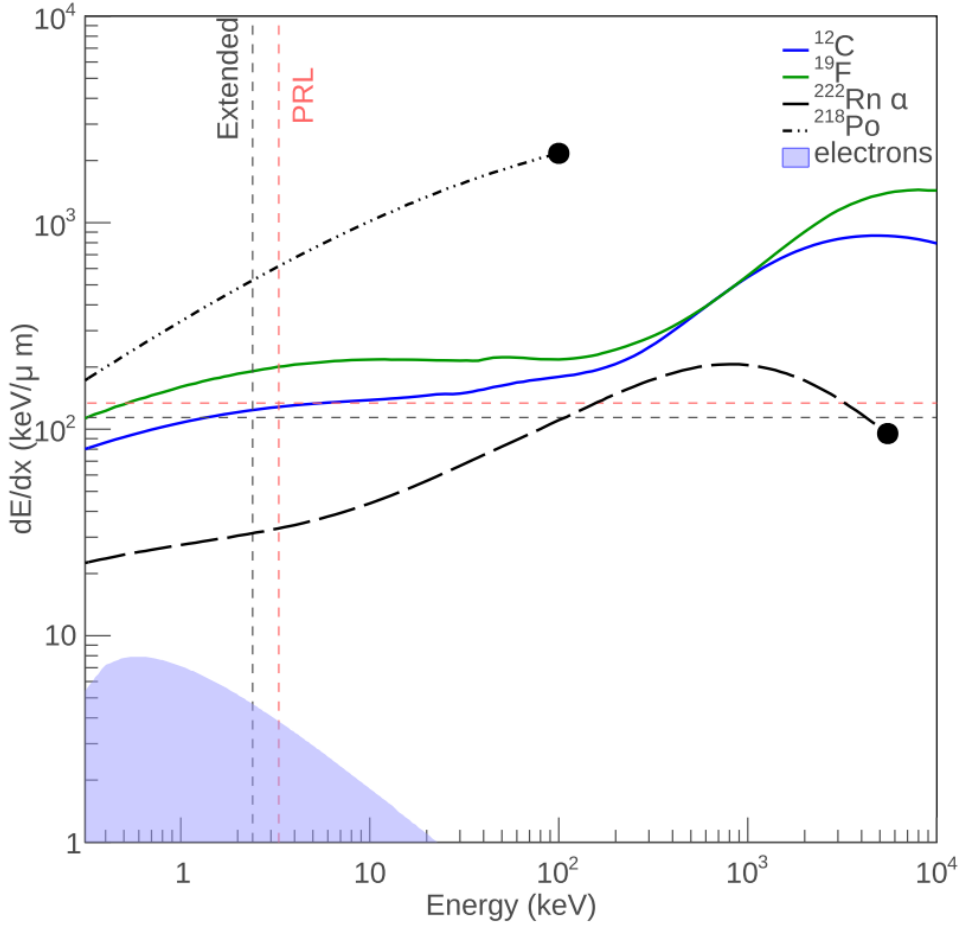
Seitz Threshold

- Energy deposition greater than the Seitz threshold (E_{th}) in a radius less than critical radius (r_c) will cause a bubble large enough to overcome surface tension (Seitz hot-spike model)
- Insensitive to electrons at our thresholds

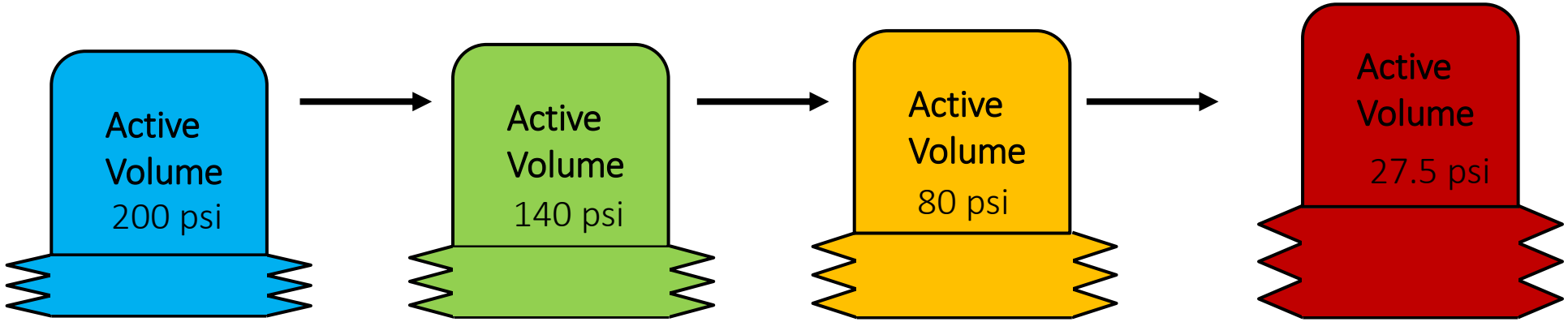
$$r_l = r_c \left(\frac{\rho_b}{\rho_l} \right)^{1/3} \qquad P_b - P_l \geq \frac{2\sigma}{r_c}$$

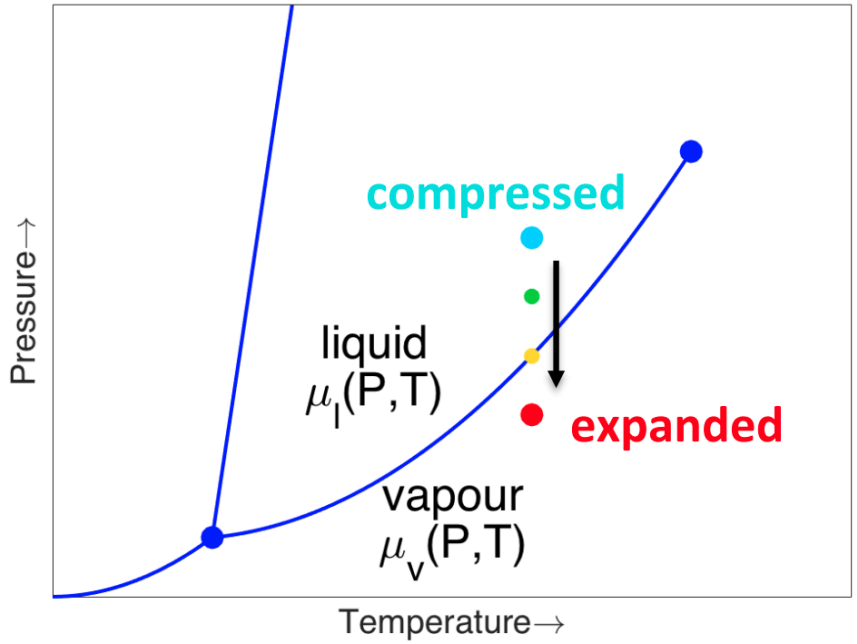
$$E_{th} = 4\pi r_c^2 \left(\sigma - T\frac{\partial \sigma}{\partial T} \right) + \frac{4}{3}\pi r_c^3 \rho_b (h_b - h_l) - \frac{4}{3}\pi r_c^3 (P_b - P_l)$$

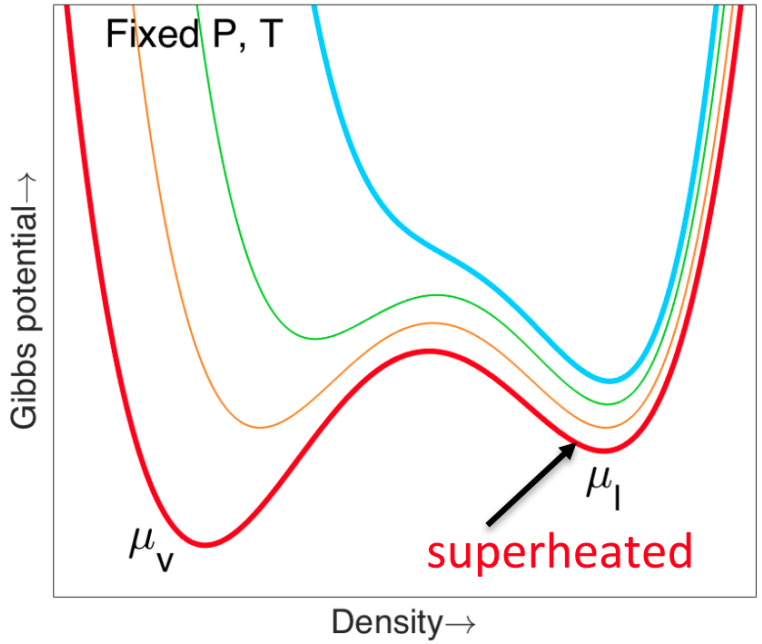
Surface energy Latent Heat Reversible work



Operating Principle



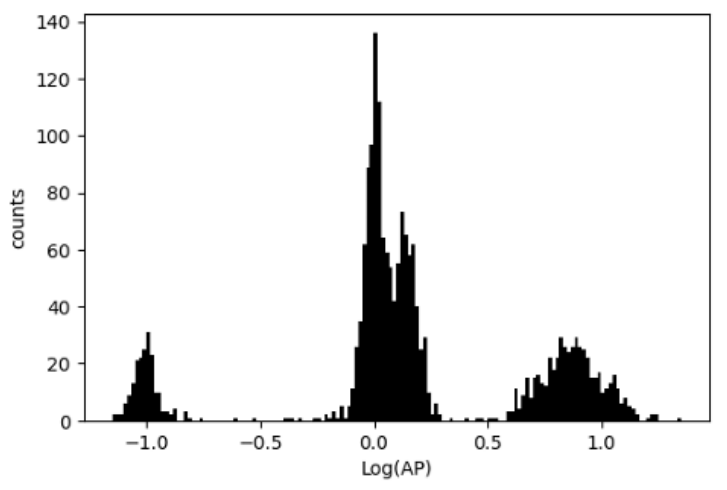




Methods of Detection

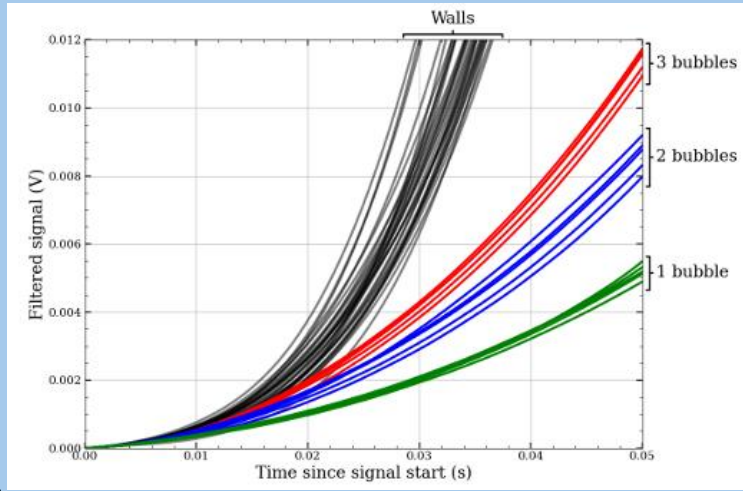
Acoustics

- Record acoustic data of bubbles
- Distinguishes nuclear recoils and alphas
- Acoustic parameter (AP), which represents energy of the signal



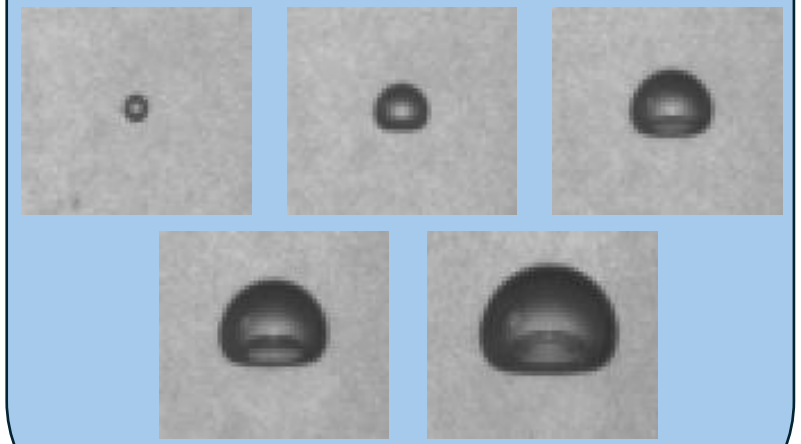
Pressure

- Record pressure in active volume
- Excellent discrimination between bulk and wall events

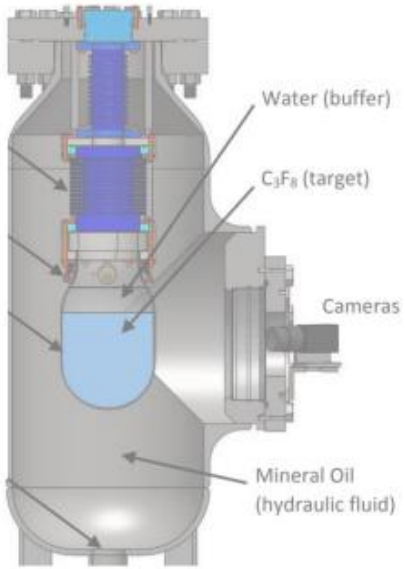


Cameras

- Record 41 frames (20 before, 20 after) event genesis at 100 fps across 4 camera
- Differentiate spatial location with stereo reconstruction



PICO Bubble Chambers



PICO-2L
2 L of C_3F_8
2013–2016

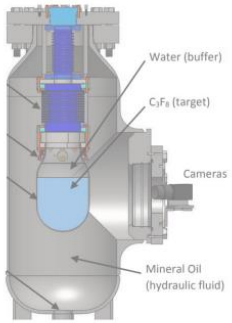
PICO-60
35 L of CF_3I and C_3F_8
2016–2017

PICO-40L
35 L of C_3F_8
2019–Present

PICO-500
260 L of C_3F_8
Proj. 2026

PICO Bubble Chambers

1m



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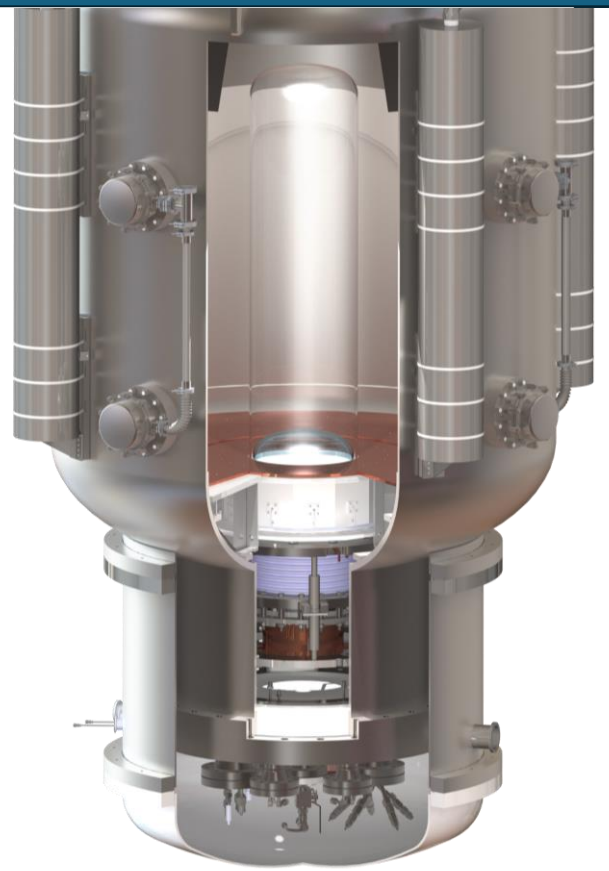
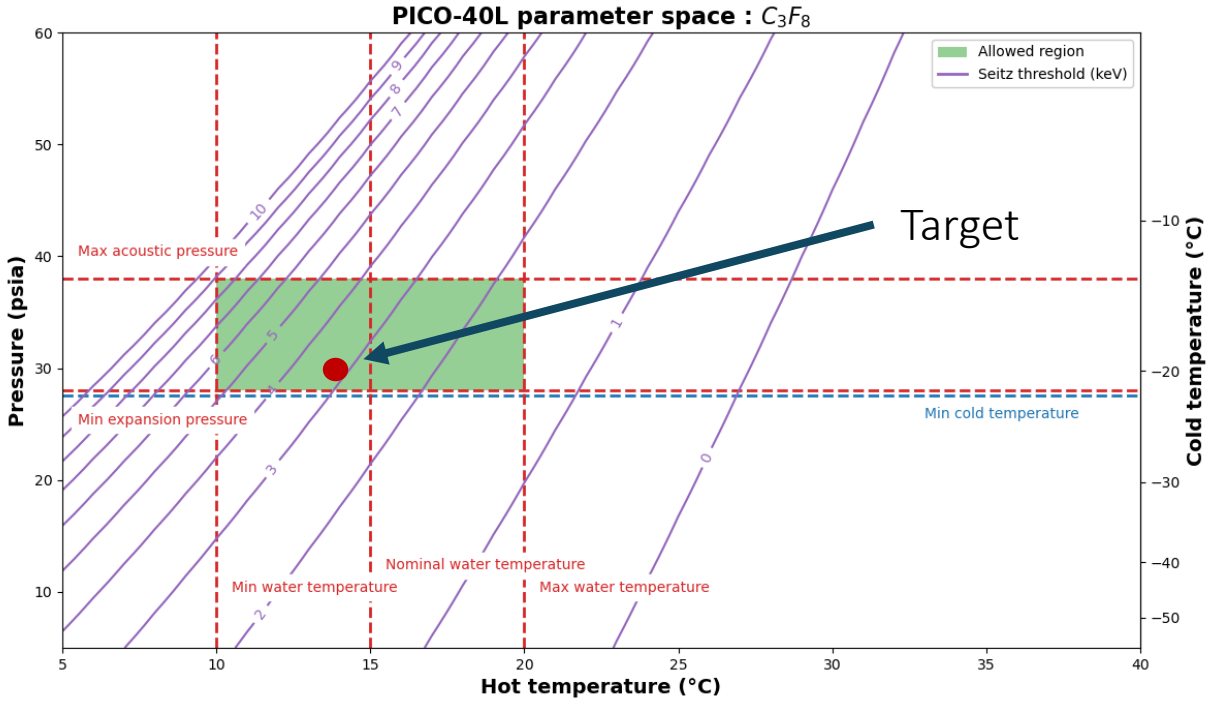
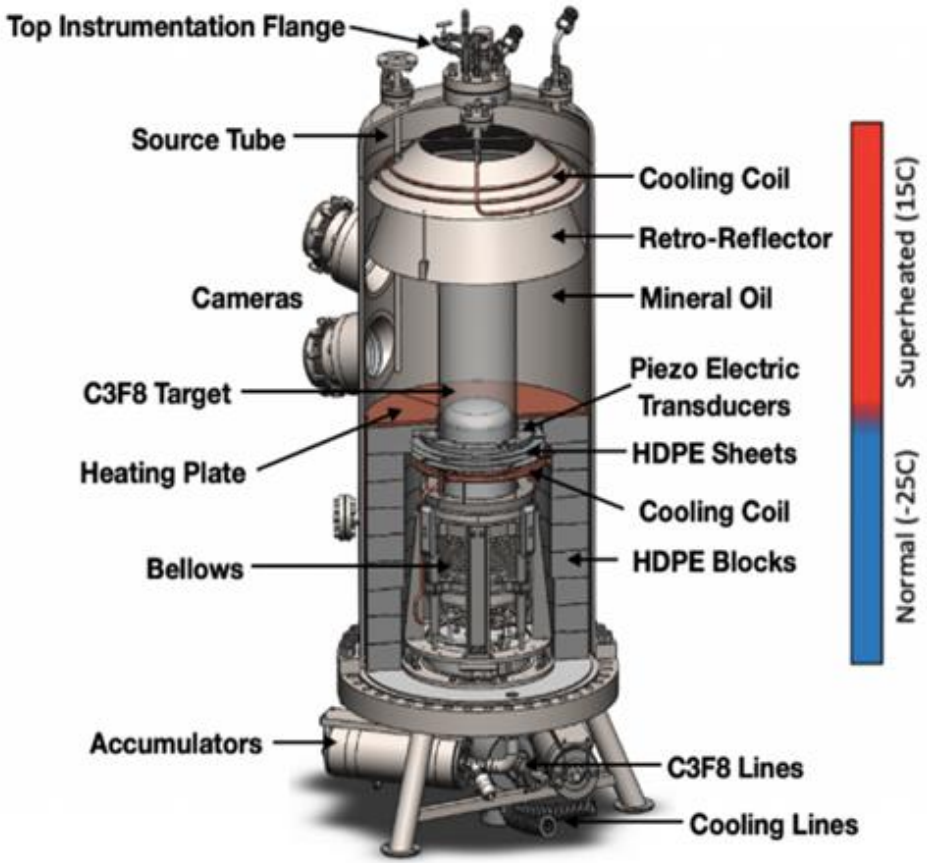


PICO-500
260 L of C_3F_8
Proj. 2026

PICO-40L

- Proof of concept for PICO-500, currently built at SNOLAB
- Hot and cold region to prevent boiling outside the camera view
- Detector paper on arXiv in the next week or so

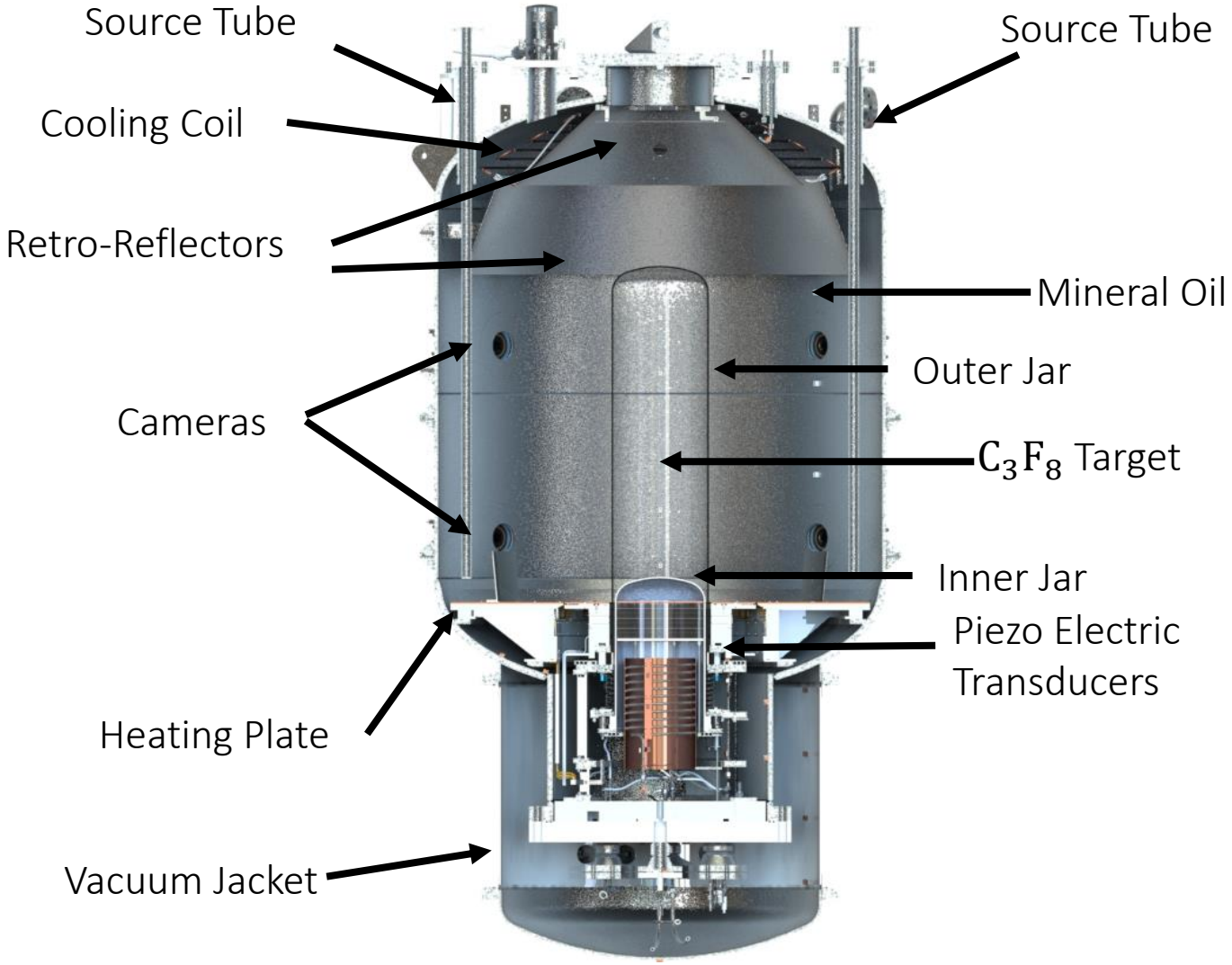




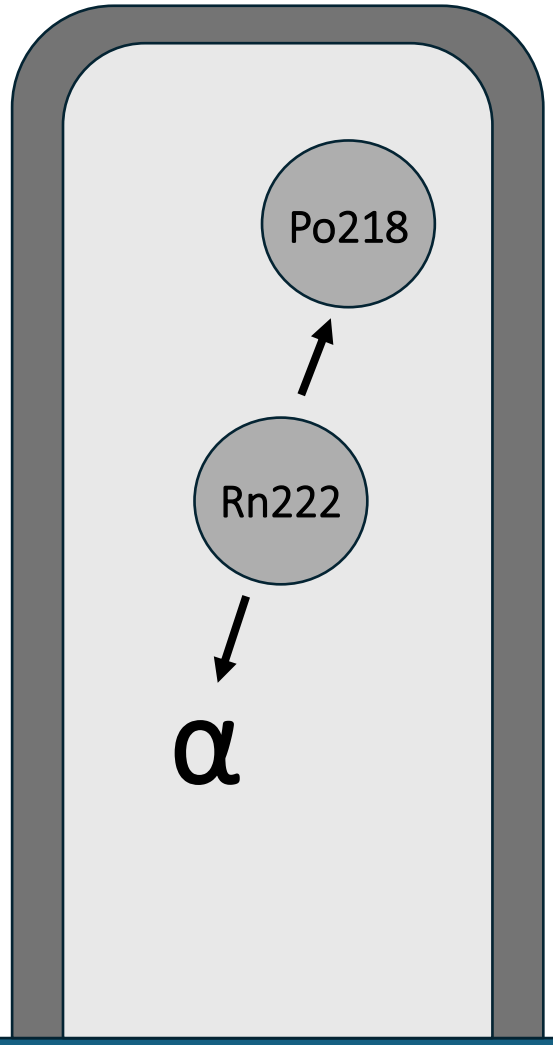
PICO-500

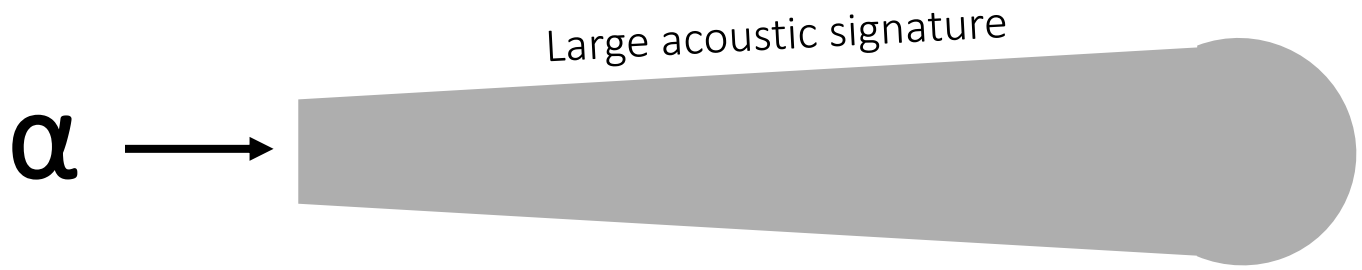
- Larger version of PICO-40L

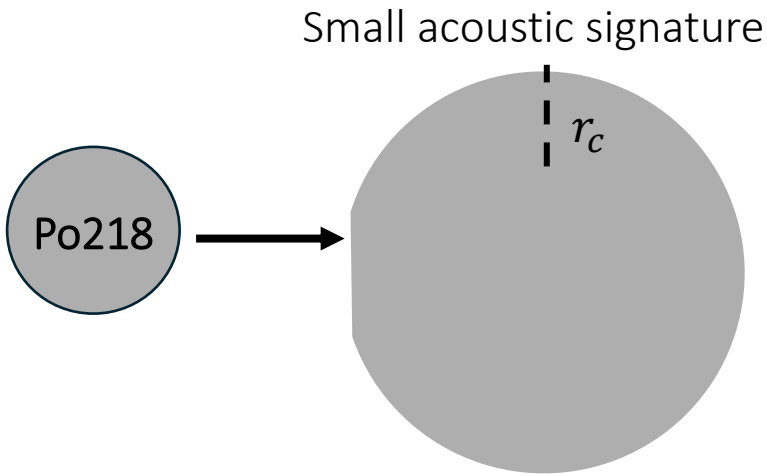
- Improvements to PICO-500
  - More rigorous cleaning and radon mitigation techniques
  - Improved heater design
  - Vacuum jacket for temperature stability
  - Spring energized PTFE seals
    - *Low radon permeation*
    - *Operate at larger temperature ranges*
  - Muon veto system
  - Variable gain piezos



Expected Interactions: Alpha decays



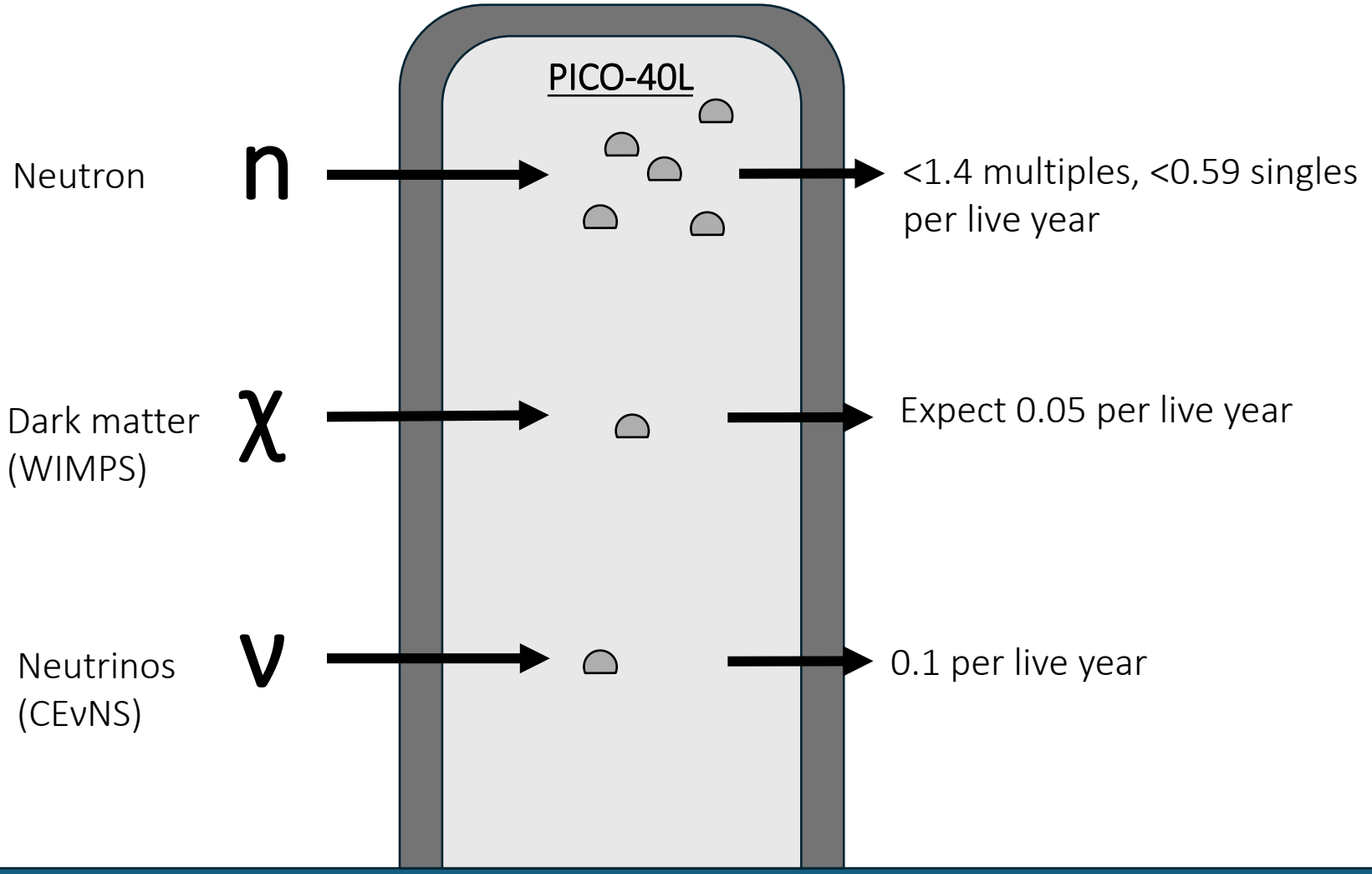




Alphas create a much larger bubble initially => record a much larger acoustic amplitude

The Rn-222 chain is our largest source of backgrounds

Expected Interactions: Nuclear Recoils



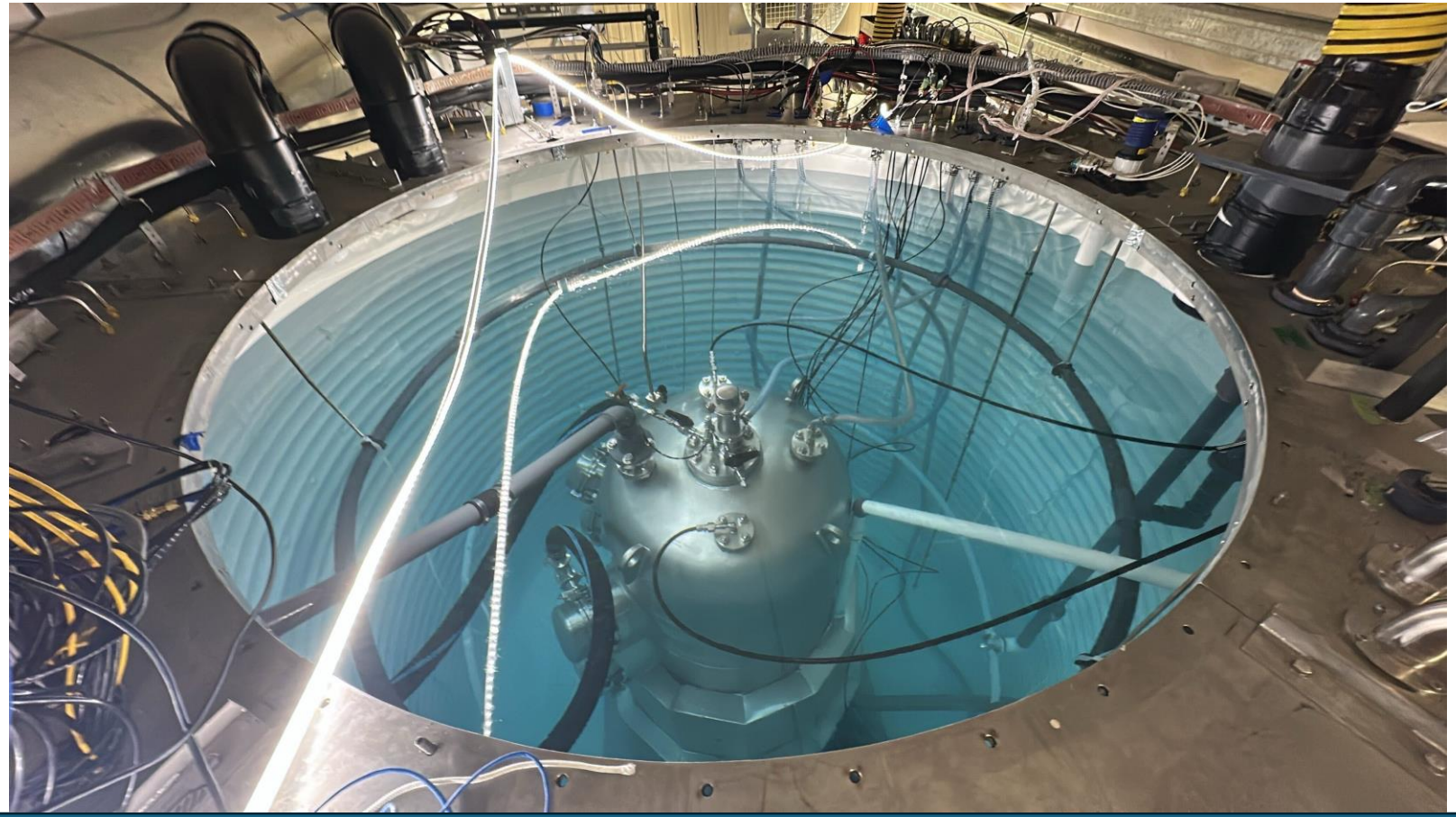
WIMPS are indistinguishable from single neutrons or CEvNS visually and acoustically

No neutrons seen in the physics data runs for PICO-40L

There's also gammas, muons, and other non-particle mechanism that cause events

Background Mitigation

- Water tank added for protection against neutrons
- Thermal bath for temperature stability

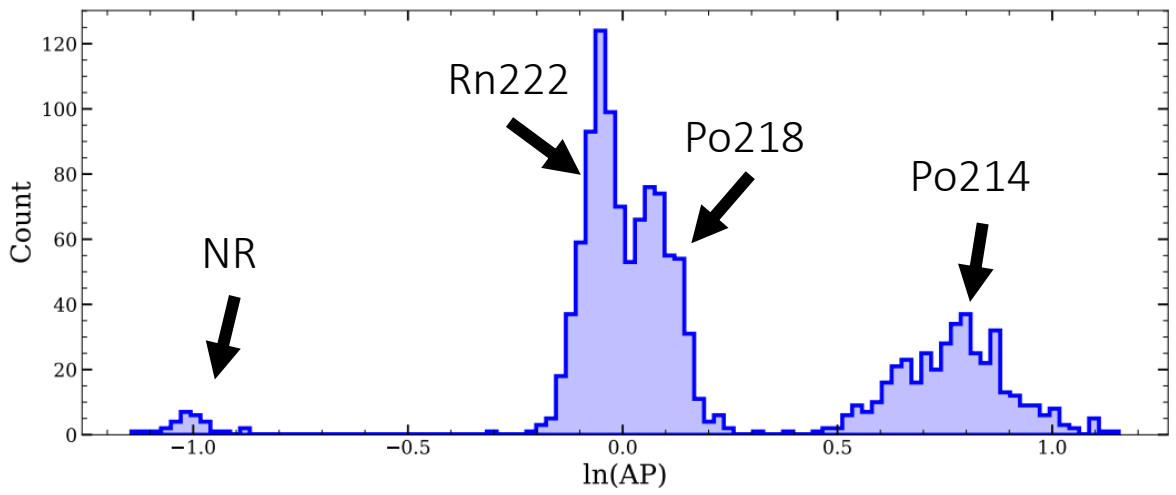


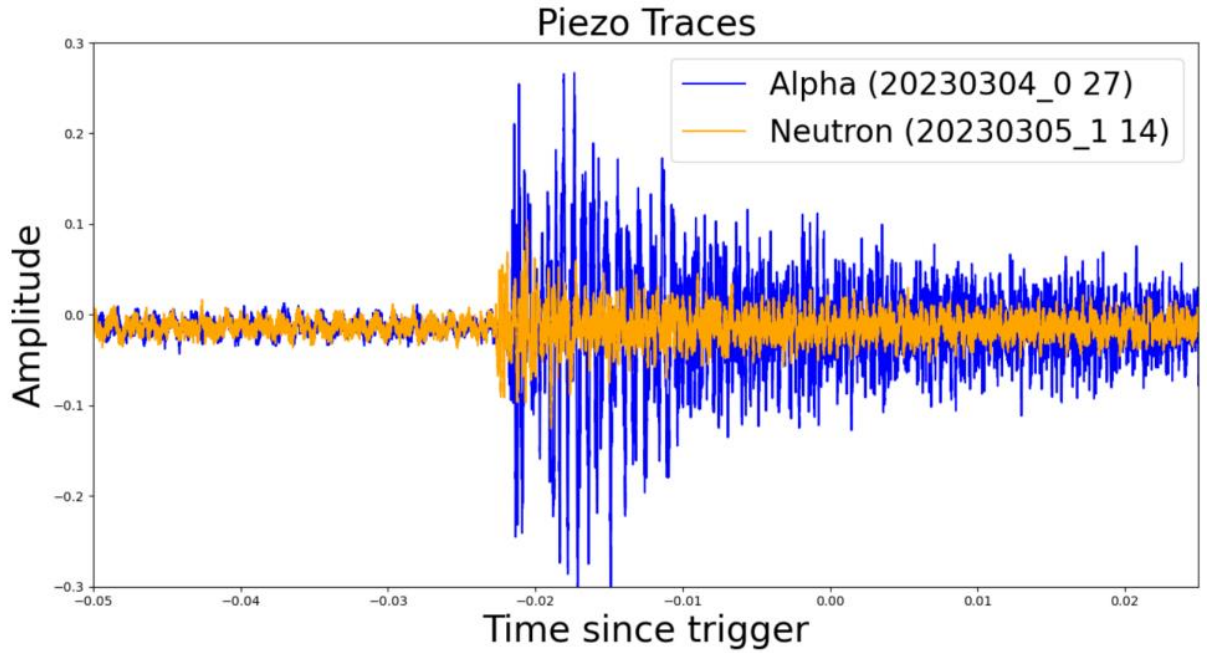
Background Mitigation

- Low background materials
  - Synthetic quartz, SS, PTFE, etc
  - With sample counting to calculate expected rates
- Extensive cleaning and radon mitigation effort
  - Achieved a 0.5 µm particulate concentration of < 4 particulates L^{-1}
  - Working on a technical paper

Background Rejection

- Acoustic Parameter (AP) is calculated from a sum of position-corrected resonant energies recorded by the piezoelectric sensors
- Allows for excellent discrimination between nuclear recoil and alphas
- Working on an alpha spectroscopy paper





Current Work on PICO-40L

- Cold region chiller needed repairs
- Water tank drained for a C_3F_8 valve repair
- Pneumatic line leak repaired
- Currently have 1 live month of data, looking to collect more data this year!

PICO-40L has an irreducible background that impacts the detector, which we believe to be from the Rn222 chain. We are currently working on it, and do not believe will be present in PICO-500

Current Work on PICO-500: Pressure Vessel

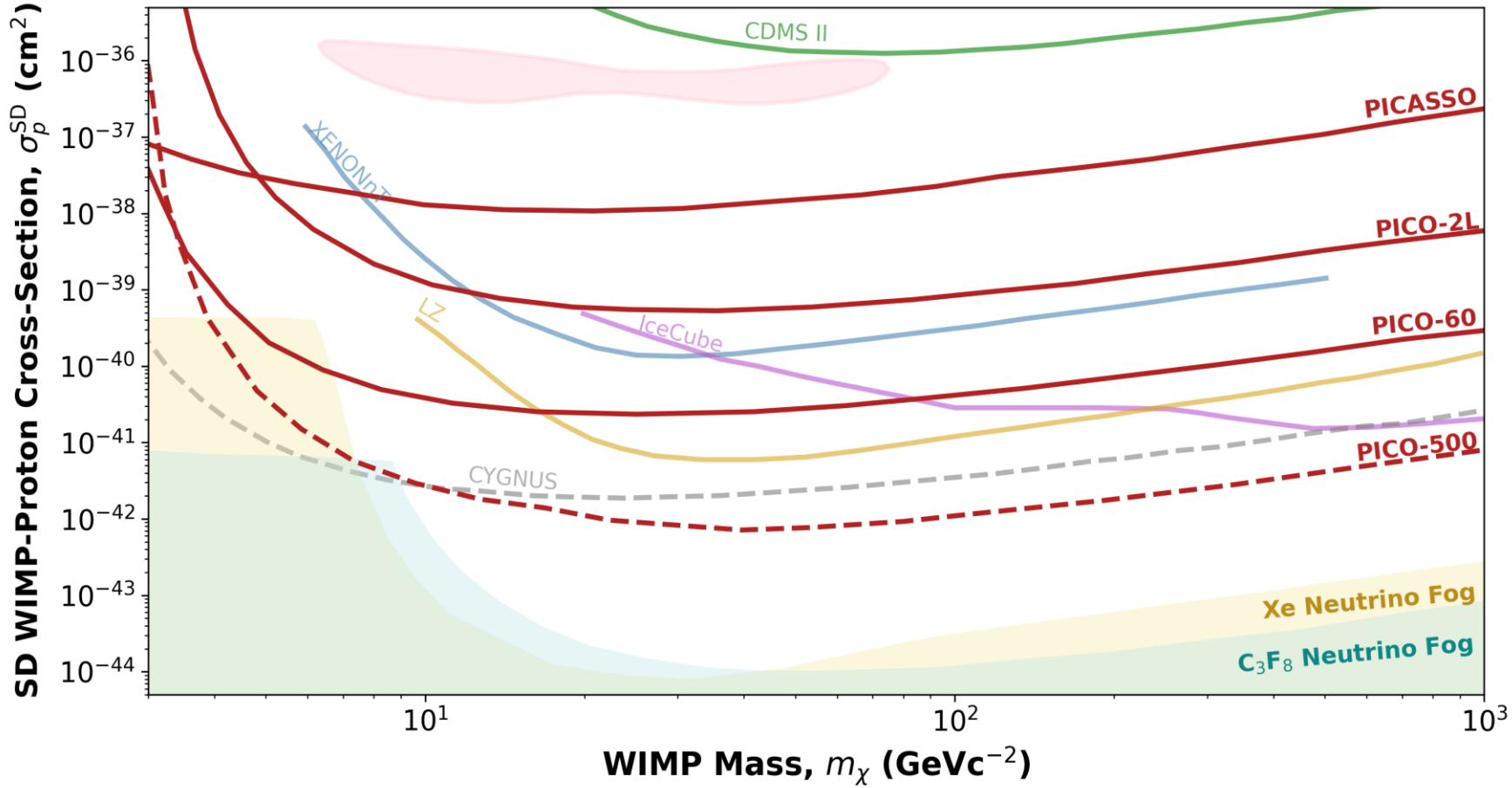
- The pressure vessel has been assembled and welded inside the water tank in the Cube Hall
- Leak checking and radon assay are now completed

Current Work on PICO-500: Inner Vessel

- Near finished with Inner Vessel assembly, to be inserted into the pressure vessel
- Active fluid fill around fall 2026

Projected Sensitivities

- PICO-500 is expected to place world leading limits in the SD WIMP cross section



Summary

- PICO-40L informs background model and operation of PICO-500
- A few papers in the works including technical papers for PICO-40L and particulate/radon mitigation for PICO-500, and an alpha spectroscopy paper
- PICO-500 is near completion, with commissioning at end of the year.
- With results, we expect to set world leading limits on the SD WIMP dark matter interactions

PICO

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