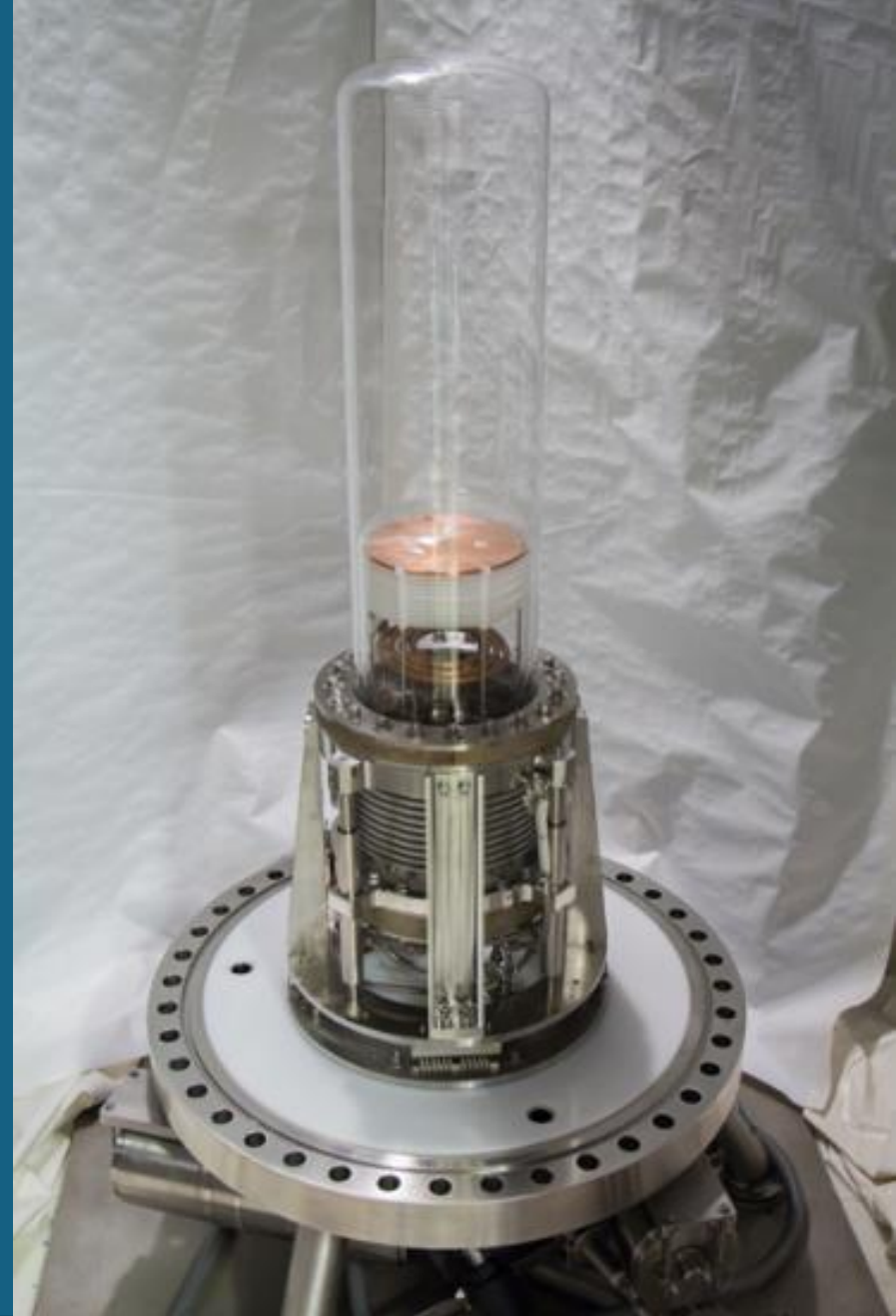


# PICO

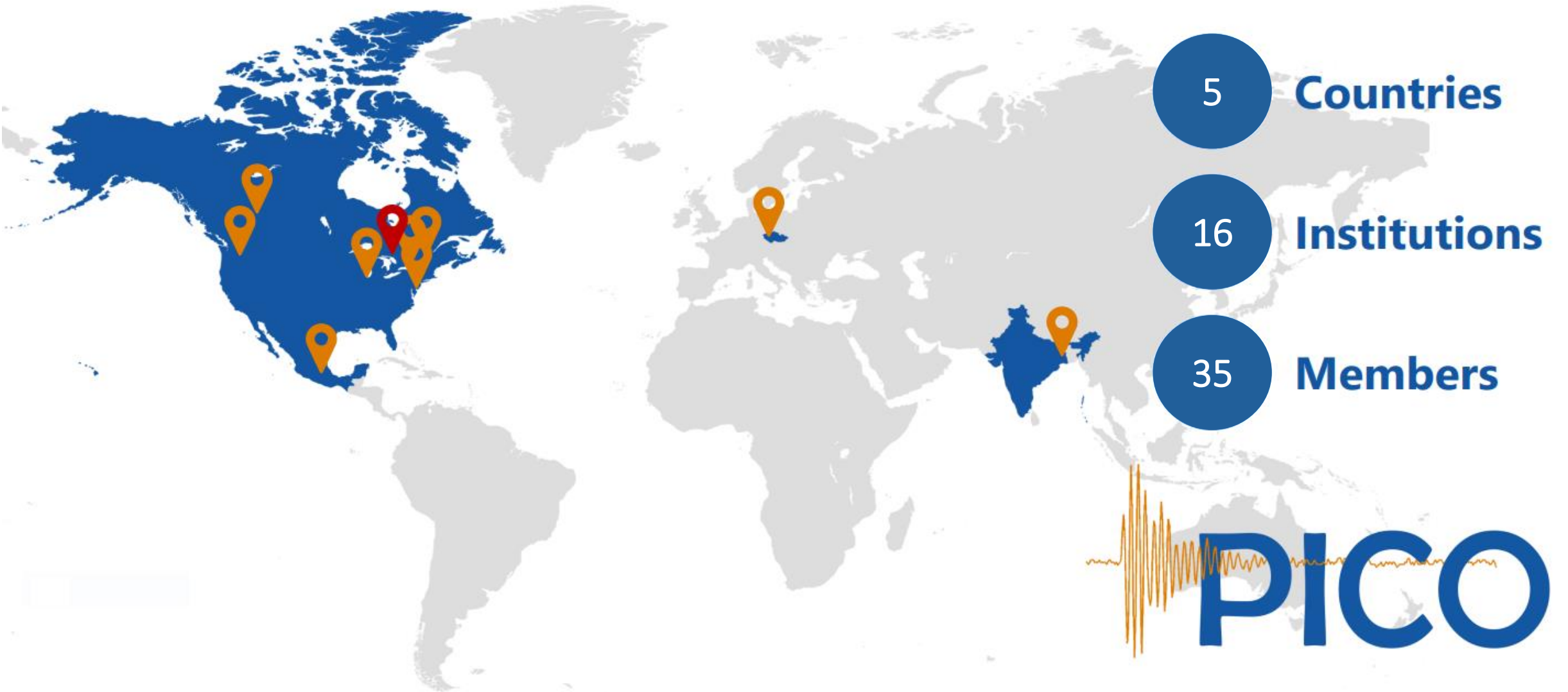
Quinn Malin, University of Alberta

On behalf of the PICO Collaboration

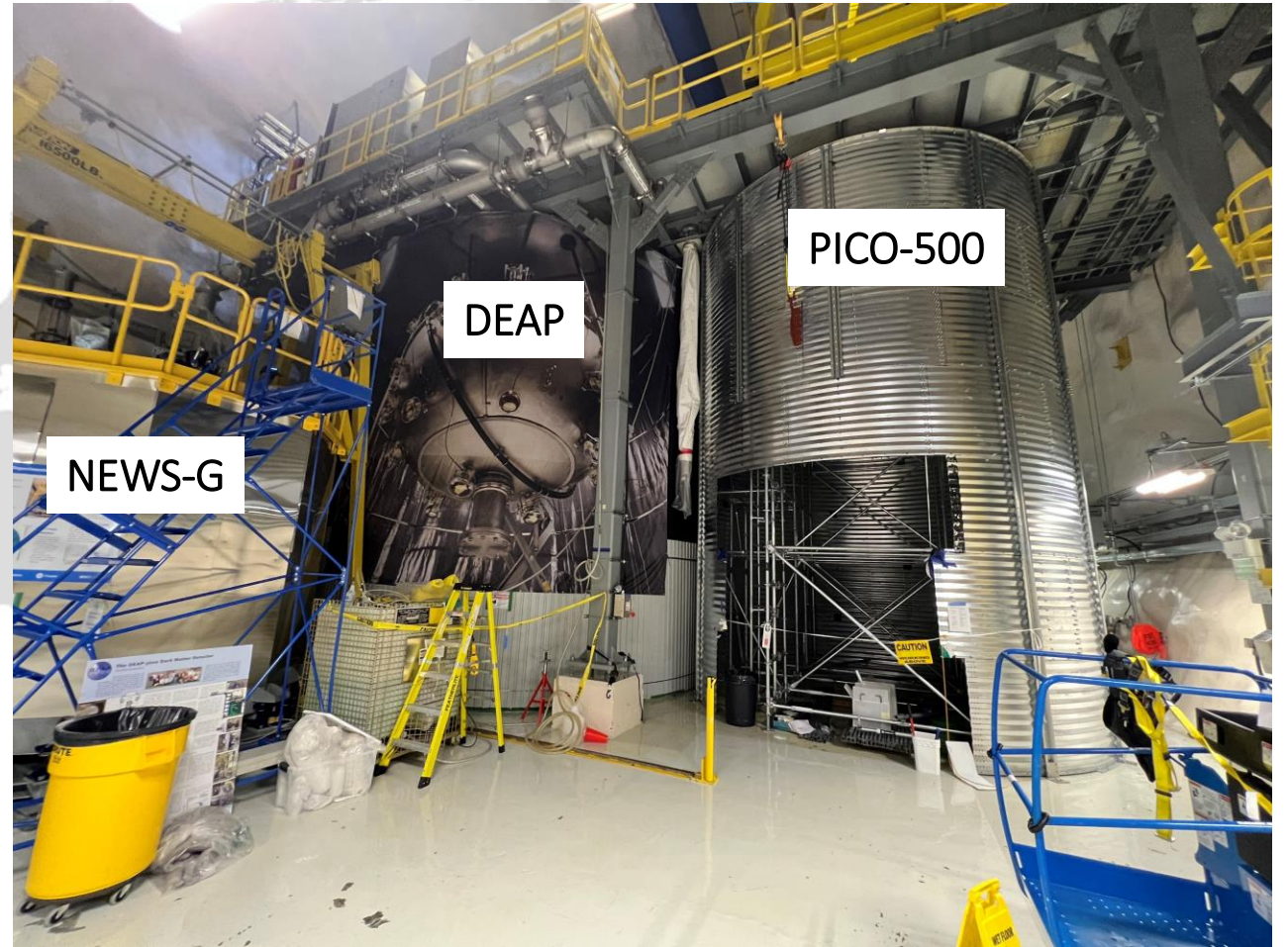
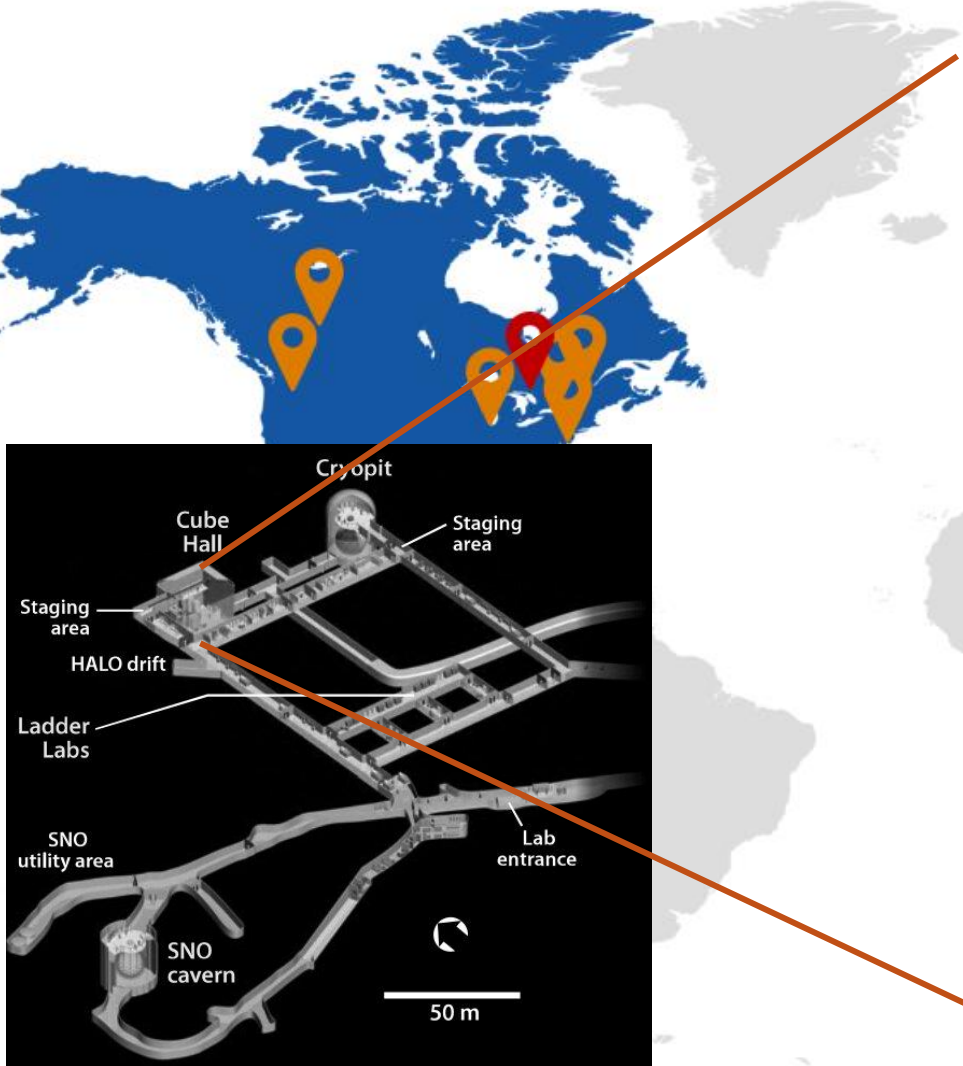
Lake Louise Winter Institute, March 2<sup>nd</sup> 2026



# The PICO Collaboration

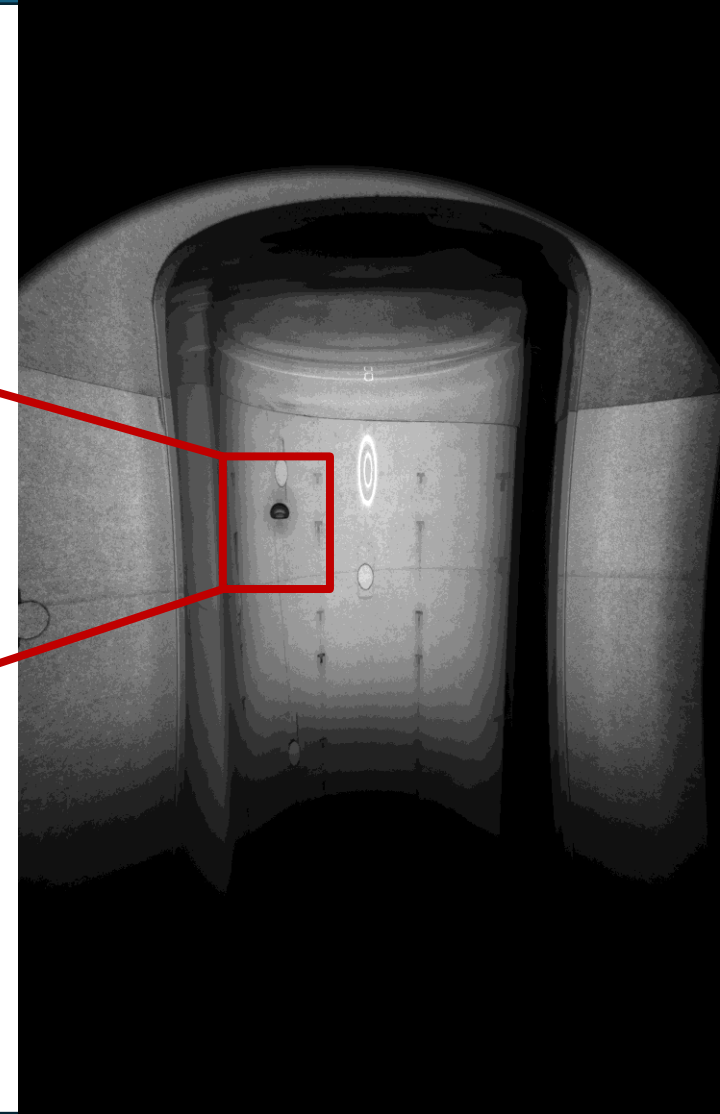


# The PICO Collaboration



# 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

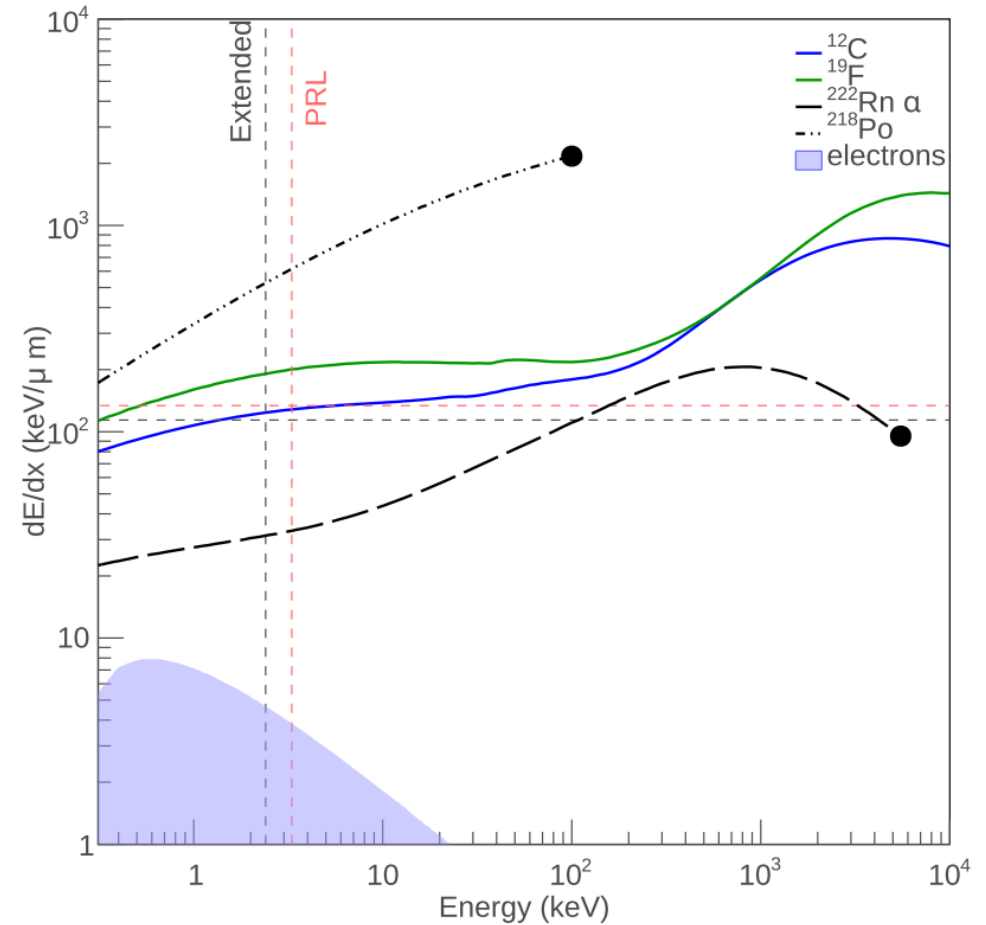
$$r_l = r_c \left( \frac{\rho_b}{\rho_l} \right)^{1/3} \quad P_b - P_l \geq \frac{2\sigma}{r_c}$$

$$E_{th} = \underbrace{4\pi r_c^2 \left( \sigma - T \frac{\partial \sigma}{\partial T} \right)}_{\text{Surface energy}} + \underbrace{\frac{4}{3} \pi r_c^3 \rho_b (h_b - h_l)}_{\text{Latent Heat}} - \underbrace{\frac{4}{3} \pi r_c^3 (P_b - P_l)}_{\text{Reversible work}}$$

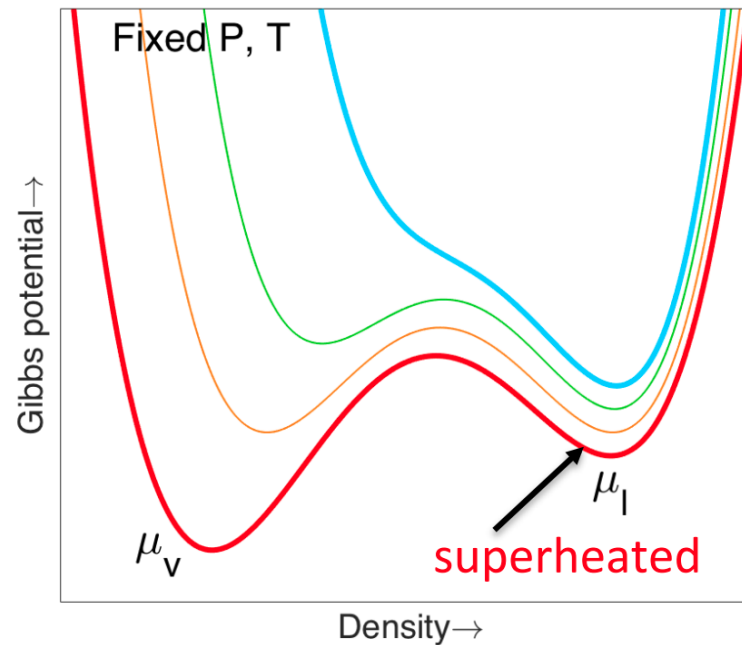
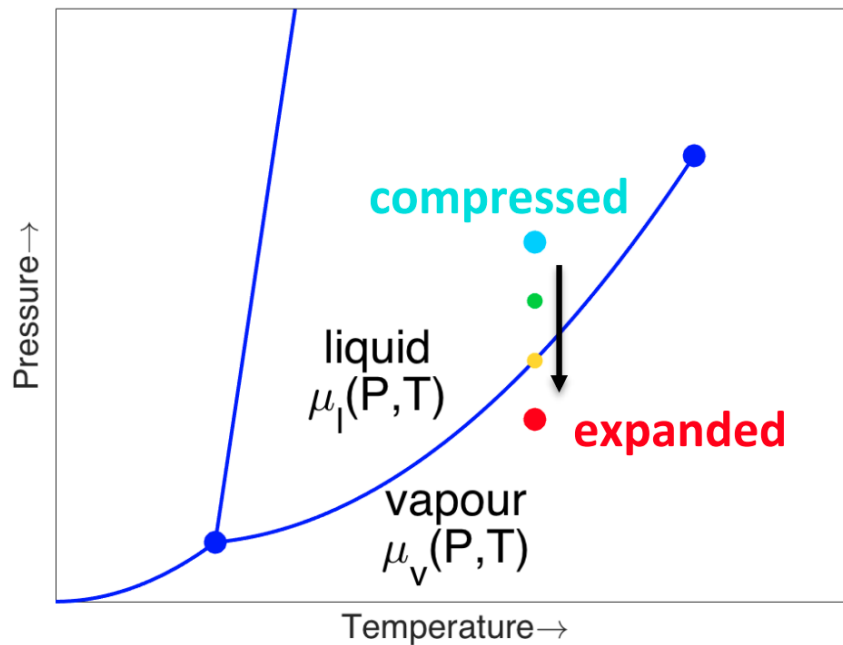
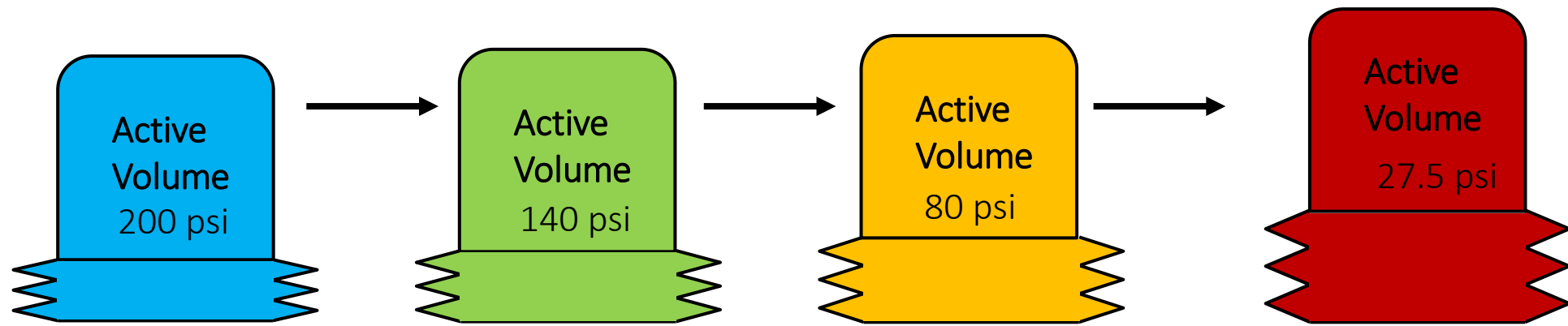
Surface energy

Latent Heat

Reversible work



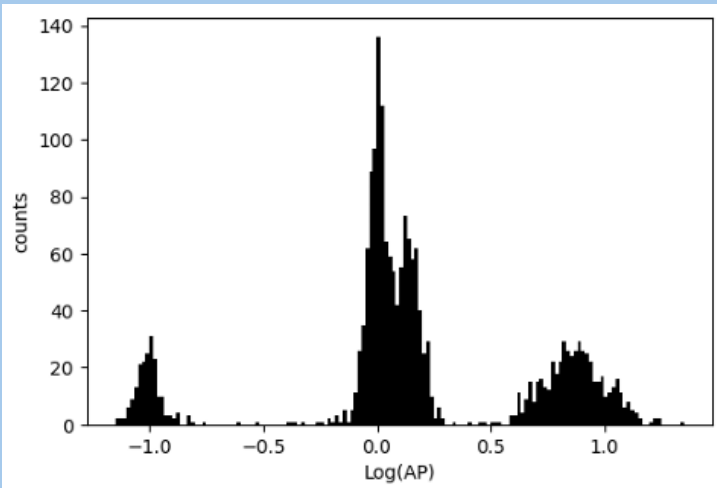
# Operating Principle



# Methods of Detection

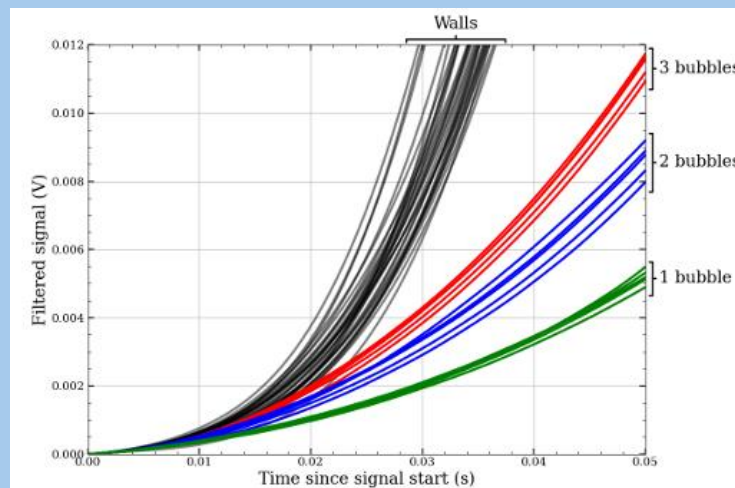
## Acoustics

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



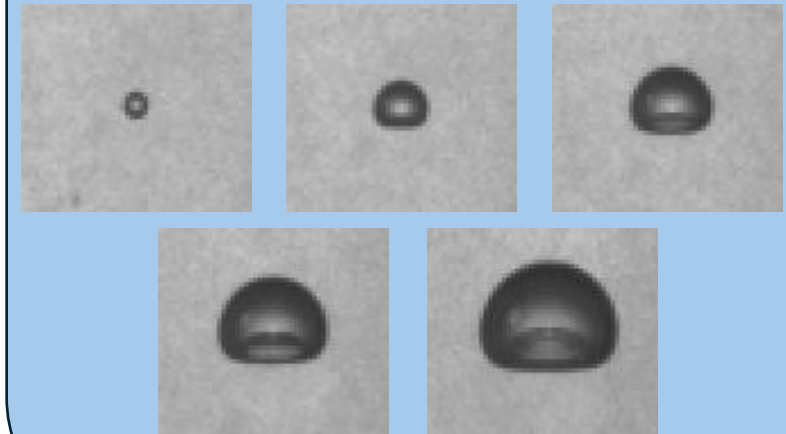
## Pressure

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

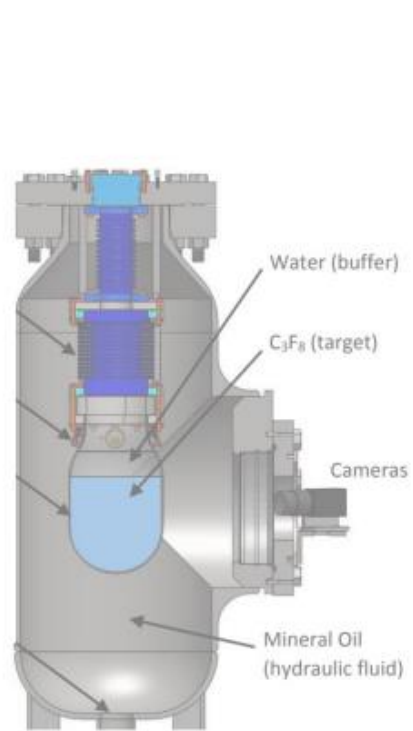


## Cameras

- 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<sub>3</sub>F<sub>8</sub>  
2013–2016



**PICO-60**  
35 L of CF<sub>3</sub>I and C<sub>3</sub>F<sub>8</sub>  
2016–2017



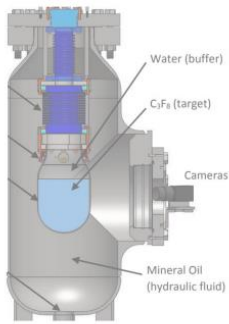
**PICO-40L**  
35 L of C<sub>3</sub>F<sub>8</sub>  
2019–Present



**PICO-500**  
260 L of C<sub>3</sub>F<sub>8</sub>  
Proj. 2026

# PICO Bubble Chambers

1m



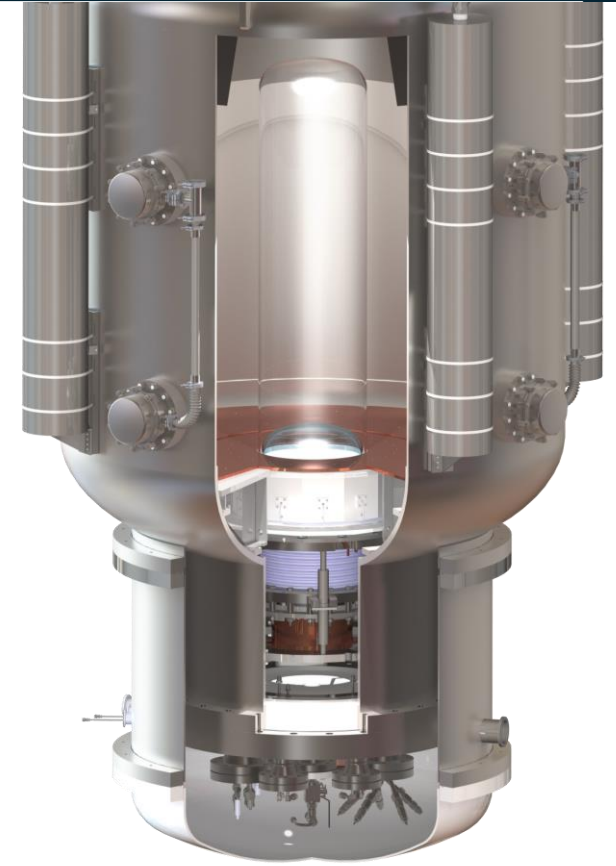
**PICO-2L**  
2 L of  $C_3F_8$   
2013–2016



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



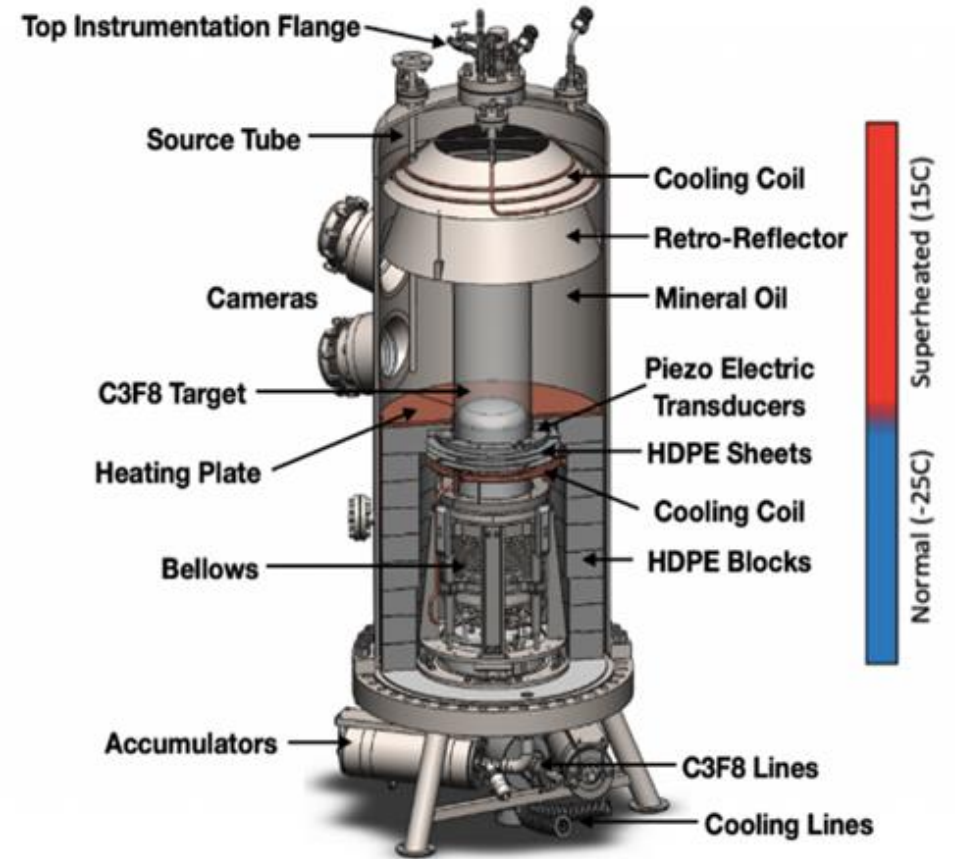
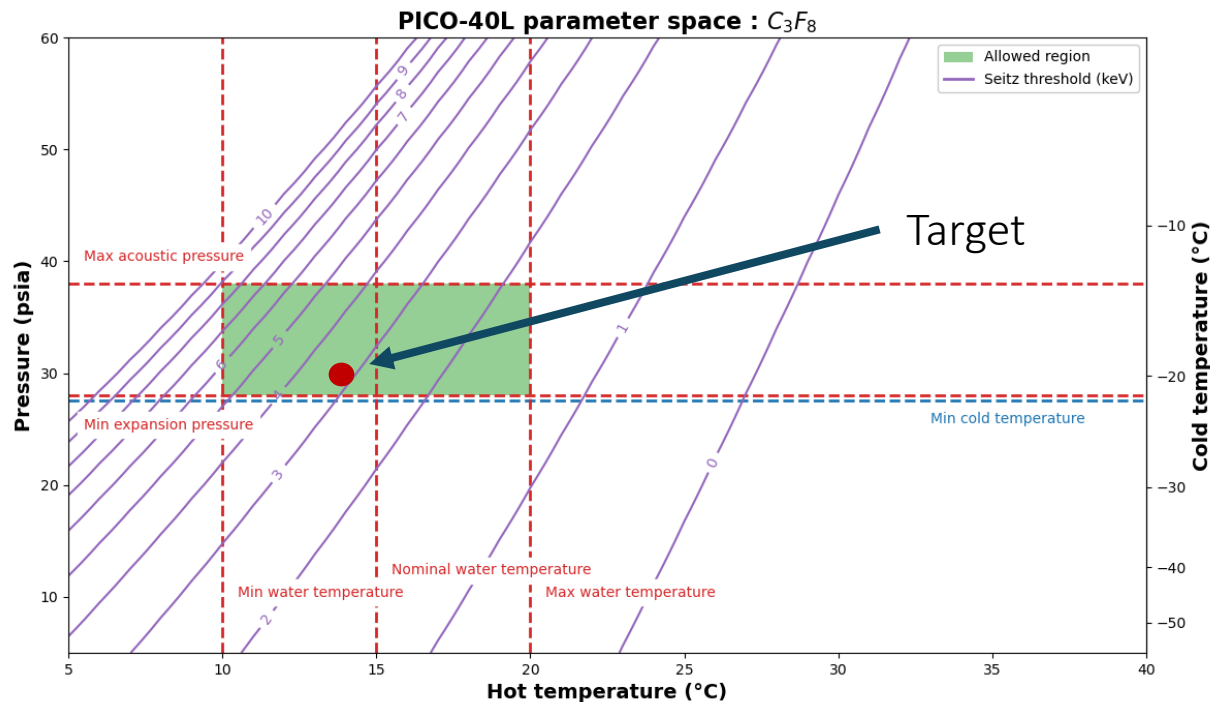
**PICO-40L**  
35 L of  $C_3F_8$   
2019–Present



**PICO-500**  
260 L of  $C_3F_8$   
Proj. 2026

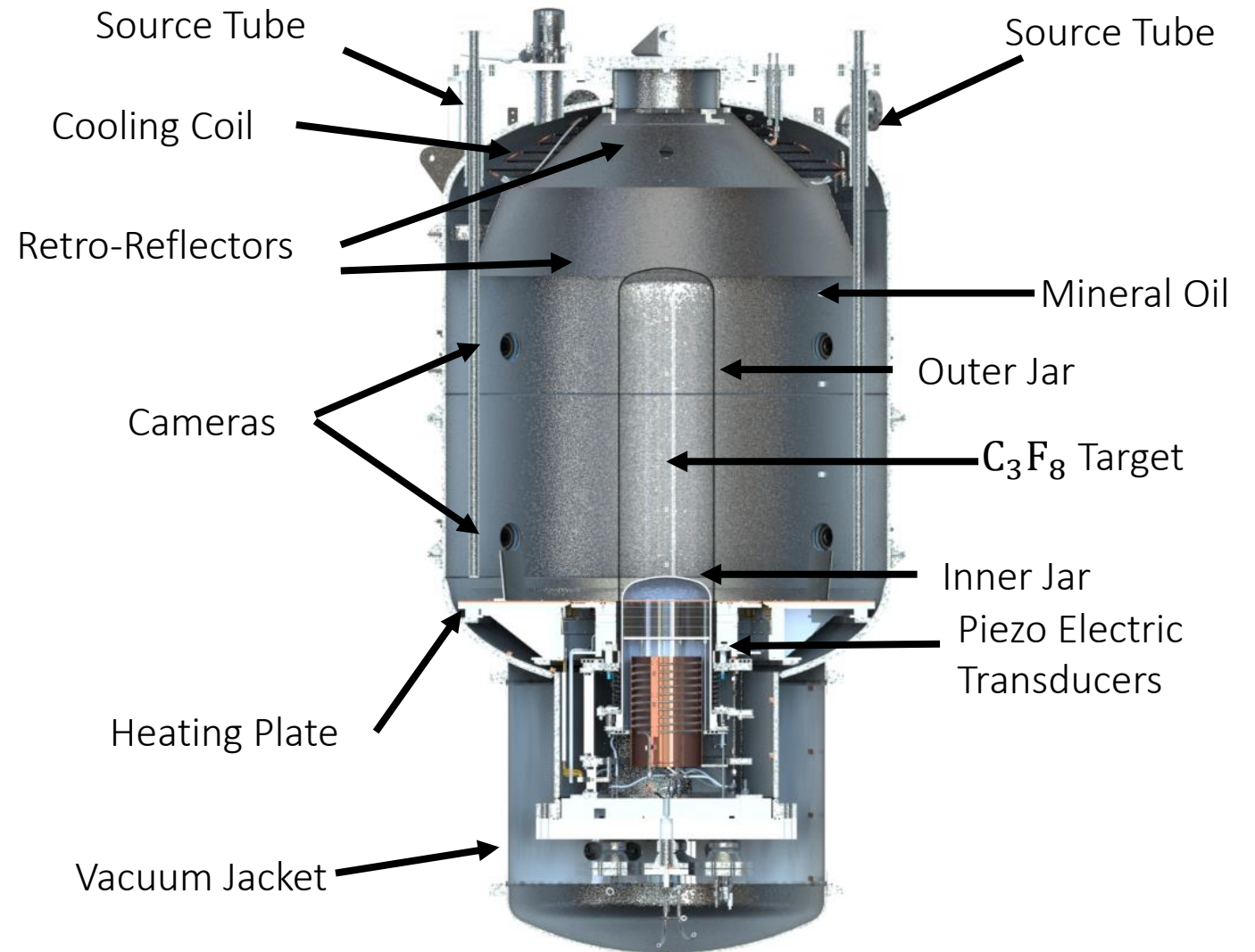
# PICO-40L

- 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

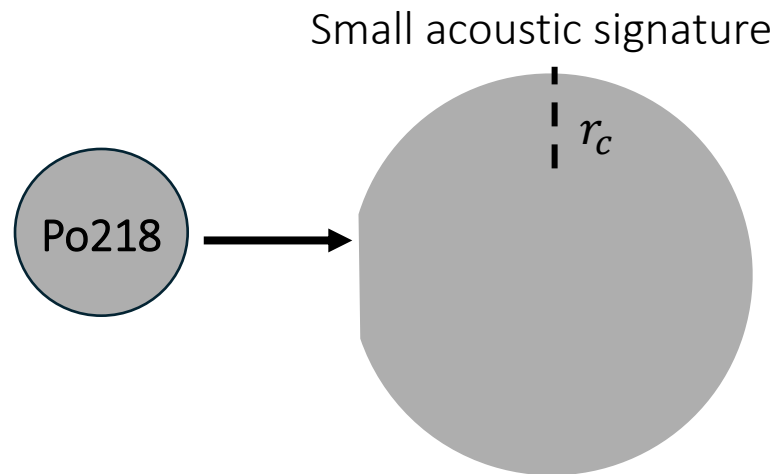
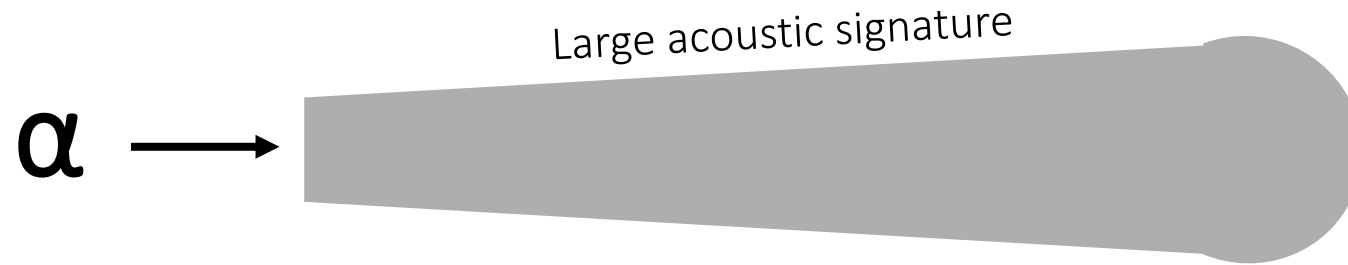
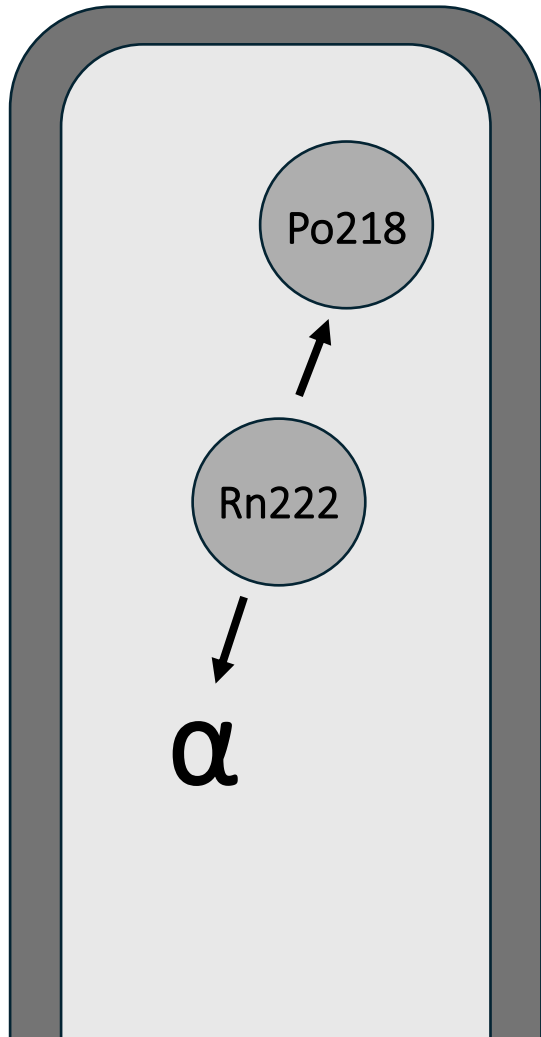


# PICO-500

- 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



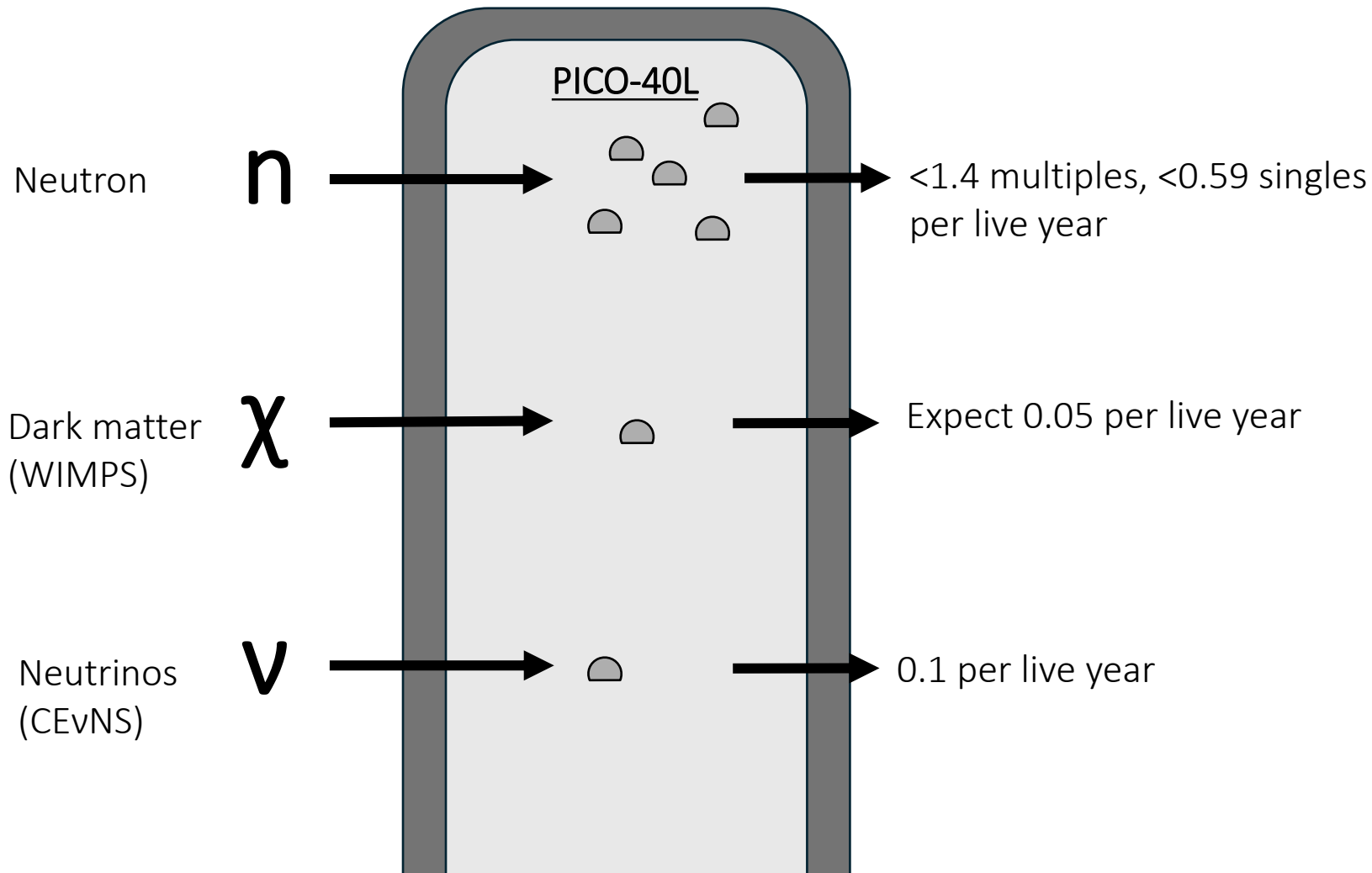
# Expected Interactions: Alpha decays



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



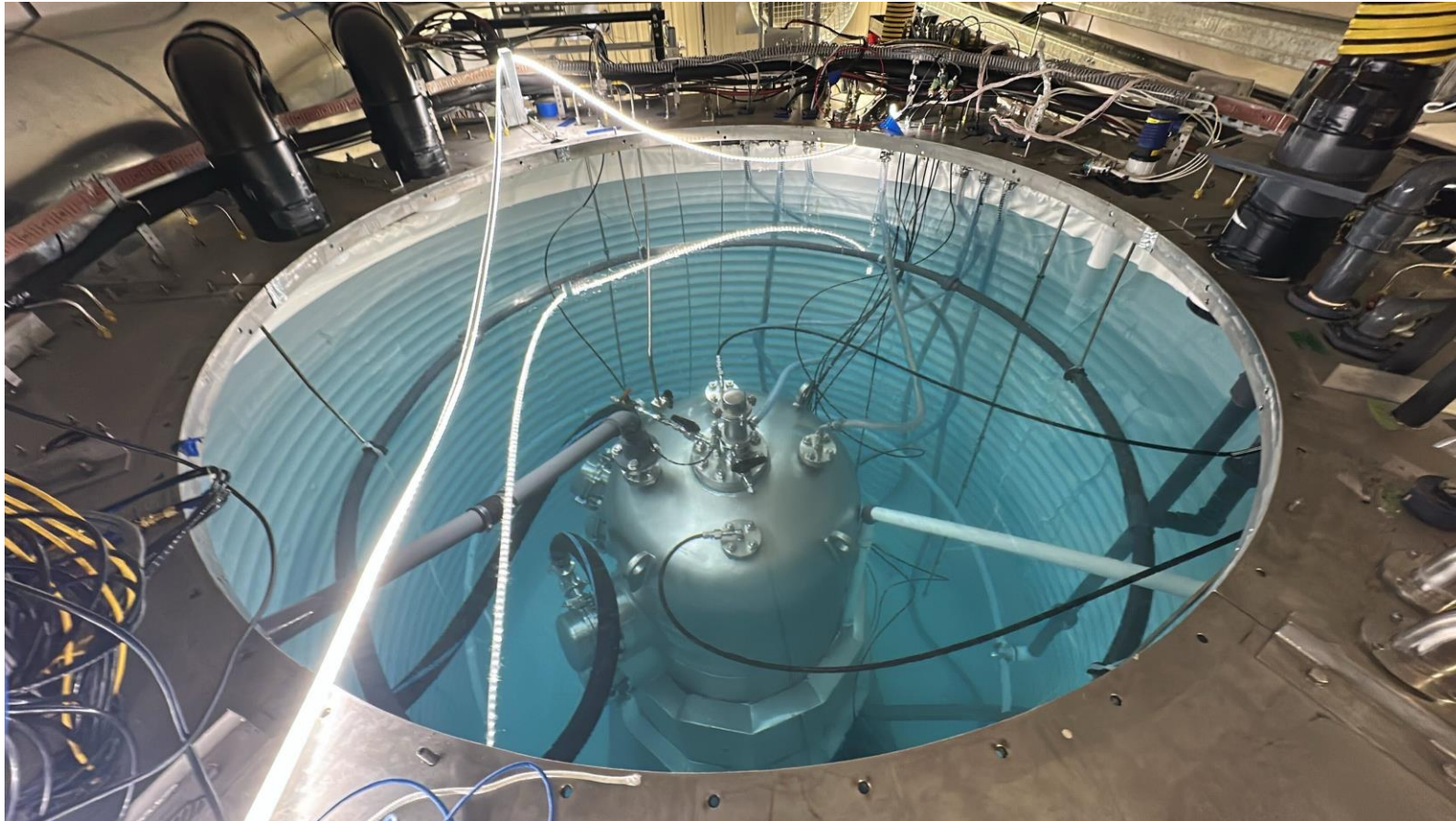
WIMPS are indistinguishable from single neutrons or CEvNS visually and acoustically

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

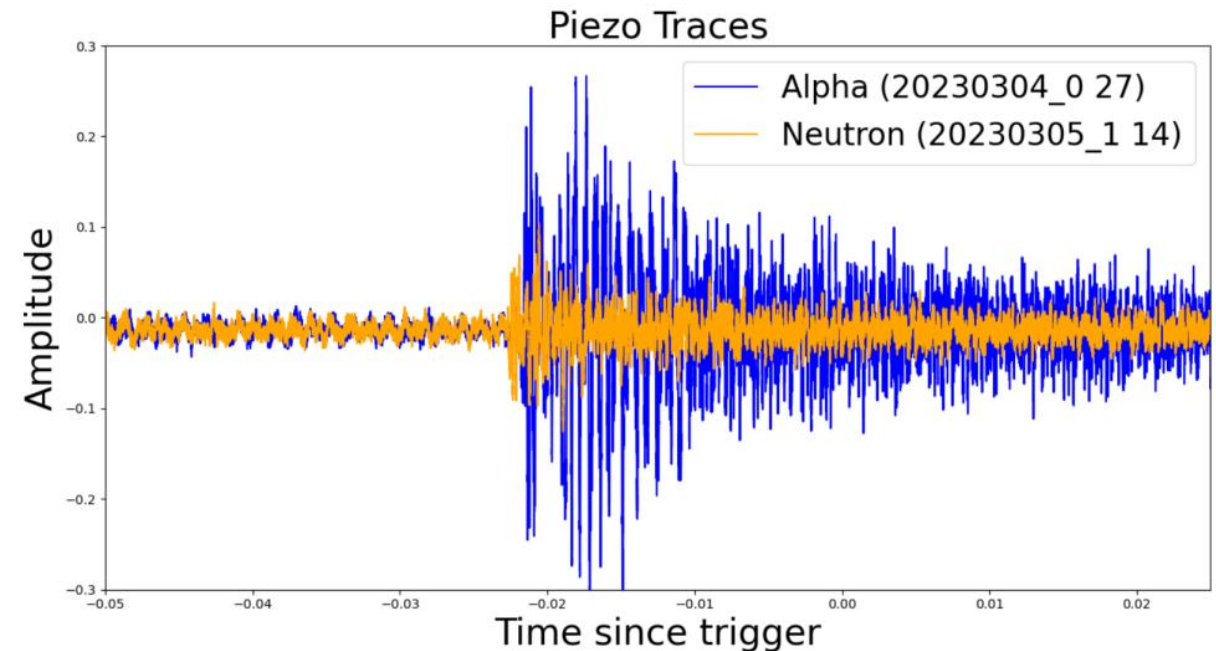
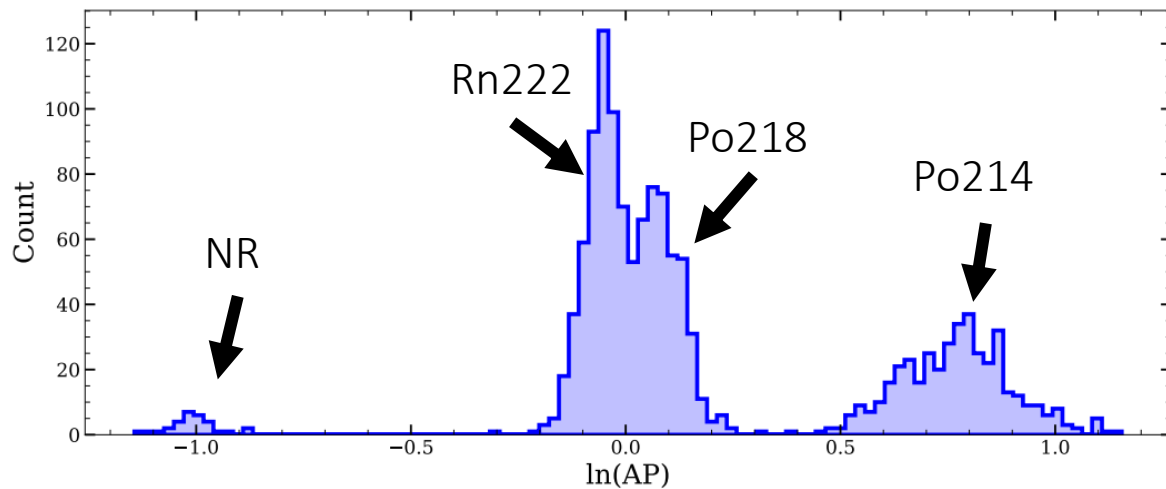


- Low background materials
  - Synthetic quartz, SS, PTFE, etc
  - With sample counting to calculate expected rates
- Extensive cleaning and radon mitigation effort
  - Achieved a  $0.5 \mu\text{m}$  particulate concentration of  $< 4$  particulates  $\text{L}^{-1}$
  - Working on a technical paper



# 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



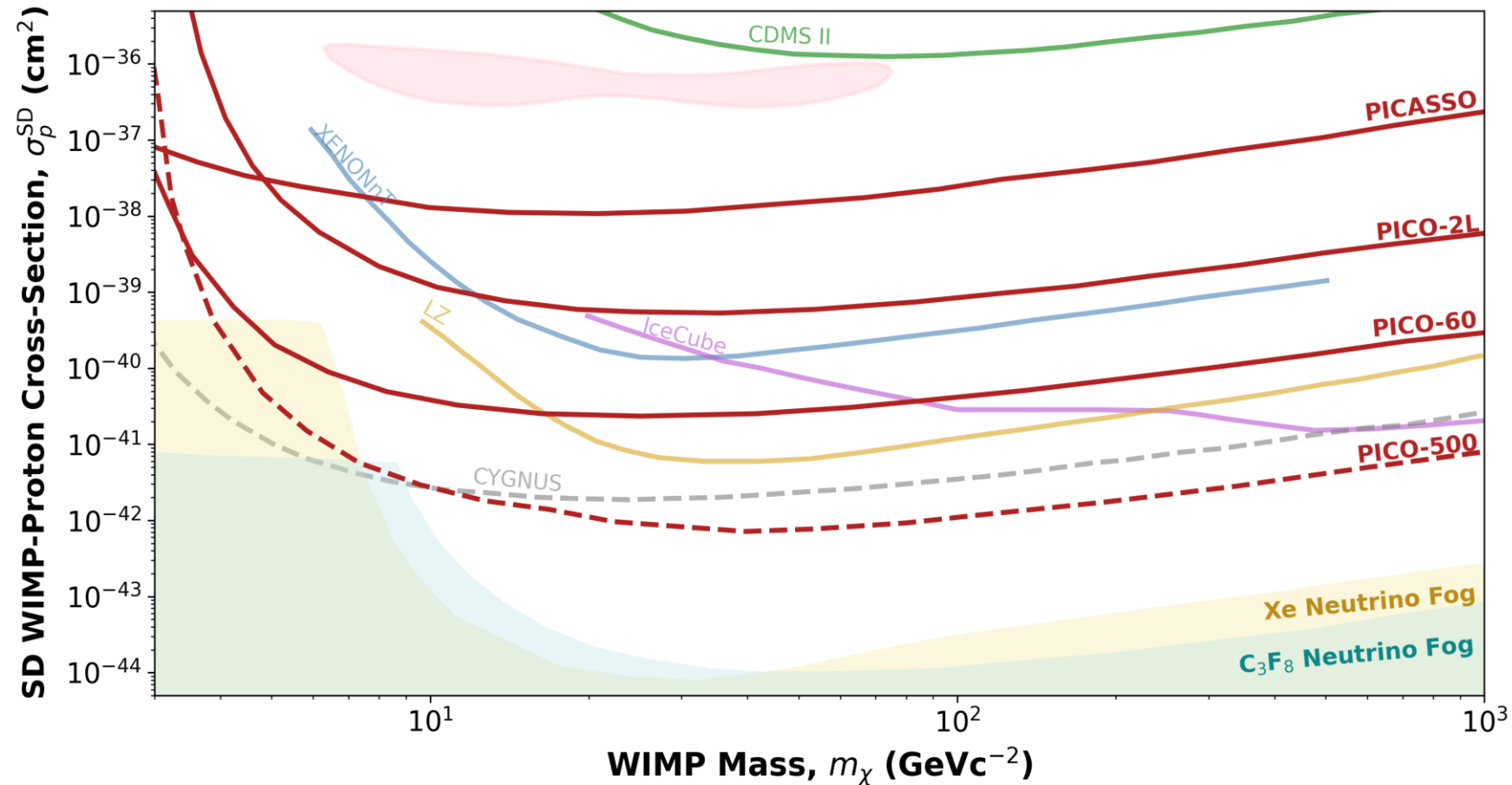
# Current Work on PICO-500: Inner Vessel

- 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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