

Anomalous Wall Events in PICO

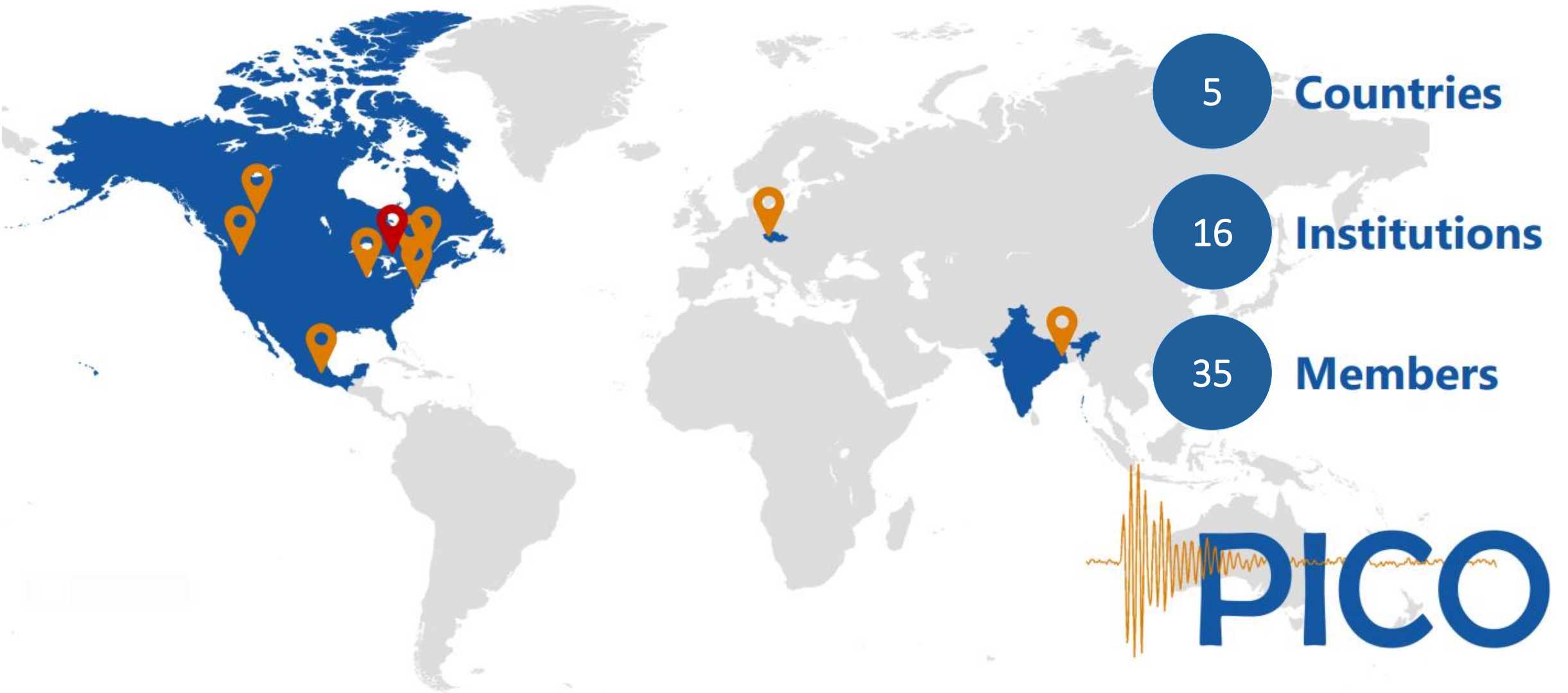
Quinn Malin, Ph.D. Student
University of Alberta
CAP 2026

Slaps Roof of Detector

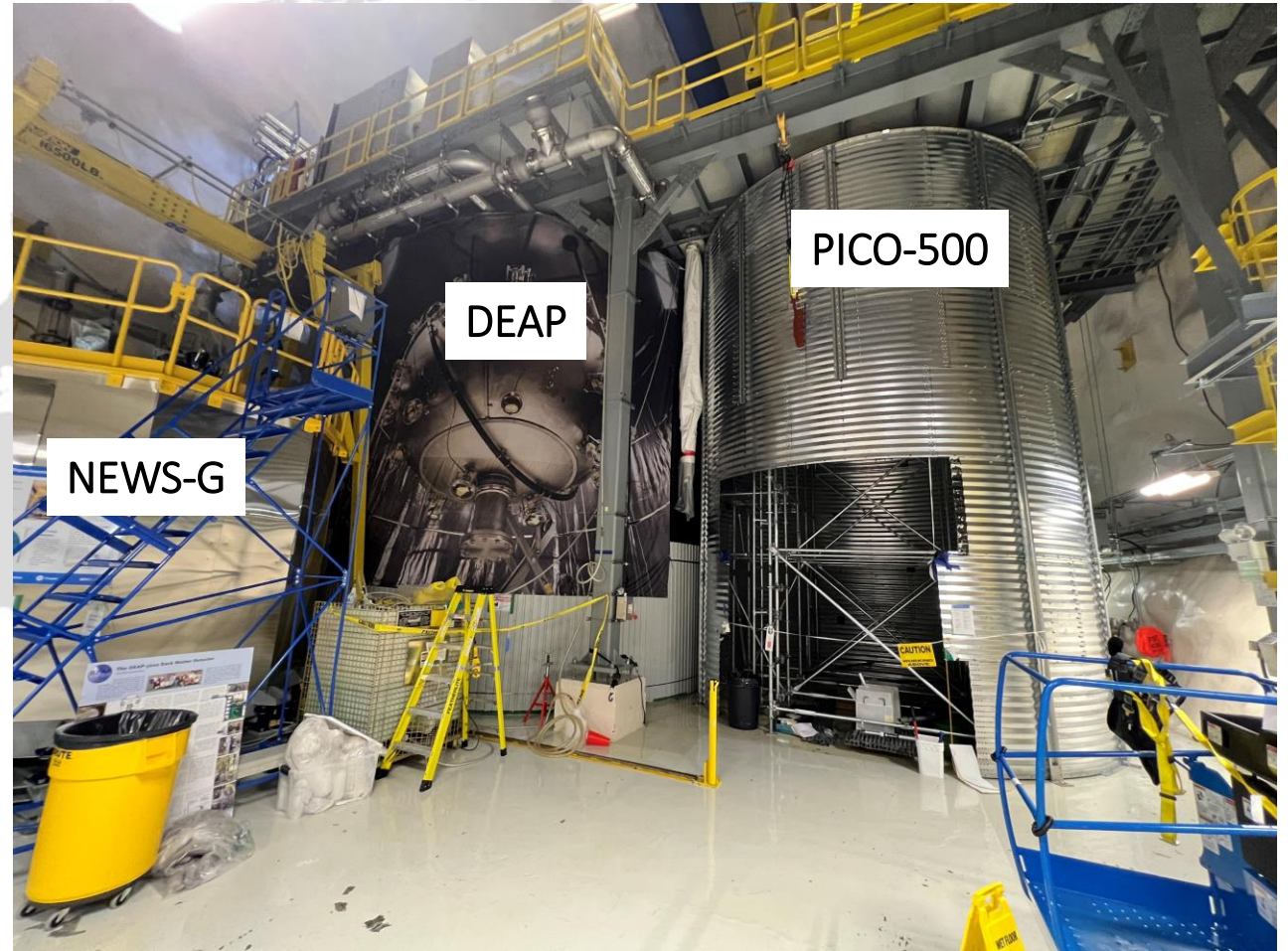
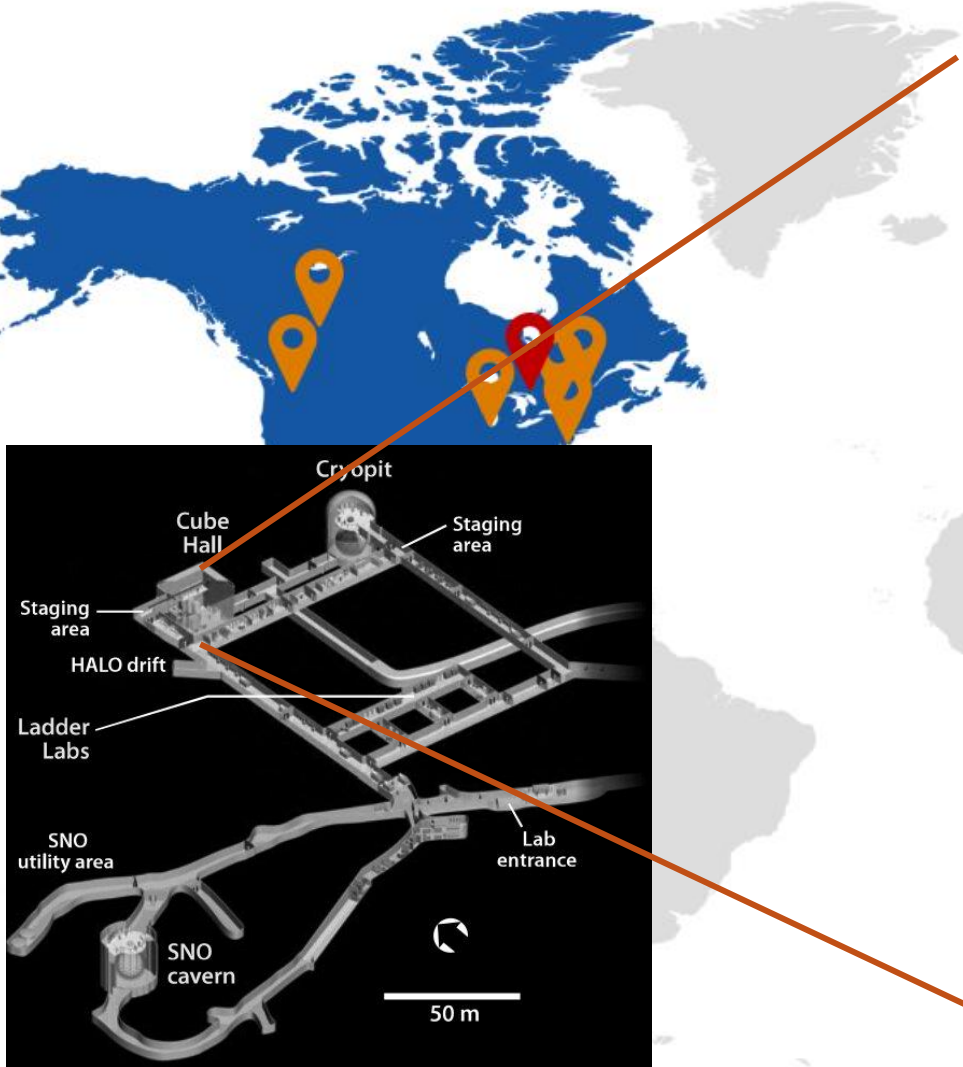


**This bad boy can fit so
many wall events in it**

The PICO Collaboration

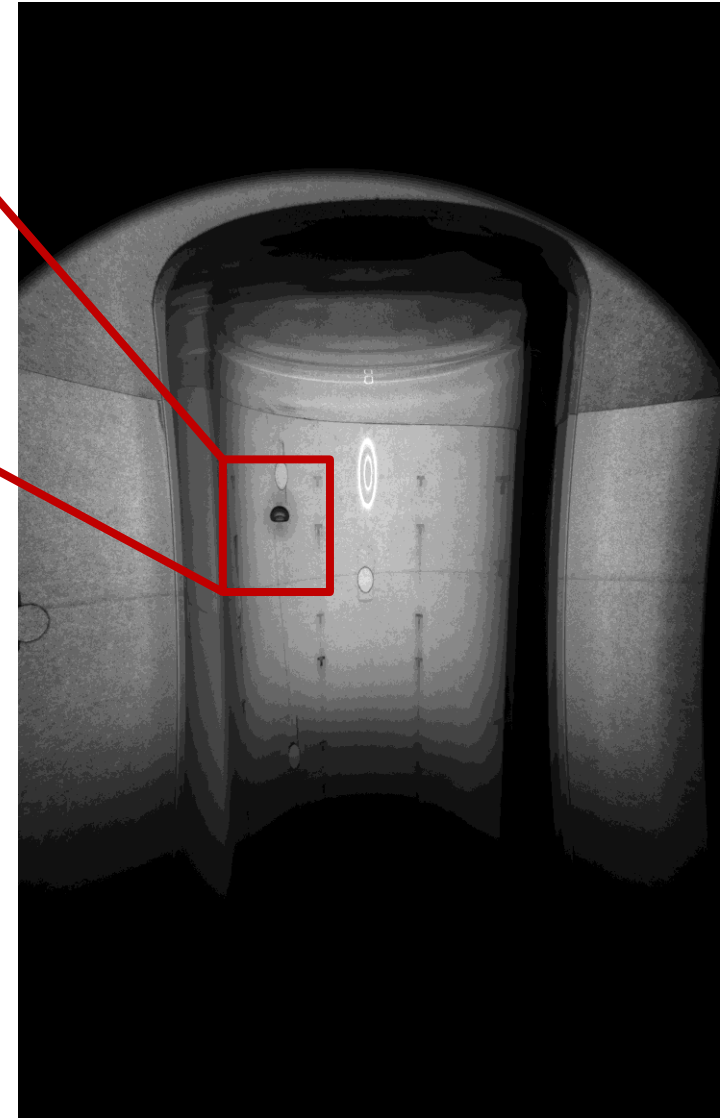
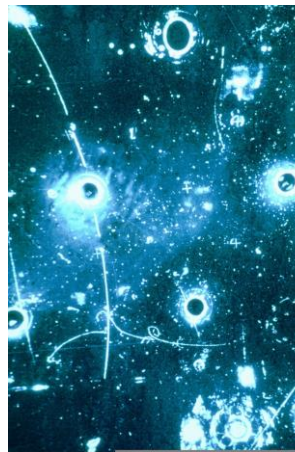


The PICO Collaboration

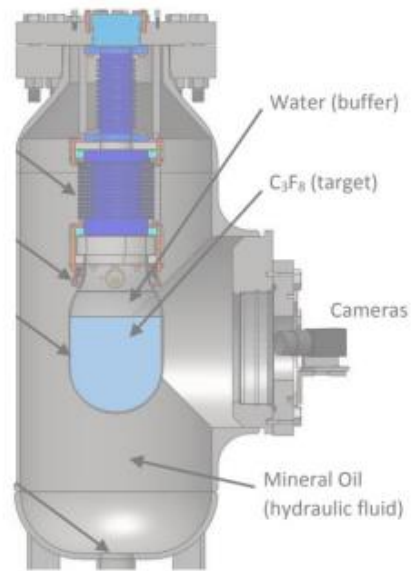


PICO Bubble Chambers

- 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)
- Higher thresholds than older bubble chambers
 - Longer livetime (~minutes)
 - Insensitive to tracks



PICO Bubble Chambers



PICO-2L
2 L of C₃F₈
2013–2016



PICO-60
35 L of CF₃I and C₃F₈
2016–2017



PICO-40L
35 L of C₃F₈
2019–Present

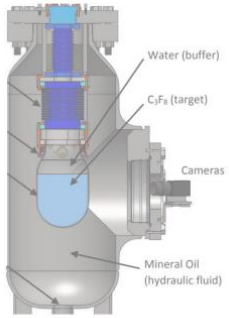
Detector paper on arXiv soon!



PICO-500
260 L of C₃F₈
Proj. 2026

PICO Bubble Chambers

1m



PICO-2L
2 L of C₃F₈
2013–2016



PICO-60
35 L of CF₃I and C₃F₈
2016–2017



PICO-40L
35 L of C₃F₈
2019–Present

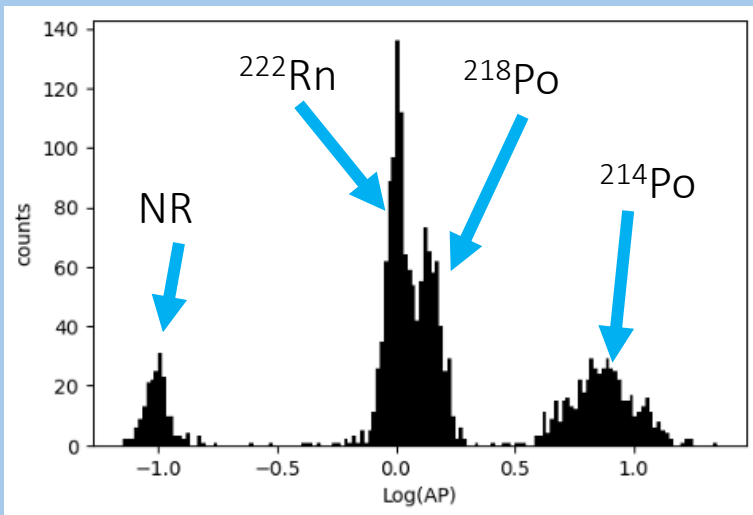


PICO-500
260 L of C₃F₈
Proj. 2026

Methods of Detection

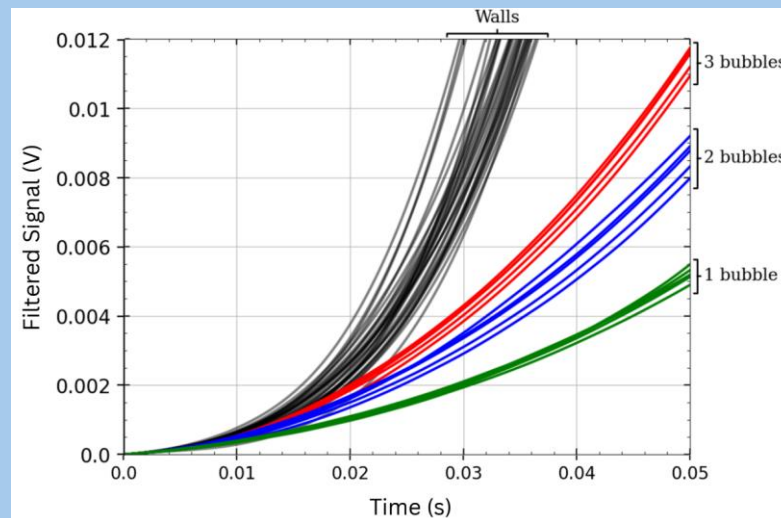
Acoustics

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



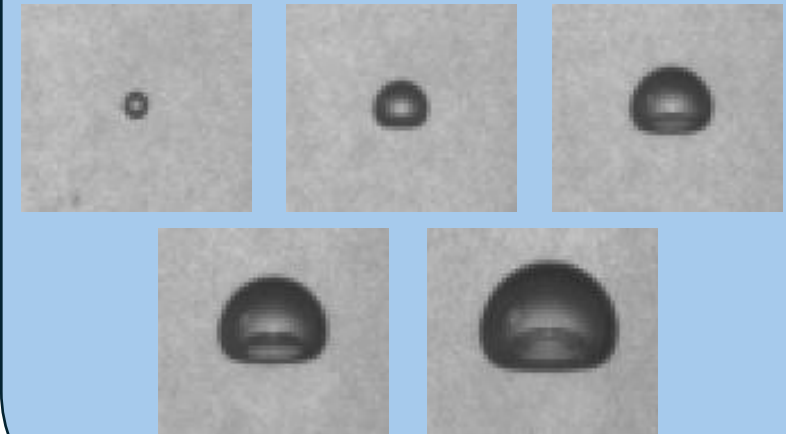
Pressure

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

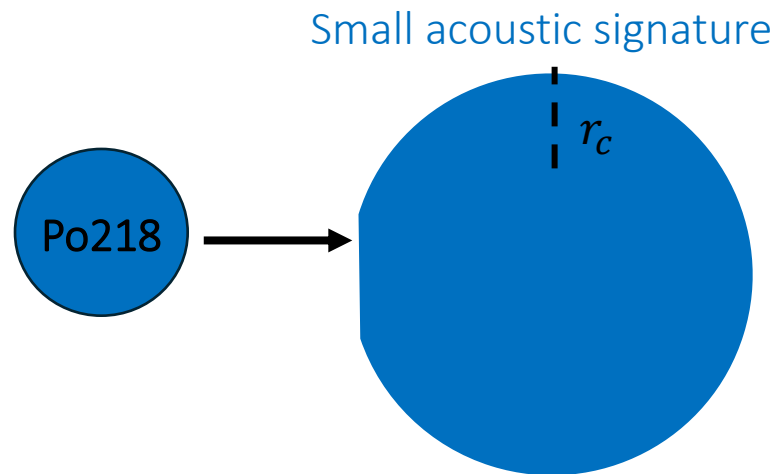
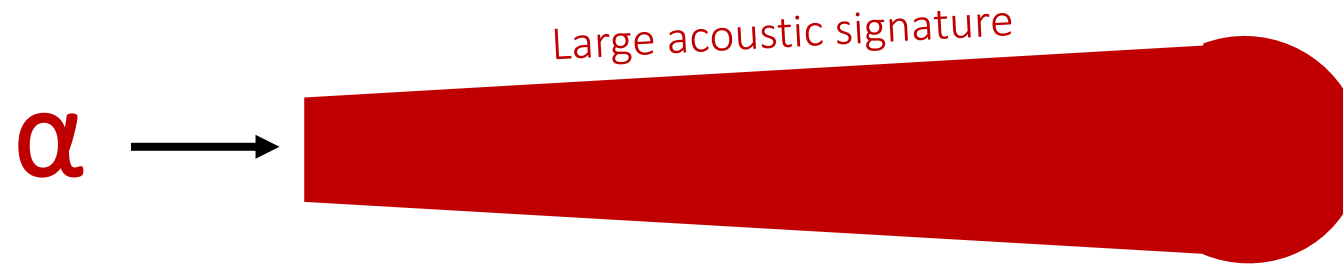
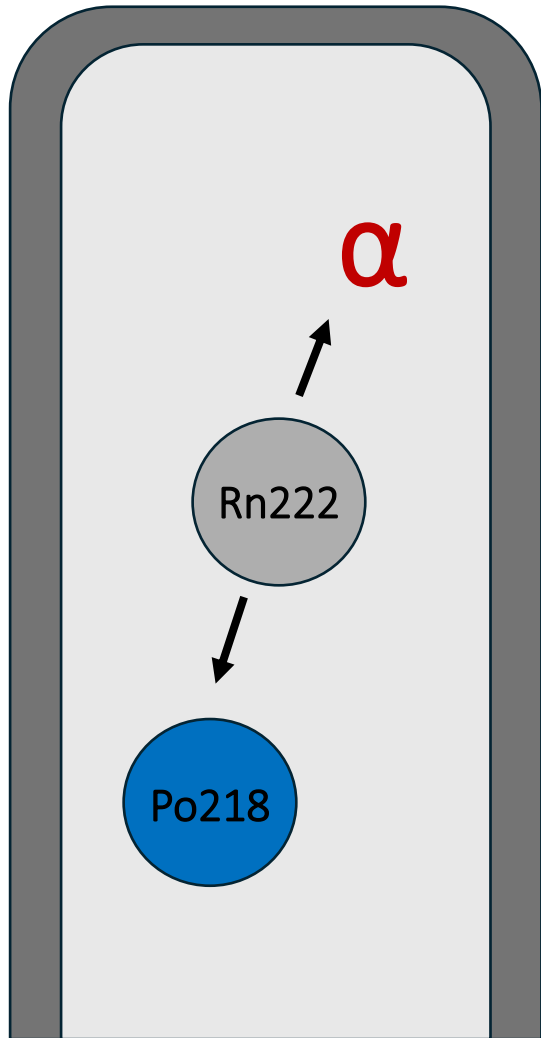


Cameras

- Record 41 frames (20 before, 20 after) event genesis at 100 fps across 4 stereoscopic camera
- XYZ spatial reconstruction



Expected Interactions: Alpha decays



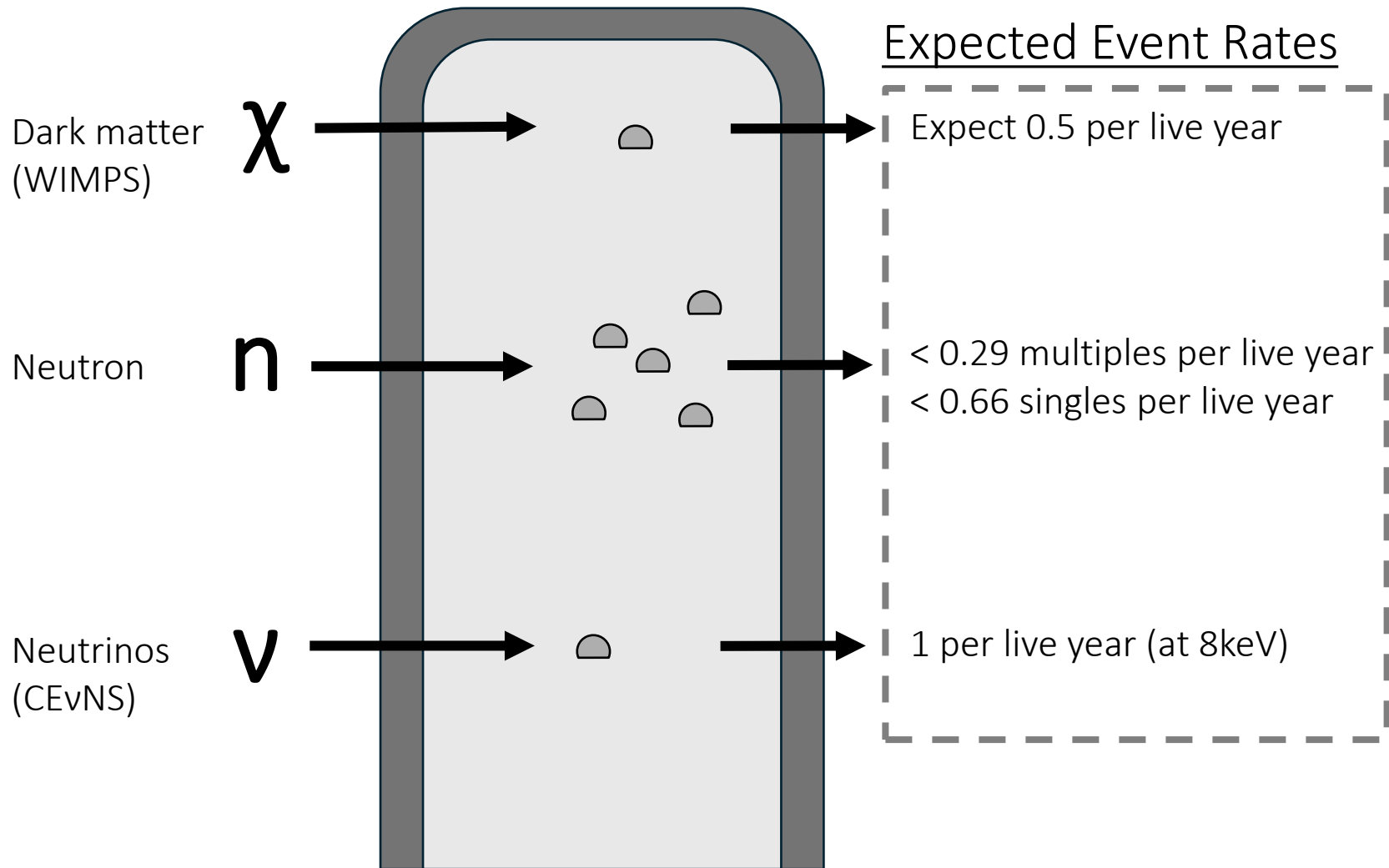
Alphas create a much larger bubble initially => record a much larger acoustic amplitude

The Rn-222 chain is our largest source of radioactive backgrounds

Next [talk](#) on Radon Mitigation in PICO-500

Expected Interactions: Nuclear Recoils

PICO-500



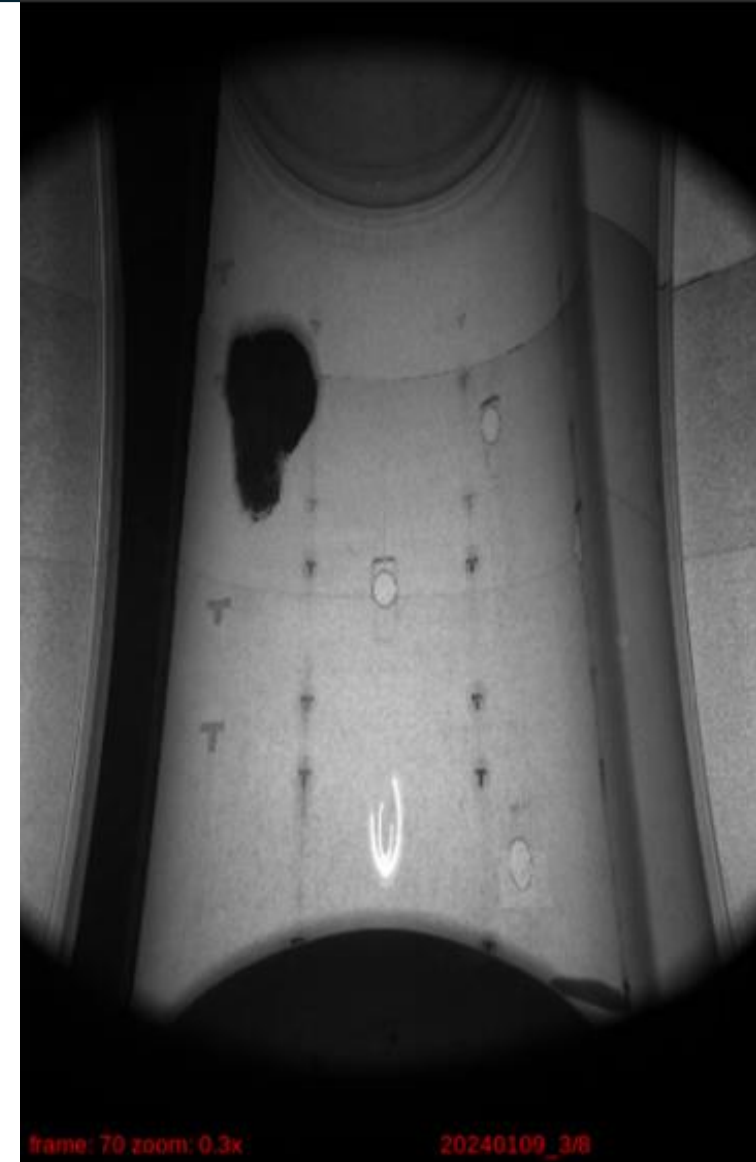
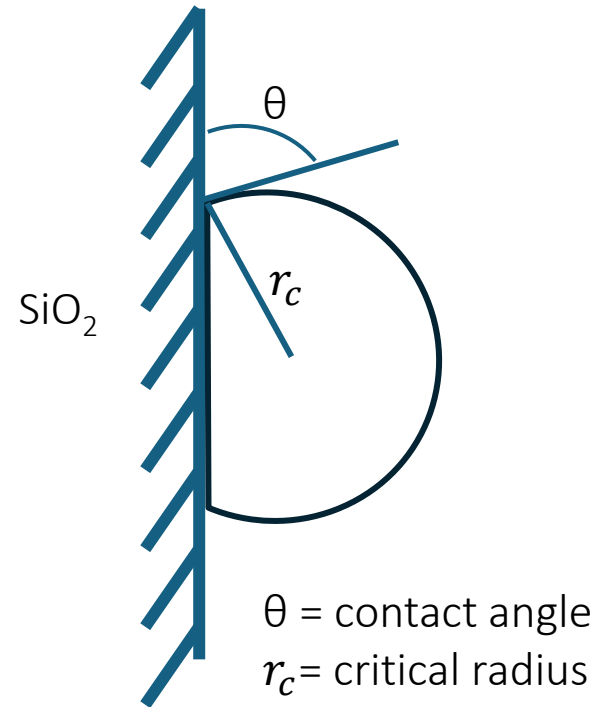
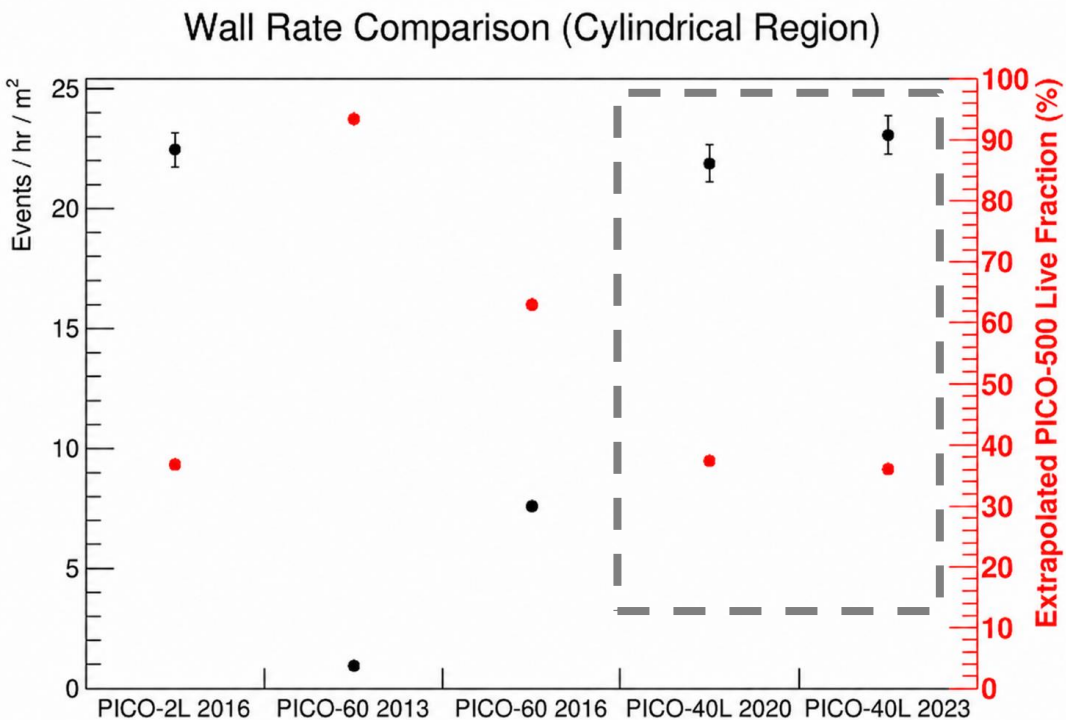
WIMPS are indistinguishable from single neutrons or CEvNS visually and acoustically

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

There are also gammas, muons, and other non-particle mechanisms that cause events

Heterogenous Nucleations

- Heterogenous nucleation: On surface
 - Homogenous nucleation: In bulk of fluid
 - Heterogeneous nucleation rates have increased since PICO-60
- } Same energy threshold for C_3F_8

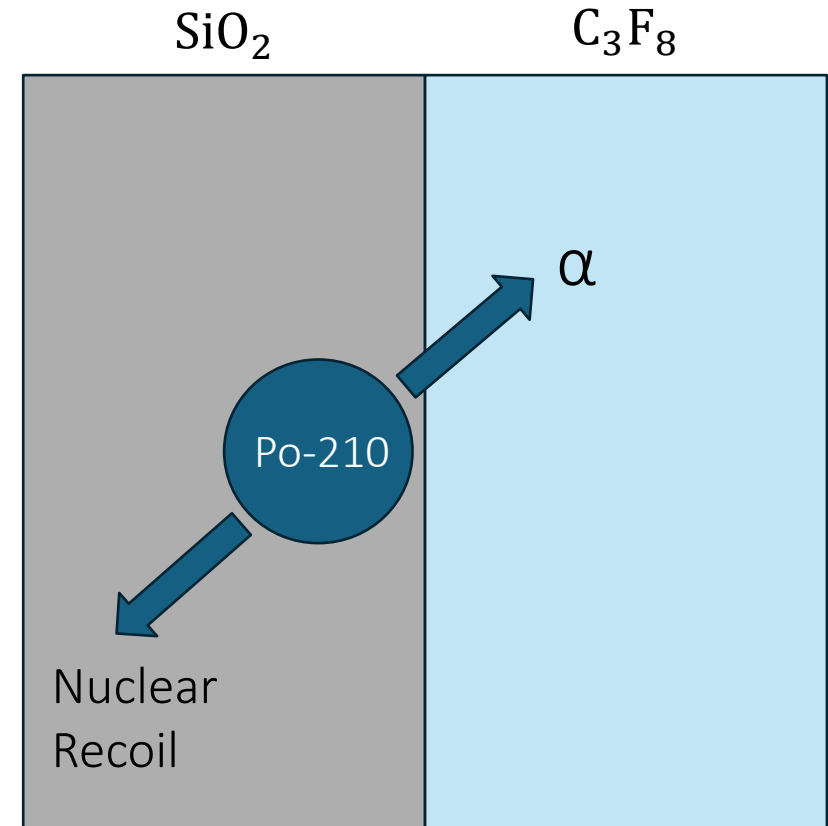


Surface Nucleations: Radioactive Backgrounds

- I built a Monte Carlo to calculate probability of nucleation due to radioactive decays from the quartz into C_3F_8
- Simulates energy deposition and tracks
- I can then find the expected wall rates based off measured activity from quartz samples

Background Rates

^{238}U	< 37.06 mBq/kg
^{235}Th	< 12.77 mBq/kg
^{210}Pb	< 360.60 mBq/kg

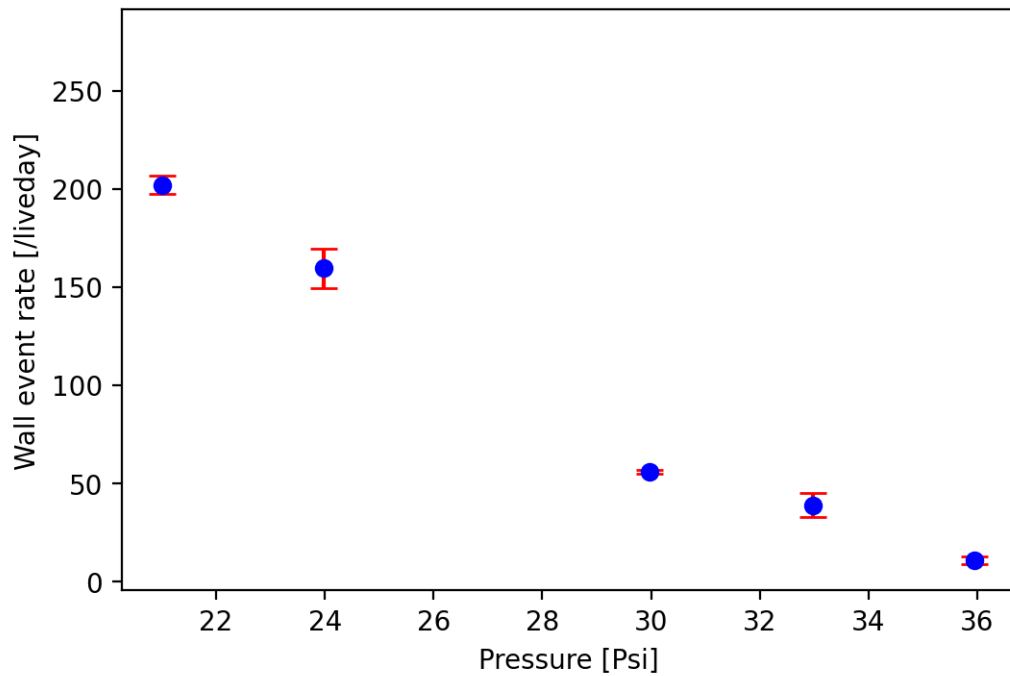


Predicted: < 139 ± 15 events/liveday*
PICO-40L: 277 ± 3 events/liveday*

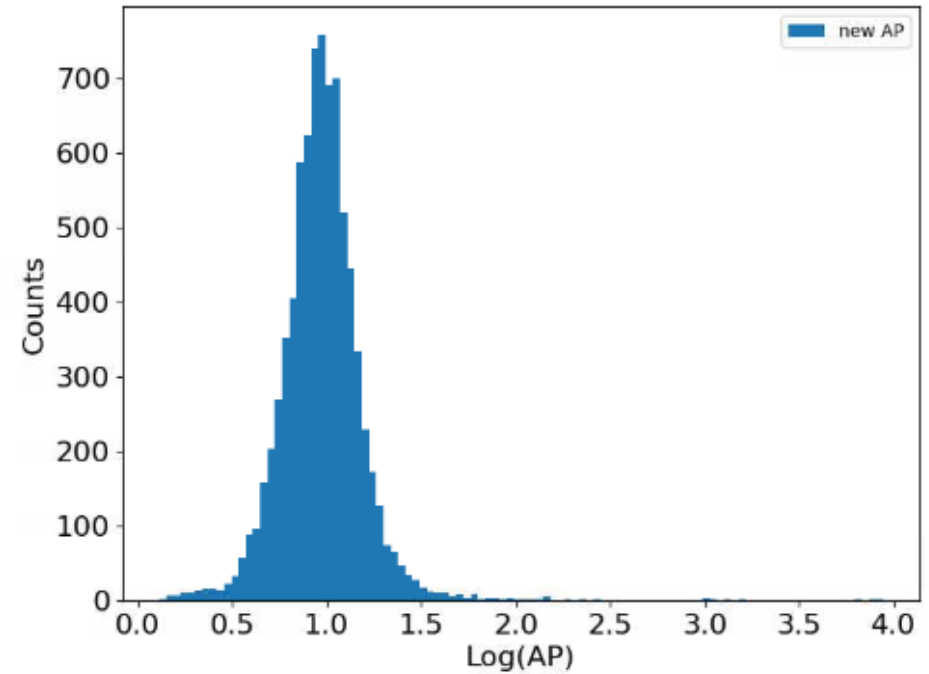
What's causing this?

- Wall rate is correlated with pressure, and hence energy threshold
- I performed a set of acoustic corrections found no evidence suggesting multiple nucleation mechanisms

PICO-60 Data



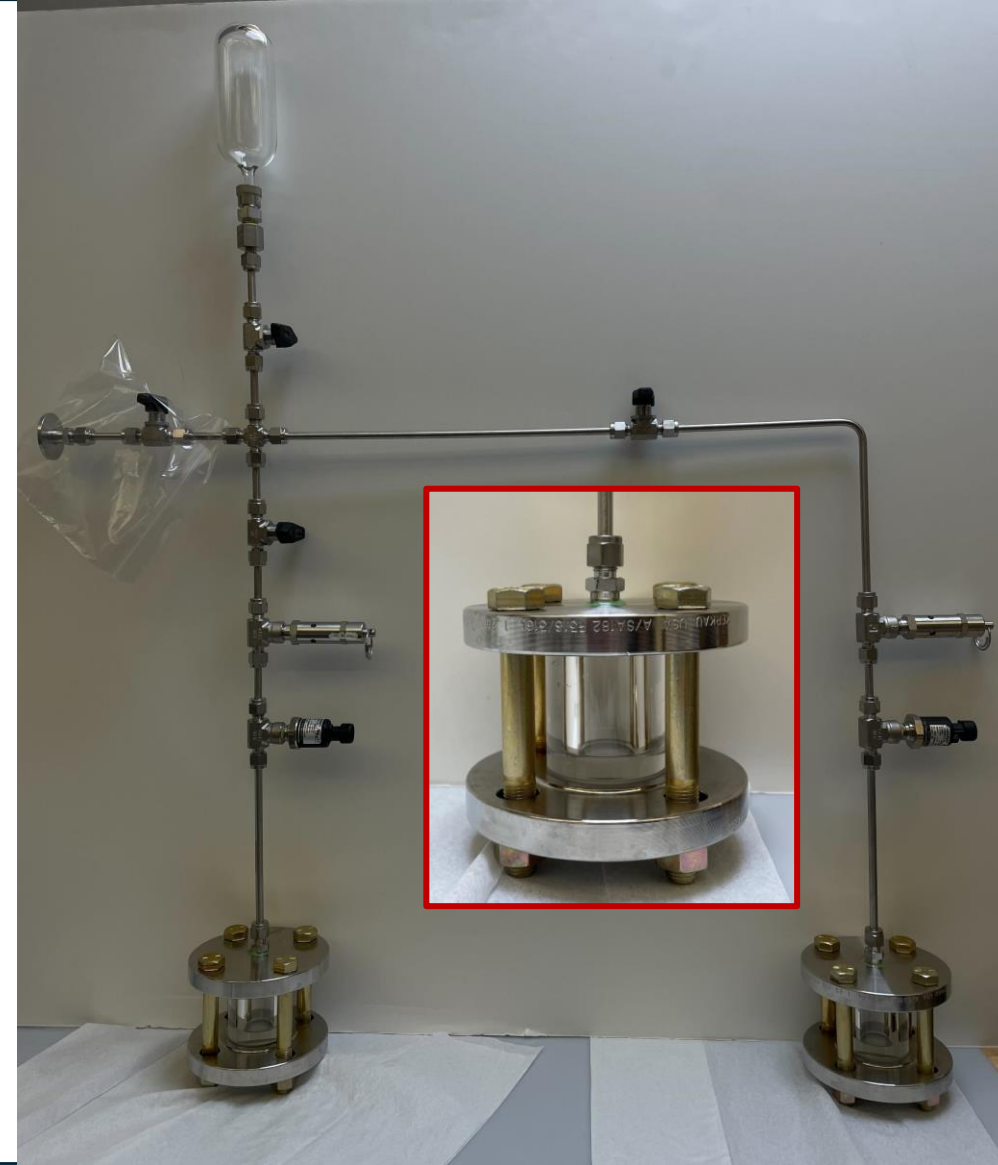
PICO-40L Data



We are at a point where experimental testing is needed

COBRA (Chamber for Optical Bubble Rate)

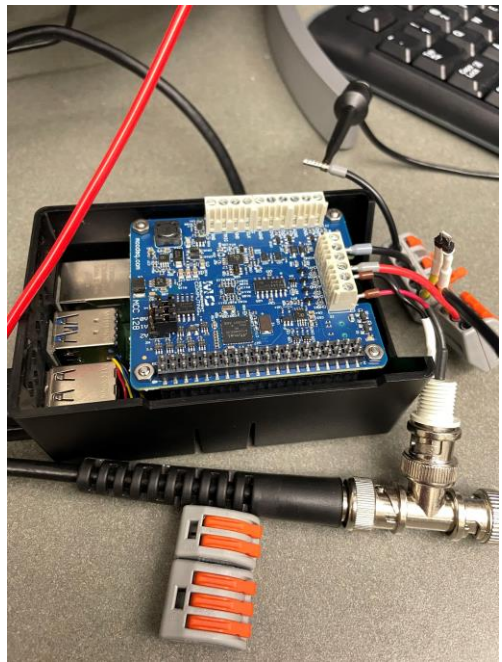
- COBRA will allow us to test different thresholds, active liquids, surface materials and coatings and measure heterogenous nucleation rates.
- 25mL C_5F_{12} operated at 70°C and 5 psi (6 keV threshold)
- Hot and cold region for superheat and condensing
- Can be operated from 0-100°C and pressures up to 150psi



COBRA Status

- Modeling, procurement, simulations, background event calculations completed
- Data acquisition software operational, nearly done testing
- Operational next week!

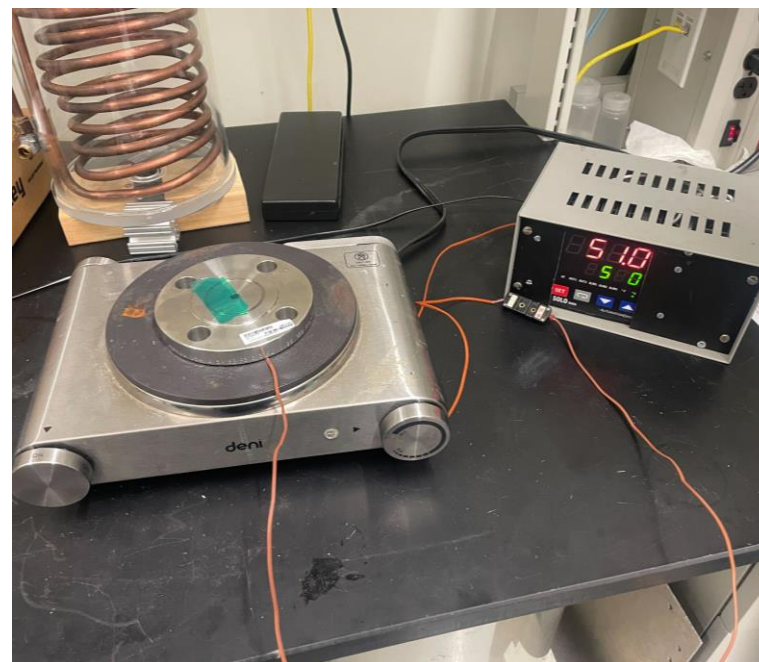
DAQ: Raspberry PI



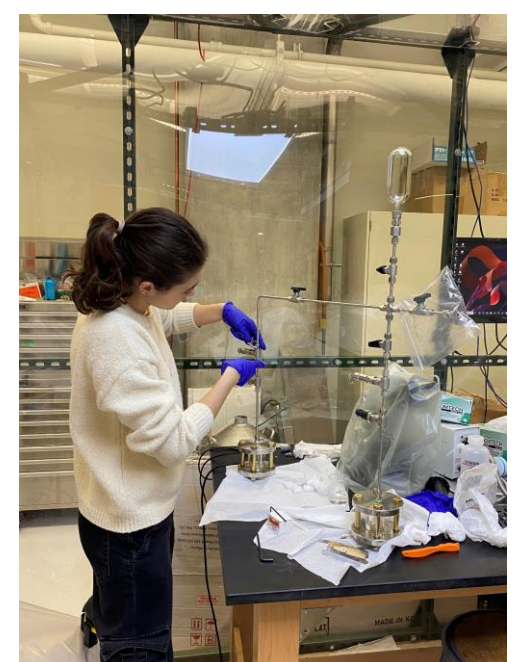
Cooling System



Heating System



My Helper Nikka



Conclusion

- PICO-40L is a bubble chamber experiment at SNOLAB with over 72 livedays of data collected
- Wall events are our largest background, and I am actively researching
- With PICO-500 assembly on way, reducing these events is critical to increase livetime of the detector
- COBRA will be operational in the coming weeks
 - Results will help inform discussions about PICO-500 and steer elements of our run plan



PICO



J. Basu, M. Das,
V. Kumar



J. Farine, A. Leblanc,
C. Licciardi, U. Wichoski



R. Anderson,
E. Vázquez-Jáuregui



NORTHWESTERN
UNIVERSITY

C. E. Dahl



O. Harris



Pacific Northwest
NATIONAL LABORATORY

I. Arnquist, C. M. Jackson,
B. Loer



R. Neilson



PennState

D. Priya, S. Priya, Y. Yan



E. Adams, J. Corbett,
D. Cranshaw, M. Dean, K. Dering,
G. Giroux, R. Hill, S. Meister,
A. Mir, A. Noble



D. Auty, Z. Doucet, M. Gill,
C. Krauss, Q. Malin, E. Pattison,
M. Rangen, W. Woodley



M. Laurin, H. Nozard,
A. Robinson, J. Savoie



C. Gaudreau, P. Grylls,
A. Mathewson,
I. Lawson, S. Sekula



P. S. Cooper, M. Crisler,
A. Sonnenschein



B. Ali, R. Filgas, D. Mamedov,
E. Rukhadze, I. Stekl



INDIANA UNIVERSITY
SOUTH BEND

E. Behnke, C. Cripe,
I. Levine



Kavli Institute
for Cosmological Physics
at The University of Chicago

J. I. Collar, M. Tripathi

BACKUP

Surface Nucleations: Surface Energy

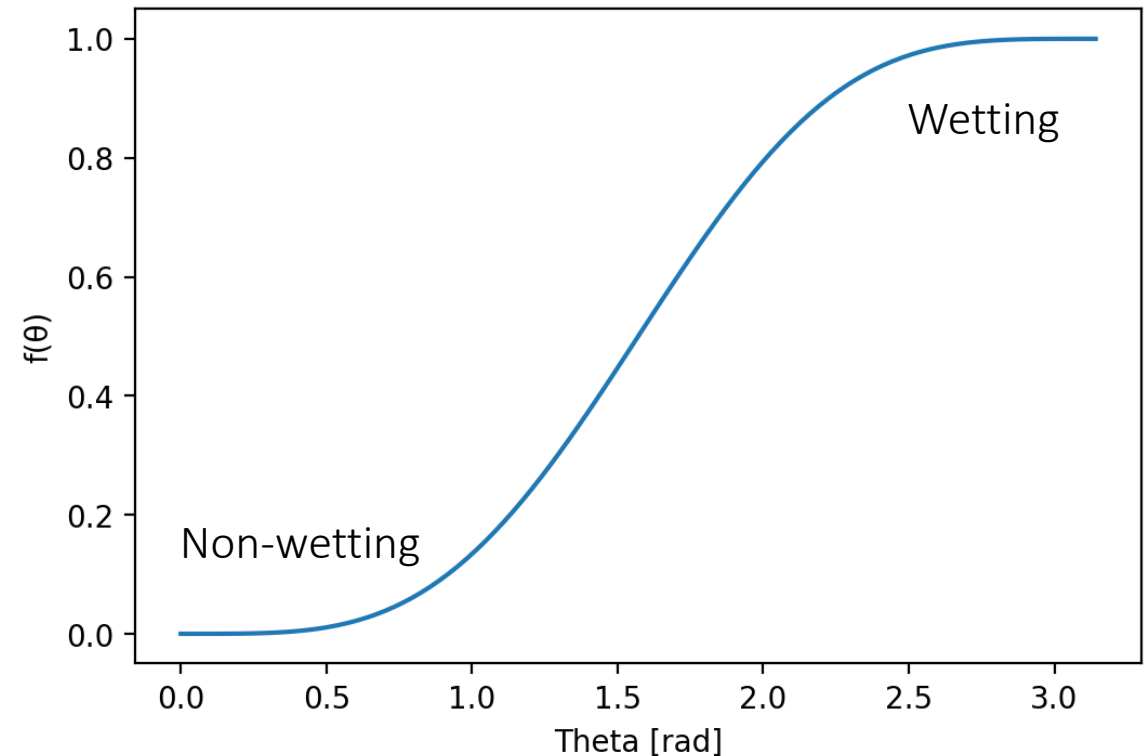
- Energy required for nucleations is dependent on surface energy
- C_3F_8 has a low surface tension, hence it fully wets synthetic quartz [1]

$$\Delta G_{het} = f(\theta)\Delta G_{homo} \quad [2,3]$$

$$f = \frac{1}{4} (2 - 3 \cos \theta + \cos^3 \theta) \quad [2,3]$$

θ = Contact Angle

G = Energy



[1] Lemal, David M. 2004. Perspective on Fluorocarbon Chemistry. The Journal of Organic Chemistry 69 (1): 1-11. doi:10.1021/jo0302556.

[2] R. Cole, Boiling nucleation, in Advances in heat transfer, vol. 10, pp. 85-166, Elsevier (1974).

[3] Sholl, C. A. and Fletcher, N. H., "Decoration criteria for surface steps," *Acta Metallurgica*, vol. 18, no. 10, pp. 1083-1086, Oct. 1970

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

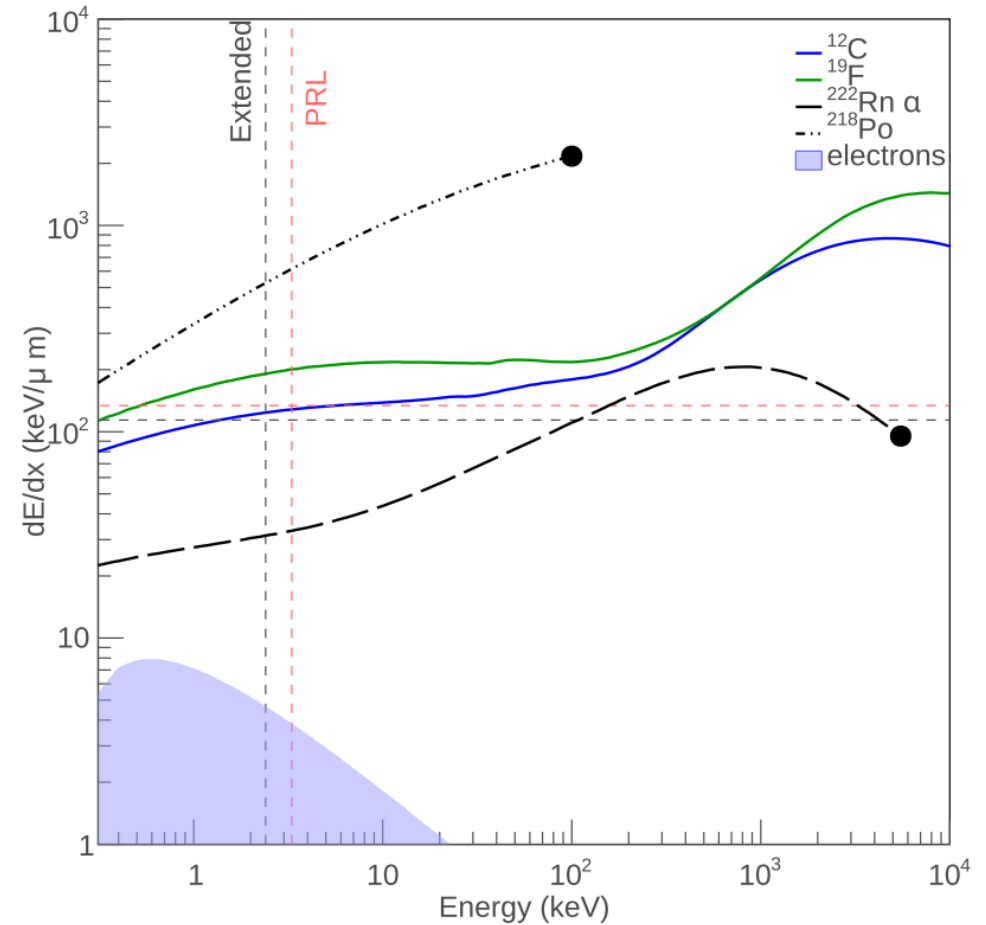
$$r_l = r_c \left(\frac{\rho_b}{\rho_l} \right)^{1/3} \quad P_b - P_l \geq \frac{2\sigma}{r_c}$$

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

Surface energy

Latent Heat

Reversible work



Operating Principle

