# PICO: Detector Status Updates and Reflections

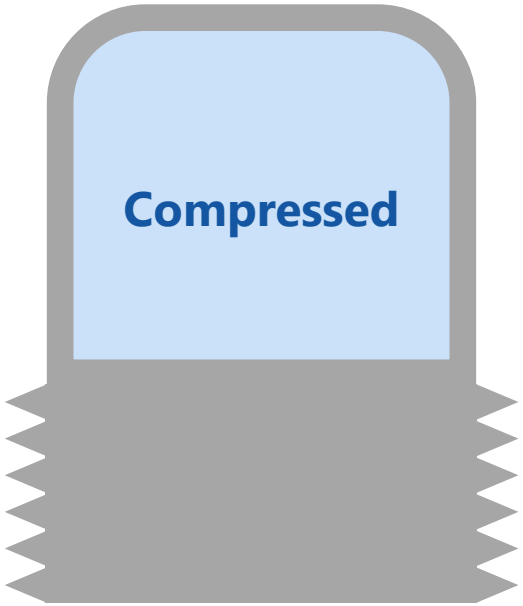
**William Woodley**

McDonald Institute Annual Community Meeting
28 July 2026

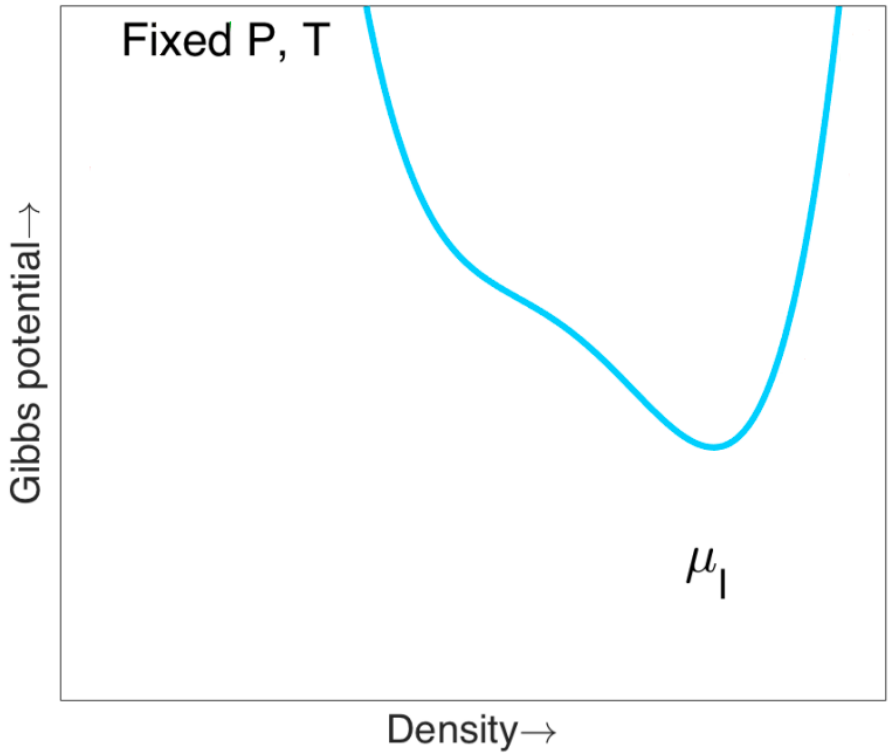

UNIVERSITY OF ALBERTA

# Overview of Bubble Chambers

# Bubble Chambers




Not ready to detect a particle!




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

# Bubble Chambers

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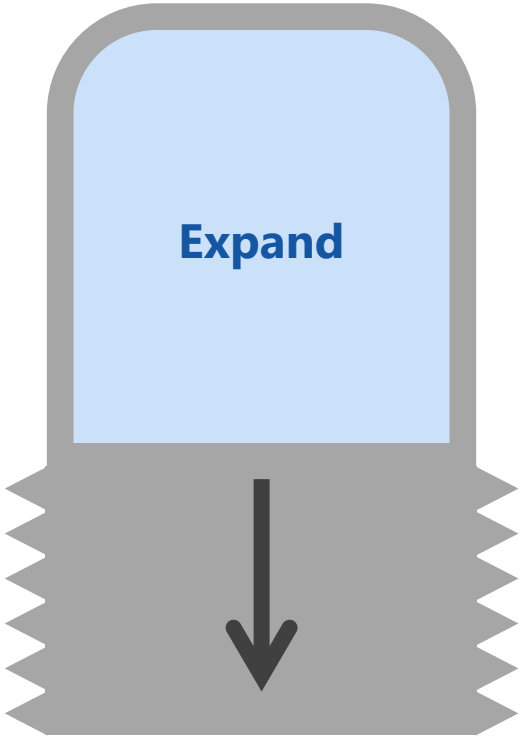


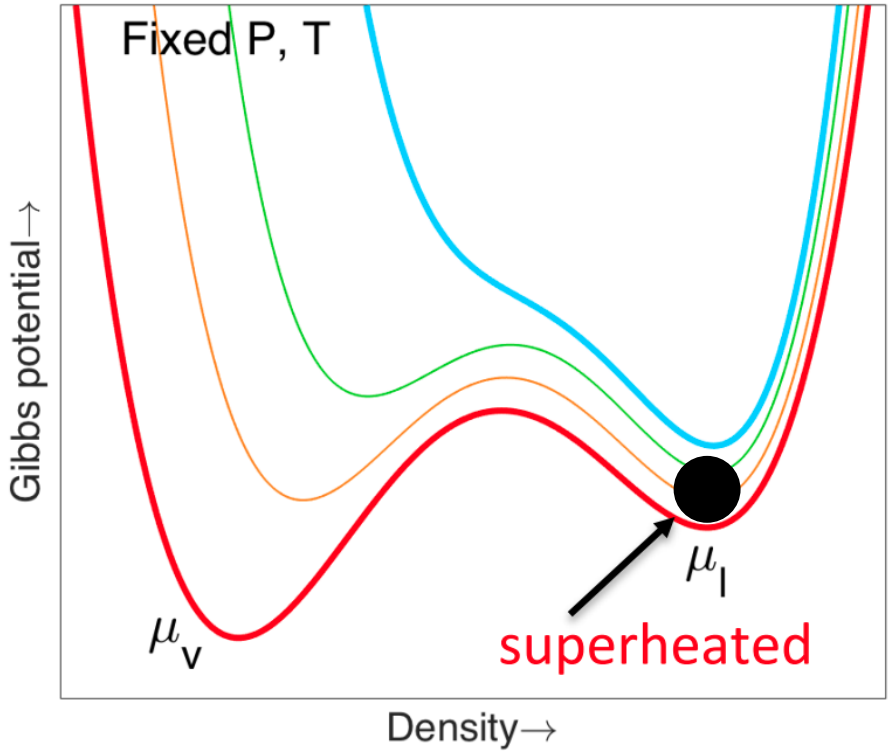


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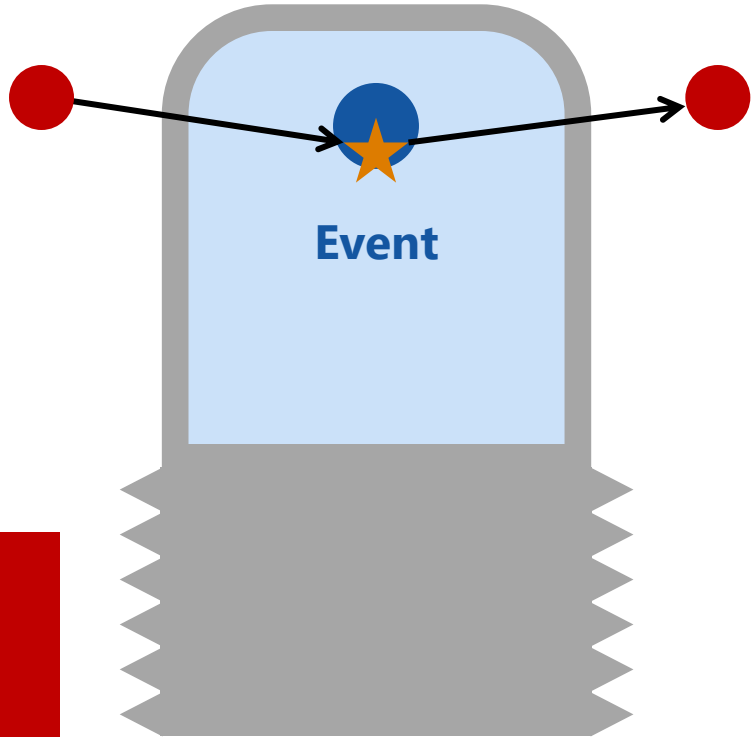
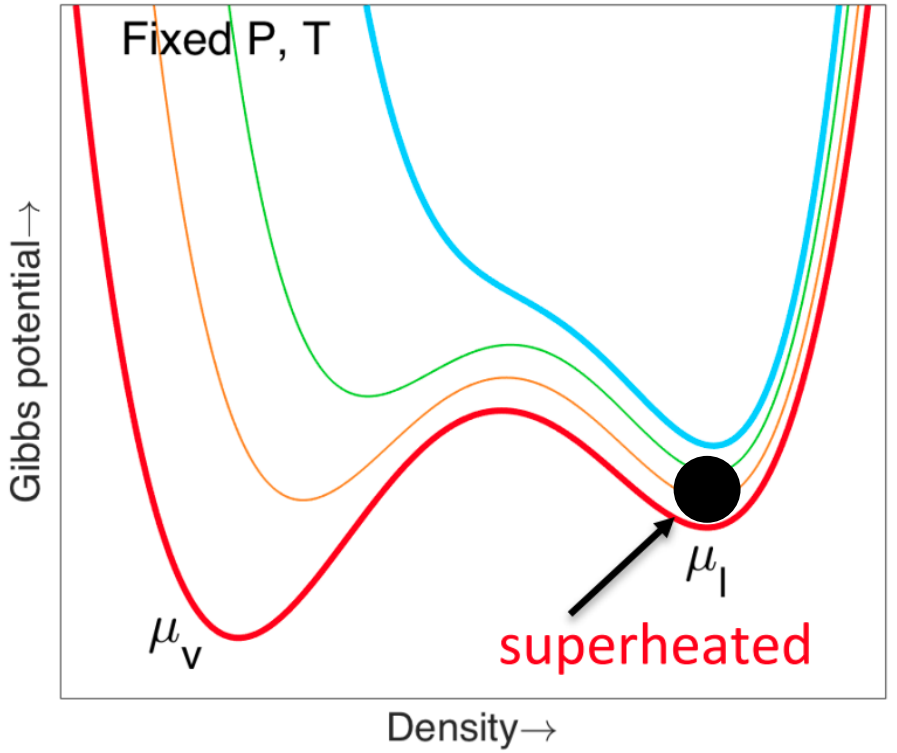



**Detects a particle!**

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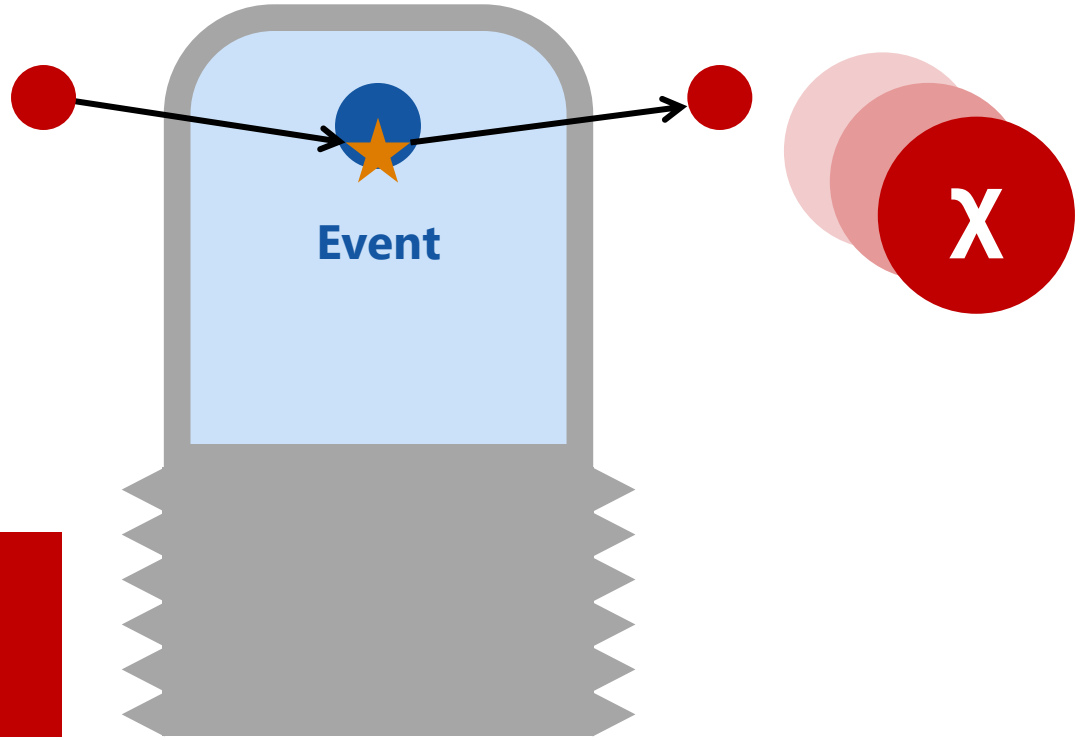





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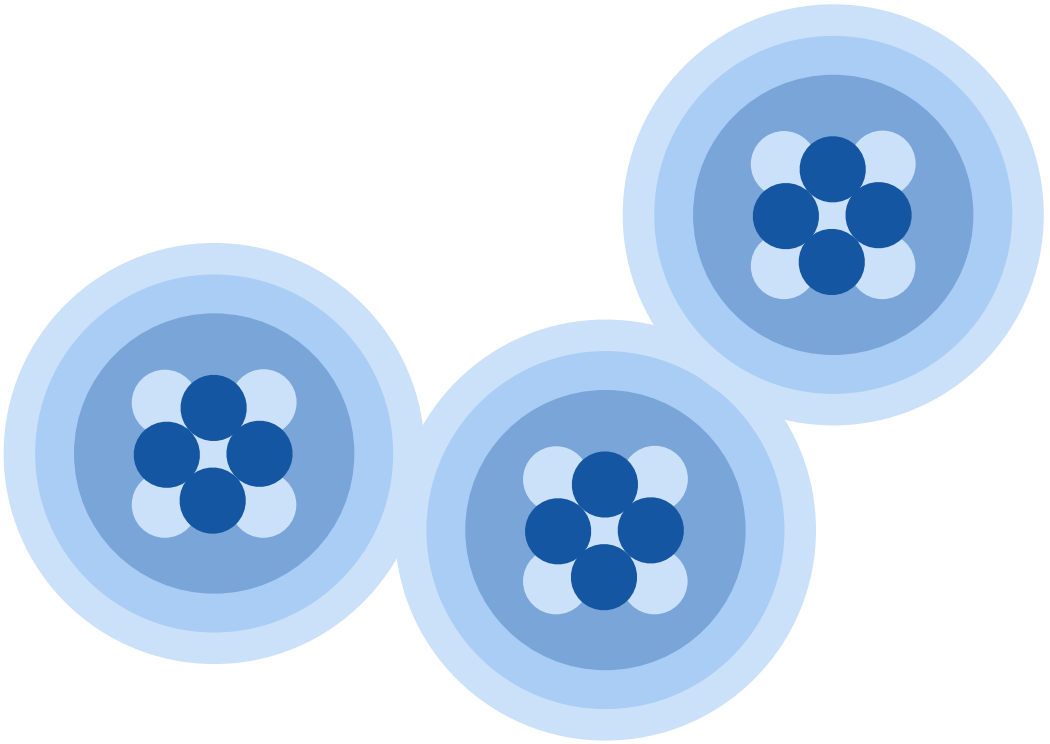

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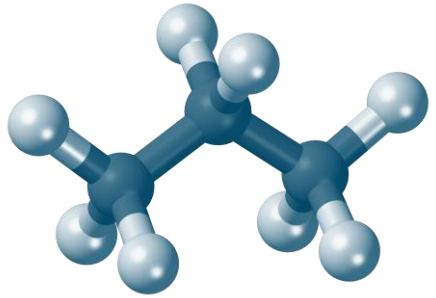

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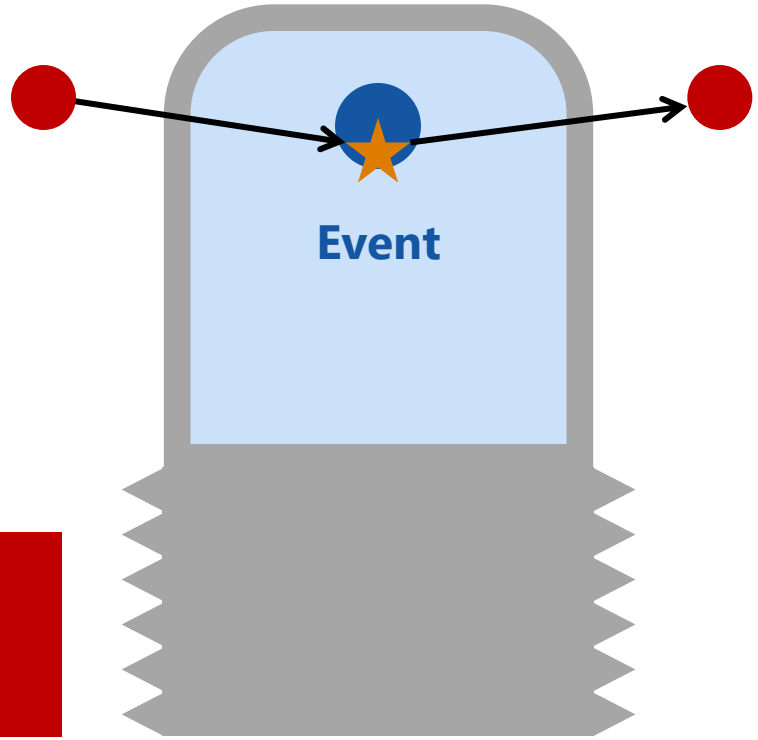
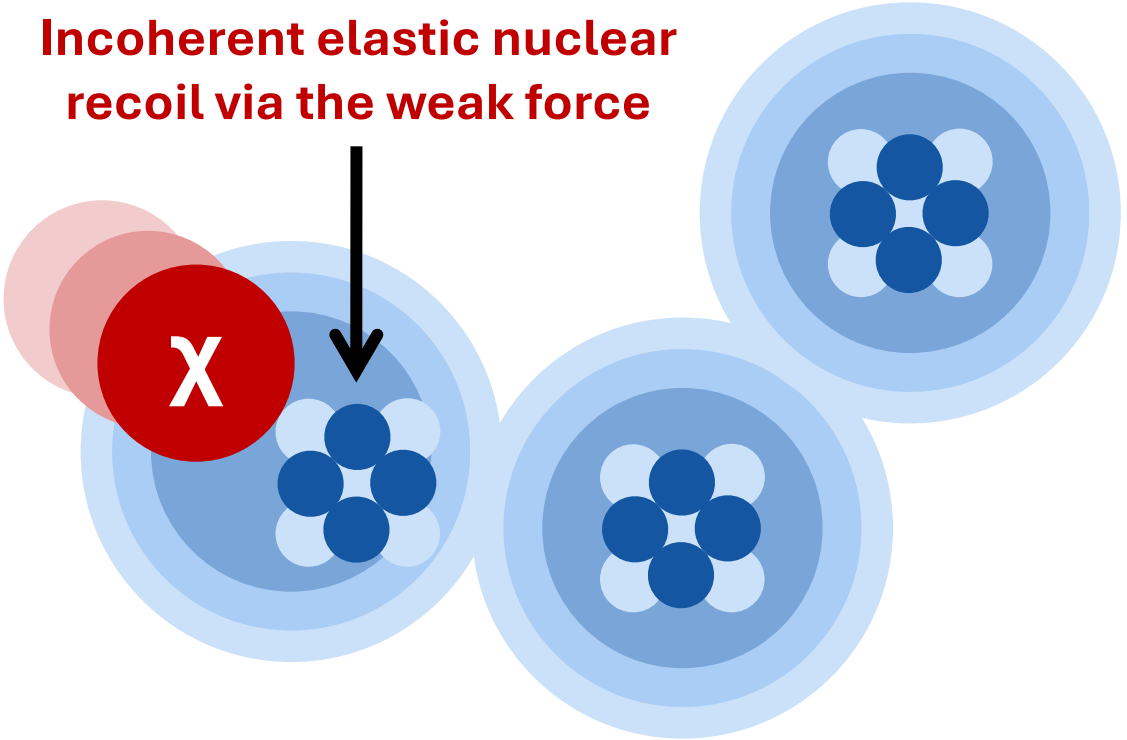



**Detects a particle!**

**Incoherent elastic nuclear recoil via the weak force**

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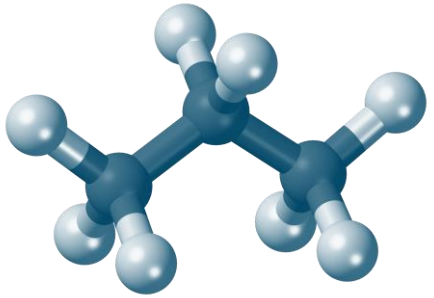

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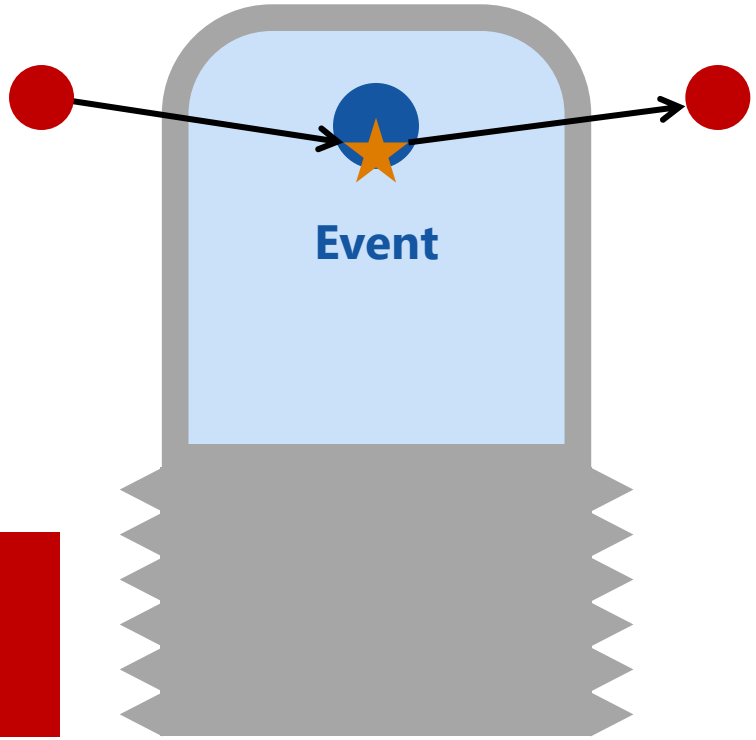


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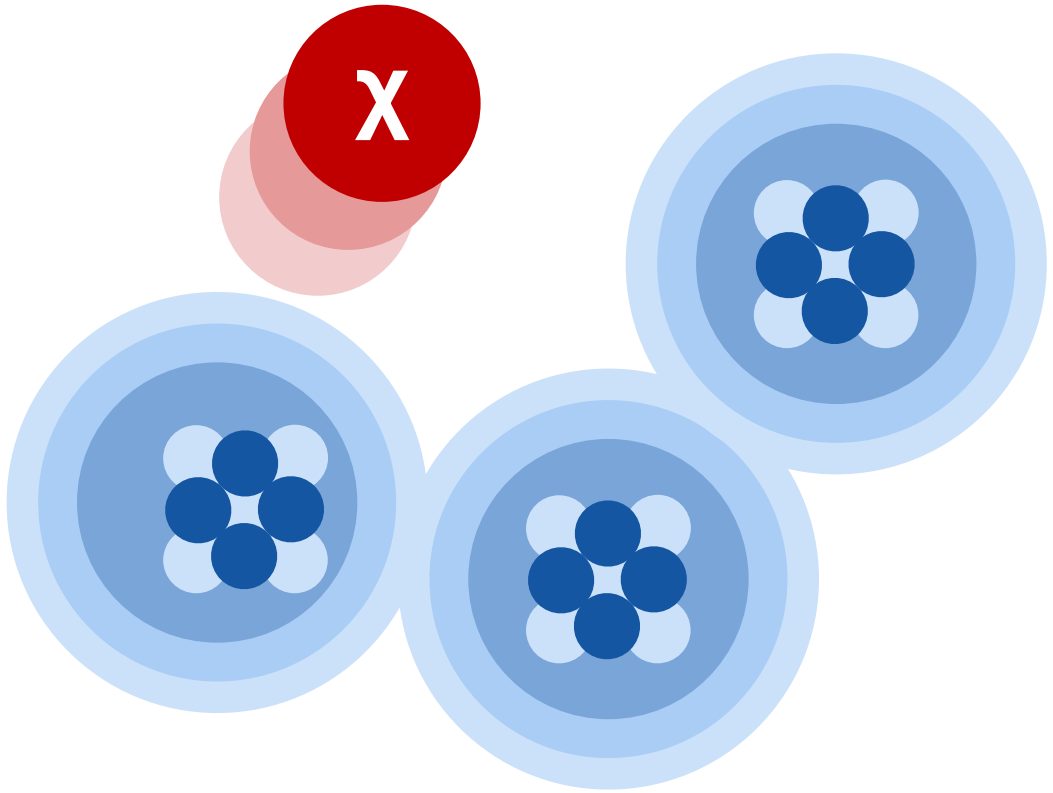


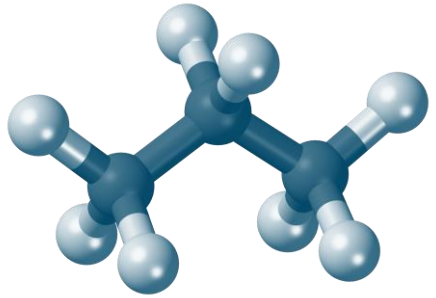

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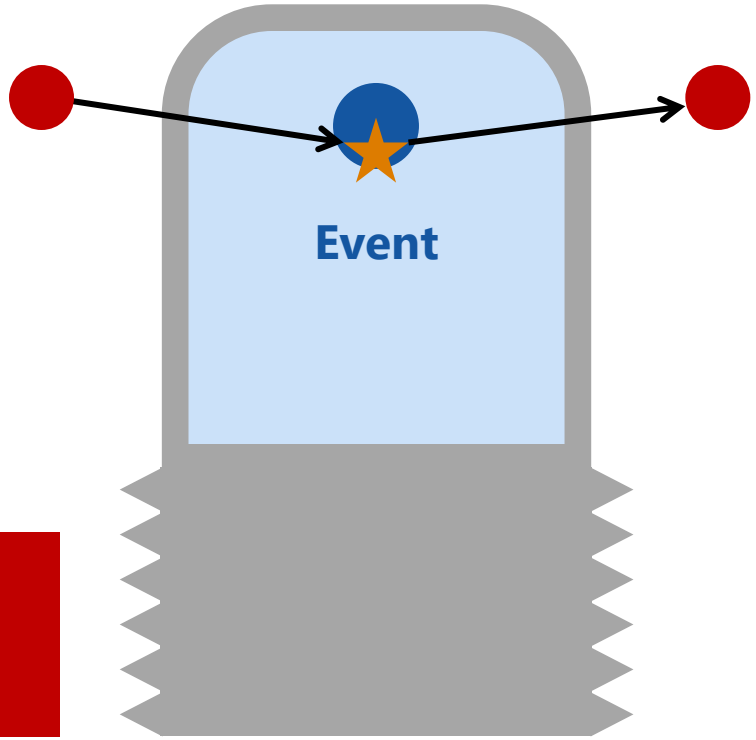


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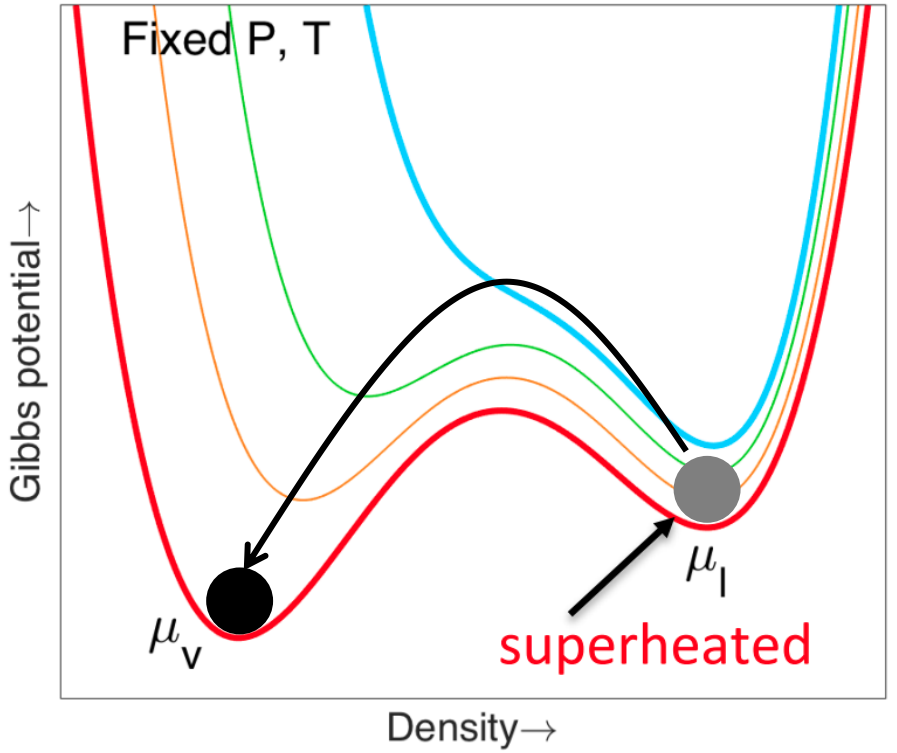


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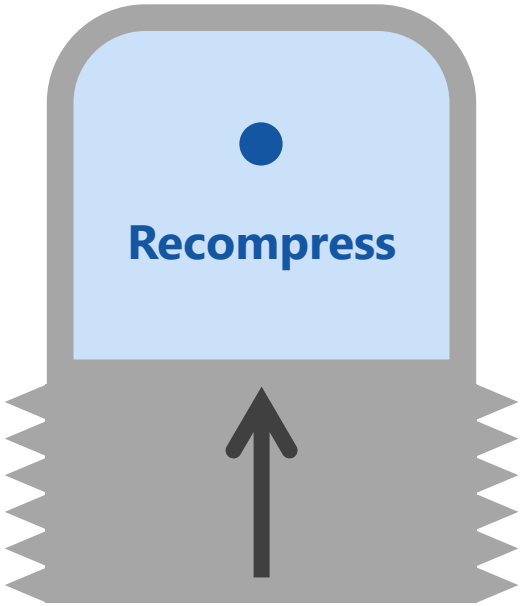


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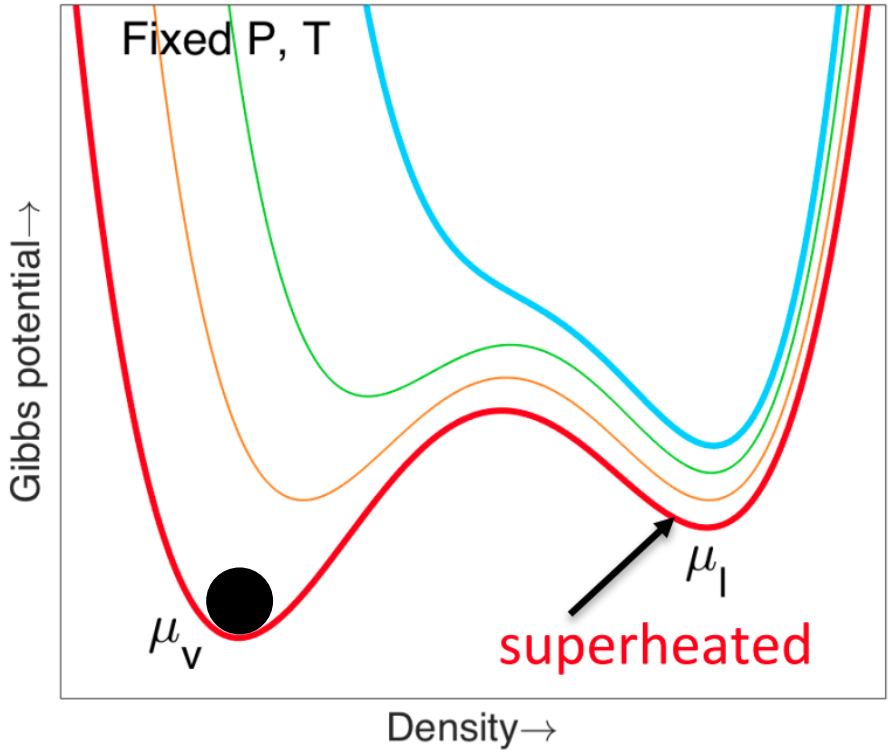


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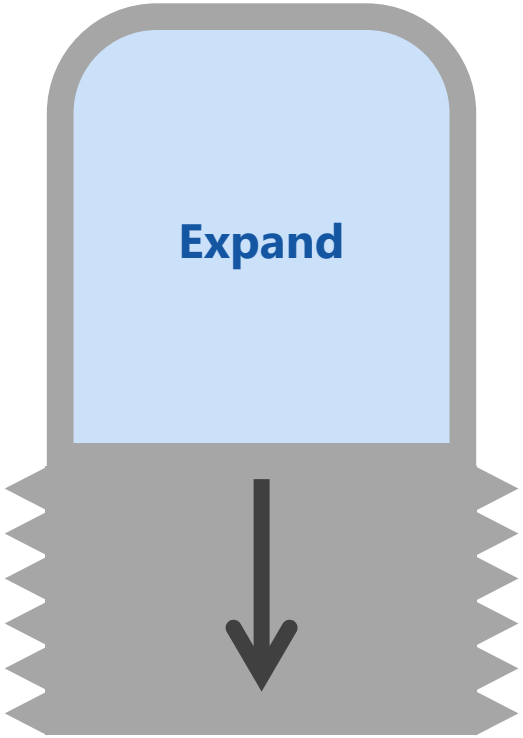


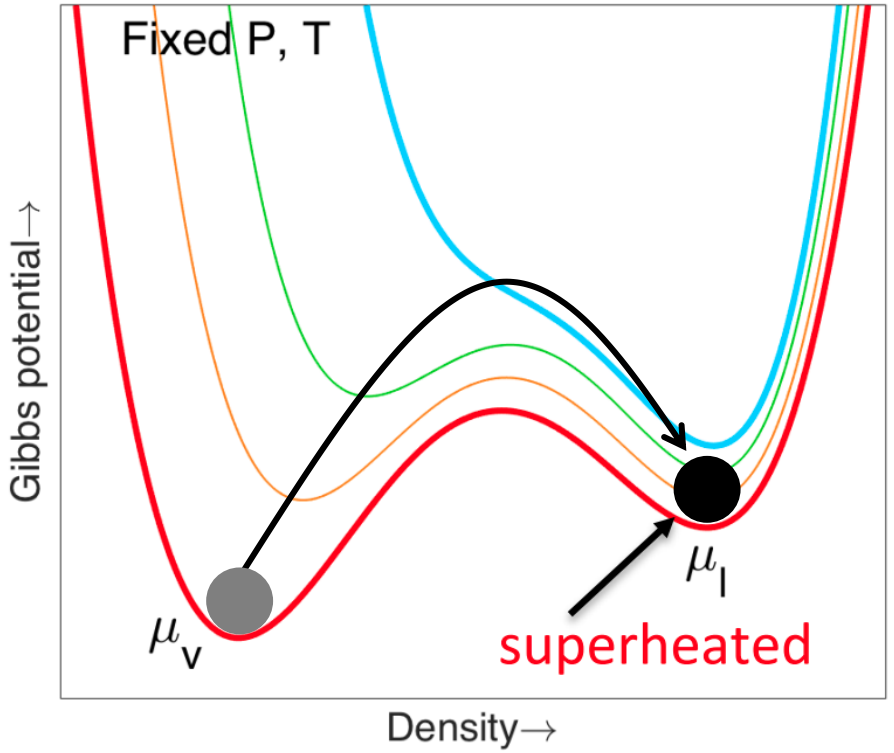


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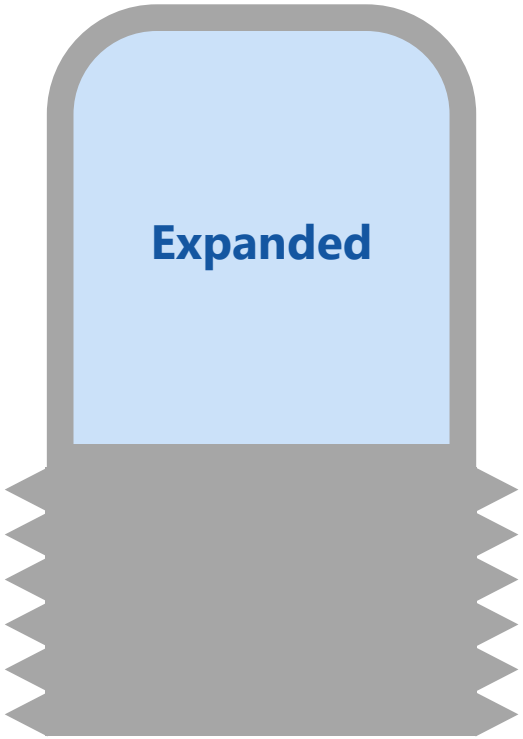


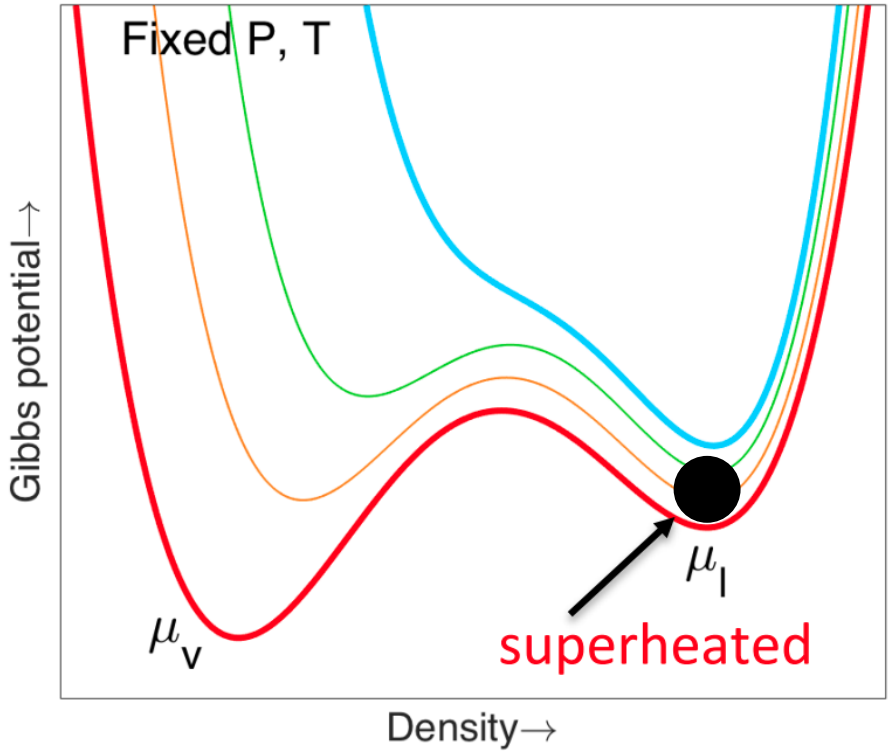


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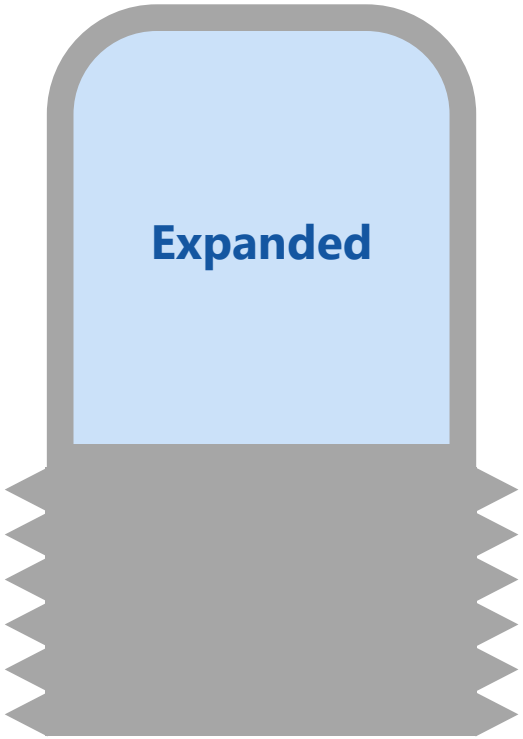


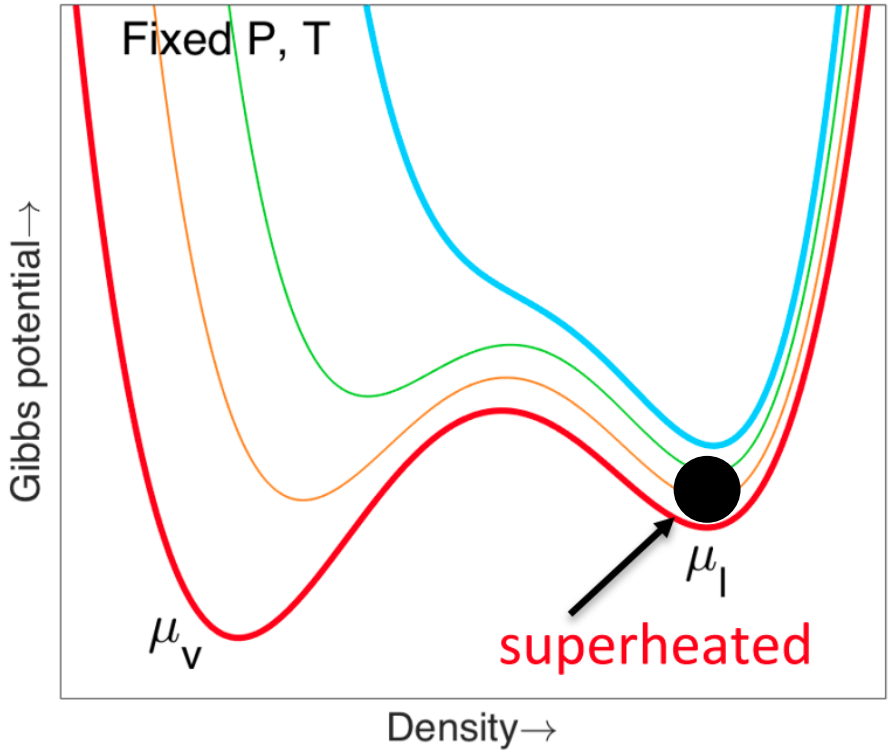


Surface Tension | Phase Transition | Expansion of Vapour

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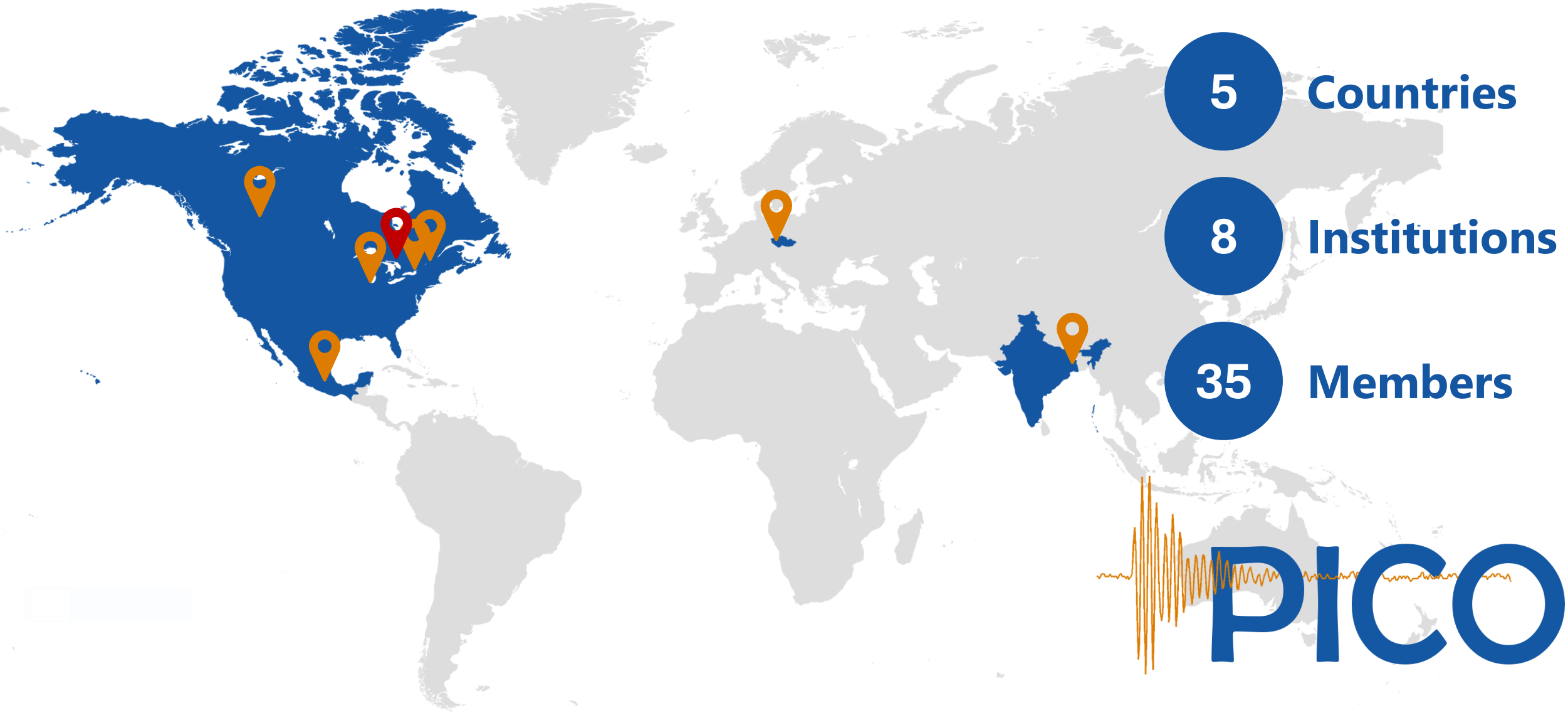
# The PICO Collaboration



**5** Countries

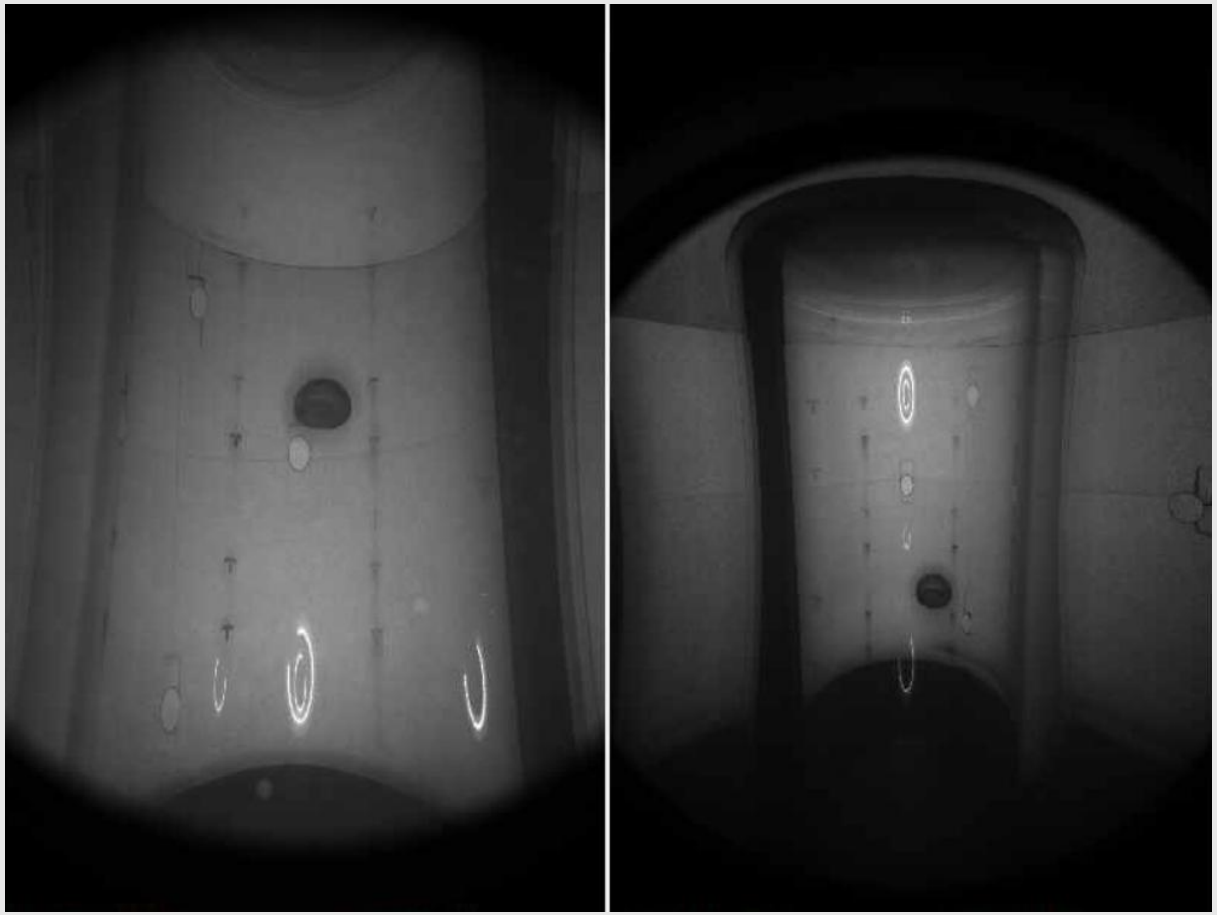
**8** Institutions

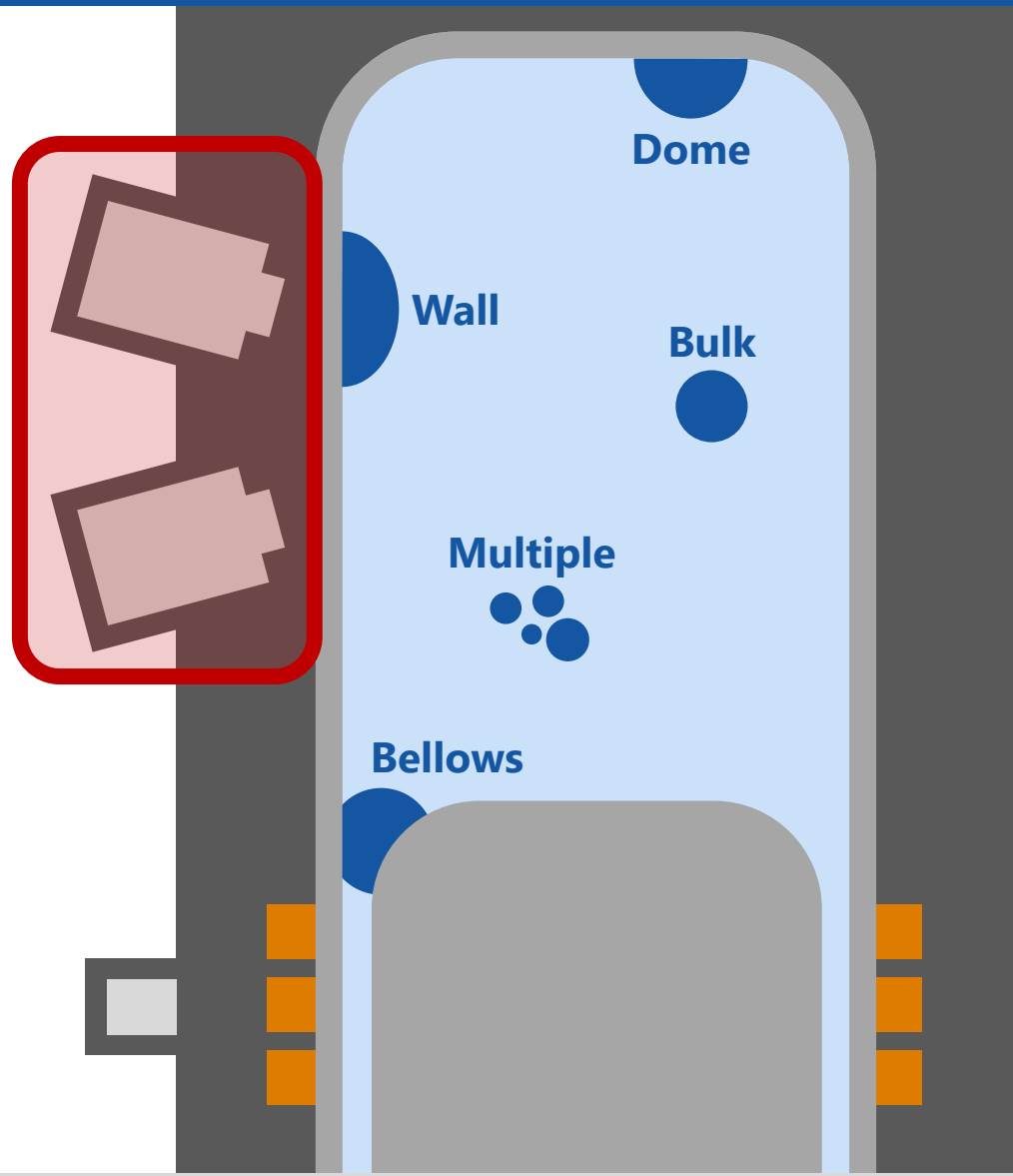
**35** Members

PICO

# Detection Channels

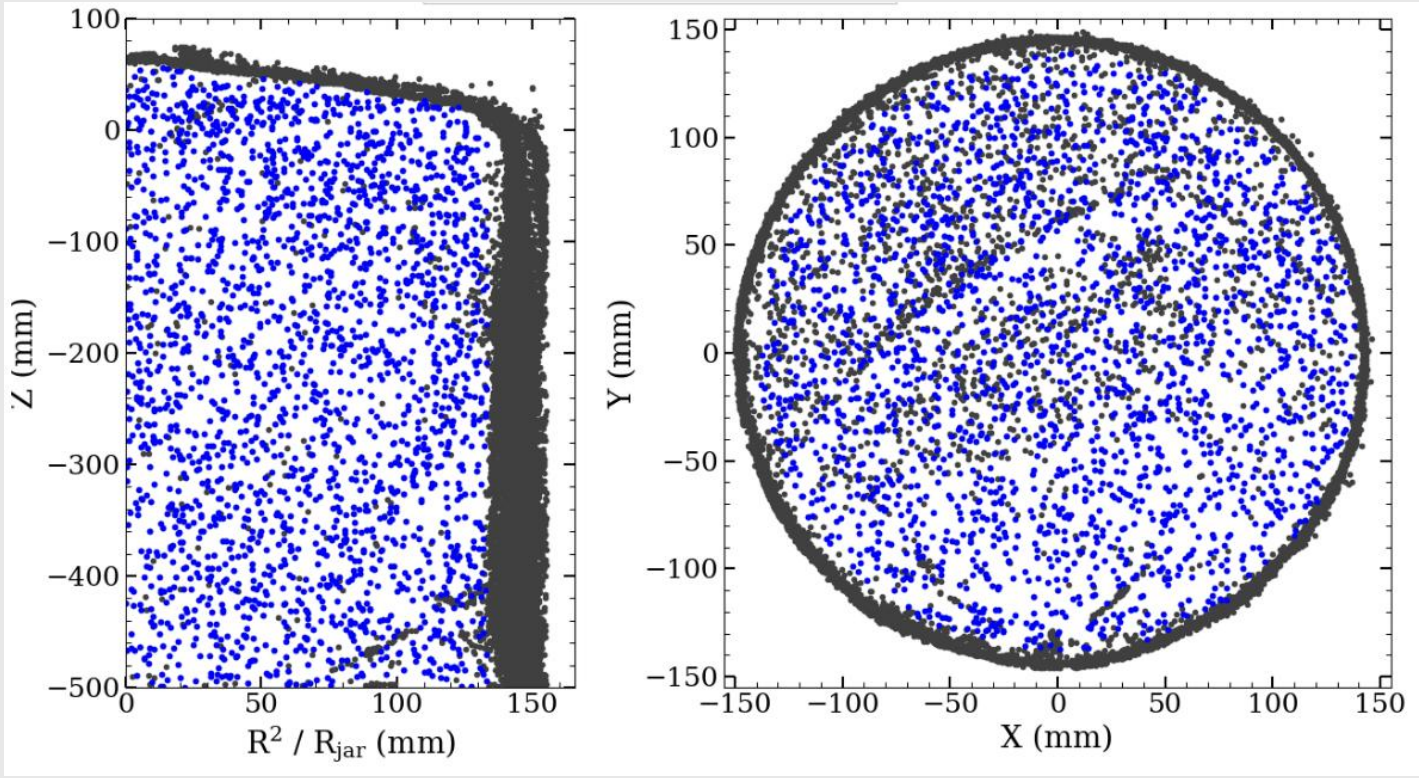
Cameras | Piezoelectric Sensors | Pressure Sensors

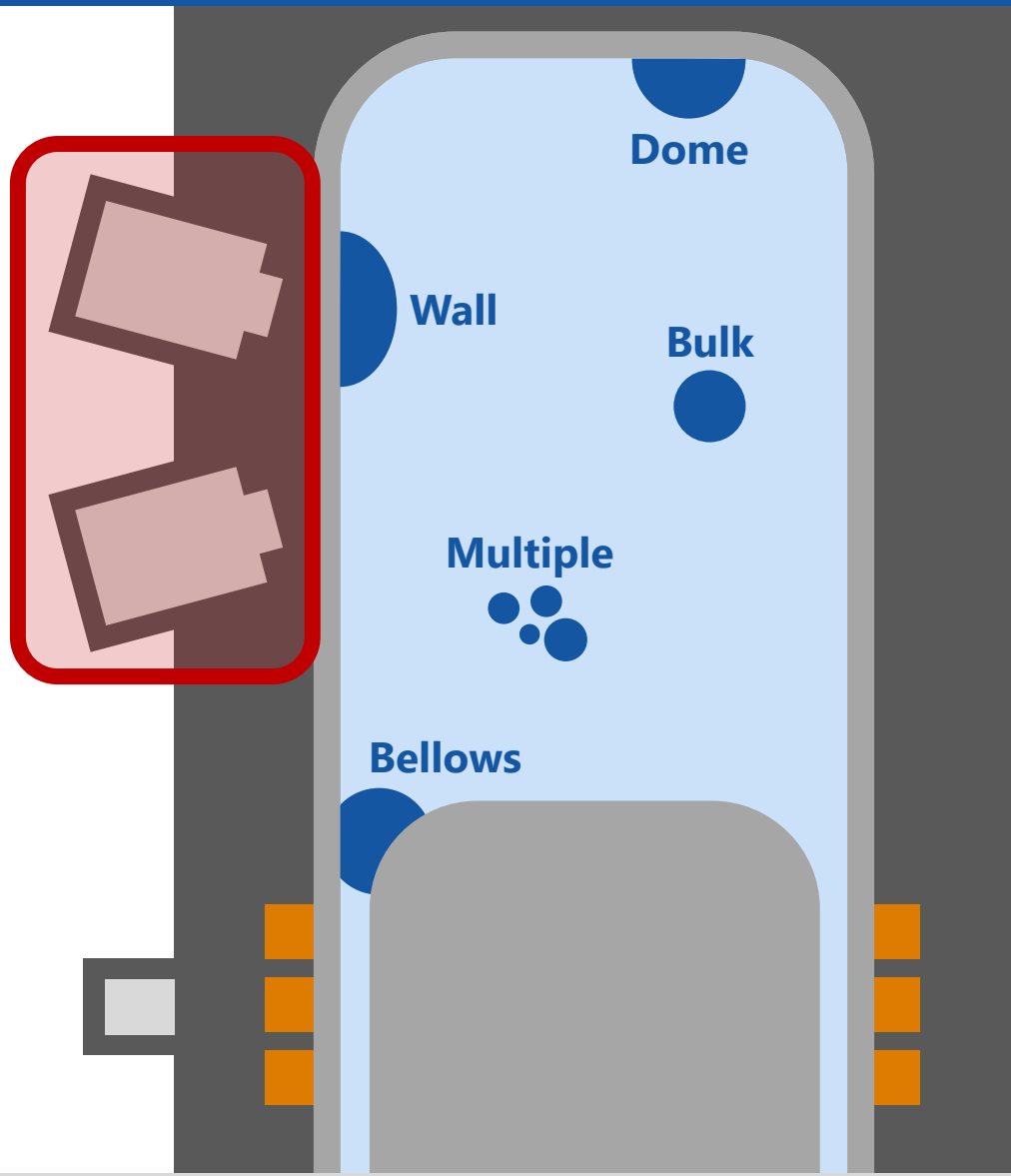




# Detection Channels

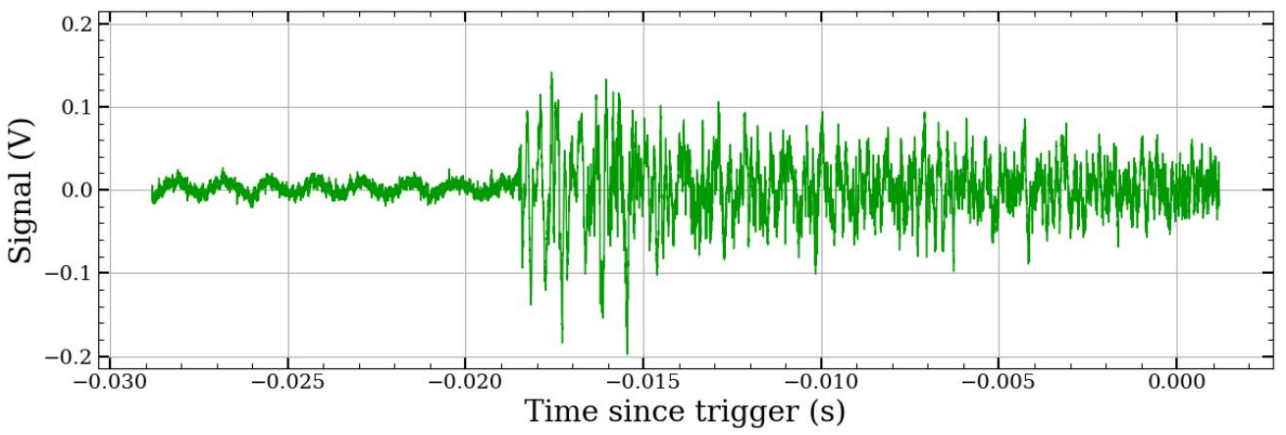
**Cameras** | Piezoelectric Sensors | Pressure Sensors

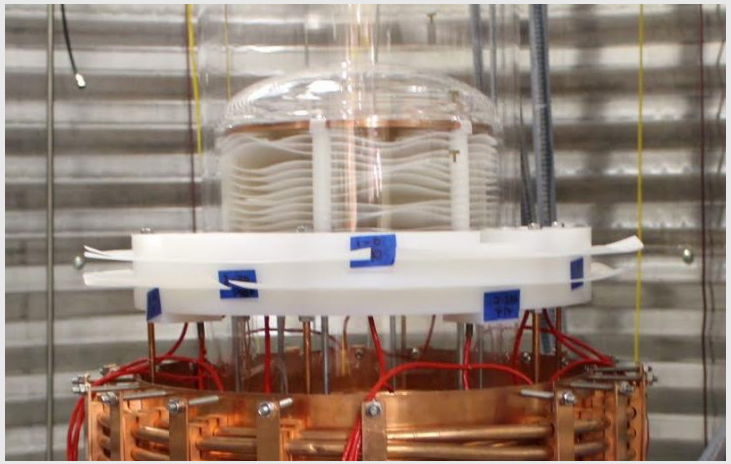


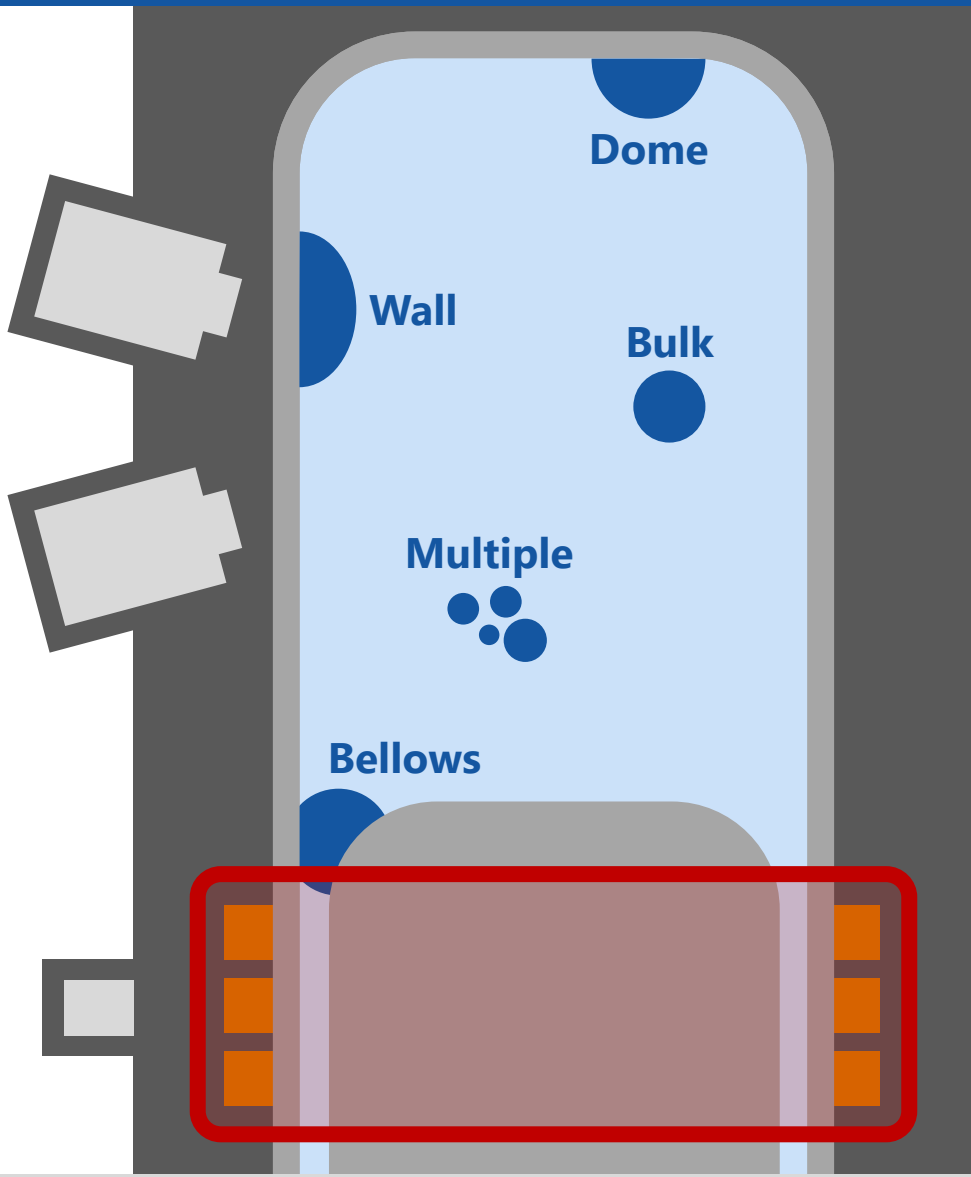



# Detection Channels

Cameras | **Piezoelectric Sensors** | Pressure Sensors

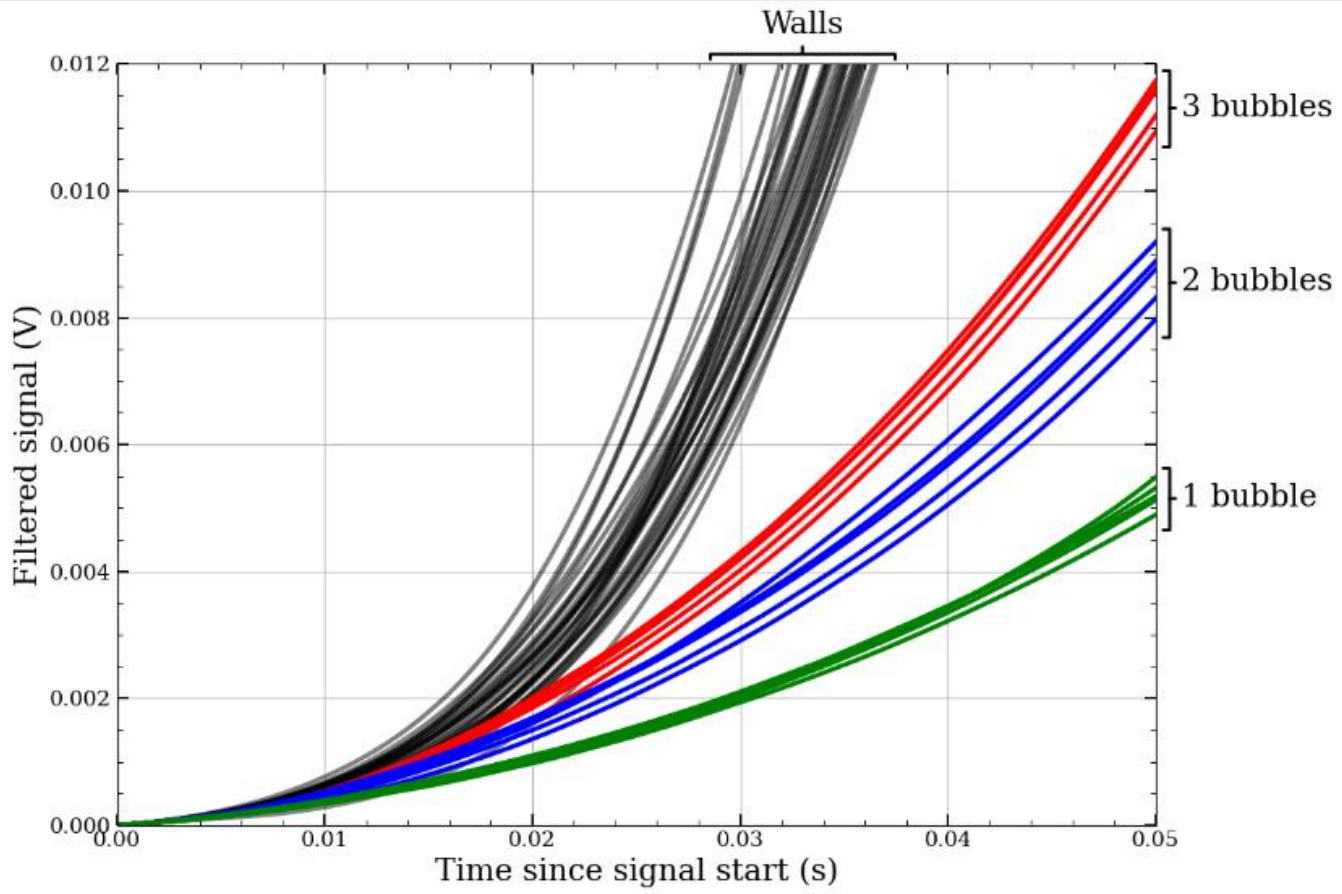


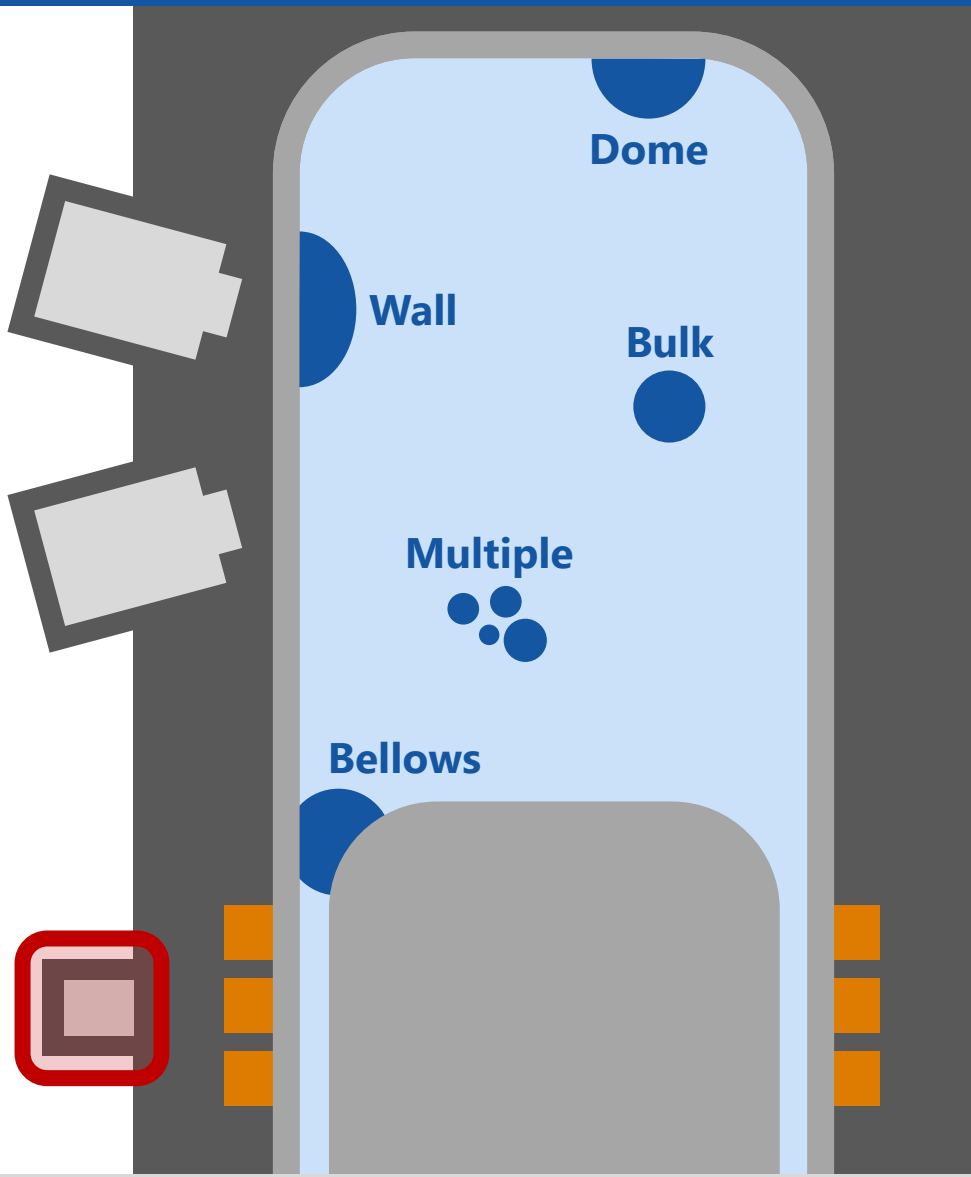





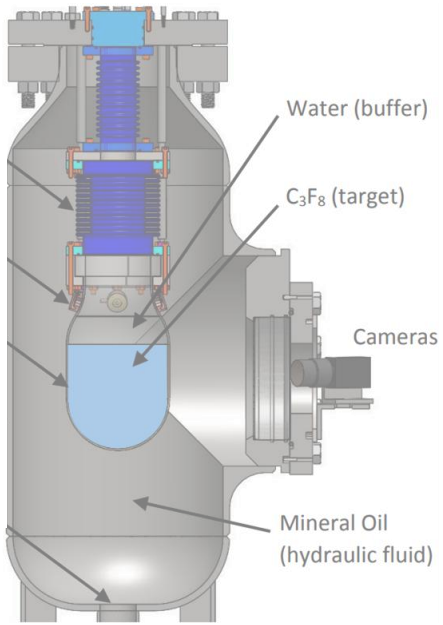
# Detection Channels

Cameras | Piezoelectric Sensors | **Pressure Sensors**



# 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

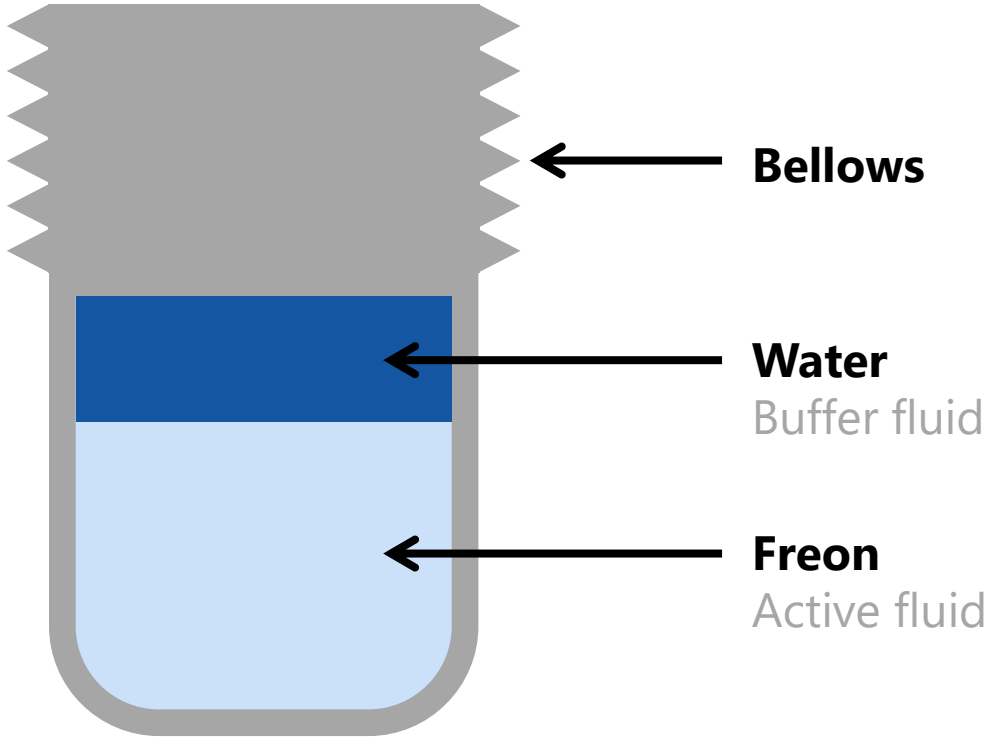
**Right-Side-up (RSU)**

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

**PICO-500**
260 L of $C_3F_8$
Proj. 2027

# Right-Side-up Design

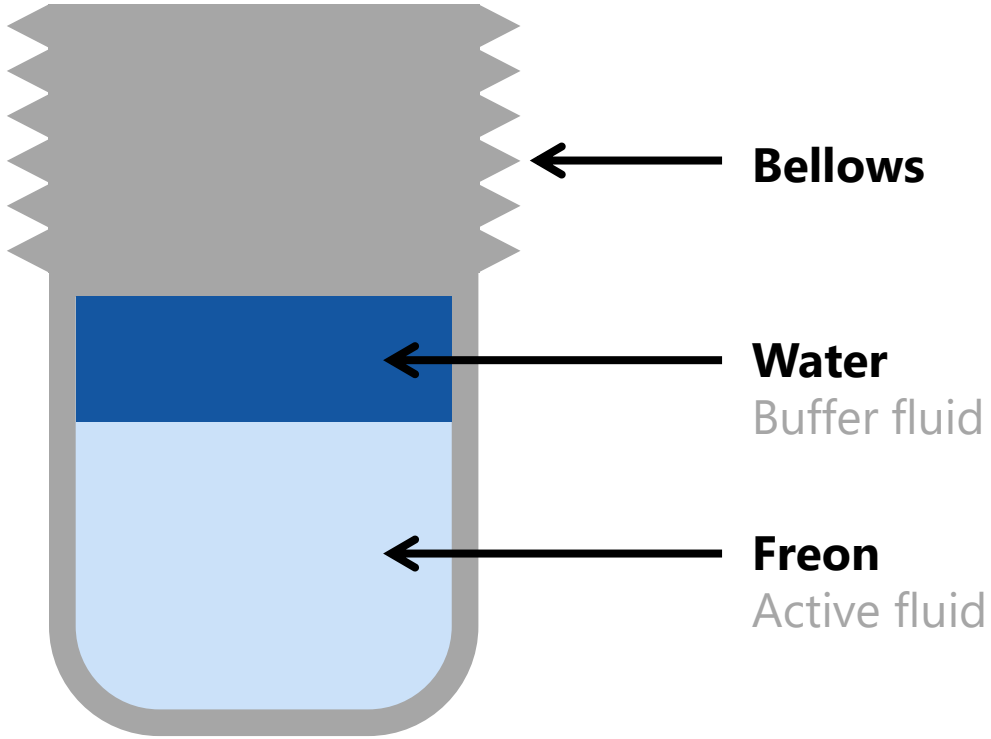
## Upside Down




## Right-Side-up (RSU)

# Right-Side-up Design

## Upside Down

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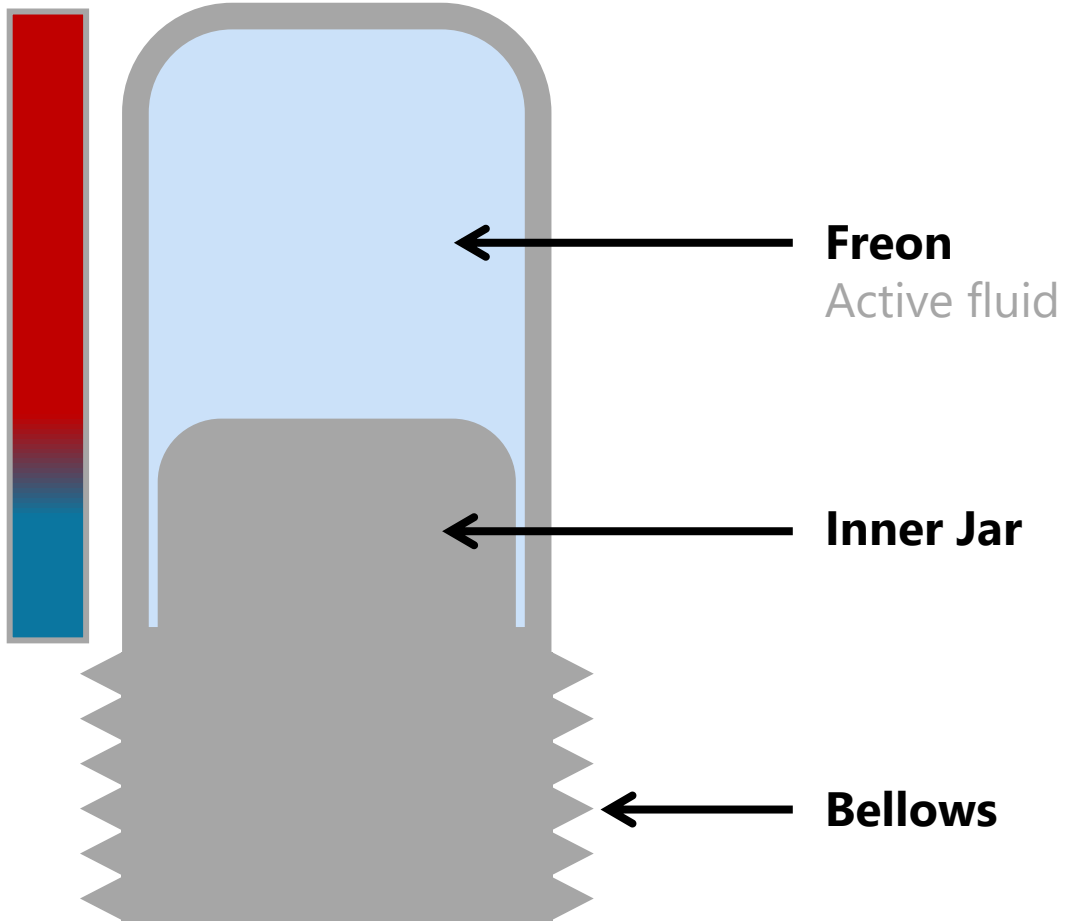
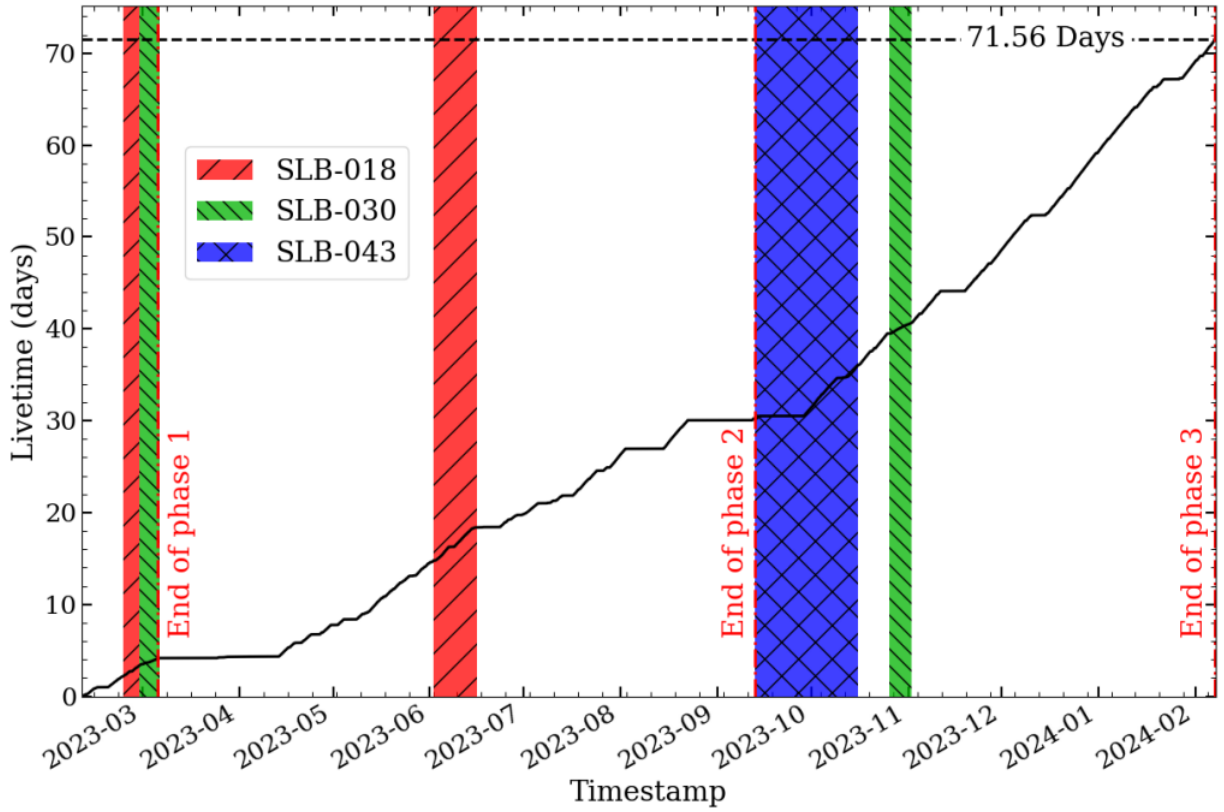
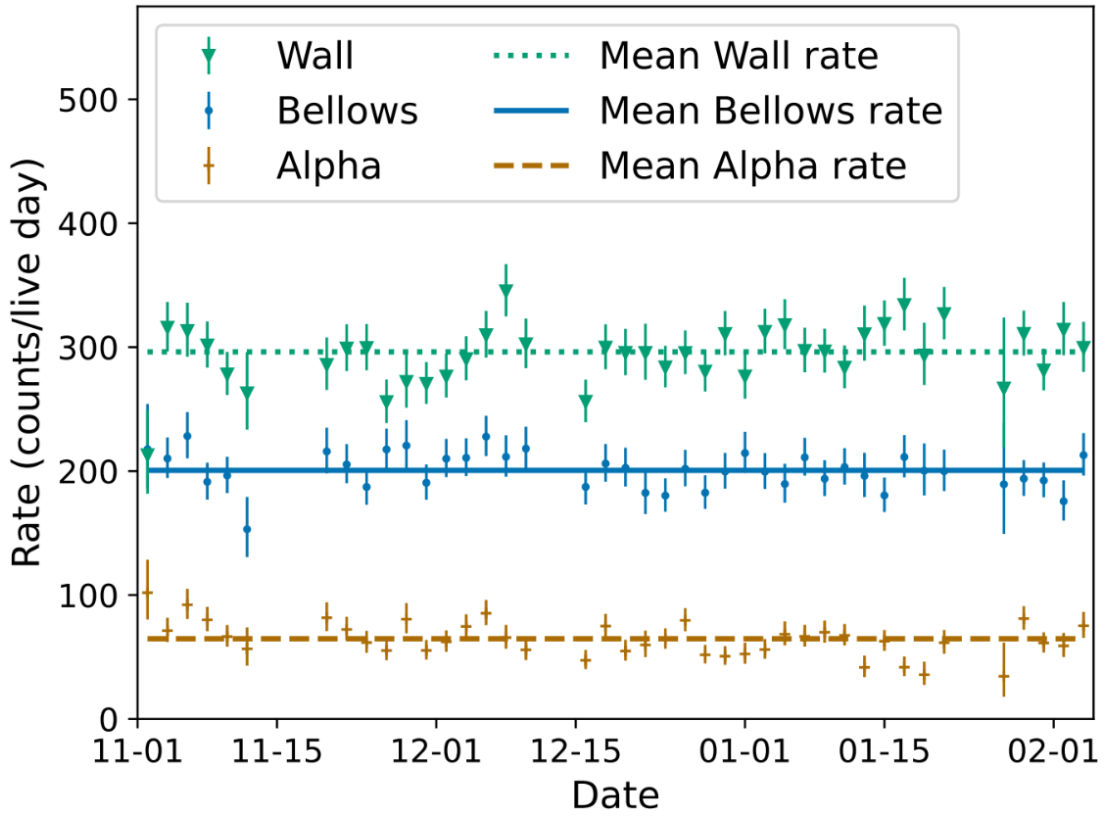


# PICO-40L Update

# PICO-40L Status

- PICO-40L took physics data for about 4 months in 2023–2024, accumulating up to 72 livedays of data.
- We have been troubleshooting issues which have kept us from running very much since then.

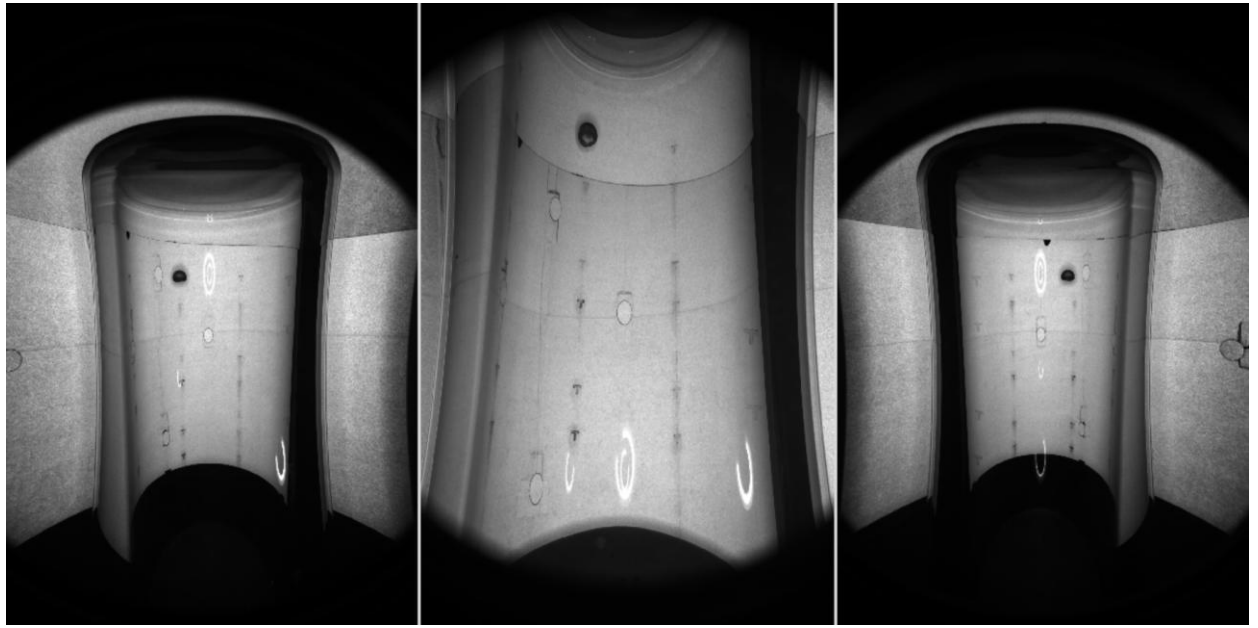



C. Moore, Ph.D. Thesis (2024)
https://inspirehep.net/literature/2829909

# PICO-40L Status

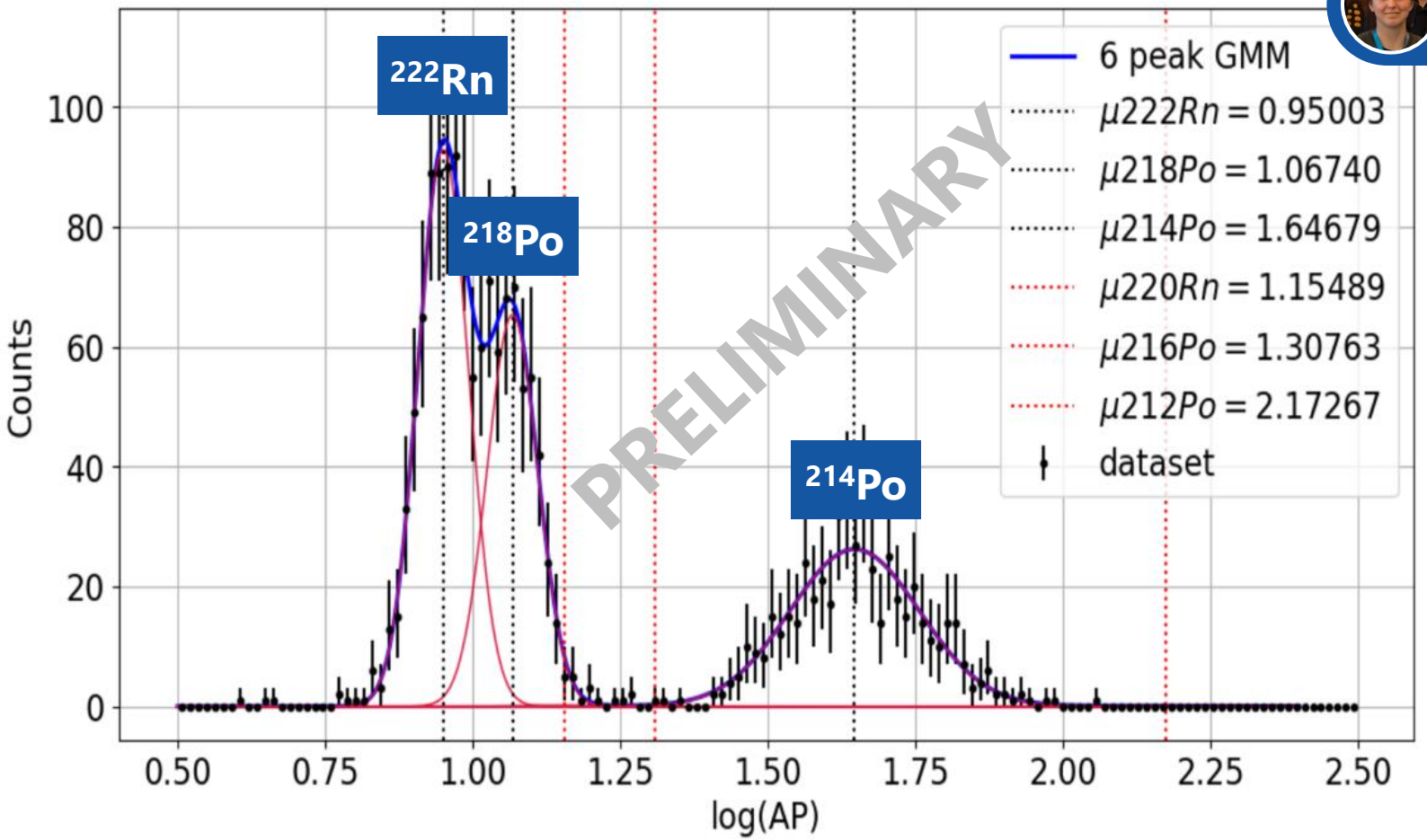
- PICO-40L took physics data for about 4 months in 2023–2024, accumulating up to 72 livedays of data.
- We have been troubleshooting issues which have kept us from running very much since then.
- As of **July 2026**, we have started running again. Focussing on engineering runs to understand detector response under different conditions to better characterise performance.
- Currently experiencing issues with the chiller unit used to set the temperature in the cold region of the detector.



# Alpha Spectroscopy

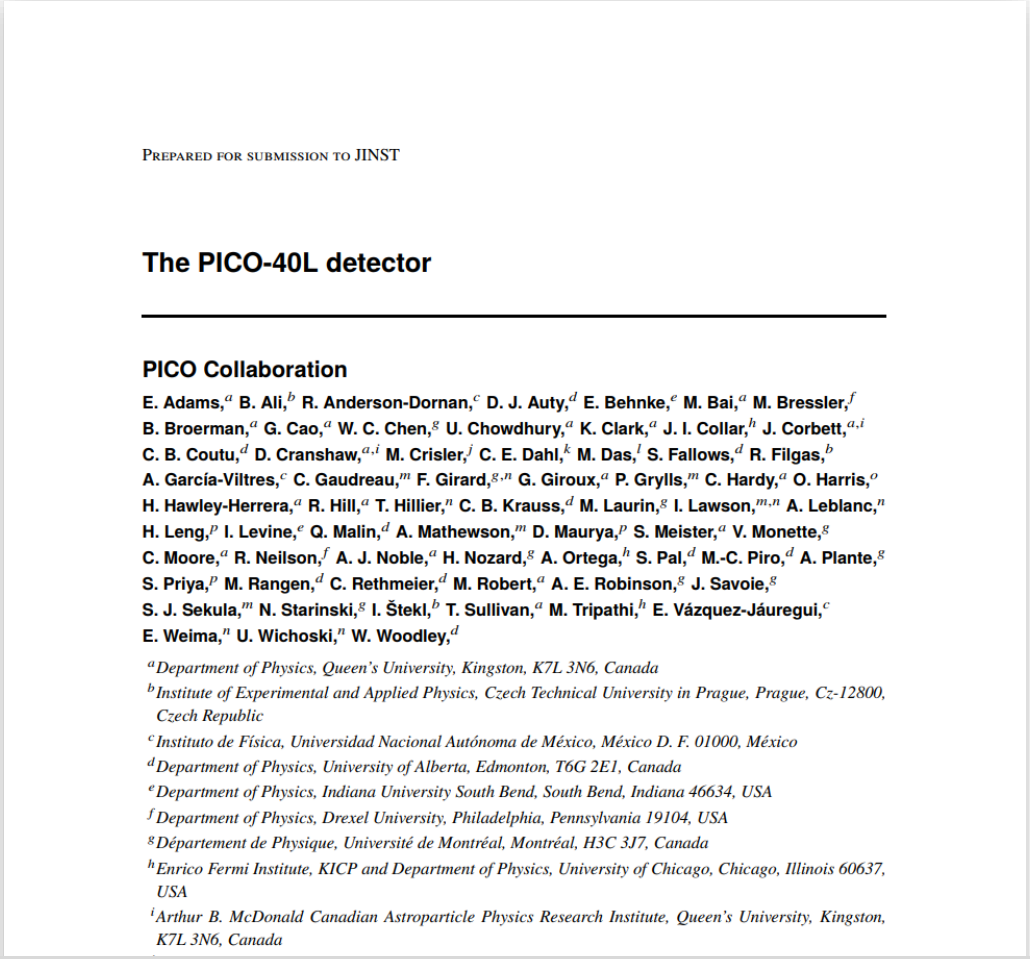
- We have been able to resolve the alpha peaks from the $^{238}U$ decay chain in our PICO-40L acoustic data, allowing us to do alpha spectroscopy. Paper in preparation at the moment.

**Emily Adams**
Queen's (Ph.D. student)



# PICO-40L Detector Paper

- As the first major implementation of the RSU design, we have written a technical paper describing the design of the PICO-40L detector, its subsystems, and its performance, which will appear on arXiv this week.



Prepared for submission to JINST

**The PICO-40L detector**

**PICO Collaboration**

E. Adams,[a] B. Ali,[b] R. Anderson-Dornan,[c] D. J. Auty,[d] E. Behnke,[e] M. Bai,[a] M. Bressler,[f] B. Broerman,[a] G. Cao,[a] W. C. Chen,[g] U. Chowdhury,[a] K. Clark,[a] J. I. Collar,[h] J. Corbett,[a,i] C. B. Coutu,[d] D. Cranshaw,[a,i] M. Crisler,[j] C. E. Dahl,[k] M. Das,[l] S. Fallows,[d] R. Filgas,[b] A. García-Viltres,[c] C. Gaudreau,[m] F. Girard,[g,n] G. Giroux,[a] P. Grylls,[m] C. Hardy,[a] O. Harris,[o] H. Hawley-Herrera,[a] R. Hill,[a] T. Hillier,[n] C. B. Krauss,[d] M. Laurin,[g] I. Lawson,[m,n] A. Leblanc,[n] H. Leng,[p] I. Levine,[e] Q. Malin,[d] A. Mathewson,[m] D. Maurya,[p] S. Meister,[a] V. Monette,[g] C. Moore,[a] R. Neilson,[f] A. J. Noble,[a] H. Nozard,[g] A. Ortega,[h] S. Pal,[d] M.-C. Piro,[d] A. Plante,[g] S. Priya,[p] M. Rangen,[d] C. Rethmeier,[d] M. Robert,[a] A. E. Robinson,[g] J. Savoie,[g] S. J. Sekula,[m] N. Starinski,[g] I. Štekl,[b] T. Sullivan,[a] M. Tripathi,[h] E. Vázquez-Jáuregui,[c] E. Weima,[n] U. Wichoski,[n] W. Woodley,[d]

[a] *Department of Physics, Queen's University, Kingston, K7L 3N6, Canada*
[b] *Institute of Experimental and Applied Physics, Czech Technical University in Prague, Prague, Cz-12800, Czech Republic*
[c] *Instituto de Física, Universidad Nacional Autónoma de México, México D. F. 01000, México*
[d] *Department of Physics, University of Alberta, Edmonton, T6G 2E1, Canada*
[e] *Department of Physics, Indiana University South Bend, South Bend, Indiana 46634, USA*
[f] *Department of Physics, Drexel University, Philadelphia, Pennsylvania 19104, USA*
[g] *Département de Physique, Université de Montréal, Montréal, H3C 3J7, Canada*
[h] *Enrico Fermi Institute, KICP and Department of Physics, University of Chicago, Chicago, Illinois 60637, USA*
[i] *Arthur B. McDonald Canadian Astroparticle Physics Research Institute, Queen's University, Kingston, K7L 3N6, Canada*

# PICO-500 Update

# PICO-500

- Next, larger generation of the PICO bubble chamber programme.
- At 260 L, this is the largest synthetic quartz vessel ever made.
- PICO-40L RSU design acts as a proof-of-concept for PICO-500.
- Design and operation informed by the successes, difficulties of PICO-40L.

- **Improvements in PICO-500:**
  - New **cleaning** and **radon mitigation** techniques
  - New **muon veto** system
  - Improved **heater design**
  - **Vacuum jacket** to help keep temperatures stable in the cold region.
  - **Degassing tank** removes air from mineral oil and reduces dead time.
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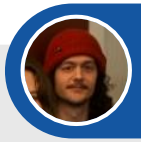

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Alberta (Ph.D. student)

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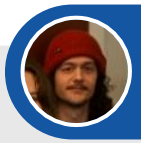

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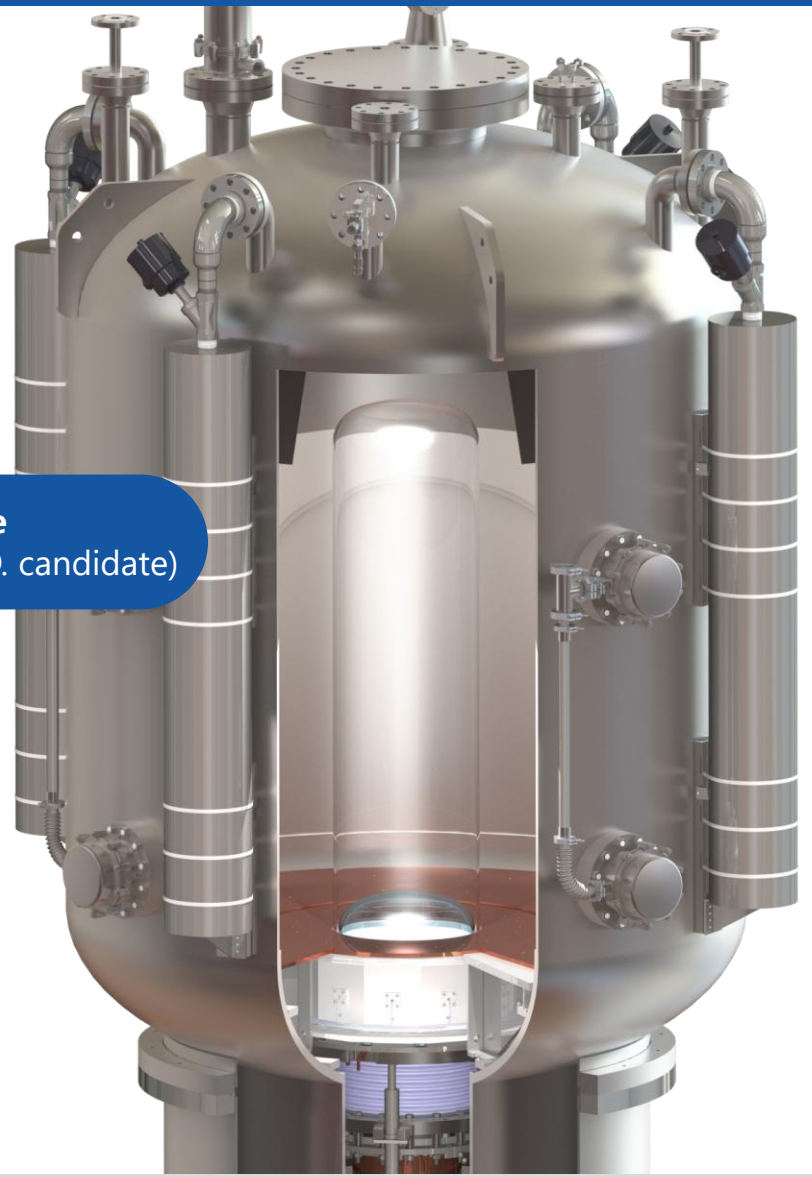

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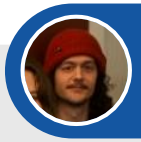

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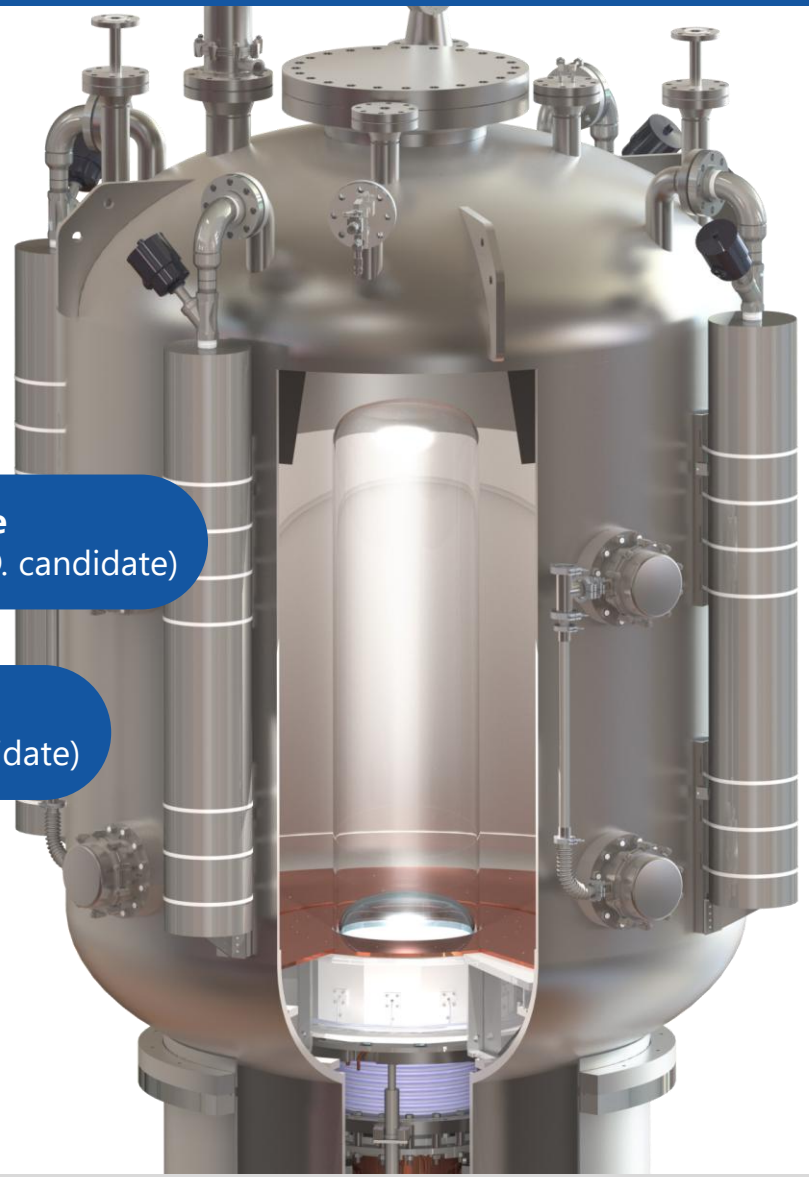
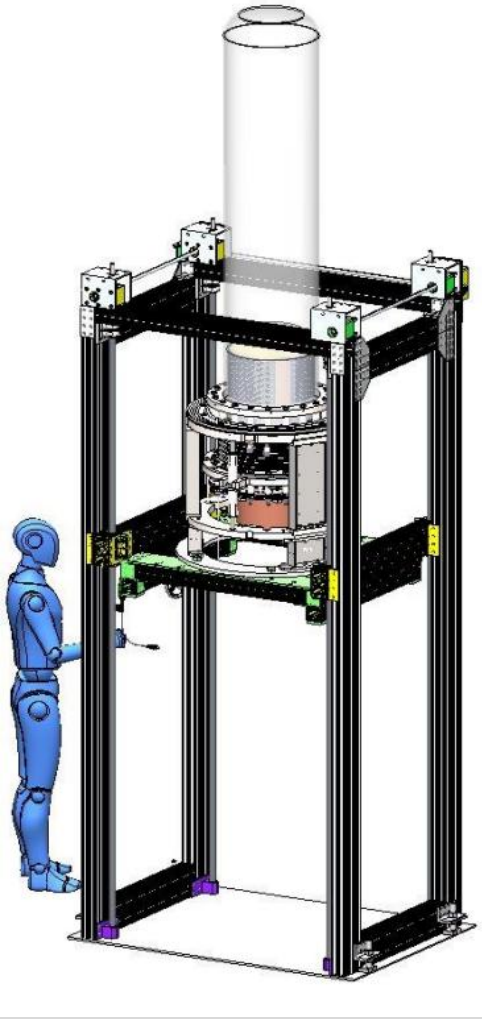


# PICO-500 Status

- The pressure vessel has been welded and leak-checked. Now in place inside the water tank in the Cube Hall.

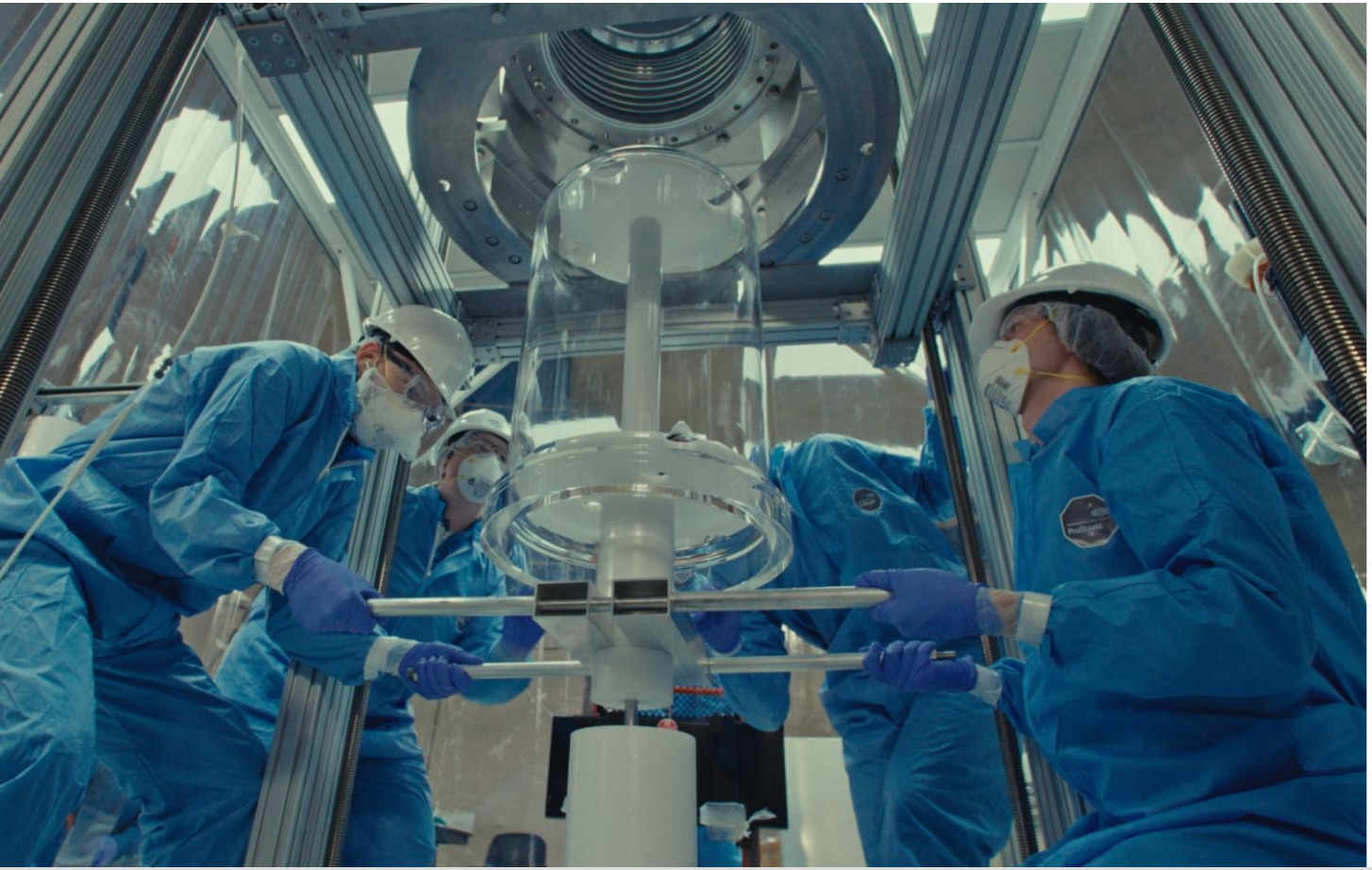
# PICO-500 Status

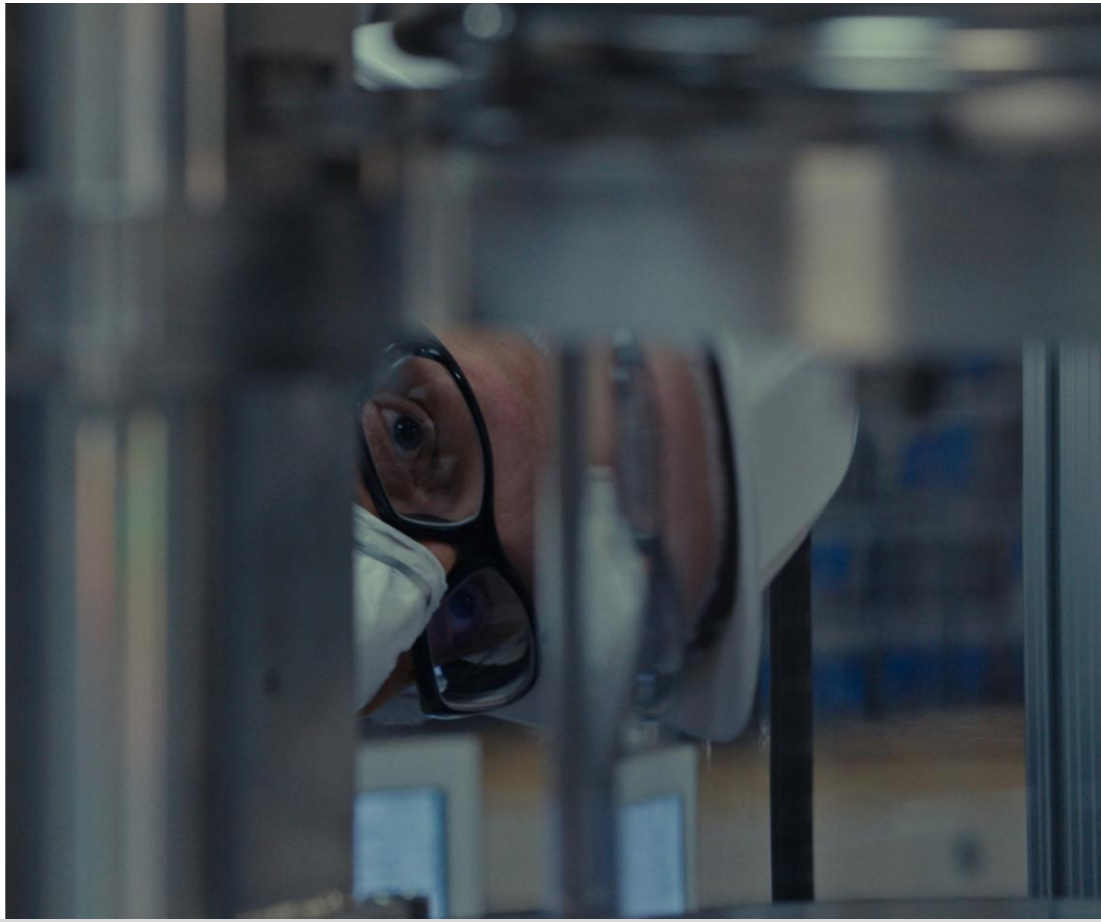
- The inner jar, outer jar, and bellows have been cleaned and put together.



# PICO-500 Status and Upcoming Work

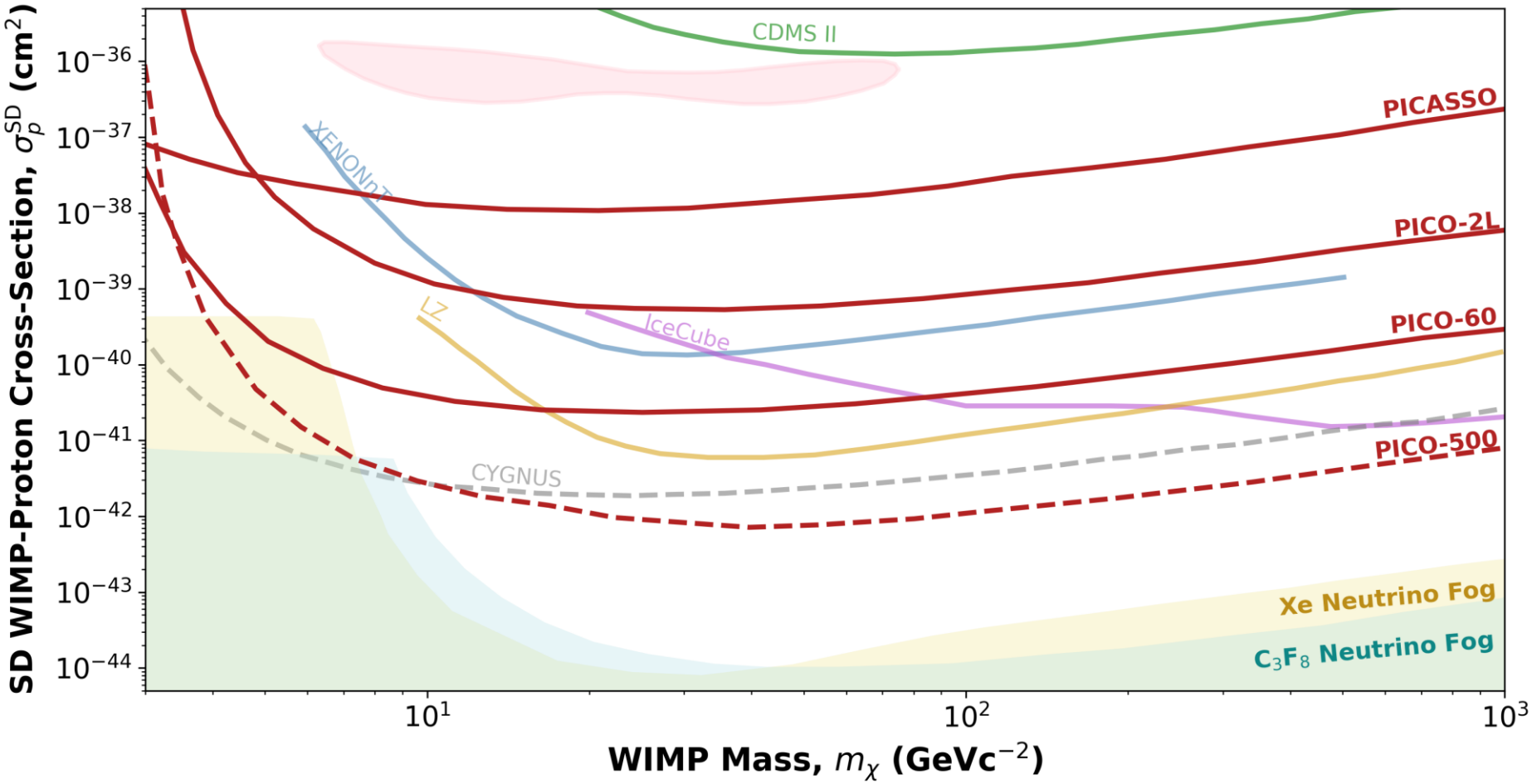
- Currently installing heating and cooling components as well as temperature sensors.
- After the PMP, will prepare heating components inside the pressure vessel, and do all plumbing and wiring.
- Expect to install the jars inside the pressure vessel by end of 2026 and start commissioning mid-2027.





# Projected Sensitivities

- Plan to run PICO-500 at a threshold of 8.2 keV for three years.
- PICO-500 is expected to set world-leading limits in the spin-dependent parameter space.




Neutrino fog from F. Ruppin, et al. (2014)
https://inspirehep.net/literature/1311290?

# Reflections on PICO

# Challenges with PICO-40L

| Dec. 2022 | Jan. 2023 | June 2023 | July 2023 | Nov. 2023 | Feb. 2024 | Sept. 2024 | Oct. 2024 | Mar. 2025 | July 2026 |
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- New detector designs (RSU) bring new challenges.
- Temperature control is hard.
- Chiller issues have kept us from taking data for a long time.
- But the vacuum jacket in PICO-500 should help with this.

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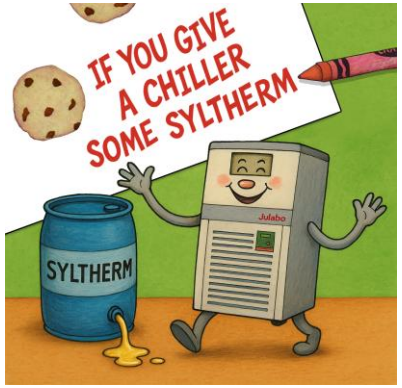


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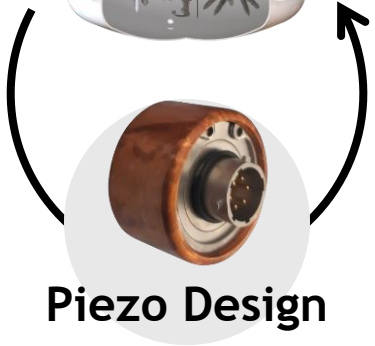

Piezo Design

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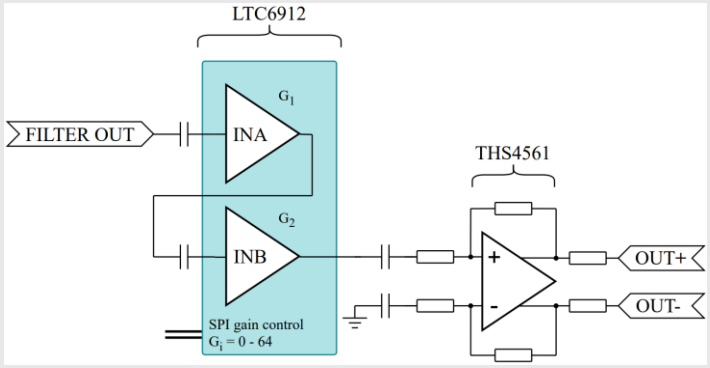


M. Agostini et al (2025)
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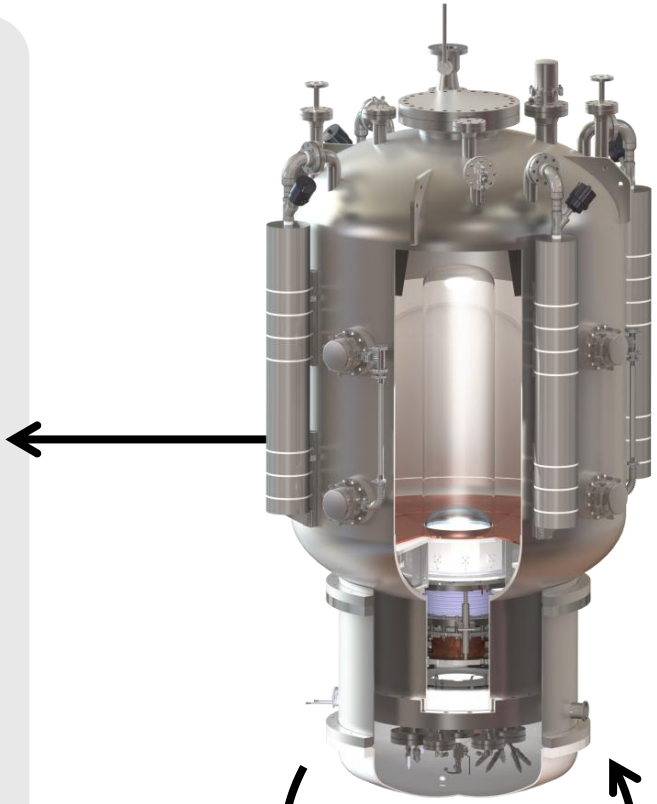

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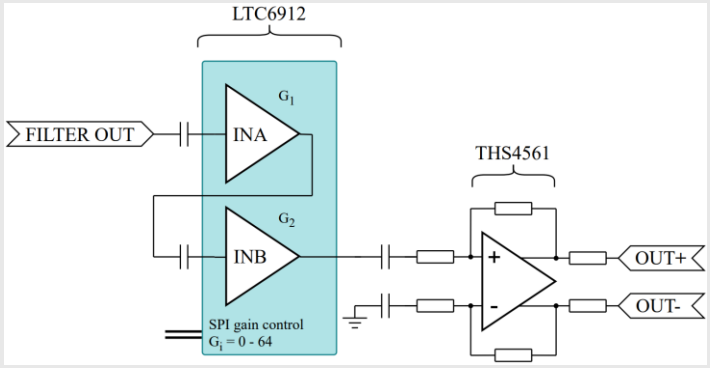


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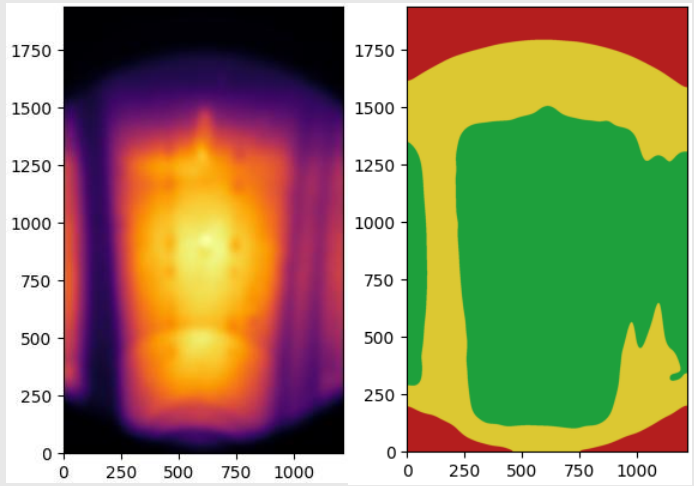
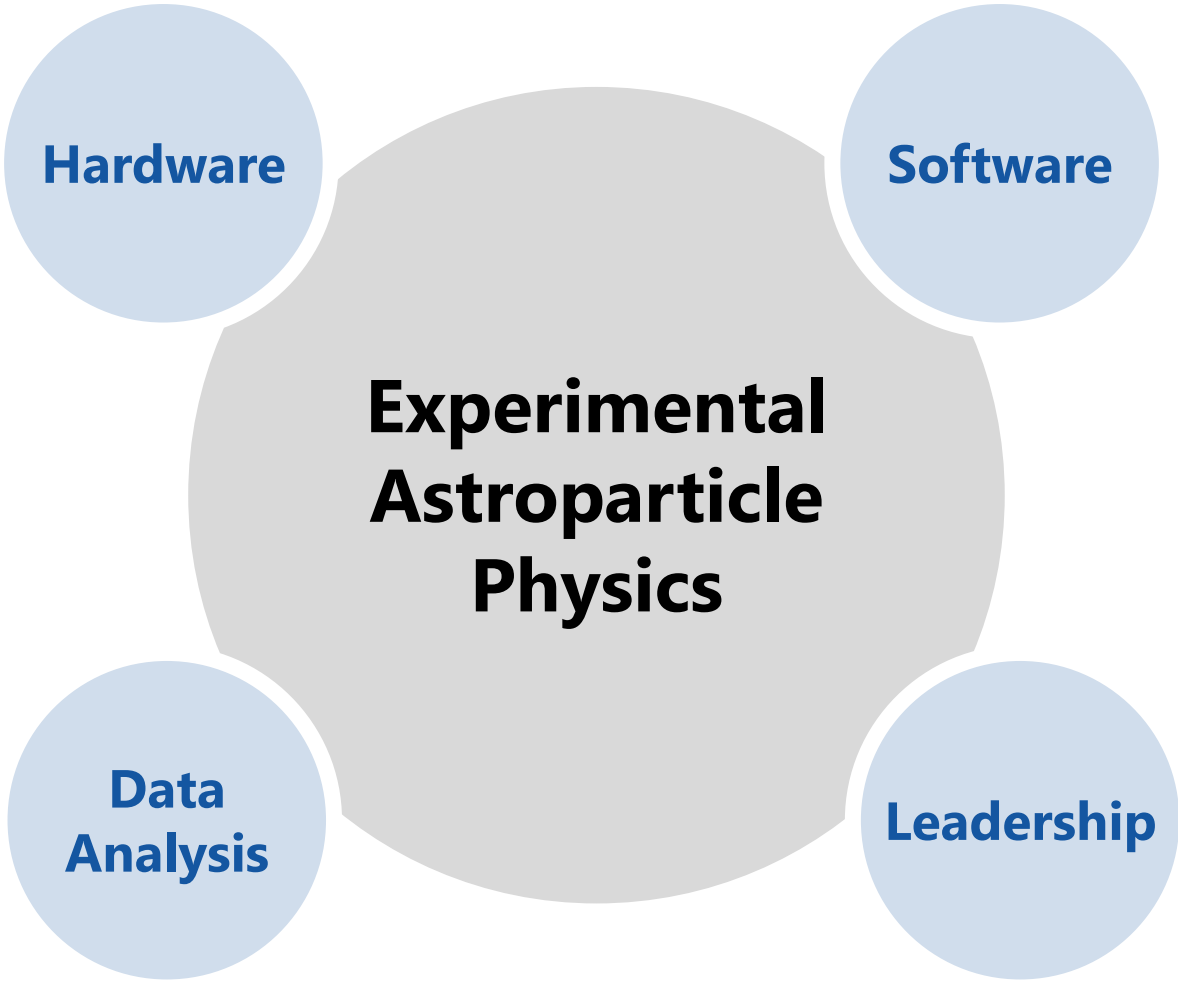
## Outside Astroparticle Physics




- Some interest in our bubble tracking optical software for medical imaging.
- PICO DAQ set-up could carry over to projects like physics of curling research, for example.

# Training the Next Generation

- A small collaboration means everyone works a bit on everything and develops diverse skills.



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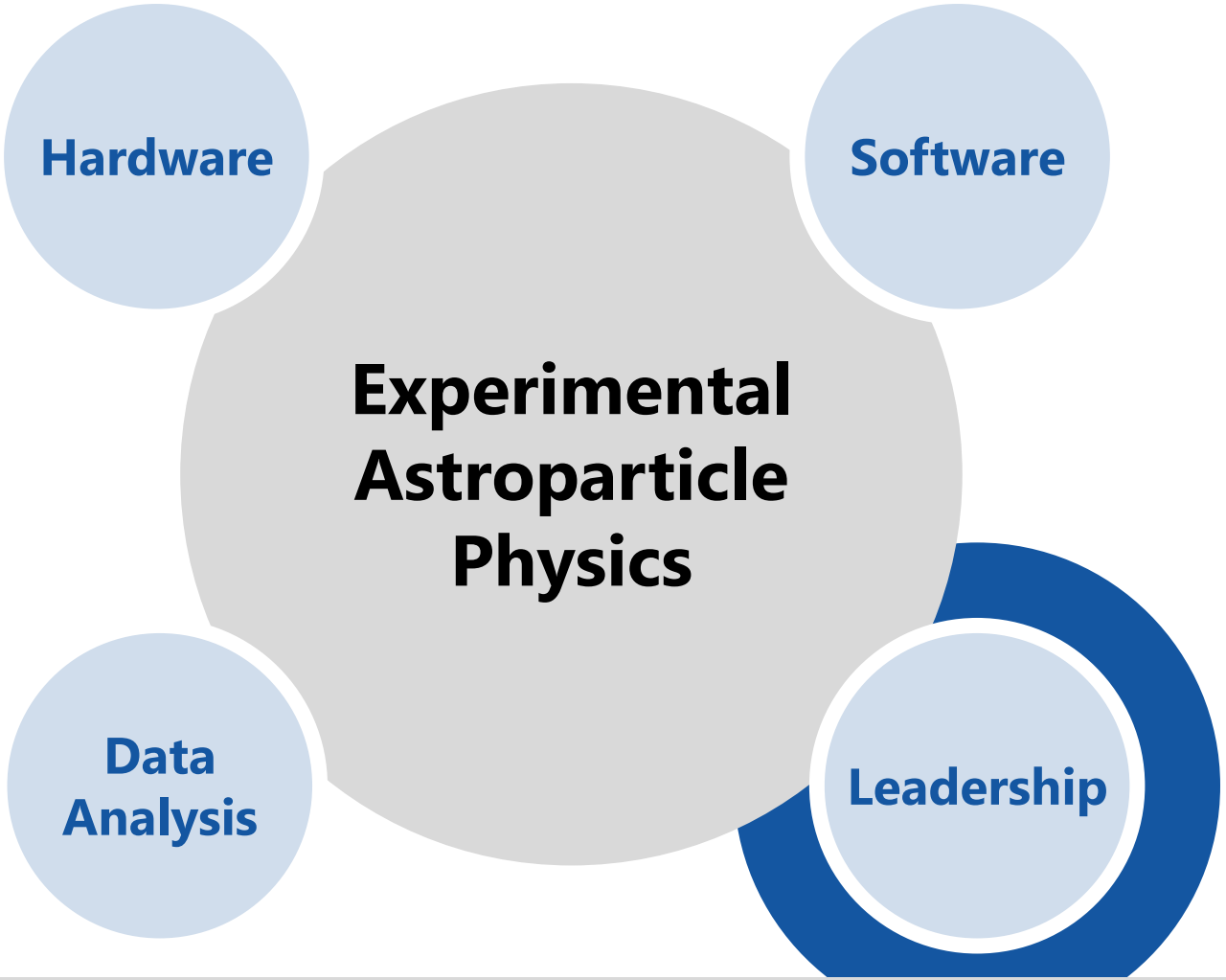

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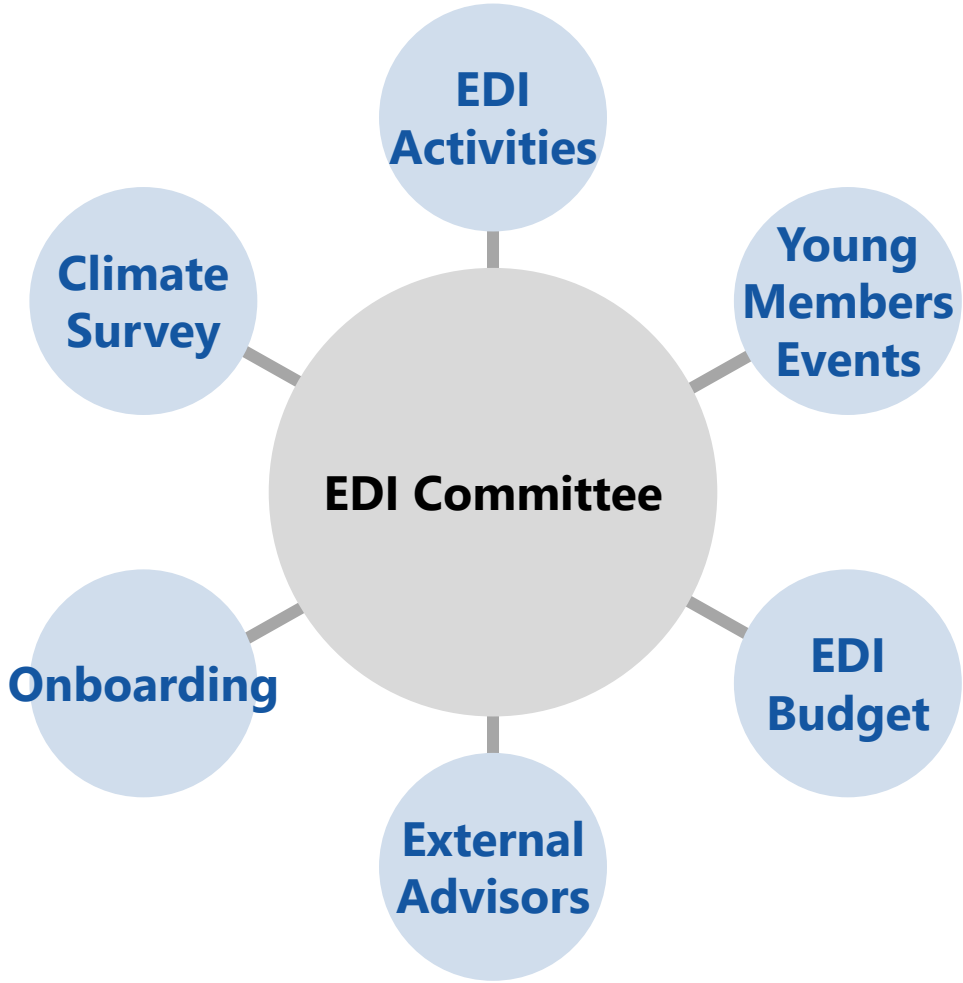

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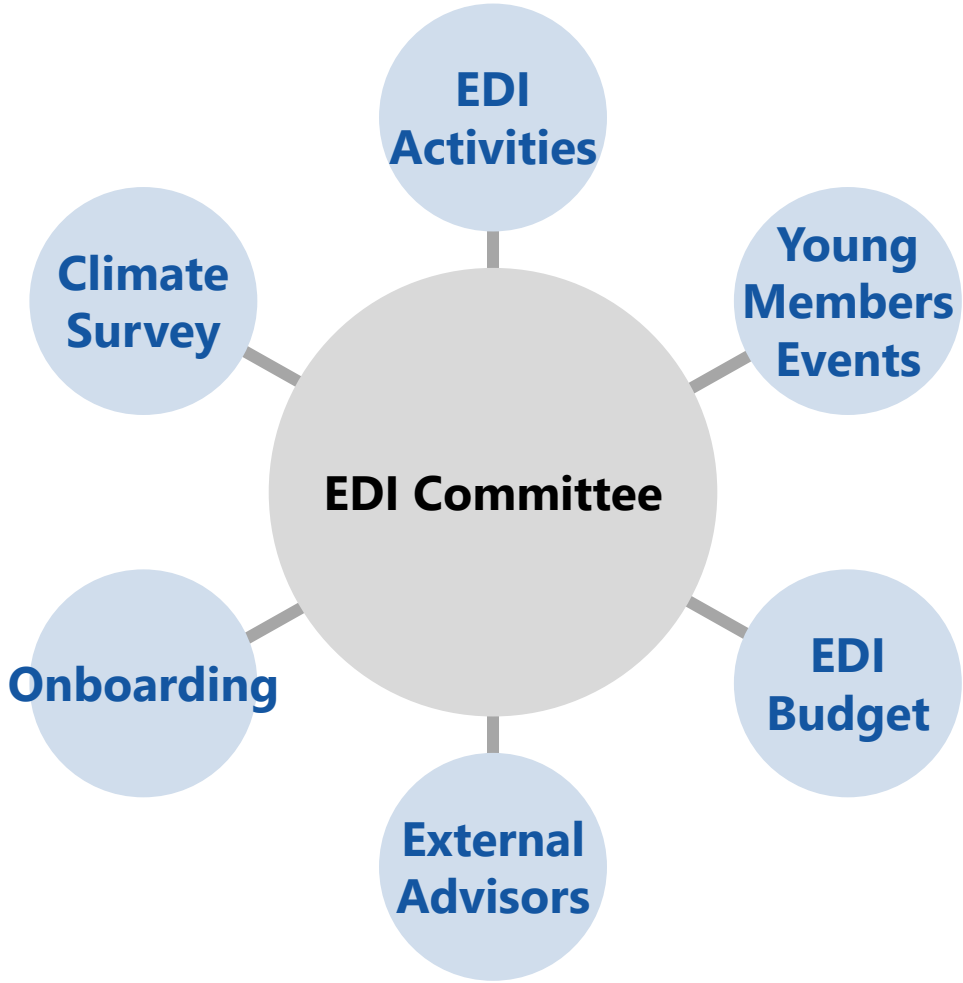

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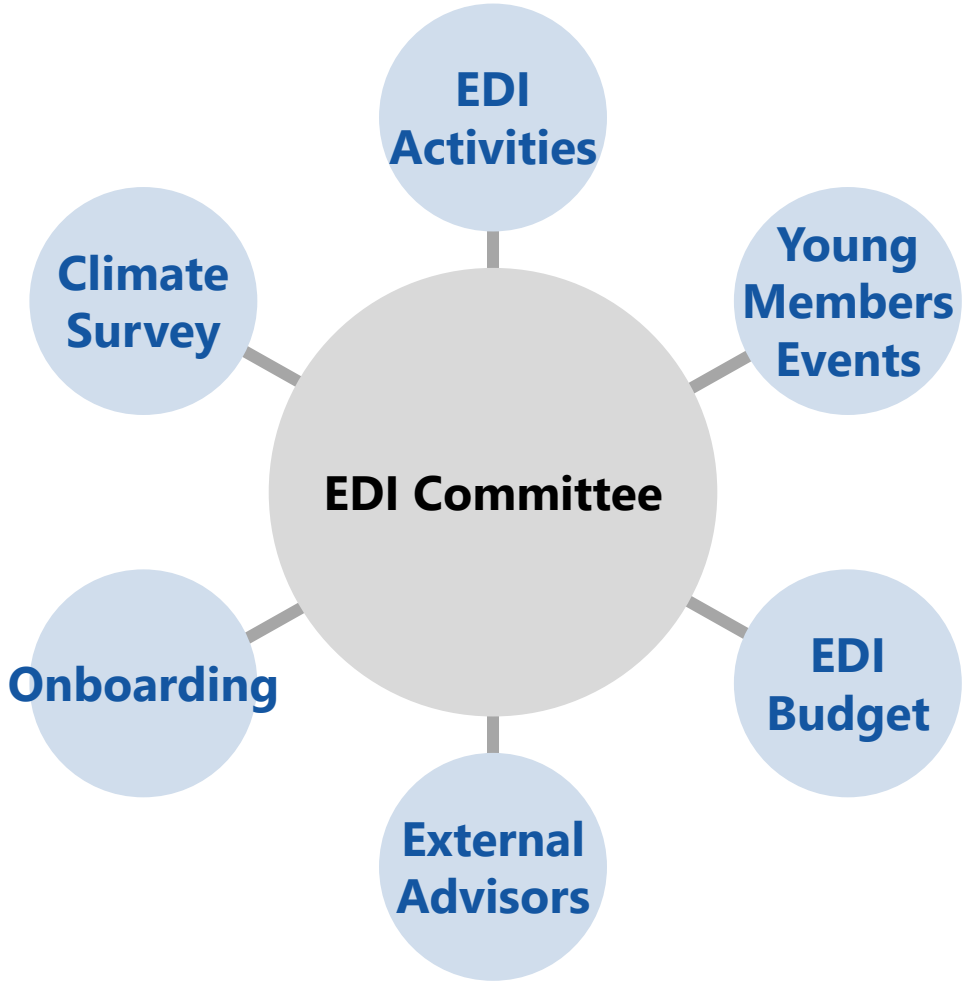
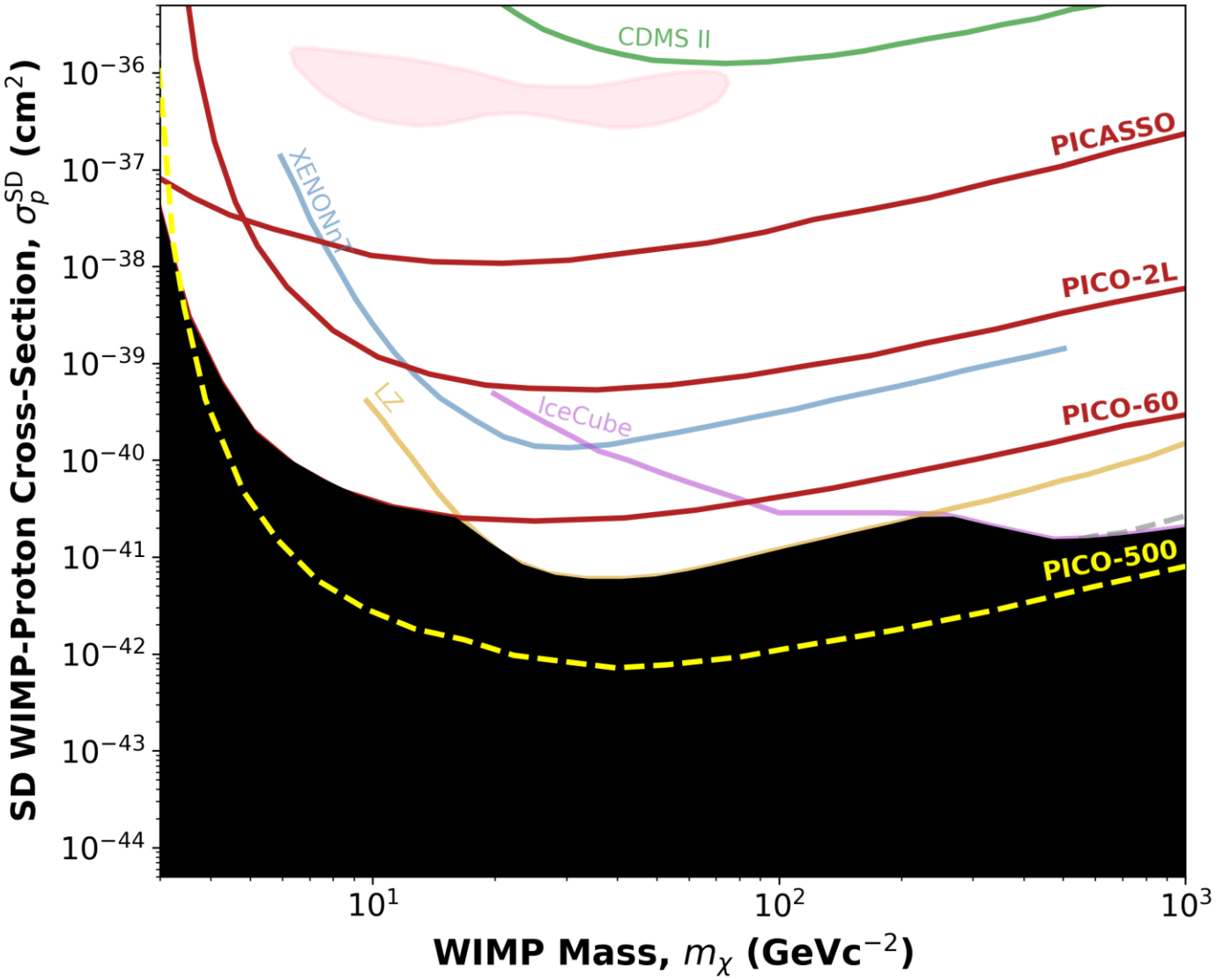


# Looking Ahead

- There is still considerable WIMP parameter space left to search.
- Low neutrino floor for $C_3F_8$ allows PICO to probe the SD parameter space more deeply than many other experiments.
- PICO also has the potential to search the low-mass region by using hydrogen-loaded target fluids such as $C_2H_2F_4$.
- Bubble chambers are a mature technology, offering low backgrounds for low cost.
- PICO-40L validates large-scale implementations of the RSU design that will be used for PICO-500.



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# PICO



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Universidad Nacional Autónoma de México, iF
R. Anderson, E. Vázquez-Jáuregui

Northwestern University
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Northeastern Illinois University
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Queen's University
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Pacific Northwest National Laboratory
I. Arnquist, C. M. Jackson, B. Loer

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Drexel University
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PennState
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SNOLAB
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Fermilab
P. S. Cooper, M. Crisler, A. Sonnenschein

České vysoké učení technické v Praze
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
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