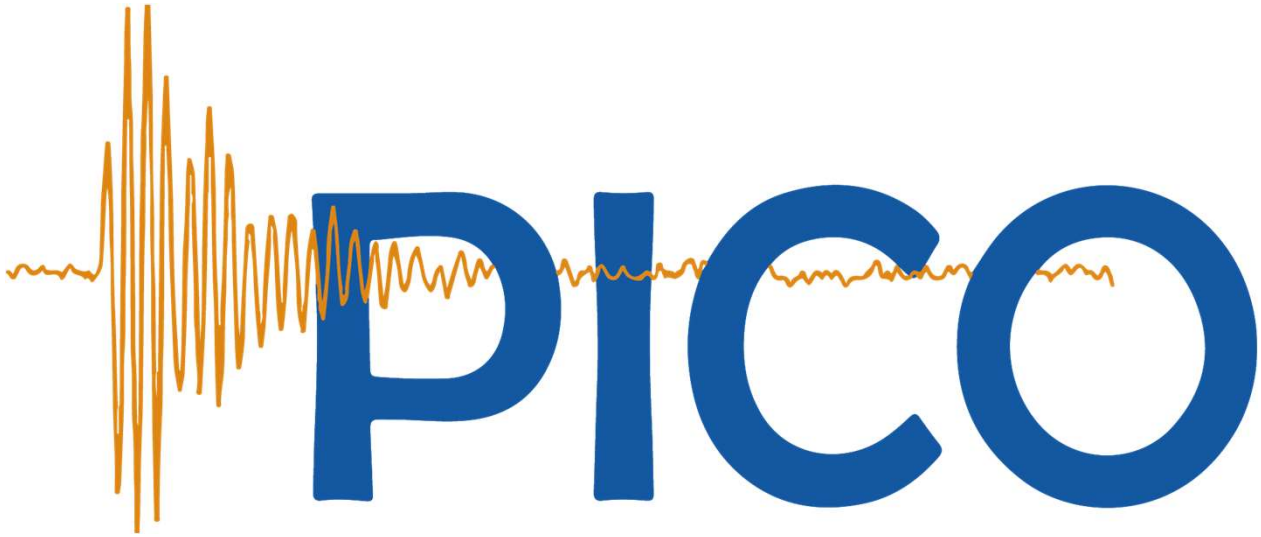
PICO-40L Status & First Data



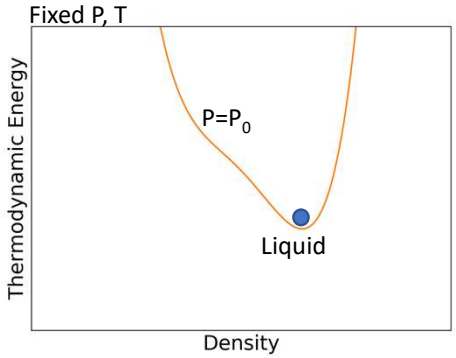
Colin Moore

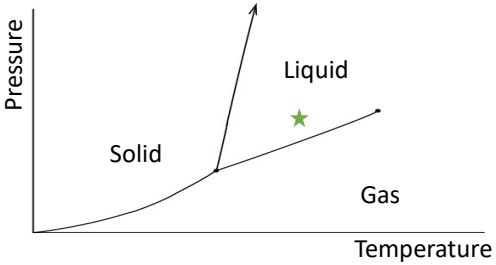
Queen's University

Aug 12, 2021

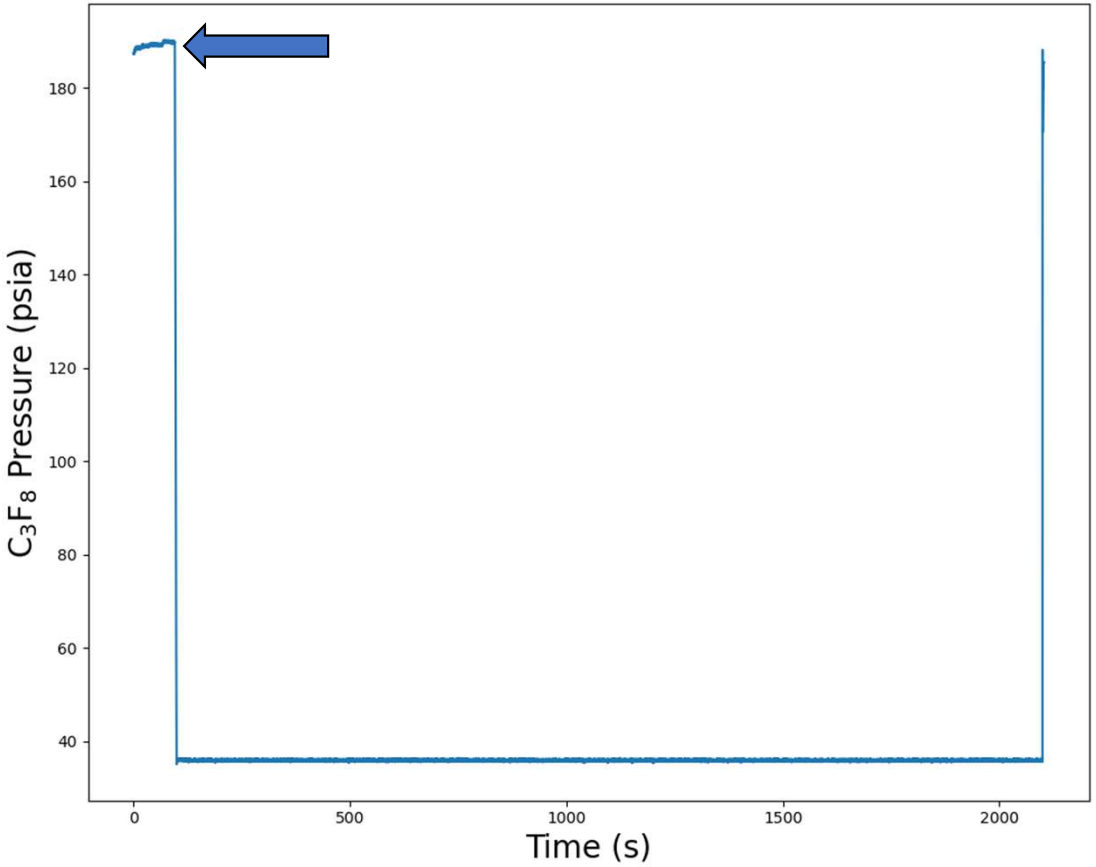
Bubble chamber basics

Begin compressed

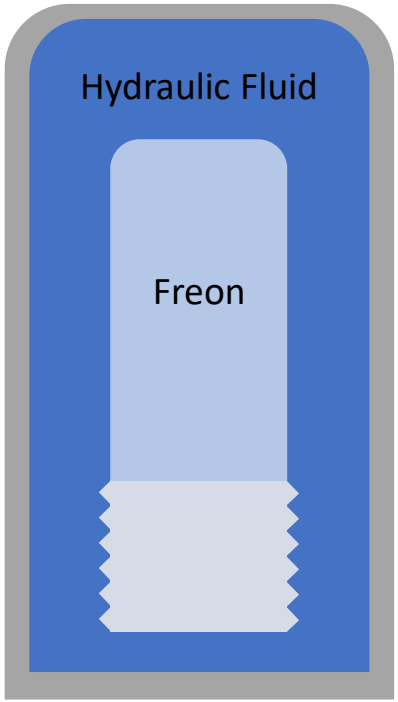




Pressure vs time for a standard event

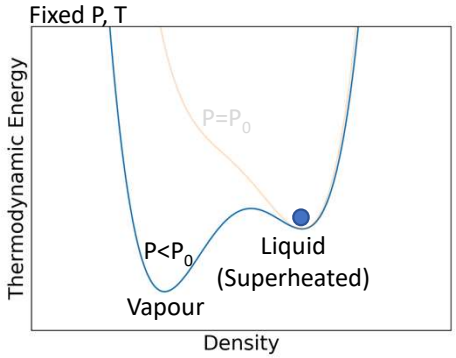


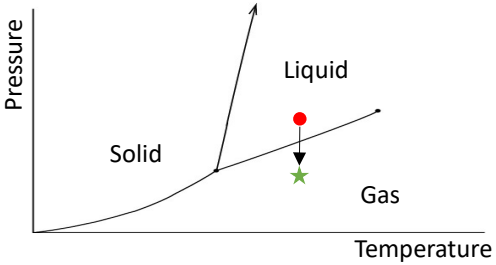
Pressure Vessel



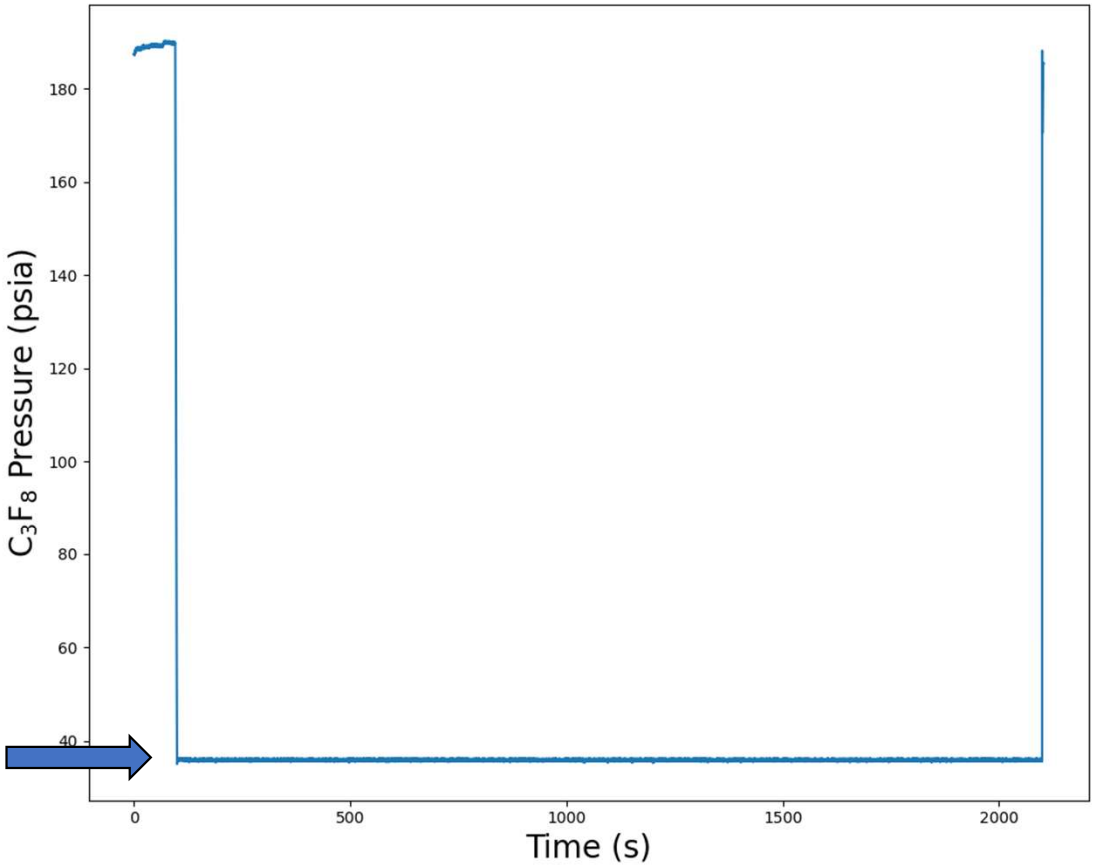
Bubble chamber basics

Expand to setpoint

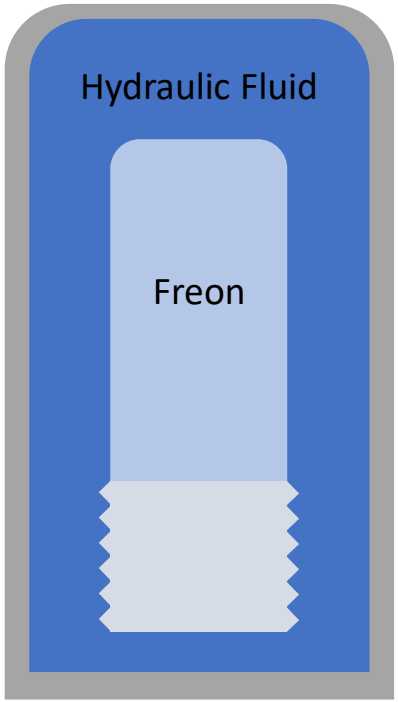




Pressure vs time for a standard event

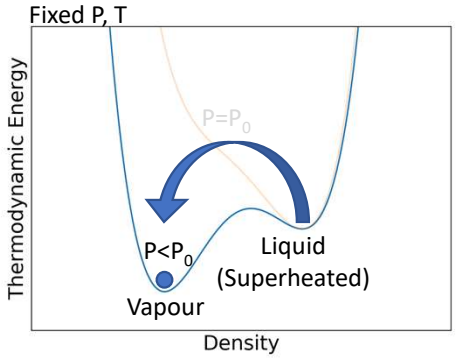


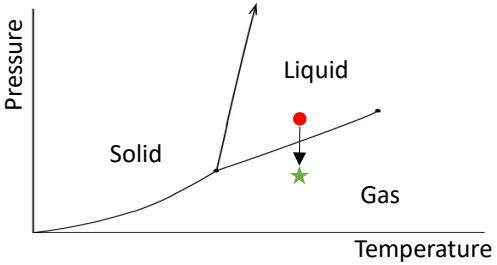
Pressure Vessel



Bubble chamber basics

Energy deposited in liquid





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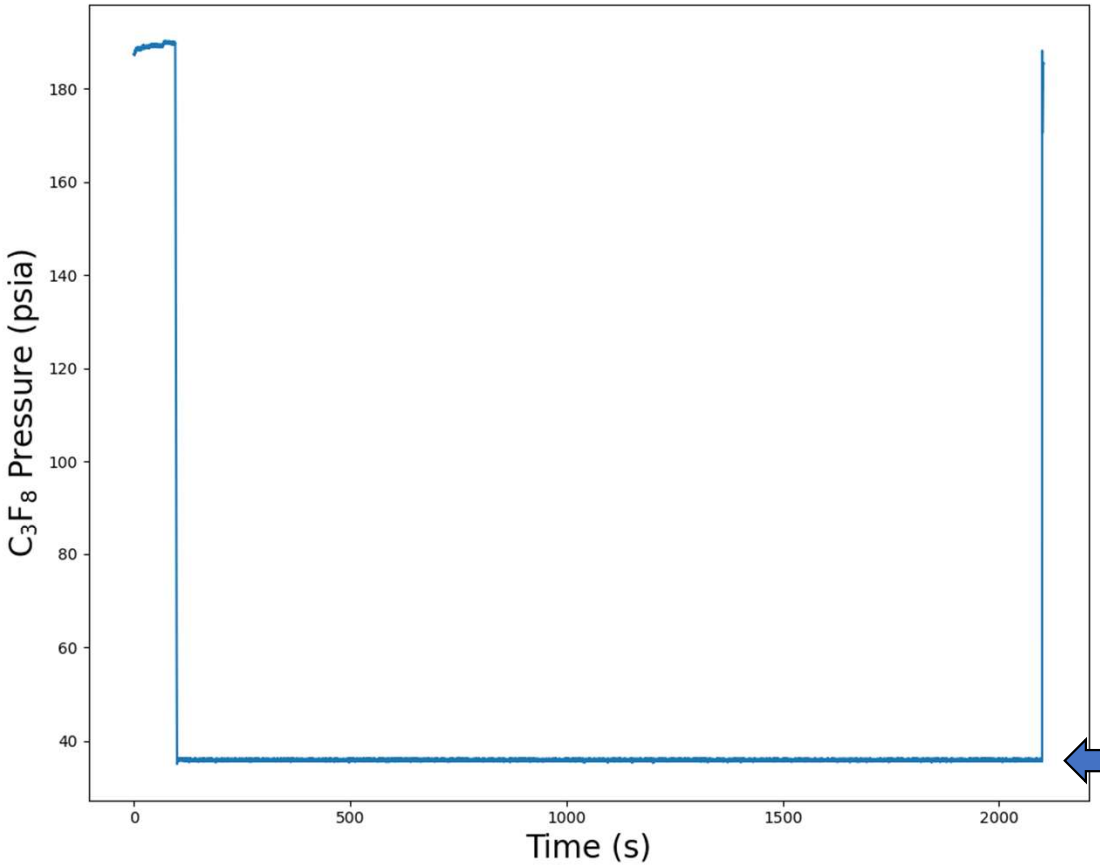
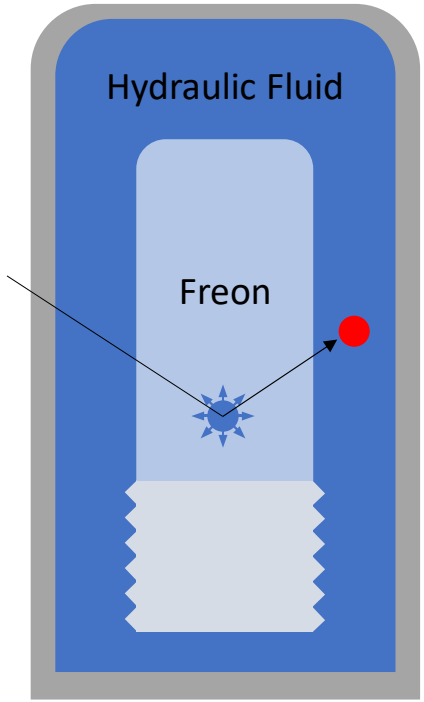
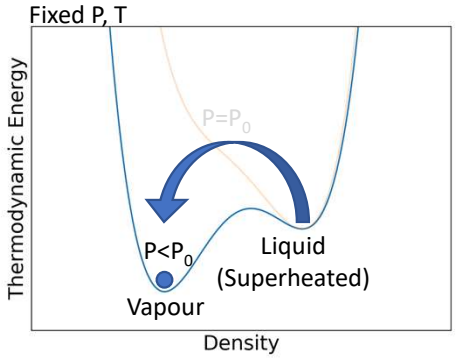


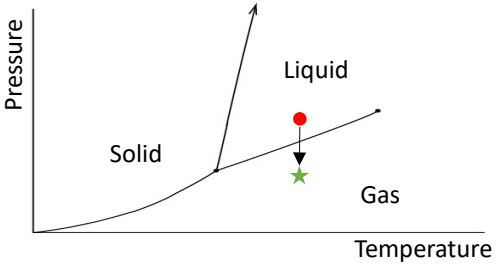
Pressure Vessel



Bubble chamber basics

Energy deposited in liquid





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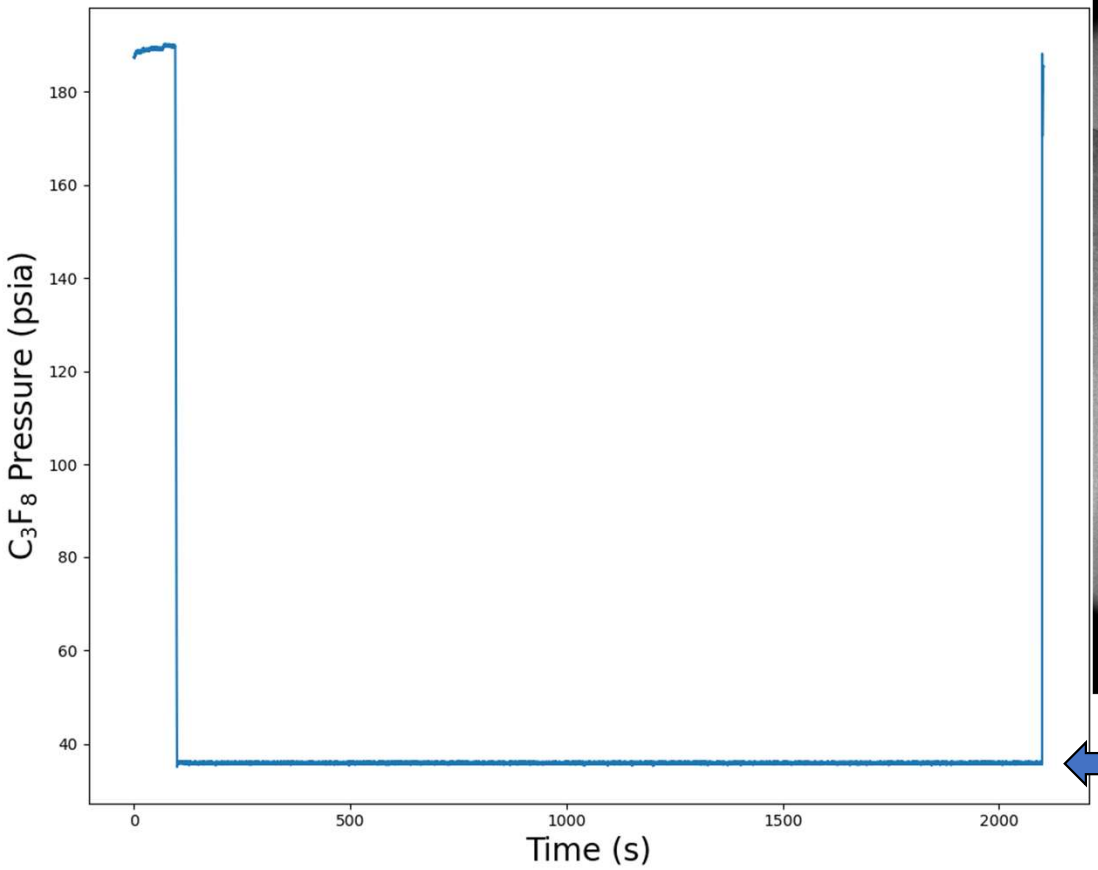
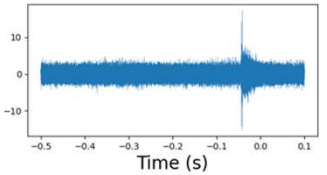
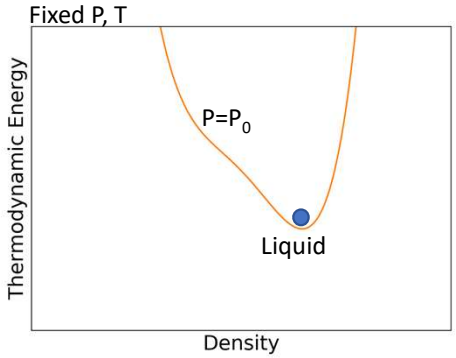
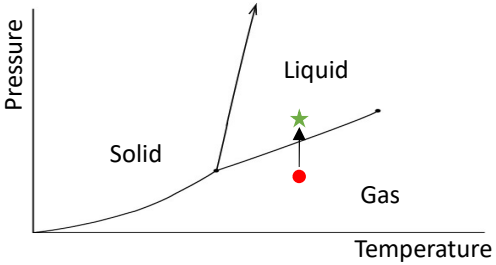




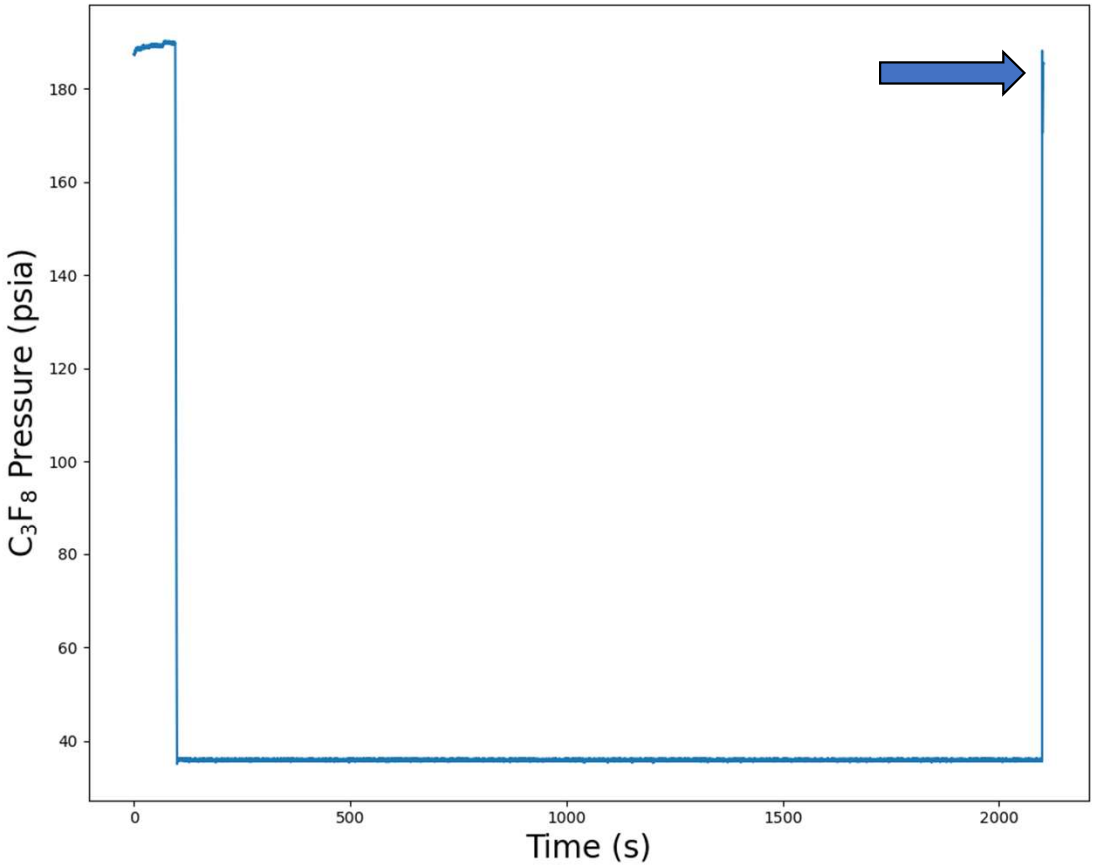
Bubble chamber basics

Recompress

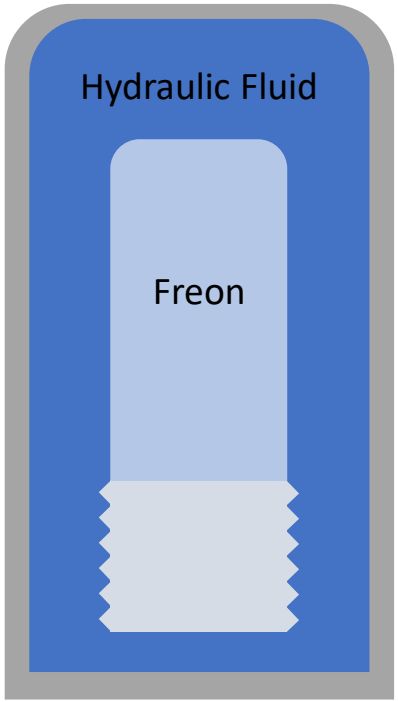




Pressure vs time for a standard event

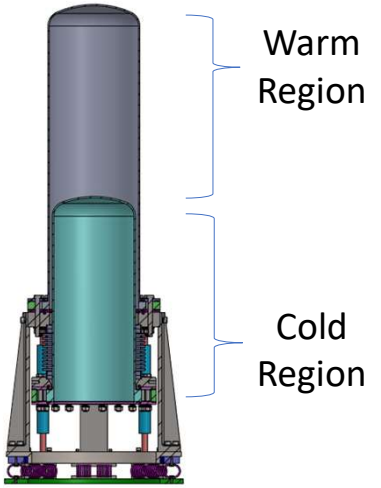


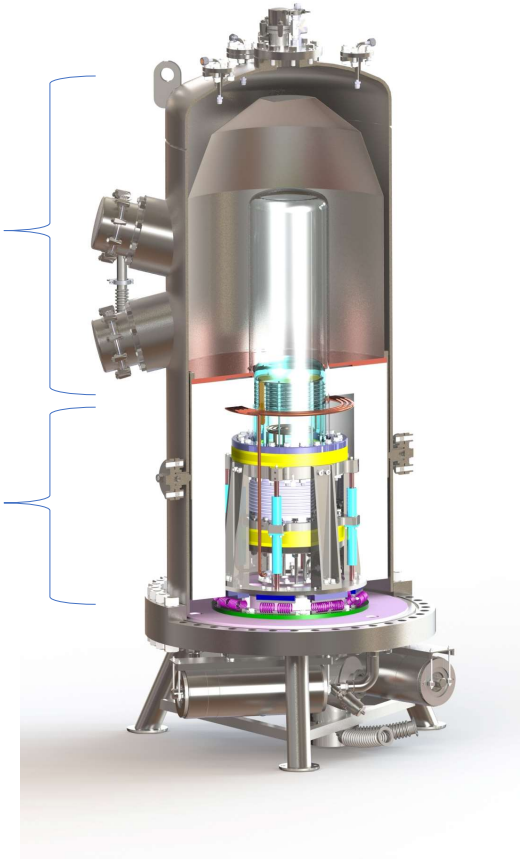
Pressure Vessel



PICO-40L

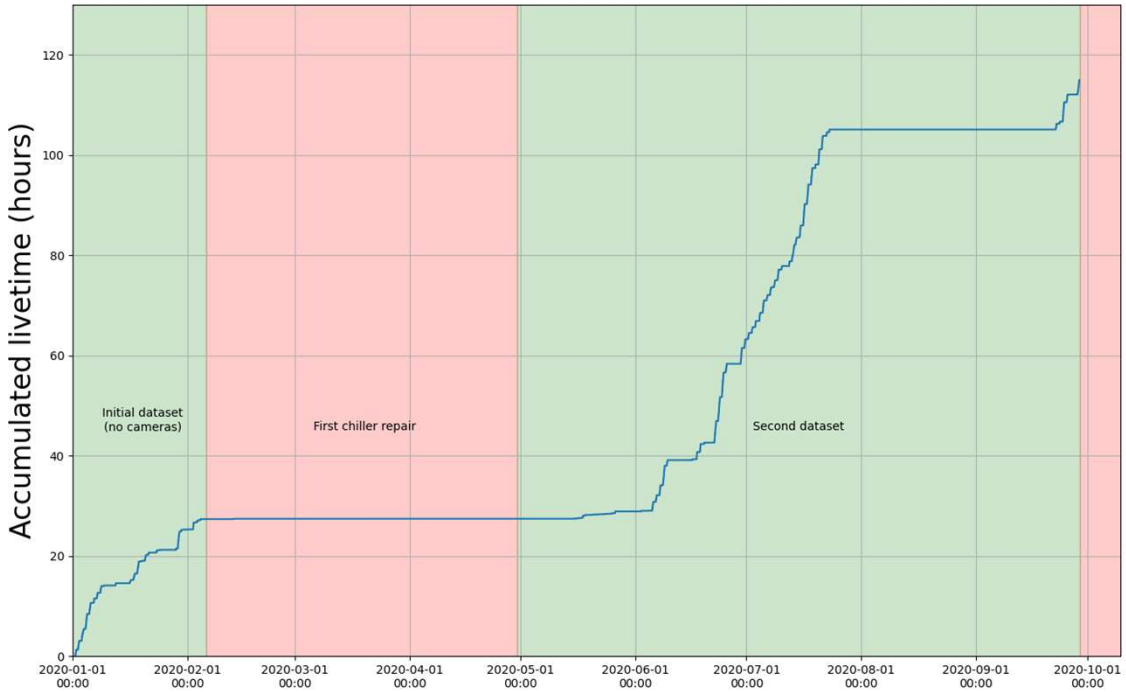
- Uses “Right-Side-Up” chamber design
- PICO-60 water buffer replaced by second inner jar
- Two thermal regions. At 30 psia:
  - Warm region (15°C): C_3F_8 is superheated
  - Cold Region (-25°C): C_3F_8 is liquid
- First large-scale use of RSU design
- Proof of concept for PICO-500





Current Status

- Issues with some subsystems prevented running Feb-May 2020
- June-July 2020, ~2500 events recorded (total livetime ~80 hours)
- September 2020, bottom chiller sent out for repair, halting running

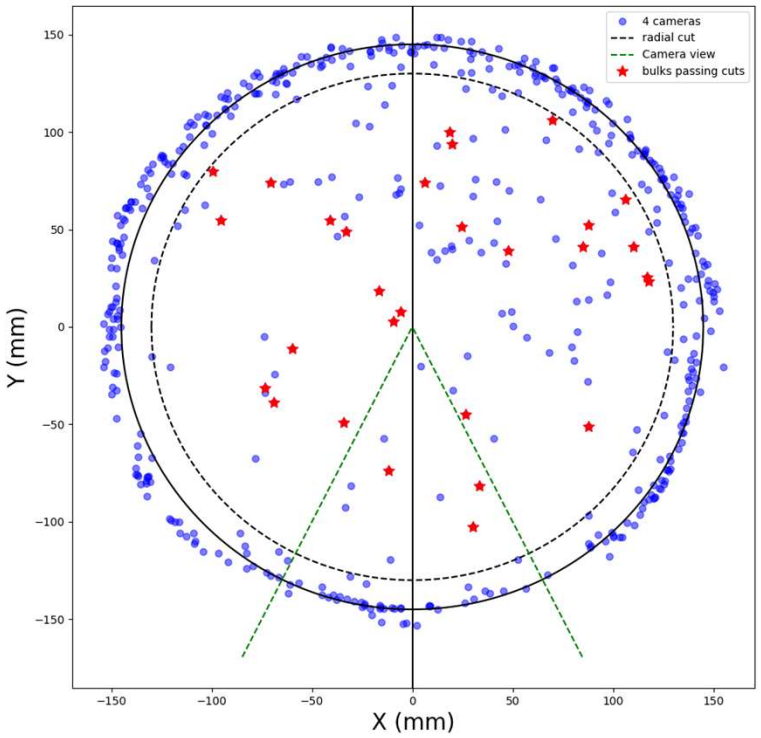


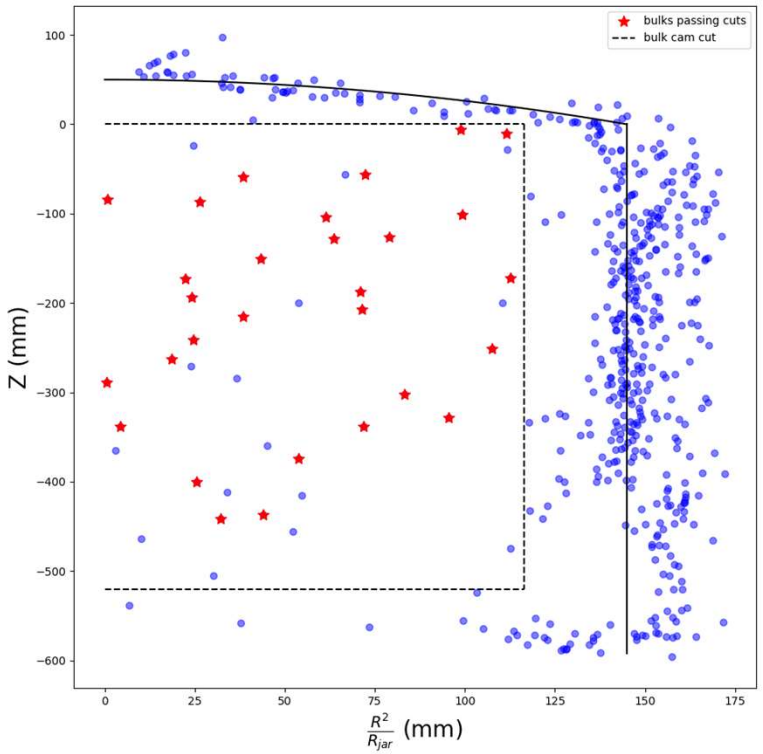
Current Status

- Issues with some subsystems prevented running Feb-May 2020
- June-July 2020, ~2500 events recorded (total livetime ~80 hours)
- September 2020, bottom chiller sent out for repair, halting running
- In March 2021, a leak formed between cooling coil and hydraulic volume
  - Inner vessel drained of freon
  - Pressure vessel drained of oil
  - Detector disassembled
- Taking this opportunity to upgrade some components (particularly the cooling system)
- Plan to be running by end of 2021

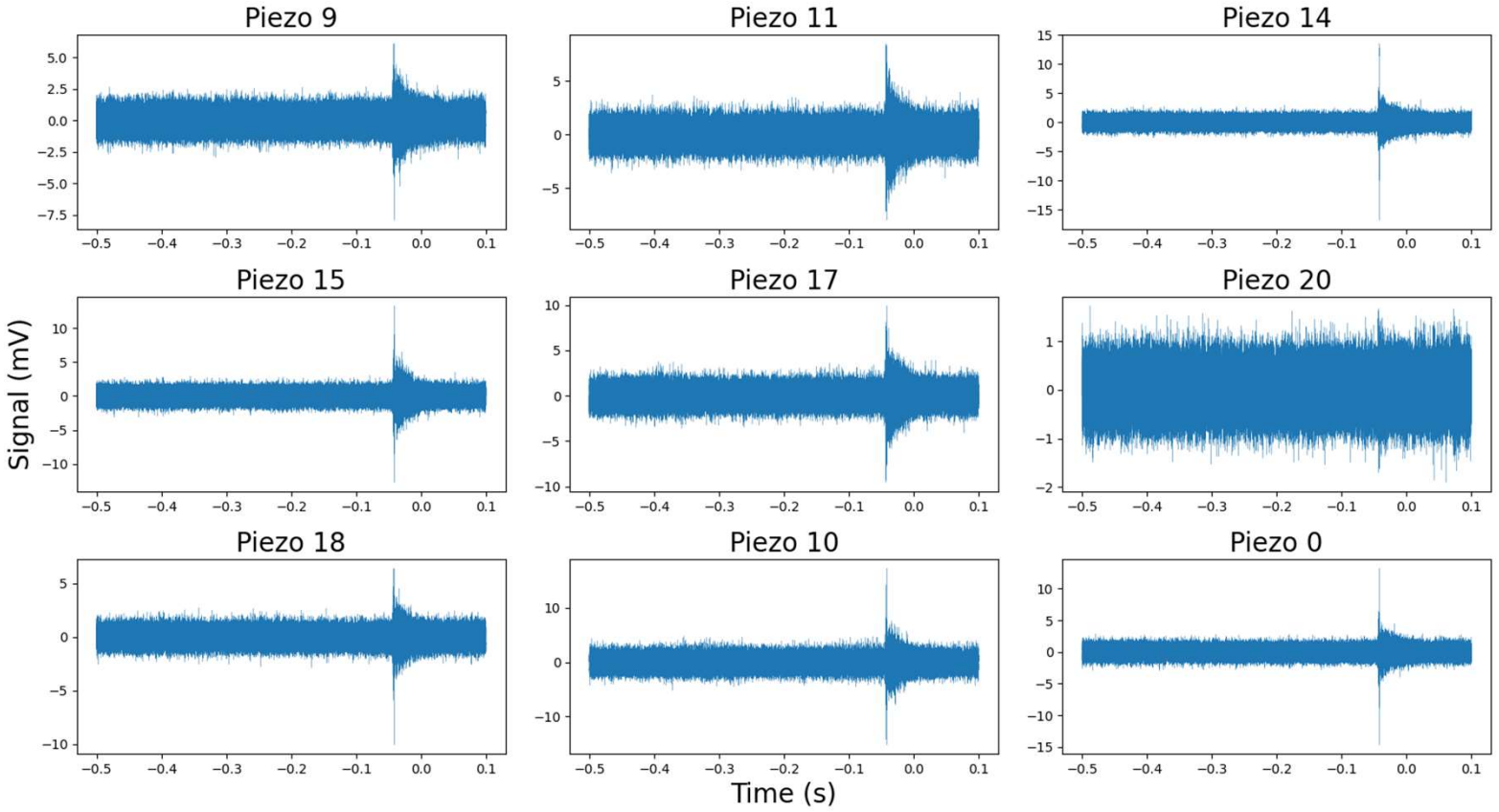
Successful 3D Reconstruction on Second Dataset

- Reconstruction from pixel positions and ray tracing



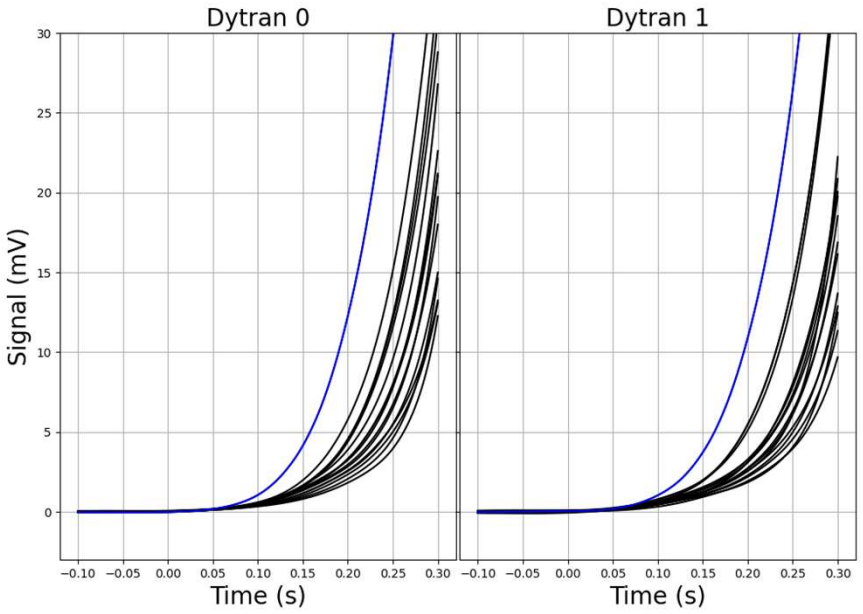


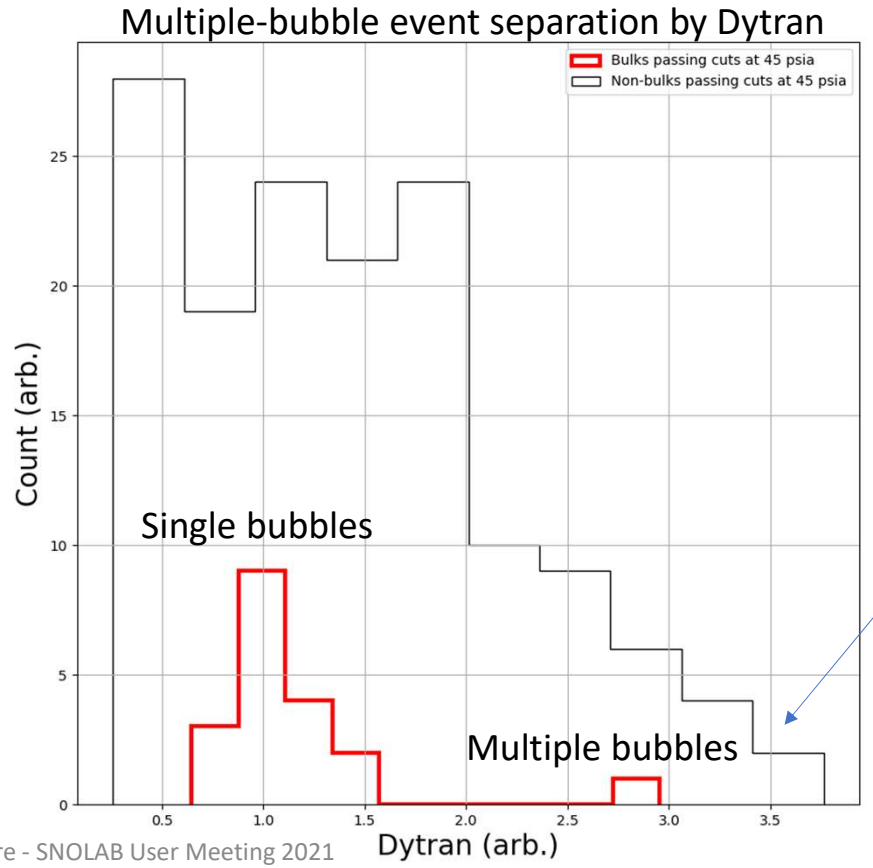
Strong Acoustic Response

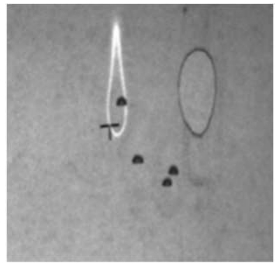


Multi-Bubble Discrimination in 45 psi Data

- Differential pressure transducers used to separate single- and multiple-bubble events



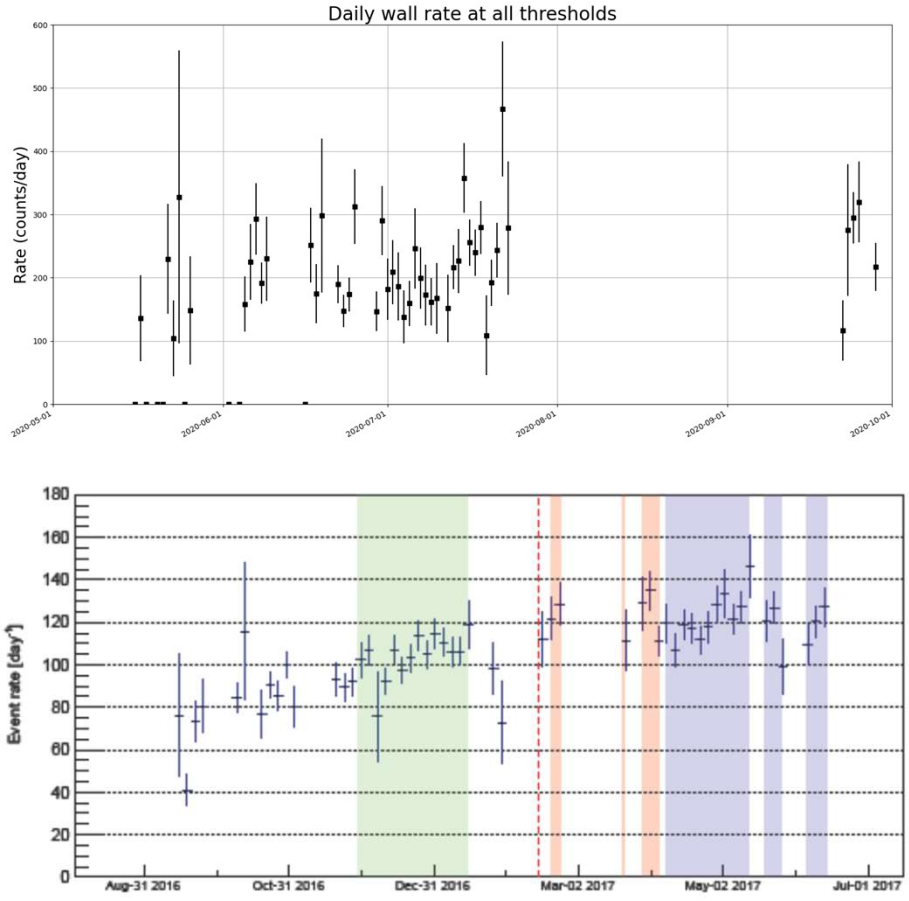




Wall Rate Higher than in PICO-60

- PICO-40L dataset (top):
  ~200 events/day
- PICO-60 dataset (bottom):
  100-120 events/day

- Treatment of quartz jars between 60 and 40L may have adversely affected jar surface
- The current jars will be replaced with untreated jars



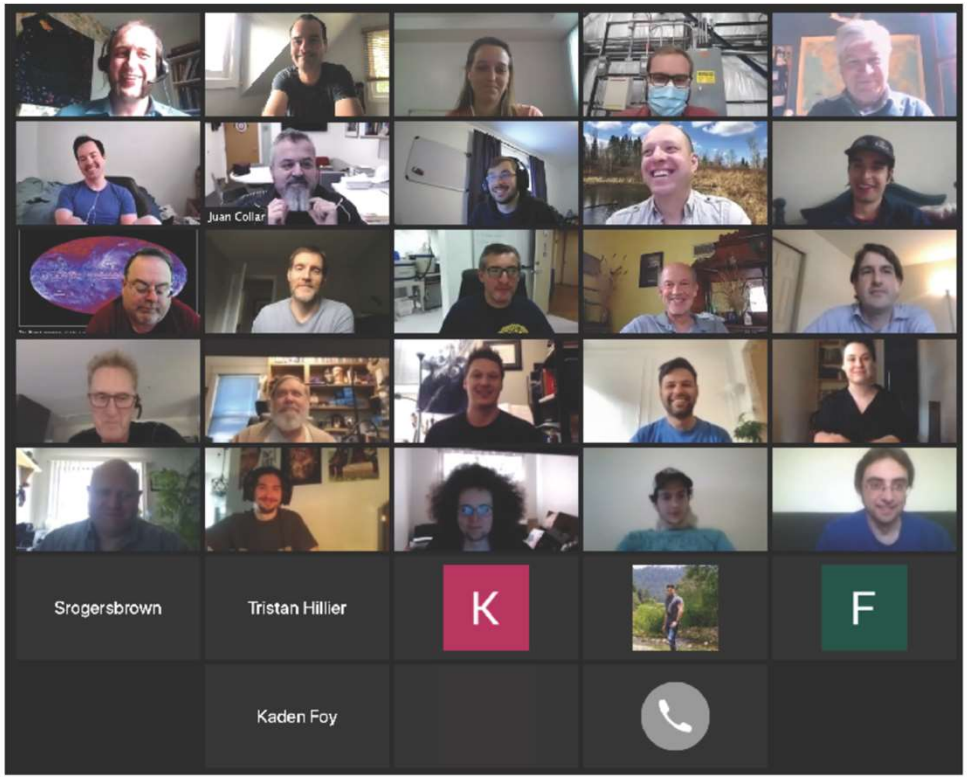
Conclusion, Current Work and Schedule

- First set of data has allowed for development of 3D reconstruction algorithms and preliminary Dytran and acoustic analysis

- Currently manufacturing new cooling coils to replace leaking ones
- Inner vessel being shipped to surface to replace jars

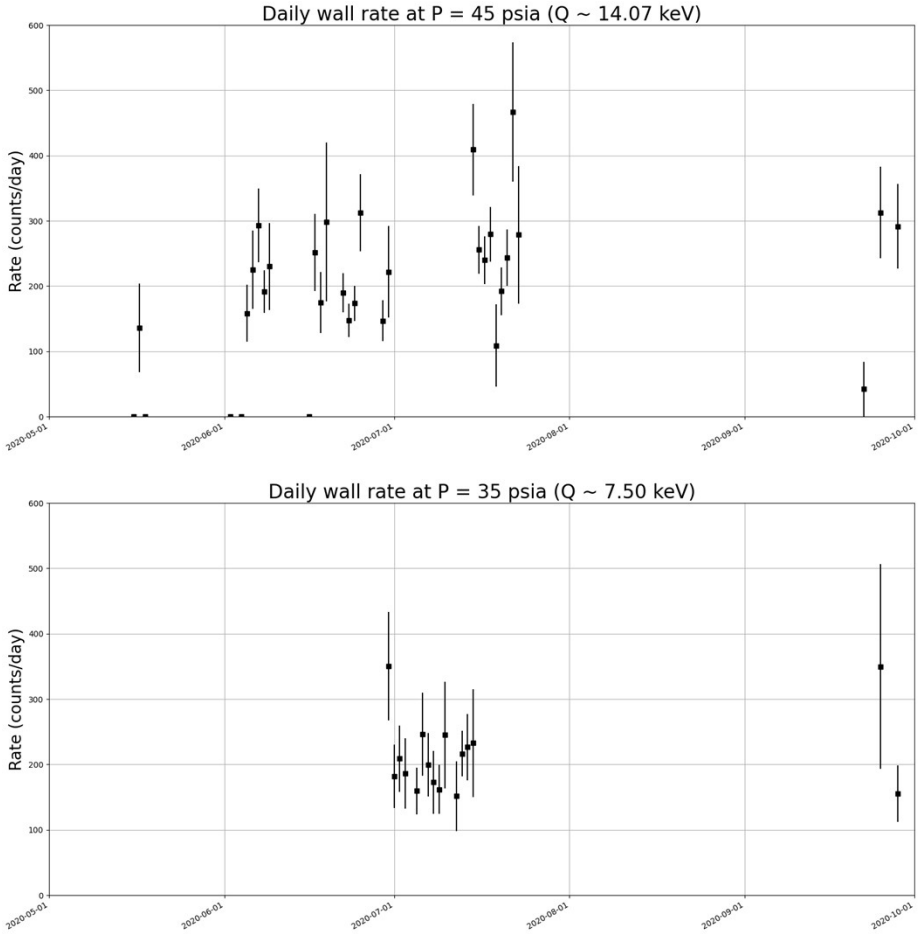
- Plan to have detector reassembled by end of the year

Thanks for listening!



Extra Slides

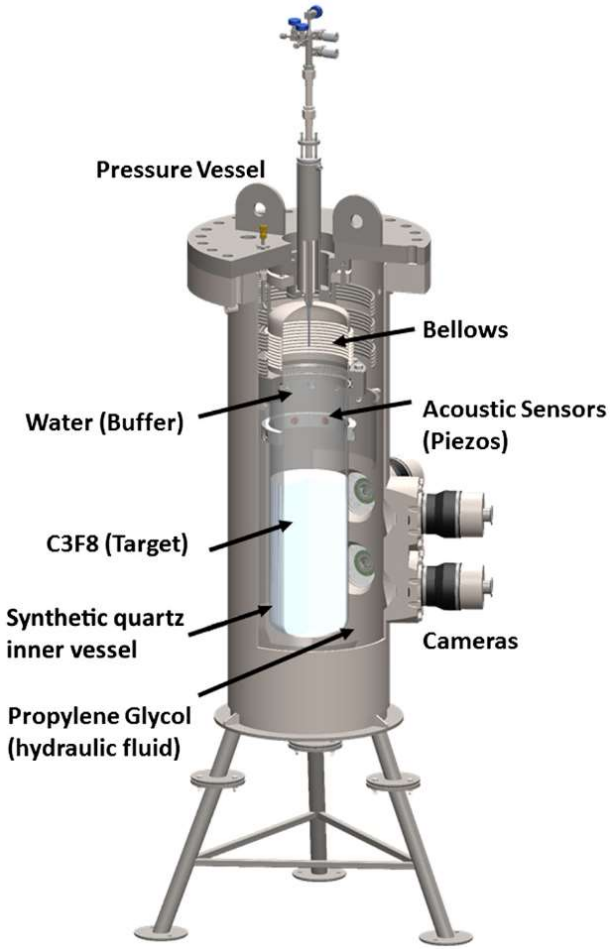
Wall rates at different thresholds



PICO-60

- Previous large-scale detector
- Active target: C_3F_8
  - Spin-dependent sensitivity due to fluorine
- Operated at SNOLAB
- Used same design as all previous PICO bubble chambers
- Produced world-leading WIMP-proton limit

- Water buffer and bellows caused issues with spurious nucleation
  - Particulate entering active region
  - Water and freon mix



How are Bubbles Formed?

- Any bubble larger than the (fluid-specific) critical radius will continue to grow to macroscopic size

$$r_c = \frac{2\sigma}{P_b - P_l}$$

  - PICO's active fluid: r_c = 20 nm
  - How does a bubble grow to the critical radius?

- Energy threshold:

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

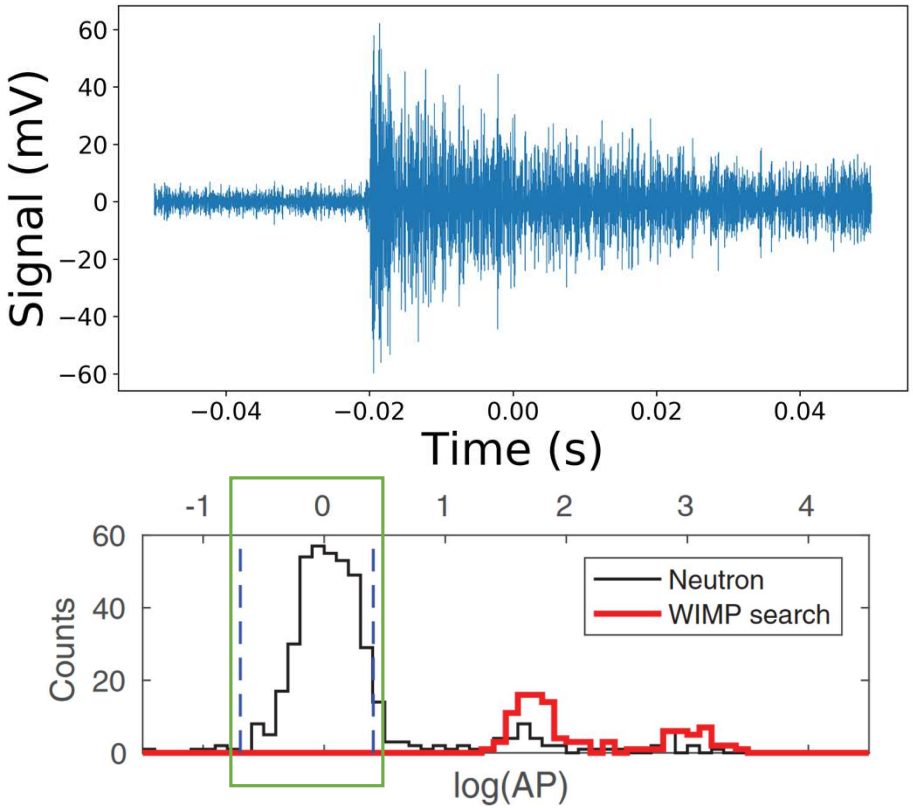
Surface tension | Converting liquid to gas | Expansion of vapour

- Energy deposited causes region to "literally explode into bubbles of larger than critical size"

What does PICO data look like?

Optical

Acoustic



WIMP Search Region