PNNL Dark Matter Bubble Chamber

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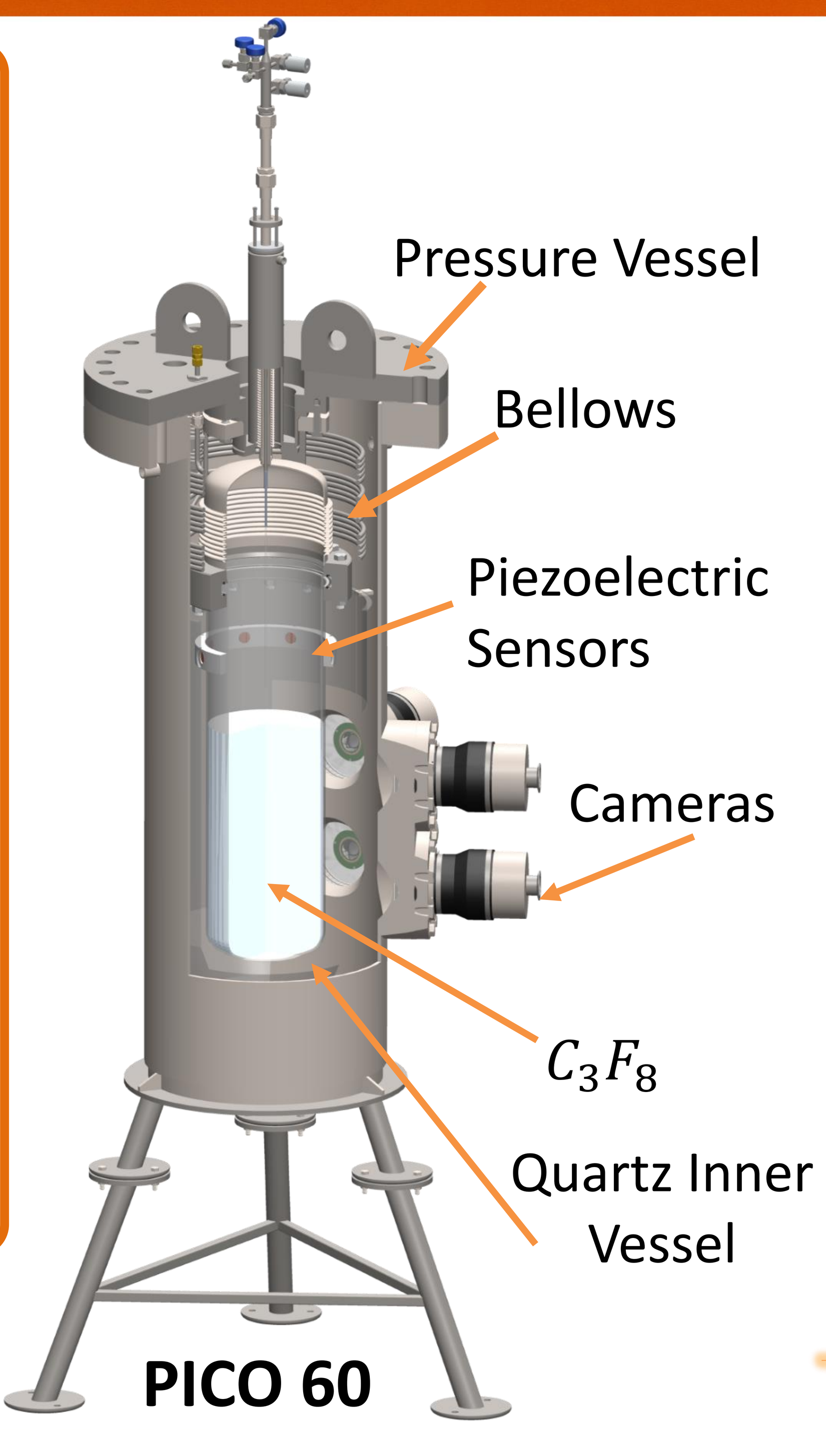
Overview

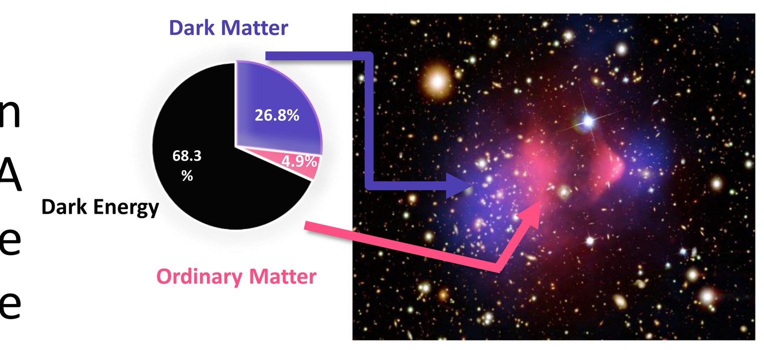
The Pacific Northwest National Laboratory (PNNL) prototype bubble chamber addresses issues encountered with the current PICO dark matter search detectors and improves the functionality of future PICO experimental designs by…

- Simplifying the interface between the hydraulic pressure controls and the target vessel.
- Altering the standard chamber design such that it can be easily exchanged and replaced with various vessel sizes and materials.
- Generating and validating data for acoustic modeling and machine deep-learning development.
- Allowing the system to utilize other target fluids.
- The chamber itself is monitored by 200 fps cameras adapted with nucleation threshold trigger algorithms.
- The chamber vessel is monitored by a series of piezo-electric acoustic sensors.



PICO 60

Introduction to Dark Matter Search



The dark matter problem is fundamental in nature and elusive in particle physics. A survey of the total mass of the universe indicates that only 5% of all matter in the observable universe is baryonic or conventional matter.

- The majority of the matter in the universe, which would account for the observed gravitational interactions, remains unidentified.
- This unidentified matter is difficult to observe because it does not interact with the electromagnetic or strong nuclear forces.
- The observations of galactic rotation and mass distribution in the universe strongly indicates the presence of dark matter.
- PNNL's bubble chamber prototype will be used to design experiments to detect non-baryonic, Weakly Interacting Massive Particles (WIMPs).
- The detection of non-baryonic matter would help to explain the nature of the universe and why matter and galaxies are able to form in the way they do.

Prototype System Design

Warm zone

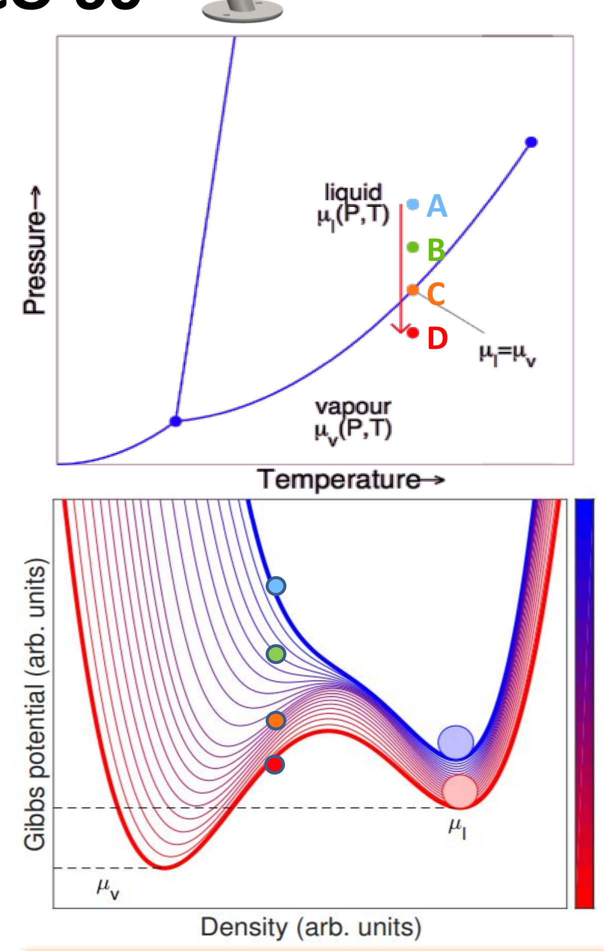
- WIMPs interact with the C_4F_{10} nuclei and bubbles begin to nucleate.
- Piezoelectric devices and cameras capture the event and data is stored.

Cold zone

- The bellows pipe compresses/expands the $C_4\ F_{10}$ in the warm zone.
- Increasing and decreasing pressure here allows for bubble nucleation and collapse.

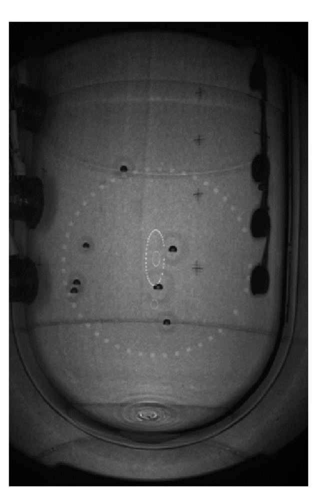
Hydraulic cart

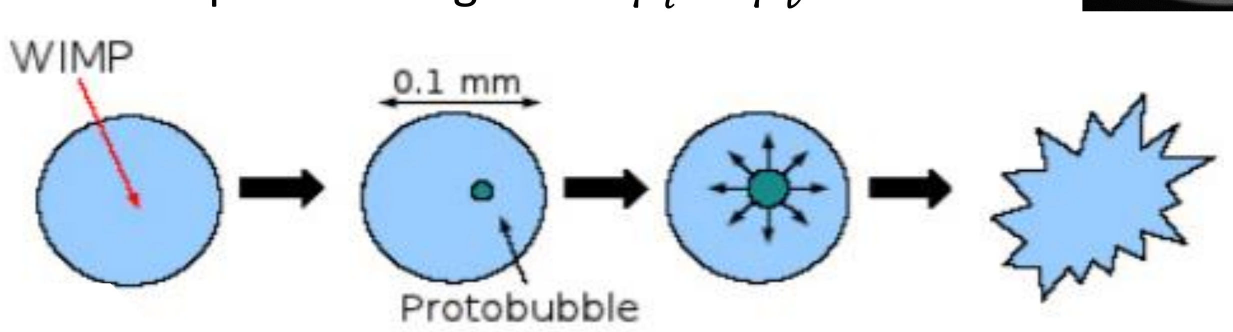
- Regulates pressure of the cold zone by compressing and expanding a bellows pipe.
- Solenoid valves and pressure regulators switch high pressure into low pressure which is used to control the compression and expansion of a bellows pipe.



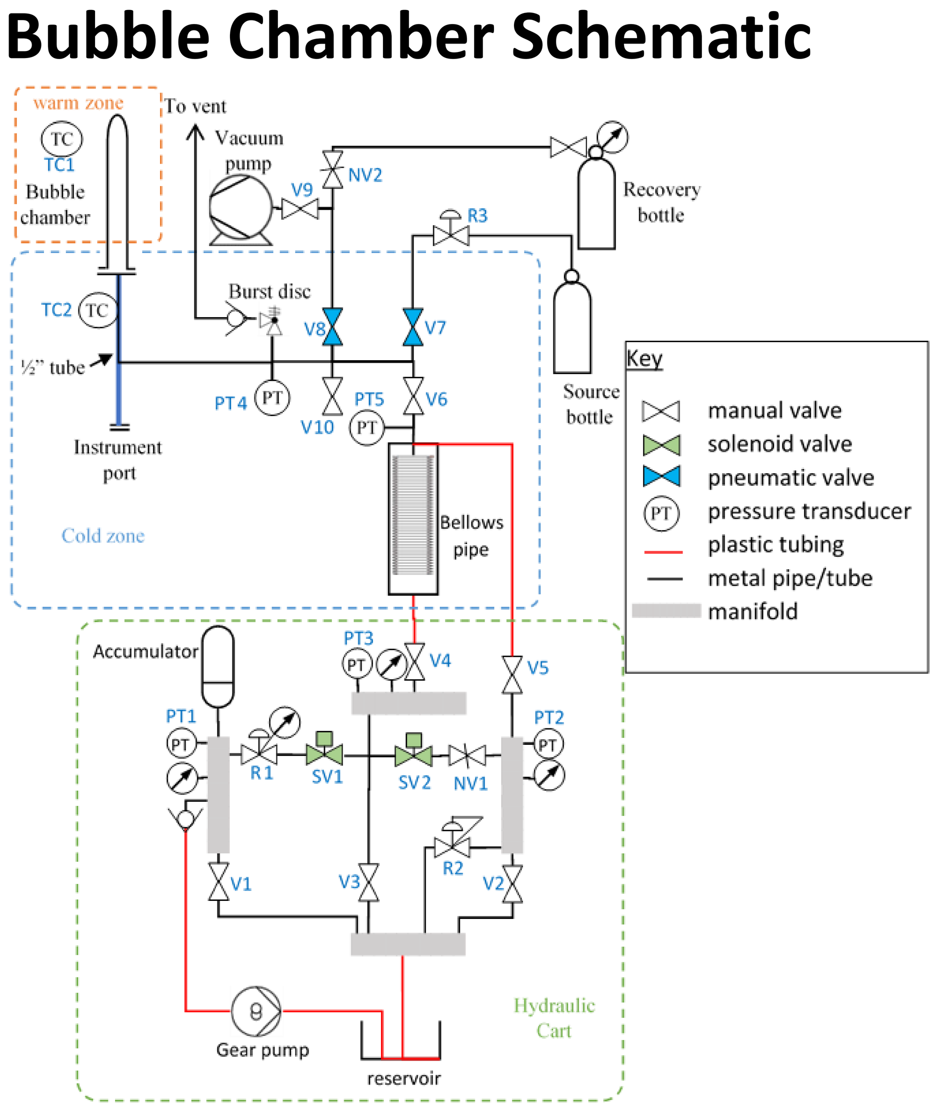
Bubble Nucleation in the Chamber

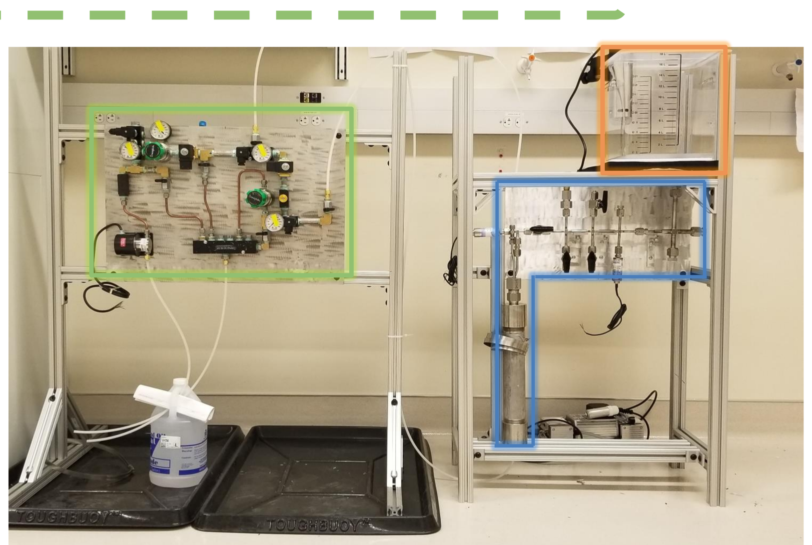
- The target fluid is held at a temperature greater than the boiling point for that liquid.
- The phase diagram to the right (top) shows the transition of a fluid from a liquid (blue) to a superheated state (red).
- In a metastable state, if sufficient energy is added to the system the superheated fluid becomes vapor.
- The energy provided by a WIMP, alpha, or neutron particle can be sufficient to overcome the energy threshold required to cause a phase change from $\mu_l \rightarrow \mu_v$.

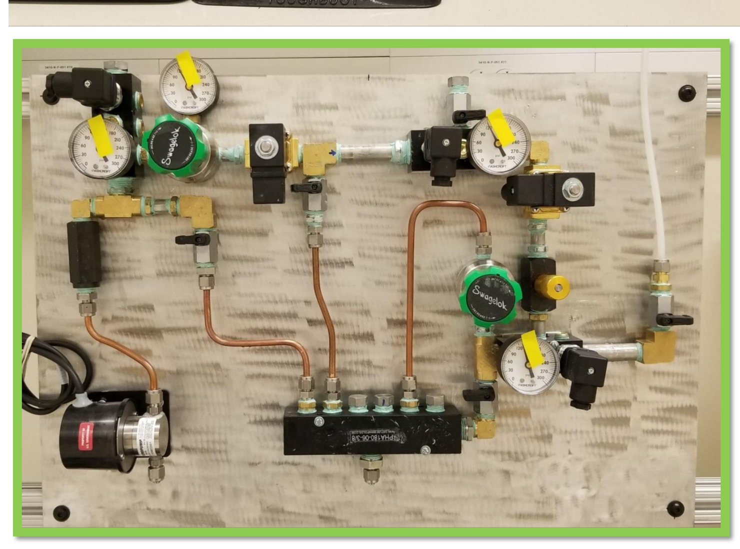


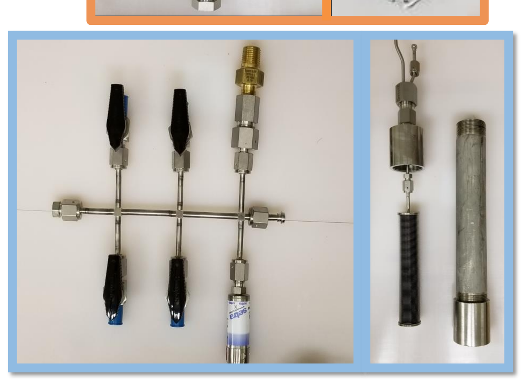


Bubble Chamber Schematic









PNNL Bubble Chamber Construction

Gasket Sealing Studies:

- Gasket material and C_4F_{10} compatibility for the chamber was investigated to prevent gasket failure and leakage.
- Buna-N and neoprene rubber was determined to be ideal for the gasket application over PTFE material.

Pressure Testing:

- The hydraulic cart was tested for leaks with pressurized air and water
- The hydraulic system and cold zone were mounted to a ¼" aluminum plate and bolted to 80/20 aluminum frameworks.
- To prevent leaking at connecting points, pipe sealant and Teflon tape was applied to the threads of the NPT connectors.

Assembly:

- The primary components of the hydraulic cart are connected by means of NPT connections and Swagelok compression fittings
- Copper piping was bent and connected to Swagelok fittings for additional routing of draining, regulating, and pumping oil.

Acknowledgements

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