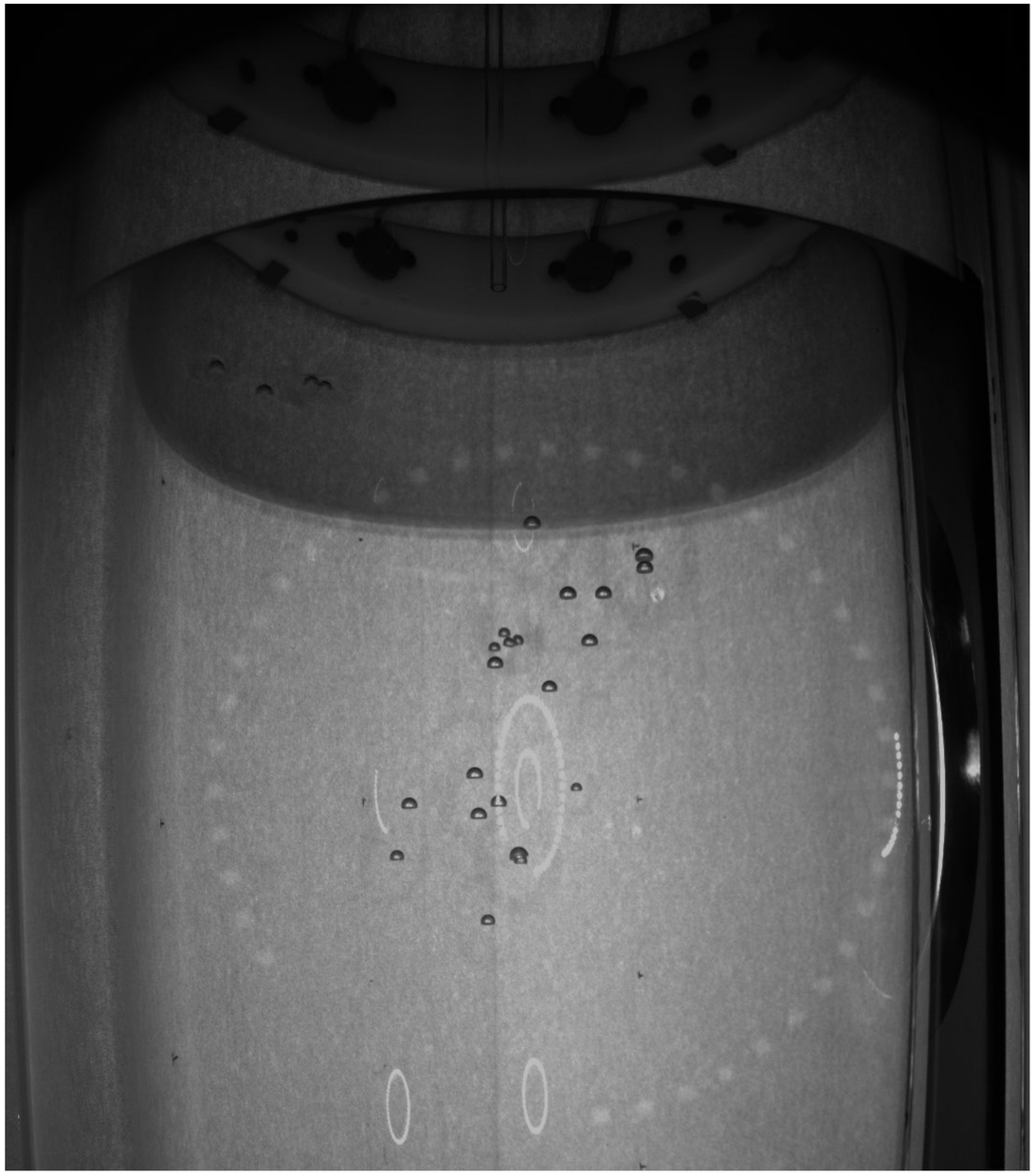
The Scintillating Bubble Chamber

Ken Clark
Queen's University

Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

Queen's University

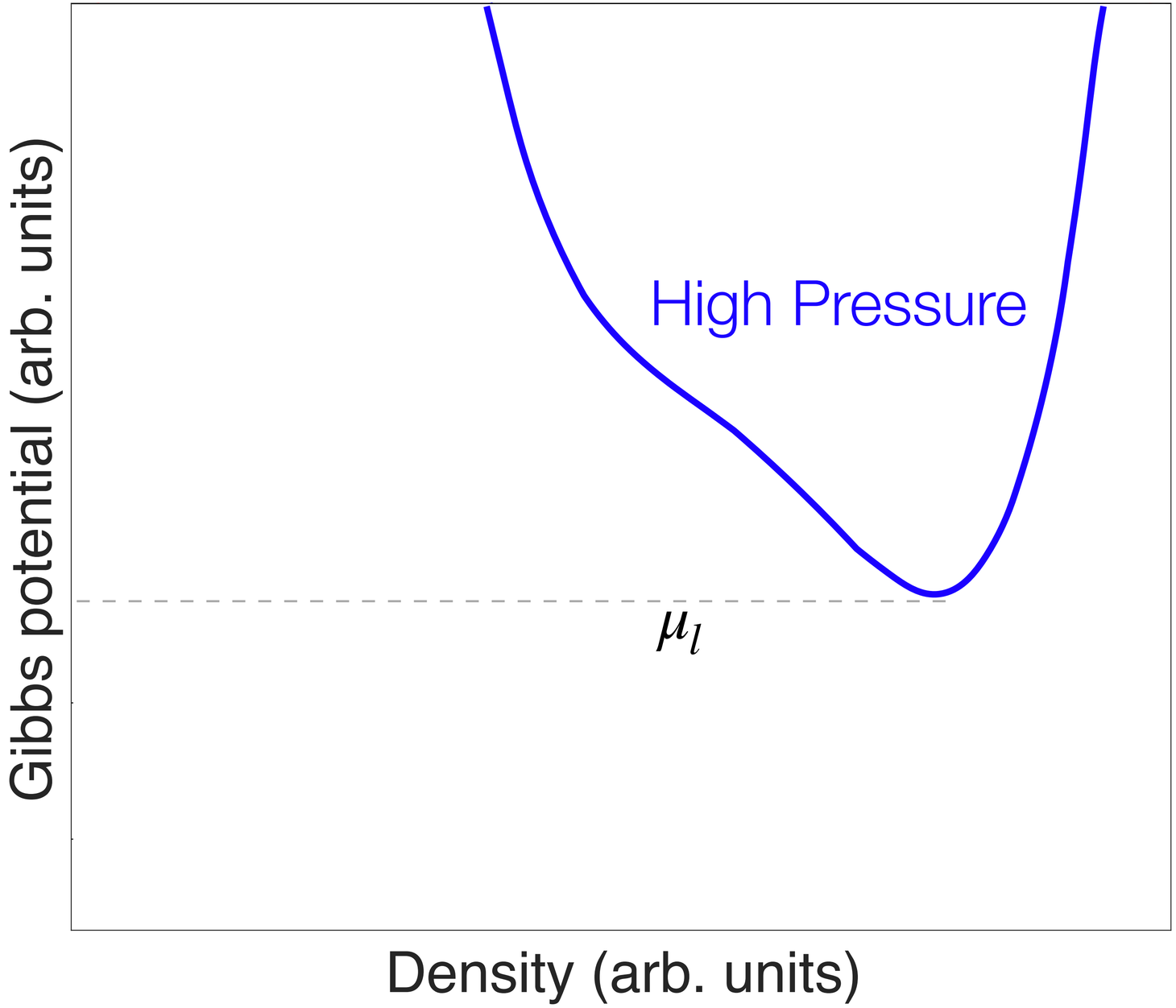
Bubble Chambers



- Long history with particle physics, and even with dark matter
- Particle interaction causes nucleation in superheated fluid
- This grows into a visible (and detectable) bubble
- Chamber can then be recompressed and ready for the next event

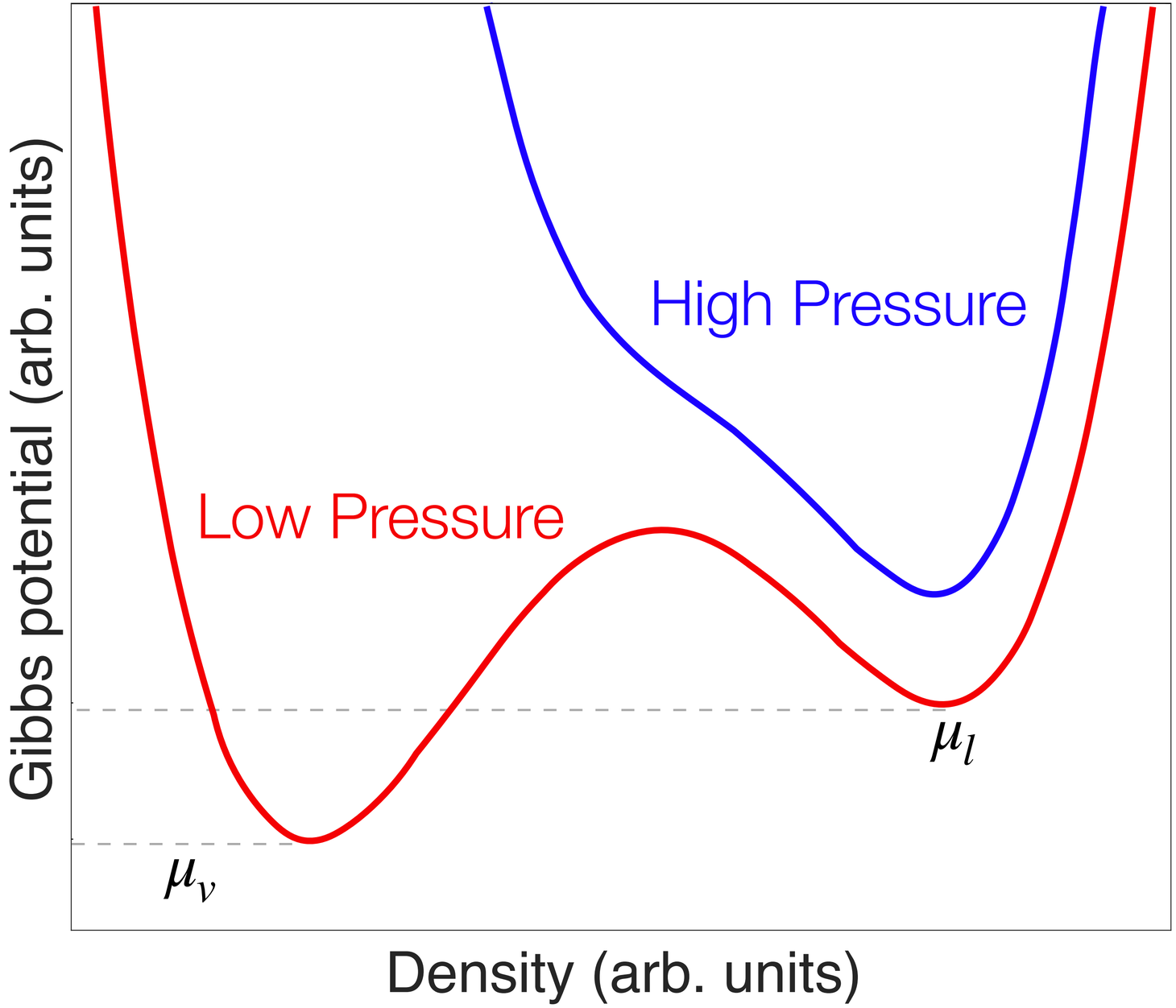
Theory, Graphically

- At high pressure the medium is stable in the liquid state



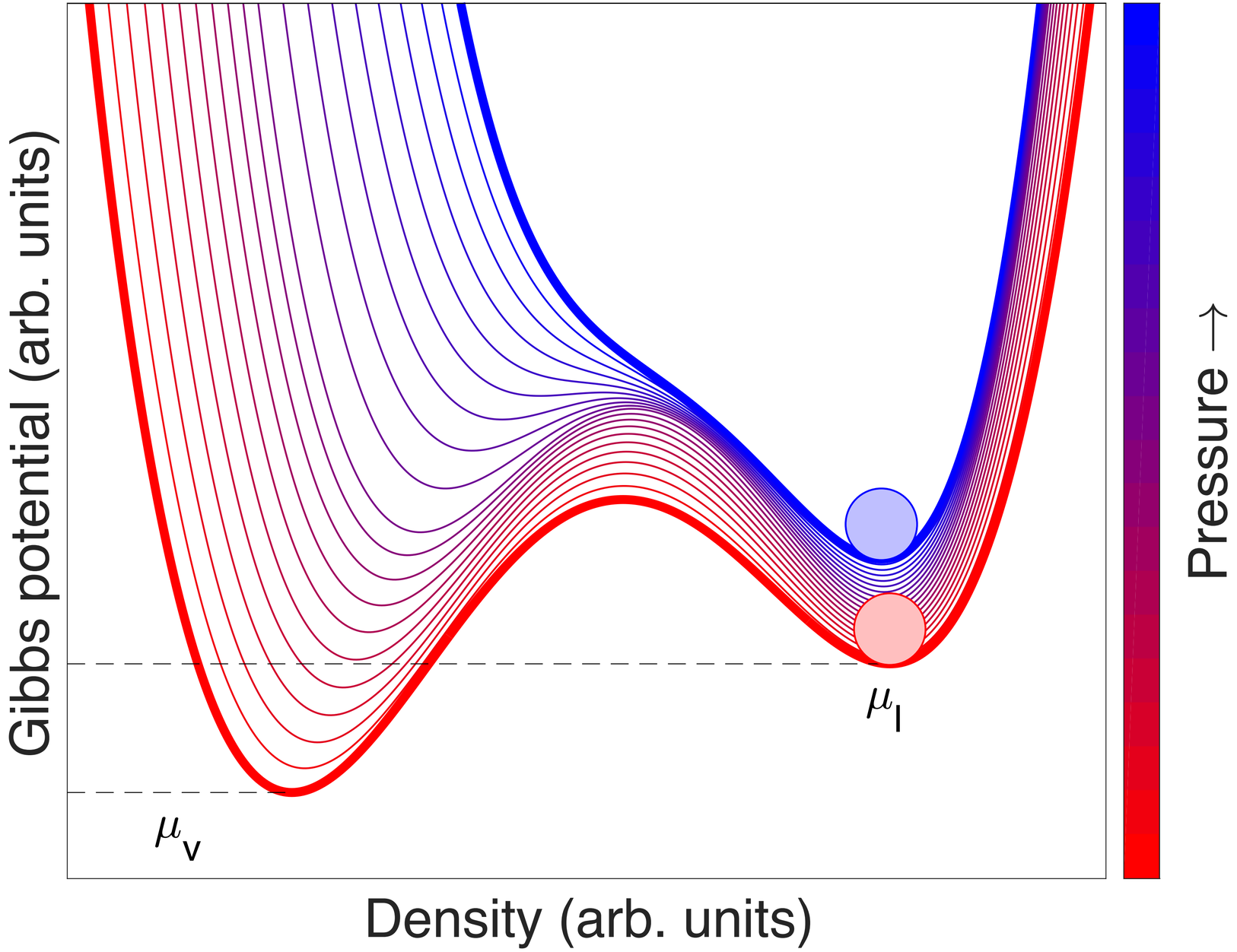
Theory, Graphically

- As the pressure is lowered, this becomes metastable, with a potential threshold to overcome before changing state



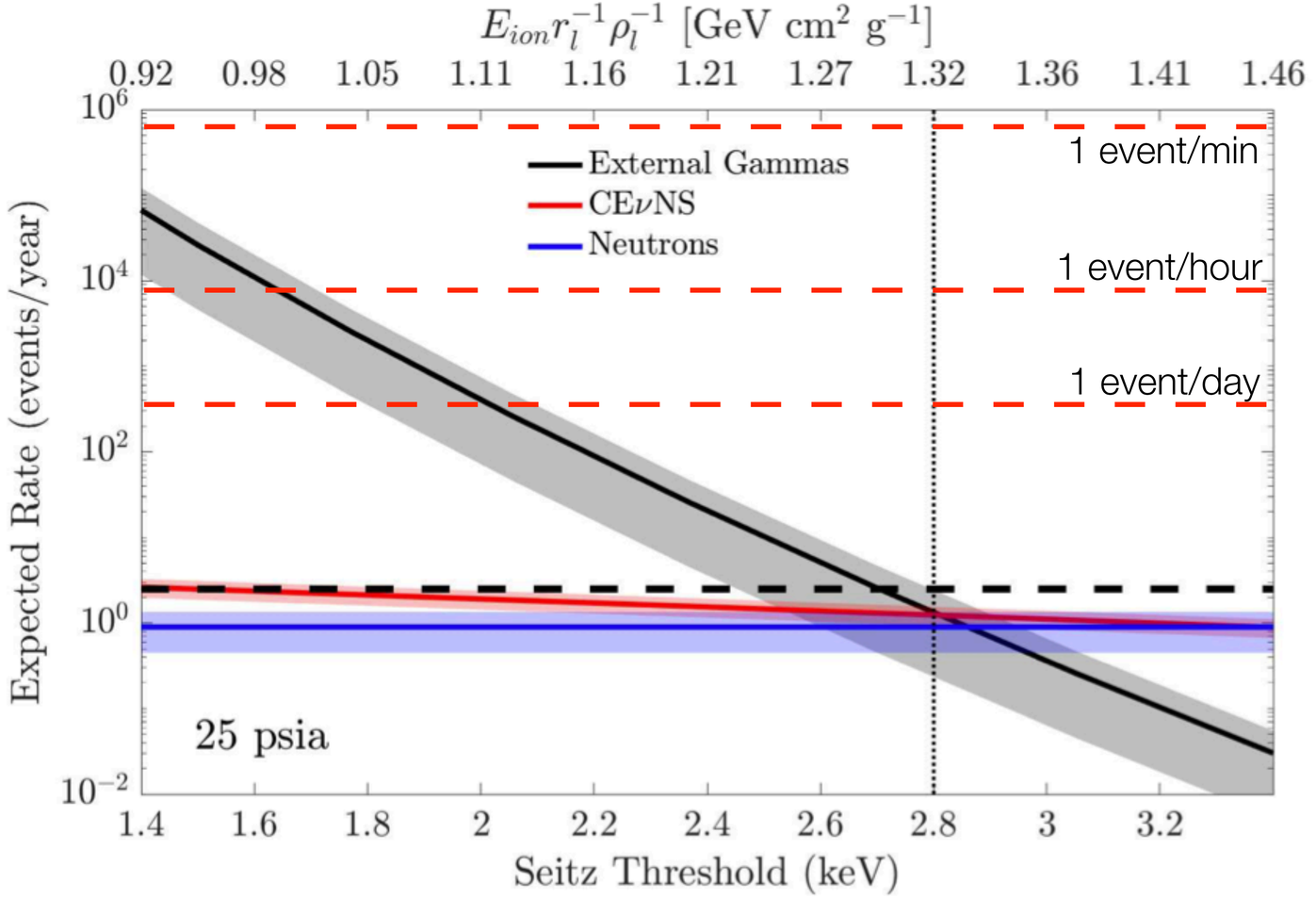
Theory, Graphically

- The potential step is controllable with pressure (or temperature) providing a variable threshold

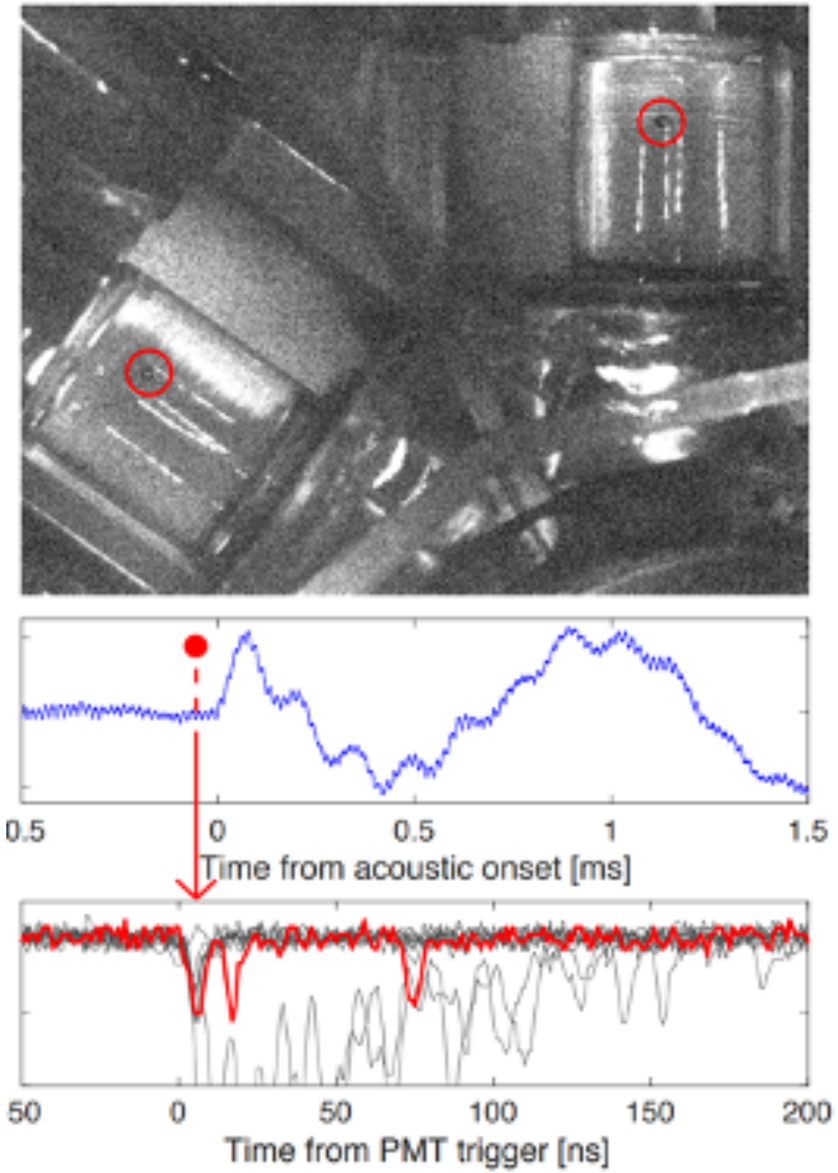


Experiment Overview

- Bubble chambers have been used for dark matter searches with success (see: PICO)
- Low mass region remained out of reach due to increased electron recoils with a lowered threshold



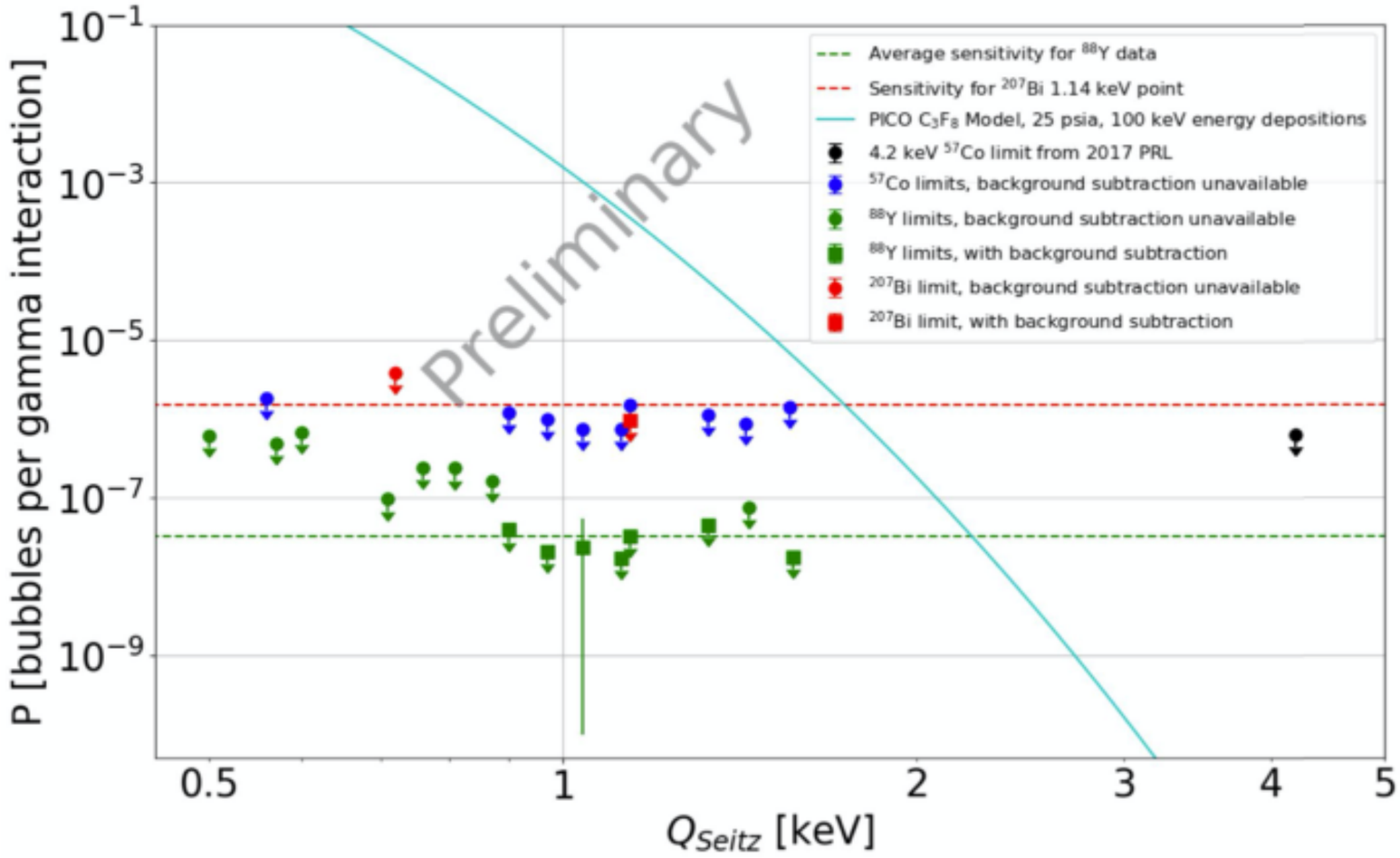
Why do we think this will work?



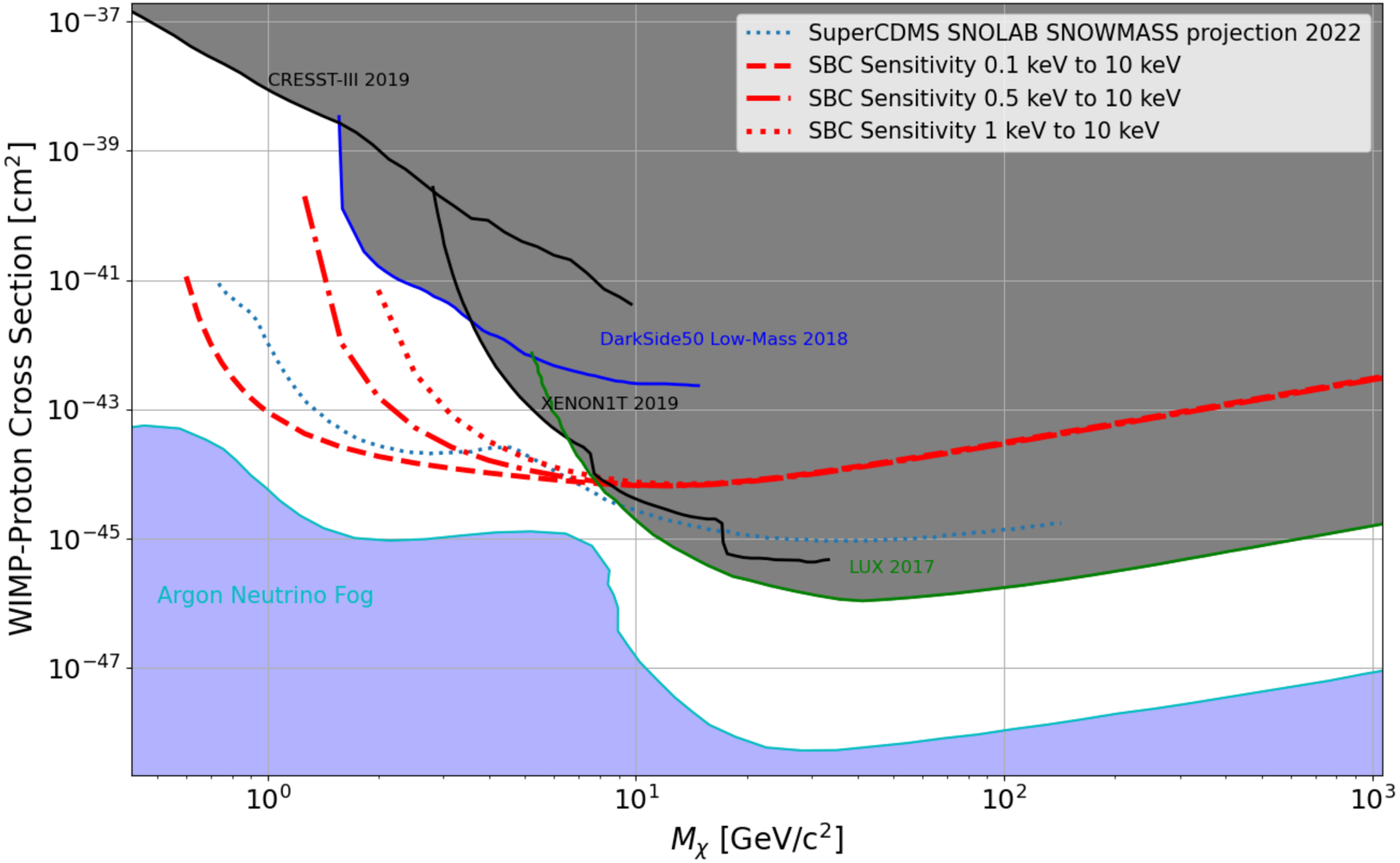
- This has been tried with a very small xenon bubble chamber at Northwestern
- Results were successful, and backed up what we thought would happen

Experiment Overview

- Bubble chambers have been used for dark matter searches with success (see: PICO)
- Low mass region remained out of reach due to increased electron recoils with a lowered threshold
- Not an issue for SBC with the changed energy deposit channels



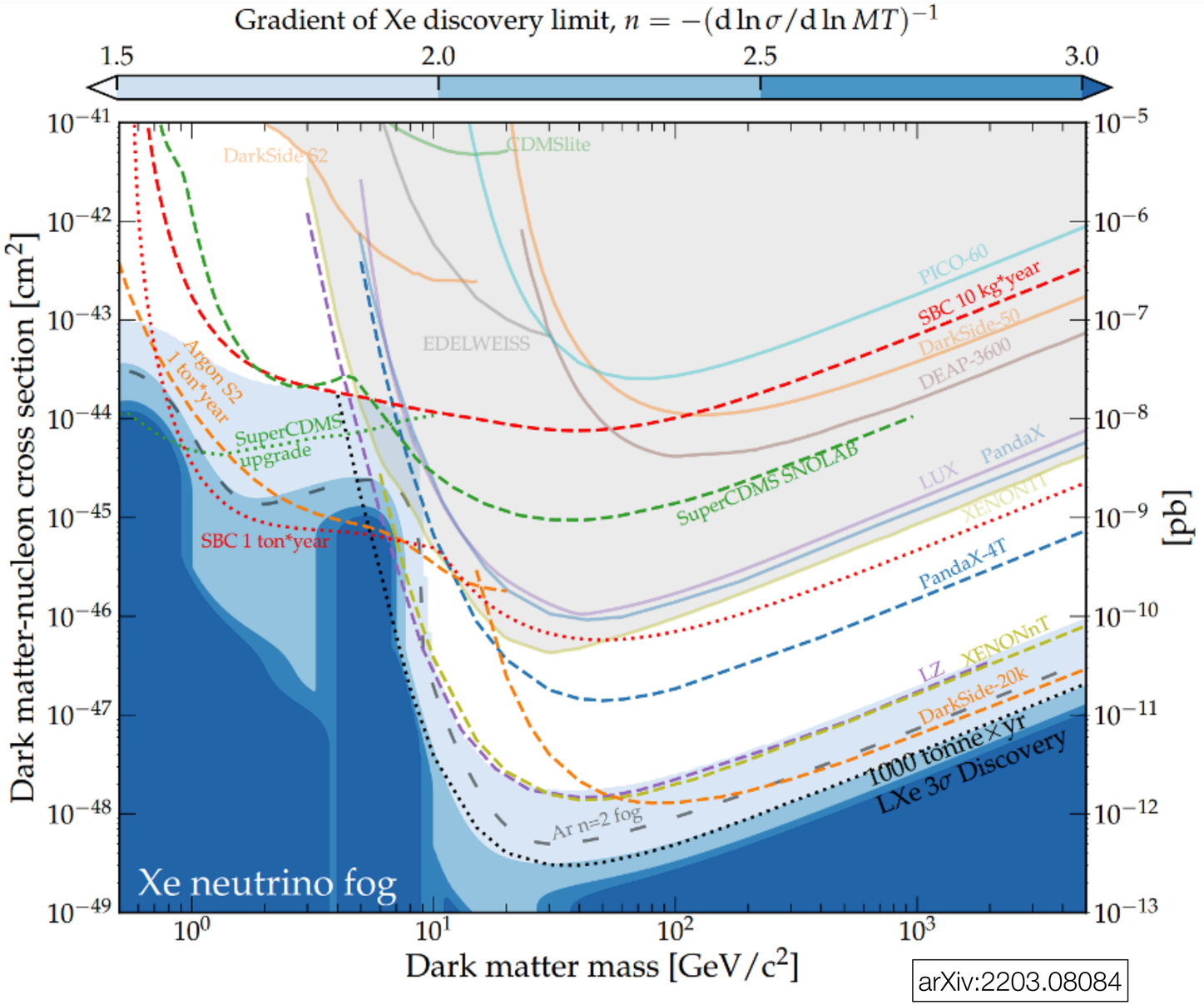
Why push this threshold?



- The ability to reach lower thresholds opens up the lower-mass phase space
- Note that this plot includes only CEvNS backgrounds and a 10kg-year live time

Limit Projections

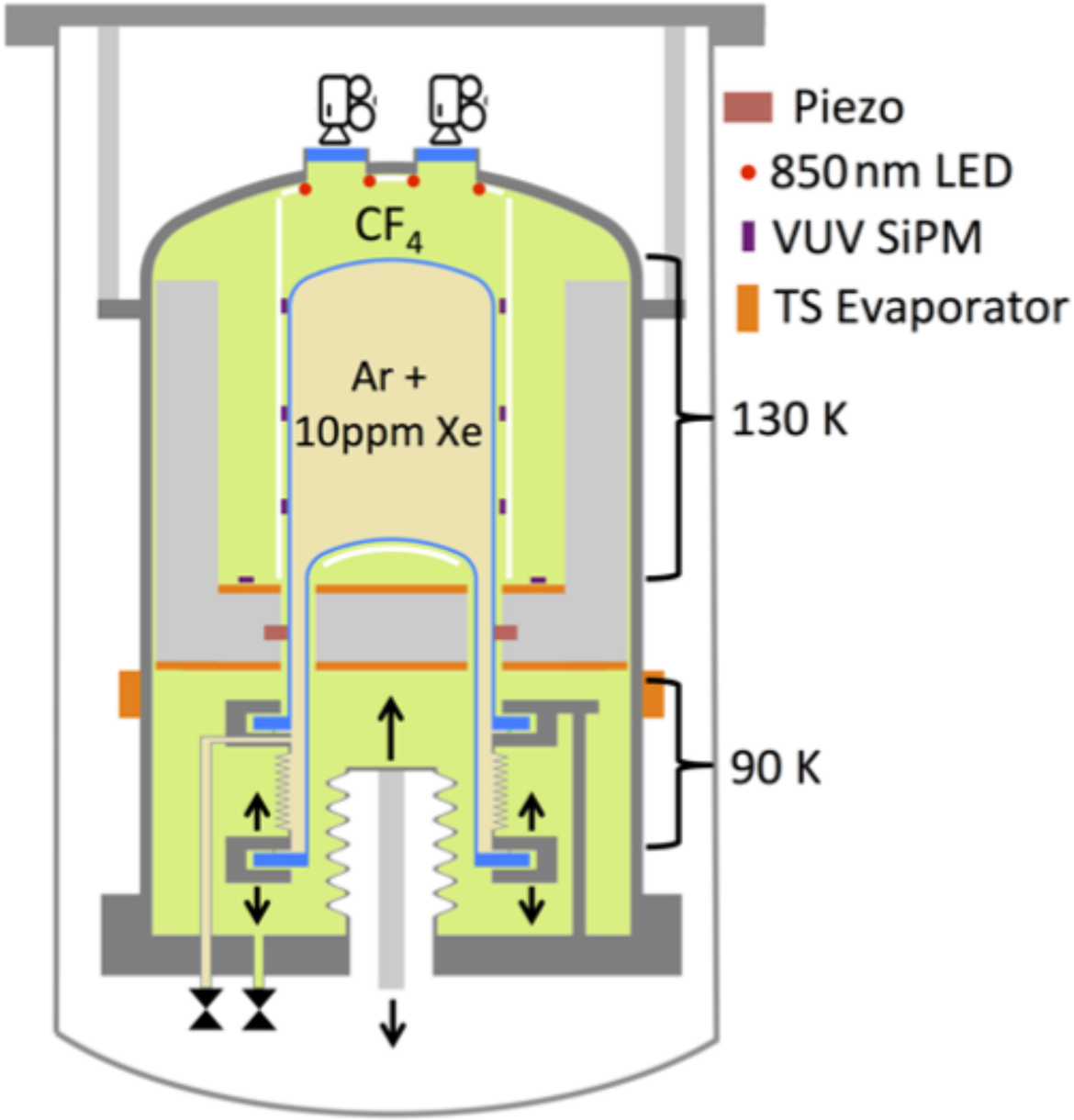
- If you wanted a more complicated plot, we've got you covered there too
- Note the lower threshold (100eV) is assumed
- Also shown is a "potential" next step



arXiv:2203.08084

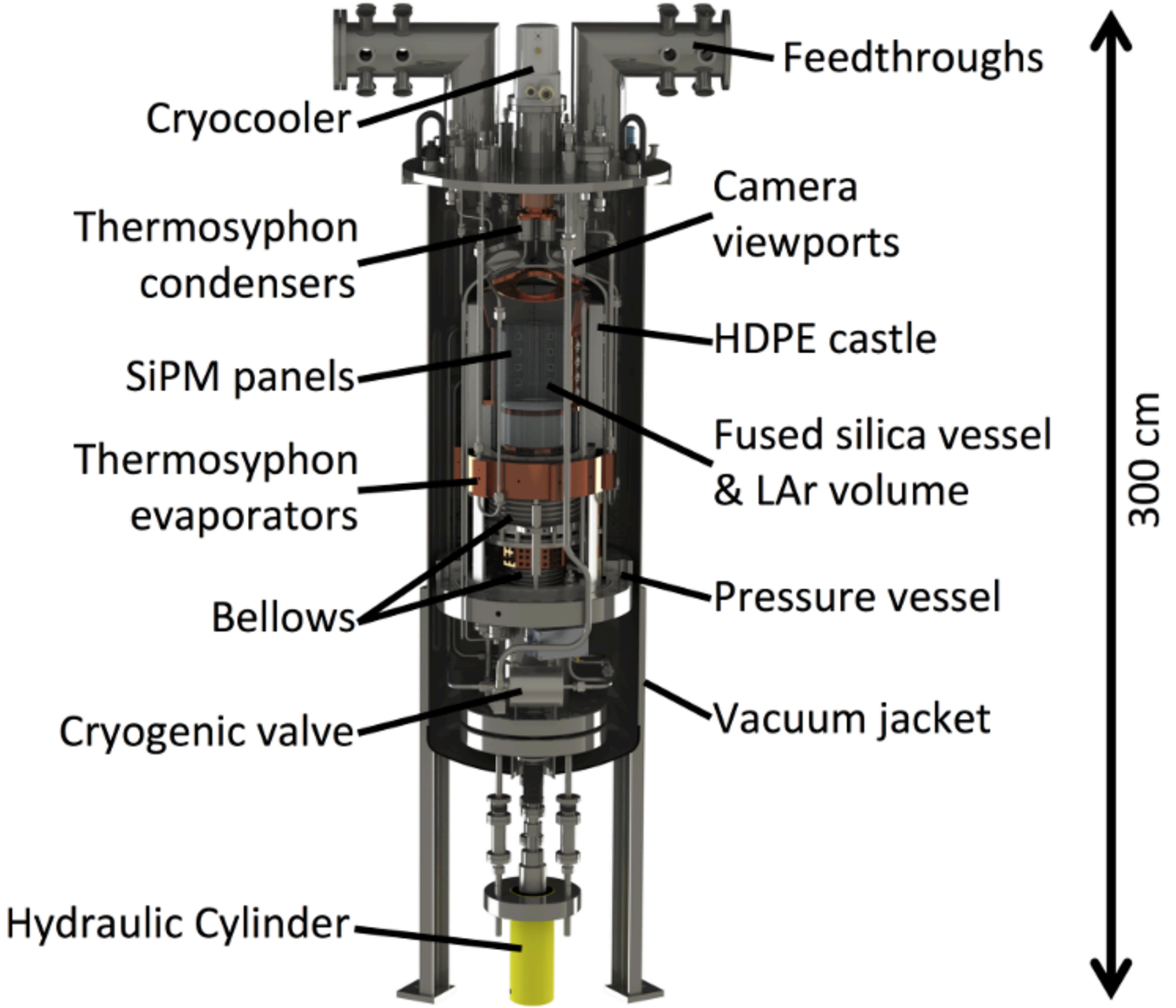
How will we do this?

- Roughly 10kg of argon
- SiPMs used for scintillation detection
- Much of the internal detail modelled on PICO 500
- “Only” added challenge is to keep it cold

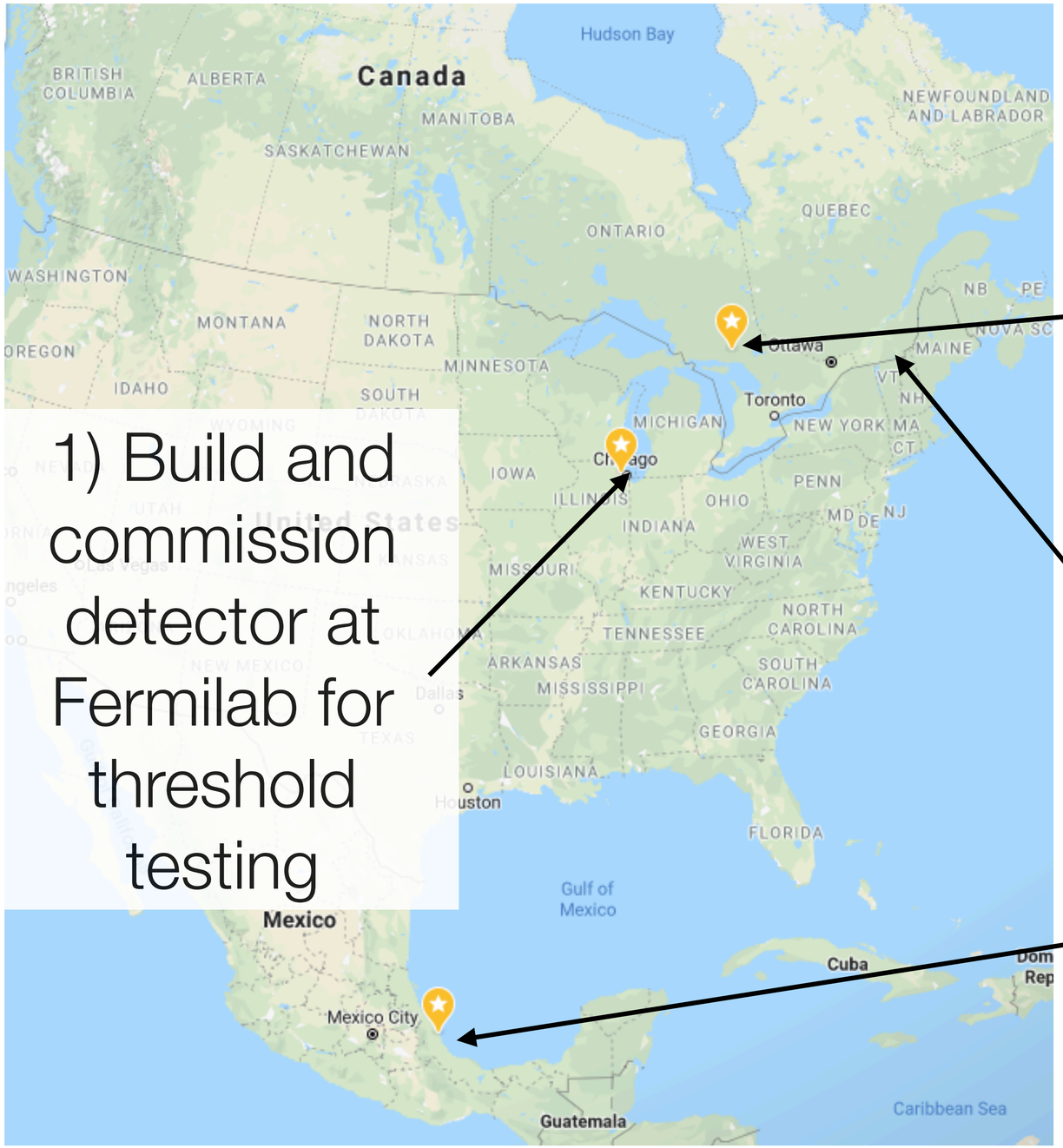


How will we do this?

- Roughly 10kg of argon
- SiPMs used for scintillation detection
- Much of the internal detail modelled on PICO 500
- “Only” added challenge is to keep it cold



Collaboration Plan

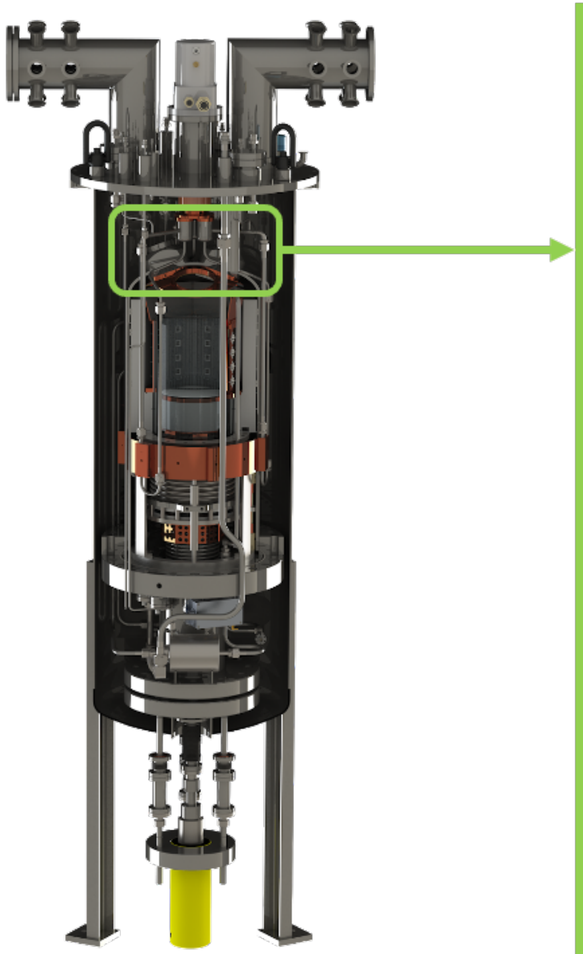


1) Build and commission detector at Fermilab for threshold testing

2) Build and install detector at SNOLAB for DM search

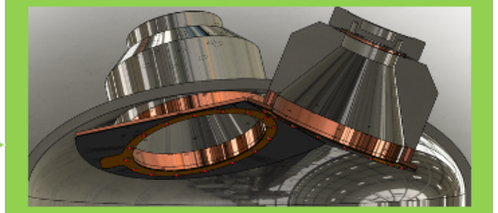
3) Upgrade and install detector from
1) at a reactor for neutrino studies

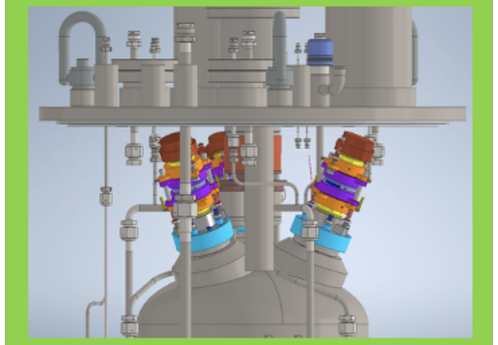
Detector Readout Systems

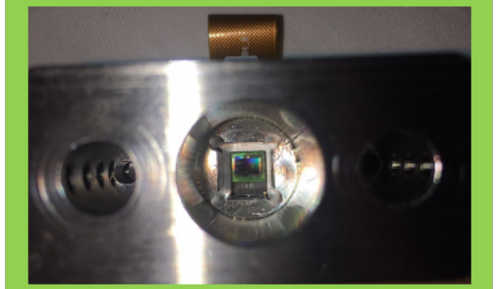


Bubble Imaging

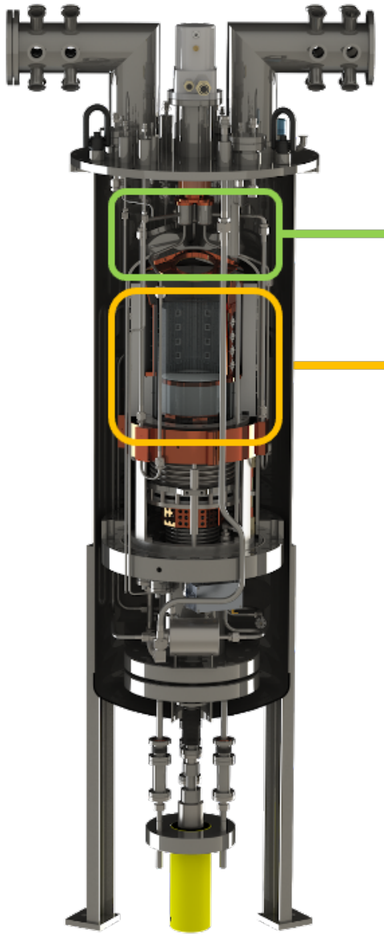
3 Raspberry-Pi Cameras + LEDs





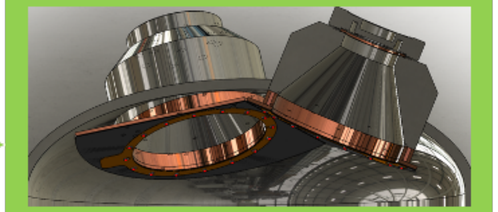


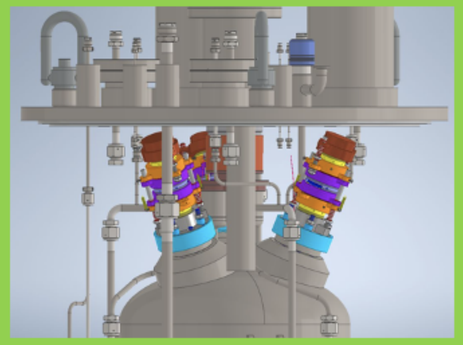
Detector Readout Systems

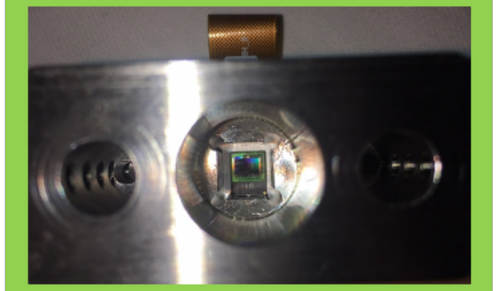


Bubble Imaging

3 Raspberry-Pi Cameras + LEDs

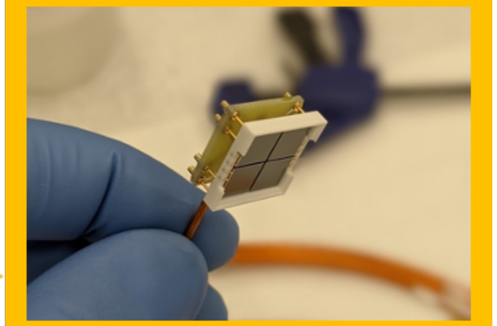




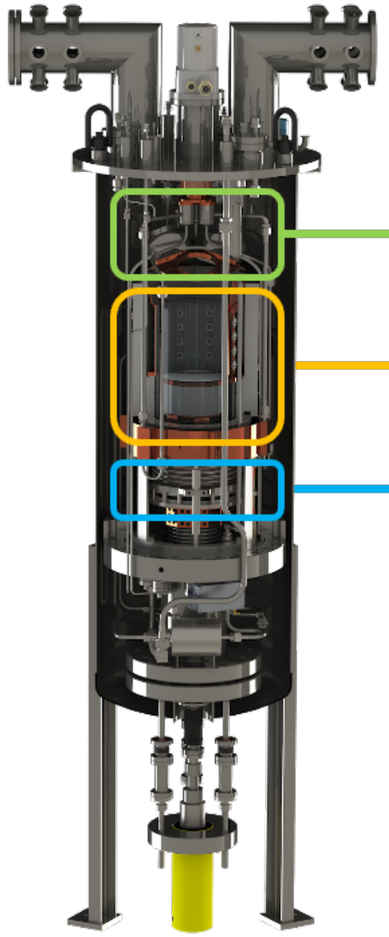


Scintillation System

32 VUV4 Hamamatsu SiPMs

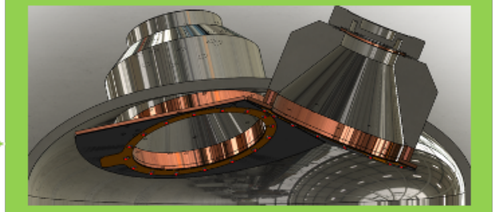


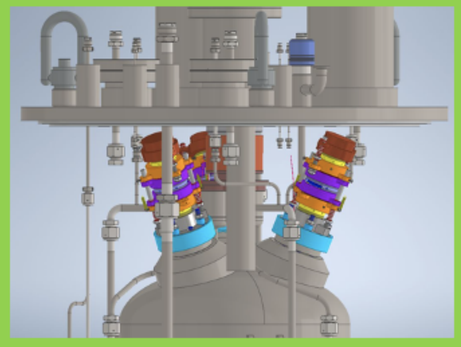
Detector Readout Systems

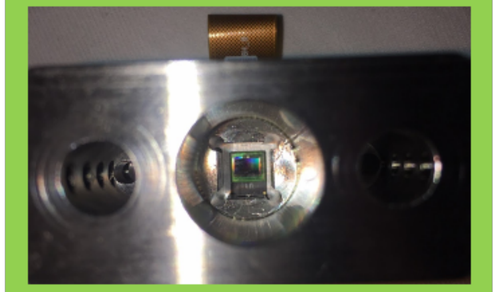


Bubble Imaging

3 Raspberry-Pi Cameras + LEDs

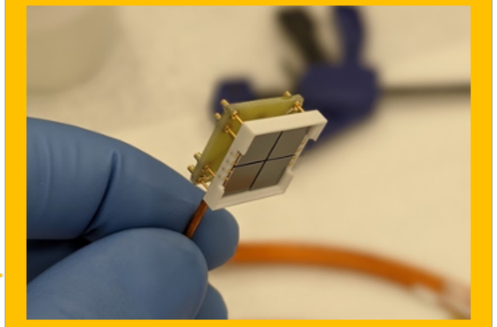






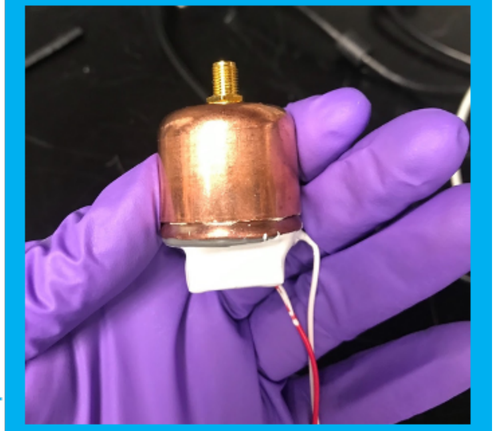
Scintillation System

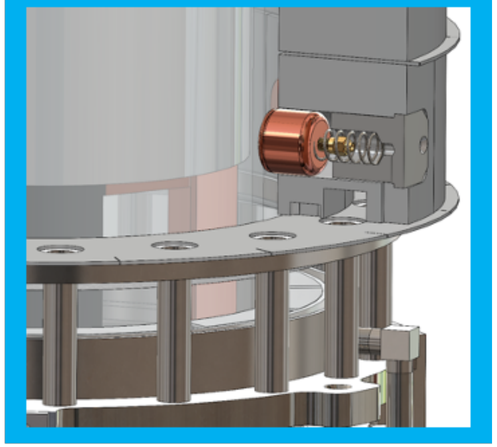
32 VUV4 Hamamatsu SiPMs



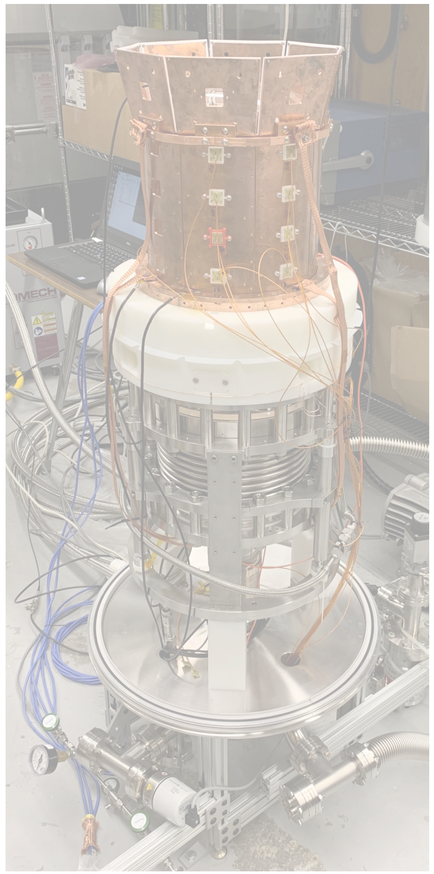
Acoustic Sensors

8 Piezoelectric Transducers

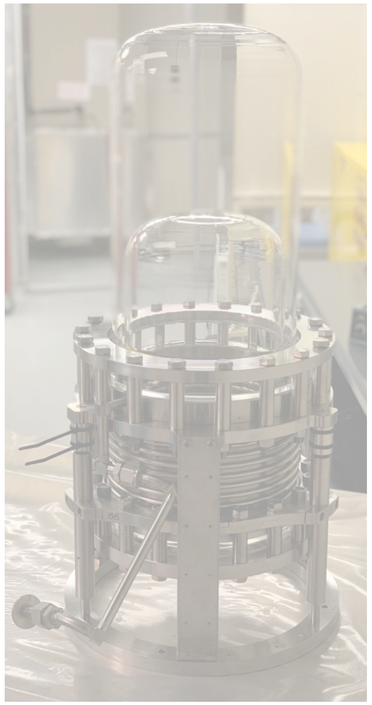


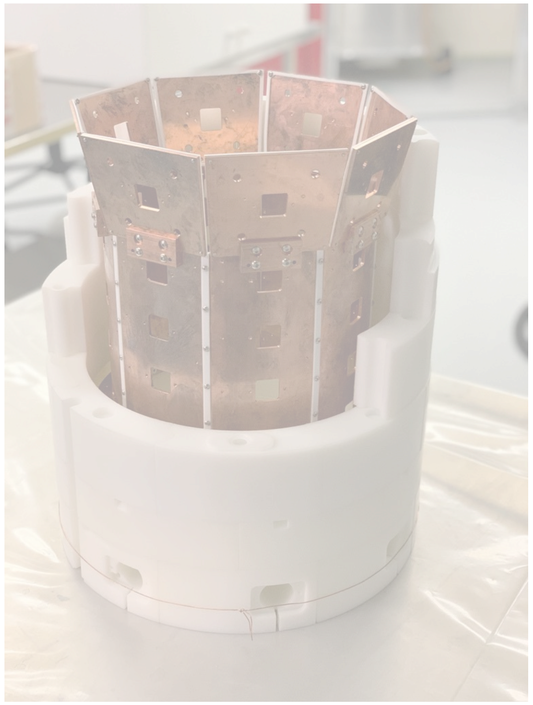


Developments



- Lots of positive developments
  - We have spent the past six months investigating and reducing risks
- Will go through these individually, as this is important



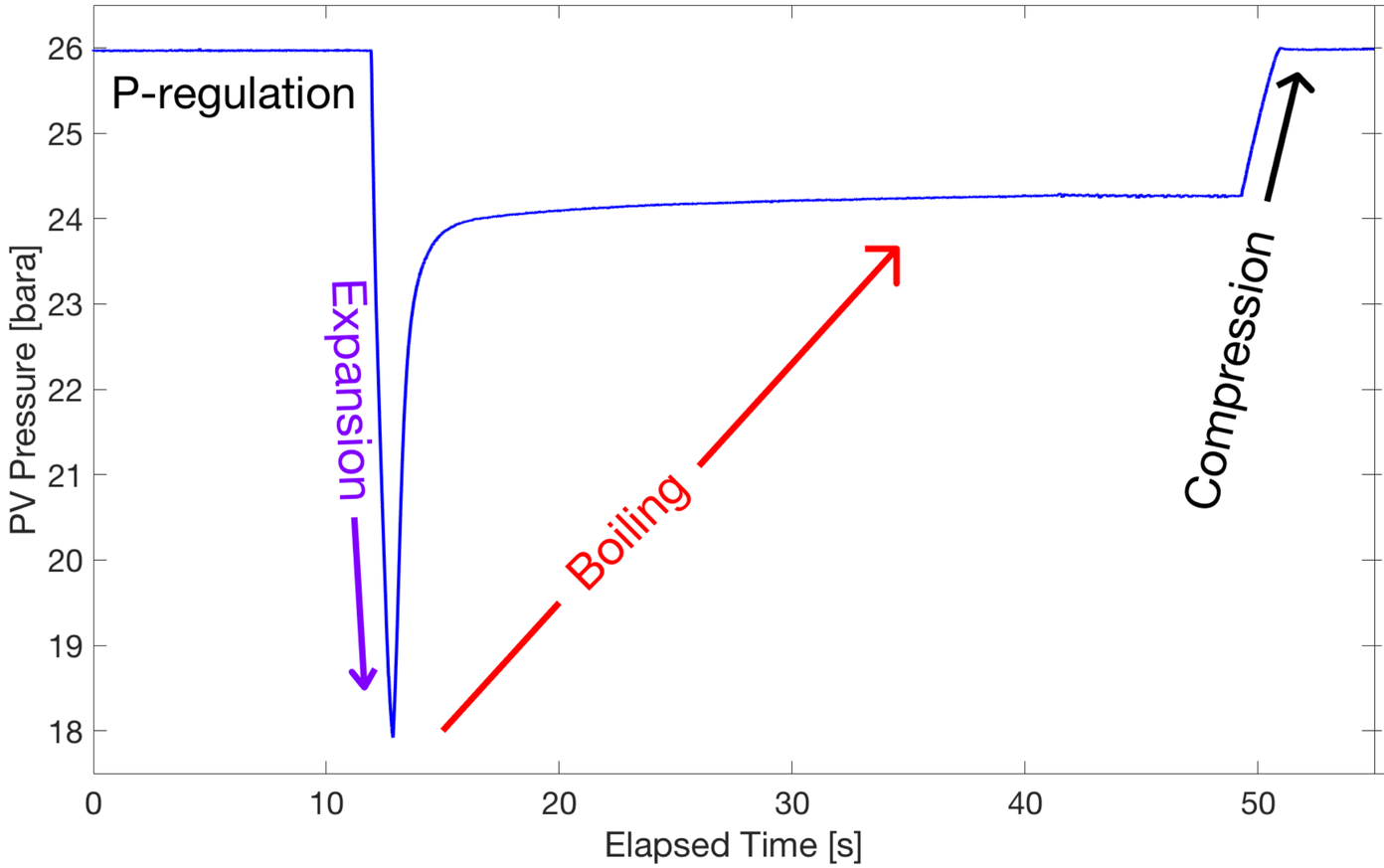


Tests at Operational Temperatures

- Tested at Fermilab
  - Passed all required tests to operate
  - Filled PV with argon, cooled using thermosyphons

Tests at Operational Temperatures

- Tested at Fermilab
  - Passed all required tests to operate
  - Filled PV with argon, cooled using thermosyphons
  - Also superheated it!



Custom Seal Test

Outer jar seal here at quartz/ glass interface

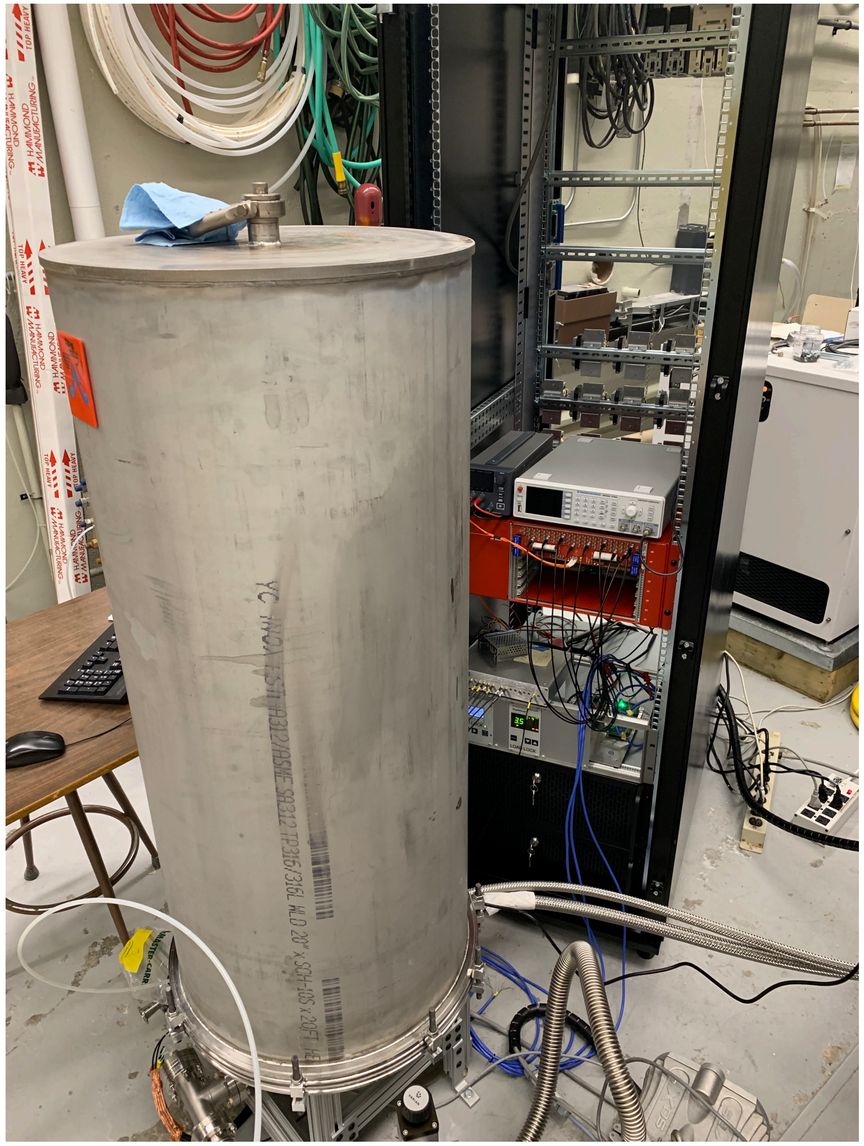
Another one here for the inner jar

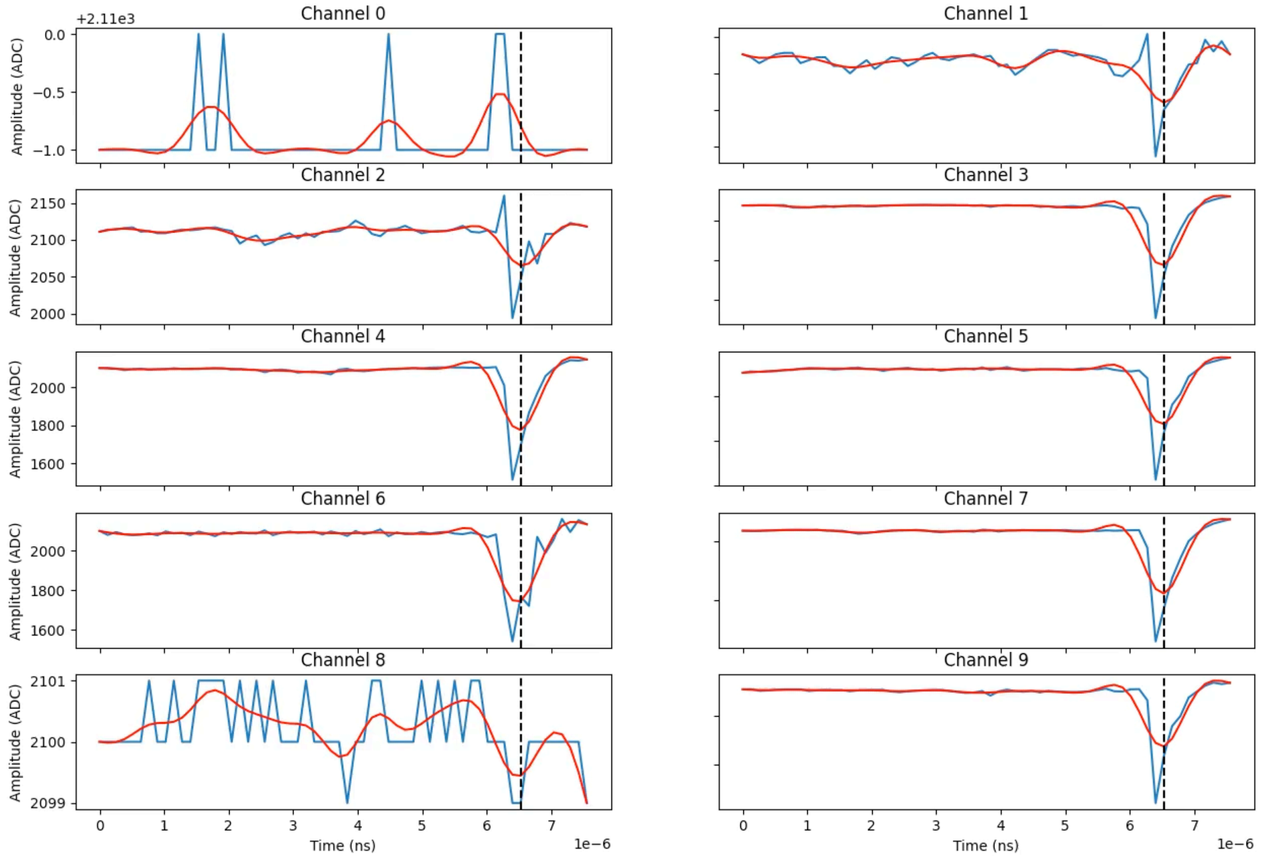
- Great concern about our spring-energized PTFE seals
- Tested at Queen's both warm and cold to leak level ~10^{-7} l mbar/s He
- Also constituted a complete construction of the inner detector

Custom Seal Test

- Great concern about our spring-energized PTFE seals
- Tested at Queen's both warm and cold to leak level ~10^{-7} l mbar/s He
- Also constituted a complete construction of the inner detector

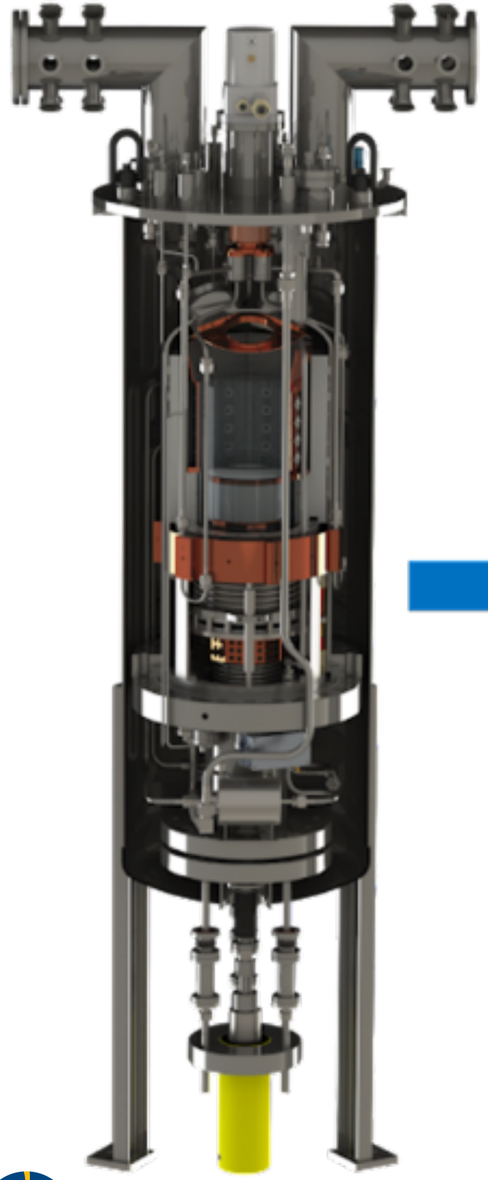
Experiment Status - SiPM DAQ





NSERC RTI meant we were able to buy the DAQ system and test it out with the SBC-Fermilab SiPMs

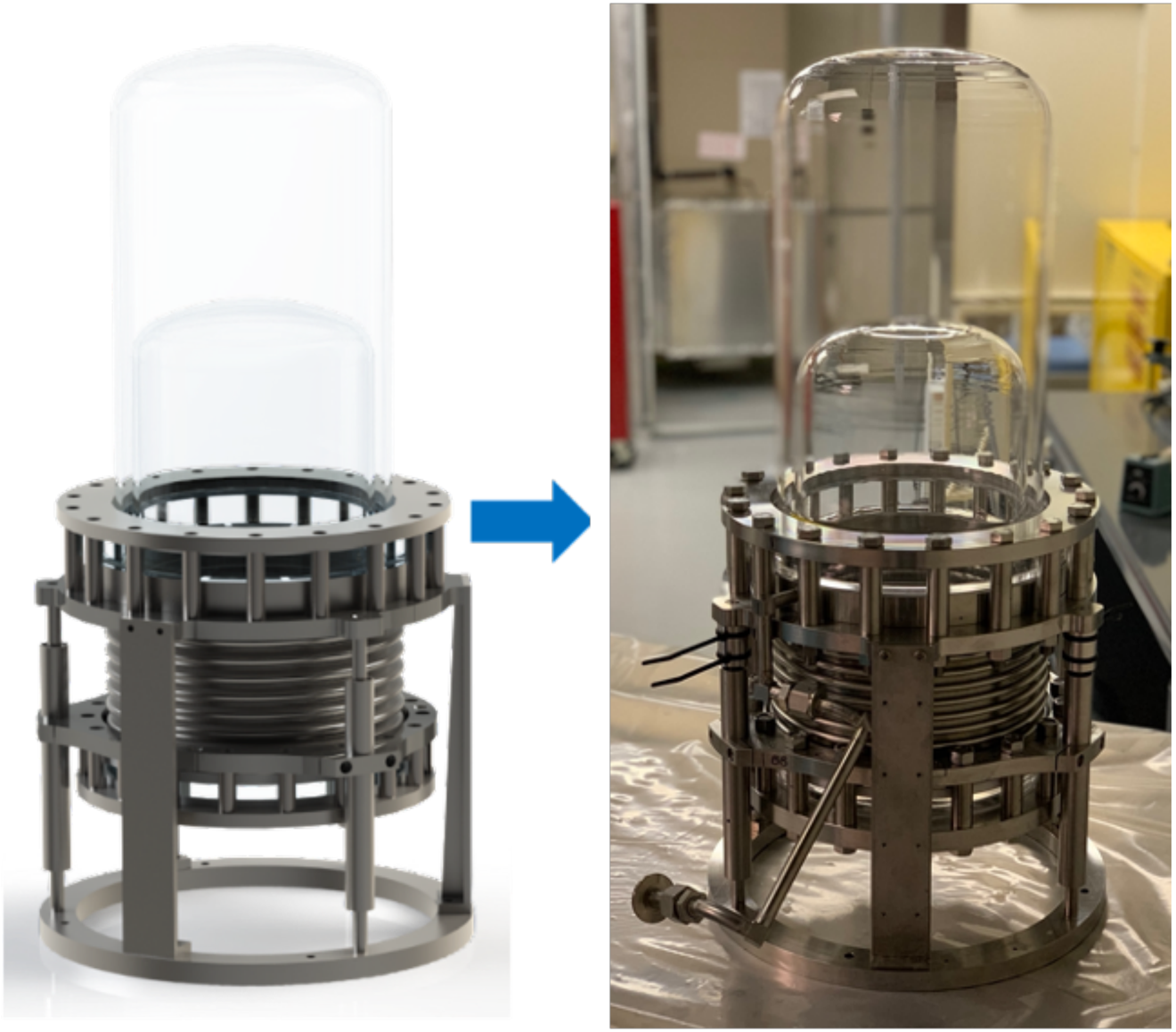
Experiment status



- Fermilab chamber assembled and ready to be installed
- Small issue with the elevator to get underground…
- All fixed now, should go down “soon”

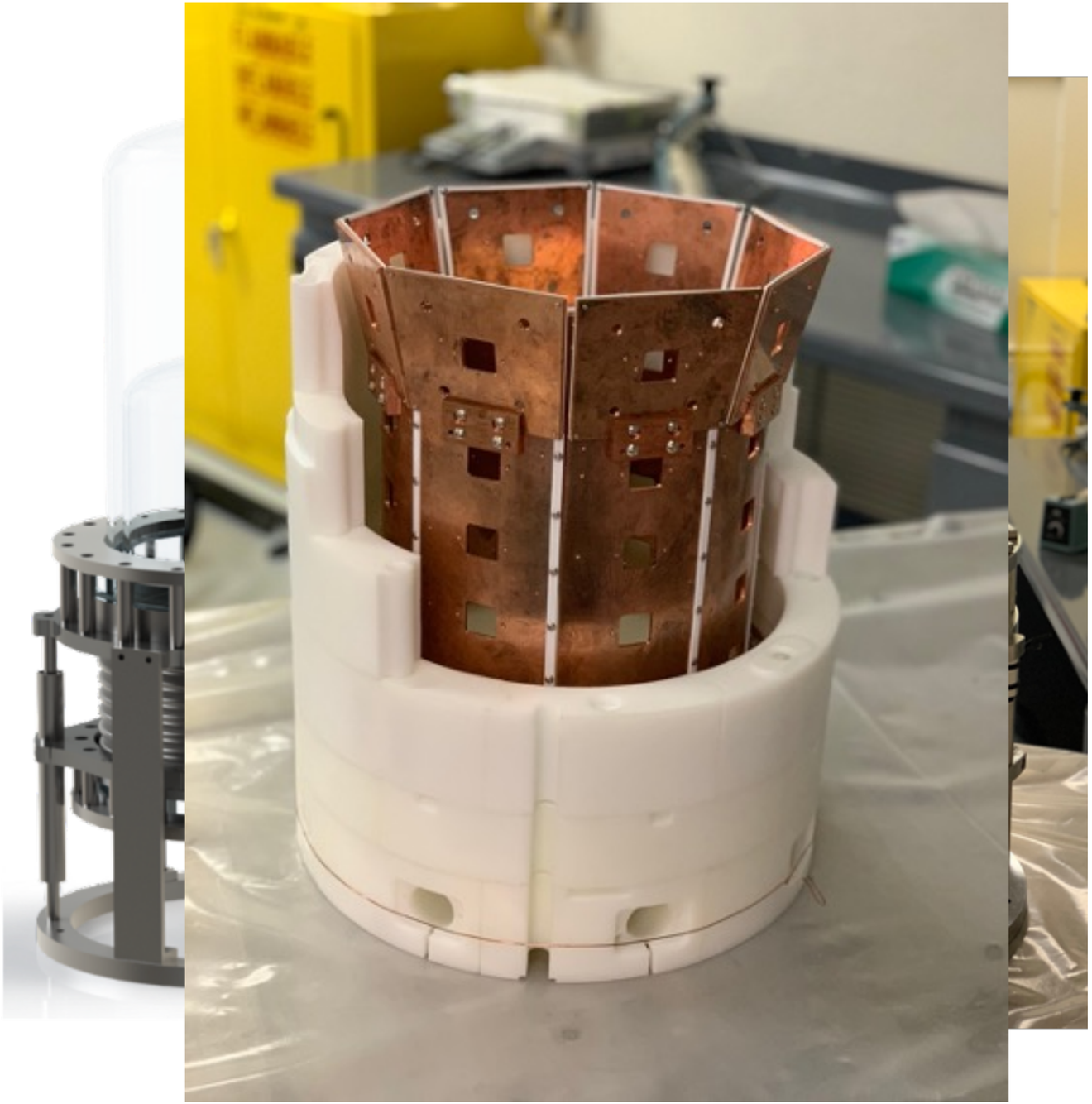
Experiment status

- Both inner assemblies constructed
- Fermilab version cleaned, transported, installed, commissioned
- SNOLAB version ready to be cleaned and transported



Experiment status

- Both inner assemblies constructed
- Fermilab version cleaned, transported, installed, commissioned
- SNOLAB version ready to be cleaned and transported

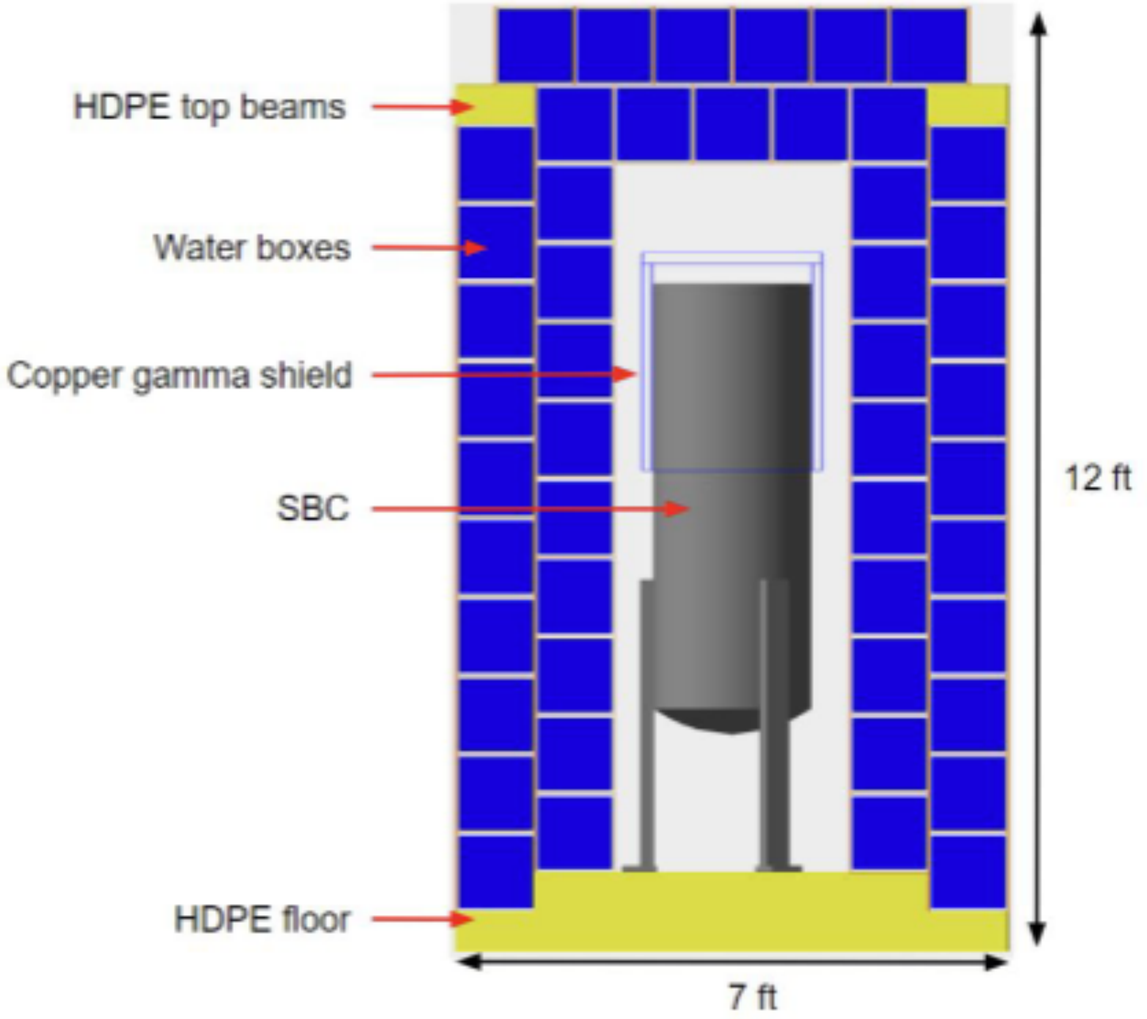


Experiment status

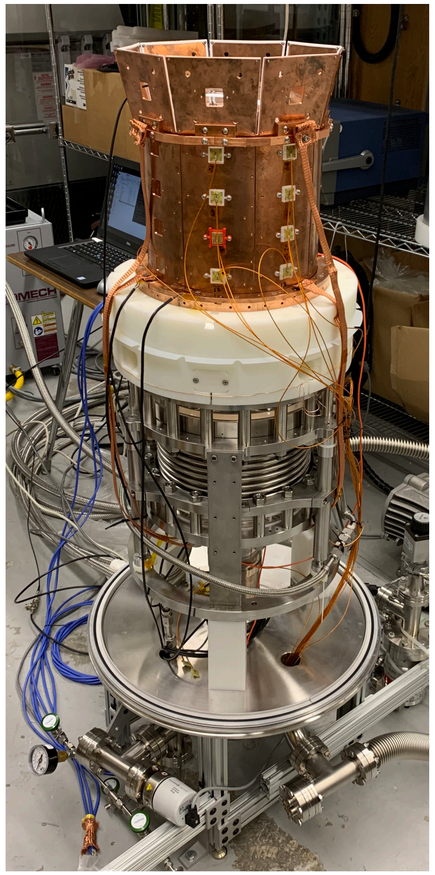
- Both inner assemblies constructed
- Fermilab version cleaned, transported, installed, commissioned
- SNOLAB version ready to be cleaned and transported

Experiment Status - Shielding

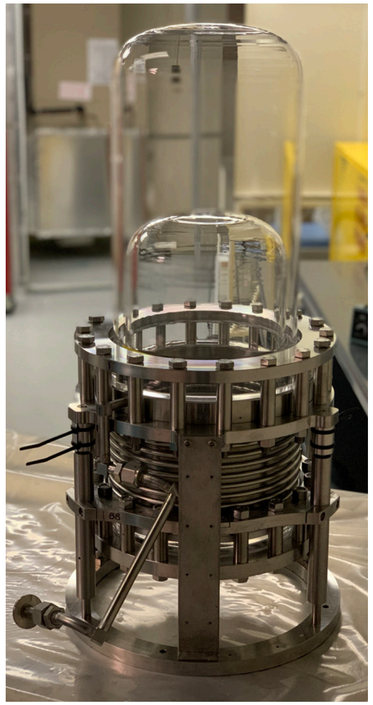
- Extensive effort put into determining shielding necessary to run
- New ideas being presented which take advantage of interplay between threshold and gamma background

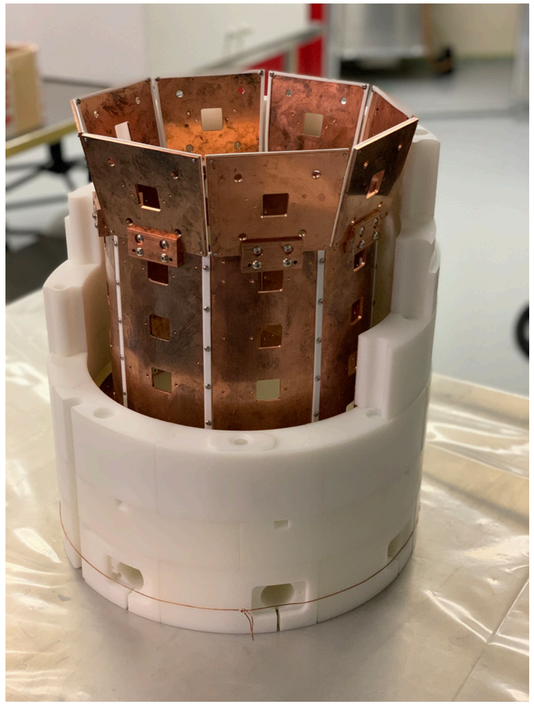


Conclusion



- SBC is a great future experiment
- The conclusion of the Fermilab tests will push more focus onto the SNOLAB chamber
- We'll be taking data soon!

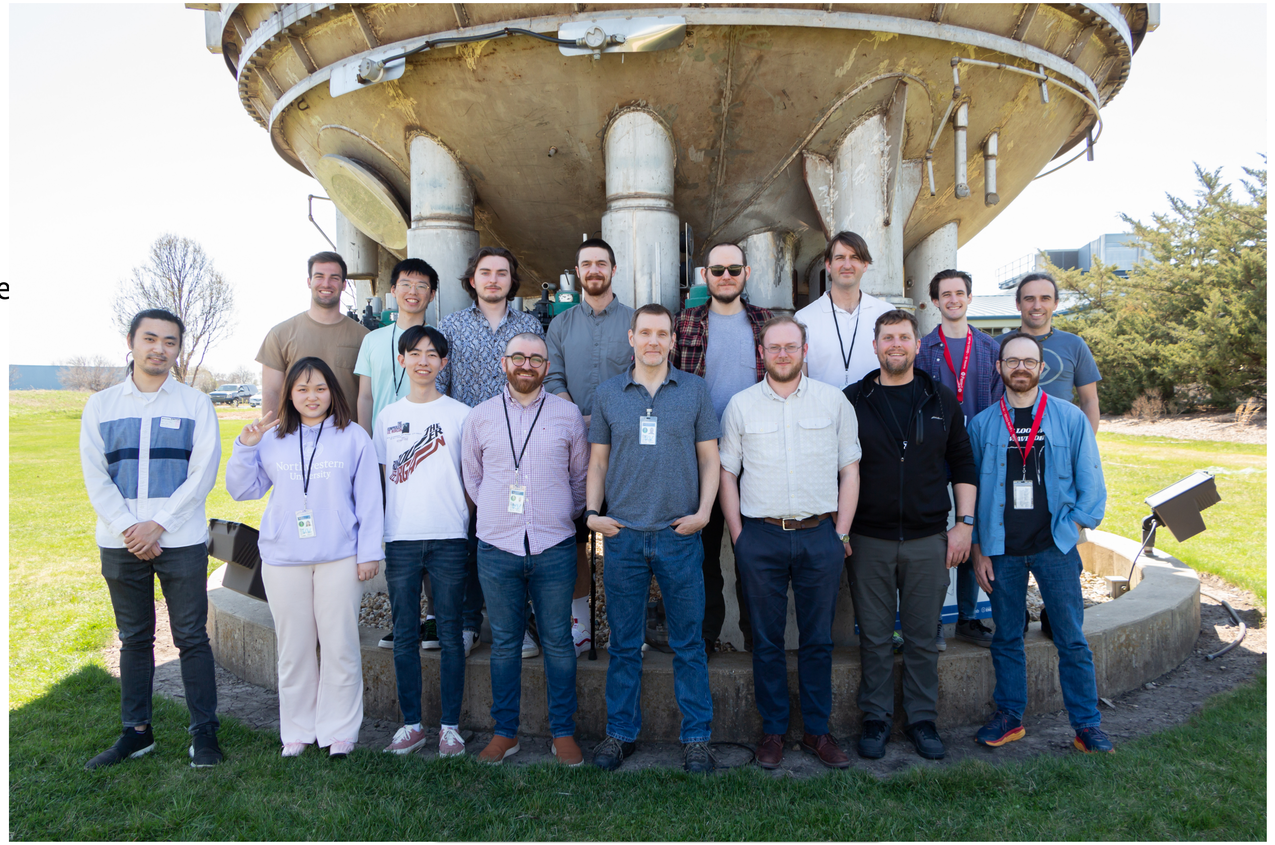




Collaboration

Queen's University

K. Clark, A. de St Croix, H. Hawley-Herrera, J. Corbett, B. Broerman, K. Dering G. Sweene



Northwestern University

C.E. Dahl, X. Liu, Z. Sheng, W. Zha

Drexel University

R. Neilson, M. Bressler, N. Lamb

University of Alberta

M.-C. Piro, M. Baker, D. Durnford

Universidad Nacional Autónoma de México

E. Vázquez-Jàuregu, E. Alfonso-Pita

Université de Montréal

M. Laurin

Indiana University South Bend

E. Behnke I. Levine

TRIUMF

P. Giampa

Fermilab

M. Crisler

Pacific Northwest National Laboratory

C.M. Jackson

PennState

S. Priya

UC Riverside

S. Westerdale

UC Santa Barbara

W.H. Lippincott, R. Zhang