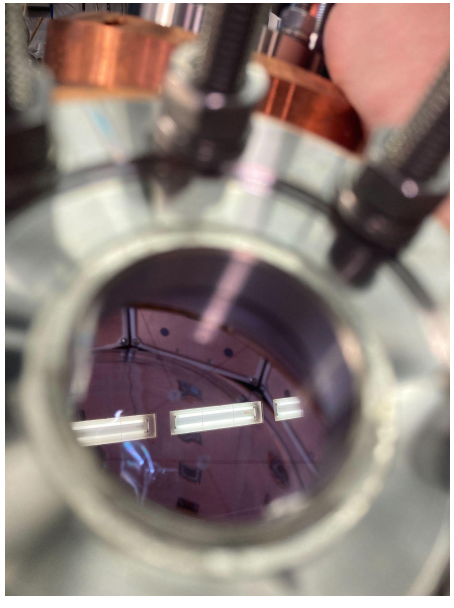
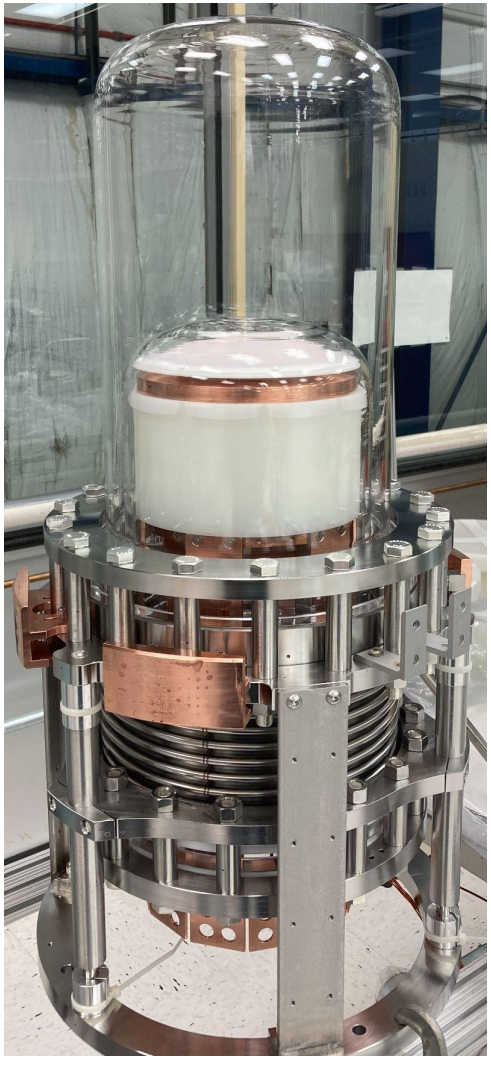
The scintillating bubble chamber at SNOLAB



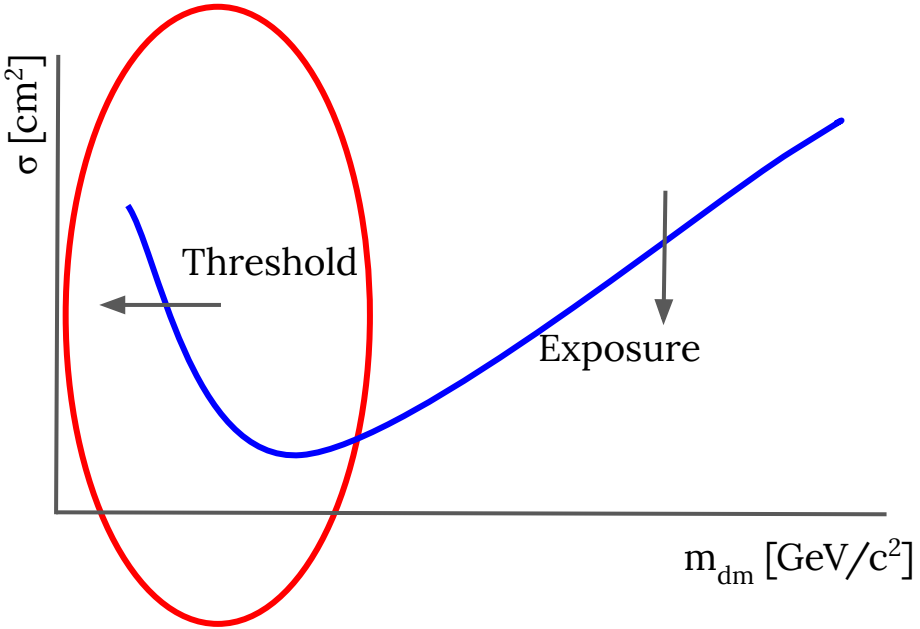


Ben Broerman

SNOLAB Users Meeting
June 2024

sub-keV nuclear recoil detection

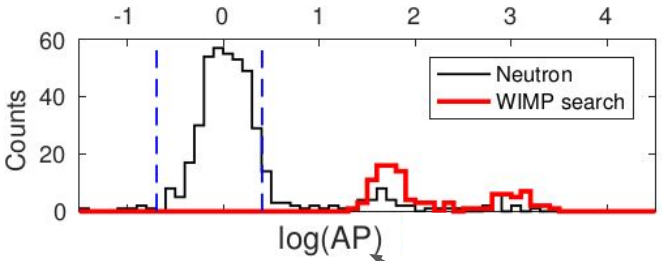
- Difficult kinematics of low mass DM-nucleon scattering require low thresholds $\lesssim 1$ keV
    - Future success here needs particle identification **and** scalability



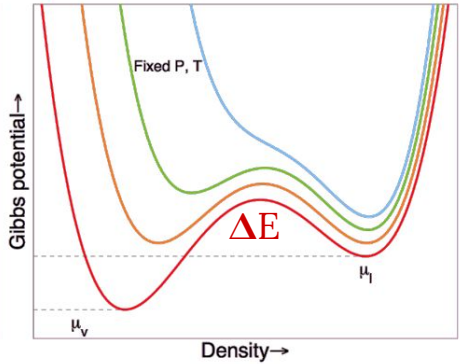
Aside:
A demonstrated technology can also go after MeV-scale reactor antineutrinos

Bubble chambers

- Maintain target fluid in a superheated state
- High efficiency @ low n.r. threshold, β/γ insensitivity, n.r./α discrimination:

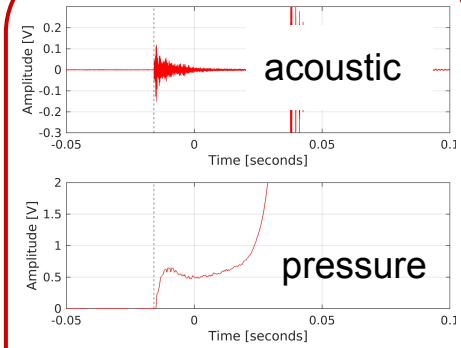


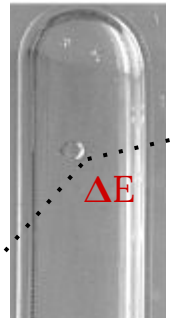
{x,y,z} + acoustics



Pressure ↓, 2 minima form

Further P ↓, Metastable superheated

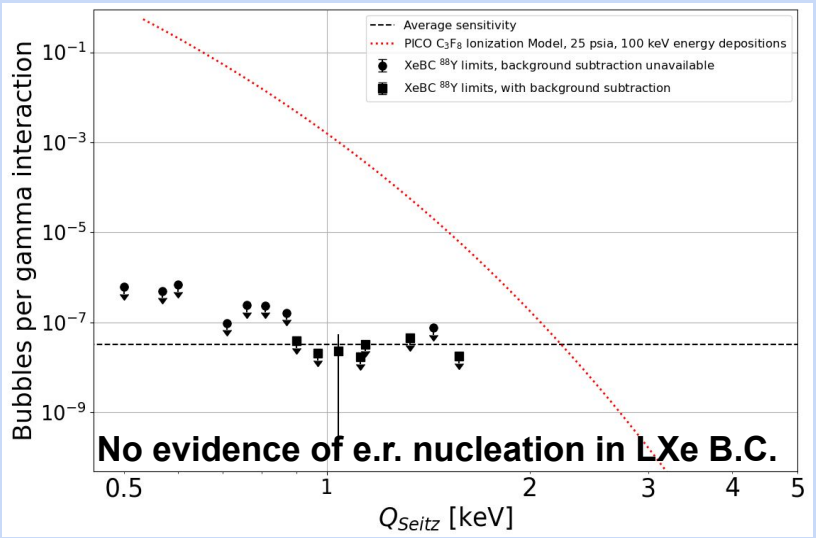




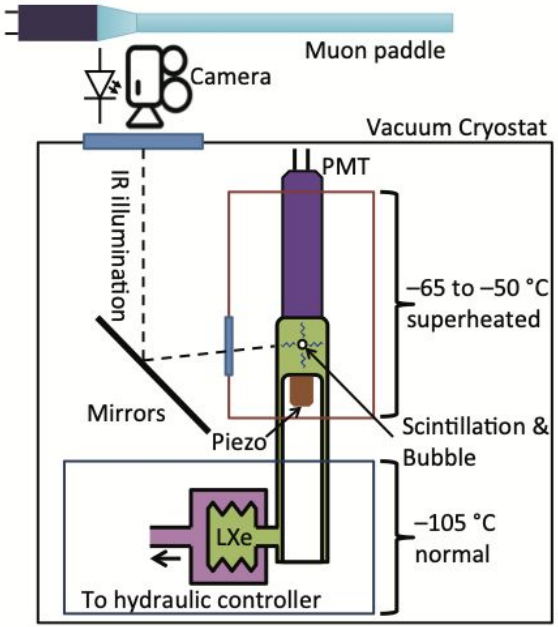
If ΔE deposited, local phase change

Limitations with Freons… and solutions

- Threshold detectors:
  no energy information
- β/γ rejection fails at low thresholds
- Liquid-noble B.C.'s
  - Energy information
  - Higher β/γ rejection than Freons
  - **Low threshold, bkg. separation, and scalable**

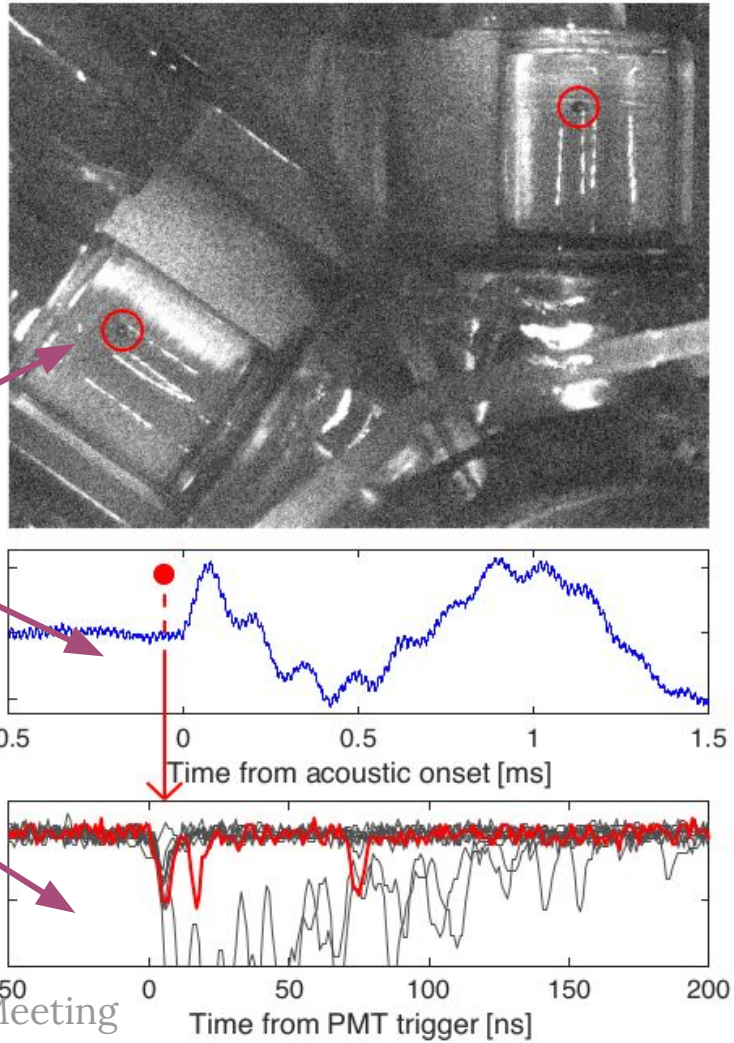


Prototype LXe bubble chamber



Simultaneous measurement of

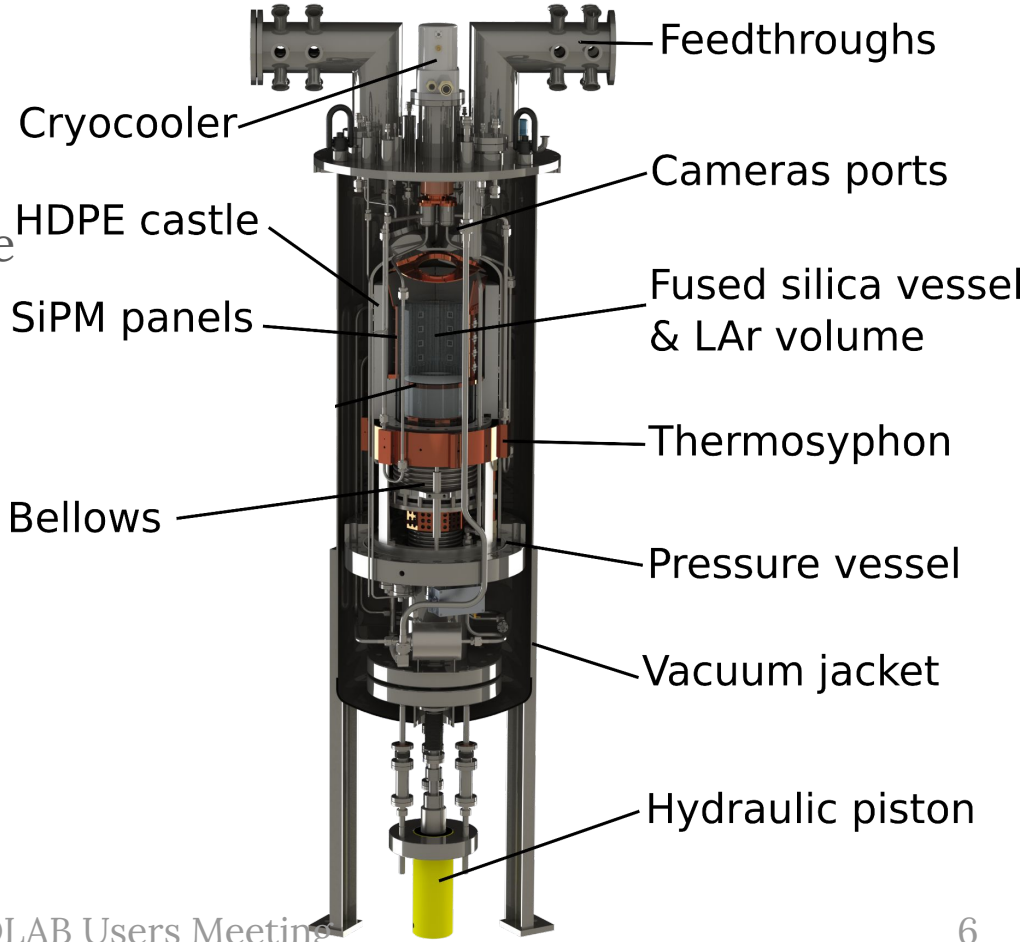
- Bubble position (cameras)
- Acoustic emission (piezo transducer)
- Scintillation (UV-grade PMT)



PRL 118.23 (2017) 231301

SBC detectors

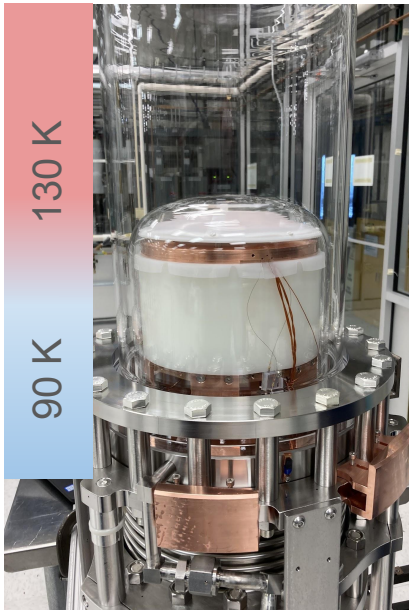
- **SBC-LAr10** @ Fermilab (engineering, calibration, future CEνNS program)
- **SBC-SNOLAB** @ SNOLAB (low bkg. dark matter)
- 10 kg LAr, doped with Xe
- 100 eV n.r. threshold (130 K, 30 psi)

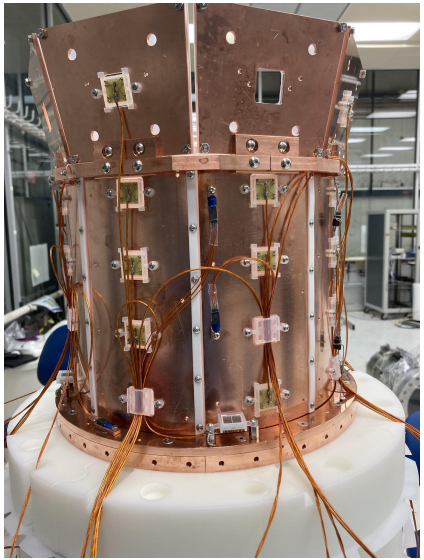


SBC-LAr10 IV assembly @ Fermilab

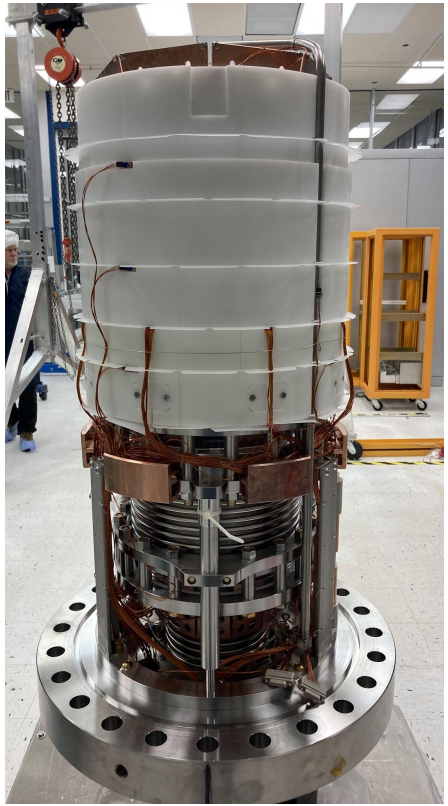
Quartz vessels

Trim heaters





SiPM wiring



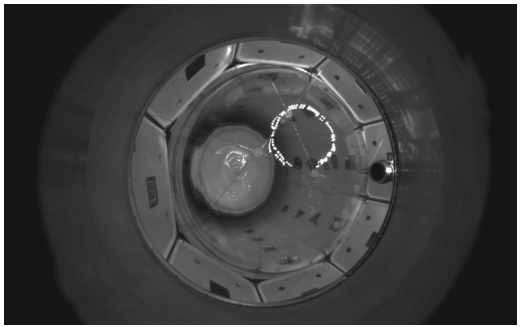
HDPE castle
w/ RTDs, piezos

Status @ Fermilab

- Hydraulic & thermal system tested
- Assembly complete, moved underground in MINOS tunnel with 100 m overburden

NEXUS

Cameras even see images →



MINOS Near Detector

Gas handling system

SBC

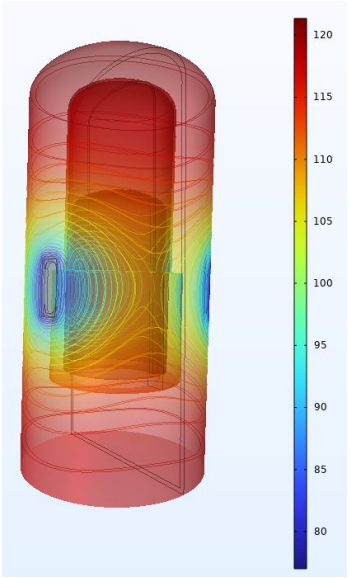
- Reassembling, then:
  - Cooldown and LAr filling

SBC-LAr10 goals for SBC-SNOLAB

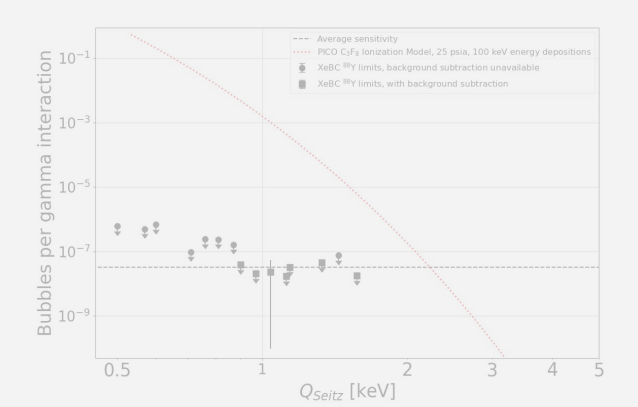
1) Stable operation
   - Homogeneous response across sensitive volume
   - Event building: scintillation [ns], acoustic [us], cameras [ms]

2) Gamma calibration
   - Confirm no e.r. nucleation at keV-scale
   - Investigate e.r. rejection at/below 100 eV

3) Nuclear recoil calibration
   - Photoneutron (keV), photon-nucleus scattering (< 300 eV), tagged neutron capture (~ 300 eV)



See next talk from Ezri Wyman



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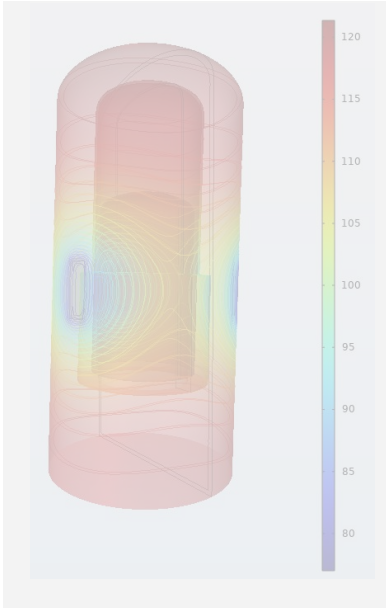
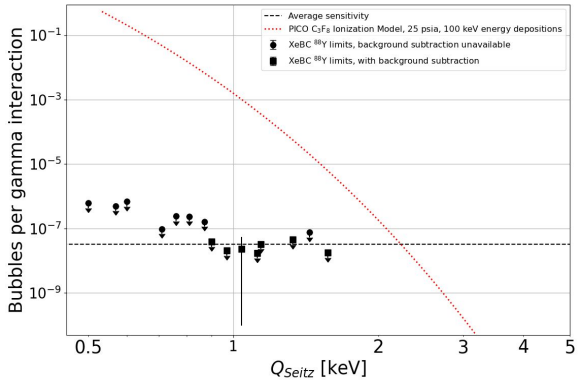
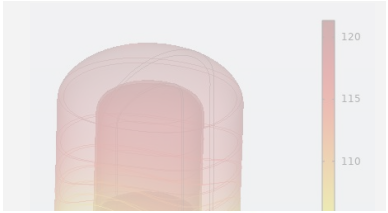




SBC-LAr10 goals for SBC-SNOLAB



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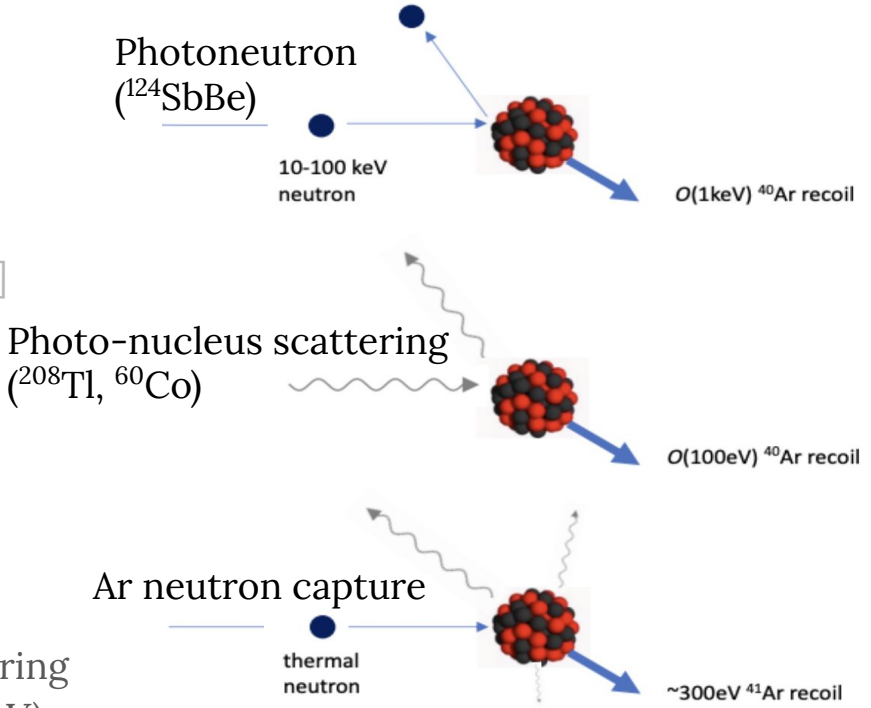
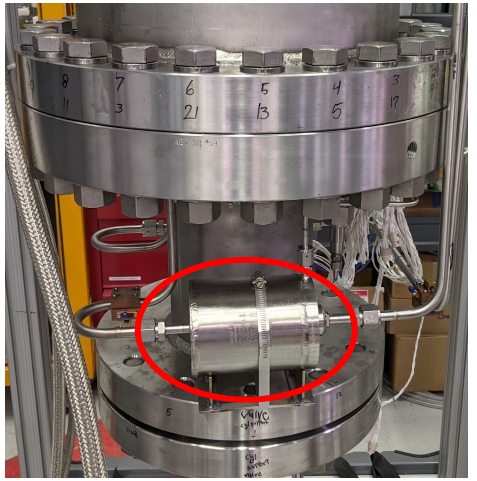
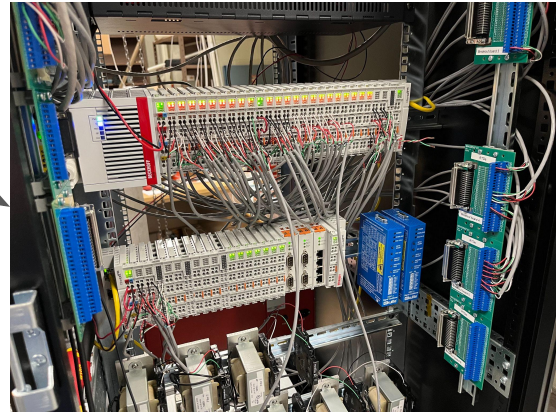


Next for SBC-SNOLAB @ SNOLAB



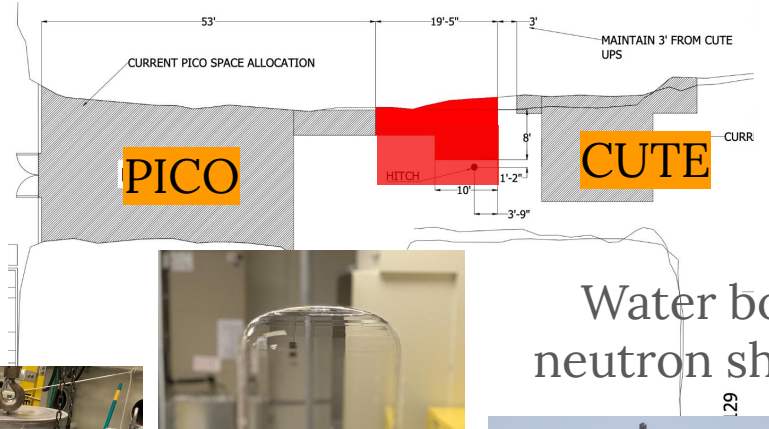
- SBC-LAr10 will demonstrate technology and operation
- Refining design for low background SBC-SNOLAB
  Notable changes:
  - SiPMs, wire management, shield
  - TSSA certified components (feedthroughs, viewports, & cryovalves)
  - Unified gas panel
- PLC cabinet wiring (@ Queen's)
- FBK SiPM bonding (@ TRIUMF)

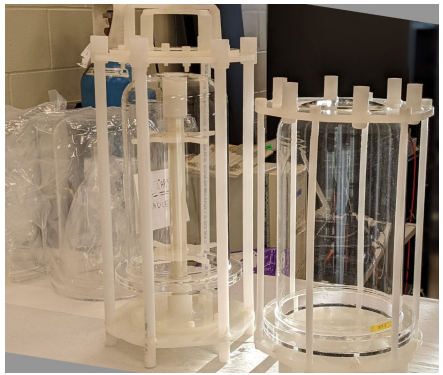


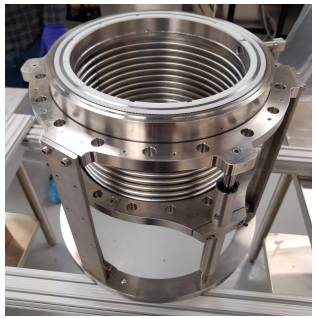
- TDR in August,
  then assembly of inner vessel @ SNOLAB

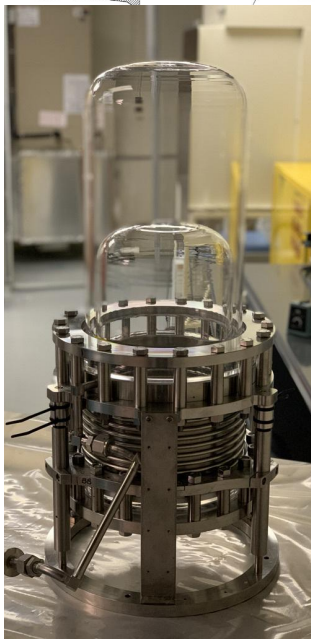
Status of SBC-SNOLAB

- Space allocated u/g
- SNOLAB IV built and tested
  (2 sets of jars, bellows assemblies, etc.)

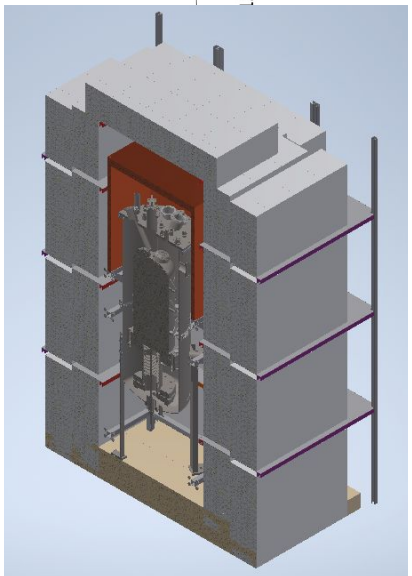






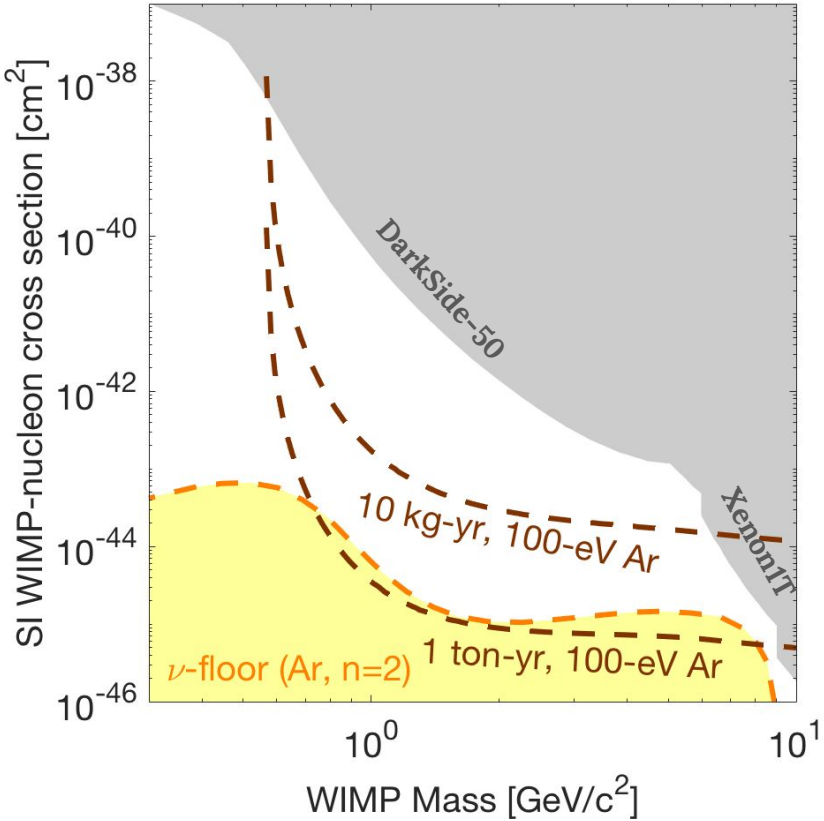


Water box neutron shield



- PV and VJ manufacturing, shield design this summer

Physics potential: dark matter



- Region of interest: 0.1 keV - 10 keV n.r. (just bubble, no scintillation)
- 10 kg-year exposure reaches 10^{-43} cm^2 @ 1 GeV/c^2, tonne-year to neutrino fog
- Fluid flexibility (SI or SD search potential)

Conclusion

- SBC has great potential to probe GeV-scale dark matter*
  - Scalable, low threshold detector with background discrimination

- Exciting time for SBC:
  - Commissioning SBC-LAr10 this summer
  - SNOLAB TDR August 2024

- More details:
  - Snowmass white paper: **arXiv: 2207.12400**
  - Also in: ***Universe* 9 (2023) 8, 346**

*and CEνNS.