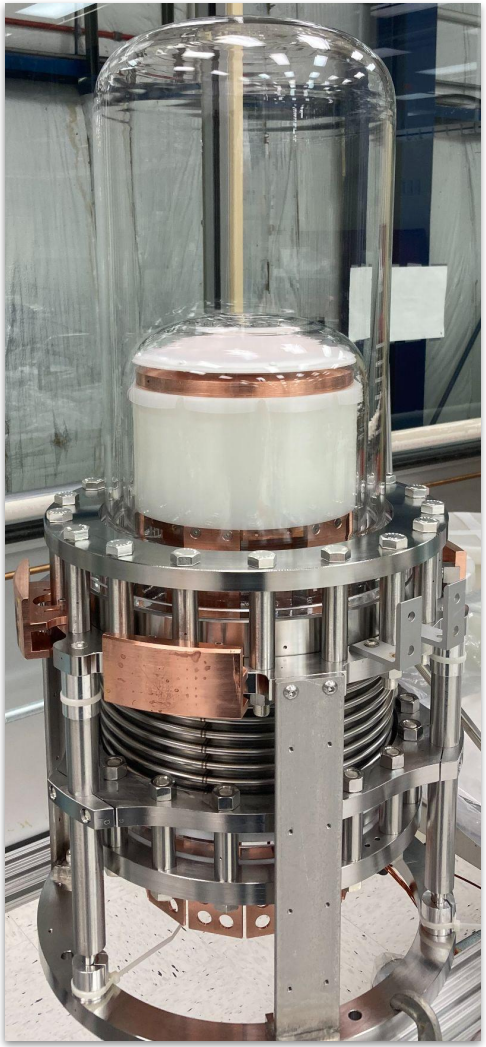
The Scintillating Bubble Chamber Experiment

Ben Broerman
for the SBC collaboration

IDM 2026

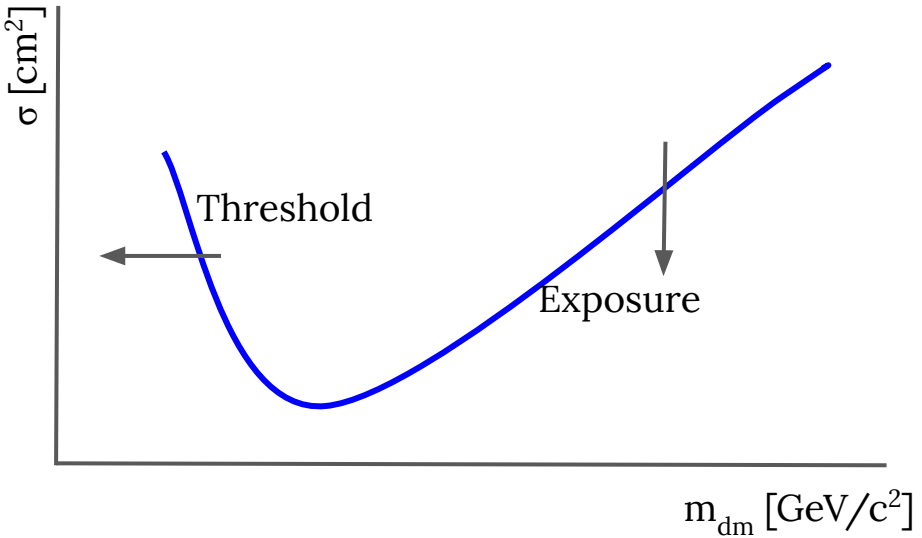
Queen's University

Arthur B. McDonald
Canadian Astroparticle Physics Research Institute



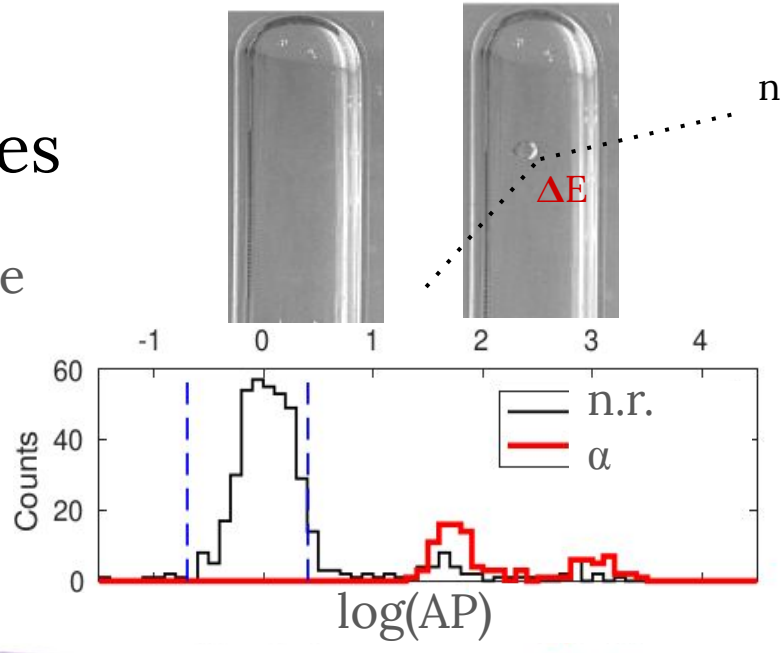
sub-keV nuclear recoils

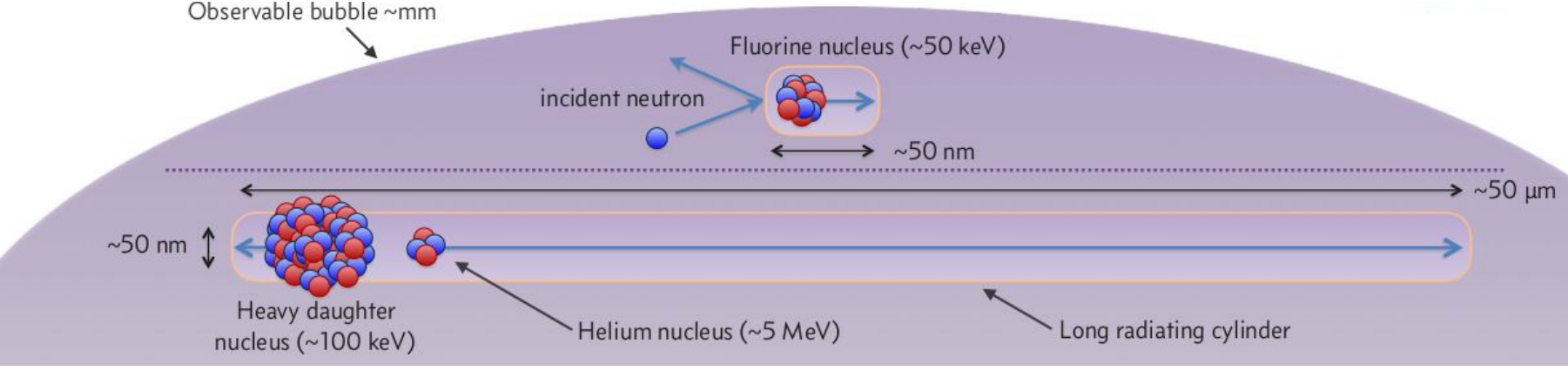
- Difficult kinematics of GeV-scale DM-nucleon scattering require low thresholds ($\lesssim 1$ keV)
    - Future success here needs background discrimination **and** scalability
- Similar challenge measuring CEνNS from MeV-scale ν's



Bubble chambers for DM searches

- Superheated liquids have efficient bubble formation at low n.r. thresholds
- Highly β/γ insensitive
- n.r./α discrimination:



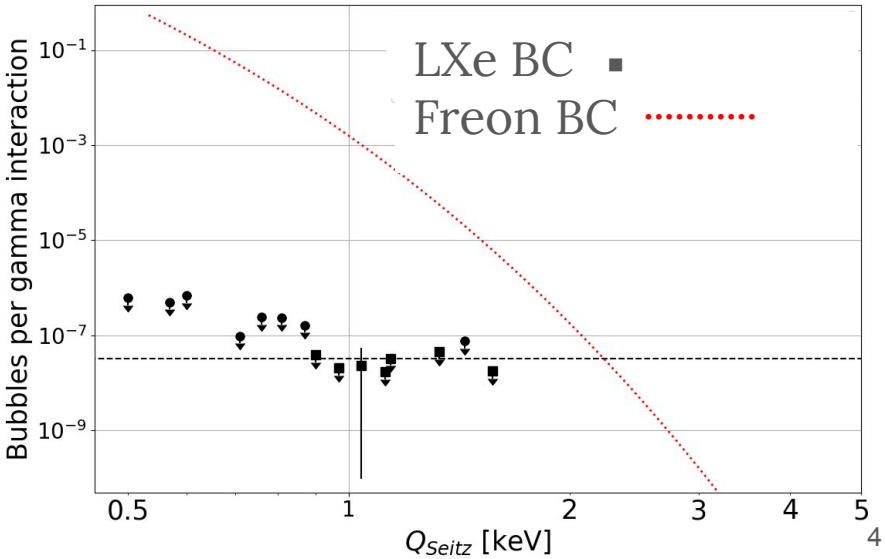


A liquid-noble bubble chamber

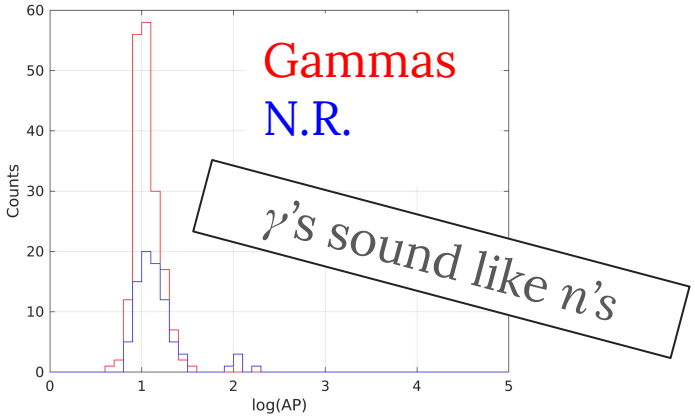
Adds in:

- Energy reconstruction

- Higher β/γ rejection than Freons
  - Lower threshold w/o e.r. backgrounds increases sensitivity to lower DM masses



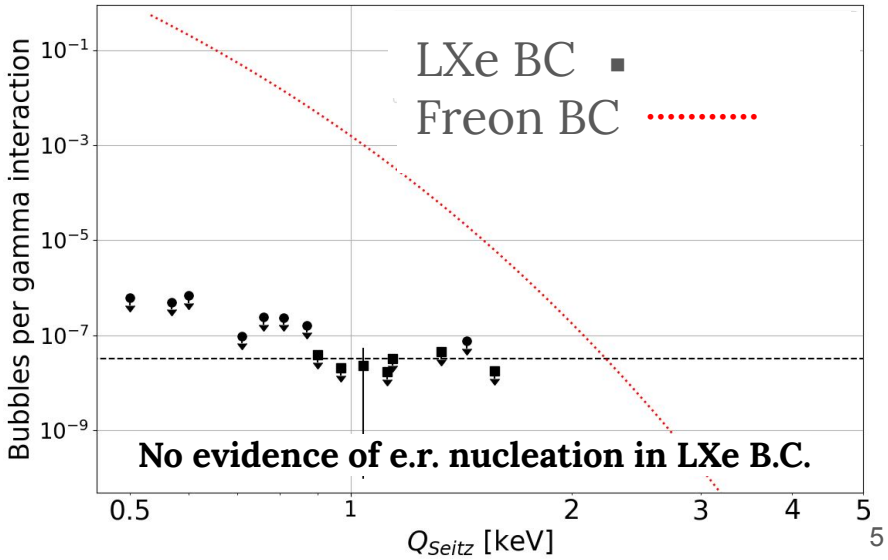
A liquid-noble bubble chamber



Adds in:

- Energy reconstruction

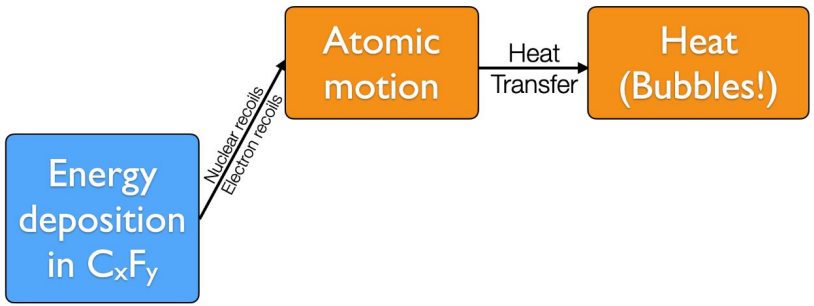
- Higher β/γ rejection than Freons*
  - Lower threshold w/o e.r. backgrounds increases sensitivity to lower DM masses



*Studied in liquid xenon: [PRD.111.032002]

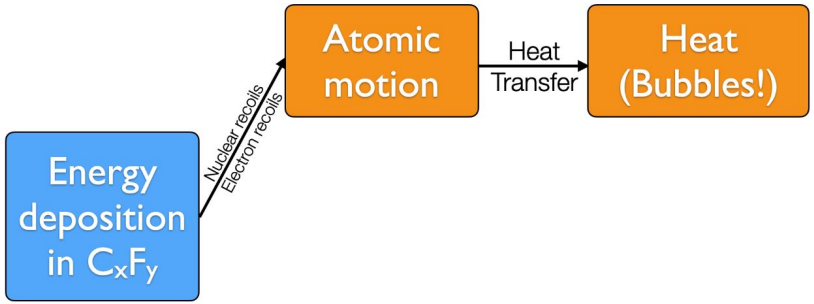
Energy deposition channels

Freon-based target fluid

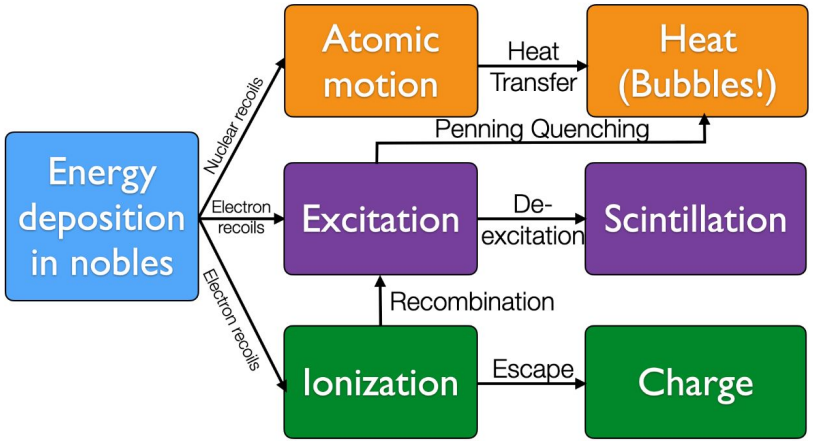


Energy deposition channels

Freon-based target fluid

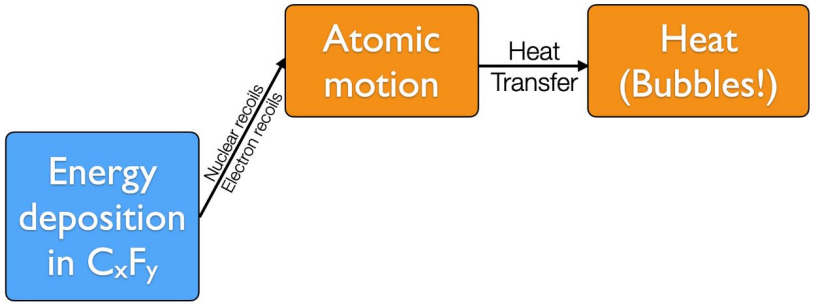


Liquid-noble target fluid

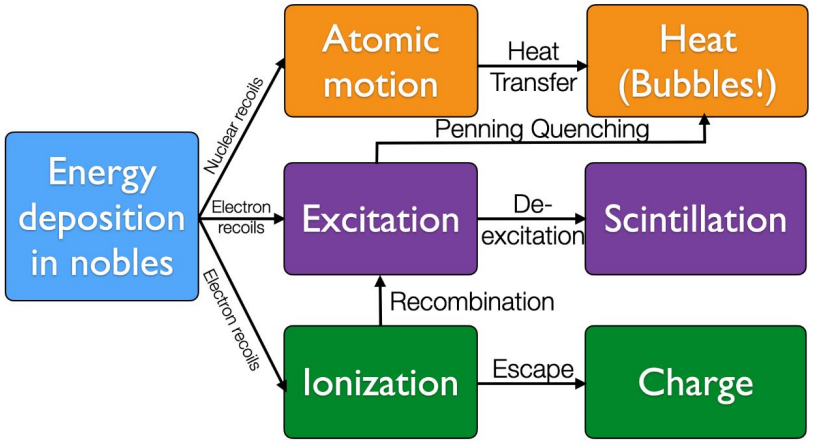


Energy deposition channels

Freon-based target fluid

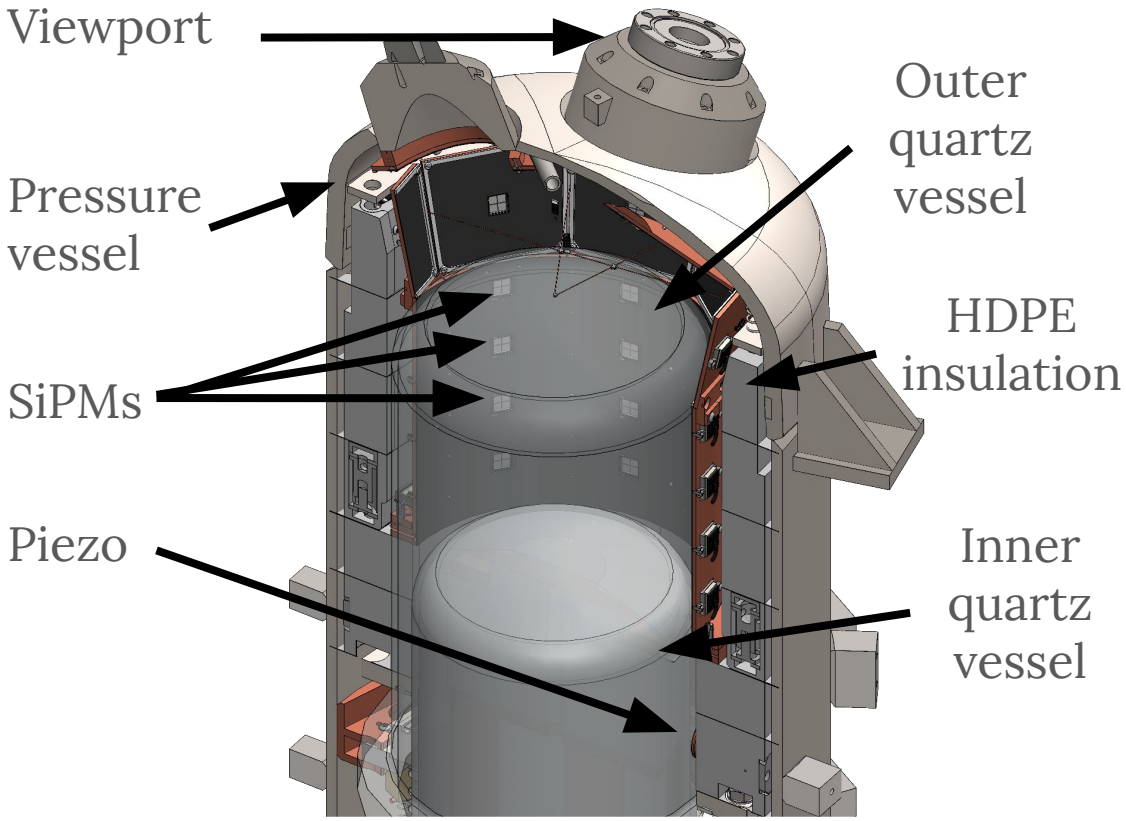


Liquid-noble target fluid



Main point: Liquid nobles remain β/γ insensitive in GeV-scale ROI
→ **sensitive to only nuclear recoils**

10 kg detector design

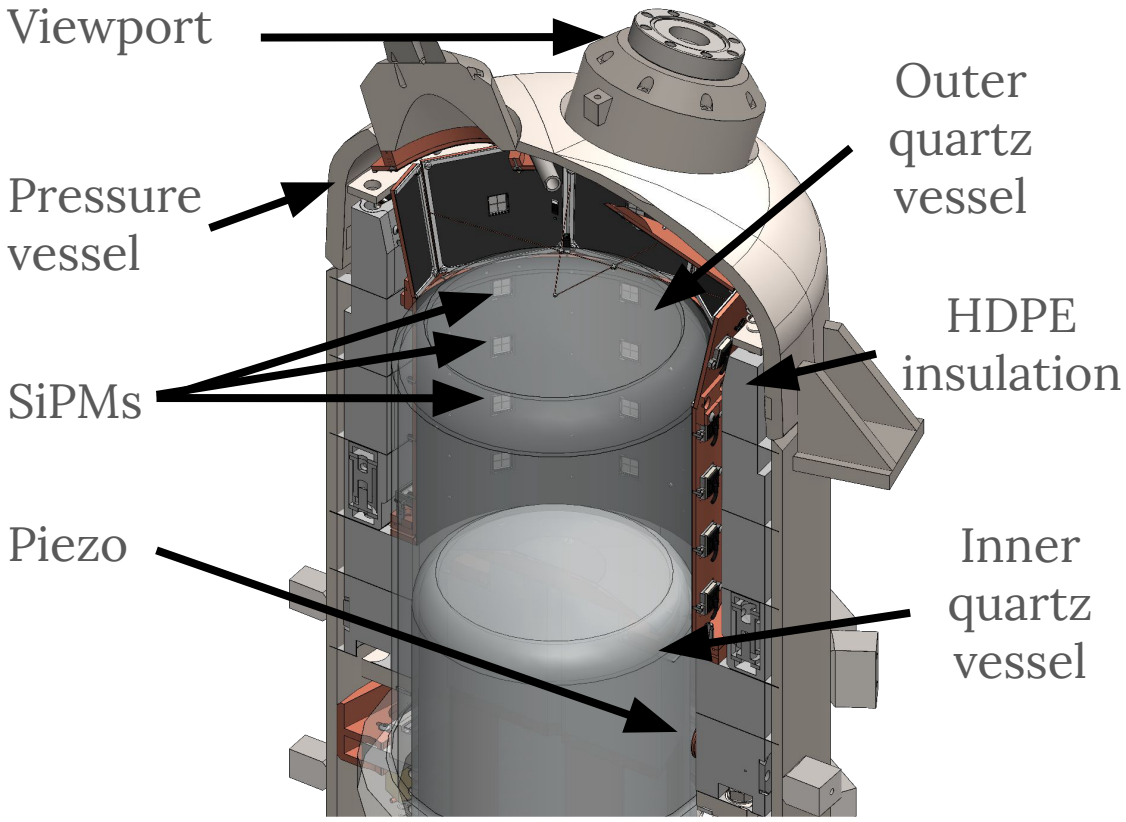


Two functionally identical detectors:

SBC-LAr10 @ Fermilab (engineering, calibration, future CEνNS program)

SBC-SNOLAB @ SNOLAB (low background dark matter search)

10 kg detector design

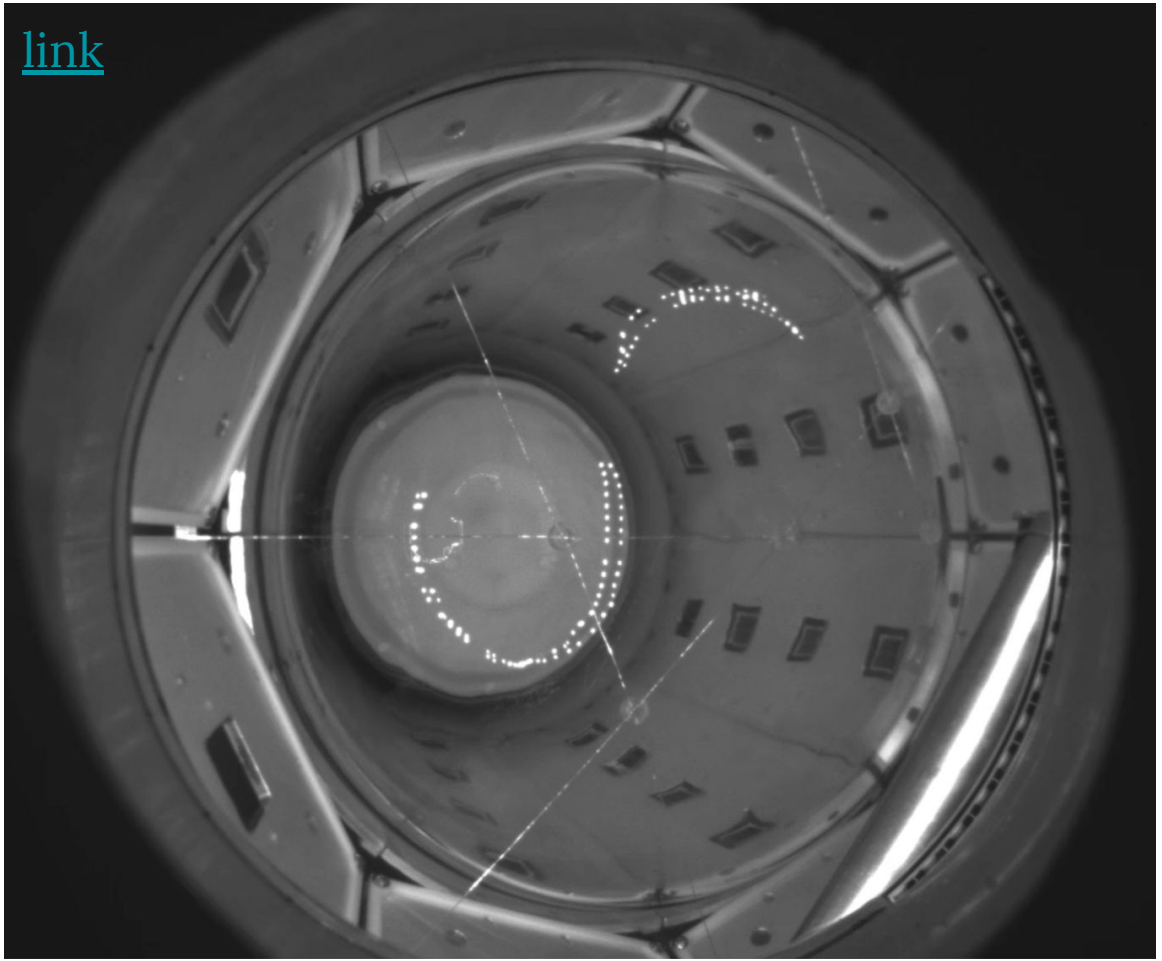


Design Goals	
Target Volume	10 L (10 kg LAr @ 130 K)
Nucleation Threshold	100 eV (30 psi , 130 K)
Thermodynamic Regulation	±0.5 K, ±0.1 bar, (± 5 eV Seitz threshold)
Scintillation Detection	~2% collection, 1 photon/ 5 keV n.r.
Bubble Imaging	100 fps, mm resolution
Acoustic Reconstruction	Time-of-nucleation to ± 25 μs

Operation at FNAL

- 6 months of stable operation with nucleation thresholds from 0.46 – 3 keV

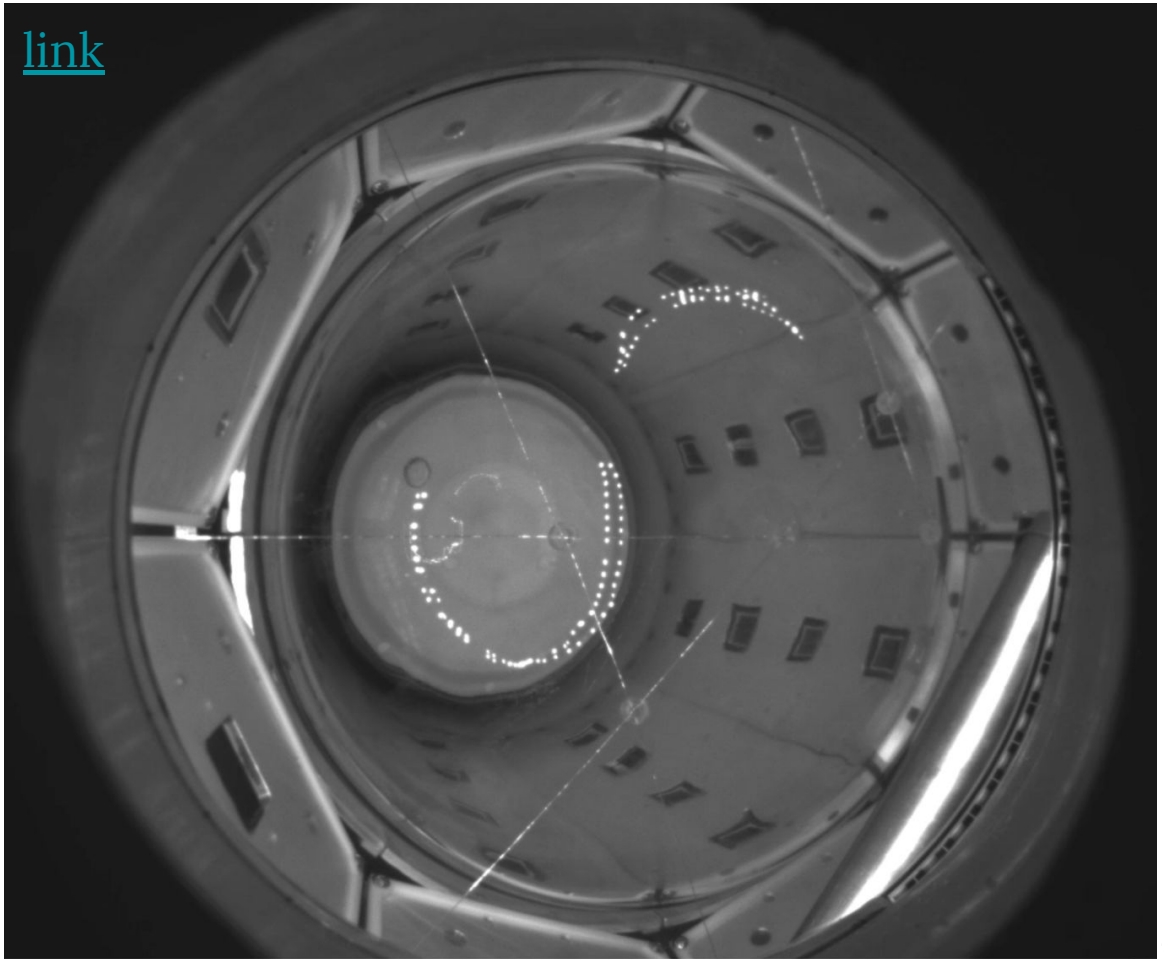
- Simultaneous measurement of scintillation and bubble nucleation observed



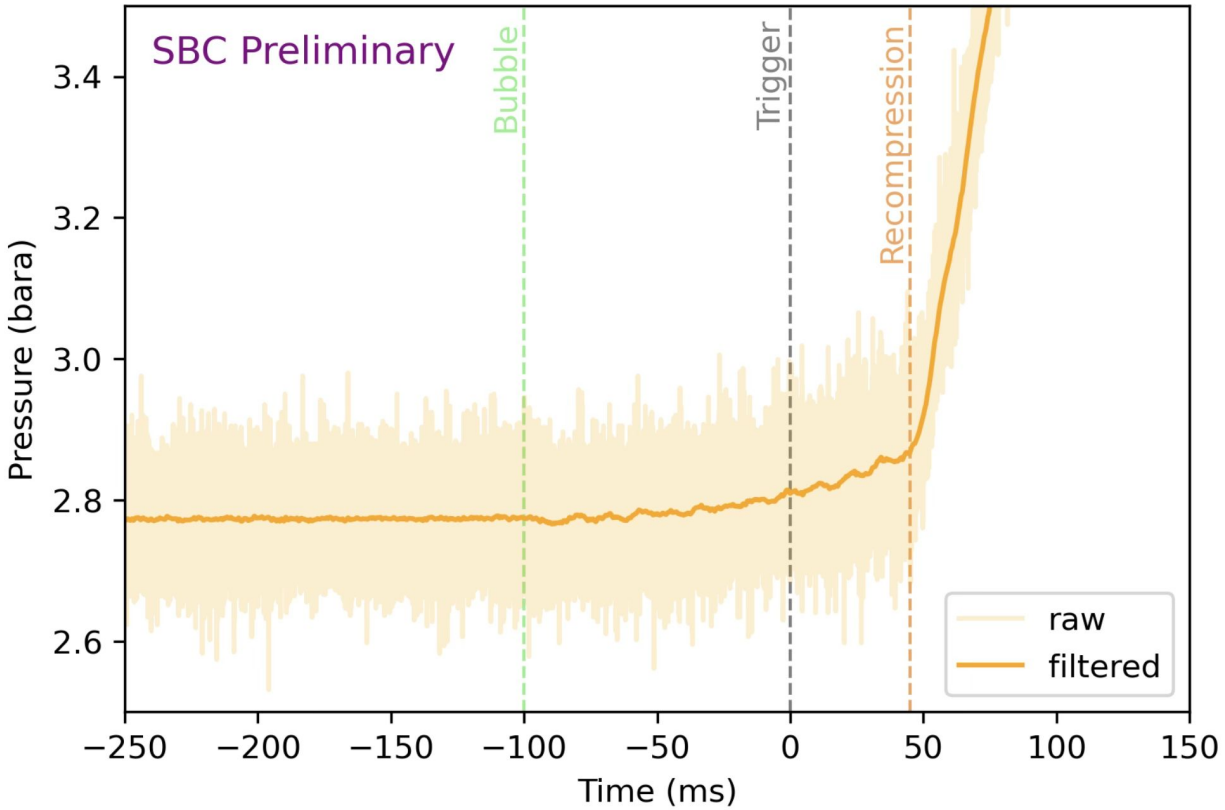
Operation at FNAL

- 6 months of stable operation with nucleation thresholds from 0.46 – 3 keV

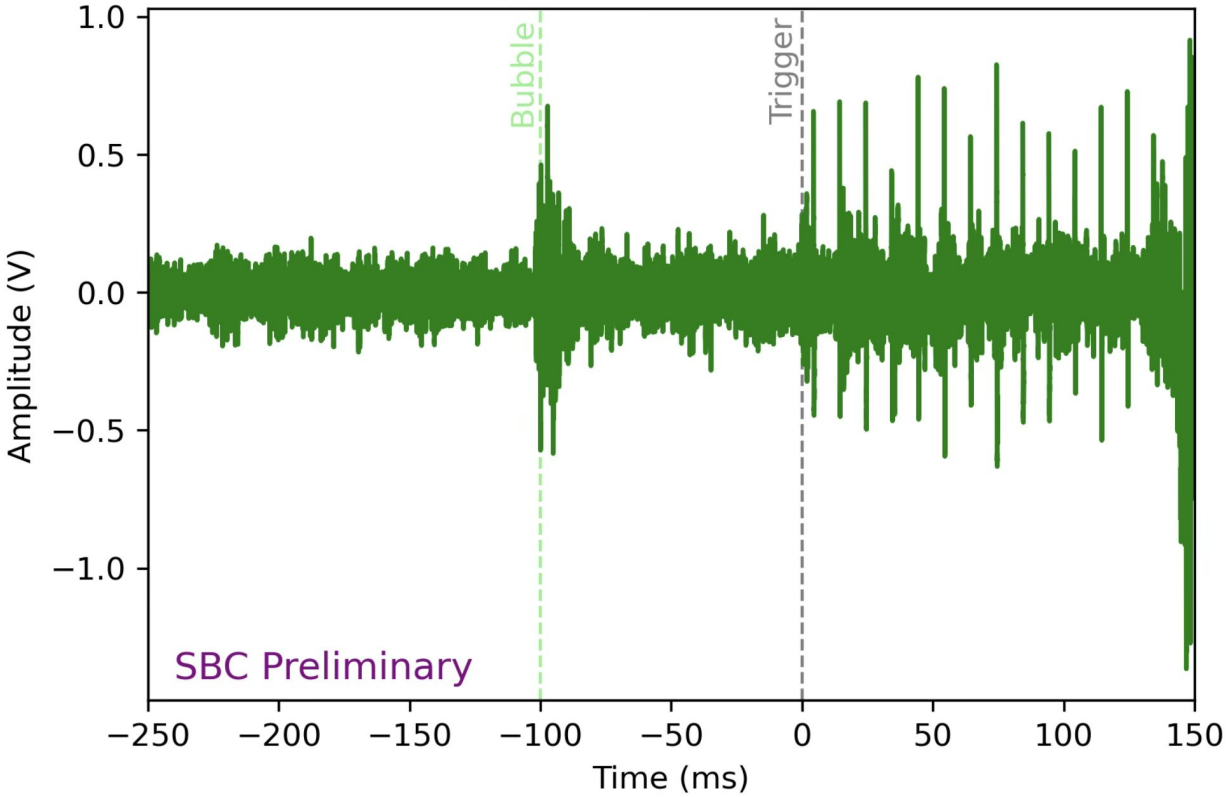
- Simultaneous measurement of scintillation and bubble nucleation observed



Example pressure signal

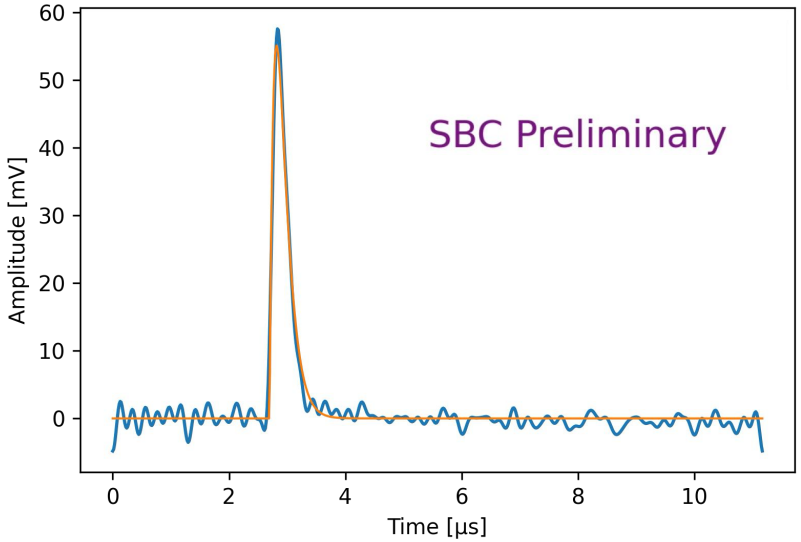


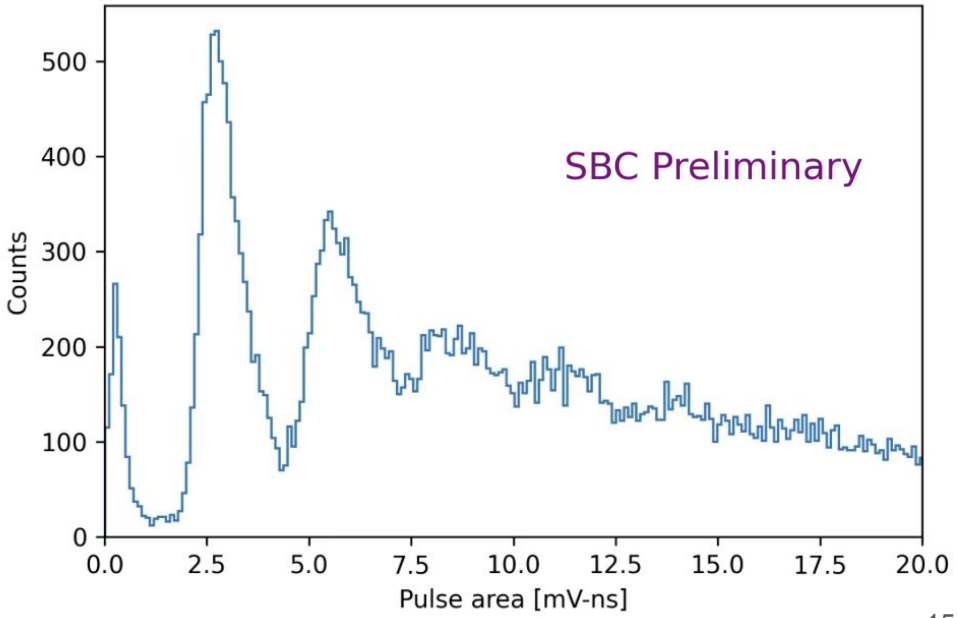
Example acoustic signal



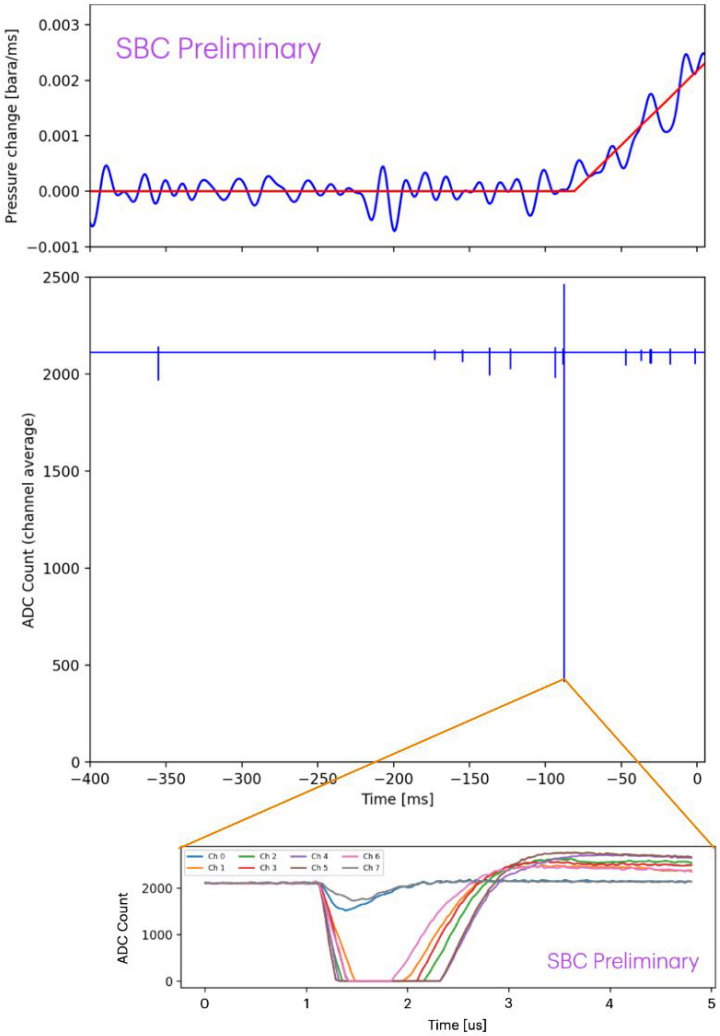
Example SiPM signal

- Pulse fitting to extract charge of the 32 SiPMs



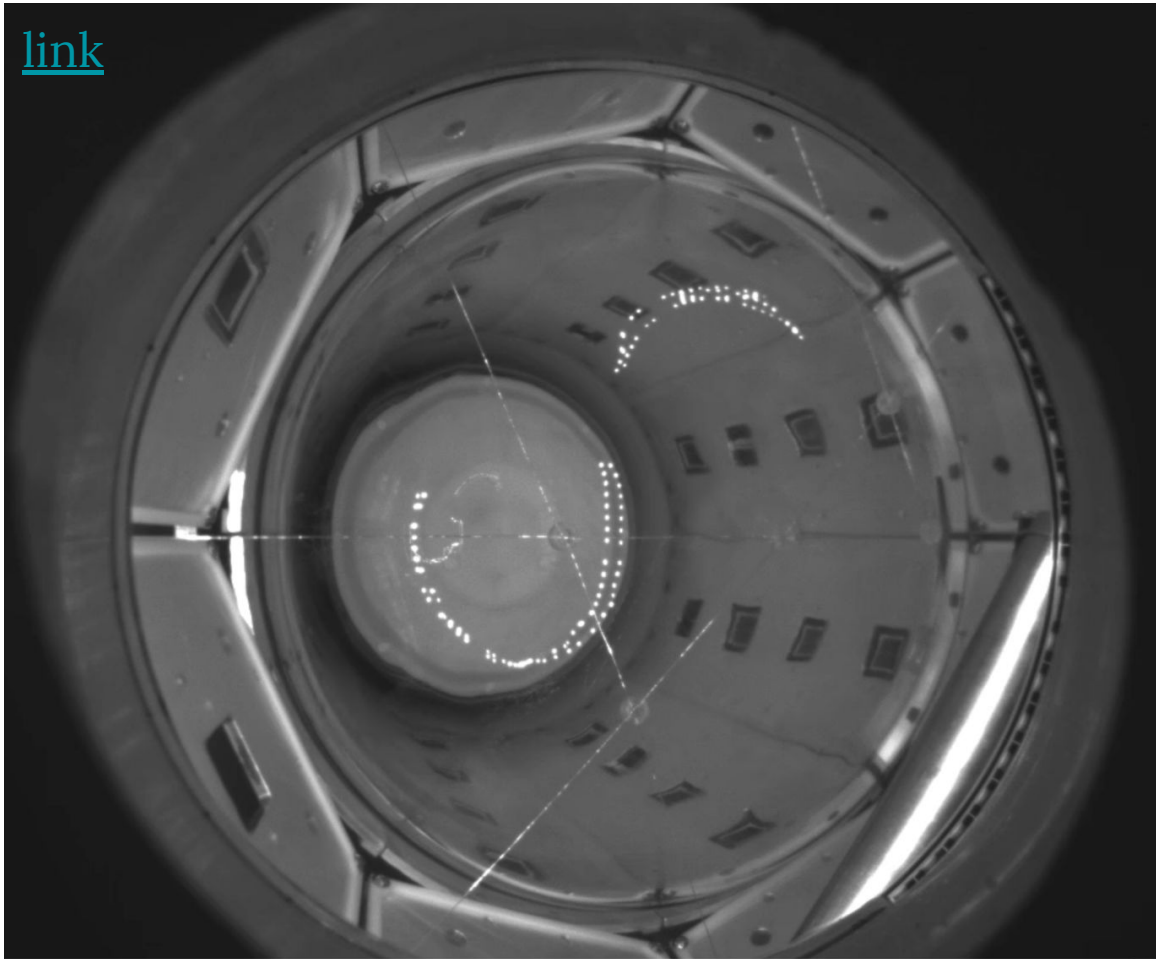


Signal coincidence:
Pressure + bubble + scintillation



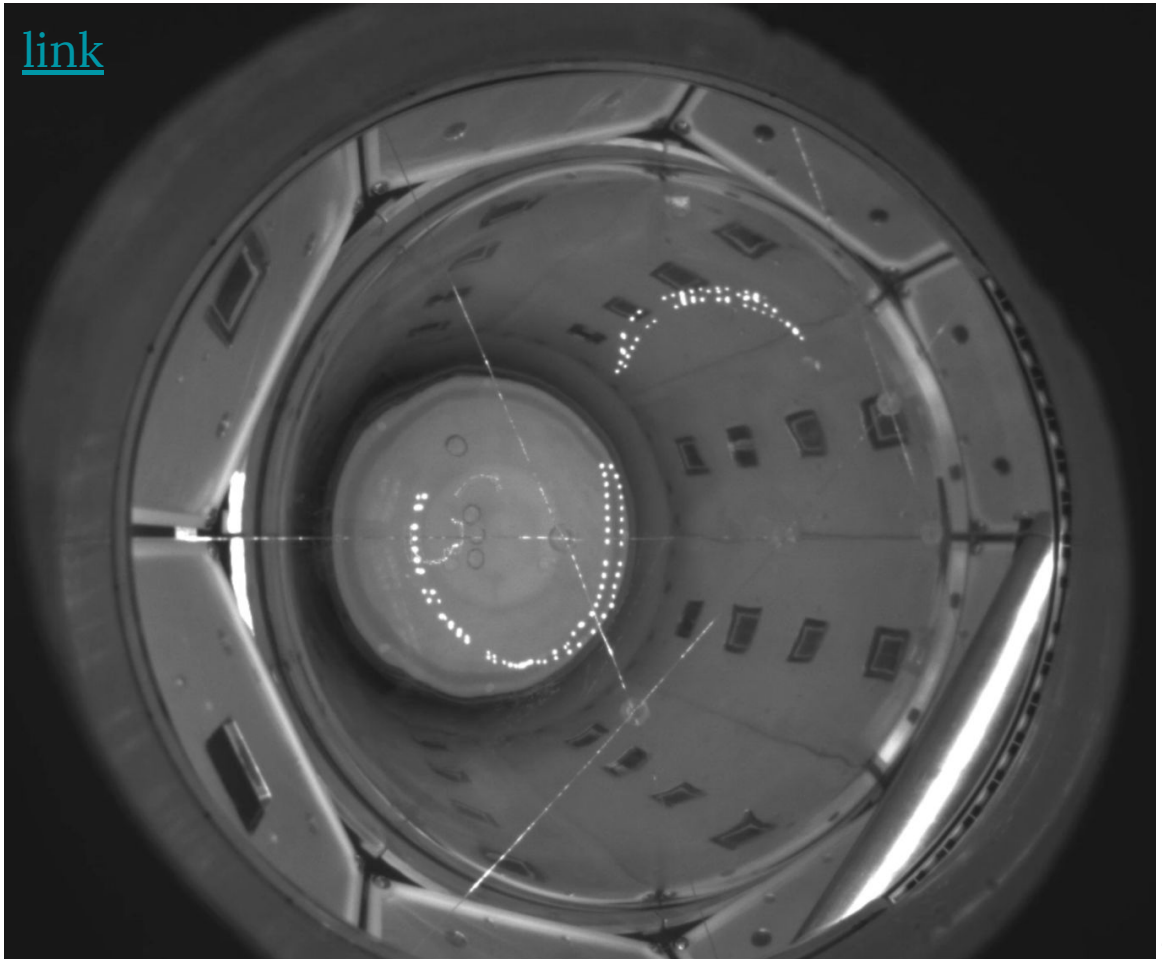
Multiscatter neutron event

link



Multiscatter neutron event

link



Component arrival at SNOLAB

Main detector components are arriving on surface at SNOLAB

Pressure vessel

Vacuum jacket

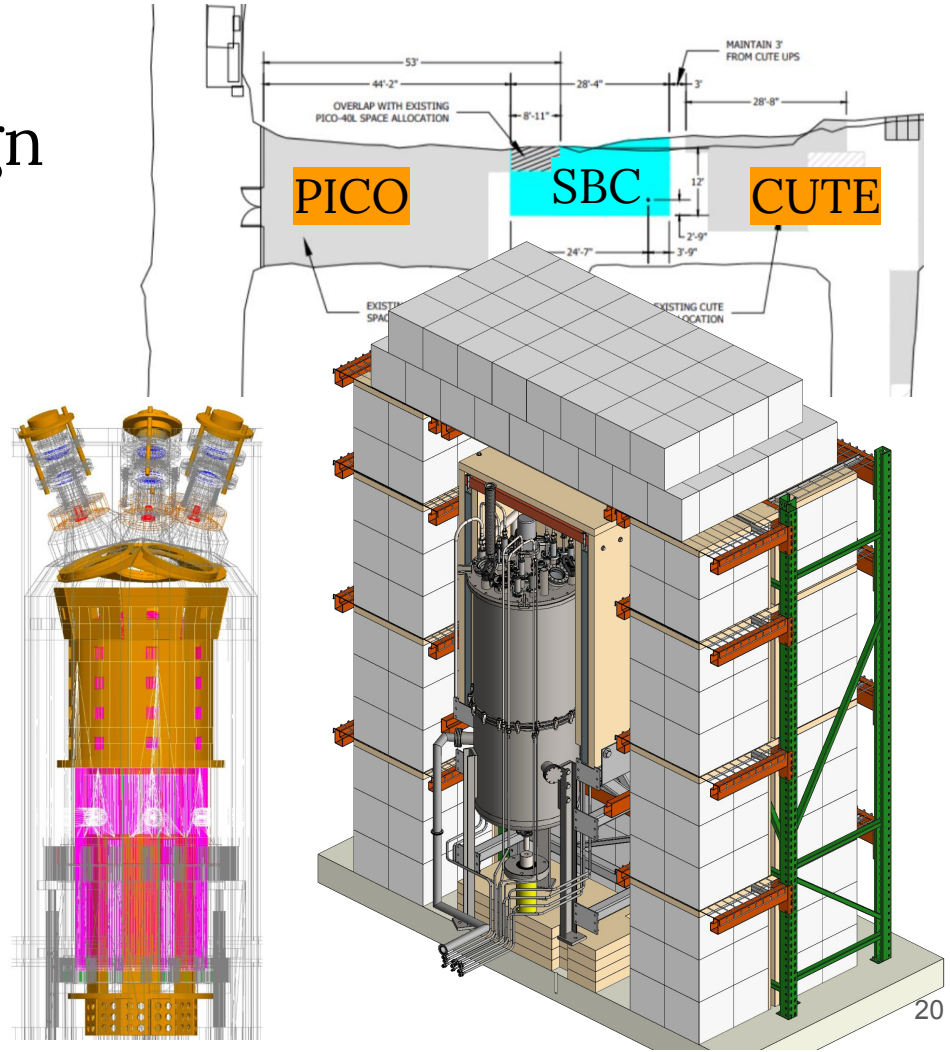
Simulation and shield design

Space allocated in the ladder labs at SNOLAB

Full assay campaign and Geant4 simulation of internal and external backgrounds

- Water shield for fast neutrons

- Lead shield for gammas ($E\gamma \gtrsim 1.4$MeV)

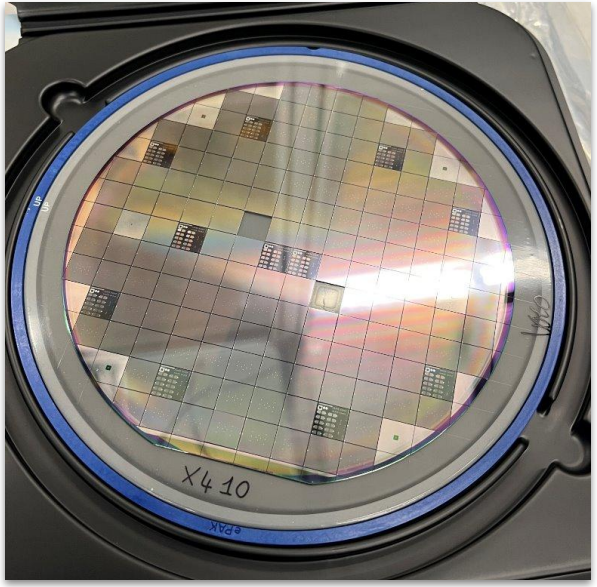


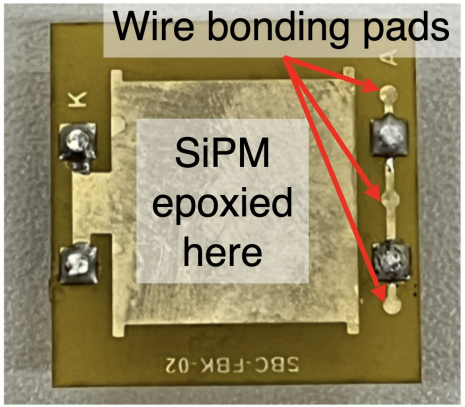
SiPM construction

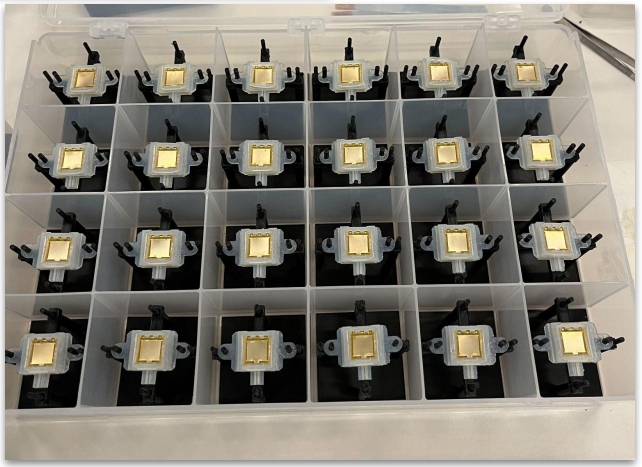
- Simulations indicate high background rate from Hamamatsu VUV4 SiPMs

- Switch to FBK VUV HD3 (courtesy of nEXO)

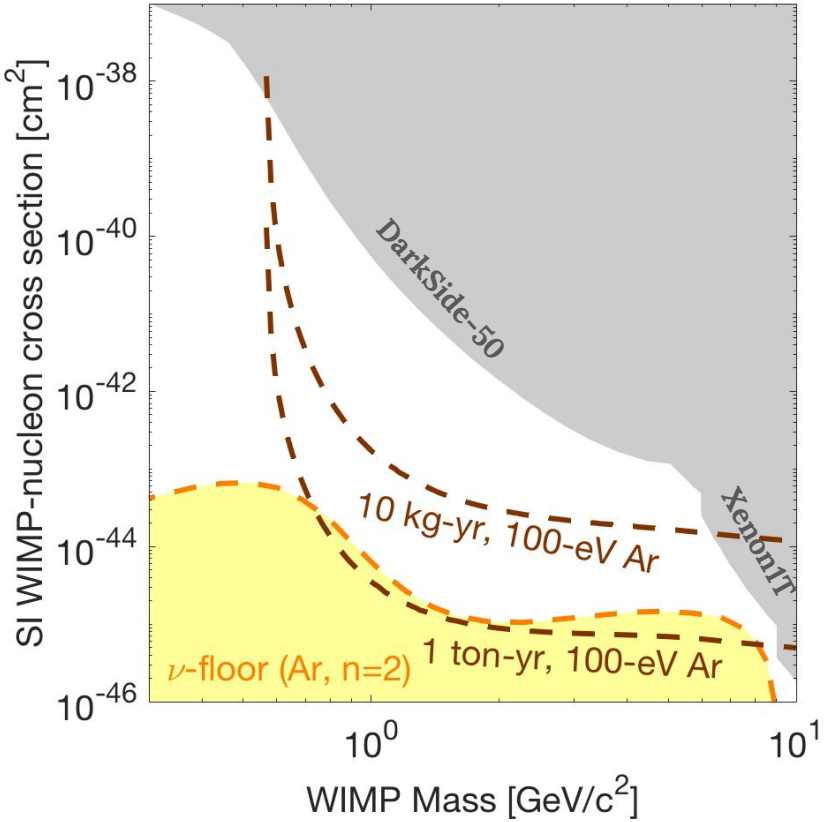
- Wire bonding completed at TRIUMF, now characterizing at Queen's







Physics potential



- ROI: 0.1 keV - 10 keV n.r.
  - just bubble, no scintillation
- SNOLAB chamber, 10 kg-year exposure can reach 10^{-43} cm^2 @ 1 GeV/c^2
- Tonne-year can reach boundary of the Ar ν-fog
- Target fluid flexibility (Xe, Ar, N_2, etc.)

Conclusion

- Exciting time for SBC-SNOLAB
  - Gateway 2 just passed and parts arriving on surface for assembly this fall

- Publications:

arXiv: 2207.12400
Universe 9 (2023) 8, 346
Phys.Rev.D 111 (2025) 3, 032002
JINST 19 (2024) 08, T08003
JINST 21 (2026) 03, P03020

Queen's University
Universidad Nacional Autónoma de México
Drexel University
Indiana University South Bend
Northwestern University
University of Alberta
UC Santa Barbara
Fermilab
Northeastern Illinois University
Université de Montréal
Pacific Northwest National Laboratory
UC Riverside