SBC'S 10 KG ARGON BUBBLE CHAMBERS FOR DARK MATTER AND REACTOR CEVNS

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SBC Collaboration

New Perspectives 2020

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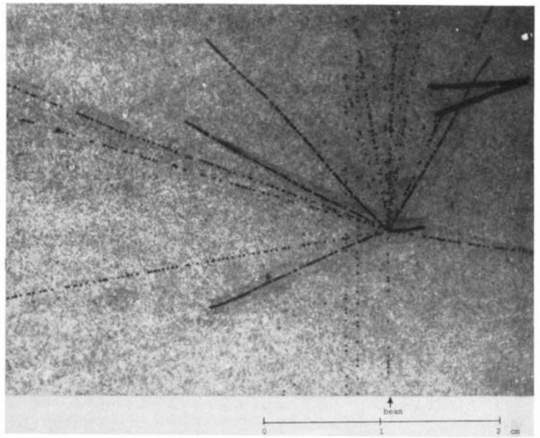
BUBBLE CHAMBERS

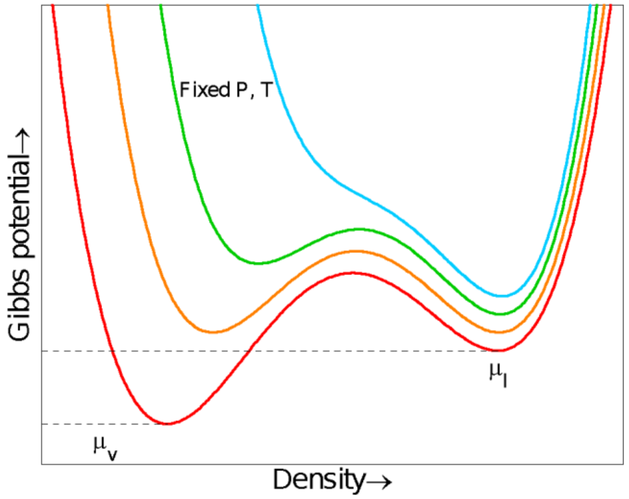


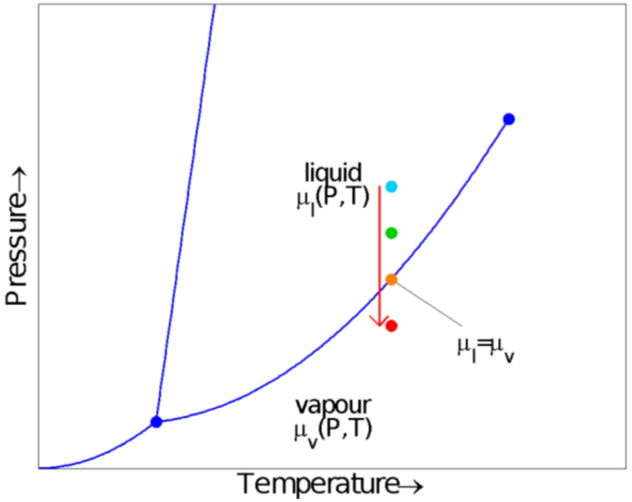
Operation of a bubble chamber filled with argon, nitrogen, and argon-nitrogen mixtures
NIM (1981)

"Cloud chambers, but better" – Glaser, 1952 (paraphrased)

Superheated liquid boils when energy is deposited, creating a bubble at the interaction site

- $E_T = 4\pi R_c^2(\sigma - T(\frac{\partial\sigma}{\partial T})_\mu) + \frac{4\pi}{3}R_c^3\rho_b(h_b - h_l) - \frac{4\pi}{3}R_c^3(P_b - P_l)$
- $R_c = \frac{2\sigma}{P_b - P_l}$





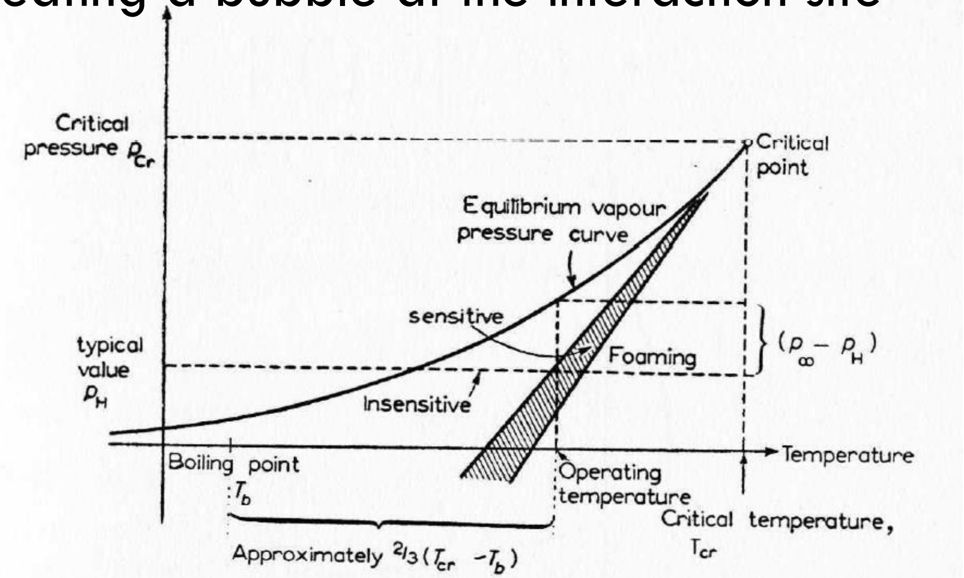


Fig. 3. The dependence of the operation of a bubble chamber on temperature and on the pressure, p_H, to which the liquid is expanded.

The Bubble Chamber
Progress in Nuclear Physics 7 (1959)

SUPERHEATED DARK MATTER SEARCHES

https://www.snolab.ca/content/picasso-detector

The goal of any direct detection dark matter search is to find single nuclear recoils, and reject or be insensitive to anything else

The hot spike nucleating a bubble must be very localized

- the energy must be deposited in approximately 2 critical radii; a few nanometers
- Recoiling nuclei (including alphas) meet this dE/dx requirement, recoiling electrons don't
- Superheated dark matter detectors offer little or no calorimetry, only a lower bound, the threshold, on the deposited energy

Bubble chambers exclude multiple-scattering neutrons visually, alphas acoustically, and electron recoils intrinsically

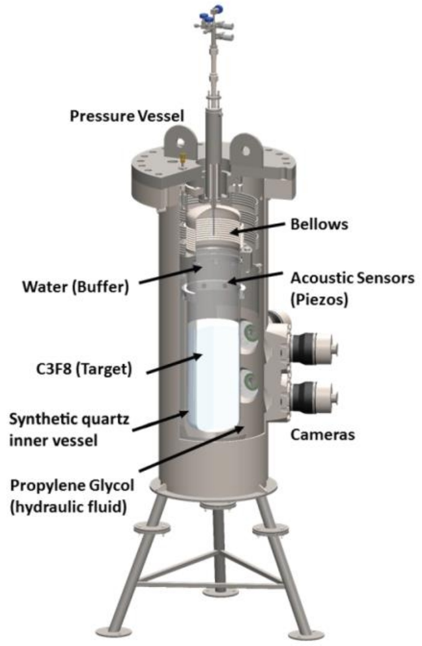
Past experiments:

- PICASSO and SIMPLE: superheated freon droplets in gel
- COUPP: freon bubble chambers

Ongoing experiments:

- PICO: freon bubble chambers
- MOSCAB: freon geysers
- SBC: liquid noble bubble chambers

arXiv:1902.04031 and PRD 2019



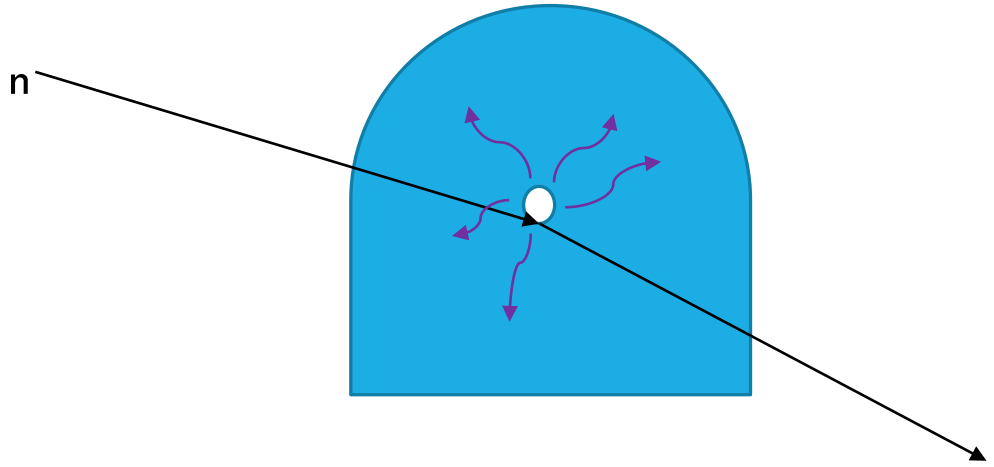
SCINTILLATING BUBBLE CHAMBERS

We retain or improve:

- the intrinsic gamma/ER insensitivity,
- multiple-scatter rejection,
- and image-based position reconstruction of other bubble chambers

With the added benefit of calorimetry in the scintillation channel!

WIMP signal: single bulk bubble with no associated light



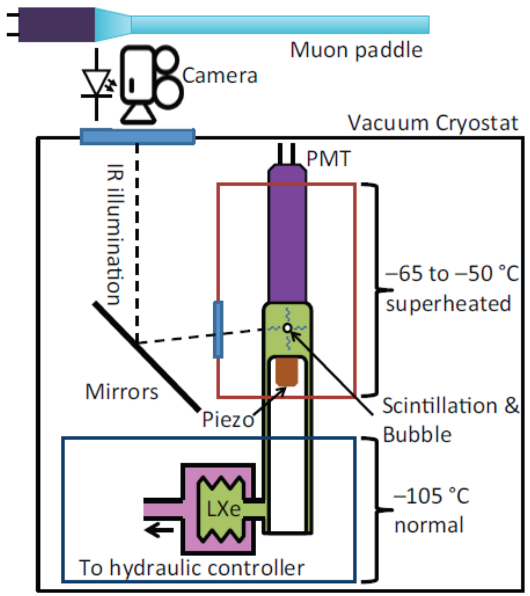
XENON BUBBLE CHAMBER

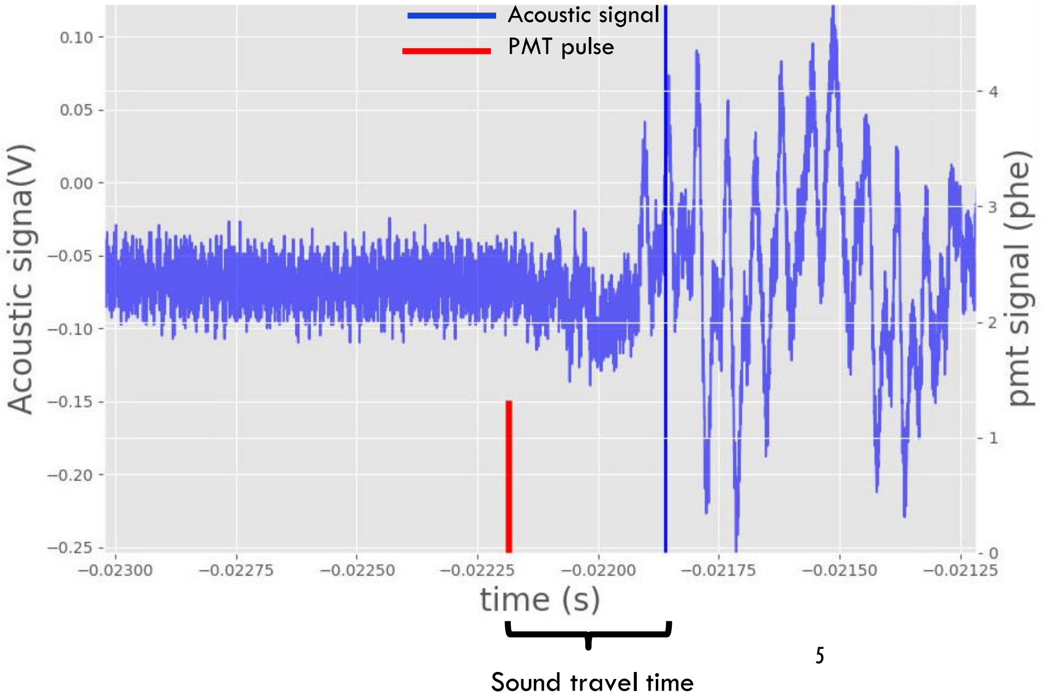
30 g prototype

Improved insensitivity to gammas over freon bubble chambers at thresholds as low as 500 eV

Even with ~0.1% efficiency, NR-associated scintillation clearly visible in background and ^{252}Cf data

arXiv:1702.08861 and PRL 2017

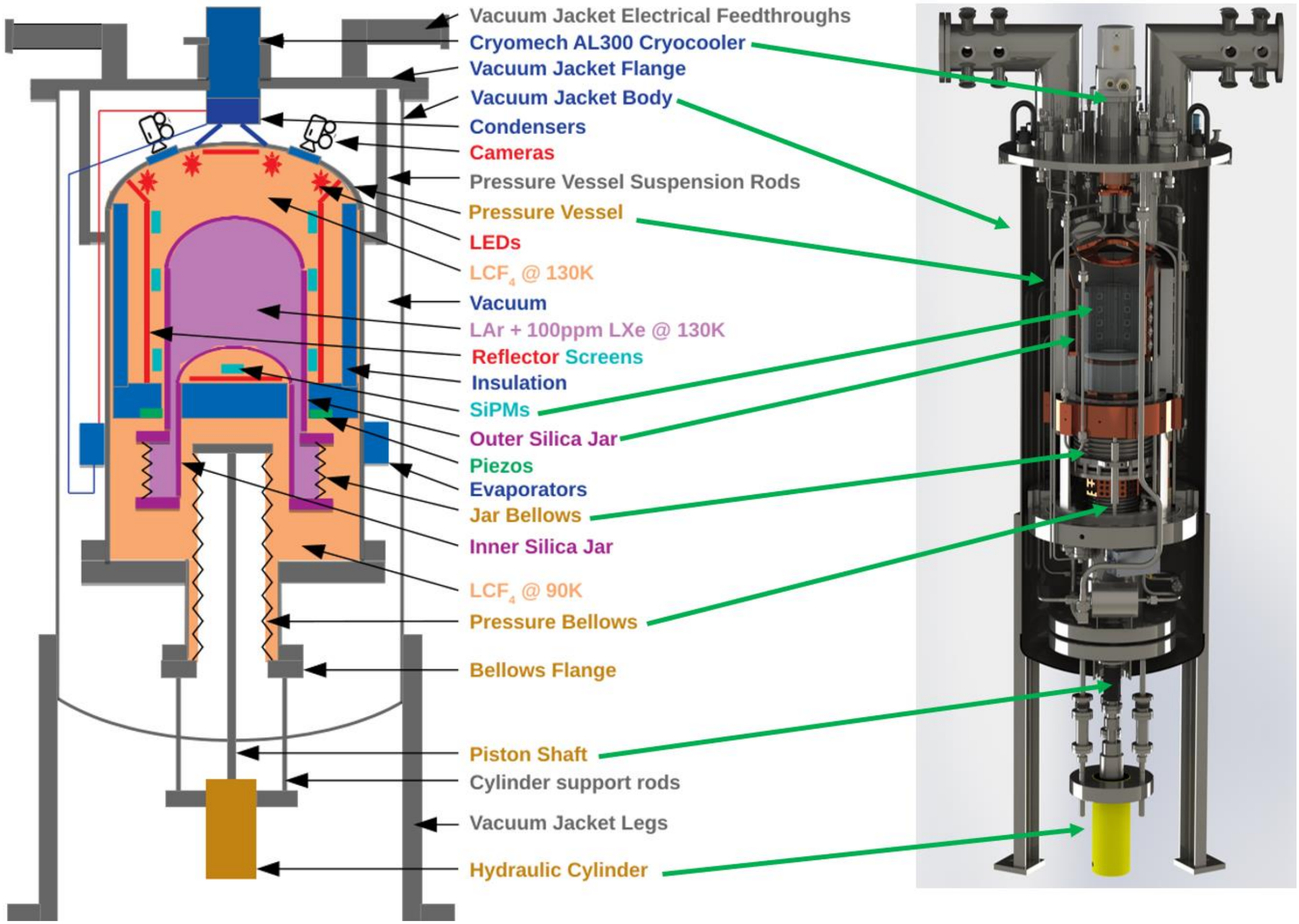




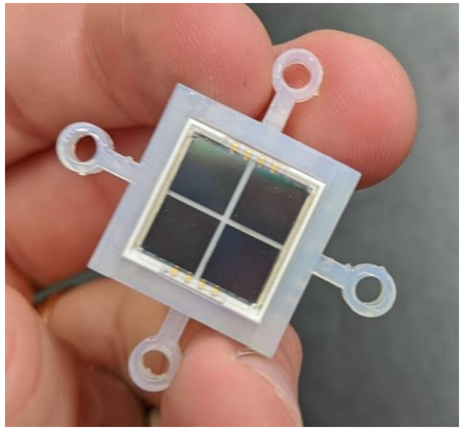
SCINTILLATING ARGON BUBBLE CHAMBERS

10 kg Argon bubble chambers:

- Include O(100) ppm xenon for wavelength shifting
- Expect to run at nuclear recoil thresholds around 100 eV, for sensitivity to 0.7 GeV/c^2 dark matter, and reactor neutrinos
- With 2% light collection efficiency, expect about 1 pe for a 5 keV NR, effectively vetoing most single bubble neutron-induced nuclear recoils



SBC-FERMILAB

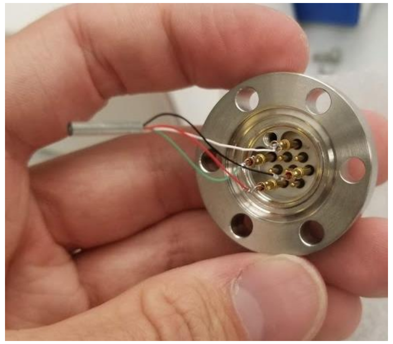


The first 10 kg argon bubble chamber is under construction at FNAL

- Pressure vessel, vacuum jacket, and active fluid panel at FNAL now
- Inner assembly design in progress
  - Working on support structure, insulation, and instrumentation placement

Instrument testing in progress

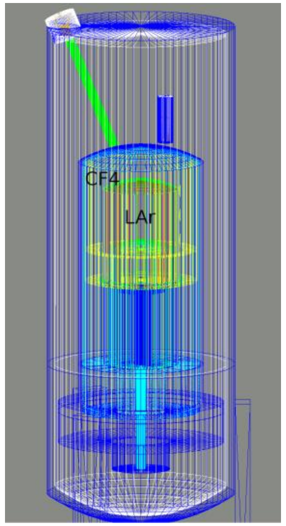
- SiPMs
- Cryo PTs
- Cameras



Goals:

- Low- threshold Nuclear recoil calibration with photoneutron sources and SF sources
- Electron recoil calibration with gamma sources
- Demonstrate scalability of SBCs

SBC-CEVNS



After calibrations and upgrades, we will re-deploy SBC-Fermilab as SBC-CEvNS

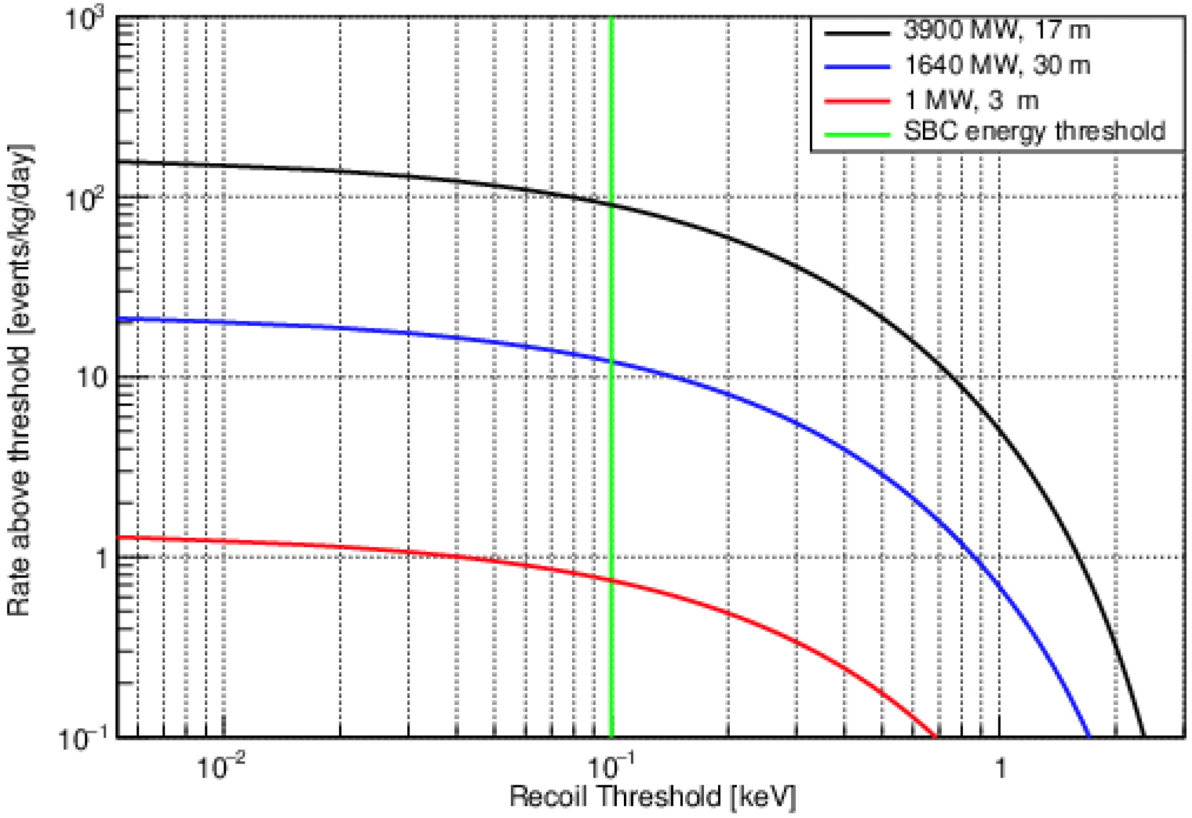
Possible reactor sites:

- Laguna Verde, 1.64 GW, 30 m baseline
- ININ, 1 MW, 3 m baseline, moveable reactor core

Goals:

- Detect a high rate of reactor neutrinos
- Precision measurement of CEvNS cross section
- Search for neutrino NSI

Background modeling simulations in progress

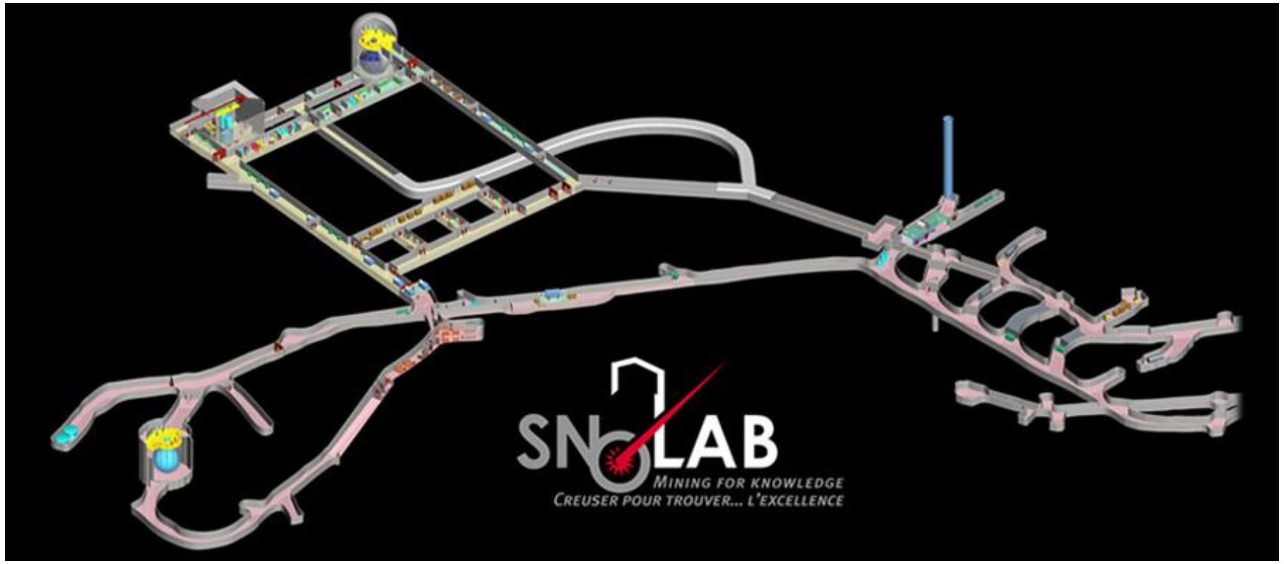


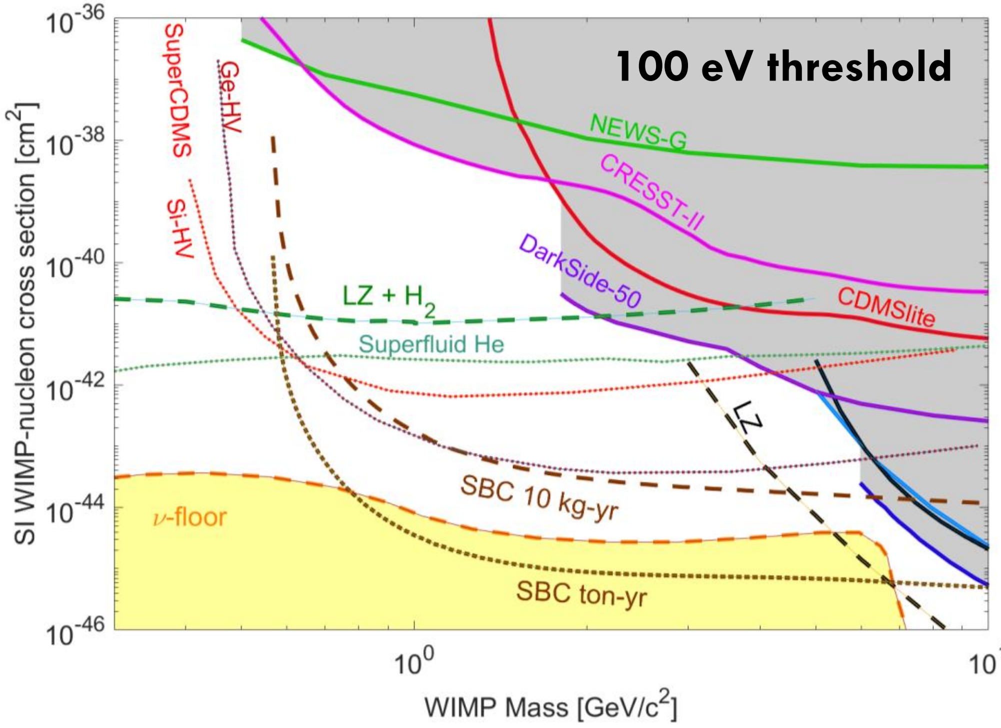
SBC-SNOLAB

While SBC-Fermilab runs, a twin detector will be built at SNOLAB

Goals:

- Build to stricter radiopurity requirements
- Search for O(1 GeV) WIMPs
- Inform future ton-scale detector





CONCLUSION

We are in the process of building our first large-scale scintillating bubble chamber

- Hope to have first bubbles next year
- Hope to perform NR and ER calibrations within 2 years

10 kg argon bubble chambers operating at O(100 eV) are projected to be sensitive to reactor CEνNS and O(1 GeV) dark matter

- Insensitive to electron-recoils (i.e. gammas)
- Veto alphas and > 5 keV NRs by scintillation

Future ton-scale argon bubble chambers are projected to reach the neutrino floor in O(1 GeV) dark matter searches

SBC: Scintillating Bubble Chamber

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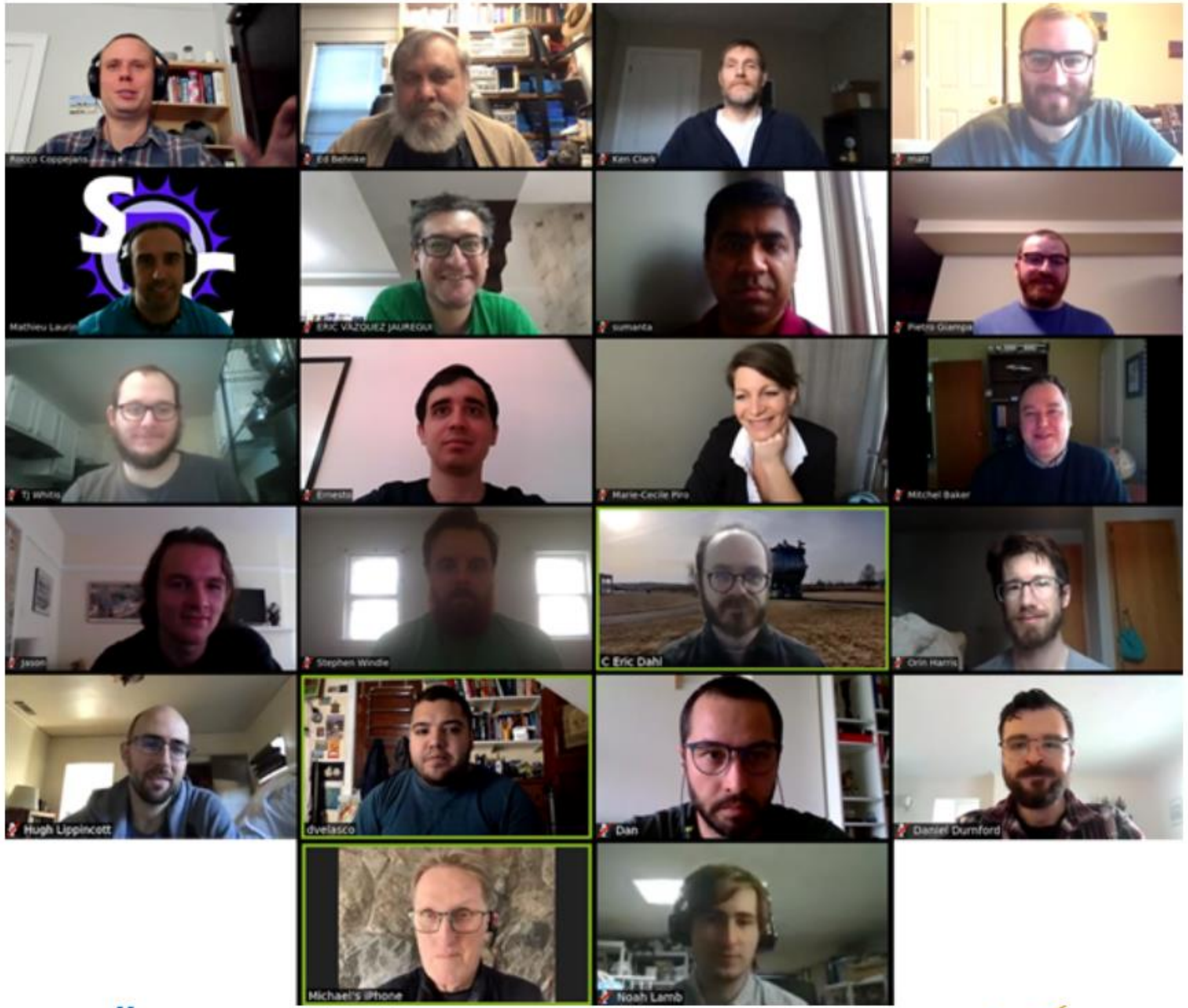
- Youngtak Ko
- Mitchel Baker



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Northeastern Illinois University

- Orin Harris

Pacific Northwest National Laboratory

- Chris Jackson

Fermilab

- Mike Crisler