The Scintillating Bubble Chamber

Ken Clark
Queen's University and TRIUMF

Arthur B. McDonald
Canadian Astroparticle Physics Research Institute

TRIUMF

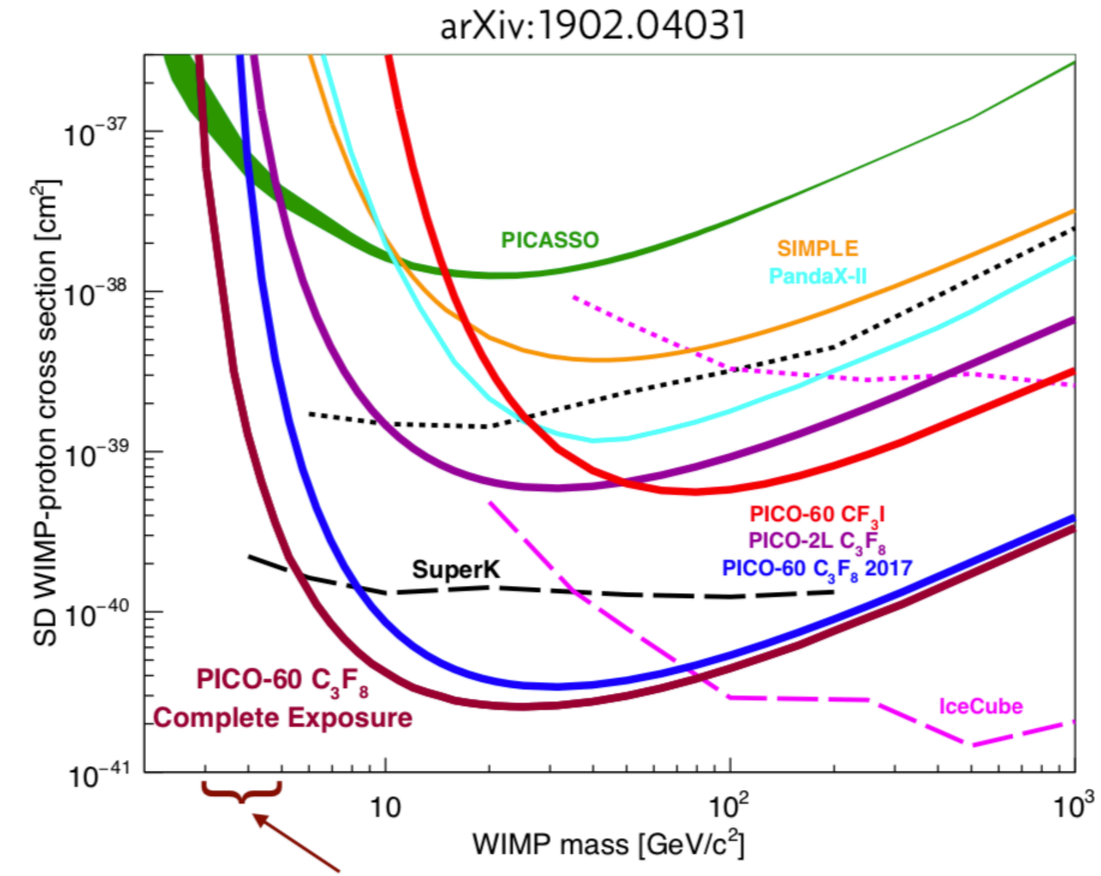
Queen's UNIVERSITY

Current Bubble Chamber Searches

- Currently there are projects that use these detectors to search for dark matter
  - See earlier talk by Alan Robinson for a great example

Current Bubble Chamber Searches

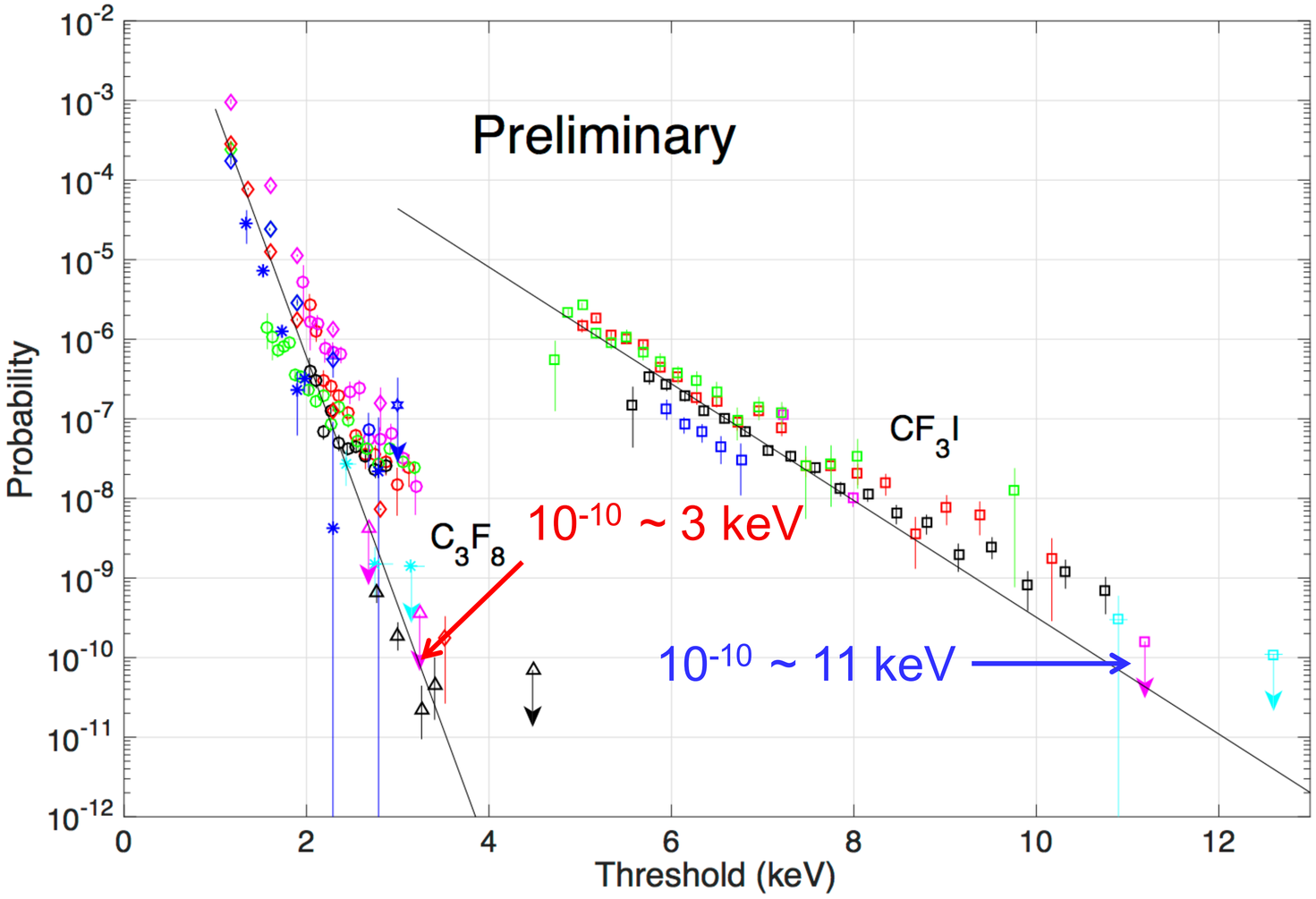
- Currently there are projects that use these detectors to search for dark matter
- These have had success… or as much as any DM search has



improved mainly in 3–5 GeV range
(order of magnitude more stringent)

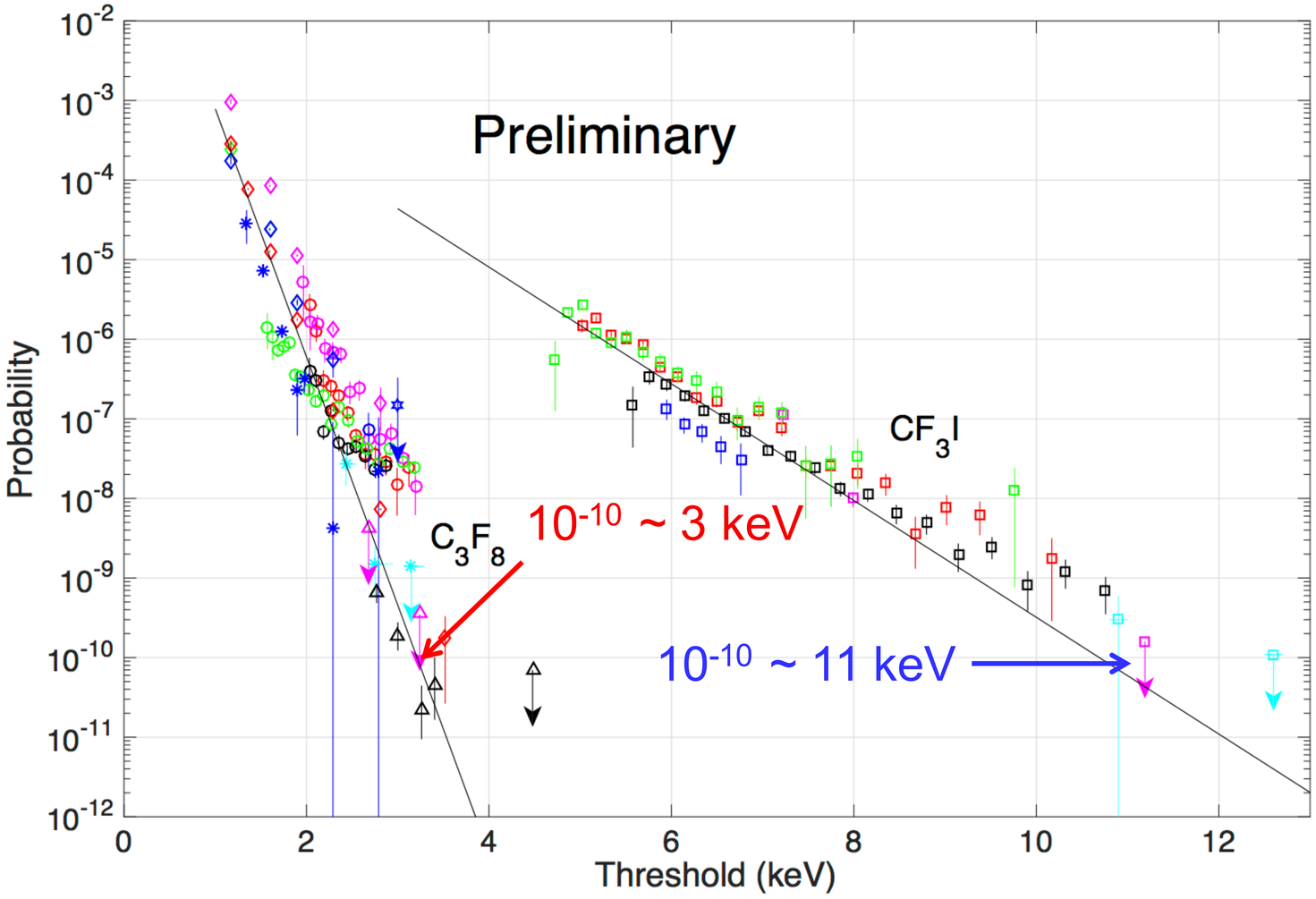
Bubble Chamber Advantages

- There are some unique aspects of the bubble chamber that make it attractive
  - Discrimination is one big one

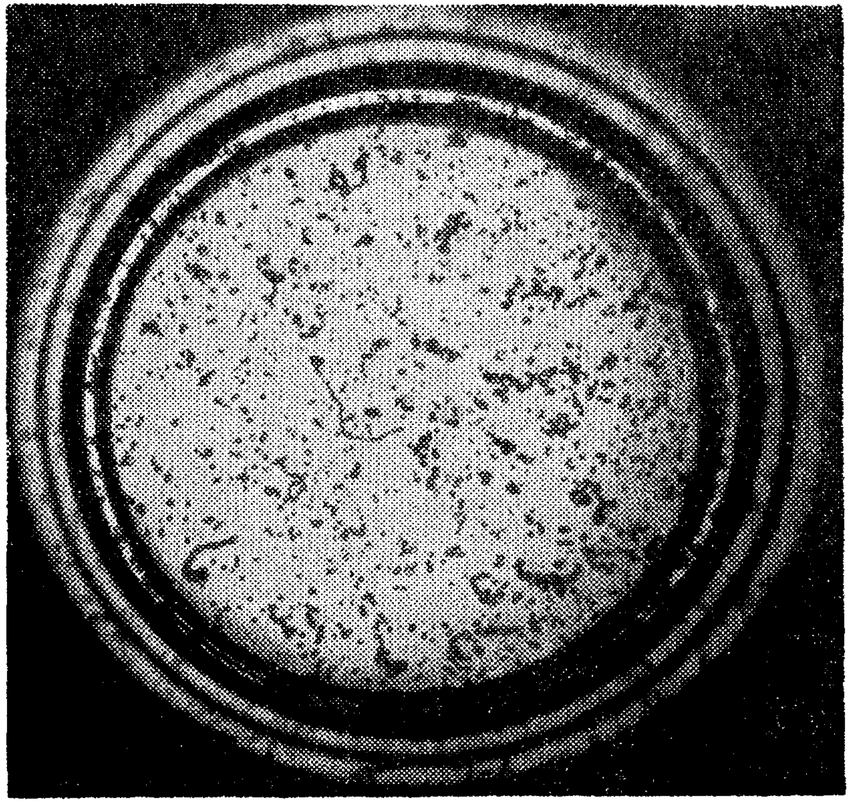


Bubble Chamber Challenges

- Discrimination is great primarily at high thresholds
  - As the threshold (mass) lowers, things get difficult very quickly



Revisit a bit of history

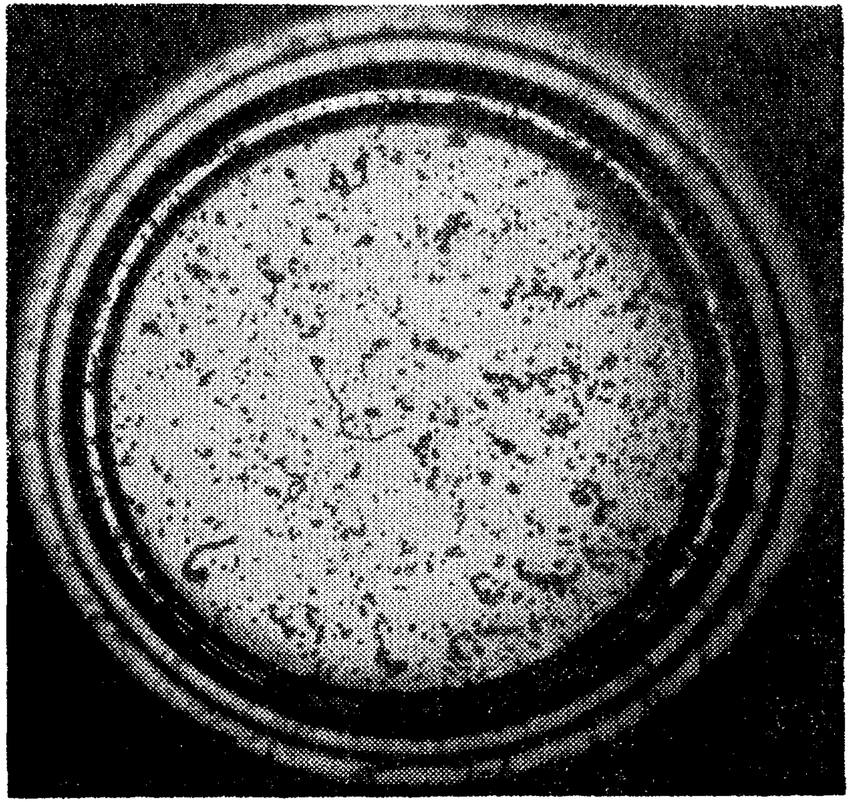


Phys. Rev. 102, 586 (1956)

- In 1956, Glaser made a xenon bubble chamber

Shortly after these failures to observe tracks, we learned[3] that gaseous xenon had been found to be an efficient scintillating material, so that some sizeable fraction of the energy lost by an ionizing particle in liquid xenon might escape in optical radiation instead of being deposited locally in the xenon itself.

Revisit a bit of history

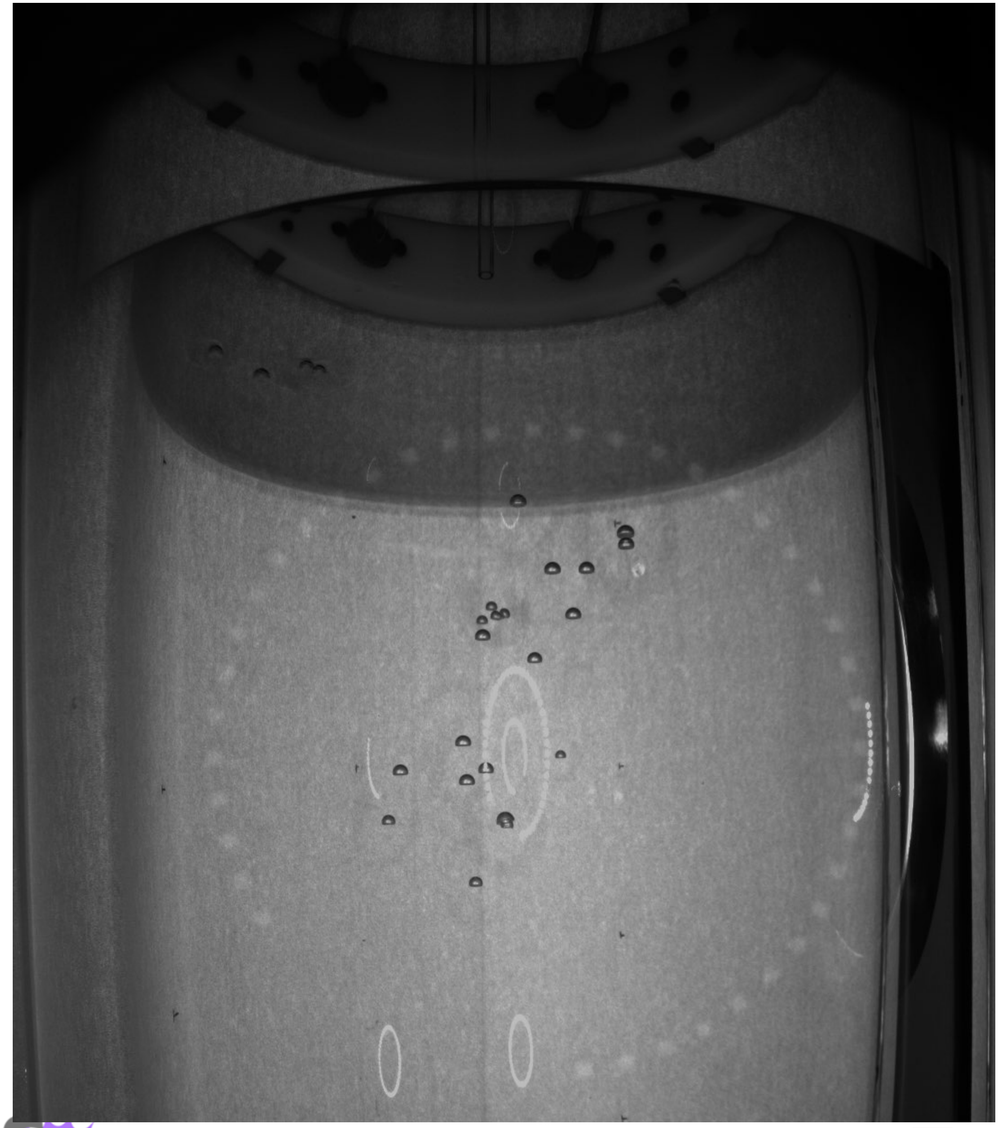


Phys. Rev. 102, 586 (1956)

- In 1956, Glaser made a xenon bubble chamber
  - No bubbles in pure xenon even at 1keV threshold with gamma source
  - Normal production in 98% xenon + 2% ethylene (scintillation completely quenched)
- Scintillation suppresses bubble nucleation (?)

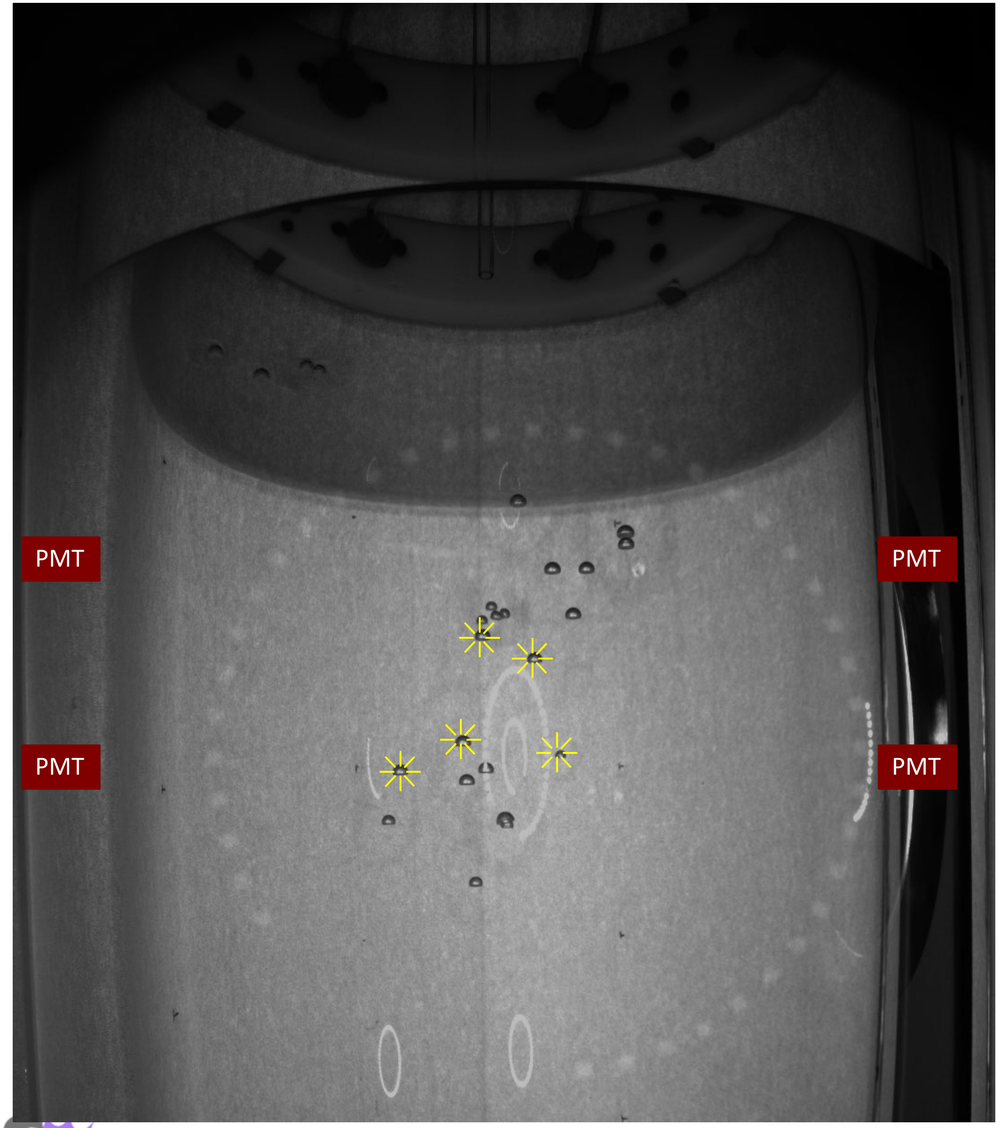
The “traditional” bubble chamber

- Superheated target (C_3F_8, CF_3I…)
- Particle interactions nucleate bubbles
- Cameras and acoustic sensors capture signals
- Chamber recompresses after each event



The “scintillating” bubble chamber

- Superheated scintillator (Xe, Ar…)
- Particle interactions nucleate bubbles and cause scintillation
- Cameras and acoustic sensors capture signals, photodetectors collect scintillation light
- Chamber recompresses after each event

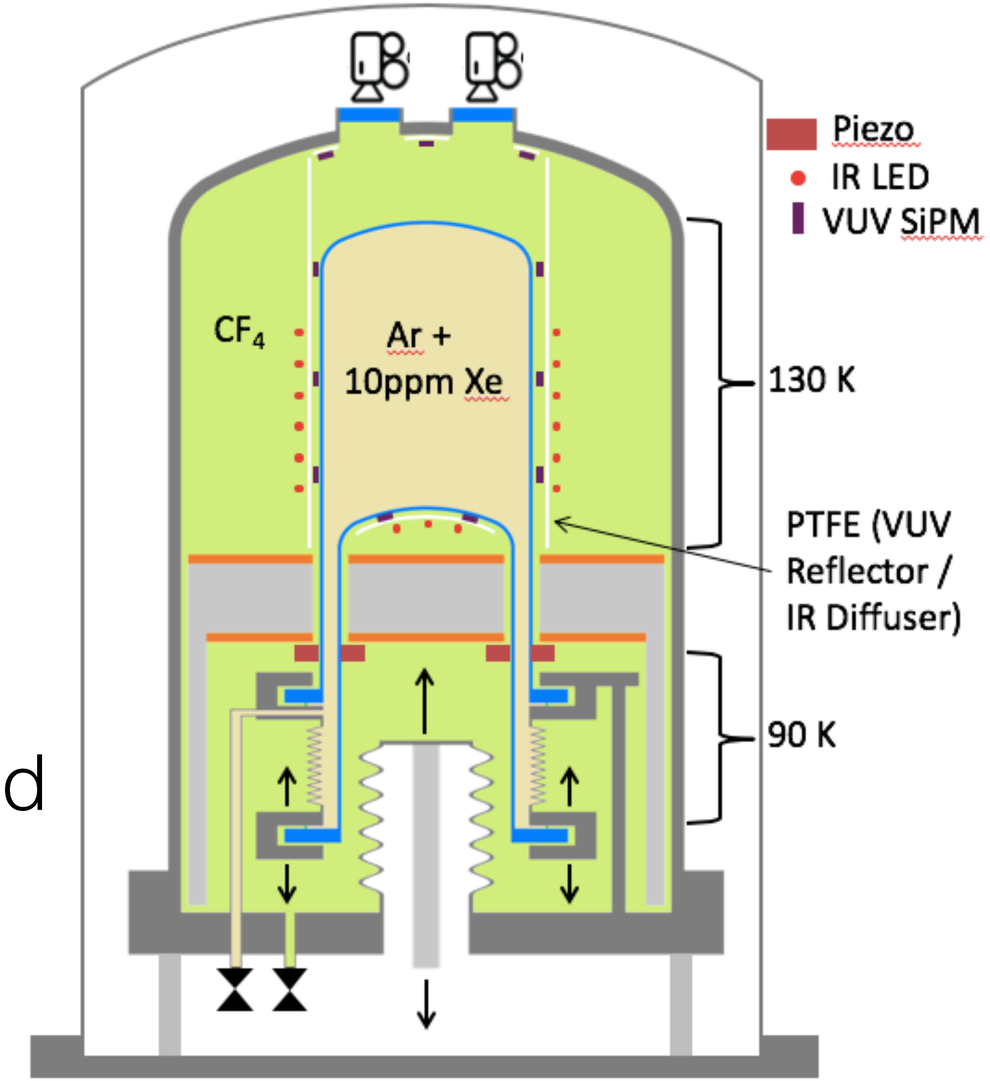


Potential Benefits

- Better background rejection compared to PICO, particularly at low thresholds
  - Improve on 10^{10} gamma rejection
- Improved information for rejection compared to usual xenon detectors
- Maintain the position reconstruction from PICO

The SBC Detector

- 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



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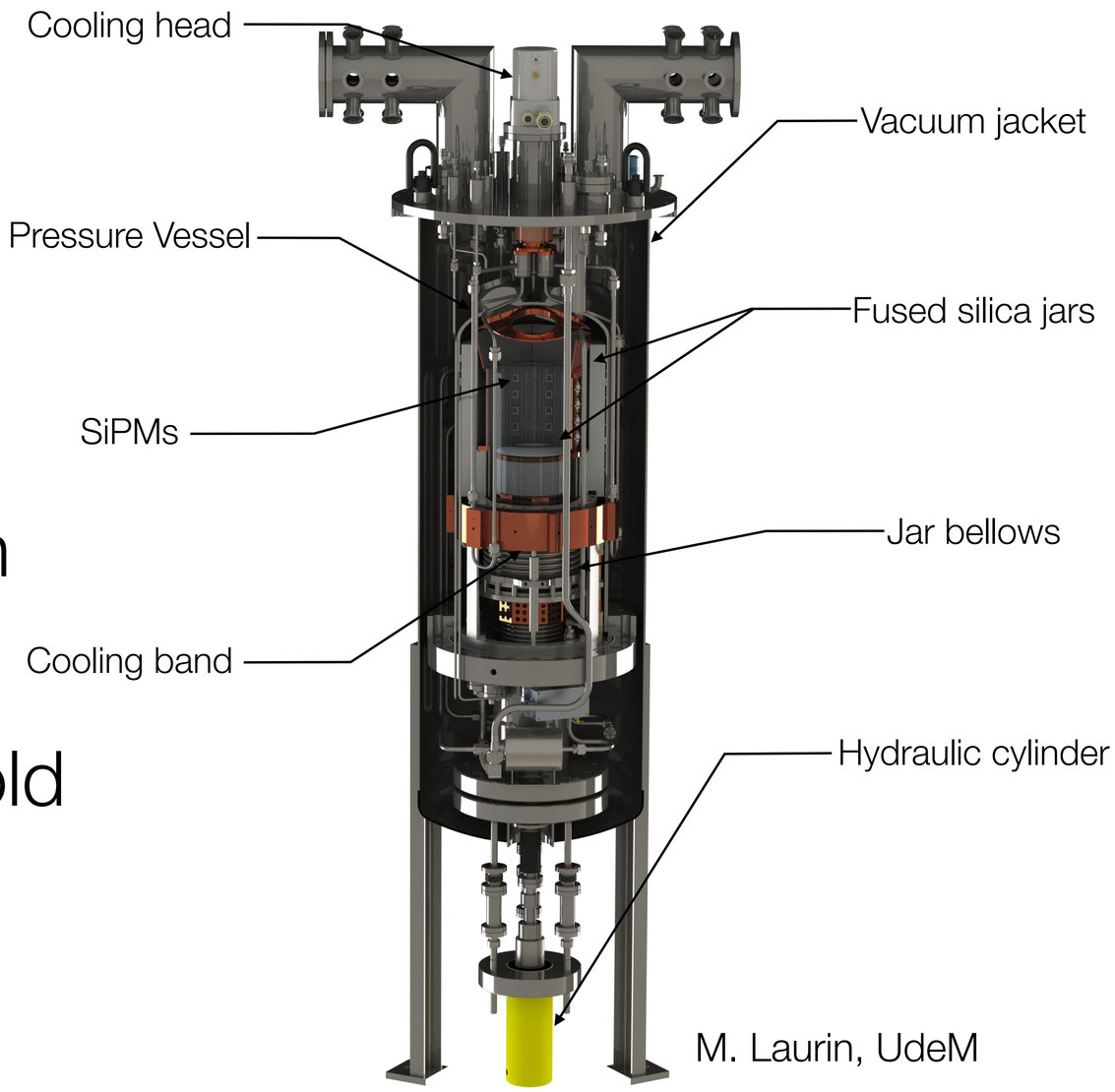
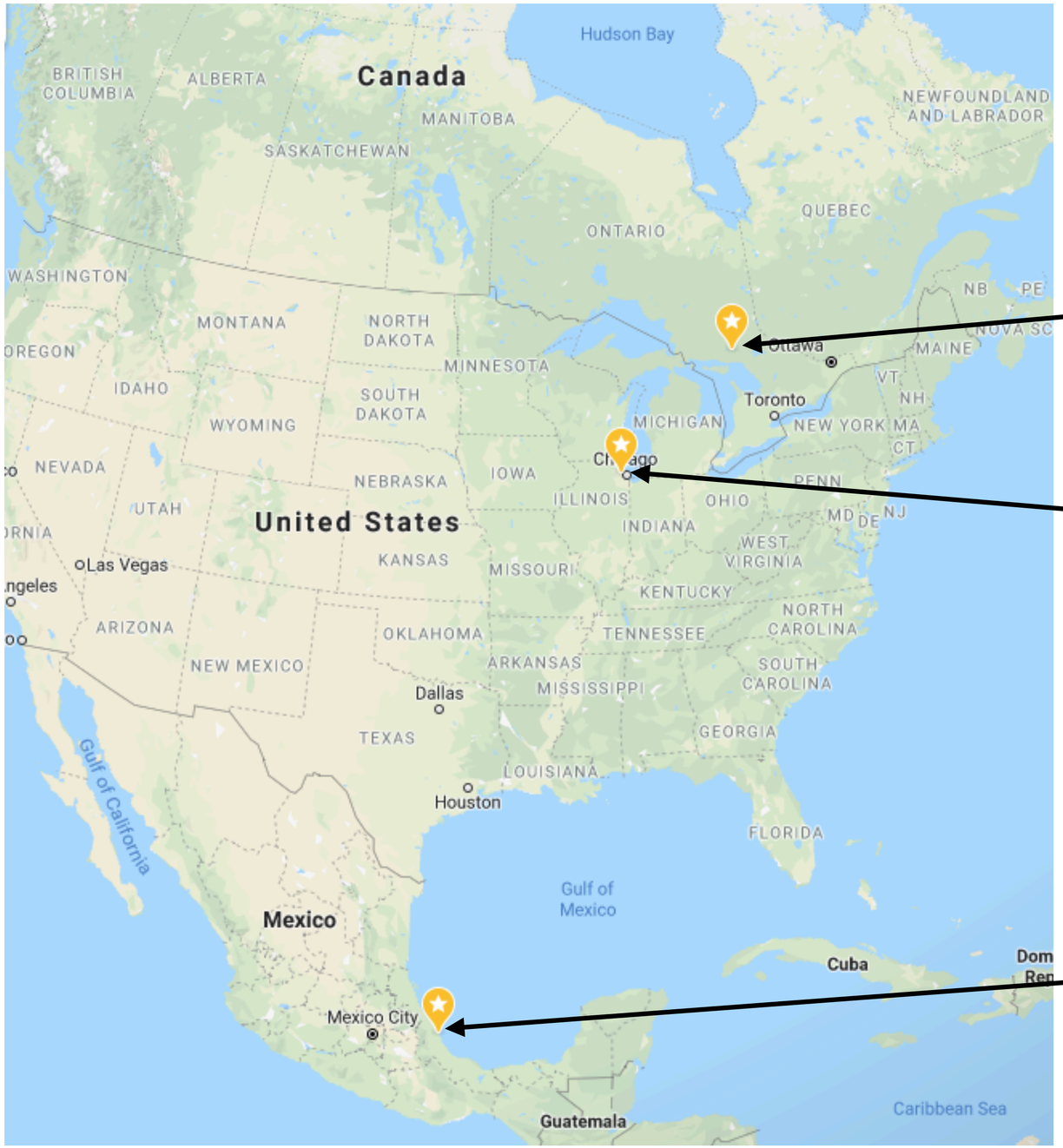


M. Laurin, UdeM

Collaboration Plan



2) Build and install detector at SNOLAB for DM search

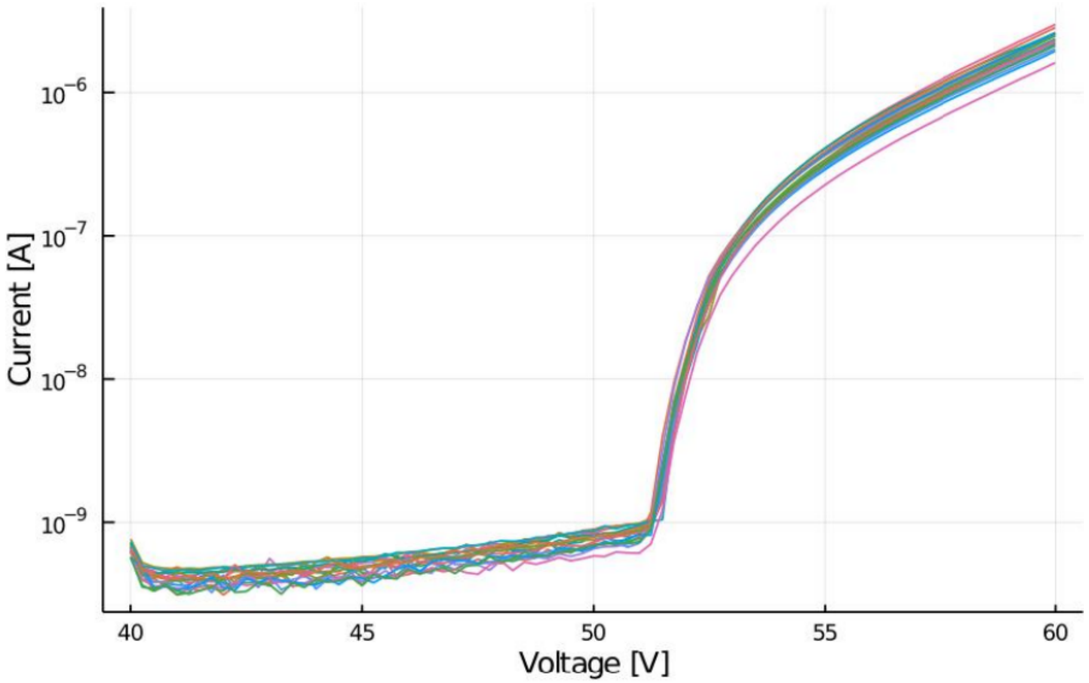
1) Build and commission detector at Fermilab

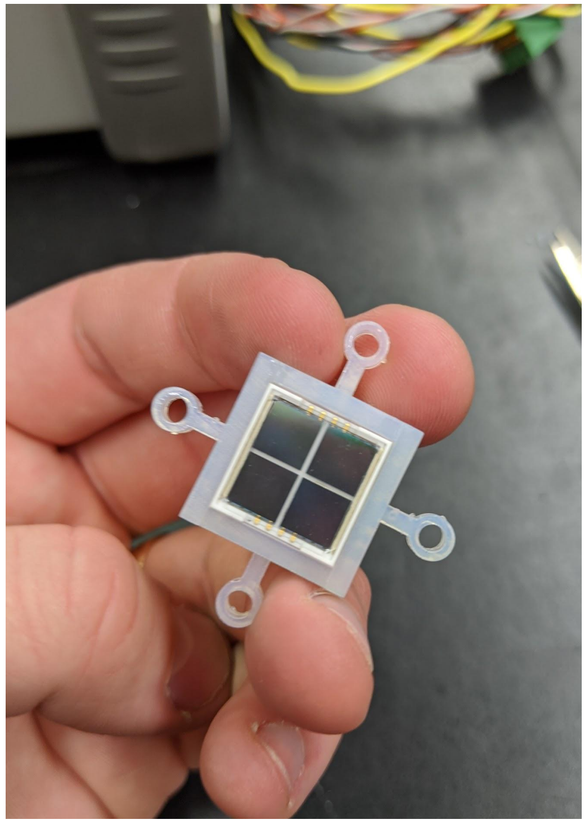
3) Upgrade and install detector from 1) at a reactor for CEvNS studies

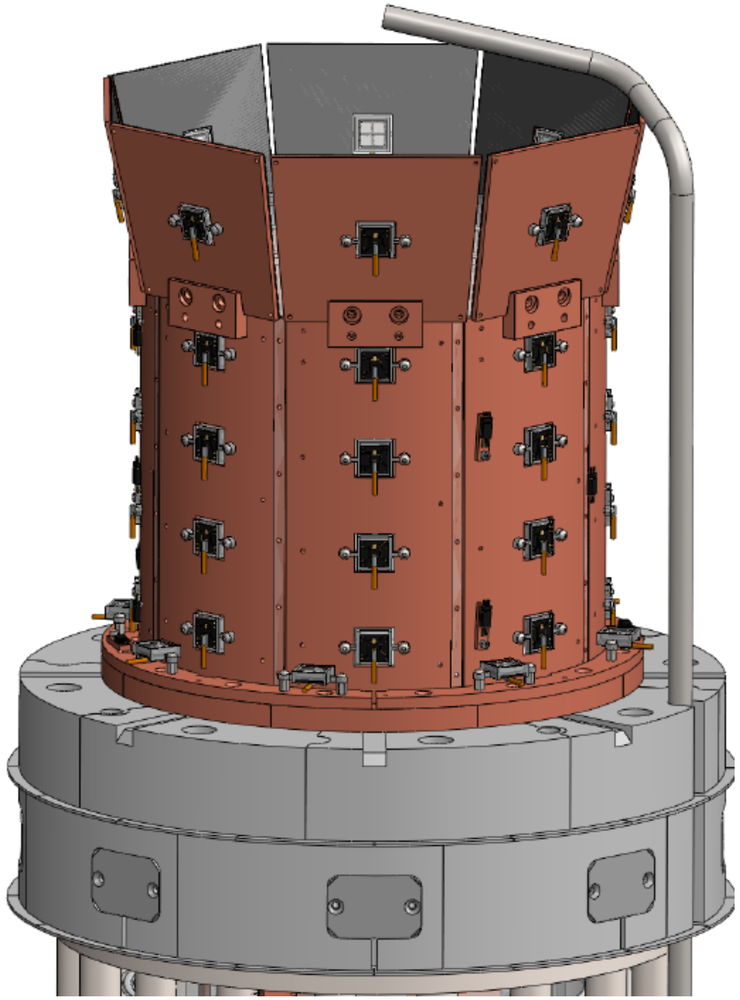
Pressure Vessel & Vacuum Jacket

Inner Assembly

Scintillation Systems

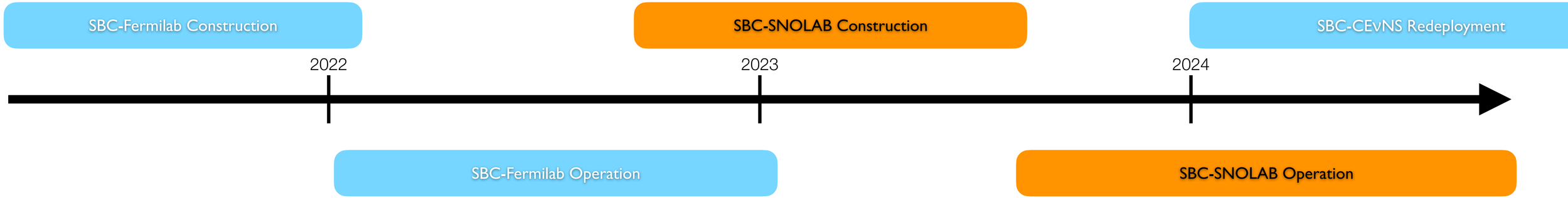




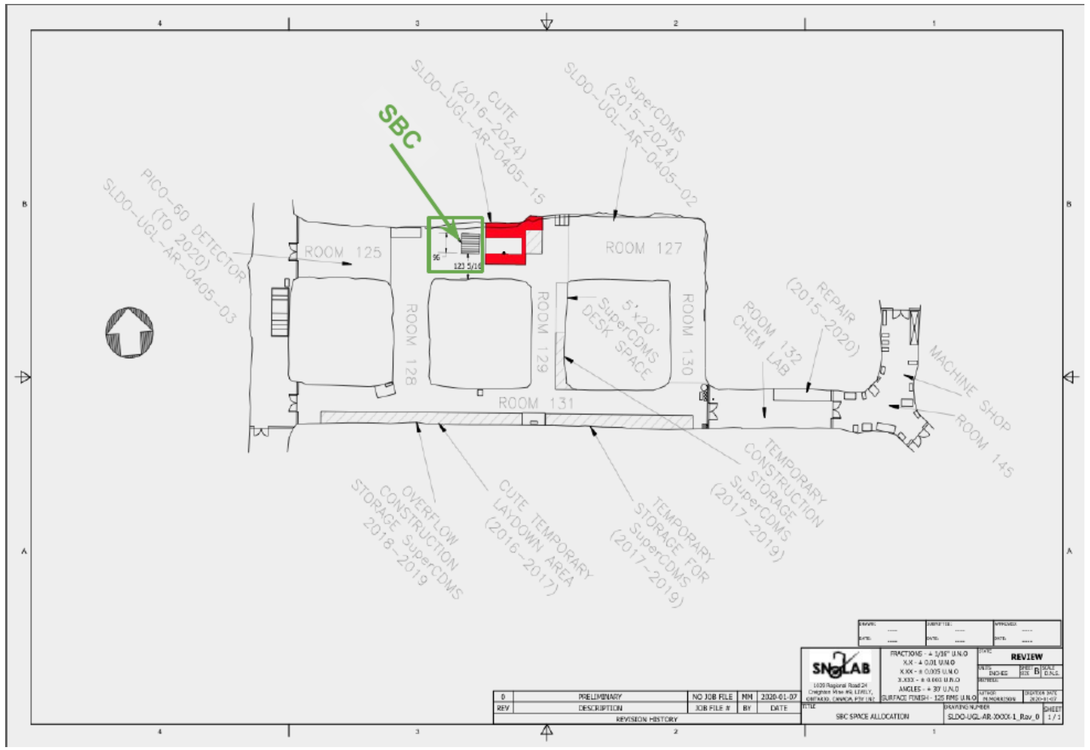


Multiple goals

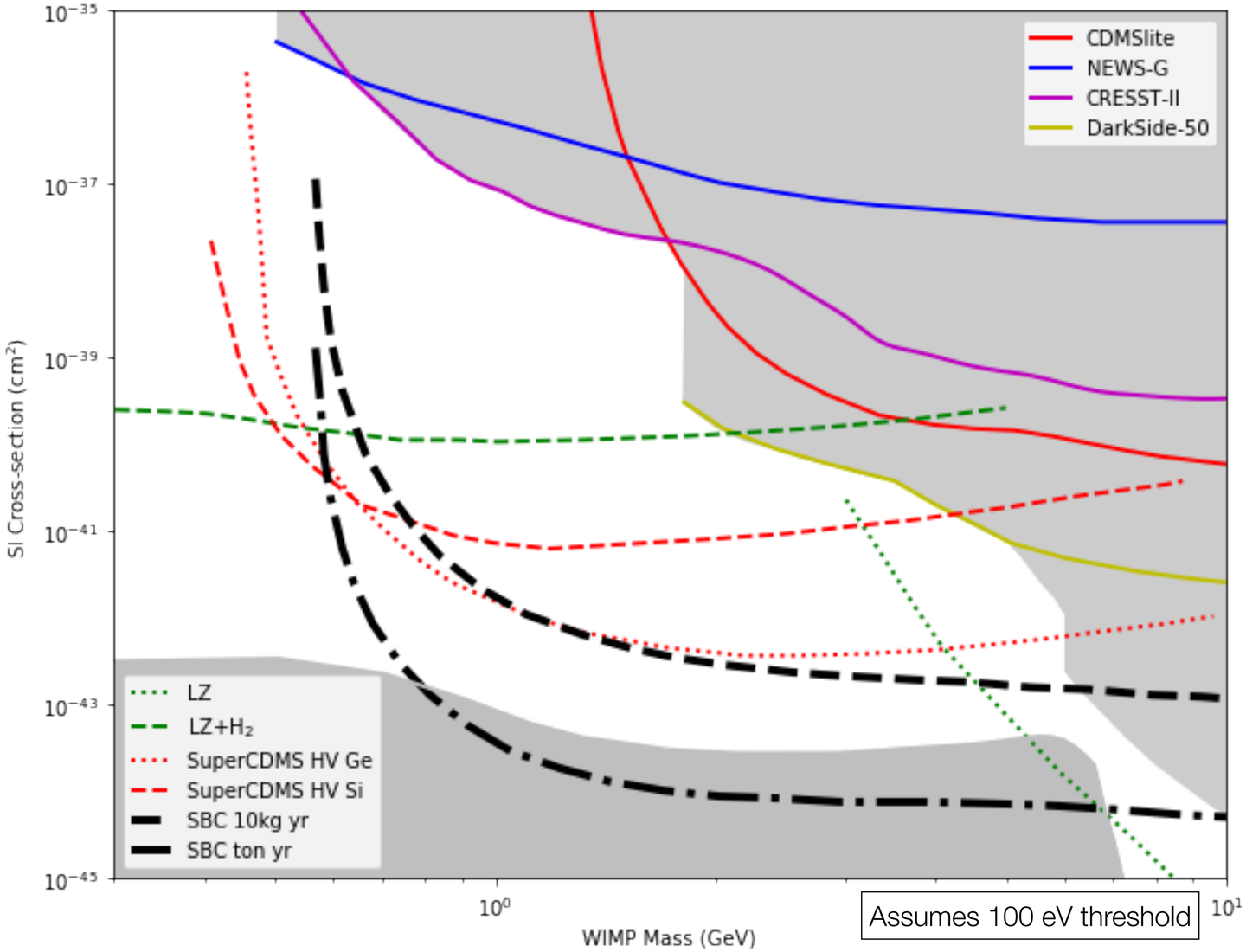
- Having several goals means building several detectors
- First undergoing construction and commissioning at Fermilab, then to be used for CEvNS
- Second to be built at SNOLAB starting in 2022



SBC SNOLAB

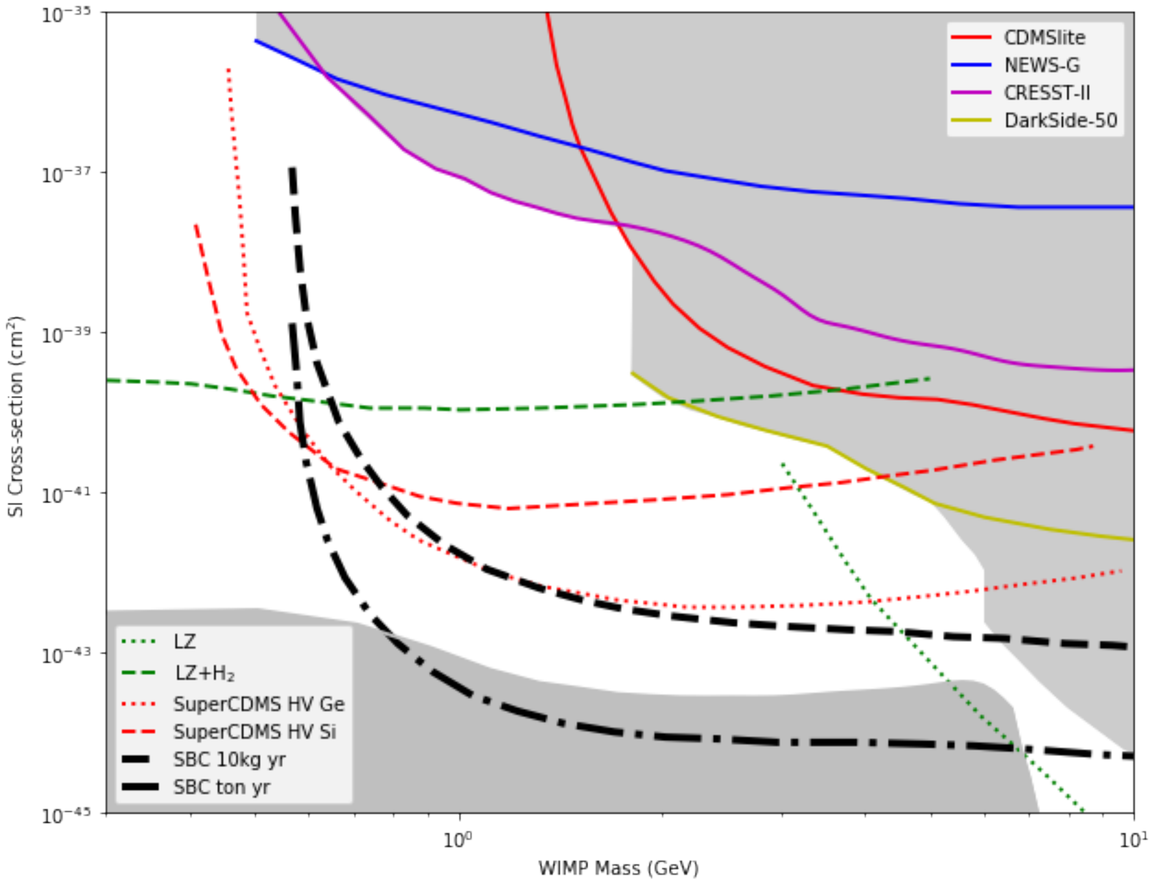


GW1 approval received Oct 2019



Assumes 100 eV threshold

SBC Future



SBC curves assume NR threshold of 100 eV

- Projections show the probable next step, a tonne scale detector
- Simultaneously explore potential for spin dependent reach with different targets — LN_2, LCF_4, etc
- Collaborate with PICO (MoU in place) in efforts to grow the bubble chamber technology

Farther Future

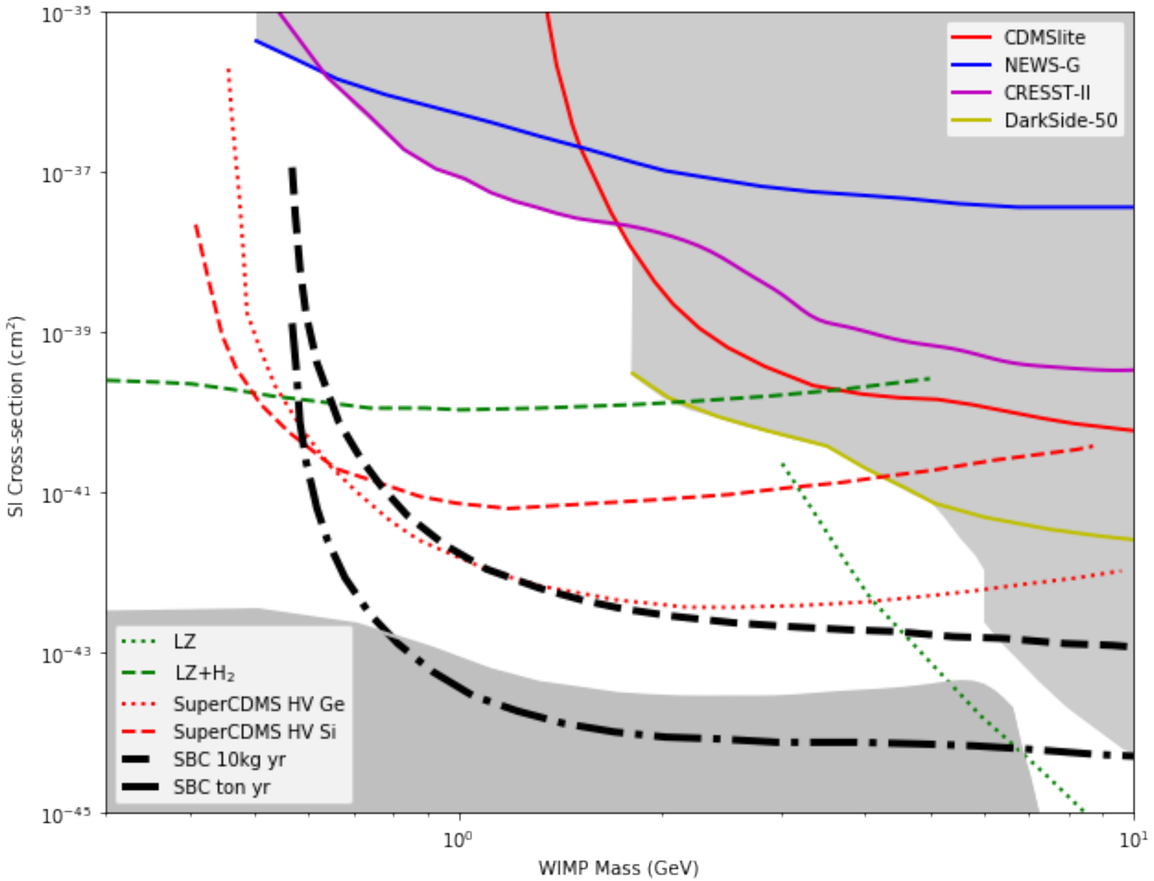
2023-2025 — operate SBC SNOLAB for DM limit

2024-2026 — investigate potential for other targets

2027-2029 — potential switch of targets at SNOLAB

- This requires no additional infrastructure beyond what SNOLAB has supplied
- Tonne-scale would require new location, more significant shielding, etc, but would only theoretically start planning in 2026

SBC Future



SBC curves assume NR threshold of 100 eV

- In the timescale of this process, SBC and PICO will continue investigating nobles and freon respectively
- With no commitments past the already planned generations, both collaborations will choose the best path forward to dominate the SD sensitivity

Conclusions

- The SBC collaboration will be investigating both CEvNS and dark matter
- Vibrant group, always looking for collaborators
- Look for us in the future!

Northwestern University

- **Eric Dahl**
- Rocco Coppejans
- Zhiheng Sheng
- Aaron Brandon
- David Velasco
- Ari Sloss
- Mahebub Khatri
- Dishen Wang
- Shishir Bandapalli

Queen's University

- **Ken Clark**
- Hector Hawley
- Patrick Hatch
- Austin De St Croix

University of Alberta

- Marie-Cécile Piro
- Carsten Krauss
- Daniel Durnford
- Sumanta Pal
- Youngtak Ko
- David Biaré
- Mitchel Baker

SNOLAB

- Pietro Giampa
- Eric Poulin

Universidad Nacional Autónoma de México

- Eric Vázquez-Jáuregui
- Ernesto Alfonso-Pita
- Ariel Zuniga-Reyes
- Daniel Lámbarri

Drexel University

- Russell Neilson
- Matt Bressler
- Noah Lamb
- Stephen Windle

Indiana University South Bend

- Ilan Levine
- Ed Behnke
- Cody Cripe

UC Santa Barbara

- Hugh Lippincott
- TJ Whitis
- Runze Zhang

Université de Montréal

- Mathieu Laurin

Northeastern University

- Orin Harris

Pacific Northwest National Laboratory

- Chris Jackson

Fermilab

- Mike Crisler