The Scintillation Bubble Chamber (SBC) experiment for dark matter and reactor CEvNS

Sumanta Pal

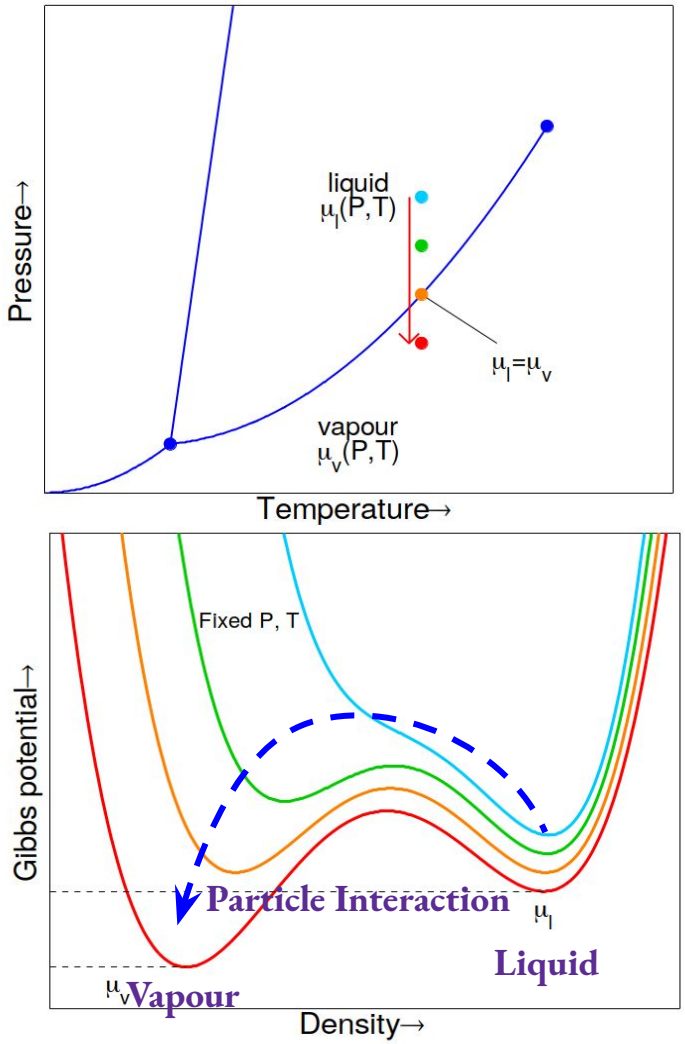
Univ. of Alberta/McDonald Institute

On behalf of the SBC collaboration

PANIC 2021

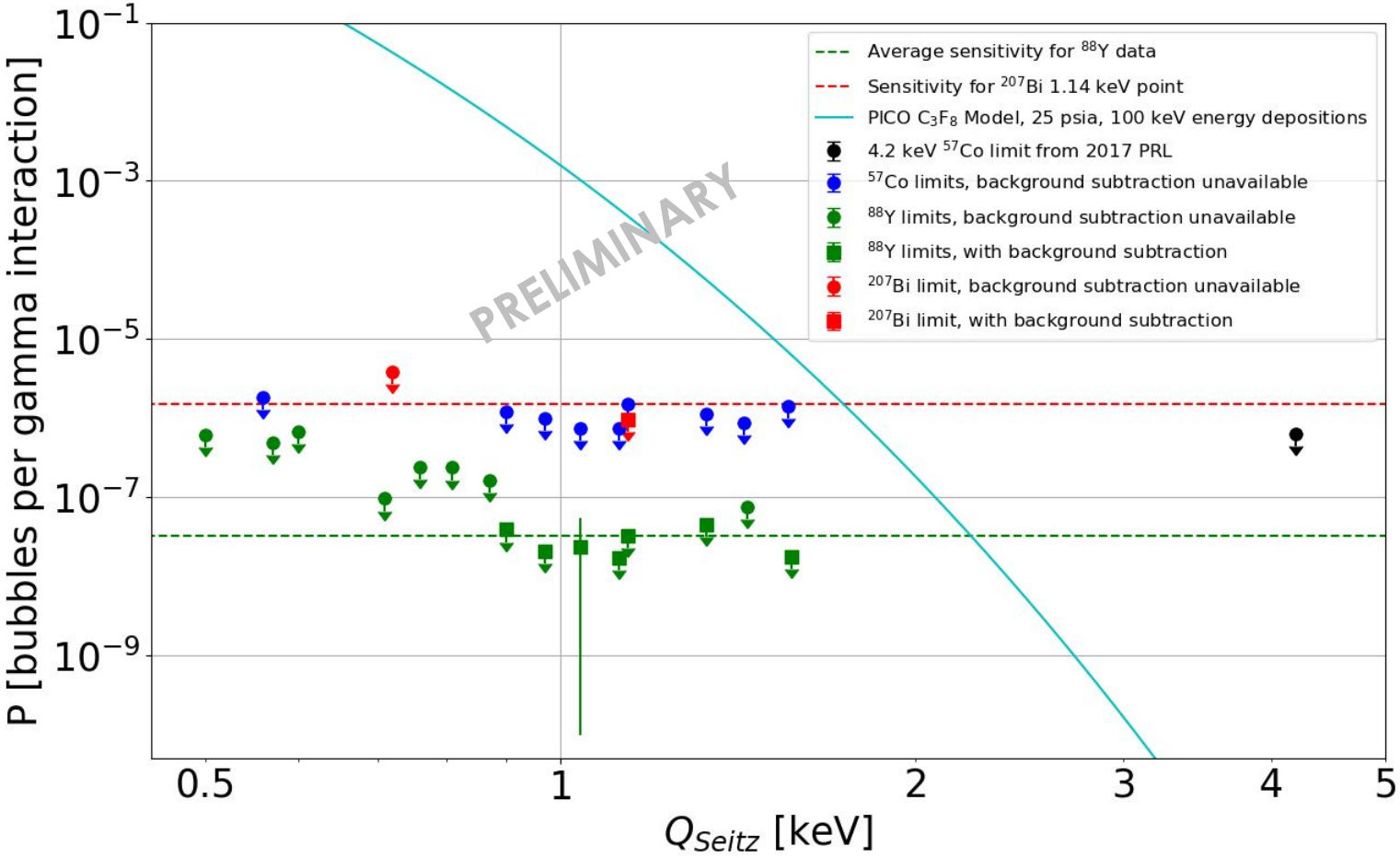
UNIVERSITY OF ALBERTA
Faculty of Science

Bubble chamber for Dark Matter experiments



- Particle interaction → energy deposition → phase transition in superheated liquid → formation of bubbles
  - Acoustic signal recorded by piezoelectric sensors
  - Bubbles are detected by a fast camera
- Inherent advantages of bubble chamber in rare event search
  - Impressive background rejection
    - Alpha acoustic discrimination
    - Gamma or electromagnetic (EM) interaction insensitivity (specific to target liquid and their thermodynamic threshold)
    - Multiple neutron scattering
- Additional advantage in **scintillating bubble chamber**
  - Noble liquid helps to go down in **gamma insensitivity**
  - Scintillating light : **calorimetry** is possible event by event

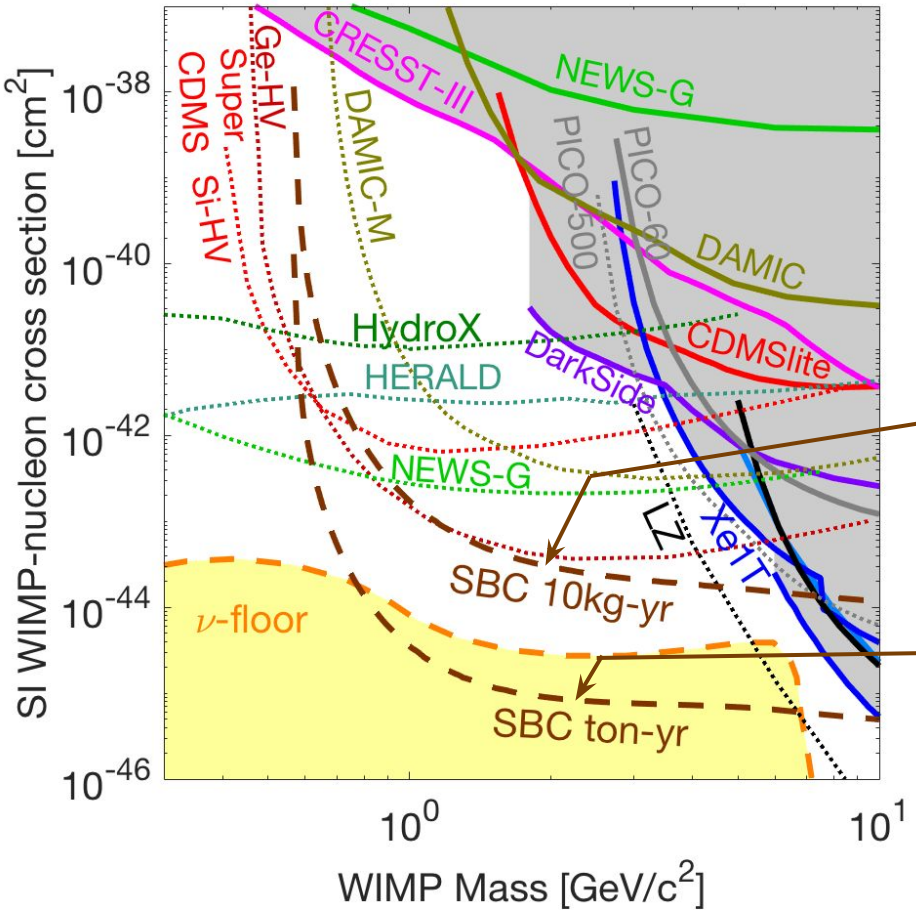
Electron Recoil Discrimination



- Seitz threshold as low as 0.5 keV : evidence of nucleation by NRs
- No sign of ER nucleation at any thresholds !

Dark Matter Detection: low mass WIMP sensitivity

SBC at SNOLAB



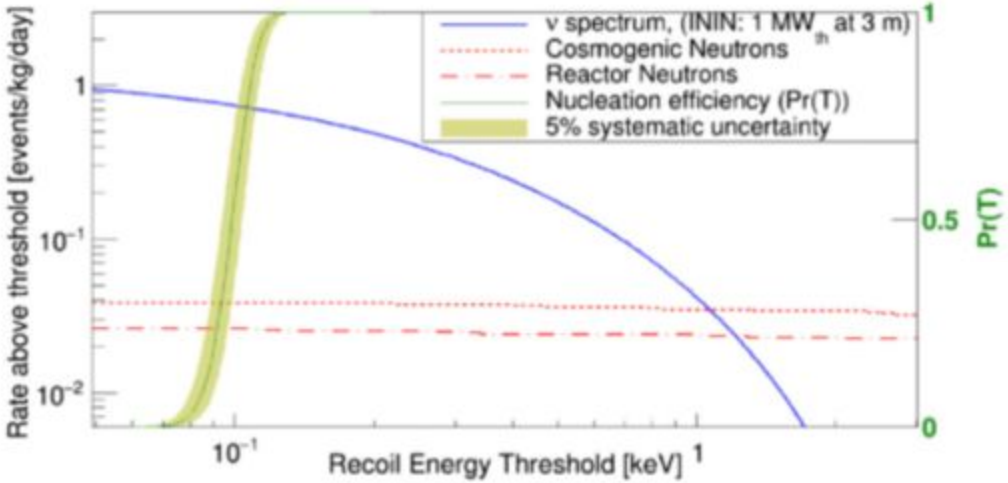
- Competitive low mass WIMP search (0.7-7 GeV/C^2)
- Reaching neutrino floor @ 1GeV requires ER discrimination at 100 eV
- SBC is the only easily scalable technology that might achieve this

10 kg-yr projection with the SNOLAB detector

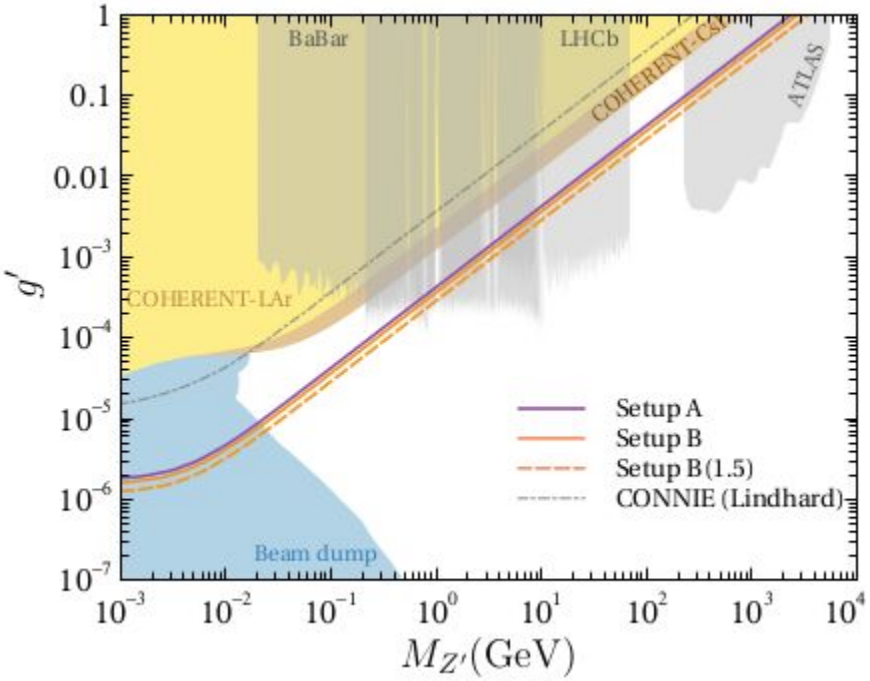
1 ton-yr projection
Sensitive to CEvNS from solar neutrinos

Predicted CEvNS sensitivity

SBC at a reactor



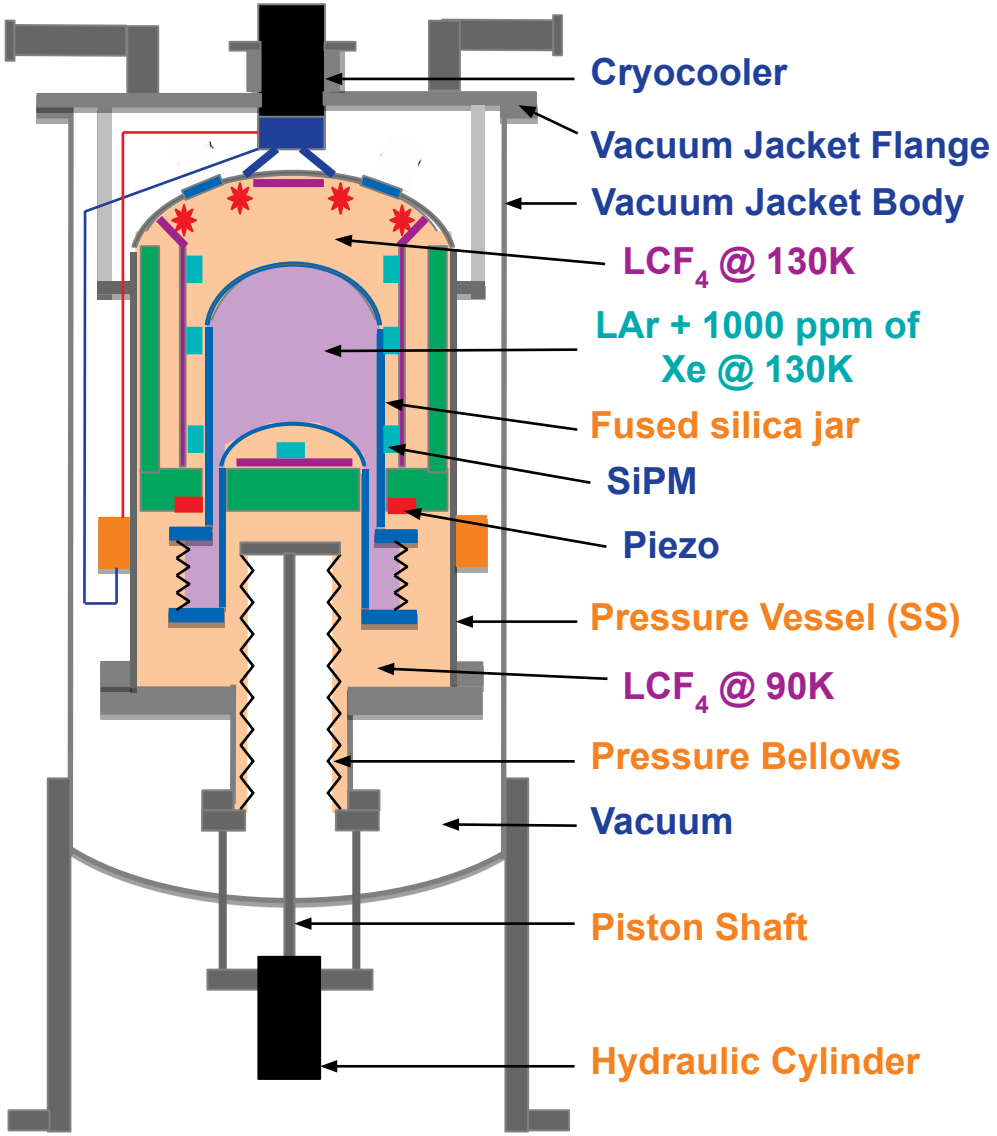
- O (0.7) CEvNS events / kg-day @ 1 MW reactor
- High statistics searches for non standard neutrino interactions



Flores L. J. et al., Physics reach of a low threshold scintillating argon bubble chamber in coherent elastic neutrino-nucleus scattering reactor experiments, **Phys. Rev. D 103, 091301 (2021)**

SBC 10 kg LAr detector overview

- '**Right-side-up**' geometry with thermal gradient
- **10 kg of LAr + Xe (~1000 ppm)** target contained within the fused silica jar
  - Xe acts as a wavelength shifter: 128 nm to 178 nm
- **Pressure cycle 20-360 psia** (~1-25 bara)
- SS Vacuum jacket: thermodynamic insulation of the active detector
- Sensors:
  - SiPMs around the jar
  - Piezoelectric acoustic sensors
  - 3 camera for stereoscopic bubble imaging



SBC-FermiLab Objectives

- Demonstrate **scalability**
- Determine the **bubble nucleation probability for electron recoils**
- Determine **nuclear recoil sensitivity**

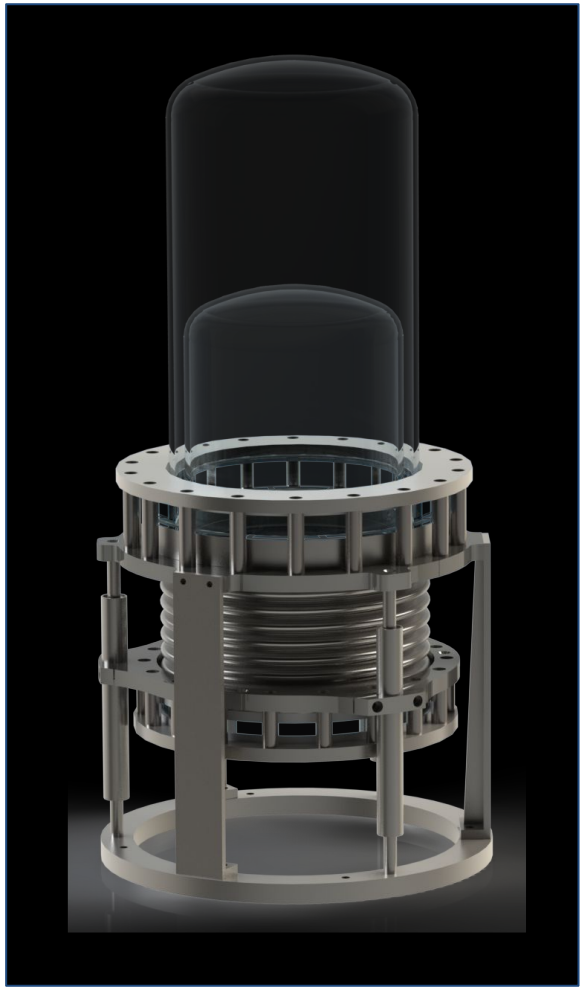
From outside: the vacuum jacket

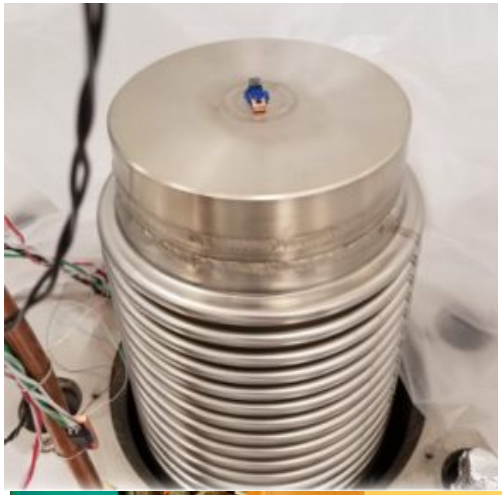
Inside the vacuum jacket : the pressure vessel (PV)

Inside the PV : cross sectional view of the fused silica jars and other controls

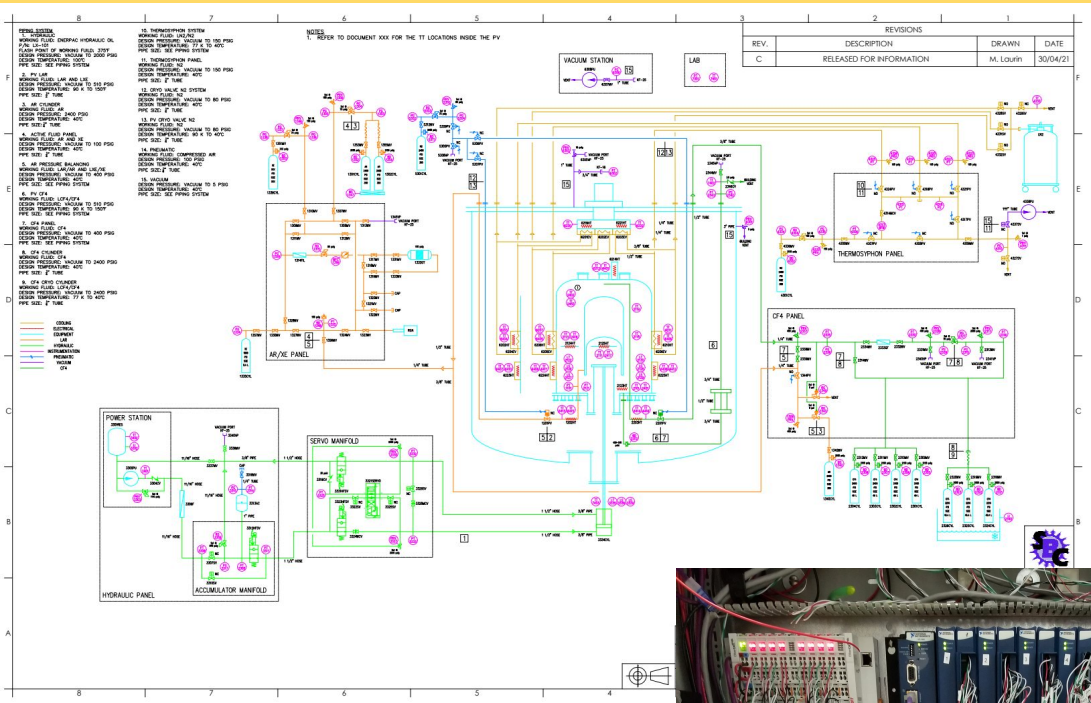
Pressure Vessel & Vacuum Jacket

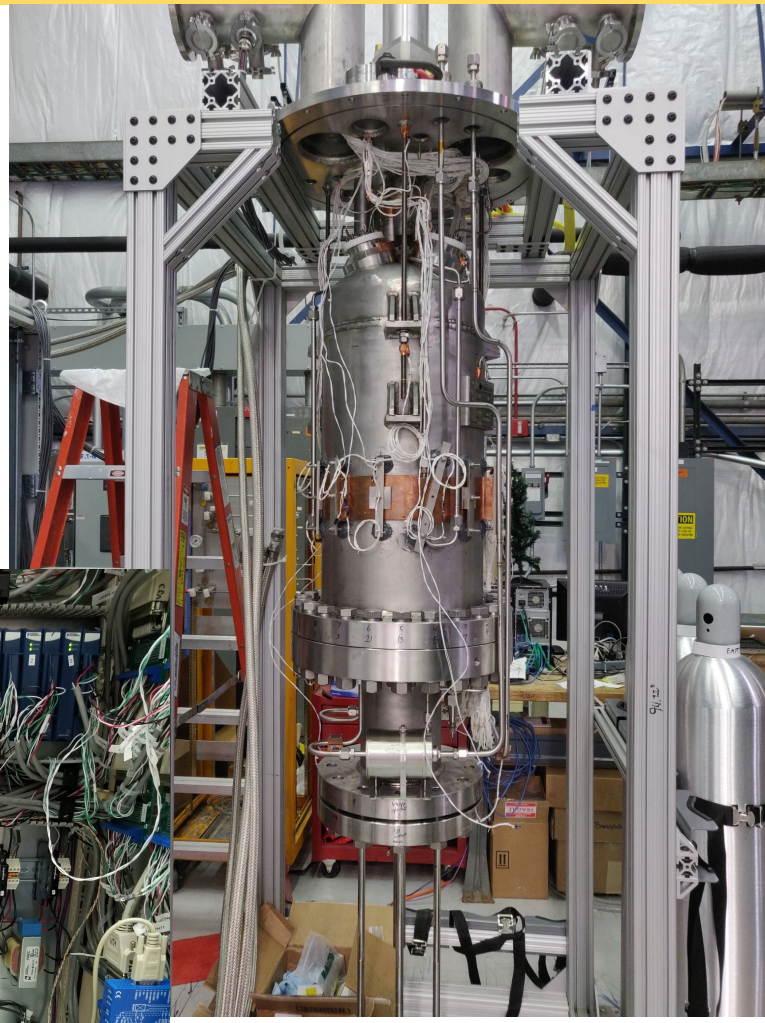
Inner Assembly : fused silica jars & the bellow system

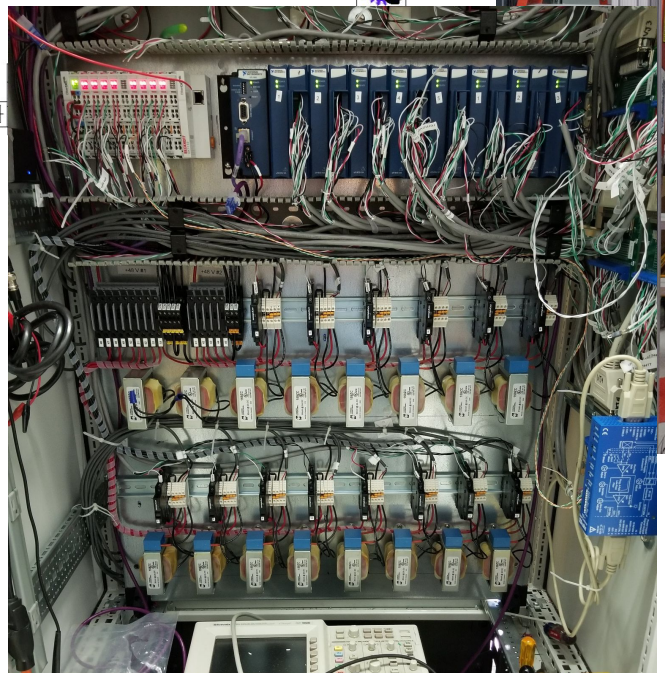




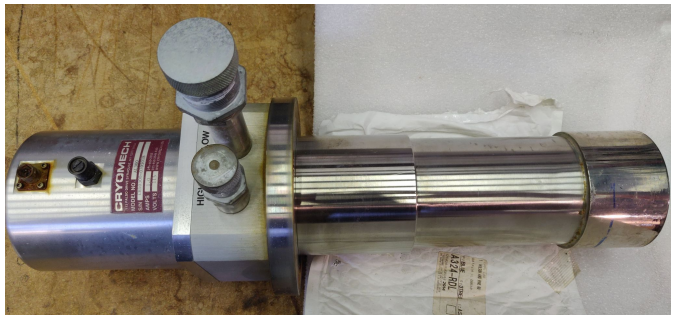
Controls

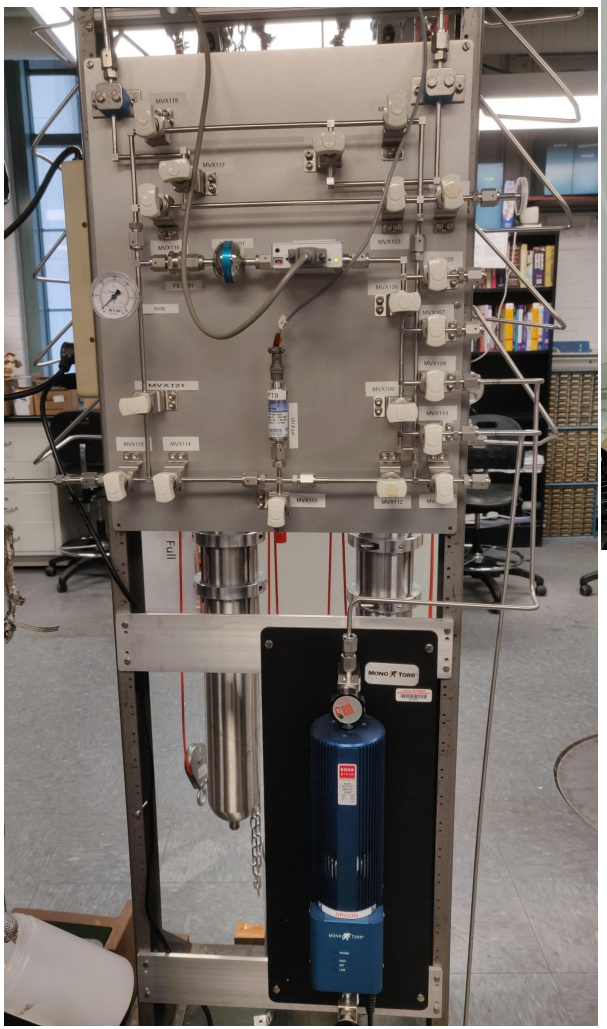

REVISIONS
REV. DESCRIPTION DRAWN DATE
C RELEASED FOR INFORMATION M. Laurin 30/04/21
VACUUM STATION
LAB
THERMOSYPHON PANEL
CF4 PANEL
AR/XE PANEL
POWER STATION
SERVO MANIFOLD
HYDRAULIC PANEL
ACCUMULATOR MANIFOLD

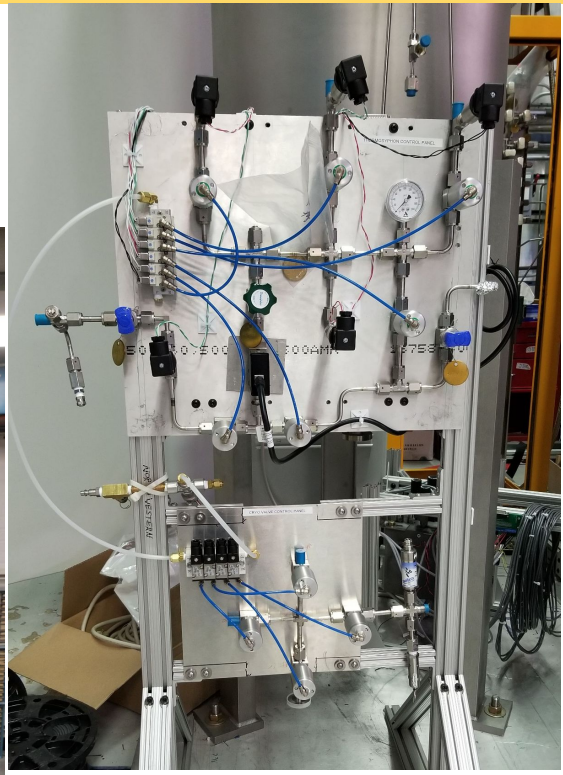




Fluid control systems



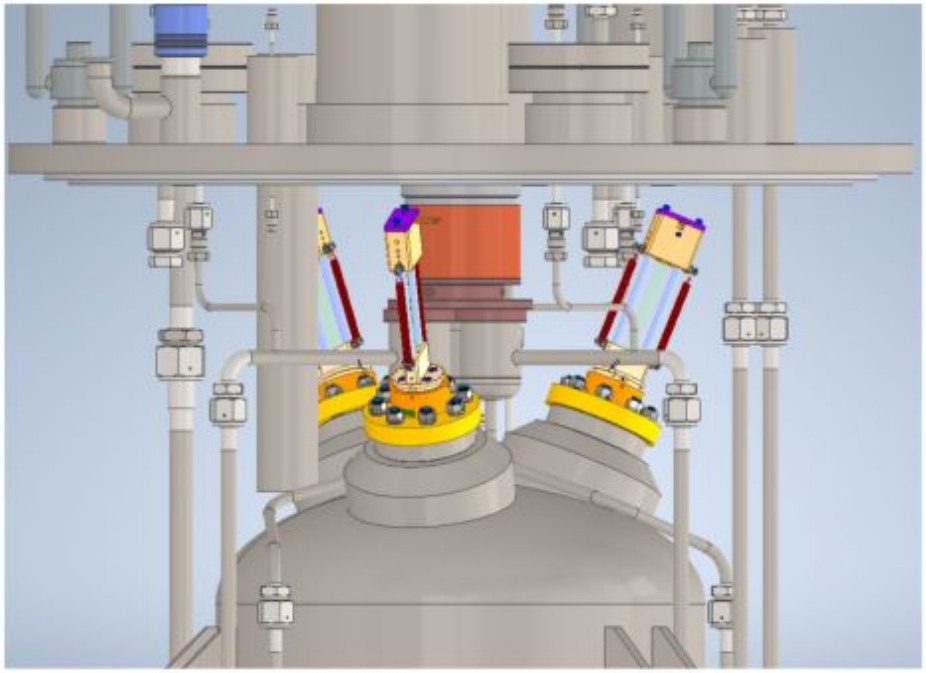


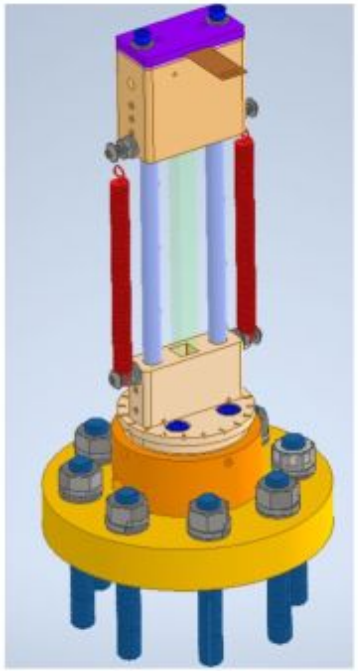


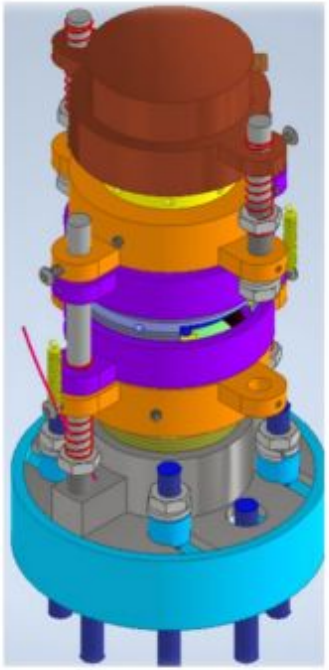
Bubble Imaging

Camera activity too high for the 10 kg LAr detector

- ➢ New design to keep them away from the active liquid
- ➢ Nanoguide system and Relay lens system under R&D

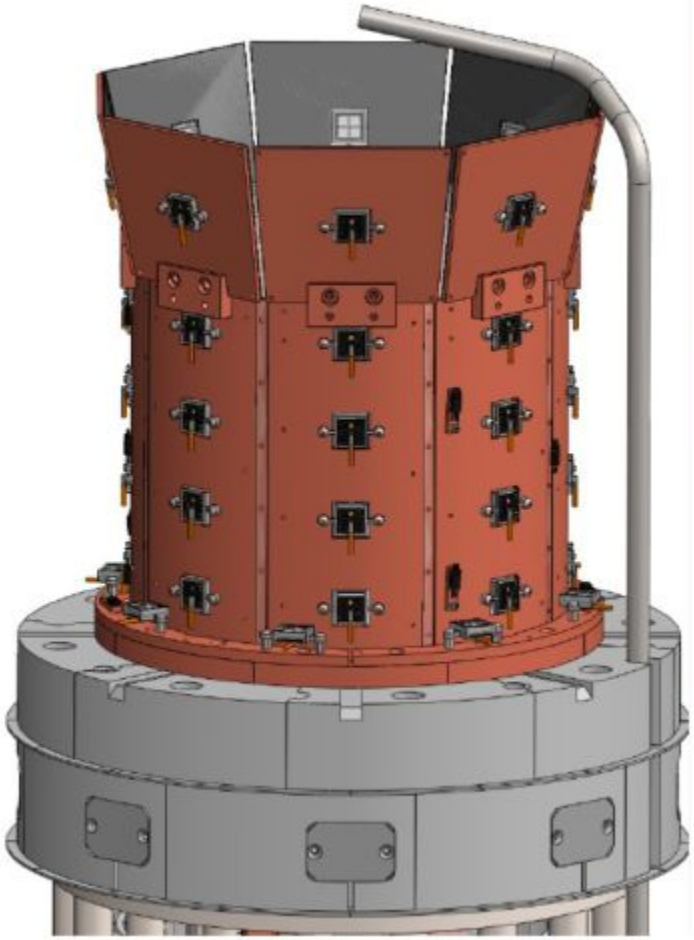


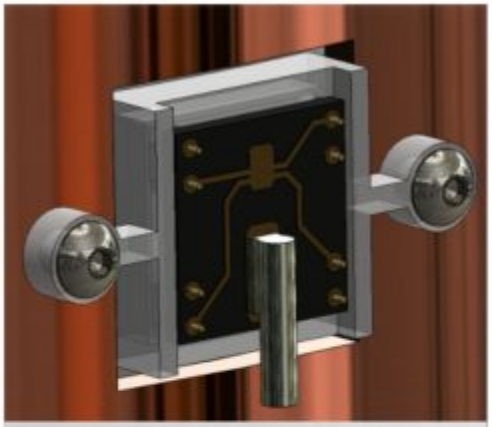


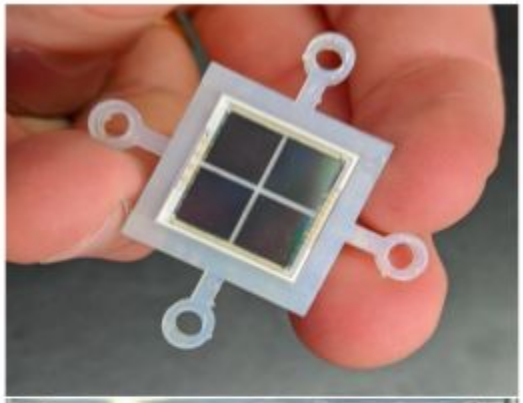


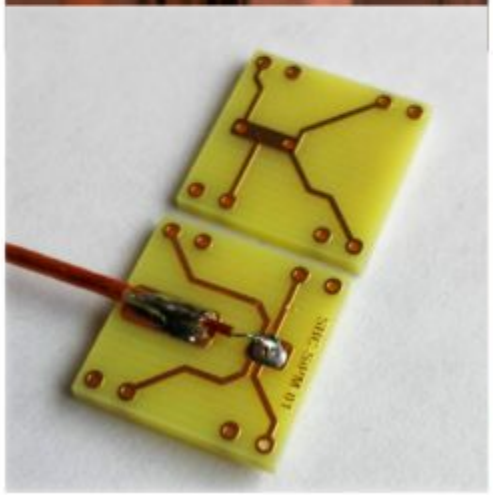
Scintillation

32 Hamamatsu VUV4 Quads to measure the scintillation light



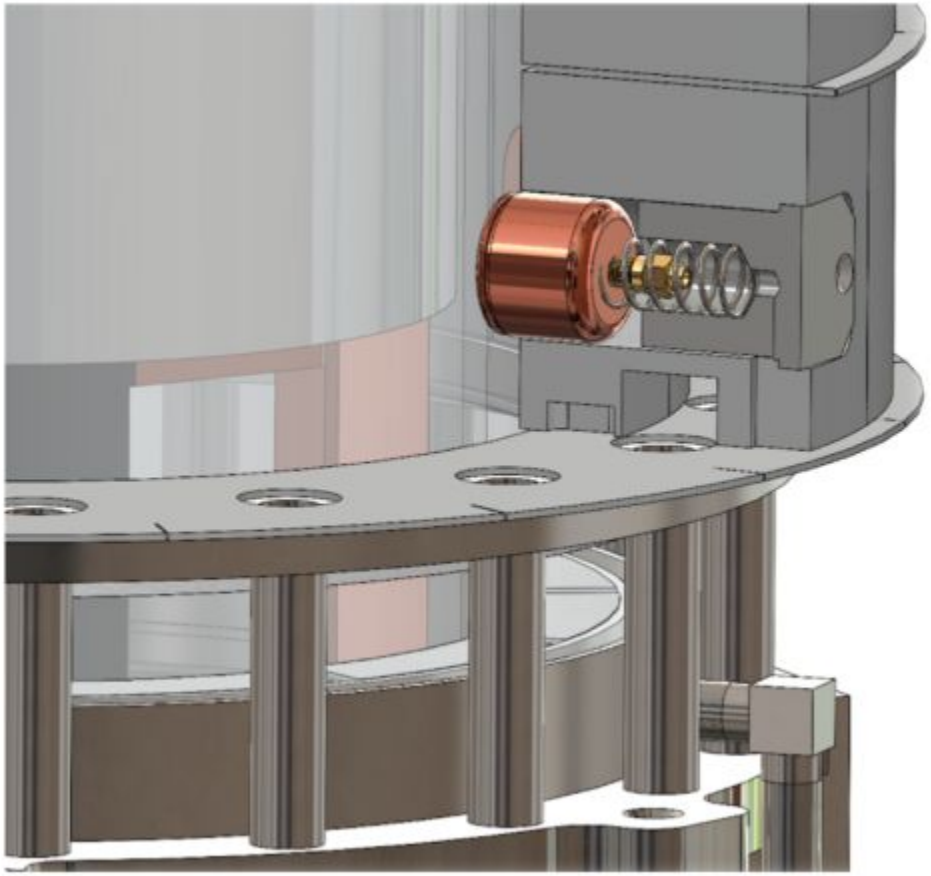


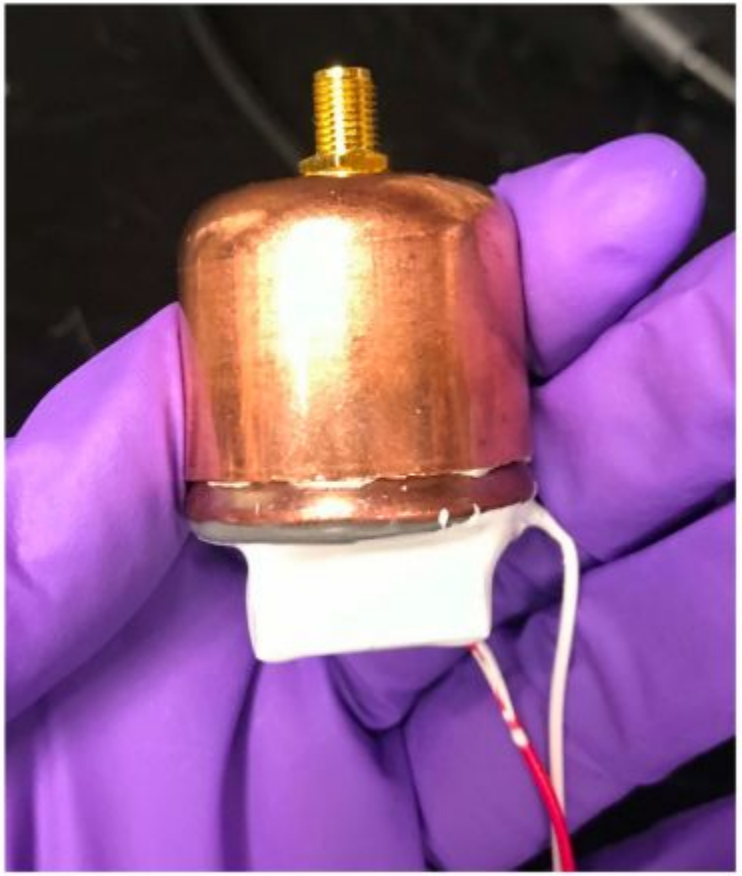




Acoustics

8 piezo acoustic sensors to monitor the sound of the nucleation process





Timelines

- **SBC-FermiLab**
  - Assembly and commissioning of 10 kg liquid argon scintillating bubble chamber
    - Present ⟶ 2022
  - Science operation
    - 2022 ⟶ 2024
- **SBC-SNOLAB**
  - GW1 approval obtained in Oct 2019
  - Construction = SBC-FermiLab + 1 year
  - DM search : 2023 ⟶ 2024
- **SBC-CEvNS**
  - Preliminary site investigations are underway
  - Conceptual design of the configuration at the ININ experimental hall (arXiv:2101.08785)
  - Experimental program follows calibration at FermiLab

The SBC Collaboration

Northwestern University
- **Eric Dahl**
- Rocco Coppejans
- Zhiheng Sheng
- Aaron Brandon
- David Velasco

Queen's University
- **Ken Clark**
- Austin De St Croix
- Hector Hawley
- Kaden Foy
- Jonathan Corbett
- Patrick Hatch

University of Alberta
- Marie-Cécile Piro
- Carsten Krauss
- Daniel Durnford
- Sumanta Pal
- Youngtak Ko
- Mitchel Baker

SNOLAB
- Pietro Giampa
- Jeter Hall
- Eric Poulin

Université de Montréal
- Mathieu Laurin

Northeastern University
- Orin Harris

Pacific Northwest National Laboratory
- Chris Jackson

Universidad Nacional Autónoma de México
- Eric Vázquez-Jáuregui
- Ernesto Alfonso-Pita
- Ariel Zuniga-Reyes

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

Fermilab
- Mike Crisler

Thank You