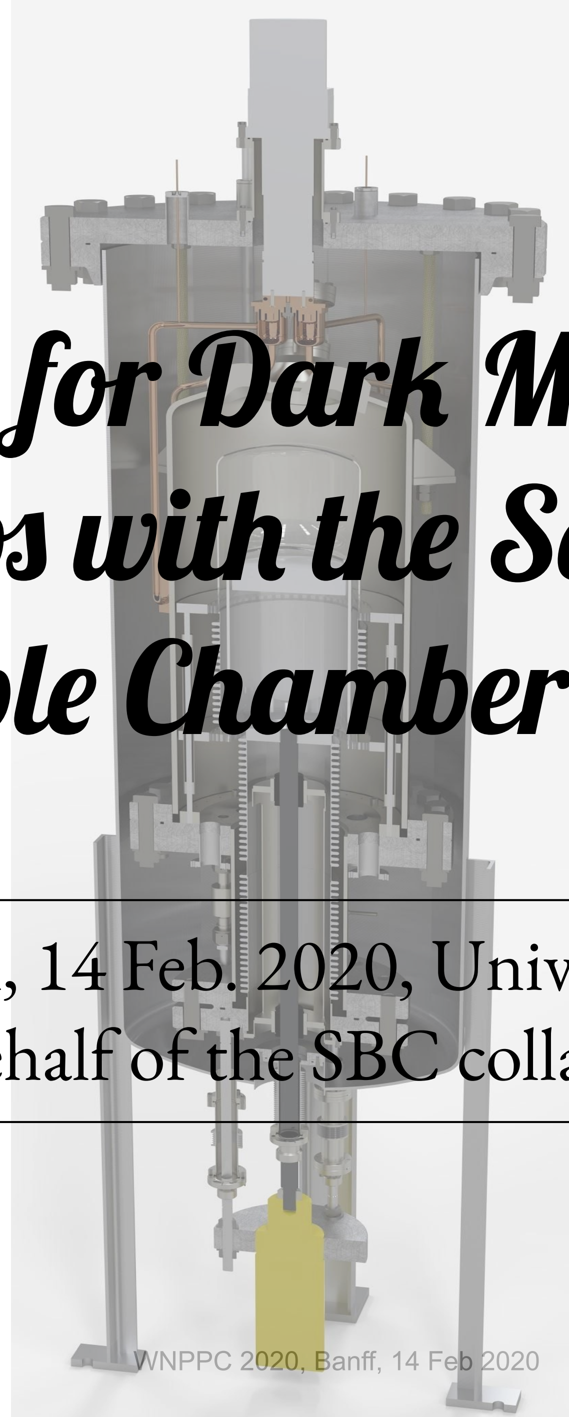


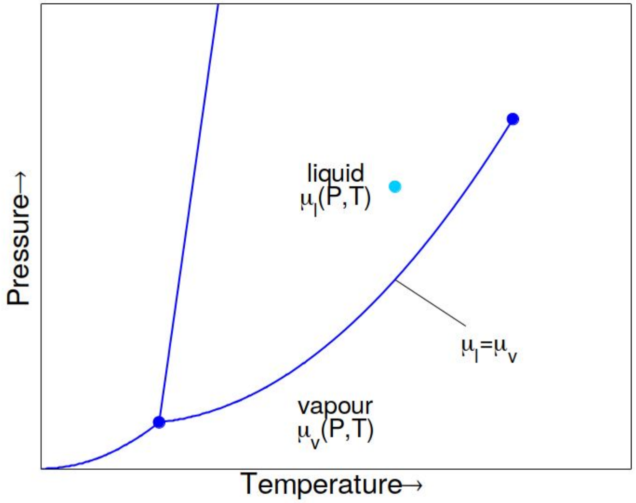
Search for Dark Matter and Neutrinos with the Scintillating Bubble Chamber (SBC)

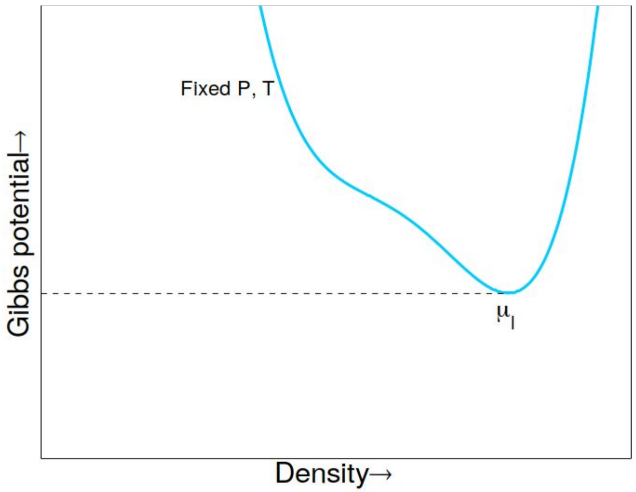
Sumanta Pal, 14 Feb. 2020, University of Alberta
(on behalf of the SBC collaboration)

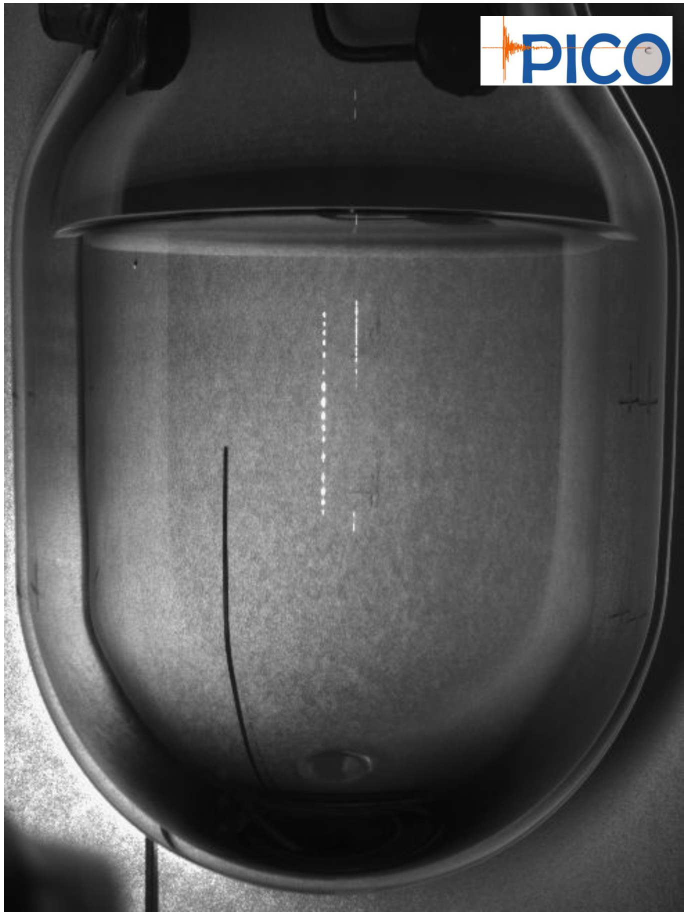
Outline

- Basic principle of a bubble chamber
- Motivation for a scintillating bubble chamber
- Physics goal
- Conceptual design of a scintillating bubble chamber
- Current activities

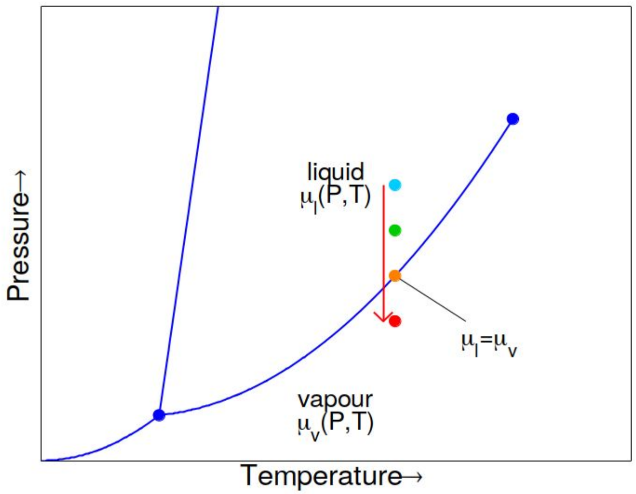
Basic principle of a bubble chamber

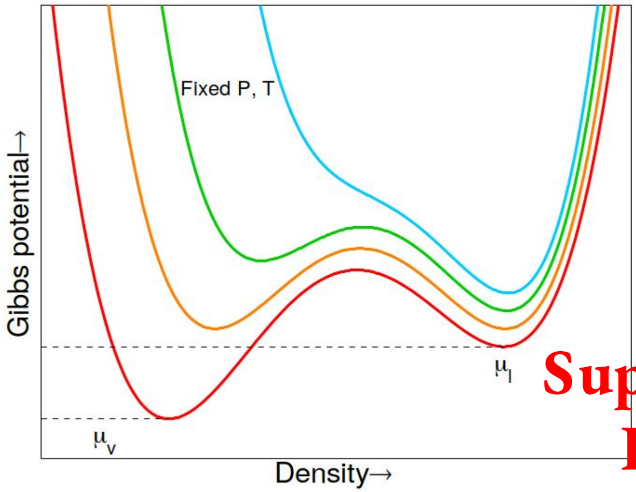


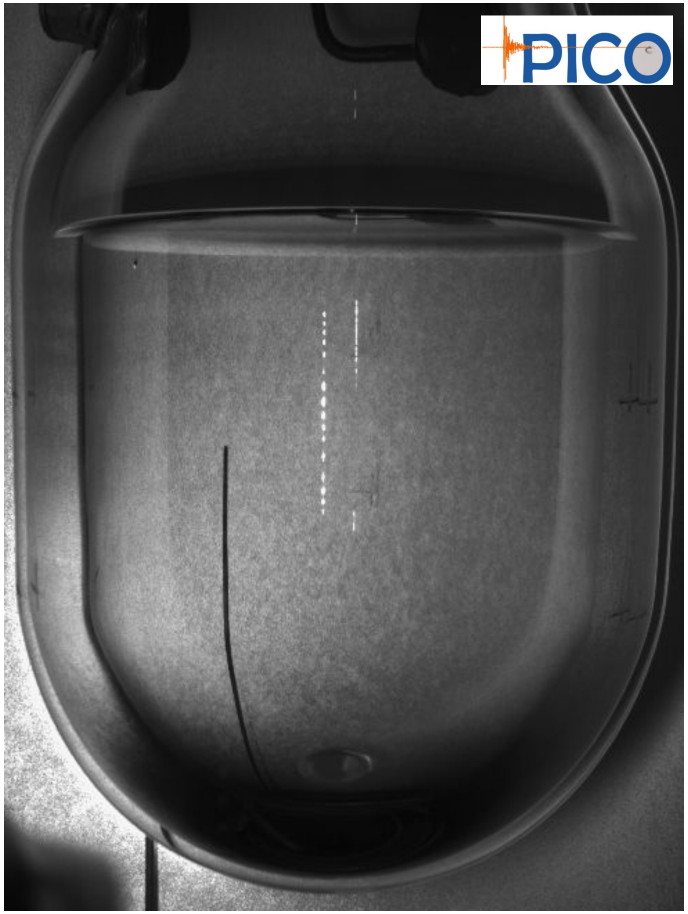




Basic principle of a bubble chamber

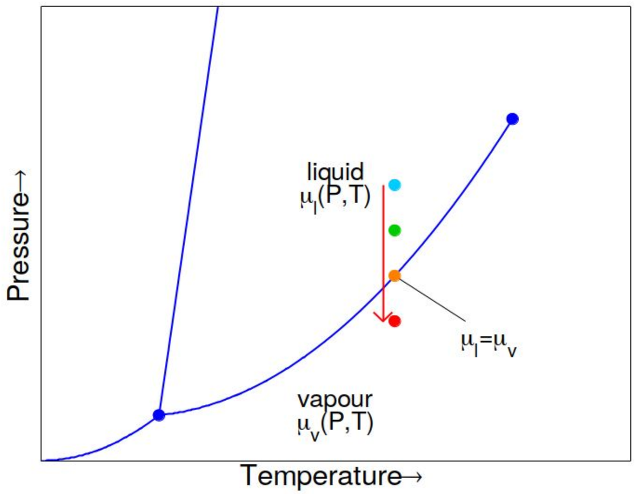


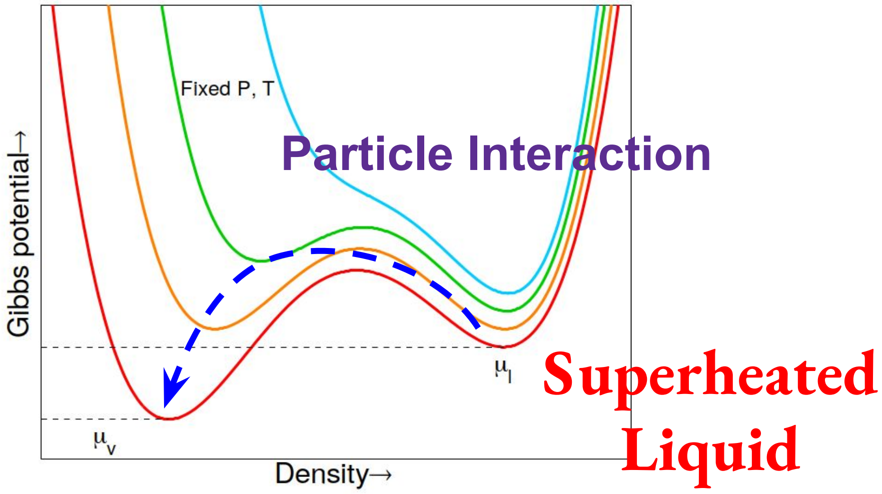


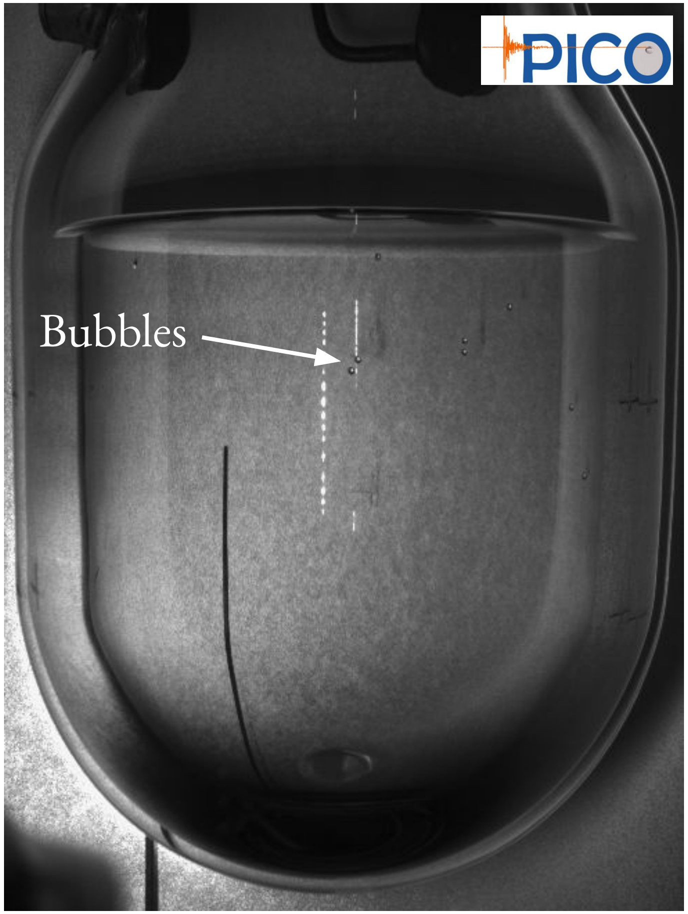


Superheated Liquid

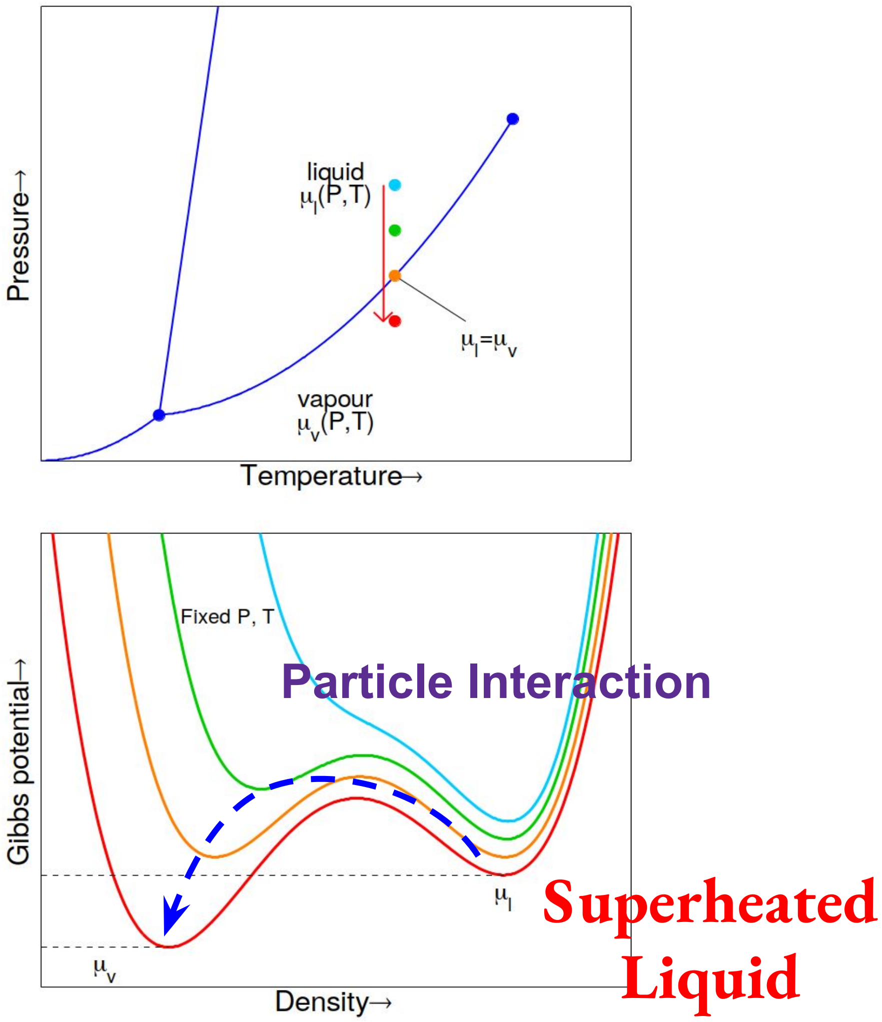
Basic principle of a bubble chamber

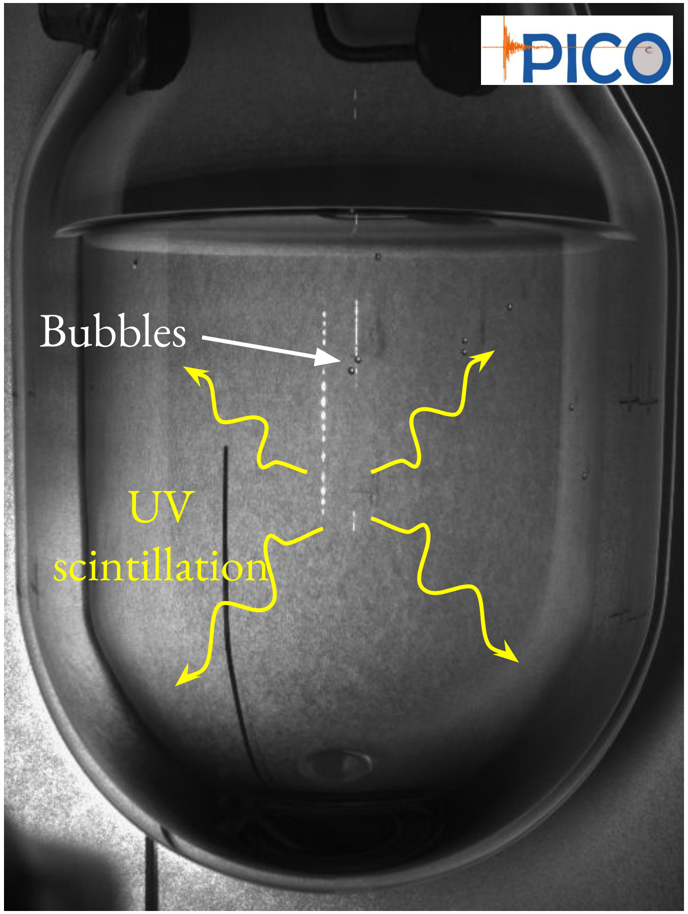




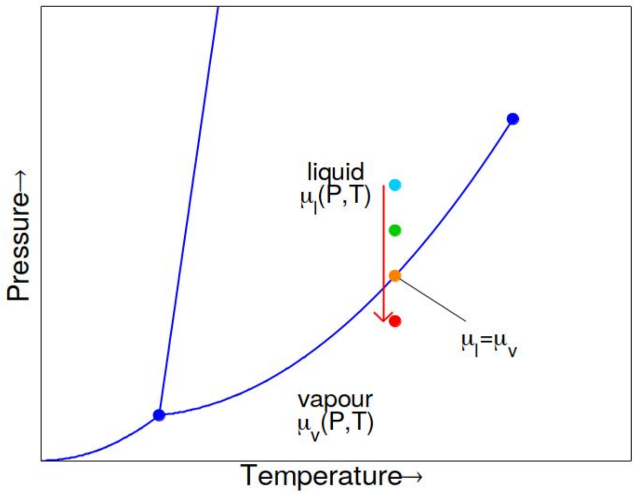


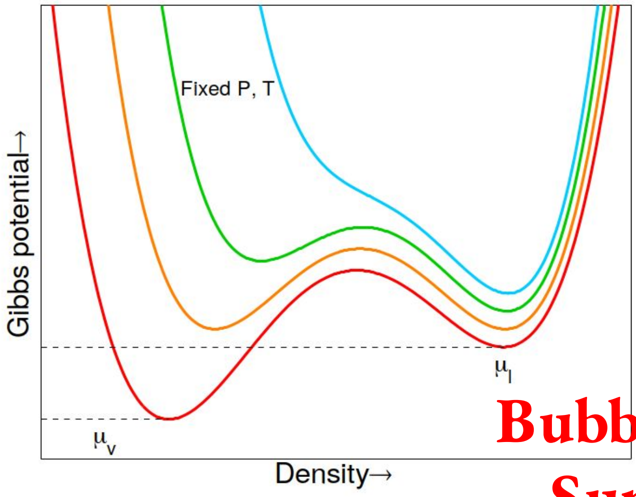
Basic principle of a bubble chamber (SBC)

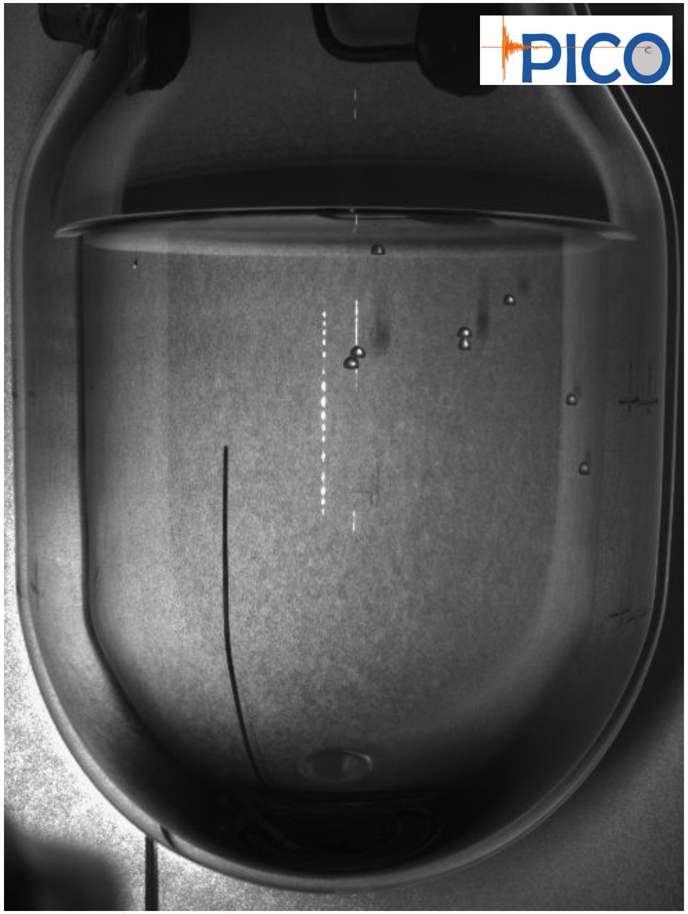




Basic principle of a bubble chamber

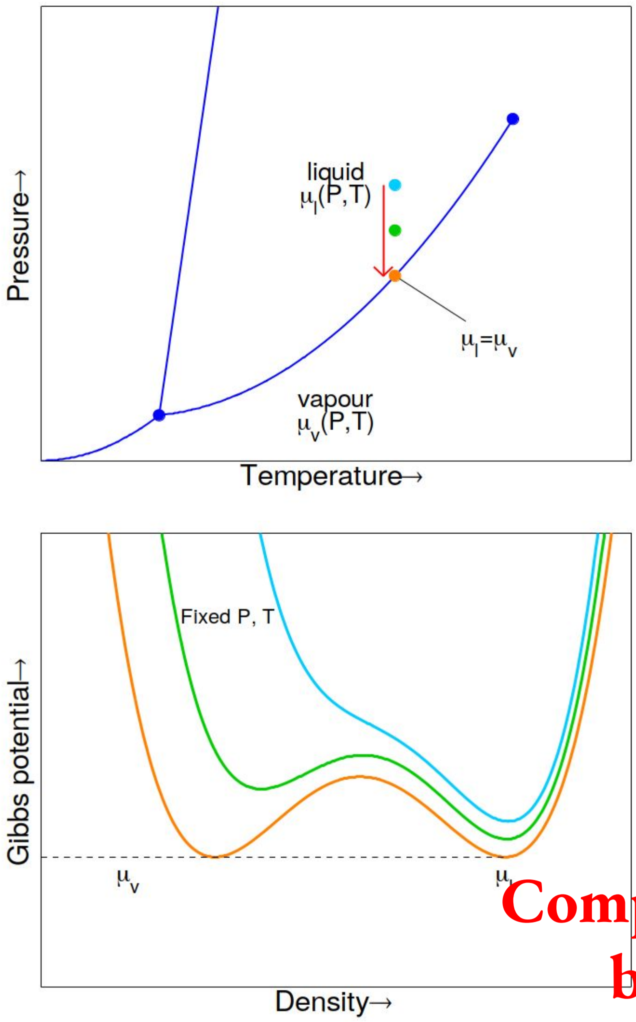


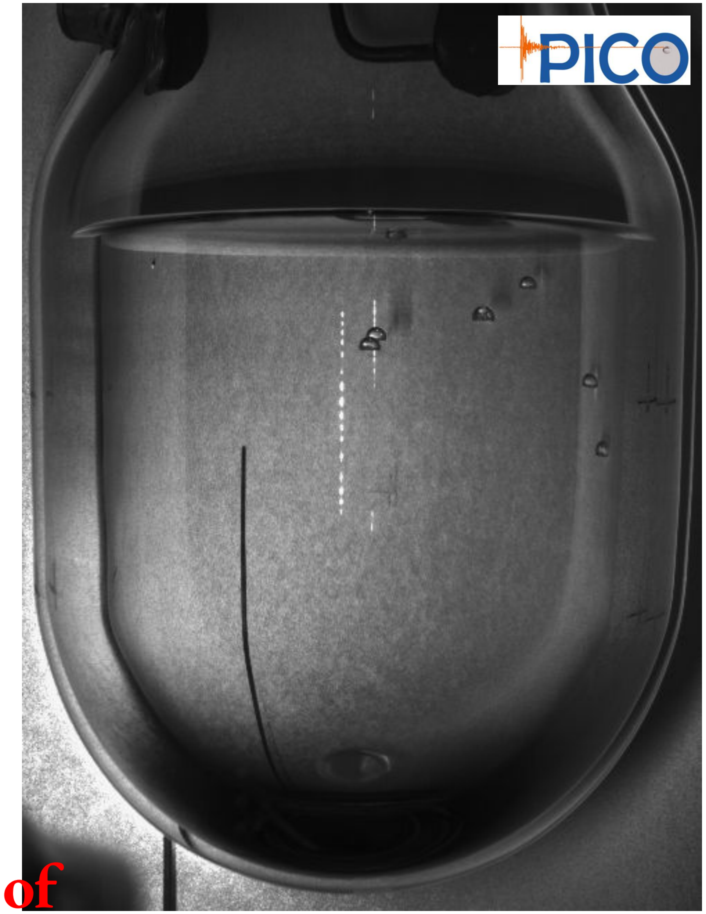




Bubbles keep growing in Superheated Liquid

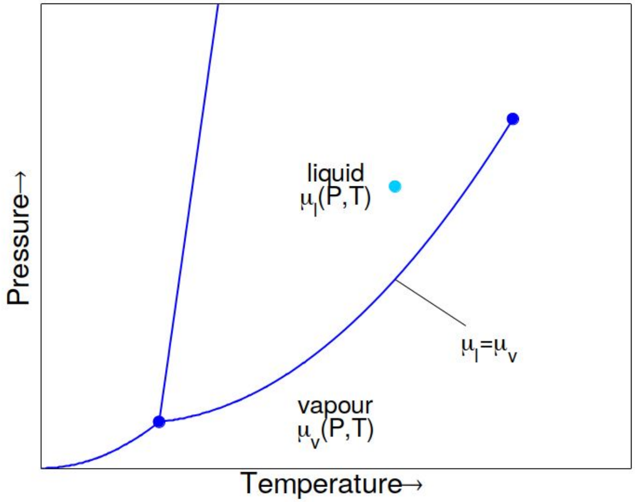
Basic principle of a bubble chamber

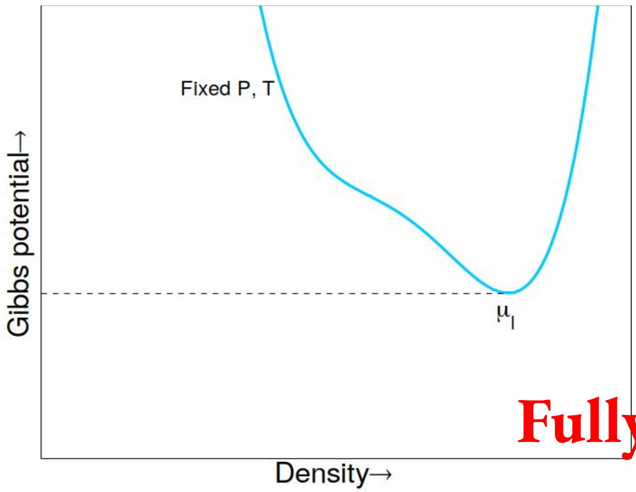


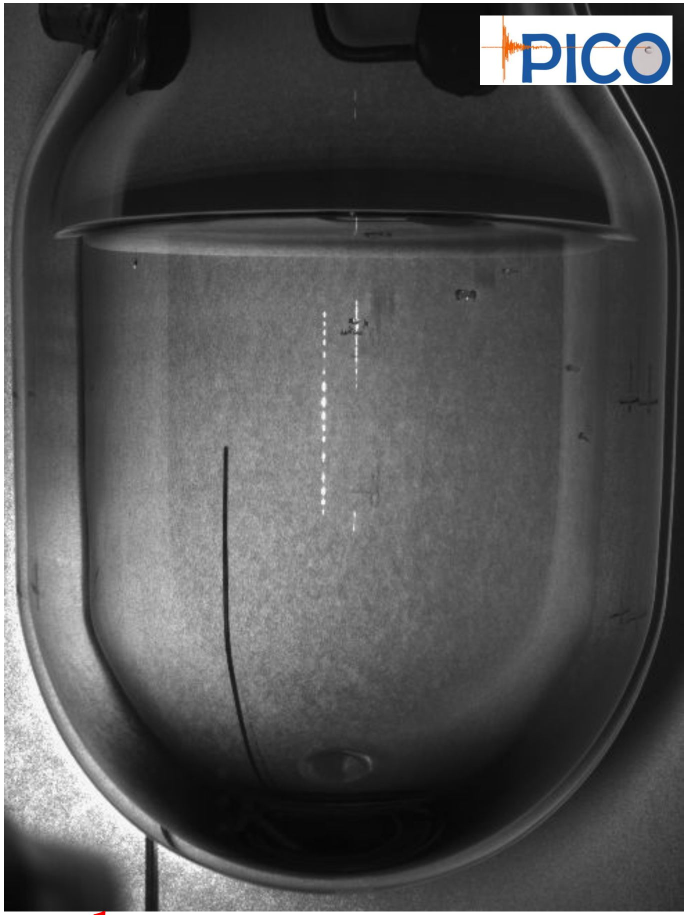


Compression of bubbles

Basic principle of a bubble chamber







Fully Compressed bubbles

Motivations for a scintillating bubble chamber

- Combine the electron recoil discrimination of bubble chambers with the event-by-event energy resolution of scintillation detectors.
- Superheated target fluid (LAr) emits scintillation light as background particles (gamma/electron) traverse it. This improves EM (electromagnetic) discrimination than PICO type bubble chamber.
- Lower energy threshold can be achieved (40 eV) compared to ~ keV threshold in PICO60.
    - NR's nucleate bubbles by direct heat deposition
    - EM interactions nucleate bubbles by exciting and breaking molecular bonds.
    - No observation of EM nucleation in noble liquids.
- Active shielding into the target fluid itself.

Timeline and Science goal

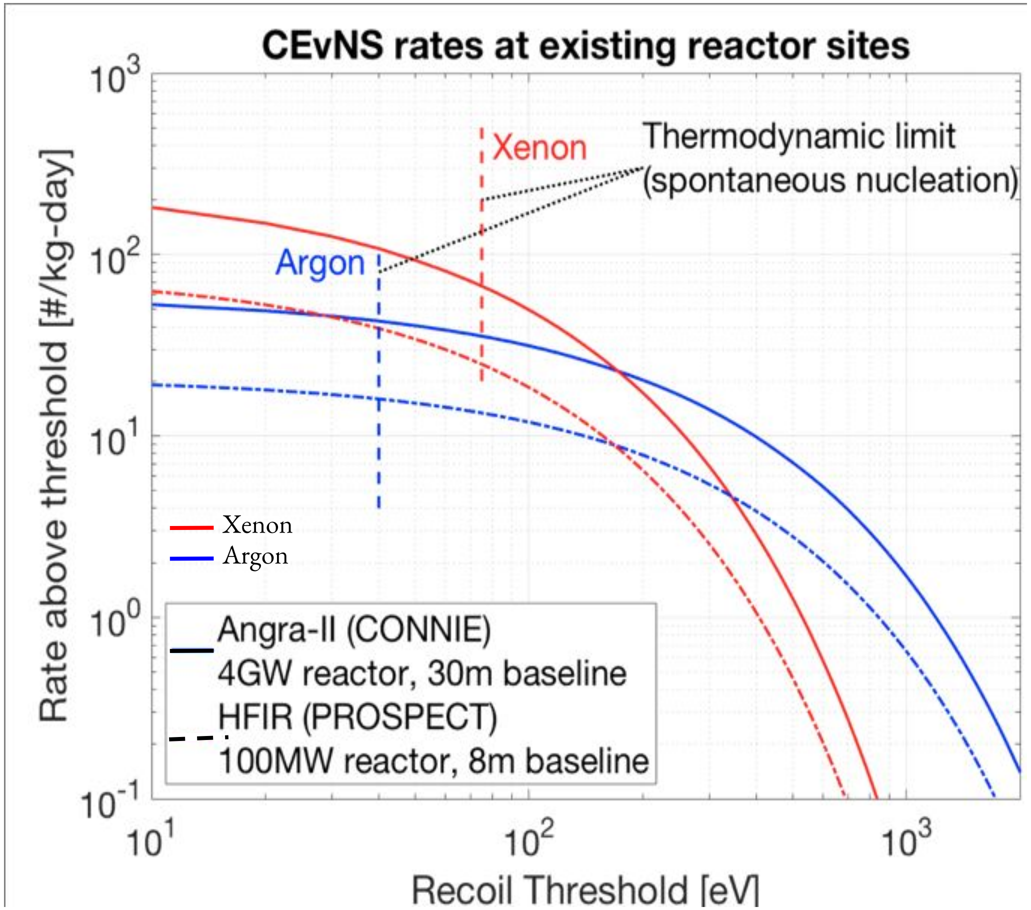
SBC-FNAL

- Funded by FNAL-LDRD 2018-003.
- Design, Construct and Calibrate a 10-kg Argon bubble chamber (9.5 L)
- Operation : under construction now at FNAL, test period 2021-2022
- Demonstrate: scalability, temperature uniformity to within 0.1 K, maintain superheat state of target fluid for 10 minutes.
- Determine: bubble nucleation probability for EM interactions, NR sensitivity.
- Goal to detect 100 eV nuclear recoil.
- Post LDRD: study CEvNS at a reactor site.

SBC-SNOLAB

- CFI Funded from Univ. of Alberta and Queen's University.
- Same 10-kg Argon bubble chamber.
- Propose installation in 2021 at SNOLAB.
- Low WIMP mass (< 10 GeV) search.

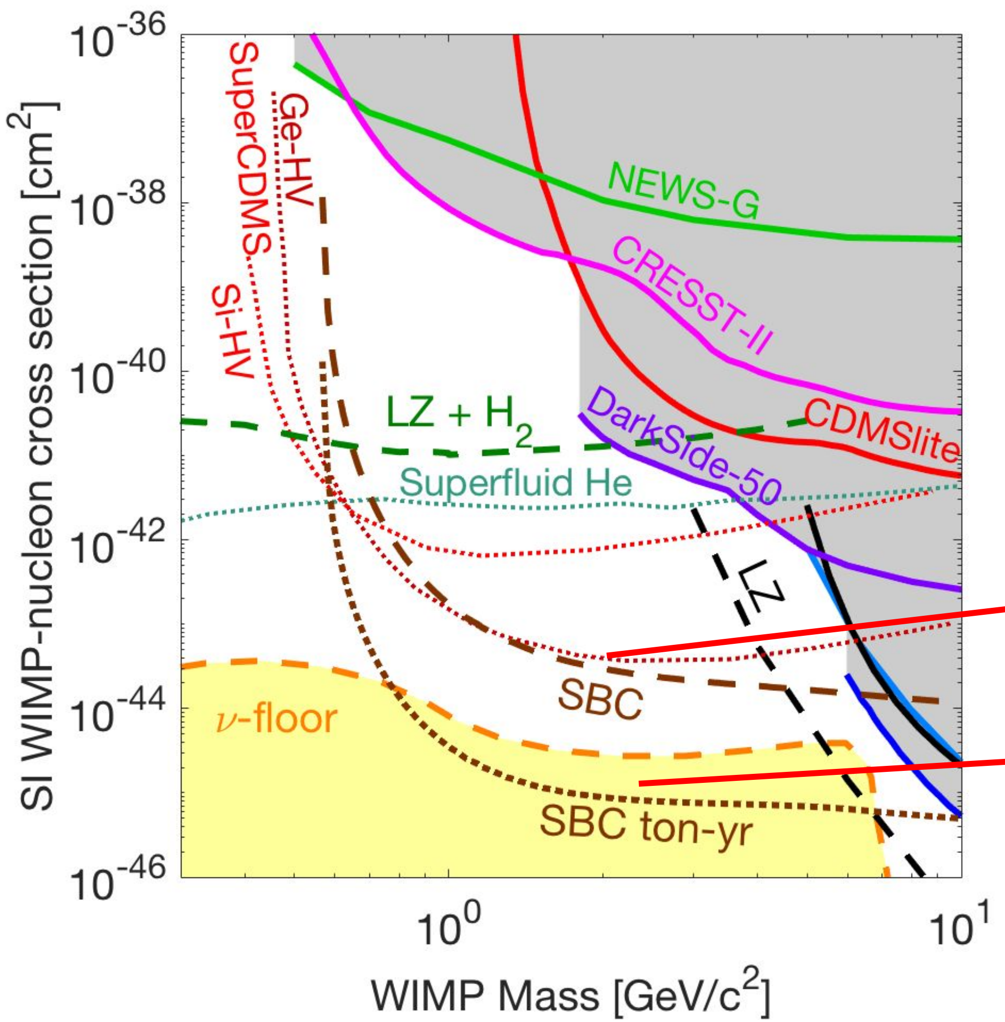
CEvNS predicted rate for SBC



- SBC has potential to detect CEvNS signal.
- As this rate changes with target material, it is possible to operate this detector initially with Ar target and later on with Xe and CF4 etc.

CEvNS : Coherent Elastic neutrino Nucleus Scattering

WIMP mass predicted sensitivity at SBC-SNOLAB



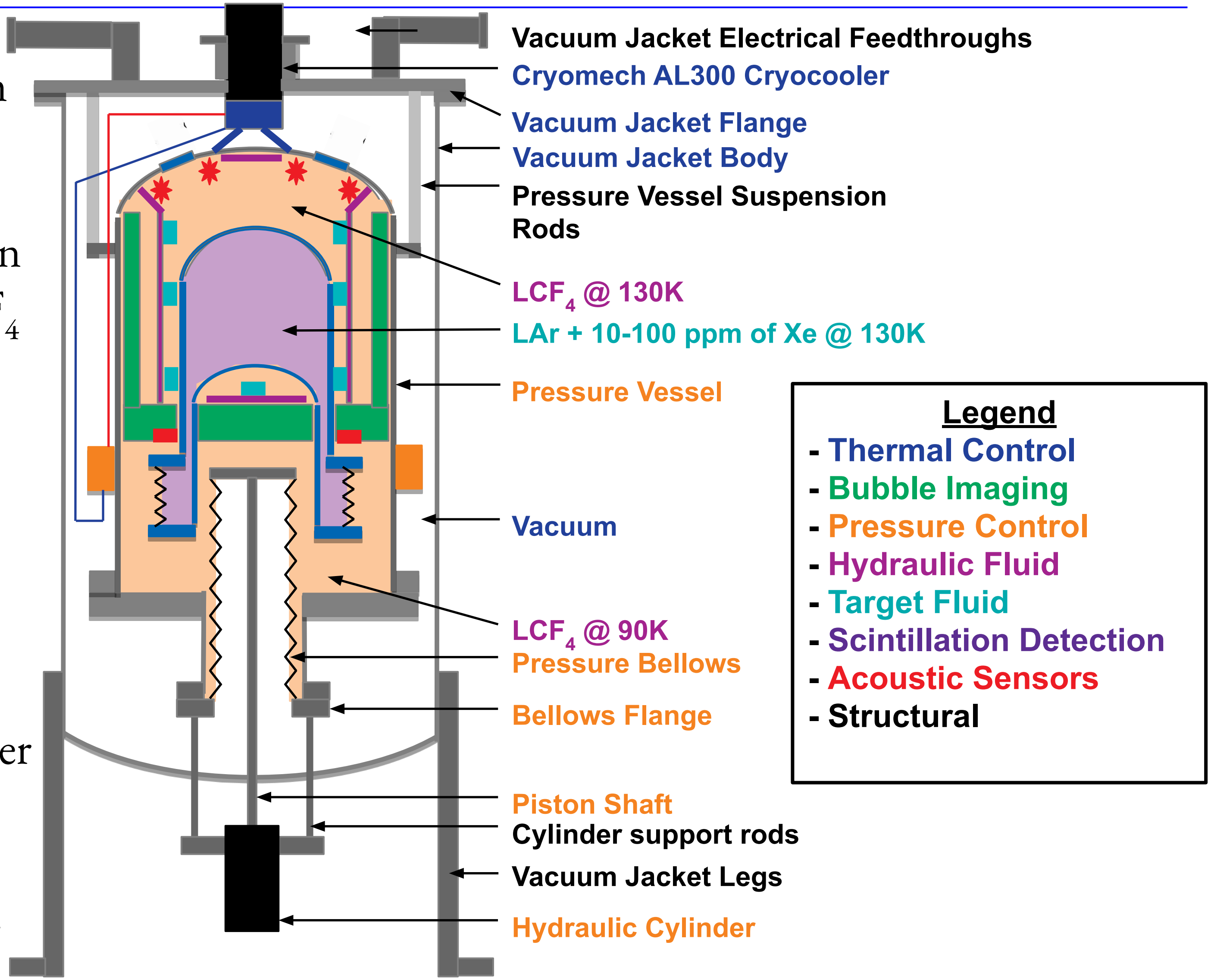
- Low threshold opens new phase space for low WIMP masses (0.7 - 7 GeV).

10 kg -year

1 ton -year

Schematic design of a scintillating bubble chamber

- Ar + (10-100) ppm Xe target, 178 nm scintillation
- SiPM's immersed in hydraulic fluid (CF_4 @ 130 K)
- 20-360 psia (~1-25 bara) cycles
- Single fluid, "right-side-up" geometry
- This whole setup will be inside a water shielding at SNOLAB site for dark matter search.

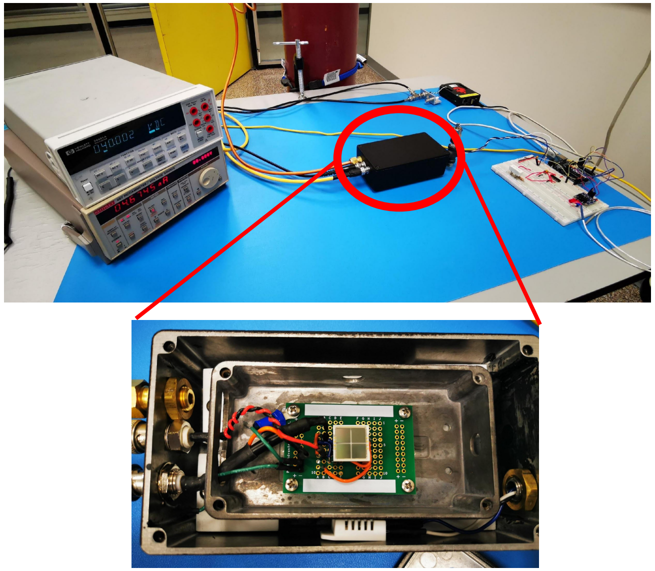


Current activities: detector fabrication

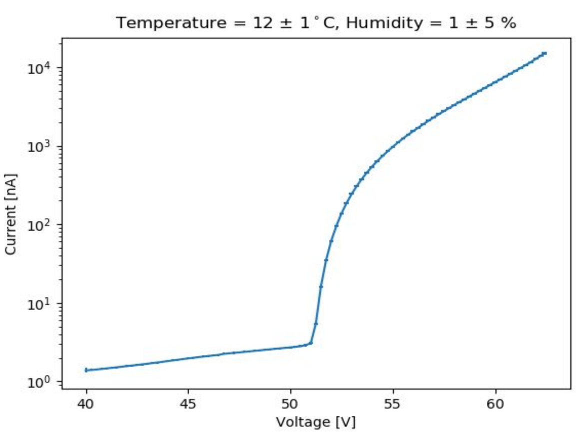
At FNAL: (left) pressure bellow, (right) pressure vessel

At Ability Engineering, Chicago: vacuum jacket has passed its leak check.

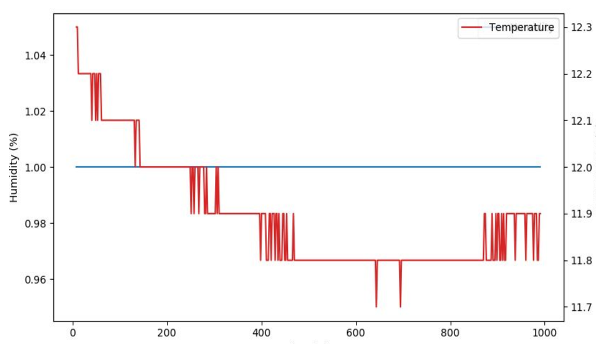
Current activities: electronics



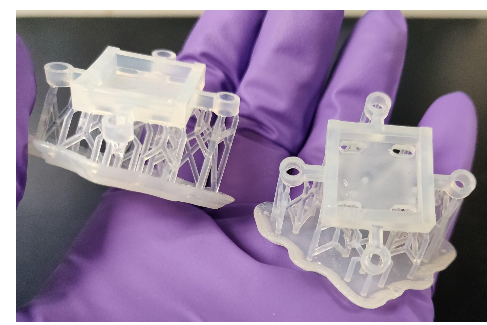
- HAMAMATSU VUV4 SiPMs.
- Stress testing is going on at Northwestern Univ.
- 3D printed SiPM holder which will be mounted on the outside surface of Inner vessel.
- TRIUMF has started production of the electronics boards.



I-V Curve using the TRIUMF VUV4 SiPM



Humidity and temperature monitor.



3D printed SiPM holder

Current activities

- Inner jar assembly design is ongoing.
- P&ID for fluid, hydraulic and thermosyphon control are on progress.
- CF_4 recovery system design is on progress.
- Fill / Empty procedure of Ar and CF4 (Normal & Emergency) is under review.
- Search for alternate optical methods to move the camera outside of the vacuum jacket to decrease radioactive backgrounds.
- Cosmogenic and radiogenic background simulations.

Detector R&D at UofA

- Develop a prototype detector of SBC (300mL) at UofA under CFI funding of Marie-Cécile Piro.
- Engineering design is ongoing.
- It will be used as a test chamber to perform various dedicated R&Ds.
  - Study EM interaction model
  - New sensors (acoustic)
  - New camera and optics
  - Radon mitigation with distillation column
  - Different active fluids

SBC Collaboration

- Northwestern University
  - **Eric Dahl**
  - Rocco Coppejans
  - Runze Zhang
  - Jason Phelan
  - Will Reinhardt
  - Lawrence Luo
  - Zhiheng Sheng
  - Fangjun Zhu
  - Aaron Brandon
- Queen's University
  - **Ken Clark**
  - Hector Hawley
  - P Hatch
- University of Alberta
  - Marie-Cécile Piro
  - Daniel Durnford
  - Sumanta Pal
  - Youngtak Ko
  - Mitchel Baker
- UCSB
  - Hugh Lippincott
  - Thomas Whitis
- TRIUMF
  - Pietro Giampa
  - P Margetak
  - M Long
- Drexel University
  - Russell Neilson
  - Matt Bressler
- PNNL
  - Chris Jackson
- NEIU
  - Orin Harris
- UNAM
  - Eric Vázquez Jáuregui
  - Ernesto Pita
  - Ariel Zuniga-Reyes
  - Daniel Lámbarri
- IUSB
  - Ilan Levine
  - Ed Behnke
  - Kelly Allen
  - Nathan Walkowski
- Université de Montréal
  - Mathieu Laurin
- FNAL
  - Mike Crisler