Designing and Building a Scintillating LAr Bubble Chamber for WIMPs and reactor CEvNS

Rocco Coppejans & the SBC Collaboration

DPF, July 2019

Northwestern
Department of
Physics and Astronomy

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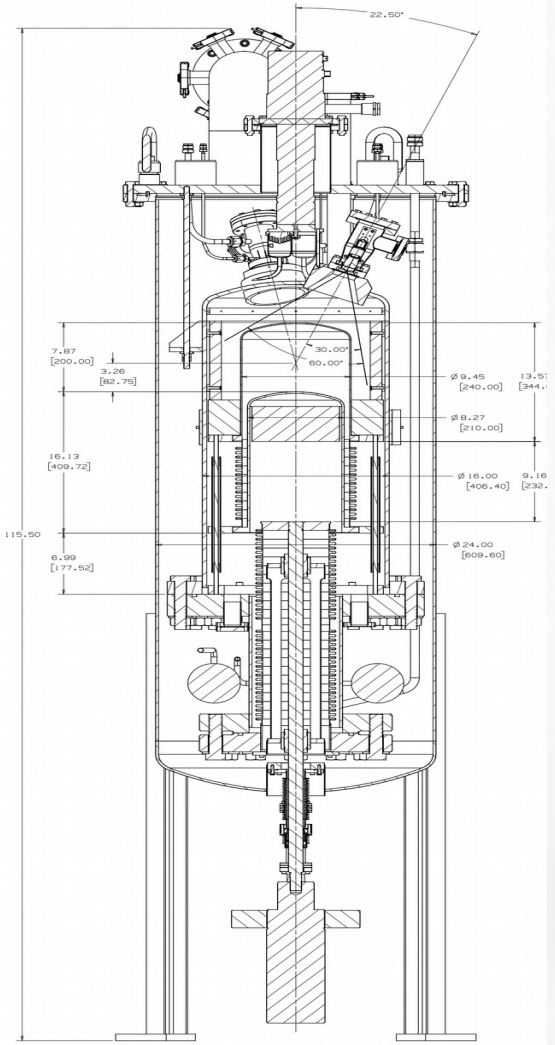
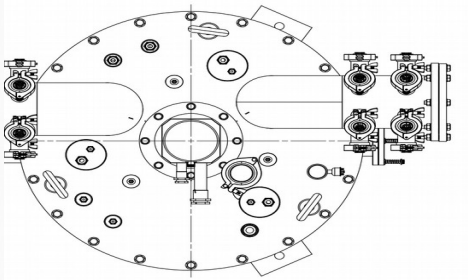
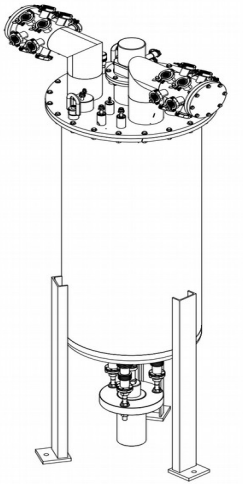
DESCRIPTION: F10113251
PROJECT: COLPRBubbleChamber
CATEGORY: ASSEMBLY

REV	REVISION CONTROL DOCUMENT	DATES	SIGNATURES
-	F10113251---RCD		DRAWN
			APPROVED



SECTION A - A





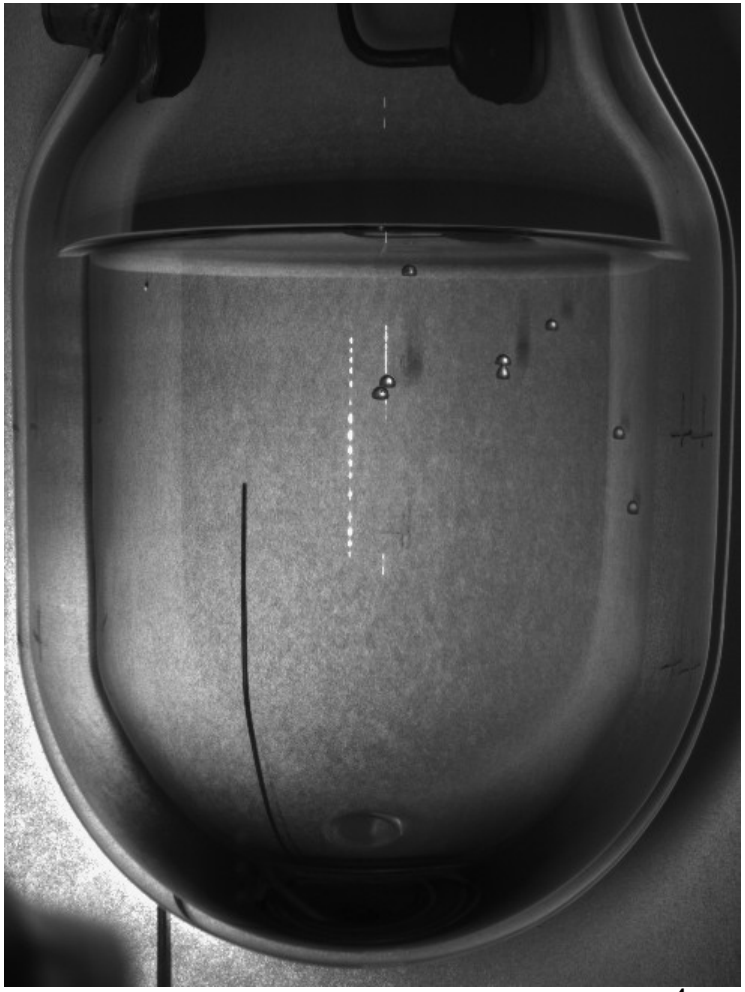
ISOMETRIC VIEW
SCALE: 1:8

UNLESS OTHERWISE SPECIFIED					DRAWN	W.CYKO	DATE	07-Dec-2018	FERMI NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY
X.X	±.XX	X.XXX	±.XXX	±X°	CHECKED		DATE		
X.XX	±.XXX	X.XXX	±.XXX	±1°	APPROVED		DATE		NAME LDRD A- BUBBLE CHAMBER ASSEMBLY, 12-07-2018
BREAK ALL SHARP EDGES MAX .015					LABEL ON				
DO NOT SCALE DRAWING									
DRAWING CONVERTED TO PDF FILE 11.6.0.2008									
MAX MACHINE ALL SURFACES 125									
DRAWING UNITS: INCHES					MATERIAL				
THIRD ANGLE PROJECTION					GROUP: Particle Physics Mechanical Support/CASE CODE: DUSPE				

SCALE	SIZE	DRAWING NUMBER	SHEET	REV
	E	F10113251	1 of 1	-

Bubble Chambers

- Established DM search technique (>10 years) e.g. PICO 500, 60L ...
- Signal: one bubble in a super heated liquid
- ERs does not make bubbles

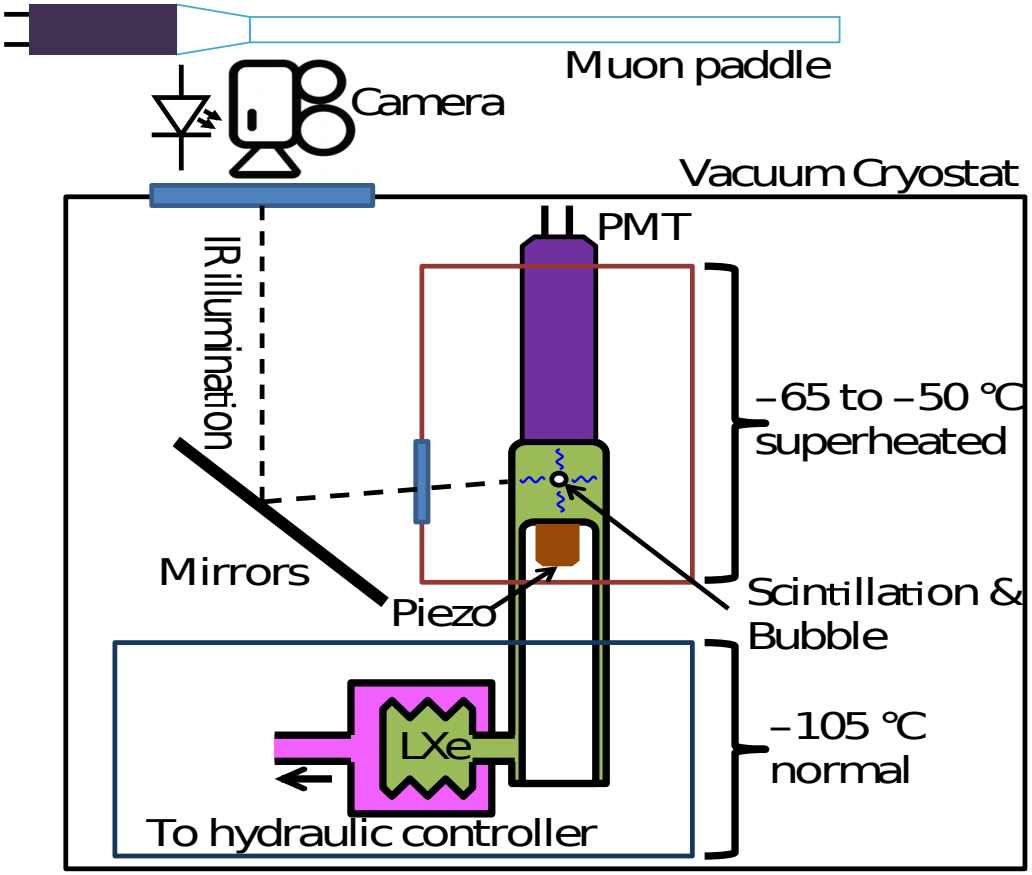


Scintillating Bubble Chamber (SBC)

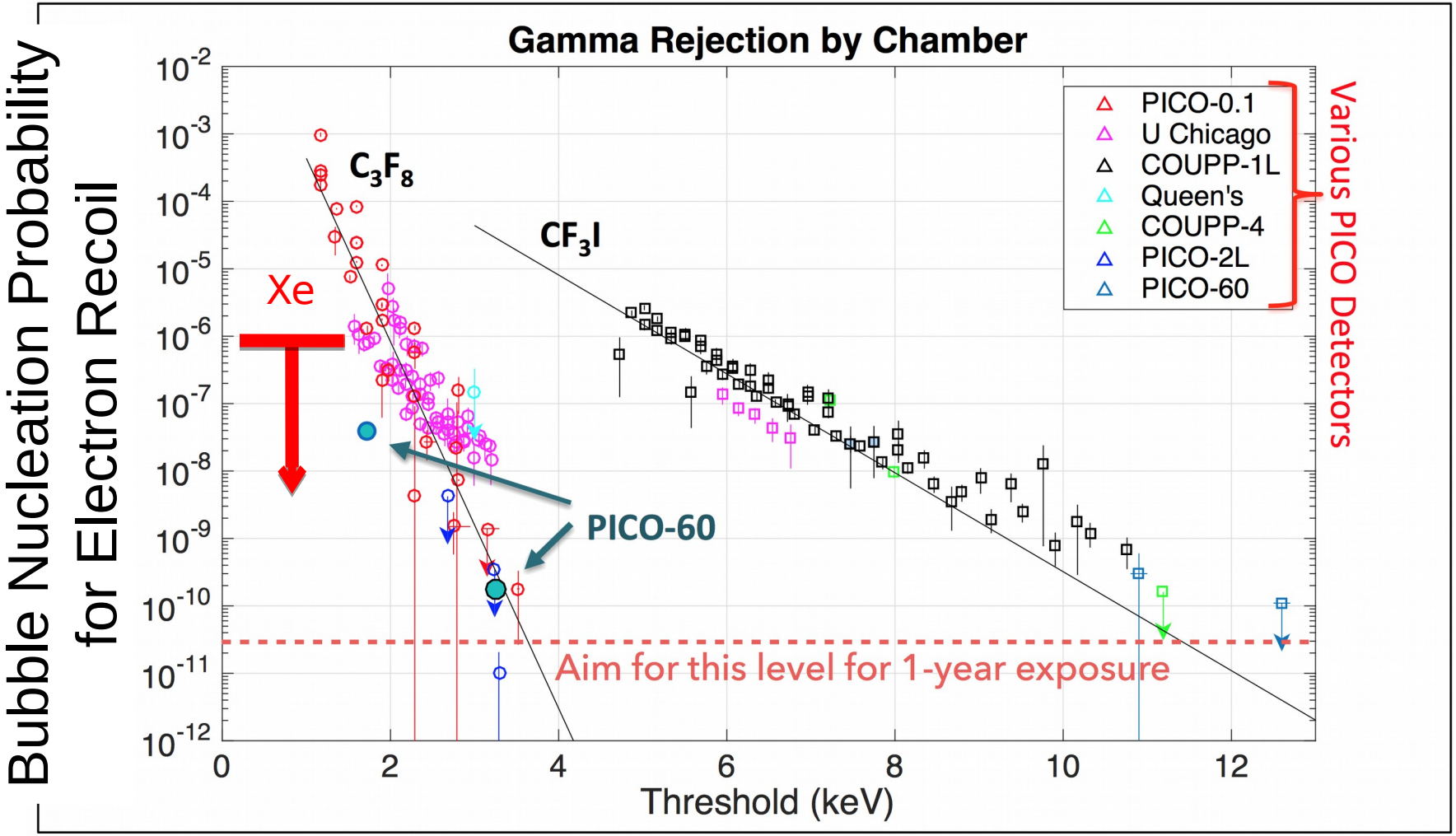
Combine the **electron recoil discrimination** of bubble chambers with the **event-by-event energy resolution** of scintillation detectors.

30g LXe SBC Prototype at NU

- 30 gram LXe target
- Pressure cycle: 25 to 200 psia
- 955 nm near-IR camera illumination
- Scintillation detection: IR-blind PMT



Electron Recoil Discrimination

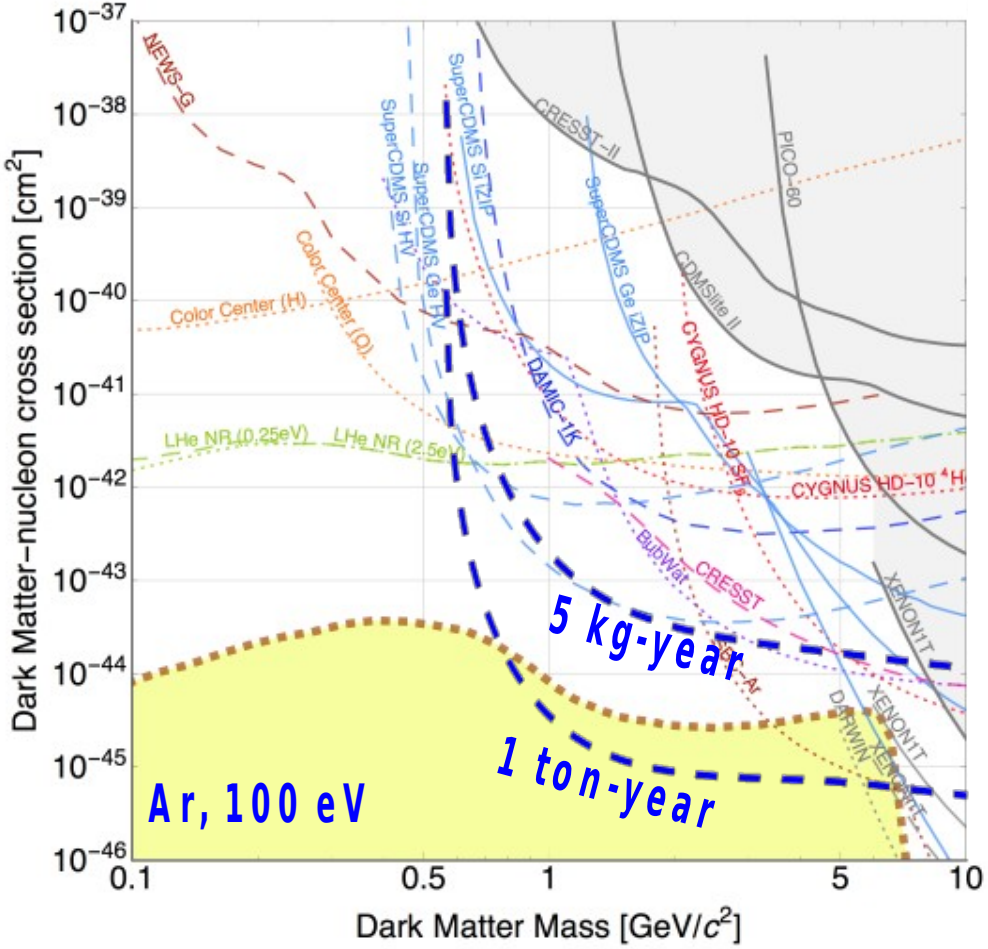


(Dan Baxter, Conference on Science at SURF, May 14, 2017)

Electron Recoil Discrimination

- Liquid nobles Vs molecular fluids: No molecular bonds → no efficient way to locally turn ER energy into heat

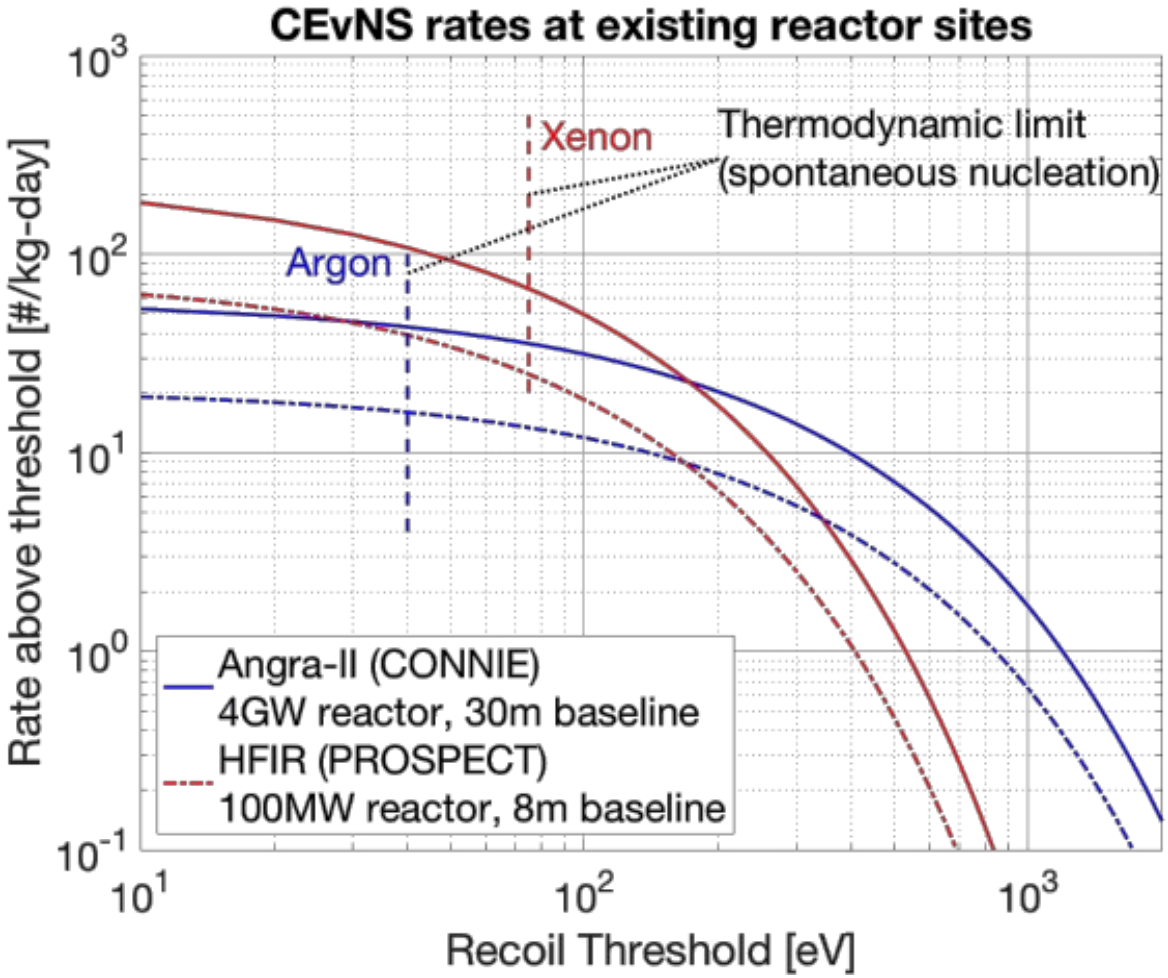
- Hypothesis: liquid nobles can be superheated to near the thermodynamic limit without encountering bubble nucleation by ERs



Battaglieri, et al. arXiv:1707.04591

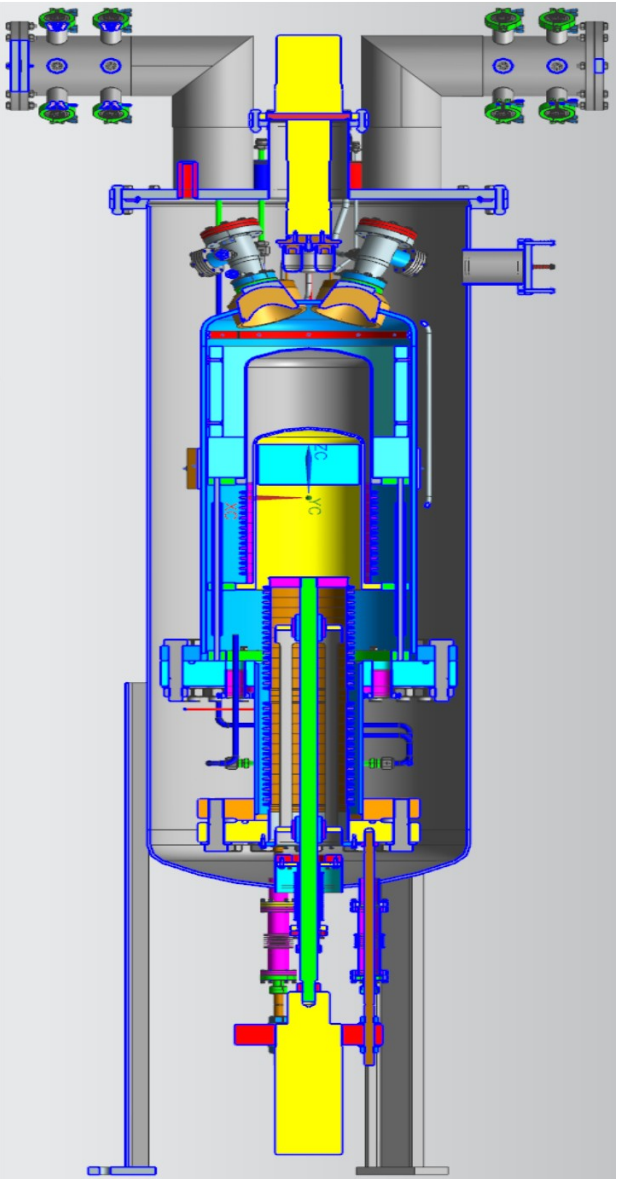
Predicted CEvNS Sensitivity

- O(10) CEvNS events / kg-day at a reactor
  - Pending calibration
  - The detector is scalable



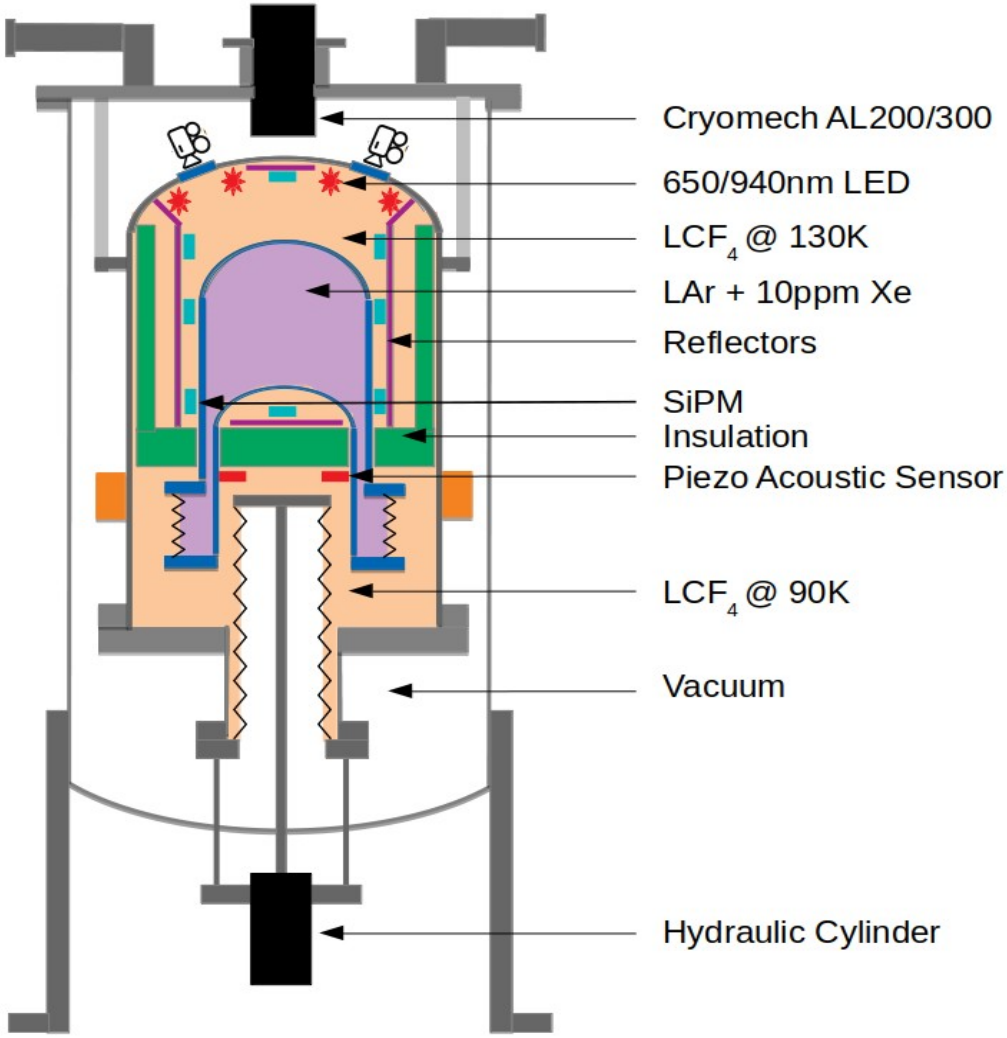
10Kg LAr SBC Objectives

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



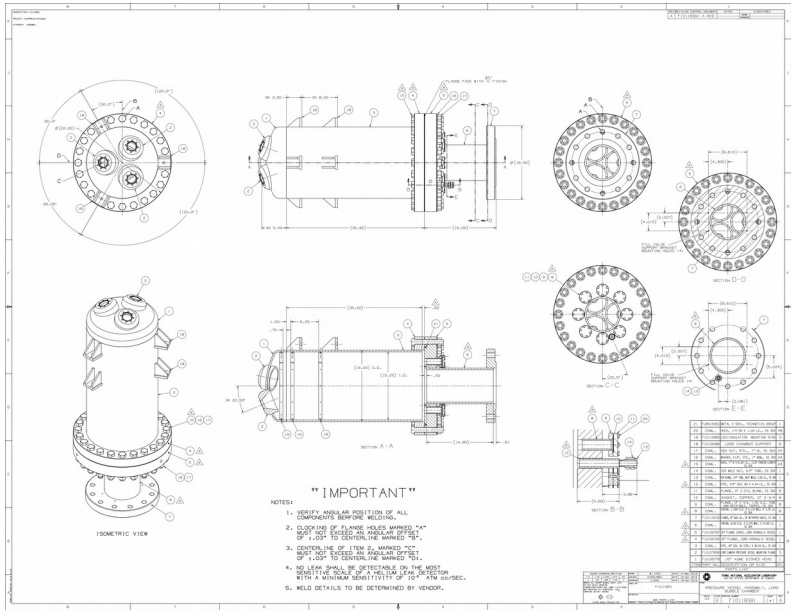
Overview and Specifications

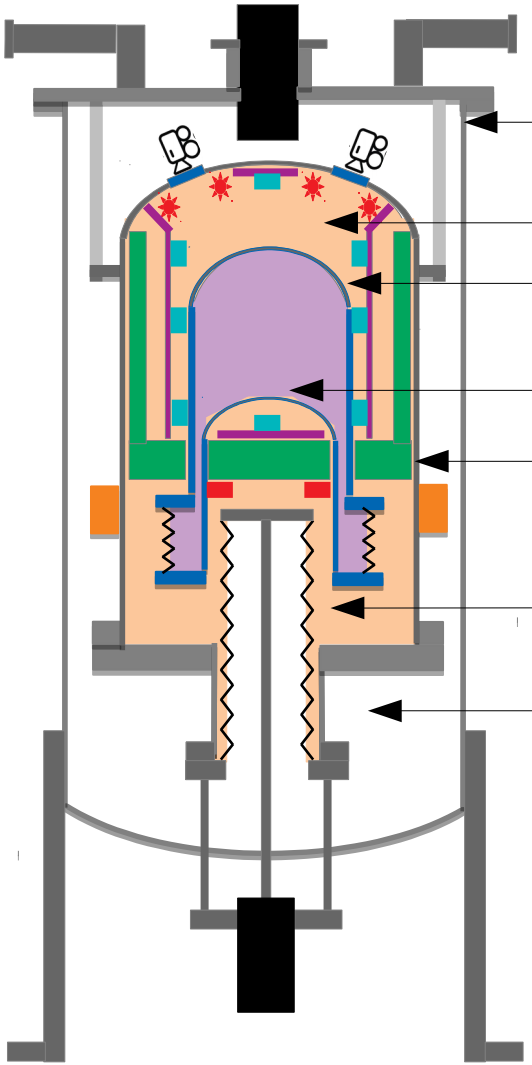
- Temperature regions
  - 90K & 130K
- Pressure cycling
  - 20 – 360 psia
- Bubble imagine
  - Stereoscopic
  - 650 nm
- Scintillation detection
  - SiPM
  - 175 nm
  - Photon starved



Jars, Pressure Vessel & Vacuum Jacket

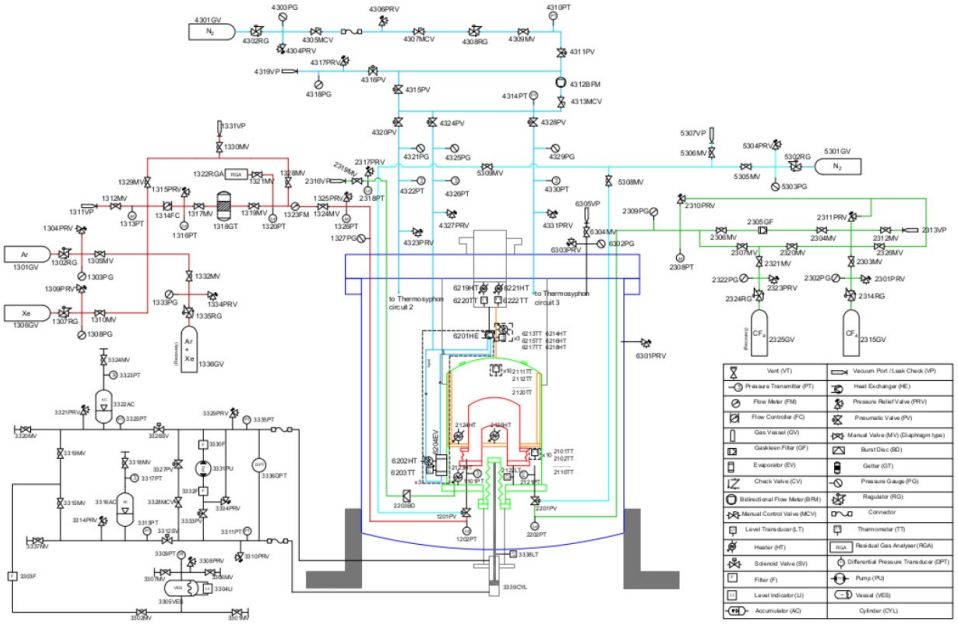
- Design is complete
- Pressure vessels now in fabrication (at vendor)
- Detector assembly now in fabrication (by collaboration)

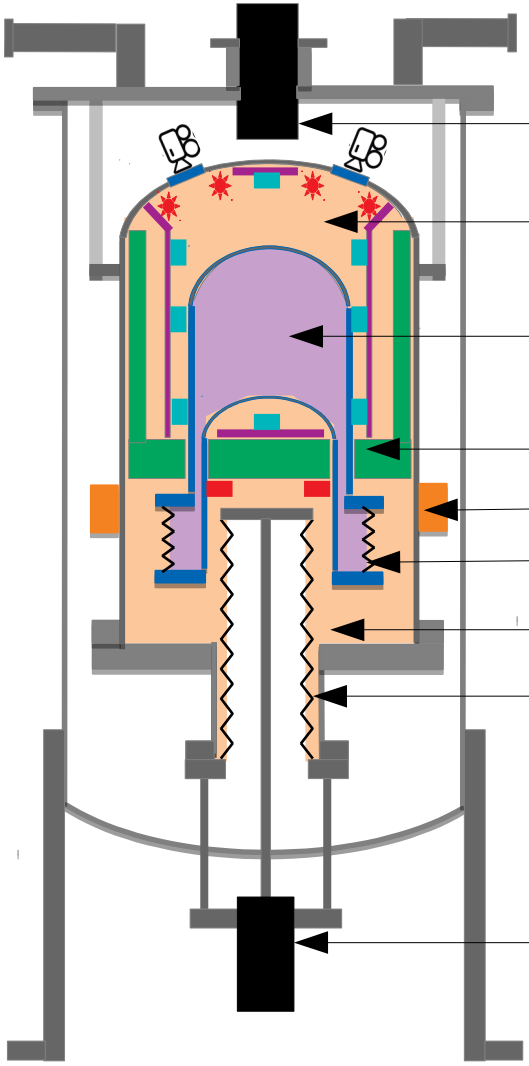




Temperature, Pressure & Control

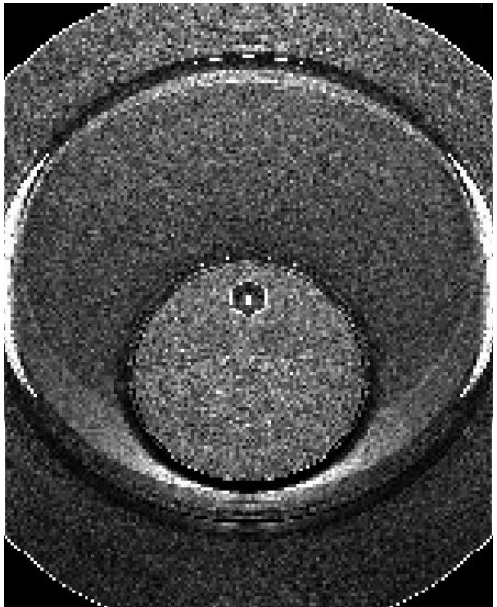
- P&ID complete, under review
- Control schemes defined for:
  - Fill / Empty
  - Routine Operation
  - Emergency Scenarios

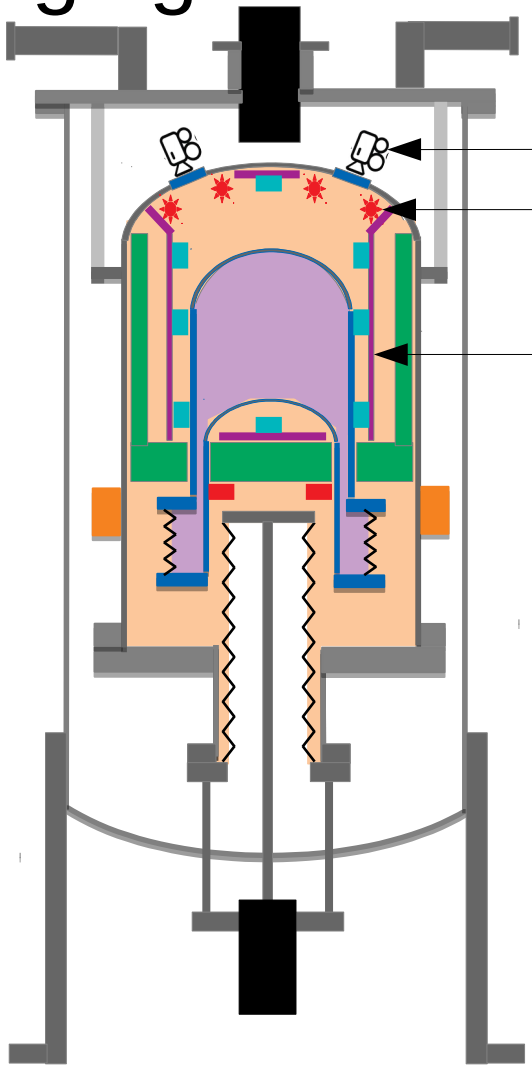




Bubble Imaging

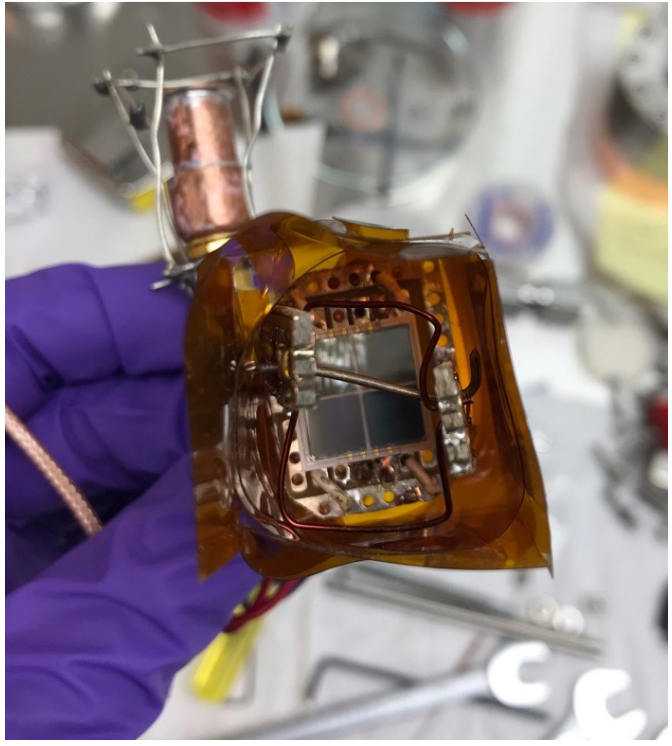
- Stress testing: cameras withstand -100°C to 50°C
- Developing thermal control system
- Developing optical model

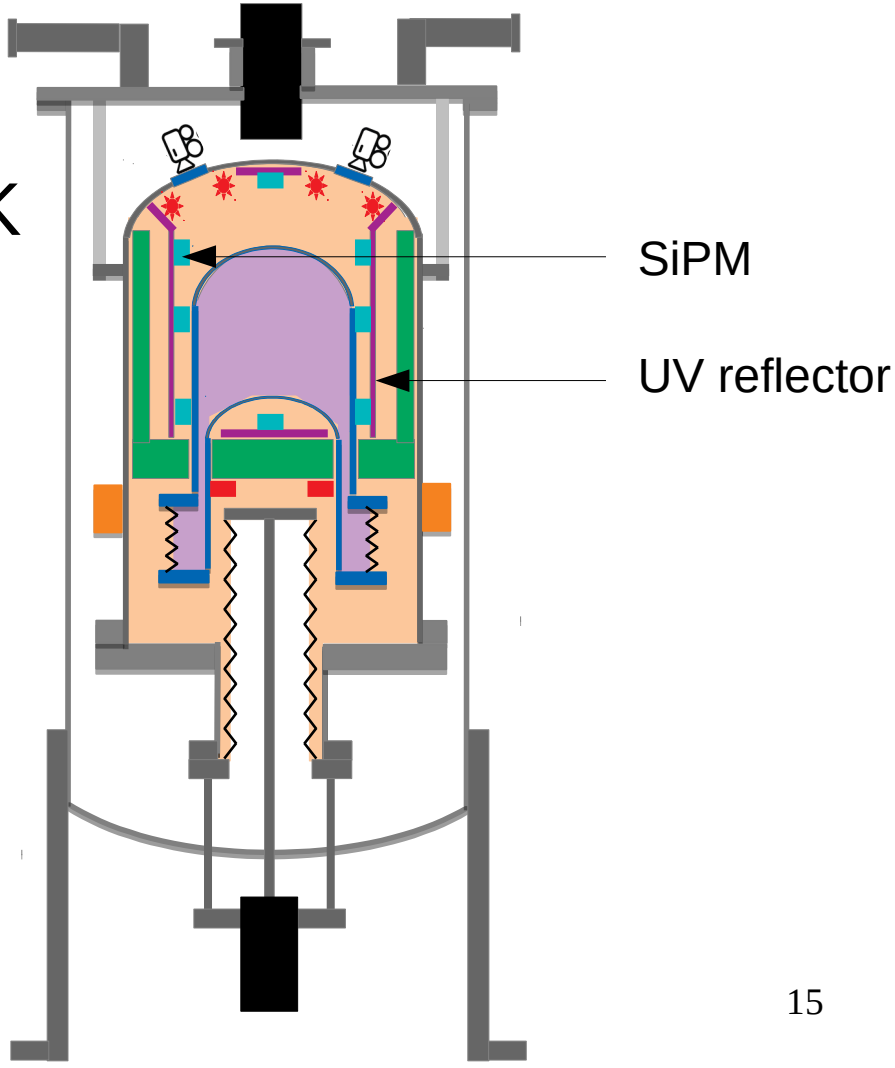




Scintillation Light

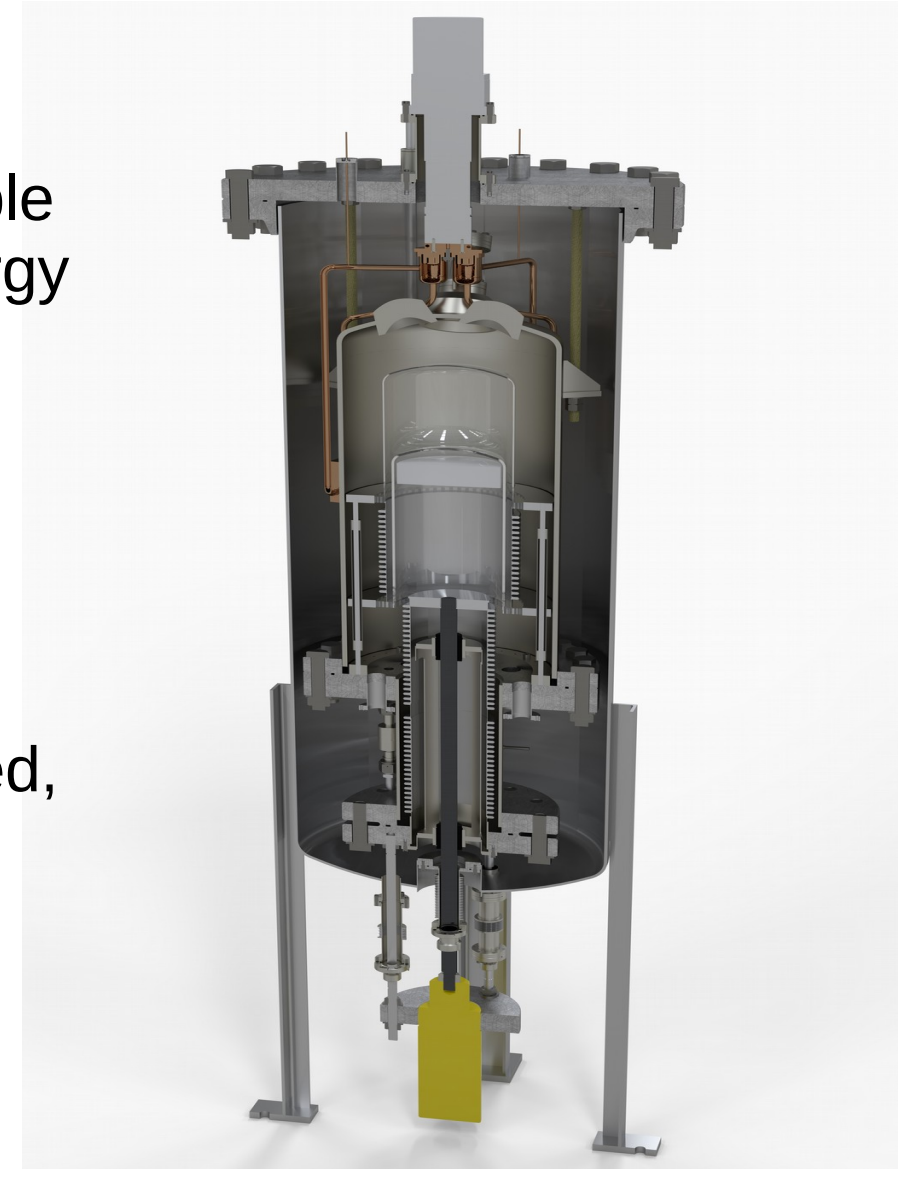
- Hamamatsu VUV4 SiPMs
- Stress testing: 20-360psia @ 90K
    - Survived >10k cycles





Conclusion

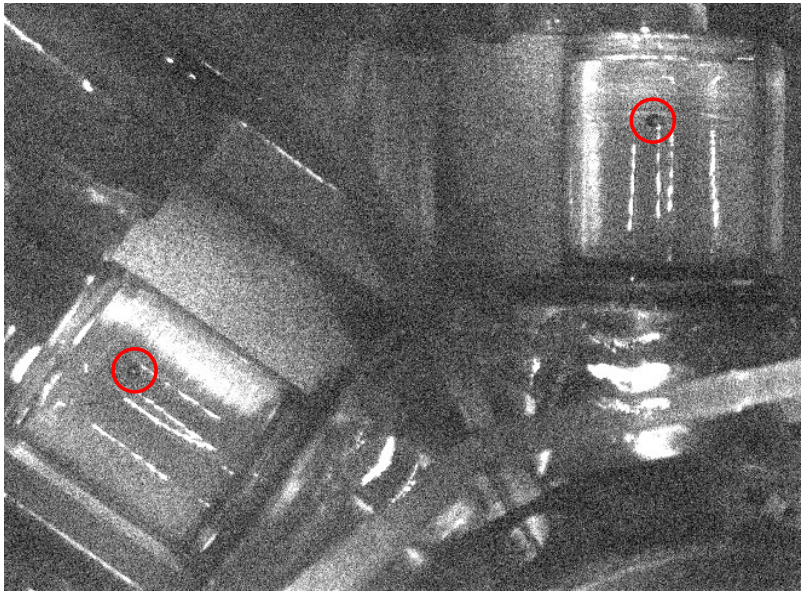
- **Motivation**
  - Combine the ER discrimination of bubble chambers with the event-by-event energy resolution of scintillation detectors
- **Objectives**
  - Demonstrate scalability
  - Bubble nucleation probability of an ER
- **Status**
  - Design is complete
  - Hardware being fabricated and procured, including vessels
  - GW-0 approval at SNOLAB secured
- **Timeline**
  - Construction: 2019 - 2020
  - Calibration @ Fermilab: 2020

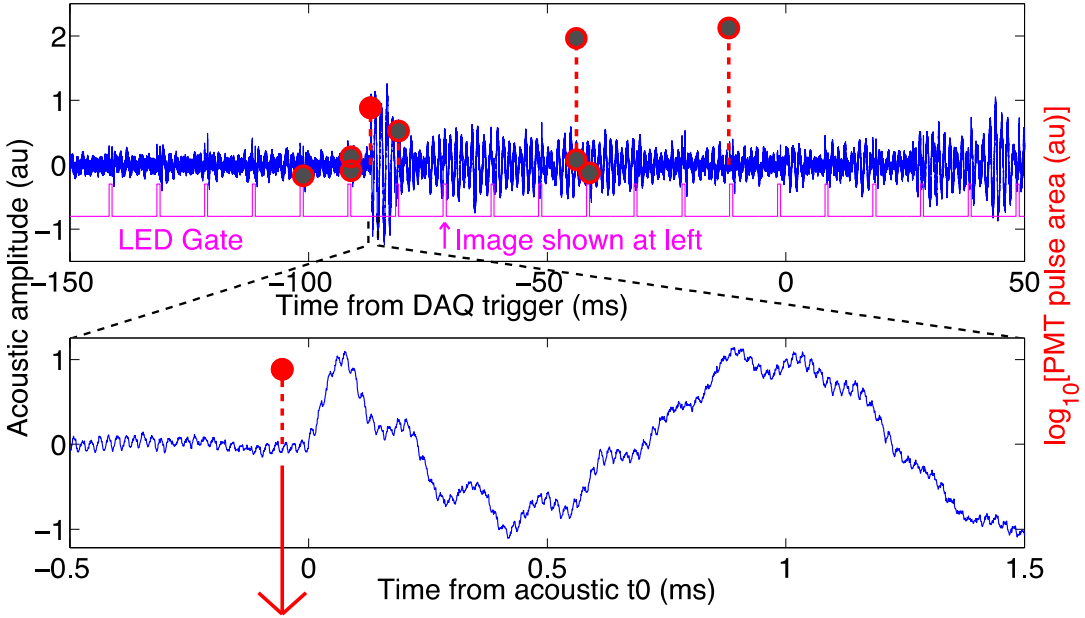


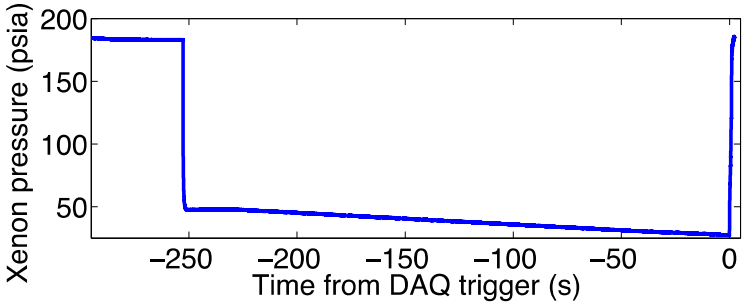
Backup Slides

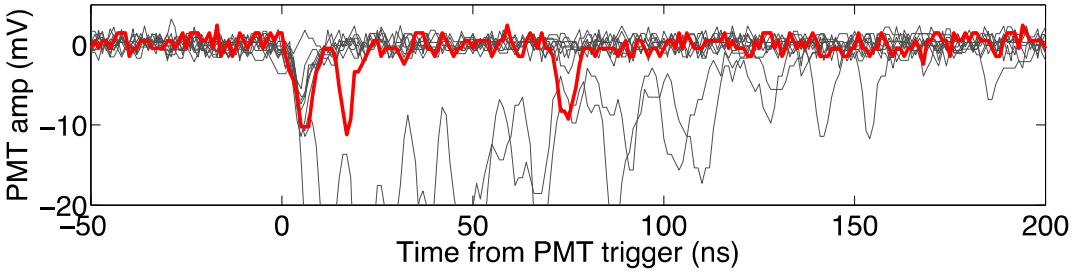
Nuclear Recoil Event

PRL 118, 231301 (2017)

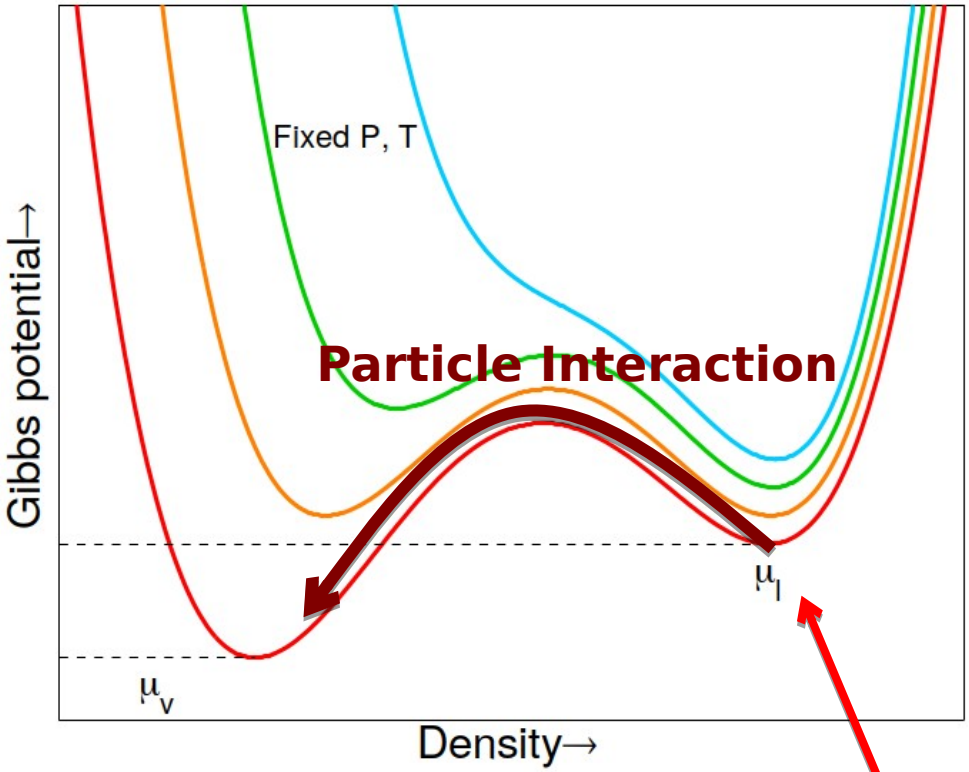


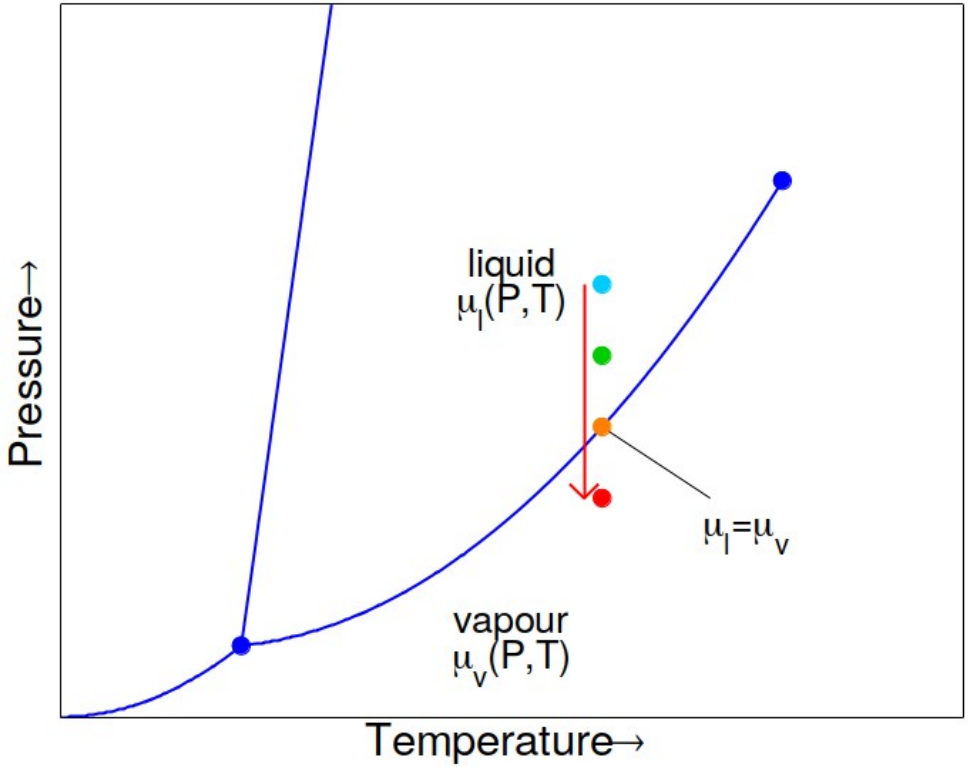






Bubble Chamber Thermodynamics: A metastable state





Superheated Liquid