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

Rocco Coppejans & the SBC Collaboration
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SBC

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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

Bubble Nucleation Probability for Electron Recoil

Gamma Rejection by Chamber

Various PICO Detectors

\( C_3F_8 \)

\( CF_3I \)

Xe

PICO-60

Aim for this level for 1-year exposure

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
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

Cryomech AL200/300
LCF$_4$ @ 130K
LAr + 10ppm Xe
Insulation
Evaporators
Jar Bellows
LCF$_4$ @ 90K
Pressure Bellows
Hydraulic Cylinder
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

![Image of Scintillation Light]

- SiPM
- UV reflector
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
Bubble Chamber Thermodynamics: A metastable state

Particle Interaction

Superheated Liquid