



UNIVERSITY OF
ALBERTA



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SUSY 2021, Virtual

The **SBC** Liquid Argon Bubble Chamber for Dark Matter and $CE\nu$ NS from reactors

Marie-Cécile Piro

On behalf of the SBC collaboration

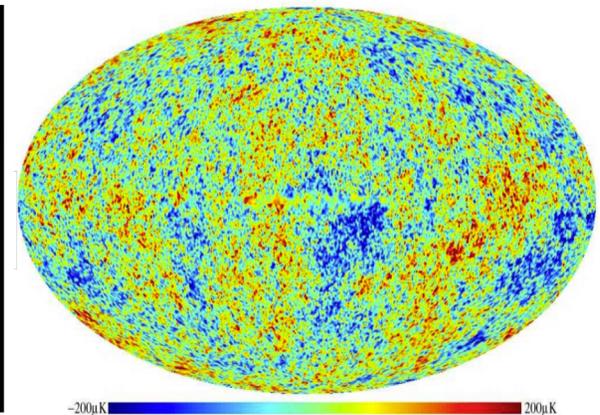
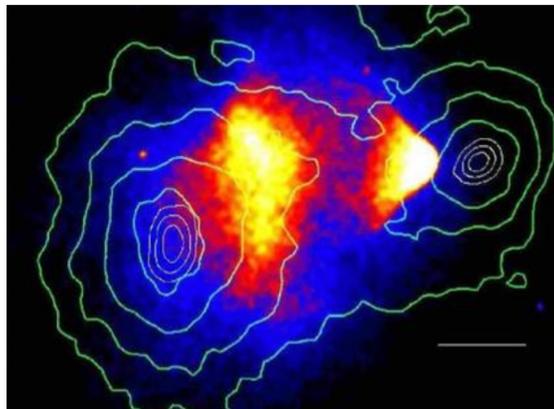
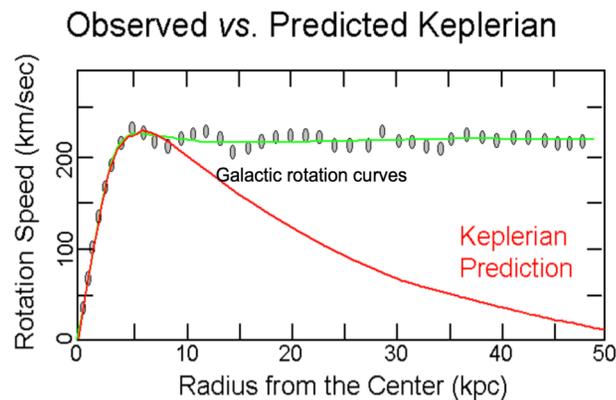


Arthur B. McDonald
Canadian Astroparticle Physics Research Institute



Dark matter evidence

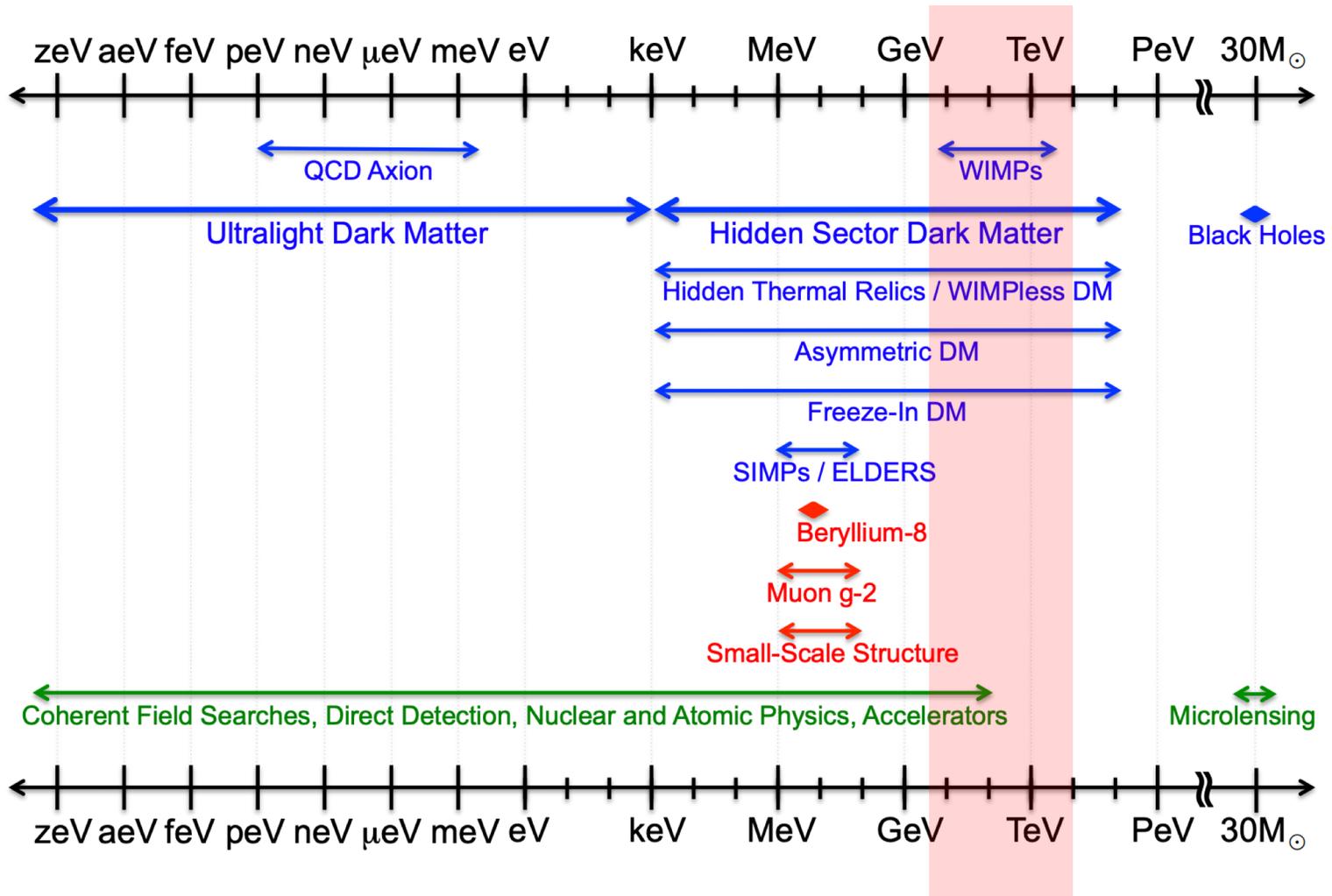
- ▶ **There is lots of evidence for dark matter (DM)**
 - ▶ Early and late cosmology (CMB, LSS)
 - ▶ Clusters of galaxies
 - ▶ Galactic rotation curves



- ▶ **No idea about its composition at the particle level**

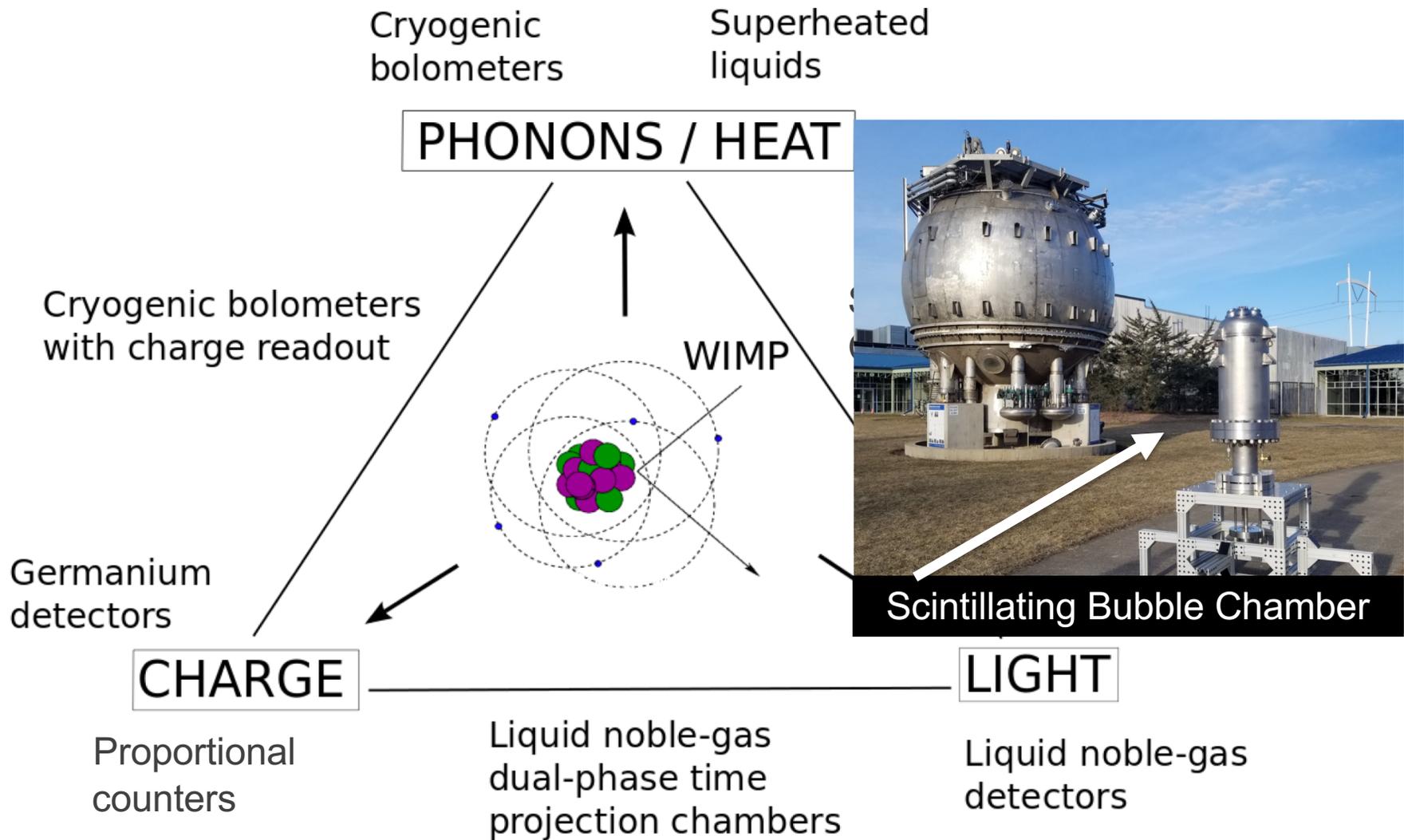


Candidates for Dark Matter





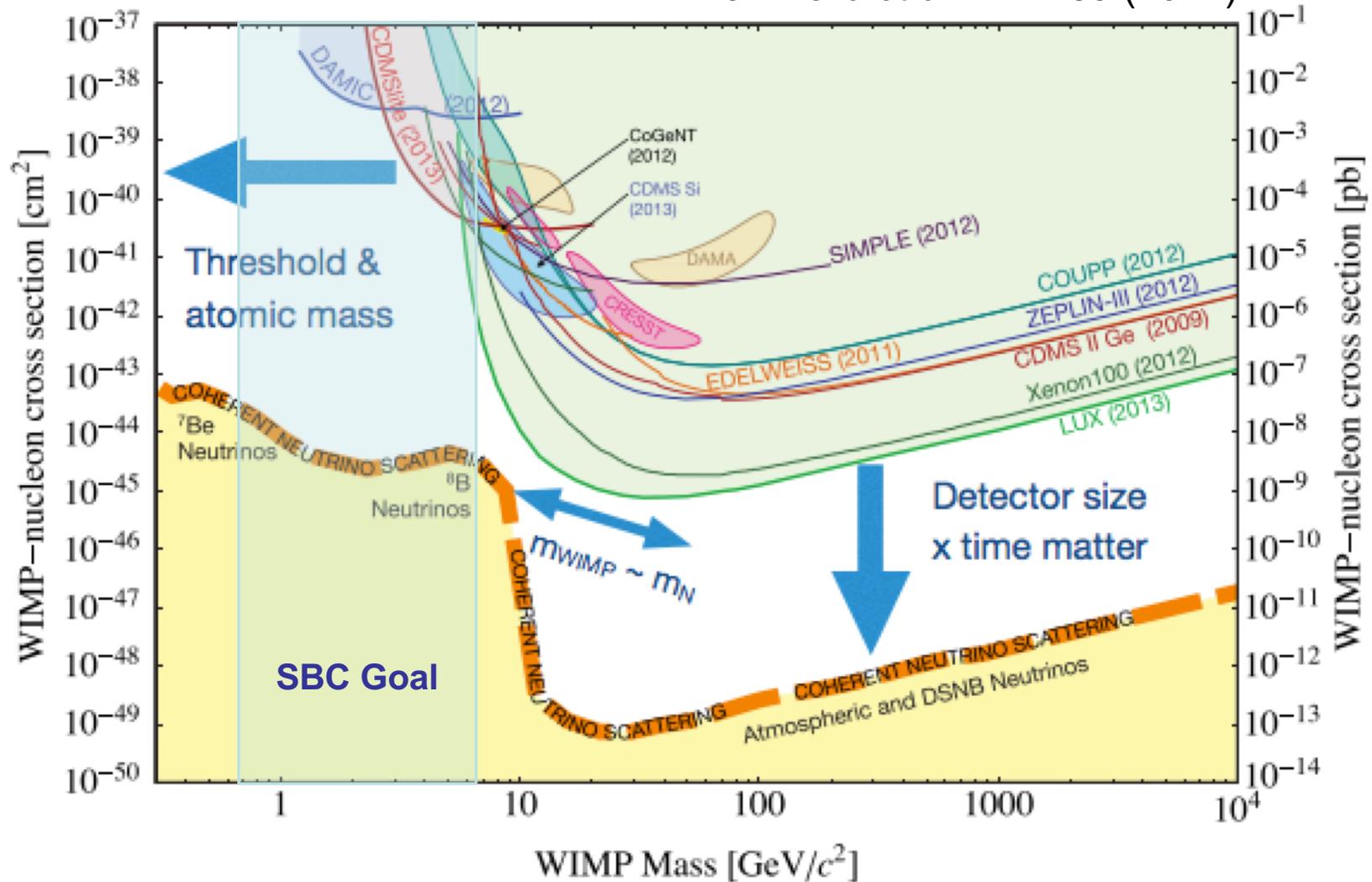
Direct Detection Experiment





Direct Detection Landscape

J.Billard *et al.* PRD **89** (2014)





What do we need for Direct Detection???

CHALLENGES FOR DIRECT DARK MATTER SEARCHES

Low Recoil Energy $\leq 100 \text{ keV}$



Low threshold detectors.

Very low Rate



Large volume detectors.

Background is the principal problem of all Dark Matter experiments!

—————> High purity level is needed!



Enemies : muon-induced neutrons, gammas, neutrons, intrinsic betas decays, alpha background, neutrinos !





The Collaboration





Bubble Chamber

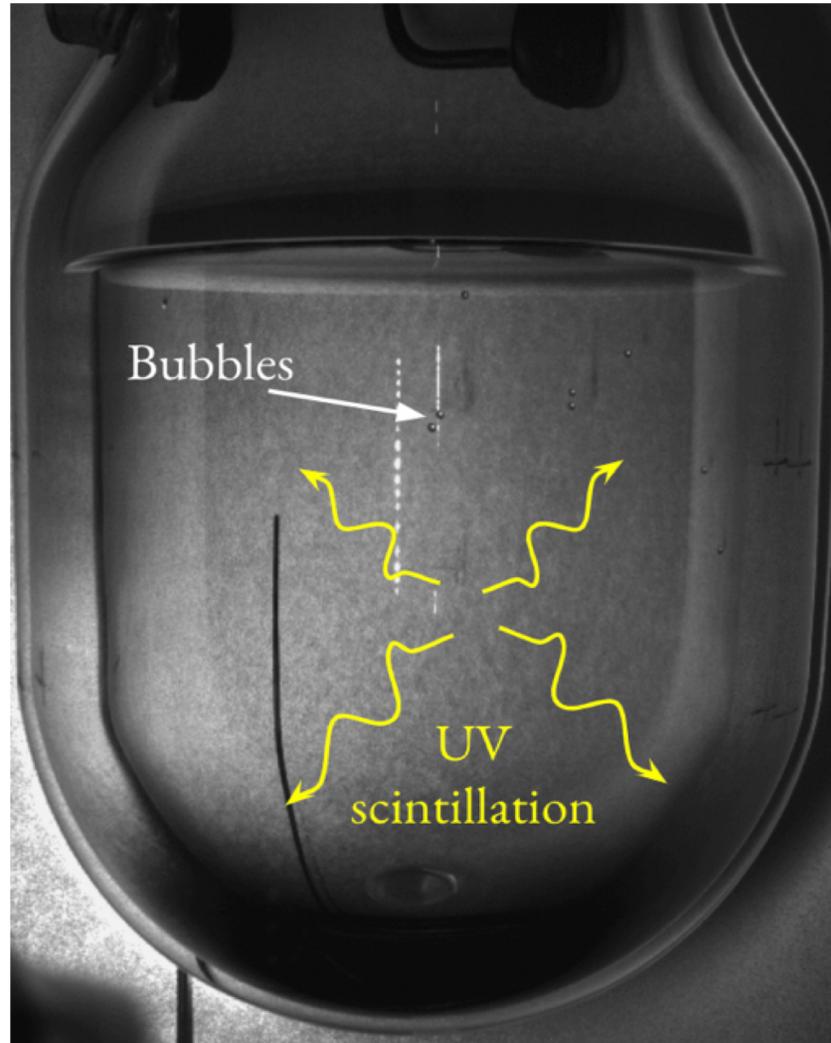
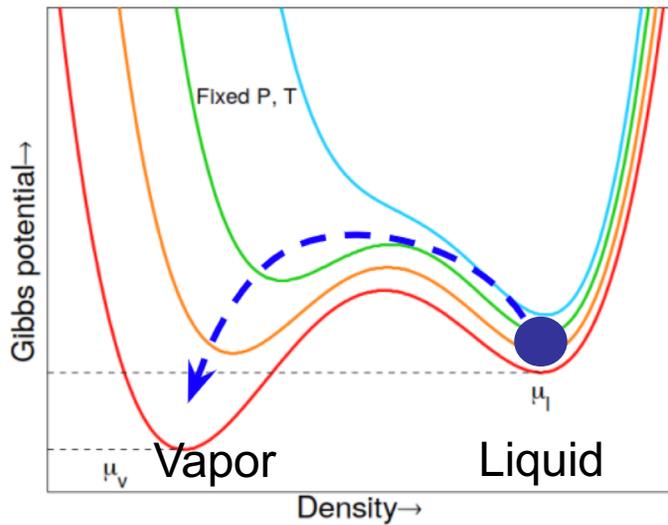
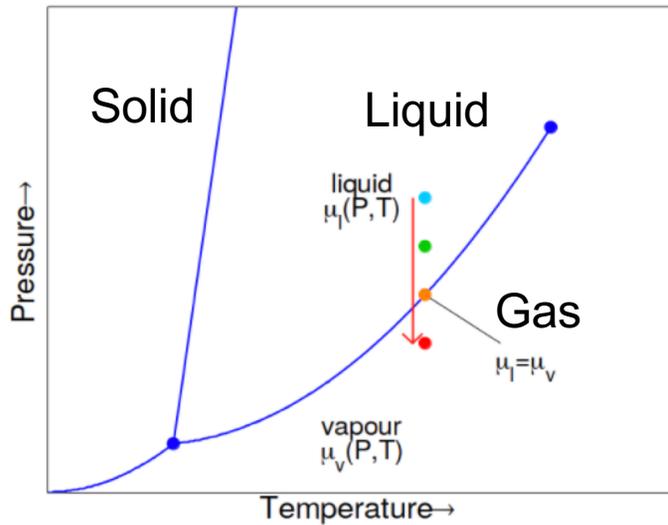
SBC: Scintillating Bubble Chamber

- Active liquid:
 - 10 kg total of Liquid Argon doped with Xenon
 - Xenon acts as a wavelength-shifter (178 nm)
- Detector:
 - Superheated liquid within a pressure controlled vessel cooled at 130° Kelvin (-143.15°C)
- Read-out:
 - Piezo-electric sensors/ pressure control unit.
 - Cameras → excellent position reconstruction.
 - Silicon Photomultipliers: SiPMs





Detector principle



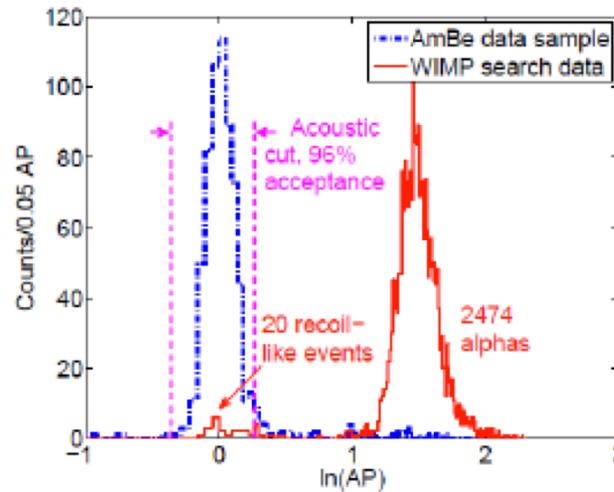


Why Bubble Chamber very good?

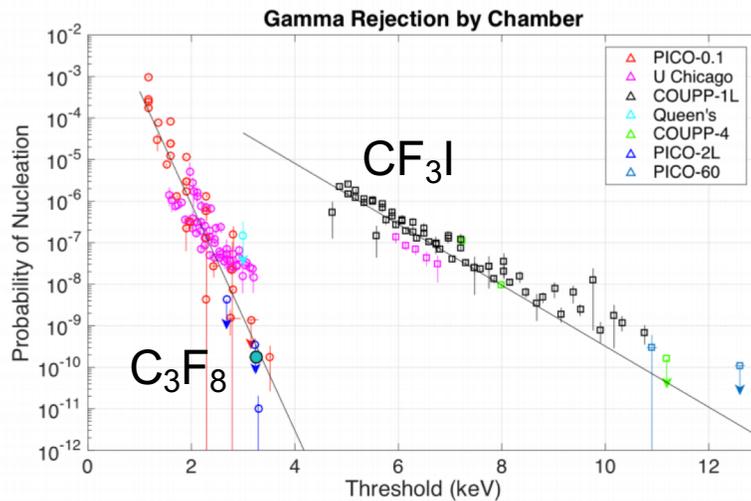
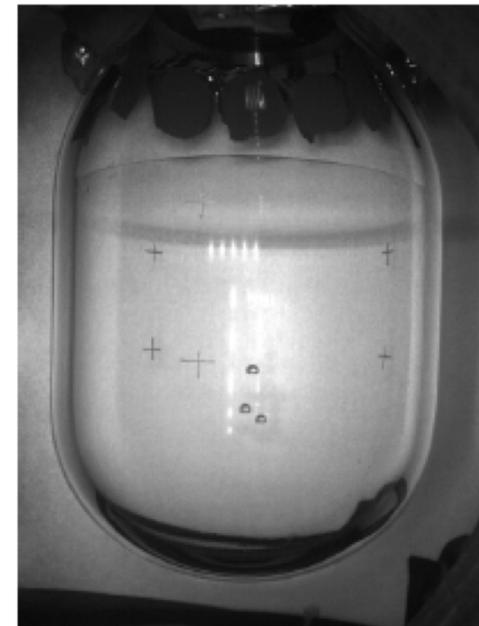
Impressive Background Rejection

Acoustic Alpha Discrimination

Gamma Interaction Insensitivity



Multiple Neutron Scattering



But no energy information!!



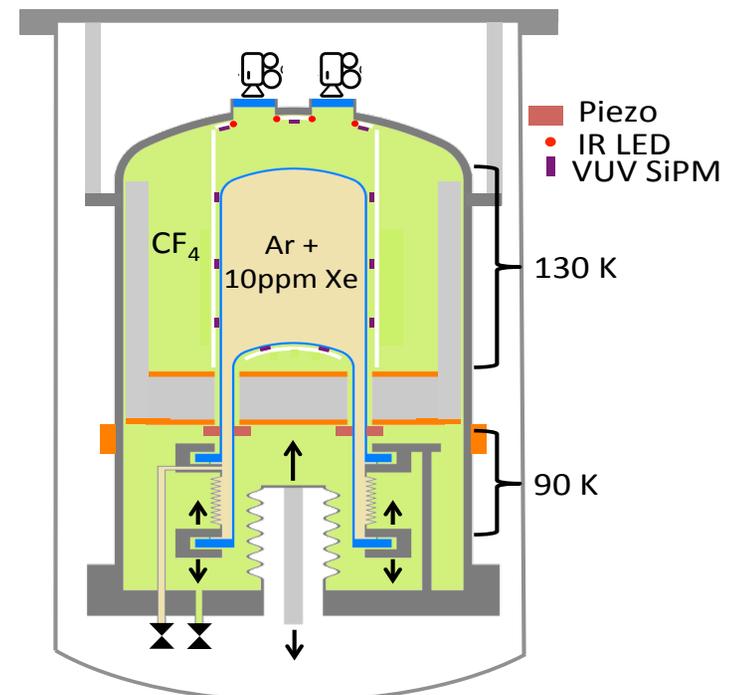
New Detector: The

M-C.Piro 11

Mixing technologies:

Bubble chamber (PICO) + Scintillation (DEAP, DarkSide)

Combine the **electron recoil discrimination** of bubble chambers and the **event-by-event energy resolution**.

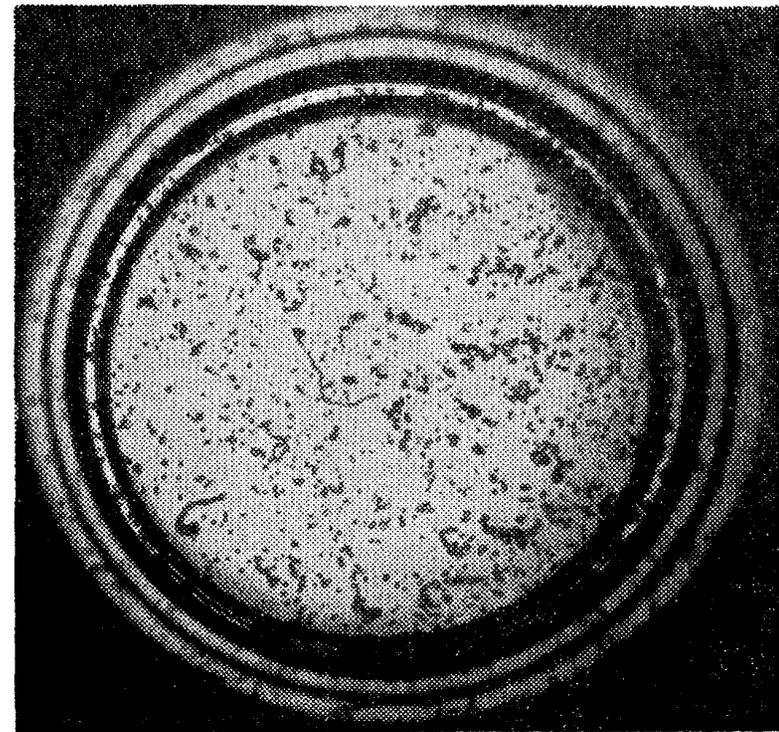




Scintillating Bubble chamber history

Liquid-noble Bubble chambers didn't seem to work...

- **1956 – Glaser finds:**
 - **No bubbles** in pure xenon even at ~ 1 keV threshold (with gamma source)
 - Normal bubble nucleation in 98% xenon + 2% ethylene (scintillation completely quenched)
- **1962 (Stump, Pellett), 1981 (Harigel, Linser, Schenk)**
 - Tracks seen in pure argon, but only at extreme ($O(10)$ eV) superheat



Phys.Rev. **102**, 586 (1956)

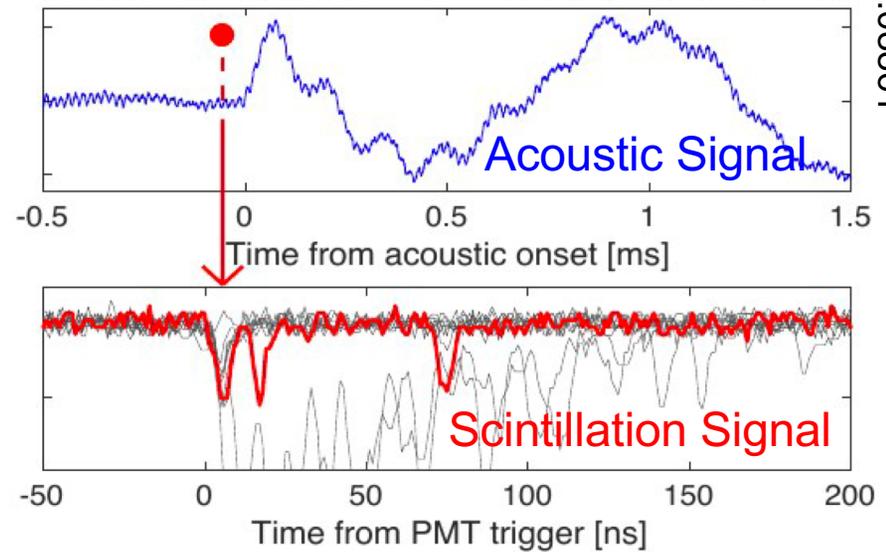
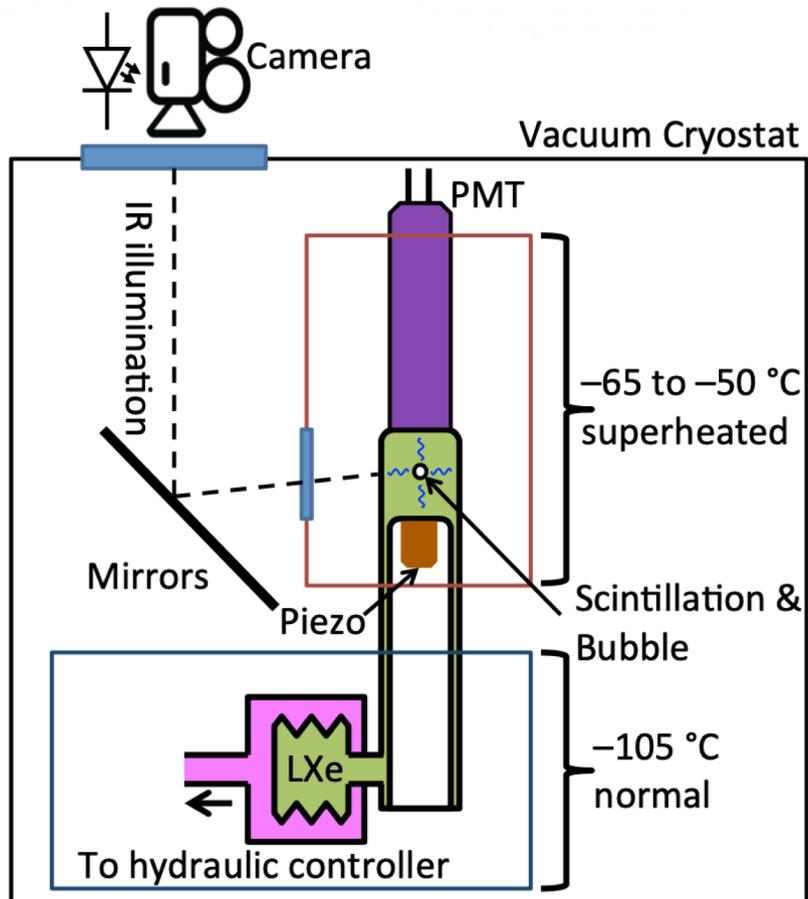
Scintillation suppresses Bubble nucleation!



Bubble Chamber

Proof of principle:

- 30g Xenon Bubble Chamber

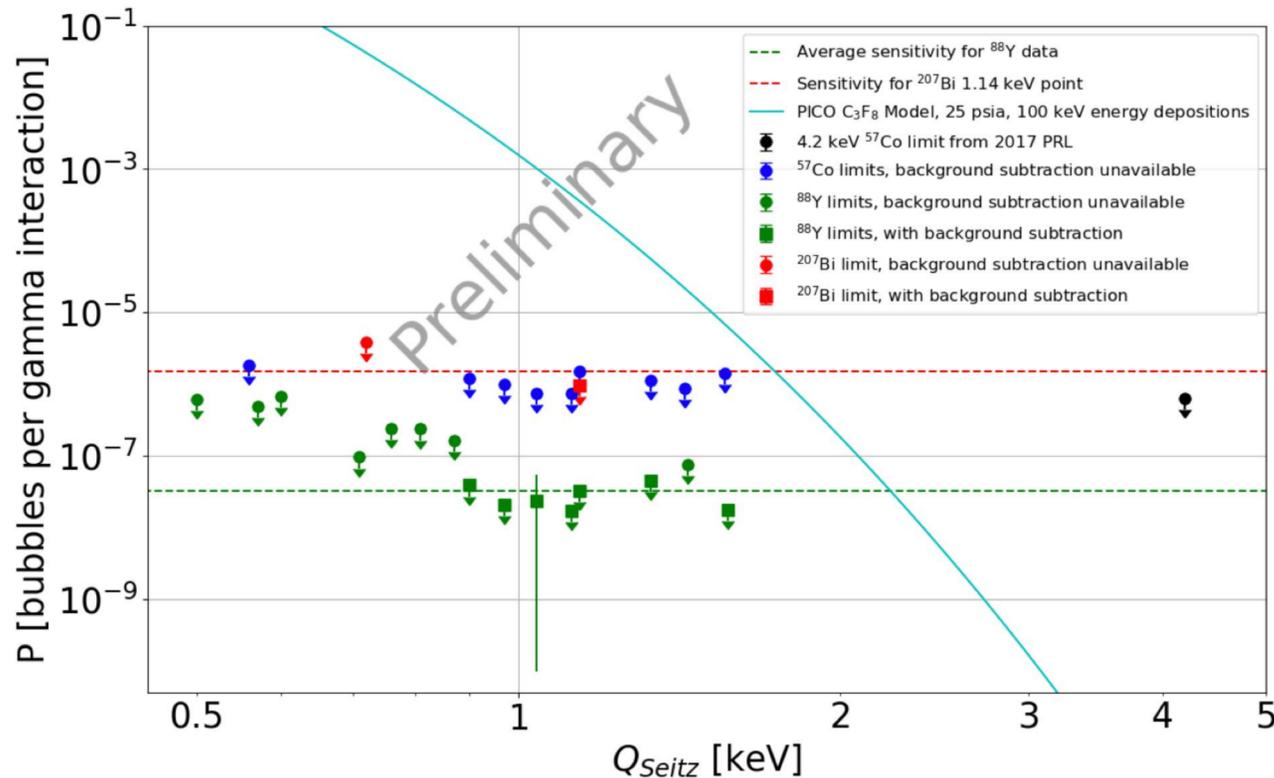


PRL 118, 231301 (2017), arXiv:1702.08861



Bubble Chamber

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



- Analysis ongoing to calculate the nuclear recoil efficiency

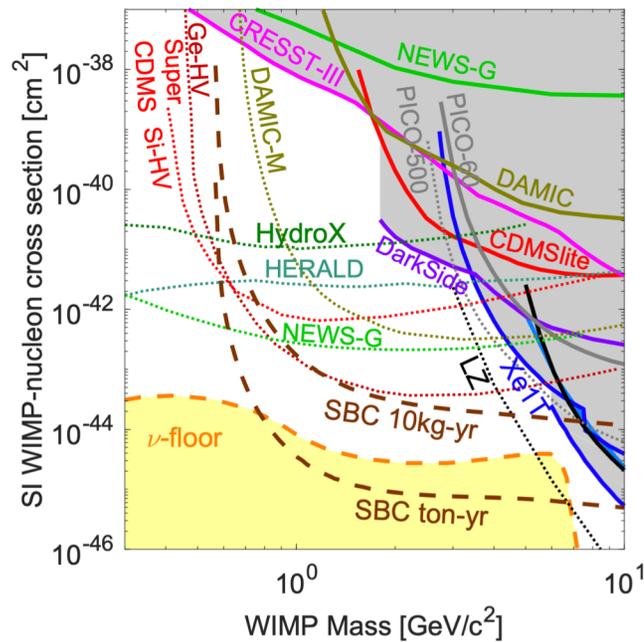


New Detector: The SBC

The Physics Reach

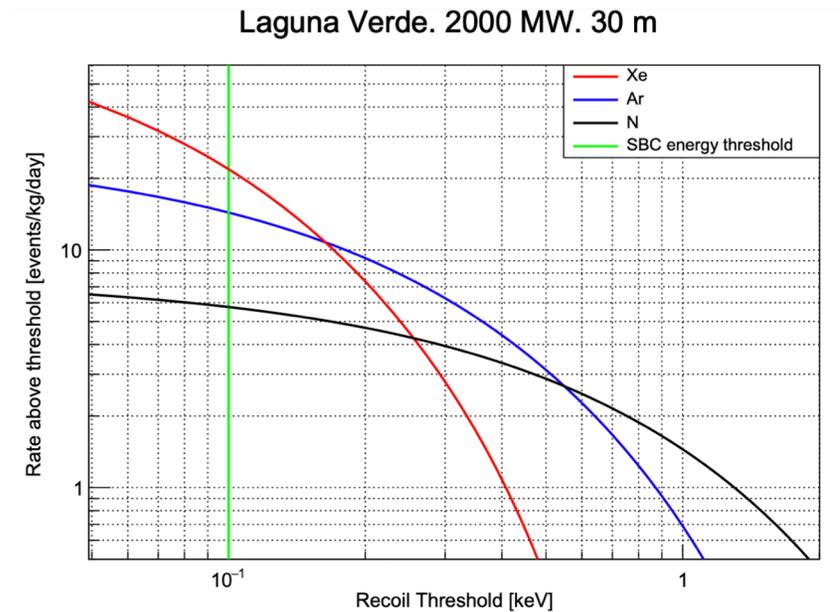
- Two detectors to be built for low-mass dark matter and CE ν NS

Perform competitive **Low-Mass WIMP** search (0.7-7 GeV/c²)



Location = SNOLAB

Precision study of **reactor CE ν NS** interactions for Argon and Xenon



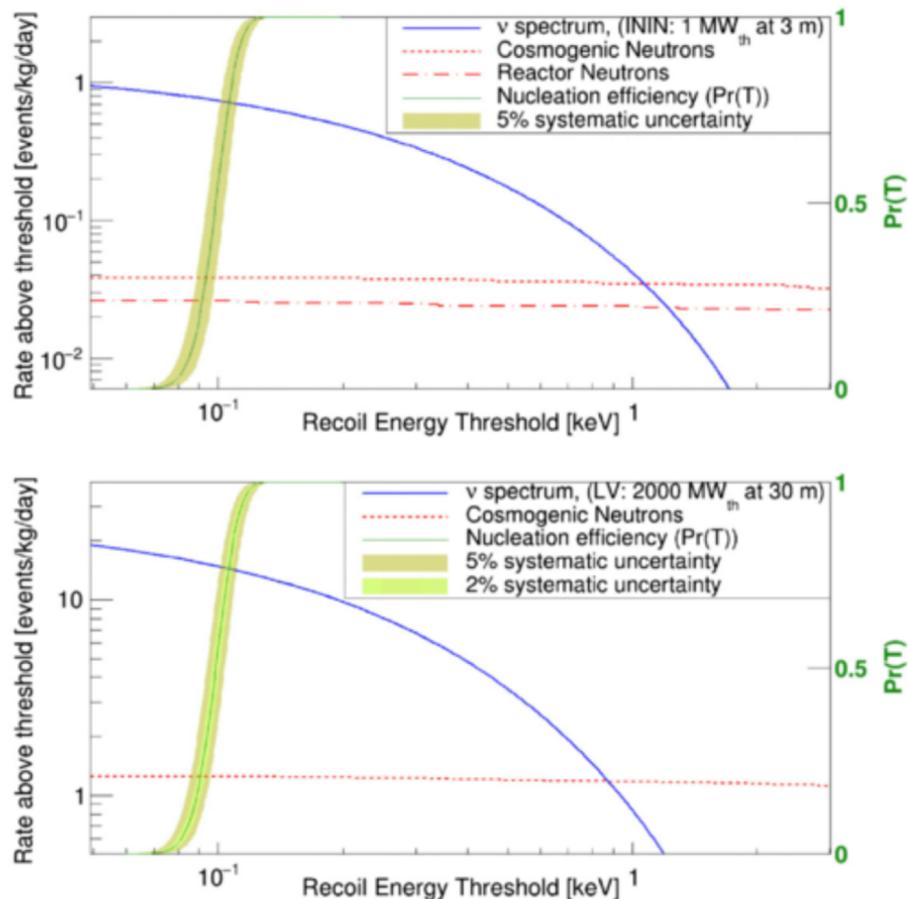
Location = under investigation



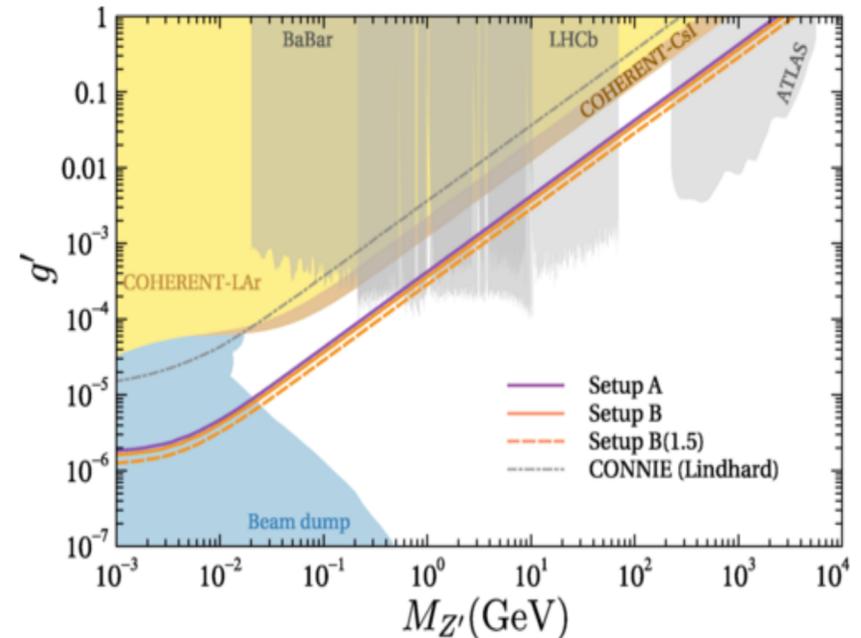
New Detector: The SBC

The Physics Reach

- $O(0.7)$ CE ν NS events / kg-day @ 1MW reactor



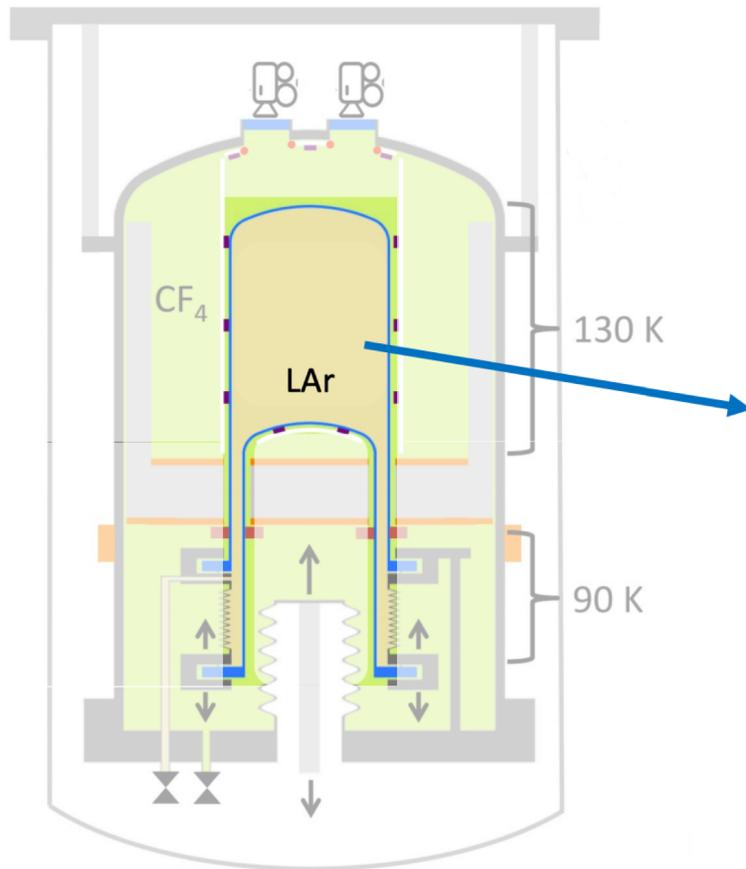
High statistics searches for non-standard neutrino Interactions





SBC Experimental Design

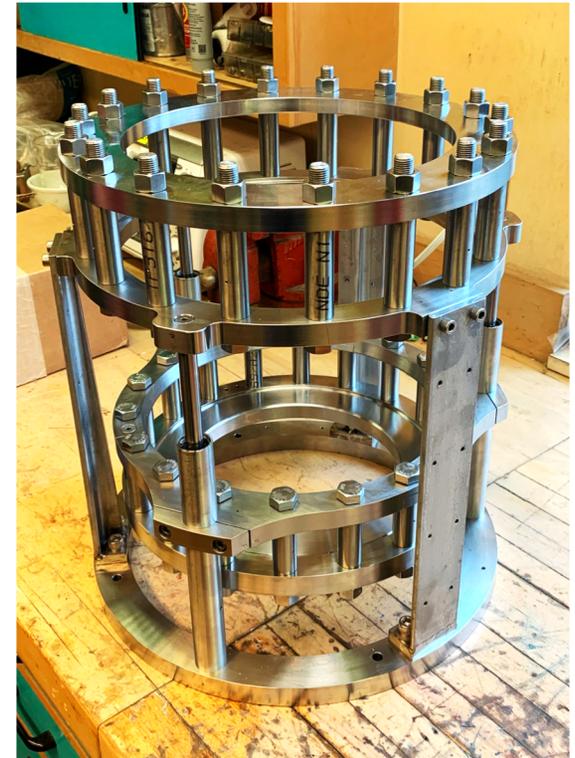
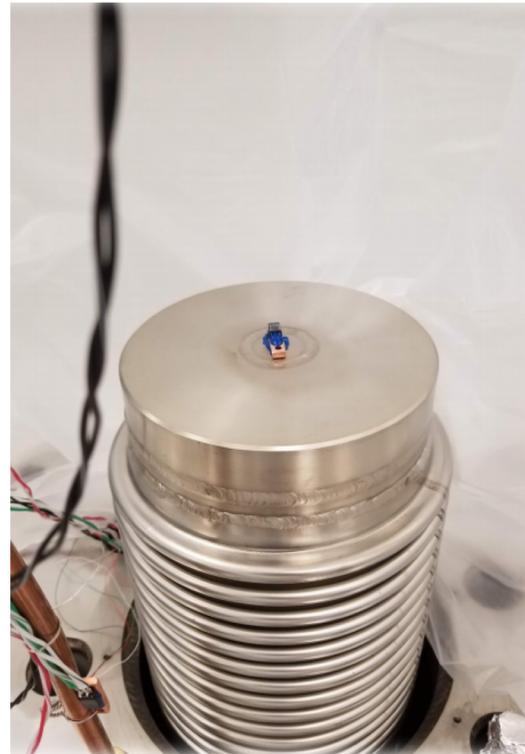
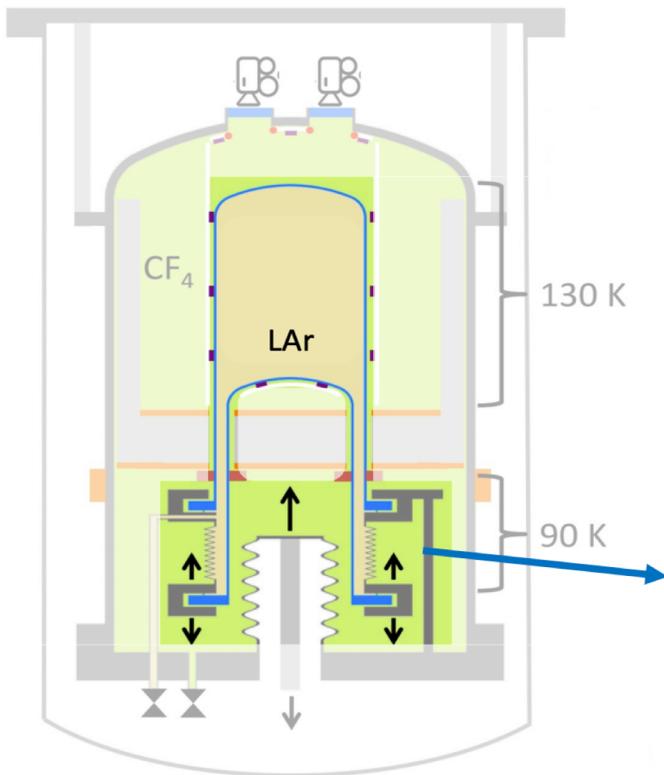
- O(10 kg) LAr contained within two fused silica jars, inner and outer jars.





SBC Experimental Design

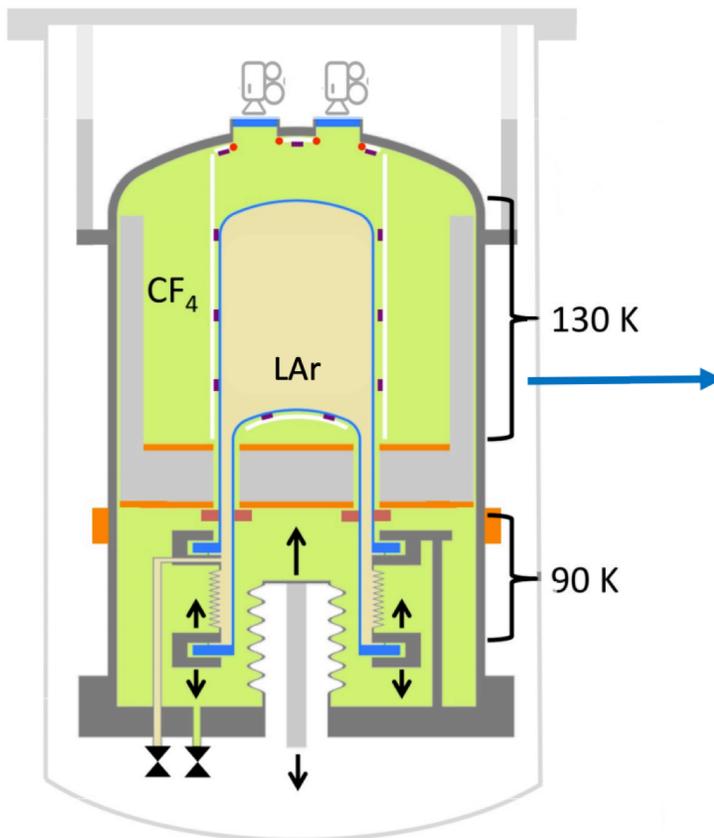
- Hydraulic piston controls the inner jar position
- Compressing/Decompressing the target fluid





SBC Experimental Design

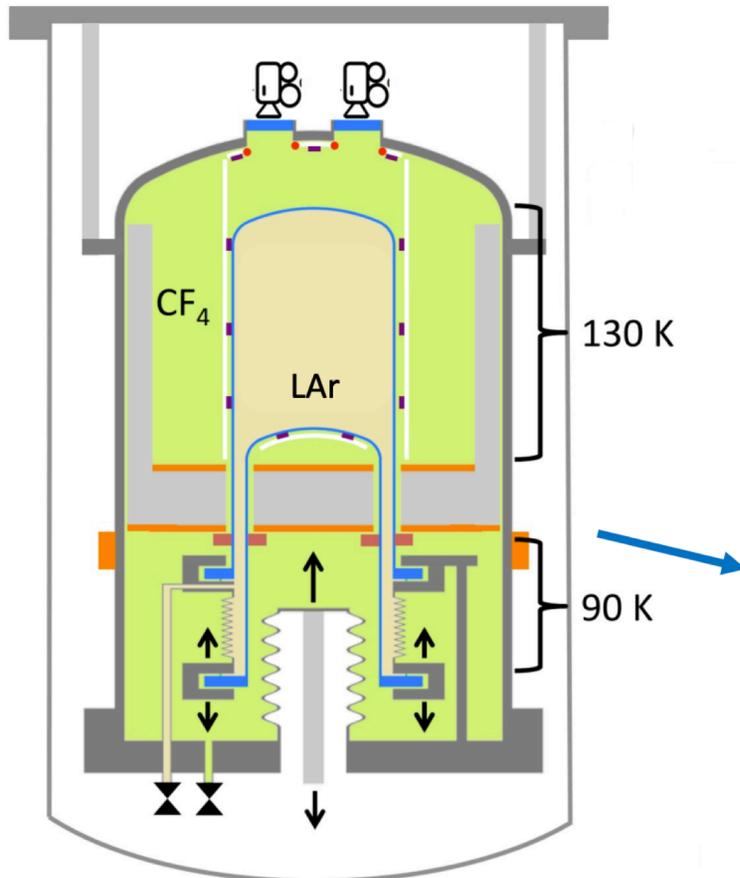
- Cryogenic hydraulic fluid: Liquid CF_4 contained within a stainless-steel pressure vessel





SBC Experimental Design

- The full inner assembly
 - placed inside a stainless-steel vacuum jacket vessel

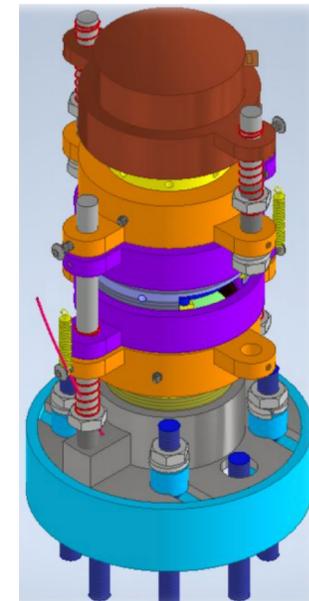
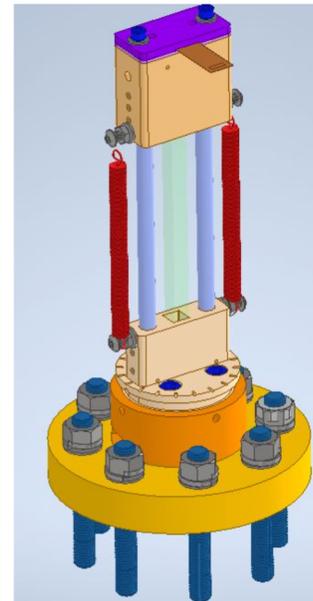
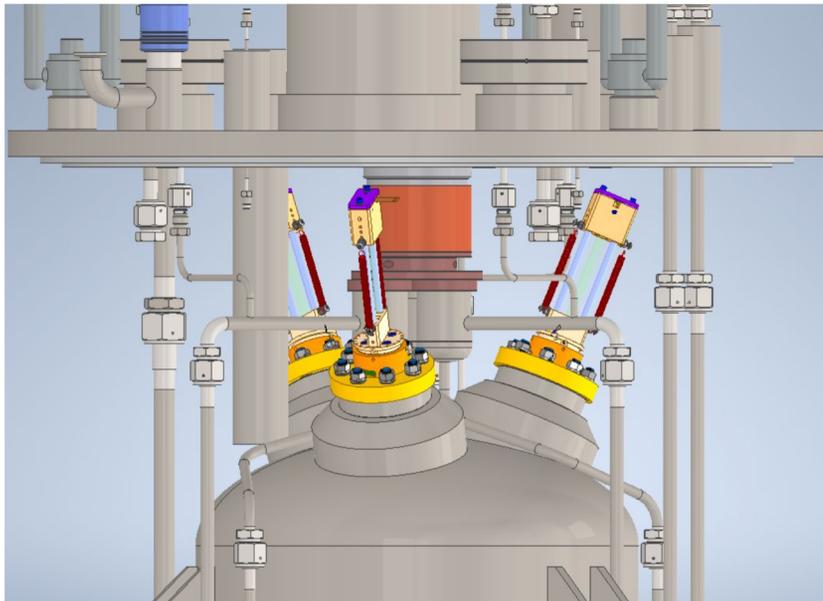




Camera new design at UofA

Camera activity too high for the SBC detector:

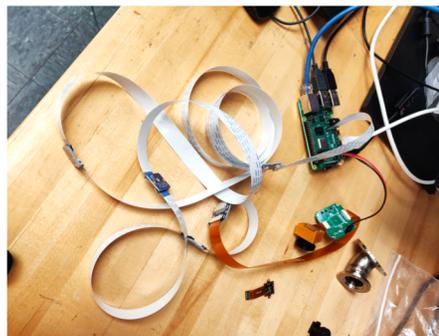
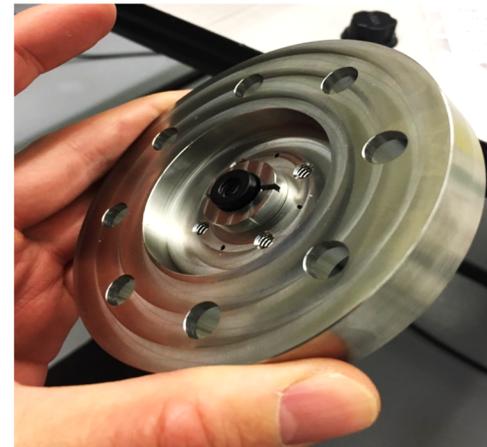
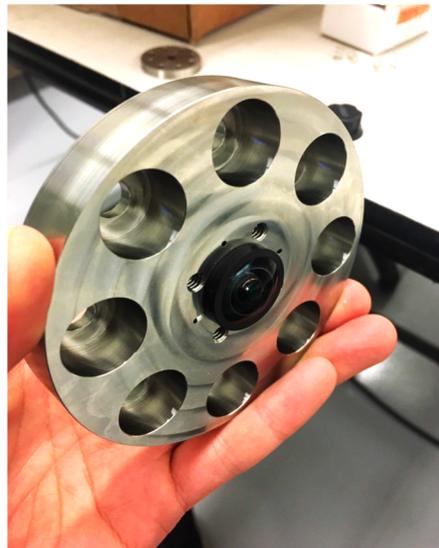
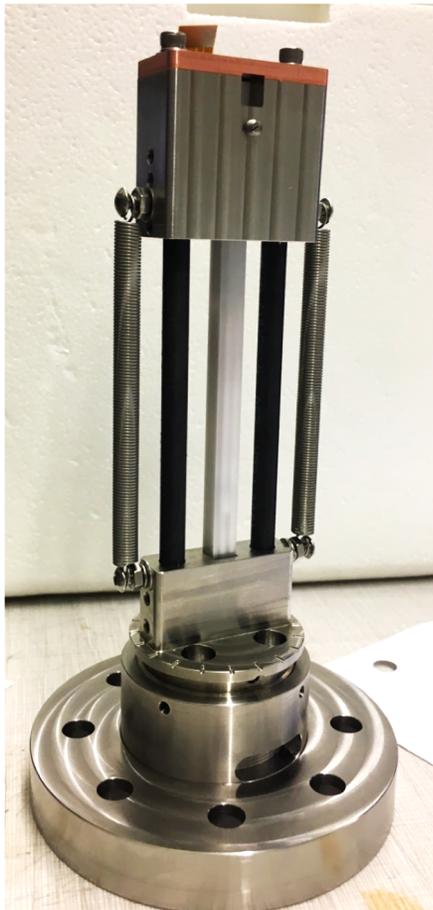
- ▶ New design to keep them away from the active liquid!
- ▶ Nanoguide system and relay lens system





SBC: Bubble Imaging

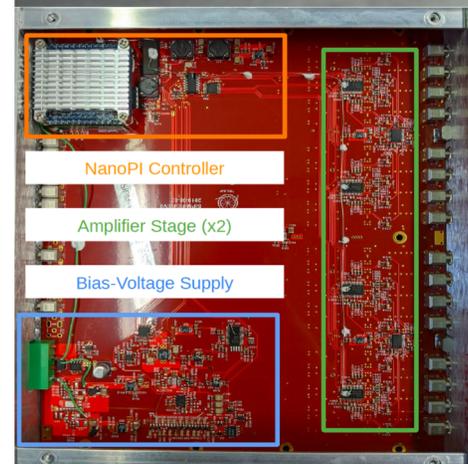
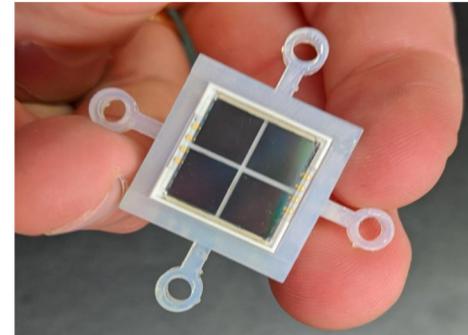
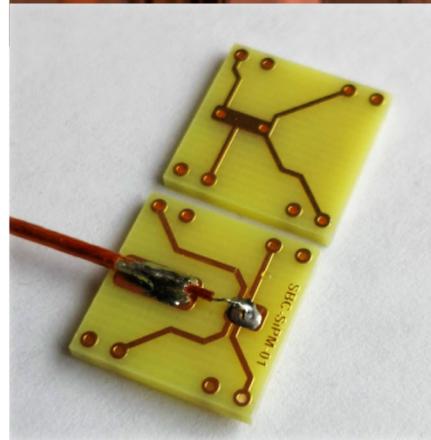
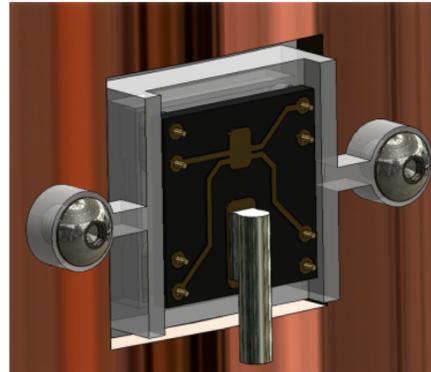
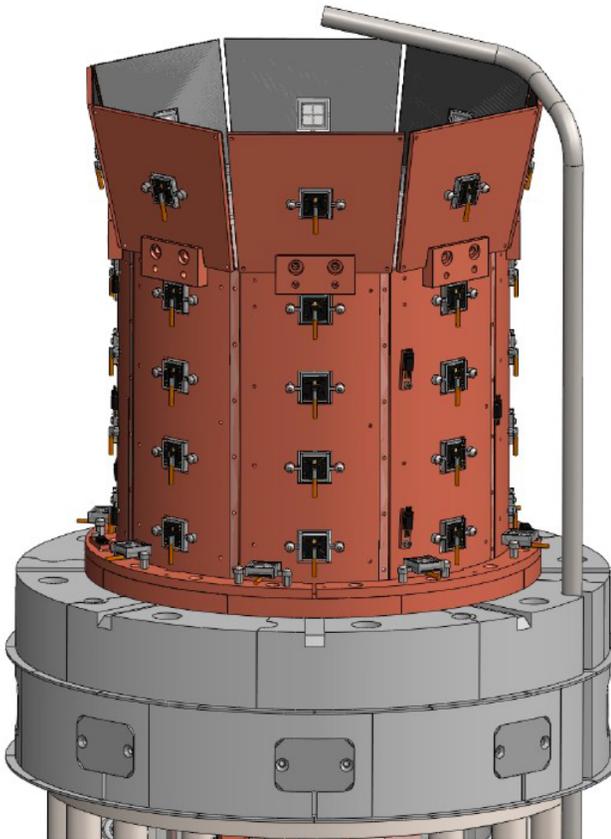
- Three raspberry-pi controlled camera system
- Three LED rings to provide illumination





SBC: Scintillation

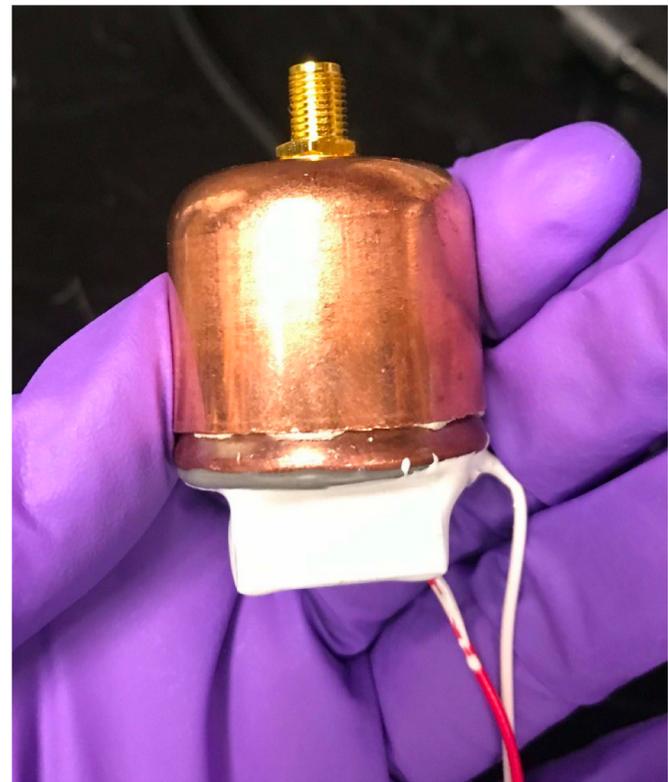
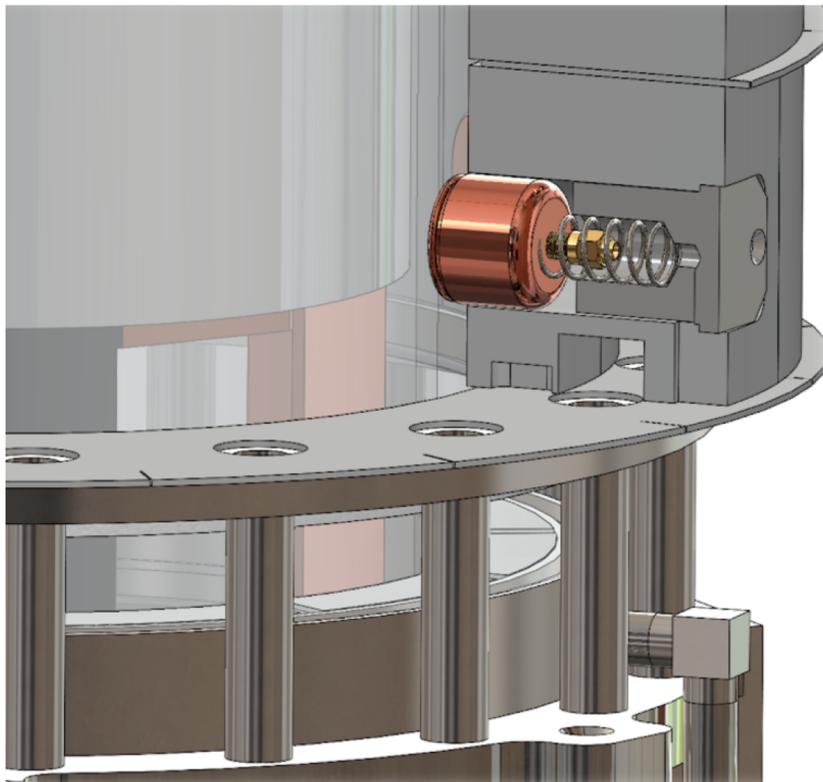
- 32 Hamamatsu VUV4 Quads
 - ▶ to measure scintillation light in the target fluid.





SBC: Acoustic

- Eight piezo acoustic sensors
 - ▶ to monitor the sound of the nucleation process.





The SBC: Timeline and Summary

- SBC at  **Fermilab**
 - Assembly and commissioning: Present → 2022
 - Science operation: 2022 → 2024
- SBC at 
 - Construction = SBC – Fermilab + 1 year
 - DM search: 2023 & 2024
- SBC-CE ν NS
 - Experimental program follows calibration at FNAL
 - Site investigations are underway → Laguna Verde

We are only at the beginning of a new era for particle physics!





Summary

Very exciting era in particle physics for discoveries and new challenges!!!

→ **Potential discovery can be achieved soon!**

→ **Future for DM detectors is: ton scale + Very low threshold!**

New challenges for future direct detection :

→ **Expected backgrounds need to be known very well**

→ **High purification needed and background understanding**

→ **Neutrino floor: the ultimate background**

→ **R&D to add the directionality channel**

→ **Dedicated calibration with neutrino reactor!**



Thank you!

*Behind the effort there is passion,
behind the passion there are people with the courage to try.*

Arthur B. McDonald, 2015