SBC-Fermilab Progress and Calibration Plans

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SBC Collaboration
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UC SANTA BARBARA

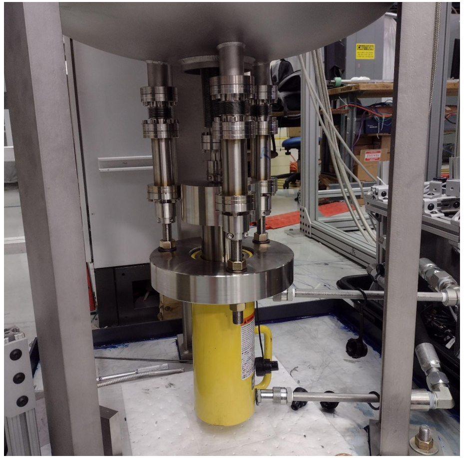
Fermilab

SBC-Fermilab

- Demonstrate detector technology
  - Thermodynamic control
  - Pressure control
  - Automation and control system
- Measure bubble nucleation threshold in Xe doped argon
- Understand detector response to different backgrounds
- Already far along in our program
  - 2 engineering runs completed
  - Preparing for calibration runs

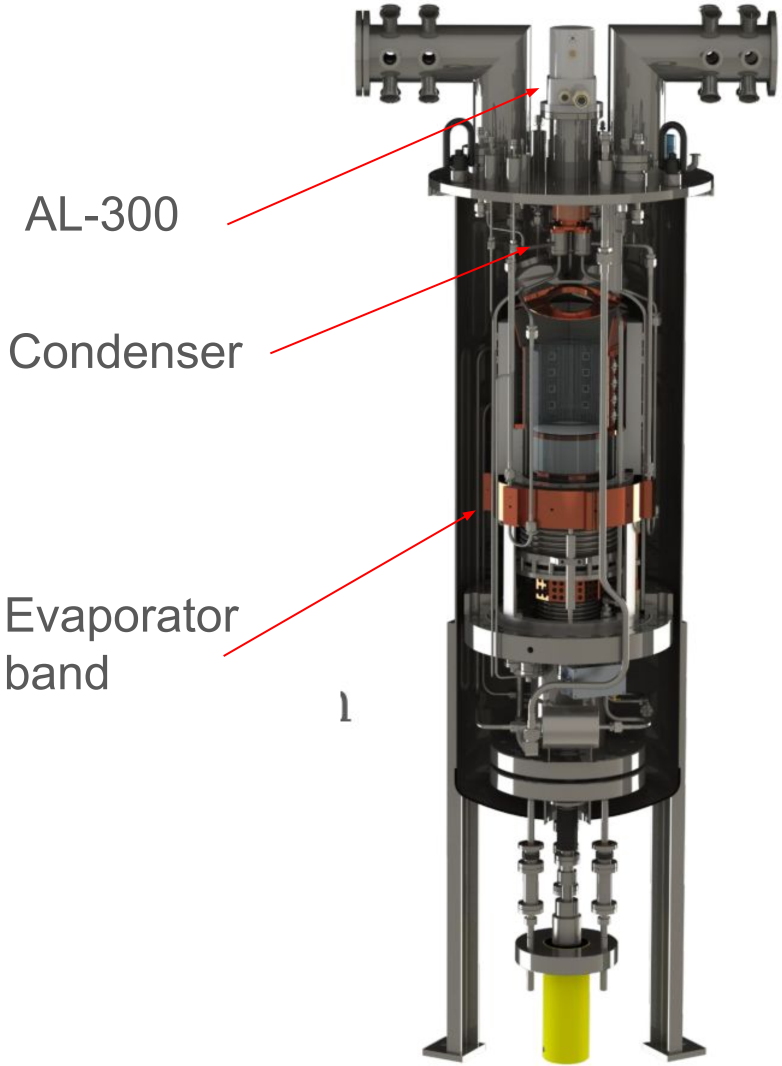
Engineering Runs

- Test of support systems for the detector
  - Cryogenics
  - Hydraulics
  - Automation/slow control
- No detector installed in the pressure vessel
  - Running on the surface
  - Quick turn around for issues
- Two runs in total
  - First discovered a problem with our cooling system
  - Second worked after repairs



Cryosystem

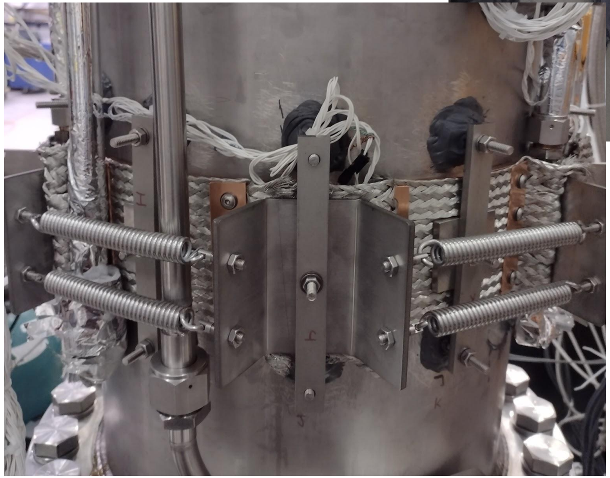
- AL-300 cryocooler provides the main cooling source for the experiment
  - Connected to a thermosiphon system for distribution to the main Pressure vessel
  - Three cooling points that distributed in a band around the center of the pressure vessel
- Designed to provide two separate thermal areas, an upper section containing the detector volume at ~130 K, and a lower section ~90 K to suppress bubble formation



First Cooldown and Thermosiphon Mounting

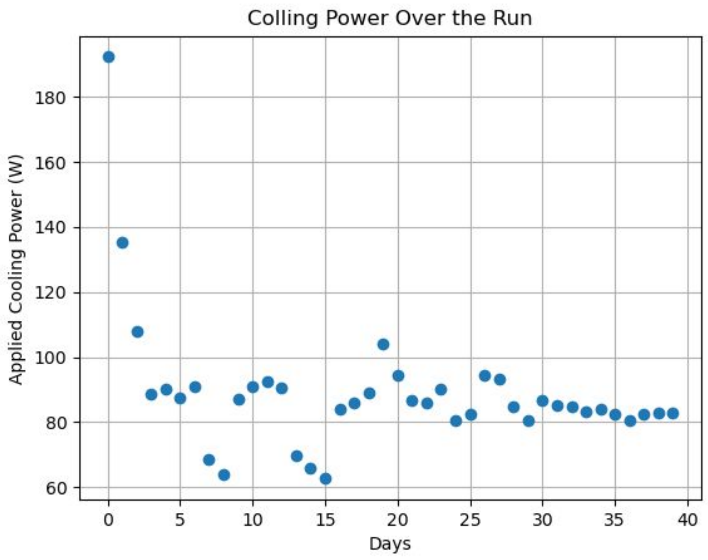
- First cooldown test discovered a mounting issue with the thermosiphon cooling band
  - Originally attached via “weld studs” epoxied to vessel
  - Thermal contraction caused a side load on the epoxy joints that was not tested for

- Cooling band redesigned to use tensioned springs to apply clamping pressure
  - Allows for movement from thermal contraction
  - Larger clamping force then original solution anyway



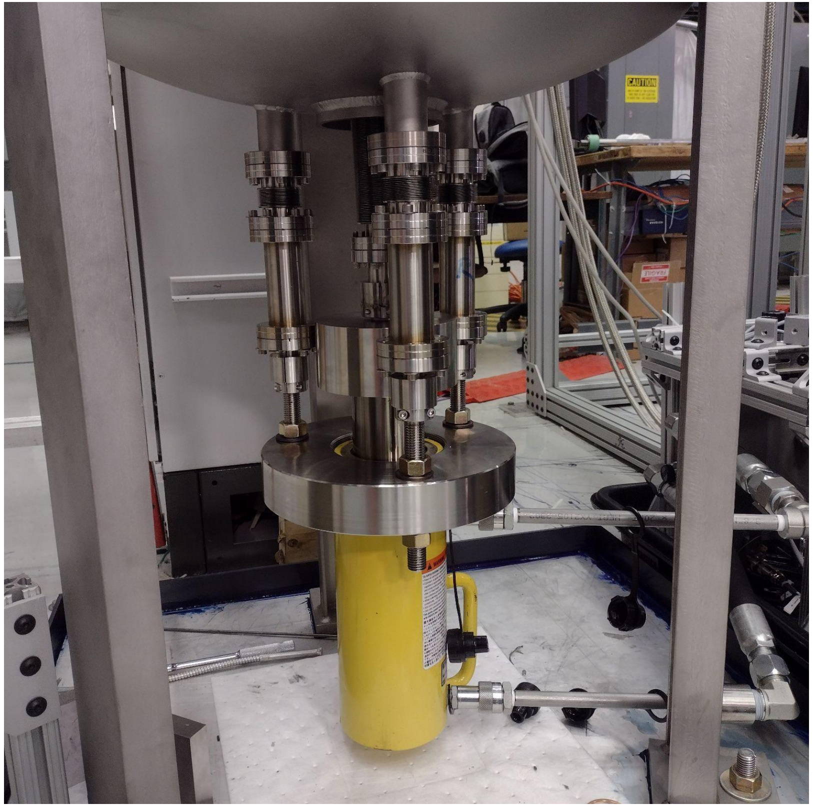
Condensing Argon

- Filled with liquid argon condensed from cylinders
    - Rapid initial condensing at an average rate of 20 SLPM, up to 100 SLPM when pulsed
    - Reduced condensing rate after filled above the cooling band of ~5 SLPM
- Found that heat load from the top of the vessel impeded condensing
    - Had already planned to add a top cooling point, but it was not ready for this run



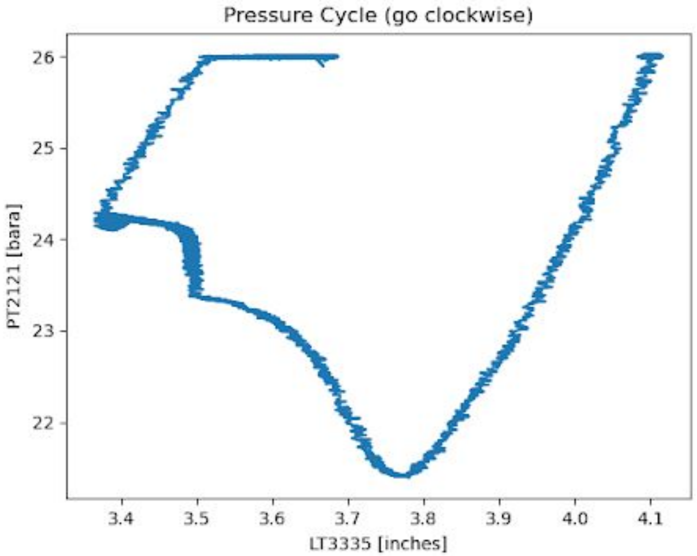
Hydraulic System

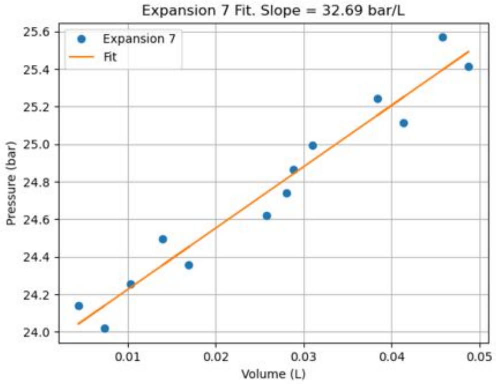
- Controls the system pressure and cycles the bubble chamber
- Uses a hydraulic cylinder and automated control system to cycle the chamber between the compressed and expanded state
  - Slowly increases detector volume to super heat the upper section of the detector
  - Quickly compress the chamber when a bubble is detected
- Connected to the pressure vessel space via a bellows on a rod that penetrates the vacuum vessel
- Uses largely standard industrial equipment



Hydraulic Tests

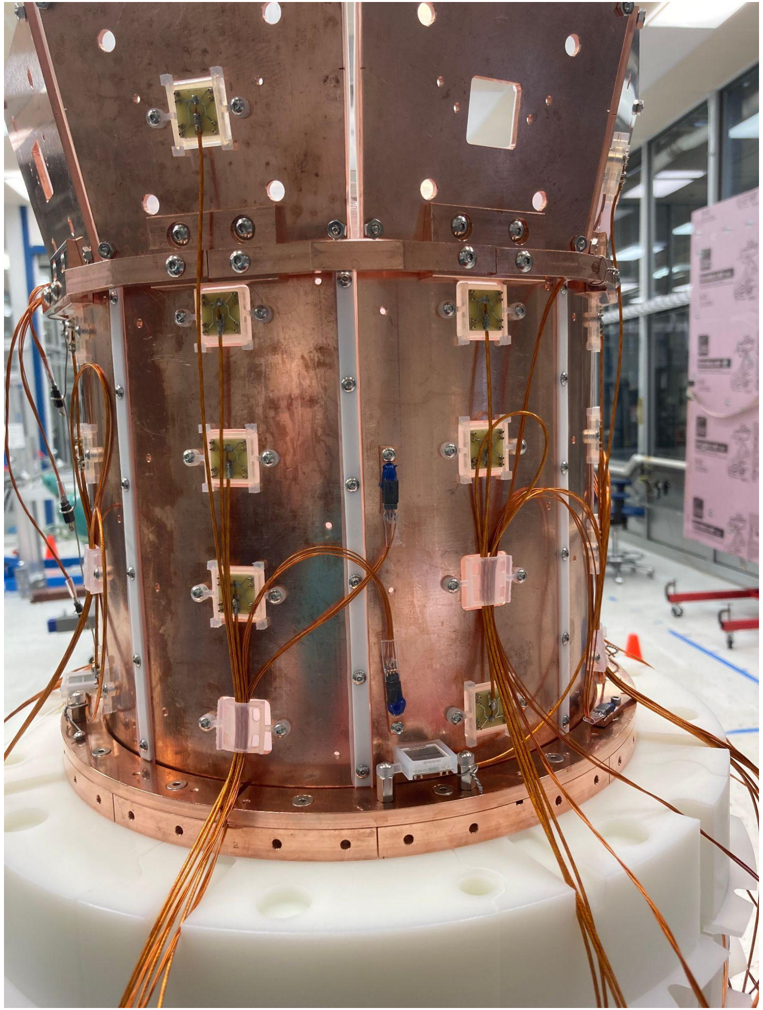
- Exercised the hydraulic system at full system pressure for the first time
- Tested multiple control modes
  - Pressure feedback
  - Position feedback
  - Scripted control
- Used to hydraulic system to characterize the fullness of the detector by measuring the compressibility of the argon



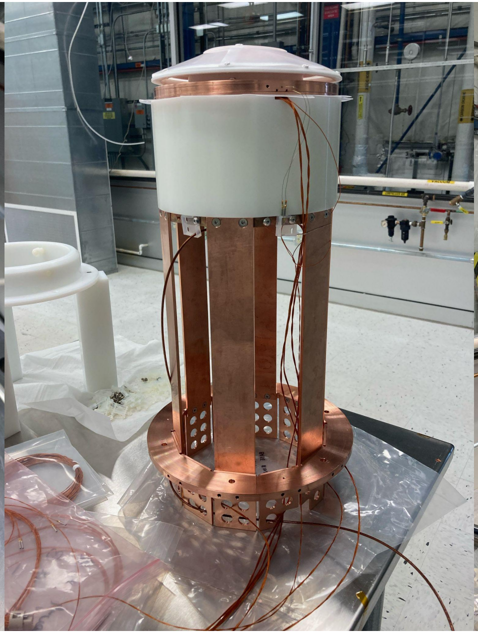


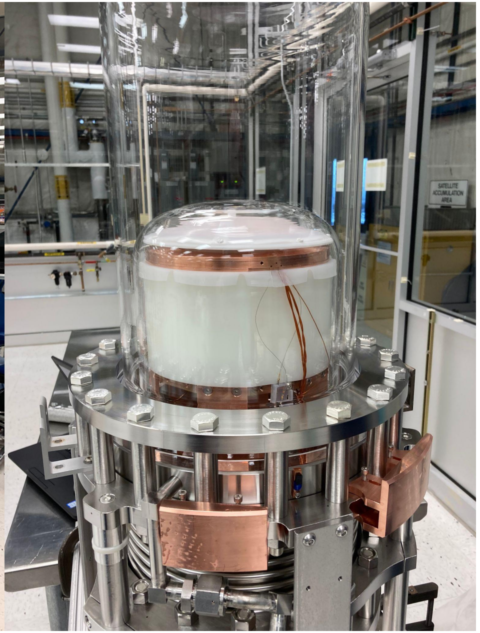
Inner Assembly

- Internal detector parts ready after the engineering run
  - Main pressure vessel was moved to a cleanroom at fermilab
- Built up in stages
  - Inner tower
  - Jar assembly
  - Lower castle
  - SIPM panel, and SIPMS
  - Upper castle

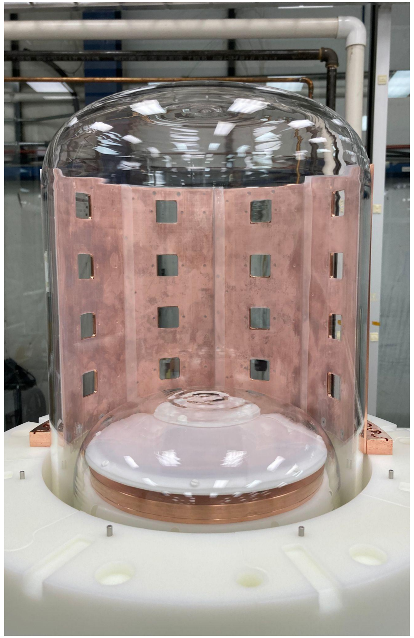


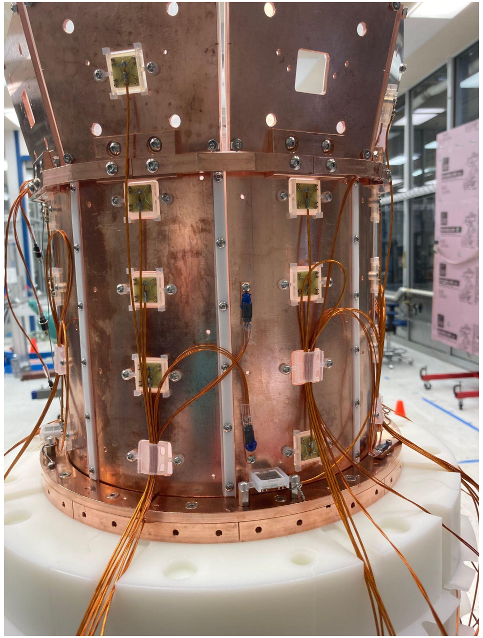
Assembly Process Jars and Support Structure

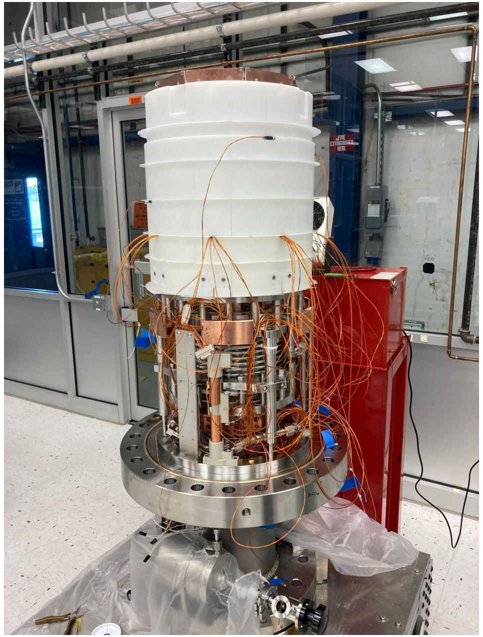




Assembly Process SiPM Panels Insulation and Wiring

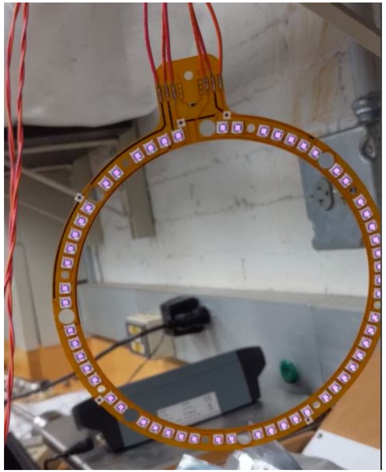


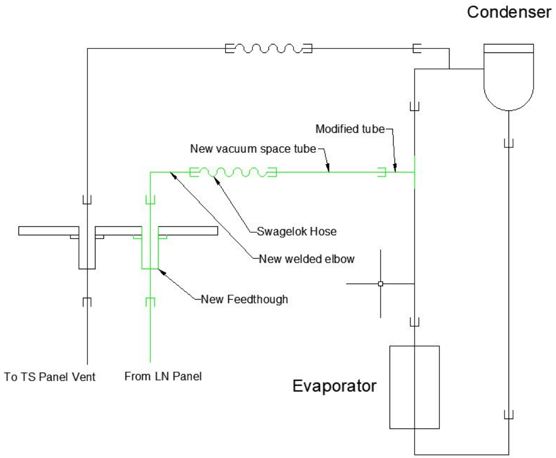


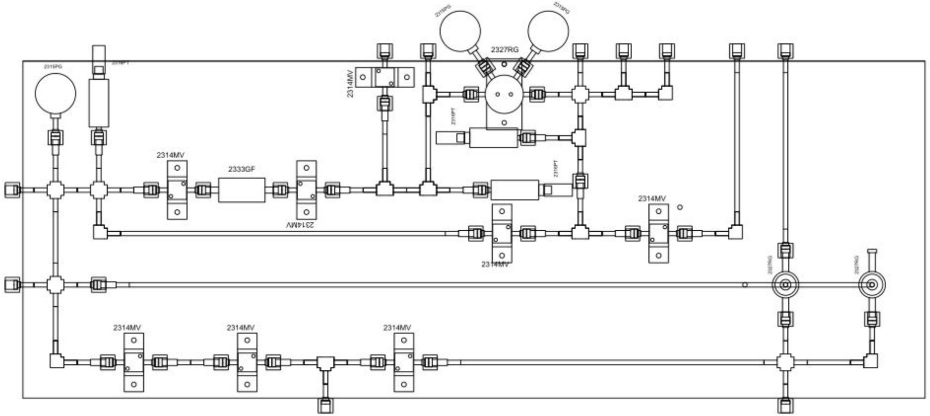


Current Progress

- Final part needed for detector being tested after delivery
  - Planning to install and close the pressure vessel in two weeks
- Currently building the remaining plumbing systems needed for operation
  - CF4 handling and storage system
  - Emergency cooling system







Calibration Plan

- Once built we plan on moving the detector underground to the MINOS tunnel at fermilab for the calibration run
  - Overburden or shielding is needed for any operations of this detector
  - Expected background rate of 1-2 bubble/hour
- No additional shielding need for the calibration in this case
- Three main calibrations planned
  - High energy gamma calibration
  - Thomson scattering
  - Photoneutron calibration
- Similar to the calibration strategy used in PICO

Underground Preparations

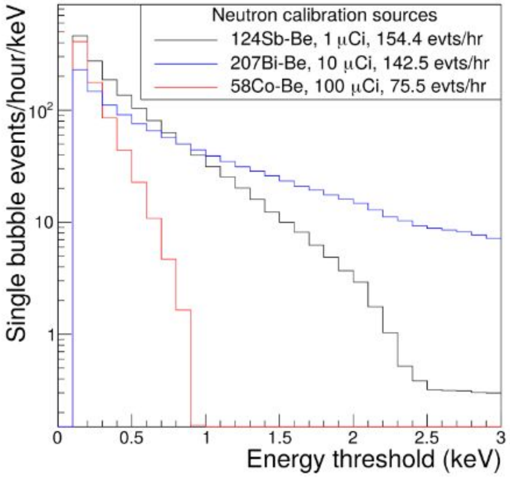
- Roof installed to keep the detector and electronics dry
- Electrical work needed to support high current / higher voltage devices
    - Cryocooler
    - Hydraulic pump
- Will soon begin moving equipment underground

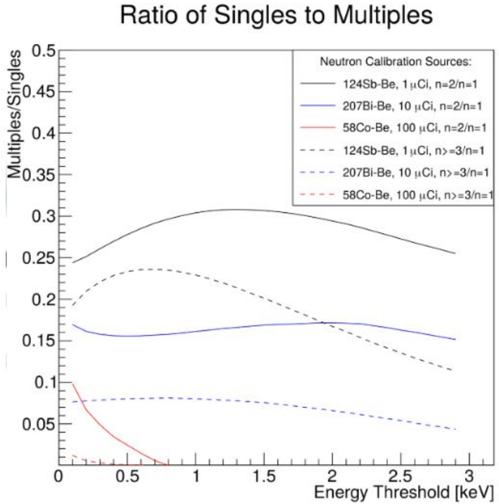
Operating Conditions / Gamma Calibration

- Goal is to tune the thermodynamic conditions so that electron recoils do not produce bubbles while still being sensitive to nuclear recoils
- Also used to calibrate Scintillation response from both the argon and the CF4
- Cs-137 sources at a few different activities
    - Expect most calibration runs to be ~100 hours to measure O(100) background events

Photoneutron calibration

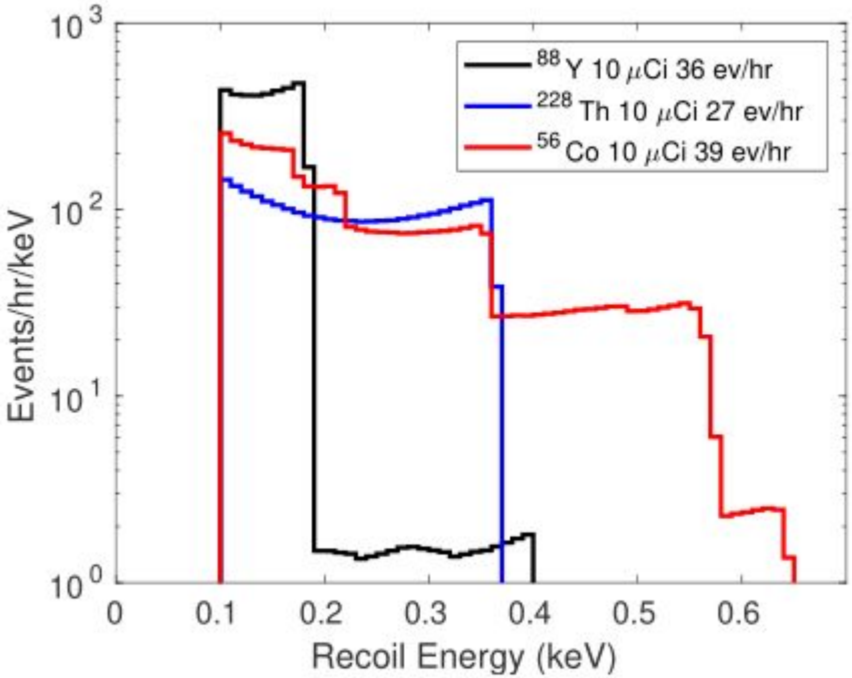
- Plan to use 3 sources tuned to produce ~30-60 events/hour
- Produces mono energetic neutron, 3 sources used to get three different lines
- Only works because of our insensitivity to ER events
- Using event rate and bubble multiplicity compared to simulations to find the NR energy threshold by comparing to Monte-carlo model





Thomson scattering calibration

- Measuring Nuclear recoils from high energy gamma events
- Possible due to very low sensitivity to Electron recoils
- Gives a second source of low energy NR events across a spectrum instead of as a line source

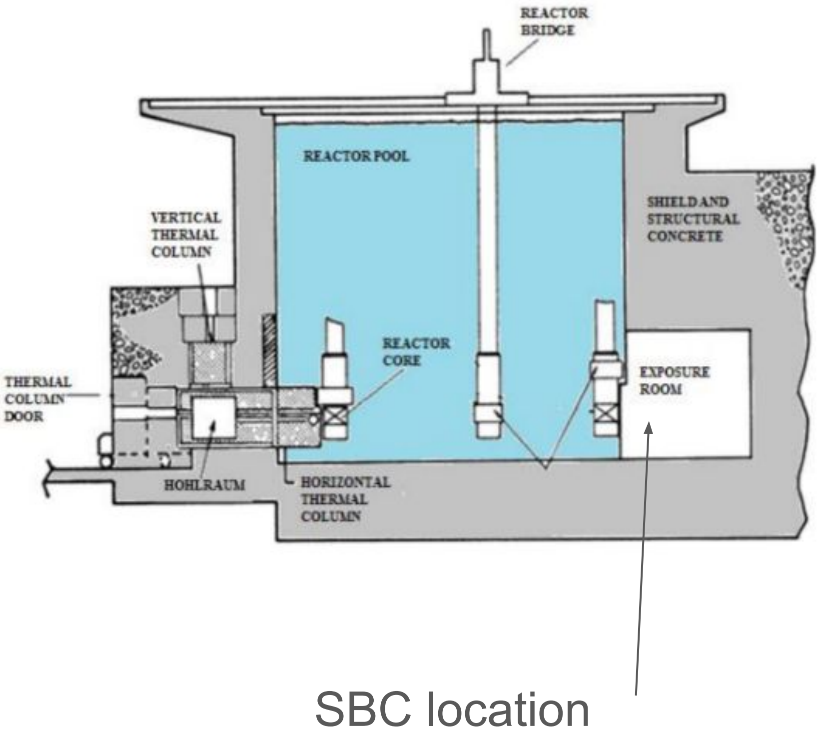


Run plans

- Main run will be a few months based on calibration run times at ~10 days per run
- Barring any complications we are not expecting to do any further runs at fermilab
  - Because of the lack of shielding / overburden and the lack of radio purity in the componentes the SBD-fermilab detector is not suited for DM searches
  - Plan is to then remove the detector from MINOS in preparation for a future CEvNS run

Future Reactor CEvNS run

- Investigating both research and power reactor locations for possible reactor CEvNS runs using the SBC-Fermilab detector
- Main candidate at the moment is the Triga Mark III research reactor at Instituto Nacional de Investigaciones Nucleares (ININ) in mexico city
- Movable reactor core
- 3m minimum distance
- Expect 12 CEvNS events/day
- Investigations underway of background rate in exposure room



Conclusions

- Plan to demonstrate and calibrate a 10 kg scintillating bubble chamber in the next year
- SBC-SNOLAB vessel procurement underway
  - Internal detector components already in hand
- Future CEvNS run being planned
  - Looking at the INNI research reactor in mexico as a possible location
- Snowmass white paper: arxiv: 2207.12400 and Universe 9 (2023) 8, 346.