A Neutron Calibration System for the Cryogenic Underground Test facility (CUTE)

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Abstract

SuperCDMS is an experiment that aims to probe the low mass region of the Dark Matter candidate called the WIMP. As a means for verification and testing of the technology used in SuperCDMS, the Cryogenic Underground TEst (CUTE) facility is being developed. A neutron calibration system was designed to understand how the SuperCDMS detectors will respond to nuclear recoils of known particles. The novelty of the proposed design is that it allows for the neutron source to be contained within the experimental setup of CUTE, and remotely controlled to deploy the source.

CUTE at SNOLAB

The Cryogenic Underground TEst (CUTE) facility will be used to test detectors for the Super Cryogenic Dark Matter Search experiment (SuperCDMS) at SNOLAB, a low background underground laboratory located in Sudbury, Canada [1,2].

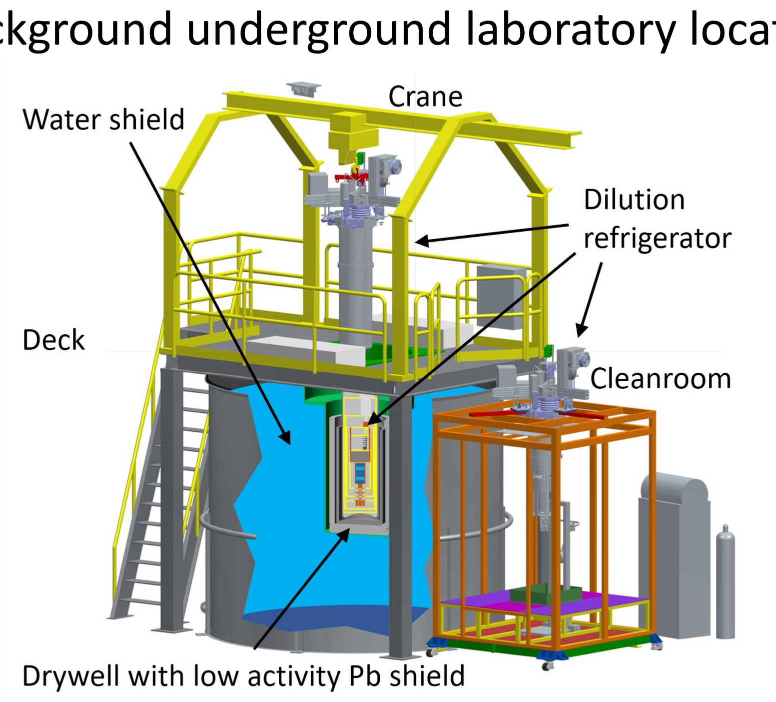

Figure 1: The CUTE facility: A monorail crane is used to lift the dilution refrigerator from the cleanroom into the shielded drywell in the water tank

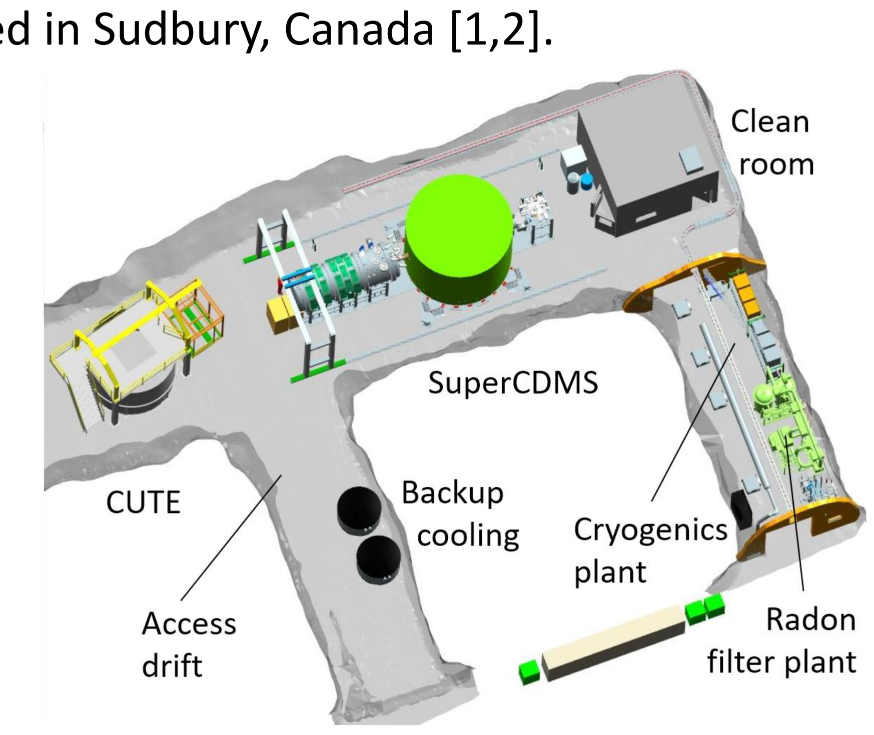

Figure 2: CUTE facility is located at SNOLAB next to the SuperCDMS setup

Design Considerations

- Calibrations are important to understand the detector response
- SNOLAB policy to protect sensitive experiments requires minimum 1 week notice for moving a neutron source
- Design a remote controlled system contained within experimental setup, while maintaining low exposure outside for personnel and neighbouring experiments

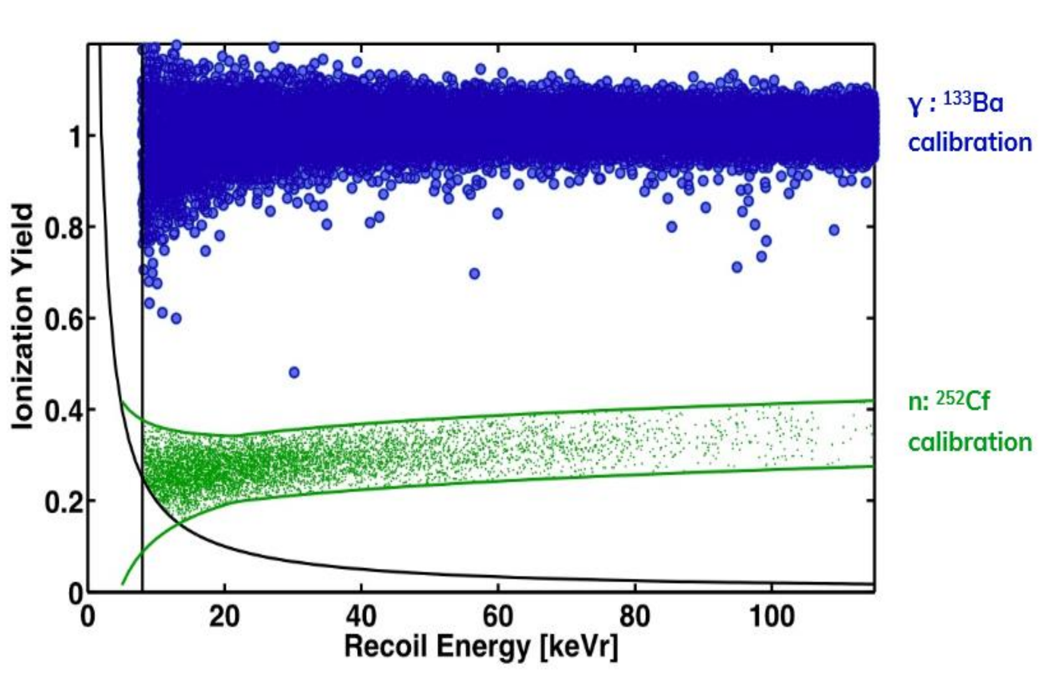

Figure 3: Example plot of the ionization yield vs. recoil energy expected for electronic recoils and nuclear recoils from two different calibration sources

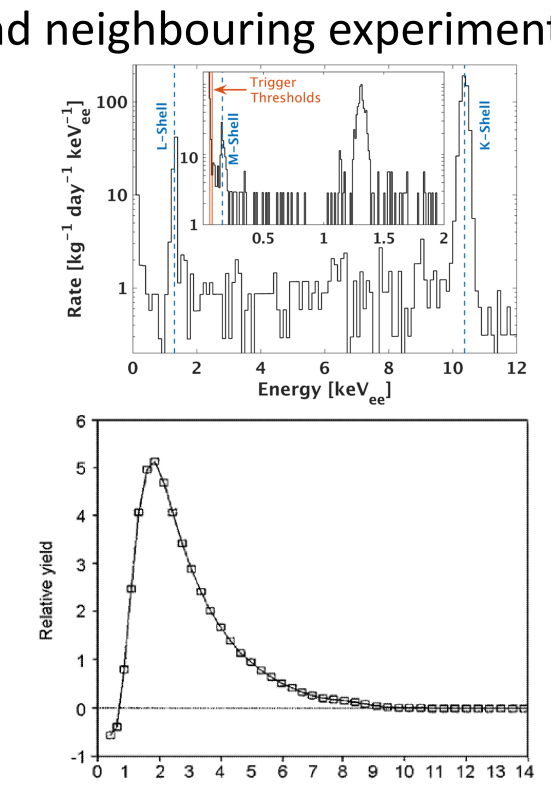

Figure 4: ^{71}Ge decay (top) spectrum and ^{252}Cf neutron energy spectrum (bottom) [3][4]

Simulation Results

The design of the shielding was implemented into GEANT4 [5] and a Monte Carlo simulation of the ^{252}Cf source in various locations was performed. From the flux of particles leaving the water tank and those arriving at various cavern surfaces, the safety of the system, and background it would produce for nearby experiments were evaluated.

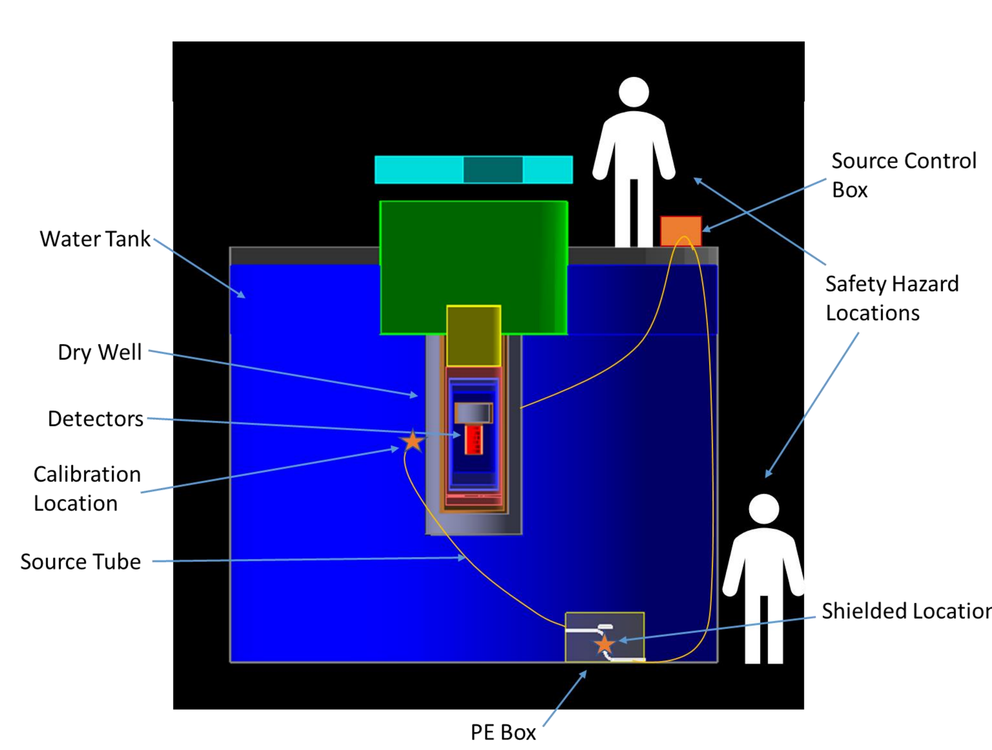

Figure 5: Rendering of the CUTE facility in GEANT4 with stand-in figures showing the locations of potential radiological hazard and starred locations for source calibration

Table 1: Summary of the simulation results. Maximum acceptable dose rate is 2.5µSv/hr for a shielded source at SNOLAB. SNOLAB Background numbers are dominated by the high radon levels underground [6][7]

Source Location	Shielded	Calibration	SNOLAB Background
Health Hazard Beside (nSv/hr)	1	~0	862
Health Hazard on Top (nSv/hr)	~0	9.7	862
Gamma/Neutron Flux @ PICO (#/m^2/day)	900/<10	2800/475	1000/4000
Gamma/Neutron Flux @ CDMS (#/m^2/day)	2400/10	10000/1603	1000/4000

Technical Design

Shielding Box:
At the bottom near the edge of the water tank sits a polyethylene box shielding the source neutrons even in absence of the water. The source guide tube forms an S-curve inside the box, avoiding lines of sight from the storage location to the outside. The storage location is surrounded by HeavyMet (W-alloy) and Pb to shield from gammas.

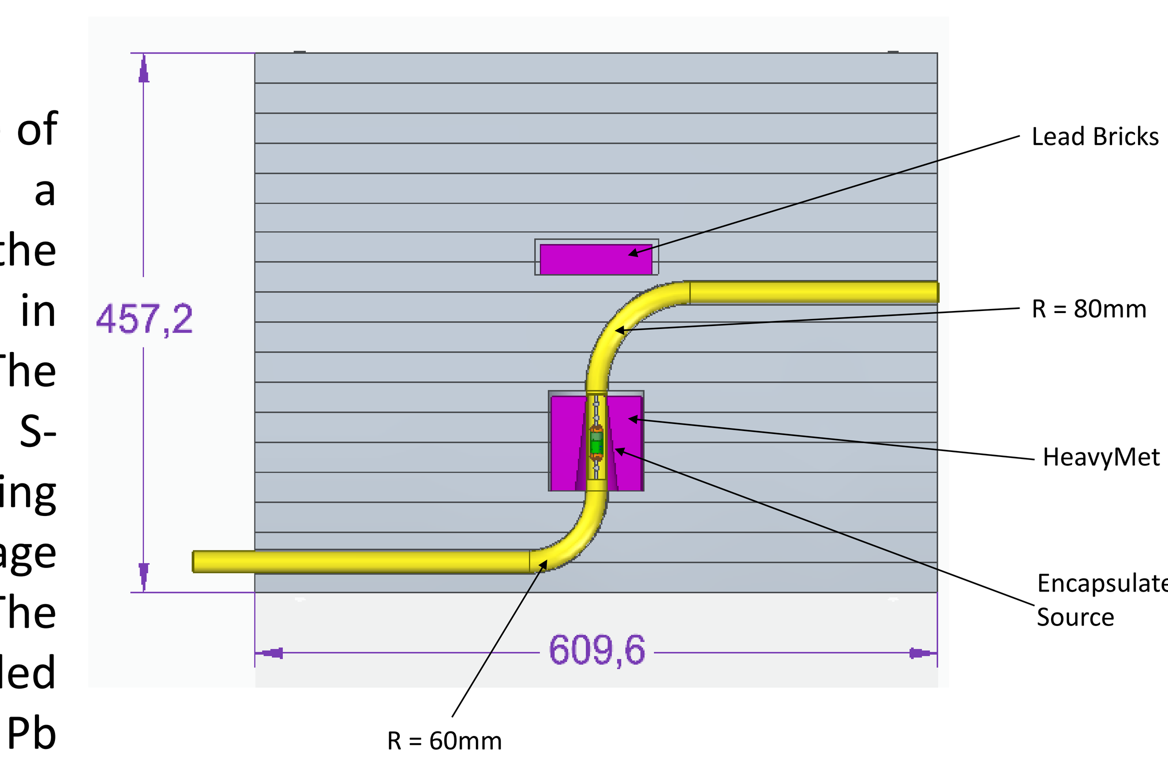

Figure 6: Cross Section of the PE shielding box, showing the gamma shields (purple) and the source guide tube (yellow)

Source:
The ~20 kBq ^{252}Cf source is doubly encapsulated (mandated by SNOLAB source policy). The capsule also provides the mechanical connection to the chain that moves the source.

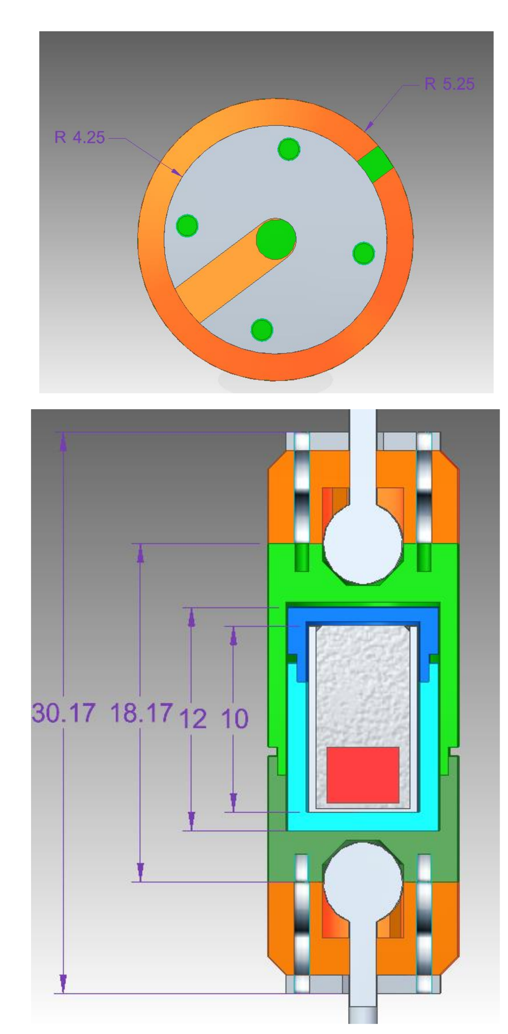

Figure 7: Source Encapsulation Design. Shown are the active volume (red), encapsulation from manufacturer (silver), two-layer encapsulaton (blue/green), attachment (orange) with washer (grey) for beaded chain (white).

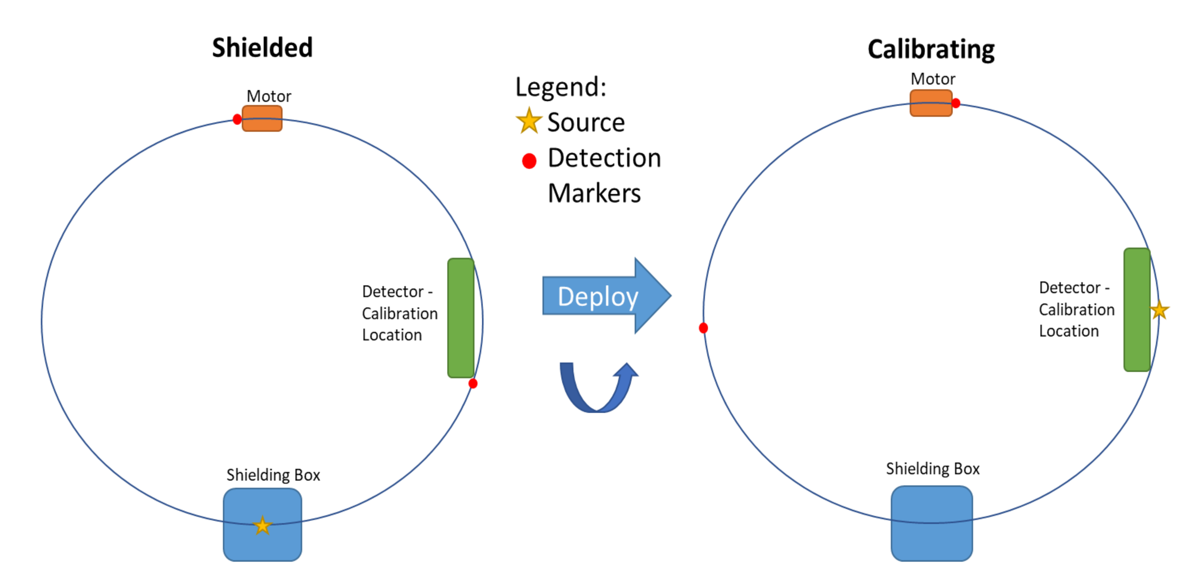

Figure 8: Block diagram of the full looped chain method for source deployment and location tracking. The arrow indicates the direction the loop would turn to deploy the source. Chain markers act as a secondary detection method since they appear at the motor box when the source is at the important locations.

Location Detection:
A stepper motor moves the source which is attached to a closed-loop chain to pull it through the guide tube. Location markers on the chain limit the motion to between storage and calibration locations.

Status and Outlook

- Conceptual design complete
- Technical design advanced (work needed on stepper motor holder, location sensor)
- Design validated for safety (personnel/other experiments) and rate detector rate by GEANT4 simulations
- Documents for approval by SNOLAB in preparation
- Quote for source (^{252}Cf, 18.5 kBq) from Eckert & Ziegler in hand
- Production of shielding box has started

References

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