Radioactive Background Characterization of the Cryogenic Underground TEst Facility (CUTE)

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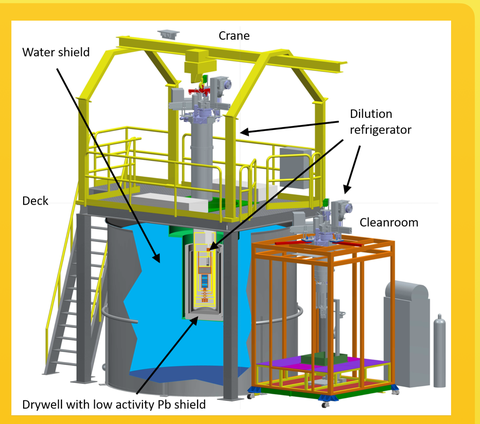
Abstract

The Cryogenic Underground TEst Facility (CUTE) is fully operational underground at SNOLAB. The facility can host up to six of the next generation SuperCDMS cryogenic detectors, and allows for the opportunity to search for low-mass dark matter while testing the new detectors. The SNOLAB cleanroom laboratory provides a low-background and low-cosmogenic-activation environment for CUTE operations. Estimating the background from radioactive processes with Geant4 simulations becomes a crucial task in informing the background budget for the experiment. This poster describes the radioactive background characterization of the CUTE facility, and discusses its validation through comparison with acquired data.

The CUTE Facility Underground at SNOLAB



Layout of the CUTE Facility [1]

Introduction to the CUTE Facility

- CUTE, the Cryogenic Underground TEst facility, is dedicated to the measurements of cryogenic detectors at a working temperature of 15 mK.
- It is located underground such that the residual muon flux is 0.27 muons/m^2/day, and the fast neutron flux is 4000 neutrons/m^2/day [2].
- The facility provides additional protection from surrounding radioactivity. From outside to the inside the components are as follows:
  - A 3.7 m diameter water tank around the cryostat and a 20 cm layer of polyethylene above it for neutron shielding
  - Two layers of low-activity and very low activity lead acting as shields from gammas
  - Cu cans composing the thermal stages of the cryostat
  - A 13 cm thick lead plug above the core of the cryostat encased by copper
- All of these materials were selected for their high radio-purity.
- A cleanroom supplied with radon-reduced air is used when changing the CUTE payload and working on the detectors.
- A computer interface allows the remote control and monitoring of temperature and data acquisition for detector operation and read out.

The facility is fully commissioned. It is currently testing SuperCDMS detector performances as part of early SuperCDMS operations. Two SuperCDMS SNOLAB towers (stacks of up to 6 detectors with mechanical, thermal and electric connections to the detectors and some electronic components) will be tested in CUTE prior to its deployment in the main SuperCDMS SNOLAB shielding scheme, allowing for early dark matter search and analysis. The characterization of the radioactive background of the facility is crucial for the understanding of these early dark matter data.

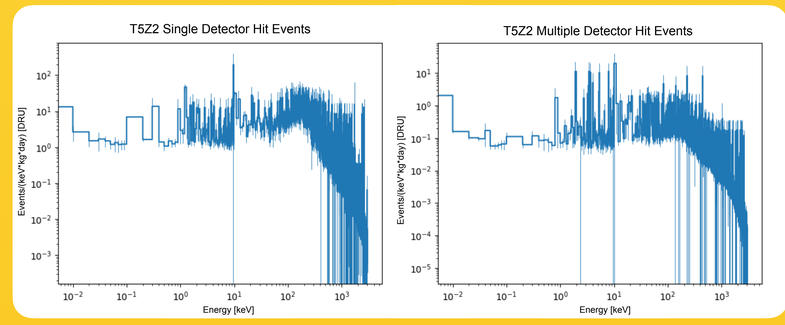
Since its commissioning, each CUTE payload has included T5Z2, a 600 g Ge iZIP detector, to characterize the background of the facility. This analysis focuses on modelling the expected background in T5Z2 for later comparison with the data it has acquired.

Building a Background Model

- CUTE materials are screened for radioactive contamination by the SNOLAB Low Background Counting facility
- Activity from the SNOLAB cavern walls (neutrons, gammas), and the facility (22 parts of the shielding and vessels, 6 tower components) was simulated in GEANT4
- For each component, the radioactive emission in terms of ^{238}U, ^{235}U, ^{210}Pb, ^{232}Th, ^{40}K, ^{60}Co etc. was obtained. ^{57}Co, and ^{58}Co was added in components that have these isotopes measured in assays, as they are indicative of cosmogenic activation in copper.
- GEANT4 simulations are used to propagate the radiation from this contamination into the detectors. The number of events generated is on average equivalent to 70 years of experimental run time for each component, and at minimum equivalent to 0.5 days for the most radioactive components.

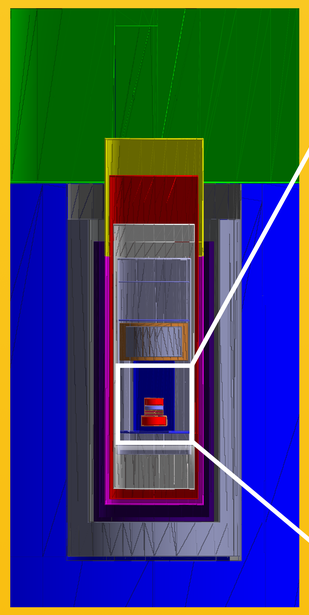
Background Explorer is a tool developed developed by SuperCDMS to handle conversion of simulated spectra into event rate. It uses a MongoDB server to store the models and simulation data. Components are added to the models and normalized automatically for each run payload.

T5Z2 Simulated Energy Spectra

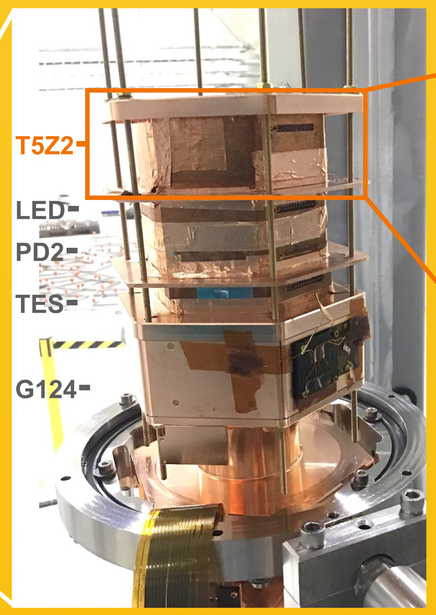


Simulated Energy spectra of the cumulative contribution of CUTE facility and detector tower components recorded in T5Z2 as single detector hit events and multiple detector hit events.

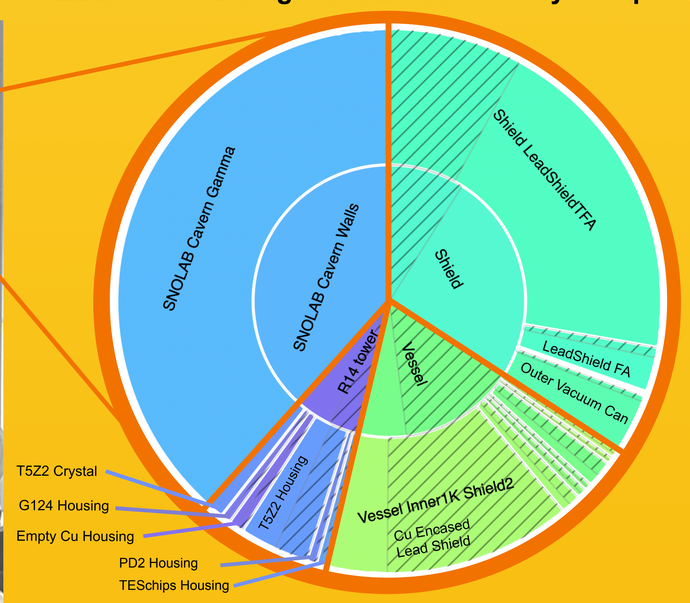
Simulated CUTE Geometry



CUTE Run 15 Tower



T5Z2 Detector Background Distribution by Component



Total T5Z2 singles: 4.04±0.24 Counts/kg/keV/day in the 1 to 1000keV range
Total T5Z2 multiples: 0.20±0.03 Counts/kg/keV/day in the 1 to 1000keV range

Summary and Outlook

- The facility's radioactive background has been modelled with GEANT4 simulations and emission results from material screening. Background Explorer hosts the complete radioactive background model, providing an interactive interface for the visualization of the different sources of background in the detectors.
- Significant sources of radioactive background to the T5Z2 detector include ^{210}Pb and the SNOLAB cavern wall gamma flux.
- The estimated electron recoil background in the T5Z2 detector is 4.04±0.24 Counts/kg/keV/day of single detector hit events and 0.20±0.03 Counts/kg/keV/day of multiple detector hit events in the region of interest 1 to 1000keV.
- This background model is soon to be validated through comparison with data taken with the detectors.
- Once SuperCDMS SNOLAB has completed its measurements in CUTE, the facility will be made available to other interested experiments with promising research programs in need of a low-radiation cryogenic environment.

References

1. Rau, W., Gerbier, G., Camus, P., Dering, K., Cazes, A., Scorza, S., Zhang, X., & Dastgheibi-Fard, A. (2020). CUTE - A Cryogenic Underground Test Facility at SNOLAB. *Journal of Physics: Conference Series*, *1342*. https://doi.org/10.1088/1742-6596/1342/1/012128
2. SNOLAB. (2006, June 26). *SNOLAB Users's Handbook, Revision 2*. http://snolab2008.snolab.ca/snolab_users_handbook_rev02.pdf.

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