Low-Background Assay Capabilities at SNOLAB

T. Sonley, S. Scorza, I. Lawson, B. Cleveland, D. Chauhan,
N. Fatemighomi, J. Hall, R. Ford

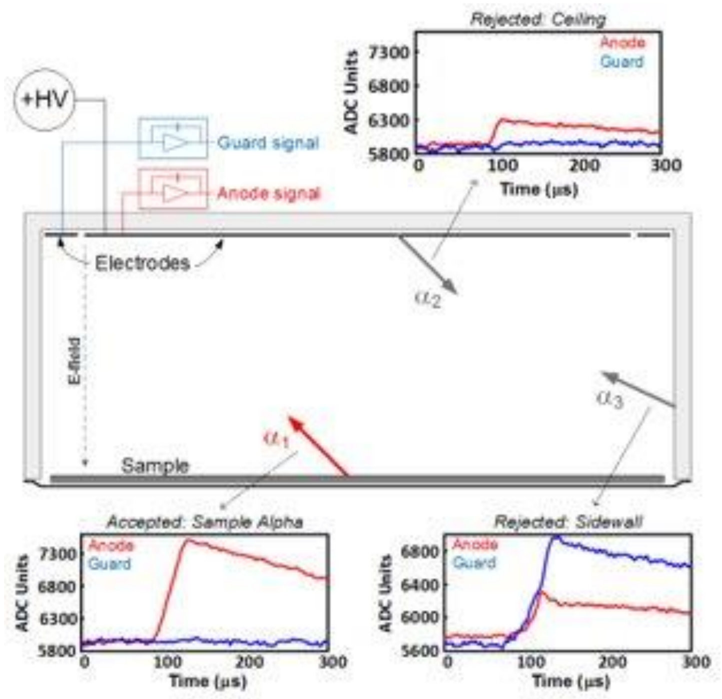
Low Background Assays

Experiments searching for rare events such as neutrinoless double beta decay and dark matter interactions need to have extremely low radioactive backgrounds. The design of the next generation of experiments will be thus driven by the intrinsic radioactivity of the materials used to construct the detectors, support systems, and shielding.

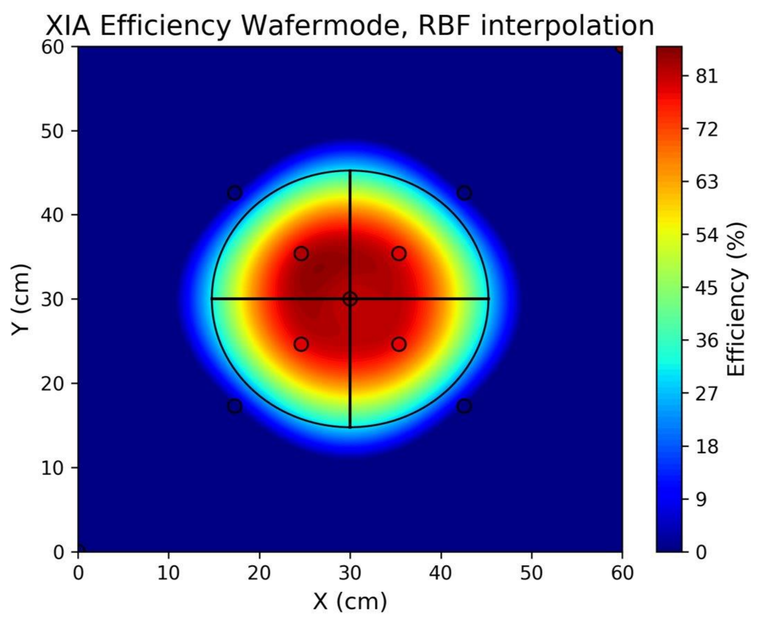
SNOLAB supports the development of these detectors with a number of dedicated assay systems which allow the direct measurement of this intrinsic radioactivity.

Surface Alpha Counting

SNOLAB has an XIA UltraLo-1800 unit for measuring surface alpha activity. This unit uses highly sensitive electronics to directly measure the movement of ionization products from alpha tracks without relying on gas amplification. Using this technology, it is able to exclude alphas from outside the sample region.



Electrode setup and sample readouts for the XIA surface alpha counter. Events are classified based on their risetime, anode charge, and guard charge.



Calibrated efficiency of the XIA surface alpha counter smaller sample region. The calibration was performed with a ^{230}Th source placed in 9 positions. (credit M. Baiocchi)

The UltraLo-1800 has 2 sample regions: a 30 cm diameter circle (707 cm^2) in the center, or the full 1800 cm^2 rectangle. The unit has an 80% collection efficiency for the smaller sample region. Samples are limited to 9 kg in mass and 6.3 mm in thickness.

The tray is covered with a mylar-coated Teflon to mitigate the contribution from the tray itself. The background measurement results in 0.00062 ± 0.00012 alpha/cm^2/hr for the circular read-out in the full energy range (1-10 MeV). The sensitivity is better than 100 nBq/cm^2 in the 1-10 MeV range.

High Purity Germanium Counters

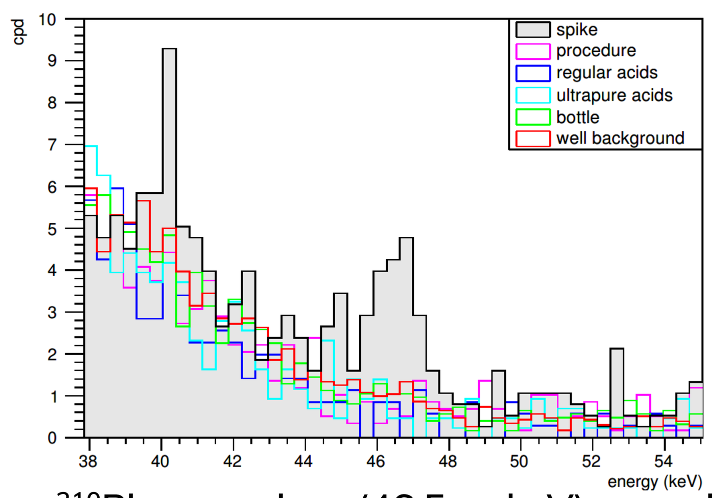
SNOLAB has 5 high purity germanium counters. Four are coaxial detectors designed for assaying large volumes of material for Uranium- and Thorium- Chain gamma rays. The fifth is a well detector, designed for assaying small samples for the low-energy gamma ray from ^{210}Pb.

When a radio-isotope decays through alpha or beta decay, it often emits gamma rays in order to reach its ground state. Germanium counters detect those gamma rays with extremely good energy resolution, which allows the parent isotope and rate of decay to be measured.

The counters at SNOLAB are well-shielded by 2 km of rock overburden and lead and copper shielding. This gives them 1-2 mBq of U- and Th- chain backgrounds. The large detectors are able to hold samples up to roughly 4L, so normal samples are 100 to 1000 g in mass.

One of the High Purity Germanium Counters along with its copper and lead shielding.

The efficiency of the counters depends greatly on the geometry of the samples, so a GEANT4 Monte Carlo is used to estimate the efficiency for each sample. In general, the efficiencies come out to be 1-20%, with better efficiencies for small samples. Combining these efficiencies and backgrounds, sensitivities of <100 mBq/kg for U- and Th- chains are readily achievable.



^{210}Pb peak (46.5 keV) and background runs for a concentrated source measured at 240 nBq in the well detector. (credit C. Nantais)

Other Techniques

SNOLAB uses a number of other techniques to monitor detector purity and cleanliness. These include radium counting of water samples use HTiO columns[1], liquid particle counting, continuous airborne particle monitoring, and X-ray fluorescence of dust samples. Details of these techniques are available upon request.

[1]Nucl. Instr. Meth A604 (2009) pp. 531-535

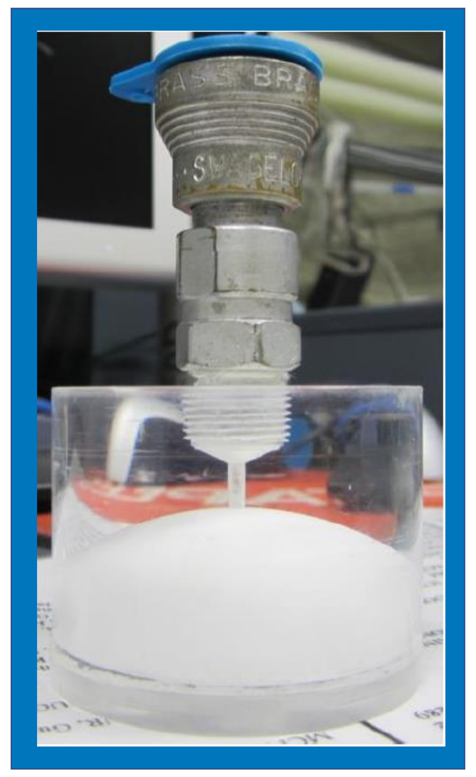
Radon Counting

SNOLAB uses two methods for directly measuring the ^{222}Rn content of gas volumes.

For volumes with high radon concentrations and for gross monitoring of purged volumes, SNOLAB owns 7 Durridge Scientific RAD-7 detectors. These use solid-state detectors to count radon decays in a 0.7 L decay cell. The counters read out in short intervals (10 minutes) and count single decays. Over 24 hours, this gives them a sensitivity of 20 mBq/m^3.

For precise measurements of low radon levels due to emanation from samples or detector components, SNOLAB has a number of cold traps for radon counting. In these assemblies, a sample gas is pulled through a liquid-nitrogen cooled bronze-wool trap. The radon from the gas sticks to the trap while the gas is released. The radon is then transferred to a smaller trap and then released into a Lucas-Cell scintillation counter. The resulting radon decays are then counted.

One of SNOLAB's radon emanation chambers and cold-traps.



A Lucas-Cell scintillation counter

This method has a detection efficiency of 44% and allows for large volumes of gas to be processed quickly. For measurements of purge gases and radon in water, hundreds of litres can be processed in an hour. For emanation of samples, the sample is placed in an emanation chamber for a week or more so that the ^{222}Rn can come into equilibrium. The gas in the container is then pulled through the trap and the radon counted.

A typical Lucas Cell has a background of 5 counts per day which corresponds to a sensitivity of 7 atoms per day of emanation. SNOLAB is commissioning a new emanation chamber that is 20 cm in diameter by 20 cm in height.