Soudan Low Background Counting Facilty (SOLO)

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Abstract. The Soudan Low Background Counting Facility (SOLO) has been in operation at the Soudan Mine, MN since March 2003. In the past two years, we have gamma–screened samples for the Majorana, CDMS and XENON experiments. With individual sample exposure times of up to two weeks we have measured sample contamination down to the 0.1 ppb level for ^{238}U / ^{232}Th, and down to the 0.25 ppm level for ^{40}K.

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INTRODUCTION

The SOudan LOw Background Counting Facility (SOLO) has been in operation at the Soudan mine in Minnesota since March 2003. The SOLO screening facility was constructed by Brown University, in conjunction with PNNL, the University of Minnesota and the Soudan Mine, and has been, and is currently being used to screen materials for the Majorana, CDMS and XENON experiments.

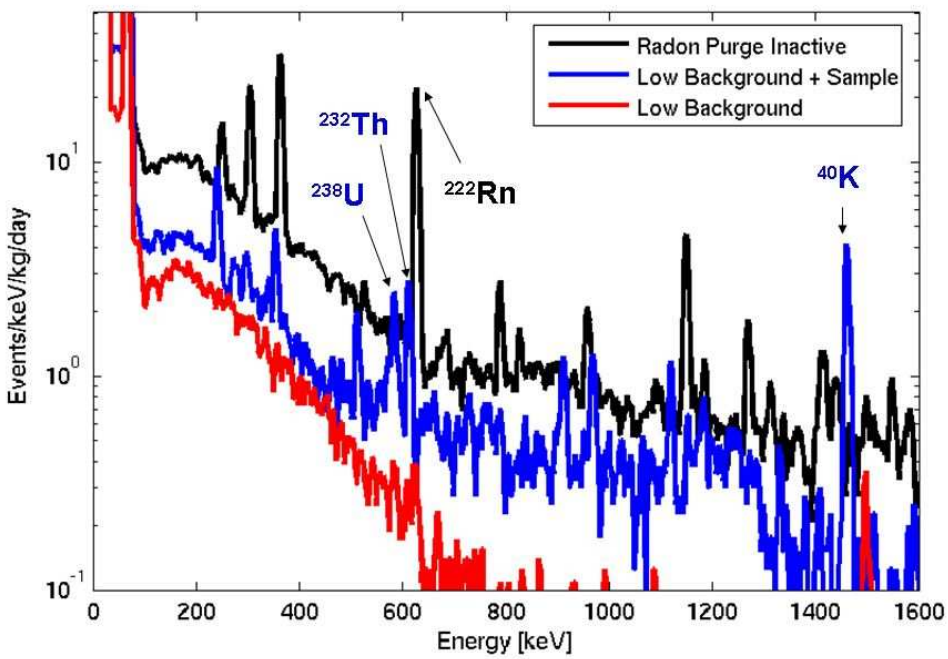

FIGURE 1. SOLO data taken using the 0.6 kg HPGe "Diode M" detector. From top to bottom: data taken without the Radon gas purge active, background data taken with a screening sample present (Hamamatsu R9288 PMTs) plus Rn purge, and background data (no sample) with Rn purge active.

The facility uses HPGe detectors and shielding previously deployed in Double Beta Decay Experiments at the Homestake Mine. Two independent detectors are housed in separate chambers, each surrounded by at least 12" of Pb, the innermost 2" of which is low ^{210}Pb-activity (German) Pb. A 2" wall of German Pb separates the chambers, each of which houses a HPGe detector; 'TWIN' (1kg Ge) and 'Diode M' (0.6kg Ge). The entire enclosure is sealed up with two airtight layers of 50μm thick white mylar, and radon gas is purged using boiloff gas from a LN dewar fed

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in through the shield. Figure 1 shows the spectra with and without the Rn purge active. At present, when samples are introduced no airlock is employed. Gamma lines due to Rn disappear less than 3 hours after the shield is closed, and the N_2 gas purge, at a rate of 3 cfh, is started.

A simple data acquisition system is used, consisting of Spectroscopy Amplifiers with 2μs shaping times, and pulse height ADCs connected to a PC running acquisition software. Spectra are integrated in 4 hour intervals, and transferred automatically to a web accessible archive.

The TWIN detector is currently offline due to a failure in its front–end FET. A low background/low noise FET is currently being prepared by PNNL as a replacement. In conjuction with the University of Florida, a 2kg HPGe detector was installed in the shield in June 2005, and will perform future screening alongside Diode M.

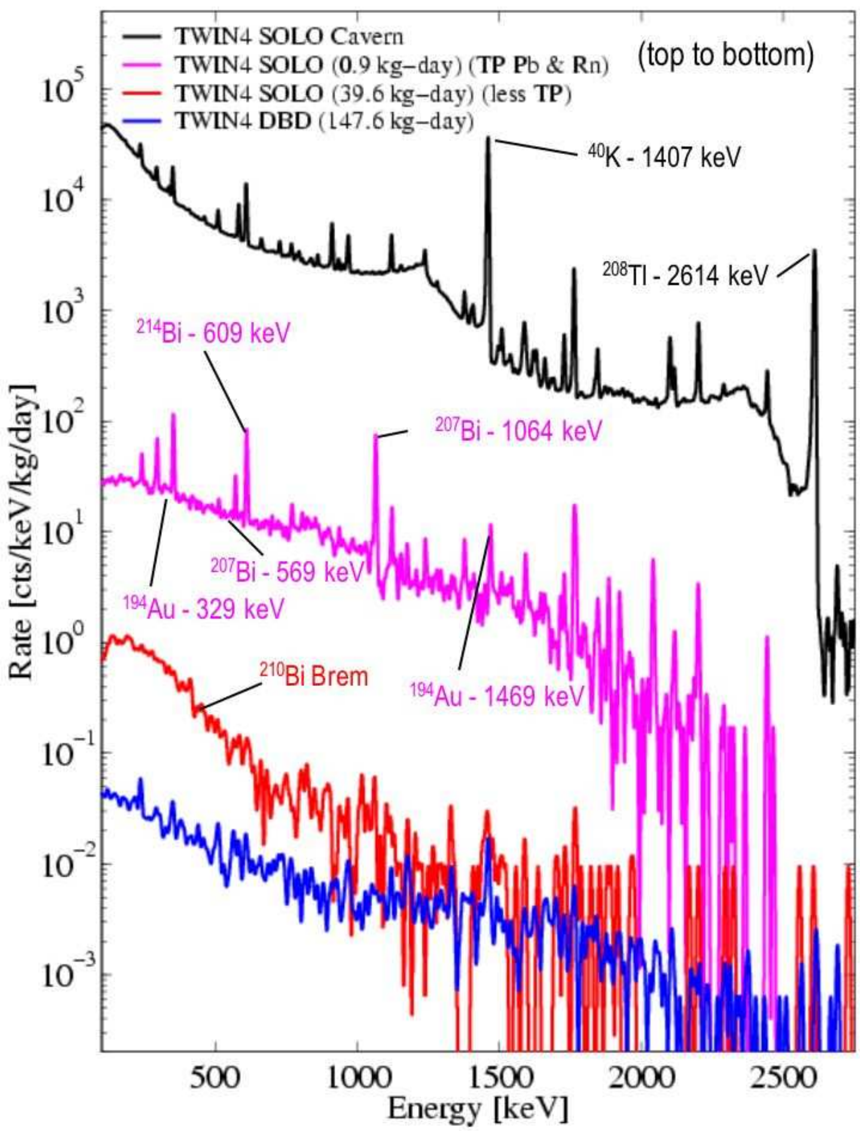

FIGURE 2. SOLO data taken with the TWIN detector. From top to bottom: cavern background rates, initial spectrum including TP brick, final spectrum without TP brick, and background taken during Double-Beta operation at Homestake.

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We relate two unusual incidents that occurred during the commissioning of the facility, in the hope that it may provide guidance to others in the future.

Upon first operation in June 2003, the TWIN spectrum showed >10 events/keV/kg/day up to 1 MeV, the same detector having operated at <1 event/keV/kg/day in the past (see Fig. 2). At the same time, Diode M observed a background rate $\sim$1 event/keV/kg/day up to 500 keV, suggesting that the TWIN detector was subject to a source that Diode M was not. Analysis of the TWIN spectral lines in the data indicated the presence of two unexpected isotopes: ^{207}Bi (33 years half-life) and ^{194}Hg (400 years half-life). The relative strengths of the lines at different energies appeared to indicate the presence of 3.5-4.5cm of Pb between the source contaminant and the detector. Both isotopes are very rare, but are known to be spallation products arising from high energy protons on Pb.

In order to test the hypothesis that contaminated bricks were causing the high background levels on TWIN, the upper section of the SOLO Pb shield was disassembled to examine the bricks surrounding the chambers. Bricks stamped with the letters 'TP' were found directly above the TWIN chamber, behind the low activity German Pb layer, in a location consistent with our calculations. We understand that these bricks came from Fermilab, where they may have been used as a proton beam stop. Unfortunately, at some stage they must have been combined with the gamma shielding stock of Pb at Soudan. Removal of these 'TP' bricks substantially reduced the background on the TWIN detector, as can be seen in Fig. 2.

In May 2004, SOLO was counting several blocks of polyethylene for the CDMS experiment, in order to establish the intrinsic levels of U/Th/K. The polyethylene data showed a large number of unexpected gamma lines. The polyethylene spectrum was $\sim$5 events/keV/kg/day above background across all energies. (On closer inspection the no–sample backgrounds also appeared elevated.) While the polyethylene lines could not be matched to the patterns from any known combination of radioactive contaminants, we realized they were characteristic of gamma cascades arising from thermal neutron capture in Ge. The low energy neutron flux coming from the rock at Soudan was insufficient to be generating such pronounced features, however, it became clear that the polyethylene was moderating neutrons from a calibration source (10^5 n/s) had been placed in storage 20ft from the SOLO experiment. Needless to say, the neutron source was moved to another storage location.

SAMPLE SCREENING AND REMAINING BACKGROUNDS

Over the past two years SOLO has screened many samples. For sample runs of two weeks, sensitivities better than 0.1 ppb level for ^{238}U/^{232}Th, and 0.25 ppm level for ^{40}K have been achieved.

As Fig. 2 shows, the SOLO background below 1 MeV is 5-10 times greater than when these detectors were in operation at Homestake, while the background above 1 MeV is very similar to the levels achieved previously. The shape of the excess background is consistent with that expected from ^{210}Pb bremsstrahlung. As a general rule of thumb, a brem spectrum with a rate at low energies ($<$ 100 keV) of 1 event/keV/kg/day would arise from Pb with an intrinsic ^{210}Pb level of 1 Bq/kg. The German Pb liner has an intrinsic activity of $<$50 mBq/kg so it is unlikely that this is the cause of the elevated background. We have systematically altered the shielding geometry, and have also cleaned the surfaces of the inner Pb liner (May 2005) using dilute nitric acid. This intervention has had little effect on the level of this background. We now believe that the brem could be arising from Rn plating on the surface of the Cu housing on the HPGe detectors. The detectors were stored in non–airtight packing cases for over 5 years in the Soudan Mine where the airborne Rn levels fluctuate between 100–500 Bq/m^3. Back of the envelop calculations indicate that Rn daughters plating onto the Cu housing could indeed lead to sufficient activity to explain the residual brem spectra. We intend to try acid etching the Cu during the next major overhaul of the system.

CONCLUSION

Photographs of the SOLO facility can be seen in Figs. 3 and 4. We would like to thank our colleagues from PNNL, UMinn, and Soudan Mine for their collaboration establishing and operating this facility, and also our new collaborators from UFlorida. Further details of the facility can be obtained at **http://particleastro.brown.edu/SOLO/**. Please contact us if you would like to make use of the facility.

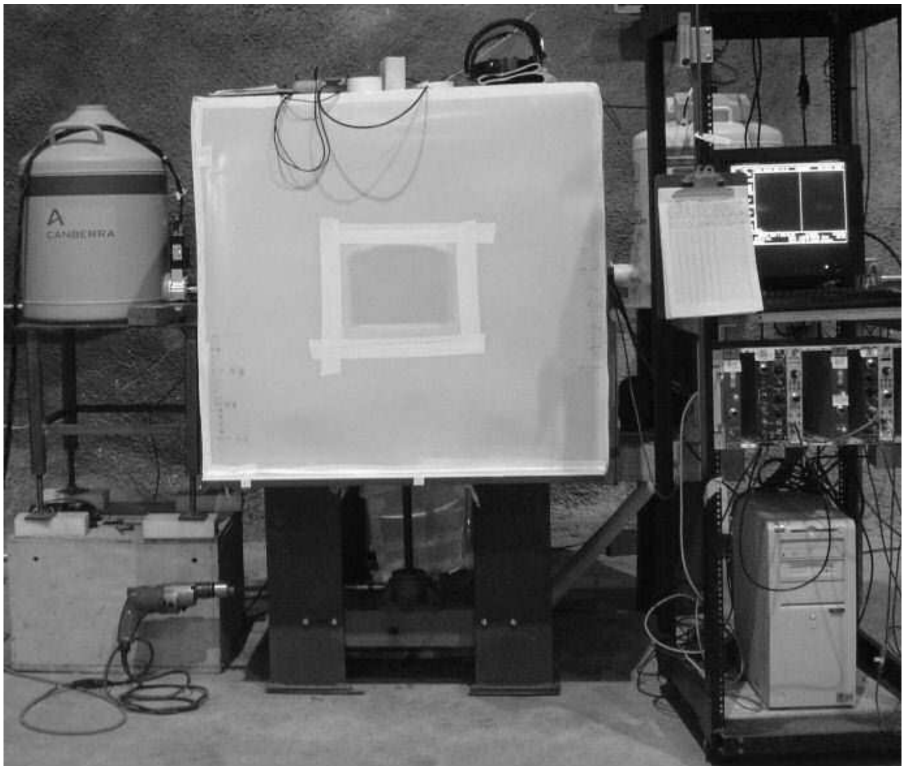

FIGURE 3. SOLO Gamma Screening Facility at Soudan Mine, MN. The Pb shield is surrounded by white mylar providing a Rn barrier. The LN dewars of the two HPGe detectors can be seen to the left and right of the main shield.

FIGURE 4. The two HPGe detectors on the ends of their Cu cold fingers can be seen, during shield assembly.