DEAP-3600 ACRYLIC ASSAY

^{238}U, ^{232}Th, ^{210}Pb in low background detectors

Low Radioactivity Techniques
Laboratori Nazionali del Gran Sasso
10-12 April 2013

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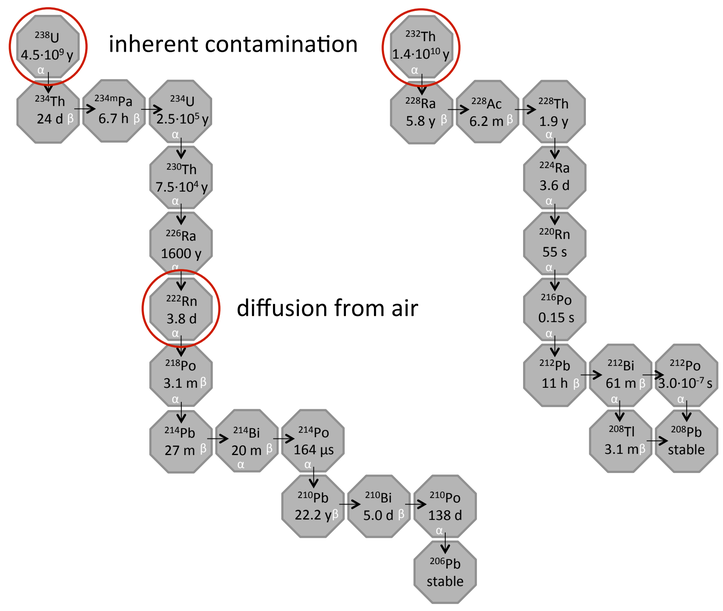
Radiopurity of acrylic is measured by vaporizing a large quantity and counting concentrated residue with low background gamma and alpha detectors. The 85 cm radius acrylic vessel that contains the liquid argon target is the most critical detector component in the DEAP-3600 dark matter experiment. DEAP-3600 is a single-phase liquid argon detector, and is currently under construction at SNOLAB. Argon provides excellent discrimination between electromagnetic interactions and nuclear recoils based on scintillation time. DEAP-3600 is designed for <1 background event in 3 years livetime.

Backgrounds from acrylic vessel inner surface

An alpha decay in the centre of the liquid argon can be tagged by its high energy; it is not a background in the low energy region of interest. Alpha decays near the surface of the acrylic vessel are one of the main sources of background. If only a fraction of the alpha energy or if the recoiling nucleus from the alpha decay is observed, the event will not be separated from a dark matter candidate event.

The materials used to make acrylic have trace levels of ^{238}U and ^{232}Th. Another concern is ^{222}Rn diffusion from the air. The acrylic assay is based on the vaporization technique used by SNO, which achieved ppt sensitivity for ^{238}U and ^{232}Th [1]. While acrylic vaporizes, ^{238}U, ^{232}Th, and ^{210}Pb remain.



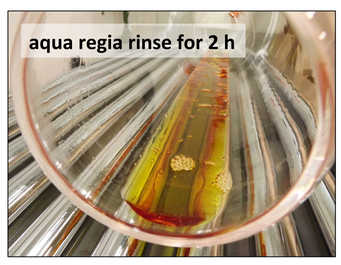
Maximum concentrations:
0.3 ppt ^{238}U
1.3 ppt ^{232}Th
1.1 x 10^{-8} ppt ^{210}Pb

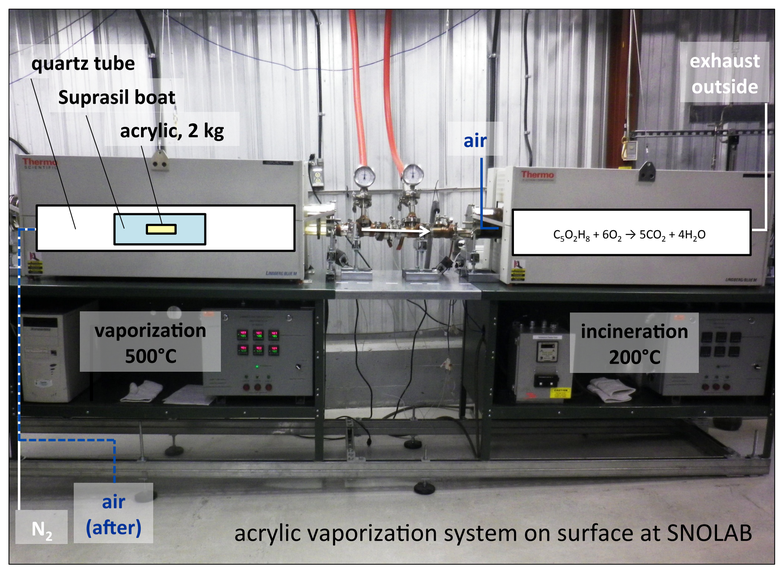
1.Vaporize 10 kg acrylic
2.Collect residue by rinsing with heated aqua regia (3:1 by vol. HCl and HNO_3)
3.Measure gammas from ^{238}U and ^{232}Th with coaxial HPGe detector
4.Measure gamma from ^{210}Pb with well HPGE detector and by ^{210}Po with α-counter

The acrylic vaporization system

Acrylic is polymethyl methacrylate (PMMA). Because of the odour of MMA, the acrylic vaporization system was designed to first vaporize acrylic and then destroy MMA by incineration. A block of acrylic is contained in a cylindrical boat made of Suprasil, ultra pure synthetic quartz. The boat sits inside the quartz tube in the vaporization furnace. A flow of N_2 is initiated and the vaporization furnace is heated to 500°C. The boiling point of MMA is 100°C. After a check valve, air is added to provide oxygen for combustion. The incineration furnace is operated at 200°C. The exhaust goes to outside.

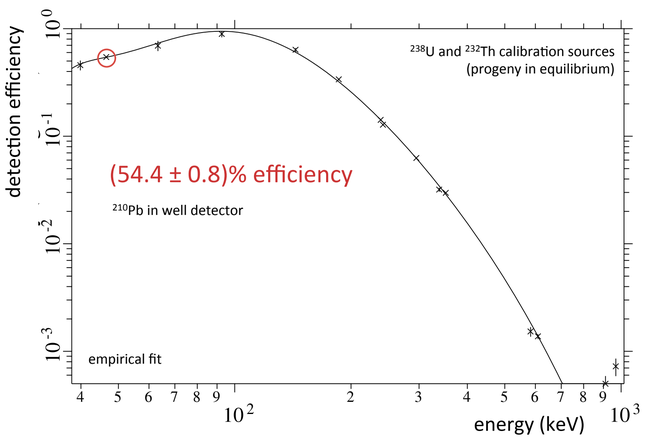
An excessive amount of carbon, 0.5% of the initial mass, is left behind and would make extraction and counting difficult. To remove carbon, air is added after vaporization. Carbon combines with oxygen to form carbon dioxide that goes to the exhaust. The acrylic vaporization system can accommodate 2 kg each day, however, on the order of 10 kg is required to increase count rates. After having vaporized five 2 kg blocks in the same boat, the boat is placed on heated rollers at 1 rpm and rinsed with aqua regia. The effluent is collected. The volume can be reduced by evaporation.

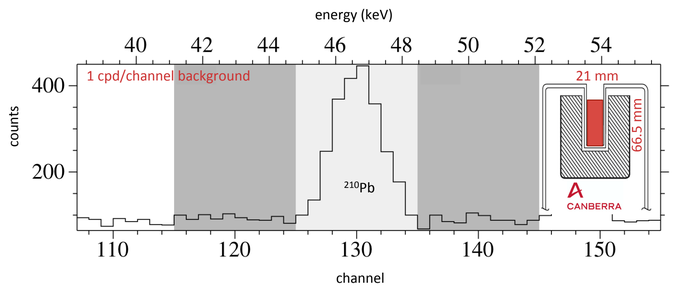




High purity germanium (HPGe) detectors

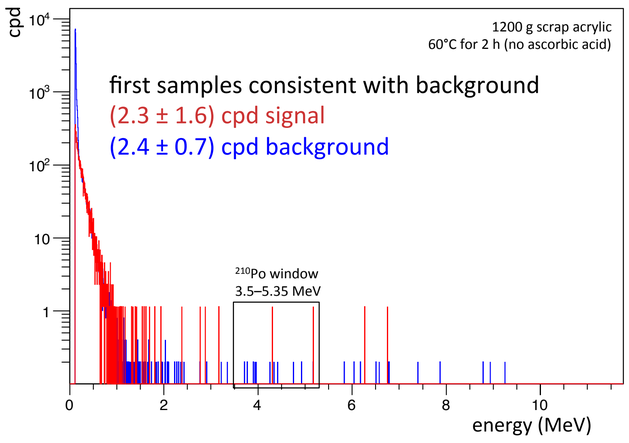
The effluent will be measured with low background high purity germanium detectors underground. SNOLAB has a well-established gamma assay program with a coaxial detector. Another coaxial detector and a well detector were recently purchased and are being commissioned. The background and detection efficiency are measured. The ^{238}U and ^{232}Th measurement will use the coaxial detector, and the ^{210}Pb measurement will use the well detector to measure 46.539 keV. A 3 ml Teflon container was selected to fit in the well detector.





^{210}Pb by ^{210}Po in alpha counter

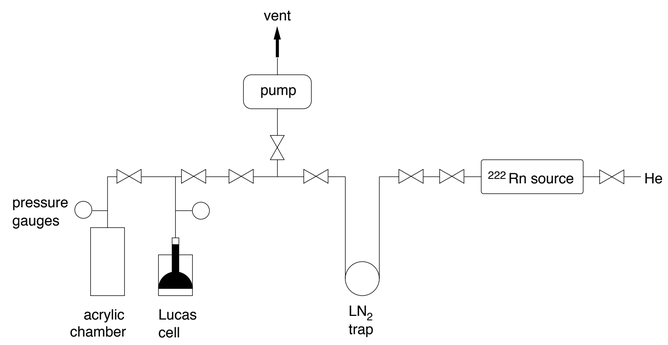
In parallel, ^{210}Pb will be measured by the 5.304 MeV alpha from its ^{210}Po daughter. There is initially no ^{210}Po in the effluent, since polonium has a tendency to volatilize at approximately 100°C and is removed during acrylic vaporization and the heated acid rinse. The effluent is sealed for a month to let ^{210}Po accumulate. Polonium spontaneously deposits on various metals, including nickel [2]. A nickel disc is submerged in the effluent for 2.5 h while the effluent is stirred and heated to 55°C [3].



Ortec Ultra AS	3-8 MeV background (cpd)
specification	6
Alpha 1	7.6 ± 1.2
Alpha 2	5 ± 1

^{210}Pb spike to measure recovery efficiency

SNO measured 4% loss from vaporization and rinsing using spikes of ^{229}Th and ^{224}Ra. To measure the loss of ^{210}Pb, ^{222}Rn will be loaded into acrylic. The ^{222}Rn source and the trap are purged with helium gas. The isolated trap is cooled with liquid nitrogen. As the source is opened, radon moves to the cold trap. Then the trap is opened and heated, and radon moves to the Lucas cell. A Lucas cell is an evacuated acrylic chamber coated with scintillating ZnS(Ag) paint and is counted with a PMT. The Lucas cell is then opened and radon moves to the evacuated acrylic chamber. After 2 weeks, in which ^{222}Rn decays to ^{210}Pb, the acrylic chamber is vaporized and rinsed. The effluent can be counted directly in the well detector, and after can be used for ^{210}Po collection efficiency and alpha counting. Determination of the recovery efficiency is in progress.



Measure ^{222}Rn with Lucas cell for known amount ^{210}Pb in acrylic chamber

Acknowledgements
Bruce Cleveland and Mark Boulay

References
[1] G.M. Milton, S.J. Kramer, R.J.E. Deal, and E.D. Earle, Appl. Radiat. Isot. **45**, 539-547 (1994)
[2] F. Henricsson, Y. Ranebo, E. Holm, and P. Roos, J. Environ. Radioact. **102**, 415-419 (2011)
[3] C.W. Baker, Nucl. Instrum. Methods Phys. Res. **223**, 218-223 (1984)