LZ Radioactive Assay Needs

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Introduction

The LZ program is a direct sequel to the ongoing LUX dark matter search experiment. It is essentially a scale up of the existing technology, with a few additional features in order to control the background levels further: optimized detector internals mass, additional instrumented volume, liquid scintillator veto, among others.

There are two phases to LZ: LZ-S, a 3 tonne detector that could be located in the Davis water tank once LUX is completed, and a 20 tonne instrument which will require a much larger cavity and water tank as part of the DUSEL extension.

The LUX program has allowed us to judge the amount of radioactive screening which should be expected for the next detectors. Thanks to the very similar designs, a lot of the material assay work conducted for LUX will also be directly transposable for LZ.

Gamma Screening

The bulk of the effort for the LZ radioactive screening program is gamma counting of parts local to the active Xe volume (internals, cryostat and nearby plumbing). The gamma background budget will be composed of a contribution from the photodetectors (PMTs), with finite contributions from the plastics forming the walls of the xenon chamber. Close to the internal volume are also a lot of small parts: bolts, sensors, cables, plumbing… For most of these, the goal of the screening program is to make sure that their activity is low enough to remain subdominant. We will therefore be looking to put upper limits of the order of ~5 mBq/part in U/Th for each of them, for sample masses which can range from ~10 g to a several hundred g (in this scenario a "part" can be defined as a single element, or a group of identical pieces used in the same area of the detector). That 5 mBq/part number is based on the current LUX background model and may change slightly as the LZ detector geometry is finalized. For very low sample masses, we plan to make use of the Oroville facility which is able to reach better sensitivities than our SOLO detector.

Other parts of the experiment will also require radioactive screening; we will want actual measurements for most construction and shielding materials. However there is no major ultra-low requirement in the current experiment design and we expect gamma screening to the 1 mBq/kg positive detection level, or <1 mBq/kg 90% CL upper limit, to be sufficient in most cases. For some special items where the amount of mass available for counting is smaller, an absolute sensitivity of 0.1 mBq per sample would be desirable.

Other Techniques

We have not to date used any other radioactive assay techniques, except neutron activation on one occasion. However, we may be interested in measuring directly e.g. surface alpha contamination, or neutron emission, for a few key elements such as the PMTs. Should such measurements be possible onsite at Homestake we would certainly try to make use of it.

Radon Considerations

The design of the experiment assumes high radon concentrations of several hundred Bq/m^3 in the underground lab.

During detector operation, the cryostat will be entirely inside the water shield with Rn-tight breakout feed-throughs for electronics and plumbing to the lab space. The water in the tank itself is constantly recirculated and filtered to avoid the accumulation of impurities including radon. We also use a nitrogen gas purge on top of the water surface, which very efficiently reduces the radon concentration above the water. The radon concentration outside the water tank is essentially irrelevant for the LZ background: the dimensions of the tank are driven by the need to moderate very-high energy neutrons; gammas, even 2+ MeV from thorium, are reduced to negligible levels by 5 meters of water.

The LUX model was to have a separate clean room in the underground lab, for working on detector internals in a radon-controlled environment. The detector can be lifted out of the water tank and rolled into the clean room with minimal disturbance to the systems. As of now there is no data point on the Rn levels that can be achieved, but we are counting on high localized air-flow and a nitrogen purge when not immediately working on the detector, to help prevent radon deposition. Air with reduced Rn at a level of 10 Bq/m^3 would be highly desirable. For LZ, that approach is not possible because the detector is too large to be moved easily. We plan instead to use the water tank itself as a temporary clean room when working on the detector assembly.

In all cases, radon diffusion and deposition is a tricky matter and minimizing the radon concentration in the overall underground lab is certainly something LZ would be very interested in seeing happen.