Introduction: WIMPs in a Liquid Xenon TPC

LZ is a dual-phase xenon Time Projection Chamber (TPC) that collects two scintillation signals for each scattering event to look for single-scatter nuclear recoil (NR) events from dark matter in the form of Weakly Interacting Massive Particles (WIMPs). Since the expected rate of dark matter events is very low — already less than one event per 100 kg of detector mass per 100 days — it is essential to reduce as much as possible all sources of radioactivity in and around the detector. Kr-85, a radioactive isotope of krypton, is one of the background sources of concern, and must be removed down to a very low level so that it does not give too many background events in the experiment. To put this background source into context, we describe briefly how the LZ detector works and how the required level of Kr-85 is determined.

LZ uses liquid xenon to generate two scintillation signals, S1 and S2, which are emitted promptly after the scattering (~10 ns) and are a “start” signal for the event clock.

- S1 is from the de-excitation of short-lived xenon molecules, or dimers, and is emitted after the S2 event in the upper PMT array gives the lateral (y,z) event position.
- The S1–S2 time difference give the depth of the event (z).
- The combined xyz position allows events near the edge, which are dominated by external sources of radioactivity, to be rejected as backgrounds.

Development system at SLAC

At SLAC, we’ve resurrected and reconfigured the Case Western Kr removal system that was used to reduce Kr in the LUX xenon from 130 ppb to 4 ppb. The system is being used as a development platform to test ideas for improving the separation and to demonstrate chromatography separation down to the LZ spec.

Chromatography

Like pigments of different size separating on filter paper under the action of a carrier fluid, Xe and Kr atoms migrate at different speeds through a charcoal column under the influence of a helium carrier gas.

Xenon assay: cold-trap assisted RGA

Our collaborators led by Carter Hall at the University of Maryland have developed an innovative system to measure trace Kr in Xe down to 10 ppq using a cold-trap assisted RGA, or Residual Gas Analyzer. Commercial RGA units have a baseline of about 1 ppm, far too insensitive for our needs. By passing xenon samples through a cold-trap in liquid nitrogen, the xenon is frozen out to a partial pressure of $10^{-5}$ mbar while allowing the trace contaminants, including Kr to pass through nearly unimpeded.

Scaling parameter from LUX to LZ

The three main loops for the xenon processing are shown. With two charcoal columns and two xenon condensers, a 16 kg slug of xenon can be introduced every two hours on a continuous basis.

Conceptual layout of production system

The removal of the helium refrigerator used for the BaBar magnet will clear space on the Bldg 624 cryopad for the installation of the LZ production system. The use of outdoor space mitigates the oxygen deficiency hazard and provides easy loading and unloading of xenon storage packs. A total of 200 cylinders will be processed twice during the production run.