Contribution ID: **7** Type: **not specified**

Towards EXCESS background suppression in the next generation (G3) Noble Liquid detectors

A ‘meta-analysis’of phenomena reported by the current generation of large dual-phase noble-liquid detectors reveals correlations between barriers for surface charge removal and unextracted electrons dwelling time, mobility, and appearance of E-bursts. An apparent “freezing in place” of unextracted electrons and E-bursts matches the appearance of charged liquid surface hydrodynamic instabilities observed in liquid helium experiments as charge concentration and electric field increase.
Another observation relates to detector designs where the active surface area is surrounded by insulating PTFE. It appears that more trapped charges result in the rate of delayed single-electron emission rising and multi-electron emission decreasing (at least relative to single-electron events). Surface-trapped electrons and impurities can form microscopic clusters (like charged water micro-droplets), and such clusters can leave liquid into gas in a strong electric field. In the gas phase, these clusters can evaporate/ release free electrons- which will look like single-electron events. Having a surface-trapped charge population could be suppressing signal extraction efficiency due to a loss mechanism that transfers signal electron kinetic energy to wave-like perturbations of the charged surface; when signal electron loses kinetic energy near the surface, it will not leave the liquid.
If these assumptions are correct, design changes to suppress charge accumulation at the liquid surface should ensure that low energy signals are extracted with high efficiency broadening the physics reach of G3 experiments. Additionally, a decrease in impurities level from ppb to ppt level should suppress delayed emission events rate in the next (G3) generation of dark matter detectors.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-864739

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