Cosmic Visions Summary Document, 23 March 2017
UA'(1) Collaboration: Direct detection of dark sector dark matter via single electron counting with a liquid xenon target
To be deployed at: Sanford Underground Research Facility (SURF)
Collaborating Institutions: LBL, LLNL, SLAC*, Brown* (*indicates foreseen)
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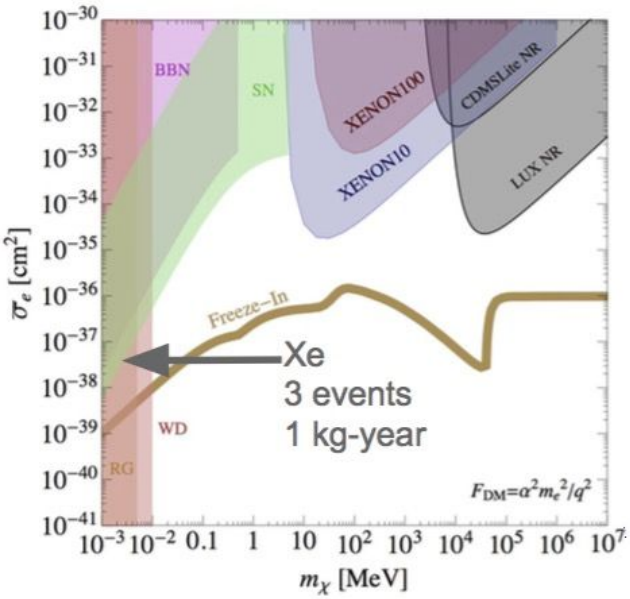
Primary Physics Goals.- Direct detection of dark sector dark matter via counting single to few electron ionization events in a liquid xenon target. The only existing limits on this class of dark matter are from the XENON10 experiment, which was background limited. A primary goal of this experiment is to understand and mitigate the electron backgrounds in this class of detector. Such mitigation R&D needs to happen in a small (10 kg scale target), flexible test bed and studies ultimately need to be carried out underground due to the long lifetime of trapped electrons at the liquid xenon surface. While this experiment is expected to be sensitive to new parameter space, success in mitigation of electron backgrounds would be a great success on it's own, because it could enable much larger detectors (e.g. LZ) to perform far more sensitive searches for this class of dark matter.

Summary of experimental approach.- Liquid xenon TPC are a fairly mature technology for dark matter search. We know how to build these detectors, but the proposed experiment will operate in a distinct "S2-only" or electron-only mode. The reason for pursuing this mode of operation is the tantalizing single electron sensitivity. The pitfalls of this mode of operation are extreme sensitivity to electron backgrounds. Two test beds (at LBL and LLNL) already exist and are exploring sources and mitigations of single-to-few electron backgrounds. The proposed experiment builds on these efforts, with a graceful scaling of approximately a factor x10 in target mass coupled with underground deployment. Several mechanisms and possible mitigations for the electron backgrounds have been identified by the LBL and LLNL groups. Once confirmed, the mitigations will be incorporated into the 10 kg scale detector for underground deployment.

Summary of existing and future physics results.- The potential reach of the proposed 10 kg UA'(1) detector is about 10^{-38} cm^2, as indicated in the figure. This is a benchmark scenario in which the dark photon is much lighter than the dark matter. Interesting parameter space would also be probed if the dark photon were heavy with a maximum sensitivity of about 10^{-39} cm^2, cf. arXiv:1608.08632 (Fig. 13). THese projections assume successful mitigation of backgrounds and one year of search time. A 10 kg liquid xenon target will have comparable sensitivity to a 100 g silicon target, assuming comparable backgrounds.



Timescale of Future Plans.-
Year 1. Surface small prototype studies to determine and minimize few-electron noise (this work has already begun)
Year 2. Surface R&D continues, also design and build O(10) kg liquid xenon TPC based on prototype for underground deployment
Year 3. Deploy at SURF, commission and obtain first results.
Result 1: Search presently unexplored dark sector parameter space.
Result 2: Significant insight into nature and mitigation of few-electron backgrounds, leading to favorable influence on either construction or operation of G3 experiments. Leads to otherwise unreachable sensitivity to few electron events and thus dark sector parameter space.