Direct Detection of Dark Matter: Developing an Experimental Test System for the LZ Experiment

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Introduction

Fig 1. The Bullet Cluster [1]

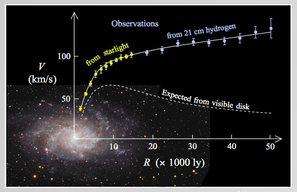


Fig. 2. Galaxy Rotation Curve [2]

As data from Cosmology (CMB anisotropies, BBN, SNe etc.) indicates that only 20% of the mass density of the Universe is composed of ordinary matter (Fig. 1-3), there is a clear scientific motivation to understand the remaining 80% of matter, dark matter. The LUX-Zeplin (LZ) experiment, an international collaboration's efforts to directly detect the nature of dark matter, focuses on the detection of predicted Weakly Interactive Massive Particles or WIMPS, a leading dark matter candidate. The research presented here focuses on the design, construction, and development of the Student Test Vessel (STV). The STV is an experimental testing system built to allow the optimization of various technical systems of the larger LZ system, including the cooling, sensing, camera, and weir systems.

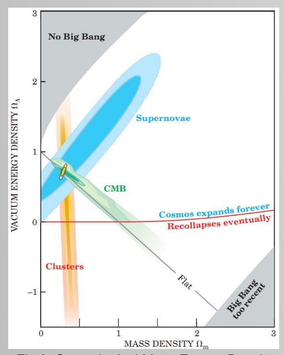
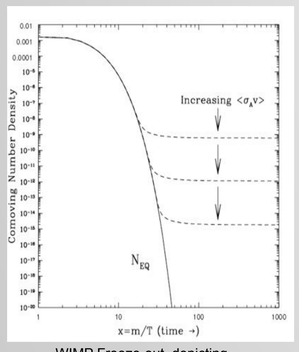
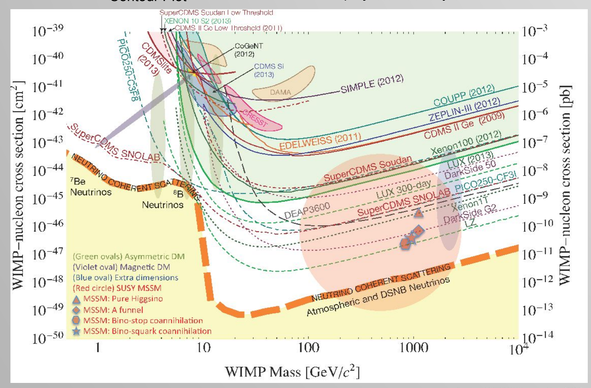


Fig 3. Cosmological Mass Energy Density Contour Plot

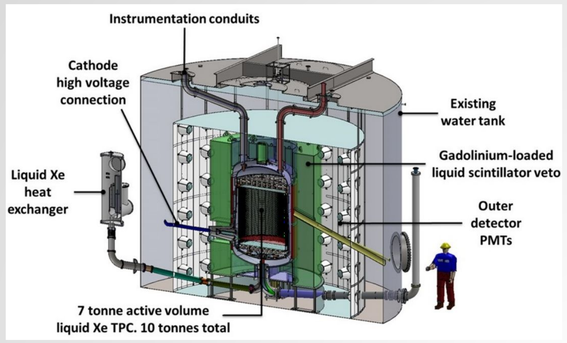


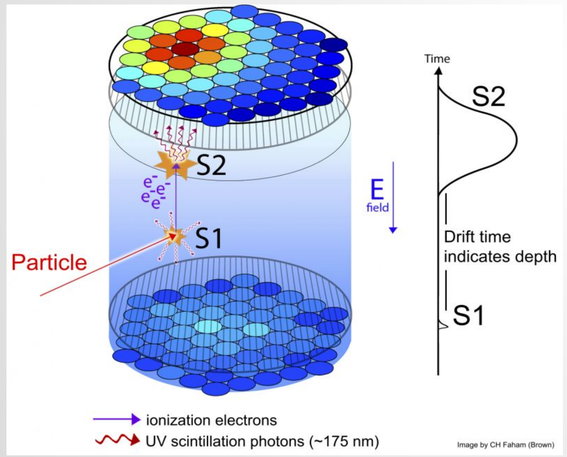
WIMP Freeze-out, depicting projected density of WIMPs [3]

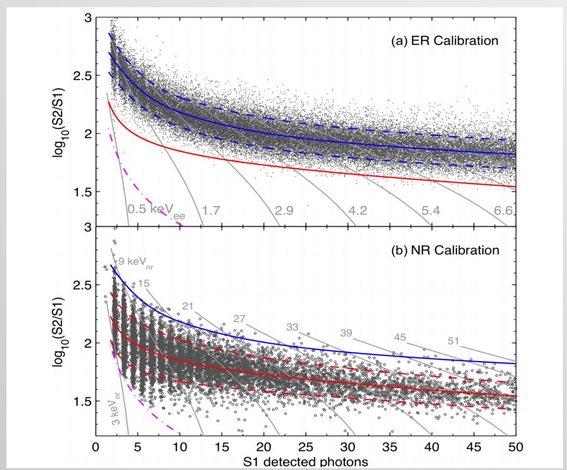


Courtesy: SNOWMASS Summer Study (2017)

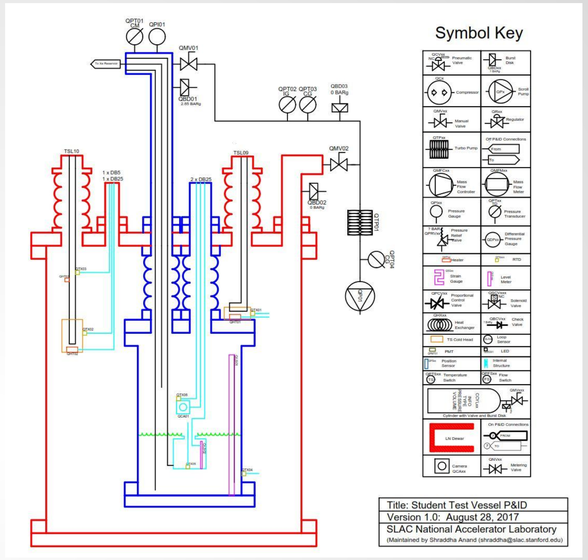
LZ Methodology







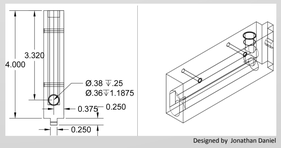
STV Methodology



The Student Test Vessel (STV) is a cryostat system that consists of an inner gas/liquid vessel (dark blue) and an outer insulating vacuum vessel (red) similar to the LZ experiment. Simulating a simplified version of the LZ experiment allows for access to a more controlled environment that can be used to conduct short-term developmental projects.

STV Objectives

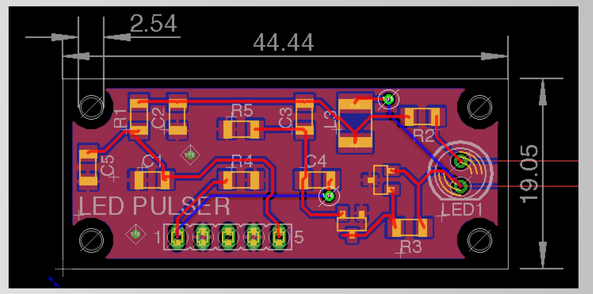
- Determine whether a standard CCD camera can sustain liquid Xe temperatures without degrading and contaminating the Xe sample.
- Record visual clips of liquid Xe flowing at the weir in order to optimize the lip of the LZ TPC. The ideal design would be such that the uniformity of the liquid surface and thus the stability of the high voltage electric field is maximized.
- Develop thermosyphon cold-heads to establish optimal geometries and heat-load limits for various research needs.



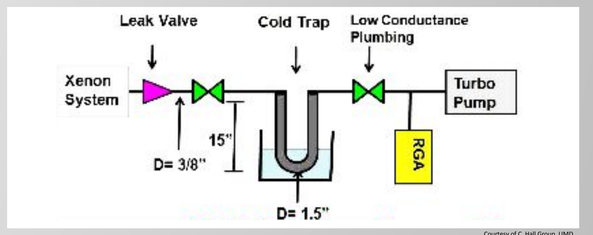
Designed by Jonathan Daniel

Other Developmental Work

In addition to developing the STV, other developmental work was conducted in the interest of assisting the various endeavours of the SLAC National Accelerator Laboratory LZ R&D Team. This included the design and construction of photomultiplier tube testing circuit boards shown below, to emit a single photon akin to a single photon released by a dark matter event.



The Sampling System shown below consists of a cold trap at < 80 K that is used to freeze the Xenon incoming through the leak valve, while the impurities such as N, O, He, Kr etc. travel through the low conductance plumbing to the Residual Gas Analyzer (RGA). The RGA analyzes the levels of the various impurities and the run through the cold trap helps clean the Xe.



Courtesy of C. Hall Group, UMD

Acknowledgements

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Image courtesy of Matt Gifford

References

[1] Courtesy of the Chandra X-Ray Observatory

[2] Freeman, Kenneth C. "On the disks of spiral and S0 galaxies." *The Astrophysical Journal 160* (1970): 814.

[3] Jungman, Gerard, Marc Kamionkowski, and Kim Griest. "Supersymmetric dark matter." Physics Reports 267.5-6 (1996): 195-373.