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Seasonal Variation of Dark Matter Signals in the LZ Experiment and for a Proposed DUNE Low-Background Module at Sanford Lab

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Despite the lack of direct evidence, there is already an abundance of indirect evidence that points to a non-luminous new form of matter that exists in significant quantities throughout our universe. The theory of Weakly Interacting Massive Particles (WIMPs) provides an attractive new candidate particle for dark matter. It describes a relatively heavy electrically-neutral particle that only interacts through gravity and via the weak nuclear force. WIMPs would describe a halo of gaseous-like dark matter surrounding galaxies which would also solve the anomalous galactic rotation velocities of stars observed in all galaxies. Due to the rotation of our galaxy our own solar system experiences an induced "WIMP wind"if passing through such a dark matter distribution, which features a Maxwell-Boltzmann velocity distribution. We hope to either discover or refute WIMPs with the LUX-ZEPLIN (LZ) detector located at the Sanford Underground Research Facility (SURF). The LZ detector is an ultra-quiet dual-phase liquid xenon Time Projection Chamber (TPC) which will be used to acquire about three years worth of data. A potentially critical tool to differentiate WIMPs from other dark matter candidates and/or background is that due to the rotation of Earth around the Sun, there would be a seasonally changing detection rate with a unique signature for the WIMP dark matter compared to radioactive background contributions. With this in mind, a well-defined annual modulation of dark matter candidate events would provide a smoking gun in discovering WIMP dark matter. Furthermore, we show that a proposed liquid argon based low-background cryostat module for the upcoming Deep Underground Neutrino Experiment (DUNE) currently offers by far the most promising seasonal variation detection that is characteristic for the nature of WIMPs.

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