Development of the Most Sensitive Dark Matter Detector with Liquid Argon

ABSTRACT

There is a wide range of observational evidence, including fluctuations in the Cosmic Microwave Background, the large-scale structure of the universe, and Big Bang nucleosynthesis, which suggests that baryonic matter only accounts for $\sim$5 % of the total mass-energy budget of the Universe, while $\sim$27 % is attributed to non-luminous but gravitationally-interacting dark matter, and the remainder to dark energy. No particle in the Standard Model satisfies these astrophysical and cosmological observations and, as of yet, no such particle has been detected in the laboratory. Dark matter is the first indisputable proof of physics beyond the Standard Model, which is our best knowledge about our universe. Its discovery would be transformational.

Direct dark matter searches look for the recoils resulting from collisions of galactic dark matters with target materials in the laboratory, which is liquid argon in our case. There is growing interest within the dark matter community in low-mass dark matter candidates that interact via couplings smaller than the weak scale. Probing the parameter space for these low-mass dark matter candidates requires detectors with exceptionally low energy thresholds and background levels. We have recently demonstrated the ability of a dual-phase liquid argon Time projection chamber (TPC) to search for such particles by exploiting the very high electron extraction efficiency and the inherent gain of the ionization signal with the DarkSide-50 detector, achieving sensitivity down to the level of a single ionized electron. A liquid argon TPC specifically built to pursue lower-energy signals by focusing on the ionization channel could realistically push the experimental sensitivity to low-mass dark matter down to the level at which irreducible background events from coherent elastic neutrino-nucleus scattering dominate the event rate.

While liquid argon TPC technology is quite mature, there are several outstanding technical issues that need to be addressed prior to fielding a dual-phase liquid argon TPC optimized for a low-mass DM search.

This project addresses the reduction of backgrounds and improving the detection sensitivity in three ways: (i) by reducing the impurities in the target material, LAr, (ii) by reducing radioactivities in silicon photo-multiplier based photo detector, (iii) by improving the knowledge of liquid argon response.