# Abstract

Advancements in the field of astroparticle physics have always hinged on the development of sensitive experiments to detect elusive natural phenomena. Despite many evidence spanning diverse cosmological scales substantiating the *existence* of dark matter, its *nature* i.e. its particle physics properties, remains undetermined. As a result, a concerted effort is underway to detect Weakly Interacting Massive Particles (WIMPs), one of the leading dark matter candidates, by employing various detection technologies. These systems are designed to detect very low energy deposits resulting from the direct interaction of WIMPs with the target material of the experiment, e.g. liquefied noble gases or solid crystals.

The pursuit has already narrowed down the parameter space of WIMPs with masses around $\mathcal{O}(10\,\mathrm{GeV/c^2})$ and cross-sections of $\mathcal{O}(10^{-45}\,\mathrm{cm^2})$. Presently, the research is progressing towards lower masses of $\mathcal{O}(1\,\mathrm{GeV/c^2})$. For liquid argon (LAr) detectors, this entails less energetic recoils i.e. the sensitivity requirement transitions from $20 - 100\,\mathrm{keV}$ to $\mathcal{O}(1\,\mathrm{keV})$.

To probe this low-mass range, it is crucial to accurately characterize the LAr response to low-energy nuclear recoils (NRs). This dissertation provides a comprehensive overview of the work carried out using the ReD experiment to measure NRs in an LAr time projection chamber (TPC), with a focus on examining the ionization yield down to $1 - 2\,\mathrm{keV}_{nr}$. A thorough understanding of this response is of fundamental importance for optimizing the sensitivity of both current and next-generation LAr-based detectors employed in rare-event searches such as dark matter detection.

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