Abstract

The quest to understand the elusive nature of dark matter, a substantial constituent of the universe, continues to be a fundamental challenge in modern physics and cosmology. This thesis delves into the intricate world of dark matter search, with a specific focus on two intriguing aspects: inelastic boosted dark matter (iBDM) and low-mass dark matter, particularly low-mass Weakly Interacting Massive Particles (WIMPs). Cutting-edge liquid argon detectors offer a unique and sensitive platform for the detection of these elusive particles.

The prevailing cosmological evidence for dark matter's existence, combined with its substantial gravitational influence on galaxies and galaxy clusters, suggests a non-baryonic nature. One of the leading candidates for dark matter is WIMPs, hypothesized to be weakly interacting, electrically neutral particles with a mass potentially spanning a wide range.

Low mass WIMPs, characterized by masses in the sub-GeV to GeV range, have gained significant attention in recent years due to their potential to address several outstanding issues while constituting a new frontier ready to be explore by experiments. To detect low-mass dark matter and iBDM, this thesis leverages the unique capabilities of two liquid argon detectors, DEAP-3600 and DarkSide-50.

Liquid argon, due to its low energy threshold, background mitigation potential and scalability, offers an ideal medium for the detection of low-energy recoils produced by interactions between dark matter particles and atomic nuclei or electrons. The thesis explores operation of these detectors in detail, highlighting their capacity to capture rare and low-energy events.

One of the central components of this research lays in the challenges and intricacies associated with low-mass dark matter detection, such as mitigating background noise. It explores novel analysis techniques and statistical approaches to enhance the sensitivity of the liquid argon detectors for low-mass WIMP searches. We have successfully investigated the energy range reaching a threshold as low as 0.04 keV, which is the lowest yet examined in an annual search for dark matter modulation. No modulation signal was identified in any of the analysed intervals. The level of significance associated with this outcome is inadequate to definitively validate or dismiss the DAMA/LIBRA finding. Nonetheless it proves liquid argon efficiency in this endeavor, and provided with sufficiently long data taking and stability, the potential for future detectors to achieve leading sensitivity.

In addition to low mass WIMPs, the thesis investigates inelastic boosted dark matter as a novel and less explored candidate. Inelastic dark matter models propose particles with mass splitting between their ground state and excited state, enabling them to kinetically access higher-energy interactions. This unique property may have profound implications for both cosmology and particle physics. The study discusses the potential astrophysical signatures

and detection strategies for inelastic boosted dark matter, emphasizing their distinctive features compared to standard WIMP scenarios.

In conclusion, this thesis provides a broad overview of dark matter phenomena, with a primary focus on low mass WIMPs and inelastic boosted dark matter. Through a blend of theoretical discussions and experimental prospects, it underscores the role of these candidates in unraveling the mysteries of the dark universe. The quest to understand dark matter remains a vibrant and evolving field, offering exciting opportunities to further our comprehension of the fundamental constituents of the Universe.