Pulse Shape Discrimination of low-energy nuclear and electron recoils in NaI:Tl for dark matter direct-detection

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One of the greatest unsolved mysteries of modern physics is the nature of dark matter, with Weakly Interacting Massive Particles (WIMPs) being a strongly motivated dark matter candidate. WIMP direct-detection experiments search for WIMP interactions in excess of known backgrounds. To date, standard WIMP assumptions have been ruled out by most direct-detection experiments, with the exception of DAMA, which uses NaI:Tl crystals. This has motivated other NaI:Tl-based direct-detection experiments, as model-independent tests of DAMA. SABRE (Sodium-Iodide with Active Background REjection) is a direct-detection experiment aiming to achieve a high sensitivity to clarify the signal claimed by DAMA.

WIMPs are expected to scatter off nuclei to produce measurable nuclear recoils, while most background events such as gamma rays will scatter off atomic electrons to produce electron recoil events. Identification and classification of recoil events is important for improving SABRE's sensitivity for direct-detection of dark matter. Different particle types are identified through the analysis the of pulse shapes, with current Pulse Shape Discrimination (PSD) studies in NaI:Tl crystals generally limited to considering mean pulse decay times. In this work, new PSD approaches are developed, with a likelihood approach in conjunction with a conventional decay time metric shown to improve discrimination power compared to previous NaI:Tl-based PSD approaches. Additionally, Machine Learning is explored as an avenue for improvement in a low-energy regime, where extraction of subtle features becomes increasingly important for classification. The application of this improved PSD approach is expected to increase the sensitivity of the SABRE experiment to WIMP events. Details of the new methods and a framework for incorporating these approaches into the SABRE analysis will be discussed.