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Characterization of argon recoils at the keV scale with ReD and ReD+

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Dual-phase liquid argon time projection chambers (LAr TPCs) are widely used in the direct search for weakly interacting massive particles (WIMPs), traditionally targeting masses of the order of 100 GeV. Future-generation LAr TPCs aim to extend this search towards lower WIMP masses, down to the GeV scale. In this regime, WIMP interactions are expected to produce nuclear recoils (NRs) in liquid argon with energies of only a few keV, where the detector response is still not fully characterized. To address this challenge, the Recoil Directionality (ReD) experiment was developed within the DarkSide-20k Collaboration to produce and characterize few-keV nuclear recoils in liquid argon. A compact dual-phase LAr TPC was irradiated with neutrons from a ^{252}Cf source, producing argon nuclear recoils through neutron scattering. A downstream spectrometer consisting of 18 plastic scintillators detected neutrons scattered by argon nuclei, enabling the recoil energy to be reconstructed through two-body kinematics. This technique allowed the ionization yield of liquid argon, Q_y , defined as the number of electrons produced per unit energy deposition, to be measured in a model-independent manner down to 2 keV. The measured Q_y is found to be consistent with existing measurements at higher recoil energies, while showing an increase towards lower energies. These results provide new experimental constraints on the modeling of low-energy nuclear recoils in liquid argon and are particularly relevant for the interpretation of Dark Matter searches in the low-mass WIMP regime. In this contribution, an overview of the ReD experiment and its measurement technique will be presented, together with the main results of the published measurement. Finally, the impact of the improved characterization of the argon response on the sensitivity of the upcoming DarkSide-20k experiment will be discussed, highlighting the enhanced discovery potential for low-mass Dark Matter candidates.

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