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Invited : Emission of Single and Few Electrons in XENON1T and Limits on Light Dark Matter

Double-phased LXe TPCs, are characterized by an exceptional sensitivity for the detection of small charge signals, derived from the ionization of xenon atoms, down to the level of one electron. These detectors are sensitive to the inelastic quantum processes occurring at the atomic level and, *par excellence*, to the ionization process of even a single atom. Nevertheless, delayed single and few-electron backgrounds are emerging as a major instrumental background in LXe TPCs. These electron-trains appear to derive from a multitude of quantum processes in the atomic level of LXe, for many yet unknown reasons. This instrumental background is dominant for the search of leptonically interacting dark matter particles with mass in the sub-GeV scale, emerging in the framework of so-called,"hidden sector" theories, predicting a leptophilic DM with a mass in $\mathcal{O}$(MeV), that could interact with atomic electrons of the target causing inelastic atomic processes, such as ionization.

Since the origin delayed electron backgrounds remains unknown, a model accurately describing their phenomenology is missing. In this work, based on the data of the XENON1T detector, we investigate their origin as well as their basic spatial and temporal characteristics. The observed intensity of delayed electron backgrounds shows that the resulting emissions are correlated, in time and position, with high-energy events preceding them even for time intervals of $\mathcal{O}$(ms). This empirical knowledge allows us to select volumes and times in the detector when the rate of correlated delayed electron emission is minimal in order to perform a low-background search for DM. This allows us to push our analysis threshold down to a single detected electron, thereby extending previous S2-only searches to lower masses.

After removing the correlated backgrounds, we observe rates < 30 events/(electron $\cdot$ kg $\cdot$ day) in the region of interest spanning 1 to 5 electrons. We derive 90% C.L. upper limits for dark matter-electron scattering, direct detection limits on the electric dipole, magnetic dipole, and anapole interactions, and bosonic dark matter models, excluding new parameter space for dark photons and solar dark photons.

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