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Prospects for dark matter detection with inelastic transitions of xenon

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Dark matter can scatter and excite a nucleus to a low-lying excitation in a direct detection experiment. This signature is distinct from the canonical elastic scattering signal because the inelastic signal also contains the energy deposited from the subsequent prompt de-excitation of the nucleus. A measurement of the elastic and inelastic signal will allow a single experiment to distinguish between a spin-independent and spin-dependent interaction. For the first time, we characterise the inelastic signal for two-phase xenon detectors in which dark matter inelastically scatters off the Xe-129 or Xe-131 isotope. We do this by implementing a realistic simulation of a typical tonne-scale two-phase xenon detector and by carefully estimating the relevant background signals. With our detector simulation, we explore whether the inelastic signal from the axial-vector interaction is detectable with upcoming tonne-scale detectors. We find that two-phase detectors allow for some discrimination between signal and background so that it is possible to detect dark matter that inelastically scatters off either the Xe-129 or Xe-131 isotope for dark matter particles that are heavier than approximately 100 GeV. If, after two years of data, the XENON1T search for elastic scattering nuclei finds no evidence for dark matter, the possibility of ever detecting an inelastic signal from the axial-vector interaction will be almost entirely excluded.

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