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Unlocking the Inelastic Dark Matter Window with Vector Mediators

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Despite robust cosmological and astrophysical evidence for the existence of non-baryonic Dark Matter (DM), its microscopic nature remains a mystery. Among the several possible scenarios, light DM candidates thermally produced in the early Universe are especially interesting, as they are both theoretically motivated and experimentally accessible. In this context, inelastic dark matter (iDM) models offer a compelling framework, since they can avoid cosmological bounds as well as indirect and direct detection searches. While most literature assume a secluded dark photon mediator, in this work we investigate the broader case of general vector mediators that can couple directly to baryon and lepton numbers. Notably, in scenarios involving couplings to lepton number, interactions with neutrinos open new invisible decay channels for the heavier dark fermion state, allowing the mass splitting to drop below the standard electron mass threshold. Besides, the neutrino decay modes significantly impact the cosmological evolution —by modifying kinetic equilibration and depletion rates —and alter experimental signatures —by shortening decay lengths and enhancing invisible signals. We demonstrate that such models, particularly those based on anomaly-free gauge groups with non-universal lepton couplings, open new windows of thermal DM parameter space previously unexplored by experiments. We also provide a numerical Python library to compute the relic densities for user-defined gauge charges.

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