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Simulation Study of Scalar and Fermionic Dark Matter Production via Dark Photons at DUNE

Dark photons, denoted by A', provide a well-motivated portal between the Standard Model and a dark sector containing light dark matter. In fixed target experiments such as the Deep Underground Neutrino Experiment (DUNE), dark photons can be produced through meson decays and subsequently decay into dark matter particles, which may scatter off electrons in the detector. The phenomenology of these processes depends on the spin of the dark matter candidate.

This work presents a Monte Carlo simulation study comparing the production and detection of scalar ($s = 0$) and fermionic ($s = 1/2$) dark matter in a dark photon beam-dump scenario at DUNE. The simulations are performed using the MadDump framework, considering dark photon production through neutral meson decays, in particular $\pi^0, \eta \to \gamma A'$, followed by the invisible decay $A' \to \bar{\chi}\chi$. The resulting dark matter flux is propagated near the detector liquid argon cube, where dark matter–electron scattering is simulated. The two dark matter scenarios are studied under common choices of the dark photon and dark matter masses and dark-sector couplings, allowing differences in the predicted event distributions to be attributed to the spin of the dark matter candidate.

The study focuses on characterizing the impact of the dark matter spin on the observable phenomenology of the process. In particular, the electron recoil energy and angular distributions, as well as the resulting event rates, are compared between scalar and fermionic dark matter scenarios. By combining the contributions from different meson production channels, this analysis aims to explore the extent to which the spin of the dark matter candidate can influence the expected signal at DUNE and to identify potentially distinguishable features between the two scenarios.

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