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Discovering Dark Matter with Ionization: DM-Electron Scattering versus the Migdal Effect

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There are currently several existing and proposed experiments designed to probe sub-GeV dark matter (DM) using electron ionization in various materials. The projected signal rates for these experiments assume that this ionization yield arises only from DM scattering directly off electron targets, ignoring secondary ionization contributions from DM scattering off nuclear targets. In this work we investigate the validity of this assumption and show that if sub-GeV DM couples with comparable strength to both protons and electrons, as would be the case for a dark photon mediator, the ionization signal from atomic scattering via the Migdal effect scales with $^2(/)^{22}$ where is the mass of the target nucleus and is the 3-momentum transferred to the atom. The result is that the Migdal effect is always subdominant to electron scattering when the mediator is light, but that Migdal-induced ionization can dominate over electron scattering for heavy mediators and DM masses in the hundreds of MeV range. We put these two ionization processes on identical theoretical footing, address some theoretical uncertainties in the choice of atomic wavefunctions used to compute rates, and discuss the implications for DM scenarios where the Migdal process dominates, including for XENON10, XENON100, and the recent XENON1T results on light DM scattering.

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