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Precise predictions and new insights for atomic ionisation from the Migdal effect

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The scattering of neutral particles by an atomic nucleus can lead to electronic ionisation and excitation through a process known as the Migdal effect. We revisit and improve upon previous calculations of the Migdal effect, using the Dirac-Hartree-Fock method to calculate the atomic wavefunctions. Our methods do not rely on the use of the dipole approximation, allowing us to present robust results for higher nuclear recoil velocities than was previously possible. Our calculations provide the theoretical foundations for future measurements of the Migdal effect using neutron sources, and searches for dark matter in direct detection experiments. We show that multiple ionisation must be taken into account in experiments with fast neutrons, and derive the semi-inclusive probability for processes that yield a hard electron above a defined energy threshold. We present projections for the capabilities of future liquid noble element-based detectors doped with hydrogen in order to increase their reach at low dark matter masses.

Primary author: Prof. DOLAN, Matthew (University of Melbourne)

Co-author: Dr COX, Peter (The University of Melbourne)

Presenter: Prof. DOLAN, Matthew (University of Melbourne)

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