The Light Dark Matter eXperiment

The search for non-gravitational interactions of dark matter has been framed by several ideas that encourage a focus on MeV to TeV mass scales. The thermal freeze-out mechanism, an elegant and quantitatively successful explanation for the origin and abundance of dark matter, strongly motivates this mass range. The origin of electroweak symmetry breaking points to new weak-scale physics, of which dark matter could be an important component. Finally, familiar stable matter resides in the lower half of this mass range, motivating searches for dark matter of comparable mass.

The WIMP paradigm is an elegant embodiment of these ideas, but the simplest scenarios and the weak-scale physics behind them, such as supersymmetry, are now disfavored by direct and indirect detection limits and LHC results. Hidden sector dark matter, coupled to normal matter by a new force, is another simple realization of thermal dark matter, which naturally extends the viable mass range into the sub-GeV region. Hidden sectors, which are common in theories of new weak-scale physics, minimally contain a new particle charged under a single Standard-Model-like force carrier, which may arise from weak-scale new physics and yet be significantly lighter. This new force has several attractive implications: it provides a natural explanation for the stability of dark matter, mediates interactions with the Standard Model, and realizes the thermal relic paradigm over the MeV to GeV mass range.

Searches for light hidden sectors can be sensitive to the force mediators, as well as to the dark matter itself. Accelerator-based fixed target searches employing the missing-momentum technique, such as the Light Dark Matter eXperiment (LDMX), are particularly comprehensive probes of hidden sector physics. In the simplest and most predictive hidden sector scenarios, those with dark matter annihilating through a light vector mediator, LDMX has the sensitivity to definitively explore thermal relic dark matter over most of the MeV to GeV range, and can also measure key properties of the mediator. In contrast, non-relativistic scattering cross sections can be velocity- or loop- suppressed, leading to thermal relic signals as much as twenty orders of magnitude below the sensitivity of current direct detection experiments. Furthermore, LDMX has the sensitivity to probe a broad range of light weakly-coupled physics beyond dark matter.

The figure below left illustrates the comprehensive capability of LDMX to confront the low-mass thermal relic hypothesis. LDMX employs a low current 4 to 8 GeV high-repetition-rate electron beam, from, for example, the proposed SLAC DASEL beamline. The dark force carrier is produced via dark bremsstrahlung in the interaction of the electron beam with a thin target. The experimental signature is a soft wide-angle scattered electron and missing energy. The detector, shown below right, is composed of a tracker surrounding the target, to measure each incoming and outgoing electron individually, and a fast hermetic calorimeter system capable of sustaining an $\mathcal{O}(100)$ MHz rate while vetoing low-multiplicity Standard Model backgrounds. LDMX leverages mature and developing detector technologies and expertise from the HPS and CMS experiments to achieve the required detector performance to discover light dark matter.