Dark Matter Searches at Future Colliders: The Unique Reach of the Muon Collider

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Colliders provide a unique window into the search for the particle nature of dark matter (DM) as the only known way to create DM in a controlled manner. Past searches for DM at both the Tevatron and LHC have primarily focused on EFT models as well as simplified models and have yet to yield any positive results. Future LHC runs are unlikely to offer considerably greater phase space for these searches. The authors of this LOI, who have been involved in building DM models and searching for them at the LHC, will study how future colliders can greatly extend the reach of collider DM searches. In particular, high-energy muon colliders, with center-of-mass energies upwards of 30 TeV, provide a unique combination of initial state knowledge and high energy. Model-independent searches for DM can be performed, relying on balancing missing energy with initial state objects, with a far greater sensitivity than at a hadron collider due to the improved missing energy resolution [1]. High-mass resonance searches can also find direct evidence for mediators coupling to dark matter with significantly higher sensitivity at a high-energy muon collider than what is achievable at the LHC [2]. While the phase space for electroweak WIMPs has closed considerably due to experimental results, a pure higgsino scenario remains elusive and difficult to discover by current collider and direct detection experiments; muon colliders would have considerably more reach, including to thermal relic higgsinos [3].

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