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Exploring the $U(1)_{L_\mu - L_\tau}$ Solution to the Muon's Anomalous Magnetic Moment Using Future Experimental Probes

The first results from the Muon $g-2$ experiment at Fermilab have strengthened hints of exciting new physics in the leptonic sector. Among the different models that can account for this anomaly, the addition of a $U(1)_{L_\mu - L_\tau}$ gauge symmetry to the SM is a particularly elegant explanation, introducing a so-called hidden photon, but not requiring any additional fermionic content. Driven by its simplicity, we outline a strategy for exploring the $(g-2)_\mu$ solution of the $U(1)_{L_\mu - L_\tau}$ parameter space using future experimental probes.

In particular, we focus on the muon fixed-target experiment NA64μ, experiments measuring coherent elastic neutrino-nucleus scattering at spallation sources, and multi-ton liquid xenon dark matter direct detection experiments. We find that each of these experiments can bring a unique piece of the puzzle to this search, allowing us to exploit their complementarity in a combined analysis and to pin down the nature of the $U(1)$ model.

Finally, we look at how the future-generation dark matter direct detector DARWIN could make a 5σ discovery of the $U(1)_{L_\mu - L_\tau}$ hidden photon. We show that, with realistic enhancements to its projected experimental configuration, DARWIN could be in a position to make this discovery in the low-mass region of this model's $(g-2)_\mu$ solution.

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