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Probing Reheating through Dark Matter Freeze-Out at Lepton Colliders

We explore the potential of future lepton colliders to shed light on the reheating era through the detection of dark matter (DM) that undergoes freeze-out during this phase of the Universe. In this framework, DM interacts with the Standard Model (SM) primarily via leptophilic effective operators, exhibiting highly suppressed couplings to quarks and gluons, consistent with the null results from LHC and direct searches. Departing from conventional WIMP scenarios, we consider the freeze-out to occur amid a prolonged reheating phase driven by inflaton decay. The ensuing entropy production modifies the thermal history, rendering the relic abundance sensitive to reheating dynamics. We perform a detailed signal–background analysis for mono-Higgs plus missing energy signatures at future lepton colliders, considering both polarized and unpolarized beams. Our analysis shows that collider observations, combined with cosmological constraints, can provide indirect information on the reheating temperature and the early thermal history of the Universe.

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