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Collider and CMB complementarity of leptophilic dark matter with light Dirac neutrinos

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We study the discovery prospects of leptophilic dark matter (DM) in future lepton colliders by considering the light neutrinos to be of Dirac type. Adopting an effective field theory (EFT) approach, we write down dimension six operators connecting the standard model (SM) fields, light Dirac neutrinos and DM. Considering DM relic to be generated via the thermal freeze-out, we check the discovery prospects at future lepton colliders via mono-photon plus missing energy searches. The right chiral parts of light Dirac neutrinos get thermalised due to their interactions with the bath as well as leptophilic DM, leading to enhanced effective relativistic degrees of freedom $N_{\rm eff}$ within reach of future cosmic microwave background (CMB) experiments. The interplay of existing bounds from cosmological observations related to DM relic and $N_{\rm eff}$, direct and indirect detection of DM, astrophysics, and collider observations leave promising discovery prospects at future electron and muon colliders along with complementary signatures at future CMB experiments. Our findings indicate that ν_R coupling to all SM fermions excludes all accessible parameter space while restricting ν_R interactions to specific SM fermions or DM alone opens up more viable regions within reach of future lepton colliders.

Author: Dr BORAH, Debasish (Indian Institute of Technology Guwahati)

Co-authors: THACKER, Bhavya (Indian Institute of Technology Guwahati); DAS, Nayan (Indian Institute of Technology, Guwahati); Mr JAHEDI, Sahabub (Indian Institute of Technology, Guwahati)

Presenter: THACKER, Bhavya (Indian Institute of Technology Guwahati)

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