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Machine Learning Analysis for Dark Matter Detection via Photon Signatures at the LHC

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The search for weakly interacting massive particles (WIMPs) remains a central goal of the High Luminosity Large Hadron Collider (HL-LHC). In this work, we explore radiative neutralino decays within the framework of the Z_3-invariant Next-to-Minimal Supersymmetric Standard Model (NMSSM), focusing on scenarios where the lightest supersymmetric particle (LSP) is a singlino-dominated neutralino. In this setting, the correct dark matter relic density can be achieved through coannihilation with higgsino- or bino-like states, while also evading current direct detection bounds via blind spot conditions. In particular, in singlino–higgsino coannihilation scenarios, radiative decays of the heavier neutralinos into the singlino LSP and a photon can be significantly enhanced, motivating dedicated searches at the HL-LHC. These decays yield challenging final states characterized by a soft photon, a lepton, and large missing transverse energy, typically accompanied by a hard initial-state radiation jet. We investigate the HL-LHC sensitivity to such signatures by employing both cut-based and machine learning (ML) analysis techniques. Our results demonstrate that the use of ML classifiers significantly improves the discrimination power against Standard Model backgrounds, offering promising discovery potential in this well-motivated dark matter scenario

Secondary track

T16 - AI for HEP (special topic 2025)

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