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Dark Matter searches with photons at the LHC

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We unveil blind spot regions in dark matter (DM) direct detection (DMDD), for weakly interacting massive particles with a mass around a few hundred GeV that may reveal interesting photon signals at the LHC. We explore a scenario where the DM primarily originates from the singlet sector within the Z_3-symmetric Next-to-Minimal Supersymmetric Standard Model (NMSSM). A novel DMDD spin-independent blind spot condition is revealed for singlino-dominated DM, in cases where the mass parameters of the higgsino and the singlino-dominated lightest supersymmetric particle (LSP) exhibit opposite relative signs (i.e., $\kappa < 0$), emphasizing the role of nearby bino and higgsino-like states in tempering the singlino-dominated LSP. Additionally, proximate bino and/or higgsino states can act as co-annihilation partner(s) for singlino-dominated DM, ensuring agreement with the observed relic abundance of DM. Remarkably, in scenarios involving singlino-higgsino co-annihilation, higgsino-like neutralinos can distinctly favor radiative decay modes into the singlino-dominated LSP and a photon, as opposed to decays into leptons/hadrons. In exploring this region of parameter space within the singlino-higgsino compressed scenario, we study the signal associated with at least one relatively soft photon alongside a lepton, accompanied by substantial missing transverse energy and a hard initial state radiation jet at the LHC. In the context of singlino-bino co-annihilation, the bino state, as the next-to-LSP, exhibits significant radiative decay into a soft photon and the LSP, enabling the possible exploration at the LHC through the triggering of this soft photon alongside large missing transverse energy and relatively hard leptons/jets resulting from the decay of heavier higgsino-like states.

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