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Dark Matter Signals at the LHC from a 3HDM

We analyse new signals of Dark Matter (DM) at the Large Hadron Collider (LHC) in a 3-Higgs Doublet Model (3HDM) where only one doublet acquires a Vacuum Expectation Value (VEV), preserving a parity Z2. The other two doublets are inert and do not develop a VEV, leading to a dark scalar sector controlled by Z2, with the lightest CP-even dark scalar H1 being the DM candidate. This leads to the loop induced decay of the next-to-lightest scalar, H2⟶H1ff (f=u,d,c,s,b,e,μ,τ) , mediated by both dark CP-odd and charged scalars. This is a smoking-gun signal of the 3HDM since it is not allowed in the 2HDM with one inert doublet and is expected to be important when H2 and H1 are close in mass. In practice, this signature can be observed in the cascade decay of the SM-like Higgs boson, h⟶H1H2⟶H1H1ff into two DM particles and di-leptons/di-jets, where h is produced from either gluon-gluon Fusion (ggF) or Vector Boson Fusion (VBF). However, this signal competes with the tree-level channel qq⟶H1H1Z*⟶H1H1ff . We devise some benchmarks, compliant with collider, DM and cosmological data, for which the interplay between these modes is discussed. In particular, we show that the resulting detector signature, with missing energy and invariant mass of ff much smaller than mZ , can potentially be extracted already during Run 2 and 3. For example, the H2 ⟶ H1γ* and γ* ⟶ e+e− case will give a spectacular QED mono-shower signal.

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