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A Smoking Gun signature of 3HDM

We analyze new signals of a 3-Higgs Doublet Model (3HDM) at the Large Hadron Collider (LHC) where only one doublet acquires a Vacuum Expectation Value (VEV), preserving a Z_2 parity. The other two doublets are inert and do not develop a VEV, leading to a dark
scalar sector controlled by Z_2, with the lightest CP-even dark scalar H11 being the Dark Matter (DM) candidate. This leads to the loop-induced decay of the next-to-lightest scalar, H2⟶H1$\ell\bar{\ell}$(ℓ=e,μ), mediated by both dark CP-odd neutral and charged scalars. This is a smoking-gun signal of the 3HDM since it is not allowed in the 2-Higgs Doublet Model (2HDM) with one inert doublet and is expected to be important when H22 and H11 are close in mass. In practice, this signature can be observed in the cascade decay of the SM-like Higgs boson, h⟶H1H2⟶H1H1$\ell\ell$ into two DM particles and di-leptons or h⟶H2H2⟶H1H1$\ell\ell\ell\ell$ into two DM particles and four-leptons, where h is produced from gluon-gluon Fusion. To test the feasibility of these channels at the LHC, we devise some benchmarks, compliant with collider, DM, and cosmological data, for which the interplay between these production and decay modes is discussed. In particular, we show that the resulting detector signatures, with the invariant mass of $\ell\bar{\ell}\ell\ell$ pairs much smaller than mZZ, can
potentially be extracted already from Run 3 data and at the High-Luminosity phase of the LHC.

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