

Scalars 2023

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A smoking gun signature of 3HDM

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Content :

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 parity Z_2 . 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 H_1 being the DM candidate. This leads to the loop-induced decay of the next-to-lightest scalar, $H_2 \rightarrow H_1 l \bar{l}$ ($l = e, \mu$), 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 H_2 and H_1 are close in mass. In practice, this signature can be observed in the cascade decay of the SM-like Higgs boson, $h \rightarrow H_1 H_2 \rightarrow H_1 H_1 l \bar{l}$ into two DM particles and di-leptons/di-jets or $h \rightarrow H_2 H_2 \rightarrow H_1 H_1 l \bar{l} l \bar{l}$ into two DM particles and four-leptons/four-jets where h is produced from either gluon-gluon Fusion (ggF) or Vector Boson Fusion (VBF). However, the di-lepton signal competes with the tree-level channel $q \bar{q} \rightarrow H_1 H_1 Z^* \rightarrow H_1 H_1 l \bar{l}$. We devise some benchmarks, with collider, DM, and cosmological data, for which the interplay between these modes is discussed. In particular, we show that the resulting detector signature, missing energy + $l \bar{l}$ or missing energy + $l \bar{l} l \bar{l}$ with an invariant mass of $l \bar{l}$ much smaller than m_Z , can potentially be extracted already during Run 2 and 3.

Primary authors : Dr. DEY, Atri (Postdoctoral Research Fellow)

Co-authors :

Presenter : Dr. DEY, Atri (Postdoctoral Research Fellow)

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