

Probing exotic Higgs decays to 4τ in single and di-Higgs production at the HL-LHC and FCC-hh

We study the prospects for observing exotic decays of the Standard Model (SM) Higgs boson h into light beyond the Standard Model (BSM) scalars a with mass m_a

$\lesssim m_h/2$ in the single Higgs and Higgs pair production channels at the High Luminosity run of the Large Hadron Collider (HL-LHC). Discovery prospects for single Higgs production in the gluon-gluon fusion and vector boson fusion modes with the Higgs boson decaying via the exotic mode $h \rightarrow aa \rightarrow 4\tau$ are analyzed at the HL-LHC. The projected sensitivity for exotic Higgs decays in the non-resonant Higgs pair production channel $pp \rightarrow hh \rightarrow (h \rightarrow b\bar{b})(h \rightarrow aa \rightarrow 4\tau)$ at the HL-LHC and a future $\sqrt{s} = 100$ TeV hadron collider (FCC-hh) are also estimated. Furthermore, we study HL-LHC's potential reach for the Higgs-strahlung process in the $2b4\tau$ channel, taking into account the contamination from non-resonant Higgs pair production.

Finally, the potential reach for resonant Higgs pair production in the $2b4\tau$ channel: $pp \rightarrow H \rightarrow hh \rightarrow (h \rightarrow b\bar{b})(h \rightarrow aa \rightarrow 4\tau)$ at the HL-LHC is also explored for several choices of $\{m_H, m_a\}$.

Our studies suggest that significant improvements over existing bounds are achievable in several production channels, motivating new dedicated searches for $h \rightarrow aa \rightarrow 4\tau$ at the HL-LHC and future colliders.

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