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Radiative Decays of the Higgs Boson to a Pair of Fermions

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We revisit the radiative decays of the Higgs boson to a fermion pair $h \to f\bar{f}\gamma$ where f denotes a fermion in the Standard Model (SM). We include the chirality-flipping diagrams via the Yukawa couplings at the order $\mathcal{O}(y_f^2 \alpha)$, the chirality-conserving contributions via the top-quark loops of the order $\mathcal{O}(y_t^2 \alpha^3)$, and the electroweak loops at the order $\mathcal{O}(\alpha^4)$. The QED correction is about $Q_f^2 \times calO(1\%)$ and contributes to the running of fermion masses at a similar level, which should be taken into account for future precision Higgs physics. The chirality-conserving electroweak-loop processes are interesting from the observational point of view. First, the branching fraction of the radiative decay $h \to \mu^+\mu^-\gamma$ is about a half of that of $h \to \mu^+\mu^-$, and that of $h \to e^+e^-\gamma$ is more than four orders of magnitude larger than that of $h \to e^+e^-$, both of which reach about 10^{-4}. The branching fraction of $h \to \tau^+\tau^-\gamma$ is of the order 10^{-3}. All the leptonic radiative decays are potentially observable at the LHC Run 2 or the HL-LHC. The kinematic distributions for the photon energy or the fermion pair invariant mass provide non-ambiguous discrimination for the underlying mechanisms of the Higgs radiative decay. We also study the process $h \to c\bar{c}\gamma$ and evaluate the observability at the LHC. We find it potentially comparable to the other related studies and better than the $h \to J/\psi\,\gamma$ channel in constraining the charm-Yukawa coupling.

Primary authors: Prof. HAN, Tao (Univ. of Pittsburgh); WANG, Xing (University of Pittsburgh)

Presenter: WANG, Xing (University of Pittsburgh)

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