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Electroweak phase transition in the 2HDM: collider and gravitational wave complementarity

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The knowledge of the Higgs potential is crucial for understanding the origin of mass and thermal history of our universe. We show how collider measurements and observations of stochastic gravitational wave signals can complement each other to explore the multiform scalar potential in the 2HDM. Accounting for theoretical and current experimental constraints, we analyze the key ingredients in the shape of the Higgs potential triggering the transmutation in phase transition, from the smooth cross-over to the strong first-order phase transition ($\xi_c > 1$), focusing on the barrier formation and the upliftment of the true vacuum. In particular, we observe that $\xi_c > 1$ regime is favored for lower scalar masses, rendering strong extra motivation for collider searches. We contrast the dominant collider signals at the HL-LHC with observable gravitational wave signals at LISA. We obtain that the HL-LHC will be able to cover a vast range of the $\xi_c > 1$ parameter space, with scalar decays to heavy fermions ($H, A, H^{\pm} \to tt, tb$) being the most promising smoking gun signature of strong first-order electroweak phase transition in the 2HDM.

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