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Search for resonant double Higgs production in the bb$\tau\tau$ final state at the CMS experiment.

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Abstract

This thesis presents a search for resonant double Higgs boson (HH) production via gluon-gluon fusion (GGF), targeting Beyond the Standard Model (BSM) theories such as the Warped Extra Dimensions (WED) model. These models predict resonances, including CP-even scalar particles, that enhance the HH production cross section at specific invariant masses. The analysis focuses on the $HH \to b\bar{b}\tau^+\tau^-$ final state, where one Higgs decays into b-quarks and the other into tau leptons, with the $\tau^+\tau^-$ system studied through three decay channels: $\tau_h\tau_h$ (hadronic decays), where τ_h is the final state including hadrons and one ν_τ, and $\tau_h\tau_\ell$ ("leptonic" decays, with ℓ being an electron or muon) together with the tau and leptons associated neutrinos. This channel offers a balance of signal purity and a branching ratio of 7.3%. However non-trivial challenges arise from the reconstruction of tau lepton decays involving undetectable neutrinos and the need to discriminate signal from background contributions, leading to the development of specialized algorithms and reconstruction techniques to improve sensitivity to the signal.

The study uses 137.1 fb^{-1} of proton-proton collision data collected at $\sqrt{s} = 13$ TeV by the CMS detector. Challenges such as tau decay reconstruction involving undetectable neutrinos and signal-background discrimination are addressed using specialized algorithms and reconstruction techniques to enhance analysis sensitivity. This marks the first time this search is conducted with the full CMS dataset from 2016–2018.

A blind analysis approach is employed to avoid biases during the statistical analysis, excluding observed data, and only expected results are reported. Upper limits on the HH production cross section are set as a function of resonance mass and interpreted within the WED framework, offering new insights into potential BSM physics.