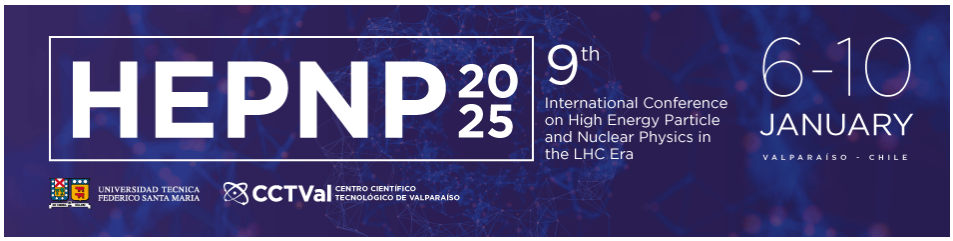

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Constraining the Higgs Potential via Di-Higgs searches with ATLAS at the LHC

The 2012 discovery of the Higgs boson (H) by the ATLAS and CMS collaborations at the Large Hadron Collider (LHC) marked the beginning of an extensive program aimed at understanding the properties of this fundamental particle. A key aspect still under investigation is the Higgs boson self-interaction, which governs the shape of the Higgs potential, $V(\phi)$. In the Standard Model (SM), non-resonant Higgs boson pair (HH) production is predicted, with the dominant production mechanism at the LHC being gluon-gluon fusion (ggF), which has a cross-section of $\sigma^{\text{SM}}_{\text{ggF}} = 31.1$ fb at NNLO, followed by vector boson fusion (VBF) with $\sigma^{\text{SM}}_{\text{VBF}} = 1.73$ fb at tree level, both at $\sqrt{s} = 13$ TeV. The coupling modifiers κ_λ (which parametrizes the triple Higgs coupling, relevant for both ggF and VBF processes) and κ_{2V} (which governs the interaction of two Higgs bosons with two vector bosons, specific to the VBF process) are defined as the ratio of the observed coupling to the SM prediction. Deviations from $\kappa_\lambda = 1$ and $\kappa_{2V} = 1$ would suggest deviation from the SM predictions. The signal strength parameter $\mu_{HH} = \frac{\sigma_{\text{ggF}}+\sigma_{\text{VBF}}}{\sigma^{\text{SM}}_{\text{ggF}}+\sigma^{\text{SM}}_{\text{VBF}}}$ is also used to evaluate the consistency of the measured HH production rate with the SM prediction. Among the most sensitive final states for probing the Higgs self-coupling and constraining κ_λ, κ_{2V}, and μ_{HH} are HH→bbbb, HH→bb$\tau\tau$, and HH→bb$\gamma\gamma$. Recent analyses of the HH→bb$\tau\tau$ final state have provided key insights into the sensitivity to κ_λ, κ_{2V}, and μ_{HH}, setting limits that approach the SM predictions. These results are further enhanced by the combination of constraints from all major Di-Higgs final states, significantly improving the precision on these parameters. Projections for the high-luminosity LHC (HL-LHC) indicate substantial sensitivity improvements, especially when combining the bb$\tau\tau$ and bb$\gamma\gamma$ channels. Such combinations are expected to provide stringent constraints on κ_λ, κ_{2V}, and μ_{HH}. These advances underscore the critical role of multi-channel analyses in understanding the Higgs boson self-interaction and the shape of the Higgs potential.

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