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Higgs self-coupling measurement from $HH + H$ combination and Higgs pairs in the $b\bar{b}\gamma\gamma$ final state

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Introduction

Higgs boson was discovered since 2012 and the measurement of its characteristics comes to a hot topic. Higgs self-coupling(κ_λ) is crucial to explore the shape of the Higgs potential. In this poster, the following two results will be talked.

- Legacy $HH \to b\bar{b}\gamma\gamma$: the most dominant and sensitive channel[1].
- $HH + H$: κ_λ devoting to single Higgs via sizeable NLO EW correction[2].

Combining single-Higgs and double-Higgs could explore the Higgs self-interaction and shed more light on the Higgs boson potential, the source of EW symmetry breaking in the SM.

$HH \to b\bar{b}\gamma\gamma$ Analysis

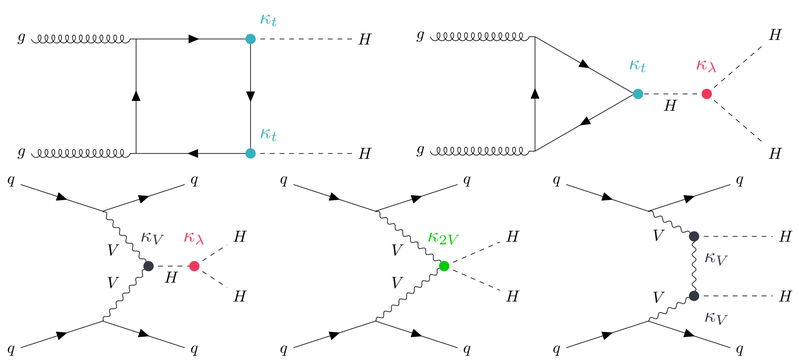

Figure 1: HH Production via ggF($\sigma = 31.02$fb) and VBF($\sigma = 1.723$fb) at 13TeV

Analysis strategy

Preselection applied to choose the events with $b\bar{b}\gamma\gamma$ signature:

- Two *tight* and *isolated* photons and (sub-)leading $pT/m_{\gamma\gamma} > 0.35(0.25)$
- Exactly 2 b-jets with WP77 for DL1r, No leptons, $N_{jet} > 2$ and $N_{central\ jet} < 6$

XGBoost classifier respectively defined for:
low mass ($M^*_{b\bar{b}\gamma\gamma} < 350$ GeV) and high mass ($M^*_{b\bar{b}\gamma\gamma} \geq 350$ GeV
Final events categorized to seven fit regions as shown in Fig 2.

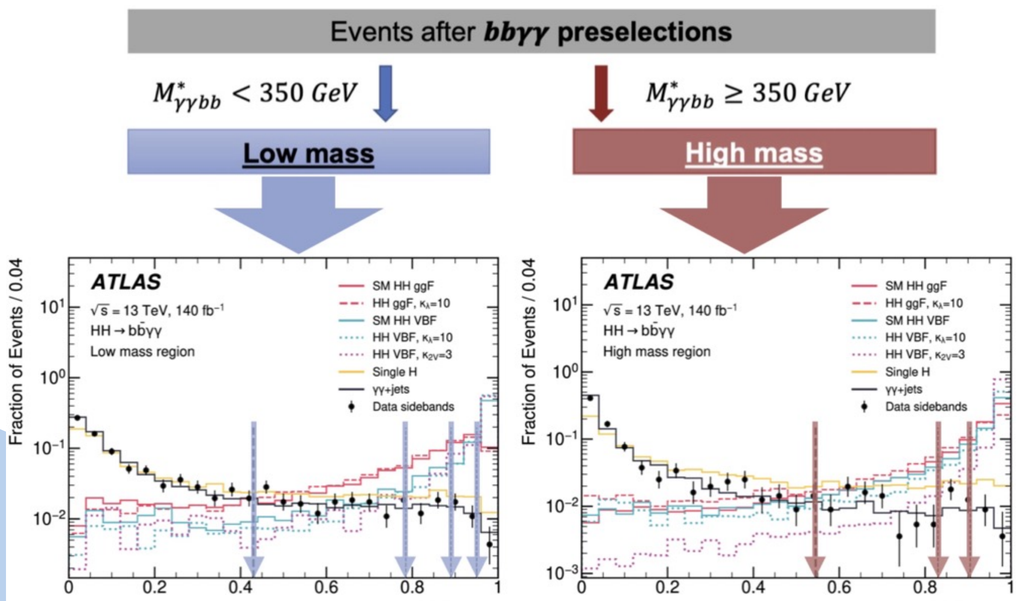

Figure 2: Event selection strategy and BDT distribution

Fitted results

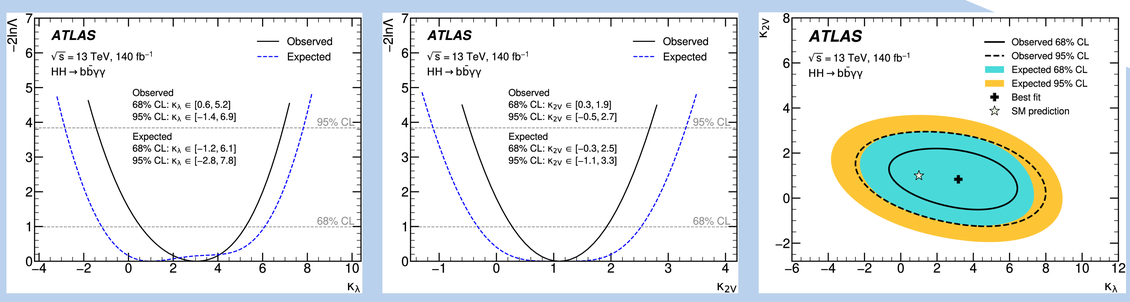

Figure 3: Negative likelihood 1D and 2D scan results for κ_λ , κ_{2V}

Unbinned likelihood was performed.No significant excess observed.The observed HH production cross-section is 4.0 times its Standard Model prediction. The observed(expected) κ_λ and κ_{2V}constraints at 95% CL are shown Fig 3.

$HH + H$ combination

The Higgs self-interaction contributes to other processes via NLO EW corrections. Particularly,the single-Higgs productions and branching ratios are modified if κ_λ deviates from the SM prediction. Thus single-Higgs and di-Higgs are combined. More stringent constraints on κ_λ are reported based on the latest ATLAS single Higgs combination results from $\gamma\gamma$, ZZ^*, WW^*, $\tau^+\tau^-$ and $b\bar{b}$ decay channel.

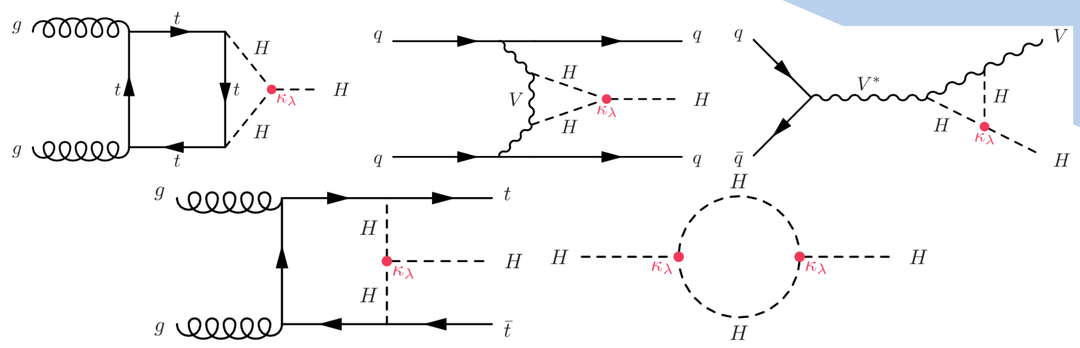

Figure 4: Examples of one-loop λ_{HHH}-dependent diagrams

HH combined from $b\bar{b}b\bar{b}$, $b\bar{b}\tau^+\tau^-$ and $b\bar{b}\gamma\gamma$ channels shown in Fig 5. The observed(expected) is $\mu_{HH} < 2.4(2.9)$ at 95% CL.

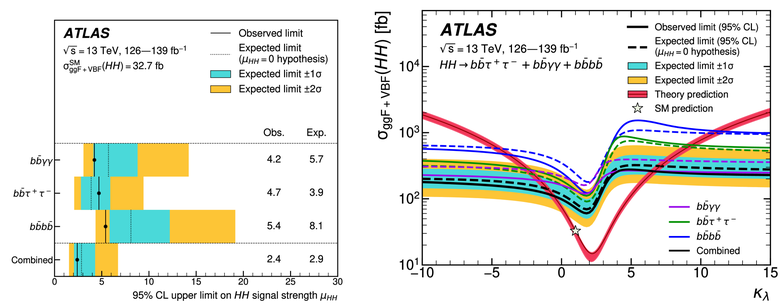

Figure 5: Di-Higgs combination results from three dominant channels.

Statistical results

Two scenarios are considered:

- κ_λ only: Fit with κ_λ floating and all other coupling modifiers fixed to unity.
- κ_λ generic: Fit with all coupling modifiers floating except for κ_{2V}fixed to unity.

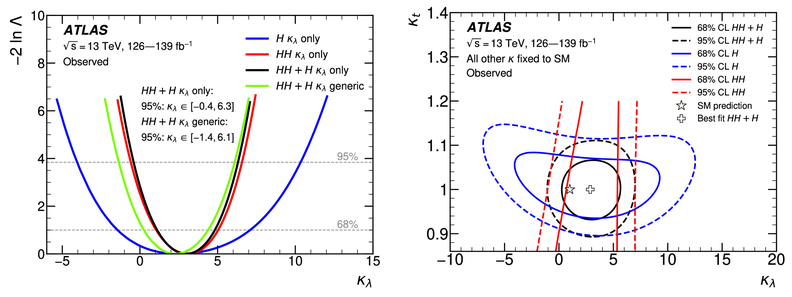

Figure 6: Observed constraints for κ_λ and κ_t.

Combination assumption	Obs. 95% CL	Exp. 95% CL	Obs. value$^{+1\sigma}_{-1\sigma}$
HH combination	$-0.6 < \kappa_\lambda < 6.6$	$-2.1 < \kappa_\lambda < 7.8$	$\kappa_\lambda = 3.1^{+1.9}_{-2.0}$
Single-H combination	$-4.0 < \kappa_\lambda < 10.3$	$-5.2 < \kappa_\lambda < 11.5$	$\kappa_\lambda = 2.5^{+4.6}_{-3.9}$
HH+H combination	$-0.4 < \kappa_\lambda < 6.3$	$-1.9 < \kappa_\lambda < 7.6$	$\kappa_\lambda = 3.0^{+1.8}_{-1.9}$
HH+H combination, κ_t floating	$-0.4 < \kappa_\lambda < 6.3$	$-1.9 < \kappa_\lambda < 7.6$	$\kappa_\lambda = 3.0^{+1.8}_{-1.9}$
HH+H combination, κ_t, κ_V, κ_b, κ_τ floating	$-1.4 < \kappa_\lambda < 6.1$	$-2.2 < \kappa_\lambda < 7.7$	$\kappa_\lambda = 2.3^{+2.1}_{-2.0}$

Figure 7: Summary of κ_λ observed and expected constraints.

Conclusion

- Comparing with previous analysis, the new selection procedure increases 5% improvements on observed μ_{HH}, 16% improvement on observed κ_{2V} and 5% reduction on observed κ_λ due to larger,less negative values of μ_{HH}.
- These results contains full Run2 dataset. Di-Higgs combination makes a significant gain (49%) on μ_{HH}, and single Higgs brings 6.94% improvements on κ_λ .The study provides the most stringent constraints on Higgs self-interaction.

References

[1] ATLAS Collaboration. Studies of new higgs boson interactions through nonresonant HH production in the $b\bar{b}\gamma\gamma$ final state in pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. https://arxiv.org/abs/2310.12301, 2023.

[2] ATLAS Collaboration. Constraints on the Higgs boson self-coupling from single- and double-Higgs production with the ATLAS detector using pp collisions at $\sqrt{s} = 13$ TeV. page 137745. Physics Letter B, 2023.