Higgs Hunting 2023

Higgs Self Coupling: discussion

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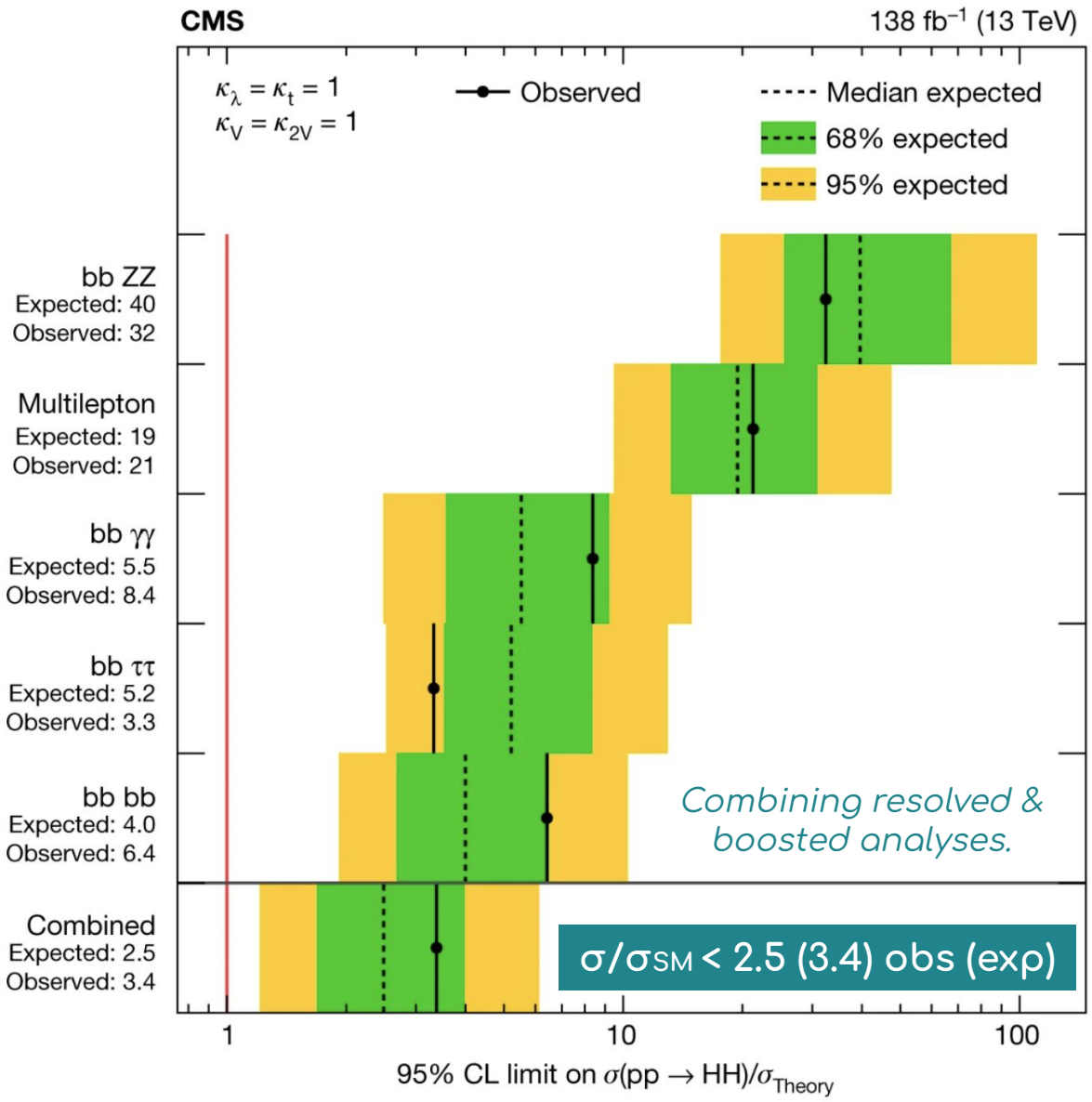
Based on slides from
Jona Mota (CMS) & Lidija Zivkovic (ATLAS)

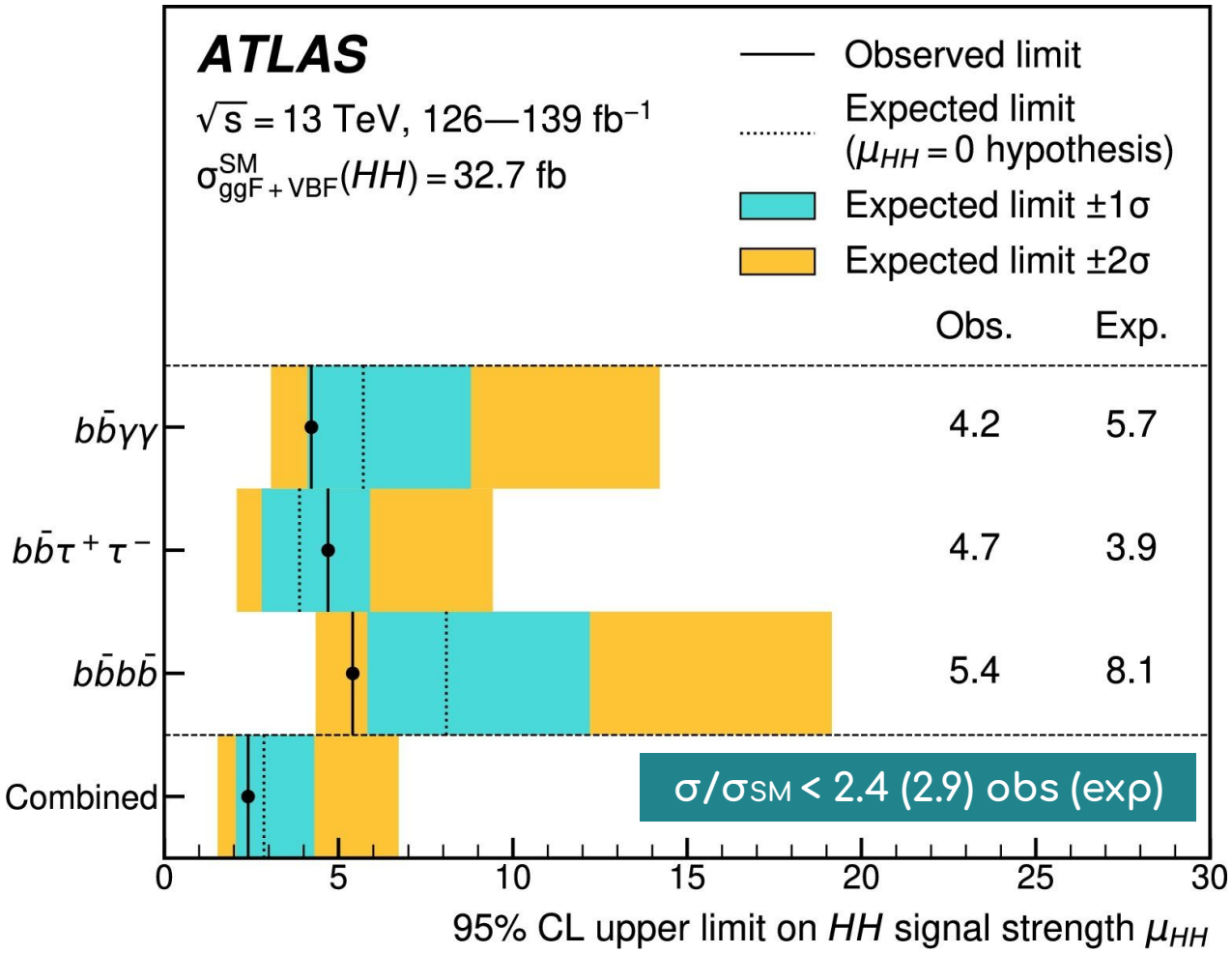
Latest results

(finding the SM HH process)

Best HH combinations from both CMS and ATLAS experiments. Both are very competitive... and approaching the SM.

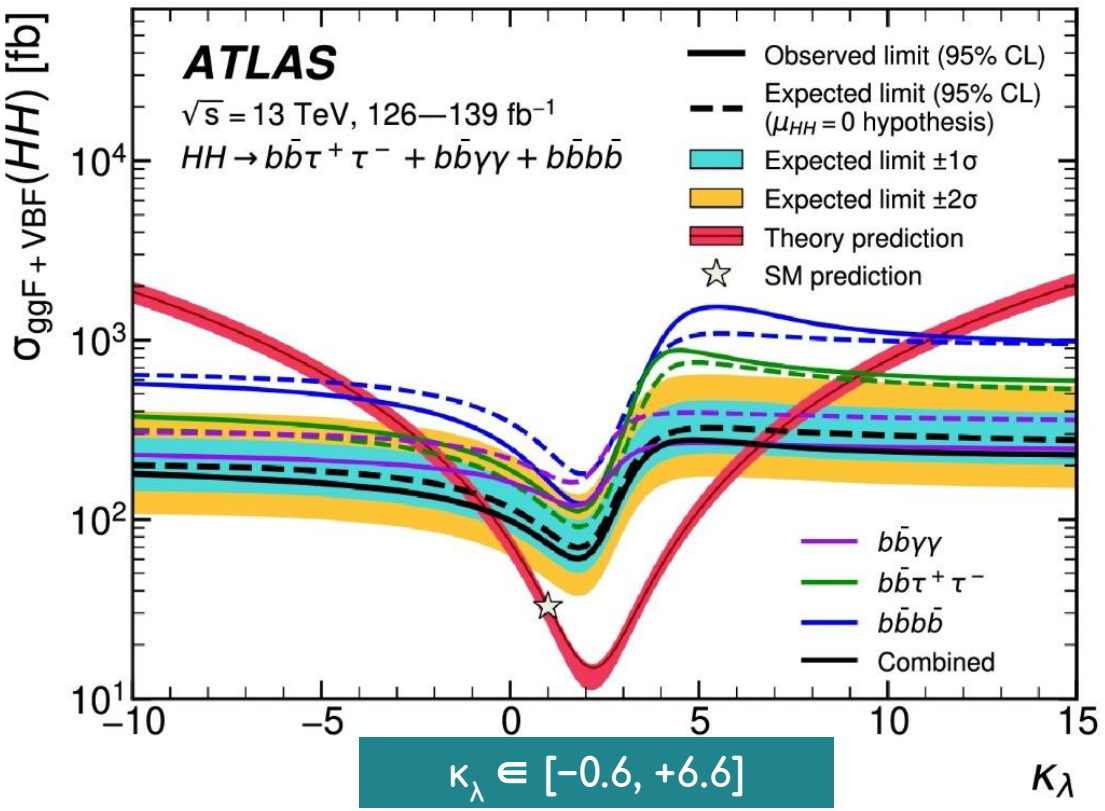
Results are ~5 better than earlier Run 2 results. Jona M.



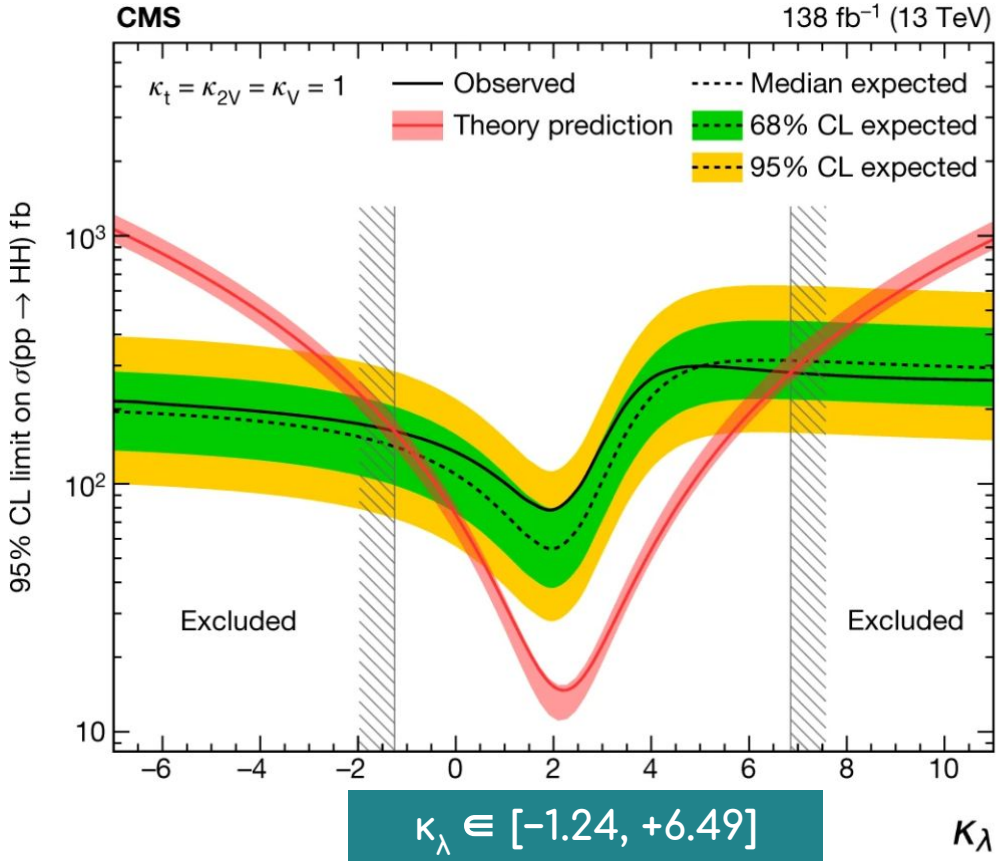


Couplings

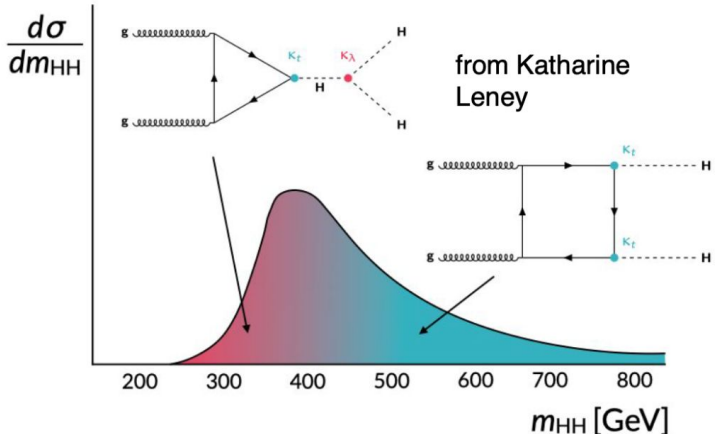
(profiling the HH process)



$\kappa_\lambda \in [-0.6, +6.6]$



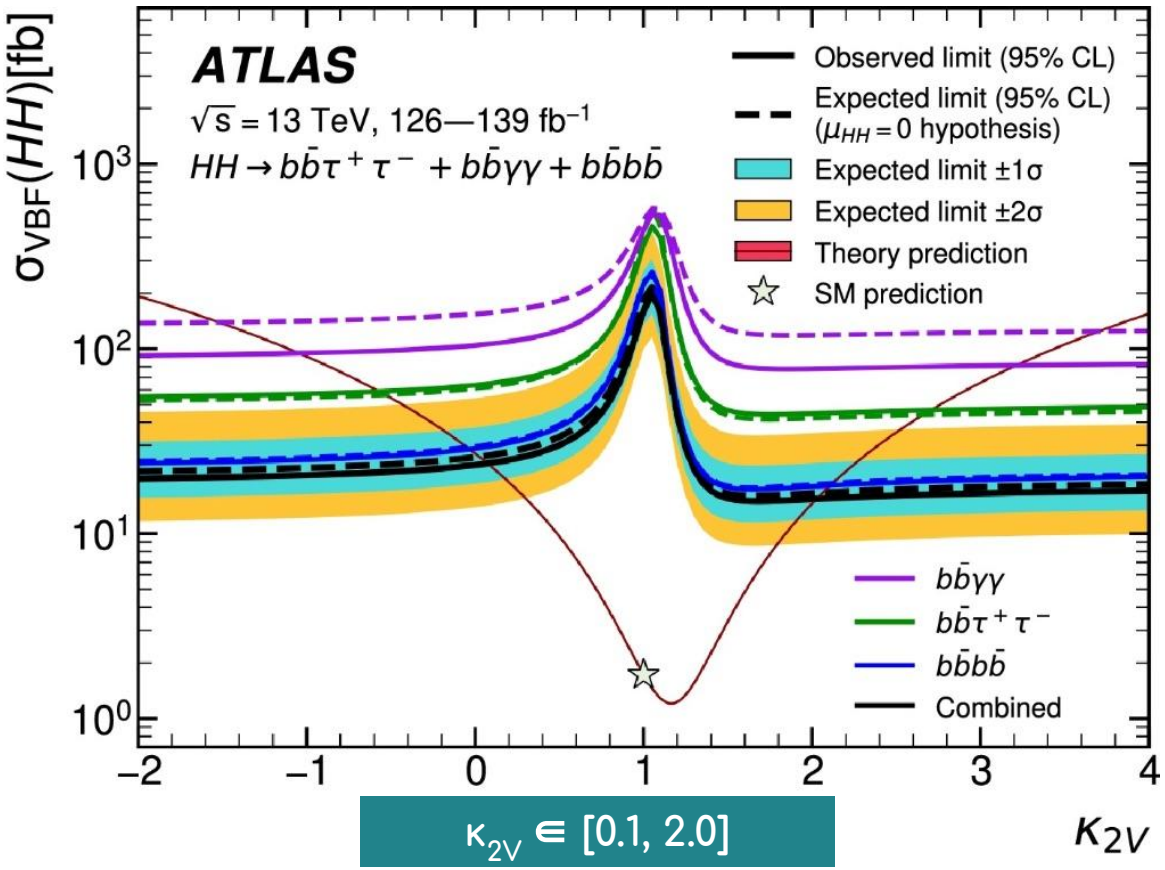
$\kappa_\lambda \in [-1.24, +6.49]$



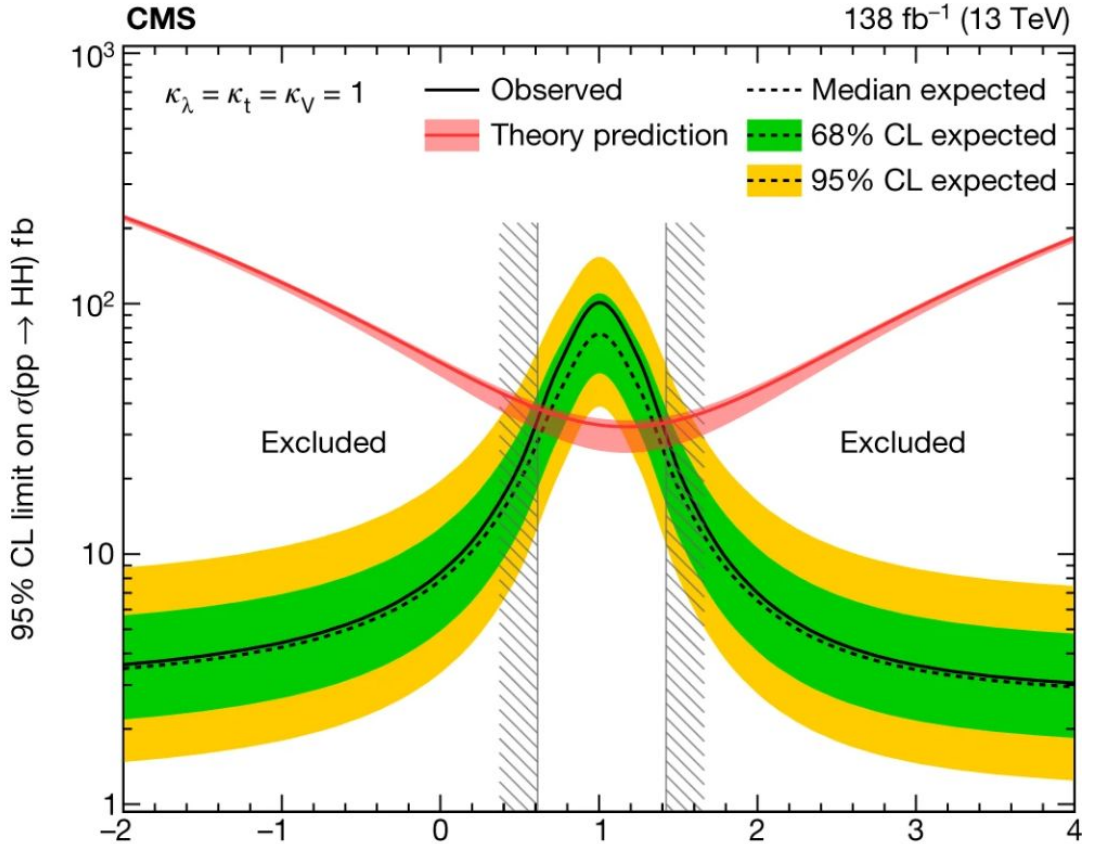
Low m_{HH} is crucial to constraint κ_λ. Lidija Z.

Couplings

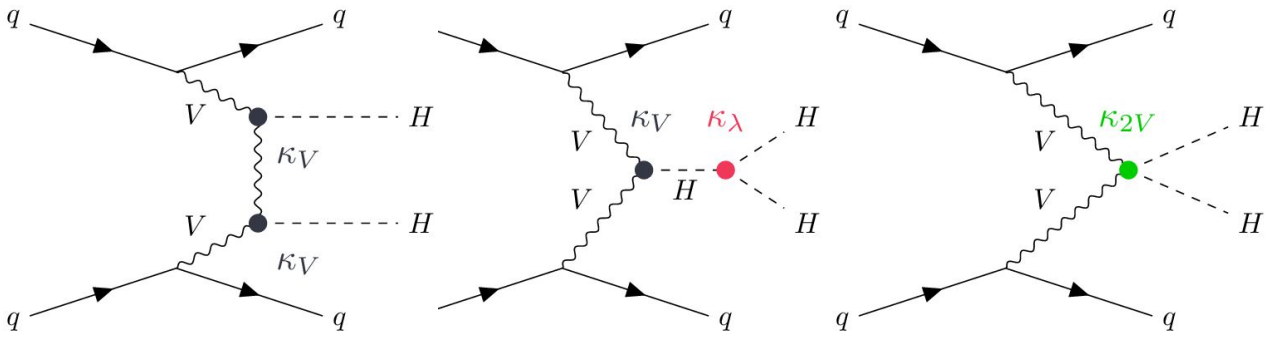
(profiling the HH process)



$\kappa_{2V} \in [0.1, 2.0]$



$\kappa_{2V} \in [0.67, 1.38]$

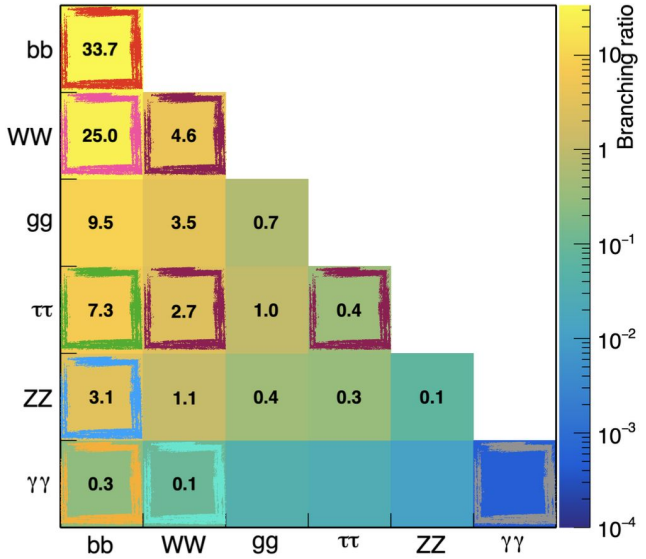


Impressive results from HH→bbbb **boosted** analysis: identifying boosted bb-tagged jets with ParticleNet.

VVHH coupling established at 6.6σ significance level.

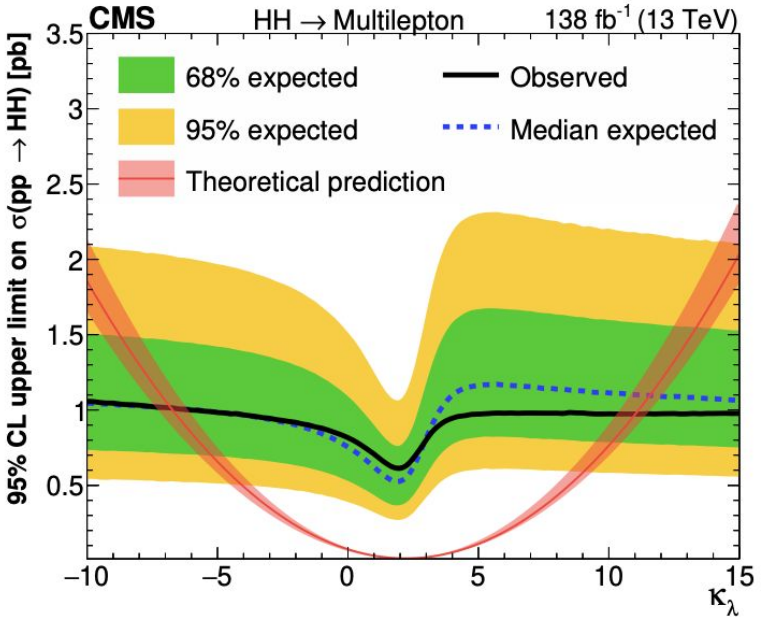
New/Uncovered areas

(turning all stones)



- Decay channels with large branching ratios may lead to challenging signatures.
- Exploring a mixture of different higgs decay channels to increase the sensitivity.
- Different analysis strategies developed.

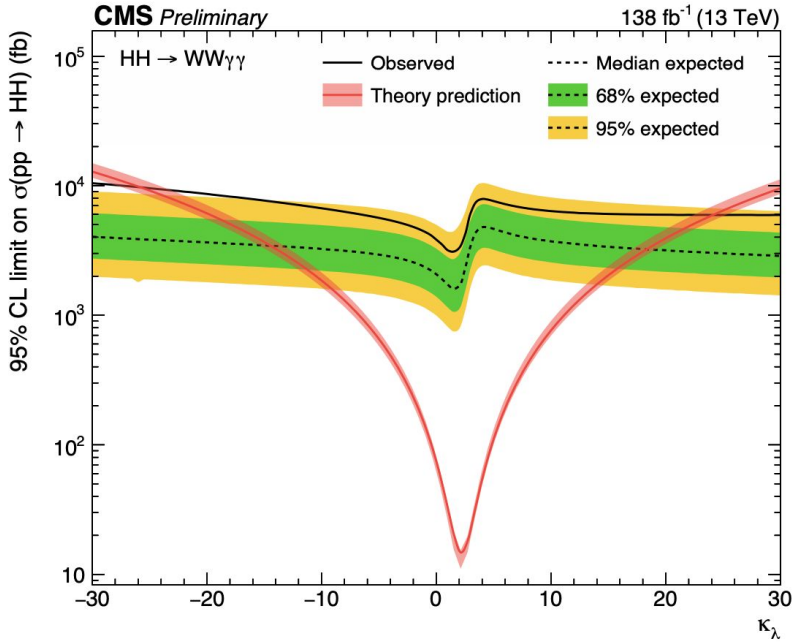
What opportunities lie in unexplored decay channels? Main challenges to explore them?



- HH → WWγγ.
  - 3 channels based on W decays.
- σ/σSM < 97 (52) obs (exp).
- $\kappa_\lambda \in [-25.8, +24.1]$

CMS has now done searches with no bb decay!

- HH → WWWW/WWττ/ττττ.
  - 7 categories based on lepton multiplicities.
- σ/σSM < 21.3 (3.40) obs (exp).
- $\kappa_\lambda \in [-6.9, +11.1]$



VHH production

(new production mechanism!)

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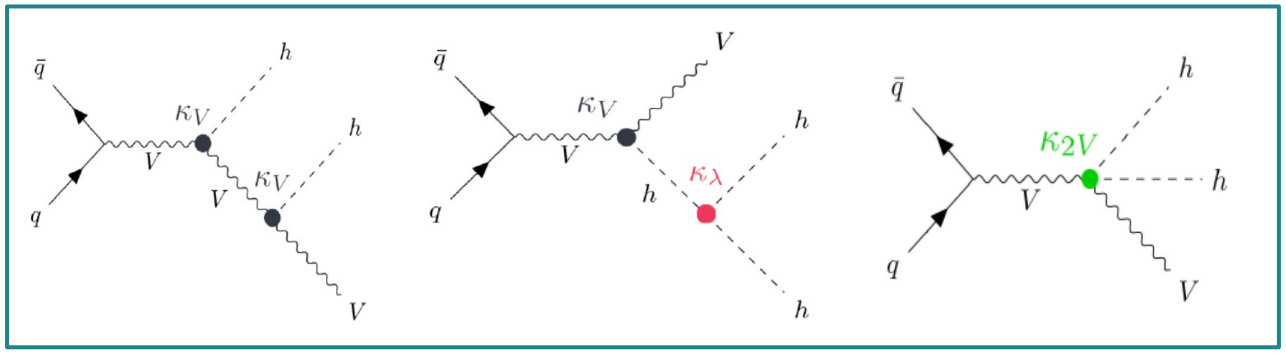


Gluon fusion (NNLO)

$$\sigma^{\mathrm{SM}}_{\mathrm{ggF}} = 31.05^{+6\%}_{-23\%}(\mathrm{scale} + m_{\mathrm{top}}) \pm 3.0\%(\mathrm{PDF} + \alpha_s)\ \mathrm{fb}$$

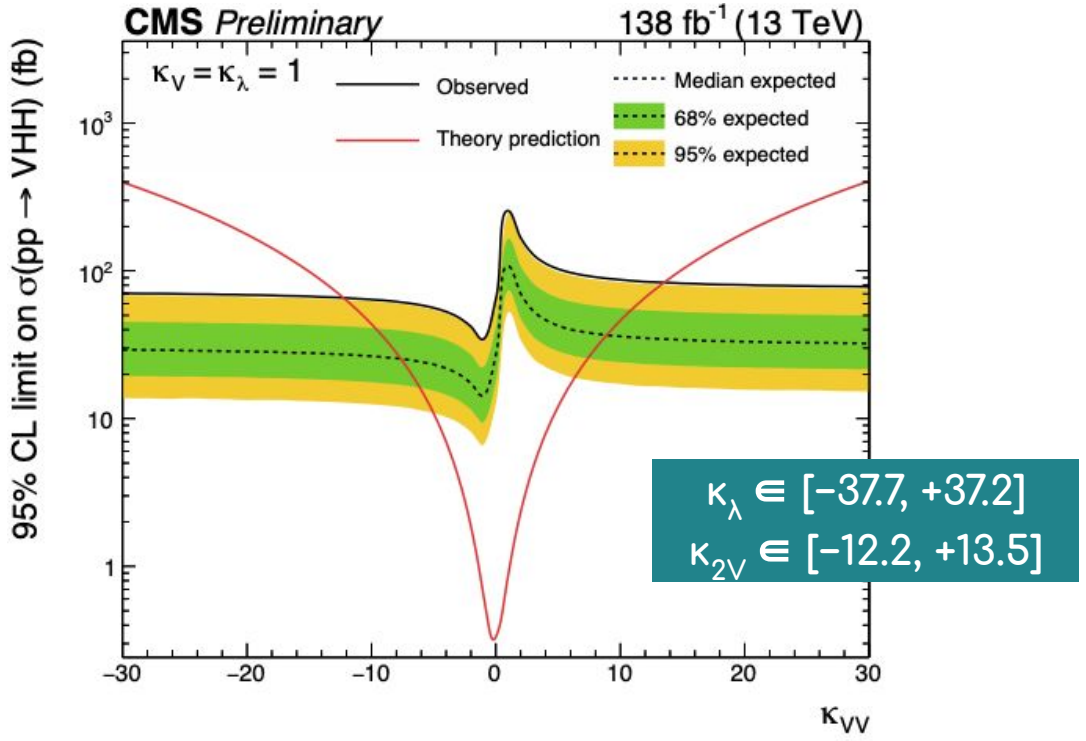
Vector boson fusion (N^{3}LO)

$$\sigma^{\mathrm{SM}}_{\mathrm{VBF}} = 1.73^{+0.03\%}_{-0.04\%}(\mathrm{scale}) \pm 2.1(\mathrm{PDF} + \alpha_s)\ \mathrm{fb}$$

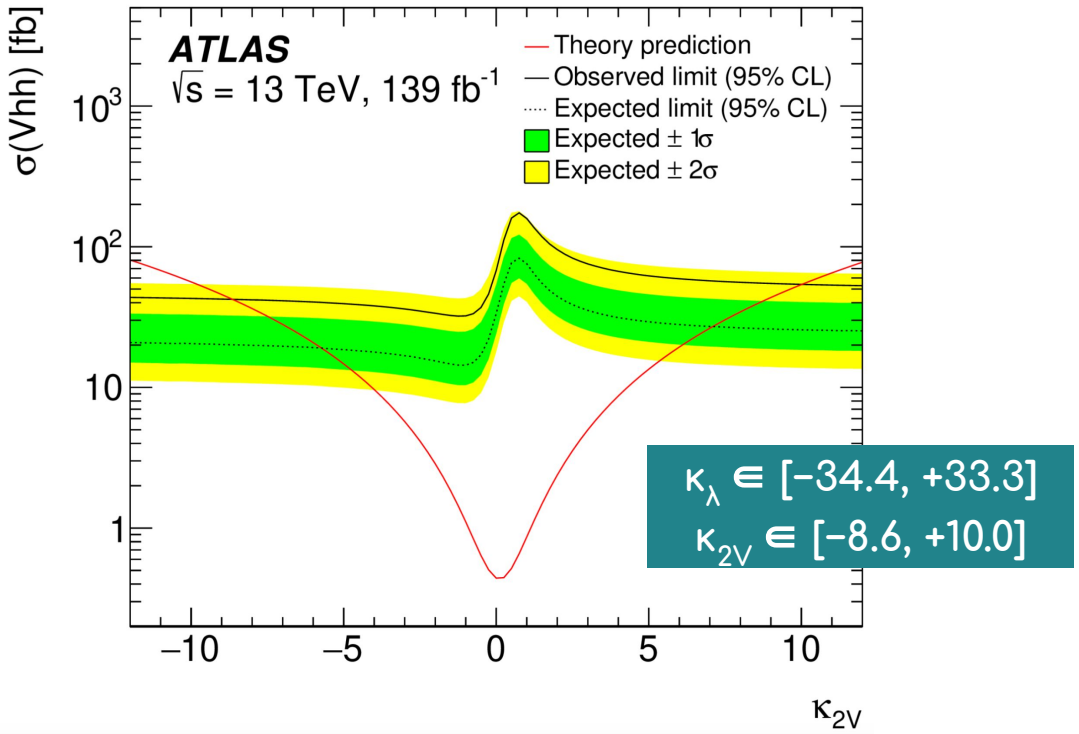
Associated production, VHH (N^{2}LO) e.g σ_{ZHH}

$$\sigma^{\mathrm{SM}}_{\mathrm{ZHH}} = 0.363^{+3.4\%}_{-2.7\%}(\mathrm{scale}) \pm 1.9(\mathrm{PDF} + \alpha_s)\ \mathrm{fb}$$

Unlikely VBF it can probe separately WWHH (κ_{2W}) and ZZHH (κ_{2Z}) interactions. Lidija Z.



$\kappa_\lambda \in [-37.7, +37.2]$
$\kappa_{2V} \in [-12.2, +13.5]$



$\kappa_\lambda \in [-34.4, +33.3]$
$\kappa_{2V} \in [-8.6, +10.0]$

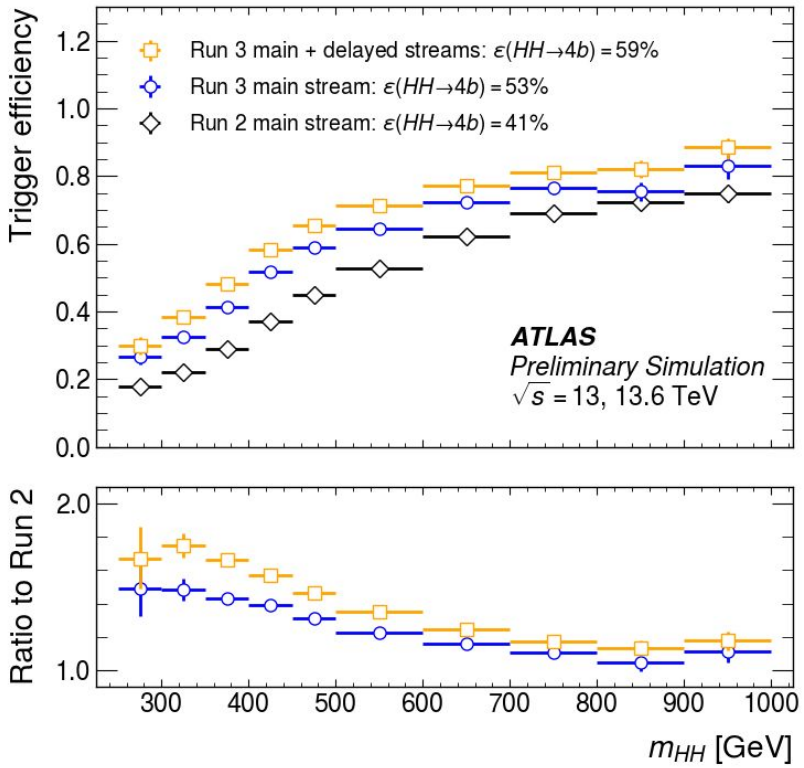
The future

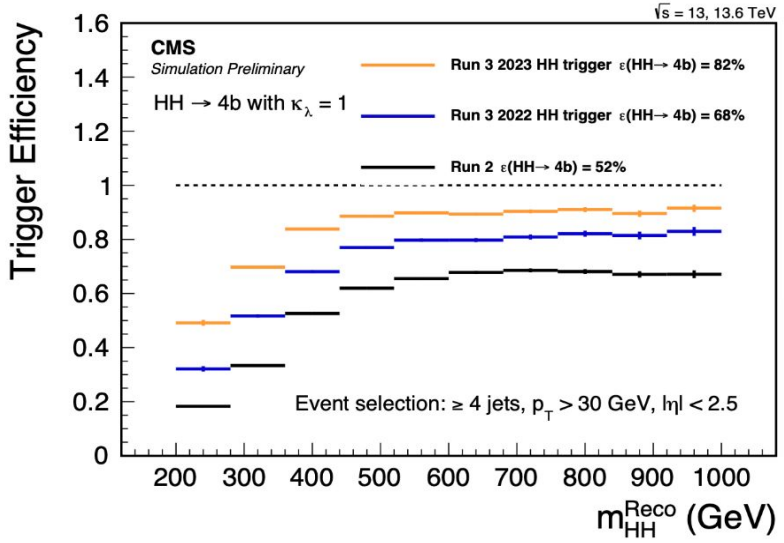
(or where the improvements will be found)

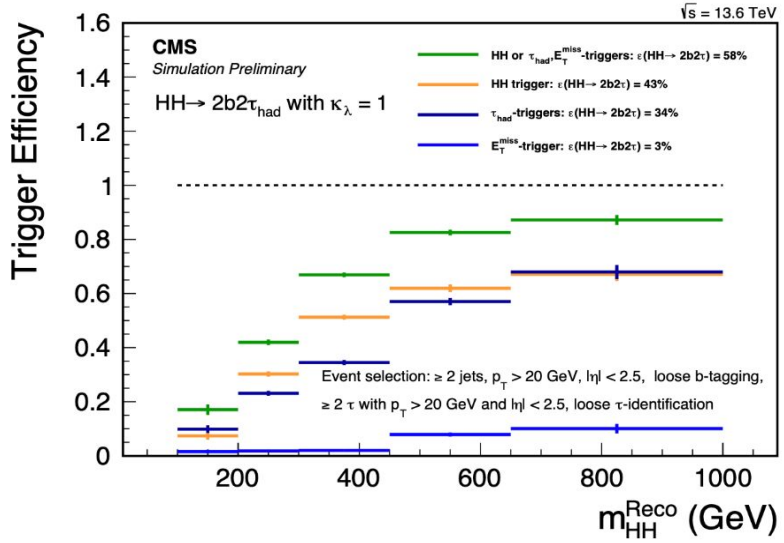
Both experiments have done great work to prepare for Run 3. Improvements for trigger and reconstruction strategies (including b-tagging) will have a direct impact on HH searches.

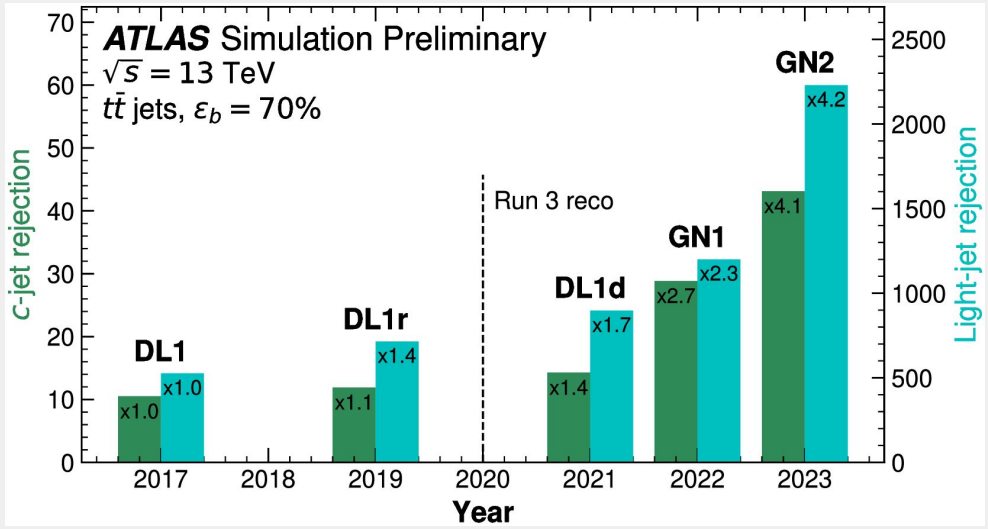
New Triggers!

New bbbb and bbττ triggers for Run-3 give improvement in efficiency at low m_{HH}. Other trigger strategies (e.g. data parking/delayed streams) also in place.









b-tagging!

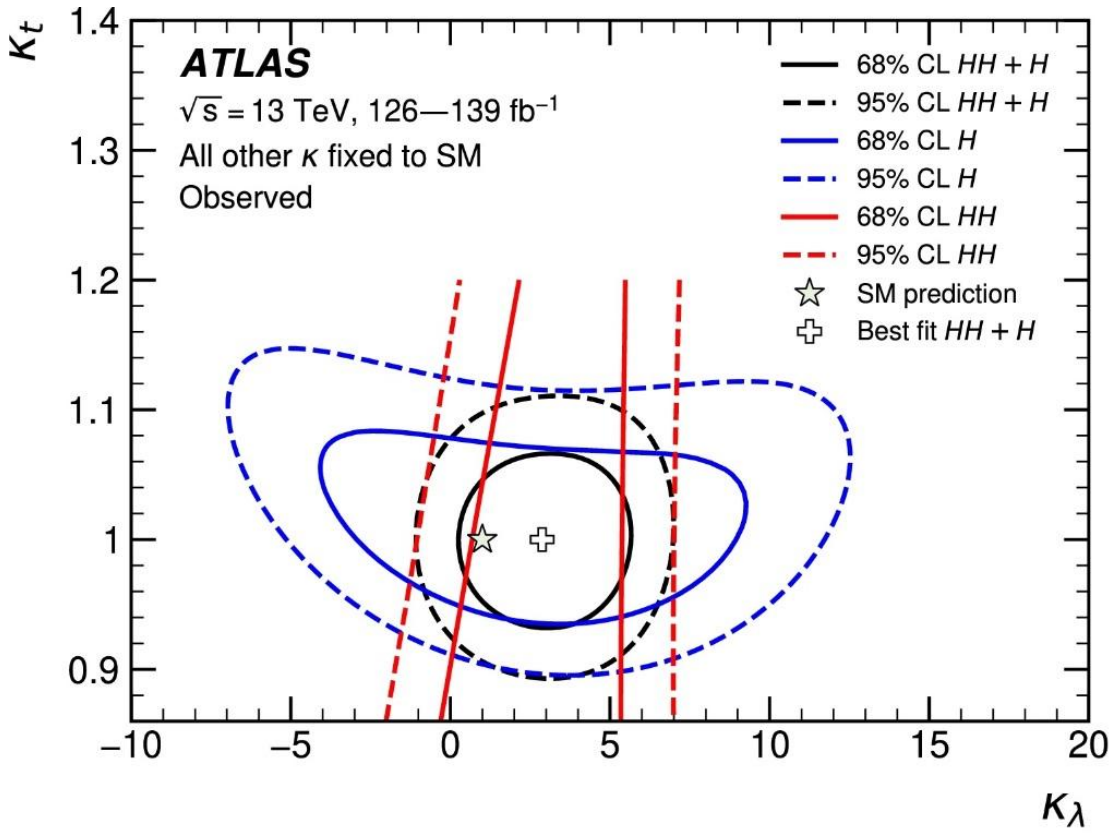
Great work in b-tagging performance will also improve the HH signal sensitivity.

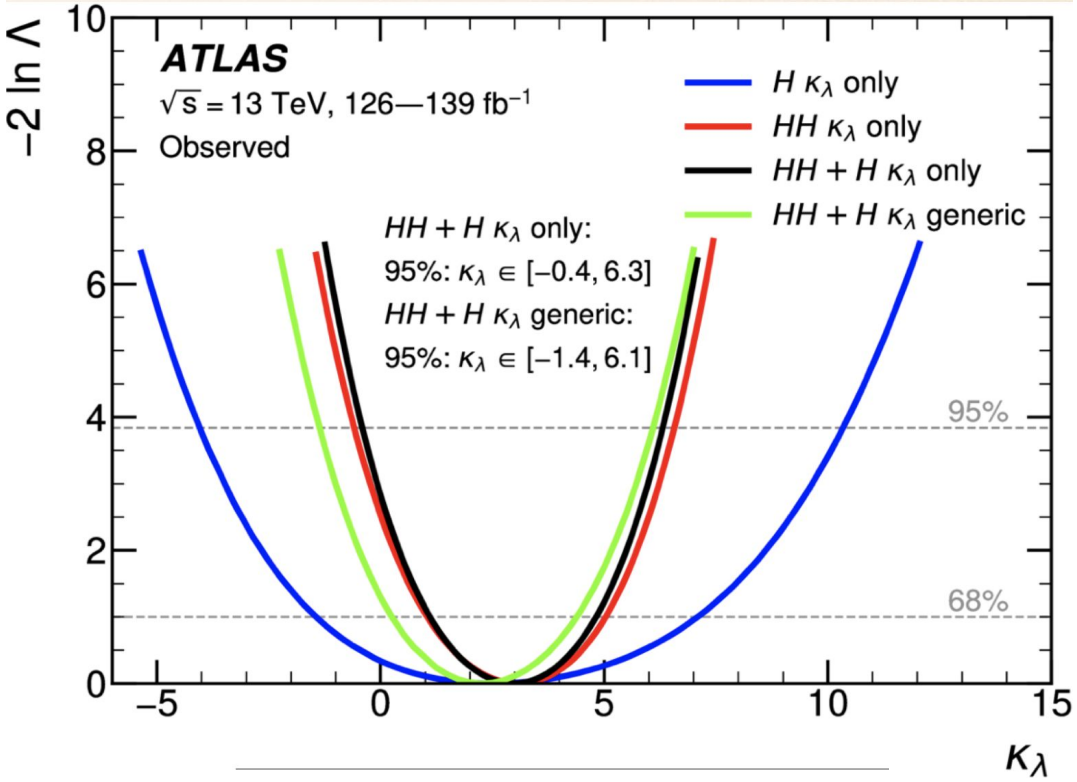
Work in other reconstruction/identification techniques will also pay off.

Bonus: Improving b-tagging at trigger level (ATLAS).

bonus

HH+H combination





Combining, not only the direct HH searches, but other measurements that may indirectly constrain κ_λ is the path forward towards discovery.

ATLAS and CMS have published H+HH combination, putting new constraints on κ_λ and κ_t.

Combination assumption	Obs. 95% CL
***HH* combination**	$-0.6 < \kappa_\lambda < 6.6$
Single-*H* combination	$-4.0 < \kappa_\lambda < 10.3$
***HH*+*H* combination**	$-0.4 < \kappa_\lambda < 6.3$
***HH*+*H* combination, κ_t floating**	$-0.4 < \kappa_\lambda < 6.3$
***HH*+*H* combination, κ_t, κ_V, κ_b, κ_τ floating**	$-1.4 < \kappa_\lambda < 6.1$

x-sections

Non-resonant HH production
Production cross sections at 13 TeV for m_H = 125 GeV

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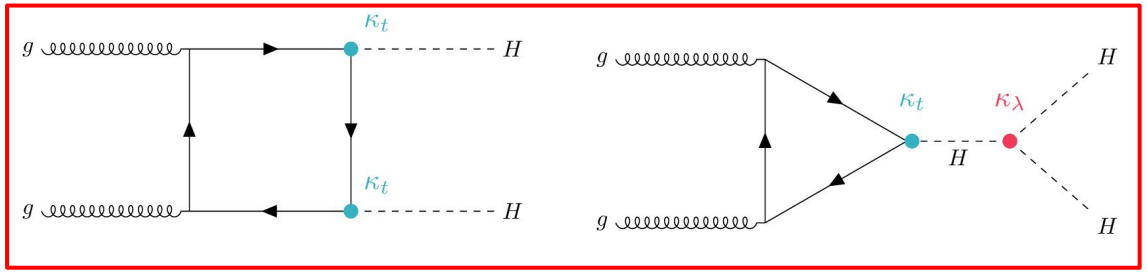

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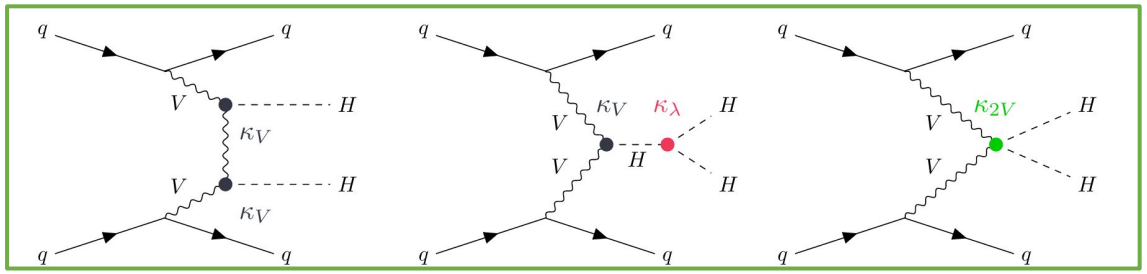

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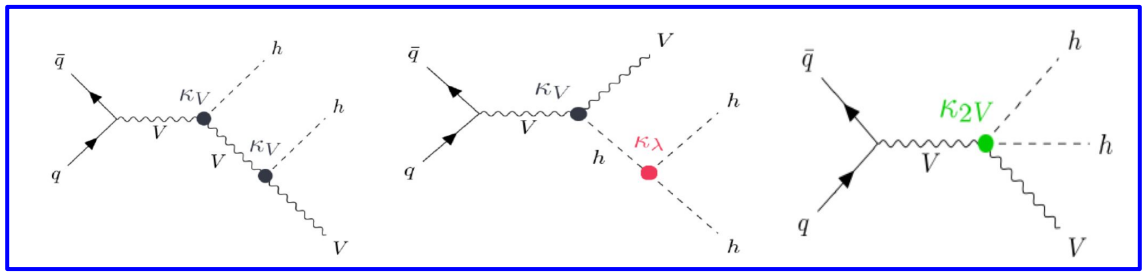

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