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

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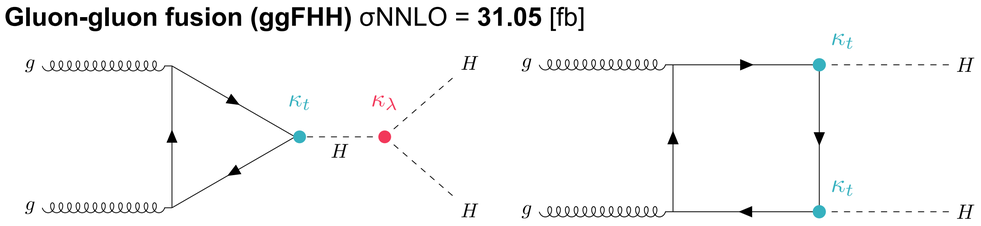
Motivation

- Since the discovery of the **Higgs boson** in 2012, a priority of the LHC physics has been to better understand its properties and couplings
- A direct probe of the **Higgs boson trilinear self-coupling** is possible via **Higgs boson pair (HH) production**
- HH production via vector boson fusion has a unique sensitivity to the **quartic couplings between two Higgs bosons and two vector bosons**
- Anomalous values of these couplings would point to **new physics beyond the Standard Model**

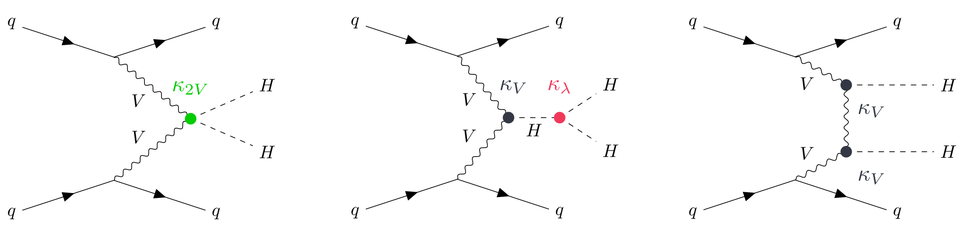
HH production (13 TeV, m_H = 125 GeV)

Gluon-gluon fusion (ggFHH) σNNLO = **31.05** [fb]



Drives the sensitivity to $\kappa_\lambda = \lambda_{HHH}/\lambda^{SM}_{HHH}$

Vector boson fusion (VBFHH) σN3LO = **1.73** [fb]



Additional sensitivity to κ_λ + unique probe to $\kappa_{2V} = g_{HHVV}/g^{SM}_{HHVV}$

HH→ $b\bar{b}\gamma\gamma$ analysis overview

- $H \to b\bar{b}$: large branching ratio
- $H \to \gamma\gamma$: excellent $m_{\gamma\gamma}$ resolution

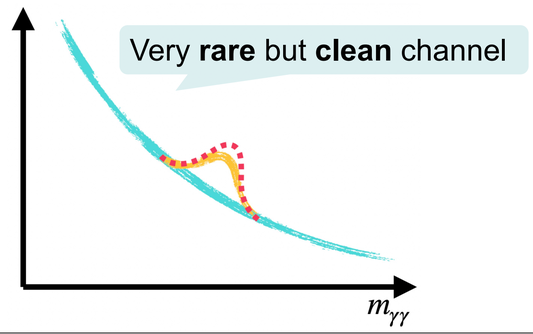
✓ **Main backgrounds**

- **Non-resonant $\gamma\gamma$ backgrounds**
- **Single Higgs production**

	bb	WW	ττ	ZZ	γγ
bb	34%				
WW	25%	4.6%			
ττ	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
γγ	0.26%	0.10%	0.028%	0.012%	0.0005%

✓ **Preselection**

- 2 identified and isolated photons
- 2 b-tagged jets (77% b-tagging efficiency)
- < 6 central jets (reject $t\bar{t}H$ events)
- 0 electrons or muons (reject $t\bar{t}H$ events)

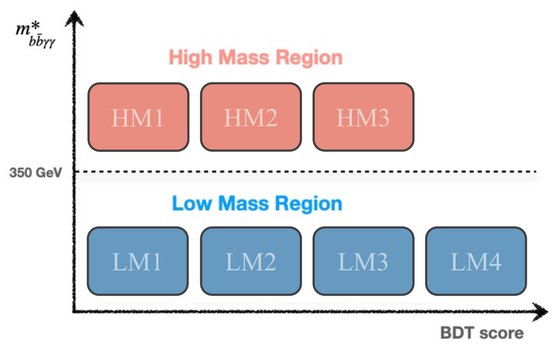


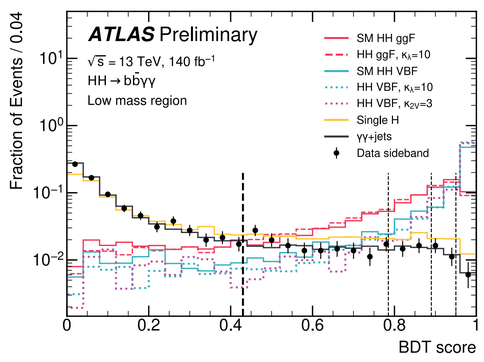
Event categorisation

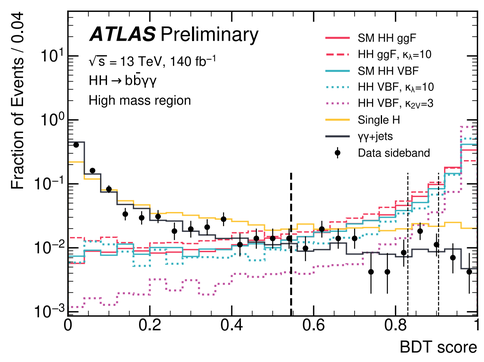
Events are first divided into 2 mass regions using $m^*_{b\bar{b}\gamma\gamma} = m_{b\bar{b}\gamma\gamma} - m_{\gamma\gamma} - m_{b\bar{b}} + 250\ GeV$ to target HH signals with different κ_λ and κ_{2V} values

Then in each mass region, a dedicated **boosted decision tree (BDT)** discriminant is trained against the continuum $\gamma\gamma$ background and single Higgs backgrounds

Input variables include event-level kinematic quantities as well as the kinematic properties of photons, b-jets, and **VBF jets identified by BDT-based jet taggers**







Category boundaries chosen by maximising the combined number-counting significance

$$Z = \sqrt{2 \cdot [(S + B) \cdot \ln(1 + S/B) - S]}$$

Signal extraction

The HH signals are extracted from an unbinned **maximum-likelihood fit** to the $\gamma\gamma$ mass spectrum across all categories

- **Signal model:** Double sided crystal ball function
- **Background model:** Exponential function

Results

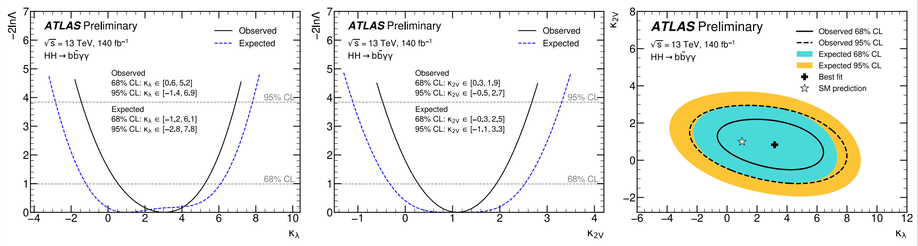
No significant excess over the expected background is observed

Upper limit at 95% CL on μ_{HH}: **4.0xSM** (obs), **5.0xSM** (exp)

Allowed κ_λ interval at 95% CL: **[-1.4, 6.9]** (obs), **[-2.8, 7.8]** (exp)

Allowed κ_{2V} interval at 95% CL: **[-0.5, 2.7]** (obs), **[-1.1, 3.3]** (exp)

2D constraints at 68% and 95% CL in the (κ_λ, κ_{2V}) plane

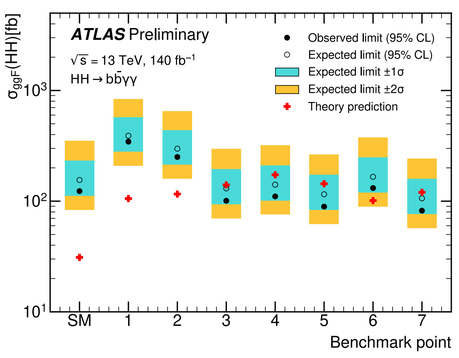


EFT interpretations

➢ **Higgs effective field theory (HEFT)**

- Constraints on three Wilson coefficients
- Upper limits on seven benchmark points

Benchmark	c_{hhh}	c_{tth}	c_{ggh}	c_{gghh}	c_{tthh}
SM	1	1	0	0	0
1	5.11	1.10	0	0	0
2	6.84	1.03	-1/3	0	1/6
3	2.21	1.05	1/2	1/2	-1/3
4	2.79	0.90	-1/3	-1/2	-1/6
5	3.95	1.17	1/6	-1/2	-1/3
6	-0.68	0.90	1/2	0.25	-1/6
7	-0.10	0.94	1/6	-1/6	1



➢ **Standard Model effective field theory (SMEFT)**

- Constraints on two Wilson coefficients

Reference

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