

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

Zihang Jia, on behalf of the ATLAS collaboration
Nanjing University, IHEP
zihang.jia@cern.ch

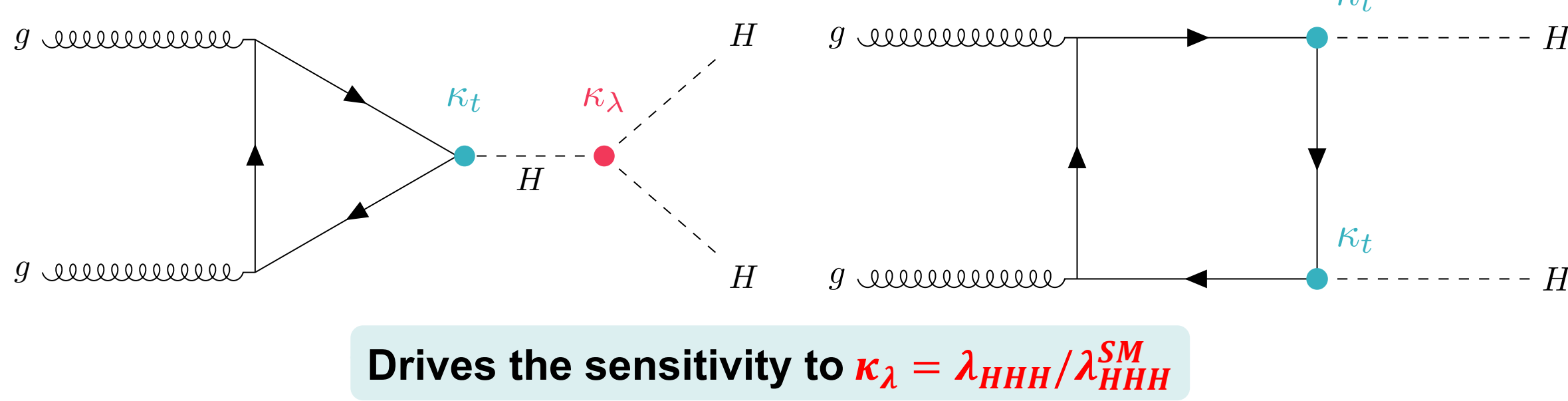


Motivation

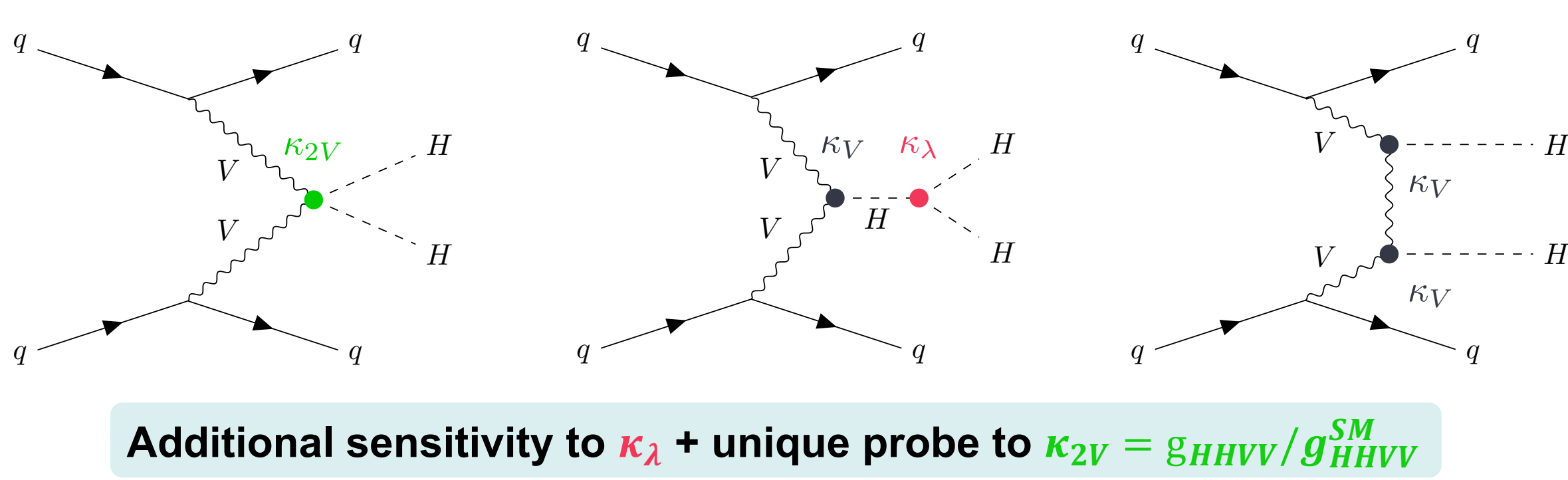
- Since the discovery of the **Higgs boson** in 2012, a priority of the LHC physics has been to better understand its properties and couplings
- A direct probe of the **Higgs boson trilinear self-coupling** is possible via **Higgs boson pair (HH) production**
- HH production via vector boson fusion has 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) $\sigma_{\text{NNLO}} = 31.05$ [fb]



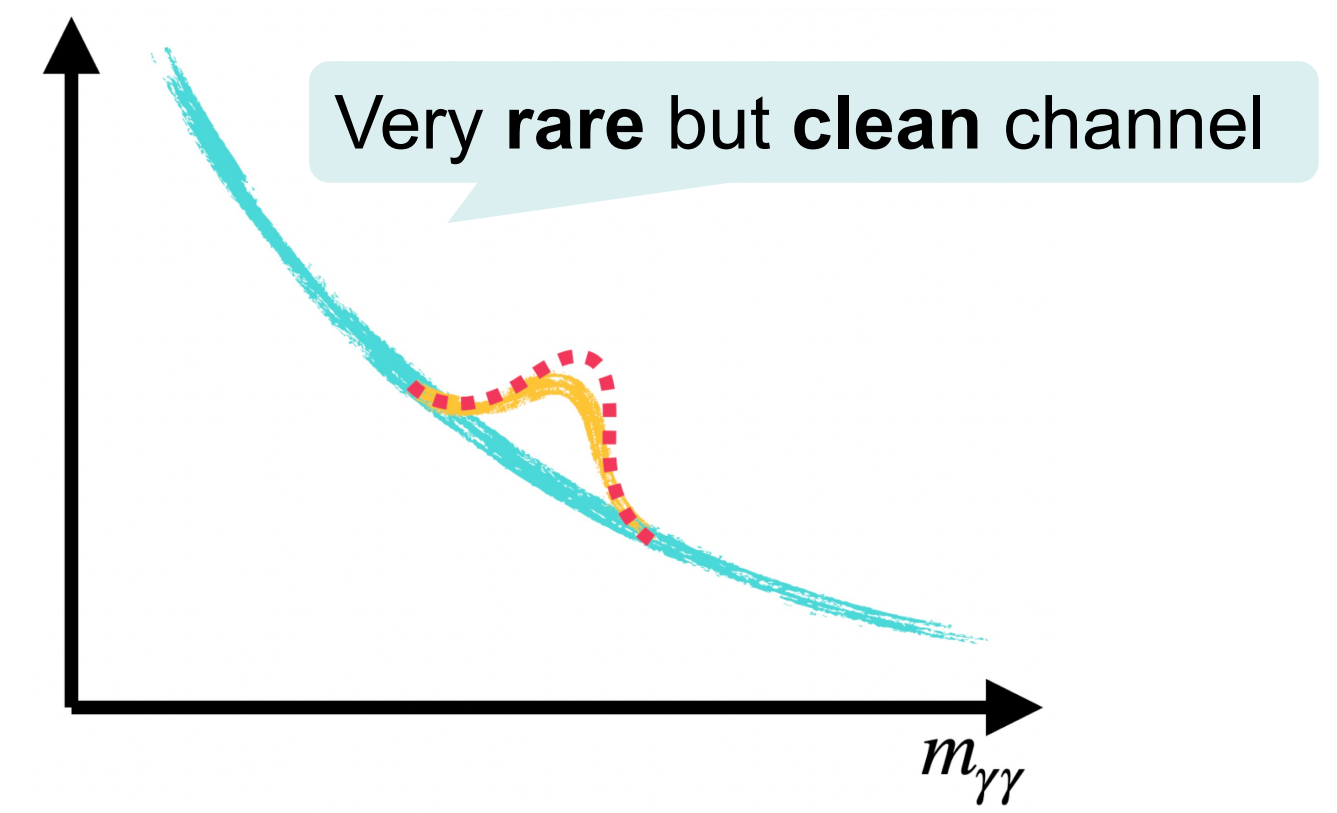
Vector boson fusion (VBFHH) $\sigma_{\text{N3LO}} = 1.73$ [fb]



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

- $H \rightarrow b\bar{b}$: large branching ratio
- $H \rightarrow \gamma\gamma$: excellent $m_{\gamma\gamma}$ resolution
- ✓ **Main backgrounds**
 - Non-resonant $\gamma\gamma$ backgrounds
 - Single Higgs production
- ✓ **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)

	bb	WW	$\tau\tau$	ZZ	$\gamma\gamma$
bb	34%				
WW	25%	4.6%			
$\tau\tau$	7.3%	2.7%	0.39%		
ZZ	3.1%	1.1%	0.33%	0.069%	
$\gamma\gamma$	0.26%	0.10%	0.028%	0.012%	0.0005%

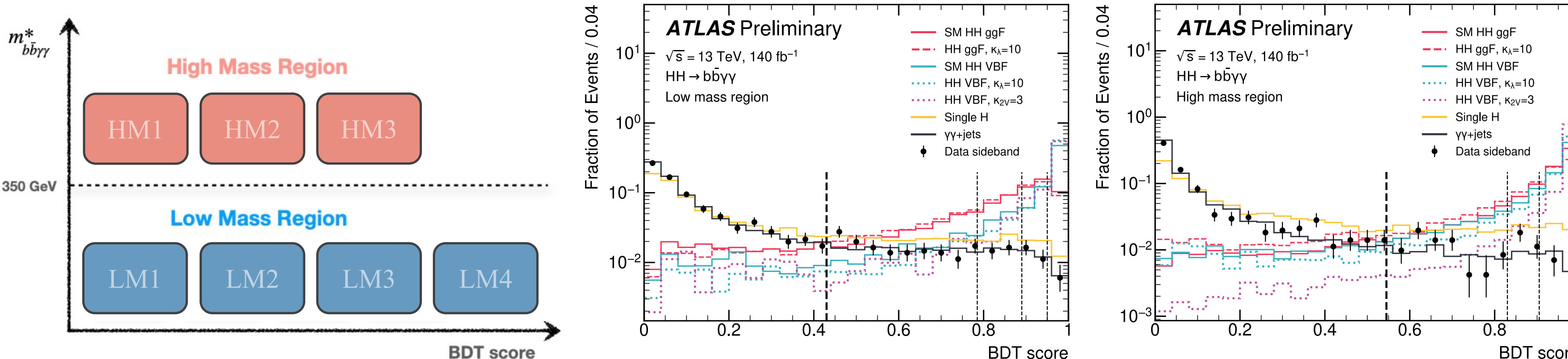


Event categorisation

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**



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

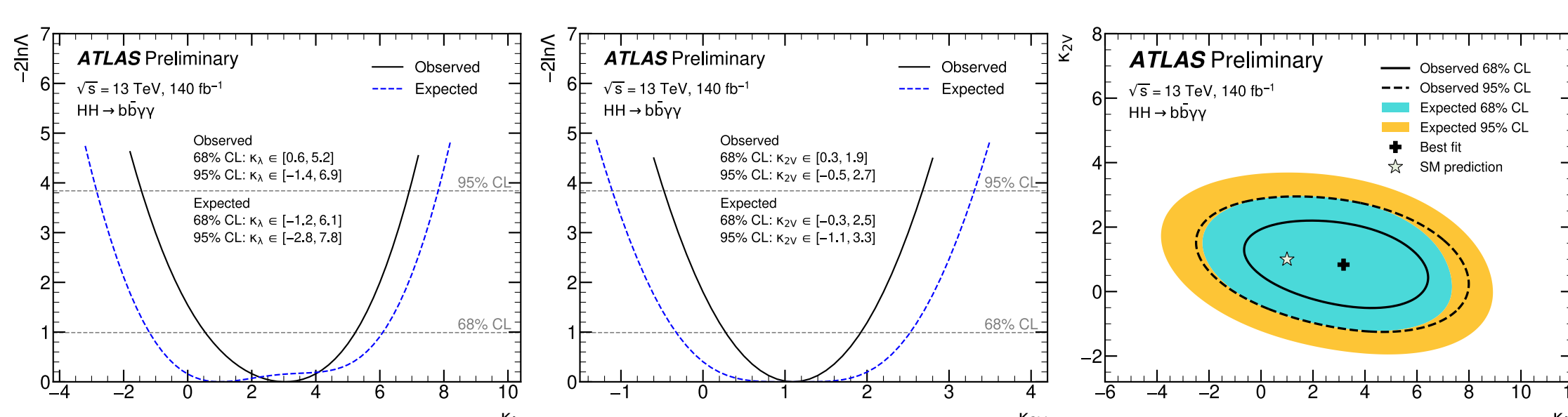
No significant excess over the expected background is observed

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 $(\kappa_\lambda, \kappa_{2V})$ plane

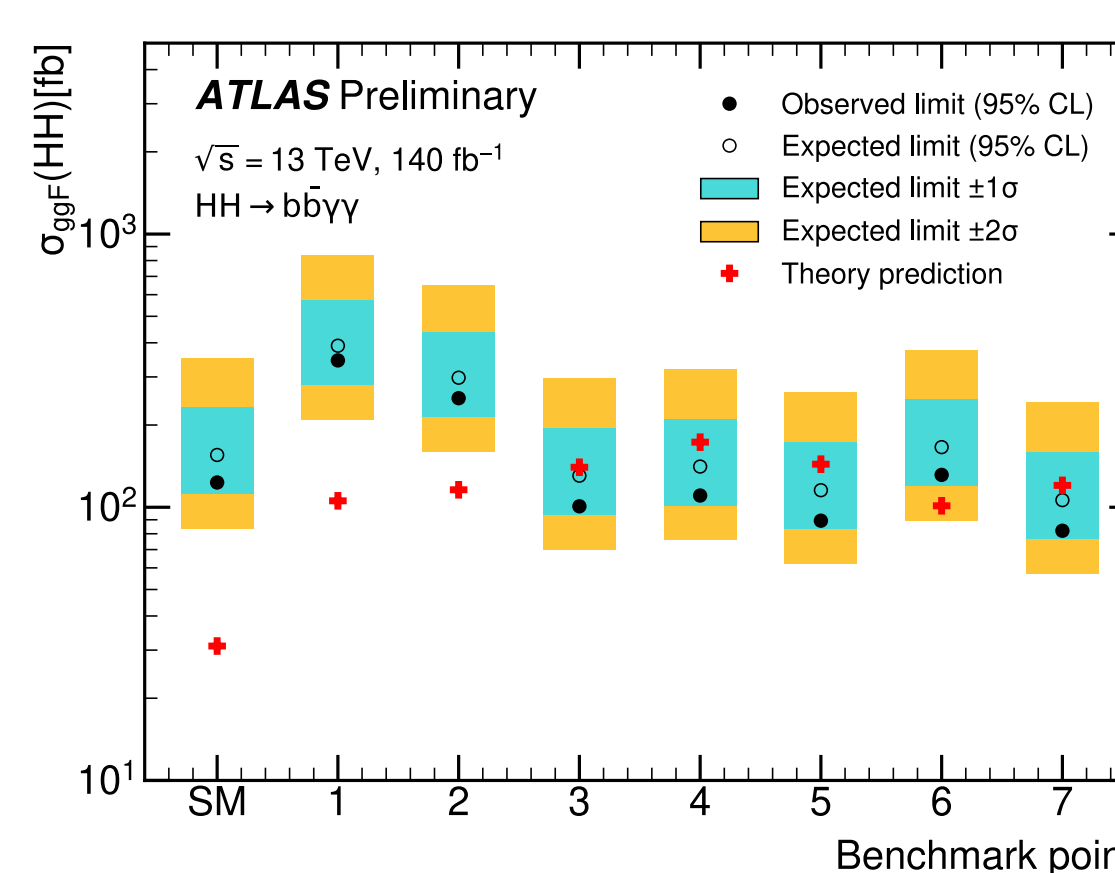


Reference [ATLAS-COM-CONF-2023-057](#)

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_{gggh}	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

