Higgs boson production and decay rate measurements with the ATLAS experiment

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on behalf of the ATLAS collaboration

Lake Louise Winter Institute 2026
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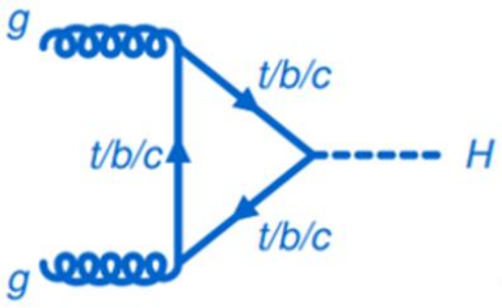
Higgs production and decay

Nature 607 52 (2022)|| arXiv:2207.00092

Production modes

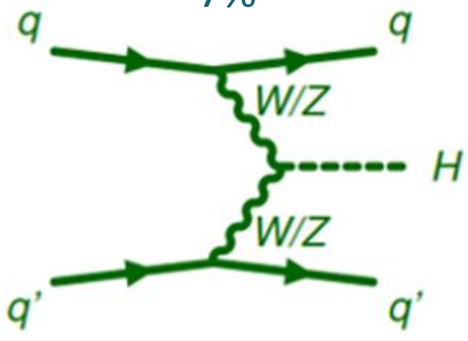
Gluon-gluon fusion (ggF)

~87%



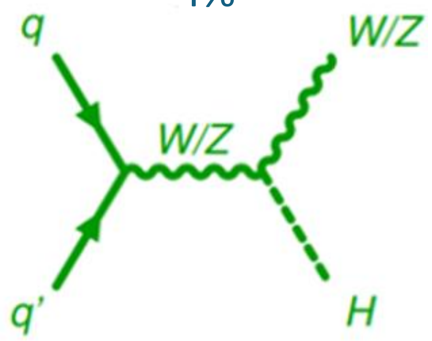
Vector-boson fusion (VBF)

~7%



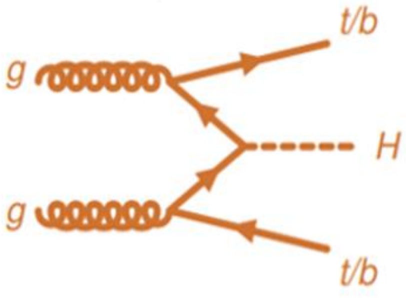
Associated production with a vector boson (VH)

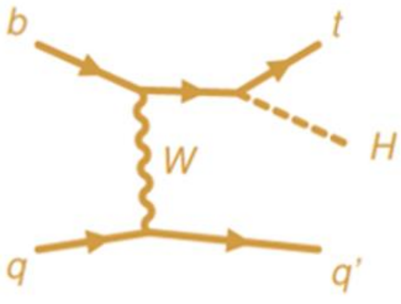
~4%



Associated production with one or two quarks (tH, $t\bar{t}H$, $b\bar{b}H$)

~2% ~0.05%

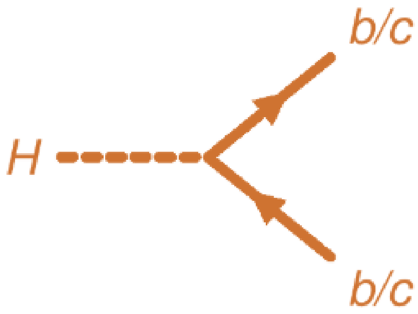




Decay modes

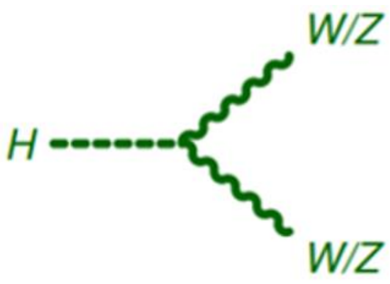
$H \rightarrow b\bar{b}$, $H \rightarrow c\bar{c}$

~58% ~3%



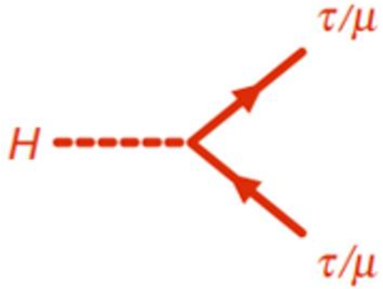
$H \rightarrow WW^*$, $H \rightarrow ZZ^*$

~22% ~3%



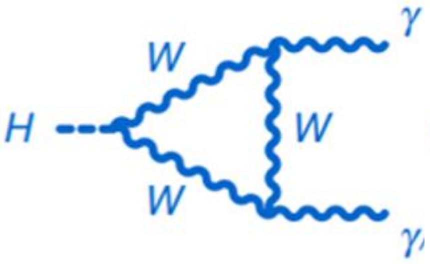
$H \rightarrow \tau^+\tau^-$, $H \rightarrow \mu^+\mu^-$

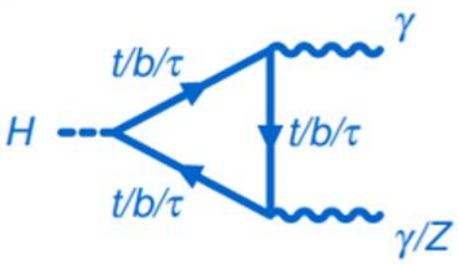
~6% ~0.02%



$H \rightarrow \gamma\gamma$, $H \rightarrow Z\gamma$

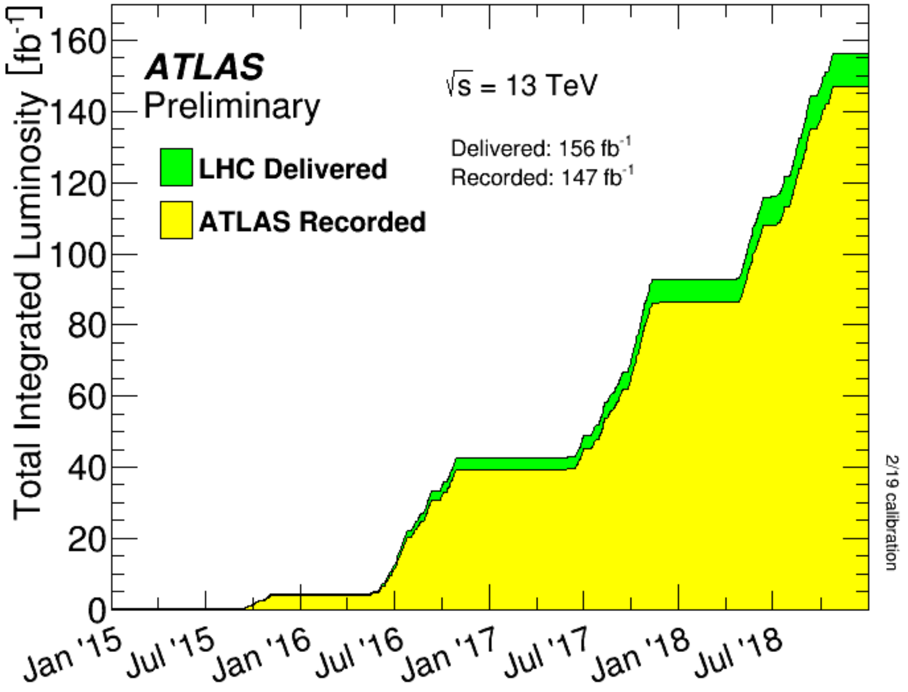
~0.2% ~0.2%



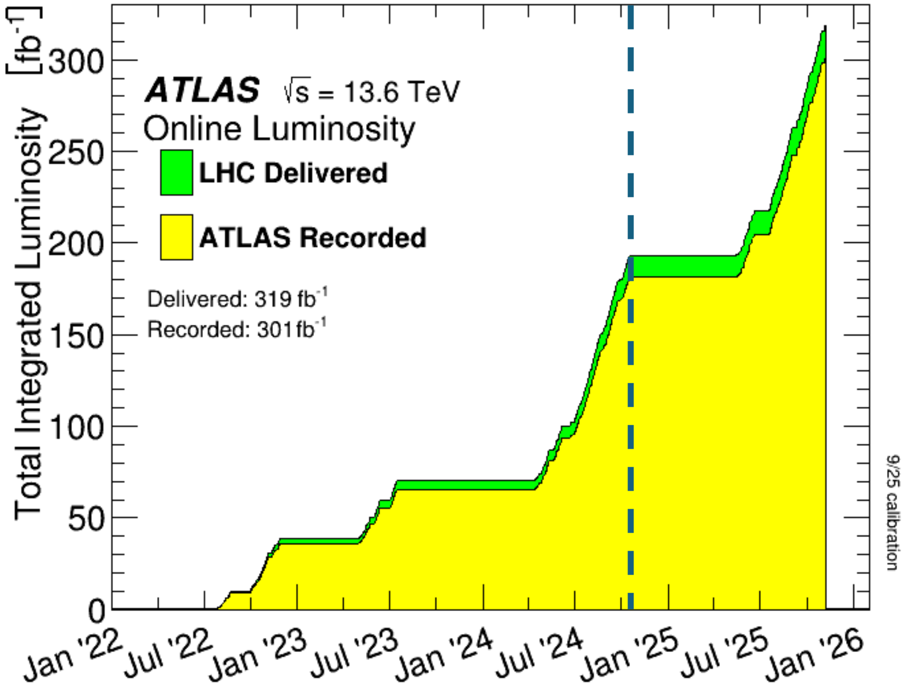


Run 2, Run 3, and Run 2+3 at ATLAS

- Most Run 2 studies now published ($\sqrt{s} = 13$ TeV).
- Run 3 data collection finishes this year ($\sqrt{s} = 13.6$ TeV).
- Partial Run 3 studies (2022-2024, up to 165 fb^{-1}, highlighted) starting to reach publication.
- Including results combining the two runs!



[Public Run 2 luminosity]



[Public Run 3 luminosity]

Cross section measurements

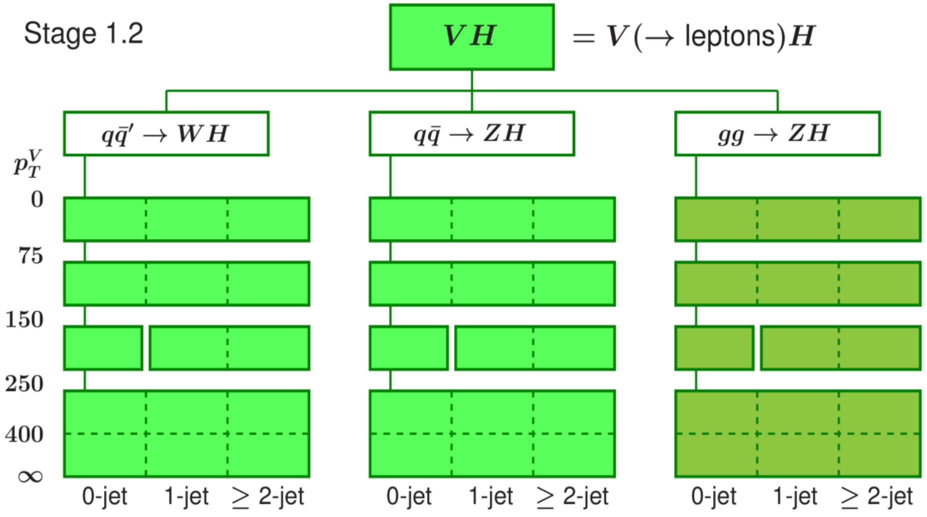
[SciPost Phys.Comm. 15 (2026)] || [arXiv:1906.02754]

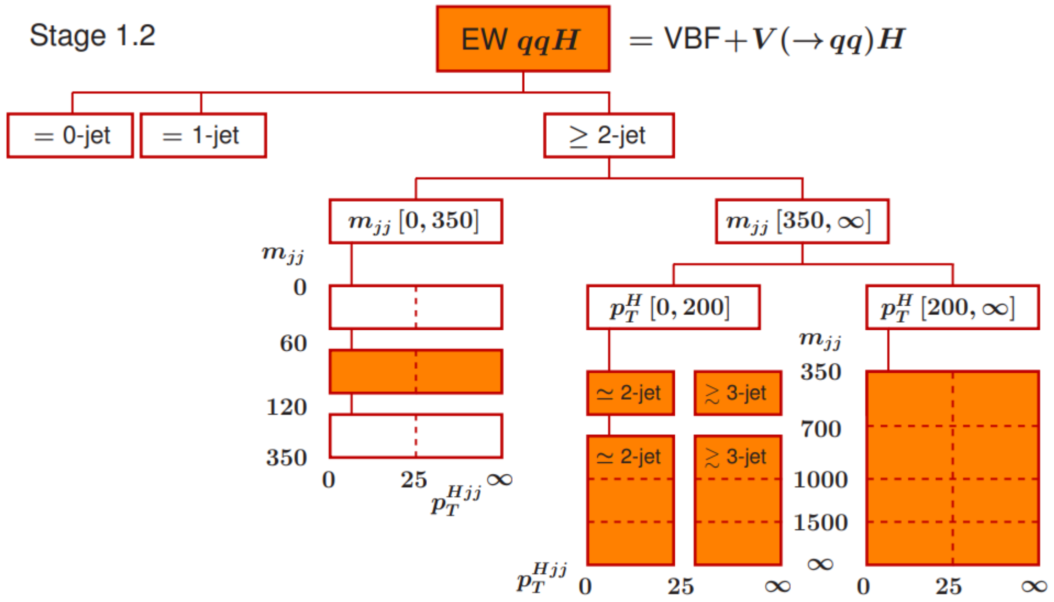
Fiducial cross section

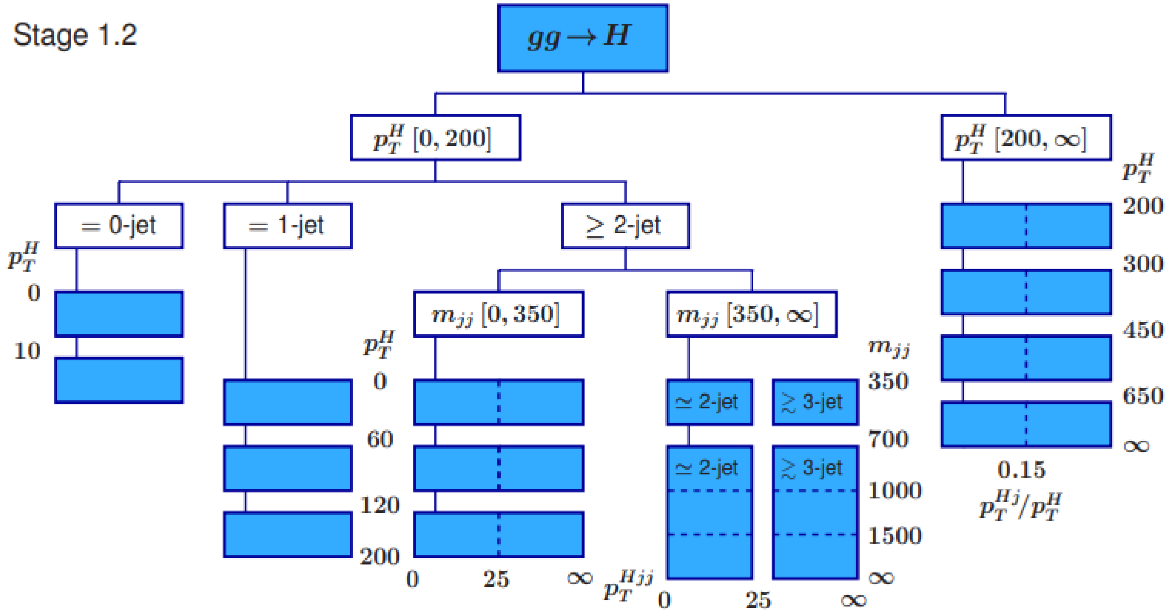
- Measurement within a limited phase space (dictated by detector).

Simplified Template Cross Sections (STXS)

- Differential cross section, organized by kinematic selections.
- Allows for easier combination of different decay channels.
- Schemes organized by Higgs production mode, measurement bins iterated upon (currently stage 1.2).







Recent measurements

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Decay: H → Zγ

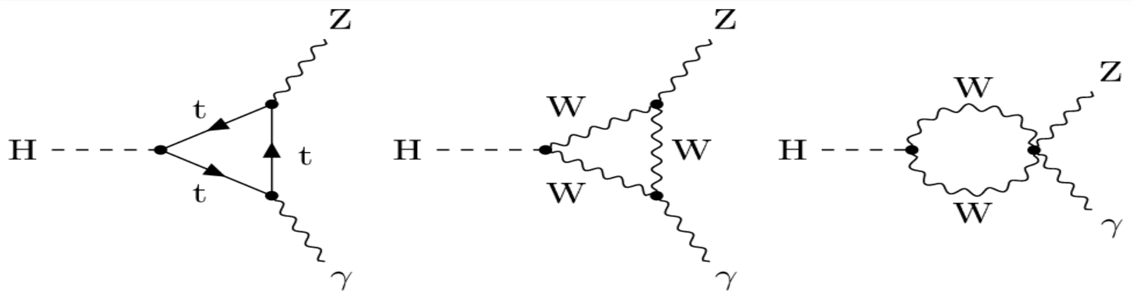
arXiv:2507.12598

Search/branching ratio measurement.

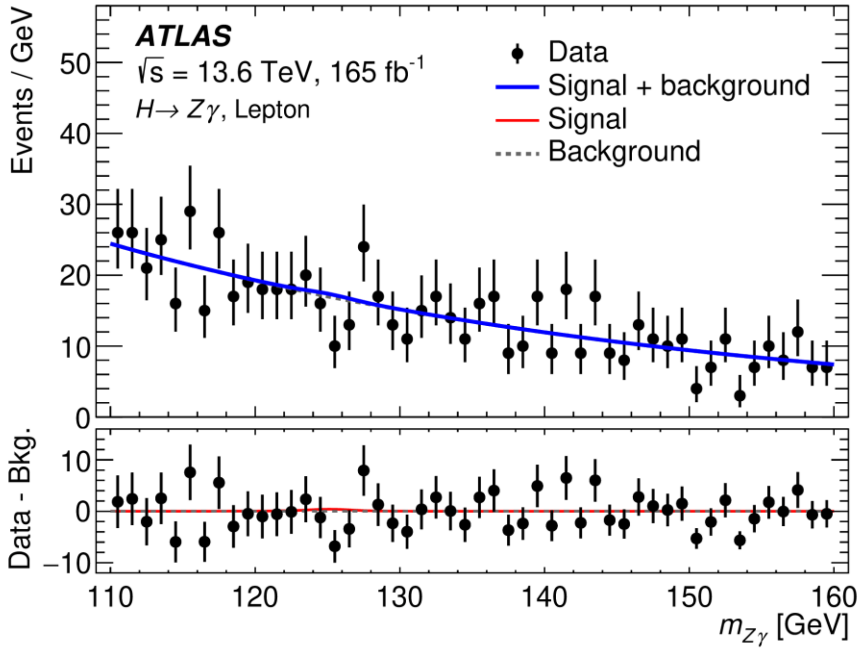
Production: Inclusive ($\ell\ell\gamma$ final state)

Data set: Early Run 3 (2022-2024, 165 fb^{-1})

Combined with Run 2 result (140 fb^{-1})



- Small branching ratio, similar to H→γγ. Many BSM candidates could influence H→Zγ BR, so BR(H→Zγ)/BR(H→γγ) = sensitive probe to new physics.



Partial Run 3:

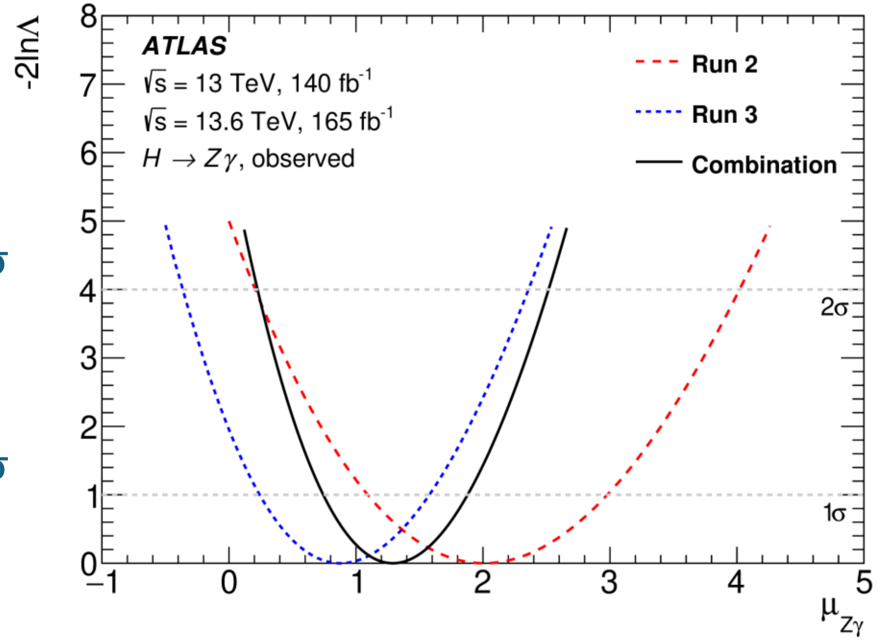
Observed signal yield: $\mu = 0.9^{+0.7}_{-0.6}$

Observed signal significance: 1.4σ

Partial Run 3 + Run 2 combination:

Observed signal yield: $\mu = 1.3^{+0.6}_{-0.5}$

Observed signal significance: 2.5σ



Decay: $\mathrm{H} \rightarrow \gamma\gamma$, $\mathrm{H} \rightarrow \mathrm{ZZ}^* \rightarrow 4\ell$

Eur. Phys. J. C 84 (2024) 78 || arXiv:2306.11379

Fiducial cross section measurement via statistical fit to invariant mass spectra.

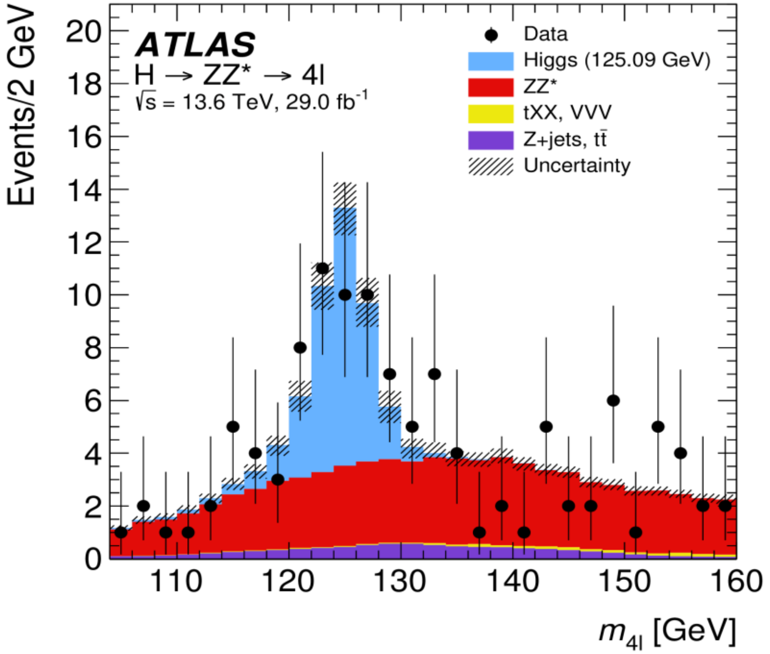
Production: Inclusive

Data set: Early Run 3 (2022)

($\mathrm{H}\rightarrow\gamma\gamma$: 31.4 fb^{-1}, $\mathrm{H}\rightarrow\mathrm{ZZ}^*\rightarrow4\ell$: 29.0 fb^{-1})

Some low efficiency muon trigger data removed.

- Small branching ratios.
- Strong lepton/photon identification efficiencies.



Fiducial measurement:

$$\sigma(\gamma\gamma)_{\mathrm{obs}}: 76^{+14}_{-13}\ \mathrm{fb}$$

$$\sigma(\gamma\gamma)_{\mathrm{SM}}: 67.6^{+3.7}_{-3.7}\ \mathrm{fb}$$

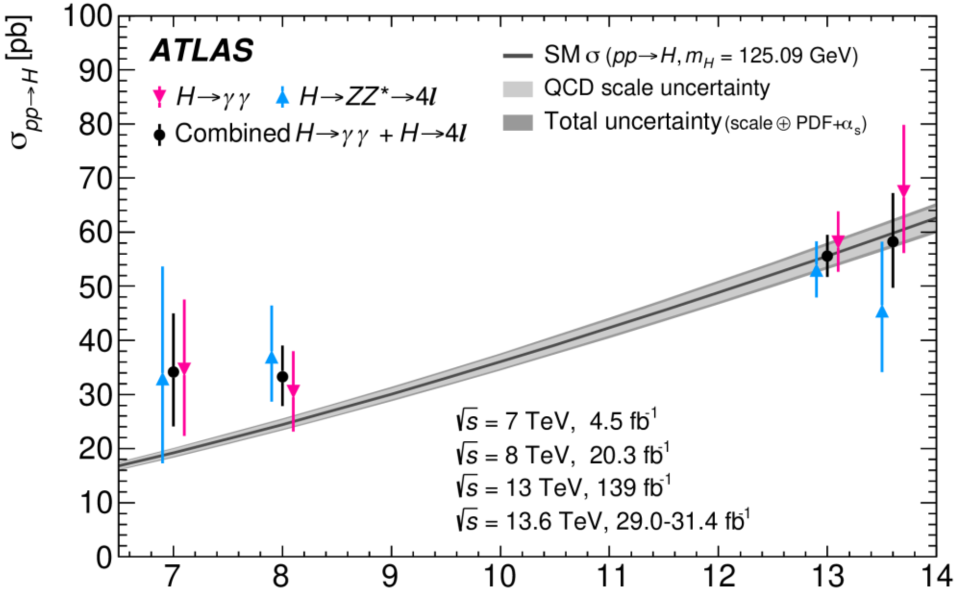
$$\sigma(4\ell)_{\mathrm{obs}}: 2.80^{+0.74}_{-0.74}\ \mathrm{fb}$$

$$\sigma(4\ell)_{\mathrm{SM}}: 3.67^{+0.19}_{-0.19}\ \mathrm{fb}$$

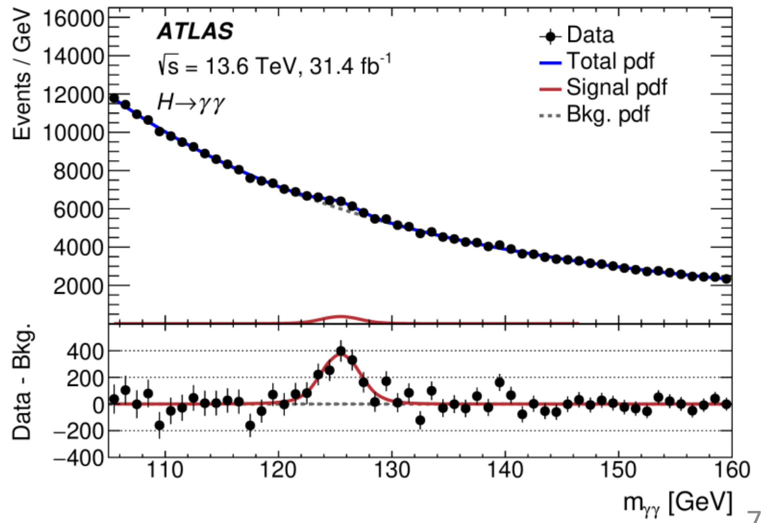
Combined measurement:

$$\sigma(\mathrm{pp}\rightarrow\mathrm{H}) = 58.2^{+8.7}_{-8.7}\ \mathrm{pb}$$

$$\sigma(\mathrm{pp}\rightarrow\mathrm{H})_{\mathrm{SM}} = 59.9^{+2.6}_{-2.6}\ \mathrm{pb}$$



Run 2 publication: arXiv:2207.08615



Decay: H → WW*

Eur. Phys. J. C 85 (2025) 1403 || arXiv:2504.07686

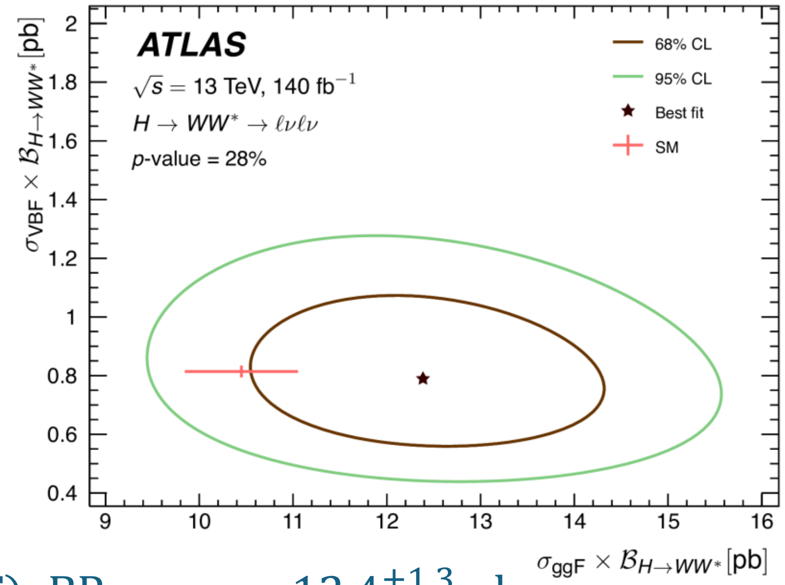
Fiducial and STXS cross section measurement via profile likelihood fit to signal and control regions.

Production: ggF, VBF ($\ell\nu\ell\nu$ final states)

Data set: Run 2 (140 fb^{-1})

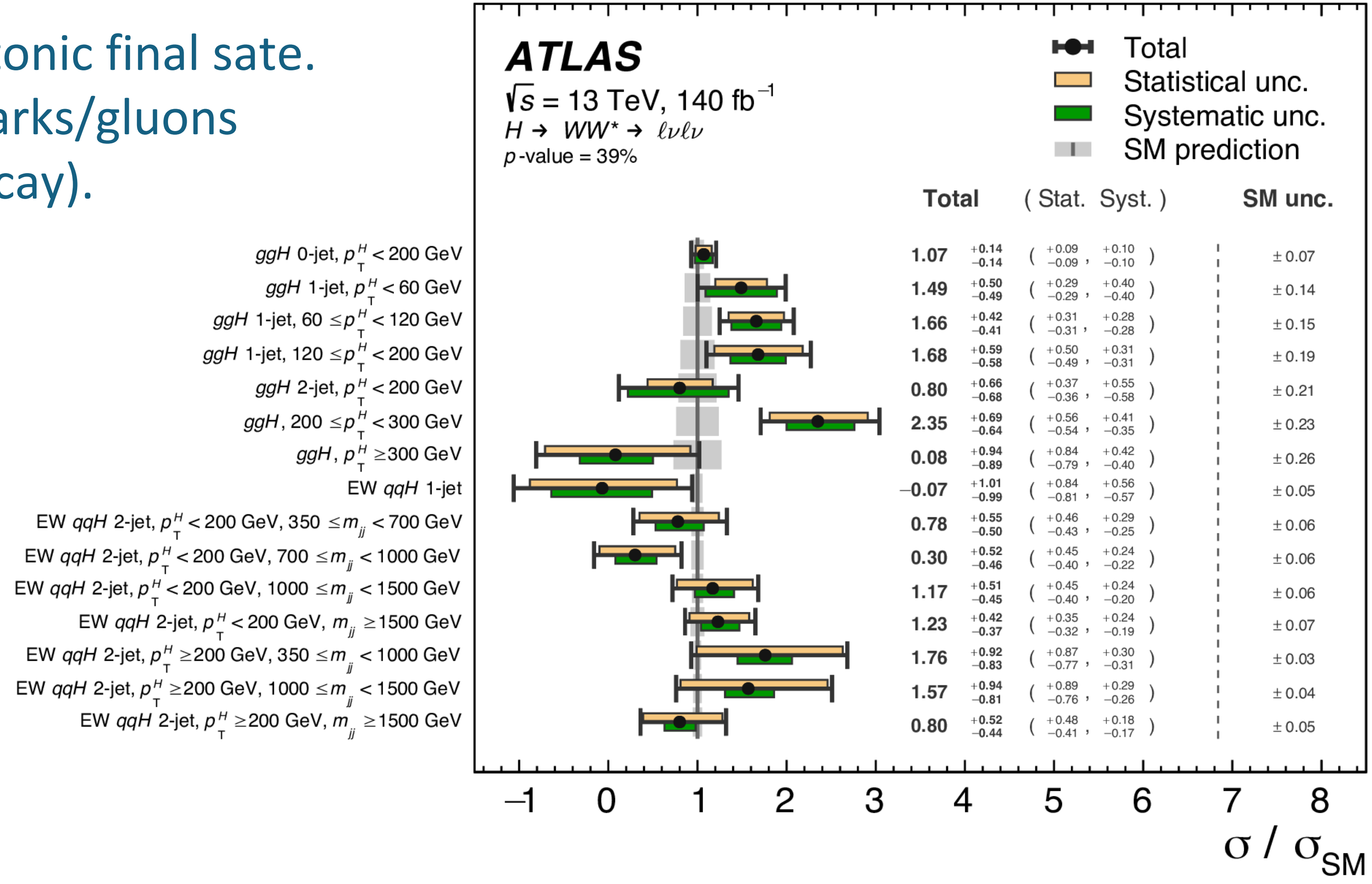
- Large Higgs branching ratio with leptonic final sate.
- Probe of Higgs coupling to heavy quarks/gluons (ggF) and vector bosons (VBF, VH decay).

- First ggF p_T^H 300 GeV split.
- First 1-jet VBF measurement.
- First 2-jet VBF p_T^H m_{jj}(350, 1000, 1500 GeV) splits.



σ(ggF)xBR$_{(H\rightarrow WW^*)}$: $12.4^{+1.3}_{-1.2}$ pb

σ(VBF)xBR$_{(H\rightarrow WW^*)}$: $0.79^{+0.18}_{-0.16}$ pb



Decay: H → WW*

JHEP 08 (2025) 034 || arXiv:2503.19420

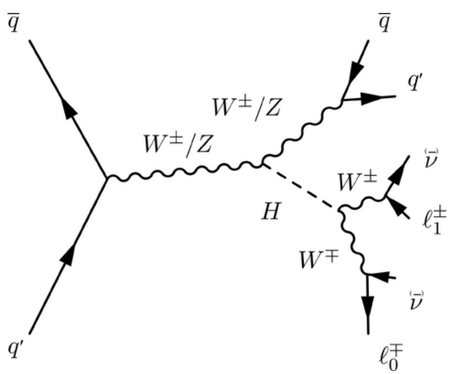
Fiduciał and STXS cross section measurement.

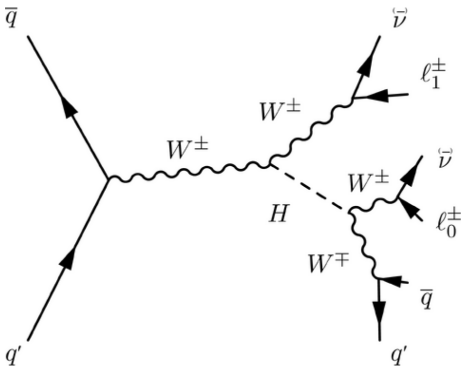
Production: WH (2ℓ, 3ℓ final states)

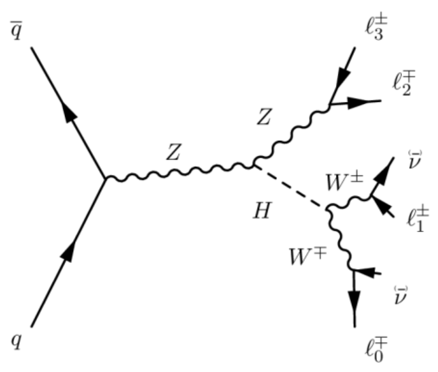
ZH (4ℓ final state)

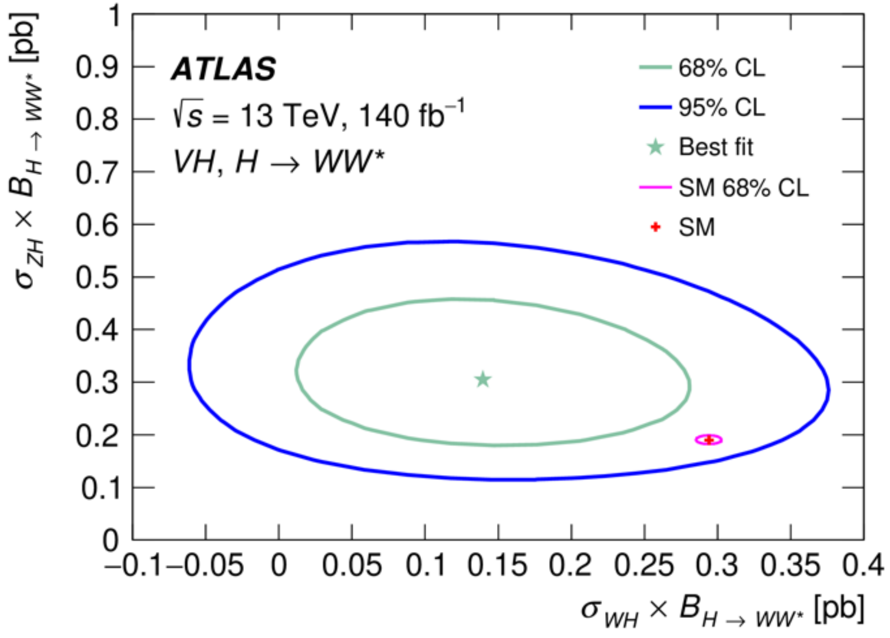
Data set: Run 2 (140 fb^{-1})

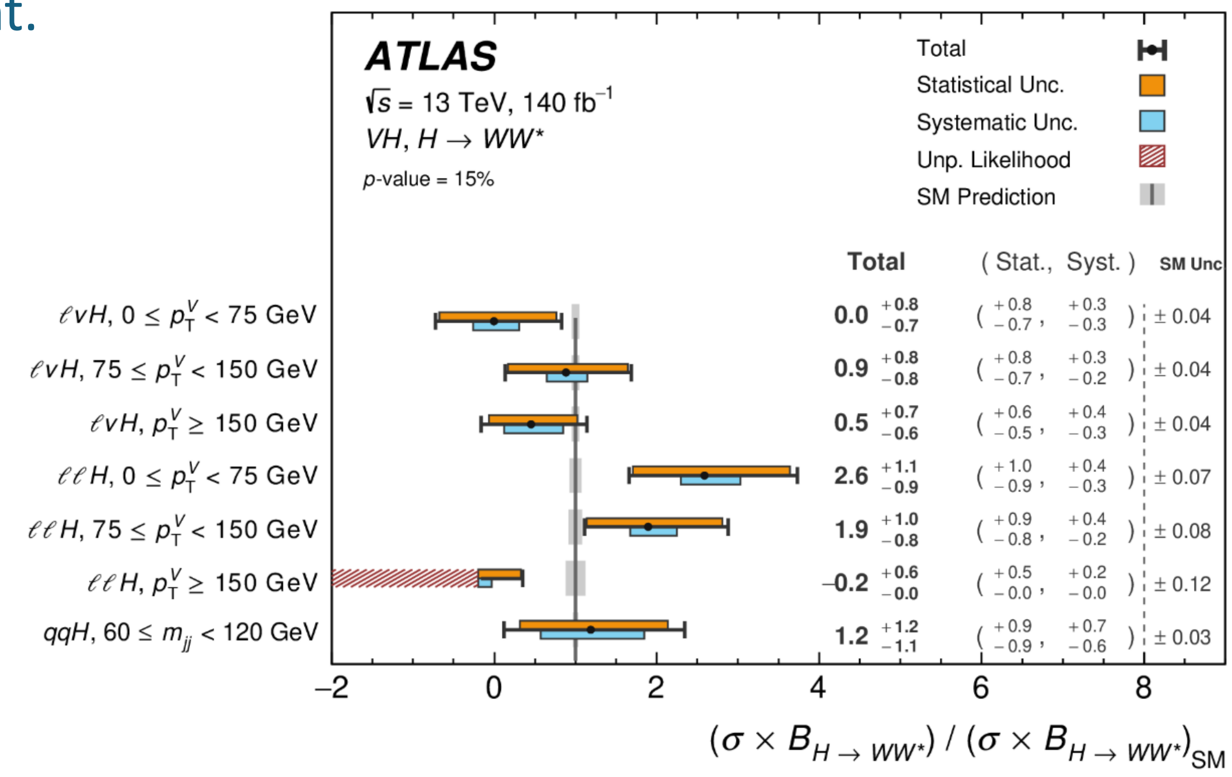
- Large branching ratio.
- Probe of Higgs coupling to vector bosons.
- First ATLAS VH, H → WW* STXS measurement.











Decay: $H \rightarrow \tau^+\tau^-$

JHEP 03 (2025) 010 | | arXiv:2407.16320

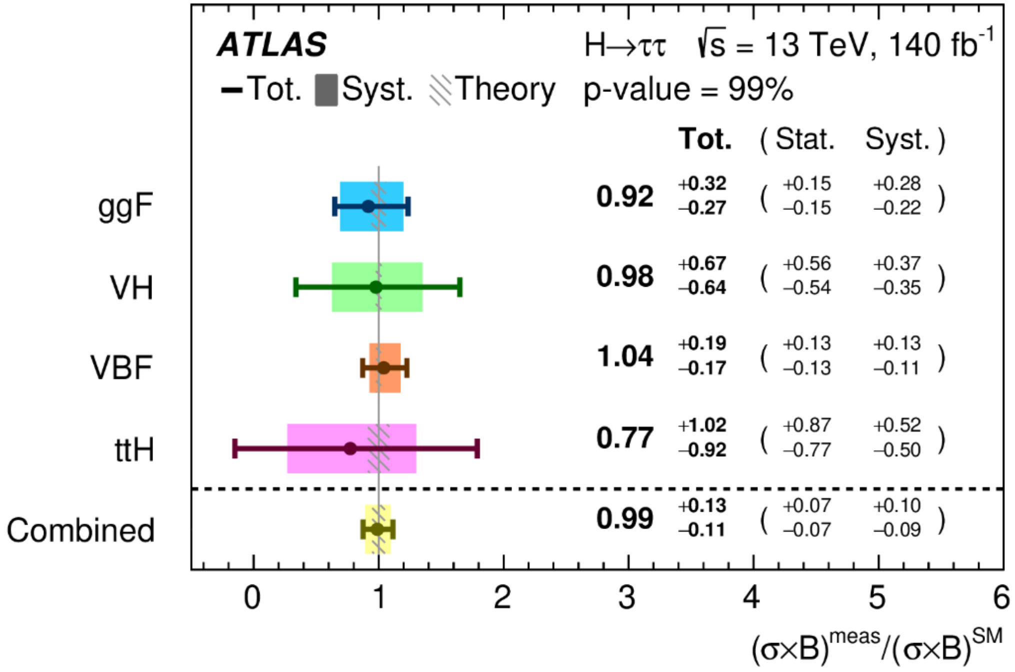
STXS & Unfolded Fiducial Differential (UFD) cross section measurements.

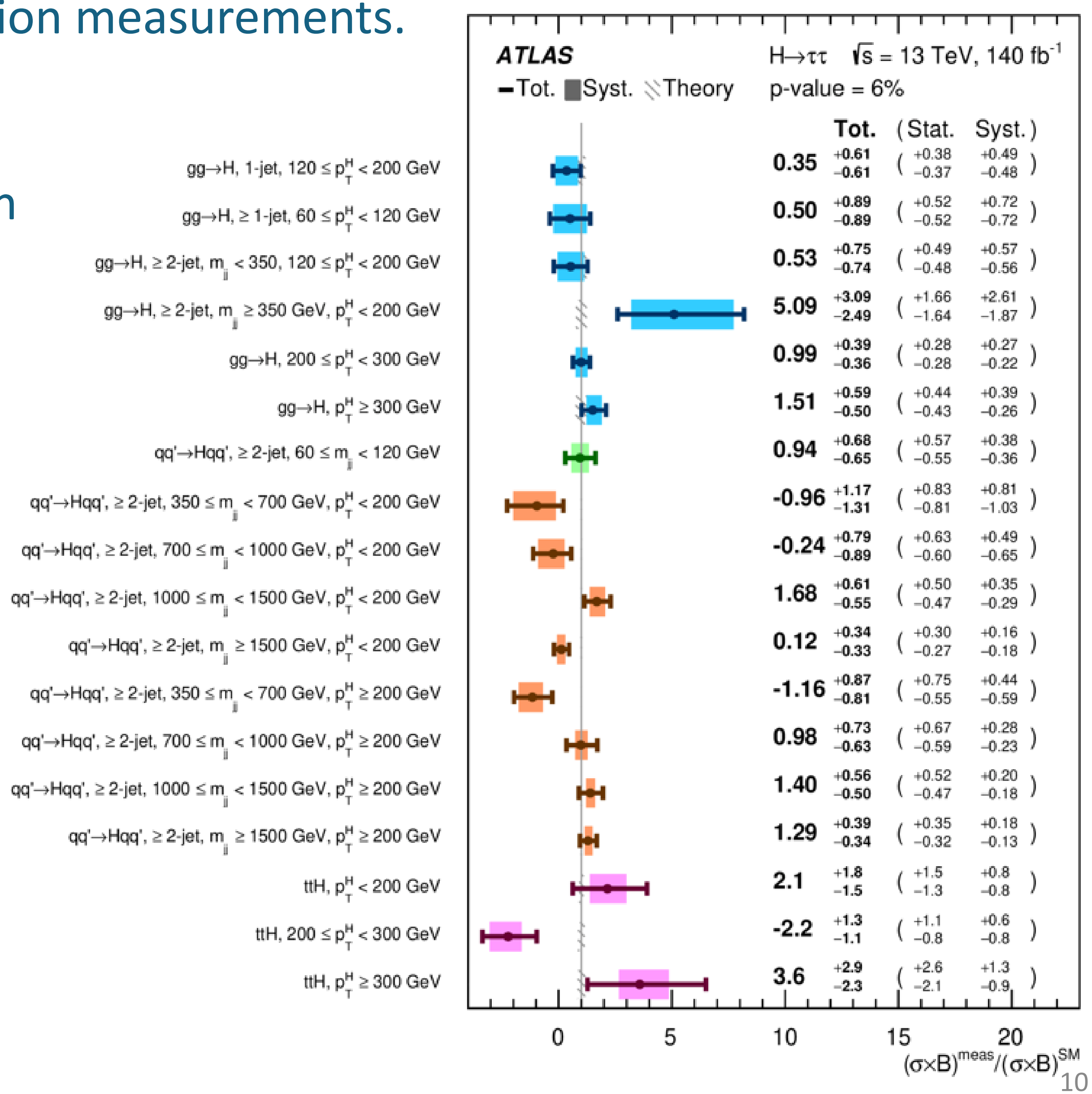
Production: ggF, VBF, VH, $t\bar{t}H$

Data set: Run 2 (140 fb^{-1})

~6% BR, many production modes considered, enough statistics for new STXS measurements:

- First VBF split in full STXS 1.2 bins.
- First $t\bar{t}H$ split at 200 and 300 GeV.





Decay: H → $\mu^+\mu^-$

Phys. Rev. Lett. 135 (2025) 231802 || arXiv:2507.03595

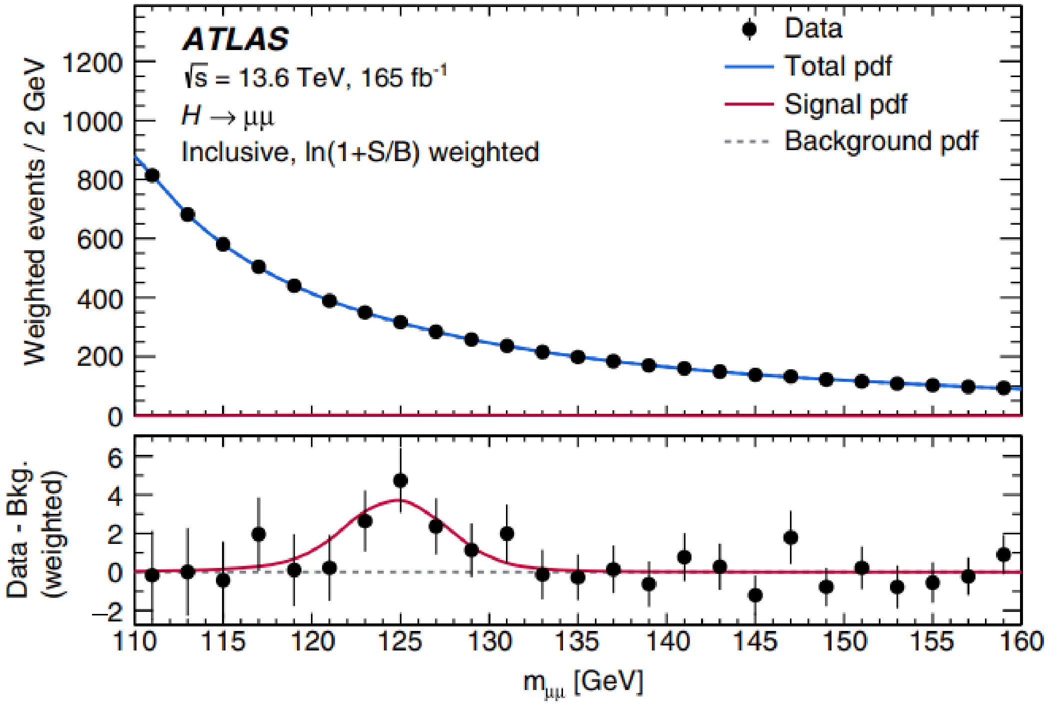
Search/branching ratio measurement

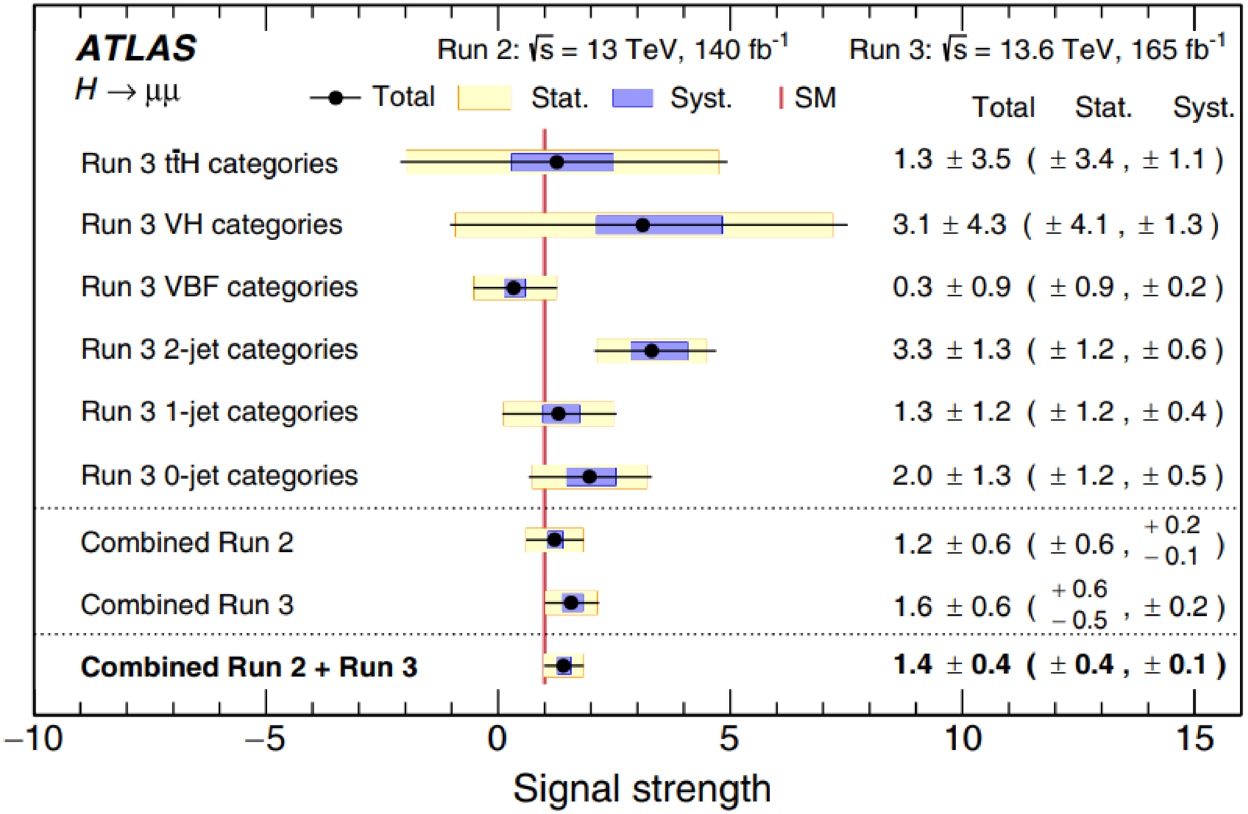
Production: ggF, VBF, VH, $t\bar{t}H$

Data set: Early Run 3 (2022-2024, 165 fb^{-1})

Combined with Run 2 result (140 fb^{-1})

- Extremely small branching ratio, but best option to study Higgs coupling to second generation fermions.





Combined signal strength $\mu = 1.4^{+0.4}_{-0.4}$

Observed significance: 3.4σ (2.5σ exp.)

Decay: $H \to b\bar{b}$, $H \to c\bar{c}$

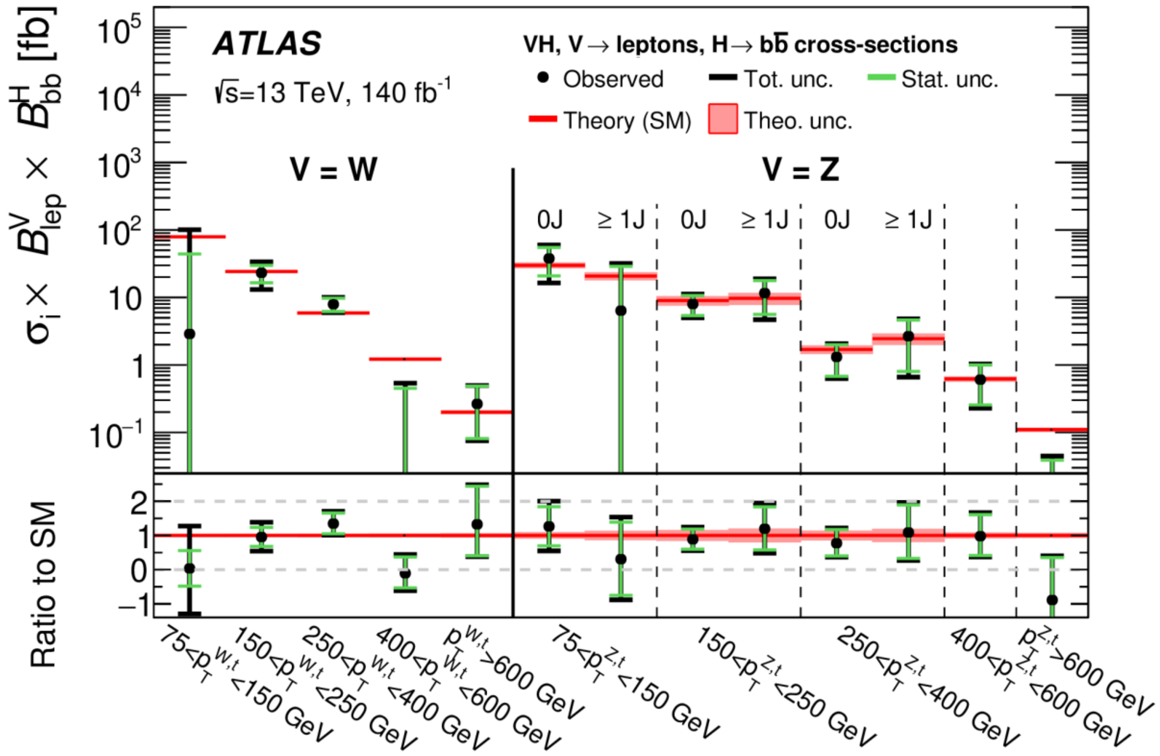
JHEP 04 (2025) 075 || arXiv:2410.19611

Search/branching ratio inclusive and STXS measurement.

Production: VH

Data set: Run 2 (140 fb^{-1})

- Looking at leptonic V decay final states (0, 1, or $2\ell^{\pm}$).
- p_T^V > 600 GeV measurement (planned for STXS stage 1.3)



$\sigma(VH) x BR_{(H \to cc)} = 11.5 * SM$

First 5σ obs of $WH_{H \to bb}$!

WH, $H \to b\bar{b}$

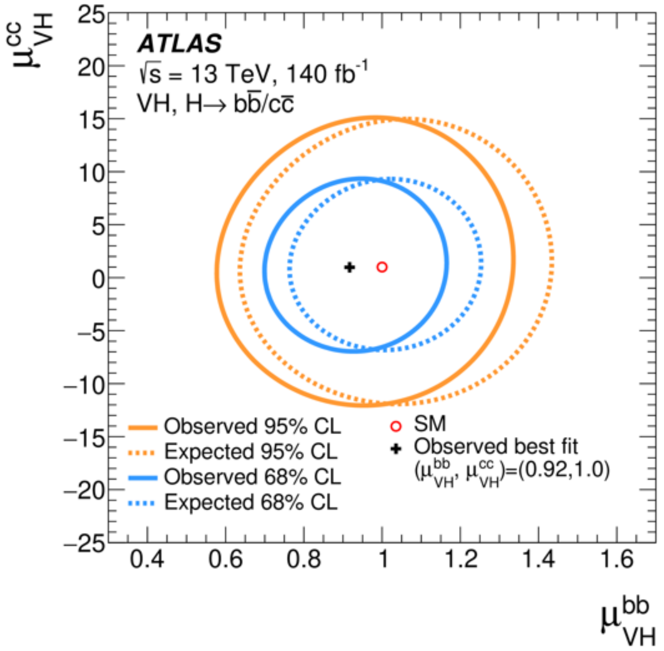
$\mu = 0.95^{+0.21}_{-0.20}$

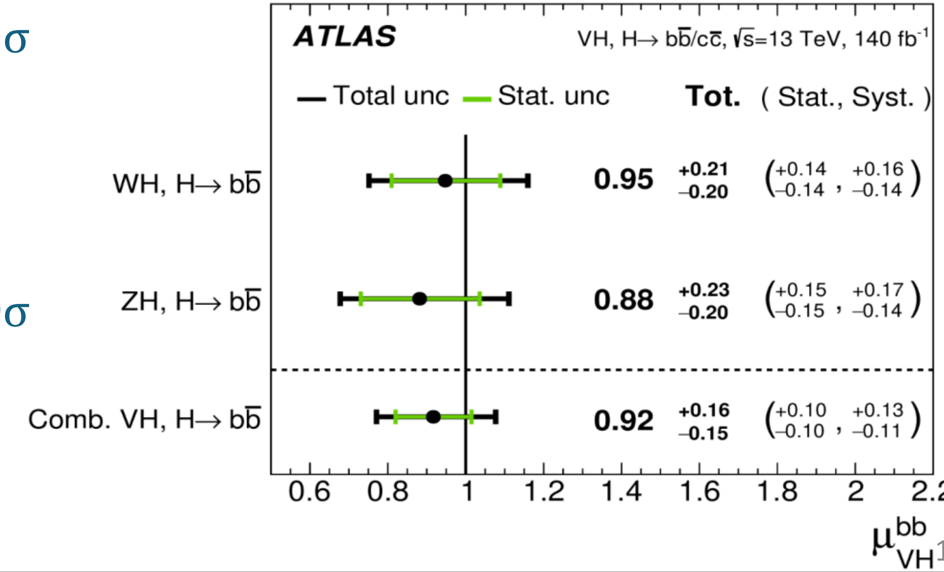
Signal signif: 5.3σ

ZH, $H \to b\bar{b}$

$\mu = 0.88^{+0.23}_{-0.20}$

Signal signif: 4.9σ





Decay: $H \rightarrow b\bar{b}$

Eur. Phys. J. C 85 (2025) 210 | | arXiv:2407.10904

Fiducial cross section and STXS measurement.

Production: $t\bar{t}H$
Data set: Run 2 (140 fb^{-1})

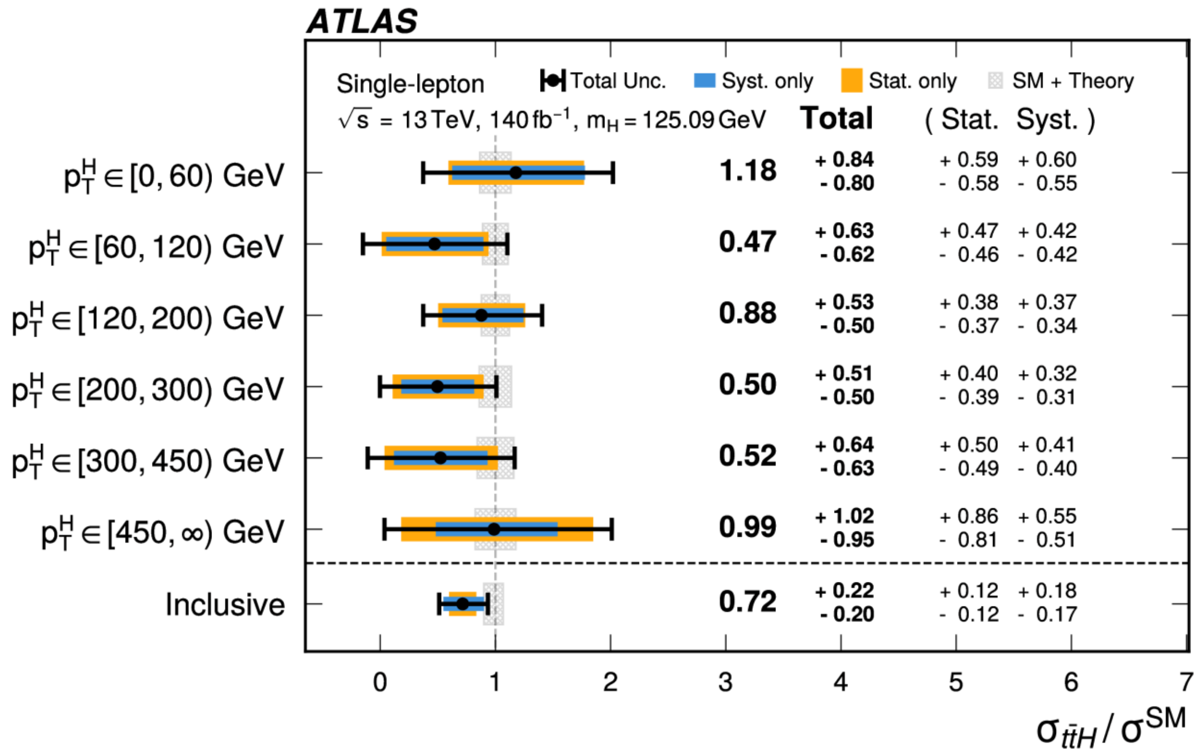
- Sensitive probe of fermionic Higgs couplings (production and decay).
- Challenging background treatment ($t\bar{t}$+jets events).
- Single lepton and dilepton channels.

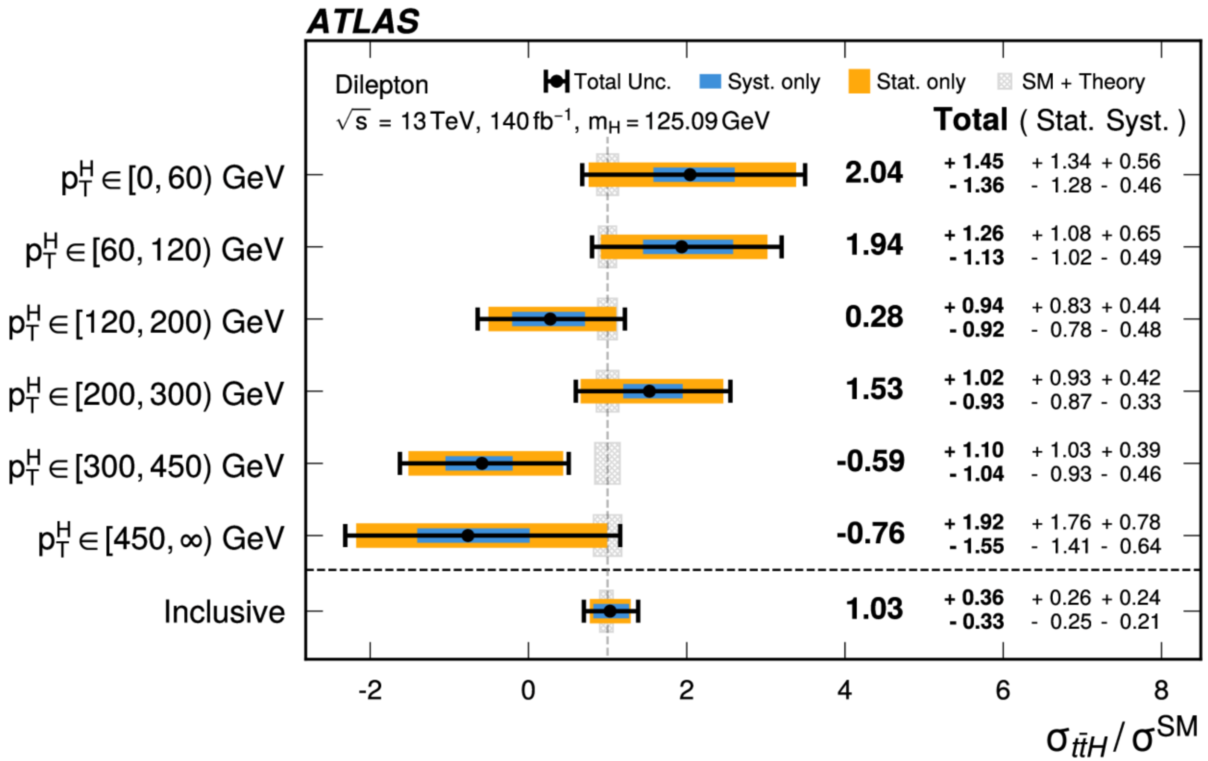
$\sigma(t\bar{t}H): 411^{+54}_{-54}(\text{stat.})^{+85}_{-75}(\text{syst.})$ fb

SM: $\sigma(t\bar{t}H): 507^{+35}_{-50}$ fb

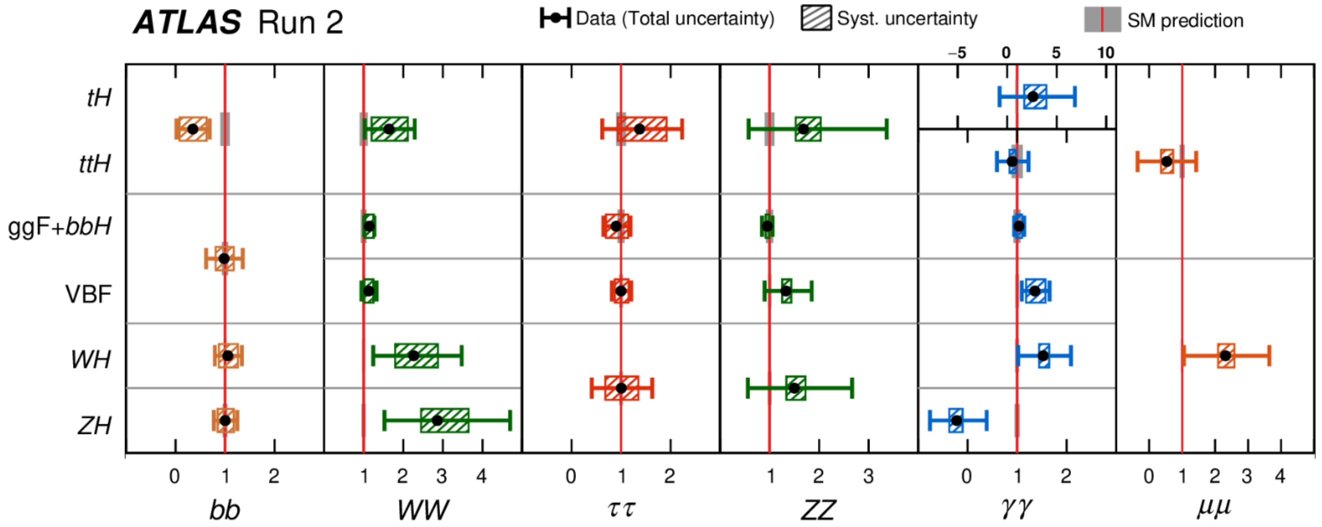
$\mu_{ttH} = 0.81^{+0.11}_{-0.11}(\text{stat.})^{+0.20}_{-0.16}(\text{syst.})$

Signal signif: 4.6σ





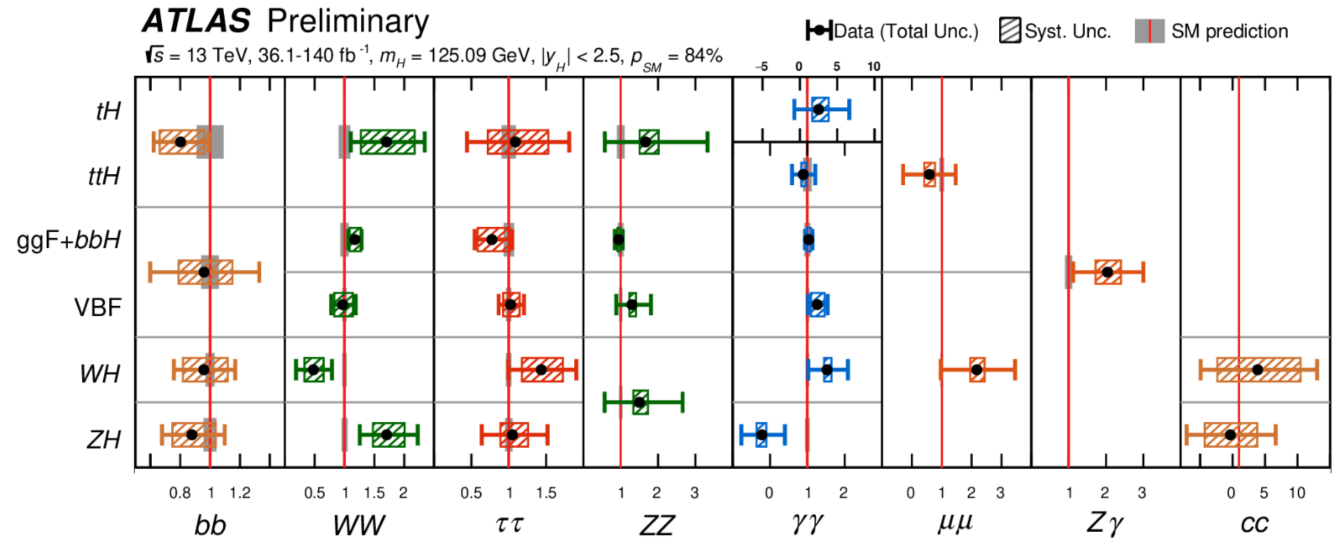
Summary & outlook



Nature 607 52 (2022) σ × B normalized to SM prediction

2022

2025



ATLAS-CONF-2025-006 σ × B normalized to SM prediction

- Great progress in recent years!
- Latest global signal strength measurement:

$$\mu = \frac{\sigma_i * BR_f}{\sigma_{SM} * BR_{SM}} = 1.023^{+0.056}_{-0.053}$$

ATLAS-CONF-2025-006

- Many cross section and BR measurements 10-40% more precise than previous studies.
- Good agreement with standard model so far!

Summary & outlook

(Marked with (A) if in appendix)

Decay mode		Targeted production processes	Latest measurement	$\mathcal{L}$ [fb^{-1}]	Ref.
$H \to \gamma\gamma$		Inclusive	Partial Run 3	31.4	arXiv:2306.11379
$H \to ZZ^* \to 4\ell$		Inclusive	Partial Run 3	29.0	arXiv:2306.11379
$H \to Z\gamma$		Inclusive	Run 2 + Partial Run 3	140 + 165	arXiv:2507.12598
$H \to WW^*$		ggF, VBF	Run 2	140	arXiv:2504.07686
		WH, ZH	Run 2	140	arXiv:2503.19420
$H \to \tau\tau$		ggF, VBF, $WH + ZH$, $t\bar{t}H$	Run 2	140	arXiv:2407.16320
$H \to \mu\mu$		ggF, VBF, VH, $t\bar{t}H$	Run 2 + Partial Run 3	140 + 165	arXiv:2507.03595
$H \to b\bar{b}$		WH, ZH	Run 2	140	arXiv:2410.19611
	(A)	VBF	Run 2 + Partial Run 3	37.5 + 51.5	arXiv:2511.21911
	(A)	VBF + γ	Run 2	133	arXiv:2509.14005
		$t\bar{t}H$	Run 2	140	arXiv:2407.10904
$H \to c\bar{c}$		$WH + ZH$	Run 2	140	arXiv:2410.19611
	(A)	VBF	Run 2 + Partial Run 3	37.5 + 51.5	arXiv:2511.21911
$H \to 4\nu$	(A)	VBF	Run 1 + Run 2	4.7 + 20.3 + 139	arXiv:2301.10731
Production mode		**Decay modes**			
$t\bar{t}H$	(A)	Inclusive (multilepton)	Run 2	140	arXiv:2510.23755
tH	(A)	Inclusive (multilepton)	Run 2	140	arXiv:2508.14695

Full Run 3 studies with 300+ fb^{-1} on the horizon!

A lot to look forward to!

Questions?

[2025]

Additional material

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Run 2 measurement tables (2025)

ATLAS-CONF-2025-006

Decay mode	Prod. mode	Measurement (pb)	SM prediction (pb)	Ratio to SM
$H \to bb$	ggF + bbH + VBF	27 ± 10	28.0 ± 1.6	1.0 ± 0.4
	WH	$0.68\,^{+0.15}_{-0.14}$	$0.706\,^{+0.018}_{-0.019}$	$0.96\,^{+0.21}_{-0.20}$
	ZH	$0.41\,^{+0.10}_{-0.09}$	0.462 ± 0.019	$0.88\,^{+0.22}_{-0.20}$
	$ttH + tH$	0.27 ± 0.06	0.340 ± 0.030	$0.80\,^{+0.19}_{-0.18}$
$H \to WW^*$	ggF + bbH	11.3 ± 1.1	9.6 ± 0.6	1.17 ± 0.11
	VBF	$0.73\,^{+0.17}_{-0.14}$	0.753 ± 0.022	$0.97\,^{+0.22}_{-0.19}$
	WH	0.13 ± 0.08	0.262 ± 0.008	$0.48\,^{+0.31}_{-0.29}$
	ZH	$0.29\,^{+0.09}_{-0.08}$	0.171 ± 0.007	$1.7\,^{+0.5}_{-0.4}$
	$ttH + tH$	0.21 ± 0.08	0.126 ± 0.011	1.7 ± 0.6
$H \to \tau\tau$	ggF + bbH	$2.2\,^{+0.8}_{-0.6}$	2.80 ± 0.17	$0.77\,^{+0.27}_{-0.23}$
	VBF	$0.226\,^{+0.040}_{-0.035}$	0.219 ± 0.007	$1.03\,^{+0.18}_{-0.16}$
	WH	$0.110\,^{+0.040}_{-0.033}$	0.0761 ± 0.0023	$1.4\,^{+0.5}_{-0.4}$
	ZH	$0.052\,^{+0.023}_{-0.020}$	0.0498 ± 0.0022	$1.1\,^{+0.5}_{-0.4}$
	$ttH + tH$	$0.040\,^{+0.026}_{-0.024}$	0.0366 ± 0.0033	$1.1\,^{+0.7}_{-0.6}$

Decay mode	Prod. mode	Measurement (fb)	SM prediction (fb)	Ratio to SM
$H \to cc$	WH	$135\,^{+320}_{-310}$	$35.1\,^{+2.4}_{-1.2}$	$3.9\,^{+9.2}_{-8.8}$
	ZH	$-8\,^{+160}_{-150}$	$23.0\,^{+1.7}_{-1.1}$	$-0.3\,^{+7.0}_{-6.8}$
$H \to ZZ^*$	ggF + bbH	$1.11\,^{+0.13}_{-0.12}$	1.18 ± 0.07	$0.94\,^{+0.11}_{-0.10}$
	VBF	$0.12\,^{+0.05}_{-0.04}$	0.0924 ± 0.0027	$1.3\,^{+0.5}_{-0.4}$
	VH	$0.08\,^{+0.06}_{-0.05}$	$0.0531\,^{+0.0016}_{-0.0017}$	$1.5\,^{+1.2}_{-0.9}$
	$ttH + tH$	$0.026\,^{+0.026}_{-0.017}$	0.0154 ± 0.0014	$1.7\,^{+1.7}_{-1.1}$
$H \to \gamma\gamma$	ggF + bbH	106 ± 10	102 ± 7	1.04 ± 0.10
	VBF	$10.0\,^{+2.2}_{-2.0}$	7.94 ± 0.28	$1.26\,^{+0.28}_{-0.25}$
	WH	$4.2\,^{+1.5}_{-1.4}$	2.76 ± 0.10	$1.5\,^{+0.6}_{-0.5}$
	ZH	$-0.4\,^{+1.1}_{-1.0}$	1.81 ± 0.08	-0.2 ± 0.6
	ttH	$1.01\,^{+0.40}_{-0.34}$	1.13 ± 0.12	$0.89\,^{+0.32}_{-0.30}$
	tH	$0.5\,^{+0.8}_{-0.6}$	$0.192\,^{+0.013}_{-0.025}$	$2.5\,^{+4.0}_{-3.3}$
$H \to Z\gamma$	All	$160\,^{+80}_{-70}$	78 ± 7	$2.0\,^{+1.0}_{-0.9}$
$H \to \mu\mu$	ggF + bbH + ttH + tH	6 ± 9	9.8 ± 0.6	0.6 ± 0.9
	VBF + VH	$2.6\,^{+1.5}_{-1.4}$	$1.197\,^{+0.035}_{-0.040}$	$2.2\,^{+1.3}_{-1.2}$

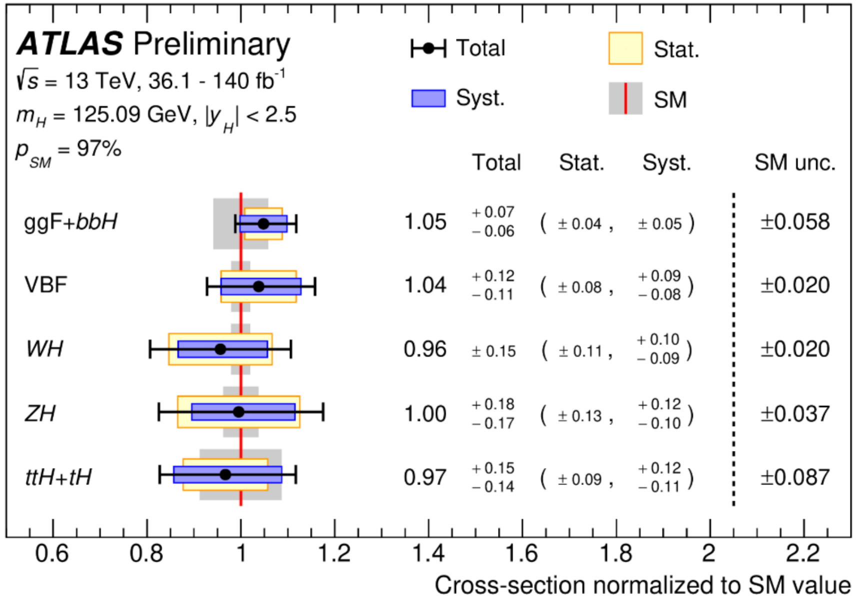
Branching ratio	Measurement	SM prediction	Ratio to SM
$H \to bb$	$0.52\,^{+0.07}_{-0.06}$	0.581 ± 0.010	$0.89\,^{+0.12}_{-0.11}$
$H \to WW^*$	$0.245\,^{+0.022}_{-0.019}$	0.215 ± 0.005	$1.14\,^{+0.10}_{-0.09}$
$H \to \tau\tau$	$(6.2\,^{+0.7}_{-0.6}) \cdot 10^{-2}$	$(6.26\,^{+0.15}_{-0.14}) \cdot 10^{-2}$	$0.99\,^{+0.11}_{-0.10}$
$H \to ZZ^*$	$(2.67 \pm 0.26) \cdot 10^{-2}$	$(2.64 \pm 0.06) \cdot 10^{-2}$	1.01 ± 0.10
$H \to \gamma\gamma$	$(2.38 \pm 0.20) \cdot 10^{-3}$	$(2.27\,^{+0.07}_{-0.06}) \cdot 10^{-3}$	1.05 ± 0.09
$H \to Z\gamma$	$(3.2\,^{+1.5}_{-1.4}) \cdot 10^{-3}$	$(1.54\,^{+0.10}_{-0.11}) \cdot 10^{-3}$	$2.1\,^{+1.0}_{-0.9}$
$H \to \mu\mu$	$(2.6 \pm 1.3) \cdot 10^{-4}$	$(2.17 \pm 0.05) \cdot 10^{-4}$	1.2 ± 0.6

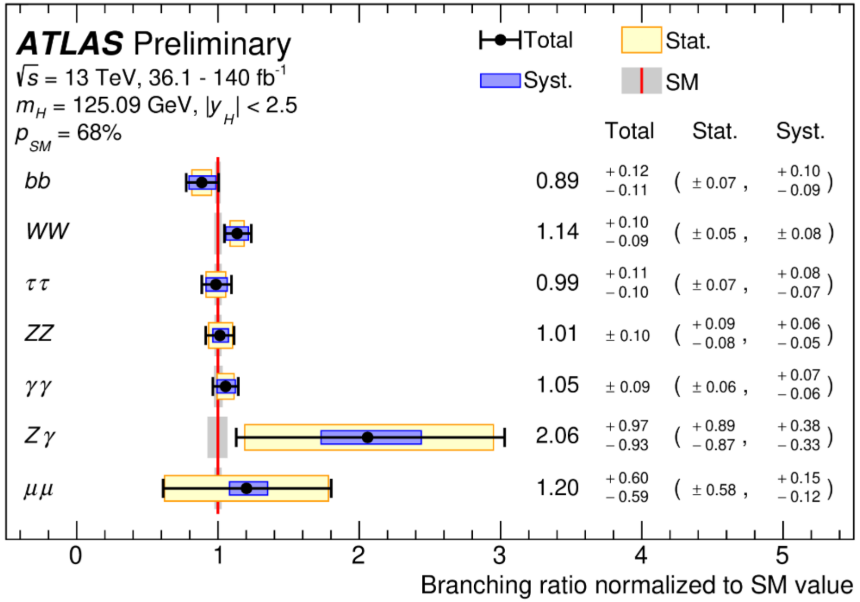
Cross-section	Measurement (pb)	SM prediction (pb)	Ratio to SM
ggF + bbH	$47.0\,^{+3.1}_{-2.7}$	44.8 ± 2.6	$1.05\,^{+0.07}_{-0.06}$
VBF	3.6 ± 0.4	3.50 ± 0.07	$1.04\,^{+0.12}_{-0.11}$
WH	1.17 ± 0.18	1.216 ± 0.024	0.96 ± 0.15
ZH	0.80 ± 0.14	0.796 ± 0.029	$1.00\,^{+0.18}_{-0.17}$
$ttH + tH$	$0.57\,^{+0.09}_{-0.08}$	0.58 ± 0.05	$0.97\,^{+0.15}_{-0.14}$

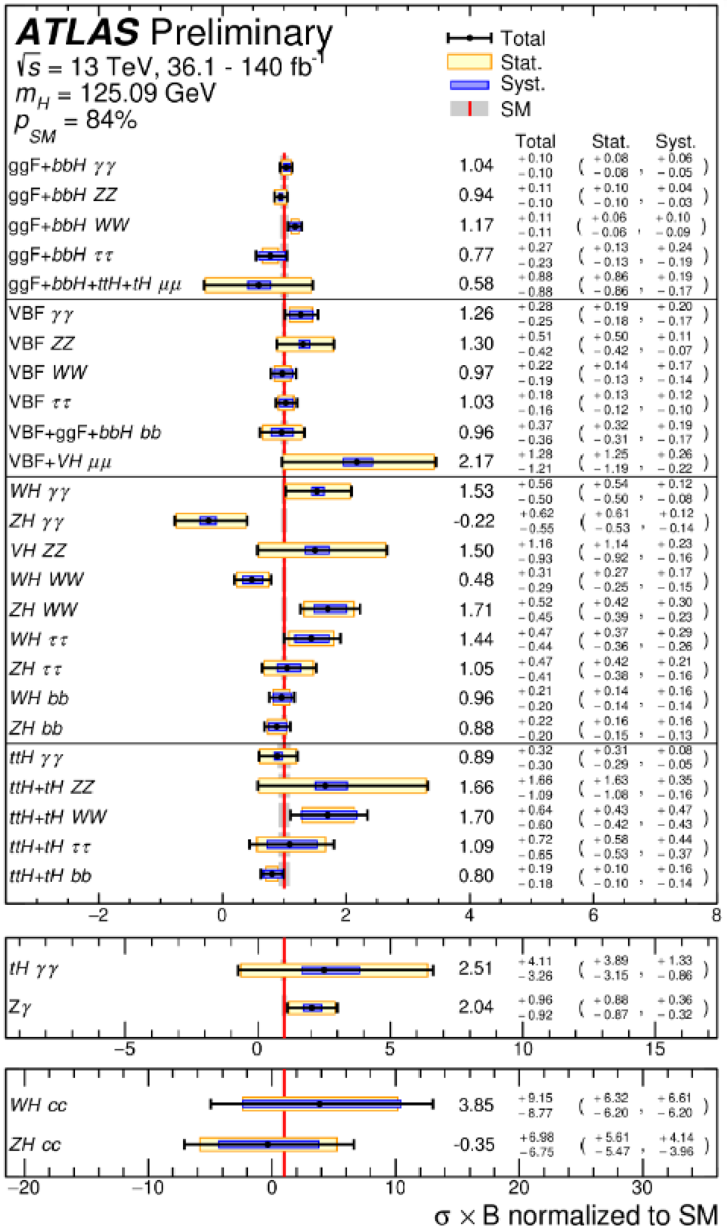
$$\mu = 1.023^{+0.056}_{-0.053} = 1.023 \pm 0.028\,(\text{stat.})\,^{+0.026}_{-0.025}\,(\text{exp.})\,^{+0.039}_{-0.036}\,(\text{sig. theo.}) \pm 0.012\,(\text{bkg. theo.})$$

Run 2 Summary details (2025)

ATLAS-CONF-2025-006

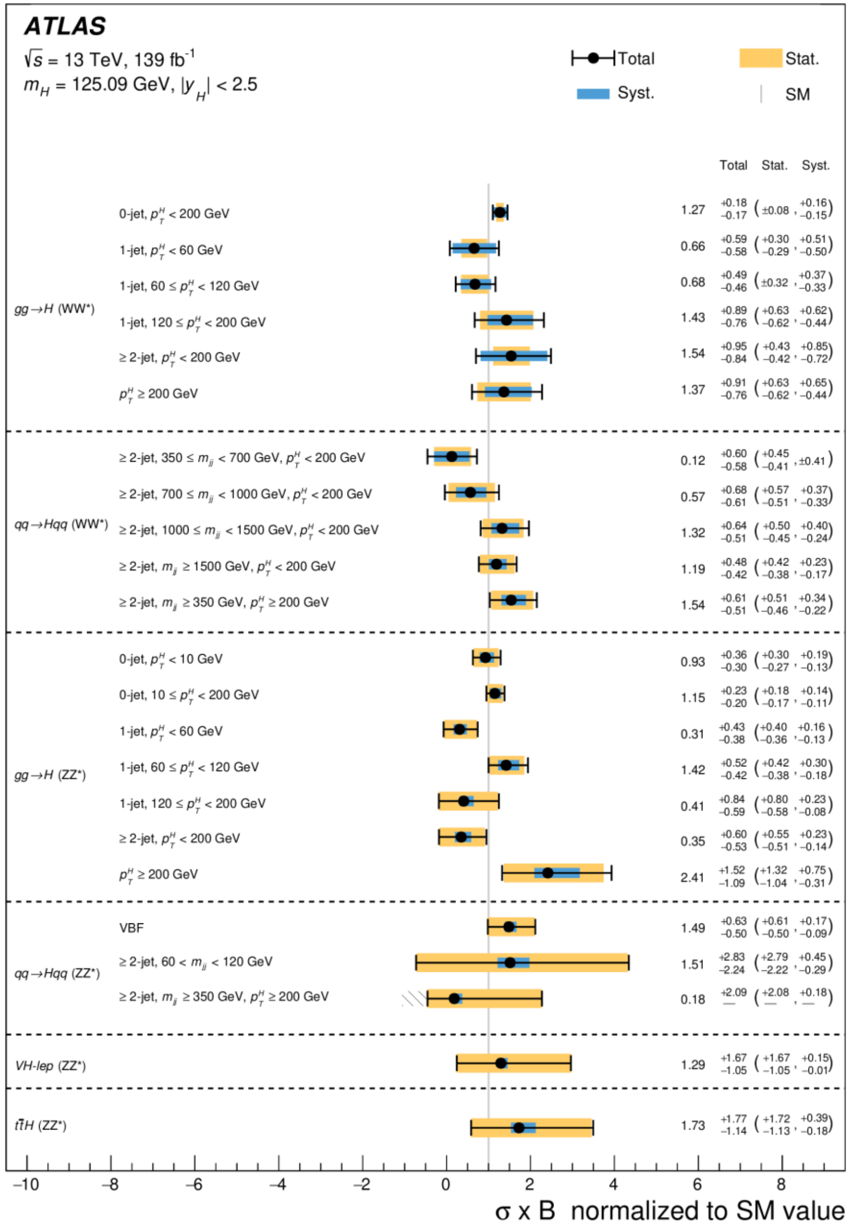


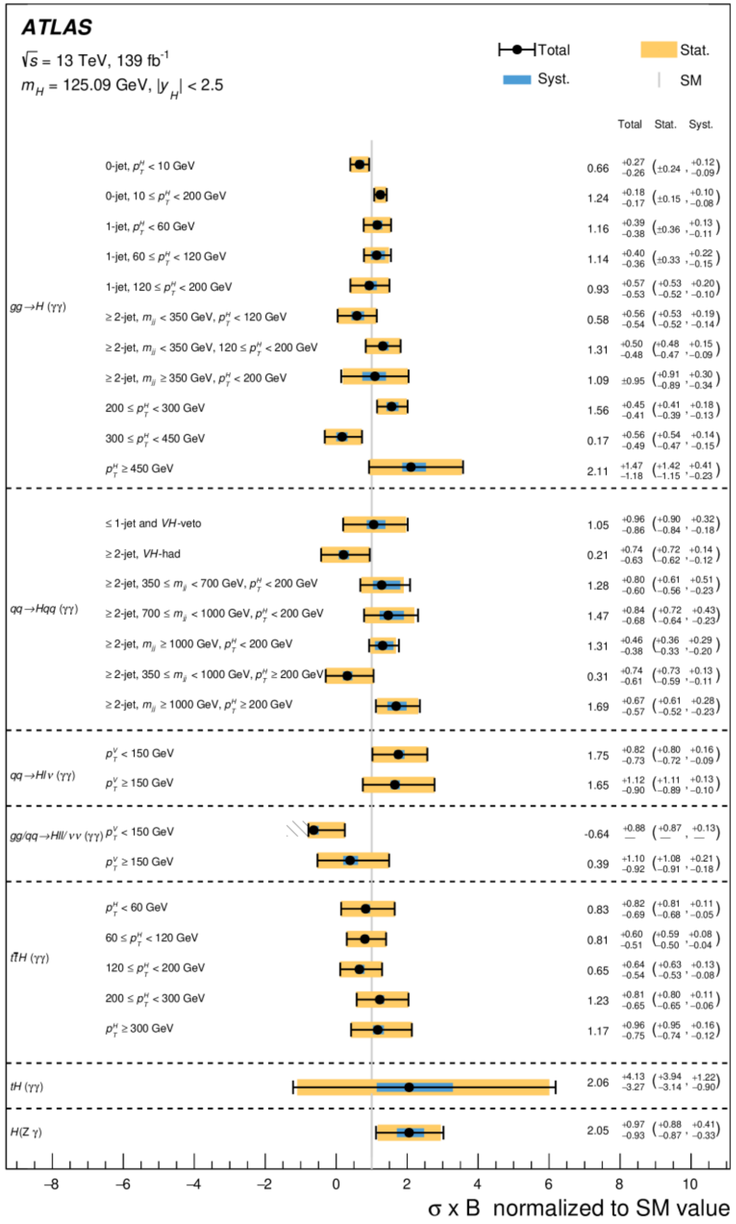


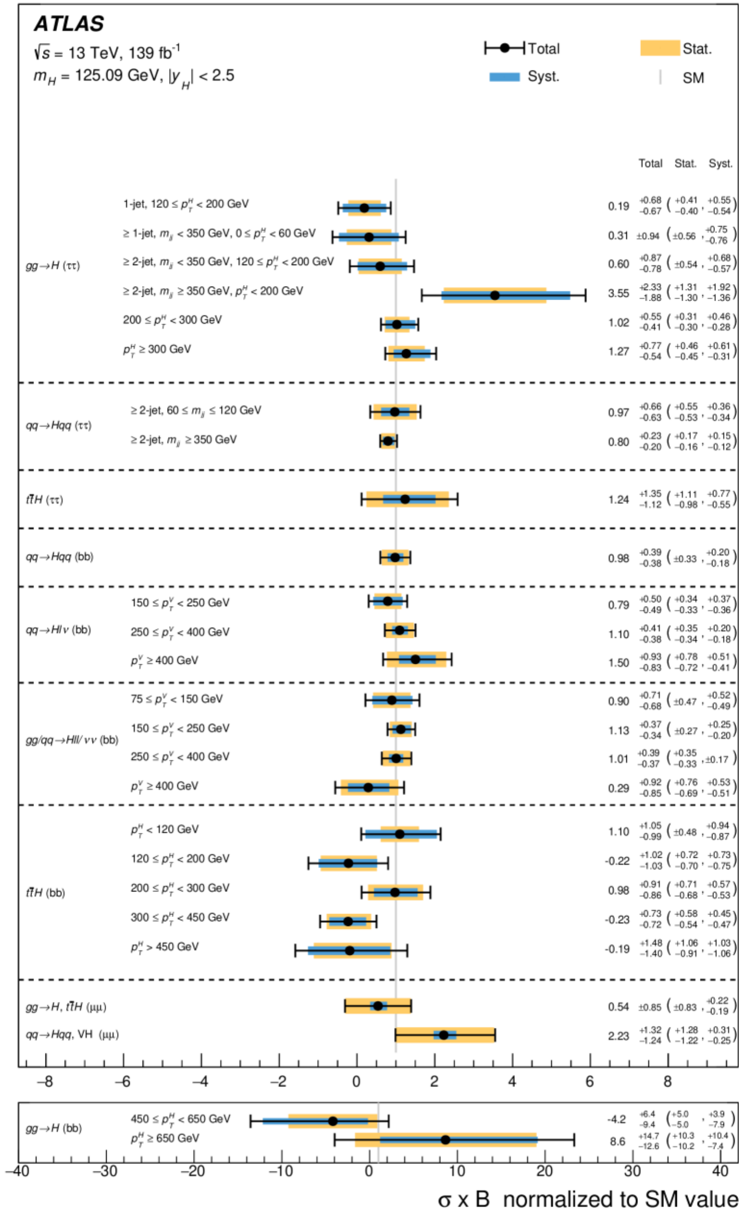


Run 2 summary details (2024)

JHEP 11 (2024) 097 || arXiv:2402.05742

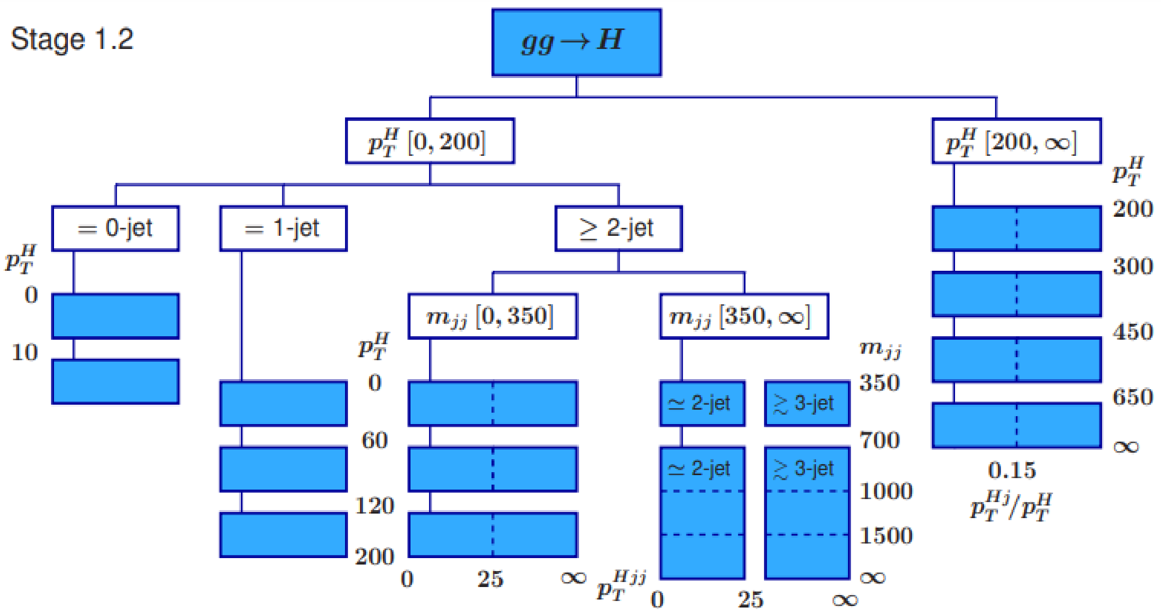


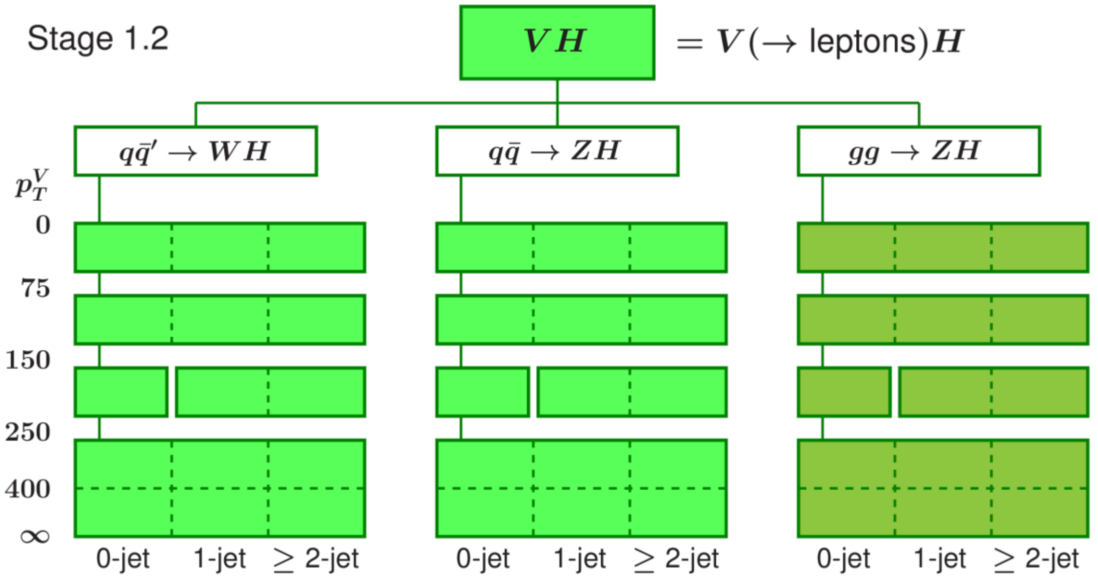


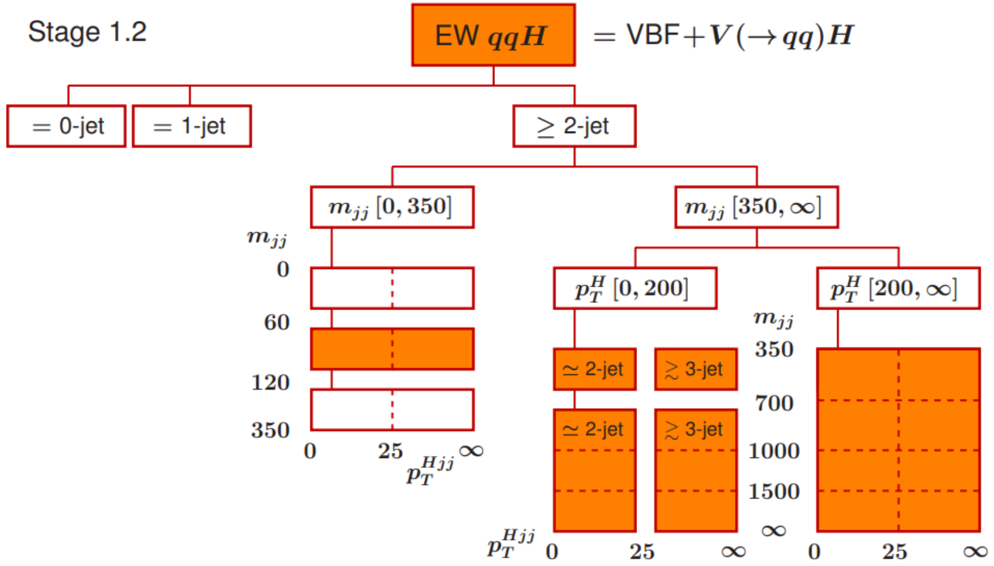


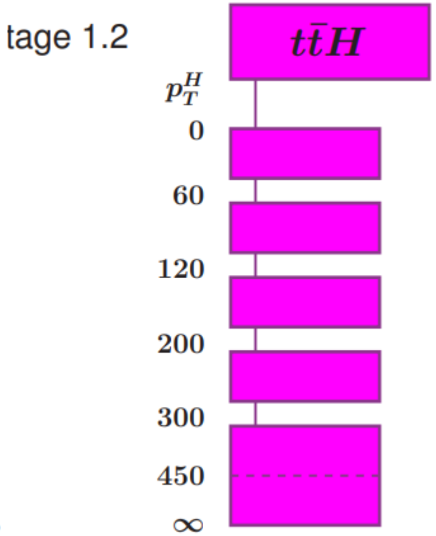
STXS schemes (Stage 1.2)

arXiv:1906.02754









The intention of performing these differential cross section measurements is to:

- Reduce theory dependence when possible.
- Better isolate possible BSM effects.

Decay: $H \to b\bar{b}$, $H \to c\bar{c}$

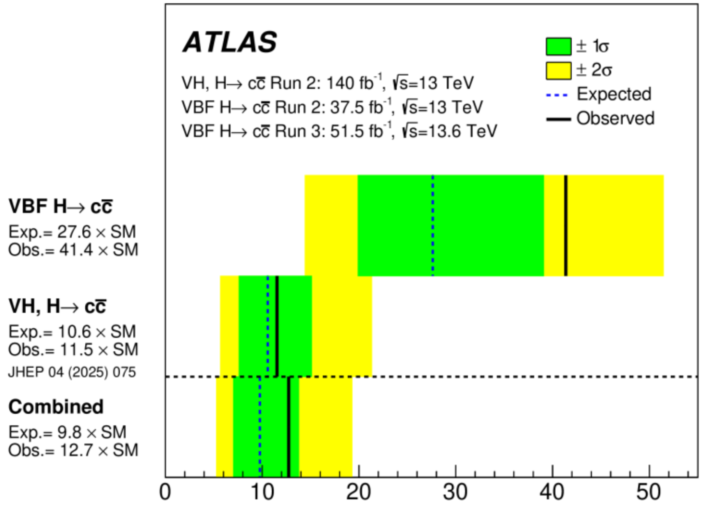
arXiv:2511.21911

Search/branching ratio measurement.

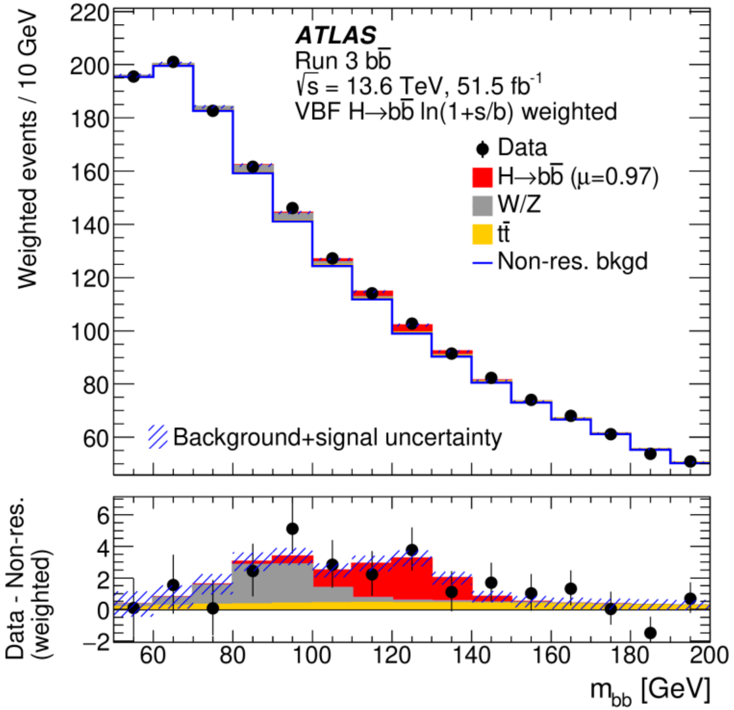
Production: VBF

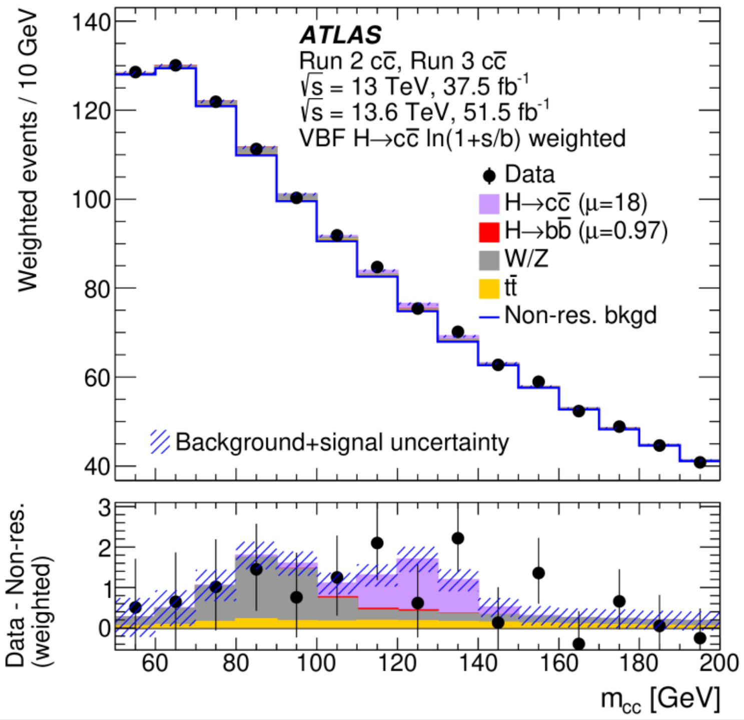
Data set: Run 2 (37.5 fb^{-1}) and early Run 3 (2022-2023, 51.5 fb^{-1})

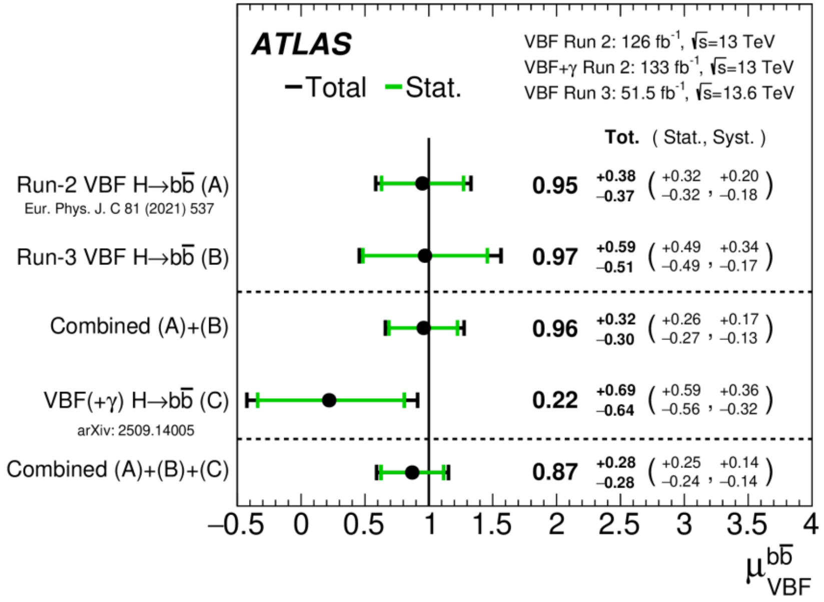
- Structured as $H \to c\bar{c}$ measurement, measured $b\bar{b}$ in parallel.
- Uses trigger developed in 2018, high VBF $H \to c\bar{c}$, $H \to b\bar{b}$ efficiency.
- Difficulty due to small Higgs Yukawa coupling to charm (relative to dominant bottom multijet background) and jet identification.



$$\sigma(\text{VBF})\times BR_{(H\to c\bar{c})} = 41 * SM$$







Decay: $H \to b\bar{b}$

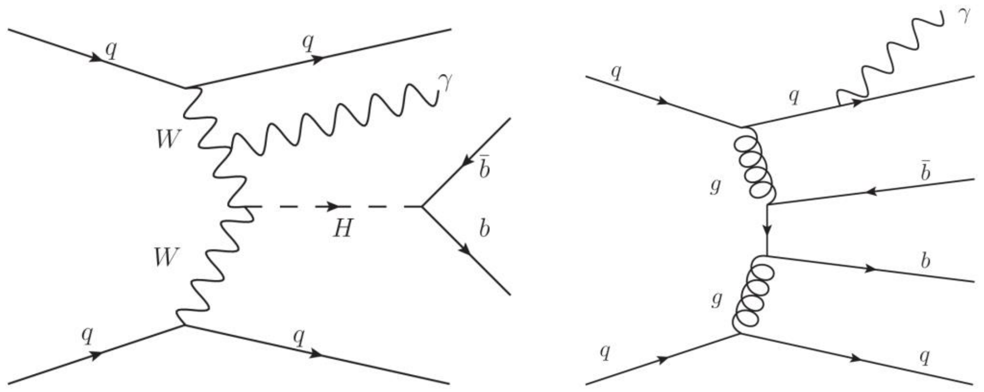
arXiv:2509.14005

Search/branching ratio measurement.

Production: VBF, with associated photon

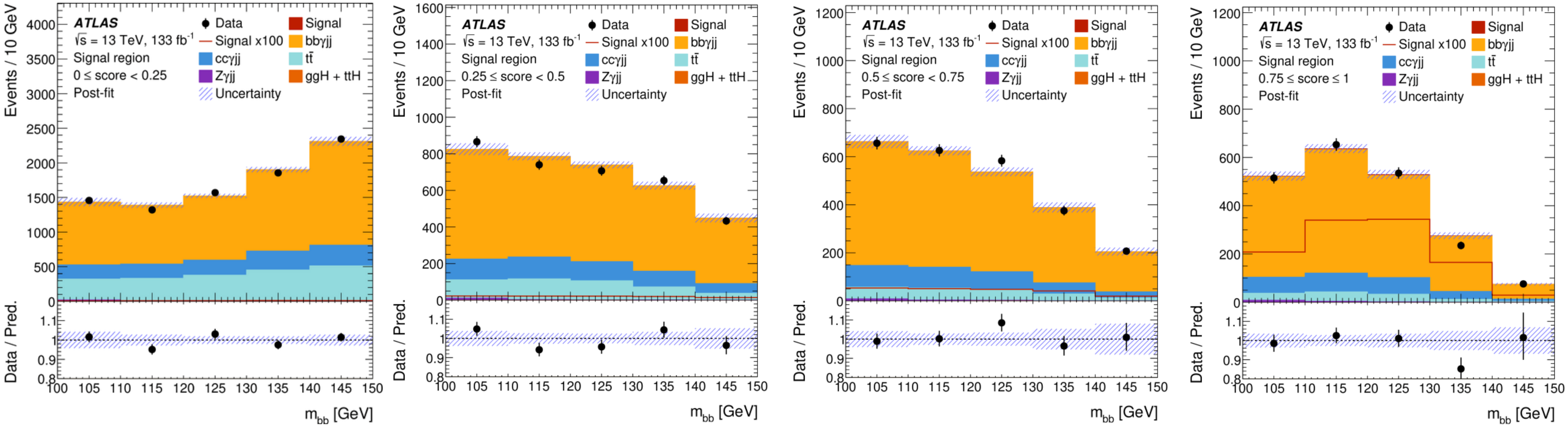
Data set: Run 2 (133 fb^{-1})

- Requirement of photon reduces impact of multijet background (right).
- Photon also provides clean trigger signature.
- Other production modes have limited contribution to signal region (VH < 5%).



Signal strength relative to SM = $0.2^{+0.7}_{-0.7}$

Observed significance: 0.3σ (1.5σ exp.)



Decay: H → Invisible (4ν)

Phys. Lett. B 842 (2023) 137963 || arXiv:2301.10731

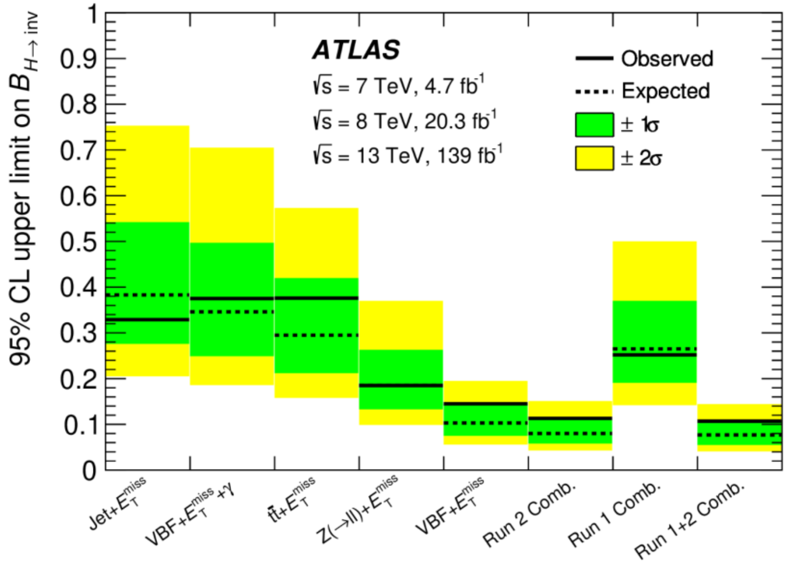
Search/branching ratio measurement.

Production: VBF, ZH, $t\bar{t}H$, ggF

Data set: Run 2 (139 fb^{-1})

Combined with Run 1 (VBF only)

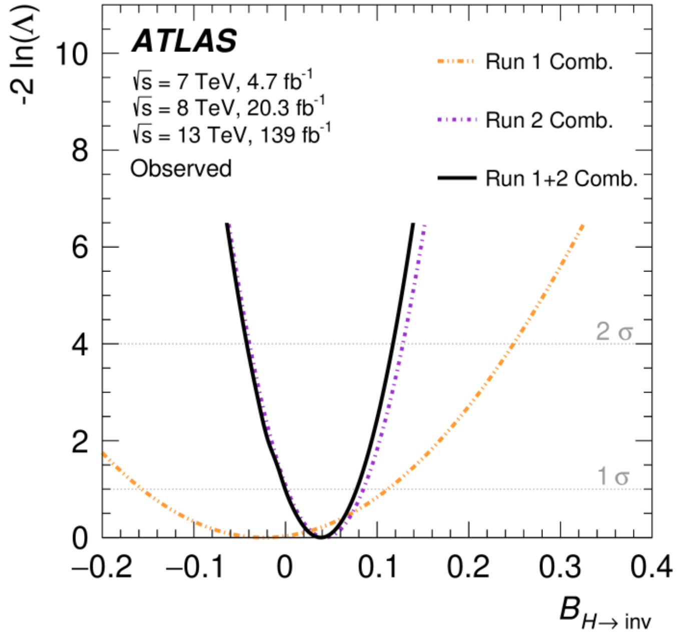
(4.7 fb^{-1} at $\sqrt{s} = 7$ TeV, 20.3 fb^{-1} at $\sqrt{s} = 8$ TeV)

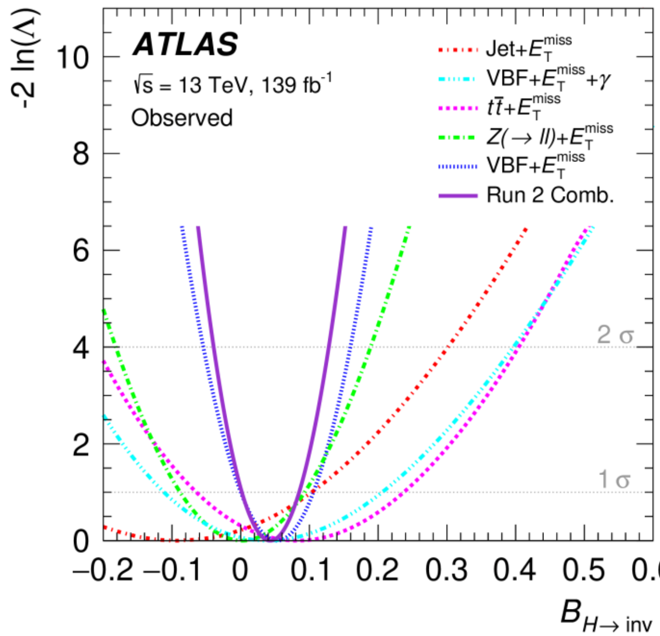


- Primarily conducted as dark matter probe.
- In the standard model extremely small branching ratio, due to $H \to ZZ^* \to 4\nu$: $BR_{(H \to Invisible)}$: $\sim 0.1\%$

Run 2: $BR_{(H \to Invisible)} < 0.113$ at 95% CL
(expected: $0.080^{+0.031}_{-0.022}$)

Combination: $BR_{(H \to Invisible)} < 0.107$ at 95% CL
(expected: $0.077^{+0.030}_{-0.022}$)





Production: tH

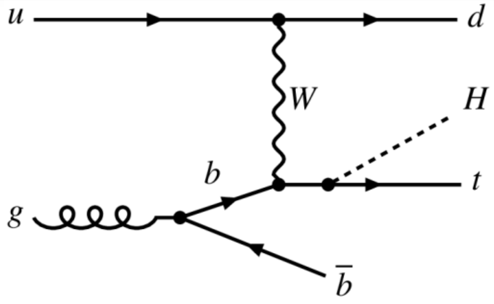
JHEP 10 (2025) 093 || arXiv:2508.14695

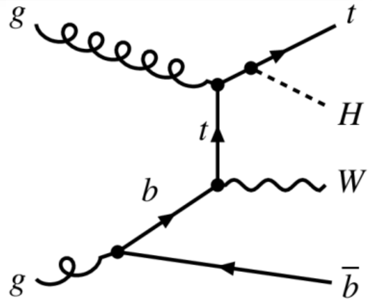
Fiducial cross section and STXS measurement.

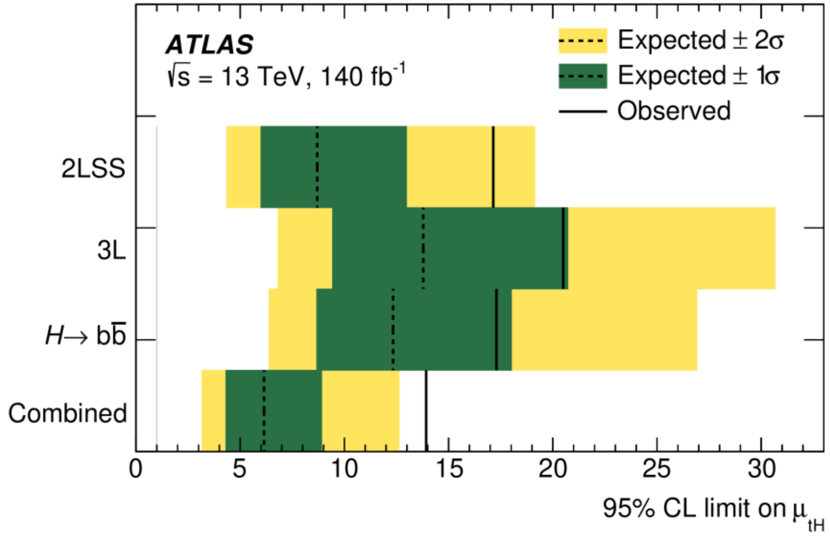
Decays: bb, WW*, ZZ*, $\tau^+\tau^-$ (Extra ℓ in final states from t.)

Data set: Run 2 (140 fb^{-1})

- Probe of Higgs Yukawa coupling to top quark → important implications for radiative corrections to Higgs potential.
- Production at LHC via tHq, tWH (and ~3% of production via s-channel, neglected here).
- Individual channels measured separately, but combined value measured via simultaneous fit.



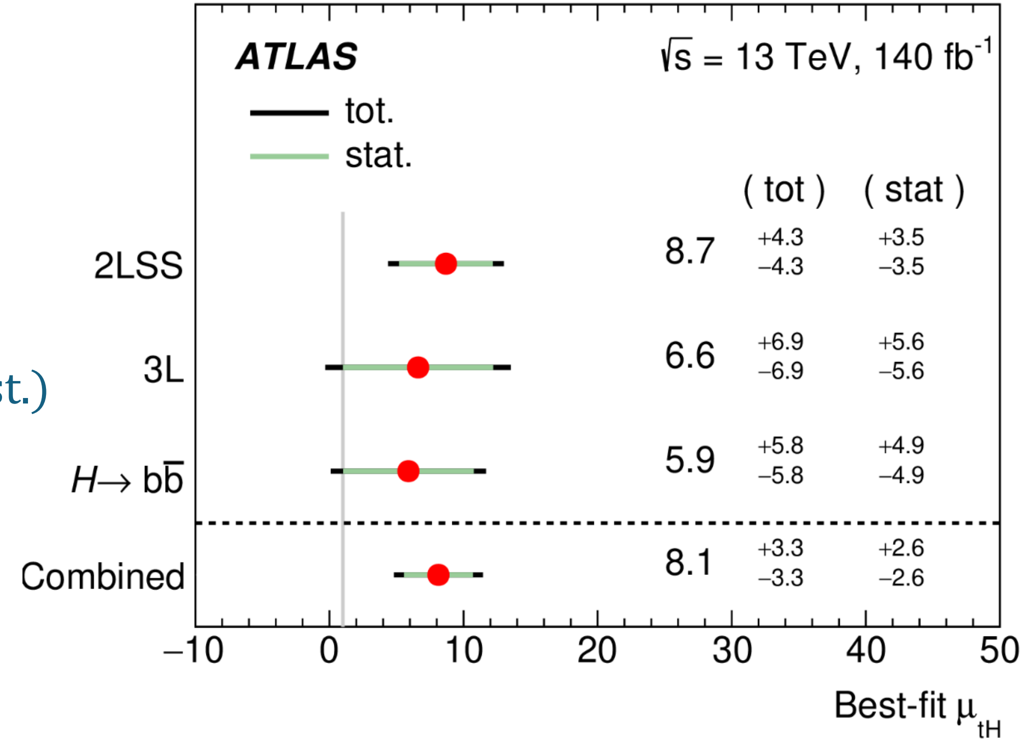




$\sigma(tH) = 13.9 * SM$

$\mu_{tH} = 8.1\,^{+2.6}_{-2.6}(\text{stat.})\,^{+2.0}_{-2.0}(\text{syst.})$

Signal signif: 2.8σ

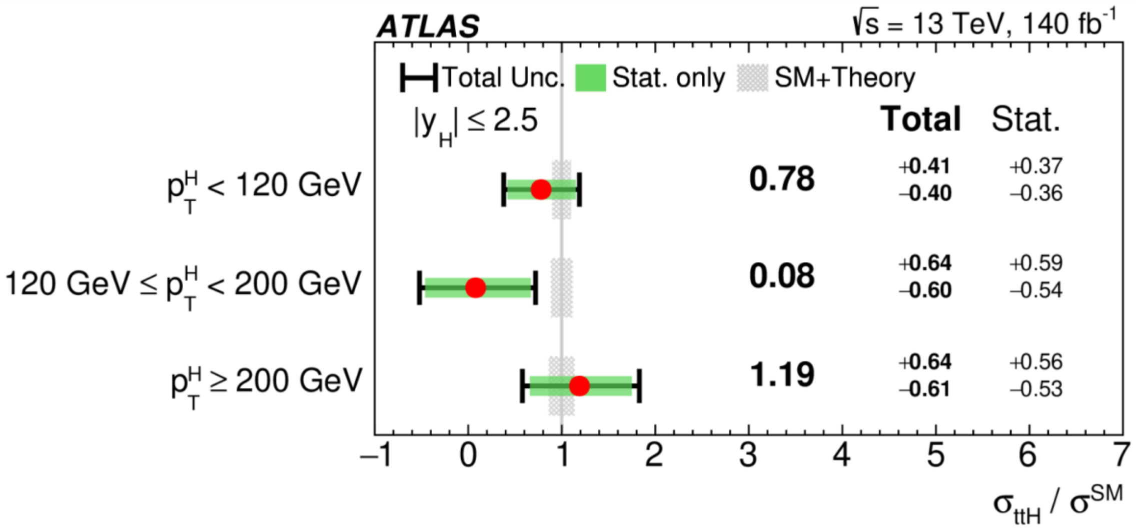


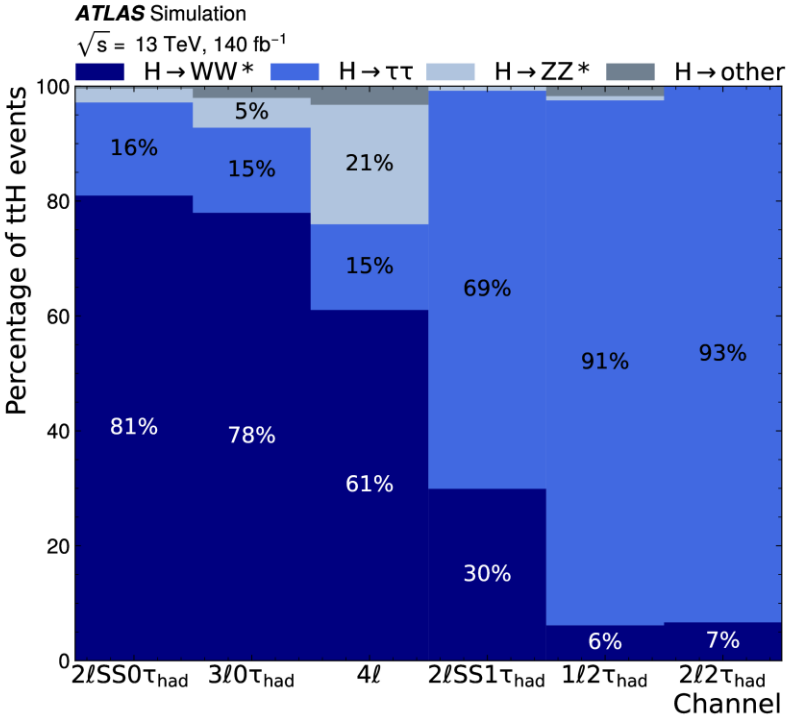
Production: $t\bar{t}H$

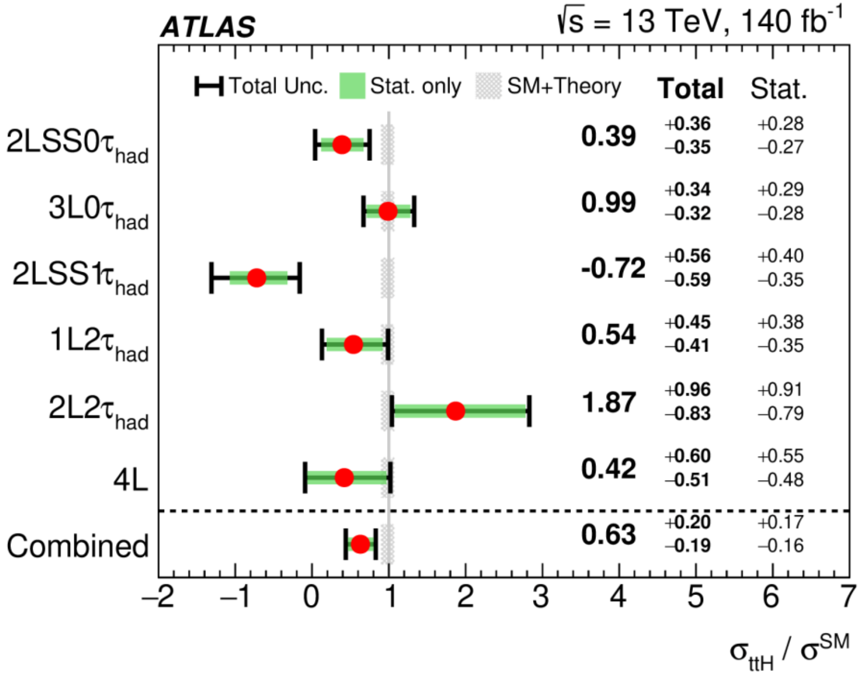
arXiv:2510.23755

Fiducial cross section and STXS measurement.
Decays: Inclusive, multilepton final states.
Data set: Run 2 (140 fb^{-1})

- Probe of Higgs Yukawa coupling to top quark → important implications for radiative corrections to Higgs potential.







$$\sigma(t\bar{t}H)_{obs}/\sigma(t\bar{t}H)_{SM} = 0.63\,^{+2.0}_{-0.19}$$

Signal signif: 3.3σ

Extra details: H→ $\gamma\gamma$, H→ ZZ*→ 4ℓ

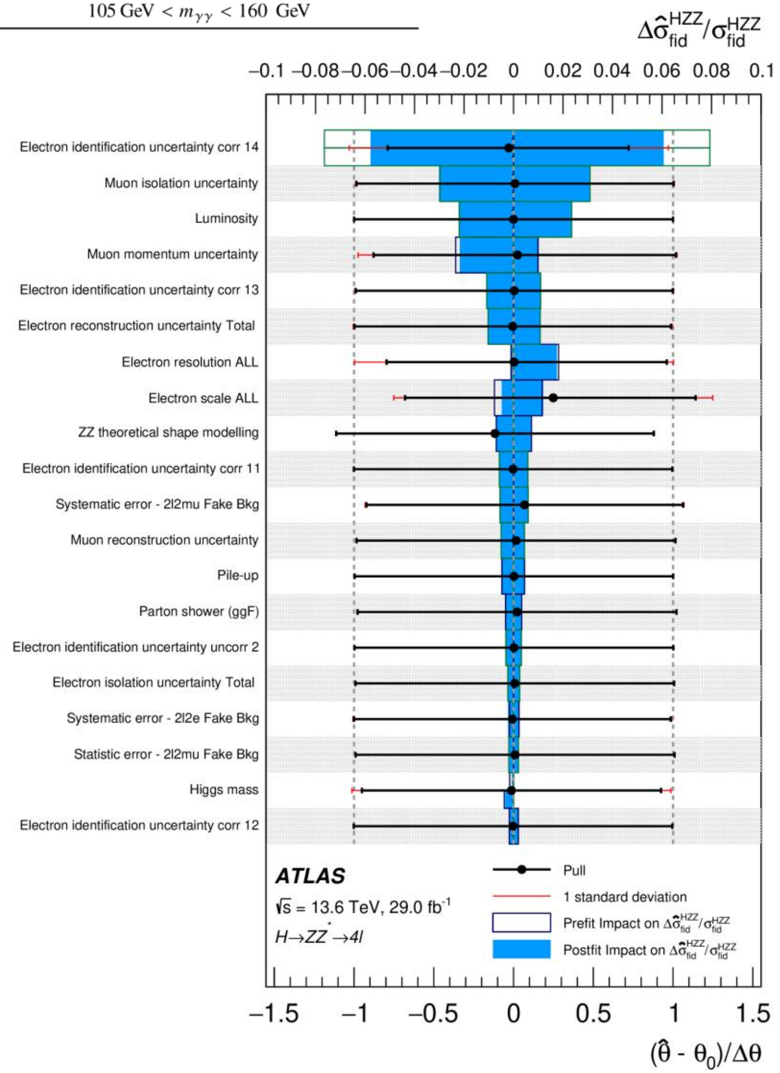
Eur. Phys. J. C 84 (2024) 78 || arXiv:2306.11379

Difference in luminosity due to 'additional requirements to remove data-taking periods with lower muon trigger efficiency applied only to the H→ZZ→4l channel.'

Leptons	
Muons	$p_T > 5$ GeV, $\lvert\eta\rvert < 2.5$
Electrons	$E_T > 7$ GeV, $\lvert\eta\rvert < 2.47$
Lepton selection and pairing	
Lepton kinematics	$p_T > 20, 15, 10$ GeV
Leading pair (m_{12})	SFOC lepton pair with smallest $\lvert m_Z - m_{\ell\ell}\rvert$
Subleading pair (m_{34})	remaining SFOC lepton pair with smallest $\lvert m_Z - m_{\ell\ell}\rvert$
Event selection (at most one Higgs boson candidate per channel)	
Mass requirements	50 GeV$< m_{12} < 106$ GeV and $m_{\text{threshold}} < m_{34} < 115$ GeV
Lepton separation	$\Delta R(\ell_i, \ell_j) > 0.1$
J/ψ veto	$m(\ell_i, \ell_j) > 5$ GeV for all SFOC lepton pairs
Impact parameter	$\lvert d_0\rvert/\sigma(d_0)$ <5 (3) for electrons (muons)
Mass window	105 GeV $< m_{4\ell} < 160$ GeV
Vertex selection	$\chi^2/N_{\text{dof}} < 6$ (9) for 4μ (other channels)
If extra lepton with $p_T > 12$ GeV	quadruplet with largest ME value

Final state	Signal SM (pre-fit)	Signal (post-fit)	ZZ^* background	Other backgrounds	Total	Observed
4μ	14.8 ± 1.0	11.3 ± 0.8	8.3 ± 0.6	1.0 ± 0.3	20.6 ± 1.0	23
$2e2\mu$	11.1 ± 0.8	8.5 ± 0.6	6.5 ± 0.4	1.0 ± 0.3	16.0 ± 0.8	13
$2\mu 2e$	7.0 ± 1.3	5.4 ± 1.0	3.2 ± 0.6	0.9 ± 0.1	9.4 ± 1.2	12
$4e$	7.4 ± 1.5	5.7 ± 1.1	3.1 ± 0.7	0.8 ± 0.2	9.6 ± 1.4	9
Total	40.3 ± 3.8	30.9 ± 2.9	21.1 ± 2.0	3.6 ± 0.7	55.6 ± 4.4	57

Photons	
Leading (sub-leading) p_T^γ	$p_T^\gamma/m_{\gamma\gamma} > 0.35(0.25)$
Pseudorapidity	$\lvert\eta\rvert < 2.47$ and outside $1.37 < \lvert\eta\rvert < 1.52$
Isolation	$E_T^{\text{iso}}/E_T^\gamma < 0.05$
Di-photon system	
Mass window	105 GeV $< m_{\gamma\gamma} < 160$ GeV



Extra details: $H \rightarrow Z\gamma$

arXiv:2306.11379

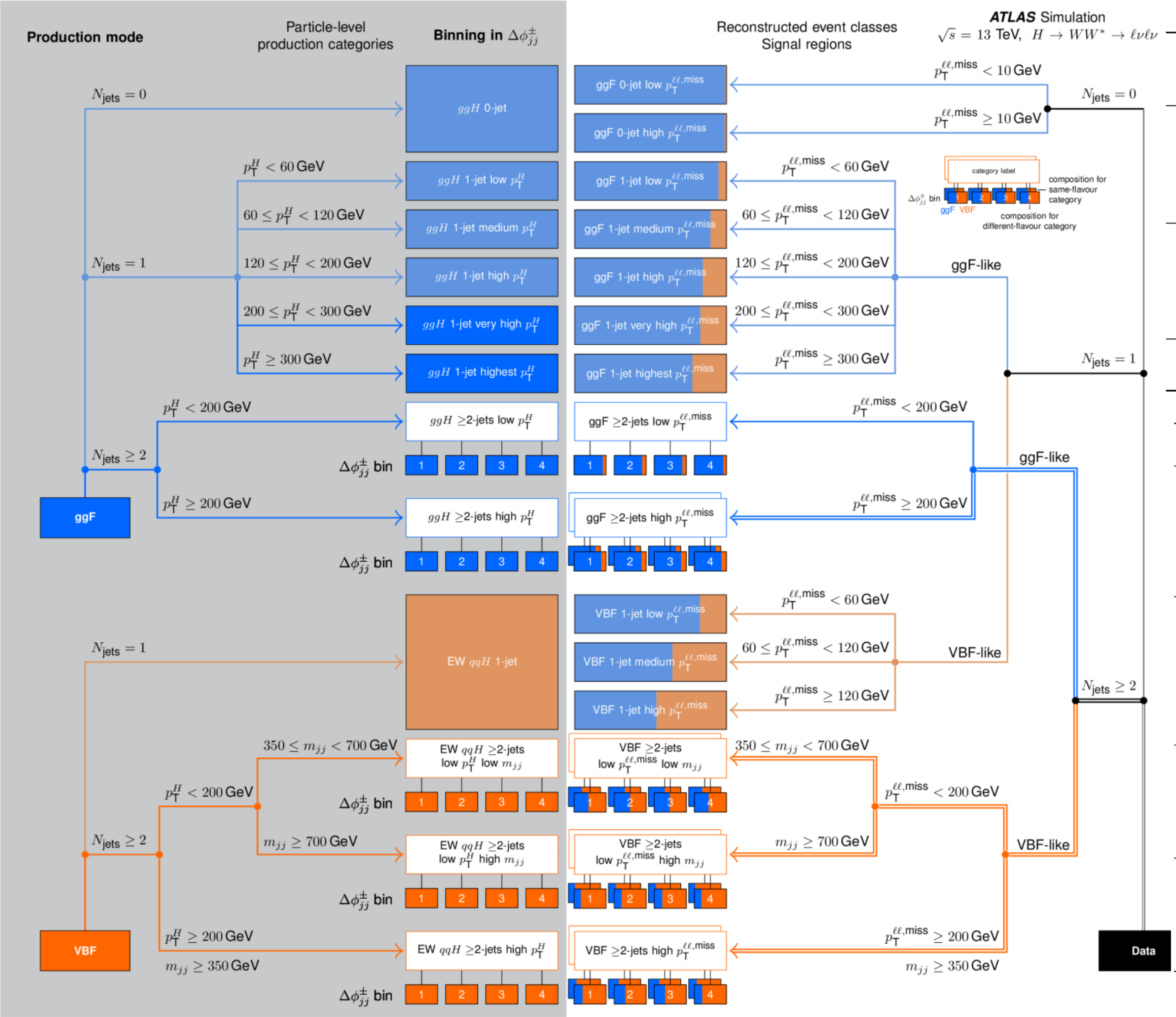
First measured in Run 2
Run 2 also has low mass dilepton measurement

Category	S_{68}^{exp}	B_{68}^{exp}	N_{68}	w_{68} [GeV]	$S_{68}^{exp}/\sqrt{S_{68}^{exp}+B_{68}^{exp}}$
Lepton	1.5 ± 1.1	75.4 ± 2.8	70	4.4	0.17
VBFT	1.5 ± 1.1	1.3 ± 0.4	3	3.8	0.92
VBFL	2.8 ± 2.0	27.2 ± 1.8	18	4.0	0.52
HRelpT-eeT	1.2 ± 0.8	6.6 ± 0.9	9	3.2	0.43
HRelpT-eeL	2.9 ± 2.1	53.9 ± 1.8	61	4.0	0.39
HRelpT-$\mu\mu$T	2.4 ± 1.7	20.3 ± 1.7	25	3.9	0.51
HRelpT-$\mu\mu$L	2.4 ± 1.7	56.5 ± 1.7	61	4.1	0.32
LRelpT-eeT	8.9 ± 6.2	231 ± 6	240	3.8	0.57
LRelpT-eeM	29 ± 20	2 562 ± 19	2 587	4.1	0.56
LRelpT-eeL	24 ± 17	13 122 ± 50	13 074	4.5	0.21
LRelpT-$\mu\mu$T	4.9 ± 3.4	95 ± 4	107	3.9	0.49
LRelpT-$\mu\mu$M	34 ± 24	2 527 ± 19	2 583	4.1	0.67
LRelpT-$\mu\mu$L	36 ± 25	16 844 ± 40	16 642	4.4	0.28
Inclusive	150 ± 110	35 625 ± 70	35 480	4.0	1.81

Uncertainty source	$\Delta\mu$	
	Expected	Observed
Statistical uncertainty	0.68	0.65
Systematic uncertainty	0.16	0.17
Spurious signal (background modelling)	0.11	0.11
QCD scale, PDF+α_S, parton shower	0.09	0.06
Branching ratio ($H \rightarrow Z\gamma$)	0.05	0.05
Luminosity	0.03	0.03
Photon efficiency	0.02	0.03
Jet	0.02	0.07
Electron and photon energy scale and resolution	0.02	0.06
Electron efficiency	0.02	0.02
Muon	< 0.01	0.02
Trigger	< 0.01	0.02
Total	0.70	0.67

Extra details: H→WW* (ggF, VBF)

Eur. Phys. J. C 85 (2025) 1403 || arXiv:2504.07686



Purpose	Event class: $N_{\text{jets}} = 0$	$N_{\text{jets}} = 1$	$N_{\text{jets}} \geq 2$ ggF-enriched	$N_{\text{jets}} \geq 2$ VBF-enriched
Preselection	Two isolated, different-flavour (same-flavour) leptons with opposite charge $p_T^{\ell_0} > 22$ GeV and $p_T^{\ell_1} > 15$ GeV $m_{\ell\ell} > 10$ GeV (12 GeV)			
	Different-flavour leptons		($\mathcal{S}_{\text{miss}} > 4$ and $p_T^{\ell\ell} > 40$ GeV) Different- or same-flavour leptons	
Background suppression	$N_{b\text{-jets}}\,[p_T > 20\,\text{GeV}] = 0$			
	$E_T^{\text{miss}} > 20$ GeV	$m_{\tau\tau} < m_Z - 25$ GeV		
	$\Delta\phi_{\ell\ell} < 2.0$ rad $m_{\ell\ell} < 55$ GeV		$\Delta\phi_{\ell\ell} < 1.8$ rad $m_{\ell\ell} < 55$ GeV	– $m_{\ell\ell} < 70$ GeV
	$\Delta R_{\ell\ell} > 0.6$			
Signal topology	$\Delta\phi_{\ell\ell,\text{miss}} > 1.57$ rad	–	VH orthogonality Fail CJV or Fail OLV	$m_{jj} > 350$ GeV Pass CJV and Pass OLV

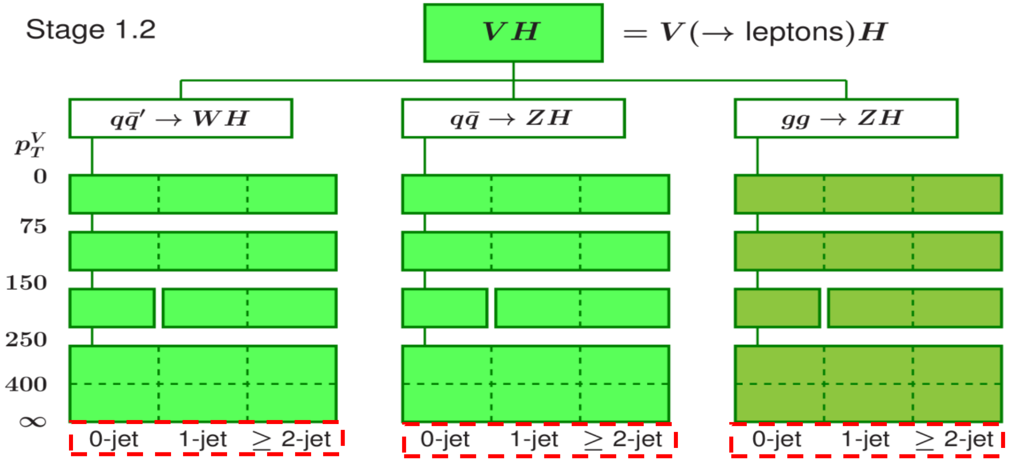
Control region	Event class: $N_{\text{jets}} = 0$	$N_{\text{jets}} = 1$	$N_{\text{jets}} \geq 2$ ggF-enriched	$N_{\text{jets}} \geq 2$ VBF-enriched
WW	DF channel preselection $N_{b\text{-jets}}\,(p_T > 20\,\text{GeV}) = 0$			N/A
	$55 < m_{\ell\ell} < 100$ GeV $\Delta\phi_{\ell\ell} < 2.0$ rad $E_T^{\text{miss}} > 20$ GeV $\Delta\phi_{\ell\ell,\text{miss}} > 1.57$ rad $\Delta R_{\ell\ell} > 0.6$	**$m_{\ell\ell} > 80$ GeV** $m_T > 110$ GeV	**$m_{\ell\ell} > 80$ GeV** $m_{T2} > 165$ GeV $m_{\tau\tau} < m_Z - 25$ GeV VH orthogonality Fail CJV or Fail OLV	
Top quark	DF channel preselection			
	$N_{b\text{-jets}}\,(20 < p_T < 30\,\text{GeV}) = 1$ $m_{\ell\ell} < 100$ GeV $E_T^{\text{miss}} > 20$ GeV $\Delta\phi_{\ell\ell} < 2.0$ rad $\Delta\phi_{\ell\ell,\text{miss}} > 1.57$ rad $\Delta R_{\ell\ell} > 0.6$	**$N_{b\text{-jets}}\,(p_T > 30\,\text{GeV}) = 1$** $N_{b\text{-jets}}\,(20 < p_T < 30\,\text{GeV}) = 0$ $m_{\ell\ell} < 100$ GeV $m_{\tau\tau} < m_Z - 25$ GeV	**$N_{b\text{-jets}}\,(p_T > 20\,\text{GeV}) = 1$**	
			$m_{\ell\ell} < 55$ GeV $m_{\tau\tau} < m_Z - 25$ GeV $\Delta\phi_{\ell\ell} < 1.8$ rad VH orthogonality Fail CJV or Fail OLV	$m_{\ell\ell} < 70$ GeV $m_{\tau\tau} < m_Z - 25$ GeV – $m_{jj} \geq 350$ GeV Pass CJV and Pass OLV
$Z/\gamma^* \to \tau\tau$	N/A	DF channel preselection $N_{b\text{-jets}}\,(p_T > 20\,\text{GeV}) = 0$		
		$m_{\tau\tau} > m_Z - 25$ GeV		**$\lvert m_{\tau\tau} - m_Z\rvert < 25$ GeV**
		$m_{\ell\ell} < 80$ GeV	$m_{\ell\ell} < 55$ GeV VH orthogonality Fail CJV or Fail OLV	$m_{\ell\ell} < 70$ GeV $m_{jj} \geq 350$ GeV Pass CJV and Pass OLV
$Z/\gamma^* \to ee/\mu\mu$	N/A		SF channel preselection $N_{b\text{-jets}}\,(p_T > 20\,\text{GeV}) = 0$ **$\lvert m_{\ell\ell} - m_Z\rvert < 15$ GeV**	
			– VH orthogonality Fail CJV or Fail OLV	$\Delta\phi_{\ell\ell} < 1.8$ rad $m_{jj} \geq 350$ GeV Pass CJV and Pass OLV

Extra details: H→WW* (VH)

JHEP 08 (2025) 034 || arXiv:2503.19420

$\sigma \times \mathcal{B}_{H\to WW^*}$ [fb]									
p_T^V scheme ($\lvert y_H \rvert < 2.5$)					STXS scheme				
p_T^V interval [GeV]	Value	Stat. unc.	Syst. unc.	SM	STXS category [p_T^V and m_{jj} in GeV]	Value	Stat. unc.	Syst. unc.	SM
$VH\ (0 \le p_T^V < 75)$	270	$^{+110}_{-100}$	$^{+40}_{-30}$	220 ± 40	$\ell\nu H\ (0 \le p_T^V < 75)$	0	$^{+40}_{-30}$	± 10	46.3 ± 1.8
$VH\ (75 \le p_T^V < 150)$	180	$^{+70}_{-60}$	$^{+30}_{-20}$	151 ± 34	$\ell\nu H\ (75 \le p_T^V < 150)$	26	$^{+22}_{-21}$	$^{+8}_{-7}$	28.9 ± 1.2
$VH\ (150 \le p_T^V < 250)$	18	$^{+28}_{-26}$	$^{+17}_{-13}$	50 ± 15	$\ell\nu H\ (p_T^V \ge 150)$	5	± 6	± 4	11.5 ± 0.5
$VH\ (p_T^V \ge 250)$	1	$^{+12}_{-11}$	$^{+7}_{-6}$	14 ± 4	$\ell\ell H\ (0 \le p_T^V < 75)$	62	$^{+25}_{-21}$	$^{+11}_{-7}$	24.1 ± 1.7
					$\ell\ell H\ (75 \le p_T^V < 150)$	35	$^{+17}_{-14}$	$^{+7}_{-4}$	18.7 ± 1.5
					$\ell\ell H\ (p_T^V \ge 150)$	-2	$^{+5}_{-0\,\text{(LL)}}$	$^{+1}_{-0\,\text{(LL)}}$	8.7 ± 1.0
					$qqH\ (60 \le m_{jj} < 120)$	110	$^{+90}_{-80}$	± 60	91.8 ± 3.3

Fit results for the STXS scheme					
Normalisation factors		$(\sigma_{\text{STXS category}} \times \mathcal{B}_{H\to WW^*})/(\sigma_{\text{STXS category}} \times \mathcal{B}_{H\to WW^*})_{\text{SM}}$			
Parameter	Fit result	STXS category	Fit result	Stat. unc.	Syst. unc.
Top	$0.9^{+0.3}_{-0.2}$	$\ell\nu H, 0 \le p_T^V < 75$ GeV	$0.0^{+0.8}_{-0.7}$	$^{+0.8}_{-0.7}$	± 0.3
Z+jets	$0.85^{+0.12}_{-0.11}$	$\ell\nu H, 75 \le p_T^V < 150$ GeV	0.9 ± 0.8	$^{+0.8}_{-0.7}$	$^{+0.3}_{-0.2}$
WW	$0.9^{+0.3}_{-0.2}$	$\ell\nu H, p_T^V \ge 150$ GeV	$0.5^{+0.7}_{-0.6}$	$^{+0.6}_{-0.5}$	$^{+0.4}_{-0.3}$
WZ (SS 2ℓ)	$1.14^{+0.17}_{-0.15}$	$\ell\ell H, 0 \le p_T^V < 75$ GeV	$2.6^{+1.1}_{-0.9}$	$^{+1.0}_{-0.9}$	$^{+0.4}_{-0.3}$
WZ 0-jet	1.00 ± 0.06	$\ell\ell H, 75 \le p_T^V < 150$ GeV	$1.9^{+1.0}_{-0.8}$	$^{+0.9}_{-0.8}$	$^{+0.4}_{-0.2}$
WZ $\ge$1-jets	$0.88^{+0.16}_{-0.15}$	$\ell\ell H, p_T^V \ge 150$ GeV	$-0.2^{+0.6}_{-0.0\,\text{(LL)}}$	$^{+0.5}_{-0.0\,\text{(LL)}}$	$^{+0.2}_{-0.0\,\text{(LL)}}$
WWW	$2.2^{+0.7}_{-0.6}$	$qqH, 60 \le m_{jj} < 120$ GeV	$1.2^{+1.2}_{-1.1}$	± 0.9	$^{+0.7}_{-0.6}$
ZZ	0.99 ± 0.03				



- STXS categorization scheme reduced due to statistical limitations.
- No splitting by jet multiplicity.
- No splitting by gg/qq→ZH

$\sigma(WH)\text{xBR}_{(H\to WW^*)}$: $0.14^{+0.08}_{-0.07}(\text{stat.})^{+0.06}_{-0.05}(\text{syst.})$ pb

SM: $\sigma(WH)\text{xBR}_{(H\to WW^*)}$: $0.294^{+0.009}_{-0.009}$ pb

$\sigma(ZH)\text{xBR}_{(H\to WW^*)}$: $0.31^{+0.09}_{-0.08}(\text{stat.})^{+0.03}_{-0.03}(\text{syst.})$ pb

SM: $\sigma(ZH)\text{xBR}_{(H\to WW^*)}$: $0.190\,^{+0.009}_{-0.008}$ pb

Extra details: H → τ⁺τ⁻

JHEP 03 (2025) 010 || arXiv:2407.16320

STXS & Unfolded Fiducial Differential cross section measurements.

Production: ggF, VBF, VH, $t\bar{t}H$

Data set: Run 2 (140 fb^{-1})

	$\tau_e\tau_\mu$	$\tau_{\text{lep}}\tau_{\text{had}}$	$\tau_{\text{had}}\tau_{\text{had}}$
Per Channel			
Object counting	$N_e = 1, N_\mu = 1, N_{\tau_{\text{truth}}} = 0$	$N_{e/\mu} = 1, N_{\tau_{\text{truth}}} = 1$	$N_{e/\mu} = 0, N_{\tau_{\text{truth}}} = 2$
p_T cut	e/μ : p_T cut 10 to 27.3 GeV	e/μ : p_T cut 27.0 to 27.3 GeV, τ_{truth}: $p_T > 30$ GeV	τ_{truth}: $p_T > 40, 30$ GeV
Kinematics	$m^{\text{coll}}_{\tau\tau} > m_Z - 25$ GeV, $30 < m_{e\mu} < 100$ GeV	$m_T < 70$ GeV	
Angular	$\Delta R_{e\mu} < 2.0$, $\lvert\Delta\eta_{e\mu}\rvert < 1.5$	$\Delta R_{\ell\tau_{\text{truth}}} < 2.5$, $\lvert\Delta\eta_{\ell\tau_{\text{truth}}}\rvert < 1.5$	$0.6 < \Delta R_{\tau_{\text{truth}}\tau_{\text{truth}}} < 2.5$, $\lvert\Delta\eta_{\tau_{\text{truth}}\tau_{\text{truth}}}\rvert < 1.5$
x_1 and x_2	$0.1 < x_1 < 1.0$, $0.1 < x_2 < 1.0$	$0.1 < x_1 < 1.4$, $0.1 < x_2 < 1.2$	$0.1 < x_1 < 1.4$, $0.1 < x_2 < 1.4$
ommon selection	leading jet $p_T > 40$ GeV, sub-leading jet $p_T > 30$ GeV; $E_T^{\text{miss}} > 20$ GeV; Opposite charge of τ-decay products; $m_{jj} > 600$ GeV, $\lvert\Delta\eta_{jj}\rvert > 3.4$, $p_T(jj) > 30$ GeV; $\eta(j_0) \times \eta(j_1) < 0$; lepton centrality: visible decay products of the τ-leptons between VBF jets; $p_T(Hjj) < 50$ GeV		

UFD measurement also performed: Agnostic to production mode, corrected for detector effects/efficiencies (unfolding).

Bins:

	$p_T(j_0)$ [GeV]	p_T^H [GeV]	$\Delta\phi_{jj}^{\text{signed}}$	$\Delta\phi_{jj}^{\text{signed}}$ vs p_T^H [GeV]
Bin 1	[40, 95]	[0, 110]	$[-\pi, -\pi/2]$	$\Delta\phi_{jj}^{\text{signed}} < 0$ & $p_T^H < 200$
Bin 2	[95, 130]	[110, 150]	$[-\pi/2, 0]$	$\Delta\phi_{jj}^{\text{signed}} > 0$ & $p_T^H < 200$
Bin 3	[130, 180]	[150, 200]	$[0, \pi/2]$	$\Delta\phi_{jj}^{\text{signed}} < 0$ & $p_T^H > 200$
Bin 4	[180, 500]	[200, 550]	$[\pi/2, \pi]$	$\Delta\phi_{jj}^{\text{signed}} > 0$ & $p_T^H > 200$

Extra details: H → $\mu^+\mu^-$

Phys. Rev. Lett. 135 (2025) 231802 || arXiv:2507.03595

Category	Data	S	B	$S/\sqrt{B}$	S/B [%]
$t\bar{t}H$-High	12	1.9 ± 0.7	15.5 ± 2.3	0.49	12.5
$t\bar{t}H$-Medium	117	3.9 ± 1.4	115 ± 7	0.36	3.4
VH4L	11	0.78 ± 0.29	12.2 ± 1.8	0.22	6.4
VH3L-High	25	1.4 ± 0.5	17.4 ± 2.9	0.33	8.0
VH3L-Medium	143	3.7 ± 1.4	136 ± 10	0.31	2.7
VH2L-High	19	1.0 ± 0.4	18.3 ± 2.9	0.23	5.3
VH2L-Medium	30	0.38 ± 0.14	31.7 ± 3.1	0.07	1.2
VBF High	9	4.3 ± 1.6	10.5 ± 1.8	1.34	41.2
VBF Medium	28	5.3 ± 2.0	25.8 ± 2.7	1.04	20.5
VBF Low	69	7.2 ± 2.7	62 ± 4	0.91	11.6
VBF Very Low	217	11 ± 4	225 ± 8	0.76	5.1
2-jet High	1 399	31 ± 12	$1\,367 \pm 25$	0.84	2.3
2-jet Medium	5 657	69 ± 26	$5\,560 \pm 50$	0.92	1.2
2-jet Low	17 684	110 ± 40	$17\,300 \pm 70$	0.87	0.7
2-jet Very Low	35 147	110 ± 40	$35\,160 \pm 140$	0.59	0.3
1-jet High	708	17 ± 6	710 ± 16	0.65	2.4
1-jet Medium	7 166	80 ± 30	$7\,140 \pm 70$	0.95	1.1
1-jet Low	31 761	180 ± 70	$31\,510 \pm 120$	1.00	0.6
1-jet Very Low	73 578	200 ± 80	$73\,330 \pm 200$	0.75	0.3
0-jet High	19 445	120 ± 50	$19\,260 \pm 90$	0.89	0.6
0-jet Medium	50 742	200 ± 80	$50\,830 \pm 190$	0.90	0.4
0-jet Low	94 032	240 ± 90	$93\,770 \pm 210$	0.78	0.3
0-jet Very Low	136 762	170 ± 60	$136\,510 \pm 290$	0.47	0.1

	Selection
Common preselection	Primary vertex Two opposite-charge muons Muons: $\|\eta\| < 2.5$, $p_T^{lead} > 27$ GeV, $p_T^{sublead} > 15$ GeV
Fit region	$m_{\mu\mu} = 110 - 160$ GeV
Jets	$p_T > 25$ GeV and $\|\eta\| < 2.4$ or with $p_T > 30$ GeV and $2.4 < \|\eta\| < 4.5$
b-tagged jets	$p_T > 25$ GeV and $\|\eta\| < 2.4$ or with $p_T > 30$ GeV and $2.4 < \|\eta\| < 2.5$ Tagging efficiency working point of 85%
$t\bar{t}H$ categories	At least one b-jet
VH 4-lepton category	Exactly two additional e or μ with $p_T > 8$ GeV, 5 GeV (μ) / 7 GeV (e), no b-jets
VH 3-lepton categories	Exactly one additional e or μ with $p_T > 15$ GeV, no b-jets
VH 2-lepton categories	No additional lepton, no b-jets, $E_T^{miss} > 120$ GeV
VBF and ggF categories	No additional lepton, no b-jets, $E_T^{miss} < 120$ GeV

Extra details: $H \to b\bar{b}$, $H \to c\bar{c}$ (VBF)

arXiv:2511.21911

VBF candidate jets selection	
j_1	$p_T > 75$ GeV and $\lvert\eta\rvert < 3.2$
j_2	$p_T > 75$ GeV and $\lvert\eta\rvert < 4.5$
m_{jj}	> 1200 GeV
$\lvert\Delta\phi_{jj}\rvert$	< 2
$\lvert\Delta\eta_{jj}\rvert$	> 4
In case of multiple jets satisfying these criteria, the pair maximizing m_{jj} is selected	
Higgs jets selection	
j_{h1}	$p_T > 20$ GeV and $\lvert\eta\rvert < 2.5$ (and not selected as VBF jet)
j_{h2}	$p_T > 20$ GeV and $\lvert\eta\rvert < 2.5$ (and not selected as VBF jet)
$\lvert\Delta\phi_{j_h j_h}\rvert$	< 2
$p_{T,j_h j_h}$	> 150 GeV
In case of multiple jets satisfying these criteria, the pair maximizing $p_{T,j_h j_h}$ is selected	
Veto	
Events with one or more isolated electrons or muons are rejected	
Flavor tagging	
$H \to b\bar{b}$ channel	j_{h1} and j_{h2} are b-tagged with 77% b-tagging efficiency
$H \to c\bar{c}$ channel	j_{h1} and j_{h2} are not b-tagged and are c-tagged with 50% c-tagging efficiency

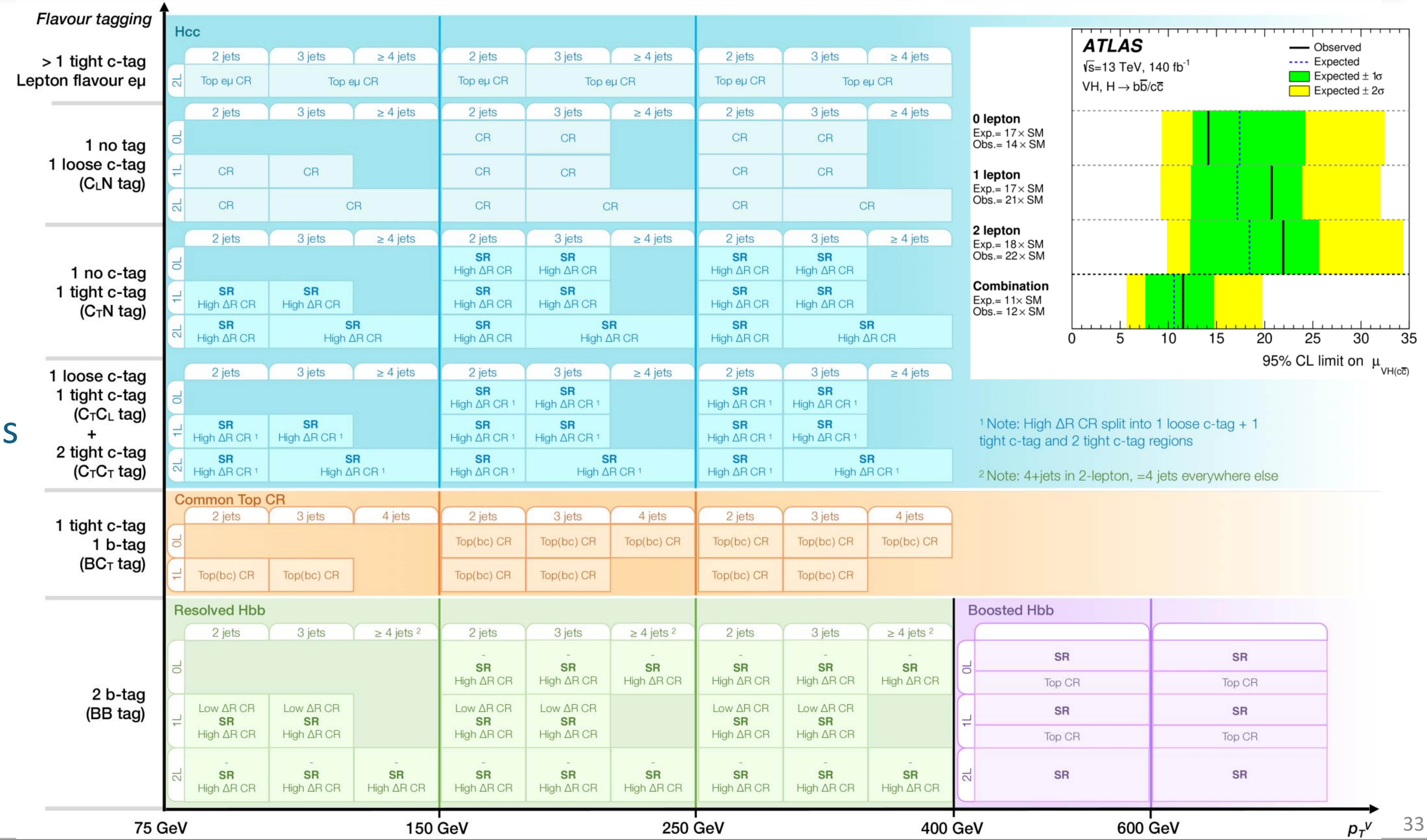
Source of uncertainty	$\sigma(\mu^{c\bar{c}})$	$\sigma(\mu^{b\bar{b}})$
Total	13	0.53
Statistical	12	0.45
Data statistical	8.7	0.32
Non-res. bkgd normalization	4.9	0.19
Non-res. bkgd shape	4.6	0.20
Non-res. bkgd residual uncertainty	1.4	0.05
Other Higgs signal normalization	0.3	0.01
Systematic	6.5	0.28
Non-res. bkgd bias uncertainty	5.8	0.19
Simulation sample sizes	3.4	0.21
Experimental	1.8	0.18
Jet	1.8	0.18
Flavor tagging	0.3	0.01
Trigger	0.3	0.02
Other	0.06	0.02
V+jets and $t\bar{t}$ background estimate	0.7	0.03
Signal theory	0.8	0.04

New trigger exploits large invariant mass and rapidity separation of two forward jets in VBF, achieves higher $H \to b\bar{b}$ efficiency, better discrimination for $H \to c\bar{c}$.

Extra details: $H \rightarrow b\bar{b}$, $H \rightarrow c\bar{c}$ (VH)

JHEP 04 (2025) 075 || arXiv:2410.19611

Signal and Control Regions



Extra details: $H \to b\bar{b}$, $H \to c\bar{c}$ (VH)

JHEP 04 (2025) 075 || arXiv:2410.19611

Event yields

p_T^V region	Num. jets	SR	$H \to b\bar{b}$	$H \to c\bar{c}$	Total bkg.	Data
150–250 GeV	2	BB	180 ± 30	0.14 ± 0.76	10030 ± 90	10138
		C_TN	8.9 ± 1.5	6 ± 33	58050 ± 210	58484
		C_TC	4.0 ± 0.6	3 ± 17	7370 ± 70	7353
	3	BB	111 ± 20	0.1 ± 0.5	16630 ± 110	16700
		C_TN	4.1 ± 0.8	3 ± 16	31730 ± 150	31527
		C_TC	2.6 ± 0.5	2 ± 10	7690 ± 70	7688
	4	BB	47 ± 11	0.1 ± 0.3	21330 ± 130	21279
250–400 GeV (> 250 GeV)	2	BB	41 ± 7	0.03 ± 0.16	750 ± 20	822
		C_TN	1.9 ± 0.3	1 ± 8	5840 ± 50	5852
		C_TC	1.2 ± 0.2	1 ± 5	773 ± 16	760
	3	BB	26 ± 4	0.02 ± 0.12	1180 ± 30	1195
		C_TN	0.9 ± 0.18	0.8 ± 4.2	4130 ± 40	4148
		C_TC	0.69 ± 0.12	0.5 ± 2.8	1039 ± 18	1063
	4	BB	14 ± 3	0.02 ± 0.09	1630 ± 30	1631
400–600 GeV	-	BB	18 ± 3	0.2 ± 1.0	1030 ± 30	1025
>600 GeV	-	BB	3.1 ± 0.5	0.04 ± 0.19	161 ± 8	162

Extra details: tH production

JHEP 10 (2025) 093 || arXiv:2508.14695

Fiducial cross section and STXS measurement.

Decays: $b\bar{b}$, WW*, ZZ*, $\tau^{+}\tau^{-}$, with extra ℓ final state.

Data set: Run 2 (140 fb^{-1})

$H \rightarrow b\bar{b}$ channel

Process	Pre-fit SR	Pre-fit CR($t\bar{t}+\geq 1b$)	Post-fit SR	Post-fit CR($t\bar{t}+\geq 1b$)
tHq	43 ± 7	9.1 ± 2.0	350 ± 130	72 ± 29
tWH	3.4 ± 2.0	14 ± 8	28 ± 20	110 ± 80
$t\bar{t}+\geq 1b$	6800 ± 1100	20100 ± 2600	8100 ± 1000	25600 ± 1900
$t\bar{t}+\geq 1c$	4000 ± 2400	11000 ± 6000	3900 ± 1500	10200 ± 3300
$t\bar{t}+\geq 0$ light	19300 ± 3300	23100 ± 3500	18500 ± 1100	23300 ± 2100
e/μ_{Fakes}	1700 ± 500	1600 ± 500	1700 ± 500	1600 ± 500
$t\bar{t}W$	20.1 ± 3.0	134 ± 19	20.2 ± 2.9	133 ± 19
$t\bar{t}H$	120 ± 15	683 ± 70	120 ± 15	683 ± 70
$t\bar{t}Z$	68 ± 9	340 ± 40	68 ± 9	340 ± 40
tZq	69 ± 7	20.4 ± 1.9	69 ± 6	20.4 ± 1.9
tWZ	0.20 ± 0.10	0.9 ± 0.5	0.20 ± 0.11	0.9 ± 0.5
Wt channel	970 ± 260	1500 ± 500	970 ± 250	1600 ± 500
t-channel	1070 ± 180	350 ± 120	1060 ± 160	350 ± 120
s-channel	43 ± 8	40 ± 11	42 ± 7	39 ± 10
W + jets	740 ± 310	900 ± 400	750 ± 300	890 ± 350
Z + jets	140 ± 50	100 ± 40	140 ± 50	100 ± 40
VV	48 ± 25	70 ± 40	41 ± 22	63 ± 33
other Higgs	6 ± 5	5.3 ± 2.9	7 ± 5	5.2 ± 2.8
Rare top	0.08 ± 0.04	3.3 ± 1.7	0.08 ± 0.04	3.4 ± 1.7
Total	35000 ± 5000	60000 ± 8000	35870 ± 210	65000 ± 340
Data	35869	65002	35869	65002

Post-fit 2ℓ SS channel

Process	SR	CR(μ_{HF})	CR(e_{HF})	CR(e_{conv})	CR($t\bar{t}W$)
tHq	25 ± 9	5.3 ± 2.1	21 ± 8	0.67 ± 0.30	2.4 ± 0.9
tWH	0.7 ± 0.4	1.6 ± 0.7	7.3 ± 3.2	0.13 ± 0.07	3.2 ± 1.4
μ_{HF}	13 ± 6	47 ± 18	15 ± 7	0.22 ± 0.17	2.9 ± 1.9
e_{HF}	2.6 ± 3.4	-	50 ± 60	0.7 ± 0.9	0.5 ± 0.7
e_{conv}	3.8 ± 3.1	-	98 ± 35	58 ± 15	3.4 ± 1.6
other mis-id leptons	4 ± 4	15 ± 11	38 ± 25	3.3 ± 2.8	3.2 ± 2.1
$e_{\text{ChargeFlip}}$	8.0 ± 1.8	-	210 ± 50	36 ± 10	4.2 ± 1.0
$t\bar{t}W$	15.0 ± 2.4	41 ± 5	178 ± 17	5.7 ± 0.6	144 ± 13
$t\bar{t}Z$	3.7 ± 0.6	7.9 ± 1.3	37 ± 6	1.07 ± 0.20	15.1 ± 2.1
$t\bar{t}H$	2.4 ± 0.4	7.3 ± 0.9	30 ± 4	0.78 ± 0.11	13.5 ± 1.9
tZq	14.1 ± 1.9	3.9 ± 0.5	22.1 ± 2.0	0.68 ± 0.09	1.03 ± 0.17
VV	6.0 ± 2.4	7.1 ± 3.5	45 ± 13	2.0 ± 1.6	6.0 ± 2.4
others	0.44 ± 0.13	1.1 ± 0.4	7.9 ± 2.1	0.28 ± 0.11	1.9 ± 0.5
4-tops	0.043 ± 0.014	0.050 ± 0.015	0.55 ± 0.15	0.017 ± 0.007	0.85 ± 0.24
Total	99 ± 8	138 ± 11	762 ± 27	109 ± 10	202 ± 12
Data	101	137	756	110	200

Post-fit 3ℓ channel

Process	SR	CR(μ_{HF})	CR(e_{HF})	CR(e_{conv})	CR($t\bar{t}W$)
tHq	12 ± 4	2.0 ± 0.9	1.3 ± 0.5	0.20 ± 0.09	2.2 ± 0.9
tWH	2.3 ± 0.9	2.0 ± 0.9	1.2 ± 0.5	0.15 ± 0.07	5.2 ± 2.2
μ_{HF}	8 ± 4	77 ± 18	3.0 ± 1.5	0.07 ± 0.09	9 ± 6
e_{HF}	8 ± 4	3.8 ± 2.9	68 ± 14	0.22 ± 0.08	10 ± 6
e_{conv}	3.1 ± 2.1	3 ± 4	11 ± 6	11 ± 5	9 ± 11
other mis-id leptons	3.8 ± 2.2	13 ± 8	7 ± 4	1.0 ± 0.9	9 ± 7
$t\bar{t}W$	8.3 ± 1.3	15.0 ± 1.6	9.3 ± 1.2	2.0 ± 0.4	131 ± 12
tWZ	0.9 ± 0.5	1.5 ± 0.7	0.9 ± 0.5	0.62 ± 0.33	3.6 ± 1.9
$t\bar{t}Z$	14.2 ± 2.0	15.5 ± 2.3	8.4 ± 1.3	4.6 ± 0.9	38 ± 5
$t\bar{t}H$	7.7 ± 1.0	7.6 ± 1.0	4.7 ± 0.7	0.48 ± 0.14	21.4 ± 2.8
tZq	10.7 ± 1.2	9.3 ± 1.1	4.9 ± 0.6	1.74 ± 0.32	6.0 ± 0.7
tW	1.1 ± 0.7	5 ± 4	4.0 ± 2.7	0.9 ± 0.7	1.4 ± 1.1
VV	10 ± 4	21 ± 6	10.6 ± 3.4	4.2 ± 1.3	11 ± 4
others	0.23 ± 0.08	0.43 ± 0.12	0.15 ± 0.05	0.037 ± 0.011	0.9 ± 0.4
4-tops	0.14 ± 0.04	0.15 ± 0.05	0.087 ± 0.026	0.035 ± 0.012	1.7 ± 0.5
Total	90 ± 7	177 ± 13	135 ± 11	27 ± 5	260 ± 11
Data	90	175	134	26	268

Extra details: $t\bar{t}H$

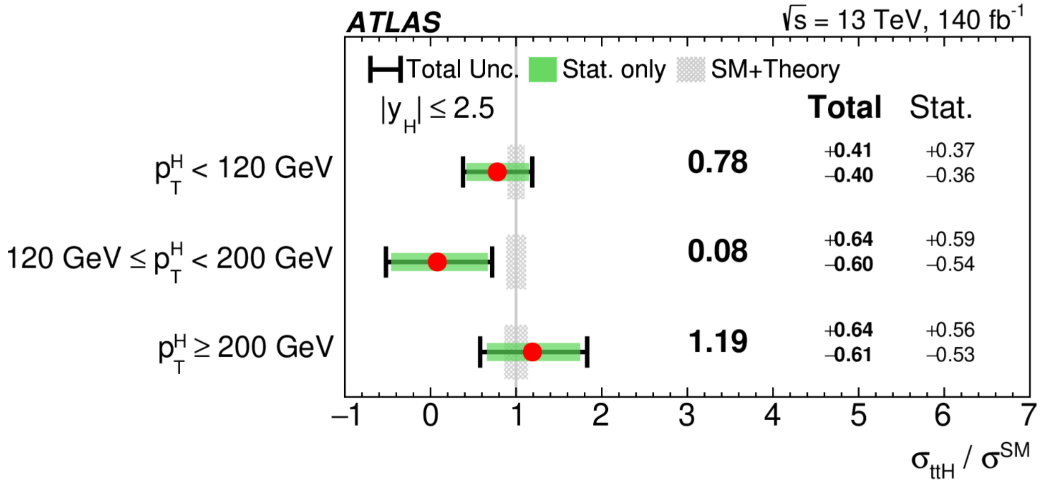
arXiv:2510.23755

Fiducial cross section and STXS measurement.

Decays: Multilepton final states.
Data set: Run 2 (140 fb^{-1})

STXS bin	$\sigma_{t\bar{t}H}$ [fb]	σ^{SM} [fb]
$p_{\mathrm{T}}^{H} < 120$ GeV	231^{+122}_{-119}	297^{+20}_{-29}
$120 \leq p_{\mathrm{T}}^{H} < 200$ GeV	10^{+81}_{-76}	127^{+9}_{-12}
$p_{\mathrm{T}}^{H} \geq 200$ GeV	92^{+49}_{-47}	77^{+5}_{-8}

	2ℓSS$0\tau_{\mathrm{had}}$ and $3\ell0\tau_{\mathrm{had}}$ channels				4ℓ channel	
Region	3ℓVV	$3\ell t\bar{t}Z$	3ℓIntC, 3ℓMatC	2ℓtt(e)$_{TM_{\mathrm{ex}}}$, 2ℓtt(e)$_{M_{\mathrm{ex}}T}$, 2ℓtt(μ)$_{TM_{\mathrm{ex}}}$, 2ℓtt(μ)$_{M_{\mathrm{ex}}T}$, 2ℓtt(e)$_{M_{\mathrm{ex}}M_{\mathrm{ex}}}$, 2ℓtt(μ)$_{M_{\mathrm{ex}}M_{\mathrm{ex}}}$	3ℓ μ HF, 3ℓ e HF	3ℓ e LF
Lepton requirement	3ℓ		$\mu\mu e^*$	2ℓSS	$e^{\mp}\mu^{\pm}\mu^{\pm}$, $\mu^{\mp}e^{\pm}e^{\pm}$	$\mu^{\pm}\mu^{\mp}e^{\mp}$
Lepton definition	$(L$ or $L', M, M)$		(L, M, M)	(T, M_{ex}) or (M_{ex}, T) or $(M_{\mathrm{ex}}, M_{\mathrm{ex}})$	L	
Lepton p_{T} [GeV]	(10, 15, 15)			(15, 15)	(10,10,10)	
$\lvert m^{\mathrm{SF}}_{\ell^+\ell^-} - m_Z\rvert$ [GeV]	< 10		> 10	–	–	< 10
$\lvert m_{\ell\ell\ell} - m_Z\rvert$ [GeV]	> 10		< 10	–	–	> 15
$m_{\mathrm{T}}(\ell_0, E_{\mathrm{T}}^{\mathrm{miss}})$ [GeV]	–			< 250 for TM_{ex} and $M_{\mathrm{ex}}T$ pairs	–	
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	–			–	–	< 20
N_{jets}	2 or 3	≥ 4	–	≥ 2	≥ 1	
$N_{b\text{-jets}}$	$1\ b^{85\%}$	$\geq 1\ b^{85\%}$	$0\ b^{85\%}$	$1\ b^{85\%}$	$\geq 1\ b^{85\%}$	$0\ b^{85\%}$
$\tau_{\text{had-vis}}$ candidates	0			0	–	
$3\ell0\tau_{\mathrm{had}}$ channel veto	–			–	Yes	
Region split	–	–	internal, material	sub-leading e/μ × (TM_{ex}, $M_{\mathrm{ex}}T$, $M_{\mathrm{ex}}M_{\mathrm{ex}}$)	$e^{\mp}\mu^{\pm}\mu^{\pm}$, $\mu^{\mp}e^{\pm}e^{\pm}$	–



κ-framework

arXiv:2207.00092

Parametrizing $\sigma * BR$ measurements in terms of multiplicative coupling strength modifiers, κ.

Cross sections: $\kappa_p^2 = \frac{\sigma_p}{\sigma_p^{SM}}$ Decays: $\kappa_p^2 = \frac{\Gamma_p}{\Gamma_p^{SM}}$

ie: Standard model: $\kappa_V = \kappa_Z = \kappa_W = \kappa_f = 1$, but <1 in SM extensions.

Best-fit values: $\kappa_V = 1.035 \pm 0.031$, $\kappa_f = 0.95 \pm 0.05$

Measurement contains large correlation (39%) between κ_V and κ_f because of vector boson decays in ggF production measurements.