

Higgs boson coupling measurements in ATLAS LHCP 2024

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Introduction

- After the discovery of the Higgs boson by ATLAS and CMS, the **measurement** of its **properties** has been a priority.
- Coupling between the Higgs boson and particles defined by the particle's mass and type. Three types of couplings to massive particles:



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Higgs boson production and decay

 ATLAS recorded 140 fb⁻¹ of *pp* collisions in Run 2 → According to SM prediction, ~9 millions of Higgs bosons, 0.3% experimentally accessible.







- All major Higgs boson production and decay modes observed during Run 2.
 Evidence for rare decays (second generation couplings, Zy) emerging.
- Experimentally well-established analyses used to probe challenging phase spaces.

Combining Run 2 data

- Combining statistical power of different decay signatures → key to achieve sensitive crosssection/branching ratio measurements.
 - Fundamental to test precisely the SM.
- Global signal strength ($\mu = \sigma / \sigma_{SM}$):
 - $\mu = 1.05 \pm 0.06 =$ = 1.05 ± 0.03 ± 0.03 ± 0.04 ± 0.02 (stat.) (exp.) (sig. th.) (bkg. th.)
- Different sensitivities to the Higgs production modes from different decay processes.
 Excellent overall agreement with the SM.



Combining Run 2 data - Coupling measurements

• Coupling fit performed within κ framework: κ modifiers affect coupling strength without altering kinematic distributions.

$$\sigma_i \times B(H \to f) = \frac{\kappa_i^2 \kappa_f^2}{\kappa_H^2} \sigma_i^{\rm SM} \times B^{\rm SM}(H \to f)$$

• Different models tested with progressively fewer assumptions:



b) Independent couplings for W, Z, t, b, c, τ and μ



 $\kappa_{H}^{2} = \left(\frac{\Gamma_{i}}{\Gamma_{i}^{SM}}\right)^{2} = \frac{\sum_{p} B_{p}^{SM} \kappa_{p}^{2}}{1 - B_{inv.} - B_{u.}}$ c) Include effective coupling

 $\kappa_i = \frac{\sigma_i}{\sigma_i^{\text{SM}}} \text{ or } \kappa_i = \frac{\Gamma_i}{\Gamma_i^{\text{SM}}}$



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Combining Run 2 data - Simplified template cross-sections

- Simplified template cross-sections (STXS):
 - Phase space partitioned using kinematic properties of the Higgs boson (and associated objects like jets or vector bosons).
 - Designed to:
 - Optimize sensitivity to **BSM effects**.
 - Keep **theory uncertainties** under control.
 - Minimize model dependence.
- Simultaneous measurement of 36 phase space regions.
- Good agreement with the SM prediction, *p*-value of 94%.



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Interpretations in SMEFT

- Combined STXS results interpreted in SM effective field theory.
- Higher-dimensional operators built upon SM fields, scaled by Wilson-coefficients.

 $\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \sum_{i}^{N_{d=6}} \frac{\overline{c_i}}{\Lambda^2} O_i^{(6)} + \sum_{j}^{N_{d=8}} \frac{\overline{b_j}}{\Lambda^4} O_j^{(8)} + \dots,$ Wilson coefficient

- Full set of Wilson coefficients of d = 6 operators cannot be constrained simultaneously:
 - Large number of degrees of freedom.
 - Degeneracies in the impact of operators.
- **Principal component analysis** performed to choose **rotated basis**.



Linear term: interference between d = 6 operators and SM. Quadratic term: Pure BSM, product of two d = 6 operators.

Relative sign of the W and Z couplings with VBF WH production

- VBF WH production provides unique sensitivity to $\lambda_{WZ} = \kappa_W / \kappa_Z$. Destructive interference predicted by the SM. Enhanced production for $\lambda_{WZ} < 0$. Combinations have measured $|\lambda_{WZ}|$.
- Two separate analyses targeting VBF $WH \rightarrow jj\ell\nu b\overline{b}$, either BSM ($\lambda_{WZ} < 0$) or SM signal with dedicated regions to normalize main backgrounds ($t\overline{t}$, tW and W+jets).
- Results compatible with SM and background-only hypothesis. Non-SM allowed region excluded with $> 5\sigma$.
- Observed (expected) upper limit on VBF WH cross-section: 9.0 (8.7) SM prediction at 95% CL.



Boosted VH production in fully hadronic *qqbb* **final states**

- First measurement of **boosted** (high $p_{\rm T}$) Higgs production with $VH \rightarrow qqbb$. Sensitivity to **BSM** effects.
- Requiring **2 large-***R* jets in signal enriched region: one passing $H \rightarrow bb$ tagging, other W/Z tagging.
- Data driven estimation of major (>90%) multijet • background and Z+jets normalization.
- Production cross section measured inclusively and in $\boldsymbol{p}_{\mathbf{T}}^{\boldsymbol{H}}$ ranges using the Higgs candidate mass.

 $\mu_{\rm inc} = 1.4^{+1.0}_{-0.9}$ 1.7σ obs. $(1.2\sigma \text{ exp})$



- New results expanding previous STXS $H \rightarrow \tau \tau$ measurements (JHEP 08 (2022) 175) in VBF and $t \bar{t} H$ phase space, keeping previous strategy for ggH (Boost) and VH.
- Events selected with two τ candidates. Three channels depending on τ decay mode: $\tau_{had} \tau_{had}$, $\tau_{lep} \tau_{had}$, $\tau_e \tau_{\mu}$.
- Additional selections to split events in ggH, VBF, VH and $t\bar{t}H$ categories. Further selections to target STXS regions.





STXS measurements in $H \rightarrow \tau \tau$

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- Fits across different regions with different free floating parameters:
 - 1 Parameter-of-interest (POI) fit to extract overall signal strength with respect to SM.
 - 4 POI fit to measure **different production** processes separately. Good agreement wih SM, *p*-value of 99%.
 - VBF production
 - Slightly better precision with respect to last publication due to improved categorization.
 - *ttH* production
 - Refined multivariate analysis approach leads to ~25% improvement.



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- Fits across different regions with different free floating parameters:
 - 18 POI fit corresponding to different STXS regions.
 - Better precision in VBF phase space for higher p_T^H and/or m_{jj} due to reduced SM backgrounds.
 - Reasonable agreement with SM prediction with *p*-value of 6%.
 - $t\bar{t}H$ results statistically limited. Upper limits at 95% CL derived for $t\bar{t}H$ in STXS framework.







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Searches for rare Higgs boson decays

- Probing the coupling of the Higgs boson to second-generation fermions:
 - $H \rightarrow \mu \mu$
 - Large **Drell-Yan background**. Events sorted targeting different production modes. Fit to $m_{\mu\mu}$.
 - Observed (expected) significance over background-only hypothesis is 2. $\mathbf{0}\sigma$ (1.7 σ) for $m_H = 125.09$ GeV.
 - $H \rightarrow cc$
 - VH, $H \rightarrow cc$. Challenging search, where **c-tagging efficiency** (27%) is crucial. Simultaneous fit on m_{cc} in various categories.
 - Observed (expected) upper limit on signal strength of 26 (31) times the SM prediction at 95% CL.



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Conclusions

- Presented a selection of ATLAS results. Very good agreement with SM.
- Precision era. Coupling measurements with uncertainties < 10%.
- Main couplings exploited to explore extreme and challenging phase space regions.
- Continuous effort to measure **rare decays** and extend coupling measurements to second-generation fermions.



Nature 607, pages 52-59 (2022)

Additional material

Coupling modifiers and STXS measurements

	(a) $B_{inv.} = B_{u.} = 0$	(b) $B_{inv.}$ free, $B_{u.} \ge 0$, $\kappa_{W,Z} \le 1$	Natu	88 88 88
KZ	$0.99^{+0.06}_{-0.06}$	$0.98^{+0.02}_{-0.05}$	re 607	88 88 88
ĸw	$1.05^{+0.06}_{-0.06}$	$1.00_{-0.02}$, pages	88 88 89
K _t	$0.94^{+0.11}_{-0.11}$	$0.94^{+0.11}_{-0.11}$	52-59	
Кb	$0.89^{+0.11}_{-0.11}$	$0.82^{+0.09}_{-0.08}$	9 (2022	q q q q q q
Kτ	$0.93^{+0.07}_{-0.07}$	$0.91\substack{+0.07 \\ -0.06}$	<u>2)</u>	99 99 99
ĸμ	$1.06^{+0.25}_{-0.30}$	$1.04^{+0.23}_{-0.30}$		q_{q}
Kg	$0.95^{+0.07}_{-0.07}$	$0.94^{+0.07}_{-0.06}$		90 90 90
κ _γ	$1.01\substack{+0.06\\-0.06}$	$0.98^{+0.05}_{-0.05}$		
$\kappa_{Z\gamma}$	$1.38^{+0.31}_{-0.37}$	$1.35^{+0.29}_{-0.36}$		88
B_{inv} .	-	< 0.13		tī tī tī
$B_{u.}$	-	< 0.12		tī tī tī

STXS	Cross section [pb]	SM prediction [pb]
$gg \to H, 0$ -jet, $p_T^H < 10 \text{ GeV}$	$5.8 \pm 1.3(^{+1.2}_{-1.1}(stat.)^{+0.7}_{-0.6}(syst.))$	6.6 ± 0.9
$gg \rightarrow H, 0$ -jet, $10 \le p_T^H < 200 \text{ GeV}$	$25.4^{+2.7}_{-2.6}(\pm 1.8(stat.)^{+2.0}_{-1.8}(syst.))$	20.6 ± 1.5
$gg \rightarrow H$, 1-jet, $p_T^H < 60 \text{ GeV}$	$5.2 \pm 1.7(\pm 1.3(stat.) \pm 1.1(syst.))$	6.5 ± 0.9
$gg \rightarrow H$, 1-jet, $60 \le p_T^H < 120 \text{ GeV}$	$5.5^{+1.2}_{-1.1}(\pm 1.0(stat.)^{+0.7}_{-0.6}(syst.))$	4.5 ± 0.6
$gg \rightarrow H$, 1-jet, 120 $\leq p_T^H < 200 \text{ GeV}$	$0.73^{+0.30}_{-0.29}(\pm 0.25(stat.)^{+0.16}_{-0.14}(syst.))$	0.75 ± 0.13
$gg \rightarrow H, \ge 2$ -jet, $m_{jj} < 350$ GeV, $p_T^H < 120$ GeV	$1.2 \pm 1.4(\pm 1.2(stat.) \pm 0.7(syst.))$	3.0 ± 0.6
$gg \rightarrow H, \ge 2$ -jet, $m_{jj} < 350$ GeV, $120 \le p_T^H < 200$ GeV	$0.9 \pm 0.4 (\pm 0.4 (stat.) \pm 0.2 (syst.))$	0.94 ± 0.22
$gg \rightarrow H, \ge 2$ -jet, $m_{jj} \ge 350$ GeV, $p_T^H < 200$ GeV	$0.9 \pm 0.7(\pm 0.6(stat.) \pm 0.3(syst.))$	0.88 ± 0.21
$gg \rightarrow H, 200 \le p_T^H < 300 \text{ GeV}$	$0.66^{+0.16}_{-0.15}({}^{+0.13}_{-0.12}(stat.){}^{+0.10}_{-0.08}(syst.))$	0.46 ± 0.10
$gg \rightarrow H, 300 \le p_T^H < 450 \text{ GeV}$	$0.08 \pm 0.05 (^{+0.05}_{-0.04} (stat.) \pm 0.02 (syst.))$	0.106 ± 0.027
$gg \rightarrow H, p_T^H \ge 450 \text{ GeV}$	$0.036^{+0.024}_{-0.020}(^{+0.023}_{-0.020}(stat.)^{+0.008}_{-0.005}(syst.))$	0.018 ± 0.005
$qq \rightarrow Hqq, \leq 1$ -jet	$0.6^{+2.0}_{-1.8}(^{+1.9}_{-1.8}(stat.) \pm 0.6(syst.))$	2.16 ± 0.06
$qq \rightarrow Hqq$, ≥ 2 -jet, $m_{jj} < 350$ GeV, VH -enriched	$0.34^{+0.26}_{-0.24}(^{+0.23}_{-0.22}(st at.)^{+0.12}_{-0.11}(syst.))$	0.510 ± 0.016
$qq \rightarrow Hqq$, ≥ 2 -jet, $m_{jj} < 350$ GeV, VBF -enriched	$1.8^{+1.1}_{-1.0}(^{+1.0}_{-0.9}(stat.)^{+0.5}_{-0.4}(syst.))$	0.735 ± 0.019
$qq \rightarrow Hqq$, ≥ 2 -jet, $350 \leq m_{jj} < 700$ GeV, $p_T^H < 200$ GeV	$0.49^{+0.26}_{-0.24}({}^{+0.23}_{-0.21}(st at.){}^{+0.13}_{-0.10}(syst.))$	0.535 ± 0.013
$qq \rightarrow Hqq$, ≥ 2 -jet, 700 $\leq m_{jj} < 1000 \text{ GeV}, p_T^H < 200 \text{ GeV}$	$0.30^{+0.14}_{-0.12} \begin{pmatrix} +0.12 \\ -0.11 \end{pmatrix} (st at.)^{+0.06}_{-0.05} (syst.))$	0.256 ± 0.007
$qq \rightarrow Hqq$, \geq 2-jet, 1000 $\leq m_{jj} <$ 1500 GeV, $p_T^H <$ 200 GeV	$0.30^{+0.11}_{-0.10}(^{+0.10}_{-0.09}(st at.)^{+0.05}_{-0.04}(syst.))$	0.224 ± 0.006
$qq \rightarrow Hqq$, ≥ 2 -jet, $m_{jj} \geq 1500$ GeV, $p_T^H < 200$ GeV	$0.26^{+0.08}_{-0.07}(\pm 0.07(stat.)^{+0.04}_{-0.03}(syst.))$	0.216 ± 0.006
$qq \rightarrow Hqq$, ≥ 2 -jet, $350 \leq m_{jj} < 1000 \text{ GeV}, p_T^H \geq 200 \text{ GeV}$	$0.04 \pm 0.05(^{+0.05}_{-0.04}(stat.)^{+0.02}_{-0.01}(syst.))$	0.0737 ± 0.0017
$qq \rightarrow Hqq$, \geq 2-jet, $m_{jj} \geq$ 1000 GeV, $p_T^H \geq$ 200 GeV	$0.086^{+0.022}_{-0.021}(\pm 0.019(stat.)^{+0.011}_{-0.009}(syst.))$	0.0732 ± 0.0019
$qq \rightarrow H l\nu, p_T^V < 75 \text{ GeV}$	$0.70^{+0.30}_{-0.27}(^{+0.29}_{-0.26}(st at.)^{+0.06}_{-0.04}(syst.))$	0.215 ± 0.008
$qq \rightarrow Hl\nu, 75 \le p_T^V < 150 \text{ GeV}$	$0.05^{+0.11}_{-0.08}(^{+0.11}_{-0.08}(st at.)^{+0.02}_{-0.01}(syst.))$	0.134 ± 0.005
$qq \rightarrow Hlv, 150 \le p_T^V < 250 \text{ GeV}$	$0.039^{+0.019}_{-0.018}(\pm 0.013(st at.)^{+0.013}_{-0.012}(syst.))$	0.0412 ± 0.0017
$qq \rightarrow Hl\nu, 250 \le p_T^V < 400 \text{ GeV}$	$0.011 \pm 0.004(^{+0.004}_{-0.003}(stat.) \pm 0.002(syst.))$	0.0100 ± 0.0004
$qq \rightarrow H l\nu, p_T^V \ge 400 \text{ GeV}$	$0.0033^{+0.0020}_{-0.0018}(^{+0.0017}_{-0.0016}(stat.)^{+0.0011}_{-0.0009}(syst.))$	0.00214 ± 0.00011
$gg/qq \rightarrow Hll, p_T^V < 150 \text{ GeV}$	$0.08 \pm 0.11(^{+0.09}_{-0.08}(stat.)^{+0.08}_{-0.07}(syst.))$	0.198 ± 0.007
$gg/qq \rightarrow Hll, 150 \le p_T^V < 250 \text{ GeV}$	$0.035^{+0.011}_{-0.010}(^{+0.009}_{-0.008}(stat.)^{+0.007}_{-0.006}(syst.))$	0.032 ± 0.004
$gg/qq \rightarrow Hll, 250 \le p_T^V < 400 \text{ GeV}$	$0.0074^{+0.0029}_{-0.0027}(^{+0.0025}_{-0.0024}(stat.)^{+0.0013}_{-0.0012}(syst.))$	0.0072 ± 0.0008
$gg/qq \rightarrow Hll, p_T^V \ge 400 \text{ GeV}$	$0.0004^{+0.0012}_{-0.0011}(^{+0.0010}_{-0.0009}(stat.)^{+0.0007}_{-0.0006}(syst.))$	0.00126 ± 0.00010
$t\bar{t}H, p_T^H < 60 \text{ GeV}$	$0.09^{+0.09}_{-0.08}(^{+0.08}_{-0.07}(st at.)^{+0.04}_{-0.03}(syst.))$	0.118 ± 0.016
$t\bar{t}H, 60 \le p_T^H < 120 \text{ GeV}$	$0.13^{+0.10}_{-0.09}(^{+0.09}_{-0.08}(st at.)^{+0.05}_{-0.04}(syst.))$	0.178 ± 0.020
$t\bar{t}H$, 120 $\leq p_T^H < 200 \text{ GeV}$	$0.05 \pm 0.06(\pm 0.05(stat.) \pm 0.03(syst.))$	0.126 ± 0.015
$t\bar{t}H$, 200 $\leq p_T^H < 300 \text{ GeV}$	$0.052^{+0.030}_{-0.027}(^{+0.026}_{-0.024}(stat.)^{+0.015}_{-0.012}(syst.))$	0.053 ± 0.007
$t\bar{t}H$, 300 $\leq p_T^H < 450 \text{ GeV}$	$0.005^{+0.012}_{-0.011}(\pm 0.010(stat.) \pm 0.006(syst.))$	0.0190 ± 0.0031
$t\bar{t}H, p_T^H \ge 450 \text{ GeV}$	$0.000 \pm 0.008(^{+0.006}_{-0.005}(stat.) \pm 0.005(syst.))$	0.0054 ± 0.0010
tH	$0.5^{+0.4}_{0.2}(\pm 0.3(stat.)^{+0.2}_{0.1}(syst.))$	0.085+0.005

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STXS measurements

ATLAS	۱۷, 100 tt-1		Stat
$v_{S} = 13$ Te $m_{ii} = 125.0$	v, 139 lb)9 GeV. v < 2.5		Sidi.
_H e.		Syst.	SM
			Total Stat. Syst.
			+0.18 / +0.16
	0-jet, $p_{\gamma}^{H} < 200 \text{ GeV}$	P 1.27	-0.17 (±0.08, -0.15
	1-jet, $p_{\tau}^{H} < 60 \text{ GeV}$	0.66	-0.58 (-0.29 '-0.50
$aa \rightarrow H (WW^*)$	1-jet, $60 \le p_T^H < 120 \text{ GeV}$	0.68	-0.46 (±0.32 , -0.33
gg ->// (****)	1-jet, 120 ≤ p_{T}^{H} < 200 GeV	1.43	-0.76 (-0.62 -0.44
	\geq 2-jet, p_T^H < 200 GeV	1.54	+0.95 (+0.43 +0.85
	$p_{\tau}^{\mu} \ge 200 \text{ GeV}$	1.37	+0.91 (+0.63 +0.65 -0.76 (-0.62 ,-0.44
	> 2.iet 350 < $m < 700$ GeV $n^{H} < 200$ GeV		+0.60 (+0.45
qq→Hqq (WW*)	$22 p_{101}^{2}$, $300 \le m_{10}^{2} \le 1000 \text{ GeV}, p_{T}^{2} \le 200 \text{ GeV}$	0.12	-0.58 -0.41 ,±0.41
	$\geq 2 e_1, 700 \leq m_{j_1} < 1000 \text{ GeV}, p_{\gamma} < 200 \text{ GeV}$	0.57	-0.61 (-0.51 '-0.33
	$\geq 2 g_1 , 1000 \leq m_y < 1500 \text{ GeV}, p_\gamma < 200 \text{ GeV}$	1.32	-0.51 -0.45 -0.24
	≥ 2 -jet, $m_j \geq 1500$ GeV, $p_{\gamma}^{*} < 200$ GeV	1.19	-0.42 (-0.38 -0.17
	\geq 2-jet, $m_j \geq$ 350 GeV, $p_{\gamma} \geq$ 200 GeV	1.54	-0.51 (-0.46 '-0.22
	0-jet, <i>p</i> ^{<i>H</i>} ₇ < 10 GeV	0.93	+0.36 (+0.30 ,+0.19 -0.30 (-0.27 ,-0.13
	0-jet, $10 \le p_{_T}^{_H} < 200 \text{ GeV}$	1.15	+0.23 (+0.18 ,+0.14 -0.20 (-0.17 ,-0.11
	1-jet, $p_{\tau}^{H} < 60 \text{ GeV}$	0.31	+0.43 (+0.40 +0.16 -0.38 (-0.36 -0.13
$gg \rightarrow H (ZZ^*)$	1-jet, 60 ≤ p_{T}^{H} < 120 GeV	1.42	+0.52 (+0.42 +0.30 -0.42 (-0.38 ,-0.18
	1-jet, 120 ≤ p_{τ}^{H} < 200 GeV	0.41	+0.84 (+0.80 +0.23 -0.59 (-0.58 -0.08
	\geq 2-jet, $p_T^H < 200 \text{ GeV}$	0.35	+0.60 (+0.55 +0.23
	$p_{_{T}}^{\scriptscriptstyle H} \ge 200~{ m GeV}$	2.41	+1.52 (+1.32 +0.75 -1.09 (-1.04 ,-0.31
	VBF	1 49	+0.63 (+0.61 +0.17
	≥2-iet. 60 < m _a < 120 GeV	1.51	+2.83 (+2.79 +0.45
qq→Hqq (ZZ*)	\geq 2-iet. $m_* \geq$ 350 GeV. $p^H \geq$ 200 GeV	0.18	-2.24 \-2.22 '-0.29 +2.09 (+2.08 +0.18
			_ 、_ ·_
VH-lep (ZZ*)	—	1.29	+1.67 (+1.67 , +0.15 -1.05 (-1.05 , -0.01
tīH (ZZ*)	H	1.73	+1.77 (+1.72 +0.39 -1.14 (-1.13 '-0.18

ATLAS			
<i>√s</i> = 13 Te	V, 139 fb ⁻¹	⊢● ⊣Total	Stat.
$m_{H} = 125.0$	09 GeV, y _µ < 2.5	Syst.	SM
			Total Stat. Syst.
			+0.27 (+0.12)
	0 -jet, $p_{\tau}^{2} < 10 \text{ GeV}$	0.6	$6 \begin{array}{c} 10.27 \\ -0.26 \end{array} (\pm 0.24 \\ -0.09 \end{array})$
	0-jet, $10 \le p_T^n < 200 \text{ GeV}$	1.24	$4 \begin{array}{c} +0.16 \\ -0.17 \end{array} (\pm 0.15 \\ -0.08 \end{array})$
	1-jet, $\rho_{T}^{\prime\prime} < 60 \text{ GeV}$	1.10	$6 \begin{array}{c} +0.39 \\ -0.38 \end{array} \left(\pm 0.36 \begin{array}{c} +0.13 \\ -0.11 \end{array} \right)$
	1-jet, 60 ≤ p_{τ}^{H} < 120 GeV	1.14	$4 \begin{array}{c} +0.40 \\ -0.36 \end{array} \left(\pm 0.33 \begin{array}{c} +0.22 \\ -0.15 \end{array} \right)$
a → Η (γγ)	1-jet, $120 \le p_{T}^{H} < 200 \text{ GeV}$	0.9	$3 \begin{array}{c} +0.57 \\ -0.53 \end{array} \begin{pmatrix} +0.53 \\ -0.52 \end{array} , \begin{array}{c} +0.20 \\ -0.52 \end{array} \end{pmatrix}$
9 (11)	≥2-jet, m_{jj} < 350 GeV, p_{T}^{H} < 120 GeV	0.5	$8 \begin{array}{c} +0.56 \\ -0.54 \end{array} \begin{pmatrix} +0.53 \\ -0.52 \end{array}, \begin{array}{c} +0.19 \\ -0.14 \end{array} \end{pmatrix}$
	\geq 2-jet, m_{jj} < 350 GeV, 120 $\leq p_{\tau}^{H}$ < 200 GeV	1.3	$1 \begin{array}{c} +0.50 \\ -0.48 \end{array} \begin{pmatrix} +0.48 \\ -0.47 \end{array} , \begin{array}{c} +0.15 \\ -0.09 \end{array} \end{pmatrix}$
	≥ 2-jet, m_{jj} ≥ 350 GeV, p_{T}^{H} < 200 GeV	1.0	9 $\pm 0.95 \left(\begin{smallmatrix} +0.91 \\ -0.89 \end{smallmatrix}, \begin{smallmatrix} +0.30 \\ -0.34 \end{smallmatrix} \right)$
	$200 \le p_T^H < 300 \text{ GeV}$	1.5	$6 \begin{array}{c} +0.45 \\ -0.41 \end{array} \begin{pmatrix} +0.41 \\ -0.39 \end{array} , \begin{array}{c} +0.18 \\ -0.13 \end{array} \end{pmatrix}$
	$300 \le p_T^H < 450 \text{ GeV}$	0.1	7 $^{+0.56}_{-0.49}$ $\begin{pmatrix} +0.54 \\ -0.47 \end{pmatrix}$ $\begin{pmatrix} +0.14 \\ -0.15 \end{pmatrix}$
	$p_{\tau}^{H} \ge 450 \text{ GeV}$	2.1	$1 \begin{array}{c} {}^{+1.47}_{-1.18} \left({}^{+1.42}_{-1.15} {}^{+0.41}_{-0.23} \right) \end{array}$
	≤ 1-jet and <i>VH</i> -veto	1.0	$5 \begin{array}{c} +0.96 \\ -0.86 \end{array} \begin{pmatrix} +0.90 \\ -0.84 \end{array} , \begin{array}{c} +0.32 \\ -0.18 \end{pmatrix}$
	≥2-jet, VH-had	0.2	$1 \begin{array}{c} +0.74 \\ -0.63 \end{array} \begin{pmatrix} +0.72 \\ -0.62 \end{array} , \begin{array}{c} +0.14 \\ -0.12 \end{array} \end{pmatrix}$
	\geq 2-jet, 350 \leq m_{j} < 700 GeV, p_{T}^{H} < 200 GeV	1.2	$8 \begin{array}{c} +0.80 \\ -0.60 \end{array} \begin{pmatrix} +0.61 \\ -0.56 \end{array} , \begin{array}{c} +0.51 \\ -0.23 \end{array} \end{pmatrix}$
lq →Hqq (γγ)	≥ 2-jet, 700 ≤ m_j < 1000 GeV, p_T'' < 200 GeV	1.4	7 $^{+0.84}_{-0.68}$ $\begin{pmatrix} +0.72 \\ -0.64 \end{pmatrix}$ $\begin{pmatrix} +0.43 \\ -0.23 \end{pmatrix}$
	\geq 2-jet, $m_{jj} \geq$ 1000 GeV, $p_T^H <$ 200 GeV	1.3	1 $^{+0.46}_{-0.38}$ $\begin{pmatrix} +0.36 \\ -0.33 \end{pmatrix}$ $, +0.29 \\ -0.20 \end{pmatrix}$
	\geq 2-jet, 350 \leq m_{ij} < 1000 GeV, $\rho_{\tau}^{\prime\prime} \geq$ 200 GeV	0.3	$1 \begin{array}{c} {}^{+0.74}_{-0.61} \left({}^{+0.73}_{-0.59} \begin{array}{c} {}^{+0.13}_{-0.11} \right) \end{array} \right)$
	\geq 2-jet, $m_{jj} \geq$ 1000 GeV, $p_{T}^{\prime\prime} \geq$ 200 GeV	1.6	9 $^{+0.67}_{-0.57}$ $\begin{pmatrix} +0.61 \\ -0.52 \end{pmatrix}$ $, \frac{+0.28}{-0.23}$
	<i>p</i> ^{<i>ν</i>} _{<i>r</i>} < 150 GeV	1.7	$5 \begin{array}{c} +0.82 \\ 0.72 \end{array} \begin{pmatrix} +0.80 \\ 0.72 \end{array} , \begin{array}{c} +0.16 \\ 0.09 \end{pmatrix}$
lq →Hlν (γγ)	p ^v ₇ ≥ 150 GeV	1.6	5 +1.12 (+1.11 +0.13) -0.90 (-0.89 ,-0.10)
			-0.30 -0.03 -0.10
ıg/qq→Hll/ vv (γ	$r_{f}^{\nu} \rho_{\tau}^{\nu} < 150 \text{ GeV}$	-0.6	$4 \stackrel{+0.88}{-} \left(\stackrel{+0.87}{-} , \stackrel{+0.13}{-} \right)$
	<i>p</i> ^{<i>ν</i>} _{<i>T</i>} ≥ 150 GeV	0.3	9 $^{+1.10}_{-0.92}$ $\begin{pmatrix} +1.08 \\ -0.91 \end{pmatrix}$ $\begin{pmatrix} +0.21 \\ -0.18 \end{pmatrix}$
	<i>p</i> ^{<i>H</i>} ₇ < 60 GeV →	0.8	3 +0.82 (+0.81 +0.11)
	$60 \le p_{\tau}^{H} < 120 \text{ GeV}$	0.8	1 +0.60 (+0.59 +0.08)
τΗ (γγ)	$120 \le p_{\tau}^{H} < 200 \text{ GeV}$	0.6	5 +0.64 (+0.63 +0.13)
	$200 \le p_{+}^{H} < 300 \text{ GeV}$	1.2	3 + 0.81 (+0.80 + 0.11)
	<i>p</i> ^{<i>H</i>} ≥ 300 GeV	1.1	7 +0.96 (+0.95 +0.16)
			-0.75 \-0.74 '-0.12
Η (γγ)		2.0	$6 {}^{+4.13}_{-3.27} \left({}^{+3.94}_{-3.14} , {}^{+1.22}_{-0.90} \right)$
			5 +0.97 (+0.88 +0.41)
n(= 7)		2.0	-0.93 \-0.87 '-0.33
-8	-6 -4 -2 0 2 4	6	8 10
	σχΒ	normalized	to SM value



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Interpretations in SMEFT



Interpretations in SMEFT

arXiv:2402 05742 ATLAS \sqrt{s} =13 TeV, 139 fb⁻¹ C_{eH,22} 0.9 С_{еН,33} 0.8 С⁽³⁾ На 0.7 C_{bH} 0.6 $e_{
m ggF}^{[1]}$ -0.03 0.5 $e_{
m ggF}^{[2]}$ 0.03 0.99 0.11 0.4 $e_{
m ggF}^{[3]}$ -0.11 0.99 0.3 $e^{[1]}_{H\gamma\gamma,Z\gamma}$ 0.85 0.25 -0.47 -0.02 -0.01 0.2 $e^{[2]}_{H\gamma\gamma,Z\gamma}$ -0.49 0.73 -0.49 -0.02 0.1 $e^{[3]}_{H\gamma\gamma,Z\gamma}$ 0.22 0.64 0.74 0.01 0.02 0 $e_{ZH}^{[1]}$ <u>-0.35 -0.27</u> 0.02 -0.02 -0.01 -0.10.9 $e_{ZH}^{[2]}$ -0.20.87 -0.39 0.19 -0.05 -0.08 -0.06 0.03 0.21 $e_{ZH}^{[3]}$ -0.3<mark>-0.32 -0.34 -0.58 0.66</mark> -0.02 -0.08 -0.06 0.02 $e_{ZH}^{[4]}$ -0.4 0.22 0.08 0.66 0.72 -0.02 -0.03 -0.02 $e_{\mathrm{ttH}}^{[1]}$ -0.50.57 0.46 0.17 0.45 0.27 0.27 0.16 0.16 0.14 0.06 0.05 0.03 0.02 -0.01 -0.6 $e_{
m ttH}^{[2]}$ 0.8 <mark>-0.34 -0.23 -0.29 -0.16 -0.15</mark> -0.05 -0.06 -0.2 -0.11 -0.03 -0.02 -0.01 -0.7 $e_{
m ttH}^{[3]}$ 0.08 -0.15 0.95 -0.13 -0.08 -0.08 -0.03 -0.03 -0.17 -0.04 -0.02 -0.01 -0.01 $e_{
m glob}^{[1]}$ -0.80.64 -0.48 -0.48 0.36 -0.9 $e_{H_{IIII}}^{[1]}$ 0.54 0.54 -0.39 -0.39 0.27 -0.14 -0.13 -1 Cettin Criet Crie Corr Cre Cre Cru Cruy Cruge Co Cr Cre Cro Cert 33 CHOD CHO 640

Relative sign of the W and Z couplings with VBF WH production

arXiv:2402.00426

		arXiv:240		Negative λ_{WZ}	Positive	λ_{WZ}				
Variable	Description	SR ⁻	SR ⁺ _{loose}	SR ⁺ _{tight}	k _{tī}	$0.88 \begin{array}{c} +0.30 \\ -0.35 \\ 1 \begin{array}{c} +0.34 \end{array}$	0.96 +(0.96 + 0.21 - 0.23		
$m_{b\bar{b}}$	Invariant mass of the two <i>b</i> -jets ($b\bar{b}$ system).	\in (105, 145) GeV	\in (105, 145) GeV	$\in (105, 145) \mathrm{GeV}$	k_W	$1.12 \begin{array}{c} +0.34 \\ -0.25 \end{array}$	1.25 + 0.21 + 0.001	0.35		
$\Delta R_{b\bar{b}}$	ΔR between the two <i>b</i> -jets.	< 1.2	< 1.6	< 1.2	k_{Wt}	$0.32 \begin{array}{c} +0.39 \\ -0.13 \end{array}$	0.31^{+0}_{-0}).14		
$p_{ m T}^{bar{b}}$	$p_{\rm T}$ of the $b\bar{b}$ system.	> 250 GeV	$0 \text{ GeV} > 100 \text{ GeV} > 180 \text{ GeV}$ $\mu = \sigma / \sigma_{\text{pred.}}$		$-0.027 {}^{+0.054}_{-0.057}$	$0.9 \ ^{+2}_{-4}$	4.0 4.3			
m_{jj}	Invariant mass of the VBF jets.	-	> 600 GeV	> 1000 GeV		GD-	an+	2D+		
Δy_{jj}	Rapidity separation of the VBF jets.	> 4.4	> 3.0	> 3.0		SR	SR_{loose}^+	SR _{tight}		
m_{top}^{lep}	Invariant mass of the W and either	> 260 GeV	> 260 GeV	> 260 GeV	$t\bar{t}$	42 ± 19	172 ± 35	15.0 ± 5.8		
top	<i>b</i> -jet that is closest to 172.7 GeV.				W+jets	26 ± 13	84 ± 32	14.1 ± 7.6		
$\xi_{Wb\bar{b}}$	$\frac{ y_{Wb\bar{b}} - y_{jj} }{\Delta y_{jj}}$, where $y_{Wb\bar{b}}$ (y_{jj}) is the	< 0.3	< 0.3	< 0.3	Wt	4.6 ± 7.0	8 ± 13	0.8 ± 1.5		
	rapidity of the <i>Wbb</i> (VBF-jet) system.				Other background	5.4 ± 1.6	16.2 ± 4.2	3.0 ± 1.5		
$\Delta \phi(W h \bar{h}, i i)$	Azimuthal separation between the		_	> 2.7						
$\Delta \varphi(i, vv, jj)$	$Wb\bar{b}$ system and the VBF-jet system.				Total background	77.7 ± 8.6	279 ± 15	32.9 ± 5.8		
N veto	Number of nontagged, non-VBF jets		z 1	- 0	VBF WH, pre-fit	285 ± 45	4.15 ± 0.56	2.30 ± 0.62		
¹ v jets	with $p_{\rm T} > 25 \text{GeV}$ and $ \eta < 2.5$.	_	≤ 1	= 0	VBF WH, post-fit	-8 ± 17	4 ± 17	2.2 ± 9.8		
					Data	70	274	37		

Relative sign of the W and Z couplings with VBF WH production

Negative λ_{WZ}

Uncertainty source	$\Delta \mu$
$t\bar{t}$ modelling	± 0.033
Jet energy resolution	± 0.017
Wt modelling	± 0.013
Jet energy scale	± 0.011
Signal modelling	± 0.007
W+jets modelling	± 0.006
MC statistical uncertainty	± 0.005
Jet vertex tagging	± 0.003
Flavor tagging	± 0.002
$E_{\rm T}^{\rm miss}$ scale and trigger efficiency	± 0.001
Luminosity and pileup reweighting	± 0.001
Other background modelling	± 0.001
Lepton scale and efficiency	< 0.001
Total systematic	± 0.045
Normalization factors	± 0.016
Total statistical	± 0.032
Total uncertainty	± 0.055

Positive λ_{WZ}

Uncertainty source	$\Delta \mu$
W+jets modelling	±1.9
$t\bar{t}$ modelling	± 1.8
Jet energy resolution	±1.3
Jet energy scale	± 0.8
MC statistical uncertainty	± 0.8
Other background modelling	± 0.5
Signal modelling	± 0.4
Wt modelling	± 0.3
$E_{\rm T}^{\rm miss}$ scale and trigger efficiency	± 0.3
Flavor tagging	± 0.1
Luminosity and pileup reweighting	± 0.1
Jet vertex tagging	± 0.1
Lepton scale and efficiency	< 0.1
Total systematic	± 3.3
Normalization factors	±1.4
Total statistical	±2.5
Total uncertainty	±4.1

arXiv:2402.00426

Boosted VH production in fully hadronic *qqbb* **final states**

Uncertainty source	$\delta \mu$
Signal modeling	$^{+0.10}_{-0.02}$
MC statistical uncertainty	$^{+0.13}_{-0.13}$
Instrumental (pileup, luminosity)	$^{+0.012}_{-0.004}$
Large- R jet	$^{+0.13}_{-0.14}$
Top-quark modeling	$^{+0.14}_{-0.15}$
Other theory modeling	$^{+0.05}_{-0.03}$
$H \to b \bar{b}$ tagging	$^{+0.52}_{-0.23}$
Multijet estimate (TF uncertainty)	$^{+0.52}_{-0.41}$
Multijet modeling (TF vs. BDT)	$^{+0.14}_{-0.18}$
Total systematic uncertainty	$^{+0.80}_{-0.61}$
Signal statistical uncertainty	$+0.60 \\ -0.60$
Z+jets normalization	$^{+0.42}_{-0.20}$
Total statistical uncertainty	$^{+0.63}_{-0.63}$
Total uncertainty	$^{+1.02}_{-0.88}$



Cross-section at 13.6 TeV with $H \rightarrow ZZ$ and $H \rightarrow \gamma\gamma$

- Inclusive Higgs boson production measured in $\gamma\gamma$ and $ZZ^* \rightarrow 4\ell$ channels using 31.4 fb⁻¹ and 29 fb⁻¹ of data from Run 3 pp collisions.
- Fiducial cross-sections measurements extracted via fit to recontructed invariant mass spectra.
- Individual measurements are extrapolated to full phase space and combined. First ATLAS Higgs production cross section measurement in Run 3, compatible with SM prediction of 59.9 ± 2.6 pb.

 $\sigma(pp \rightarrow H) = 58.2 \pm 7.5 \text{ (stat.)} \pm 4.2 \text{ (syst.) pb}$



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	$ au_e au_\mu$	$rac{ au_{ m lep} au_{ m had}}{e au_{ m had}} \hspace{1.5cm} \mu au_{ m had}$	$ au_{ m had} au_{ m had}$			
Preselection Object counting	# of $e = 1$, # of $\mu = 1$, # of $\tau_{\text{had-vis}} = 0$	# of $e/\mu = 1$, # of $\tau_{\text{had-vis}} = 1$	# of $e/\mu = 0$, # of $\tau_{\text{had-vis}} = 2$			
p_{T} cut	e/μ : $p_{\rm T}$ cut 10 GeV to 27.3 GeV	e/μ : $p_{\rm T}$ cut 21 GeV to 27.3 GeV, $ au_{\rm had\text{-}vis}$: $p_{\rm T} > 30 {\rm GeV}$	$\tau_{\rm had\text{-}vis}\text{:}~p_{\rm T}>40,\!\!30{\rm GeV}$			
ID, Isolation, and <i>e</i> -veto	e/μ : Medium e : Loose, μ : Tight	e/μ : Medium, $\tau_{had-vis}$: Medium e : Loose, μ : Tight 1-prong $\tau_{had-vis}$: eleBDT e -veto	$\tau_{\rm had\text{-}vis}$: Medium			
Charge product	Opposite charge	Opposite charge	Opposite charge			
Kinematics	$\begin{array}{l} m_{\tau\tau}^{\rm coll} > m_Z - 25 {\rm GeV} \\ 30 < m_{e\mu} < 100 {\rm GeV} \end{array}$	$m_{\rm T} < 70 {\rm GeV}$				
<i>b</i> -veto	# of b -jets = 0 DL1r 85% WP	# of b -jets = 0 DL1r 85% WP	# of b-jets = 0 DL1r 70% WP not applied in tt(0L) $H \rightarrow \tau_{had} \tau_{had}$			
$E_{\mathrm{T}}^{\mathrm{miss}}$	$E_{\rm T}^{\rm miss} > 20 {\rm GeV}$	$E_{\rm T}^{\rm miss} > 20 {\rm GeV}$	$E_{\mathrm{T}}^{\mathrm{miss}} > 20\mathrm{GeV}$			
Leading jet	$p_{\rm T} > 40 {\rm GeV}$	$p_{\rm T} > 40 {\rm GeV}$	$p_{\rm T} > 70 {\rm GeV}, \ \eta < 3.2$			
Angular	$\Delta R_{e\mu} < 2.0, \Delta \eta_{e\mu} < 1.5$	$\Delta R_{\ell\tau_{\rm had-vis}} < 2.5, \Delta\eta_{\ell\tau_{\rm had-vis}} < 1.5$	$\begin{array}{l} 0.6 < \Delta R_{\tau_{\mathrm{had-vis}}\tau_{\mathrm{had-vis}}} < 2.5 \\ \Delta \eta_{\tau_{\mathrm{had-vis}}}\tau_{\mathrm{had-vis}} < 1.5 \end{array}$			
Coll. app. x_1/x_2	$0.1 < x_1 < 1.0, 0.1 < x_2 < 1.0$	$0.1 < x_1 < 1.4, 0.1 < x_2 < 1.2$	$0.1 < x_1 < 1.4, 0.1 < x_2 < 1.4$			



VBF inclusive	sub-leading jet $p_{\rm T} > 30 {\rm GeV}$ $m_{jj} > 350 {\rm GeV}, \ \Delta \eta_{jj} > 3$ $\eta(j_0) \times \eta(j_1) < 0$ lepton centrality: visible decay products of the τ leptons between VBF jets
VH inclusive	$60{\rm GeV} < m_{jj} < 120{\rm GeV}$ sub-leading jet $p_{\rm T} > 30{\rm GeV}$
${ m tt}(0\ell)H o au_{ m had} au_{ m had}$	# of jets ≥ 6 and # of <i>b</i> -jets ≥ 1 or # of jets ≥ 5 and # of <i>b</i> -jets ≥ 2
Boost inclusive	Not VBF inclusive Not VH inclusive $p_{\rm T}(H) > 100 {\rm GeV}$



	Variable	VBF	ttH multiclass
Jet properties	Invariant mass of the two leading jets $p_{T}(jj)$ Product of η of the two leading jets Sub-leading jet p_{T} η of the 5 leading jets Scalar sum of all jets p_{T} Scalar sum of all <i>b</i> -tagged jets p_{T} Best <i>W</i> -candidate dijet invariant mass Best <i>t</i> -quark-candidate three-jet invariant mass	• • •	• • • •
Angular distances	$\begin{array}{l} \Delta\phi \text{ between the two leading jets} \\ \Delta\eta \text{ between the two leading jets} \\ \text{Minimum } \Delta R \text{ between two jets} \\ \text{Minimum } \Delta R \text{ between a } b\text{-tagged jet and a } \tau_{\text{had-vis}} \\ \Delta\eta(\tau,\tau) \\ \Delta R(\tau,\tau) \end{array}$	•	• • • •
au prop.	$p_{\rm T}(\tau \tau)$ Sub-leading $\tau p_{\rm T}$ Leading $\tau \eta$		•
H cand. plus jets system	$p_{\mathrm{T}}(Hjj)$	•	
$ec{E}_{ ext{T}}^{ ext{miss}}$	Missing transverse momentum $E_{\rm T}^{\rm miss}$ Smallest $\Delta \phi \ (\tau, \vec{E}_{\rm T}^{\rm miss})$		•

		ATLAS $\sqrt{s} = 13$	Simula	ation Pr 40 fb ⁻¹ .	eliminary H $\rightarrow \tau \tau$	y																
>	ttH p ^H > 300 Window		1 01 , 1	1010,	29	77	-	16	-	1		Ū	Ū		0.1		03	9.8	77 5		100	5
5	ttH, $p_{+}^{H} \ge 300$, Sideband	F			2.5	92		1.0	· · · ·						0.1		4 1	16.6	70.1			2
50	ttH, 200 $\leq p_{+}^{H} < 300$, Window	-			27	J.L											6.7	85.4	5.4	-	90	2
ate	ttH. 200 $\leq p_{+}^{H} < 300$. Sideband				2.7	3.0							3.4				14.1	66.6	12.9		33	Ē
õ	ttH, p ^H _T < 200, Window	0.3		1.2	0.3		1.4	0.7	0.7								92.1	3.4	-	-	80	2
σ	ttH, p _T ^H < 200, Sideband																93.6	5.6	0.7			-
te	VBF_1, m _{ji} ≥ 1500, p _T ^H ≥ 200	F			2.1	1.7	0.1				0.4	4.0			5.0	86.6				-	70	na
9	VBF_0, m _{ii} ≥ 1500, p _T ^H ≥ 200	F			10.6	7.9	0.6	0.6			0.7	3.5	0.2	0.2	7.2	68.3			-			g
Ħ	$VBF_1, 1000 \le m_{jj} < 1500, p_T^H \ge 200$	100			6.2	2.8	0.3			0.6	4.2	0.2		6.5	73.9	5.2					60	S
US NS	$VBF_0, 1000 \le m_{jj} < 1500, p_T^H \ge 200$				18.4	10.4	1.4	0.6		0.8	3.2	0.2	0.4	7.5	53.1	3.8					00	^o
0	$VBF_1, 700 \le m_{jj} < 1000, p_T^H \ge 200$		0.2		11.8	3.5	0.6		0.7	4.0	0.2		5.5	66.7	6.9				- 1		-	ä
e	VBF_0, 700 \le m _{jj} < 1000, p _T ^H \ge 200	Γ	0.2	0.2	27.3	12.1	1.7	0.8	0.8	3.1	0.2		5.8	42.8	4.4	0.2		0.1	1		50	e
r	$VBF_1, 350 \le m_{jj} < 700, p_T^H \ge 200$	Γ	0.2		18.4	2.0	2.1		7.2	0.5			59.4	10.1					1			Q
	$VBF_0, 350 \le m_{jj} < 700, p_T^H \ge 200$	Γ	0.6	0.5	45.2	8.3	3.2	0.8	3.5	0.3			33.5	3.5	0.2			0.1	1	-	40	Ш
	$VBF_1, m_{jj} \ge 1500, p_T^H < 200$	0.3	0.3		1		3.6				10.0	83.2			0.1	2.3						
	$VBF_0, m_{jj} \ge 1500, p_T^H < 200$	2.4	1.5	0.9	0.8		19.8	0.7	0.4	0.3	11.6	59.5			0.3	1.7	0.1			-	30	
	$VBF_1,1000 \le m_{jj} < 1500,p_T^H < 200$	0.2	0.4		0.4		5.5			13.0	74.3	3.9			2.0	0.2						
	$VBF_0,1000 \le m_{jj} < 1500,p_T^H < 200$	3.1	1.8	1.1	0.7		23.3	0.6	0.5	11.1	52.6	3.5		0.2	1.1	0.1	0.1]	-	20	
	$VBF_1, 700 \le m_{jj} < 1000, p_T^H < 200$	0.6	0.6		0.5		11.2		12.4	67.5	5.3		0.1	1.5	0.3]			
	VBF_0, 700 \le m _{jj} < 1000, p_T^H < 200	4.7	3.1	1.8	1.1		30.3	0.6	10.0	43.2	3.7	0.2	0.1	0.9	0.1		0.2			_	10	
	$VBF_1, 350 \le m_{jj} < 700, p_T^H < 200$	1.1	0.6	0.2	0.6		18.5		72.9	5.1			1.0	0.1								
	VBF_0, $350 \le m_{jj} < 700, p_T^H < 200$	8.3	4.2	3.5	1.0		37.7	0.5	41.8	2.0	0.1		0.6			ĺ	0.1					
	N(jets) p _T (H) [GeV] m _{ii} [GeV]	: ≥ 1 : [60, 120] : [0, 350]	1 [120	≥ 2 , 200] [0, 350]	≥ <mark>0</mark> [200, 300]	≥ 0 [300, ∞[≥ <mark>2</mark> [0, 200] [350, ∞[≥ 2 [60, 120]	[350,700	≥ [0, 2 [700,1000]	2 200] [1000,1500][1500,∞[[350, 700]	≥ [200 [700,1000]	2 , ∞[[1000,1500][1500,∞[[0, 200]	[200, 300]] [300, ∞[
	* (1	9	gluon fu	usion +	$gg \rightarrow Z$	$(\rightarrow qq)$	H V	$(\rightarrow qq)$	Н			VE	BF					ttH				
																	ST	TXS B	Sinning			



STXS measurements in $H \rightarrow \tau \tau$





- Better precision in VBF phase space for higher $p_{\rm T}^H$ and/or m_{jj} due to reduced SM backgrounds.
- VBF cross-sections at lower m_{jj} and $p_{\rm T}^H$ < 200 GeV slightly below SM predition.
- Significant VBF-like ggH (ggH+2 jet production with mjj>350 GeV, pTH<200 GeV) contribution in reconstructed level categories targeting VBF signal.
 - → Anti-correlation in the measurements.





******* ATLAS Preliminary + Data Top √s = 13 TeV, 140 fb⁻¹ Uncertainty Misidentified 400 $H \rightarrow \tau \tau$ H→ττ (×0.93) ■ Others VBF 0 ma > 1000 GeV Z-TT Post-Fit 300 200 100 25 50 75 100 125 150 175 0 200 m^{MMC} [GeV]









STXS measurements in $H \rightarrow \tau \tau$





Top

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STXS measurements in $H \rightarrow \tau \tau$





STXS measurements in $H \rightarrow \tau \tau$

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Searches for rare Higgs boson decays

Phys. Lett. B 812 (2021) 135980





Searches for rare Higgs boson decays



Source of uncertainty		$\mu_{VH(c\bar{c})}$	$\mu_{VW(cq)}$	$\mu_{VZ(c\bar{c})}$	
Total		15.3	0.24	0.48	
Statistical		10.0	0.11	0.32	
Systematic		11.5	0.21	0.36	
Statistical uncertainties					
Signal normalisation		7.8	0.05	0.23	
Other normalisations		5.1	0.09	0.22	
Theoretical and modelling uncertainties					
$VH(\rightarrow c\bar{c})$		2.1	< 0.01	0.01	
Z + jets		7.0	0.05	0.17	
Top quark		3.9	0.13	0.09	
W+ jets		3.0	0.05	0.11	
Diboson		1.0	0.09	0.12	
$VH(\rightarrow b\bar{b})$		0.8	< 0.01	0.01	
Multi-jet		1.0	0.03	0.02	
Simulation samples size		4.2	0.09	0.13	
Experimental uncertainties					
Jets		2.8	0.06	0.13	
Leptons		0.5	0.01	0.01	
$E_{\mathrm{T}}^{\mathrm{miss}}$		0.2	0.01	0.01	
Pile-up and luminosity		0.3	0.01	0.01	
Flavour tagging	<i>c</i> -jets	1.6	0.05	0.16	
	<i>b</i> -jets	1.1	0.01	0.03	
	light-jets	0.4	0.01	0.06	
	au-jets	0.3	0.01	0.04	
Truth-flavour tagging	ΔR correction	3.3	0.03	0.10	
	Residual non-closure	1.7	0.03	0.10	