ATLAS Higgs cross section combination and EFT interpretations

Nicolas Berger (LAPP Annecy)
on behalf of the ATLAS Collaboration

Introduction

Run 2 : focus on increasingly precise measurements of Higgs couplings:

ATLAS Run 1
Eur. Phys. J. C (2016) 76:6

$$\mu = 1.18 \begin{array}{l} +0.15 \\ -0.14 \end{array}$$

ATLAS Run 2 (2018 results)
ATLAS-CONF-2018-031

$$\mu = 1.13 \begin{array}{l} +0.09 \\ -0.08 \end{array}$$

⊕ **Better constraints on BSM models (predict $\lesssim$10% level couplings deviations)**

⊕ **Stronger constraints from now-established subdominant modes:**

ttH, **VH** and **H→bb** now above 5σ for both ATLAS and CMS

⇒ Combination all the more important to obtain best constraints

⊖ **Systematics play increasingly important role**

⇒ Focus on measurement frameworks giving low theory systematics, in particular differential measurements.

Introduction

Run 2 : focus on increasingly precise measurements of Higgs couplings:

ATLAS Run 1
Eur. Phys. J. C (2016) 76:6

$$\mu = 1.18 \pm 0.10\,(\text{stat}) \pm 0.07\,(\text{exp}) \begin{array}{l} +0.08 \\ -0.07 \end{array} (\text{theo})$$

ATLAS Run 2 (2018 results)
ATLAS-CONF-2018-031

$$\mu = 1.13 \pm 0.05\,(\text{stat}) \pm 0.05\,(\text{exp}) \begin{array}{l} +0.06 \\ -0.05 \end{array} (\text{theo})$$

⊕ Better constraints on BSM models (predict $\lesssim$10% level couplings deviations)

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⇒ Focus on measurement frameworks giving low theory systematics, in particular differential measurements.

Input Analyses

☑ [orange] Included results is not the most recent.
☑ [blue] New since last combination.

Analyses mostly using the 2015-2017 (~80 fb^{-1}) or 2015-2016 (~36 fb^{-1}) datasets.

		L (fb^{-1})	ggF	VBF	VH	ttH
H→γγ ATLAS-CONF-2018-028		**80**	☑ [green]	☑ [green]	☑ [green]	☑ [orange]
H→ ZZ*→4l ATLAS-CONF-2018-018		**80**	☑ [orange]	☑ [orange]	☑ [orange]	☑ [orange]
H→WW*→ eνμν PLB 789 (2019) 508		**36**	☑ [green]	☑ [green]	**Not yet included**	☑ [orange]
H→ττ PRD 99 (2019) 072001		**36**	☑ [green]	☑ [green]		☑ [orange]
H→bb JHEP 05 (2019) 141		**80**		☑ [blue]	☑ [blue]	☑ [green]
H→μμ ATLAS-CONF-2018-026	**Not included in all results**	**80**	☑ [orange]	☑ [orange]		
H→invisible PRL 122 (2019) 231801	**Not included in all results**	**24-30**		☑ [blue]	☑ [blue]	
Off-shell H*→ZZ PLB 786 (2018) 223	**Not included in all results**	**36**	**Provides constraint on Γ_H**			

ttH→ leptons
PRD 97 (2018) 072003

ttH→bb
PRD 97 (2018) 072016

VBF H→bb
PRD 98 (2018) 052003

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		L (fb^{-1})	ggF	VBF	VH	ttH
$H \to \gamma\gamma$ ATLAS-CONF-2018-028	STXS	80	✓ (green)	✓ (green)	✓ (green)	✓ (orange)
$H \to ZZ^* \to 4l$ ATLAS-CONF-2018-018	STXS	80	✓ (orange)	✓ (orange)	✓ (orange)	✓ (orange)
$H \to WW^* \to e\nu\mu\nu$ PLB 789 (2019) 508	STXS	36	✓ (green)	✓ (green)	Not yet included	✓ (orange)
$H \to \tau\tau$ PRD 99 (2019) 072001	STXS	36	✓ (green)	✓ (green)		✓ (orange)
$H \to bb$ JHEP 05 (2019) 141	STXS	80		✓ (blue)	✓ (blue)	✓ (green)
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STXS : Higgs signal described in bins of initial-state kinematics, details later

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PRD 98 (2018) 052003

Talk by P. Lenzi yesterday

Talk by G. di Gregorio yesterday

Talk by P. Onyisi yesterday

Talk by P. A Deviveros yesterday

Talk by J. Kretschmar yesrterday

Talk by C. Sander tomorrow

Signal-strength and cross-section measurements

1909.02845

Measurements of μ & production cross-sections

1909.02845

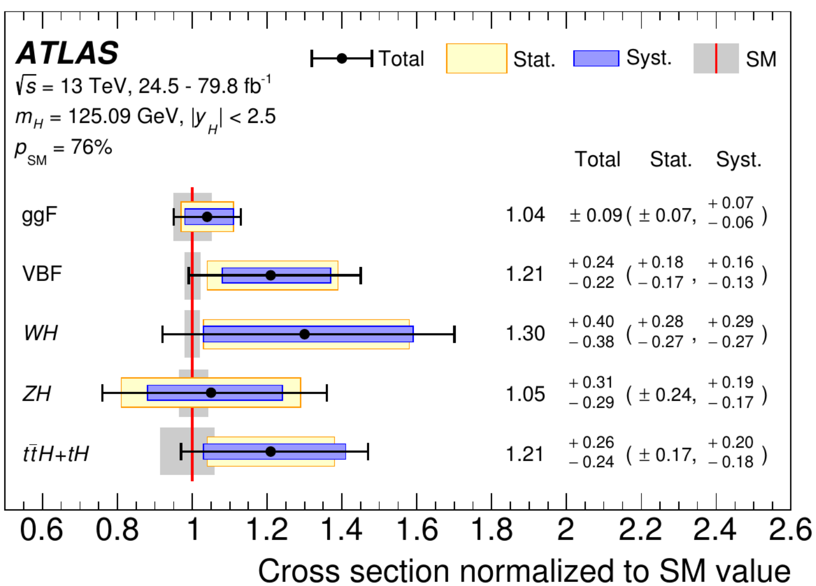
Parameterize all Higgs signal rates using a single **signal strength μ**:

$$\mu = 1.11^{+0.09}_{-0.08} = 1.11 \pm 0.05\,(\text{stat.})\,^{+0.05}_{-0.04}\,(\text{exp.})\,^{+0.05}_{-0.04}\,(\text{sig. th.}) \pm 0.03\,(\text{bkg. th.})$$

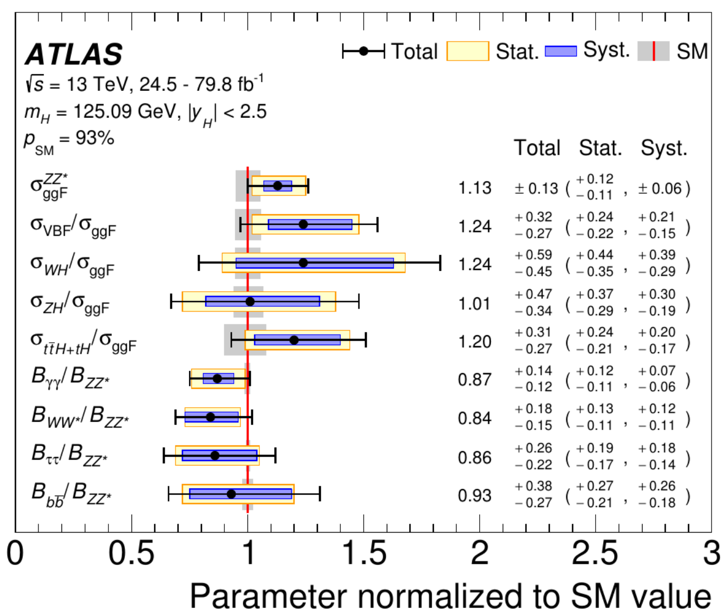
Systematics ~ 1.5 × Stat uncertainty, **Theory systs. ≳ Experimental systs.**

Reduce theory dependence: measure **cross-sections :**

σ_{prod} for main modes, BRs fixed to SM:



Normalize to $\sigma^{ZZ^*}_{ggF}$, measure ratios



Stat ~ Syst, All results in good agreement with the SM

Simplified Template Cross-sections (STXS)

Bin Higgs production in $|y_H| < 2.5$

by **initial state**, **associated jets/W/Z**

+ **kinematics**.

Default modeling for main input analyses

Here use **Stage 1** (YR4, Ch. III.2)

⊕ **Provides differential information**

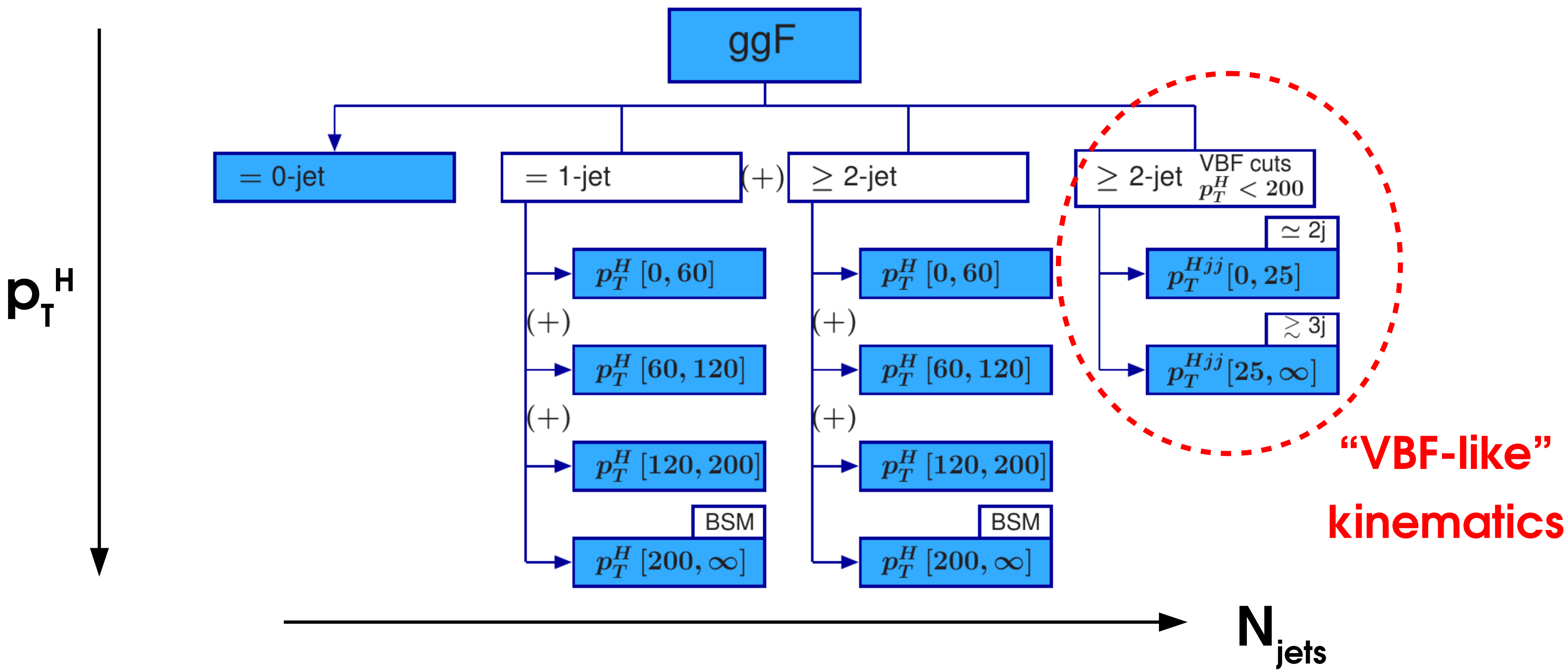
⊕ **Better control over theory uncertainties**

⊕ **Can be measured in all decay modes**

⇒ Suitable for global combinations

⊖ **Not fully fiducial** ⇒ Residual extrapolations

⊖ **No Higgs decay information**



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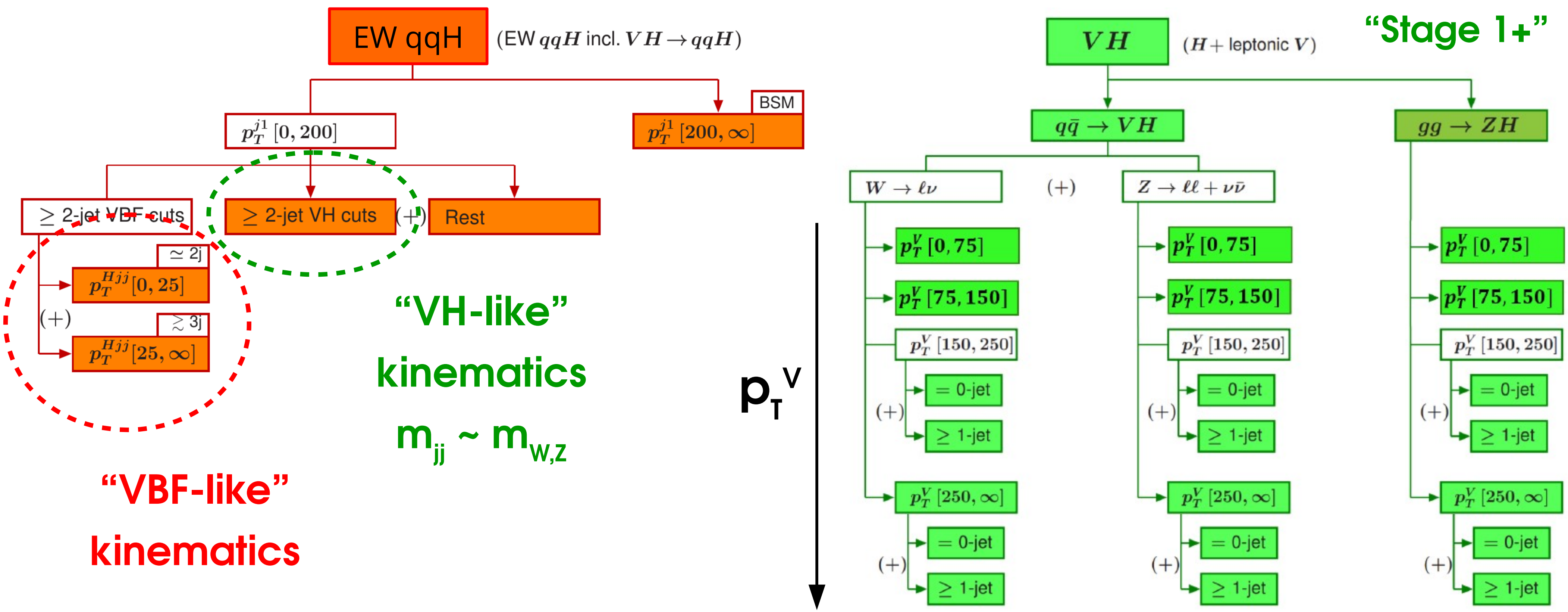

Simplified Template Cross-sections

See ATL-PHYS-PUB-2018-035
and the talk by T. Calvet yesterday

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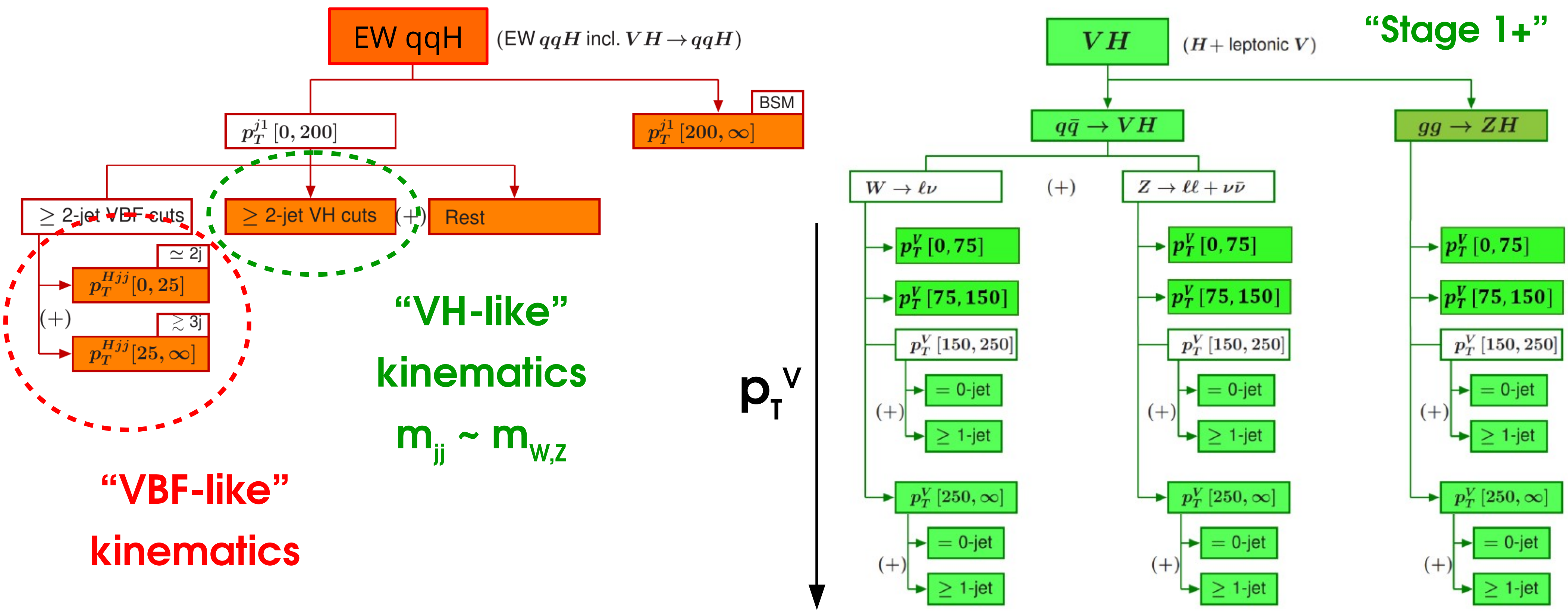
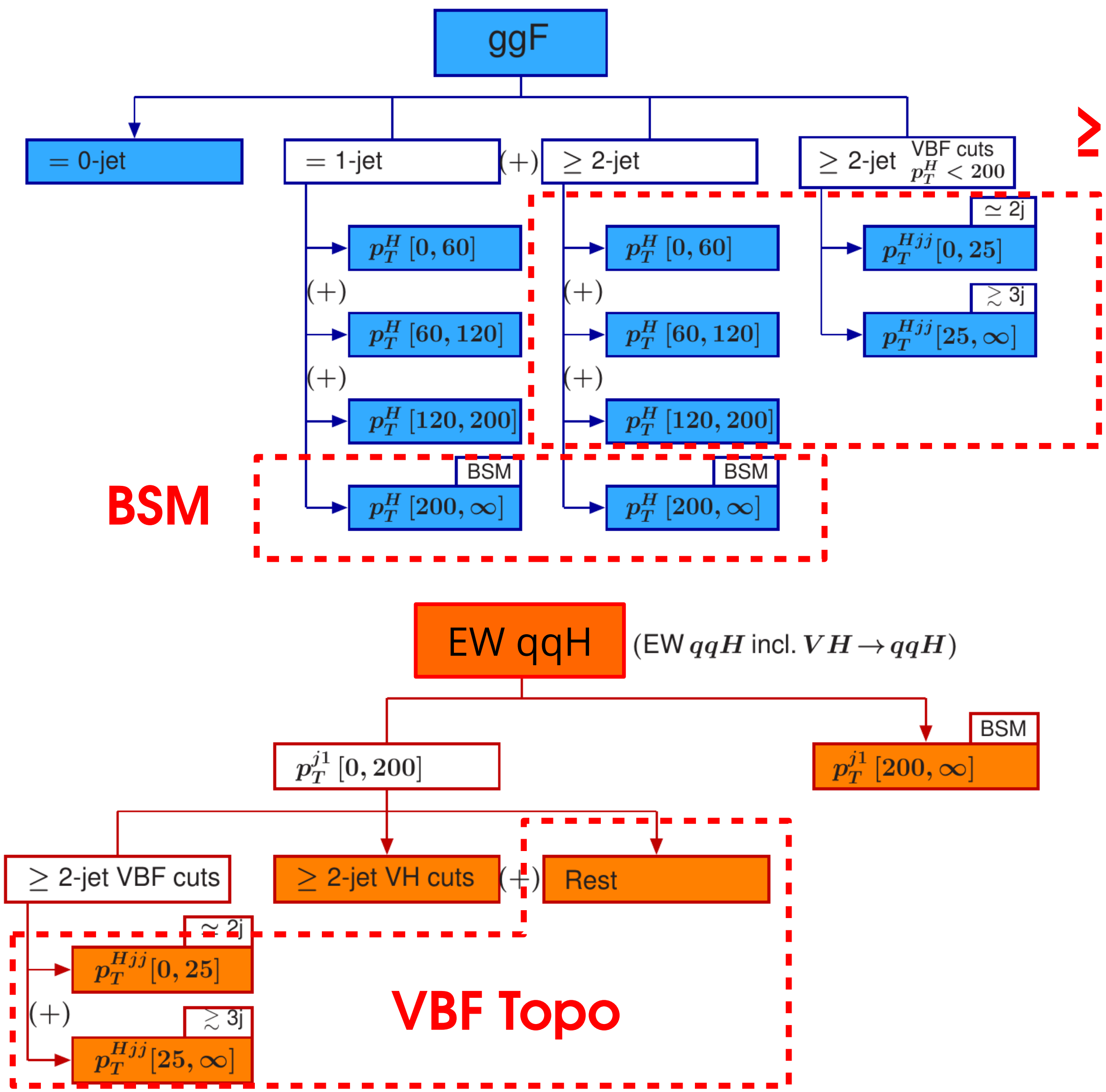
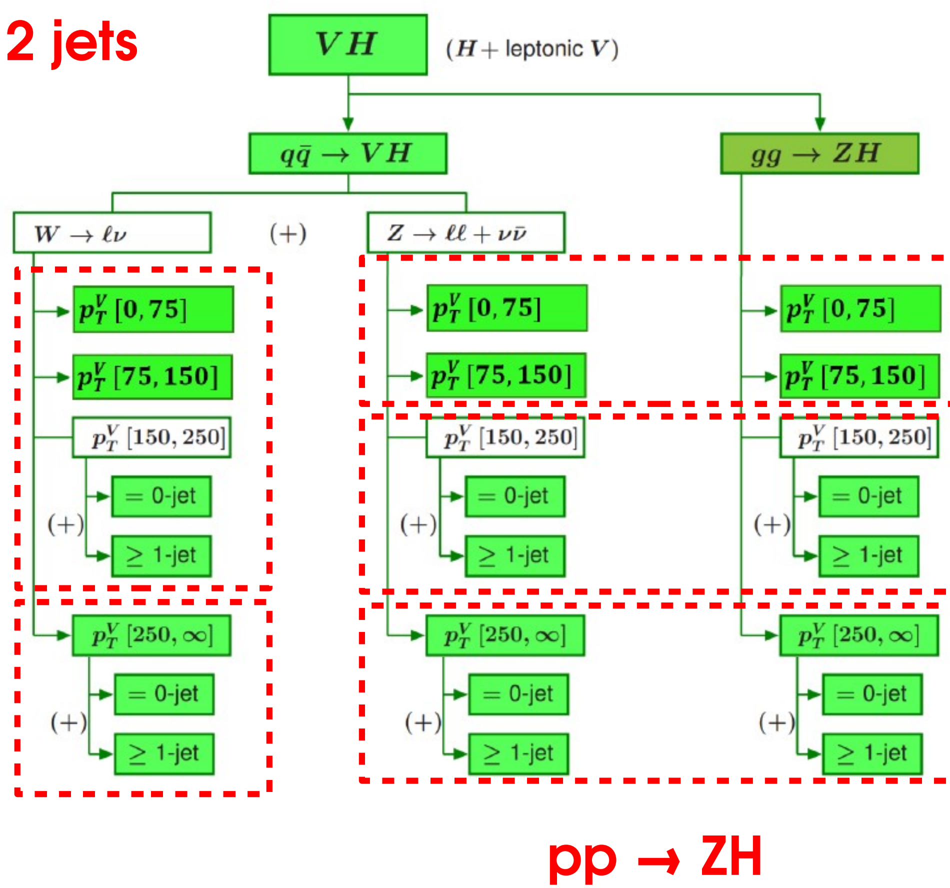


STXS Merging scheme

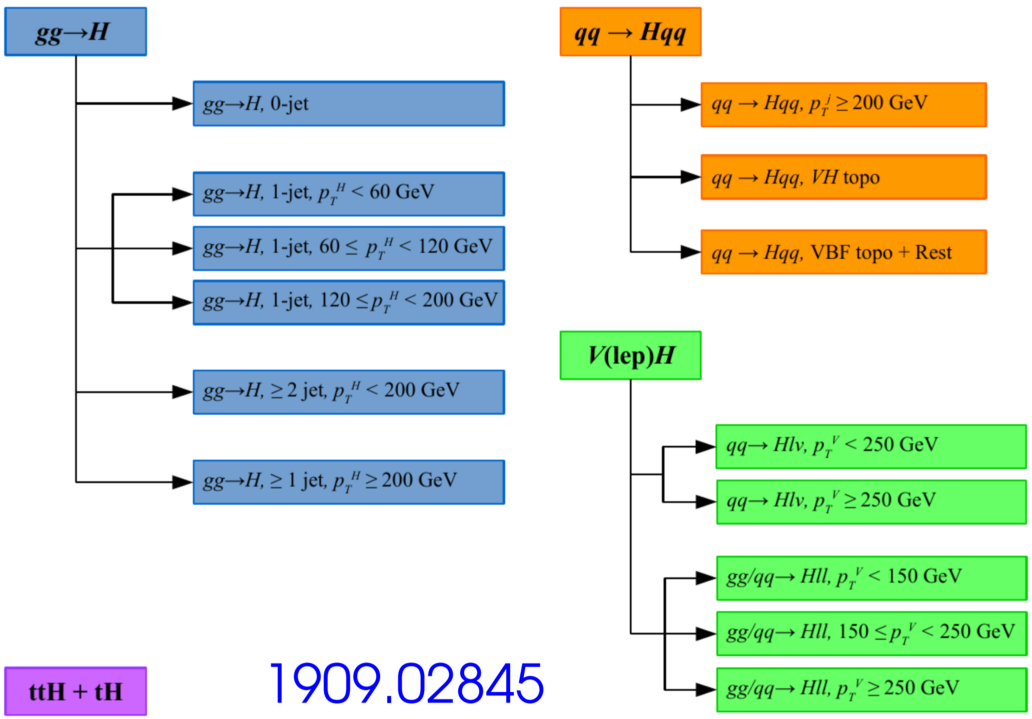
Not (yet) sensitive to all Stage-1 bins ⇒ **merge**

⊖ **Increases model dependence** ⇒ Only for bins with very low sensitivity (rel. unc. > 100%) or large (anti-)correlations





STXS Measurements



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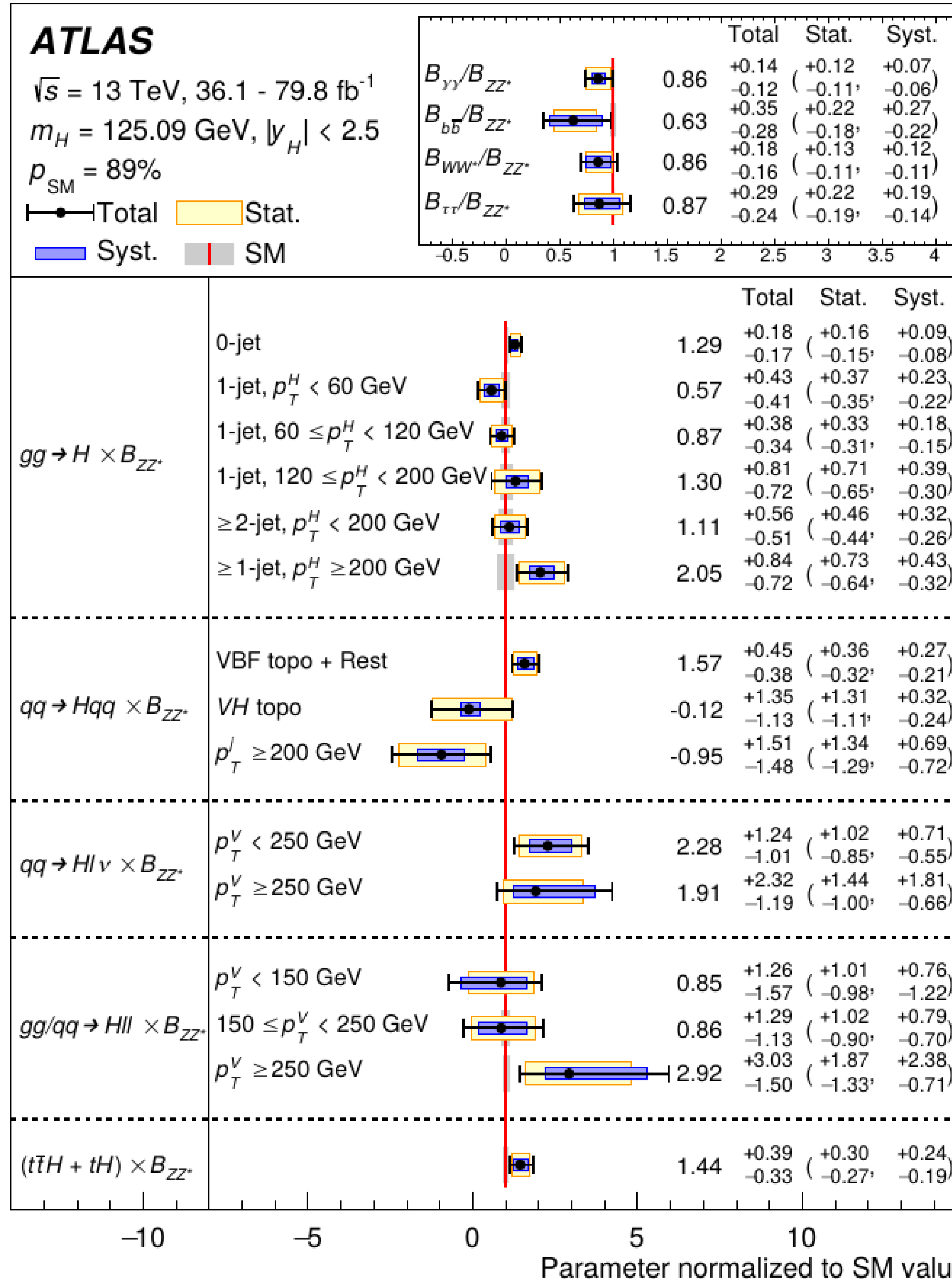


- **Differential measurements in gg→H and pp→VH**

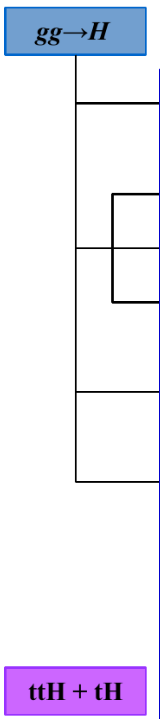
→ Bins at high $p_T^{H,V}$ sensitive to BSM

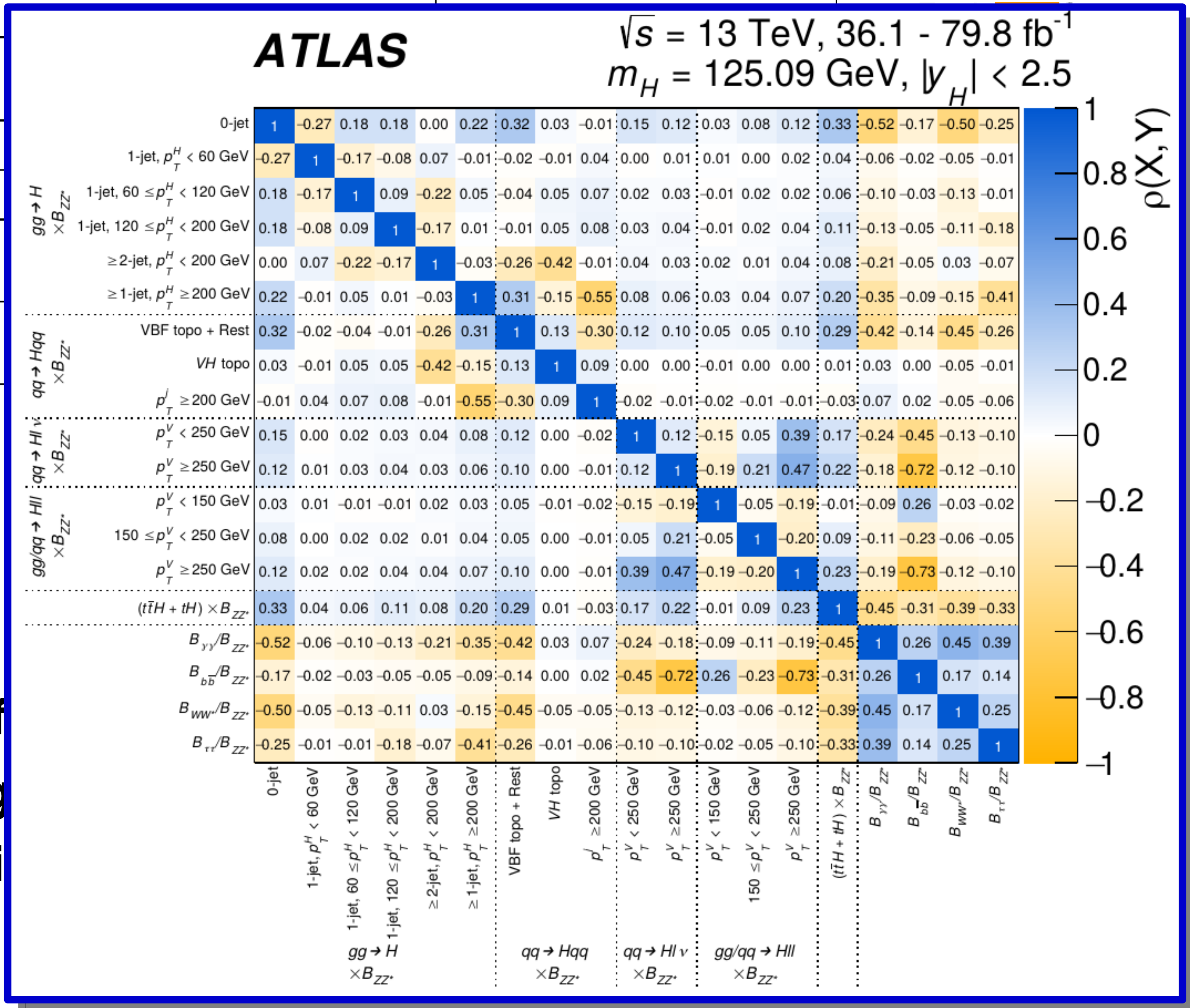
- **Stat unc. > Syst almost everywhere**

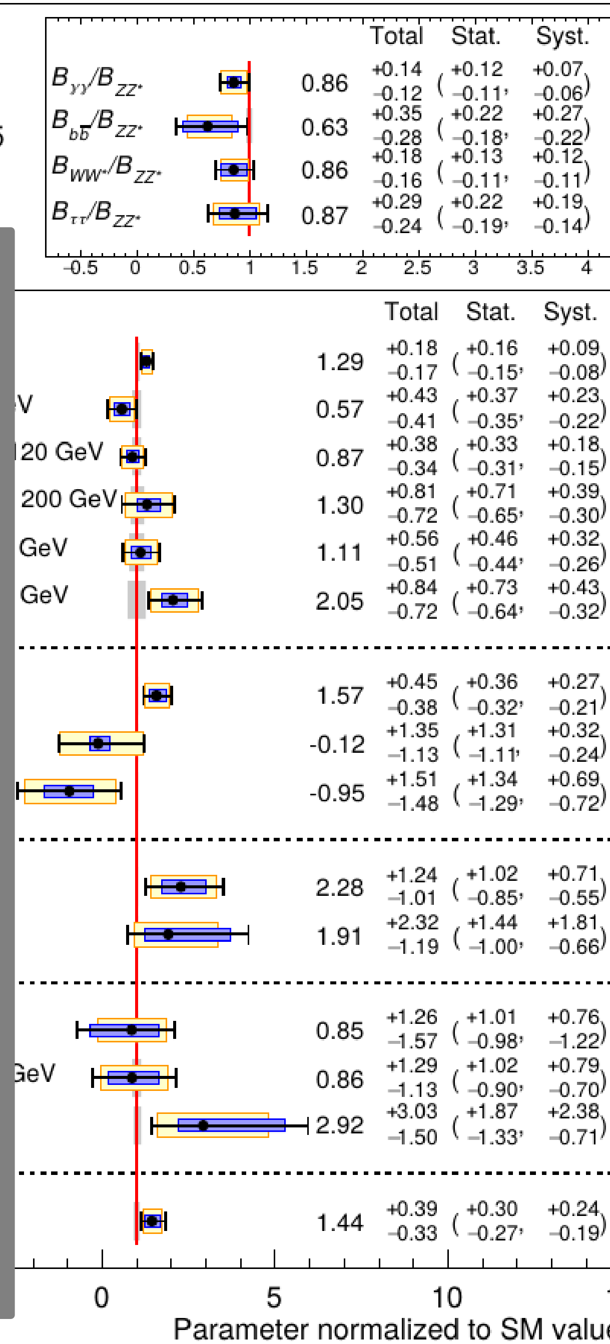
- **Excellent agreement with SM**

Measurements also provided with finer binning for reinterpretations

STXS Measurements







- Dif…

  gg…

  → Bi…

- Stat unc. > Syst almost everywhere

- Excellent agreement with SM

Measurements also provided with finer binning for reinterpretations

STXS Sensitivity per decay channel

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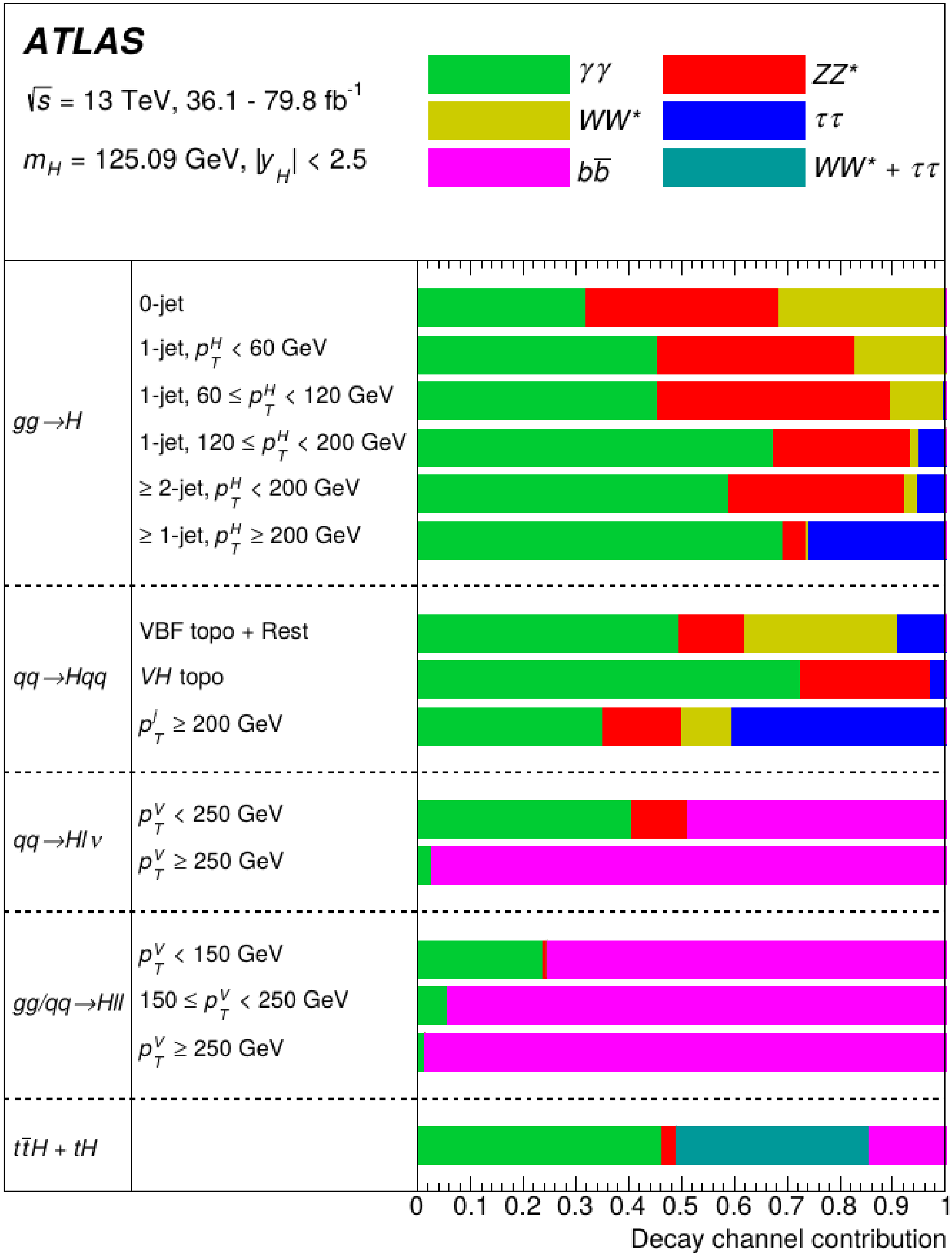


Estimate using "**BLUE weights**"

$$w_i = \frac{1/\sigma_i^2}{\sum_j 1/\sigma_j^2}$$

gg→ H:

- Mainly γγ and ZZ
- WW mainly at low N_{jets}.
- ττ at high p_T^H

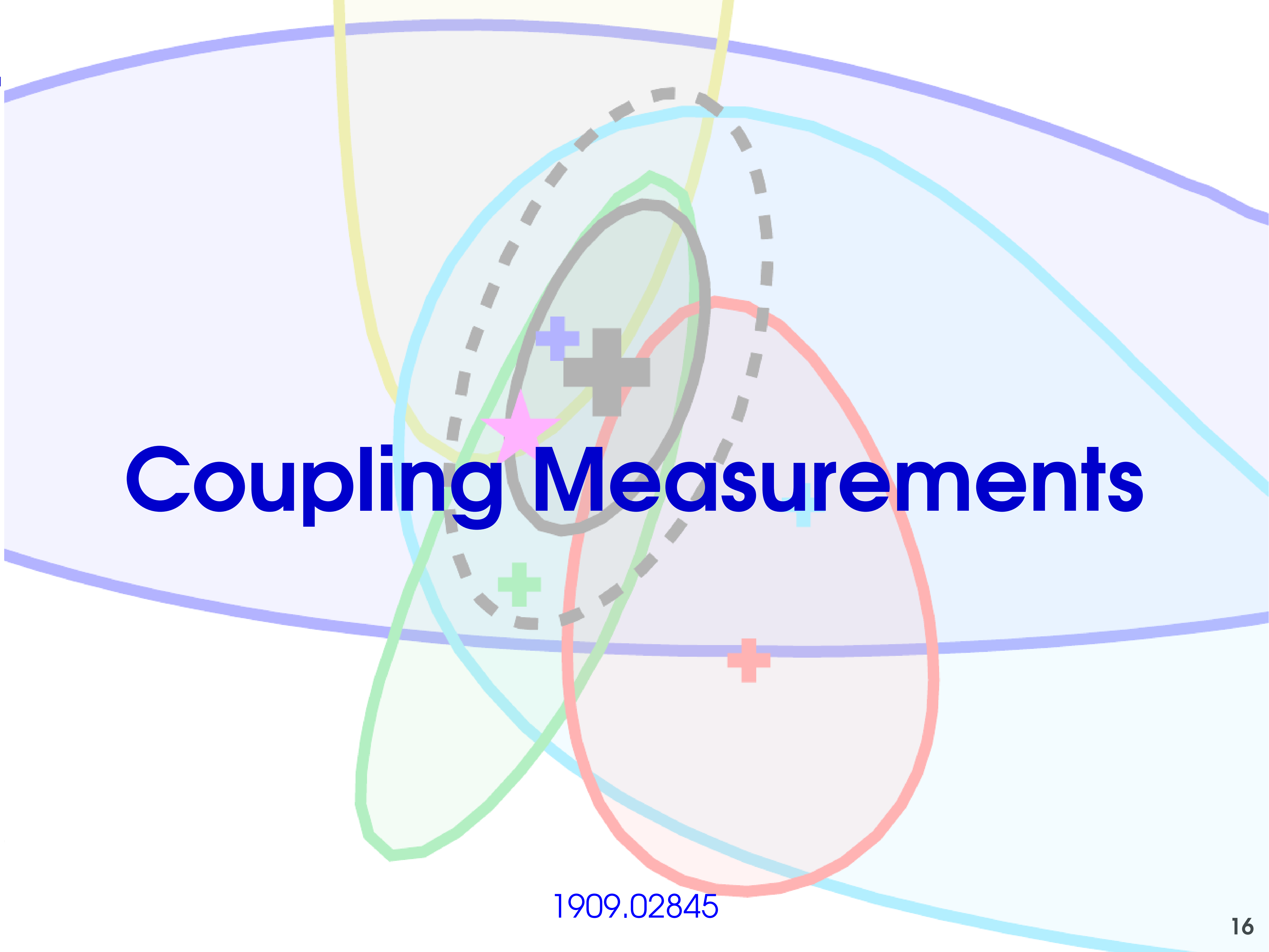
qq→Hqq :

- γγ, WW in VBF-like region
- ττ at high p_T^H

pp→VH: mostly VH→bb

ttH: mostly γγ and multileptons

Coupling Measurements



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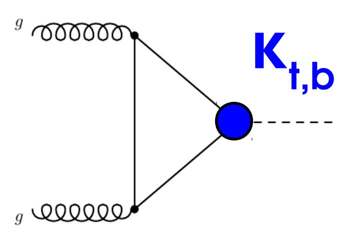
κ framework

Multiplicative coupling corrections, framework based on LO diagrams.

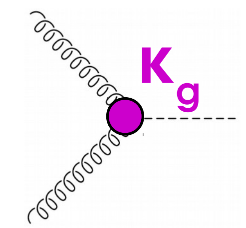
Production	Loops	Interference	Effective modifier	Resolved modifier
$\sigma(\text{ggF})$	✓	t–b	κ_g^2	$1.04\,\kappa_t^2 + 0.002\,\kappa_b^2 - 0.04\,\kappa_t\kappa_b$
$\sigma(\text{VBF})$	-	-	-	$0.73\,\kappa_W^2 + 0.27\,\kappa_Z^2$
$\sigma(qq/qg \to ZH)$	-	-	-	κ_Z^2
$\sigma(gg \to ZH)$	✓	t–Z	$\kappa_{(ggZH)}$	$2.46\,\kappa_Z^2 + 0.46\,\kappa_t^2 - 1.90\,\kappa_Z\kappa_t$
$\sigma(WH)$	-	-	-	κ_W^2
$\sigma(t\bar{t}H)$	-	-	-	κ_t^2
$\sigma(tHW)$	-	t–W	-	$2.91\,\kappa_t^2 + 2.31\,\kappa_W^2 - 4.22\,\kappa_t\kappa_W$
$\sigma(tHq)$	-	t–W	-	$2.63\,\kappa_t^2 + 3.58\,\kappa_W^2 - 5.21\,\kappa_t\kappa_W$
$\sigma(b\bar{b}H)$	-	-	-	κ_b^2
Partial decay width				
Γ^{bb}	-	-	-	κ_b^2
Γ^{WW}	-	-	-	κ_W^2
Γ^{gg}	✓	t–b	κ_g^2	$1.11\,\kappa_t^2 + 0.01\,\kappa_b^2 - 0.12\,\kappa_t\kappa_b$
$\Gamma^{\tau\tau}$	-	-	-	κ_τ^2
Γ^{ZZ}	-	-	-	κ_Z^2
Γ^{cc}	-	-	-	$\kappa_c^2\ (= \kappa_t^2)$
$\Gamma^{\gamma\gamma}$	✓	t–W	κ_γ^2	$1.59\,\kappa_W^2 + 0.07\,\kappa_t^2 - 0.67\,\kappa_W\kappa_t$
$\Gamma^{Z\gamma}$	✓	t–W	$\kappa_{(Z\gamma)}^2$	$1.12\,\kappa_W^2 - 0.12\,\kappa_W\kappa_t$
Γ^{ss}	-	-	-	$\kappa_s^2\ (= \kappa_b^2)$
$\Gamma^{\mu\mu}$	-	-	-	κ_μ^2

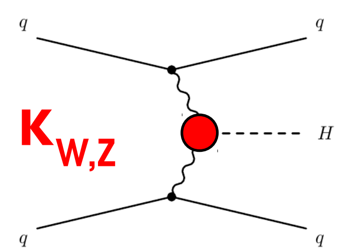
Loop diagrams can be either:

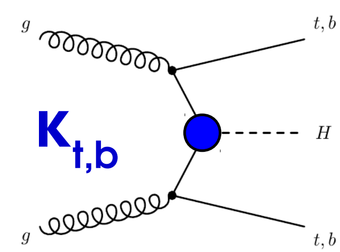
- Resolved to their SM structure, or
- Treated as effective vertices

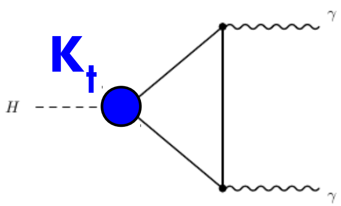


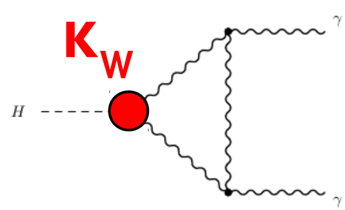
or











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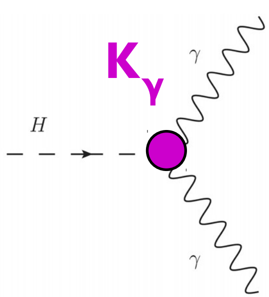
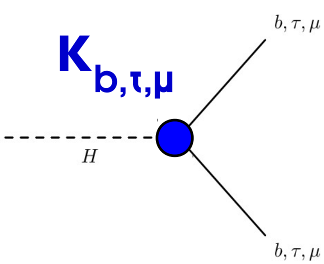




κ measurements with no other BSM effects

Higgs width Γ_H not directly accessible using on-shell measurements

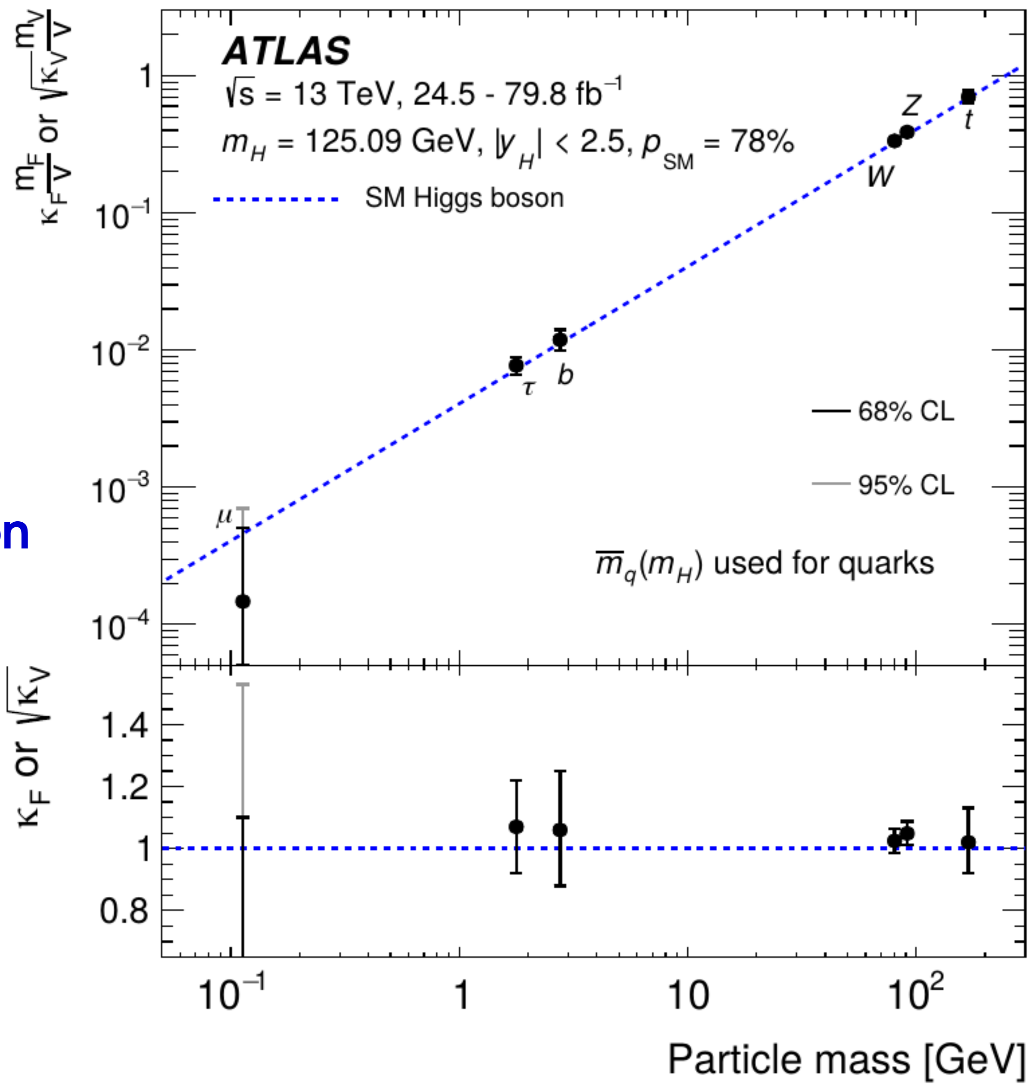
⇒ Propagate effect of κs, assume no other BSM effects.

Assume SM structure for the loops.

Parameter	Result
κ_Z	1.10 ± 0.08
κ_W	1.05 ± 0.08
κ_b	$1.06\ ^{+\ 0.19}_{-\ 0.18}$
κ_t	$1.02\ ^{+\ 0.11}_{-\ 0.10}$
κ_τ	1.07 ± 0.15
κ_μ	< 1.53 at 95% CL

±8% on gauge boson couplings

±10-20% on 3rd generation fermion couplings



H→μμ analysis included to constrain κ_μ.

Excellent agreement with SM

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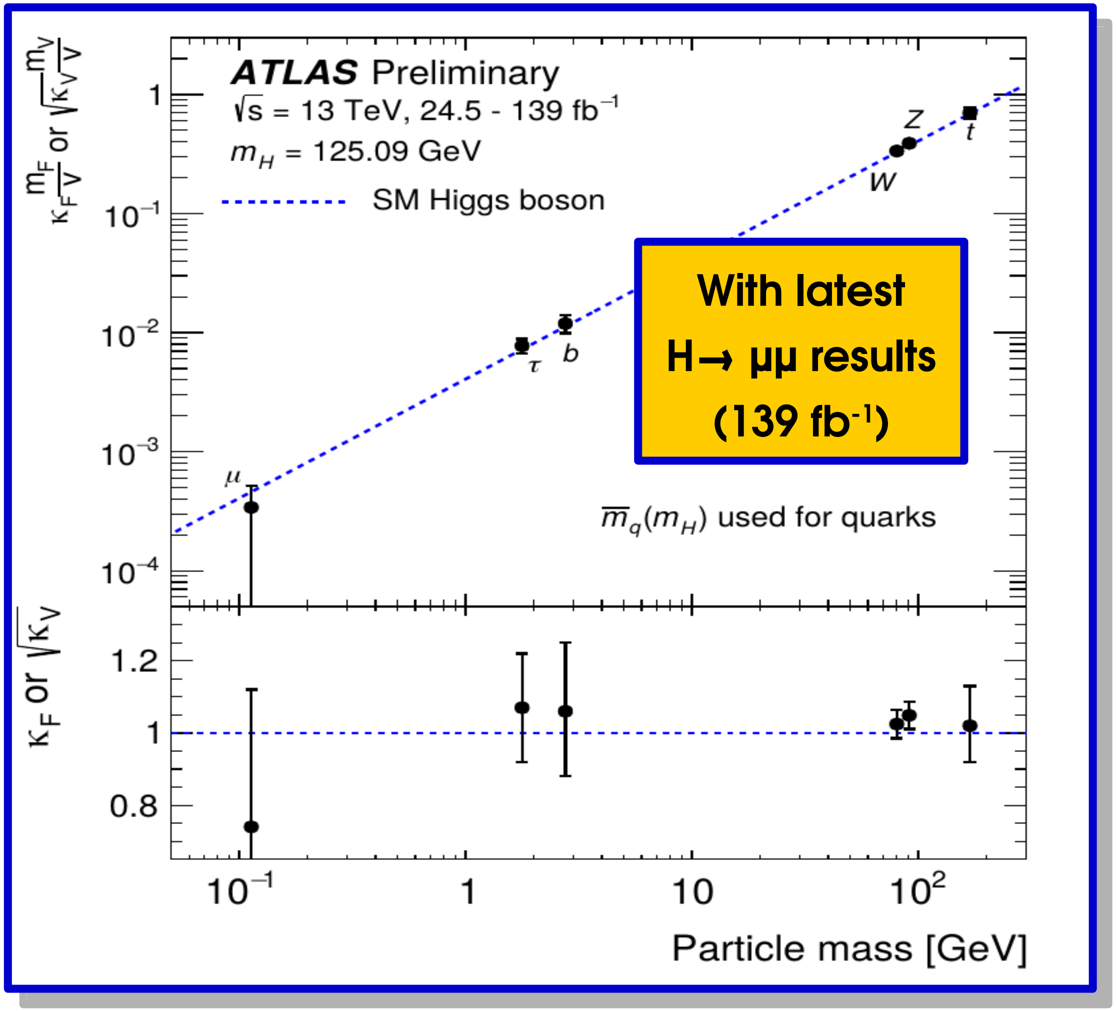
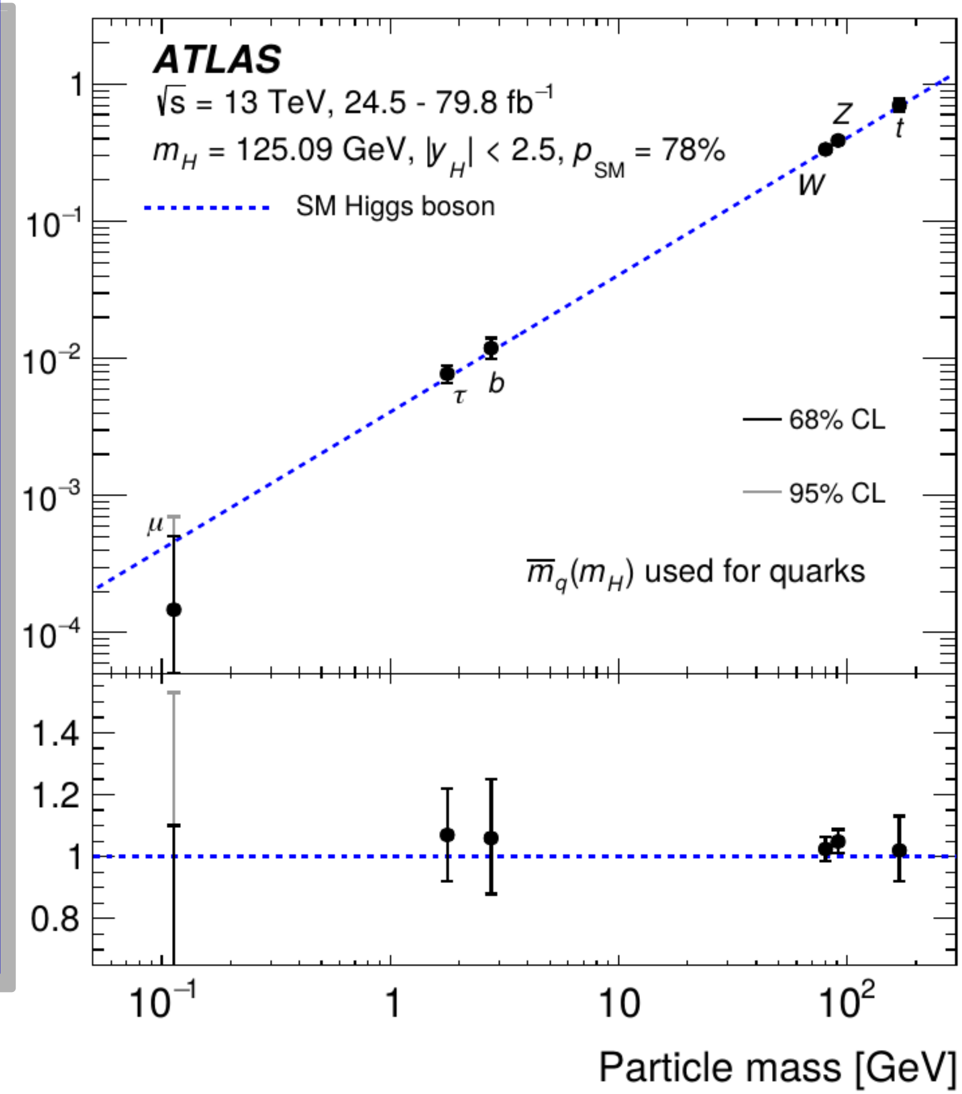


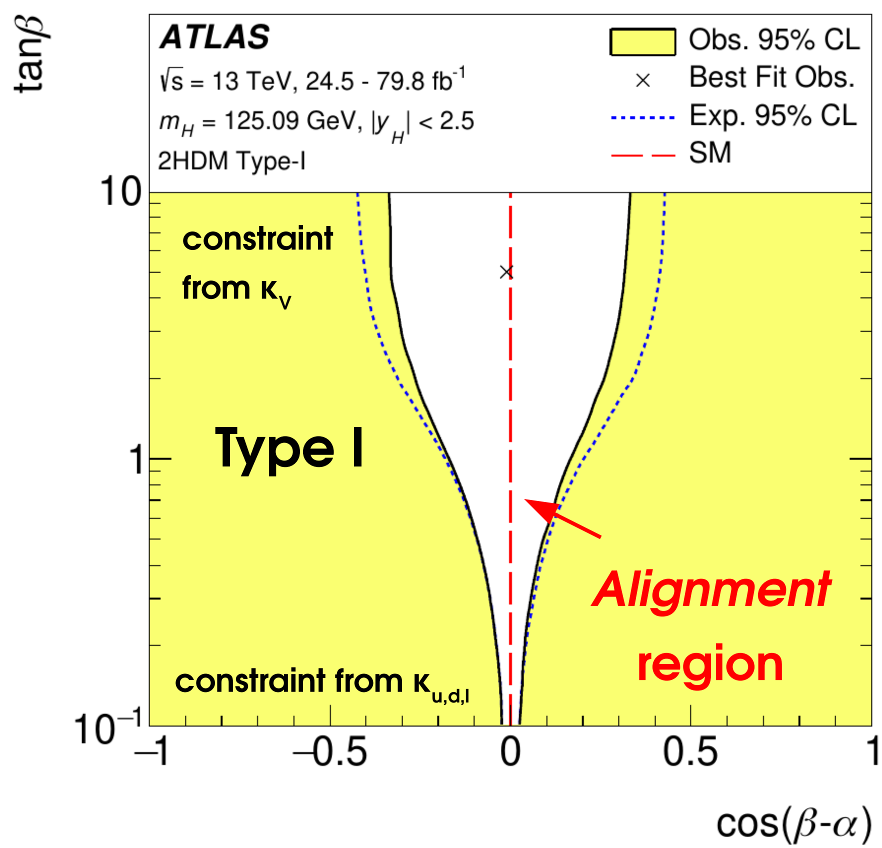


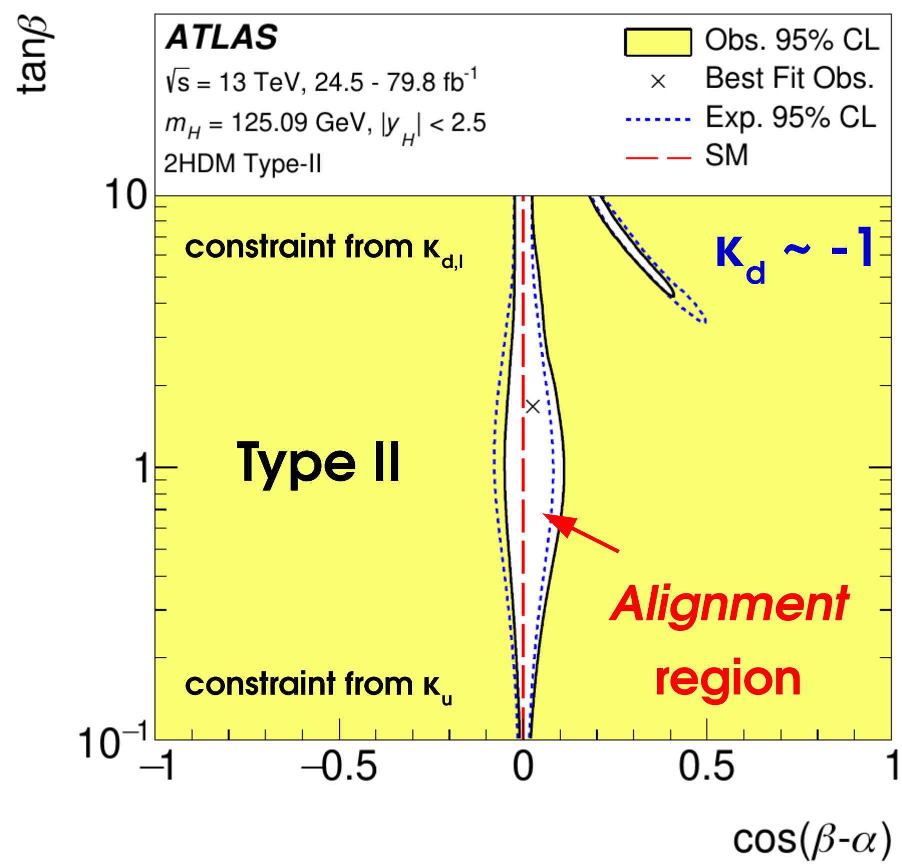
Excellent agreement with SM

BSM interpretations: 2HDM

Reinterpret κ_V, κ_u, κ_d, κ_l measurements in the context of 2HDM models

	Coupling scale factor	Type I	Type II	Lepton-specific	Flipped
Coupling to **W, Z bosons** →	κ_V	$\sin(\beta-\alpha)$			
Coupling to **up-type quarks** →	κ_u	$\cos(\alpha)/\sin(\beta)$			
Coupling to **down-type quarks** →	κ_d	$\cos(\alpha)/\sin(\beta)$	$-\sin(\alpha)/\cos(\beta)$	$\cos(\alpha)/\sin(\beta)$	$-\sin(\alpha)/\cos(\beta)$
Coupling to **leptons** →	κ_ℓ	$\cos(\alpha)/\sin(\beta)$	$-\sin(\alpha)/\cos(\beta)$	$-\sin(\alpha)/\cos(\beta)$	$\cos(\alpha)/\sin(\beta)$





Measurements favor *Alignment* region ⇒ SM-like light h^0 boson

BSM interpretations: hMSSM

$$\kappa_V = \frac{s_d(m_A,\tan\beta)+\tan\beta\; s_u(m_A,\tan\beta)}{\sqrt{1+\tan^2\beta}}$$

$$\kappa_u = s_u(m_A,\tan\beta)\frac{\sqrt{1+\tan^2\beta}}{\tan\beta}$$

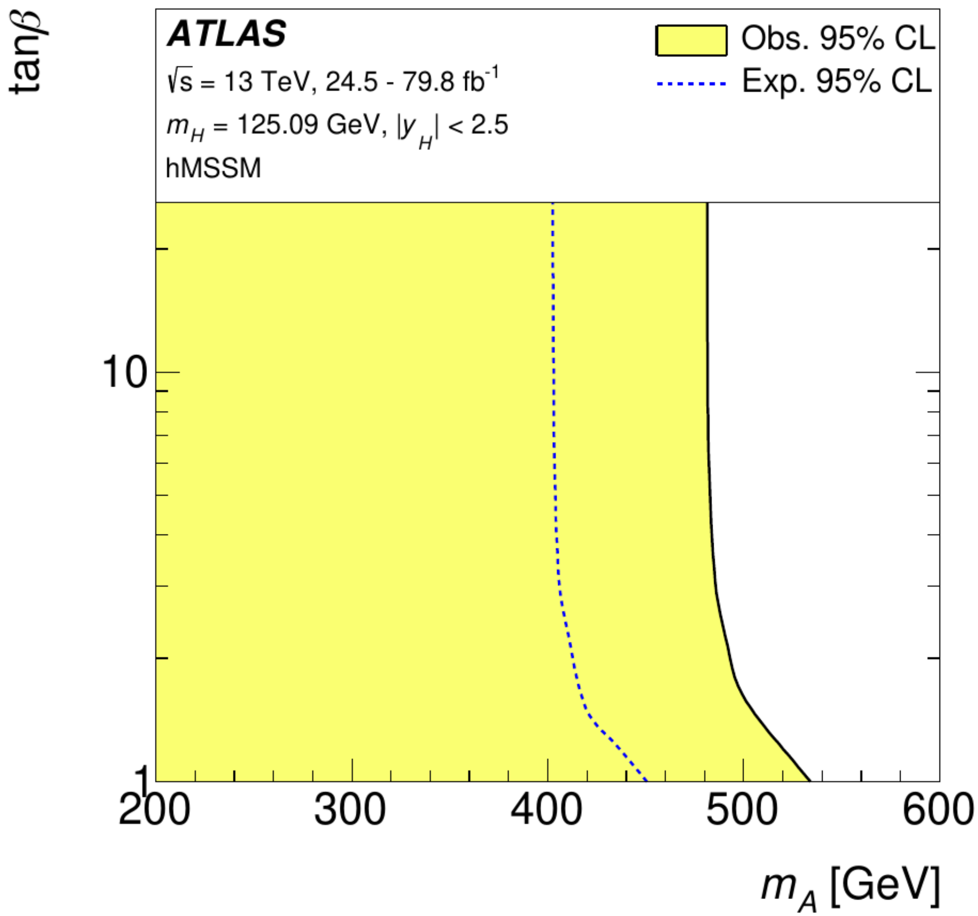
$$\kappa_d = s_d(m_A,\tan\beta)\sqrt{1+\tan^2\beta}\quad,$$

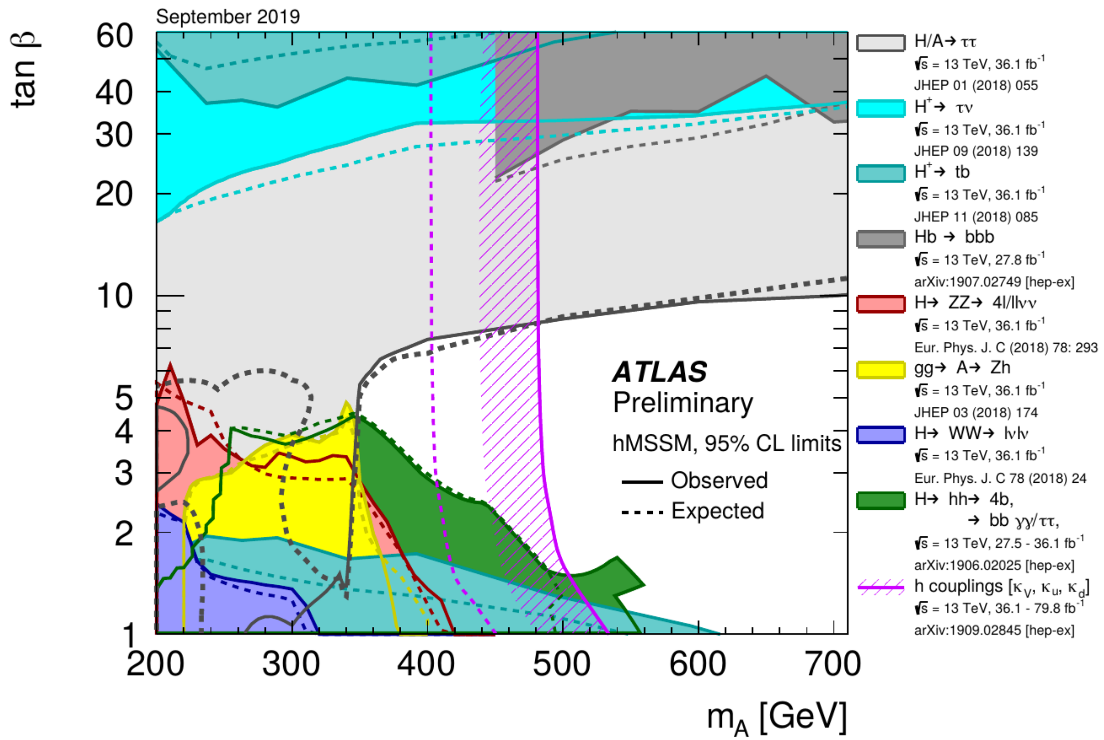
$$s_u = \frac{1}{\sqrt{1+\frac{\left(m_A^2+m_Z^2\right)^2\tan^2\beta}{\left(m_Z^2+m_A^2\tan^2\beta-m_h^2(1+\tan^2\beta)\right)^2}}}$$

$$s_d = \frac{\left(m_A^2+m_Z^2\right)\tan\beta}{m_Z^2+m_A^2\tan^2\beta-m_h^2(1+\tan^2\beta)}\, s_u$$

Reinterpret κ_V, κ_u, κ_d measurements to set constraints in the (m_A, tan β) plane of the hMSSM

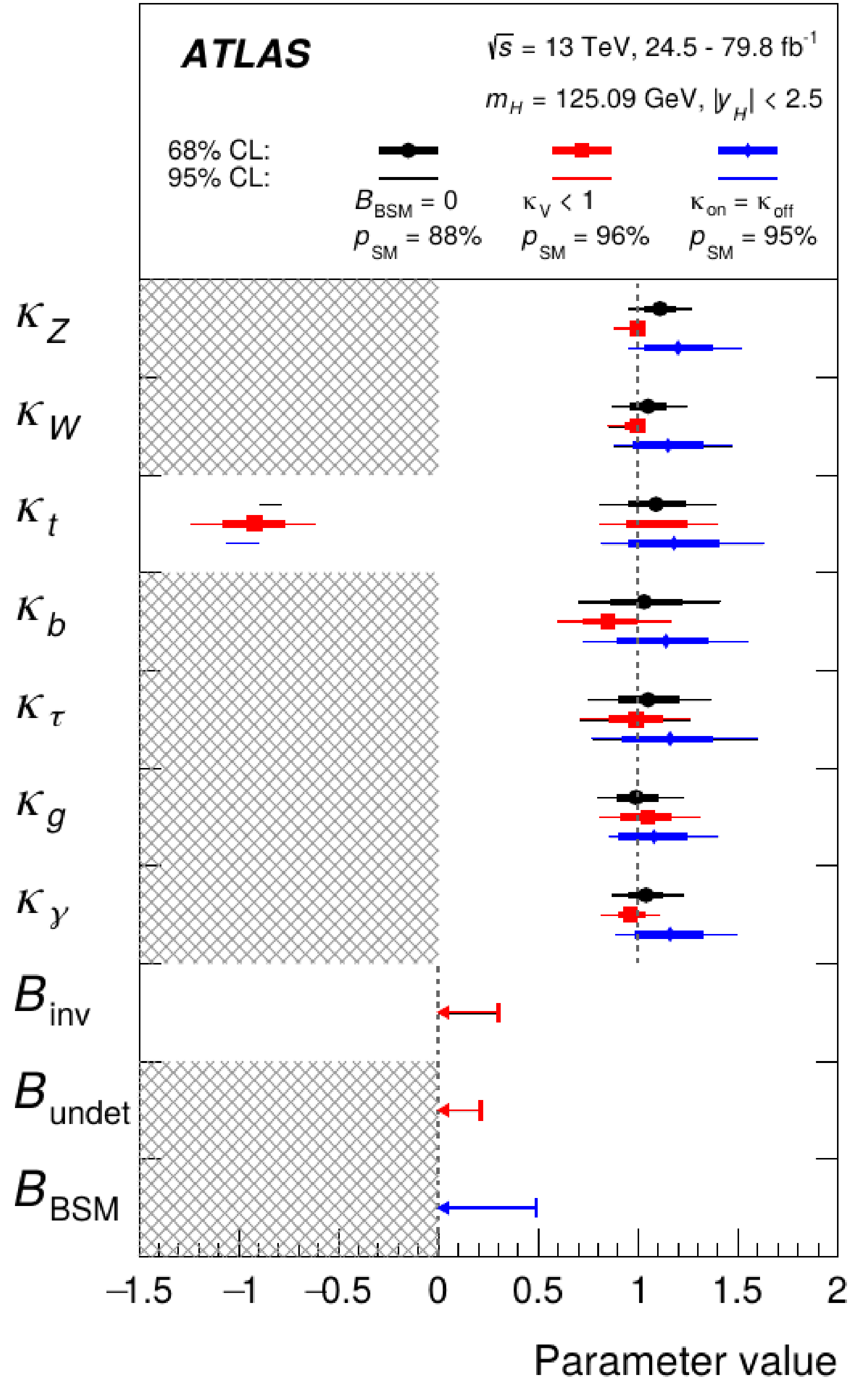
⇒ Exclude $m_A \lesssim 500$ GeV at 95% CL





Complementary to direct searches

κ measurements with BSM effects in Γ_H and loops



Γ_H affected by:

$$\sigma^{\rm on}(i \to H \to j) \sim \frac{\kappa_i^2\, \kappa_f^2}{\Gamma_H(\boldsymbol{\kappa}, B_{\rm inv}, B_{\rm undet})}$$

- κ parameters
- H→invisible decays (**B_{inv}**)

  → B_{inv} accessible through H→invisible searches (MET signature)

  Talk by C. Sander this afternoon

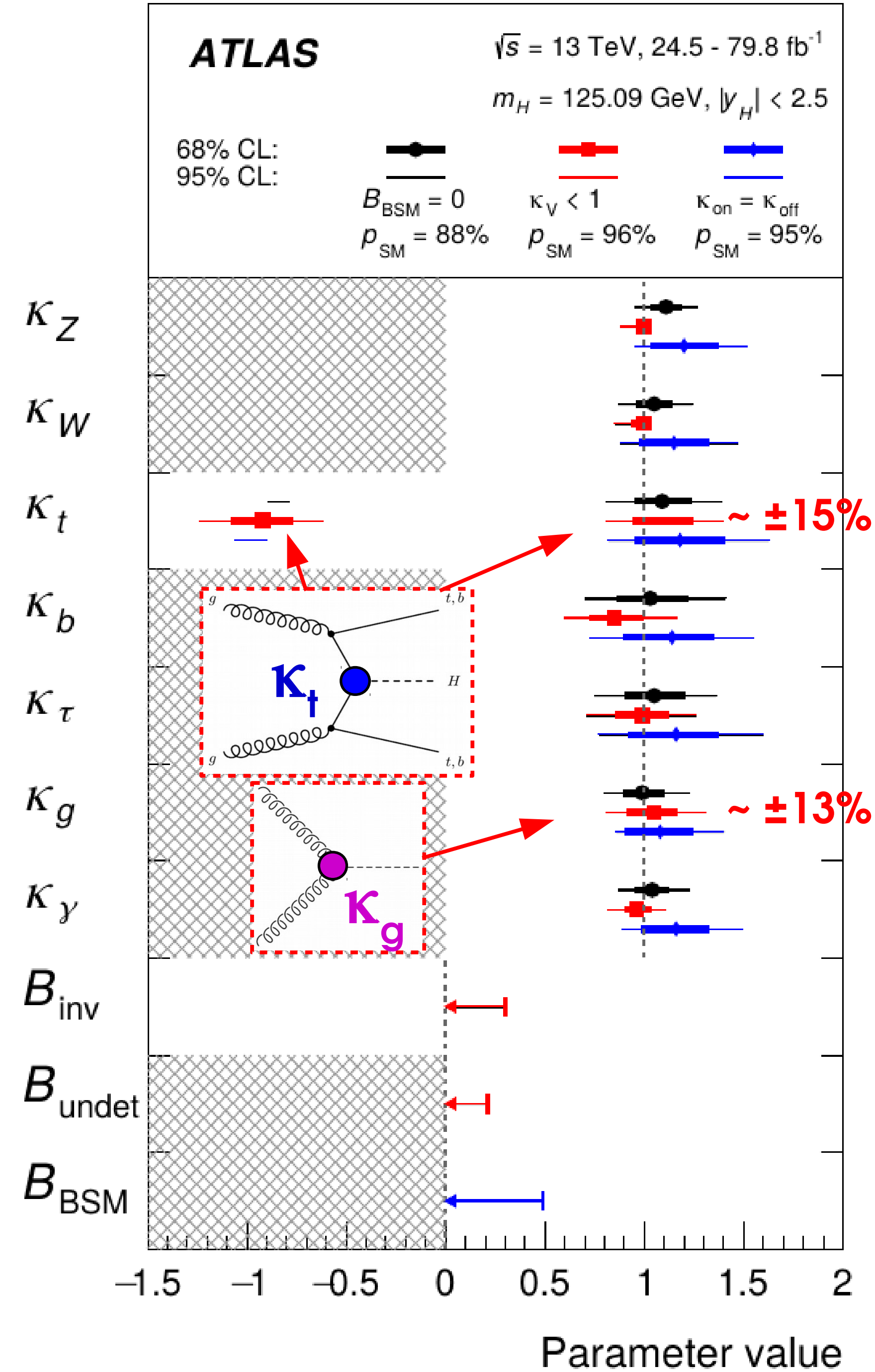
- Decays to final states not measured (**B_{undet}**)
  - **B_{undet} bounded through assuming B_{undet} > 0 and $\kappa_V \lesssim 1$**
  - **$B_{BSM} = B_{undet} + B_{inv}$ bounded by off-shell $H^* \to ZZ$ measurements, assuming $\kappa_{off} = \kappa_{on}$.**

$$\sigma^{\rm off}(i \to H^* \to j) \sim \kappa_{i,\rm off}^2\, \kappa_{f,\rm off}^2$$

All measurements compatible with SM

$\kappa_V \lesssim 1$: B_{inv} < 30%, B_{undet} < 21% at 95% CL

κ measurements with BSM effects in Γ_H and loops



Γ_H affected by:

$$\sigma^{\rm on}(i\to H\to j) \sim \frac{\kappa_i^2\,\kappa_f^2}{\Gamma_H(\boldsymbol{\kappa}, B_{\rm inv}, B_{\rm undet})}$$

- κ parameters
- H→invisible decays (**B_{inv}**)
  → B_{inv} accessible through H→invisible searches (MET signature)

Talk by C. Sander this afternoon

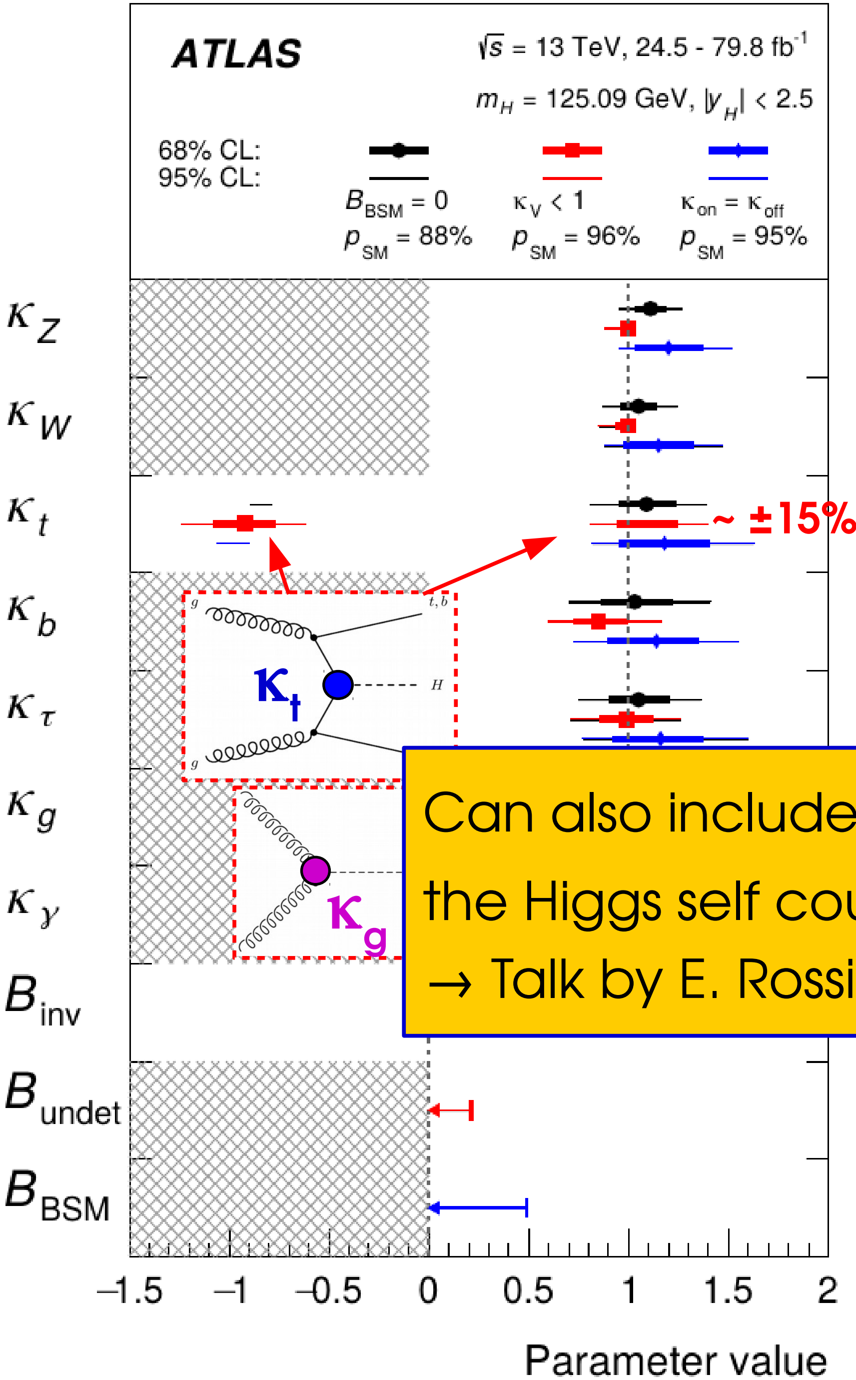
- Decays to final states not measured (**B_{undet}**)
  - **B_{undet} bounded through assuming B_{undet} > 0 and $\kappa_V \lesssim 1$**
  - **$B_{BSM} = B_{undet} + B_{inv}$ bounded by off-shell H*→ZZ measurements, assuming $\kappa_{off}=\kappa_{on}$,**

$$\sigma^{\rm off}(i\to H^*\to j) \sim \kappa_{i,\rm off}^2\,\kappa_{f,\rm off}^2$$

All measurements compatible with SM

$\kappa_V \lesssim 1$: B_{inv} < 30%, B_{undet} < 21% at 95% CL

κ measurements with BSM effects in Γ_H and loops



Γ_H affected by:

$$\sigma^{on}(i \to H \to j) \sim \frac{\kappa_i^2 \kappa_f^2}{\Gamma_H(\boldsymbol{\kappa}, B_{inv}, B_{undet})}$$

- κ parameters
- H→invisible decays (**B_{inv}**)

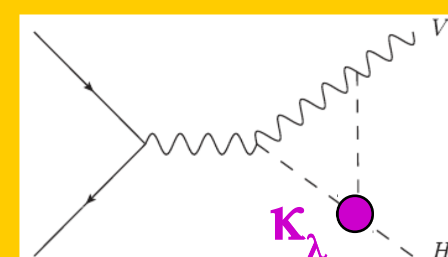
  → B_{inv} accessible through H→invisible searches (MET signature)

Talk by C. Sander this afternoon

- Decays to final states not measured (**B_{undet}**)

Can also include κ_λ modifier for the Higgs self coupling

→ Talk by E. Rossi this afternoon



-shell

H*→ZZ measurements, assuming $\kappa_{off}=\kappa_{on}$:

$$\sigma^{off}(i \to H^* \to j) \sim \kappa_{i,off}^2 \kappa_{f,off}^2$$

All measurements compatible with SM

$\kappa_V \lesssim 1$: B_{inv} < 30%, B_{undet} < 21% at 95% CL

EFT Measurements

EFT Framework

κ model not consistent beyond LO ⇒ not suited to precision measurements

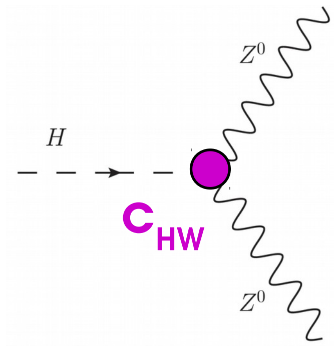
⇒ Parameterize BSM physics using an **EFT extension of the SM**

$$L = L_{SM}^{(d\leq 4)} + \frac{1}{\Lambda^2}\sum_i c_i^{(d=6)} O_i^{(d=6)} + \frac{1}{\Lambda^4}\sum_i c_i^{(d=8)} O_i^{(d=8)} + \ldots$$

In this talk: constraints on a subset of d=6 operators in the SILH basis implemented in the HEL model within MG5_aMC@NLO, **Λ = 1 TeV**

κ-like modifications but also allows modifications of kinematics (measured in STXS kinematic bins), e.g.

$$O_{HW} = i(D^\mu H)^\dagger \sigma^i (D^\nu H) W^i_{\mu\nu}$$



depends on momentum transfer

VH→bb EFT parameterization

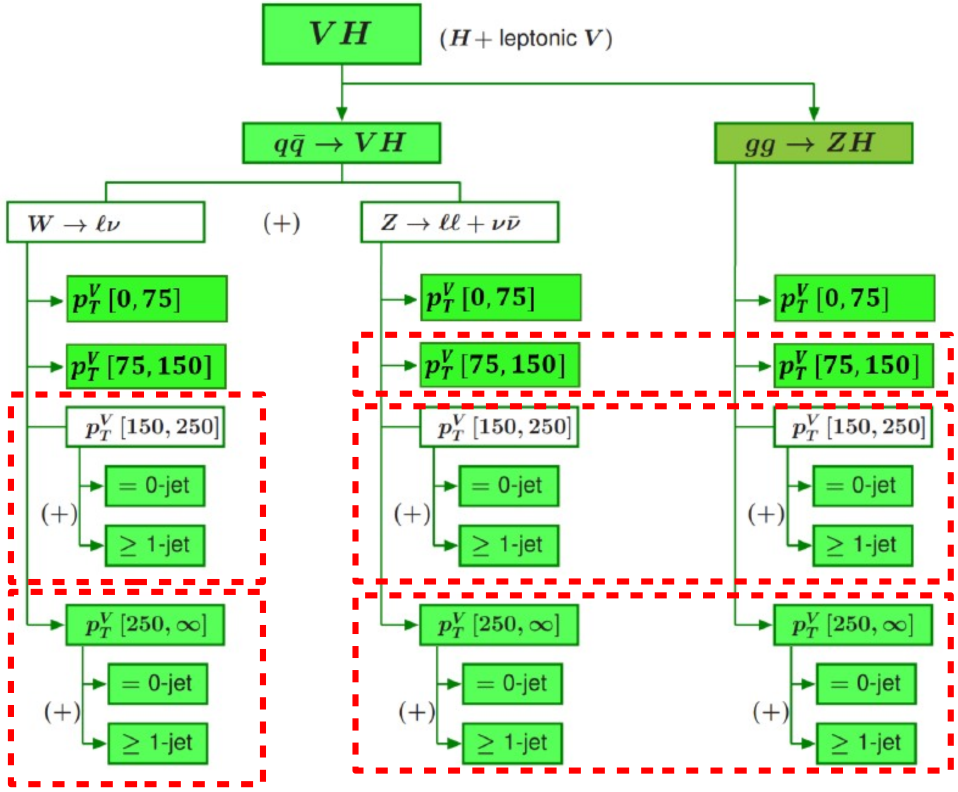
JHEP 05 (2019) 141

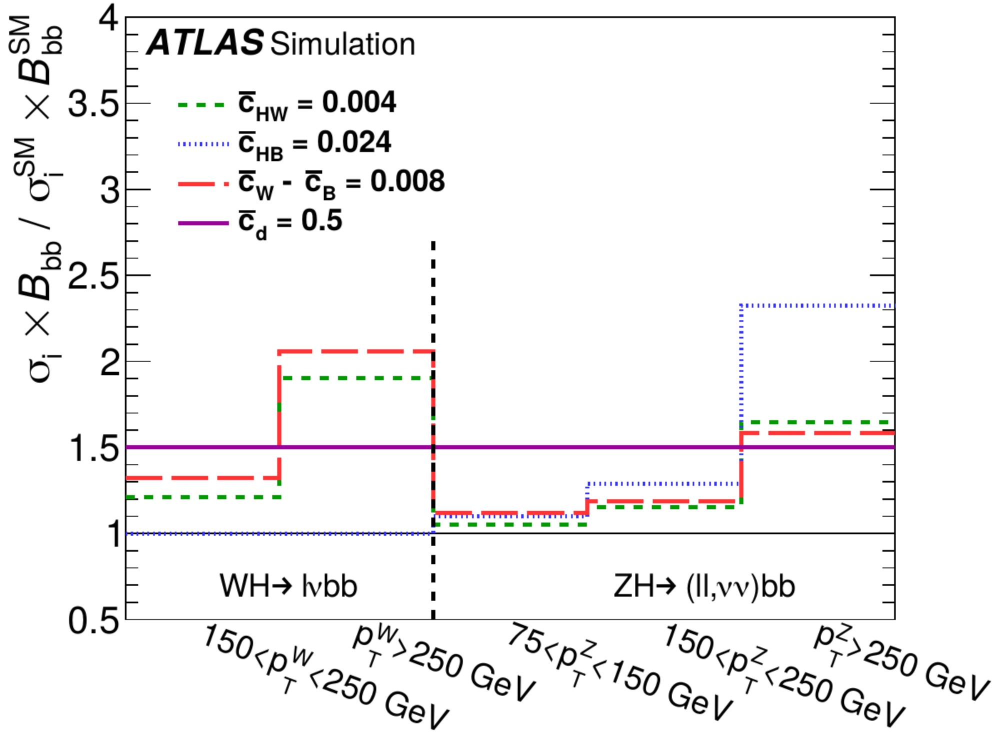
Consider **5 HEL operators** (CP-even only)
Parameterizations from
LHCHXSWG-INT-2017-001

$$\mathcal{O}_{HW} = i\,(D^\mu H)^\dagger\,\sigma^a\,(D^\nu H)\,W^a_{\mu\nu},$$
$$\mathcal{O}_{HB} = i\,(D^\mu H)^\dagger\,(D^\nu H)\,B_{\mu\nu},$$
$$\mathcal{O}_W = \frac{i}{2}\left(H^\dagger\sigma^a \overleftrightarrow{D}^\mu H\right) D^\nu W^a_{\mu\nu},$$
$$\mathcal{O}_B = \frac{i}{2}\left(H^\dagger \overleftrightarrow{D}^\mu H\right)\partial^\nu B_{\mu\nu}.$$
$$\mathcal{O}_d = y_d|H|^2\bar{Q}_L H d_R$$

Input from STXS Stage 1 measurements in 5 merged bins
Focus on high-p_T^V region: higher sensitivity to operators above

Details in G. Di Gregorio's talk yesterday

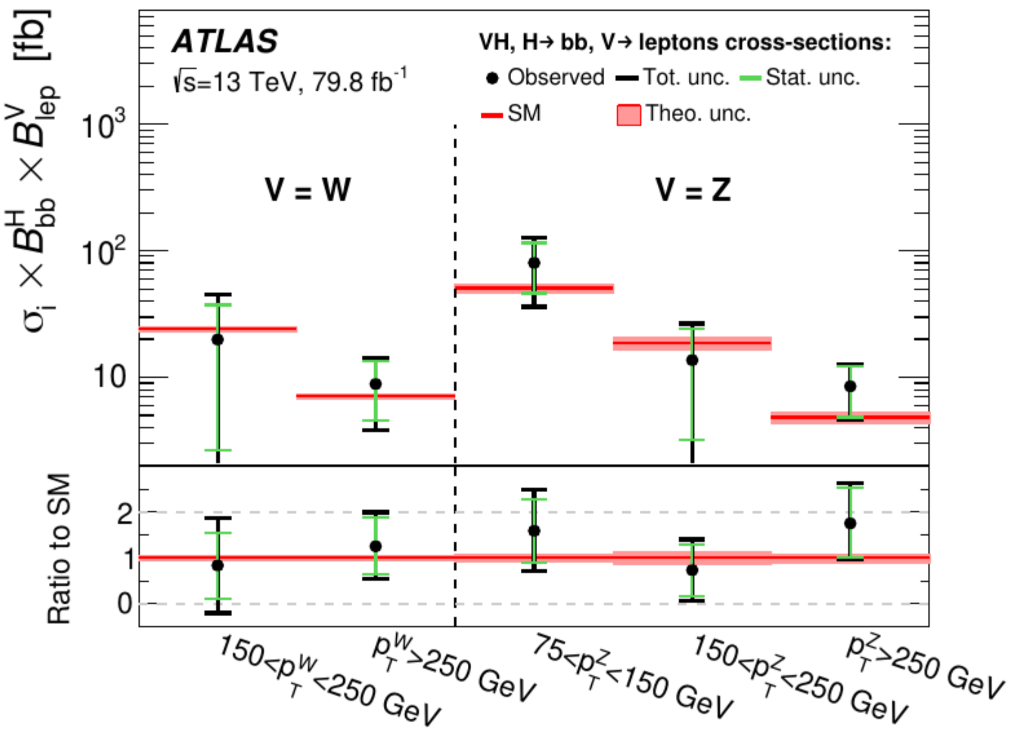


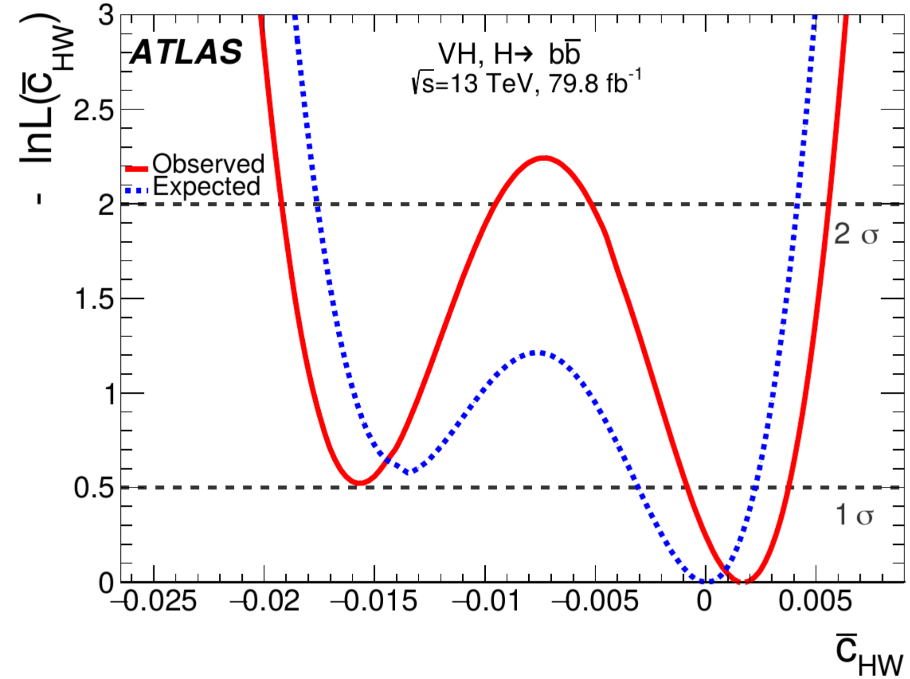


VH→bb EFT Results

JHEP 05 (2019) 141

Scan each parameter in turn, assuming others are 0 as in the SM.





Coefficient	Expected interval	Observed interval
$\bar{c}_{HW}$	$[-0.003, 0.002]$	$[-0.001, 0.004]$
$\bar{c}_{HB}$	$[-0.066, 0.013]$	$[-0.078, -0.055] \bigcup [0.005, 0.019]$
$\bar{c}_W - \bar{c}_B$	$[-0.006, 0.005]$	$[-0.002, 0.007]$
$\bar{c}_d$	$[-1.5, 0.3]$	$[-1.6, -0.9] \bigcup [-0.3, 0.4]$

Orthogonal combination strongly constrained by Precision EW measurements.

EFT Interpretation of the H→γγ differential XS analysis

Reinterpret differential fiducial cross-sections measured in H→γγ

Details in D. Börner's talk yesterday and L. Ma's talk tomorrow

HEL Operators Considered:

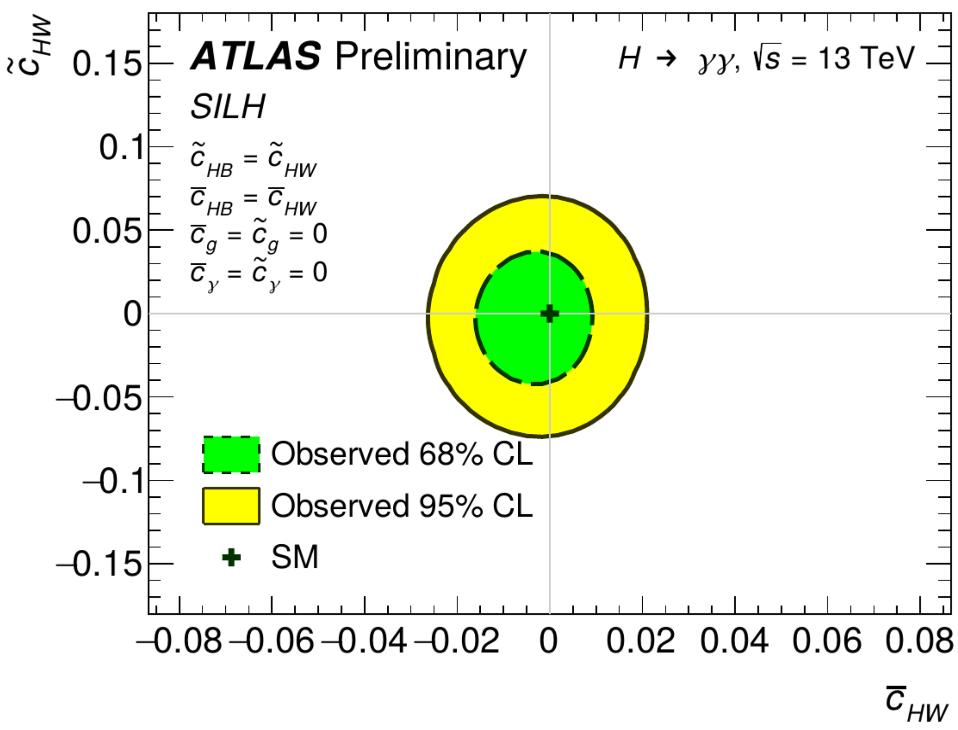
(Results also provided in SMEFT basis)

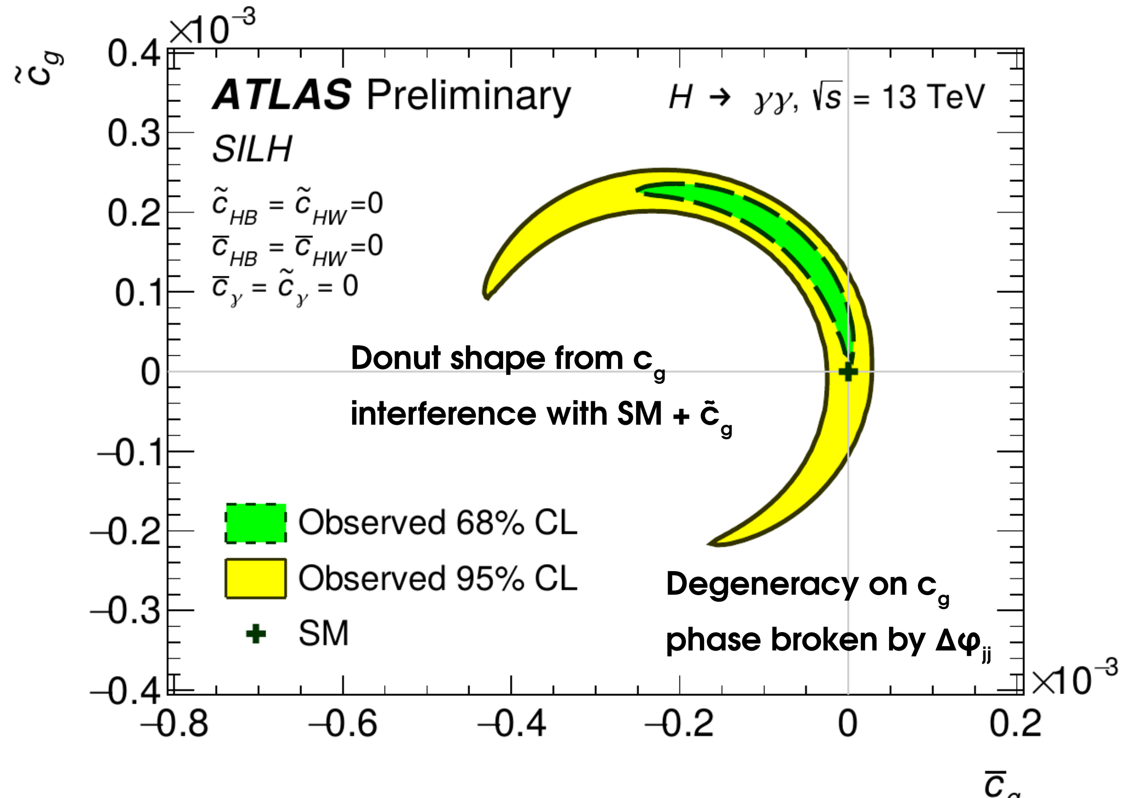
$$O_g = H^\dagger H G_{\mu\nu} G^{\mu\nu} \quad \bar{c}_g$$
$$O_\gamma = H^\dagger H B_{\mu\nu} B^{\mu\nu} \quad \bar{c}_\gamma$$
$$O_{HW} = i(D^\mu H)^\dagger \sigma^i (D^\nu H) W^i_{\mu\nu} \quad \bar{c}_{HW}$$
$$O_{HB} = i(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu} \quad \bar{c}_{HB}$$

+ CP-odd operators → $\tilde{c}_g$, $\tilde{c}_\gamma$, $\tilde{c}_{HW}$, $\tilde{c}_{HB}$

ATLAS-CONF-2019-029

Consider $\bar{c}_{HW}=\bar{c}_{HB}$ and $\tilde{c}_{HW}=\tilde{c}_{HB}$ only to avoid too-large H→Zγ rates





Conclusion

- **Precise coupling results from the combined measurement of Higgs cross-section properties using up to ~80 fb^{-1} of Run 2 data**
- **Cross-section results reported in the STXS Stage 1 framework providing fine-grained measurements of Higgs production**
- **Higgs couplings reported in the κ framework already used in Run 1**
- **Recent emphasis on EFT interpretations**, in particular using
  - STXS VH→bb results
  - H→γγ differential fiducial cross-section measurements
- **Most of these results use only a fraction of the full Run 2 dataset: more precise measurements are still ahead – especially if experimental and theory systematics continue to improve.**

Input Analyses

Analysis	Dataset	Integrated luminosity [fb^{-1}]
$H \to \gamma\gamma$ (including $t\bar{t}H$, $H \to \gamma\gamma$)	2015–2017	79.8
$H \to ZZ^* \to 4\ell$ (including $t\bar{t}H$, $H \to ZZ^* \to 4\ell$)		79.8
VH, $H \to b\bar{b}$		79.8
$H \to \mu\mu$		79.8
$H \to WW^* \to e\nu\mu\nu$	2015–2016	36.1
$H \to \tau\tau$		36.1
VBF, $H \to b\bar{b}$		24.5 – 30.6
$t\bar{t}H$, $H \to b\bar{b}$ and $t\bar{t}H$ multilepton		36.1
$H \to$ invisible		36.1
Off-shell $H \to ZZ^* \to 4\ell$ and $H \to ZZ^* \to 2\ell 2\nu$		36.1

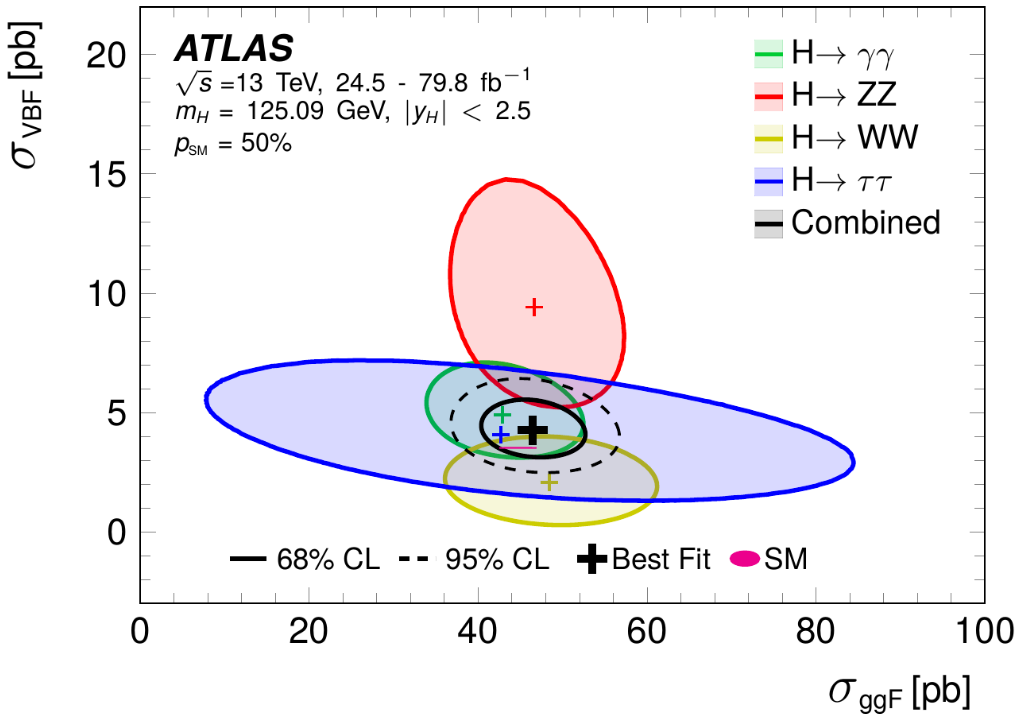
Previous combination (ATLAS-CONF-2018-031)

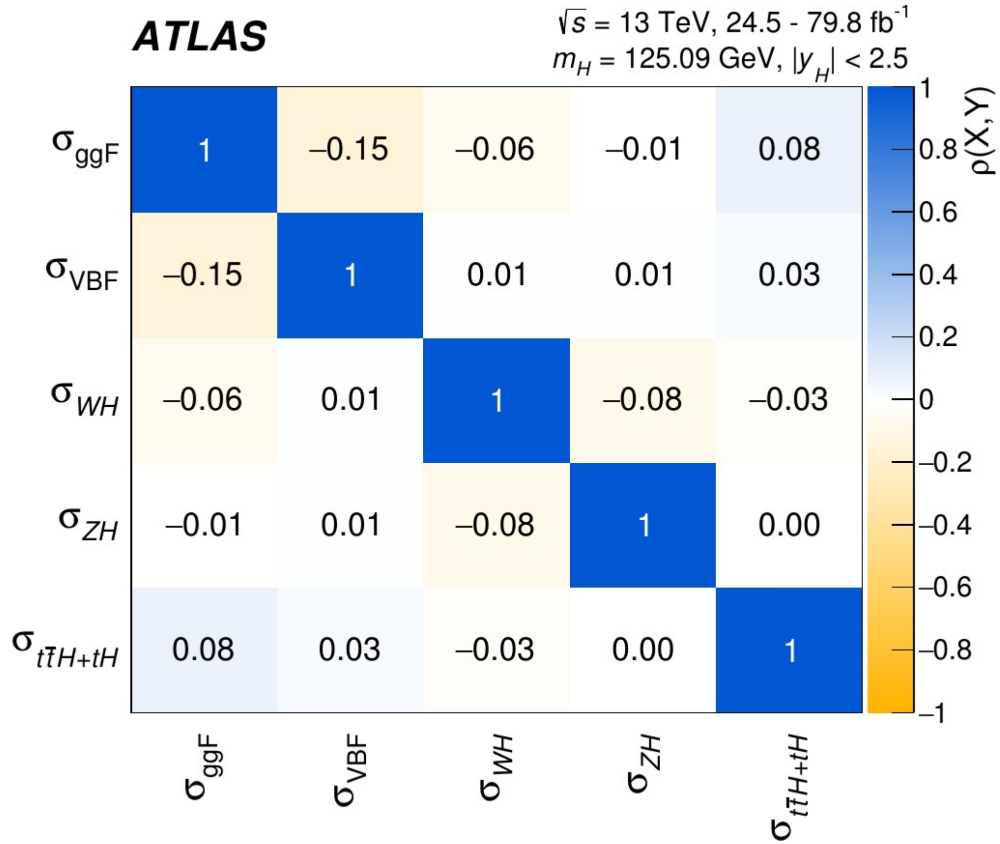
Analysis	Integrated luminosity (fb^{-1})
$H \to \gamma\gamma$ (including $t\bar{t}H$, $H \to \gamma\gamma$)	79.8
$H \to ZZ^* \to 4\ell$ (including $t\bar{t}H$, $H \to ZZ^* \to 4\ell$)	79.8
$H \to WW^* \to e\nu\mu\nu$	36.1
$H \to \tau\tau$	36.1
VH, $H \to b\bar{b}$	36.1
$H \to \mu\mu$	79.8
$t\bar{t}H$, $H \to b\bar{b}$ and $t\bar{t}H$ multilepton	36.1

Categories

	$H\to\gamma\gamma$	$H\to ZZ^*$	$H\to WW^*$	$H\to\tau\tau$	$H\to b\bar{b}$
$t\bar{t}H$	$t\bar{t}H$ leptonic (3 categories) $t\bar{t}H$ hadronic (4 categories)	$t\bar{t}H$ multilepton 1 ℓ + 2 τ_{had} $t\bar{t}H$ multilepton 2 opposite-sign ℓ + 1 τ_{had} $t\bar{t}H$ multilepton 2 same-sign ℓ (categories for 0 or 1 τ_{had}) $t\bar{t}H$ multilepton 3 ℓ (categories for 0 or 1 τ_{had}) $t\bar{t}H$ multilepton 4 ℓ (except $H\to ZZ^*\to 4\ell$) $t\bar{t}H$ leptonic, $H\to ZZ^*\to 4\ell$ $t\bar{t}H$ hadronic, $H\to ZZ^*\to 4\ell$			$t\bar{t}H$ 1 ℓ, boosted $t\bar{t}H$ 1 ℓ, resolved (11 categories) $t\bar{t}H$ 2 ℓ (7 categories)
VH	VH 2 ℓ VH 1 ℓ, $p_T^{\ell+E_T^{\text{miss}}} \geq 150$ GeV VH 1 ℓ, $p_T^{\ell+E_T^{\text{miss}}} < 150$ GeV VH E_T^{miss}, $E_T^{\text{miss}} \geq 150$ GeV VH E_T^{miss}, $E_T^{\text{miss}} < 150$ GeV VH+VBF $p_T^{j1} \geq 200$ GeV VH hadronic (2 categories)	VH leptonic 0-jet, $p_T^{4\ell} \geq 100$ GeV 2-jet, $m_{jj} < 120$ GeV			2 ℓ, $75 \leq p_T^V < 150$ GeV, $N_{\text{jets}} = 2$ 2 ℓ, $75 \leq p_T^V < 150$ GeV, $N_{\text{jets}} \geq 3$ 2 ℓ, $p_T^V \geq 150$ GeV, $N_{\text{jets}} = 2$ 2 ℓ, $p_T^V \geq 150$ GeV, $N_{\text{jets}} \geq 3$ 1 ℓ $p_T^V \geq 150$ GeV, $N_{\text{jets}} = 2$ 1 ℓ $p_T^V \geq 150$ GeV, $N_{\text{jets}} = 3$ 0 ℓ, $p_T^V \geq 150$ GeV, $N_{\text{jets}} = 2$ 0 ℓ, $p_T^V \geq 150$ GeV, $N_{\text{jets}} = 3$
VBF	VBF, $p_T^{\gamma\gamma jj} \geq 25$ GeV (2 categories) VBF, $p_T^{\gamma\gamma jj} < 25$ GeV (2 categories)	2-jet VBF, $p_T^{j1} \geq 200$ GeV 2-jet VBF, $p_T^{j1} < 200$ GeV	2-jet VBF	VBF $p_T^{\tau\tau} > 140$ GeV ($\tau_{\text{had}}\tau_{\text{had}}$ only) VBF high-m_{jj} VBF low-m_{jj}	VBF, two central jets VBF, four central jets VBF+γ
ggF	2-jet, $p_T^{\gamma\gamma} \geq 200$ GeV 2-jet, 120 GeV$\leq p_T^{\gamma\gamma} < 200$ GeV 2-jet, 60 GeV$\leq p_T^{\gamma\gamma} < 120$ GeV 2-jet, $p_T^{\gamma\gamma} < 60$ GeV 1-jet, $p_T^{\gamma\gamma} \geq 200$ GeV 1-jet, 120 GeV$\leq p_T^{\gamma\gamma} < 200$ GeV 1-jet, 60 GeV$\leq p_T^{\gamma\gamma} < 120$ GeV 1-jet, $p_T^{\gamma\gamma} < 60$ GeV 0-jet (2 categories)	1-jet, $p_T^{4\ell} \geq 120$ GeV 1-jet, 60 GeV$\leq p_T^{4\ell} < 120$ GeV 1-jet, $p_T^{4\ell} < 60$ GeV 0-jet, $p_T^{4\ell} < 100$ GeV	1-jet, $m_{\ell\ell} < 30$ GeV, $p_T^{\ell_2} < 20$ GeV 1-jet, $m_{\ell\ell} < 30$ GeV, $p_T^{\ell_2} \geq 20$ GeV 1-jet, $m_{\ell\ell} \geq 30$ GeV, $p_T^{\ell_2} < 20$ GeV 1-jet, $m_{\ell\ell} \geq 30$ GeV, $p_T^{\ell_2} \geq 20$ GeV 0-jet, $m_{\ell\ell} < 30$ GeV, $p_T^{\ell_2} < 20$ GeV 0-jet, $m_{\ell\ell} < 30$ GeV, $p_T^{\ell_2} \geq 20$ GeV 0-jet, $m_{\ell\ell} \geq 30$ GeV, $p_T^{\ell_2} < 20$ GeV 0-jet, $m_{\ell\ell} \geq 30$ GeV, $p_T^{\ell_2} \geq 20$ GeV	Boosted, $p_T^{\tau\tau} > 140$ GeV Boosted, $p_T^{\tau\tau} \leq 140$ GeV	

5XS Results

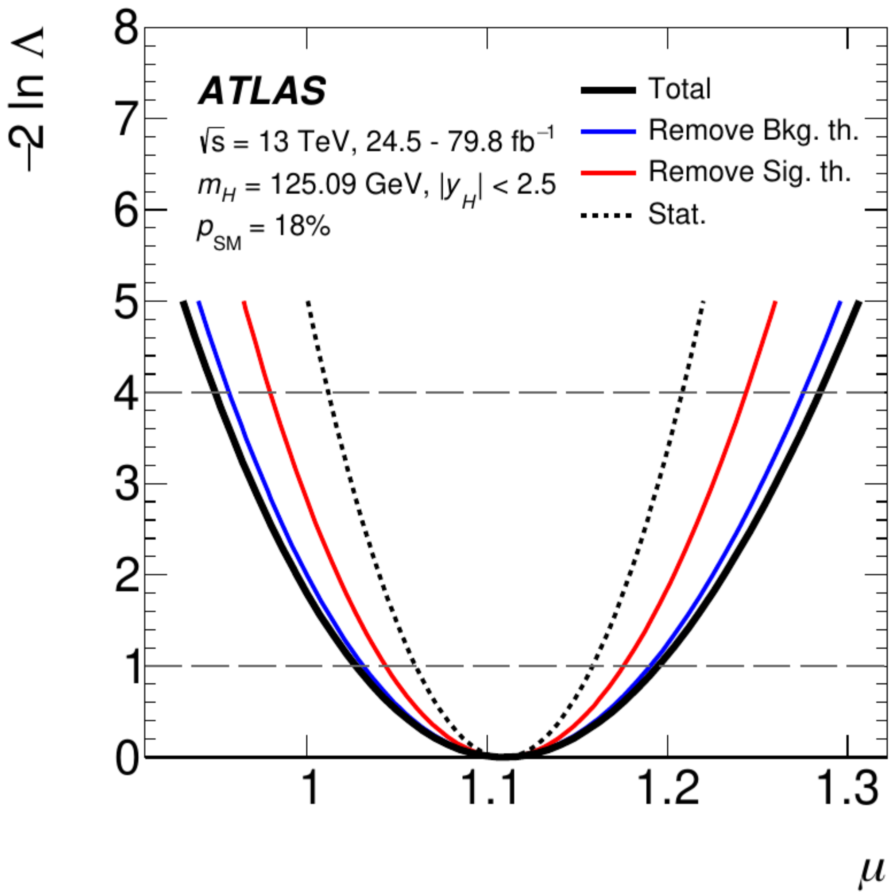




Process ($\lvert y_H\rvert < 2.5$)	Value [pb]	Uncertainty [pb] Total	Stat.	Exp.	Sig. th.	Bkg. th.	SM pred. [pb]	Significance obs. (exp.)
ggF	46.5	$\pm$ 4.0	$\pm$ 3.1	$\pm$ 2.2	$\pm$ 0.9	$\pm$ 1.3	44.7 $\pm$ 2.2	-
VBF	4.25	$^{+0.84}_{-0.77}$	$^{+0.63}_{-0.60}$	$^{+0.35}_{-0.32}$	$^{+0.42}_{-0.32}$	$^{+0.14}_{-0.11}$	3.515 $\pm$ 0.075	6.5 (5.3)
WH	1.57	$^{+0.48}_{-0.46}$	$^{+0.34}_{-0.33}$	$^{+0.25}_{-0.24}$	$^{+0.11}_{-0.07}$	$\pm$ 0.20	1.204 $\pm$ 0.024	3.5 (2.7) } 5.3 (4.7)
ZH	0.84	$^{+0.25}_{-0.23}$	$\pm$ 0.19	$\pm$ 0.09	$^{+0.07}_{-0.04}$	$\pm$ 0.10	0.797 $^{+0.033}_{-0.026}$	3.6 (3.6)
$t\bar{t}H+tH$	0.71	$^{+0.15}_{-0.14}$	$\pm$ 0.10	$^{+0.07}_{-0.06}$	$^{+0.05}_{-0.04}$	$^{+0.08}_{-0.07}$	0.586 $^{+0.034}_{-0.049}$	5.8 (5.4)

Uncertainties on μ

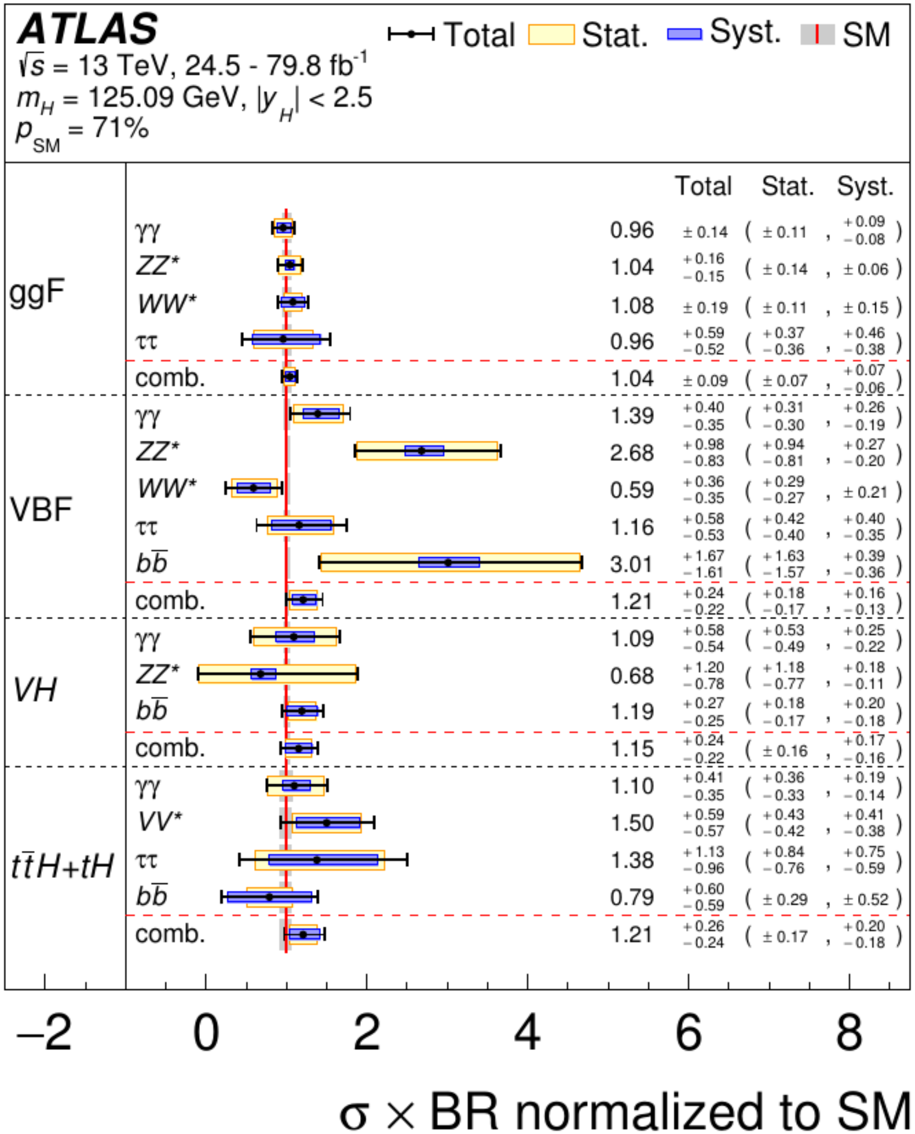
Uncertainty source	$\Delta\mu/\mu$ [%]
Statistical uncertainty	4.4
Systematic uncertainties	6.2
Theory uncertainties	4.8
Signal	4.2
Background	2.6
Experimental uncertainties (excl. MC stat.)	4.1
Luminosity	2.0
Background modeling	1.6
Jets, $E_{\mathrm{T}}^{\mathrm{miss}}$	1.4
Flavor tagging	1.1
Electrons, photons	2.2
Muons	0.2
τ-lepton	0.4
Other	1.6
MC statistical uncertainty	1.7
Total uncertainty	7.6

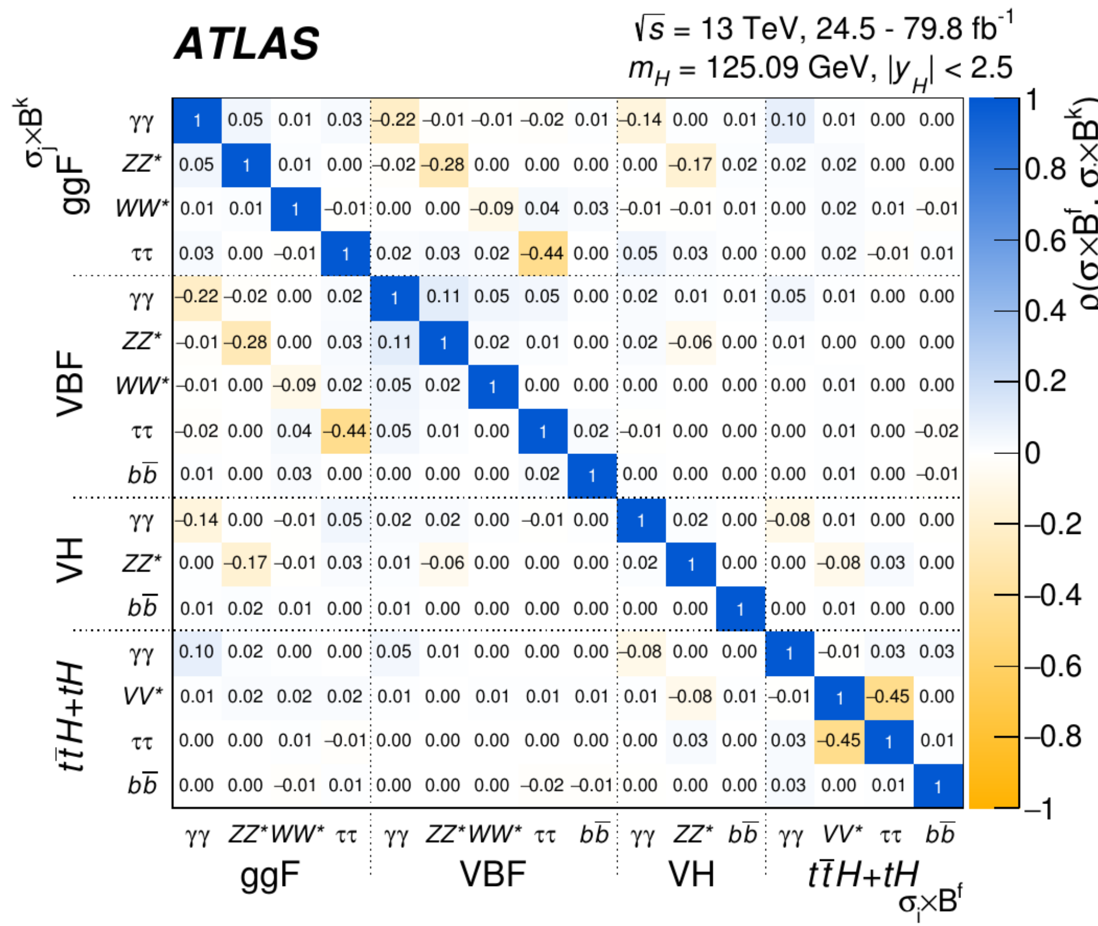


Uncertainties on σ_{prod}

Uncertainty source	$\frac{\Delta\sigma_{ggF}}{\sigma_{ggF}}$ [%]	$\frac{\Delta\sigma_{VBF}}{\sigma_{VBF}}$ [%]	$\frac{\Delta\sigma_{WH}}{\sigma_{WH}}$ [%]	$\frac{\Delta\sigma_{ZH}}{\sigma_{ZH}}$ [%]	$\frac{\Delta\sigma_{t\bar{t}H+tH}}{\sigma_{t\bar{t}H+tH}}$ [%]
Statistical uncertainties	6.4	15	21	23	14
Systematic uncertainties	6.2	12	22	17	15
Theory uncertainties	3.4	9.2	14	14	12
Signal	2.0	8.7	5.8	6.7	6.3
Background	2.7	3.0	13	12	10
Experimental uncertainties (excl. MC stat.)	5.0	6.5	9.9	9.6	9.2
Luminosity	2.1	1.8	1.8	1.8	3.1
Background modeling	2.5	2.2	4.7	2.9	5.7
Jets, E_T^{miss}	0.9	5.4	3.0	3.3	4.0
Flavor tagging	0.9	1.3	7.9	8.0	1.8
Electrons, photons	2.5	1.7	1.8	1.5	3.8
Muons	0.4	0.3	0.1	0.2	0.5
τ-lepton	0.2	1.3	0.3	0.1	2.4
Other	2.5	1.2	0.3	1.1	0.8
MC statistical uncertainties	1.6	4.8	8.8	7.9	4.4
Total uncertainties	8.9	19	30	29	21

5×5 Results


ATLAS
√s = 13 TeV, 24.5 - 79.8 fb-1
mH = 125.09 GeV, |yH| < 2.5
pSM = 71%
Total
Stat.
Syst.
SM
Total Stat. Syst.
ggF
γγ 0.96 ± 0.14 (± 0.11 , +0.09 −0.08)
ZZ* 1.04 +0.16 −0.15 (± 0.14 , ± 0.06)
WW* 1.08 ± 0.19 (± 0.11 , ± 0.15)
ττ 0.96 +0.59 −0.52 (+0.37 −0.36 , +0.46 −0.38)
comb. 1.04 ± 0.09 (± 0.07 , +0.07 −0.06)
VBF
γγ 1.39 +0.40 −0.35 (+0.31 −0.30 , +0.26 −0.19)
ZZ* 2.68 +0.98 −0.83 (+0.94 −0.81 , +0.27 −0.20)
WW* 0.59 +0.36 −0.35 (+0.29 −0.27 , ± 0.21)
ττ 1.16 +0.58 −0.53 (+0.42 −0.40 , +0.40 −0.35)
bb̄ 3.01 +1.67 −1.61 (+1.63 −1.57 , +0.39 −0.36)
comb. 1.21 +0.24 −0.22 (+0.18 −0.17 , +0.16 −0.13)
VH
γγ 1.09 +0.58 −0.54 (+0.53 −0.49 , +0.25 −0.22)
ZZ* 0.68 +1.20 −0.78 (+1.18 −0.77 , +0.18 −0.11)
bb̄ 1.19 +0.27 −0.25 (+0.18 −0.17 , +0.20 −0.18)
comb. 1.15 +0.24 −0.22 (± 0.16 , +0.17 −0.16)
tt̄H+tH
γγ 1.10 +0.41 −0.35 (+0.36 −0.33 , +0.19 −0.14)
VV* 1.50 +0.59 −0.57 (+0.43 −0.42 , +0.41 −0.38)
ττ 1.38 +1.13 −0.96 (+0.84 −0.76 , +0.75 −0.59)
bb̄ 0.79 +0.60 −0.59 (± 0.29 , ± 0.52)
comb. 1.21 +0.26 −0.24 (± 0.17 , +0.20 −0.18)
−2 0 2 4 6 8
σ × BR normalized to SM


ATLAS
√s = 13 TeV, 24.5 - 79.8 fb-1
mH = 125.09 GeV, |yH| < 2.5
σj×Bk
ggF
VBF
VH
tt̄H+tH
γγ 1 0.05 0.01 0.03 −0.22 −0.01 −0.01 −0.02 0.01 −0.14 0.00 0.01 0.10 0.01 0.00 0.00
ZZ* 0.05 1 0.01 0.00 −0.02 −0.28 0.00 0.00 0.00 0.00 −0.17 0.02 0.02 0.02 0.00 0.00
WW* 0.01 0.01 1 −0.01 0.00 0.00 −0.09 0.04 0.03 −0.01 −0.01 0.01 0.00 0.02 0.01 −0.01
ττ 0.03 0.00 −0.01 1 0.02 0.03 0.02 −0.44 0.00 0.05 0.03 0.00 0.00 0.02 −0.01 0.01
γγ −0.22 −0.02 0.00 0.02 1 0.11 0.05 0.05 0.00 0.02 0.01 0.01 0.05 0.01 0.00 0.00
ZZ* −0.01 −0.28 0.00 0.03 0.11 1 0.02 0.01 0.00 0.02 −0.06 0.00 0.01 0.00 0.00 0.00
WW* −0.01 0.00 −0.09 0.02 0.05 0.02 1 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.00
ττ −0.02 0.00 0.04 −0.44 0.05 0.01 0.00 1 0.02 −0.01 0.00 0.00 0.00 0.01 0.00 −0.02
bb̄ 0.01 0.00 0.03 0.00 0.00 0.00 0.00 0.02 1 0.00 0.00 0.00 0.00 0.01 0.00 −0.01
γγ −0.14 0.00 −0.01 0.05 0.02 0.02 0.00 −0.01 0.00 1 0.02 0.00 −0.08 0.01 0.00 0.00
ZZ* 0.00 −0.17 −0.01 0.03 0.01 −0.06 0.00 0.00 0.00 0.02 1 0.00 0.00 −0.08 0.03 0.00
bb̄ 0.01 0.02 0.01 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 1 0.00 0.01 0.00 0.00
γγ 0.10 0.02 0.00 0.00 0.05 0.01 0.00 0.00 0.00 −0.08 0.00 0.00 1 −0.01 0.03 0.03
VV* 0.01 0.02 0.02 0.02 0.01 0.00 0.01 0.01 0.01 0.01 −0.08 0.01 −0.01 1 −0.45 0.00
ττ 0.00 0.00 0.01 −0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.03 0.00 0.03 −0.45 1 0.01
bb̄ 0.00 0.00 −0.01 0.01 0.00 0.00 0.00 −0.02 −0.01 0.00 0.00 0.00 0.03 0.00 0.01 1
γγ ZZ* WW* ττ γγ ZZ* WW* ττ bb̄ γγ ZZ* bb̄ γγ VV* ττ bb̄
ggF VBF VH tt̄H+tH
σi×Bf
1 0.8 0.6 0.4 0.2 0 −0.2 −0.4 −0.6 −0.8 −1
ρ(σi×Bf, σj×Bk)

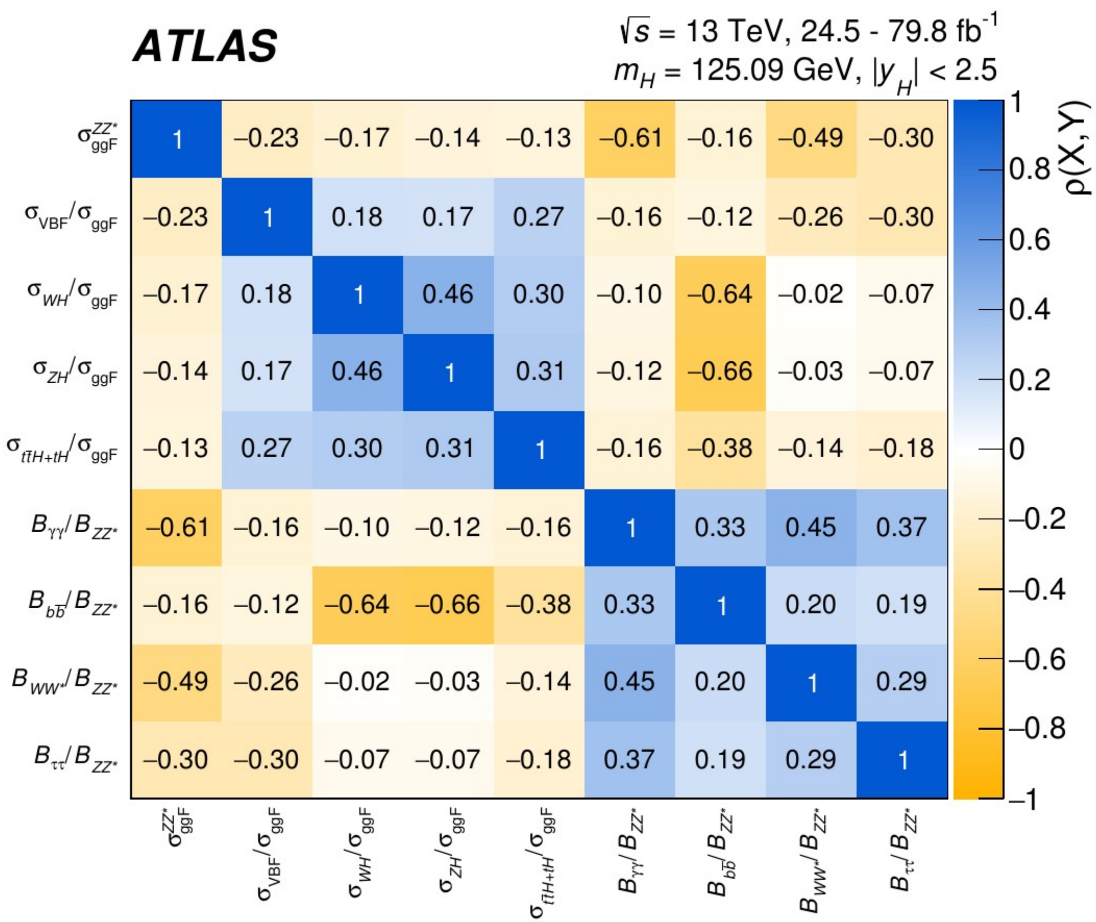
5×5 Results

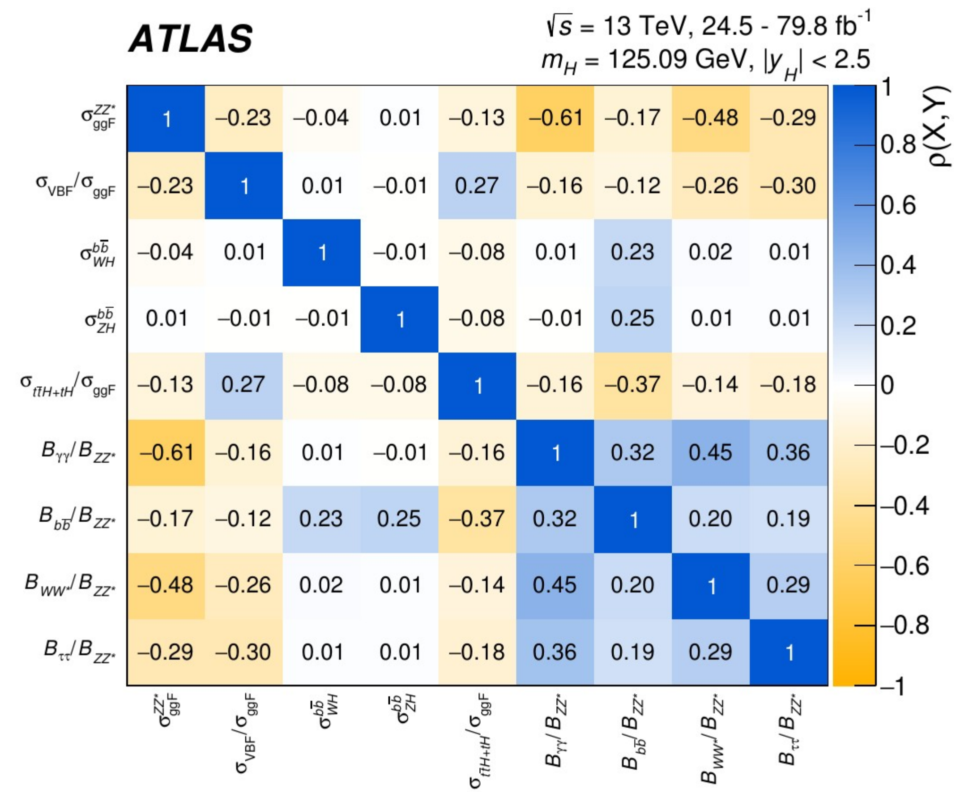
Process ($\lvert y_H \rvert < 2.5$)	Value [fb]	Uncertainty [fb] Total	Stat.	Exp.	Sig. th.	Bkg. th.	SM pred. [fb]
ggF, $H \to \gamma\gamma$	97	± 14	± 11	± 8	± 2	$^{+2}_{-1}$	101.5 ± 5.3
ggF, $H \to ZZ^*$	1230	$^{+190}_{-180}$	± 170	± 60	± 20	± 20	1181 ± 61
ggF, $H \to WW^*$	10400	± 1800	± 1100	± 1100	± 400	$^{+1000}_{-900}$	9600 ± 500
ggF, $H \to \tau\tau$	2700	$^{+1700}_{-1500}$	± 1000	± 900	$^{+800}_{-300}$	± 400	2800 ± 140
VBF, $H \to \gamma\gamma$	11.1	$^{+3.2}_{-2.8}$	$^{+2.5}_{-2.4}$	$^{+1.4}_{-1.0}$	$^{+1.5}_{-1.1}$	$^{+0.3}_{-0.2}$	7.98 ± 0.21
VBF, $H \to ZZ^*$	249	$^{+91}_{-77}$	$^{+87}_{-75}$	$^{+16}_{-11}$	$^{+17}_{-12}$	$^{+9}_{-7}$	92.8 ± 2.3
VBF, $H \to WW^*$	450	$^{+270}_{-260}$	$^{+220}_{-200}$	$^{+120}_{-130}$	$^{+80}_{-70}$	$^{+70}_{-80}$	756 ± 19
VBF, $H \to \tau\tau$	260	$^{+130}_{-120}$	± 90	$^{+80}_{-70}$	$^{+30}_{-10}$	$^{+30}_{-20}$	220 ± 6
VBF, $H \to b\bar{b}$	6100	$^{+3400}_{-3300}$	$^{+3300}_{-3200}$	$^{+700}_{-600}$	± 300	± 300	2040 ± 50
VH, $H \to \gamma\gamma$	5.0	$^{+2.6}_{-2.5}$	$^{+2.4}_{-2.2}$	$^{+1.0}_{-0.9}$	± 0.5	± 0.1	$4.54\ ^{+0.13}_{-0.12}$
VH, $H \to ZZ^*$	36	$^{+63}_{-41}$	$^{+62}_{-41}$	$^{+5}_{-4}$	$^{+6}_{-4}$	$^{+4}_{-2}$	52.8 ± 1.4
VH, $H \to b\bar{b}$	1380	$^{+310}_{-290}$	$^{+210}_{-200}$	± 150	$^{+120}_{-80}$	± 140	$1162\ ^{+31}_{-29}$
$t\bar{t}H+tH$, $H \to \gamma\gamma$	1.46	$^{+0.55}_{-0.47}$	$^{+0.48}_{-0.44}$	$^{+0.19}_{-0.15}$	$^{+0.17}_{-0.11}$	± 0.03	$1.33\ ^{+0.08}_{-0.11}$
$t\bar{t}H+tH$, $H \to VV^*$	212	$^{+84}_{-81}$	$^{+61}_{-59}$	$^{+47}_{-44}$	$^{+17}_{-10}$	$^{+31}_{-30}$	$142\ ^{+8}_{-12}$
$t\bar{t}H+tH$, $H \to \tau\tau$	51	$^{+41}_{-35}$	$^{+31}_{-28}$	$^{+26}_{-21}$	$^{+6}_{-4}$	$^{+8}_{-6}$	$36.7\ ^{+2.2}_{-3.1}$
$t\bar{t}H+tH$, $H \to b\bar{b}$	270	± 200	± 100	± 80	$^{+40}_{-10}$	$^{+150}_{-160}$	$341\ ^{+20}_{-29}$

Ratio Model results

Quantity		Value	Uncertainty: Total	Stat.	Exp.	Sig. th.	Bkg. th.	SM prediction
$\sigma^{ZZ}_{\mathrm{ggF}}$	[pb]	1.33	± 0.15	$^{+0.14}_{-0.13}$	± 0.06	$^{+0.02}_{-0.01}$	$^{+0.04}_{-0.02}$	1.181 ± 0.061
$\sigma_{\mathrm{VBF}}/\sigma_{\mathrm{ggF}}$		0.097	$^{+0.025}_{-0.021}$	$^{+0.019}_{-0.017}$	$^{+0.010}_{-0.008}$	$^{+0.011}_{-0.008}$	$^{+0.006}_{-0.005}$	0.0786 ± 0.0043
$\sigma_{WH}/\sigma_{\mathrm{ggF}}$		0.033	$^{+0.016}_{-0.012}$	$^{+0.012}_{-0.009}$	$^{+0.007}_{-0.006}$	$^{+0.003}_{-0.002}$	$^{+0.007}_{-0.005}$	$0.0269\ ^{+0.0014}_{-0.0015}$
$\sigma_{ZH}/\sigma_{\mathrm{ggF}}$		0.0180	$^{+0.0084}_{-0.0061}$	$^{+0.0066}_{-0.0052}$	$^{+0.0034}_{-0.0021}$	$^{+0.0016}_{-0.0009}$	$^{+0.0037}_{-0.0025}$	$0.0178\ ^{+0.0011}_{-0.0010}$
$\sigma_{t\bar{t}H+tH}/\sigma_{\mathrm{ggF}}$		0.0157	$^{+0.0041}_{-0.0035}$	$^{+0.0031}_{-0.0028}$	$^{+0.0020}_{-0.0017}$	$^{+0.0012}_{-0.0008}$	$^{+0.0013}_{-0.0012}$	$0.0131\ ^{+0.0010}_{-0.0013}$
$B_{\gamma\gamma}/B_{ZZ}$		0.075	$^{+0.012}_{-0.010}$	$^{+0.010}_{-0.009}$	$^{+0.006}_{-0.005}$	± 0.001	± 0.002	0.0860 ± 0.0010
B_{WW}/B_{ZZ}		6.8	$^{+1.5}_{-1.2}$	$^{+1.1}_{-0.9}$	$^{+0.8}_{-0.7}$	± 0.2	$^{+0.6}_{-0.5}$	$8.15 \pm\ < 0.01$
$B_{\tau\tau}/B_{ZZ}$		2.04	$^{+0.62}_{-0.52}$	$^{+0.45}_{-0.40}$	$^{+0.36}_{-0.31}$	$^{+0.17}_{-0.09}$	$^{+0.12}_{-0.09}$	2.369 ± 0.017
B_{bb}/B_{ZZ}		20.5	$^{+8.4}_{-5.9}$	$^{+5.9}_{-4.6}$	$^{+3.7}_{-2.4}$	$^{+1.3}_{-0.9}$	$^{+4.2}_{-2.9}$	22.00 ± 0.51

Ratio Model Correlations



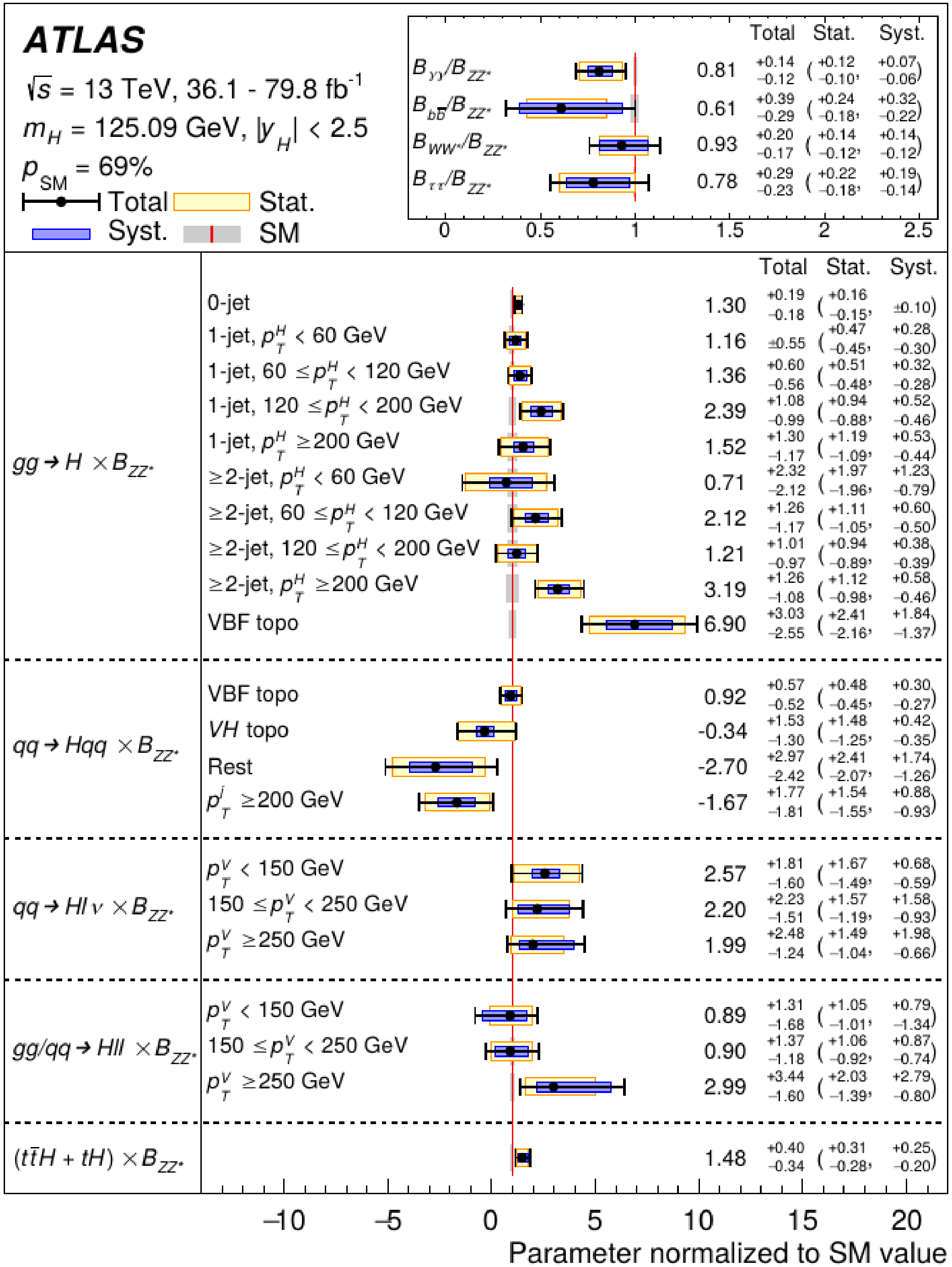


STXS Results

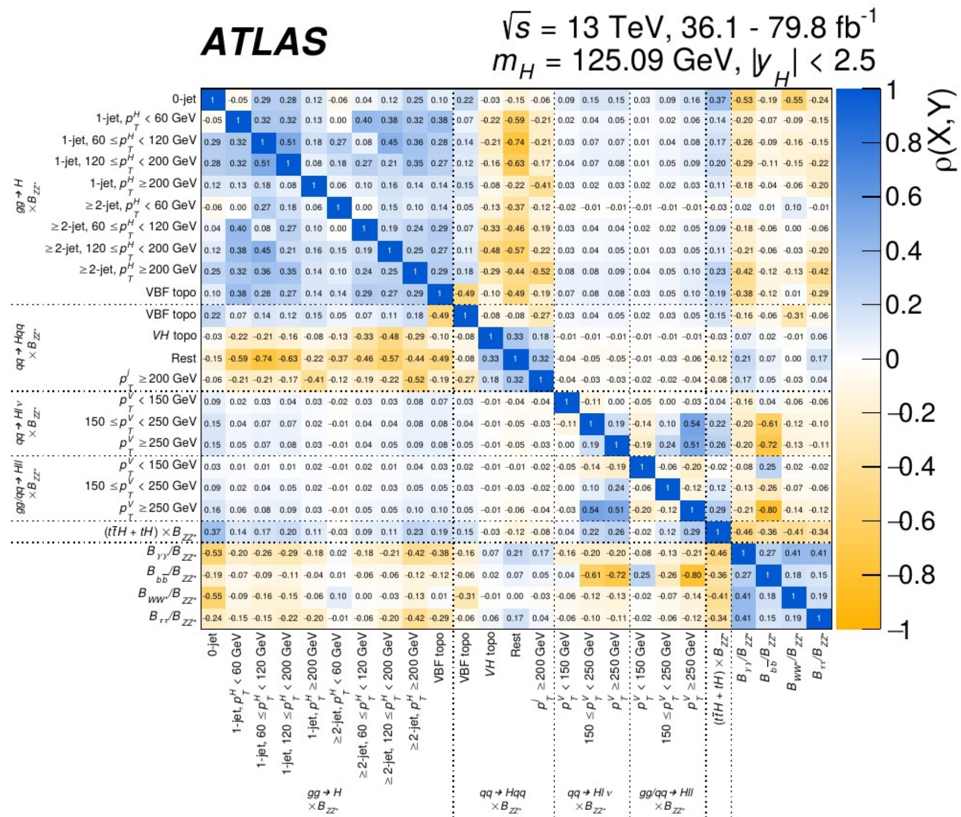
Measurement region $\left((\sigma_i \times B_{ZZ})/B_{ZZ}^{SM}\right)$	Value [pb]	Uncertainty [pb] Total	Stat.	Syst.	SM prediction [pb]
$gg \to H$, 0-jet	35.5	$^{+5.0}_{-4.7}$	$^{+4.4}_{-4.1}$	$^{+2.5}_{-2.2}$	27.5 ± 1.8
$gg \to H$, 1-jet, $p_T^H < 60$ GeV	3.7	$^{+2.8}_{-2.7}$	$^{+2.4}_{-2.3}$	$^{+1.5}_{-1.4}$	6.6 ± 0.9
$gg \to H$, 1-jet, $60 \le p_T^H < 120$ GeV	4.0	$^{+1.7}_{-1.5}$	$^{+1.5}_{-1.4}$	$^{+0.8}_{-0.7}$	4.6 ± 0.6
$gg \to H$, 1-jet, $120 \le p_T^H < 200$ GeV	1.0	$^{+0.6}_{-0.5}$	± 0.5	$^{+0.3}_{-0.2}$	0.75 ± 0.15
$gg \to H$, $\ge$ 1-jet, $p_T^H \ge 200$ GeV	1.2	$^{+0.5}_{-0.4}$	± 0.4	$^{+0.3}_{-0.2}$	0.59 ± 0.16
$gg \to H$, $\ge$ 2-jet, $p_T^H < 200$ GeV	5.4	$^{+2.7}_{-2.5}$	$^{+2.2}_{-2.1}$	$^{+1.5}_{-1.3}$	4.8 ± 1.0
$qq \to Hqq$, VBF topo + Rest	6.4	$^{+1.8}_{-1.5}$	$^{+1.5}_{-1.3}$	$^{+1.1}_{-0.9}$	4.07 ± 0.09
$qq \to Hqq$, VH topo	−0.06	$^{+0.70}_{-0.58}$	$^{+0.68}_{-0.57}$	$^{+0.16}_{-0.12}$	0.515 ± 0.019
$qq \to Hqq$, $p_T^j \ge 200$ GeV	−0.21	± 0.33	$^{+0.29}_{-0.28}$	$^{+0.15}_{-0.16}$	0.220 ± 0.005
$qq \to H\ell\nu$, $p_T^V < 250$ GeV	0.90	$^{+0.49}_{-0.40}$	$^{+0.40}_{-0.33}$	$^{+0.28}_{-0.22}$	0.393 ± 0.009
$qq \to H\ell\nu$, $p_T^V \ge 250$ GeV	0.023	$^{+0.028}_{-0.015}$	$^{+0.018}_{-0.012}$	$^{+0.022}_{-0.008}$	0.0122 ± 0.0006
$gg/qq \to H\ell\ell$, $p_T^V < 150$ GeV	0.17	$^{+0.25}_{-0.31}$	± 0.20	$^{+0.15}_{-0.24}$	0.200 ± 0.008
$gg/qq \to H\ell\ell$, $150 \le p_T^V < 250$ GeV	0.028	$^{+0.042}_{-0.037}$	$^{+0.033}_{-0.029}$	$^{+0.026}_{-0.023}$	0.0324 ± 0.0041
$gg/qq \to H\ell\ell$, $p_T^V \ge 250$ GeV	0.024	$^{+0.025}_{-0.013}$	$^{+0.016}_{-0.011}$	$^{+0.020}_{-0.006}$	0.0083 ± 0.0009
$t\bar{t}H$+tH	0.84	$^{+0.23}_{-0.19}$	$^{+0.18}_{-0.16}$	$^{+0.14}_{-0.11}$	$0.59\ ^{+0.04}_{-0.05}$

Branching fraction ratio	Value	Uncertainty Total	Stat.	Syst.	SM prediction
$B_{\gamma\gamma}/B_{ZZ}$	0.074	$^{+0.012}_{-0.010}$	$^{+0.010}_{-0.009}$	$^{+0.006}_{-0.005}$	0.0860 ± 0.0010
$B_{b\bar{b}}/B_{ZZ}$	14	$^{+8}_{-6}$	$^{+5}_{-4}$	$^{+6}_{-5}$	22.0 ± 0.5
B_{WW}/B_{ZZ}	7.0	$^{+1.5}_{-1.3}$	$^{+1.1}_{-0.9}$	$^{+1.0}_{-0.9}$	$8.15 \pm\ < 0.01$
$B_{\tau\tau}/B_{ZZ}$	2.1	$^{+0.7}_{-0.6}$	± 0.5	$^{+0.5}_{-0.3}$	2.37 ± 0.02

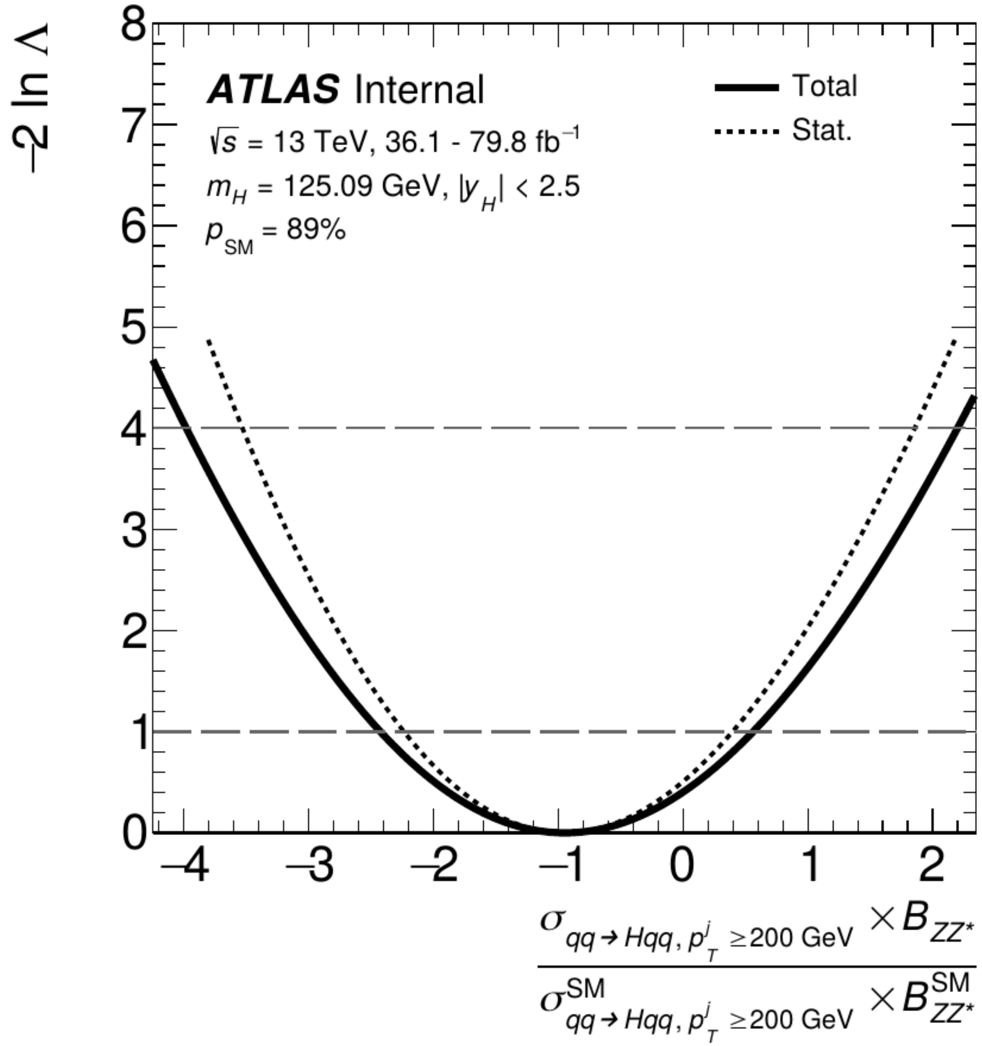
Weakly-Merged STXS results



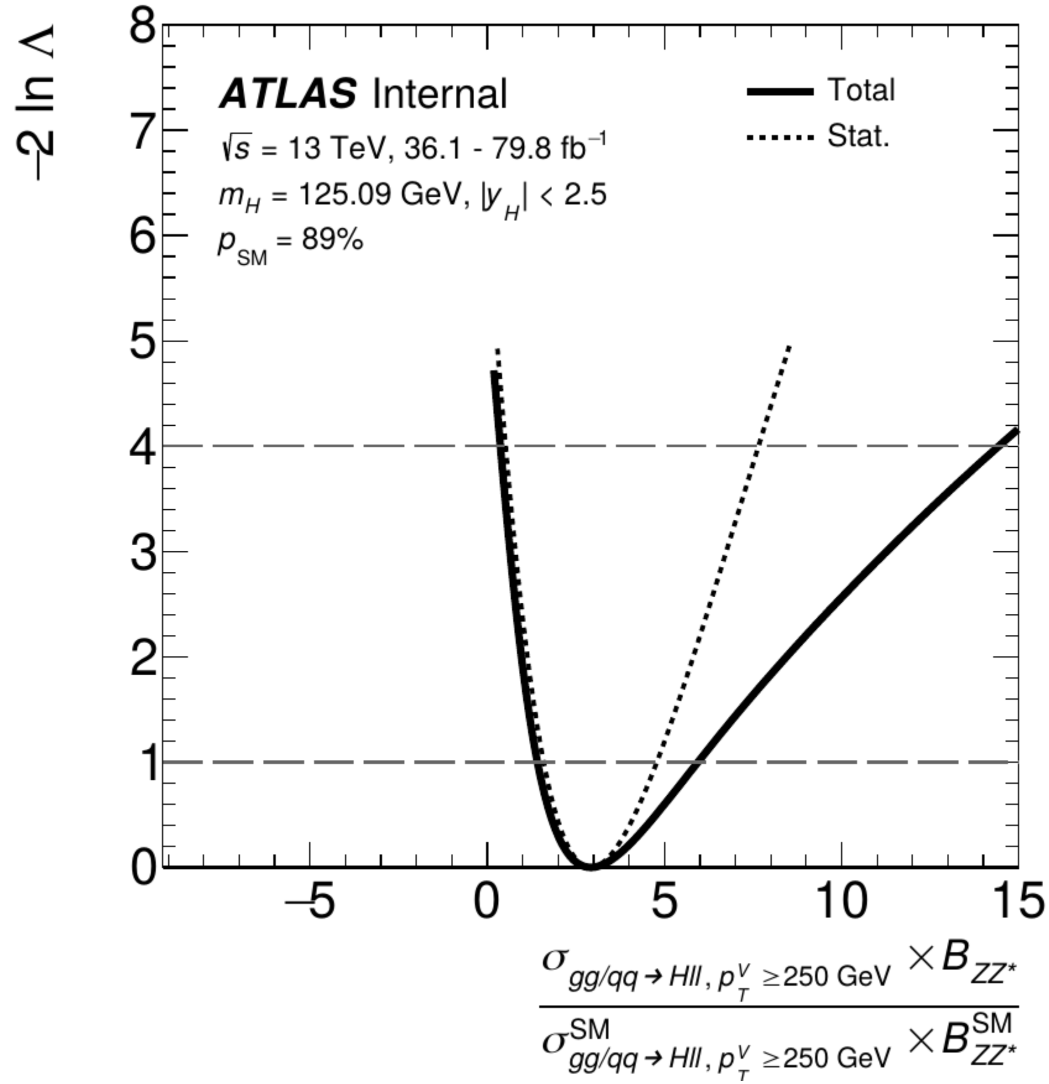
- Merge VBF-topo bins in gg→H and EW qqH
- Merge qq→ZH and gg→ZH
- Merge VH jet bins and (0,75) GeV and (75,150) GeV bins



STXS Scans

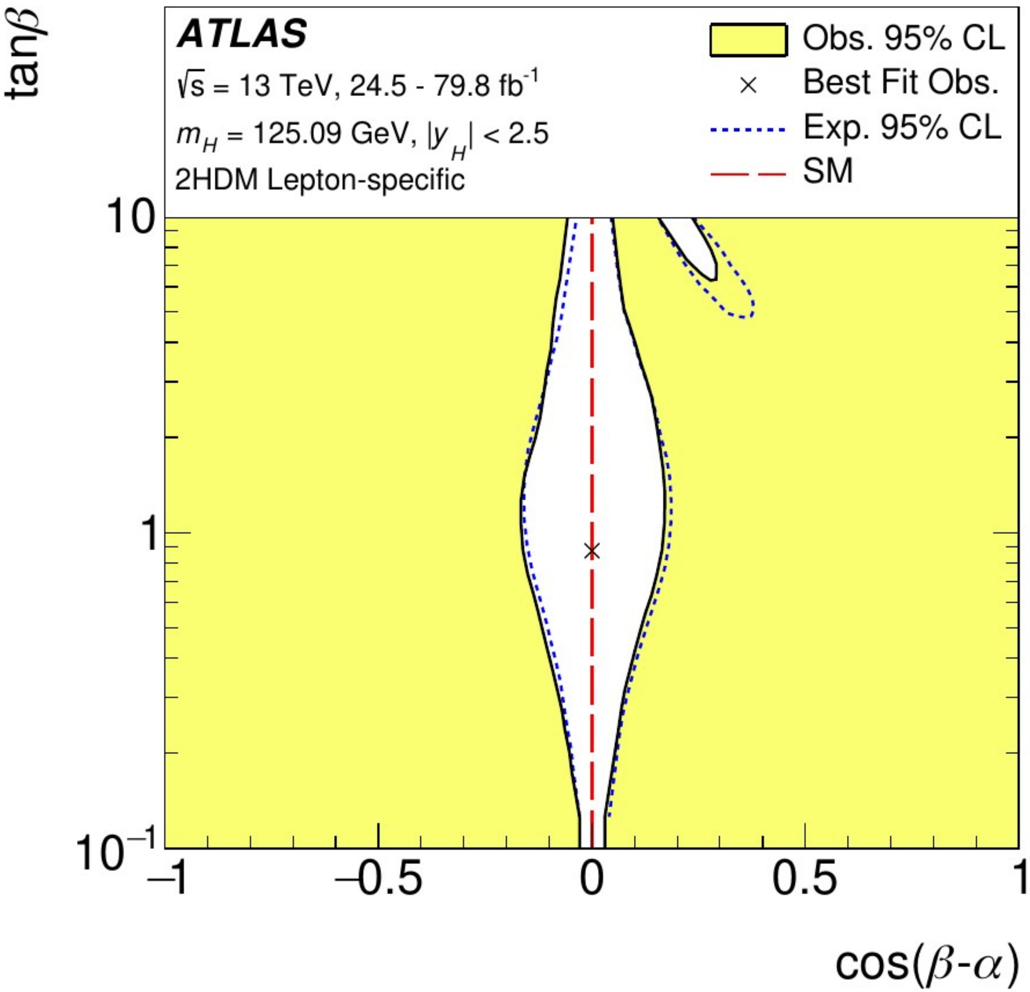


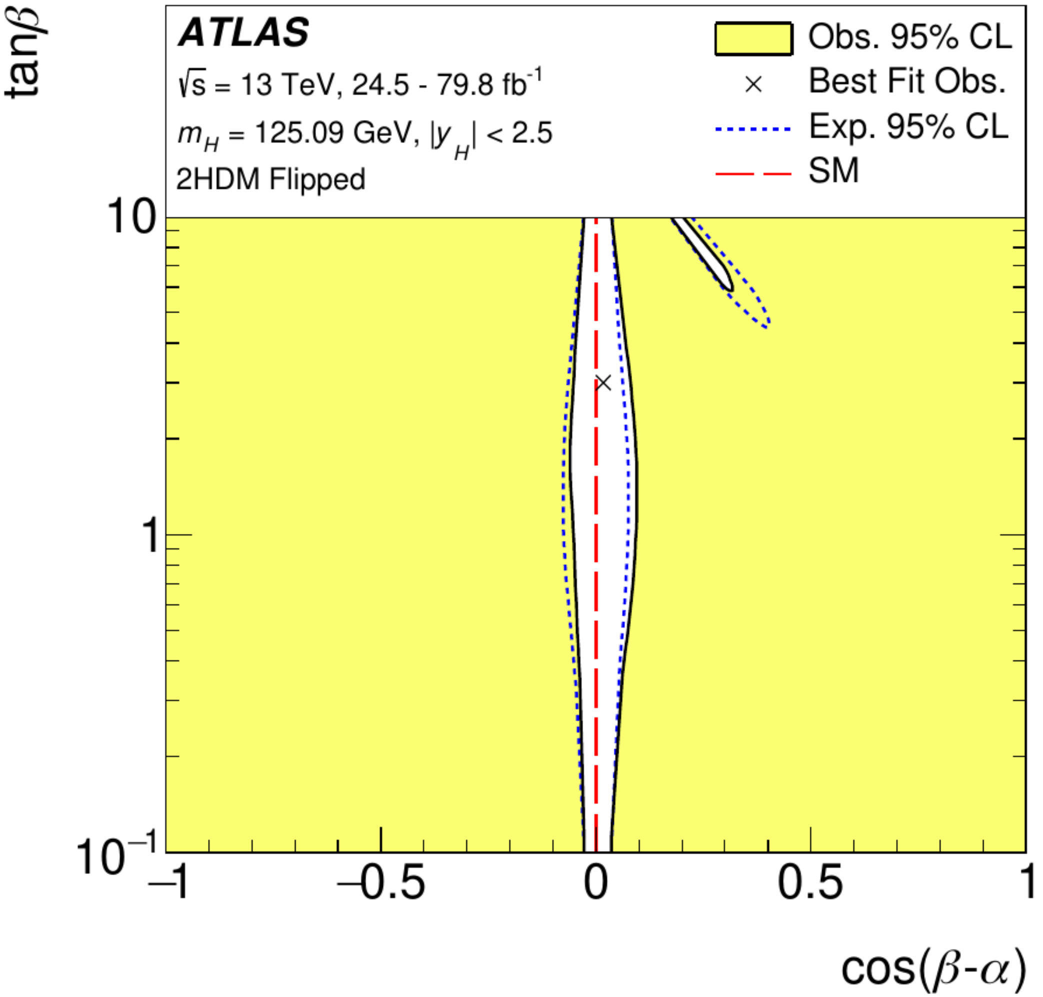
ATLAS Internal
$\sqrt{s}$ = 13 TeV, 36.1 - 79.8 fb^{-1}
m_H = 125.09 GeV, $|y_H|$ < 2.5
p_{SM} = 89%
Total
Stat.
$-2 \ln \Lambda$
$\frac{\sigma_{qq \to Hqq,\, p_T^j \geq 200\ \mathrm{GeV}} \times B_{ZZ^*}}{\sigma^{SM}_{qq \to Hqq,\, p_T^j \geq 200\ \mathrm{GeV}} \times B^{SM}_{ZZ^*}}$



ATLAS Internal
$\sqrt{s}$ = 13 TeV, 36.1 - 79.8 fb^{-1}
m_H = 125.09 GeV, $|y_H|$ < 2.5
p_{SM} = 89%
Total
Stat.
$-2 \ln \Lambda$
$\frac{\sigma_{gg/qq \to Hll,\, p_T^V \geq 250\ \mathrm{GeV}} \times B_{ZZ^*}}{\sigma^{SM}_{gg/qq \to Hll,\, p_T^V \geq 250\ \mathrm{GeV}} \times B^{SM}_{ZZ^*}}$

2HDM Results

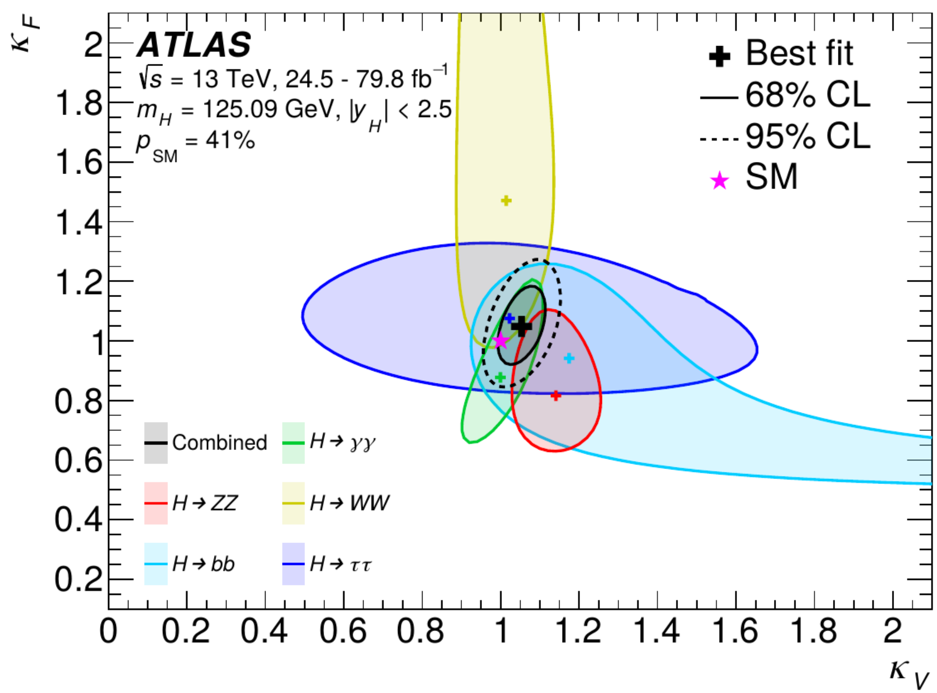


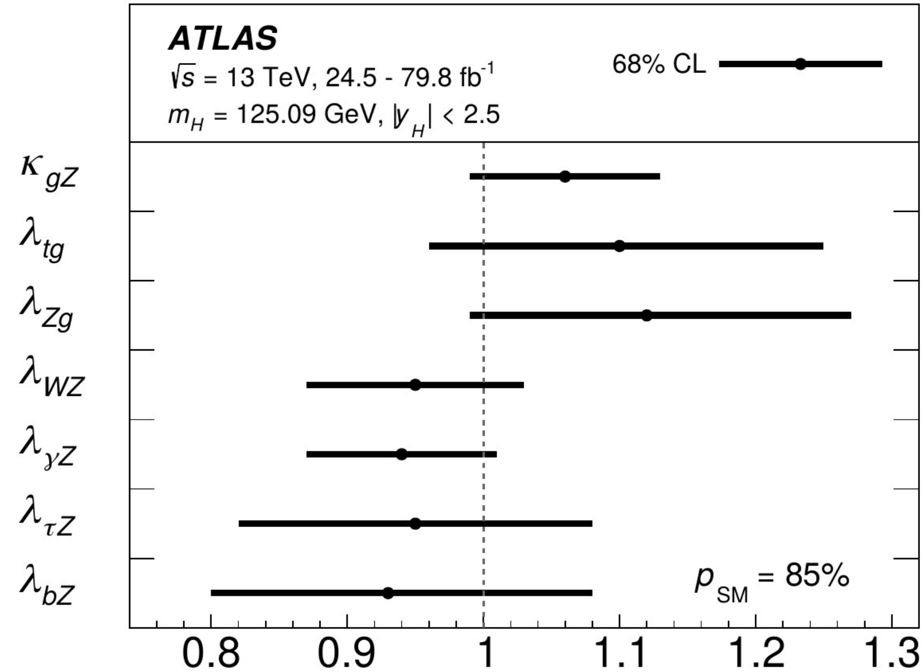


Generic model results

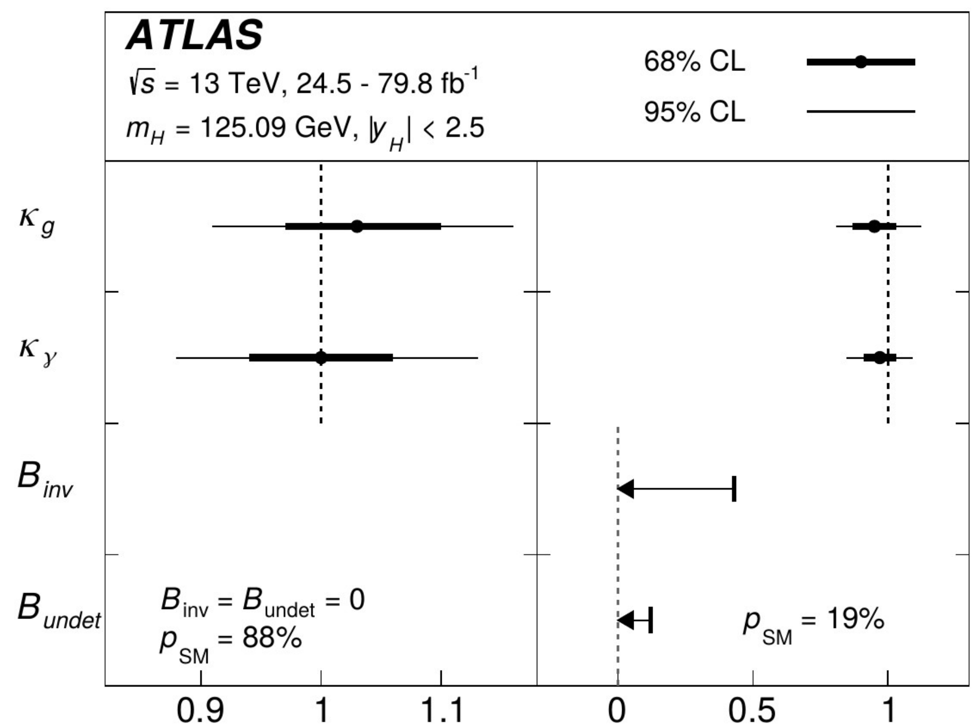
Parameter	(a) $B_{\text{inv}} = B_{\text{undet}} = 0$	(b) B_{inv} free, $B_{\text{undet}} \geq 0$, $\kappa_{W,Z} \leq 1$	(c) $B_{\text{BSM}} \geq 0$, $\kappa_{\text{off}} = \kappa_{\text{on}}$
κ_Z	1.11 ± 0.08	> 0.88 at 95% CL	$1.20\,^{+\,0.18}_{-\,0.17}$
κ_W	1.05 ± 0.09	> 0.85 at 95% CL	1.15 ± 0.18
κ_b	$1.03\,^{+\,0.19}_{-\,0.17}$	$0.85\,^{+\,0.15}_{-\,0.13}$	$1.14\,^{+\,0.21}_{-\,0.25}$
κ_t	$1.09\,^{+\,0.15}_{-\,0.14}$	$[-1.08, -0.77] \cup [0.96, 1.23]$ at 68% CL	1.18 ± 0.23
κ_τ	$1.05\,^{+\,0.16}_{-\,0.15}$	0.99 ± 0.14	$1.16\,^{+\,0.22}_{-\,0.24}$
κ_γ	1.05 ± 0.09	$0.96\,^{+\,0.08}_{-\,0.06}$	$1.16\,^{+\,0.17}_{-\,0.18}$
κ_g	$0.99\,^{+\,0.11}_{-\,0.10}$	$1.05\,^{+\,0.12}_{-\,0.14}$	$1.08\,^{+\,0.17}_{-\,0.18}$
B_{inv}	-	< 0.30 at 95% CL	-
B_{undet}	-	< 0.21 at 95% CL	-
B_{BSM}	-	-	< 0.49 at 95% CL

κ Model Results

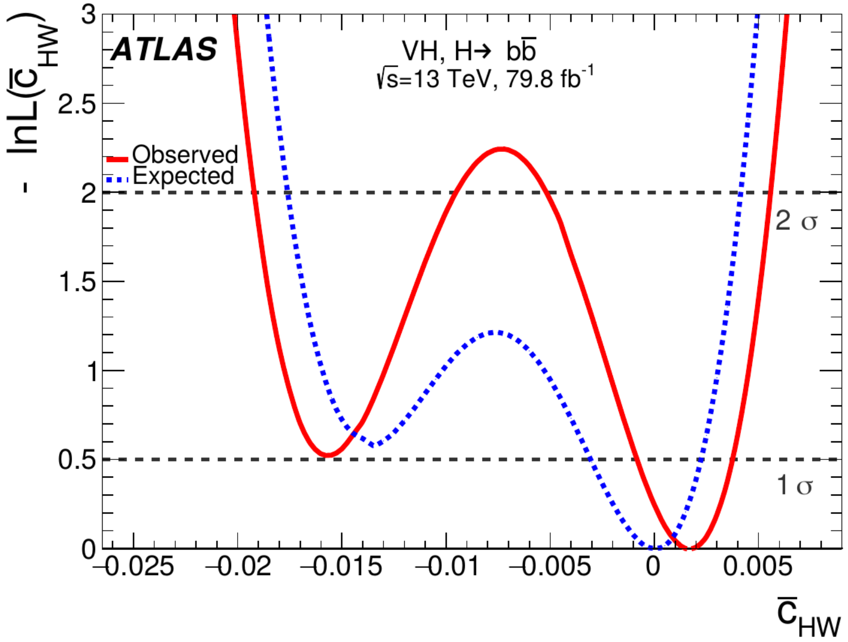


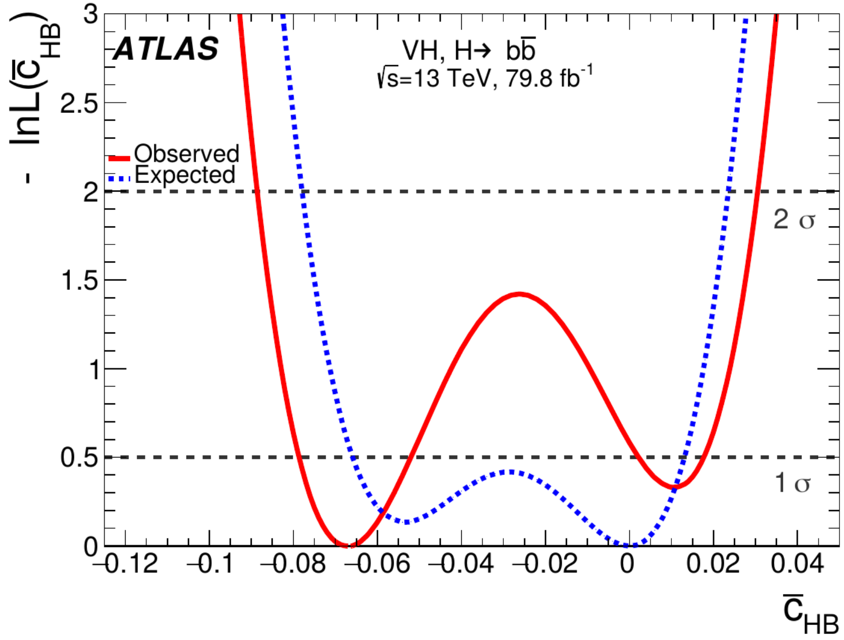


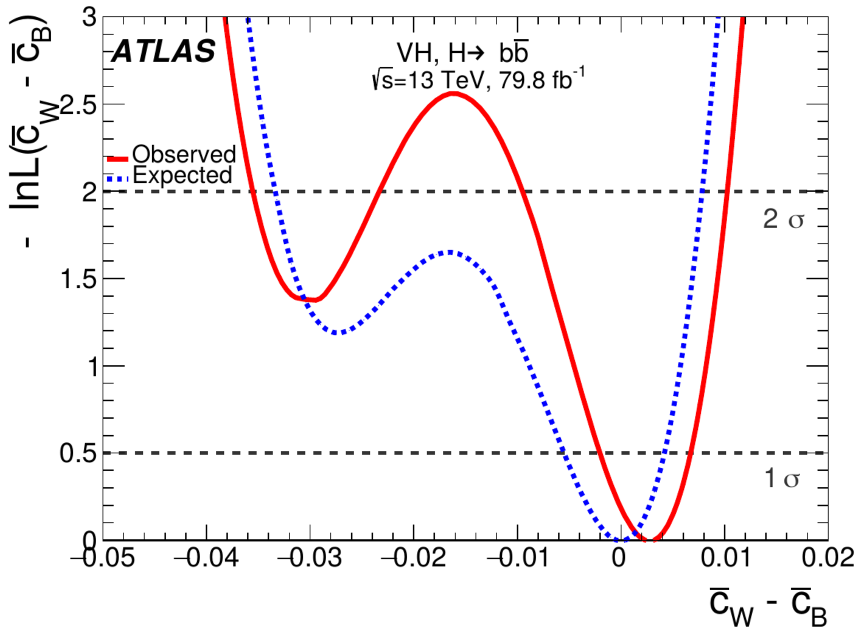
Parameter	Definition in terms of κ modifiers	Result
κ_{gZ}	$\kappa_g \kappa_Z / \kappa_H$	1.06 ± 0.07
λ_{tg}	κ_t / κ_g	$1.10^{+0.15}_{-0.14}$
λ_{Zg}	κ_Z / κ_g	$1.12^{+0.15}_{-0.13}$
λ_{WZ}	κ_W / κ_Z	0.95 ± 0.08
$\lambda_{\gamma Z}$	κ_γ / κ_Z	0.94 ± 0.07
$\lambda_{\tau Z}$	κ_τ / κ_Z	0.95 ± 0.13
λ_{bZ}	κ_b / κ_Z	$0.93^{+0.15}_{-0.13}$

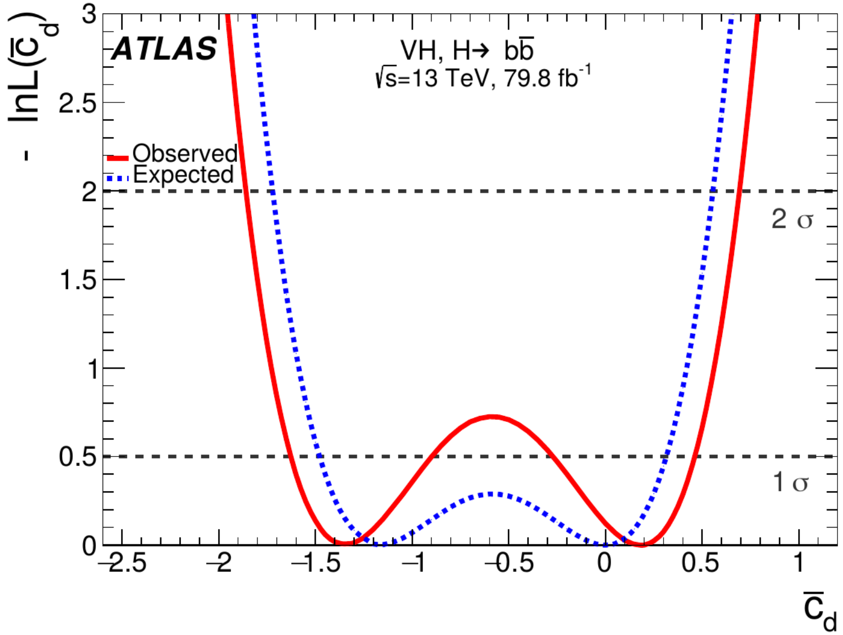


VH→bb EFT


ATLAS
VH, H→ bb̄
√s=13 TeV, 79.8 fb-1
Observed
Expected
2 σ
1 σ
- lnL($\bar{c}_{HW}$)
$\bar{c}_{HW}$


ATLAS
VH, H→ bb̄
√s=13 TeV, 79.8 fb-1
Observed
Expected
2 σ
1 σ
- lnL($\bar{c}_{HB}$)
$\bar{c}_{HB}$


ATLAS
VH, H→ bb̄
√s=13 TeV, 79.8 fb-1
Observed
Expected
2 σ
1 σ
- lnL($\bar{c}_W$ - $\bar{c}_B$)
$\bar{c}_W$ - $\bar{c}_B$


ATLAS
VH, H→ bb̄
√s=13 TeV, 79.8 fb-1
Observed
Expected
2 σ
1 σ
- lnL($\bar{c}_d$)
$\bar{c}_d$

EFT Interpretation of the H→γγ differential XS analysis

Details in D. Boerner's talk yesterday

Differential fiducial cross-sections measured in H→γγ

→ Use unfolded distributions in $p_T^{\gamma\gamma}$, N_{jets}, m_{jj}, $\Delta\varphi_{jj}$ and p_T^{j1}

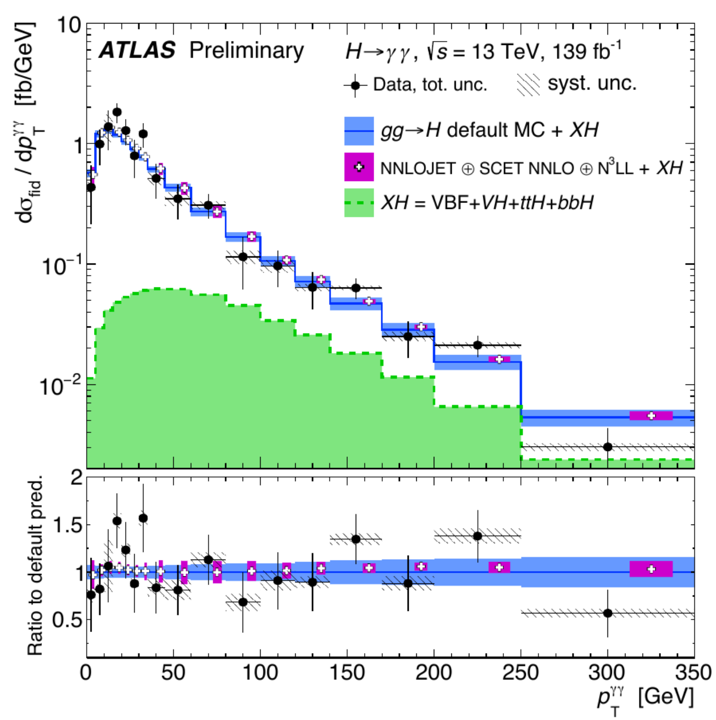
→ Correlations between distributions obtained from bootstrap

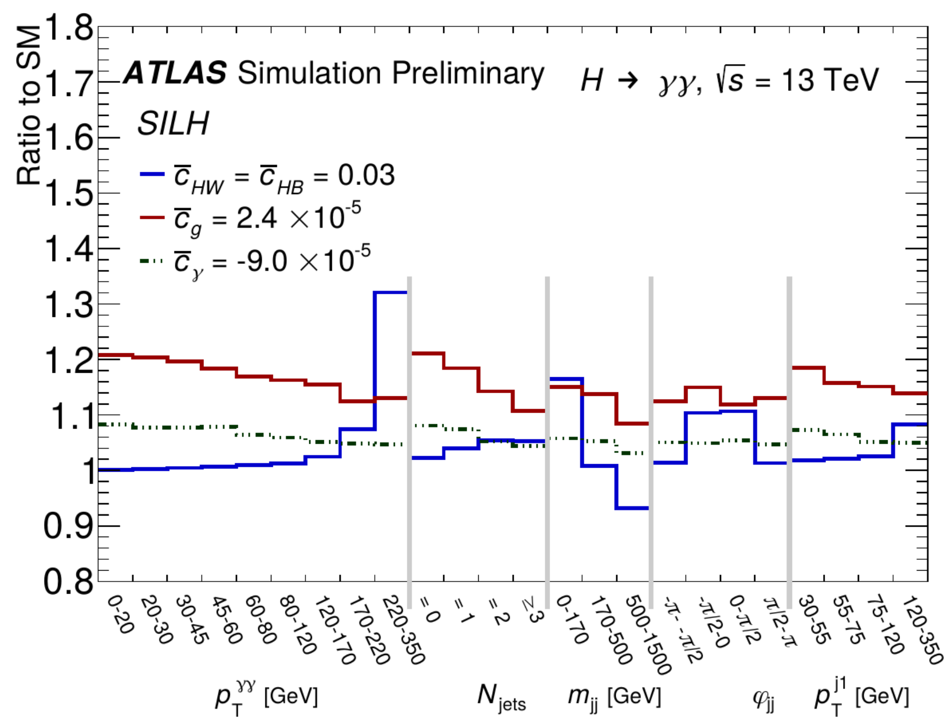
HEL Operators Considered:

(Results also provided in SMEFT basis)

Operator	CP-even		CP-odd
$O_g = H^\dagger H G_{\mu\nu} G^{\mu\nu}$	$\bar{c}_g$	+ CP-odd operators →	$\tilde{c}_g$
$O_\gamma = H^\dagger H B_{\mu\nu} B^{\mu\nu}$	$\bar{c}_\gamma$		$\tilde{c}_\gamma$
$O_{HW} = i(D^\mu H)^\dagger \sigma^i (D^\nu H) W^i_{\mu\nu}$	$\bar{c}_{HW}$		$\tilde{c}_{HW}$
$O_{HB} = i(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$	$\bar{c}_{HB}$		$\tilde{c}_{HB}$

Consider $\bar{c}_{HW}=\bar{c}_{HB}$ and $\tilde{c}_{HW}=\tilde{c}_{HB}$ only to avoid too-large H→Zγ rates

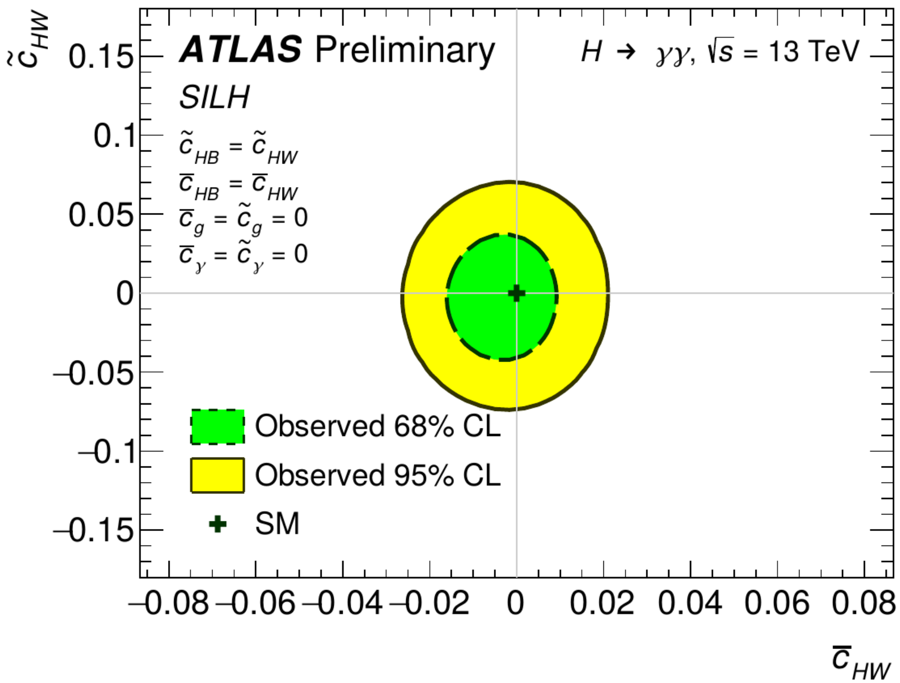


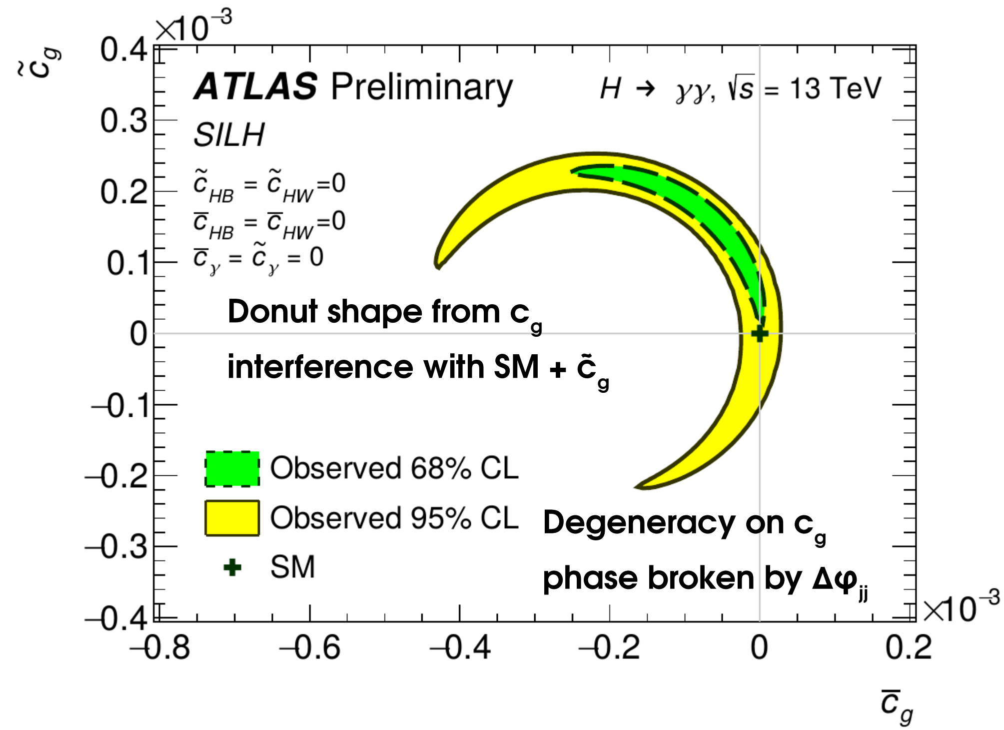


ATLAS-CONF-2019-029

H→γγ differential XS EFT Results

ATLAS-CONF-2019-029





Coefficient	Observed 95% CL limit	Expected 95% CL limit
$\bar{c}_g$	$[-0.26, 0.26] \times 10^{-4}$	$[-0.25, 0.25] \cup [-4.7, -4.3] \times 10^{-4}$
$\tilde{c}_g$	$[-1.3, 1.1] \times 10^{-4}$	$[-1.1, 1.1] \times 10^{-4}$
$\bar{c}_{HW}$	$[-2.5, 2.2] \times 10^{-2}$	$[-3.0, 3.0] \times 10^{-2}$
$\tilde{c}_{HW}$	$[-6.5, 6.3] \times 10^{-2}$	$[-7.0, 7.0] \times 10^{-2}$
$\bar{c}_\gamma$	$[-1.1, 1.1] \times 10^{-4}$	$[-1.0, 1.2] \times 10^{-4}$
$\tilde{c}_\gamma$	$[-2.8, 4.3] \times 10^{-4}$	$[-2.9, 3.8] \times 10^{-4}$