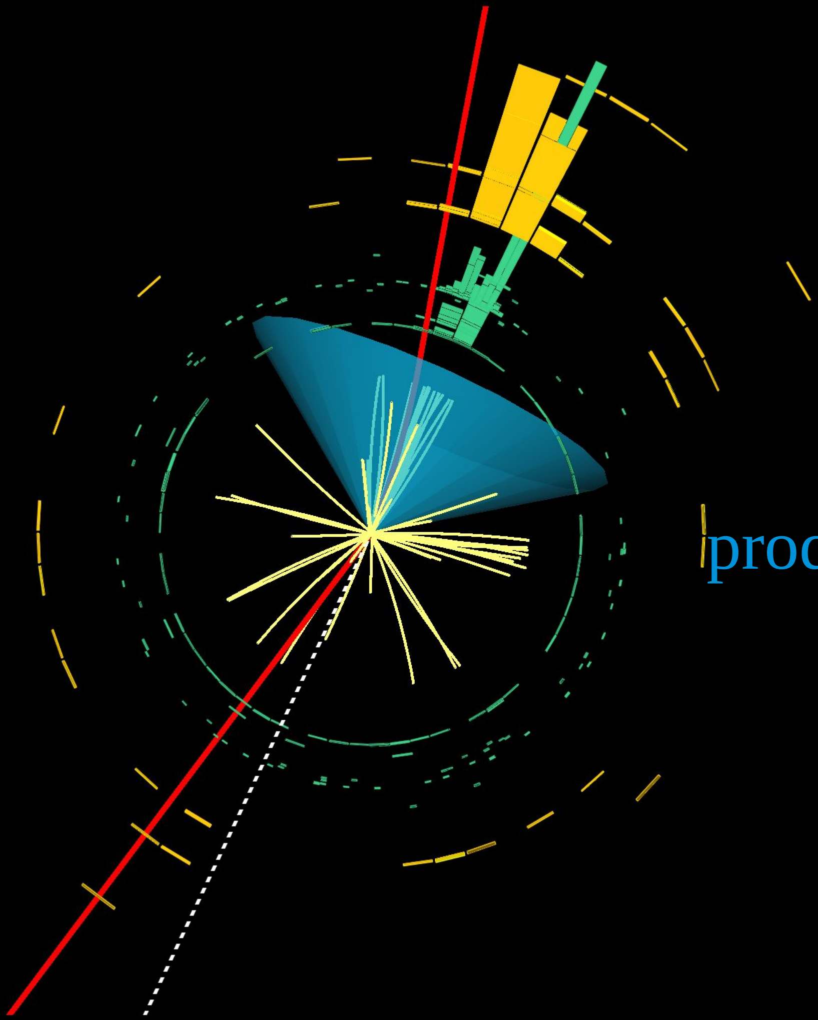


Stronger together:

Combined measurements of Higgs boson production and decays with the ATLAS detector

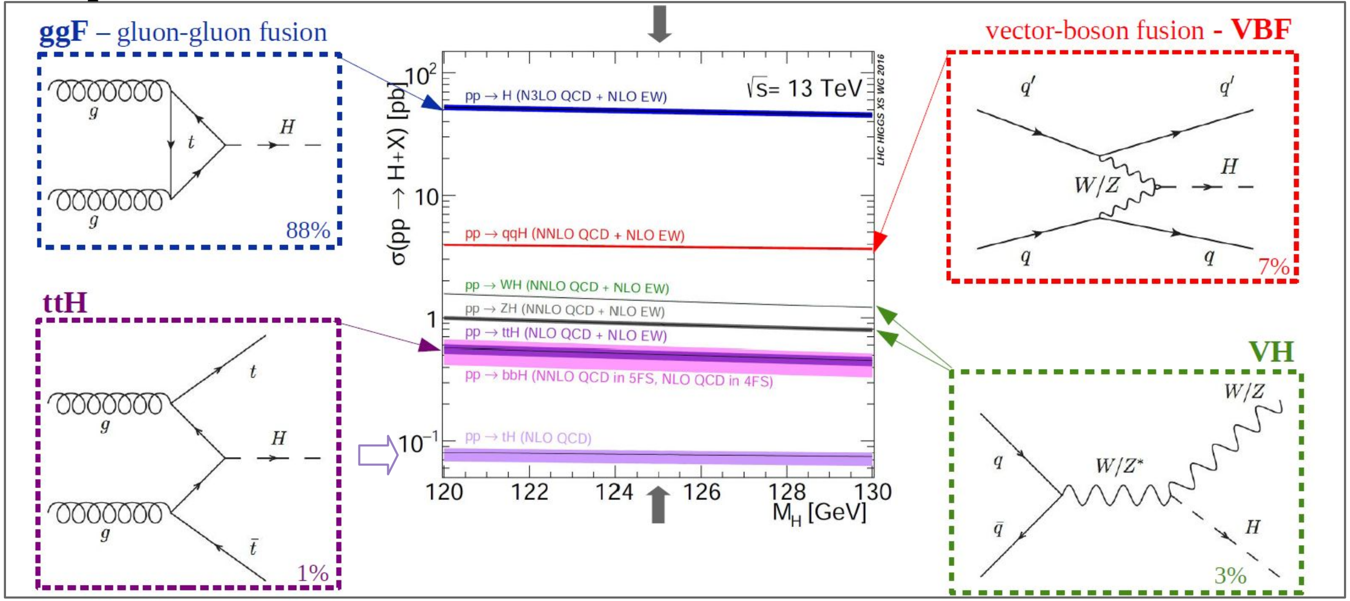
Hannah Arnold (Nikhef)
on behalf of the ATLAS collaboration

Higgs 2021
October 21, 2021

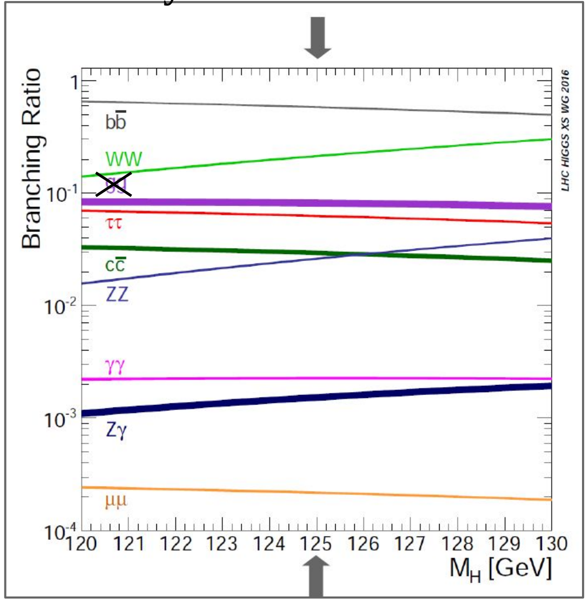
Introduction

- Since the Higgs boson discovery in 2012, many properties studied – in particular its production and decay
- Most combinations of the dominant production times decay modes have been probed; also thanks to the wealth and high-quality of the *pp* data of LHC Run-2
- **Combinations** of the individual measurements allow to provide the **most precise measurements and most stringent constraints** on potential beyond-the-Standard Model (BSM) modifications with **minimal assumptions**

SM production



SM decay



Outline

Nikhef

- **Combined measurements of Higgs-boson production and decay** (ATLAS-CONF-2021-053)

New for Higgs 2021

  - Global signal-strength / production cross section (× branching ratios)

See also Q. Buat's talk (Mo, 12:05; ATLAS: Wildcard)

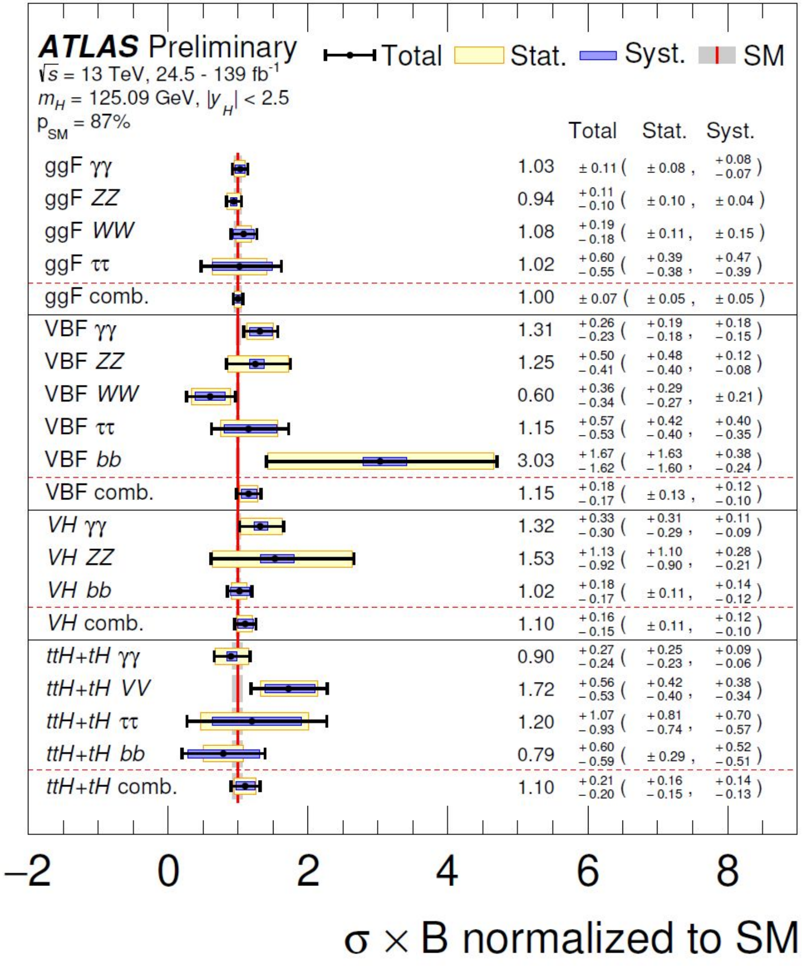
  - *Simplified Template Cross-Section* (STXS) measurement
    - **Intermezzo: *VH, H→bb* combination** (ATLAS-CONF-2021-051)
  - Model-independent interpretation: couplings constraints in the *κ framework*
    - EFT interpretation discussed in C. Burgard's talk (Tue, 15:00; Parallel: EFT) and M. Battaglia's talk (Thu, 10:00, Plenary: EFT)
  - Model-dependent interpretation in the *Two Higgs Doublet Model (2HDM)*

- **Combination of searches for invisible Higgs-boson decays** (ATLAS-CONF-2020-052)

See also S. Snyder's talk (Wed 14.30 pm, Plenary: BSM)

- **Combined (differential) cross-section measurement of $H\rightarrow\gamma\gamma$ and $H\rightarrow ZZ^{*}\rightarrow 4l$** (ATLAS-CONF-2019-032)

Combined Higgs boson measurements – last year



Last year's status – ICHEP 2020 ATLAS-CONF-2020-027

Analysis decay channel	Target Prod. Modes	$\mathcal{L}$ [fb^{-1}]	Ref.	Used in meas.
$H \to \gamma\gamma$	ggF, VBF, $WH, ZH, t\bar{t}H, tH$	139	[10]	Everywhere
$H \to ZZ^*$	ggF, VBF, $WH, ZH, t\bar{t}H(4\ell)$	139	[11]	Everywhere
	$t\bar{t}H$ excl. $H \to ZZ^* \to 4\ell$	36.1	[16, 18]	Sec. 5 & 7
$H \to WW^*$	ggF, VBF	36.1	[12]	Sec. 5 & 7
	$t\bar{t}H$		[16, 18]	
$H \to \tau\tau$	ggF, VBF	36.1	[13]	Sec. 5 & 7
	$t\bar{t}H$		[16, 18]	
$H \to b\bar{b}$	VBF	24.5 – 30.6	[15]	Sec. 5 & 7
	WH, ZH	139	[14]	Everywhere
	$t\bar{t}H$	36.1	[17, 18]	Sec. 5 & 7
$H \to \mu\mu$	ggF, VBF, $VH, t\bar{t}H$	139	[19]	Sec. 7.4
$H \to inv$	VBF	139	[20]	Sec. 7.3 & 7.5

STXS

Sec. 5 - μ, σ (×BR)

Sec 7 - coupling interpretation

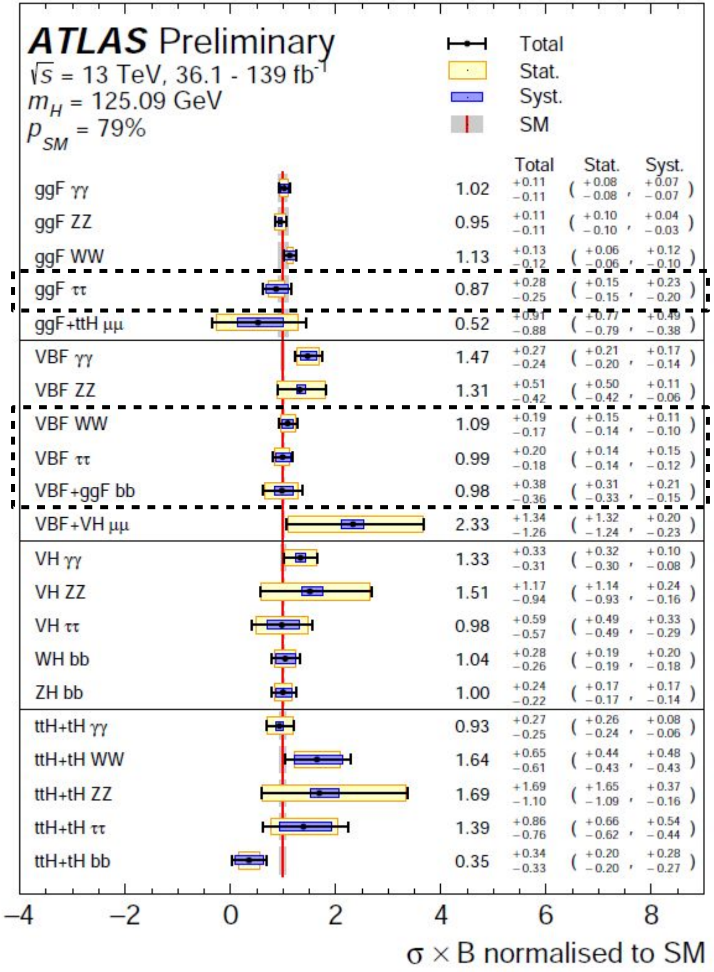
Lots happened since then

– will discuss in the following the **new results** and *highlight differences to this preliminary result* where relevant

Combined Higgs boson measurements – this year

Nikhef

Total uncertainties greatly reduced (-50-80%)



ATLAS-CONF-2021-053 **New**

Input analyses

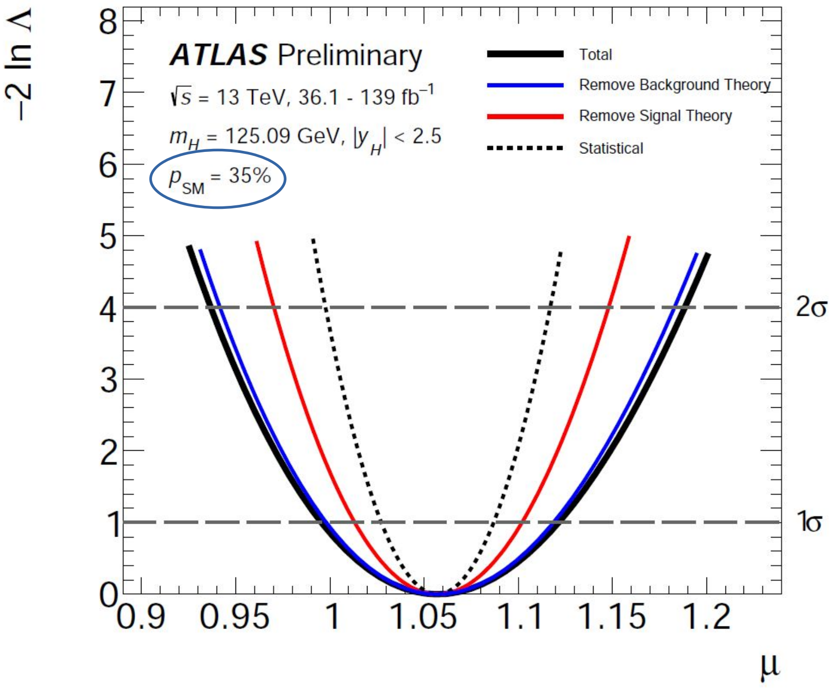
Decay channel	Target Production Modes	$\mathcal{L}$ [fb^{-1}]	Ref.	Used in combined measurement
$H \to \gamma\gamma$	ggF, VBF, $WH, ZH, t\bar{t}H, tH$	139	[10]	Everywhere
$H \to ZZ^*$	ggF, VBF, $WH, ZH, t\bar{t}H(4\ell)$	139	[11]	Everywhere
	$t\bar{t}H$ excl. $H \to ZZ^* \to 4\ell$	36.1	[18]	Everywhere but STXS and SMEFT
$H \to WW^*$	ggF, VBF	139	[12]	Everywhere
	$t\bar{t}H$	36.1	[18]	Everywhere but STXS and SMEFT
$H \to \tau\tau$	ggF, VBF, $WH, ZH, t\bar{t}H$	139	[13]	Everywhere
	$t\bar{t}H$	36.1	[18]	Everywhere but STXS and SMEFT
$H \to b\bar{b}$	WH, ZH	139	[14, 15]	Everywhere
	VBF	126	[16]	Everywhere
	$t\bar{t}H$	139	[17]	Everywhere
$H \to \mu\mu$	ggF, VBF, $VH, t\bar{t}H$	139	[19]	Everywhere but STXS and SMEFT
$H \to Z\gamma$	ggF, VBF, $VH, t\bar{t}H$	139	[20]	Everywhere but STXS and SMEFT
$H \to inv$	VBF	139	[21]	Sec. 6.3 & 6.5

- All analyses use **full Run-2 dataset** (except ttH(→mult. Leptons))
  - Systematic uncertainties start to dominate (**!**)
- ***H*→ *Zγ*** and **VH/ttH(→ *ττ*)** **included for the first time**
- **Improved analysis techniques** and **more granular kinematic categorisation** targeting stage 1.2 **STXS measurement**
  - e.g. ≥ 2-jet category in ggF, $H \to WW^*$; more bins at high p_T(V/H) in *VH*/ttH(→*bb*)

Global signal strength

ATLAS-CONF-2021-053

New



$$\mu_{if} = \frac{\sigma_i}{\sigma_i^{SM}} \times \frac{B_f}{B_f^{SM}}$$

Signal strength
for *production mode i* and *final state f*

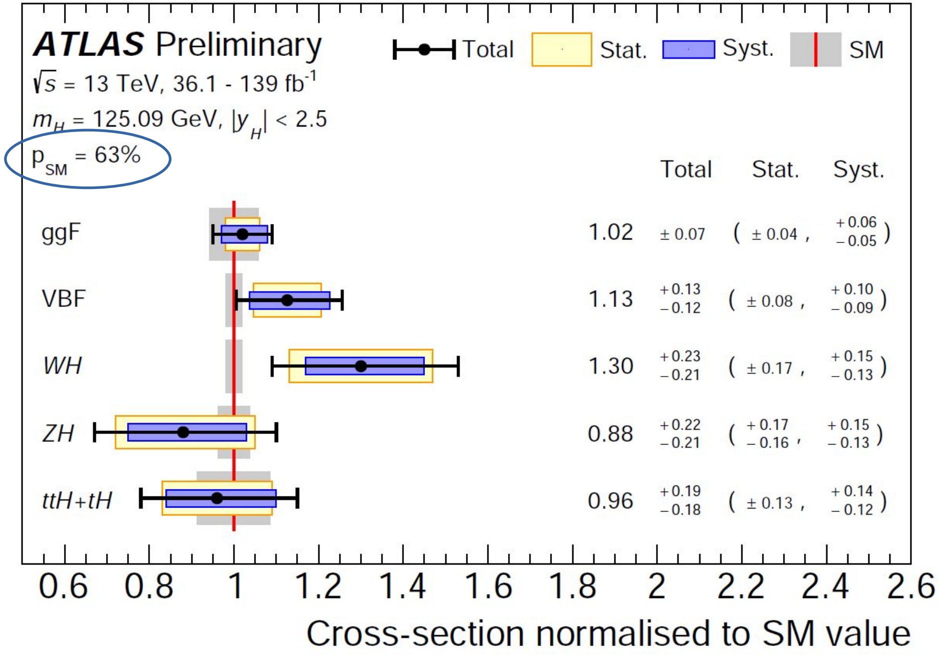
Assume same signal strength for all *i×f*

$$\mu = 1.06 \pm 0.06 \;=\; 1.06 \pm 0.03\,(\text{stat.}) \;\pm 0.03\,(\text{exp.}) \;\pm 0.04\,(\text{sig. th.}) \;\pm 0.02\,(\text{bkg. th.})$$

- Central value ~unchanged
- **Total unc. reduced by ~10%** → mainly because of increase in analysed data (in $H \rightarrow WW^*$ and $H \rightarrow \tau\tau$)
  - Signal theory → largest source of uncertainties
- Good agreement with **SM expectation**

Production cross-sections

ATLAS-CONF-2021-053



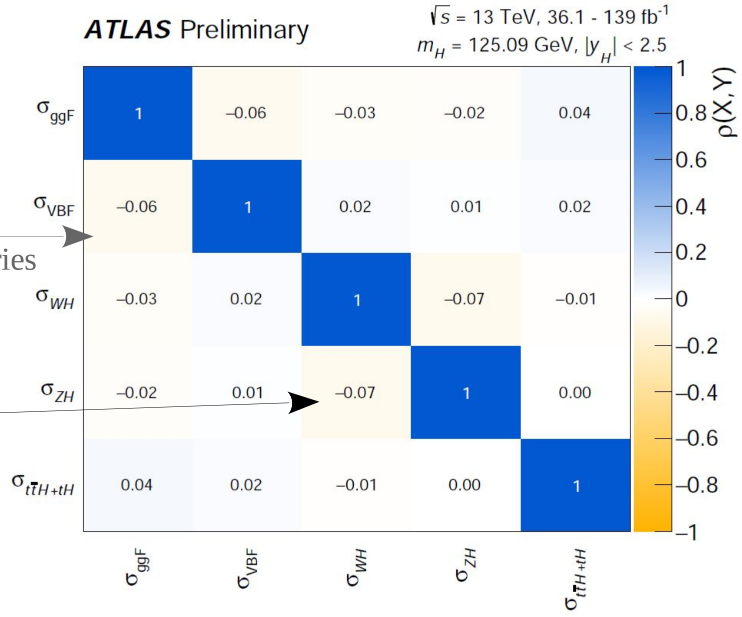
New

...for the main production modes

- **Assumption**: SM branching ratios (→ *fixed*)
- Each mode measured with **<~20% precision**
  - **Total unc. on VBF production reduced by ~30%**
- In general, reduced correlations (< 10%)

Unchanged; ggF contamination in VBF-enriched categories

×2 larger



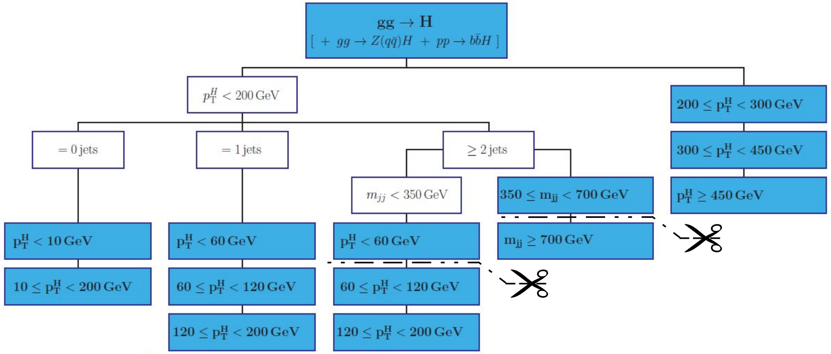
- **Increased difference between *WH* and *ZH* cross-sections** mainly due to $H \rightarrow WW^*$ and (new) $H \rightarrow \tau\tau$ *only sensitive to VH* (due to limited data stat.)
- **Good agreement with SM expectation**

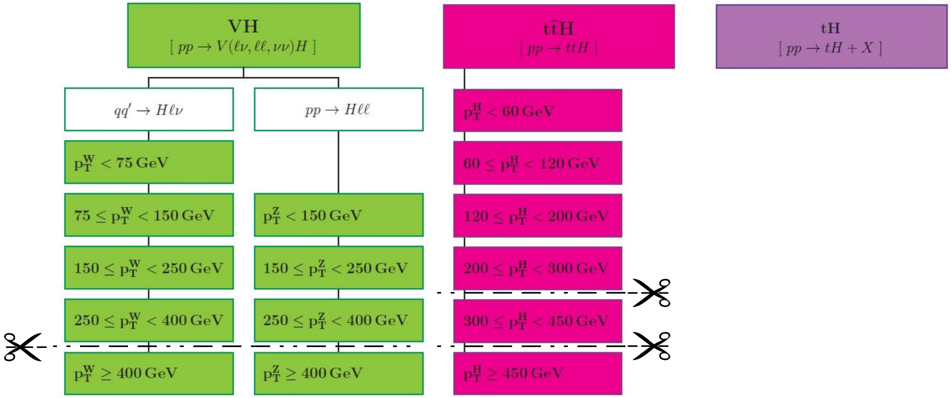
STXS measurement

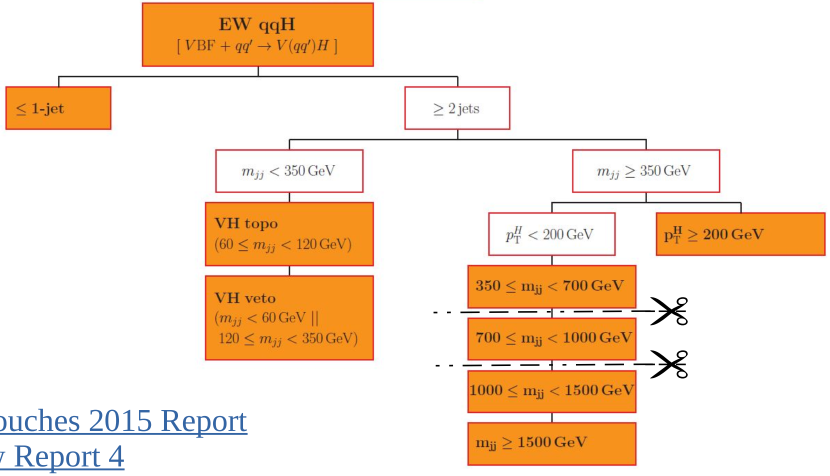
ATLAS-CONF-2021-053

Simplified Template Cross-Sections → **Higgs cross-section measurements *per production mode***
in exclusive kinematic regions

New







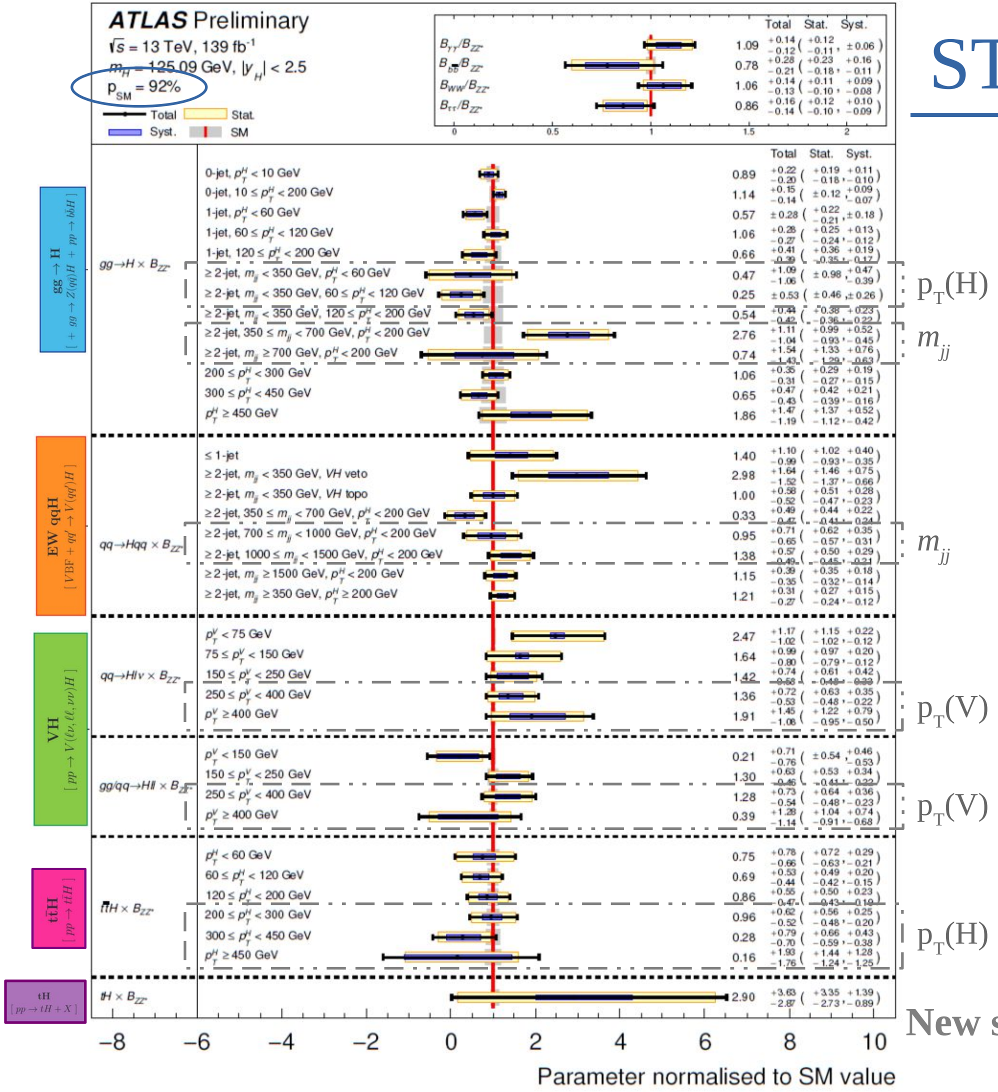
✂ = **newly introduced splits**

Les Houches 2015 Report
Yellow Report 4

Some "dashed" bins split, some bins merged relative to Stage 1.2 scheme

STXS results

New



New splits

$$(\sigma \times B)_{if} = (\sigma \times B)_{i,ZZ} \cdot \left(\frac{B_f}{B_{ZZ}}\right)$$

$f \neq ZZ^*$

- **Most granular, simultaneous measurement** to date (41 POI-fit!) – thanks to inclusion of new data and improved analyses
- For all bins **stat. unc. dominating**; only in few bins syst. unc. start to matter (e.g. ggF 0 jet)
- tH production:
  - Obs. (exp.) significance: 1.0 (0.4)σ
  - Obs. (exp.) limit @95% CL: 9.3 (6.7) × SM prediction
- **Very good agreement with SM prediction**

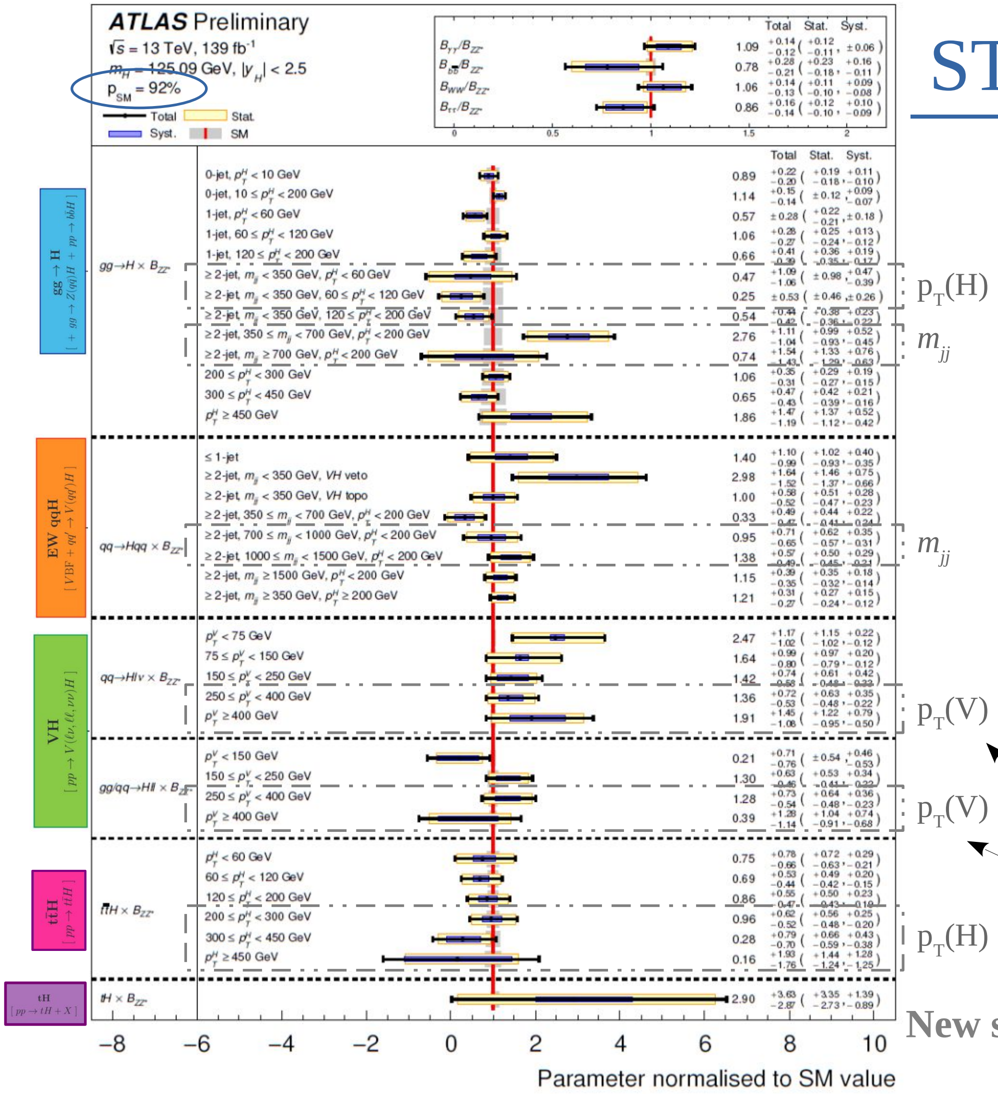
w/o $H\rightarrow\mu\mu$, $H\rightarrow inv.$, $H\rightarrow Z\gamma$, ttH(→ multi. leptons)

STXS results

ATLAS-CONF-2021-053

Nikhef

New



New splits

$$(\sigma \times B)_{if} = (\sigma \times B)_{i,ZZ} \cdot \left(\frac{B_f}{B_{ZZ}}\right)$$

$f \neq ZZ^*$

- **Most granular, simultaneous measurement** to date (41 POI-fit!) – thanks to inclusion of new data and improved analyses
- For all bins **stat. unc. dominating**; only in few bins syst. unc. start to matter (e.g. ggF 0 jet)
- tH production:
  - Obs. (exp.) significance: 1.0 (0.4) σ
  - Obs. (exp.) limit @95% CL: 9.3 (6.7) × SM prediction
- **Very good agreement with SM prediction**

Thanks to *VH*, $H\rightarrow bb$ combination

w/o $H\rightarrow\mu\mu$, $H\rightarrow inv.$, $H\rightarrow Z\gamma$, ttH(→ multi. leptons)

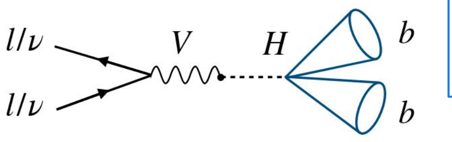
Intermezzo: VH, $H \rightarrow bb$ combination

ATLAS-CONF-2021-051

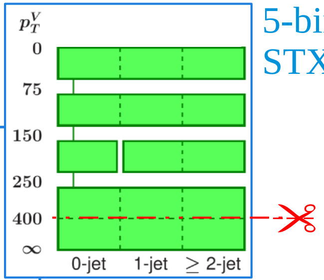
Nikhef

Resolved

Eur. Phys. J. C 81 (2021) 178



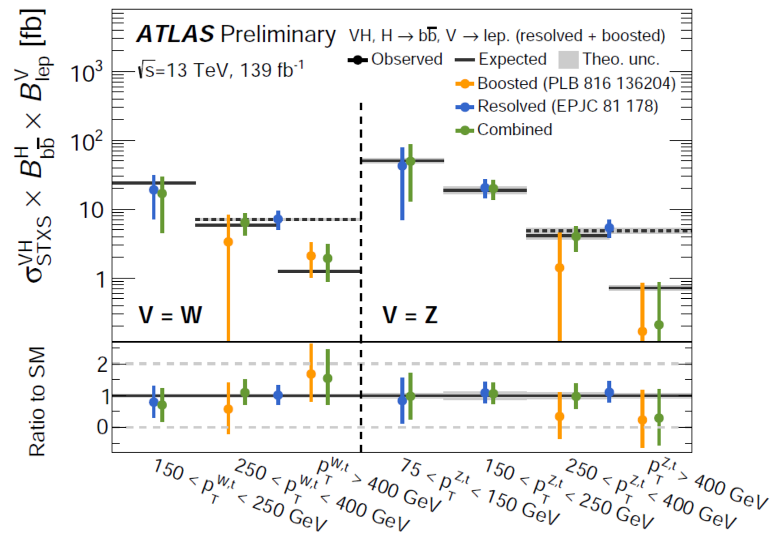
O(30%) measurement of Stage 1.2 STXS bins (..,>250 GeV)



5-bin STXS

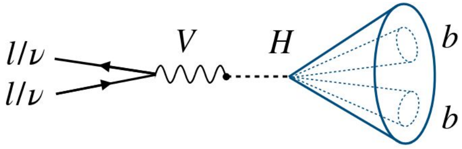
Drop $p_T(V)$ > 400 GeV events

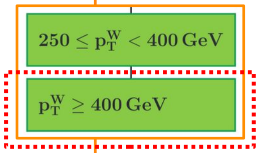
Provide > 400 GeV region



Boosted

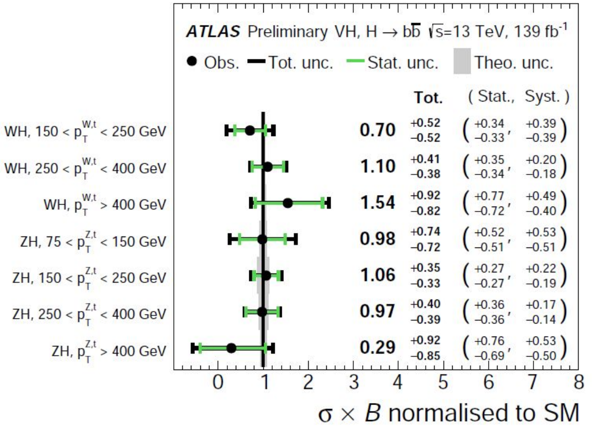
Phys. Lett. B 816 (2021) 136204





Probes high-$p_T(V)$ regime: 2 STXS bins [250, 400] GeV, [400,∞) GeV

4-bin STXS



7-bin STXS measurement

Statistically limited

Interpretation in the κ **framework**

Assumption: BSM physics modifies only the *strength* of the Higgs-boson coupling

⇒ assign (effective) **coupling-strength modifiers $\boldsymbol{\kappa}$** to leading-order diagrams of Higgs-boson production and decay

Modifier of the *Higgs-boson total width*

$$\kappa_H^2(\boldsymbol{\kappa}, B_{\text{i.}}, B_{\text{u.}}) = \frac{\sum_j B_j^{\text{SM}} \kappa_j^2}{(1 - B_{\text{i.}} - B_{\text{u.}})}$$

$B_{i./u.}$: branching ratio of invisible/ undetected BSM decays

Different scenarios are considered with varying levels of assumptions

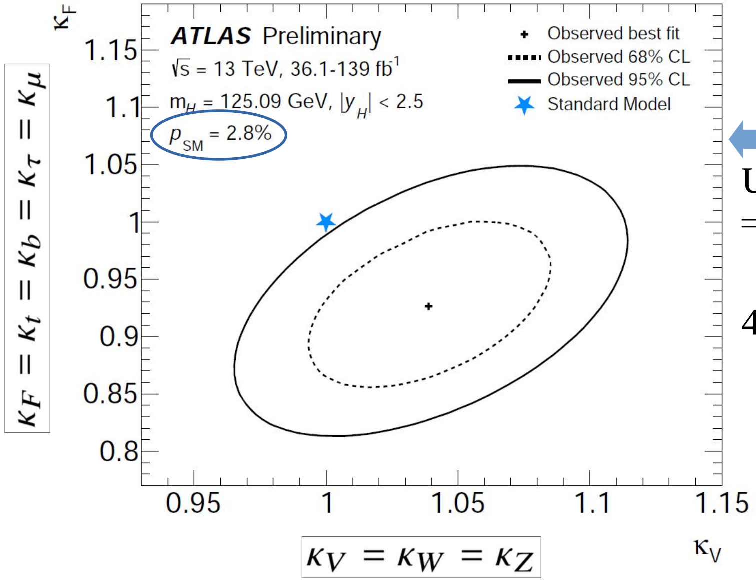
Interpretation: couplings to SM particles

ATLAS-CONF-2021-053

New

General assumptions

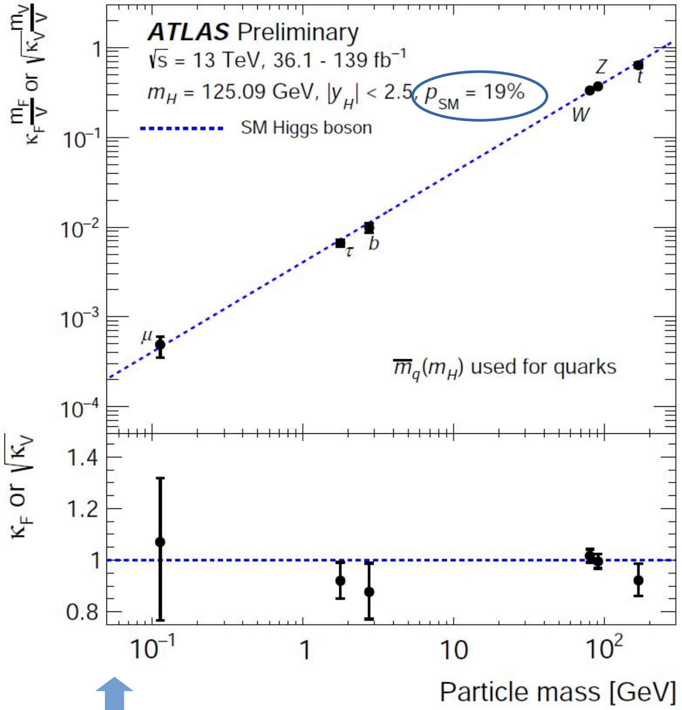
- Only decays to SM particles ($B_{i.} = B_{u.} = 0$)
- Only SM particles contribute to loops; loops are resolved
- $\kappa_{c/s}$ scales as $\kappa_{t/b}$; $\kappa_{u/d/e} = 1$
- All κ's are positive



Updated $ttH(\rightarrow bb)$ and ggF, $H \rightarrow \tau\tau$
⇒ lower κ_F

43% linear correlation

Results are compatible with SM expectation



Updated $ttH(\rightarrow bb)$ yields lower κ_b
⇒ lower κ_μ (due to smaller contribution to Γ_H)

Obs. (exp.) significance on κ_μ: 2.1 (1.7) σ

Interpretation: probing BSM contributions

General assumptions

- *Effective* coupling strength to photons, gluons and $Z\gamma$ (new!)
  - All other loop-induced processes are resolved
- All κ's are positive
- $\kappa_{c/s}$ scales as $\kappa_{t/b}$; $\kappa_{u/d/e} = 1$

All other κ's are fixed to 1

In loops

$$\kappa_g = 1.00 \pm 0.05$$
$$\kappa_\gamma = 1.06 \pm 0.05$$
$$\kappa_{Z\gamma} = 1.43^{+0.31}_{-0.38}.$$

- Only decays to SM particles ($B_{i.} = B_{u.} = 0$)

Obs. (exp.) sign.: 2.2 (1.1) σ

SM consistency: $p_{SM} = 36\%$

In loops and decays

$$\kappa_g = 0.98 \pm 0.06$$
$$\kappa_\gamma = 1.06 \pm 0.05$$
$$\kappa_{Z\gamma} = 1.43^{+0.31}_{-0.37}$$
$$B_{i.} < 0.14 \text{ at } 95\% \text{ CL}$$
$$B_{u.} < 0.15 \text{ at } 95\% \text{ CL.}$$

- VBF, $H \rightarrow$ *inv.* included to constrain invisible BSM decays $B_{i.}$

Undetected BSM decays constrained from processes not involving loops

SM consistency: $p_{SM} = 60\%$

Interpretation: probing BSM contributions

New

ATLAS-CONF-2021-053

Nikhef

General assumptions

- *Effective* coupling strength to photons, gluons and $Z\gamma$ (new!)
  - All other loop-induced processes are resolved
- All κ's are positive — *lifted*: $\kappa_t < 0$ excluded at 4.3 σ (from tH and $gg \rightarrow ZH$)
- $\kappa_{c/s}$ scales as $\kappa_{t/b}$; $\kappa_{u/d/e} = 1$

All other κ's are fixed to 1

In loops

κ_g	$= 1.00 \pm 0.05$
κ_γ	$= 1.06 \pm 0.05$
$\kappa_{Z\gamma}$	$= 1.43^{+0.31}_{-0.38}$.

- Only decays to SM particles ($B_{i.} = B_{u.} = 0$)

Obs. (exp.) sign.: 2.2 (1.1) σ

SM consistency: $p_{SM} = 36\%$

In loops and decays

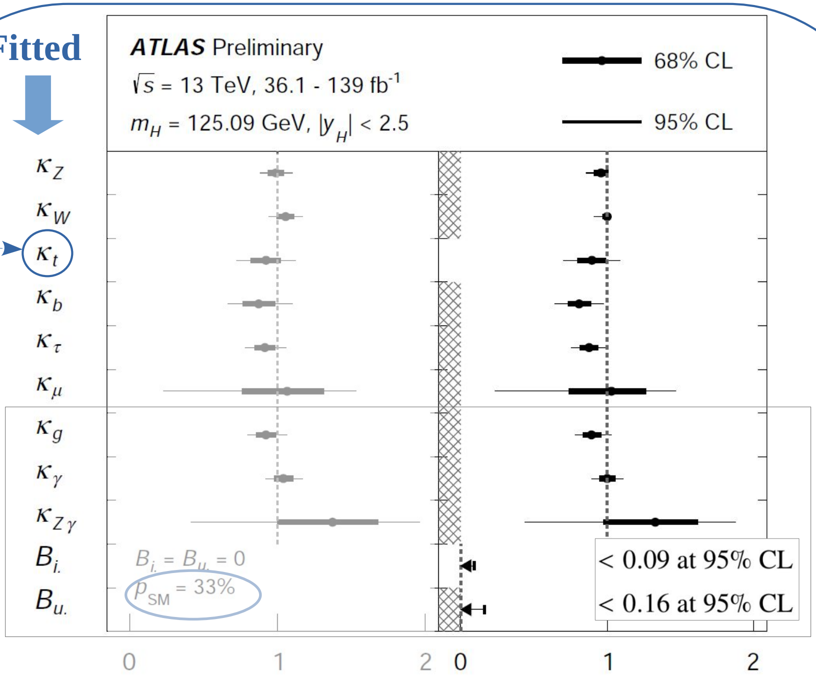
κ_g	$= 0.98 \pm 0.06$
κ_γ	$= 1.06 \pm 0.05$
$\kappa_{Z\gamma}$	$= 1.43^{+0.31}_{-0.37}$
$B_{i.}$	< 0.14 at 95% CL
$B_{u.}$	< 0.15 at 95% CL.

- VBF, $H \rightarrow$ *inv.* included to constrain invisible BSM decays $B_{i.}$

Undetected BSM decays constrained from processes not involving loops

SM consistency: $p_{SM} = 60\%$

Fitted



In loops ($B_{i.} = B_{u.} = 0$)

In loops and decays

SM consistency: $p_{SM} = 33\%$

- VBF, $H \rightarrow$ *inv.* included to constrain $B_{i.}$
- $\kappa_{W(Z)} \leq 1$ **to constrain** $B_{u.}$
- $B_{u.} > 0$

Model-dependent interpretation: 2HDM

Nikhef

Benchmark model for UV-complete BSM theory

- Extended Higgs sector (2nd SU(2) doublet) → 5 Higgs boson
- **Light CP-even Higgs boson *h*** identified with **observed Higgs boson**
  - SM production and decay modes
  - Deviations from SM prediction expressed in terms of **α** and **tan*β***
    - **α**: mixing angle between two CP-even Higgs bosons (*h*, *H*)
    - **tan*β*:** ratio of the vevs of the two SU(2) doublets

Four 2HDM types w/o tree-level FCNCs

- different couplings to up/down-type quarks and leptons

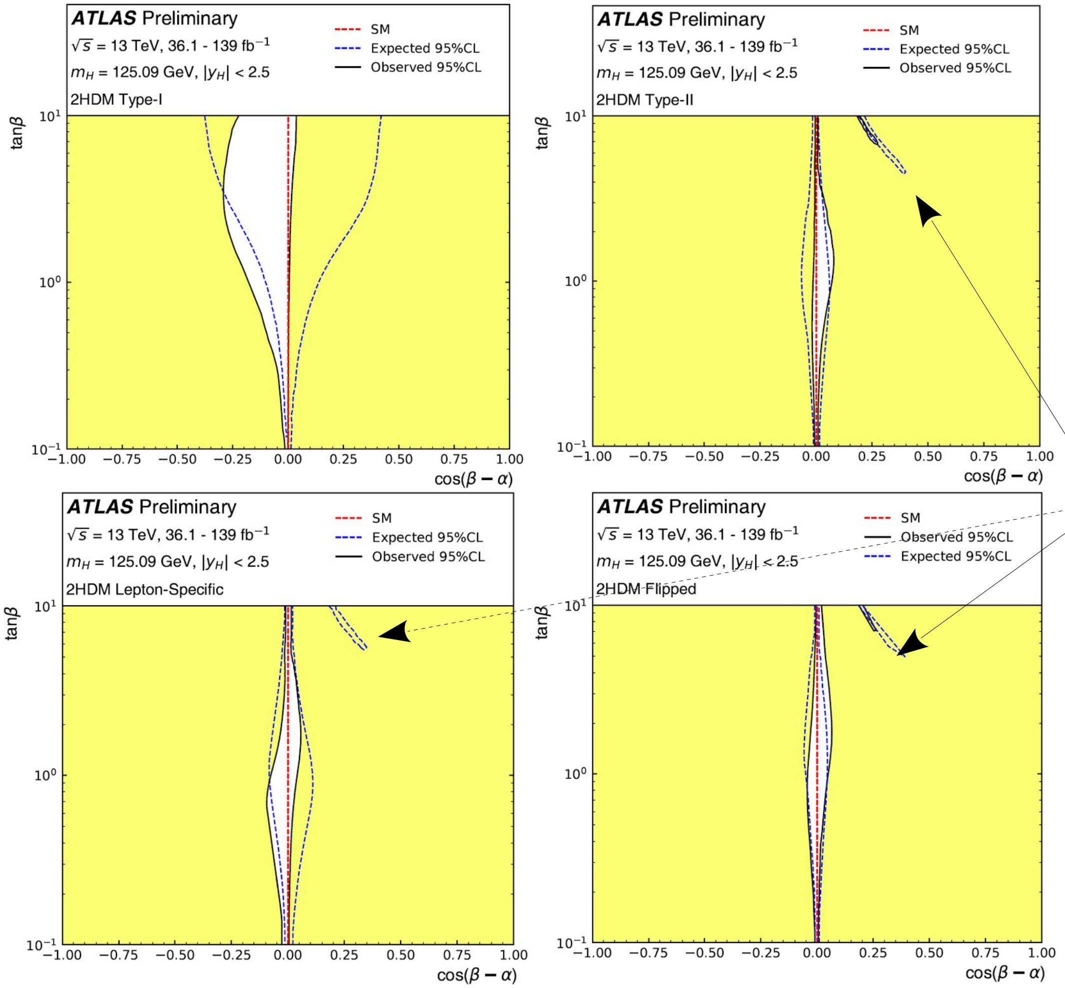
Coupling modifiers	Model			
	Type I	Type II	Lepton-specific	Flipped
ξ_h^u	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$	$\cos\alpha/\sin\beta$
ξ_h^d	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$
ξ_h^l	$\cos\alpha/\sin\beta$	$-\sin\alpha/\cos\beta$	$-\sin\alpha/\cos\beta$	$\cos\alpha/\sin\beta$

2HDM interpretation: results

ATLAS-CONF-2021-053

Nikhef

New



$$H_{\mathrm{SM}} = h \cdot \sin(\beta - \alpha) + H \cdot \cos(\beta - \alpha).$$

$\cos(\beta - \alpha) = 0$ ***alignment limit***

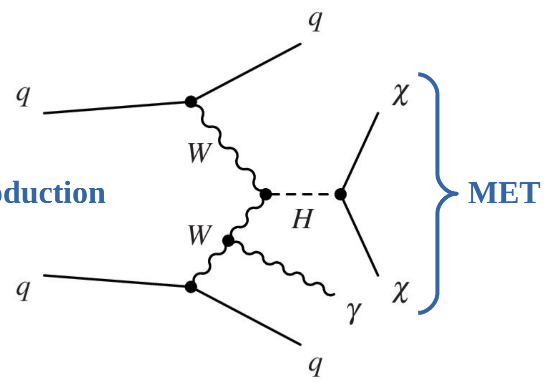
→ h indistinguishable from H_{SM}

- The data is consistent with the ***alignment limit*** within 1 std. or better
- "petal" allowed regions: some fermion couplings have the same *magnitude* as in the SM, but the opposite *sign*

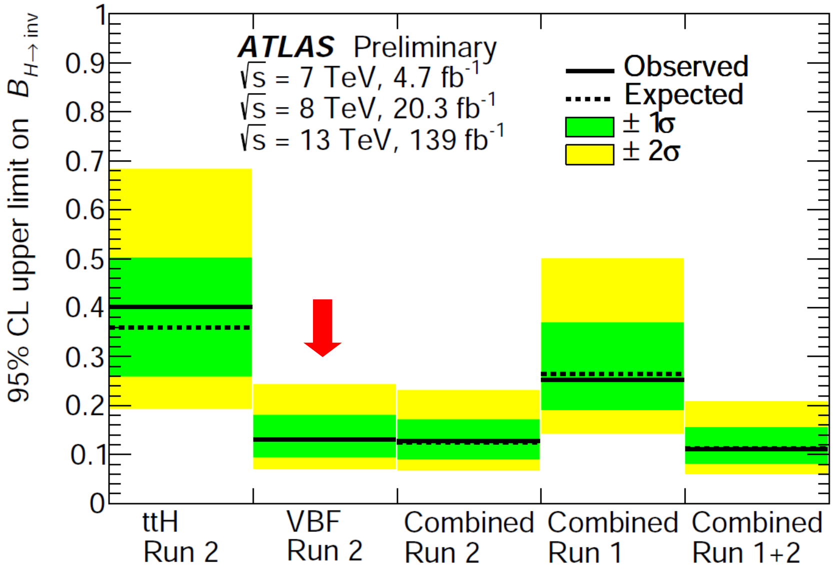
No surprises:
the observed Higgs boson is SM-like

$H \rightarrow$ *invisible*

SM production



- "Invisible" = missing transverse momentum (MET)
- **<u>In the SM</u>**, $H \rightarrow$ *invisible* is from $H \rightarrow ZZ^* \rightarrow 4\nu$ – BR = 0.1%
- **<u>In Higgs portal models</u>**, $H \rightarrow$ *invisible* contributions arise from $H \rightarrow XX$; X: dark matter (DM) particle, e.g. WIMPs



Run-1 combination 'inputs': VBF, *Z(→ ll)H, V(→had.)H*

Run 2 'inputs': VBF, *H→ inv.*; ttH (0/2 lepton) [reinterpretation of SUSY/DM searches]

Observed (expected) upper limit @95% CL on B(*H→ inv.*):

- Run 2 combination: 0.13 (0.12+0.05-0.04)
- Run 1+2 combination: 0.11 (0.11+0.04-0.03)

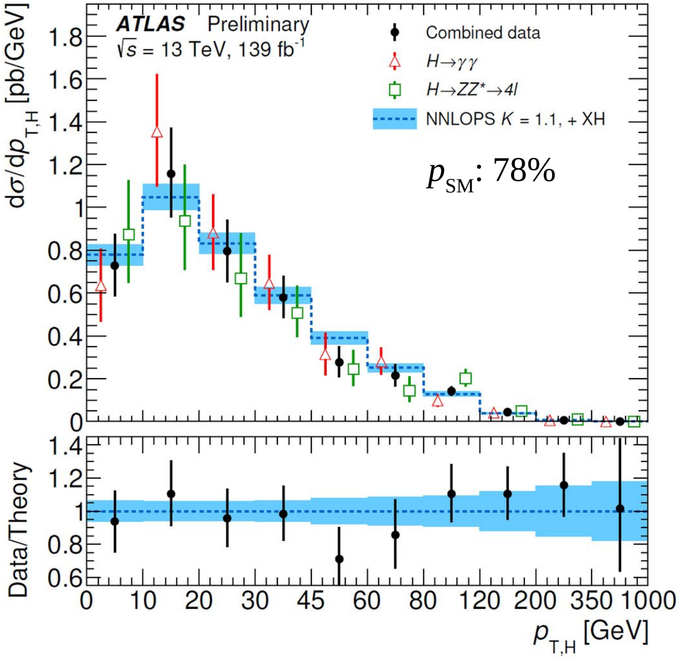
→ **Dominated by VBF channel**

Three new 'inputs' ready: VBF+γ [EXOT-2021-17], *ZH* [ATLAS-CONF-2021-029], *mono-jet* [Phys. Rev. D 103 (2021) 112006]

Combination of cross-section measurements ATLAS-CONF-2019-032

- Input analyses: $\boldsymbol{H \to \gamma\gamma}$ *and* $\boldsymbol{H \to ZZ^* \to 4l}$ using full Run-2 dataset
- Assumes SM predictions for branching fractions and acceptances

Higgs boson differential cross-section as function of p_T(H)

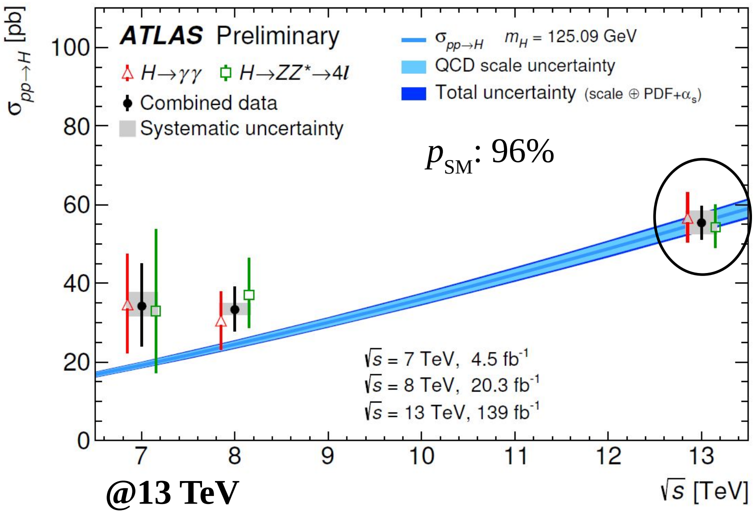


~20% precision per bin
(except highest bin)

Stat. unc. dominating

Finer binning in $H \to \gamma\gamma$, but same bin boundaries
→ respective bins are combined with a single $H \to ZZ^* \to 4l$ bin

Higgs boson production cross-section



@13 TeV

- **Combination:** 55.4+4.3-4.2 pb
  - ~8% precision
  - Stat. and syst. unc. of the same order
- **Prediction**: 55.6±2.5 pb

Results are in **good agreement** with each other and the **SM prediction**

Summary & conclusion

- Combinations of individual Higgs-boson production and decay measurements provide unprecedented precision and reduced assumptions in interpretations
- Almost all input analyses use the full Run-2 dataset; new channels are explored and analysis improvements implemented
- Presented most granular STXS measurement to date – in particular, new bins at high p_T(V/H) promise improved constraints in EFT interpretations
- In general, results show very good agreement with the SM expectation
- More data is coming...

BACKUP

This year's input analyses

Nikhef

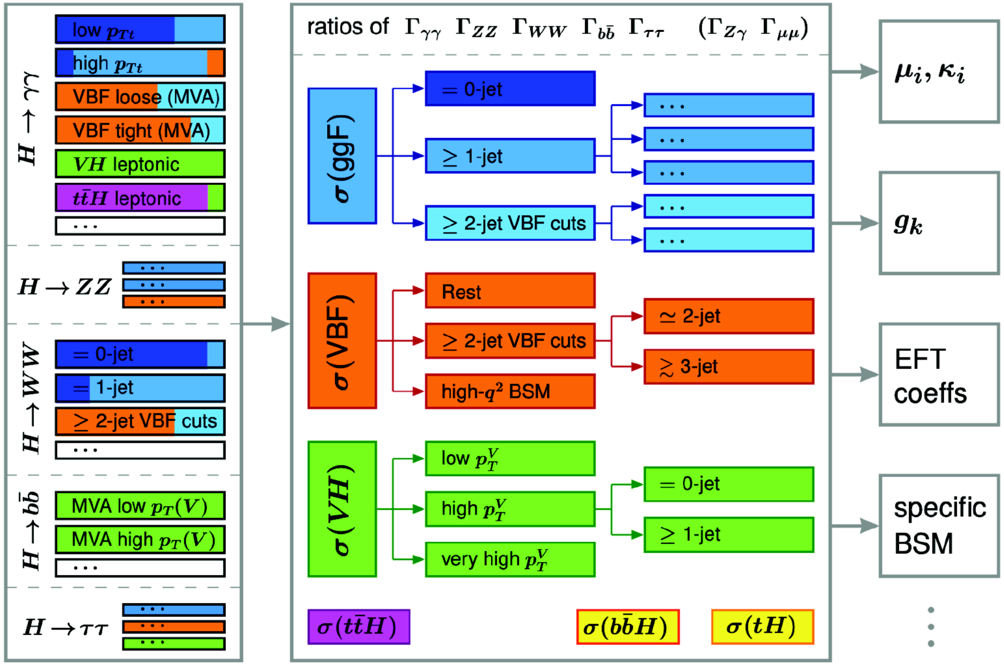
Analysis improvements relative to ICHEP 2020

- $H \rightarrow WW^{*}$: ≥ 2-jet category in ggF
- $H \rightarrow \tau\tau$:
  - boosted ggF: more granular binning (reco $p_T(H)$, #jets)
  - VBF: improved selection through MVA
- $H \rightarrow bb$:
  - VH: inclusion of *boosted categories* → more granular $p_T(V)$ binning
  - VBF: improved analysis strategy (ANN, bkg. control regions, ...)
  - ttH: introduction of reco $p_T(H)$ binning

The STXS framework

Les Houches 2015 Report
Yellow Report 4

Simplified Template Cross-Sections: common framework for **Higgs cross-section measurements per production mode** in exclusive kinematic regions



Schematic

- Minimize theory dependence
  – theory uncertainties can evolve with time for different phase-space regions
- Isolate regions where BSM effects are predicted to appear enhanced
- Maximise the experimental sensitivity
  - by allowing use of e.g. MVAs
- Simplify combination of measurements in different decay channels

How: Signal predictions per STXS 'bins' provide **templates** that are simultaneously fit to the data

- evolves in 'stages' with increasing granularity and precision: 1.0, 1.1, 1.2,..

κ framework

CERN-2013-004 (2013)

To study modifications of the *strength* of the Higgs-boson couplings related to BSM physics

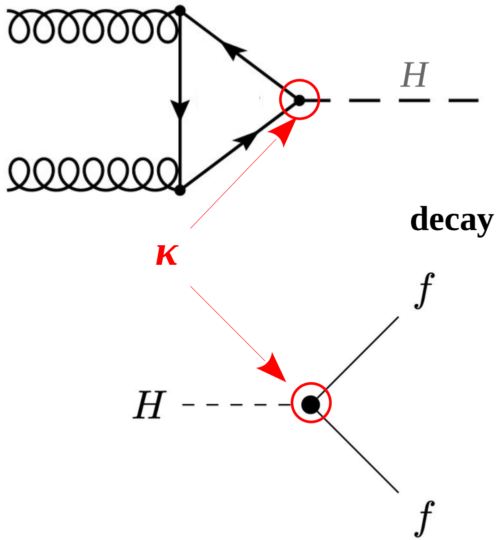
- Assigns (effective) **coupling-strength modifiers** $\boldsymbol{\kappa}$ to leading-order diagrams of production and decay processes, assuming *factorisation*

$$\sigma_i \times B_f = \frac{\sigma_i(\boldsymbol{\kappa}) \times \Gamma_f(\boldsymbol{\kappa})}{\Gamma_H}$$

- **Cross-sections** $\boldsymbol{\sigma_j}$ and **partial decay width** $\boldsymbol{\Gamma_j}$ for SM process *j:*

$$\kappa_j^2 = \frac{\sigma_j}{\sigma_j^{\rm SM}} \quad \text{or} \quad \kappa_j^2 = \frac{\Gamma_j}{\Gamma_j^{\rm SM}}$$

$\boldsymbol{\kappa_j}$ **= 1** is the **SM prediction**



- **Higgs total decay width**

$$\Gamma_H(\boldsymbol{\kappa}, B_{\rm i.}, B_{\rm u.}) = \kappa_H^2(\boldsymbol{\kappa}, B_{\rm i.}, B_{\rm u.})\,\Gamma_H^{\rm SM}$$

where

$$\kappa_H^2(\boldsymbol{\kappa}, B_{\rm i.}, B_{\rm u.}) = \frac{\sum_j B_j^{\rm SM} \kappa_j^2}{(1 - B_{\rm i.} - B_{\rm u.})}$$

$\boldsymbol{B_{i./u.}}$**: branching ratio of invisible/undetected BSM decays**

⇒ **BSM contributions** may manifest themselves as $\boldsymbol{\kappa_j \neq 1}$ **or** $\boldsymbol{B_{i./u.} \neq 0}$

$B_{u.}$ Can't be directly constrained by measurements → **extracting** $\boldsymbol{\kappa_j}$ ***and*** $\boldsymbol{B_{u.}}$ **simultaneously requires assumptions**

κ framework

Parametrisations

Production cross section	Loops	Main interference	Effective modifier	Resolved modifier
$\sigma(\text{ggF})$	✓	t–b	κ_g^2	$1.040\,\kappa_t^2 + 0.002\,\kappa_b^2 - 0.038\,\kappa_t\kappa_b - 0.005\,\kappa_t\kappa_c$
$\sigma(\text{VBF})$	-	-	-	$0.733\,\kappa_W^2 + 0.267\,\kappa_Z^2$
$\sigma(qq/qg \to ZH)$	-	-	-	κ_Z^2
$\sigma(gg \to ZH)$	✓	t–Z	$\kappa_{(ggZH)}$	$2.456\,\kappa_Z^2 + 0.456\,\kappa_t^2 - 1.903\,\kappa_Z\kappa_t - 0.011\,\kappa_Z\kappa_b + 0.003\,\kappa_t\kappa_b$
$\sigma(WH)$	-	-	-	κ_W^2
$\sigma(t\bar{t}H)$	-	-	-	κ_t^2
$\sigma(tHW)$	-	t–W	-	$2.909\,\kappa_t^2 + 2.310\,\kappa_W^2 - 4.220\,\kappa_t\kappa_W$
$\sigma(tHq)$	-	t–W	-	$2.633\,\kappa_t^2 + 3.578\,\kappa_W^2 - 5.211\,\kappa_t\kappa_W$
$\sigma(b\bar{b}H)$	-	-	-	κ_b^2
Partial decay width				
Γ^{bb}	-	-	-	κ_b^2
Γ^{WW}	-	-	-	κ_W^2
Γ^{gg}	✓	t–b	κ_g^2	$1.111\,\kappa_t^2 + 0.012\,\kappa_b^2 - 0.123\,\kappa_t\kappa_b$
$\Gamma^{\tau\tau}$	-	-	-	κ_τ^2
Γ^{ZZ}	-	-	-	κ_Z^2
Γ^{cc}	-	-	-	$\kappa_c^2\ (= \kappa_t^2)$
$\Gamma^{\gamma\gamma}$	✓	t–W	κ_γ^2	$1.589\,\kappa_W^2 + 0.072\,\kappa_t^2 - 0.674\,\kappa_W\kappa_t + 0.009\,\kappa_W\kappa_\tau + 0.008\,\kappa_W\kappa_b - 0.002\,\kappa_t\kappa_b - 0.002\,\kappa_t\kappa_\tau$
$\Gamma^{Z\gamma}$	✓	t–W	$\kappa_{(Z\gamma)}^2$	$1.118\,\kappa_W^2 - 0.125\,\kappa_W\kappa_t + 0.004\,\kappa_t^2 + 0.003\,\kappa_W\kappa_b$
Γ^{ss}	-	-	-	$\kappa_s^2\ (= \kappa_b^2)$
$\Gamma^{\mu\mu}$	-	-	-	κ_μ^2
Total width ($B_{\text{i.}} = B_{\text{u.}} = 0$)				
Γ_H	✓	-	κ_H^2	$0.581\,\kappa_b^2 + 0.215\,\kappa_W^2 + 0.082\,\kappa_g^2 + 0.063\,\kappa_\tau^2 + 0.026\,\kappa_Z^2 + 0.029\,\kappa_c^2 + 0.0023\,\kappa_\gamma^2 + 0.0015\,\kappa_{(Z\gamma)}^2 + 0.0004\,\kappa_s^2 + 0.00022\,\kappa_\mu^2$

Ratios of coupling modifiers

ATLAS-CONF-2021-053

New

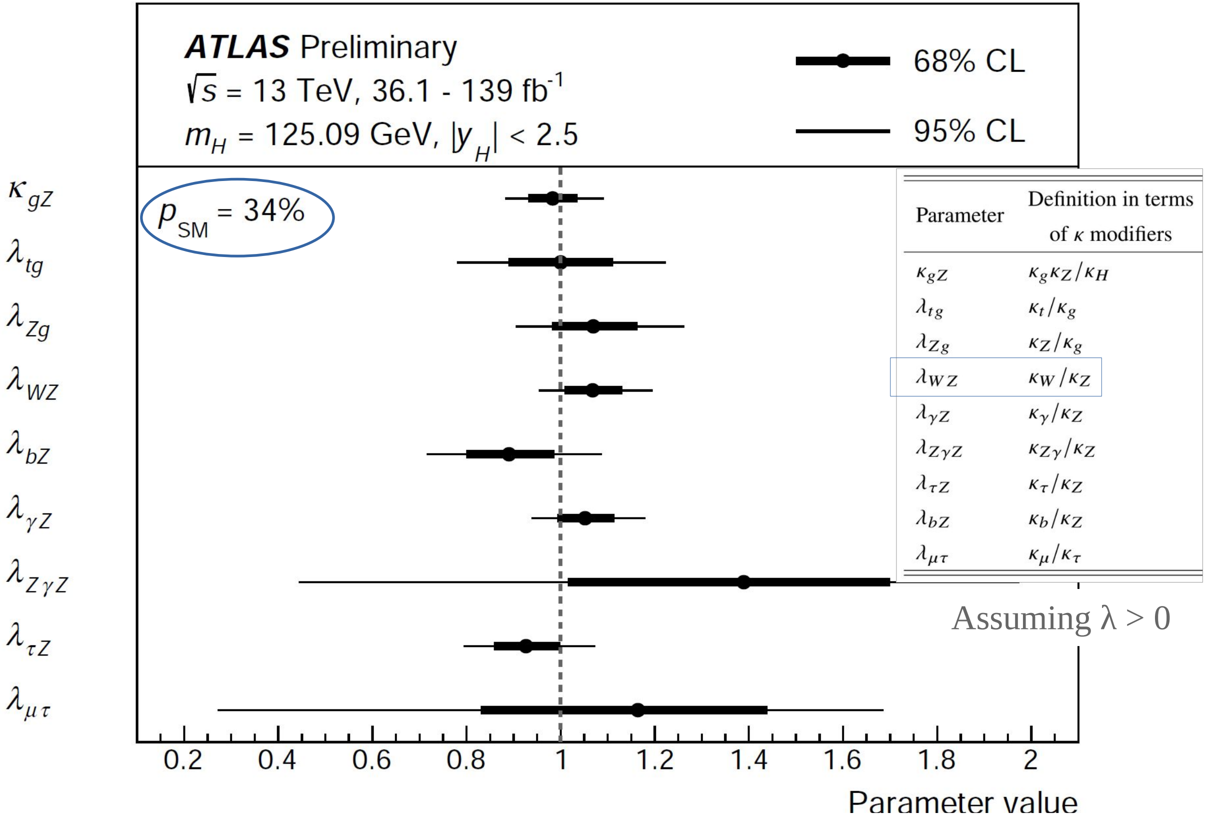
- Independent of assumptions on the Higgs-boson total width
  - With global scale factor determined by $gg \rightarrow H \rightarrow ZZ^*$
  - **Most model-independent** interpretation within the κ framework

Sensitive to new coloured particles in ggF loop

Tight bounds on identical *W/Z* coupling-strength modifiers from SU(2) custodial symmetry and LEP and Tevatron measurements

Sensitive to new charged particles contributing to $H \rightarrow \gamma\gamma$ and $H \rightarrow Z\gamma$

Bound on relation of Yukawa couplings between fermion generations

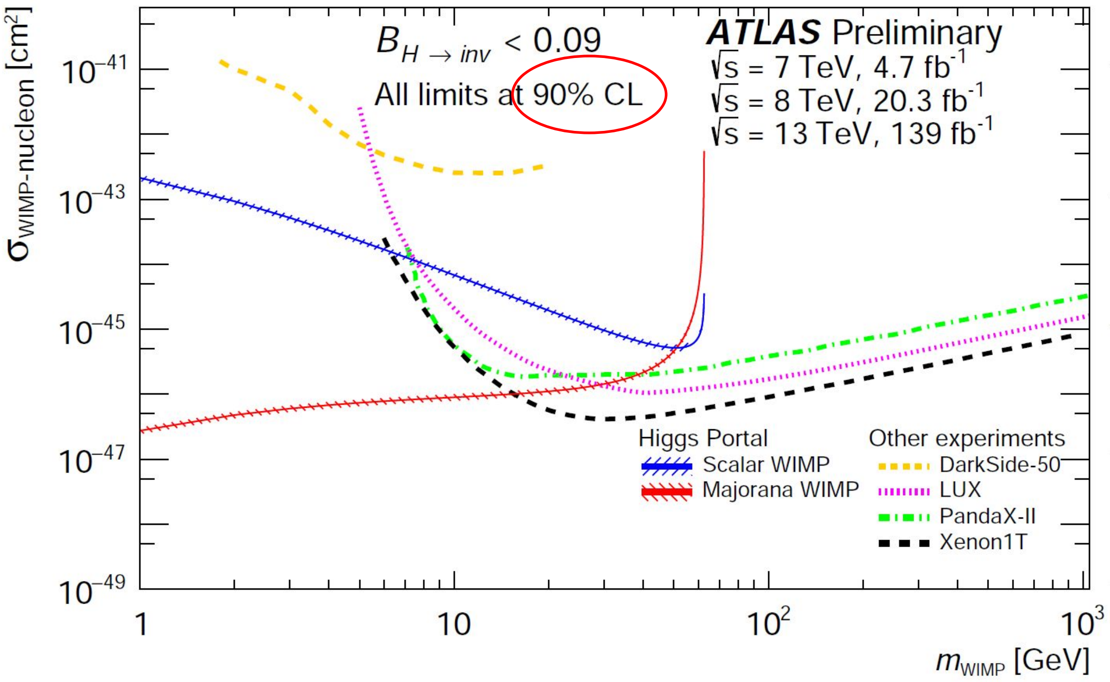


Parameter	Definition in terms of κ modifiers
κ_{gZ}	$\kappa_g \kappa_Z / \kappa_H$
λ_{tg}	κ_t / κ_g
λ_{Zg}	κ_Z / κ_g
λ_{WZ}	κ_W / κ_Z
$\lambda_{\gamma Z}$	κ_γ / κ_Z
$\lambda_{Z\gamma Z}$	$\kappa_{Z\gamma} / \kappa_Z$
$\lambda_{\tau Z}$	κ_τ / κ_Z
λ_{bZ}	κ_b / κ_Z
$\lambda_{\mu\tau}$	κ_μ / κ_τ

Good agreement with the SM prediction

$H \rightarrow$ *invisible* combination: DM interpretation ATLAS-CONF-2020-052

In the context of Higgs-portal models and comparison to **direct DM detection experiments**



Translation of upper limit on B($H\rightarrow$ *inv.*) (@90% CL) into limit on (spin-independent) **WIMP-nucleon scattering cross-section** via an EFT approach

→ the regions *above* the limit contours are *excluded*

→ **DM searches at the LHC and direct detection experiments are complementary**