中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Measurements of Higgs boson production cross-sections and couplings in the diphoton decay channel at 13 TeV

Muhammad Aamir Shahzad
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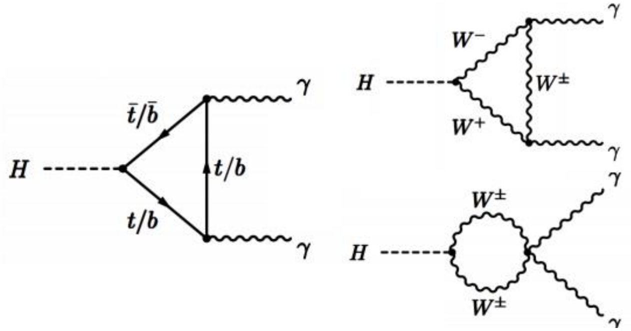
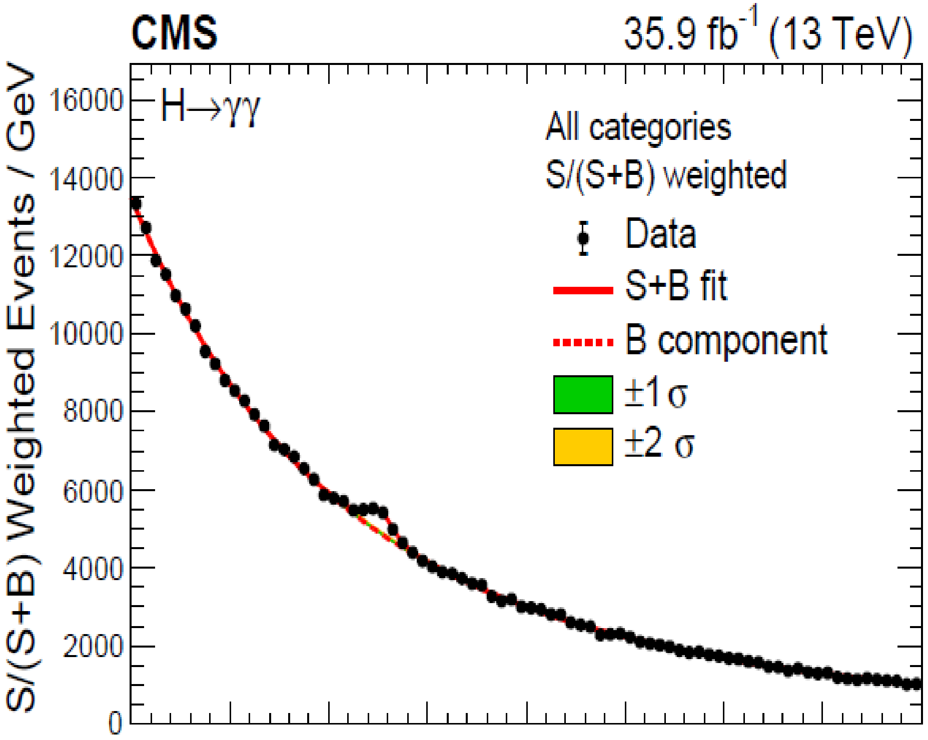
Higgs Boson decaying into $\gamma\gamma$

- At LHC, $H \rightarrow \gamma\gamma$ channel plays a key role first in the **discovery of the Higgs boson**, and then in the **measurements of Higgs boson properties** and also in **searches for new physics**
- **Loop-induced decay**
  - ✓ **Interference** helps probe sign of couplings to SM particles
  - ✓ **New physics** could contribute to the loop



- **Small branching fraction** (0.2%), but clean final state with two highly **energetic and isolated photons, so** final state can be **fully reconstructed** with **excellent mass resolution** (1-2%)
- **Large backgrounds**
  - ✓ Continuum $\gamma\gamma$ (irreducible)
  - ✓ Fakes from γj and jj (reducible)
- Measurement of Higgs boson production **cross-section** and **couplings** in the diphoton decay channel with **full Run2** data at 13 TeV, Published in JHEP (JHEP07(2021)027)
  - ✓ PAS was public with 2017 re-reco data and in paper, results were updated with UL2017 data

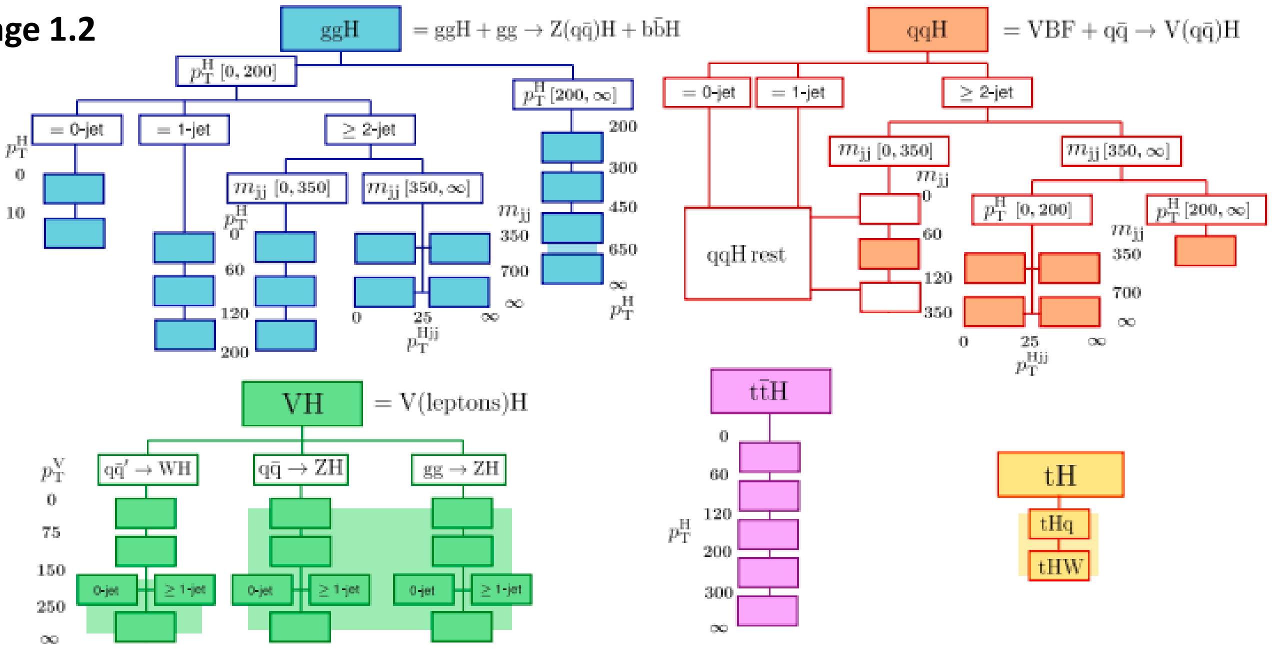


Search for a narrow peak on a larger falling background in mass distribution

STXS Framework

- STXS provides a framework for making measurements in increasingly finer bins of the Higgs boson phase space
  - ✓ STXS bins are mutually exclusive
  - ✓ Bins of phase space are split by production mode and further by kinematic variables within each production mode
- Maximize experimental sensitivity
- Less dependence of measurements on theory
- BSM physics is isolated in a separate bin
- Coherence allows for decay channels to be combined
- Fine bins => allow for broader re-interpretations by theorists
- STXS framework developed in stages: stage 1.0, stage 1.1, stage 1.2
- STXS stage 1.0 analysis **(2016+2017)** in **HIG-18-029**

Stage 1.2

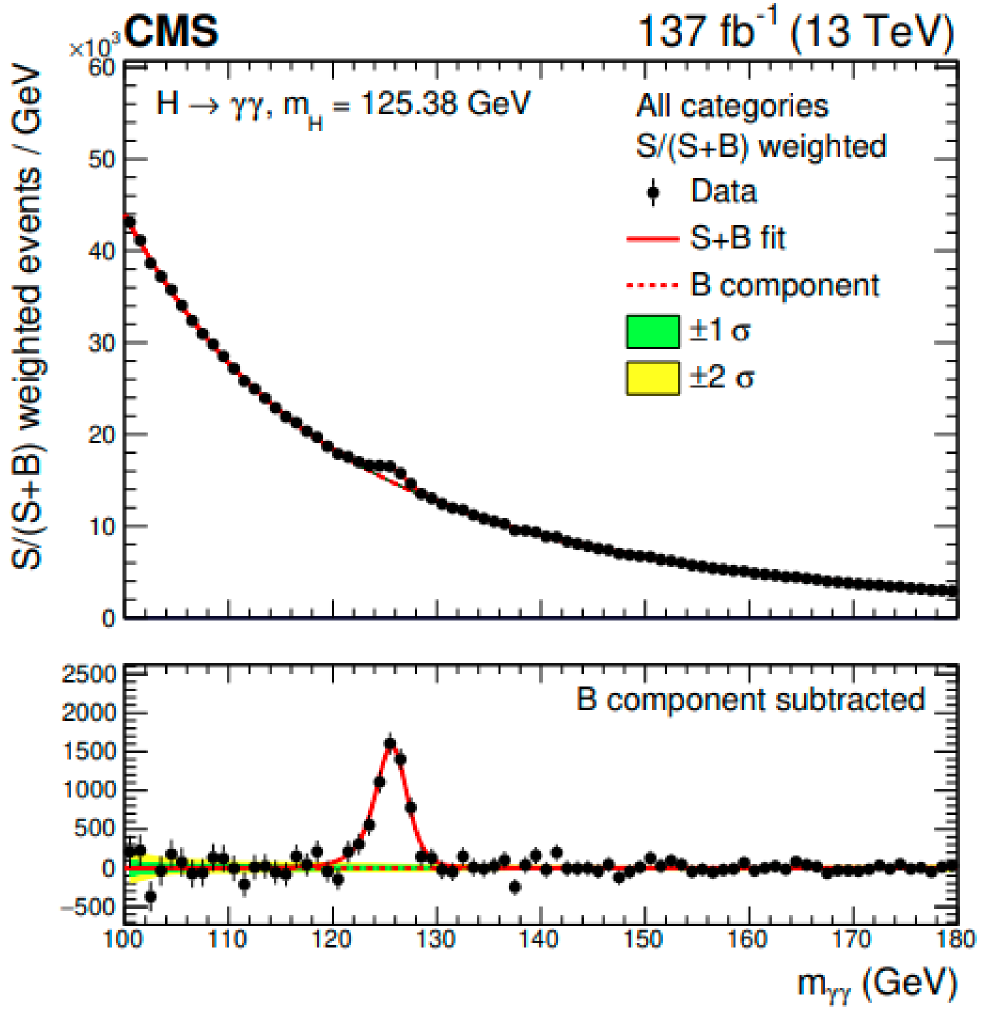


Categorisation: targeting STXS Stage 1.2 binning

- **ggH categorization:** New multiclassifier to assign most probable STXS bin
- **VBF categorization:** Data-driven technique + Three-Class BDT
- **VH hadronic categorization:** Data-driven technique + VH hadronic tag
- **VH leptonic categorization:** WH leptonic, ZH leptonic, VH MET MVA + data-driven technique for VH MET
- **ttH and tH categorization:** ttH leptonic and hadronic tags from HIG-19-013, tHq tag

Analysis Strategy

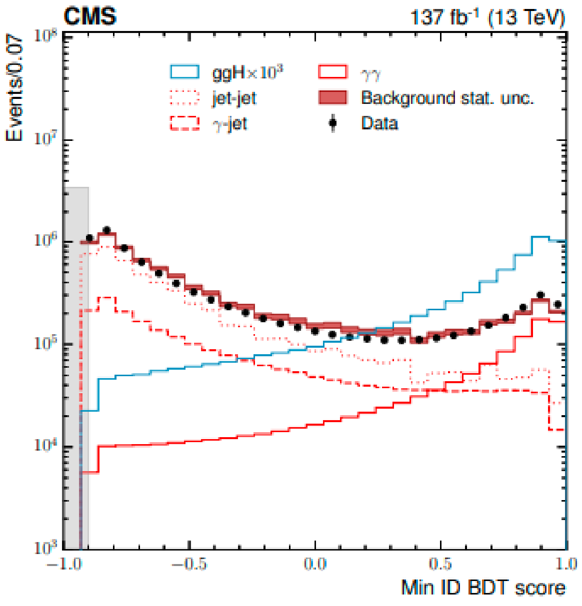
- Analysis is targeting ggH, qqH (VBF and VH hadronic), ttH and tH, VH leptonic Stage 1.2 STXS bins
- In each production mode categories are defined to **target as many STXS bins as possible.** Categories are divides depending on available statistics
- Build analysis categories to **target as many STXS bins as possible**
- **MVAs** are used to reduce the contamination from other H production modes and also for Background reduction
- Simultaneous fit to the diphoton invariant mass distributions in all categories, with the background determined from data

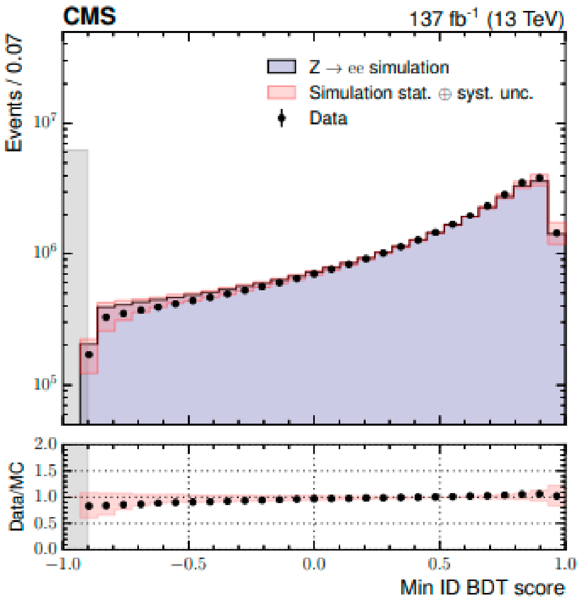


tHq leptonic tag → **ttH leptonic tags** → **VH leptonic tags** → **VH MET tag** → **ttH hadronic tags** → **qqH tags (including VH hadronic)** → **ggH tags**

Photon Identification, diphoton vertex identification

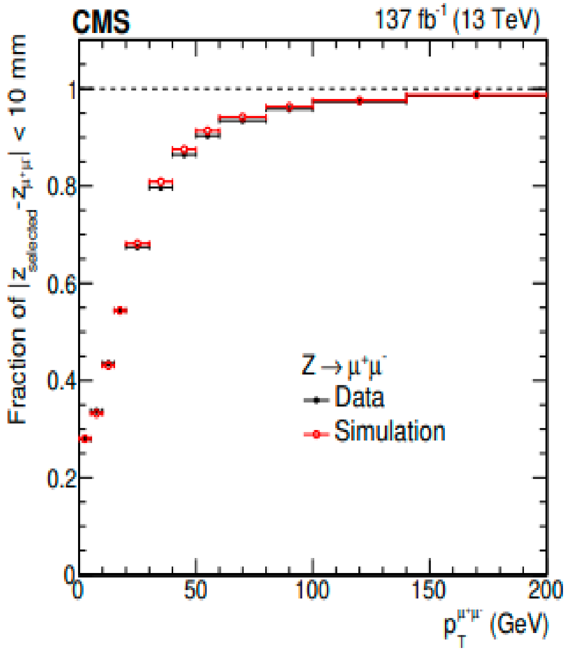
- **Photon IDMVA** is used to classify prompt photons from fake photons (jets)
- **Input variables:** shower shape variables, isolation variables
- **IDMVA** validated with $Z \rightarrow \mu\mu\gamma$ and $Z \rightarrow ee$ event

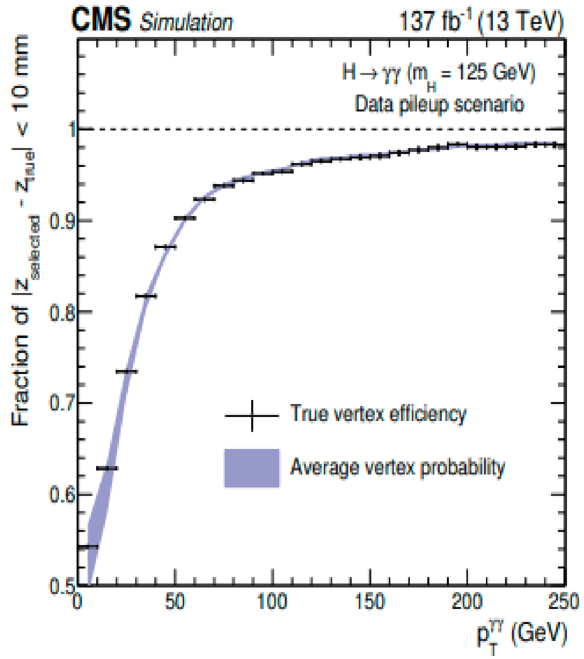




photons required to have IDMVA score > -0.9 (preselection)

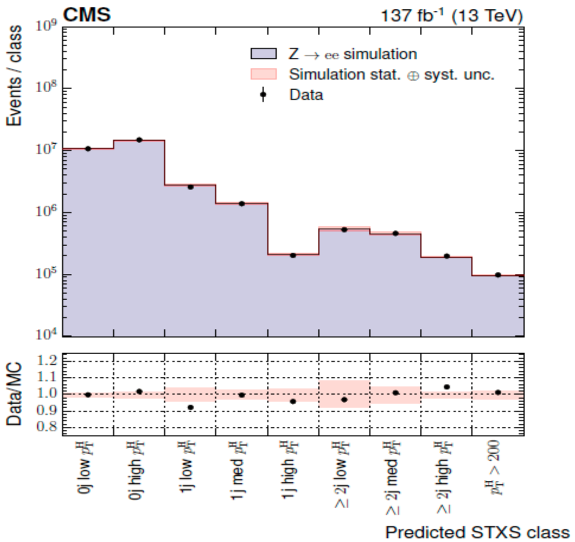
- **Vertex Identification BDT:**
  - if vertex position is true within 1 cm => $m_{\gamma\gamma}$ resolution is dominated by γ energy resolution (true for ~79% events in simulation)
  - Trained on ggH events and identifies a single vertex in each event
- **Vertex ID BDT validated with $Z \rightarrow \mu\mu$ events:** μ tracks are omitted to mimic a diphoton system

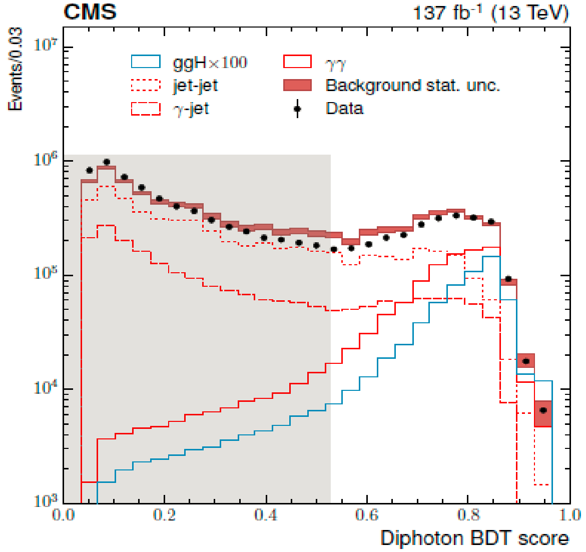




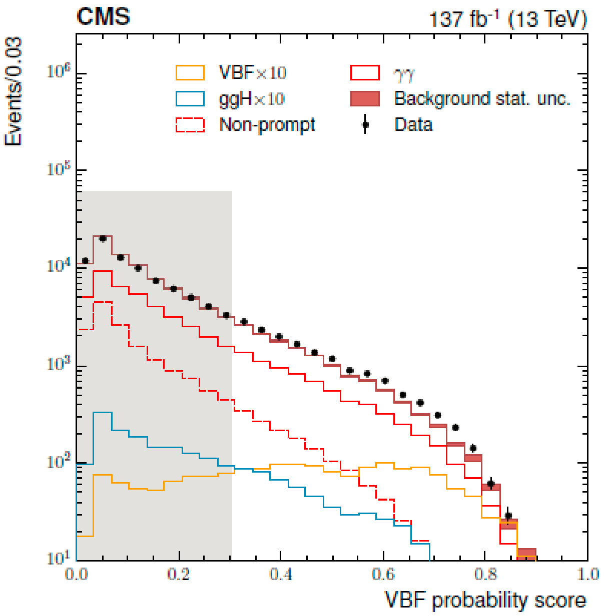
ggH event categorization and other production modes

- Use a multi-class BDT (9 Classes): Predicts the probability that an event belongs to a given ggH STXS bin
- After being classified by the ggH BDT, events are divided into analysis categories using the diphoton BDT

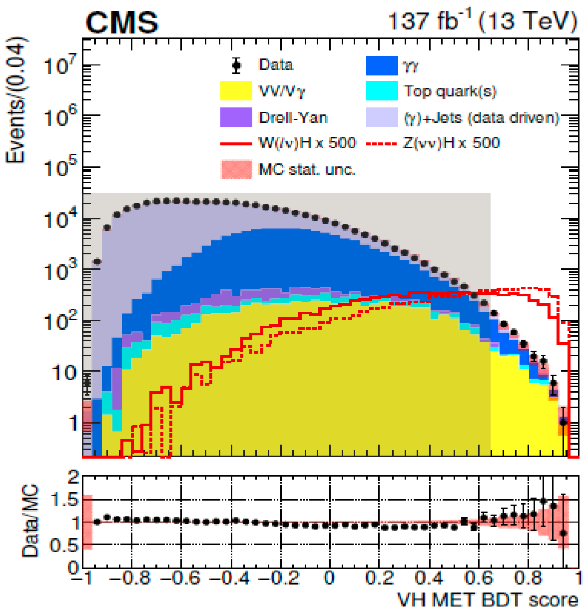




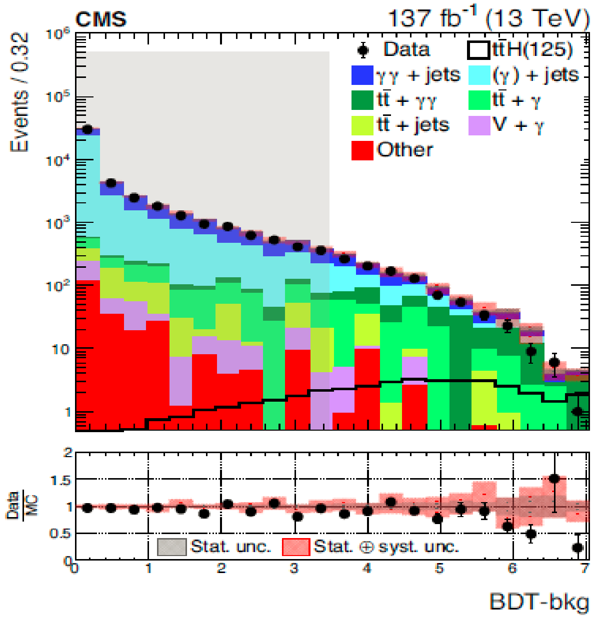
- Dedicated categorization for **tHq events (tHq Leptonic)**
- Data-driven estimation of key backgrounds for MVA training i.e. **VBF, VH MET, ttH Hadronic**



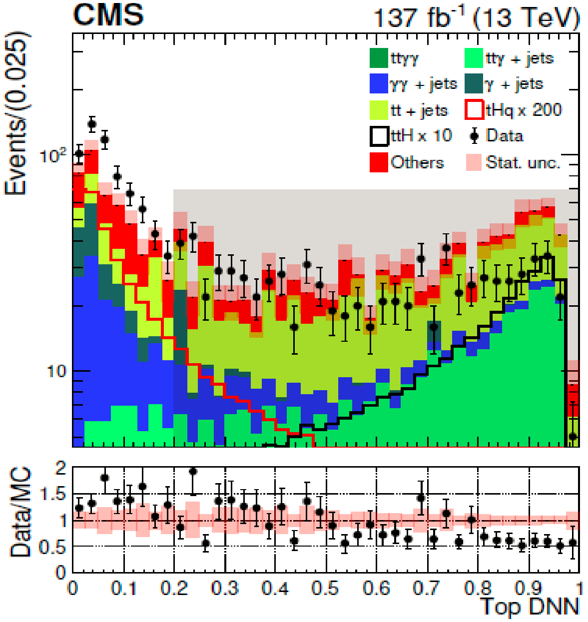
VBF



VH MET

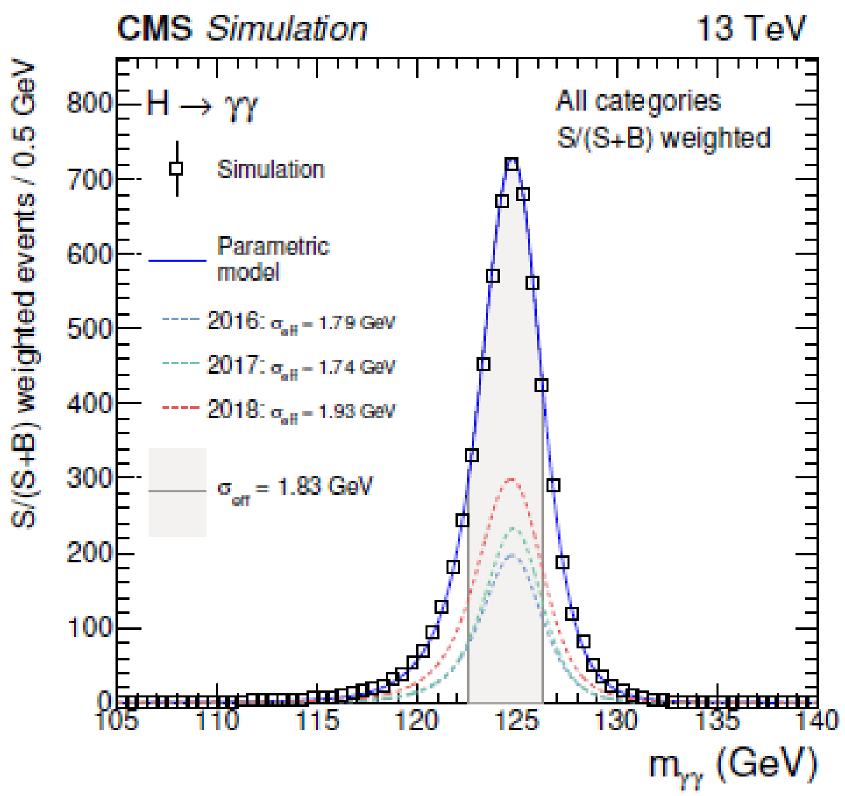


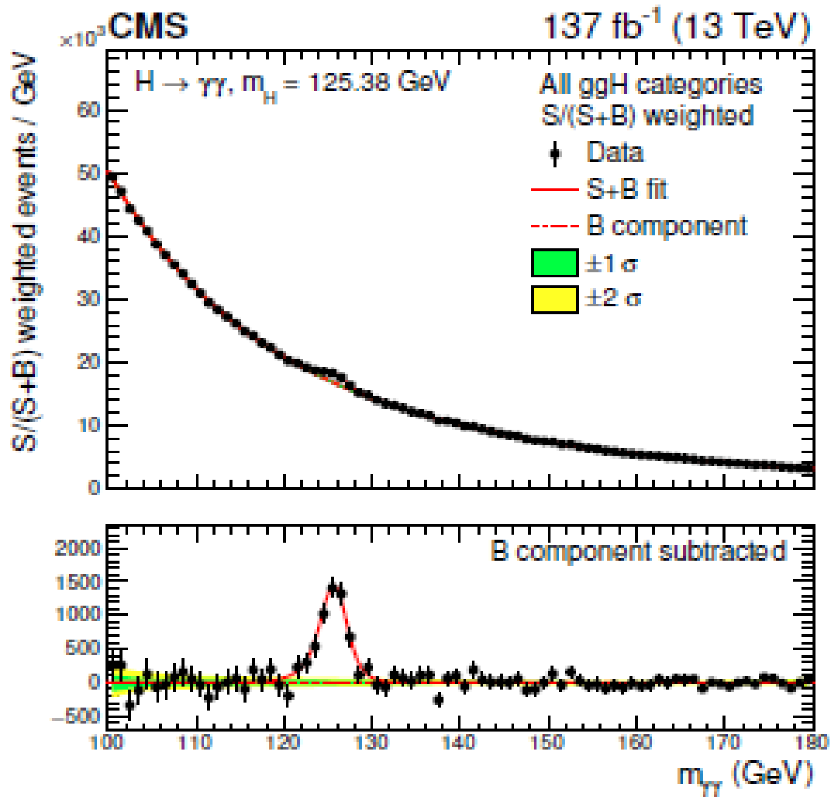
ttH Hadronic



tHq Leptonic

Signal & Background Modelling





- ➢ Shape of the **parametric signal model** for each year of simulated data, and for the sum of all years together
- ➢ MC tuning and **Data/MC** scale factors have been applied
- ➢ Better resolution in 2017 using Ultra-Legacy 2017 data set

- ➢ Model used to describe the background is extracted from data using the discrete profiling method
- ➢ A large set of candidate function families is considered, including **exponential functions, Bernstein polynomials, Laurent series** and **power law functions**

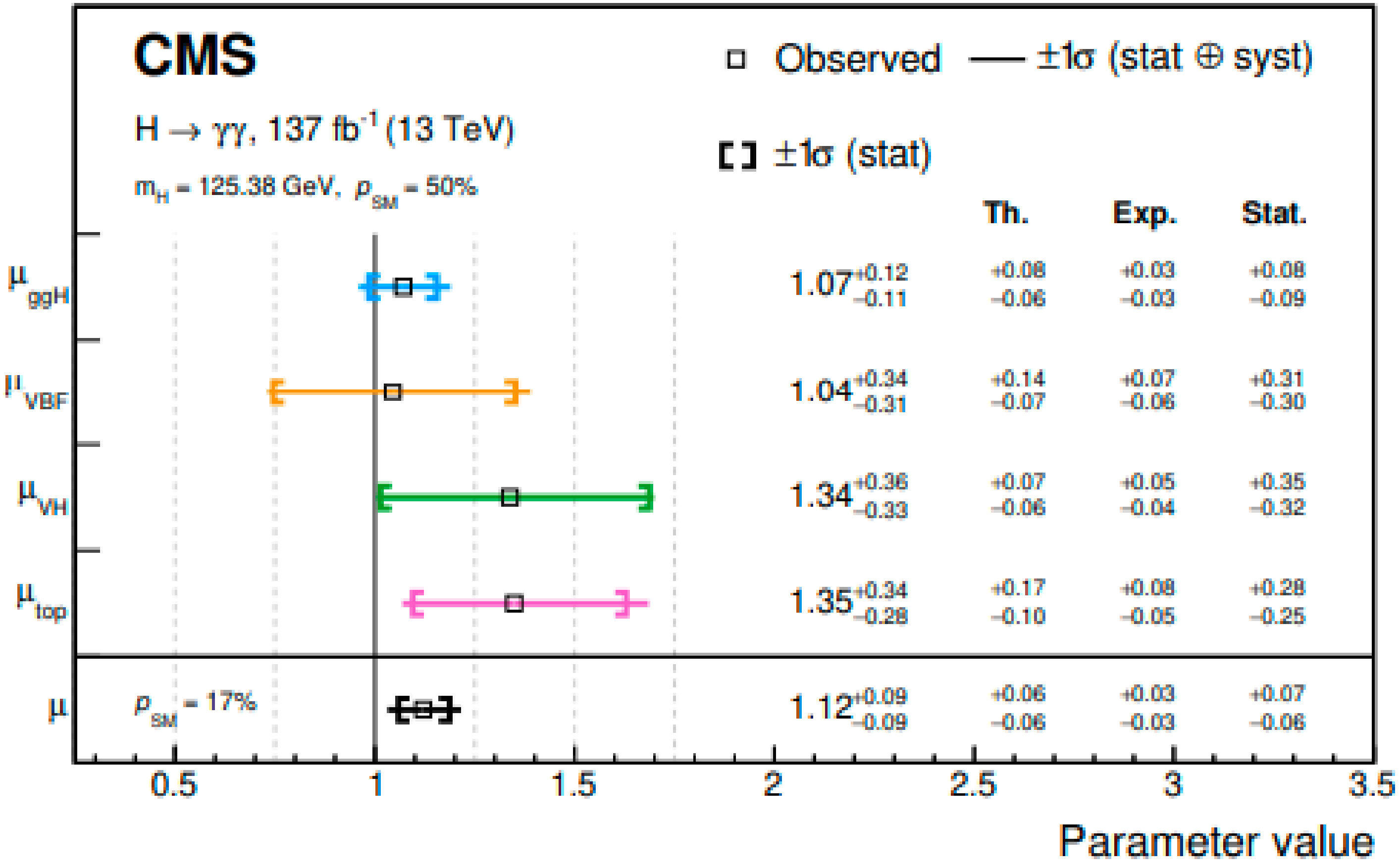
Signal Strength modifiers

$$\mu_i^f = \frac{\sigma_i \mathcal{B}^f}{(\sigma_i)_{\mathrm{SM}} (\mathcal{B}^f)_{\mathrm{SM}}}$$

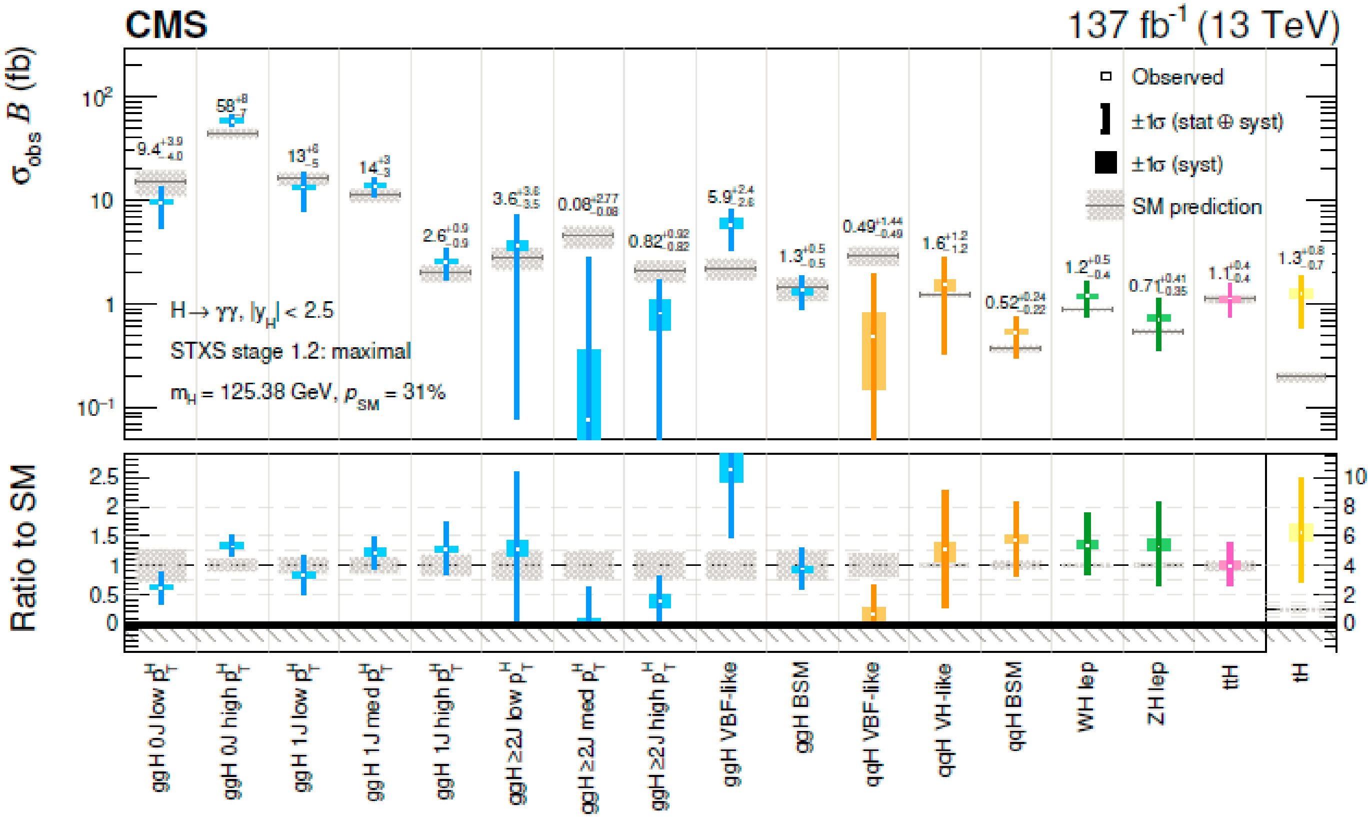
- Best-fit signal + background model shown with data for sum of all categories
- common signal strength modifier (μ): ratio of observed ($\boldsymbol{\sigma}_{\mathrm{H}}$ x diphoton BR) to SM prediction
- The overall precision is about 8%

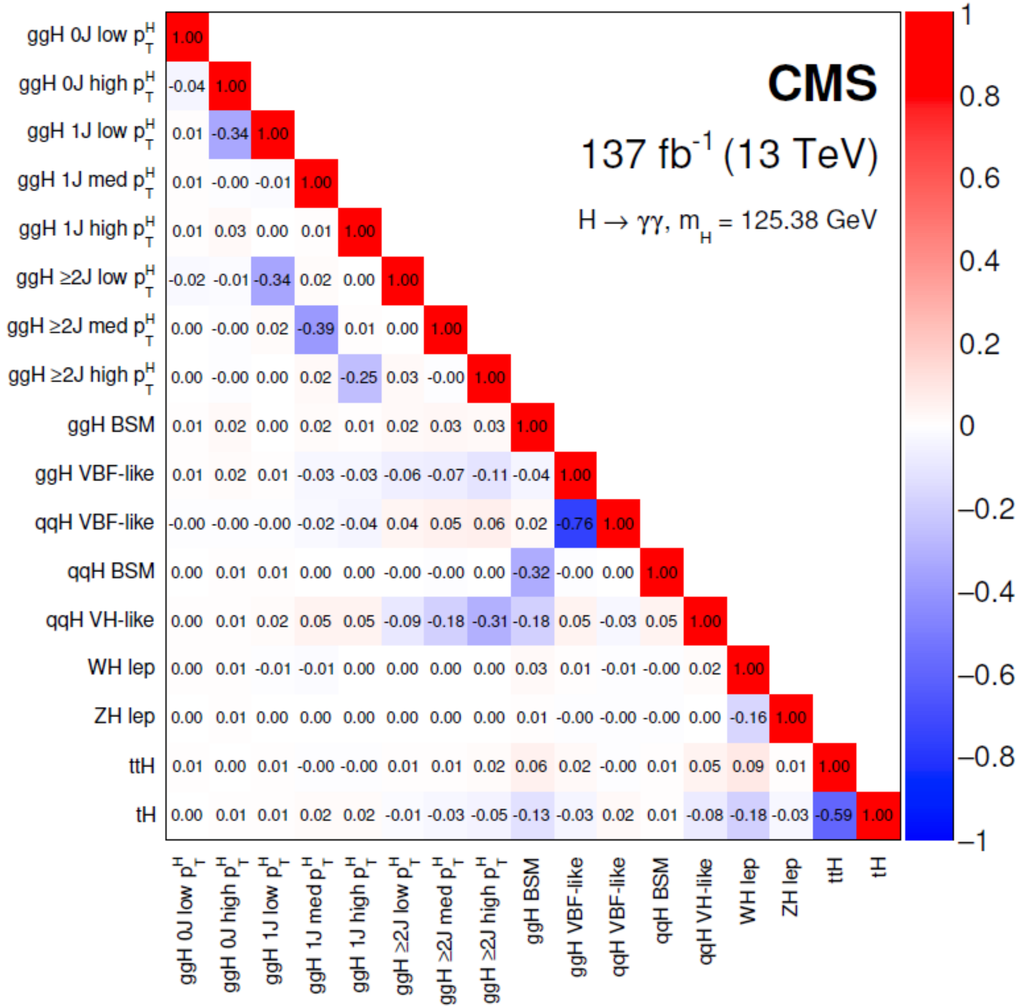
$$\mu = 1.12^{+0.09}_{-0.09} = 1.12^{+0.06}_{-0.06}\,(\mathrm{theo})^{+0.03}_{-0.03}\,(\mathrm{syst})^{+0.07}_{-0.06}\,(\mathrm{stat})$$

- **Signal strength modifiers per production mode**
  - μ_{VH} (VH hadronic + VH leptonic)
  - μ_{VBF} (VBF production)
  - μ_{top} (ttH + tHq + tHW)
  - μ_{ggH} (ggH + bbH)



“Maximal” Merging Scenario (17 parameters of interest)

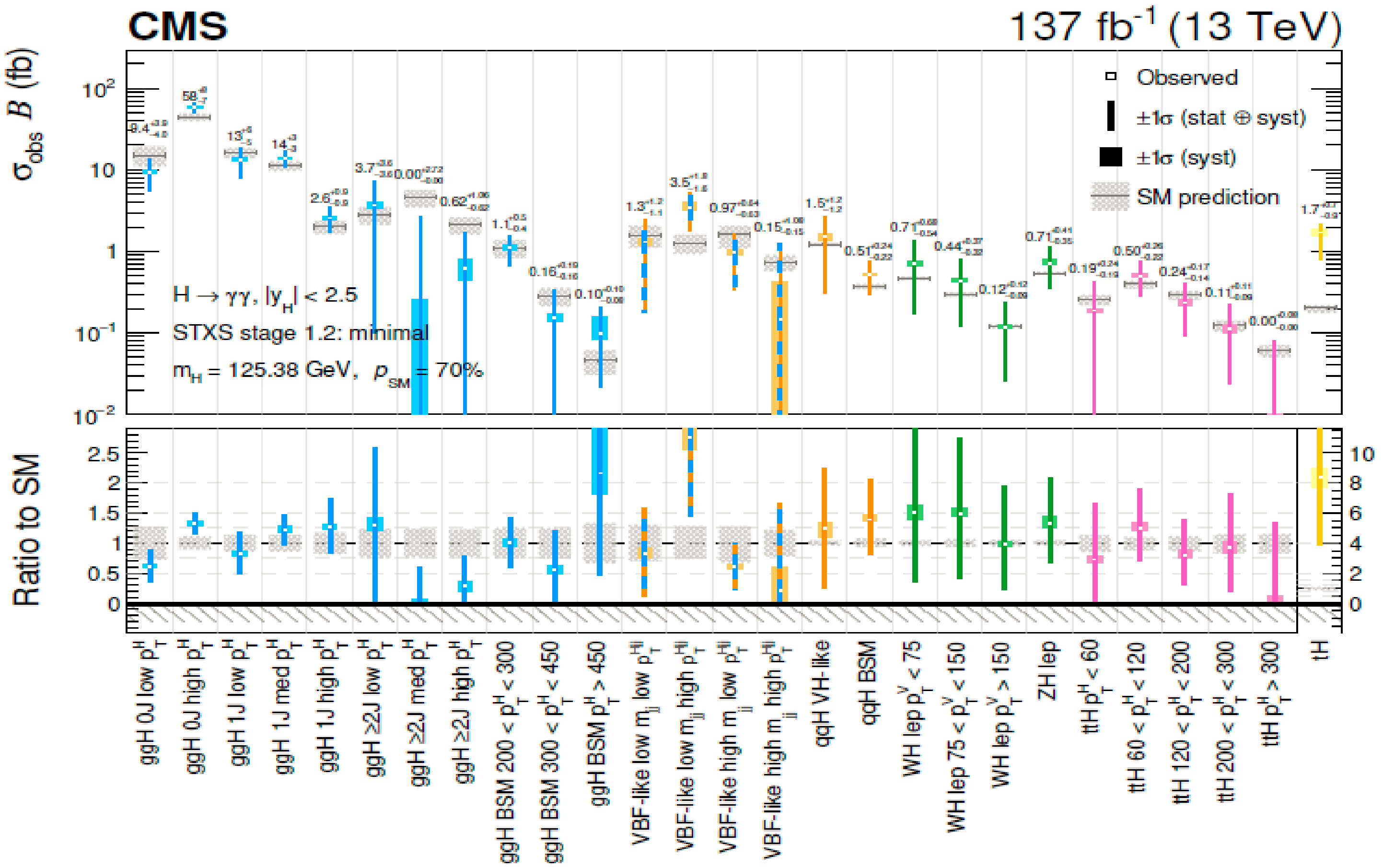




- STXS bins are merged until their expected uncertainty is less than **150%** of the SM prediction
- Measurement of **ttH** and **tH** simultaneously
- Best **tH** measurement: rate of **tH** production of **14 (8)** times the SM expectation is **observed (expected)** to be excluded at the 95% CL , **σxB** is $1.27^{+0.76}_{-0.69}$ fb

- Observed correlations between 17 parameters considered in the maximal merging STXS fit
- BSM bins (in qqH and ggH) : in agreement with SM

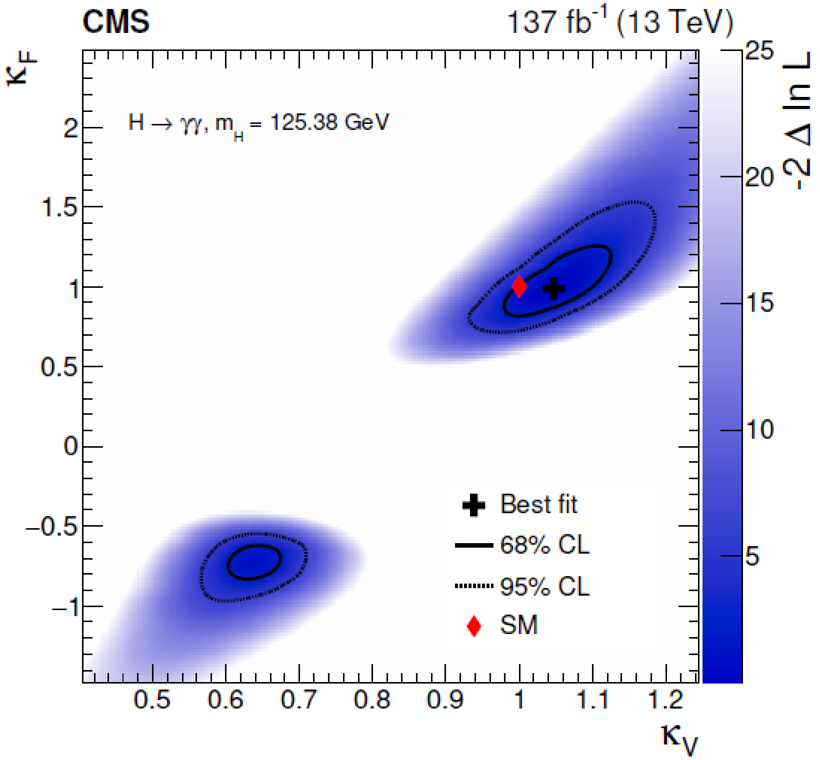
“Minimal” Merging Scenario (27 parameters of interest)

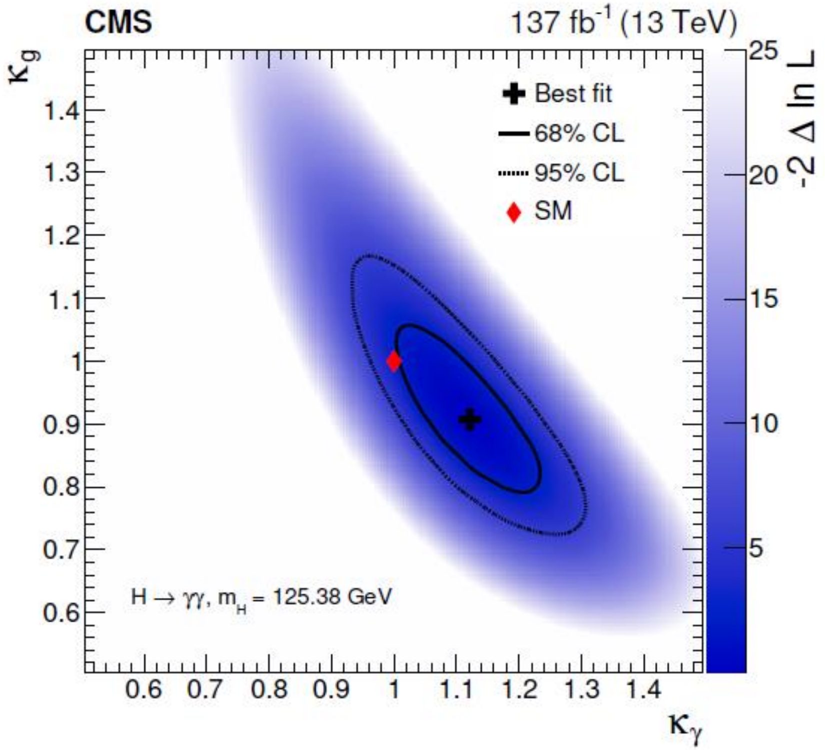


- Merges as few bins as possible that parameters do not become too anti-correlated (values of less than around 90%)
- Measurement with additional stage 1.2 splitting (**ttH** and **ggH BSM**)
  - Splitting **ttH** production into five separate parameters introduces larger correlations into the measurement
- All $\boldsymbol{\sigma}$ results are in agreement with the SM predictions
- Merged **ggH** and **VBF** bins (blue/orange lines): less model dependence and reduced correlations

Coupling Modifiers

- The κ-framework defines coupling modifiers to directly parametrize deviations from the SM expectation in the couplings of the Higgs boson to other particles





- **Resolved κ model** is used: Here the scaling factors of loops present in Higgs boson production and decay are resolved into their SM components, in terms of the other parameters
- Exclude negative κ_f with **0.5 (2.4) σ** confidence

- **Unresolved κ model** is used: parameterise deviations in ggH and H→γγ loops using effective coupling modifiers (κ_g, κ_γ)
- The g and γ parameters are particularly sensitive to additional BSM states, that contribute towards the rate of Higgs boson production and decay via loop processes

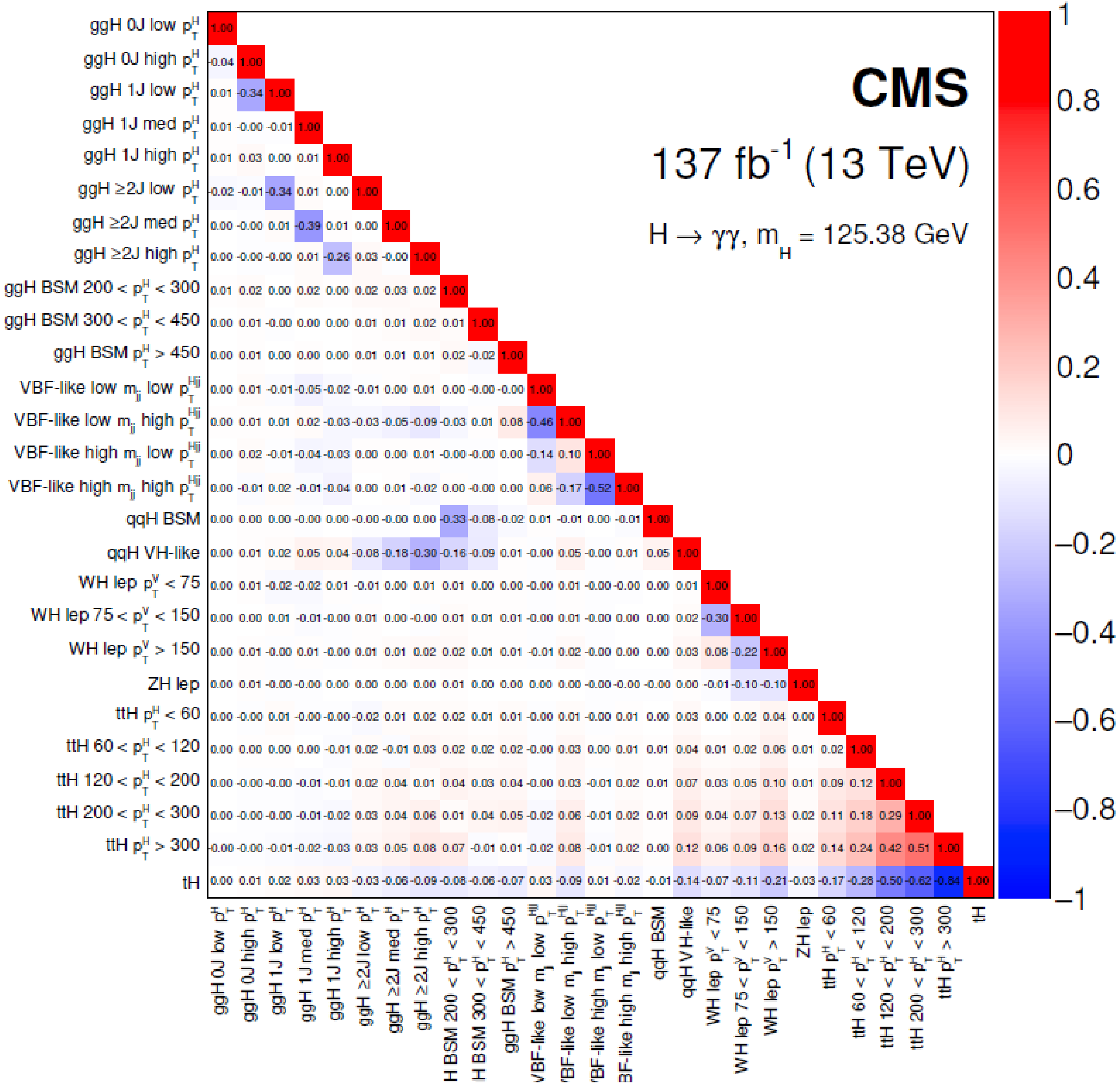
Summary

- Measurements of Higgs boson properties with the Higgs boson decaying into a pair of photons are reported
- The total Higgs boson signal strength, relative to the standard model **(SM)** prediction, is measured to be **1.12 ± 0.09**
- Two different measurements are performed within the simplified template cross section framework, in which **17** and **27** independent kinematic regions are measured simultaneously
- Several additional measurements are the most precise made in a single channel to date
- Measurements of the Higgs boson's couplings to vector bosons and to fermions, are also in agreement with the SM expectations

Thanks

Backup

“Minimal” Merging Scenario



The expected number of signal events for $m_{\mathrm{H}} = 125\,\mathrm{GeV}$ in analysis categories targeting ggH production, excluding those targeting the VBF-like phase space, shown for an integrated luminosity of $137\,\mathrm{fb}^{-1}$. The fraction of the total number of events arising from each production mode in each analysis category is provided, as is the fraction of events originating from the targeted STXS bin or bins. Entries with values less than 0.05% are not shown. Here qqH includes contributions from both VBF and hadronic VH production, whilst "Top" includes $\mathrm{t\bar{t}H}$ and tH together. The σ_{eff}, defined as the smallest interval containing 68.3% of the $m_{\gamma\gamma}$ distribution, is listed for each analysis category. The final column shows the expected ratio of signal to signal-plus-background, S/(S+B), where S and B are the numbers of expected signal and background events in a $\pm 1\sigma_{\mathrm{eff}}$ window centred on m_{H}.

	SM 125 GeV Higgs boson expected signal								
Analysis categories	Total	Target STXS bin(s)	Fraction of total events					σ_{eff}	S/(S+B)
			ggH	$\mathrm{b\bar{b}H}$	qqH	VH lep	Top	(GeV)	
0J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag0	296.2	86.6%	97.9%	1.1%	0.8%	0.1%	—	1.89	0.06
0J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag1	340.0	88.5%	98.0%	1.0%	0.8%	0.1%	—	2.31	0.03
0J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag2	279.6	89.3%	98.1%	1.0%	0.8%	0.1%	—	2.53	0.02
0J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag0	612.4	81.9%	95.6%	1.4%	2.6%	0.4%	—	1.64	0.09
0J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag1	1114.6	79.4%	95.4%	1.3%	2.8%	0.4%	—	2.19	0.05
0J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag2	1162.6	78.3%	95.3%	1.4%	2.7%	0.5%	—	2.56	0.02
1J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag0	132.0	66.2%	88.8%	0.8%	9.4%	0.8%	0.1%	1.53	0.11
1J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag1	340.0	66.3%	88.6%	0.8%	9.6%	0.9%	0.1%	1.95	0.05
1J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag2	260.6	66.2%	88.3%	0.8%	9.7%	1.0%	0.1%	2.37	0.02
1J med $p_{\mathrm{T}}^{\gamma\gamma}$ Tag0	184.1	65.2%	81.7%	0.5%	16.3%	1.4%	0.2%	1.65	0.15
1J med $p_{\mathrm{T}}^{\gamma\gamma}$ Tag1	310.2	66.3%	83.6%	0.4%	14.3%	1.6%	0.1%	1.91	0.08
1J med $p_{\mathrm{T}}^{\gamma\gamma}$ Tag2	291.4	65.0%	83.7%	0.5%	13.8%	1.8%	0.2%	2.13	0.03
1J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag0	37.3	61.9%	75.7%	0.2%	22.8%	1.0%	0.2%	1.55	0.30
1J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag1	31.2	61.7%	75.0%	0.3%	23.4%	1.1%	0.2%	1.73	0.16
1J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag2	80.9	62.2%	76.5%	0.2%	21.5%	1.6%	0.2%	1.97	0.07
≥2J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag0	17.7	52.7%	76.7%	0.6%	19.0%	1.3%	2.4%	1.56	0.06
≥2J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag1	57.6	54.0%	74.4%	0.6%	20.5%	1.4%	3.0%	1.88	0.03
≥2J low $p_{\mathrm{T}}^{\gamma\gamma}$ Tag2	43.9	50.5%	72.7%	0.6%	20.8%	1.7%	4.2%	2.46	0.01
≥2J med $p_{\mathrm{T}}^{\gamma\gamma}$ Tag0	21.2	64.9%	80.6%	0.3%	16.3%	1.0%	1.8%	1.42	0.17
≥2J med $p_{\mathrm{T}}^{\gamma\gamma}$ Tag1	70.1	61.4%	77.9%	0.3%	18.1%	1.1%	2.6%	1.82	0.07
≥2J med $p_{\mathrm{T}}^{\gamma\gamma}$ Tag2	135.4	57.5%	74.8%	0.4%	19.7%	1.4%	3.8%	2.08	0.03
≥2J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag0	29.0	65.5%	77.8%	0.2%	18.7%	1.3%	2.1%	1.48	0.23
≥2J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag1	52.5	62.3%	76.1%	0.2%	19.6%	1.5%	2.6%	1.76	0.11
≥2J high $p_{\mathrm{T}}^{\gamma\gamma}$ Tag2	45.5	58.4%	73.8%	0.2%	20.4%	1.9%	3.7%	1.92	0.05
BSM $200 < p_{\mathrm{T}}^{\gamma\gamma} < 300$ Tag0	30.7	75.8%	77.5%	0.2%	19.4%	1.2%	1.6%	1.41	0.39
BSM $200 < p_{\mathrm{T}}^{\gamma\gamma} < 300$ Tag1	39.6	69.9%	73.8%	0.1%	21.5%	1.7%	2.8%	1.90	0.11
BSM $300 < p_{\mathrm{T}}^{\gamma\gamma} < 450$ Tag0	15.5	74.8%	76.3%	0.1%	19.7%	1.7%	2.2%	1.53	0.34
BSM $300 < p_{\mathrm{T}}^{\gamma\gamma} < 450$ Tag1	2.6	66.3%	67.9%	0.1%	22.5%	2.6%	7.0%	1.42	0.09
BSM $450 < p_{\mathrm{T}}^{\gamma\gamma} < 650$	3.1	58.1%	61.8%	0.1%	30.0%	2.4%	5.6%	1.55	0.20
BSM $p_{\mathrm{T}}^{\gamma\gamma} > 650$	0.9	72.5%	72.3%	0.1%	21.0%	2.9%	3.8%	1.21	0.36

STXS bin	Definition units of p_T^H, m_{jj} and p_T^{Hjj} in GeV	Fraction of cross section VBF	$q\overline{q}' \to W(q\overline{q}')H$	$q\overline{q} \to Z(q\overline{q})H$	$\sigma_{SM}\mathcal{B}$ (fb)
qqH forward	$\lvert y_H \rvert > 2.5$	6.69%	12.57%	9.84%	0.98
qqH 0J	Exactly 0 jets	6.95%	5.70%	3.73%	0.77
qqH 1J	Exactly 1 jet	32.83%	31.13%	25.03%	3.82
qqH $m_{jj} < 60$	At least 2 jets, $m_{jj} < 60$	1.36%	3.58%	2.72%	0.23
qqH VH-like	At least 2 jets, $60 < m_{jj} < 120$	2.40%	29.43%	28.94%	1.23
qqH $120 < m_{jj} < 350$	At least 2 jets, $120 < m_{jj} < 350$	12.34%	13.92%	12.59%	1.53
qqH VBF-like low m_{jj} low p_T^{Hjj}	At least 2 jets, $p_T^H < 200$, $350 < m_{jj} < 700$, $p_T^{Hjj} < 25$	10.26%	0.44%	0.35%	0.90
qqH VBF-like low m_{jj} high p_T^{Hjj}	At least 2 jets, $p_T^H < 200$, $350 < m_{jj} < 700$, $p_T^{Hjj} > 25$	3.85%	1.86%	1.74%	0.39
qqH VBF-like high m_{jj} low p_T^{Hjj}	At least 2 jets, $p_T^H < 200$, $m_{jj} > 700$, $p_T^{Hjj} < 25$	15.09%	0.09%	0.08%	1.30
qqH VBF-like high m_{jj} high p_T^{Hjj}	At least 2 jets, $p_T^H < 200$, $m_{jj} > 700$, $p_T^{Hjj} > 25$	4.25%	0.40%	0.39%	0.38
qqH BSM	At least 2 jets, $m_{jj} > 350$, $p_T^H > 200$	3.98%	0.88%	0.71%	0.37

Definition of the qqH STXS bins. The product of the cross section and branching fraction ($\mathcal{B}$), evaluated at $\sqrt{s} = 13\,\text{TeV}$ and $m_H = 125\,\text{GeV}$, is given for each bin in the last column. The fraction of the total production mode cross section from each STXS bin is also shown. Unless stated otherwise, the STXS bins are defined for $\lvert y_H \rvert < 2.5$. Events with $\lvert y_H \rvert > 2.5$ are mostly outside of the experimental acceptance and therefore have a negligible contribution to all analysis categories.

Analysis categories	SM 125 GeV Higgs boson expected signal: Total	Target STXS bin(s)	Fraction of total events: ggH	VBF	VH had	VH lep	Top	σ_{eff} (GeV)	S/(S+B)
ggH VBF-like Tag0	14.1	37.7%	65.9%	27.3%	3.8%	0.8%	2.3%	1.85	0.14
ggH VBF-like Tag1	32.5	30.2%	61.3%	29.8%	4.1%	1.1%	3.7%	1.83	0.10
qqH low m_{jj} low p_T^{Hjj} Tag0	17.2	48.2%	36.6%	62.6%	0.4%	0.1%	0.3%	1.89	0.20
qqH low m_{jj} low p_T^{Hjj} Tag1	13.5	48.5%	35.5%	63.4%	0.6%	0.1%	0.3%	1.74	0.19
qqH high m_{jj} low p_T^{Hjj} Tag0	27.0	70.4%	17.1%	82.7%	0.2%	—	0.1%	1.78	0.49
qqH high m_{jj} low p_T^{Hjj} Tag1	12.9	58.2%	20.8%	78.7%	0.3%	0.1%	0.2%	1.99	0.27
qqH low m_{jj} high p_T^{Hjj} Tag0	10.4	15.0%	56.0%	41.3%	1.3%	0.4%	1.0%	1.92	0.12
qqH low m_{jj} high p_T^{Hjj} Tag1	20.2	17.0%	57.9%	36.9%	2.4%	0.7%	2.1%	1.74	0.08
qqH high m_{jj} high p_T^{Hjj} Tag0	18.1	25.6%	28.1%	70.8%	0.4%	0.1%	0.5%	1.88	0.29
qqH high m_{jj} high p_T^{Hjj} Tag1	17.5	23.8%	39.5%	57.8%	0.9%	0.3%	1.5%	1.98	0.13
qqH BSM Tag0	11.2	71.2%	24.4%	74.8%	0.1%	0.1%	0.6%	1.62	0.56
qqH BSM Tag1	6.8	56.4%	36.9%	59.9%	1.1%	0.4%	1.7%	1.67	0.39
qqH VH-like Tag0	16.3	55.8%	36.5%	2.8%	55.0%	1.4%	4.2%	1.72	0.25
qqH VH-like Tag1	47.1	26.8%	64.9%	4.7%	26.4%	1.2%	2.9%	1.66	0.13

The expected number of signal events for $m_H = 125\,\text{GeV}$ in analysis categories targeting VBF-like phase space and VH production in which the vector boson decays hadronically, shown for an integrated luminosity of $137\,\text{fb}^{-1}$. The fraction of the total number of events arising from each production mode in each analysis category is provided, as is the fraction of events originating from the targeted STXS bin or bins. Entries with values less than 0.05% are not shown. Here ggH includes contributions from the $ggZ(q\overline{q})H$ and $b\overline{b}H$ production modes, whilst "Top" represents both $t\overline{t}H$ and tH production together. The σ_{eff}, defined as the smallest interval containing 68.3% of the $m_{\gamma\gamma}$ distribution, is listed for each analysis category. The final column shows the expected ratio of signal to signal-plus-background, S/(S+B), where S and B are the numbers of expected signal and background events in a $\pm 1\sigma_{eff}$ window centred on m_H.

STXS bin	Definition units of p_T^V in GeV	Fraction of cross section $q\overline{q}' \to WH$	$q\overline{q} \to ZH$	$gg \to ZH$	$\sigma_{SM}\mathcal{B}$ (fb)
WH lep forward		12.13%	—	—	0.123
ZH lep forward	$\|y_H\| > 2.5$	—	11.21%	—	0.058
ggZH lep forward		—	—	2.71%	0.002
WH lep $p_T^V < 75$	No jet requirements, $p_T^V < 75$	46.55%	—	—	0.473
WH lep $75 < p_T^V < 150$	No jet requirements, $75 < p_T^V < 150$	29.30%	—	—	0.298
WH lep 0J $150 < p_T^V < 250$	Exactly 0 jets, $150 < p_T^V < 250$	5.10%	—	—	0.052
WH lep ≥1J $150 < p_T^V < 250$	At least 1 jet, $150 < p_T^V < 250$	3.97%	—	—	0.040
WH lep $p_T^V > 250$	No jet requirements, $p_T^V > 250$	2.95%	—	—	0.030
ZH lep $p_T^V < 75$	No jet requirements, $p_T^V < 75$	—	45.65%	—	0.237
ZH lep $75 < p_T^V < 150$	No jet requirements, $75 < p_T^V < 150$	—	30.70%	—	0.160
ZH lep 0J $150 < p_T^V < 250$	Exactly 0 jets, $150 < p_T^V < 250$	—	5.16%	—	0.027
ZH lep ≥1J $150 < p_T^V < 250$	At least 1 jet, $150 < p_T^V < 250$	—	4.27%	—	0.022
ZH lep $p_T^V > 250$	No jet requirements, $p_T^V > 250$	—	3.01%	—	0.016
ggZH lep $p_T^V < 75$	No jet requirements, $p_T^V < 75$	—	—	15.96%	0.013
ggZH lep $75 < p_T^V < 150$	No jet requirements, $75 < p_T^V < 150$	—	—	43.32%	0.036
ggZH lep 0J $150 < p_T^V < 250$	Exactly 0 jets, $150 < p_T^V < 250$	—	—	9.08%	0.008
ggZH lep ≥1J $150 < p_T^V < 250$	At least 1 jet, $150 < p_T^V < 250$	—	—	20.49%	0.017
ggZH lep $p_T^V > 250$	No jet requirements, $p_T^V > 250$	—	—	8.45%	0.007

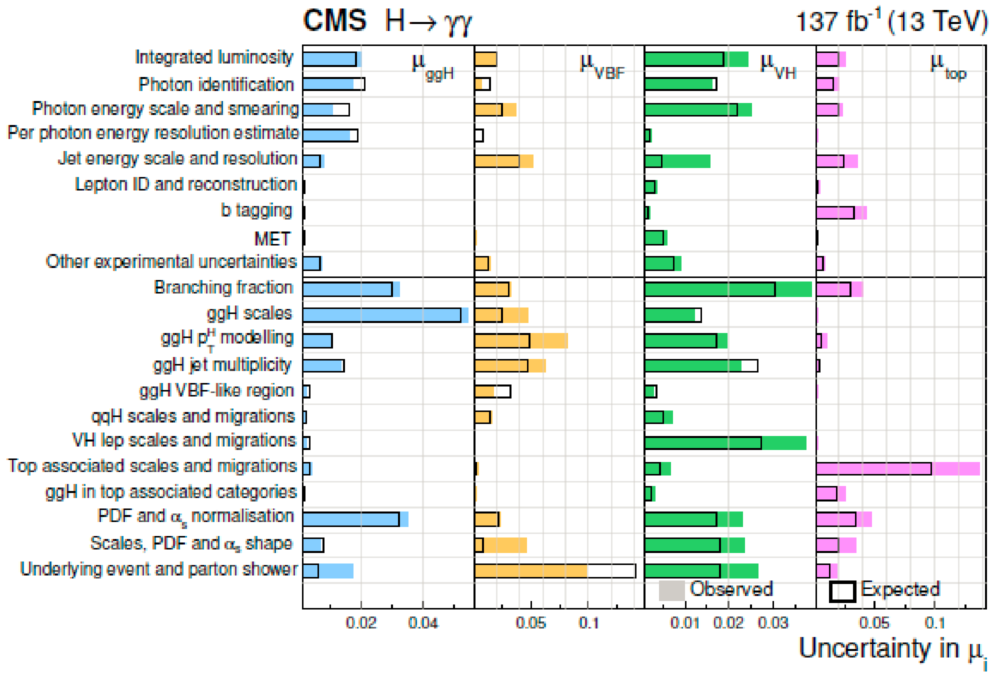
Definition of the VH leptonic STXS bins. The product of the cross section and branching fraction ($\mathcal{B}$), evaluated at $\sqrt{s} = 13$ TeV and $m_H = 125$ GeV, is given for each bin in the last column. The fraction of the total production mode cross section from each STXS bin is also shown. Unless stated otherwise, the STXS bins are defined for $|y_H| < 2.5$. Events with $|y_H| > 2.5$ are mostly outside of the experimental acceptance and therefore have a negligible contribution to all analysis categories. Only leptonic decays of the W and Z bosons are included in these definitions.

Analysis categories	SM 125 GeV Higgs boson expected signal Total	Target STXS bin(s)	Fraction of total events ggH	qqH	WH lep	ZH lep	ggZH lep	Top	σ_{eff} (GeV)	S/(S+B)
ZH lep Tag0	2.4	99.6%	—	—	—	82.0%	17.7%	0.4%	1.67	0.57
ZH lep Tag1	0.9	97.5%	0.1%	—	0.2%	80.7%	16.9%	2.2%	1.85	0.32
WH lep $p_T^V < 75$ Tag0	2.0	81.1%	—	0.2%	95.0%	3.3%	0.2%	1.3%	1.89	0.43
WH lep $p_T^V < 75$ Tag1	4.5	75.7%	2.6%	0.5%	87.2%	7.0%	0.3%	2.4%	1.85	0.19
WH lep $75 < p_T^V < 150$ Tag0	3.0	77.7%	0.7%	0.3%	93.2%	3.4%	0.8%	1.6%	1.94	0.56
WH lep $75 < p_T^V < 150$ Tag1	3.3	60.8%	1.7%	1.4%	83.1%	7.7%	1.6%	4.4%	2.02	0.33
WH lep $p_T^V > 150$ Tag0	3.5	79.9%	0.5%	0.4%	91.5%	3.6%	1.1%	2.8%	1.84	0.77
VH MET Tag0	2.2	97.9%	0.4%	0.9%	23.5%	56.9%	17.6%	0.8%	2.22	0.48
VH MET Tag1	3.6	90.5%	4.6%	3.1%	28.8%	46.0%	15.7%	1.9%	2.30	0.34
VH MET Tag2	6.6	72.2%	15.5%	8.8%	27.7%	33.5%	11.0%	3.5%	2.15	0.18

The expected number of signal events for $m_H = 125$ GeV in analysis categories targeting Higgs boson production in association with a leptonically decaying W or Z boson, shown for an integrated luminosity of 137 fb^{-1}. The fraction of the total number of events arising from each production mode in each analysis category is provided, as is the fraction of events originating from the targeted STXS bin or bins. Entries with values less than 0.05% are not shown. Here ggH includes contributions from the $ggZ(q\overline{q})H$ and $b\overline{b}H$ production modes, qqH incorporates both VBF and VH production with hadronic vector boson decays, and "Top" represents both $t\overline{t}H$ and tH production together. The σ_{eff}, defined as the smallest interval containing 68.3% of the $m_{\gamma\gamma}$ distribution, is listed for each analysis category. The final column shows the expected ratio of signal to signal-plus-background, S/(S+B), where S and B are the numbers of expected signal and background events in a $\pm 1\sigma_{eff}$ window centred on m_H.

STXS bin	Definition units of p_T^H in GeV	Fraction of cross section $t\bar{t}H$	tHq	tHW	$\sigma_{SM}\mathcal{B}$ (fb)
$t\bar{t}H$ forward		1.35%	—	—	0.016
tH forward	$\lvert y_H \rvert > 2.5$	—	2.79%	1.06%	0.005
$t\bar{t}H$ $p_T^H < 60$	No jet requirements, $p_T^H < 60$	22.42%	—	—	0.259
$t\bar{t}H$ $60 < p_T^H < 120$	No jet requirements, $60 < p_T^H < 120$	34.61%	—	—	0.400
$t\bar{t}H$ $120 < p_T^H < 200$	No jet requirements, $120 < p_T^H < 200$	25.60%	—	—	0.296
$t\bar{t}H$ $200 < p_T^H < 300$	No jet requirements, $200 < p_T^H < 300$	10.72%	—	—	0.124
$t\bar{t}H$ $p_T^H > 300$	No jet requirements, $p_T^H > 300$	5.31%	—	—	0.061
tH	No additional requirements	—	97.21%	98.94%	0.204

Definition of the $t\bar{t}H$, tH, and $b\bar{b}H$ STXS bins. The product of the cross section and branching fraction ($\mathcal{B}$), evaluated at $\sqrt{s} = 13$ TeV and $m_H = 125$ GeV, is given for each bin in the last column. The fraction of the total production mode cross section from each STXS bin is also shown. Unless stated otherwise, the STXS bins are defined for $\lvert y_H \rvert < 2.5$. Events with $\lvert y_H \rvert > 2.5$ are mostly outside of the experimental acceptance and therefore have a negligible contribution to all analysis categories.



A summary of the impact of the main sources of systematic uncertainty in the fit to signal strength modifiers of the four principal production modes. The observed (expected) impacts are shown by the solid (empty) bars.