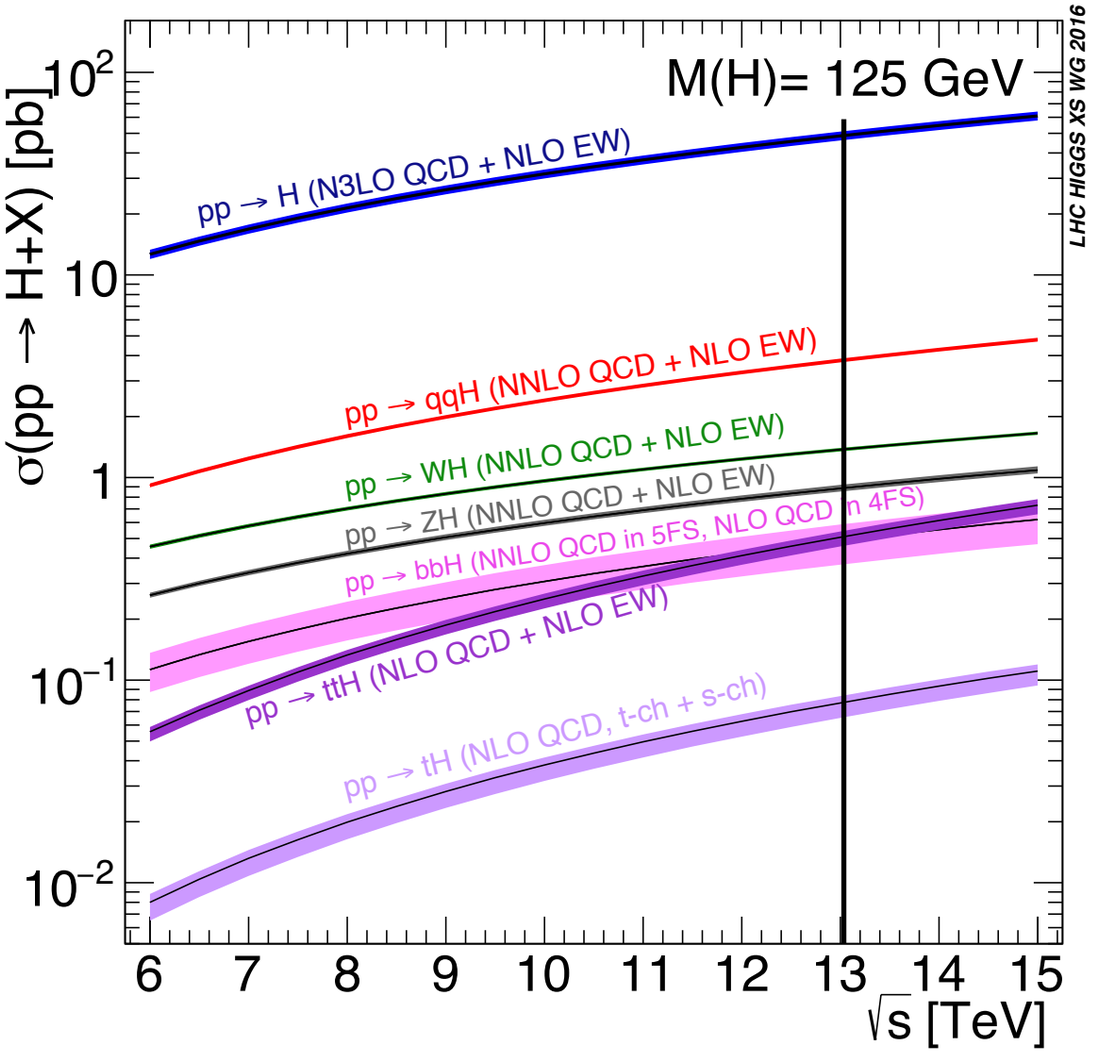
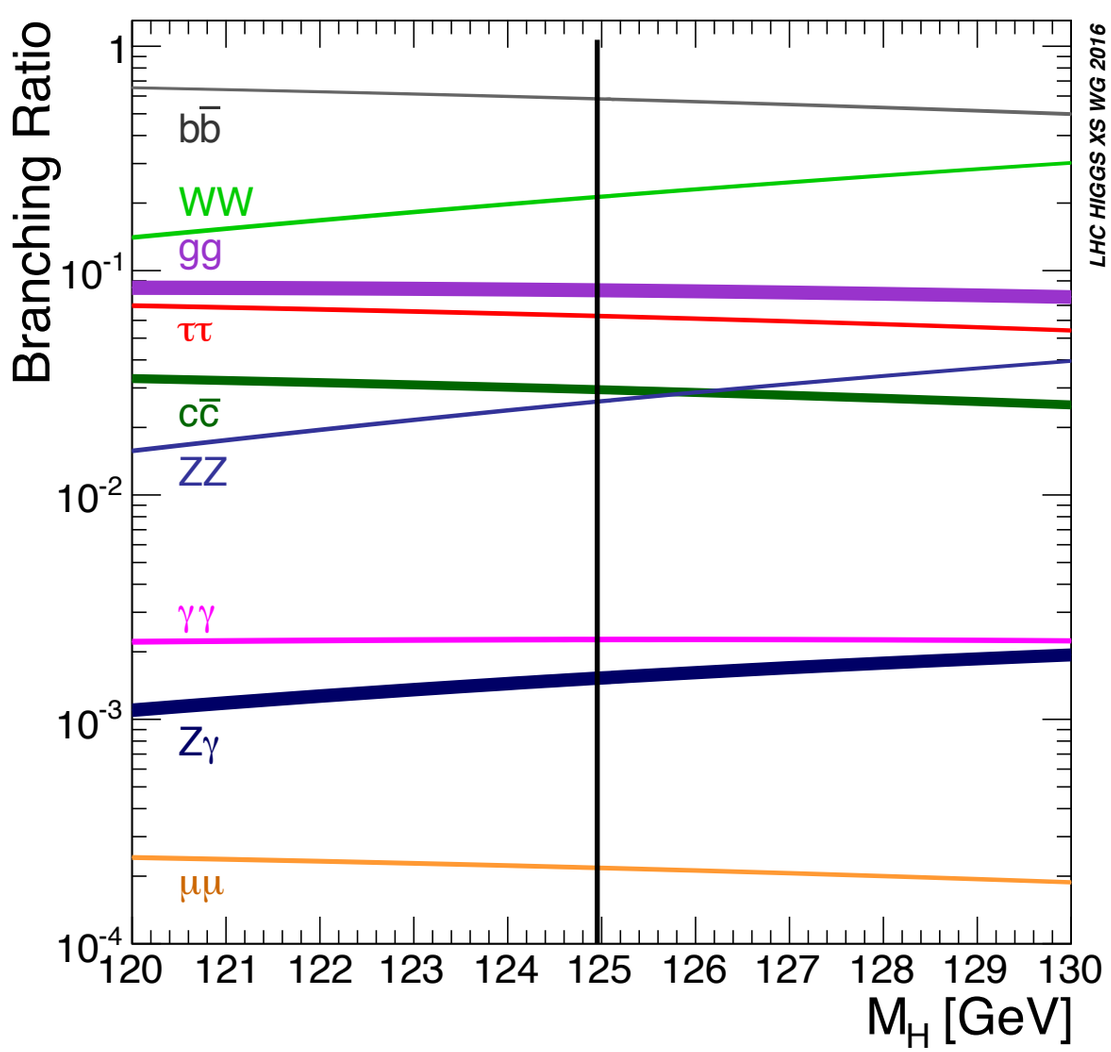
Precision SM Higgs measurements at ATLAS

Chikuma Kato for the ATLAS collaboration
ckato@cern.ch
6 July 2021, LISHEP 2021

Introduction

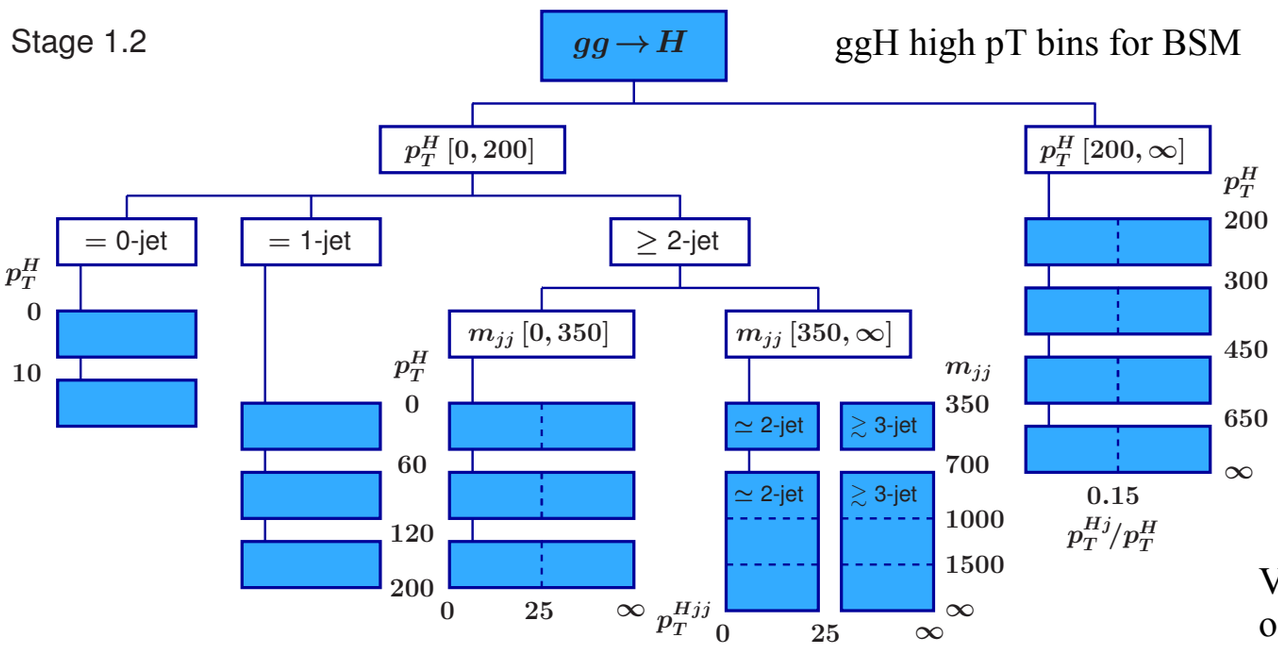
[LHCHWG]





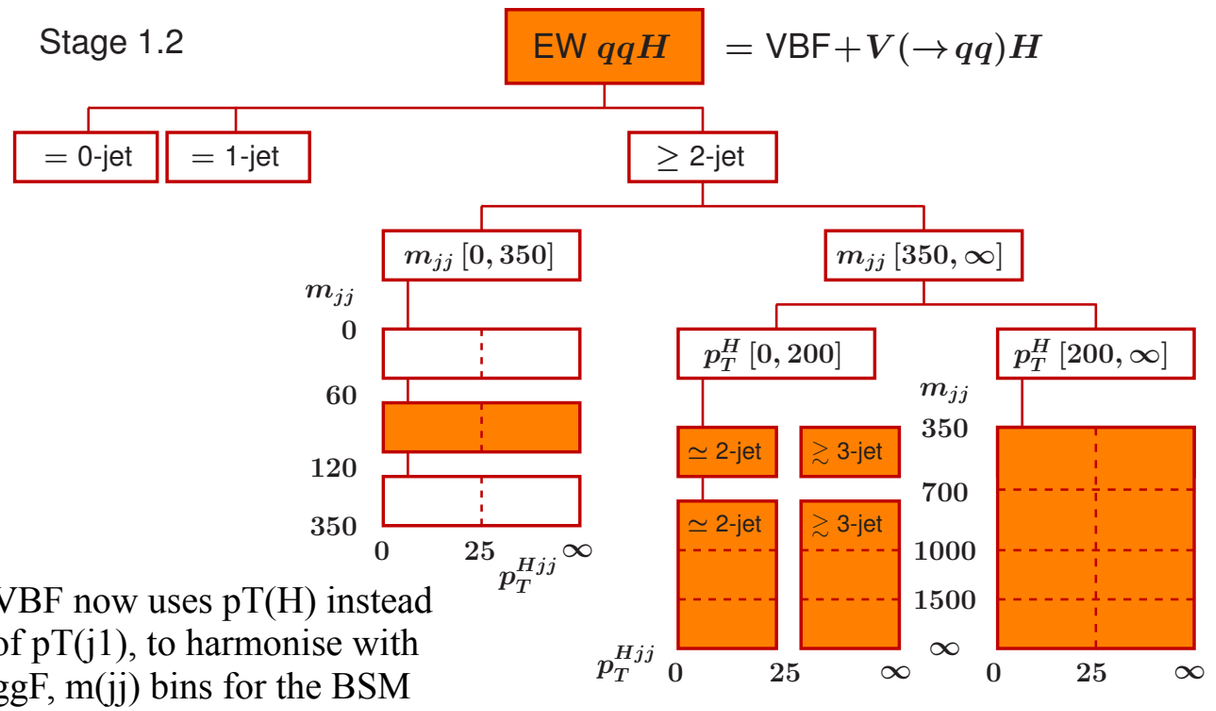
- Highlight full Run 2 Higgs measurements to test the SM
- Total, fiducial, differential, simplified template cross sections (STXS) → Coupling modifiers, EFT coefficients, BSM tests

STXS stage 1.2 binning [STXS]

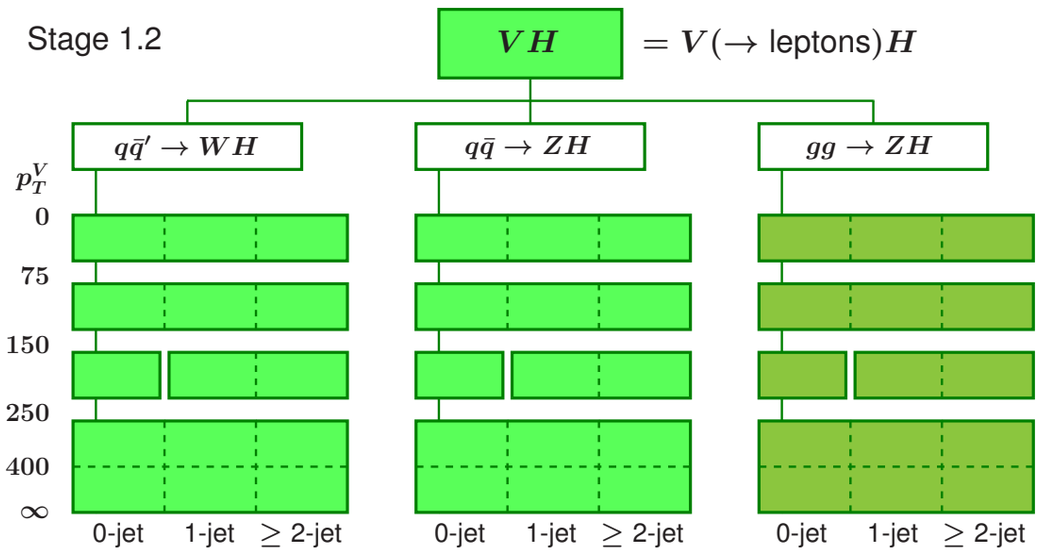


Also ggH low pT bins for couplings

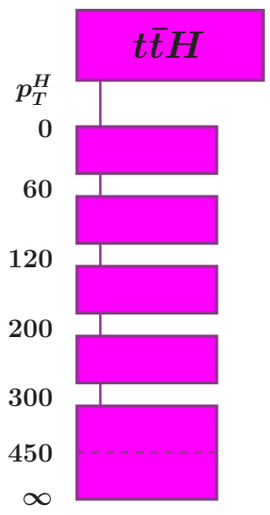
ggH high pT bins for BSM



VBF now uses pT(H) instead of pT(j1), to harmonise with ggF, m(jj) bins for the BSM



VH high pT(V) bins for the BSM, njet bins not yet split

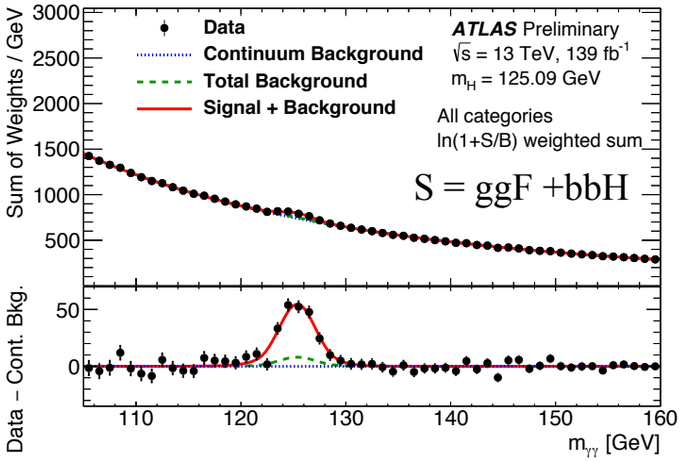


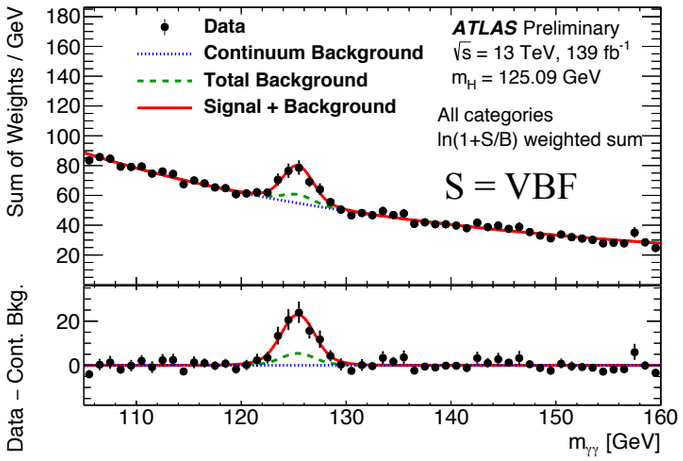
Also started to split pT(H) in ttH

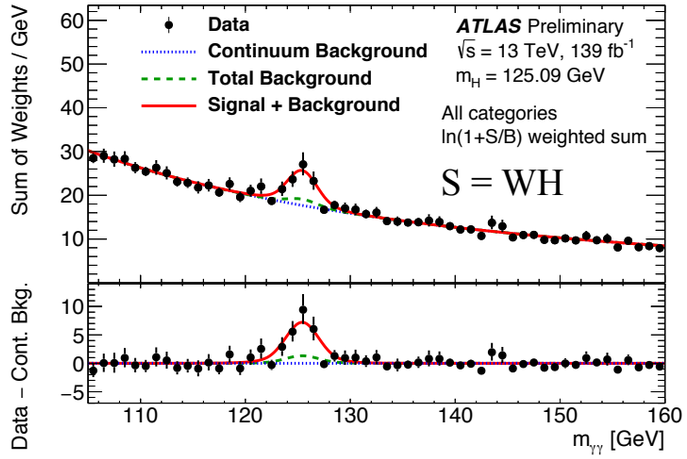
- Higgs boson production cross sections in exclusive kinematic bins
- Bins are split from main production cross sections in $|y_H| < 2.5$ (stage 0, stage 1), and merged based on sensitivity

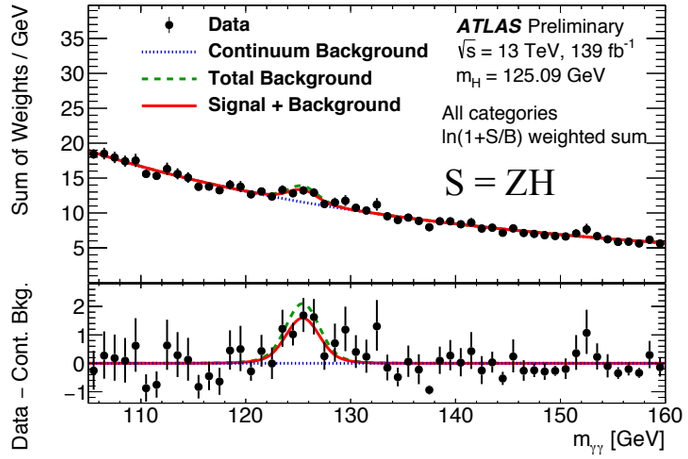
Hγγ

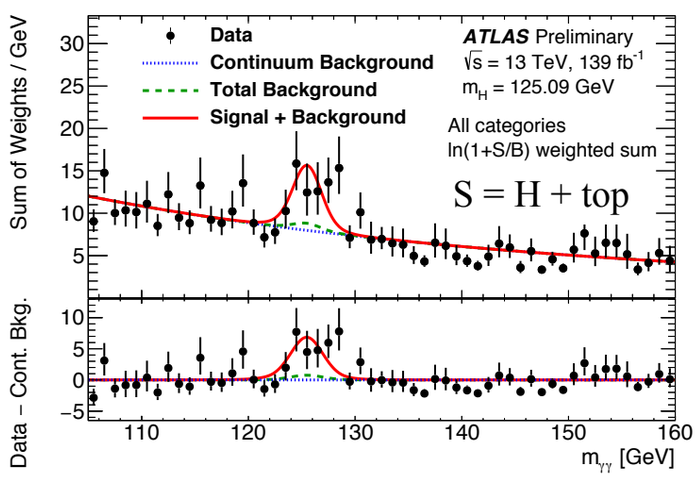
[CONF-2020-026]

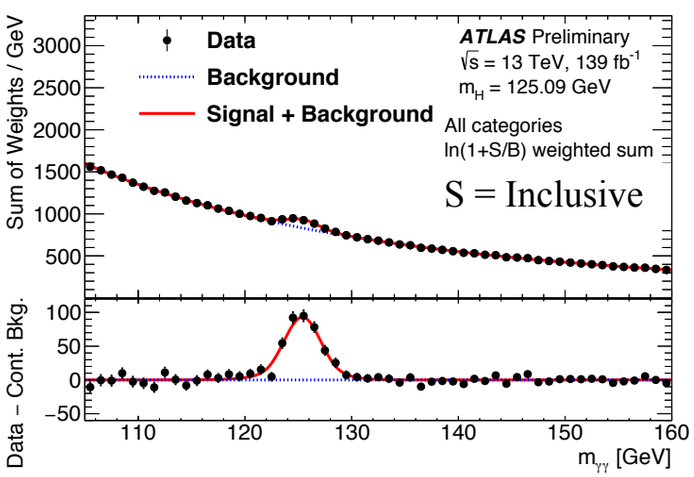








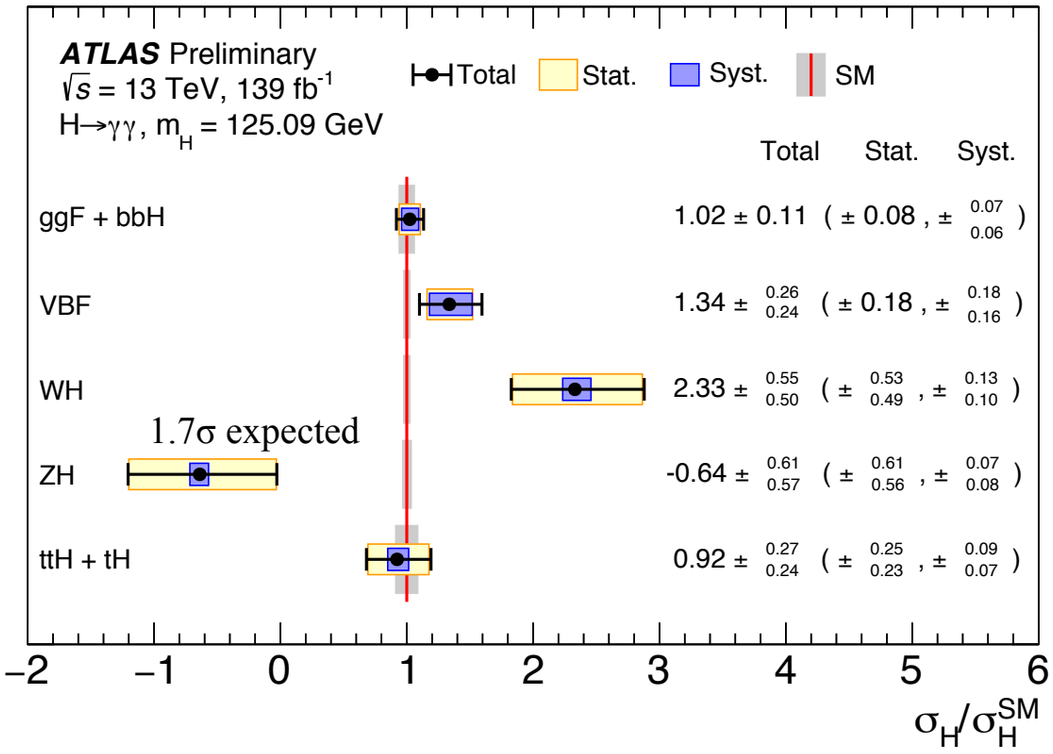


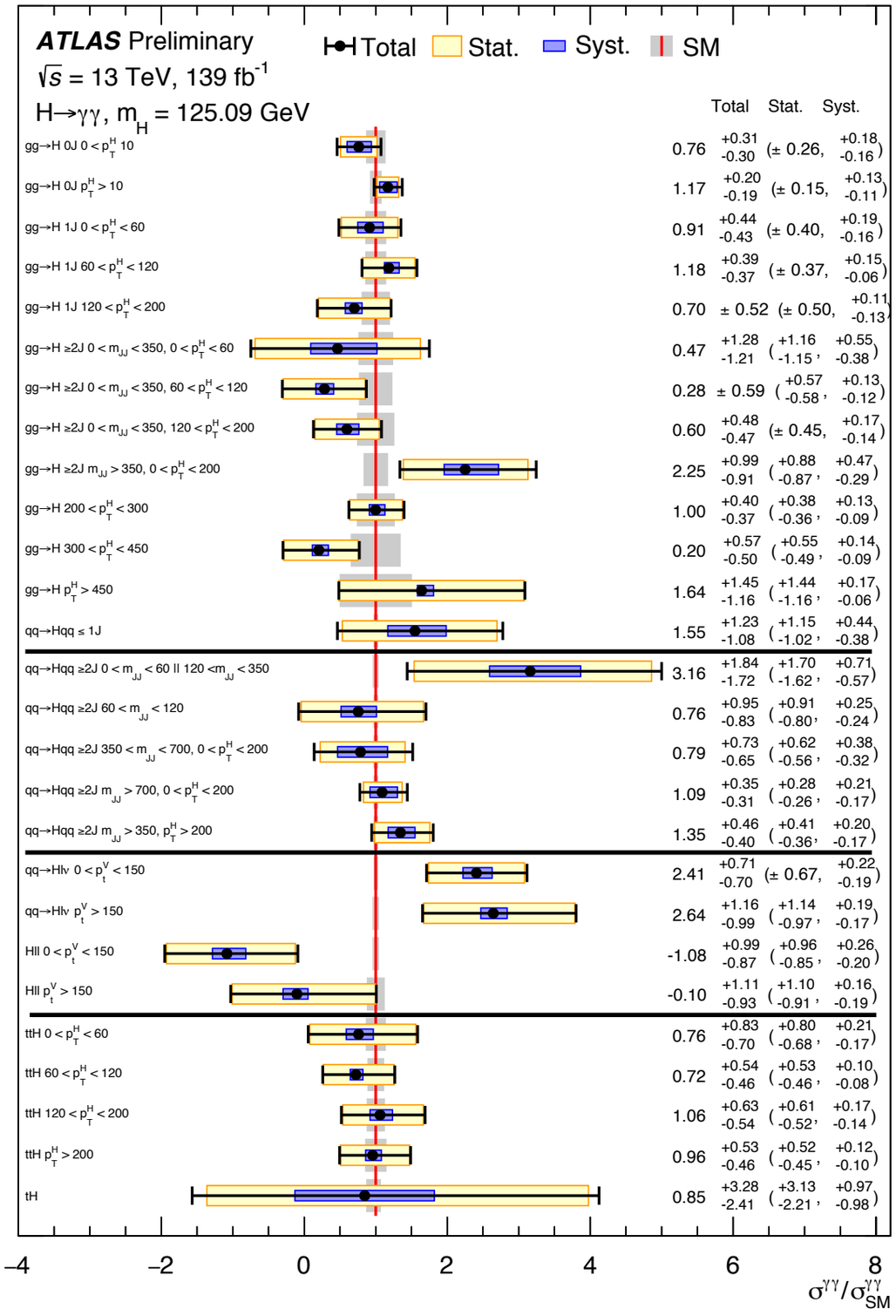


- Sensitivity in all production modes: ggF, VBF, VH, ttH
- Diphoton primary vertex using tracking and position extrapolation in NN (76% efficiency for ggF)
- 39% efficiency after overall selection for $|y_H| < 2.5$
- Background: γγ (80%) γj (20%), jj (few% in high μ)
- Improved categorisation using BDT classes to separate STXS signals, and BDT categories to separate signal from continuum background in each class

Hγγ

[CONF-2020-026]

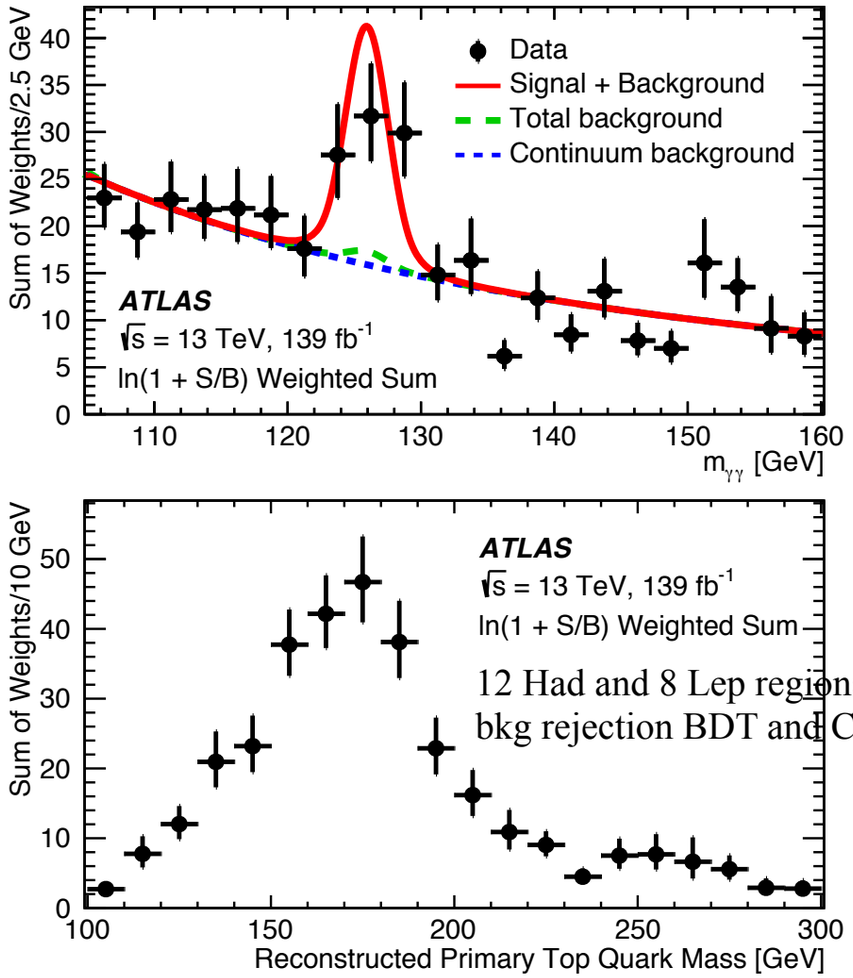


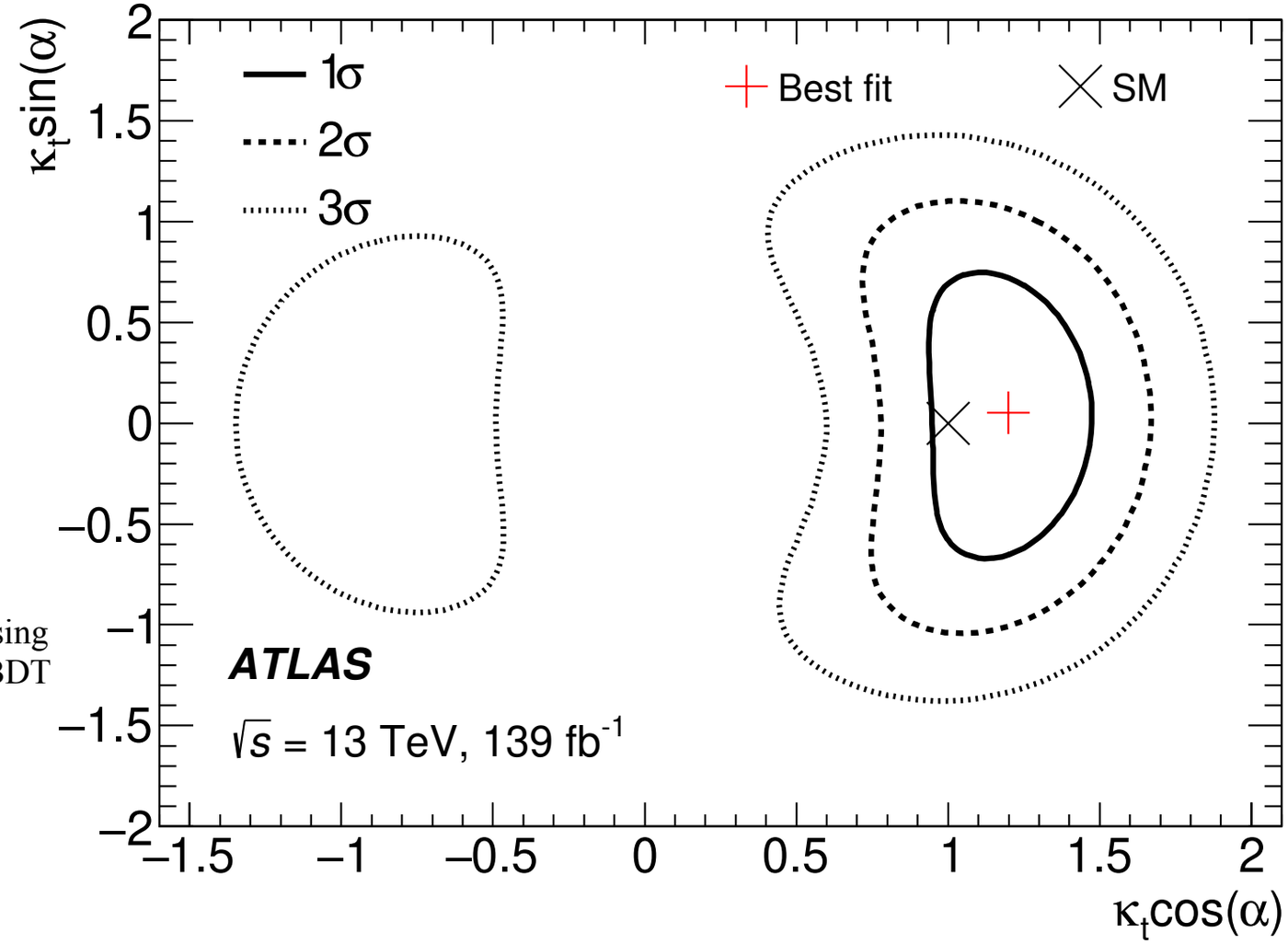


- Inclusive (σBγγ)obs = 127 ± 10 fb, (σBγγ)exp = 116 ± 5 fb
- VBF, WH, ttH+tH: 7.5 (6.1)σ, 5.6 (2.8)σ, 4.7 (5.0)σ
- 14% correlation between ggF and VBF (30% improvement)

ttHγγ CP

[HIGG-2019-01]

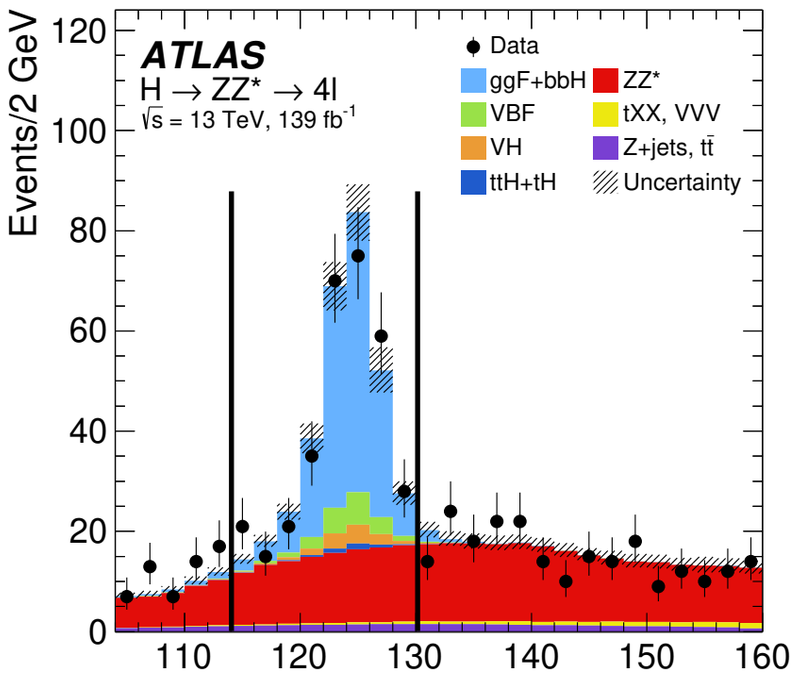


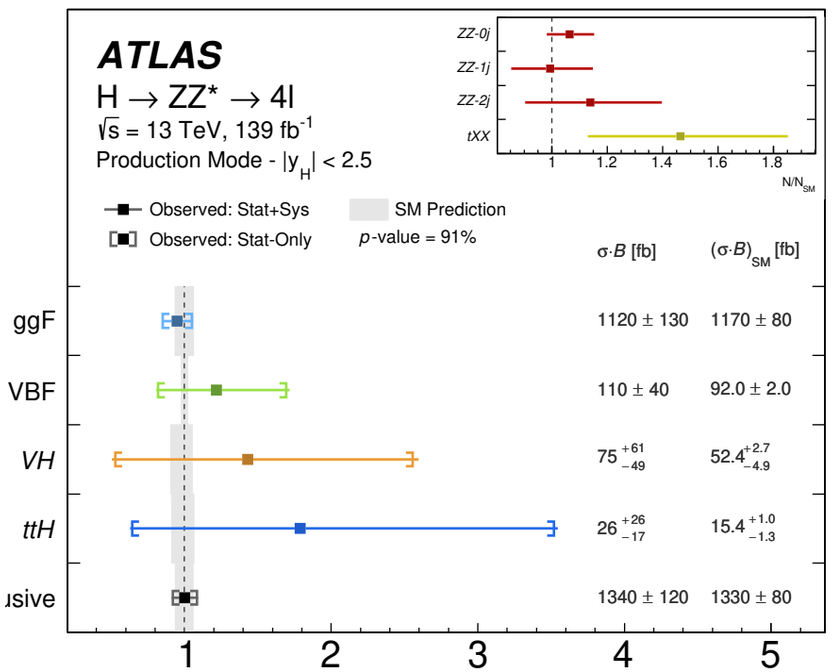


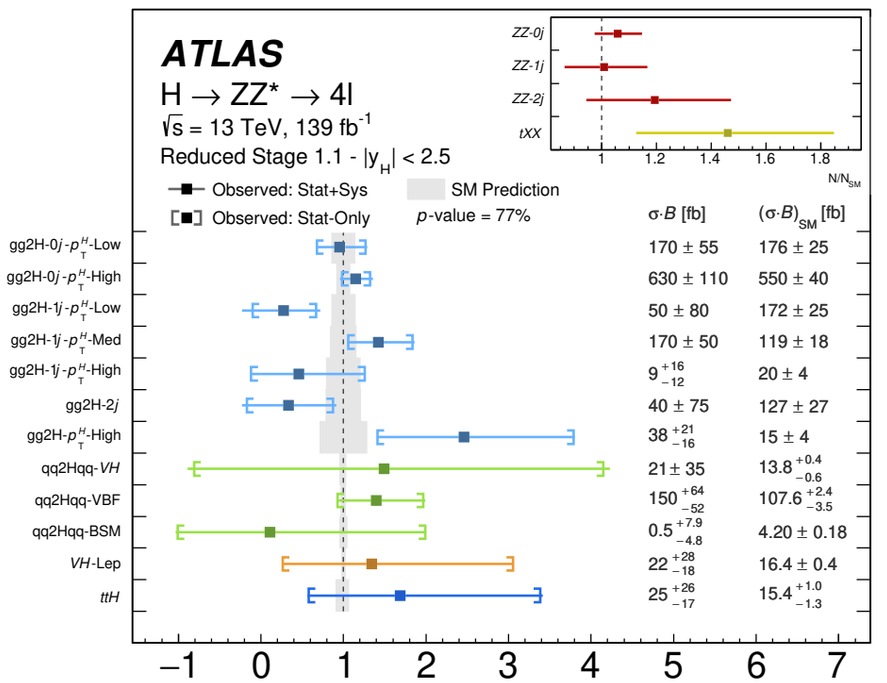
- Describe the top Yukawa by: $L = -\frac{m_t}{v}\{\bar{\psi}_t \kappa_t[\cos(\alpha) + i\sin(\alpha)\gamma_5]\psi_t\}H$
- ttH: 5.2 (4.4) σ, tH: < 12 (12) SM, pure CP-odd coupling is excluded at 3.9 (2.5) σ, CP mixing angle $|\alpha| > 43°$ is excluded at 95% CL

HZZ

[HIGG-2018-28]



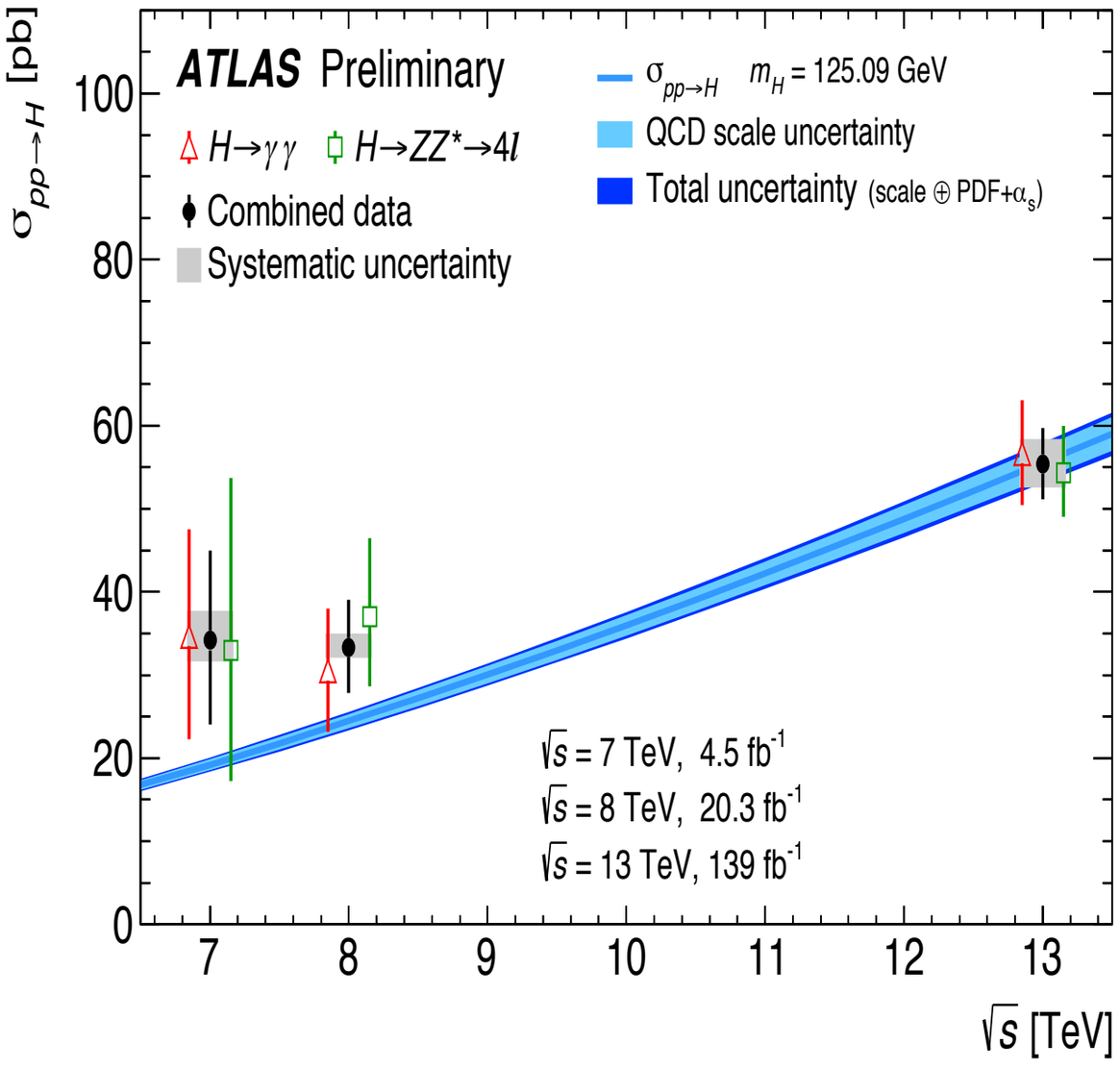


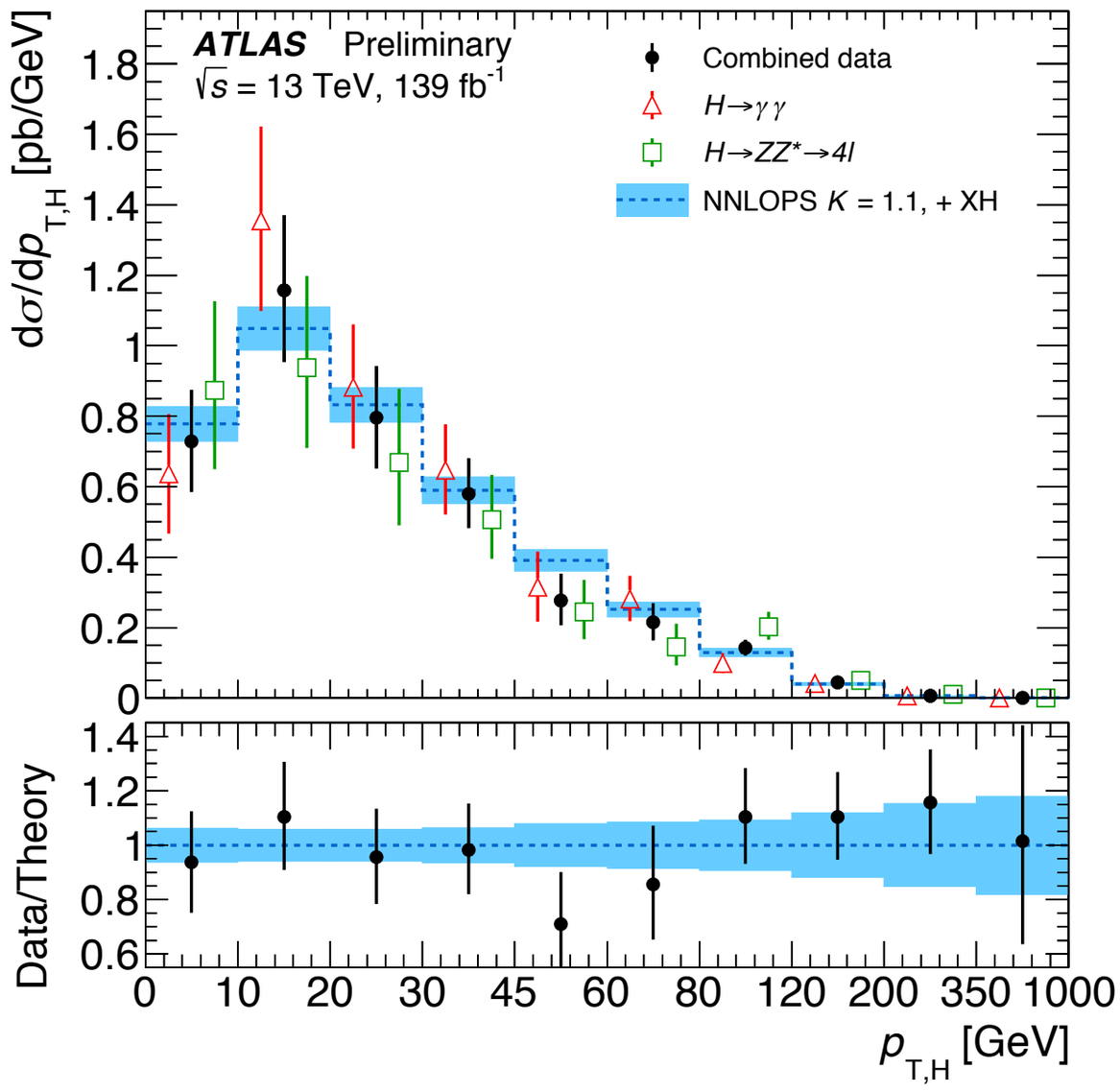


STXS are used to constrain the EFT coefficients

- Select Higgs boson candidates in m(4l) = 115–130 GeV
- Matrix-element-based pairing for > 4l events, FSR correction
- Categorise events and fit NN outputs for the separation
- Inclusive (σBzz)obs = 1.34 ± 0.11 (stat.) ± 0.04 (exp.) ± 0.03 (theo.) pb = 1.34 ± 0.12 pb, (σBzz)exp = 1.33 ± 0.08 pb
- Dominant systematics: lepton efficiency, luminosity, parton shower

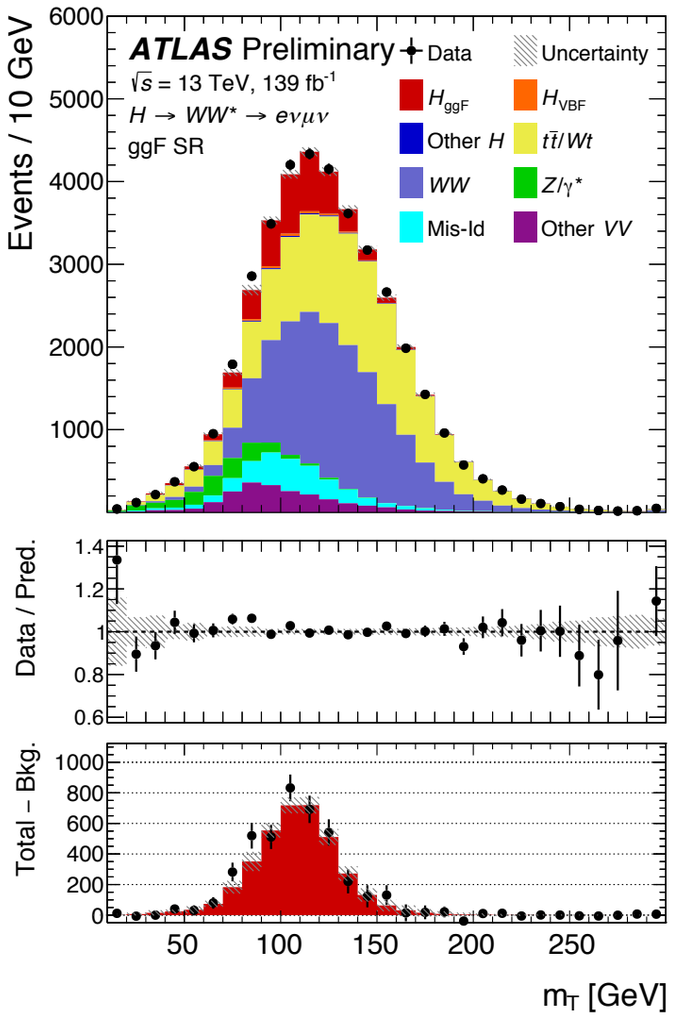
Hγγ and HZZ combination [CONF-2019-032]



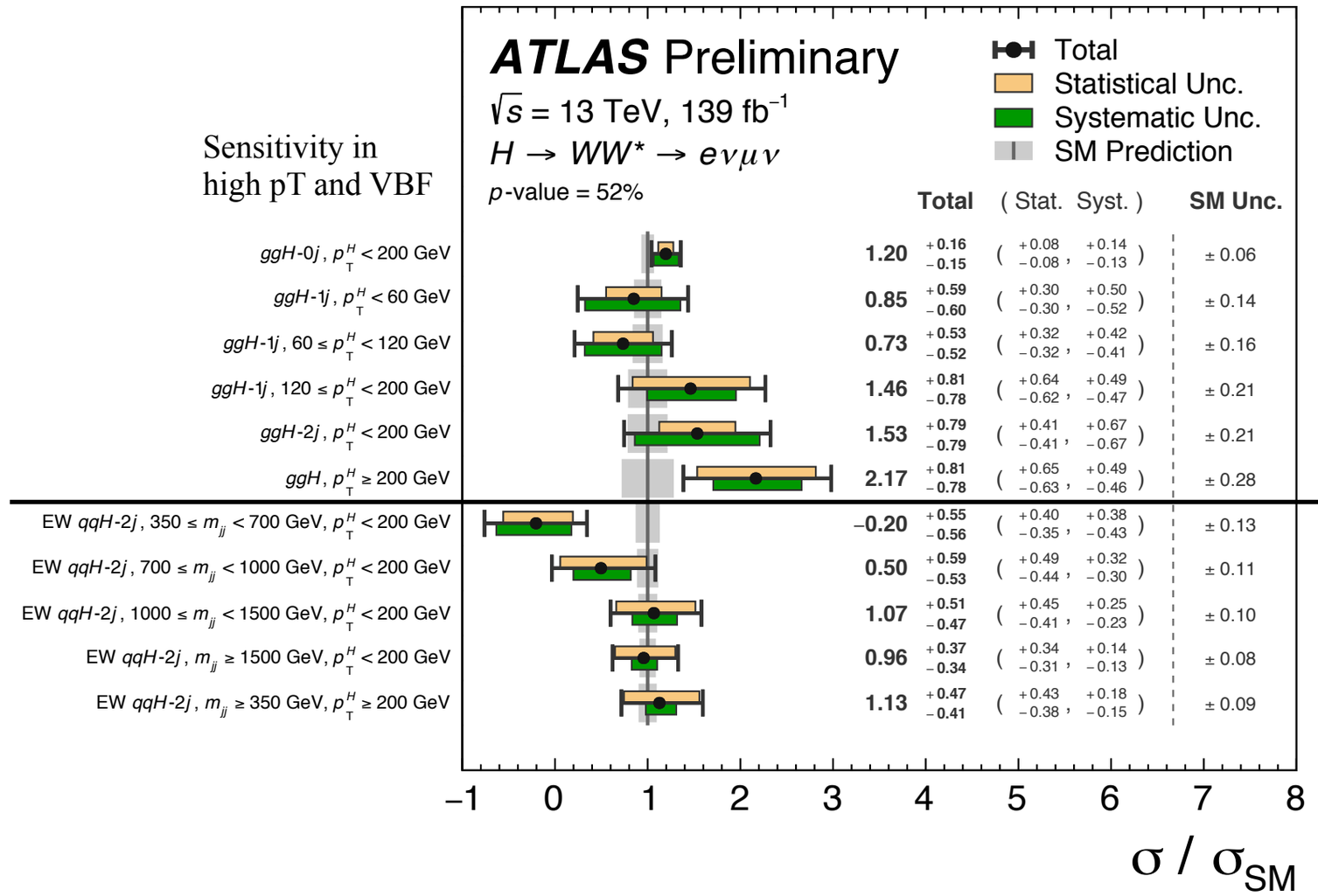


- Total cross section: $55.4^{+4.3}_{-4.2}$ pb, compared to SM of 55.6 ± 2.5 pb
- Hγγ, HZZ and the combination in agreement with the SM

HWW→eνμν [CONF-2021-014]



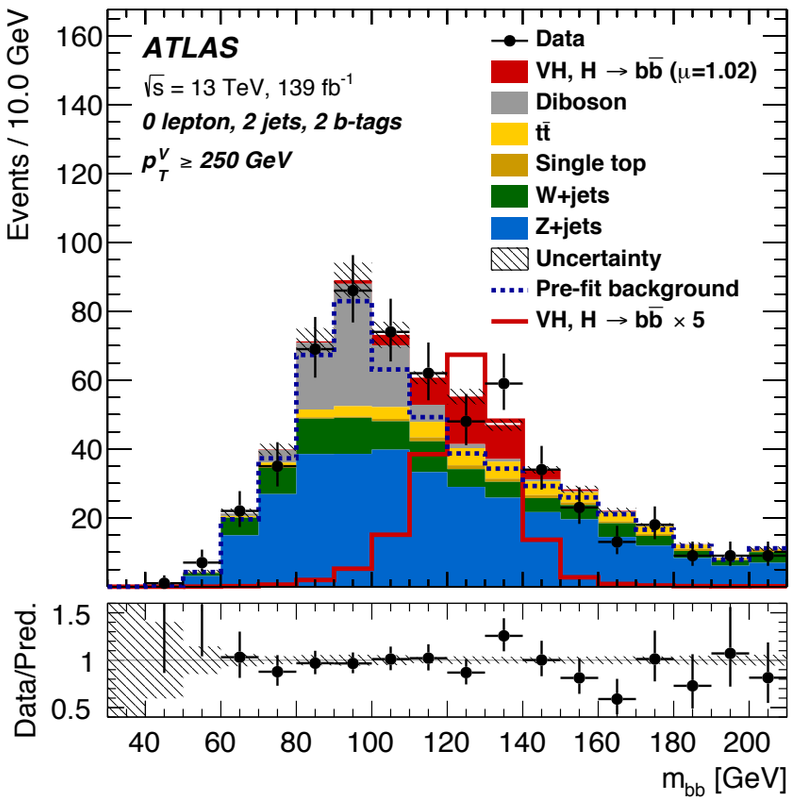
Sensitivity in high pT and VBF

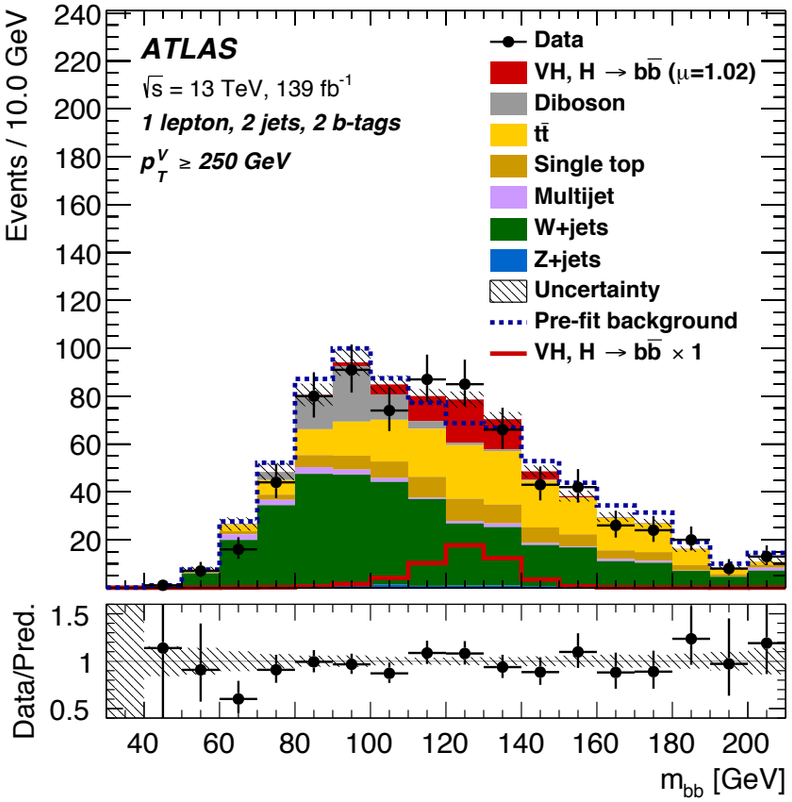


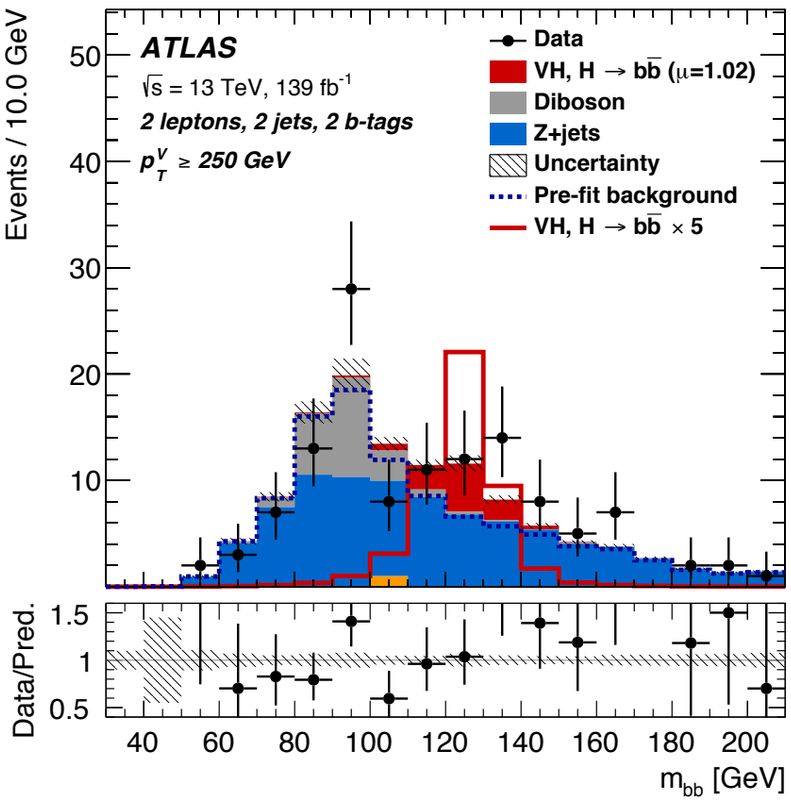
- 0/1/2+ jet categories for ggF (mT), 2+ jets category for VBF (DNN)
- σ(ggF)B(WW) = 12.4 ± 1.5 pb, expected 10.4 ± 0.6 pb
- σ(VBF)B(WW) = $0.79\ ^{+0.19}_{-0.16}$ pb, expected 0.81 ± 0.02 pb

VHbb

[HIGG-2018-51] [HIGG-2018-52]



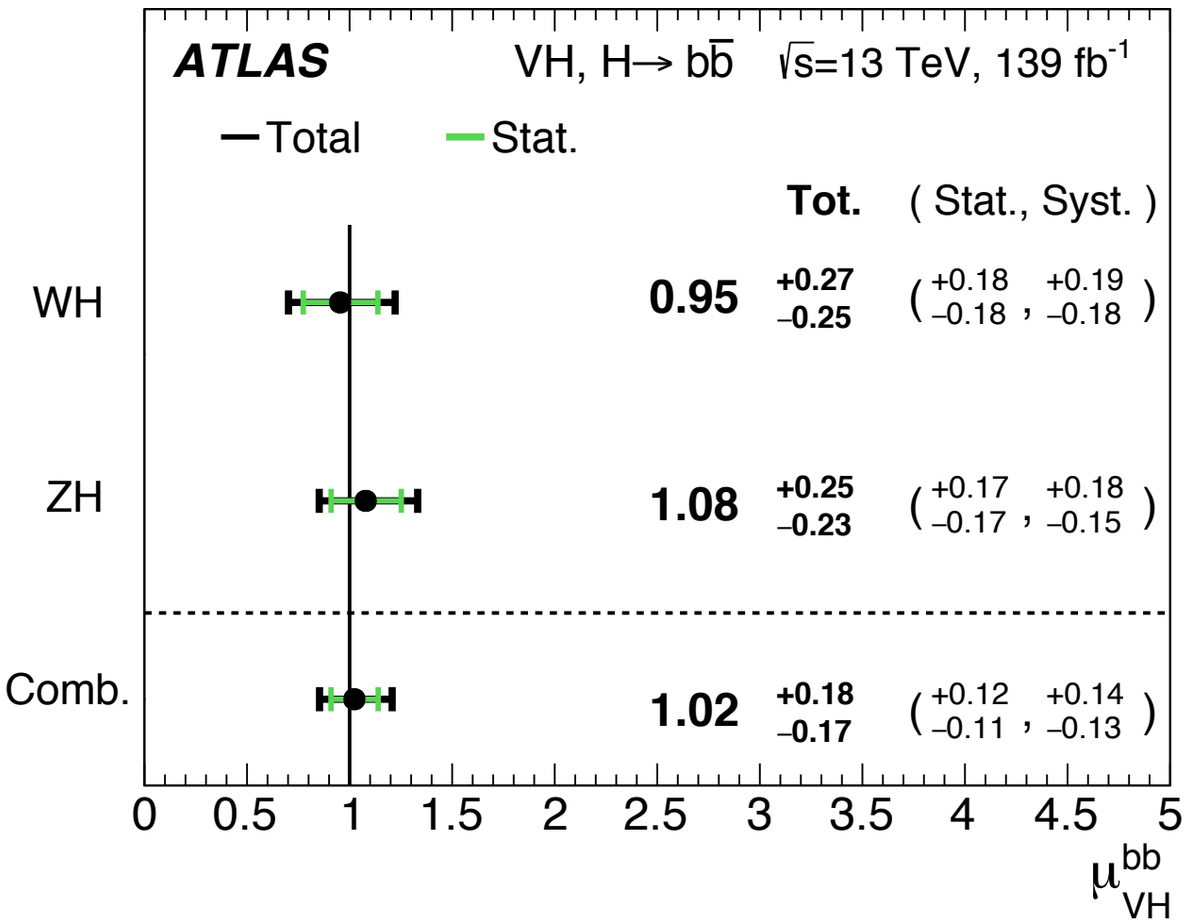


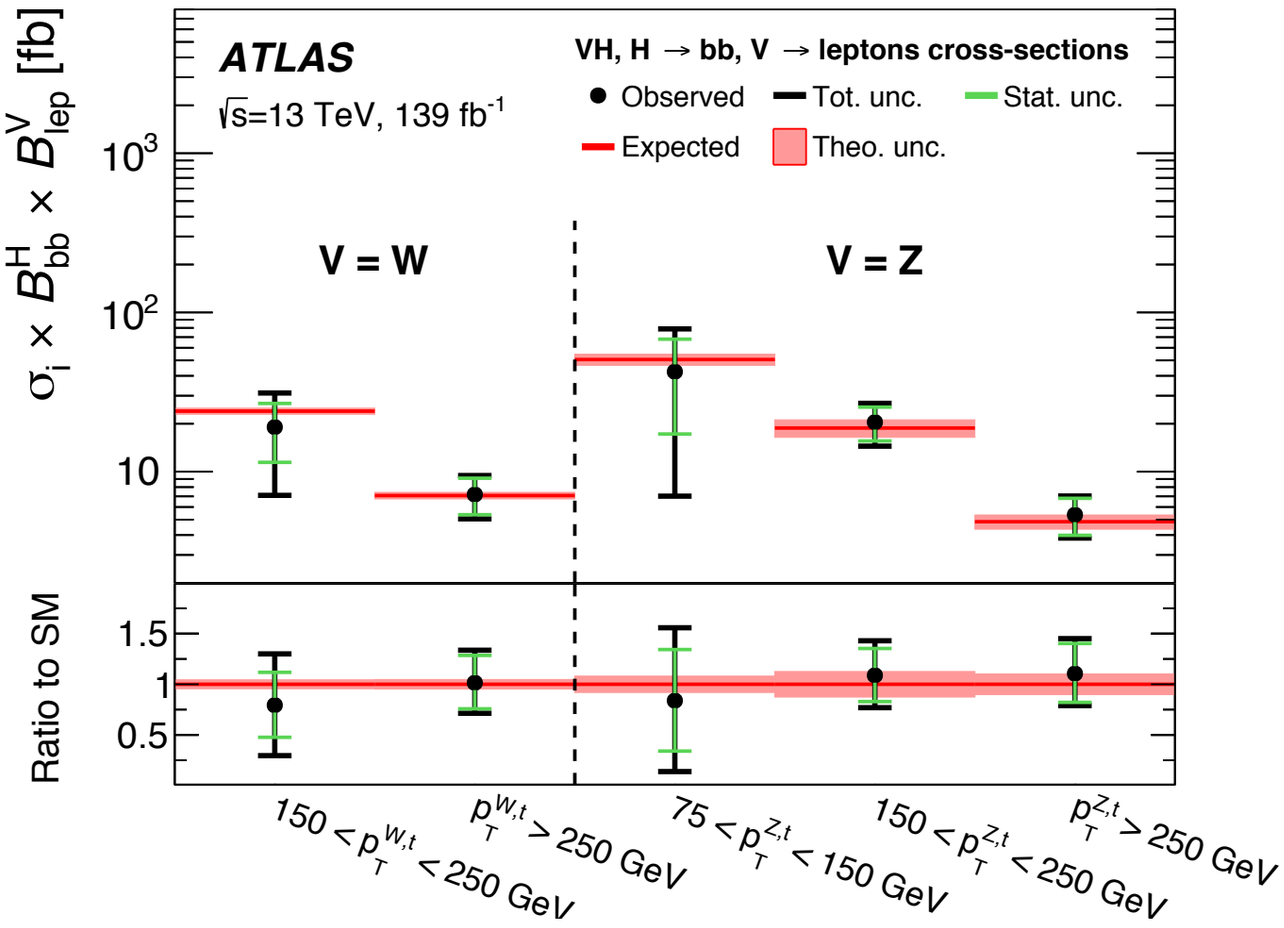


- ZH→vvbb (0-lepton), WH→lvbb (1-lepton), ZH→llbb (2-lepton)
- New SR using pTV vs dRBB, pTV split at 250 GeV
- Improvements: 2-lepton Kinematic Fit using soft track information, new BDT using new variables, W+jets and ttbar MC uncertainties using BDT ratio, 2-lepton top estimation using emu CR data, etc.

VHbb

[HIGG-2018-51] [HIGG-2018-52]

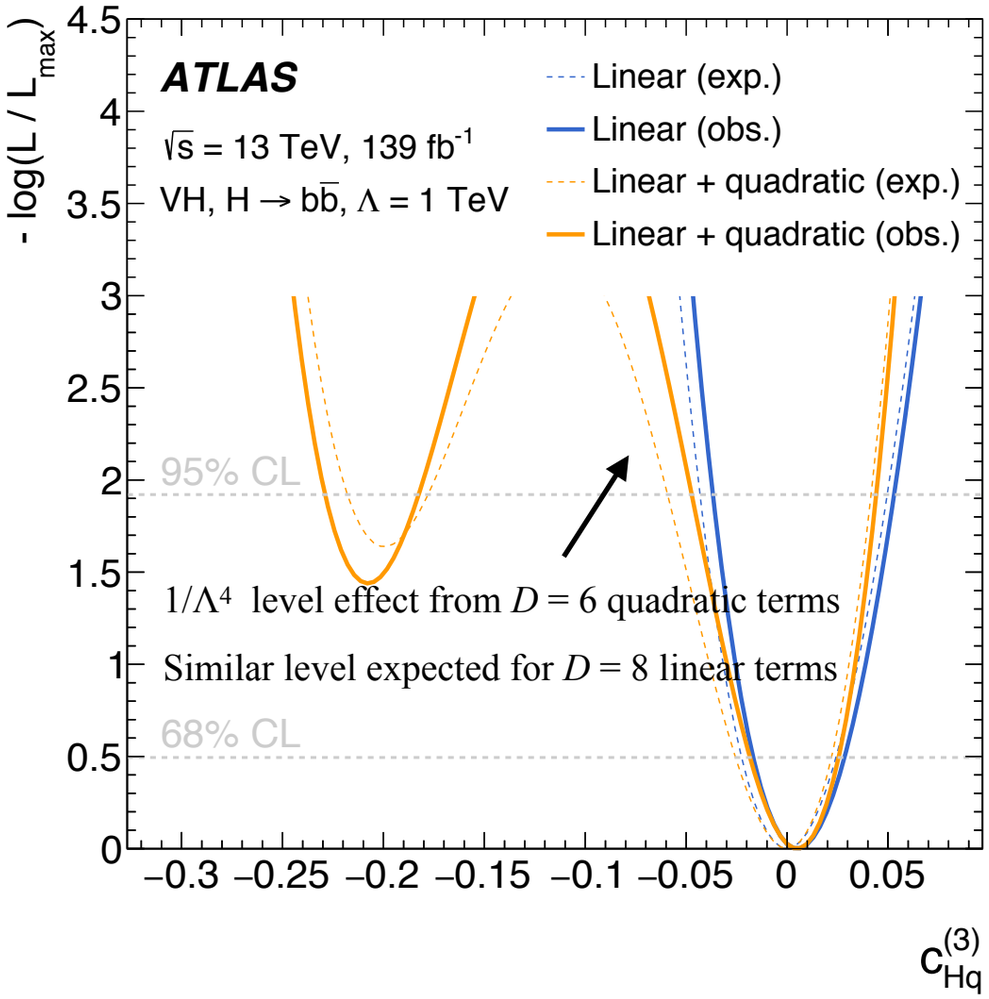


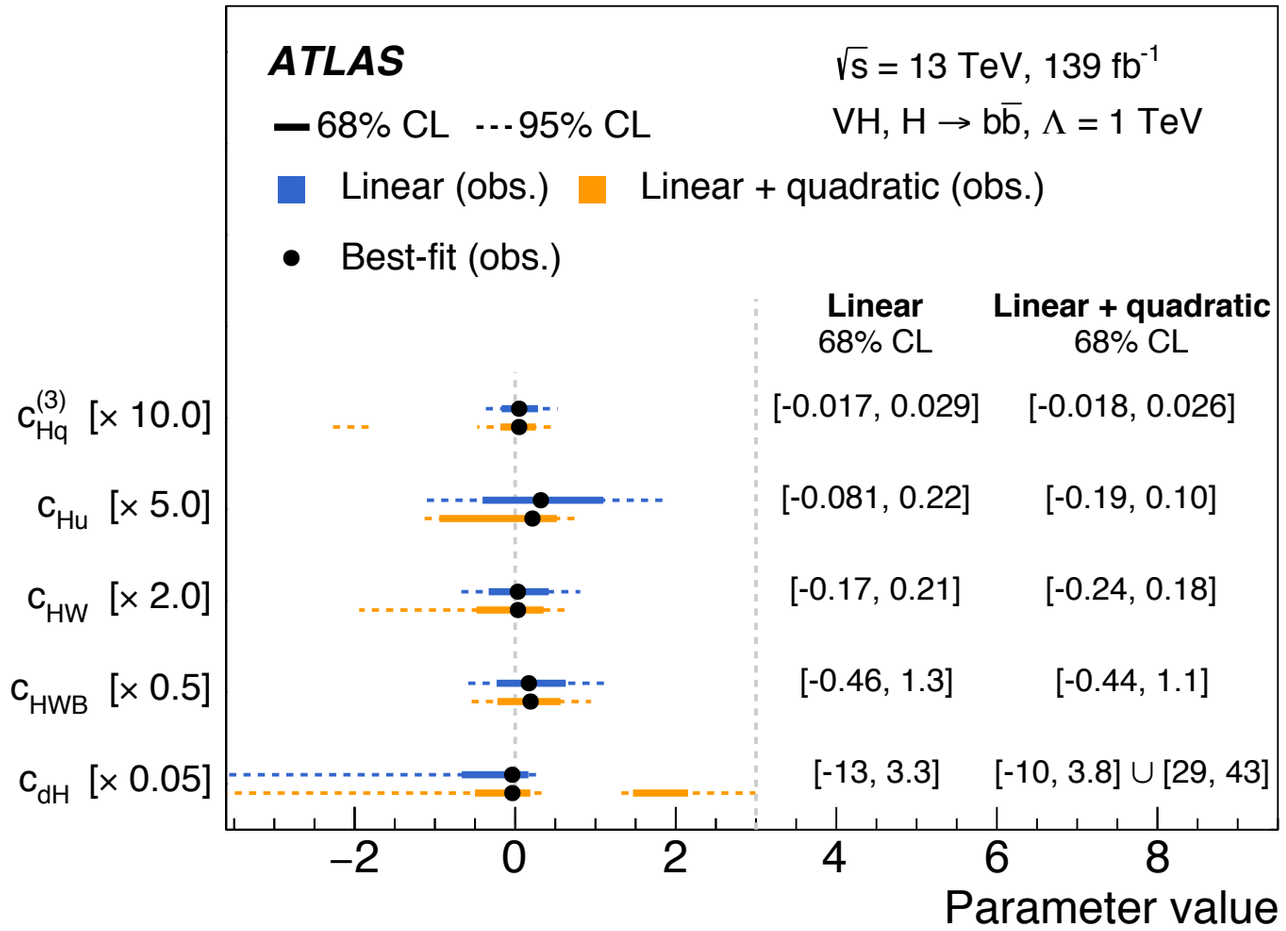


- WH, ZH 2 POI fit (left) and the STXS 5 POI fit (right)
- Maximize $L(\mu, \boldsymbol{\theta}) = \Pi_{i \in \text{bins}} P(n_i \,|\, \mu s_i(\boldsymbol{\theta}) + b_i(\boldsymbol{\theta}))\ \Pi_{j \in \boldsymbol{\theta}} G(\theta_j)$
- WH 4.0 (4.1) σ, ZH 5.3 (5.1) σ, VH combined signal strength with 18% level precision, WH and ZH STXS with 30–85% precision

VHbb

[HIGG-2018-51] [HIGG-2018-52]

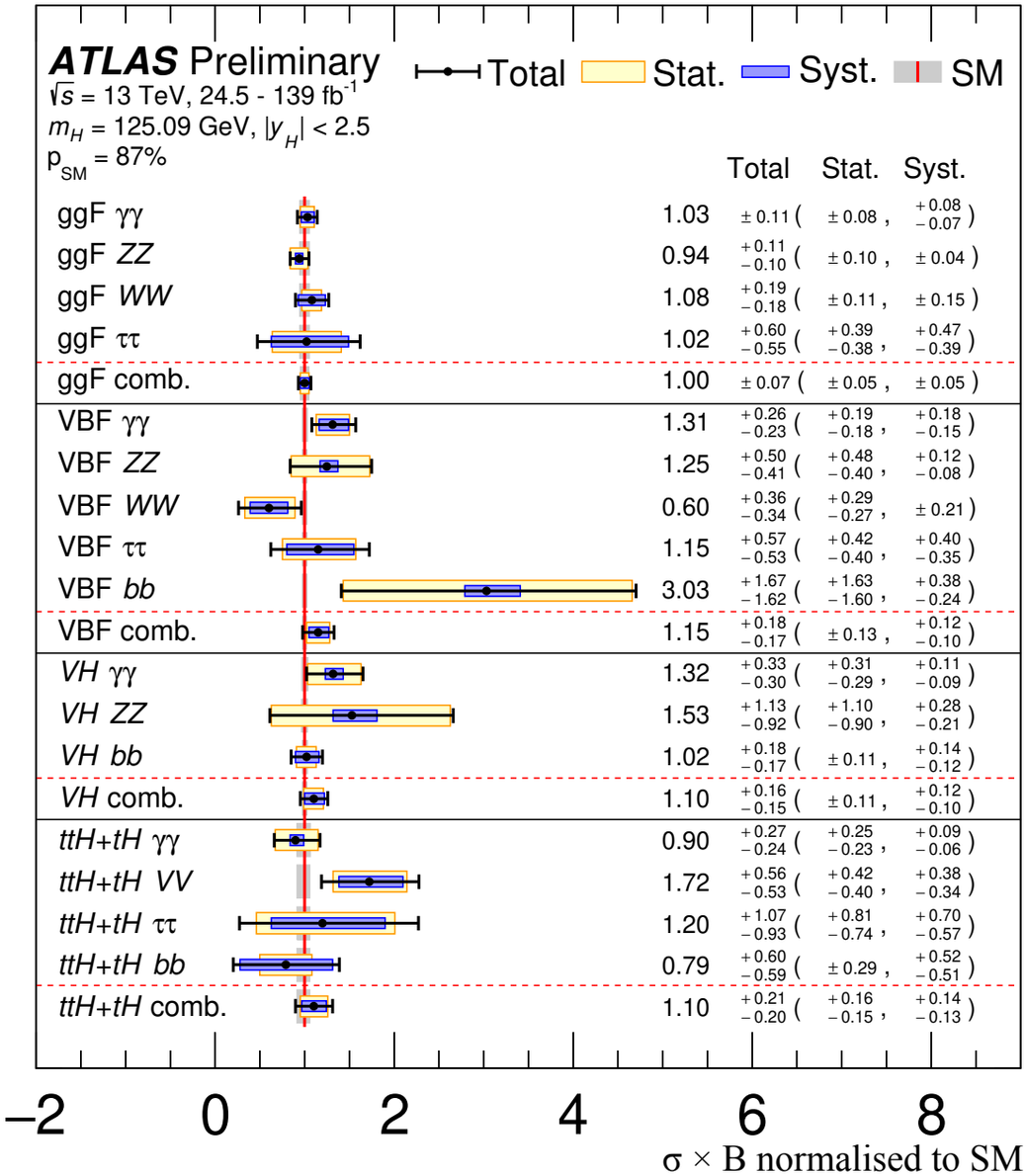


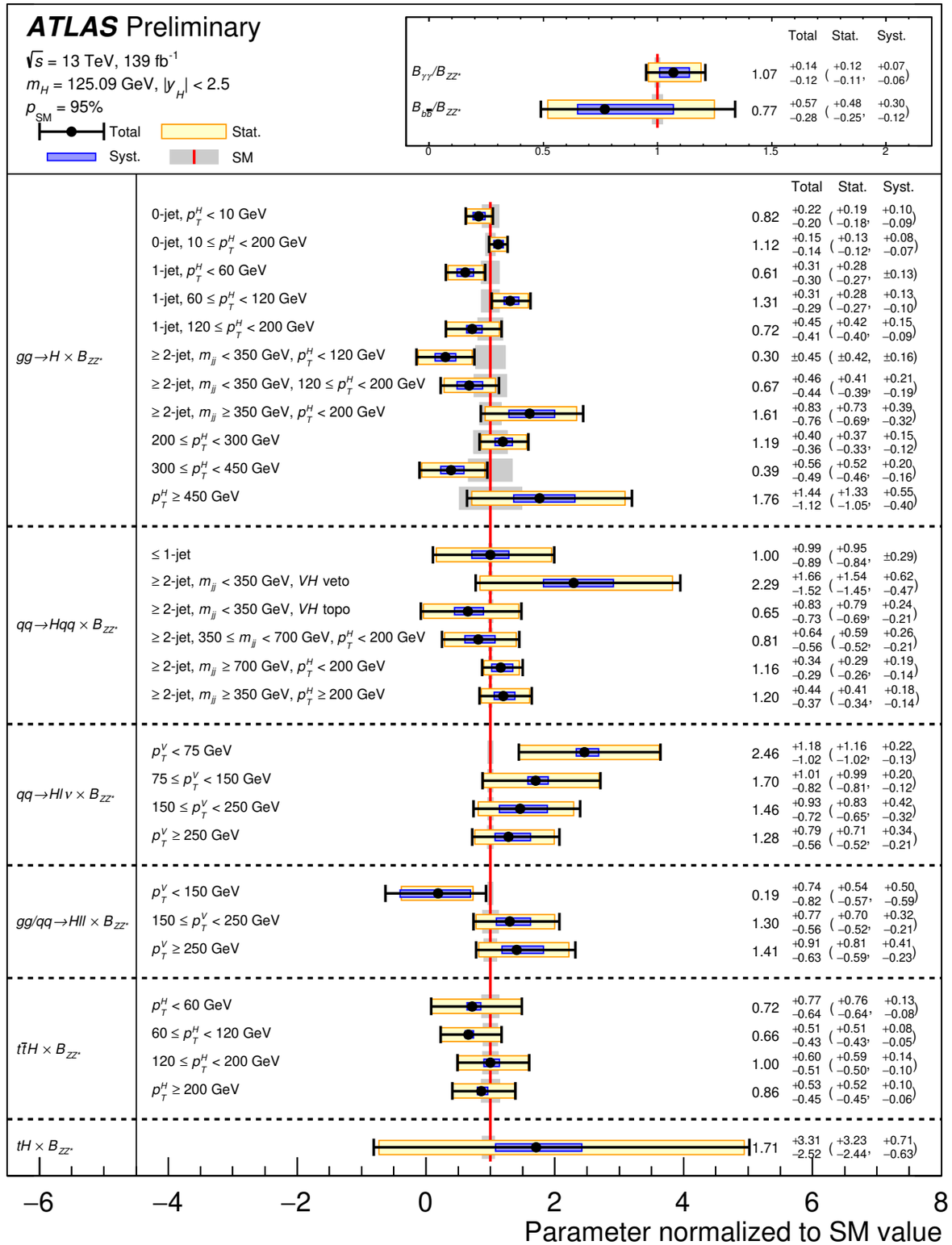


- Parameterise σ×BR by $L_{\mathrm{SMEFT}} = L_{\mathrm{SM}} + \Sigma_i c_i^{(D)} O_i^{(D)} / \Lambda^{D-4}$ [SMEFT]
- $c_{Hq}^{(3)}$ changes the cross-sections of the qqVH at high pT → constrained to a few% level, c_{dH} changes the Hbb decay but weaker constraint

Combination

[CONF-2020-027] [CONF-2020-053]

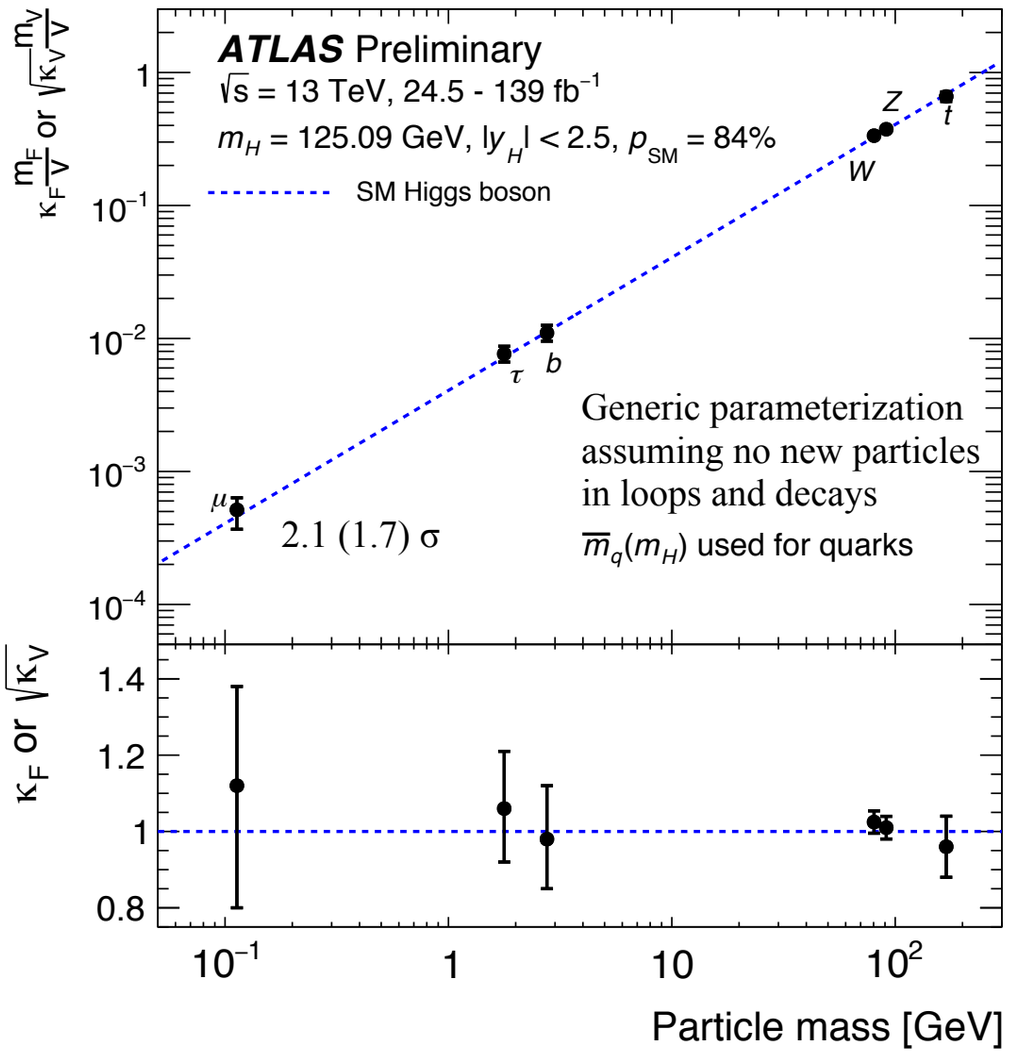


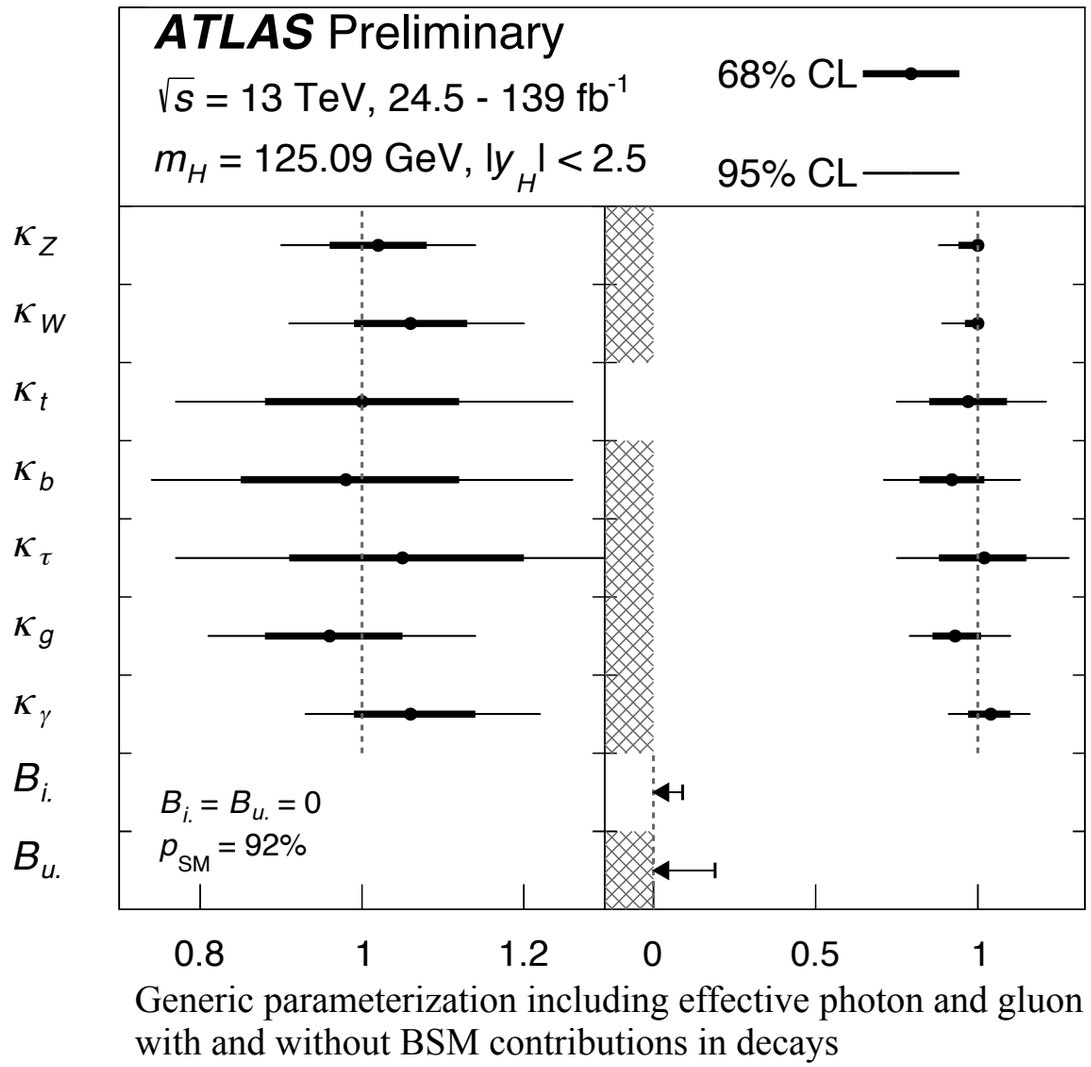


- Global $\mu = 1.06 \pm 0.07$
- First observation of WH: 6.3 (5.2) σ
- tH: < 8.4 (8.2) SM

Combination

[CONF-2020-027] [CONF-2020-053]





Generic parameterization including effective photon and gluon couplings with and without BSM contributions in decays

- All coupling strength scale factors are compatible with the SM
- Invisible and undetected branches are limited to < 0.09 and < 0.19
- Results are also used to constrain the EFT and 2HDM

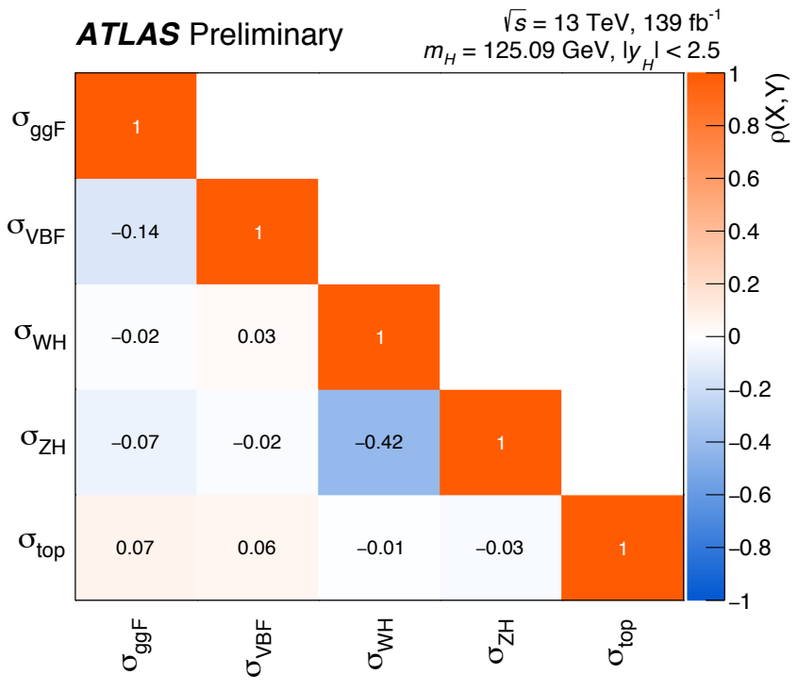
Summary

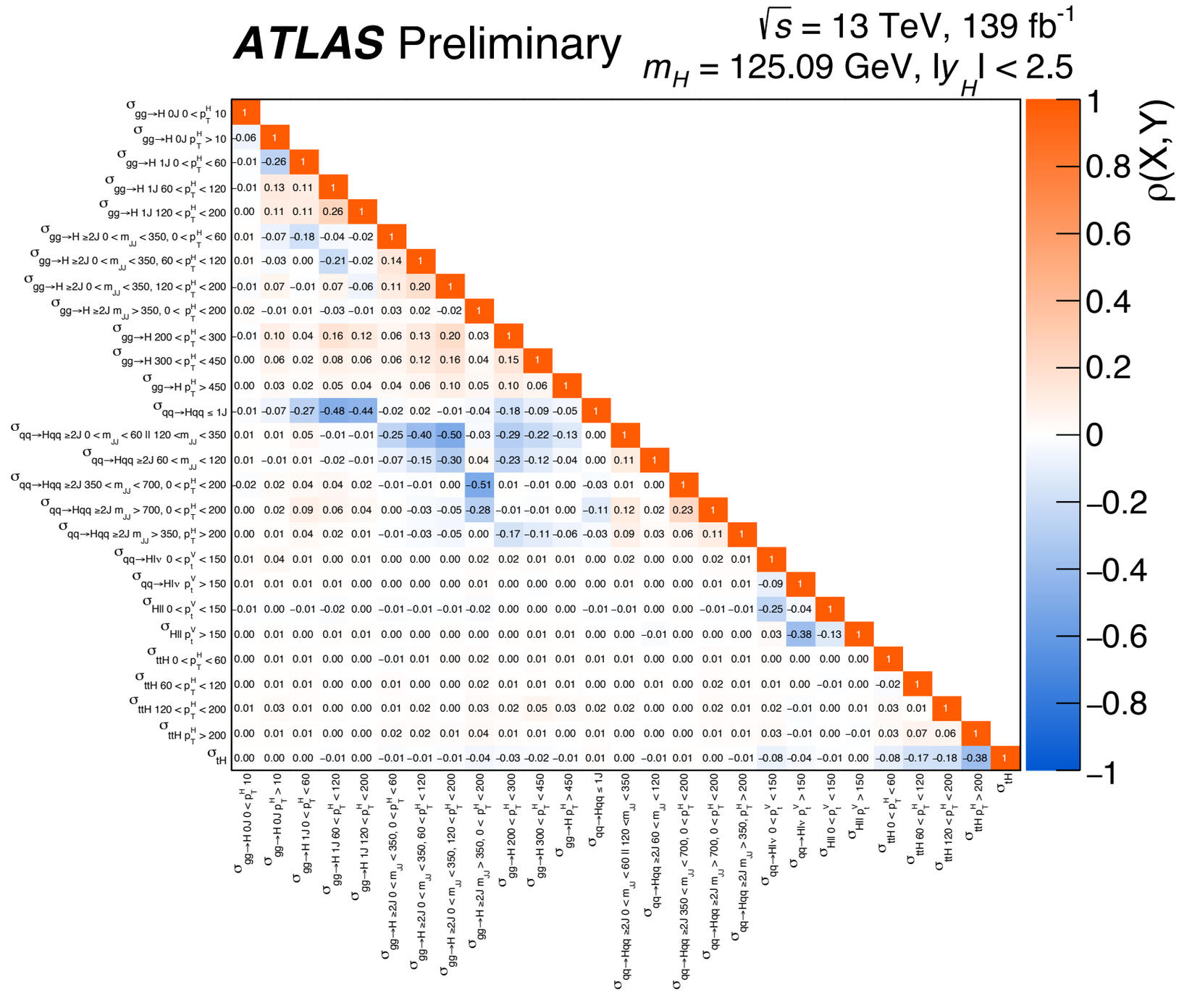
- Highlighted full Run 2 Higgs measurements to test the SM
- Total, fiducial, differential, simplified template cross sections (STXS) → Coupling modifiers, EFT coefficients, BSM tests
- Main production modes are observed with > 5σ
- Top and bottom Yukawa couplings are also established
- No significant deviation from the SM so far
- New results, more channels, combination and interpretation are actively developed

Backup

Hγγ

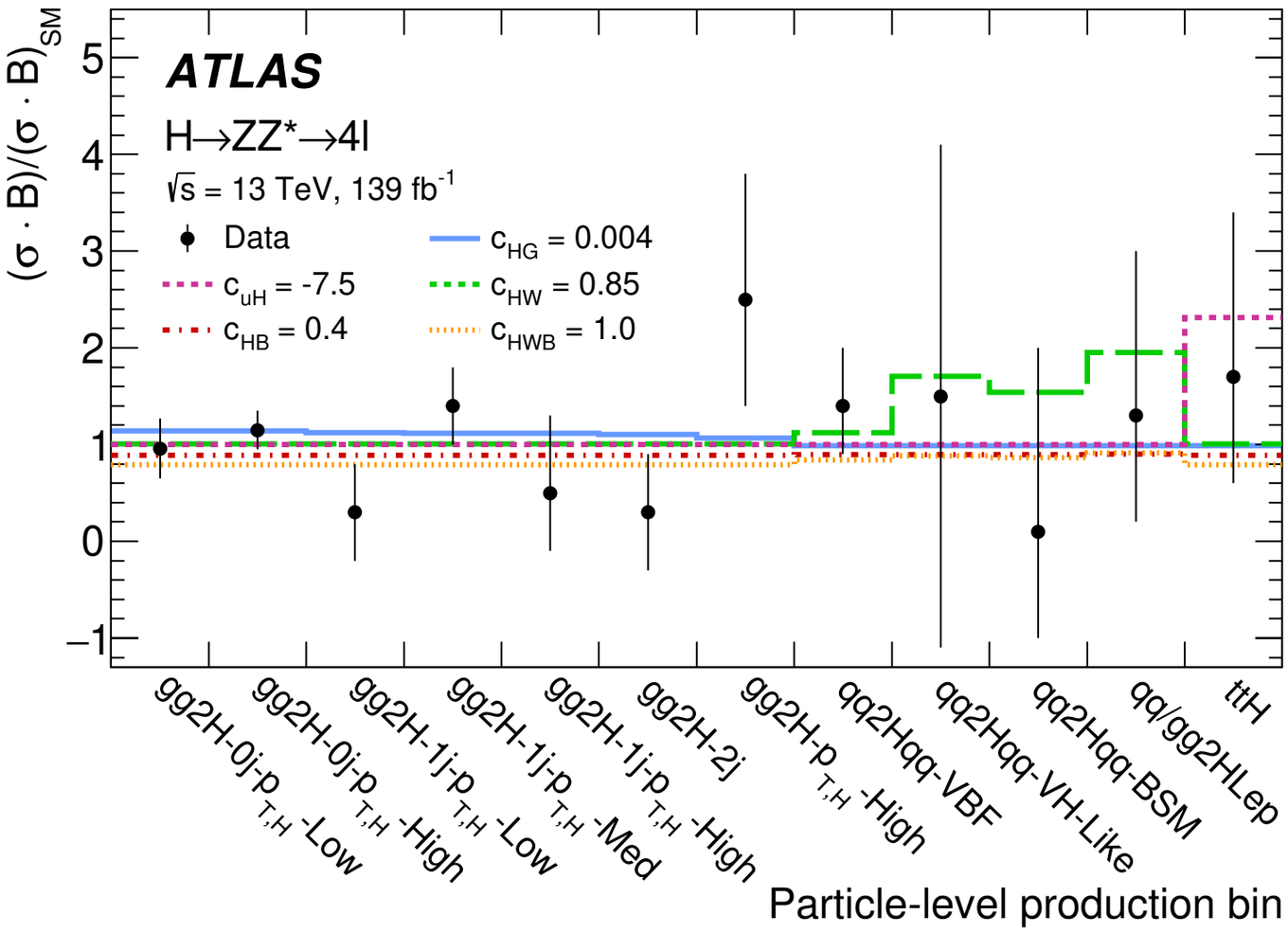
[CONF-2020-026]

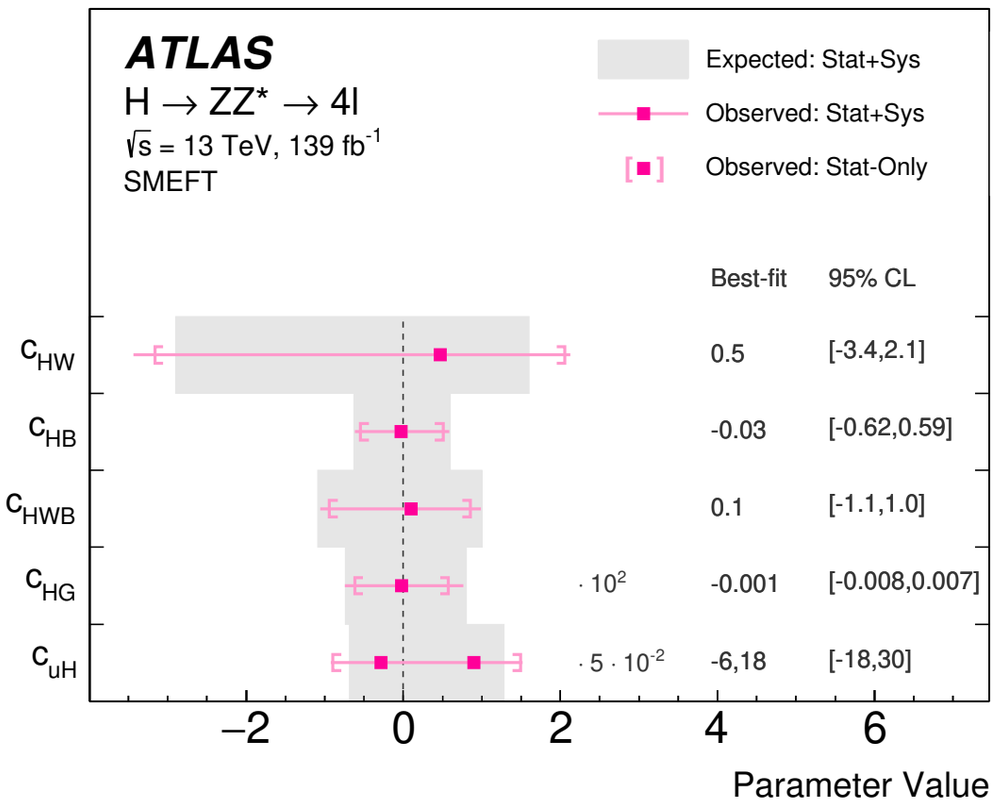




HZZ

[HIGG-2018-28]

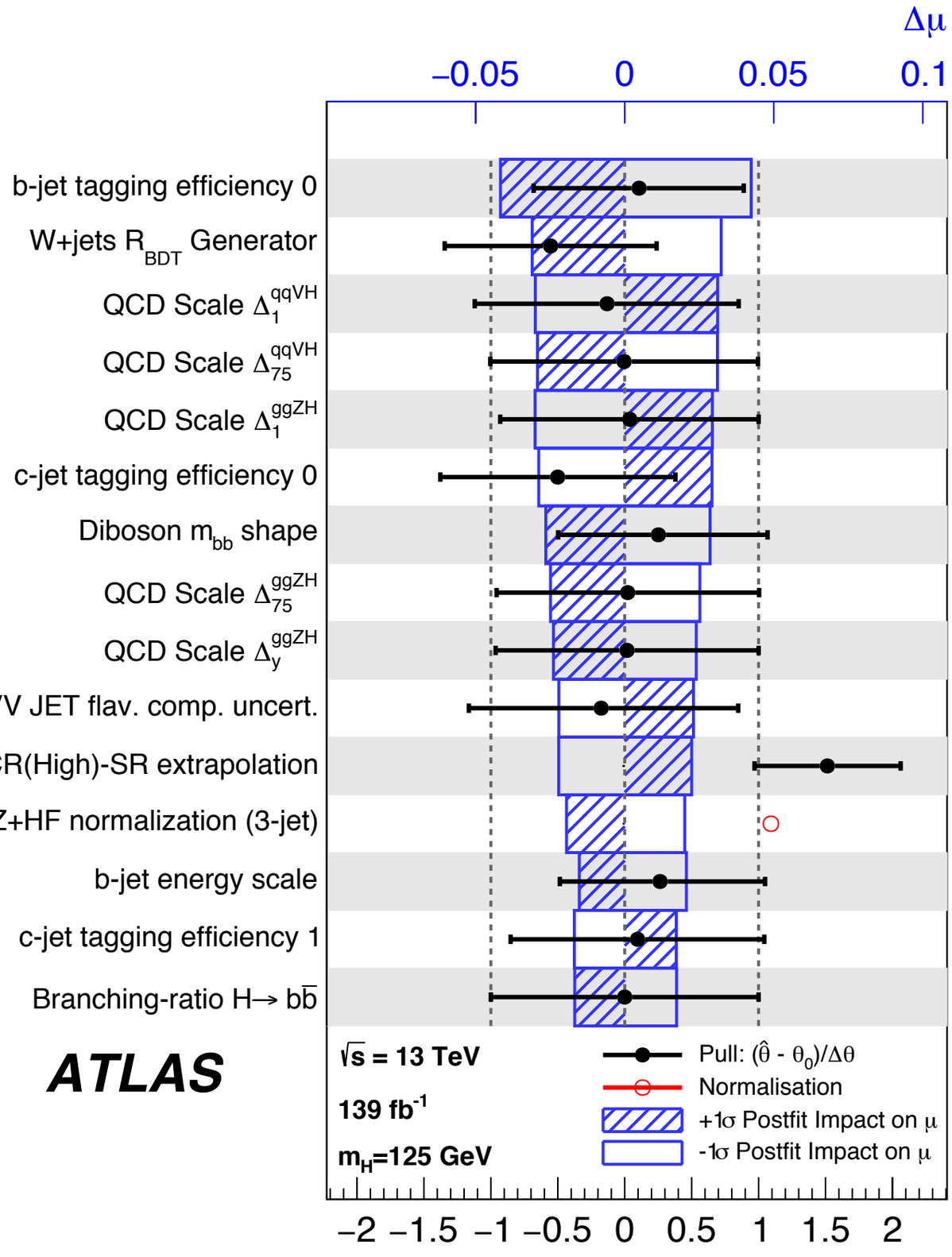




VHbb

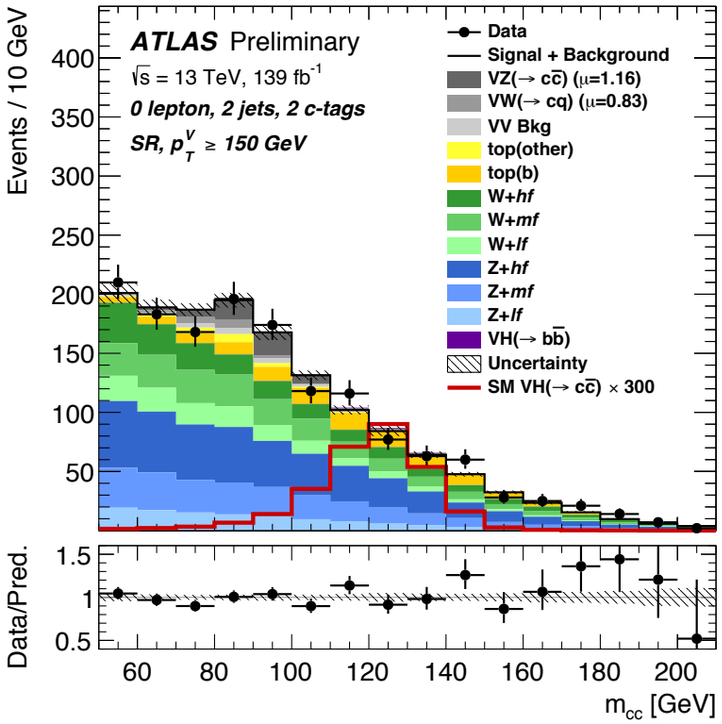
[HIGG-2018-51] [HIGG-2018-52]

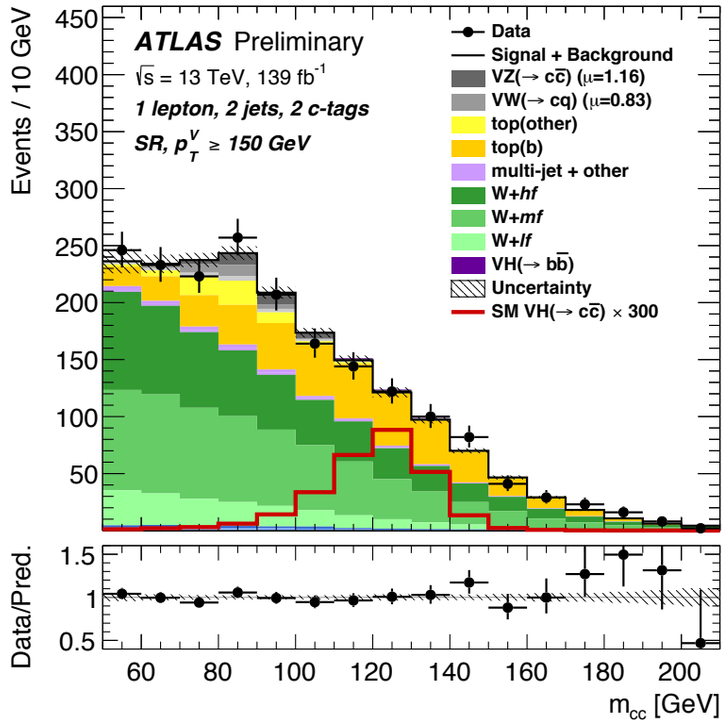
Source of uncertainty		σ_μ VH	WH	ZH
Total		0.177	0.260	0.240
Statistical		0.115	0.182	0.171
Systematic		0.134	0.186	0.168
Statistical uncertainties				
Data statistical		0.108	0.171	0.157
$t\bar{t}$ $e\mu$ control region		0.014	0.003	0.026
Floating normalisations		0.034	0.061	0.045
Experimental uncertainties				
Jets		0.043	0.050	0.057
$E_{\mathrm{T}}^{\mathrm{miss}}$		0.015	0.045	0.013
Leptons		0.004	0.015	0.005
b-tagging	b-jets	0.045	0.025	0.064
	c-jets	0.035	0.068	0.010
	light-flavour jets	0.009	0.004	0.014
Pile-up		0.003	0.002	0.007
Luminosity		0.016	0.016	0.016
Theoretical and modelling uncertainties				
Signal		0.072	0.060	0.107
Z + jets		0.032	0.013	0.059
W + jets		0.040	0.079	0.009
$t\bar{t}$		0.021	0.046	0.029
Single top quark		0.019	0.048	0.015
Diboson		0.033	0.033	0.039
Multi-jet		0.005	0.017	0.005
MC statistical		0.031	0.055	0.038

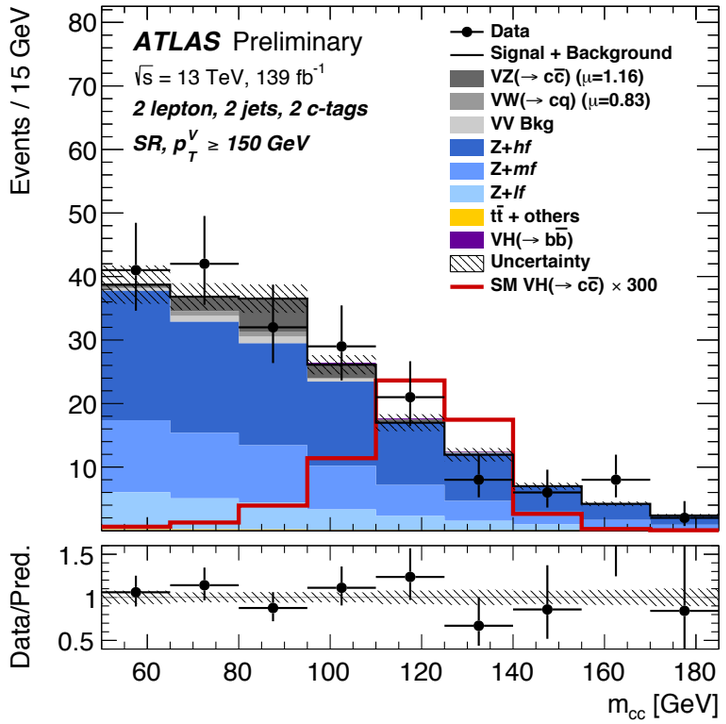


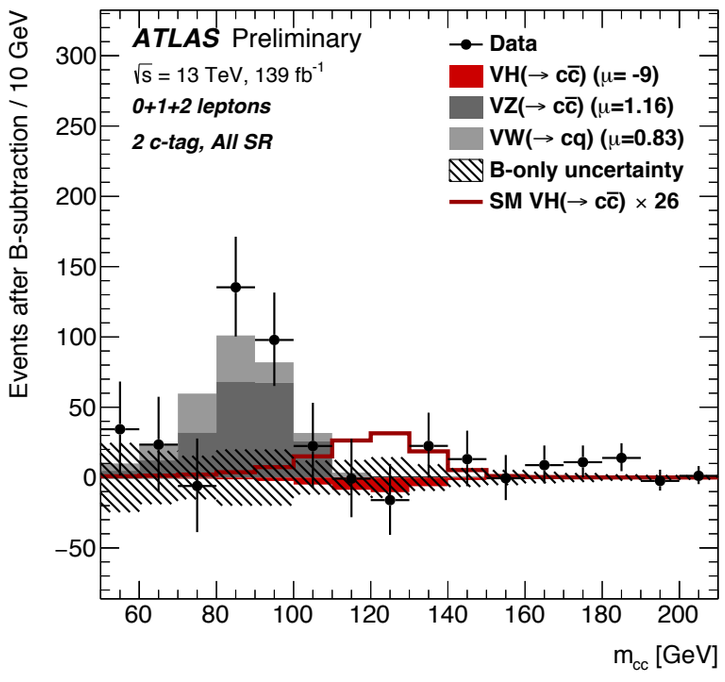
VHcc

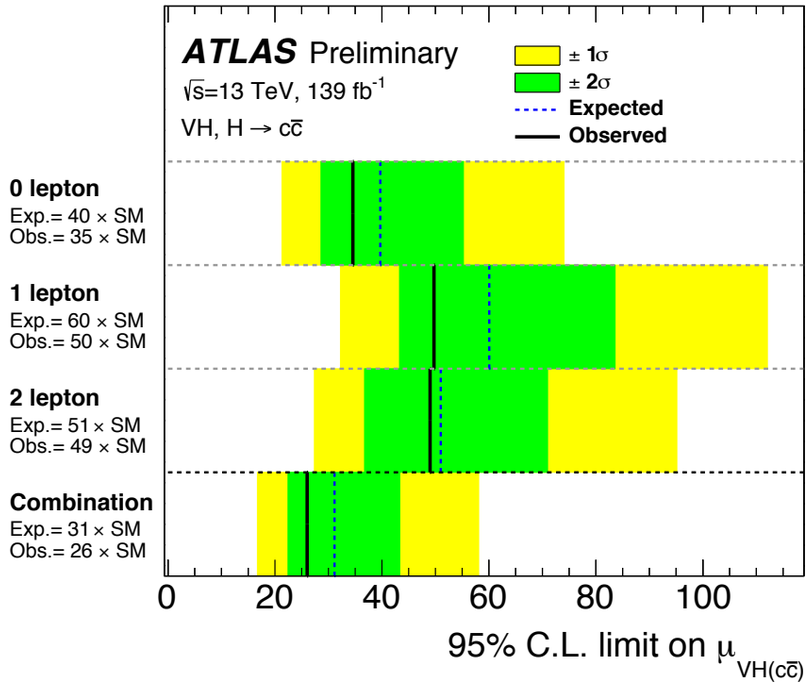
[CONF-2021-021]

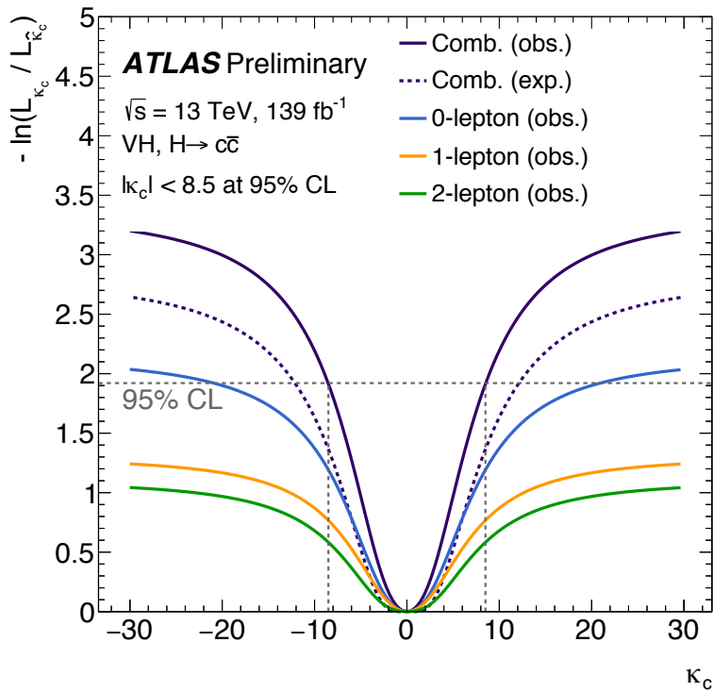












Combination

[CONF-2020-027] [CONF-2020-053]