Combined measurement of the Higgs boson couplings with ATLAS detector

Guoqiang Zheng
University of Science and Technology of China

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Introduction

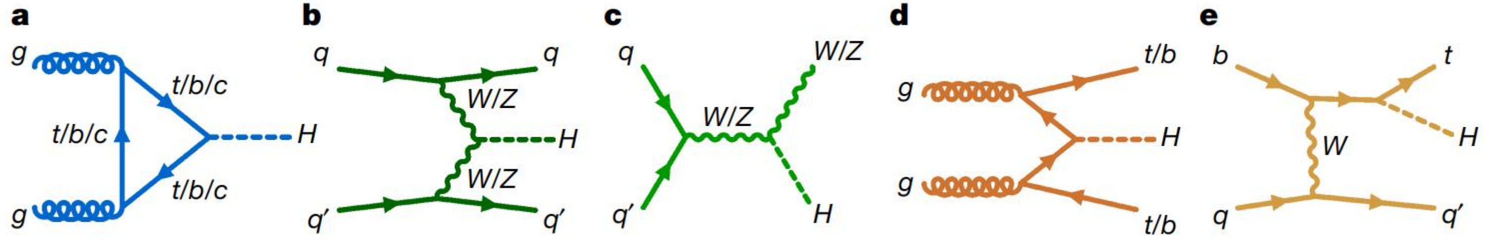
- The Higgs boson, which discovered by ATLAS and CMS at 2012, plays a fundamental role in the Standard Model.

- Many properties have been tested and they are compatible with SM.
  - Possible Extensions to SM Higgs Sector could modify Higgs couplings
  - Higher precision measurement still needed.

- The combination approach could provide us the best precision and sensitivity for Higgs coupling properties, which is an essential experimental method

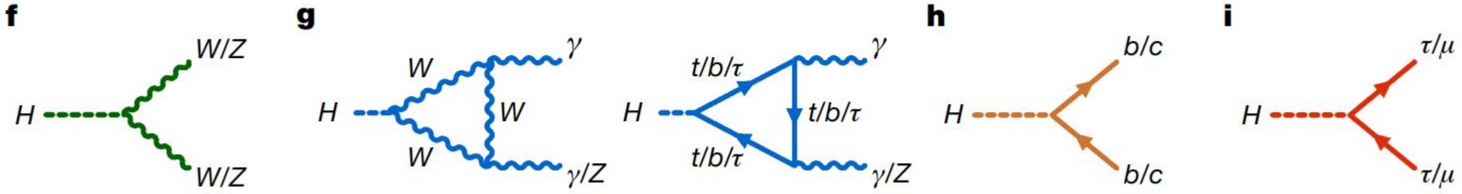
Higgs production and decay modes

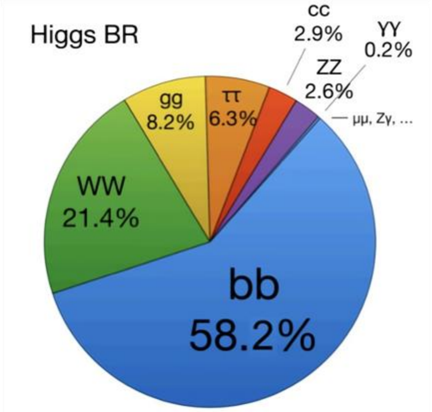
- The Higgs boson production modes on LHC:



SM cross section at $\sqrt{s} = 13$ TeV: ~49 pb ~4 pb ~2 pb ~1 pb ~0.08 pb

- The Higgs boson decay modes:

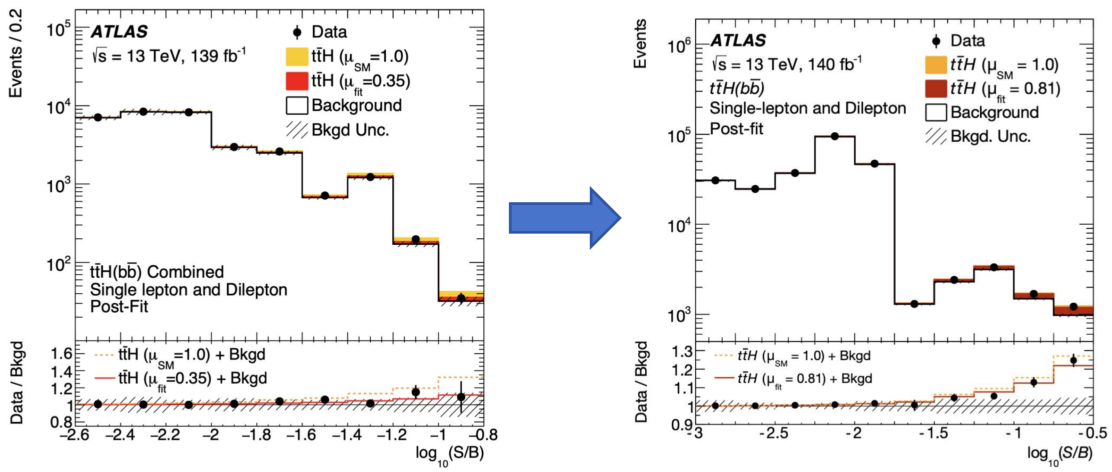




Input Channels for combination study

- Input analysis channels(12 analyses)
  - All workspaces have been well validated
  - Compare to the previous ATLAS(Nature 607, 52–59 (2022)) results, some channels are updated and add some new channels

Analysis	Prod. modes	$\mathcal{L}$ (fb^{-1})	Reference	STXS stage	Improvements relative to Ref. [3]
$H \to ZZ^* \to 4\ell$	All	140	[19]	1.2	-
$H \to WW^* \to \ell\nu\ell\nu$	ggF,VBF	140	[20]	0	Reanalysis
$H \to WW^* \to \ell\nu\ell\nu$	VH	140	[21]	1.2	Full Run 2
$H \to \gamma\gamma$	All	140	[22]	1.2	-
$H \to Z\gamma$	All	140	[23]	0	-
$H \to \tau\tau$	All	140	[24]	1.2	Reanalysis
$H \to \tau\tau$	VH	140	[25]	0	New analysis
$H \to \mu\mu$	All	140	[26]	0	-
$H \to bb$	VBF	126	[5]	1.2	-
$H \to bb, cc$	VH	140	[27]	1.2	Reanalysis
$H \to$ multileptons	ttH	36.1	[4]	0	-
$H \to bb$	ttH	140	[28]	1.2	Reanalysis



ttH, $H \to b\bar{b}$

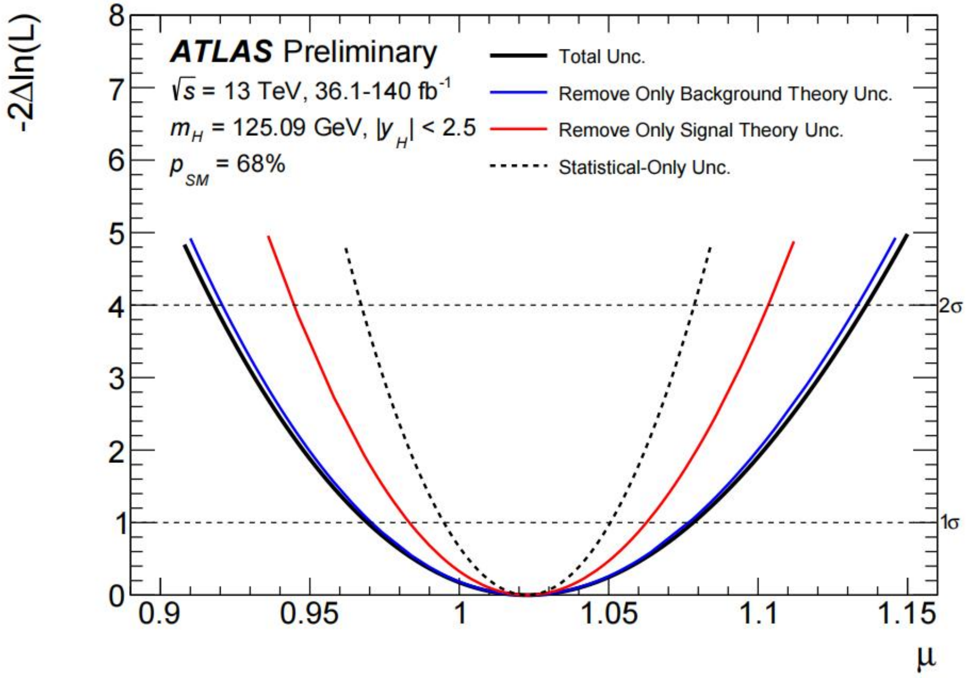
Global Signal Strength

- Inclusive rate of Higgs boson production and decay processes
  - The signal strength of the process is defined by the ratio of the measured event rate to its SM prediction
  - The measurement result is:

$$\mu = 1.023^{+0.056}_{-0.053} = 1.023 \pm 0.028\,(\text{stat.})\ ^{+0.026}_{-0.025}\,(\text{exp.})\ ^{+0.039}_{-0.036}\,(\text{sig. theo.})\ \pm 0.012\,(\text{bkg. theo.})$$

- The result is in good agreement with the SM, with a compatibility corresponding to a p-value = 68%

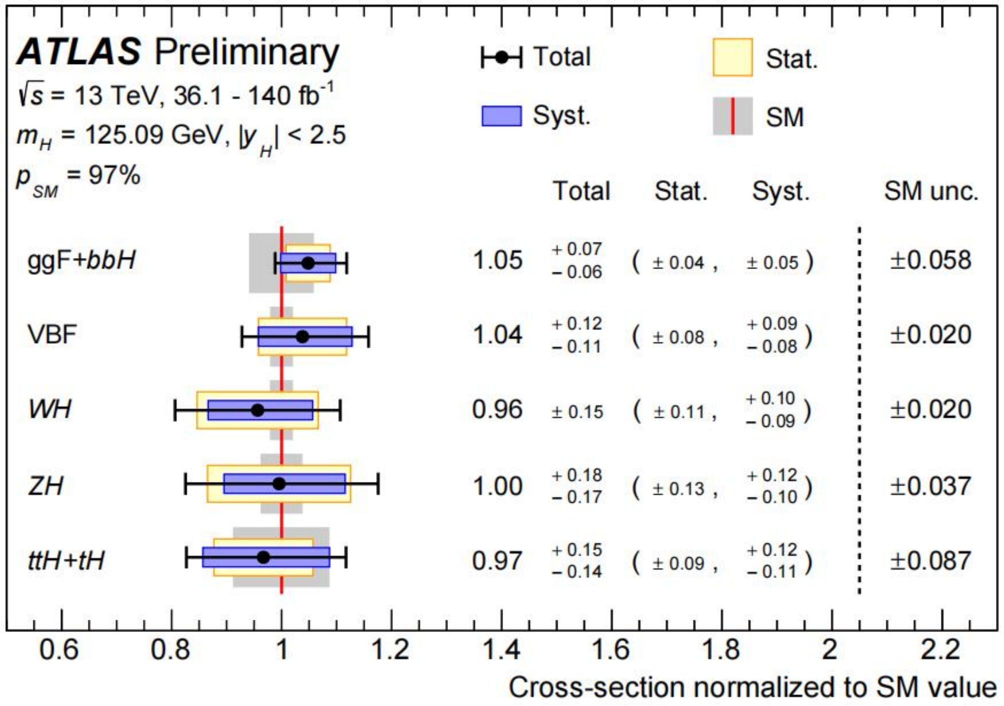
- Around 10% reduction in the total uncertainty with respect to Nature result (1.05 ± 0.06)



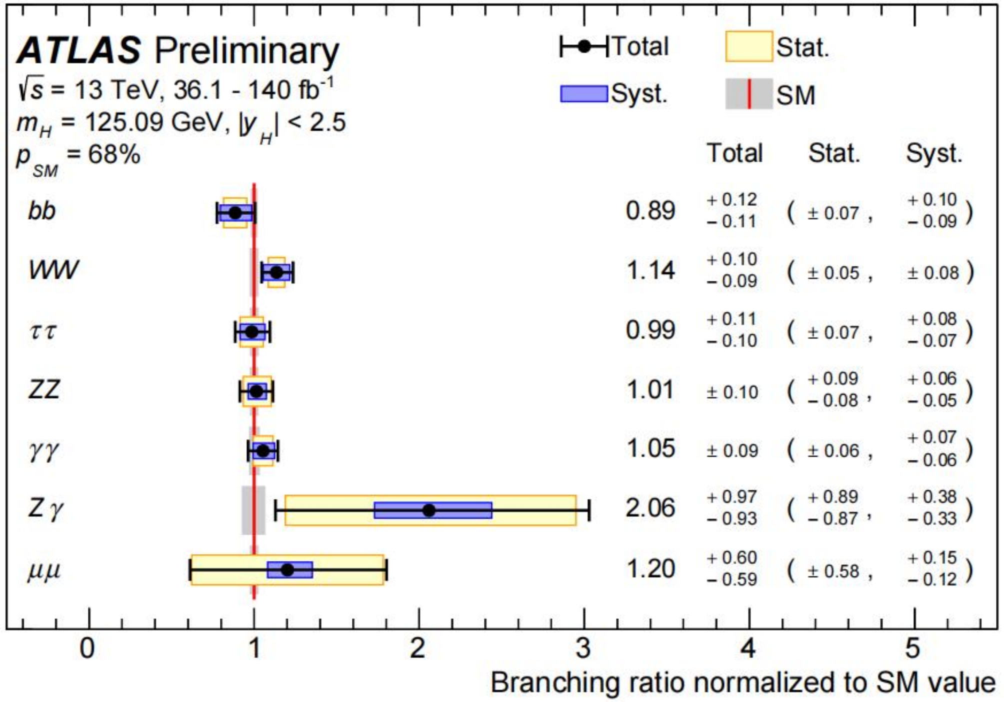
Higgs Boson Production and Branch Ratio Measurements

- Higgs boson production cross-section
  - 5 production modes: ggF+bbH, VBF, WH, ZH, ttH+tH
  - The precision of σ_{WH}, σ_{ZH}, σ_{ttH} improves about 30%, 20% and 40%

- Higgs boson branching ratios measurements
  - 7 decay modes: bb, WW, $\tau\tau$, ZZ, $\gamma\gamma$, $Z\gamma$, $\mu\mu$
  - The precision of B_{WW}, B_{bb}, $B_{\tau\tau}$ improves up to 20%



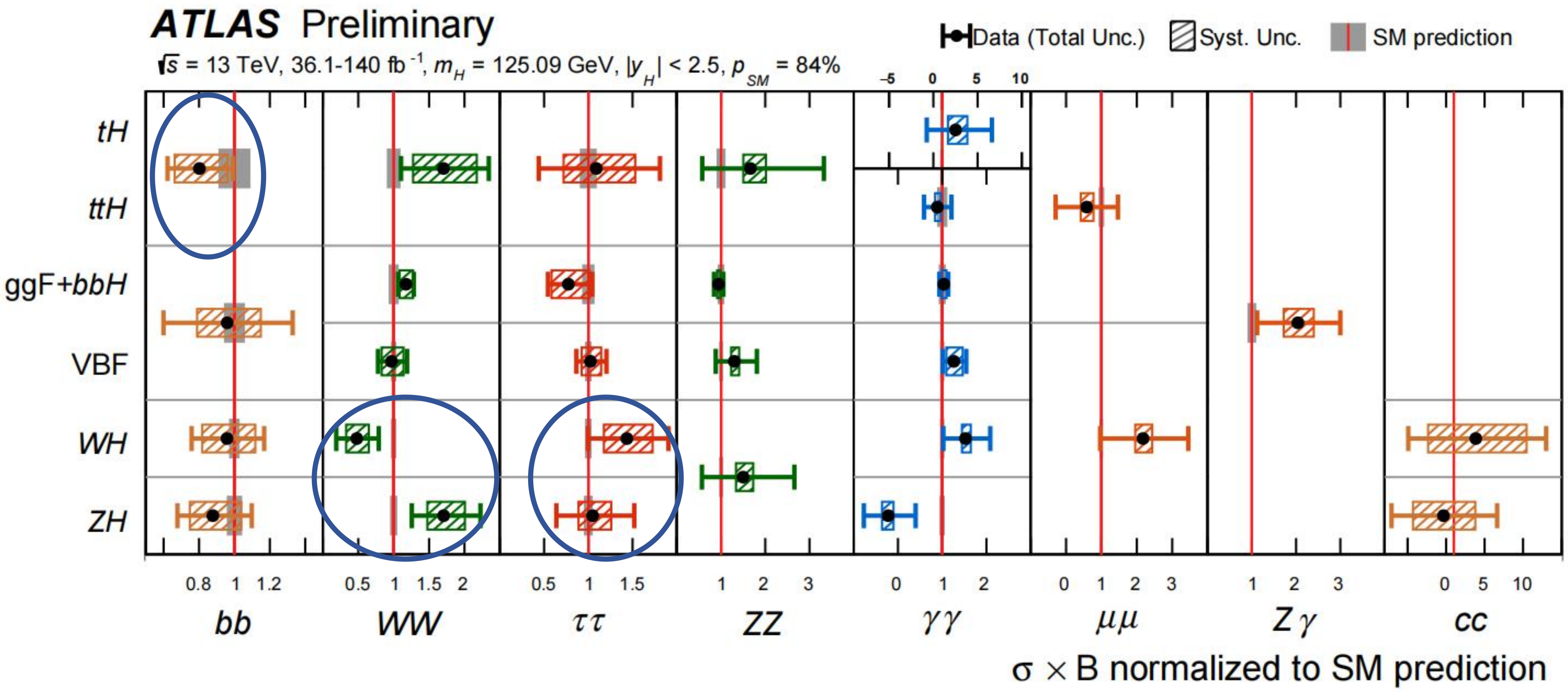
Cross-section
(Branching ratio fixed to SM)



Branching ratio
(Cross-section fixed to SM)

Production and decay measurements

- Measurements for $\sigma \times B$
- Combining or separating production modes:
  - some adjustments due to the different sensitivities in some combinations of production and decay final states
- Good agreement between the measurements and SM predictions(p-value of 84%)



Coupling results in κ framework

- The cross-section and branching ratio can be parameterized into modifiers:

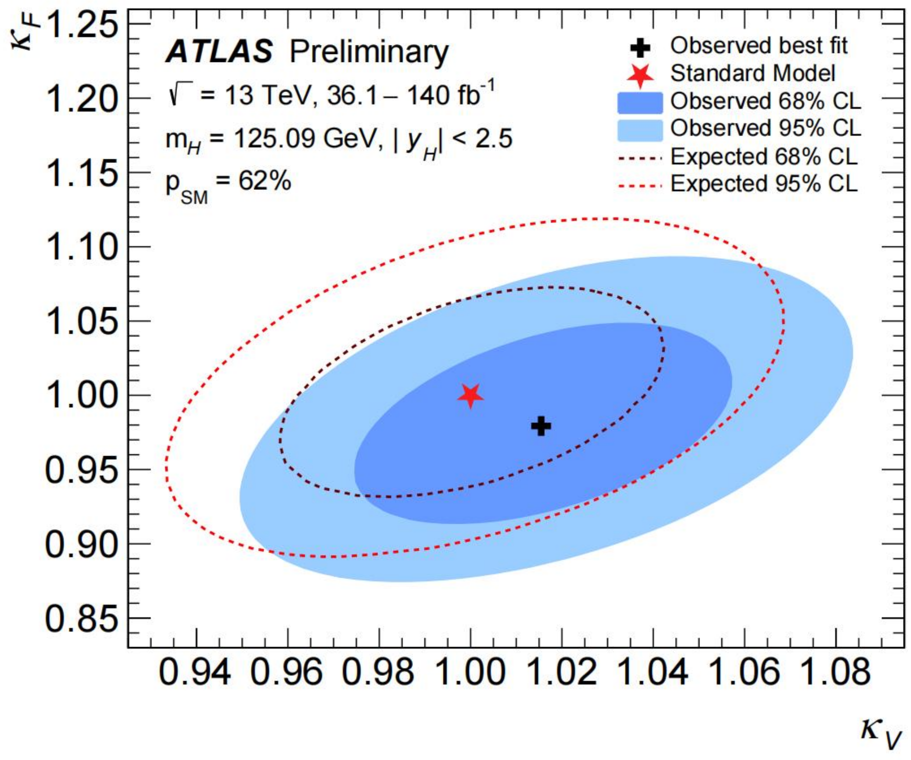
$$\sigma_i \times \mathrm{B}(H \to f) = \frac{\sigma_i \times \Gamma_f}{\Gamma_H} = \frac{\kappa_i^2 \kappa_f^2}{\kappa_H^2} \sigma_i^{\mathrm{SM}} \times \mathrm{B}^{\mathrm{SM}}(H \to f)$$

  - The other Higgs processes not probed by the analyses are assumed to correspond to their SM expectations, and only SM decays of the Higgs boson are considered

- κ_V and κ_F framework
  - The observed values of the coupling modifiers are:

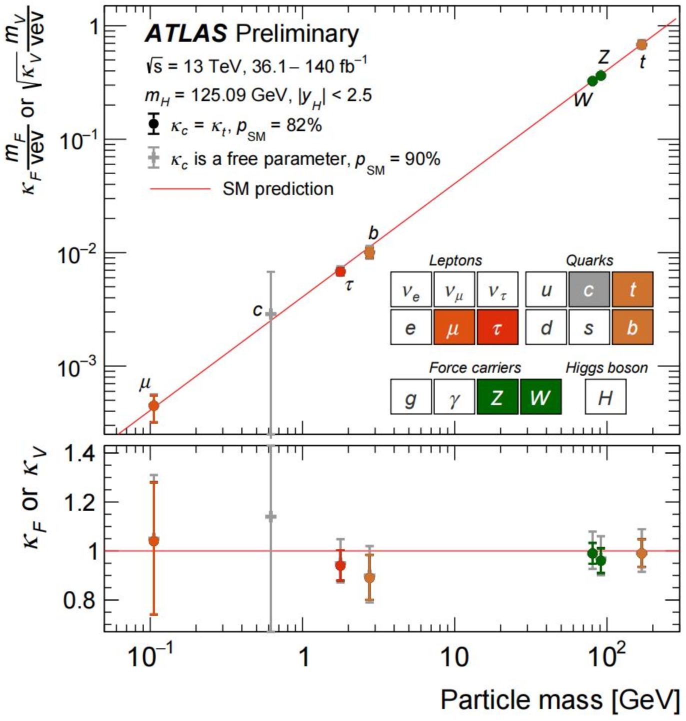
$$\kappa_V = 1.015^{+0.028}_{-0.027} \quad \kappa_F = 0.979^{+0.044}_{-0.045}$$

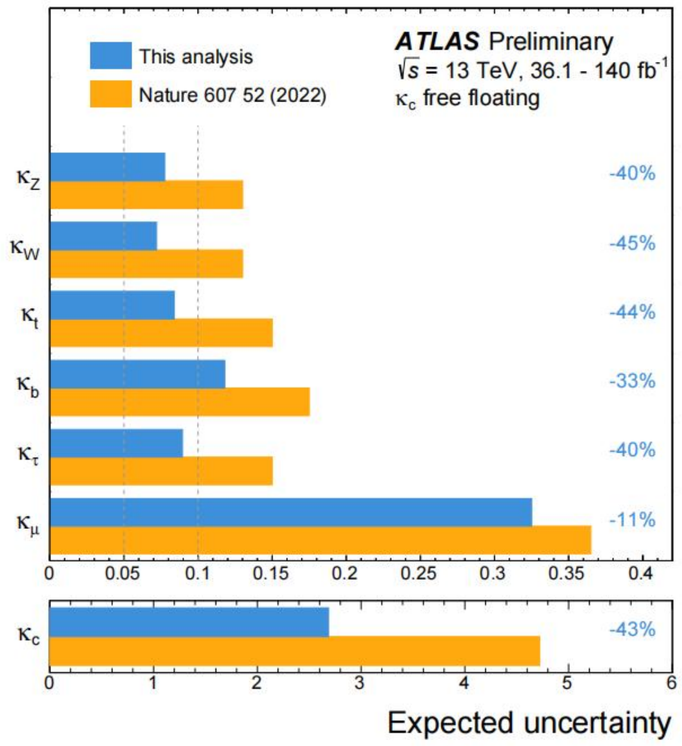
  - SM compatibility: p-value = 62%(14% in Nature result)



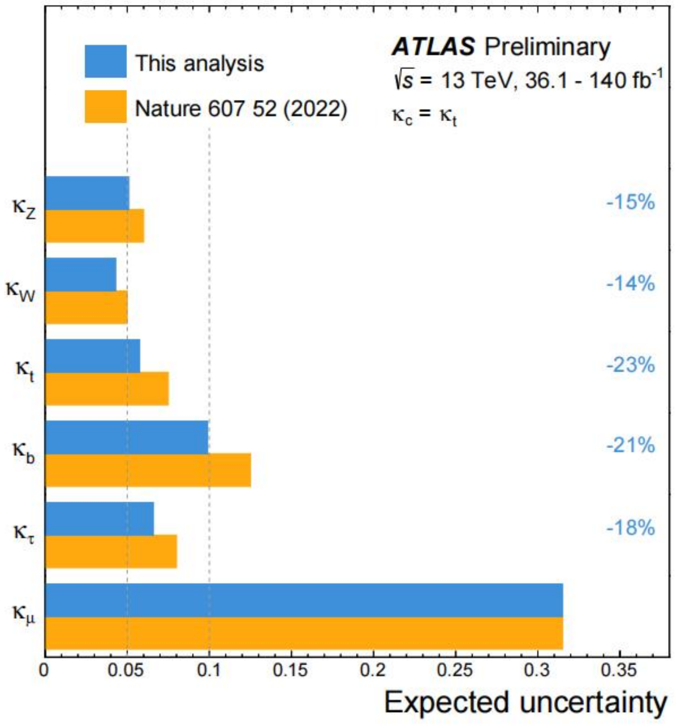
Coupling results in κ framework

- A more general model considers independent κ modifiers for Higgs couplings to each of W, Z, t, b, c, τ and μ
  - For the effective modifiers κ_g, κ_γ, $\kappa_{Z\gamma}$, the resolved scenario parameterized them into other kappa modifiers
  - Significant reduction of uncertainties





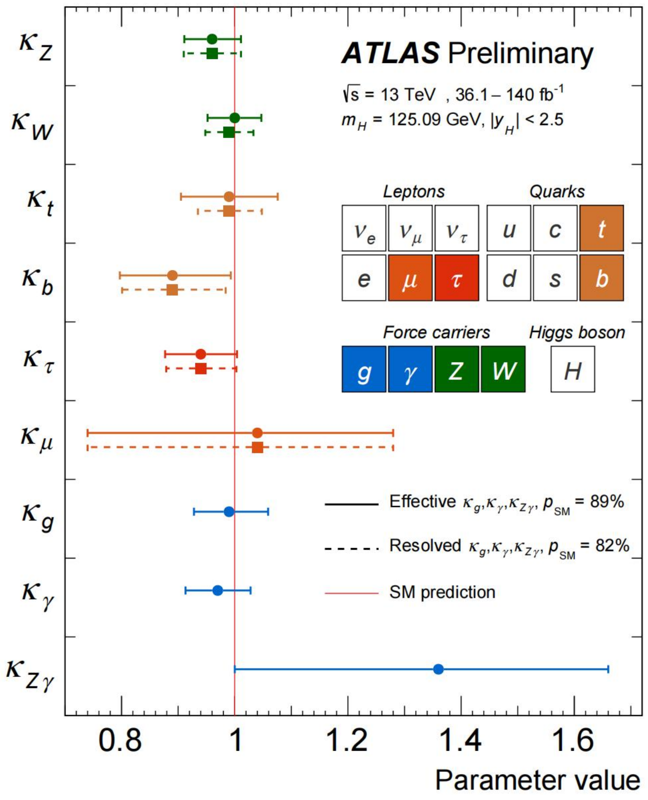
(κ_c is free floating)

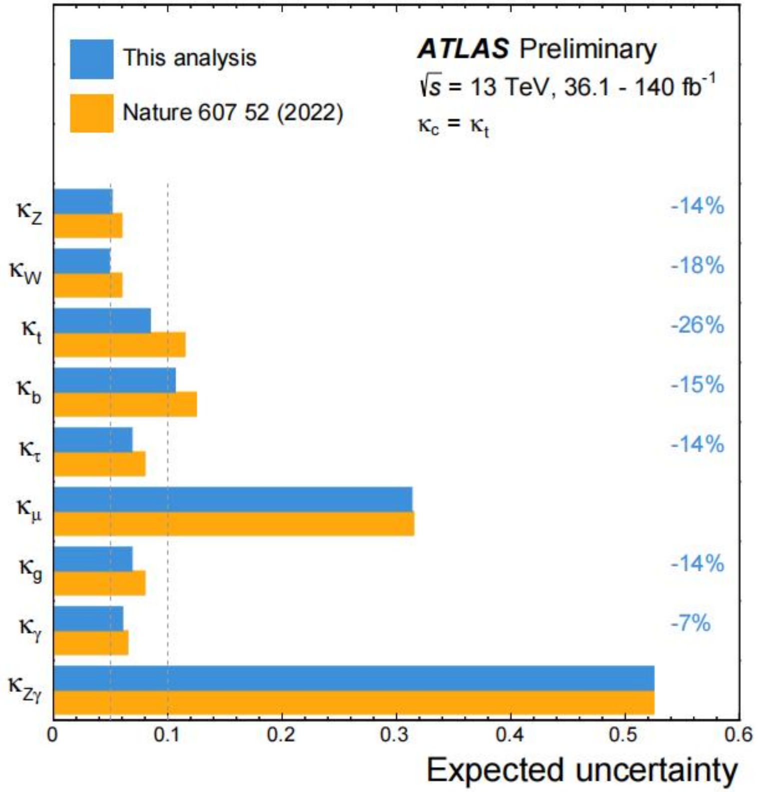


($\kappa_c = \kappa_t$)

Coupling results in κ framework

- κ_g, κ_γ, $\kappa_{Z\gamma}$ free floating as effective modifiers
  - Improvements from 7% to 26% for all kappa modifiers, except for κ_μ and $\kappa_{Z\gamma}$



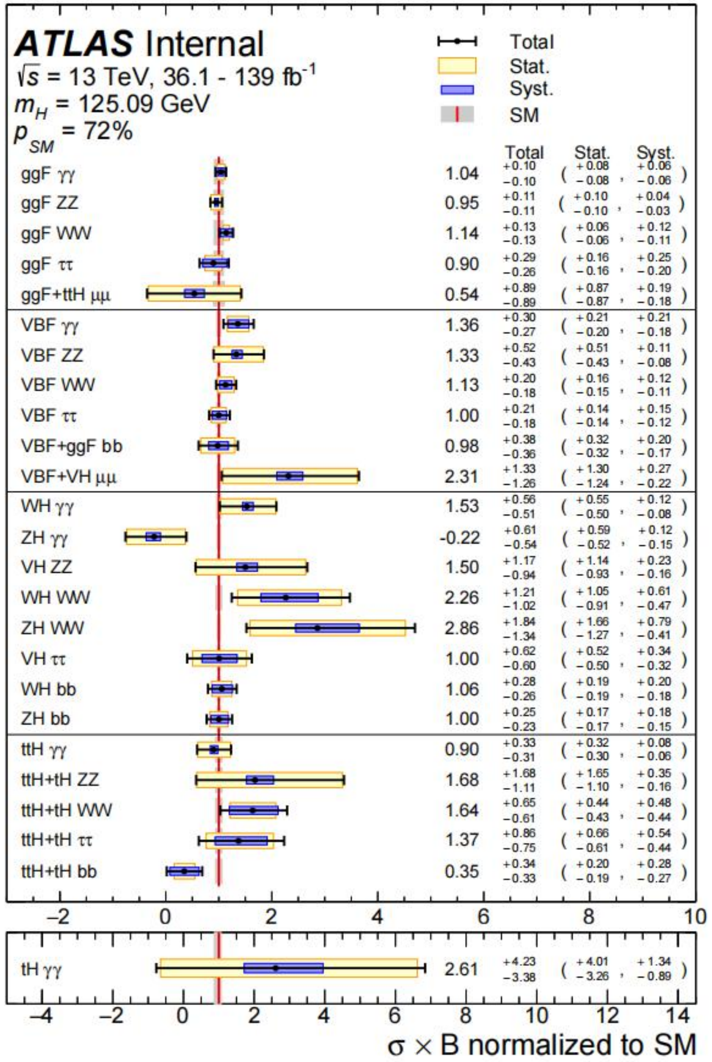


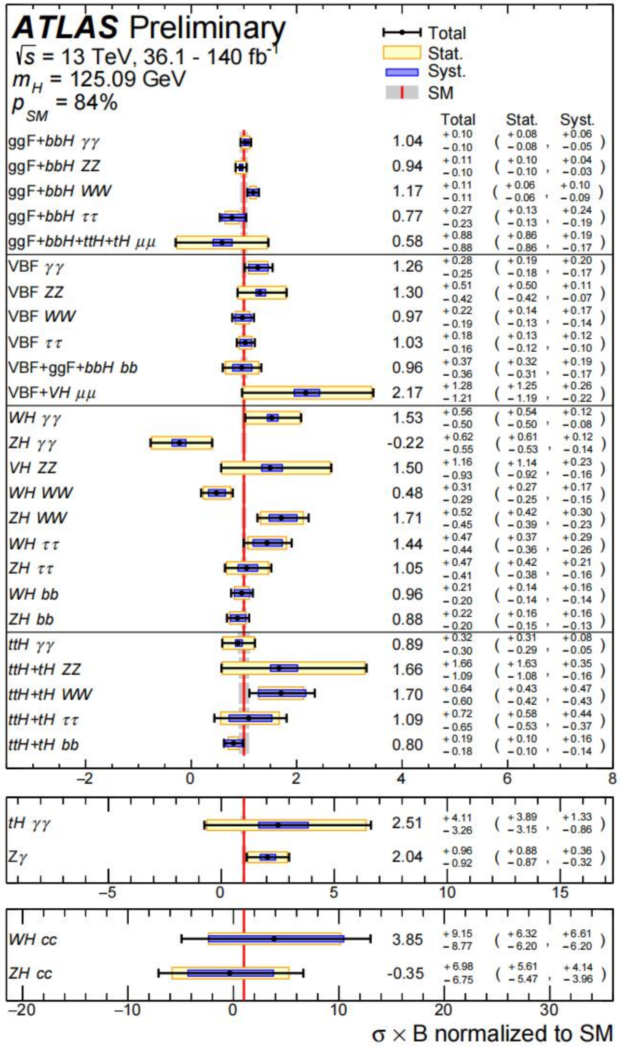
Summary

- The Run2 ATLAS Legacy Higgs combination has made a nice progress with updated input channels
  - All the results are compatible with SM prediction, no significant deviations from the SM are observed
  - Many results are improved due to the updated input channels
    - Global signal strength: ~10% improvement
    - Production cross sections and branching ratios
      - 30%, 20%, 40% improvement for WH/ZH/ttH+tH
      - 20%, 20%, 10% improvement for $H\rightarrow bb/WW^*/\tau\tau$
    - Up to 40% improvement for Kappa framework measurements

Back up

compare with previous results





partial Run 3 results