Higgs boson combination measurements using up to 139 fb^{-1} of pp collision data at $\sqrt{s}$=13 TeV collected by the ATLAS

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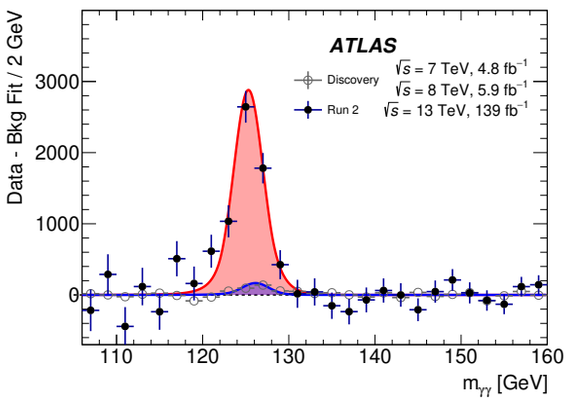
Introduction

Higgs boson was observed in 2012 by the ATLAS and CMS experiments at the LHC at CERN [1,2]. Since then, 30 times more Higgs bosons have been recorded by the ATLAS experiment, allowing much more precise measurement and new tests.

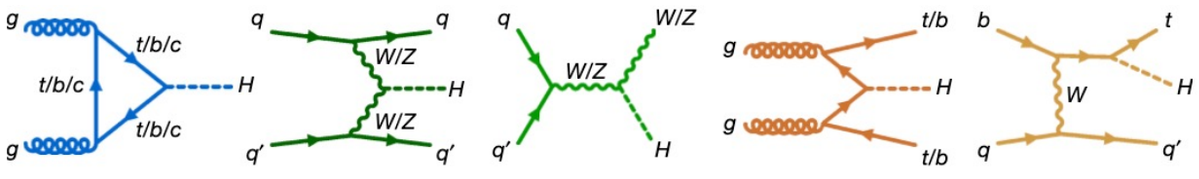


An example, comparison of diphoton invariant mass spectrums in the $H \to \gamma\gamma$ channel betw. the discovery dataset (~ 4.8 fb^{-1} @ 7 TeV + 5.9 fb^{-1} @ 8 TeV) and Run 2 dataset (139 fb^{-1} @ 13 TeV).

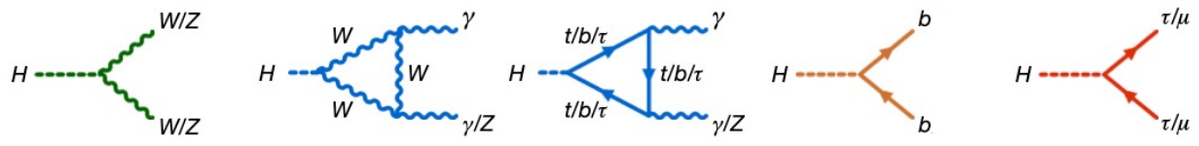
Marker: Data - Bkg.

Curves: fitted signal shape

An unprecedented number of production and decay processes of the Higgs boson is combined to test its interactions with elementary particles. [3]



↑ Feynman diagrams for Higgs boson production ↓ Feynman diagrams for Higgs boson decay



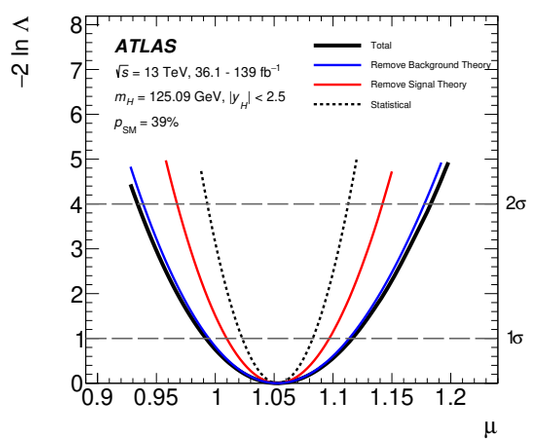
Global signal strength

Parameterized all Higgs signal rates using a single modifier:

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

In this model, all the μ_{if} are set to a global signal strength μ, describing a common scaling of the expected Higgs boson yield in all categories. μ is measured with the likelihood scan:

$$\mu = 1.05 \pm 0.06$$
$$= 1.05 \pm 0.03\,(\mathrm{stat.}) \pm 0.03\,(\mathrm{exp.}) \pm 0.04\,(\mathrm{sig.th}) \pm 0.02\,(\mathrm{bkg.th})$$



total uncertainty is decomposed into:

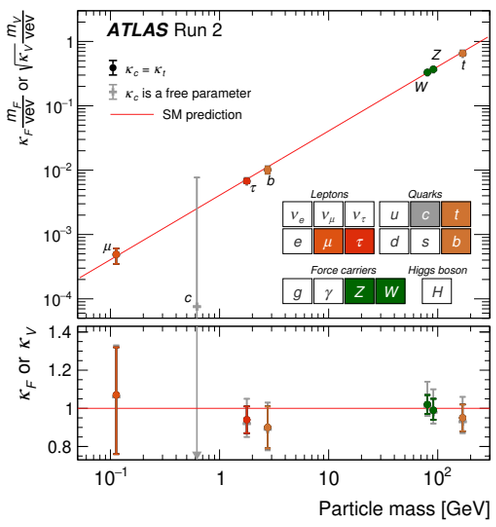
- statistical uncertainties
- experimental systematic uncertainties
- theory uncertainties in signal modelling
- theory uncertainties in bkg modelling

The measurements is consistent with SM prediction with a *p*-value of 39%.

Interpretation of measurements in κ framework

Introduce modifiers to the leading-order contributions to each production and decay

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



- Assume SM structure for the loops
- Non-SM decay not allowed
- κ_u, κ_d, κ_e assumed ~ 1, neglected

Two fit scenarios:

1. $\kappa_c = \kappa_t$ (coloured circle markers)
2. κ_c floated (grey cross marker)

The *p*-values for compatibility of the combined measurement and SM prediction are 56% and 65% for the respective scenarios.

Excellent agreement with SM at such wide mass range

Methodology

- Combined likelihood built as the product of the likelihood of the individual analyses
- Negligible overlap in the event selection across the analyses
- Nuisance parameters accounted for systematics: fully correlated whenever possible
- Signal parameterization in each category k:

$$n_k^{signal} = \mathcal{L}_k \sum_i \sum_f (\sigma \times B)_{if} (A \times \epsilon)_{if}^k$$

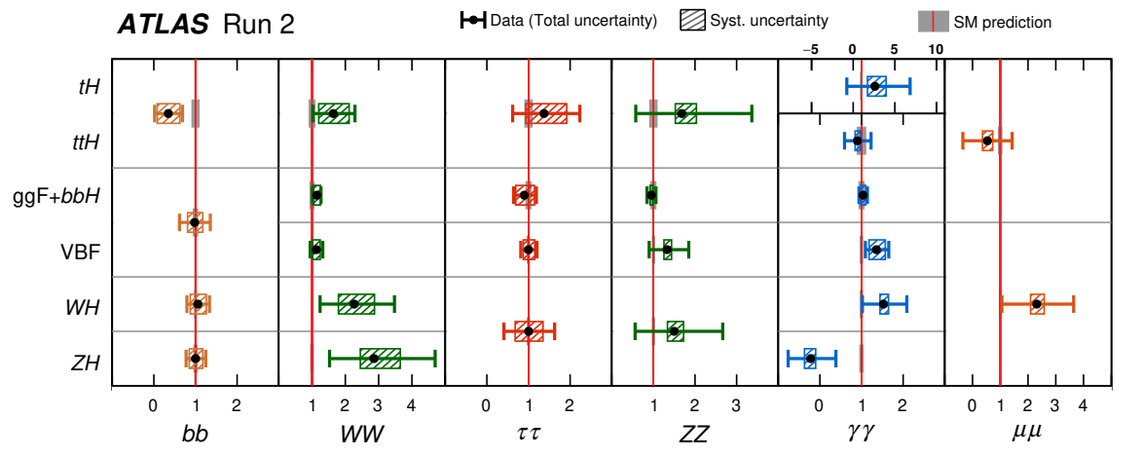
($\mathcal{L}_k$: Integrated luminosity of the data set used in category k; $(A \times \epsilon)_{if}^k$: Acceptance times efficiency factor; $(\sigma \times B)_{if}$: Cross section times branching fraction)

where the sum runs over production mode i ($i = \mathrm{ggF}, \mathrm{VBF}, \mathrm{WH}, \mathrm{ZH}, t\bar{t}H, \ldots$) and decay final states f ($f = \gamma\gamma, ZZ^*, WW^*, \tau\tau, b\bar{b}, \mu\mu, \ldots$)

Production and Decay

Production cross-section (XS) times decay branching ratio (BR)

XS and BR are tested together, thus no assumptions about the relative contribution of different decay or production processes.



σ × B normalized to SM prediction

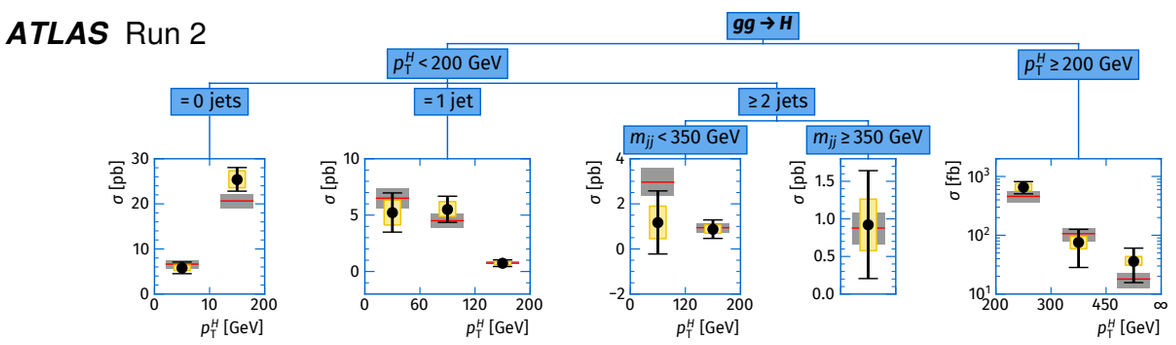
All available cross sections and branching ratios are measured.

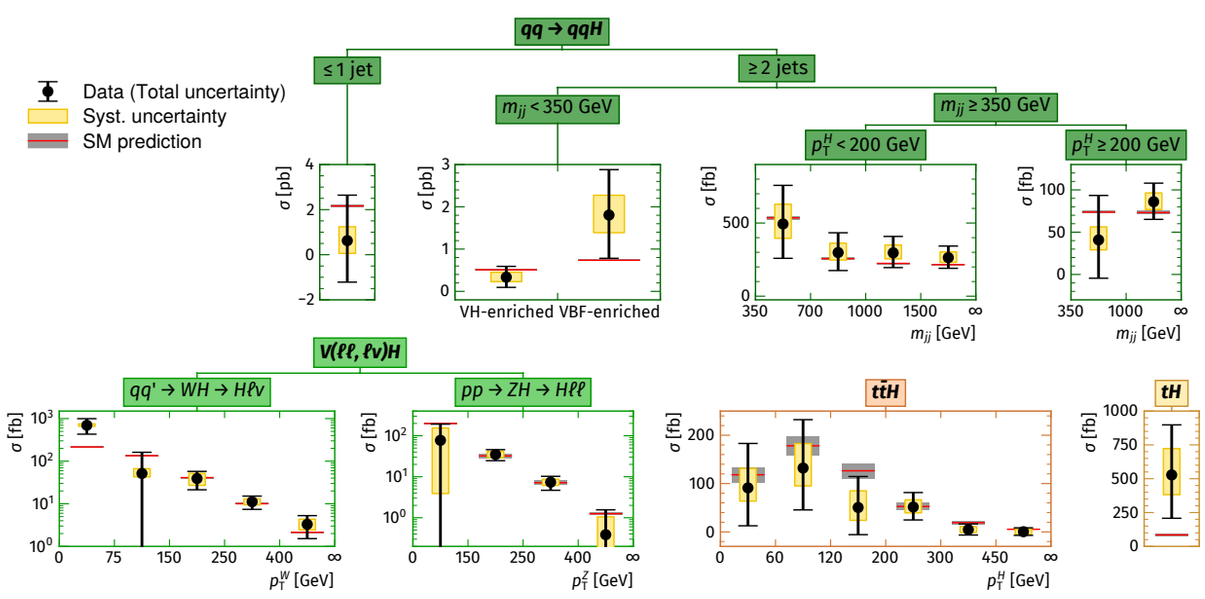
The measurements is consistent with SM prediction with a *p*-value of 72%.

Simplified Template Cross-Sections (STXS)

Split phase space of Higgs production processes in $|y_H| < 2.5$ by initial state, associated jets/W/Z and kinematics into 36 kinematic regions:

- provide experimental sensitivity to deviations from the SM
- better control over theory uncertainties in the regions
- minimize the model-dependence of their extrapolations to signal region





All BR and kinematics of Higgs Boson decays are assumed to be SM-like.

The measurements is consistent with SM prediction with a *p*-value of 94%.

[1] Phys. Lett. B 716 (2012) 1
[2] Phys. Lett. B 716 (2012) 30
[3] Nature 607, pages 52–59 (2022)