

Higgs boson production and decay rate measurements with the ATLAS experiment

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on behalf of the ATLAS Collaboration

Phenomenology 2026 Symposium

Pittsburgh, May 11, 2026

Yale

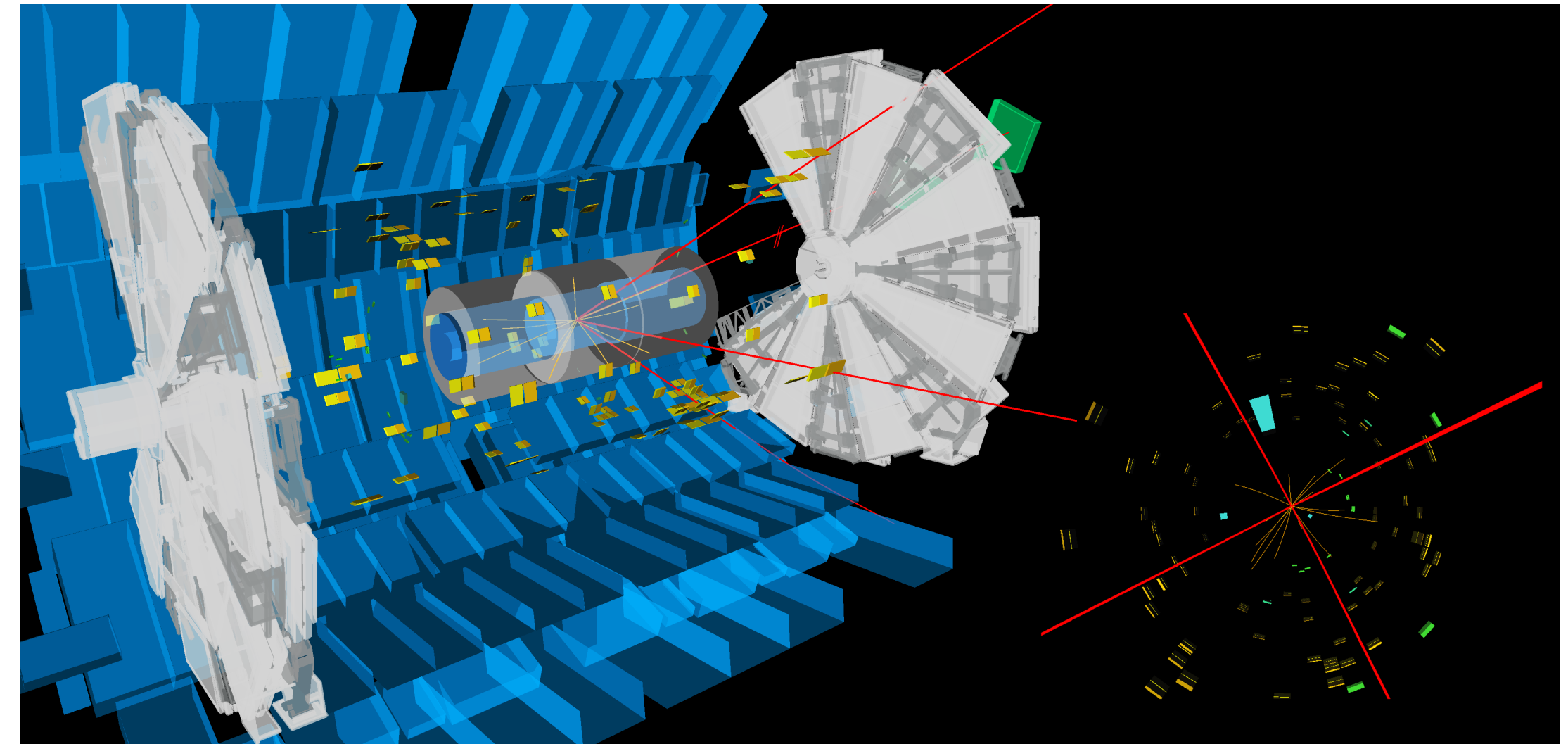


Why measure Higgs production and decay rates?

The Higgs boson is a laboratory for testing electroweak symmetry breaking and the SM pattern of couplings.

- Mass generation: couplings scale with particle masses
- Precision couplings: compare bosons, fermions, loops
- BSM sensitivity: deviations in rates or kinematics

Focus of this talk: production and decay rate measurements



ATLAS event display

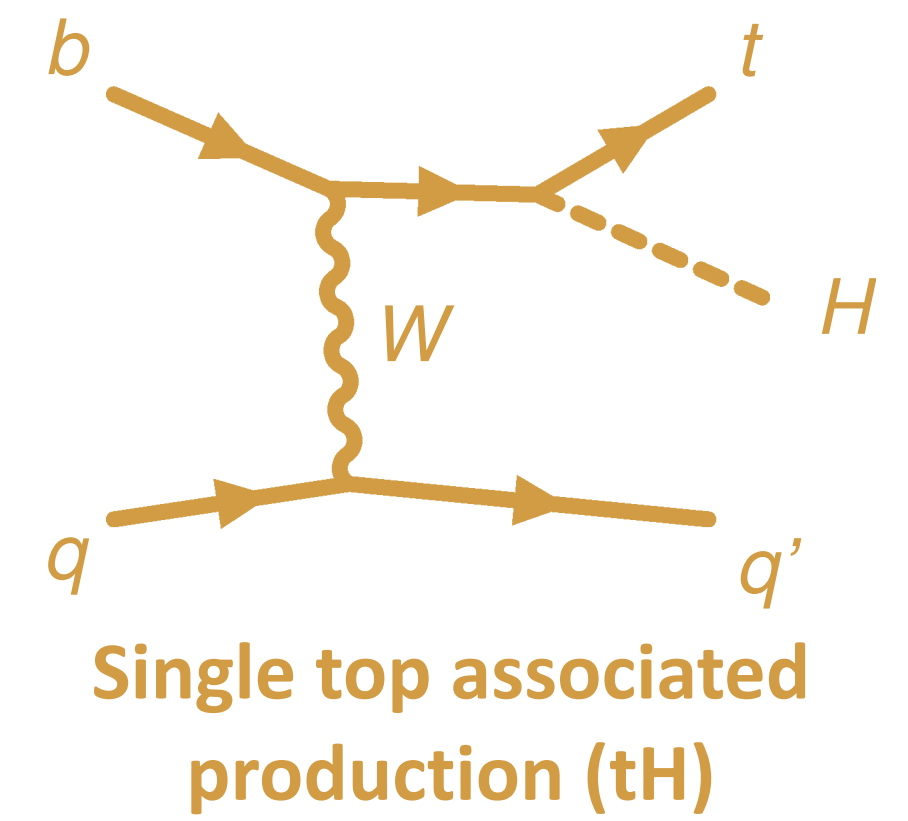
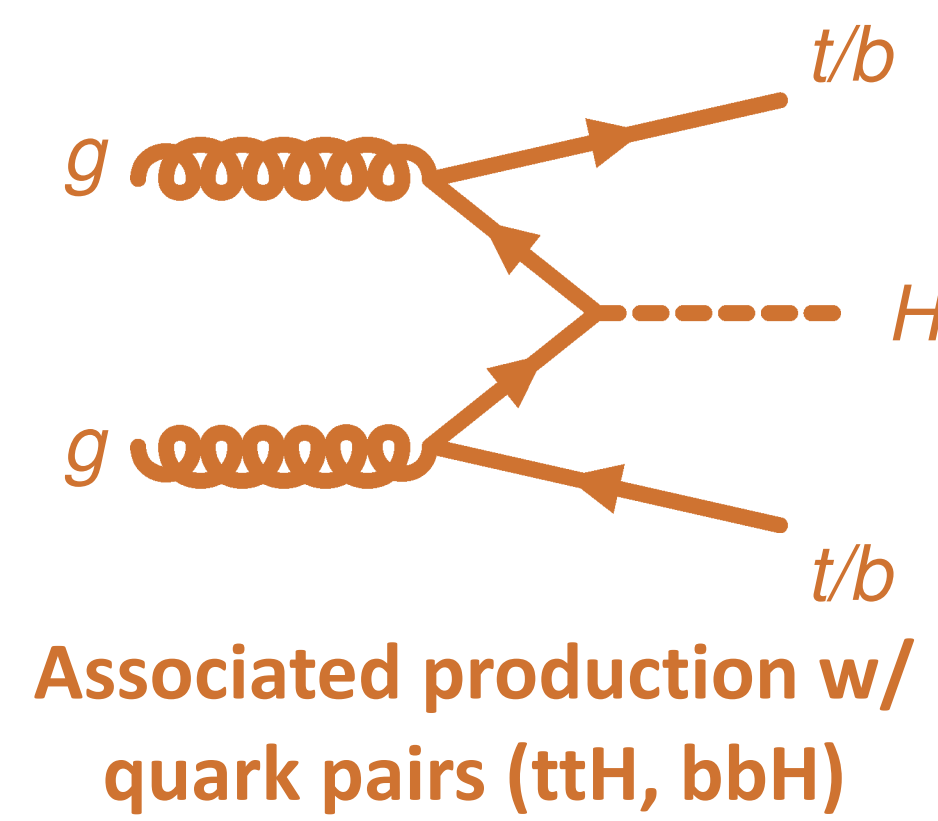
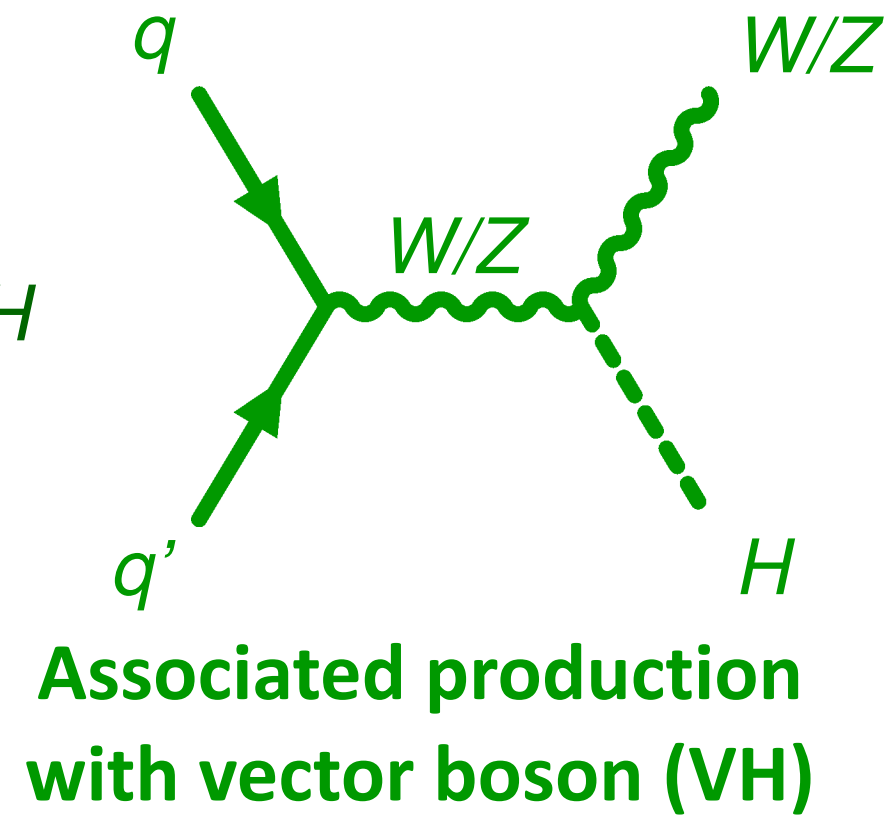
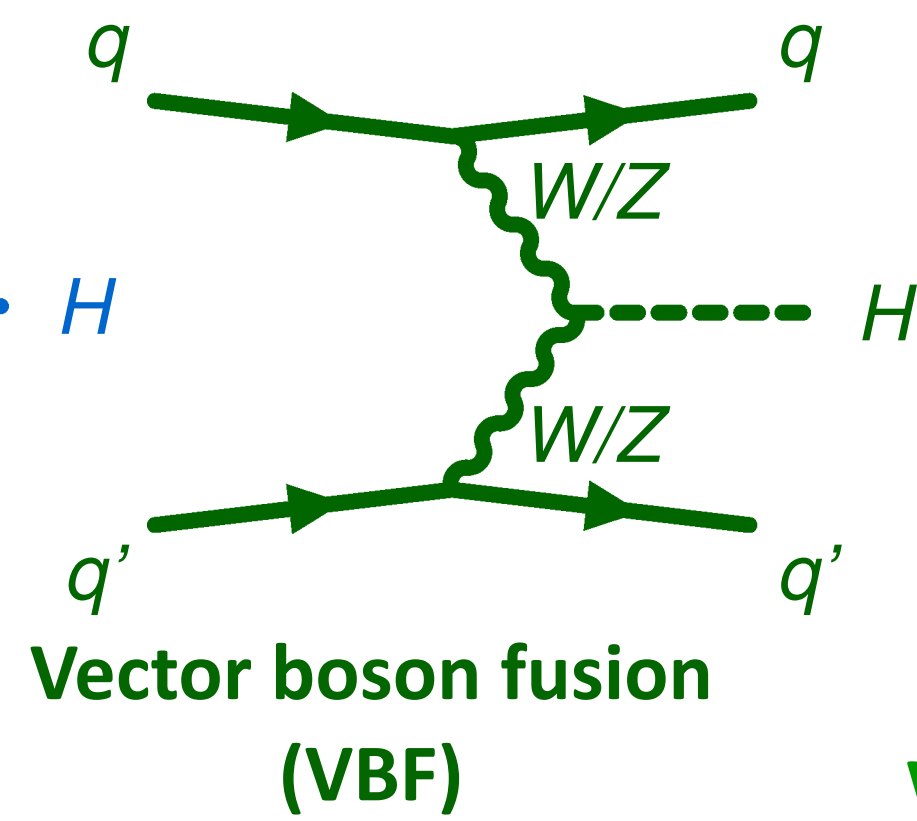
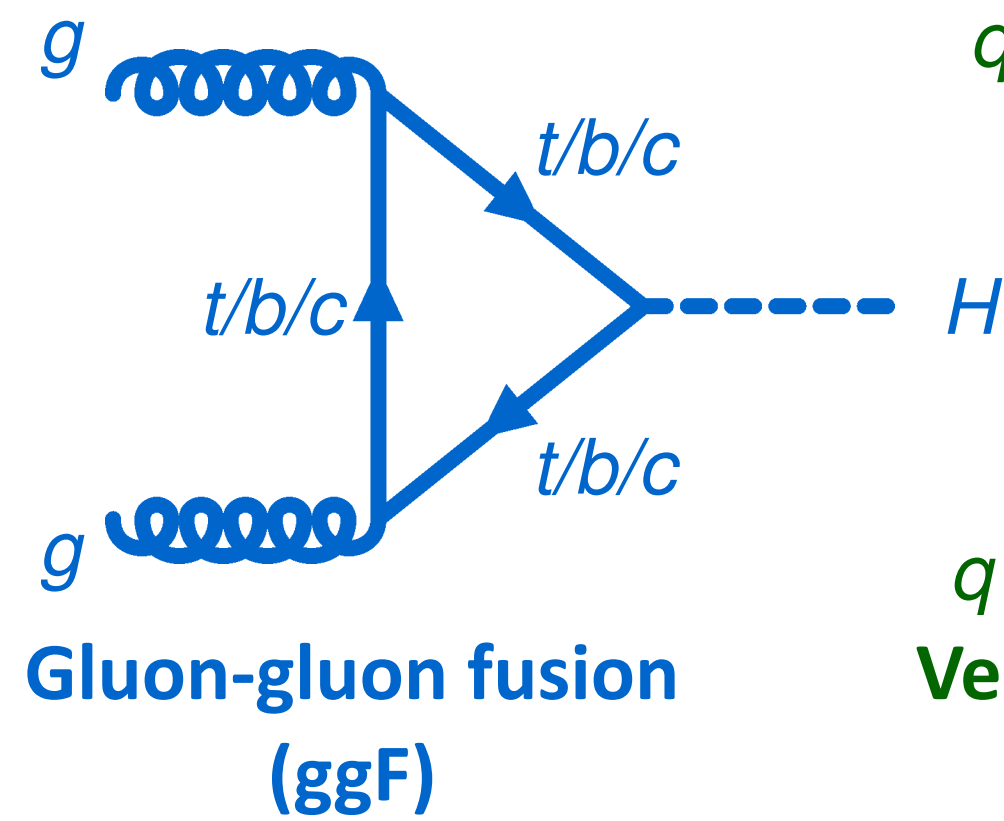
Measured yields → cross sections, branching-ratio constraints, STXS and coupling modifiers

Rate measurements connect reconstructed events to Higgs production and decay probabilities.

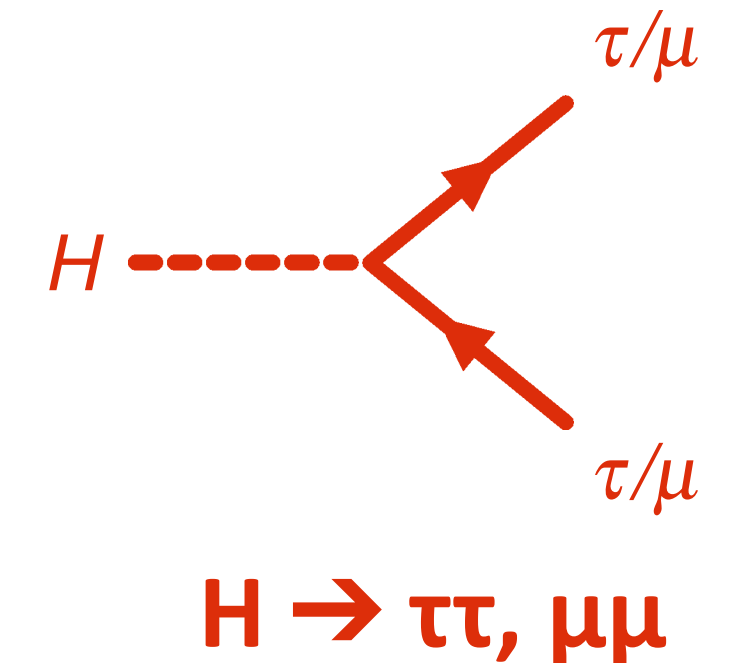
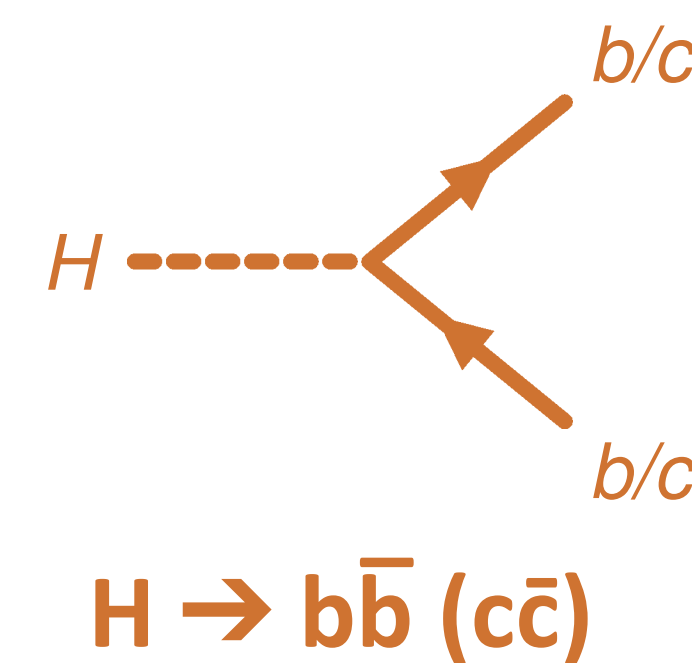
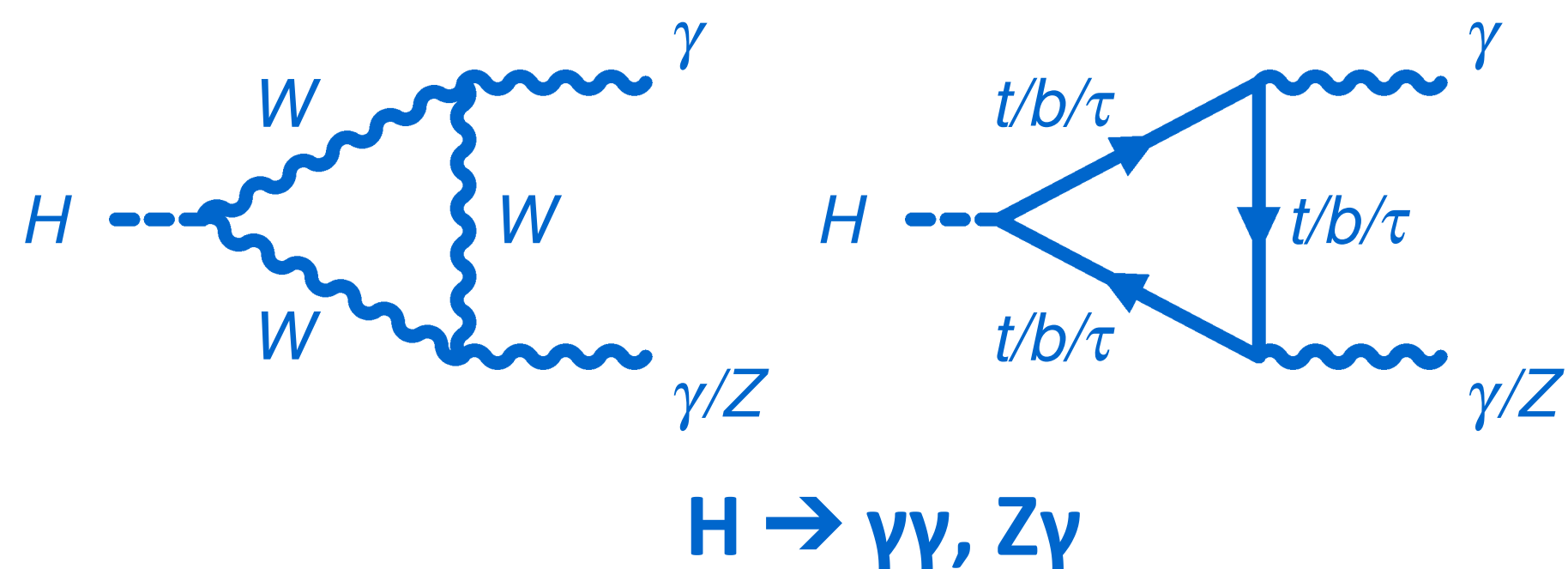
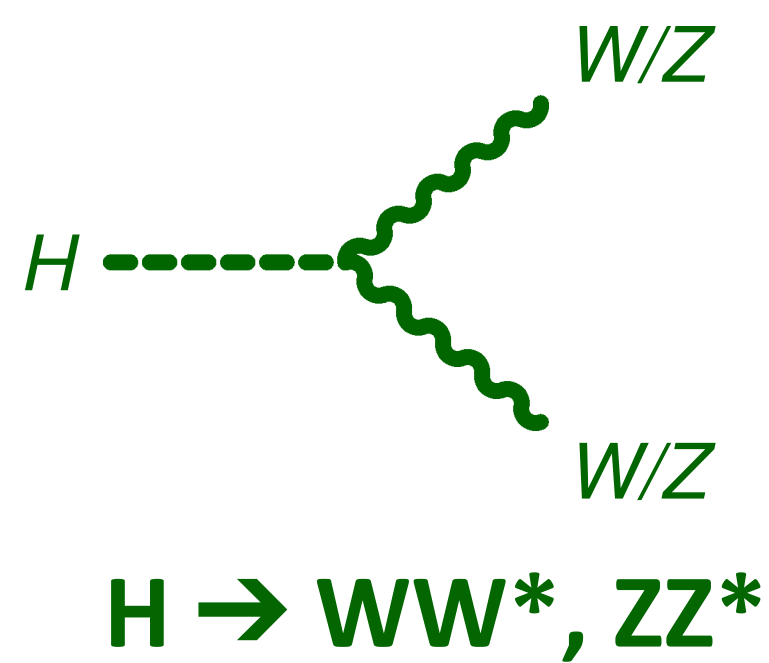
Inclusive rates test the overall normalization; differential and STXS bins test production kinematics.

Higgs production and decay channels

Production modes



Decay modes



Each $\sigma \times BR$ measurement constrains a product of production and decay couplings; combinations separate production rates, branching fractions and coupling modifiers.

What is a “rate measurement”?

A Higgs rate is extracted from fitted signal yields and reported with a specified phase-space definition.

Schematic selected-yield relation

$$N_{\text{sig}} \approx \mathcal{L} \times \sigma_i \times \mathcal{B}(H \rightarrow f) \times A \times \varepsilon$$

- \mathcal{L} : integrated luminosity
- i : production mode, differential bin, or STXS bin
- $\mathcal{B}(H \rightarrow f)$: branching fraction for decay channel f
- $A \times \varepsilon$: acceptance and reconstruction/selection efficiency

What we report

- Inclusive: one number for a production or decay mode
- Fiducial: measured in a detector-like phase space
- Differential: cross section vs. $p_T(H)$, N_{jets} , m_{jj} , ...
- STXS: production-mode and kinematic bins designed for combinations

Less extrapolation → closer to the detector-level measurement.

The same selected events can support inclusive, fiducial, differential and STXS results depending on the unfolding or reinterpretation used.

$H \rightarrow ZZ^* \rightarrow 4\ell$: benchmark channel for Run 3 rates

A fully reconstructed, low-background channel for Run 3 Higgs rate measurements.

- Data: $\sqrt{s} = 13.6$ TeV, 56 fb^{-1} , $H \rightarrow ZZ^* \rightarrow 4\ell$
- Fit to $m_{4\ell}$ and unfolded cross sections in fiducial phase space
- Inclusive fiducial: $\sigma_{\text{fid}} = 3.5 (+0.6/-0.5) \text{ fb}$; SM = $3.7 \pm 0.1 \text{ fb}$
- Production-mode and differential cross sections measured; all compatible with SM

σ_{fid}

3.5 (+0.6/-0.5) fb

SM: $3.7 \pm 0.1 \text{ fb}$

σ_{total}

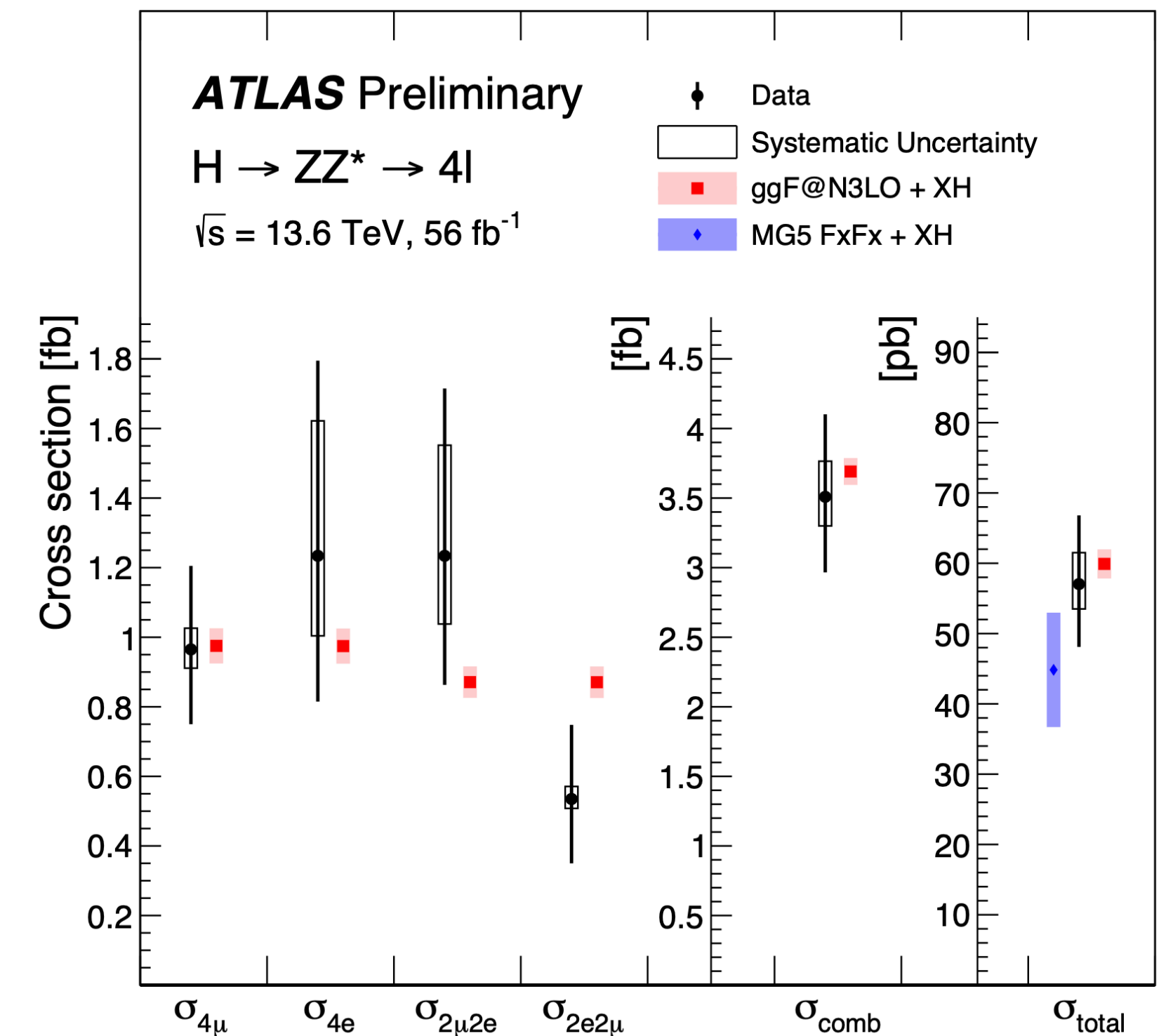
57 (+10/-9) pb

SM: $59.9 \pm 2.6 \text{ pb}$

dataset

56 fb^{-1}

Run 3, 13.6 TeV



Fiducial and total cross sections vs SM predictions.

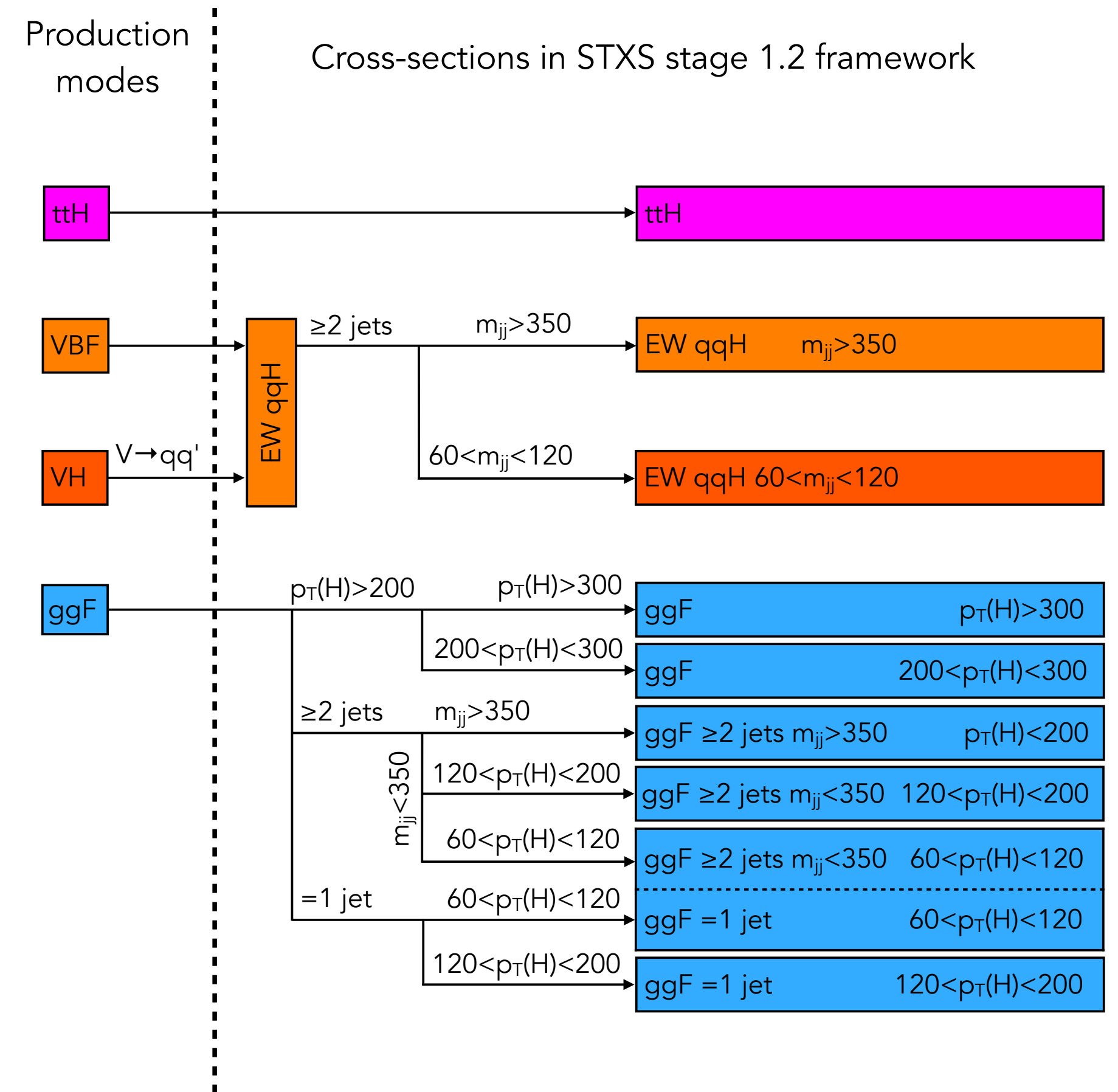
The same candidate sample supports fiducial, total, differential and production-mode cross-section measurements.

What do we actually measure?

Rate measurements are now differential measurements of Higgs production kinematics.

- Differential spectra: $p_T(H)$, N_{jets} , m_{jj} probe production dynamics.
- High- p_T tails: enhanced sensitivity to new heavy states.
- STXS: organize events into production-mode bins for combinations.

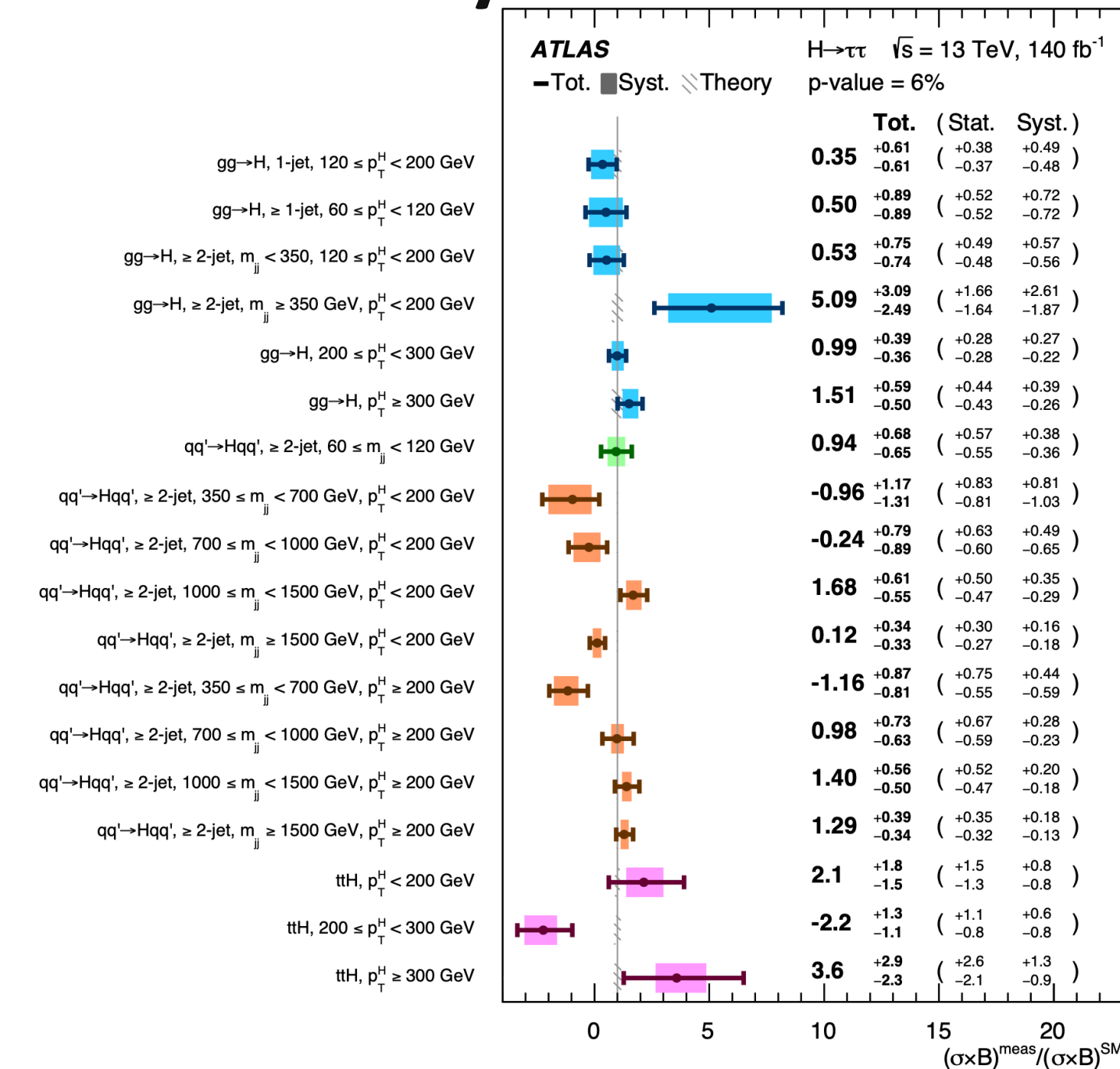
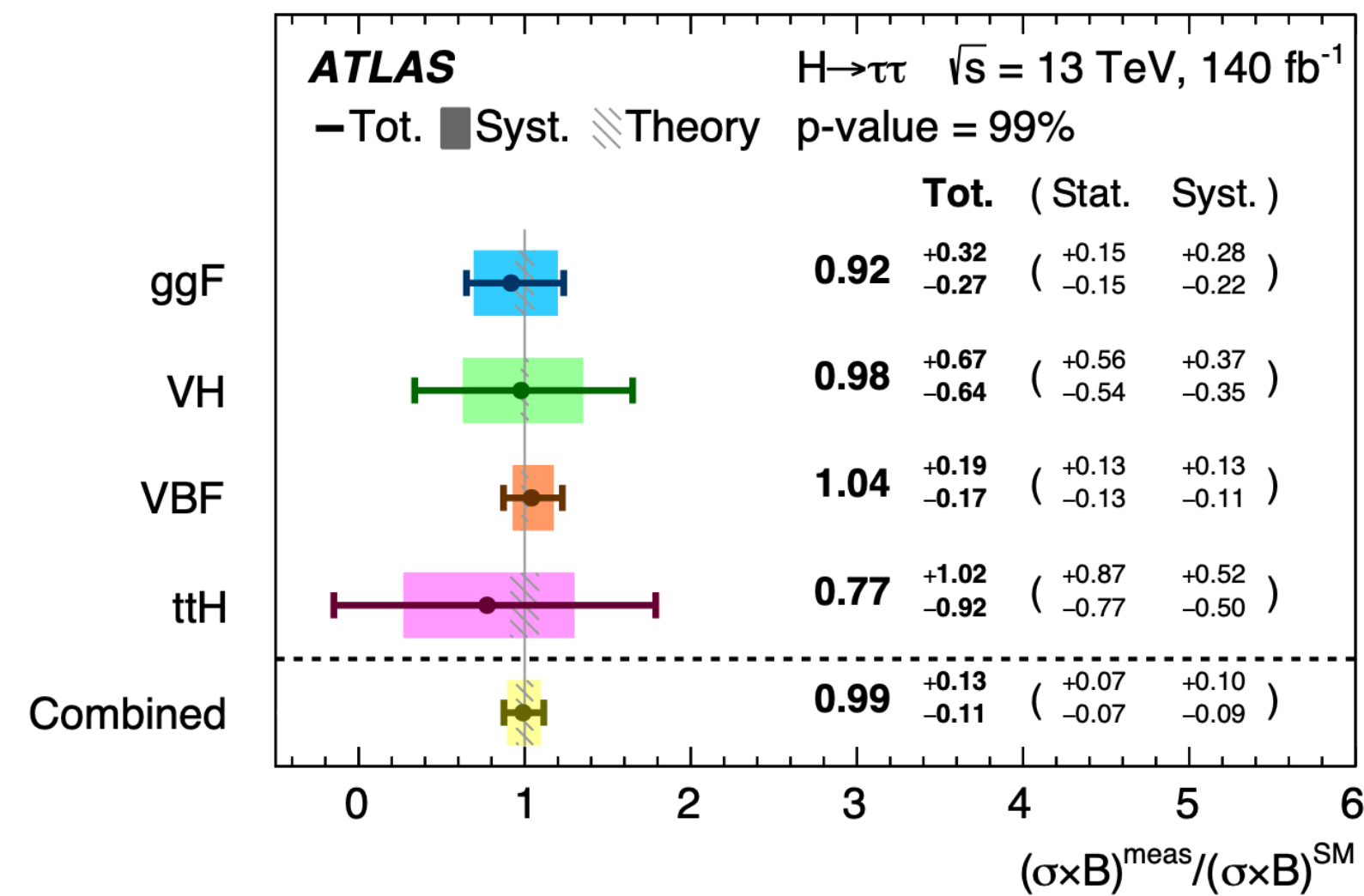
Fiducial and STXS measurements enable combinations and facilitate reinterpretation while preserving sensitivity to Higgs production kinematics.



STXS stage-1.2 bins divide Higgs production by production mode and kinematic regime.

Fermionic decays: $H \rightarrow \tau^+ \tau^-$

$H \rightarrow \tau\tau$ gives the largest leptonic Higgs branching fraction, so the Run 2 sample can be split into production and kinematic categories while retaining useful sensitivity.



Analysis scope: ggF, VBF, VH and ttH considered; STXS measurement and VBF-enriched unfolded fiducial differential measurement.

Physics reach: VBF kinematics such as m_{jj}, p_T(H) and signed Δφ_{jj} probe the HWW/HZZ vertex and constrain CP-odd SMEFT contributions.

Result: production-mode and differential measurements are broadly compatible with the SM across; the growing number of STXS bins reflects increasing sensitivity to Higgs production kinematics.

High-statistics and heavy-flavor channels

ATLAS, [Eur. Phys. J. C 85, 1403](#)

ATLAS, [JHEP 08 \(2025\) 034](#)

ATLAS, [arXiv:2511.21911](#)

ATLAS, [arXiv:2603.19369](#)

These channels extend Higgs rate measurements beyond clean final states and probe complementary couplings.

$H \rightarrow WW^*$: high-stats channel

- Large bosonic branching ratio; complementary to $H \rightarrow ZZ^*$
- Run 2 ggF/VBF fiducial and STXS measurements
- VH, $H \rightarrow WW^*$: WH/ZH in 2ℓ , 3ℓ and 4ℓ final states
- First ATLAS VH, $H \rightarrow WW^*$ STXS measurement

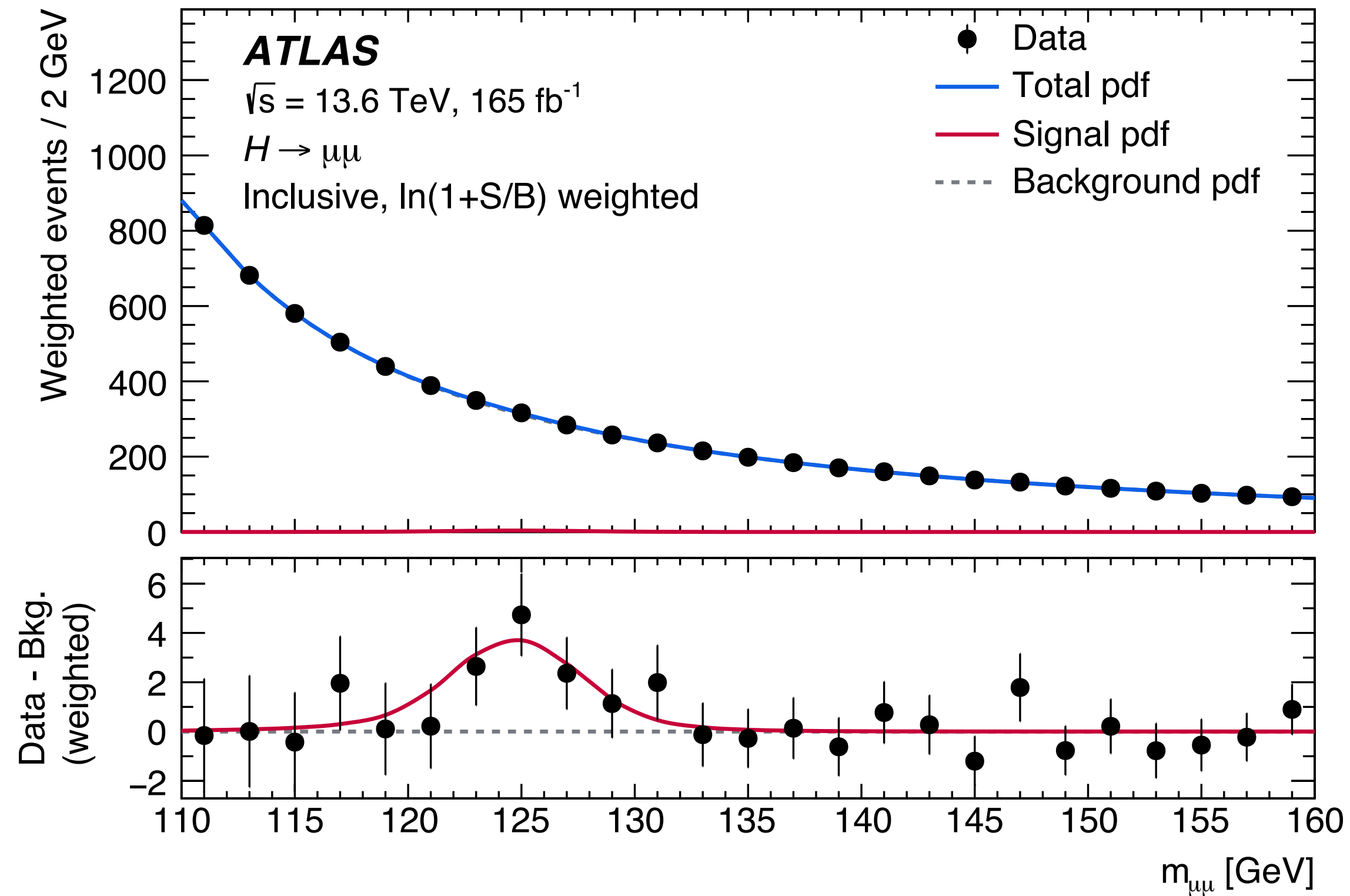
$H \rightarrow bb/cc$: dominant decay + high- p_T regime

- $H \rightarrow bb$ is the dominant Higgs decay; backgrounds are challenging
- VBF $H(bb,cc)$: all-hadronic Run 2 + partial Run 3 measurement
- Boosted $H \rightarrow bb$ probes the high p_T -regime of Higgs production, where BSM effects can become enhanced
- $H \rightarrow bb$ is reconstructed as a single large-R jet for $p_T(H) > 450$ GeV using 301 fb^{-1}
- Observed 3.8σ evidence for boosted $H \rightarrow bb$ production

Rare decays

$H \rightarrow \mu\mu$

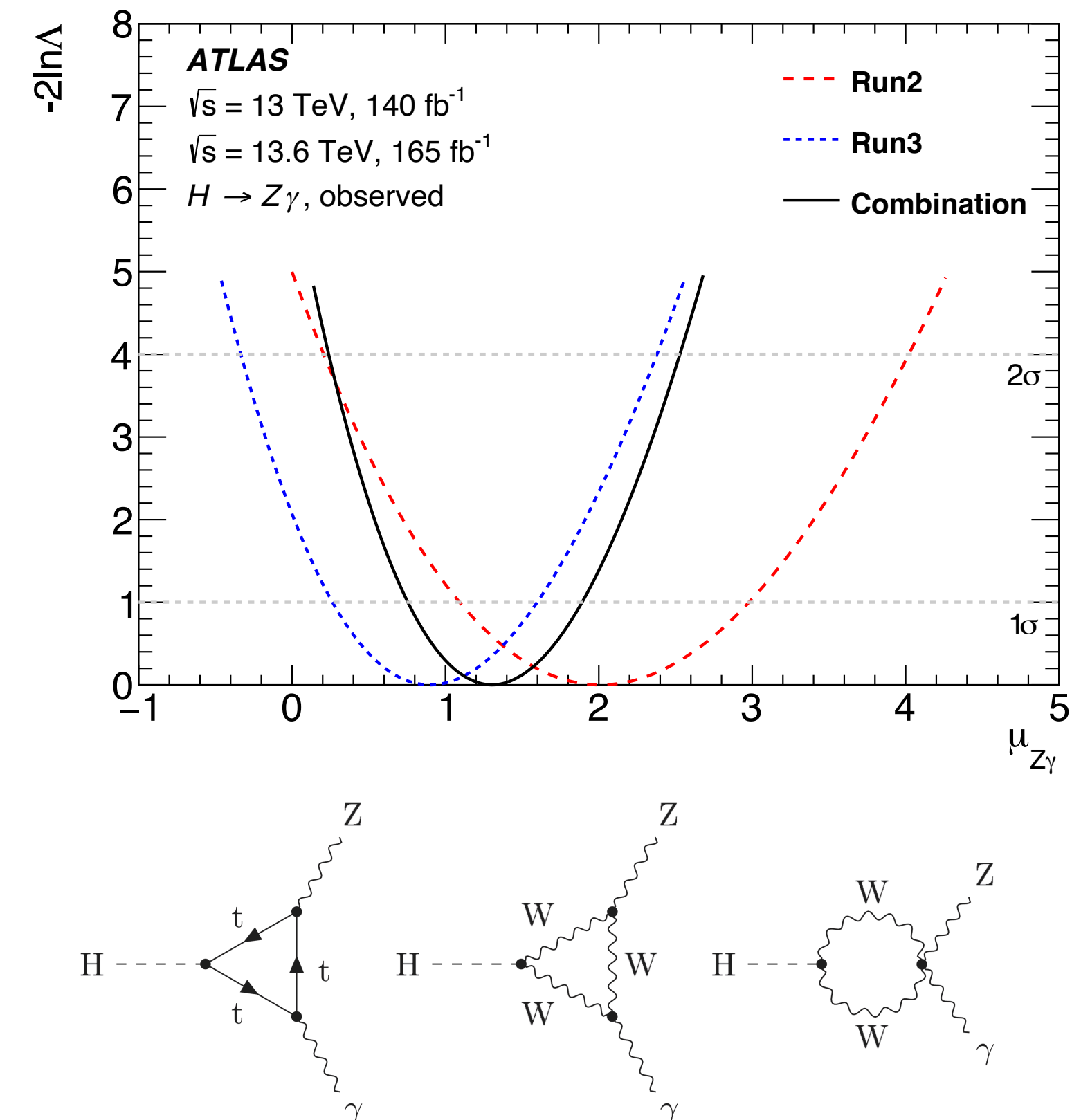
Direct probe of the second-generation Yukawa coupling



Run 2 + Run 3: $\mu = 1.4 \pm 0.4$, observed significance 3.4σ .

$H \rightarrow Z\gamma$

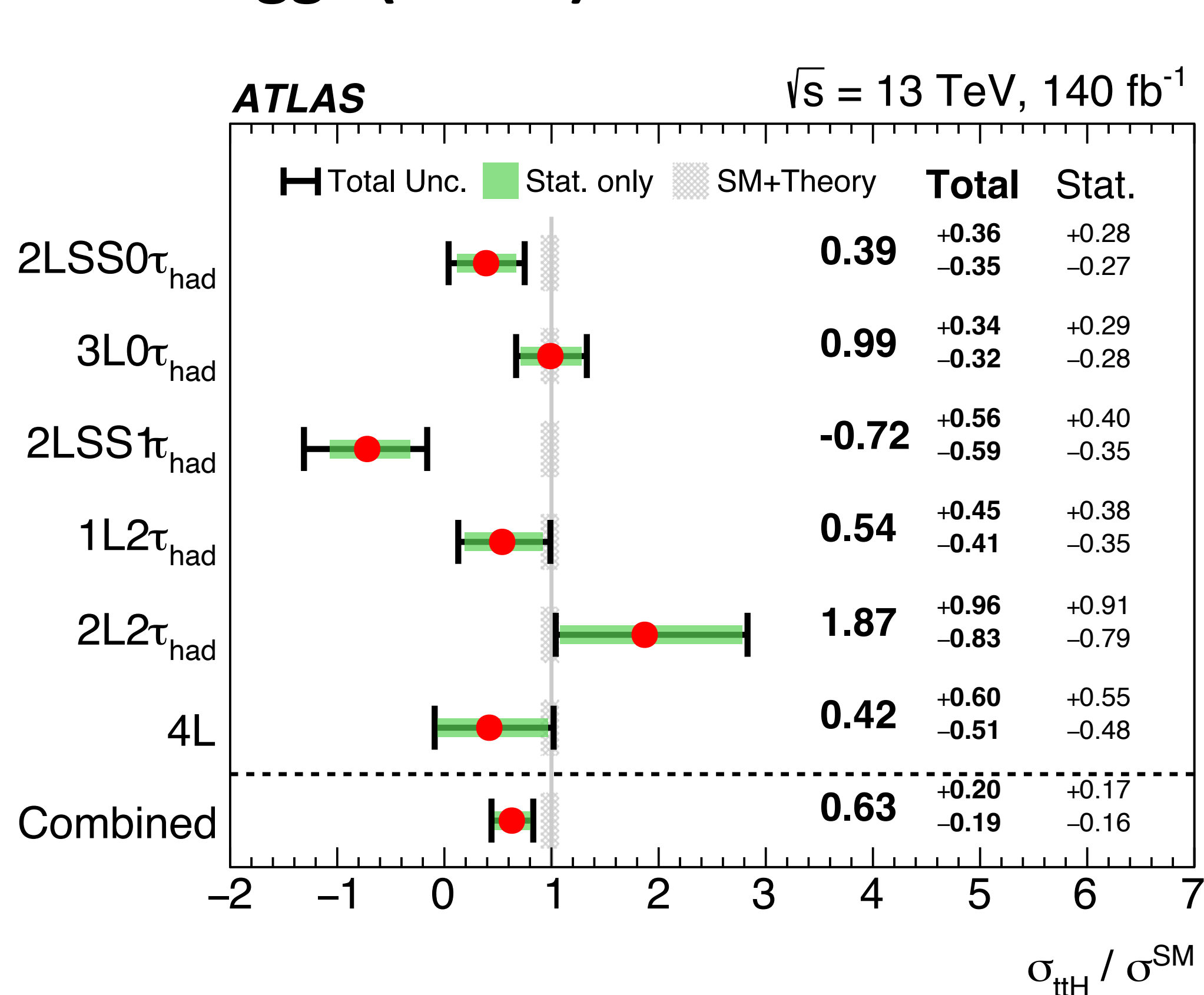
Loop-induced decay, sensitive to new charged particles



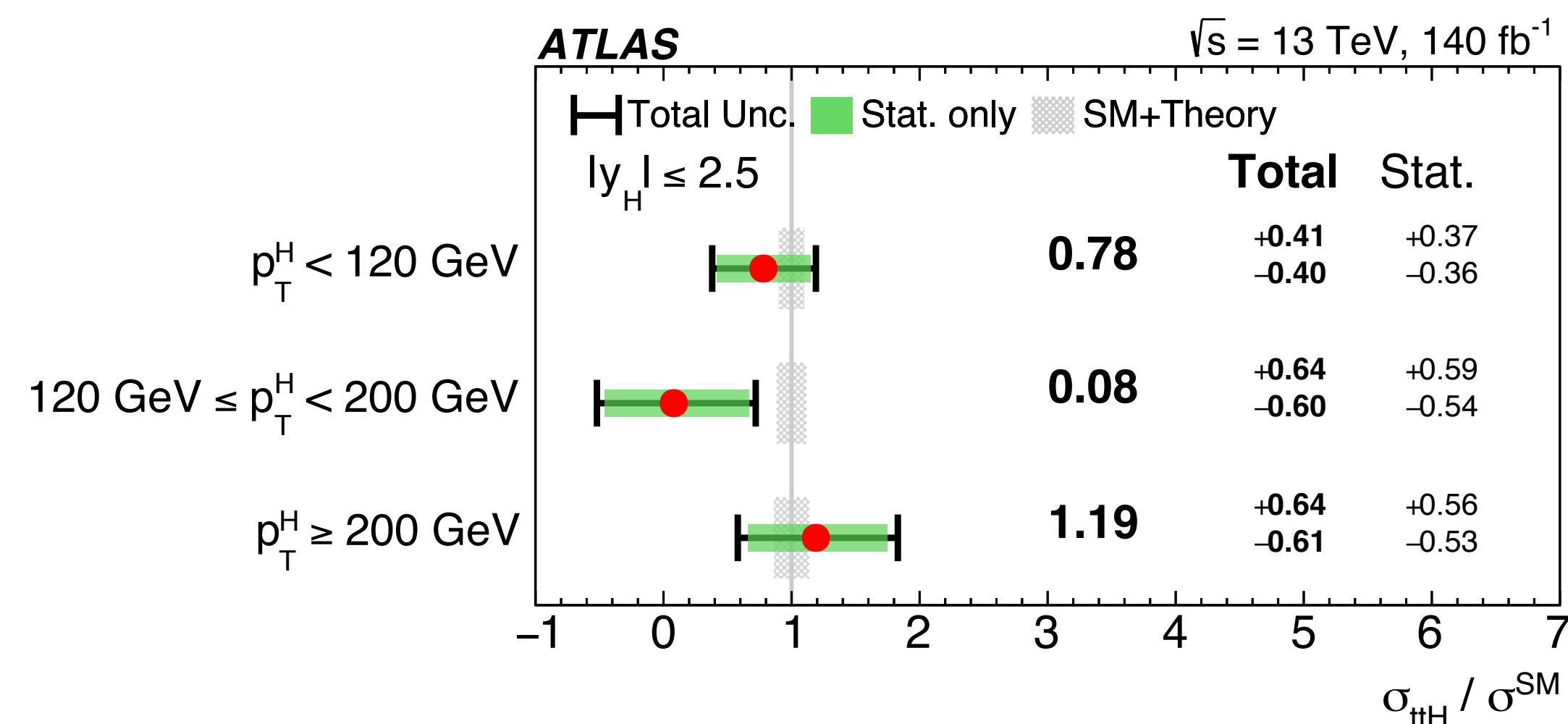
Run 2 + Run 3: $\mu = 1.3^{+0.6}_{-0.5}$, observed significance 2.5σ .

Top-associated Higgs production

ttH provides a direct probe of the top-Higgs Yukawa coupling, complementary to loop-induced ggF (Run 2).

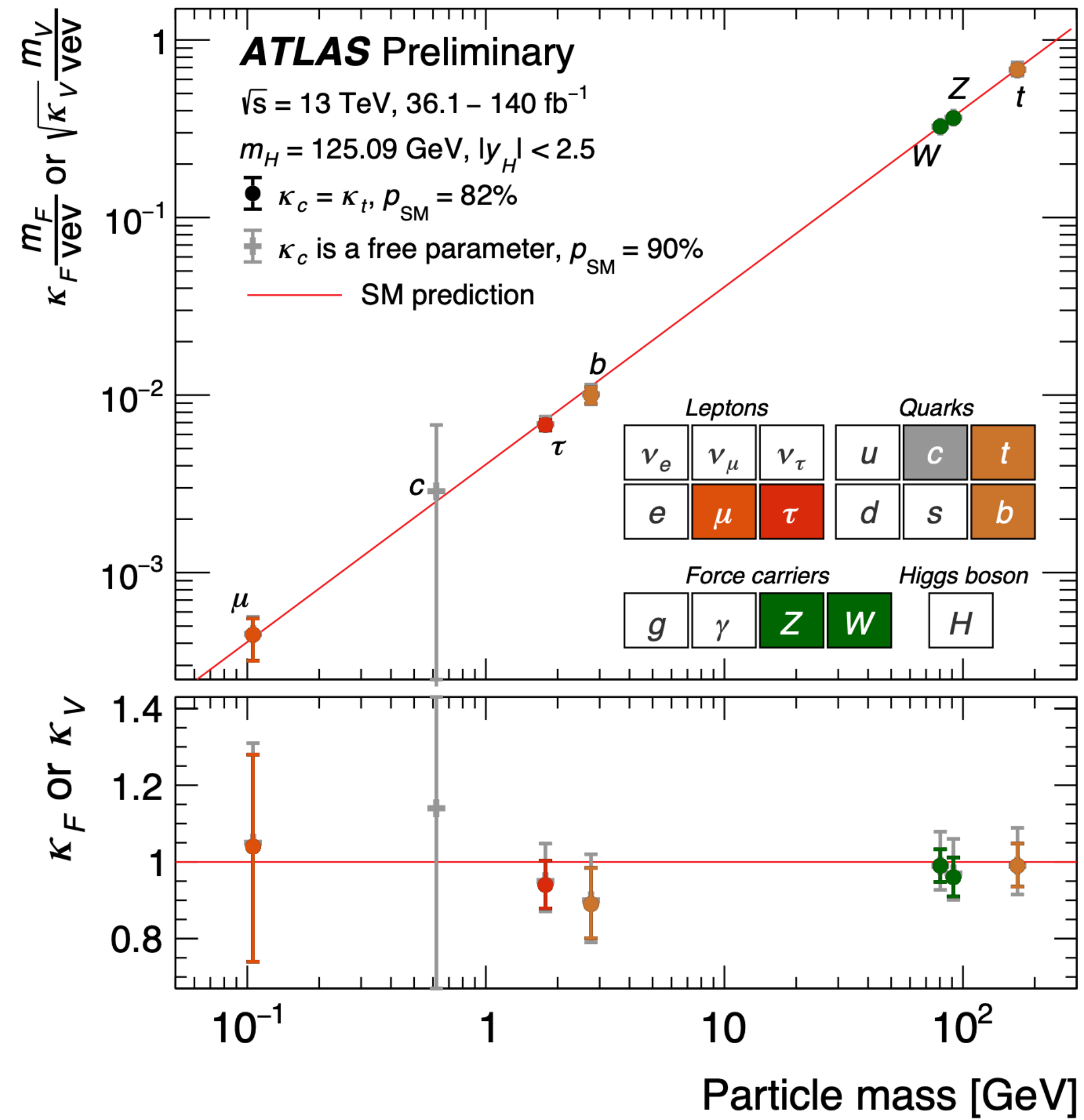


Left: inclusive ttH signal strength by channel.
Right: ttH $p_{\text{T}}(\text{H})$ STXS measurement.



- $\sigma_{\text{ttH}} / \sigma^{\text{SM}} = 0.63^{+0.20}_{-0.19}$ in a simultaneous fit to six multilepton final states.
- Observed ttH significance: 3.3σ (5.3σ expected).
- Additional fits measure ttH in $p_{\text{T}}(\text{H})$ STXS bins and extract tH together with ttH.
- CP interpretation compatible with the SM; excludes $|\alpha| > 62^\circ$ at 68% CL

Global combination: production rates, BRs, couplings

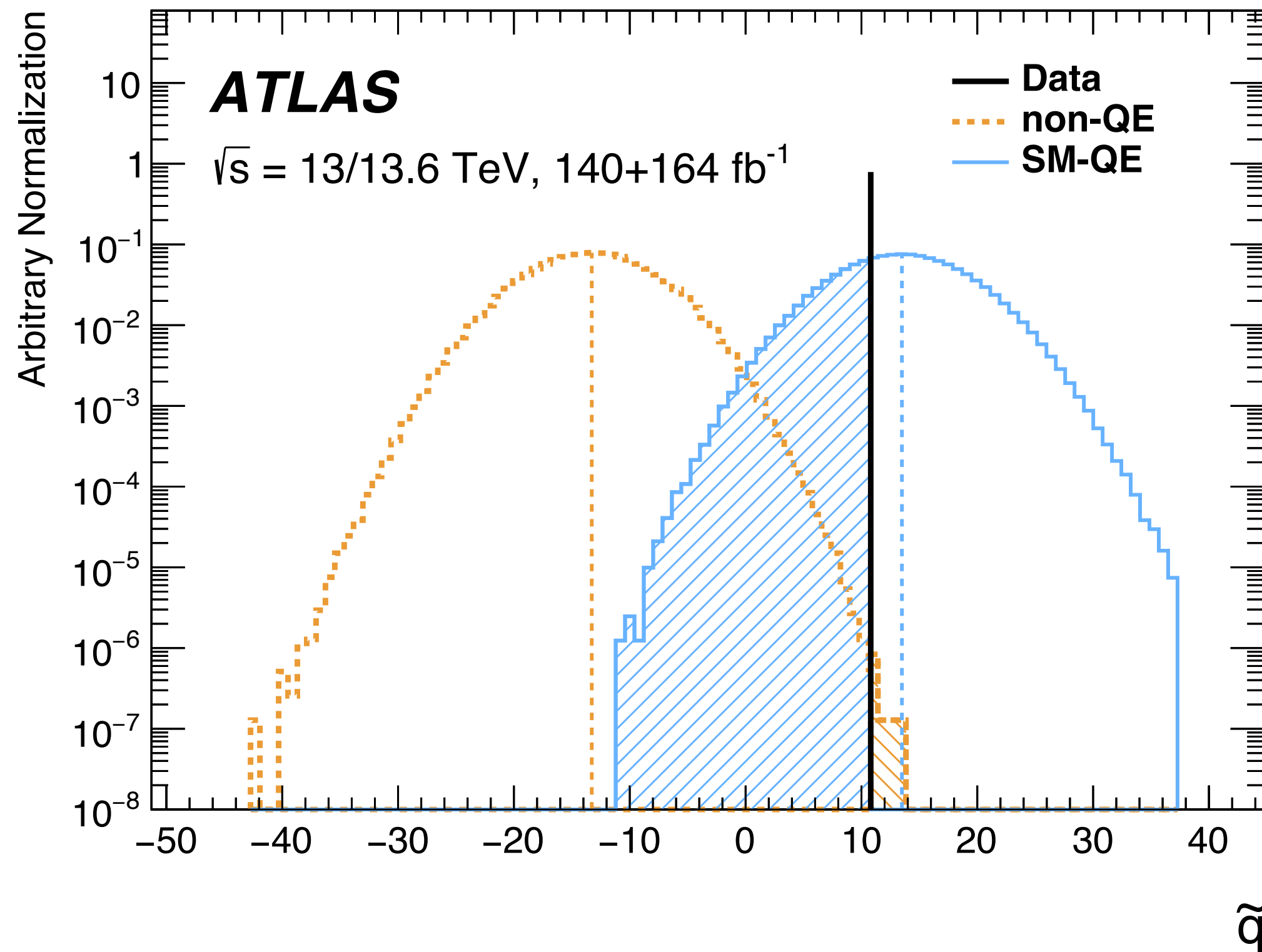


- Full Run 2 combination using up to 140 fb^{-1} at 13 TeV
- Global signal strength: $\mu = 1.023^{+0.056}_{-0.053}$
- Measures production cross sections, branching ratios, $\sigma \times \text{BR}$ combinations and κ -framework coupling modifiers
- No significant deviation from the SM is observed

In the κ -framework, measured rates test whether Higgs couplings follow the SM mass-dependent pattern.

Beyond rates with $H \rightarrow ZZ^* \rightarrow 4\ell$ angular correlations

This is not a rate measurement. It is an example of what the same fully reconstructed 4ℓ sample enables once rate and kinematic measurements are under control.



What is measured

- Angular distributions in $H \rightarrow ZZ^* \rightarrow 4\ell$ reconstruct spin-density-matrix information for the Z-boson pair (Run 2 + partial Run 3).
- Entanglement-sensitive coefficients are measured: $C_{2,1,2,-1} = -0.71 \pm 0.45$ and $C_{2,2,2,-2} = 0.08 \pm 0.44$.
- A full angular-distribution hypothesis test disfavors a separable-state hypothesis at 4.7σ (4.9σ expected).

Connection to this talk: $H \rightarrow 4\ell$ rate measurements establish the event selection, mass peak, background control and reconstruction precision used for deeper angular tests.

Summary

ATLAS Higgs rate measurements now form a precision, multi-channel consistency test of the EW symmetry breaking sector.

$$\mu = 1.023 (+0.056/-0.053)$$

Run 2 global signal strength

$$\sigma_{\text{fid}}(4\ell) = 3.5 (+0.6/-0.5) \text{ fb}$$

Run 3 $H \rightarrow ZZ^* \rightarrow 4\ell$ benchmark

$$3.4\sigma$$

Run 2 + Run 3 ATLAS evidence for
 $H \rightarrow \mu\mu$

$$3.8\sigma$$

Run 2 and Run 3 evidence for
boosted $H \rightarrow bb$, $p_T(H) > 450 \text{ GeV}$

- Inclusive rates remain SM-like, while combinations now measure production, decay and coupling patterns at the few-percent-to-tens-of-percent level.
- Fiducial, differential and STXS measurements turn rate extraction into a kinematic map of Higgs production.
- Fermionic and rare decays extend the tests to τ , μ , b , c and loop-induced electroweak channels.
- The high- p_T frontier and top-associated production are especially important for BSM and CP-sensitive interpretations.
- Run 3 is already improving mass-peak, rare-decay and boosted measurements; the next step is coherent Run 2 + Run 3 combinations.