Measurements and interpretations of Simplified Template Cross Sections, differential and fiducial cross sections in Higgs boson decays to four leptons with the ATLAS detector

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on behalf of the ATLAS collaboration

Relevant Atlas Publications

Eur. Phys. J. C 80 (2020) 942	**Measurements of the Higgs boson inclusive and differential fiducial cross sections in the 4ℓ decay channel at $\sqrt{s}$ = 13 TeV**	**139 fb^{-1}**
Eur. Phys. J. C 80 (2020) 957	**Higgs boson production cross-section measurements and their EFT interpretation in the 4ℓ decay channel at $\sqrt{s}$ = 13 TeV with the ATLAS detector**	**139 fb^{-1}**

Relevant Atlas Publications

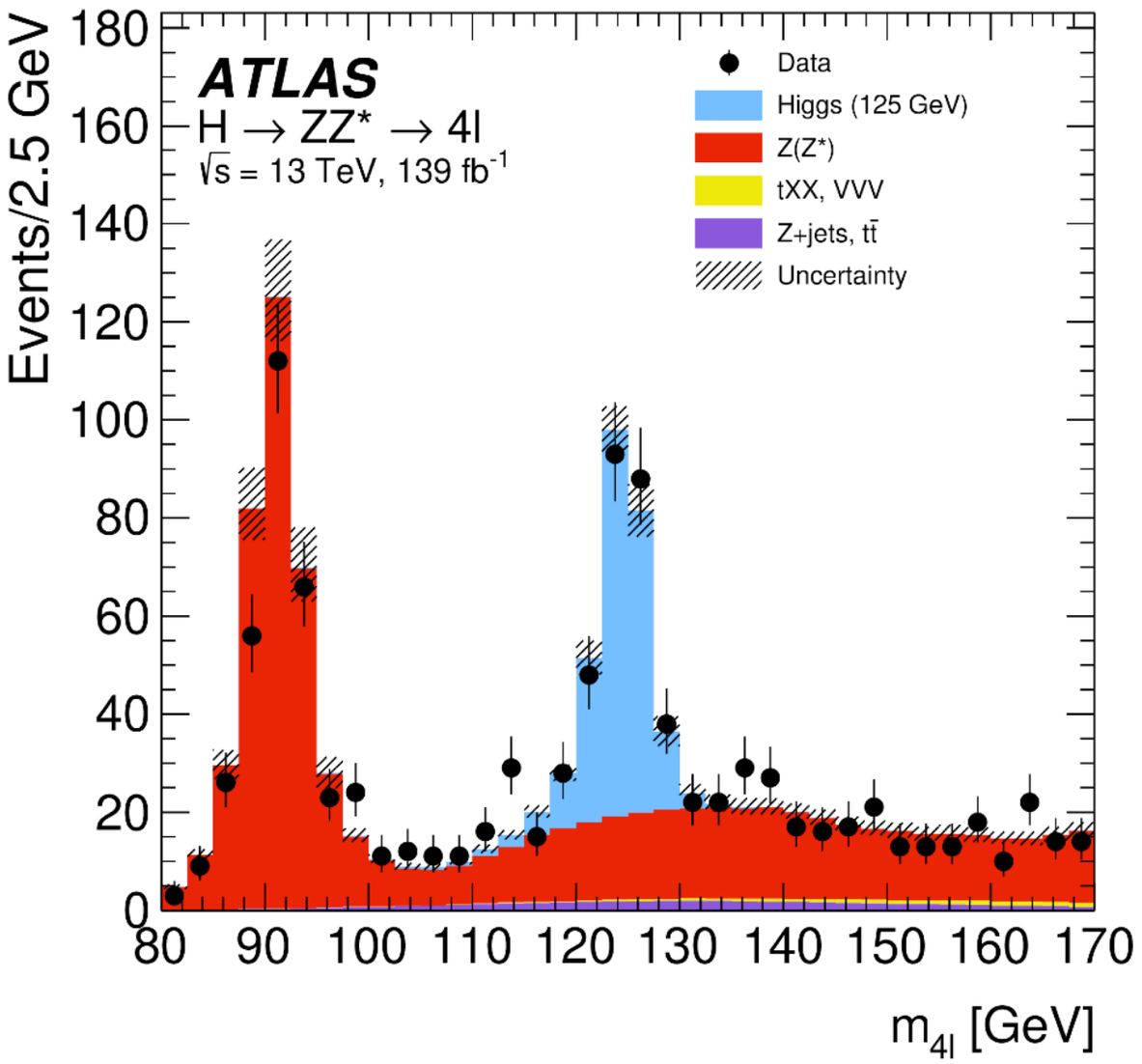
Fully fiducial differential measurements :
“Essential but can only be carried out in a subset of decay channels”.
“They are explicitly optimised for maximal theory independence.”

STXS :
“Optimised for sensitivity while reducing the dominant theory dependence in the measurement”.
“As they are extrapolated from a simultaneous fit, this allows for advanced experimental techniques (including multi-variate observables and discriminants) to be employed in the analyses. The use of such techniques is not possible, for instance, when measuring fiducial cross sections, as it is very hard, if not impossible, to define the fiducial volume for a multi-variate observable.”

(Handbook of LHC Higgs cross sections:4 , arXiv:1610.07922)

ATLAS H→4l selection

Our understanding has evolved. But the “baseline” selections are not that different to the one that served us well for the discovery and Run-I measurement

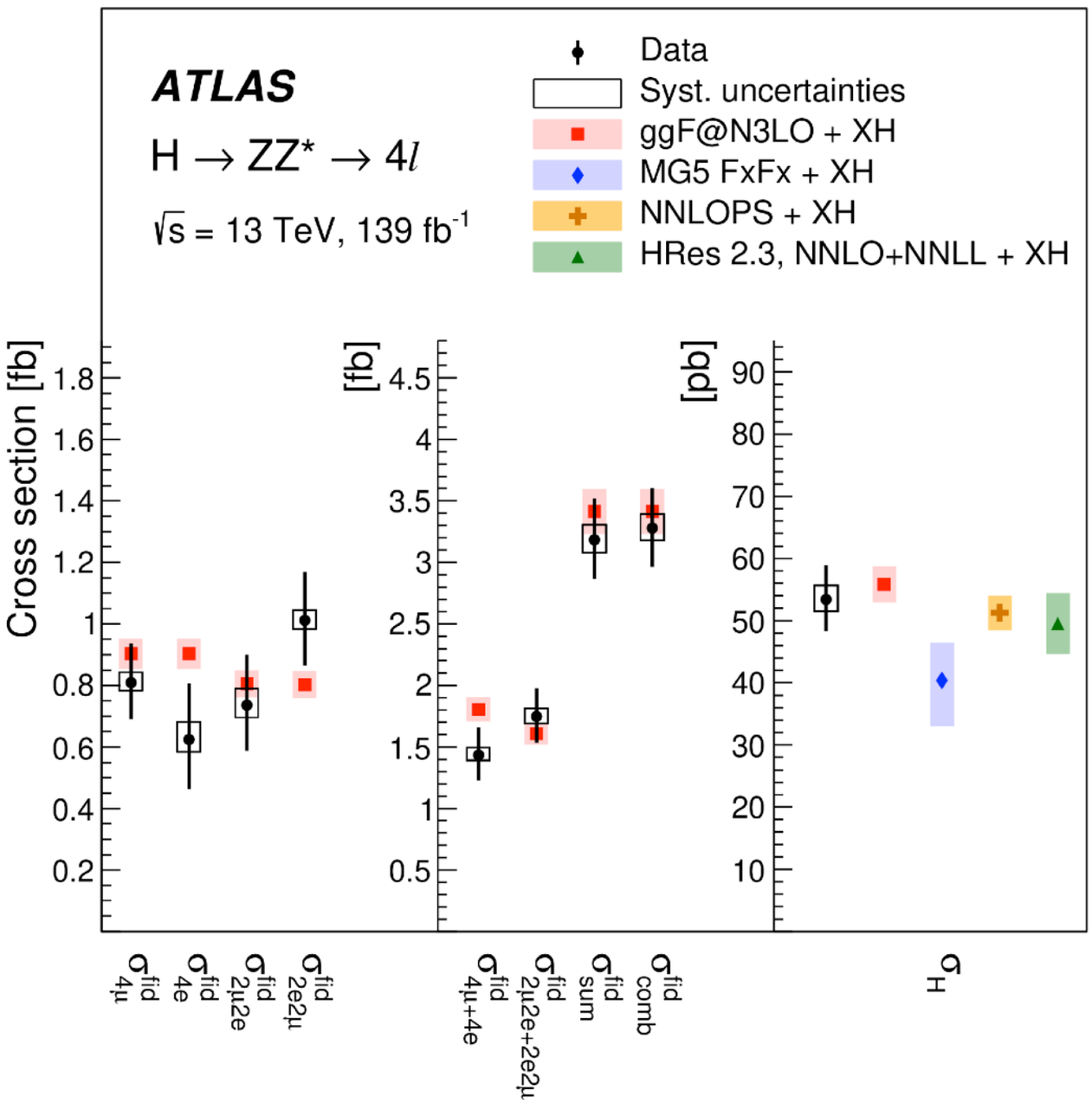


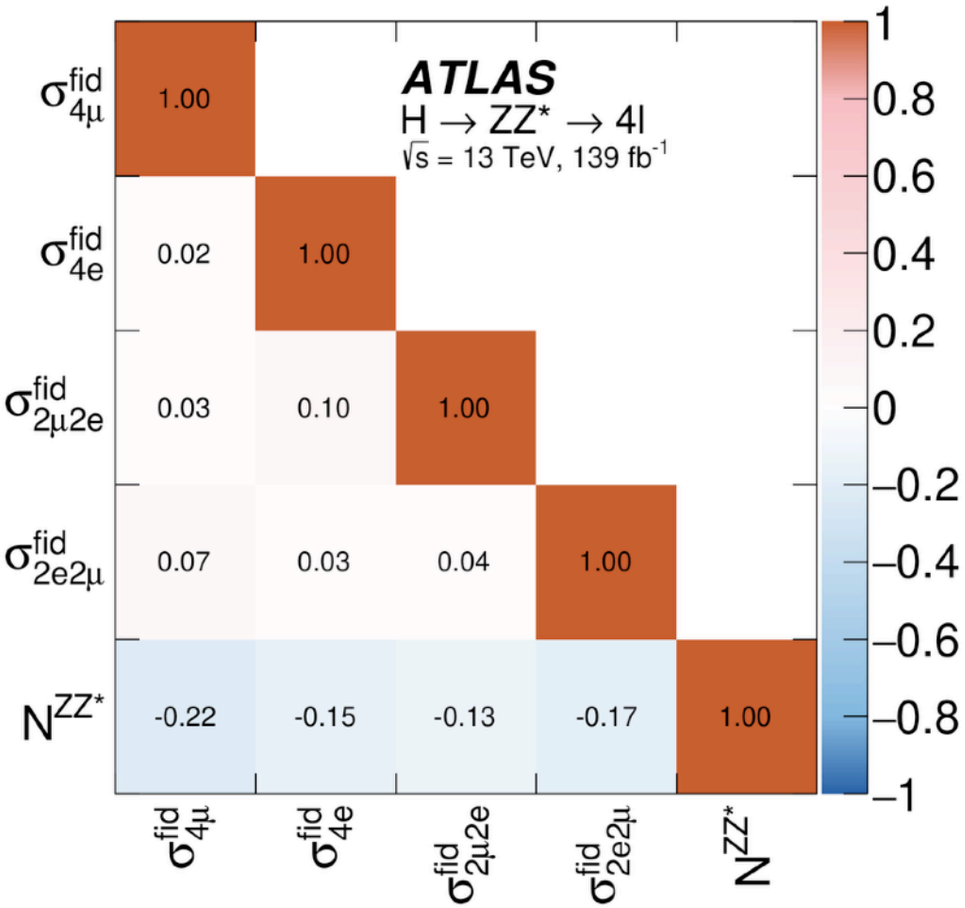
ATLAS H→4l selection :
- muons (electrons)
- |η|< 2.7 (2.47)
- Pt 20 GeV, 15 GeV, 10 GeV , 5(7) GeV
- 50 GeV < m12 < 106 GeV
- 12 GeV < m34 < 115 GeV

Normalisation of dominant ZZ* background is obtained from 105 -160 GeV “sideband”.
It is estimated separately in each bin of each differential observable

Fiducial volume :
Leptons pT > 5 GeV, |η| < 2.7
Jets pT > 30 GeV, |y| < 4.4.
105 GeV< m4l < 160 GeV
and the above selection

H→4l fiducial and total cross sections





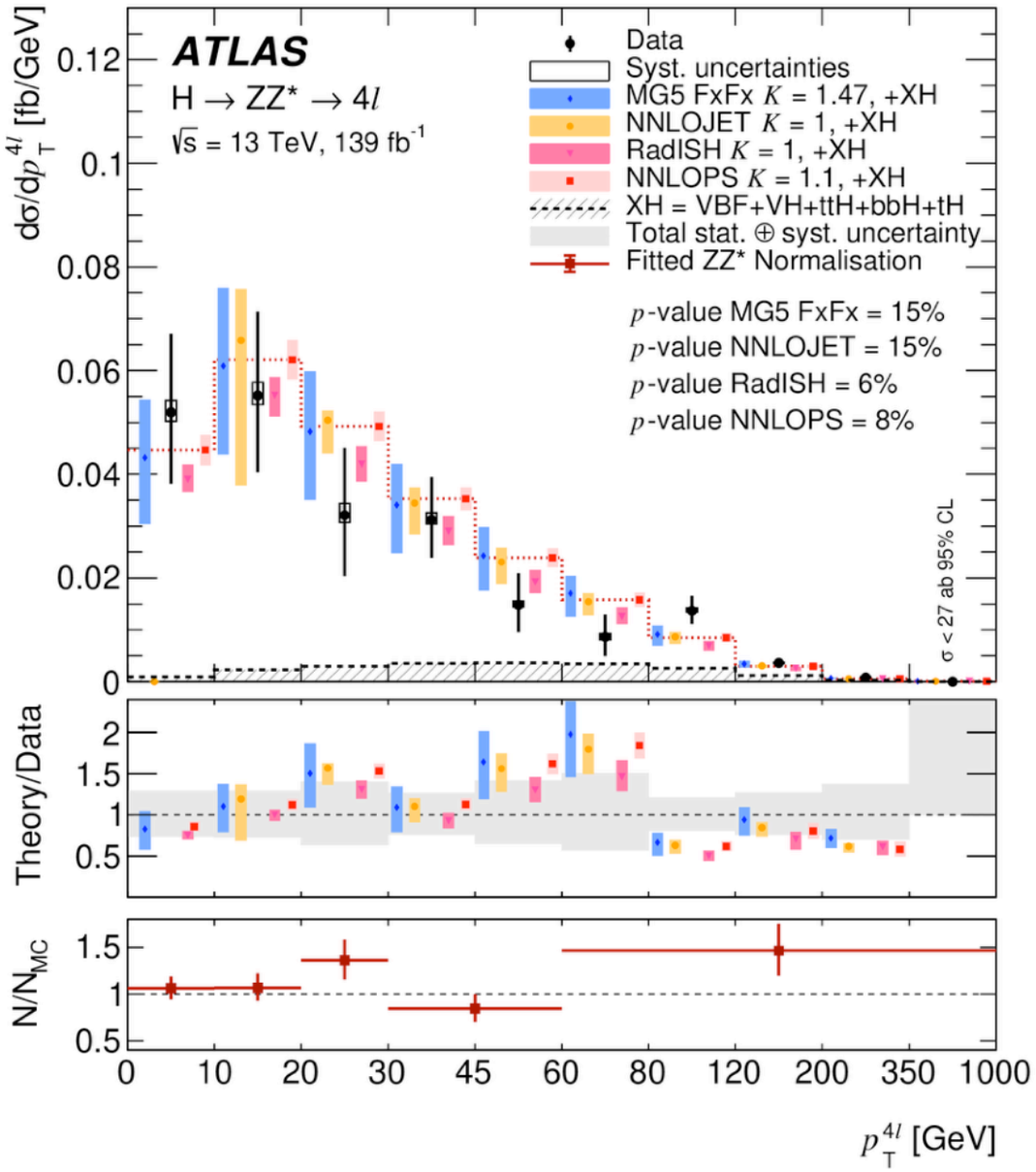
Correlation between the fiducial cross sections for the four individual decay final states and the ZZ* background normalisation factor

σfid = 3.28 ± 0.32 fb
σfid,SM = 3.41 ± 0.18 fb.

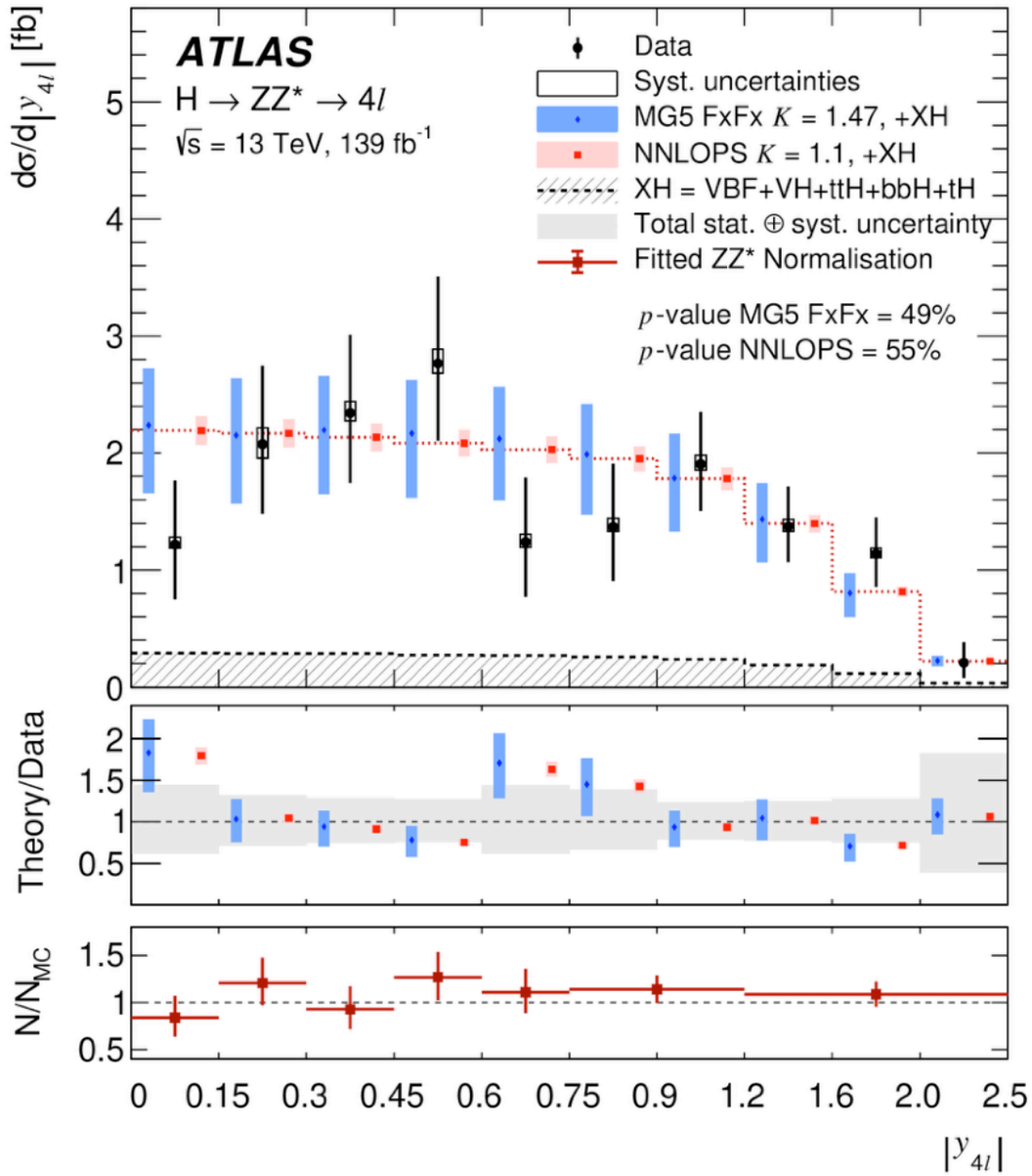
σtot [pb] 53.5 ± 4.9 ± 2.1
σtot,SM 55 .7 ± 2.8

Differential cross sections

Differential fiducial cross section for the transverse momentum $p_T^{4\ell}$ sensitive to light quarks or heavy BSM particles in top loop



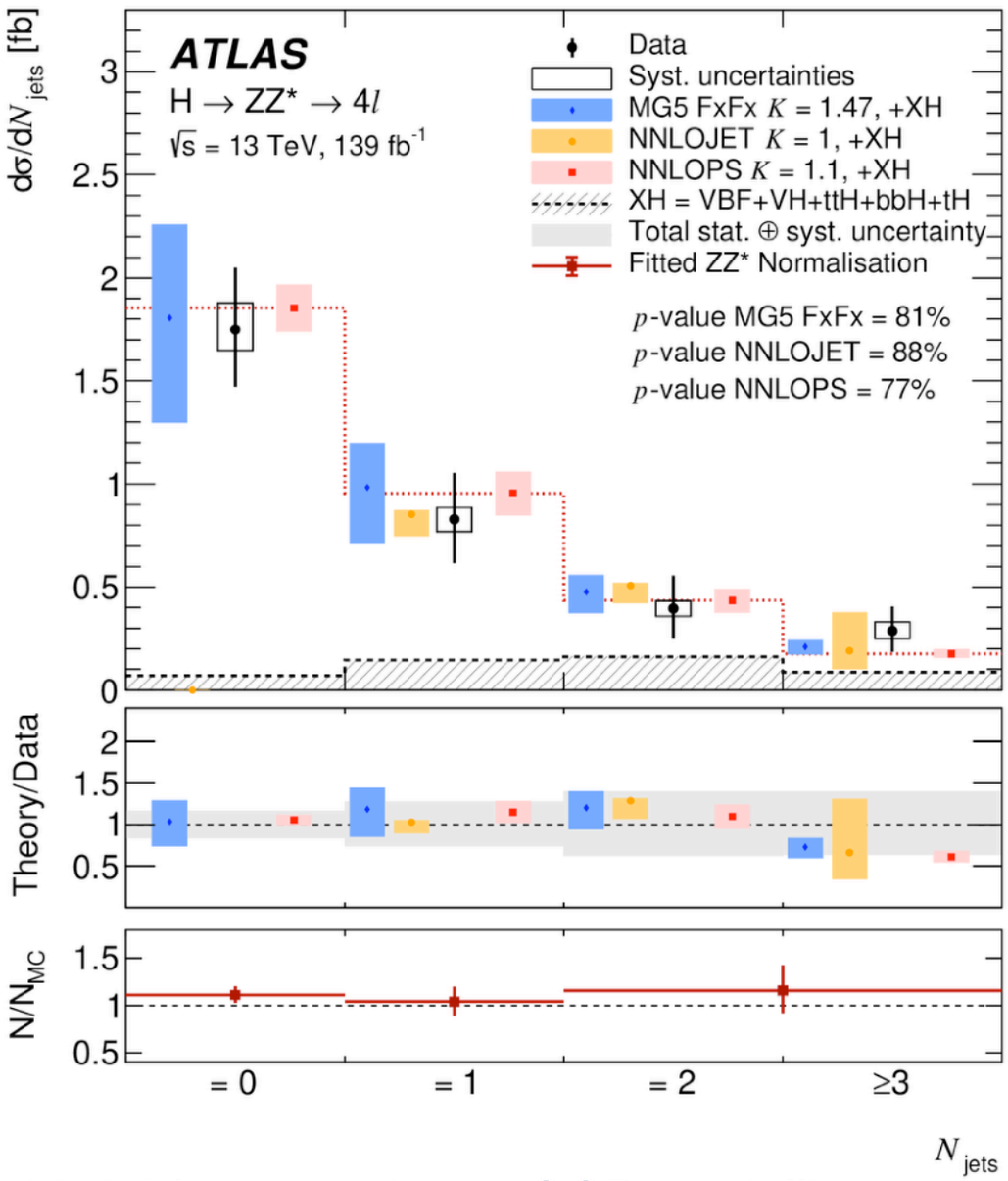
Differential fiducial cross section for the rapidity $|y_{4\ell}|$ of the Higgs boson sensitive to PDF effects.



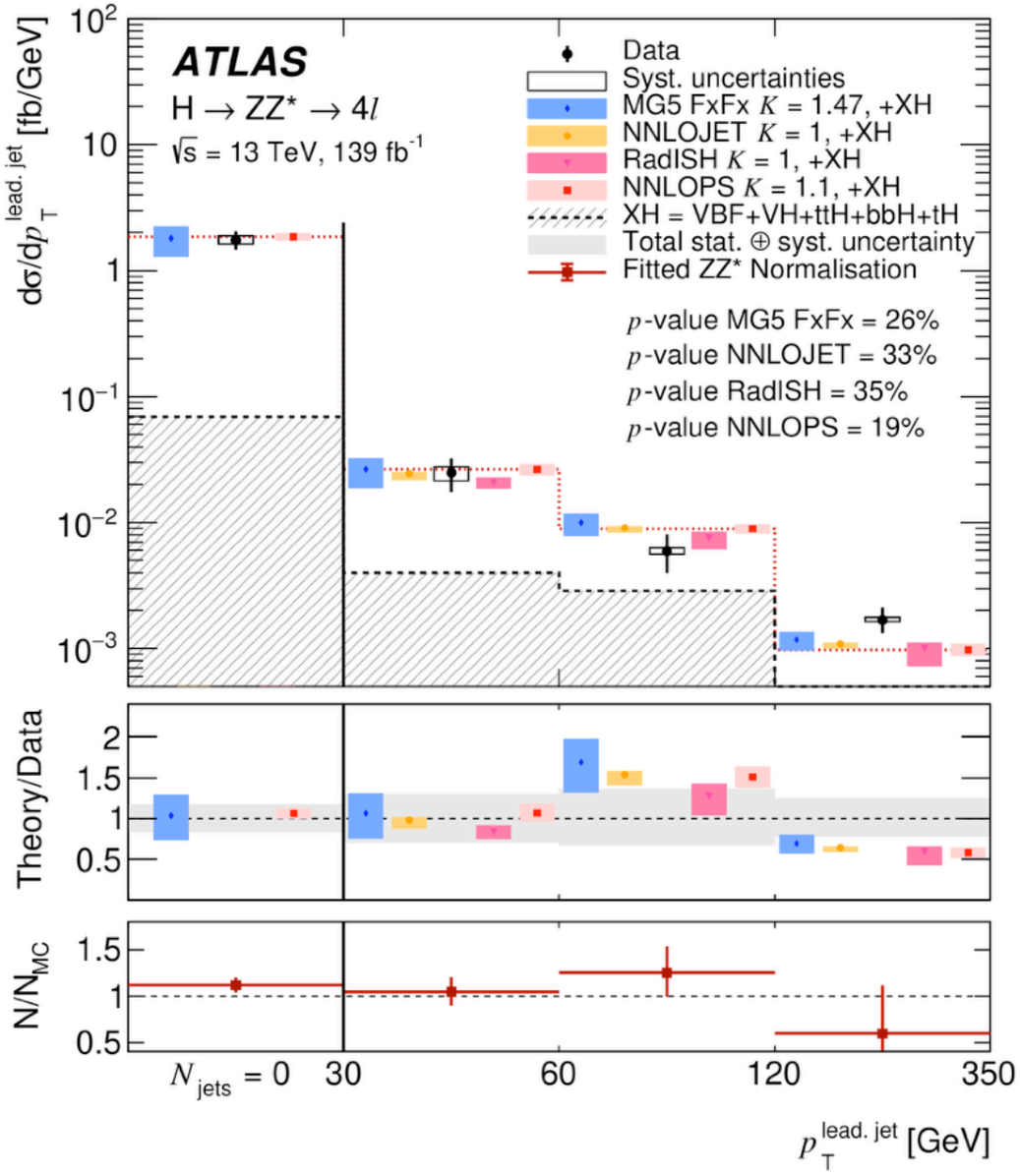
Overall, there is good agreement between measured cross sections and predictions. Constrains to BSM effects and Yukawa couplings.

Differential cross sections

Differential fiducial cross section for the jet multiplicity, N_{jets}, in the selected events,



Differential fiducial cross section for the transverse momentum of the leading jet, $p_T^{lead.\ jet}$, in events with at least one jet.

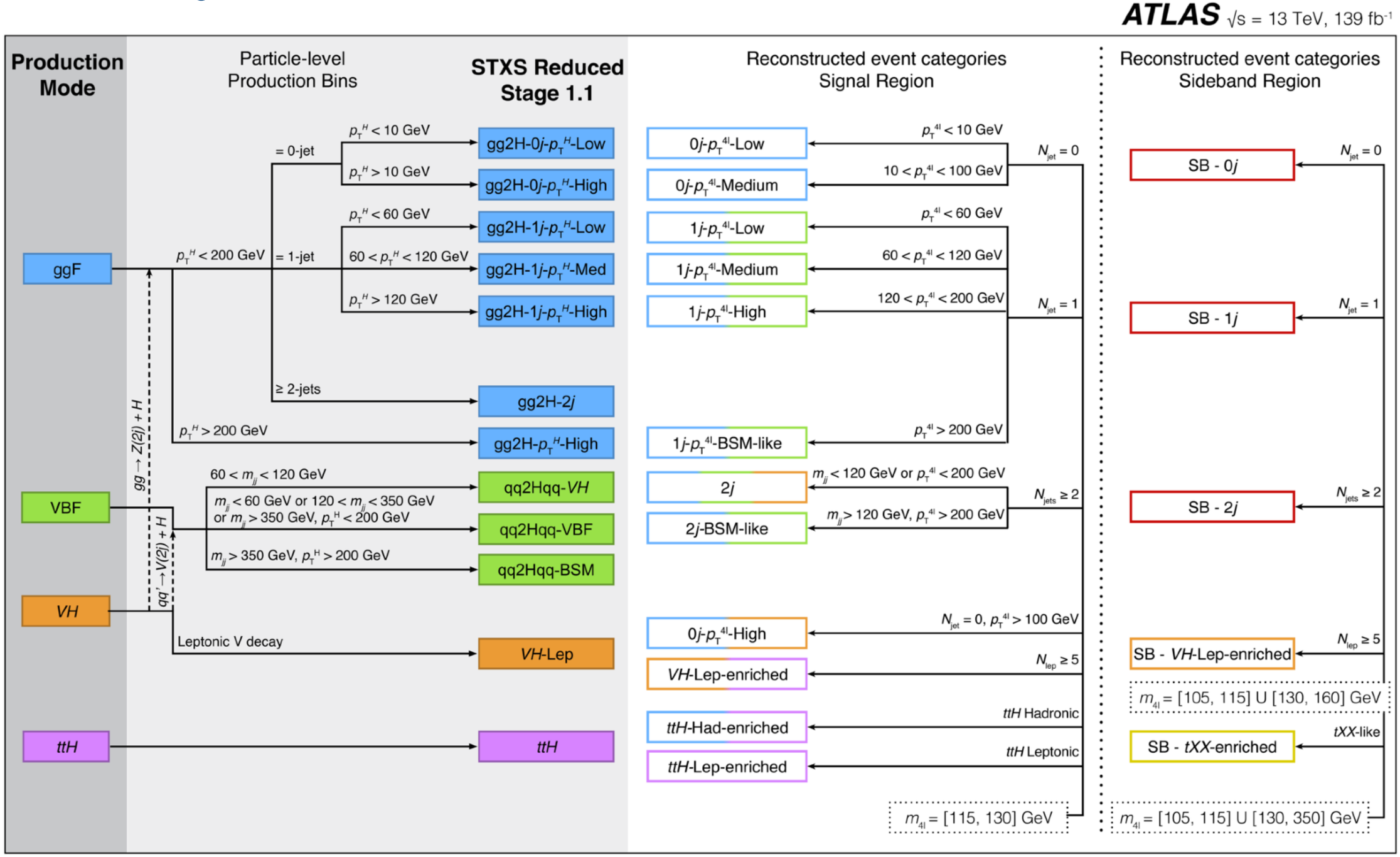


Variables sensitive to QCD modelling

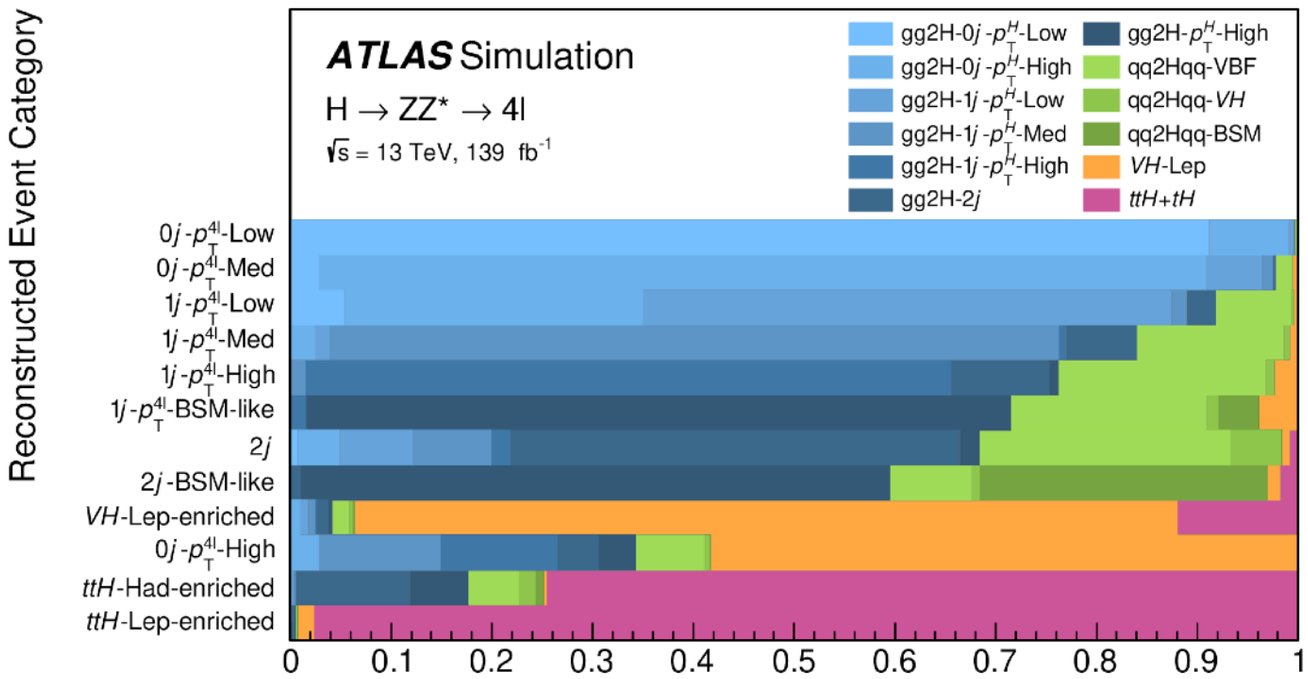
Overall, there is good agreement between measured cross sections and predictions

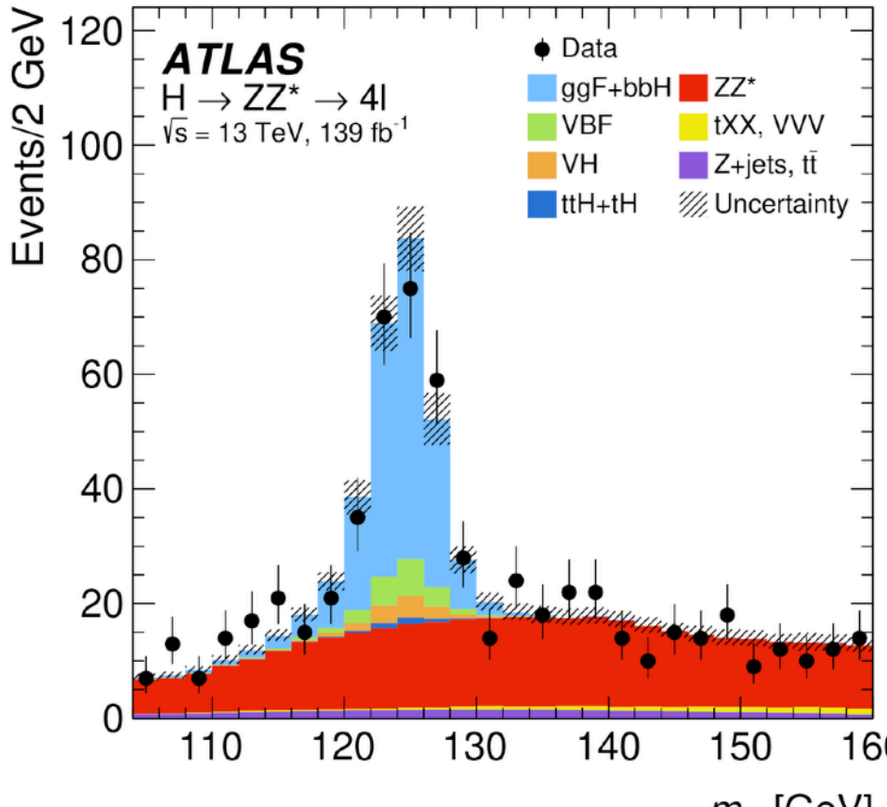
STXS Framework

Reduced Stage 1.1 STXS



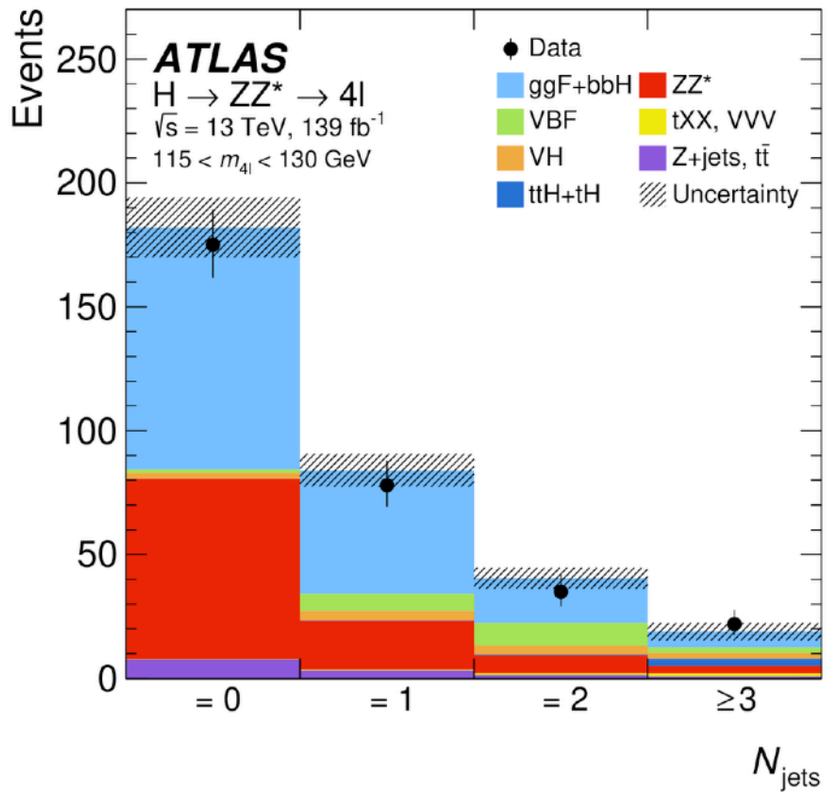
H→4l STXS



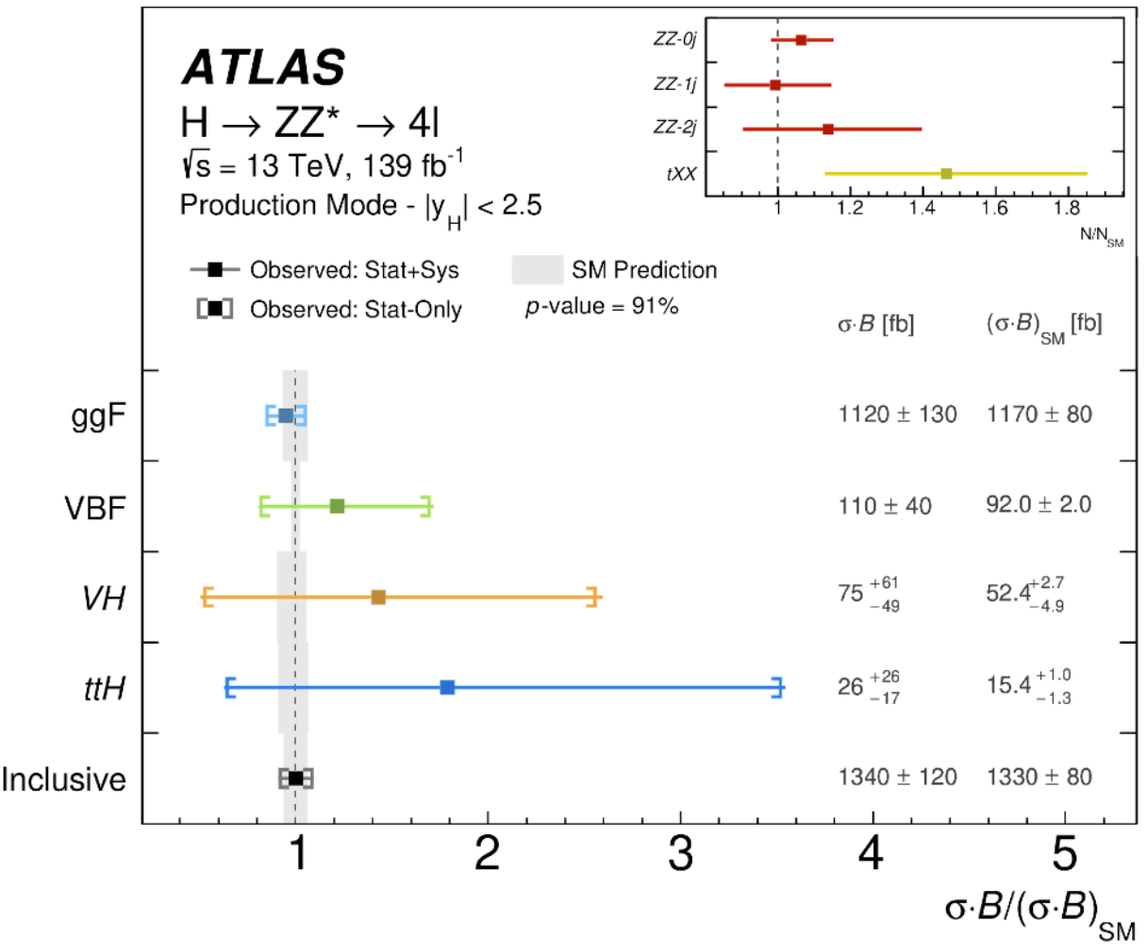


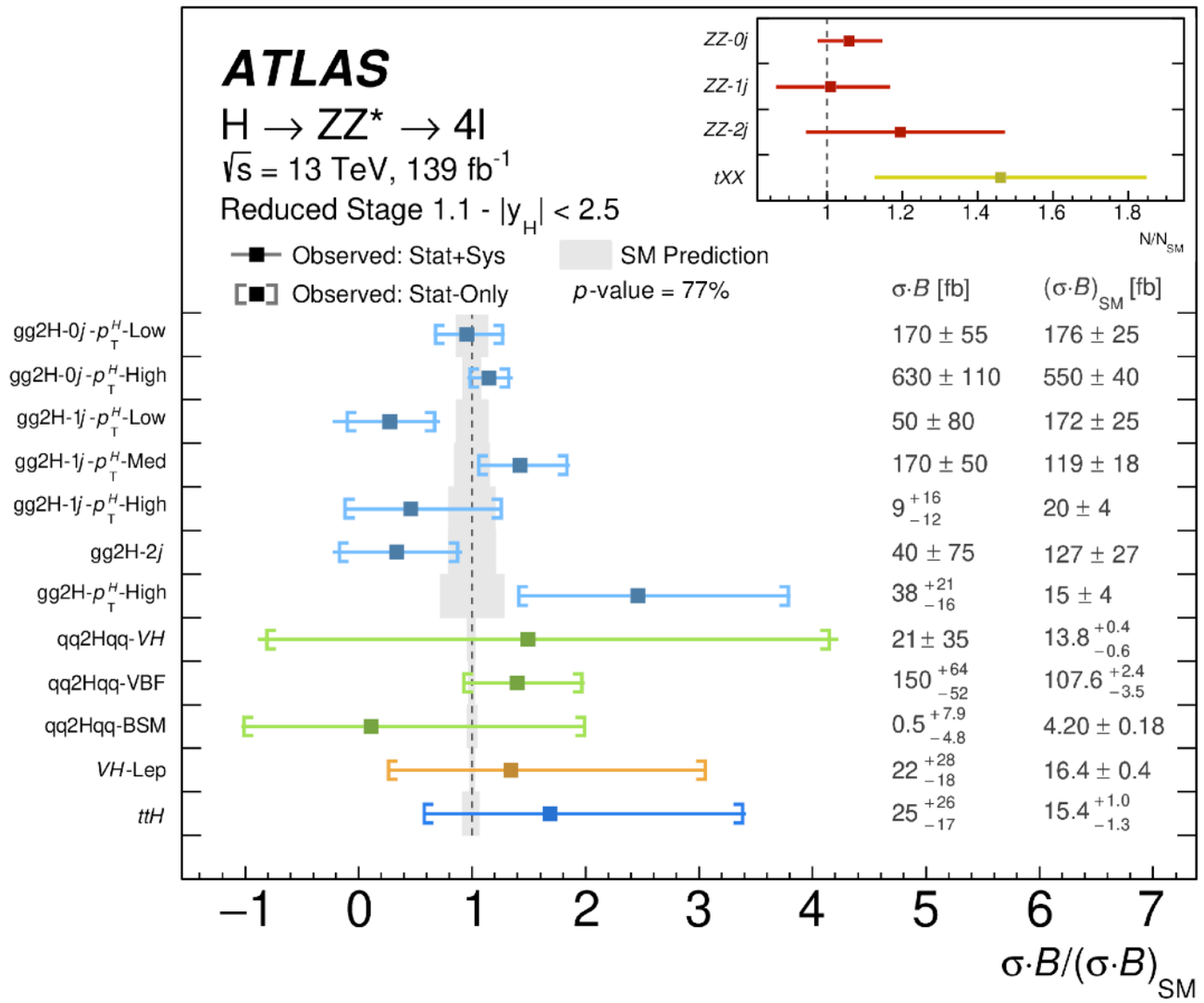
STXS : “maximally benefit from the use of event categories and multivariate techniques.”

Usage of event categories and multivariate techniques is essential. Multivariate NN to improve purity



H→4l STXS

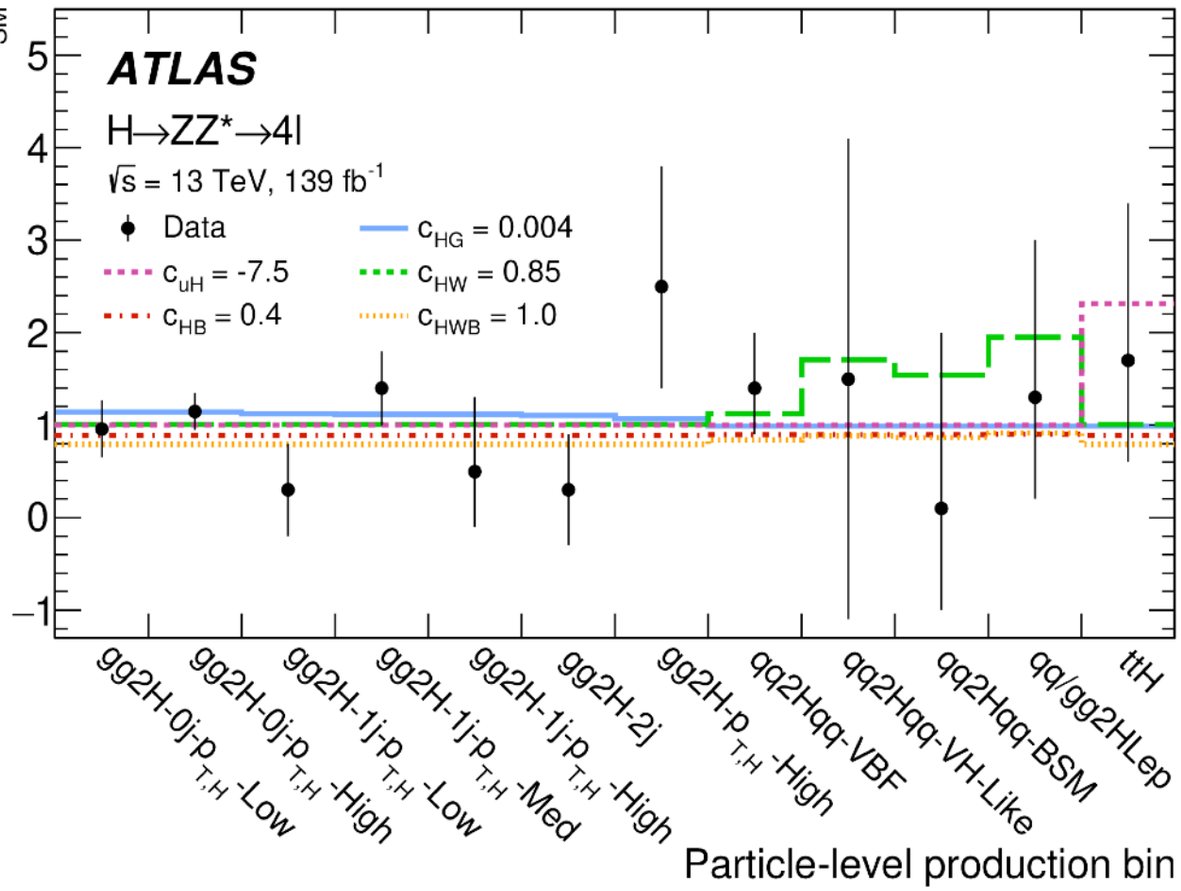


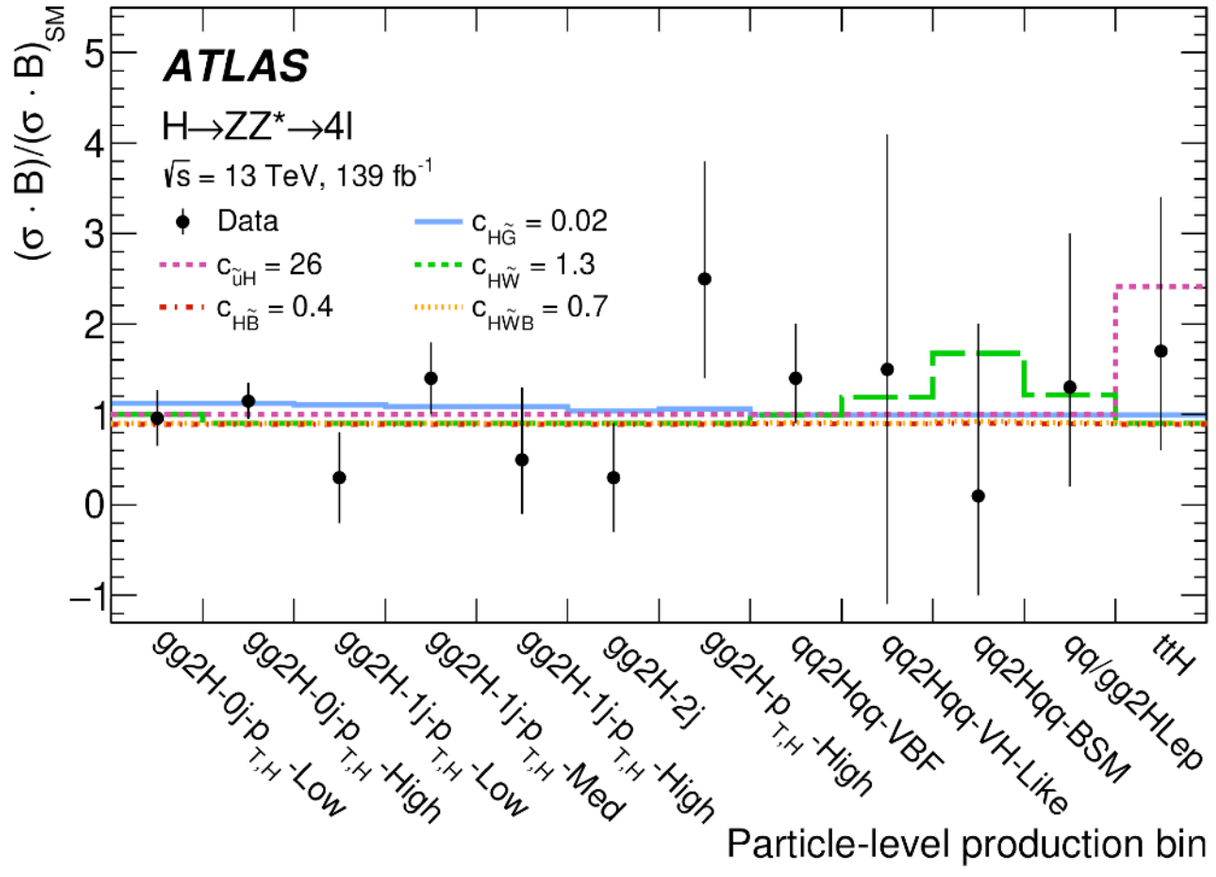


Limits are set on the CP-even and CP-odd ‘beyond the Standard Model’ couplings of the Higgs boson to vector bosons, gluons and top quarks

EFT interpretation

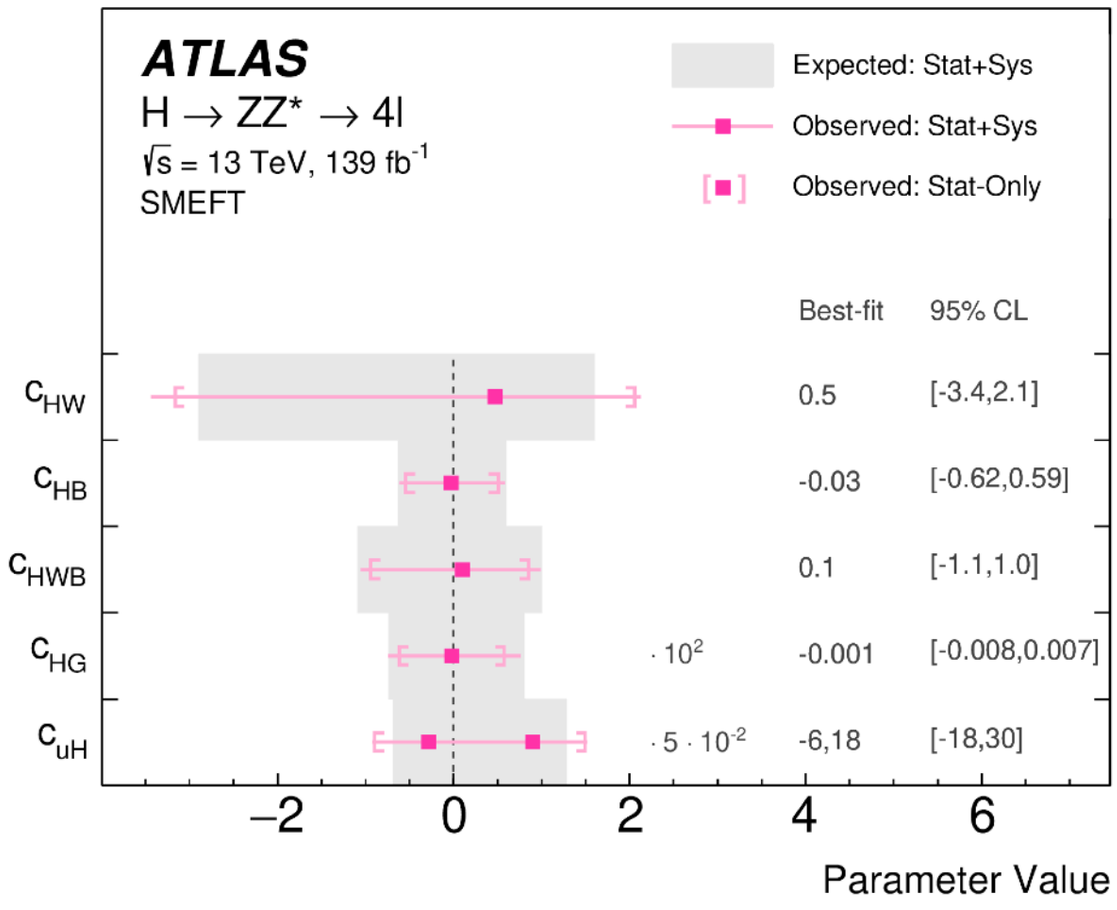
Expected signal yield ratio for chosen (left) CP-even and (right) CP-odd EFT parameter values together with the corresponding cross-section measurement in each production.

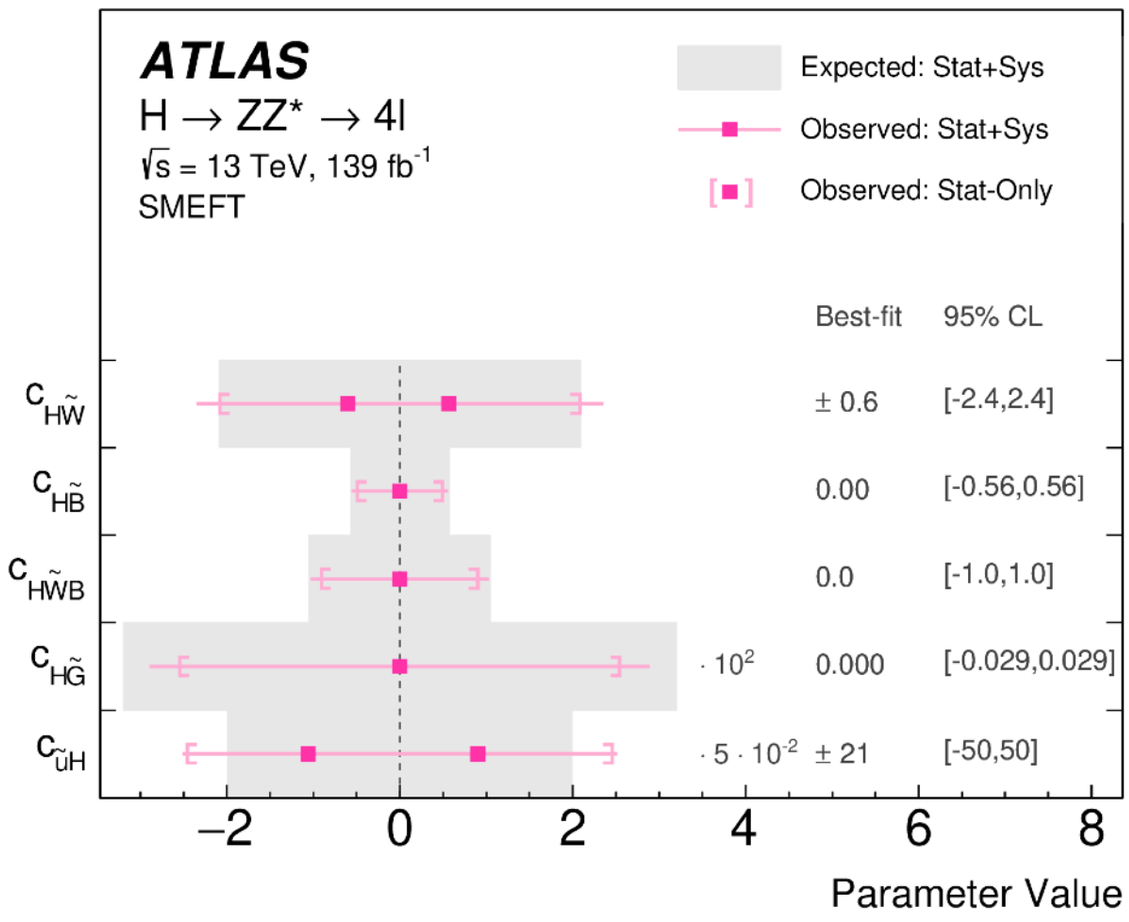




EFT interpretation

The observed and expected values of SMEFT Wilson coefficients from CP-even and CP-odd operators. Only one Wilson coefficient is fitted at a time while all others are set to zero.





The values for the c_{HG} and $c_{H\tilde{G}}$ coefficients are scaled by a factor of 100, and for the c_{uH} and $c_{\tilde{u}H}$ coefficients by a factor of 0.05.

Last Slide

- **H→4l is a very clean experimental signature**
- **With more LHC data less statistics limited.**
- **Allowing for interesting measurements/results.**
- **The Run-II data taking has finished expect a few more ATLAS H→4l results with full Luminosity.**
- **Run 3 data to come, these results will be updated with finer granularity and more bins. Expect improvement from the new Muon Small Wheel.**