7th Red LHC workshop, 10th-12th May 2023, IFT

Measurements of Higgs couplings in $H \rightarrow \gamma\gamma$ at 13 TeV with the ATLAS experiment

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HIGG-2020-16

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GOBIERNO DE ESPAÑA

MINISTERIO DE CIENCIA E INNOVACIÓN

Plan de Recuperación, Transformación y Resiliencia

AGENCIA ESTATAL DE INVESTIGACIÓN

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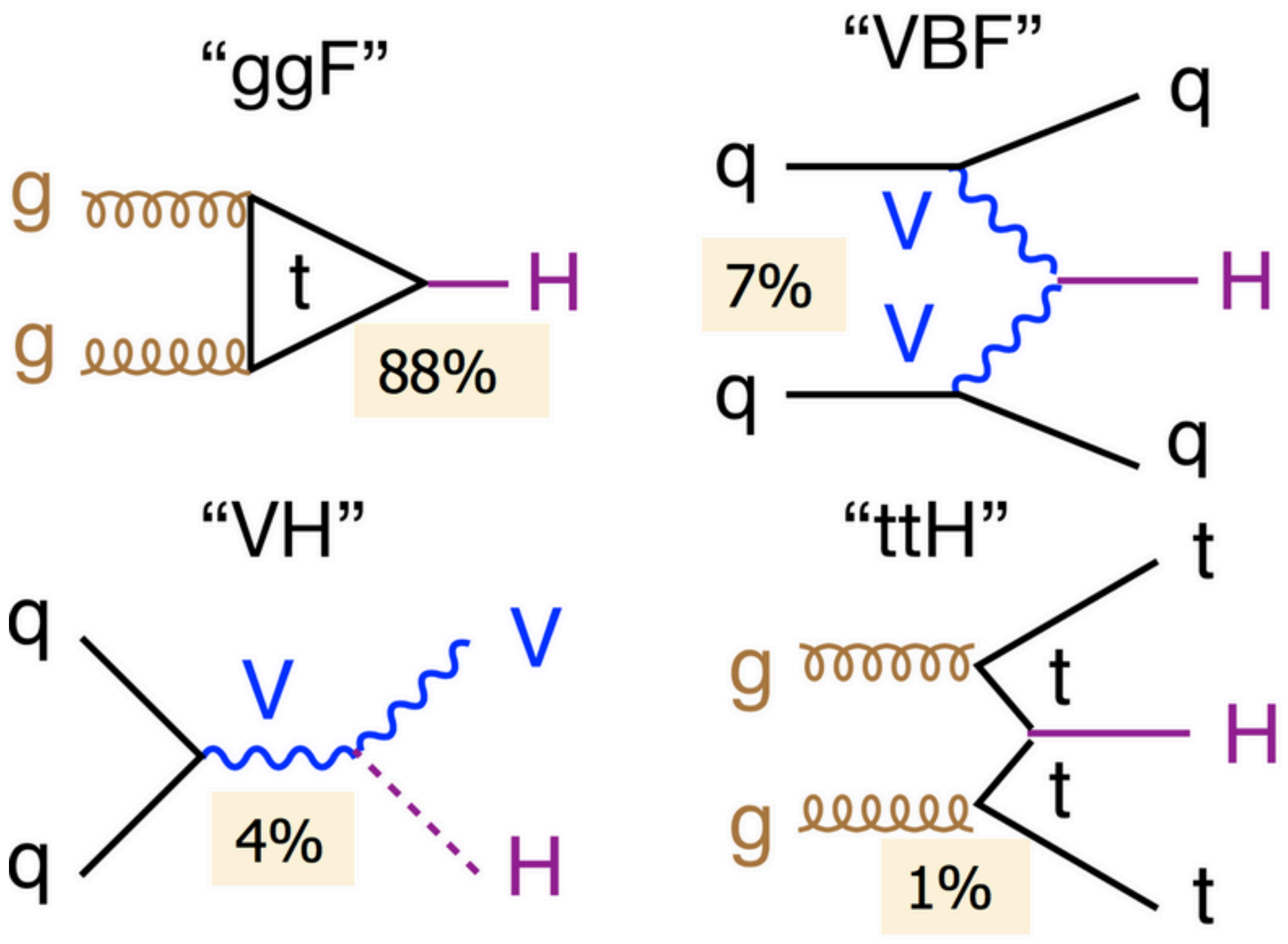
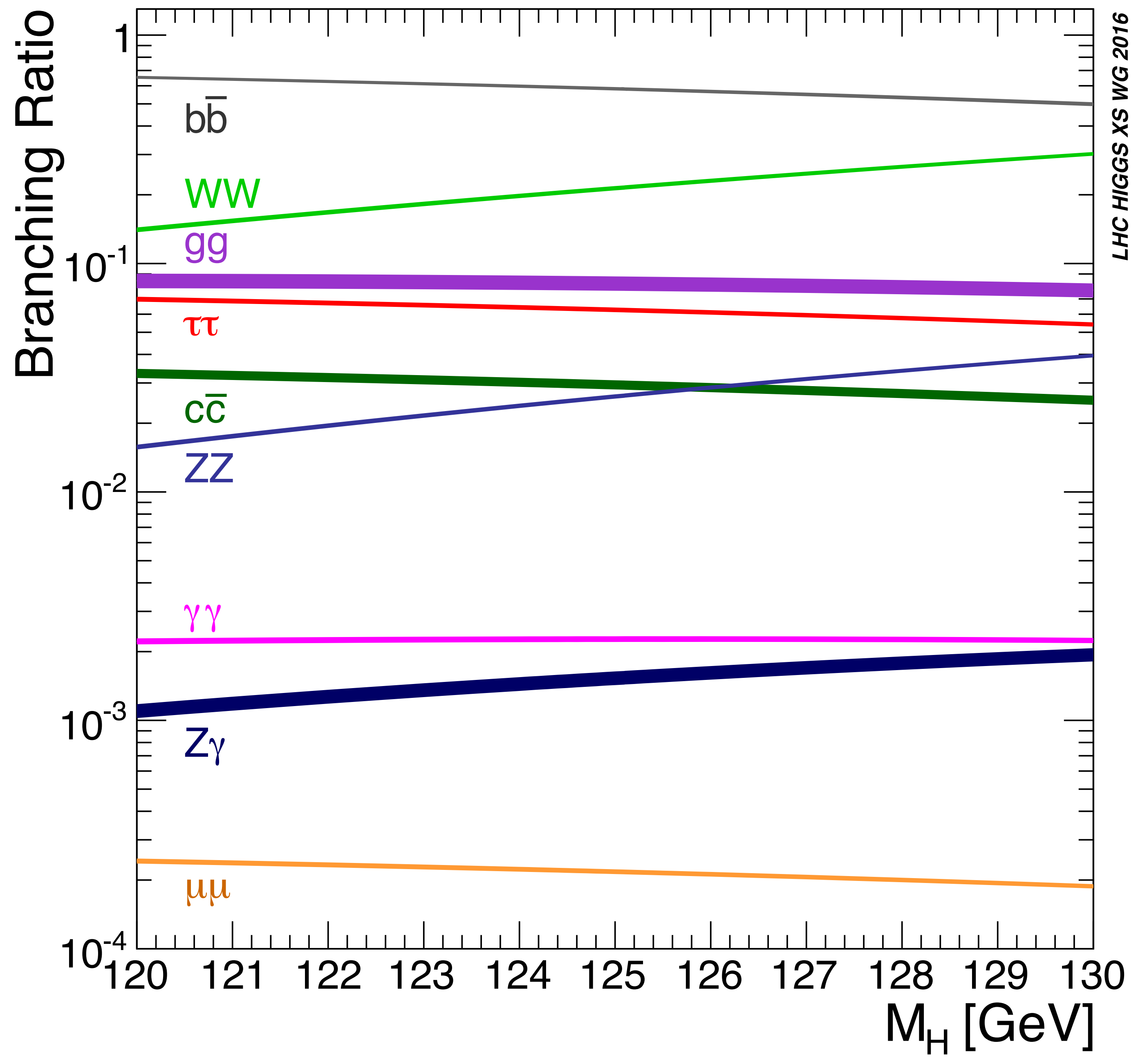
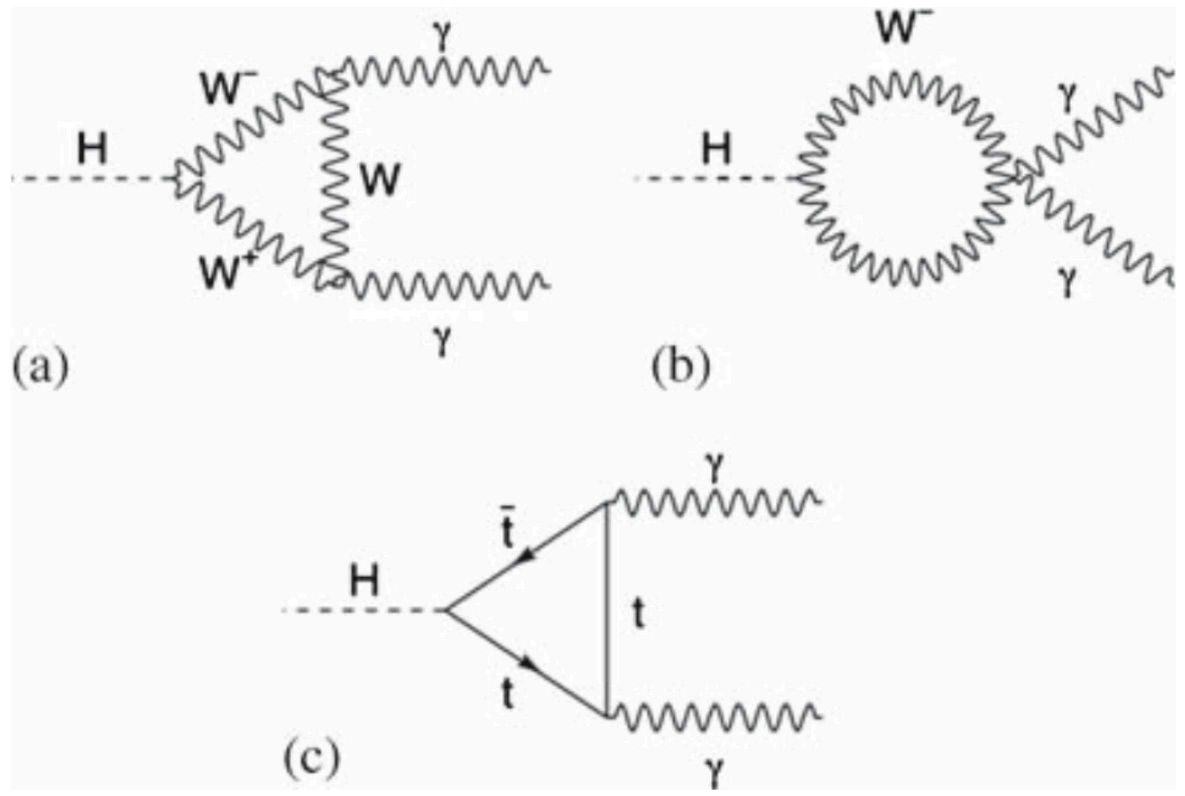
Introduction

- Studies of Higgs properties and production rates are one of the main lines of the LHC research program
- The diphoton channel offers a very clean signature in spite of its small branching ratio







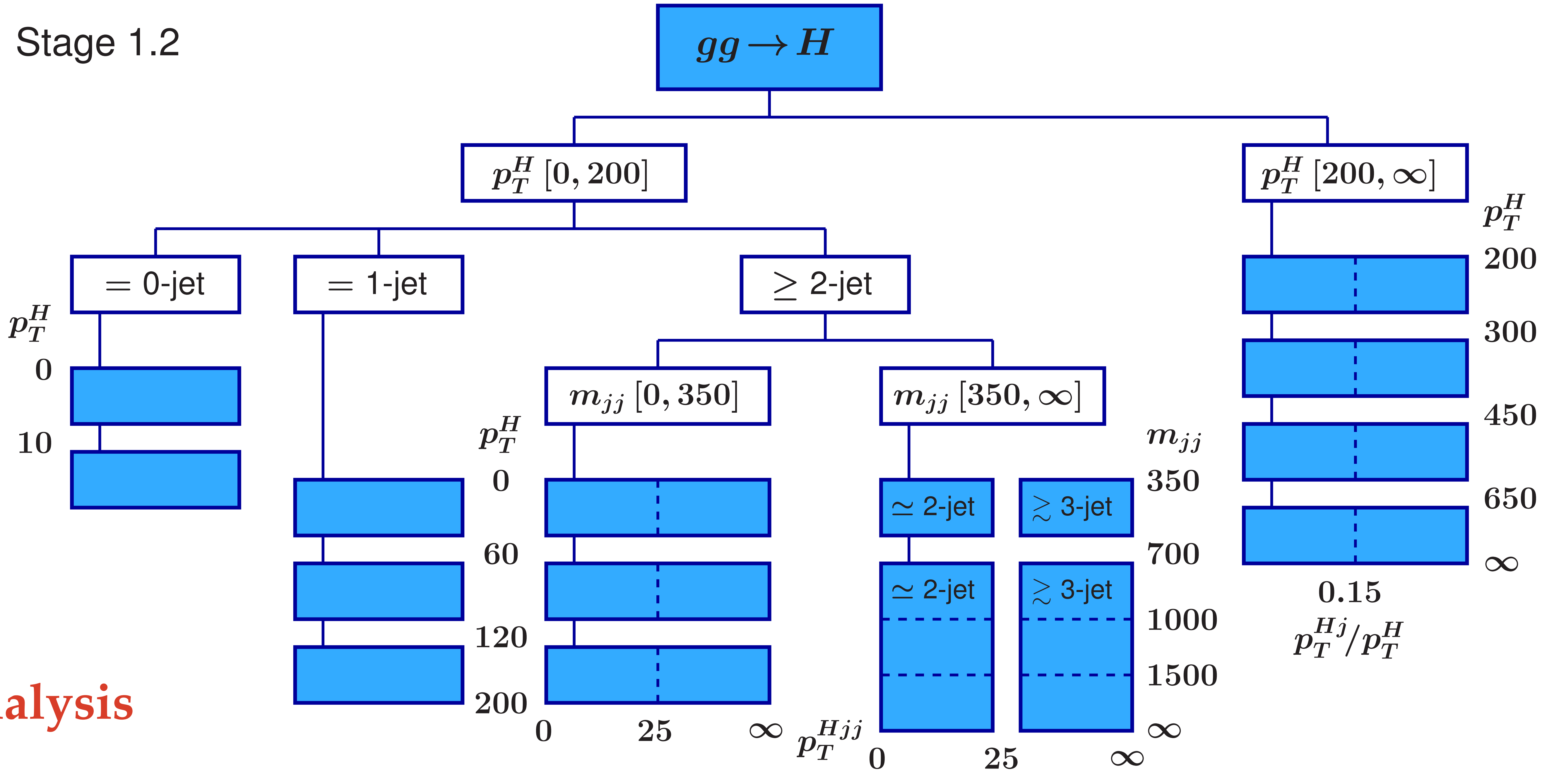
Simplified template cross sections

- Measure cross-sections in the different production modes, agnostic to Higgs decays, in mutually exclusive regions of the phase-space (bins)

✓Maximizes experimental sensitivity
✓Isolates possible BSM effects
✓Minimize the dependence on theoretical uncertainties (folded in the measurements)
✓Suitable for combinations

-No fully fiducial measurement
-No Higgs decay information (for the moment)

Stage 1.2



Sensitivity to resummation effects

Larger sensitivity to BSM

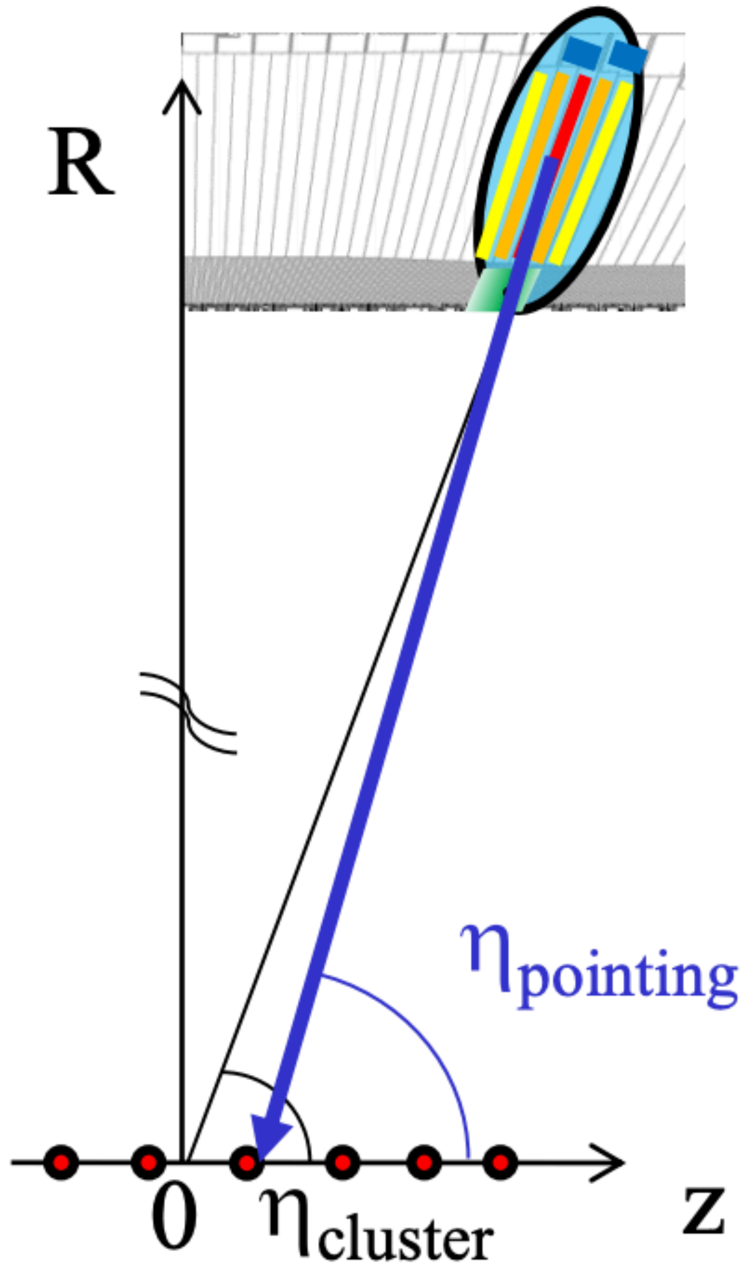
28 bins measured in this analysis

ggF background to VBF

Analysis strategy

Selection

- Target H-> $\gamma\gamma$ decays
  - At least two tight-ID and isolated photons
  - Dedicated vertex selection using photon pointing information
  - Additional objects: jets, b-jets, muons, electrons and missing energy used in the categorisation

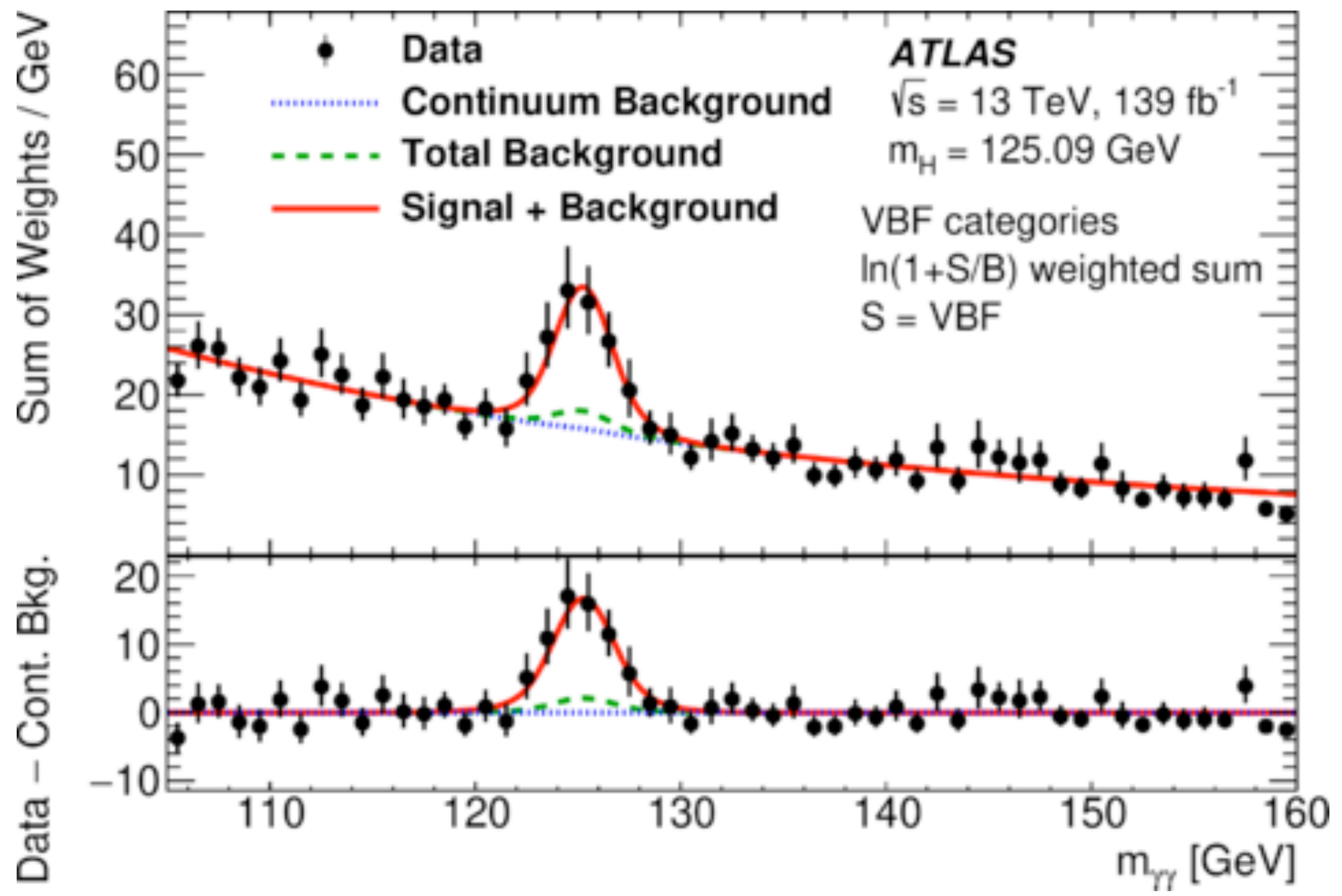


Categorisation

- Define orthogonal reco categories to target specific STXS bins

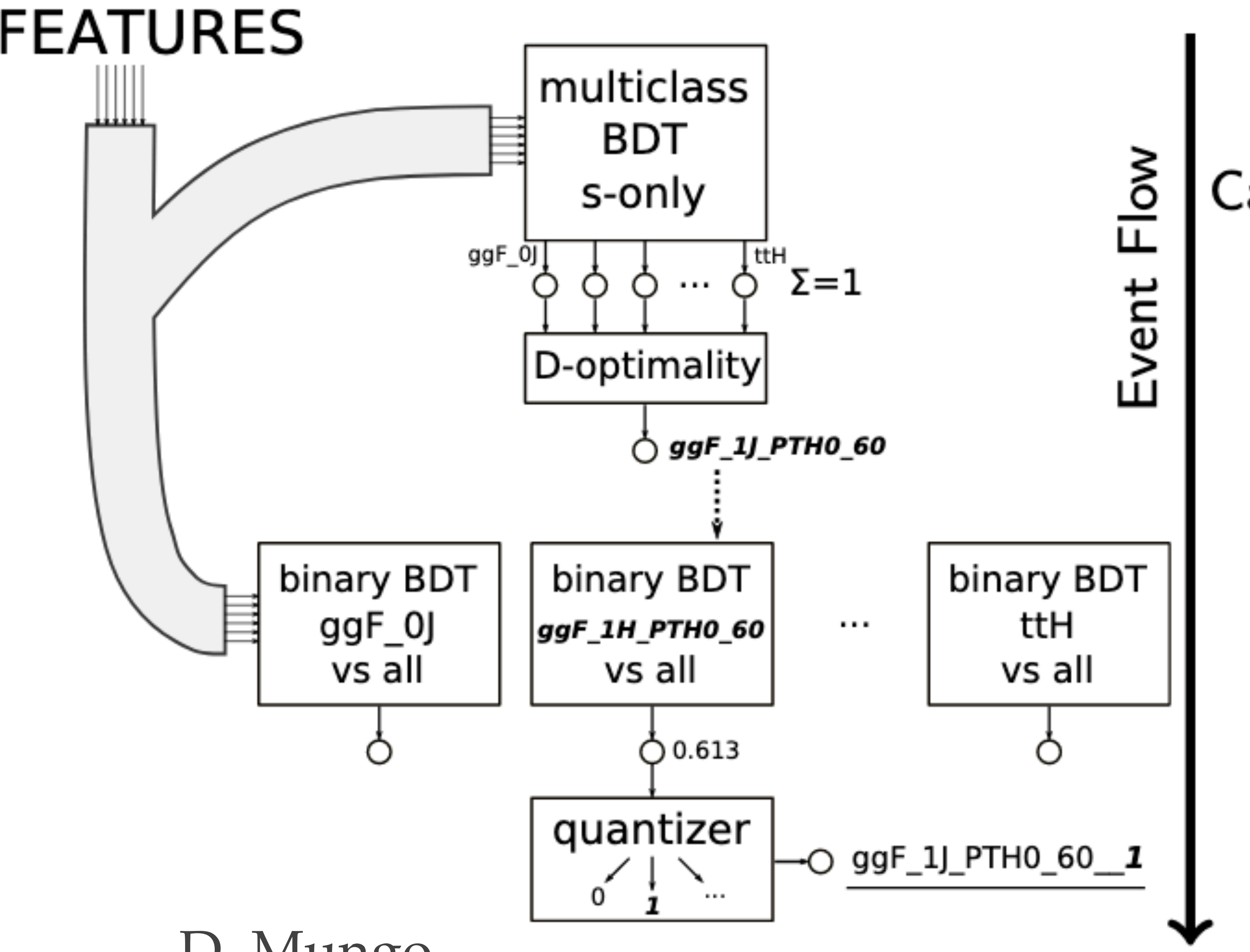
Cross section extraction

- Signal+Background parametric model for each category. Simultaneous fit over $m_{\gamma\gamma}$



Event categorisation

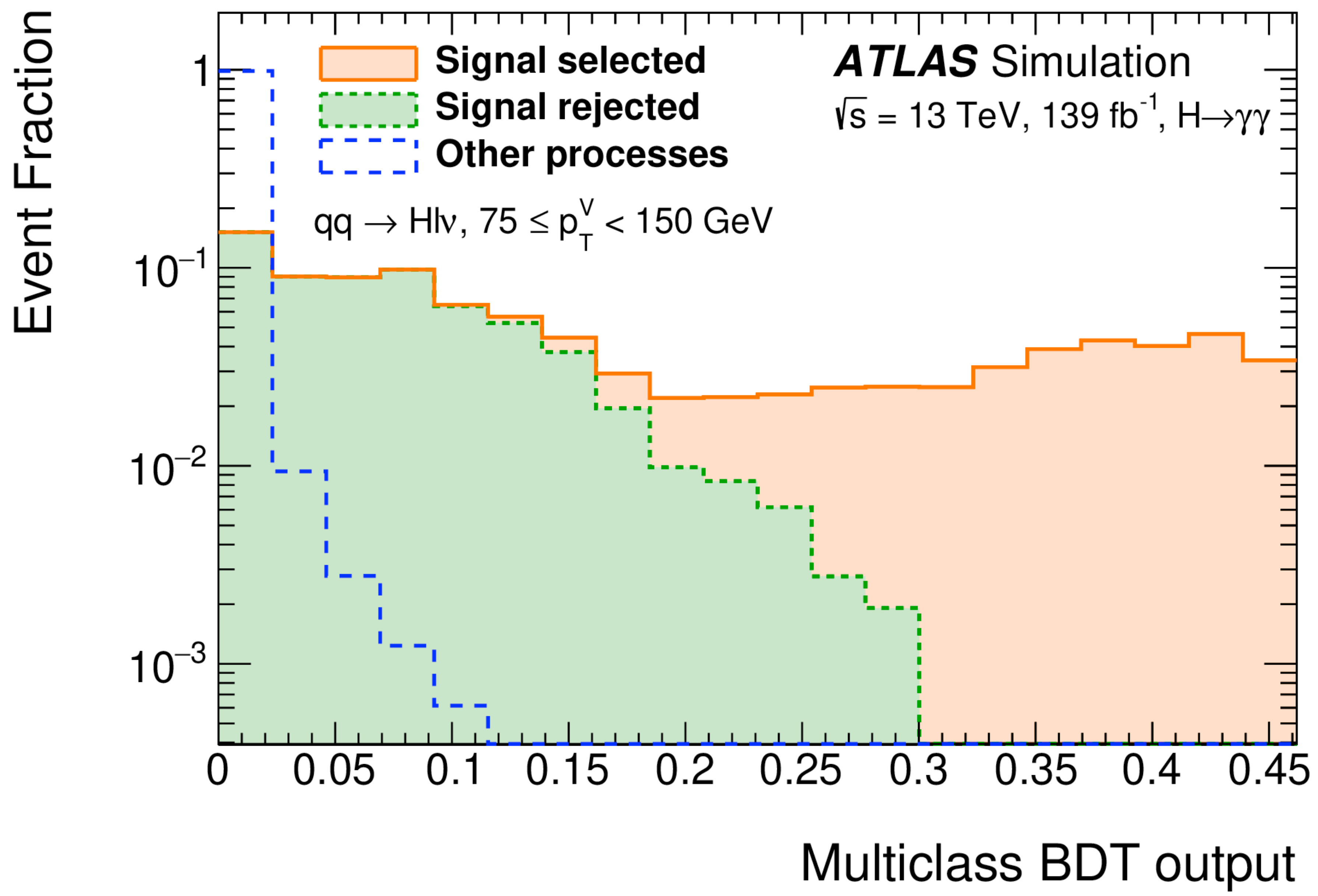
- Each event is assigned to the optimal category based on its properties in a global way
- Targeting directly the STXS 1.2 bins (with minimal changes)

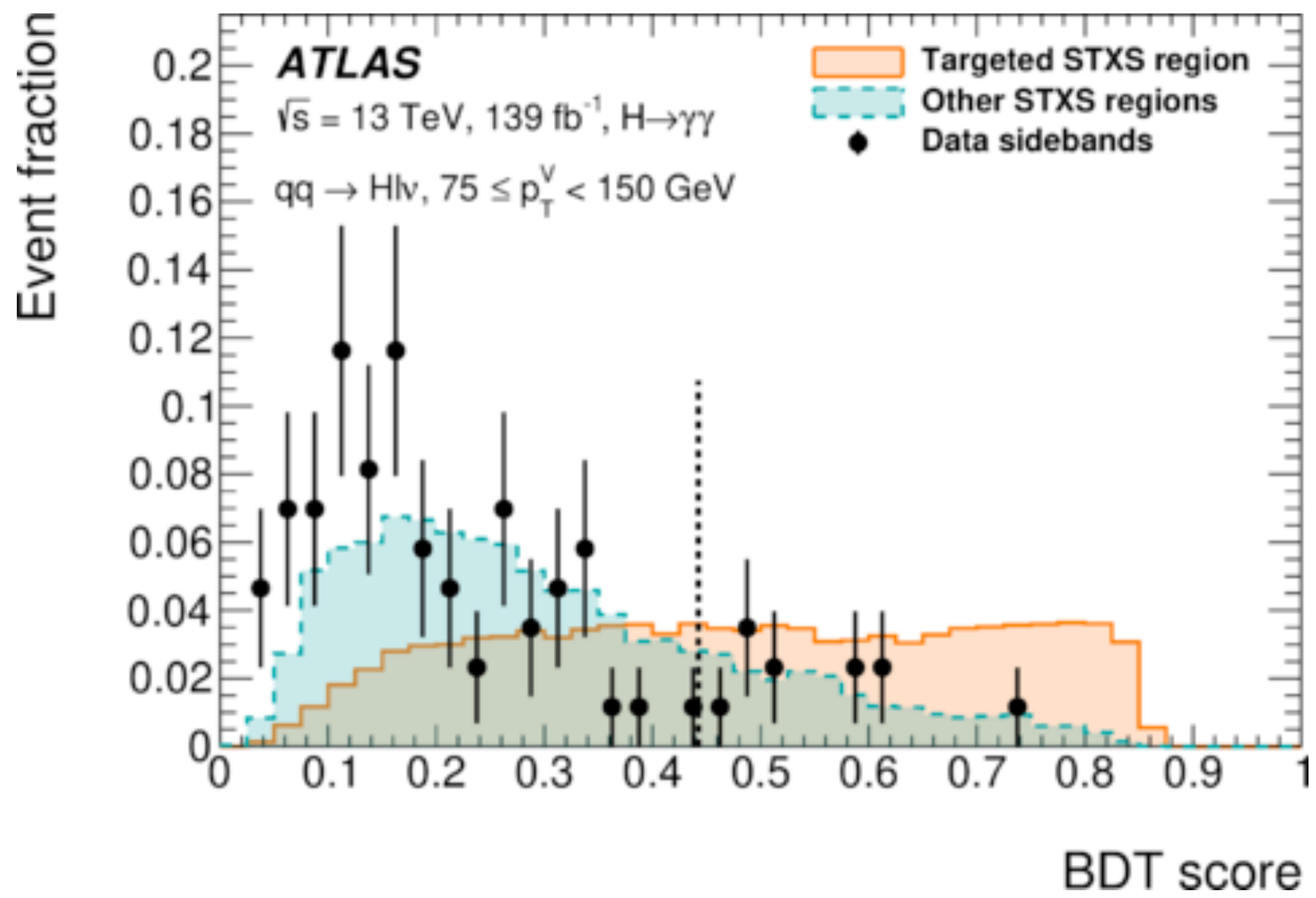


Categorization in 3 steps

- Signal only multiclass BDT
- Usage of multiclass output ⇒ **D-optimality** optimizes both error and correlation on final measurements
- Binary BDTs in each multiclass category: final significance scan maximizing significance

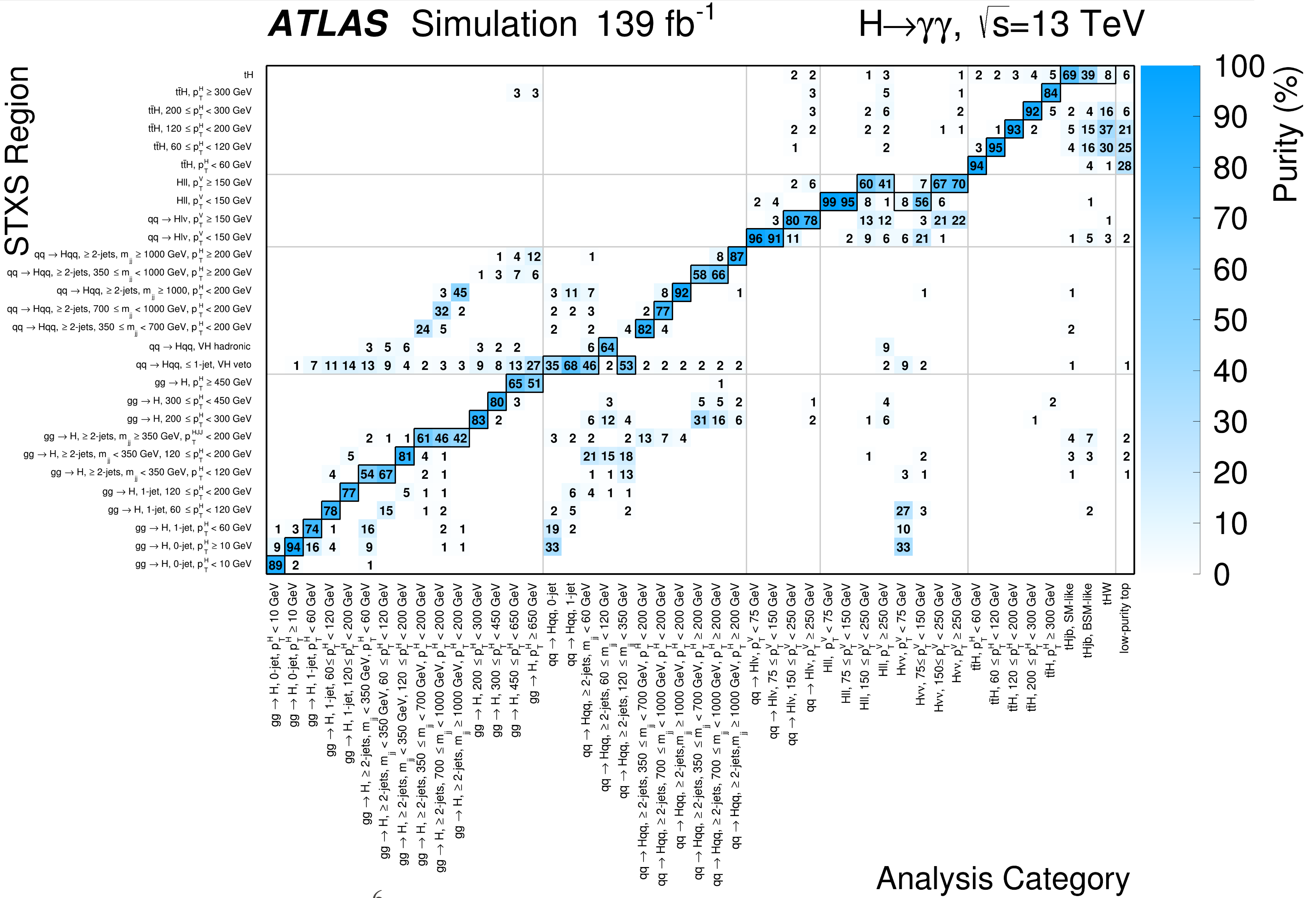
D. Mungo





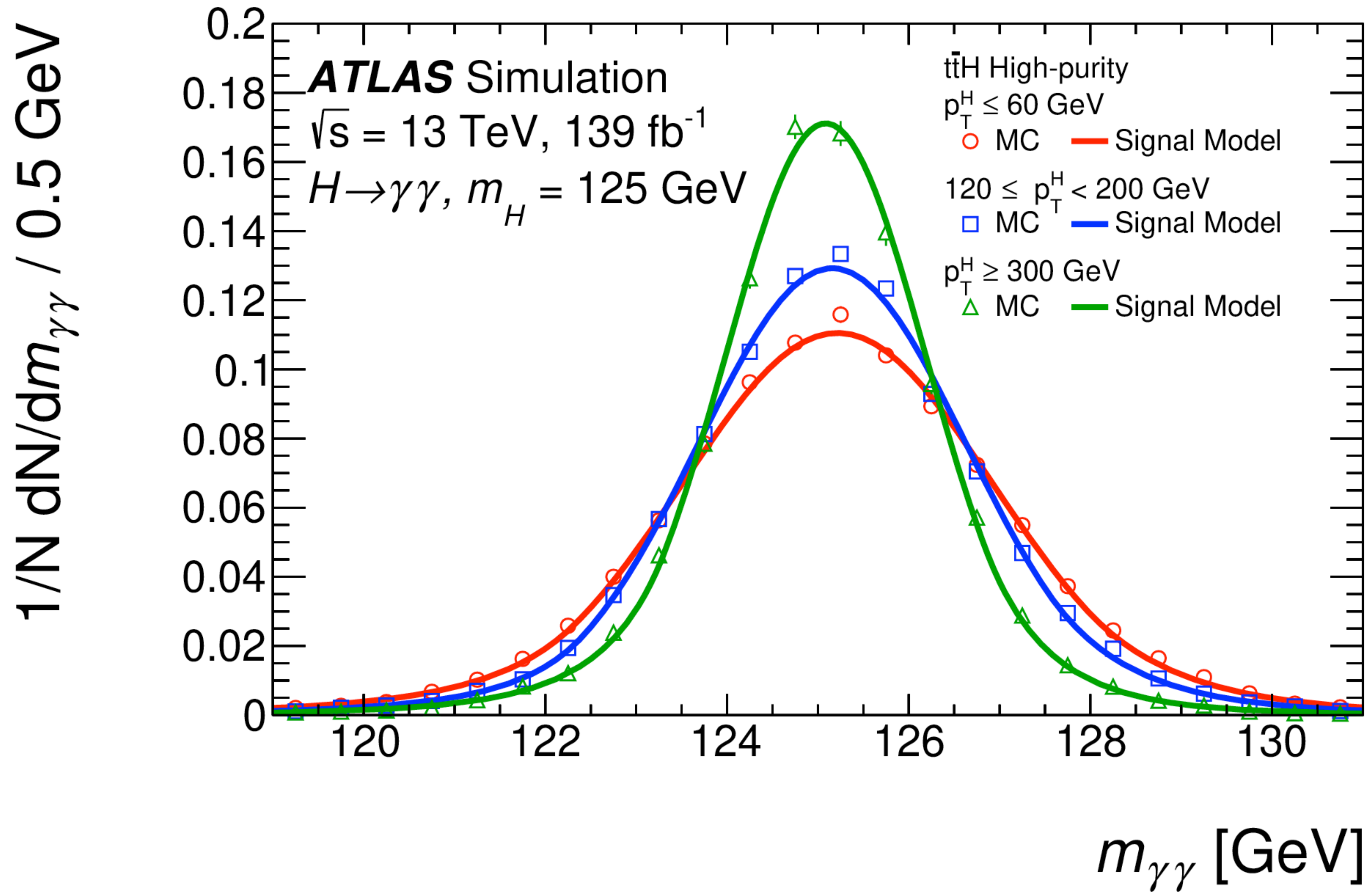
Event categorisation

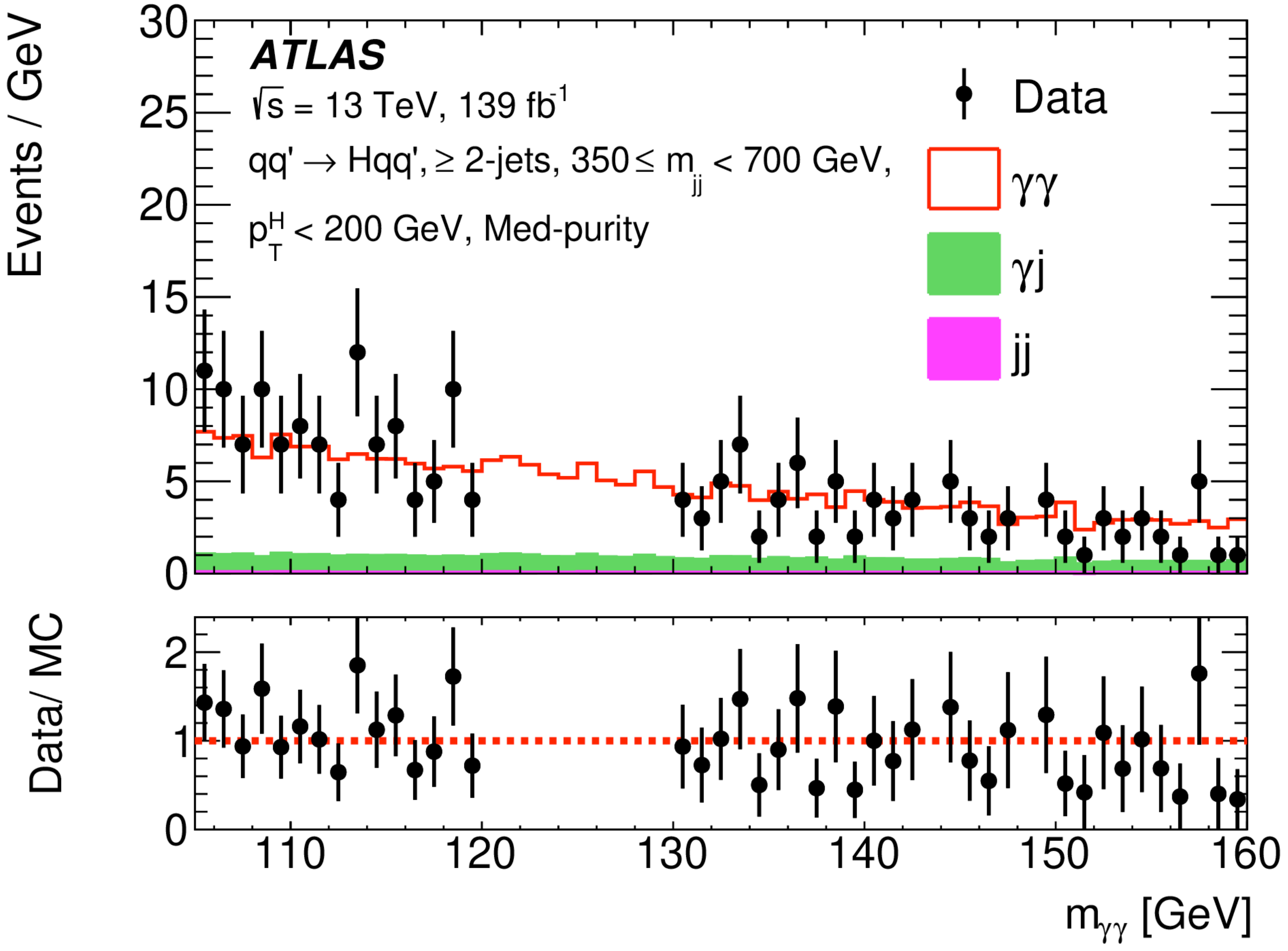
- Good diagonality between targeted STXS bin and analysis category
- More analysis categories than STXS regions (additional splits in signal purity not shown in the image)



Signal and background modelling

- Signal processes generated mostly by Powheg+Pythia (NNLOPs for ggF, MiNLO for VH), tH with aMC@NLO+Pythia
- Double-sided crystal ball fits in individual categories



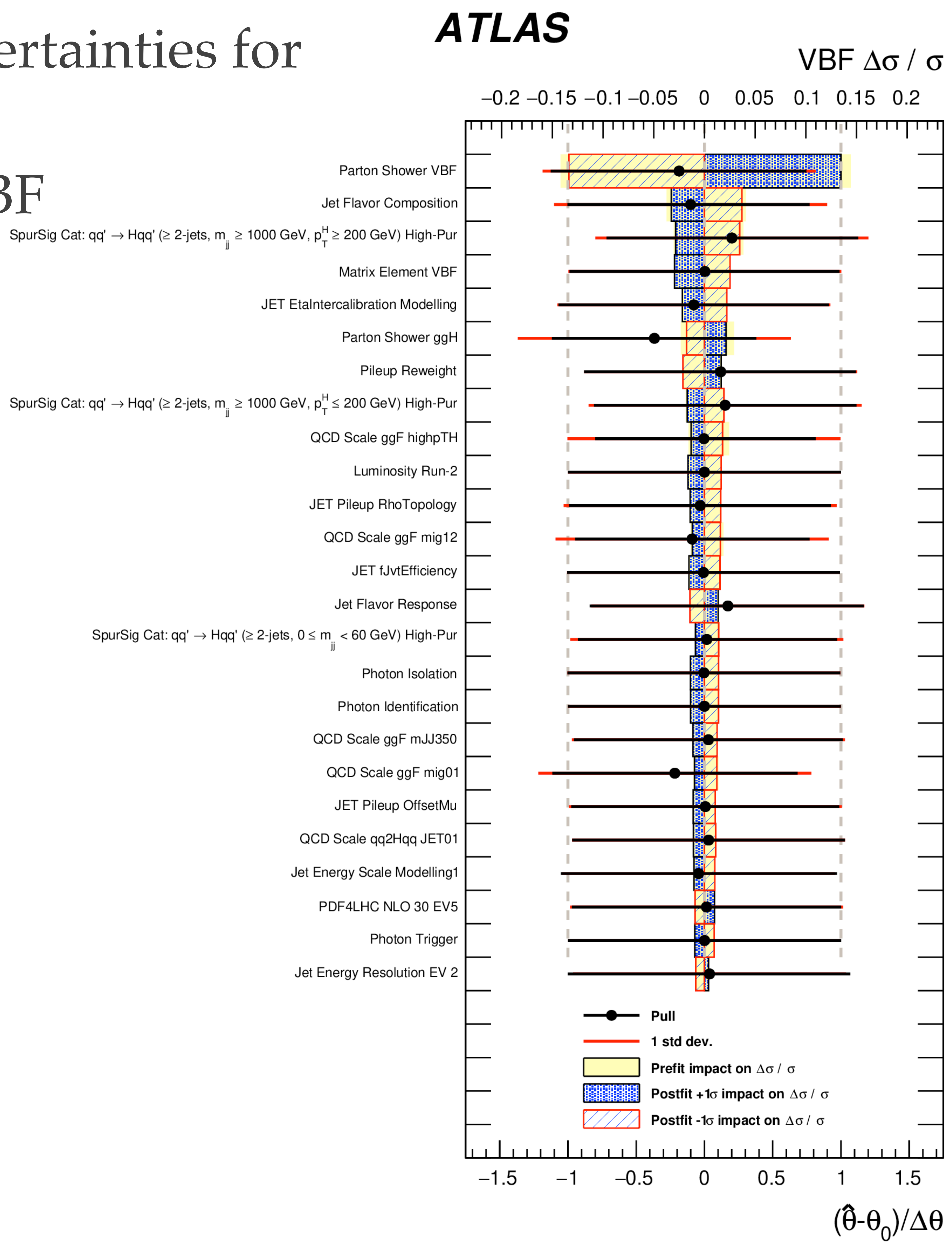


- Background templates from $\gamma\gamma$ QCD Sherpa NLO (multi-leg), V$\gamma\gamma$ from Sherpa NLO and tt$\gamma\gamma$ in MadGraph+Pythia at LO
- Data-driven background decomposition to extract $\gamma\gamma$,γj and jj contributions
- Spurious signal test to select analytical function describing the background and its bias
  - Smoothed templates with GPR in high stat. categories

Uncertainties

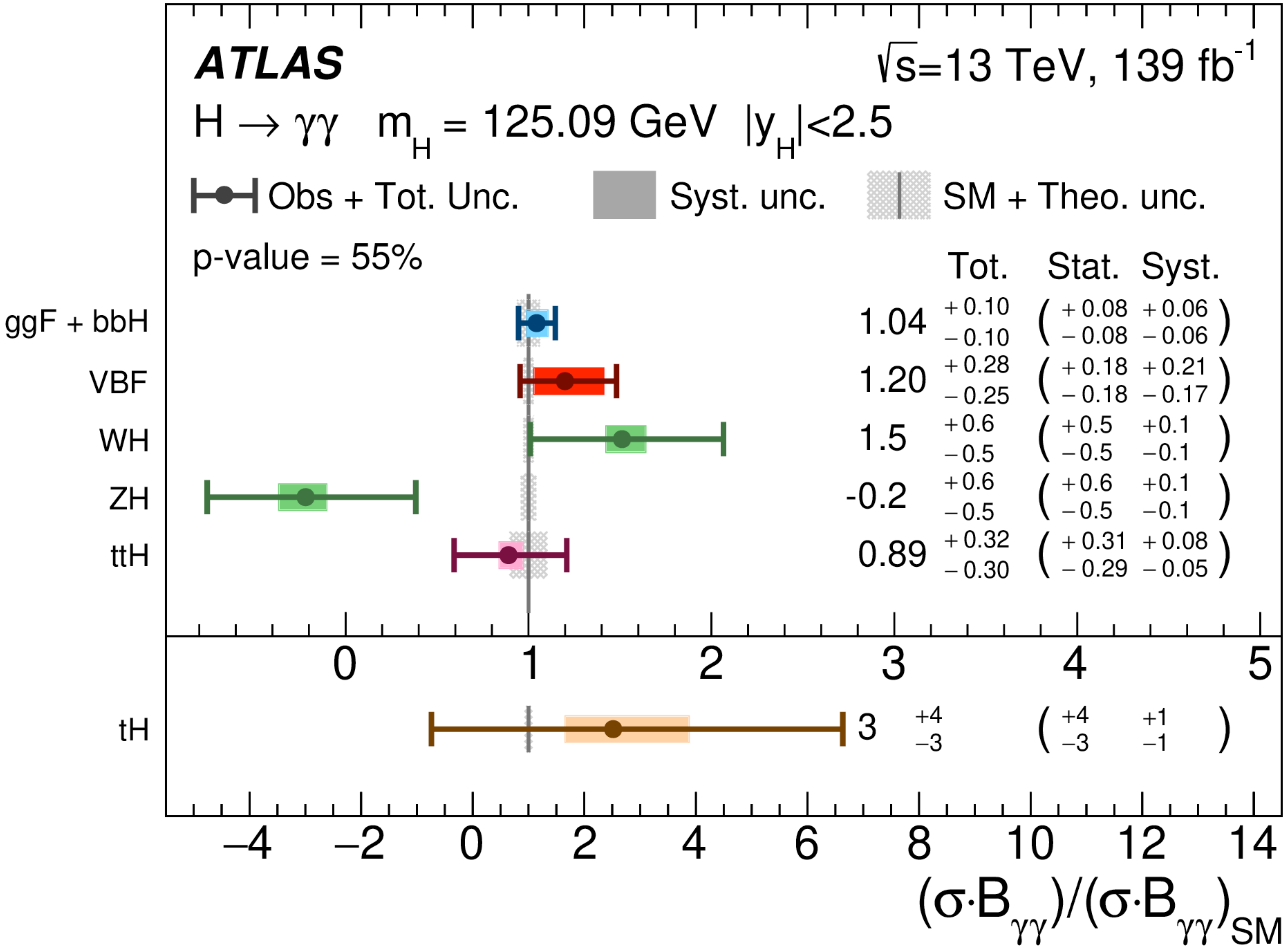
- Theory uncertainties even larger than experimental uncertainties for inclusive measurement
  - Clear dominance of parton shower uncertainties in VBF

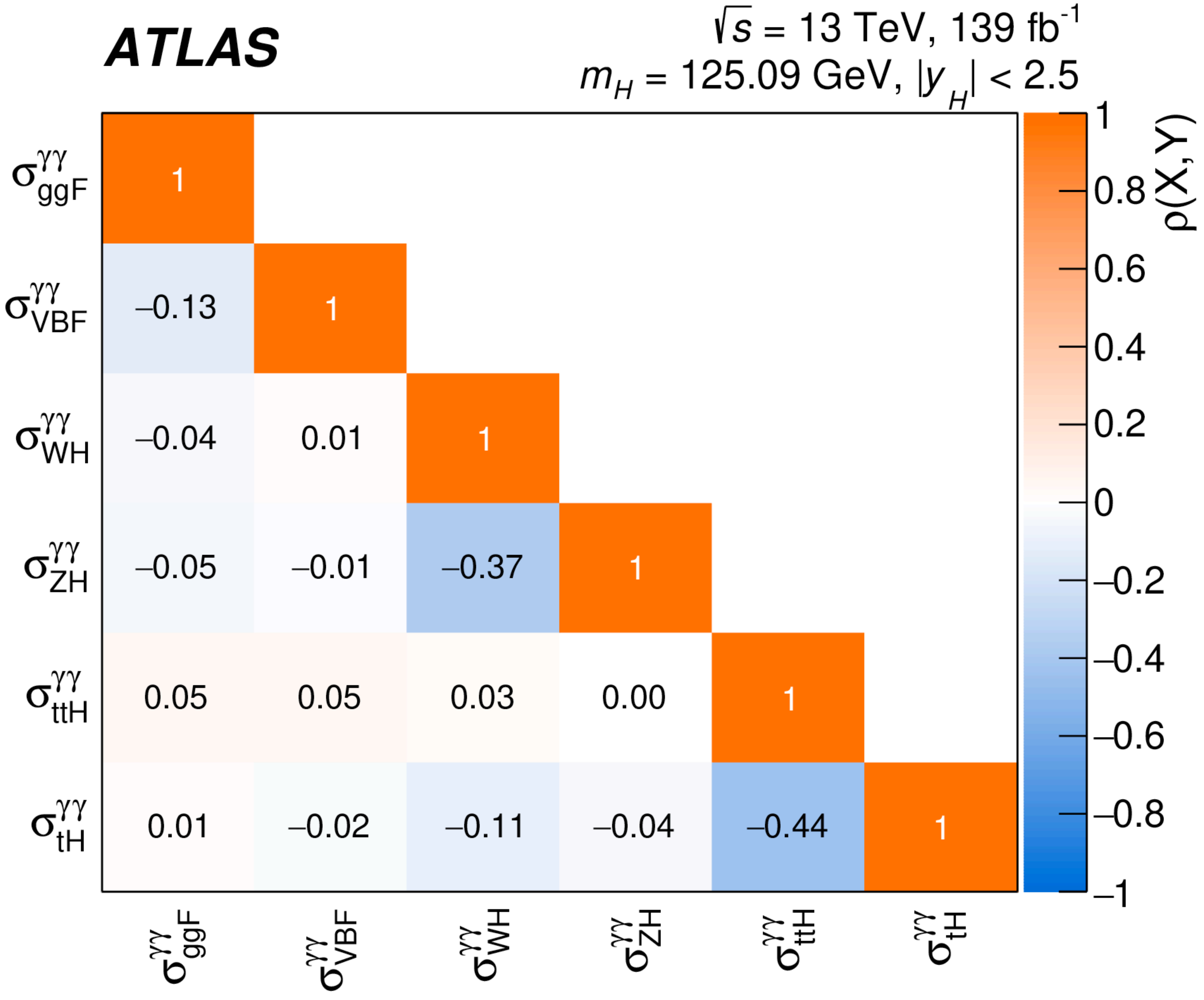
Uncertainty source	$\Delta\mu$ [%]
Theory uncertainties	
Higher-Order QCD Terms	±3.8
Branching Ratio	±3.0
Underlying Event and Parton Shower	±2.5
PDF and α_s	±2.1
Matrix Element	±1.0
Modeling of Heavy Flavor Jets in non-$t\bar{t}H$ Processes	$< \pm1$
Experimental uncertainties	
Photon energy resolution	±2.8
Photon efficiency	±2.6
Luminosity	±1.8
Pile-up	±1.5
Background modelling	±1.3
Photon energy scale	$< \pm1$
Jet/$E_{\mathrm{T}}^{\mathrm{miss}}$	$< \pm1$
Flavour tagging	$< \pm1$
Leptons	$< \pm1$
Higgs boson mass	$< \pm1$



Results

$$\mu = 1.04^{+0.10}_{-0.09} = 1.04 \pm 0.06\ (\text{stat.})^{+0.06}_{-0.05}\ (\text{theory syst.})\ ^{+0.05}_{-0.04}\ (\text{exp. syst.}).$$

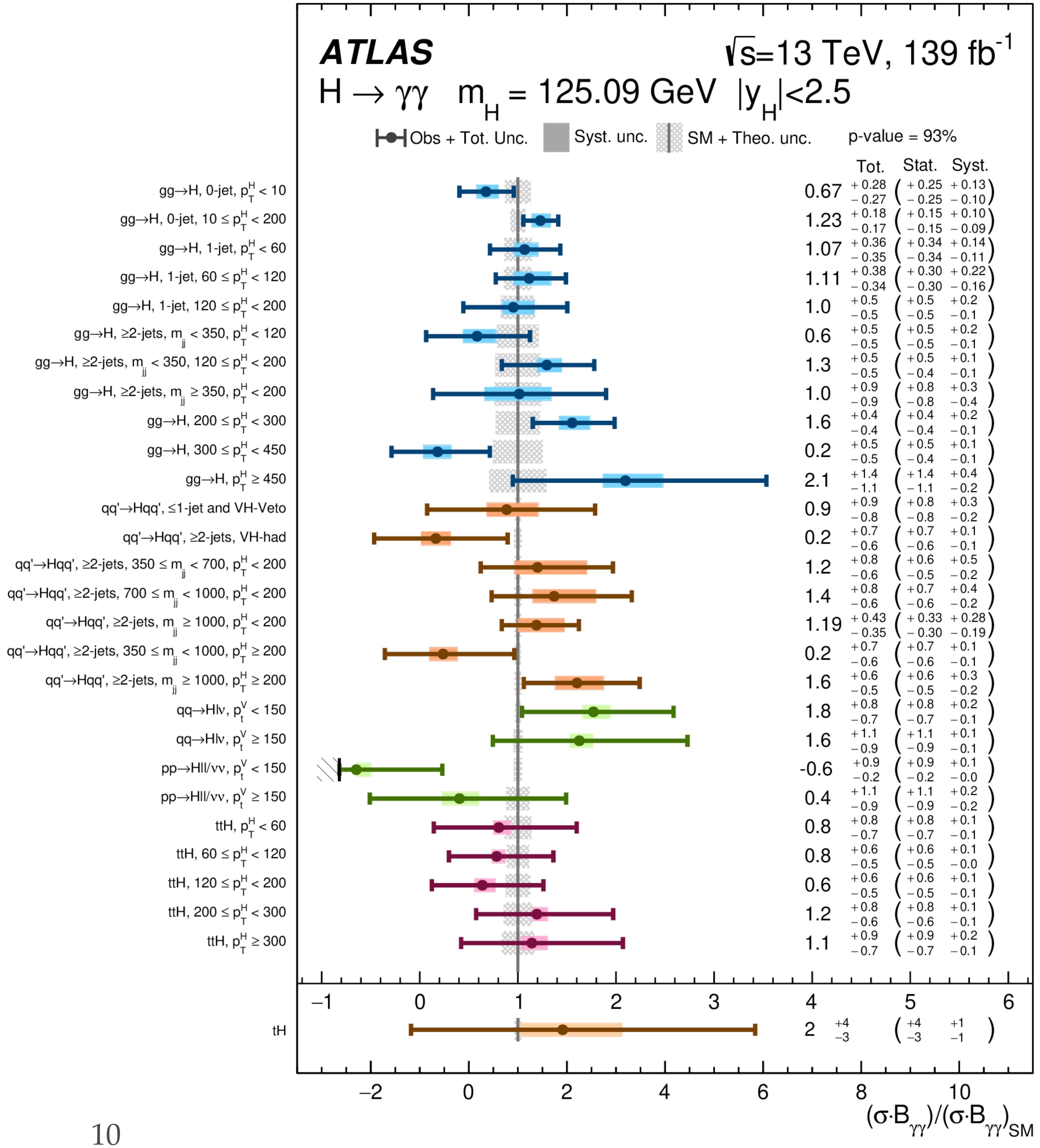




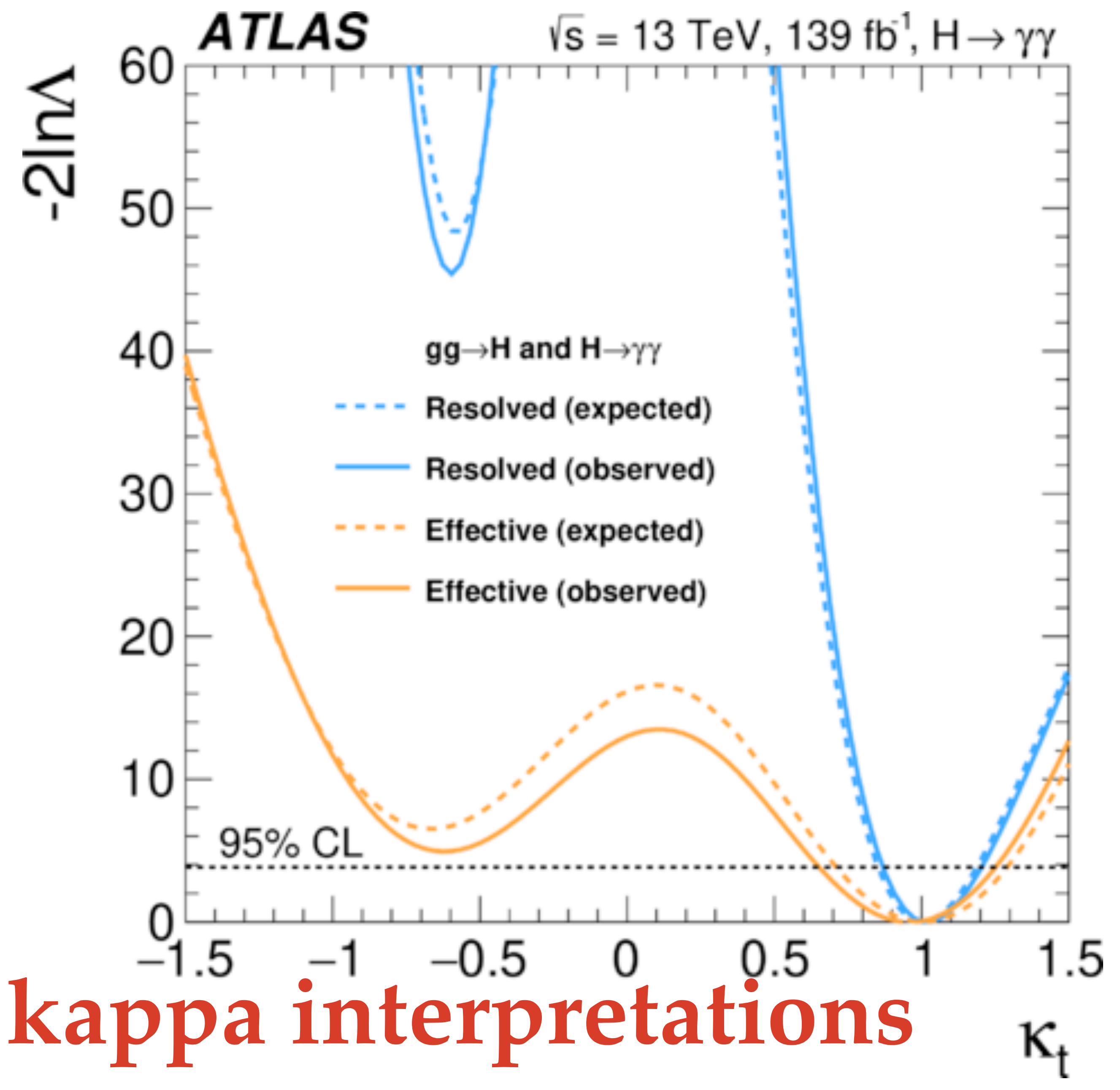
	$\sigma^{\gamma\gamma}_{ggF}$	$\sigma^{\gamma\gamma}_{VBF}$	$\sigma^{\gamma\gamma}_{WH}$	$\sigma^{\gamma\gamma}_{ZH}$	$\sigma^{\gamma\gamma}_{ttH}$	$\sigma^{\gamma\gamma}_{tH}$
$\sigma^{\gamma\gamma}_{ggF}$	1					
$\sigma^{\gamma\gamma}_{VBF}$	–0.13	1				
$\sigma^{\gamma\gamma}_{WH}$	–0.04	0.01	1			
$\sigma^{\gamma\gamma}_{ZH}$	–0.05	–0.01	–0.37	1		
$\sigma^{\gamma\gamma}_{ttH}$	0.05	0.05	0.03	0.00	1	
$\sigma^{\gamma\gamma}_{tH}$	0.01	–0.02	–0.11	–0.04	–0.44	1

Results

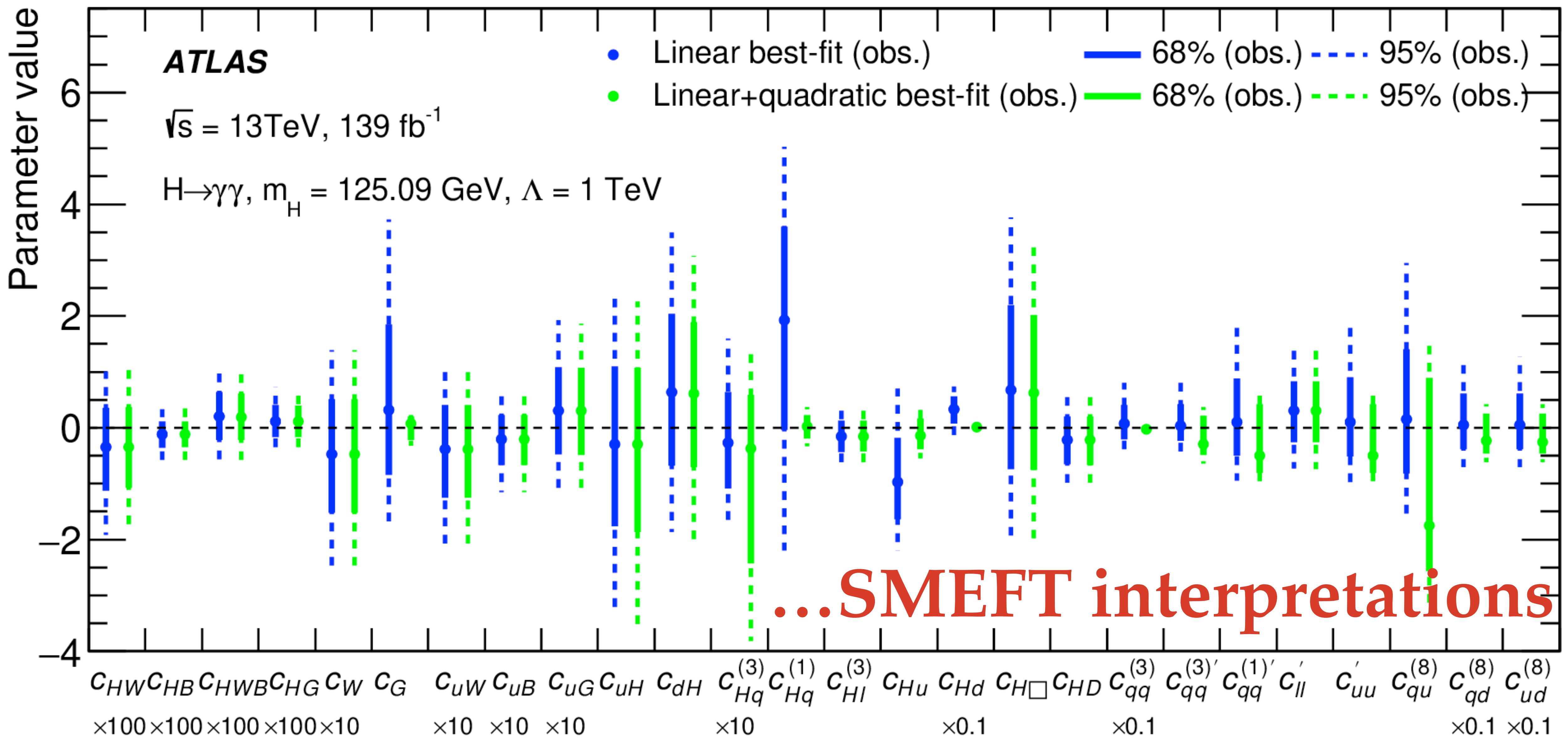
- SM expectations from MC normalised to the best-known total cross section according to the LHC Higgs WG
- Uncertainties of 10% in ggF
- Negative best fit value in ZH (observed yield below the background expectation)
- Observed (expected) limit on tH cross section of 10 (6.8) times the SM
- 28 STXS bins measured (merging of bins based on expected sensitivity)
  - 93% compatibility with the SM



And that was only a part of the story…



…kappa interpretations



…SMEFT interpretations

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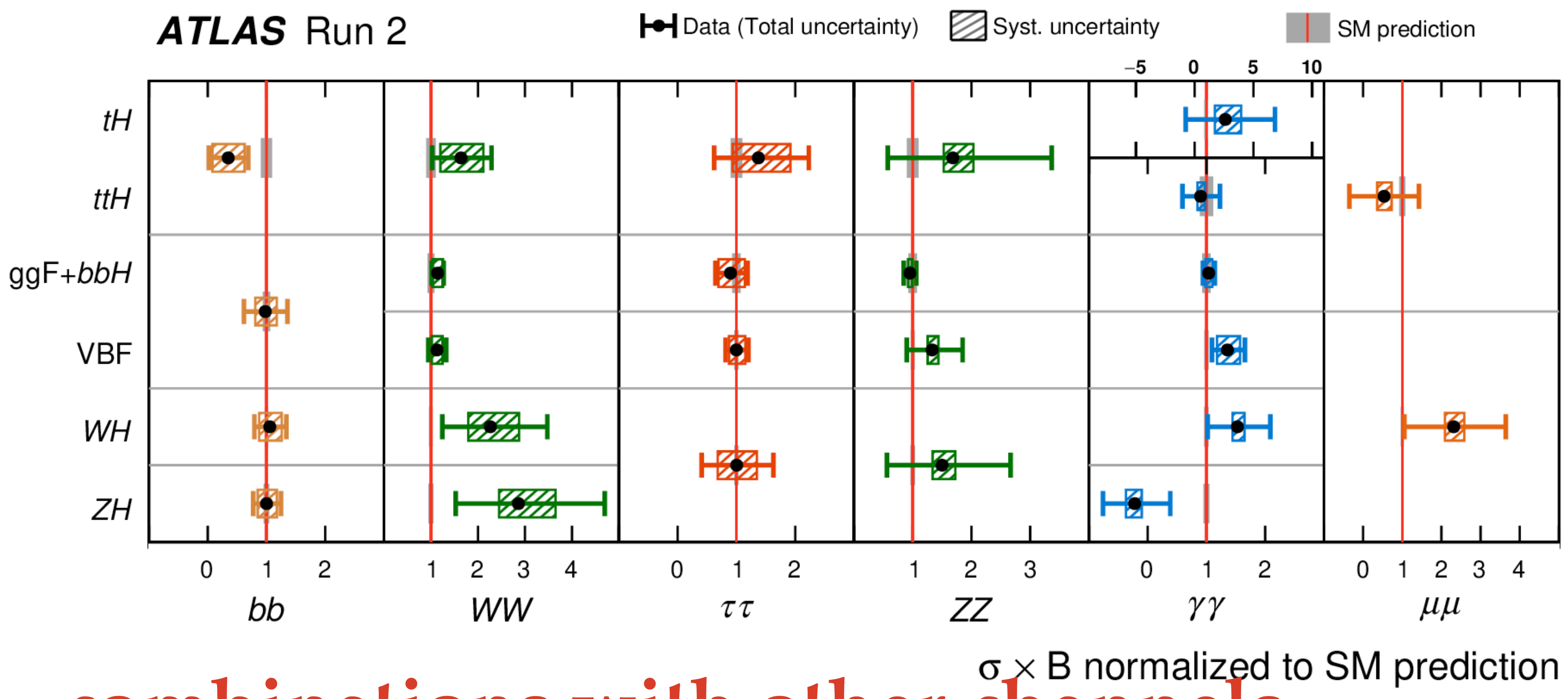
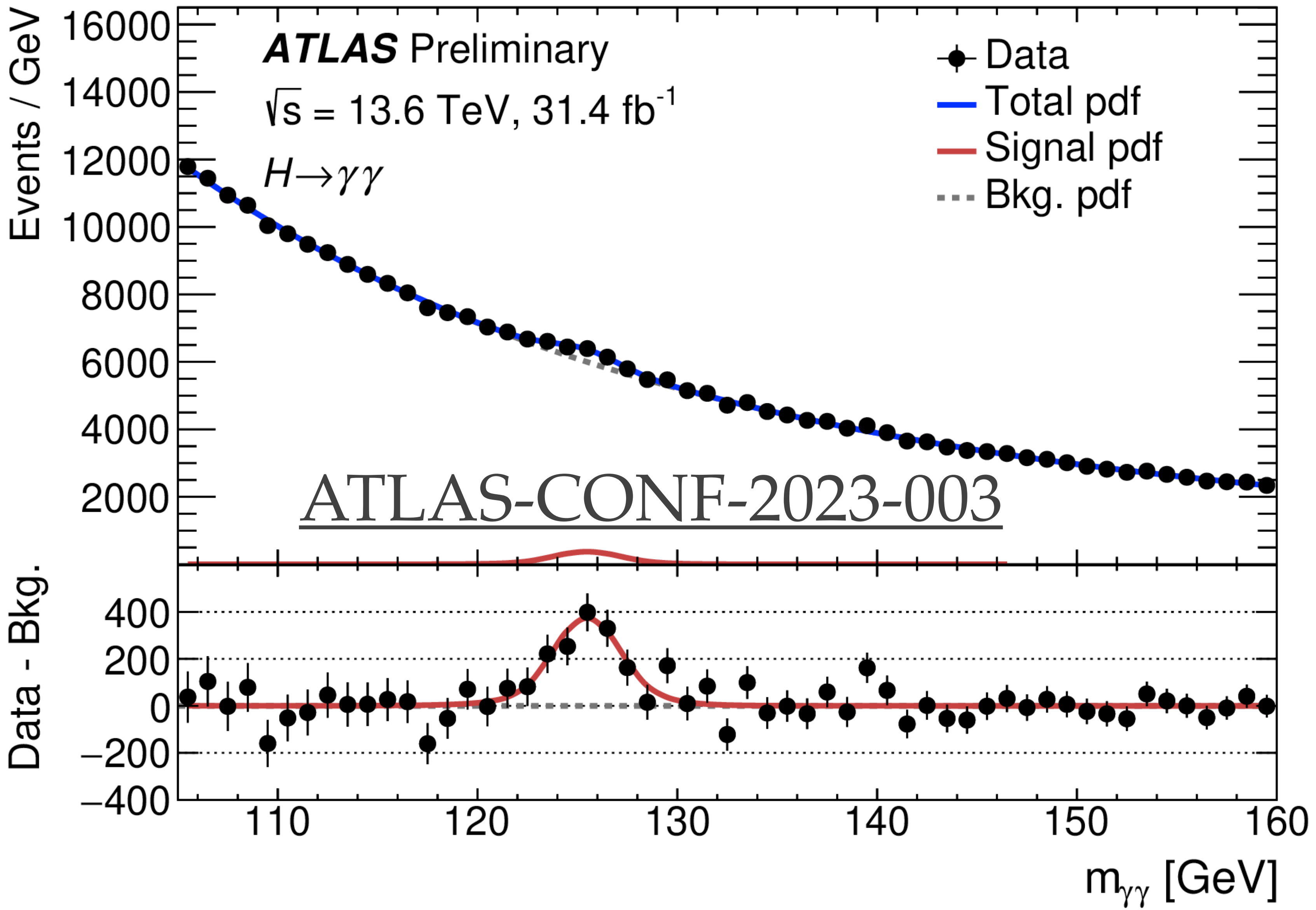


… combinations with other channels

… and the Higgs is still there in Run 3. STAY TUNED!



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Thanks!