H combination at the CMS

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Introduction

- The Higgs couplings to elementary particles: a tool to examine SM and probe BSM
- Combination of all the production and decay channels: get the best precision
- From Run1 to Run2: higher granularity, μ => STXS
- Self-coupling probe through single H production

Processes in the combination

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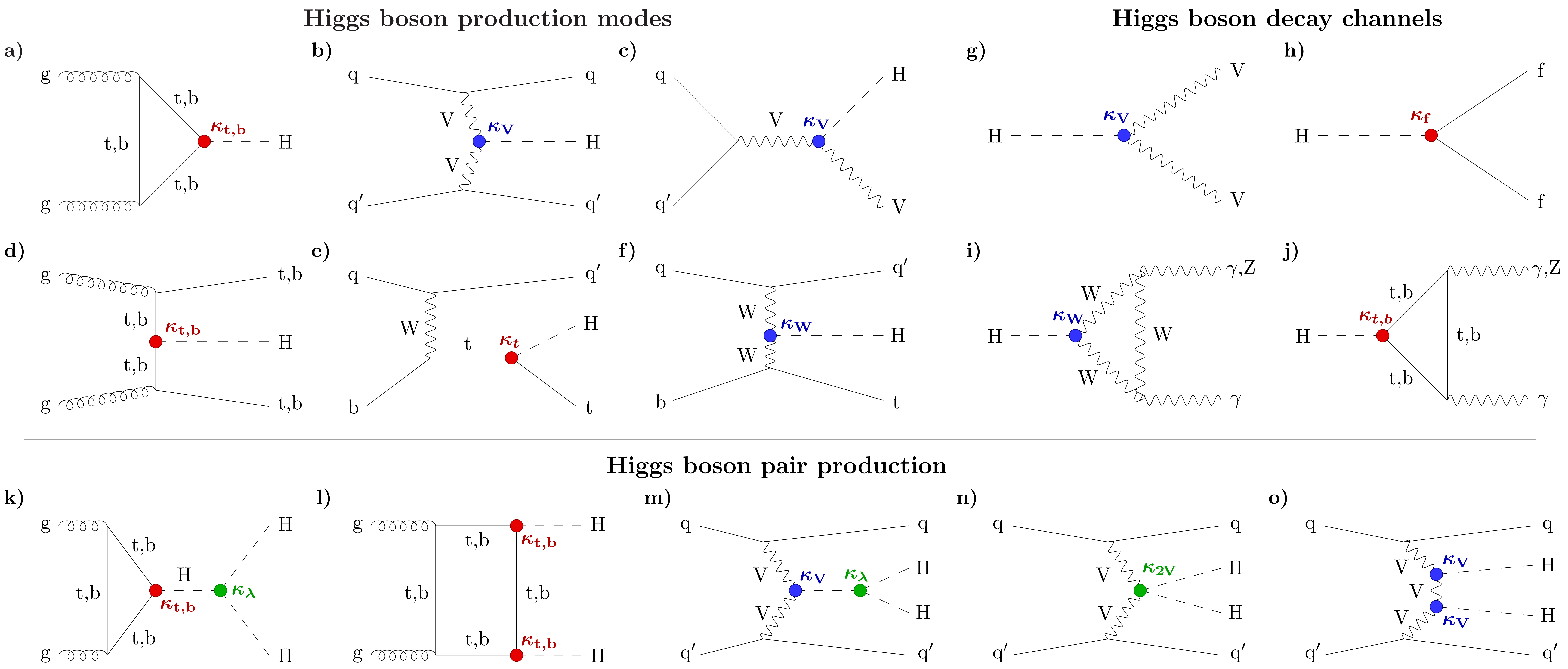


Production and decay rates

$$\mu_i = \frac{\sigma_i}{(\sigma_i)_{SM}} \qquad \mu^f = \frac{\mathcal{B}^f}{(\mathcal{B}^f)_{SM}}$$

The most straightforward checks on SM

Overall μ=1.002±0.057

0.029 (stat)+ 0.036 (theo) + 0.033 (exp)

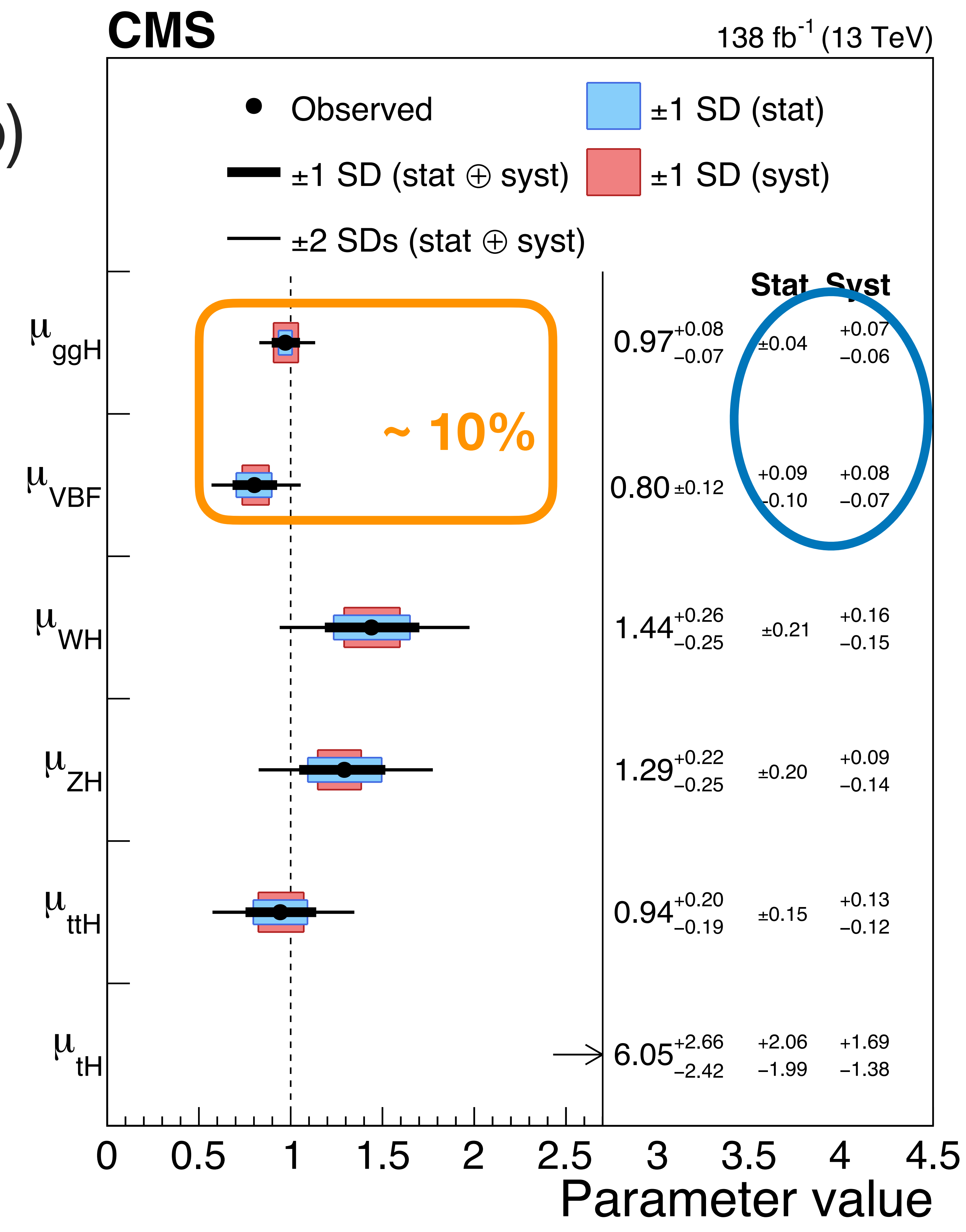
6 production modes

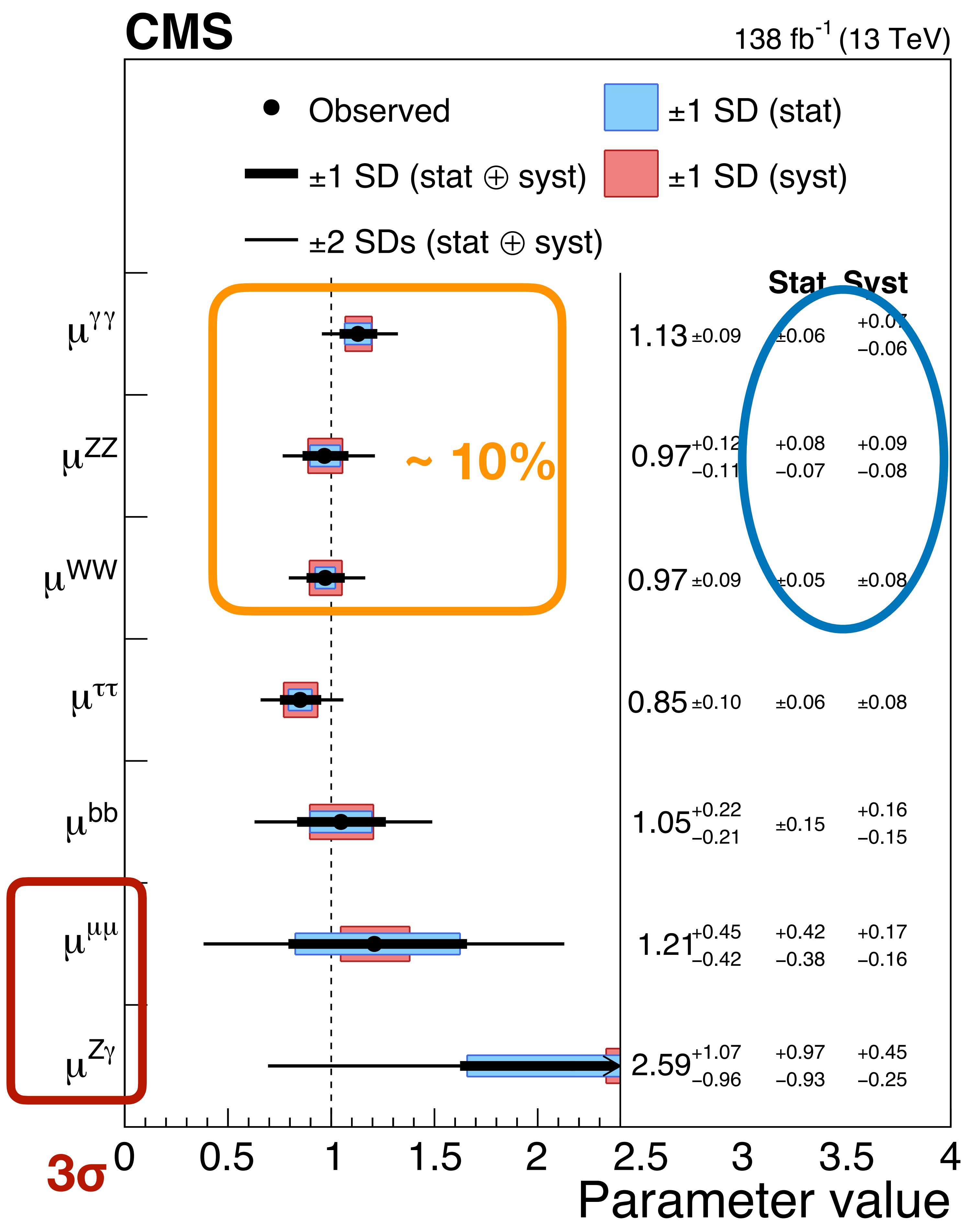
ggH, VBF, WH, ZH, ttH, tH

7 final states

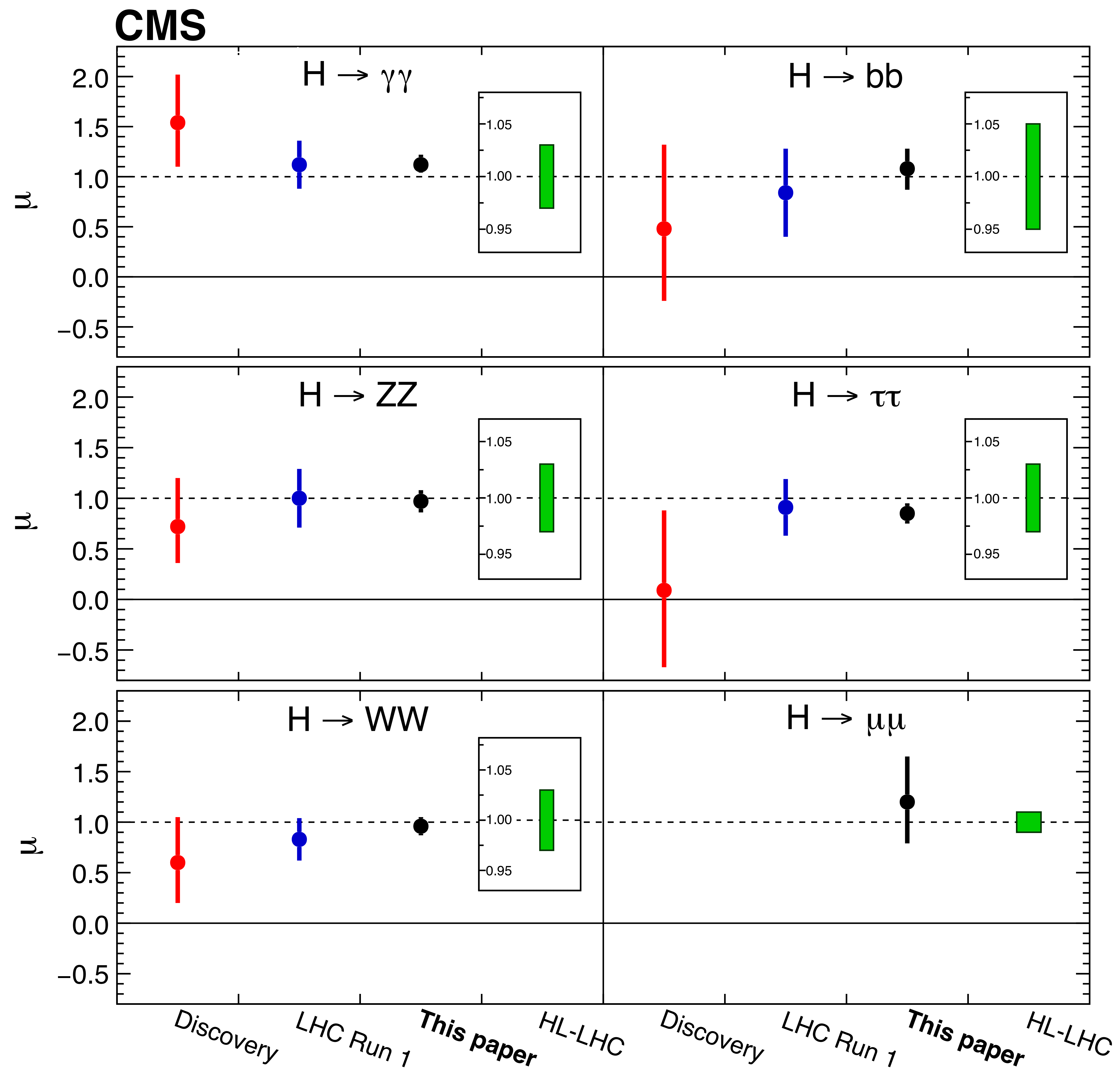
H→ γγ, ZZ, WW, ττ, bb, μμ, Zγ

New in Run2



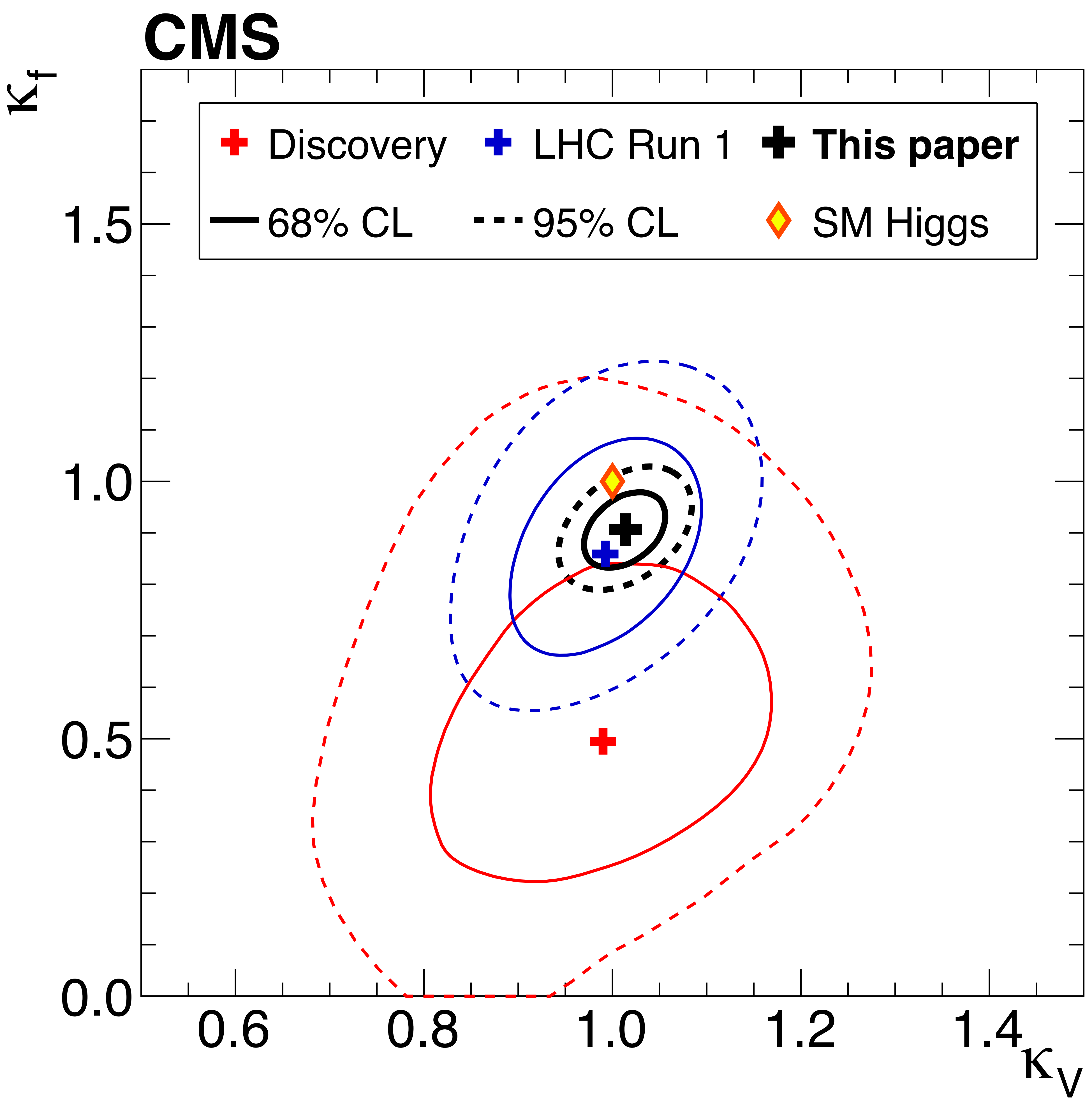


A long journey



~ 2-5% expected at HL-LHC

Vector boson and fermion couplings



Significant improvement in the precision

A bit further

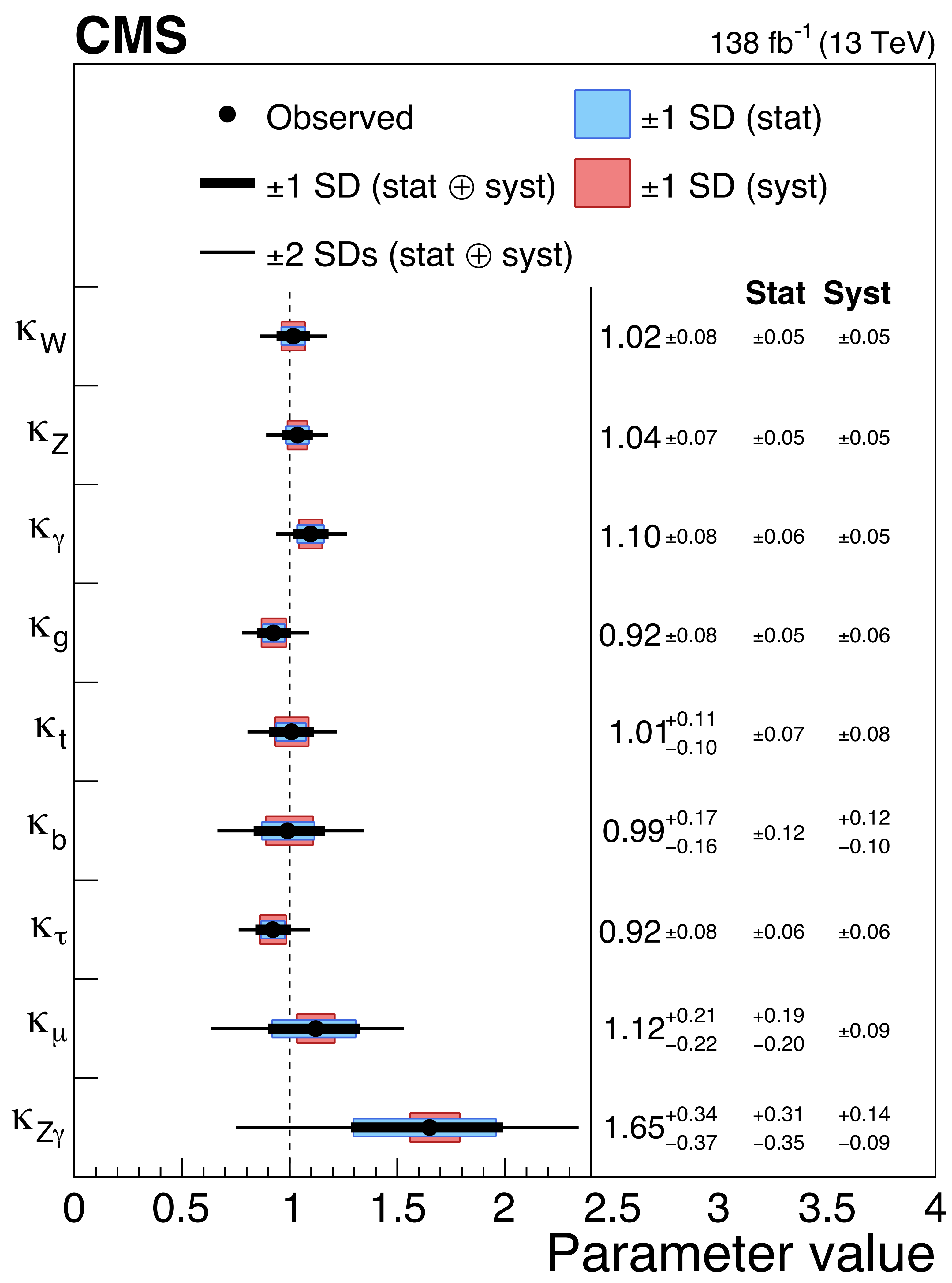
Zoom in interactions between H and other particles

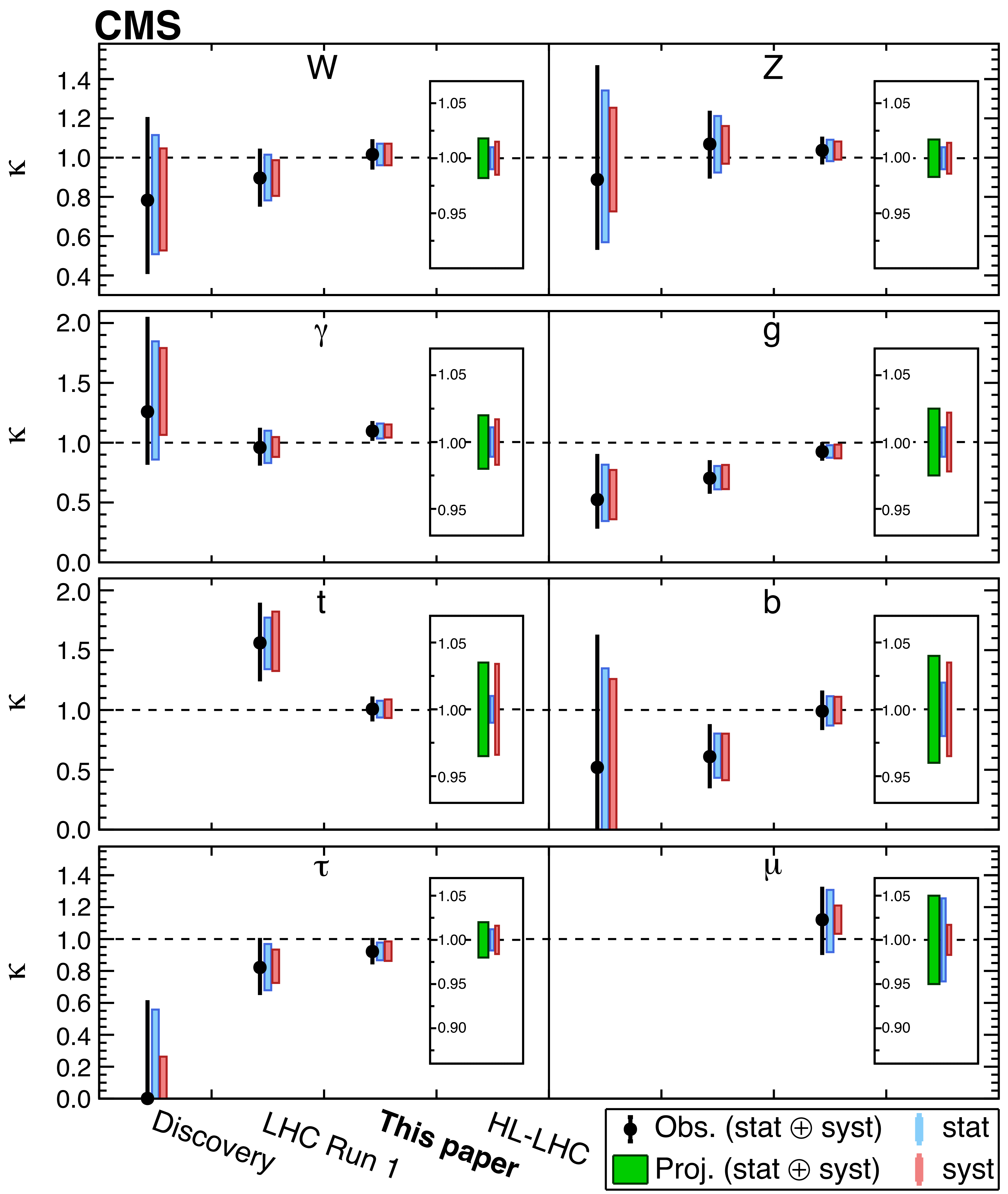
Prod

$$\kappa^2 = \sigma/\sigma^{\mathrm{SM}}$$

Decay

$$\kappa^2 = \Gamma/\Gamma^{\mathrm{SM}}$$

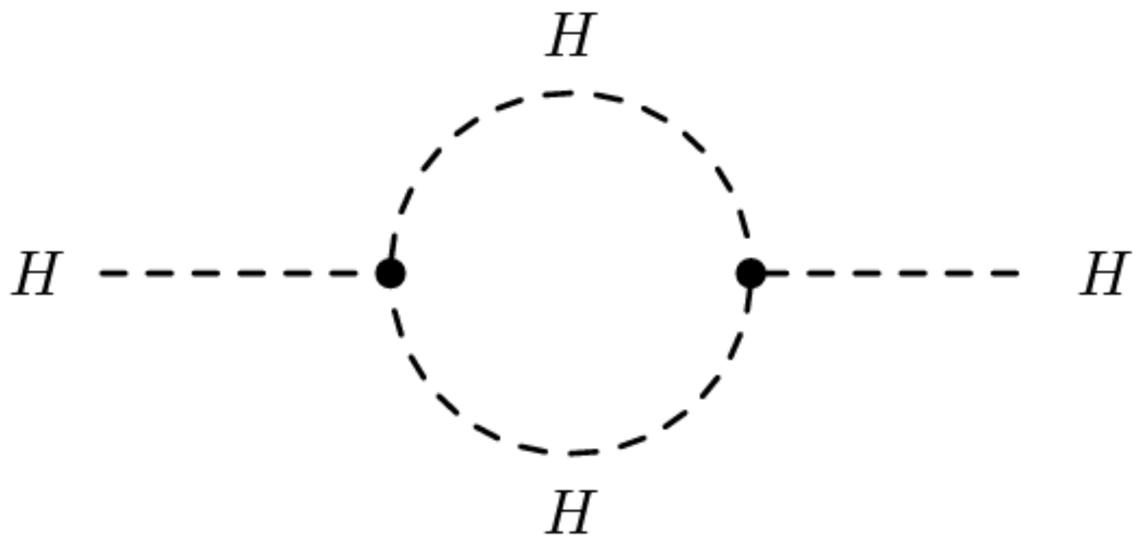




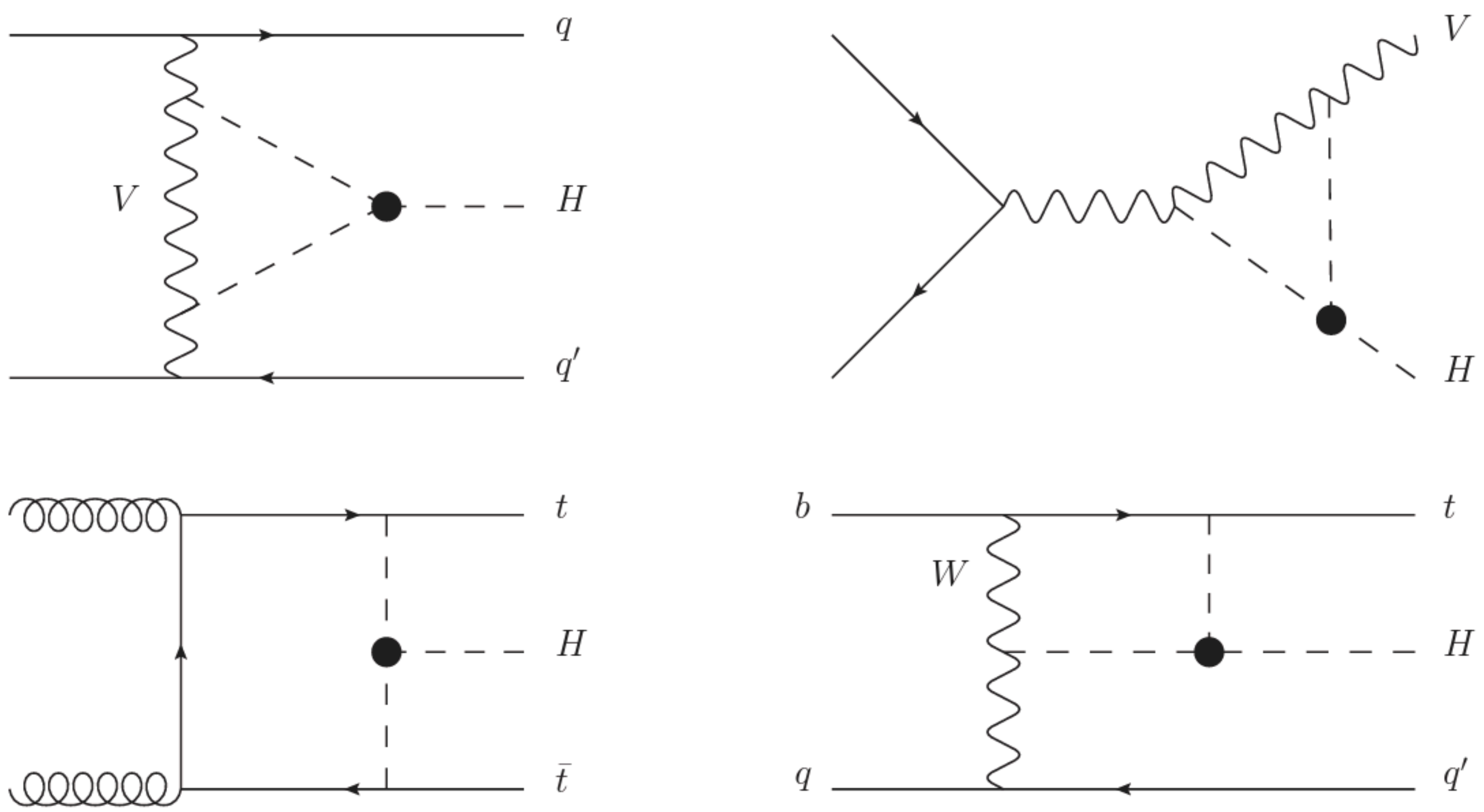
H self-coupling

- Directly measured in HH production
- Does it modify the single H xsec?
  - Yes, through NLO EW corrections

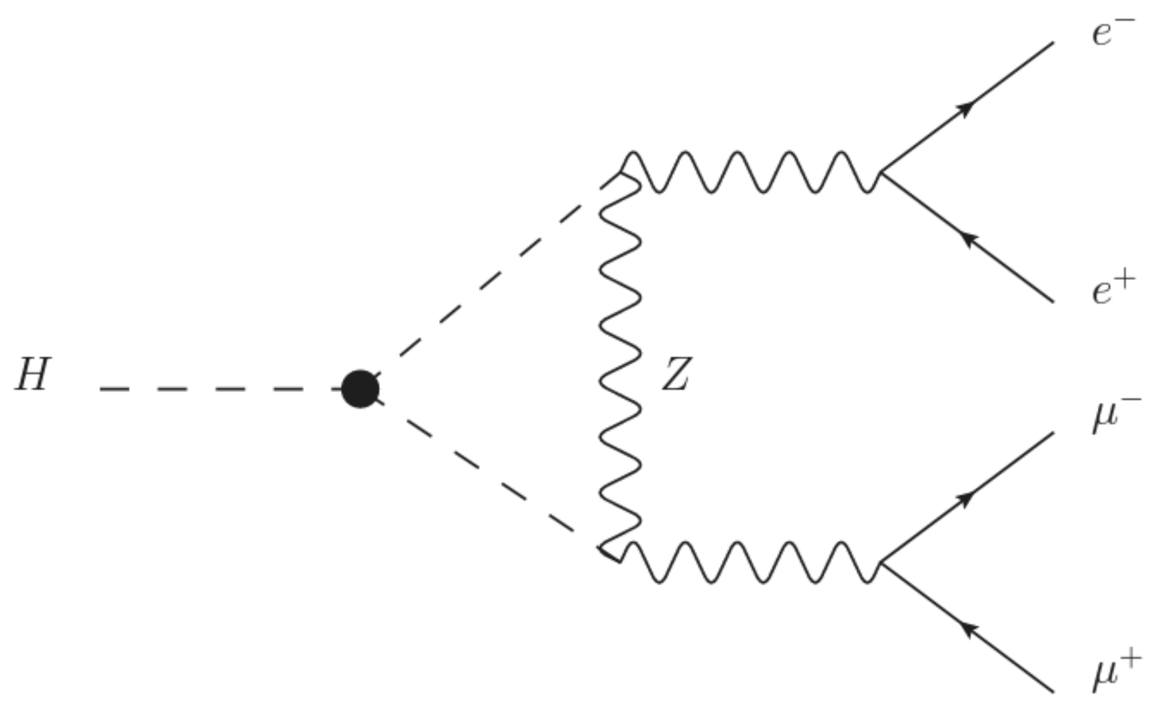
JHEP 1612,080 (2016)
Eur. Phys. J. C77 (2017) 887



A universal correction



On production



On decay

The size of correction

$$V(H) = \frac{1}{2} m_H^2 H^2 + \lambda_3 v H^3 + \frac{1}{4}\lambda_4 H^4 \qquad \kappa_\lambda = \lambda_3/\lambda_3^{SM}$$

$$\Sigma_{\rm NLO} = Z_H \, \Sigma_{\rm LO} \, (1 + \kappa_\lambda C_1)$$

Universal correction

$$\frac{1}{1 - \kappa_\lambda^2 \delta Z_H}$$

$$\delta Z_H = -1.536 \times 10^{-3}$$

Interference between LO and NLO EW

Prod and decay dependent

Channels	ggF	VBF	ZH	WH	$t\bar{t}H$	tHj
$C_1(\%)$	0.66	0.63	1.19	1.03	3.52	0.91

$C_1^\Gamma[\%]$	$\gamma\gamma$	ZZ	WW	$f\bar{f}$	gg
on-shell H	0.49	0.83	0.73	0	0.66

The size of correction

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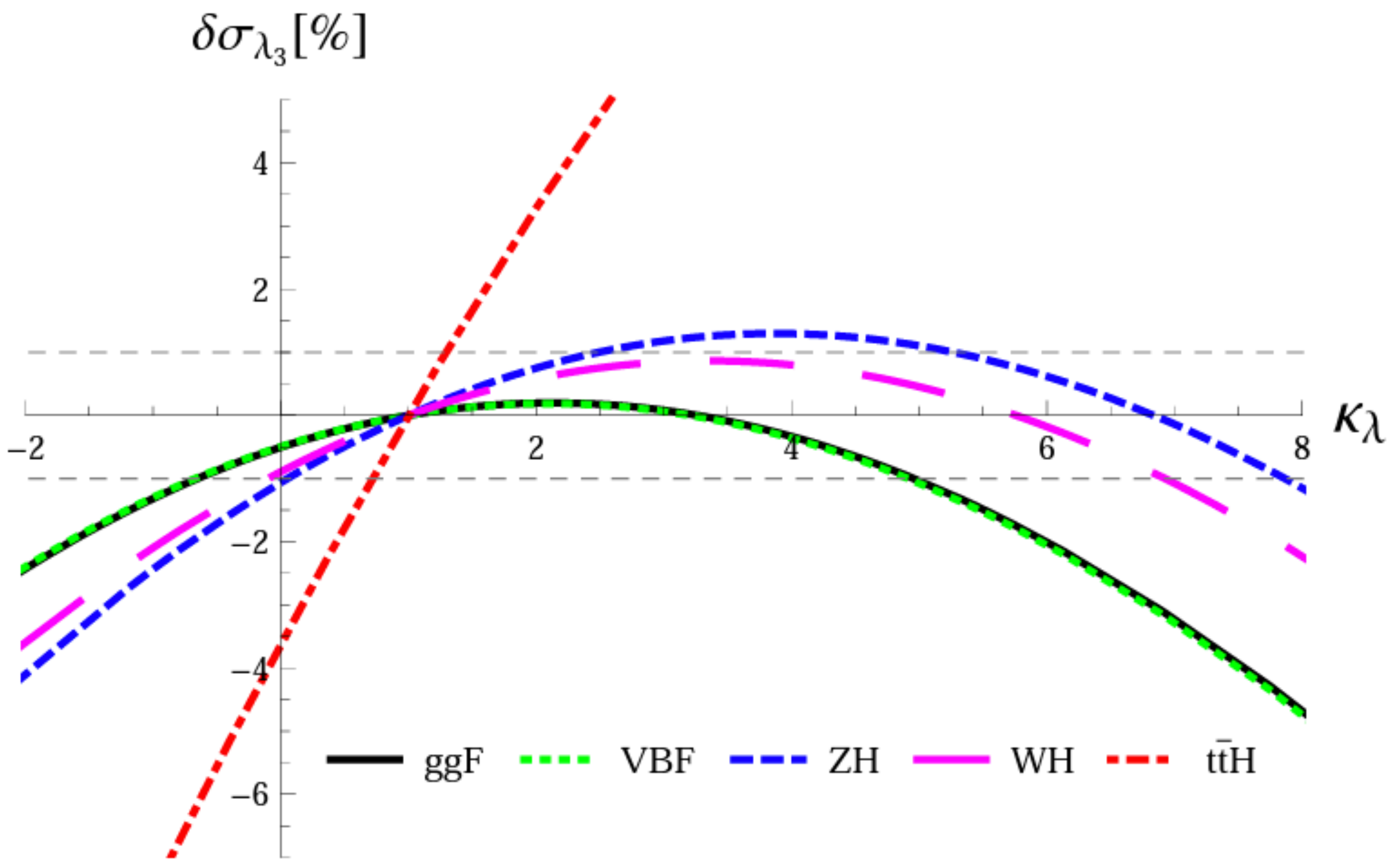
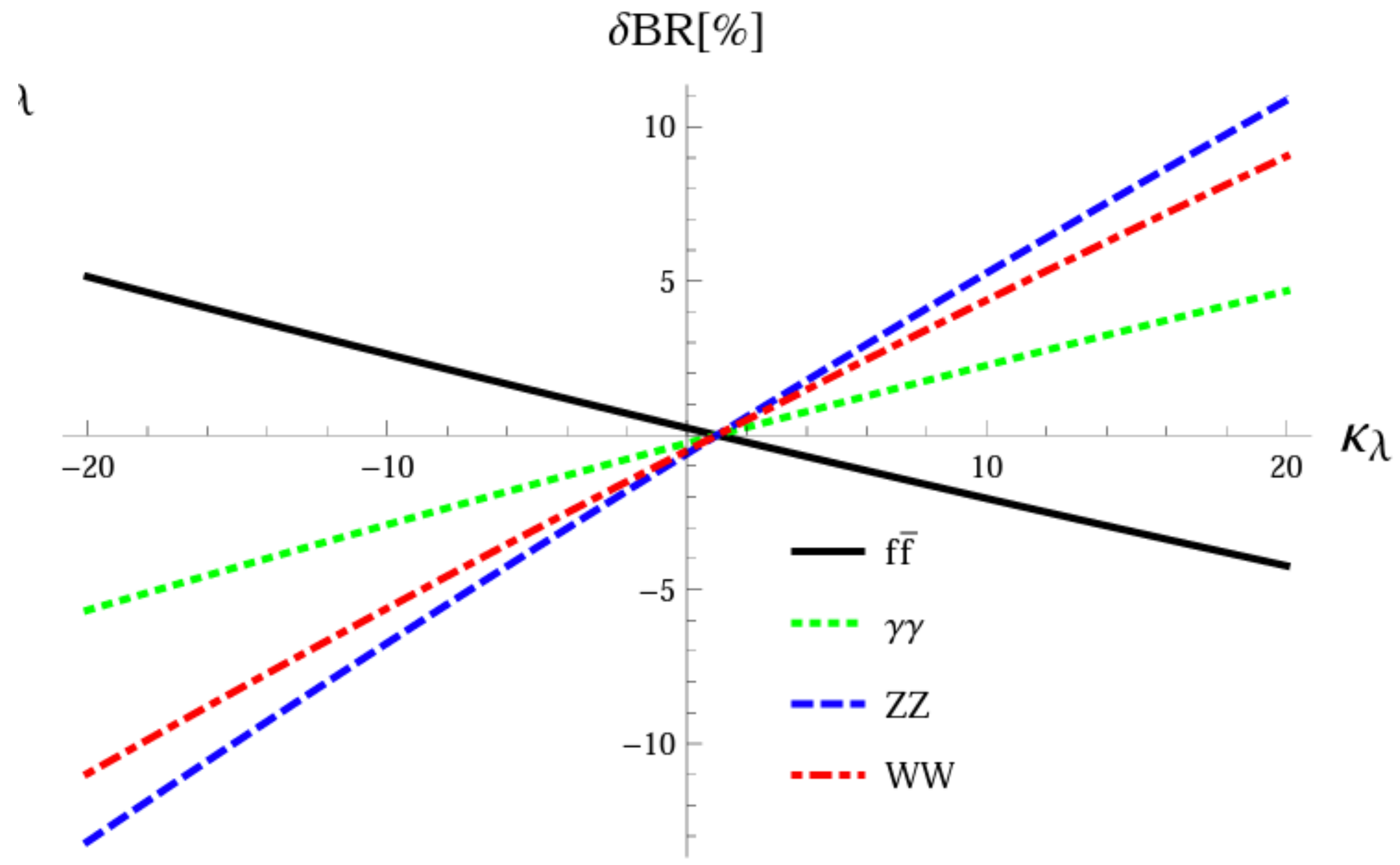


$$\Sigma_{\rm NLO} = Z_H \, \Sigma_{\rm LO} \, (1 + \kappa_\lambda C_1)$$



$$\delta {\rm BR}_{\lambda_3}(i) = \frac{(\kappa_\lambda - 1)(C_1^\Gamma(i) - C_1^{\Gamma_{\rm tot}})}{1 + (\kappa_\lambda - 1) C_1^{\Gamma_{\rm tot}}},$$

Interference between LO and NLO EW
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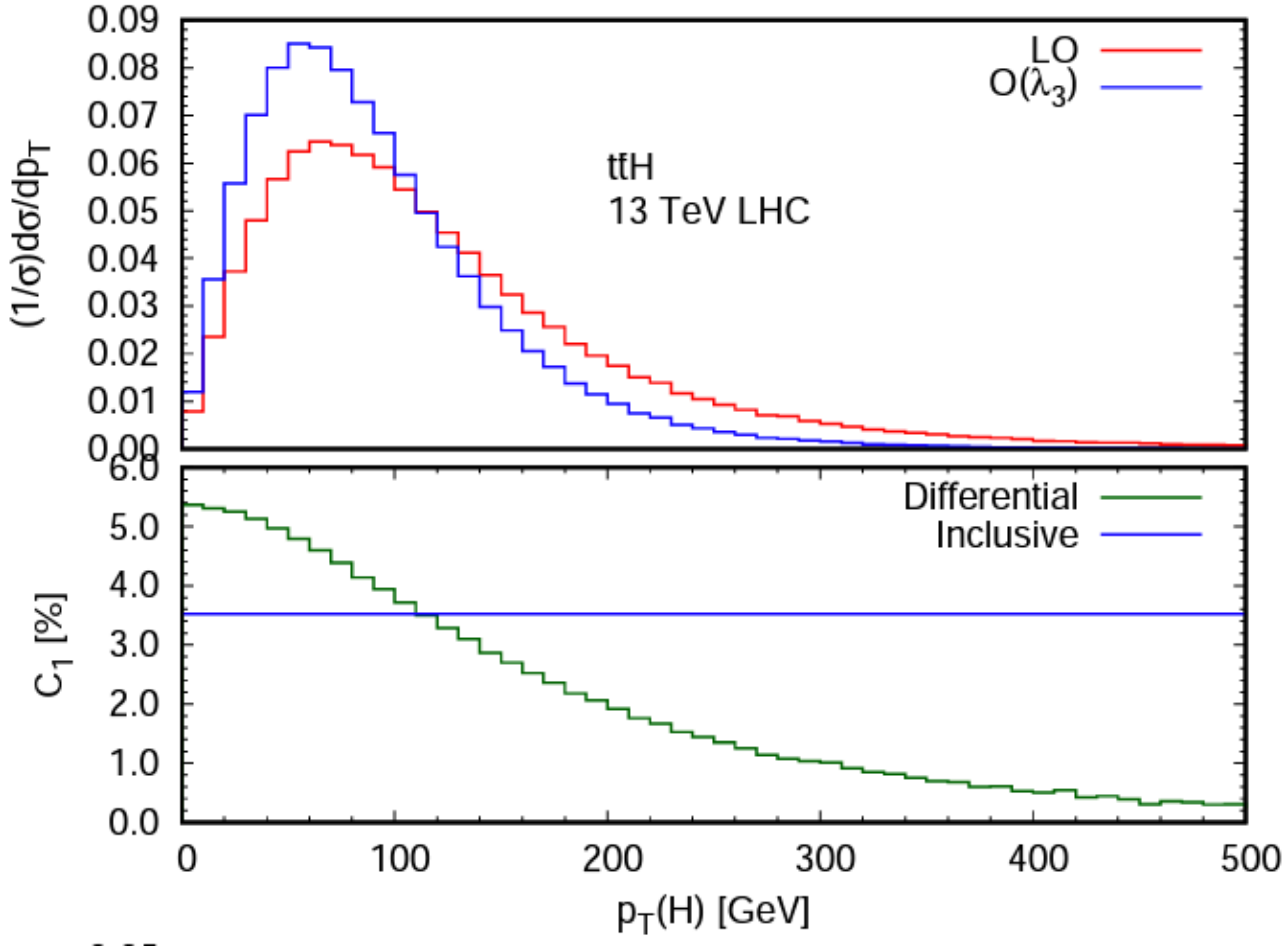
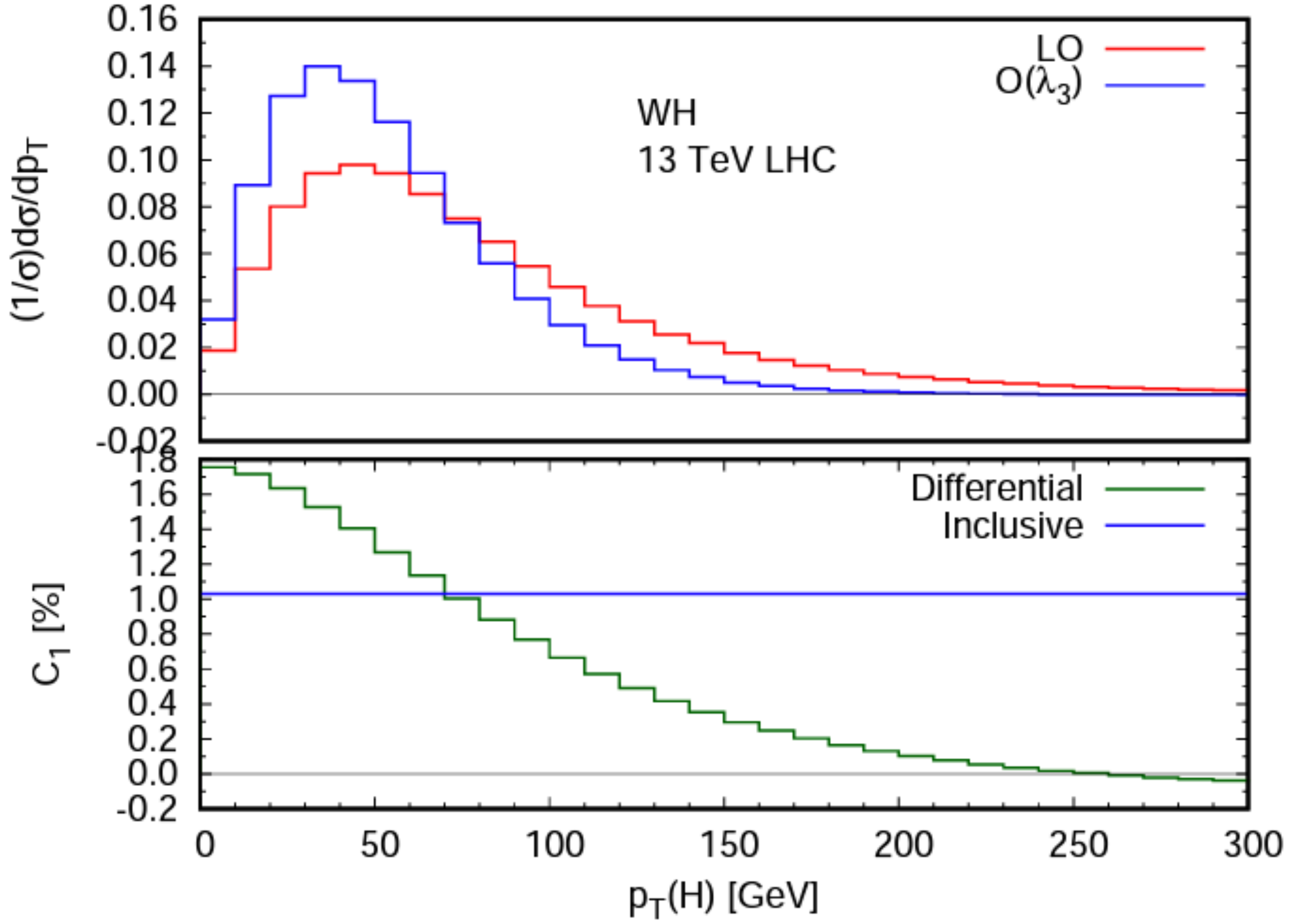
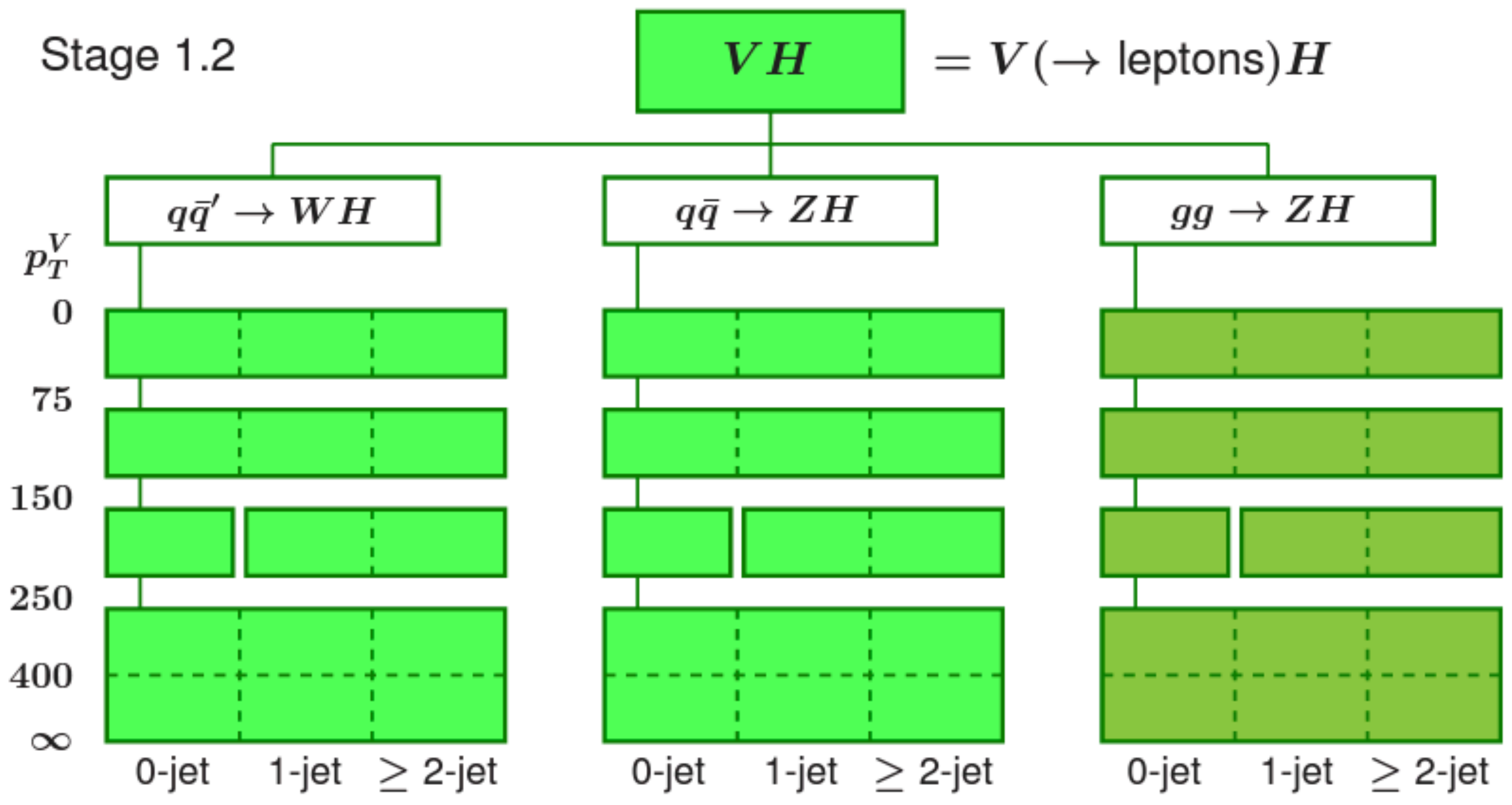
Go differential

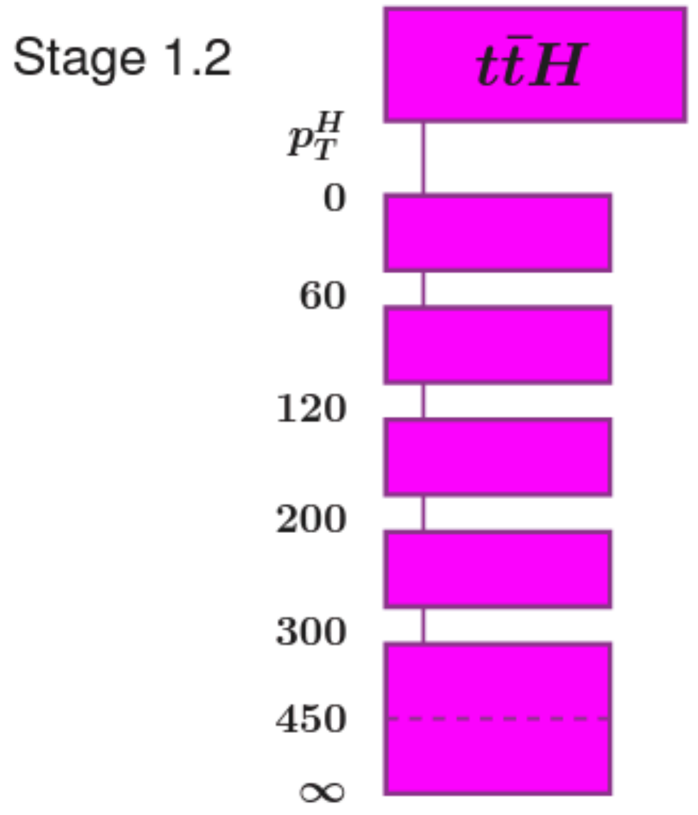


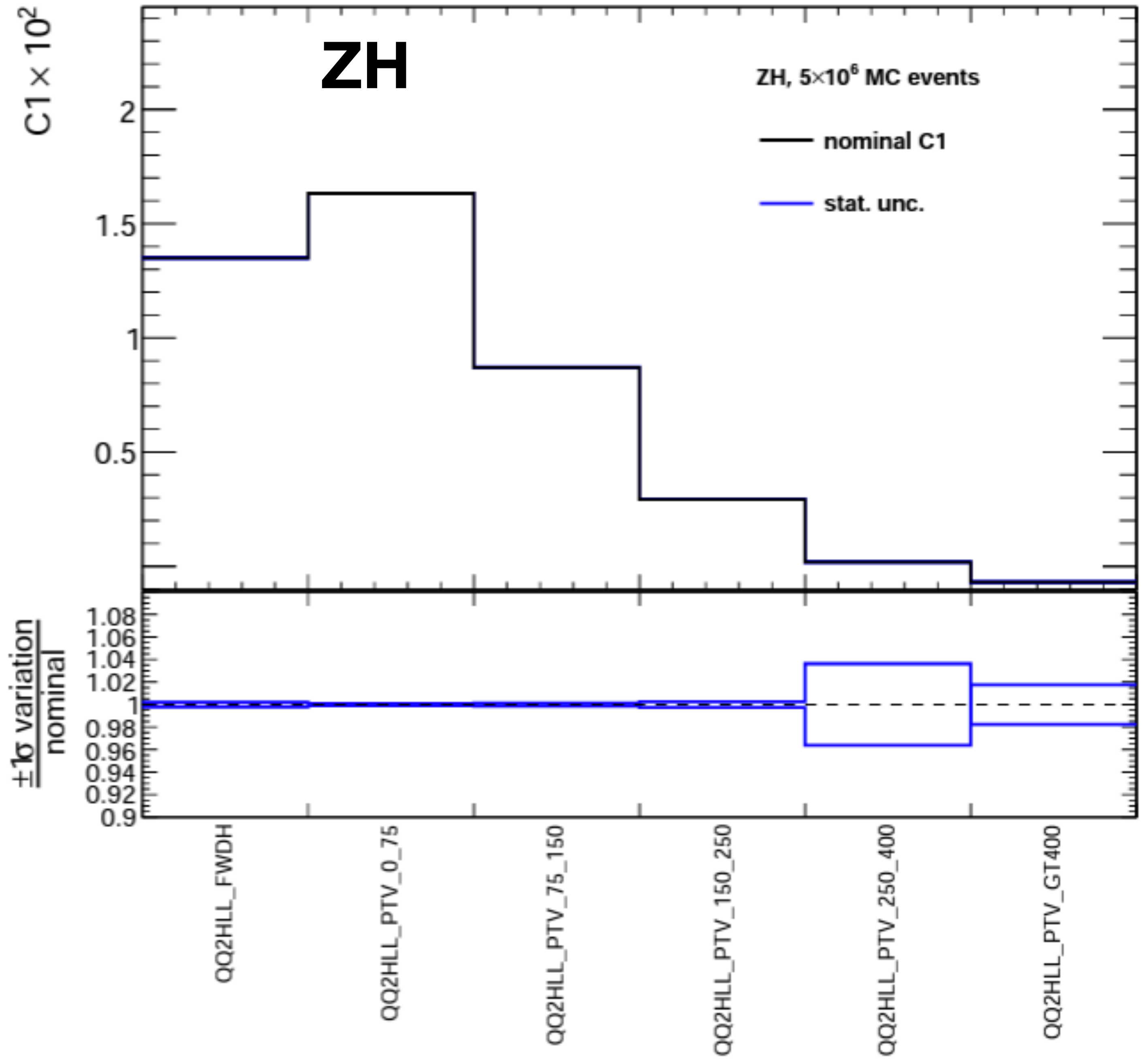


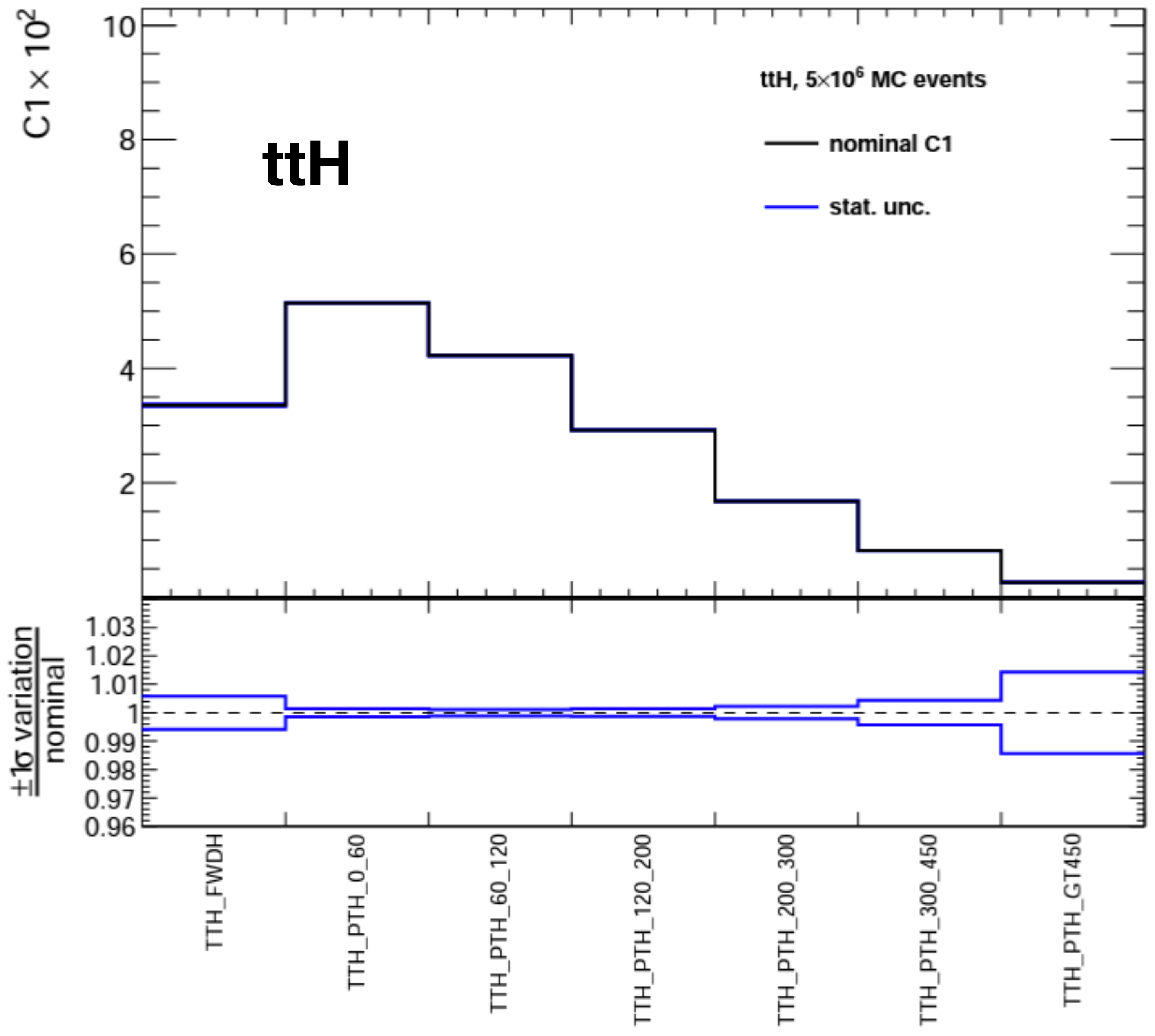
Most pronounced differential effects at the VH and ttH production
No differential effect at the decay

STXS bins and parameterization



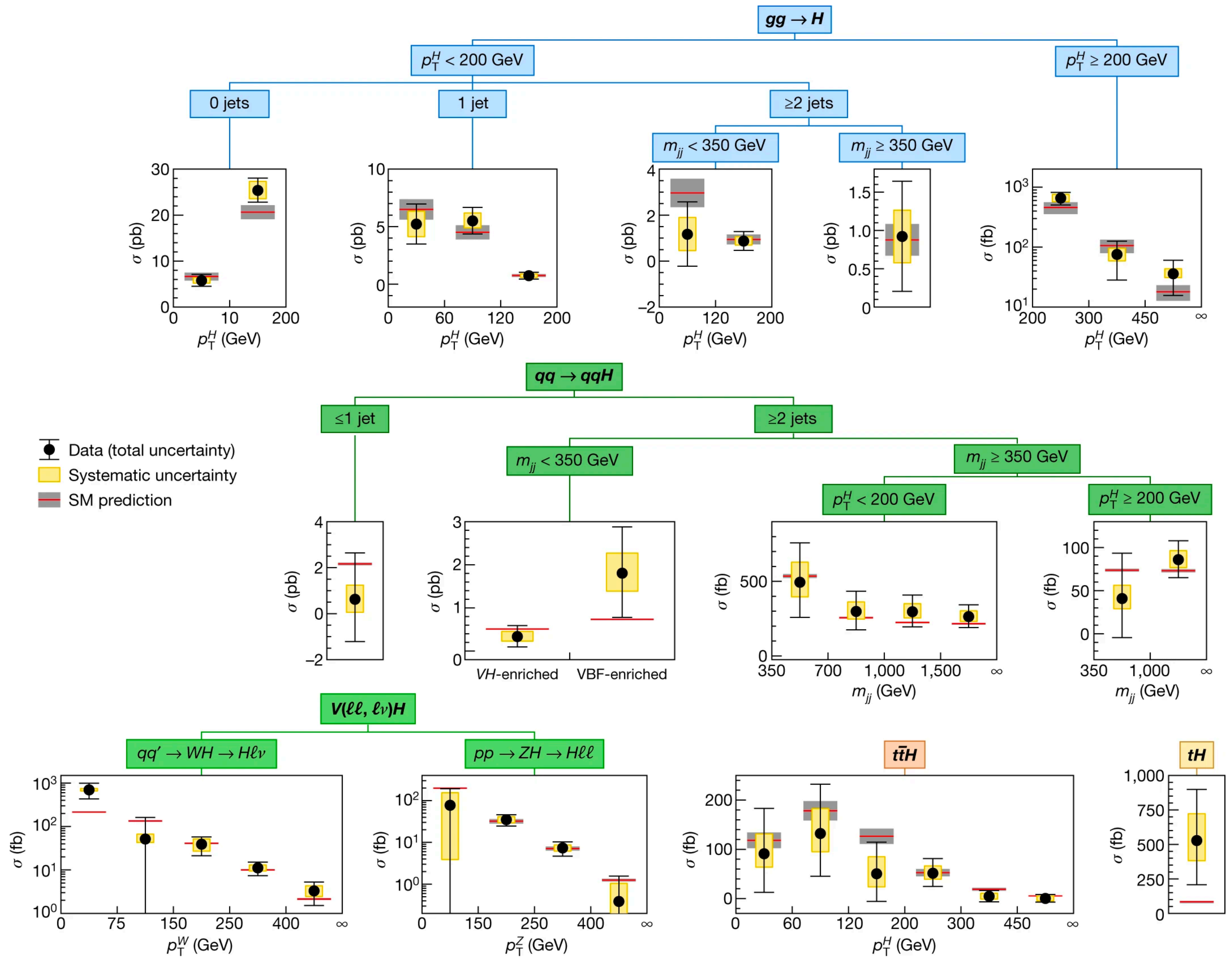






LHCHWG-2022-002

An example of STXS measurement from ATLAS



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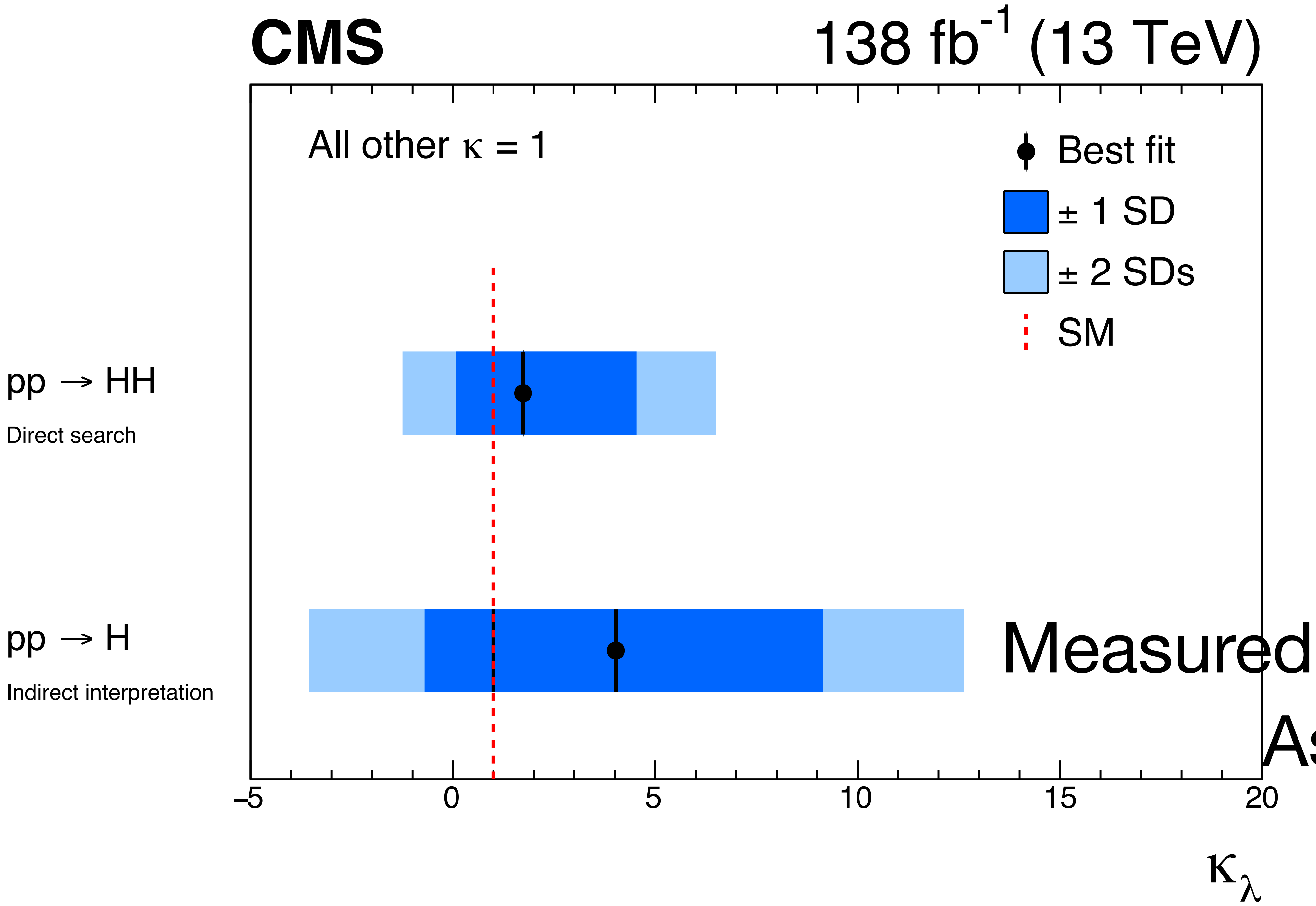
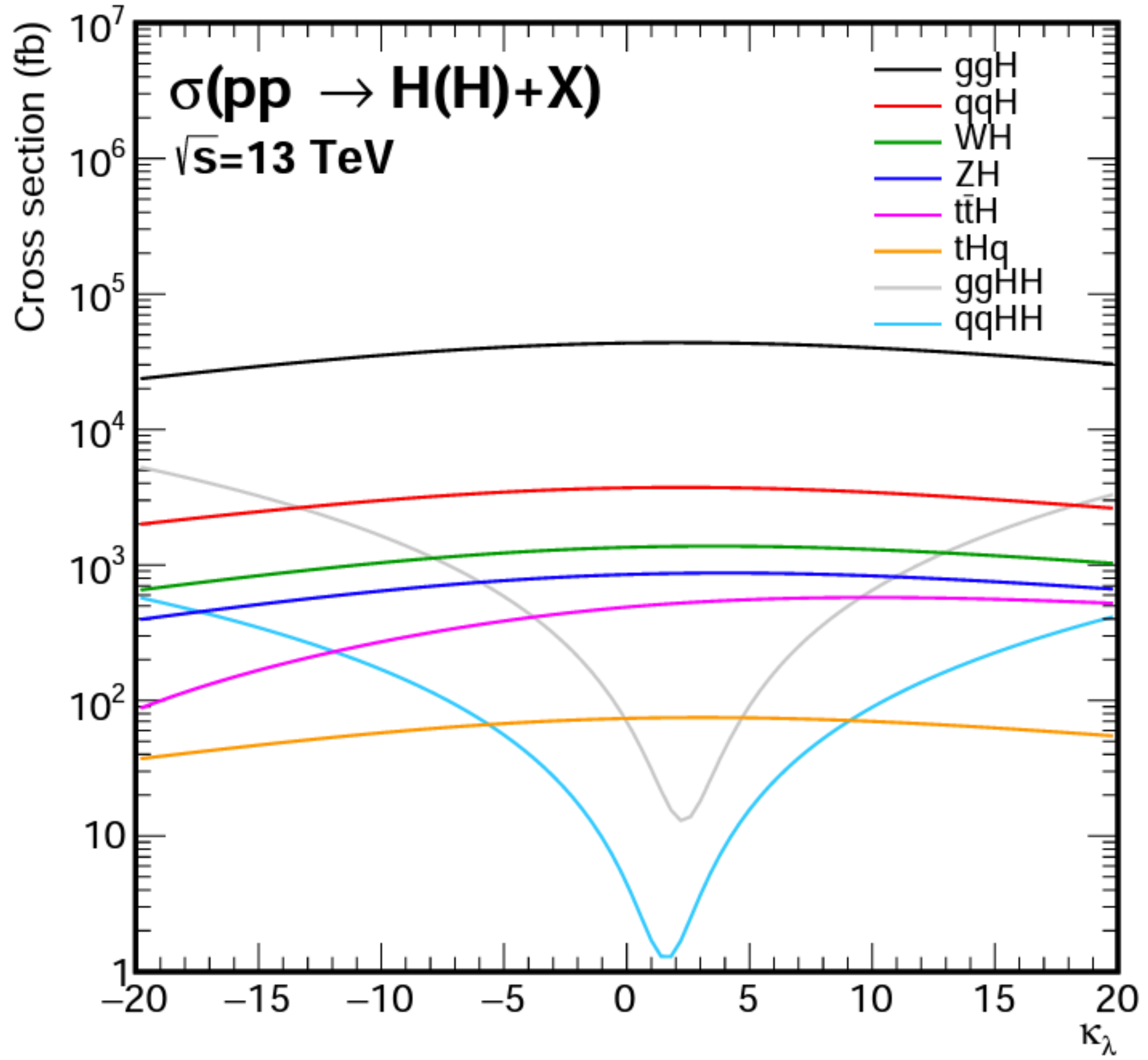
κ_λ from H comb



Measured from H STXS combination

Assuming $\kappa_f = \kappa_V = 1$



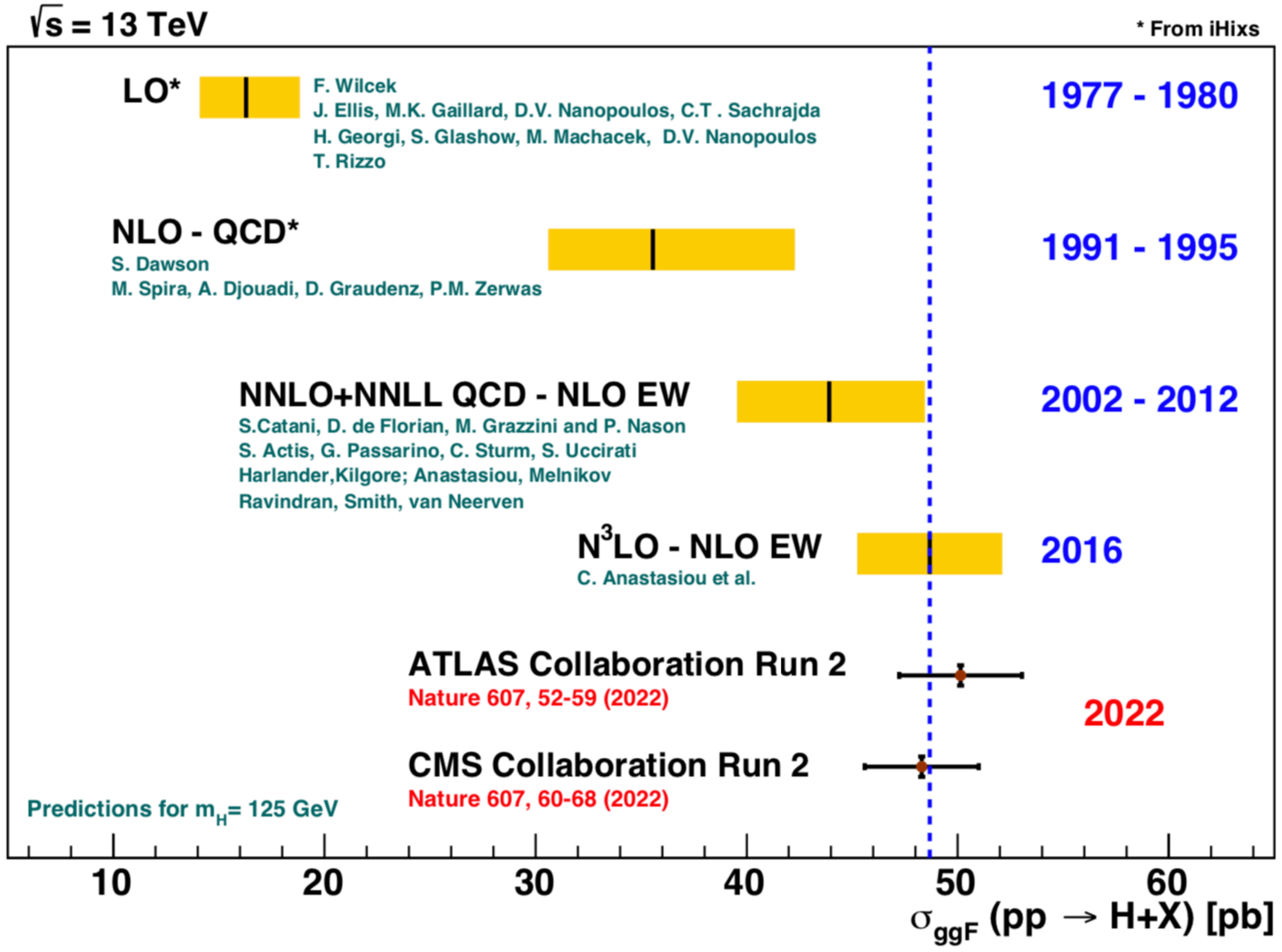
Expect to improve further since some STXS analyses were not included

H vs HH: Less variation, higher xsec

Summary

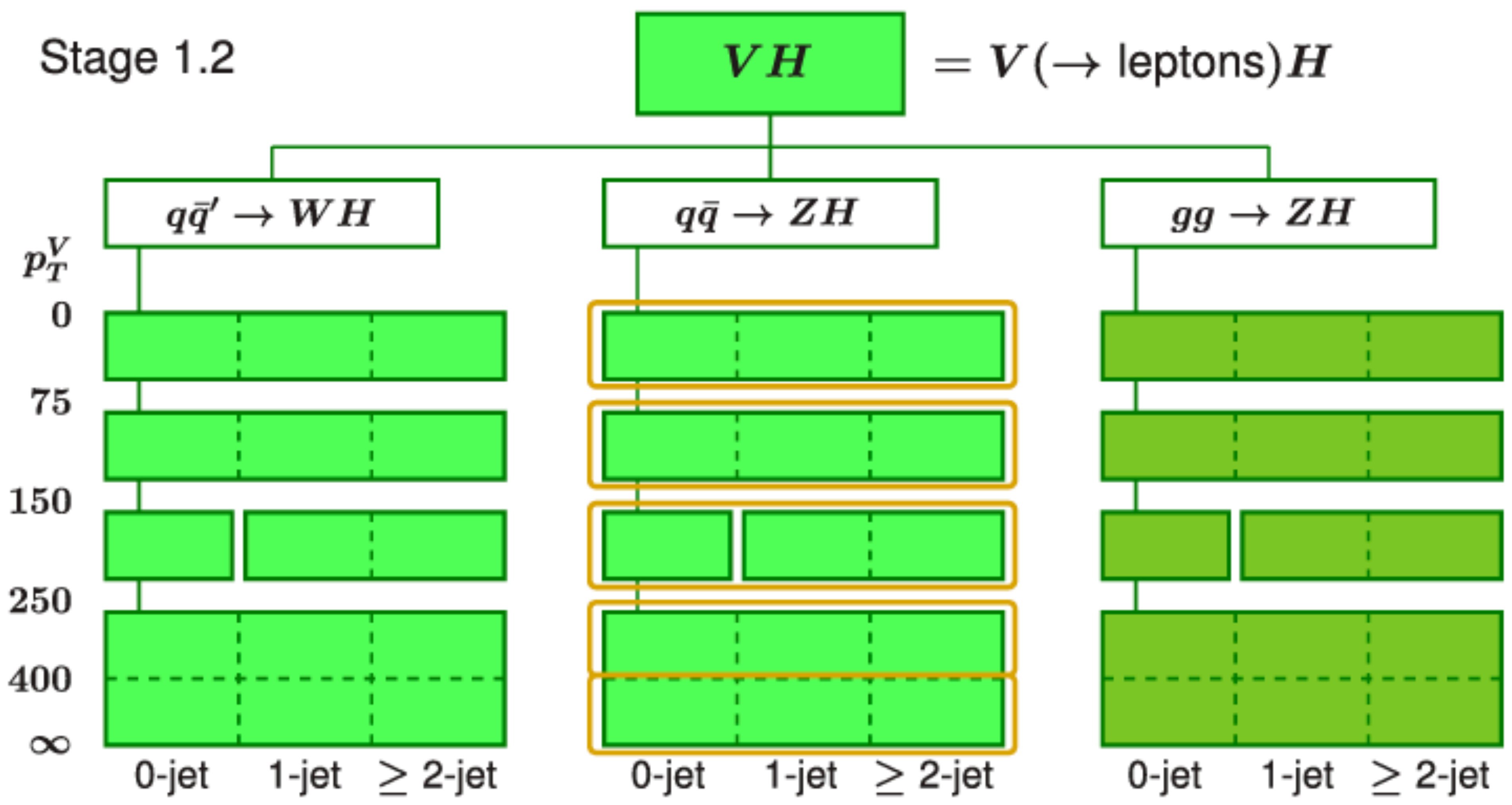
- An ever increasing precision of the H coupling to particles
- Useful to examine both direct and indirect couplings
- Further interpretation could be explored: specific BSM models, EFT..
- Improvements expected at Run3 and HL-LHC

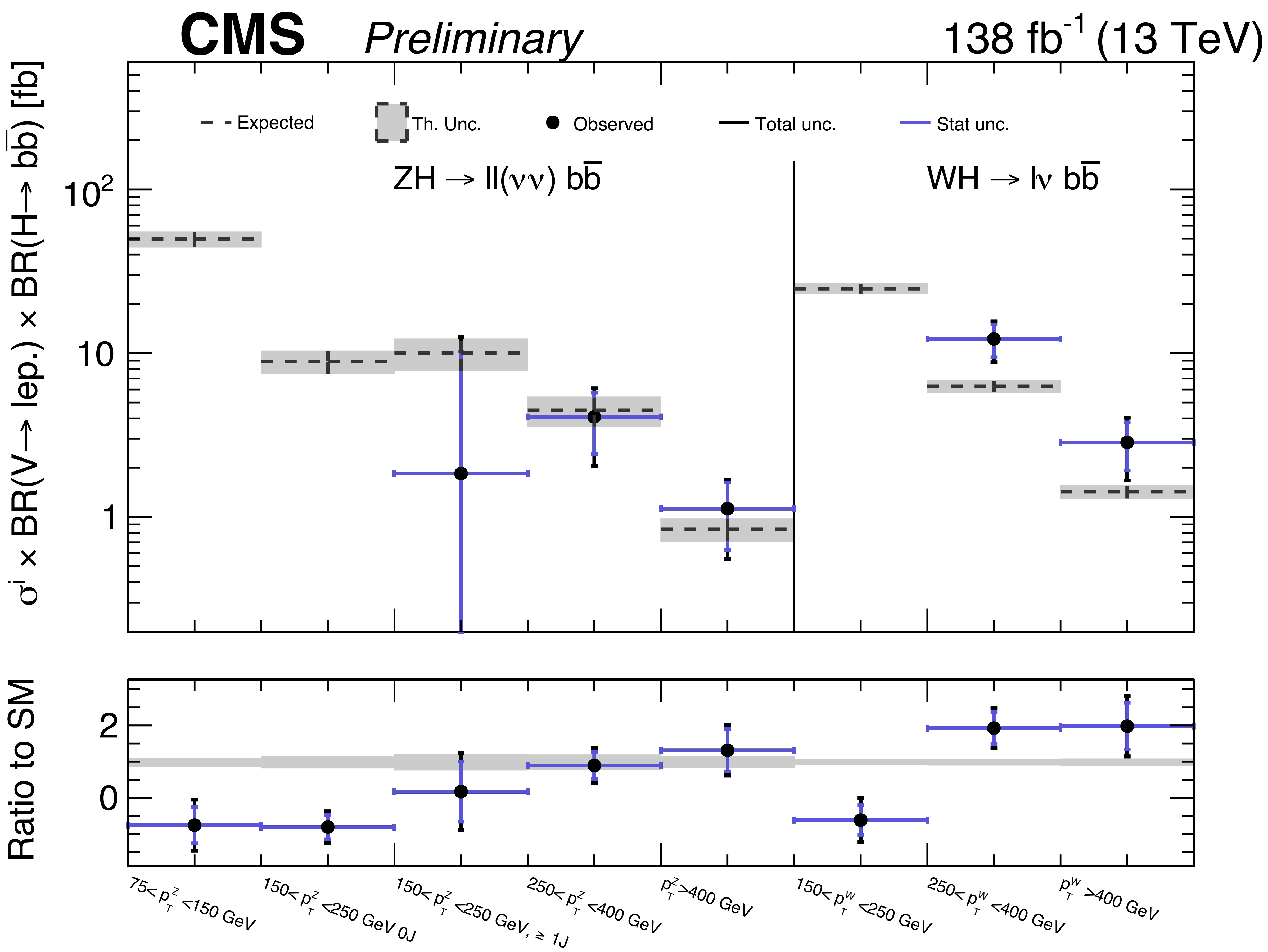
ggH prediction and measurements

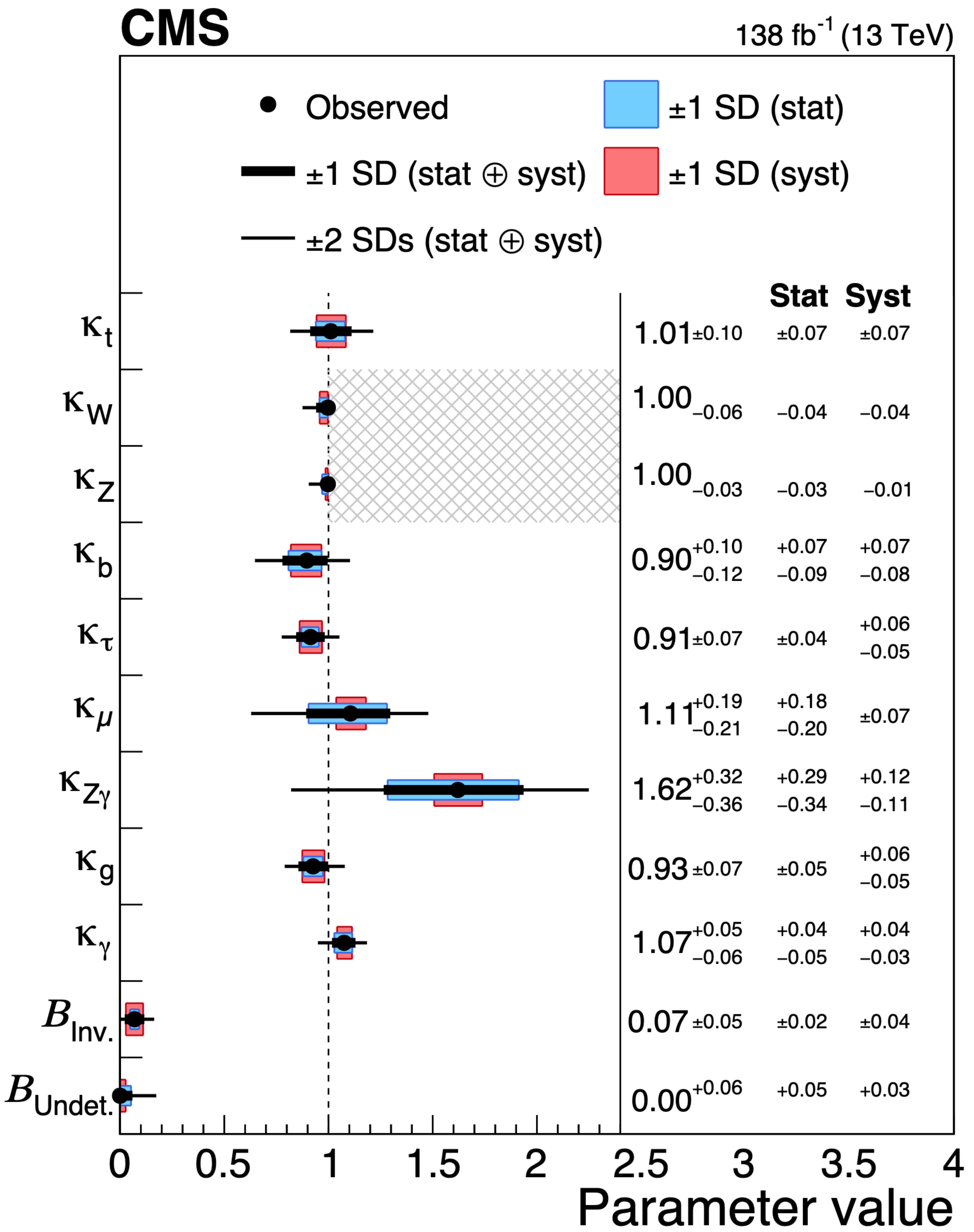


Courtesy Grazzini and Kado

An example of STXS measurement







CMS
138 fb-1 (13 TeV)
Observed
±1 SD (stat)
±1 SD (stat ⊕ syst)
±1 SD (syst)
±2 SDs (stat ⊕ syst)
Stat Syst
κt 1.01 ±0.10 ±0.07 ±0.07
κW 1.00 −0.06 −0.04 −0.04
κZ 1.00 −0.03 −0.03 −0.01
κb 0.90 +0.10 −0.12 +0.07 −0.09 +0.07 −0.08
κτ 0.91 ±0.07 ±0.04 +0.06 −0.05
κμ 1.11 +0.19 −0.21 +0.18 −0.20 ±0.07
κZγ 1.62 +0.32 −0.36 +0.29 −0.34 +0.12 −0.11
κg 0.93 ±0.07 ±0.05 +0.06 −0.05
κγ 1.07 +0.05 −0.06 +0.04 −0.05 +0.04 −0.03
B Inv. 0.07 ±0.05 ±0.02 ±0.04
B Undet. 0.00 +0.06 +0.05 +0.03
0 0.5 1 1.5 2 2.5 3 3.5 4
Parameter value