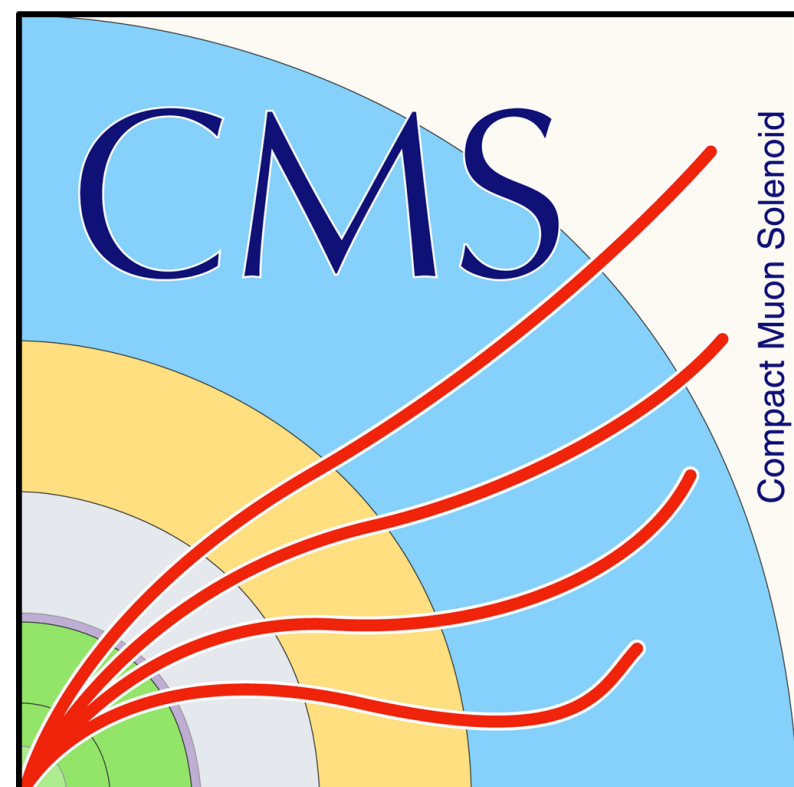


Status of Higgs boson precision measurements

Johannes Erdmann
on behalf of the ATLAS and CMS Collaboration

QCD@LHC 2024
Freiburg
October 8, 2024



Higgs Precision

events



$\sigma_{(\text{fid})}$ & $\frac{d\sigma}{dX}$

Y_f , & m & ...

rare H

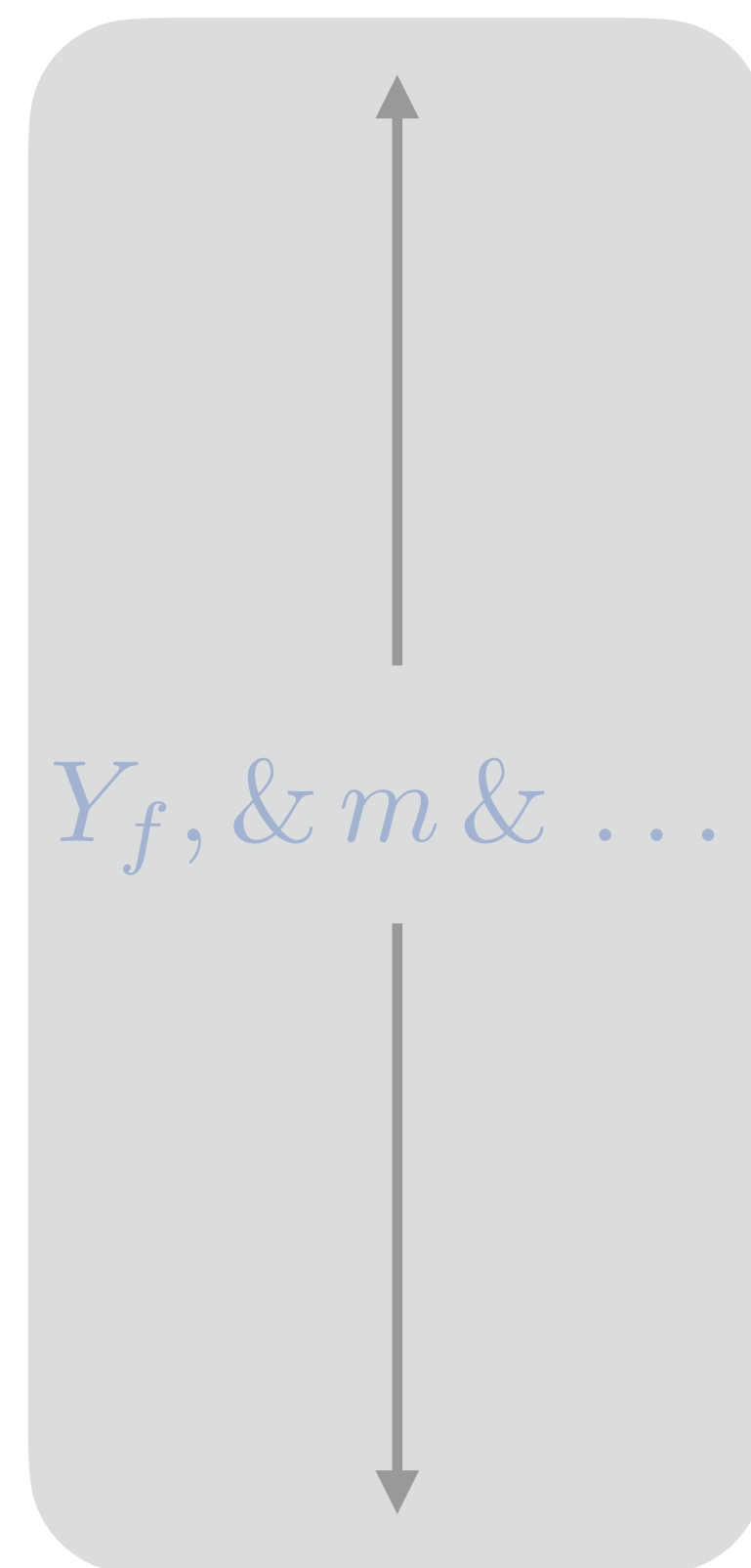
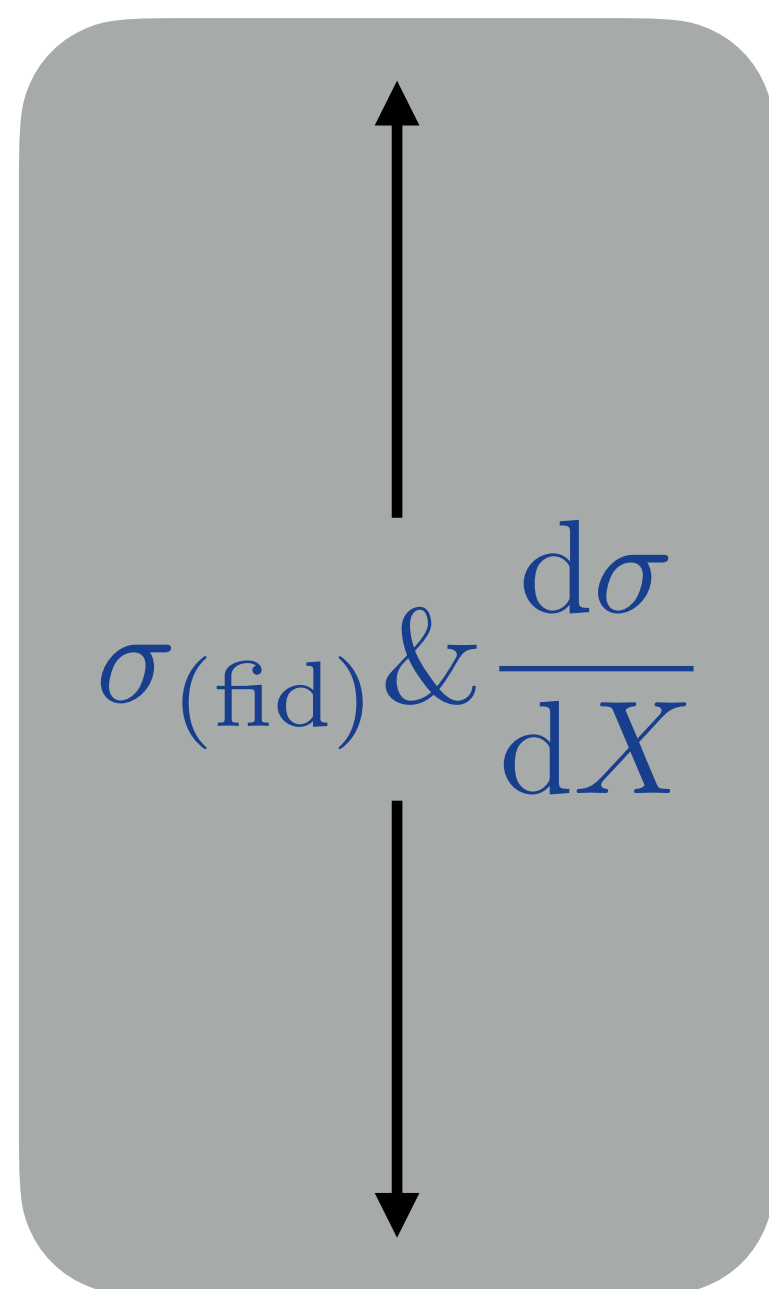
not in this talk

~~BSM H~~

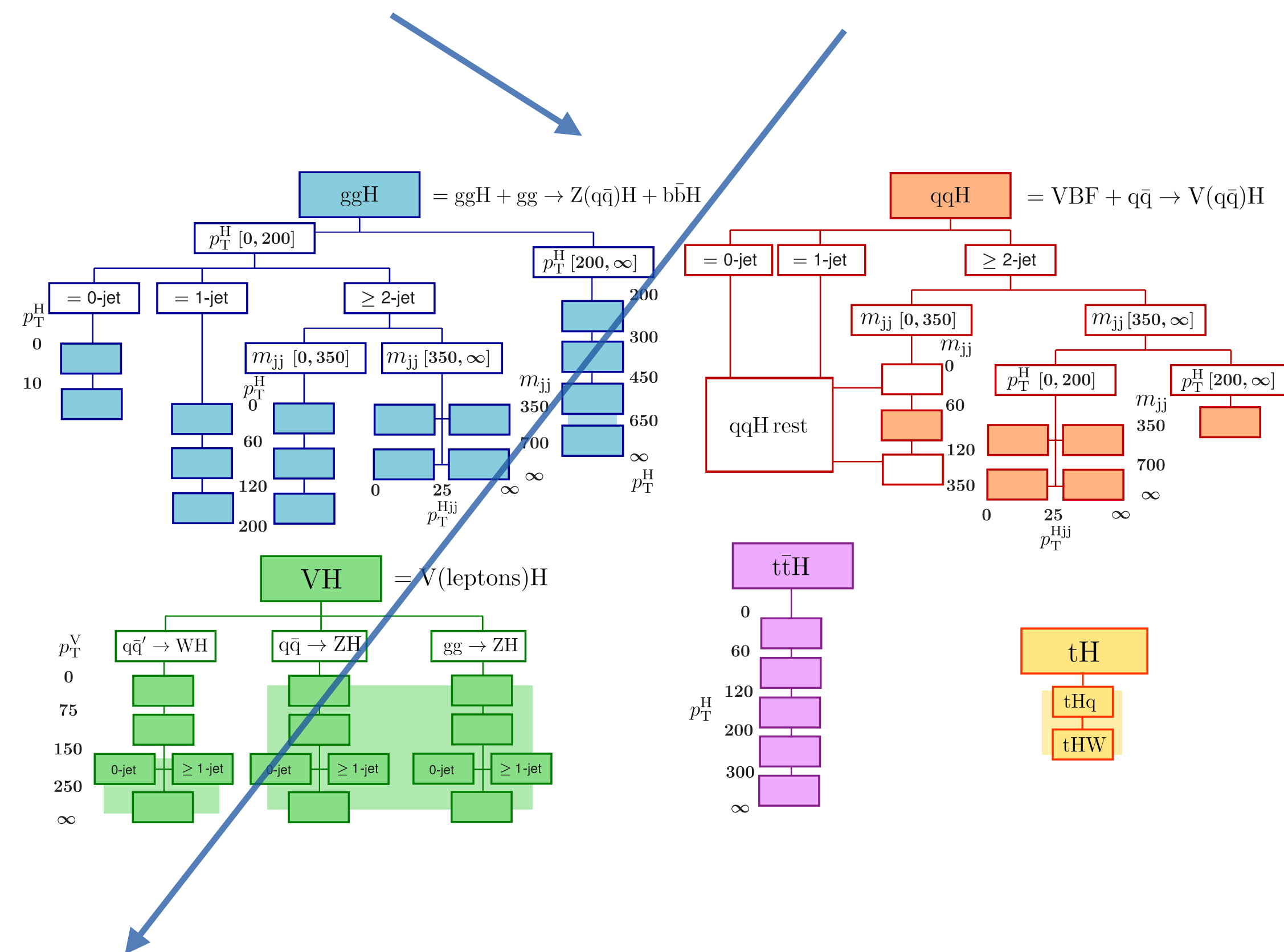
I will report on 12 new analyses that came out after Moriond this year

Fiducial Cross Sections

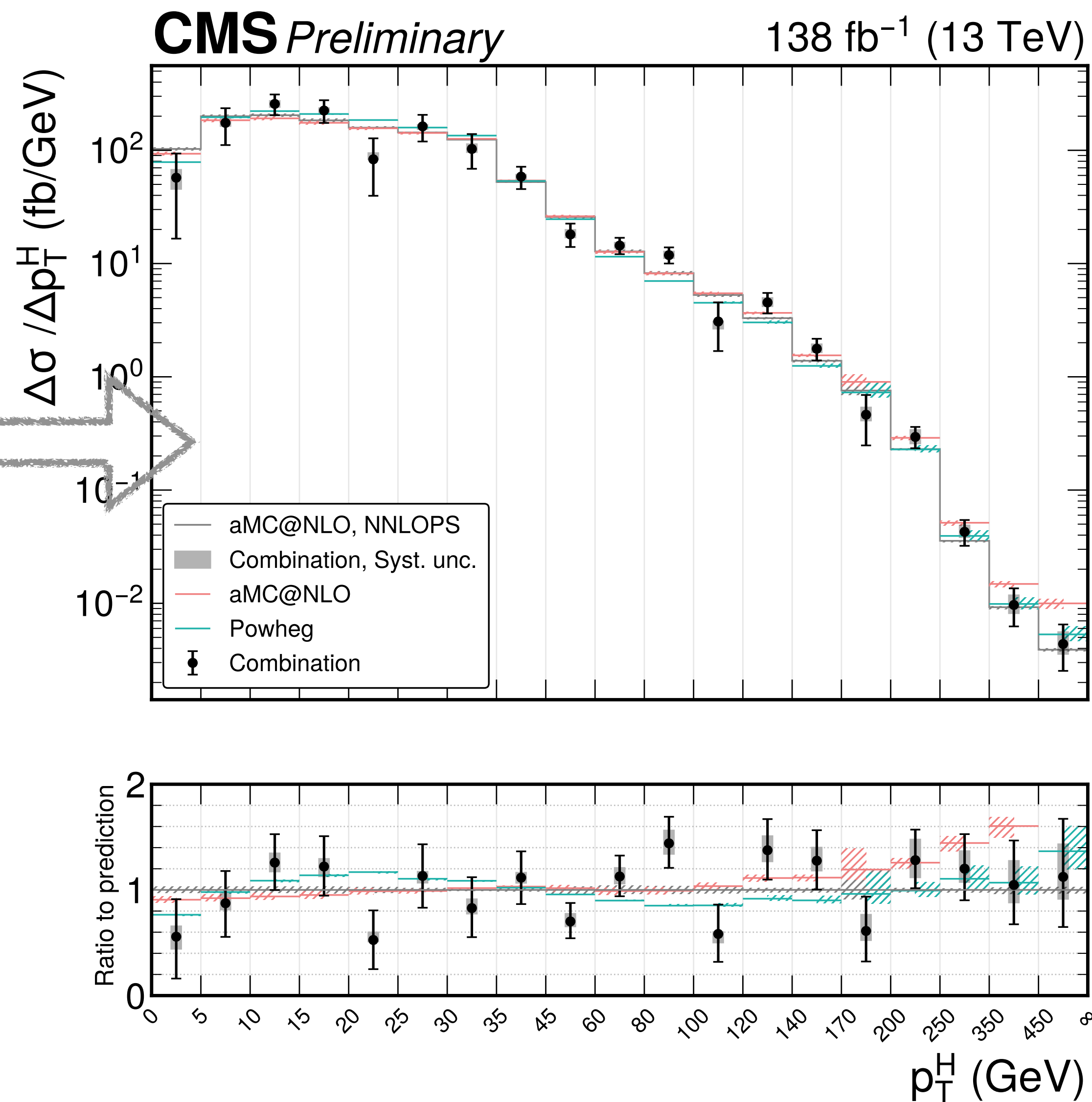
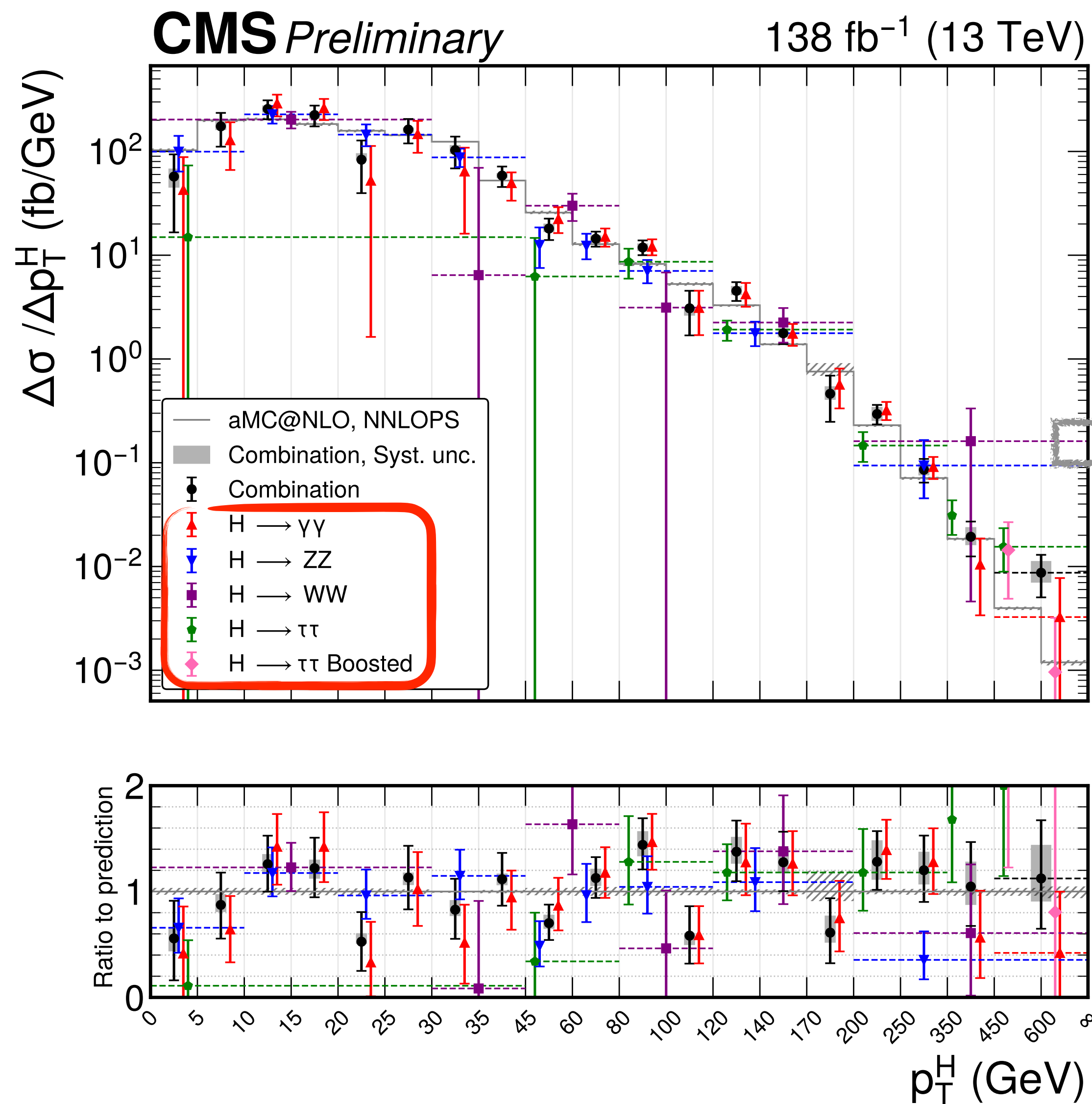
events



Two setups for differentials:
STXS & fiducial differential



[CMS-PAS-HIG-23-013](#) [CMS-PAS-HIG-24-013](#) [CMS-PAS-HIG-23-014](#)
[arXiv:2407.16320 \(ATLAS\)](#) [ATLAS-CONF-2024-010](#)

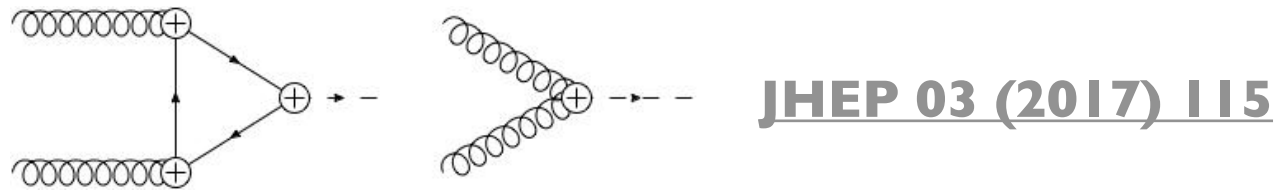


+ N_{jets} , p_{T}^{jet} , $|y_H|$, $\Delta\eta_{jj}$, m_{jj} , τ_c^j from the combination of 2-4 channels

Measurements mostly sensitive to gluon fusion and BRs

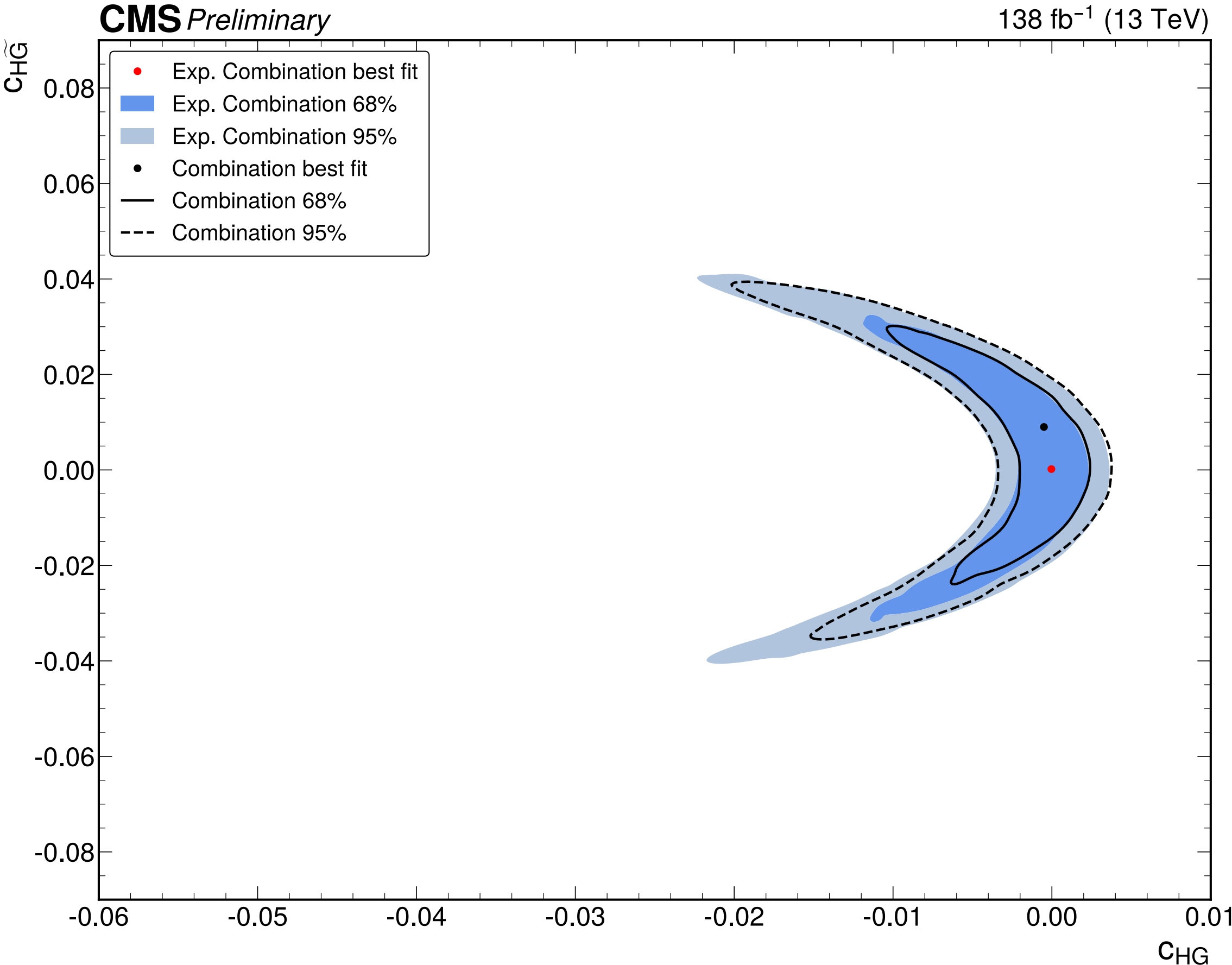
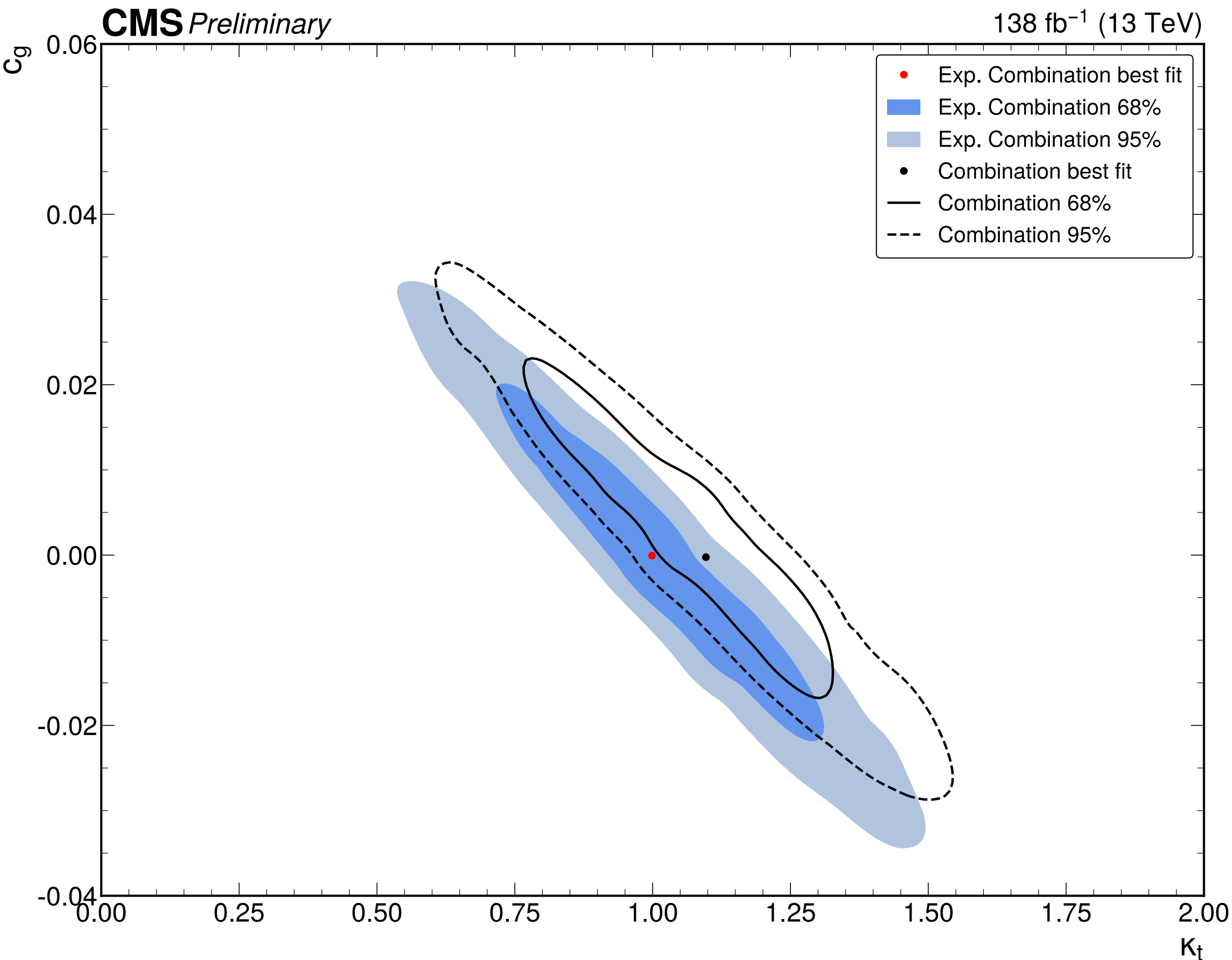
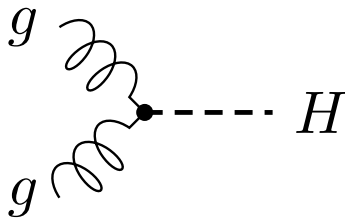
Interpretations in K framework ...

... and in dim-6 SMEFT



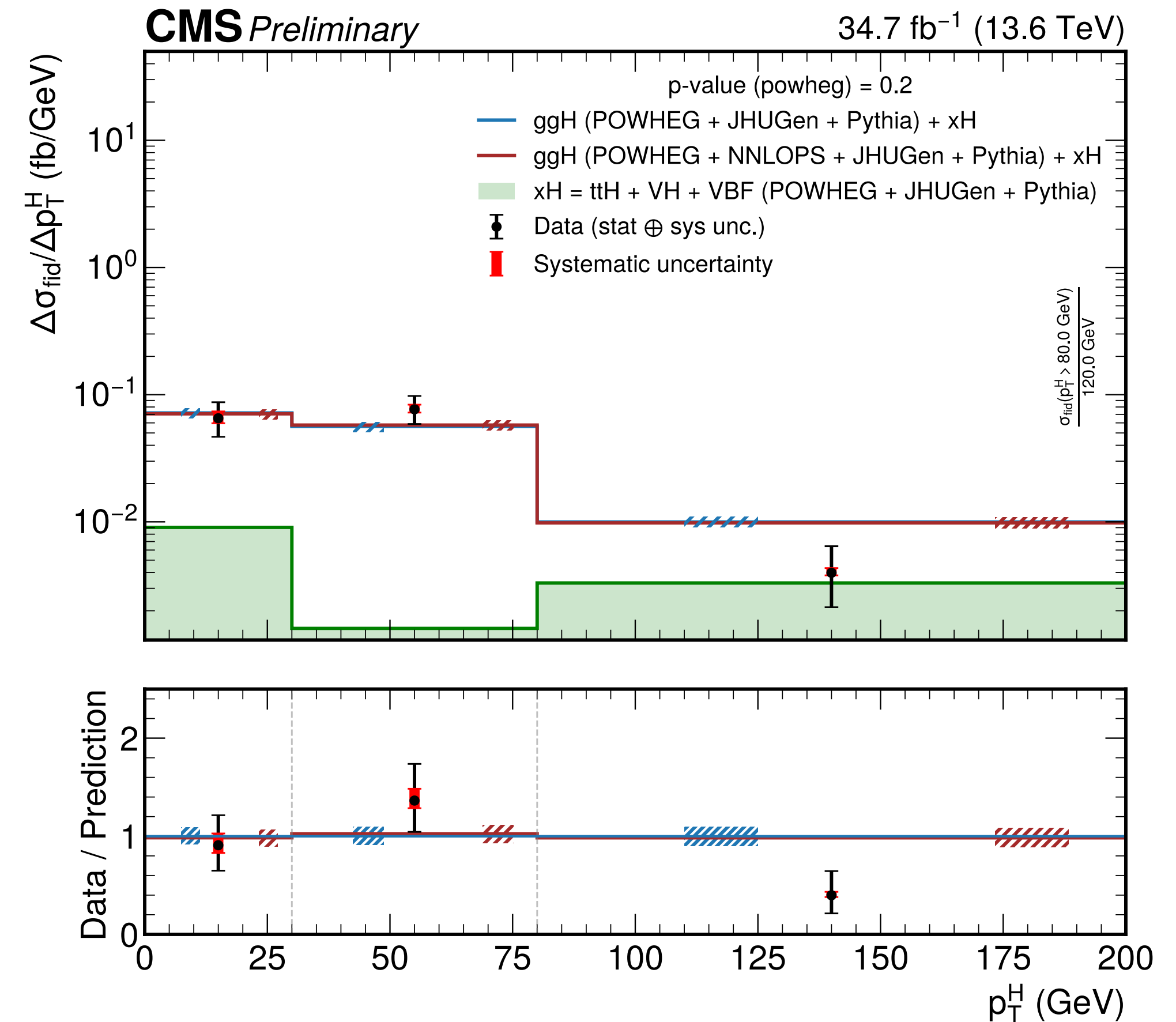
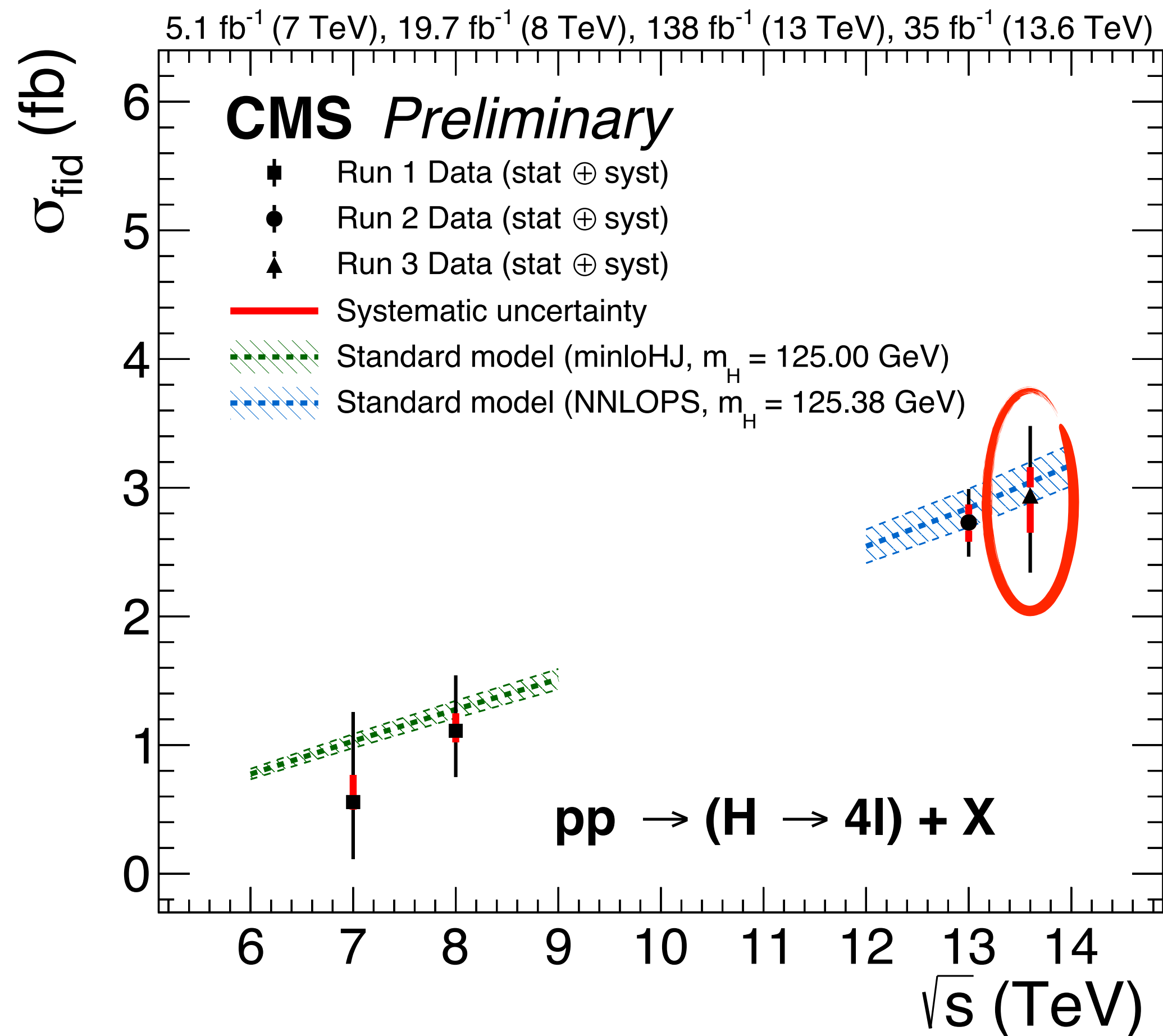
$$H^\dagger H G_{\mu\nu}^a G^{a\mu\nu} \quad c_{HG}$$

$$H^\dagger H \tilde{G}_{\mu\nu}^a G^{a\mu\nu} \quad \tilde{c}_{HG}$$



Fiducial, total and first differential measurements with Run-3 data ($p_T, |y|$)

$$\sigma_{\text{fid}} = 2.94^{+0.53}_{-0.49} \text{ (stat.) } ^{+0.29}_{-0.22} \text{ (syst.) fb} \quad \text{with} \quad \sigma_{\text{fid}} = 3.09^{+0.27}_{-0.24} \text{ fb predicted}$$



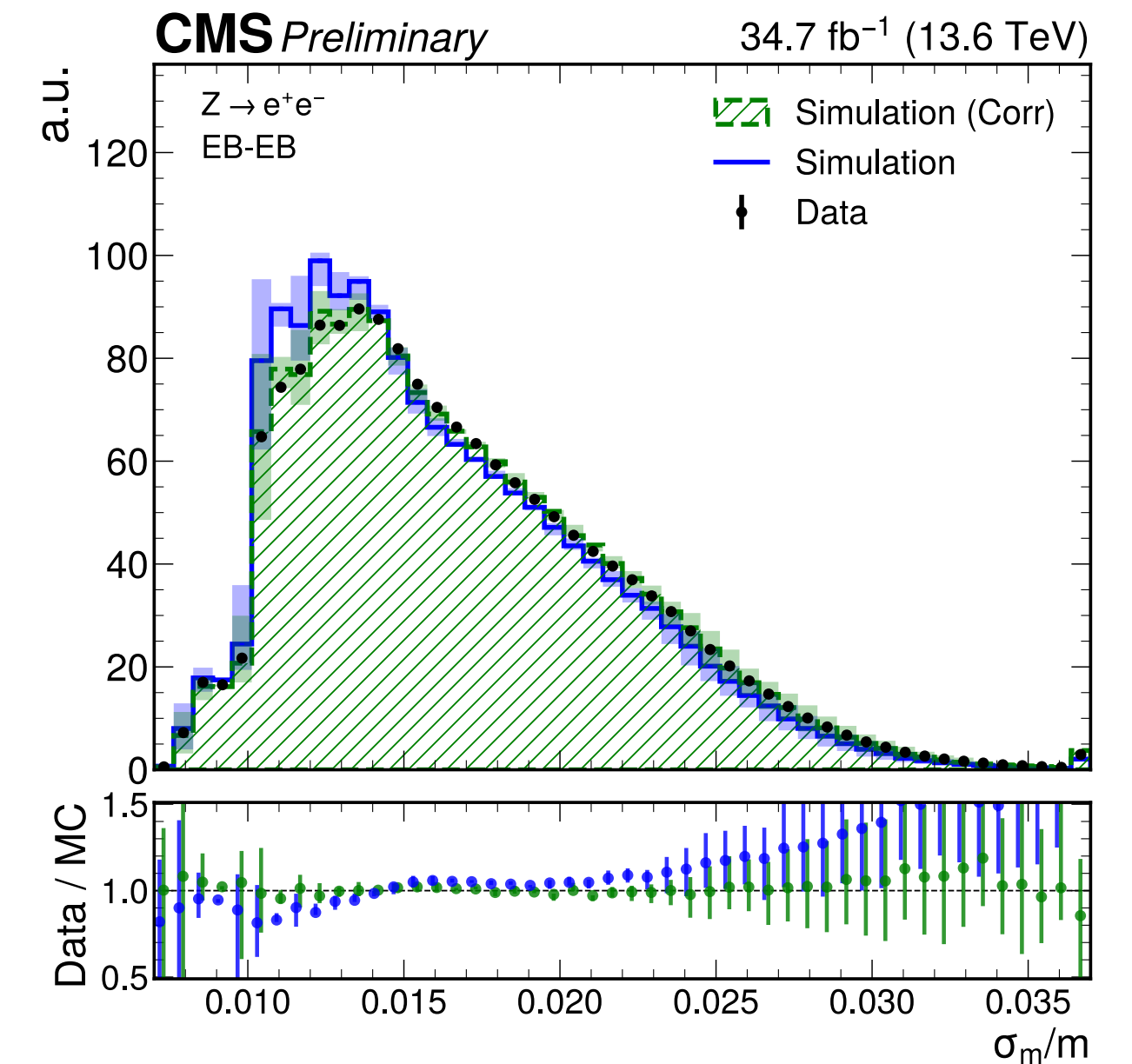
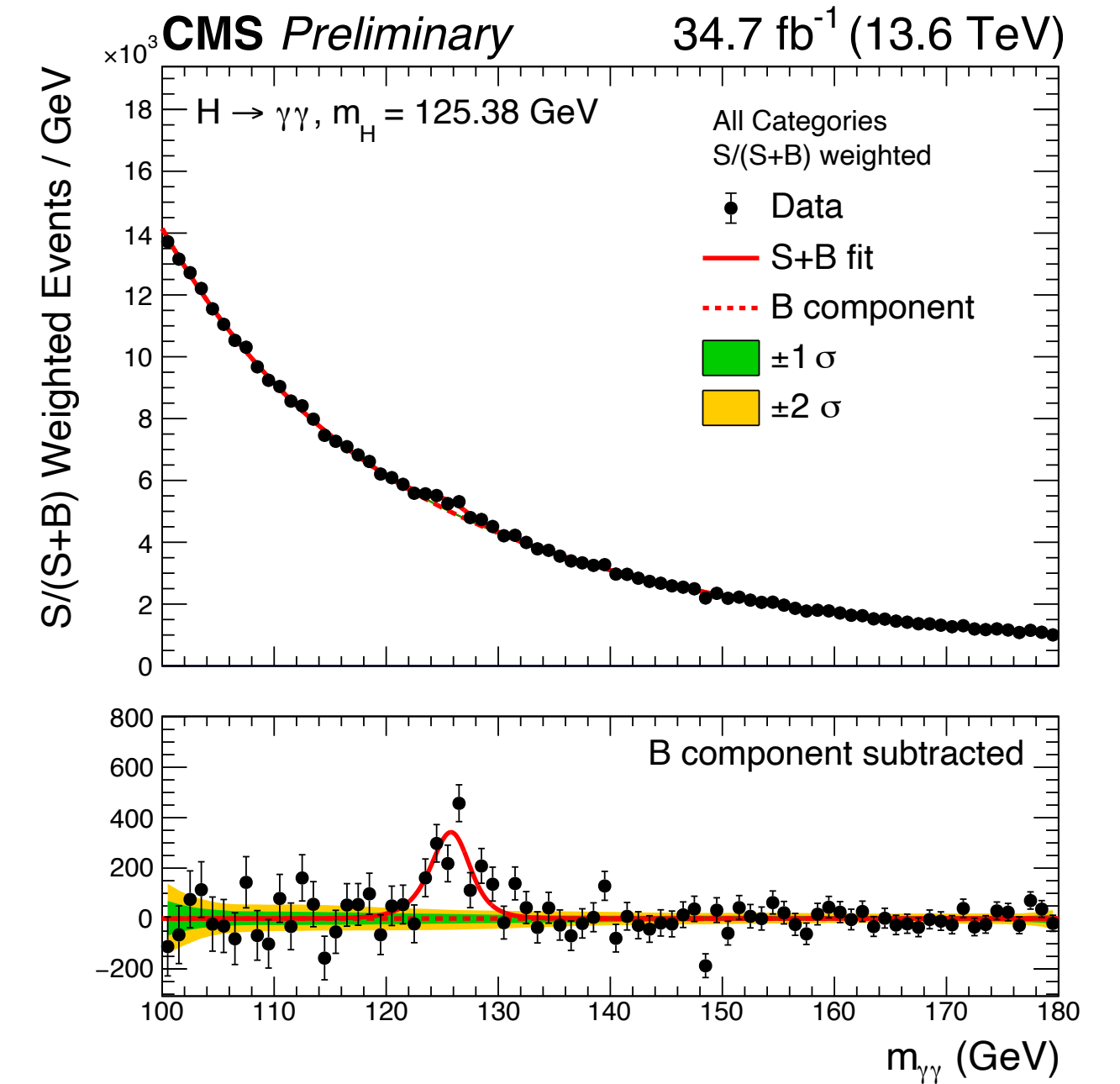
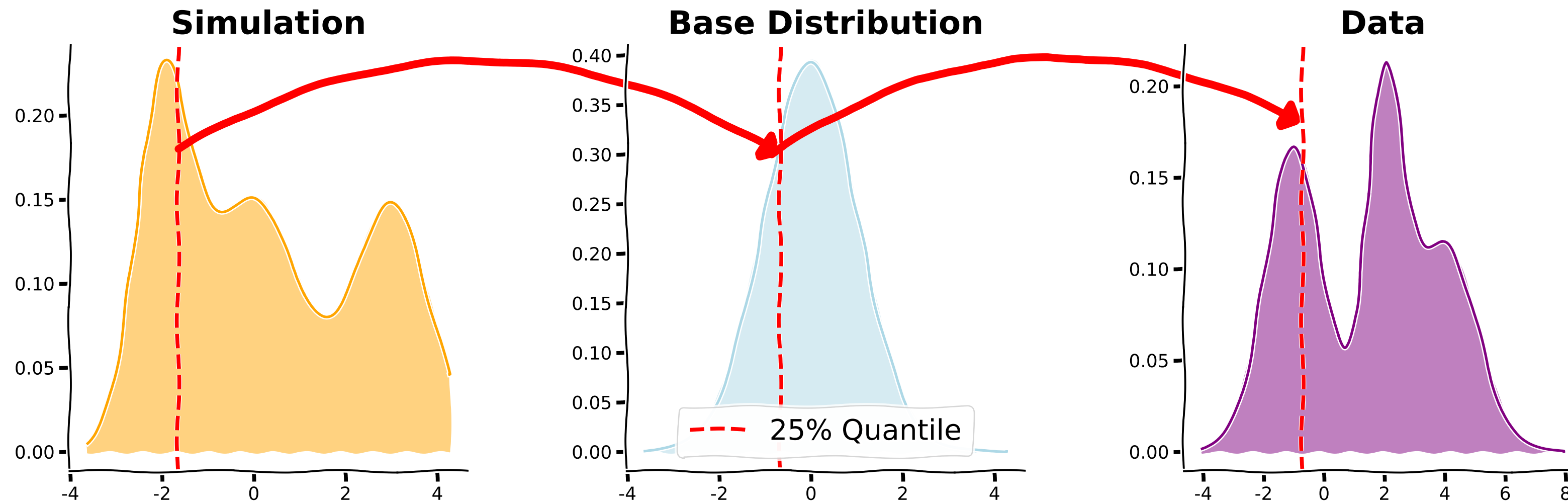
$m_{\gamma\gamma}$ fits in categories meant to reduce model dependence

- Photon ID & $m_{\gamma\gamma}$ resolution

Novel multi-dimensional corrections for simulations

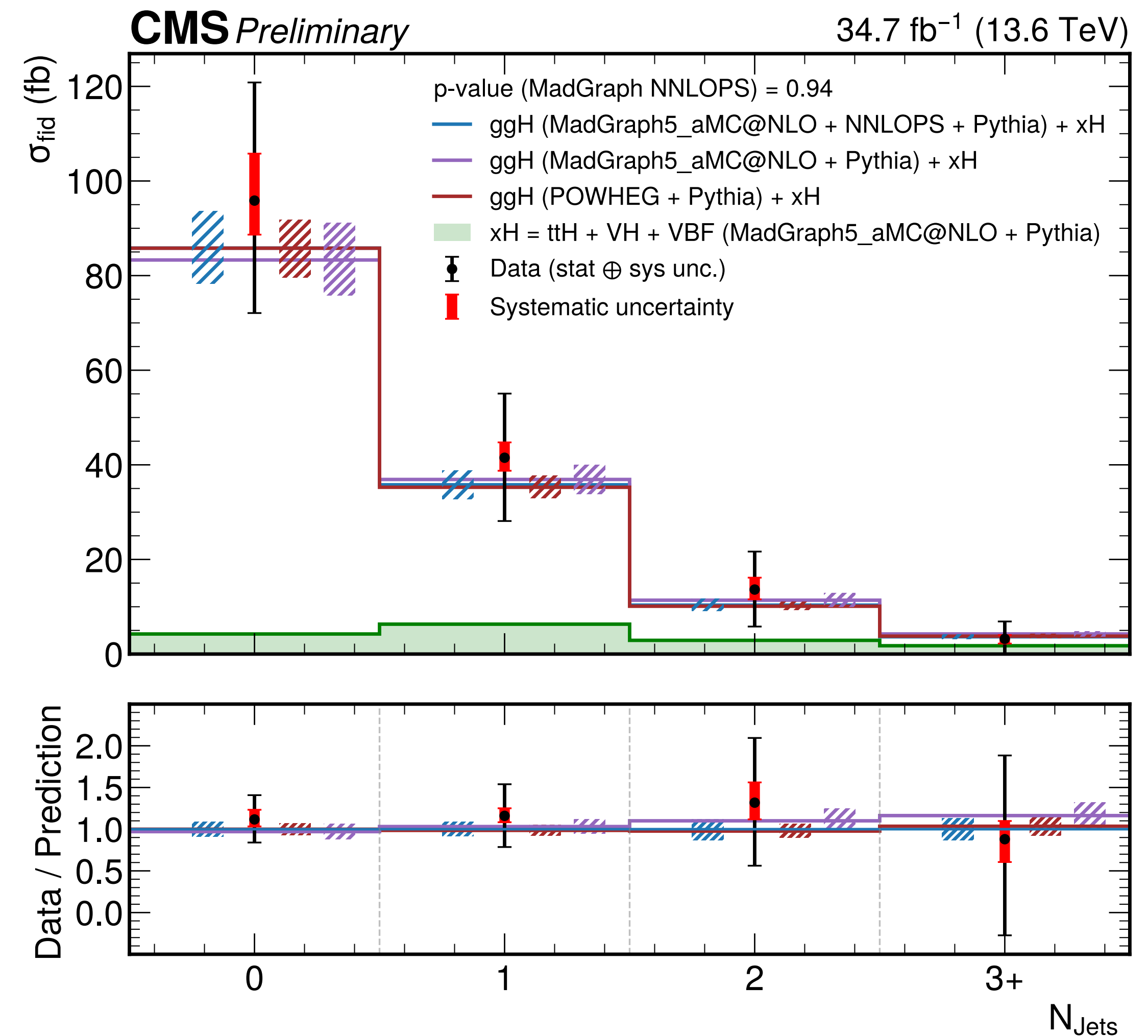
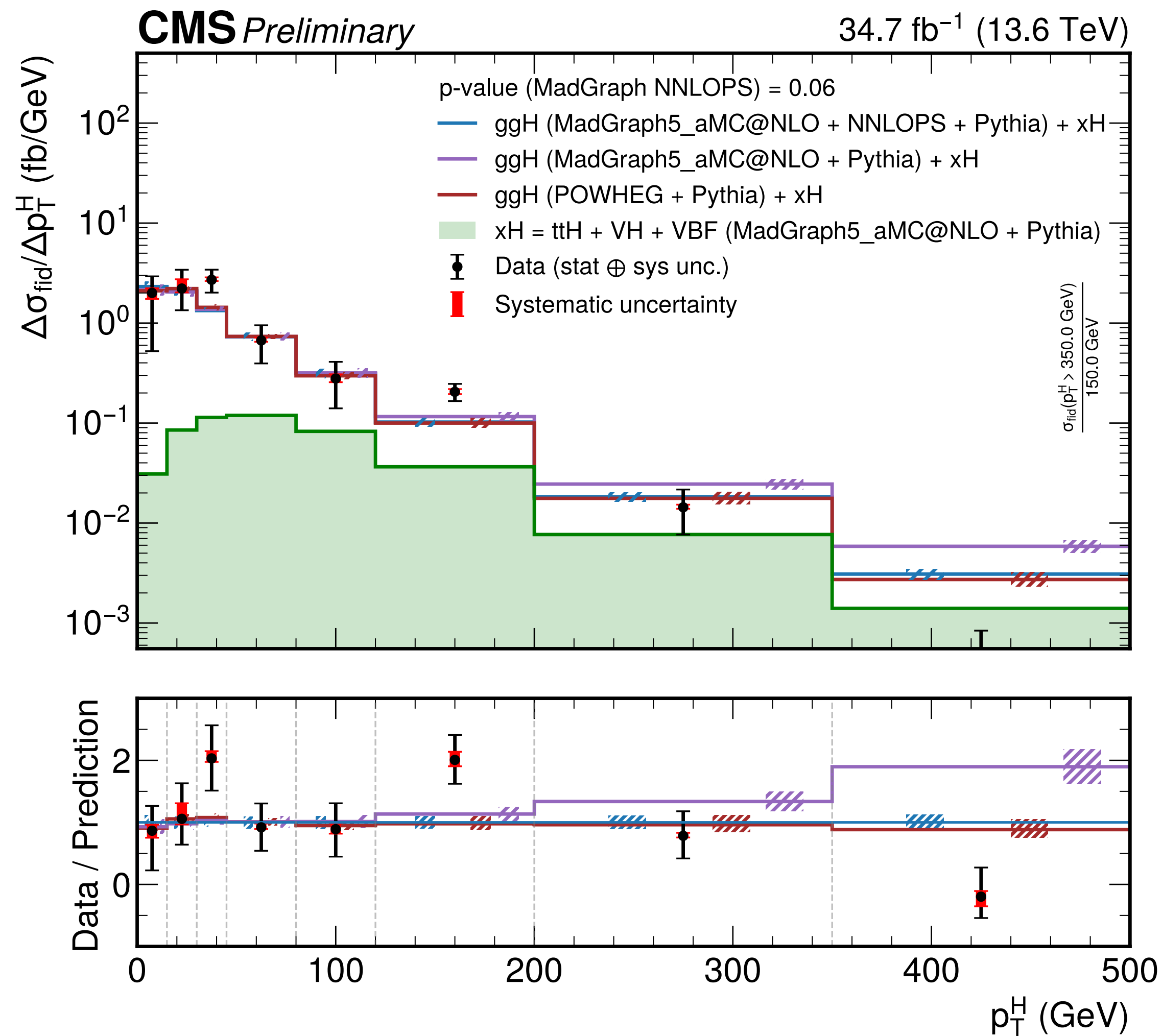
based on rational quadratic spline flows

CSBS 8 (2024) 15



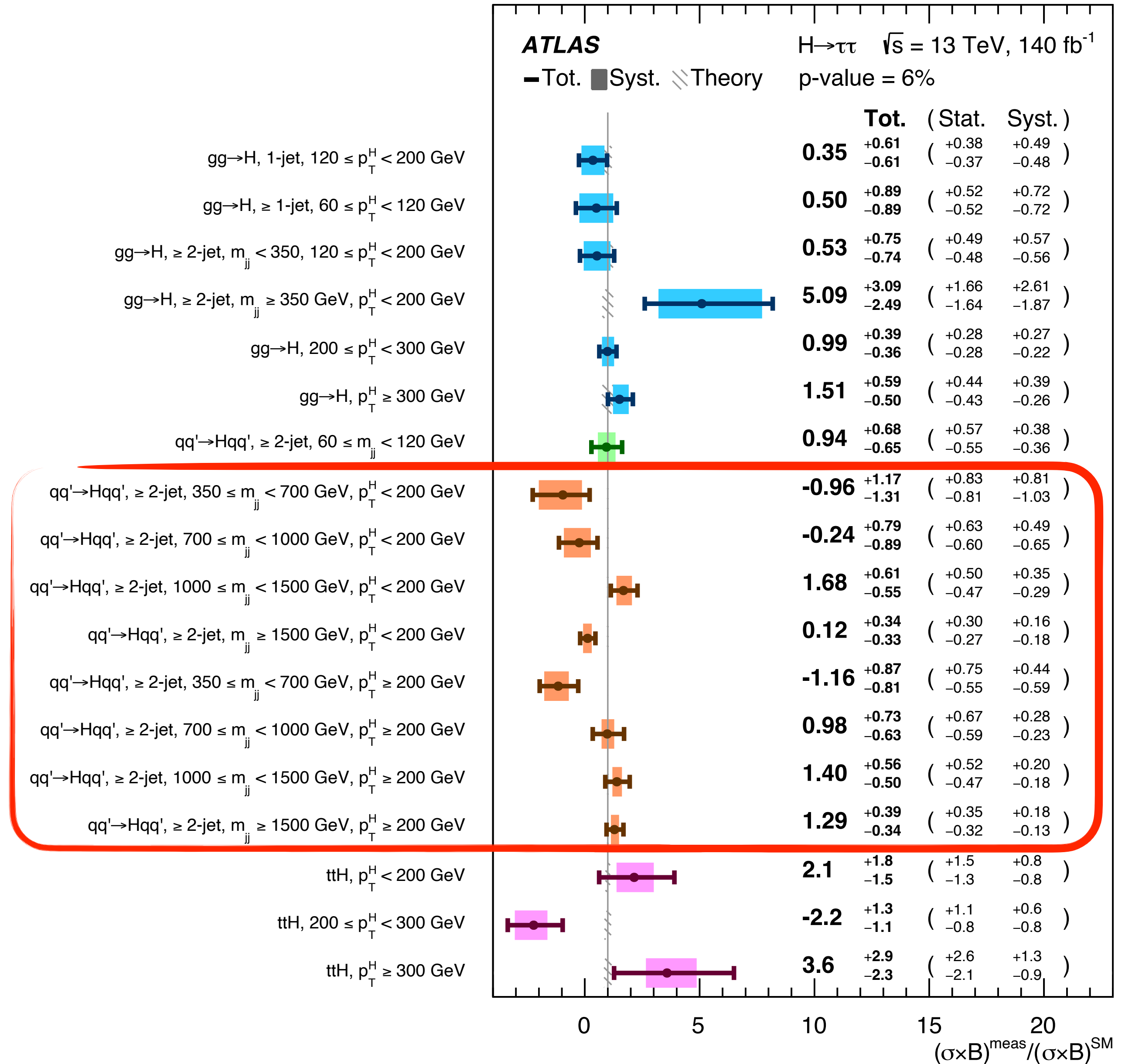
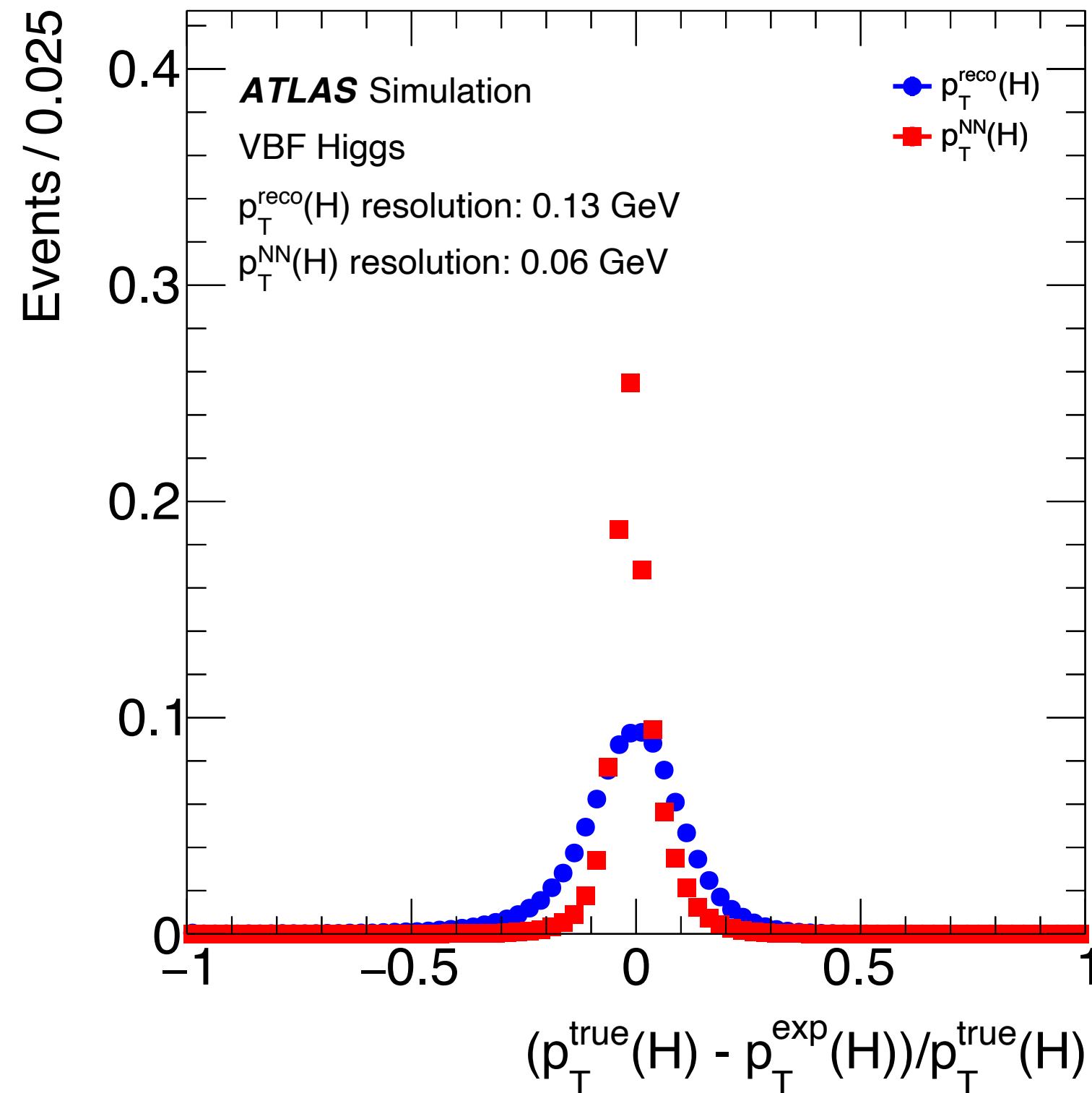
Fiducial and first differential measurements with Run-3 data (p_T , $|y|$, N_{jets})

$\sigma_{\text{fid}} = 78 \pm 11 \text{ (stat.) } {}^{+6}_{-5} \text{ (syst.) fb}$ with $\sigma_{\text{fid}} = 67.8 \pm 3.8 \text{ fb}$ expected

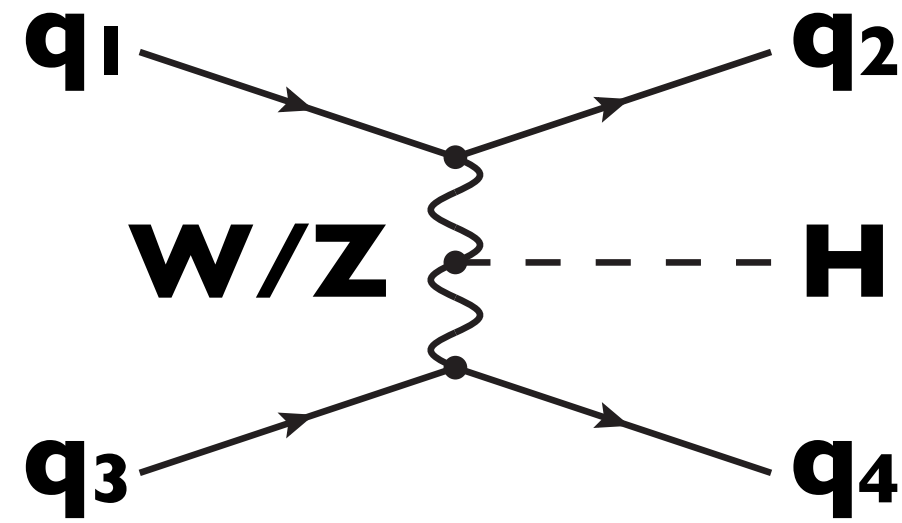


Updated measurement of [JHEP 08 \(2022\) 175](#)

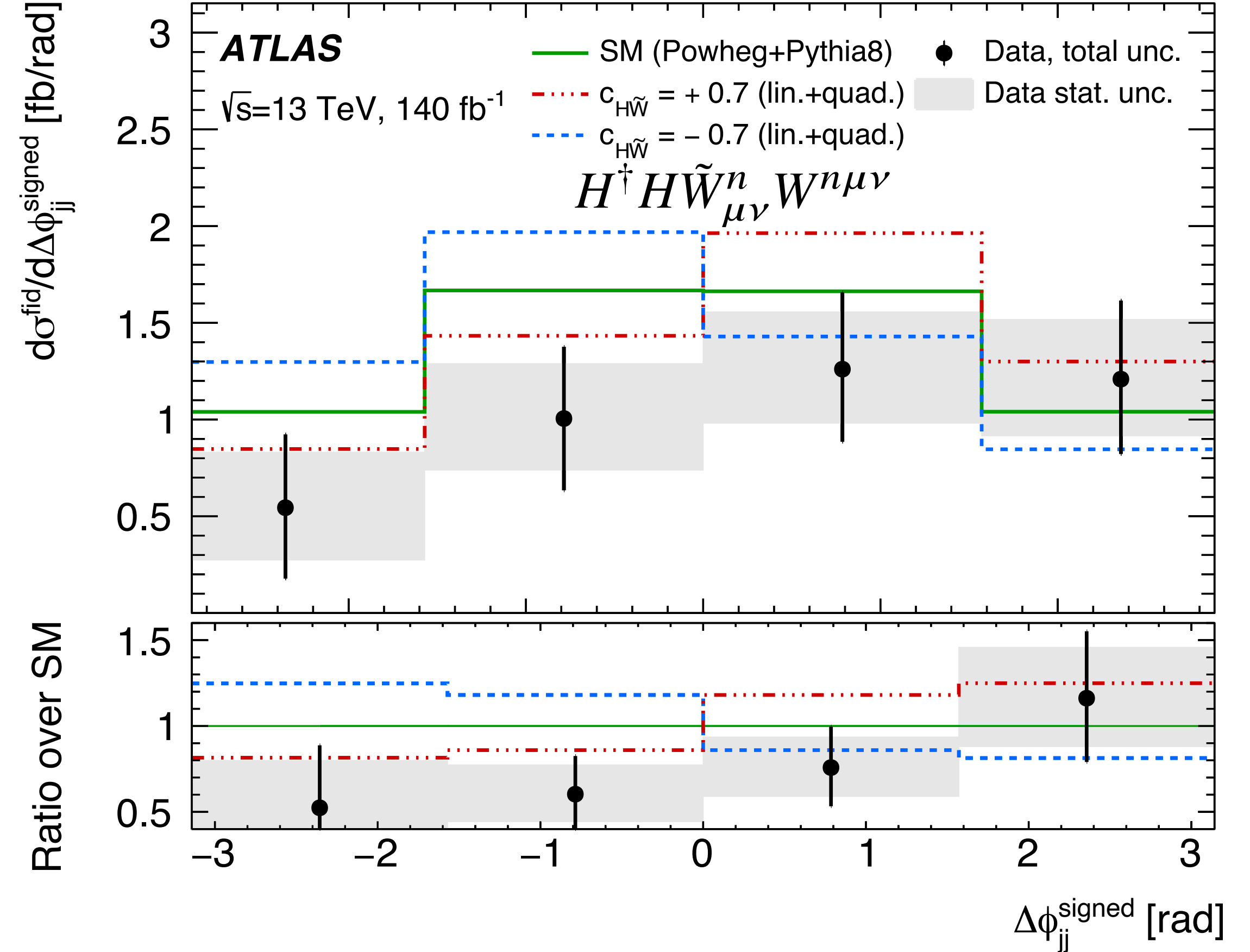
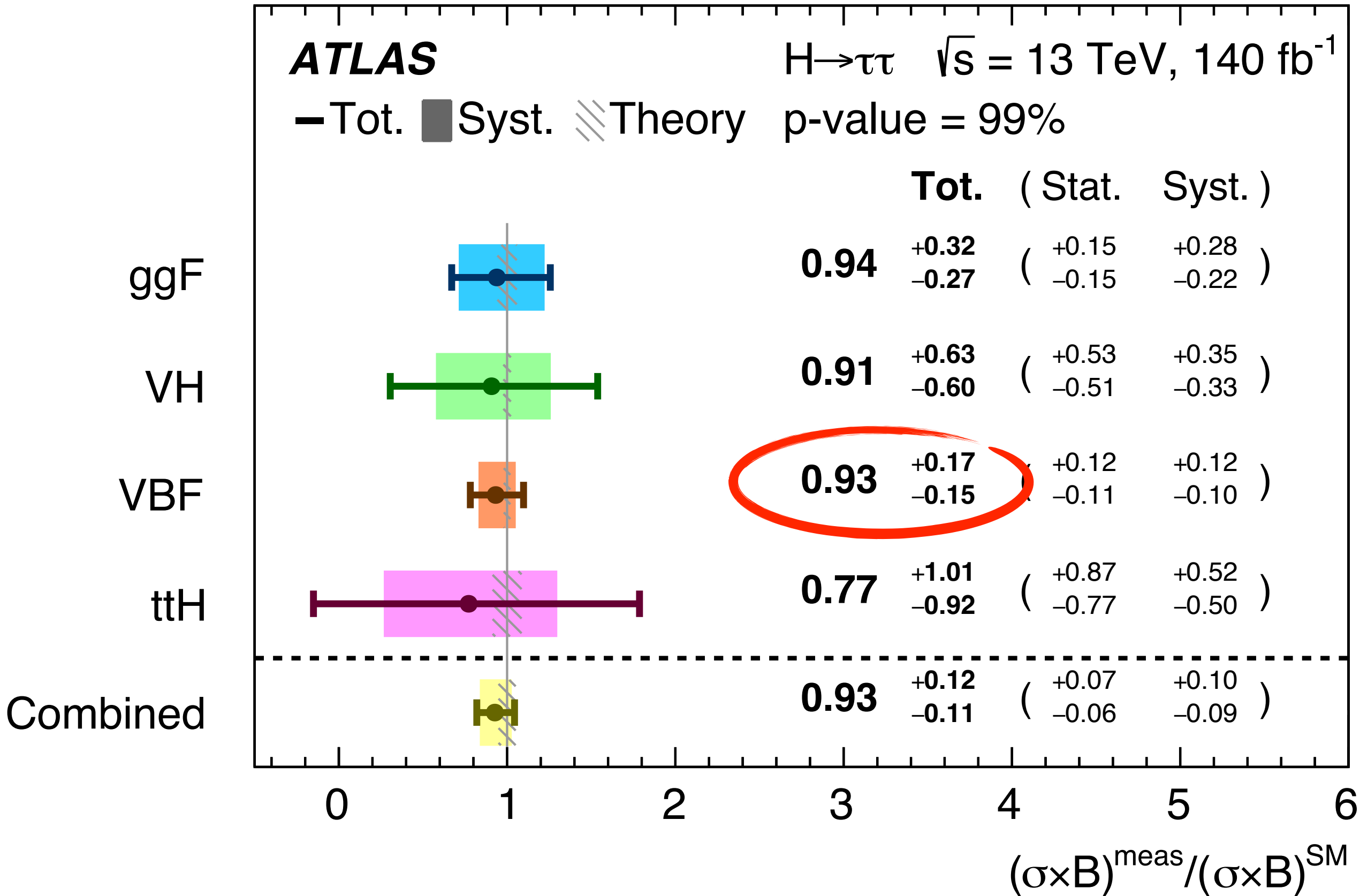
- 8 STXS bins for VBF
- improved $t\bar{t}H$ (had.) classification
- p_T^H regression with NN



Best single measurement of VBF production



Also $d\sigma_{\text{fid}}/dX$ in VBF phase space, including CP-interpretation of $\Delta\phi_{jj}^{\text{signed}}$



Updated measurement of [PLB 816 \(2021\) 136204](#), [EPJC 81 \(2021\) 178](#) and [EPJC 82 \(2022\) 717](#)

- Now $H \rightarrow b\bar{b}$ and $H \rightarrow c\bar{c}$ combined

Improvements to

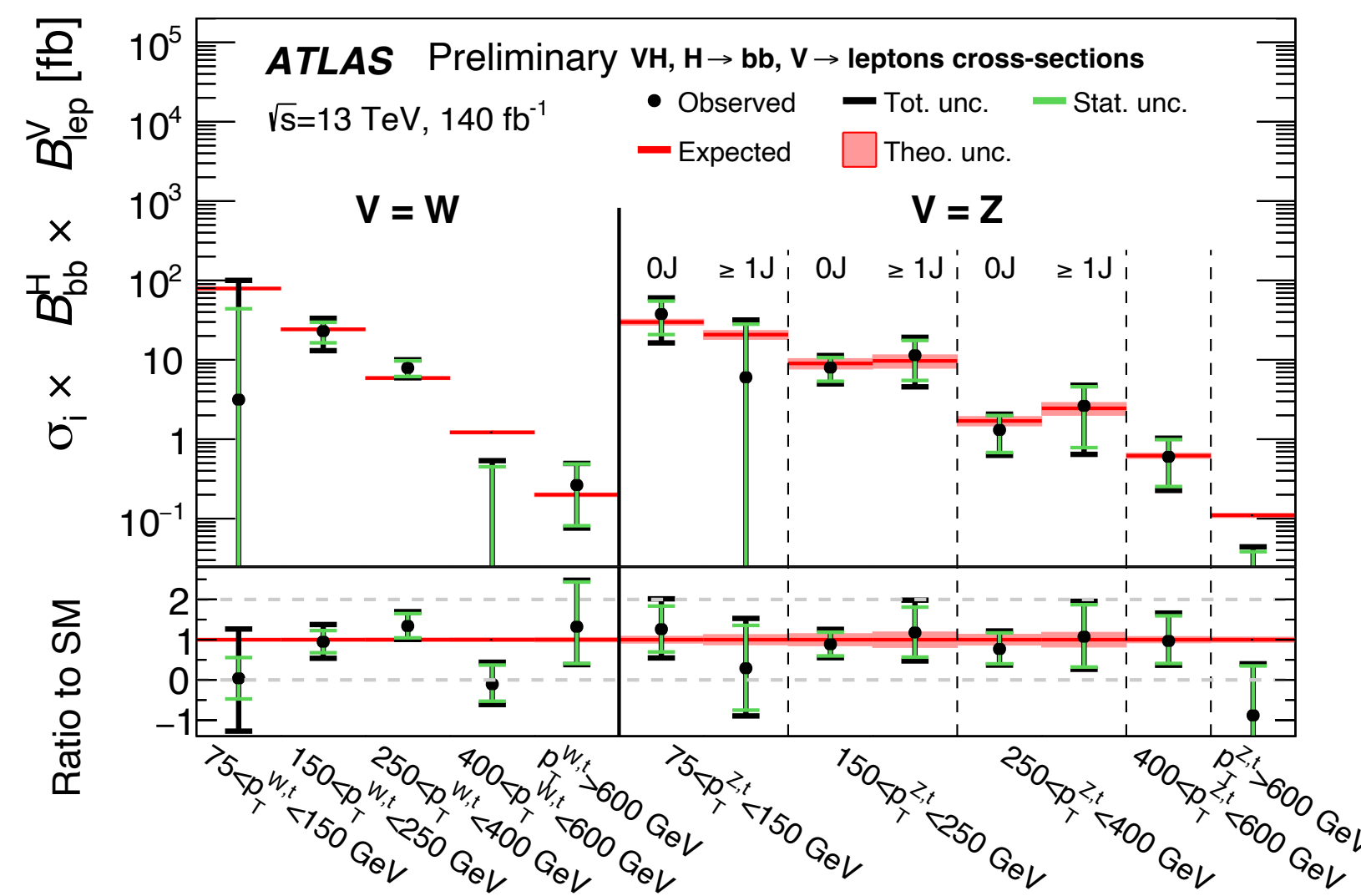
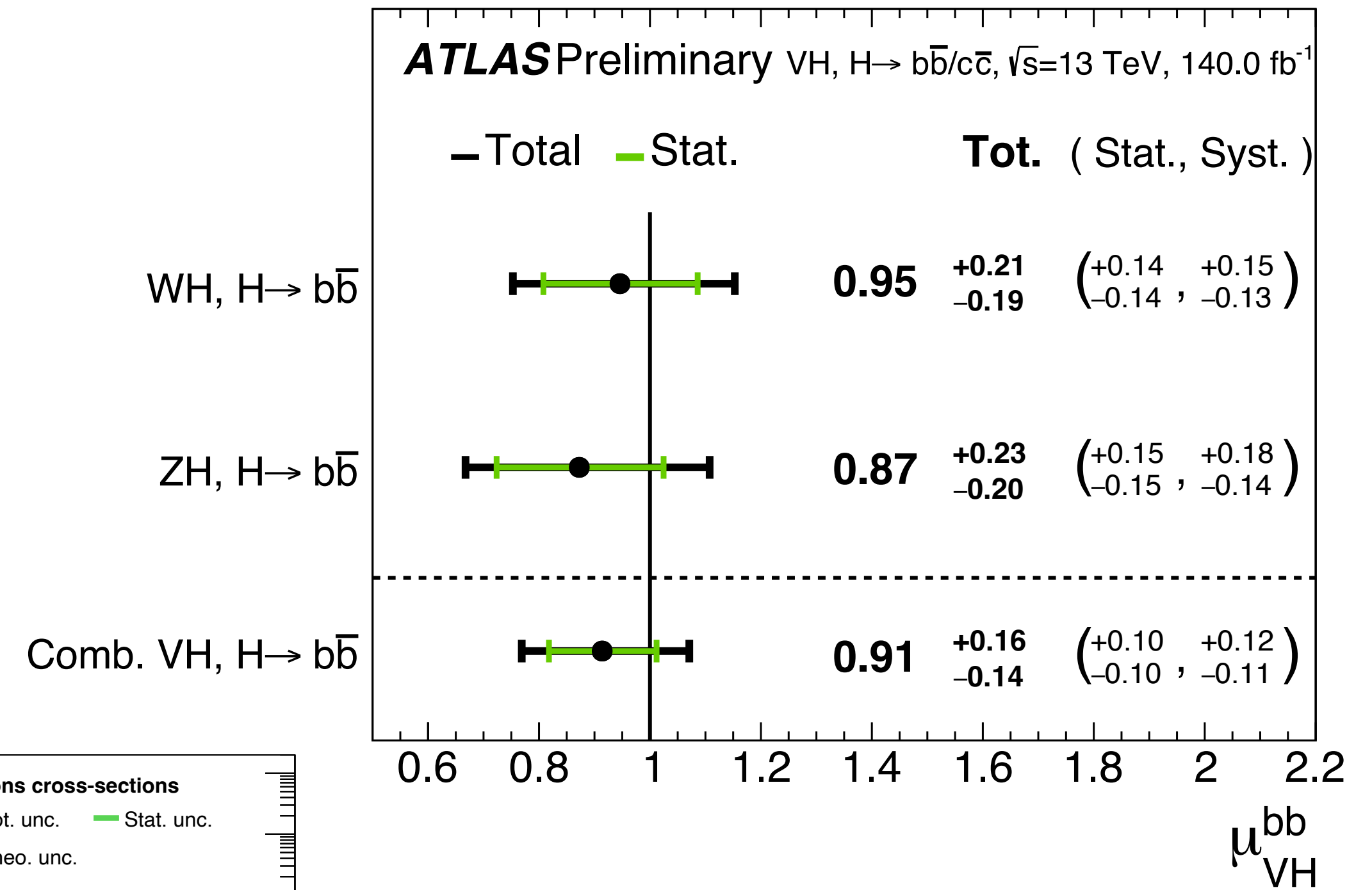
- Flavour tagging (DL1r), event classification
- Monte Carlo statistics (Sherpa 2.2.11, truth-tagging, CARL)

~20% improvement in $\sigma_{VH(b\bar{b})}$

First single observations of

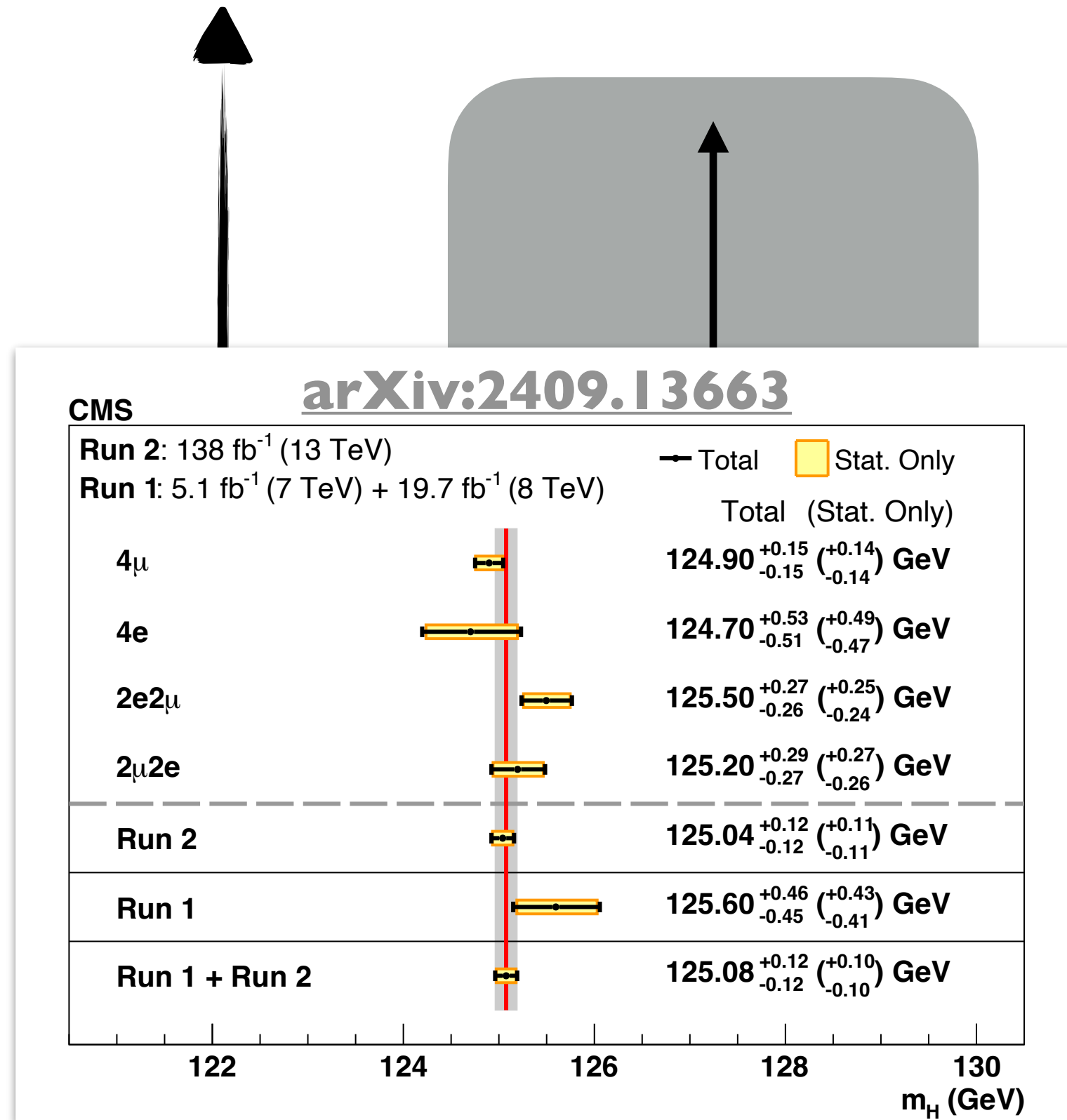
- $WH(b\bar{b})$ with 5.3σ

+ STXS

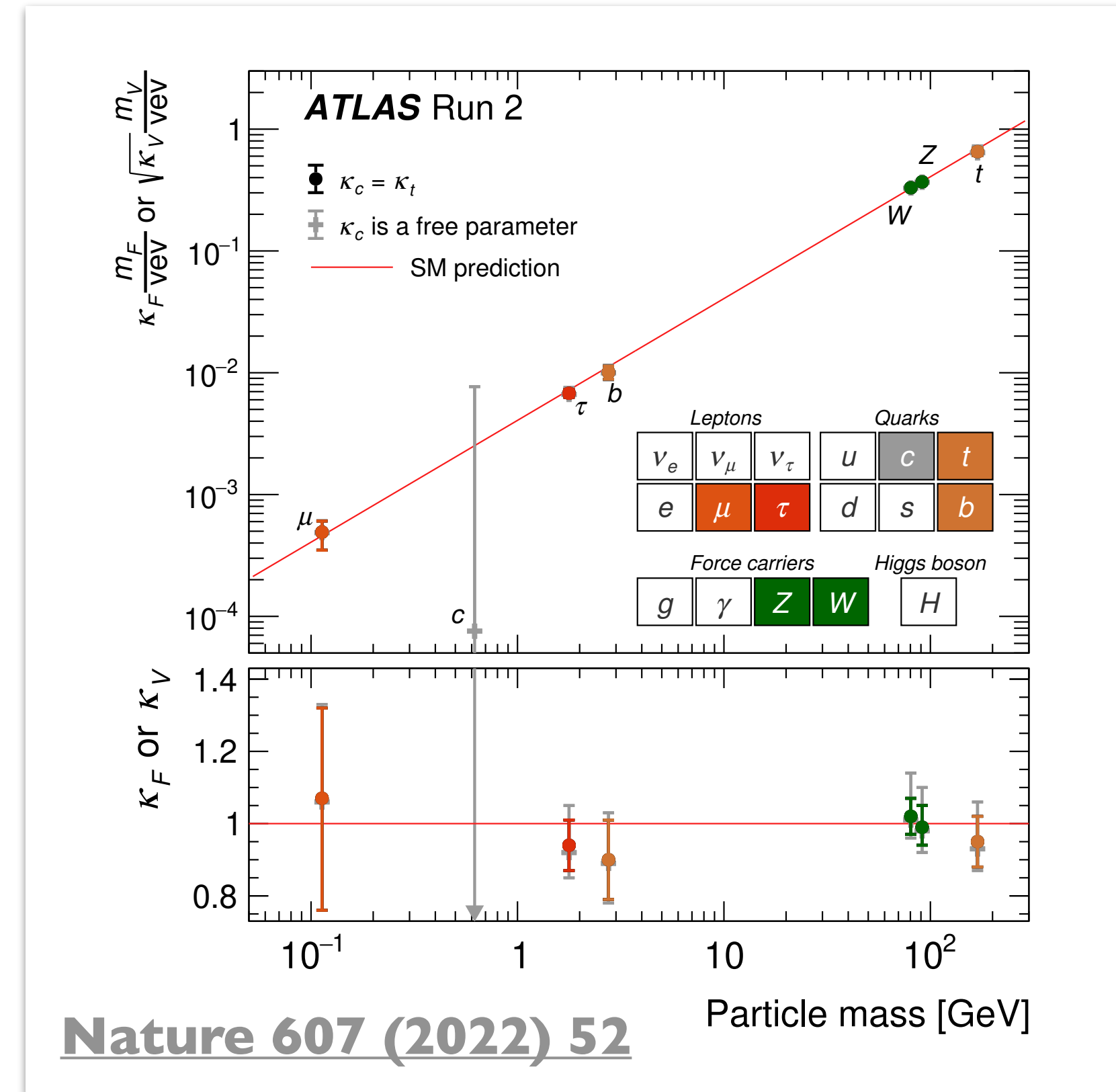


Yukawa Couplings

events



$Y_f, & m & \dots$

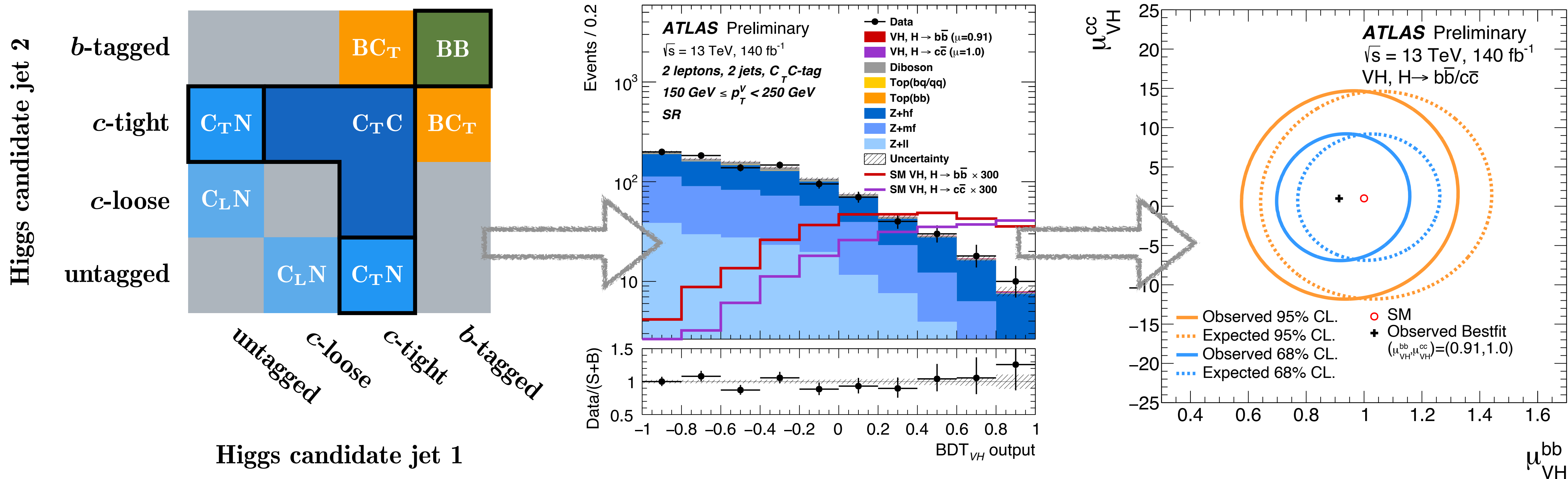


s talk

H

Updated measurement of [PLB 816 \(2021\) 136204](#), [EPJC 81 \(2021\) 178](#) and [EPJC 82 \(2022\) 717](#)

- Now $H \rightarrow bb$ and $H \rightarrow cc$ combined

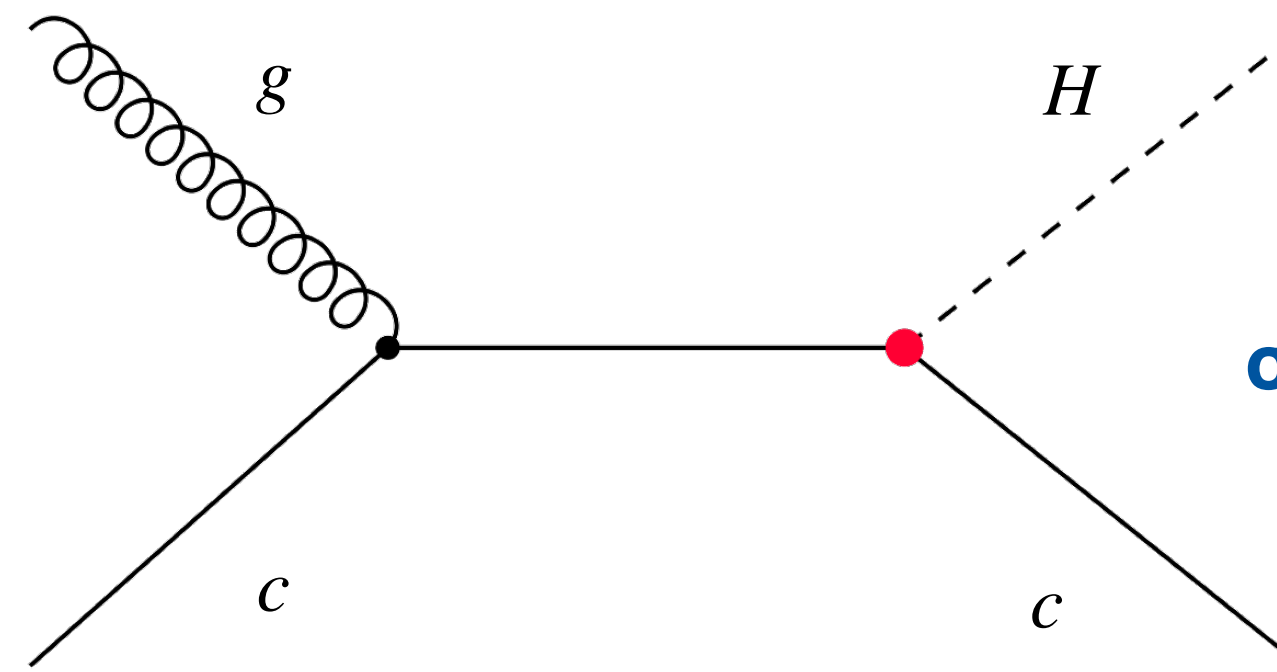


95% CL upper limit on μ_{VH}^{cc} : 11 (10) observed (expected)

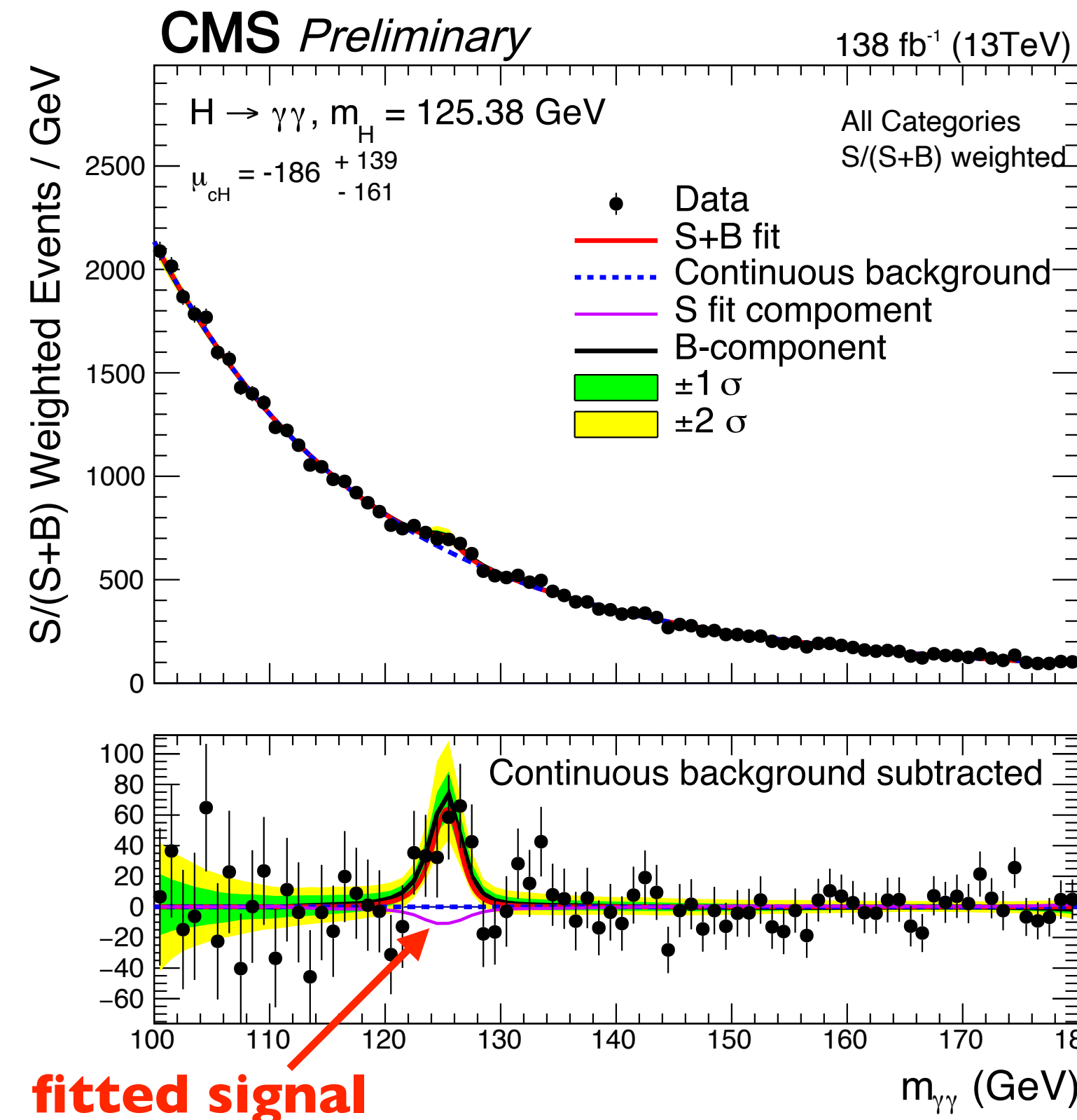
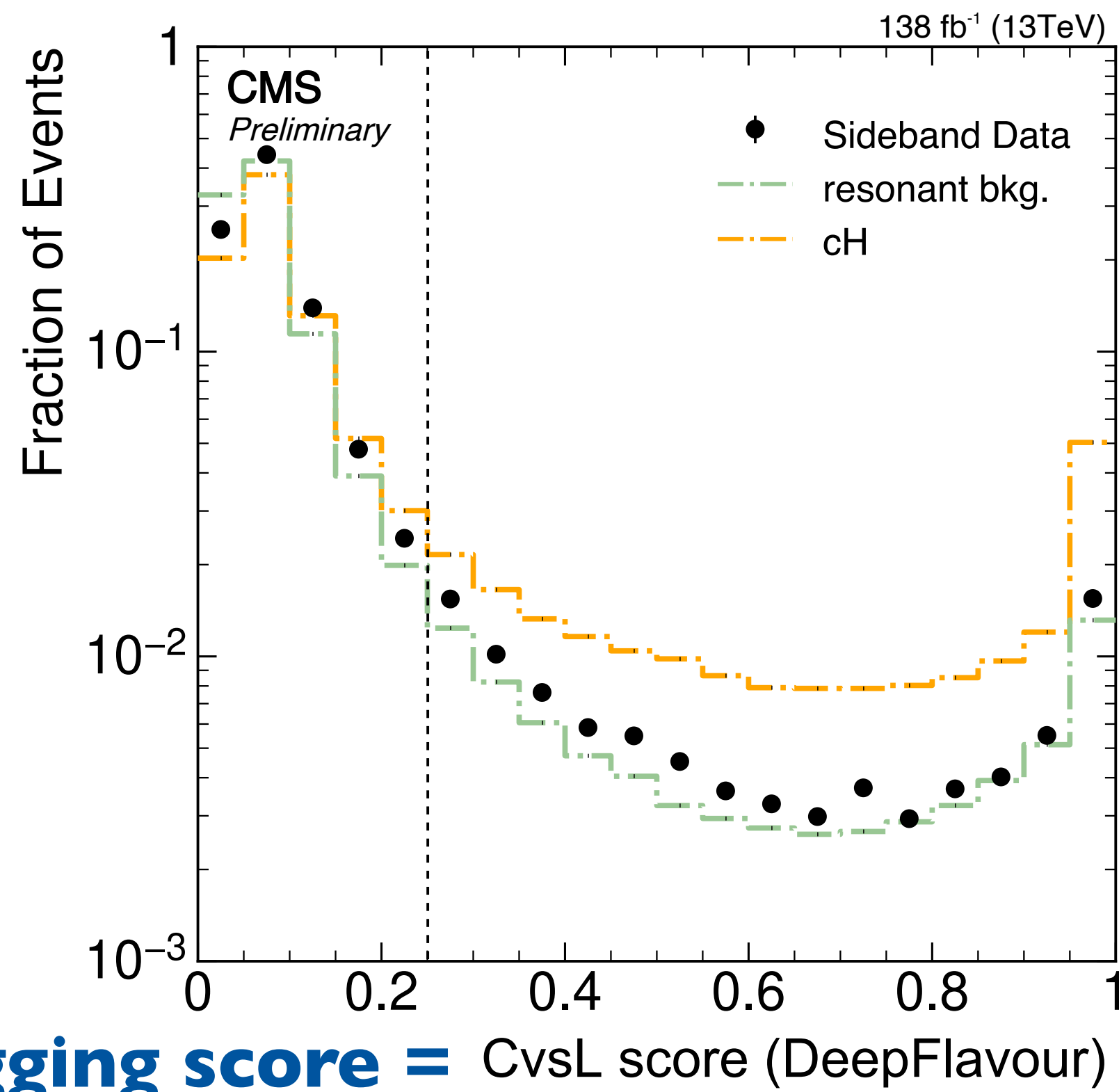
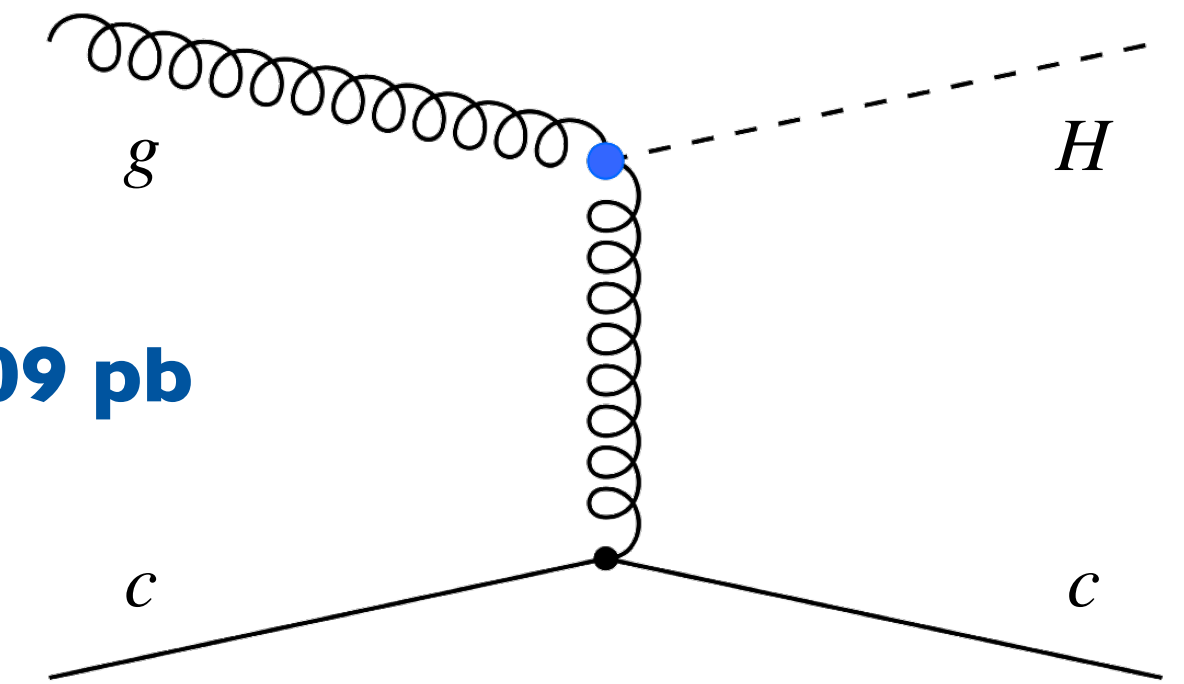
and on κ_c of 4.2 (4.1) observed (expected)

First searches for H+c production
by CMS and ATLAS

- using $H \rightarrow \gamma\gamma$ (low backgrounds)



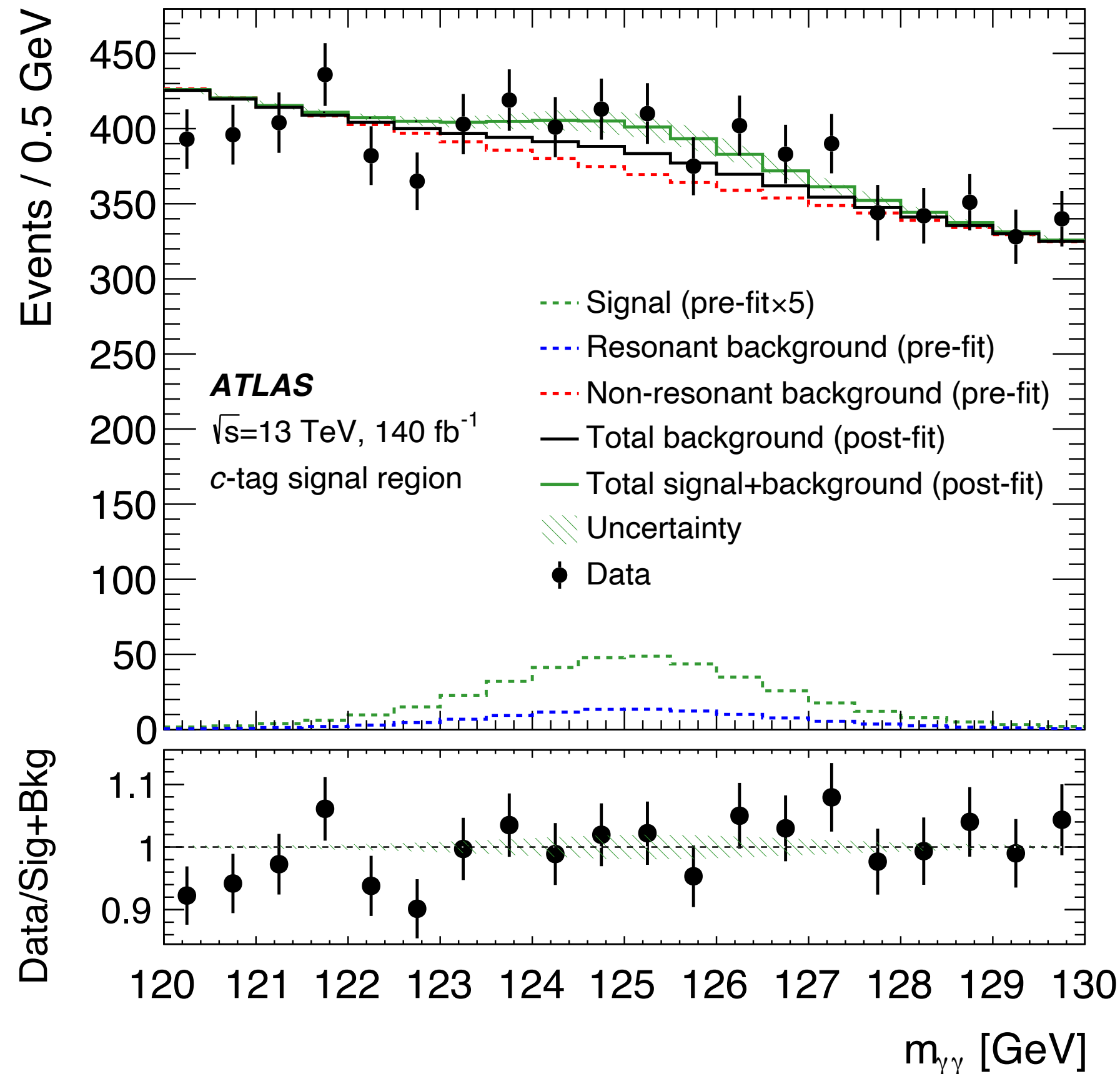
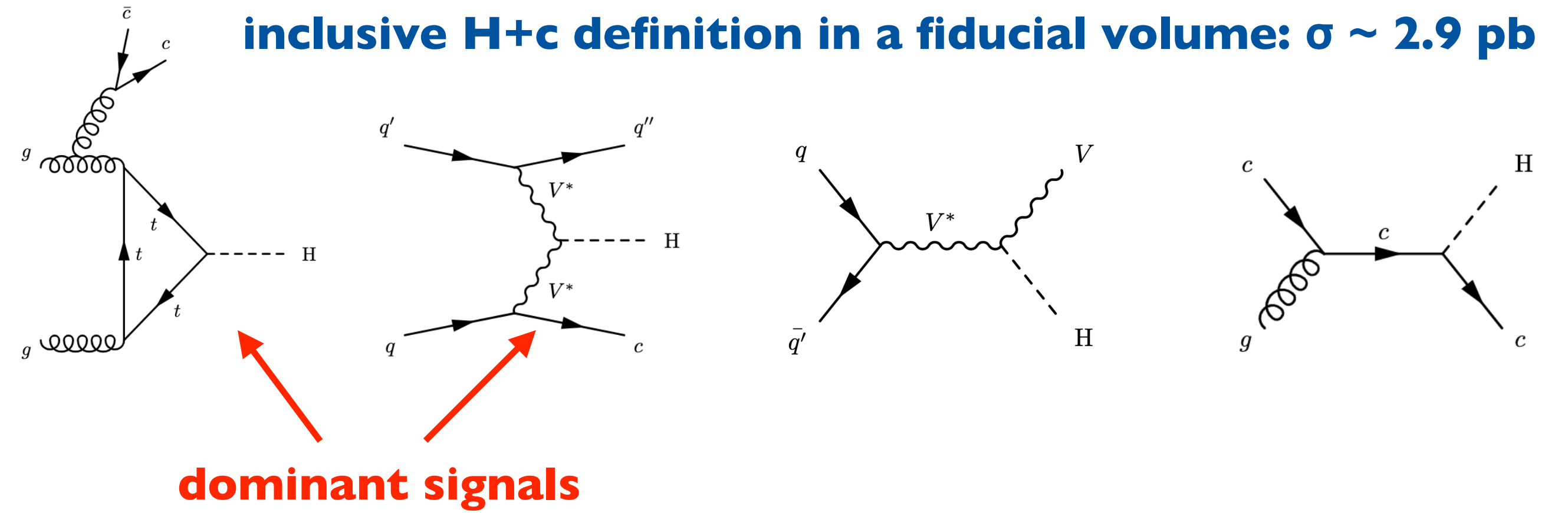
$\sigma \sim 0.09 \text{ pb}$



- Upward fluctuation of the background
- $\mu_{cH} < 243$ (355) obs. (exp.)
- $\kappa_c < 38.1$ (72.5), with $\mu_{\text{non-cH}, H \rightarrow \gamma\gamma} = 1$

First searches for H+c production
by CMS and ATLAS

- using $H \rightarrow \gamma\gamma$ (low backgrounds)



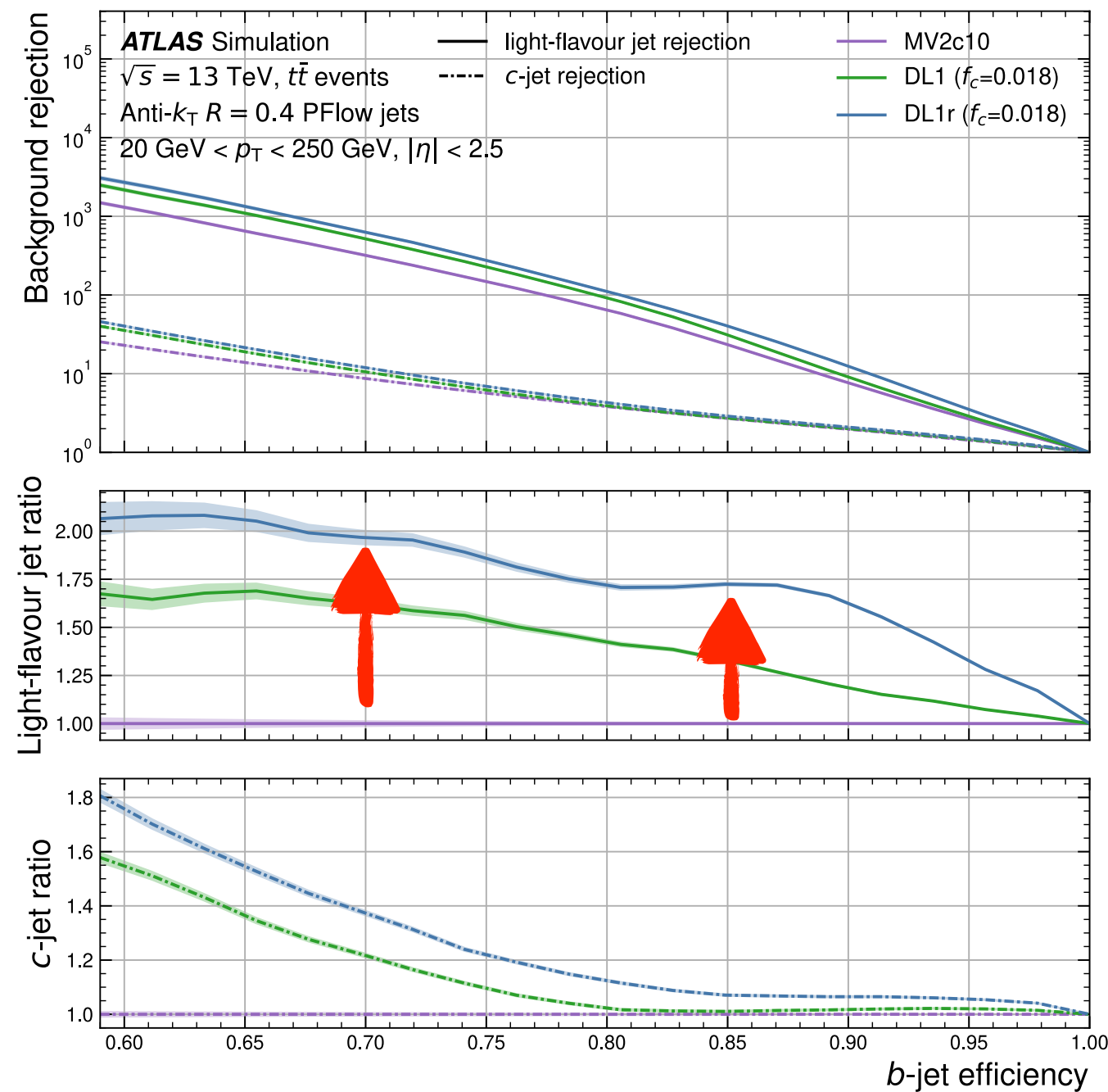
- Gaussian process regression with $K(m, m') = \exp\left(-\frac{(m - m')^2}{2\ell^2}\right)$ to interpolate from sidebands to $m_{\gamma\gamma} \in [120, 130]$ GeV

ATL-PHYS-PUB-2020-028

- Upper limit on σ_{H+c} of 10.4 pb (8.6 pb expected)
- $\sigma_{H+c} = 5.2 \pm 3.0$ pb

Updated measurement of [JHEP 06 \(2022\) 097](#) with expected sensitivity $2.7\sigma \rightarrow 5.4\sigma$ (!)

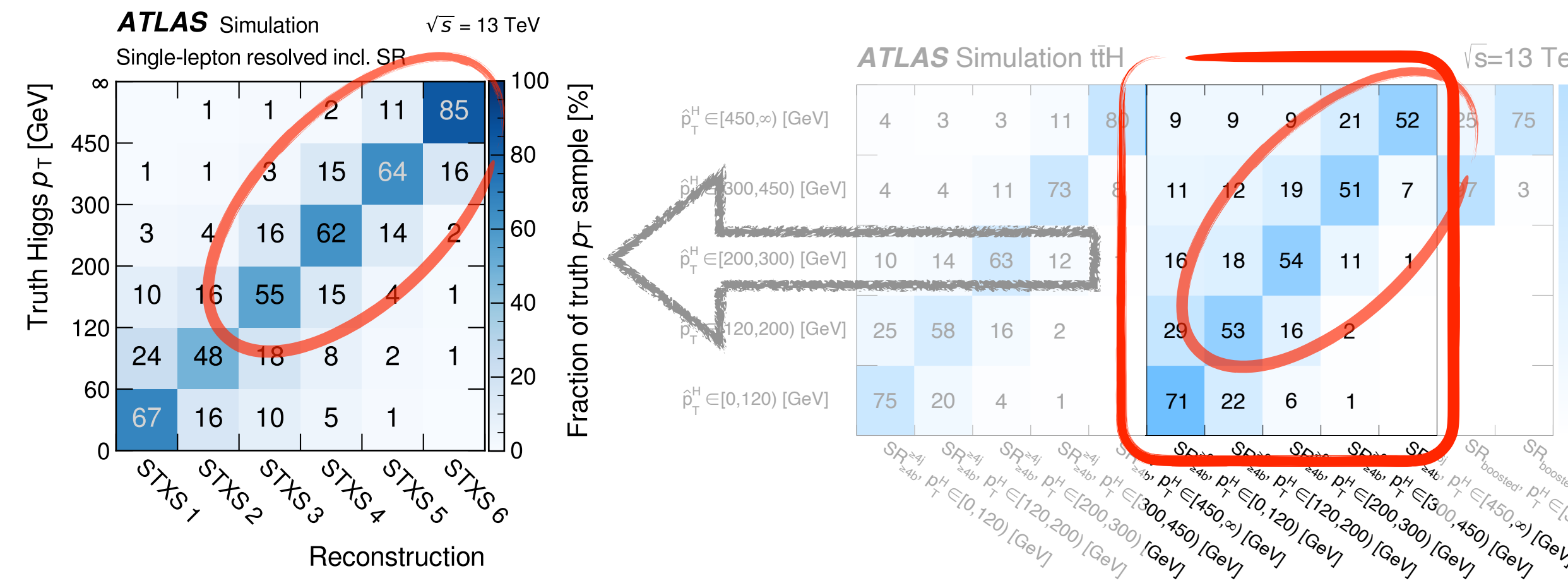
- better b-tagging [EPJC 83 \(2023\) 681](#)



- looser preselection:
 $1\ell 5j 3b$ & $2\ell 3j 3b$ with control regions
 defined by multiclass classifier

- event classification

& p_T^H reconstruction with transformer



- $t\bar{t}+b\bar{b}$ simulation setup in 4FS

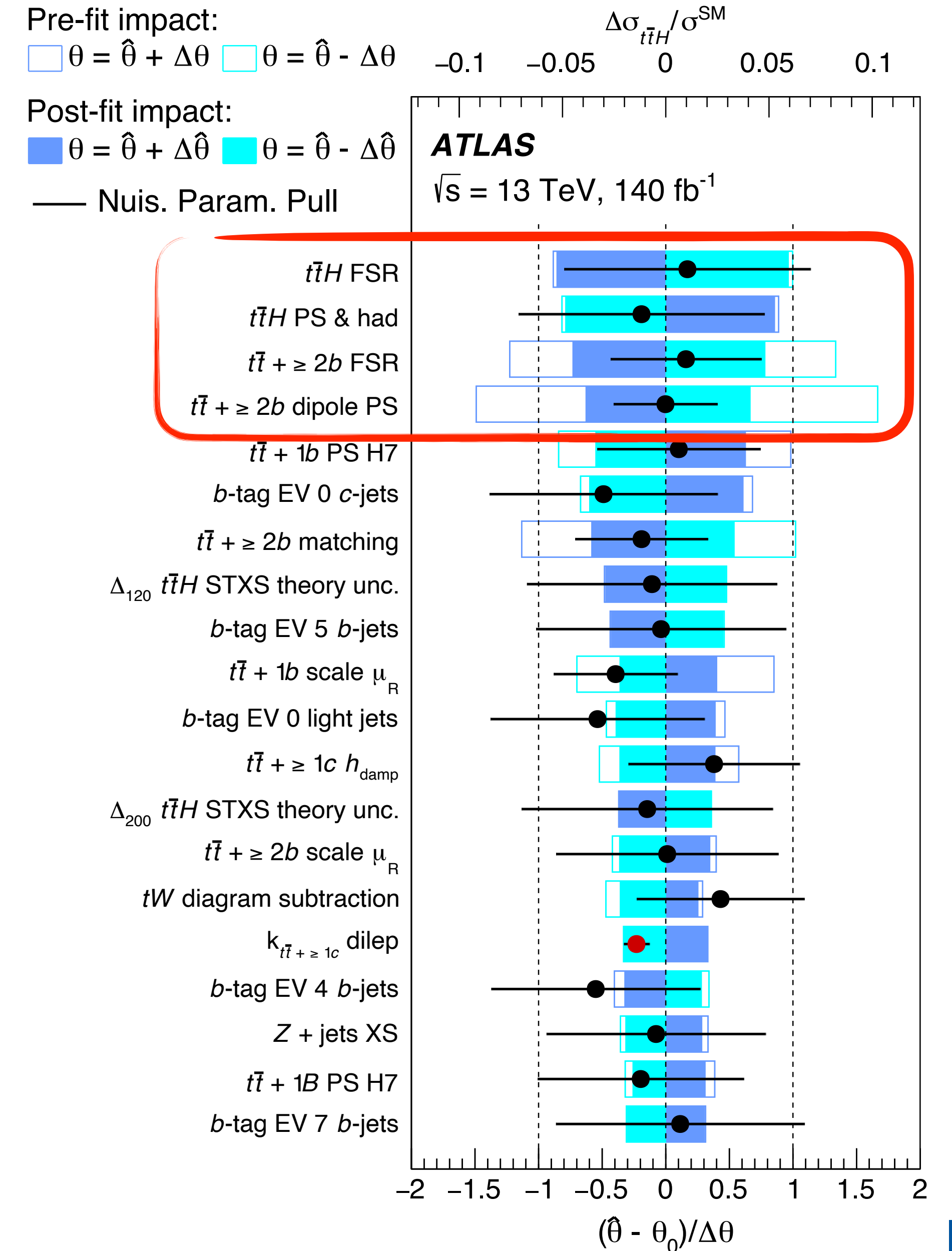
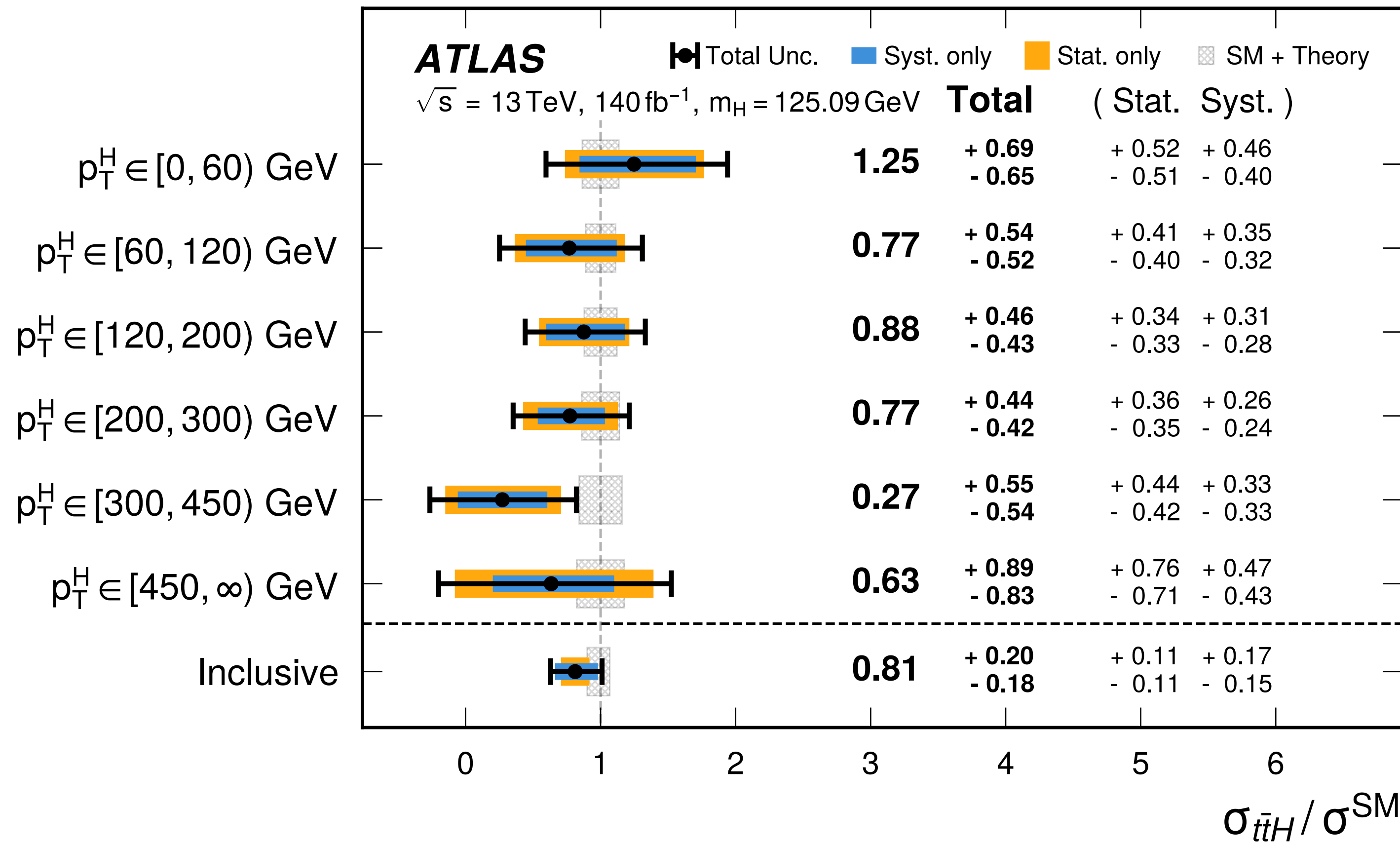
[EPJC 78 \(2018\) 502](#)

Powheg-Box-Res + OpenLoops

with settings from [ATL-PHYS-PUB-2022-006](#)

Observed significance: 4.6σ

Measurement is dominated by modeling systematics



Rare Processes

events



$\sigma_{(\text{fid})}$ & $\frac{d\sigma}{dX}$

Y_f , & m & ...

rare H

not in this talk

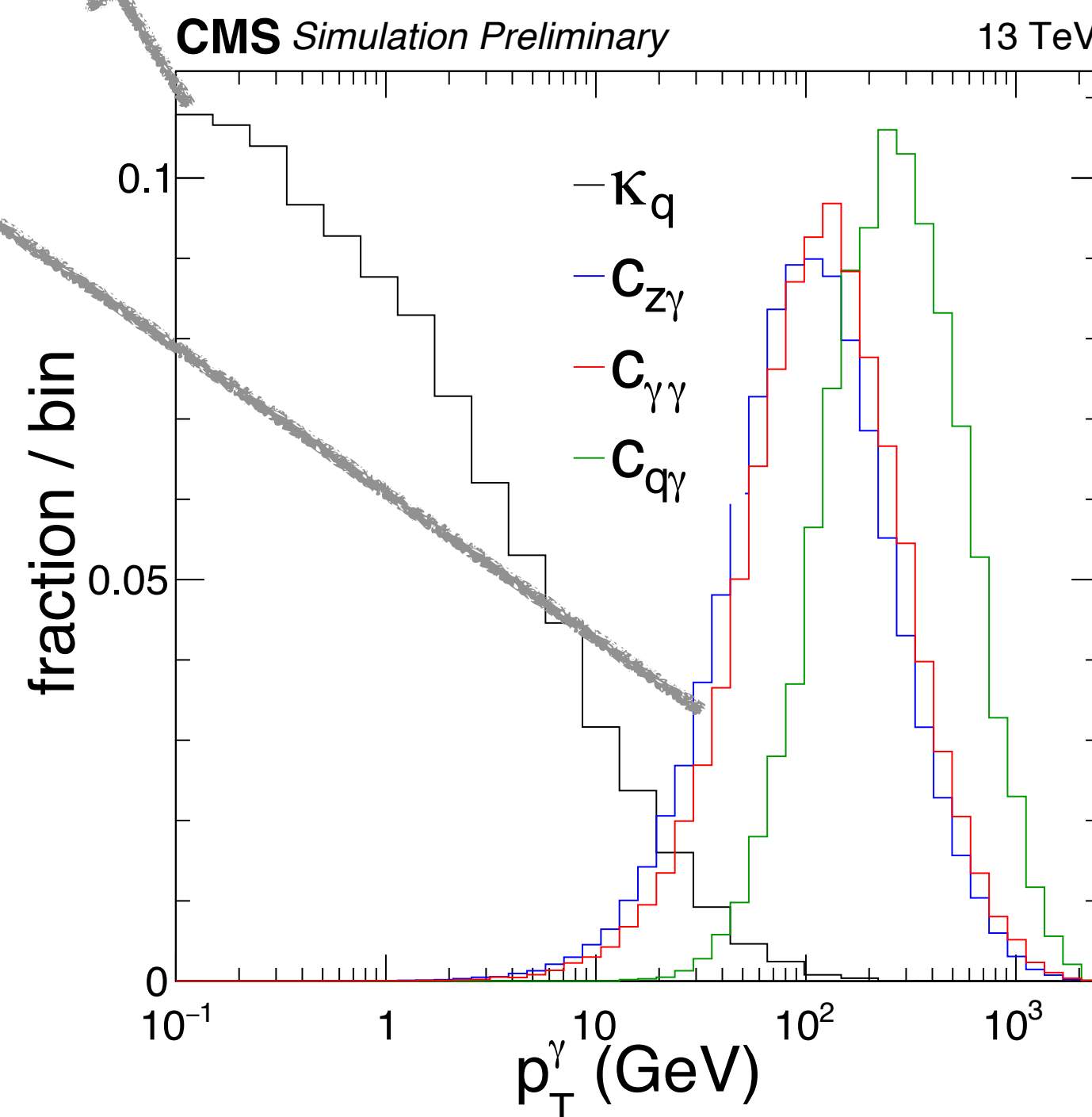
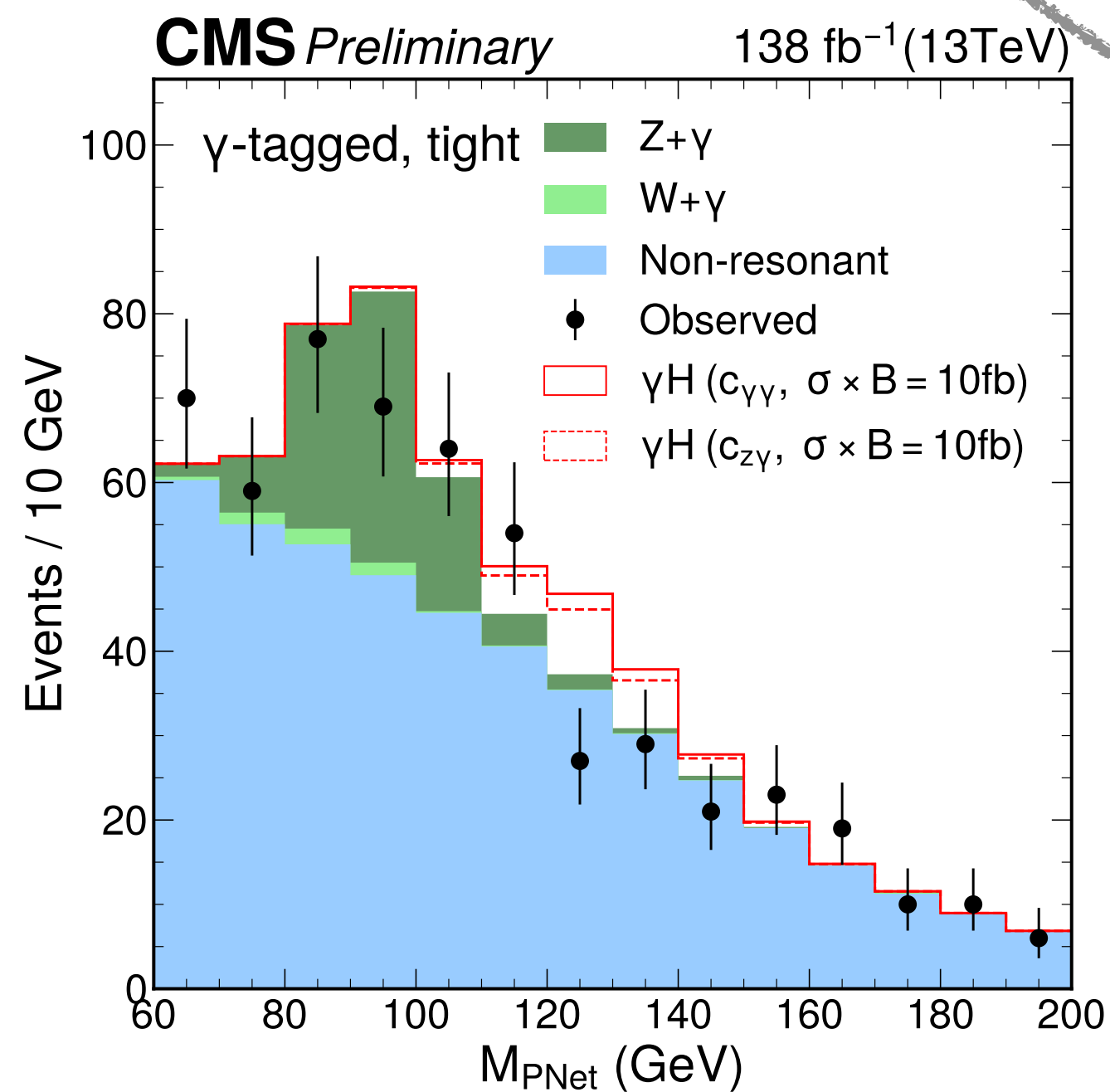
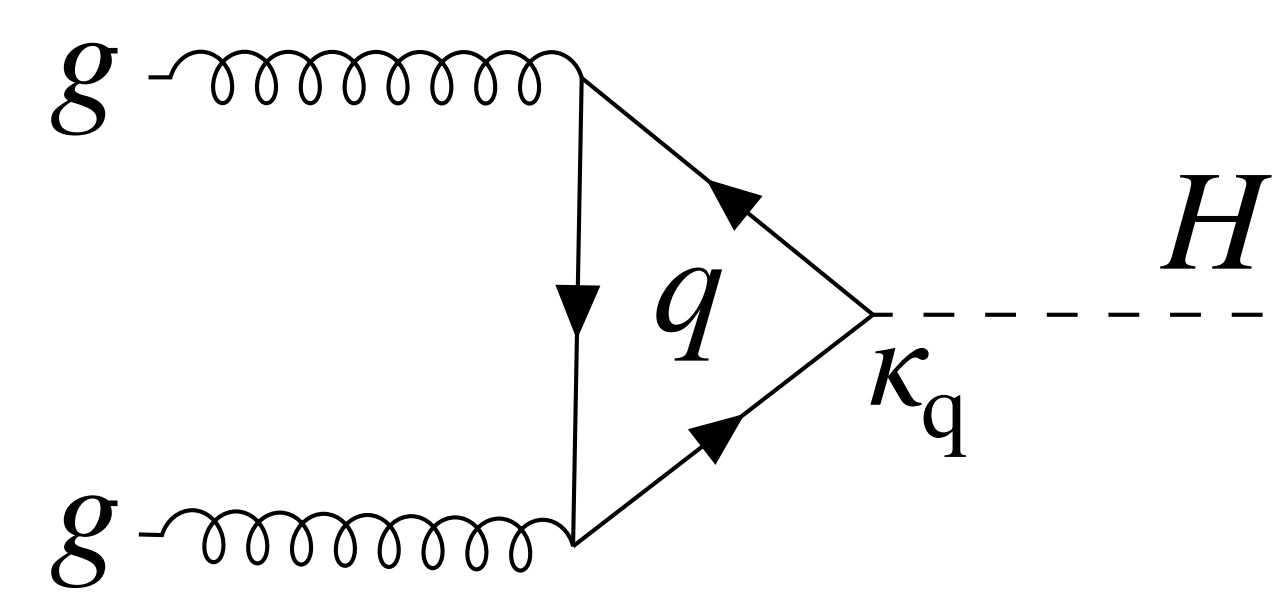
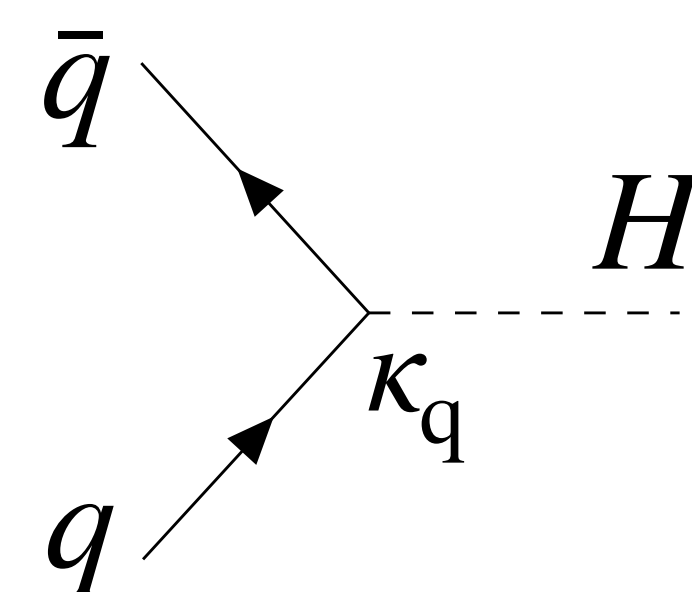
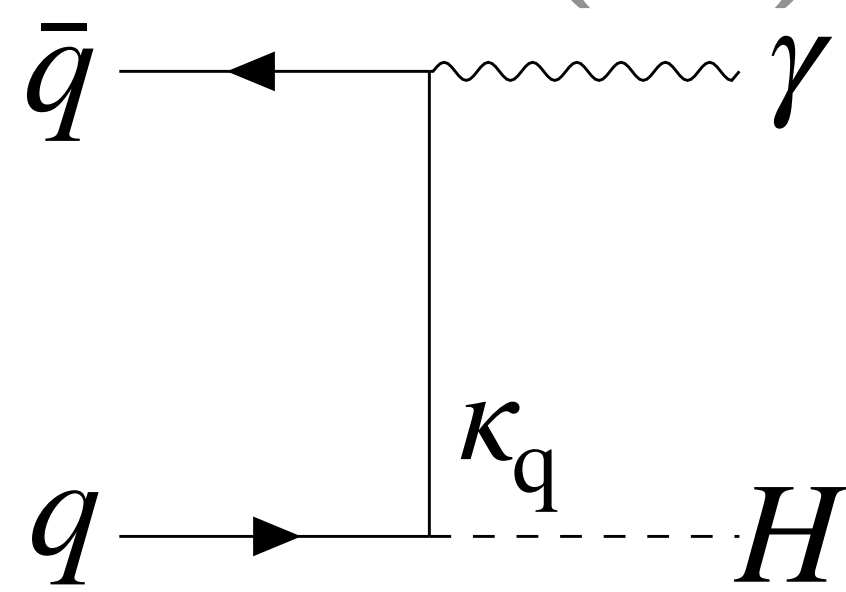
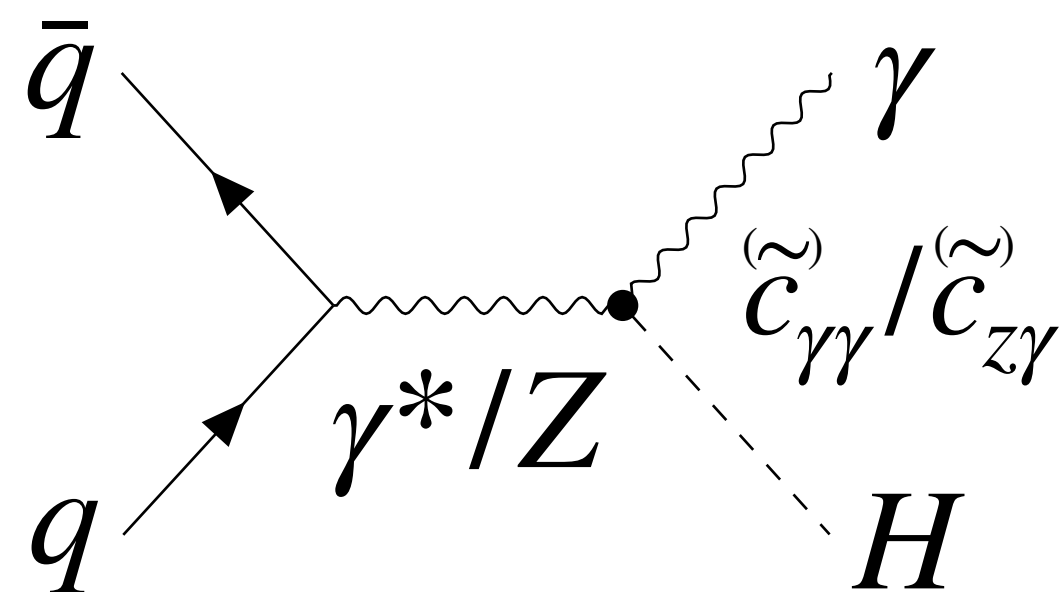
~~BSM H~~

First search for $H\gamma$ (dominated by $H \rightarrow b\bar{b}$)

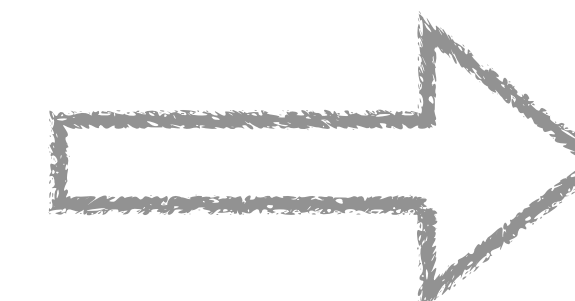
Light-quark Yukawas from $\sigma_H \times \text{BR}(4\ell)$

$\sigma_{H\gamma} < 15.7 \text{ fb @ 95 CL (SM: few fb)}$

PRD 58 (1998) 057301



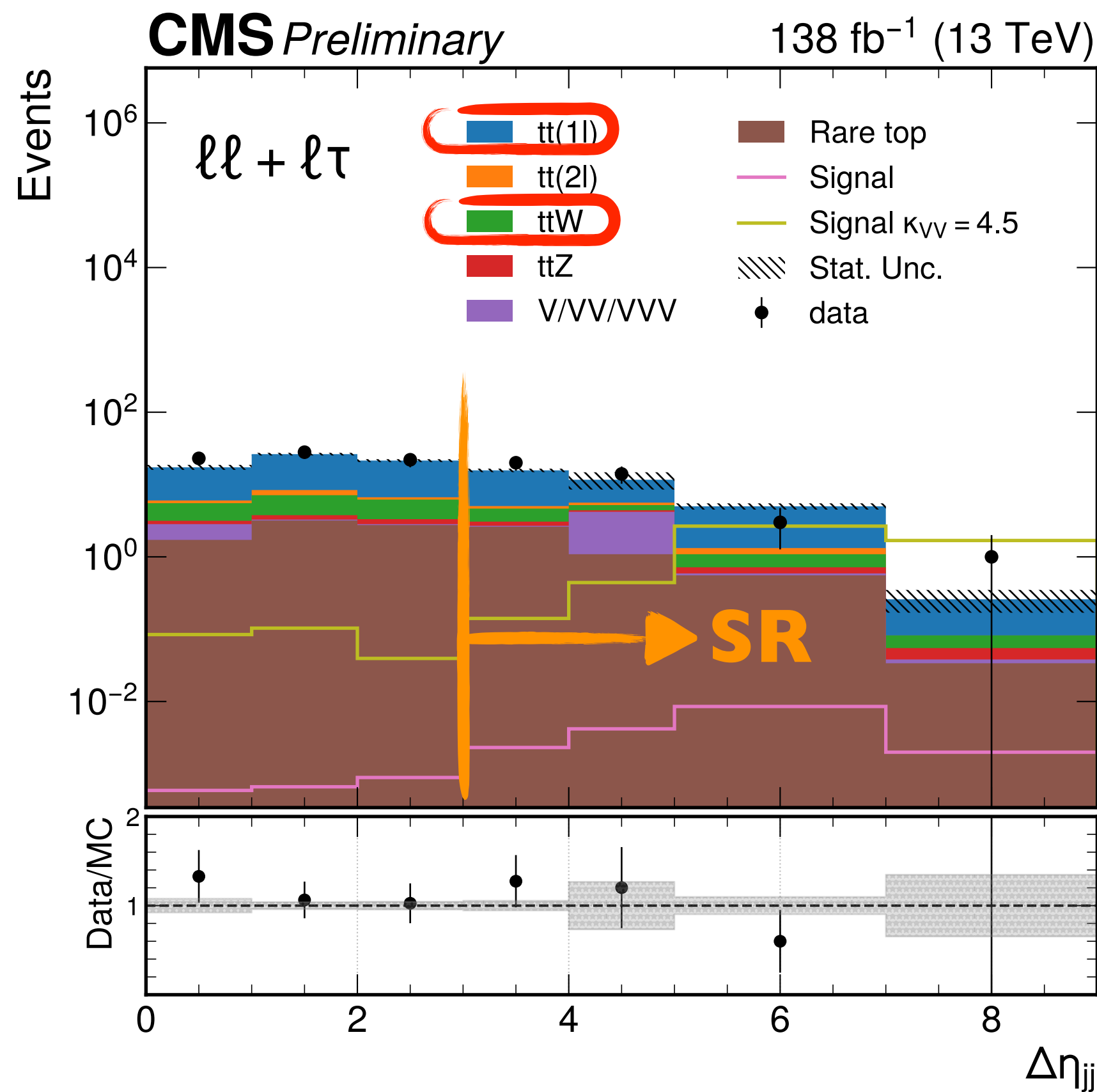
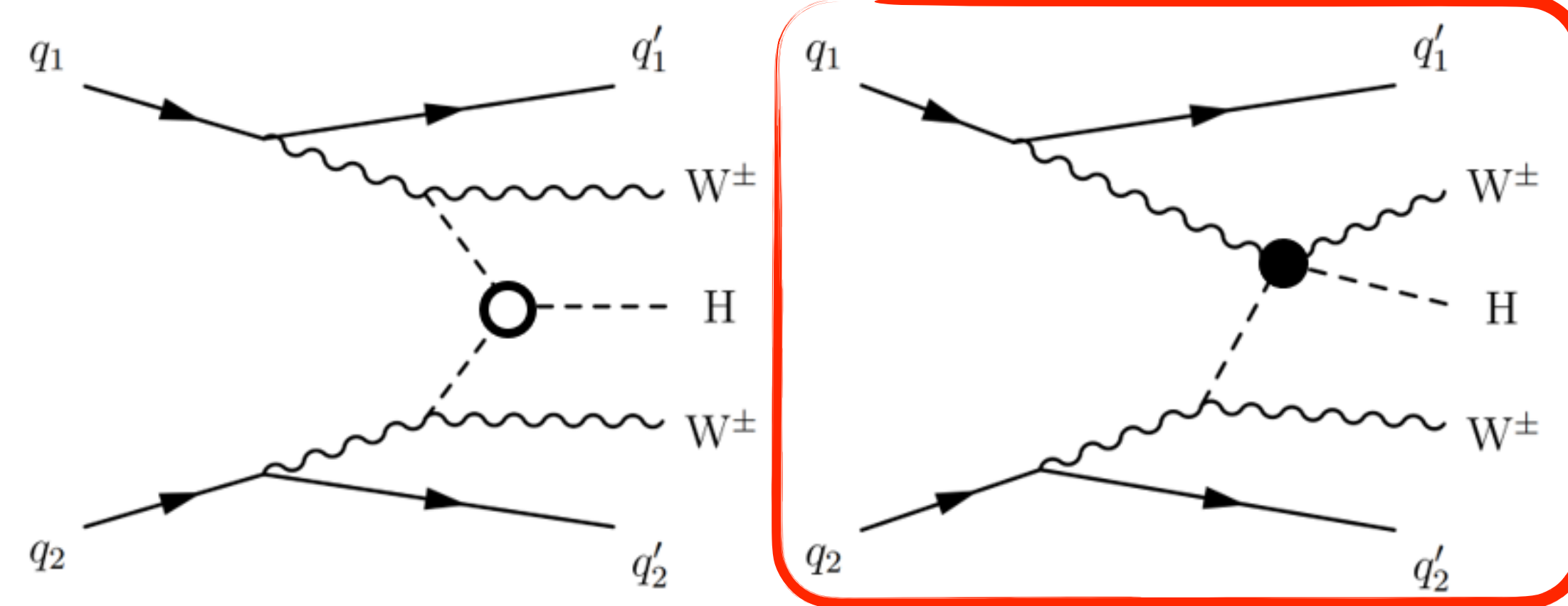
$\sigma_{H \rightarrow 4\ell} \downarrow$ with $\kappa_q \uparrow$, as
 $\sigma_{H \rightarrow 4\ell} \sim 1/\Gamma_H(\kappa_q)$



- $|\bar{\kappa}_u| < 1.06$
- $|\bar{\kappa}_d| < 0.97$
- $|\bar{\kappa}_s| < 0.89$
- $|\bar{\kappa}_c| < 0.88$

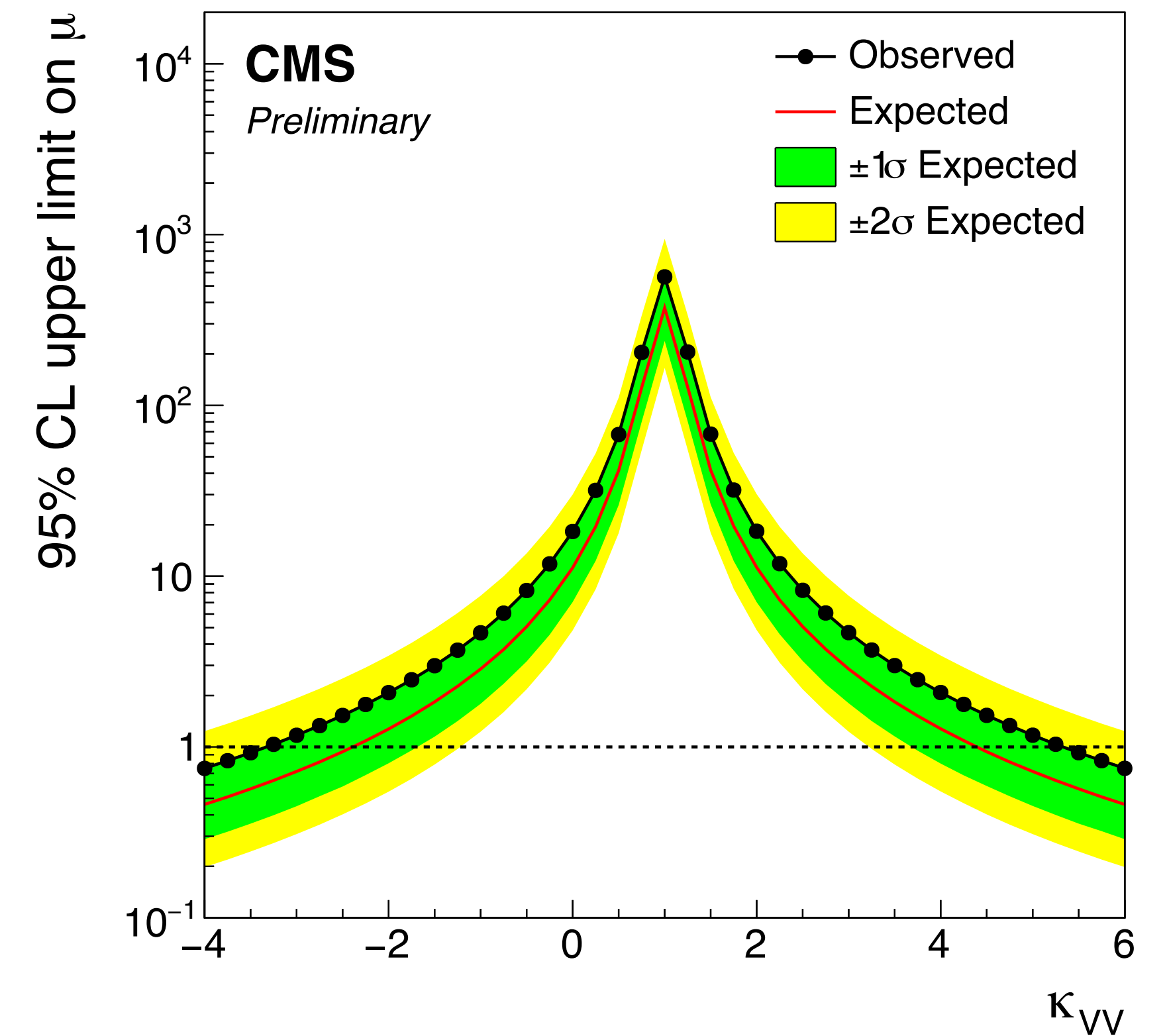
First search for $WWHjj$

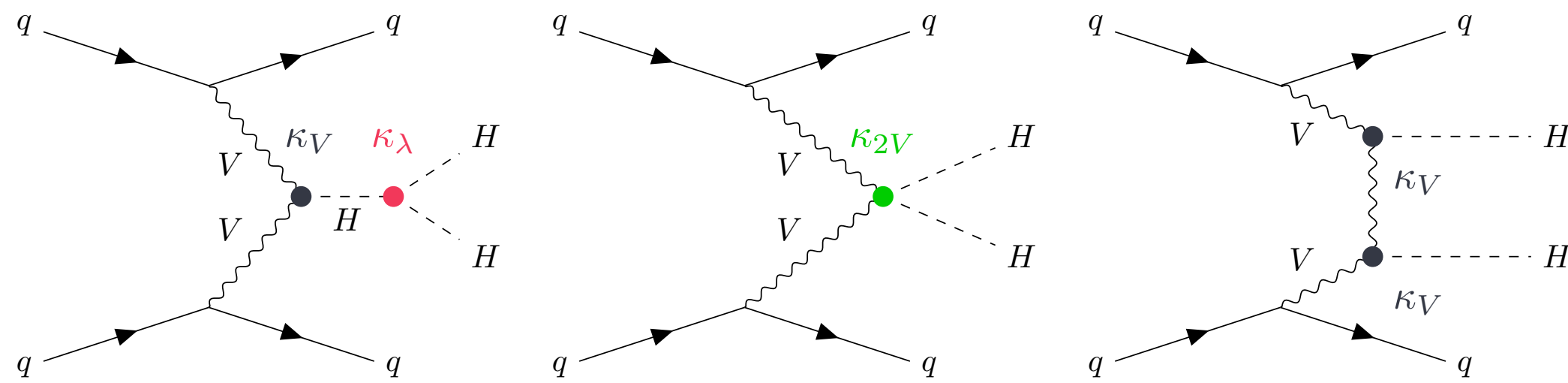
- same-sign $e/\mu/\tau_{\text{had}}$ to suppress $t\bar{t}$ production
- boosted Higgs



η_J
 $p_{T,J}$
 $p_{T,jj}$
 P_{j_0}
 P_{j_1}
 $M_{\ell\ell}$
 p_{T,l_0}
 p_{T,l_1}
 E_T^{miss}
 L_T
 S_T

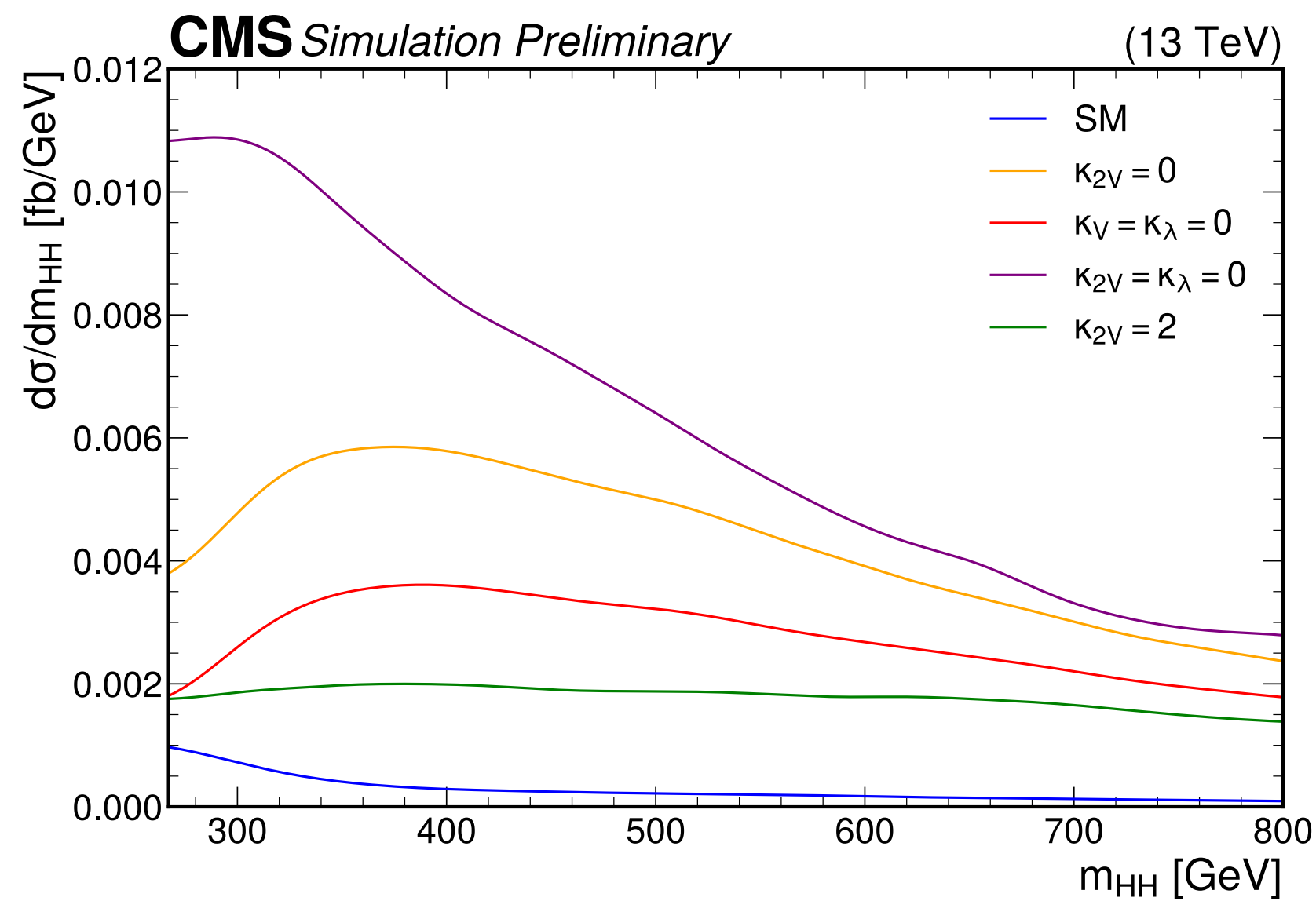
BDT





Updated combination of [PLB 843 \(2023\) 137745](#)

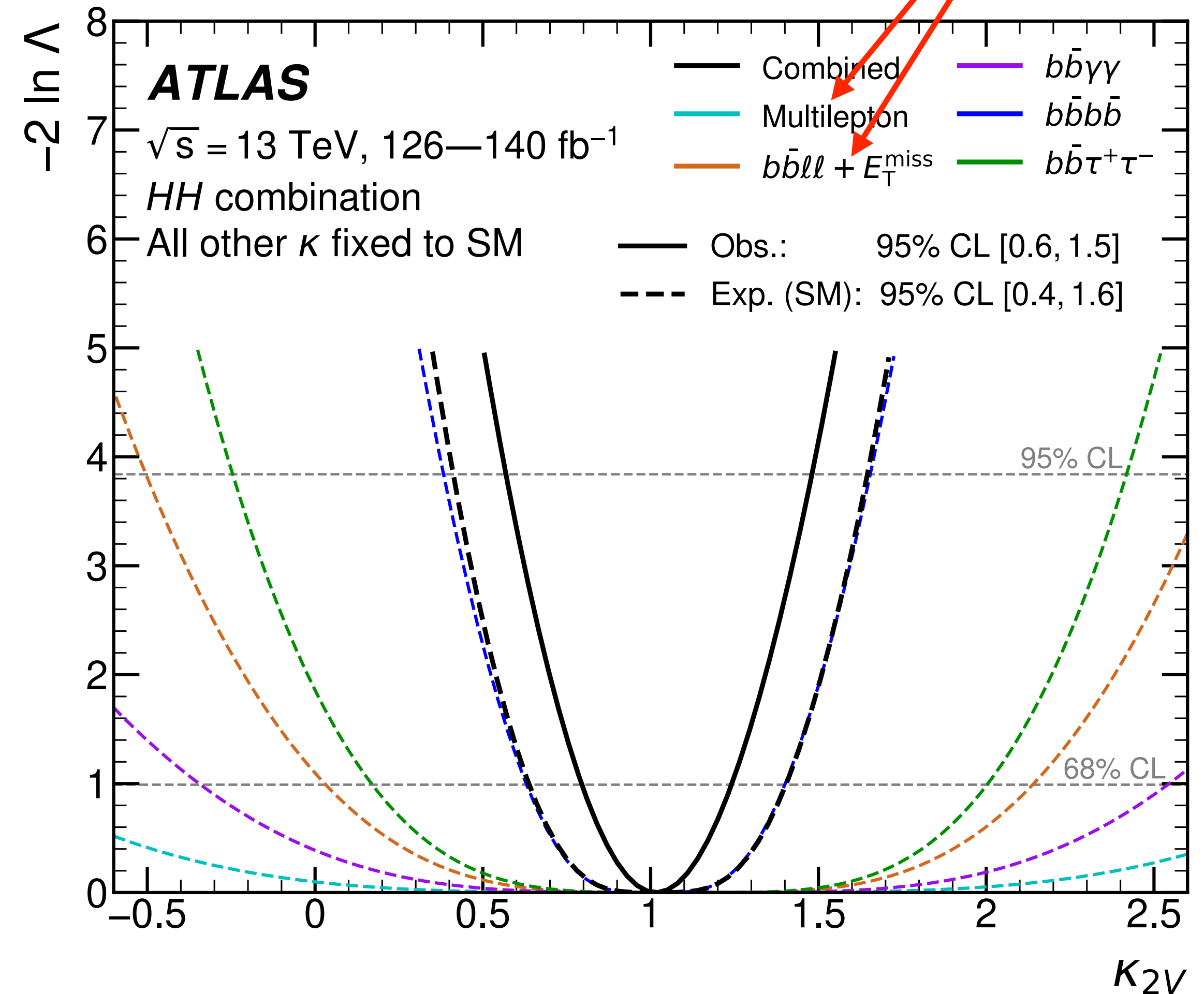
- improved $b\bar{b}b\bar{b}$, $b\bar{b}\tau\tau$, $b\bar{b}\gamma\gamma$ + 2 new

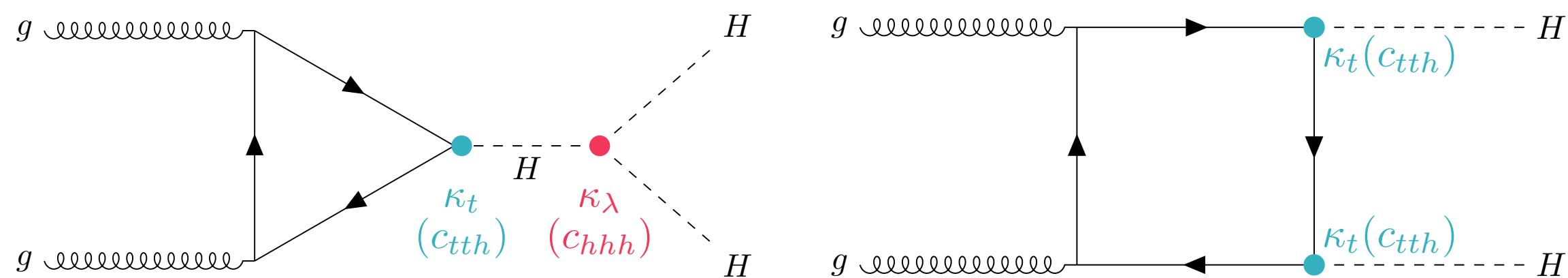


$HH \rightarrow b\bar{b}VV \rightarrow b\bar{b}q\bar{q}q\bar{q}$ (boosted)

VV-tagging with ParticleTransformer

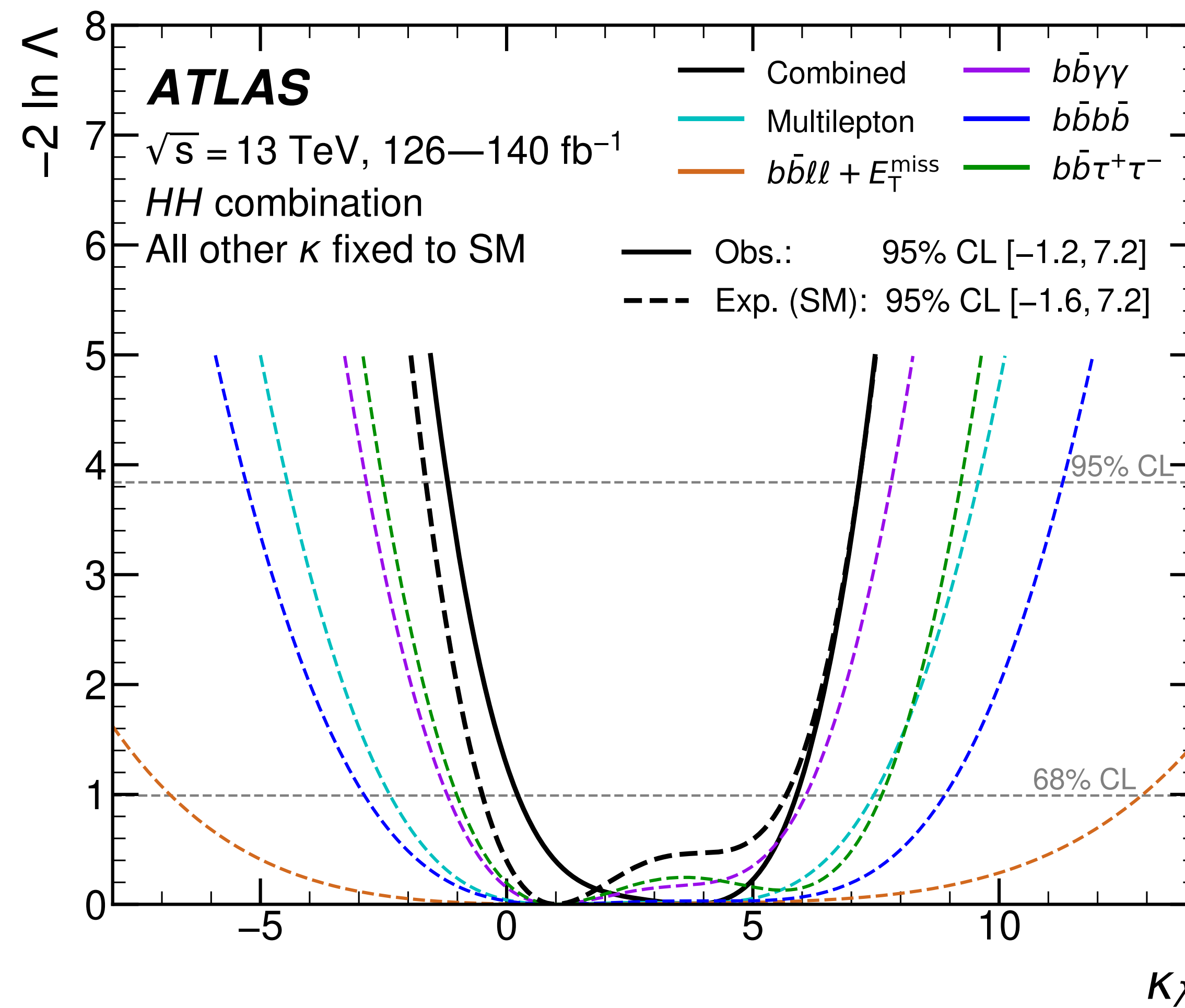
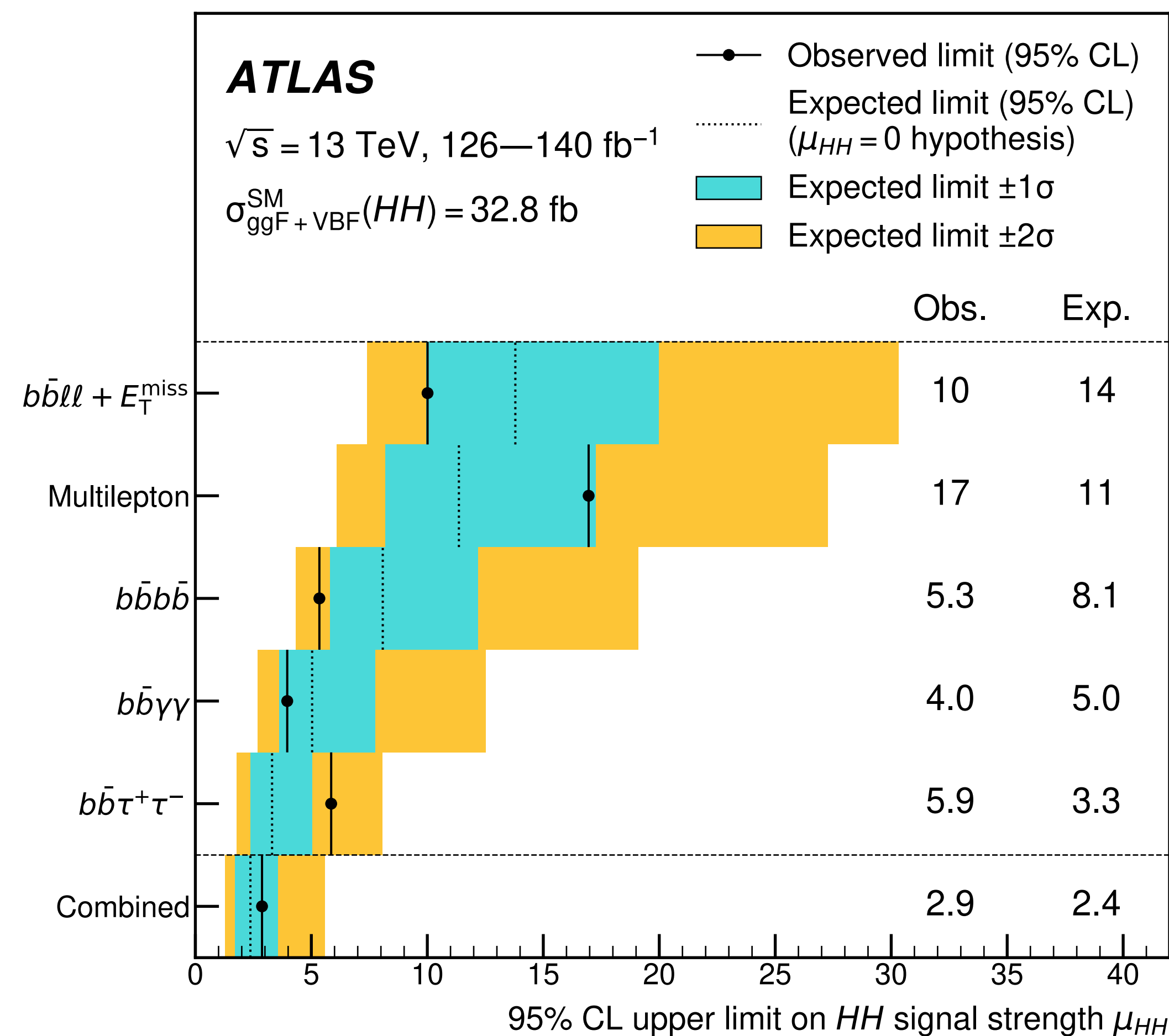
$-0.04 < \kappa_{2V} < 2.05$ @ 95% CL





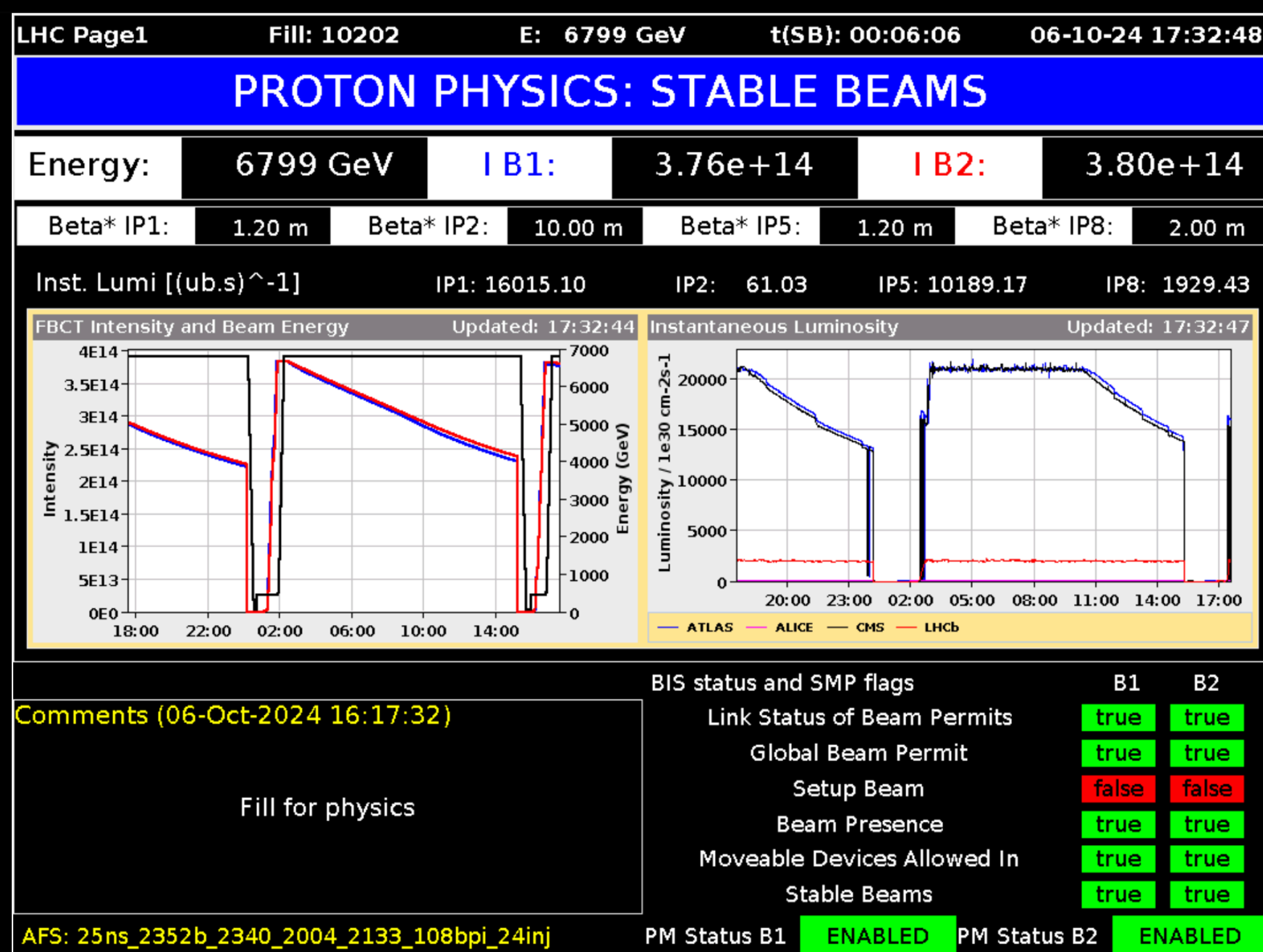
Updated combination of [PLB 843 \(2023\) 137745](#)

- exp. upper limits on μ_{HH} : 2.9 \rightarrow 2.4

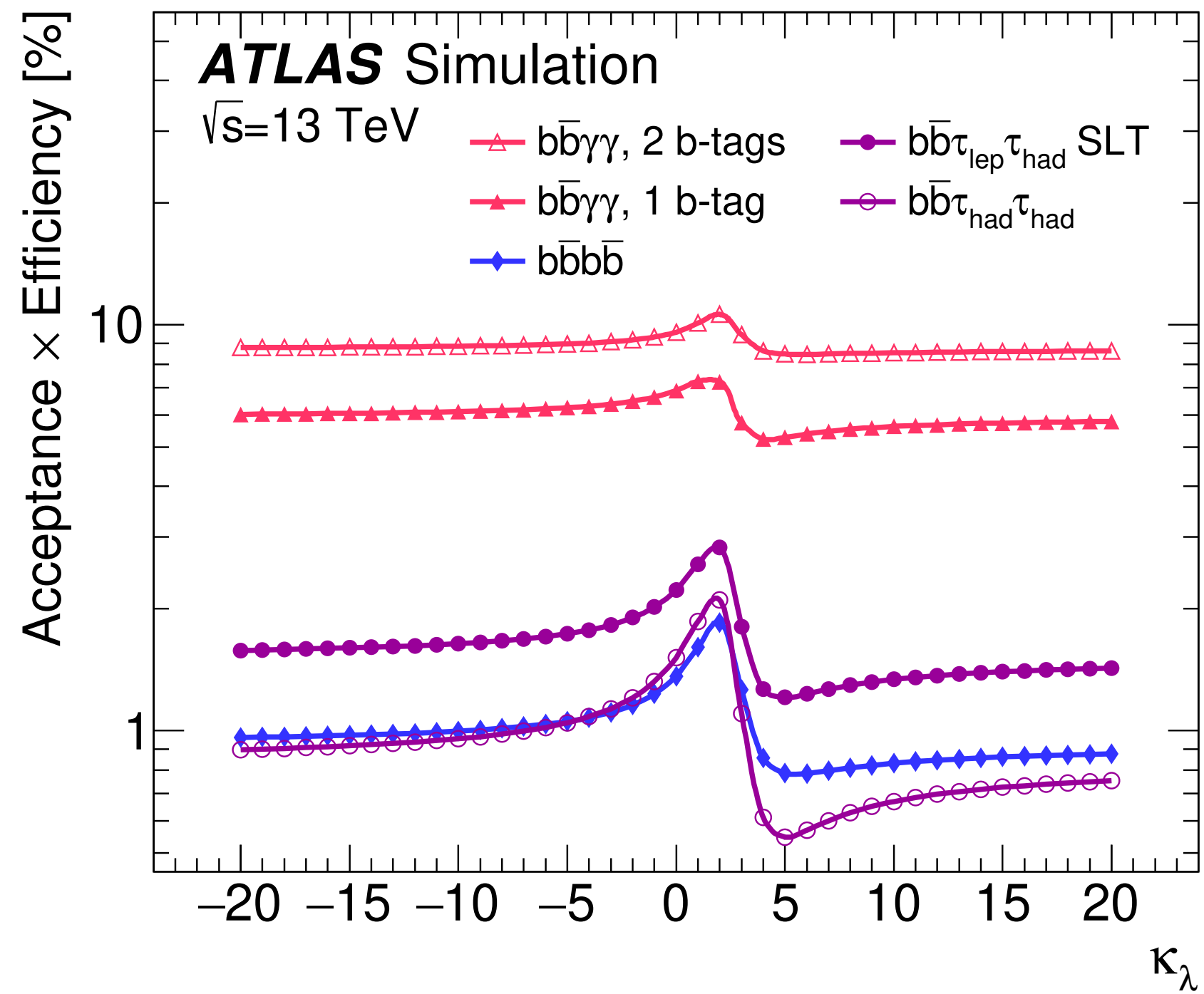


Summary

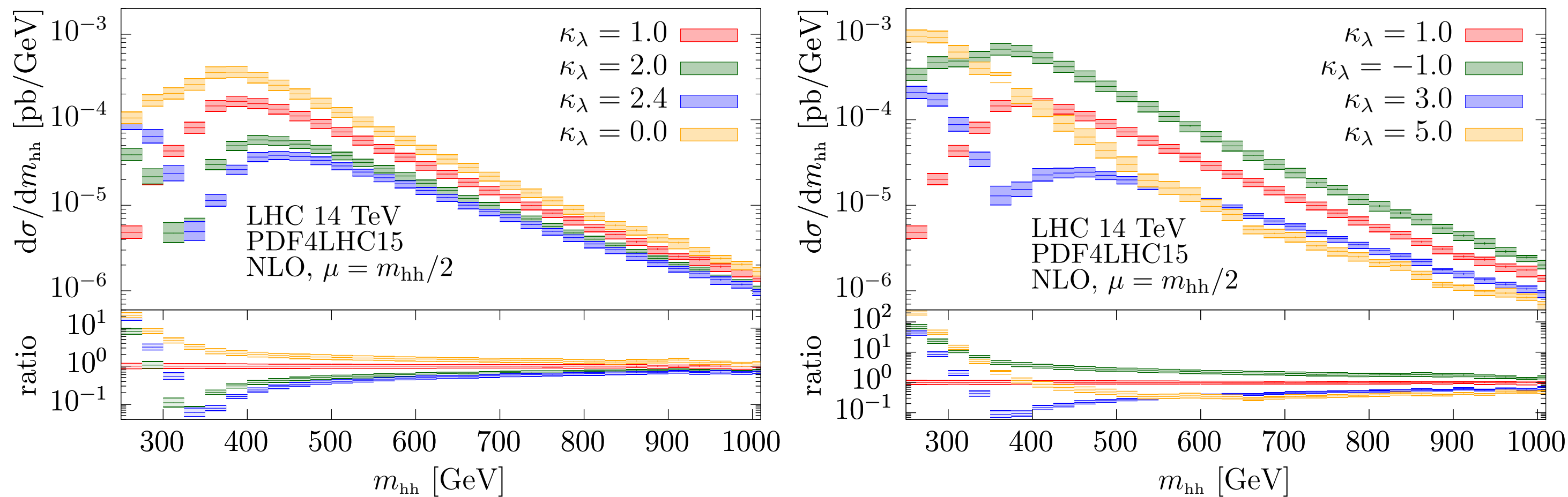
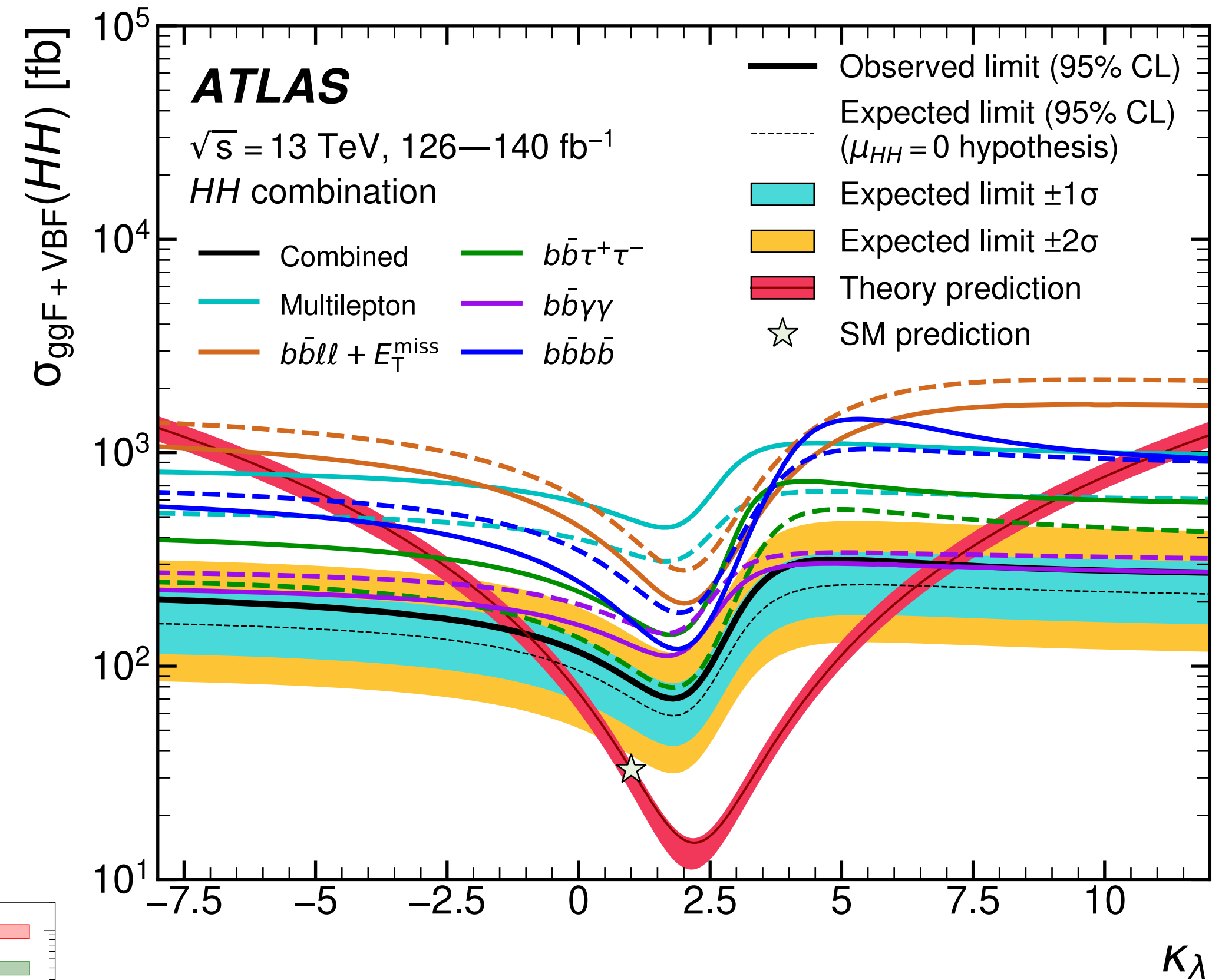
- Reported on 12 new analyses since Moriond
- Run-2 data is a treasure that keeps being explored with new ideas and methods
- Run-3 data analysis has started and is long not over
- see also talks by M. Golbirsch-Kolb (Thursday), N. Readioff, A. Raspiareza & J.J. Teoh (yesterday)



Bonus



PLB 800 (2020) 135103 (36/fb analysis)



JHEP 06 (2019) 066

