Higgs to Bosons

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Comparison

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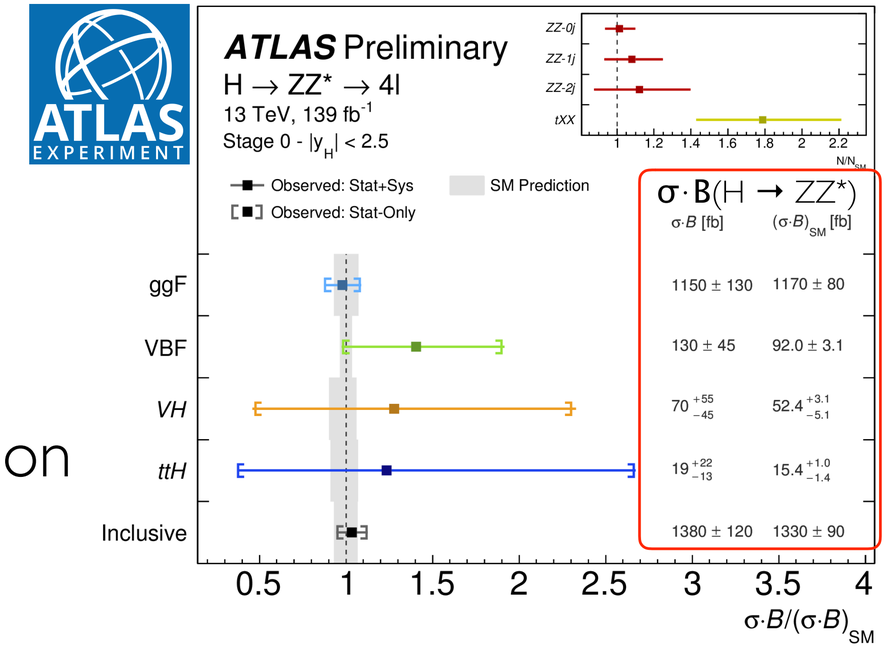
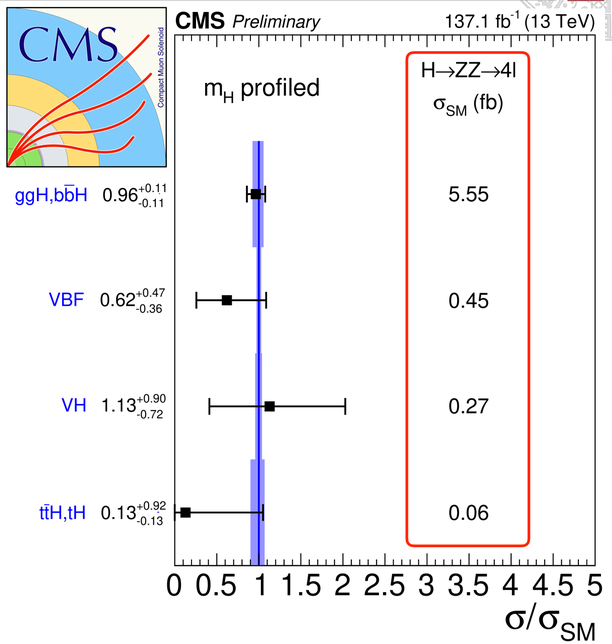
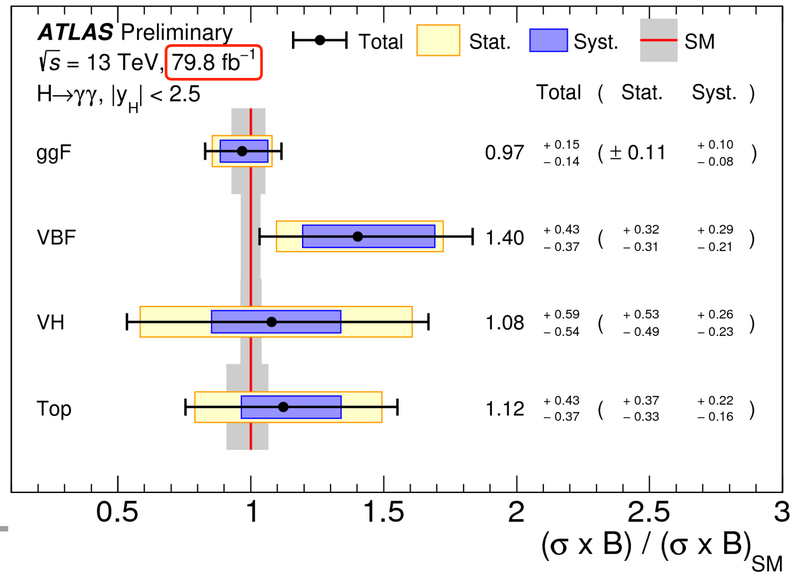
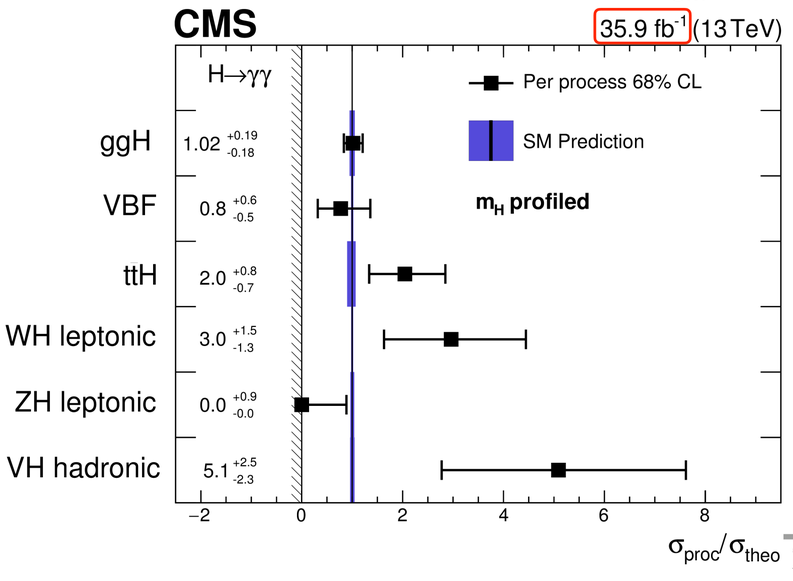
STXS Stage-0 Results

- $H \rightarrow ZZ^* \rightarrow 4\ell$
  - Still statistics limited with 140 fb^{-1}
  - ggF measurement precision reaches precision of SM prediction
- $H \rightarrow \gamma\gamma$
  - Systematics for ggF and VBF similar size as 80 fb^{-1} statistics



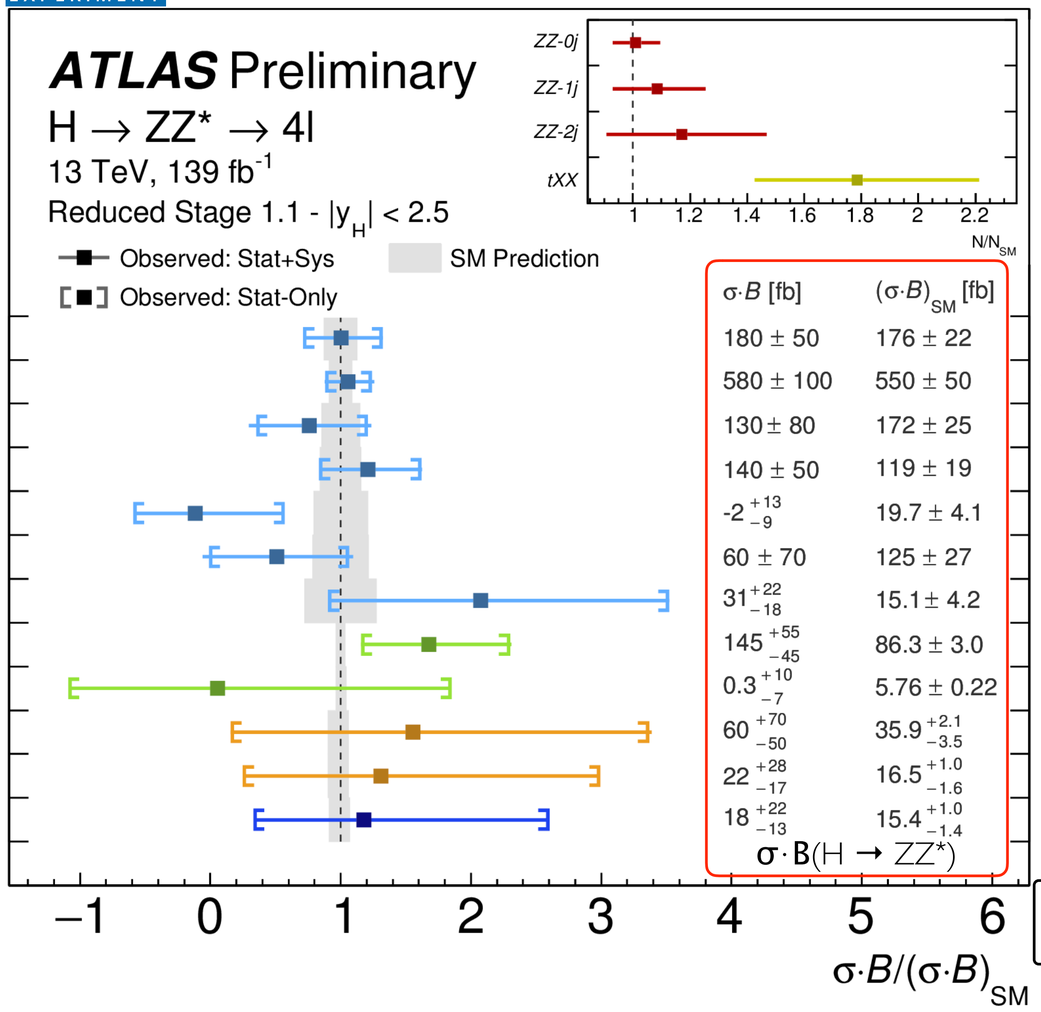


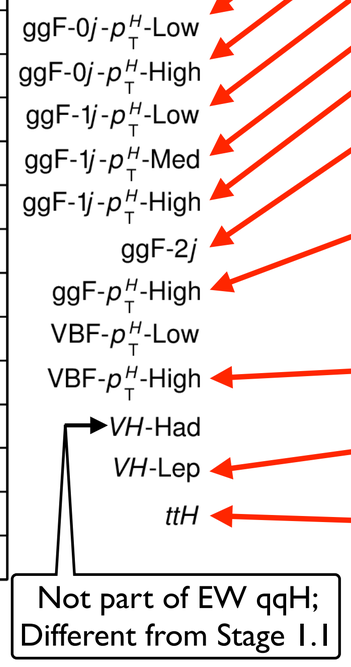


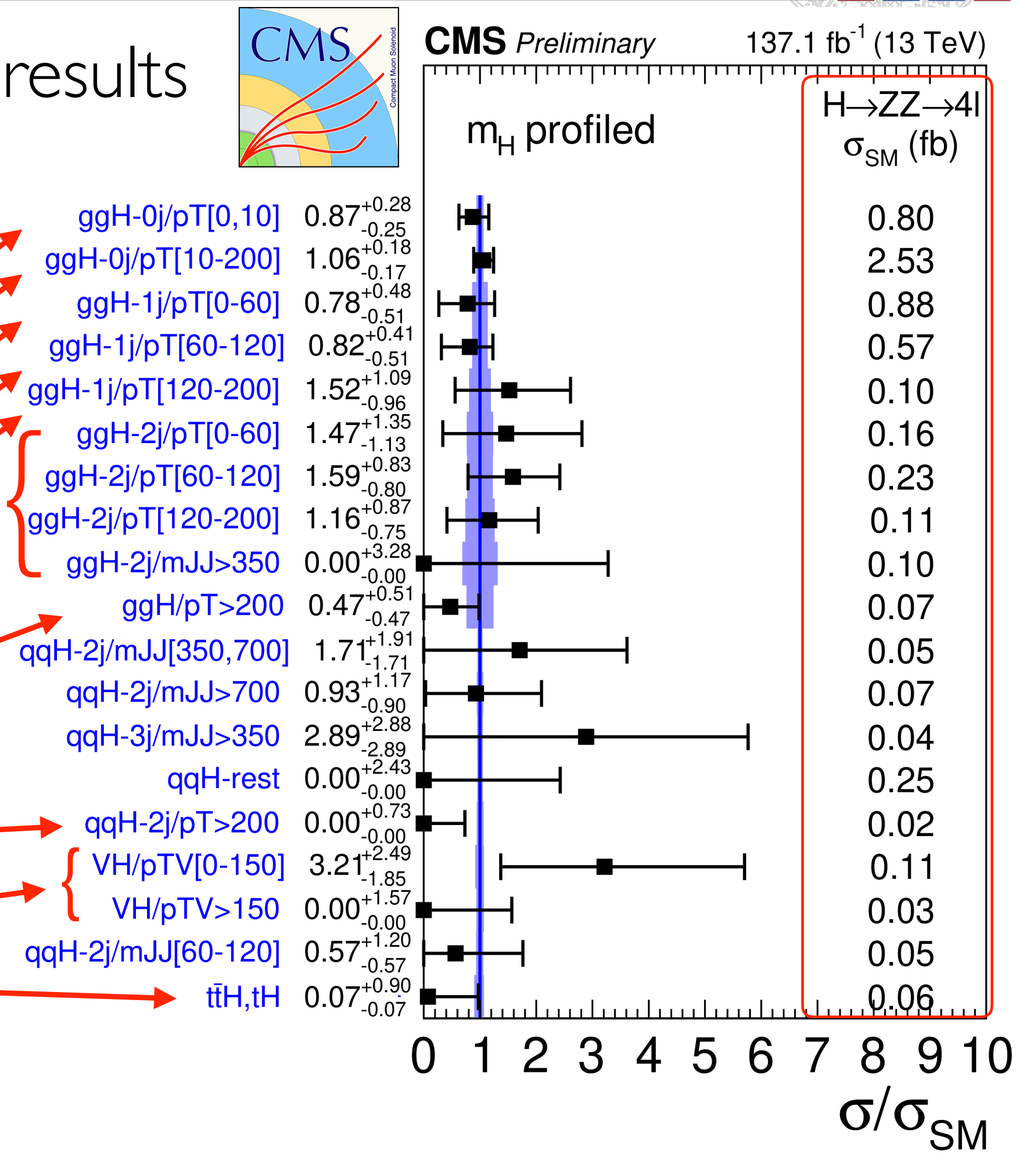


Full Run-2 H → ZZ* → 4ℓ STXS Stage 1.1

- Impressive STXS Stage 1.1 full Run-2 data results







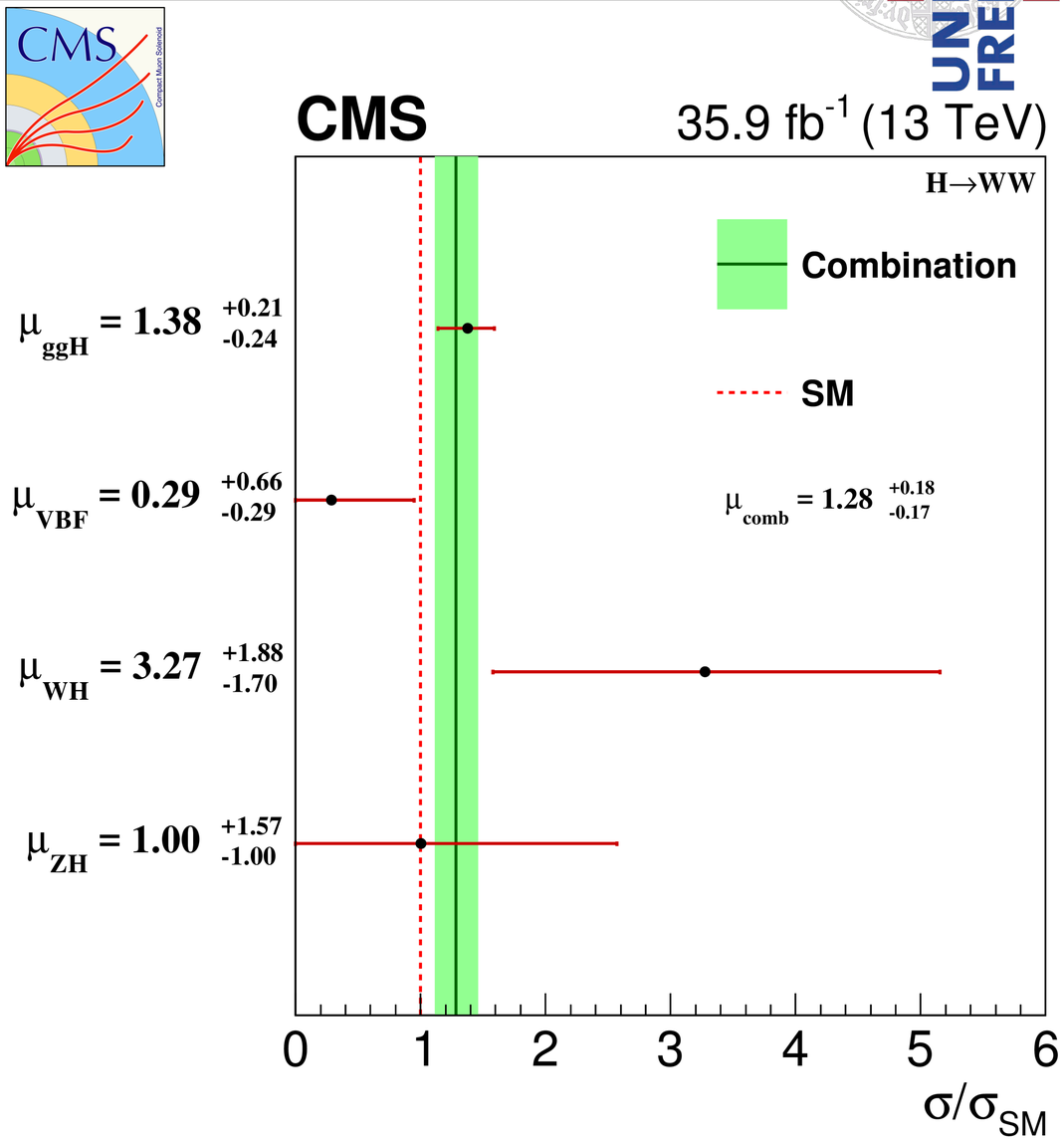
~36 fb^{-1} $H \rightarrow WW^* \rightarrow \ell\nu\ell\nu$

$$\mu_{\mathrm{ggF}} = 1.10^{+0.10}_{-0.09}(\mathrm{stat.})^{+0.13}_{-0.11}(\mathrm{theo\ syst.})^{+0.14}_{-0.13}(\mathrm{exp\ syst.}) = 1.10^{+0.21}_{-0.20}$$

$$\mu_{\mathrm{VBF}} = 0.62^{+0.29}_{-0.27}(\mathrm{stat.})^{+0.12}_{-0.13}(\mathrm{theo\ syst.}) \pm 0.15(\mathrm{exp\ syst.}) = 0.62^{+0.36}_{-0.35}$$

$$\mu_{WH} = 2.3^{+1.1}_{-0.9}(\mathrm{stat.})^{+0.41}_{-0.33}(\mathrm{theo\ syst.})^{+0.49}_{-0.36}(\mathrm{exp\ syst.}) = 2.3^{+1.2}_{-1.0}$$

$$\mu_{ZH} = 2.9^{+1.7}_{-1.3}(\mathrm{stat.})^{+0.66}_{-0.27}(\mathrm{theo\ syst.})^{+0.54}_{-0.28}(\mathrm{exp\ syst.}) = 2.9^{+1.9}_{-1.3}$$



- Experimental and theoretical systematic ~equal
- Statistical uncertainty in ggF < systematic

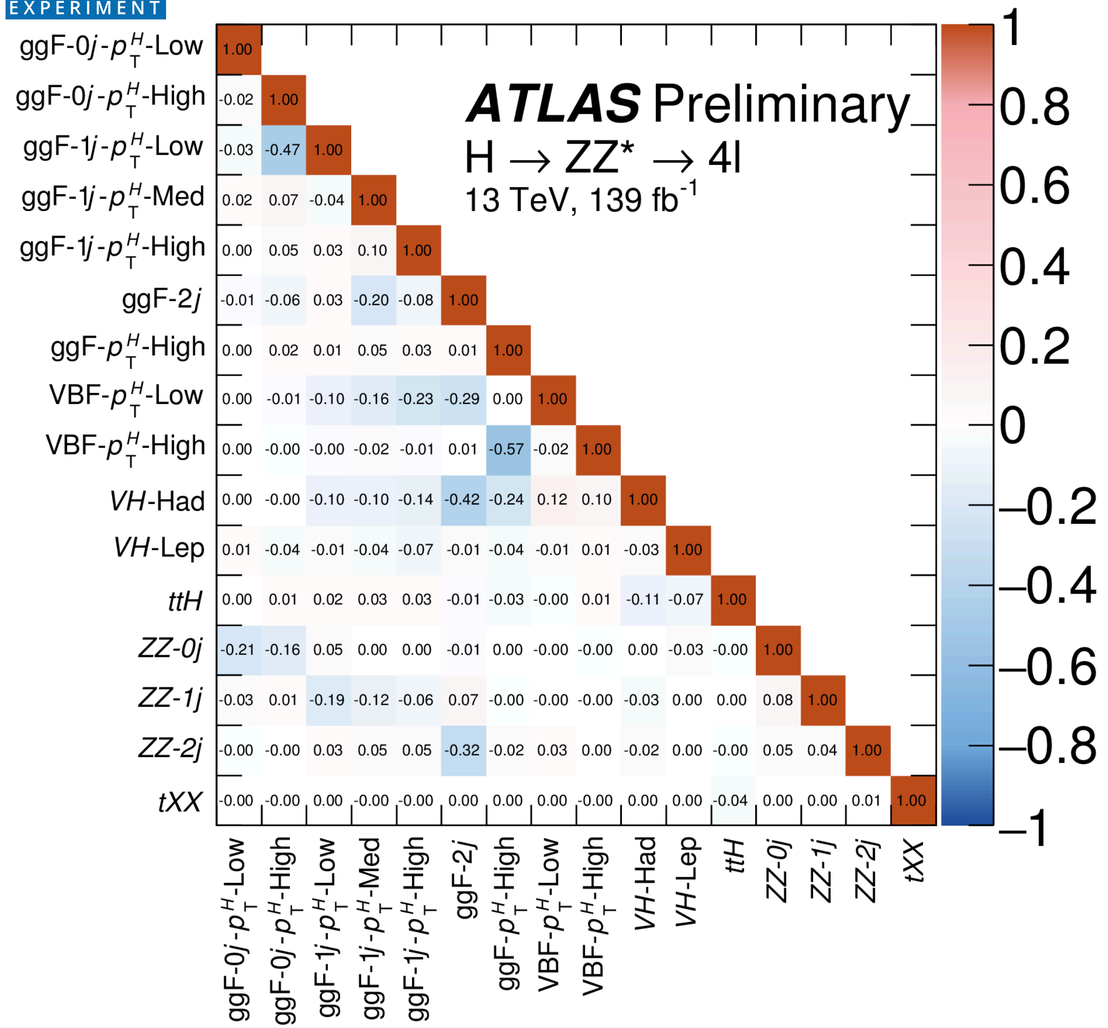
Treatment of Theory Uncertainties

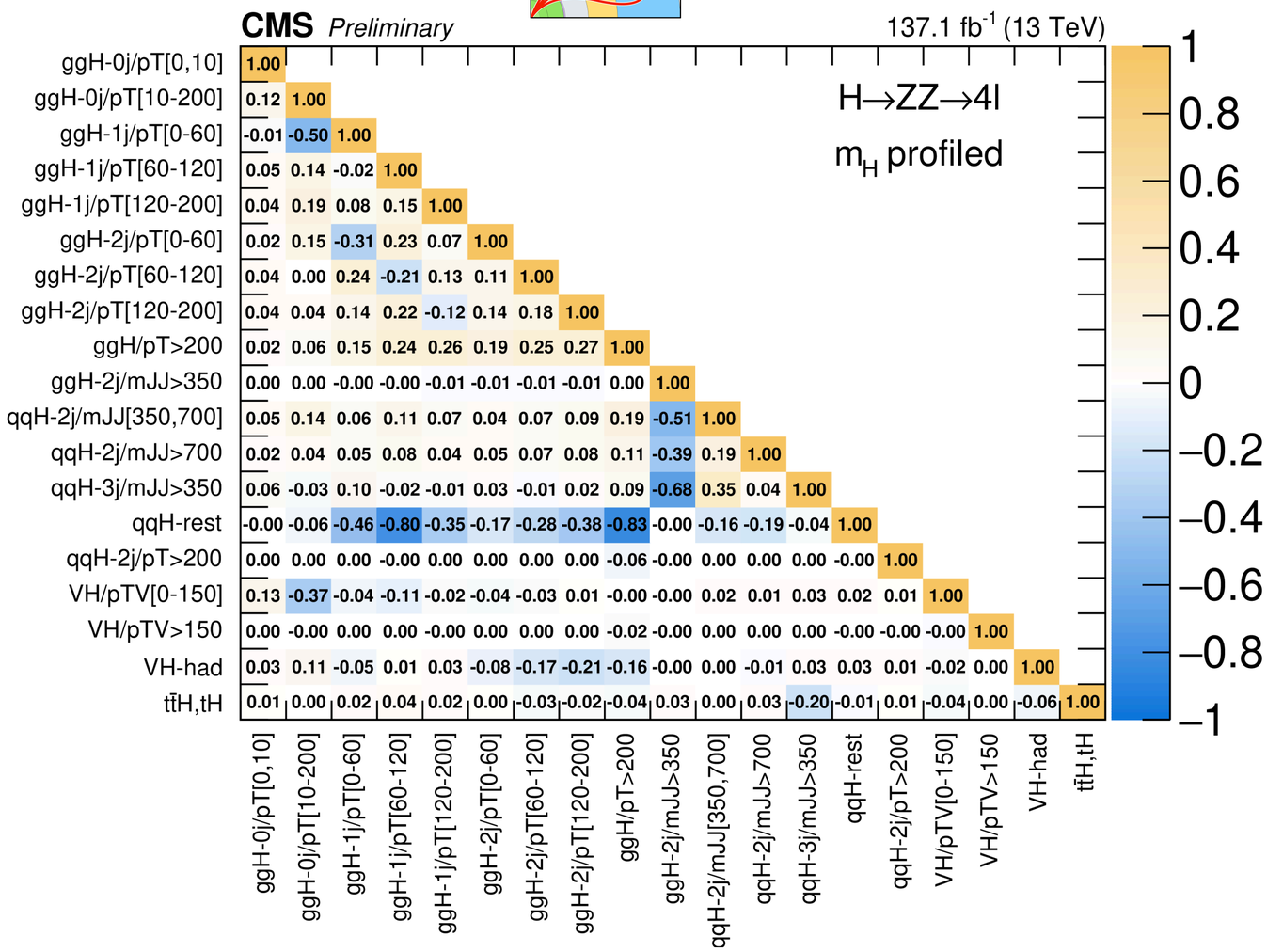
- Example: $H \rightarrow ZZ^* \rightarrow 4\ell$

Systematic	ATLAS	CMS
μ_R and μ_F	8-point variation: Vary by 0.5 and 2.0; No further constraint	6-point variation: Vary by 0.5 and 2.0; Constrain $0.5 < \mu_R/\mu_F < 2.0$
PDF	PDF4LHC_NLO_30 Hessian eigenvector variations: NNPDF3.0 eigenvectors + alternative nominal (MMHT2014, CT14)	NNPDF eigenvector variations

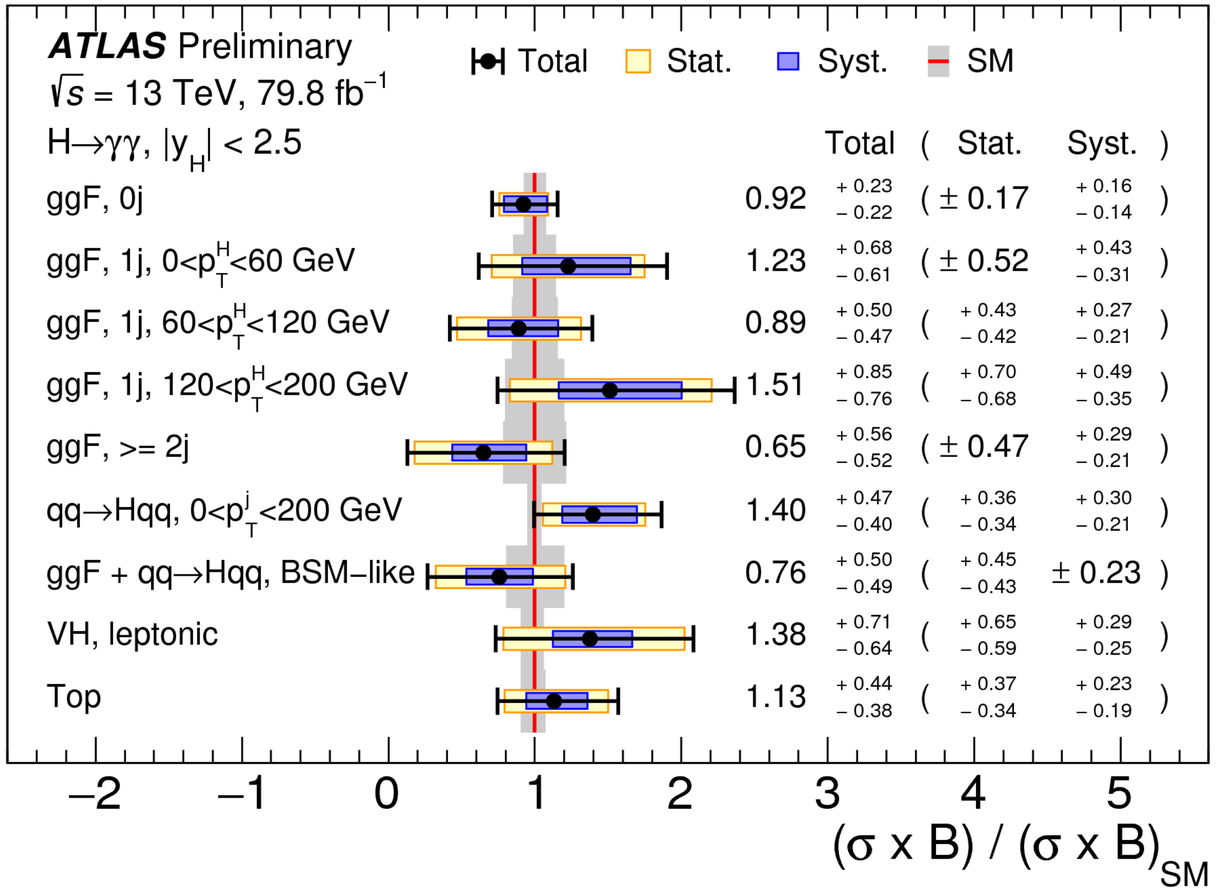
Full Run-2 H → ZZ* → 4ℓ STXS Stage 1.1

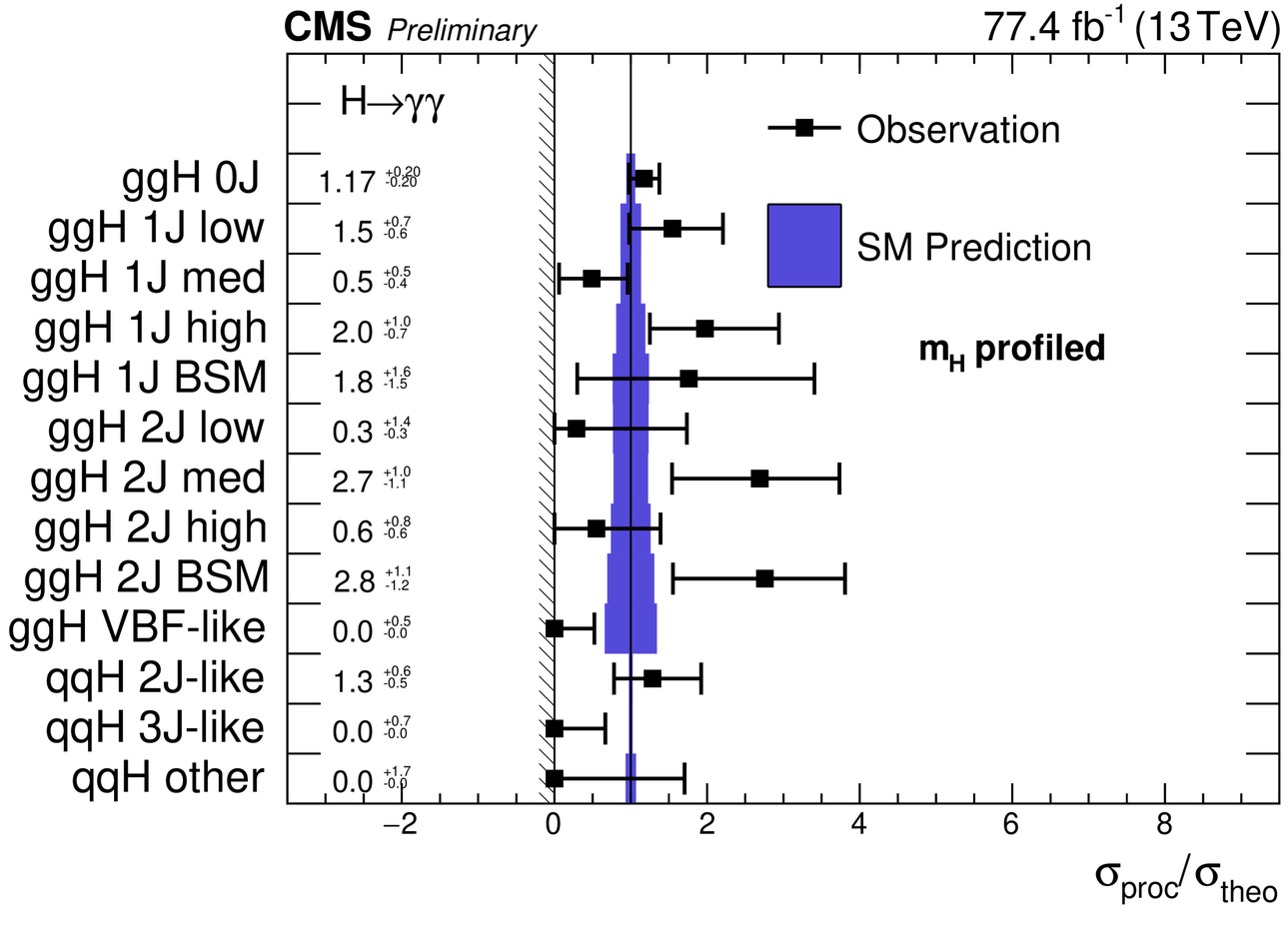
- Impressive STXS Stage 1.1 full Run-2 data results





~80 fb^{-1} H → γγ STXS Stage 1.1





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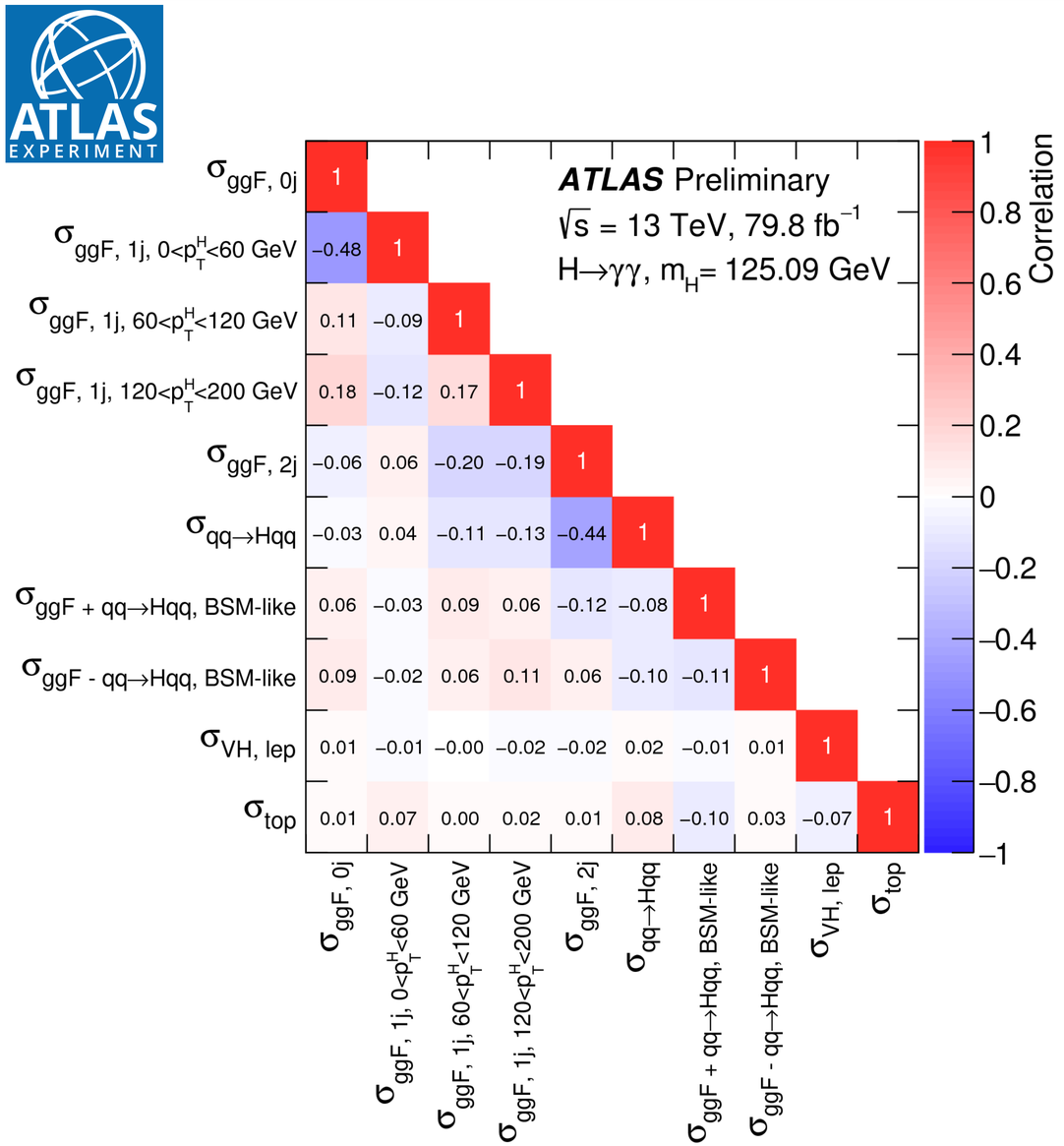

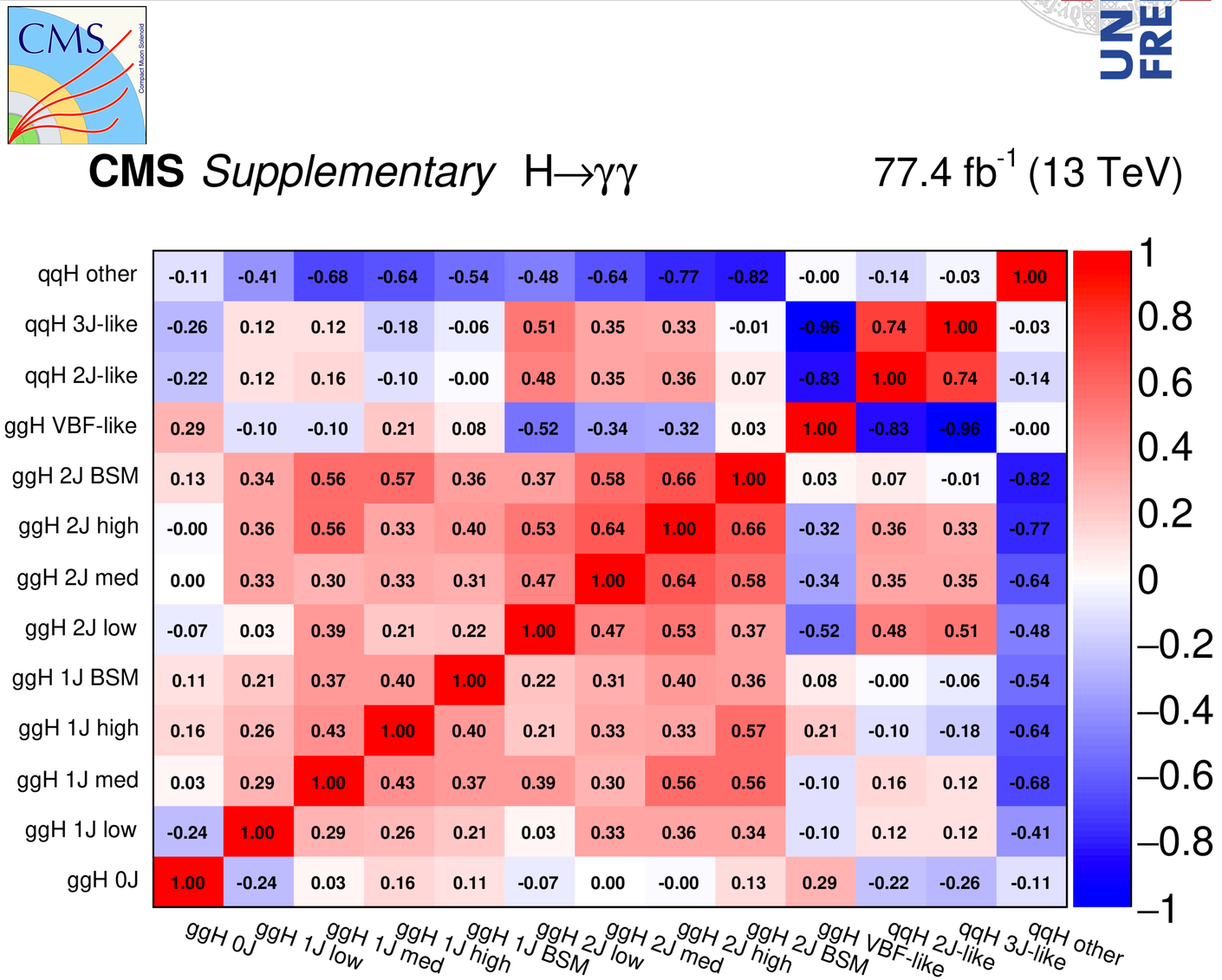

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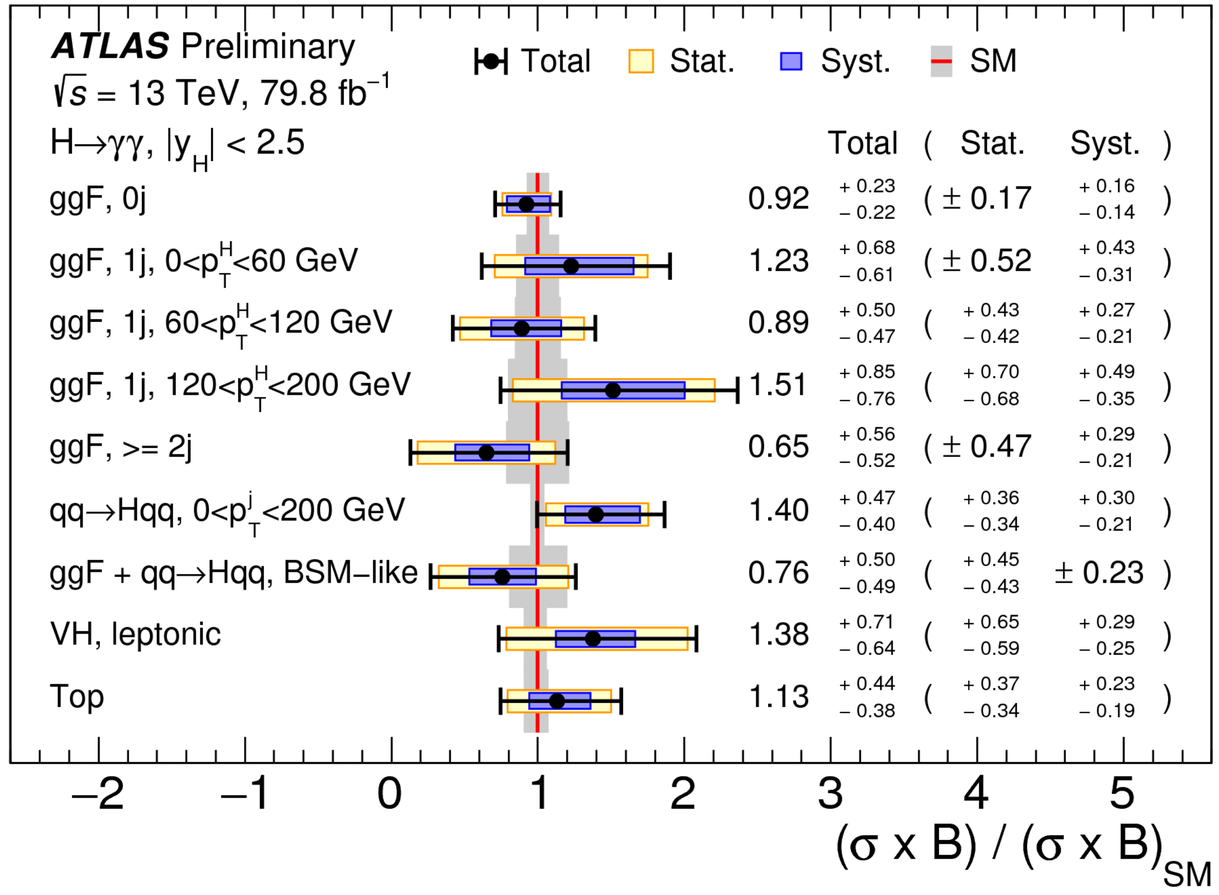

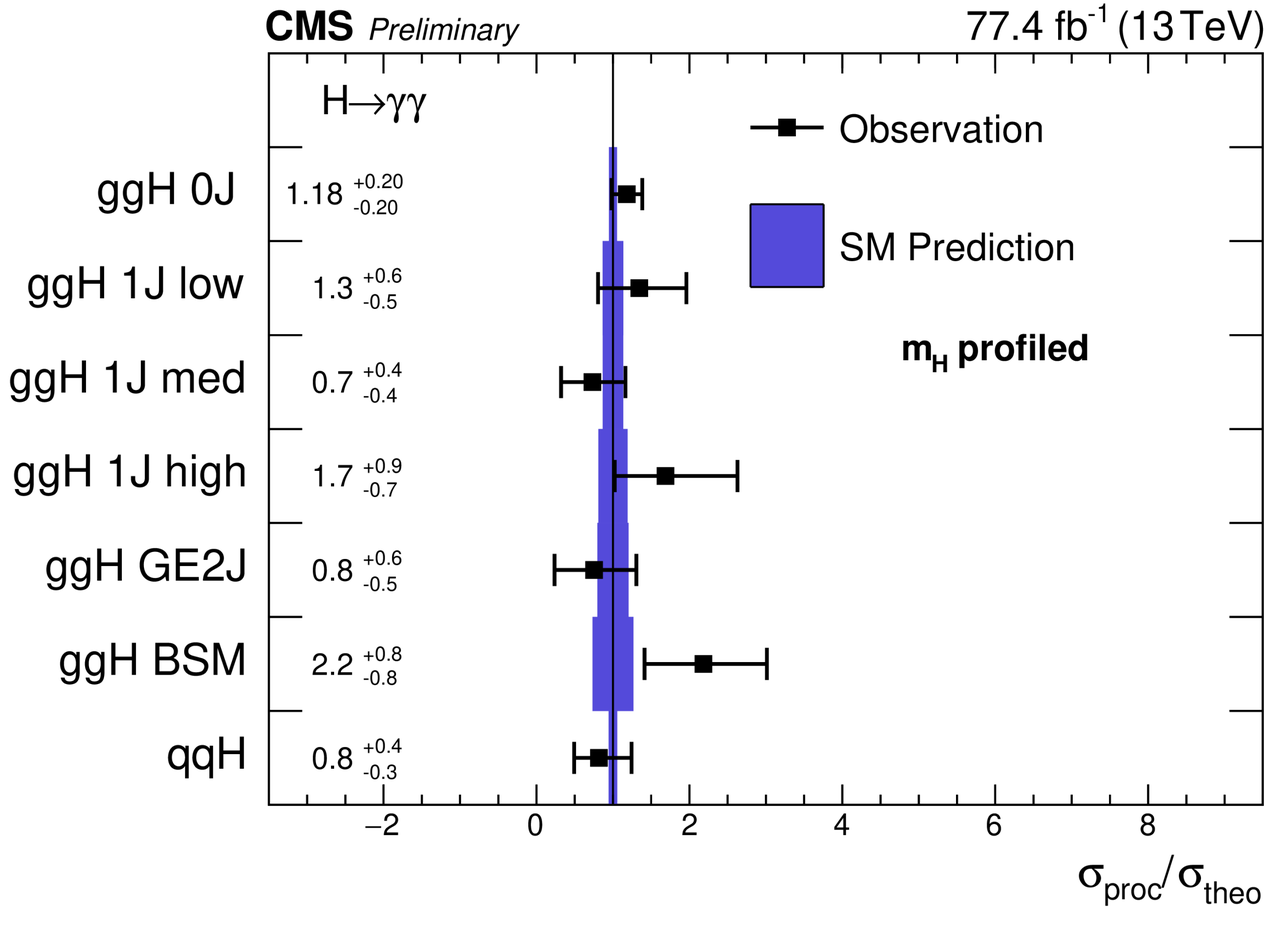

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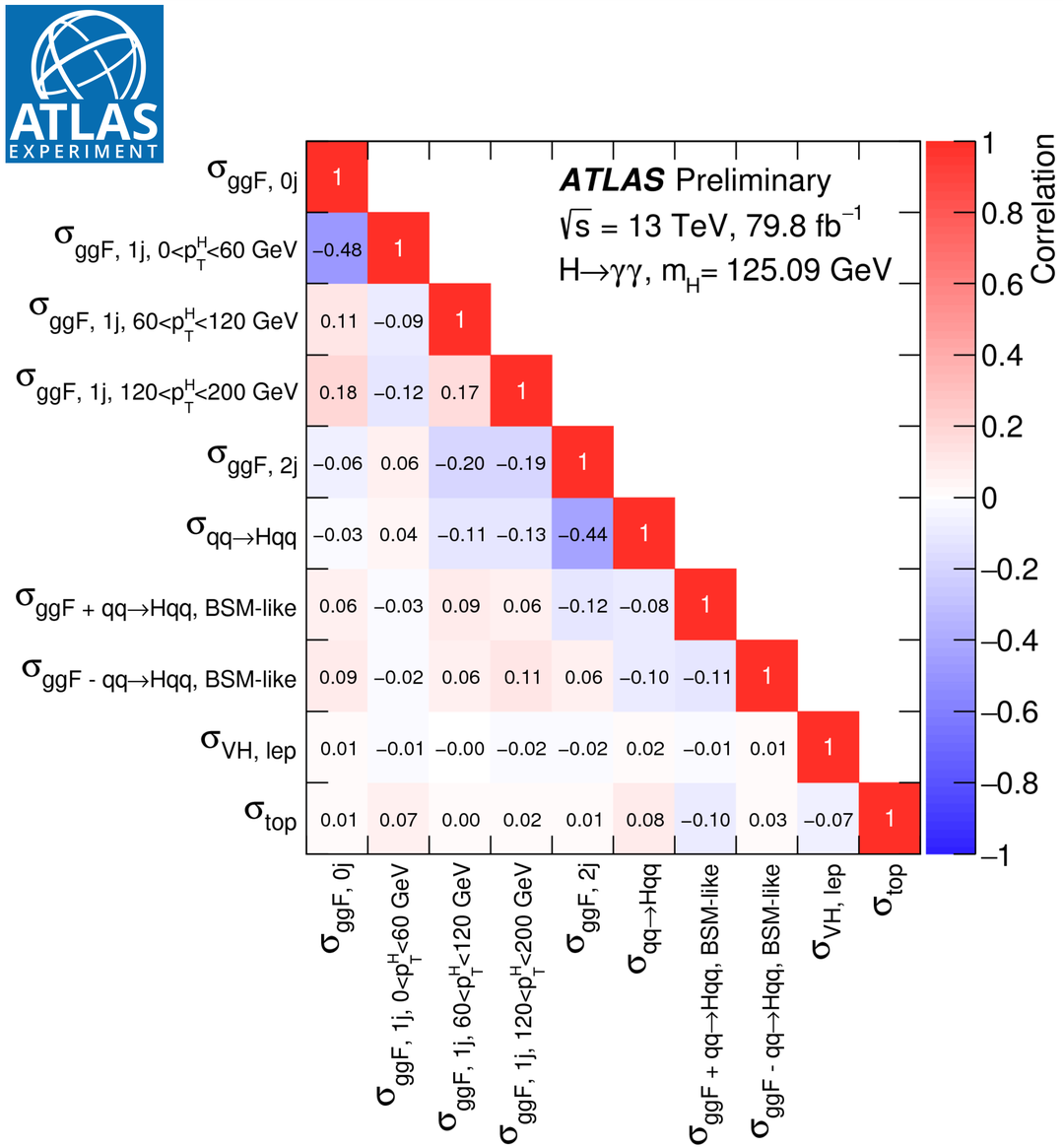

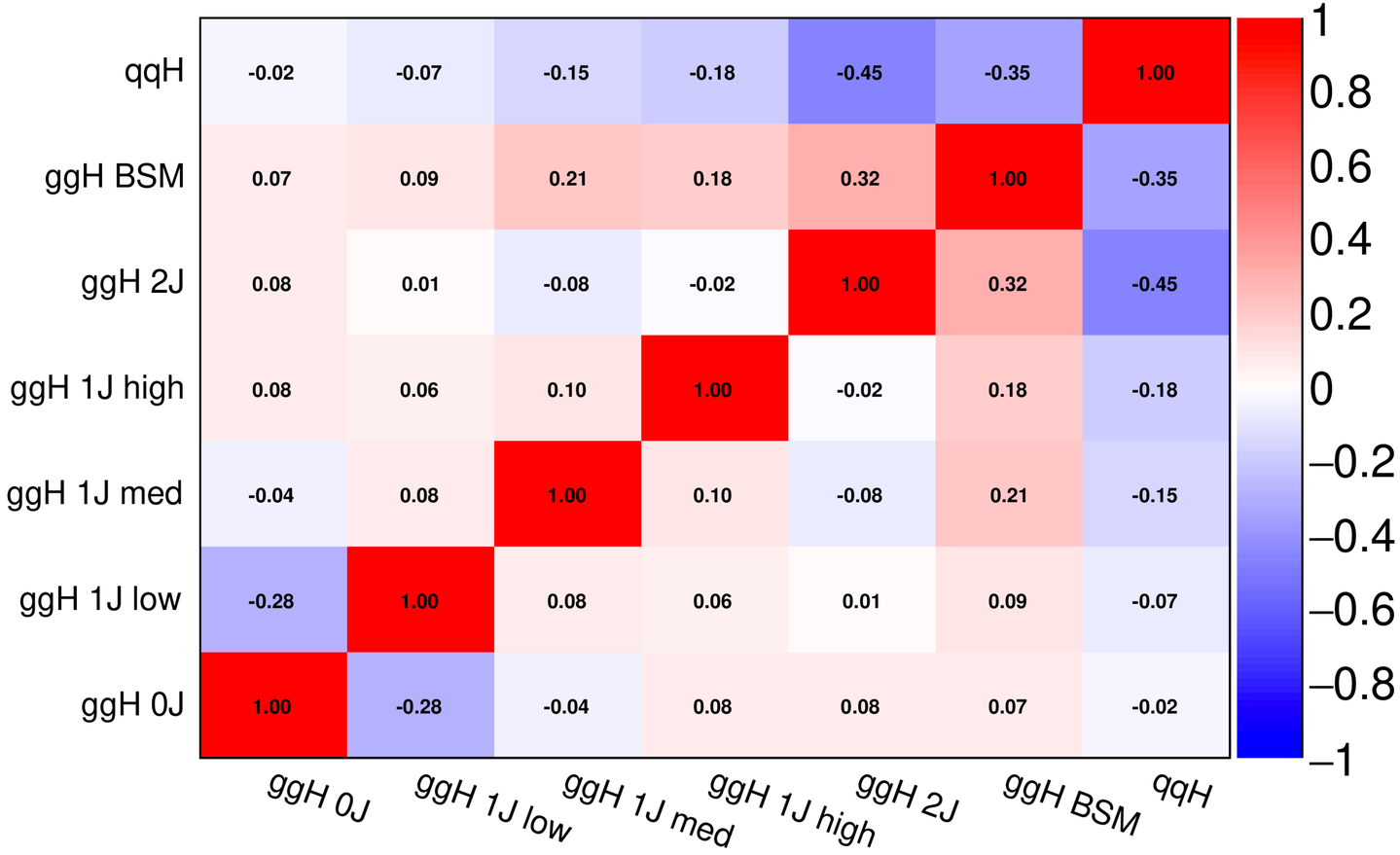

(Fiducial) Cross-Sections and μ

- Different definitions of fiducial phase space

Channel	ATLAS	CMS
$H \to ZZ^* \to 4\ell$	$\sigma \cdot \mathcal{B}(H \to ZZ^*) = 1.38 \pm 0.11(\text{stat.})^{+0.05}_{-0.03}(\text{exp.}) \pm 0.03(\text{th.})$ pb $= 1.38 \pm 0.12$ pb (SM: 1.33 ± 0.09 pb) $\sigma^{\text{comb}}_{\text{fid.}} = 3.35 \pm 0.30(\text{stat.}) \pm 0.12(\text{syst.})$fb $(\text{SM} : 3.41 \pm 0.18)$fb	$\sigma_{\text{fid.}} = 2.73^{+0.30}_{-0.29} = 2.73^{+0.23}_{-0.22}(\text{stat.})^{+0.24}_{-0.19}(\text{syst.})$ fb $\sigma^{\text{SM}}_{\text{fid.}} = 2.76 \pm 0.14$ fb
$H \to \gamma\gamma$	$\sigma_{\text{fid}} = 65.2 \pm 4.5\,(\text{stat.}) \pm 5.6\,(\text{syst.}) \pm 0.3\,(\text{theo.})$ fb SM prediction: 63.3 +- 3.3 fb	$\sigma_{ggH}/\sigma^{\text{SM}}_{ggH} = 1.15^{+0.15}_{-0.15}$ $\sigma_{qqH}/\sigma^{\text{SM}}_{qqH} = 0.8^{+0.4}_{-0.3}$
$H \to WW^* \to \ell\nu\ell\nu$	$\sigma_{\text{ggF}} \cdot \mathcal{B}_{H\to WW^*} = 11.4^{+1.2}_{-1.1}(\text{stat.})^{+1.2}_{-1.1}(\text{theo syst.})^{+1.4}_{-1.3}(\text{exp syst.})$ pb $= 11.4^{+2.2}_{-2.1}$ pb (SM: 10.4 ± 0.6 pb) $\sigma_{\text{VBF}} \cdot \mathcal{B}_{H\to WW^*} = 0.50^{+0.24}_{-0.22}(\text{stat.}) \pm 0.10(\text{theo syst.})^{+0.12}_{-0.13}(\text{exp syst.})$ pb $= 0.50^{+0.29}_{-0.28}$ pb (SM: 0.81 ± 0.02 pb) $\sigma_{WH} \cdot \mathcal{B}_{H\to WW^*} = 0.67^{+0.31}_{-0.27}(\text{stat.})^{+0.11}_{-0.09}(\text{theo syst.})^{+0.14}_{-0.11}(\text{exp syst.})$ pb (SM: 0.293 ± 0.007 pb) $\sigma_{ZH} \cdot \mathcal{B}_{H\to WW^*} = 0.54^{+0.31}_{-0.24}(\text{stat.})^{+0.11}_{-0.05}(\text{theo syst.})^{+0.10}_{-0.05}(\text{exp syst.})$ pb (SM: 0.189 ± 0.007 pb)	$\mu = 1.28 \pm 0.10\,(\text{stat}) \pm 0.11\,(\text{syst})^{+0.10}_{-0.07}\,(\text{theo})$ $= 1.28^{+0.18}_{-0.17}$

Example of different fiducial definitions

$H \to ZZ^* \to 4\ell$

Leptons and jets	
Leptons	$p_T > 5$ GeV, $\lvert\eta\rvert < 2.7$
Jets	$p_T > 30$ GeV, $\lvert y\rvert < 4.4$
remove jets with	$\Delta R(\text{jet}, \ell) < 0.1$
Lepton selection and pairing	
Lepton kinematics	$p_T > 20, 15, 10$ GeV
Leading pair (m_{12})	SFOS lepton pair with smallest $\lvert m_Z - m_{\ell\ell}\rvert$
Subleading pair (m_{34})	remaining SFOS lepton pair with smallest $\lvert m_Z - m_{\ell\ell}\rvert$
Event selection (at most one quadruplet per event)	
Mass requirements	50 GeV$< m_{12} <$ 106 GeV and 12 GeV $< m_{34} <$ 115 GeV
Lepton separation	$\Delta R(\ell_i, \ell_j) > 0.1$
J/ψ veto	$m(\ell_i, \ell_j) > 5$ GeV for all SFOS lepton pairs
Mass window	105 GeV $< m_{4\ell} <$ 160 GeV
If extra leptons with $p_T > 12$ GeV	Quadruplet with the largest ME

Requirements for the $H \to 4\ell$ fiducial phase space	
Lepton kinematics and isolation	
Leading lepton p_T	$p_T > 20$ GeV
Next-to-leading lepton p_T	$p_T > 10$ GeV
Additional electrons (muons) p_T	$p_T > 7(5)$ GeV
Pseudorapidity of electrons (muons)	$\lvert\eta\rvert < 2.5(2.4)$
Sum of scalar p_T of all stable particles within $\Delta R < 0.3$ from lepton	$< 0.35 \cdot p_T$
Event topology	
Existence of at least two same-flavor OS lepton pairs, where leptons satisfy criteria above	
Inv. mass of the Z_1 candidate	40 GeV $< m_{Z_1} <$ 120 GeV
Inv. mass of the Z_2 candidate	12 GeV $< m_{Z_2} <$ 120 GeV
Distance between selected four leptons	$\Delta R(\ell_i, \ell_j) > 0.02$ for any $i \neq j$
Inv. mass of any opposite sign lepton pair	$m_{\ell^+\ell^-} > 4$ GeV
Inv. mass of the selected four leptons	105 GeV $< m_{4\ell} <$ 140 GeV

$H \to \gamma\gamma$

Objects	Fiducial definition
Photons	$\lvert\eta\rvert < 2.37$ (excluding $1.37 < \lvert\eta\rvert < 1.52$), $\sum p_T^i / p_T^\gamma < 0.05$
Jets	anti-k_t, $R = 0.4$, $p_T > 30$ GeV, $\lvert y\rvert < 4.4$
Diphoton	$N_\gamma \geq 2$, $105\,GeV < m_{\gamma\gamma} < 160\,GeV$, $p_T^{\gamma_1}/m_{\gamma\gamma} > 0.35$, $p_T^{\gamma_2}/m_{\gamma\gamma} > 0.25$