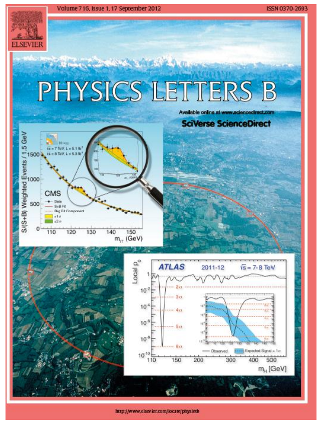
Study of the H→VV decays (ZZ,γγ,WW)

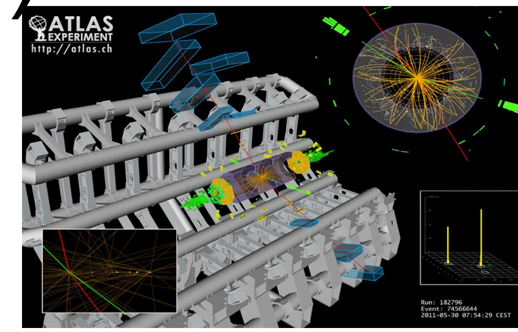
Christos Anastopoulos

ATLAS EXPERIMENT
CMS Compact Muon Solenoid
The University Of Sheffield.
THE ROYAL SOCIETY

H→VV decays (ZZ,γγ,WW)



From: Higgs boson discovery



To: Understanding of Higgs boson properties

CMS-PAS-HIG-18-029	**Measurements of Higgs boson production via gluon fusion and vector boson fusion in the diphoton decay channel at √s = 13 TeV**	**77.4 fb^{-1}**
CMS-PAS-HIG-19-001	**Measurements of properties of the Higgs boson in the four-lepton final state in proton-proton collisions at √s = 13 TeV**	**137.1 fb^{-1}**
Physics Letters B 791 (2019) 96–129	**Measurements of properties of the Higgs boson decaying to a W boson pair in pp collisions at √s = 13 TeV**	**35.9 fb^{-1}**
CMS-PAS-FTR-16-002	**Projected performance of Higgs analyses at the HL-LHC for ECFA 2016**	**HL-LHC**
ATLAS-CONF-2018-028	**Measurements of Higgs boson properties in the diphoton decay channel using 80 fb^{-1} of pp collision data at √s= 13 TeV with the ATLAS detector**	**79.8 fb^{-1}**
ATLAS-CONF-2018-018	**Measurements of the Higgs boson production, fiducial and differential cross sections in the 4ℓ decay channel at √s =13 TeV with the ATLAS detector**	**79.8 fb^{-1}**
arXiv:1903.10052	**Measurement of the production cross section for a Higgs boson in association with a vector boson in the H→WW*→ℓνℓν channel in pp collisions at s√ = 13 TeV with the ATLAS detector**	**36.1 fb^{-1}**
ATL-PHYS-PUB-2017-018	**Constraints on an effective Lagrangian from the combined *H*→*ZZ**→4ℓ and *H*→*γγ* channels using 36.1 fb–1 of √s = 13 TeV *pp* collision data collected with the ATLAS detector**	**36.1 fb^{-1}**
ATL-PHYS-PUB-2018-040	**Prospects for differential cross-section measurements of Higgs boson production measured in decays to ZZ and γγ with the ATLAS experiment at the High-Luminosity LHC**	**HL-LHC**

H→ZZ

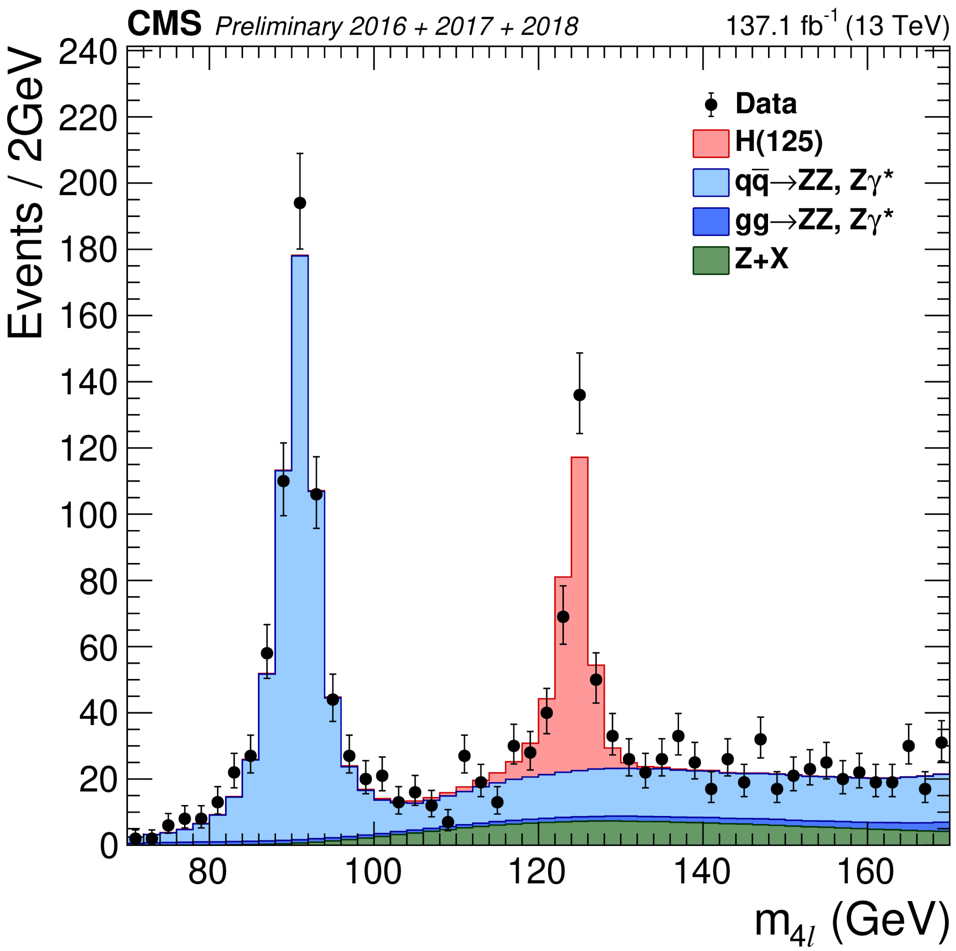
Our understanding has evolved. But the "baseline" selections are not that different to the one that served us well for the discovery and Run-I measurement.

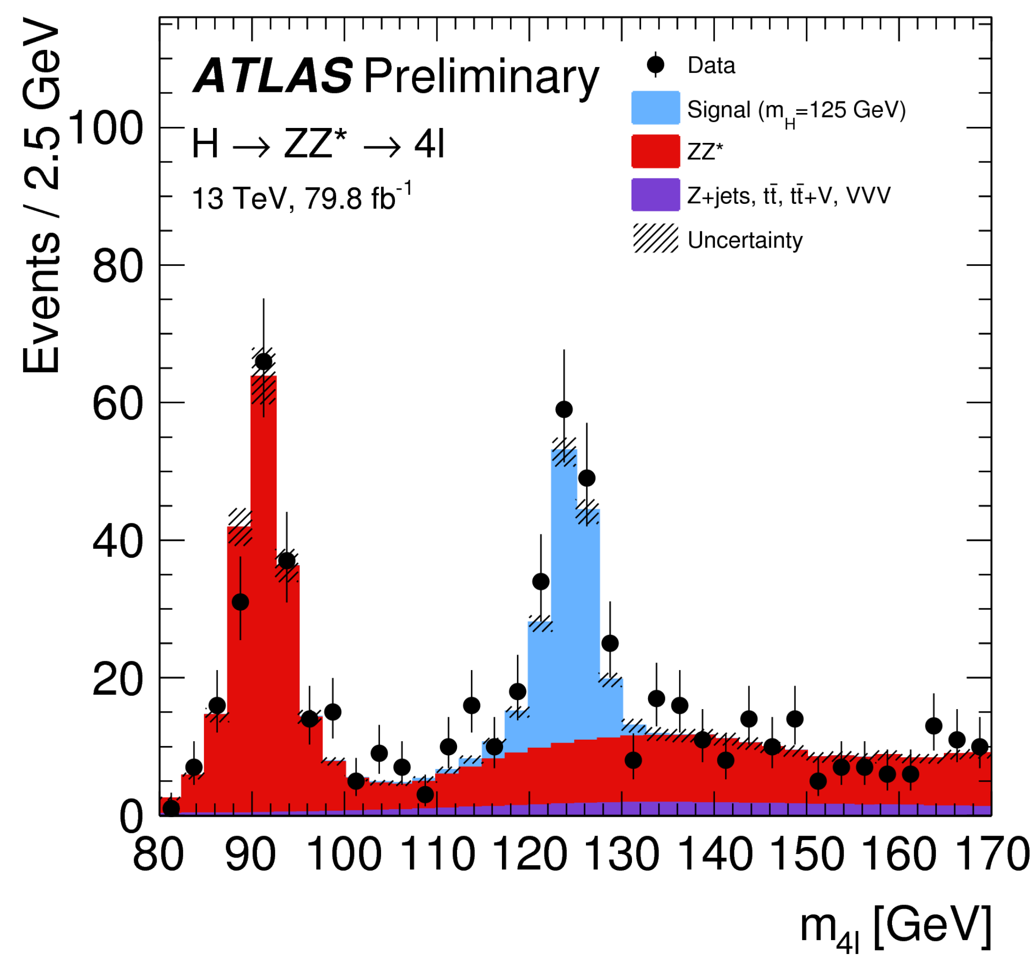
CMS H→ZZ selection :

- ***muons (electrons)***
- ***$|\eta|$< 2.4 (2.5)***
- ***P_t 20 GeV, 10 GeV, 10 GeV, 5(7) GeV***
- ***12 GeV < m_{ll} < 120 GeV***
- ***Z_1 > 40 GeV***

ATLAS H→ZZ selection :

- ***muons (electrons)***
- ***$|\eta|$< 2.7 (2.47)***
- ***P_t 20 GeV, 15 GeV, 10 GeV , 5(7) GeV***
- ***50 GeV < m_{12} < 106 GeV***
- ***12 GeV < m_{34} < 115 GeV***





H→γγ

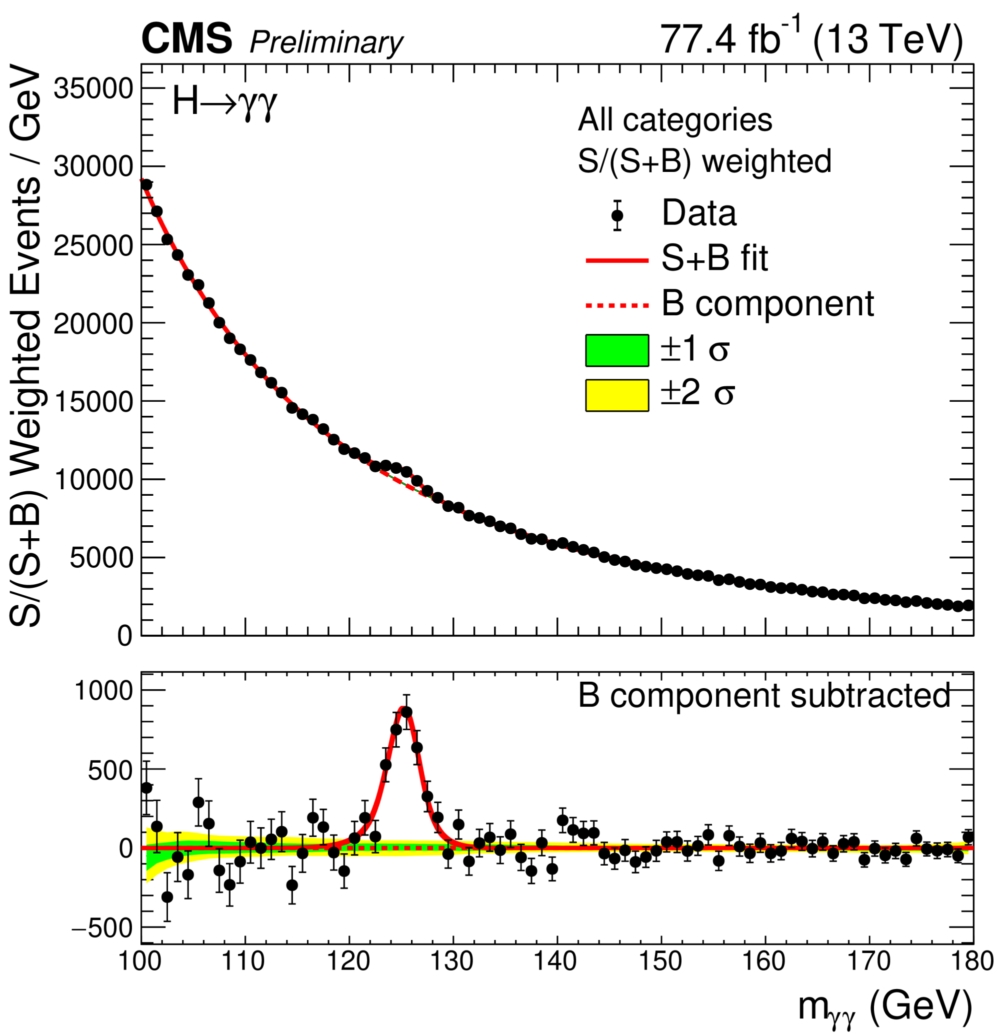
Our understanding has evolved. But the "baseline" selections are not that different to the one that served us well for the discovery and Run-I measurement.

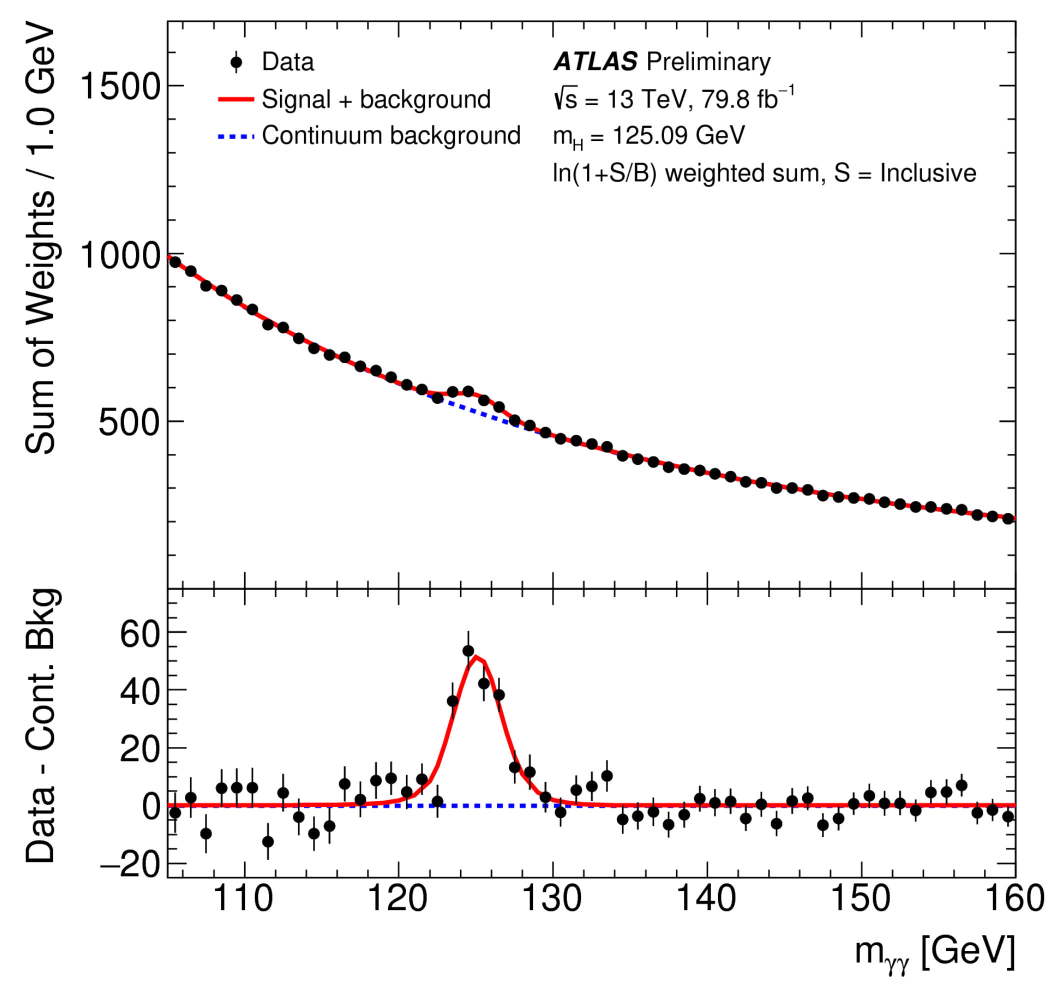
CMS H→γγ selection :

- ***P_t 35 GeV, 25 GeV***
- ***$|\eta|< 2.4$ (exclude 1.44-1.57)***
- ***$100 < m_{\gamma\gamma} < 180$ GeV***
- ***$p_t^{\gamma 1} > m_{\gamma\gamma}/3$, $p_t^{\gamma 2} > m_{\gamma\gamma}/4$***

ATLAS H→γγ selection :

- ***P_t 35 GeV, 25 GeV***
- ***$|\eta|< 2.37$ (exclude 1.37-1.52)***
- ***$105 < m_{\gamma\gamma} < 160$GeV***
- ***$p_t^{\gamma 1} > 0.35 \cdot m_{\gamma\gamma}$, $p_t^{\gamma 2} > 0.25 \cdot m_{\gamma\gamma}$***





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H→WW

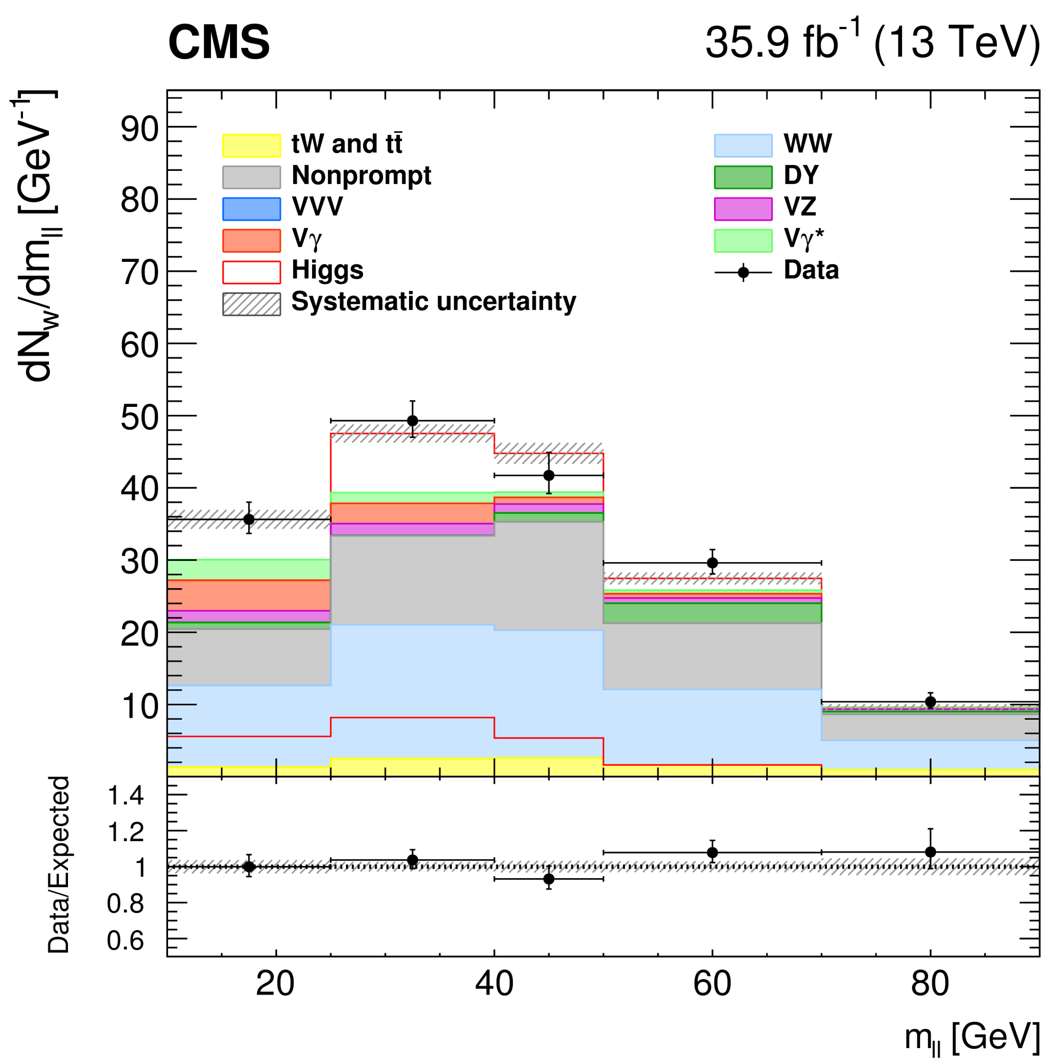
Our understanding has evolved. But the "baseline" selections are not that different to the one that served us well for the discovery and Run-I measurement.

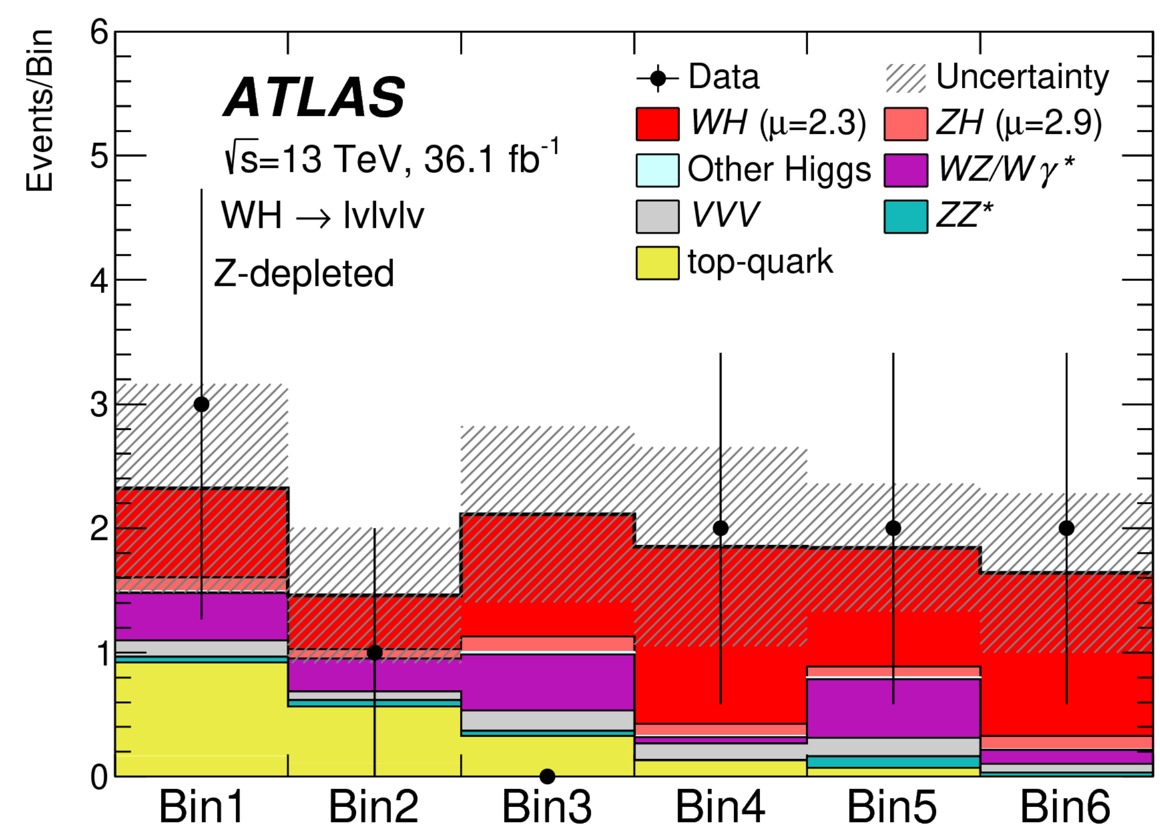
CMS H→WW selection :

- ***e^+e^- P_t >25 GeV , 13 GeV***
- ***$\mu^+\mu^-$ P_t>20 GeV, 10 GeV***
- ***eμ P_t> 25 GeV 10 (13) GeV***
- ***eμ Pflow P_t^{miss}***
- ***e^+e^- , $\mu^+\mu^-$ track P_t^{miss}***

ATLAS H→WW selection :

- ***eμ***
- ***electron P_t > 24-26 GeV***
- ***muon P_t > 20-26 GeV***
- ***Both track and calorimeter based P_t^{miss}***





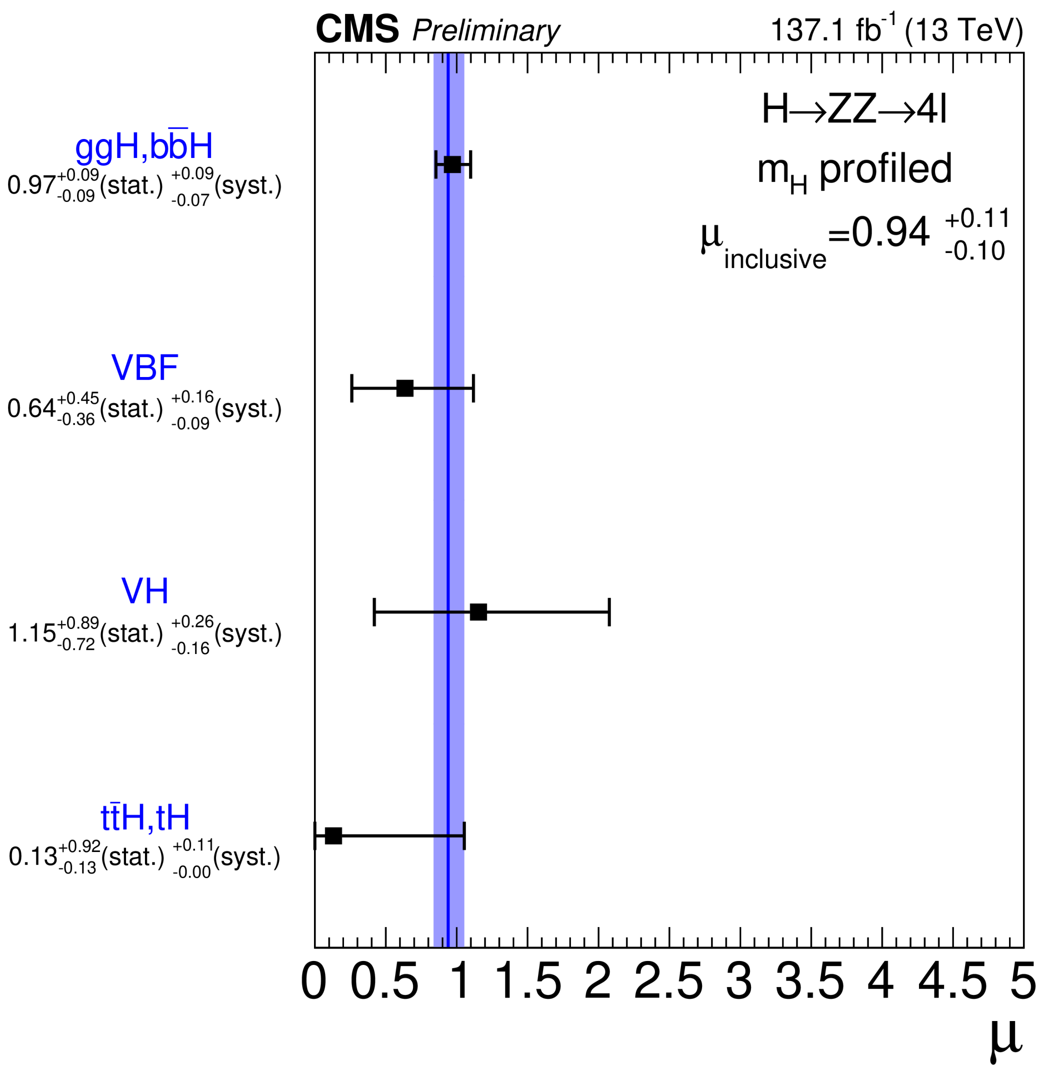
$H \rightarrow VV$ decays

The new challenge is *“Deciphering the nature of the Higgs sector”*
(Handbook of LHC Higgs cross sections:4 , arXiv:1610.07922)

H→ZZ/WW

Signal strength (μ) and x-section * BR measurements still performed. Similar to Run-I

H→ZZ



VH→WW ATLAS

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

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

$$\mu_{VH} = 2.5^{+0.8}_{-0.7}(\text{stat.})^{+0.37}_{-0.26}(\text{theo syst.})^{+0.30}_{-0.23}(\text{exp syst.}) = 2.5^{+0.9}_{-0.8}.$$

$$\sigma_{WH} \cdot \mathcal{B}_{H\to WW^*} = 0.67^{+0.31}_{-0.27}(\text{stat.})^{+0.11}_{-0.09}(\text{theo syst.})^{+0.14}_{-0.11}(\text{exp syst.})\text{ pb},$$

$$\sigma_{ZH} \cdot \mathcal{B}_{H\to WW^*} = 0.54^{+0.31}_{-0.24}(\text{stat.})^{+0.11}_{-0.05}(\text{theo syst.})^{+0.10}_{-0.05}(\text{exp syst.})\text{ pb}.$$

H→WW CMS (combined)

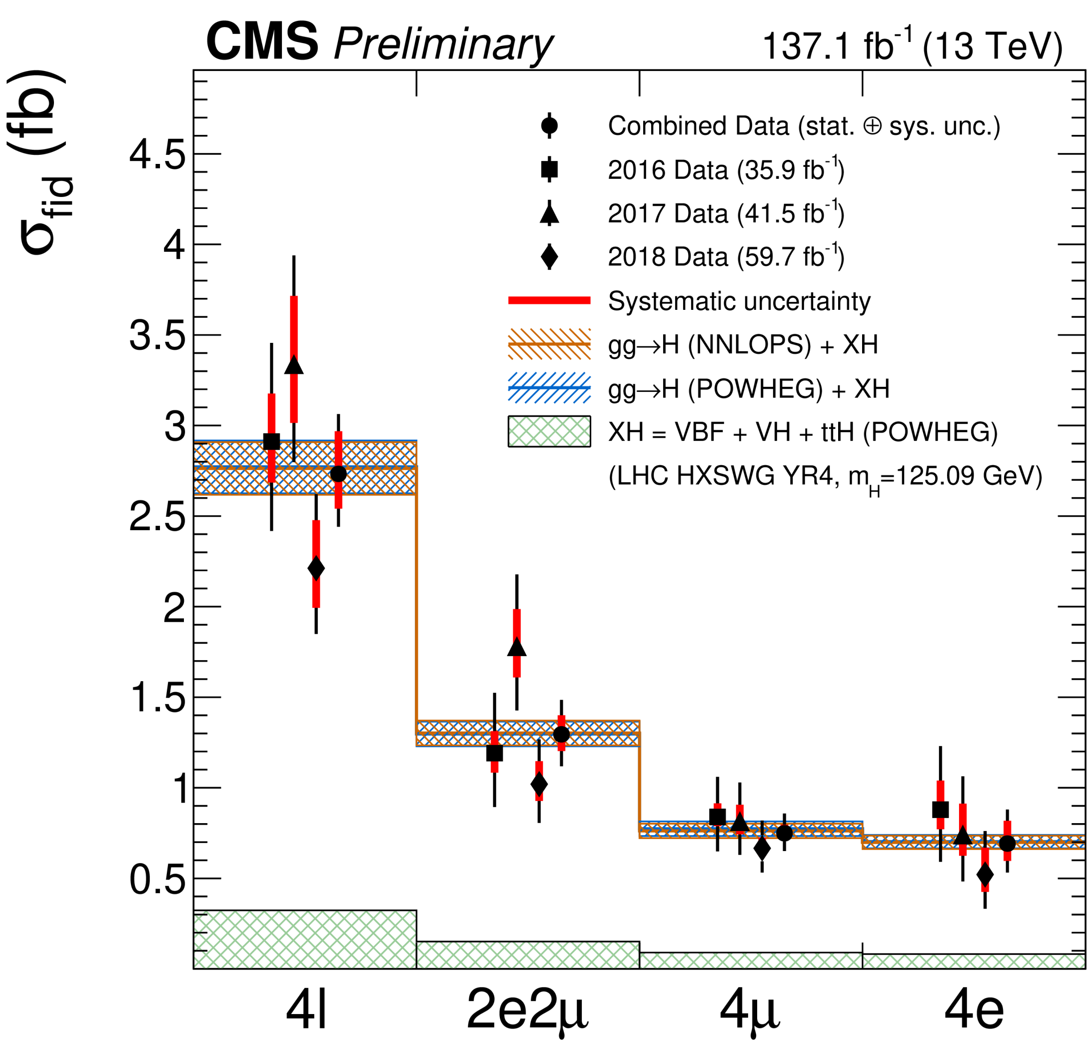
$$\mu = 1.28^{+0.18}_{-0.17} = 1.28 \pm 0.10\,(\text{stat}) \pm 0.11\,(\text{syst})^{+0.10}_{-0.07}\,(\text{theo})$$

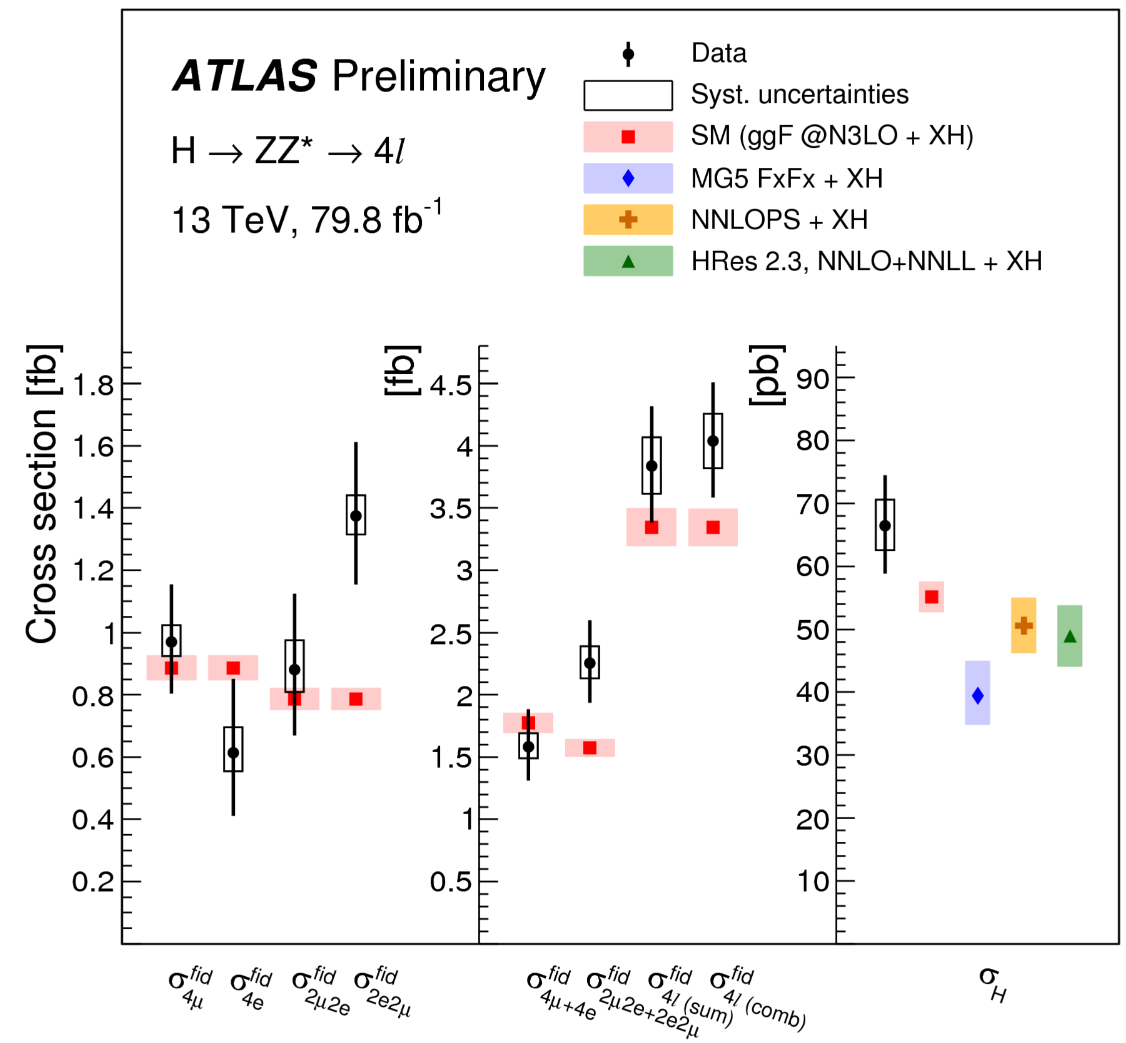
H→ZZ

"Over the past years fiducial measurements, both differential and total, became standard practice for characterising Standard Model (SM) processes at the LHC."

The fiducial cross section $\sigma_{i,\mathrm{fid}}$ for a given final state or bin of the differential distribution, i, is defined as:

$$\sigma_{i,\mathrm{fid}} = \sigma_i \times A_i \times \mathcal{B} = \frac{N_{i,\mathrm{fit}}}{\mathcal{L} \times C_i}, \quad C_i = \frac{N_{i,\mathrm{reco}}}{N_{i,\mathrm{part}}}, \qquad (1)$$

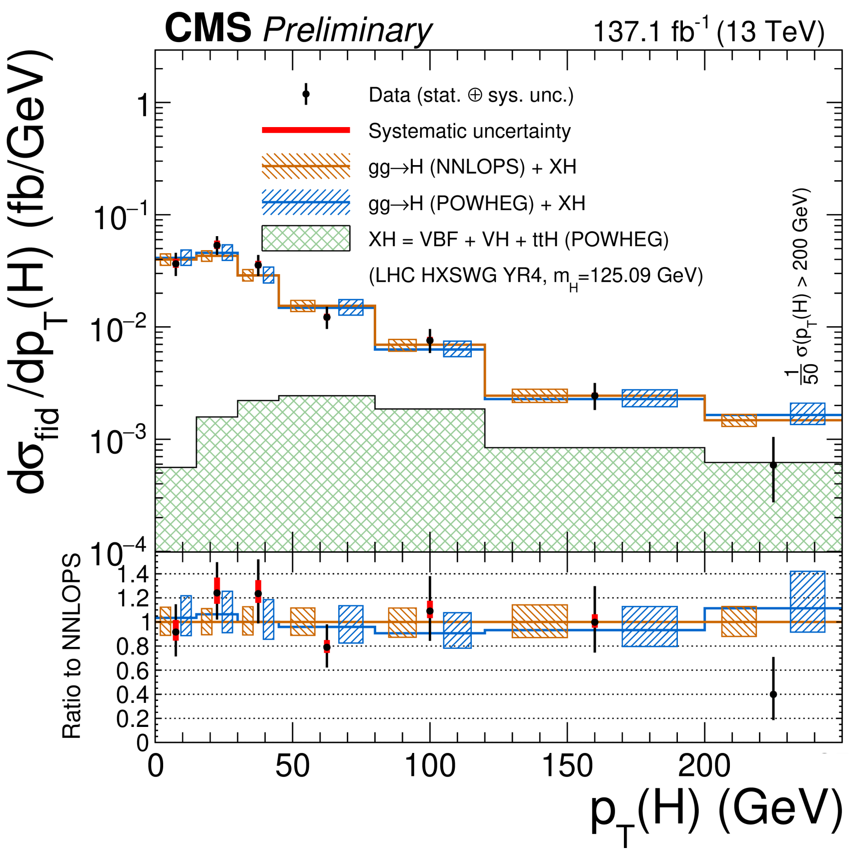




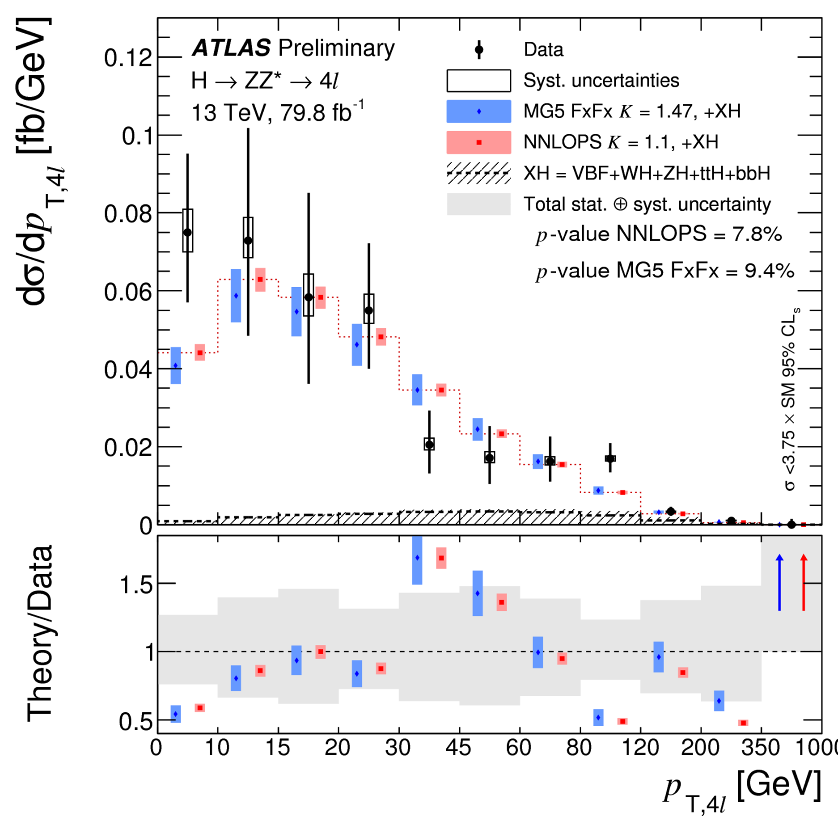
H→ZZ/γγ

Higgs Kinematics P_t^H y^H QCD modelling, PDF , ggF production

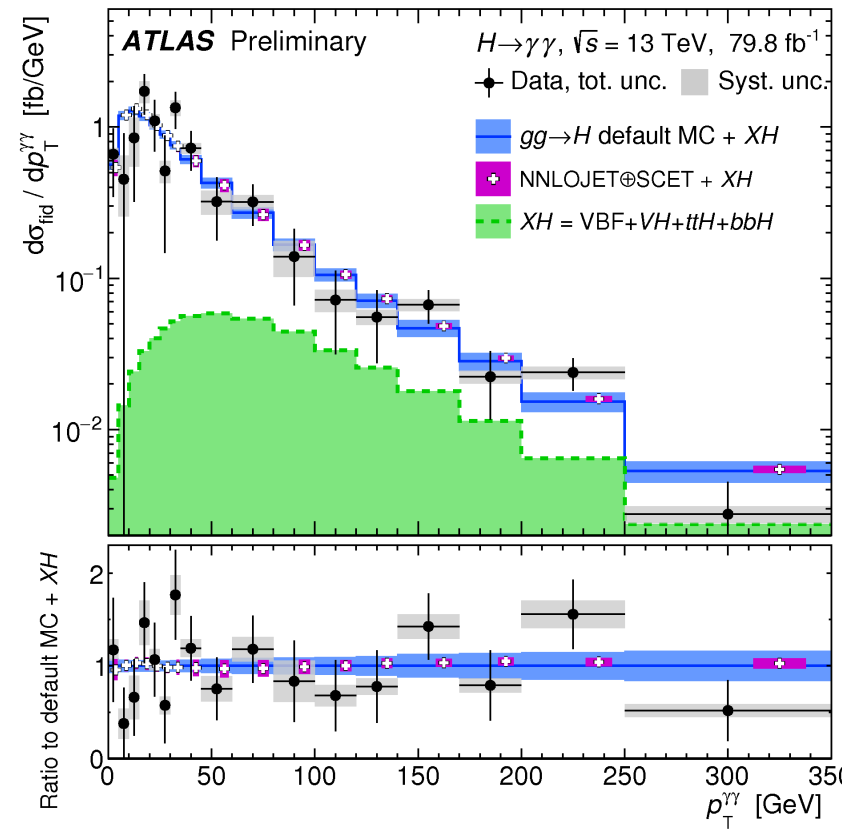
H→ZZ



H→ZZ



H→γγ

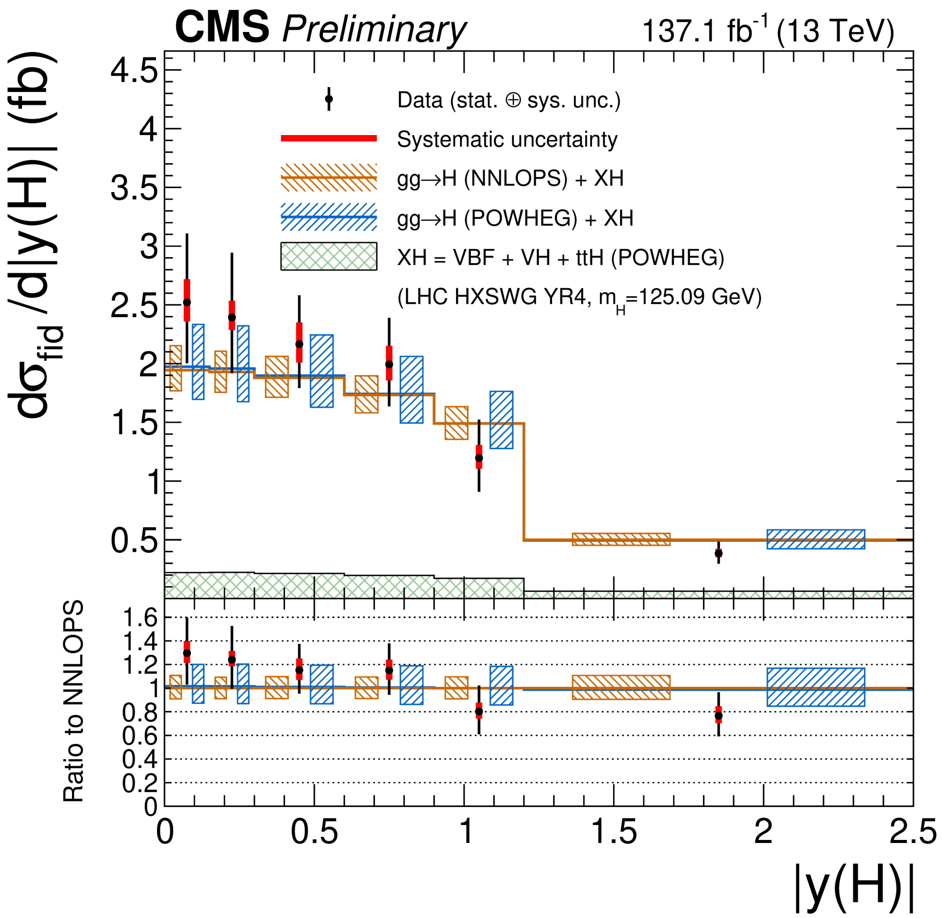


Default MC : ggF component modelled using PowhegNNLOPS and normalised to the N3LO(QCD) +NLO(EW) prediction

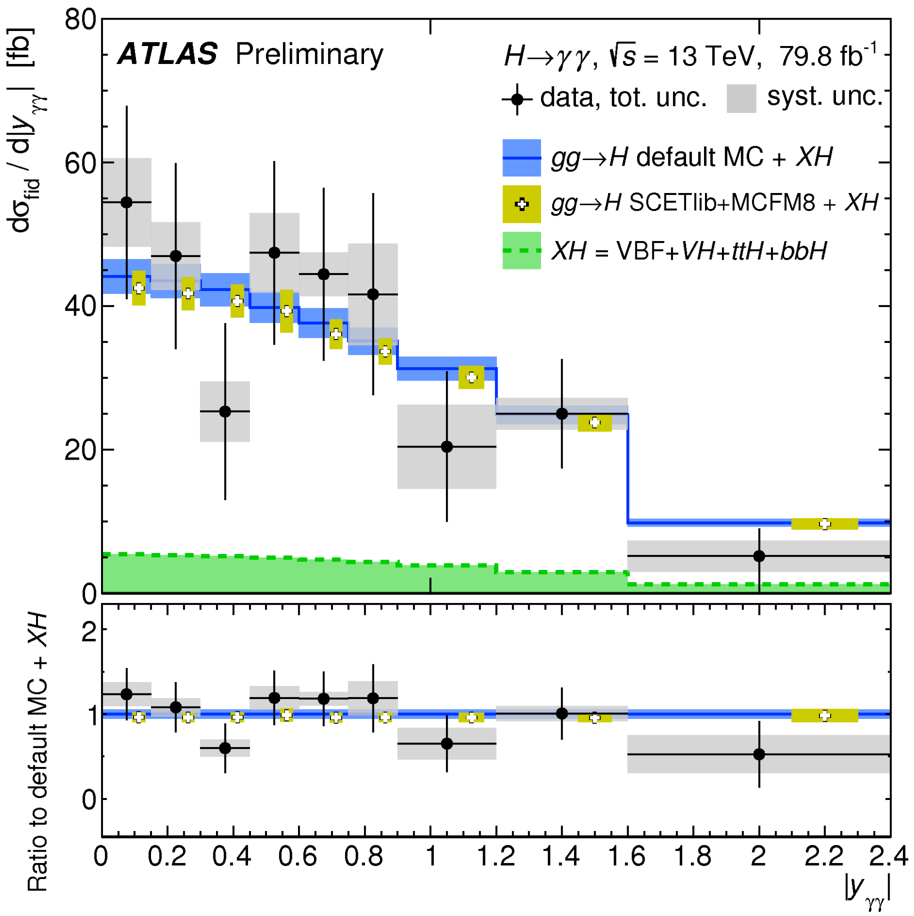
H→ZZ/γγ

Higgs Kinematics P_t^H y^H QCD modelling, PDF , ggF production

H→ZZ



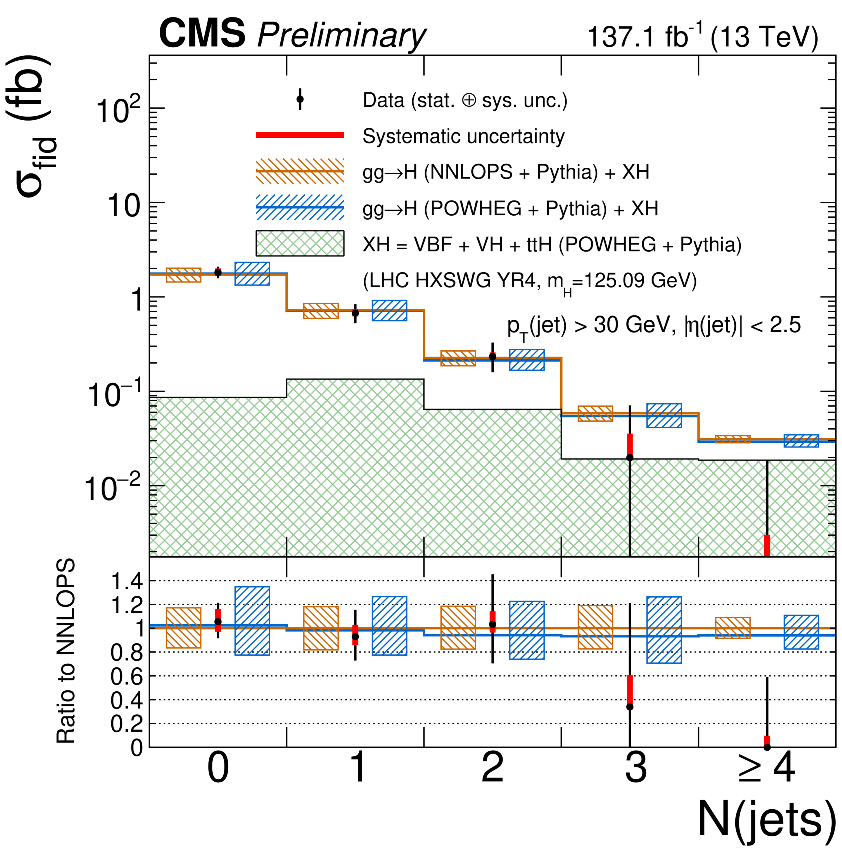
H→γγ



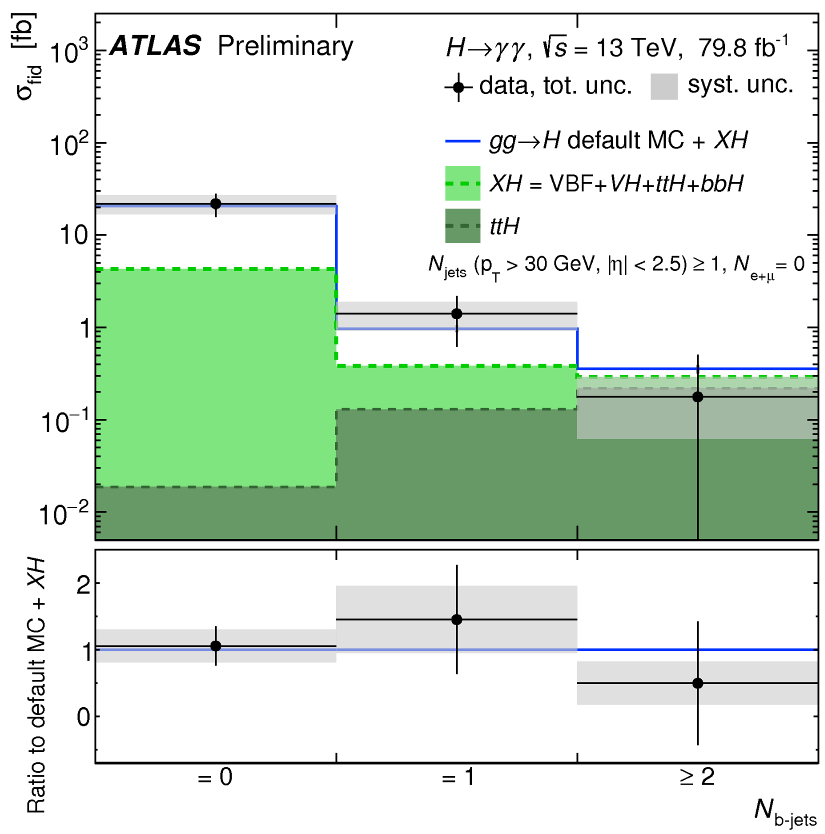
H→ZZ/γγ

<u>Jet Activity</u> : theoretical modelling and relative contributions of different Higgs boson production mechanisms

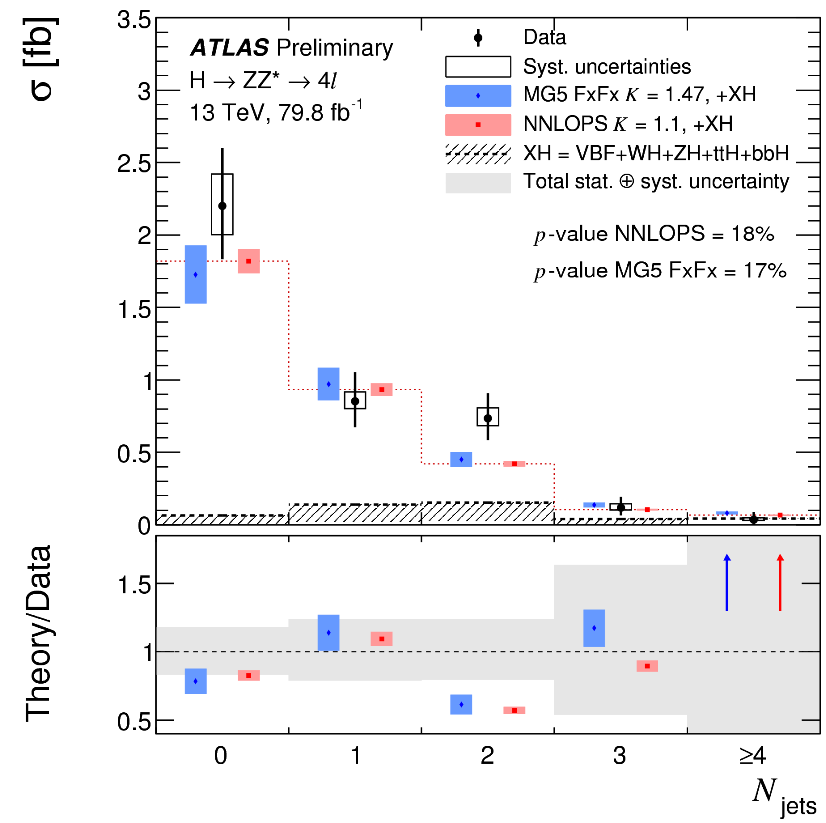
H→ZZ



H→ZZ



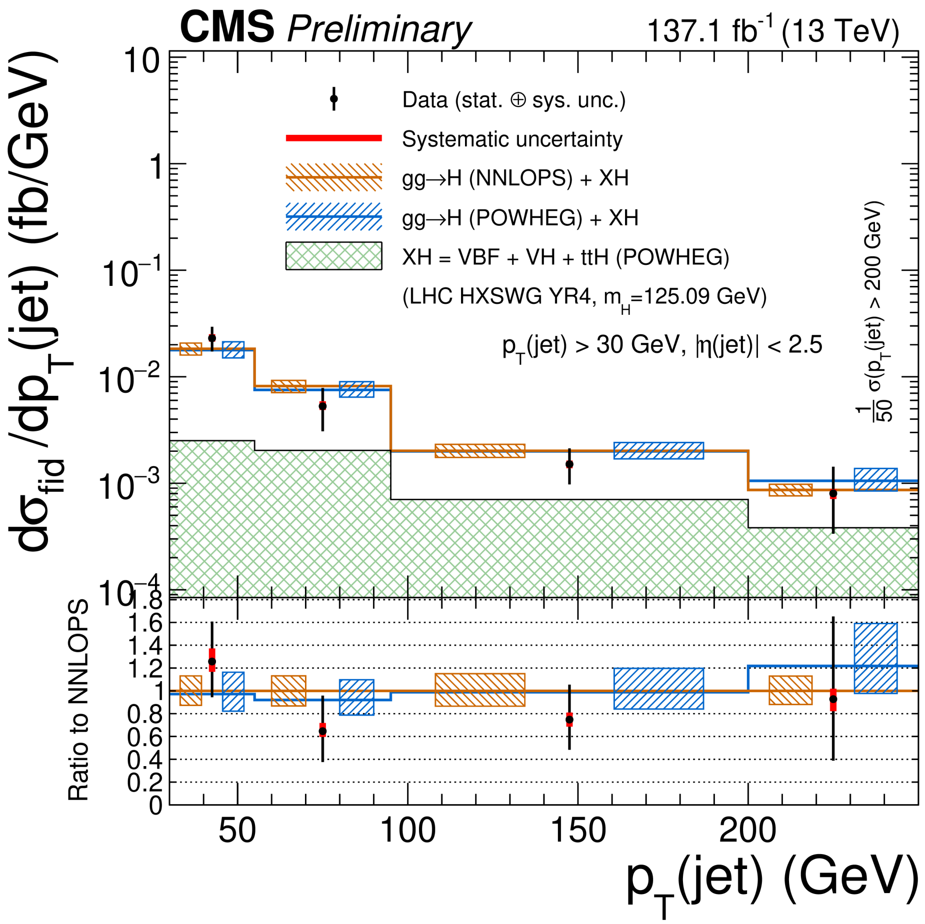
H→γγ



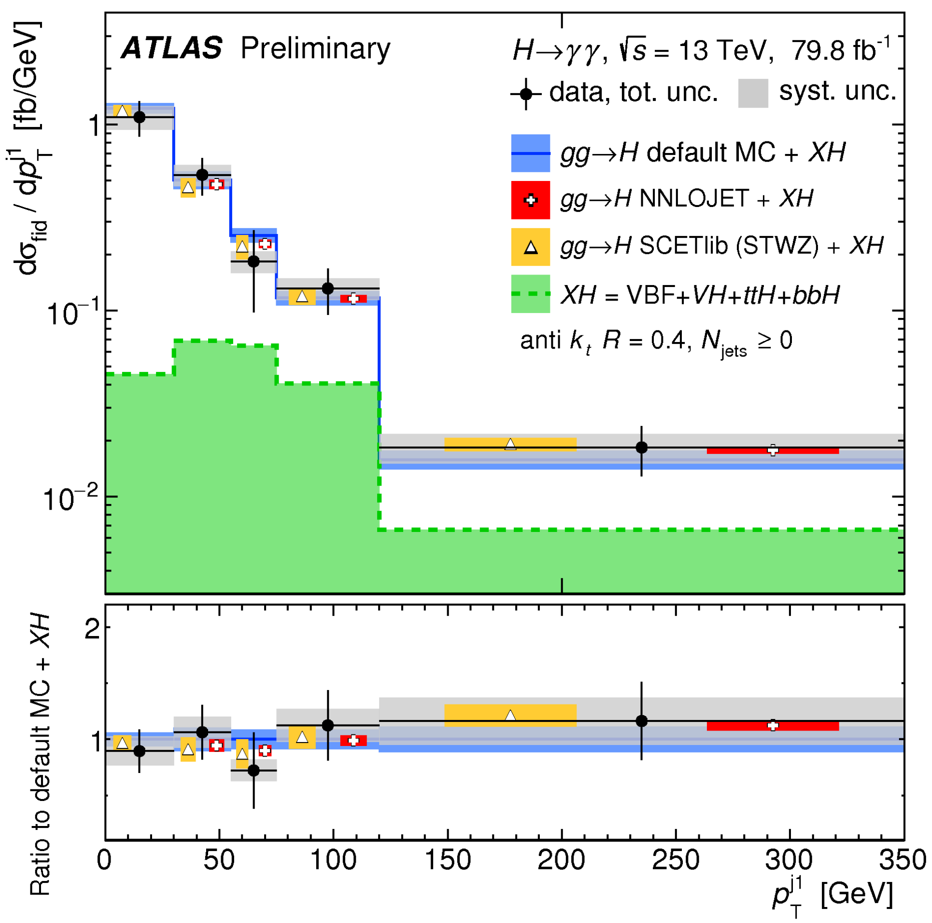
H→ZZ/γγ

Jet Activity : theoretical modelling and relative contributions of different Higgs boson production mechanisms

H→ZZ



H→γγ



H→VV decays

Simplified template cross sections (STXS) used heavily in Run-II.

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”.

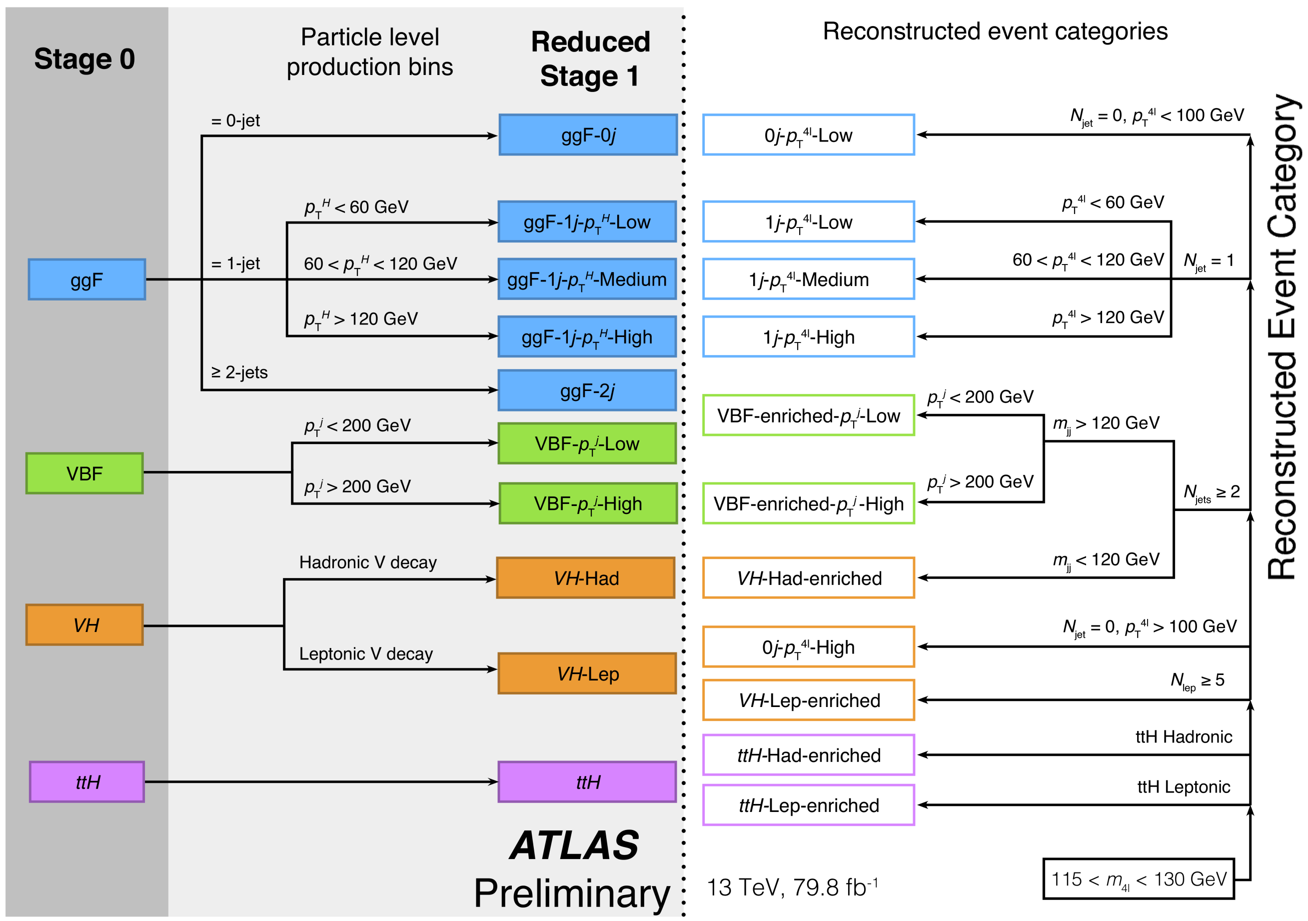
“As they are extrapolated from a simultaneous fit, this allows for advanced experimental techniques (including multi-variate observables and discriminants) to be em-ployed in the analyses. The use of such techniques is not possible, for instance, when measuring fiducial cross-sections, as it is very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

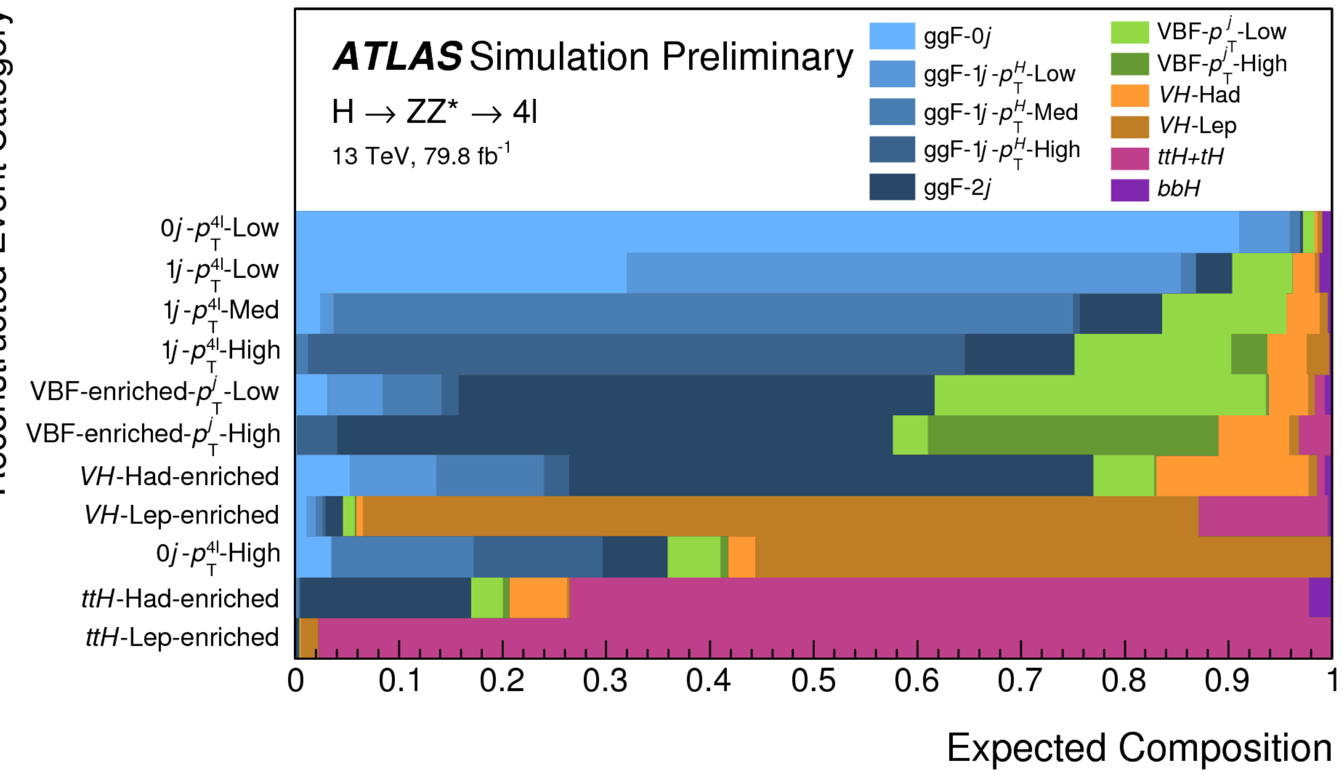
(Quotes from Handbook of LHC Higgs cross sections:4 , arXiv:1610.07922)

H→ZZ

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

Reduced Stage 1 STXS





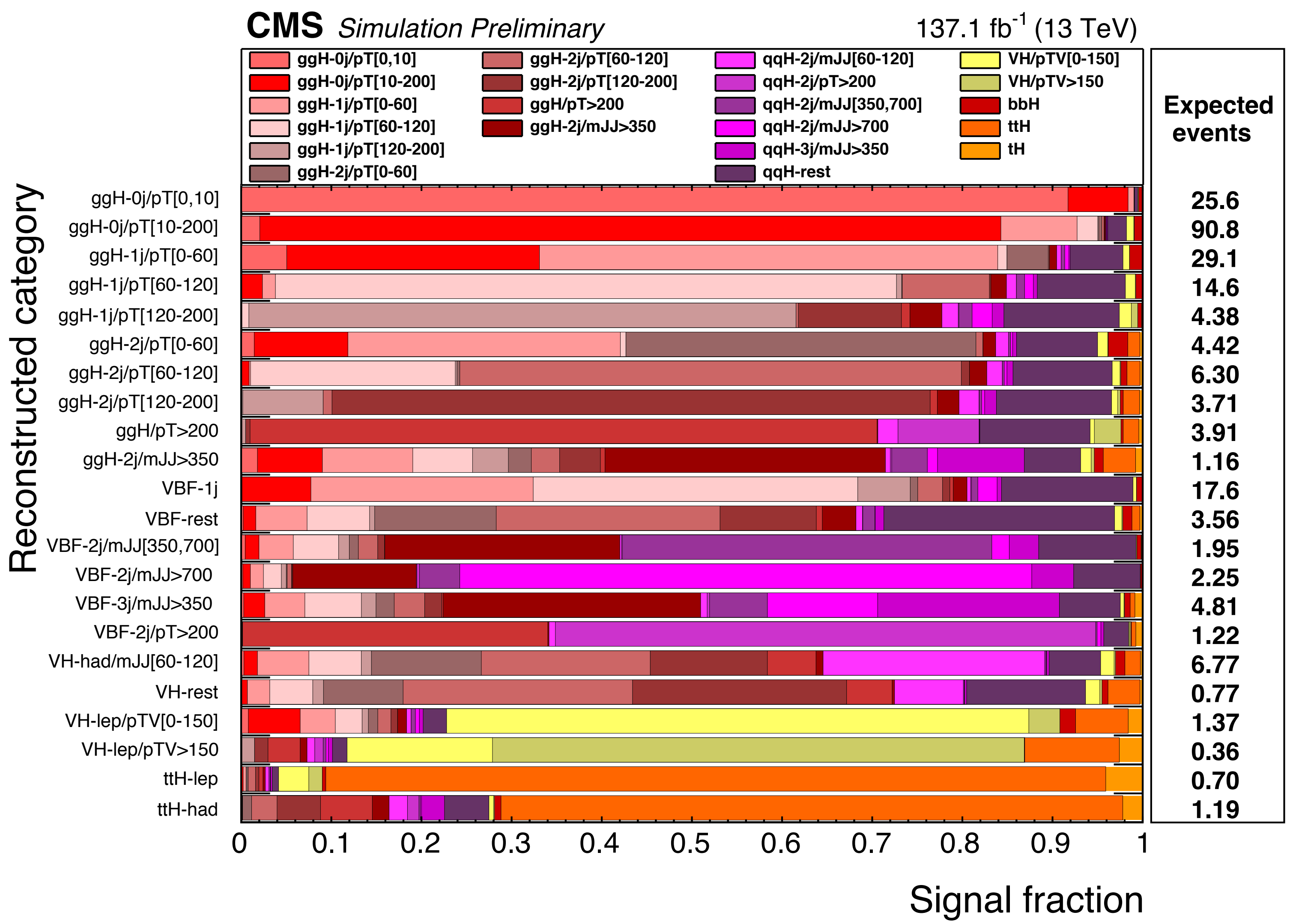
Atlas H→ZZ → 4l event kinematic discriminants.

Reconstructed event category	BDT discriminant	Input variables
$0j$-$p_T^{4\ell}$-Low	$\mathrm{BDT_{ggF}}$	$p_T^{4\ell}$, $\eta_{4\ell}$, D_{ZZ^*}
$1j$-$p_T^{4\ell}$-Low	$\mathrm{BDT}_{\mathrm{VBF}}^{1j\text{-}p_T^{4\ell}\text{-Low}}$	p_T^j, η_j, $\Delta R(j, 4\ell)$
$1j$-$p_T^{4\ell}$-Med	$\mathrm{BDT}_{\mathrm{VBF}}^{1j\text{-}p_T^{4\ell}\text{-Med}}$	p_T^j, η_j, $\Delta R(j, 4\ell)$
VBF-enriched-p_T^j-Low	$\mathrm{BDT_{VBF}}$	m_{jj}, $\Delta\eta_{jj}$, p_T^{j1}, p_T^{j2}, $\eta_{4\ell}^*$, $\Delta R_{jZ}^{\min}$, $p_T^{4\ell jj}$
VH-Had-enriched	$\mathrm{BDT}_{VH\text{-Had}}$	m_{jj}, $\Delta\eta_{jj}$, p_T^{j1}, p_T^{j2}, $\eta_{4\ell}^*$, $\Delta R_{jZ}^{\min}$, η_{j1}
ttH-Had-enriched	$\mathrm{BDT}_{ttH\text{-Had}}$	m_{jj}, $\Delta\eta_{jj}$, $\Delta R_{jZ}^{\min}$, $\Delta R(j, 4\ell)$, $\eta_{4\ell}^*$, E_T^{miss}, p_T^{jj}, N_{jets}, $N_{b-\mathrm{jets}}$, H_T, $\mathcal{M}_{sig}$

H→ZZ

Use of event categories and multivariate techniques →Essential in this approach.

Stage 1.1 STXS

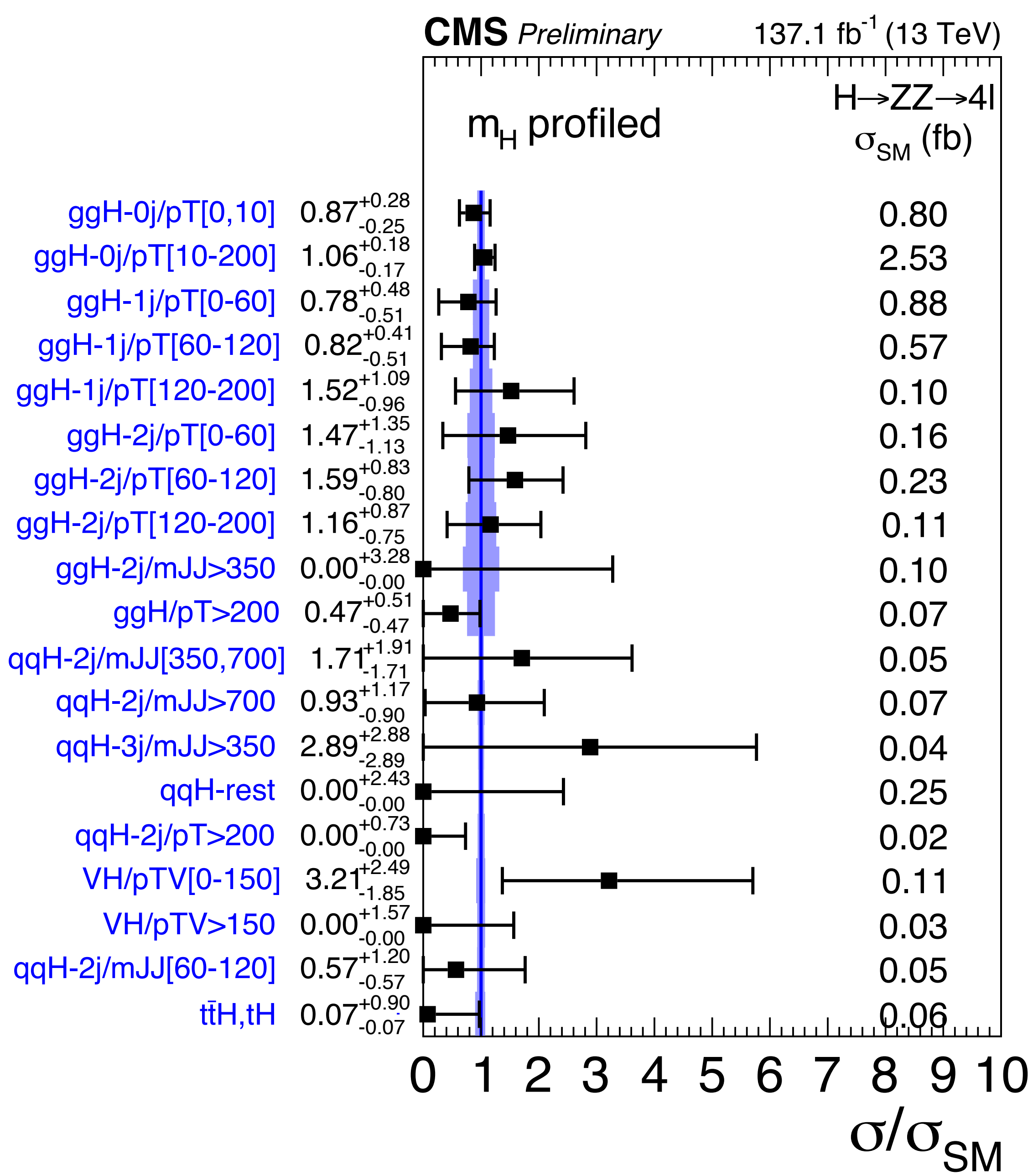


MELA

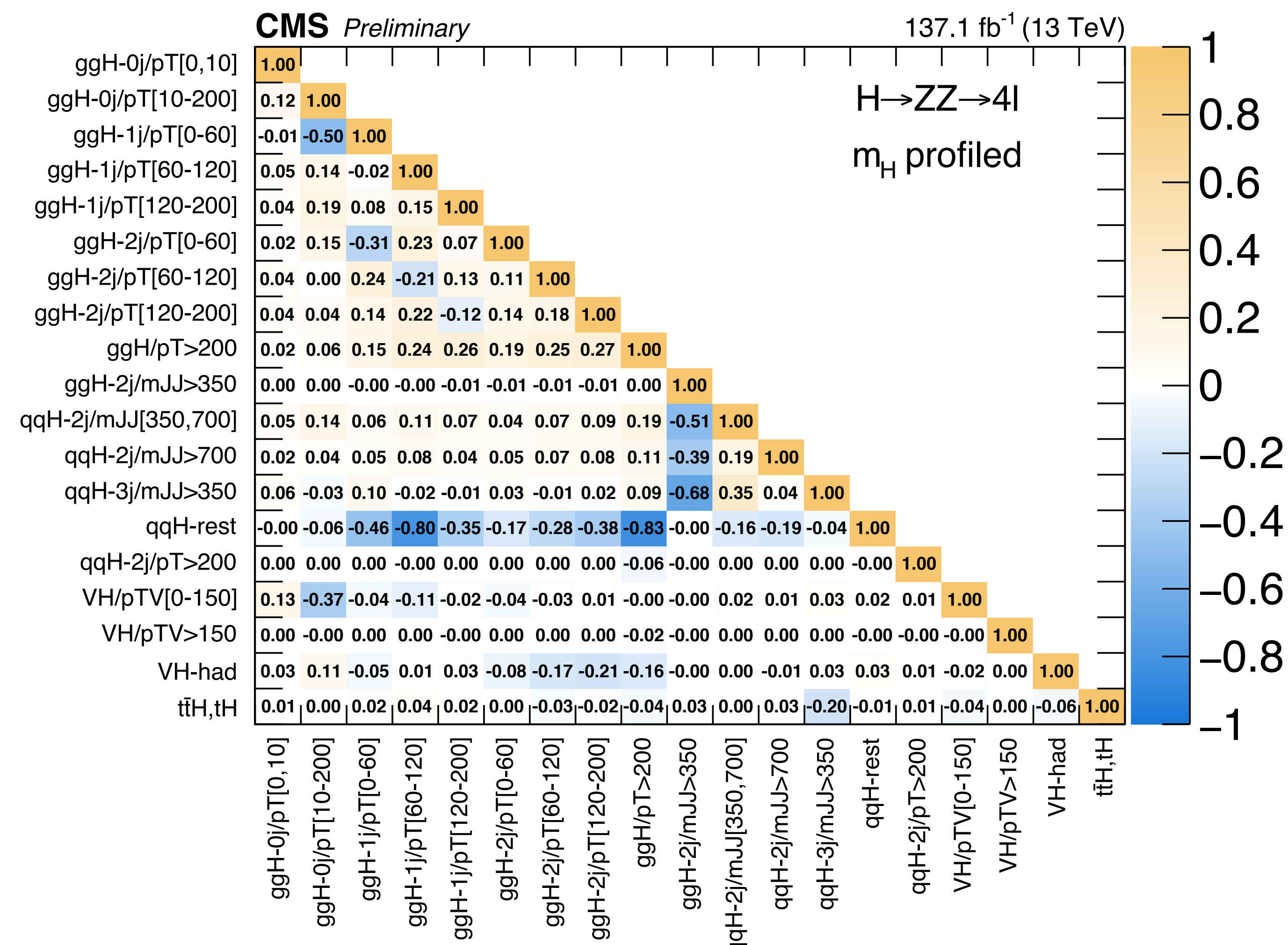
$$\mathcal{D}_{\text{2jet}} = \left[1 + \frac{\mathcal{P}_{\text{HJJ}}(\vec{\Omega}^{\text{H+JJ}}|m_{4\ell})}{\mathcal{P}_{\text{VBF}}(\vec{\Omega}^{\text{H+JJ}}|m_{4\ell})}\right]^{-1} \qquad \mathcal{D}_{\text{1jet}} = \left[1 + \frac{\mathcal{P}_{\text{HJ}}(\vec{\Omega}^{\text{H+J}}|m_{4\ell})}{\int d\eta_{\text{J}} \mathcal{P}_{\text{VBF}}(\vec{\Omega}^{\text{H+JJ}}|m_{4\ell})}\right]^{-1}$$

$$\mathcal{D}_{\text{WH}} = \left[1 + \frac{\mathcal{P}_{\text{HJJ}}(\vec{\Omega}^{\text{H+JJ}}|m_{4\ell})}{\mathcal{P}_{\text{WH}}(\vec{\Omega}^{\text{H+JJ}}|m_{4\ell})}\right]^{-1} \qquad \mathcal{D}_{\text{ZH}} = \left[1 + \frac{\mathcal{P}_{\text{HJJ}}(\vec{\Omega}^{\text{H+JJ}}|m_{4\ell})}{\mathcal{P}_{\text{ZH}}(\vec{\Omega}^{\text{H+JJ}}|m_{4\ell})}\right]^{-1} \qquad (4)$$

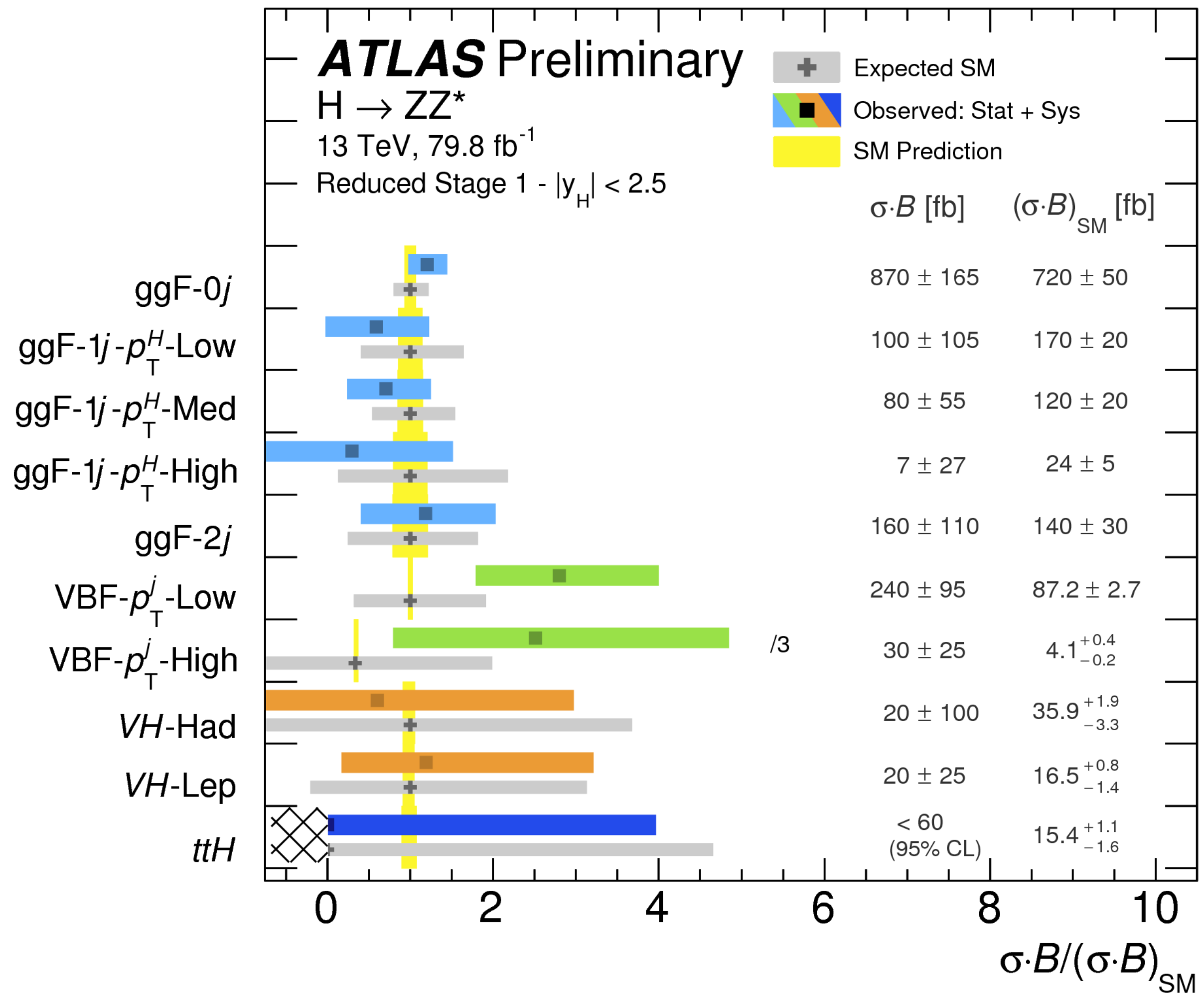
H→ZZ


CMS Preliminary
137.1 fb-1 (13 TeV)
mH profiled
H→ZZ→4l
σSM (fb)
ggH-0j/pT[0,10] 0.87 +0.28 -0.25 0.80
ggH-0j/pT[10-200] 1.06 +0.18 -0.17 2.53
ggH-1j/pT[0-60] 0.78 +0.48 -0.51 0.88
ggH-1j/pT[60-120] 0.82 +0.41 -0.51 0.57
ggH-1j/pT[120-200] 1.52 +1.09 -0.96 0.10
ggH-2j/pT[0-60] 1.47 +1.35 -1.13 0.16
ggH-2j/pT[60-120] 1.59 +0.83 -0.80 0.23
ggH-2j/pT[120-200] 1.16 +0.87 -0.75 0.11
ggH-2j/mJJ>350 0.00 +3.28 -0.00 0.10
ggH/pT>200 0.47 +0.51 -0.47 0.07
qqH-2j/mJJ[350,700] 1.71 +1.91 -1.71 0.05
qqH-2j/mJJ>700 0.93 +1.17 -0.90 0.07
qqH-3j/mJJ>350 2.89 +2.88 -2.89 0.04
qqH-rest 0.00 +2.43 -0.00 0.25
qqH-2j/pT>200 0.00 +0.73 -0.00 0.02
VH/pTV[0-150] 3.21 +2.49 -1.85 0.11
VH/pTV>150 0.00 +1.57 -0.00 0.03
qqH-2j/mJJ[60-120] 0.57 +1.20 -0.57 0.05
tt̄H,tH 0.07 +0.90 -0.07 0.06
0 1 2 3 4 5 6 7 8 9 10
σ/σSM

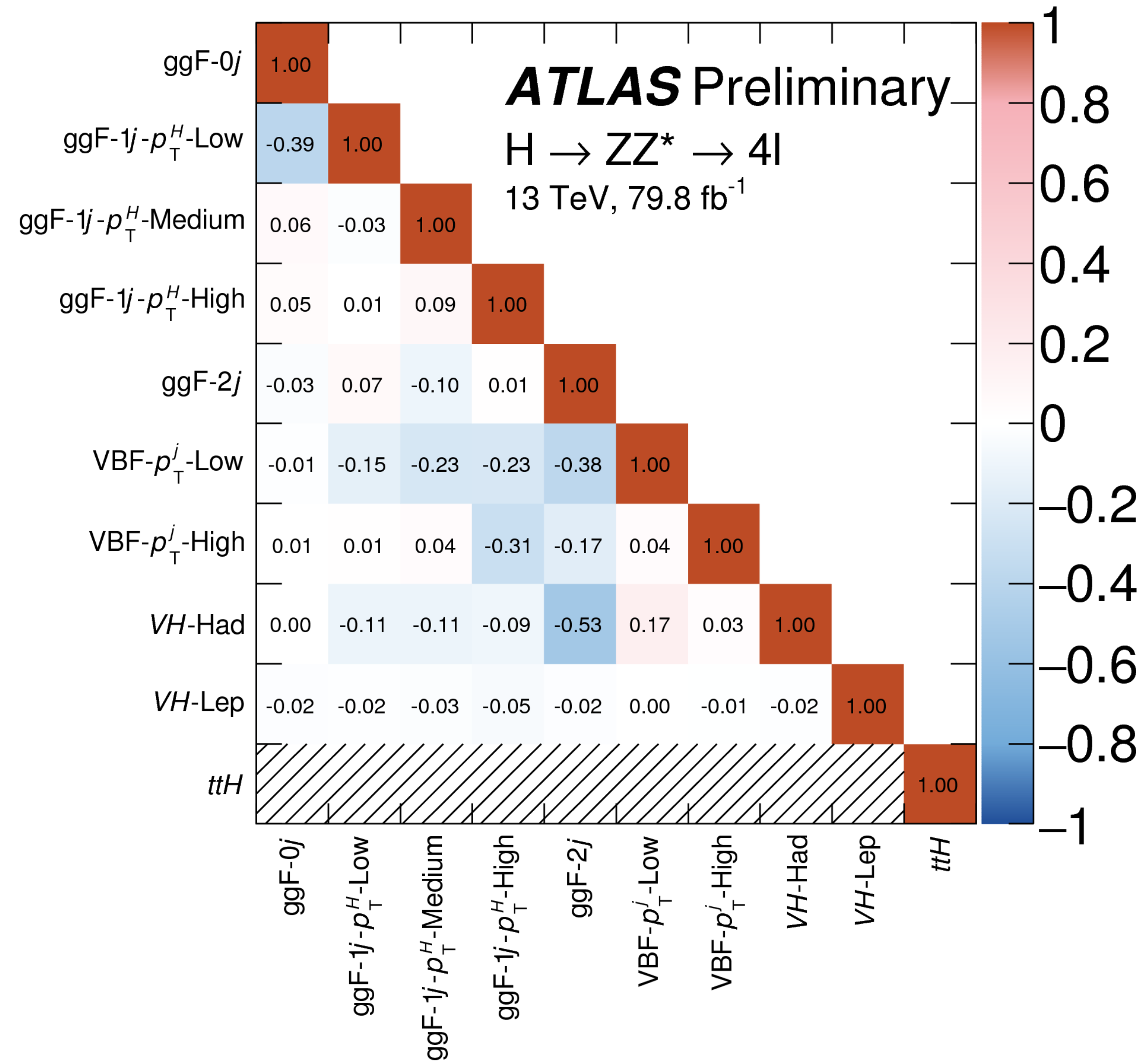
Stage 1.1


CMS Preliminary
137.1 fb-1 (13 TeV)
H→ZZ→4l
mH profiled
ggH-0j/pT[0,10]
ggH-0j/pT[10-200]
ggH-1j/pT[0-60]
ggH-1j/pT[60-120]
ggH-1j/pT[120-200]
ggH-2j/pT[0-60]
ggH-2j/pT[60-120]
ggH-2j/pT[120-200]
ggH/pT>200
ggH-2j/mJJ>350
qqH-2j/mJJ[350,700]
qqH-2j/mJJ>700
qqH-3j/mJJ>350
qqH-rest
qqH-2j/pT>200
VH/pTV[0-150]
VH/pTV>150
VH-had
tt̄H,tH
1.00
0.12 1.00
-0.01 -0.50 1.00
0.05 0.14 -0.02 1.00
0.04 0.19 0.08 0.15 1.00
0.02 0.15 -0.31 0.23 0.07 1.00
0.04 0.00 0.24 -0.21 0.13 0.11 1.00
0.04 0.04 0.14 0.22 -0.12 0.14 0.18 1.00
0.02 0.06 0.15 0.24 0.26 0.19 0.25 0.27 1.00
0.00 0.00 -0.00 -0.00 -0.01 -0.01 -0.01 -0.01 0.00 1.00
0.05 0.14 0.06 0.11 0.07 0.04 0.07 0.09 0.19 -0.51 1.00
0.02 0.04 0.05 0.08 0.04 0.05 0.07 0.08 0.11 -0.39 0.19 1.00
0.06 -0.03 0.10 -0.02 -0.01 0.03 -0.01 0.02 0.09 -0.68 0.35 0.04 1.00
-0.00 -0.06 -0.46 -0.80 -0.35 -0.17 -0.28 -0.38 -0.83 -0.00 -0.16 -0.19 -0.04 1.00
0.00 0.00 0.00 -0.00 0.00 0.00 0.00 0.00 -0.06 -0.00 0.00 0.00 0.00 -0.00 1.00
0.13 -0.37 -0.04 -0.11 -0.02 -0.04 -0.03 0.01 -0.00 -0.00 0.02 0.01 0.03 0.02 0.01 1.00
0.00 -0.00 0.00 0.00 -0.00 0.00 0.00 0.00 -0.02 -0.00 0.00 0.00 0.00 -0.00 -0.00 -0.00 1.00
0.03 0.11 -0.05 0.01 0.03 -0.08 -0.17 -0.21 -0.16 -0.00 0.00 -0.01 0.03 0.03 0.01 -0.02 0.00 1.00
0.01 0.00 0.02 0.04 0.02 0.00 -0.03 -0.02 -0.04 0.03 0.00 0.03 -0.20 -0.01 0.01 -0.04 0.00 -0.06 1.00
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1

H→ZZ

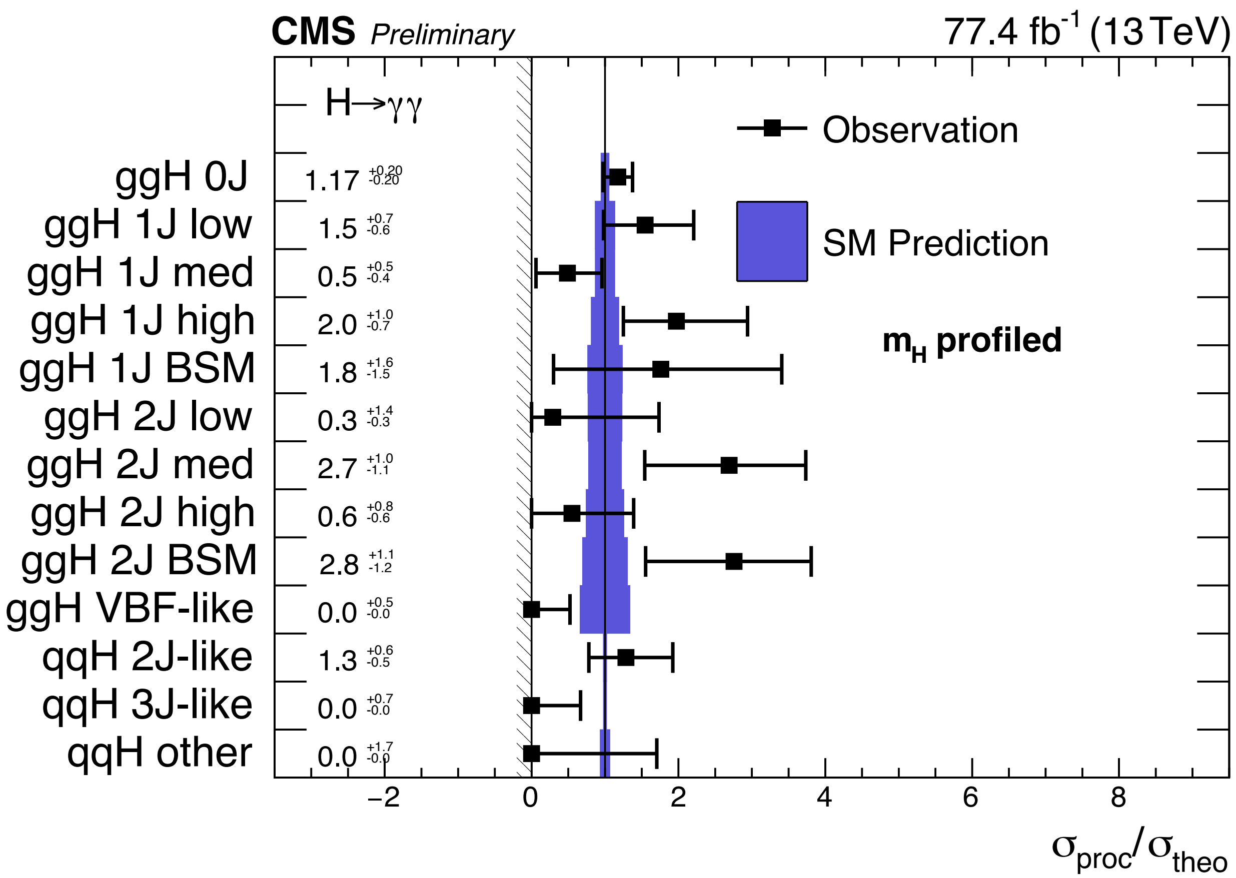


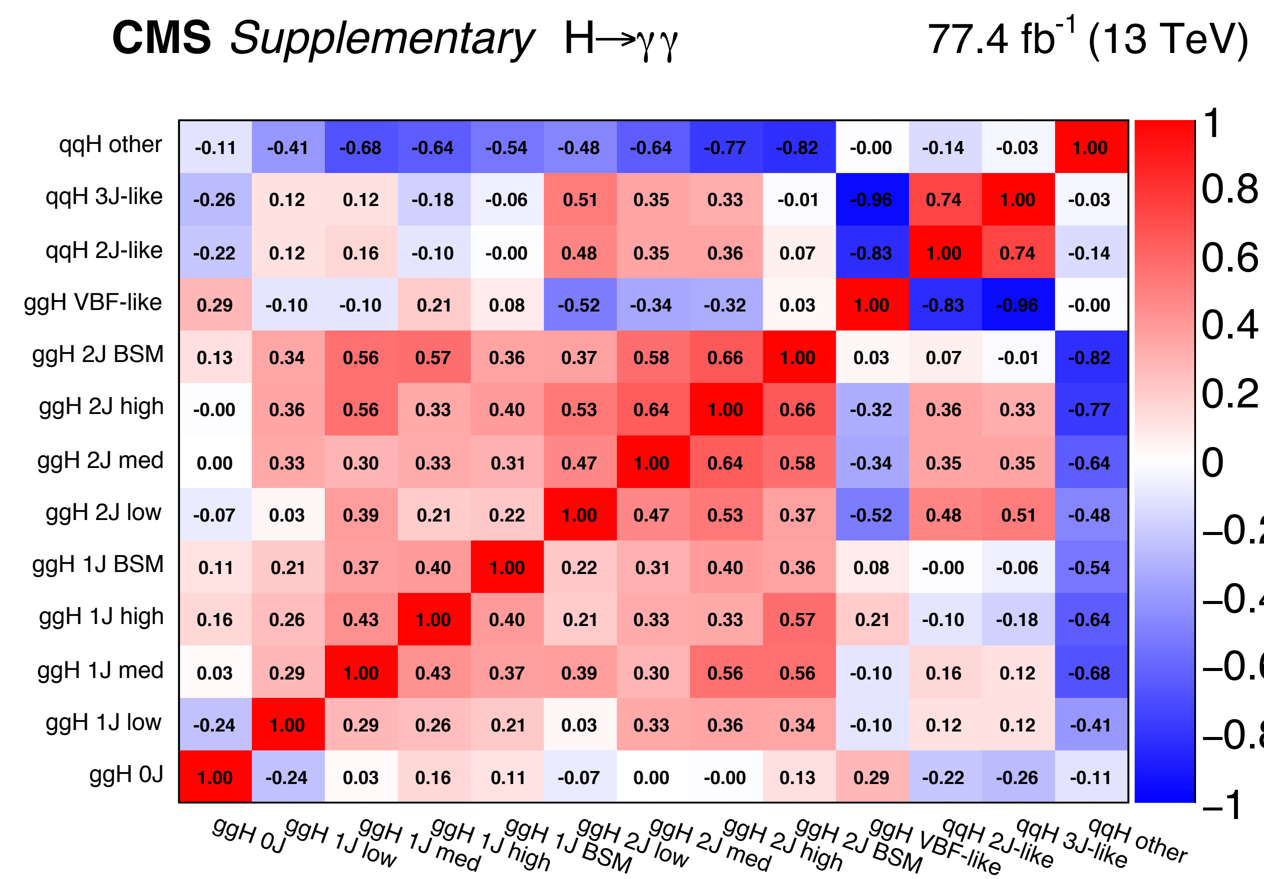
Reduced stage 1



	ggF-0j	ggF-1j-pT^H-Low	ggF-1j-pT^H-Medium	ggF-1j-pT^H-High	ggF-2j	VBF-pT^j-Low	VBF-pT^j-High	VH-Had	VH-Lep	ttH
ggF-0j	1.00									
ggF-1j-pT^H-Low	-0.39	1.00								
ggF-1j-pT^H-Medium	0.06	-0.03	1.00							
ggF-1j-pT^H-High	0.05	0.01	0.09	1.00						
ggF-2j	-0.03	0.07	-0.10	0.01	1.00					
VBF-pT^j-Low	-0.01	-0.15	-0.23	-0.23	-0.38	1.00				
VBF-pT^j-High	0.01	0.01	0.04	-0.31	-0.17	0.04	1.00			
VH-Had	0.00	-0.11	-0.11	-0.09	-0.53	0.17	0.03	1.00		
VH-Lep	-0.02	-0.02	-0.03	-0.05	-0.02	0.00	-0.01	-0.02	1.00	
ttH										1.00

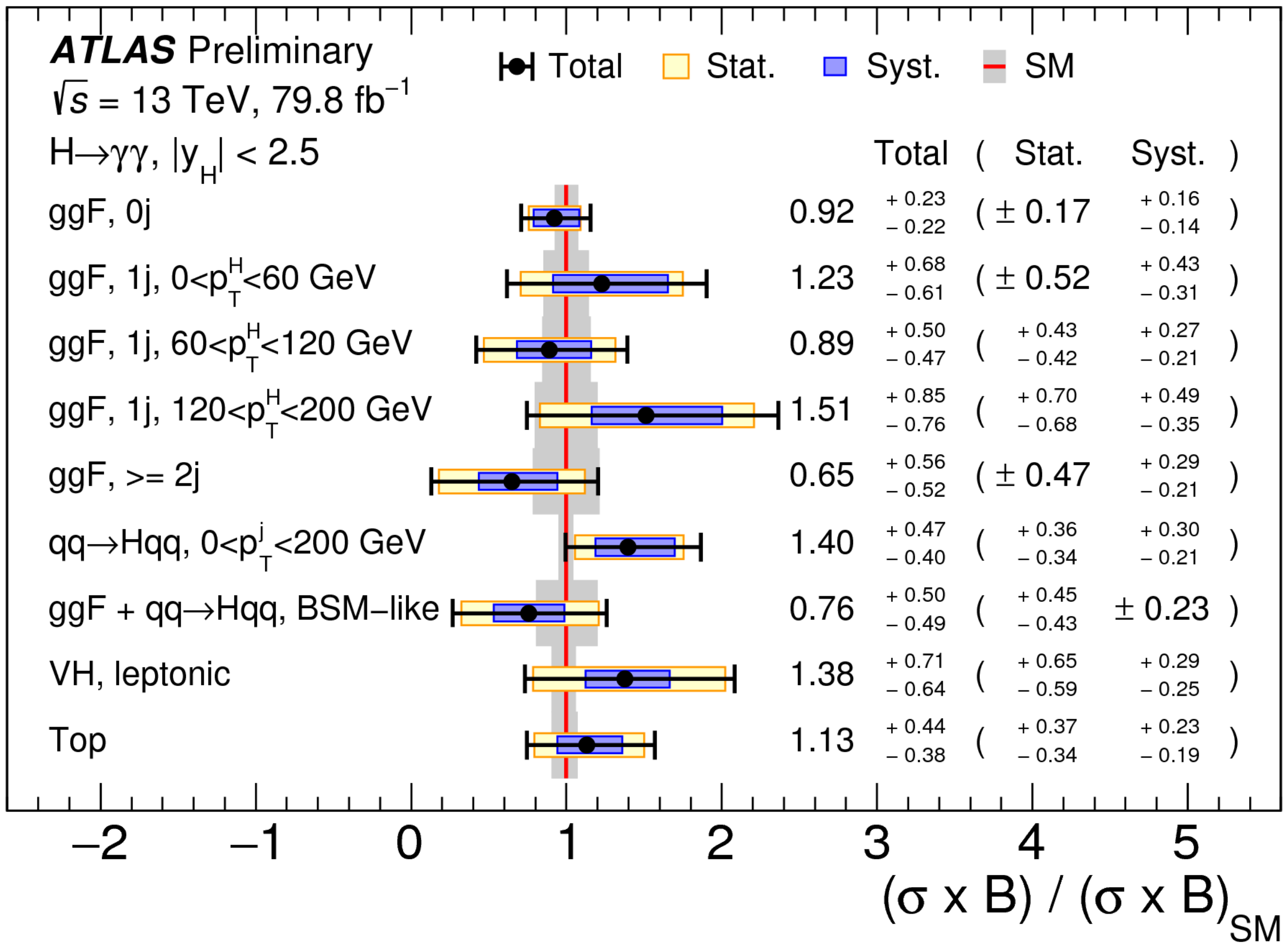
$H \rightarrow \gamma\gamma$

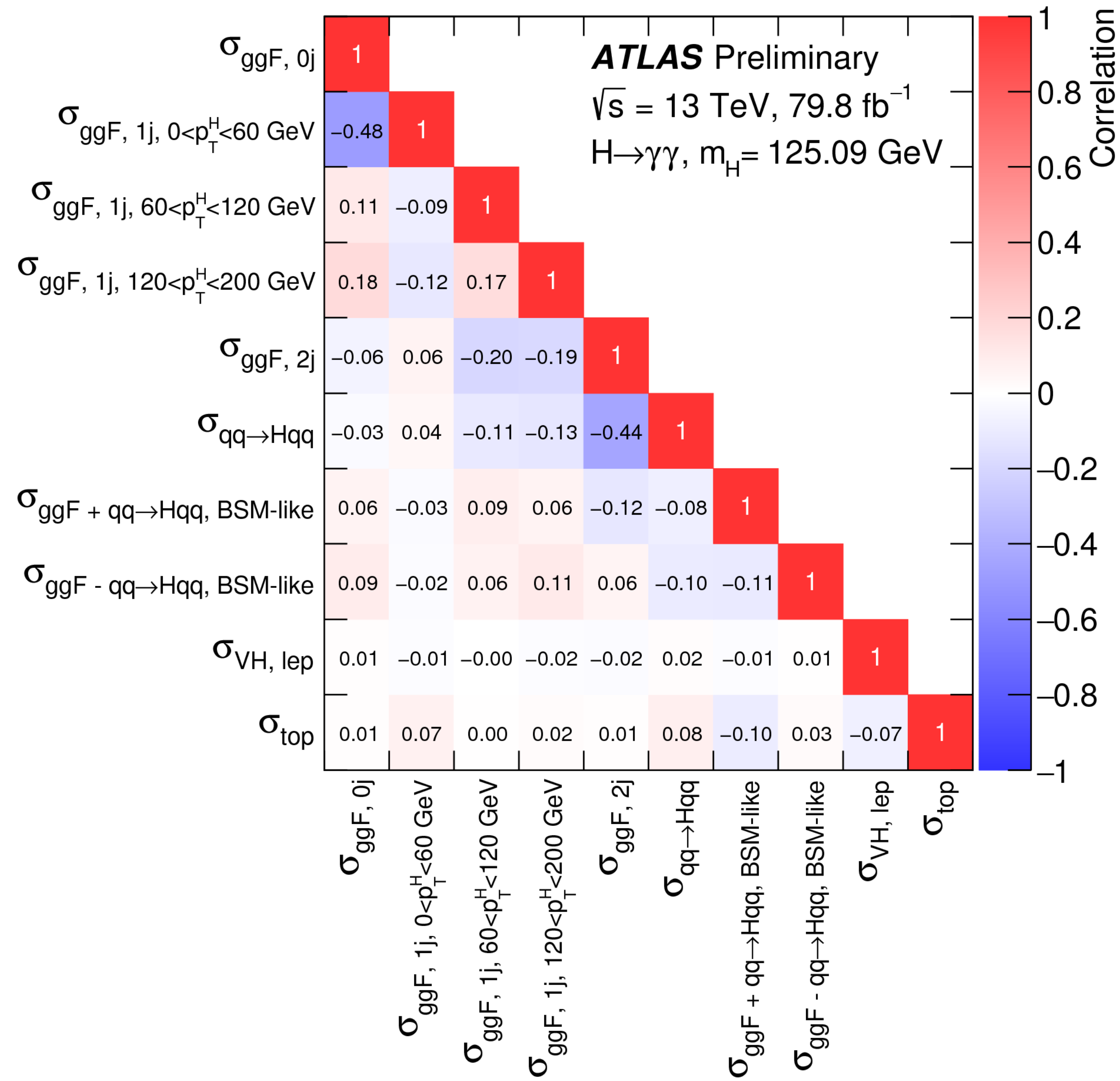




Stage 1

$H \rightarrow \gamma\gamma$





	$\sigma_{ggF,0j}$	$\sigma_{ggF,1j,0<p_T^H<60}$	$\sigma_{ggF,1j,60<p_T^H<120}$	$\sigma_{ggF,1j,120<p_T^H<200}$	$\sigma_{ggF,2j}$	$\sigma_{qq\to Hqq}$	$\sigma_{ggF+qq\to Hqq, BSM}$	$\sigma_{ggF-qq\to Hqq, BSM}$	$\sigma_{VH,lep}$	σ_{top}
$\sigma_{ggF,0j}$	1									
$\sigma_{ggF,1j,0<p_T^H<60\ GeV}$	−0.48	1								
$\sigma_{ggF,1j,60<p_T^H<120\ GeV}$	0.11	−0.09	1							
$\sigma_{ggF,1j,120<p_T^H<200\ GeV}$	0.18	−0.12	0.17	1						
$\sigma_{ggF,2j}$	−0.06	0.06	−0.20	−0.19	1					
$\sigma_{qq\to Hqq}$	−0.03	0.04	−0.11	−0.13	−0.44	1				
$\sigma_{ggF+qq\to Hqq, BSM-like}$	0.06	−0.03	0.09	0.06	−0.12	−0.08	1			
$\sigma_{ggF-qq\to Hqq, BSM-like}$	0.09	−0.02	0.06	0.11	0.06	−0.10	−0.11	1		
$\sigma_{VH,lep}$	0.01	−0.01	−0.00	−0.02	−0.02	0.02	−0.01	0.01	1	
σ_{top}	0.01	0.07	0.00	0.02	0.01	0.08	−0.10	0.03	−0.07	1

Stage 1

$H \to ZZ/\gamma\gamma$

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

Quite generally, the EFT Lagrangian takes the form:

$$\mathcal{L}_{\rm eff} = \mathcal{L}_{\rm SM} + \sum_i \frac{c_i^{(5)}}{\Lambda}\mathcal{O}_i^{(5)} + \sum_i \frac{c_i^{(6)}}{\Lambda^2}\mathcal{O}_i^{(6)} + \sum_i \frac{c_i^{(7)}}{\Lambda^3}\mathcal{O}_i^{(7)} + \sum_i \frac{c_i^{(8)}}{\Lambda^4}\mathcal{O}_i^{(8)} + \cdots, \qquad \text{(II.2.1)}$$

where each $\mathcal{O}_i^{(D)}$ is an $SU(3)\times SU(2)\times U(1)$ invariant operator of dimension D and the parameters $c_i^{(D)}$ multiplying the operators in the Lagrangian are called the *Wilson coefficients*. This EFT is intended to parameterize observable effects of a large class of BSM theories where new particles, with mass of order Λ, are much heavier than the SM ones and much heavier than the energy scale at which the experiment is

$$\mathcal{L}_{\rm EFT} = \mathcal{L}_{\rm SM} + \sum_i \bar{c}_i^{(6)} O_i^{(6)}.$$

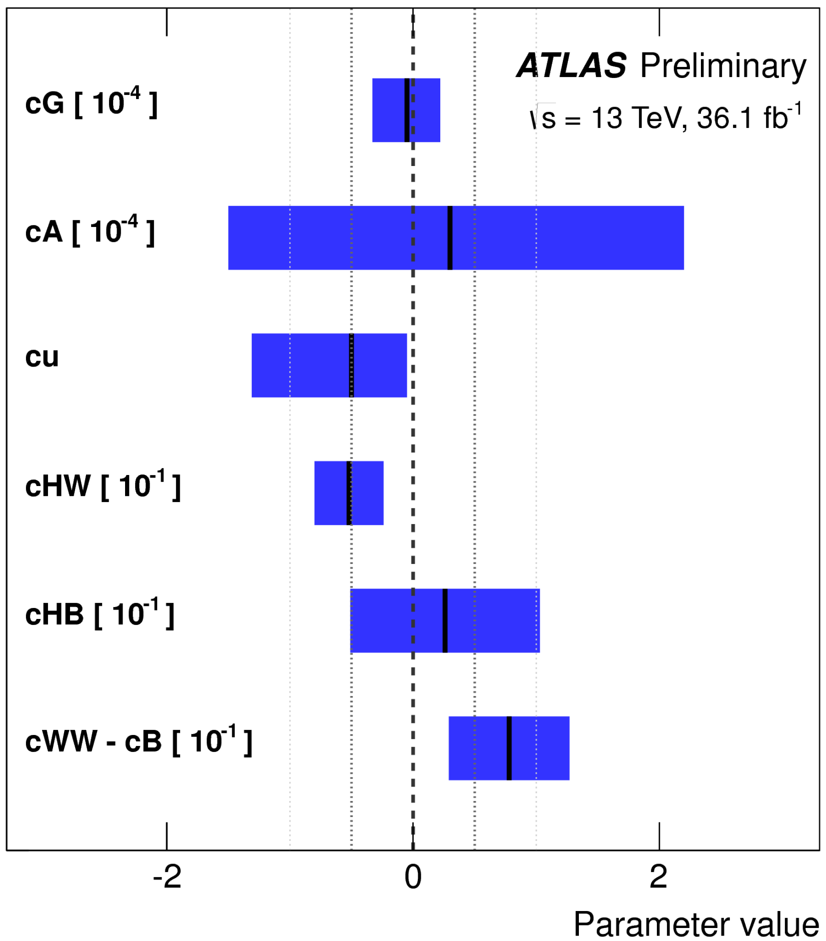
Operator	Expression	HEL coefficient	Vertices
$\mathcal{O}_g$	$\lvert H\rvert^2 G^A_{\mu\nu}G^{A\mu\nu}$	$\texttt{cG} = \frac{m_W^2}{g_s^2}\bar{c}_g$	Hgg
$\mathcal{O}_\gamma$	$\lvert H\rvert^2 B_{\mu\nu}B^{\mu\nu}$	$\texttt{cA} = \frac{m_W^2}{g'^2}\bar{c}_\gamma$	$H\gamma\gamma, HZZ$
$\mathcal{O}_u$	$y_u \lvert H\rvert^2 \bar{u}_l H u_R +$ h.c.	$\texttt{cu} = v^2 \bar{c}_u$	$Ht\bar{t}$
$\mathcal{O}_{HW}$	$i\,(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$	$\texttt{cHW} = \frac{m_W^2}{g}\bar{c}_{HW}$	HWW, HZZ
$\mathcal{O}_{HB}$	$i\,(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$	$\texttt{cHB} = \frac{m_W^2}{g'}\bar{c}_{HB}$	HZZ
$\mathcal{O}_W$	$i\left(H^\dagger \sigma^a D^\mu H\right) D^\nu W^a_{\mu\nu}$	$\texttt{cWW} = \frac{m_W^2}{g}\bar{c}_W$	HWW, HZZ
$\mathcal{O}_B$	$i\left(H^\dagger D^\mu H\right) \partial^\nu B_{\mu\nu}$	$\texttt{cB} = \frac{m_W^2}{g'}\bar{c}_B$	HZZ

H→ZZ/γγ

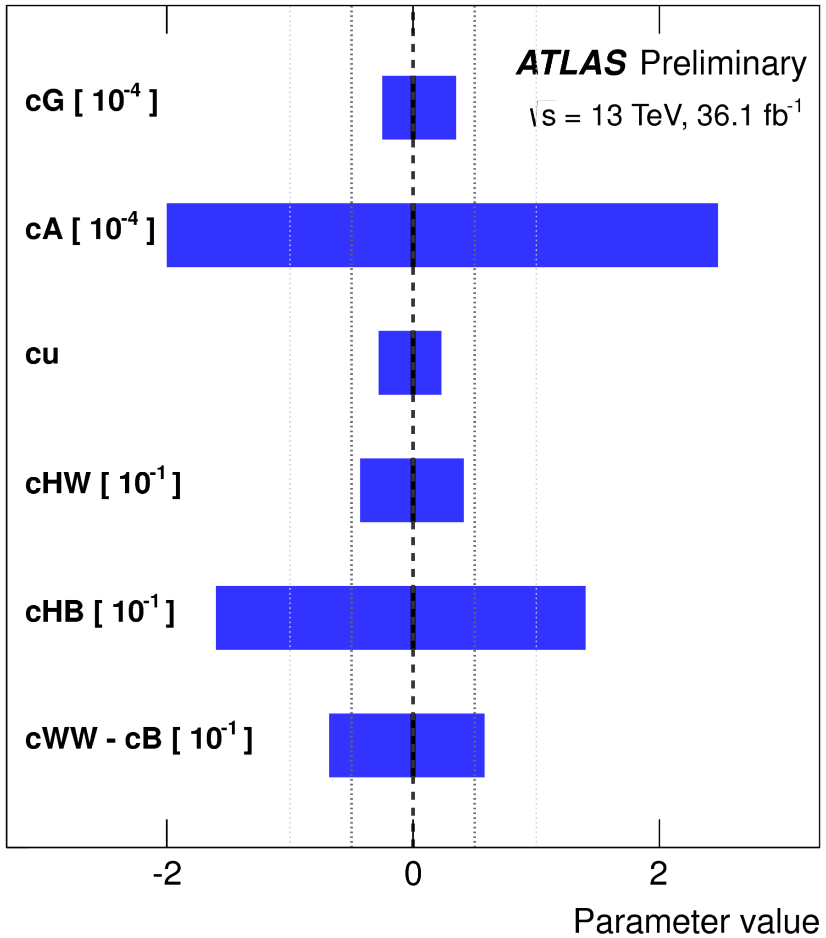
Towards EFT interpretation

Fit result (observed)	Fit result (SM expected)
$\mathtt{cG} = -0.05^{+0.27}_{-0.28} \times 10^{-4}$	$\mathtt{cG} = 0.00^{+0.38}_{-0.26} \times 10^{-4}$
$\mathtt{cA} = 0.3^{+1.9}_{-1.8} \times 10^{-4}$	$\mathtt{cA} = 0.0^{+2.8}_{-2.2} \times 10^{-4}$
$\mathtt{cu} = -0.50^{+0.45}_{-0.81}$	$\mathtt{cu} = 0.00^{+0.24}_{-0.28}$
$\mathtt{cHW} = -0.052 \pm 0.028$	$\mathtt{cHW} = 0.000^{+0.041}_{-0.043}$
$\mathtt{cHB} = 0.026 \pm 0.077$	$\mathtt{cHB} = 0.00^{+0.14}_{-0.16}$
$\mathtt{cWW} - \mathtt{cB} = 0.078 \pm 0.049$	$\mathtt{cWW} - \mathtt{cB} = 0.000^{+0.057}_{-0.074}$

Observed HEL constraints with H → ZZ* and H → γγ



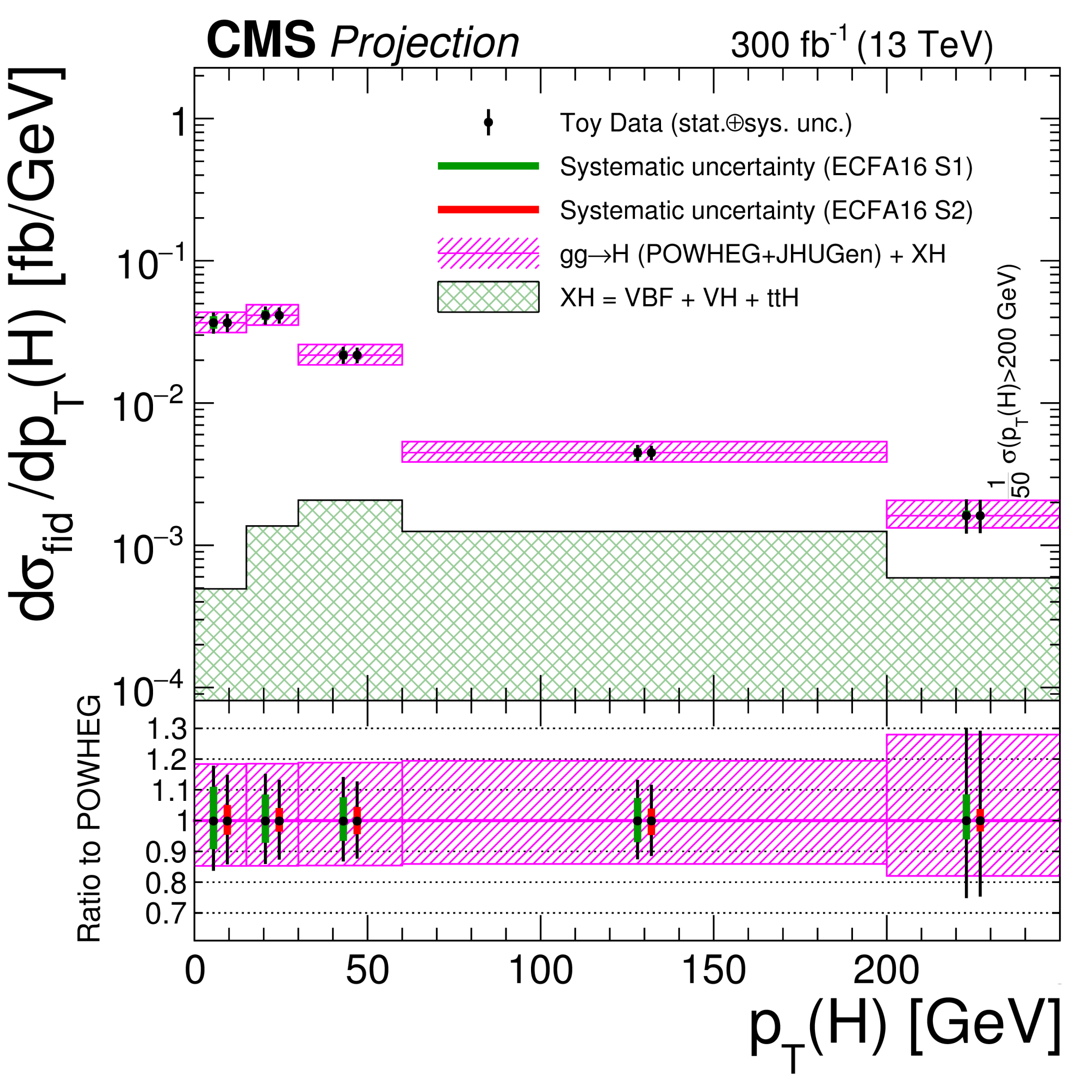
SM expected HEL constraints with H → ZZ* and H → γγ

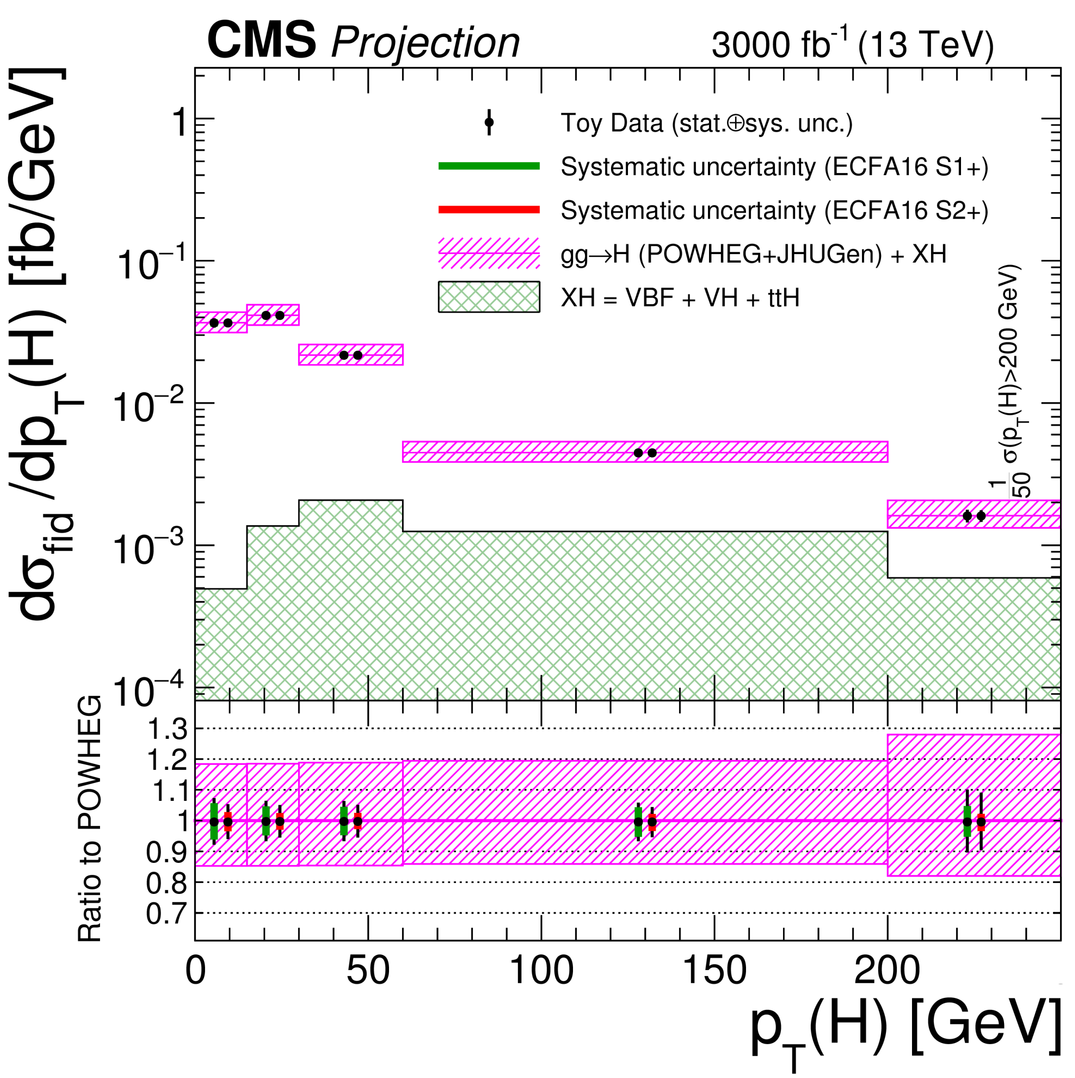


H→VV decays

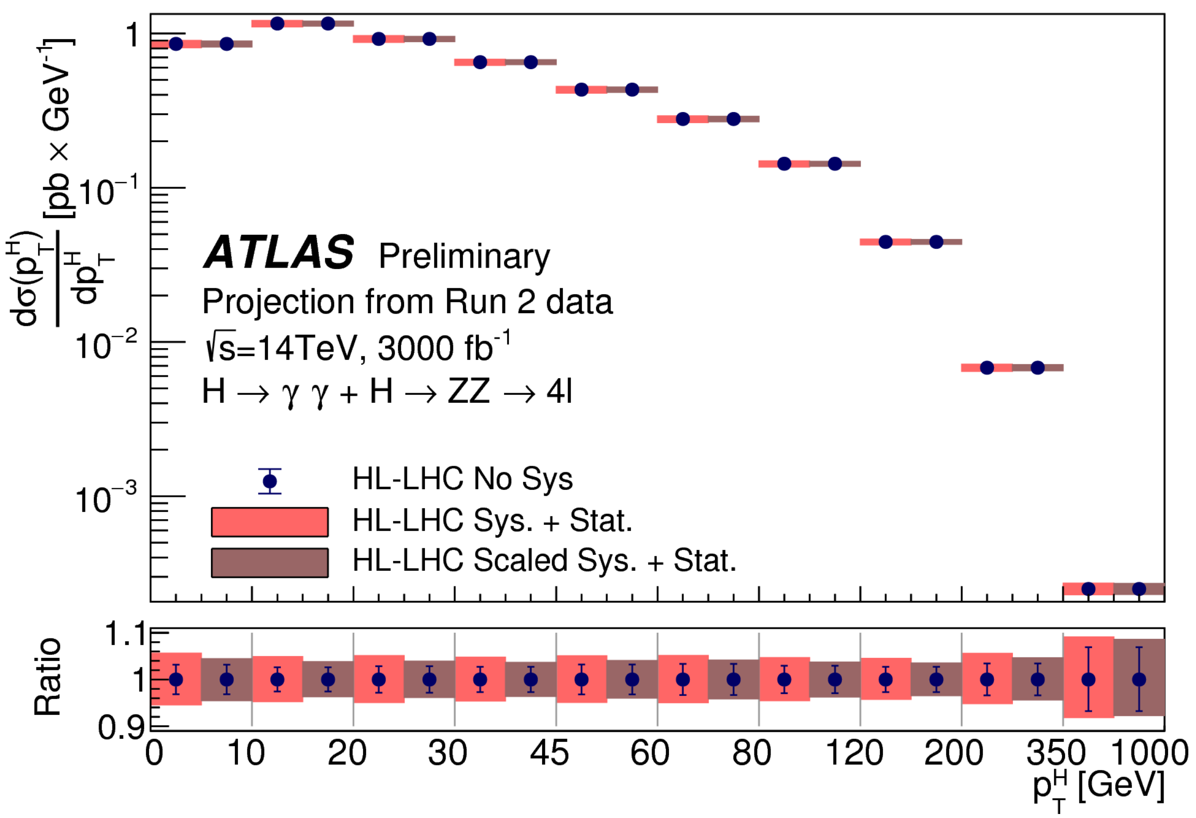
Further in the future
HL-LHC

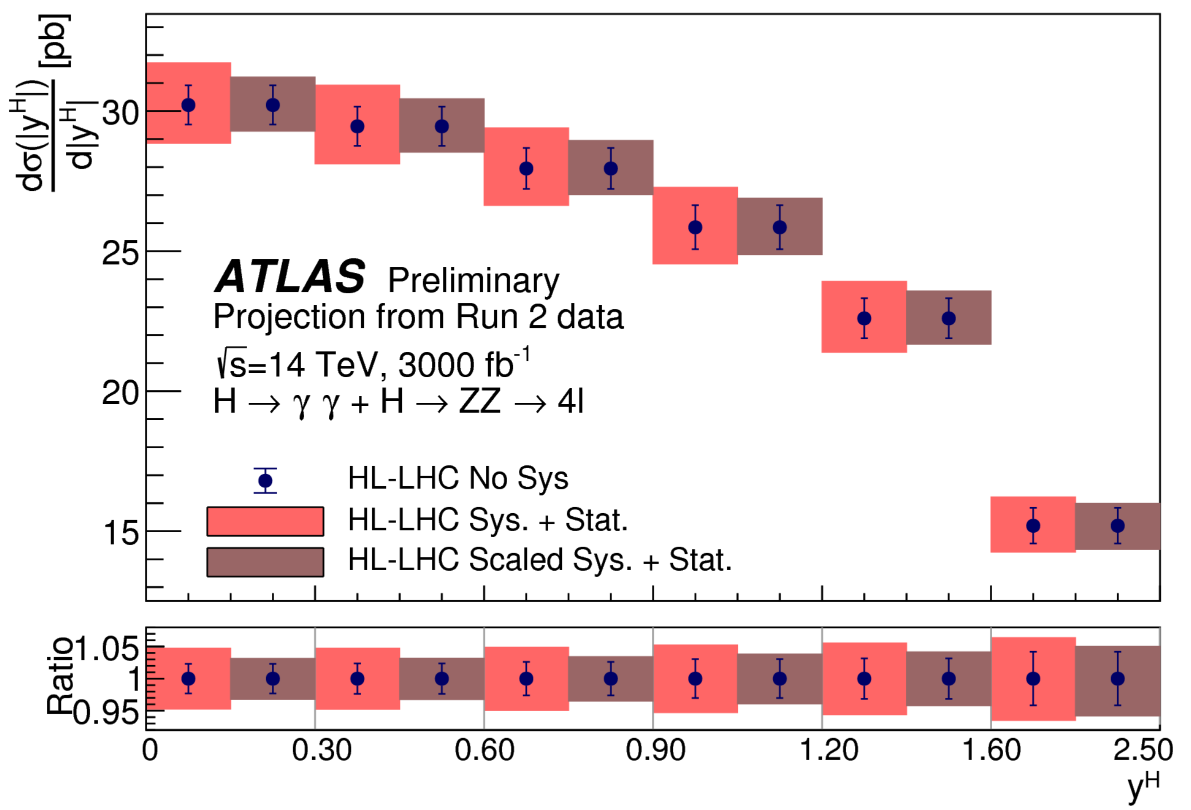
H→VV decays

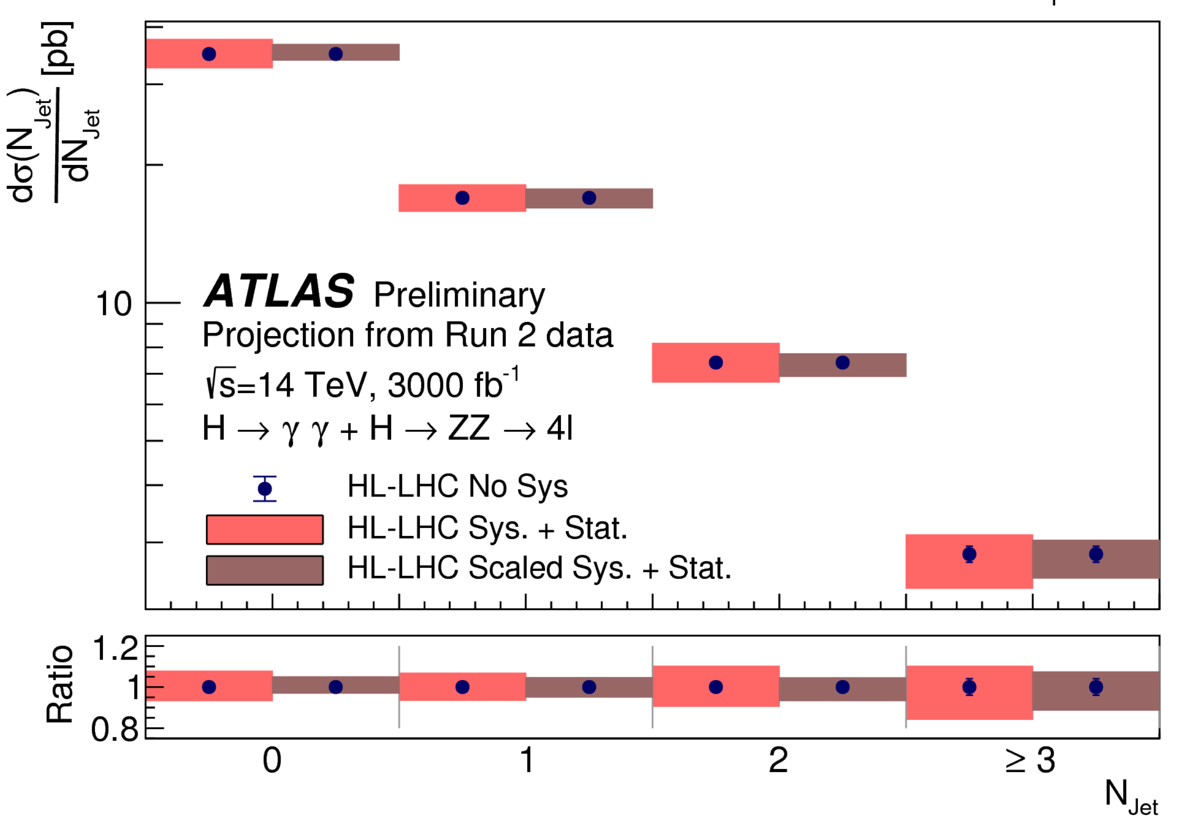

CMS Projection
300 fb^{-1} (13 TeV)
Toy Data (stat.⊕sys. unc.)
Systematic uncertainty (ECFA16 S1)
Systematic uncertainty (ECFA16 S2)
gg→H (POWHEG+JHUGen) + XH
XH = VBF + VH + ttH
$\frac{1}{50}$ σ(p$_T$(H)>200 GeV)
dσ$_{fid}$/dp$_T$(H) [fb/GeV]
Ratio to POWHEG
p$_T$(H) [GeV]

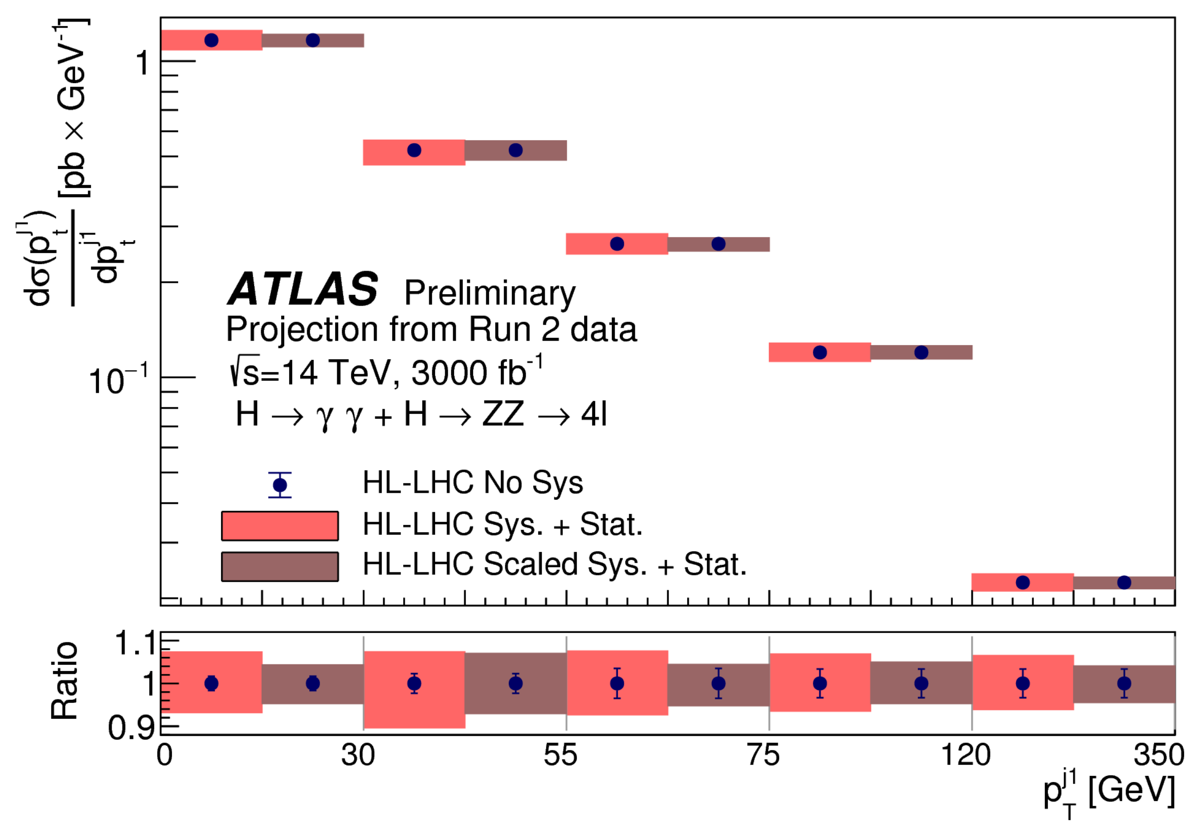

CMS Projection
3000 fb^{-1} (13 TeV)
Toy Data (stat.⊕sys. unc.)
Systematic uncertainty (ECFA16 S1+)
Systematic uncertainty (ECFA16 S2+)
gg→H (POWHEG+JHUGen) + XH
XH = VBF + VH + ttH
$\frac{1}{50}$ σ(p$_T$(H)>200 GeV)
dσ$_{fid}$/dp$_T$(H) [fb/GeV]
Ratio to POWHEG
p$_T$(H) [GeV]

H→VV decays


ATLAS Preliminary
Projection from Run 2 data
√s=14TeV, 3000 fb-1
H → γ γ + H → ZZ → 4l
HL-LHC No Sys
HL-LHC Sys. + Stat.
HL-LHC Scaled Sys. + Stat.
dσ(pTH)/dpTH [pb × GeV-1]
Ratio
pTH [GeV]


ATLAS Preliminary
Projection from Run 2 data
√s=14 TeV, 3000 fb-1
H → γ γ + H → ZZ → 4l
HL-LHC No Sys
HL-LHC Sys. + Stat.
HL-LHC Scaled Sys. + Stat.
dσ(|yH|)/d|yH| [pb]
Ratio
yH


ATLAS Preliminary
Projection from Run 2 data
√s=14 TeV, 3000 fb-1
H → γ γ + H → ZZ → 4l
HL-LHC No Sys
HL-LHC Sys. + Stat.
HL-LHC Scaled Sys. + Stat.
dσ(NJet)/dNJet [pb]
Ratio
NJet


ATLAS Preliminary
Projection from Run 2 data
√s=14 TeV, 3000 fb-1
H → γ γ + H → ZZ → 4l
HL-LHC No Sys
HL-LHC Sys. + Stat.
HL-LHC Scaled Sys. + Stat.
dσ(ptj1)/dptj1 [pb × GeV-1]
Ratio
pTj1 [GeV]

Last Slide

- Run-II data taking is finished

- Combinations

- Collaboration between experiment and theory in order to “decipher” the Higgs sector code

BACKUP