H→VV decays and Higgs Measurements

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on behalf of the ATLAS and CMS collaborations

Multi-Boson Interactions 2017

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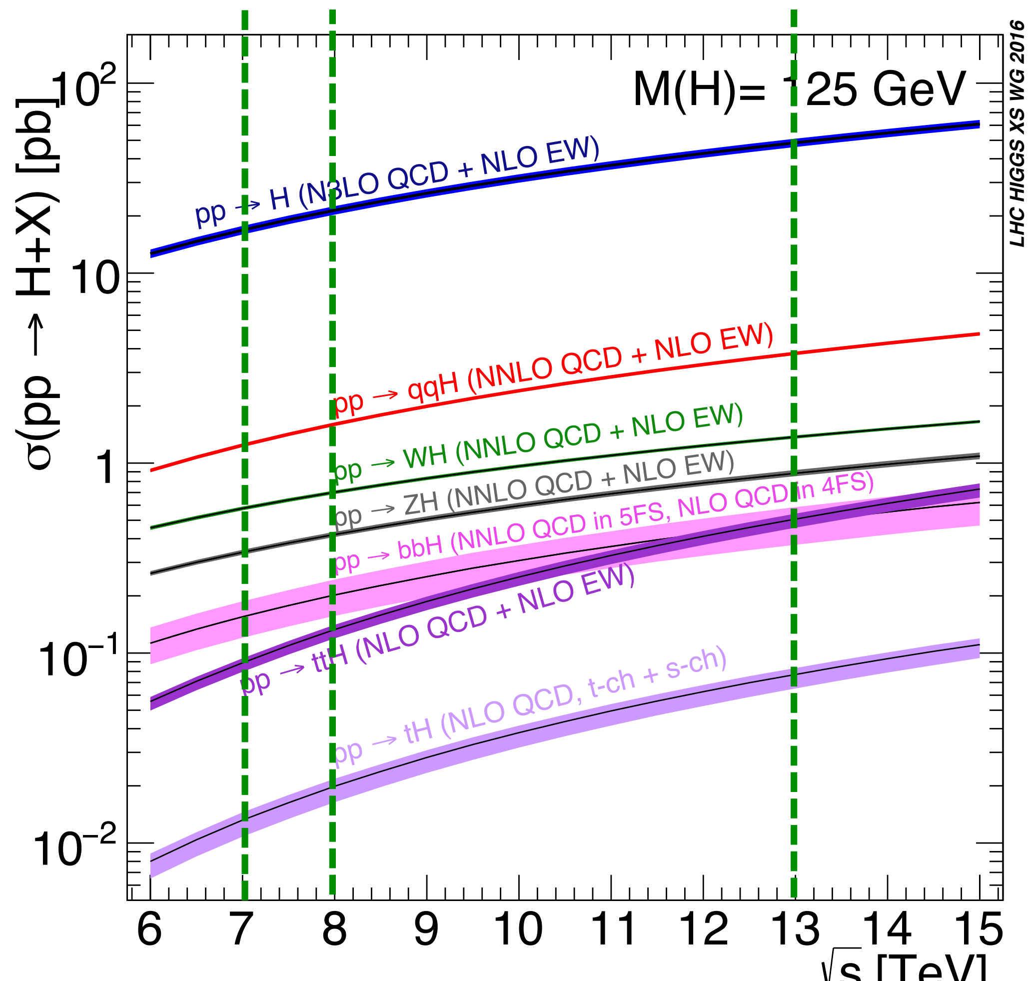
Higgs production at LHC

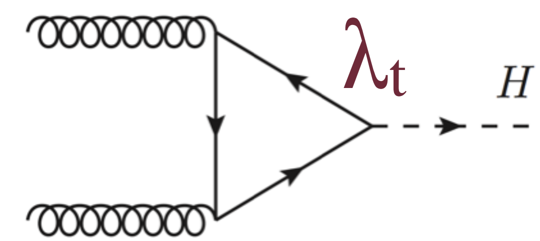
4 production modes at LHC

$\sigma_{H(125GeV)}$

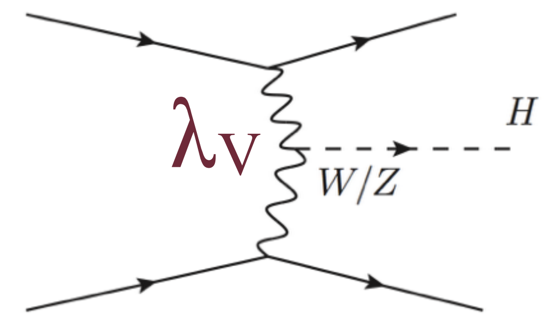
- fusion gluon mode dominant,
- others can help <u>improving s/b</u> and are sensitive to different <u>Higgs coupling</u>



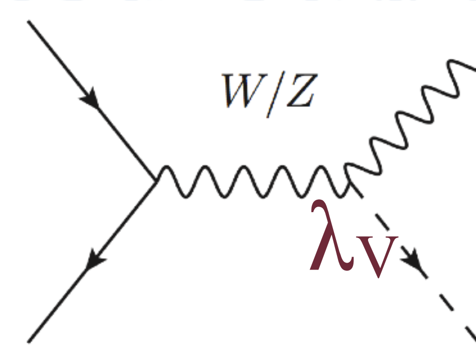
fusion gluon :



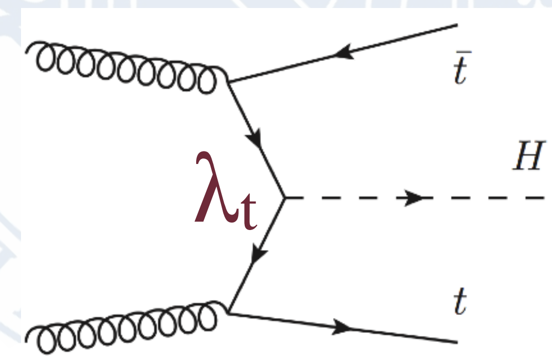
VBF :



Associated production :



top fusion :



Status after LHC run I:

JHEP 08, 045 (2016)

- **Signal Strength:**
  - defined as the ratio of the cross section x BR with respect to the SM :

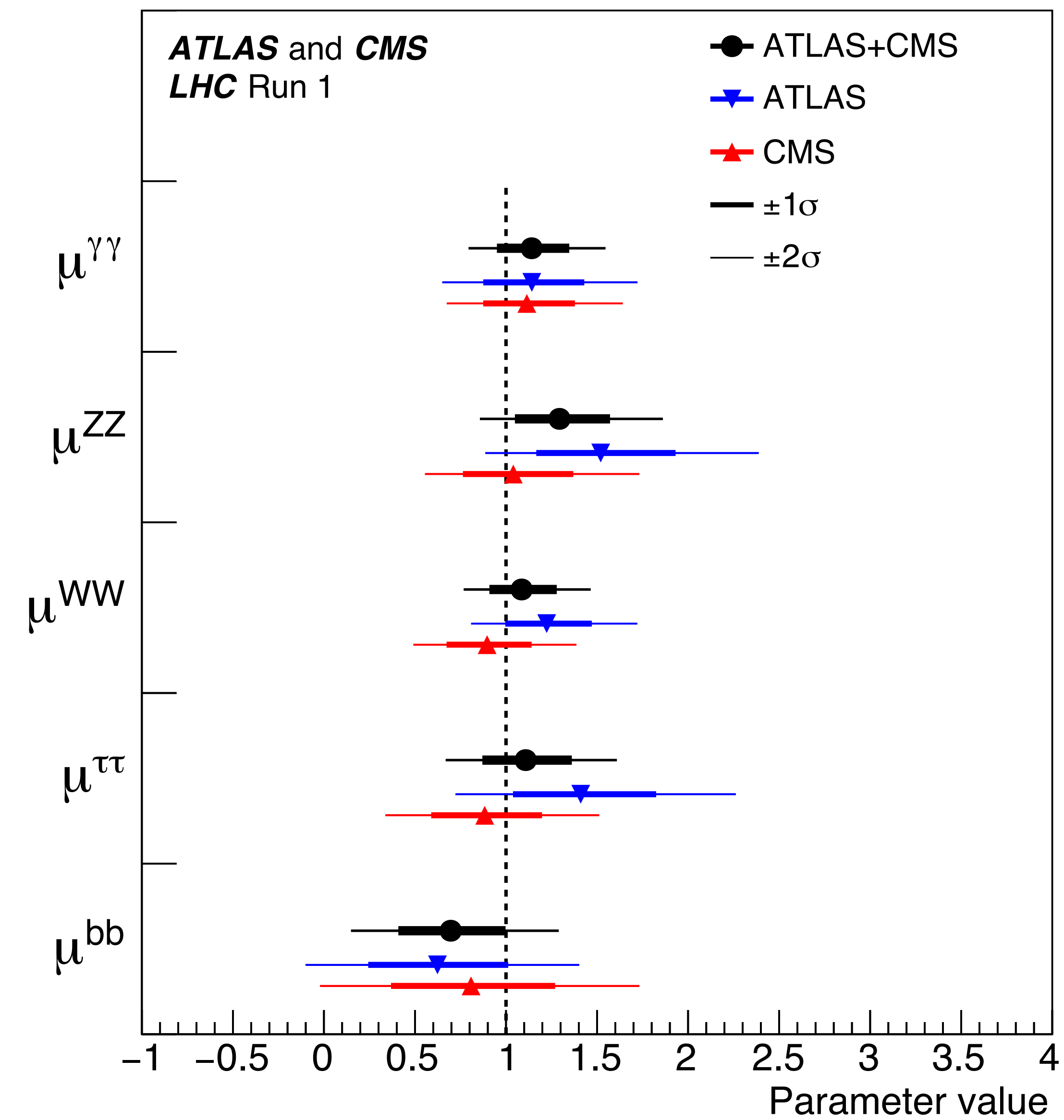
$$\mu = (\sigma.BR)_{obs}/(\sigma.BR)_{SM}$$

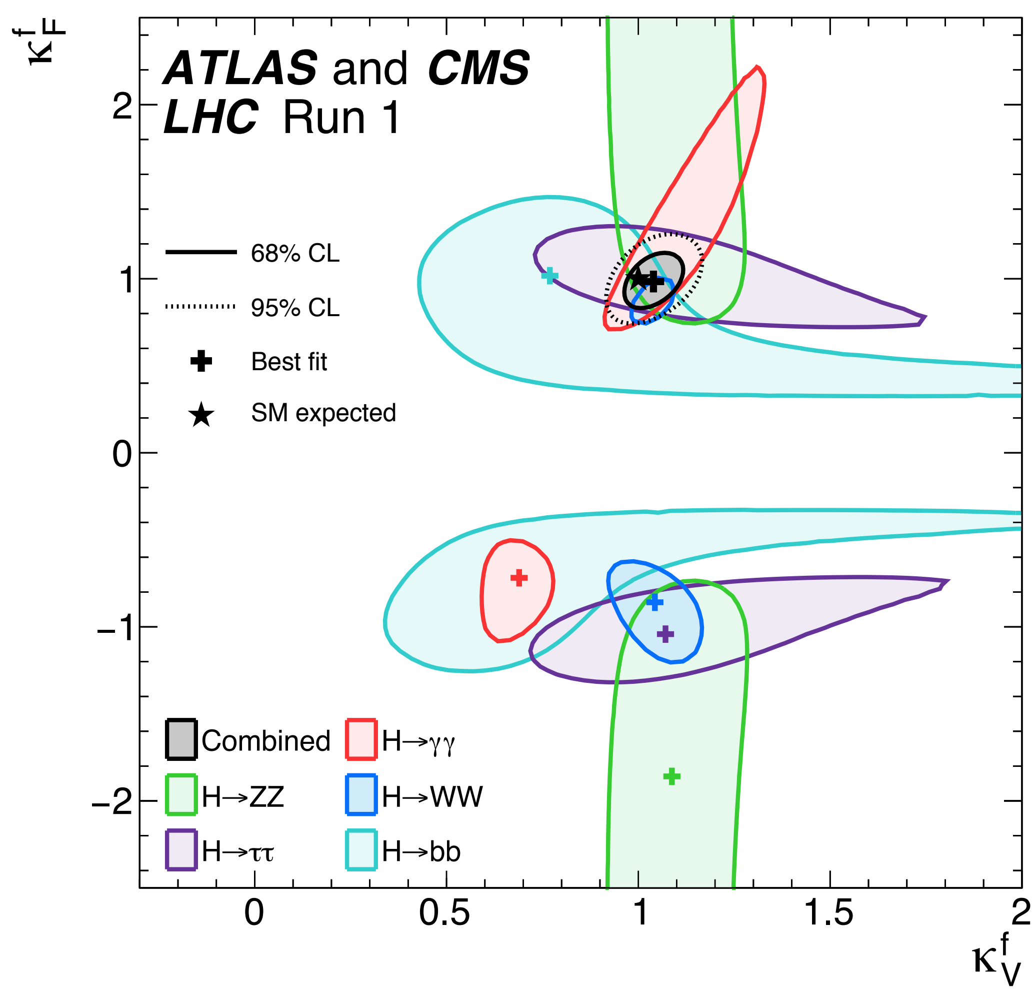
- **Coupling modifiers (κ_j) :**

$$\sigma_i \times BR^f = \frac{\sigma_i(\vec{\kappa}) \times \Gamma^f(\vec{\kappa})}{\Gamma_H}$$

$$\kappa_j^2 = \sigma_j/\sigma_j^{SM}$$

$$\kappa_j^2 = \Gamma^j/\Gamma^j_{SM}$$





ATLAS +CMS:

observed $\mu = 1.09^{+0.07}_{-0.07}(\text{stat})^{+0.03}_{-0.03}(\text{exp})^{+0.07}_{-0.06}(\text{th})$

$= 1.09^{+0.11}_{-0.10}$

H→VV in run 2

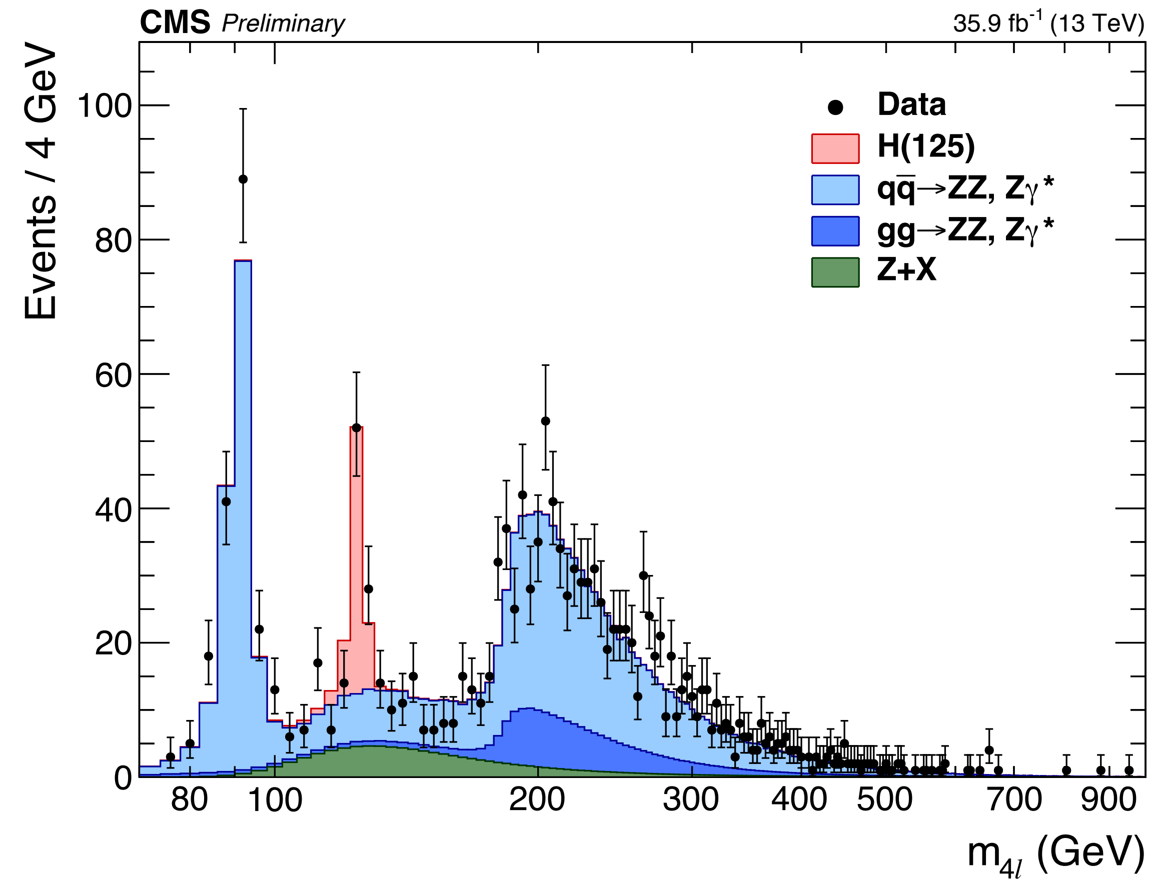
- Increased cross section
- Large amount of data collected by the experiments (~36fb^{-1} in 2016)
  ⇒ 4x increase in number of Higgs wrt run1: Enhanced sensitivity to production modes for coupling measurements
- **Results presented in this talk:**

	ATLAS	CMS
H→ZZ→4l: Signal Strength/Cross section/ Couplings	ATLAS-CONF-2017-043 (36fb-1 @ 13TeV)	CMS-HIG-16-041 (36fb-1 @ 13TeV)
H→ZZ→4l: Differential Cross section	ATLAS-CONF-2017-032 (36fb-1 @ 13TeV)	CMS-HIG-16-041 (36fb-1 @ 13TeV)
H→ZZ→4l: Tensor/Anomalous couplings	ATLAS-CONF-2017-043 (36fb-1 @ 13TeV)	CMS-HIG-17-011 (38.6fb-1 @ 13 TeV + comb. with run I)
H→ZZ→4l: Mass/width	ATLAS-CONF-2017-046 (36fb-1 @ 13TeV + comb. with run I)	CMS-HIG-16-041 (36fb-1 @ 13TeV)
H→WW→2l2v	ATLAS-CONF-2016-112 (5.8fb-1 @ 13TeV)	CMS-PAS-HIG-16-021 (2.3fb-1 + 12.9fb-1 @ 13 TeV)
Width from offshell	Eur. Phys. C(2015) 75:335 (20.3fb-1 @ 8 TeV)	Phys. Lett B 736 (2014), 64 (5.1fb-1 @ 7 TeV + 19.7 @ 8 TeV) CMS PAS HIG-16-033 (12.9fb-1 @ 13 TeV)

H→ZZ→4l

H→ZZ→4l: Analysis in a nutshell:

- **Signal** = 4 isolated leptons, narrow resonance in the 4l spectrum
  - 2 pairs of opposite sign, same flavour leptons (OSSF): 4e, 4μ, 2e2μ, 2μ2e
  - ZZ candidates: Z1 closest to the PDG mass, the other as Z2
- **Backgrounds**:
  - Main irreducible background: non resonant qq→ZZ and gg→ZZ ⇒ estimated from MC (cross section corrected with higher QCD orders)
  - Reducible backgrounds: Z+fake leptons, ttbar ⇒ estimated using data driven methods (control regions)
- **Large s/b ratio**, possibility of using kinematic discriminant based on Matrix Element



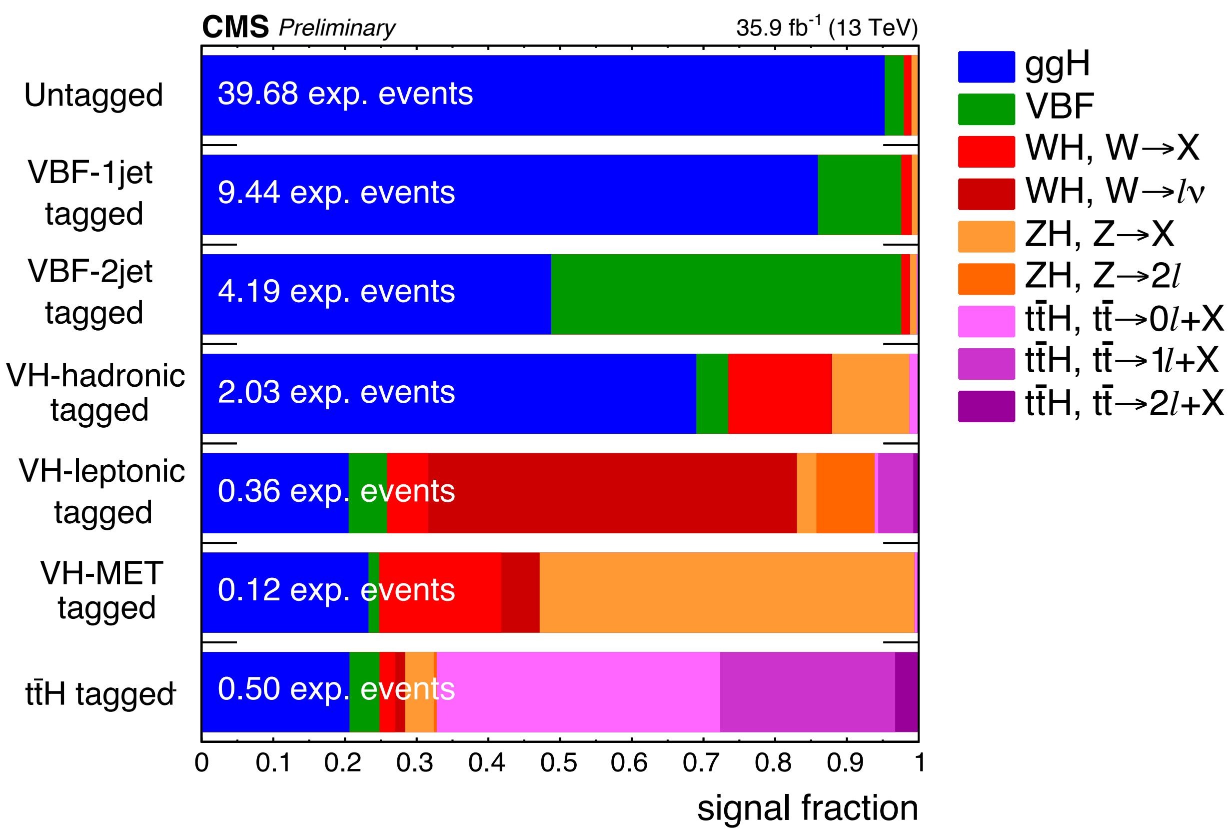
Channel	4e	4μ	$2e2\mu$	4ℓ
$q\bar{q} \to ZZ$	$192.7^{+18.6}_{-20.1}$	$360.2^{+24.9}_{-27.3}$	$471.0^{+32.6}_{-35.7}$	$1023.9^{+68.9}_{-76.0}$
$gg \to ZZ$	$41.2^{+6.3}_{-6.1}$	$69.0^{+9.5}_{-9.0}$	$101.7^{+14.0}_{-13.3}$	$211.8^{+28.9}_{-27.5}$
Z+X	$21.1^{+8.5}_{-10.4}$	$34.4^{+14.5}_{-13.2}$	$59.9^{+27.1}_{-25.0}$	$115.4^{+31.9}_{-30.1}$
Sum of backgrounds	$255.0^{+23.9}_{-25.1}$	$463.5^{+31.9}_{-33.7}$	$632.6^{+44.2}_{-46.1}$	$1351.1^{+85.8}_{-91.2}$
Signal ($m_H = 125$ GeV)	$12.0^{+1.3}_{-1.4}$	23.6 ± 2.1	30.0 ± 2.6	65.7 ± 5.6
Total expected	$267.0^{+24.9}_{-26.1}$	$487.1^{+33.1}_{-34.9}$	$662.6^{+45.7}_{-47.5}$	$1416.8^{+89.1}_{-94.3}$
Observed	293	505	681	1479

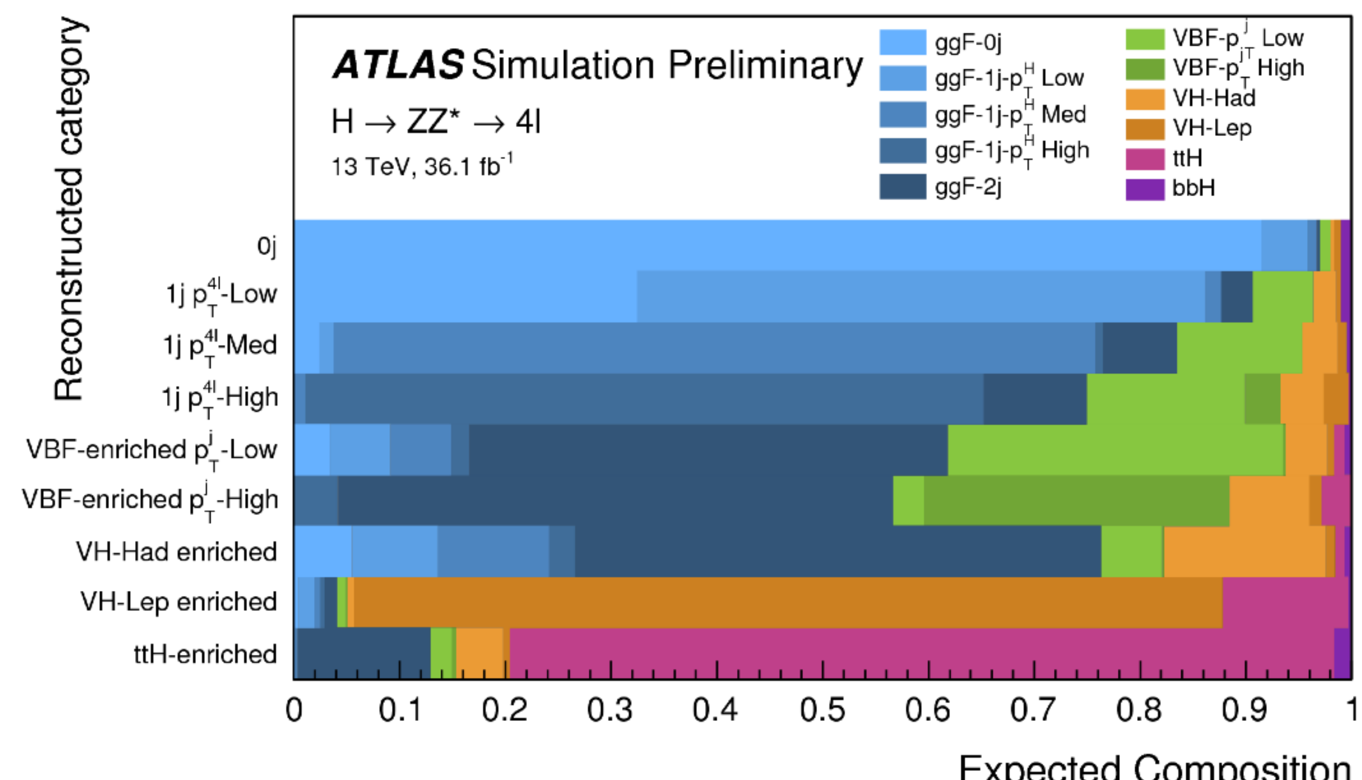
- **Analysis in categories:**
  - sensitivity to the Higgs production mode
  - categories with VBF or lepton tag very pure (but much less statistic)

H→ZZ→4l: Categories definition

- CMS:
  - categories build using cuts + kinematic discriminants
  - signal extraction using (m_{4l} x K_D) shape

- ATLAS:
  - categories build using cuts
  - signal extraction using shape of BDT output



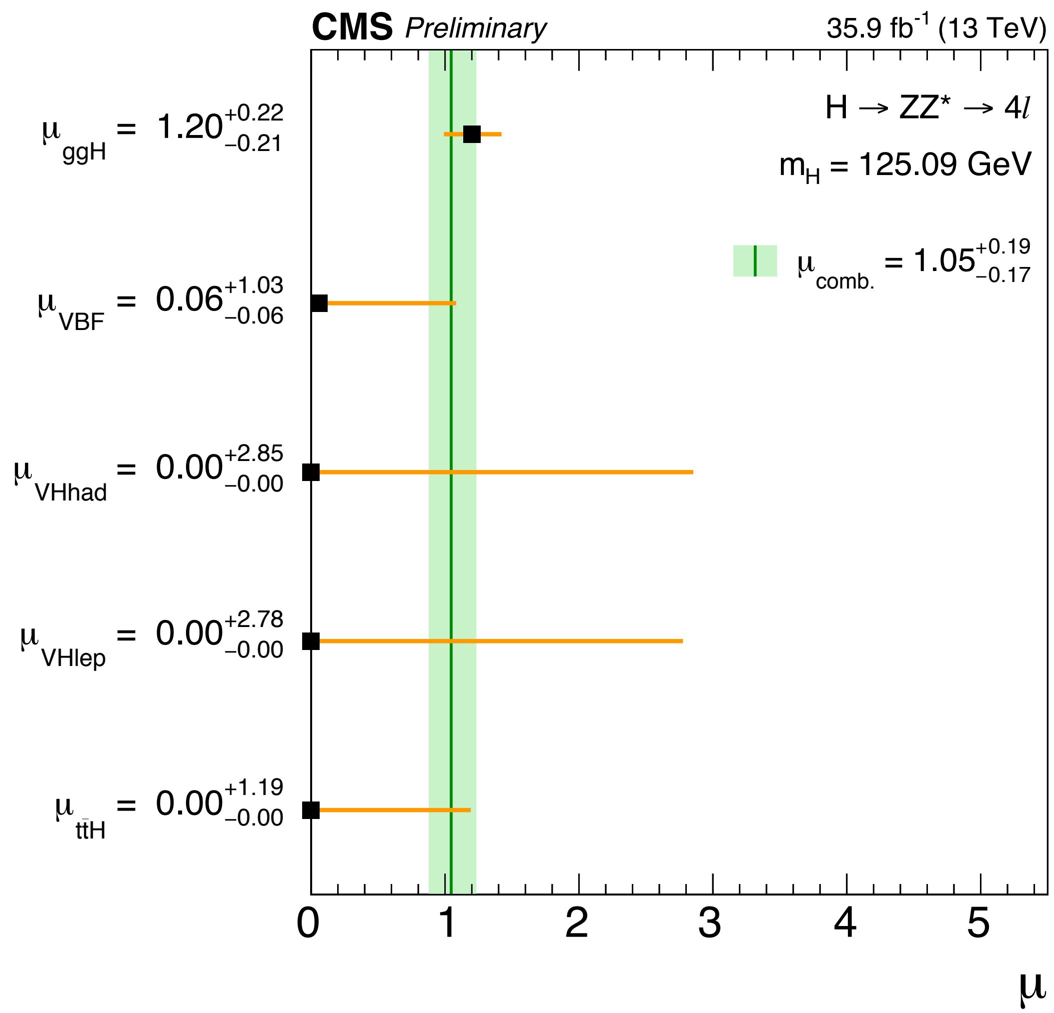


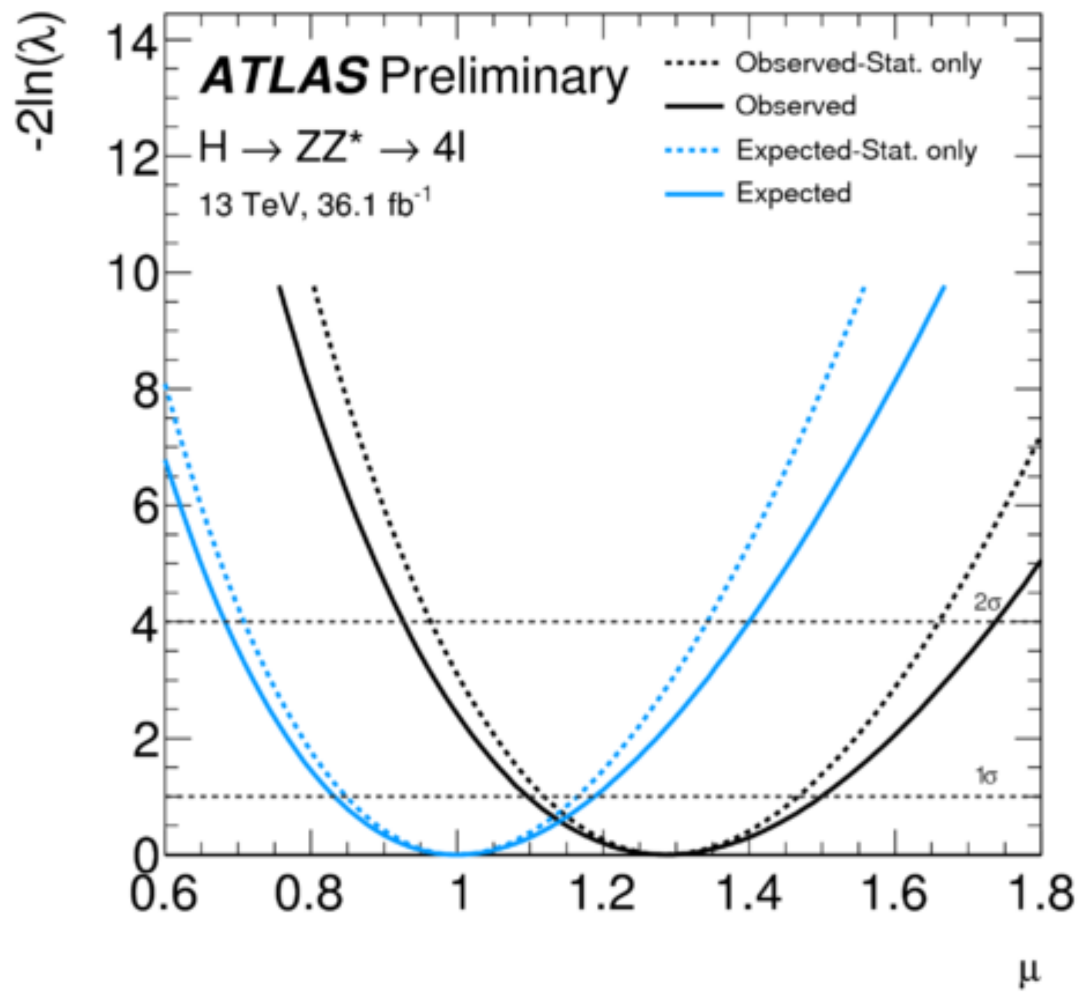
~stage 0 in STXS*

reduced stage 1 in STXS*

*STXS more details in P. Vanlear talk this afternoon

Signal Strength



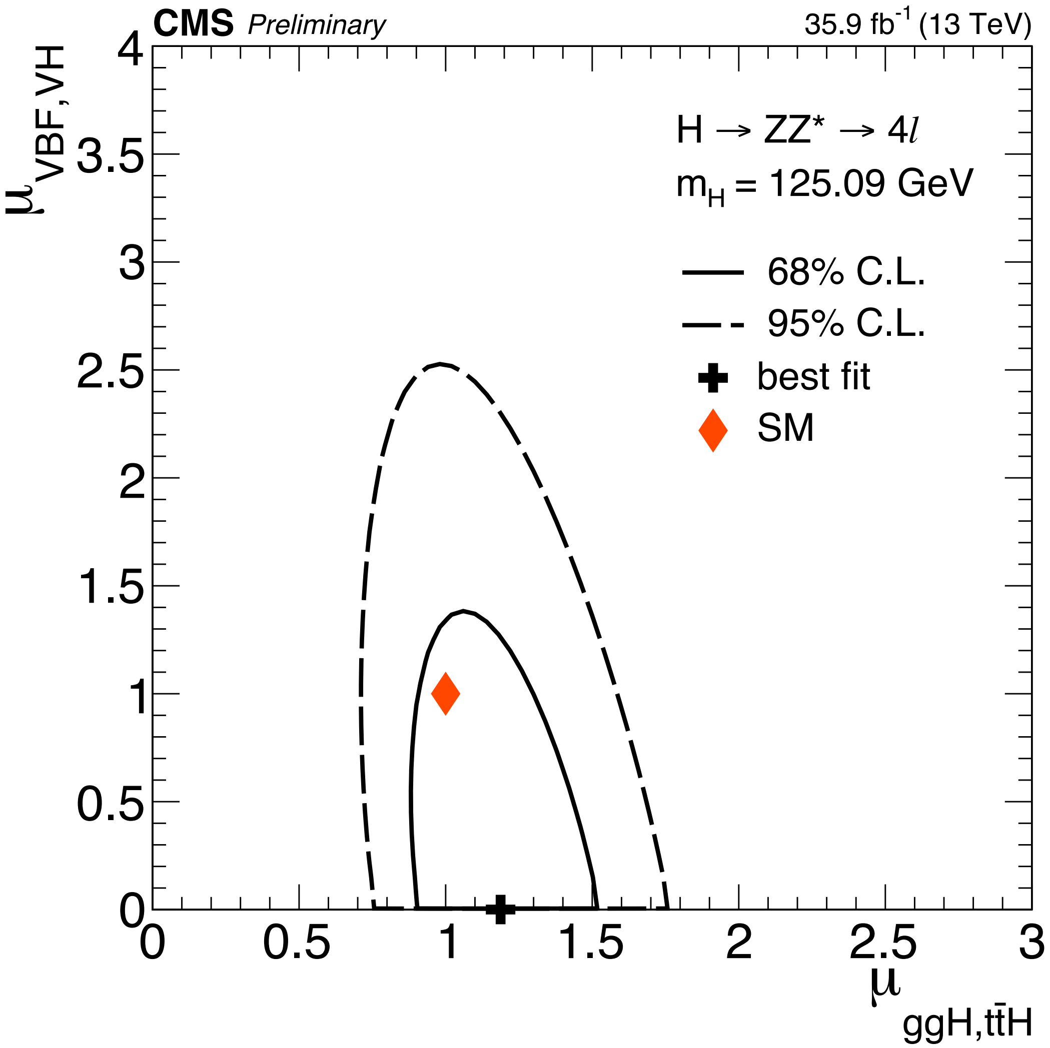


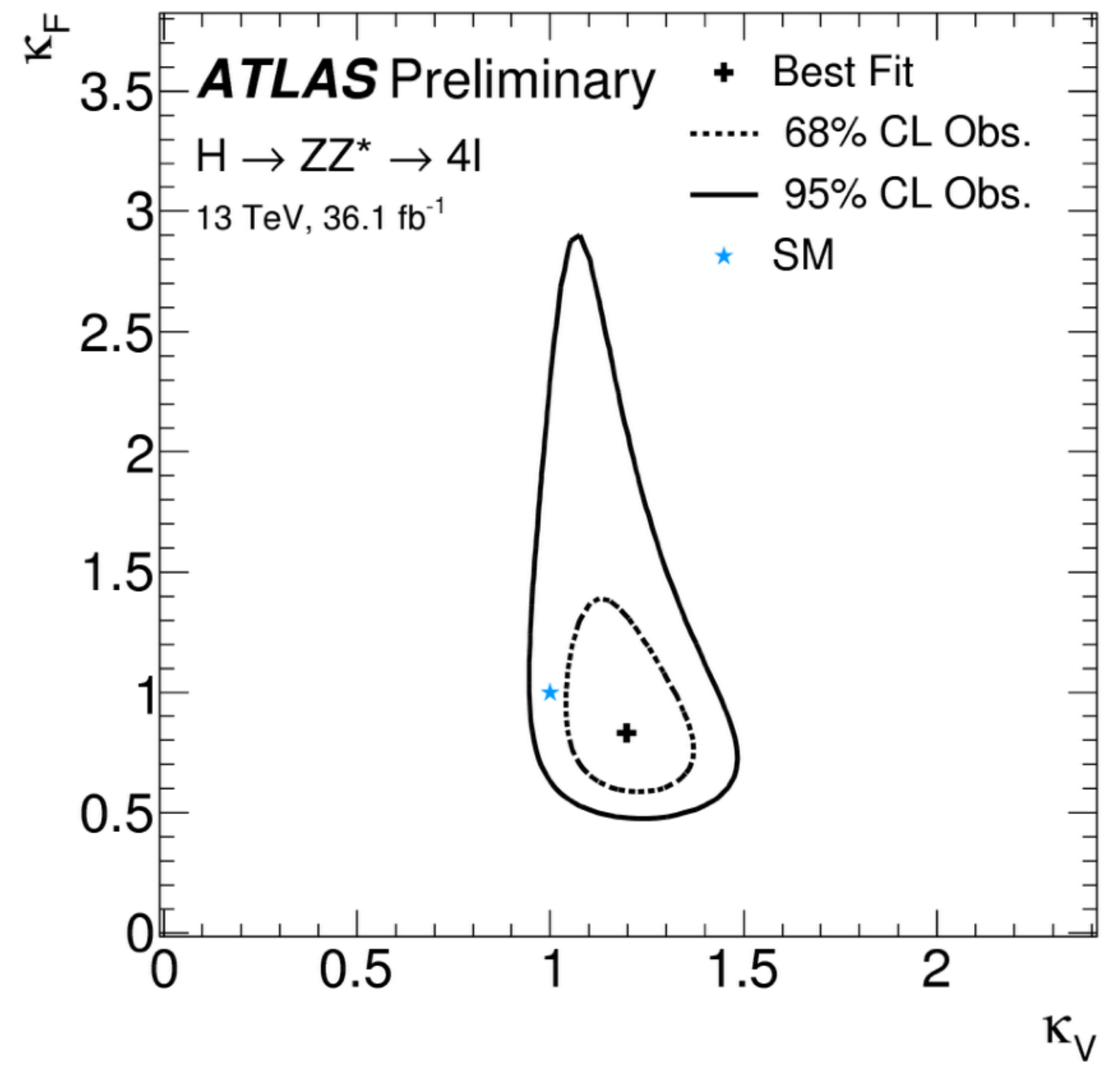
CMS:
observed $\mu=1.05^{+0.15}_{-0.14}(stat)^{+0.11}_{-0.09}(syst)=1.05^{+0.19}_{-0.17}$
expected $\mu=1.00^{+0.15}_{-0.14}(stat)^{+0.10}_{-0.08}(syst)$

ATLAS:
observed $\mu=1.28^{+0.18}_{-0.17}(stat)^{+0.08}_{-0.06}(exp)^{+0.08}_{-0.06}(th)=1.28^{+0.21}_{-0.19}$

Main uncertainties:
-exp: leptons efficiencies, lumi
-th: ggf cross section, ggf category migration

Coupling to fermions/bosons





signal strength and coupling modifier consistent in 2σ
with the Standard Model expectation

Differential cross-section measurements (1)

- **Fiducial cross-section:**
  - Kinematic and other selection cuts consistent with the sensitive detector acceptance
    ⇒ minimise extrapolation into experimentally invisible phase space
  - Correction for detector effects (resolutions, efficiencies)

Fiducial phase space definition in CMS:

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)	$\|\eta\| < 2.5(2.4)$
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	$40\,\text{GeV} < m_{Z_1} < 120\,\text{GeV}$
Inv. mass of the Z_2 candidate	$12\,\text{GeV} < m_{Z_2} < 120\,\text{GeV}$
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	$m_{\ell^+\ell'^-} > 4\,\text{GeV}$
Inv. mass of the selected four leptons	$105\,\text{GeV} < m_{4\ell} < 140\,\text{GeV}$

Use of dressed leptons in both ATLAS and CMS

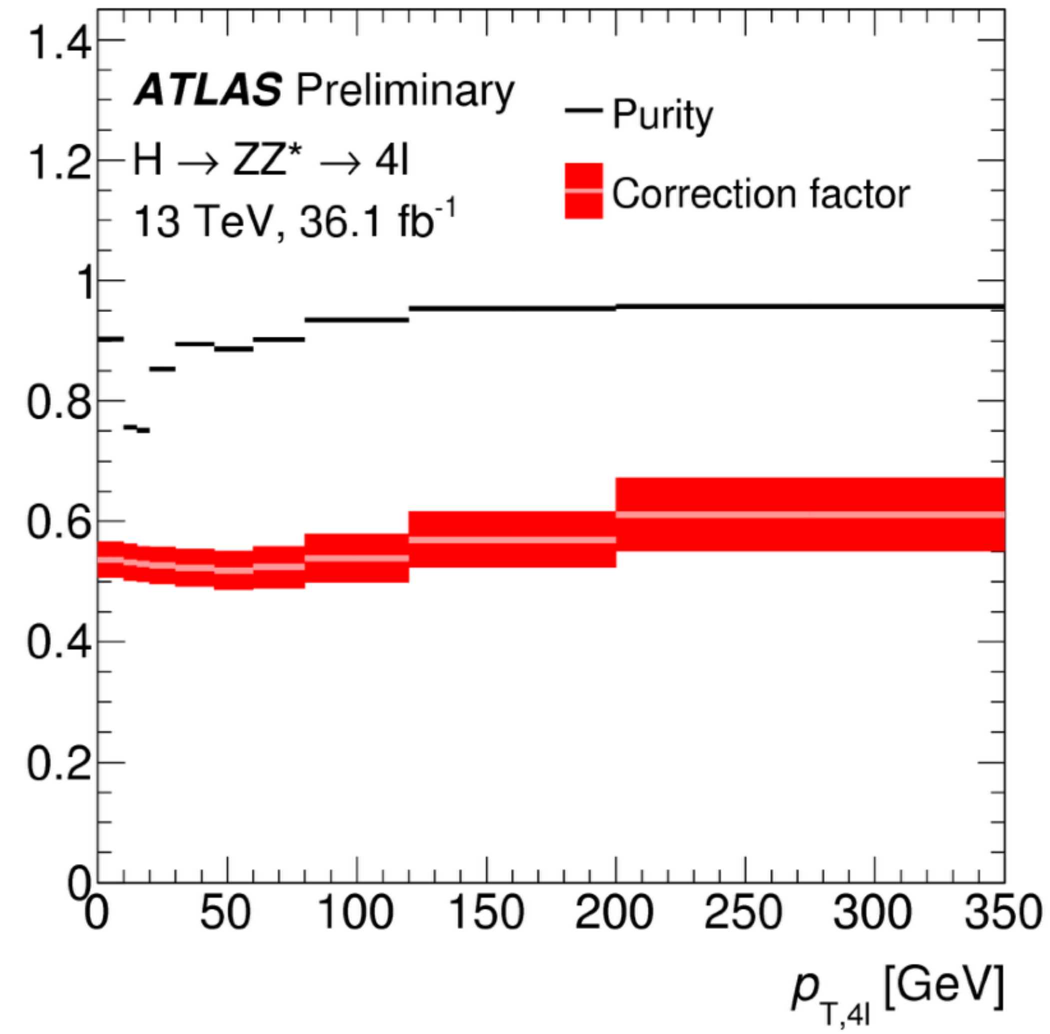
Differential cross-section measurements (2)

- **Signal extraction:**
  - fit of the m4l resonance in both ATLAS and CMS (no kinematic discriminant to be model independent)

- *For a given bin i :*

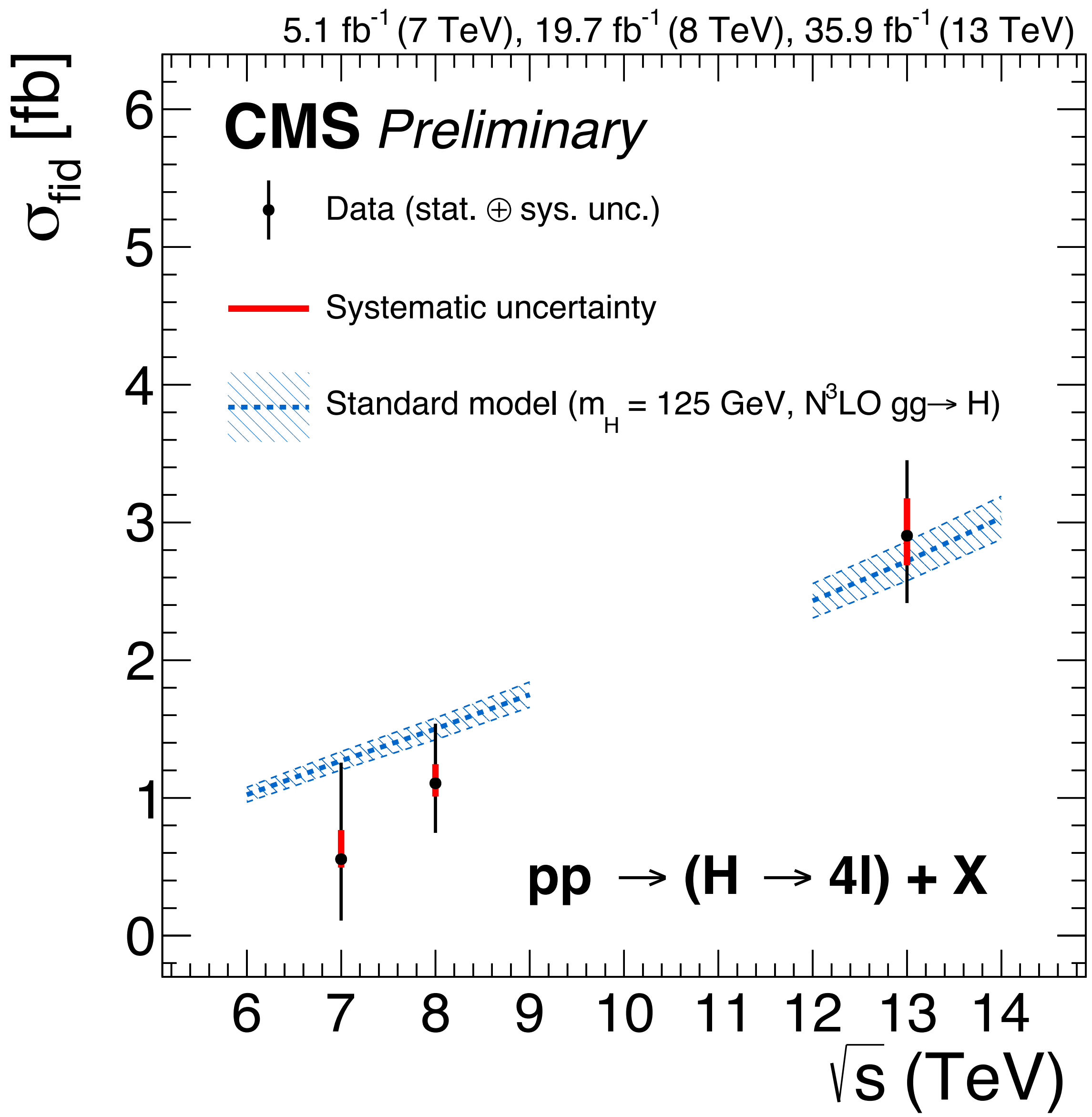
$$\sigma_{i,fid} = \sigma_i \times A_i \times BR = \frac{N_{i,fit}}{\mathcal{L} \times C_i}$$

  - A_i = acceptance at particle level
  - C_i = correction for detector efficiency and resolution
  - Ni,fit = number of signal events event observed

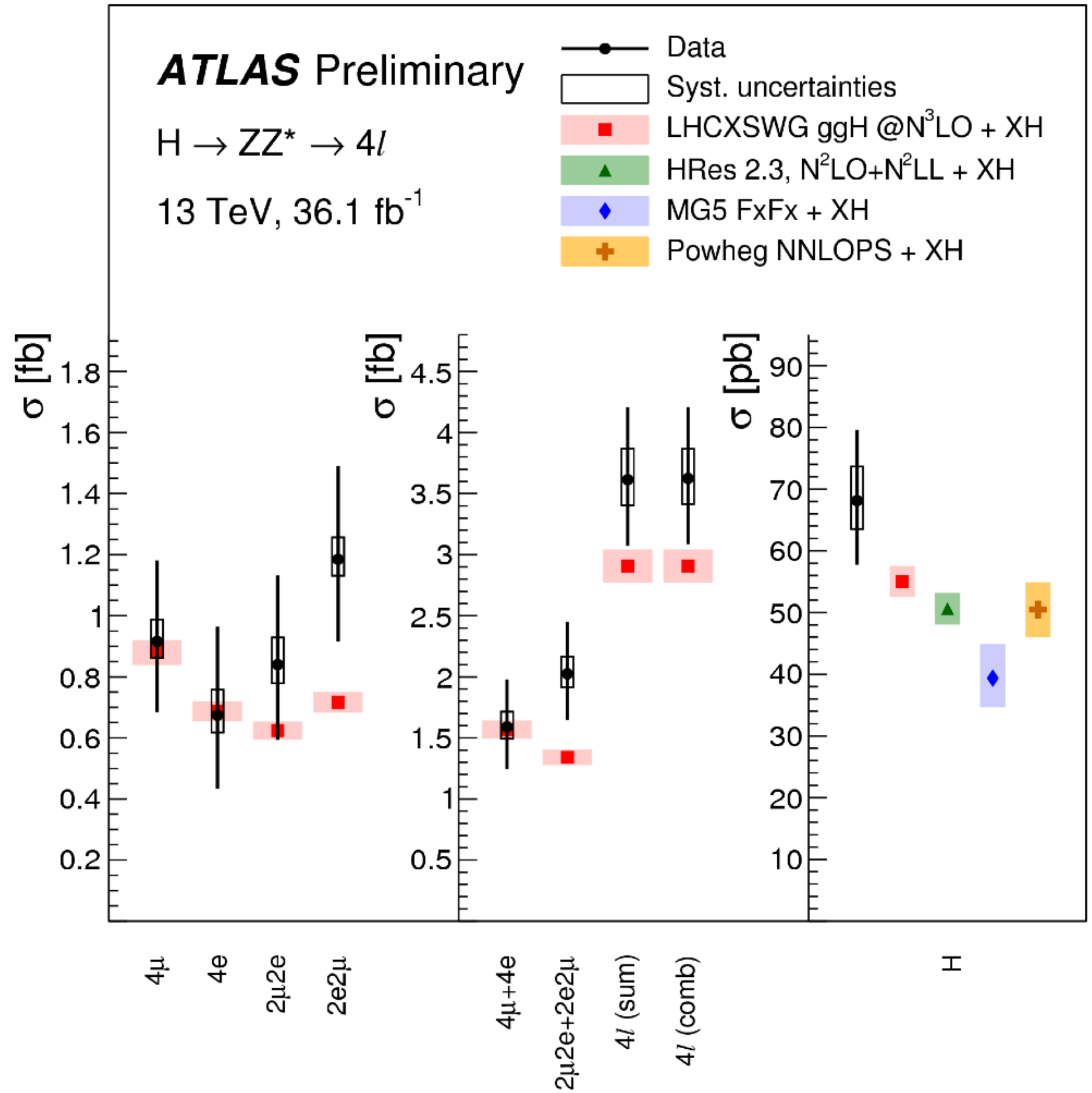


Results :

versus √s:

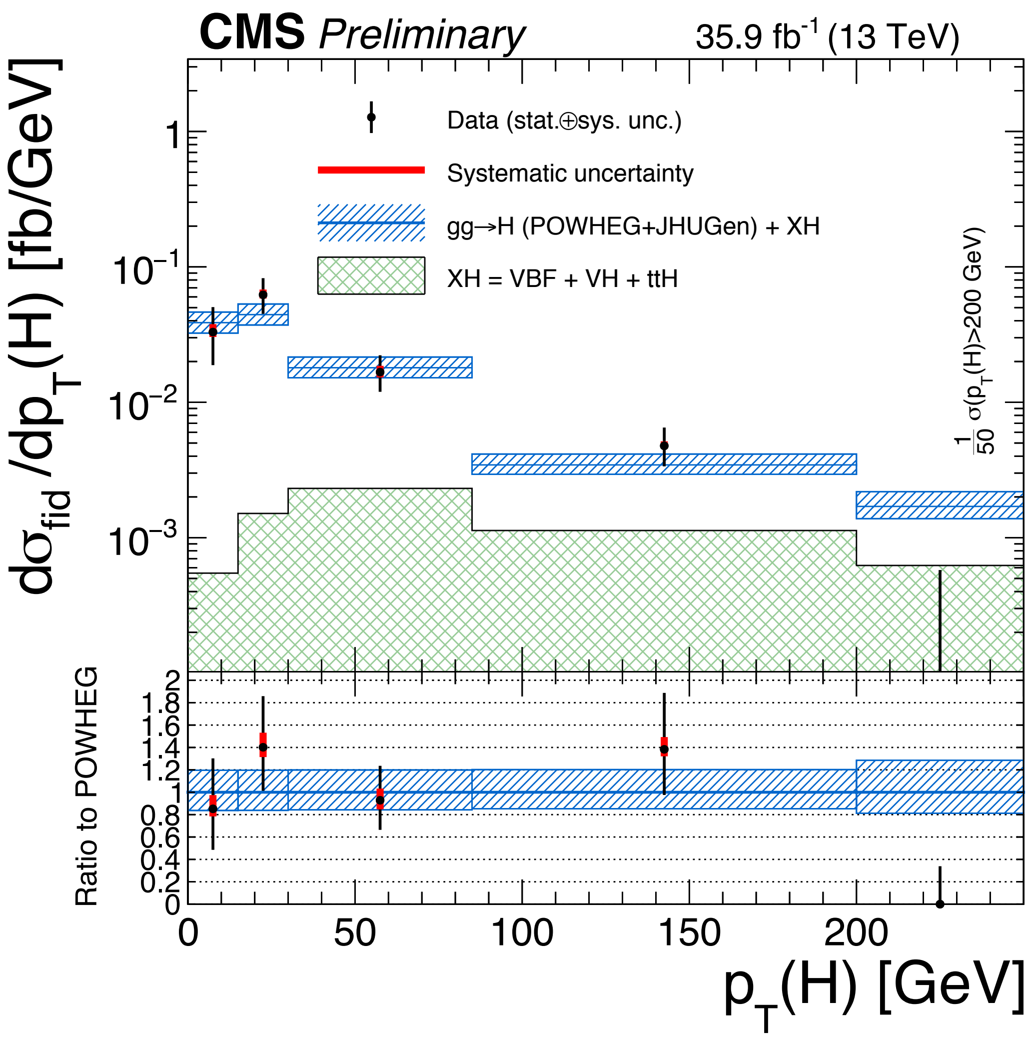


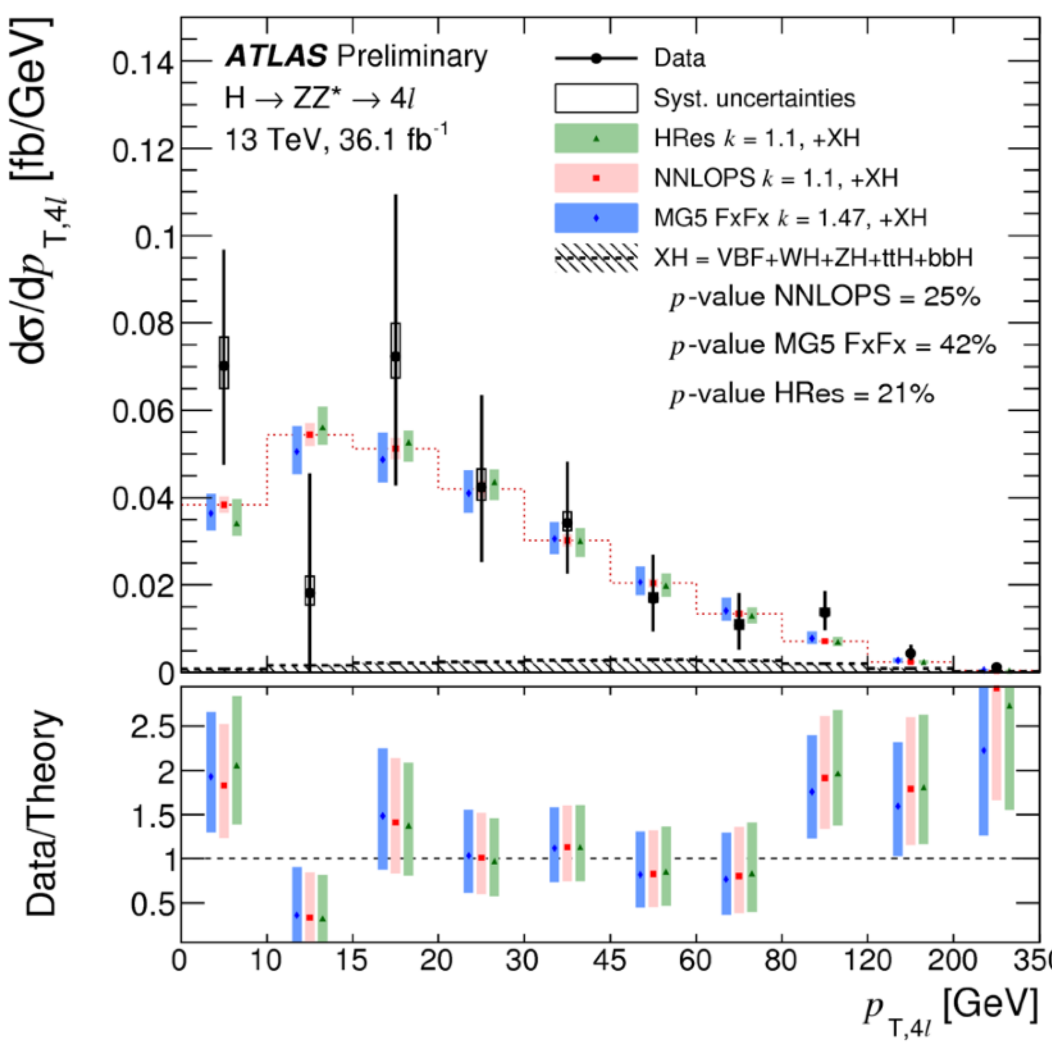
for the various 4l final states:



Differential cross section in $p_T(H)$

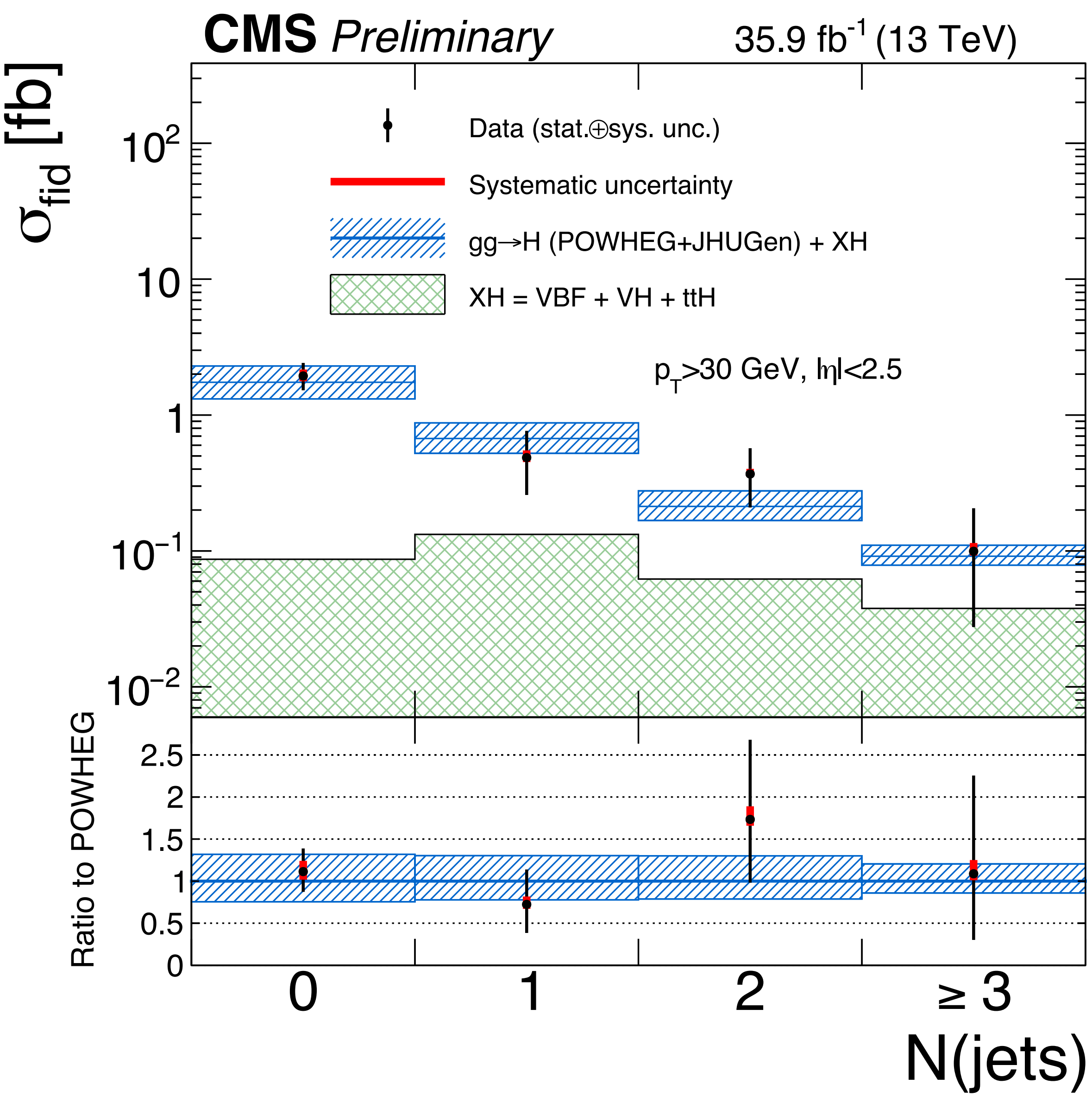
- **Higgs boson transverse momentum sensitive to:**
  - perturbative QCD calculations
  - heavy additional particle in the loop would change the high Higgs p_T region
  - low Higgs p_T region is sensitive to the Yukawa coupling of the b and charm quark

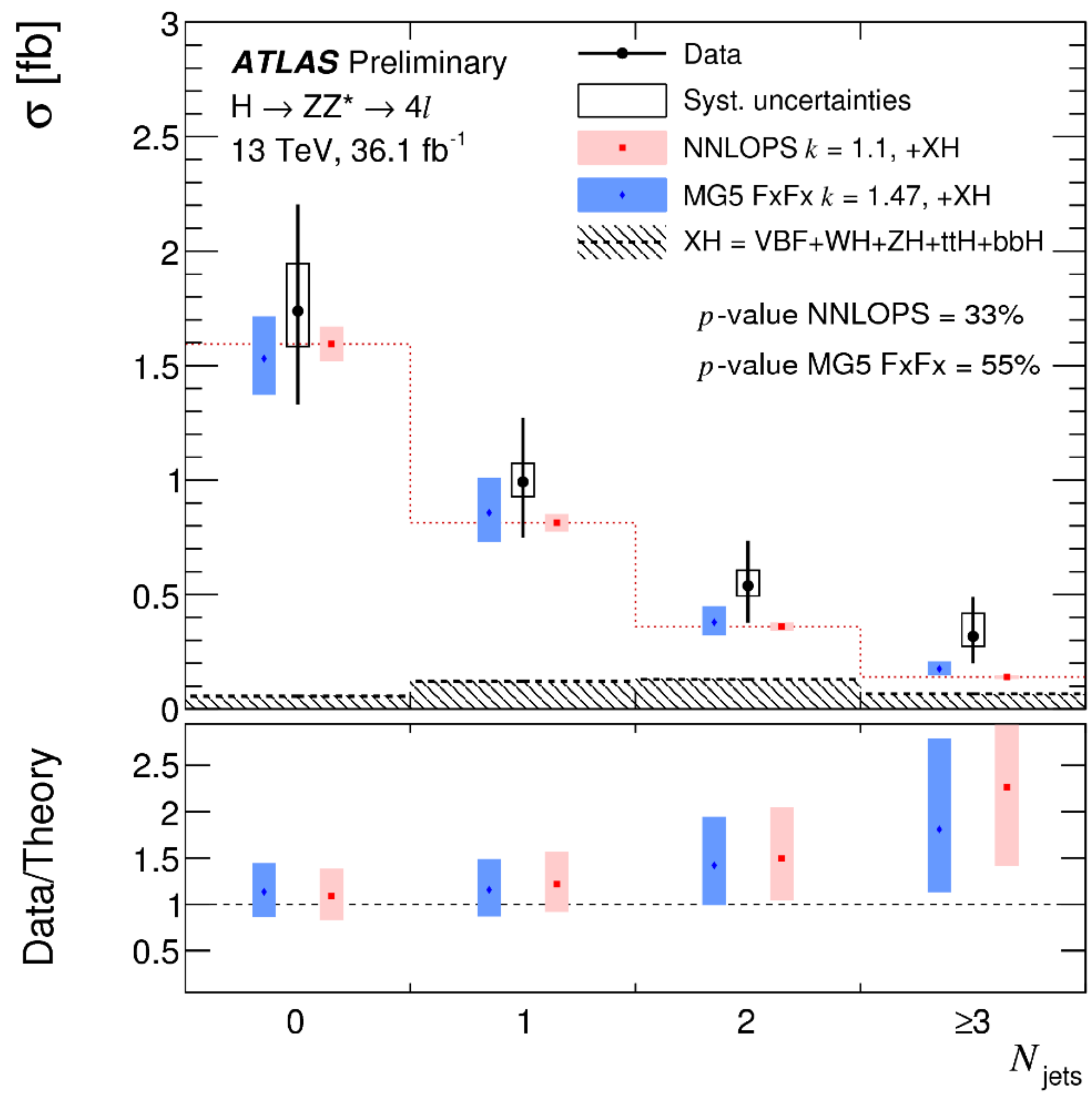




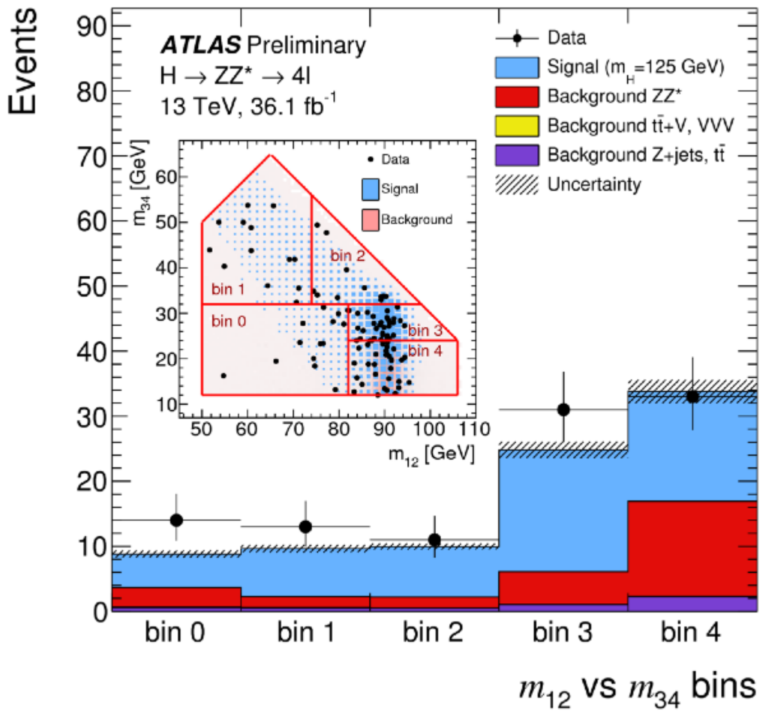
Differential cross section in N jets

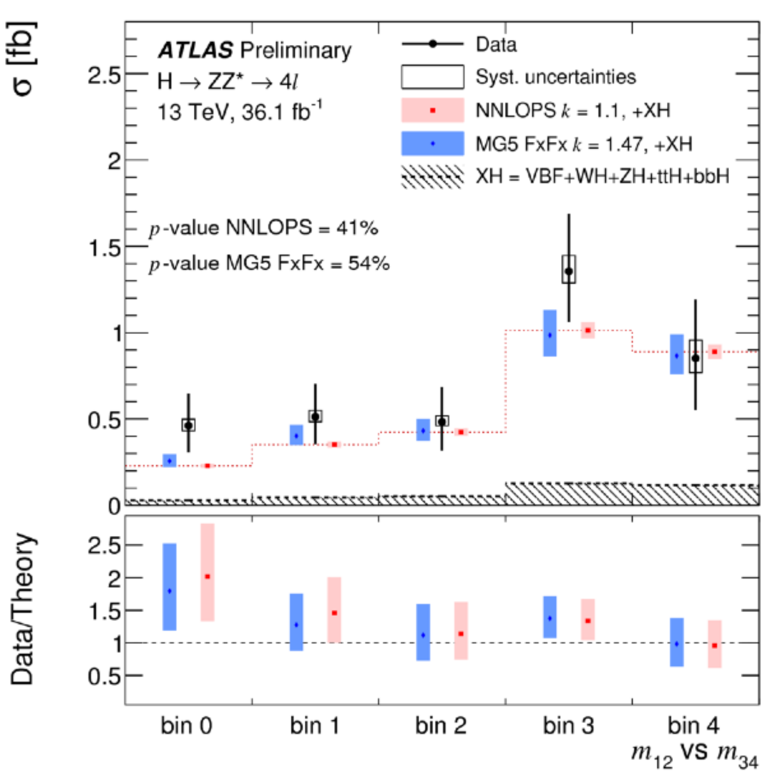
- number of jets is sensitive to Higgs production mode composition and to gluon emission



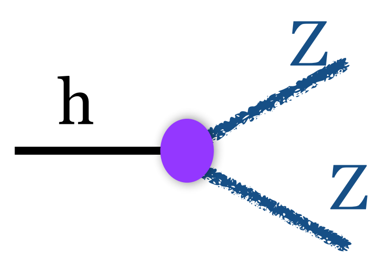


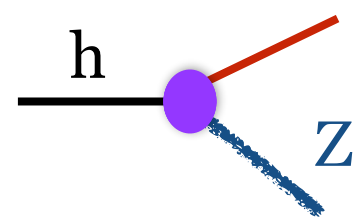
Higgs pseudo observables (ATLAS)

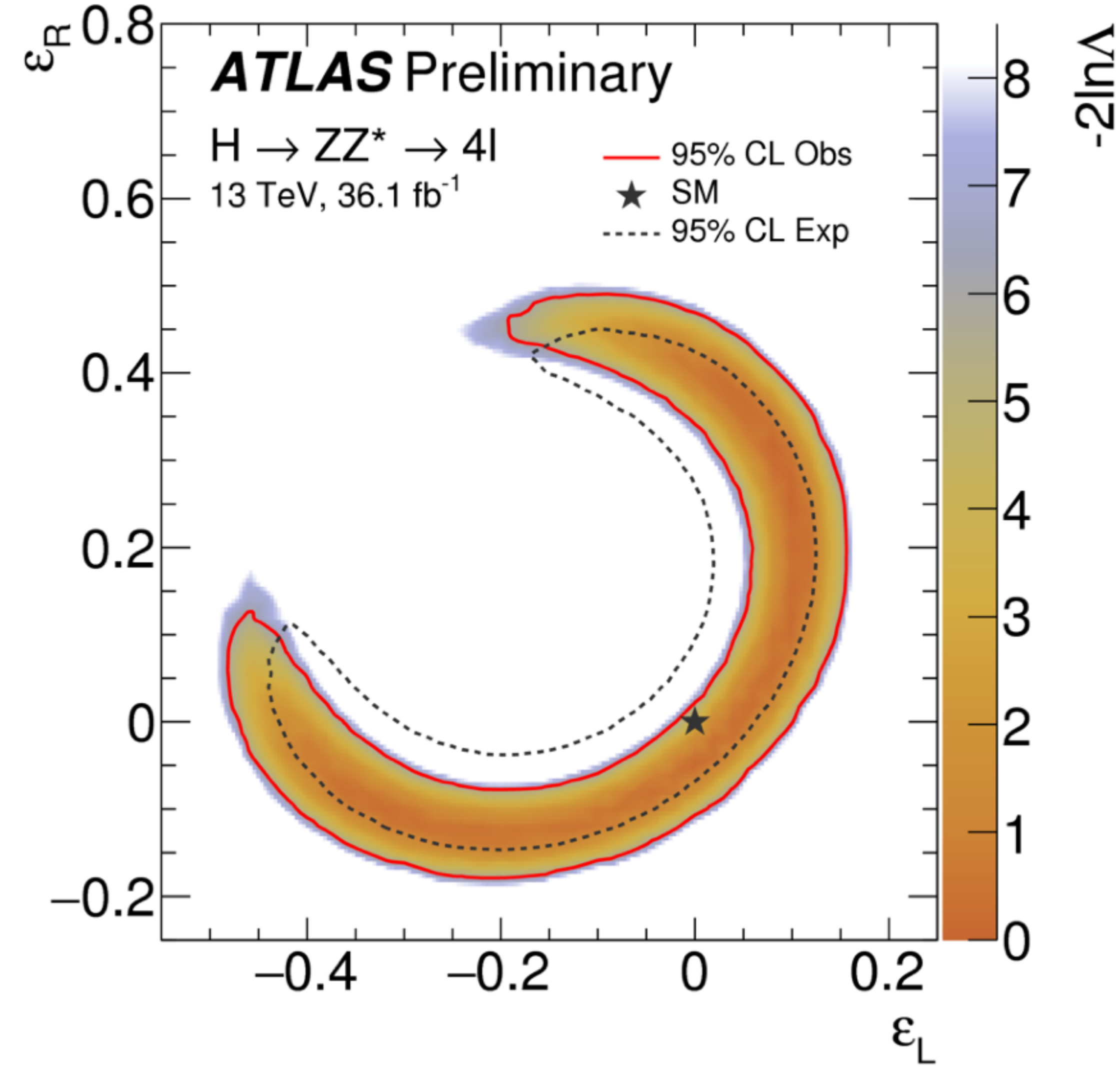




- Double differential cross section m_{12} vs m_{34} is used to put limits on anomalous couplings within the pseudo-observables framework (Eur. Phys. J. C (2015) 75: 128)
  - Limits on contact interaction terms between Higgs and leptons left(right)-handed $\varepsilon_L(\varepsilon_R)$ assuming lepton flavour universality







Anomalous couplings: (CMS)

- CMS H*→ZZ→4l also performed to constrain possible anomalous couplings

$$A(\mathrm{HVV}) \sim \left[a_1^{\mathrm{VV}} + \frac{\kappa_1^{\mathrm{VV}} q_1^2 + \kappa_2^{\mathrm{VV}} q_2^2}{\left(\Lambda_1^{\mathrm{VV}}\right)^2}\right] m_{\mathrm{V1}}^2 \epsilon_{\mathrm{V1}}^* \epsilon_{\mathrm{V2}}^* + a_2^{\mathrm{VV}} f_{\mu\nu}^{*(1)} f^{*(2),\mu\nu} + a_3^{\mathrm{VV}} f_{\mu\nu}^{*(1)} \tilde{f}^{*(2),\mu\nu}$$

  - anomalous coupling to be tested: a2, a3, κ^2/Λ^2_{1}, $\kappa^2/(\Lambda_1^{Z\gamma})^2$
  - SM: a1 = 1 + BSM anomalous couplings = 0
  - Effectives fractional cross-section and phase can be defined from that:

$$f_{ai} = |a_i|^2\sigma_i \Big/ \sum |a_j|^2\sigma_j, \text{ and } \phi_{ai} = \arg\left(a_i/a_1\right)$$

  - Use of kinematic discriminants:

$$\mathcal{D}_{\mathrm{alt}} = \frac{\mathcal{P}_{\mathrm{sig}}\left(\vec{\Omega}\right)}{\mathcal{P}_{\mathrm{sig}}\left(\vec{\Omega}\right) + \mathcal{P}_{\mathrm{alt}}\left(\vec{\Omega}\right)}$$

discriminate the SM from a given alternative model obtained by having only a_i=1

$$\mathcal{D}_{\mathrm{int}} = \frac{\mathcal{P}_{\mathrm{int}}\left(\vec{\Omega}\right)}{\mathcal{P}_{\mathrm{sig}}\left(\vec{\Omega}\right) + \mathcal{P}_{\mathrm{alt}}\left(\vec{\Omega}\right)},$$

contains all the information available to separate the interference component

Anomalous couplings: (CMS)

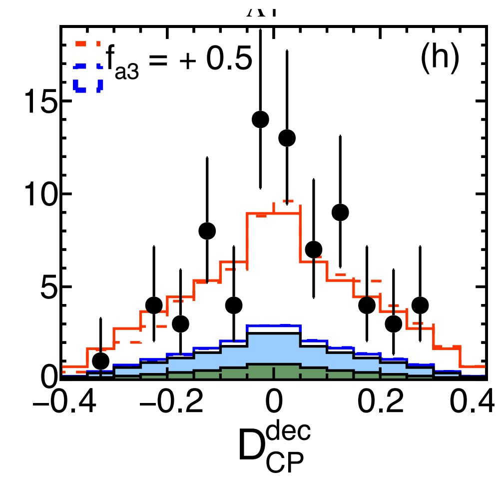
Kinematic Discriminants used for each f_i scan:

Category	VBF-jet	VH-jet	Untagged
Target	$qq'VV \to qq'H \to (jj)(4\ell)$	$q\bar{q} \to VH \to (jj)(4\ell)$	$H \to 4\ell$
Selection	$\mathcal{D}_{2jet}^{VBF}$ or $\mathcal{D}_{2jet}^{VBF,BSM} > 0.5$	$\mathcal{D}_{2jet}^{ZH}$ or $\mathcal{D}_{2jet}^{ZH,BSM}$ or $\mathcal{D}_{2jet}^{WH}$ or $\mathcal{D}_{2jet}^{WH,BSM} > 0.5$	not VBF-jet, not VH-jet
f_{a3} obs.	$\mathcal{D}_{bkg}, \mathcal{D}_{0-}^{VBF+dec}, \mathcal{D}_{CP}^{VBF}$	$\mathcal{D}_{bkg}, \mathcal{D}_{0-}^{VH+dec}, \mathcal{D}_{CP}^{VH}$	$\mathcal{D}_{bkg}, \mathcal{D}_{0-}^{dec}, \mathcal{D}_{CP}^{dec}$
f_{a2} obs.	$\mathcal{D}_{bkg}, \mathcal{D}_{0h+}^{VBF+dec}, \mathcal{D}_{int}^{VBF}$	$\mathcal{D}_{bkg}, \mathcal{D}_{0h+}^{VH+dec}, \mathcal{D}_{int}^{VH}$	$\mathcal{D}_{bkg}, \mathcal{D}_{0h+}^{dec}, \mathcal{D}_{int}^{dec}$
$f_{\Lambda1}$ obs.	$\mathcal{D}_{bkg}, \mathcal{D}_{\Lambda1}^{VBF+dec}, \mathcal{D}_{0h+}^{VBF+dec}$	$\mathcal{D}_{bkg}, \mathcal{D}_{\Lambda1}^{VH+dec}, \mathcal{D}_{0h+}^{VH+dec}$	$\mathcal{D}_{bkg}, \mathcal{D}_{\Lambda1}^{dec}, \mathcal{D}_{0h+}^{dec}$
$f_{\Lambda1}^{Z\gamma}$ obs.	$\mathcal{D}_{bkg}, \mathcal{D}_{\Lambda1}^{Z\gamma,VBF+dec}, \mathcal{D}_{0h+}^{VBF+dec}$	$\mathcal{D}_{bkg}, \mathcal{D}_{\Lambda1}^{Z\gamma,VH+dec}, \mathcal{D}_{0h+}^{VH+dec}$	$\mathcal{D}_{bkg}, \mathcal{D}_{\Lambda1}^{Z\gamma,dec}, \mathcal{D}_{0h+}^{dec}$

0- → a3=1

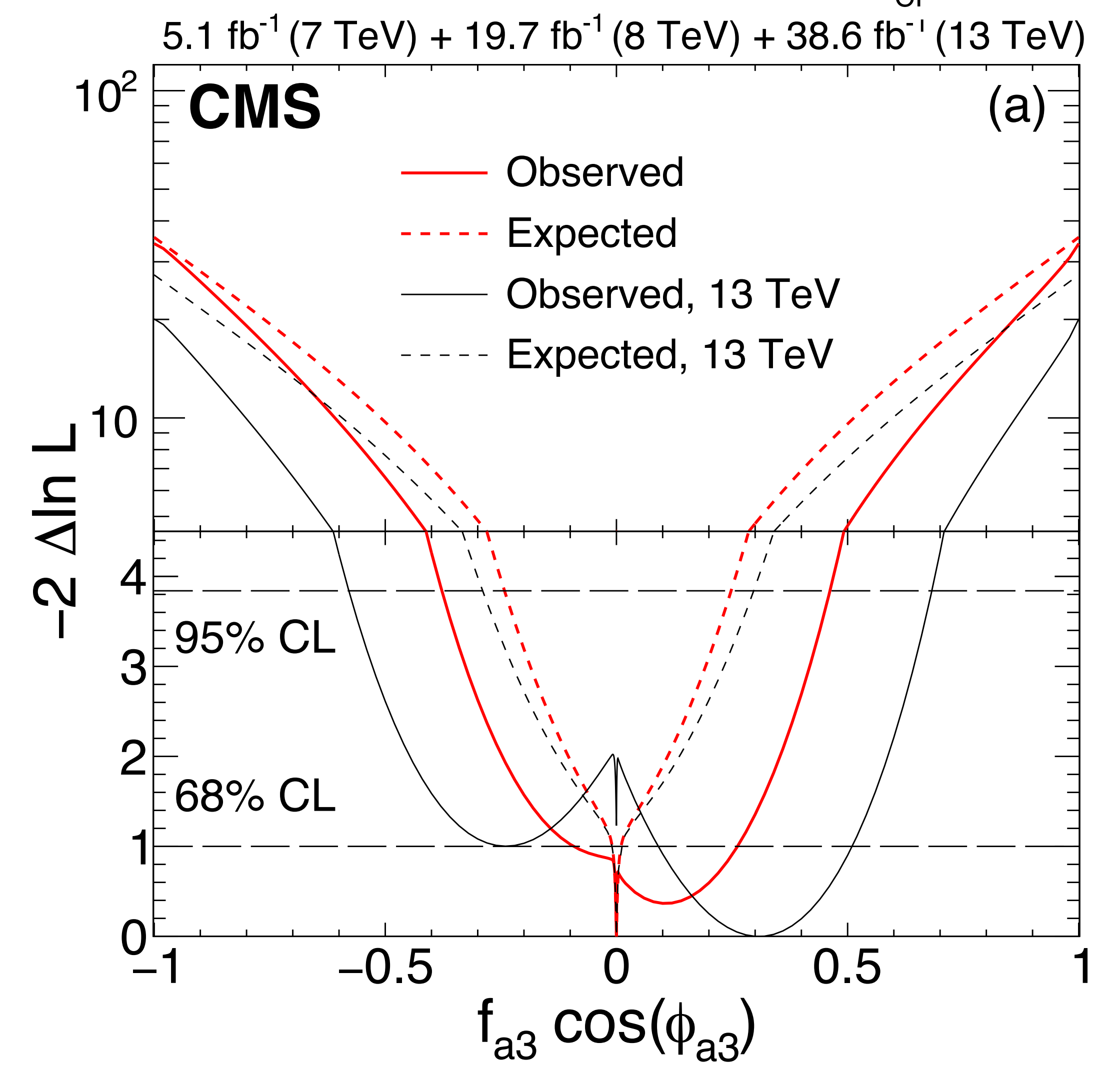
0h+ → a2 = 1

...



Results:

Parameter	Observed	Expected
$f_{a3}\cos(\phi_{a3})$	$0.00^{+0.26}_{-0.09}$ $[-0.38, 0.46]$	$0.000^{+0.010}_{-0.010}$ $[-0.25, 0.25]$
$f_{a2}\cos(\phi_{a2})$	$0.01^{+0.12}_{-0.02}$ $[-0.04, 0.43]$	$0.000^{+0.009}_{-0.008}$ $[-0.06, 0.19]$
$f_{\Lambda1}\cos(\phi_{\Lambda1})$	$0.02^{+0.08}_{-0.06}$ $[-0.49, 0.18]$	$0.000^{+0.003}_{-0.002}$ $[-0.60, 0.12]$
$f_{\Lambda1}^{Z\gamma}\cos(\phi_{\Lambda1}^{Z\gamma})$	$0.26^{+0.30}_{-0.35}$ $[-0.40, 0.79]$	$0.000^{+0.019}_{-0.022}$ $[-0.37, 0.71]$



measurements of anomalous couplings are expressed as relative cross sections

⇒ dominant uncertainty is the statistical uncertainty

No deviation from SM observed

Anomalous couplings: (ATLAS)

- Effective Lagrangian approach for the description of BSM interactions – Higgs Characterisation Model. (JHEP 1311 (2013) 043)

$$\mathcal{L}_0^V = \Big\{ \kappa_{SM} \left[\tfrac{1}{2} g_{HZZ} Z_\mu Z^\mu + g_{HWW} W_\mu^+ W^{-\mu} \right] - \tfrac{1}{4} \left[\kappa_{Hgg} g_{Hgg} G^a_{\mu\nu} G^{a,\mu\nu} + \tan\alpha\, \kappa_{Agg} g_{Agg} G^a_{\mu\nu} \tilde{G}^{a,\mu\nu} \right] - \tfrac{1}{4} \tfrac{1}{\Lambda} \left[\kappa_{HZZ} Z_{\mu\nu} Z^{\mu\nu} + \tan\alpha\, \kappa_{AZZ} Z_{\mu\nu} \tilde{Z}^{\mu\nu} \right] - \tfrac{1}{2} \tfrac{1}{\Lambda} \left[\kappa_{HWW} W^+_{\mu\nu} W^{-\mu\nu} + \tan\alpha\, \kappa_{AWW} W^+_{\mu\nu} \tilde{W}^{-\mu\nu} \right] \Big\} X_0.$$

assuming no new BSM particles below Λ (1TeV)

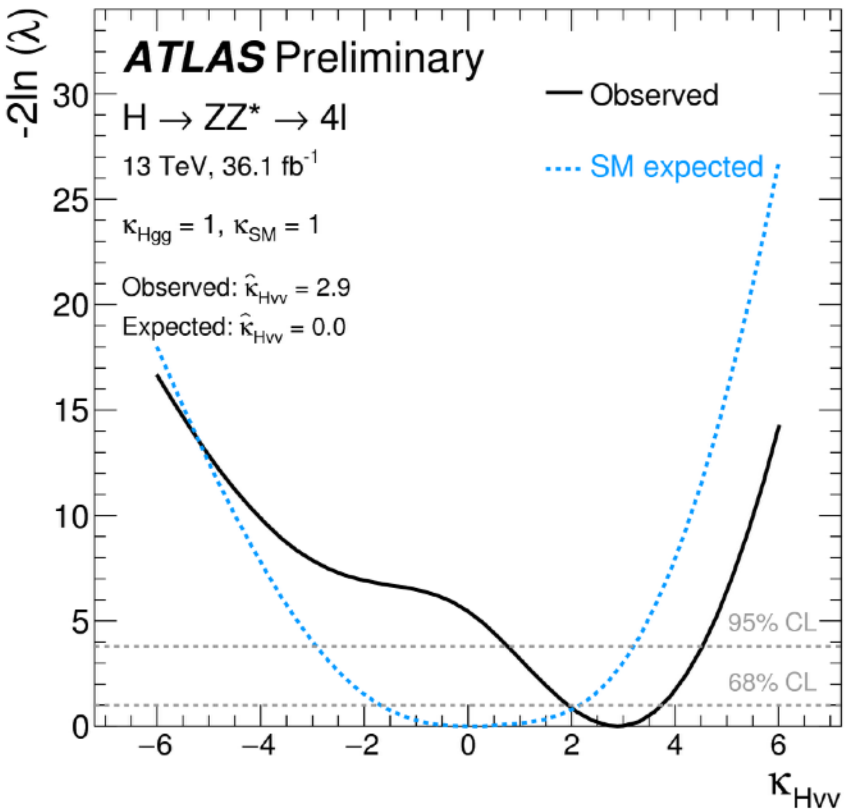
- **BSM couplings:**
  - κ_{HVV} = CP-even scalar iteration with vector bosons
  - κ_{AVV} = CP-odd pseudo-scalar iteration with vector bosons
  - κ_{Agg} = CP-odd BSM iteration with gluons
  - assumed to be the same for W and Z, α taken as 45 degrees

- **SM Higgs:**
  - κ_{SM} = 1, κ_{Hgg}=1 + other BSM couplings set to 0

Anomalous couplings: (ATLAS)

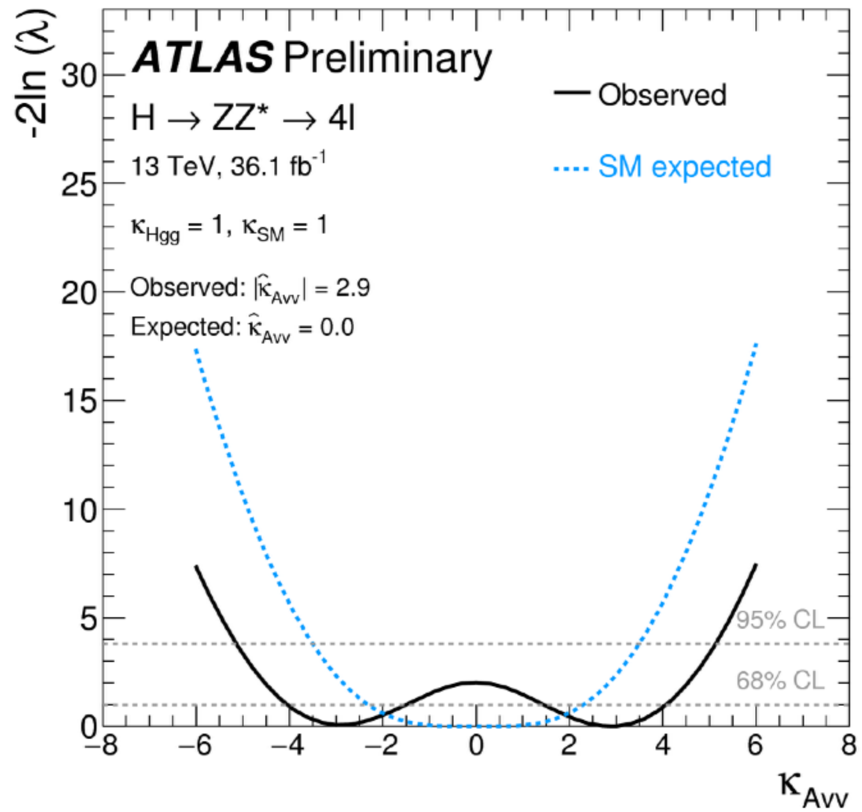
- Results :

CP-even coupling to vector bosons



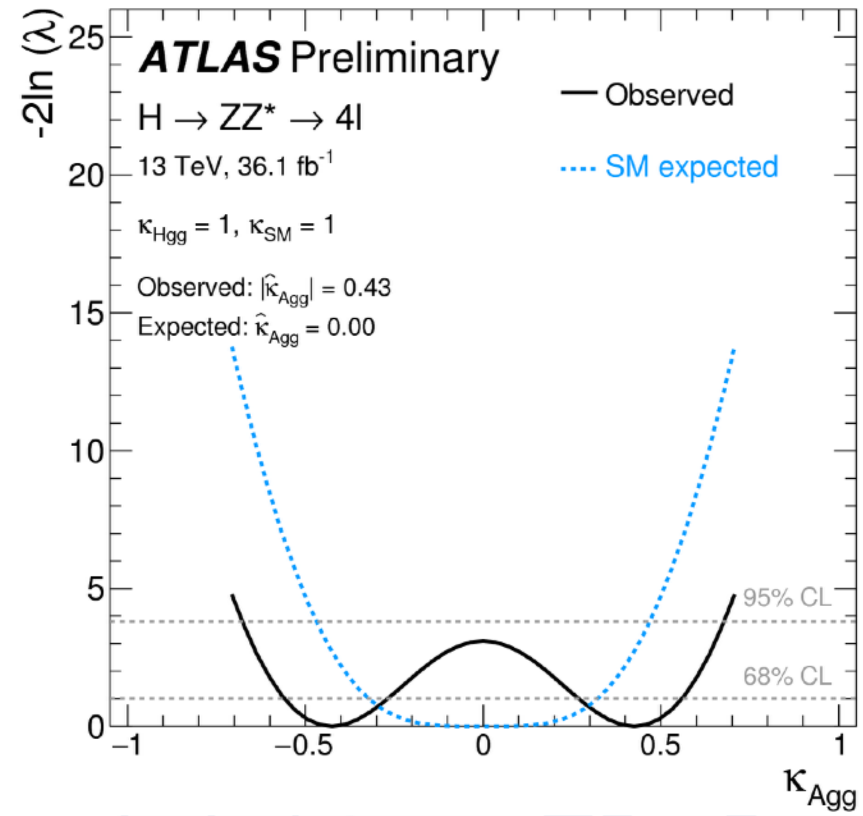
Agreement with SM 2.3σ for κ_{Hvv}

CP-odd coupling to vector bosons



Agreement with SM 1.4σ for κ_{Avv}

CP-odd coupling to gluons

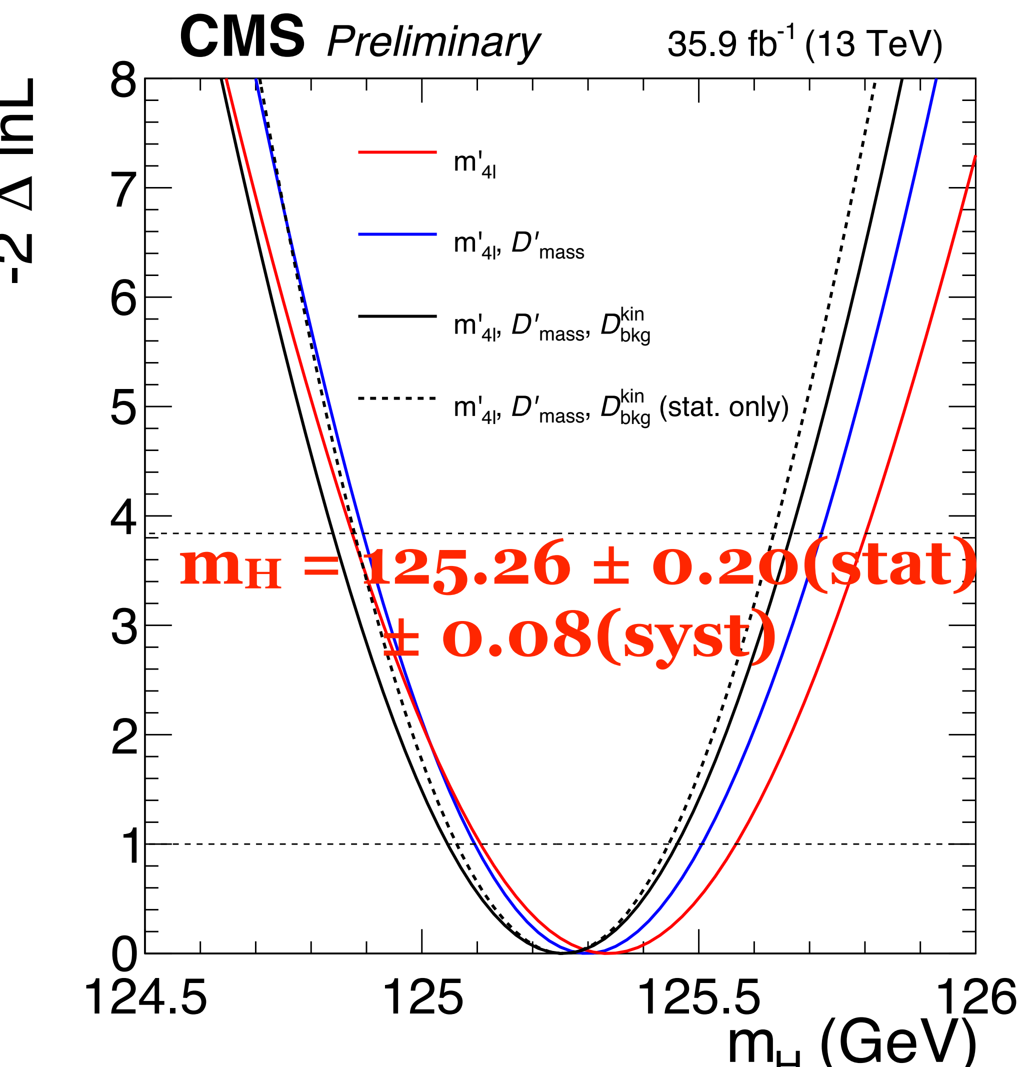


Agreement with SM 1.8σ for κ_{Agg}

No deviation from SM observed

Mass measurement:

- CMS: based on a 3D fit:
  - m_{4l}, D_{mass}, D^{kin}_{bgk}
- ATLAS: fit on m_{4l} on a per event basis (kinematic discriminant used for event selection)

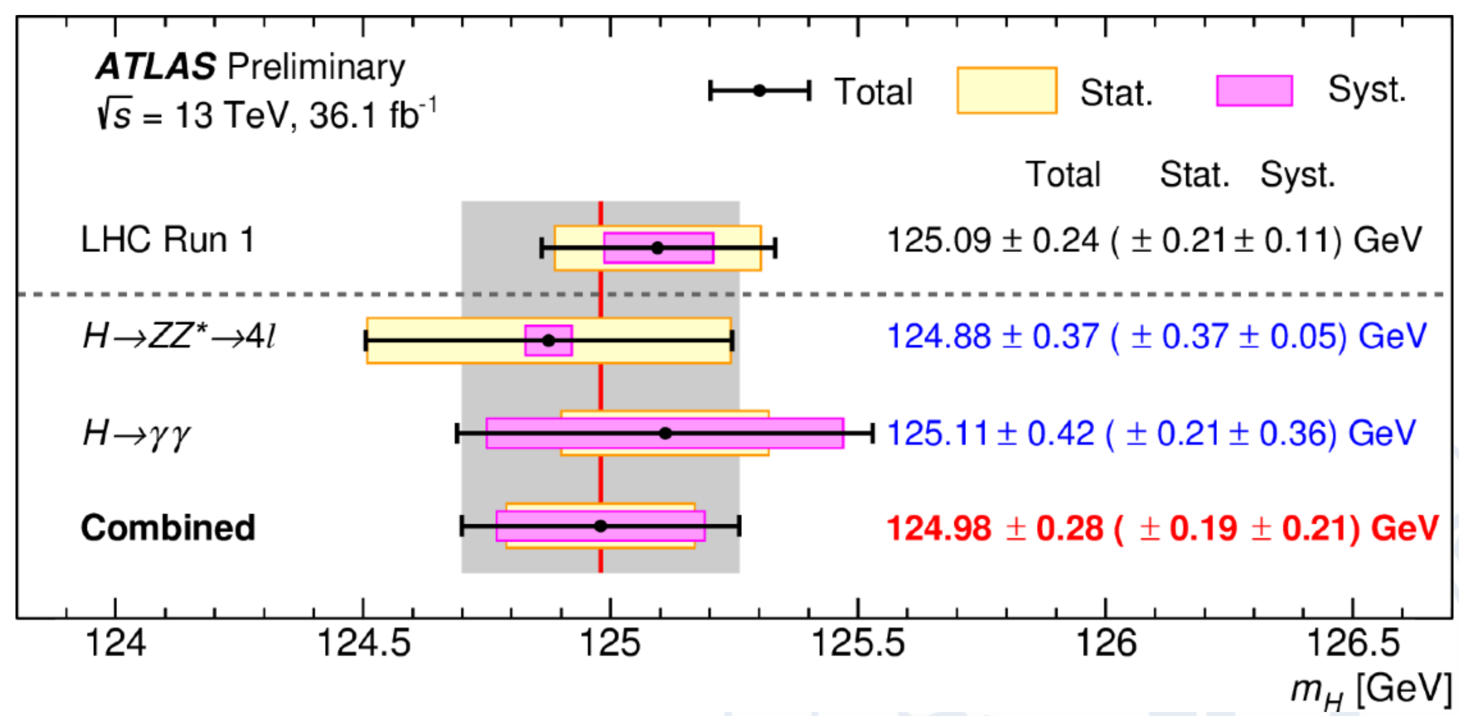


m_H = 125.26 ± 0.20(stat) ± 0.08(syst)

In CMS, direct constrain on the width:

Γ_H < 1.1 GeV @ 95% CL (m_H floated)

In ATLAS, combination with H→γγ :

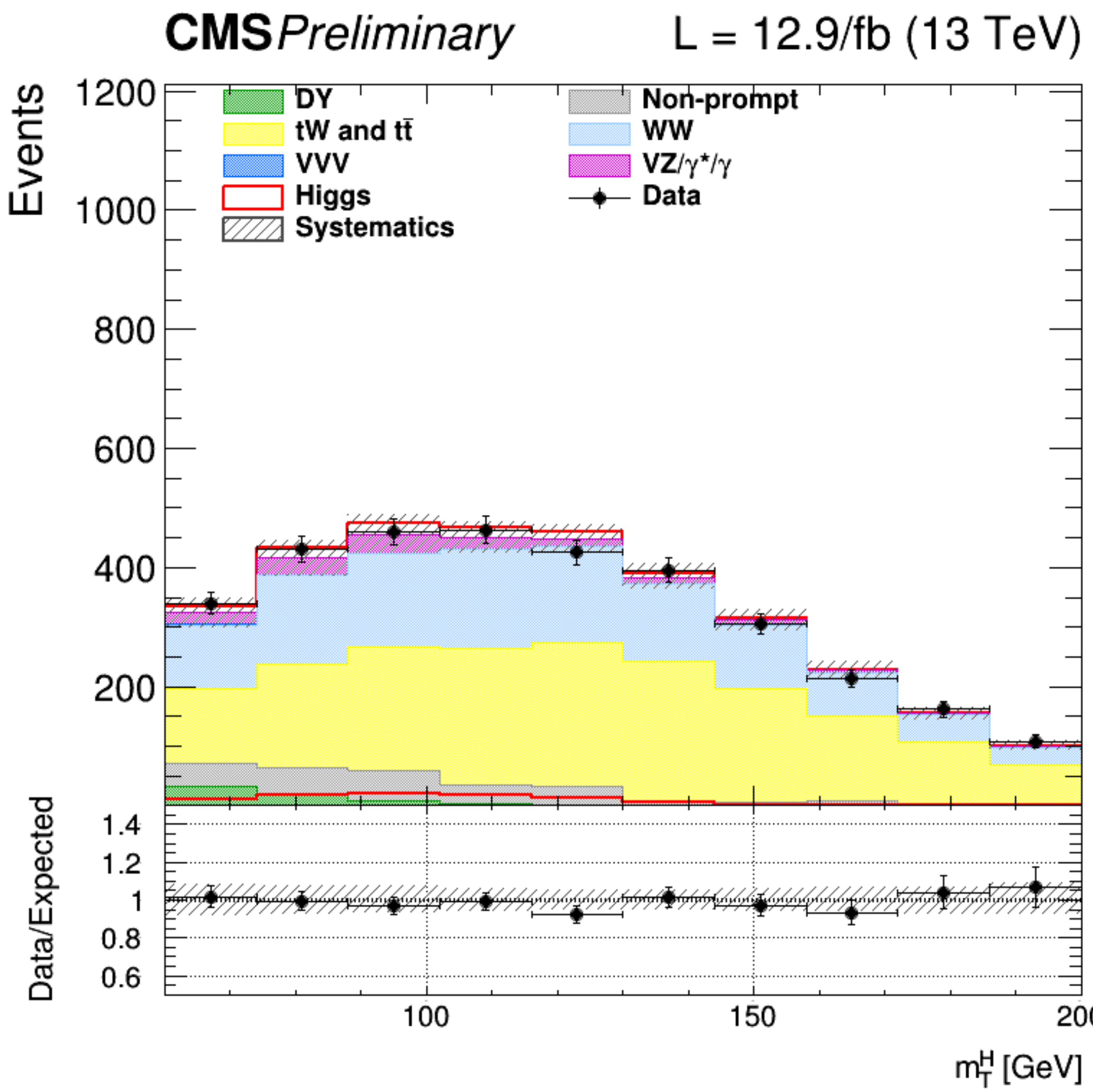


Main syst. : muon momentum scale, electron energy scale

H→WW→2l2v

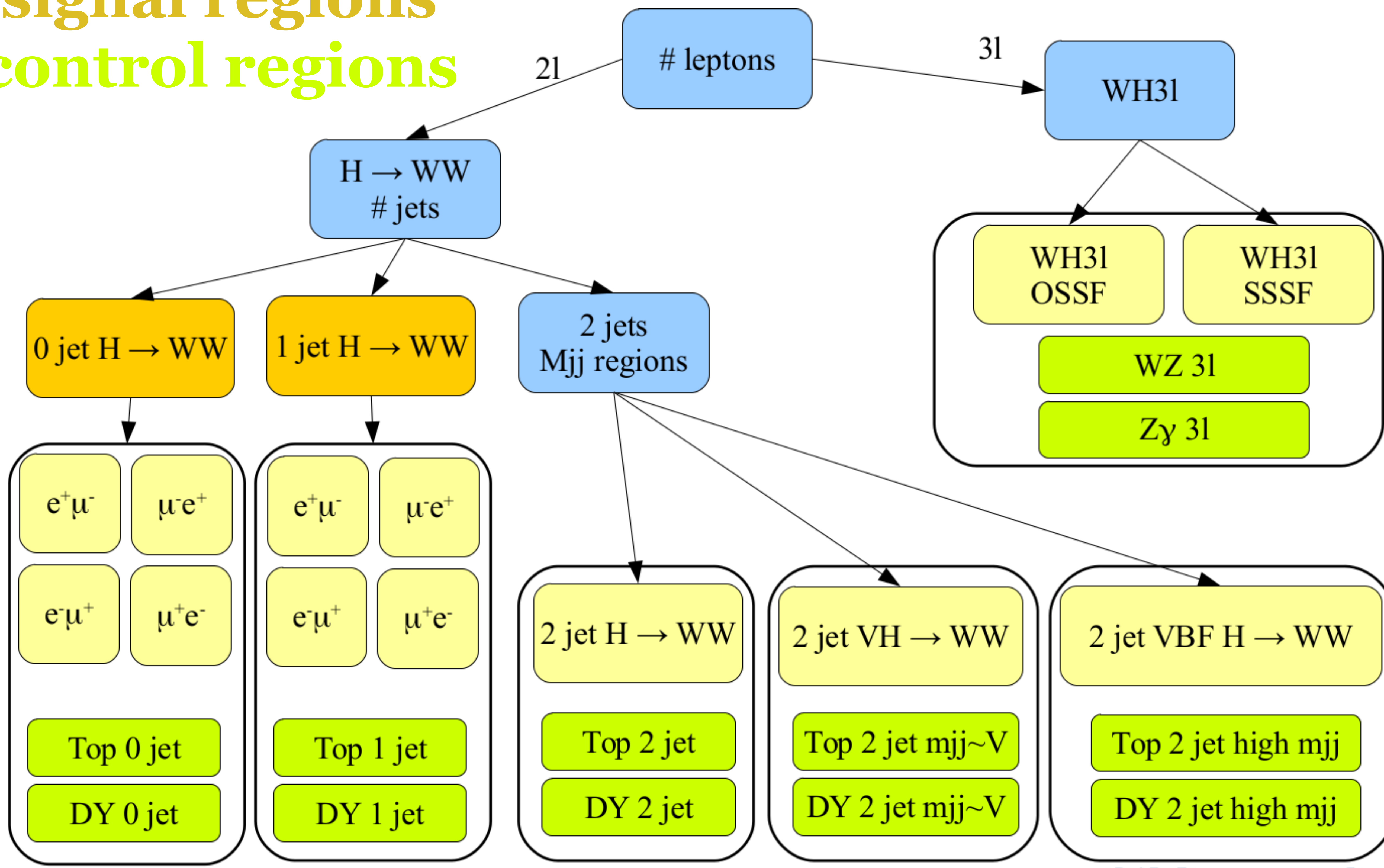
H→WW→eνμν (CMS)

- **Signal:**
  - 2 leptons + MET
  - only the eνμν final state used (best s/b ratio)
  - analysis in jet categories (0, 1, VBF)
- **Backgrounds:**
  - irreducible = WW
  - reducible = W+jets, top, DY
- Signal extraction strategy depending of the category



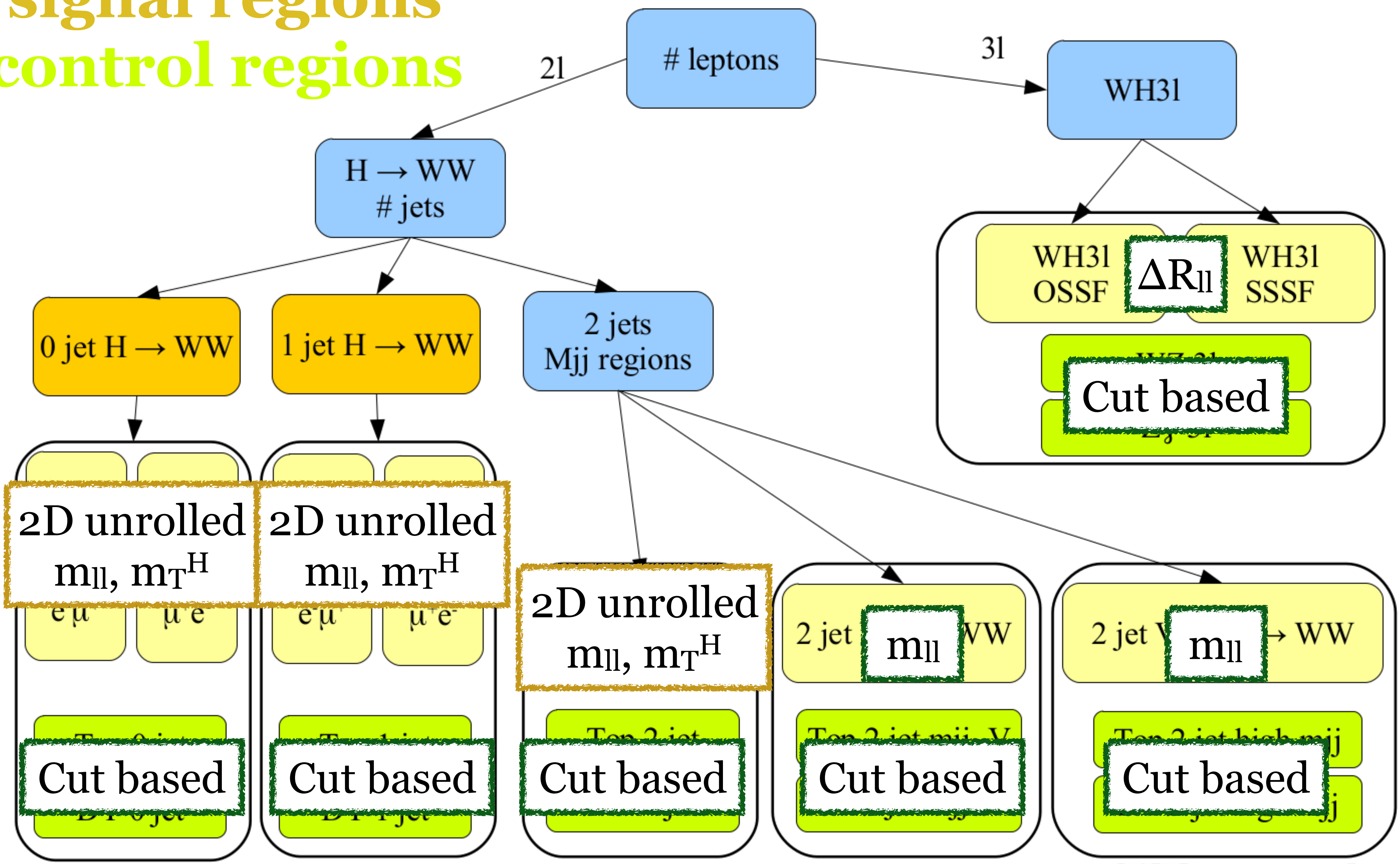
Analysis strategy: (CMS)

signal regions
control regions



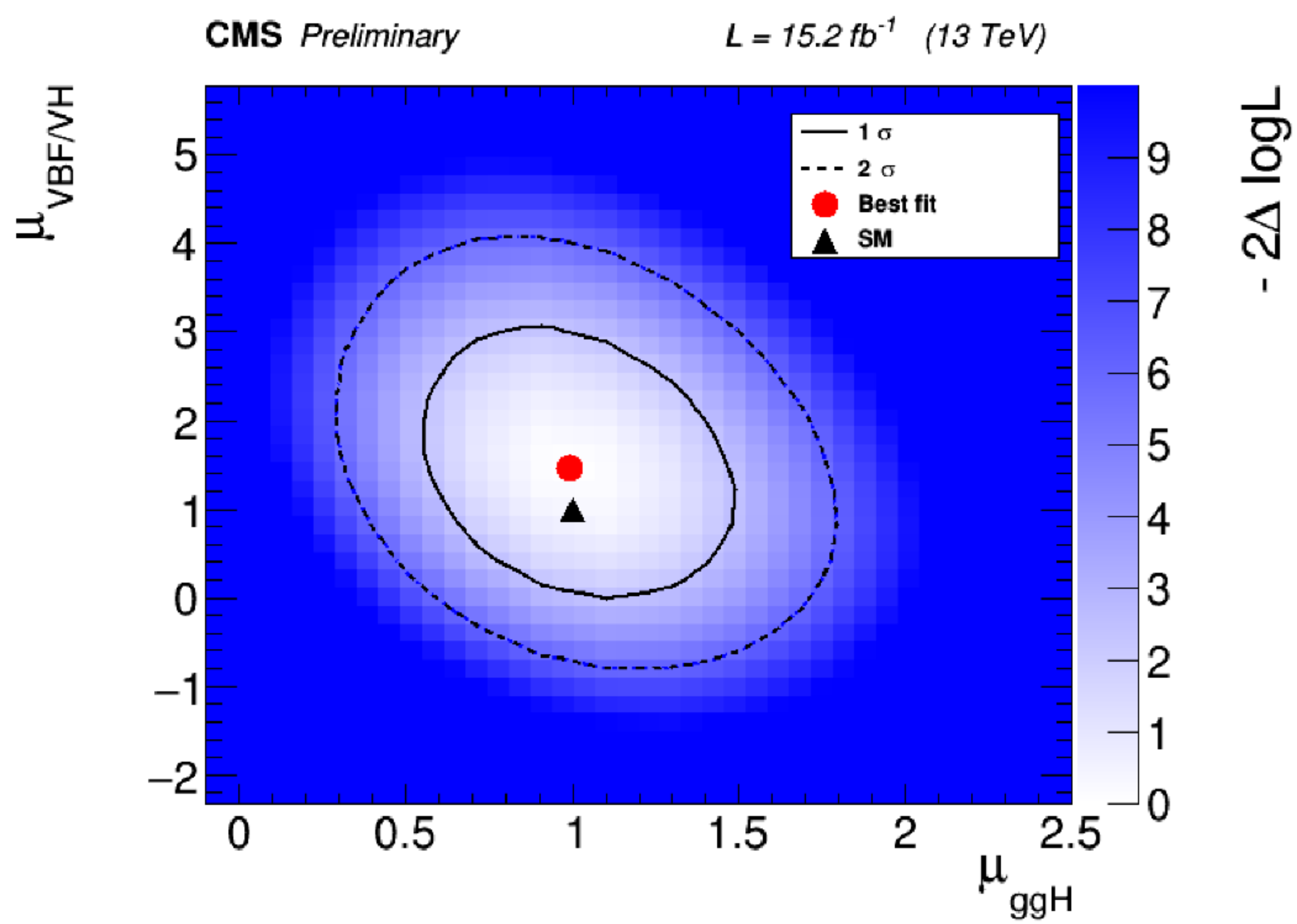
Analysis strategy: (CMS)

signal regions
control regions



Result: (CMS)

category	significance	σ/σ_{SM}
0-jet	2.7 (2.9)	$0.9\,^{+0.4}_{-0.3}$
1-jet	2.1 (2.5)	$1.1\,^{+0.4}_{-0.4}$
2-jet	2.0 (1.0)	$1.3\,^{+1.0}_{-1.0}$
VBF 2-jet	2.2 (1.5)	$1.4\,^{+0.8}_{-0.8}$
VH 2-jet	1.0 (0.4)	$2.1\,^{+2.3}_{-2.2}$
WH 3-lep	0.0 (0.5)	$-1.4\,^{+1.5}_{-1.5}$
combination	4.3 (4.1)	$1.05\,^{+0.27}_{-0.25}$



Signal strength: Combined with 2015 data (for m_H=125GeV) :

$\mu = 1.05 \pm 0.26$

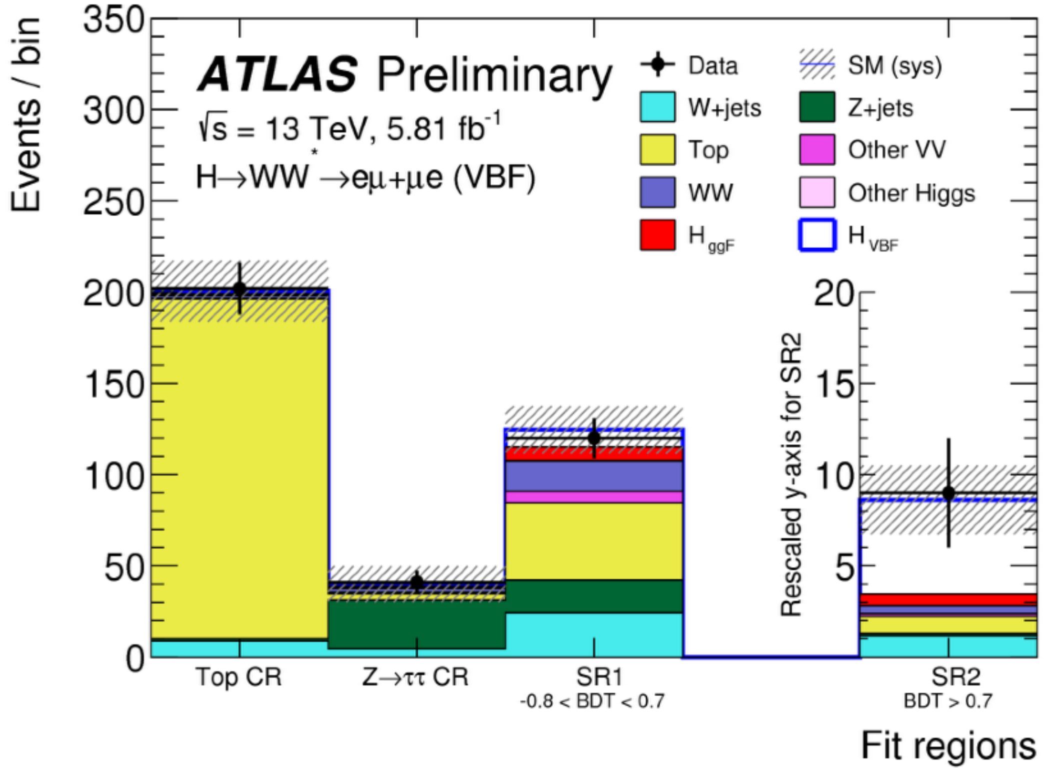
$= 1.05 \pm 0.25(\text{stat.}) \pm 0.03(\text{th.}) \pm 0.07(\text{syst.})$

2015 data $\mu = 0.89_{-0.31}^{+0.44}$

2016 data $\mu = 1.4_{-0.3}^{+0.3}$

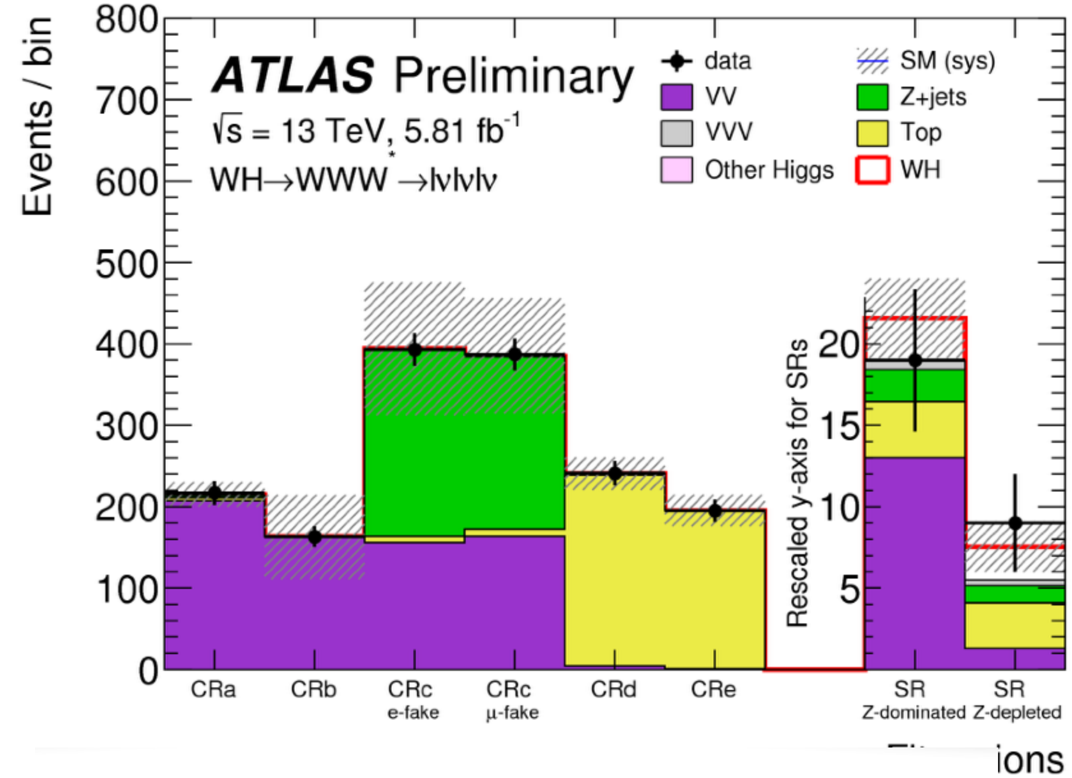
ATLAS H→WW @ 13 TeV

- Analysis done for the VBF and WH productions
  - VBF: e/μ pair + 2 jet, VBF categorisation with a BDT (+'central jet veto' + 'outside-lepton veto')
  - WH: Three leptons (Σq = ± 1) + MET, 2 signal region to cope with different background composition 'Z-dominated' and 'Z-depleted'



$$\mu_{\text{VBF}} = 1.7^{+1.0}_{-0.8}(\text{stat})^{+0.6}_{-0.4}(\text{sys})$$

$$\sigma_{\text{VBF}} \cdot \mathcal{B}_{H\to WW^*} = 1.4^{+0.8}_{-0.6}(\text{stat})^{+0.5}_{-0.4}(\text{sys})\ \text{pb}$$



$$\mu_{WH} = 3.2^{+3.7}_{-3.2}(\text{stat})^{+2.3}_{-2.7}(\text{sys})$$

$$\sigma_{WH} \cdot \mathcal{B}_{H\to WW^*} = 0.9^{+1.1}_{-0.9}(\text{stat})^{+0.7}_{-0.8}(\text{sys})\ \text{pb}$$

Indirect Constraints on Higgs Width

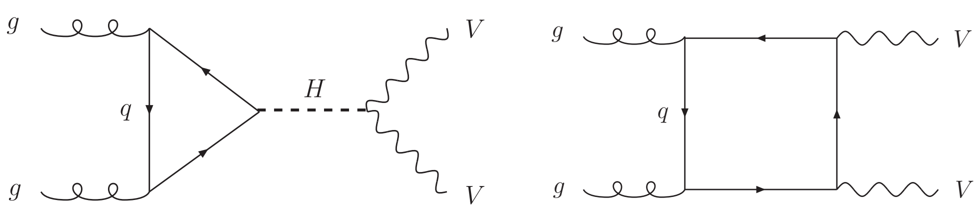
From off-shell measurement to Higgs width

- Off-Shell production of the Higgs boson in VV gives interesting extra information about the coupling structure of the Higgs boson
  - Also sensitive to possible new physics that changes the interaction between the Higgs and the SM particles in this region
- Off-shell cross section does not depend on total width (Γ_H) as $\sigma_{\text{On-shell}}$ does:

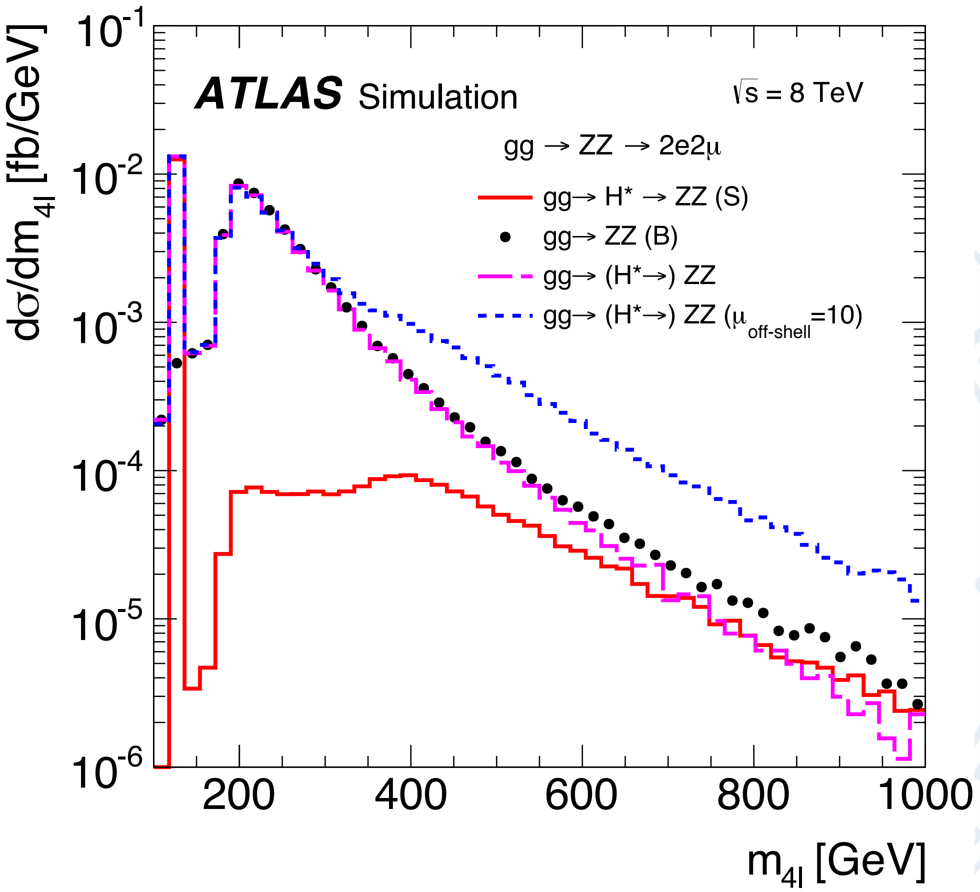
$$\frac{\sigma^{gg\to H^*\to ZZ}_{\text{off-shell}}}{\sigma^{gg\to H^*\to ZZ}_{\text{off-shell, SM}}} = \mu_{\text{off-shell}} = \kappa^2_{g,\text{off-shell}} \cdot \kappa^2_{V,\text{off-shell}}$$

$$\frac{\sigma^{gg\to H\to ZZ}_{\text{on-shell}}}{\sigma^{gg\to H\to ZZ}_{\text{on-shell, SM}}} = \mu_{\text{on-shell}} = \frac{\kappa^2_{g,\text{on-shell}} \cdot \kappa^2_{V,\text{on-shell}}}{\Gamma_H/\Gamma_H^{SM}}$$

  - In the SM, assuming that the on peak and the off peak couplings are scaling the same, combined measurement of $\mu_{\text{on-shell}}$ and $\mu_{\text{off-shell}}$, can be interpreted as a limit on Γ_H



➡In the high mass region, interference between gg→H*→VV and gg→VV is sizeable and negative in SM
➡Similar for qq →VV + 2 jet and VBF production



Analysis in a nutshell :

- Off shell region:
  - $H \to ZZ \to 4l$: $m_{4l} > 220$ GeV
  - $H \to ZZ \to 2l2\nu$: ATLAS : $350\text{GeV} < m_T < 1\text{TeV}$, CMS : $180\text{GeV} < mT < 1\text{TeV}$
  - $H \to WW \to e\nu\mu\nu$: use of m_T and m_{ll}

- Off-shell signal extraction:
  - $H \to ZZ \to 4l$: binned maximum-likelihood using kinematic discriminant (+ m4l for CMS)
  - $H \to ZZ \to 2l2\nu$: binned maximum-likelihood fit to transverse mass m_T
  - $H \to WW \to e\nu\mu\nu$: MVA or (m_T, m_{ll}) depending of the dataset and jet category (CMS) or maximum-likelihood fit is using the event yields in the signal region and in control regions (ATLAS)

Analysis in a nutshell :

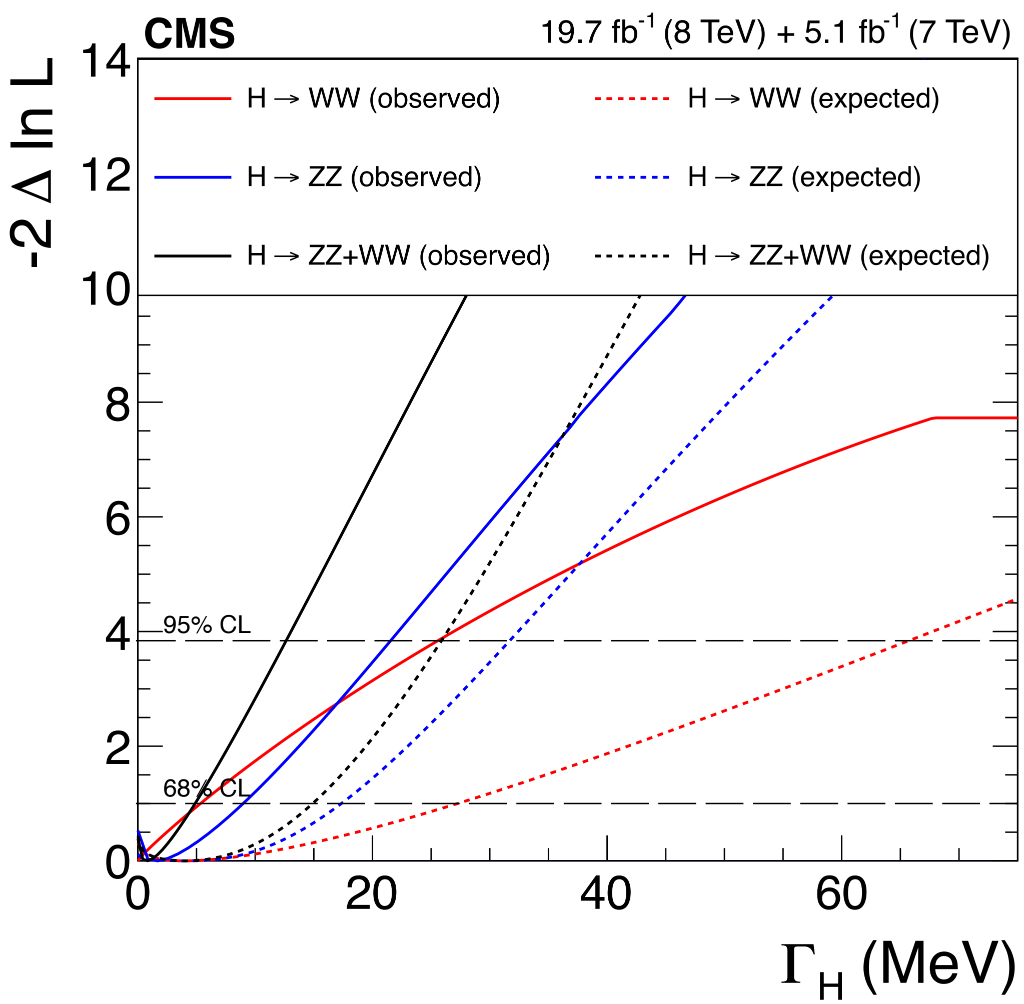
- Scanning off-shell cross-section with signal strength:
  - H→ZZ→4l: binned maximum-likelihood using kinematic discriminant (+ m4l for CMS)

$$
\begin{aligned}
\text{Expected event rate } = & \mu_{\mathrm{GF}}\, r\, \mathcal{P}^{gg}_{\mathrm{H,\,off\text{-}shell}} + \sqrt{\mu_{\mathrm{GF}}\, r}\, \mathcal{P}^{gg}_{\mathrm{int}} + \mathcal{P}^{gg}_{\mathrm{bkg}} \\
& + \mu_{\mathrm{VBF}}\, r\, \mathcal{P}^{\mathrm{VBF}}_{\mathrm{H,\,off\text{-}shell}} + \sqrt{\mu_{\mathrm{VBF}}\, r}\, \mathcal{P}^{\mathrm{VBF}}_{\mathrm{int}} + \mathcal{P}^{\mathrm{VBF}}_{\mathrm{bkg}} \\
& + \mu_{\mathrm{GF}}\, \mathcal{P}^{gg}_{\mathrm{H,\,on\text{-}shell}} + \mu_{\mathrm{VBF}}\, \mathcal{P}^{\mathrm{VBF}}_{\mathrm{H,\,on\text{-}shell}} + \mathcal{P}^{q\bar{q}}_{\mathrm{bkg}} + \mathcal{P}_{\mathrm{other\ bkg}},
\end{aligned}
$$

$$r = \Gamma_{\mathrm{H}} / \Gamma_{\mathrm{H}}^{\mathrm{SM}}$$

- Systematics from theory are the dominants:
  - QCD scale uncertainty for gg→H*→VV and qq→VV
  - PDF for qq→VV and gg→VV processes
  - Uncertainty due to unknown k-factor for the gg→VV
    - ATLAS: result as a function of $R^{B}_{H*} = \frac{K(gg \to VV)}{K(gg \to H* \to VV)}$
    - CMS: assumes same signal NNLO K-factor for the bkg and adds a 10% syst uncertainties
  - Additional 30% uncertainty considered for the interference terms for ATLAS

Results: Limit on Higgs Width (CMS)



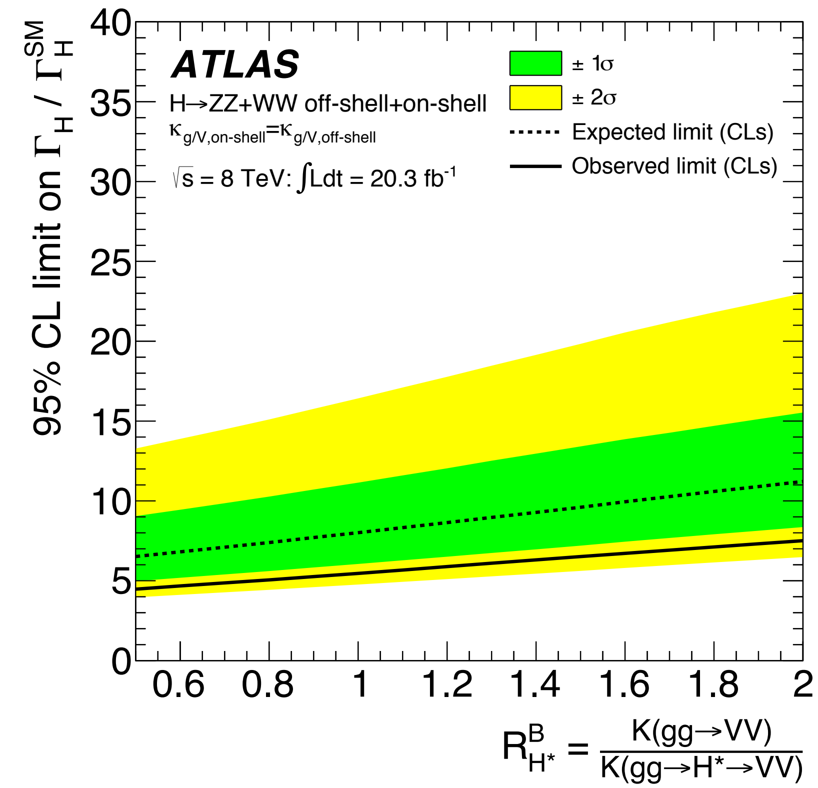
$\Gamma_H < 13$ MeV @ 95% CL
(expected $\Gamma_H < 26$ MeV)

- limit obtained under the assumption $\mu_{gg}^{ZZ}/\mu_{gg}^{WW} = \mu_{VBF}^{ZZ}/\mu_{VBF}^{WW}$
  - relaxing it brings the limit @95% CL to $\Gamma_H < 15$ MeV
- WW decay channel alone: $\Gamma_H < 26$ MeV (expected 66 MeV)
  ZZ decay channel alone:
  $\Gamma_H < 22$ MeV
  (expected 33 MeV)
- p-value of the observed limit = 7.4 %

Results: Limit on Higgs Width (ATLAS)

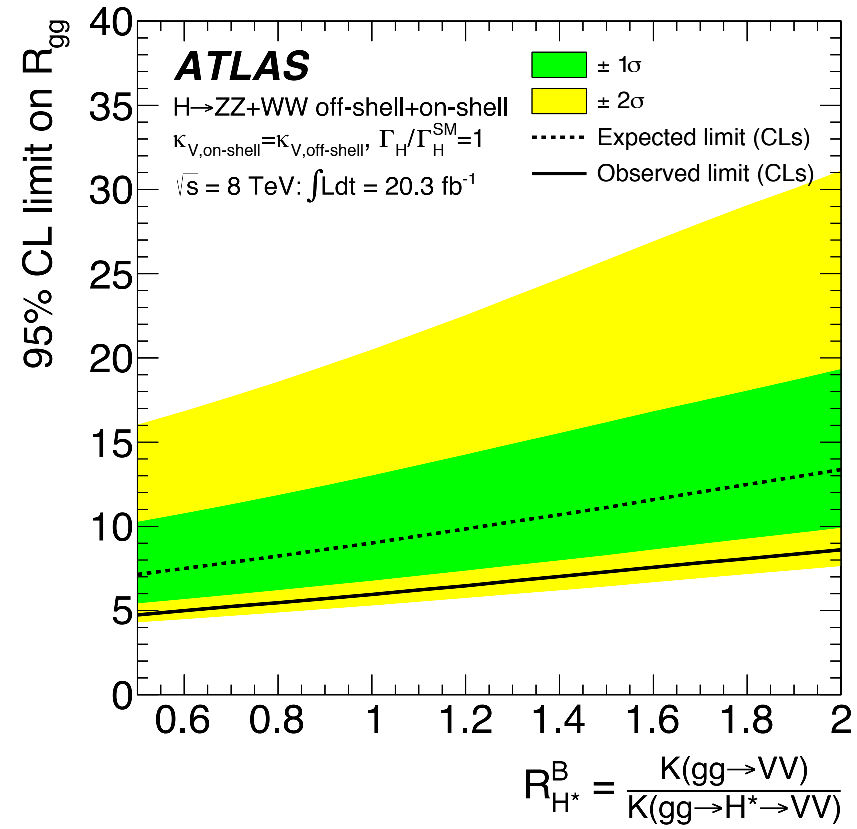
- Limit on Γ_H can be obtained by combining the on-shell with the off-shell signal strength measurement
  - μ_{ggH} and μ_{VBF} profiled on the data
  - assume same on-shell and off-shell couplings ($\kappa_{g/V,\text{ on-shell}} = \kappa_{g/V,\text{ off-shell}}$)

$\Gamma_H < 22.7$ MeV @ 95% CL for $R_{H^*}{}^B = 1$
(expected $\Gamma_H < 33$ MeV)



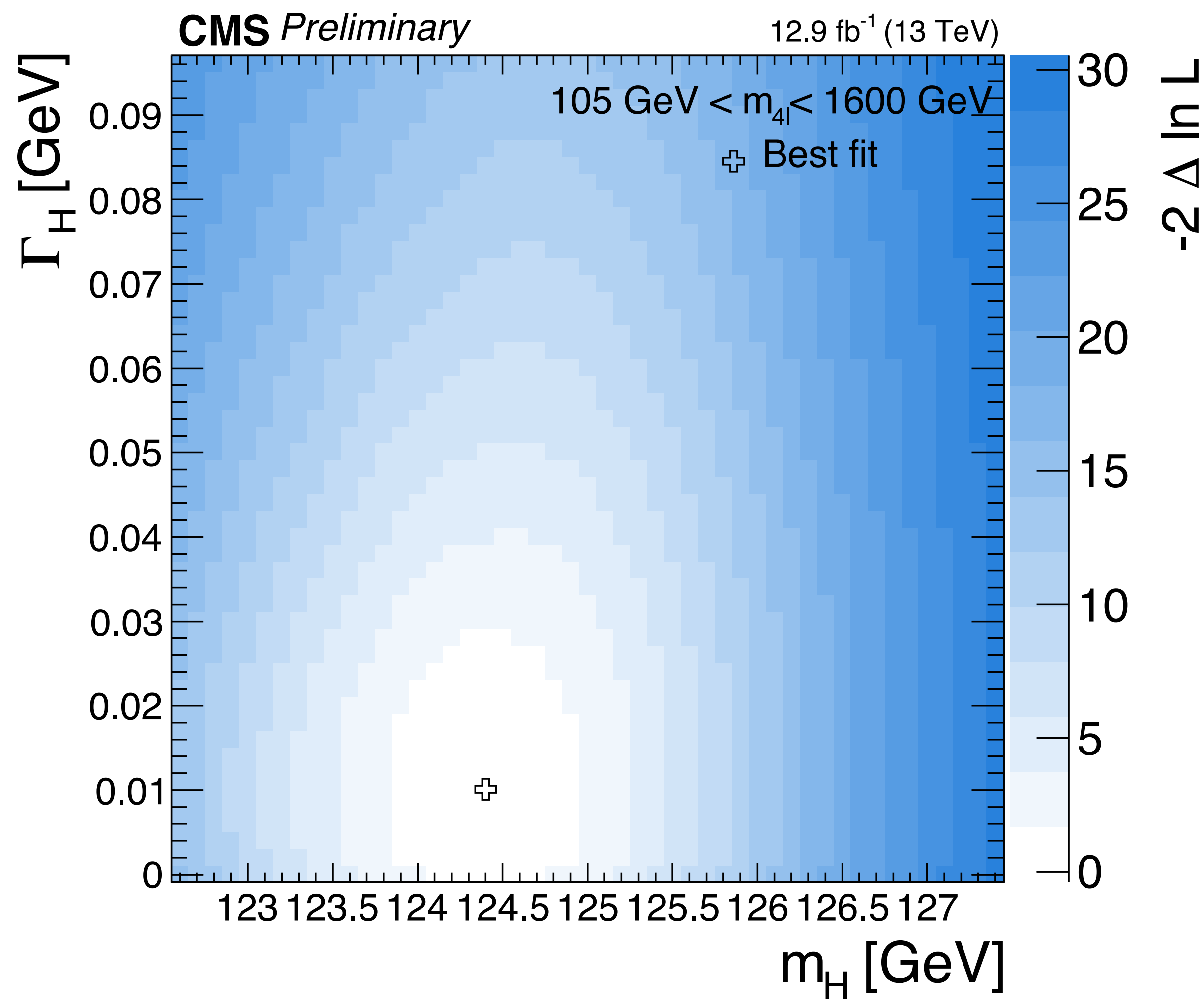
- Assuming $\Gamma_H = \Gamma_H^{SM}$ and $\kappa_{V,\text{ on-shell}} = \kappa_{V,\text{ off-shell}}$, can interpret result as a limit on $R_{gg} = \kappa_{g,\text{ on-shell}}/\kappa_{g,\text{ off-shell}}$

$R_{gg} < 6.0$ @ 95% CL for $R_{H^*}{}^B = 1$
(expected $R_{gg} < 9.0$)



First Results with 2016 data

- In H*→ZZ→4l channel:
  - Constraint on the width from the first 12.9 fb-1 of 2016 data analysed
  - Addition in the high mass region of a 2 jet category, sensitive to VBF



Γ_H < 41 MeV @ 95% CL (expected Γ_H < 32 MeV)
best-fit = $0.01^{+0.014}_{-0.01}$ GeV

Conclusion:

- Already interesting results on H→VV available with run 2 data for both ATLAS and CMS
  - precision already comparable compared to run 1 results.
- At present, measurements an properties compatible with the SM Higgs Boson
- Results are still statistically limited
  - by the end of the Run 2, more that ~100fb-1 expected
    ⇒ precision of the measurement still expected to improve

BackUp