Search for the 125 GeV Higgs Boson at 13 TeV in diboson decay channels by the ATLAS collaboration

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on behalf of the ATLAS Collaboration

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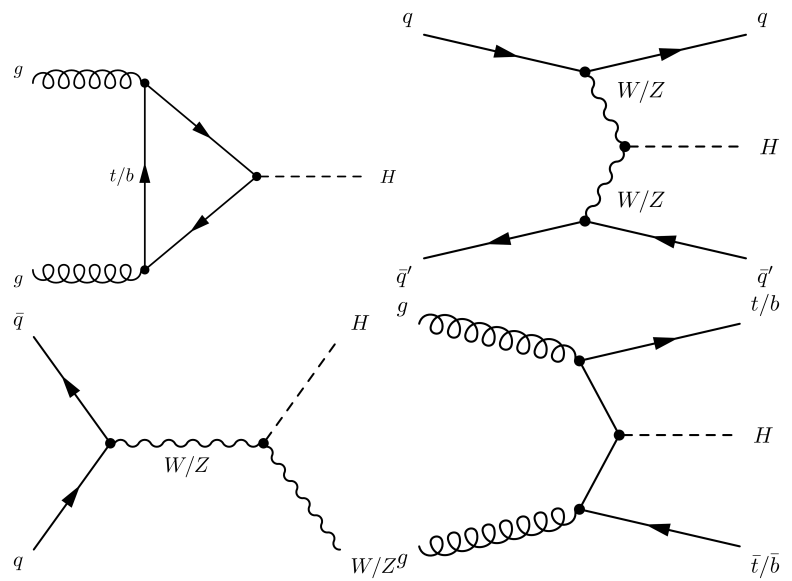
overview

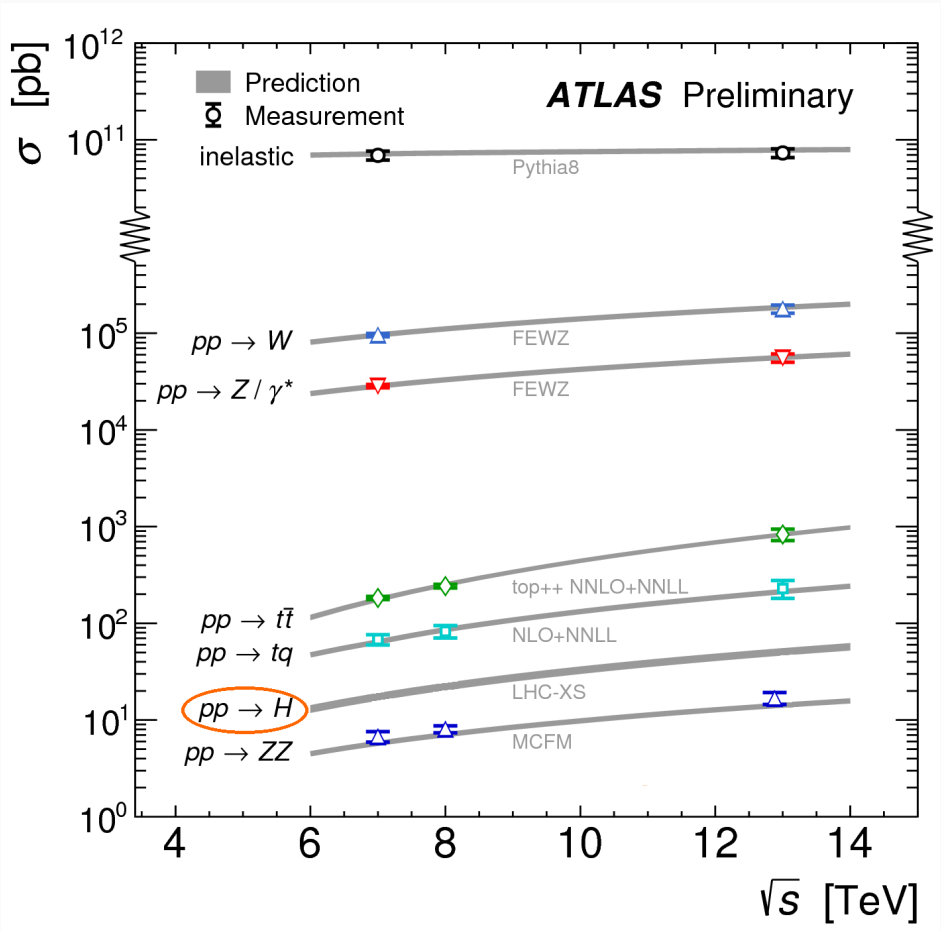
- production modes
- $H \to \gamma\gamma$ and $H \to ZZ^*$
- analyses description
- fiducial and total cross sections
- cross section combination
- $H \to WW^*$ (8 TeV) fiducial cross section
- $H(\to \gamma\gamma)$ + MET
- $hh \to b\bar{b}\gamma\gamma$

Higgs production at the LHC

production modes



- ggF 87%
- VBF 7%
- VH 5%
- ttH / bbH 1%



- Only one in 10^{10} events will be a Higgs boson

Higgs diboson decays

H→ZZ*→ 4ℓ

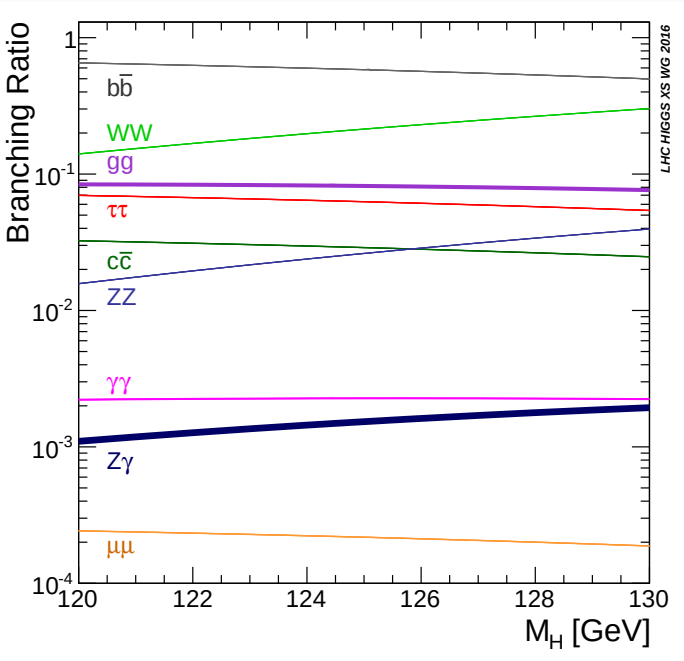
H→$\gamma\gamma$

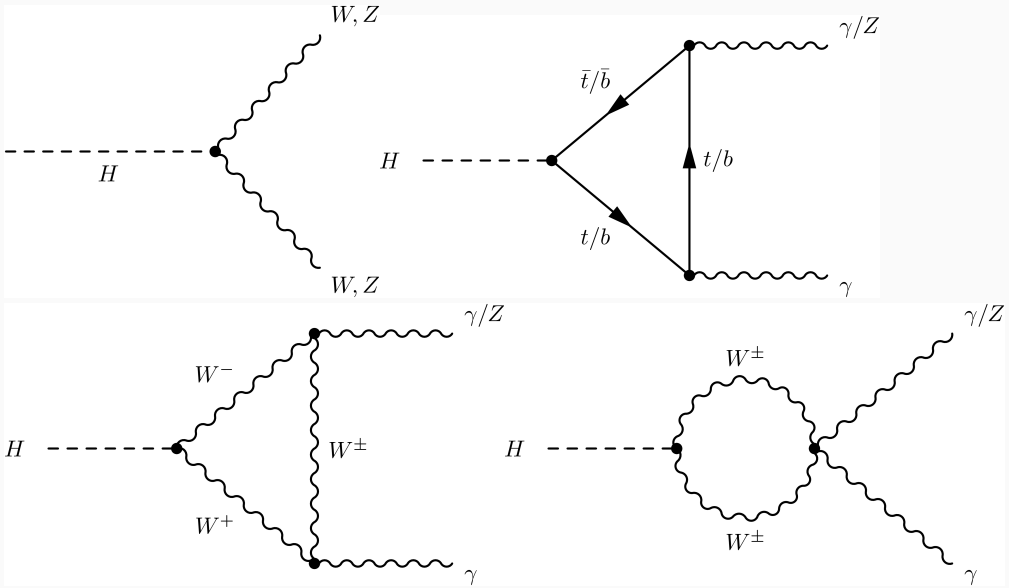
13 TeV

H→WW*→ $2\ell 2\nu$

H→Zγ

- Excellent mass resolution: $\gamma\gamma$ and ZZ*
- Large cross section: WW*





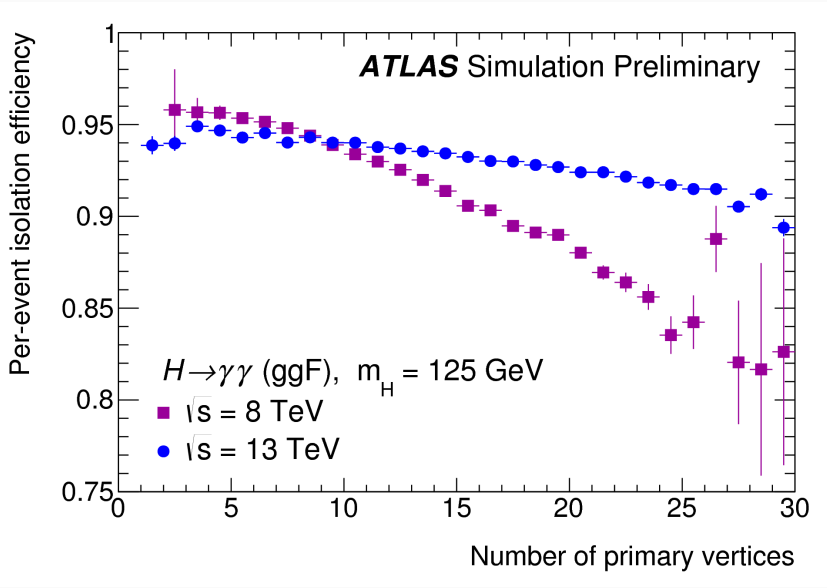
$H \to \gamma\gamma$ CONF-2015-060

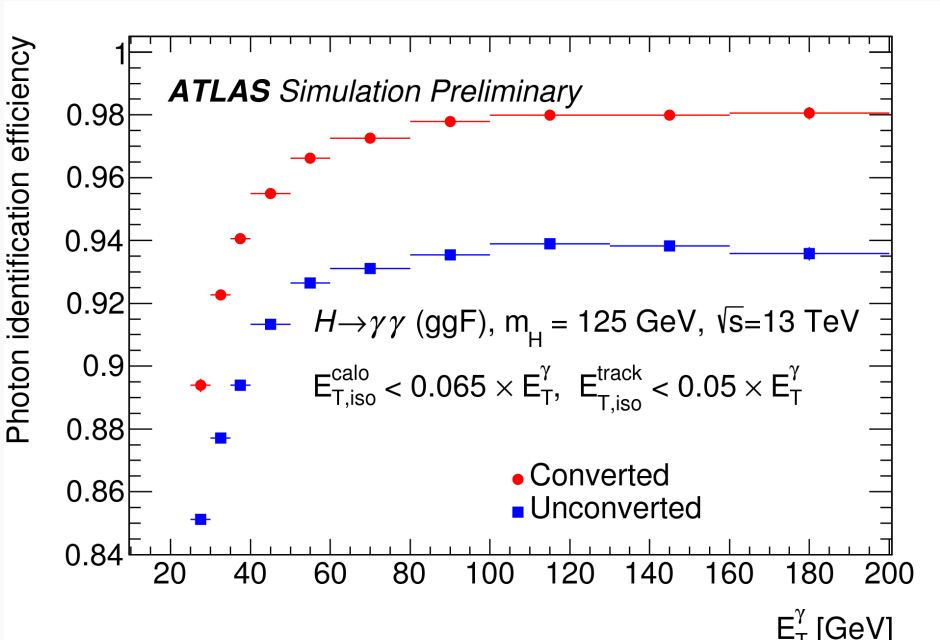
event selection

- Two highest-p_T photons: $|\eta| < 2.37$, exclude $1.37 < |\eta| < 1.52$
- Relative-p_T : $E_T^{\gamma 1}/m_{\gamma\gamma} \geq 0.35\, E_T^{\gamma 2}/m_{\gamma\gamma} \geq 0.25$
- Mass window: 105 GeV $\leq m_{\gamma\gamma} \leq$ 160 GeV
- Photon isolation: $E_{T,iso}^{calo} < 0.065 \times E_T^{\gamma}$

  $E_{T,iso}^{track} < 0.05 \times E_T^{\gamma}$

13 TeV sample
with 8 TeV iso (purple) and 13 TeV iso (blue)



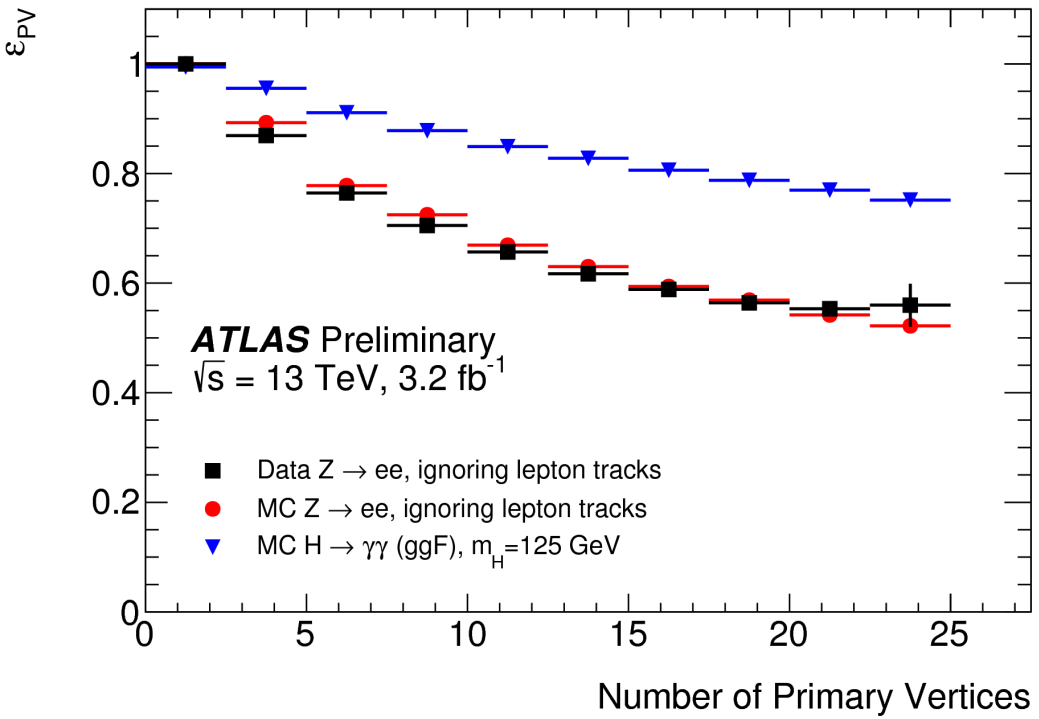


photon identification

- transverse shower shape in 2nd layer of Ecal: consistent with that expected for a single EM shower
- high-granularity 1st layer of Ecal: discriminate single γ from overlapping γs coming from π^0
- $\varepsilon_{ID}^{conv} \sim 98\%$
- $\varepsilon_{ID}^{unconv} \sim 94\%$

$H \to \gamma\gamma$ Vertex Identification

$m_{\gamma\gamma}$ calculation: precise knowledge of the position of the diphoton production



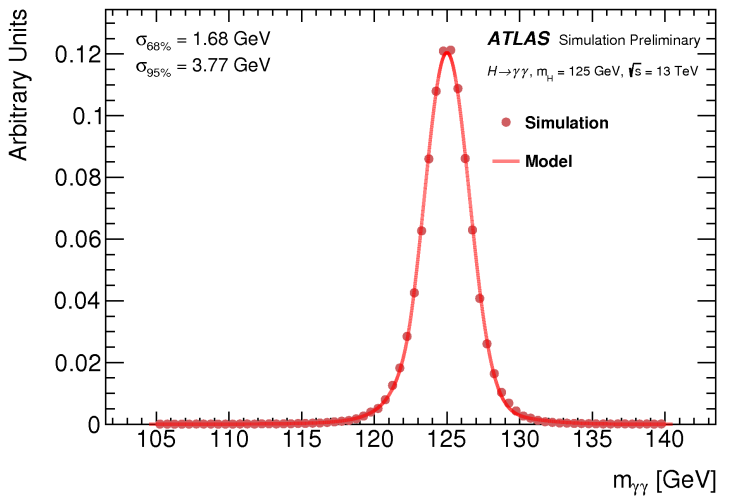
Efficiency to select a diphoton vertex within 0.3 *mm* of the production vertex

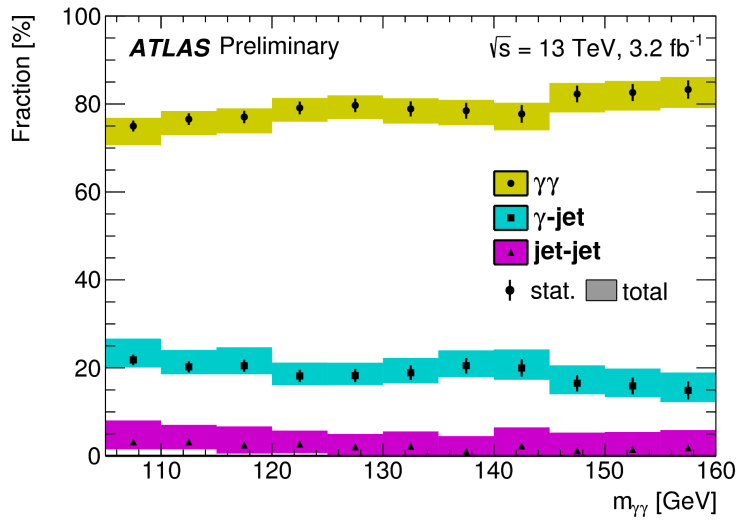
- vertex selection inclusive efficiency: 87%

MVA

- $\sum p_T^2$ of vertex tracks
- $\sum p_T$ of vertex tracks
- diphoton balancing with vertex tracks
- trajectory from calo segmentation

$H \to \gamma\gamma$ s+b modelling





bkg composition: sidebands fit

signal shape: MC Gauss+CB

background shape: MC exp (2nd order polynomial)

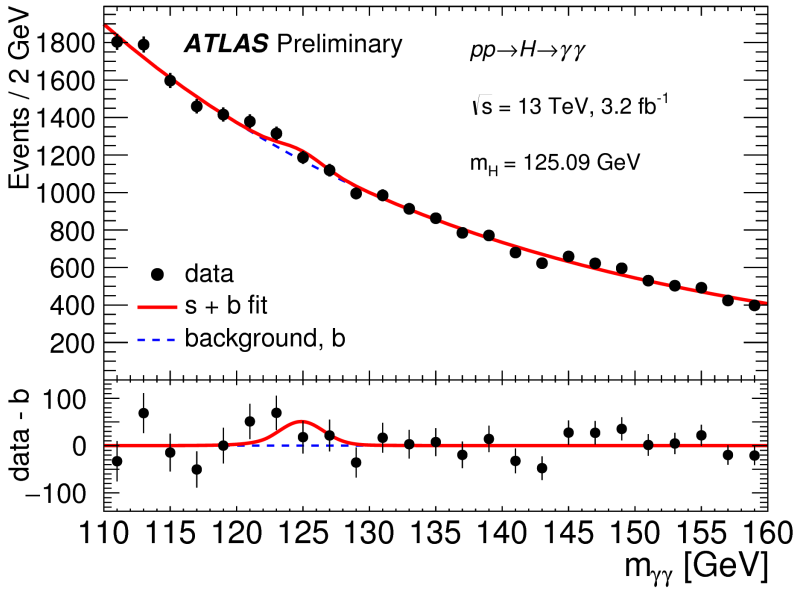
- background model bias: s+b fit to bkg only sample → signal events from fit: N_{sp}

main systematic uncertainties:

- photon energy resolution
- bkg modelling uncertainty: 8%

$N_{exp} = 143 \pm 71\,(stat)\,^{+39}_{-6}\,(syst.)$

$N_S = 113 \pm 74\,(stat)\,^{+43}_{-25}\,(syst.)$

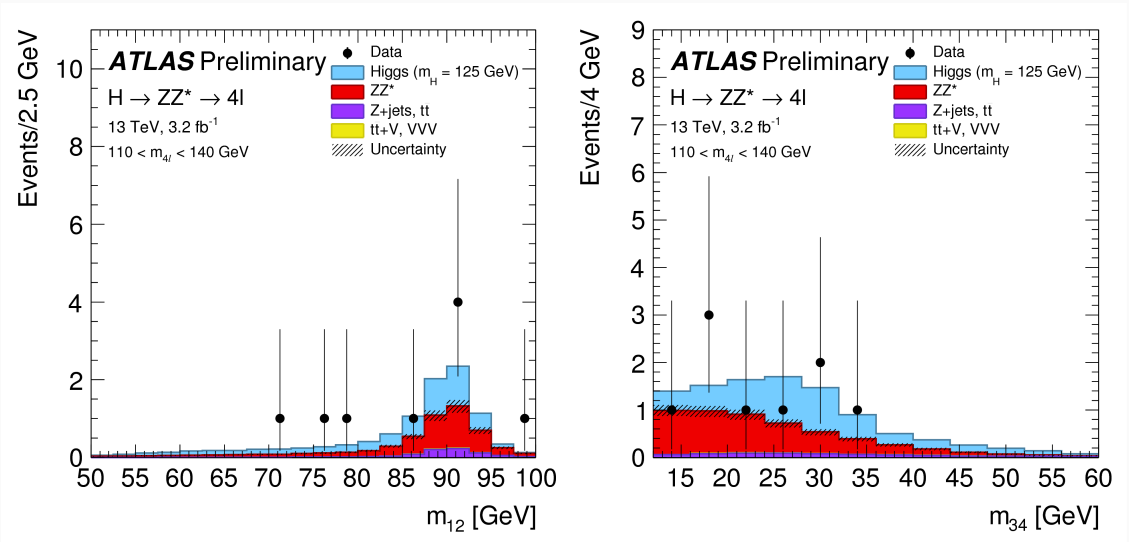


$H \rightarrow ZZ^* \rightarrow 4\ell$ CONF-2015-059

- **RUN 1 S/B: 1.7**
- **RUN 2 S/B 2.2**

Two same-flavour opposite-sign lepton pairs

- ℓ = e, μ
- e(μ) p_T(E_T) > 7 (6) GeV, $|\eta|$<2.47 (2.7)
- Leading three leptons: p_T > 20, 15, 10 GeV
- 50 < m_{Z1} < 106 GeV, 12-50 < m_{Z2} < 115 GeV
- FSR γ correction, Z mass constraint: 15% improvement on resolution



$H \to ZZ^* \to 4\ell$ CONF-2015-059

main background: non-resonant ZZ* (irreducible)

- simulation shape prediction
- normalisation checked in $m_{4\ell}$ sidebands

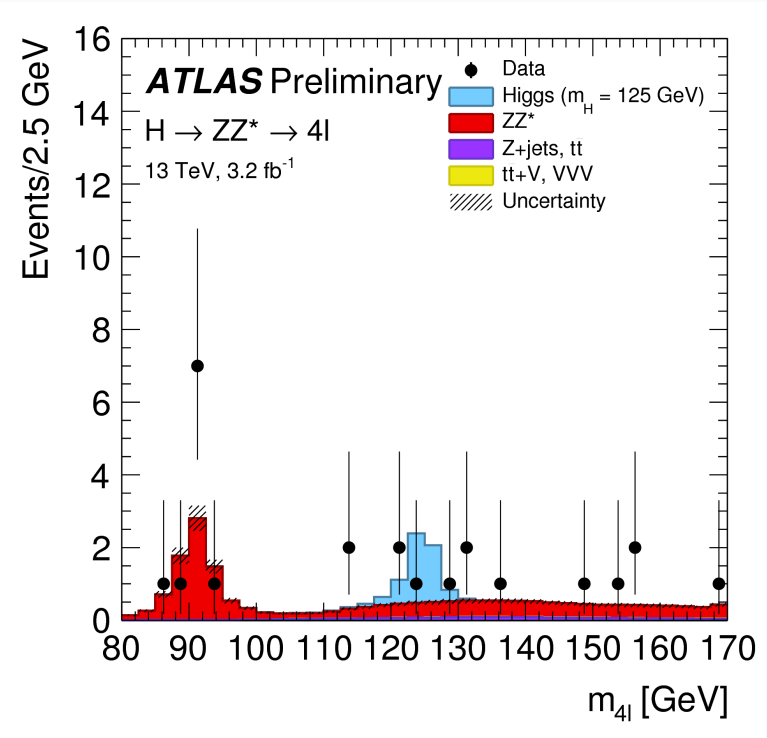
smaller (reducible) backgrounds: Z+jets, tt

- measured from control regions

main systematic uncertainties: lepton efficiency (5.6%), luminosity (5%)

$118 < m_{4\ell} < 129$ GeV

Signal (full mass range)	5.06 ± 0.60
Signal	4.57 ± 0.54
ZZ*	1.74 ± 0.19
Z+j,$t\bar{t}$,$t\bar{t}V$ VVV,WZ	0.34 ± 0.06
S/B	2.2
Expected	6.65 ± 0.58
Observed	4



cross sections: $\gamma\gamma$ and ZZ*

- Fiducial σ extracted for $\gamma\gamma$ and ZZ*
- Measurements extrapolated to total σ and combined

Fiducial selection: designed to closely replicate the analysis selection at particle level

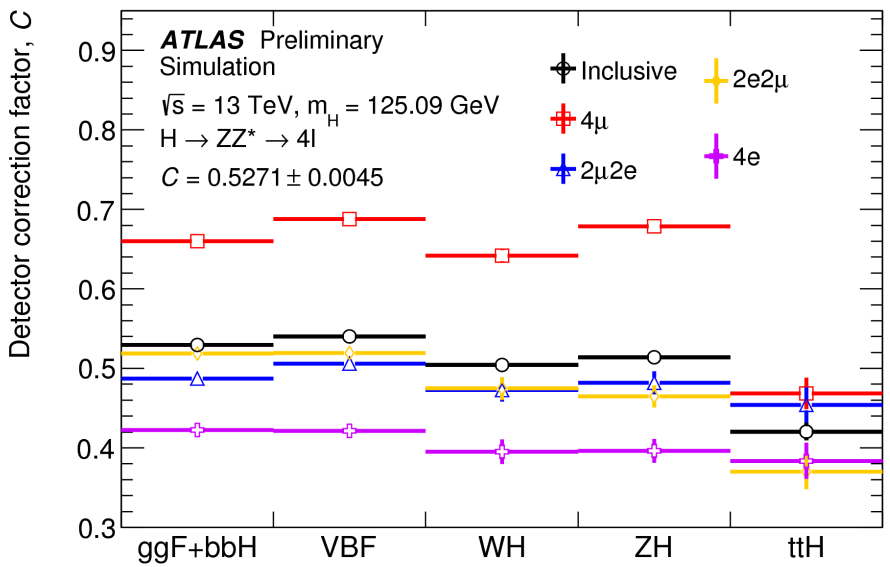
$$\sigma^{tot} = \frac{N_S}{\mathcal{A}.\mathcal{C}.\mathcal{B}.\mathcal{L}_{int}}$$

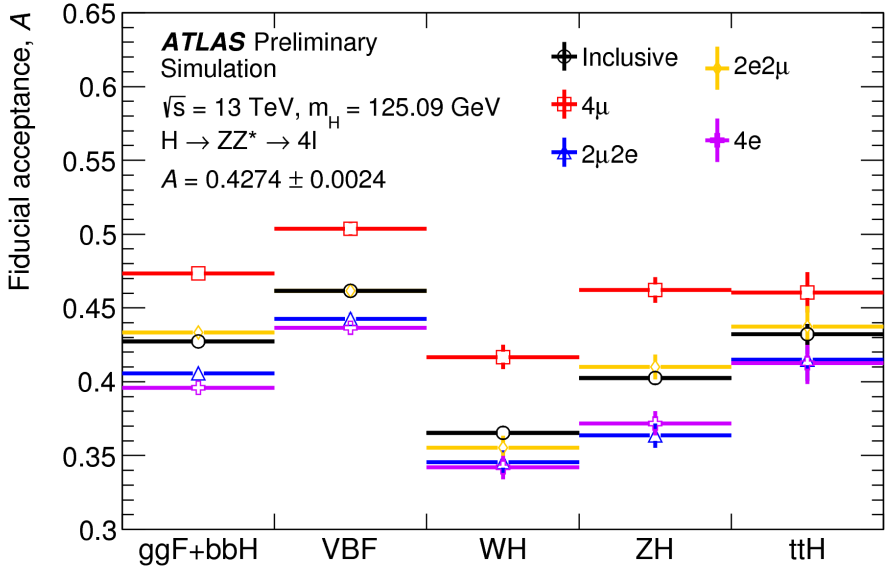
$$\sigma^{fid}_{channel} = \frac{N_S}{\mathcal{C}.\mathcal{L}_{int}}$$

N_S: # of observed signal events

$\mathcal{A}$: kinematic and geometric acceptance in the fiducial region

$\mathcal{C}$: detector correction factor (reco, trigger and id efficiences, reco resolution)

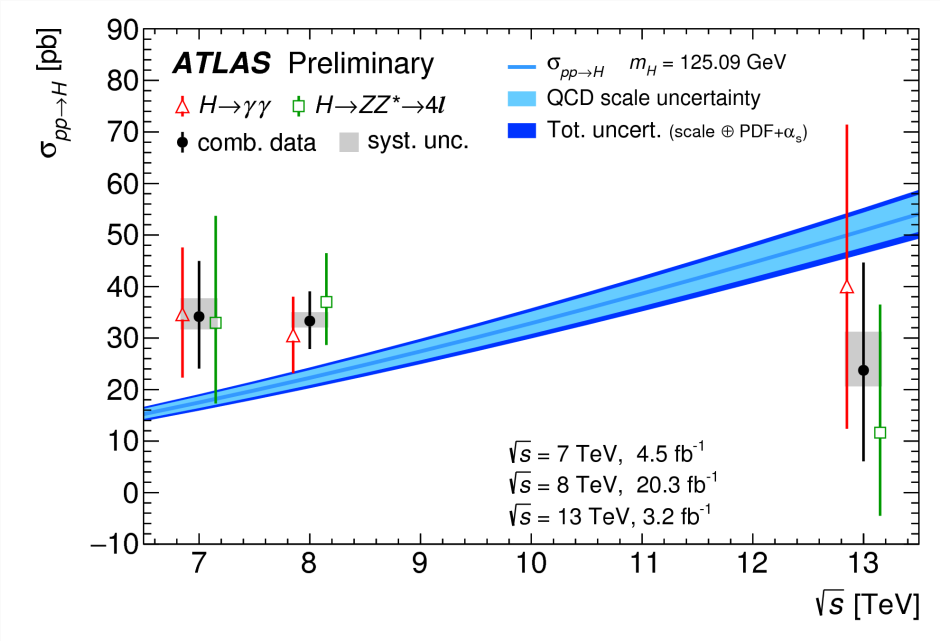




$$C = \frac{\#\text{ of selected reco events}}{\#\text{ of particle level events}}$$

cross sections: combination

- ATLAS-CONF-2015-069
- maximise the product of individual likelihoods $\mathcal{L}_{\mathcal{TOT}} = \mathcal{L}_{\gamma\gamma} \times \mathcal{L}_{4\ell} \times \prod_k \mathcal{G}(\theta_k; 0, 1)$



	13 TeV
Acceptance factor	
$H \to \gamma\gamma$	0.570 ± 0.006
$H \to ZZ^* \to 4\ell$	0.427 ± 0.006
Fiducial cross section [fb]	
$H \to \gamma\gamma$	$52\ ^{+40}_{-37}$
$H \to ZZ^* \to 4\ell$	$0.6\ ^{+1.3}_{-0.9}$
Total cross section [pb]	
$H \to \gamma\gamma$	$40\ ^{+31}_{-28}$
$H \to ZZ^* \to 4\ell$	$12\ ^{+25}_{-16}$
Combination	$24\ ^{+20}_{-17}$ (stat.) $^{+7}_{-3}$ (syst.)
LHC-XS	$50.9\ ^{+4.5}_{-4.4}$

- compatibility 13 TeV measurement / SM prediction: 1.3 σ
- combined observation significance:

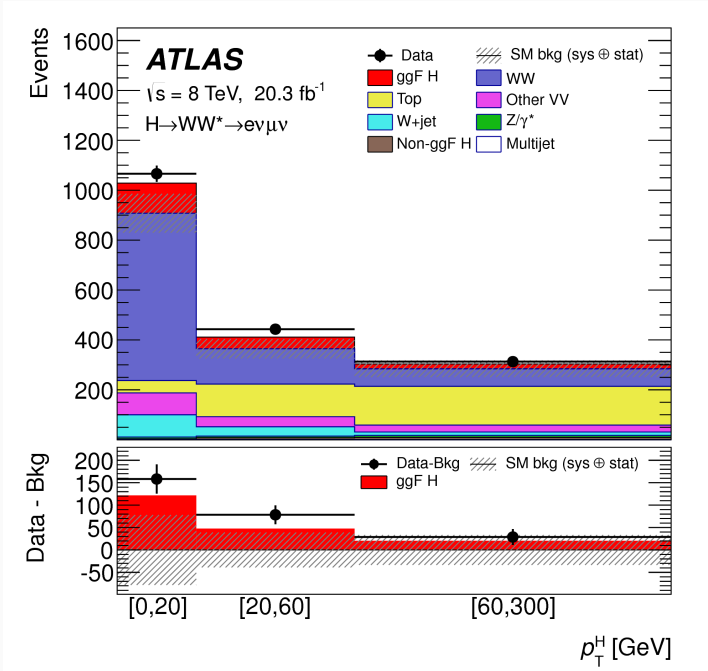
  3.4 σ (expected) 1.4 σ (observed)
- combined upper limit of 68 pb at 95% confidence level on the σ_{TOT}

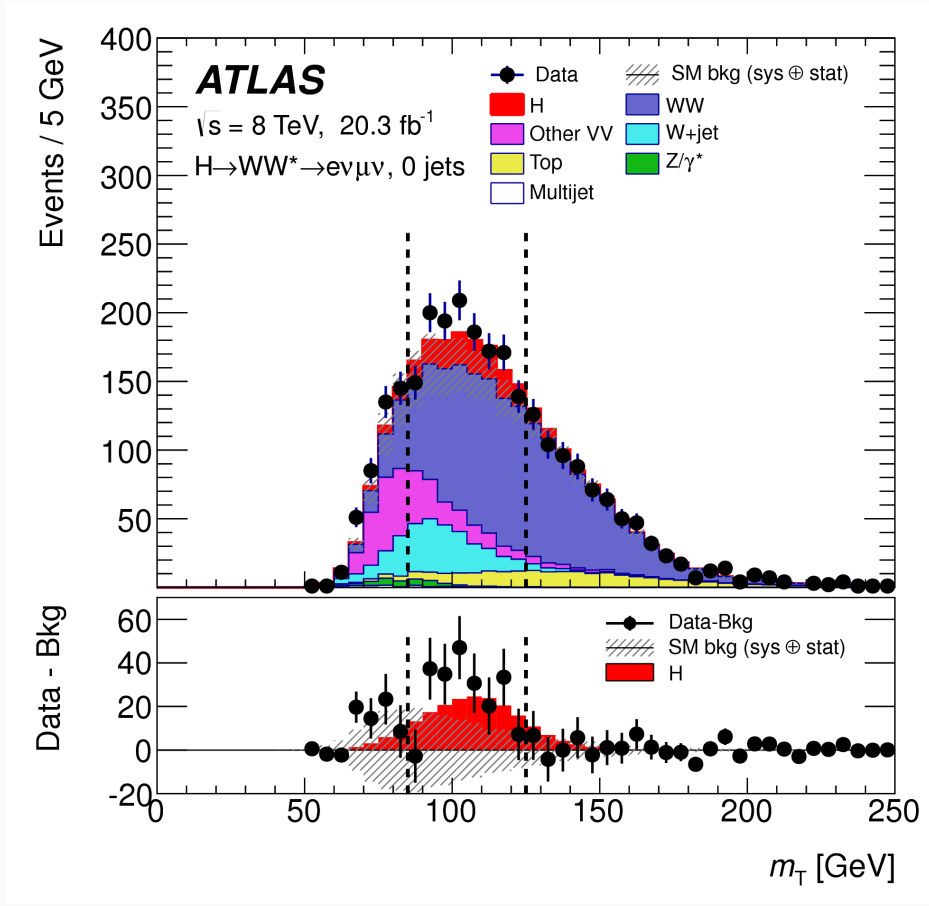
$H \rightarrow WW^* \rightarrow e\nu\mu\nu$

- **8 TeV results just submitted!**
  (Phys. Rev. D 92, 012006 (2015))

1 e and 1 μ with oposite charge

- $m_{\ell\ell} > 10$ GeV
- $p_T^{lead.\,\ell} > 22$ GeV $p_T^{sublead.\,\ell} > 15$ GeV
- 3 signal regions: $N_{jet} = 0, 1, \geq 2$
- dominant background: WW for $N_{jet} = 0$
- top-quark background: $N_{jet} \geq 2$
- mixture: $N_{jet} = 1$





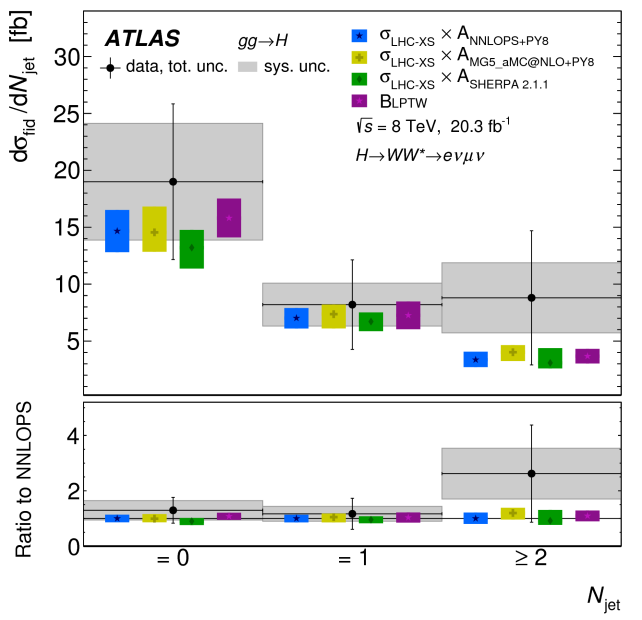
$$m_T = \sqrt{(E_T^{\ell\ell} + p_T miss)^2 - |p_T^{\ell\ell} + p_T^{miss}|^2}$$

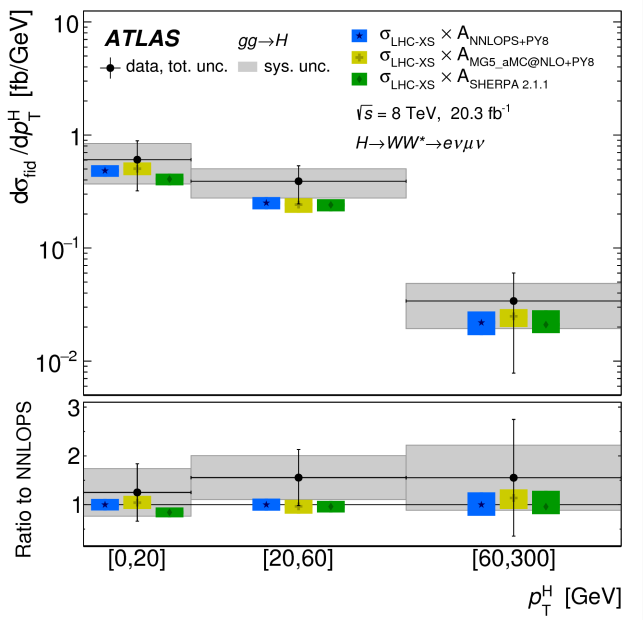
$$\sigma_{ggF}^{fid} = 36.0 \pm 9.7\ \text{fb}$$

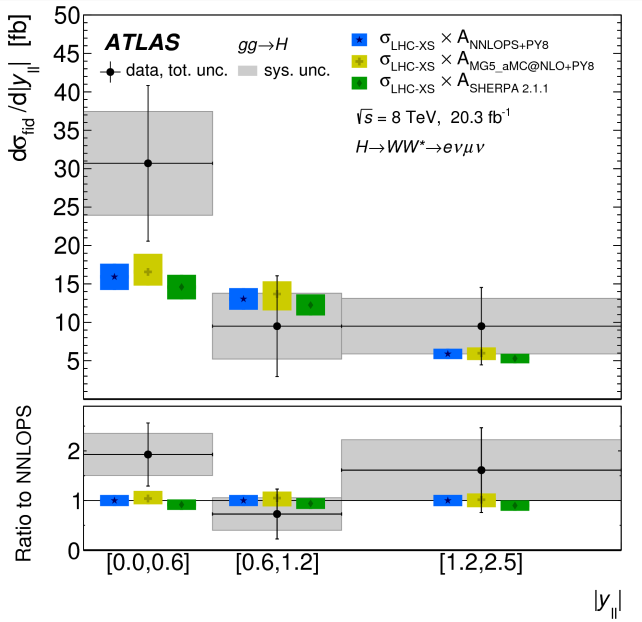
LHC-XS: $\sigma_{ggF}^{fid} = 25.1 \pm 2.6\ \text{fb}$

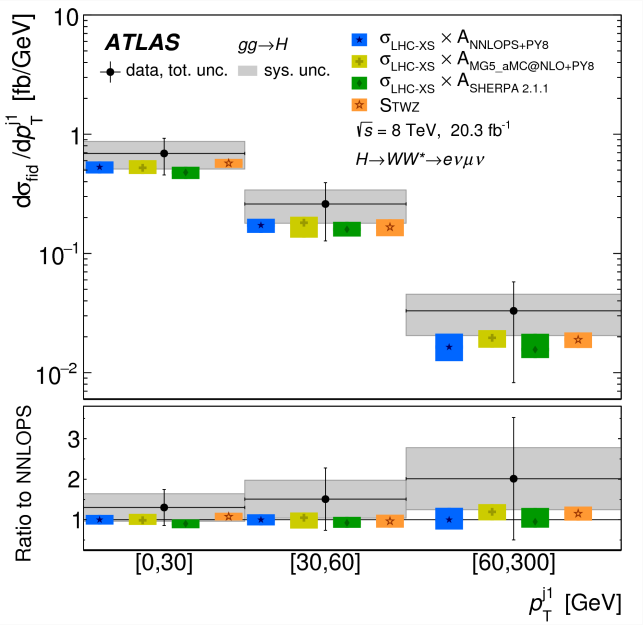
$H \to WW^* \to e\nu\mu\nu$

- fiducial differential distributions







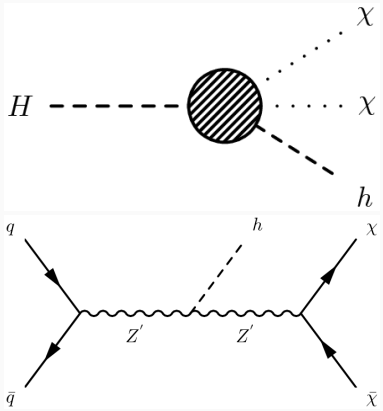


$H(\rightarrow \gamma\gamma) + \boldsymbol{MET}$ CONF-2016-011

Two theory models:

heavy scalar → H + pair of DM candidates

massive vector mediator emits H and decays into a pair of DM candidates



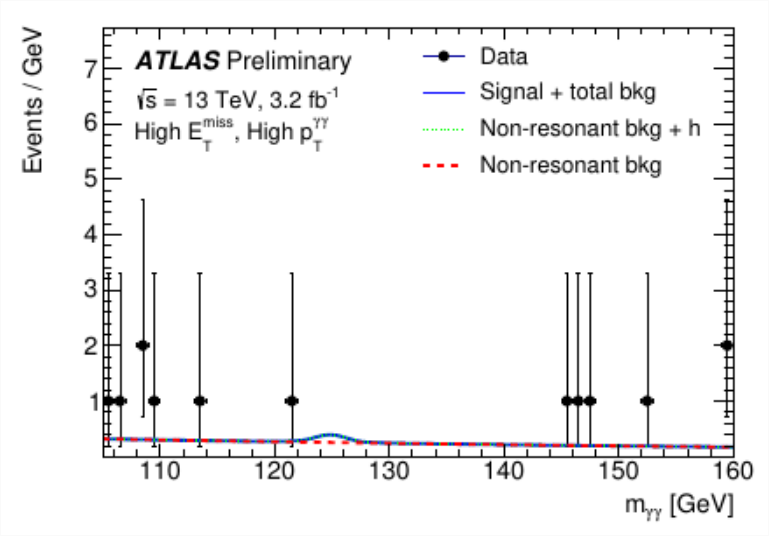
- same selection as $\gamma\gamma$ analysis
- divide events into categories:

increase sensitivity to two signal models

signal model: MC double sided CB

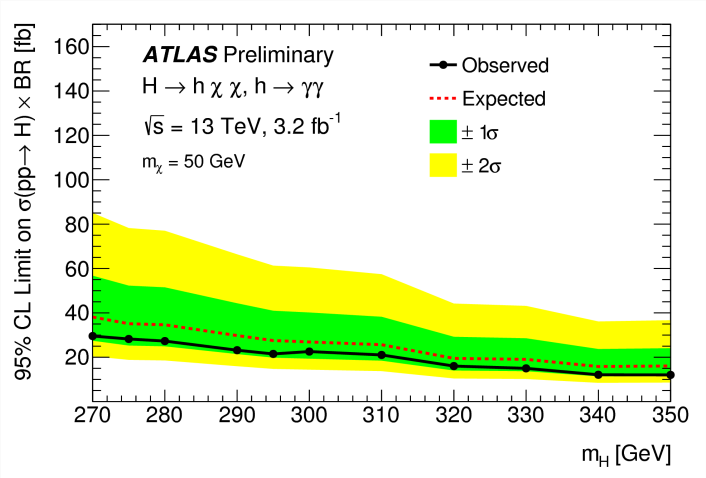
bkg model: same as $\gamma\gamma$ analysis

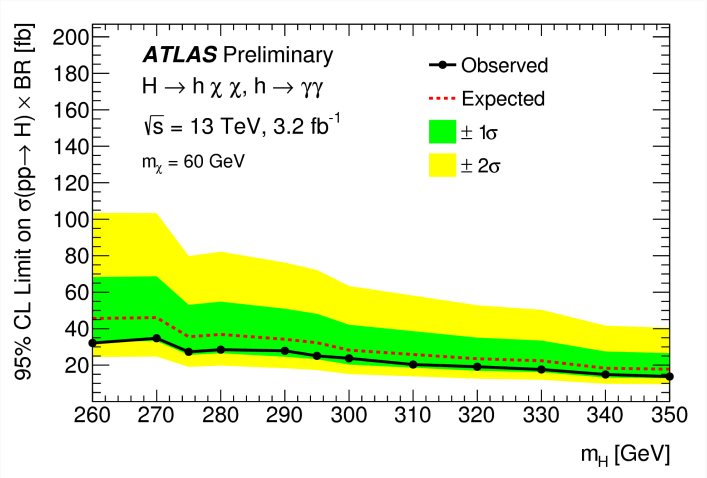
category	E_T^{miss} [GeV]	p_T^{hard} [GeV]	$p_T^{\gamma\gamma}$ [GeV]
High E_T^{miss}, high $p_T^{\gamma\gamma}$	> 100	-	>100
High E_T^{miss}, low $p_T^{\gamma\gamma}$	> 100	-	$\leq$ 100
Intermediate High E_T^{miss}	> 50 $\leq$ 100	> 40	-
Rest	-	-	> 15

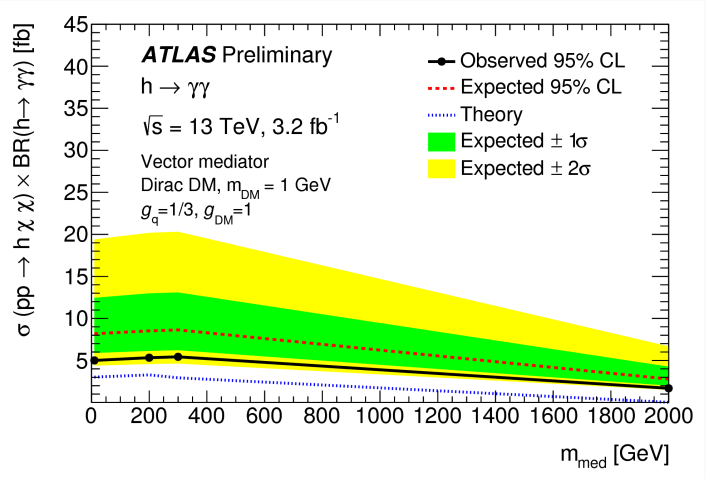


$H(\rightarrow \gamma\gamma) + \boldsymbol{MET}$ CONF-2016-011

- heavy scalar production model: 29.6 fb ($m_H = 270\ GeV$) 95% CL upper limit on $\sigma(pp \rightarrow h\chi\chi) \times BR(h \rightarrow \gamma\gamma)$

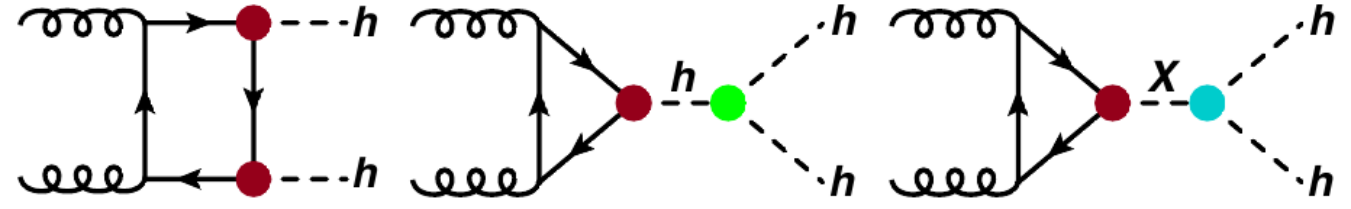






- DM production involving a massive mediator model: 5.3 fb ($m_{med} = 10\ GeV$ and $m_DM = 1\ GeV$) 95% CL upper limit on $\sigma(pp \rightarrow h\chi\chi) \times BR(h \rightarrow \gamma\gamma)$

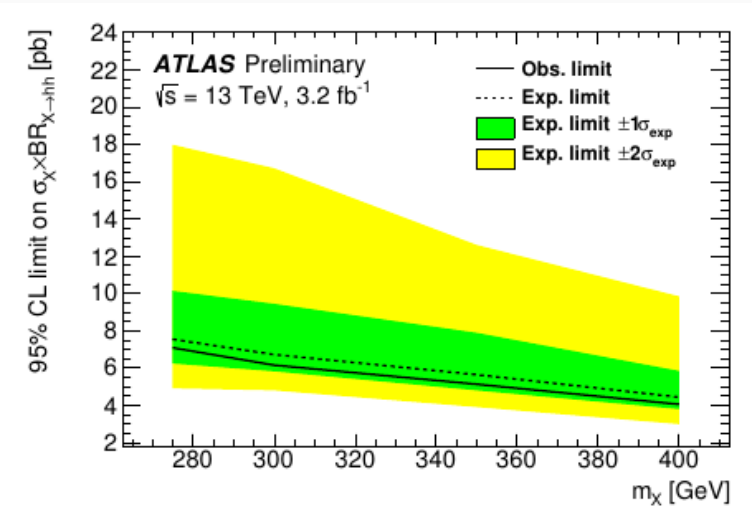
hh→ $b\bar{b}\gamma\gamma$ CONF-2016-004



- resonant and non-resonant processes
- destructive interference: low σ
- $b\bar{b}$ large BR, $\gamma\gamma$ good resolution
- 2.4 σ excess in run-1

fit in 0-tag region obtain continum bkg shape

process	0-tag	2-tag
continuum background	35.8 ± 2.1	1.63 ± 0.30
SM single Higgs	1.8 ± 1.5	0.14 ± 0.05
SM di-Higgs	< 0.001	0.027 ± 0.006



event selection

- same as run-1 (except performance)
- $\gamma\gamma$ similar to $\gamma\gamma$ analysis
- require 2 b-jets, 95 GeV < $m_{b\bar{b}}$ < 135 GeV
- events passing selection: 2-tag
- events passing selection but no b-jets: 0-tag

limits at 95% CL

- non-resonant
  - $\sigma < 3.9\,pb$ (obs)
  - $\sigma < 5.4\,pb$ (exp)
- $X \rightarrow hh$
  - $\sigma < 7 \ldots 4\,pb$ (obs) for $m_X = 275 \ldots 400\,GeV$
  - $\sigma < 7.5\,pb \ldots 4.4\,pb$ (exp) same m_X region

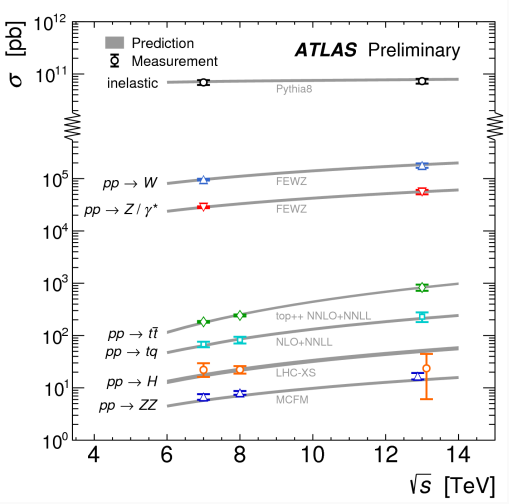
conclusions

first 13 TeV results of $H \to \gamma\gamma$ and $H \to ZZ^* \to 4\ell$

- results consistent with SM
- limited statistics in 2015

$H \to WW^*$ 8 TeV

- fiducial σ just submitted!



limits for 13 TeV searches:

- $\gamma\gamma$ + MET
- $hh \to b\bar{b}\gamma\gamma$

looking forward to 2016 collisions!

- properties measurement
- differential cross sections