Studies on VBF H→ $\gamma\ \gamma$ in ATLAS detector

reference :

ATLAS-CONF-2016-067
ATLAS-CONF-2016-081

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IHEP, CAS

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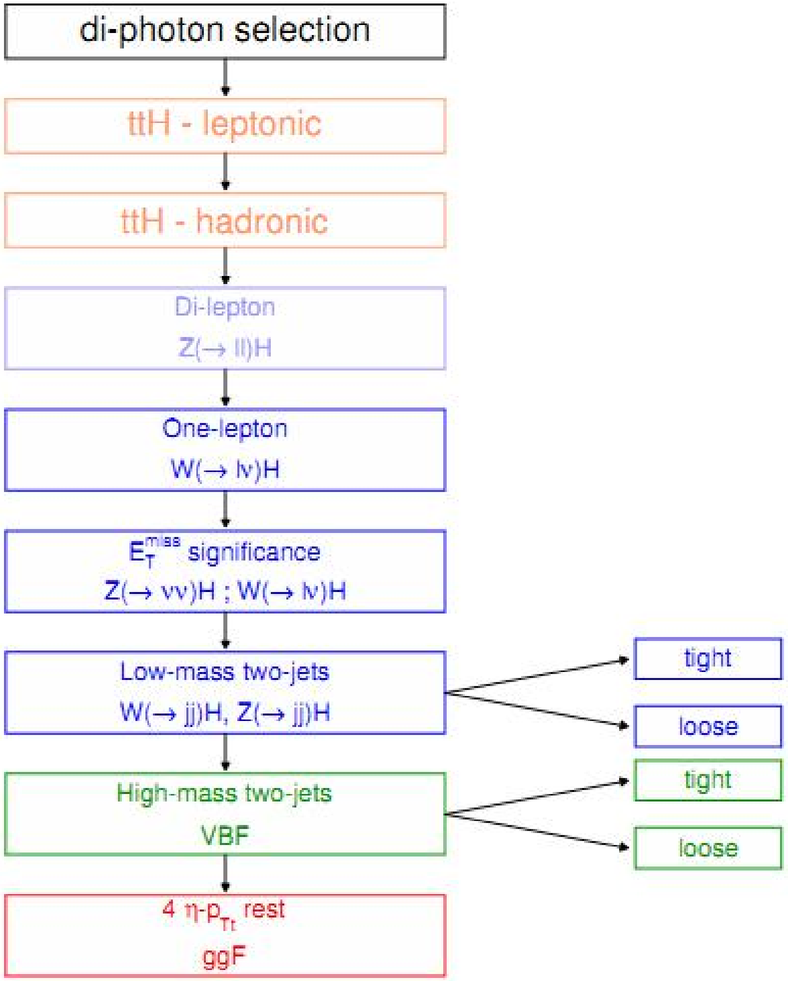
Introduction

- HGam Coupling analysis:
  – aim : measure the signal strength : $\mu = \sigma_{obs} / \sigma_{SM}$ and fiducial cross section in each production mode in diphoton final state

- Contents **Focus on VBF**
  - ➢ VBF signature
    - ✓ high-pt forward dijet
  - ➢ define two VBF-sensitive categories by cut-based and MVA (BDT)
  - ➢ results in 2015+2016 data



- Diphoton selection
  - pT>25GeV, | η |<2.37,exclude crack region
  - two tight, isolated photon
  - $p_T^{\gamma 1(\gamma 2)}/m_{\gamma\gamma} > 0.35(0.25)$

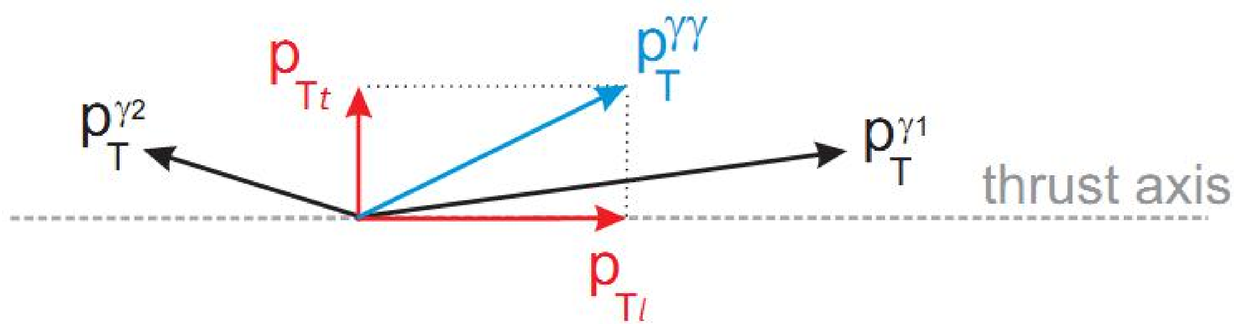
Discriminating variables used in Run1

- variables used in Run1

Variables	Definition	Separation power
m_{jj}	Invariant mass of dijet	0.256
$\Delta\eta_{jj}$	Pseudo-rapidity separation of dijet	0.130
$\Delta\Phi_{\gamma\gamma,jj}$	Azimuthal angle between diphoton and dijet system	0.199
p_{Tt}	Diphoton p_T projected perpendicular to the diphoton thrust axis	0.235
$\Delta R^{min}_{\gamma,j}$	Minimum ΔR between one of the two leading photons and the corresponding leading jets	0.185
$\eta^{Zeppenfeld}$	$\lvert\eta_{\gamma\gamma} - 0.5 * (\eta_{j1} + \eta_{j2})\rvert$	0.126

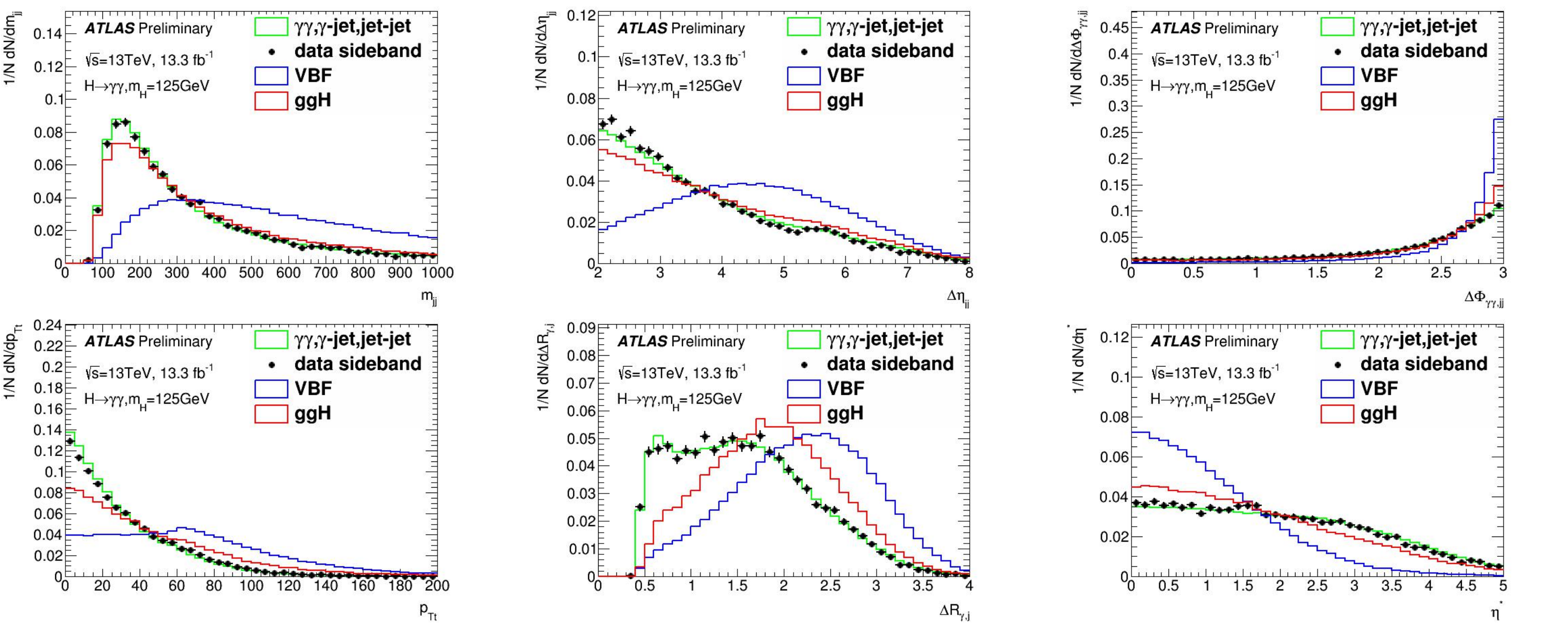
$$< S^2 >= \frac{1}{2}\int \frac{(\hat{y}_s(y) - \hat{y}_b(y))^2}{\hat{y}_s(y) + \hat{y}_b(y)} dy$$

- Separation power
  - two forward jet → large $\Delta\eta_{jj}$
  - high pT and large $\Delta\eta_{jj}$ → large m_{jj}
  - central diphoton and forward dijet → large $\Delta R^{min}_{\gamma,j}$, η^{Zepp}
  - two balance high pT jet → high pTt



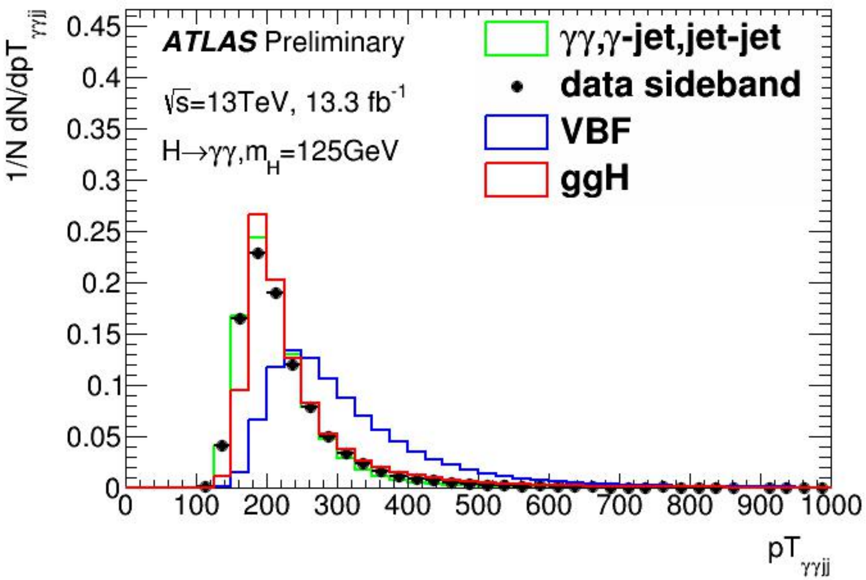
Distributions of variables

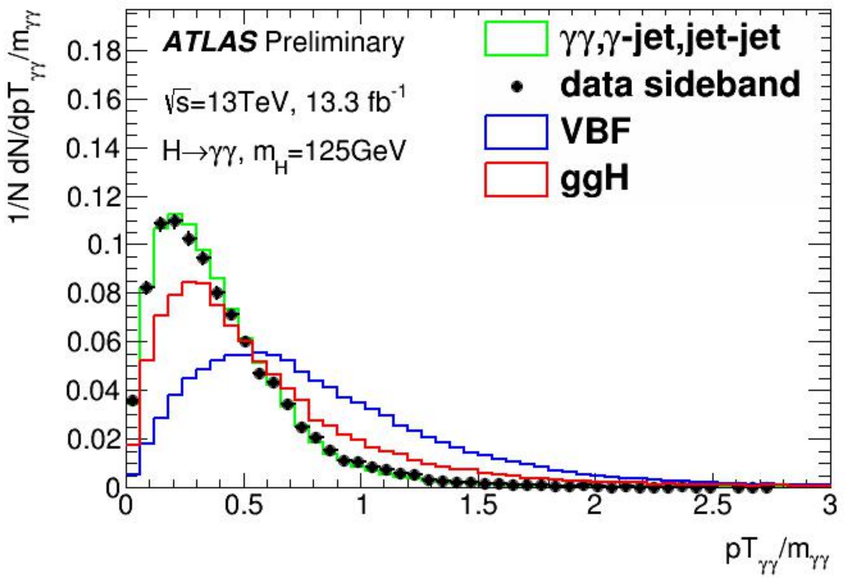
- data sideband (exculde 120-130GeV) is consistent with $\gamma\ \gamma + \gamma$ j+jj background
- these variables show good separation power
- they are to be used in category optimization



investigate more variables

- two more variables :
  - scalar pT sum of γ, γ, j, j
  - $pT_{\gamma\gamma}/m_{\gamma\gamma}$
- do not use these two variables due to correlation with $m_{\gamma\gamma}$





Variables	separation power	correlation with $m_{\gamma\gamma}$ in signal sample	correlation with $m_{\gamma\gamma}$ in background sample
sum $p_{T\gamma,\gamma,j,j}$	0.263	0.015	0.18
$p_{T\gamma\gamma}/m_{\gamma\gamma}$	0.250	-0.008	-0.066

correlation to $m_{\gamma\gamma}$

- the used variables should not be correlated to $m_{\gamma\gamma}$
- correlation with $m_{\gamma\gamma}$

	in signal	in background
m_{jj}	0	0.01
$\Delta\eta_{jj}$	-0.01	-0.02
$\Delta\phi_{\gamma\gamma,jj}$	0	0.04
$p_{Tt\gamma\gamma}$	0.03	0.04
$\Delta R_{\gamma,j}^{min}$	-0.01	-0.02
η^{Zepp}	-0.01	0.03
$pT_{\gamma\gamma jj}$	0.02	0.18
$pT_{\gamma\gamma}/m_{\gamma\gamma}$	0.01	-0.07

- stick to the same 6 variables as Run1

opimization strategy

- Normalized to 4 fb-1
- Background modelling
  - Sherpa $\gamma\ \gamma$ is used to describe irreducible $\gamma\ \gamma$ background
  - RevID+RevIso (events fail ID or ISO from data control region) is used to describe reducible γ j and jj background
- Scan the cut and get the highest significance

$$\sigma_{VBF} = \sqrt{2 \times \left\{ (N_{VBF} + N_{ggF} + N_{background}) \times ln(1 + \frac{N_{VBF}}{N_{ggF} + N_{background}}) - N_{VBF} \right\}}$$

Cut-based optimization

- In each signal efficiency point, decide a best background-rejection selection
- Scan the signal efficiency and calculate the significance
- First optimize a cut-based tight category and then a cut-based loose category

follow the variable combination in Run1

	m_{jj}	$\Delta\eta_{jj}$	$\Delta\Phi_{\gamma\gamma,jj}$	$\Delta R^{min}_{\gamma,j}$	$\eta^{Zeppenfeld}$
tight category	> 500 GeV	> 3.9	> 3	> 1.4	> 2.4
loose category	> 350 GeV	> 2.5	> 2.7	-	-

MVA optimization

- Training strategy:
  - I : training Sherpa $\gamma\gamma$+RevID+RevIso(bkg) against VBF
  - II : training $\gamma\gamma$+RevID+RevISO+ggF(bkg) against VBF
- Use same 6 variables as Run1
-

	BDT cut for tight category	BDT cut for loose category
6 variables, ggF not included	[0.88, 1]	[0.61, 0.88]
6 variables, ggF included	[0.87, 1]	[0.58, 0.87]

- Expected significance is same

6 variables	not include ggF		include ggF	
	MVA tight	MVA loose	MVA tight	MVA loose
VBF	1.64	2.17	1.71	2.18
ggF	0.51	1.90	0.56	2.00
background	2.42	17.71	2.70	19.04
VBF purity	0.76	0.53	0.75	0.52
significance	0.88	0.47	0.88	0.47
combined significance	1.00		1.00	

comparison between cut-based and MVA

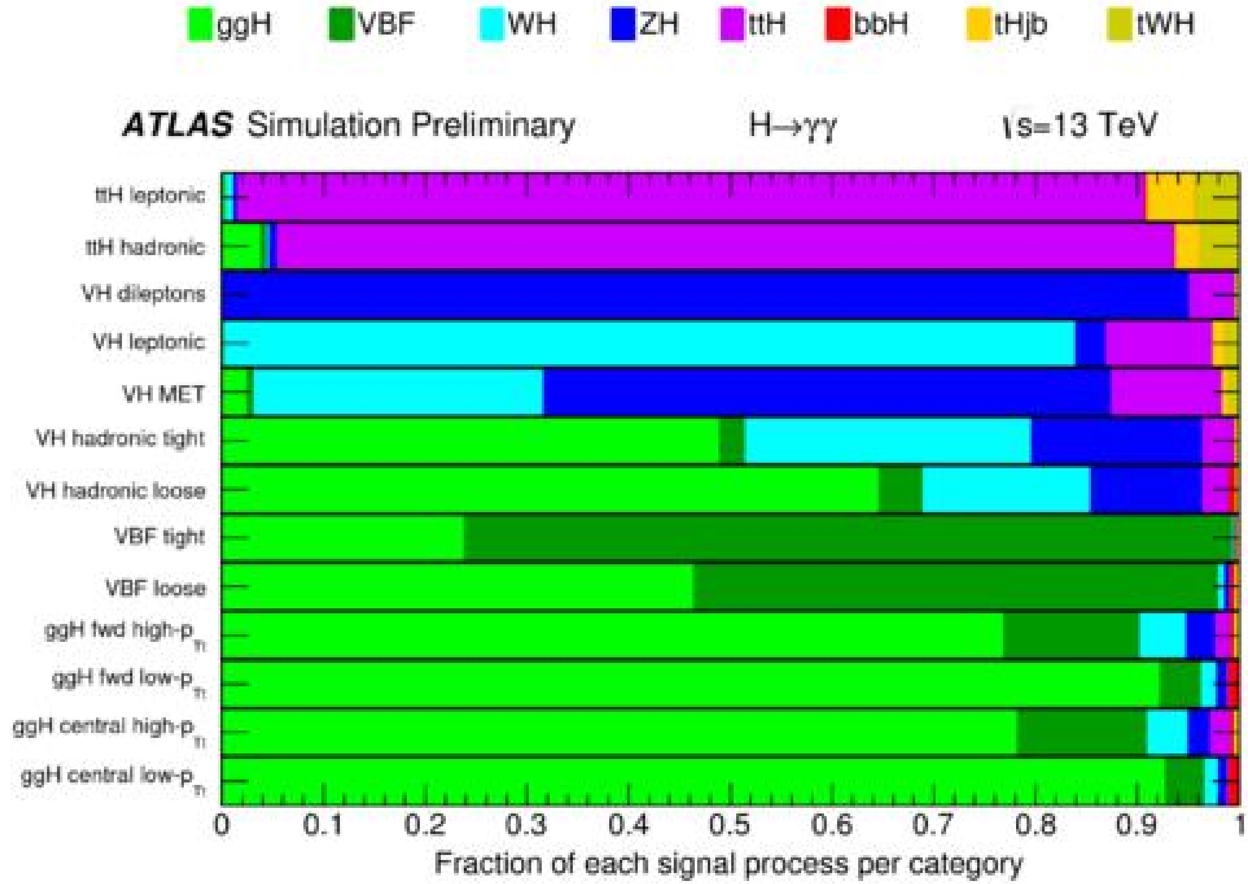
- normalized to 4 fb^{-1}

	cut-based tight	cut-based loose	MVA tight	MVA loose
VBF	2.22	2.57	1.64	2.17
ggF	0.83	3.51	0.51	1.90
background	8.06	74.74	2.42	17.71
VBF purity	0.73	0.42	0.76	0.53
significance	0.72	0.29	0.88	0.47
combined significance	0.78		1.00	

- MVA deals with the correlation between different variables better than cut-based , so it improves the significance
- gain 0.22 from MVA (BDT)

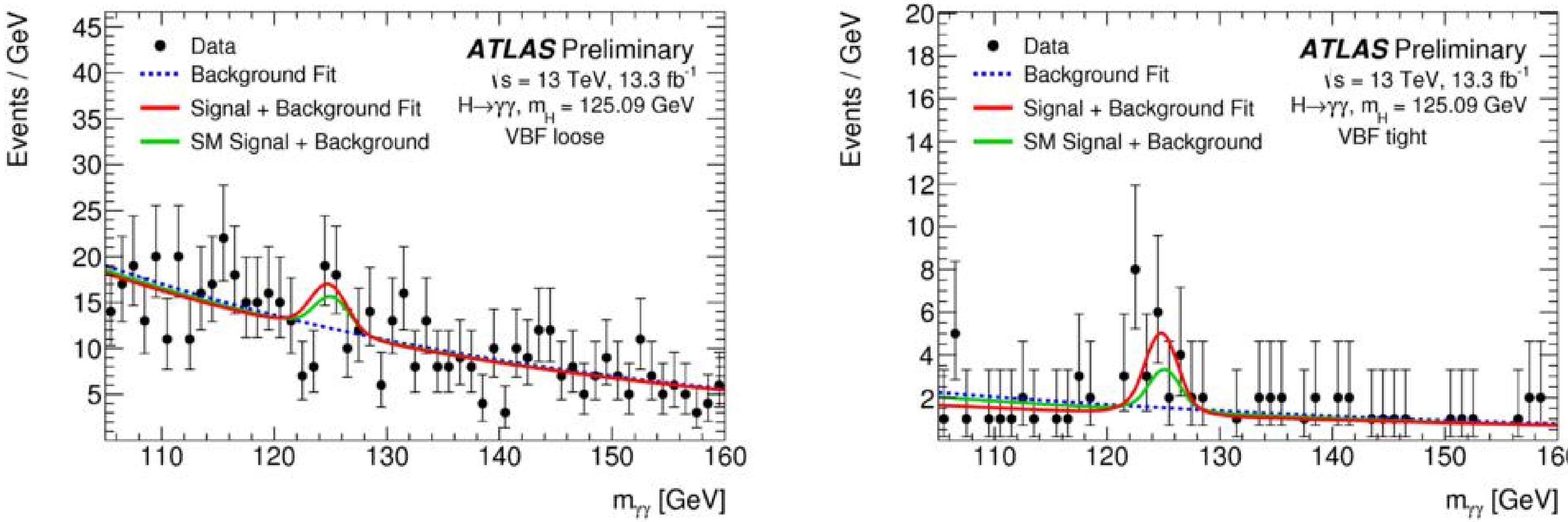
signal purity

- the fraction of different production mode in each category



result in 2015+2016 data

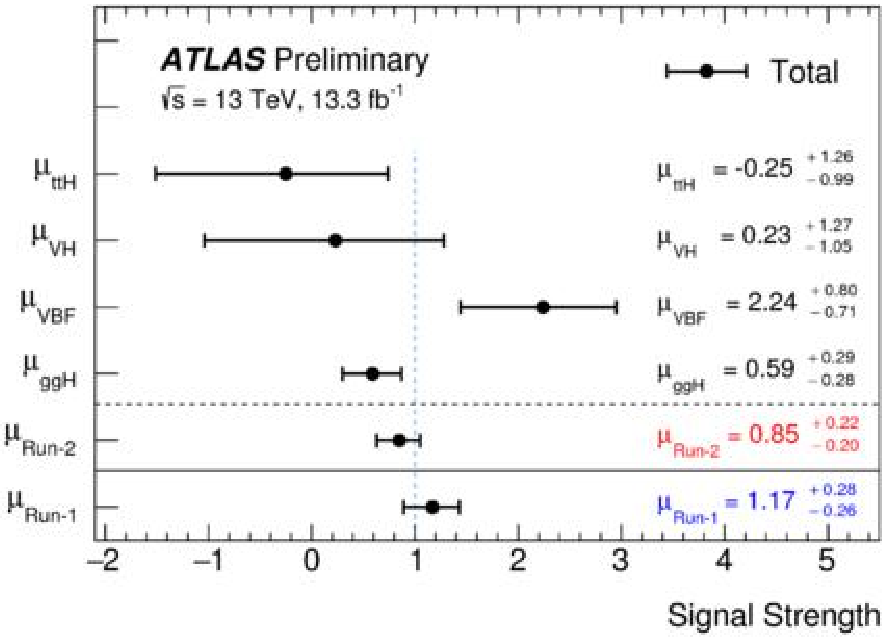
- 3.2 + 10.1 = 13.3 fb^{-1}



- the red and green show the difference between observation and SM prediction
- observed signal strength is 124% larger than SM, but within 2 sigma

$$\mu_{VBF} = 2.24^{+0.80}_{-0.71}$$

result with 2015+2016 data

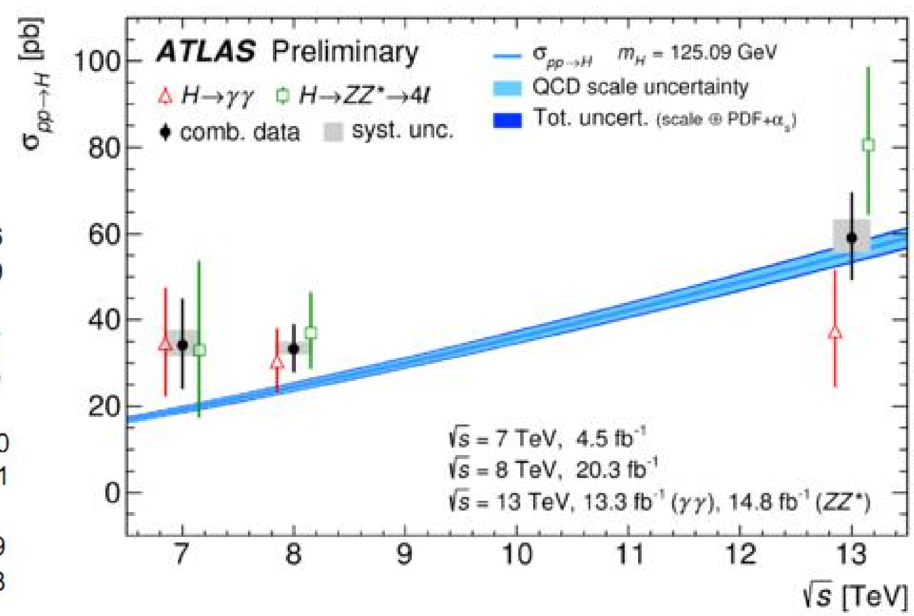


- global signal strength is consistent with SM prediction

$$\sigma_{ggH} \times \mathcal{B}(H \to \gamma\gamma) = 65 \,^{+32}_{-31} \text{ fb}$$
$$\sigma_{\mathrm{VBF}} \times \mathcal{B}(H \to \gamma\gamma) = 19.2 \,^{+6.8}_{-6.1} \text{ fb}$$
$$\sigma_{\mathrm{VH}} \times \mathcal{B}(H \to \gamma\gamma) = 1.2 \,^{+6.5}_{-5.4} \text{ fb}$$
$$\sigma_{t\bar{t}H} \times \mathcal{B}(H \to \gamma\gamma) = -0.3 \,^{+1.4}_{-1.1} \text{ fb}$$

- combind signal strength is consistent with SM

$$\mu_{ttH} = -0.25 \,^{+1.26}_{-0.99}$$
$$\mu_{VH} = 0.23 \,^{+1.27}_{-1.05}$$
$$\mu_{VBF} = 2.24 \,^{+0.80}_{-0.71}$$
$$\mu_{ggH} = 0.59 \,^{+0.29}_{-0.28}$$



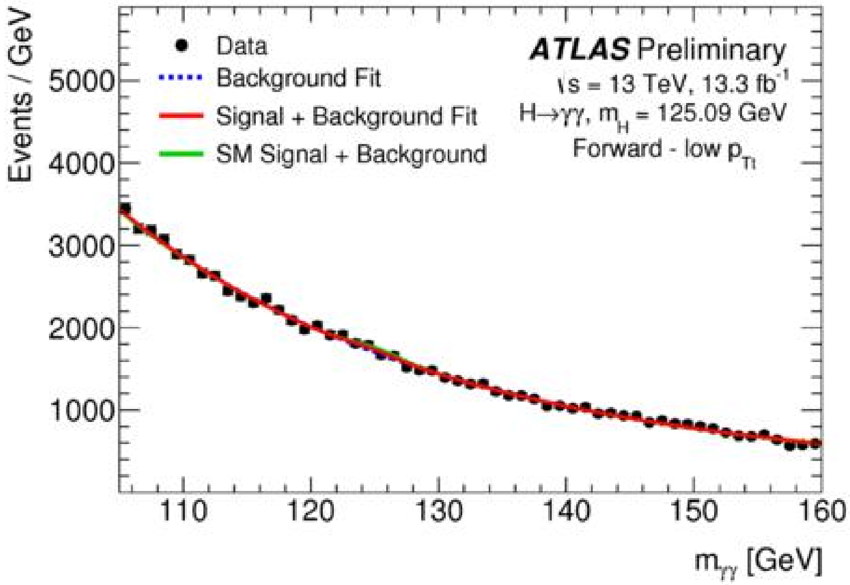
Summary

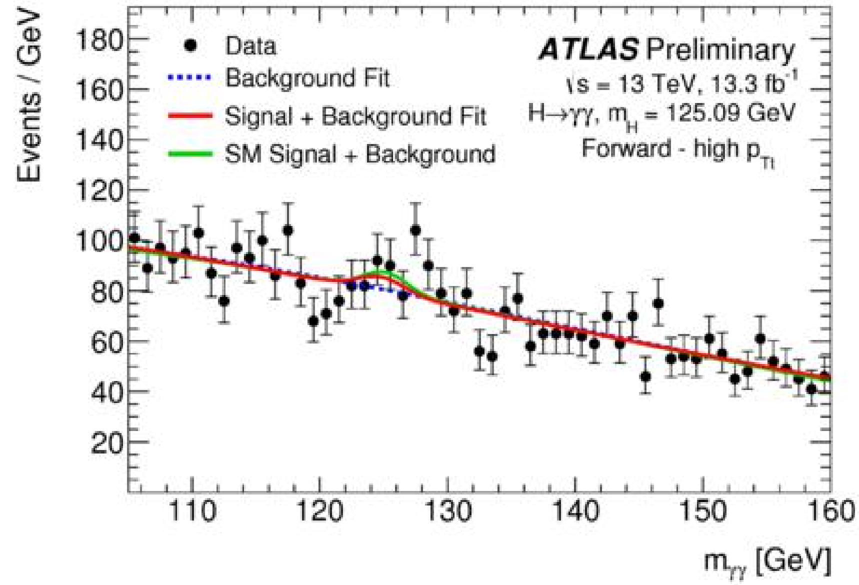
- Conference note is approved in ICHEP

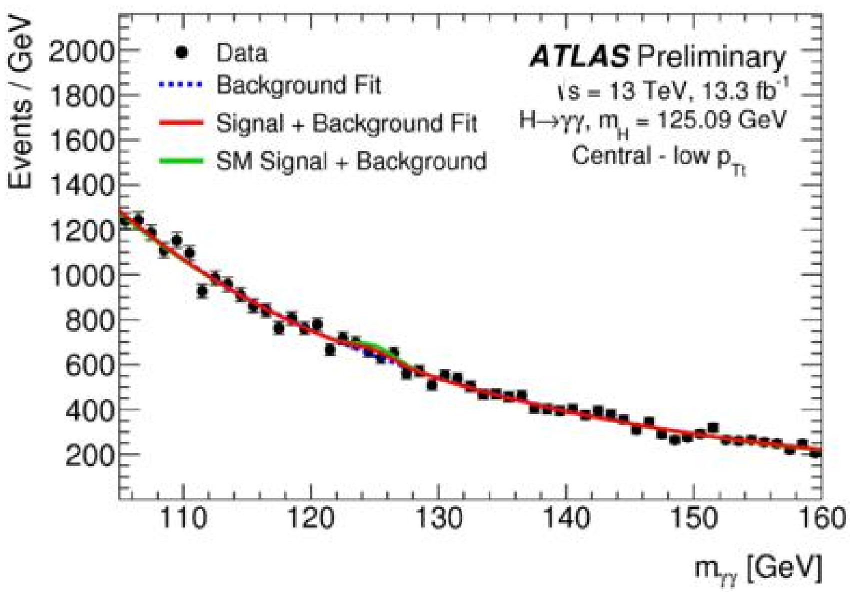
- Global signal strength , including VBF , is consistent with SM predition

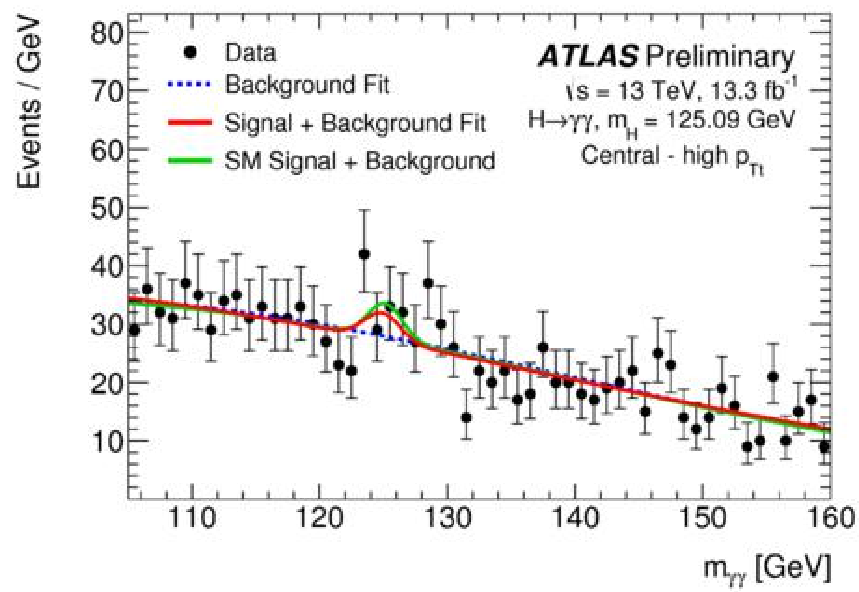
- More data is needed to confirm whether there is excess with respect to SM and investigate the Higgs property back up

m γ γ distribution

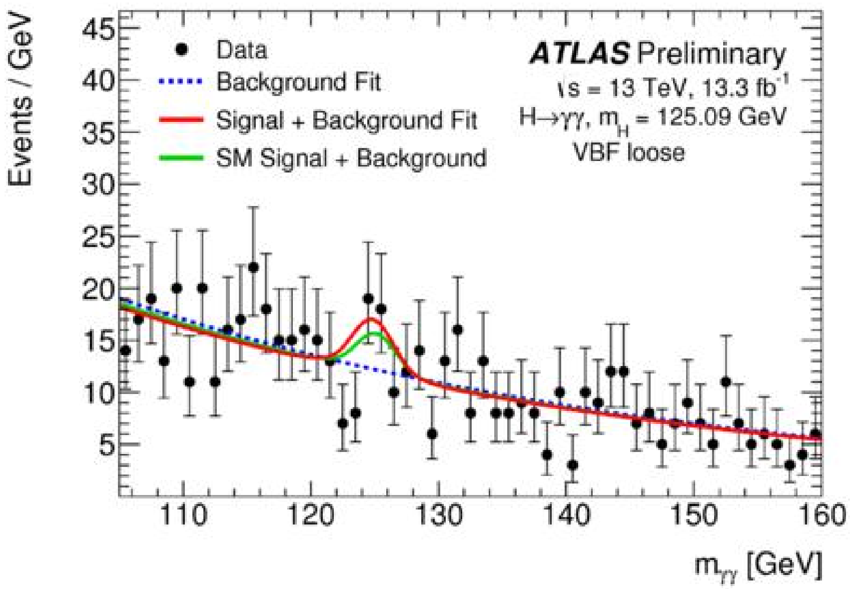


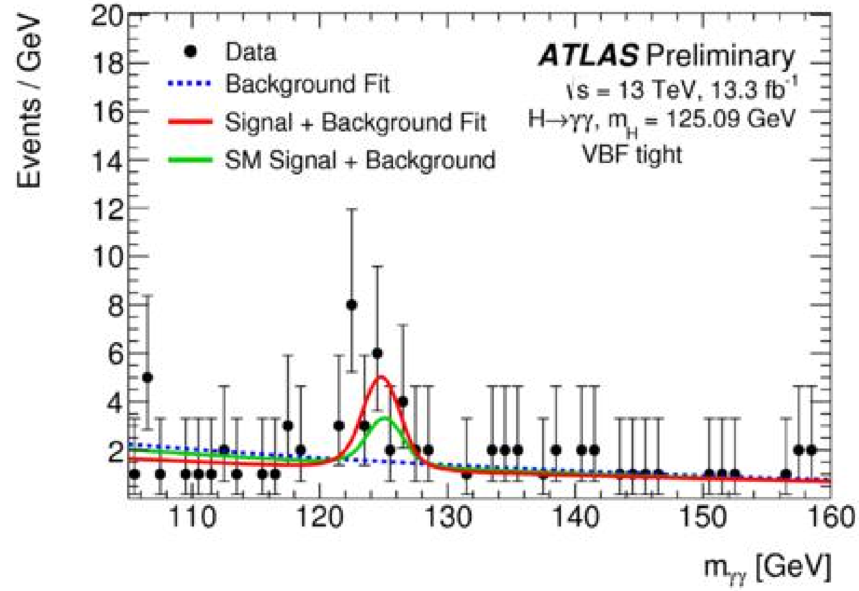


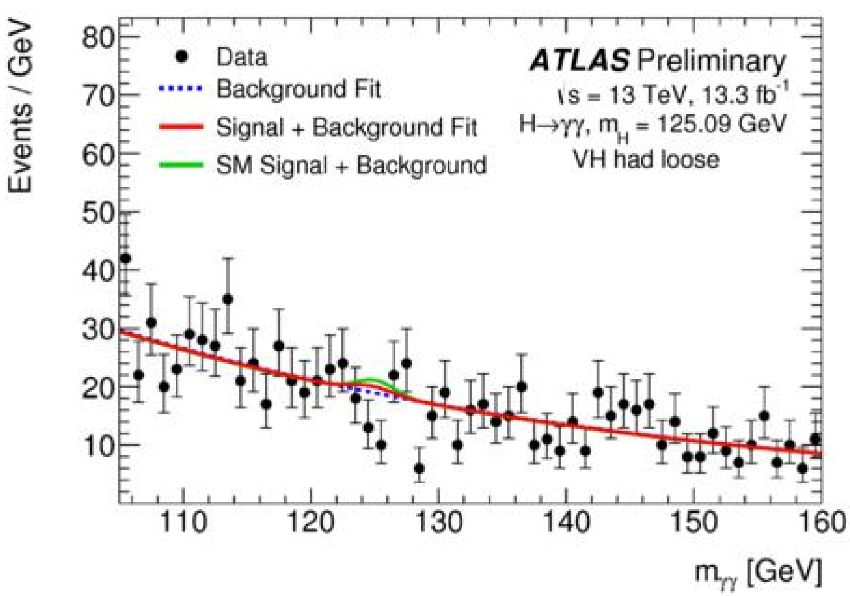


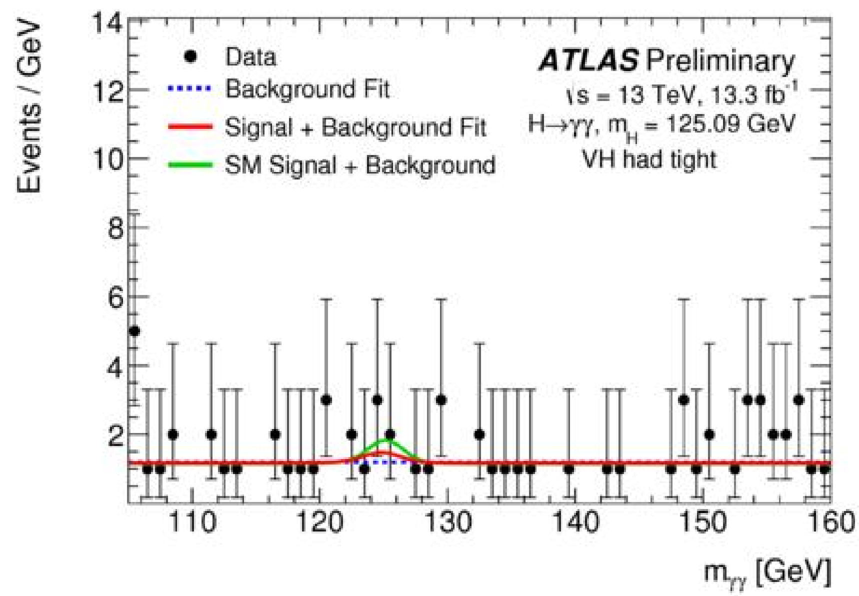


m γ γ distribution

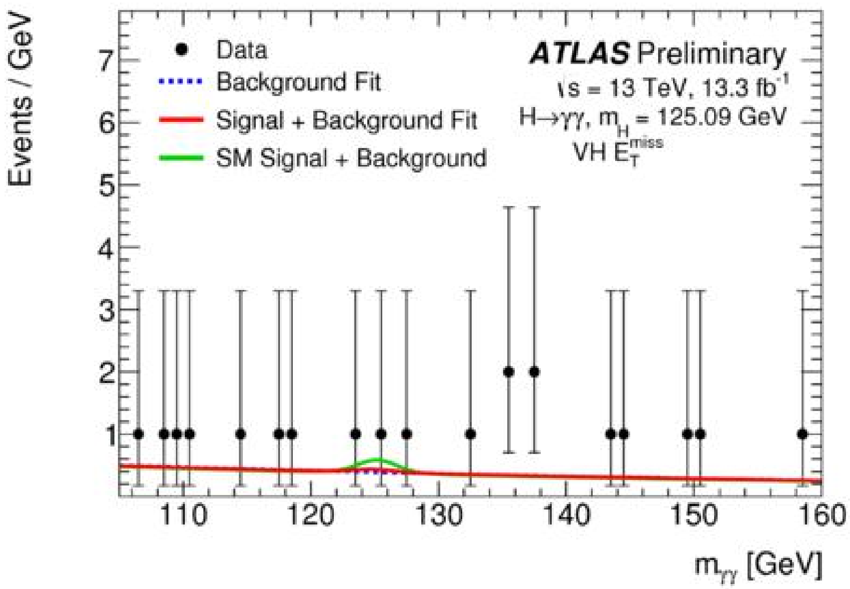


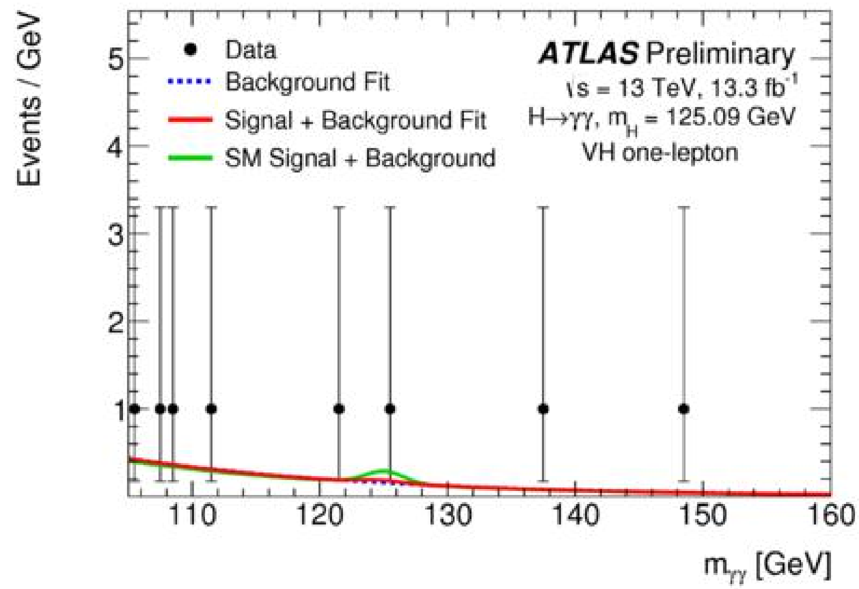


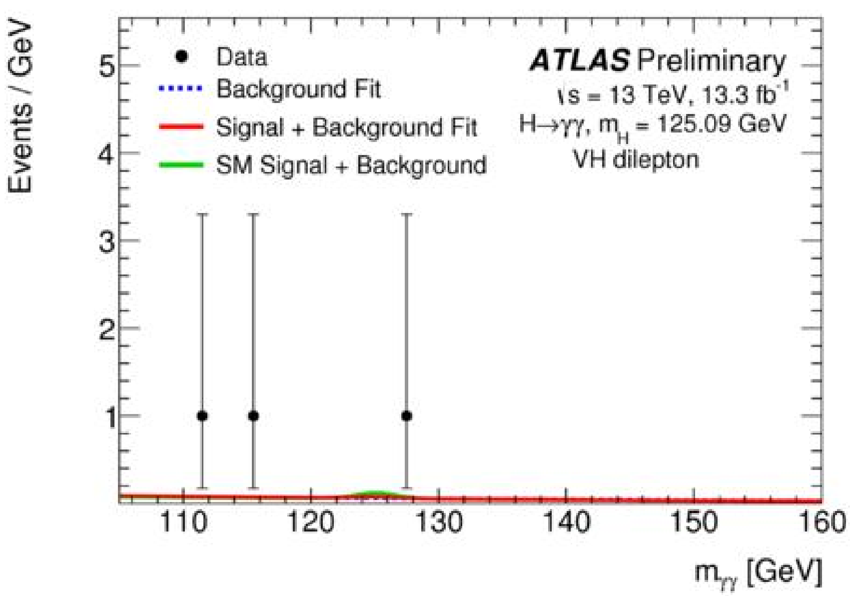




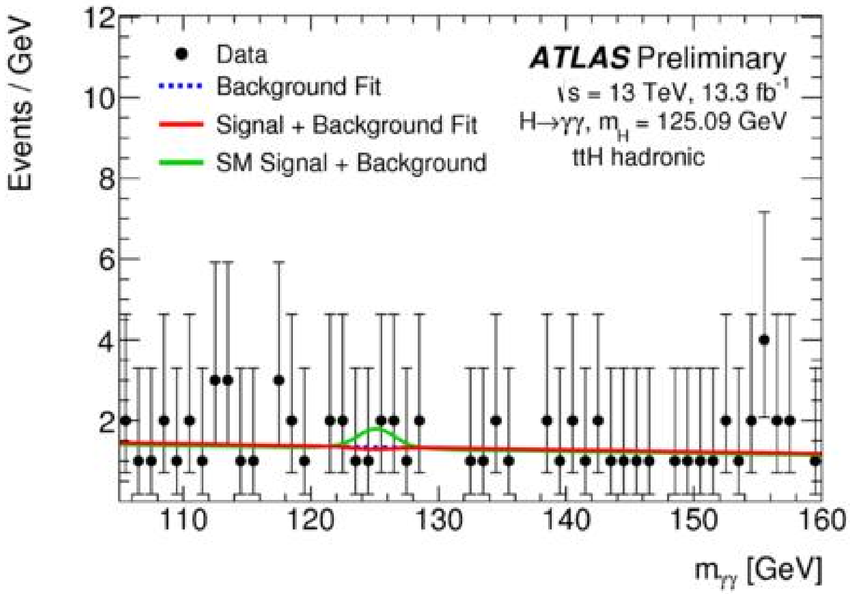
m γ γ distribution

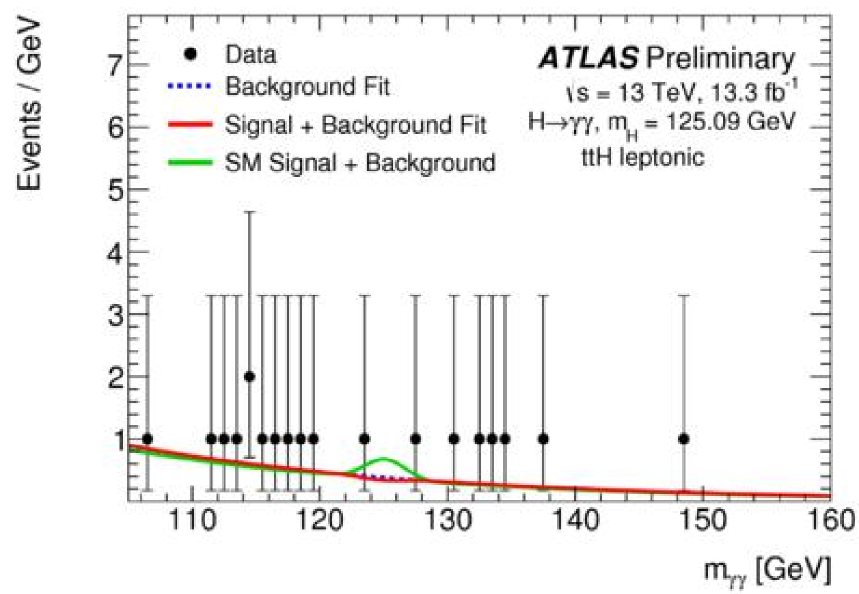




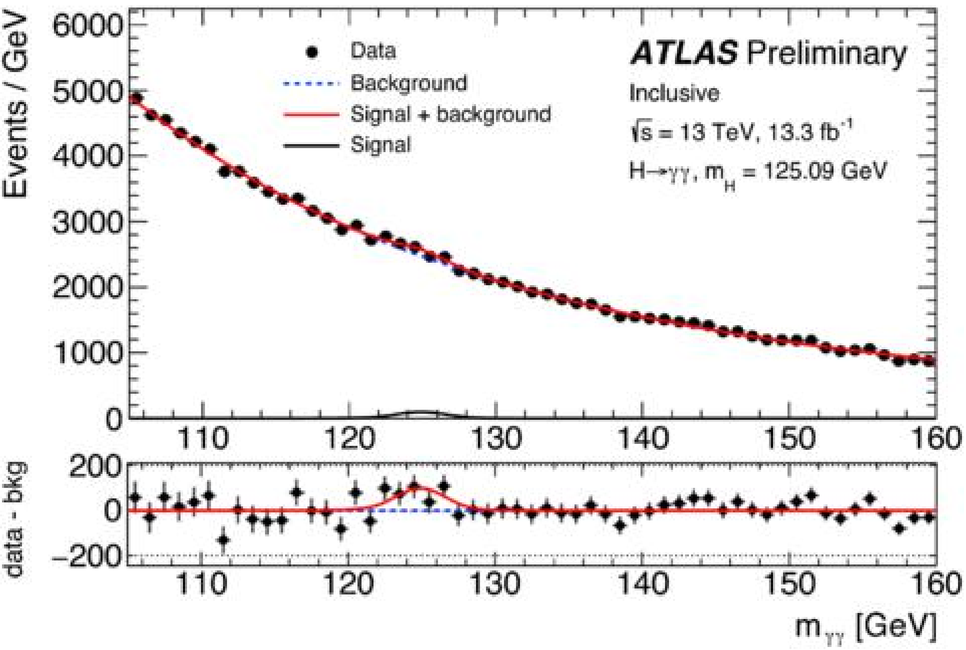


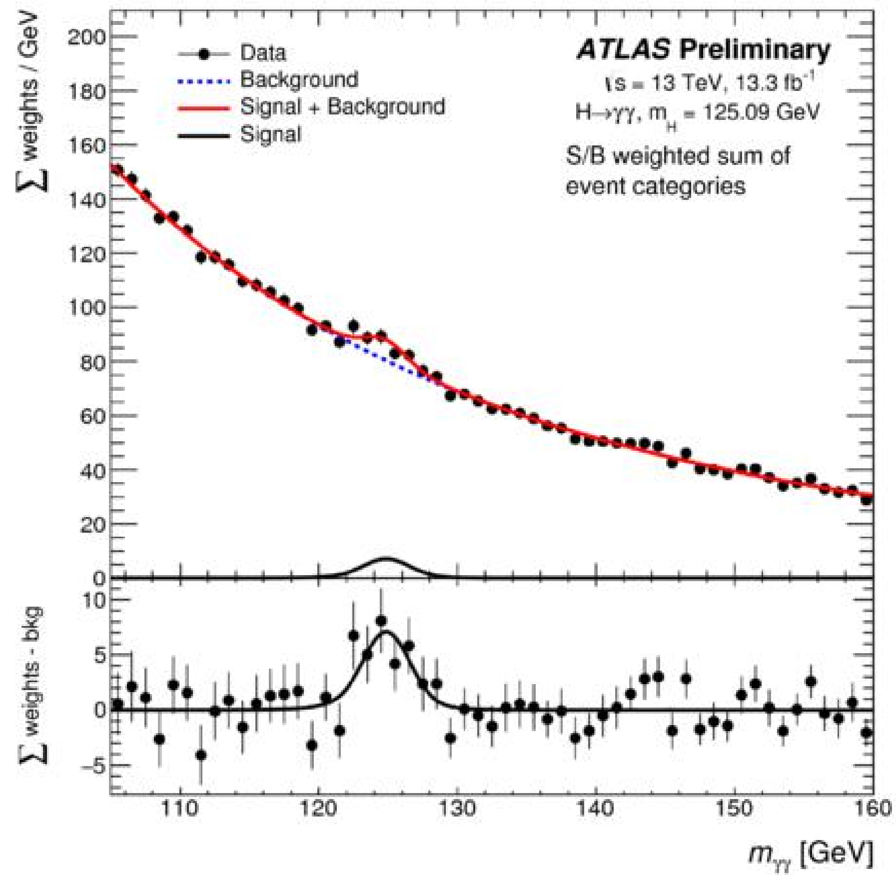
m γ γ distribution





inclusive


Data
Background
Signal + background
Signal
ATLAS Preliminary
Inclusive
√s = 13 TeV, 13.3 fb⁻¹
H→γγ, m_H = 125.09 GeV
Events / GeV
data - bkg
m_γγ [GeV]


Data
Background
Signal + Background
Signal
ATLAS Preliminary
√s = 13 TeV, 13.3 fb⁻¹
H→γγ, m_H = 125.09 GeV
S/B weighted sum of
event categories
∑ weights / GeV
∑ weights - bkg
m_γγ [GeV]

systematic of VBF

- mass fixed to 125.09 GeV