Search for VBF production mode in diphoton final state with ATLAS detector

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IHEP, CAS

2nd CLHCP

Analysis Team

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1, IHEP
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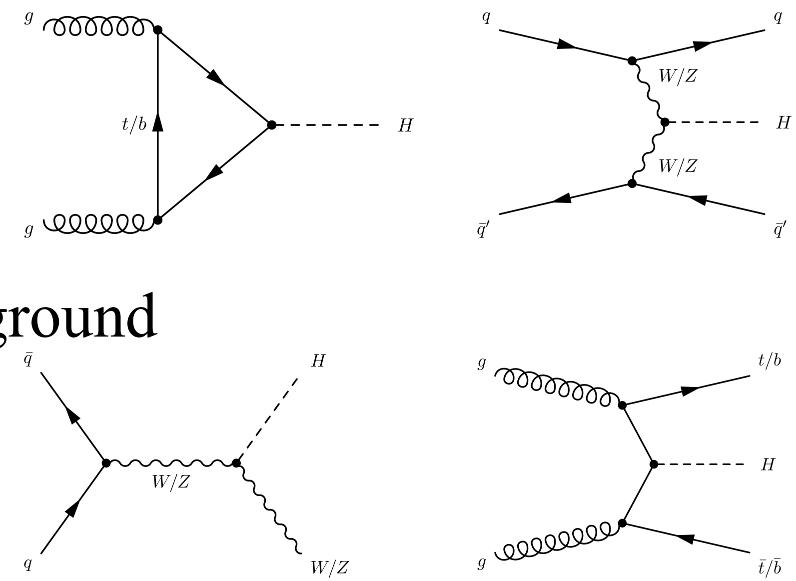
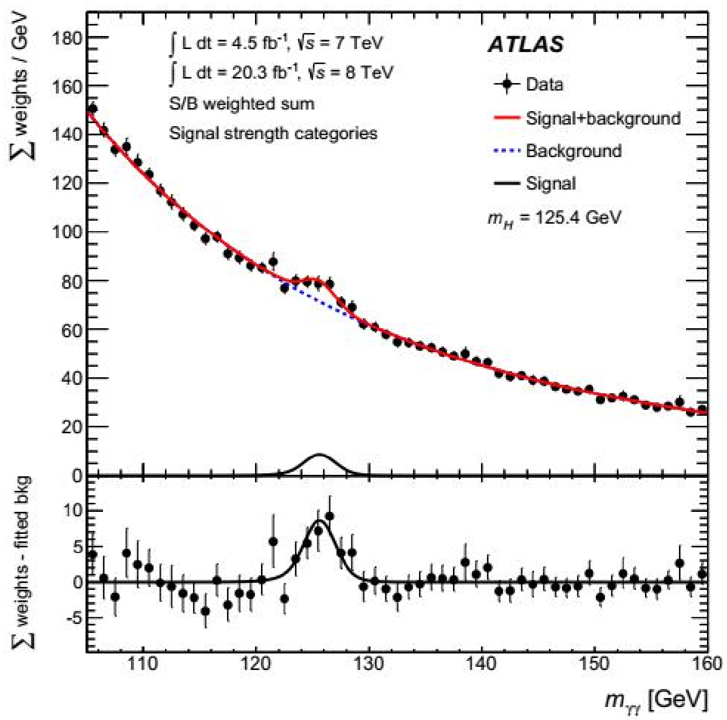
Motivation

- Four main production mode of SM Higgs
- VBF is 2nd dominant
- Diphoton
  - good mass resolution
  - narrow peak on smooth background
  - good sensitivity



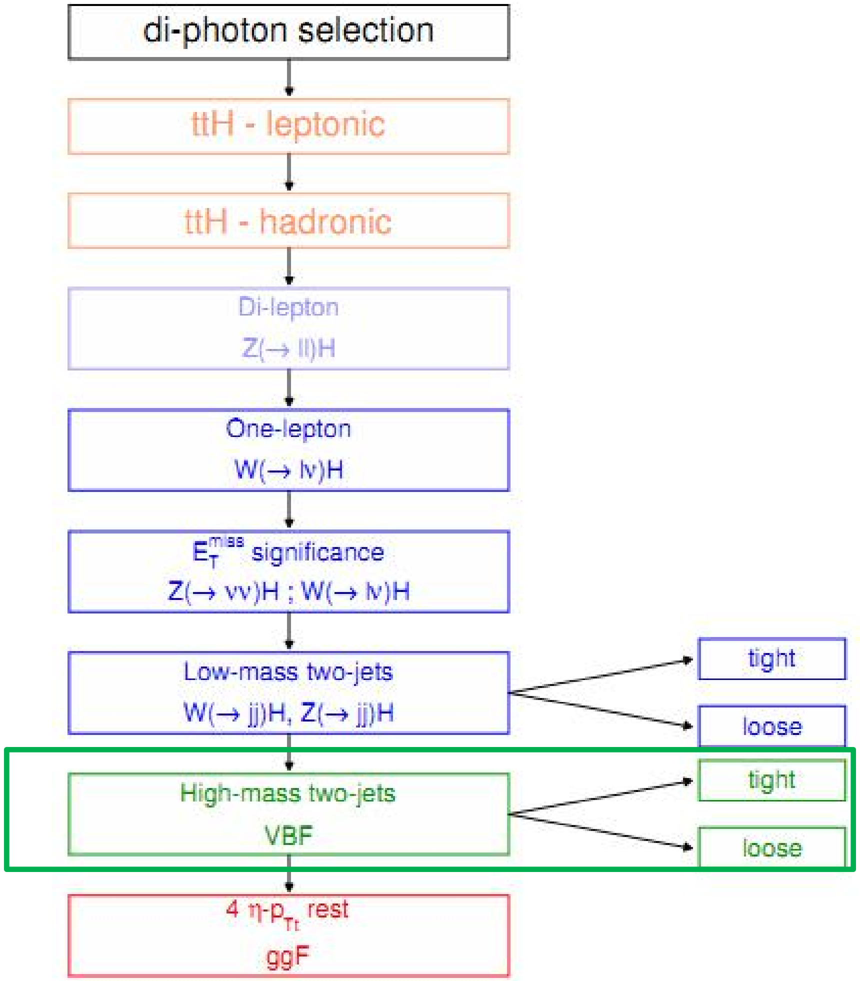


- 2015+2016 dataset(ICHEP): 13.3/fb
- aim : measure the signal strength : $\mu = \sigma_{obs} / \sigma_{SM}$ of each production mode in diphoton final state

Introduction

- 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
  - $p_T^{\gamma 1(\gamma 2)}/m_{\gamma\gamma} > 0.35(0.25)$
  - $105 < m_{\gamma\gamma} < 160$



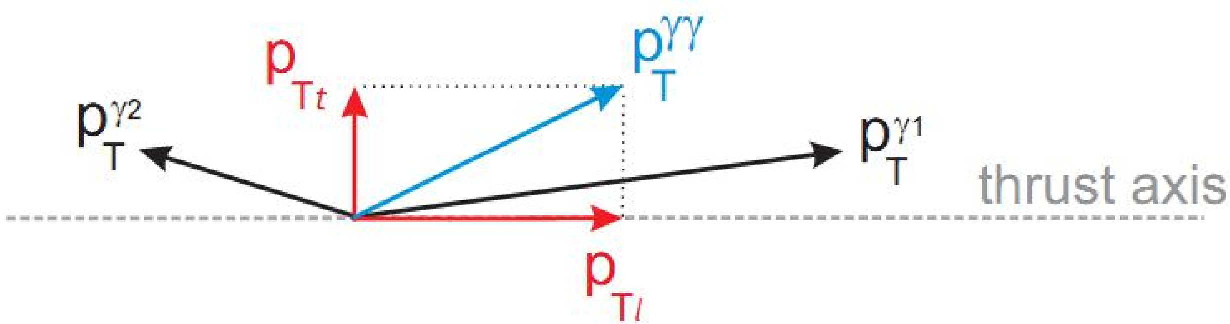
Discriminating variables used in Run1

- 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

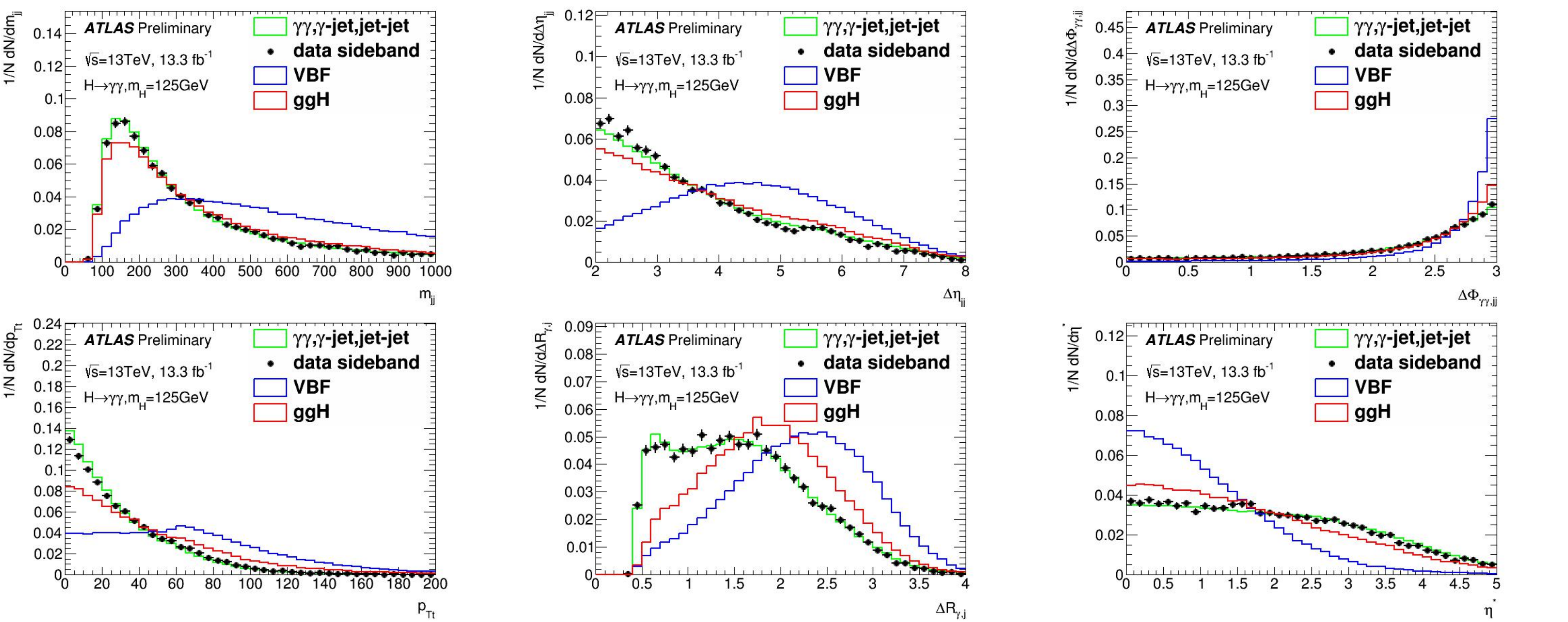
$$< S^2 >= \frac{1}{2}\int \frac{(\hat{y}_s(y) - \hat{y}_b(y))^2}{\hat{y}_s(y) + \hat{y}_b(y)} dy$$

- 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



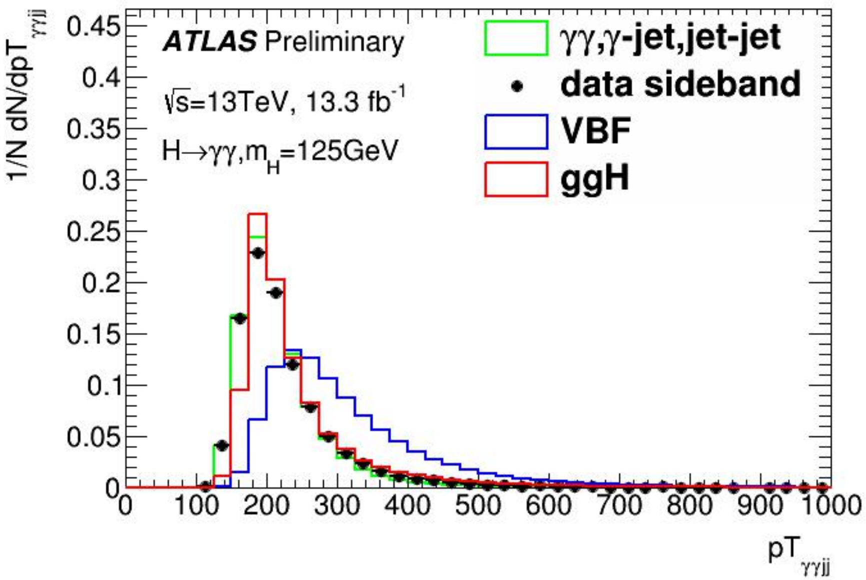
Distributions of variables

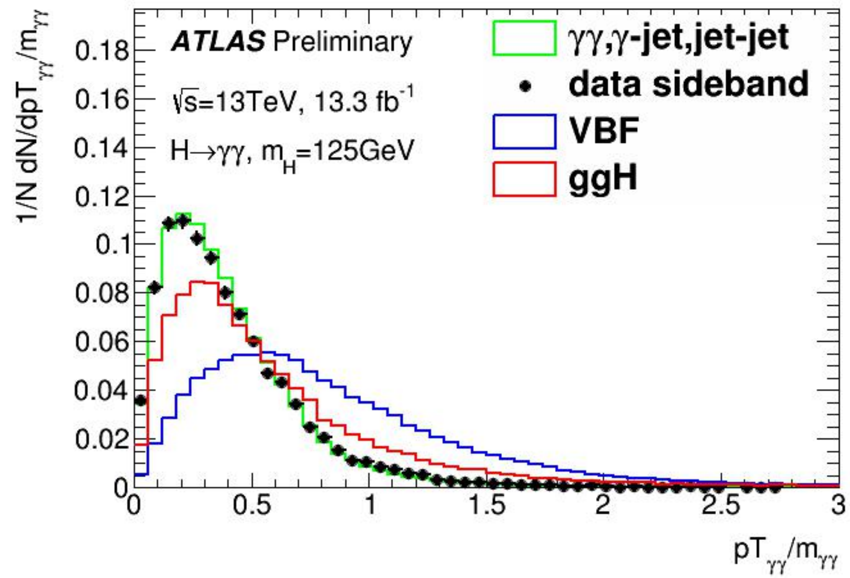
- Data sideband (exculde 120-130GeV) is consistent with γ γ + γ j+jj background
- These variables show good separation power
- They are to be used in category optimization



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

optimization 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

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

comparison between cut-based and MVA

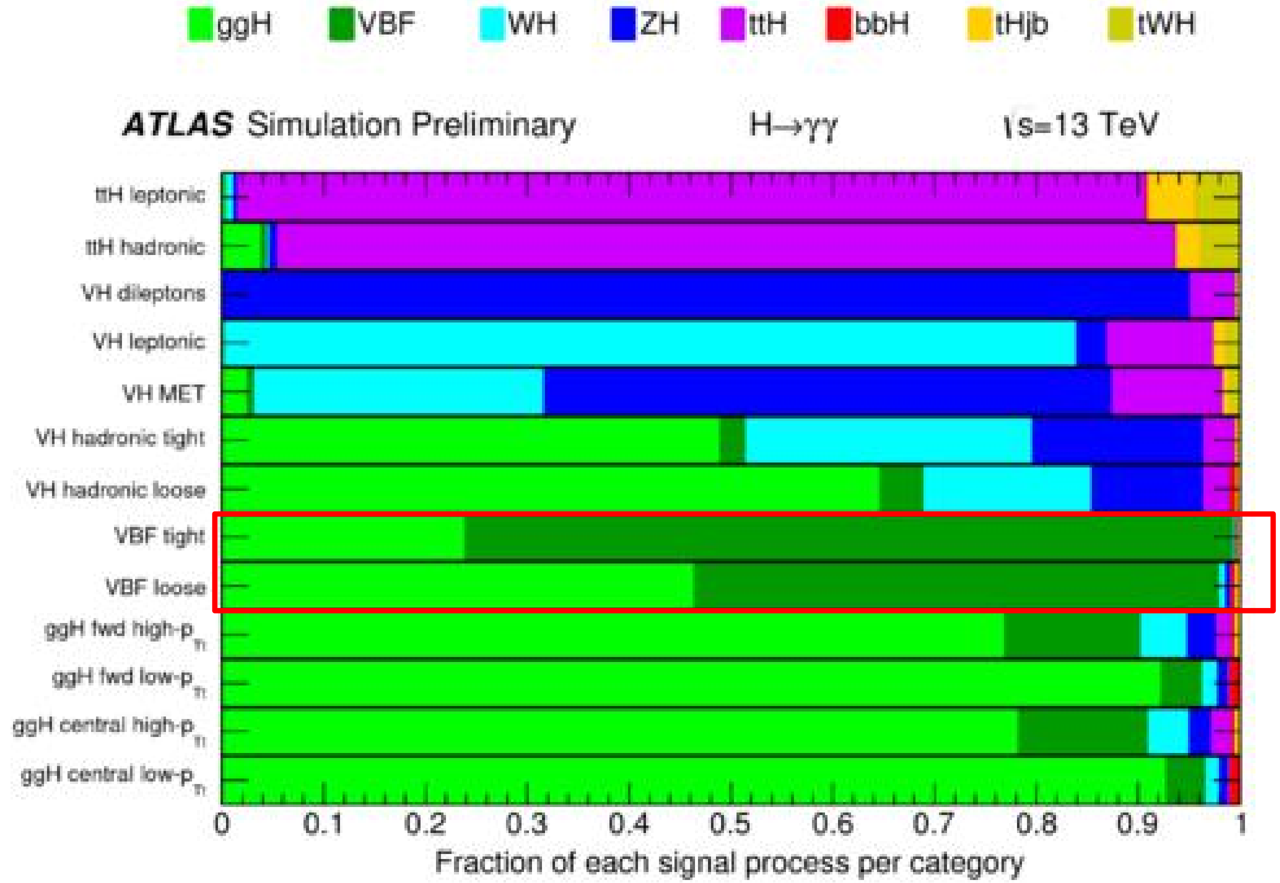
- Normalized to 4 fb^{-1}

	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



Systematic

- Background modelling
  - spurious signal is used for function selection and uncertainty estimation
  - Perform S+B fit on background-only sample
  - Required fitted signal yield (so-called s
    - <10%*N(expected signal)
    - <20%*N(background fluctuation)
  - Test Exp, ExpPoly2, Bern3
  - Choose the function with least DOF

Category	Model	$\sqrt{s}$ = 13 TeV $N_{\rm spur}$	$Z_{\rm spur}$	$\mu_{\rm spur}$
ggH CenLow	Exp2	-2.93	-4.2 %	2.1 %
ggH CenHigh	Exp2	1.49	12.0 %	8.1 %
ggH FwdLow	Exp2	-12.7	-9.4 %	-5.2 %
ggH FwdHigh	Exp2	-4.25	-16.3%	-14.3 %
VBF loose	Exp1	0.91	10.8 %	7.6 %
VBF tight	Exp1	-0.26	-8.3 %	-4.2 %

- QCD high order correction of ggF+jets: evaludated by MCFM

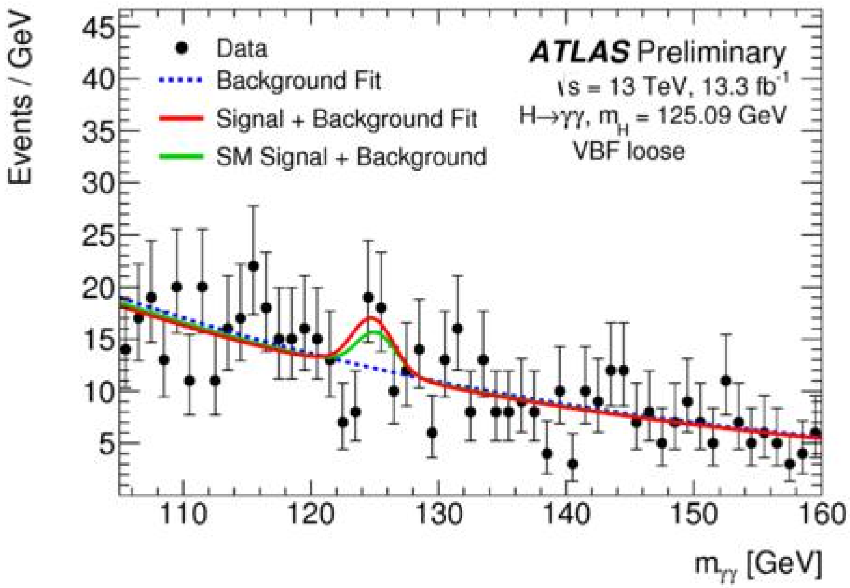
Category	VBF loose	VBF tight
$\geq$ 2 jets uncertainty	24.8%	24.8%

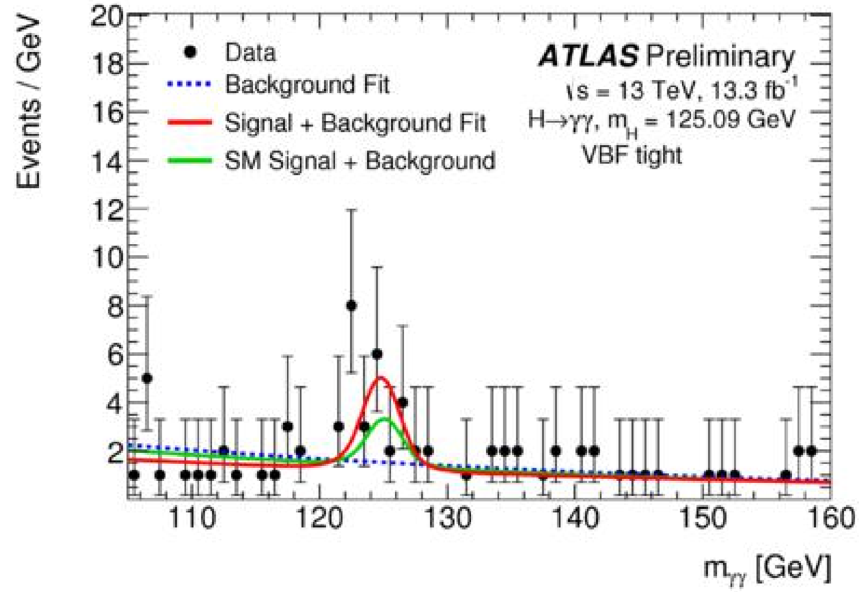
- Mismodelling : The 2nd jet in nominal ggF Powheg+Pythia is generated by shower and always mismodelled --- use MINLO HJJ to do reweight with Δ Φjj and η *

Re-weighted Sample	Loose VBF	Tight VBF
HJJ $\Delta\phi$	-6.5	-10.7
HJJ $\eta*$	-7.4	-8.7

result in 2015+2016 data

- $3.2 + 10.1 = 13.3\ \mathrm{fb}^{-1}$



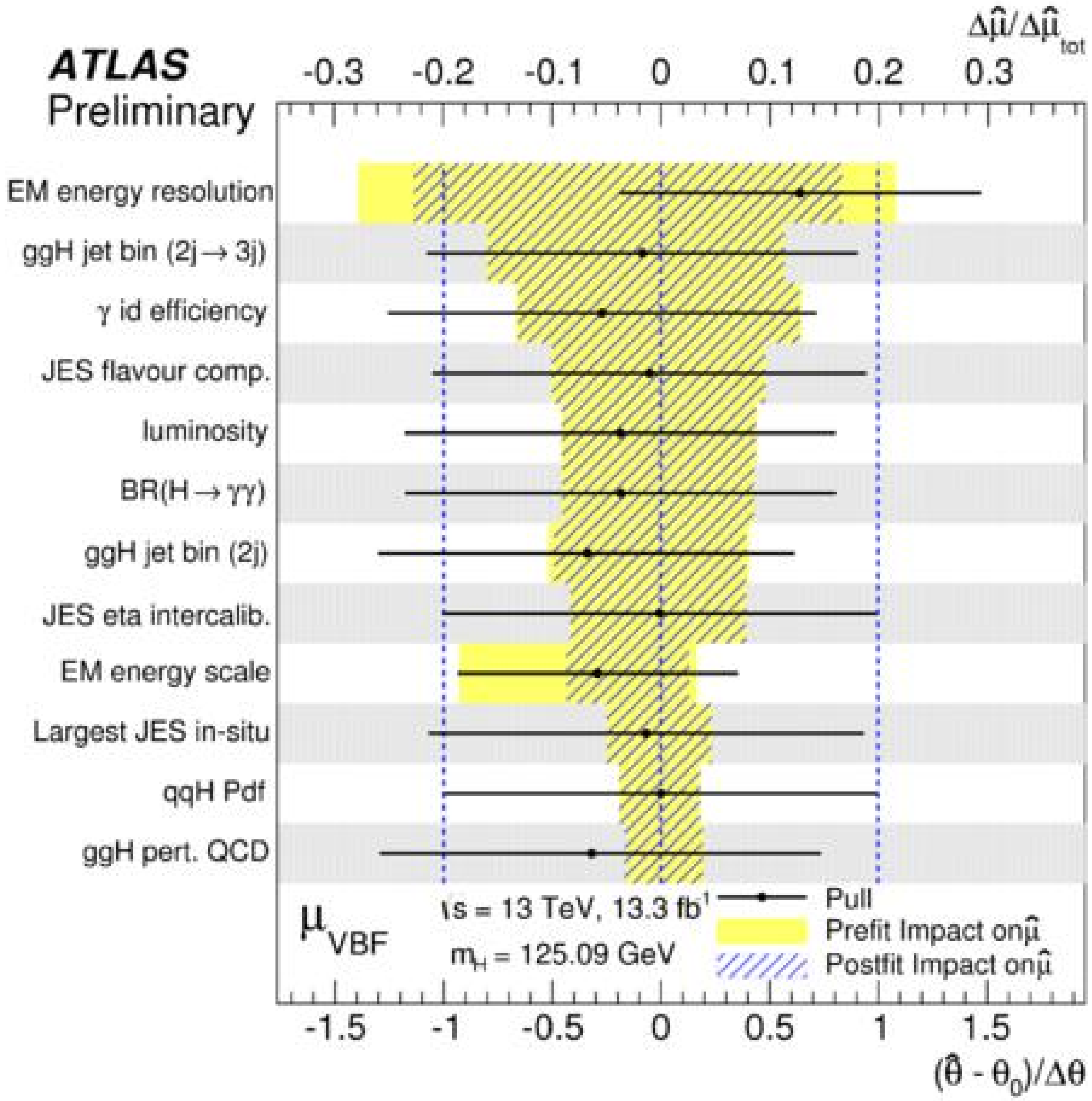


- the red and green show the difference between observation and SM prediction
- observed signal strength is 124% larger than SM, but within 2 sigma

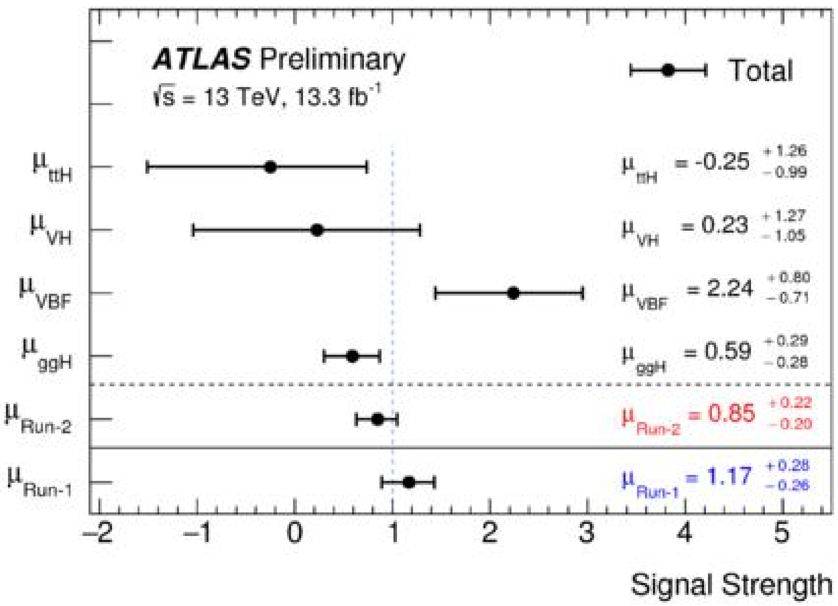
$$\mu_{VBF} = 2.24^{+0.80}_{-0.71}$$

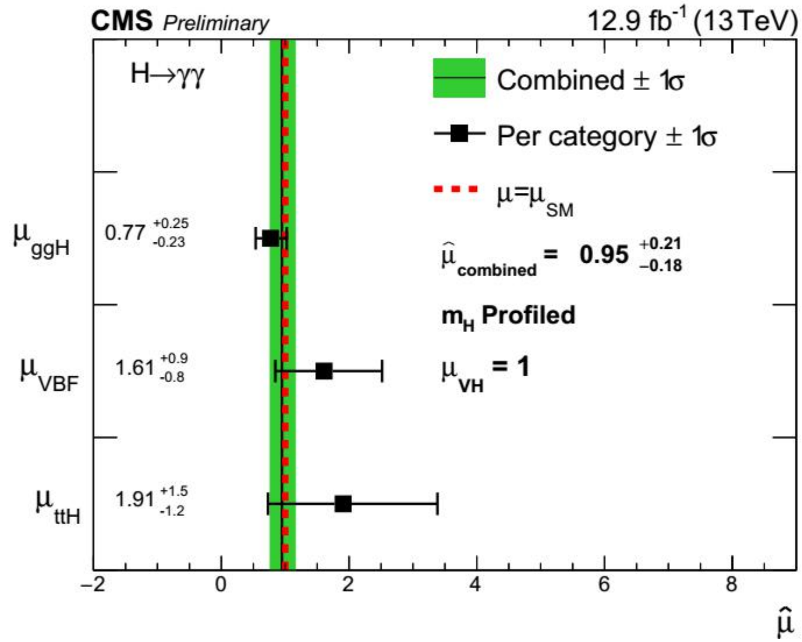
systematic of VBF

- mass fixed to 125.09 GeV



result with 2015+2016 data





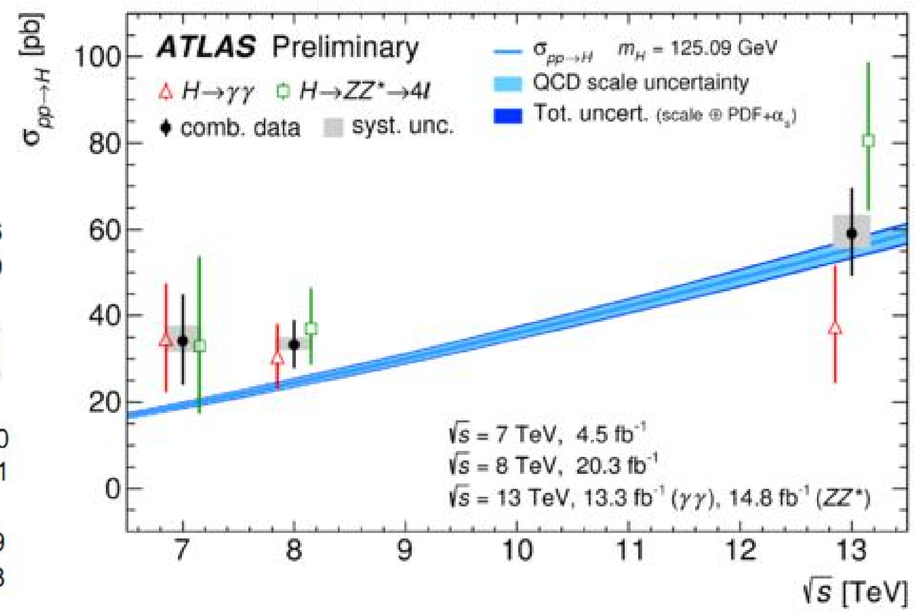
- combind signal strength is consistent with SM

$$\mu_{ttH} = -0.25 \,{}^{+1.26}_{-0.99}$$

$$\mu_{VH} = 0.23 \,{}^{+1.27}_{-1.05}$$

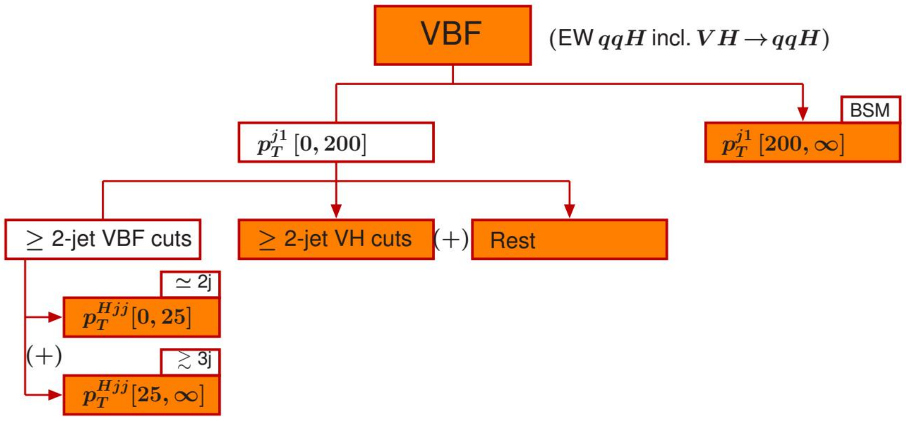
$$\mu_{VBF} = 2.24 \,{}^{+0.80}_{-0.71}$$

$$\mu_{ggH} = 0.59 \,{}^{+0.29}_{-0.28}$$



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 derivation with respect to SM and investigate the Higgs property
- Next step
  - categorization for Simplified Template X-Section (STXS) stage 1
- Reference:



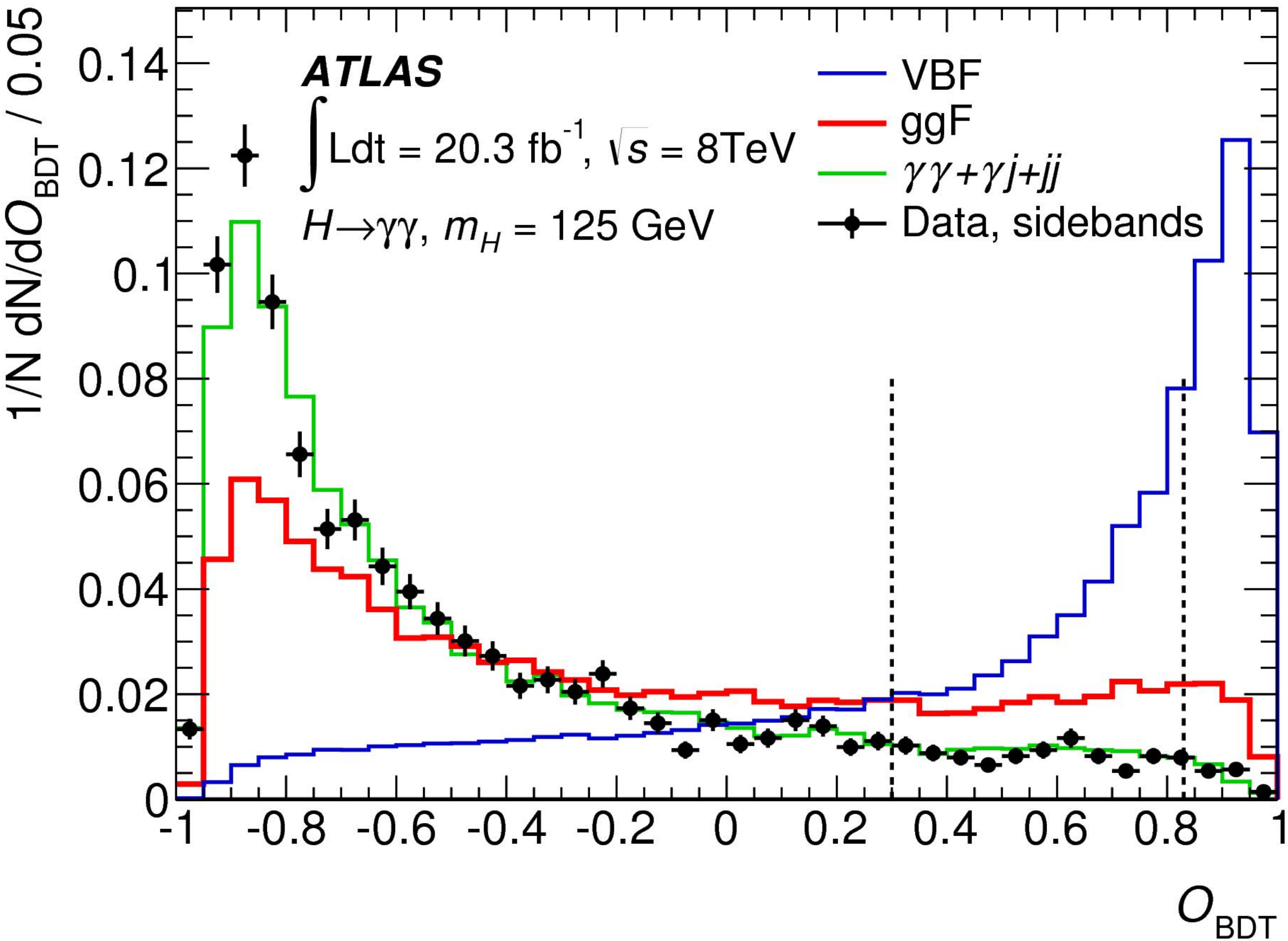
ATLAS-CONF-2016-067

ATLAS-CONF-2016-081

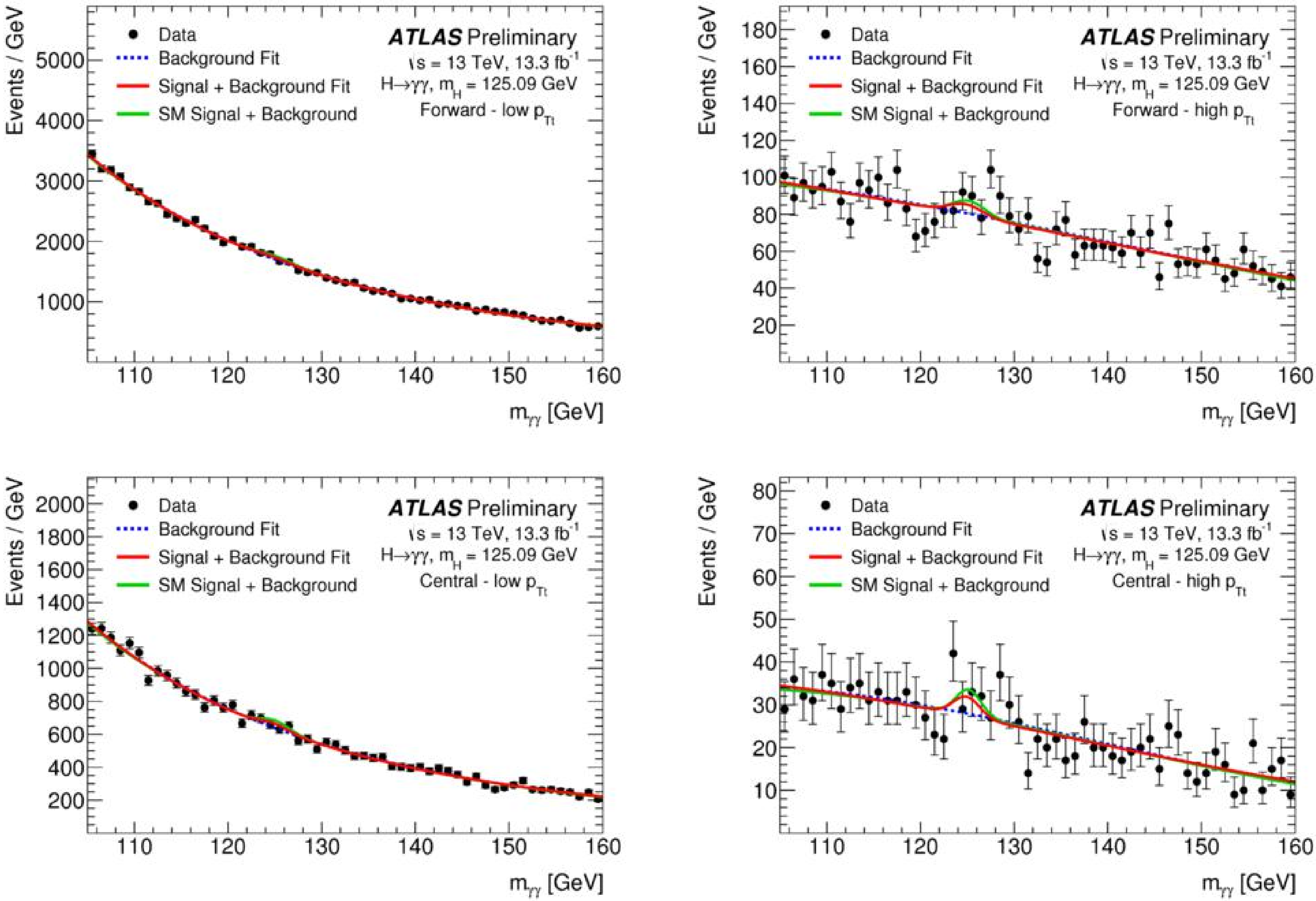
CMS-PAS-HIG-16-020

back up

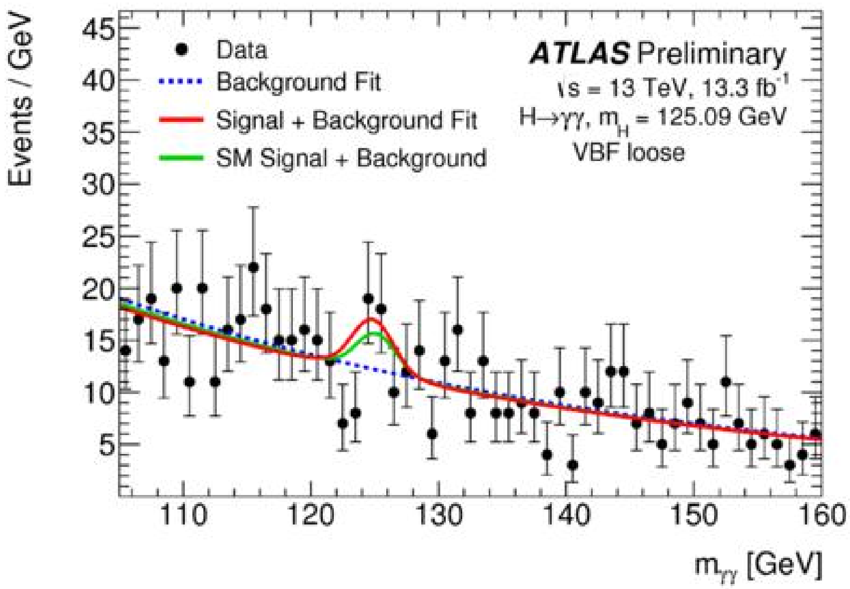
BDT in Run1

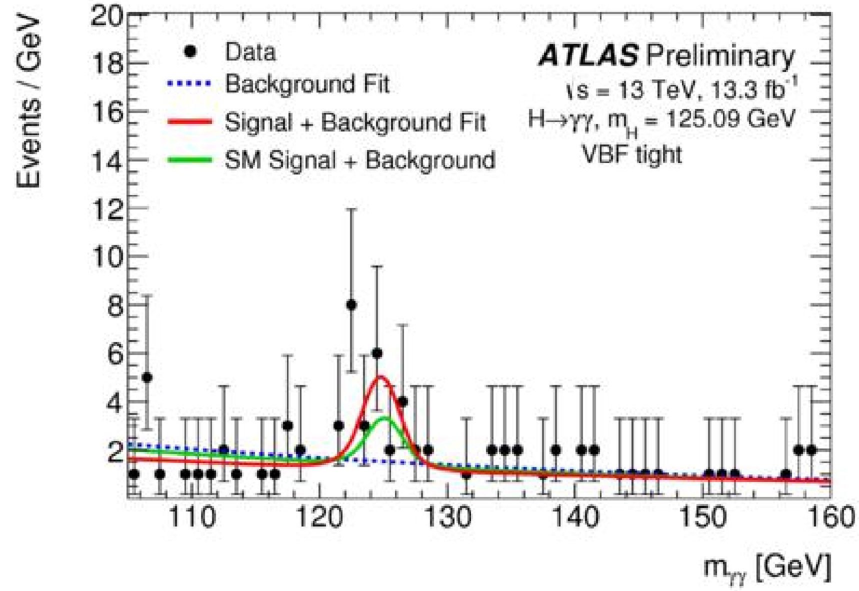

ATLAS
$\int Ldt = 20.3\ fb^{-1}$, $\sqrt{s} = 8$TeV
$H\rightarrow\gamma\gamma$, m_H = 125 GeV
VBF
ggF
$\gamma\gamma+\gamma j+jj$
Data, sidebands
1/N dN/dO_{BDT} / 0.05
O_{BDT}
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

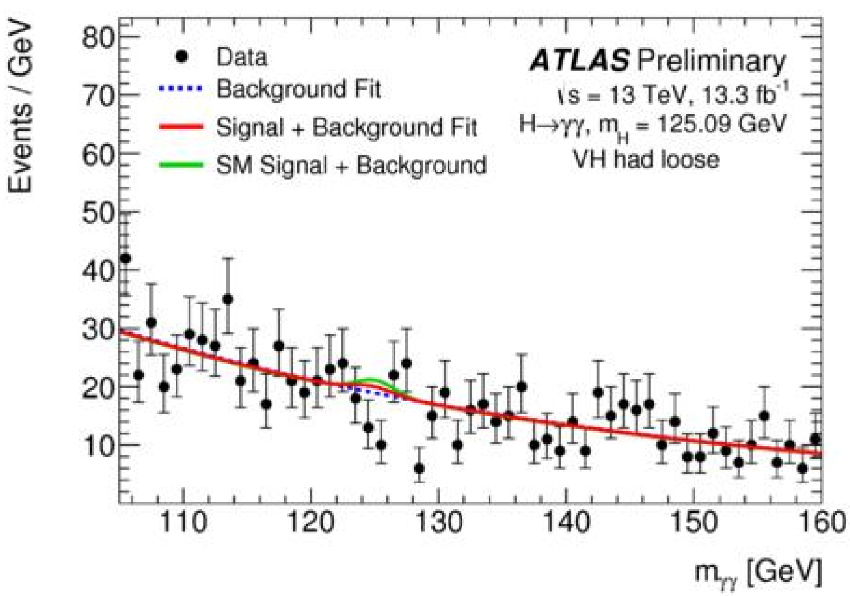
m γ γ distribution

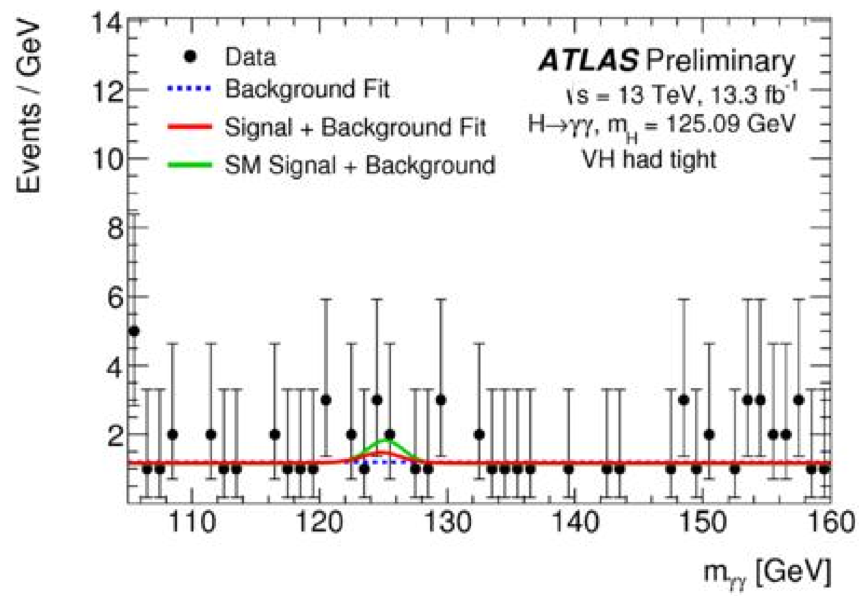


m γ γ distribution

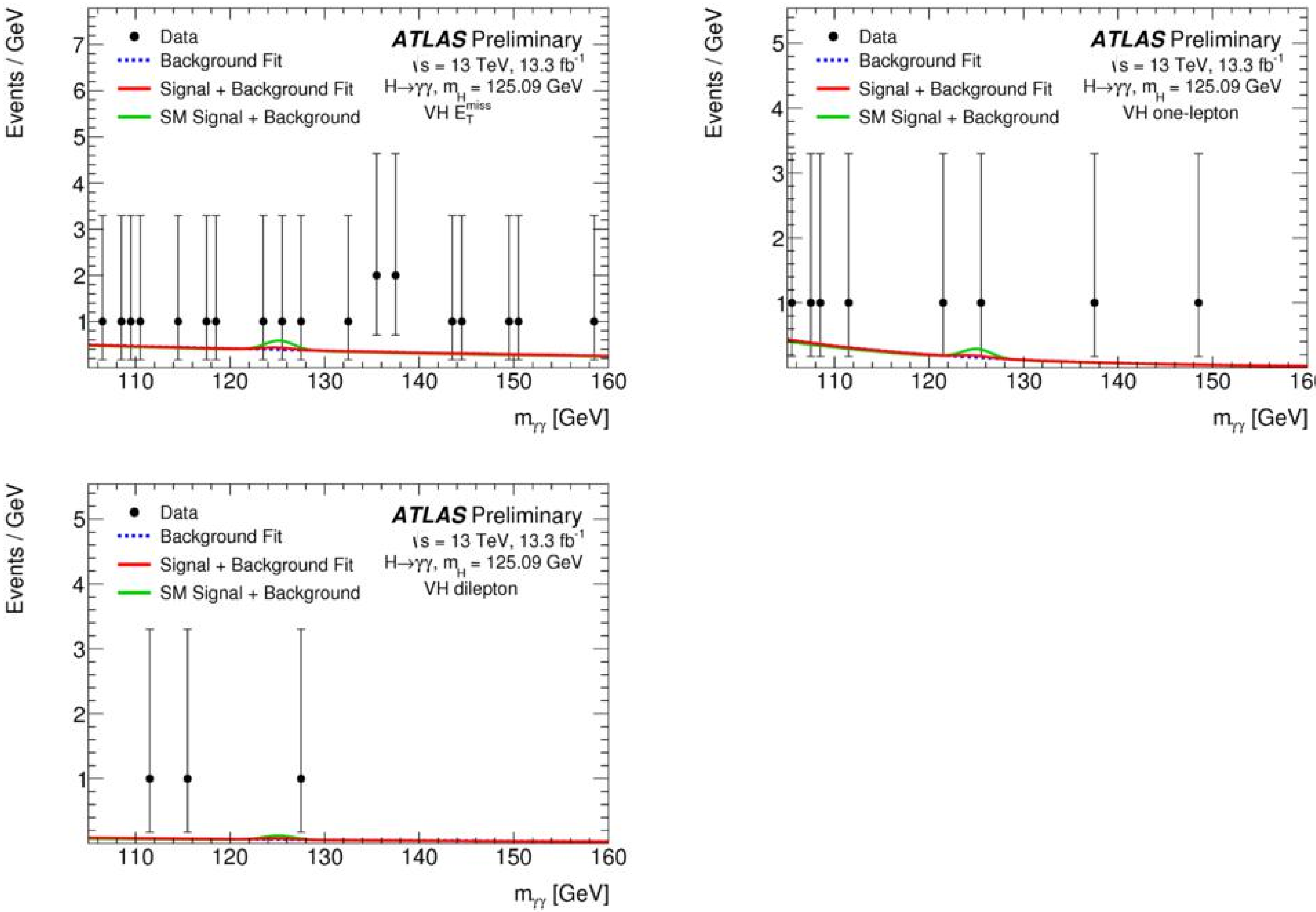




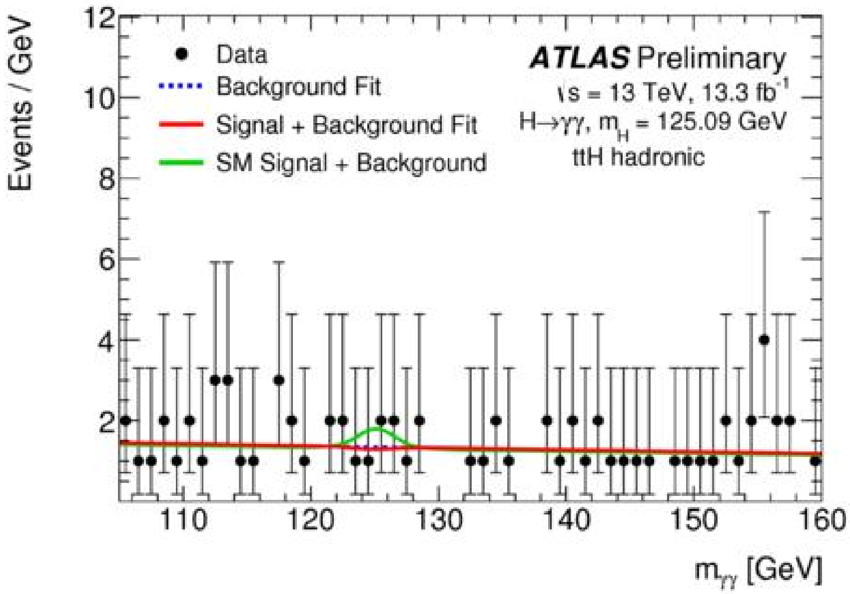


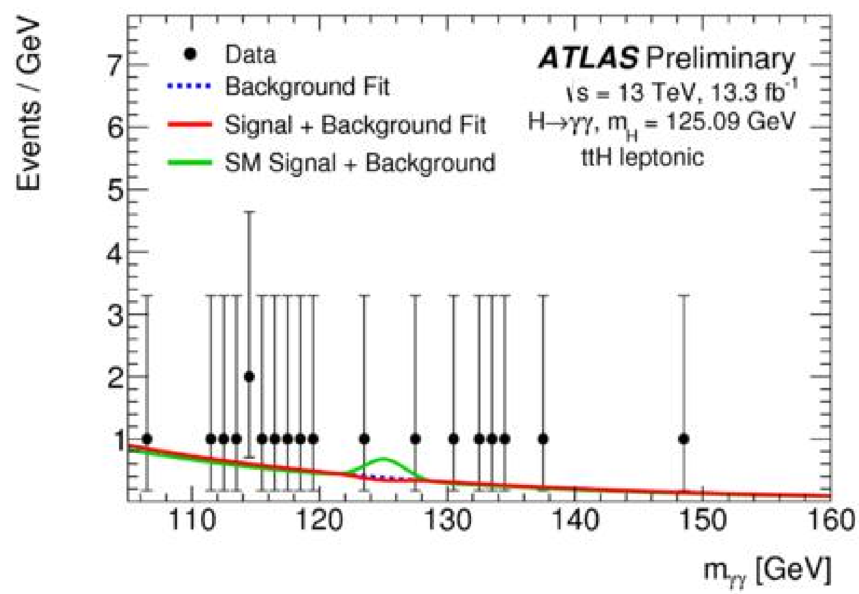


m γ γ distribution

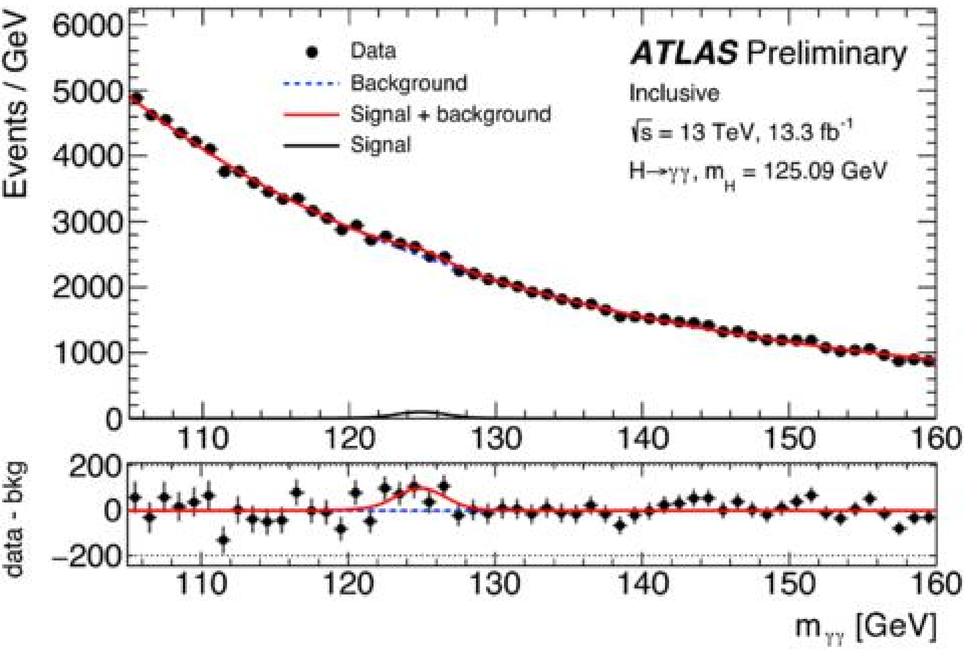


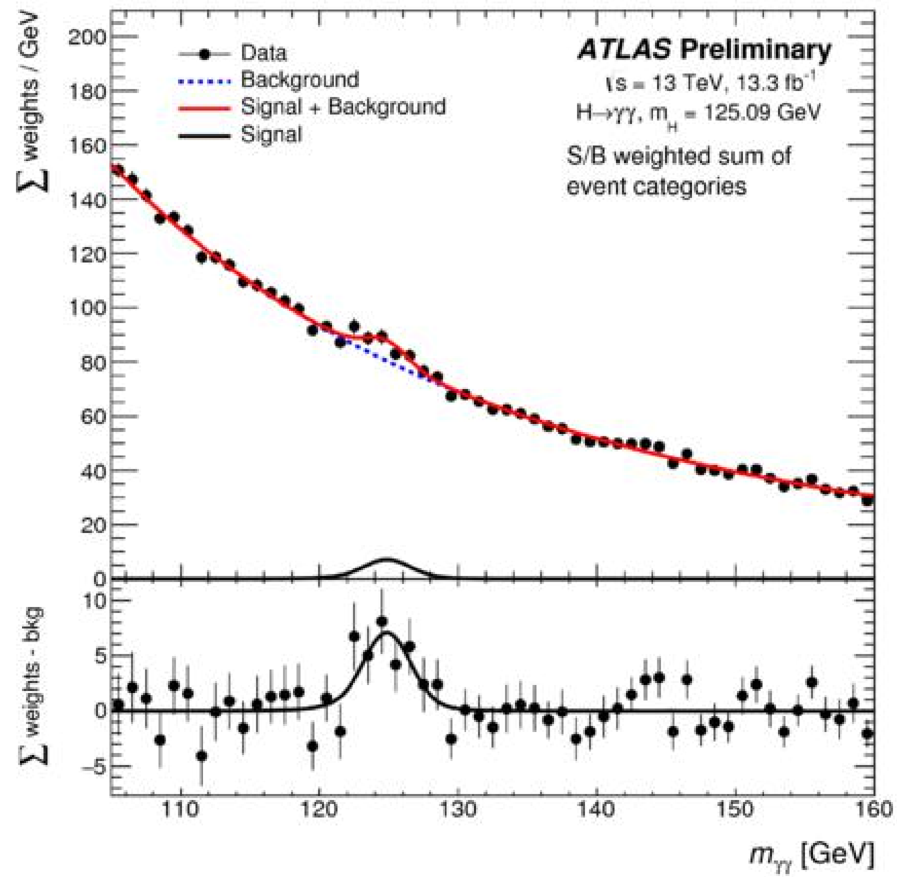
m γ γ distribution





inclusive


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


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