Measurement of Higgs properties in diphoton channel in ATLAS

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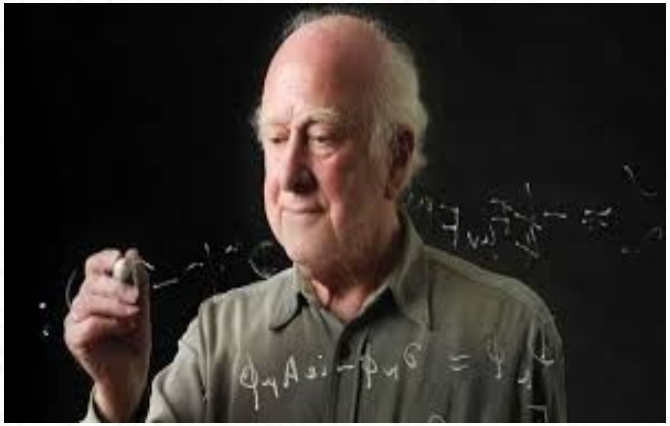
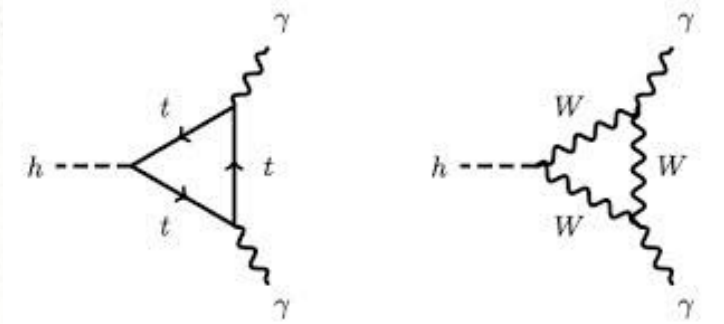
Introduction

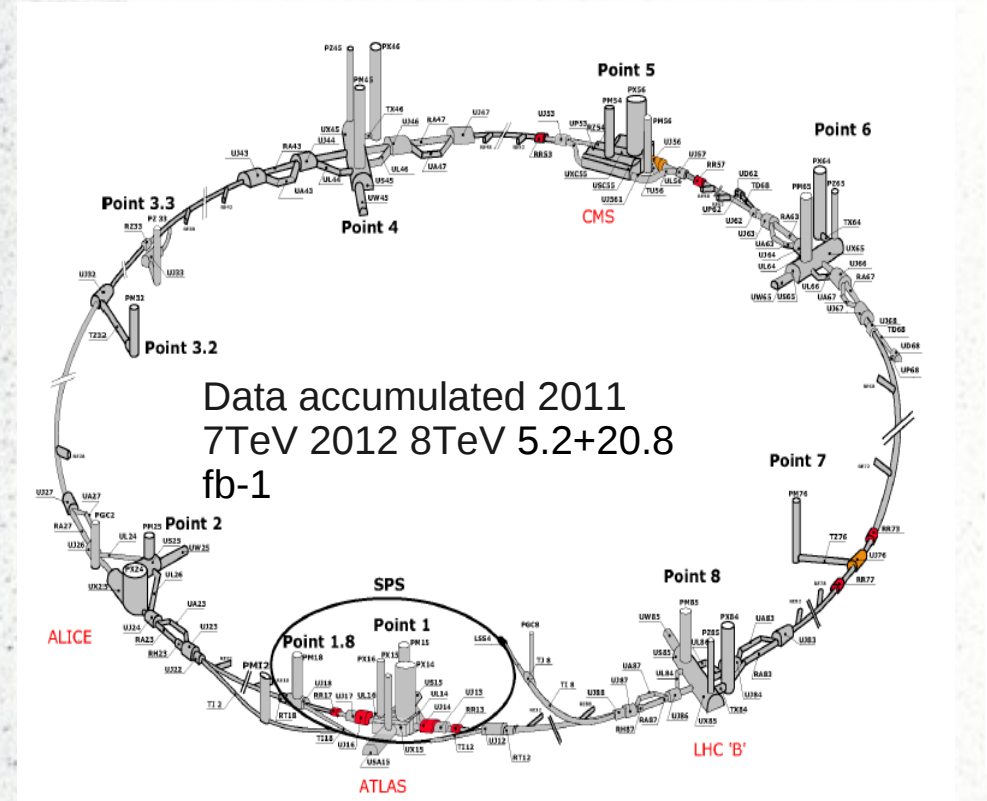
Higgs discovered in 2012

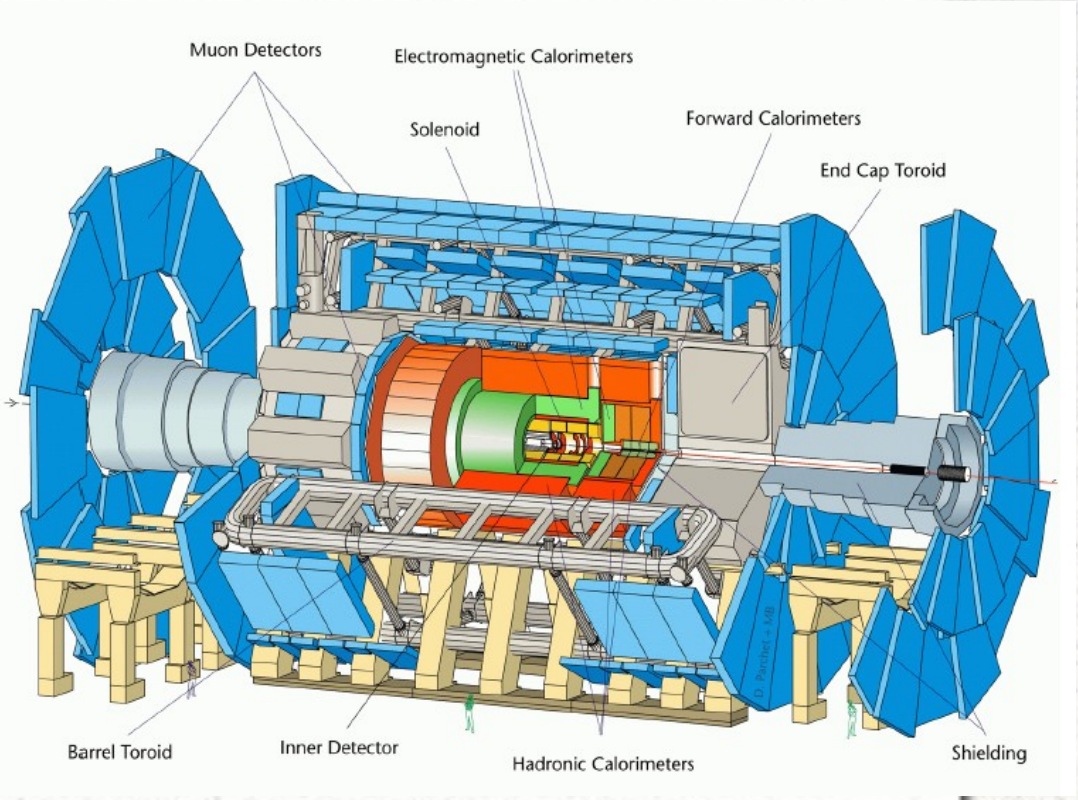


More work? Measurements on:
Coupling
Mass
Differential xsection
Fiducial xsection
In two photon final state



LHC and ATLAS detector





ATLAS detector:

- Inner detector
- EM calorimeter
- Hadronic calorimeter
- Muon Spectrometer
- Magnet system
- Trigger
- DAQ system

Measurements:

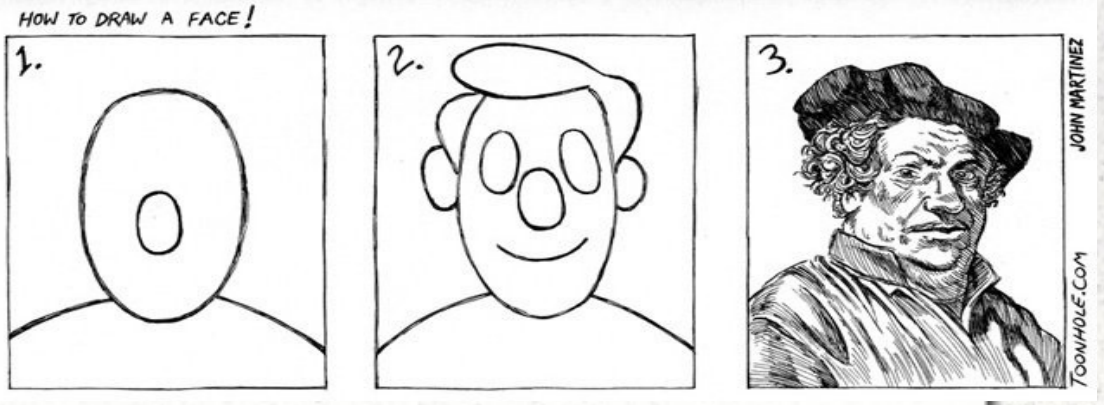
- Track (ID, MS)
- Energy
- Position of vertices

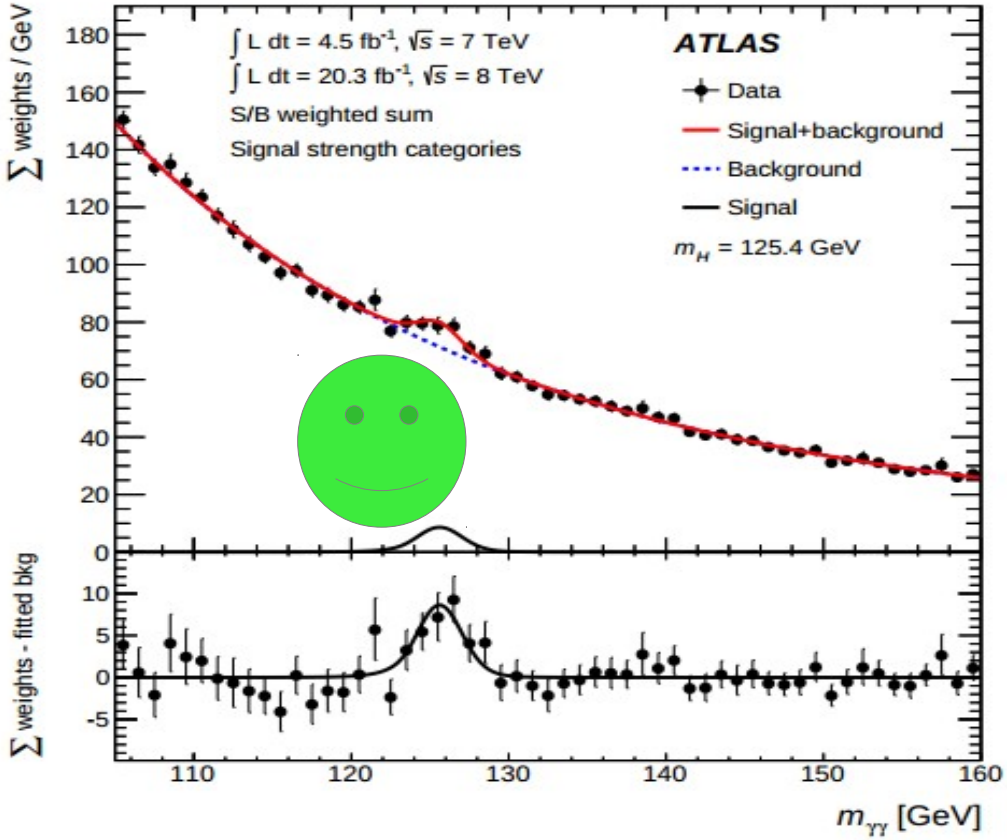
Objects provided:

- Electron
- Muons
- **Photons**
- Jets
- Transverse missing energy (MET)

The mass spectrum

- Find Higgs?
  - 1) At least two photons
  - 2) well identified and isolated
  - 3) Invariant mass peak!





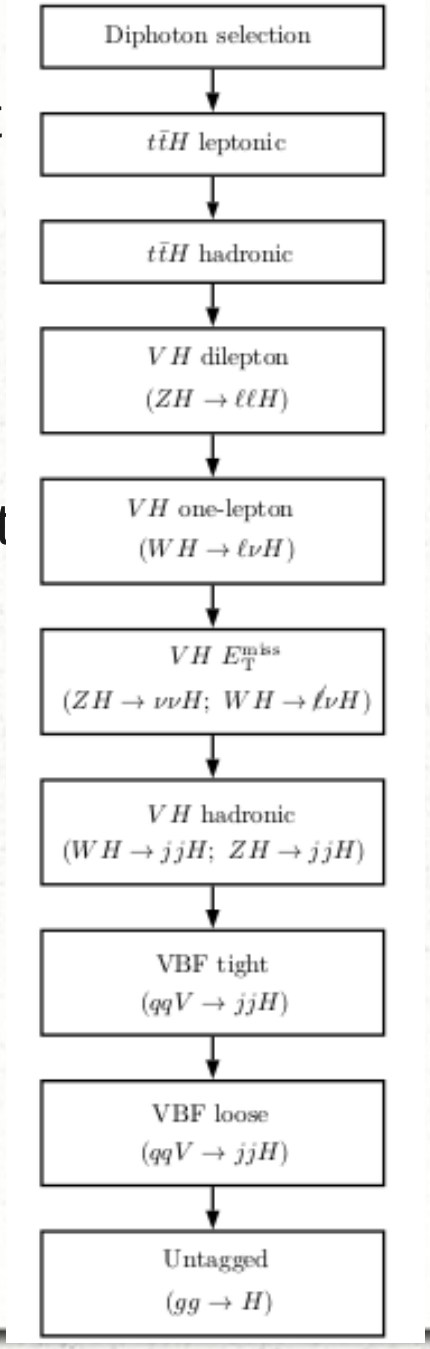
What can a mass peak do?
a) compare to the MonteCarlo Event yields—Coupling
b) Measure the position of mass peak
c) Measure event yields in a dedicated bins/phase space—differential measurement

Categorization

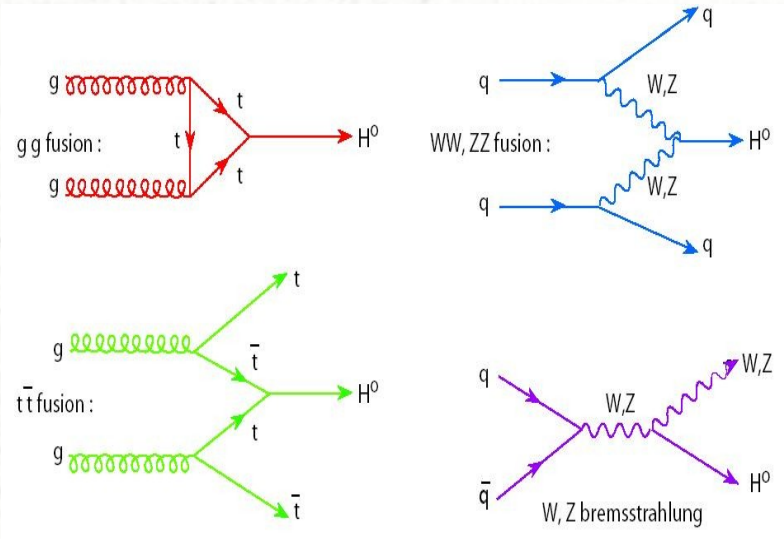
We have the invariant mass spectrum in many categories instead an inclusive one

Dedicated for different physics region,
VBF enriched,
VH enriched,
ttH enriched.....

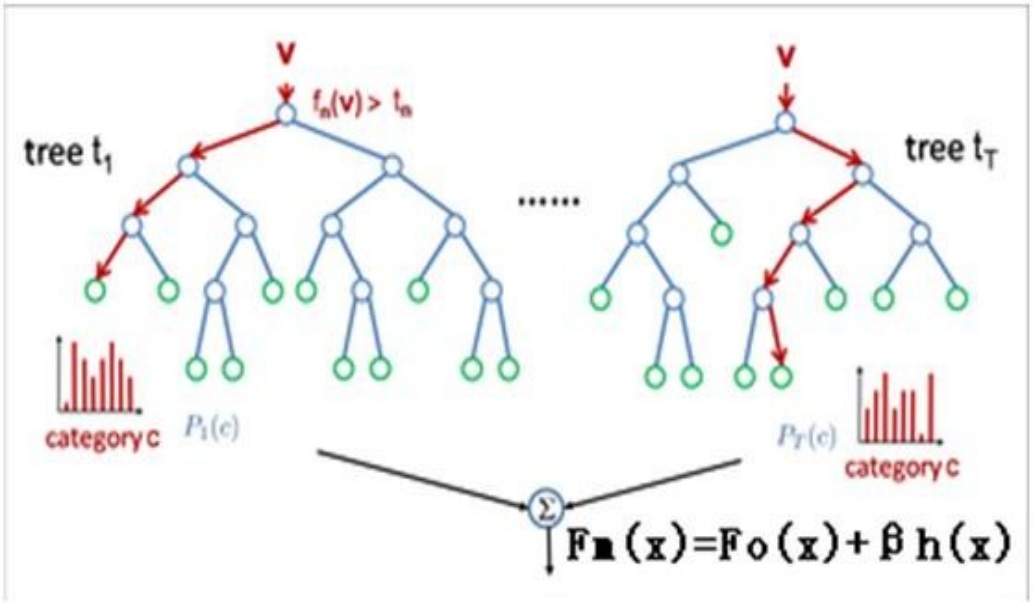
Bring more complicity



To measure the different Higgs production mode

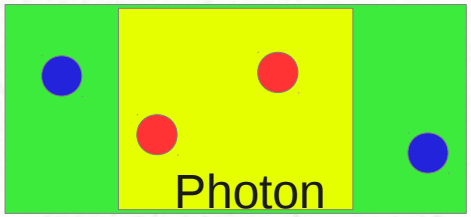


MultiVariate Analysis in Vector Boson Fusion categories



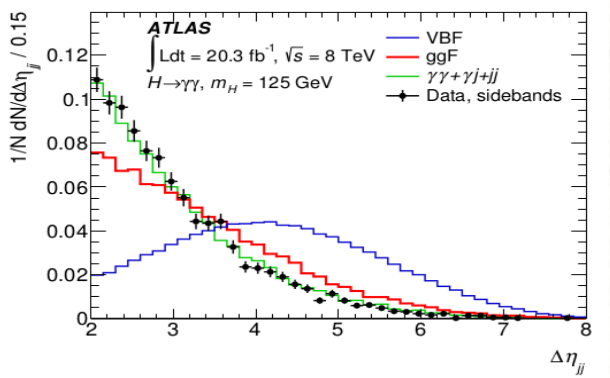
Treat complicated situation, 2 photon + 2 forward jets

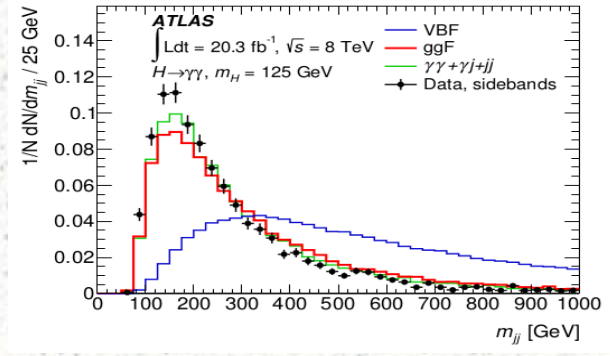
jets

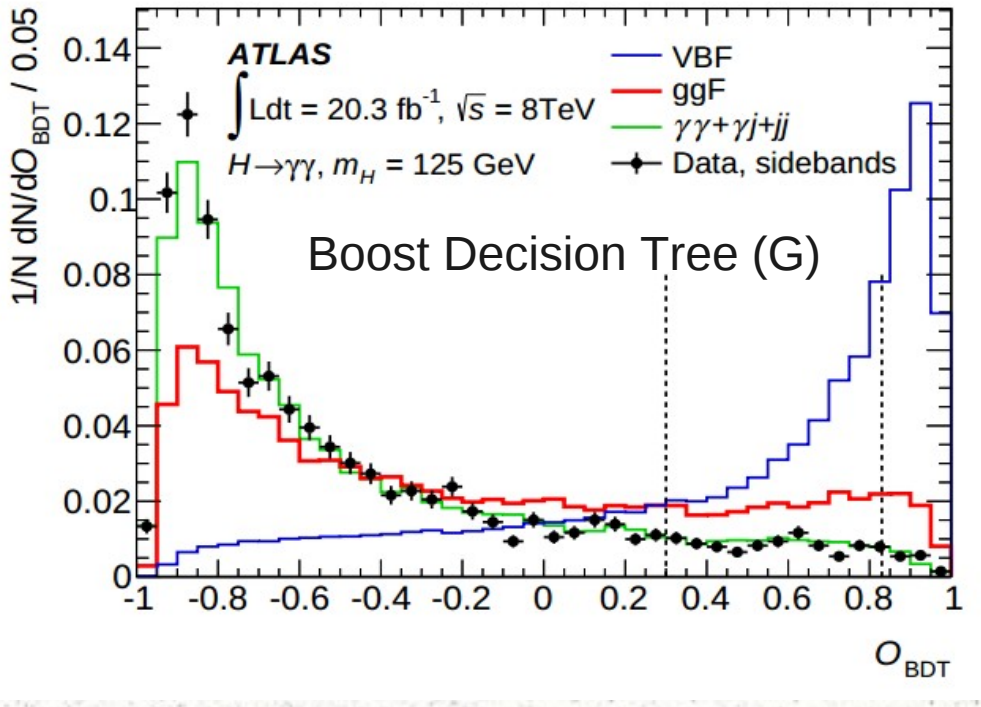


Pseudo Rapidity

6 Kinematic variables







Higgs mass and coupling measurement

Fit all categories simultaneously, immediately we have:

$$\mu_{\mathrm{ggF}} = 1.32 \pm 0.32\ (\mathrm{stat.})\ ^{+0.13}_{-0.09}\ (\mathrm{syst.})\ ^{+0.19}_{-0.11}\ (\mathrm{theory}) = 1.32 \pm 0.38,$$

$$\mu_{\mathrm{VBF}} = 0.8 \pm 0.7\ (\mathrm{stat.})\ ^{+0.2}_{-0.1}\ (\mathrm{syst.})\ ^{+0.2}_{-0.3}\ (\mathrm{theory}) = 0.8 \pm 0.7,$$

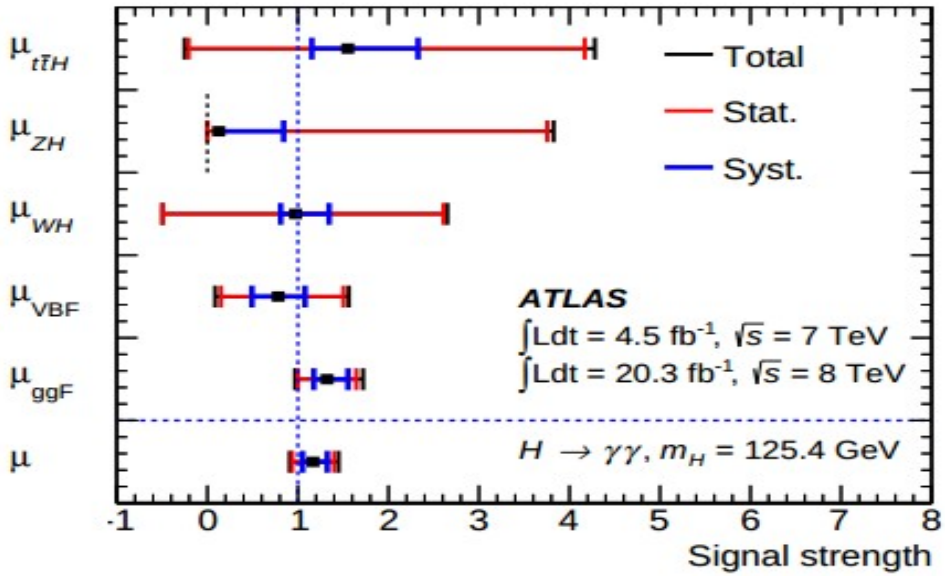
$$\mu_{WH} = 1.0 \pm 1.5\ (\mathrm{stat.})\ ^{+0.3}_{-0.1}\ (\mathrm{syst.})\ ^{+0.2}_{-0.1}\ (\mathrm{theory}) = 1.0 \pm 1.6,$$

$$\mu_{ZH} = 0.1\ ^{+3.6}_{-0.1}\ (\mathrm{stat.})\ ^{+0.7}_{-0.0}\ (\mathrm{syst.})\ ^{+0.1}_{-0.0}\ (\mathrm{theory}) = 0.1\ ^{+3.7}_{-0.1},$$

$$\mu_{t\bar{t}H} = 1.6\ ^{+2.6}_{-1.8}\ (\mathrm{stat.})\ ^{+0.6}_{-0.4}\ (\mathrm{syst.})\ ^{+0.5}_{-0.2}\ (\mathrm{theory}) = 1.6\ ^{+2.7}_{-1.8}.$$

Signal strength of different production mode are measured

The Higgs mass is measured as well, using data in Higgs to diphoton and four-lepton channel.

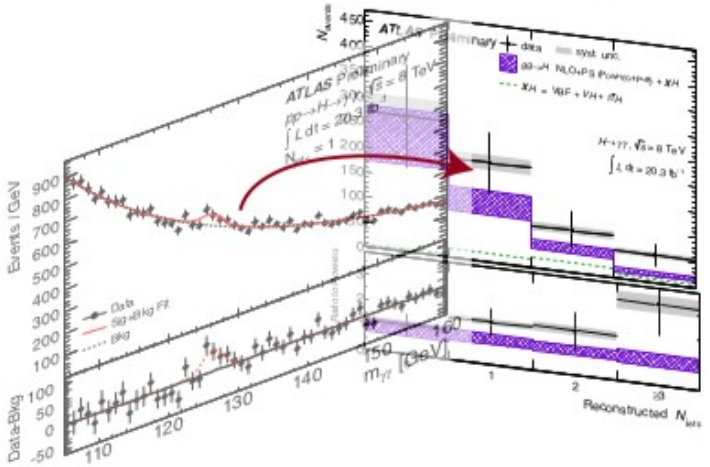


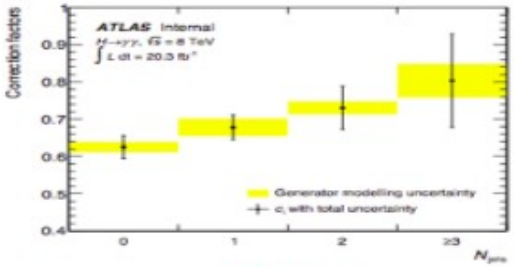
Channel	Mass measurement [GeV]
$H \to \gamma\gamma$	$125.98 \pm 0.42\,(\mathrm{stat}) \pm 0.28\,(\mathrm{syst}) = 125.98 \pm 0.50$
$H \to ZZ^* \to 4\ell$	$124.51 \pm 0.52\,(\mathrm{stat}) \pm 0.06\,(\mathrm{syst}) = 124.51 \pm 0.52$
Combined	$125.36 \pm 0.37\,(\mathrm{stat}) \pm 0.18\,(\mathrm{syst}) = 125.36 \pm 0.41$

Differential measurement

I

Reco-level Fiducial





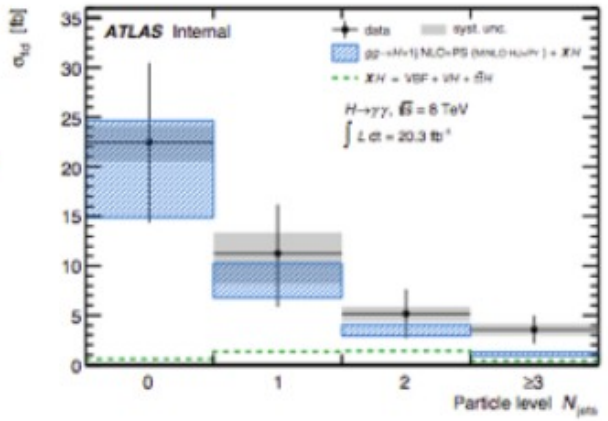
unfolding

$$\sigma_i = \frac{\nu_i^{\mathrm{sig}}}{c_i \int \mathcal{L}\ \mathrm{d}t},$$

II

III

Particle-level Fiducial



- Steps:
  - I. Measure the Higgs boson yields in differential bins by fitting the data invariant mass spectrum.
    - Now we have the Higgs yields distribution
  - II. use bin by bin method to unfold the detector effect.
    - This is to remove detector effect, reconstruction level->particle level
  - III. Divided by the luminosity, convert event yields to cross section
    - Now ready to compare with the theoretical prediction

NP Corr.

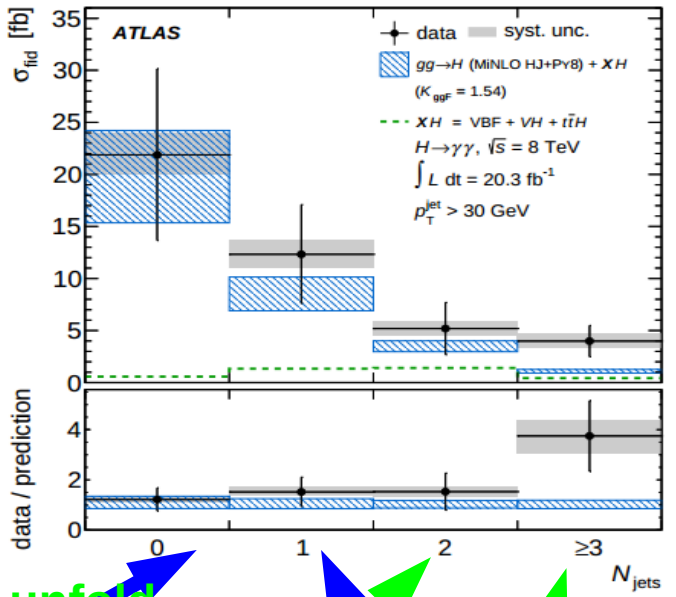
Parton-level Fiducial

Fid. Corr.

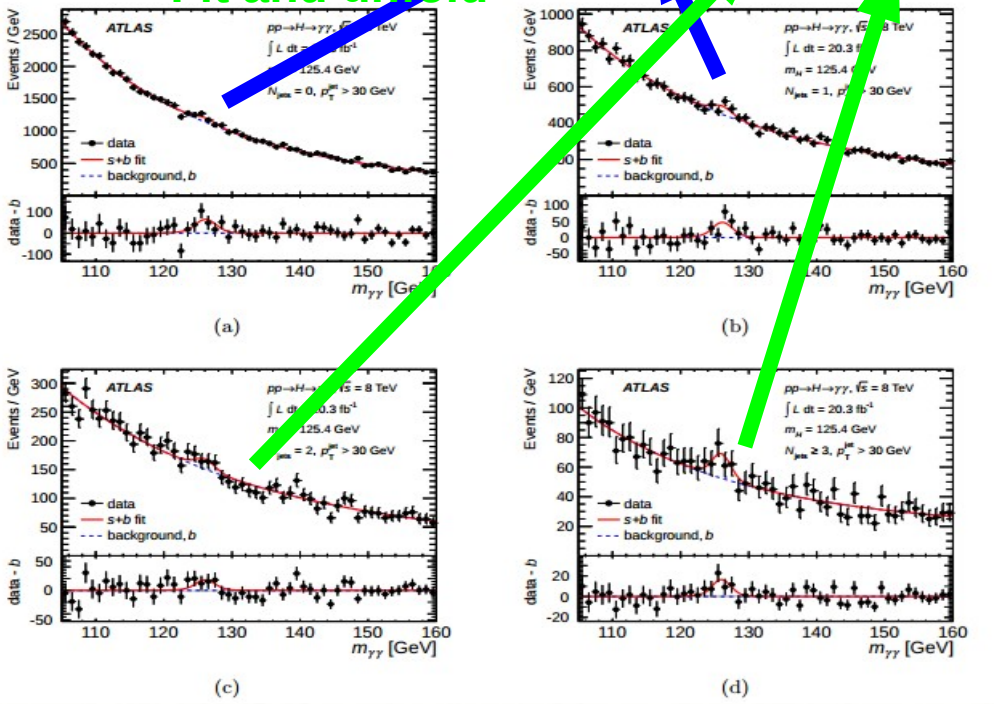
Parton-level Inclusive

Binning and variables

Variable	Binning	N_{bins}
$N_{\text{jets}}(p_T > 30\ \text{GeV})$	$\{0, 1, 2, \geq 3\}$	4
$p_{\text{T}\gamma\gamma}$	$\{0, 20, 30, 40, 50, 60, 80, 100, 200\}$ GeV	8 + rest
$\lvert y_{\gamma\gamma}\rvert$	$\{0.0, 0.3, 0.6, 0.9, 1.2, 1.6, 2.4\}$	6
$\lvert\cos\theta^*\rvert$	$\{0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0\}$	10
$p_{\text{T,jet1}}$	$\{0, 30, 50, 70, 100, 140\}$	5 + rest
m_{jj}	$\{0, 200, 400, 650, 1000\}$	4 + rest
$H_{\text{T,jets}}$	$\{0, 30, 50, 70, 150, 250\}$	5 + rest
$N_{\text{jets}}(p_T > 50\ \text{GeV})$	$\{0, 1, 2, \geq 3\}$	4
$\lvert y_{\text{jet1}}\rvert$	$\{0.0, 1.0, 2.0, 3.0, 4.4\}$	4 + rest
$p_{\text{T,jet2}}$	$\{0, 30, 50, 70, 140\}$	4 + rest
$\Delta\phi_{\text{jj}}$	$\{0.0, \pi/3, 2\pi/3, 5\pi/6, \pi\}$	4 + rest
$\Delta\phi_{\gamma\gamma,\text{jj}}$	$\{0.0, 2.6, 2.9, 3.1, \pi\}$	4 + rest

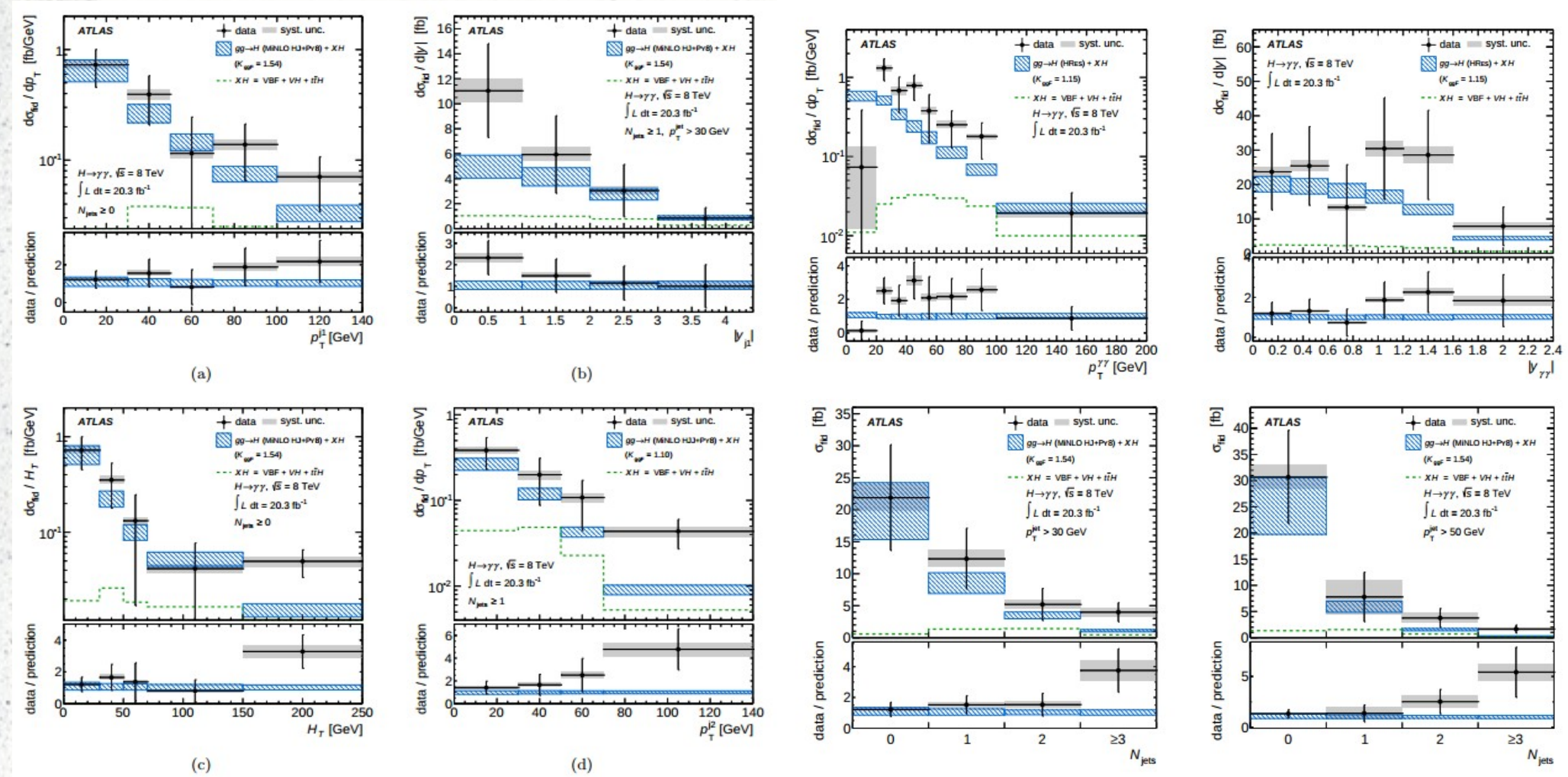


Fit and unfold

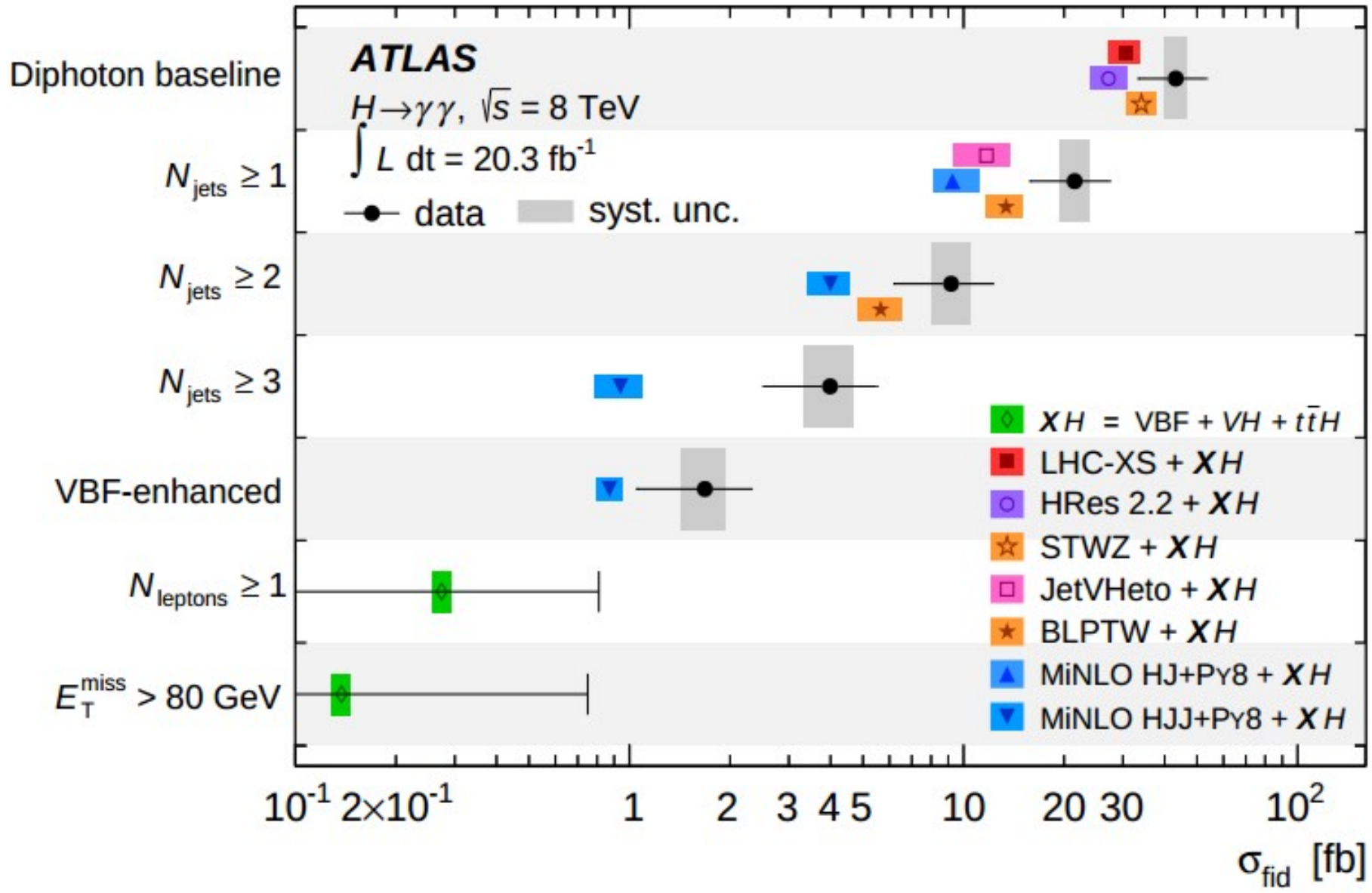


- Higgs kinematics
- Spin C-P variable
- Jet activity
- VBF sensitive variables

Differential cross section



Fiducial cross section



Fiducial volume

- 2 photons $p_{T\gamma1}(p_{T\gamma2})/m_{\gamma\gamma}>0.35(0.25)105<m\gamma\gamma<160$GeV

Fiducial cross section results

Fiducial region	Measured cross section (fb)
Baseline	$43.2 \pm 9.4\,(\text{stat.})\,^{+3.2}_{-2.9}\,(\text{syst.}) \pm 1.2\,(\text{lumi})$
$N_{\text{jets}} \geq 1$	$21.5 \pm 5.3\,(\text{stat.})\,^{+2.4}_{-2.2}\,(\text{syst.}) \pm 0.6\,(\text{lumi})$
$N_{\text{jets}} \geq 2$	$9.2 \pm 2.8\,(\text{stat.})^{+1.3}_{-1.2}\,(\text{syst.}) \pm 0.3\,(\text{lumi})$
$N_{\text{jets}} \geq 3$	$4.0 \pm 1.3\,(\text{stat.}) \pm 0.7\,(\text{syst.}) \pm 0.1\,(\text{lumi})$
VBF-enhanced	$1.68 \pm 0.58\,(\text{stat.})^{+0.24}_{-0.25}\,(\text{syst.}) \pm 0.05\,(\text{lumi})$
$N_{\text{leptons}} \geq 1$	< 0.80
$E_{\text{T}}^{\text{miss}} > 80$ GeV	< 0.74

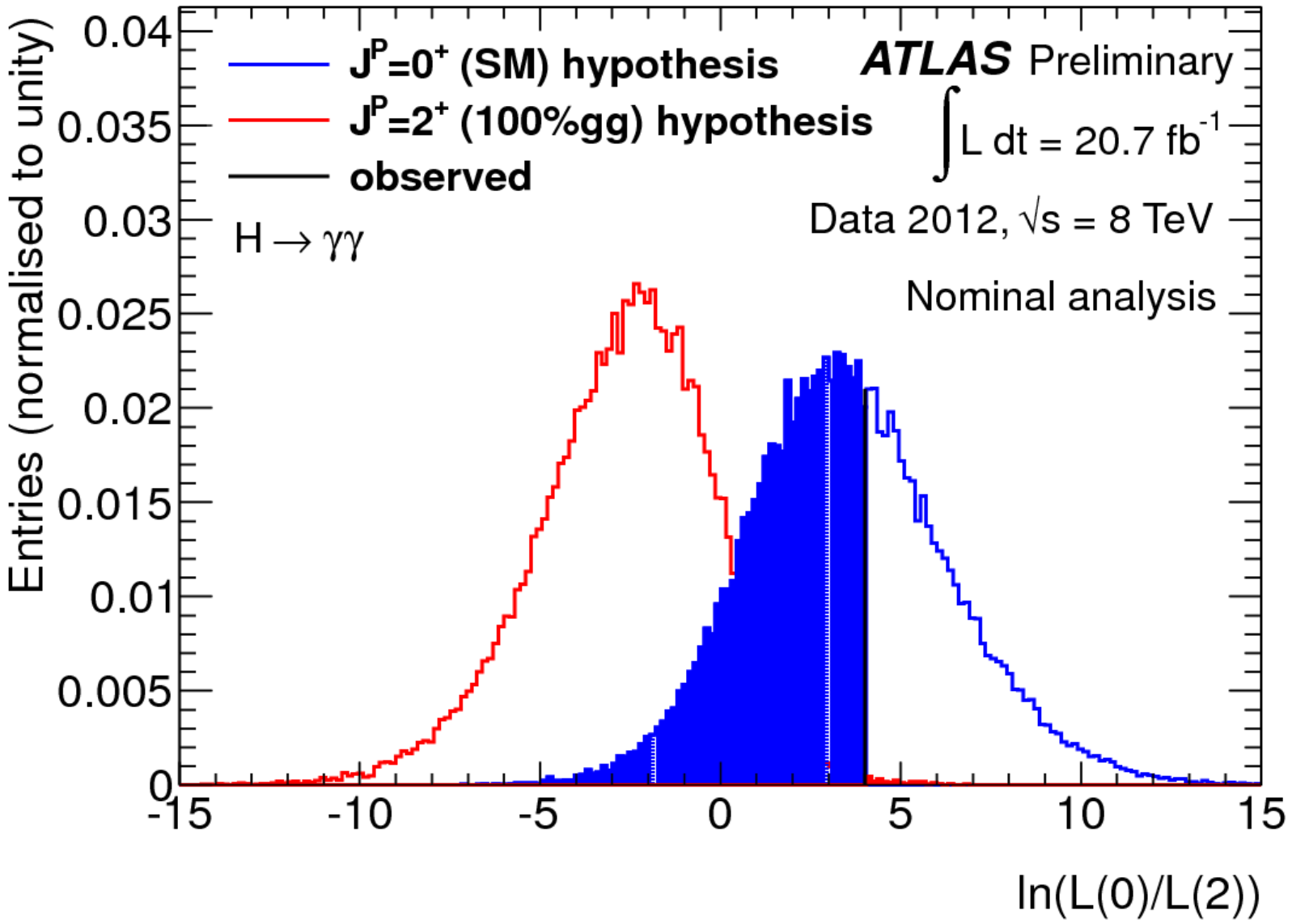
Fiducial region	Theoretical prediction (fb)	Source
Baseline	30.5 ± 3.3	LHC-XS [57] + XH
	$34.1\,^{+3.6}_{-3.5}$	STWZ [99] + XH
	$27.2\,^{+3.6}_{-3.2}$	HRES [103] + XH
$N_{\text{jets}} \geq 1$	13.8 ± 1.7	BLPTW [106] + XH
	$11.7\,^{+2.0}_{-2.4}$	JetVHeto [107] + XH
	$9.3\,^{+1.8}_{-1.2}$	MINLO HJ + XH
$N_{\text{jets}} \geq 2$	5.65 ± 0.87	BLPTW + XH
	$3.99\,^{+0.56}_{-0.59}$	MINLO HJJ + XH
$N_{\text{jets}} \geq 3$	0.94 ± 0.15	MINLO HJJ + XH
VBF-enhanced	0.87 ± 0.08	MINLO HJJ + XH
$N_{\text{leptons}} \geq 1$	0.27 ± 0.02	XH
$E_{\text{T}}^{\text{miss}} > 80$ GeV	0.14 ± 0.01	XH

Conclusion

- The measurement on Higgs boson properties benefits from the two photon invariant mass peak.
- The 2011 and 2012 data taking in ATLAS provided fruitful discoveries and measurement, including the coupling, mass, differential and fiducial cross section measrement.
- Looking forward to 2015 data taking and any possible new physics.

Back up

Spin analysis



Nominal MC samples

Process	Generator	Showering	PDF set	Order of calculation	σ[pb] $\sqrt{s} = 7$ TeV	σ[pb] $\sqrt{s} = 8$ TeV
ggF	POWHEG-BOX	PYTHIA8	CT10	NNLO(QCD)+NLO(EW)	15.04	19.15
VBF	POWHEG-BOX	PYTHIA8	CT10	NLO(QCD+EW)+app.NNLO(QCD)	1.22	1.57
WH	PYTHIA8	PYTHIA8	CTEQ6L1	NNLO(QCD)+NLO(EW)	0.57	0.70
ZH	PYTHIA8	PYTHIA8	CTEQ6L1	NNLO(QCD)+NLO(EW)	0.33	0.41
$t\bar{t}H$	POWHEL	PYTHIA8	CT10	NLO(QCD)	0.09	0.13
$tHbj$	MADGRAPH	PYTHIA8	CT10	NLO(QCD)	0.01	0.02
tHW	MADGRAPH5_AMC@NLO	HERWIG++	CT10	NLO(QCD)	<0.01	<0.01
$b\bar{b}H$	-	-	-	5FS(NNLO)+4FS(NLO)	0.15	0.20

Reference

- Fiducial& differential xsection http://arxiv.org/abs/1407.4222
- Mass: http://arxiv.org/abs/1406.3827
- Coupling: http://arxiv.org/abs/1408.7084