Higgs boson interactions with the gauge sector (ATLAS)

Tomoe Kishimoto (Tomoe.Kishimoto@cern.ch)

on behalf of the ATLAS collaboration

Kobe University

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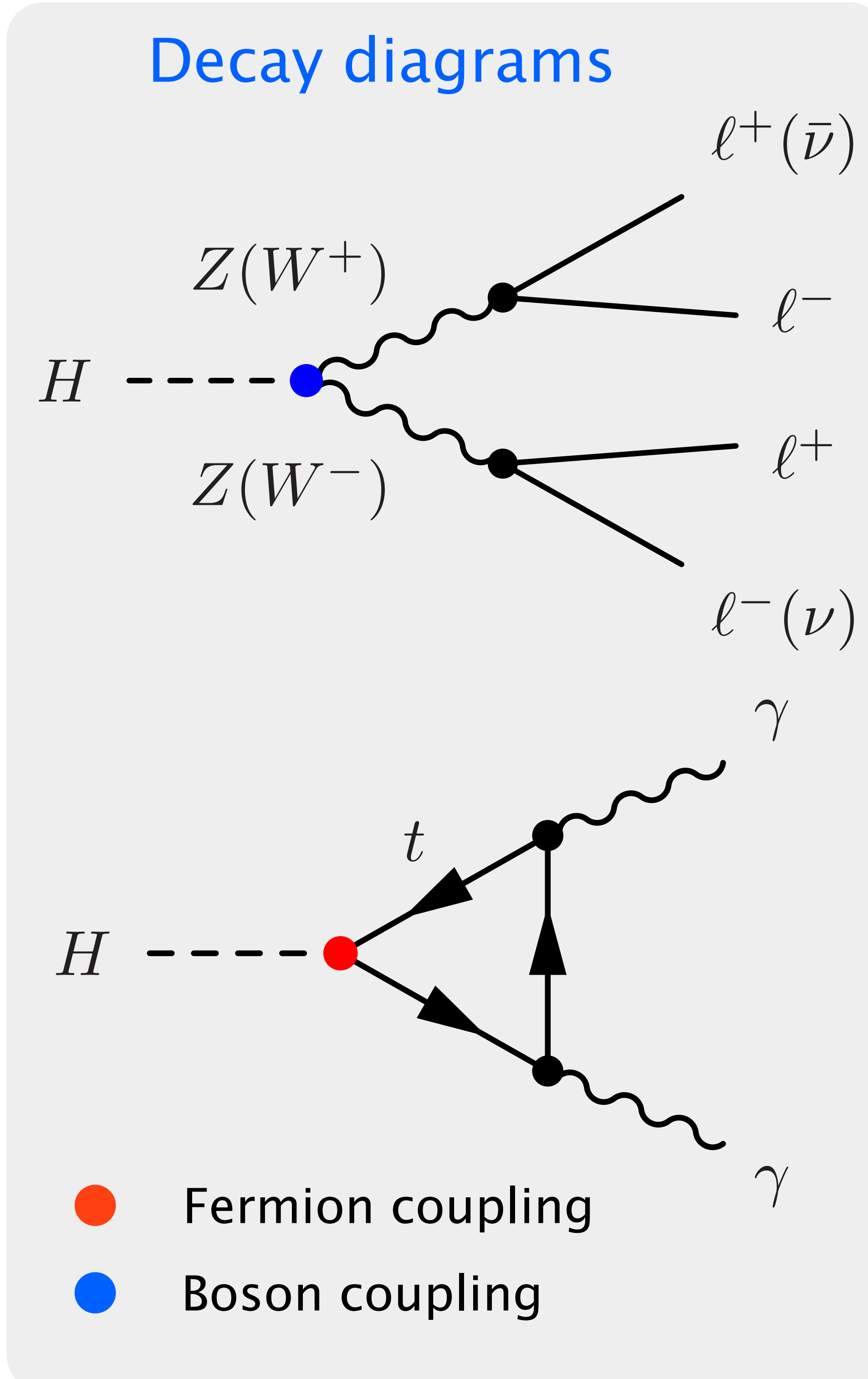
Outline

- ✓ Introduction
- ✓ Experimental techniques and results of μ measurements:
  - ▸ H → ZZ*
  - ▸ H → WW*
  - ▸ H → γγ (Zγ)
- ✓ Conclusions and outlook

* Mass, Spin, differential measurements are covered by other speakers

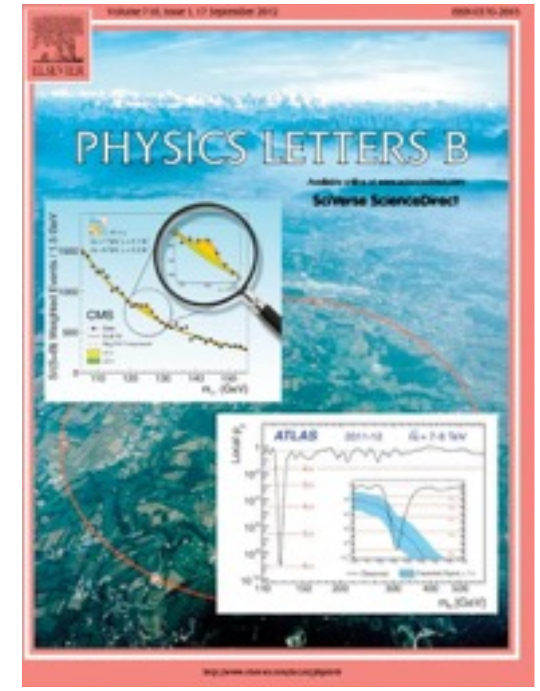


Introduction

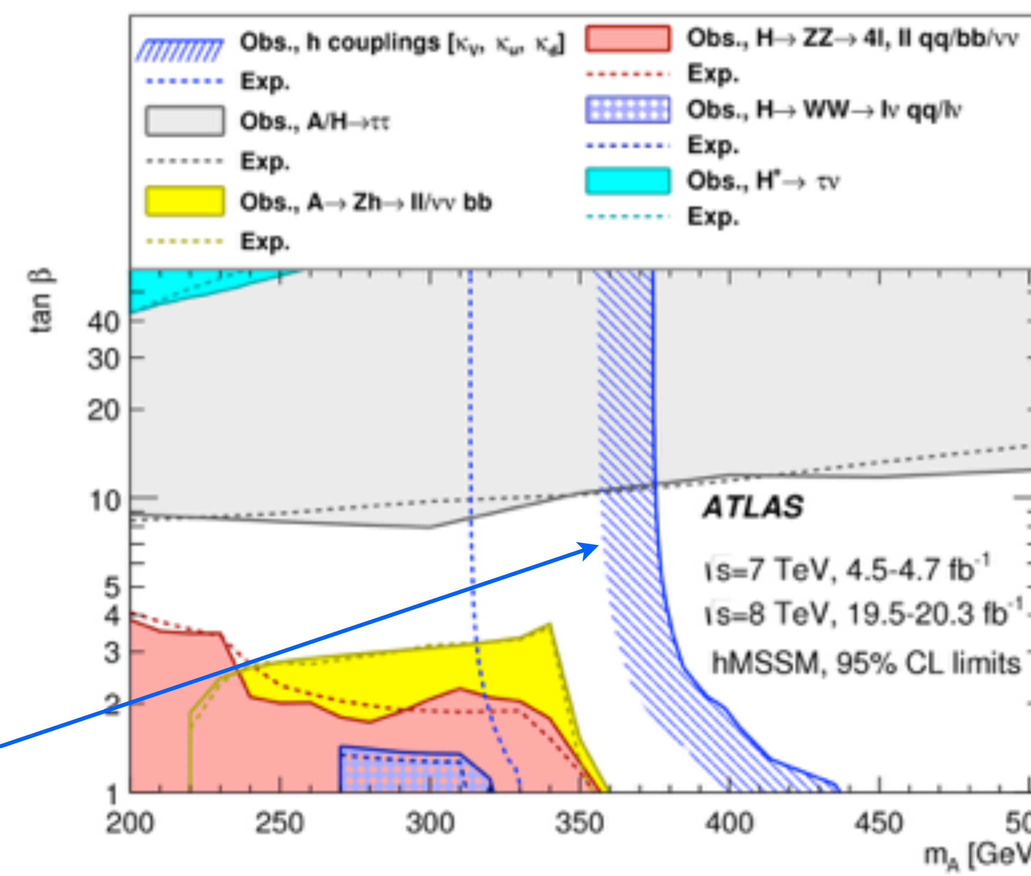
✓ Very successful Run1 at the LHC

- Discovery of the Higgs boson with **bosonic decay channels**

  → Relatively clean signature with excellent detector capabilities



- Precision measurement of the Higgs boson production/decay rates (couplings) provides constraints on BSM scenarios, or is capable of observing deviations from the SM



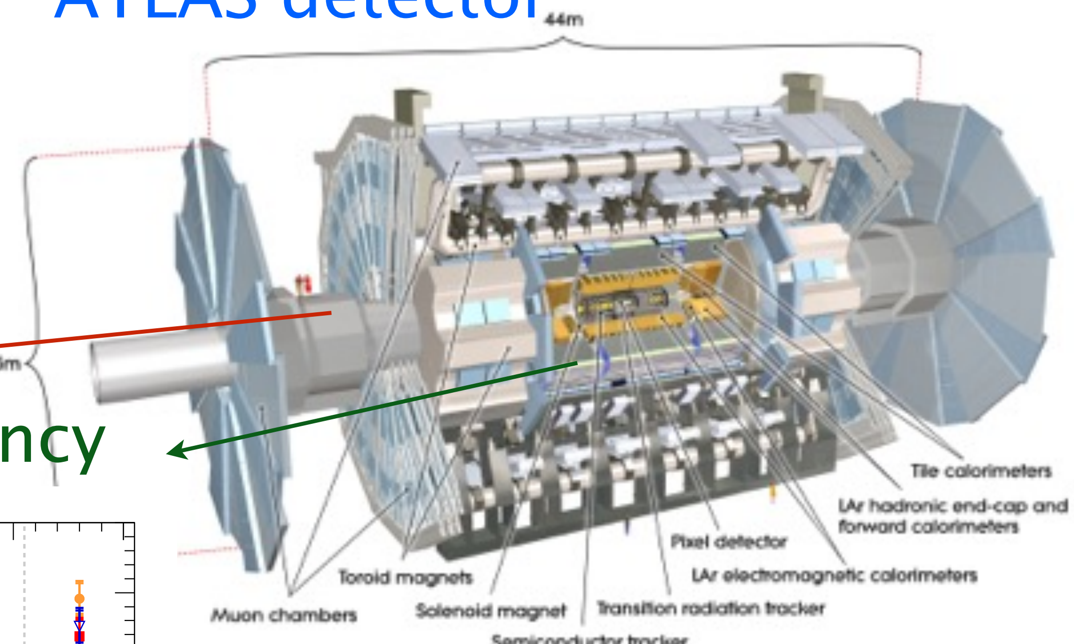
Constraint on hMSSM model as an example

ATLAS performance in Run1

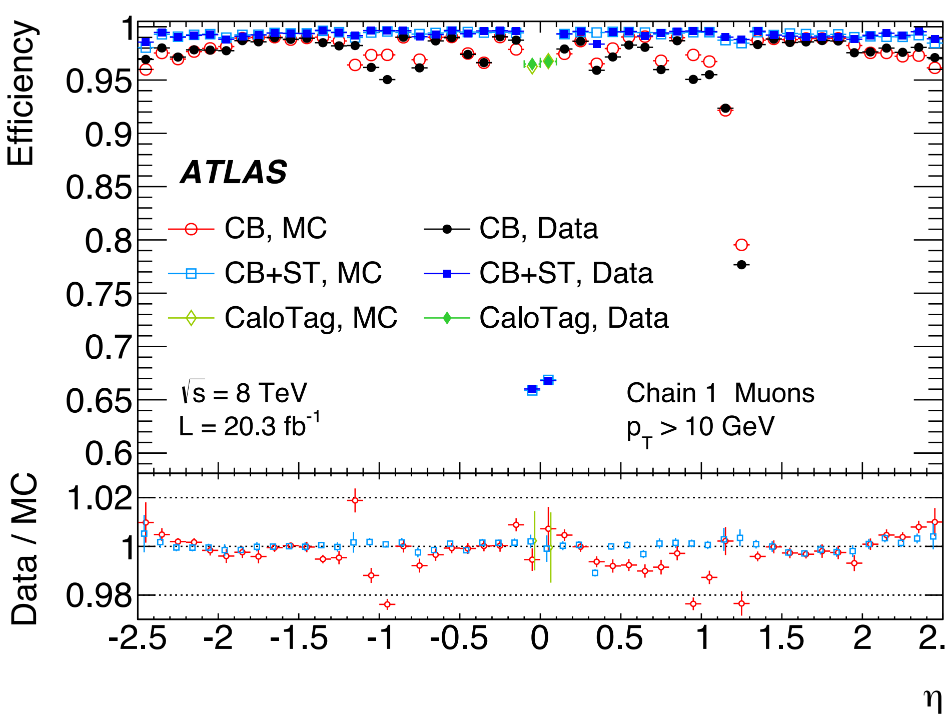
- ✓ All results presented in this talk are based on
  - **<u>4.6 fb^{-1} at 7 TeV (2011) and 20.7 fb^{-1} at 8 TeV (2012)</u>**

- ✓ Data taking efficiency: 94%;
  physics quality: 91%

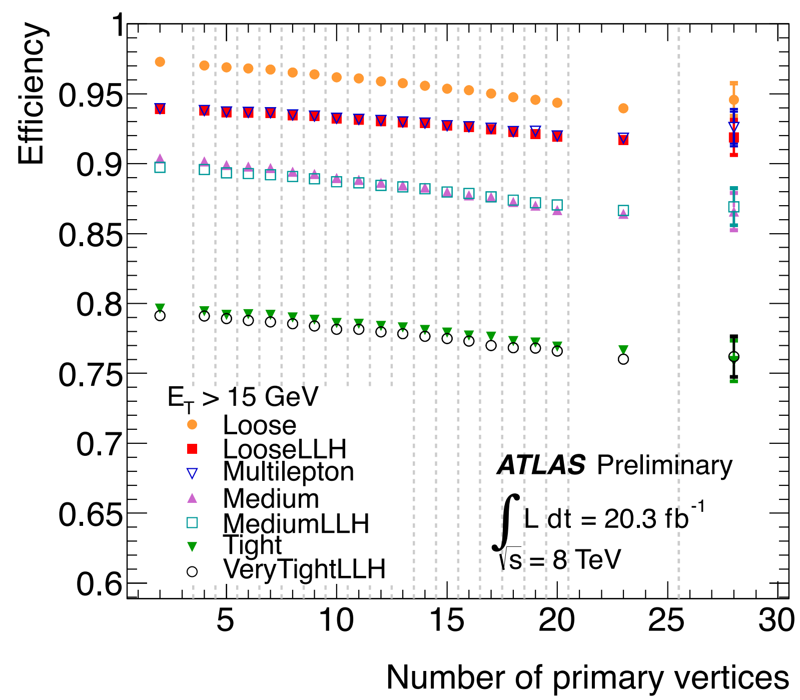
ATLAS detector



Muon efficiency



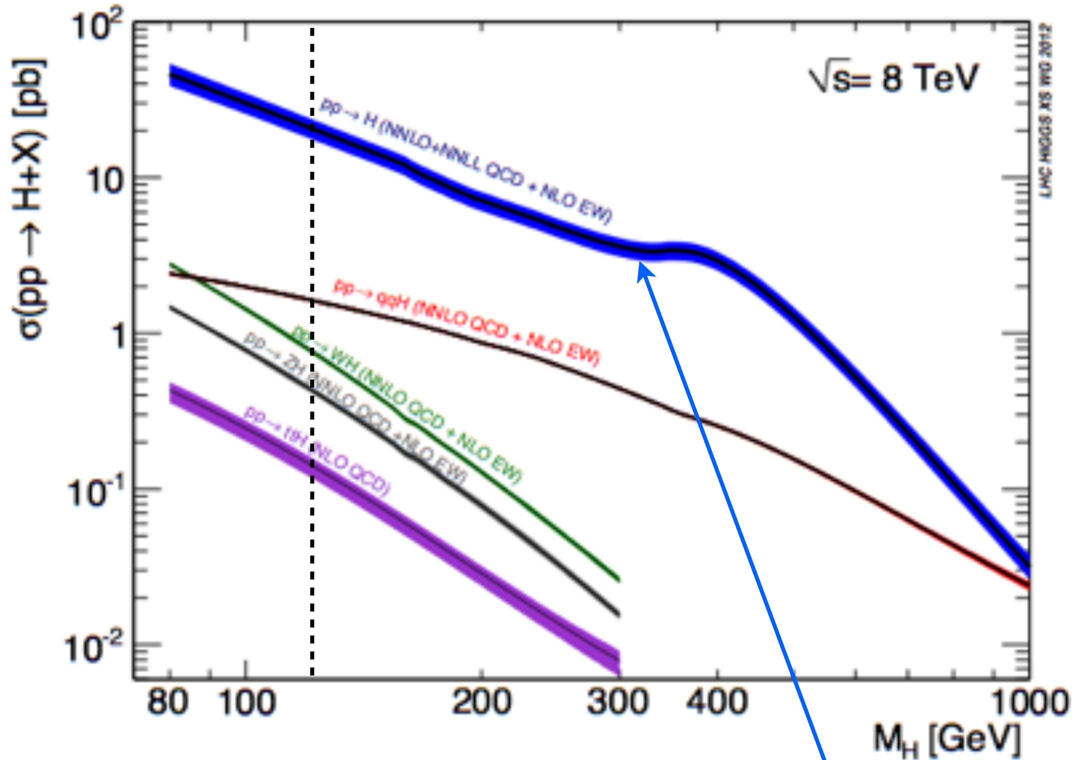
Electron efficiency



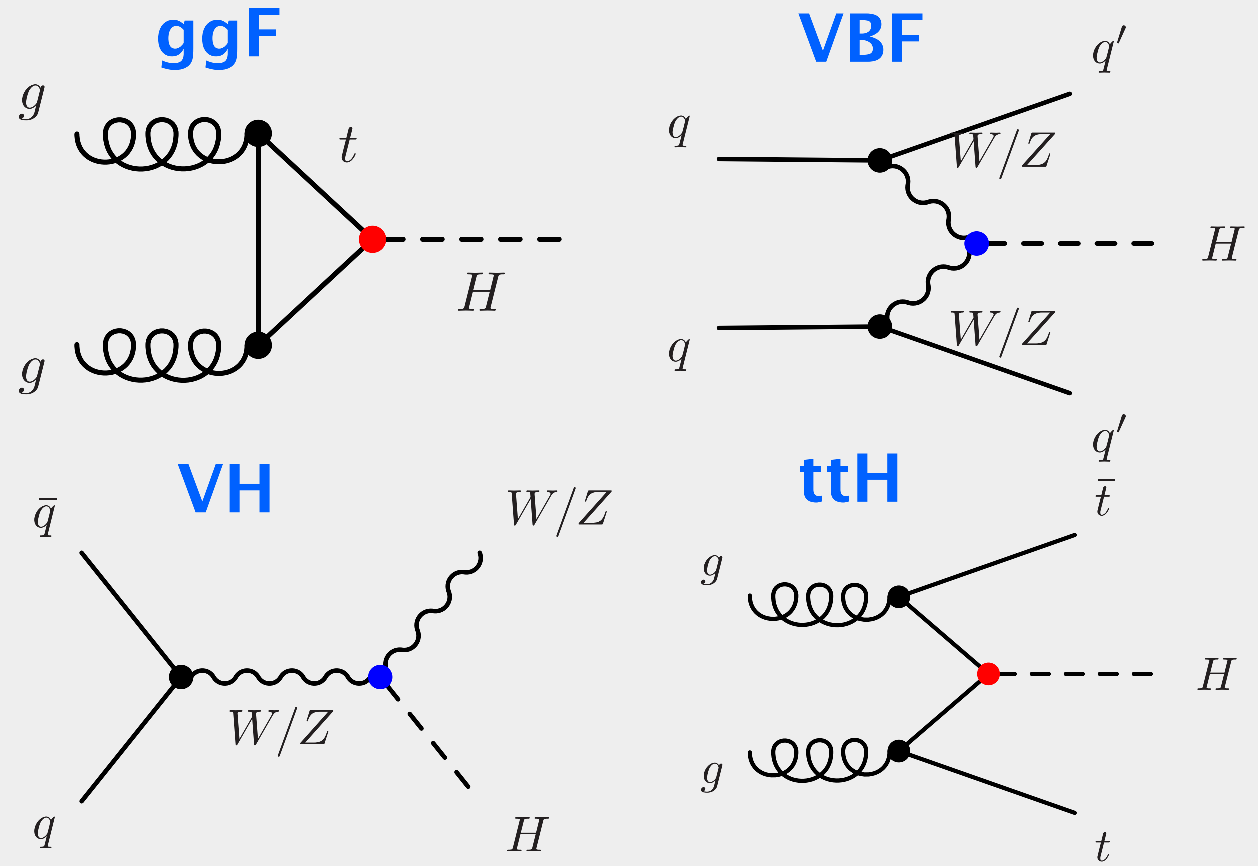
Reco/ID performance almost independent of pile-up conditions

Higgs production at LHC

∼125 GeV



ggF is the dominant process at the LHC



✓ This talk covers μ measurements using bosonic decay modes:

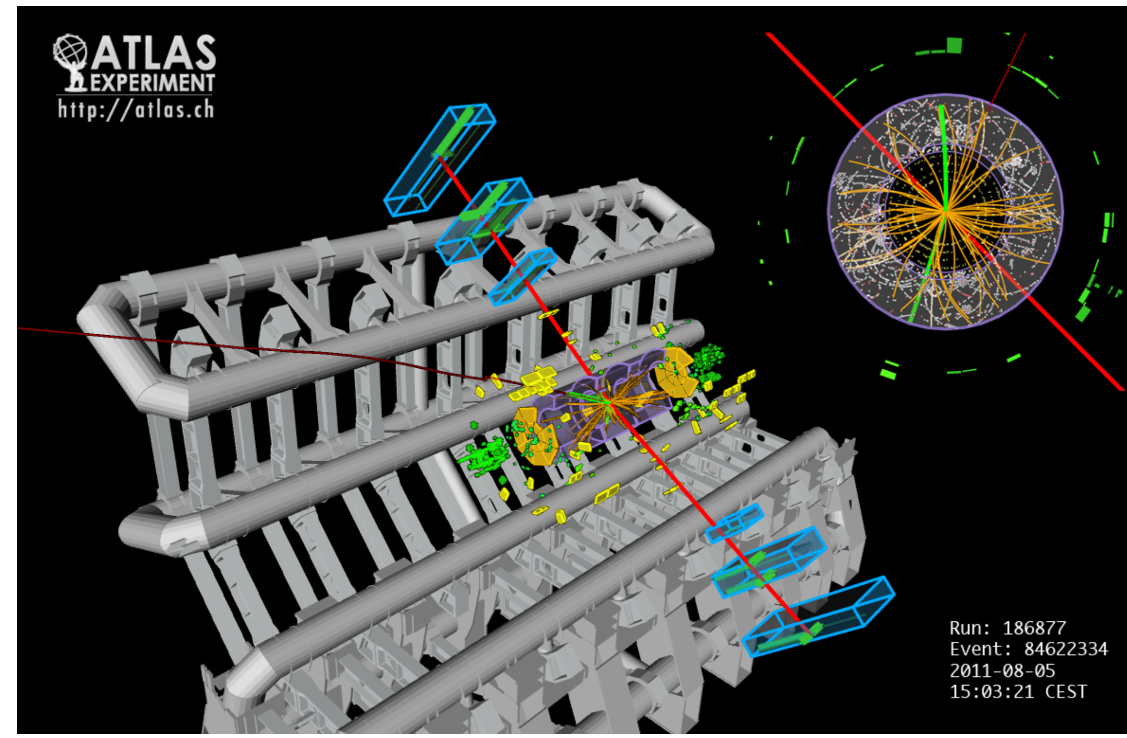
	ggF	VBF	VH	ttH
H→ZZ*	✔	✔	✔	-
H→WW*	✔	✔	✔	–
H→γγ	✔	✔	✔	✔

- H→ZZ*: Phys. Rev. D. 91, 012006 (2015)
- H→WW*: Phys. Rev. D. 92, 012006 (2015) JHEP 08 (2015) 137
- H→γγ: Phys. Rev. D. 90, 112015 (2014)

H → ZZ*→4l: overview

- ✓ Final state particles can be fully reconstructed
  - Two same flavor and opposite-sign lepton pairs
- ✓ Low branching fraction, but very clean signature
  - <u>Signal to background ratio ˜2</u>

H→ZZ*→2μ2e candidate



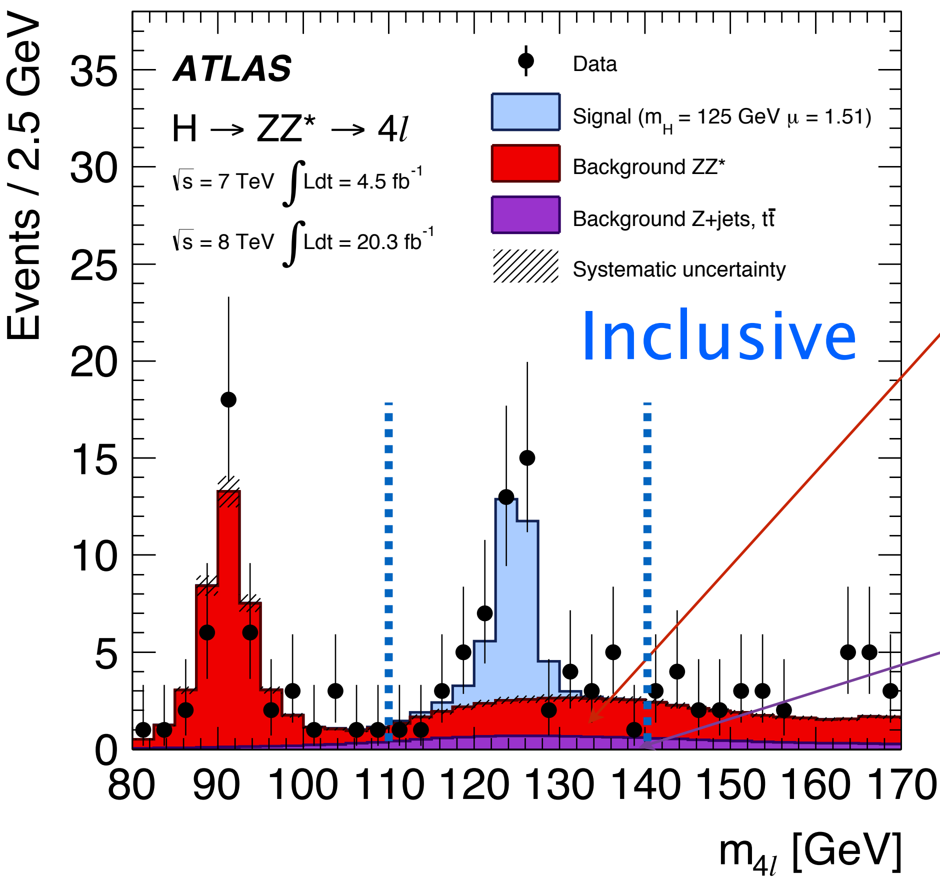
- ✓ Event categories for rate measurements:

˜90% of final events

4l selection → High mass two jets **VBF** → Low mass two jets **W(→jj)H, Z(→jj)H** → Additional lepton **W(→lν)H, Z(→ll)H** → **ggF**

VBF enriched | VH enriched | ggF enriched

H → ZZ*→4l: backgrounds



ZZ

- Simulation normalized to the SM cross section (Powheg+GG2ZZ)

Z+jets, tt

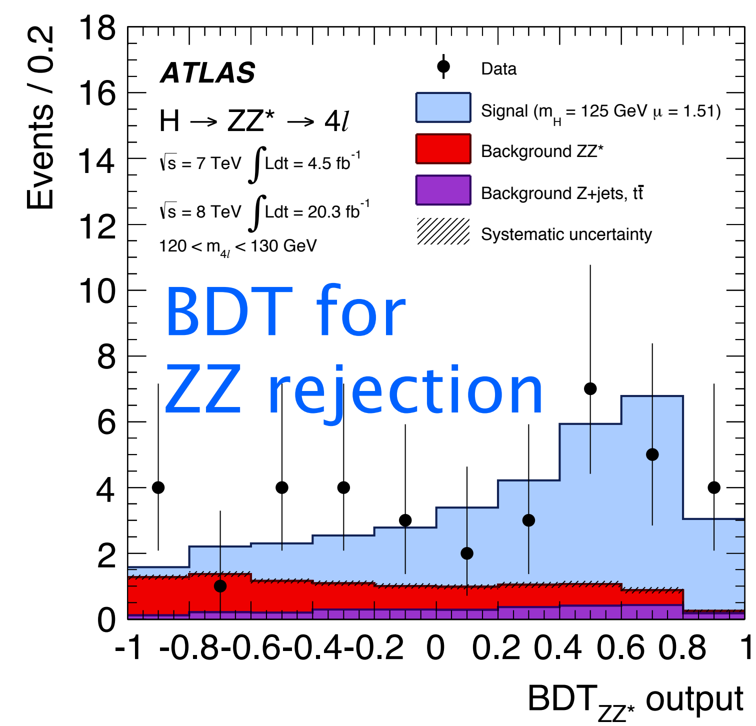
- Estimated using data-driven methods
  - Background enriched CR
  - Extrapolate CR to SR using transfer factors

✓ Discriminating variables:

- m_{4l}
- BDT ← For ZZ rejection, trained by p_T^{4l}, η^{4l}, $D_{ZZ}=\ln(|M_{sig}|^2/|M_{ZZ}|^2)$

  *M is matrix element

<u>→ 2D fit to m_{4l} and BDT is baseline method to extract the signal</u>

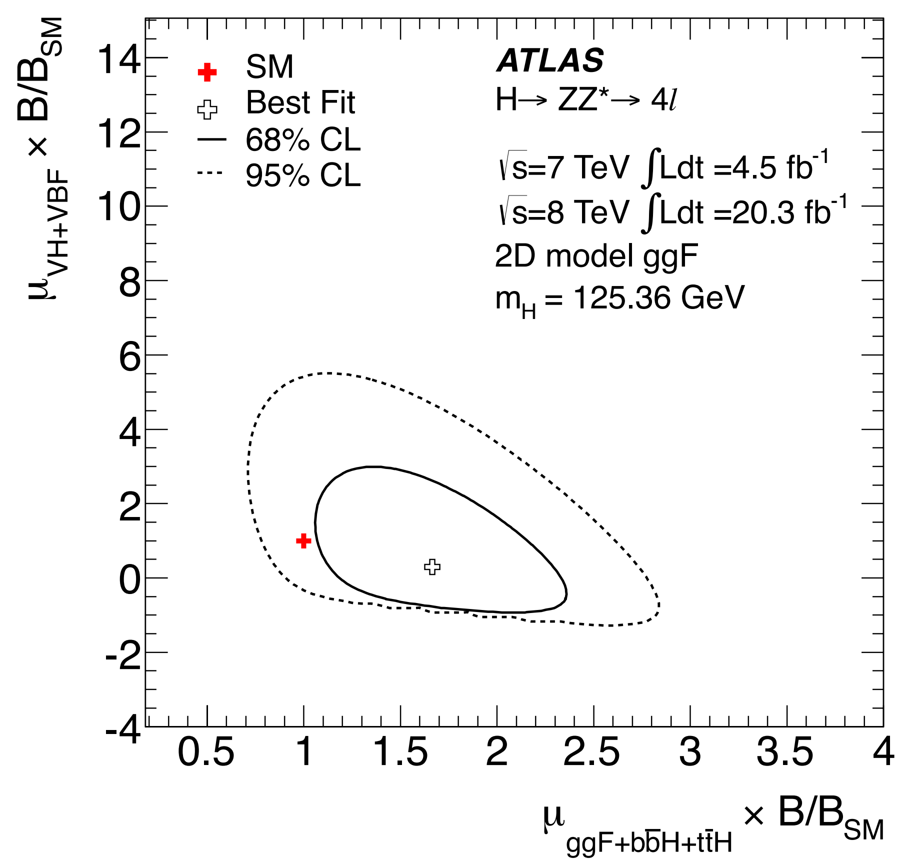


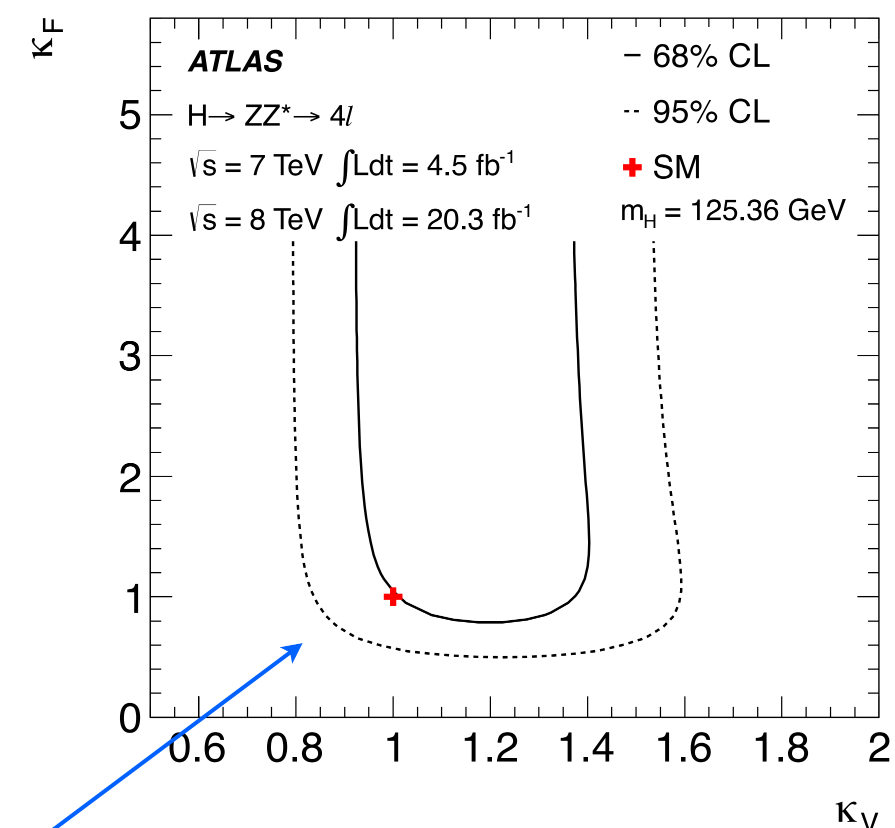
$H \rightarrow ZZ^{*} \rightarrow 4l$: results

- ✓ Summary of signal strength measurements:
  - Ratio μ_{VBF+VH}/μ_{ggF} is $0.2^{+1.2}_{-0.9}$

	μ
ggF	**1.7 +0.5 −0.4**
VBF + VH	**0.3 +1.6 −0.9**
Combined	**$1.44\ ^{+0.34}_{-0.31}(\text{stat})\ ^{+0.21}_{-0.11}(\text{syst})$**

  - Consistent with the SM expectation
  - Currently statistically limited



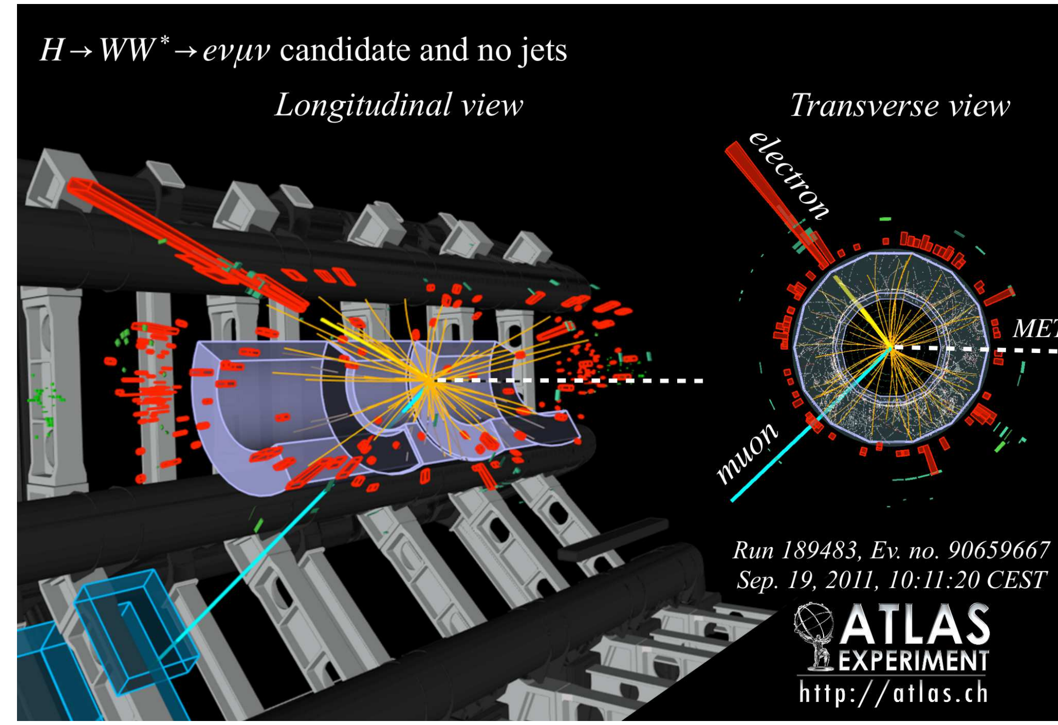


Coupling strength scale factors for vector bosons (κ_V) and fermions (κ_F)

H → WW*: overview

- ✓ Large branching fraction
  - VBF and VH productions can be studied
    → <u>Purely bosonic channels</u>
- ✓ Relatively clean signatures by selecting isolated leptons

ggF H → WW* candidate



Production modes	Decay modes	Lepton requirements
ggF and VBF	H→WW*→ lνlν	Opposite-sign di-leptons
WH	W(H→WW*)→ lνlνqq	Same-sign di-leptons
WH	W(H→WW*)→ lνlνlν	3 leptons
WH, ZH	V(H→WW*)→ qqlνlν	Opposite-sign di-leptons
ZH	Z(H→WW*)→ lllνlν	4 leptons

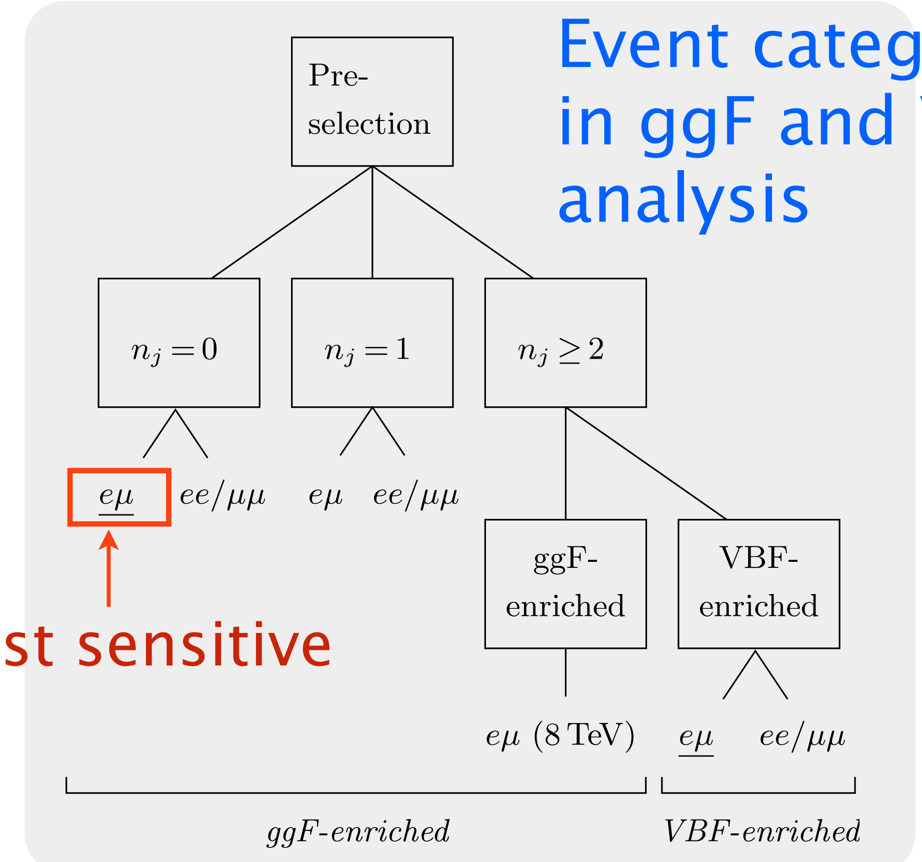
ggF and VBF H → WW*: overview

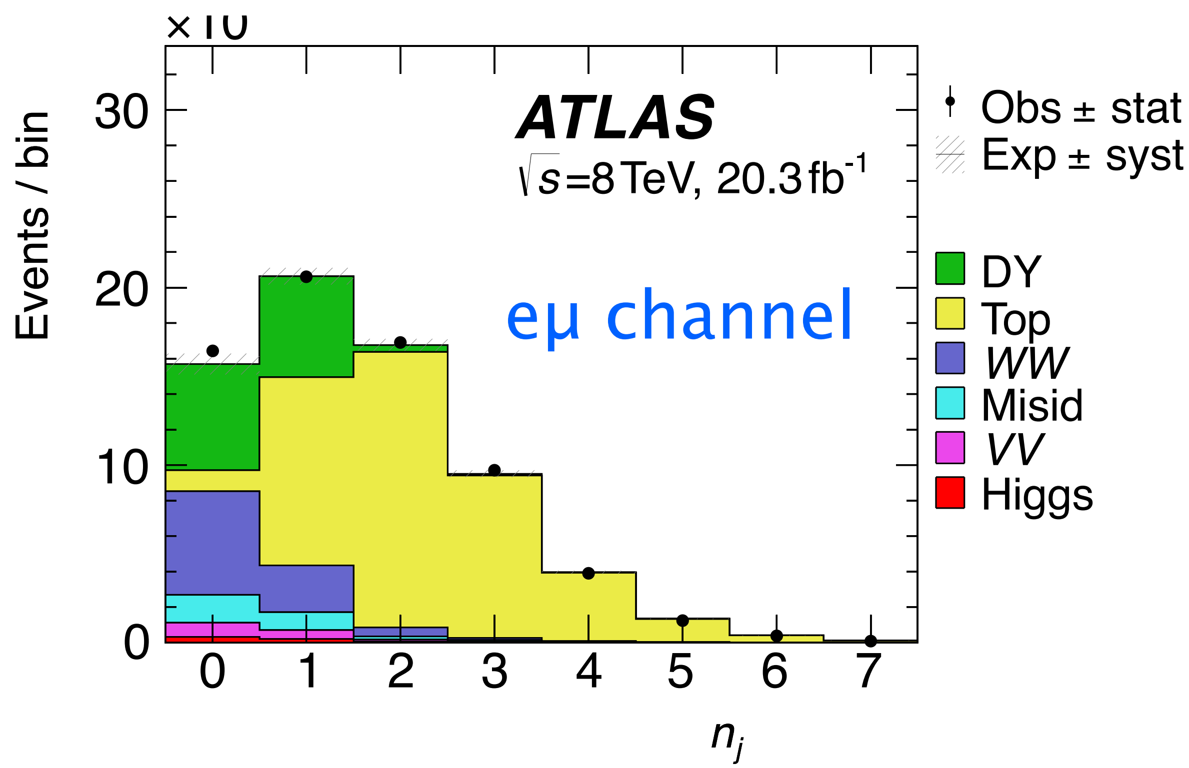
- ✓ Analysis is split by lepton flavor and number of jets due to different bkg. composition

- ✓ Discriminating variables:
  - $\Delta\Phi_{ll}$
    → Small opening angle of two leptons from W decays due to spin-0 nature of the Higgs boson
  - m_T, m_{ll}, p_T of sub leading lepton

→Final variable used in fit to extract the signal is m_T or BDT score

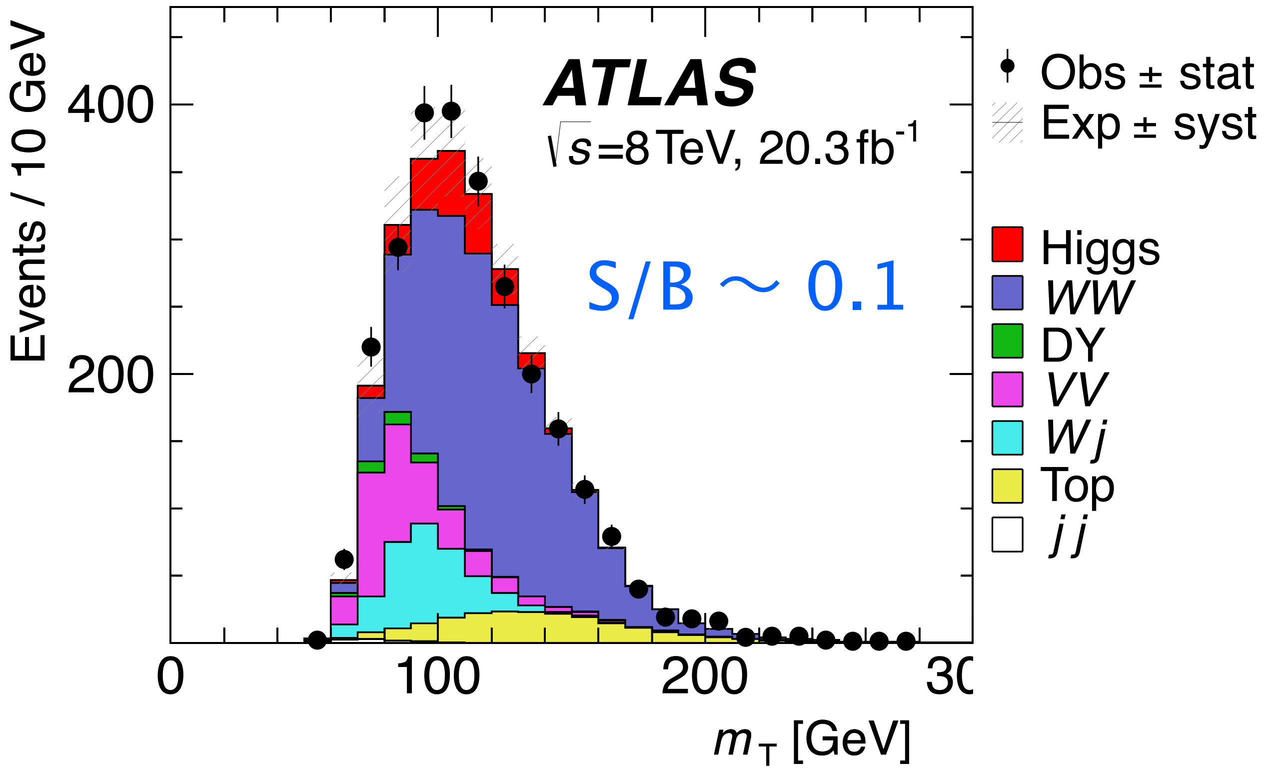
Event categories in ggF and VBF analysis





ggF and VBF H → WW*: backgrounds

- ✓ Various physics processes contaminate to signal regions as backgrounds
- ✓ ggF-enriched category as an example:

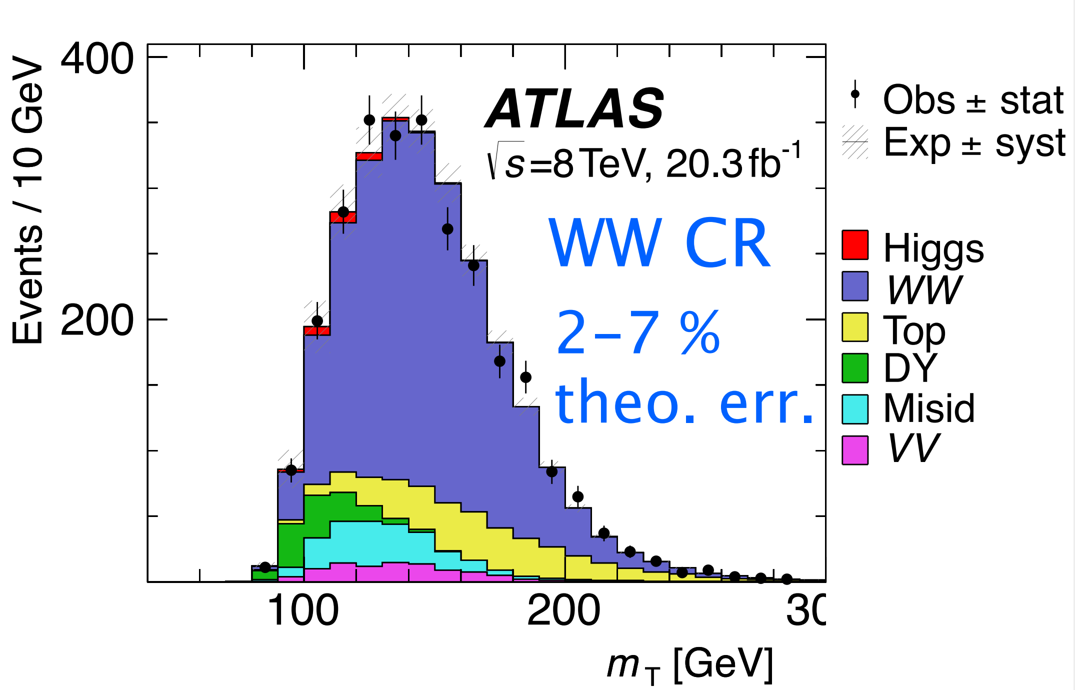


W+jets, QCD (Misid)

- Rates and shapes are extracted from data using transfer factors

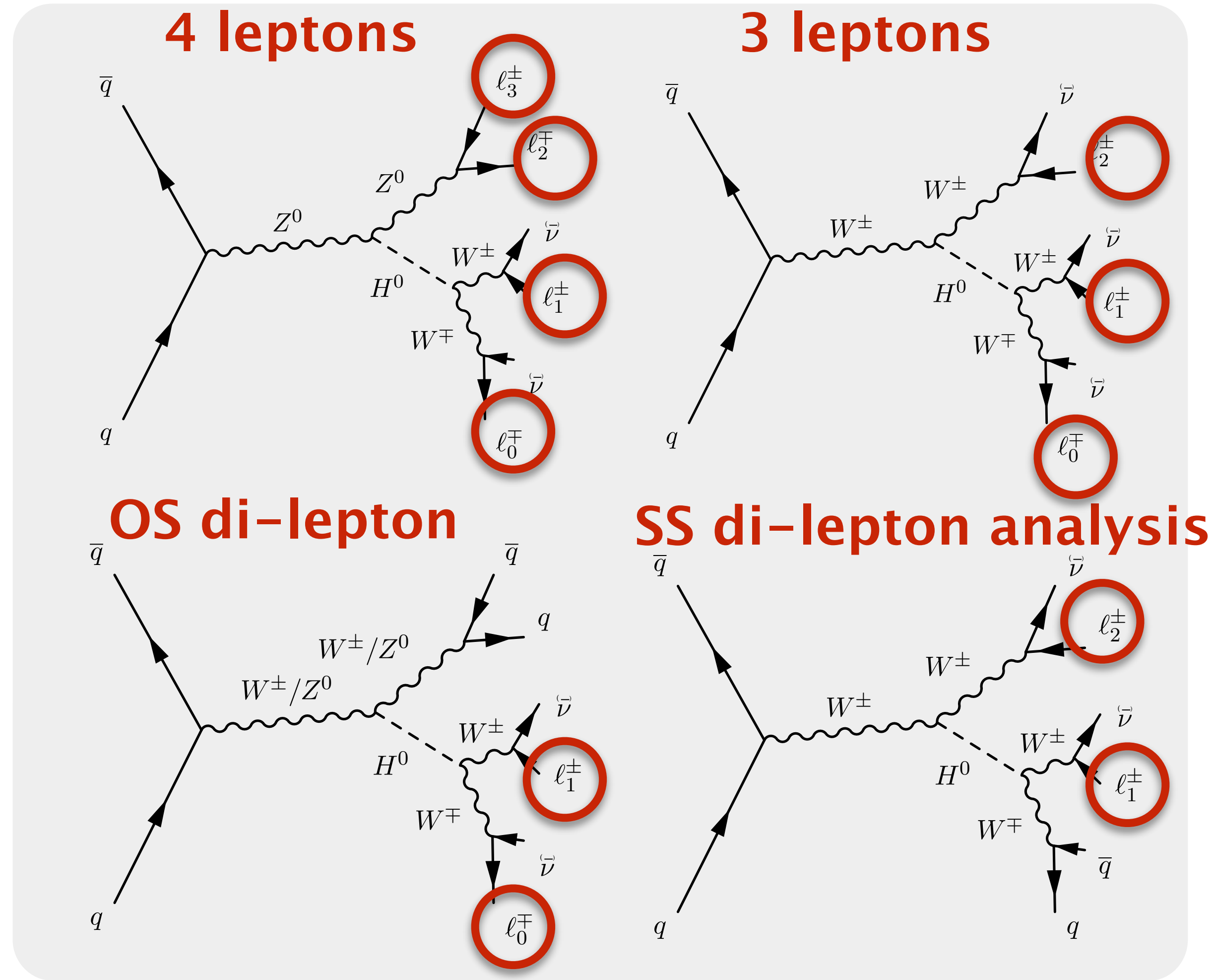
WW, Top, di-boson(VV), Z+jets(DY)

- Rates are extracted from data in control regions but shapes are extracted from simulation

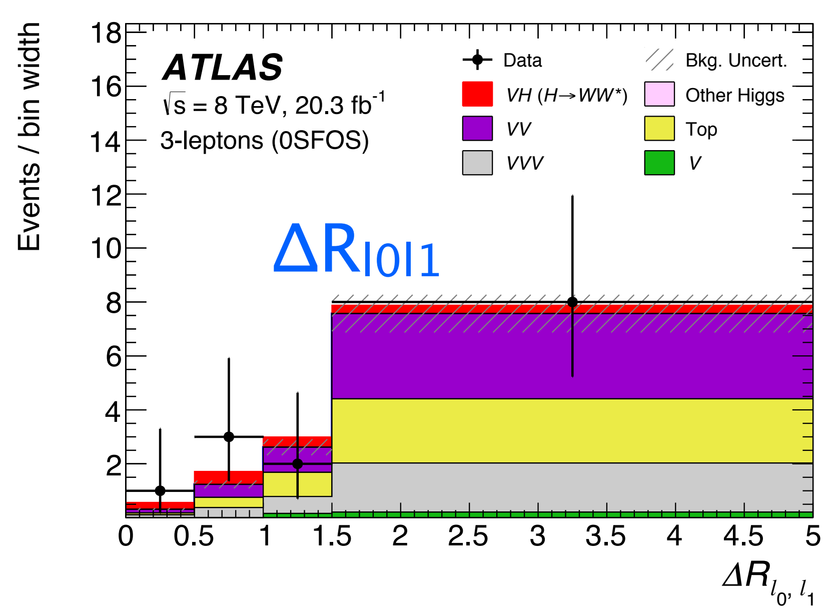


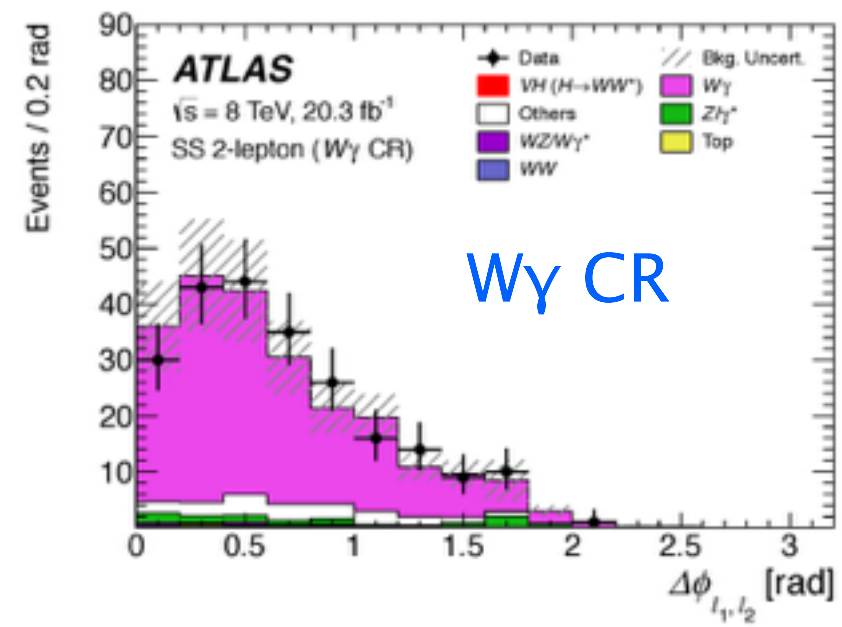
VH H → WW*: overview

✓ Analysis is split by lepton multiplicity and charge
- 3 lepton analysis: shape fit to BDT score and ΔR_{l0l1}
- Other analysis: fit without shape information



✓ Major backgrounds are normalized using CRs
- Di-bosons, Top, Z→ττ, etc





H → WW*: results

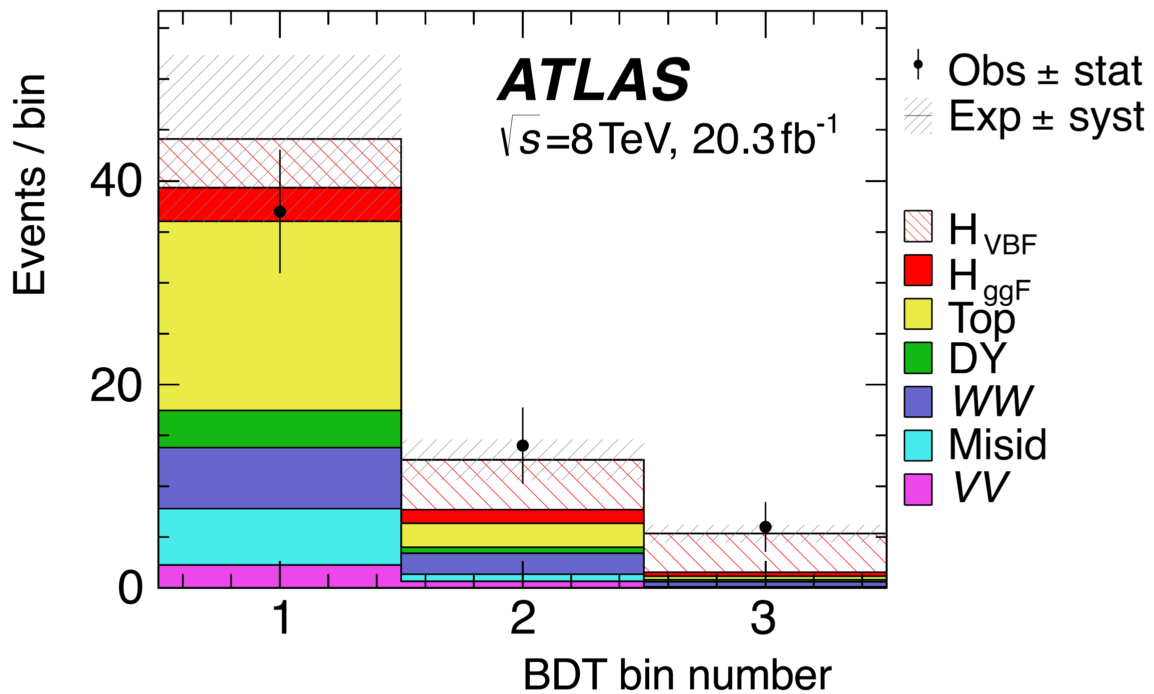
✓ Summary of signal strength measurements:

	μ	Exp Z_0	Obs Z_0
ggF	**0.98** +0.29 −0.26	**4.4**	**4.2**
VBF	**1.28** +0.55 −0.32	**2.6**	**3.2**
VH	**3.0** +1.6 −1.3	**0.93**	**2.5**
Combined	**1.16** +0.24 −0.21	**5.9**	**6.5**

- Consistent with the SM expectation
- Stat. and syst. uncertainties contribute approximately equal

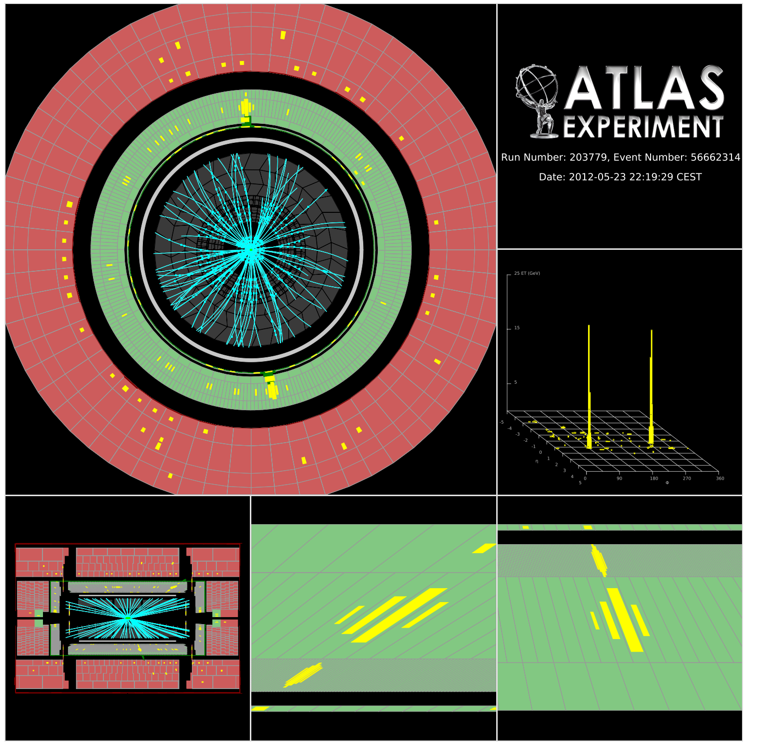
  ← Dominant systematics are theory uncertainties on the signals (cross section, acceptance)

BDT in VBF-enriched



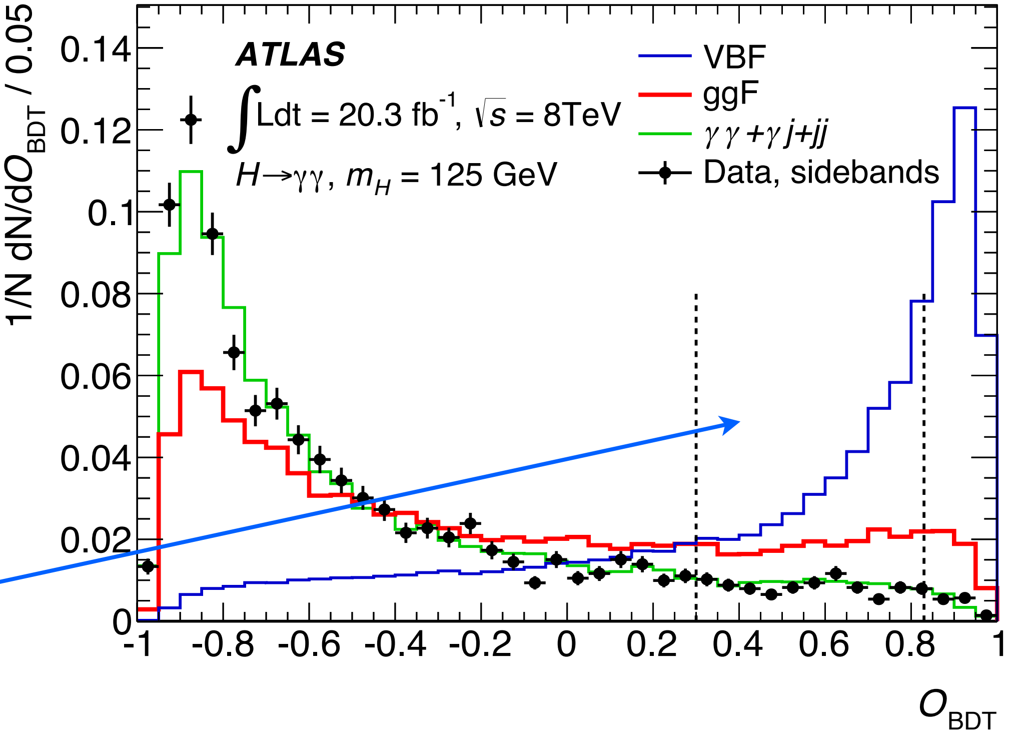
$H \rightarrow \gamma\gamma$: overview

H → γγ candidate



- ✓ Decay to two photons via loop of other particles
  - Sensitive to new phenomena
  - $E_T/m_{\gamma\gamma} > 0.35$ (0.25) for leading (sub-leading) photon

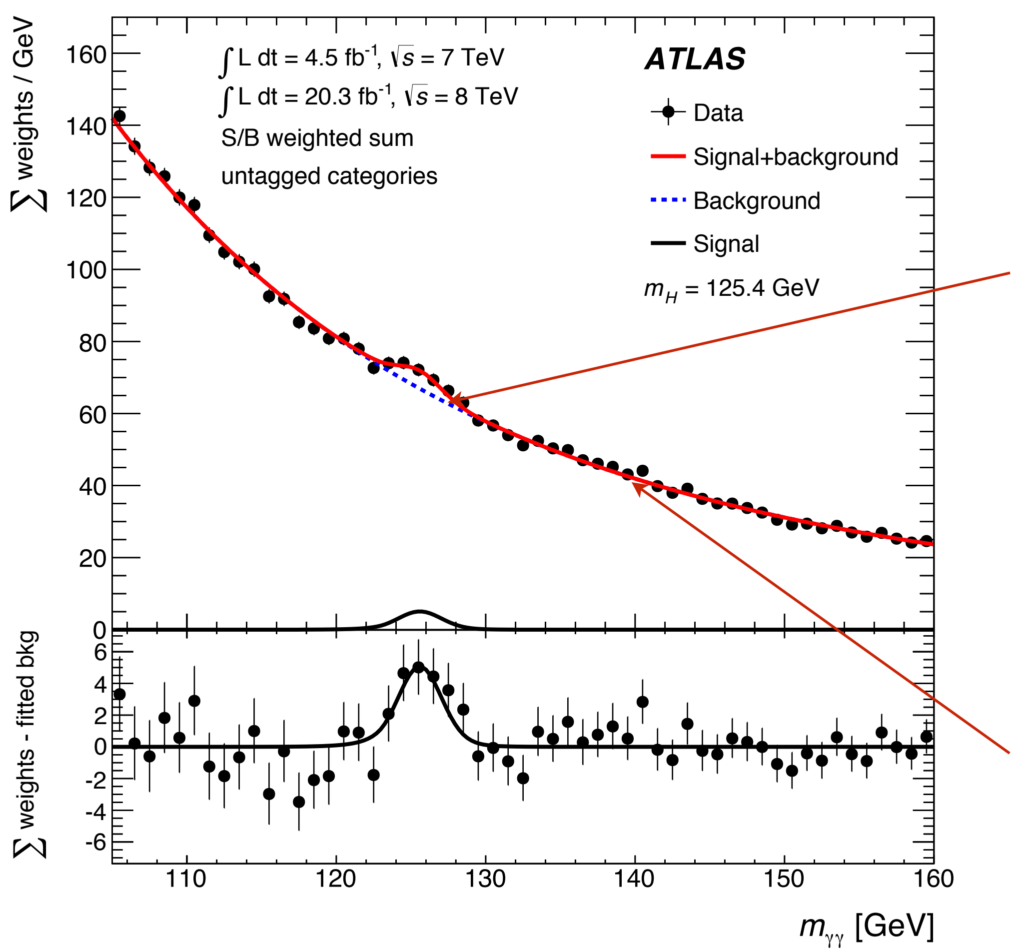
- ✓ Event categorization
  - ttH enriched:
    - b-tagged jets from top decay
  - VH enriched:
    - Lepton, MET and jets from V decay
  - VBF enriched:
    - BDT score based on VBF topology



H → γγ: signal and background modeling

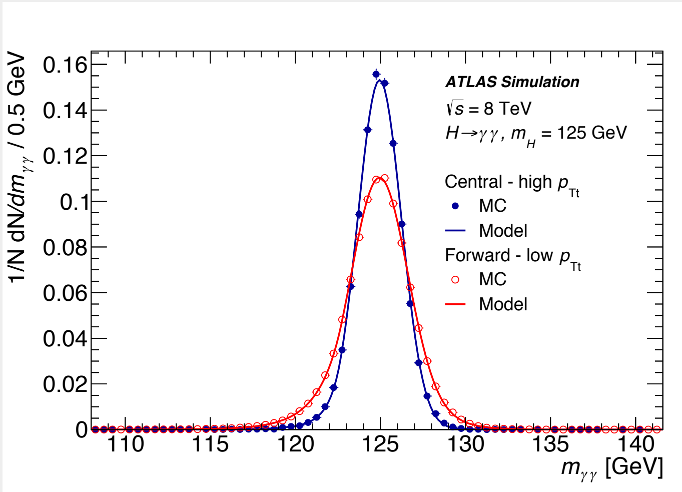
✓ Signals are extracted from $m_{\gamma\gamma}$ distribution by fit

$m_{\gamma\gamma}$ distribution



Signal

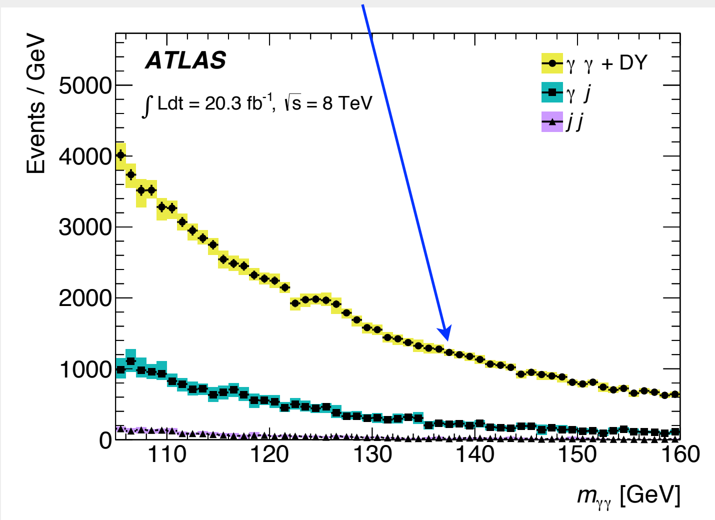
- Crystal Ball function (a Gaussian core with one exponential tail)
- + small-wider Gaussian component



Backgrounds

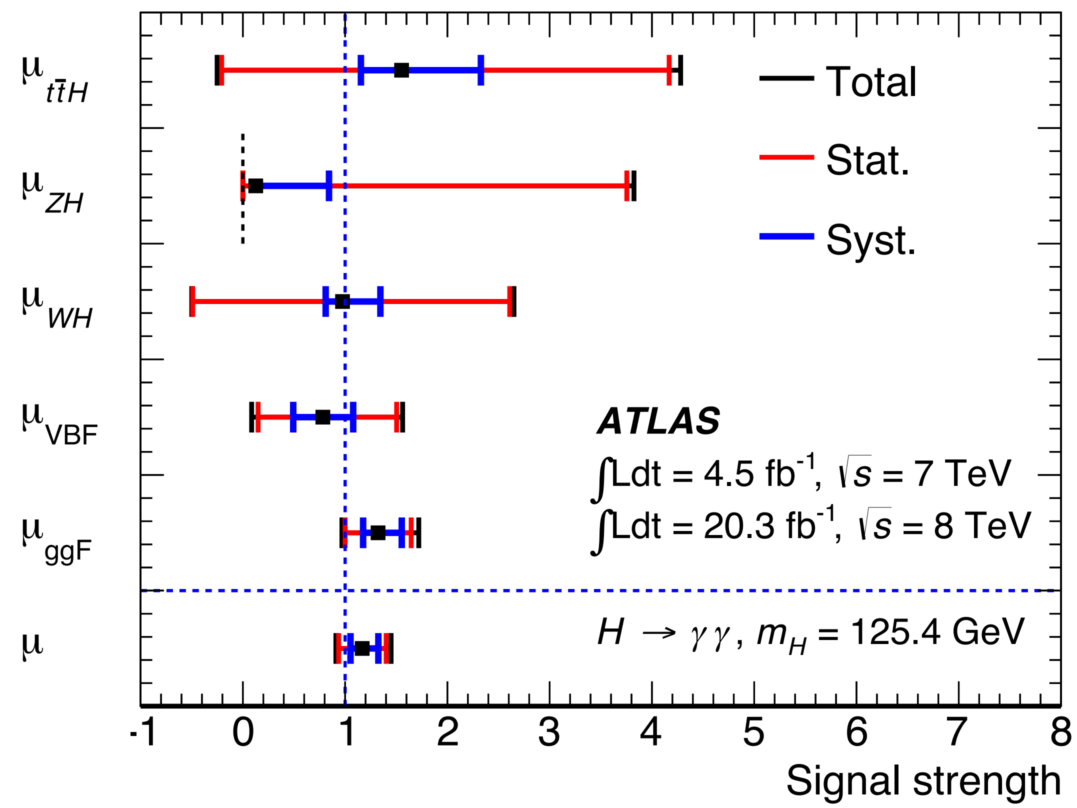
77% is SM γγ (8TeV)

- Exponential of a first-order or second-order polynomial
- Components are well understood



H → γγ: results

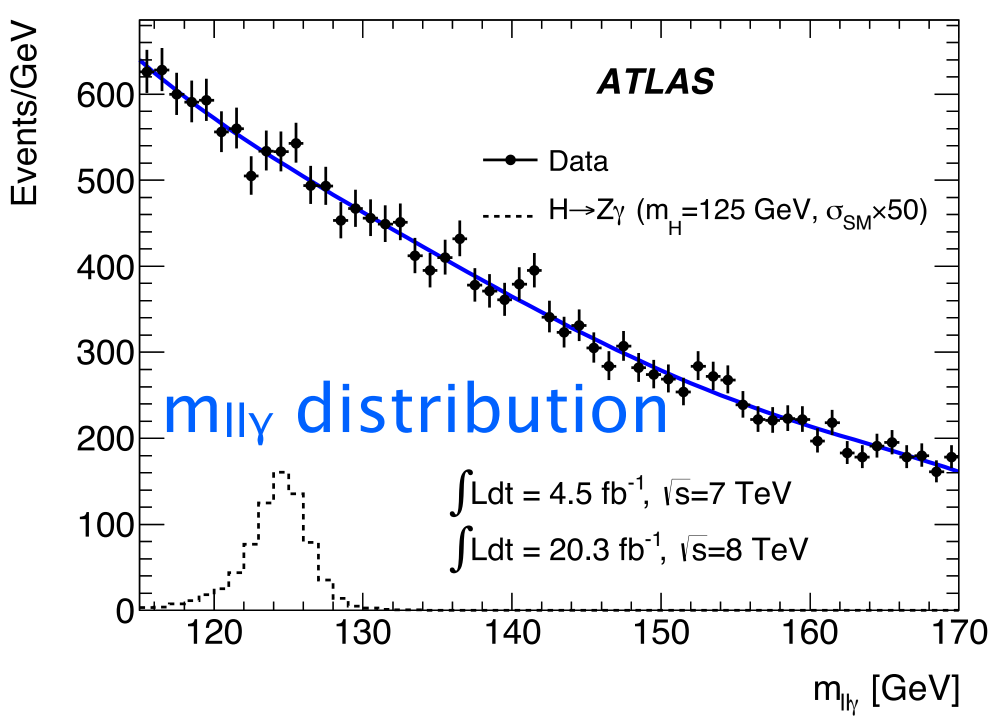
- ✓ Summary of signal strength measurements:
  - $\mu_{comb} = 1.17 \pm 0.27$
  - Consistent with the SM expectation
  - Uncertainties are dominated by the statistical uncertainty
    ←More data are needed to establish evidence for VBF,VH and ttH

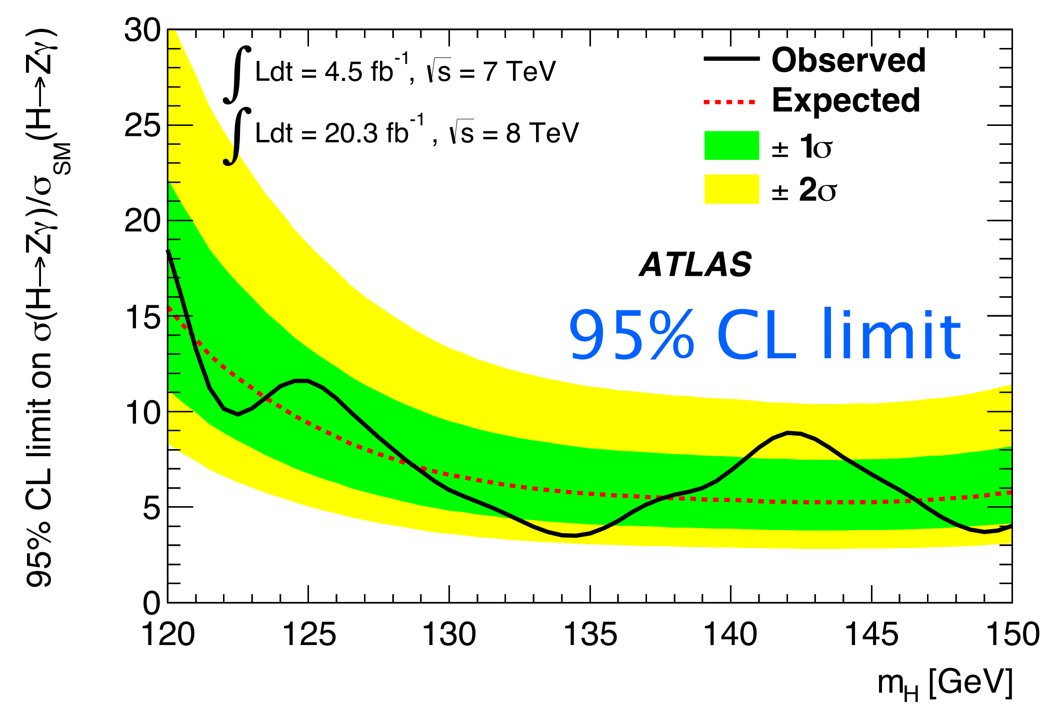


	Ratio
μ_{VBF}/μ_{ggF}	**0.6** +0.8 −0.5
μ_{VH}/μ_{ggF}	**0.6** +1.1 −0.6
μ_{ttH}/μ_{ggF}	**1.2** +2.2 −1.4

H → Zγ

- ✓ Signature: opposite-sign lepton pair + photon
  - Branching ratio of $H \to Z(\to ll)\gamma$ is only 5% of $H \to \gamma\gamma$
- ✓ No excess is found in $m_{ll\gamma}$ distribution
  - Observed 95% CL limit at 125.5 GeV is 11 × SM expectation





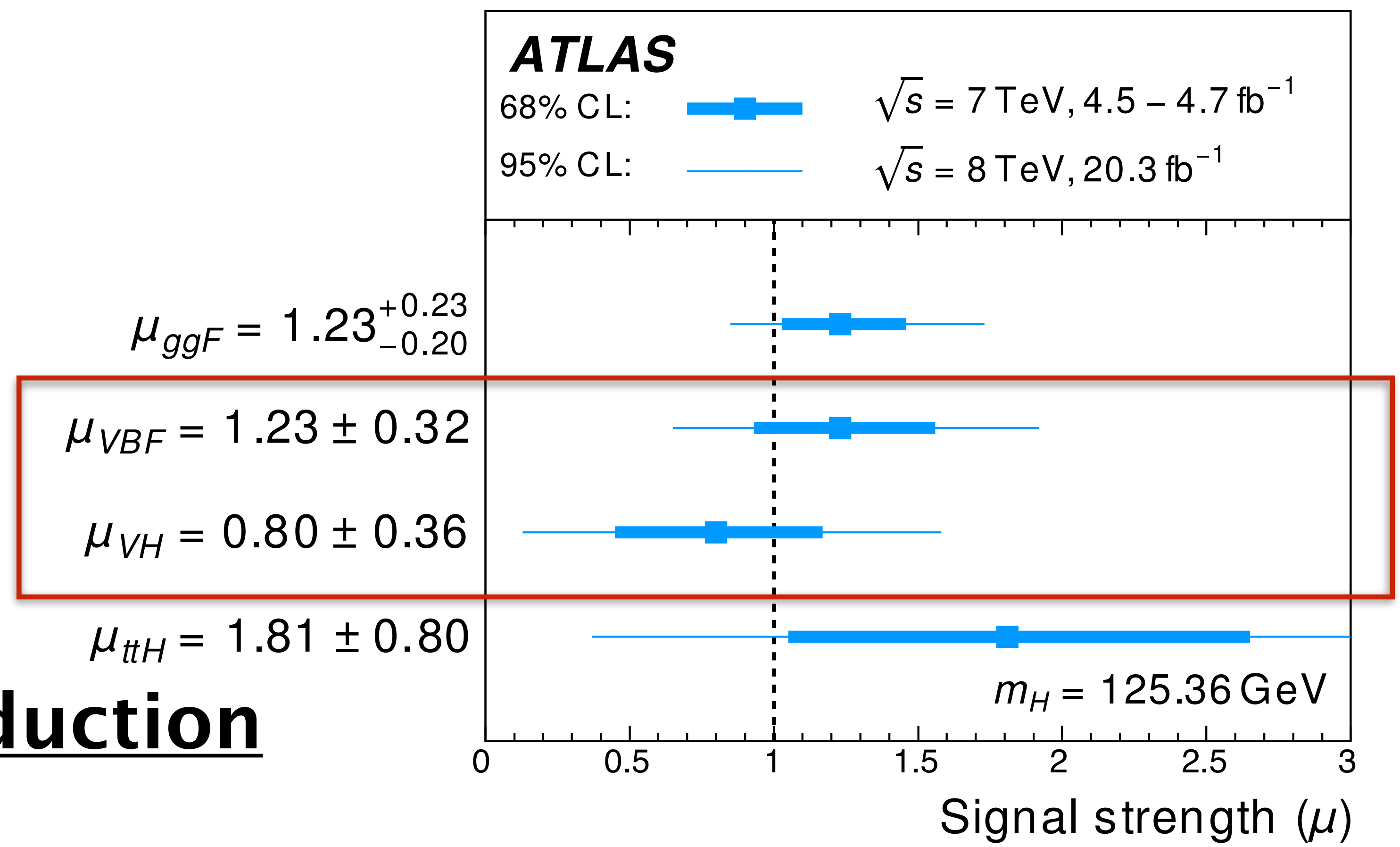
- ✓ Prospects for $H \to Z\gamma$ search [ATL-PHYS-PUB-2014-006]
  - p-value = 2.3σ (3.9σ) with 300 fb^{-1} (3000 fb^{-1})

VBF/VH productions

- ✓ Combined results of focusing on individual production processes [arXiv:1507.04548]
  <u>← VBF and VH productions are good probes to test Higgs and gauge boson interactions</u>

- ✓ Assume the SM Higgs decay ratios for μ measurements
  - $\mu_{VBF} = 1.23 \pm 0.32$
  - $\mu_{VH} = 0.80 \pm 0.36$
  - Consistent with the SM expectation

– **<u>4.3σ evidence of VBF production</u>**



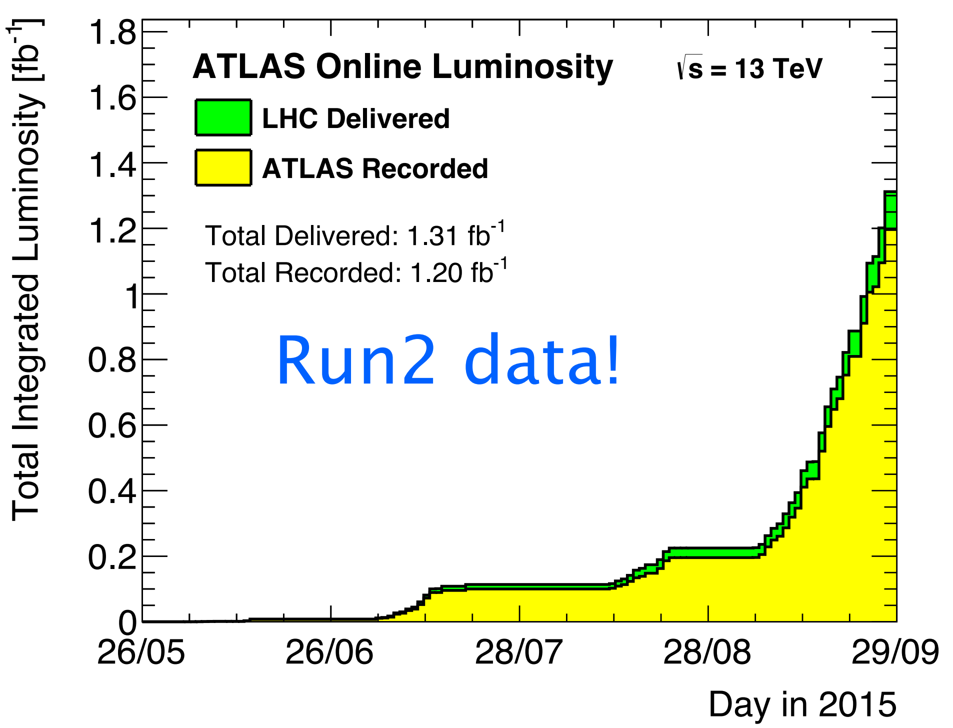
Conclusions and outlook

- ✓ The measurements of the production and bosonic decay rates of the Higgs boson are consistent with the SM expectation so far..

$H \to ZZ^*$	$1.44\ ^{+0.34}_{-0.31}(\text{stat})^{+0.21}_{-0.11}(\text{syst})$
$H \to WW^*$	$1.16\ ^{+0.16}_{-0.15}(\text{stat})^{+0.18}_{-0.15}(\text{syst})$
$H \to \gamma\gamma$	$1.17\ \pm 0.23(\text{stat})^{+0.10}_{-0.08}(\text{syst})^{+0.12}_{-0.08}(\text{theory})$

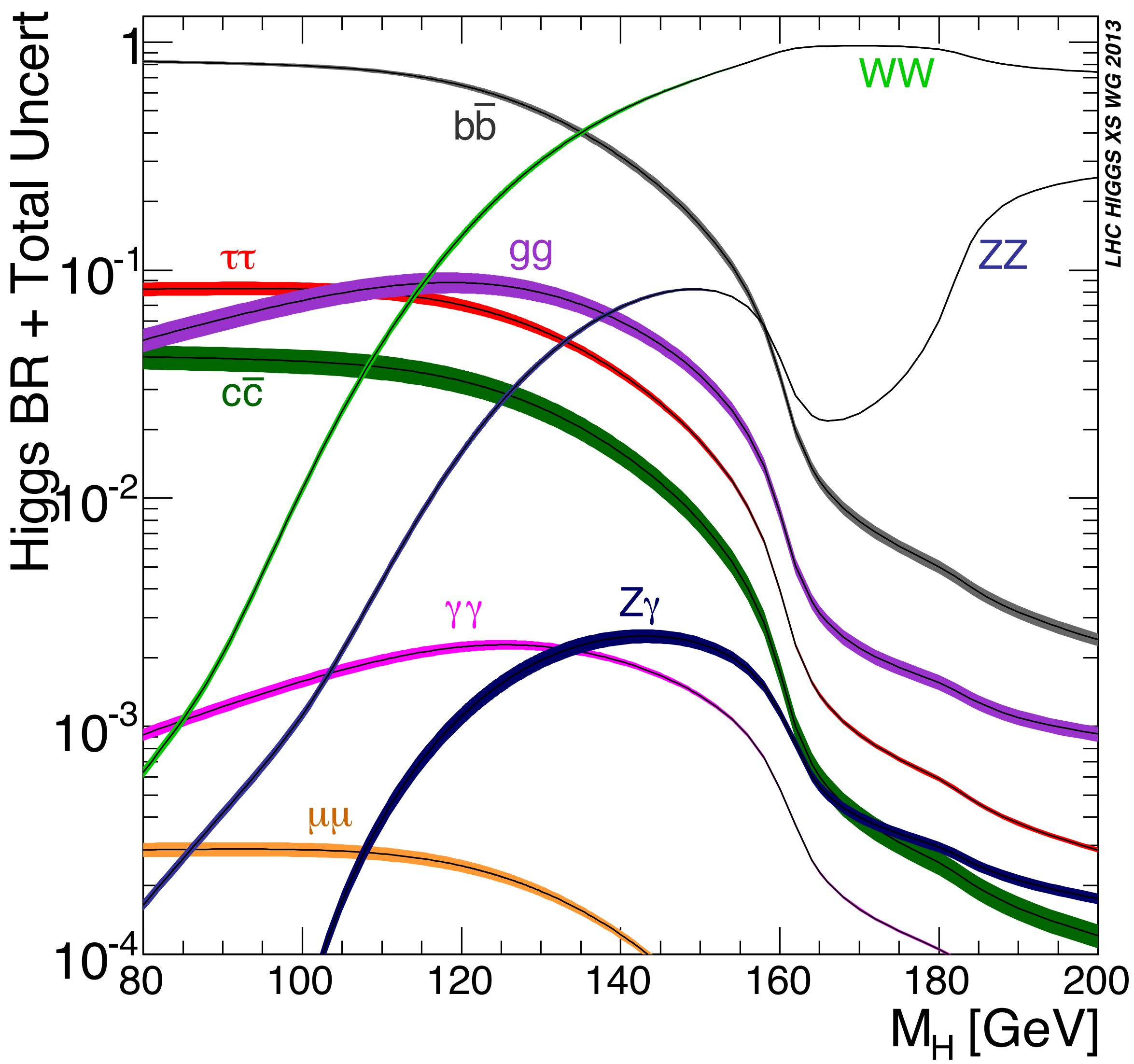
- ✓ In general, the analyses are still statistically limited
  - ← Also systematic uncertainty is often stemmed from the statistic nature

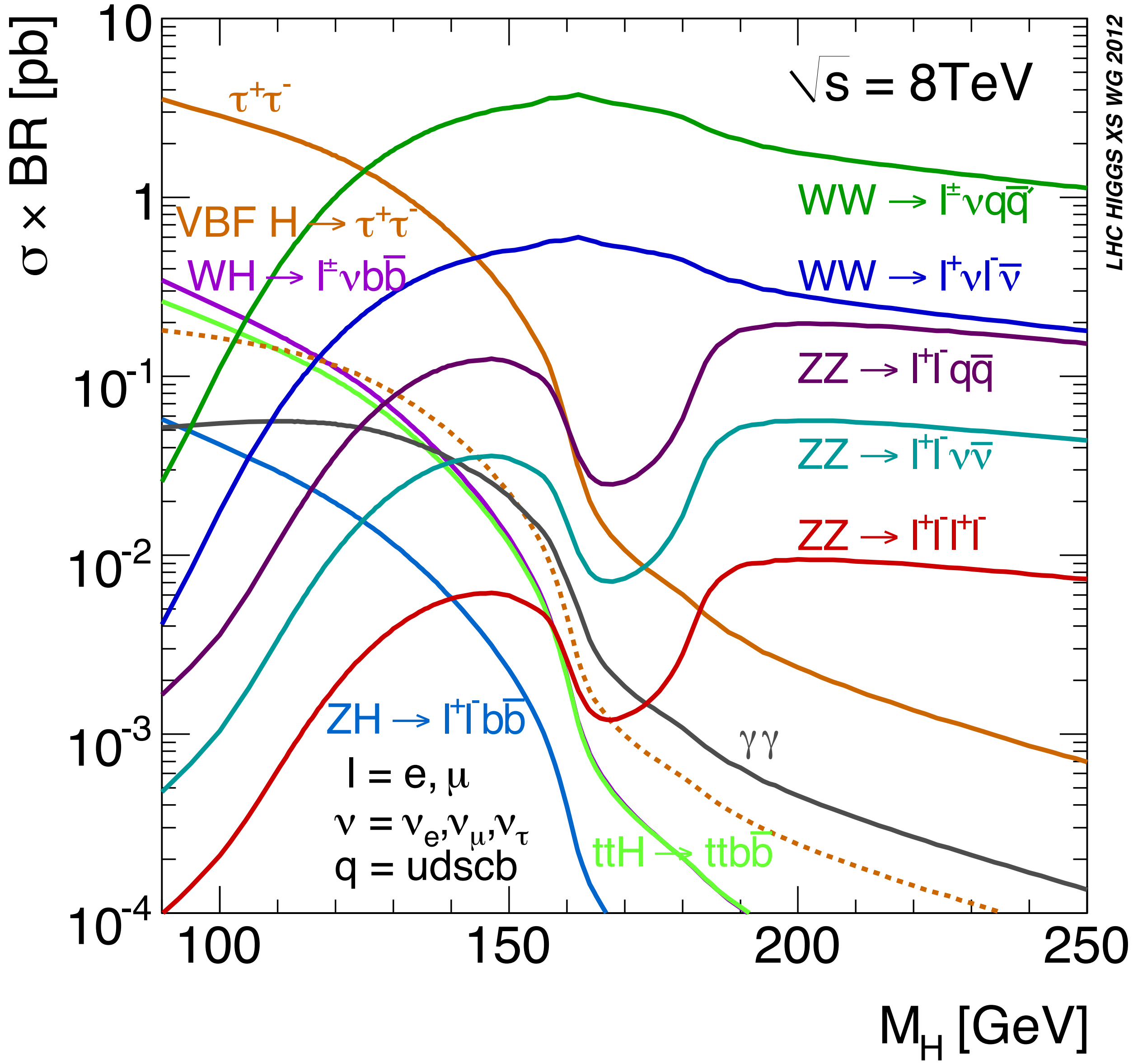
<u>More precise measurements will be performed using Run2 data!</u>



Backup

Decay fraction





H → ZZ*→4l: event selections

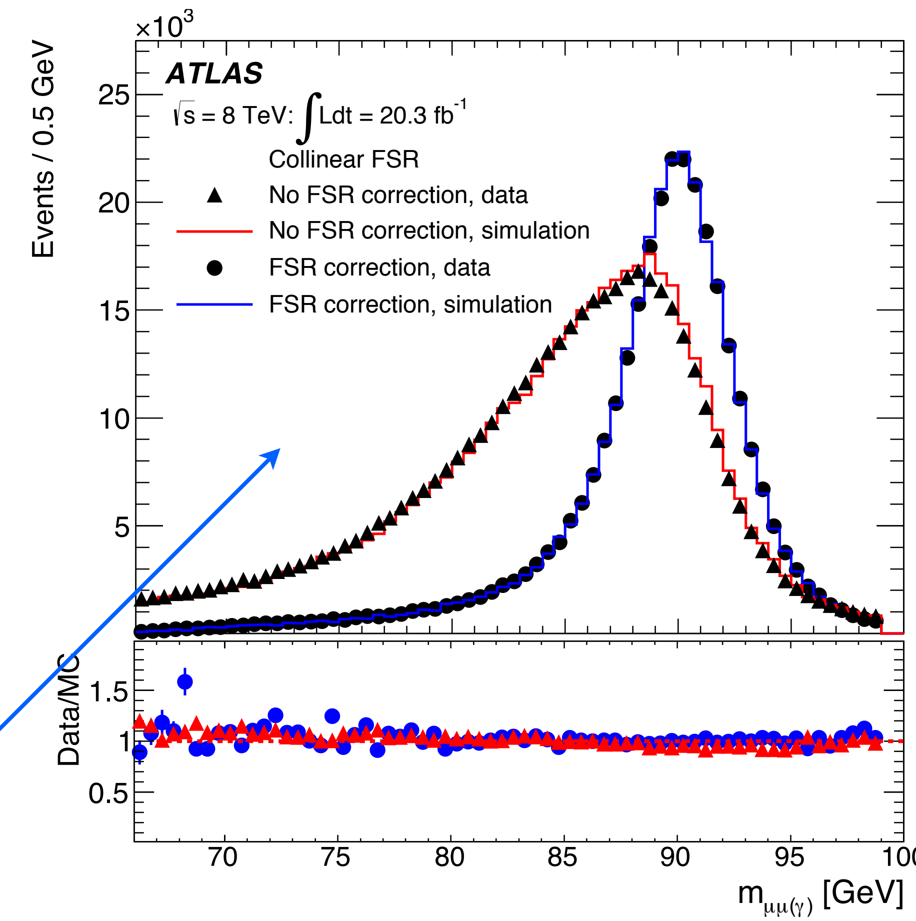
✓ Four isolated leptons

- p_T > 20, 15, 10, 6 (7) GeV
- electron: |η| < 2.47, muon: |η| < 2.7

✓ Two opposite-sign lepton pairs

- on-shell Z: m_{12} = [50,106] GeV
- off-shell Z: m_{34} = [m_{min},115] GeV

m_{min}=[12, 50] GeV depending on m_{4l}



✓ FSR recovery

- 4 % (1%) recovery for collinear (non-collinear)

✓ Event categorization

- m_{jj} > 130 GeV with $p_{T,jet}$ > 25(30) GeV — VBF enriched
- 40 < m_{jj} < 130 GeV and BDT_{VH} > −0.4 — VH enriched
- additional lepton with pT > 8 GeV — VH enriched
- Other events — ggF enriched

H → ZZ*: expected signals

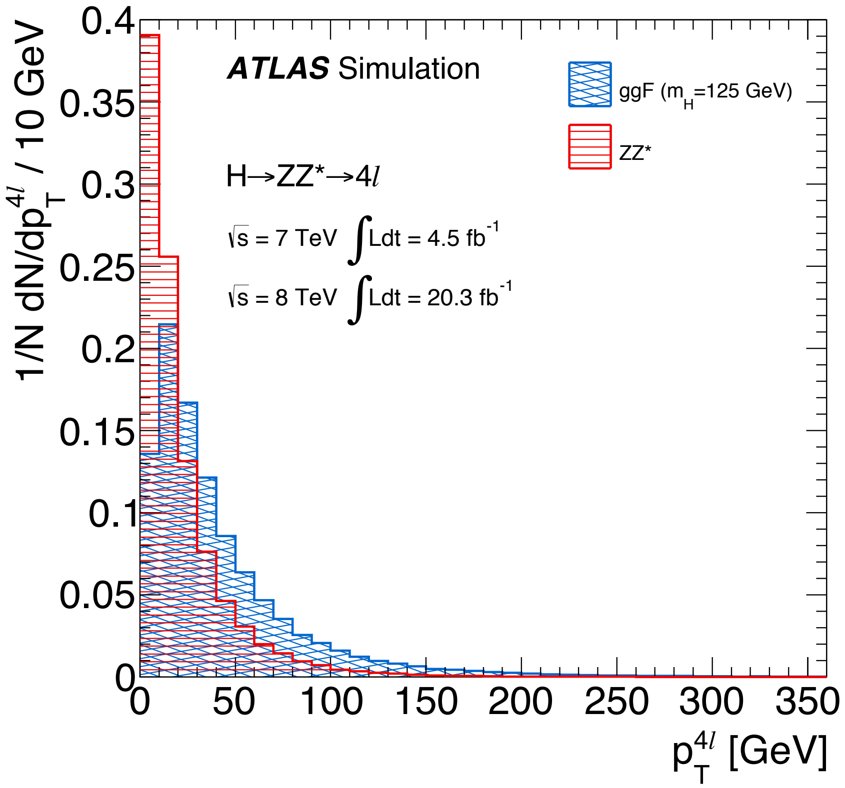
Category	$gg \to H, q\bar{q}/gg \to b\bar{b}H/t\bar{t}H$	$qq' \to Hqq'$	$q\bar{q} \to W/ZH$
	$\sqrt{s} = 7$ TeV		
ggF enriched	2.06 ± 0.25	0.114 ± 0.005	0.067 ± 0.003
VBF enriched	0.13 ± 0.04	0.137 ± 0.009	0.015 ± 0.001
VH-hadronic enriched	0.053 ± 0.018	0.007 ± 0.001	0.038 ± 0.002
VH-leptonic enriched	0.005 ± 0.001	0.0007 ± 0.0001	0.023 ± 0.002
	$\sqrt{s} = 8$ TeV		
ggF enriched	12.0 ± 1.4	0.52 ± 0.02	0.37 ± 0.02
VBF enriched	1.2 ± 0.4	0.69 ± 0.05	0.10 ± 0.01
VH-hadronic enriched	0.41 ± 0.14	0.030 ± 0.004	0.21 ± 0.01
VH-leptonic enriched	0.021 ± 0.003	0.0009 ± 0.0002	0.13 ± 0.01

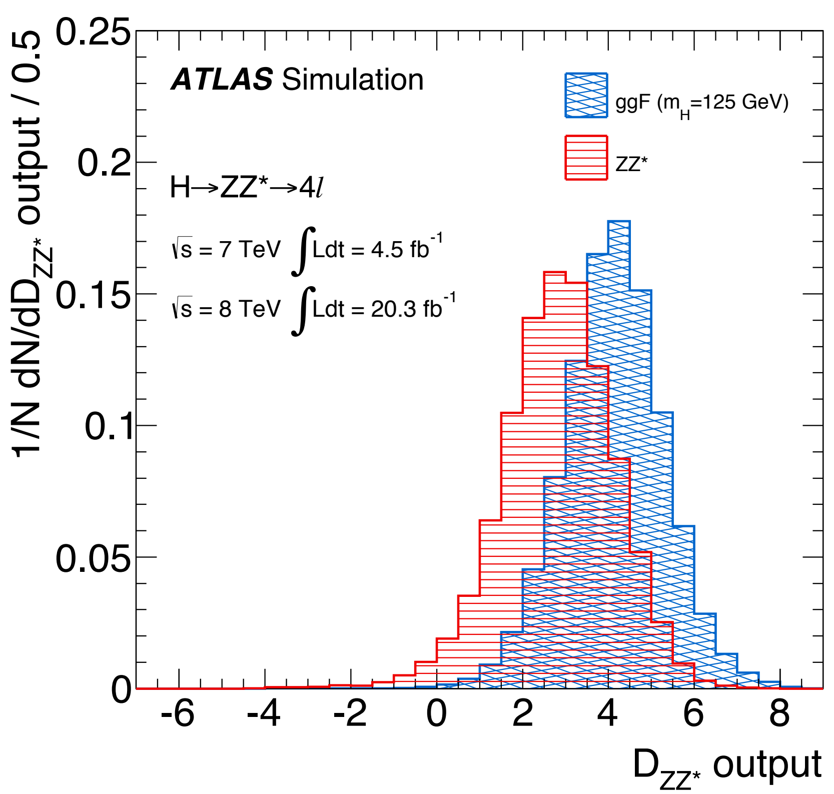
93% purity

35% purity

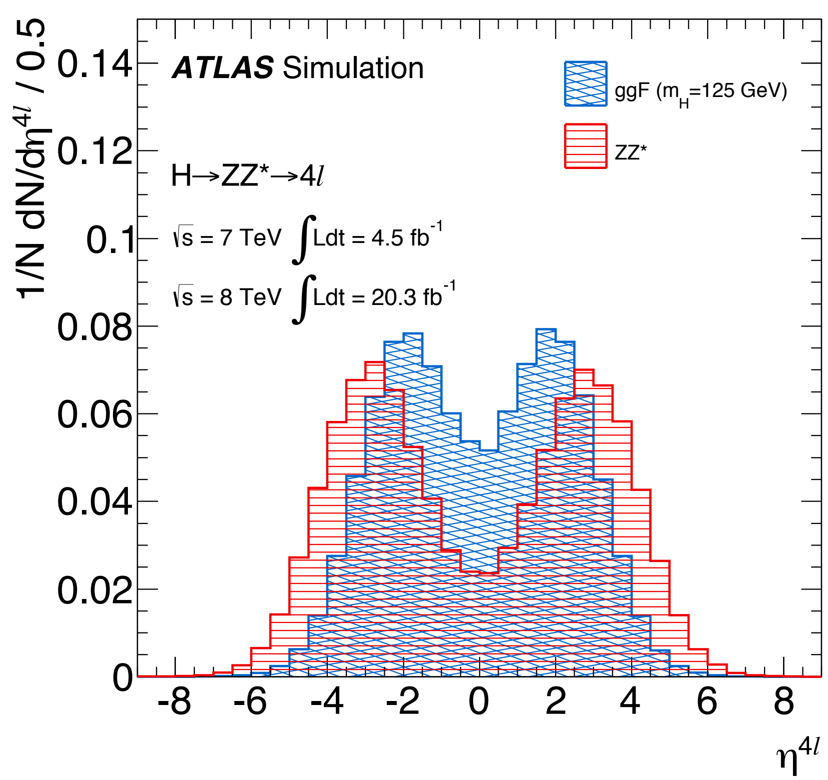
34% purity

$H \rightarrow ZZ^*$: BDT_{ZZ^*}

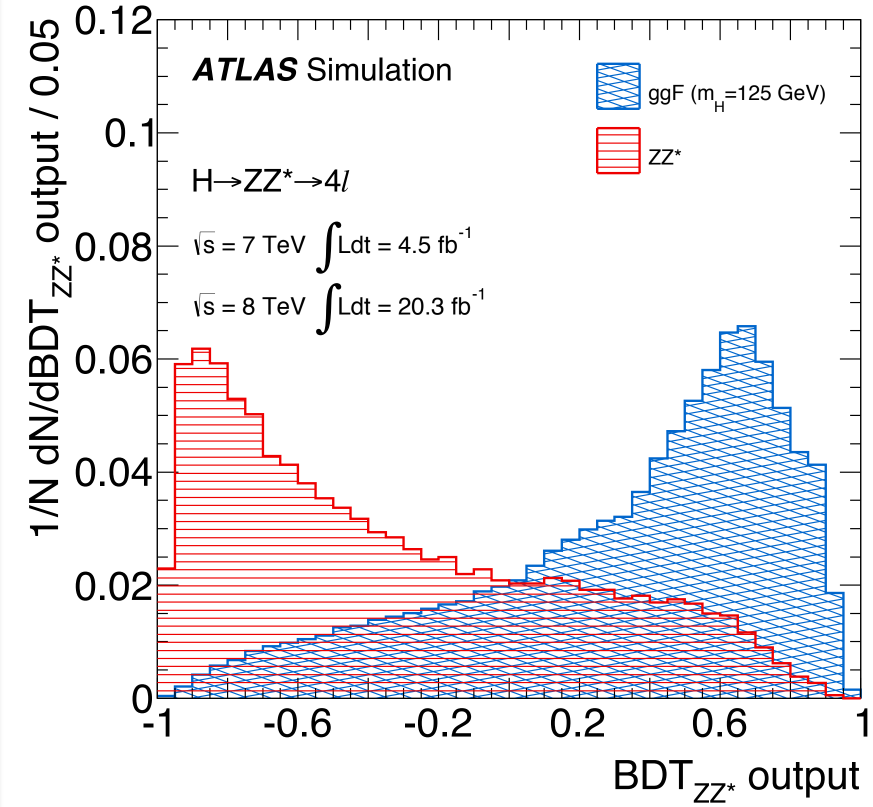




Training variables

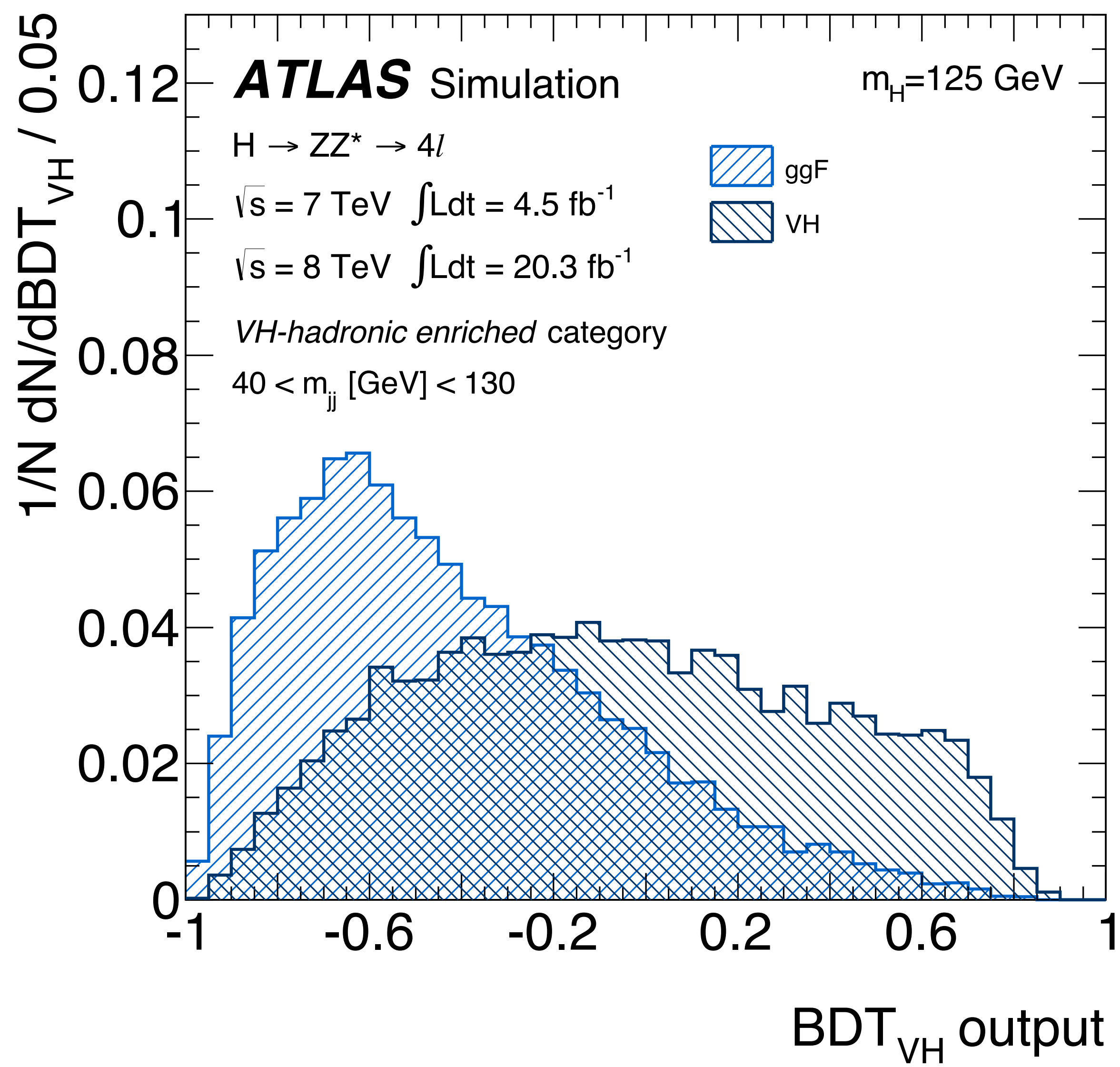


BDT_{ZZ^*} output



$H \rightarrow ZZ^*$: BDT_{VH}

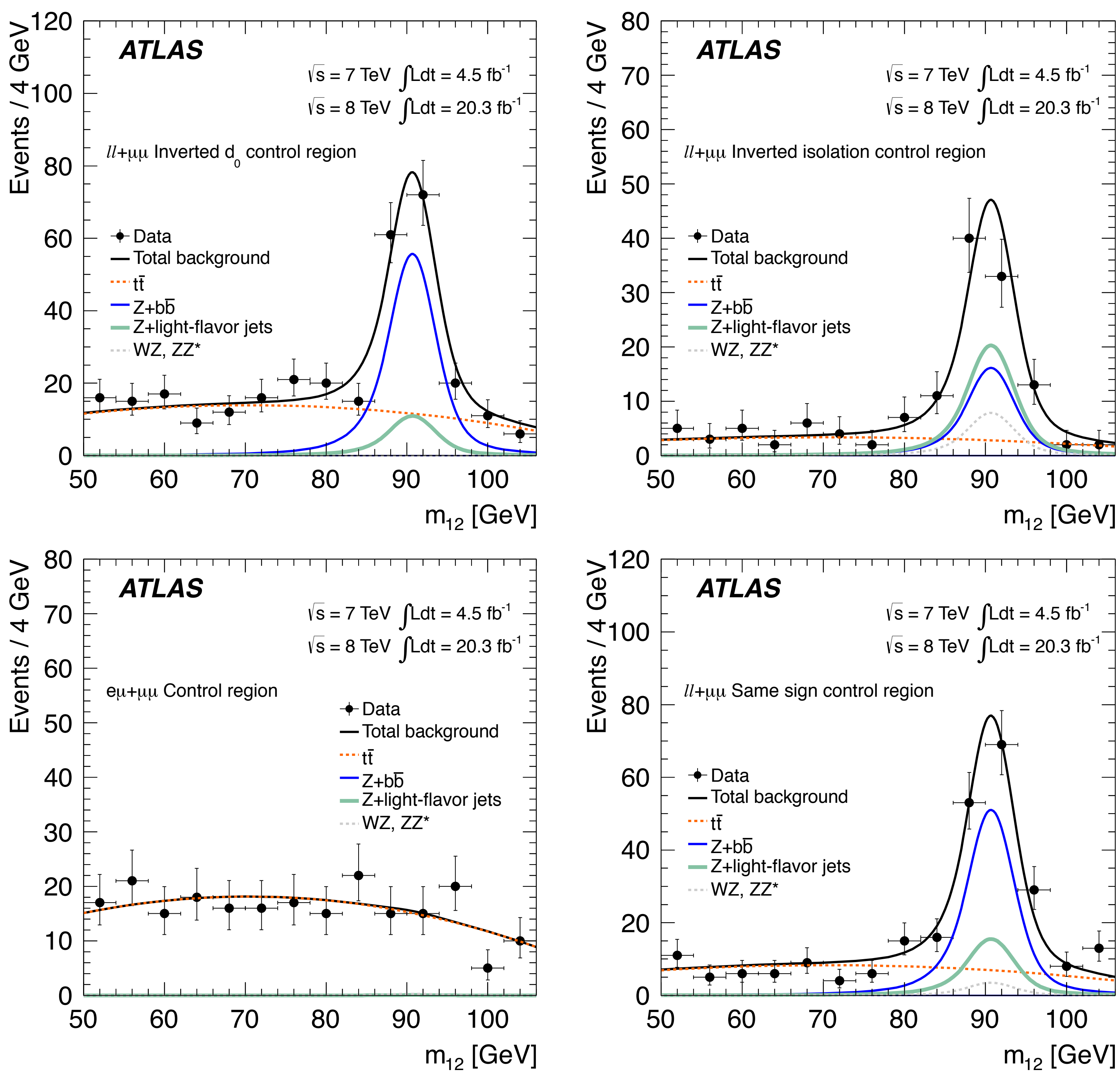
BDT_{VH} output



- ✓ a) invariant mass of the dijet system
- ✓ b) η separation between the jets
- ✓ c) p_T of each jet
- ✓ d) η of the leading jet

H → ZZ*: ll+μμ background

ll+μμ control regions

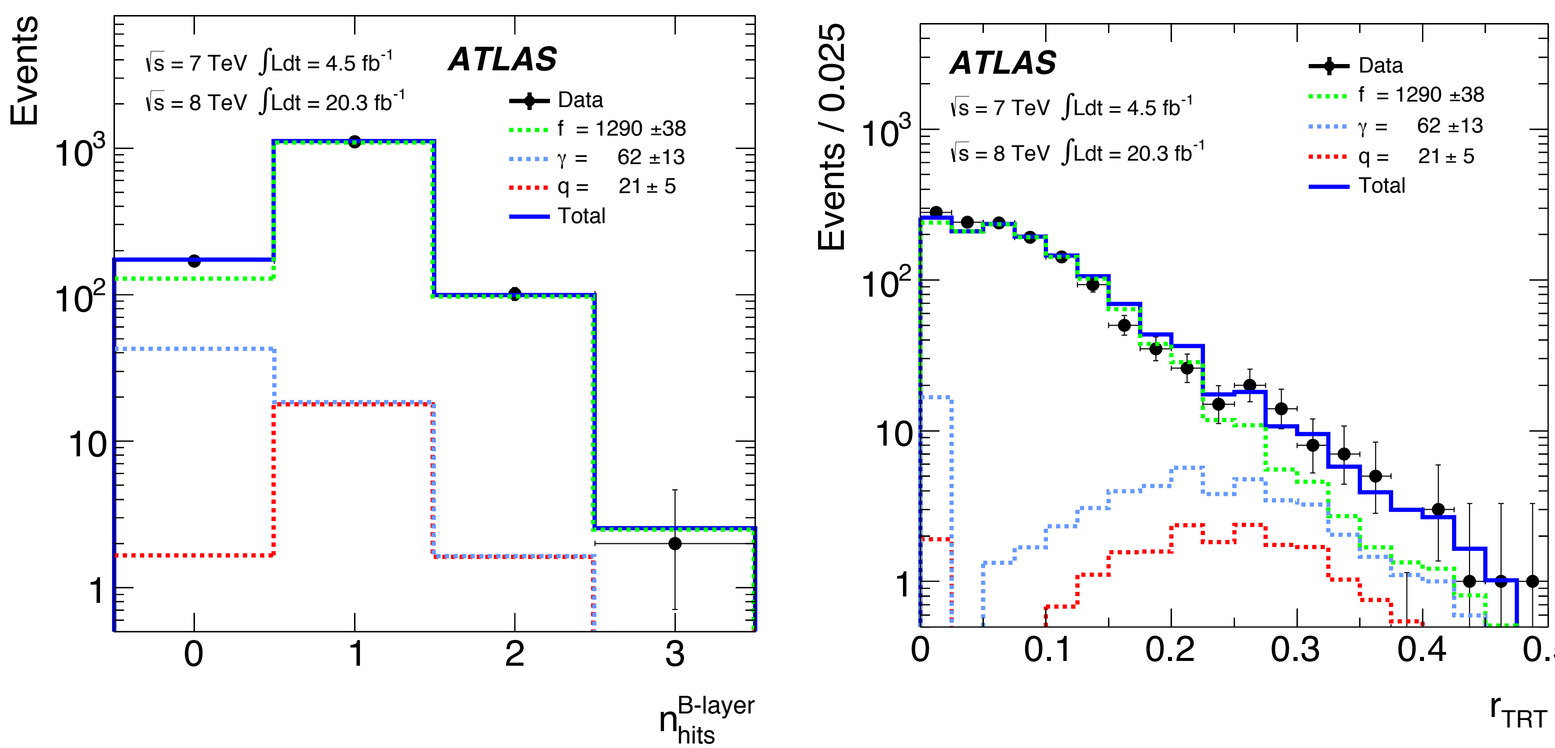


- ✓ 1) Reference region is defined by applying analysis event selection except for the isolation and impact parameter
- ✓ 2)Number of Z+jets and ttbar backgrounds in a reference region are estimated from fit on CRs
- ✓ 3) Apply transfer factors estimated from MC (reference to signal)

H → ZZ*: ll+ee background

- ✓ 1) Define a control region by:
  - ✓ relaxing selection of the lowest pt electron
  - ✓ requiring same-sign for sub-leading electron pair
- ✓ 2) Estimate composition of light flavor jets, photon conversions and heavy flavor semi-leptonic decay by fit
- ✓ 3) Apply transfer factor from Z+X simulation with data corrections

ll+ee control regions



H → ZZ*: systematics

Table 9: The expected impact of the systematic uncertainties on the signal yield, derived from simulation, for $m_H = 125$ GeV, are summarized for each of the four final states for the combined 4.5 fb^{-1} at $\sqrt{s} = 7$ TeV and 20.3 fb^{-1} at $\sqrt{s} = 8$ TeV. The symbol "–" signifies that the systematic uncertainty does not contribute to a particular final state. The last three systematic uncertainties apply equally to all final states. All uncertainties have been symmetrized.

Source of uncertainty	4μ	$2e2\mu$	$2\mu 2e$	$4e$	combined
Electron reconstruction and identification efficiencies	–	1.7%	3.3%	4.4%	1.6%
Electron isolation and impact parameter selection	–	0.07%	1.1%	1.2%	0.5%
Electron trigger efficiency	–	0.21%	0.05%	0.21%	<0.2%
$\ell\ell + ee$ backgrounds	–	–	3.4%	3.4%	1.3%
Muon reconstruction and identification efficiencies	1.9%	1.1%	0.8%	–	1.5%
Muon trigger efficiency	0.6%	0.03%	0.6%	–	0.2%
$\ell\ell + \mu\mu$ backgrounds	1.6%	1.6%	–	–	1.2%
QCD scale uncertainty					6.5%
PDF, α_s uncertainty					6.0%
$H \to ZZ^*$ branching ratio uncertainty					4.0%

$H \to ZZ^*$: systematics

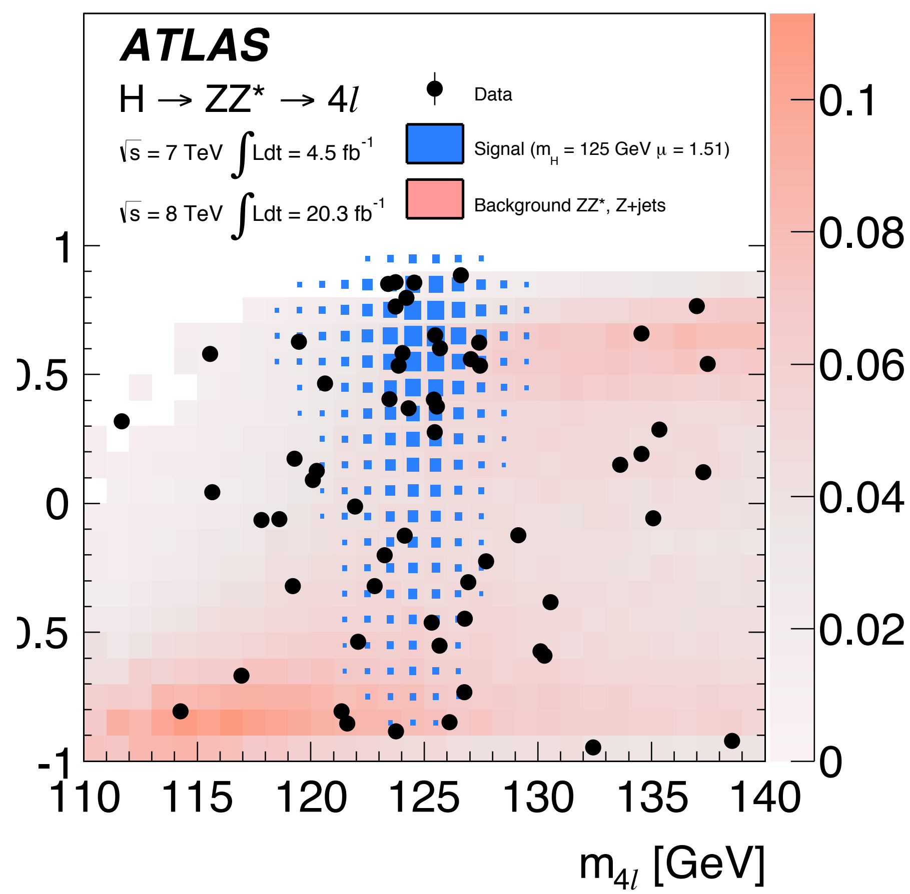
Table 10: Systematic uncertainties on the yields expected from various processes contributing to the *VBF enriched*, *VH leptonic enriched*, *VH-hadronic enriched* and *ggF enriched* categories expressed as percentages of the yield. The variou uncertainties are added in quadrature. Uncertainties that are negligible are denoted by a "–". All uncertainties have bee symmetrized.

Process	$gg \to H, q\bar{q}/gg \to b\bar{b}H/t\bar{t}H$	$qq' \to Hqq'$	$q\bar{q} \to W/ZH$	ZZ^*
VBF enriched category				
Theoretical cross section	20.4%	4%	4%	8%
Underlying event	6.6%	1.4%	–	–
Jet energy scale	9.6%	4.8%	7.8%	9.6%
Jet energy resolution	0.9%	0.2%	1.0%	1.4%
Total	23.5%	6.4%	8.8%	12.6%
VH-hadronic enriched category				
Theoretical cross section	20.4%	4%	4%	2%
Underlying event	7.5%	3.1%	–	–
Jet energy scale	9.4%	9.3%	3.7%	12.6%
Jet energy resolution	1.0%	1.7%	0.6%	1.8%
Total	23.7%	10.7%	5.5%	12.9%
VH-leptonic enriched category				
Theoretical cross section	12%	4%	4%	5%
Leptonic VH-specific cuts	1%	1%	5%	–
Jet energy scale	8.8%	9.9%	1.7%	3.2%
Total	14.9%	10.7%	6.6%	5.9%
ggF enriched category				
Theoretical cross section	12%	4%	4%	4%
Jet energy scale	2.2%	6.6%	4.0%	1.0%
Total	12.2%	7.7%	5.7%	4.1%

H → ZZ*: results

Table 11: The number of events expected and observed for a m_H=125 GeV hypothesis for the four-lepton final states in a window of $120 < m_{4\ell} < 130$ GeV. The second column shows the number of expected signal events for the full mass range, without a selection on $m_{4\ell}$. The other columns show for the 120–130 GeV mass range the number of expected signal events, the number of expected ZZ^* and reducible background events, and the signal-to-background ratio (S/B), together with the number of observed events, for 4.5 fb^{-1} at $\sqrt{s} = 7$ TeV and 20.3 fb^{-1} at $\sqrt{s} = 8$ TeV as well as for the combined sample.

Final state	Signal full mass range	Signal	ZZ^*	$Z+$jets, $t\bar{t}$	S/B	Expected	Observed
			$\sqrt{s} = 7$ TeV				
4μ	1.00 ± 0.10	0.91 ± 0.09	0.46 ± 0.02	0.10 ± 0.04	1.7	1.47 ± 0.10	2
$2e2\mu$	0.66 ± 0.06	0.58 ± 0.06	0.32 ± 0.02	0.09 ± 0.03	1.5	0.99 ± 0.07	2
$2\mu 2e$	0.50 ± 0.05	0.44 ± 0.04	0.21 ± 0.01	0.36 ± 0.08	0.8	1.01 ± 0.09	1
$4e$	0.46 ± 0.05	0.39 ± 0.04	0.19 ± 0.01	0.40 ± 0.09	0.7	0.98 ± 0.10	1
Total	2.62 ± 0.26	2.32 ± 0.23	1.17 ± 0.06	0.96 ± 0.18	1.1	4.45 ± 0.30	6
			$\sqrt{s} = 8$ TeV				
4μ	5.80 ± 0.57	5.28 ± 0.52	2.36 ± 0.12	0.69 ± 0.13	1.7	8.33 ± 0.6	12
$2e2\mu$	3.92 ± 0.39	3.45 ± 0.34	1.67 ± 0.08	0.60 ± 0.10	1.5	5.72 ± 0.37	7
$2\mu 2e$	3.06 ± 0.31	2.71 ± 0.28	1.17 ± 0.07	0.36 ± 0.08	1.8	4.23 ± 0.30	5
$4e$	2.79 ± 0.29	2.38 ± 0.25	1.03 ± 0.07	0.35 ± 0.07	1.7	3.77 ± 0.27	7
Total	15.6 ± 1.6	13.8 ± 1.4	6.24 ± 0.34	2.00 ± 0.28	1.7	22.1 ± 1.5	31
			$\sqrt{s} = 7$ TeV and $\sqrt{s} = 8$ TeV				
4μ	6.80 ± 0.67	6.20 ± 0.61	2.82 ± 0.14	0.79 ± 0.13	1.7	9.81 ± 0.64	14
$2e2\mu$	4.58 ± 0.45	4.04 ± 0.40	1.99 ± 0.10	0.69 ± 0.11	1.5	6.72 ± 0.42	9
$2\mu 2e$	3.56 ± 0.36	3.15 ± 0.32	1.38 ± 0.08	0.72 ± 0.12	1.5	5.24 ± 0.35	6
$4e$	3.25 ± 0.34	2.77 ± 0.29	1.22 ± 0.08	0.76 ± 0.11	1.4	4.75 ± 0.32	8
Total	18.2 ± 1.8	16.2 ± 1.6	7.41 ± 0.40	2.95 ± 0.33	1.6	26.5 ± 1.7	37



H → ZZ*: results

Table 12: Expected and observed yields in the *VBF enriched*, *VH-hadronic enriched*, *VH-leptonic enriched* and *ggF enriched* categories. The yields are given for the different production modes and the ZZ^* and reducible background for 4.6 fb^{-1} at $\sqrt{s} = 7$ TeV and 20.3 fb^{-1} at $\sqrt{s} = 8$ TeV. The estimates are given for both the $m_{4\ell}$ mass range 120–130 GeV and the mass range above 110 GeV.

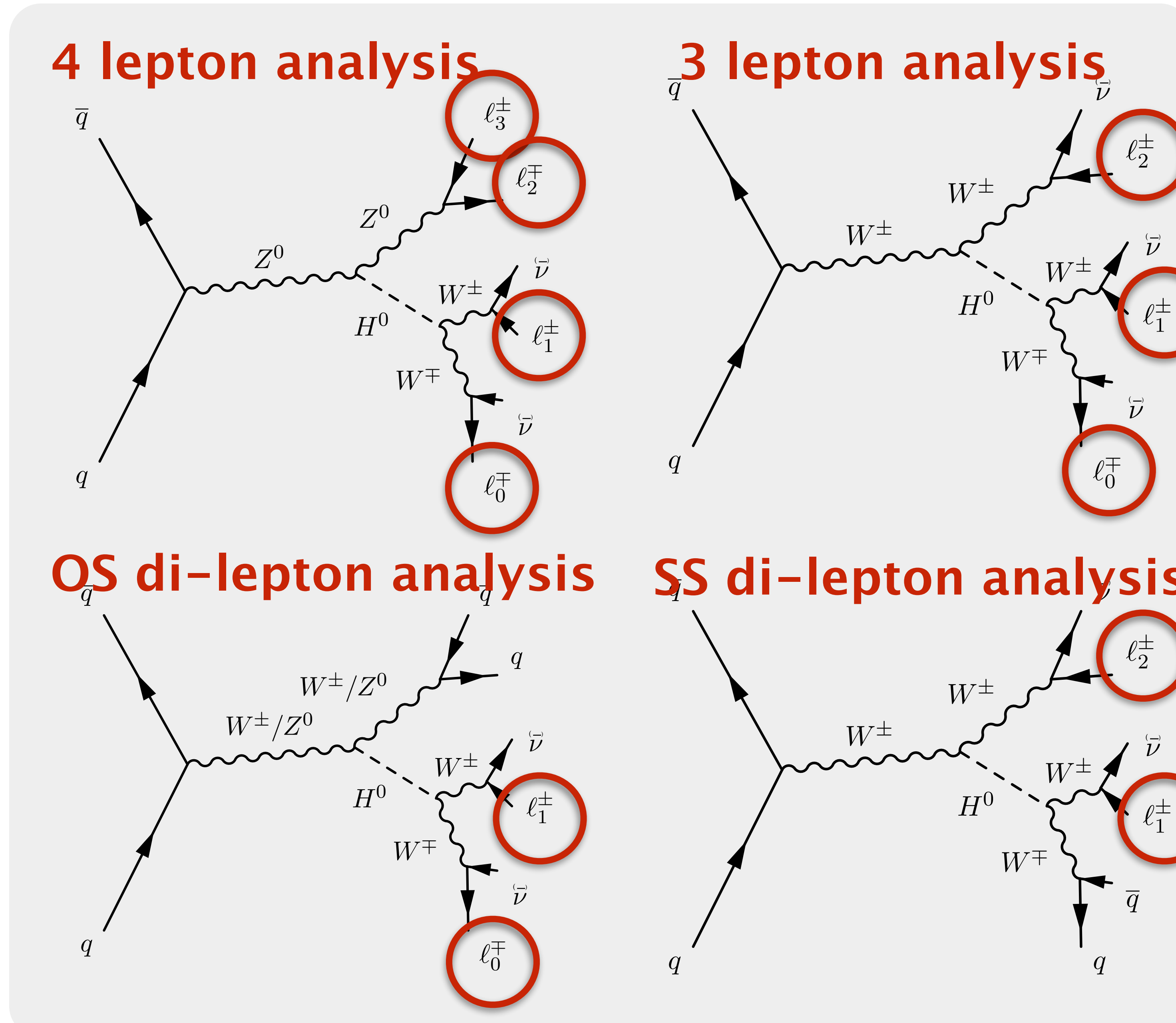
Enriched category	Signal $ggF + b\bar{b}H + t\bar{t}H$	Signal VBF	Signal VH-hadronic	Signal VH-leptonic	Background ZZ^*	Background $Z+$jets, $t\bar{t}$	Total expected	Observed
$120 < m_{4\ell} < 130$ GeV								
VBF	1.18 ± 0.37	0.75 ± 0.04	0.083 ± 0.006	0.013 ± 0.001	0.17 ± 0.03	0.25 ± 0.14	2.4 ± 0.4	3
($\text{BDT}_{\text{VBF}} > 0$)	0.48 ± 0.15	0.62 ± 0.04	0.023 ± 0.002	0.004 ± 0.001	0.06 ± 0.01	0.10 ± 0.05	1.26 ± 0.15	1
VH-hadronic	0.40 ± 0.12	0.034 ± 0.004	0.20 ± 0.01	0.009 ± 0.001	0.09 ± 0.01	0.09 ± 0.04	0.80 ± 0.12	0
VH-leptonic	0.013 ± 0.002	< 0.001	< 0.001	0.069 ± 0.004	0.015 ± 0.002	0.016 ± 0.019	0.11 ± 0.02	0
ggF	12.8 ± 1.3	0.57 ± 0.02	0.24 ± 0.01	0.11 ± 0.01	7.1 ± 0.2	2.7 ± 0.4	23.5 ± 1.4	34
$m_{4\ell} > 110$ GeV								
VBF	1.4 ± 0.4	0.82 ± 0.05	0.092 ± 0.007	0.022 ± 0.002	20 ± 4	1.6 ± 0.9	24. ± 4.	32
($\text{BDT}_{\text{VBF}} > 0$)	0.54 ± 0.17	0.68 ± 0.04	0.025 ± 0.002	0.007 ± 0.001	8.2 ± 1.6	0.6 ± 0.3	10.0 ± 1.6	12
VH-hadronic	0.46 ± 0.14	0.038 ± 0.004	0.23 ± 0.01	0.015 ± 0.001	9.0 ± 1.2	0.6 ± 0.2	10.3 ± 1.2	13
VH-leptonic	0.026 ± 0.004	< 0.002	< 0.002	0.15 ± 0.01	0.63 ± 0.04	0.11 ± 0.14	0.92 ± 0.16	1
ggF	14.1 ± 1.5	0.63 ± 0.02	0.27 ± 0.01	0.17 ± 0.01	351. ± 20	16.6 ± 2.2	383. ± 20	420

$H \to WW^*$: event selection

Objective	ggF-enriched			VBF-enriched
	$n_j = 0$	$n_j = 1$	$n_j \geq 2$ ggF	$n_j \geq 2$ VBF
Preselection, All n_j	$p_T^{\ell 1} > 22$ for the leading lepton ℓ_1			
	$p_T^{\ell 2} > 10$ for the subleading lepton ℓ_2			
	Opposite-charge leptons			
	$m_{\ell\ell} > 10$ for the $e\mu$ sample			
	$m_{\ell\ell} > 12$ for the $ee/\mu\mu$ sample			
	$\lvert m_{\ell\ell} - m_Z \rvert > 15$ for the $ee/\mu\mu$ sample			
	$p_T^{miss} > 20$ for $e\mu$	$p_T^{miss} > 20$ for $e\mu$	$p_T^{miss} > 20$ for $e\mu$	No MET requirement for $e\mu$
	$E_{T,rel}^{miss} > 40$ for $ee/\mu\mu$	$E_{T,rel}^{miss} > 40$ for $ee/\mu\mu$	-	-
Reject backgrounds, DY	$p_{T,rel}^{miss\,(trk)} > 40$ for $ee/\mu\mu$	$p_{T,rel}^{miss\,(trk)} > 35$ for $ee/\mu\mu$	-	$p_T^{miss} > 40$ for $ee/\mu\mu$
	$f_{recoil} < 0.1$ for $ee/\mu\mu$	$f_{recoil} < 0.1$ for $ee/\mu\mu$	-	$E_T^{miss} > 45$ for $ee/\mu\mu$
	$p_T^{\ell\ell} > 30$	$m_{\tau\tau} < m_Z - 25$	$m_{\tau\tau} < m_Z - 25$	$m_{\tau\tau} < m_Z - 25$
	$\Delta\phi_{\ell\ell,MET} > \pi/2$	-	-	-
Misid.	-	$m_T^{\ell} > 50$ for $e\mu$	-	-
Top	$n_j = 0$	$n_b = 0$	$n_b = 0$	$n_b = 0$
	-	-	-	p_T^{sum} inputs to BDT
	-	-	-	$\Sigma m_{\ell j}$ inputs to BDT
VBF topology	-	-	See Sec. IV D for rejection of VBF & VH ($W, Z \to jj$), where $H \to WW^*$	m_{jj} inputs to BDT
				Δy_{jj} inputs to BDT
				ΣC_ℓ inputs to BDT
				$C_{\ell 1} < 1$ and $C_{\ell 2} < 1$
				$C_{j3} > 1$ for j_3 with $p_T^{j3} > 20$
				$O_{BDT} \geq -0.48$
$H \to WW^* \to \ell\nu\ell\nu$ decay topology	$m_{\ell\ell} < 55$	$m_{\ell\ell} < 55$	$m_{\ell\ell} < 55$	$m_{\ell\ell}$ inputs to BDT
	$\Delta\phi_{\ell\ell} < 1.8$	$\Delta\phi_{\ell\ell} < 1.8$	$\Delta\phi_{\ell\ell} < 1.8$	$\Delta\phi_{\ell\ell}$ inputs to BDT
	No m_T requirement	No m_T requirement	No m_T requirement	m_T inputs to BDT

VH H → WW*: overview

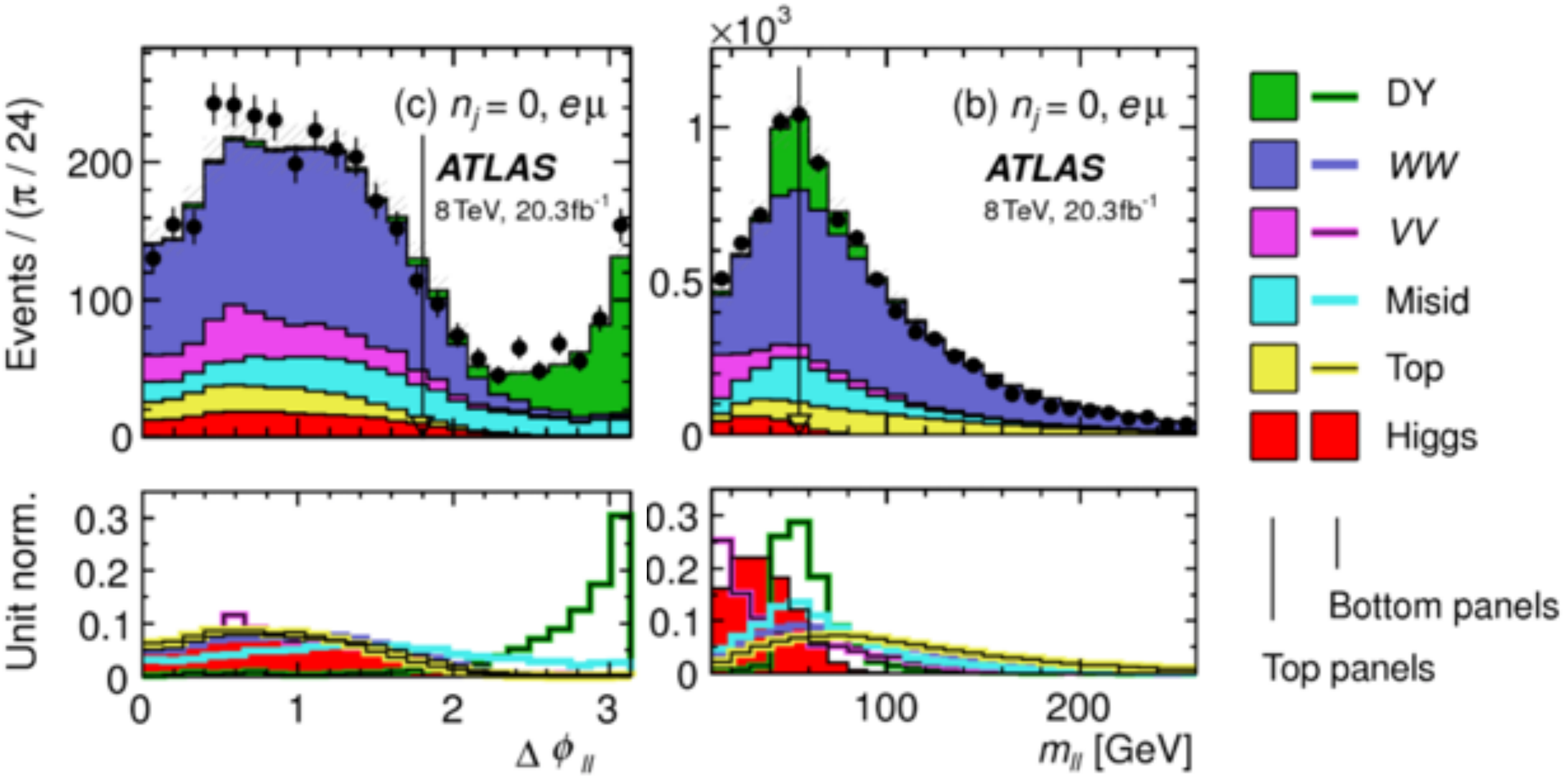
- ✓ Analysis is split by lepton multiplicity and charge
  - In 3 lepton analysis, shape fit to ΔR_{l0l1} and BDT score is performed to extract the signals
  - Other analyses use the fit without shape information



* ΔR_{l0l1} is the angle separation between the lepton with unique charge (l0) and the lepton closest to l0

ggF and VBF H → WW*: event selections

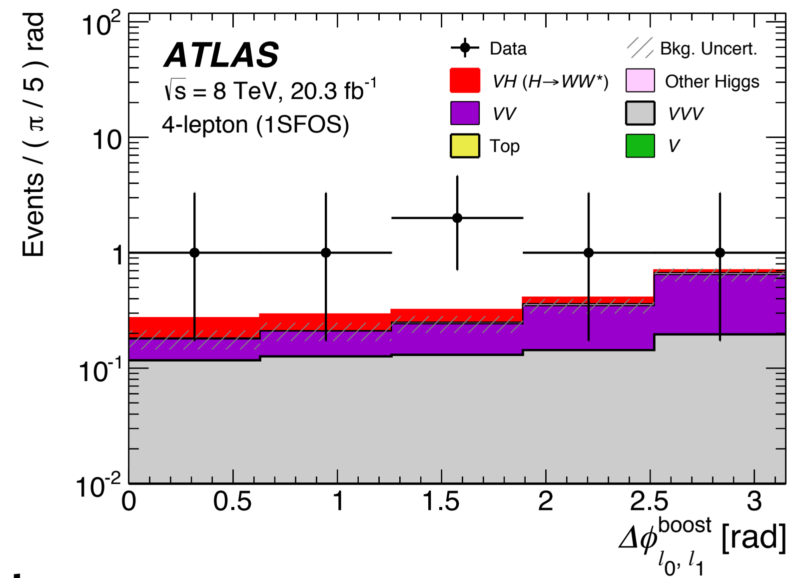
- ✓ Opposite-sign lepton pair
  - $p_T > 22, 10$ GeV
  - $|\eta| < 2.47$ (2.5) for e (μ)
  - $m_{ll} > 10$ (12) GeV for eμ (ee/μμ)
- ✓ Jet for categorization
  - $p_T > 25$ (30) GeV for $|\eta| < 2.4$ ($2.4 < |\eta| < 4.5$)
  - $n_{jet} = 0,1$ → ggF enriched
  - $n_{jet} > 1$ → VBF enriched
- ✓ Background rejection
  - $\Delta\Phi_{ll} < 1.8$ and $m_{ll} < 55$ GeV for ggF enriched
  - $BDT_{VBF} > -0.48$ for VBF enriched
  - ..etc (backup)



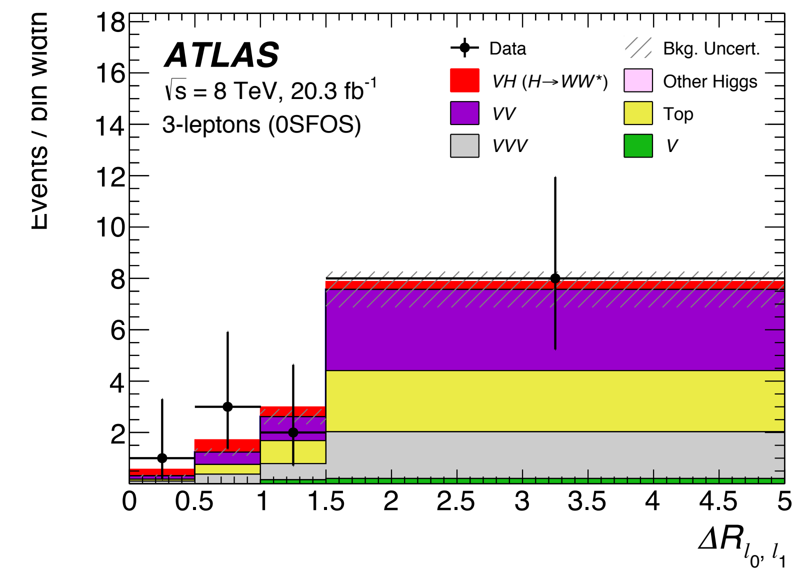
VH H → WW*: event selections and backgrounds

- ✓ 4 lepton analysis
  - 1 SFOS or 2 SFOS leptons
  - $|m_{l2l3} - m_Z| < 10$ GeV, etc
  - Background: **ZZ***
- ✓ 3 lepton analysis
  - 3 SF or 1 SFOS or 0 SFOS leptons
  - $\Delta R_{l0l1} < 2.0$, etc
  - Background: **WZ/Wγ*, ZZ*** and VVV
- ✓ OS di-lepton analysis
  - Only eμ events, $|m_{jj} - 85| < 15$ GeV, etc
  - Background: **Top, Z→ττ**
- ✓ SS di-lepton analysis
  - Split jet multiplicity and lepton flavor
  - Background: W+jets, **Top, WZ/Wγ*, Wγ**

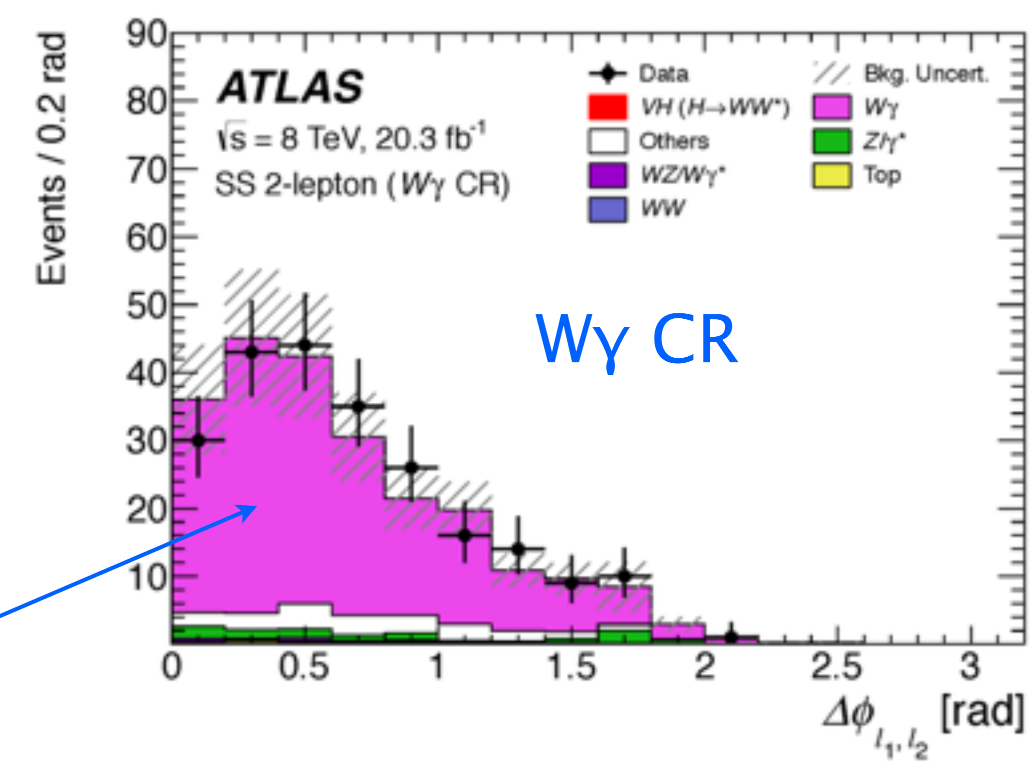
1 SFOS SR



0 SFOS SR



* Backgrounds in bold are normalized using CRs



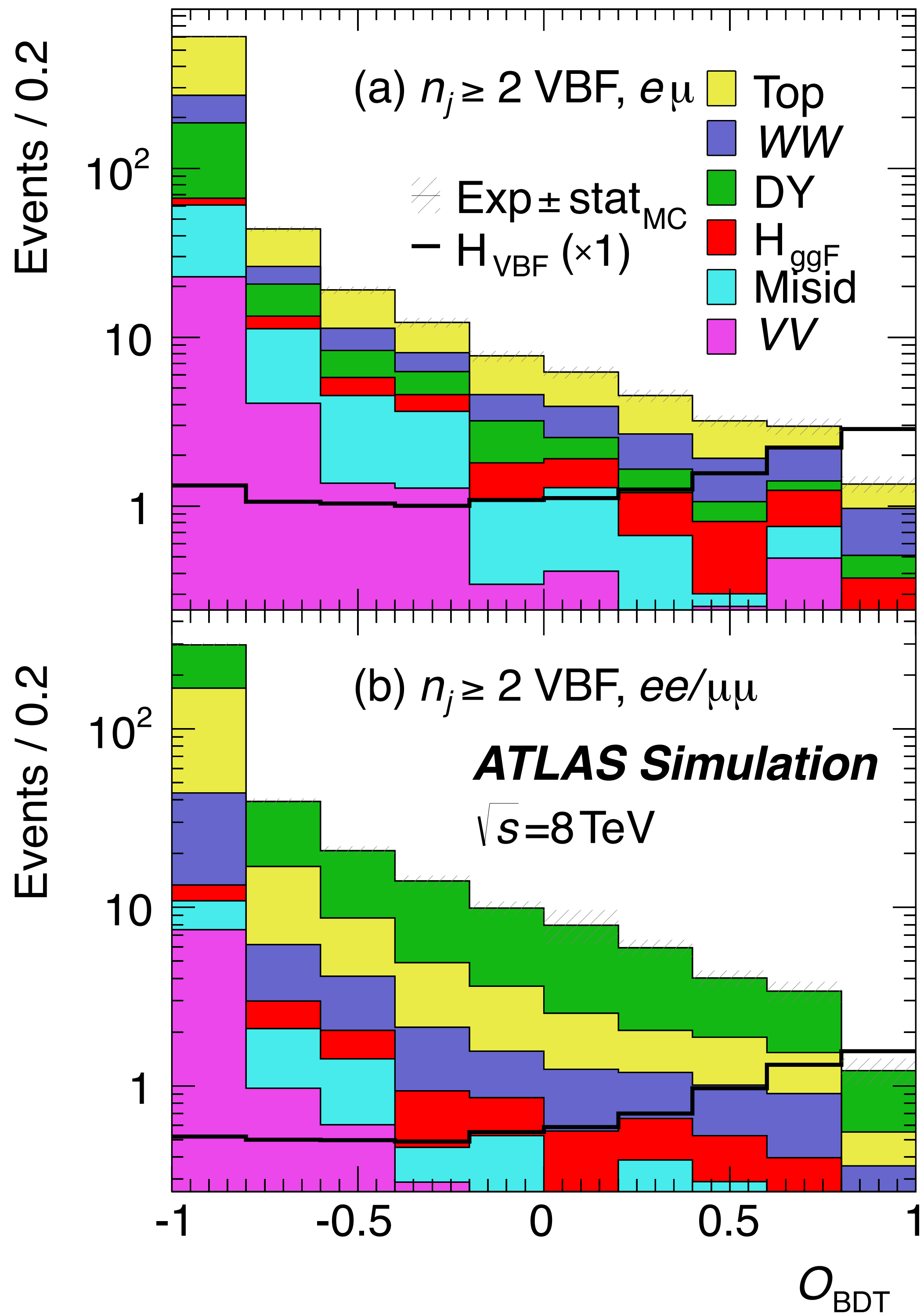
H → WW*: event selection

Channel	4ℓ		3ℓ			2ℓ		
Category	2SFOS	1SFOS	3SF	1SFOS	0SFOS	DFOS	SS2jet	SS1jet
Trigger	single-lepton triggers		single-lepton triggers			single-lepton & dilepton triggers		
Num. of leptons	4	4	3	3	3	2	2	2
$p_{\mathrm{T,leptons}}$ [GeV]	$> 25, 20, 15$	$> 25, 20, 15$	> 15	> 15	> 15	$> 22, 15$	$> 22, 15$	$> 22, 15$
Total lepton charge	0	0	± 1	± 1	± 1	0	± 2	± 2
Num. of SFOS pairs	2	1	2	1	0	0	0	0
Num. of jets	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1	≥ 2	2	1
$p_{\mathrm{T,jets}}$ [GeV]	> 25 (30)	> 25 (30)	> 25 (30)	> 25 (30)	> 25 (30)	> 25 (30)	> 25 (30)	> 25 (30)
Num. of b-tagged jets	0	0	0	0	0	0	0	0
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 20	> 20	> 30	> 30	—	> 20	> 50	> 45
$p_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 15	> 15	> 20	> 20	—	—	—	—
$\lvert m_{\ell\ell} - m_Z \rvert$ [GeV]	< 10 ($m_{\ell_2\ell_3}$)	< 10 ($m_{\ell_2\ell_3}$)	> 25	> 25	—	—	> 15	> 15
Min. $m_{\ell\ell}$ [GeV]	> 10 ($m_{\ell_0\ell_1}$)	> 10 ($m_{\ell_0\ell_1}$)	> 12	> 12	> 6	> 10	> 12 ($ee, \mu\mu$) > 10 ($e\mu$)	> 12 ($ee, \mu\mu$) > 10 ($e\mu$)
Max. $m_{\ell\ell}$ [GeV]	< 65 ($m_{\ell_0\ell_1}$)	< 65 ($m_{\ell_0\ell_1}$)	< 200	< 200	< 200	< 50	—	—
$m_{4\ell}$ [GeV]	> 140	—	—	—	—	—	—	—
$p_{\mathrm{T},4\ell}$ [GeV]	> 30	—	—	—	—	—	—	—
$m_{\tau\tau}$ [GeV]	—	—	—	—	—	$< (m_Z - 25)$	—	—
$\Delta R_{\ell_0\ell_1}$	—	—	< 2.0	< 2.0	—	—	—	—
$\Delta\phi_{\ell_0\ell_1}$ [rad]	< 2.5 ($\Delta\phi_{\ell_0\ell_1}^{\mathrm{boost}}$)	< 2.5 ($\Delta\phi_{\ell_0\ell_1}^{\mathrm{boost}}$)	—	—	—	< 1.8	—	—
m_{T} [GeV]	—	—	—	—	—	< 125	—	> 105 ($m_{\mathrm{T}}^{\mathrm{lead}}$)
Min. $m_{\ell_i j(j)}$ [GeV]	—	—	—	—	—	—	< 115	< 70
Min. $\phi_{\ell_i j}$ [rad]	—	—	—	—	—	—	< 1.5	< 1.5
Δy_{jj}	—	—	—	—	—	< 1.2	—	—
$\lvert m_{jj} - 85 \rvert$ [GeV]	—	—	—	—	—	< 15	—	—

$H \rightarrow WW^*$: BDT_{VBF}

- ✓ a) p_T^{sum}: $p_T^{ll}+p_T^{miss}+\Sigma p_T^{jet}$
- ✓ b) Σm_{lj}: $m_{l1j1}+m_{l1j2}+m_{l2j1}+m_{l2j2}$
- ✓ c) m_{jj}
- ✓ d) Δy_{jj}
- ✓ e) ΣC_l: $C_{l1}+C_{l2}$
- ✓ f) m_{ll}
- ✓ g) $\Delta\varphi_{ll}$
- ✓ h) m_T

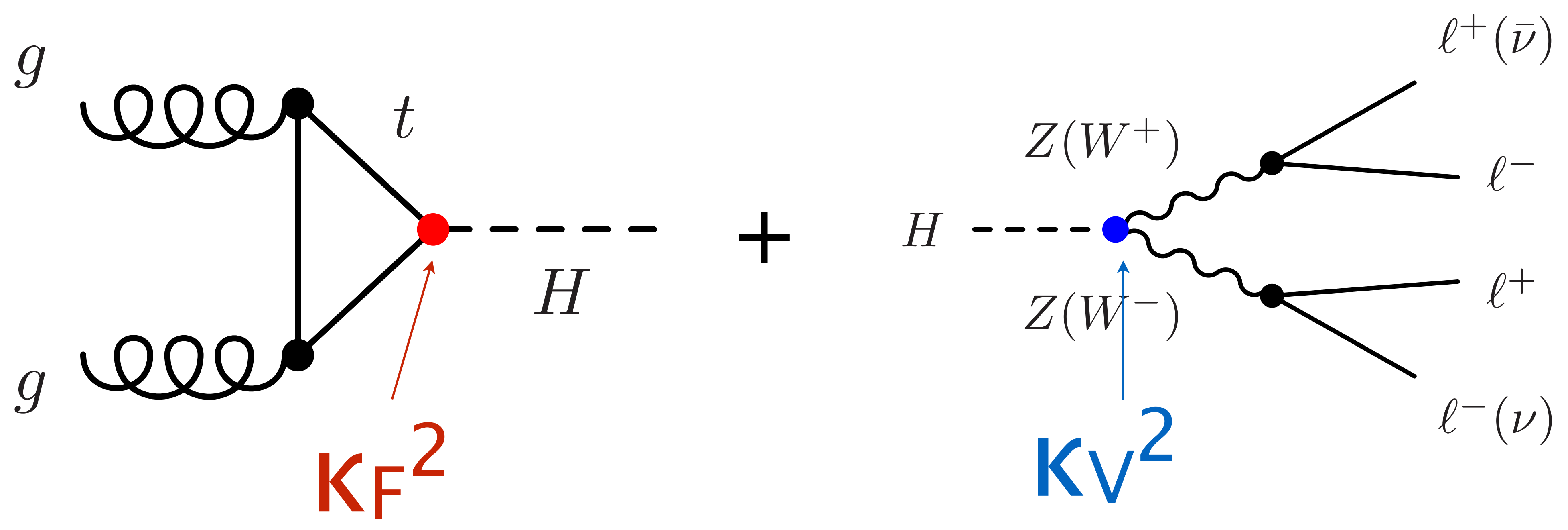
BDT_{VBF} output



H → WW*: systematics

Source	Observed $\mu = 1.09$ Error +	−	Plot of error (scaled by 100)	Observed $\mu_{ggF} = 1.02$ Error +	−	Plot of error (scaled by 100)	Observed $\mu_{VBF} = 1.27$ Error +	−	Plot of error (scaled by 100)
Data statistics	0.16	0.15		0.19	0.19		0.44	0.40	
Signal regions	0.12	0.12		0.14	0.14		0.38	0.35	
Profiled control regions	0.10	0.10		0.12	0.12		0.21	0.18	
Profiled signal regions	-	-	-	0.03	0.03		0.09	0.08	
MC statistics	0.04	0.04		0.06	0.06		0.05	0.05	
Theoretical systematics	0.15	0.12		0.19	0.16		0.22	0.15	
Signal $H \to WW^* \mathcal{B}$	0.05	0.04		0.05	0.03		0.07	0.04	
Signal ggF cross section	0.09	0.07		0.13	0.09		0.03	0.03	
Signal ggF acceptance	0.05	0.04		0.06	0.05		0.07	0.07	
Signal VBF cross section	0.01	0.01		-	-	-	0.07	0.04	
Signal VBF acceptance	0.02	0.01		-	-	-	0.15	0.08	
Background WW	0.06	0.06		0.08	0.08		0.07	0.07	
Background top quark	0.03	0.03		0.04	0.04		0.06	0.06	
Background misid. factor	0.05	0.05		0.06	0.06		0.02	0.02	
Others	0.02	0.02		0.02	0.02		0.03	0.03	
Experimental systematics	0.07	0.06		0.08	0.08		0.18	0.14	
Background misid. factor	0.03	0.03		0.04	0.04		0.02	0.01	
Bkg. $Z/\gamma^* \to ee, \mu\mu$	0.02	0.02		0.03	0.03		0.01	0.01	
Muons and electrons	0.04	0.04		0.05	0.04		0.03	0.02	
Missing transv. momentum	0.02	0.02		0.02	0.01		0.05	0.05	
Jets	0.03	0.02		0.03	0.03		0.15	0.11	
Others	0.03	0.02		0.03	0.03		0.06	0.06	
Integrated luminosity	0.03	0.03		0.03	0.02		0.05	0.03	
Total	0.23	0.21		0.29	0.26		0.53	0.45	
			-30 -15 0 15 30			-30 -15 0 15 30			-60 -30 0 30 60

H → WW*: κ calculation

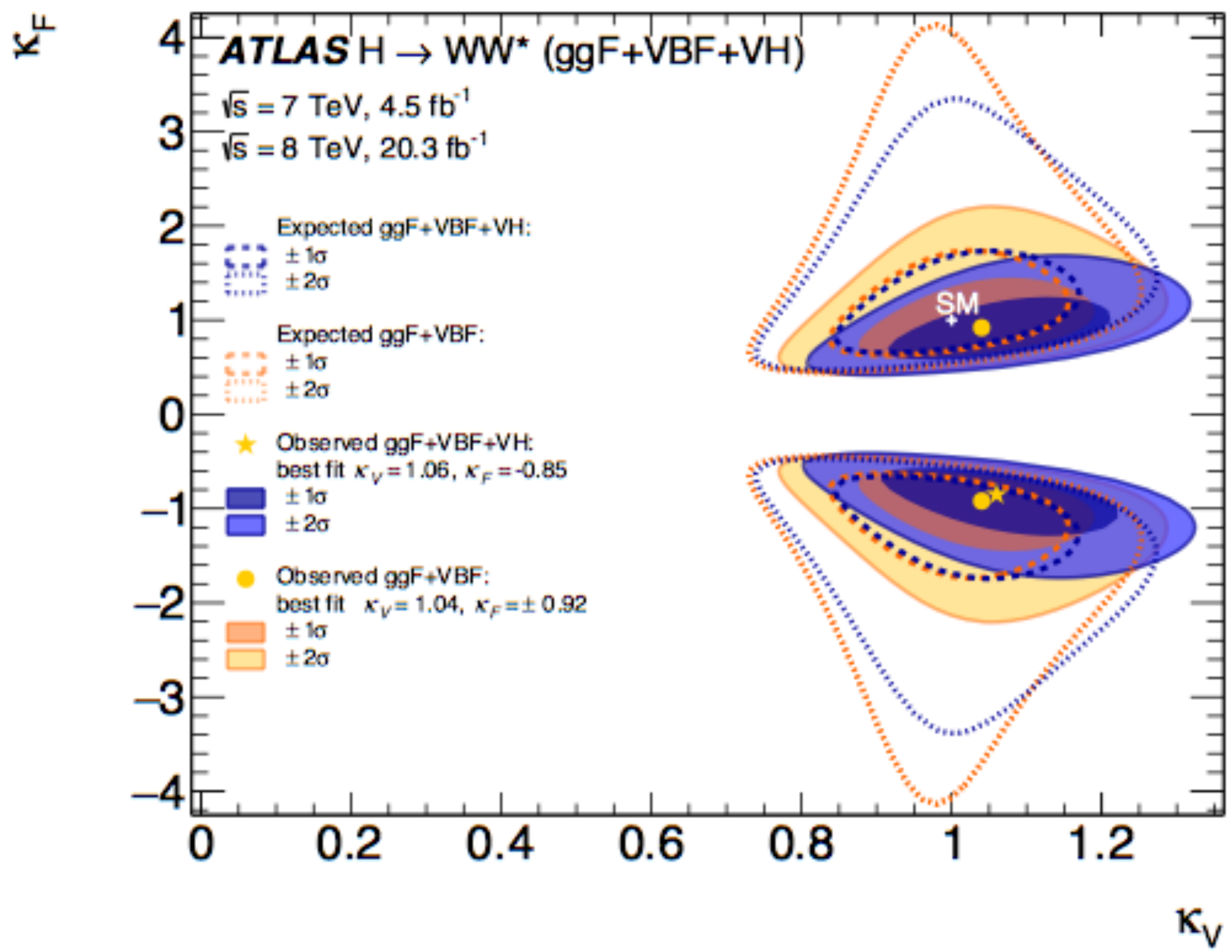


$$\mu_{\rm ggF} \propto \frac{\kappa_F^2 \cdot \kappa_V^2}{\left(\mathcal{B}_{H\to f\bar{f}} + \mathcal{B}_{H\to gg}\right)\kappa_F^2 + \left(\mathcal{B}_{H\to VV}\right)\kappa_V^2},$$

$$\mu_{\rm VBF} \propto \frac{\kappa_V^4}{\left(\mathcal{B}_{H\to f\bar{f}} + \mathcal{B}_{H\to gg}\right)\kappa_F^2 + \left(\mathcal{B}_{H\to VV}\right)\kappa_V^2}.$$

H → WW*: results

✓ Likelihood scan as function of κ_V and κ_F:



$$\kappa_F = 0.85^{+0.26}_{-0.20}$$

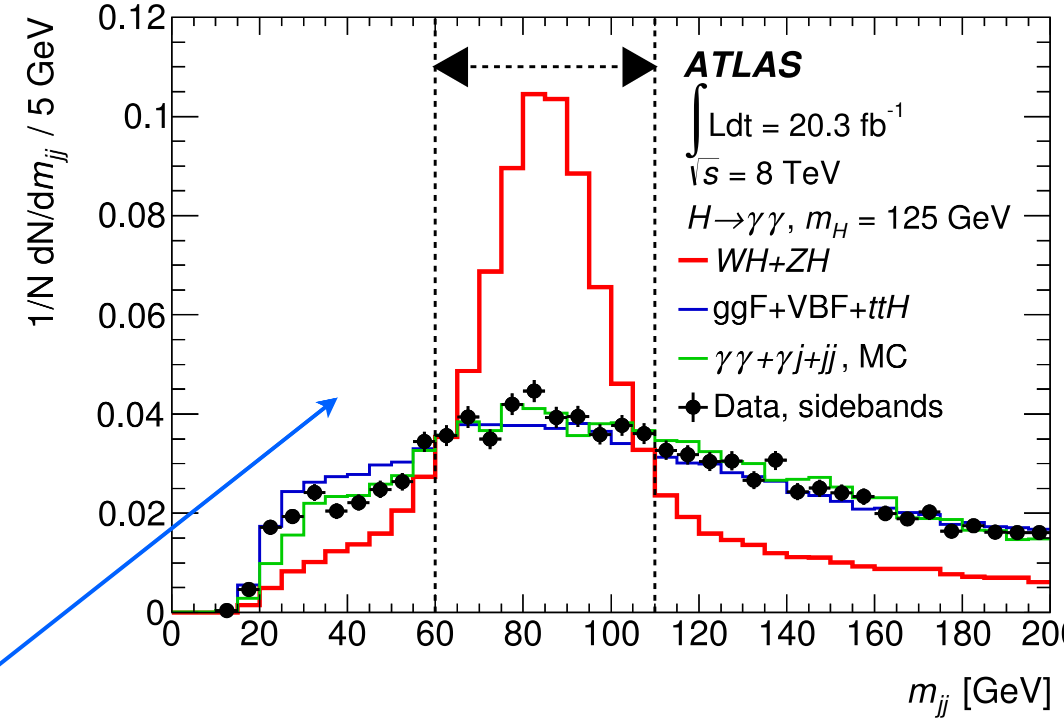
$$\kappa_V = 1.06^{+0.10}_{-0.10}$$

– Consistent with the SM expectation

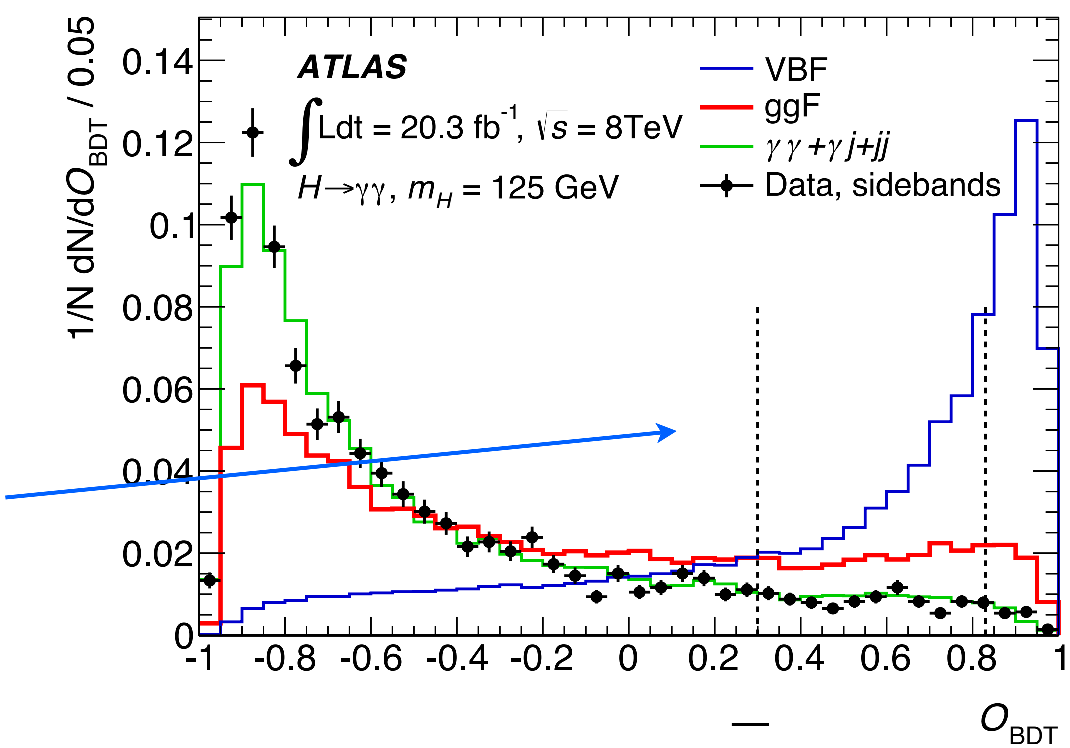
– Total uncertainty is ~10% for boson coupling

H → γγ: event selections

- ✓ At least two photon candidates
  - $E_T/m_{\gamma\gamma} > 0.35$ (0.25) for leading (sub-leading) photon



- ✓ Event categorization
  - ttH enriched:
    - b-tagged jets from top decay
  - VH enriched:
    - Lepton, MET and jets from V decay
  - VBF enriched:
    - BDT score based on VBF topology

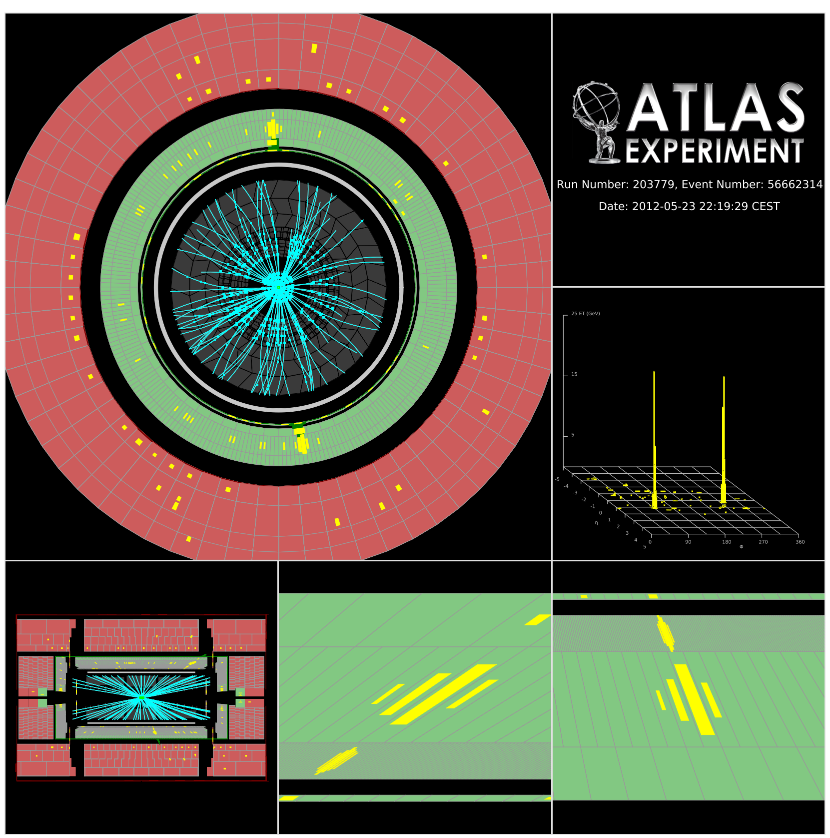


backup for details

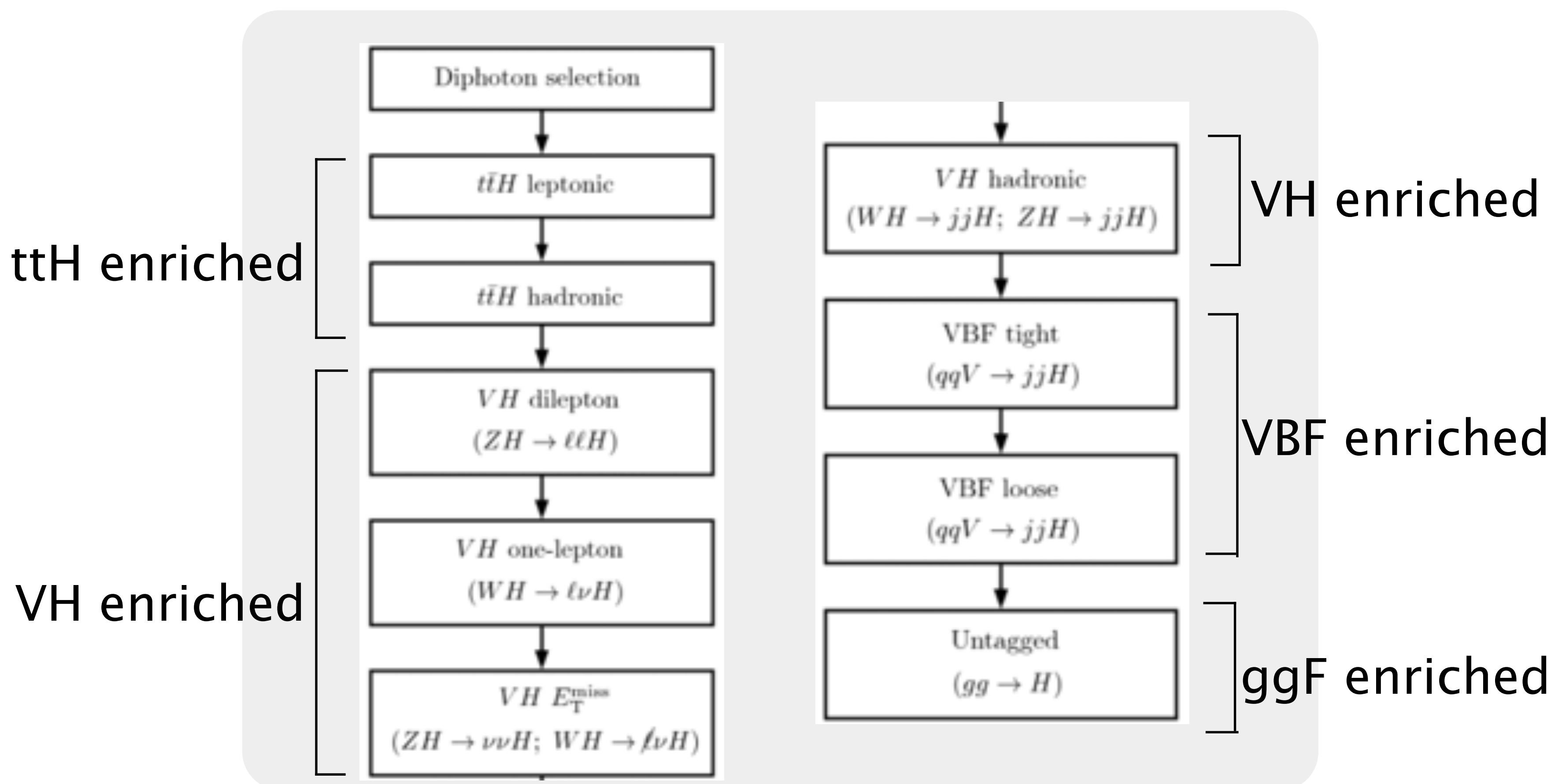
H → γγ: overview

- ✓ Decay to two photons via loop of other particles
  - Event topology can be fully reconstructed
  - Sensitive to new phenomena
- ✓ Diphoton events are divided into 12 categories to maximize sensitivities

H → γγ candidate



Event categories

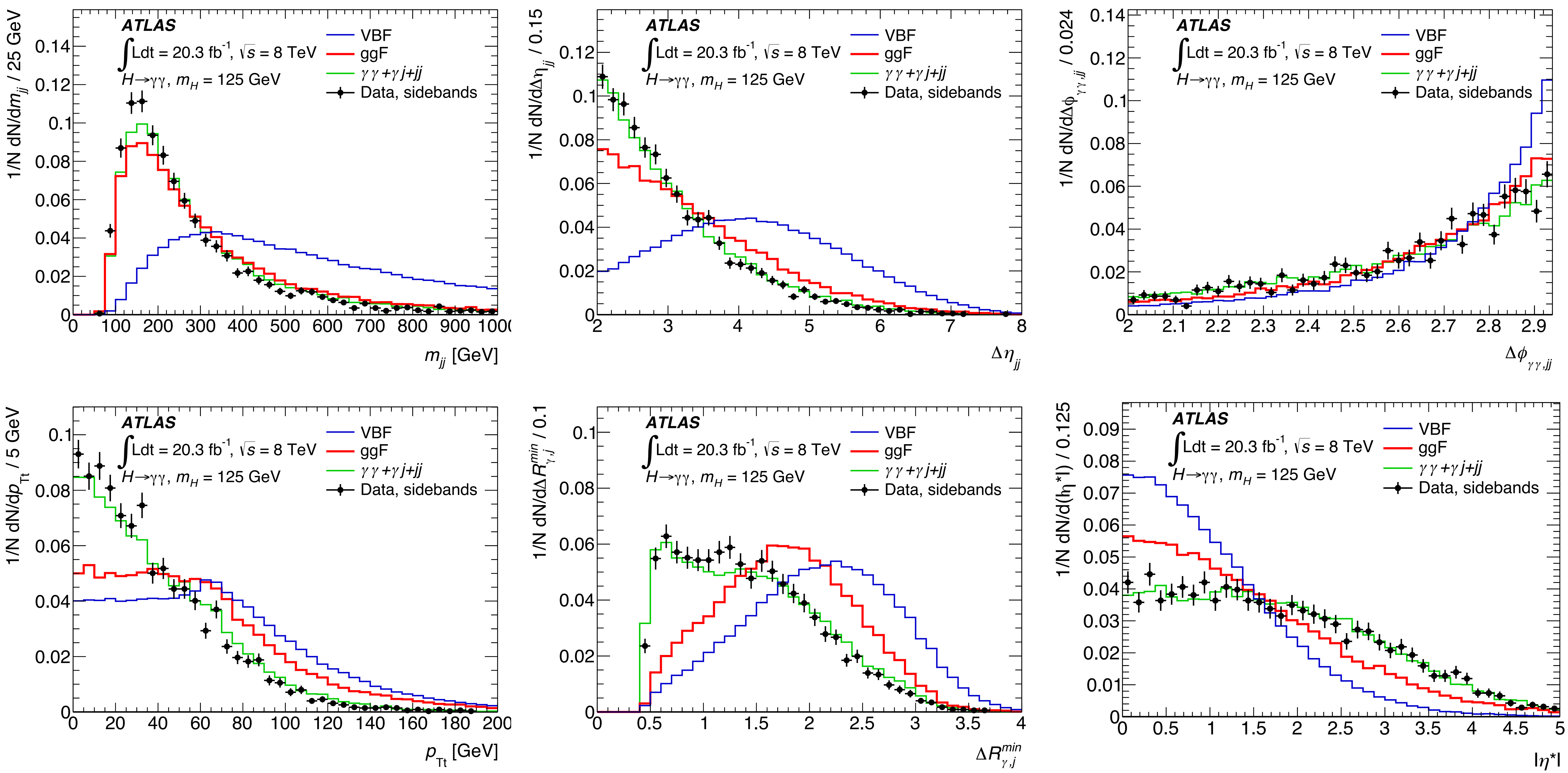


H → WW*: VH results

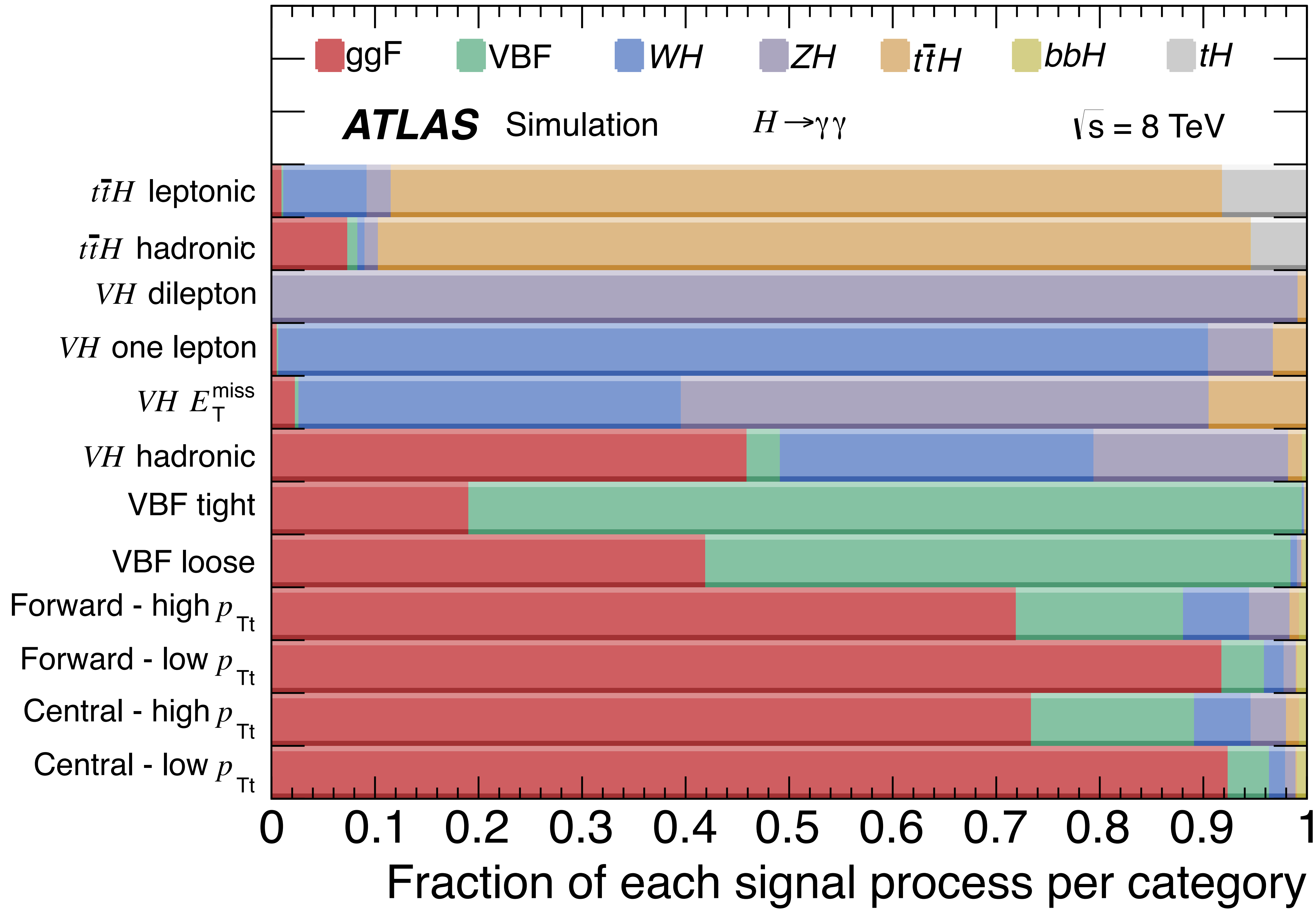
8 TeV data sample

Process	4ℓ		3ℓ			2ℓ		
Category	2SFOS	1SFOS	3SF	1SFOS	0SFOS	DFOS	SS2jet	SS1jet
Higgs boson								
$VH\ (H \to WW^*)$	0.203±0.030	0.228±0.034	0.73±0.10	1.61±0.18	1.43±0.16	2.15±0.30	1.04±0.18	2.04±0.30
$VH\ (H \to \tau\tau)$	0.0084±0.0032	0.012±0.004	0.057±0.011	0.152±0.023	0.248±0.035	—	0.036±0.008	0.27±0.04
ggF	—	—	0.076±0.015	0.085±0.018	—	2.4±0.5	—	—
VBF	—	—	—	—	—	0.180±0.025	—	—
ttH	—	—	—	—	—	—	—	—
Background								
V	—	—	0.22±0.16	1.9±0.6	0.37±0.15	14±4	8±4	15±5
VV	1.17±0.20	0.31±0.06	19±3	28±4	4.7±0.6	10.1±1.6	11.2±2.1	26±4
VVV	0.12±0.04	0.10±0.04	0.8±0.3	2.2±0.7	2.93±0.29	—	—	0.47±0.05
Top	0.014±0.011	—	0.91±0.26	2.4±0.6	3.7±0.9	24±4	0.75±0.19	1.3±0.5
Others	—	—	—	—	—	2.3±0.9	0.71±0.30	0.60±0.24
Total	1.30±0.23	0.41±0.09	22±4	34±6	11.7±1.8	50±5	21±5	44±6
Observed events	0	3	22	38	14	63	25	62

H → γγ: BDT$_{VBF}$


ATLAS
∫Ldt = 20.3 fb⁻¹, √s = 8 TeV
H→γγ, m_H = 125 GeV
VBF
ggF
γγ+γj+jj
Data, sidebands
1/N dN/dm_jj / 25 GeV
m_jj [GeV]
1/N dN/dΔη_jj / 0.15
Δη_jj
1/N dN/dΔφ_γγ,jj / 0.024
Δφ_γγ,jj
1/N dN/dp_Tt / 5 GeV
p_Tt [GeV]
1/N dN/dΔR^min_γ,j / 0.1
ΔR^min_γ,j
1/N dN/d(|η*|) / 0.125
|η*|

H → γγ: event categorization

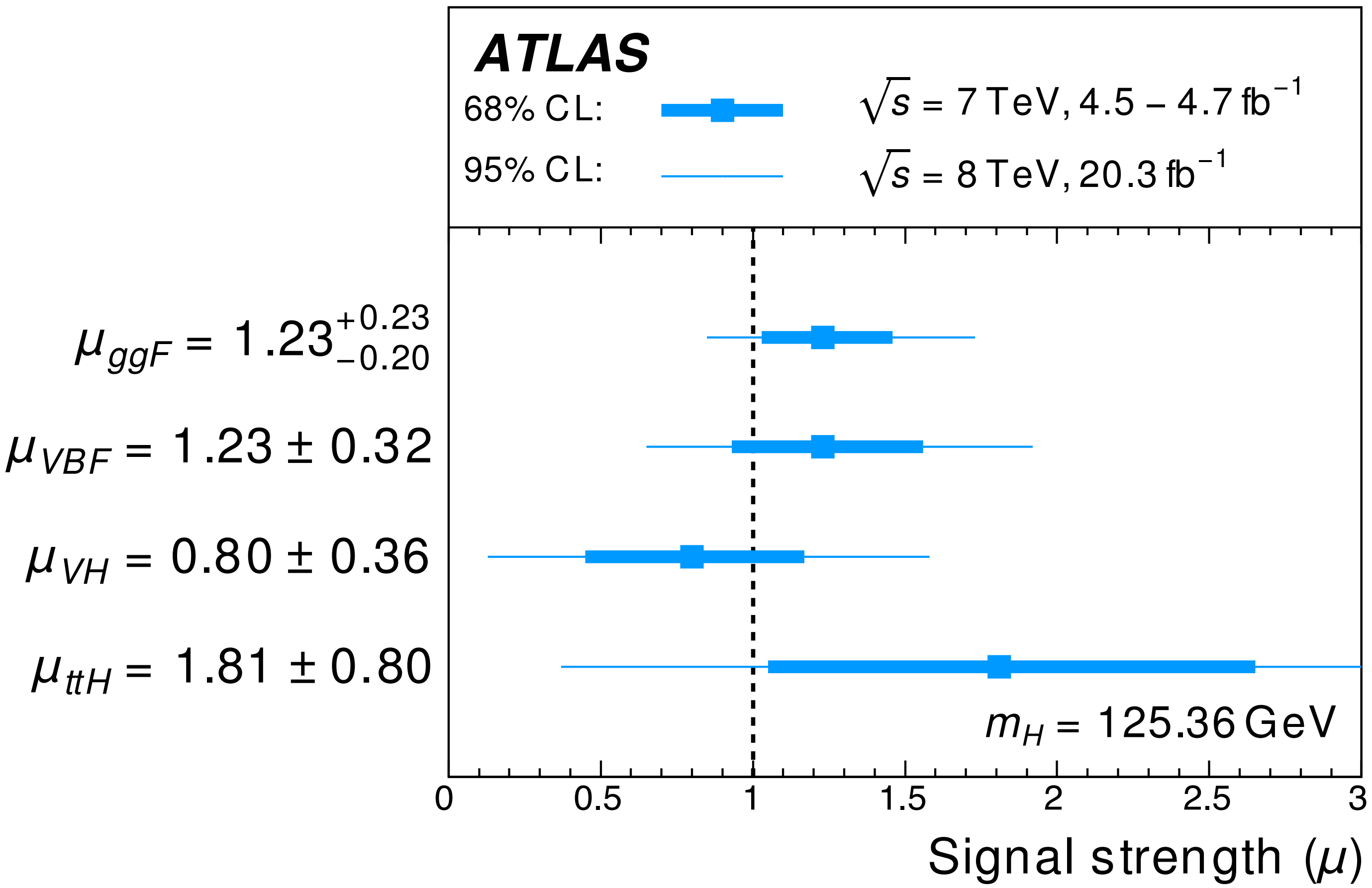


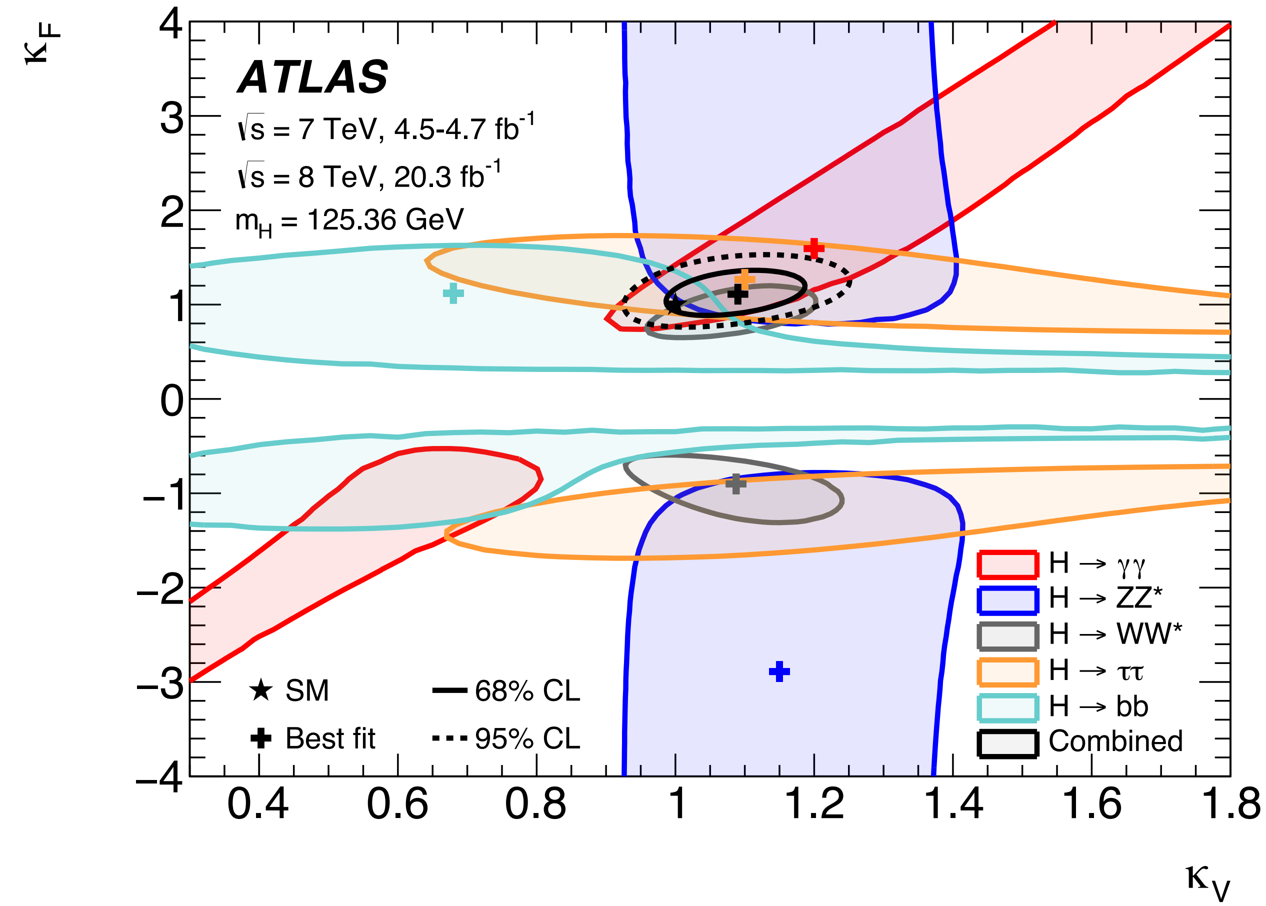
$H \to \gamma\gamma$: systematics

		Syst. source	N_{NP}	Implementation	Section
Yield	Theory	Scales	7	$N_{\mathrm{S}}^{p}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$	VIII A 1
		PDF+α_{S}	2	$N_{\mathrm{S}}^{p}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$	VIII A 1
		Br. ratio	1	$N_{\mathrm{S}}^{\mathrm{tot}}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$	VIII A 1
	Exp.	Luminosity	2	$N_{\mathrm{S}}^{\mathrm{tot}}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$	VIII A 3 1
		Trigger	2	$N_{\mathrm{S}}^{\mathrm{tot}}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$	VIII A 3 2
		Photon ID	2	$N_{\mathrm{S}}^{p}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$	VIII A 3 3
		Isolation	2	$N_{\mathrm{S}}^{p}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$	VIII A 3 4
MC		MC stats.	14	$N_{\mathrm{S}}^{p}\, F_{\mathrm{G}}(\sigma_i^{p}, \theta_i)$	VIII A 2
Migrations	Theory	Jet-bin	2	$N_{\mathrm{S}}^{\mathrm{ggF}}\, F_{\mathrm{LN}}(\sigma_i^{\mathrm{ggF}}, \theta_i^{\mathrm{ggF}})$	VIII B 1 1
		UE+PS	1	$N_{\mathrm{S}}^{p}\, F_{\mathrm{G}}(\sigma_i^{p}, \theta_i)$	VIII B 1 2
		Higgs p_{T}	1	$N_{\mathrm{S}}^{\mathrm{ggF}}\, F_{\mathrm{G}}(\sigma_i^{\mathrm{ggF}}, \theta_i^{\mathrm{ggF}})$	VIII B 1 3
		$\Delta\phi_{jj}$	1	$N_{\mathrm{S}}^{\mathrm{ggF}}\, F_{\mathrm{LN}}(\sigma_i^{\mathrm{ggF}}, \theta_i^{\mathrm{ggF}})$	VIII B 1 4
		η^*	1	$N_{\mathrm{S}}^{\mathrm{ggF}}\, F_{\mathrm{LN}}(\sigma_i^{\mathrm{ggF}}, \theta_i^{\mathrm{ggF}})$	VIII B 1 4
		$t\bar{t}H$ model	2	$N_{\mathrm{S}}^{t\bar{t}H}\, F_{\mathrm{LN}}(\sigma_i^{t\bar{t}H}, \theta_i^{t\bar{t}H})$	VIII B 1 5
		HF content	1	$N_{\mathrm{S}}^{p}\, F_{\mathrm{LN}}(\sigma_i^{p}, \theta_i)$	VIII B 1 5
		Scale ($t\bar{t}H$ cat.)	4	$N_{\mathrm{S}}^{p}\, F_{\mathrm{LN}}(\sigma_i^{t\bar{t}H}, \theta_i^{t\bar{t}H})$	VIII B 1 5
	Exp.	Jet reco.	20	$N_{\mathrm{S}}^{p}\, F_{\mathrm{G}}(\sigma_i^{p}, \theta_i)$	VIII B 2 1
		$E_{\mathrm{T}}^{\mathrm{miss}}$	5	$N_{\mathrm{S}}^{p}\, F_{\mathrm{G}}(\sigma_i^{p}, \theta_i)$	VIII B 2 1
		b-tagging	13	$N_{\mathrm{S}}^{p}\, F_{\mathrm{G}}(\sigma_i^{p}, \theta_i)$	VIII B 2 2
		Lepton ID+isol.	2	$N_{\mathrm{S}}^{p}\, F_{\mathrm{G}}(\sigma_i^{p}, \theta_i)$	VIII B 2 3
		Lepton isolation	2	$N_{\mathrm{S}}^{p}\, F_{\mathrm{G}}(\sigma_i^{p}, \theta_i)$	VIII B 2 3
Mass		Resolution	4	$\sigma_{\mathrm{CB}}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$ $\sigma_{\mathrm{GA}}\, F_{\mathrm{LN}}(\sigma_i, \theta_i)$	VIII C 1
		Scale	43	$\mu_{\mathrm{CB}}\, F_{\mathrm{G}}(\sigma_i, \theta_i)$ $\mu_{\mathrm{GA}}\, F_{\mathrm{G}}(\sigma_i, \theta_i)$	VIII C 2
Back.		Spurious signal	12	$N_{\mathrm{spur},c}\, \theta_{\mathrm{spur},c}$	VII B

Uncertainty group	$\sigma_{\mu}^{\mathrm{syst.}}$
Theory (yield)	0.09
Experimental (yield)	0.02
Luminosity	0.03
MC statistics	< 0.01
Theory (migrations)	0.03
Experimental (migrations)	0.02
Resolution	0.07
Mass scale	0.02
Background shape	0.02

Combined results





$\mu_{comb} = 1.18^{+0.15}_{-0.14}$ [± 0.10(stat.)± 0.07(syst.)$^{+0.08}_{-0.07}$(theo.)]

$\kappa_V = 1.09 \pm 0.07$ [$^{+0.05}_{-0.05}$(stat.)$^{+0.03}_{-0.03}$(syst.)$^{+0.04}_{-0.03}$(theo.)]

$\kappa_F = 1.11 \pm 0.16$ [$^{+0.12}_{-0.11}$(stat.)$^{+0.10}_{-0.09}$(syst.)$^{+0.06}_{-0.05}$(theo.)]

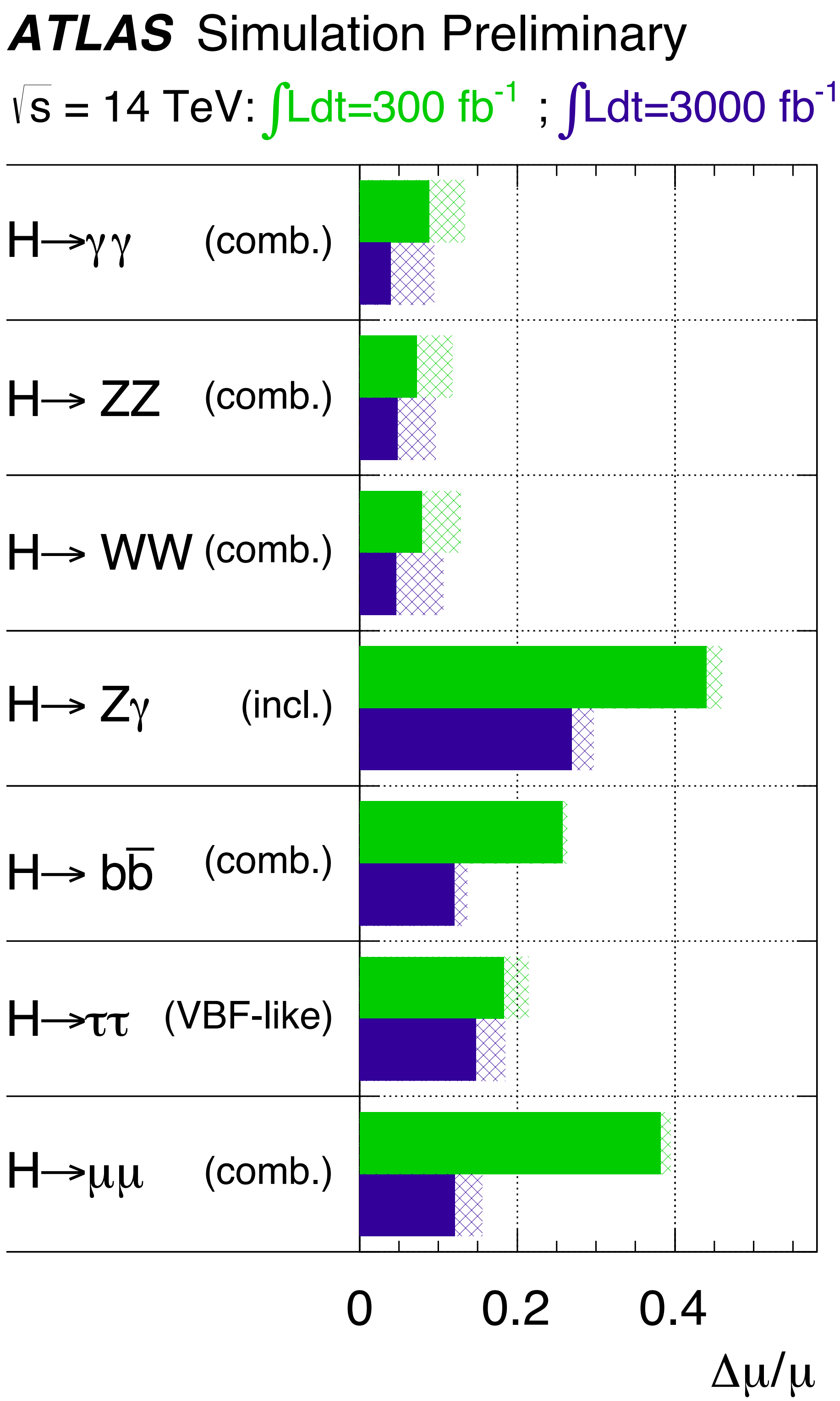
Combined results

$$\sigma_i \cdot \mathrm{BR}_f = \left(\sigma_{\mathrm{ggF}} \cdot \mathrm{BR}_{WW^*}\right) \times \left(\frac{\sigma_i}{\sigma_{\mathrm{ggF}}}\right) \times \left(\frac{\mathrm{BR}_f}{\mathrm{BR}_{WW^*}}\right) = \sigma(gg \to H \to WW^*) \times \left(\frac{\sigma_i}{\sigma_{\mathrm{ggF}}}\right) \times \left(\frac{\Gamma_f}{\Gamma_{WW^*}}\right).$$

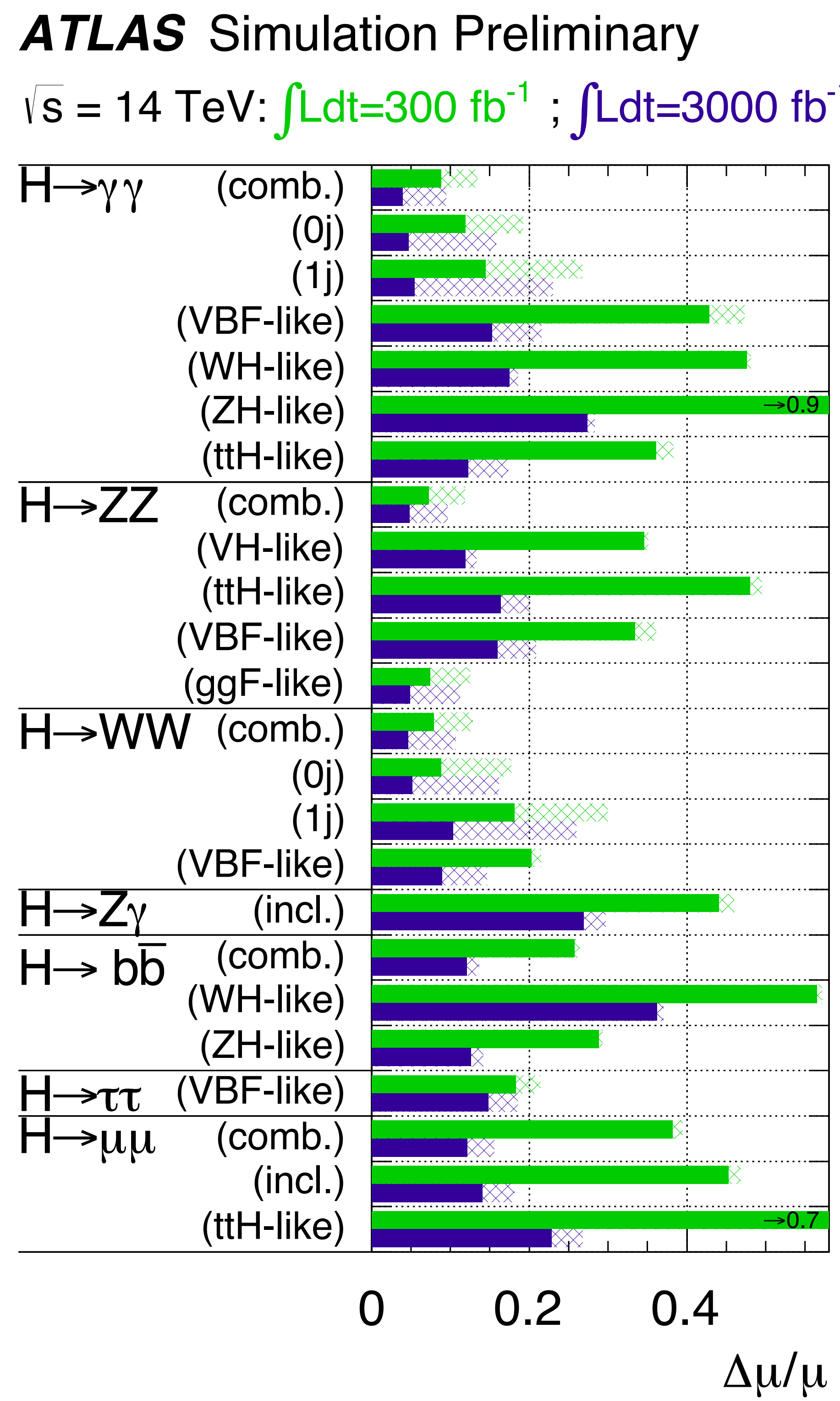
Parameter	Best-fit value		SM prediction
$\sigma(gg \to H \to WW^*)$ (pb)	$4.86\,^{+0.95}_{-0.90}$	$\left[\begin{smallmatrix}+0.76 & +0.52 & +0.26 \\ -0.74 & -0.48 & -0.18\end{smallmatrix}\right]$	4.22 ± 0.47
$\sigma_{\mathrm{VBF}}/\sigma_{\mathrm{ggF}}$	$0.081\,^{+0.035}_{-0.026}$	$\left[\begin{smallmatrix}+0.031 & +0.016 & +0.008 \\ -0.024 & -0.010 & -0.005\end{smallmatrix}\right]$	0.082 ± 0.009
$\sigma_{WH}/\sigma_{\mathrm{ggF}}$	$0.053\,^{+0.037}_{-0.026}$	$\left[\begin{smallmatrix}+0.032 & +0.018 & +0.008 \\ -0.023 & -0.012 & -0.004\end{smallmatrix}\right]$	0.036 ± 0.004
$\sigma_{ZH}/\sigma_{\mathrm{ggF}}$	$0.013\,^{+0.030}_{-0.014}$	$\left[\begin{smallmatrix}+0.021 & +0.020 & +0.005 \\ -0.013 & -0.005 & -0.002\end{smallmatrix}\right]$	0.021 ± 0.002
$\sigma_{ttH}/\sigma_{\mathrm{ggF}}$	$0.012\,^{+0.007}_{-0.005}$	$\left[\begin{smallmatrix}+0.005 & +0.004 & +0.0014 \\ -0.004 & -0.003 & -0.0005\end{smallmatrix}\right]$	0.007 ± 0.001
$\Gamma_{\gamma\gamma}/\Gamma_{WW^*}$	$0.010\,^{+0.003}_{-0.003}$	$\left[\begin{smallmatrix}+0.003 & +0.002 & +0.0006 \\ -0.002 & -0.001 & -0.0004\end{smallmatrix}\right]$	0.01036 ± 0.00011
$\Gamma_{ZZ^*}/\Gamma_{WW^*}$	$0.15\,^{+0.05}_{-0.04}$	$\left[\begin{smallmatrix}+0.046 & +0.022 & +0.008 \\ -0.036 & -0.013 & -0.005\end{smallmatrix}\right]$	$0.124 \pm <0.001$
$\Gamma_{\tau\tau}/\Gamma_{WW^*}$	$0.34\,^{+0.14}_{-0.11}$	$\left[\begin{smallmatrix}+0.112 & +0.084 & +0.032 \\ -0.090 & -0.053 & -0.017\end{smallmatrix}\right]$	0.285 ± 0.006
$\Gamma_{bb}/\Gamma_{WW^*}$	$1.53\,^{+1.64}_{-0.94}$	$\left[\begin{smallmatrix}+1.17 & +1.11 & +0.30 \\ -0.69 & -0.63 & -0.12\end{smallmatrix}\right]$	2.60 ± 0.12

Process	VBF	ttH	WH	ZH	VH
Observed	4.3	2.5	2.1	0.9	2.6
Expected	3.8	1.5	2.0	2.1	3.1

Prospects

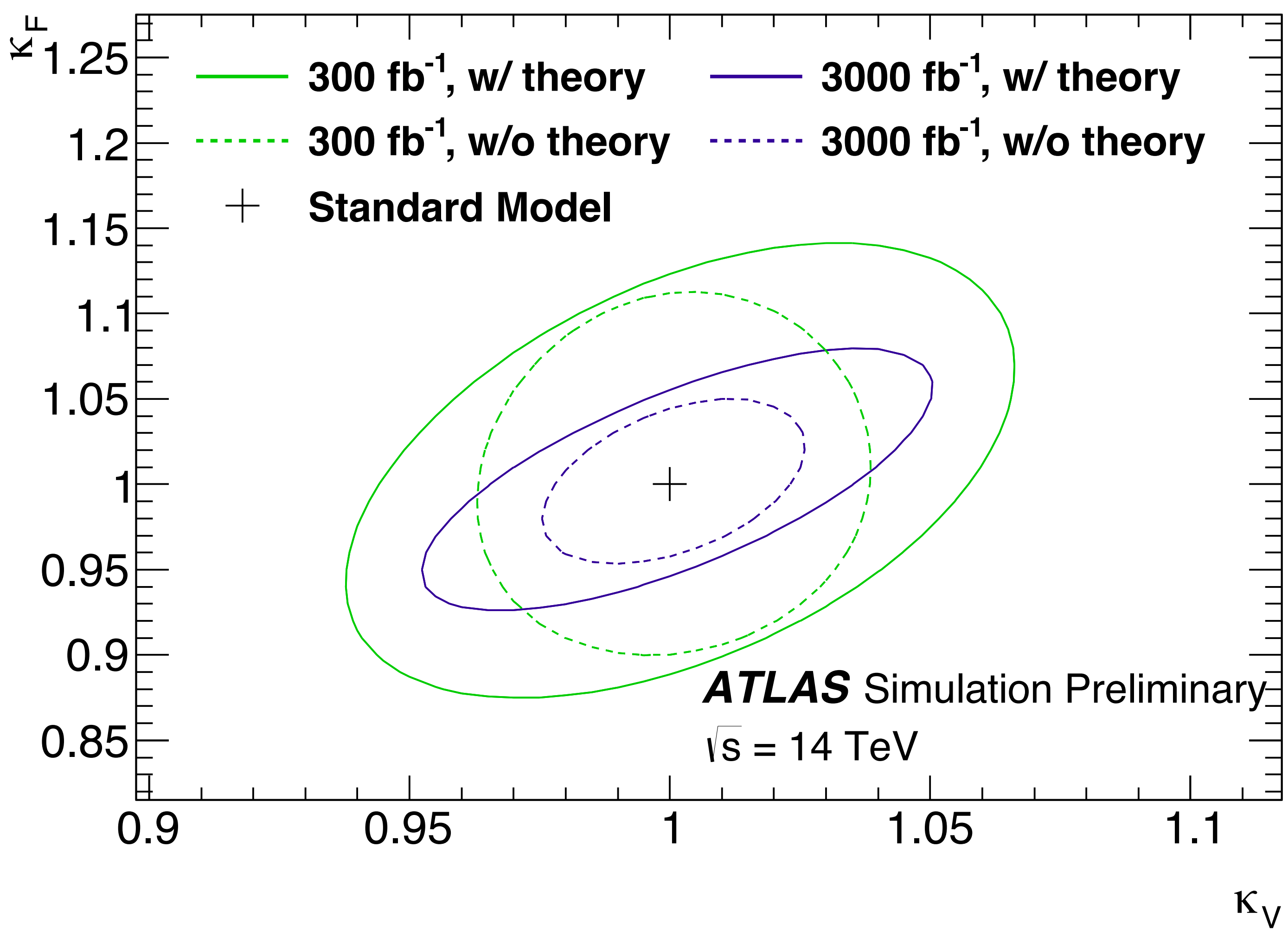


ATLAS Simulation Preliminary
√s = 14 TeV: ∫Ldt=300 fb-1 ; ∫Ldt=3000 fb-1
H→γγ (comb.)
H→ ZZ (comb.)
H→ WW (comb.)
H→ Zγ (incl.)
H→ bb̄ (comb.)
H→ττ (VBF-like)
H→μμ (comb.)
0
0.2
0.4
Δμ/μ

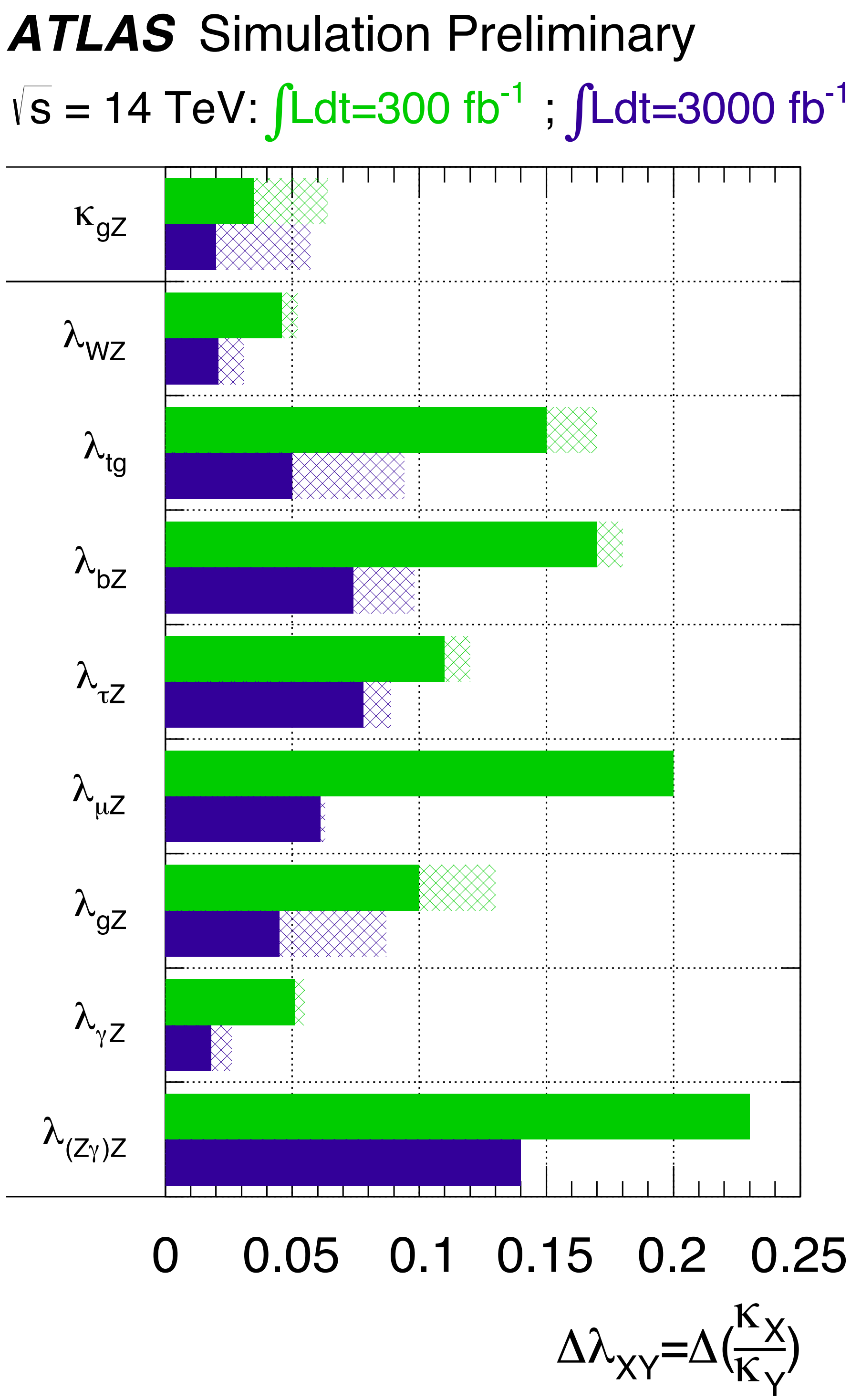


ATLAS Simulation Preliminary
√s = 14 TeV: ∫Ldt=300 fb-1 ; ∫Ldt=3000 fb-1
H→γγ (comb.)
(0j)
(1j)
(VBF-like)
(WH-like)
(ZH-like)
→0.9
(ttH-like)
H→ZZ (comb.)
(VH-like)
(ttH-like)
(VBF-like)
(ggF-like)
H→WW (comb.)
(0j)
(1j)
(VBF-like)
H→Zγ (incl.)
H→ bb̄ (comb.)
(WH-like)
(ZH-like)
H→ττ (VBF-like)
H→μμ (comb.)
(incl.)
(ttH-like)
→0.7
0
0.2
0.4
Δμ/μ

Prospects



κ_F
300 fb^{-1}, w/ theory
3000 fb^{-1}, w/ theory
300 fb^{-1}, w/o theory
3000 fb^{-1}, w/o theory
Standard Model
ATLAS Simulation Preliminary
$\sqrt{s}$ = 14 TeV
κ_V



ATLAS Simulation Preliminary
$\sqrt{s}$ = 14 TeV: $\int$Ldt=300 fb^{-1} ; $\int$Ldt=3000 fb^{-1}
κ_{gZ}
λ_{WZ}
λ_{tg}
λ_{bZ}
$\lambda_{\tau Z}$
$\lambda_{\mu Z}$
λ_{gZ}
$\lambda_{\gamma Z}$
$\lambda_{(Z\gamma)Z}$
$\Delta\lambda_{XY}=\Delta(\frac{\kappa_X}{\kappa_Y})$