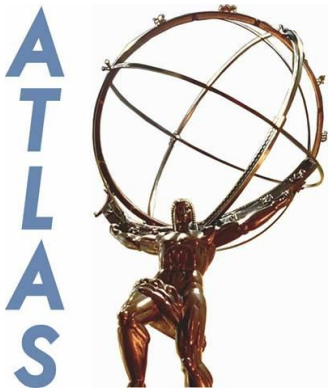
Search for the Higgs boson in $WH \rightarrow l\nu bb$ and $WW^{(*)} \rightarrow l\nu l\nu$ decay modes on ATLAS



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Outline

- Data samples
- *WH, H –> bb:*

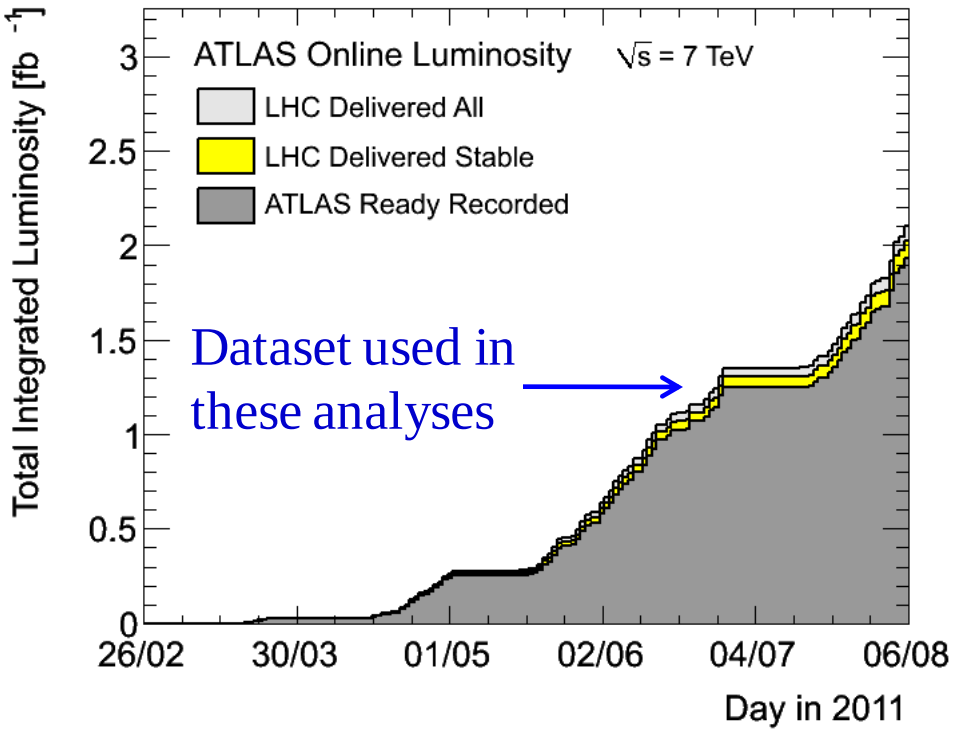
  - event selection
  - backgrounds
  - systematics
  - exclusion limit on Higgs cross-section

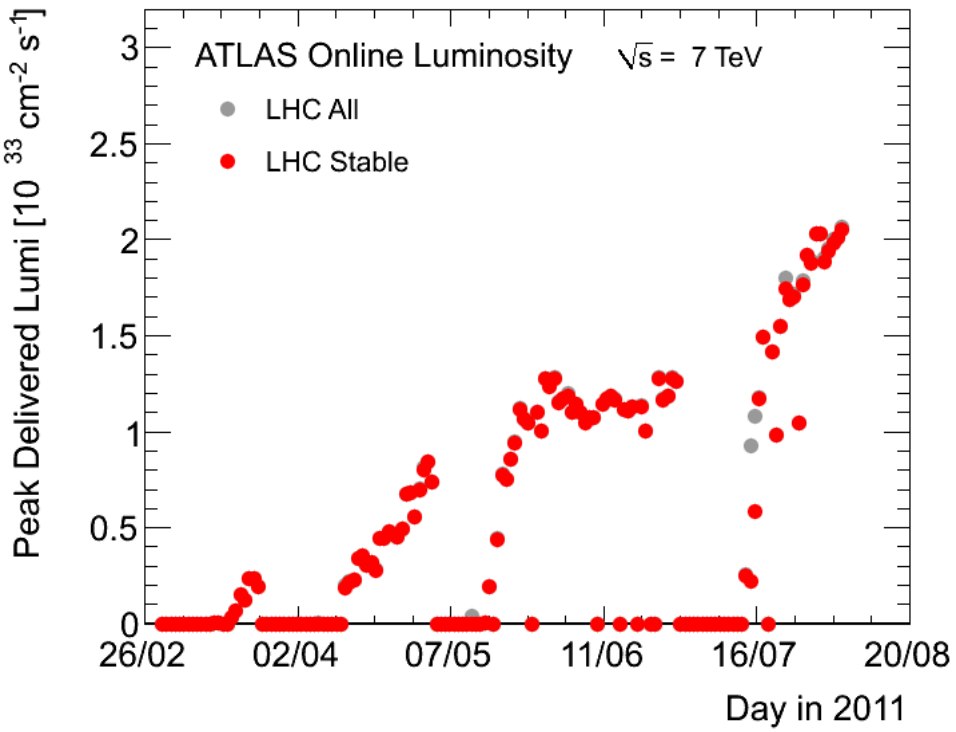
- $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$:

  - event selection in *0*- and *1-jet* channels
  - backgrounds
  - exclusion limit

- Conclusion and outlook

Data sample





- These analyses based on 1.04 fb^{-1} data from March-June 2011
- Maximum instantaneous luminosity ~1.26 * 10^{33} cm^{-2} s^{-1}
- Error on luminosity: 3.7%
- Average #interactions per bunch crossing ~6

The $WH \rightarrow l\nu bb$ channel

- $H \rightarrow bb$ branching fraction is large at low masses

  ~2/3 at $M_H = 120$ GeV

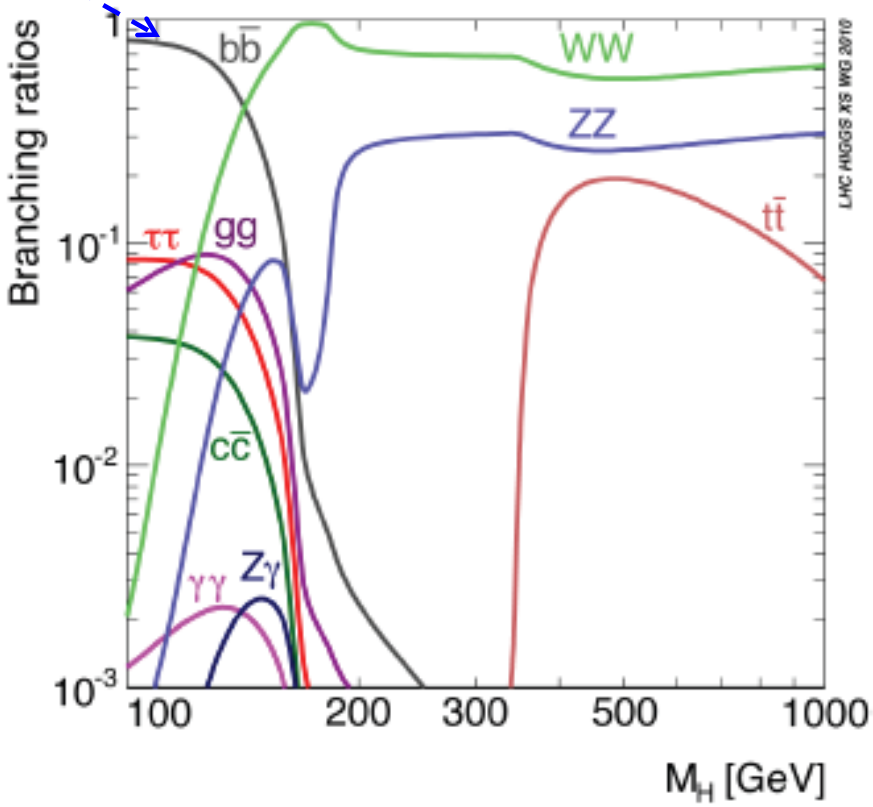
- Inclusive $H \rightarrow bb$ search difficult owing to large prompt bb background

- Assoc. production with leptonically decaying W makes a search feasible

  - cross-section*BR ~ 85 fb for $M_H = 120$ GeV

- Simple cut-based analysis: require two b-tagged jets in addition to W search criteria

- Higgs signal would show up as excess in bb invariant mass spectrum



WH: event selection

- Trigger: lowest-threshold unprescaled triggers

  electron: 20 GeV

  muon: 18 GeV

- Exactly 1 lepton in event:

  $P_T > 25$ GeV, $|\eta^{\mu}| < 2.4$, $|\eta^{e}| < 2.47$

- Exactly 2 jets in event:

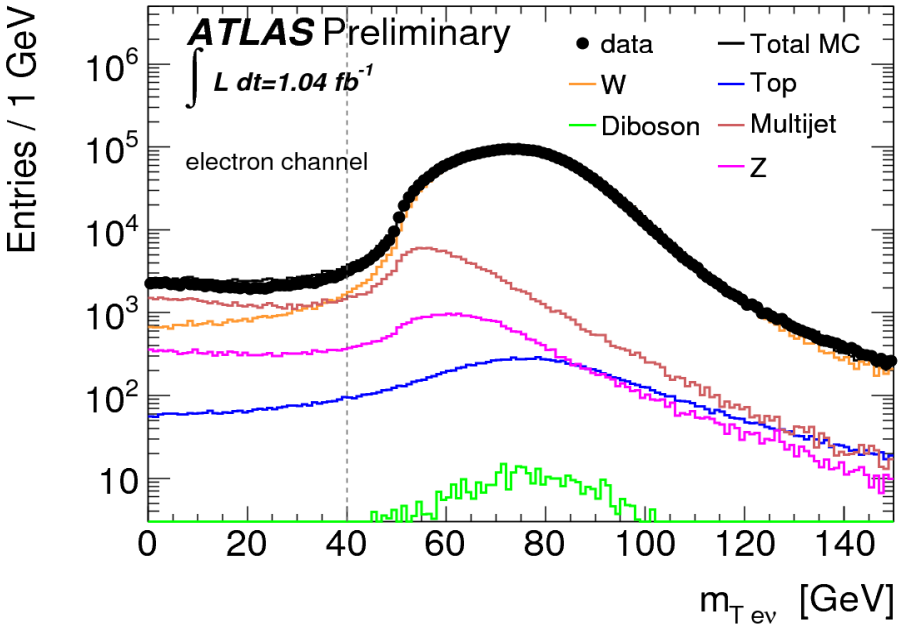
  $E_T > 25$ GeV, $|\eta| < 2.5$

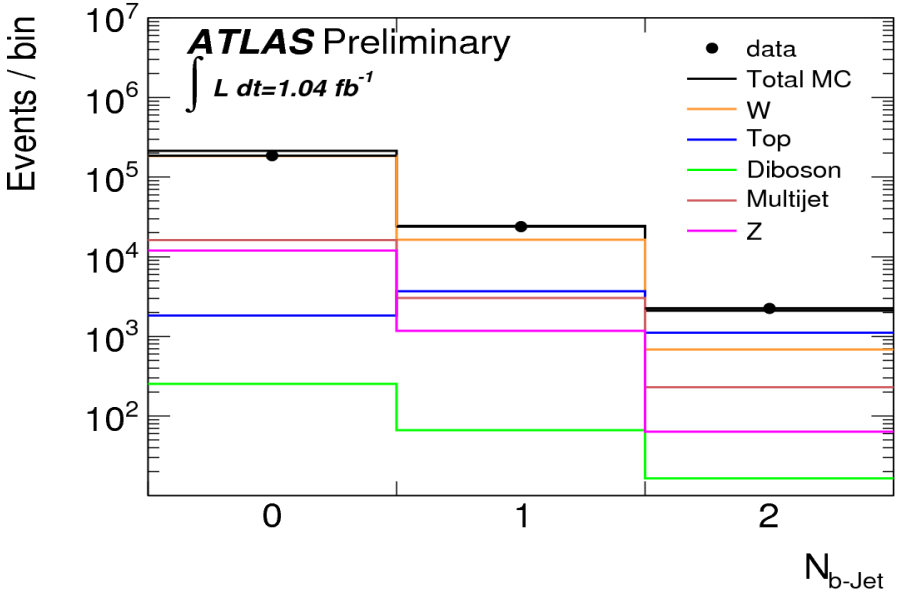
  - reconstructed using anti-k_T algorithm

  - both jets must be *b*-tagged

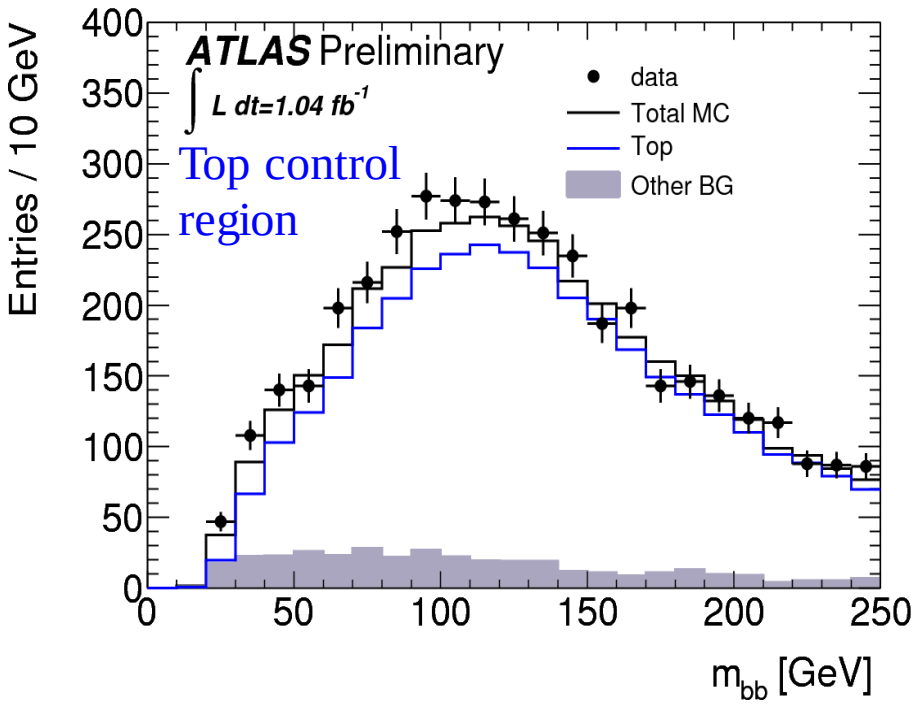
- $E_T^{miss} > 25$ GeV

- Transverse mass $M_T > 40$ GeV





WH: backgrounds



- *Top*: dominant at high m_{bb}
  - ➢ Take shape from MC, but extract normalization using m_{bb} sidebands in data
    - $m_{bb} < 80$ GeV, $140 < m_{bb} < 250$ GeV
  - ➢ Cross-check in top control region in data requiring 3 jets

- *W+bb*: main contribution at low m_{bb}
  - ➢ Take shape from m_{jj} distribution of un-*b*-tagged jets in MC
  - ➢ Get normalization from sidebands as for top background
- *QCD*: extracted from template fit, using E_T^{miss} template from data
- *WZ* (irreducible), *WW*: small, estimated from MC

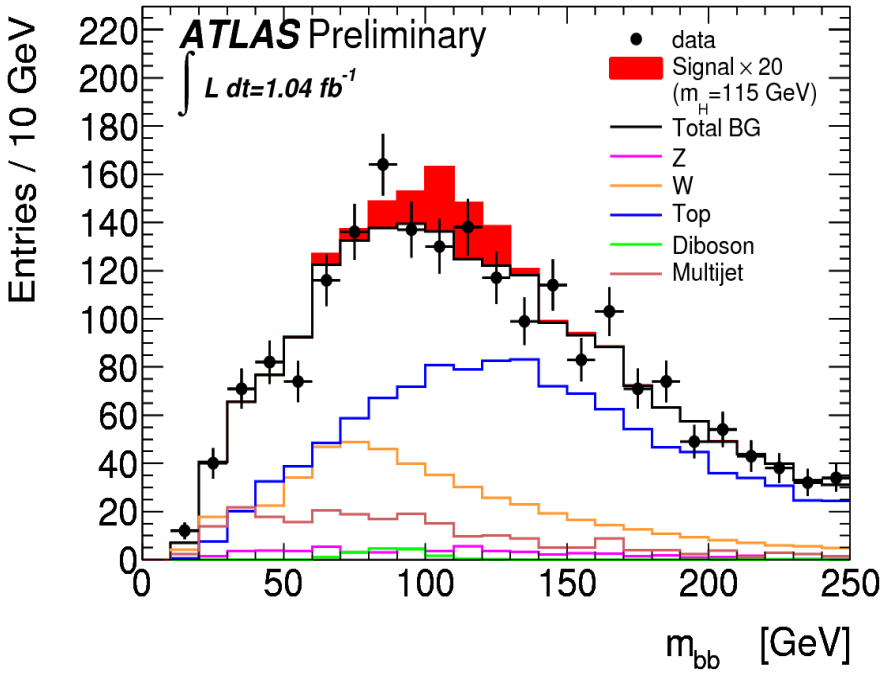
WH: systematic uncertainties on event yield

Source of Uncertainty	Effect on $WH \to \ell\nu b\bar{b}$ signal	
	$m_H = 115$ GeV	$m_H = 130$ GeV
Electron Energy Scale	1%	1%
Electron Energy Resolution	1%	1%
Muon Momentum Resolution	4%	1%
Jet Energy	1%	3%
Jet Energy Resolution	1%	1%
Missing Transverse Energy	2%	3%
b-tagging Efficiency	16%	17%
b-tagging Mis-tag Fraction	3%	3%
Electron Efficiency	1%	1%
Muon Efficiency	1%	1%
Luminosity	4%	4%
Higgs Cross-section	5%	5%

- By far, dominant systematic uncertainty is from *b*-tagging
- Uncertainties on background estimates:
  top: 6%, *W* + *bb*: 9%, *QCD*: 50%, *diboson*: 11%

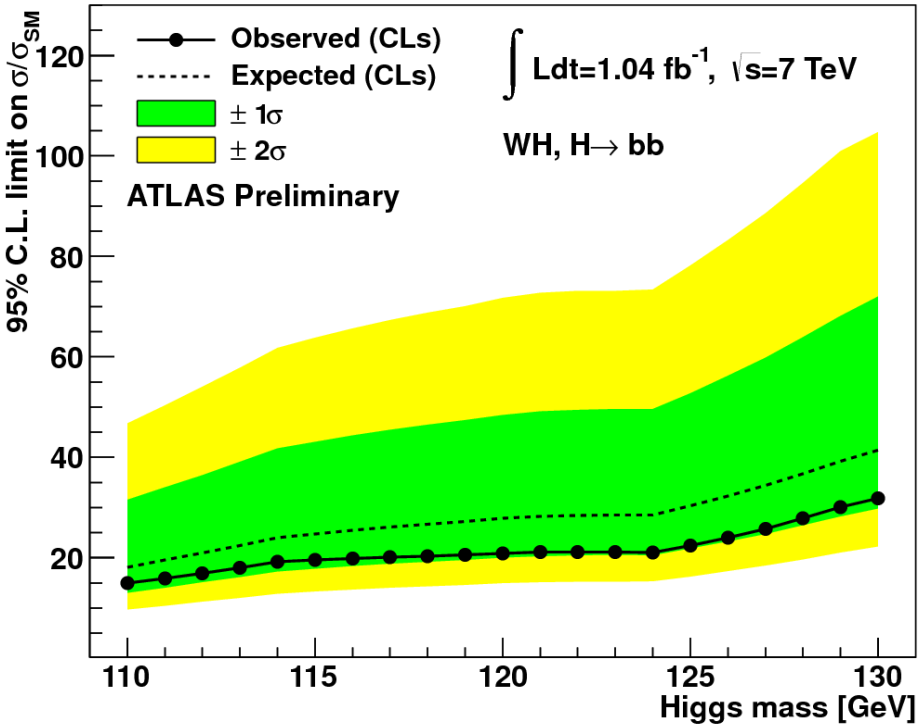
WH: results

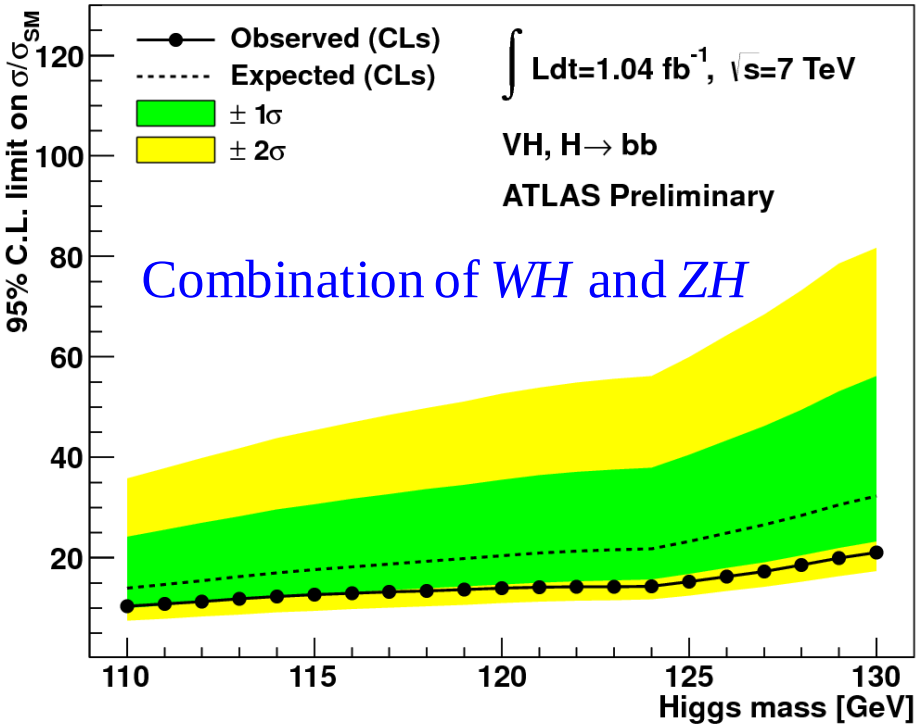
Source	expected events		(stat.)		(sys.)
Z+jets	54.4	±	3.9	±	12.3
W+jets	466.7	±	1.4	±	66.5
Top-quark	1141.8	±	8.8	±	78.0
Multijet	193.0	±	9.4	±	96.5
WZ	16.1	±	2.2	±	3.4
WW	4.8	±	1.1	±	1.4
Total background	1876.8	±	13.7	±	147.2
Data	1888				
Signal m_H = 110 GeV	6.72	±	0.31	±	1.20
Signal m_H = 115 GeV	5.25	±	0.30	±	0.97
Signal m_H = 120 GeV	4.54	±	0.25	±	0.83
Signal m_H = 125 GeV	4.08	±	0.21	±	0.77
Signal m_H = 130 GeV	3.28	±	0.17	±	0.62



- We compare observed event count with expectation, including signal in range 110 GeV < M_H < 130 GeV
- No significant excess over background is observed –> set limits

WH: limits





- Cross-section limits at 95% CL are 15-30 times the Standard Model cross-section for 110 GeV < M_H < 130 GeV
- Combination with *ZH* channel yields limits between 10 and 15 times SM cross-section

The $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ channel

- $H \rightarrow WW \rightarrow l\nu l\nu$ is a very sensitive channel for $M_H \sim 2\ M_W$

  - one of two channels that currently exclude the SM Higgs at LHC for some masses

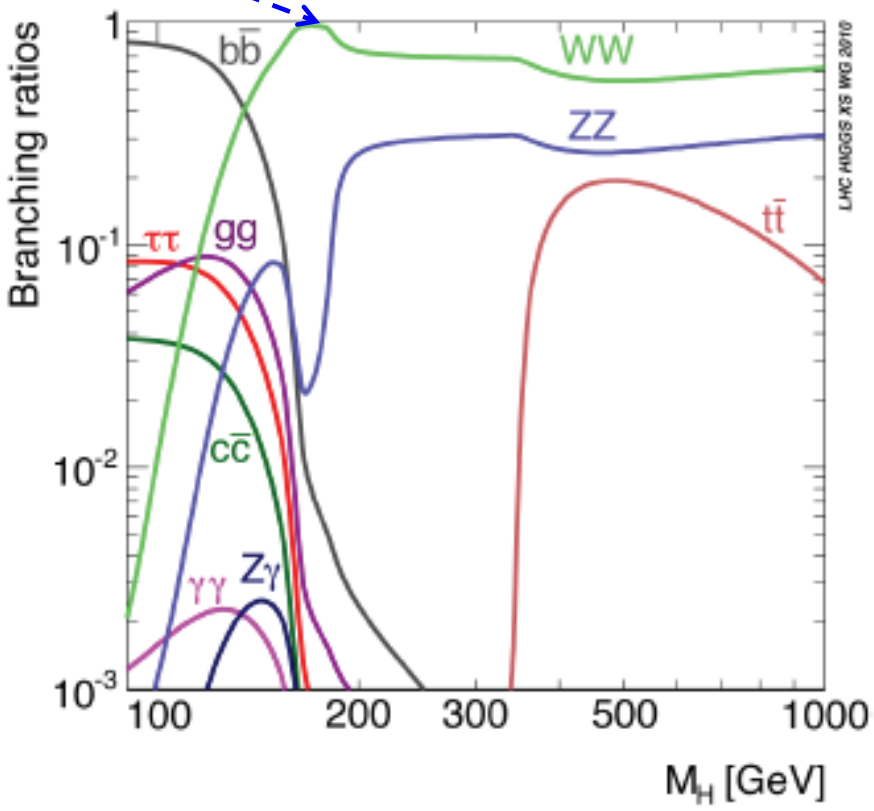
  - very promising discovery channel

- Cross-section*BR ~ 0.45 pb for M_H = 150 GeV

- 6 final states: *ee*, *eμ*, *μμ* channels, each accompanied by 0 or 1 jet

  - event selection is basically selecting two leptons and large missing E_T

- Currently, the analysis covers mass range of 110 GeV < M_H < 240 GeV



$H \to WW$: event selection

- Trigger depends on lepton channel:

  ee: 20 GeV single electron trigger

  $\mu\mu$: OR of two single muon triggers

  $e\mu$: OR of above three triggers

- Exactly 2 leptons in event, leading lepton $P_T > 25$ GeV

  - subleading lepton: $P_T\,(e) > 20$ GeV, $P_T\,(\mu) > 15$ GeV

- ee, $\mu\mu$ channels:

  $m_{ll} > 15$ GeV, $|m_{ll} - m_Z| > 15$ GeV, $MET_{rel} > 40$ GeV

- $e\mu$ channel:

  $m_{ll} > 10$ GeV, $MET_{rel} > 25$ GeV

❑ $$MET_{rel} = \begin{cases} E_T^{miss} \text{ if } \Delta\phi_{min} > \pi/2 \\ E_T^{miss} * sin(\Delta\phi_{min}) \text{ if } \Delta\phi_{min} < \pi/2 \end{cases}$$

where $\Delta\phi_{min} = \min[\Delta\phi(E_T^{miss}, l), \Delta\phi(E_T^{miss}, j)]$

H–>WW: topological selections

- Events are divided into *0*- and *1-jet* final states

  - if *1-jet* event, apply *b*-jet veto to reduce top background

- Apply Higgs mass-dependent cuts

➢ $M_H < 170$ GeV:

$m_{ll} < 50$ GeV

$\Delta\phi_{ll} < 1.3$

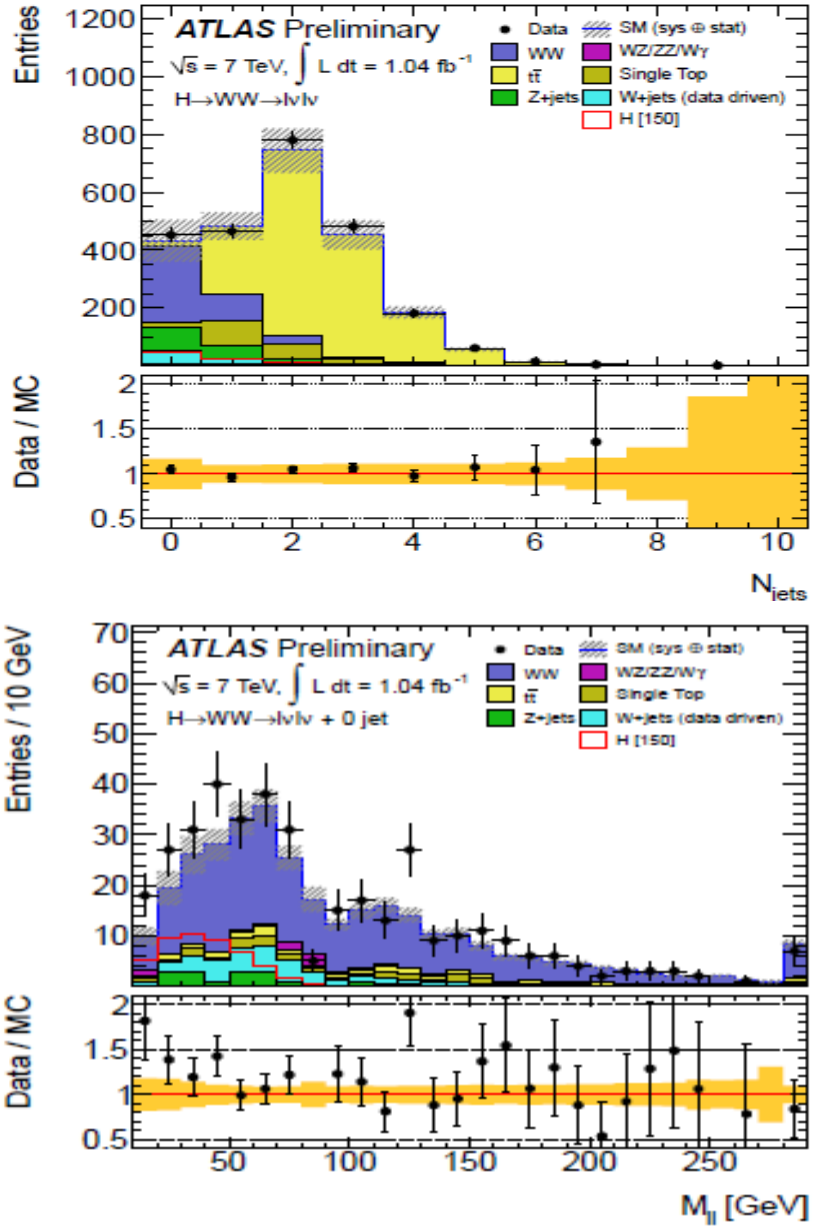
➢ $M_H >= 170$ GeV:

$m_{ll} < 65$ GeV

$\Delta\phi_{ll} < 1.8$

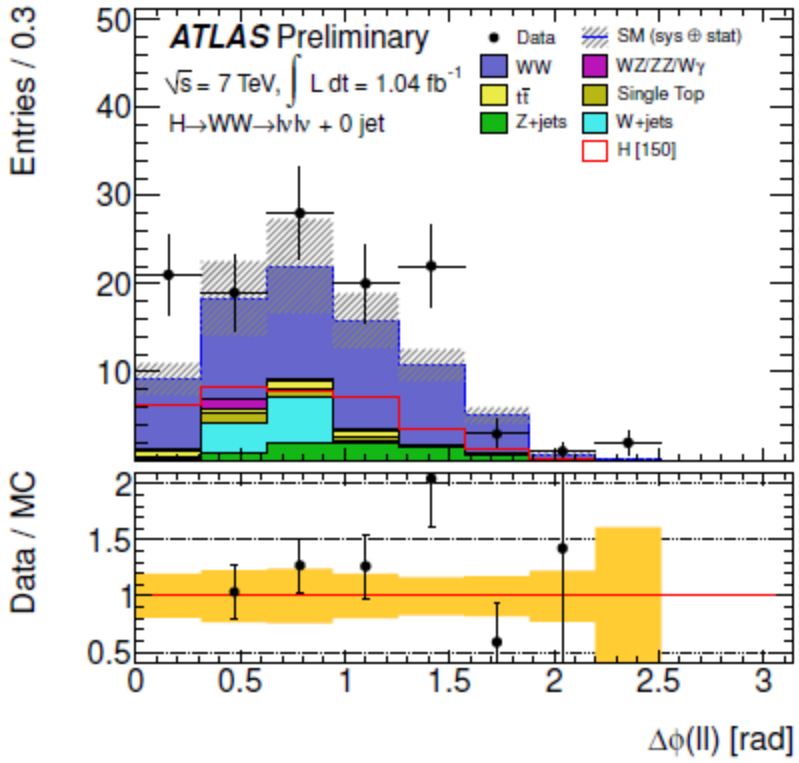
- $0.75*M_H < m_T < M_H$

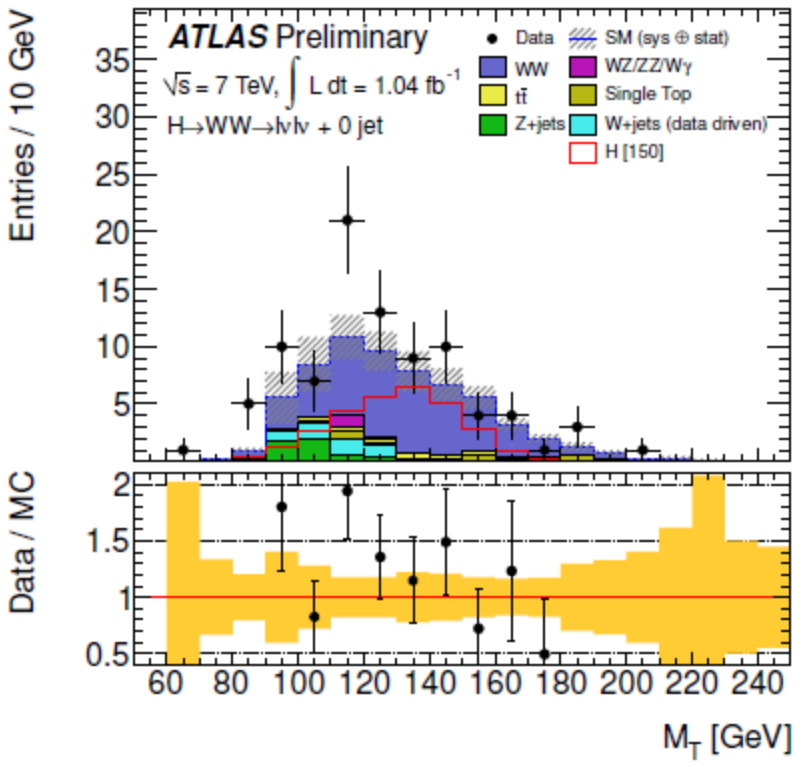
$$m_T = \sqrt{(E_T^{ll} + E_T^{miss})^2 - (P_T^{ll} + P_T^{miss})^2}$$



H–>WW: 0-jet channel

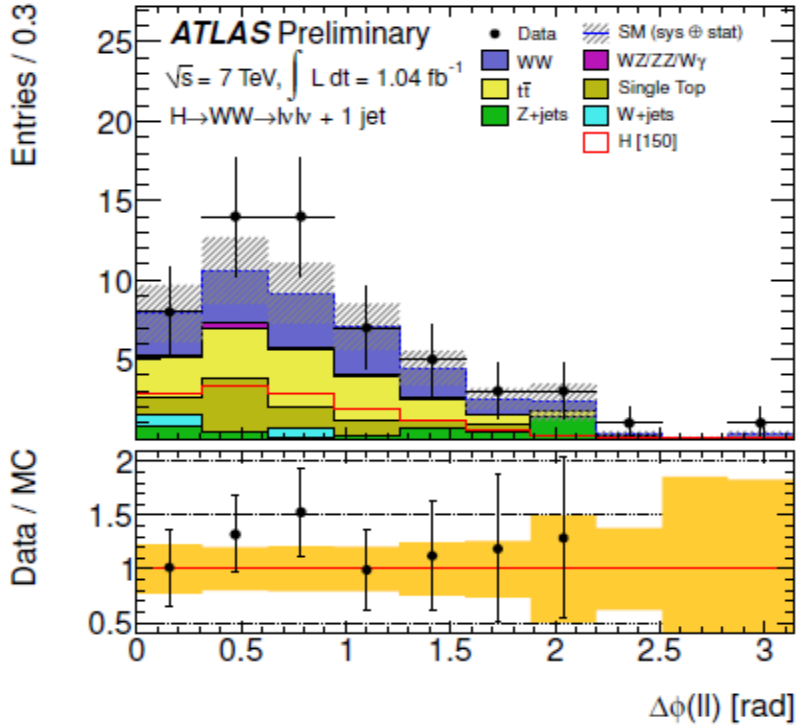
Selection	Signal	WW	W+jets	Z/γ^*+jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
Jet Veto	50 ± 11	260 ± 30	46 ± 17	80 ± 70	22 ± 8	17 ± 4	7.8 ± 1.5	430 ± 100	453
$\lvert\mathbf{p}_{\mathrm{T}}^{\ell\ell}\rvert > 30$ GeV	48 ± 10	230 ± 20	38 ± 14	15 ± 6	19 ± 7	16 ± 4	7.3 ± 1.4	330 ± 50	371
$m_{\ell\ell} < 50$ GeV	34 ± 7	59 ± 8	11 ± 3	7 ± 4	2.7 ± 1.8	2.8 ± 0.8	0.9 ± 0.3	83 ± 11	116
$\Delta\phi_{\ell\ell} < 1.3$	30 ± 7	46 ± 6	5.8 ± 1.8	5 ± 3	2.7 ± 1.7	2.8 ± 0.8	0.8 ± 0.2	63 ± 9	89
$0.75 \times m_H < m_{\mathrm{T}} < m_H$	21 ± 4	26 ± 3	2.9 ± 0.9	1 ± 2	1.6 ± 1.2	0.7 ± 0.4	0.6 ± 0.2	33 ± 5	49
ee	3.1 ± 0.7	3.7 ± 0.7	0.5 ± 0.2	0.4 ± 0.6	0.0 ± 0.6	0.0 ± 0.2	0.05 ± 0.19	4.7 ± 1.2	7
$e\mu$	11 ± 2	13.4 ± 1.9	1.7 ± 0.7	0 ± 0	1.1 ± 0.8	0.4 ± 0.3	0.4 ± 0.3	17 ± 2	21
$\mu\mu$	6.9 ± 1.5	8.8 ± 1.3	0.7 ± 0.5	0.5 ± 2.0	0.4 ± 0.8	0.3 ± 0.3	0.18 ± 0.19	11 ± 3	21

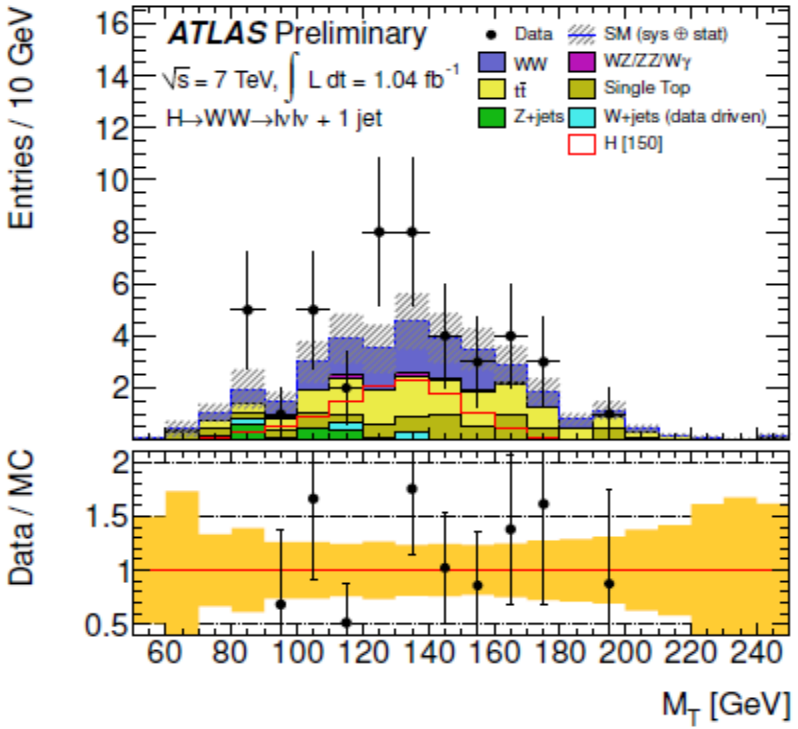




H–>WW: 1-jet channel

Selection	Signal	WW	W+jets	Z/γ^*+jets	$t\bar{t}$	$tW/tb/tqb$	$WZ/ZZ/W\gamma$	Total Bkg.	Observed
1 jet	23 ± 4	92 ± 9	20 ± 10	40 ± 30	240 ± 60	88 ± 13	6.2 ± 0.8	490 ± 70	465
b-jet veto	23 ± 4	91 ± 9	19 ± 10	40 ± 30	140 ± 40	45 ± 7	6.1 ± 0.8	340 ± 50	333
$\lvert\mathbf{P}_T^{\text{tot}}\rvert < 30$ GeV	19 ± 3	76 ± 8	9 ± 5	25 ± 19	80 ± 20	35 ± 6	4.1 ± 0.5	230 ± 40	221
$Z \to \tau\tau$ veto	19 ± 4	74 ± 8	9 ± 5	20 ± 10	80 ± 19	33 ± 5	4.0 ± 0.7	220 ± 17	212
$m_{\ell\ell} < 50$ GeV	13 ± 3	16 ± 3	1.2 ± 0.5	3.4 ± 1.6	12 ± 4	7.2 ± 1.7	0.9 ± 0.2	41 ± 5	56
$\Delta\phi_{\ell\ell} < 1.3$	11 ± 2	13 ± 2	1.0 ± 0.5	1.5 ± 1.2	11 ± 4	6.3 ± 1.5	0.74 ± 0.20	33 ± 5	44
$0.75 \times m_H < m_T < m_H$	7.2 ± 1.6	6.2 ± 1.3	0.5 ± 0.9	0.4 ± 0.6	4.9 ± 1.7	2.3 ± 0.7	0.34 ± 0.16	15 ± 3	21
ee	0.9 ± 0.3	0.8 ± 0.3	0.08 ± 0.04	0.0 ± 0.4	0.8 ± 1.0	0.2 ± 0.4	0.06 ± 0.08	2.0 ± 1.2	4
$e\mu$	4.0 ± 0.9	3.5 ± 0.8	0.4 ± 0.2	0.4 ± 0.7	3.1 ± 1.3	1.2 ± 0.6	0.24 ± 0.13	8.8 ± 1.9	8
$\mu\mu$	2.3 ± 0.5	1.9 ± 0.4	0.0 ± 0.8	0.0 ± 0.4	1.1 ± 1.1	0.8 ± 0.7	0.04 ± 0.07	3.9 ± 1.7	9





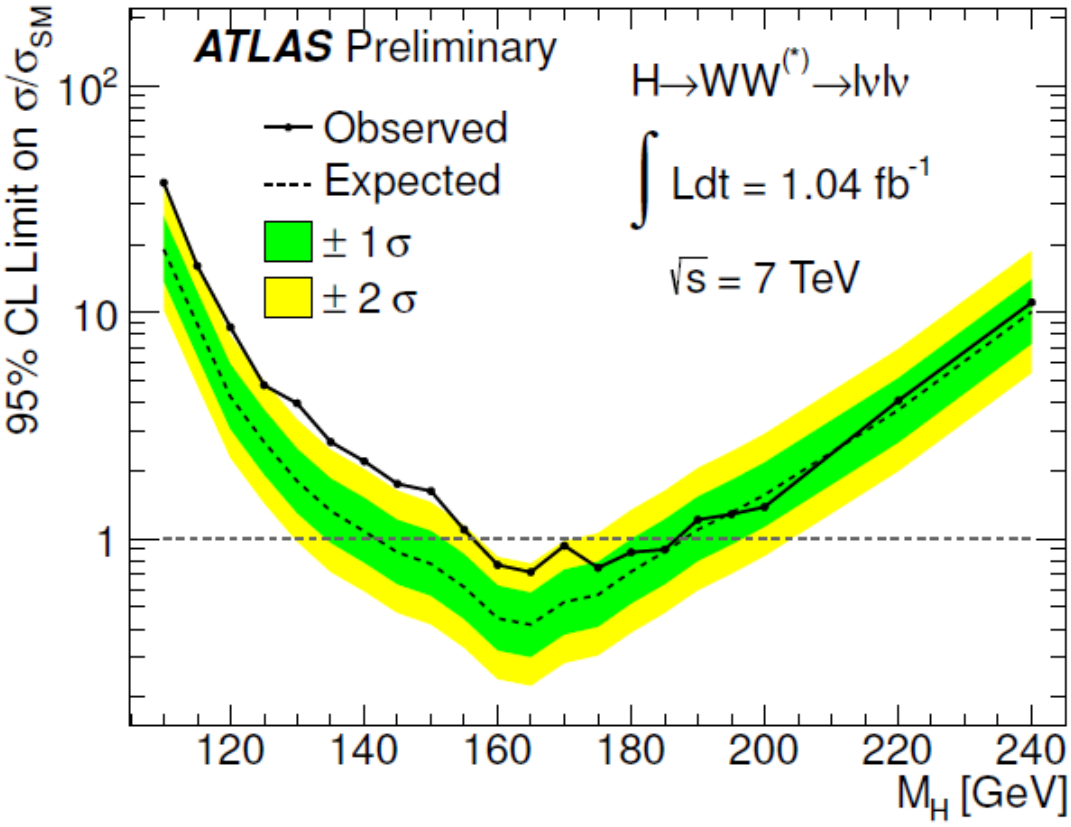
H–>WW: backgrounds

- *WW*: dominant background in *0-jet* channel
  - Dedicated control region in data used to derive normalization in signal region
  - Require $m_{ll} > 80$ GeV, remove topological cuts

	Signal	*WW*	*W*+jets	Z/γ^*+jets	$t\bar{t}$	*tW*/*tb*/*tqb*	*WZ*/*ZZ*/*W*γ	Total Bkg.	Observed
$ee + e\mu + \mu\mu$	0.73 ± 0.16	111 ± 15	13 ± 7	2 ± 3	10 ± 4	8 ± 2	4.3 ± 1.2	150 ± 30	153
ee	0.01 ± 0.07	13 ± 2	2 ± 2	0.2 ± 1.7	1.4 ± 1.6	0.5 ± 1.0	0 ± 2	17 ± 5	28
$e\mu$	0.73 ± 0.17	76 ± 10	9 ± 6	0 ± 0	6 ± 3	4.6 ± 1.4	3 ± 2	100 ± 20	98
$\mu\mu$	0.00 ± 0.07	23 ± 3	1.8 ± 1.2	1.9 ± 1.2	2.2 ± 1.7	2.6 ± 1.1	1 ± 2	32 ± 6	27

- *Top*: dominant background in *1-jet* channel
  - Normalization from control region: reverse *b*-jet veto and remove topological cuts
- *W+jets*: fully data-driven, control sample in data obtained requiring one loose lepton, while other lepton must pass tight selection
  - Estimate a fake factor in dijet data using an orthogonal trigger
- *Z + jets:* 'ABCD' method: derive MET mismodelling factor

H–>WW: limits



- We exclude a SM Higgs with 158 GeV < M_H < 186 GeV at 95% CL
- Observed limit is >=2σ higher than expected in range 126 GeV < M_H < 154 GeV

Conclusion and outlook

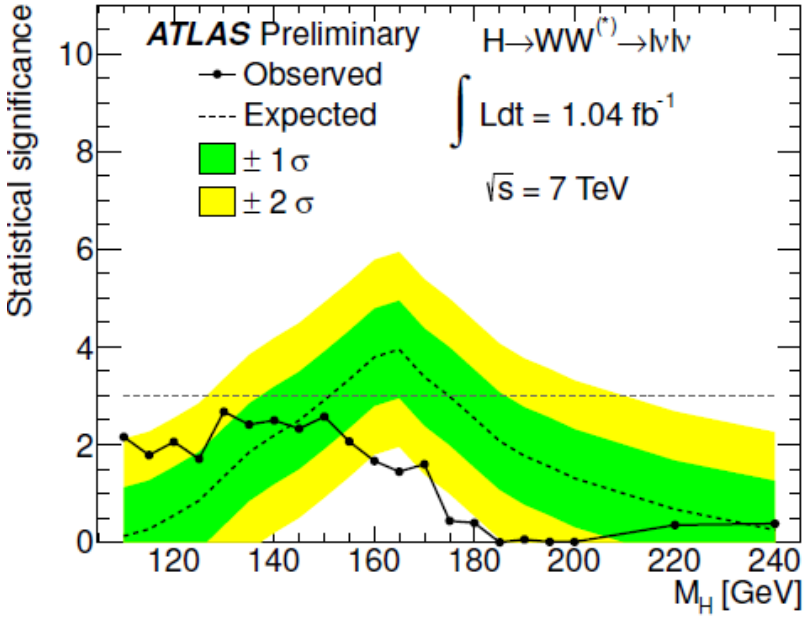
- We have presented ATLAS Higgs search results in the $WH \rightarrow l\nu bb$ and $H \rightarrow WW^{(*)}$ di-leptonic decay channels
- $WH \rightarrow l\nu bb$ sets limits on Higgs production cross-section 15-30 times the Standard Model cross-section for 110 GeV < M_H < 130 GeV
- $H \rightarrow WW^{(*)} \rightarrow l\nu l\nu$ excludes Standard Model Higgs in mass range 158 GeV < M_H < 186 GeV at 95% confidence level

  - intriguing excess seen at lower masses

- The LHC is increasing our dataset fast → new results expected soon
- Analysis improvements meanwhile

➢ multivariate analyses

➢ reduced systematics



Signal significance in $H \rightarrow WW \rightarrow l\nu l\nu$