A search for H->WW->lνlν with first ATLAS data

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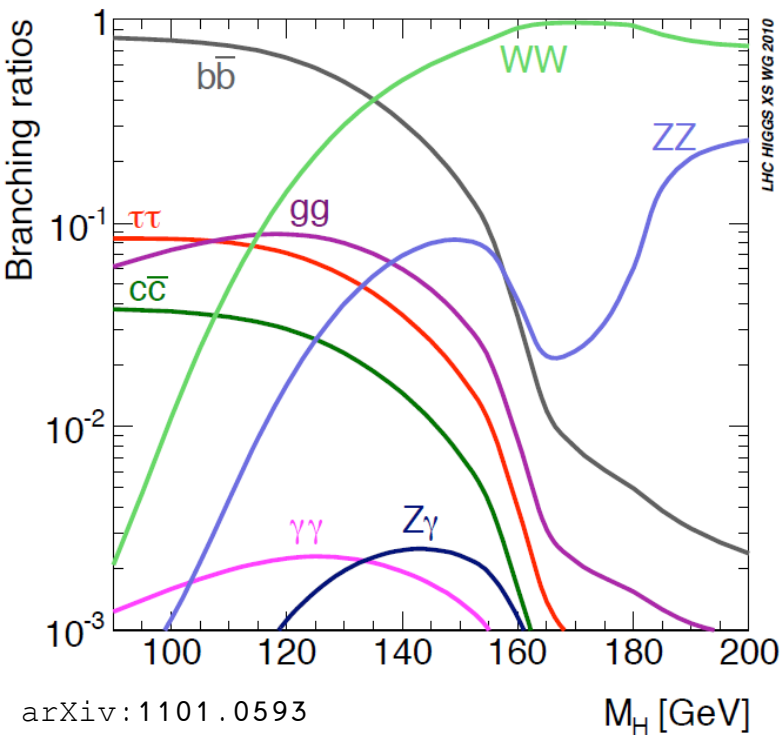
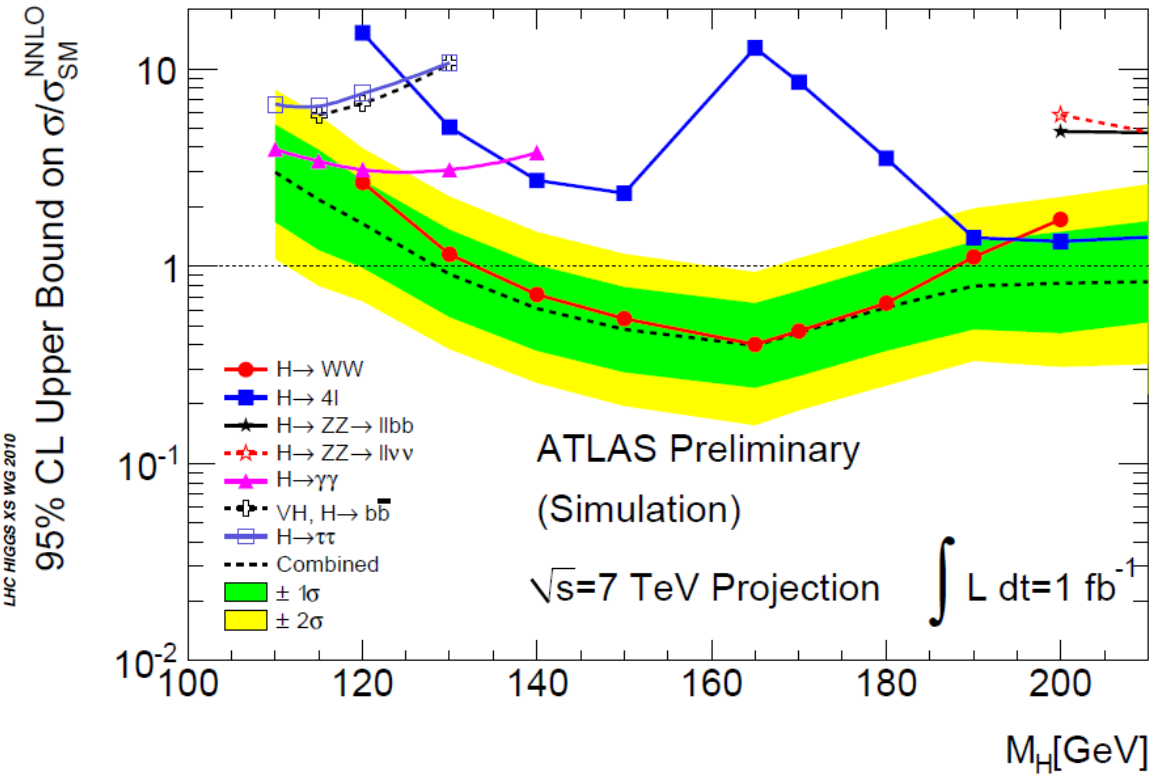
Motivation

- With 1 fb^{-1} ATLAS can exclude a Higgs boson with $129 < M_H < 460$ GeV
- Can also achieve 3σ evidence with 1 fb^{-1} for Higgs masses between $139 < M_H < 180$ GeV



arXiv:1101.0593

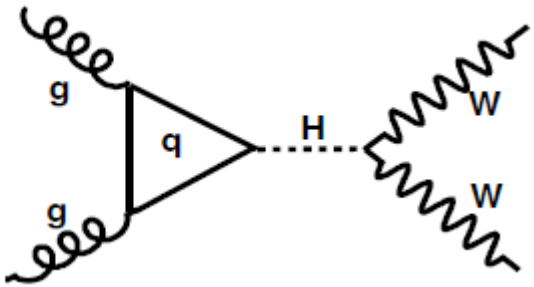


- **H->WW** is the **dominant decay mode** in the intermediate mass region
- This channel alone provides main contribution to exclusion potential in this region

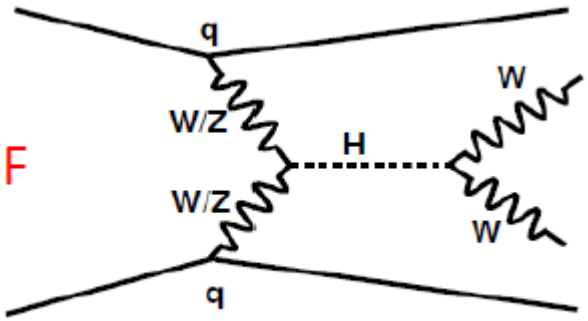
Overview of Higgs search

- Higgs produced via gluon-gluon fusion (ggF) and vector-boson fusion (VBF):

ggF



VBF



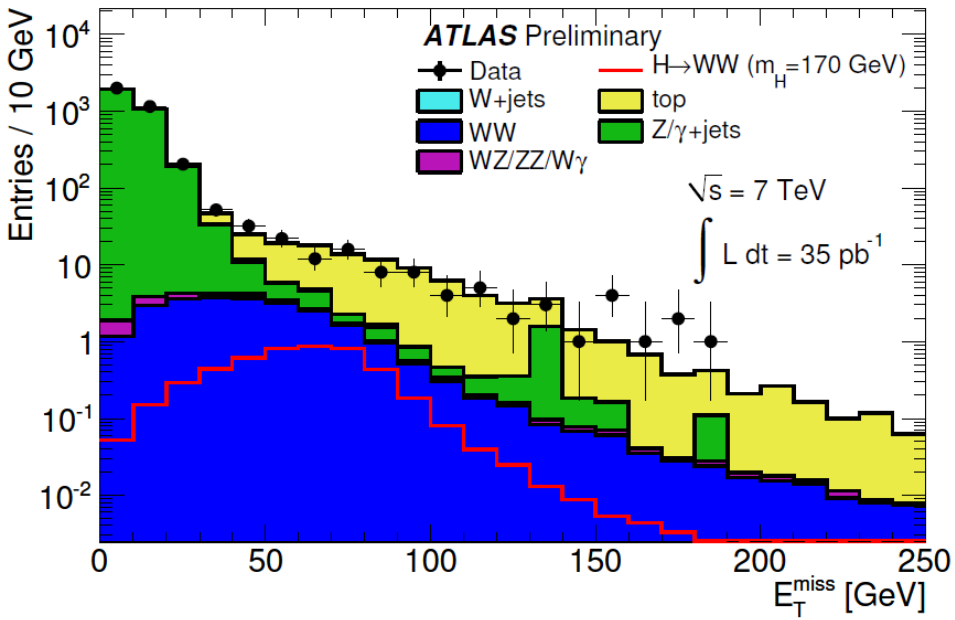
- Search for Higgs via H->WW->lνlν, l = e,μ
- Separate search into 0, 1 and 2 jet bins
- Select events with two well-identified leptons
- Further separate into ee, μμ and eμ channels
- Apply preselection then further cuts, tailored to the jet channel

Obtained **first LHC Higgs search** result
(ATLAS-CONF-2011-005)

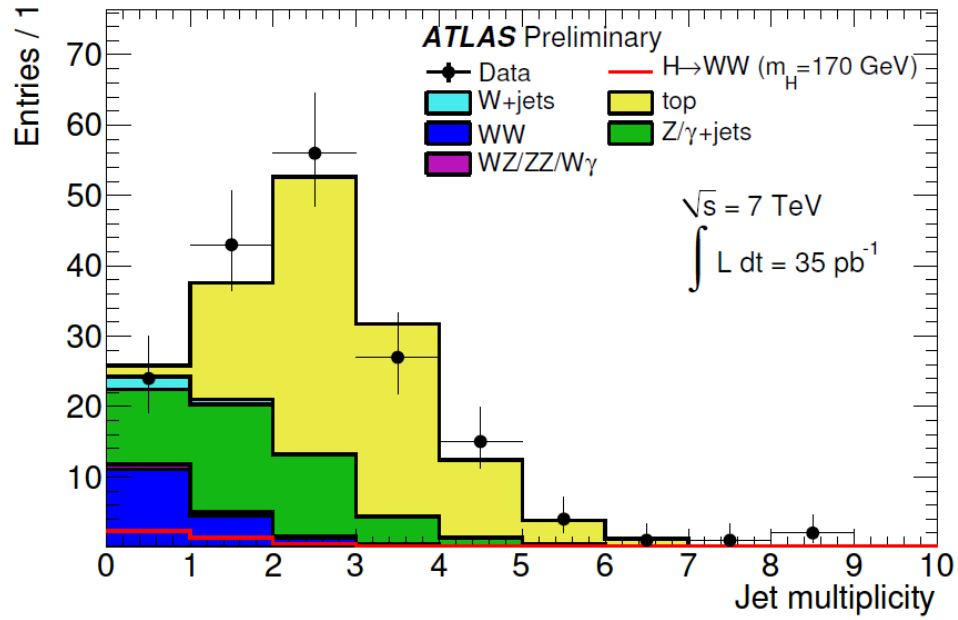
Preselection requirements

- Require $M_{ll} > 15$ GeV and $|M_{ll} - M_Z| > 10$ GeV in ee and $\mu\mu$ channels
- Additionally require missing E_T (MET) > 30 GeV
- Then separate into 0, 1 and 2 jet channels

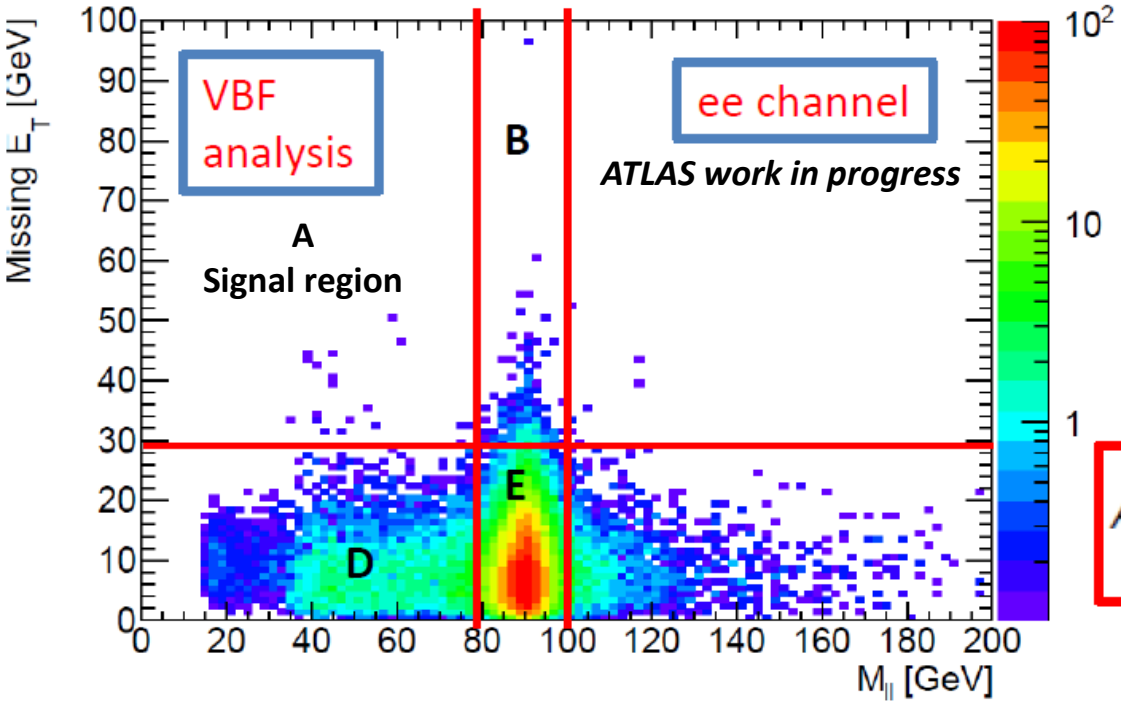
MET distribution after requiring 2 leptons



Number of jets after MET cut



Z background estimation



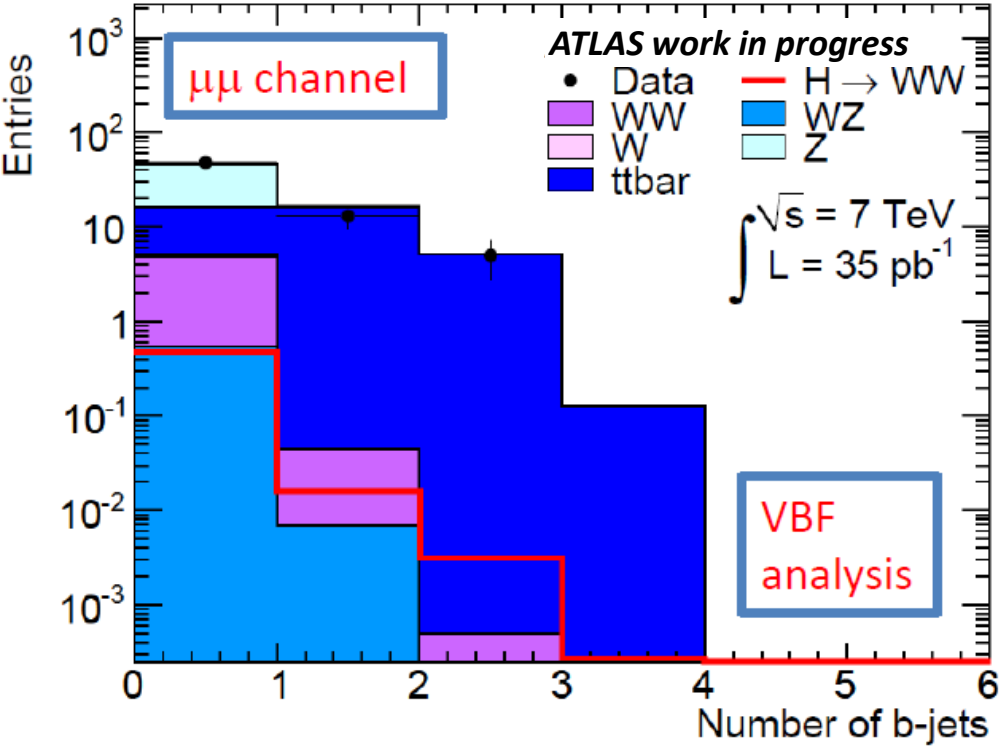
- Use Z dominated control regions to estimate Z background in signal regions
- Correct for mis-modelling of MET tails using events in Z peak region

$$A_{data}^{estimate} = D_{data} \times \frac{A_{MC}}{D_{MC}} \times \frac{B_{data}}{E_{data}} \frac{E_{MC}}{B_{MC}}$$

- Calculate ratios A/D & B/E as a function of MET cut
- Fit with an exponential & evaluate at MET cut used in analysis (30 GeV)
- Good agreement between MC and data-driven estimate:
  - **Estimate/MC = 1.02** for ee channel and **0.98** for μμ channel

Top background estimation

- Use WW sample with >=1 b-jet as a ttbar control region
- This is completely dominated by top, with contamination from other backgrounds much less than 1 event after preselection



- Estimate top background in 0 b-jet signal region using:

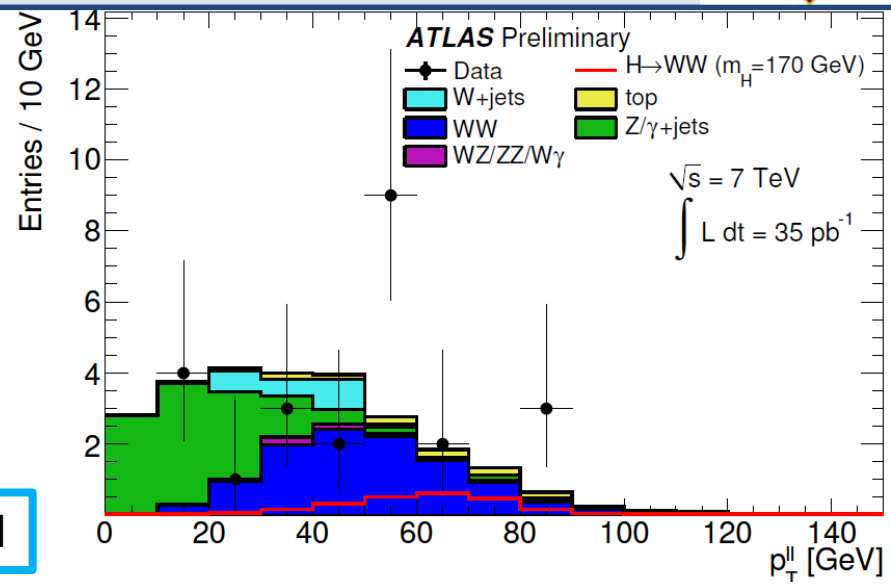
$$N^{SR}_{data} = N^{CR}_{data} \times \frac{N^{SR}_{MC}}{N^{CR}_{MC}}$$

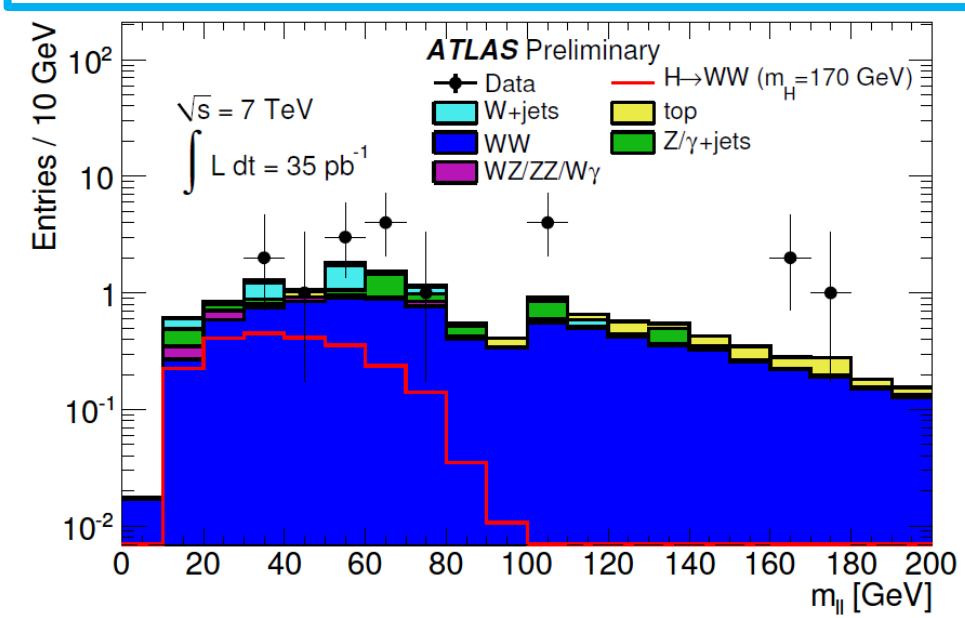
- Improves agreement between data and MC

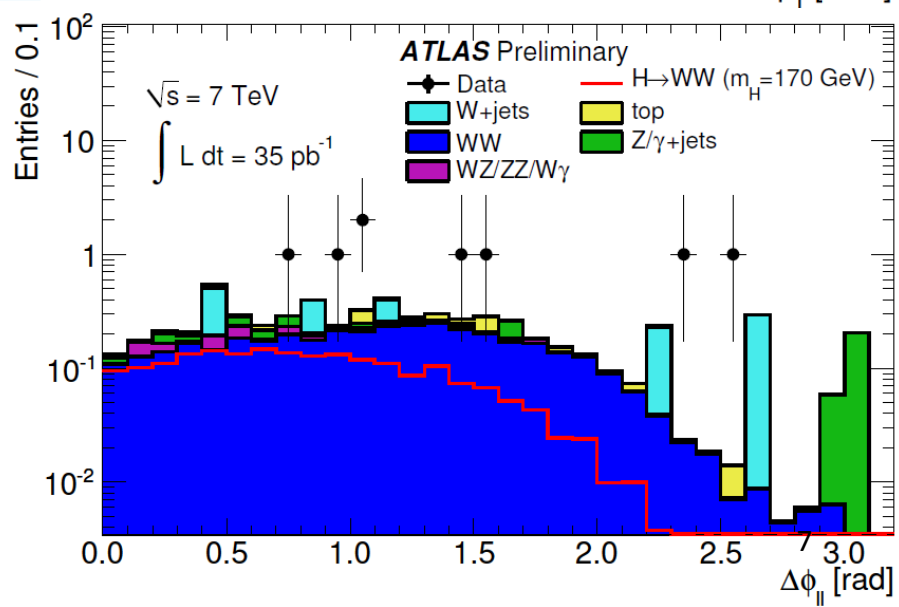
0 jet channel

- Apply additional requirement of $P_T^{ll} > 30$ GeV
- Then apply topological cuts to separate Higgs from WW:
  - $M_{ll} < 65$ GeV
  - $\Delta\phi_{ll} < 1.8$
  - $0.75 \times M_H < M_T < M_H$

Plots are after all previous cuts have been applied



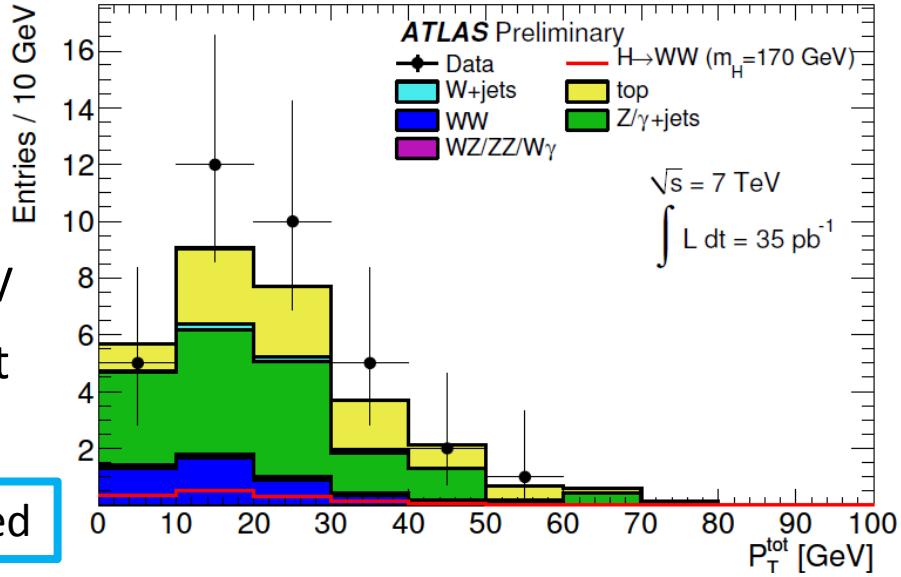


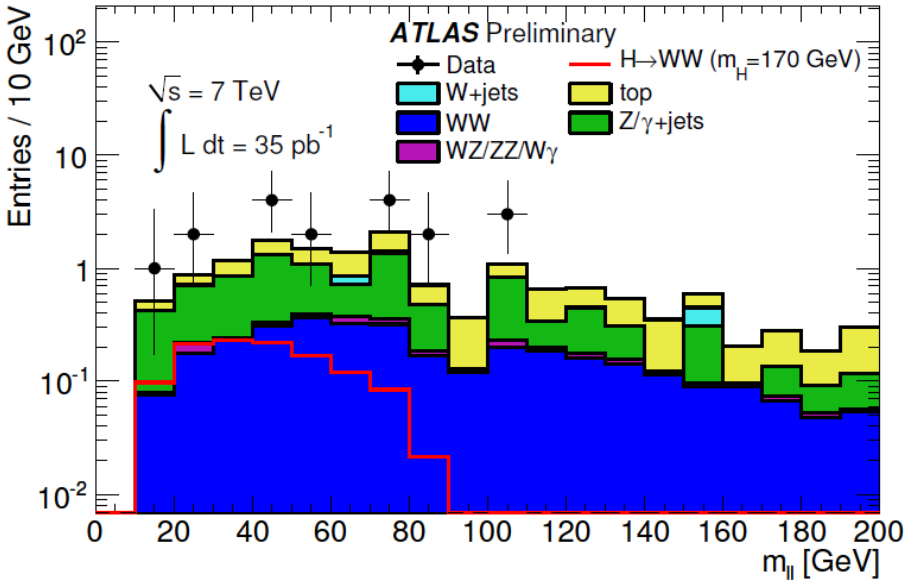


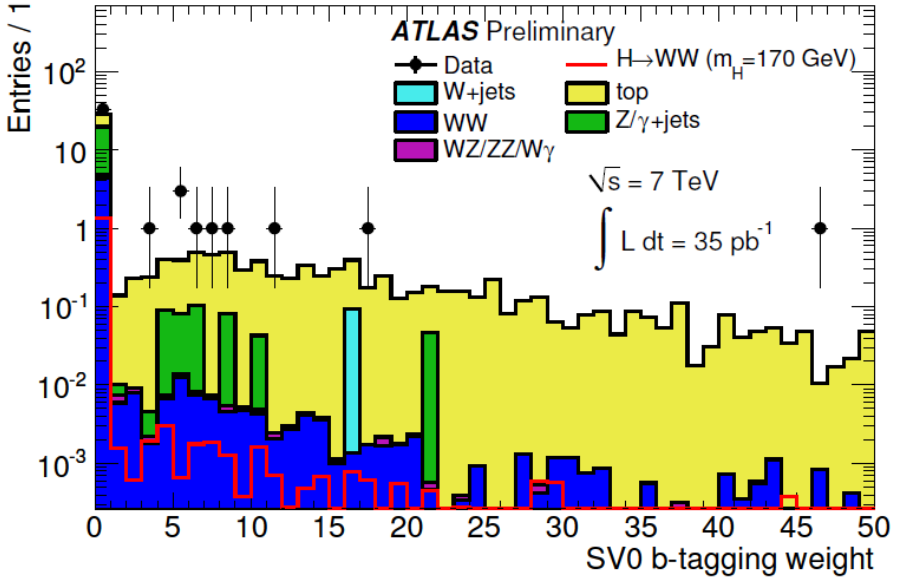
1 jet channel

- Require $P_T^{tot} < 30$ GeV
- Veto events with b-jets
- Use collinear approx. to calculate $M_{\tau\tau}$
- Remove events with $|M_{\tau\tau} - M_Z| < 25$ GeV
- Cut on same topological variables as 0 jet channel

Plots are after all previous cuts have been applied



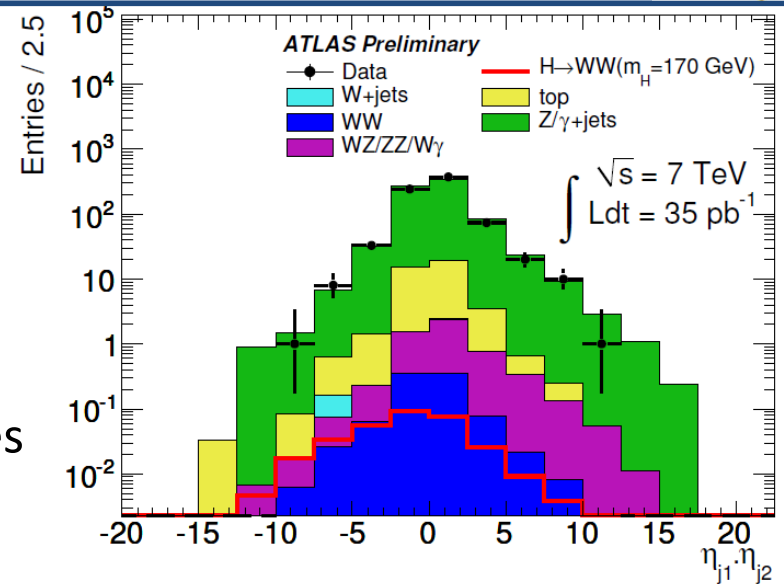


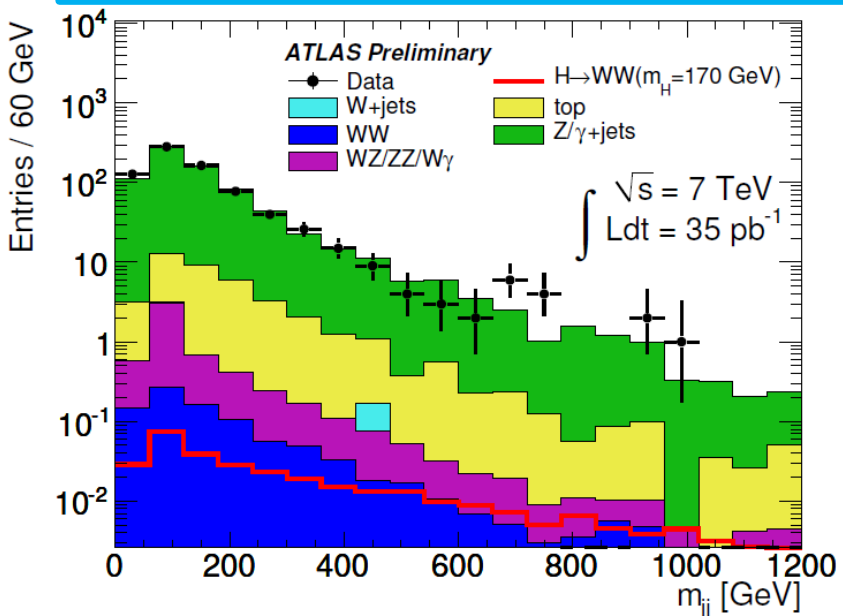


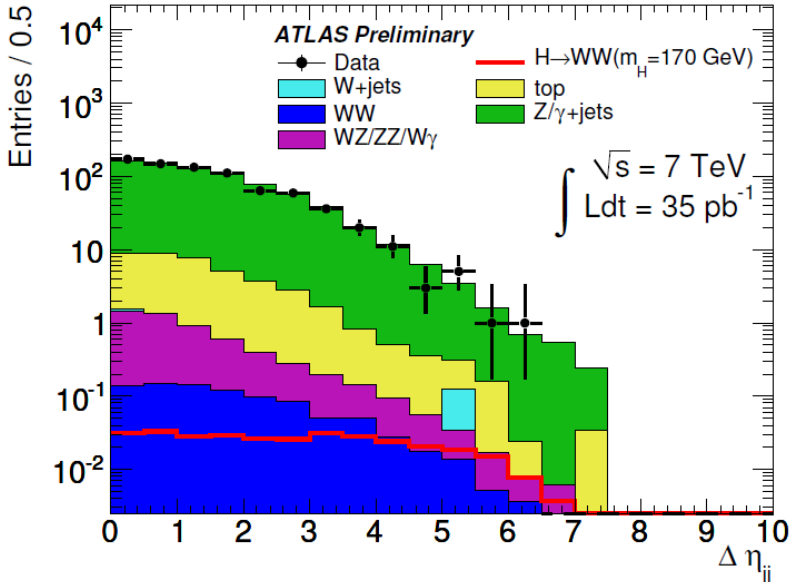
2 jet channel

- Apply cuts to select VBF events:
  - $\eta_{j1} x \eta_{j2} < 0$
  - $\Delta\eta_{jj} > 3.8$
  - $M_{jj} > 500$
- Veto events with b-jets and central jets
- Cut on 0 & 1 jet channel topological variables

Plots are after requiring 2 good leptons

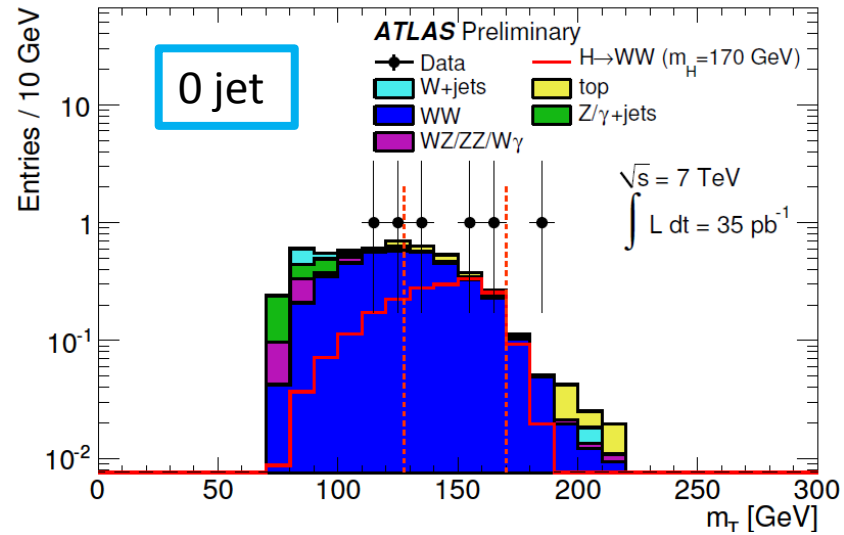


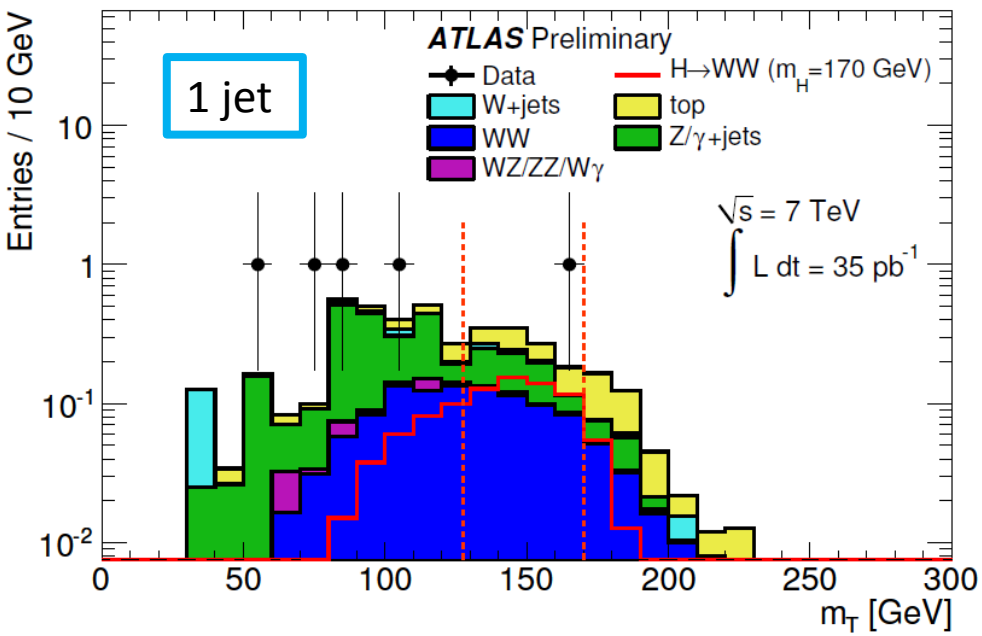


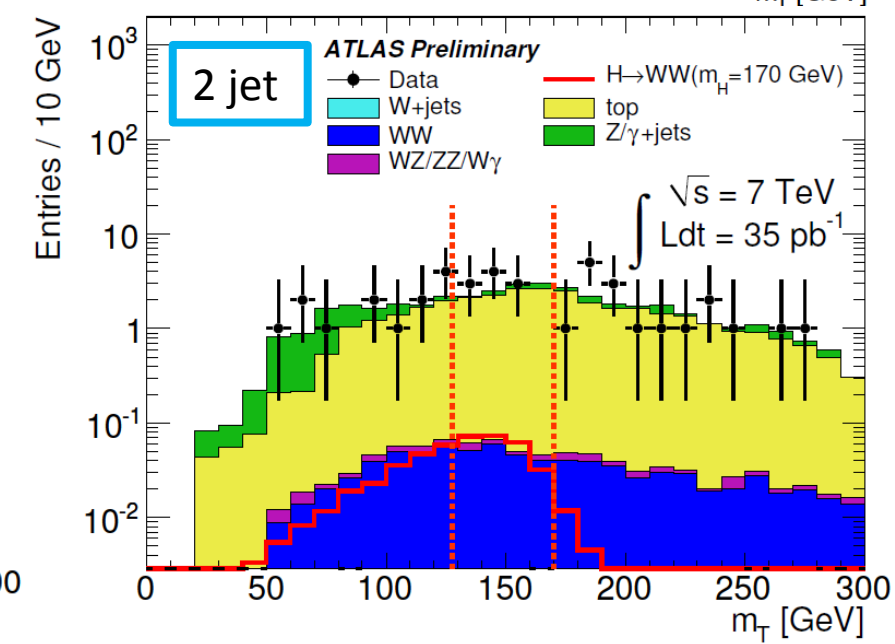


Results

- M_T distributions:
  - After all other cuts for 0 and 1 jet channels
  - After $\eta_{j1} x \eta_{j2}$ cut for 2 jet channel (due to low statistics)
- Signal region lies within the dotted lines







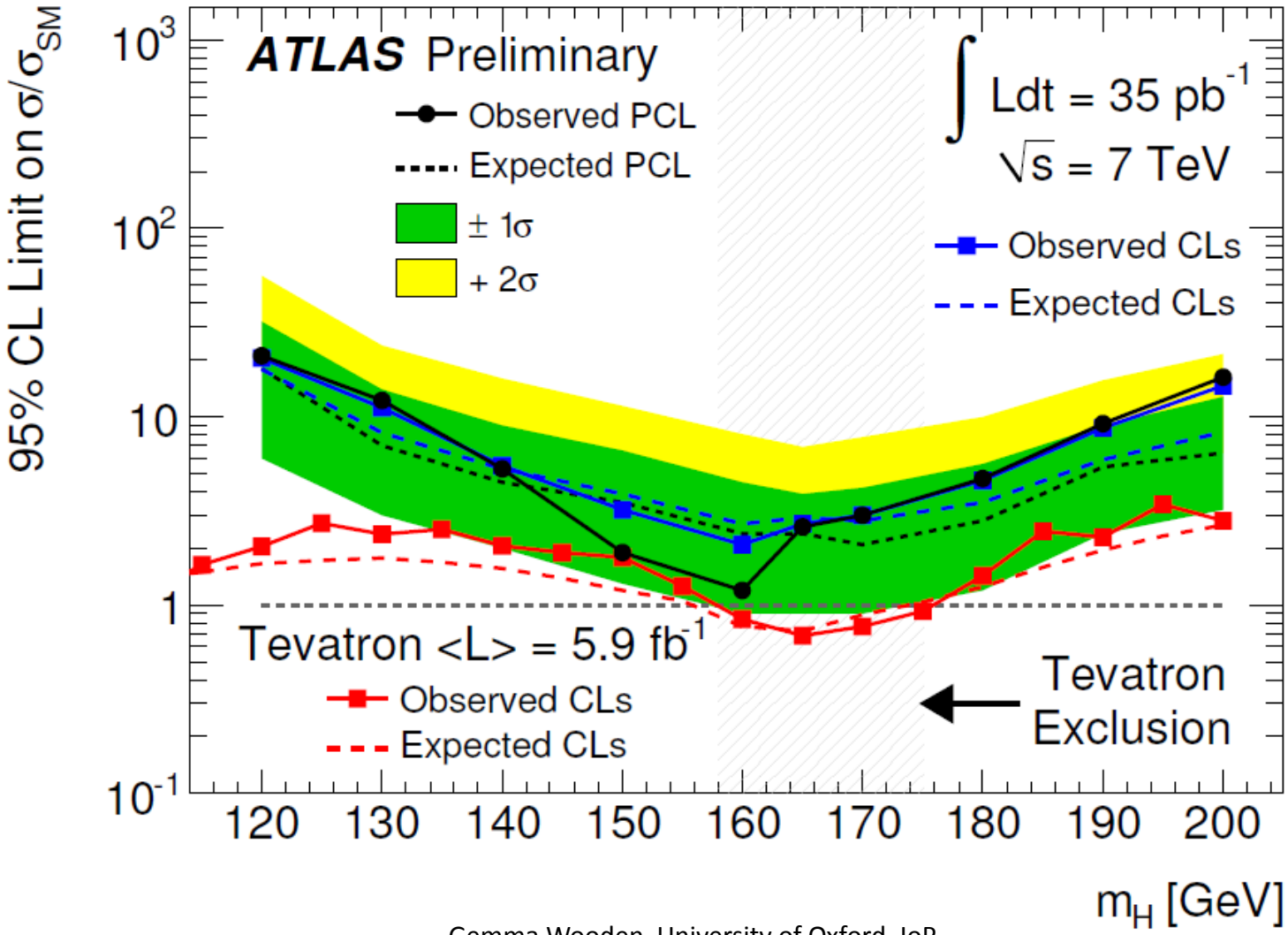
Systematics

- The uncertainty on the extrapolation from CRs to SRs is taken into account
- Additional systematics also accounted for

	α_{WW}	α_{top}	α_{W+jets}	β_{top}	α_{Z+jets}
	$H+0j$ analysis				
Total Uncertainty	7%	69%	52/46%		47/22%
	$H+1j$ analysis				
Total Uncertainty	19%	42%	52/46%	20%	30/21%
	$H+2j$ analysis				
Total Uncertainty		44%	–	18%	42/29%

Source of Uncertainty	Treatment in analysis
Jet Energy Resolution (JER)	~ 14%,
Jet Energy Scale (JES)	< 10% for $p_T > 15$ GeV and $\|\eta\| < 4.5$,
Electron Selection Efficiency	6 – 16% as a function of p_T
Electron Energy Scale	1% for $\|\eta\| < 1.4$, 3% for $1.4 < \|\eta\| < 2.5$
Electron Energy Resolution	Sampling term 20%, a small constant term has a large variation with η
Muon Selection Efficiency	1.2% for $p_T < 20$ GeV and 0.4% for $p_T > 20$ GeV
Muon Momentum Scale	η dependent scale offset in p_T, up to ~ 3.5%
Muon Momentum Resolution	p_T and η dependent resolution smearing functions, $\leq 10\%$
b-tagging Efficiency	p_T dependent scale factor uncertainties, 10-12%,
b-tagging Mis-tag Rate	up to 26%
Missing Transverse Energy	Add/subtract object uncertainties into the E_T^{miss}, up to 20%
Luminosity	11%

Limits


ATLAS Preliminary
Observed PCL
Expected PCL
± 1σ
+ 2σ
∫ Ldt = 35 pb-1
√s = 7 TeV
Observed CLs
Expected CLs
Tevatron <L> = 5.9 fb-1
Observed CLs
Expected CLs
Tevatron Exclusion
95% CL Limit on σ/σSM
mH [GeV]
10^3
10^2
10
1
10^-1
120
130
140
150
160
170
180
190
200

Outlook

- Have performed first Higgs search at ATLAS using the **H->WW** decay mode
- Even with only 35 pb^{-1} of data, able to **exclude** a Higgs boson with a production rate of **1.2 times the SM at 160 GeV** at 95% C.L.
- With 2011 data, will be able to completely exclude the SM Higgs down to at least 130 GeV
  - This will largely be due to the sensitivity offered by the H->WW channel
- Could also observe a 3σ excess if the Higgs mass lies between $139 < M_H < 180$ GeV

- **Note:** these are only the **baseline expectations**
- Much work is in progress to **improve the analyses**
  - Should be able to achieve even better exclusion/observation sensitivity in practice

Backup slides

Number of events observed

- This table shows the expected and observed no. of events:
  - At each hypthosized Higgs mass
  - For each jet bin
- Agreement between data and background only MC is good

m_H [GeV]	Jet bin	Signal	Total Bkg.	Observed
120	$H+0j$	0.15	0.87	1
	$H+1j$	0.05	1.05	1
	$H+2j$	0.01	0.00	0
130	$H+0j$	0.34	0.97	2
	$H+1j$	0.13	1.07	1
	$H+2j$	0.03	0.01	0
140	$H+0j$	0.56	1.07	2
	$H+1j$	0.22	1.02	0
	$H+2j$	0.03	0.03	0
150	$H+0j$	0.78	1.12	1
	$H+1j$	0.32	1.03	0
	$H+2j$	0.04	0.03	0
160	$H+0j$	1.11	1.09	1
	$H+1j$	0.50	0.93	0
	$H+2j$	0.06	0.03	0
165	$H+0j$	1.13	1.03	2
	$H+1j$	0.50	0.93	0
	$H+2j$	0.06	0.02	0
170	$H+0j$	1.26	1.70	3
	$H+1j$	0.6	1.26	1
	$H+2j$	0.06	0.02	0
180	$H+0j$	0.85	1.33	3
	$H+1j$	0.42	1.25	1
	$H+2j$	0.05	0.01	0
190	$H+0j$	0.45	0.97	3
	$H+1j$	0.24	1.12	1
	$H+2j$	0.03	0.01	0
200	$H+0j$	0.29	0.72	3
	$H+1j$	0.15	0.85	1
	$H+2j$	0.02	0.01	0

Number of events observed at M_H = 170 GeV

- This table shows the expected no. of events in data and MC at M_H = 170 GeV
- It can be seen clearly that WW and top are the dominant backgrounds

Channel	Signal	top	WW	$WZ/ZZ/W\gamma$	Z+jets	W+jets	Total Bkg.	Observed
				$H+0j$				
$e\mu$	$0.62 \pm 0.01 \pm 0.18$	0.09	0.71	0.02	0.00	0.01	$0.83 \pm 0.07 \pm 0.13$	1
ee	$0.20 \pm 0.01 \pm 0.07$	0.03	0.20	0.00	0.00	0.02	$0.25 \pm 0.08 \pm 0.04$	1
$\mu\mu$	$0.44 \pm 0.01 \pm 0.12$	0.08	0.53	0.01	0.00	0.00	$0.62 \pm 0.05 \pm 0.10$	1
				$H+1j$				
$e\mu$	$0.31 \pm 0.01 \pm 0.09$	0.26	0.18	0.01	0.00	0.02	$0.47 \pm 0.08 \pm 0.16$	0
ee	$0.08 \pm 0.01 \pm 0.03$	0.10	0.05	0.00	0.05	0.03	$0.23 \pm 0.04 \pm 0.06$	0
$\mu\mu$	$0.21 \pm 0.01 \pm 0.06$	0.15	0.16	0.00	0.25	0.00	$0.56 \pm 0.09 \pm 0.14$	1
				$H+2j$				
$e\mu$	$0.03 \pm 0.01 \pm 0.01$	0.01	0.00	0.00	0.00	0.00	$0.01 \pm 0.01 \pm 0.01$	0
ee	$0.01 \pm 0.01 \pm 0.01$	0.00	0.00	0.00	0.00	0.00	0.00	0
$\mu\mu$	$0.02 \pm 0.01 \pm 0.01$	0.00	0.01	0.00	0.00	0.00	$0.01 \pm 0.01 \pm 0.01$	0

CMS H->WW limits

arXiv:1102.5429

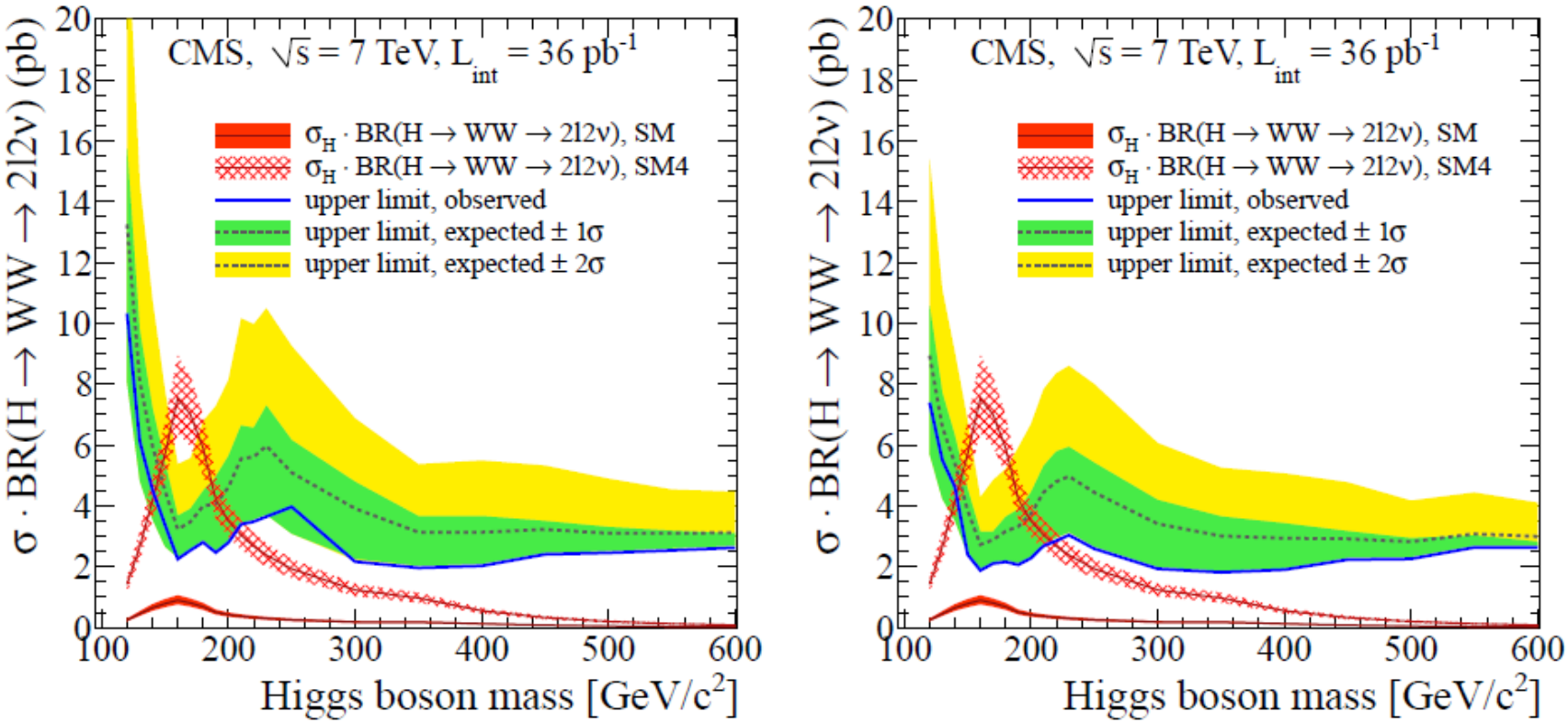


Figure 6: 95% mean expected and observed C.L. upper limits on the cross section $\sigma_H \cdot BR(H \to W^+W^- \to 2\ell 2\nu)$ for masses in the range 120-600 GeV/c^2 using (a) cut-based and (b) multivariate BDT event selections. Results are obtained using a Bayesian approach. The expected cross sections for the SM and for the SM with a fourth-fermion family cases (SM4) are also presented. The dash line indicates the mean of the expected results.

Tevatron Higgs limits

arXiv:1103.3233