



Search for the Standard Model Higgs Boson in the H→WW→lvlv, lvqq decay modes with the ATLAS detector

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on the behalf of the ATLAS collaborat

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RESULTS SHOWN

2011 DATA $\sqrt{s} = 7 \text{ TeV}$

 $\int Ldt = 4.7 f b^{-1}$



The main production mode is the gluon fusion process, WW^* decay (W^* for off-shell W's) is the largest decay mode for $m_H \ge 135$ GeV. Competitive with $\gamma\gamma$ for $m_h \ge 120$ GeV.

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ICHEP 2012 Melbourne (Australia)

WW->lvlv, lvqq analysis strategy

Reconstruct the neutrino p_T evaluating the total transverse missing energy Using the W mass constraint, the η of the neutrino is reconstructed and the 4 body invariant mass can be computed, reconstructing the Higgs

mass.



·> lvqq

Main background from $pp \rightarrow W^+W^- \rightarrow lvlv$





spin 0 H

spin conservation

maximal parity violation

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 $m_{\ell\ell} = \sqrt{2E_1E_2(1 - \cos\theta_{\ell\ell})}$ used to define signal and background enriched regions

 $m_{\rm T} = \sqrt{(E_{\rm T}^{\ell\ell} + E_{\rm T}^{\rm miss})^2 - |\mathbf{p}_{\rm T}^{\ell\ell} + \mathbf{p}_{\rm T}^{\rm miss}|^2} \quad E_{\rm T}^{\ell\ell} = \sqrt{|\mathbf{p}_{\rm T}^{\ell\ell}|^2 + m_{\ell\ell}^2} \quad E_{\rm T}^{\rm miss} = |\mathbf{P}_{\rm T}^{\rm miss}|^2$

(it is the Higgs mass if all leptons decay in the transverse plane)

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WW \rightarrow lvlv analysis selection.

Events

(sub. to PLB, arXiv: 1206.0756)

• object selection e: $p_T > 15 \text{ GeV}$, $|\eta| < 2.47$ μ : $p_T > 15 \text{ GeV}$, $|\eta| < 2.4$ jets: $p_T > 25 \text{ GeV}$, $|\eta| < 4.5$ associated to the hard interaction vertex and not b jets • p_T leading lepton > 25 GeV

• **&** categorisation in 0,1,2 jets bin to handle different top background contamination

MET > 45 GeV ee,μμ (Same Flavour) MET > 25 GeV eμ (Different Flavour)

m_{ll} > 12 GeV (10 GeV) ee,μμ (eµ) (γ^{*} and quarkonia rejection)

Z veto $|m_{ll} - m_Z| > 15$ GeV ee, $\mu\mu$





WW→lvlv background treatment

• WW (simulated with MC@NLO + Herwig), for $m_H < 200$ normalised for each jet bin to data in $m_{ll} >$ 80 GeV Control Region (CR)

• Impossible to find a signal free C.R. at high mass (use directly MC yield with th. uncertainties)

• \rbrace S.R. include $\Delta \phi_{ll} < 1.8, m_{ll} < 50 \ GeV$

• top (important in 1 jet for both S.R. and C.R) normalised using the b-tagged 1 jet sample (syst. dominated by the b-tagging efficiency)

• W+jets (data driven, leptons failing isolation. Fake probability determined on di-jet sample, yield estimate using loose isolated lepton data sample)

• \mathcal{Z}/γ^* using mc for shapes, normalised using a pure data driven method.

Final signal extraction using an m_T shape fit. Data sample divided in SF, DF, jet bins to maximise S/B ratio.





• & Observed exclusion range @95% C.L.

 $133 \text{ GeV} < m_H < 261 \text{ GeV}$

• Expected exclusion range @95% C.L.

 $127 GeV < m_H < 233 GeV$

Results

• $b_{0:}$ probability that an excess is produced by a background fluctuation



visualisation of the observed p0





 $127 GeV < m_H < 255 GeV$

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 $130 \text{ GeV} < m_H < 281 \text{ GeV}$







CONCLUSIONS

- A Standard Model Higgs boson is excluded in the range 130 < m_H < 281 GeV in the WW channel, the expected exclusion is 127 < m_H < 255 GeV, the minimum p₀ corresponds to ~1σ;
- * 2012 data have been analysed and results will be shown in the future
- * Adding 2012 WW data to ATLAS combination:

- in case of no signal observed (μ =0) WW would bring the combined significance to 4.6 σ and the best fit to μ =0.99

- in case of an observation at $\mu=1$, the significance will go to 5.4 σ and $\mu=1.18$
- did this guy jump enough in WW to show up? stay tuned...







0-jet	Signal	WW	$WZ/ZZ/W\gamma$	tt	tW/tb/tqb	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
Jet Veto	56.7 ± 0.2	1273 ± 79	97 ± 4	174 ± 12	95 ± 7	1039 ± 28	217 ± 4	2890 ± 120	2849
$m_{\ell\ell} < 50 \text{ GeV}$	45.2 ± 0.2	312 ± 20	41 ± 3	29 ± 2	19 ± 2	168 ± 10	70 ± 2	639 ± 28	645
$p_{\rm T}^{\ell\ell}$ cut	40.1 ± 0.2	282 ± 18	35 ± 3	28 ± 2	18 ± 2	28 ± 6	49 ± 2	439 ± 26	443
$\Delta \phi_{\ell\ell} < 1.8$	39.0 ± 0.2	276 ± 17	33 ± 2	27 ± 2	18 ± 2	28 ± 6	44 ± 1	425 ± 26	429
1-jet	Signal	WW	$WZ/ZZ/W\gamma$	tt	tW/tb/tqb	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
1 jet	22.7 ± 0.1	343 ± 54	56 ± 3	1438 ± 60	436 ± 19	357 ± 17	85 ± 3	2720 ± 140	2706
<i>b</i> -jet veto	20.9 ± 0.1	319 ± 50	52 ± 3	412 ± 18	139 ± 7	332 ± 16	76 ± 3	1330 ± 84	1369
$ \mathbf{p}_{\mathrm{T}}^{\mathrm{tot}} < 30 \mathrm{~GeV}$	14.0 ± 0.1	226 ± 35	34 ± 2	181 ± 8	80 ± 4	108 ± 8	37 ± 2	666 ± 51	684
$Z \rightarrow \tau \tau$ veto	14.0 ± 0.1	220 ± 34	34 ± 2	173 ± 8	77 ± 4	85 ± 7	37 ± 2	627 ± 50	644
$m_{\ell\ell} < 50 \text{ GeV}$	10.9 ± 0.1	49 ± 8	14 ± 2	33 ± 2	18 ± 1	24 ± 3	12 ± 1	148 ± 12	170
$\Delta \phi_{\ell\ell} < 1.8$	10.1 ± 0.1	44 ± 7	13 ± 2	31 ± 2	17 ± 1	10 ± 2	10 ± 1	126 ± 10	145
2-jet	Signal	WW	$WZ/ZZ/W\gamma$	tt	tW/tb/tqb	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
≥ 2 jets	11.4 ± 0.1	142 ± 2	26 ± 2	5939 ± 17	339 ± 5	120 ± 7	40 ± 4	6605 ± 20	6676
Central jet veto	9.0 ± 0.1	113 ± 2	20 ± 1	3279 ± 13	238 ± 4	89 ± 6	25 ± 3	3765 ± 15	3811
<i>b</i> -jet veto	7.6 ± 0.1	98 ± 1	18 ± 1	353 ± 4	51 ± 2	77 ± 5	19 ± 2	615 ± 8	667
Opp. hemispheres	4.2 ± 0.1	46 ± 1	7 ± 1	149 ± 3	21 ± 1	32 ± 3	9 ± 1	264 ± 5	269
$ \Delta \eta_{\rm jj} > 3.8$	1.8 ± 0.1	8.4 ± 0.4	0.9 ± 0.2	23.2 ± 1.0	2.2 ± 0.4	5.8 ± 1.7	1.7 ± 0.4	42.2 ± 2.1	40
$m_{\rm jj} > 500 {\rm GeV}$	1.3 ± 0.1	3.9 ± 0.3	0.4 ± 0.1	10.4 ± 0.6	1.0 ± 0.3	0.7 ± 0.4	0.9 ± 0.3	17.3 ± 0.9	13
$m_{\ell\ell} < 80 \text{ GeV}$	0.9 ± 0.1	1.1 ± 0.2	0.1 ± 0.1	1.4 ± 0.2	0.4 ± 0.1	0.2 ± 0.2	0.2 ± 0.2	3.2 ± 0.4	2
$\Delta \phi_{\ell\ell} < 1.8$	0.8 ± 0.1	0.8 ± 0.1	0.1 ± 0.1	0.9 ± 0.2	0.1 ± 0.1	negl.	negl.	1.8 ± 0.3	1
Control Regions	Signal	WW	$WZ/ZZ/W\gamma$	tt	tW/tb/tqb	Z/γ^{\star} + jets	W + jets	Total Bkg.	Obs.
WW 0-jet	0.3 ± 0.1	471 ± 3	26 ± 1	87 ± 2	42 ± 2	7 ± 2	49 ± 2	682 ± 5	697
WW 1-jet	0.1 ± 0.1	128 ± 2	12 ± 1	89 ± 2	34 ± 2	9 ± 2	11 ± 1	282 ± 4	270
Top 1-jet	1.2 ± 0.1	20 ± 1	1.9 ± 0.5	434 ± 4	169 ± 4	7 ± 2	4 ± 1	635 ± 6	676
Top 2-jet	0.1 ± 0.1	0.4 ± 0.1	negl.	10.0 ± 0.7	1.0 ± 0.3	negl.	negl.	11.4 ± 0.7	10

Lepton Channels	0-jet ee	0-jet <i>µµ</i>	0-jet <i>eµ</i>	1-jet ee	1-jet <i>µµ</i>	1-jet <i>eµ</i>
Total bkg.	60 ± 5	116 ± 10	249 ± 12	19 ± 2	34 ± 4	72 ± 6
Signal	4.0 ± 0.1	9.4 ± 0.1	25.7 ± 0.2	1.2 ± 0.1	2.5 ± 0.1	6.4 ± 0.1
Observed	52	138	239	19	36	90

Table 3: The expected numbers of signal ($m_H = 125$ GeV and 240 GeV) and background events after the full low m_H and intermediate m_H selections, including a cut on the transverse mass of $0.75 m_H < m_T < m_H$ for $m_H = 125$ GeV and $0.6 m_H < m_T < m_H$ for $m_H = 240$ GeV. The observed numbers of events are also displayed. The uncertainties shown are the combination of the statistical and all systematic uncertainties, taking into account the constraints from control samples. These results and uncertainties differ from those given in Table 2 due to the application of the additional m_T cut. All numbers are summed over lepton flavours.

	Signal	WW	$WZ/ZZ/W\gamma$	tt	tW/tb/tqb	Z/γ^{\star} + jets	W + jets	Total Bkg.	Obs.
$\underline{5} m_H = 125 \mathrm{GeV}$	26 ± 7	108 ± 12	12 ± 2	7 ± 2	5 ± 1	14 ± 6	27 ± 16	172 ± 21	174
$ \dot{\circ} m_H = 240 \text{ GeV} $	61 ± 16	450 ± 48	24 ± 3	73 ± 15	42 ± 9	6 ± 3	36 ± 24	632 ± 64	627
$\underline{\breve{o}} m_H = 125 \text{ GeV}$	6 ± 2	16 ± 3	5 ± 2	8 ± 2	4 ± 2	5 ± 2	5 ± 3	42 ± 6	56
$-m_H = 240 \text{ GeV}$	24 ± 8	95 ± 20	9 ± 1	84 ± 23	39 ± 16	5 ± 2	8 ± 7	241 ± 48	232
$\underline{5} m_H = 125 \text{ GeV}$	0.5 ± 0.1	0.2 ± 0.2	negl.	0.2 ± 0.1	negl.	$0.0^{+0.1}_{-0.0}$	negl.	0.4 ± 0.3	0
$n_H = 240 \text{ GeV}$	2.6 ± 0.4	1.2 ± 0.8	0.1 ± 0.1	2.2 ± 1.0	0.3 ± 0.2	negl.	0.1 ± 0.1	3.9 ± 1.5	2











Figure 1: Fits of the background model described in the text to the reconstructed invariant mass $m(\ell v j j)$ when m_{jj} is in the W sidebands for the $\ell v j j + 0 j$ selection. The left (right) figure shows the electron (muon) channel distribution. The χ^2 /dof and χ^2 probability of these fits are also shown in the figure.

Signal Selections						
Cut1	require at most 1 jet with transverse momentum ab	oove 25 GeV				
Cut2	the jet should not be <i>b</i> -tagged					
Cut3	$E_{\rm T,rel}^{\rm miss}$ above a threshold					
	Z enriched	Z depleted				
	$E_{\rm T,rel}^{\rm miss} > 40 { m GeV}$	$E_{\rm T,rel}^{\rm miss} > 25 { m GeV}$				
Cut4	invariant masses of all SFOS pairs					
	should be at least 25 GeV away from the Z boson mass					
	Z enriched	Z depleted				
1.5	require Z-veto	not applicable				
Cut5	the smallest invariant mass of opposite sign pairs is required to be above 12 GeV					
Cut6	the smallest angular distance between oppositely charged leptons, $\Delta R_{lep0,lep1}$, is required to be below 2.0					
Cut7	overlap removal with the di-lepton analy	sis				



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Ģ	ATLAS Preliminary	→ Data //// SM (sys ⊕ stat)	-
5 2	$700 - \sqrt{s} = 7 \text{ TeV}, \int L dt = 4.7 \text{fb}^{-1}$	$W(Z/\gamma)$ WW	_





