Search for the Higgs boson in the WW decay channel with ATLAS using 4.7 fb$^{-1}$ of data from 2011

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Rencontres de Moriond 2012

http://cdsweb.cern.ch/record/1429660
H → WW → l^+νl^-ν

Higgs production

Higgs decay

If $M_H < 2 M_W$ one W is off shell
Why we search in $H\rightarrow WW\rightarrow l^+\nu l^-\bar{\nu}$

- Large branching fraction for wide range of masses – Large window of sensitivity

- Expected sensitivity extends to low $m_H$ (127 GeV with 4.7 fb$^{-1}$). Competitive with $H\rightarrow\gamma\gamma$

Why is $H\rightarrow WW\rightarrow l^+\nu l^-\bar{\nu}$ difficult?

Two neutrinos in final state → no mass reconstruction. Signal is a broad excess of events

Must have confidence in background model to identify an emerging signal
How to select $H \rightarrow WW \rightarrow l^+ \nu l^- \nu$

- Opposite-sign lepton pairs – $e e \mu \mu \epsilon \mu$
- Large missing transverse momentum from neutrinos
- Use 0 and 1 jet final states + 2 jet VBF (tag forward jets)

**WW Spin correlation:**

Require small $\Delta \phi(l^+, l^-)$

**Low $m_H$:**

Require low $m(l^+, l^-)$

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H$\rightarrow$WW$\rightarrow$l$^+\nu l^-\nu

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# Backgrounds to $H \rightarrow WW \rightarrow l^+v_l^-v$

Use data-driven estimates for main backgrounds

<table>
<thead>
<tr>
<th>Background</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>W + jets</td>
<td>Reject with isolation, PID&lt;br&gt;10% of Background&lt;br&gt;Extrapolate from inverted lepton PID control region</td>
</tr>
<tr>
<td>Z/$\gamma^*$ + jets</td>
<td>Reject with met cut&lt;br&gt;5% of Background&lt;br&gt;Normalize MC using Z control region</td>
</tr>
<tr>
<td>Top</td>
<td>Reject with jet cuts&lt;br&gt;5% of Background&lt;br&gt;Jet veto efficiency derived in b-tag control region</td>
</tr>
<tr>
<td>WW</td>
<td>Reject with $\Delta\phi(l,l)$, $m(l,l)$ cut&lt;br&gt;65% of Background&lt;br&gt;Normalize MC using high $m(l^+,l^-)$ control region</td>
</tr>
</tbody>
</table>

Remaining backgrounds from Di-Bosons are estimated using simulation
Final distributions

After all analysis cuts

Transverse Mass ($m_T$) is a proxy for Higgs mass for WW channel

125 GeV Higgs signal shown

No significant excess observed

Fit $m_T$ shape to extract limits

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H→WW→l⁺vl⁻ν

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Limit results

Likelihood for each $M_H$ in 9 channels (ee, mm, em) x (0 jet, 1 jet, 2 jet)

Expected 95% C.L. Exclusion: $127 \text{ GeV} < m_H < 234 \text{ GeV}$

Observed 95% C.L. Exclusion: $130 \text{ GeV} < m_H < 260 \text{ GeV}$
H→WW→l⁺vl⁻ν is one of the most sensitive Higgs search channels

Combine WW and 11 other channels (right)

We will “close the gap” with the 2012 data

Expect discovery or exclusion this year!

See Sandra Kortner's talk for details on ATLAS Higgs combination results

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Signal Strength

$H \rightarrow WW \rightarrow l^+ l^- \nu \bar{\nu}$

$\Delta s = 7$ TeV

$-2 \ln \lambda(\mu) < 1$ 

$Ldt = 4.7 \text{ fb}^{-1}$

$m_H [\text{GeV}]$

$m_H [\text{GeV}]$
$m_T$ distribution for 2 jet analysis

ATLAS Preliminary

\( \sqrt{s} = 7 \text{ TeV}, \int L \, dt = 4.7 \text{ fb}^{-1} \)

\( H \rightarrow WW^{(*)} \rightarrow l^+l^-\nu\bar{\nu} + \geq 2 \text{ jets} \)
Compare to 2 fb\(^{-1}\) results

**Exclusion regions:**

- **Expected:** 127 GeV < \(m_H\) < 234 GeV
- **Observed:** 130 GeV < \(m_H\) < 260 GeV

- **Expected:** 134 GeV < \(m_H\) < 200 GeV
- **Observed:** 145 GeV < \(m_H\) < 206 GeV
Changes since 2 fb$^{-1}$ publication

**Analysis changes**: 

Extend analysis up to $M_H = 600$ GeV (does not affect low $M_H$ limits)

Add VBF channel – Improves expected limit (a few GeV at low $M_H$ and 10 GeV at high $M_H$)

Fit $M_T$ shape in limit extraction – Improves limit by 10 – 20%

**Analysis changes**: 

Improved background determination:

$W\gamma^*$ - Studies to better understand contribution

DY – Study different methods for extrapolating from Z peak

**Conditions changes**: 

Increased Pileup
Increase trigger thresholds
Top control region

**ATLAS** Preliminary

\( \sqrt{s} = 7 \text{ TeV}, \int L \, dt = 4.7 \text{ fb}^{-1} \)

H→WW\(^\ast\)→l⁺l⁻νlν + 1 jet

\[ m_T [\text{GeV}] \]

Events / 10 GeV

\[ m_T [\text{GeV}] \]

Events / 10 GeV

**ATLAS** Preliminary

\( \sqrt{s} = 7 \text{ TeV}, \int L \, dt = 4.7 \text{ fb}^{-1} \)

H→WW\(^\ast\)→l⁺l⁻νlν + 2 jets

\[ m_T [\text{GeV}] \]

Events / 10 GeV

\[ m_T [\text{GeV}] \]

Events / 10 GeV
**ATLAS Preliminary**

\[ \sqrt{s} = 7 \text{ TeV}, \int L \, dt = 4.7 \text{ fb}^{-1} \]

- Data
- SM (sys $\oplus$ stat)
- WW
- $WZ/ZZ/W_\gamma$
- Single Top
- $W$+jets
- $Z$+jets
- $H$ [125 GeV]

**Events / 10 GeV**

- **Left Panel:** $H \rightarrow WW^{(*)} \rightarrow l^+l^-\nu\bar{\nu}$ + 0 jets
- **Right Panel:** $H \rightarrow WW^{(*)} \rightarrow l^+l^-\nu\bar{\nu}$ + 1 jet

**WW control region**
Jet multiplicity

- VBF analysis in 2 jet bin to remove top background

- While the VBF channel cannot exclude the Higgs alone, it does contribute to the combined limit
Missing Energy Distributions

Missing Energy distributions for the eμ (top right), ee (bottom left), μμ (bottom right) channels. The cut removes a majority of Z+jets events.

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H→WW→l⁺νl⁻ν

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Other Backgrounds

WZ + ZZ – Small backgrounds. Estimate from Simulation

Single Top – Included in the Top background. Differences in b-jet kinematics shown to be negligible

Wγ* - Important at low mass. Background estimate currently from Monte Carlo. Data driven methods are being developed.
Full combined limit plot

ATLAS Preliminary

2011 Data

\[ \int L dt = 4.6-4.9 \text{ fb}^{-1} \]

\[ \sqrt{s} = 7 \text{ TeV} \]

95% CL Limit on \( \sigma/\sigma_{SM} \)

LEP exclusion

ATLAS exclusion

\( m_H \) [GeV]

\( CL_s \) Limits

Obs.

Exp.

\( \pm 1 \sigma \)

\( \pm 2 \sigma \)