Search for a heavy gauge boson decaying to a charged lepton and a neutrino in 1 fb$^{-1}$ of $pp$ collisions at $\sqrt{s} = 7$ TeV using the ATLAS detector

ATLAS Collaboration

1. Introduction

The high-energy collisions at the CERN Large Hadron Collider provide new opportunities to search for physics beyond the Standard Model (SM) of strong and electroweak interactions. One extension common to many models is the existence of additional heavy gauge bosons, the charged ones commonly denoted $W'$. Such particles are most easily searched for in their decay to a charged lepton (electron or muon) and a neutrino.

This Letter describes such a search performed using 7 TeV $pp$ collision data collected with the ATLAS detector during 2011 and corresponding to a total integrated luminosity of 1.04 fb$^{-1}$. The significant improvement over the previous ATLAS result comes mostly from the increase in available luminosity, but also reflects optimization of the event selection and increased acceptance in the muon channel. A lower total background in the electron channel and a negligible fraction of events misidentified as an electron, are estimated to be at most 10% of the total background after event selection. Other strong-interaction background sources, where a light or heavy hadron decays semileptonically or a jet is misidentified as an electron, are estimated to be at most 10% of the total background after event selection. Other strong-interaction background sources, where a light or heavy hadron decays semileptonically or a jet is misidentified as an electron, are estimated to be at most 10% of the total background after event selection. Other strong-interaction background sources, where a light or heavy hadron decays semileptonically or a jet is misidentified as an electron, are estimated to be at most 10% of the total background after event selection.

2. Data

The ATLAS detector [6] has three major components: the inner tracking detector, the calorimeter and the muon spectrometer. Charged particle tracks and vertices are reconstructed with silicon pixel and silicon strip detectors covering $|\eta| < 2.5$ and transition radiation detectors covering $|\eta| < 2.0$, all immersed in a homogeneous 2 T magnetic field provided by a superconducting solenoid. This tracking detector is surrounded by a finely-segmented, hermetic calorimeter system that covers $|\eta| < 4.9$ and
provides three-dimensional reconstruction of particle showers. It uses liquid argon for the inner, electromagnetic compartment followed by a hadronic compartment based on scintillating tiles in the central region \((|\eta| < 1.7)\) and additional liquid argon for higher \(|\eta|\). Outside the calorimeter, there is a muon spectrometer with air-core toroids providing a magnetic field, whose integral averages about 3 Tm. The deflection of the muons in the magnetic field is measured with three layers of precision drift-tube chambers for \(|\eta| < 2.0\) and one layer of cathode-strip chambers followed by two layers of drift-tube chambers for \(2.0 < |\eta| < 2.7\). Additional resistive-plate and thin-gap chambers provide muon triggering capability and measurement of the \(\phi\) coordinate.

The data used in the electron channel are the events recorded with a trigger requiring the presence of an electron with \(p_T > 20\) GeV. The efficiency of this trigger is 98%. For the muon channel, matching tracks in the muon spectrometer and inner detector with combined \(p_T > 22\) GeV are used to identify events. Events are also recorded if a muon with \(p_T > 40\) GeV is found in the muon spectrometer. The muon trigger efficiency is 80–90% in the regions of interest.

Each energy cluster reconstructed in the electromagnetic compartment of the calorimeter with \(E_T > 25\) GeV and \(|\eta| < 1.37\) or \(1.52 < |\eta| < 2.47\) is considered as an electron candidate if it matches with an inner detector track. The electron direction is defined as that of the reconstructed track and its energy as that of the cluster, with a small (less than 2%) \(\eta\)-dependent energy scale correction. The resolution of the energy measurement is 2% for \(E_T \approx 50\) GeV and approaches 1% in the high-\(E_T\) range relevant to this analysis. To discriminate against hadronic jets, requirements are imposed on the lateral shower shapes in the first two layers of the electromagnetic part of the calorimeter and the fraction of energy leaking into the hadronic compartment. A hit in the first pixel layer is required to reduce background from photon conversions in the inner detector material. These requirements give about 90% identification efficiency for electrons with \(E_T > 25\) GeV and a \(2 \times 10^{-4}\) probability to falsely identify jets as electrons before isolation requirements are imposed.

Muon tracks can be reconstructed independently in both the inner detector and muon spectrometer, and the muons used in this study are required to have matching tracks in both systems. The muons are required to have \(p_T > 25\) GeV, where the momentum of the muon is obtained by combining the inner detector and muon spectrometer measurements. To ensure precise measurement of the momentum, muons are required to have hits in all three muon layers and are restricted to those \(\eta\)-ranges where the muon spectrometer alignment is best understood: approximately \(|\eta| < 1.0\) and \(1.3 < |\eta| < 2.0\). The average momentum resolution is currently about 15% at \(p_T = 1\) TeV. About 80% of the muons in these \(\eta\)-ranges are reconstructed, with most of the loss coming from regions with limited detector coverage.

The missing \(E_T\) in the electron channel is obtained from a vector sum over calorimeter cells associated with topological clusters and using local hadronic calibration [8]:

\[
E_T^{\text{miss}} = E_T^{\text{miss, calo}} = - \sum_{\text{topo}} E_{\text{cell}}.
\]

The topological clusters reduce contributions from electronic noise. The \(E_T\) of cells associated with the electron is corrected so their sum equals the electron \(E_T\). Muons only deposit a small fraction of their energy in the calorimeter, and so, in the muon channel, the missing \(E_T\) is obtained from

\[
E_T^{\text{miss}} = E_T^{\text{miss, calo}} - p_T + E_T^{\text{muon, loss}}.
\]

The second term in this vector sum subtracts the muon transverse momentum and the last corrects for the transverse component of the energy deposited in the calorimeter by the muon, which is included in both of the first two terms. The energy loss is estimated by integrating the amount of material traversed and applying a calibrated conversion from path length to energy for each material type.

This analysis makes use of all the \(\sqrt{s} = 7\) TeV data collected in March–June 2011 that satisfy data quality requirements which guarantee the relevant detector systems were operating properly. The integrated luminosity for the data used in this study is 1.04 fb\(^{-1}\) in both the electron and muon decay channels. The uncertainty on this estimate is 3.7%.

### 3. Simulation

Except for the QCD background, which is estimated from data, expected signal and background levels are evaluated with simulated samples and normalized using calculated cross sections and the integrated luminosity of the data.

The \(W'\) signal and the \(W/Z\) boson backgrounds are generated with Pythia 6.421 [9] using MRST LO* [10] parton distribution functions (PDFs). The \(t\bar{t}\) background is generated with MC@NLO 3.41 [11]. For all samples, final-state photon radiation is handled by Photos [12]. ATLAS full detector simulation [13] based on GEANT4 [14] is used to propagate the particles and account for the response of the detector.

The Pythia signal model for \(W'\) has \(V-A\) SM couplings but does not include interference between \(W\) and \(W'\). Decays to channels other than \(e\nu\) and \(\mu\nu\), including \(\tau\nu\), \(ud\), \(sc\) and \(t\bar{b}\) are included in the calculation of the \(W'\) widths but are not explicitly included as signal or background. At high mass (\(m_{W'} > 1\) TeV), the branching fraction to any of the lepton decay channels is 8.2%.

The \(W \rightarrow e\nu\) events are reweighted to have the NNLO (next-to-next-to-leading-order QCD) mass dependence of ZWPROD [15] with MSTW2008 PDFs [16] and following the \(G_{HH}\) scheme [17]. Higher-order electroweak corrections (in addition to the photon radiation included in the simulation) are calculated using HO-OCT [17,18]. In the high-mass region of interest, the electroweak corrections reduce the cross sections by 11% at \(m_{W'} = 1\) TeV and by 18% at \(m_{W'} = 2\) TeV.

The \(W \rightarrow \ell\nu\) and \(Z \rightarrow \ell\ell\) cross sections are calculated at NNLO using FEWZ [19,20] with the same PDFs, scheme and electroweak corrections used in the ZWPROD event reweighting. The \(W' \rightarrow \ell\nu\) cross sections are calculated in the same way, except the electroweak corrections beyond final-state radiation are not included because the calculation for the SM \(W\) cannot be applied directly. The \(t\bar{t}\) cross section is calculated at approximate-NNLO [21–23] assuming a top-quark mass of 172.5 GeV. The signal and most important background values for \(s = b\) are listed in Table 1.

Cross-section uncertainties for \(W' \rightarrow \ell\nu\) and \(W/Z\) [7] and \(t\bar{t}\) [24] backgrounds are estimated from the MSTW2008 PDF error sets, the difference between MSTW2008 and CTEQ6.6 [25] PDF sets, and variation of renormalization and factorization scales by a factor of two. The estimates from the three sources are combined in quadrature. Most of the net uncertainty comes from the error sets and the MSTW–CTEQ difference, in roughly equal proportion. The uncertainty on the cross section for the \(W \rightarrow e\nu\) background varies from 5% at \(m_{e\nu} = 500\) GeV to 19% at \(m_{e\nu} = 2500\) GeV.

### 4. Event selection

Events are required to have their primary vertex reconstructed from at least three tracks with \(p_T > 0.4\) GeV and longitudinal distance less than 200 mm from the center of the collision region. Due to the high luminosity, there were typically five additional interactions per event and the primary vertex is defined to be the
Table 1
Calculated values of $\sigma B$ for $W' \to \ell\ell$ and the leading backgrounds. The value for $t\bar{t} \to t\bar{t}X$ includes all final states with at least one lepton ($e, \mu$ or $\tau$). The others are exclusive and are used for both $\ell = e$ and $\ell = \mu$. All calculations are NNLO except $t\bar{t}$ which is approximate-NNLO.

<table>
<thead>
<tr>
<th>Process</th>
<th>Mass [GeV]</th>
<th>$\sigma B$ [pb]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W \to \ell\nu$</td>
<td>500</td>
<td>17.25</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>8.27</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>3.20</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>0.837</td>
</tr>
<tr>
<td></td>
<td>1250</td>
<td>0.261</td>
</tr>
<tr>
<td></td>
<td>1500</td>
<td>0.0887</td>
</tr>
<tr>
<td></td>
<td>1750</td>
<td>0.0325</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>0.0126</td>
</tr>
<tr>
<td></td>
<td>2250</td>
<td>0.00526</td>
</tr>
<tr>
<td></td>
<td>2500</td>
<td>0.00234</td>
</tr>
<tr>
<td>$Z/\gamma \to t\bar{t}$ ($(m_{Z/\gamma} &gt; 60$ GeV))</td>
<td></td>
<td>10.460</td>
</tr>
<tr>
<td>$\tilde{t}\tilde{t} \to tX$</td>
<td></td>
<td>989</td>
</tr>
</tbody>
</table>

Table 2
Expected numbers of events in 1.04 fb$^{-1}$ from the various background sources in each decay channel for $m_T > 891$ GeV, the region used to search for a $W'$ with a mass of 1500 GeV. The $W \to \ell\nu$ and $Z \to \ell\ell$ entries include the expected contributions from the $r$-lepton. No muon events are found in the $t\bar{t}$ sample above this $m_T$ threshold. The uncertainties are statistical.

<table>
<thead>
<tr>
<th>Process</th>
<th>$\ell\nu$</th>
<th>$\mu\nu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W \to \ell\nu$</td>
<td>1.59 ± 0.13</td>
<td>1.36 ± 0.13</td>
</tr>
<tr>
<td>$Z \to \ell\ell$</td>
<td>0.00010 ± 0.00004</td>
<td>0.095 ± 0.005</td>
</tr>
<tr>
<td>diboson</td>
<td>0.08 ± 0.08</td>
<td>0.11 ± 0.08</td>
</tr>
<tr>
<td>$t\bar{t}$</td>
<td>0.0 ± 0.08</td>
<td>0</td>
</tr>
<tr>
<td>QCD</td>
<td>0.01 ± 0.02</td>
<td>0.01 ± 0.01</td>
</tr>
<tr>
<td>Total</td>
<td>1.75 ± 0.24</td>
<td>1.57 ± 0.15</td>
</tr>
</tbody>
</table>

The same reconstruction and event selection are applied to both data and simulated samples. Fig. 1 shows the $p_T$, missing $E_T$, and $m_T$ spectra for each channel after event selection for the data, for the expected background, and for three examples of $W'$ signals at different masses. The agreement between the data and expected background is good. Table 2 shows as an example how different sources contribute to the background for $m_T > 891$ GeV, the region used to search for a $W'$ with a mass of 1500 GeV. The $W \to \ell\nu$ background dominates. The $Z \to \ell\ell$ background is much larger in the muon channel because most of the energy of the undetected muon is not captured in the calorimeter.

5. Statistical analysis
A Bayesian analysis is performed to determine if there is significant evidence for existence of a $W' \to \ell\ell$ signal above the SM background and to set limits on that process. For each candidate mass and decay channel, events are counted above an $m_T$ threshold, $m_T > m_T^{\text{min}}$, with the threshold chosen to maximize sensitivity. The expected number of events in each channel is

$$N_{\text{exp}} = \varepsilon_{\text{sig}} L \sigma_{\text{B}} B + N_{\text{bg}}.$$  

where $L \sigma_{\text{B}} B$ is the integrated luminosity of the data sample and $\varepsilon_{\text{sig}}$ is the event selection efficiency, i.e. the fraction of events that pass event selection criteria and have $m_T$ above threshold. $N_{\text{bg}}$ is the expected number of background events. Using Poisson statistics, the likelihood to observe $N_{\text{obs}}$ events is

$$L(N_{\text{obs}} | \sigma B) = \frac{(L \sigma_{\text{B}} B + N_{\text{bg}})^{N_{\text{obs}}}}{N_{\text{obs}}!} e^{-(L \sigma_{\text{B}} B + N_{\text{bg}})}.$$  

Uncertainties are handled by introducing Gaussian nuisance parameters $\theta_i$, each with a probability density function (pdf) $g_i(\theta_i)$, and integrating the product of the Poisson likelihood with the pdfs. The integrated likelihood is

$$L_\theta (N_{\text{obs}} | \sigma B) = \int L(N_{\text{obs}} | \sigma B) \prod_i g_i(\theta_i) d\theta_i.$$  

The nuisance parameters are taken to be the explicit dependencies: $L_{\text{int}}$, $\varepsilon_{\text{sig}}$, and $N_{\text{bg}}$, with the latter evaluated at the central value of $L_{\text{int}}$. Correlations between the nuisance parameters are neglected. This is justified by the small effect that the nuisance parameters themselves have on the limits, as demonstrated below.

The measurements in the two decay channels are combined assuming the same branching fraction for each. Eq. (6) remains valid with the Poisson likelihood replaced by the product of the Poisson likelihoods for the two channels. The electron and muon integrated luminosities are fully correlated. The selection efficiencies are uncorrelated and the background levels are partly correlated, including only the full correlation between the cross section uncertainties in the two channels. The effect of this correlation is small: if it is not included, the observed $\sigma B$ limits for
the lowest mass points improve by 2% and those for the high-mass points are unchanged.

Bayes theorem gives the posterior probability that the $W' \rightarrow \ell \nu$ has signal strength $\sigma_B$:

$$P_{\text{post}}(\sigma_B|N_{\text{obs}}) = N L_B(N_{\text{obs}}|\sigma_B) P_{\text{prior}}(\sigma_B)$$

(7)

where $P_{\text{prior}}(\sigma_B)$ is the assumed prior probability, here chosen to be one (i.e. flat in $\sigma_B$) for $\sigma_B > 0$. The constant factor $N$ normalizes the total probability to one. The posterior probability is evaluated for each mass and each decay channel and their combination, and then used to assess discovery significance and set a limit on $\sigma_B$.

6. Parameter estimation and systematics

The inputs for the evaluation of $L_B$ (and hence $P_{\text{post}}$) are $L_{\text{int}}$, $\varepsilon_{\text{sig}}$, $N_{\text{bg}}$, $N_{\text{obs}}$ and the uncertainties on the first three. Except for $L_{\text{int}}$ and its uncertainty, these inputs are all listed in Table 3. The uncertainties on $\varepsilon_{\text{sig}}$ and $N_{\text{bg}}$ account for simulation statistics and all relevant experimental and theoretical effects except for the uncertainty on the integrated luminosity. The latter is included separately to allow for the correlation between signal and background. The table also lists the predicted numbers of signal events, $N_{\text{sig}}$, with their uncertainties accounting for the uncertainties in both $\varepsilon_{\text{sig}}$ and the cross-section calculation.
The maximum value for the signal selection efficiency is at \( m_W' = 1500 \text{ GeV} \). For lower masses, the efficiency falls because the relative \( m_T \) threshold, \( m_T/\sqrt{s} \), increases to reduce the background level. For higher masses, the efficiency falls because a large fraction of the cross section goes to off-shell production with \( m_\ell \ll m_W' \).

The fraction of fully simulated signal events that pass the event selection and are above the \( m_T \) threshold provides the initial estimate of \( \varepsilon_{\text{sig}} \) for each mass. Small corrections are made to account for the difference in acceptance at NNLO (obtained from FEWZ) and that in the LO simulation. These vary from a 7% increase for \( m_W' = 500 \text{ GeV} \) to a 10% decrease for \( m_W' = 2500 \text{ GeV} \). Contributions from \( W' \rightarrow \tau \ell \) with the \( \tau \)-lepton decaying leptonically have been neglected and would increase the \( W' \) event selection efficiencies by \( 3-4\% \) for the highest masses. The background level is estimated for each mass by summing the EW and \( \tau \ell \) event counts from simulation, and adding the small QCD contribution in the electron channel.

The experimental systematic uncertainties include efficiencies for the electron or muon trigger, reconstruction and selection. Lepton momentum and missing \( E_T \) response, characterized by scale and resolution, are also included. Most of these performance metrics are measured at relatively low \( p_T \) and their values are extrapolated to the high-\( p_T \) regime relevant to this analysis. The uncertainties in these extrapolations are included but are too small to significantly affect the results. The uncertainty on the QCD background estimate also contributes to the background level uncertainties for the electron channel. In some cases, e.g. the missing \( E_T \) scale and the muon QCD background, the experimental systematic uncertainties are significantly reduced from the previous study [4] because the additional available data allow more precise determination. In other cases they are similar or even larger, but have little effect on the final results.

### Table 3

Inputs for the \( W' \rightarrow e\nu \) and \( W' \rightarrow \mu\nu \) \( \sigma \beta \) limit calculations. The first three columns are the \( W' \) mass, \( m_T \) threshold and decay channel. The next two are the signal selection efficiency, \( \varepsilon_{\text{sig}} \), and the prediction for the number of signal events, \( N_{\text{sig}} \), obtained with this efficiency. The last two columns are the expected number of background events, \( N_{\text{bg}} \), and the number of events observed in data, \( N_{\text{obs}} \). The uncertainties on \( N_{\text{sig}} \) and \( N_{\text{bg}} \) include contributions from the uncertainties on the cross sections but not from that on the integrated luminosity.

<table>
<thead>
<tr>
<th>( m_W' ) [GeV]</th>
<th>( m_{T_{\text{min}}} ) [GeV]</th>
<th>( \varepsilon_{\text{sig}} )</th>
<th>( N_{\text{sig}} )</th>
<th>( N_{\text{bg}} )</th>
<th>( N_{\text{obs}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>398</td>
<td>0.388 ± 0.019</td>
<td>6930 ± 620</td>
<td>101.9 ± 10.8</td>
<td>121</td>
</tr>
<tr>
<td>600</td>
<td>447</td>
<td>0.456 ± 0.022</td>
<td>3910 ± 330</td>
<td>62.1 ± 7.1</td>
<td>69</td>
</tr>
<tr>
<td>750</td>
<td>562</td>
<td>0.429 ± 0.020</td>
<td>1420 ± 110</td>
<td>20.7 ± 3.7</td>
<td>20</td>
</tr>
<tr>
<td>1000</td>
<td>708</td>
<td>0.482 ± 0.022</td>
<td>417 ± 35</td>
<td>6.13 ± 0.92</td>
<td>4</td>
</tr>
<tr>
<td>1250</td>
<td>794</td>
<td>0.527 ± 0.024</td>
<td>143 ± 14</td>
<td>3.09 ± 0.49</td>
<td>3</td>
</tr>
<tr>
<td>1500</td>
<td>891</td>
<td>0.541 ± 0.026</td>
<td>49.6 ± 6.0</td>
<td>1.75 ± 0.32</td>
<td>2</td>
</tr>
<tr>
<td>1750</td>
<td>1000</td>
<td>0.515 ± 0.024</td>
<td>17.3 ± 2.4</td>
<td>0.89 ± 0.20</td>
<td>1</td>
</tr>
<tr>
<td>2000</td>
<td>1122</td>
<td>0.472 ± 0.023</td>
<td>6.16 ± 0.99</td>
<td>0.48 ± 0.10</td>
<td>1</td>
</tr>
<tr>
<td>2250</td>
<td>1122</td>
<td>0.415 ± 0.019</td>
<td>2.84 ± 0.50</td>
<td>0.48 ± 0.10</td>
<td>1</td>
</tr>
<tr>
<td>2500</td>
<td>1122</td>
<td>0.333 ± 0.018</td>
<td>0.81 ± 0.16</td>
<td>0.48 ± 0.10</td>
<td>1</td>
</tr>
</tbody>
</table>

### Table 4

Relative uncertainties on the event selection efficiency and background level for a \( W' \) with a mass of 1500 GeV. The efficiency uncertainties include contributions from trigger, reconstruction and event selection. The cross section uncertainty for \( \varepsilon_{\text{sig}} \) is that assigned to the acceptance correction described in the text. The last row gives the total uncertainties.

<table>
<thead>
<tr>
<th>Source</th>
<th>( \varepsilon_{\text{sig}} )</th>
<th>( N_{\text{bg}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Energy/momentum resolution</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>Energy/momentum scale</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>QCD background</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Monte Carlo statistics</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Cross section (shape/level)</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Table 4 summarizes the uncertainties on the event selection efficiencies and background levels for the \( W' \rightarrow e\nu \) signal with \( m_W' = 1500 \text{ GeV} \) using \( m_T > 891 \text{ GeV} \).

### 7. Results

None of the observations for any mass in either channel or their combination has a significance above three-sigma, so there is no evidence for the observation of \( W' \rightarrow e\nu \). Table 5 and Fig. 2 present the 95% CL (confidence level) observed limits on \( \sigma \beta \) for both \( W' \rightarrow e\nu \) decay channels and their combination. The figure also shows the expected limits and the theoretical \( \sigma \beta \) for an SSM \( W' \). The intersection between the central theoretical prediction and the observed limits provides the 95% CL lower limit on the mass. Table 6 presents the expected and observed \( W' \) mass limits for the electron and muon decay channels and for the combination of the two channels. The observed combined mass limit is 2.15 TeV.
Channels. The NNLO calculated cross section and its uncertainty are also shown.

The above results are obtained using a prior probability flat in $\sigma B$. If this prior is replaced by one flat in coupling strength, the $\sigma B$ limits improve by 20–28% for $m_{W'} > 1000$ GeV and by smaller amounts at the lower masses. The reference prior [28,29], which minimizes the information supplied by the prior, gives intermediate results. Limits evaluated with $\text{CL}_s$ [30] for the electron and

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
$m_{W'}$ [GeV] & 95% CL limit on $\sigma B$ [fb] & none & S & SB & SBL \\
\hline
500 & $e\nu$ & 97 & 98 & 117 & 121 \\
& $\mu\nu$ & 171 & 174 & 186 & 191 \\
& both & 109 & 110 & 127 & 130 \\
600 & $e\nu$ & 49 & 49 & 59 & 61 \\
& $\mu\nu$ & 99 & 100 & 108 & 110 \\
& both & 55 & 55 & 64 & 65 \\
750 & $e\nu$ & 23.0 & 23.1 & 28.1 & 28.5 \\
& $\mu\nu$ & 49.2 & 49.8 & 50.9 & 51.7 \\
& both & 23.7 & 23.8 & 27.8 & 28.1 \\
1000 & $e\nu$ & 10.1 & 10.2 & 10.5 & 10.6 \\
& $\mu\nu$ & 16.1 & 16.3 & 16.5 & 16.7 \\
& both & 7.3 & 7.3 & 7.6 & 7.7 \\
1250 & $e\nu$ & 9.8 & 9.9 & 10.0 & 10.1 \\
& $\mu\nu$ & 14.4 & 14.5 & 14.6 & 14.7 \\
& both & 7.3 & 7.3 & 7.4 & 7.5 \\
1500 & $e\nu$ & 8.8 & 8.9 & 9.0 & 9.0 \\
& $\mu\nu$ & 13.0 & 13.2 & 13.2 & 13.3 \\
& both & 6.6 & 6.6 & 6.7 & 6.7 \\
1750 & $e\nu$ & 7.8 & 7.9 & 7.9 & 7.9 \\
& $\mu\nu$ & 12.0 & 12.1 & 12.1 & 12.2 \\
& both & 5.6 & 5.6 & 5.7 & 5.7 \\
2000 & $e\nu$ & 8.9 & 9.0 & 9.0 & 9.1 \\
& $\mu\nu$ & 13.2 & 13.3 & 13.3 & 13.4 \\
& both & 6.6 & 6.7 & 6.7 & 6.7 \\
2250 & $e\nu$ & 10.2 & 10.2 & 10.3 & 10.3 \\
& $\mu\nu$ & 14.8 & 14.9 & 14.9 & 15.0 \\
& both & 7.5 & 7.5 & 7.6 & 7.6 \\
2500 & $e\nu$ & 12.7 & 12.8 & 12.8 & 12.9 \\
& $\mu\nu$ & 19.2 & 19.5 & 19.6 & 19.7 \\
& both & 9.5 & 9.6 & 9.6 & 9.6 \\
\hline
\end{tabular}
\caption{Upper limits on $\sigma B$ for $W' \to e\nu$. The first two columns are the decay and channel and the following columns are the 95% CL limits with headers indicating the nuisance parameters for which uncertainties are included: $S$ for the event selection efficiency ($e_{\text{sel}}$), $B$ for the background level ($N_{\text{bgd}}$), and $L$ for the integrated luminosity ($L_{\text{int}}$). Columns labeled SBL include all uncertainties and are used to evaluate mass limits. Results are given for the electron and muon channels and including all uncertainties are nearly identical to the corresponding values in Table 5.}
\end{table}

Prior to this Letter, the best limits for $500 < m_{W'} < 800$ GeV were established by CDF [2] in $W' \to e\nu$ with $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV using an integrated luminosity of 5.3 fb$^{-1}$. At higher masses, the best limits were set by CMS [3] and ATLAS [4], each combining electron and muon channels and using $p\bar{p}$ collisions at $\sqrt{s} = 7$ TeV with 36 pb$^{-1}$ of data acquired in 2010. The CDF and CMS limits were obtained with a Bayesian approach, and the earlier ATLAS results were established with CLs. Fig. 3 compares the limits obtained here with those earlier measurements. The comparison is made using the ratio of the limit to the calculated value of $\sigma B$, a quantity that is proportional to the square of the coupling strength. The NNLO cross sections in Table 1 are used

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
$m_{W'}$ [TeV] & Exp. & Obs. \\
\hline
$e\nu$ & 2.17 & 2.08 \\
$\mu\nu$ & 2.08 & 1.98 \\
both & 2.23 & 2.15 \\
\hline
\end{tabular}
\caption{Lower limits at 95% CL on the SSM $W'$ mass. The first column is the decay channel ($e\nu$, $\mu\nu$ or both combined) and the following columns give the expected (Exp.) and observed (Obs.) mass limits.}
\end{table}
for both the ATLAS and CMS points. The limits presented here provide significant improvement for masses above 600 GeV.

8. Conclusions

The ATLAS detector has been used to search for new high-mass states decaying to a lepton plus missing \( E_T \). The search is performed in pp collisions at \( \sqrt{s} = 7 \text{ TeV} \) using \( 1.04 \text{ fb}^{-1} \) of integrated luminosity. No excess above SM expectations is observed. Bayesian limits on \( \sigma B \) are shown in Figs. 2 and 3. These are the best published limits for \( m_{W'} > 600 \text{ GeV} \). A \( W' \) with SM couplings is excluded for masses up to 2.15 TeV at the 95% CL.

Acknowledgements

We thank CERN for the very successful operation of the LHC, as well as the support staff from our institutions without whom ATLAS could not have been operated efficiently.

We acknowledge the support of ANPCyT, Argentina; YerPhI, Armenia; ARC, Australia; BMWF, Austria; ANAS, Azerbaijan; SSTC, Belarus; CNPq and FAPESP, Brazil; NSERC, NRC and CFI, Canada; CERN; CONICYT, Chile; CAS, MOST and NSFC, China; COLCIENCIAS, Colombia; MSMT CR, MPO CR and VSC CR, Czech Republic; DLRF, DNNRC and Lundbeck Foundation, Denmark; ARTEMIS, European Union; IN2P3–CNRS, CEA-DSM/IRFU, France; GNSA, Georgia; BMBF, DFG, MPG and AvH Foundation, Germany; GSRT, Greece; ISF, MINERVA, GIF, DIP and Benoziyo Center, Israel; INFN, Italy; MEXT and JSPS, Japan; CNRST, Morocco; FOM and NWO, Netherlands; RCN, Norway; MNiSW, Poland; GRICES and FCT, Portugal; MERSYS (MECTS), Romania; MES of Russia and ROSATOM, Russian Federation; JINR; MSTD, Serbia; MSSR, Slovakia; ARRS and MVZT, Slovenia; DST/NRF, South Africa; MICINN, Spain; SRC and Wallenberg Foundation, Sweden; SER, SNSF and Cantons of Bern and Geneva, Switzerland; NSC, Taiwan; TAEK, Turkey; STFC, the Royal Society and Leverhulme Trust, United Kingdom; DOE and NSF, United States of America.

The crucial computing support from all WLCG partners is acknowledged gratefully, in particular from CERN and the ATLAS Tier-1 facilities at TRIUMF (Canada), NDCG (Denmark, Norway, Sweden), CC-IN2P3 (France), KIT/GridKA (Germany), INFN-CNAF, (Italy), NL-T1 (Netherlands), PIC (Spain), ASGC (Taiwan), RAL (UK) and BNL (USA) and in the Tier-2 facilities worldwide.

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References


ATLAS Collaboration

ABSTRACT

The ATLAS Collaboration presents results from the search for supersymmetry at the LHC. The analysis is based on proton-proton collision data corresponding to an integrated luminosity of 20.3 fb⁻¹ recorded at a center-of-mass energy of 8 TeV by the ATLAS detector. The data were recorded during Run 1 of the LHC operation. The search is performed in a model-independent approach, using multivariate methods and a simplified event simulation designed for the so-called simplified supersymmetry models. The results are interpreted in the context of models of supersymmetry breaking, in which the LSP is a neutralino and the lighter sparticle is a chargino. The results are translated into the 1- and 2-fermion production cross sections in units of fb and are compared to the predictions of the leading-order supersymmetry models. The observed limits on the product of the squark and/or gluino production cross section times the branching fraction to the selected final state are consistent with the standard model predictions. The results are also consistent with the supersymmetry models below the reach of the leading-order models, which is limited by the current values of the parameters in the models. The results are also consistent with the results of the other experiments at the LHC, which are also presented in this issue.


159 (a) TRIUMF, Vancouver, BC; (b) Department of Physics and Astronomy, York University, Toronto, ON, Canada

160 Institute of Pure and Applied Sciences, University of Tsukuba, Ibaraki, Japan

161 Science and Technology Center, Tufts University, Medford, MA, United States

162 Centro de Investigaciones, Universidad Antonio Nariño, Bogota, Colombia

163 Department of Physics and Astronomy, University of California Irvine, Irvine, CA, United States

164 (a) INFN Gruppo Collegato di Udine; (b) ICTP, Trieste; (c) Dipartimento di Fisica, Università di Udine, Udine, Italy

165 Department of Physics, University of Illinois, Urbana, IL, United States

166 Department of Physics and Astronomy, University of Uppsala, Uppsala, Sweden

167 Instituto de Fisica Corpuscular (IFIC) and Departamento de Fisica Atomica, Molecular y Nuclear and Departamento de Ingeniería Electrónica and Instituto de Microelectrónica de Barcelona (IMB-CNM), University of Valencia and CSIC, Valencia, Spain

168 Department of Physics, University of British Columbia, Vancouver, BC, Canada

169 Department of Physics and Astronomy, University of Victoria, Victoria, BC, Canada

170 Waseda University, Tokyo, Japan

171 Department of Particle Physics, The Weizmann Institute of Science, Rehovot, Israel

172 Department of Physics, University of Wisconsin, Madison, WI, United States

173 Fakultät für Physik und Astronomie, Julius-Maximilians-Universität, Würzburg, Germany

174 Fachbereich C Physik, Bergische Universität Wuppertal, Wuppertal, Germany

175 Department of Physics, Yale University, New Haven, CT, United States

176 Yerevan Physics Institute, Yerevan, Armenia

177 Domaine scientifique de la Doua, Centre de Calcul CNRS/IN2P3, Villeurbanne Cedex, France

a Also at Laboratorio de Instrumentacao e Fisica Experimental de Particulas – LIP, Lisboa, Portugal.

b Also at Faculdade de Ciencias and CFNUL, Universidade de Lisboa, Lisboa, Portugal.

c Also at Particle Physics Department, Rutherford Appleton Laboratory, Didcot, United Kingdom.

Also at CPPM, Aix-Marseille Université and CNRS/IN2P3, Marseille, France.

Also at TRIUMF, Vancouver, BC, Canada.

Also at Department of Physics, California State University, Fresno, CA, United States.

Also at Faculty of Physics and Applied Computer Science, AGH – University of Science and Technology, Krakow, Poland.

Also at Fermilab, Batavia, IL, United States.

Also at Department of Physics, University of Coimbra, Coimbra, Portugal.

Also at Università di Napoli Parthenope, Napoli, Italy.

Also at Institute of Particle Physics (IPP), Canada.

Also at Department of Physics, Middle East Technical University, Ankara, Turkey.

Also at Louisiana Tech University, Ruston, LA, United States.

Also at Group of Particle Physics, University of Montpellier, Montpellier, QC, Canada.

Also at Institute of Physics, Azerbaijan Academy of Sciences, Baku, Azerbaijan.

Also at Institut für Experimentalphysik, Universität Hamburg, Hamburg, Germany.

Also at Manhattan College, New York, NY, United States.

Also at School of Physics and Engineering, Sun Yat-sen University, Guangzhou, China.

Also at Academia Sinica Grid Computing, Institute of Physics, Academia Sinica, Taipei, Taiwan.

Also at High Energy Physics Group, Shandong University, Shandong, China.

Also at Section de Physique, Université de Genève, Geneva, Switzerland.

Also at Departamento de Fisica, Universidade de Minho, Braga, Portugal.

Also at Department of Physics and Astronomy, University of South Carolina, Columbia, SC, United States.

Also at KFKI Research Institute for Particle and Nuclear Physics, Budapest, Hungary.

Also at California Institute of Technology, Pasadena, CA, United States.

Also at Institute of Physics, Jagiellonian University, Krakow, Poland.

Also at Department of Physics, Oxford University, Oxford, United Kingdom.

Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.

Also at Department of Physics, The University of Michigan, Ann Arbor, MI, United States.

Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l’Univers), CEA Saclay (Commissariat a l’Energie Atomique), Gif-sur-Yvette, France.

Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.

Also at Department of Physics, Nanjing University, Jiangsu, China.

Also at Department of Physics, Oxford University, Oxford, United Kingdom.

Also at Institute of Physics, Jagiellonian University, Krakow, Poland.

Also at Department of Physics, Oxford University, Oxford, United Kingdom.

Also at Institute of Physics, Academia Sinica, Taipei, Taiwan.

Also at Department of Physics, The University of Michigan, Ann Arbor, MI, United States.

Also at DSM/IRFU (Institut de Recherches sur les Lois Fondamentales de l’Univers), CEA Saclay (Commissariat a l’Energie Atomique), Gif-sur-Yvette, France.

Also at Laboratoire de Physique Nucléaire et de Hautes Energies, UPMC and Université Paris-Diderot and CNRS/IN2P3, Paris, France.

Also at Department of Physics, Nanjing University, Jiangsu, China.

Also at Department of Physics, Nanjing University, Jiangsu, China.

* Deceased.