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W+jets in pp collisions at 7 TeV with ATLAS

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Abstract. Measurements of differential cross-sections of W boson production in association with jets, and jets containing b hadrons are presented. The measurements are based on 35 pb^{-1} of pp collisions at $\sqrt{s} = 7$ TeV collected with the ATLAS detector at the LHC, using the electron and muon decay channels of the W boson. The data are found to be compatible with next-to-leading order predictions. In addition, a study of the invariant mass distribution of jet pairs produced in association with a W boson is presented, based on an integrated luminosity of 1.02 fb^{-1}. The measured dijet mass shows no significant excess over the Standard Model expectation.

Keywords. W bosons; W+jets; dijet mass, b-jets.

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The Large Hadron Collider (LHC), with a centre-of-mass energy of 7 TeV, allows the study of W boson production in association with jets (W+jets), and specifically with jets containing b hadrons (W+b-jets), with a wider kinematic reach and a higher number of jets in the final state than previous experiments. Compared with the Tevatron, the high-energy proton–proton (pp) environment also leads to increased contributions of qg and gg scattering, and to a non-negligible presence of b quarks in the initial state. Differential and inclusive measurements of W+jets and W+b-jets are used to test the validity of NLO calculations in perturbative quantum chromodynamics (pQCD). These calculations are fundamental to identify and measure heavy particles, within and outside the Standard Model (SM), which decay into W+jets and W+b-jets final states (dibosons, $t\bar{t}$, single-top and Higgs among others).

We present measurements of the production cross-sections of W bosons in association with jets and b-jets, performed using data collected during 2010 with the ATLAS detector [1]. The results, described in detail here [2,3], are based on the electron and muon decay channels of the W boson. In addition, we present a study, based on 2011 data and described in detail in [4], of the invariant mass distribution of jet pairs produced in association with a W. This study is motivated by the excess of events observed by the CDF Collaboration in the 120–160 GeV mass range [5,6].

All the results presented here use similar methods for event selection, object reconstruction, and background estimation, as described below (additional details can be found

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in the individual publications [2–4]). Events are selected using a single electron or muon high p_T trigger, requiring a primary vertex (PV) with at least three tracks. Events with a leptonically decaying W boson are selected based on exactly one isolated lepton with $p_T > 20$ GeV, a missing transverse energy satisfying $E_T^{miss} > 25$ GeV, and a transverse mass [6a] $m_T > 40$ GeV.

Jets are reconstructed from calorimeter clusters using the anti-k_T algorithm with radius parameter 0.4. The jet energy is calibrated to account for the differences in calorimeter response to electrons and hadrons by applying p_T- and η-dependent scale factors, derived from simulated events [7]. The SV0 algorithm [8] is used to reconstruct a displaced vertex within each jet, and measure its distance (decay length) from the PV. Candidate b-jets are chosen based on their decay length significance, exploiting the long lifetime of b hadrons ($\sim$1.5 ps). The b, c and light components in the resulting sample are measured with a maximum likelihood fit to m_{SV}, the invariant mass of all tracks associated with the displaced vertex.

The data used for the W+jets and W+b-jets measurements [2,3] correspond to 35 pb^{-1} recorded in 2010. The W+jets differential cross-section, measured as a function of a number of variables including jet multiplicity, jet p_T, jet rapidity, and the sum E_T of all reconstructed objects in the event, is found to be in agreement with NLO pQCD predictions from MCFM [9] and BLACKHAT-SHERPA [10], and with LO calculations from multiparton matrix element generators ALPGEN [11] and SHERPA [12], whereas PYTHIA [13] does not describe the high jet multiplicity measurements well (see [2] for a full comparison of differential distributions between data and Monte Carlo predictions).

The W+b-jets cross-section, measured in the 1, 2, and 1+2 exclusive jet bins, where at least one jet is required to be a b-jet, is shown in figure 1a. The measurements are compared with NLO predictions obtained by combining contributions from the 4-flavour number scheme (4FNS), where b quarks are considered massive, and the 5FNS, where b quarks are assumed massless and are allowed in the initial state [14]. A comparison is

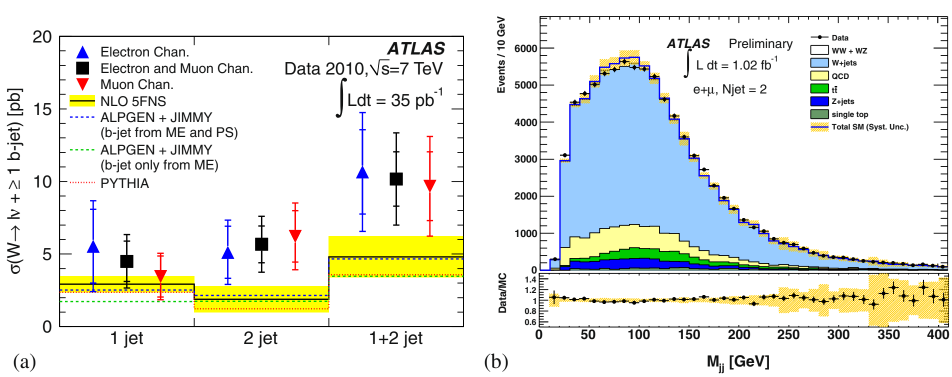

Figure 1. **(a)** Measured fiducial cross-section of W+b-jets with statistical (inner error bar) and statistical plus systematic (outer error bar) uncertainties in the electron, muon, and combined electron plus muon channel [3]. **(b)** Dijet mass distribution for electron and muon events combined, with $N_{jet} = 2$. The data points are plotted (full circles) with their statistical uncertainties. The blue solid line is the total SM prediction and the yellow hatched band indicates the systematic uncertainties [4].

also made with LO predictions from ALPGEN [11] interfaced with HERWIG [15] and JIMMY [16], which are given for b-jets generated only by the matrix element (ME) and by the matrix element and the parton shower (PS). The dominant systematic uncertainties are associated with the b-tagging efficiency and the m_{SV} templates. The cross-sections are measured to be 1.5σ above the NLO prediction.

The CDF Collaboration at the Tevatron has studied the invariant mass distribution of jet pairs produced in association with a W boson, using 7.3 fb^{-1} of $p\bar{p}$ collisions at $\sqrt{s} =$ 1.96 TeV. An excess of events is observed in the 120–160 GeV dijet mass range [5,6]. The D0 Collaboration finds no evidence for such an effect in a 4.3 fb^{-1} data sample [17]. The same final state is produced in pp collisions at the LHC, and ATLAS has examined the dijet mass distribution in a 33 pb^{-1} data sample recorded in 2010 [18]. We present an update of the ATLAS study based on a sample of 1.02 fb^{-1} recorded in 2011 [4], using event selection criteria as close as possible to those used by CDF [18a]. The dijet mass distribution, shown in figure 1b, is compared to a combination of Monte Carlo simulation and data-driven background estimates [18b].

The dijet mass spectrum is analysed to establish the absence or presence of a resonance [21]. Systematic uncertainties are assumed to follow Gaussian distributions, and their nuisance parameters are varied to best describe the data with the background-only hypothesis. The region between 100 and 300 GeV is analysed using both a sliding window (accounting for the look-elsewhere effect) and a fixed window centred at the location of the CDF excess, and no significant excess is observed. However, without making model-dependent assumptions on the possible production mechanism for the reported excess, it is impossible to predict the importance of such a mechanism with respect to diboson and W+jet production at the LHC.

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[18b] ALPGEN [11] interfaced to HERWIG [15] is used for W+jets and Z+jets. MC@NLO [19] interfaced to HERWIG is used to generate $t\bar{t}$ and single top events. Diboson (WW, WZ, ZZ) production is simulated by HERWIG. PYTHIA [13] is used to study dijet background, with fake leptons or leptons from heavy flavour decays, although this contribution is assessed directly from data. The detector simulation is performed using GEANT4 [20]
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