PROCEEDINGS OF SCIENCE

W+jets backgrounds in charged Higgs boson searches with the ATLAS experiment at the LHC

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W+jets events with one lepton in the final state could be an important background for charged Higgs boson searches with the ATLAS experiment (A Toroidal Lhc ApparatuS) [1] [2] at the LHC (Large Hadron Collider). In the $H^+ \rightarrow \tau\nu$ channel for instance, W+jets will contribute to the backgrounds where a light jet fakes a hadronic τ-jet. Below the top quark mass, where the decay $H^+ \rightarrow \tau\nu$ will appear as an excess of tau leptons compared to electrons or muons from Standard Model expectation, the understanding of fake rates of τs from background sources including W+jets will be essential to establish the existence of a viable signal. Data driven methods for the measurement of the W+jets background are needed. We will describe the available methods to estimate this background from data and their relevance to charged Higgs boson searches.

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1. Introduction

The charged Higgs boson is of special interest since its observation would be a definite sign of physics beyond the Standard Model [3]. W+jets events with one or two real and/or fake leptons in the final state could be an important background for charged Higgs boson searches.

2. Motivations

The production of a light charged Higgs boson, below the top quark mass, at the LHC occurs via $gg \to t\bar{t} \to bWbH^+$. For $\tan\beta < 1$ [1], the $BR(H^+ \to c\bar{s})$ may reach 40% for $m_{H^+} \sim 130$ GeV [4] where the main background is $t\bar{t}$ [5]. The identification of τ-jets [6] is very important since the $BR(H^+ \to \tau\nu) \sim 1$ (with the exception of small $\tan\beta$ values) [7] . $H^+ \to \tau\nu$ will give rise to an excess of τ leptons compared to electrons or muons from Standard Model expectation, therefore the understanding of fake τ from background sources including W+jets will be essential to establish the existence of a viable signal. In the $H^+ \to \tau\nu$ channel for instance, W+jets will contribute to the backgrounds where a light jet fakes a hadronic τ-jet.

3. Data taking

Since the start of the LHC collisions at $\sqrt{s} = 7$ TeV, the luminosity has been increasing exponentially as illustrated on Fig. 1. The ATLAS detector is performing remarkably well [8] and a total integrated luminosity of 45 pb^{-1} was recorded. The results shown use just a subset of the full data sample.

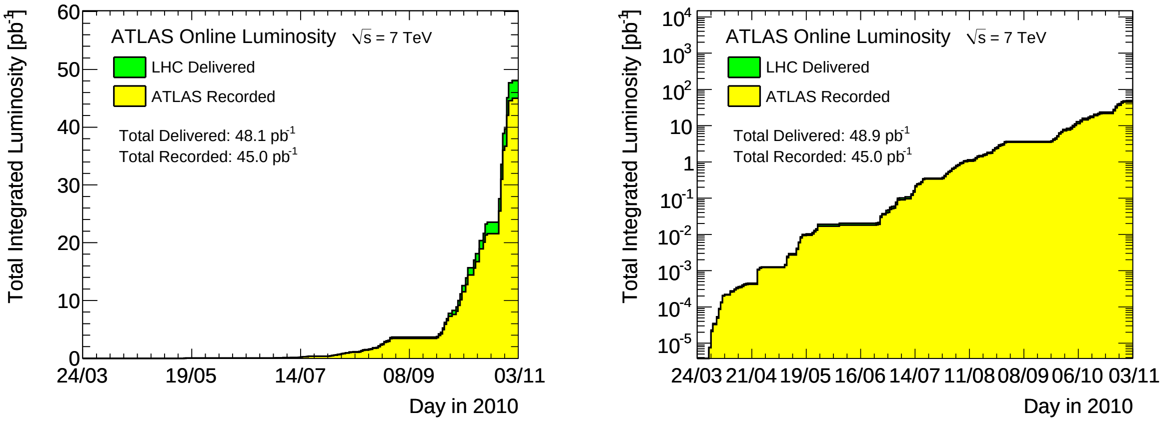

Figure 1: Cumulative luminosity versus day, delivered to (green), and recorded by (yellow), ATLAS during stable beams and for pp collisions at 7 TeV center-of-mass energy [9].

4. Rediscovering the Standard Model : W+jets

With the amount of data collected in 2010 we started to look at the Standard Model processes like jets produced in association with $W \to l\nu$ where $l = e, \mu$. The inclusive jet multiplicity and the

[1] ratio of vacuum expectation values of the two Higgs doublets : $\tan\beta = v2/v1$

leading jet p_T are illustrated on Fig. 2 for the muon channel and Fig. 3 for the electron channel. There is already a good agreement between data and Monte Carlo.

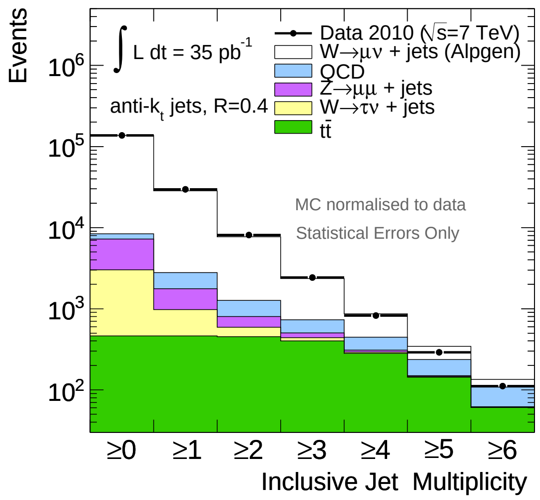

Figure 2: Jet multiplicity for jets produced in association with the $W \rightarrow \mu\nu$ final state (Alpgen [10] is used for the MC signal). The jet algorithm used is Anti-kT with $R = 0.4$ and the jets are selected with $|\eta| < 2.8$ and $p_T > 20$ GeV. The MC is normalized to the inclusive data sample [9].

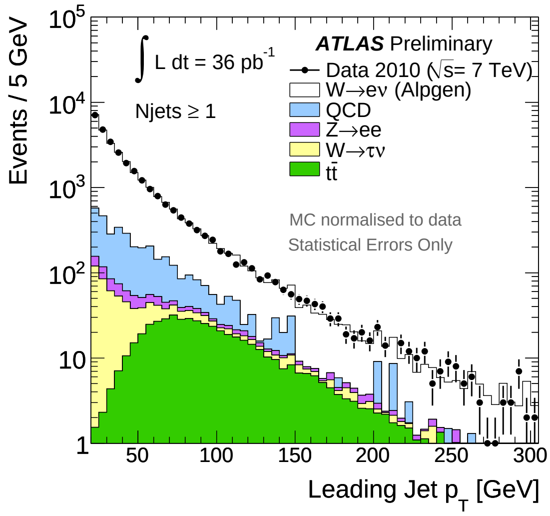

Figure 3: Leading jet p_T for jets produced in association with the $W \rightarrow e\nu$ final state (Alpgen [10] is used for the MC signal). The jet algorithm used is Anti-kT with $R = 0.4$ and the jets are selected with $|\eta| < 2.8$ and $p_T > 20$ GeV. The MC is normalized to the inclusive 1-jet bin in data. [9]

5. W+jets background

Even if we see a good agreement between data and Monte Carlo there is a large uncertainty on Monte Carlo predictions of W+jets events. Especially there are difficulties in accurately simulating events with jets misidentified as leptons (e, μ) or as τ-jets. Hence we need to estimate the W+jets background using data driven methods. We will review the different methods based on both data and Monte Carlo which are used in different analysis : top, Higgs boson searches.

One data driven method [11] estimates the W+jets background by using the W to Z ratio which is predicted with a small uncertainty as illustrated on Fig. 4. The jet multiplicity distribution for Z events can be measured to reduce Monte Carlo uncertainty on the fraction of W+jets. The expected total uncertainties on the W+jets background estimation are respectively 24% (17%) for $W \rightarrow e\ \nu + jets$ ($W \rightarrow \mu\ \nu + jets$) and with 200 pb^{-1} of pseudo data.

Another data driven method [12] [13] estimates the lepton misidentification. The probability of a jet to fake a lepton can be determined from the data. Two different selections are used, a tight selection dominated by real leptons and a loose selection dominated by fakes. The probability of a fake lepton to be reconstructed as a tight lepton is illustrated on Fig. 5. Both the real and fake lepton efficiencies can be measured from the pseudo data and in some independent samples (tag and probe, and samples dominated by fakes). The number of fakes is obtained by inverting a 4×4

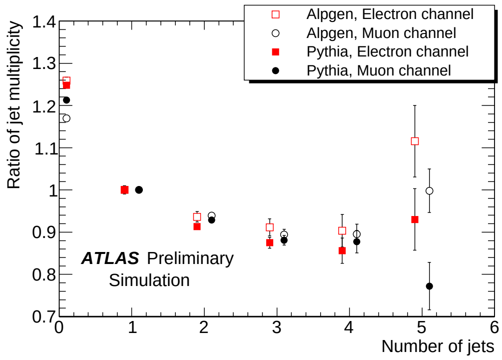

Figure 4: Ratio of reconstructed jet multiplicity for $W \to l\nu + jets$ over $Z \to ll + jets$ events. The ratio is taken after event selection cuts and normalizing the ratio to the 1 jet bin. Statistical errors are shown. Alpgen [10] and Pythia [14] MC are used.

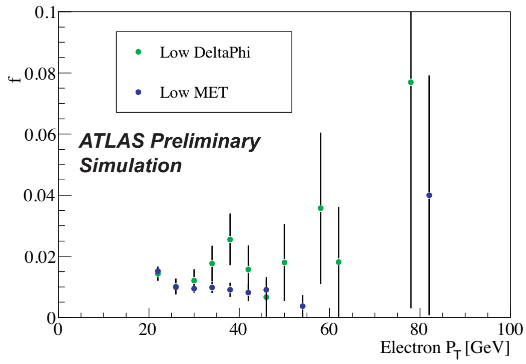

Figure 5: Tight fake probabilities f measured as a function of p_T for electrons in a multijet sample.

matrix as described in [12] [13]. With this method we expected total uncertainties on the fake rates of 50% (100%) for the electron (muons) channel with 200 pb^{-1} of pseudo data.

The previously-described data-driven method [15] was used with the early data for the observation of the background from W+jets to the $H \to WW^* \to l\nu l\nu$ at $\sqrt{s} = 7$ TeV. The goal is the

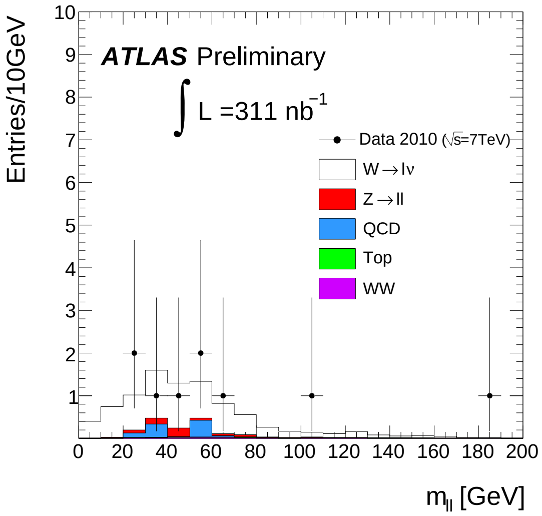

Figure 6: Kinematic distributions of the W+jets candidates relevant to the Higgs boson search after some pre selection cuts. The plot shows the invariant mass of the two lepton candidates.

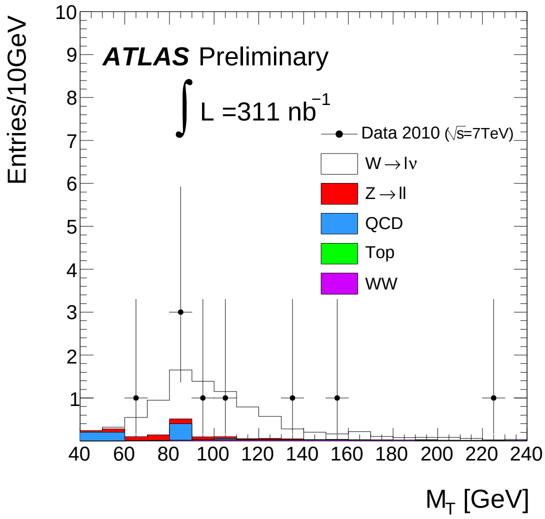

Figure 7: Kinematic distributions of the W+jets candidates relevant to the Higgs boson search after some pre selection cuts. The plot shows the transverse mass.

measurement of $W + jets \to l(good) + l(fake)$ background. Candidate events were selected with a tight and a loose lepton and as an additional cross check we look for the same sign pair. Nine events pass these requirements and are consistent with Monte Carlo expectation. The distributions of the invariant mass of the two leptons candidates and the transverse mass are shown on Fig. 6 and Fig. 7. The fake rate is extracted from data using a dijet data sample dominated by fake lepton and by calculating the ratio between a very loose and a tight lepton selection. The p_T distribution of muons for the loose and tight selection is shown on Fig. 8 and the fake rate is shown on Fig. 9. As can be seen there is a good agreement between data and Monte Carlo. The important point of this method is that the background is taken from data. The fractional difference in the observed fake rate in dijet Monte Carlo and W+jets Monte Carlo is found to be 39% for both electrons and muons which is the main uncertainty.

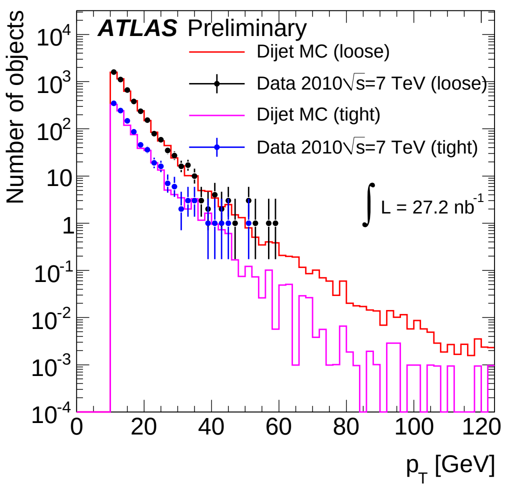

Figure 8: The muon pT distribution. The dijet Monte Carlo is normalised to the number of loose muon objects in data.

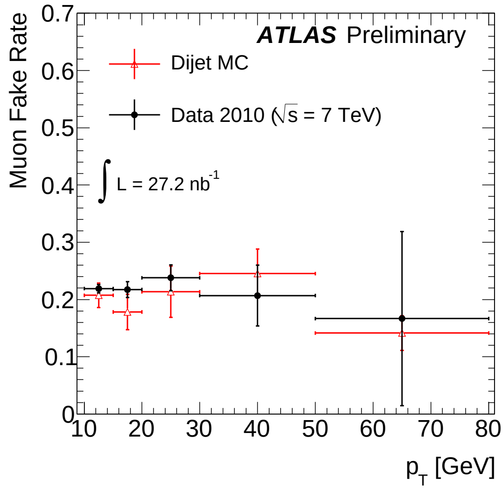

Figure 9: The muon fake rate as a function of pT. The fake rate obtained from data is compared with the fake rate from Monte Carlo.

6. Conclusion and Outlook

The search for charged Higgs bosons is very important since they are a clear signature of physics beyond the Standard Model, with early sensitivity. For these searches, W+jets can be an important background. We presented several methods to estimate the W+jets background with a data driven estimation. With the first 0.3 pb^{-1} at $\sqrt{s} = 7$ TeV, ATLAS published a first W+jets background estimation as well as a lepton fake rate estimation. With the total amount of data accumulated in 2010, new methods are being developed and being used in charged Higgs boson searches.

References

[1] G. Aad et al. (The ATLAS Collaboration), *Detector and Physics Performance Technical Design Report*, CERN-LHCC/99-14/15, Jun, 1999.

[2] G. Aad et al. (The ATLAS Collaboration), *Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics*, [hep-ex/0901.0512].

[3] A. Ferrari, *Search strategies for charged Higgs in ATLAS*, in proceedings of *Third International Workshop on Prospects for Charged Higgs Discovery at Colliders*, `PoS(Charged 2010)010`.

[4] U. Yang, *ATLAS discovey prospects for a light charged Higgs in the* $H^+ \rightarrow c\bar{s}$ *channel*, in proceedings of *Third International Workshop on Prospects for Charged Higgs Discovery at Colliders*, `PoS(Charged 2010)018`.

[5] M. Flechl, $t\bar{t}$ *backgrounds in charged Higgs searches*, in proceedings of *Third International Workshop on Prospects for Charged Higgs Discovery at Colliders*,`PoS(Charged 2010)014`.

[6] Y. Coadou, *Tau trigger and tau reconstruction, efficiency and fake rates in ATLAS*, in proceedings of *Third International Workshop on Prospects for Charged Higgs Discovery at Colliders*, `PoS(Charged 2010)007` .

[7] M. Klemetti, *ATLAS discovery prospects for the charged Higgs in the* $H^+ \rightarrow \tau\nu$ *final state*, in proceedings of *Third International Workshop on Prospects for Charged Higgs Discovery at Colliders*, `PoS(Charged 2010)017`.

[8] D. Orestano, *Status of the ATLAS experiment*, in proceedings of *Third International Workshop on Prospects for Charged Higgs Discovery at Colliders*, `PoS(Charged 2010)002`.

[9] G. Aad et al. (The ATLAS Collaboration), *ATLAS Public Collision Plots*, https://twiki.cern.ch/twiki/bin/view/AtlasPublic, Dec 2010.

[10] M. Mangano, M. Moretti, F. Piccinini, R. Pittau and A. Polosa, *ALPGEN, a generator for hard multiparton processes in hadronic collisions*, JHEP 0307 (2003) 001, [`hep-ph/0206293`].

[11] G. Aad et al. (The ATLAS Collaboration), *Prospects for the Top Pair Production Cross-section at* $\sqrt{s}$*= 10 TeV in the Single Lepton Channel in ATLAS*, ATL-PHYS-PUB-2009-087, Aug 2009.

[12] G. Aad et al. (The ATLAS Collaboration), *Prospects for measuring top pair production in the dilepton channel with early ATLAS data at* $\sqrt{s}$*=10 TeV*, ATL-PHYS-PUB-2009-086, Aug 2009.

[13] G. Aad et al. (The ATLAS Collaboration), *Expected Sensitivity in Light Charged Higgs Boson Searches for* $H^+ \rightarrow \tau\nu$ *and* $H^+ \rightarrow c\bar{s}$ *with Early LHC Data at the ATLAS Experiment*, ATL-PHYS-PUB-2010-006, Jun 2010.

[14] T. Sjostrand, S. Mrenna, and P. Skands, *PYTHIA 6.4 physics and manual*, JHEP 0605 (2006) 026, [`hep-ph/0603175`].

[15] G. Aad et al. (The ATLAS Collaboration), *Observation of the Background from W+jets to the* $H \rightarrow WW \rightarrow ll\nu\nu$ *Search with the ATLAS detector at 7 TeV*, ATLAS-CONF-2010-092, Jun 2010.

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