Top Physics Results from the ATLAS Experiment

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1 Introduction

In 2010 (2011), the ATLAS [1] experiment has collected 45 (767 [1]) pb^{-1} of proton-proton collisions data, with a peak luminosity of 2.1×10^{32} (1.3×10^{33}) cm^{-2}s^{-1}. The average pile-up was of 2 (6) vertices, and the integrated luminosity has been measured with an uncertainty of 3.4% (4.5%). During all this period, ATLAS has been characterised by a quite high data taking efficiency and fraction of good quality data from all sub-detectors, which allowed the experiment to succesfully analyse the new data. In this paper, the results obtained in the field of top quark studies are summarised. The cross section ($\sigma_{t\bar{t}}$) for top quark pair production at a 7 TeV center of mass energy and for a top mass (m$_{top}$) of 172.5 GeV is equal to 165^{+11}_{-16} pb [2], which is about 25 times the $\sigma_{t\bar{t}}$ at the Tevatron accelerator. By the end of 2011, ATLAS should be able to analyse few fb^{-1} of data, about 500,000 $t\bar{t}$ pairs, that is six times the events collected by Tevatron. Most of the results presented here, if not stated otherwise, have been produced by analysing 35 pb^{-1} of data collected in 2010.

2 Top Quark Cross Section

The cross section $\sigma_{t\bar{t}}$ has been evaluated in the single-lepton channel (where one of the W-boson from the $t\bar{t}$ pairs decays leptonically, and the other one hadronically, so that the typical signature of the $t\bar{t}$ event is a high P$_T$ isolated lepton (electron, or muon), missing E$_T$ and jets), with and without the use of the b-tagging information and exploiting various analysis techniques, eg: a simple counting experiment and a more complex profile likelihood in which systematic variations are not simply used to test the bias of the fit, but enter directly in the minimisation process as parameters of the fit [3]. Complementary and consistent results have been obtained, in agreement with the theoretical prediction. The results of the studies performed in the single-lepton channel are summarised in Fig. 1. The baseline analysis, which

[1]This number refers to the luminosity collected at the time of the conference.

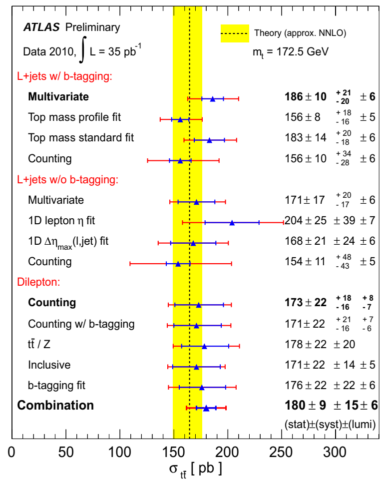

Figure 1: Measured $\sigma_{t\bar{t}}$ using several analyses in each decay channel, including errors bars for both statistical uncertainties only (blue) and all systematics (red). The combined result is based on the L+jets b-tag multivariate and the dilepton counting analyses. The approximate NNLO prediction is shown as a vertical dotted line with its error in yellow.

is a multivariate method using the b-tagging information, finds a cross section of $\sigma_{t\bar{t}} = 186 \pm 10(stat)^{+21}_{-20}(syst) \pm 6(lumi)$ pb. Several studies have been performed in the dilepton channel too [4], as shown in Fig. 1. In the dilepton channel the cross-section is extracted using a cut-and-count method and there is no b-tagging requirement. Event candidates are selected by asking for exactly two opposite-signed leptons: ee, $e\mu$ and $\mu\mu$. The main background contribution comes from Drell-Yan production and fake leptons, both estimated via data-driven techniques. The cross-section is extracted using a profile likelihood with a simultaneous fit to the three channels, and the value $\sigma_{t\bar{t}} = 174 \pm 23(stat.)^{+19}_{-17}(syst.) \pm 7(lumi)$ pb is obtained. This, and the other cross-check measurements which have been performed, are found to be in good agreement with each other and with the SM prediction. Combining the results from the single-lepton channel (multivariate analysis with b-tagging) and from the dilepton channel (counting experiment without b-tagging), a $\sigma_{t\bar{t}} = 180 \pm 9(stat.) \pm 15(syst.) \pm 6(lumi.)$ pb is found, which is characterised by an overall uncertainty of about 10% (see Fig. 1), competitive with the latest Tevatron measurement.

3 Top Quark Mass

The baseline measurement of m_{top} has been performed with a template method [5]. The 1-D templates are made of the reconstructed top quark/W-boson mass ratio distribution (R_{32}). Due to the stability of R_{32} against jet energy scale (JES) variations, this method avoids the need to use in-situ calibrations techniques to reduce the impact of JES. Top pair events in the single-lepton decay channel are selected from data sample, and m_{top} is calculated from the three jets with the highest vector-p_T sum. The W-boson mass (m_W) is calculated from the invariant mass of the two jets that are not tagged. Events with two or more b-tagged jets in the jet-triplet are rejected and the event selection is further restricted to events with $60 < m_W < 100$ GeV. Then, m_{top} is extracted from an unbinned likelihood fit to the R_{32} distributions generated at different top mass values. Combining the electron and muon channels gives $m_{top} = 169.3 \pm 4.0(stat.) \pm 4.9(syst.)$ GeV. The largest systematic uncertainties come from initial and final state radiation (ISR/FSR) modeling and from light and b-jet energy scale. Cross checks have been performed with other methods as well.

4 Single Top Quark Searches

Electroweak production of single top quarks was observed about two years ago at Fermilab [6]. It provides a direct probe of the $W - tb$ coupling and is sensitive to many models of new physics [7]. The measurement of the single top production cross-section determines the magnitude of the quark mixing matrix element V_{tb} without assumptions about the number of quark generations. In the $t-$channel, the search is based on the selection of events with a single-lepton, jets and missing E_T. The analysis is based on the application of sequential cuts: imposing requirements on the pseudo-rapidity of the leading untagged jet and the reconstructed m_{top}, a high significance, including statistical and systematics uncertainties on the background estimates, can be reached. The QCD multi-jet and W+jets backgrounds are evaluated using a data-driven method, and a $\sigma_t = 97^{+54}_{-30}$ pb with an observed (expected) significance of 6.3 (4.5)σ is estimated. The Wt-channel associated production is more difficult to be observed than the t-channel production due to its smaller cross-section [8]. This process contains two W-bosons in the final state. The single and dilepton channels are combined and a 95% C.L. upper limit is set on the Wt-channel production cross-section of $\sigma_{Wt} < 158$ pb.

5 Flavour Changing Neutral Currents

In the SM flavour changing neutral current (FCNC) processes are highly suppressed, and can only occur through loop diagrams. However, new physics are expected to enhance their contribution by several orders of magnitude. Searches for $t \rightarrow Zq$ have been performed [9] looking at events where both the W and the Z bosons from the top quarks decay leptonically in order to minimise the amount of background. Events are selected by requiring three leptons in order to suppress QCD multi-jet background. The three leptons are required to pass different p_T thresholds and two of them must have the same flavor and opposite charge. After this stringent selection only one candidate event is found in the data sample and a limit of BR < 17 % (observed limit at 95% CL) is calculated.

The vertex $qg \rightarrow t$ ($q = u, c$ quarks) was investigated through the measurement of anomalous single top production. Events were selected by requiring exactly one b-tagged jet and one lepton, and a neural network with 13 input variables to separate the signal from background (mainly W+jets but also standard single top). Within the uncertainties, no events were seen above the SM prediction, corresponding to a $qg \rightarrow t \times BR(t \rightarrow)Wb < 17.3$ pb limit at a 95% CL.

6 W-boson helicity in top-quark decays

The polarization states of the W-boson in top-quark decays are well defined in the SM, due to the V-A structure of the charged current weak interactions. The SM predicts that 70% of W-bosons in top-quark decays are longitudinal (F_0=0.7), and that there is no right-handed polarization (F_R=0). In ATLAS the W-boson helicity fractions and angular asymmetries are measured in top-quark pair production in the single-lepton channel exploiting the angular distributions of the $t \rightarrow bW \rightarrow bl\nu$ decay products [10]. The distribution of θ^*, the angle between the direction of the lepton and the reversed momentum of the b-quark from the top-quark decay, both boosted into the W-boson rest frame, is distorted by the detector response, kinematic cuts, off-line event selection and reconstruction. In a first measurement, templates of cosθ^* are created and used to fit the data and extract the W-boson helicity fractions. Assuming F_R=0 one founds F_L= 0.41 $\pm$ 0.12 and F_0 = 0.59 $\pm$ 0.12. A second measurement is based on angular asymmetries constructed from the cos θ^* variable. Selected events are reconstructed using a 2-D fit and an iterative procedure is applied to correct for detector and reconstruction effects. Helicity fractions are measured to be $F_L = 0.36 \pm 0.10$, $F_0 = 0.65 \pm 0.15$ and F_R = -0.01 $\pm$ 0.07. The results are in very good agreement with the SM predictions and are used to place limits on anomalous couplings that arise in models for New Physics beyond the SM.

7 Search for $m_{t\bar{t}}$ + anomalous missing E_T

A search for anomalous $t\bar{t}$ + missing E_T in the single-lepton final state has been performed [11]. Such phenomena can arise from a number of SM extensions, but we focus here on the search for a pair produced top partner decaying to a top-quark and a long lived neutral particle which escape undetected, a stable neutral scalar A_0. The benchmark model considered is the production of a top-quark partner T with T$\rightarrow$ tA_0, A_0 being a Dark Matter candidate. The final state is identical to the SM $t\bar{t}$ case but with a larger missing E_T. Events are selected in the single-lepton channel, and a good agreement between SM and data is found (17 events observed, 17.2 expected). Through the study of event yield distributions from pseudo experiments for signal and background only hypothesis, this model is excluded at 95% CL for $m_T < 300$ GeV and $m_{A_0}= 10$ GeV and for $m_T< 275$ GeV and $m_{A_0}= 50$ GeV. These limits can be interpreted quite broadly for a number of new physics scenarios [12].

8 Search for high $m_{t\bar{t}}$

In many models the top quark plays a special role and interacts via the strong force in a number models of exotic physics. The predictions foresee new narrow or wide resonances, that preferentially decay into top pairs or an enhanced productions of high mass top pairs ($m_{t\bar{t}}$) [13]. One therefore can look for anomaly in the $m_{t\bar{t}}$ spectrum. The benchmark model used to quantify the experimental sensitivity to narrow resonances is a top-colour Z_0 boson arising in models of strong electroweak symmetry breaking through top quark condensation. The model used for wide resonances is instead a Kaluza-Klein gluon g_{KK}, which appears in Randall-Sundrum (RS) models with a warped extra dimension in which particles are located in the extra-dimension. In this case, the resonance is predicted to be significantly wider than the detector and reconstruction algorithm's resolution. This model is taken as a proxy for coloured resonances. Different $m_{t\bar{t}}$ reconstruction methods are compared, and a cross-check is performed between the attempt to assign reconstructed objects to top quarks decays or not. No evidence for a resonance is found. For a narrow Z', observed 95% C.L. limits range from 38 pb to 3.2 pb for masses from $m_Z= 500$ GeV to 1300 GeV. In RS models, KK gluons with masses below 650 GeV are excluded at 95% C.L.

9 Conclusions

Top physics at the LHC has just started. With only 35 pb^{-1} of collected data, the ATLAS top quark pair production cross section determination is already competitive with Tevatron, and a number of measurements have been already performed in the various decay channels. New results have been presented on the single top searches and on the study of the $m_{t\bar{t}}$ distribution. The studies which are presently statistics limited will soon become very competitive as well, since LHC has already collected $\simeq$ 1 fb^{-1} of data which will be soon analysed. The ATLAS Top working group is now concentrating the efforts to reduce the impact of systematics in the measurements:

this means improving even further the detector understanding as well as using advanced analysis techniques.

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