Top quark property measurements at ATLAS

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1 Introduction

The top quark is the heaviest known fundamental particle and has a mass of $m_{top} = 173.3 \pm 1.1$ GeV [1]. Detailed studies of the properties of the top quark are useful to constrain the Standard Model (SM) and set limits on possible sources of new physics such as, anomalous production or couplings, rare decays and new final states. The ATLAS collaboration has recently measured the top anti-top pair production cross section at a centre-of-mass energy of 7 TeV to be $\sigma_{t\bar{t}} = 180 \pm 18$ pb with 35 pb^{-1} [2], which is in good agreement with the approximate NNLO [3] prediction of 165^{+11}_{-16} pb. Such cross-section will allow to collect a very large top sample at LHC for precise measurements; the full Tevatron statistics will be exceeded with the first 500 pb^{-1} of data.

This paper presents measurements of the top quark mass and several top quark properties with the ATLAS detector [4] using data collected during 2010 for an equivalent luminosity of 35 pb^{-1}. Since the top-quark decays almost entirely into a W-boson and a b-quark, the event topology is determined by the W-boson decay. The 'lepton+jets' final state was used for several of the properties analyses, since it provides a good balance between high branching ratio and a favourable signal/background (S/B). It consists of one isolated lepton (electron or muon) used to trigger on the event, missing transverse energy from the neutrino and at least four anti-kt [5] jets. In several of these analyses a b-tag requirement is made using the SV0 algorithm [6], which increases the S/B ratio above three.

2 Top quark mass

The top-quark mass is a fundamental parameter of the SM and it can be used to derive constraints on the Higgs boson mass or heavy particles predicted in SM extensions.

The top mass has been directly measured by the ATLAS collaboration [7] using a kinematic fit of a single variable R_{32}, which is defined as the ratio of the per event reconstructed top mass over the W-boson mass. The top mass is then calculated from the three jets with the highest vector-p_T sum while the W-boson mass is calculated from the invariant mass of the two (of the three) jets which are not b-tagged. The use of this ratio variable causes partial cancellation of the jet energy scale (JES) uncertainties. Templates for R_{32} are constructed as a function of the top mass and the best value is extracted from an unbinned likelihood fit to the data. Figure 1 (left) shows the result of the fit in the muon channel; combining the both lepton channels, the measured top-quark mass is $m_{top} = 169.3 \pm 4.0(stat.) \pm 4.9(syst.)$ GeV . The main sources of systematic uncertainties are the modelling of the initial and final state radiation (2.2 and 2.6 GeV for electron and muon channel respectively) and JES ($\approx$ 2 GeV). An additional uncertainty of 2.5 % on the calibration is included for tagged jets resulting in a 2.5 GeV uncertainty in the mass.

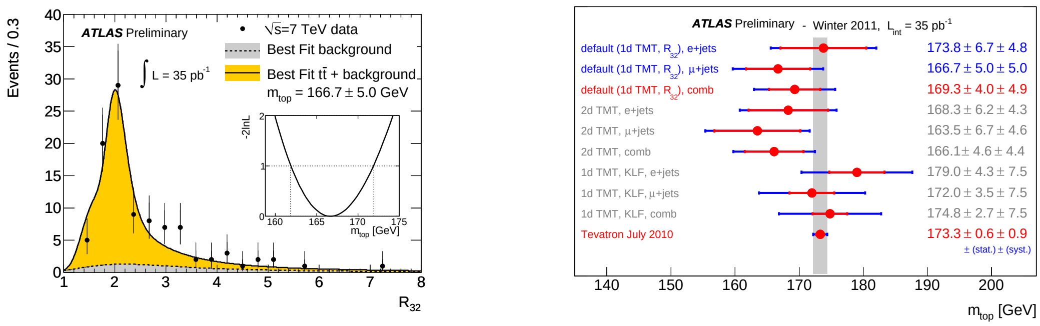

Figure 1: (left) R_{32} distributions for the data in the electron muon channel together with the best fit template. (right) A summary of top mass measurements made by the ATLAS Collaboration.

The result has been cross-checked with two other analyses that address the JES uncertainty in a different way. A two-dimensional simultaneous fit extracting m_{top} and a global jet energy scale factor between data and predictions, and another 1D template analysis exploiting a kinematical likelihood fit to all decay products of the $t\bar{t}$ system. As summarized in Figure 1 (right), all the methods give compatible results and are well in agreement with the previous world average.

The top mass has also been extracted indirectly by exploiting the dependency of the $t\bar{t}$ cross section from the mass itself [8]. Using the cross section measurement in the lepton+jets channel [2], a value of $m_{top} = 166.4^{+7.8}_{-7.3}$ GeV was obtained, well in agreement with the direct measurements.

3 W-boson polarisation

The W-boson polarisation fractions in the top decay are fully determined by the V-A nature of the tWb decays vertex; the expected values are $F_0 = 0.698$, $F_L = 0.301$,

$F_R = 4.1 \cdot 10^{-4}$ at LO [9] respectively for the longitudinal, left-handed and right-handed states. They are measured through the angular distribution θ^*, the angle between the direction of the lepton and the reversed momentum direction of the b-quark from the top-quark decay in the W-boson rest frame. The $t\bar{t}$ kinematics have been reconstructed in a kinematic fit from the final state particles in which the decay kinematics and the top/W boson masses enter as constraints.

A first measurement [10] is performed with a template fit to the $cos(\theta^*)$ data distribution; templates for the different helicity states were obtained from MC after full simulation. Assuming $F_R = 0$ and combining both lepton channel the helicity fractions $F_0 = 0.59 \pm 0.12$ and $F_L = 0.41 \pm 0.12$ are obtained. The results are still statistically dominated and the main sources of systematics are the background modelling, the JES and the ISR. A second method consisted of computing three angular asymmetries, corrected for detector effects, linearly related to helicity fractions. Both results are found to be in good agreement with SM predictions.

4 FCNC in the top sector

In the SM flavour changing neutral current processes are highly suppressed, and can only occur through loop diagrams. New physics are expected to enhance their contribution by several orders of magnitude.

Searches for $t \to Zq$ [11] have been performed 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. The event selection required three leptons (the same flavor pair need to be of opposite sign), two jets and $E_{\mathrm{T}}^{\mathrm{miss}}$. One event fulfilled this criteria, resulting in an upper limit of $BR(t \to qZ) < 17\%$ at 95 % confidence level (CL).

The vertex $qg \to t$ (q=u,c quarks) was investigated through the measurement of anomalous single top production [11]. 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 $\sigma_{qg \to t} \times BR(t \to Wb) < 17.3$ pb limit at the 95% CL. The main sources of systematic uncertainties are the ISR modeling, the JES and the W+jets heavy flavour content.

5 Anomalous $E_{\mathrm{T}}^{\mathrm{miss}}$ events

A search for anomalous missing transverse energy in the lepton+jets $t\bar{t}$ final state was performed [12]. The analysis searched for the pair production of fermionic top partner (T) decay into $t\bar{t}$ and two long lived neutral scalars that escape the detection. Data were selected with $E_{\mathrm{T}}^{\mathrm{miss}} > 80$ GeV and W transverse mass > 120 GeV in addition to the standard $t\bar{t}$ selection. The dilepton contamination was reduced by vetoing events with additional leptons, corresponding to isolated tracks or loose electron quality criteria. No excess above the predicted background was found, corresponding to limits of the top partner mass: $m(T) < 300$ GeV for $m(A_0) = 10$ GeV and $m(T) < 275$ GeV for $m(A_0) = 50$ GeV at 95% CL.

6 Conclusions

The ATLAS experiment has performed the first measurements of the top properties, using the 35 pb^{-1} to perform the first measurement of top properties at LHC. No evidence of deviation above the SM expectations has been found for the W helicity fractions, FCNC phenomena and in the high $E_{\mathrm{T}}^{\mathrm{miss}}$ region of the $t\bar{t}$ phase space. The top mass measurement yielded a value of $m_{top} = 169.3 \pm 4.0(stat.) \pm 4.9(syst.)$ GeV .

The presented analyses will greatly profit from the much larger amount of data that will be collected by ATLAS during 2011 where also systematic uncertainties will be better constrained by improved detector understanding.

References

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