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Top quark pair production measurements using the ATLAS detector at the LHC

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Abstract

Inclusive and differential cross sections of top quark pair production at have been measured with the ATLAS detector at the LHC at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 8 TeV. Inclusive measurements are in good agreement with Standard Model predictions. Differential cross section measurements are compared to different sets of generators, parton showering and hadronization simulations, PDF and calculations. This provides constraints to improve the MC modeling.

Keywords: top quark, cross section, ATLAS, LHC

1. Introduction

The top quark is the heaviest known fundamental particle, with a mass close to the scale of the electroweak symmetry breaking. Hence, it plays a special role in many theories beyond the Standard Model. New physics may be observed in additional top quark decay channels. New mechanisms of $t\bar{t}$ production can also cause deviations of the measured cross section from the Standard Model predictions. Moreover, $t\bar{t}$ events represent a background for many new physics channels. The study of this quark is also important for the QCD sector : comparisons with production calculations, tests of the Monte Carlo simulations, information about modeling of PDF and ISR/FSR etc...
For all these reasons, the measurements of the inclusive and differential cross section represent an important part of the ATLAS top physics program.

2. Decay of a $t\bar{t}$ pair

According to the Standard Model, over 99 % of top quarks decay into W+b. The final state of $t\bar{t}$ pair decay is determined by the W-decay channels: only jets if the two W's decay into quarks, one charged lepton and jets if one of the W's decays into leptons and the other into quarks and dilepton channel if the two W's decay into leptons. The first channel suffers from a large multijet and combinatorial background. The second channel (called lepton+jets) benefits from a large statistics (45 %). The main backgrounds for this final state are W+jets and single top events, but also multi-jet events where one of the jets is misidentified as a lepton. The dilepton channel has a low background but a low statistics, too.

For the ATLAS results presented here, the channels used are the dilepton channel for an inclusive cross section measurements and the lepton+jets channel for inclusive and differential cross section measurements. In that case, the reconstructed lepton is a muon or an electron.

3. Inclusive cross section measurements

3.1. Dilepton channel

As for all results presented here, this analysis, fully described in [1], is performed on events collected with the ATLAS detector [2]. The events taken in 2011 at $\sqrt{s}$ = 7 TeV correspond to an integrated luminosity of 4.6 fb^{-1} and those taken in 2012 at $\sqrt{s}$ = 8 TeV correspond to an integrated luminosity of 20.3 fb^{-1}.

In this analysis, events must contain one electron and one muon of opposite sign and exactly one or two b-tagged jets. The algorithm of b-tagging is neural network-based and makes use of track impact parameter and reconstructed secondary vertices. The number of events is counted and used to simultaneously determine the $t\bar{t}$ cross section and the efficiency to reconstruct and tag a b-jet from a top quark decay, thereby minimizing

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the associated systematic uncertainty.
Figure 1 shows the distribution of the number of b-tagged jets in preselected opposite-sign e-mu events in 8 TeV data. The data are shown compared to the expectation from simulation, with the contributions from $t\bar{t}$, Wt single top, Z+jets, dibosons, and events with misidentified electrons or muons.

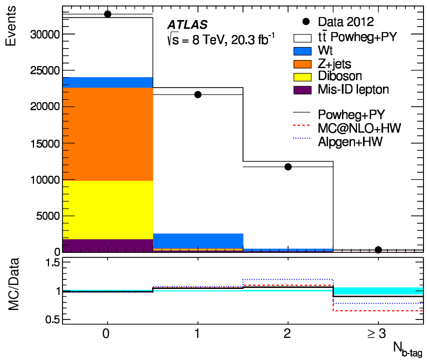

Figure 1: Distribution of the number of b-tagged jets in preselected opposite-sign e-mu events in 8 TeV data. The data are shown compared to the expectation from simulation, broken down into contributions from ttbar, Wt single top, Z+jets, dibosons, and events with misidentified electrons or muons, normalized to the same integrated luminosity as the data. The lower parts of the figure show the ratios of simulation to data, using various $t\bar{t}$ signal samples generated with POWHEG + PYTHIA6 (PY), MC@NLO + HERWIG (HW) and ALPGEN + HERWIG, and with the cyan band indicating the statistical uncertainty.

The cross section is measured at $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 8 TeV:

$$\sigma_{t\bar{t}} = 182.9 \pm 3.1(\text{stat}) \pm 4.2(\text{syst}) \pm 3.6(\text{lumi}) \pm 3.3(\text{beam})\ pb \text{ (at } \sqrt{s} = 7 \text{ TeV)} \quad (1)$$

$$\sigma_{t\bar{t}} = 242.4 \pm 1.7(\text{stat}) \pm 5.5(\text{syst}) \pm 7.5(\text{lumi}) \pm 4.2(\text{beam}) \text{ pb (at } \sqrt{s} = 8 \text{ TeV)} \quad (2)$$

For both measurements, the fractional uncertainty is 4 %. These results are consistent with the recent calculations of the $t\bar{t}$ pair production at full next-to-next-to-leading-order (NNLO) accuracy in the strong coupling constant α_S, including the resummation of the next-to-next-to-leading logarithmic (NNLL) soft gluon terms [3]:

$$\sigma_{(pp\to t\bar{t})} = 177^{+10}_{-11} \text{ pb (at 7 TeV)} \quad (3)$$

$$\sigma_{(pp\to t\bar{t})} = 253^{+13}_{-15} \text{ pb (at 8 TeV)} \quad (4)$$

3.2. Lepton+jets channel

As described in [4], this analysis was performed on data at $\sqrt{s}$ = 8 TeV. The criteria to select events are the following: one electron or one muon, at least three jets, with at least one b-tagged jet among them, and for the W decaying into the leptons, a large transverse mass (greater than 30 GeV) and a missing transverse momentum also greater than 30 GeV to take into account the neutrino.

The cross section is obtained using a likelihood discriminant variable (LHD) built from lepton pseudo-rapidity, η, and the transformed Aplanarity $A' = exp(-8A)$ [1]. A fit of template in binned LHD to data is performed to extract the cross section. Distribution of the likelihood discriminant LHD in the μ+jets channel is shown Figure 2 for the data and for a weighted sum of templates from the $t\bar{t}$ signal and various backgrounds.

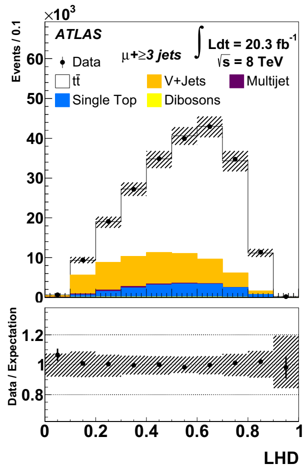

Figure 2: Distribution of the likelihood discriminant LHD in the μ+jets channel for the data and for a weighted sum of templates from the $t\bar{t}$ signal and various backgrounds. The contributions from $t\bar{t}$ and V+jets production are normalized according to the results of the likelihood discriminant fit; the single top and dibosons contributions are normalized according to their theoretical cross-sections, and the multijet background is normalized using a data-driven method. The bottom part of the figure shows the ratio of the data to the predicted value together with combined statistical and systematic uncertainties.

The extracted cross-section at $\sqrt{s}$ = 8 TeV is:

$$\sigma_{(pp\to t\bar{t})} = 260 \pm 1(\text{stat})^{+20}_{-21}(\text{syst}) \pm 8(\text{lumi}) \pm 4(\text{beam}) \text{ pb} \quad (5)$$

The fractional uncertainty is 8 % and these results are consistent with the theoretical calculations given Eq. (4).

3.3. Summary for the measurements of the inclusive cross section at the LHC

Figure 3 shows the summary of measurements of the top-pair production cross-section at 8 TeV for ATLAS

[1] A is the aplanarity, defined as 3/2 times the smallest eigenvalue of the momentum tensor $M_{ij} = \Sigma_{k=1}^{N_{objects}} P_{ik} P_{jk} / \Sigma_{k=1}^{N_{objects}} P_k^2$, where P_{ik} is the i-th momentum component and P_k is the modulus of the momentum of object k.