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ATLAS results on inclusive top quark pair production cross section at the LHC

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We present measurements of the top-quark pair production cross section in proton-proton collisions at 7 TeV with the ATLAS detector at the Large Hadron Collider. They are measured in several channels, including the single lepton, dilepton, all hadronic as well as channels involving τ leptons. Finally a combination of these measurements leads to $\sigma_{t\bar{t}} = 177 \pm 3(\mathrm{stat})^{+8}_{-7}(\mathrm{syst}) \pm 7(\mathrm{lumi})$ pb in good agreement with Standard Model expectation.

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1. Introduction

The precision measurement of the top-antitop quark pair production cross-section ($\sigma_{t\bar{t}}$) provides not only an important test of perturbative QCD, but also a variable to observe deviations from Standard Model (SM) predictions, that could indicate new physics. In proton-proton (pp) collisions at the LHC, are dominantly produced top-antitop pairs ($t\bar{t}$) and are classified according to their decay modes. Within the SM the top quark decays essentially via the weak process t$\rightarrow$Wb. The predicted SM $t\bar{t}$ cross section for pp collisions at a centre-of-mass energy of $\sqrt{s} = 7$ TeV is $\sigma_{t\bar{t}} = 167^{+16.5}_{-17.8}$ pb for a top quark mass of 172.5 GeV/c^2 as obtained from approximate NNLO QCD calculations[1]. Measurements of $\sigma_{t\bar{t}}$ in several final states have been carried out by the ATLAS collaboration and are presented in these proceedings.

2. The ATLAS detector and data taking

The ATLAS (A Toroidal LHC ApparatuS) detector [2] consists of an inner detector (ID) tracking system surrounded by a superconducting solenoid providing a 2 T magnetic field, electromagnetic and hadronic calorimeters, and a muon spectrometer (MS). The ID consists of pixel and silicon microstrip detectors inside a transition radiation tracker. The electromagnetic calorimeter is a lead liquid-argon (LAr) detector in the barrel ($|\eta| < 1.475$) and the endcap ($1.375 < |\eta| < 3.2$) regions. Hadron calorimetry is based on two different detector technologies. The barrel ($|\eta| < 0.8$) and extended barrel ($0.8 < |\eta| < 1.7$) calorimeters are composed of scintillator/steel, while the hadronic endcap calorimeters ($1.5 < |\eta| < 3.2$) are LAr/copper. The forward calorimeters ($3.1 < |\eta| < 4.9$) are instrumented with LAr/tungsten and LAr/copper, providing electromagnetic and hadronic energy measurements, respectively. The MS consists of three large superconducting toroids and a system of three stations of trigger chambers and precision tracking chambers.

In the year 2011 the ATLAS experiment has collected 5.25 fb^{-1} of data at a center-of-mass energy of 7 TeV. After application of data quality requirements, 0.70 to 4.70 fb^{-1} of data have been used in the different analyses described below. Monte Carlo (MC) simulated event samples with full detector simulation are used to model the signal and backgrounds[3].

3. Top quark pair production cross section

The decay topologies of $t\bar{t}$ events are determined by the decay of the W boson, either into a lepton-neutrino pair (W$\rightarrow l\nu$), or into a pair of quarks (W$\rightarrow q\bar{q}$). In the lepton+jets mode, with a branching ratio (BR) of $\sim$ 45%, one top quark decays leptonically and the other hadronically, whereas in the dilepton mode (BR $\sim$ 11%), both top quarks decay leptonically. These channels have a final state signature involving one or two isolated leptons, missing transverse momentum (E_T^{miss}), at least two jets with secondary vertices from the *B*-mesons decays (*b*-tagged jets) and light jets for the lepton+jets mode. In the all-hadronic mode (BR $\sim$ 46%), both top quarks decay hadronically producing a final state signature of six jets where two originate from *b*-quarks. The cross-section using final states including a τ-lepton is sensitive to new physics such as the charged Higgs boson, predicted by supersymetric models. Special treatment is done for final states with a τ lepton decaying hadronically; they represent about 5% of events in the τ+jets channel and $\sim$ 3% in the $\tau + l$ ($l = e, \mu$) channel. In the following, the measurements by the ATLAS collaboration of the $t\bar{t}$ cross section in these various final state topologies are presented. Thanks to the large data sample that has been recorded, all measurements presented here are limited by systematic uncertainties.

3.1 Single lepton channel

The single lepton channel currently provides the most precise measurement of the $t\bar{t}$ cross section. The event trigger and selection is based on the identification of one isolated lepton, at least 4 jets, with the possibility to tag two of them as originating from *b*-quarks, and E_T^{miss}. The dominant contributions to the background come from W+jet events and multi-jet events, where one jet is mis-identified as a reconstructed lepton. Since the background from these sources is difficult to simulate correctly, its modeling is based on data. A likelihood function is built from various kinematic variables and templates are constructed for signal and backgrounds, separating the sample in the electron and muon channel and different jet multiplicities. The cross section measured by ATLAS, based on an analysis without explicit identification of *b*-jets and with a data sample corresponding to 0.70 fb^{-1} is $\sigma_{t\bar{t}} = 179.0 \pm 3.9(\text{stat}) \pm 9.0(\text{syst}) \pm 6.6(\text{lumi})$ pb[4]. The main systematics uncertainties are associated with the Monte Carlo generator, jet energy calibration and lepton identification. It is worth noting that the overall uncertainty of the measurement is below the uncertainty of the approximate NNLO calculation mentioned in section 1.

3.2 Dilepton channel

The dilepton channel contains two lepton-neutrino pairs in the final state. The event selection is based on the presence of two opposite-signs leptons, two jets and large E_T^{miss}. Leptons are either well-identified electron or muon candidates that are selected using the full detector or, to reduce losses from lepton identification inefficiencies, isolated tracks. The analysis with the *b*-tag requirement uses only identified leptons. Eight exclusive channels, i.e. having no overlap between each other, are made and combined to extract a cross section measurement from a profile likelihood. In the dilepton channel ATLAS reports $\sigma_{t\bar{t}} = 176 \pm 5(\text{stat})^{+14}_{-11}(\text{syst}) \pm 8(\text{lumi})$ pb[5]. The measurement is based on a total integrated luminosity of 0.70 fb^{-1}. The main systematics uncertainties are associated with the Monte Carlo generator, the jet energy calibration and lepton identification.

3.3 τ+lepton channel

Candidates in the τ+lepton channel are extracted from 2.05 fb^{-1} data, selected using a single muon or electron at trigger and offline levels, at least one hadronically decaying τ candidate, large E_T^{miss} and two or more energetic jets, with at least one of them identified as a *b*-jet. The dominant background which is estimated on data arises from jets faking τs. One of the pivotal elements of this measurement is the τ-identification algorithm. A boosted decision tree, which distinguishes between one and three-prong τ decays, is used. The cross section reported in this channel is $\sigma_{t\bar{t}} = 186 \pm 13(\text{stat}) \pm 20(\text{syst}) \pm 7(\text{lumi})$ pb[6]. The main systematics uncertainties are associated with τ identification and *b*-tagging efficiency.

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3.4 τ+jets channel

This channel is characterized by one hadronically decaying τ-lepton and jets. In this analysis, events with at least five jets are selected, where two of the jets are identified as b-quark jets. One of the remaining jets is selected as the $\tau_{\rm had}$ candidate. First, the reconstruction of the hadronically decaying top is attempted by selecting the three jets (including exactly one b-jet among the two b-jets) which give the highest 4-vector p_T sum. The remaining jet with the highest p_T, excluding the remaining b-jet is selected as the $\tau_{\rm had}$ candidate. The background to this final state is mainly due to electrons from $t\bar{t}$ events and jets both from $t\bar{t}$ events (combinatorics) and multijet events. For the multi-jet and $t\bar{t}$ backgrounds, templates are derived from data in a background enriched region. The contribution from the background from $t\bar{t}$ events with electrons in the final state is estimated from simulation. The $\tau_{\rm had}$ contribution is separated from quark or gluon jets with a one-dimensional fit to the number of tracks associated with the $\tau_{\rm had}$ candidate. Since the $\tau_{\rm had}$ decays preferentially to 1 or 3 charged particles (and other neutral decay products), this variable offers a good separation between τ leptons and jets. The cross section reported in this channel is then $\sigma_{t\bar{t}} = 200 \pm 19(\text{stat}) \pm 43(\text{syst})$ pb[7] and is based on a data sample corresponding to an integrated luminosity of 1.67 fb^{-1}. The main systematic uncertainties arise from ISR/FSR and b-tagging efficiency.

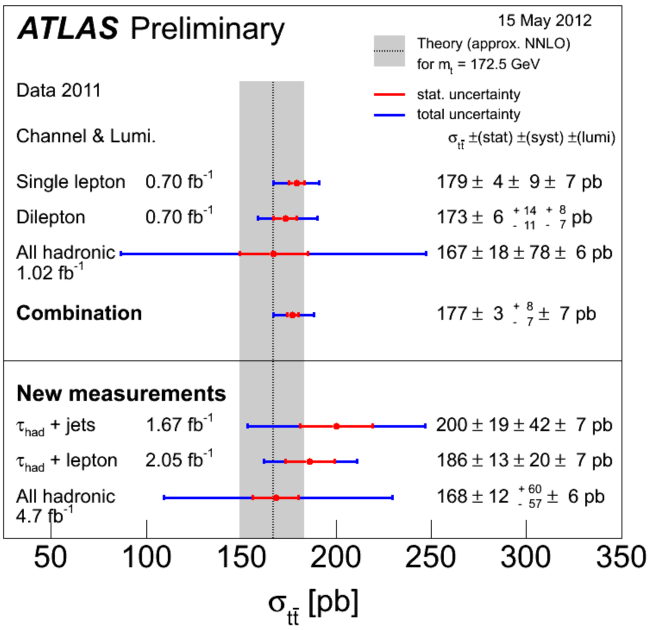

Figure 1: Summary of $t\bar{t}$ measurements compared to the theoretical expectation. This includes the individual and combined measurements (upper part) and the new measurements (lower part) as described in [9]. Dilepton channel results are based only of the three channels with well identified leptons as compared to section 3.2.

3.5 All hadronic channel

The all hadronic channel is the final state of $t\bar{t}$ events with the largest branching ratio ($\sim$46%), but suffers from a large multi-jet background. The signal extraction is based on a kinematical fit that exploits the characteristic topology of a hadronic $t\bar{t}$ event. It maximizes a likelihood function with respect to the jet energies, which are varied in the fit, and using the constraints of the W and top mass when associating jets. For the background modeling, the ATLAS measurement derives the shape of the multi-jet background by performing the kinematical fit on the data sample without applying the *b*-tagging requirement. The measurement is based on a data sample corresponding to an integrated luminosity of 4.70 fb^{-1}. The dominant systematic uncertainties include ISR/FSR, *b*-tagging efficiency and mistag rate, and jet energy scale uncertainties. The result is a value of $\sigma_{t\bar{t}} = 168 \pm 12(\mathrm{stat})^{+60}_{-57}(\mathrm{syst}) \pm 6(\mathrm{lumi})$ pb[8].

3.6 Combination of measurements

The combination takes into account correlated systematic uncertainties between the channels. The result combines the single-lepton, dilepton and all-hadronic final states. The statistical combination of these measurements leads to a value of $\sigma_{t\bar{t}} = 177 \pm 3(\mathrm{stat})^{+8}_{-7}(\mathrm{syst}) \pm 7(\mathrm{lumi})$ pb[9]. The single measurements and their combination are compared with the approximate NNLO calculation in Fig. 1. Good agreement is observed between measurement and the SM expectation.

4. Conclusion

The pp run in 2010-2011 at $\sqrt{s} = 7$ TeV of the LHC has been very successful, with up to 4.70 fb^{-1} of data analysed by the ATLAS experiment. The measured $t\bar{t}$ cross section in various final states is found to be in agreement with the SM expectation. The precision of all the measurements presented here is driven by systematic uncertainties, and reaches levels that are comparable or below the uncertainties of theoretical predictions.

5. Acknowledgments

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References

[1] Aliev et. al., HATHOR, arXiv:1007.1327 [hep-ph]

[2] The ATLAS Collaboration, JINST 3 S08003 (2008)

[3] The ATLAS Collaboration, Eur. Phys. J. C 70 (2010) 823

[4] The ATLAS Collaboration, ATLAS-CONF-2011-121

[5] The ATLAS Collaboration, JHEP 1205 (2012) 059

[6] The ATLAS Collaboration, Physics Letters B717 (2012) 89-108

[7] The ATLAS Collaboration, ATLAS-CONF-2012-032

[8] The ATLAS Collaboration, ATLAS-CONF-2012-031

[9] The ATLAS Collaboration, ATLAS-CONF-2012-024