Top Quark Pair Production Cross-Section at ATLAS

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DOI: `http://dx.doi.org/10.3204/DESY-PROC-2012-02/89`

Measurements of the top quark pair ($t\bar{t}$) production cross-section in proton-proton collisions at $\sqrt{s} = 7$ TeV are presented using data recorded with the ATLAS detector at the Large Hadron Collider (LHC). The statistical combination of $t\bar{t}$ production cross-section ($\sigma_{t\bar{t}}$) measurements is presented using the lepton+jets, dilepton and all-hadronic channel. A new measurement of $\sigma_{t\bar{t}}$ with a hadronically decaying tau lepton and jets is also shown, together with an updated measurement in the all-hadronic channel. Finally a measurement of the jet activity in $t\bar{t}$ events using a veto on additional central jet activity is presented.

1 Introduction

The precision measurement of the top quark pair ($t\bar{t}$) production cross-section ($\sigma_{t\bar{t}}$) provides not only a vital test of perturbative QCD, but also an important variable to observe deviations from Standard Model (SM) predictions, that could indicate new physics.

In the SM, for pp collisions at $\sqrt{s} = 7$ TeV $\sigma_{t\bar{t}}$ is calculated to be 167^{+17}_{-18} pb [2]. The lifetime of the top quark is shorter than the hadronisation time scale, thus it decays almost 100% of the time to a W boson and a b-quark. The decay topologies are determined by the decay of the W boson, either into a lepton-neutrino pair ($W \rightarrow lv$), or into a pair of quarks ($W \rightarrow qq'$). In the lepton+jets mode, with a branching ratio (BR) of 37.9%, one top quark decays leptonically and the other hadronically, whereas in the dilepton mode (BR = 6.5%), both top quarks decay leptonically. These channels have a final state signature involving one or two leptons, missing transverse momentum (E_T^{miss}) and jets. In the all-hadronic mode (BR = 46%), both top quarks decay hadronically producing a final state signature of 6 jets where two originate from b-quarks.

2 Statistical Combination

A combination of $\sigma_{t\bar{t}}$ measurements [3] is presented in the lepton + jets [4] and dilepton [5] channels, both using 0.70 fb^{-1} of data, and the all-hadronic channel [6] using 1.02 fb^{-1} of data.

In the lepton + jets channel events are selected with exactly one lepton (electron (e) or muon (μ)), at least three jets and large E_T^{miss}. The backgrounds include W+jets (dominant), single top, diboson, Z+jets, and QCD multijet production. Kinematic variables are selected to distinguish between the $t\bar{t}$ signal and background, and a likelihood discriminant is constructed. The cross-section is extracted from a maximum likelihood fit to these discriminant distributions.

In the dilepton channel final states comprise of two oppositely-charged leptons (ee, $\mu\mu$, eμ), E_T^{miss} and at least two jets. The background includes Z/γ^* events, W+jets, diboson, $t\bar{t}$

lepton+jets, and single top quark production. The cross-section is measured using a cut-based analysis with a profile likelihood fit to the number of observed events.

The all-hadronic channel event selection applies a veto on isolated leptons, requires at least five jets of which two are b-tagged. The dominant background is from QCD multijets which is modelled using a data-driven approach to reproduce the shapes of various kinematic and topological distributions from alternative data samples. The cross-section is extracted using a binned maximum-likelihood fit of signal and background templates using the χ^2 of a kinematic fit to the top mass as a discriminant. Section 4 presents an update of this measurement.

A combination is obtained from the product of the individual likelihoods of each analysis and measured as $\sigma_{t\bar{t}}$ = 177±3(stat.)$^{+8}_{-7}$(syst.)±7(lumi.) pb, showing good agreement with the SM prediction and the uncertainty is smaller than the theoretical uncertainty. The main systematics are from uncertainties associated with the Monte Carlo (MC) generator, Jet Energy Scale (JES), Initial and Final State Radiation (ISR/FSR) and lepton identification. The individual and combined cross-section measurements are shown on the upper part of the left plot of Figure 1.

3 Cross-section measurement in $t\bar{t} \to \tau_{\text{had}}$+jets channel

A new measurement of $\sigma_{t\bar{t}}$ based on 1.67 fb^{-1} of data is presented, where one top quark decays into a tau lepton, a b-quark and a neutrino, and the other decays hadronically [7], resulting in a final state consisting of a hadronically decaying tau lepton and jets ($t\bar{t} \to \tau_{\text{had}}$+jets).

The data sample is selected using a b-jet trigger requiring more than three jets where two are identified as b-jets using a dedicated high-level trigger b-tagging algorithm. Events are selected with at least five jets (two b-tagged) where one is selected as a tau (τ_{had}) candidate. The hadronic top quark is reconstructed using the combination of three jets where one is b-tagged, that have the highest 4-vector p_T sum (with a reconstruction efficiency ϵ ∼70%). The τ_{had} candidate is chosen from the remaining non-b-tagged jets that has the highest p_T (ϵ ∼50%).

The tau lepton decays hadronically 65% of the time, ∼77% (∼23%) of these decays produce one (three) charged hadron(s) (i.e. one (three) track(s)). This characteristic track multiplicity (n_{track}) distribution provides an excellent variable to separate the signal from the background, which is dominated by multijet events.

The data sample n_{track} distribution is fitted with three templates and the τ_{had} signal is extracted using an extended binned-likelihood fit. The cross-section is measured to be $\sigma_{t\bar{t}}$ = 200 ± 19(stat.)±43(syst.) pb, shown in the lower part of the left plot in Figure 1. The main systematics arise from ISR/FSR uncertainty and b-tagging efficiency.

4 Cross-section measurement in the all-hadronic channel

The measurement of $\sigma_{t\bar{t}}$ in the all-hadronic channel has the advantage of a large BR but suffers from a large multijet background. Events are selected with at least six jets where two are b-tagged and a veto on events with isolated leptons. Starting from the reconstructed jets a likelihood approach is used to perform a kinematic fit to reconstruct the top quark mass (m_t).

The m_t distribution for the multijet background is modelled from events passing event selection with no b-tagged jets. An unbinned likelihood fit to the m_t distribution obtained from the kinematic fit is used to determine the event yield and background normalisation. The dominate systematic uncertainties include ISR/FSR, b-tagging efficiency and mistag rate, and JES uncertainties. The cross-section is measured using 4.7 fb^{-1} of data [8] to be $\sigma_{t\bar{t}} = 168 \pm 12(\text{stat.})^{+60}_{-57}(\text{syst.})\pm 7(\text{lumi.})$ pb, shown in the lower part of the left hand plot in Figure 1.

5 Measurement of $t\bar{t}$ production with a veto on additional central jet activity

A measurement is presented of the jet activity arising from hard, wide angle QCD emission from $t\bar{t}$ events using 2.05 fb^{-1} of data in the dilepton channel [9]. Events are selected with two opposite sign leptons (e or μ), E_T^{miss} and two b-tagged jets. A veto is then applied to events which contain an additional jet with a p_T above a defined threshold in a central rapidity region. The background to this signal includes single top, W+jets and multijet events. The measurement of jet activity is presented as the fraction of events surviving the jet veto, known as the gap fraction defined as $f(Q_0) = \frac{n(Q_0)}{N} \equiv \frac{\sigma(Q_0)}{\sigma}$ where N is the number of selected $t\bar{t}$ events passing selection, $n(Q_0)$ is the subset of these events that do not contain an additional jet with a $p_T > Q_0$, σ is the fiducial cross-section for inclusive $t\bar{t}$ production, and $\sigma(Q_0)$ is the fiducial cross-section for events passing the jet veto.

The measured $f(Q_0)$ from data is compared to multi-leg LO and NLO generator predictions, and reasonable agreement is seen in the full rapidity interval. However in the most central (forward) rapidity region the $f(Q_0)$ predicted by MC@NLO [10] is larger (smaller) than that measured in data. Furthermore the predictions from the ACERMC [11] generator with varied PYTHIA [12] parton shower parameters are compared to data, and is shown on the right plot in Figure 1 where the data points and therefore the statistical uncertainties are correlated. As a results of this measurement ATLAS has updated it's ISR systematic prescriptions, which will lead to all future ISR systematic uncertainties associated with future measurements being approximately 50% smaller.

6 Summary

These proceedings present various measurements of $\sigma_{t\bar{t}}$, including a statistical combination of the lepton+jets, dilepton and all-hadronic channels, and measurements in the $t\bar{t} \to \tau_{had}$+jets and all-hadronic channels, all agreeing well with SM predictaions. A study on the jet activity in $t\bar{t}$ events was performed resulting in a 50% reduction in future measurements' ISR systematic uncertainties.

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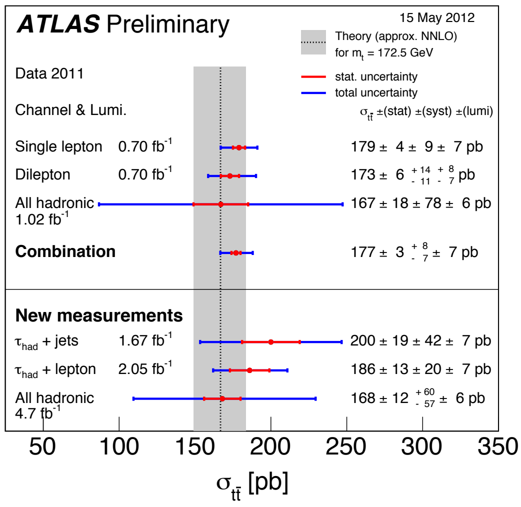

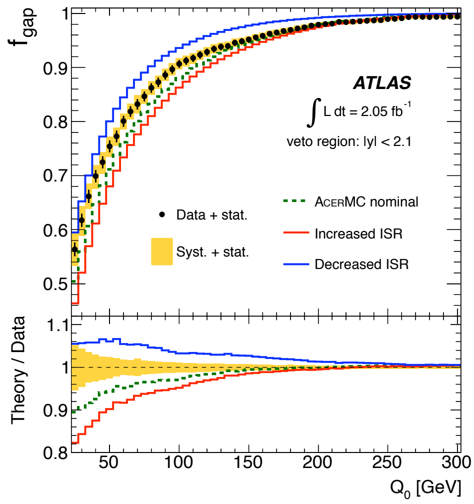

Figure 1: The left plot [3][13] shows a summary of $\sigma_{t\bar{t}}$ measurements compared to the theoretical expectation, including the individual and combined measurements (upper part) and the new measurements (lower part) including the $\tau_{\rm had}$+lepton [14] channel. The right plot [9] shows the measured $f(Q_0)$ compared with the ACERMC prediction, where PYTHIA parton shower parameters are varied to produce samples with nominal, increased and decreased ISR.

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