Top Quark Pair Production Cross Section Measurement at LHC with ATLAS

Alexander Doxiadis on behalf of the ATLAS Collaboration

Nikhef, Science Park 105, 1098 XG Amsterdam, the Netherlands

Several approaches for measuring the top quark pair production cross section with the ATLAS detector, designed for the early data taking period and therefore quite simple, are presented here, using decays with one or two leptons (electrons and muons) in the final state. Both in the single lepton and the dilepton channels the measurement is performed without identifying jets originated from a b-quark. The study aims to establish a top signal at the LHC.

1 Introduction

At the LHC, top quark pairs ($t\bar{t}$) will be produced mainly via gluon fusion (∼87%). The cross section for $t\bar{t}$ production has been calculated at an approximate next-to-NLO (NNLO) with next-to-NLL (NNLL) resummation for $\sqrt{s}$=10 TeV, m_{top}=172.5 GeV and using the CTEQ6.5 PDF's [1]: $\sigma^{NNLOapprox}_{pp\to t\bar{t}} = 401.6 \; ^{+3.6\%}_{-4.3\%}$ (scale) $^{+4.6\%}_{-4.5\%}$ (PDF) pb. Only decay channels of the $t\bar{t}$-pair that produce at least one electron or muon have been investigated. Presented here are commissioning analyses for $\sqrt{s}$=10 TeV and an integrated luminosity of 200 pb^{-1} that do not make use of b-tagging [2, 3].

2 Single Lepton Channel

2.1 Cut and Count method and fit method

The baseline analysis in the semi-leptonic channel consists of two complementary methods: the cut and count method and the fit method. Both methods analyze events that pass the following selection criteria: a single high-p_T lepton trigger, one isolated high-p_T lepton (e, μ) with $p_T > 20$ GeV, $\not{E}_T > 20$ GeV, four jets with $p_T > 20$ GeV of which three jets with $p_T >$ 40 GeV. The hadronic top mass is then reconstructed by taking the invariant mass of the three jet combination, M_{jjj}, with the highest vector-summed p_T. At least one di-jet combination is required to be compatible with the W-boson mass: $|M_{jj} - M_W| < 10$ GeV.

In the cut and count method the cross section is calculated by counting the selected events in the three-jet invariant mass (M_{jjj}) plot, subtracting the expected number of background events and dividing by the expected efficiency and luminosity. In Figure 1 (left) the expected distribution of the three-jet invariant mass is shown. The main background for this analysis is

W+jets which can be determined from data. The largest systematic uncertainty, $\sim 10\%$, comes from the uncertainty in the jet energy scale (JES).

In the fit method, the M_{jjj} distribution is modeled by a Gaussian on top of a Chebychev polynomial. In Figure 1 (right) the likelihood fit of the three-jet invariant mass in the muon channel is shown. The cross section is then the number of events under the peak divided by the efficiency and the luminosity. The largest expected uncertainty, $\sim 13\%$, comes from the uncertainty in the amount of initial and final state radiation (ISR and FSR).

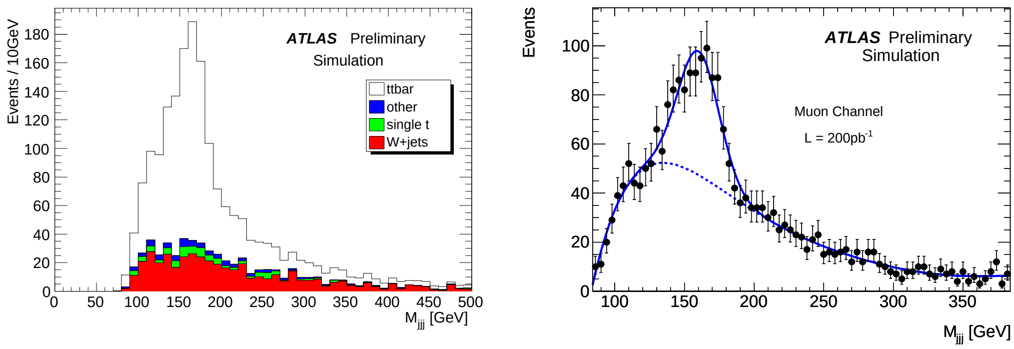

Figure 1: Left: expected distribution of the three-jet invariant mass in the electron channel after the standard selection and the M_W-cut, normalized to 200 pb^{-1}. Right: the likelihood fit in the three-jet invariant mass in the muon channel. The statistics correspond to an integrated luminosity of 200 pb^{-1}.

2.2 Variant analysis

The variant analysis does not rely on the $\not{E}_{\mathrm{T}}$-variable. The selection requires: single high-$\mathrm{p_T}$ lepton trigger, one isolated central lepton (e, μ) with $\mathrm{p_T}(\mathrm{e}) > 40$ GeV or $\mathrm{p_T}(\mu) > 30$ GeV, four jets with $\mathrm{p_T} > 20$ GeV of which three jets with $\mathrm{p_T} > 40$ GeV and HT2 > 160 GeV (the scalar sum of the $\mathrm{p_T}$ of the lepton, 2^{nd}, 3^{rd} and 4^{th} jet). The cross section is determined by either a cut and count analysis or a template method. In the template method three templates are used to fit the data in M_{jjj}: $\mathcal{D}_{data} = A \times \mathcal{D}_{t\bar{t}} + B \times \mathcal{D}_{W,QCD} + C \times \mathcal{D}_{other}$, where $\mathcal{D}_{W,QCD}$ is the weighted sum of W+jets and QCD and $\mathcal{D}_{other}$ includes single top and Z+jets. The largest systematic uncertainty, $\sim 12\%$, comes from the uncertainty in the JES.
The expected uncertainties on the cross section for the muon channel (electron results are similar) are:

Cut&Count	3 (stat)	$^{+12}_{-15}$ (syst)	± 22 (lumi)	%
Likelihood fit	15 (stat)	$^{+6}_{-15}$ (syst)	± 20 (lumi)	%
Variant Cut&Count	3 (stat)	$^{+20}_{-20}$ (syst)	± 23 (lumi)	%
Variant Template	6 (stat)	$^{+9}_{-15}$ (syst)	± 20 (lumi)	%

3 Dilepton Channel

The following cuts are used: a single high-p_T lepton trigger, two oppositely charged isolated leptons (e, μ) with $p_T > 20$ GeV, $\not\!\!E_T > 35$ GeV ($\not\!\!E_T > 20$ GeV in the $e\mu$ channel) and two jets with $p_T > 20$ GeV. A Z-mass veto is used in the ee and $\mu\mu$ channels: $|M_{l^+l^-} - M_Z| > 5$ GeV. Any remaining backgrounds after the selection cuts will be estimated using data-driven methods. After selection the largest background is Z+jets ($\mu\mu$) and fake leptons from jets ($ee, e\mu$).

The method to extract the cross section is a cut and count method, where the result is given by a maximum likelihood estimate. All uncertainties are combined through a likelihood function for each channel. These are fitted and the final sensitivity is obtained from a profile likelihood ratio. In Figure 2 the log-likelihood curves for the ee channel is shown.

For the ee and $e\mu$ channels the largest expected uncertainty, $\sim 6-10\%$, is coming from the uncertainty in the fake rate. In the $\mu\mu$ channel uncertainty in the muon efficiency and the signal generator gives the largest expected uncertainty, $\sim 5\%$ each. The expected uncertainties on the cross section are:

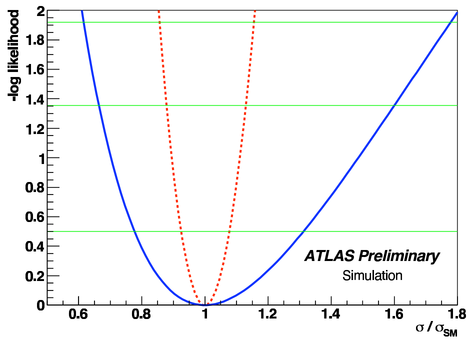

Figure 2: The log-likelihood curves for the ee channel. The solid dark curve is the log of the profile likelihood ratio - $\log\lambda(\sigma_{Sig})$, which includes all sources of systematics. The dotted light curve is the log of the likelihood ratio - $\log r(\sigma_{Sig})$, which was derived including only statistical uncertainties.

ee channel	8 (stat)	$^{+14}_{-13}$ (syst)	$^{+26}_{-17}$ (lumi)	%
$\mu\mu$ channel	6 (stat)	$^{+10}_{-9}$ (syst)	$^{+26}_{-17}$ (lumi)	%
eμ channel	4 (stat)	$^{+10}_{-9}$ (syst)	$^{+26}_{-17}$ (lumi)	%
combined	3 (stat)	$^{+10}_{-9}$ (syst)	$^{+26}_{-17}$ (lumi)	%

4 Conclusions

It has been shown that with a luminosity of 200 pb^{-1} it is possible to measure the top quark pair production cross section with complementary analyses, both in the single lepton and dilepton channels, while being conservative in the evaluation of the systematic uncertainties assuming a detector not working yet at its best. Understanding top quark production is a stepping stone towards understanding the ATLAS detector, the Standard Model and finally new physics.

References

[1] Sven Moch and Peter Uwer. Theoretical status and prospects for top-quark pair production at hadron colliders. *Phys. Rev.*, D78:034003, 2008.

[2] The ATLAS collaboration. Prospects for the top pair production cross-section at $\sqrt{s}$=10 TeV in the single lepton channel in ATLAS. ATL-PHYS-PUB-2009-087.

[3] The ATLAS collaboration. Prospects for measuring top pair production in the dilepton channel with early ATLAS data at $\sqrt{s}$=10 TeV. ATL-PHYS-PUB-2009-086.