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Top quark pair production at the LHC with the ATLAS detector

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on behalf of the ATLAS collaboration

We present a study of the prospects for measuring the $t\bar{t}$ production cross-section with the ATLAS detector, using decays with one or two leptons (electrons and muons) in the final state. The cross section is measured in the single lepton channel (e+jets, μ+jets) and the dilepton channel not making use of the identification of jets from b-quarks. The measurements aim to re-establish the top signal at the LHC with first data.

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1. Introduction

The top quark pair production cross section will be measured in the two most promising decay channels of the top quark characterized by the subsequent decay of the W bosons: The dilepton channel and the single-lepton channel. In the following the two decay channels and the sensitivity of the analyses [1] with ATLAS [2] with early data ($100\,\mathrm{pb}^{-1}$) at 14 TeV are presented.

2. Dilepton channel

The characteristic dilepton signature is given by two opposite charged leptons from the W decay and at least two jets from the hadronisation of the two b-quarks as well as a large amount of missing transverse energy ($\not{E}_T$) from the neutrinos. Although the branching ratio is only about 5%, the dilepton channel has a very clean signature with the two leptons that give a very high trigger efficiency for the event.

The leptonically decaying Z boson in Drell-Yan events are an important background process for the dileptonic subchannels with same flavor leptons. A very similar signature to the signal is produced by diboson (W/Z) decays. Background processes that arise by misidentified leptons are $t\bar{t}$ single-lepton events, singly produced top, leptonically decaying W bosons with accompanying jets (W+jets).

A simple analysis based on cuts on the lepton p_T, jet p_T and on $\not{E}_T$ has been optimized for the best $S/\sqrt{S+B}$. Exactly two good, calorimeter isolated leptons within the tracker acceptance are required. Events with same flavored leptons and an invariant dilepton mass compatible with the Z mass were rejected. The optimized results require cuts of $p_T > 20$ GeV for all visible objects and $\not{E}_T > 35$ GeV for ee and $\mu\mu$ channel and 25 GeV for the $e\mu$ channels. A S/B of 3:1 up to 6:1 is achieved.

A second method employs the different shapes of signal and background in selected observables, such as $|\Delta\varphi|$ between the highest p_T lepton and the $\not{E}_T$ vector, and $|\Delta\varphi|$ between the highest p_T jet and the $\not{E}_T$ vector. A likelihood fit can determine the fraction of signal and background events in the total sample by fitting to the total event shape.

An alternate inclusive template method uses histograms based on the two-dimensional distributions of the $\not{E}_T$ and the jet multiplicity for the three dominant sources of $e\mu$ dileptons, i.e. $t\bar{t}$ dilepton, $Z \to \tau\tau$ and WW. This method requires leptons with tighter isolation criteria and rejects events with $\not{E}_T$ energy aligned with the muon in order to minimize events with misidentified leptons. The final fit has ten variables including the cross sections for the three processes.

3. Single lepton channel

The characteristic signature consists of a single lepton, $\not{E}_T$ from the accompanying neutrino and at least four jets, two from the decaying b-quarks, two from the W boson decay. The channel has high BR of 44% and benefits from a lepton in the signature. The kinematics in this channel is over-constrained, so that the kinematics can be reconstructed from the calorimeter isolated lepton, $\not{E}_T$ and the four jets. The main background processes considered here are W+jets and singly produced tops with a leptonically decaying W.

The selection requires exactly one good, calorimeter isolated lepton within the tracker coverage and $p_T > 20$ GeV and $\not{E}_T > 20$ GeV. At least four jets with $p_T > 20$ GeV of which at least three jets with $p_T > 40$ GeV. The three jets with the highest vectorial p_T sum form the top candidate. Selecting events with m_t of 141 GeV $< m_t <$ 189 GeV gives a purity of 80% and S/B of 2.2 can be achieved.

In the selection of the single lepton events one can exploit the fact that two jets originate from a W and hence the invariant mass gives the W mass. The refined selection requires that at least one of the three two-jet combinations lies within 10 GeV around the W mass value. The S/B improves to ~ 3.3.

The default selection can also be improved by requiring that the three highest p_T jets are confined to $|\eta| < 1$. This may be of interest in case that forward jets are not well understood yet in early data. This variation gives a similar S/B as the W mass constraint.

An exercise with the requirement of one b-tagged jet shows that a S/B of almost 10 can be achieved, but would rely on b-tagging which might not be well understood with early data.

The number of signal events in the peak can be determined by a maximum likelihood fit of the distribution. The distribution of the invariant mass of the top candidates is composed of a Gaussian peak and a background distribution that can be described by a Chebychev-polynomial. This method is competitive to the cut and count method, but the sensitivities to systematics are different. This analysis is not sensitive to the background normalisation, but it needs a good understanding of the jet multiplicities in signal events.

4. Systematic uncertainties

The main common systematic uncertainties that are considered are as follows: The effect of the jet energy scale uncertainty was estimated by rescaling all reconstructed jet vectors by ±5% and changing $\not{E}_T$ to preserve the total transverse momentum in the event. Initial and final state radiation (ISR/FSR) was investigated with fast simulated samples in which ISR and FSR parameters were increased by 100% or halved. Finally the uncertainties from PDF variations were investigated by reweighting the events with the probability of both initial partons evaluated at the same x_1, x_2 and Q^2 value as in the generated event but with the error PDFs provided by the CTEQ and MRST collaboration. The error was evaluated by the Hessian approach [3].

5. Summary

The following table summarizes the anticipated statistical and systematic errors evaluated at an integrated luminosity of $100\,\mathrm{pb}^{-1}$:

- dilepton channel:

$$\text{Cut and Count method: } \Delta\sigma/\sigma = (4(\text{stat})^{+5}_{-2}(\text{syst}) \pm 2(\text{pdf}) \pm 5(\text{lumi}))\%$$

$$\text{Template method: } \Delta\sigma/\sigma = (4(\text{stat}) \pm 4(\text{syst}) \pm 2(\text{pdf}) \pm 5(\text{lumi}))\%$$

$$\text{Likelihood method: } \Delta\sigma/\sigma = (5(\text{stat})^{+8}_{-5}(\text{syst}) \pm 2(\text{pdf}) \pm 5(\text{lumi}))\%$$

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- single lepton channel:

$$\text{Cut and Count method: } \Delta\sigma/\sigma = (3(\text{stat}) \pm 16(\text{syst}) \pm 3(\text{pdf}) \pm 5(\text{lumi}))\%$$
$$\text{Likelihood method: } \Delta\sigma/\sigma = (5(\text{stat}) \pm 15(\text{syst}) \pm 3(\text{pdf}) \pm 3(\text{lumi}))\%$$

The two analyses were updated after this conference assuming a center-of-mass energy of 10 TeV and a sample of $200\,\text{pb}^{-1}$ of data [4, 5].

References

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