Estimation of Top Background to Supersymmetry Searches from Data

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The Standard Model process of $t\bar{t}$ production is one of the most important backgrounds in searches for Supersymmetry (SUSY) at the LHC. We describe some of the methods to estimate it with the first data of the ATLAS experiment. The performance of the methods has been evaluated with simulated data.

1 Introduction

High-energy jets, missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$) and possibly leptons are the typical signature of R-parity conserved SUSY events at the LHC. The observation of deviations from the Standard Model may manifest the presence of SUSY. Due to the limited knowledge of Standard Model cross-sections, parton distribution functions, underlying event and parton showering at the LHC energy scale, as well as insufficient knowledge of the ATLAS detector itself, a reliable prediction of the Standard Model backgrounds should be derived mainly from the experimental data. In this note we present an overview of some of data-driven methods developed recently to estimate $t\bar{t}$ background in SUSY searches with zero, one or two isolated leptons, energetic jets and significant missing transverse energy. Due to lack high energy data, this note only deals with Monte Carlo simulations.

2 Data-driven methods

There are several kinds of data-driven methods in inclusive SUSY searches. One approach is the so called "ABCD" method, which is using a pair of uncorrelated variables with good signal versus background separation power and extrapolating the background from a background-dominated control region into the signal region. Another approach is called "Replacement Method". The example of this approach is the estimation of $Z \to \nu\nu$ background in the no-lepton mode from $Z \to \ell\ell$ ($\ell = e, \mu$) by replacement of leptons by neutrinos.

3 $t\bar{t} \to b\bar{b}l\nu l\nu$ in the two-lepton SUSY search mode

Monte Carlo studies show that $t\bar{t} \to b\bar{b}l\nu l\nu$ with both W bosons decaying leptonically is the dominant Standard Model background in the two-lepton SUSY search mode. The method of

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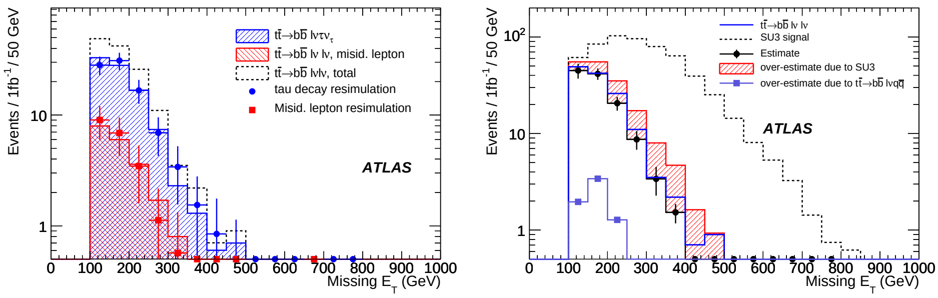

Figure 1: Left: $E_{\rm T}^{\rm miss}$ distribution of $t\bar{t} \to b\bar{b}l\nu l\nu$ events passing the one-lepton mode selection (open histogram) and fractions of events with a tau lepton (left hatching), a lost lepton (right hatching), compared to the estimate of these fractions from the data-like sample. Right: $E_{\rm T}^{\rm miss}$ distribution of $t\bar{t} \to b\bar{b}l\nu l\nu$ from MC prediction and from data-driven estimation with and without the presence of a SUSY signal with 1 fb^{-1} at 14 TeV (SU3 is a mSUGRA benchmark point with 650-700 GeV squark and gluino masses).

estimation of it is to select a control sample with pure $t\bar{t} \to b\bar{b}l\nu l\nu$ events by requiring at least one jet pair fulfilling the system of $t\bar{t} \to b\bar{b}l\nu l\nu$ kinematic equations.

$$\begin{aligned} m_W^2 &= (p_{l1} + p_{\nu 1})^2 \\ m_W^2 &= (p_{l2} + p_{\nu 2})^2 \\ m_t^2 &= (p_{l1} + p_{\nu 1} + p_{b1})^2 \\ m_t^2 &= (p_{l2} + p_{\nu 2} + p_{b2})^2 \\ E_x^{miss} &= p_{(\nu 1)x} + p_{(\nu 2)x} \\ E_y^{miss} &= p_{(\nu 1)y} + p_{(\nu 2)y} \end{aligned} \tag{1}$$

Then “ABCD” method is applied with number of jet pairs satisfying the system of equation (1) and $E_{\rm T}^{\rm miss}$ as two uncorrelated variables.

4 $t\bar{t} \to b\bar{b}l\nu l\nu$ in the one-lepton SUSY search mode

The dominant background in the one-lepton SUSY search mode is $t\bar{t}$ events with both W bosons decaying leptonically, where one lepton can be missing mainly because it is τ or not reconstructed electron or muon. The method of estimation of these two contributions is based on the “seed sample” with pure $t\bar{t} \to b\bar{b}l\nu l\nu$ extracted from data similar to the above section. The contribution from the events with W decaying into τ is estimated by replacing one of the lepton in the “seed sample” with a τ lepton and simulating the tau lepton decay. To estimate the contribution from the not reconstructed leptons, if the lepton is an electron, we replace the electron of the seed event by a jet reconstructed along with the electron, otherwise if the lepton is a muon, we remove the lepton from seed sample. Lepton identification efficiency is taken into account and all variables are recalculated. Fig. 1 (right) shows the $E_{\rm T}^{\rm miss}$ distribution of $t\bar{t}$ background compared to the data-driven estimates. The statistical (systematic) uncertainty of the method is estimated to be 12% (21%) for an integrated luminosity of 1 fb^{-1} [1].

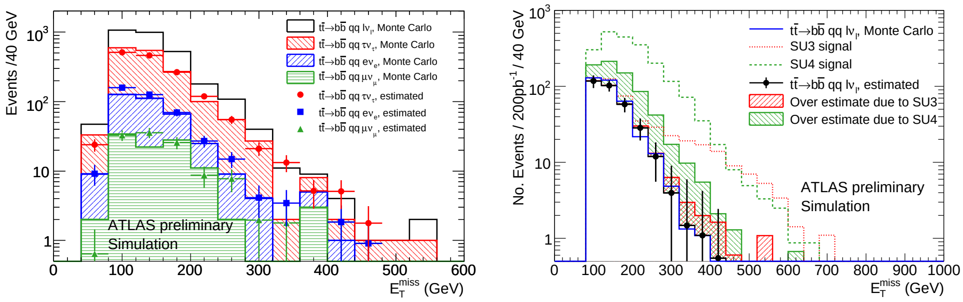

Figure 2: Left: $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution of $t\bar{t} \to b\bar{b}l\nu q\bar{q}$ events (open histogram) and fractions of events with a tau lepton (left hatching), a lost electron (right hatching) and a lost muon (horizontal hatching), compared to the estimate of these fractions from the data-like sample. Right: $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution of $t\bar{t} \to b\bar{b}l\nu q\bar{q}$ from MC prediction and from data-driven estimate with and without the presence of a SUSY signal with 200 pb^{-1} at 10 TeV (SU4 is a mSUGRA benchmark point with 400 GeV squark and gluino masses).

5 $t\bar{t} \to b\bar{b}l\nu q\bar{q}$ in the no-lepton SUSY search mode

Monte Carlo simulations show that the $t\bar{t} \to b\bar{b}l\nu q\bar{q}$ channel gives an important contribution to the Standard Model background in the no-lepton mode, where the lepton can be missing due to the lepton being a tau lepton or a non-identified electron or muon. The method of estimation of these two contributions is based on the "seed sample" enriched by the $t\bar{t} \to b\bar{b}l\nu q\bar{q}$ events extracted from the data. The replacement procedure is very similar to the above section. Fig. 2 (right) shows the $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution of $t\bar{t} \to b\bar{b}l\nu q\bar{q}$ background compared to the data-driven estimates. The statistical (systematic) uncertainty of the method is estimated to be 8% (36%) for an integrated luminosity of 200 pb^{-1} [2].

6 Conclusion

Several complementary methods of background estimation are an important ingredient of SUSY discovery. Data-driven methods for top background estimation in the no, one and two-lepton SUSY search modes have been developed and tested with the Monte Carlo simulation.

References

[1] G. Akimoto *et al.*, *Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics*, CERN-OPEN-2008-020, 1525-1561 (2009).

[2] Data-Driven Determination of $t\bar{t}$ Background to Supersymmetry Searches in ATLAS, ATLAS Public Note, ATL-PHYS-PUB-2009-083 (2009)