PROCEEDINGS OF SCIENCE

PoS(EPS-HEP 2009)424

New developments in data-driven background determination for supersymmetry searches in ATLAS

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The LHC will open a whole new window on supersymmetry (SUSY) searches, probing energies where also the Standard Model (SM) behavior is unknown. To find evidence for physics beyond the SM like SUSY, the first challenge is to understand the backgrounds from SM processes at high energy.

To this end we present a method that determines the background using as little information from Monte Carlo simulation as possible. We construct three-dimensional models for the three main backgrounds. These models are created such that known and understood physics features, like a top or W mass peak, are incorporated. We parametrize these models, and fit them to our data set. By floating the shape parameters in the models, we minimize our dependence on the Monte Carlo information.

We can show that this method can determine the composition of the background accurately. By fitting to the data in a control (sideband) region, with low S/B, and extrapolating to a region with high S/B, we can reliably predict the expected number of background events in the signal region, and determine the significance when an excess caused by SUSY events would be found. We can show that this method works even when SUSY events contaminate the control region.

The 2009 Europhysics Conference on High Energy Physics,
July 16 - 22 2009
Krakow, Poland

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1. Introduction

Supersymmetry (SUSY) is an extension to the Standard Model (SM) that predicts high mass supersymmetric partners to all SM particles. In the case of broken symmetry, these particles are expected to have masses of the order of 1 TeV. It is not possible to confidently claim discovery of particles without a thorough understanding of the SM at these high energies. This method aims at understanding the SM without relying too much on Monte Carlo (MC) simulations.

This method is developed to use data from the ATLAS detector at the LHC. The ATLAS[1] detector is designed to cover a large range of the possibilities for new particles and phenomena, such as SUSY. The LHC[2] is designed to collide protons at an energy of 14 TeV.

If SUSY exists large numbers of squarks and gluinos will be created at the LHC, which will decay in several steps to the lightest SUSY particle (LSP). This will show in the detector as large numbers of energetic jets and leptons. We assume that the LSP is stable (due to *R-parity* conservation), which results in high E_T^{miss}. We can use these signatures to distinguish SUSY from many backgrounds. In addition, we define two variables besides E_T^{miss} to study SUSY:

- M_T = invariant mass of the transverse component of the lepton momentum and P_T^{miss}
- M_{top} = invariant mass of 3 jets with highest $\Sigma\vec{P}_T$

2. Approach

We start out by defining a L-shaped region in M_T/E_T^{miss}space where there are many background and relatively few SUSY events. We try to determine the amount of background events in this region, taking a small contamination from SUSY into account. If we can extrapolate this background yield to a SUSY-rich signal region, we have an estimate for the expected number of background events in that region, wich we can compare to the measured number of events.

The Combined Fit Method aims at determining the contributions of all three important backgrounds in the control region at once. These backgrounds are W+jets, semileptonic and dileptonic $t\bar{t}$. For each background, the shapes of three observable distributions (E_T^{miss}, M_T and M_{top}), which display distinct physics features such as top and W mass, are parameterized. This gives three 3D probability density functions (PDF), which are combined into one model. By fitting these parameters to data instead of fixing them from simulation, we reduce the dependence of this method to MC. Figure 1 shows the distributions in the three observables of the three components of the background model.

To study the vast phase space of SUSY, ATLAS fixed several benchmark points in the SUSY parameter space. Since the distributions of M_T and E_T^{miss} of a given SUSY benchmark point depends mainly on the SUSY mass scale of that point, and since most points that were studied here have a similar, high mass scale, we can make an ansatz for the shape of the E_T^{miss} and M_T distribution, which we add to the 3D model used in the fit to take contamination of SUSY events in the control region into account.

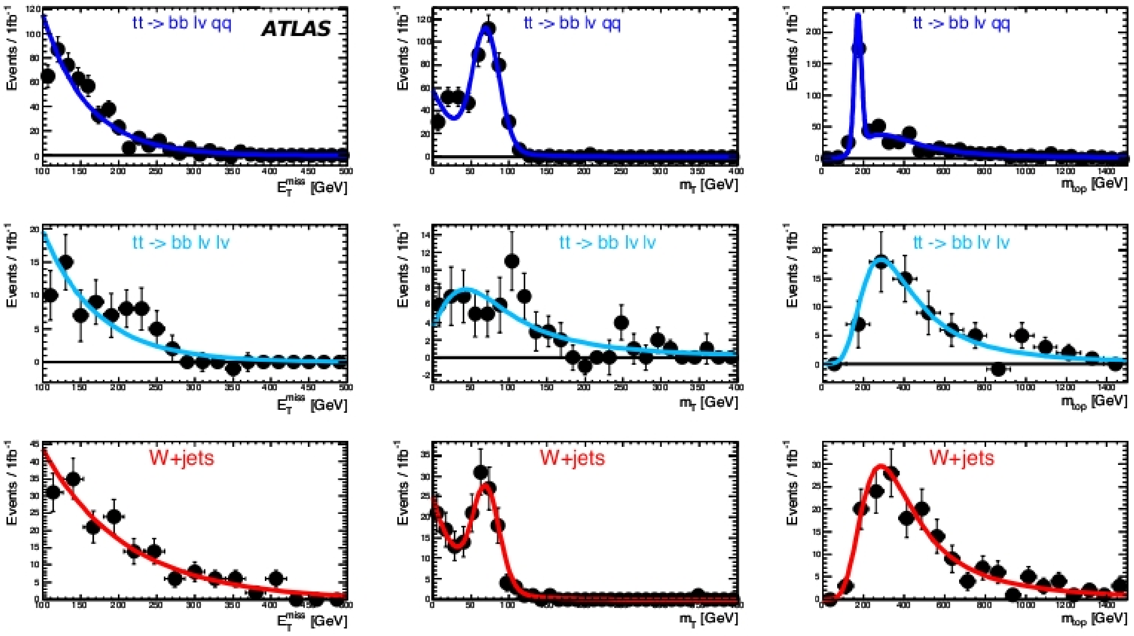

Figure 1: Distribution in the three observables of the three components of the background model

3. Results and Conclusions

To test the combined fit method, we take some combination of the background and signal MC as 'data'. We then fit the combined PDF to this data, floating as many shape parameters as possible. For all high mass SUSY benchmark points we correctly predict the number of background and SUSY events in the signal region. We have shown that this fit result is unbiased using a toy MC study. For detailed results, see the reference [3].

Because the Standard Model has never been tested at LHC energies, we assume that Monte Carlo predictions will not be sufficient to understand and control SM backgrounds. This fit based approach to estimate SM background from data and determine a possible excess due to Supersymmetry looks promising. We are now testing this method outside the ATLAS benchmark points and trying to stabilize the contribution of the dileptonic $t\bar{t}$ background. We are also working on making this method robust enough to use at lower statistics (lower integrated luminosity), and to generalize the ansatz to use at all SUSY mass scales. Thus we hope to apply this method to the very first LHC data.

References

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[3] The ATLAS collaboration, *Expected performance of the ATLAS experiment: detector trigger and physics*, *CERN-OPEN* **020** (2008) [`hep-ex:0901.0512`]