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The Compact Muon Solenoid Experiment

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DETERMINATION OF INVISIBLE Z BOSON+JETS BACKGROUND TO HADRONIC SUSY SEARCH

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Abstract

One of the most popular models beyond the Standard Model (SM) is Supersymmetry (SUSY). In many such models, decay chains of gluinos and squarks lead to the production of two Lightest Supersymmetric Particles (LSPs), which pass through the detectors without interactions. Thus, a classic signature of SUSY is the presence of events with large missing transverse energy (E_T^{miss}) and multiple jets. Many SM processes produce the same signatures and form background to SUSY signal. Z boson+jets production with $Z \to \nu\nu$ is one such process. The $Z \to \nu\nu$ background can be estimated by measuring the same process but where Z boson decaying into an opposite sign same flavour (OSSF) lepton pair (LP). In this study lepton pair is $\mu^+\mu^-$. We present procedures to estimate this background directly from data exclusively and also using a combination of data and simulated events. These studies were performed using simulated event samples at $\sqrt{s}$=14 TeV.

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1 Introduction

One of the most popular models beyond the Standard Model is the Supersymmetry, SUSY. All SUSY particles in a model with R parity conservation eventually decay to the Lightest Supersymmetric Particles (LSPs) [1]. R parity is a multiplicative quantum number, $R = (-1)^{3(B-L)+2s}$, where s is the spin, B is the baryon and L is the lepton numbers for each particles. R parity is 1 for all SM particles and -1 for SUSY particles. If R parity is conserved, the LSP is stable and leaves the detector without interacting, leading to large E_T^{miss}. The jets are generated in the hadronic decays of the squark and/or gluino decays. Therefore, a classic signature of SUSY is multi-jet events associated with a large missing transverse energy, E_T^{miss}. There are many SM processes which give rise to same signature and thus are background to the SUSY signal. Thus an accurate determination of the SM processes is essential part of the SUSY search. The main background to the jet-MET topology arises from QCD dijet production, $t\bar{t}$ production and Z+jet production where Z boson decays into neutrinos.

The Z boson+jet events where Z boson decays into neutrinos represent an irreducible background. The size of this background must be estimated and then subtracted from the final distributions. A method to estimate this background by first measuring the amount of events with a Z boson decaying to muons, and with at least three jets as required in the search for SUSY signal with jet-MET topology [2]. This number of events is then scaled by the theoretical ratio of $\Gamma(Z \to \nu\nu)$ and $\Gamma(Z \to \mu\mu)$ to find the estimated size of the $Z \to \nu\nu$+jets background to SUSY signal. Selection requirements for muons are $P_T^{Muons} \geq$20 GeV/c and $|\eta^{Muons}| <$2.4. The efficiency of the muon selection will be determined in the data using the Tag-and-Probe technique.

2 CMS and LHC

The Compact Muon Solenoid (CMS) detector is a multi-purpose apparatus due to operate at the Large Hadron Collider (LHC) at CERN. The major CMS features are the large silicon pixel and strip tracking system, which is embedded together with the lead-tungstate crystal electromagnetic and the brass-scintillator hadronic calorimeter in a 4 Tesla solenoid. The LHC is presently being constructed in the already existing 27 km LEP tunnel in the Geneva region. It will yield head-on collisions of two proton beams of 7 TeV each, with a design luminosity of 10^{34} cm^{-2}s^{-1}. More information can be found in Ref. [3].

3 Samples and event selection

We use $Z \to \mu\mu$+jets events generated with PYTHIA for various ranges of the tranverse momentum of the Z boson. The muons are required to have $P_T \geq$20 GeV/c and $|\eta| \leq$2.4. The event selection in analysis is $N_{jet} \geq$3, $P_T^{jet} >$30 GeV/c, $|\eta^{jet}| <$3 rad and $R_{1,2} >$0.5 rad, where $R_1 = \sqrt{\delta\phi_2^2 + (\pi - \delta\phi_1)^2}$ and $R_2 = \sqrt{\delta\phi_1^2 + (\pi - \delta\phi_2)^2}$, $\delta\phi_{1,2} = |\phi_{1,2}^{jet} - \phi(E_T^{miss})|$. The Z-boson is identified as the pair of muons that has an invariant mass within 20 GeV/c^2 of the Z-boson mass pole of 91.2 GeV/c^2.

4 Estimation procedure

We take advantage of the fact that in the Standard Model the $Z \to \nu\nu$+jets events have the same kinematic characteristics as the $Z \to \mu\mu$+jets events and they have only different production rates. According to theoretical calculations, a Z boson decays into any pair of neutrinos 5.95 [4] times more often than into a pair of muons. Therefore one can estimate N_μ, the number of events where a Z boson decaying to muons is produced, and then multiply this number by the ratio of $\Gamma(Z \to \nu\nu)$ and $\Gamma(Z \to \mu\mu)$ to obtain an estimate of N_ν, the number of events where a Z boson decaying to neutrinos is produced.

$$N_\nu = N_\mu \times \frac{\Gamma(Z \to \nu\nu)}{\Gamma(Z \to \mu\mu)} \tag{1}$$

where N_μ is the acceptence- and efficiency-corrected number of $Z \to \mu^+\mu^-$ events in the sample.

Jet mismeasurements create fake E_T^{miss} and second or third jets are generally mismeasured ones in QCD dijet events. In such cases, the direction of E_T^{miss} tends to be aligned with a jet. Azimuthal direction (ϕ) of second or third jets are close to the phi of E_T^{miss} direction. The 2-dimensional requirements for the correlation variables are shown in Figure 1. Low Mass Point 1 (LM1) is a particular mSUGRA benchmark point used by CMS. The values for $R1$ and $R2$ are used to clean QCD events.

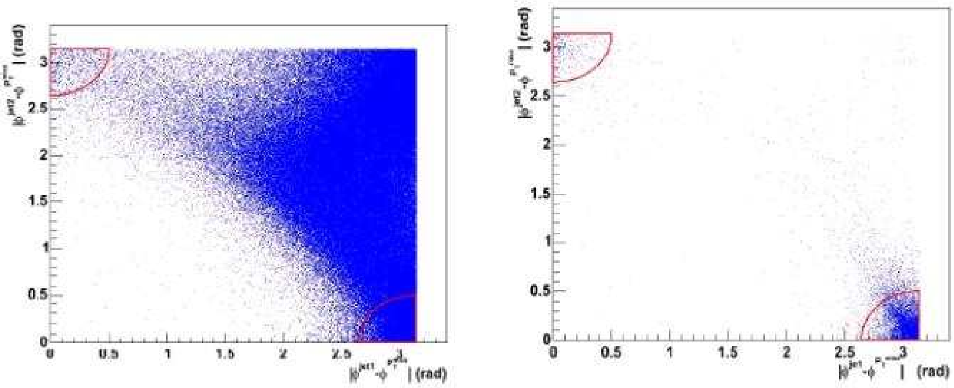

Figure 1: The angular correlation between the first and second jet, and E_T^{miss} in LM1 sample (left) and QCD dijet (right).

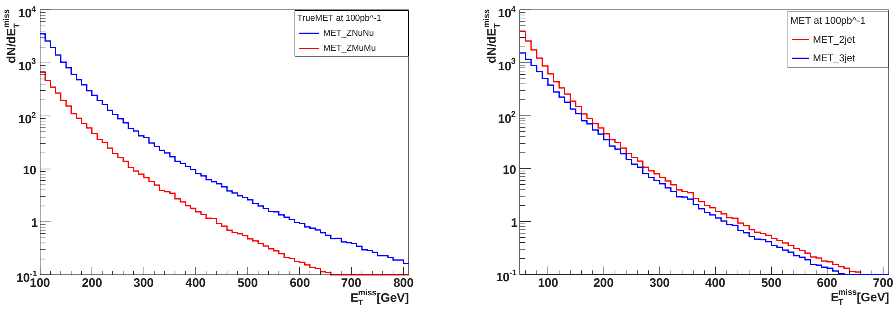

Figure 2: E_T^{miss} in $Z \to \nu\nu$ and $Z \to \mu\mu$ samples(right) and for 2,and 3 jets in the events in $Z- > \mu\mu$ samples (left).

E_T^{miss} distributions are shown in the Figure 2 (left) in $Z \to \nu\nu$ and $Z \to \mu\mu$ samples for 100 pb^{-1}. The event rate in $Z \to \nu\nu$ is higher than the event rate in $Z \to \mu\mu$ samples. The ratio of event rates should be closed to the theoretical value which was given in Section 4. If events have 2 jets and 3 jets E_T^{miss} distribution in $Z \to \mu\mu$ is shown in Figure 2 (right) for 100 pb^{-1}.

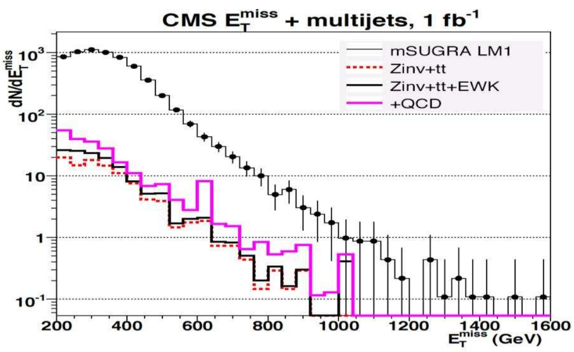

Figure 3: E_T^{miss} LM1 signal and Standard Model background distributions.

5 Conclusion

E_T^{miss} distributions in LM1 signal and Standard Model backgrounds are shown in Figure 3. The size of the SM backgrounds are smaller than the signal size and the high energy of the LHC provides significant discovery reach for SUSY models. CMS has developed inclusive search strategies as well as more dedicated searches for Supersymmetry, that can not all be possible discussed in these procedings.

References

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