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Searching for SUSY with multijets and missing trasnverse momentum

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Abstract

The proton-proton collisions at $\sqrt{s}$=13 TeV at the LHC, CERN provide an unique opportunity to search for new particles. An inclusive search for supersymmetry is performed in final states containing multiple jets and missing transverse momentum using 12.9 data collected by the CMS experiment in the year 2016. The main backgrounds originating from standard model processes are estimated using data driven methods. The results are interpreted in a variety of simplified models of pair production of supersymmetric particles.

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Searching for SUSY with multijets and missing transverse momentum

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Abstract

The proton-proton collisions at $\sqrt{s}$=13 TeV at the LHC, CERN provide an unique opportunity to search for new particles. An inclusive search for supersymmetry is performed in final states containing multiple jets and missing transverse momentum using 12.9 fb^{-1} data collected by the CMS experiment in the year 2016. The main backgrounds originating from standard model processes are estimated using data driven methods. The results are interpreted in a variety of simplified models of pair production of supersymmetric particles.

1 Introduction

Supersymmetry (SUSY) is a popular extension of the standard model (SM) of elementary particles and it proposes a superpartner to the every SM particle differing by spin-half. A simple yet wide scope of the SUSY to answer unresolved questions in particle physics has motivated the community to continue searching for the production of SUSY particles in proton-proton collisions at the Large Hadron Collider (LHC). Depending on the SUSY model, the presence of new particles can be manifested in a variety of final states containing jets originating from light flavor quarks or gluons or bottom quarks, and an imbalance in total momentum in direction transverse to the beam direction ($p_{\mathrm{T}}^{\mathrm{miss}}$). A few representative models of production and decay of gluinos and top squarks are shown in Figure 1.

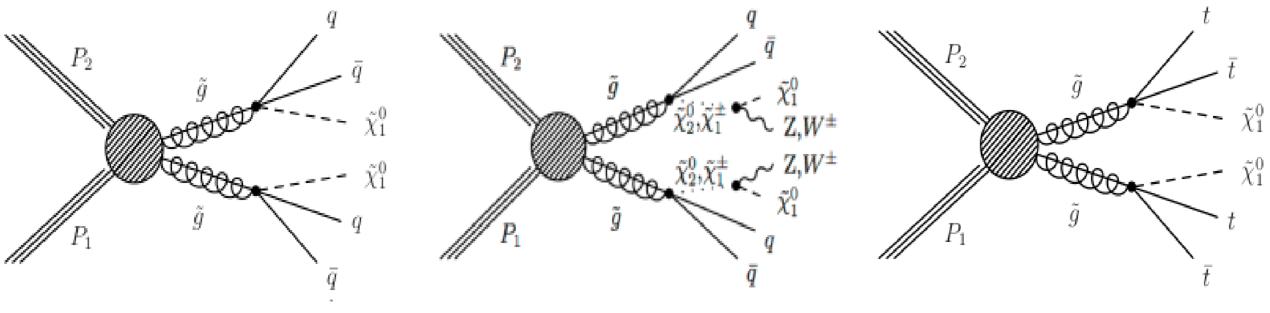

Figure 1: Representative diagrams of the SUSY particle pair production: (left) pp$\rightarrow\tilde{g}\ \tilde{g}$, $\tilde{g}\rightarrow q\bar{q}+\tilde{\chi}_1^0$, (center) pp$\rightarrow\tilde{g}\ \tilde{g}$, $\tilde{g}\rightarrow q\bar{q}+W/Z+\tilde{\chi}_1^0$ via a $\tilde{\chi}_1^\pm$ or $\tilde{\chi}_2^0$, , and (right) pp$\rightarrow\tilde{g}\ \tilde{g}$, $\tilde{g}\rightarrow t\bar{t}+\tilde{\chi}_1^0$ [1]

This report presents an inclusive analysis to search for pair production of gluinos and squark-antisquark pairs using the data from pp collisions at $\sqrt{s}$ = 13 TeV collected by the CMS experiment in 2016 equivalent to an integrated luminosity of 12.9 fb^{-1}. Every gluino and squark decays directly or via a cascade into the quarks and neutralino. The neutralino is assumed to be the lightest SUSY particle, neutral, weakly interacting and stable, hence is a source of true $p_{\mathrm{T}}^{\mathrm{miss}}$ in the events. The quarks and gluons are measured as jets reconstructed from their hadronization productions and those originating from b-quarks are identified using their characteristic displaced vertices. To render this search sensitive to various final state topologies, the search regions are defined using the number of jets with p_{T} >30GeV and $|\eta|$ <2.4, and the number of b-tagged jets with $p_{\mathrm{T}} > 30$ GeV and $|\eta| < 2.4$. In the following, these are denoted by N_{jet} and $N_{\mathrm{b-jet}}$ respectively. Each event is further categorized using scalar sum of p_{T} of jets, H_{T}, and magnitude of negative of vector sum of p_{T} of jets, $H_{\mathrm{T}}^{\mathrm{miss}}$.

2 The SM backgrounds and event selection

Several SM processes can give rise to final states of jets and $p_{\mathrm{T}}^{\mathrm{miss}}$. To select the event likely to be SUSY like, we start with the events with $N_{\mathrm{jet}} \geq 3$, H_{T} >300 GeV, $H_{\mathrm{T}}^{\mathrm{miss}}$ >300 GeV. The Z+jets events in which Z boson decaying to a pair of neutrinos, is an irreducible background as shown in Figure 2 (left). The events containing a W boson, direct production or from decay of top quarks, contribute to the backgrounds if it decays to a lepton (e, μ, or τ) and a neutrino (Fig. 2 center). This background is suppressed by vetoing the events which contain an isolated e, μ, or an isolated track. The QCD multijet

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events are a source of fake $p_{\mathrm{T}}^{\mathrm{miss}}$ resulting from jet mismeasurement or detector malfunctioning as well as true $p_{\mathrm{T}}^{\mathrm{miss}}$ from the semileptonic decay b-hadrons. A characteristic feature of these events is that a high p_{T} jet is aligned with the direction of $H_{\mathrm{T}}^{\mathrm{miss}}$ in azimuth as shown in Figure 2 (right). This background is effectively mitigated by rejecting the events with $\Delta\Phi(\text{jets}, H_{\mathrm{T}}^{\mathrm{miss}}) < 0.3,0.3,0.5,0.5$ for four highest p_{T} jets.

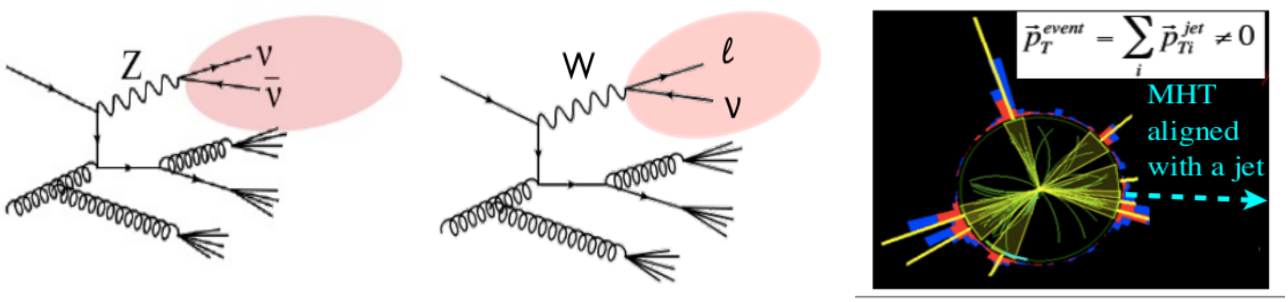

Figure 2: Schematic sketch of SM backgrounds: (left) Z + jets, (center) W + jets, and (right) QCD multijet.

The events surviving the above selections are further categorized in the following bins of N_{jet}: [3-4], [5-6], [7-8], and $\geq$9. For separating the events containing more heavy flavors, we require $N_{\mathrm{b-jet}}$:0,1,2,$\geq$3. Each [N_{jet},$N_{\mathrm{b-jet}}$] bin is further divided into 10 H_{T}-$H_{\mathrm{T}}^{\mathrm{miss}}$ bins as shown in Figure 3. Thus each bin in search region has unique [N_{jet},$N_{\mathrm{b-jet}}$,H_{T},$H_{\mathrm{T}}^{\mathrm{miss}}$] address.

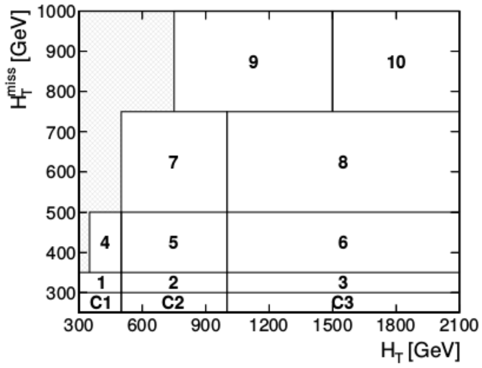

Figure 3: Two-dimensional plane in H_{T} and $H_{\mathrm{T}}^{\mathrm{miss}}$ showing the signal bins and the QCD side-band bins [1]

3 Estimation of backgrounds

Analysis uses data driven technique to estimate the remaining backgrounds in signal region. A method is developed to predict the background yield in signal region from corresponding yield in an orthogonal(signal free) region called control region. Method is validated using Monte Carlo (MC) samples and then applied on data control sample to get background prediction in signal region.

For hadronic tau background estimation $\mu + jets$ sample with exactly one well identified muon is used as a control sample. At the generator level, $\mu + jets$ and τ + jets have similar event kinematics but at detector level μ is reconstructed with good resolution while hadronic τ is reconstructed as a τ jet plus partial contribution to MET from τ neutrino. To account for these differences in the detector response to the two particles, the μ p_{T} is replaced by the response of the τ p_{T} using the response template derived from τ + jets MC events.

The response templates give distribution of the ratio of p_{T} of reconstructed τ jet to p_{T} of gen τ in intervals of gen τ p_{T}. As reconstructed μ is equivalent to gen τ, we replace μ from μ + jets control sample event with response to mimic τ + jets event. The variables N_{jet}, H_{T}, $H_{\mathrm{T}}^{\mathrm{miss}}$ are recalculated after this replacement. Also we account for intrinsic b-mistag probability of τ jet obtained from τ + jets MC sample to redefine $N_{\mathrm{b-jet}}$. A bin defined by new [N_{jet},$N_{\mathrm{b-jet}}$,H_{T},$H_{\mathrm{T}}^{\mathrm{miss}}$] is filled with proper event weight. The Fig. 4 shows validation of hadtau estimation method in 160 search bins. Direct count of hadtau events expected from MC in various bins is compared against those predicted from μ + jets control sample. The method closes well with expectation within 10% on average.

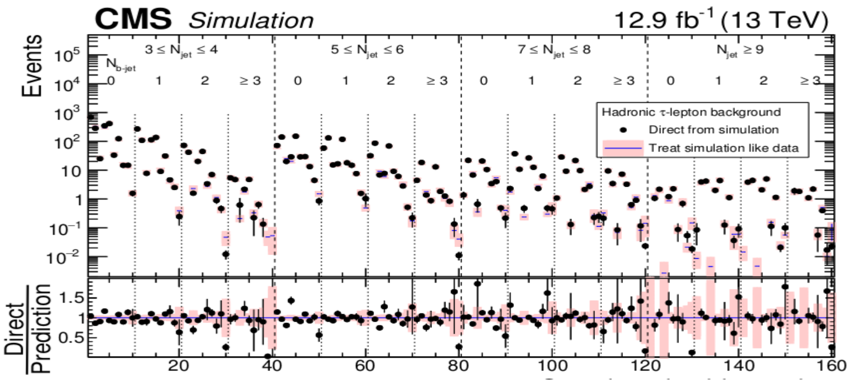

Figure 4: Hadronic τ background in 160 search bins as predicted directly from MC simulation (solid dots) and as predicted by data driven background estimation procedure (shaded regions). Simulation makes use of $t\bar{t}$, W+jets and single top MC event samples.[1]

4 Results and Outlook

Similar to hadronic tau, all background teams validate their prediction method using MC. Then methods are applied on respective control samples from data to get background prediction in data signal region. Figure 5 shows comparison of observed data against various background predictions.

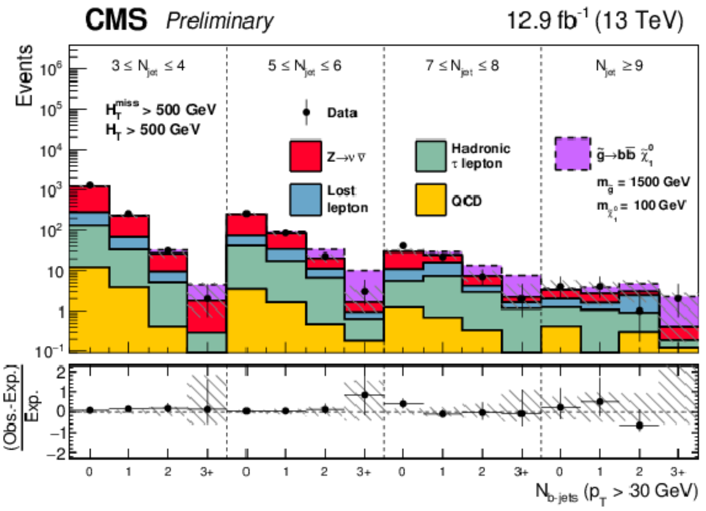

Figure 5: Observed number of events and pre-fit background predictions in all search bins obtained from data [1]

Data agrees with SM background prediction within uncertainties and no significant excess is observed in any of the search bins. Likelihood fit to the data based on SUSY signal strength, background yields and nuisance parameters associated with uncertainties is used to set limits on production cross section of various signal scenarios. Figure 6 shows exclusion plots for three different signal scenarios where gluino masses up to 1680 GeV, 1630 GeV and 1610 GeV respectively are excluded to 95% confidence level(CL).

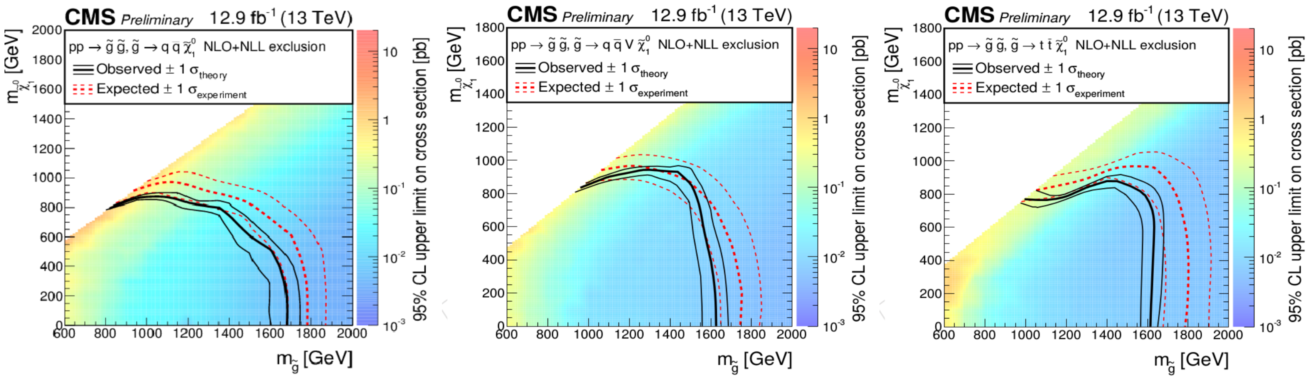

Figure 6: Observed and Expected Upper Limit exclusion at 95% CL for T1qqqq(left), T5qqqqVV(center) and T1tttt(right)[1]

References

[1] CMS Collaboration, *Search for supersymmetry in the multijet and missing transverse momentum channel in pp collisions at 13 TeV*, CMS-PAS-SUS-16-014.

[2] CMS Collaboration, JINST 3 S08004 (2008)