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Searches for high-mass supersymmetry using masses of large-radius jets

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Results are reported from two searches for supersymmetric particles in final states with multiple jets, including several b-tagged jets, with and without large missing transverse momentum. The data sample corresponds to 2.3 fb^{-1} (2.7 fb^{-1} without missing transverse momentum) of pp collisions recorded by the CMS experiment at $\sqrt{s} = 13$ TeV. The searches focus on processes with massive, high multiplicity final states, such as gluino pair production with the gluino decaying to top quarks and a neutralino, and gluino pair production with R-parity violating gluino decay to top, bottom and strange quarks. Both searches use the quantity M_J, the sum of the masses of the large-radius jets, to discriminate between signal and background, establish control regions for other discriminating variables, and as a central piece of the background estimation. The observed event yields are consistent with the standard model expectations, and the results are interpreted in terms of limits on simplified supersymmetric models. Gluinos with mass less than 1600 GeV are excluded for models with $\widetilde{\text{g}} \rightarrow \text{t}\bar{\text{t}}\widetilde{\chi}_1^0$ and light neutralinos, and gluinos with mass less than 1360 GeV are excluded for the decay $\widetilde{\text{g}} \rightarrow \text{tbs}$.

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1. Introduction

We present two searches for massive gluinos in high multiplicity final states that use the quantity M_J, the sum of masses of large-radius jets (R=1.2). M_J is used in both searches to provide discrimination between signal and background, and to define control regions for other discriminating variables including m_{T} and N_{b}. Events containing decays of massive gluinos tend to have large values of M_J arising from accidental overlap of hard scatter partons, as well as boosted top quarks. The dominant background processes, $\mathrm{t\bar{t}}$ pair production and multijet events, can only reach very large values of M_J with additional mass from the parton shower, suppressed by a factor of α_s [2].

Section 2 describes a search for a traditional natural SUSY signature with missing transverse energy ($E_{\mathrm{T}}^{\mathrm{miss}}$) and a single charged lepton [3]. Section 3 describes a search for R-parity violating SUSY with many b-tagged jets, 0 or 1 charged lepton, and no requirement on $E_{\mathrm{T}}^{\mathrm{miss}}$ [4].

2. Search for gluinos in a final state with missing energy, many jets, and a single lepton

This search focuses on gluino pair production with R-parity conserving decay $\tilde{\mathrm{g}} \to \mathrm{t\bar{t}}\tilde{\chi}_1^0$. We select events containing exactly one isolated charged lepton, $H_{\mathrm{T}} > 500$, $E_{\mathrm{T}}^{\mathrm{miss}} > 200$, and six or more jets, at least one of which must be b-tagged. The dominant standard model background in this selection is $\mathrm{t\bar{t}}$ pair production. Additional background suppression is obtained from selections on M_J and m_{T}, the transverse mass of the lepton and $E_{\mathrm{T}}^{\mathrm{miss}}$. Figure 1 shows distributions of M_J and m_{T} in signal and background events.

Events passing the baseline selection are divided into four orthogonal regions in the M_J-m_{T} plane, defined by two bins in M_J: $250 < M_J \leq 400$ GeV and $M_J > 400$ GeV, and two bins in m_{T}: $m_{\mathrm{T}} \leq 140$ GeV and $m_{\mathrm{T}} > 140$ GeV. The data-driven background estimate for the high M_J, high m_{T} signal region is based on the fact that in the high-multiplicity regime, the M_J tail in $\mathrm{t\bar{t}}$ arises largely from accidental overlap with initial state radiation, washing out differences stemming from the intrinsic masses of the visible $\mathrm{t\bar{t}}$ decay products, and causing the M_J spectra for single and dileptonic $\mathrm{t\bar{t}}$ to converge. This makes it possible to measure the M_J shape of the high m_{T} regions, dominated by dilepton $\mathrm{t\bar{t}}$, using the low m_{T} control regions, which are dominated by single lepton $\mathrm{t\bar{t}}$. The high m_{T} normalization is simultaneously constrained using the two low M_J regions, and

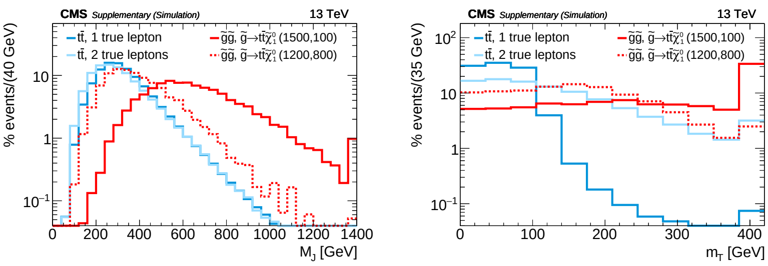

Figure 1: Distributions of M_J (left) and m_{T} (right) after the baseline selection, normalized to the same area, from simulated event samples. $\mathrm{t\bar{t}}$ events are plotted in blue, and signal is plotted in red for two models with different ($m_{\tilde{g}}$, $m_{\tilde{\chi}_1^0}$). The m_{T} distribution falls steeply above m_W for $\mathrm{t\bar{t}}$ with only one leptonically decaying W boson.

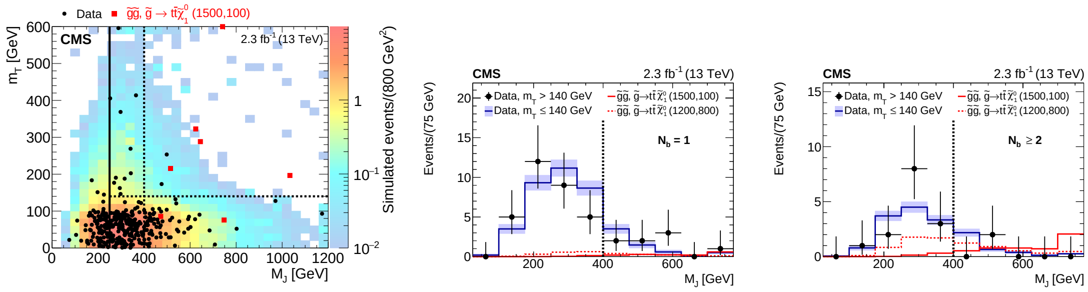

Figure 2: Left: Two-dimensional distributions for data and simulated events in the M_J-m_T plane in the $N_\mathrm{b} \geq 2$ region after the baseline selection. The black dots are the data; the colored histogram is the total simulated background, normalized to the data; and the red dots represent possible signal events for an integrated luminosity of 2.3 fb^{-1}. Right: Comparison of the M_J distributions for low- and high-m_T in data with $N_\mathrm{b} = 1$ (center) and $N_\mathrm{b} \geq 2$ (right) after the baseline selection. The low-m_T distribution is normalized to the number of events in the high-m_T region.

the prediction for the high m_T, high M_J signal region is corrected with any (small) non-closure observed in simulated event samples arising correlations between M_J and m_T shapes.

The distribution of data in the M_J-m_T plane can be seen in Fig. 2 (left), superimposed over a shape derived from simulation. The distribution is consistent with expectations of SM background processes, with most events concentrated in the low M_J and low m_T regions. The M_J shapes in data at low and high m_T are compared in Fig 2 (right). Since there is no excess of events in the high M_J, high m_T region, the results are interpreted as an exclusion limit on the production cross section for gluino pairs with $\widetilde{\mathrm{g}} \to \mathrm{t\bar{t}}\widetilde{\chi}^0_1$. The excluded region in the $m_{\widetilde{\mathrm{g}}}$-$m_{\widetilde{\chi}^0_1}$ plane can be seen in Fig 5 (left).

3. Search for R-parity violating gluino decay with zero or one lepton and high multiplicity of jets and b-tagged jets

This search targets gluino pair production with R-parity violating decay $\widetilde{\mathrm{g}} \to \mathrm{tbs}$, but is generically applicable to any model that results in final states with high multiplicity of jets and b-tagged jets, and does not make any requirement on $E_\mathrm{T}^\mathrm{miss}$. The primary search variable is the number of b-tagged jets, N_b, with additional background discrimination from M_J and N_jets. The dominant SM background processes are multijet QCD events in the hadronic bins, and $\mathrm{t\bar{t}}$ pair production in the single lepton bins. Fig. 3 shows shape comparisons of M_J, N_b, and N_jets between multijet background and signal events.

The principle of the analysis is to predict the N_b spectrum using corrected Monte Carlo simulations (MC) constrained by data in control regions with lower M_J or N_jets requirements. The N_b spectrum is determined by just two factors: the true flavor composition, and the tagging efficiencies for heavy and light flavor jets. To understand and constrain these effects, events are separated into kinematic bins based on N_lep = 0 or 1, N_jets = 4-5, 6-7, 8-9 or $\geq$ 10, and $500 < M_J \leq 800$ or $M_J >$ 800 GeV. A simultaneous fit to the N_b spectra in all kinematic bins is performed, allowing coherent variation of parameters including tagging efficiencies, hard scatter flavor composition, and the rate of gluon splitting to $\mathrm{b\bar{b}}$. An advantage of the binning in M_J is that it yields signal-depleted bins at highest N_jets that match very closely the kinematics of the high M_J search bins and constrain the

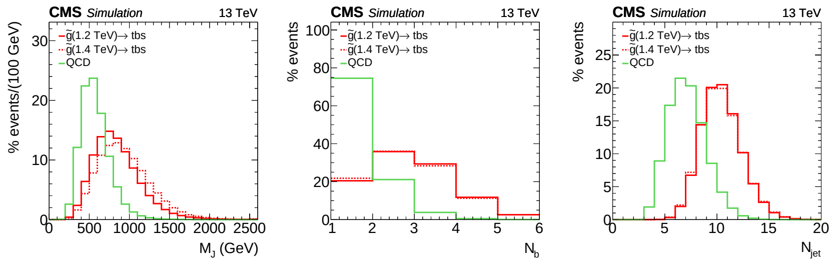

Figure 3: Comparison of M_J, $N_{\rm b}$ and $N_{\rm jets}$ distributions from simulation. A selection of $N_{\rm lep}$ = 0, $H_{\rm T}$> 1500 GeV, M_J > 500 GeV, $N_{\rm b} \geq 1$, and $N_{\rm jets} \geq 8$ is applied (excluding requirement on the plotted variable).

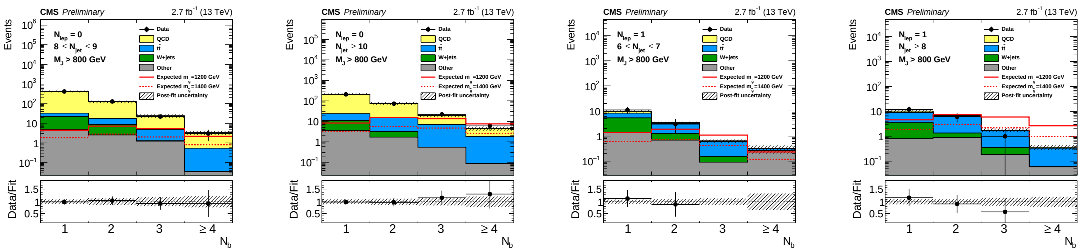

Figure 4: The post-fit $N_{\rm b}$ distributions in the high M_J signal regions. From left to right: hadronic bins, $8 \leq N_{\rm jets} \leq 9$, $N_{\rm jets} \geq 10$; and single lepton bins, $6 \leq N_{\rm jets} \leq 7$, and $N_{\rm jets} \geq 8$.

$N_{\rm b}$ shapes at high multiplicity. Rather than relying on the MC to predict tails in M_J or $N_{\rm jets}$, the background normalization in each M_J, $N_{\rm jets}$, $N_{\rm lep}$ bin is floated independently.

The results of the simultaneous fit in the high M_J regions can be seen in Fig 4. As no excess at high $N_{\rm b}$ is observed, the results are interpreted as an exclusion limit on the model $\tilde{g} \to$ tbs, shown in Fig. 5 (right). For this model, $m_{\tilde{g}} <$ 1360 GeV is excluded.

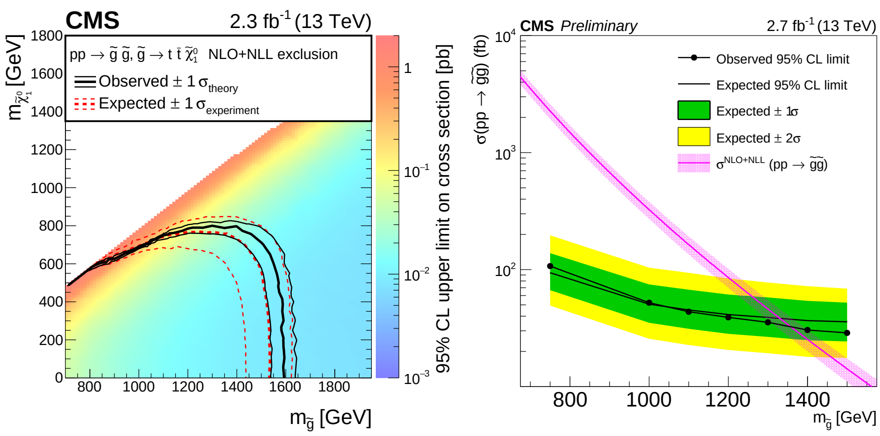

Figure 5: Left: Excluded region for the model $\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$ in the $m_{\tilde{g}}$-$m_{\tilde{\chi}_1^0}$ plane. Right: Observed cross section upper limits at 95% CL for $\tilde{g} \to$ tbs (black) compared to the gluino pair production cross section (magenta).

References

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