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Search for SUSY with razor variables at CMS

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Abstract

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Search for natural Supersymmetry in events with 1 b-tagged jet using razor variables at $\sqrt{s} = 8$ TeV

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ABSTRACT

We discuss a search for natural Supersymmetry using razor variables in pp collisions at $\sqrt{s} = 8$ TeV with the CMS detector. The 95% C.L. limit on the masses of the gluino and lightest supersymmetric particle in a benchmark simplified model are presented.

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1 Introduction

R-parity conserving, weak-scale supersymmetry (SUSY) is a well-motivated theory, which provides a suitable dark matter candidate and predicts events at the LHC with jets and large missing transverse momentum $\mathrm{E_T^{miss}}$. Natural SUSY models contain a light chargino $\tilde{\chi}^{\pm}$ and a neutralino $\tilde{\chi}^{0}$ nearly degenerate in mass, a light top or a bottom squark ($\tilde{t}$ or $\tilde{b}$), and potentially a slightly heavier gluino $\tilde{g}$ in order to minimize the fine-tuning associated with the observed value of the Higgs mass $m_H = 124.70 \pm 0.34$ GeV [1].

We discuss a search for squarks and gluinos in the context of natural SUSY spectra, performed on events with two or more jets, at least one of which is identified as originating from a bottom quark. The search is carried out on the data collected by the Compact Muon Solenoid (CMS) Collaboration in proton-proton collisions at $\sqrt{s} = 8$ TeV in 2012, corresponding to an integrated luminosity of 19.3 $\mathrm{fb^{-1}}$. A complete description of the CMS detector is given in [2]. We utilize the razor kinematic variables $\mathrm{R^2}$ and $\mathrm{M_R}$ [3, 4] to search for a broadly peaking signal on the smoothly falling standard model (SM) background. The analysis is performed in several disjoint datasets (referred to as *boxes*), differing in the lepton and the jet multiplicity. In the following, we discuss the results relating to the zero-lepton boxes, which are analyzed in exclusive b-tagged jet multiplicity bins, to maximize the sensitivity to direct and cascade production of third generation squarks. This search extends a previous analysis by CMS, performed with the same technique on the data collected at a center-of-mass energy of 7 TeV [5, 6].

2 Razor variables and event selection

In the canonical two-jet topology resulting from the production of two squarks each decaying to a quark and the lightest SUSY particle (LSP), the razor variables $\mathrm{M_R}$ and $\mathrm{R^2}$ are intended to characterize the mass scale of the of SUSY particles and the transverse momentum imbalance of the events. The four-momenta of the two jets as well as the missing transverse momentum $\vec{\mathrm{E}}_\mathrm{T}^\mathrm{miss}$ may be used to compute $\mathrm{M_R}$, $\mathrm{M_R^T}$, and $\mathrm{R^2}$, defined as

$$\mathrm{M_R} \equiv \sqrt{(|\vec{p}_{\mathrm{j}_1}| + |\vec{p}_{\mathrm{j}_2}|)^2 - (p_z^{\mathrm{j}_1} + p_z^{\mathrm{j}_2})^2} \tag{1}$$

$$\mathrm{M_T^R} \equiv \sqrt{\frac{\mathrm{E_T^{miss}}(p_\mathrm{T}^{\mathrm{j}_1} + p_\mathrm{T}^{\mathrm{j}_2}) - \vec{\mathrm{E}}_\mathrm{T}^\mathrm{miss} \cdot (\vec{p}_\mathrm{T}^{\,\mathrm{j}_1} + \vec{p}_\mathrm{T}^{\,\mathrm{j}_2})}{2}} \tag{2}$$

$$\mathrm{R^2} \equiv \left(\frac{\mathrm{M_T^R}}{\mathrm{M_R}}\right)^2 \tag{3}$$

where $\vec{p}_{\mathrm{j}_i}$, $\vec{p}_\mathrm{T}^{\,\mathrm{j}_i}$, and $p_z^{\mathrm{j}_i}$ are the momentum of the ith-jet, its transverse component, its longitudinal component, respectively, while $\mathrm{E_T^{miss}}$ and $p_\mathrm{T}^{\mathrm{j}_i}$ are the magnitude of $\vec{\mathrm{E}}_\mathrm{T}^\mathrm{miss}$ and $\vec{p}_\mathrm{T}^{\,\mathrm{j}_i}$, respectively. While $\mathrm{M_R^T}$ quantifies the absolute transverse momentum imbalance, $\mathrm{M_R}$ estimates a characteristic mass scale.

The search for SUSY is carried out on the events selected by a set of criteria summarized in Table 1. The events are detected by a set of dedicated triggers, consisting of a loose selection on $\mathrm{M_R}$ and $\mathrm{R^2}$. The events are also required to satisfy a requirement of two jets in the central part of the detector. The trigger efficiency, studied using a dedicated prescaled trigger, is measured to be $(95 \pm 5)\%$.

Jets are reconstructed by clustering the Particle Flow (PF) [9, 10] candidates with the FastJet [12] implementation of the anti-$\mathrm{k_T}$ [13] algorithm with the jet size set to $R = 0.5$. We select events containing at least two jets with $p_\mathrm{T} > 80$ GeV and $|\eta| < 2.4$. For each event, the $\vec{\mathrm{E}}_\mathrm{T}^\mathrm{miss}$ and the four-momenta of all the jets with $p_\mathrm{T} > 40$ GeV and $|\eta| < 2.4$ are used to compute the razor variables.

The medium working point of the combined secondary vertex algorithm [8] is used for jet b-tagging. Events without at least one b-tagged jet are discarded, a criterion motivated by the expectation of a light top or bottom squark accessible at LHC from naturalness considerations. A tighter requirement (≥ 2 b-tagged jets) is imposed on events with less than four jets to reduce the $\mathrm{Z}(\to \nu\overline{\nu})$+jets background to a negligible level.

Requirements				
Box	lepton	b-tag	kinematic	jet
MultiJet	none	≥ 1 b-tag	($M_R > 400$ GeV and $R^2 > 0.25$) and ($M_R > 450$ GeV or $R^2 > 0.3$)	≥ 4 jets
2b-tagged jet	none	≥ 2 b-tag	($M_R > 400$ GeV and $R^2 > 0.25$) and ($M_R > 450$ GeV or $R^2 > 0.3$)	2 or 3 jets

Table 1: Kinematic and multiplicity requirements defining the two zero-lepton razor boxes.

3 Modeling the standard model backgrounds

Under the hypothesis of no contribution from new physics processes, the event distribution in the (M_R, R^2) plane can be described by the sum of the weak vector boson plus jets production (V+jets where $V = W, Z$) and the top quark-antiquark and the top single-quark production, generically referred to as the $t\bar{t}$ contribution.

Based on the study of the data collected at $\sqrt{s} = 7$ TeV and the corresponding MC samples [5, 6], the two-dimensional probability density function $P_{SM}(M_R, R^2)$ of each SM process is found to be well described by the template function:

$$f(M_R, R^2) = [b(M_R - M_R^0)^{1/n}(R^2 - R_0^2)^{1/n} - 1]e^{-bn(M_R - M_R^0)^{1/n}(R^2 - R_0^2)^{1/n}}. \quad (4)$$

where b, n, M_R^0, and R_0^2 are free parameters of the background model. For $n = 1$, this function recovers the two-dimensional exponential function used for previous studies [5, 6]. The shape of the template function is determined through an extended maximum likelihood (ML) fit to the data. The template function is found to adequately describe the standard model background in each of the boxes, for each b-tagged jet multiplicity.

The background shape parameters are estimated from the events in two sidebands at low M_R ($M_R < 550$) and at low R^2 ($R^2 < 0.3$). This shape is then used to derive a background prediction in the signal-sensitive region: an ensemble of background shape parameters is sampled from the covariance matrix returned by the fit. This ensemble is used to determine the observed numbers of standard deviations with respect to the background prediction as a function of M_R and R^2. Figure 1 illustrates this in the MultiJet box, as well as the one-dimensional projections (on R^2 and M_R) of the agreement between the extrapolation of the fit results and the data. No significant deviation is observed.

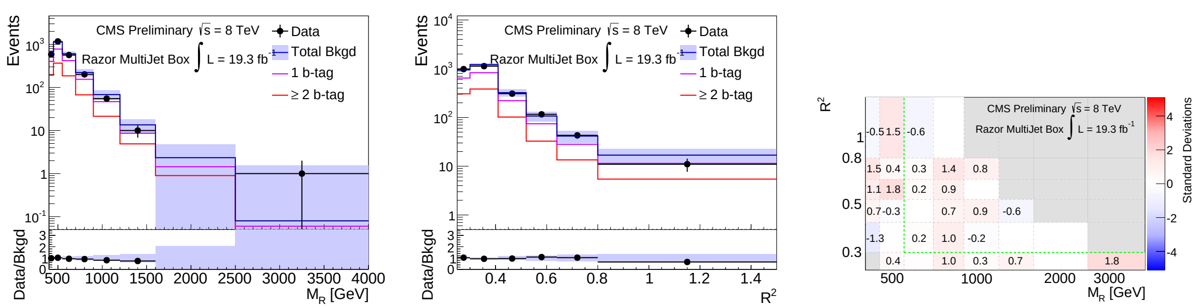

Figure 1: (Left and middle) Projection of the sideband fit result in the MultiJet box on M_R and R^2, respectively. The solid line and the filled band represent the total background prediction and its uncertainty. The points and the band in the bottom panel represent the data-to-prediction ratio and the prediction uncertainty, respectively. (Right) Comparison of the expected background and the observed yield in the MultiJet box. A two-sided p-value (translated into the corresponding number of standard deviations) is computed comparing the observed yield to the distribution of expected background yields.

4 Interpretation and Conclusions

An interpretation of the results in a representative SUSY simplified model is shown in Figure 2. The model topology consists of gluino pair-production, in which each gluino decays to a bottom quark, a bottom antiquark and a LSP. Events for this SUSY simplified model are generated with the MadGraph v5 simulation [14], while the SUSY particles are decayed and the event is showered in the Pythia v6 simulation code [15], before being processed through a fast simulation of the CMS detector [11]. The SUSY particle production cross sections are calculated to next-to-leading order (NLO) and next-to-leading-logarithm (NLL) accuracy [16, 17, 18, 19, 20], assuming the decoupling of the other SUSY partners. The NLO+NLL cross section and the associated theoretical uncertainty [21] are taken as a reference to derive exclusion limits on SUSY particle masses.

The inclusive razor search was translated into at 95% confidence level exclusion limits on the masses of the gluino and the LSP, in the context of a simplified natural SUSY model. For a LSP mass of 100 GeV and depending on the branching ratios, the pair production of gluinos in multi-bottom topologies was excluded for gluino masses up to 1375 GeV.

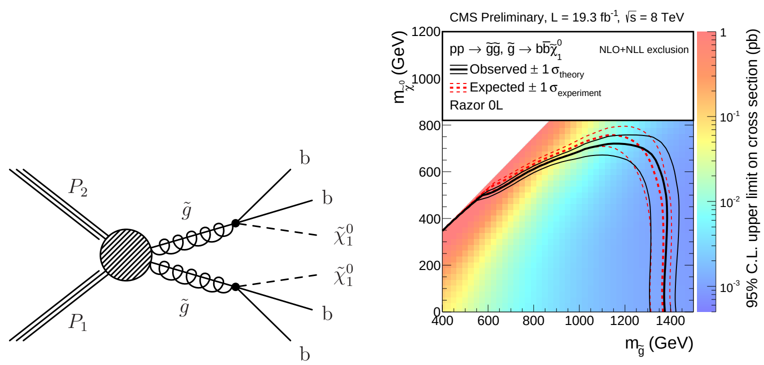

Figure 2: (Left) A diagram displaying the event topology of a gluino-mediated SUSY model in the multi-bottom final state. (Right) Interpretation of the inclusive search with razor variables in the context of a gluino-mediated model. The color coding denotes the observed 95% CL upper limit on the SUSY signal cross section. The dashed and solid lines represent the expected and observed exclusion contours at 95% CL, respectively.

References

[1] V. Khachatryan *et al.* [CMS Collaboration], arXiv:1407.0558 [hep-ex].

[2] S. Chatrchyan *et al.* [CMS Collaboration], JINST **3**, S08004 (2008).

[3] C. Rogan, arXiv:1006.2727 [hep-ph].

[4] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. D **85**, 012004 (2012) [arXiv:1107.1279 [hep-ex]].

[5] S. Chatrchyan *et al.* [CMS Collaboration], Phys. Rev. Lett. **111**, no. 8, 081802 (2013)

[6] S. Chatrchyan *et al.* [CMS Collaboration], arXiv:1405.3961 [hep-ex].

[7] W. Verkerke, *et al.*, arXiv:physics/0306116

[8] S. Chatrchyan *et al.* [CMS Collaboration], CMS-PAS-BTV-13-001

[9] S. Chatrchyan *et al.* [CMS Collaboration], CMS-PAS-PFT-09-001

[10] S. Chatrchyan *et al.* [CMS Collaboration], CMS-PAS-PFT-10-011

[11] S. Chatrchyan *et al.* [CMS Collaboration], CMS-DP-2010-03

[12] M. Cacciari *et al.*, Eur. Phys. J. C **72**, 1896 (2012) [arXiv:1111.6097 [hep-ph]].

[13] M. Cacciari *et al.*, JHEP **0804**, 063 (2008) [arXiv:0802.1189 [hep-ph]].

[14] J. Alwall *et al.*, JHEP **1407**, 079 (2014) [arXiv:1405.0301 [hep-ph]].

[15] S. Hoeche *et al.*, hep-ph/0602031.

[16] W. Beenakker *et al.*, Nucl. Phys. B **492**, 51 (1997) [hep-ph/9610490].

[17] A. Kulesza *et al.*, Phys. Rev. Lett. **102**, 111802 (2009) [arXiv:0807.2405 [hep-ph]].

[18] A. Kulesza *et al.*, Phys. Rev. D **80**, 095004 (2009) [arXiv:0905.4749 [hep-ph]].

[19] W. Beenakker *et al.*, JHEP **0912**, 041 (2009) [arXiv:0909.4418 [hep-ph]].

[20] W. Beenakker *et al.*, Int. J. Mod. Phys. A **26**, 2637 (2011) [arXiv:1105.1110 [hep-ph]].

[21] M. Kramer *et al.*, arXiv:1206.2892 [hep-ph].