Inclusive Search for SUSY with the Razor Variables in CMS

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Introduction

- Analyses of LHC Run I data placed constraints on weak-scale supersymmetry (SUSY), but large regions of parameter space are still unexplored.
- Some strongly interacting SUSY particles are expected to have much larger cross sections at 13 TeV than at 8 TeV.
- Searches with 2.1 fb⁻¹ of 13 TeV data can already improve on Run I results with 20 fb⁻¹.

Razor variables provide a unique model-inclusive probe of new physics and were used successfully in many CMS searches in Run I.

In this analysis the razor variables are used to search for SUSY in hadronic and leptonic final states at 13 TeV.

Razor Variables

- In each event all selected jets and leptons are clustered into two “megajets”.
- The megajet four-momenta are used to compute the razor variables $M_R$ and $R^2$:
  
  $M_R = \sqrt{(P_{j1} + P_{j2})^2 - (P_{j1}^2 + P_{j2}^2)}$
  
  $R^2 = \frac{M_{M}^{2} - \left(\frac{1}{2} (P_{j1}^2 + P_{j2}^2) - \frac{1}{2} (\text{min}(P_{j1}^2, P_{j2}^2) - \frac{1}{2} (P_{j1}^2 + P_{j2}^2))\right)}{4}$

- $M_R$ peaks at a characteristic mass scale for a SUSY signal process, and is exponentially falling for background.
- $R^2$ is related to the missing transverse momentum in the event and can be used to efficiently reject QCD multijet events.

Event Selection and Categorization

- Events are required to have at least four jets with $p_T > 40$ GeV.
- The analysis is performed in three event categories divided according to jet and lepton content:
  - **Two jets $p_T > 80$ GeV, No leptons**
  - ** Exactly one selected Muon**, $M_0 > 500$ GeV, $R > 0.25$
    - | $M_0 > 400$ GeV, $R > 0.15$ |
    - $M_0 > 120$ GeV
  - ** Exactly one selected Electron**, $M_0 > 400$ GeV, $R > 0.15$
    - $M_0 > 120$ GeV

- Each category is divided into four bins according to the number of b-tagged jets:
  - $0, 1, 2, \geq 3$ b-tags

- A search for excesses is carried out in the two-dimensional plane defined by $M_R$ and $R^2$.

Fit-Based Background Estimation

- The standard model background in the 2-D razor plane exhibits a characteristic exponential falloff, which is well described by an analytical shape:
  
  $f_{SM}(M_R, R^2) = \frac{b (M_R - M_0)^{1/n} (R^2 - R_0^2)^{1/n} - 1}{e^{-b(M_0 - M_0)^{1/n} (R^2 - R_0^2)^{1/n}}}$

- In each analysis category and b-tag bin, a maximum likelihood fit to the data is performed in a sideband of $M_R$ and $R^2$.
- The fit shape is extrapolated into the full 2-D plane and used to predict the distribution of background events.

Limits on SUSY Particle Masses

- 95% upper limits on SUSY particle masses are obtained using the LHC CL_s procedure.
- For neutralinos of mass 100 GeV, gluinos with masses below 1650 GeV, 1600 GeV, and 1350 GeV are excluded in the cases of decays to bottom quarks, top quarks, and light quarks, respectively.

Conclusion

- An inclusive search for supersymmetric particles decaying leptonically or hadronically is performed with 2.1 fb⁻¹ of CMS data collected at 13 TeV in 2015.
- No excess above the standard model background is observed.
- The results are used to derive new limits on simplified models of gluino production as a function of the decay mode and SUSY particle masses.