PROCEEDINGS OF SCIENCE

Search for squarks and gluinos in final states with jets and missing transverse momentum at $\sqrt{s} = 13$ TeV using 139 fb^{-1} data with the ATLAS detector

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A search for squarks and gluinos is one of the primary targets among the supersymmetry particles at the Large Hadron Collider experiments because their cross sections are relatively large. Multi-bin and multivariate techniques are newly introduced in the searches for squarks and gluinos in final states with jets and missing transverse momentum in an event. This analysis uses data corrected in 2015-2018 with the ATLAS detector at $\sqrt{s} = 13$ TeV, corresponding to the integrated luminosity of 139 fb^{-1}. No significant excess over the Standard Model predictions is observed and the exclusion limits for the squark and gluino pair production in simplified models are set. In case of massless neutralino, squark (gluino) masses are excluded up to 1940 (2350) GeV at the 95 % confidence level.

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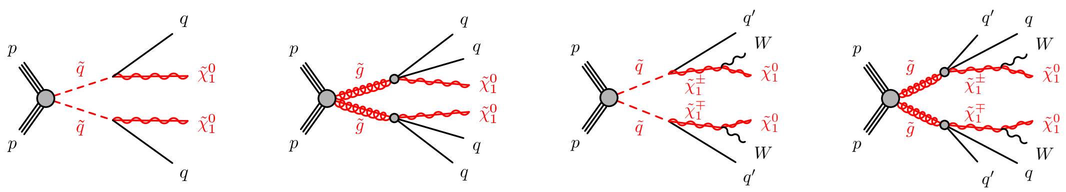
1. Introduction

Supersymmetry (SUSY) [1] is a theoretically promising extension of the Standard Model (SM). SUSY can provide an elegant solution to the dark matter and hierarchy problems [2]. Since squarks and gluinos could be produced at the LHC via the strong interaction, their production cross sections can be relatively large. Therefore, this search is one of the primary targets among the SUSY particles. Under the hypothesis of R-parity conservation, SUSY paritcles are produced in pairs and decay into final states with the Lightest Supersymmetric Particle (LSP). The LSP is stable and a candidate of dark matter [3]. In this analysis, the signals as shown in Fig. 1 are considered [4].



(a) $\tilde{q} \to q\tilde{\chi}_1^0$ (b) $\tilde{g} \to qq\tilde{\chi}_1^0$ (c) $\tilde{q} \to qW\tilde{\chi}_1^0$ (d) $\tilde{g} \to qqW\tilde{\chi}_1^0$

Figure 1: The decay topologies of squark-pair/gluino-pair production with (a,b) direct decays and (c,d) one-step decays.

2. Analysis strategy

Two different approaches are introduced to improve the sensitivity with respect to the previous results [5]. One is a multi-bin approach where the signal and background separation is performed by simultaneously fitting to multiple observables. In this analysis, three key variables are used. The first one is the effective mass (m_{eff}), that is the scalar sum of $E_{\mathrm{T}}^{\mathrm{miss}}$ and the transverse momenta of all jets with $p_{\mathrm{T}} > 50$ GeV. It has the strong separation power between the signal and SM backgrounds as shown in Fig. 2(a). The second one is $E_{\mathrm{T}}^{\mathrm{miss}}$ significance, $E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{m_{\mathrm{eff}} - E_{\mathrm{T}}^{\mathrm{miss}}} = E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{\mathrm{H_T}}$, which also has separation power as shown in Fig. 2(b). The last one is the jet multiplicity. The other approach is a multi-variate analysis technique, which uses correlations between input variables. Boosted Decision Trees (BDT) are used in this analysis [6]. BDT signal regions target models with the gluino direct decay and the gluino one-step decay. 8 BDTs are trained separately for specific $\Delta m(\tilde{g}, \tilde{\chi}_1^0)$ ranges, which is the mass difference between gluino and LSP. 10 - 12 variables are selected from $E_{\mathrm{T}}^{\mathrm{miss}}$, m_{eff}, aplanarity, jet p_{T} and jet η in order to make BDT score. Figure 2(c) shows a BDT output variable (BDT score) that has strong separation power between signal and SM backgrounds.

There are four main backgrounds: $Z(\to \nu\nu)$+jets, $W(\to \ell\nu)$+jets, $t\bar{t}$ and multi-jet productions. These backgrounds are estimated via partial data-driven techniques with dedicated control regions (CR). The CR is designed to be kinematically close but orthogonal to the signal regions (SR). Monte Carlo (MC) simulations are used to model the shape of background in the SR, and the noramlization is set at the CR. The modeling of MC simulations are tested in validation regions (VR), which are used to validate the modeling and normalization.

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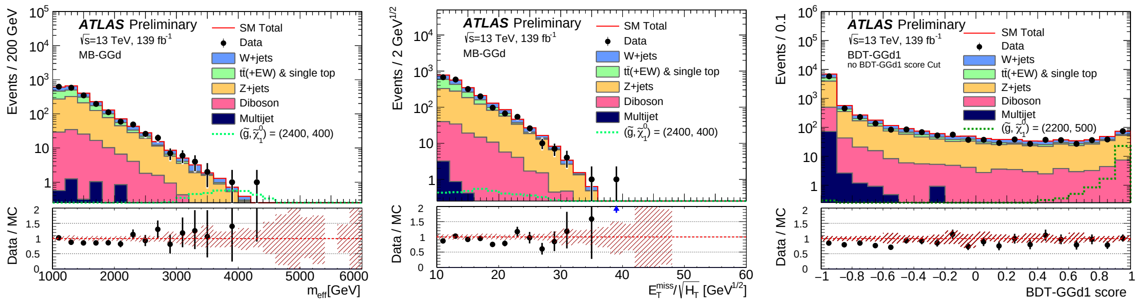

(a) $m_{\rm eff}$ (b) $E_{\rm T}^{\rm miss}$ significance (c) BDT score

Figure 2: Comparison of data and MC distribution. (a) $m_{\rm eff}$ distribution, (b) $E_{\rm T}^{\rm miss}$ significance distribution and (c) BDT score distribution targeting models with gluino direct decay [4].

3. Result

Figure 3 shows the results of multi-bin and BDT analyses. No significant excess is observed over the SM background predictions. The model-dependent fits exclude the signal in the simplified models. Figure 4 shows the exclusion limits at 95 % confidence level (CL).

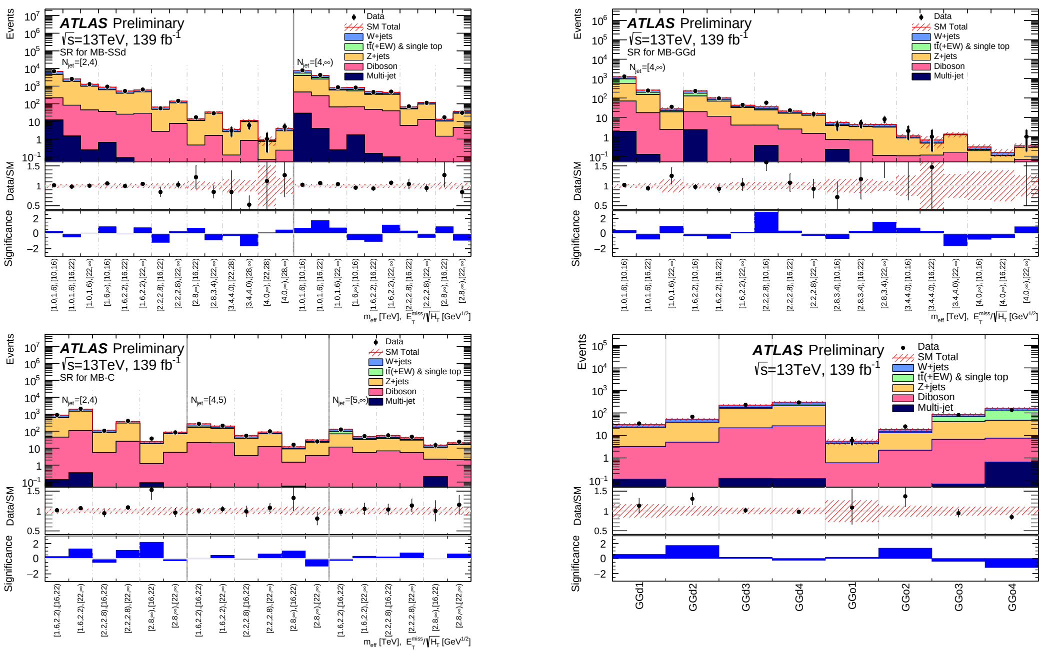

Figure 3: Comparison of the observed and expected event yields in each SR [4]. The left-top, right-top and left-bottom figures are multi-bin analysis. The right-bottom figure is BDT analysis. The x-axis corresponds to the binning in variables for multi-bin and the SR for BDT.

4. Conclusion

A search for squarks and gluinos in final state with jets, missing transverse momentum re-

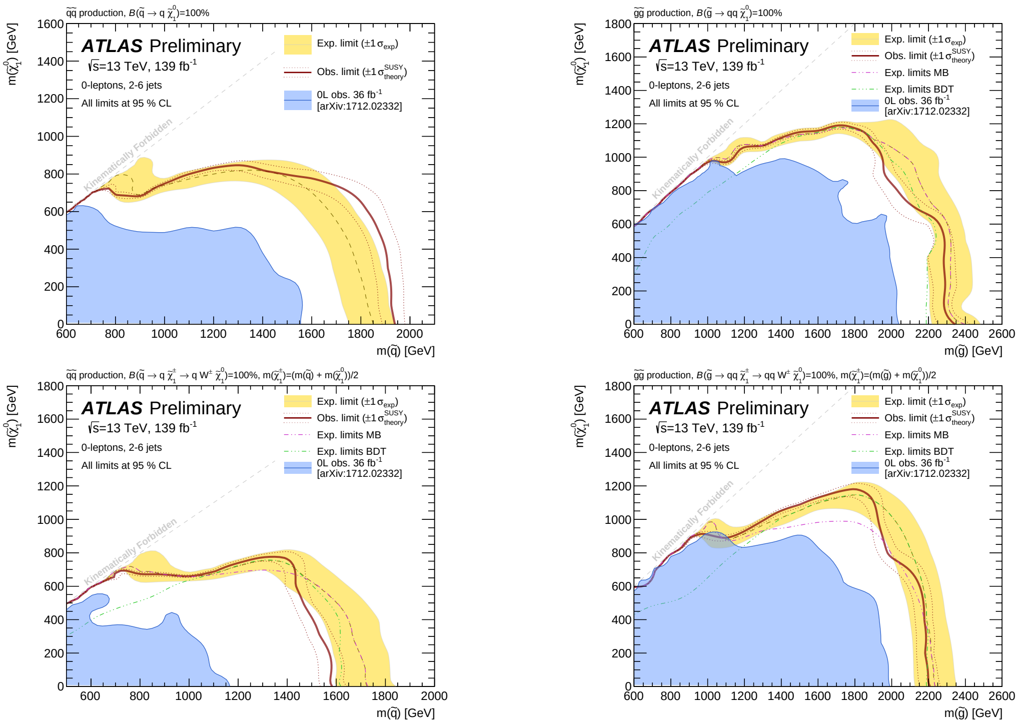

Figure 4: Expected and observed exclusion limits in mass plane of squark and LSP (left-top and left-bottom) and gluino and LSP (right-top and right-bottom) in the simplified models. The top figures are direct decay secinario and bottom figures are one-step decay secinario [4].

quiring no electron or muon has been performed on 139 fb^{-1} data in 2015-2018 with the ATLAS detector [7]. No significant excess over the SM background predictions is observed. Exclusion limits are set at 95 % CL on the simplified model and extend up to 1940 GeV in squark mass and 2350 GeV in gluino mass in case of massless LSP.

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