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Search for supersymmetry at 13 TeV in final states with two same-sign leptons or at least three leptons and jets using pp collisions recorded with the ATLAS detector

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A search for strongly produced supersymmetric particles decaying into final states with multiple energetic jets and either two isolated leptons (e or μ) with the same electric charge or at least three isolated leptons is presented in these proceedings. To extend its sensitivity, the search uses jets originating from b-quarks, missing transverse momentum, and other observables. The analysis uses 13.2 fb^{-1}of proton-proton collision data at $\sqrt{s}$ = 13 TeV recorded with the ATLAS detector at the LHC. Results are interpreted in the framework of simplified models featuring gluino and squark production.

38th International Conference on High Energy Physics
3-10 August 2016
Chicago, USA

*Speaker.

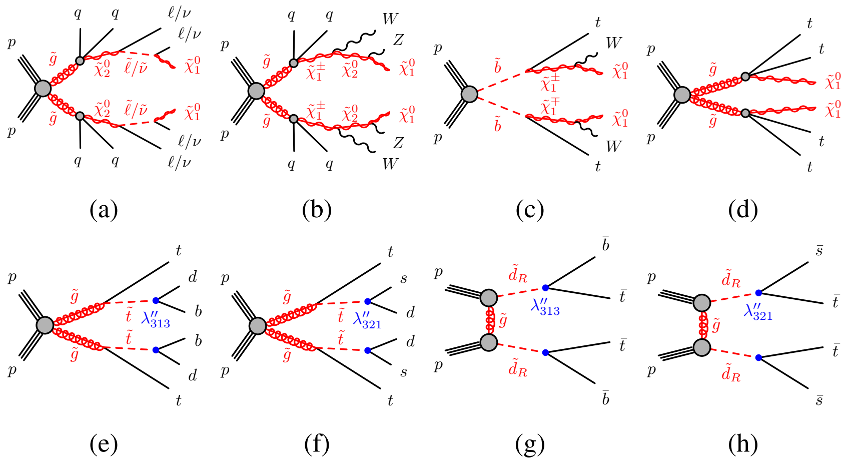


Figure 1: RPC SUSY processes featuring gluino (a, b, d) or bottom squark (c) pair production, and RPV SUSY processes featuring gluino (e,f) or right-handed down squark (g,h) pair production and decays via baryon number-violating couplings λ'' considered in this analysis[1].

1. Introduction

Supersymmetry (SUSY) is a well motivated extension of the Standard Model (SM) that predicts a superpartner for every SM particle with the same quantum numbers, except spin. A search for SUSY [1] was conducted with events containing multiple jets and either two isolated leptons (electrons or muons) of the same electric charge (same-sign leptons, SS) or at least three isolated leptons (3L) with the ATLAS detector [2]. Since gluinos are Majorana fermions, their pair production equally leads to same-sign or opposite sign leptons or produces multiple leptons via the cascade decays. Despite the penalty in signal yields due to the low branching ratio to SS/3L, the extreme background reduction achieved in this signature is a very good opportunity to discover new physics with sensitivity to many different models. In particular, the search has a higher sensitivity to scenarios with small mass differences between SUSY particles (compressed scenarios) or to R-parity violating scenarios than other beyond the SM searches. Four scenarios with R-parity conservation (RPC) shown in Figure 1 (a-d), and four other scenarios with R-parity violation (RPV) shown in Figure 1 (e-h), are explored within the context of simplified models.

2. Signal Regions

Nine overlapping signal regions (SRs) are defined to target the RPC and RPV models considered in this analysis based on the number of leptons and their charges, the number of b-jets, the number of jets, the missing transverse momentum (its magnitude $E_{\mathrm{T}}^{\mathrm{miss}}$)[1], and the effective mass (m_{eff})[2], as shown in Table 1.

The RPC SRs feature the SR3Lx and SR0bx regions that target gluinos with generic squark-mediated decays of the models in Figure 1 (a-b) where $x = 1$ targets a high $\tilde{\chi}_1^0$ mass while $x = 2$ targets a high $\tilde{g}$ mass. The SR1b and SR3b address scenarios motivated by naturalness with a

[1] $E_{\mathrm{T}}^{\mathrm{miss}}$: Negative vector sum of the transverse momenta of all identified physics objects

[2] m_{eff}: Scalar sum of the p_{T} of the leptons and jets in the event plus the $E_{\mathrm{T}}^{\mathrm{miss}}$

Table 1: Summary of the event selection criteria for the signal regions[1].

Signal region	N_{lept}	$N^{20}_{b-\text{jets}}$	N_{jets}	$p_{\text{T,jets}}$ [GeV]	$E_{\text{T}}^{\text{miss}}$ [GeV]	m_{eff} [GeV]	Other
SR3L1	≥ 3	$= 0$	≥ 4	40	> 150	-	-
SR3L2	≥ 3	$= 0$	≥ 4	40	> 200	> 1500	-
SR0b1	≥ 2	$= 0$	≥ 6	25	> 150	> 500	-
SR0b2	≥ 2	$= 0$	≥ 6	40	> 150	> 900	-
SR1b	≥ 2	≥ 1	≥ 6	25	> 200	> 650	-
SR3b	≥ 2	≥ 3	≥ 6	25	> 150	> 600	-
SR1b-DD	≥ 2	≥ 1	≥ 4	50	-	> 1200	≥ 2 negatively-charged leptons
SR3b-DD	≥ 2	≥ 3	≥ 4	50	-	> 1000	≥ 2 negatively-charged leptons
SR1b-GG	≥ 2	≥ 1	≥ 6	50	-	> 1800	-

lighter 3rd squark generation with the processes in Figure 1 (c-d) that are enhanced in the production of b-jets. The RPV SRs do not have a $E_{\text{T}}^{\text{miss}}$ requirement where SR1b-DD and SR3b-DD target direct down squark production while SR1b-GG targets gluino production.

3. Background estimation

An important part of this analysis is to achieve reliable predictions of irreducible and reducible backgrounds. The irreducible backgrounds consist of rare SM processes, dominated by the production of a top quark pair in association with a massive boson ($t\bar{t}V$) in SRs with b-jets, and multiple bosons in SRs without b-jets. These backgrounds are estimated with MC predictions normalized with the best known theoretical cross-sections, and dedicated validation regions (VRs) enhanced in the dominant backgrounds (WW, WZ, $t\bar{t}W$, and $t\bar{t}Z$) are used to verify the predictions. The reducible background is due to detector effects such as the mis-identification of hadrons as prompt leptons or non-prompt leptons (referred to as fakes), or the mis-reconstruction of the electron charge (referred to as charge flip). Data-driven methods are used to estimate these backgrounds. Fake leptons are estimated from data with a matrix method that relies on probabilities that loosely identified real or fake leptons pass tight isolation cuts. Electron charge flip is estimated by measuring charge flip rates in a $Z/\gamma^* \to ee$ data sample that are then used to re-weight data events with an opposite sign lepton requirement.

The regions used to validate the main SM backgrounds as well as the fake and charge flip estimates show a reasonable agreement between the observations and predictions in all regions.

4. Results

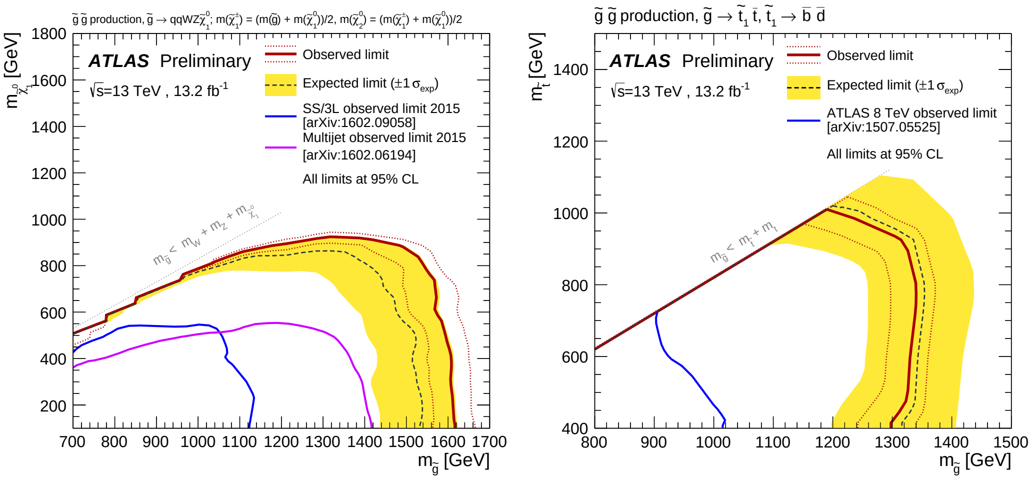
As shown in Table 2, there is no excess over the predicted SM background. As a result, upper limits on possible beyond the SM contributions to the SRs are computed in the context of several SUSY benchmark scenarios to obtain 95% confidence levels as shown in Figure 2. For RPC simplified models, gluino masses are excluded up to 1.7 TeV for a light $\tilde{\chi}_1^0$ and $\tilde{\chi}_1^0$ masses up to $m_{\tilde{\chi}_1^0} \approx 1.1$ TeV for gluinos with $m_{\tilde{g}} \approx 1.4$ TeV are excluded, and bottom squark masses up to $m_{\tilde{b}_1} \lesssim 690$ GeV for a light $\tilde{\chi}_1^0$ are excluded. For RPV simplified models, excluded right-

Table 2: The number of observed data events and expected background contributions in the signal regions[1].

	SR3L1	SR3L2	SR0b1	SR0b2	SR1b
Observed	6	2	5	0	12
Total SM background	6.1 ± 2.2	1.2 ± 0.5	8.8 ± 2.9	1.6 ± 0.8	11.4 ± 2.8

	SR3b	SR1b-GG	SR1b-DD	SR3b-DD
Observed	2	2	12	4
Total SM background	1.6 ± 0.6	1.7 ± 0.5	12.0 ± 2.7	1.9 ± 0.8

handed down squark masses reach up to $m_{\tilde{d}_R} \approx 700$ GeV. The current set of searches extended the sensitivity to new physics beyond that of the Run 1 and early Run-2 searches [3].



(a) SR0b1 and SR0b2, $\tilde{g} \to q\bar{q}'WZ\tilde{\chi}_1^0$ scenario (b) SR1b-GG, $\tilde{g} \to \bar{t}\bar{b}\bar{d}$ ($\lambda''_{331} \neq 0$)

Figure 2: Examples of (a) an RPC scenario and (b) an RPV scenario showing the observed and expected exclusion limits on the $\tilde{g}$ with simplified models. The signal region used to obtain the limits is specified for each scenario[1].

5. Acknowledgment

We would like to thank the U.S. Department of Energy grant DE-SC0009956 for support of the speaker in the work presented in this proceeding.

References

[1] ATLAS Collaboration. Search for supersymmetry with two same-sign leptons or three leptons using 13.2 fb^{-1} of 13 TeV *pp* collision data. ATLAS-CONF-2016-037, 2016.

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