Search for Supersymmetry in final states with jets and missing transverse momentum with the ATLAS detector

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1 Introduction

The production of supersymmetric particles at the LHC is dominated by squark-squark($\tilde{q}\tilde{q}$), squark-gluino($\tilde{q}\tilde{g}$) and gluino-gluino($\tilde{g}\tilde{g}$) pair production. Assuming R-Parity conservation these decay subsequently into the Lightest Supersymmetric Particle (LSP). The LSP espaces the detector unseen, thus leading to final states with jets and missing transverse momentum. The ATLAS detector [1] is a multipurpose particle physics apparatus with a forward-backward symmetric cylindrical geometry and nearly 4π coverage. An update of the result of searches for Supersymmetry in final states with jets and missing transverse momentum with the ATLAS detector [2] is presented and is documented in more detail in [3]. A data sample of 165 pb^{-1} of proton-proton collisions at $\sqrt{7}$ TeV was analyzed.

2 Object reconstruction, event selection and background estimation

Jet candidates are reconstructed using the anti-kt jet clustering algorithm [4] with a distance parameter of 0.4. All jet candidates with $|\eta| > 2.8$ are discarded. Electrons and muons are required to have transverse momentum $p_T > 20$ GeV and $p_T > 10$ GeV and $|\eta| < 2.47$ and $|\eta| < 2.4$, respectively. Jet candidates lying within a distance $\Delta R < 0.2$ of an electron are removed and lepton candidates within a distance $\Delta R < 0.4$ of any surviving jet are also discarded. The missing transverse momentum vector $\mathbf{P}_{T,miss}$ (and its magnitude $E_{T,miss}$) is reconstructed using the transverse momenta of all remaining object candidates and all calorimeter clusters not associated to them. Three signal regions have been defined; SR A targeting $\tilde{q}\tilde{q}$ production, SR B targeting $\tilde{q}\tilde{g}$ production and SR C targeting $\tilde{g}\tilde{g}$ production. They require the following selection cuts:

- Two or more, three or more and four or more jets, respectively.

- The leading jet $p_T > 130$ GeV, subsequent jets to have $p_T > 40$ GeV.
- $E_{T,miss} > 130$ GeV.
- The minimal azimuthal separation between $\mathbf{P}_{T,miss}$ and jets with $p_T > 40$ GeV to be > 0.4.
- The effective mass m_{eff}, is defined as the scalar sum of the transverse momenta of the two, three or four highest p_T jets used to define the signal region and $E_{T,miss}$. The ratio of $E_{T,miss}$ over $m_{\mathrm{eff}}$is required to be > 0.3, 0.25 and 0.25, respectively.
- $m_{\mathrm{eff}}$is required to be > 1000 GeV in all signal regions.
- Any event with a lepton with $p_T > 20$ GeV is discarded.

The dominant sources of background are: W +jets, Z +jets, top pair, multi-jet and single top production. Non-collision backgrounds are negligible.
For each of the main background component a control region (CR) was defined. The CR selections are chosen such that systematic uncertainties arising from extrapolation from each CR to the SR are minimized. For each signal region a simultaneous fit is performed to the observed event counts in the SR and CRs, taking into account correlations in the systematic uncertainties. The combined and simultaneous fit across all regions ensures that the background estimates are consistent for all processes.
The irreducible background Z +jets is dominated by $Z \to \nu\nu$ events with large $E_{T,miss}$. Control samples requiring isolated photons and jets are used to estimate this background. The reconstructed momentum of the photon is added to the $\mathbf{P}_{T,miss}$ vector to estimate the $E_{T,miss}$. $Z \to ee \setminus \mu\mu$ + jets events are used via di-leptonic control regions to cross check the photon + jets results and are found to be in good agreement.
The multi-jet background is caused by rare instances of poor reconstruction of jet energies in calorimeters leading to fake missing transverse momentum and as well by neutrinos in the semileptonic decay of heavy quarks. It is estimated using control regions in which the cut on the minimum azimuthal separation between $\mathbf{P}_{T,miss}$ and jets is reversed and set to be smaller than 0.2, thus selecting events in which the $\mathbf{P}_{T,miss}$ is aligned with one of the three leading jets in the transverse plane.
The W +jets background is composed of $W \to \tau\nu$ events or $W \to l\nu$ events in which no electron or muon candidate is reconstructed. It is estimated from a sample of events with a lepton, significant $E_{T,miss}$ and a transverse mass of the lepton- $E_{T,miss}$ system between 30 GeV and 100 GeV consistent with the W mass. A veto on jets from b-quark decays, using a secondary vertex requirement, is applied to split events with top decays. The lepton in the events is treated as a jet to calculate the kinematic variables.

Hadronic τ decays in $tt \rightarrow bb\tau\nu qq$ and single top events can generate large $E_{T,miss}$ and pass the jet and lepton requirements. The background from top quark events is estimated using the same procedure as that used for $W \rightarrow \nu$+jets events, but replacing the b-veto with a b-tag requirement.
Monte Carlo simulation samples used in this analysis to estimate backgrounds from W +jets, Z +jets and top quark production and SUSY samples used to optimize the event selection are described in [2].

3 Results and Interpretation

The number of observed data events and the number of SM events expected of each of the signal regions, determined using the simultaneous fit, are shown in Table 1. No excess is observed and the background expectation is in good agreement with the data. The main sources of systematic uncertainties are the jet energy scale calibration, jet energy resolution calibration, MC modelling uncertainties and uncertainty on reconstruction performance in the presence of pile-up. A discussion of those can be found in [3].
As test statistic the profile log likelihood ratio is used. The test statistic for each channel is obtained from the simultaneous fit to the signal region and each of the control regions taking into account systematic uncertainties and any correlations. Limits on models are set choosing for each specific model the best expected channel in terms of exclusion power.
An interpretation of the results is presented in Figure 1 on the left side as a 95% confidence exclusion region in the $m_{\tilde{q}}$-$m_{\tilde{g}}$ plane for a simplified set of SUSY models with a massless neutralino. In these models the gluino mass and the masses of the squarks of the first two generations are set to the values shown in the figure. All other supersymmetric particles, including the squarks of the third generation, are decoupled by being given masses of 5 TeV. In this model the limit on the gluino mass

Process	SR A	SR B	SR C
$Z \rightarrow \nu\nu$ + jets	5.6 ± 1.2	4.4 ± 1.6	3.0 ± 1.3
$W \rightarrow l\nu$ + jets	6.2 ± 1.8	4.5 ± 1.6	2.7 ± 1.3
top	0.2 ± 0.3	1.0 ± 0.9	1.4 ± 0.9
QCD jets	0.05 ± 0.04	0.21 ± 0.07	0.16 ± 0.11
Total	12.1 ± 2.8	10.1 ± 2.3	7.3 ± 1.7
Observed	10	8	7

Table 1: Observed events and expected event yield after simultaneous fit for each of the main backgrounds.

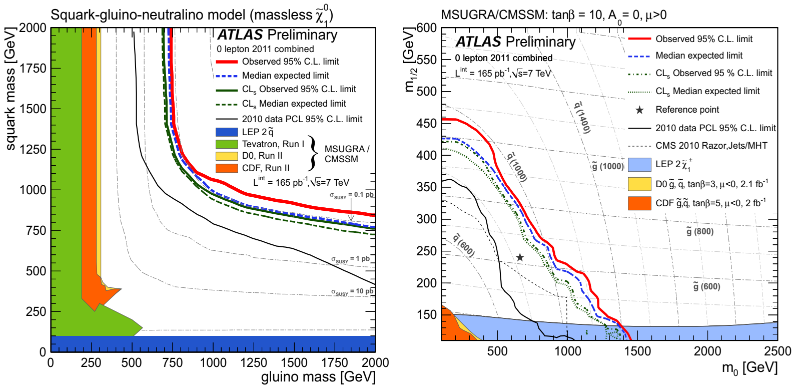

Figure 1: Left plot: Combined exclusion limits (solid red line) in the ($m_{\tilde{q}}$;$m_{\tilde{g}}$) plane for the simplified squark-gluino model with a massless neutralino. The dashed-blue line corresponds to the expected 95% C.L. limit and the red line to the equivalent observed limit. Right plot: Combined exclusion limits in the (m_0 ; $m_{1/2}$) plane of CMSSM for which $tan\beta = 10, A_0 = 0, \mu > 0$. The dashed-blue line corresponds to the expected 95% C.L. limit and the red line the equivalent observed limit.

is approximately 725 GeV, rising to 1025 GeV if the squarks and gluinos are assumed to be mass-degenerate.
The results are also interpreted in the $tan\beta = 10, A_0 = 0, \mu > 0$ slice of the CMSSM in 1 on the right side. Here, the limit on $m_{1/2}$ reaches 455 GeV for low values of m_0, and equal mass squarks and gluinos are excluded below 950 GeV. Model independent limits on non-SM process cross sections are measured to be 35, 30 and 35 fb respectively, at 95% confidence level.

References

[1] ATLAS Collaboration, JINST **3** (2008), S08003

[2] ATLAS Collaboration, Phys. Lett. B **701** (2011),186

[3] ATLAS Collaboration, ATLAS-CONF-2011-086.

[4] M. Cacciari, G. P. Salam, and G. Soyez, JHEP **04** (2008), 063