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Search for supersymmetry in jets plus missing transverse momentum final states with the ATLAS detector

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The ATLAS collaboration has searched for squarks and gluinos in final states with different jet multiplicities and large missing transverse momentum using 1.04 fb^{-1} of proton-proton collisions at $\sqrt{s} = 7$ TeV collected during 2011. No excess above the Standard Model predictions has been observed. The results has been interpreted as a 95% CL limit in simplified models and in MSUGRA/CMSSM with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$.

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1. Introduction

A large variety of *R*-parity conserving supersymmetric models ([1] and references therein) predict that, if kinematically accessible, squarks and gluinos can be abundantly produced in pairs at the LHC, and can decay into $\tilde{q} \rightarrow q\tilde{\chi}_1^0$, $\tilde{g} \rightarrow qq\tilde{\chi}_1^0$, giving therefore rise to final states with different jet multiplicities and large missing transverse momentum caused by the neutralinos being undetected. The search described in this paper is based on a purely hadronic selection and has been designed to be sensitive to such final states. Several different signal regions, differing by the jet multiplicity and the kinematical selection applied, are used to maximise the sensitivity to different production channels. The results presented here, based on an integrated luminosity of 1 fb^{-}1 of proton-proton collisions at $\sqrt{s} = 7$ TeV recorded by the ATLAS experiment at the LHC, significantly extend the previous published ATLAS exclusion limits obtained with 35 pb^{-1} of data [2].

2. The ATLAS Detector and Data Samples

The ATLAS detector is a multipurpose particle physics apparatus with a forward-backward symmetric cylindrical geometry and nearly 4π coverage in solid angle. A full description of the detector can be found in Ref. [3]. The data used for the analysis described here correspond to those recorded by ATLAS in the first half of 2011. After the application of the beam, detector and data quality requirements, they correspond to an integrated luminosity of 1.04 ± 0.04 fb^{-1}. Events are triggered using the combined presence of an high p_{T} jet and large missing momentum. The trigger is full efficient for events with an offline leading jet p_{T} of 130 GeV and missing transverse momentum (whose magnitude will be in the following indicated as $E_{\mathrm{T}}^{\mathrm{miss}}$) of 130 GeV. The average number of minimum bias collisions superimposed to the hard scattering is approximately five.

3. Object Reconstruction

Jets in the final state are reconstructed using an anti-k_t [4, 5] algorithm with $\Delta R = 0.4$ using three-dimensional clusters of topologically connected calorimeter cell energy deposits [6]. The jet energy scale is corrected for detector inhomogeneities and calorimeter non compensation using p_{T} and pseudo-rapidity[1] (η in the following) dependent correction factors determined using Monte Carlo (MC) di-jet events generated with Pythia [7] and validated with in-situ measurements [8]. Jets with $p_{\mathrm{T}} > 20$ GeV and $|\eta| < 2.8$ are retained for further processing.

A lepton veto is applied in this analysis. Candidate electrons are reconstructed based on shower shape and track matching criteria, and retained if $p_{\mathrm{T}} > 20$ GeV and $|\eta| < 2.47$. Candidate muons are reconstructed based on matching criteria between tracks reconstructed in the inner detector and those reconstructed in the muon spectrometer, and retained if $p_{\mathrm{T}} > 10$ GeV and $|\eta| < 2.4$. Further details on lepton definitions can be found in Ref. [9]. Events containing one or more leptons (*e*

[1] ATLAS uses a right-handed coordinate system with its origin at the nominal interaction point in the centre of the detector and the *z*-axis along the beam pipe. Cylindrical coordinates (r, ϕ) are used in the transverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudo-rapidity η is defined in terms of the polar angle θ as $\eta = -\ln\tan(\theta/2)$.

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Signal Region	$\geq$ 2-jet	$\geq$ 3-jet	$\geq$ 4-jet	High mass
$E_{\mathrm{T}}^{\mathrm{miss}}$	>130	>130	>130	>130
Leading jet p_{T}	>130	>130	>130	>130
Second jet p_{T}	>40	>40	>40	>80
Third jet p_{T}	–	>40	>40	>80
Fourth jet p_{T}	–	–	>40	>80
$\Delta\phi(\mathrm{jet},\vec{P}_T^{miss})_{\mathrm{min}}$	>0.4	>0.4	>0.4	>0.4
$E_{\mathrm{T}}^{\mathrm{miss}}/\mathrm{m_{eff}}$	>0.3	>0.25	>0.25	>0.2
$\mathrm{m_{eff}}$	>1000	>1000	$>500/1000$	>1100

Table 1: Criteria for admission to each of the five overlapping signal regions ($\mathrm{m_{eff}}$, $E_{\mathrm{T}}^{\mathrm{miss}}$ and p_{T} in GeV). The $\mathrm{m_{eff}}$ is defined with a variable number of jets, appropriate to each signal region. In the high mass selection, all jets with $p_{\mathrm{T}} > 40$ GeV are used to compute the $\mathrm{m_{eff}}$ value used in the final cut.

or μ) are rejected (although they are the subject of a separate ATLAS analysis [10]). A dedicated procedure is used to remove possible overlaps between final state objects reconstructed both as leptons and as jets.

The missing transverse momentum is reconstructed from the vectorial sum of all identified final state objects and cells belonging to clusters not associated with any object.

4. Event Selection

Several signal regions are defined aiming at different squark/gluino production and decay channels. If a squark pair is produced, and assuming $\tilde{q} \rightarrow q\tilde{\chi}_1^0$, two jets are expected in the final state. The associated $\tilde{q}\tilde{g}$ production, with the subsequent three-body decay of the gluino $\tilde{g} \rightarrow qq\tilde{\chi}_1^0$, leads to three jets in the final state. The gluino pair production followed by the gluino three-body decay leads to four jets in the final state. Five signal regions are defined and summarised in Table 1 in terms of the kinematic selection applied in each region. The four jets signal selection comprises two signal regions that differ by the selection applied on the $\mathrm{m_{eff}}$ variable, defined as the scalar sum of the transverse momenta of the selected jets and the missing transverse momentum. The $\Delta\phi(\mathrm{jet},\vec{P}_T^{miss})_{\mathrm{min}}$, defined as the minimum transverse plane angular separation of any of the leading three jets and the missing transverse momentum, and the $E_{\mathrm{T}}^{\mathrm{miss}}/\mathrm{m_{eff}}$ cuts are designed to strongly suppress backgrounds from QCD multi-jet production.

5. Background Estimation and Systematic Uncertainties

The main Standard Model processes contributing to the background are W+jets, Z+jets, $t\bar{t}$, single top and QCD multi-jet production. For each signal region, five control regions (CR) are defined, for a total of 25 CRs. The definition of the CRs is such that each of them has a high purity (at least above 50%) for one of the main background processes. The normalisation of each

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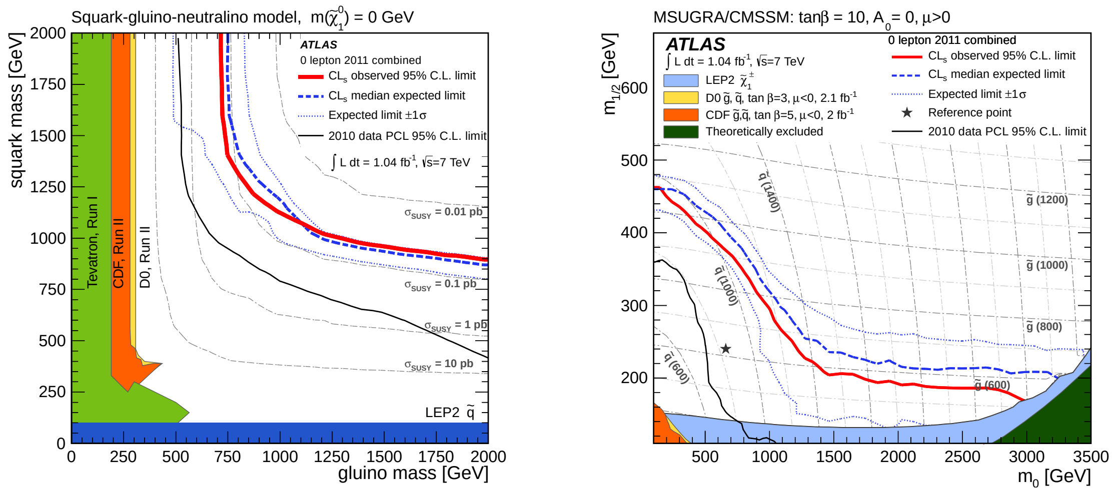

Figure 1: Combined exclusion limits for simplified SUSY models with $m(\tilde{\chi}_1^0) = 0$ (left) and MSUGRA/CMSSM models with $\tan\beta = 10$, $A_0 = 0$ and $\mu > 0$ (right). The combined limits are obtained by using the signal region which generates the best expected limit at each point in the parameter plane. The dashed-blue line corresponds to the median expected 95% C.L. limit and the red line corresponds to the observed limit at 95% C.L. The dotted blue lines correspond to the $\pm1\sigma$ variation in the expected limits. Also shown for comparison purposes in the figures are limits from the Tevatron and LEP, although it should be noted that some of these limits were generated with different models or parameter choices. The previous published ATLAS limits from this analysis [2] are also shown.

background process is obtained with a combined likelihood fit to all the control regions. The estimate of the background process in the signal region is then obtained by the use of transfer factors (TF), equivalent to the ratio of the number of expected events in the signal region with respect to that in the high purity control region. The TFs are obtained using a combination of MC and data inputs. The TF for the QCD multi-jet production process is obtained by normalising the number of pseudo-data events to that of the measured events in a region at small $\Delta\phi(\text{jet}, \vec{P}_T^{miss})_{\text{min}}$. The pseudo-data events are derived by smearing low $E_{\mathrm{T}}^{\mathrm{miss}}$ events by a jet response function tuned to data. The W+jets TF is obtained from control regions with similar kinematics as the signal region where, in addition, a requirement of the presence of one lepton and a b-jet veto is applied. Similar regions, but with the requirement of at least one b-tag, provide the TF for the top pair production background. The $Z \to \nu\nu$ background is estimated from two control regions consisting of $Z \to ll$ and γ+jets events respectively, where the vector boson (or its decay products, in the case on the Z) is replaced by missing transverse momentum.

Systematic uncertainties arising mainly from jet energy scale and MC mismodelling uncertainties affect the determination of the TFs. The former includes contribution from calorimeter scale, hadronic shower modelling, parton shower, underlying event and pile-up contributions. The latter, evaluated by comparing different generators, different parton shower settings, different PDF sets, typically dominate the TFs total uncertainty.

Systematic uncertainties on the expected SUSY signal cross sections are evaluated for each production process separately ($\tilde{g}\tilde{g}, \tilde{q}\tilde{q}, \tilde{q}\tilde{g}$) and include renormalisation and factorization scale and PDF uncertainties.

6. Results and Conclusions

The number of observed data events is consistent with the Standard Model prediction in all the five SRs considered. The result is used to set first a 95% CL limit on production cross section times acceptance, then this limit is interpreted in specific models.

The first interpretation is shown in Figure 1 (left). The model is a phenomenological MSSM one, where the mass of the neutralino (assumed to be the lightest stable SUSY particle) is set to zero, and the masses of all SUSY particles, but the gluino and first and second generation squarks, are set to 5 TeV. The expected and observed 95% exclusion limits are shown as a function of the gluino and common squark mass. Gluino and squark masses below 700 and 875 GeV respectively are excluded.

The result is also interpreted in MSUGRA/CMSSM models, with $\tan\beta = 10$, $A_0 = 0$, and $\mu > 0$ (Figure 1 right). For equal squark and gluino masses, the limit extends up to 950 GeV.

References

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