PROCEEDINGS OF SCIENCE

ATLAS searches for squarks and gluinos using leptons or multiple b-jets with 3.2 fb^{-1} of pp collisions at 13 TeV

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ATLAS performed various searches for supersymmetric squarks and gluinos decaying into different final states containing leptons, jets, b-tagged jets, and missing transverse momentum. The analyses use a data sample collected during 2015, which corresponds to a total integrated luminosity of 3.2 $\mathrm{fb}^{-1}$of 13 TeV proton-proton collisions. The results from these searches are interpreted in a variety of simplified models featuring gluino production. The experimental sensitivity reached gluino masses up to 1.6 TeV in the leptonic channels.

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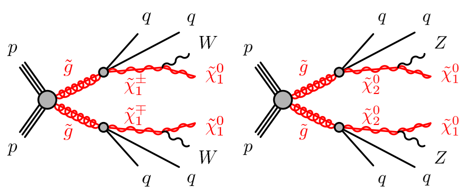
1. Introduction

Supersymmetry (SUSY) is a well motivated extension of the Standard Model (SM) that postulates a super-partner for each SM particle, all with identical quantum numbers to their SM partners, except spin. These super-partners are the scalar partners of quarks and leptons (squarks ($\tilde{q}$) and sleptons ($\tilde{\ell}$)), fermionic partners of gauge and Higgs bosons (gluinos ($\tilde{g}$), charginos ($\tilde{\chi}_i^{\pm}$, with i = 1,2) and neutralinos ($\tilde{\chi}_i^0$ with i = 1,2,3,4)). In the context of R-parity conserving SUSY, the Lightest Supersymmetric Particle (LSP) is considered a good dark matter candidate since it is stable and is assumed to be the lightest neutralino ($\tilde{\chi}_1^0$) which escapes detection. Due to the increase in the center-of-mass energy from 8 TeV to 13 TeV, the expected production cross section of gluinos and squarks scales faster than the SM backgrounds. As a result, all analyses targetting these processes exceeded the Run 1 sensitivity with just 3.2 fb^{-1}of data collected in 2015. In these proceedings, we summarize three leptonic searches that ATLAS [1] performed for squarks and gluinos using events containing leptons, jets, b-tagged jets, and missing transverse momentum with 3.2 fb^{-1}of data collected at 13 TeV.

2. One lepton and jets

The one lepton and jets analysis [2] requires the presence of one isolated lepton (electron or muon) in the event, multiple jets and substantial missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$). The one lepton requirement helps reduce the predominant QCD multijet background associated with the hadronic activity that result from pp collisions. For benchmarking, the analysis uses a simplified model that involves a gluino pair production decaying to the LSP via the lightest chargino ($\tilde{\chi}_1^{\pm}$) as shown in Figure 1a.



(a) (b)

Figure 1: SUSY processes featuring gluino pair production considered in the (a) one lepton and (b) two leptons on-Z analyses [2].

Two complementary search channels are considered and are characterized by the presence of a low transverse momentum (p_{T}) lepton (7/6 GeV< $p_{\mathrm{T}}(e/\mu)$ < 35 GeV) referred to as the soft-lepton channel, or high-p_{T} lepton ($p_{\mathrm{T}}(e/\mu)$ > 35 GeV) referred to as the hard-lepton channel. The low-p_{T} and high-p_{T} channels target models with small and large mass differences between the supersymmetric particles, respectively. In each of the channels, signal regions (SRs) were optimized for specific mass hierarchy between the gluino, chargino, and the neutralino by placing cuts on jet multiplicity, missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$), effective mass ($m_{\mathrm{eff}}$)[1], transverse mass ($m_{\mathrm{T}}$)[2] , and aplanarity.

[1] $m_{\mathrm{eff}} = \sum_i p_{\mathrm{T}}^{\mathrm{jet}} + \sum_j p_{\mathrm{T}}^{\ell_j} + E_{\mathrm{T}}^{\mathrm{miss}}$

[2] $m_{\mathrm{T}} = \sqrt{2 p_{\mathrm{T}}^{\ell} E_{\mathrm{T}}^{\mathrm{miss}} \{1 - \cos\left[\Delta\phi\left(p_{\mathrm{T}}^{\mathrm{miss}}, \ell\right)\right]\}}$

The main backgrounds affecting this analysis are $t\bar{t}$ and W+jets which are normalized to data in control regions (CR) enriched in these processes. The normalization is extrapolated to the SRs using transfer factors that rely on the shape information obtained from MC simulation.

Validation regions (VR) that are kinematically close to the SRs are used to check the reliability of the extrapolation. The estimates are consistent with the observations in all validation regions as can be seen from the results of the background-only fit shown in Figure 2.

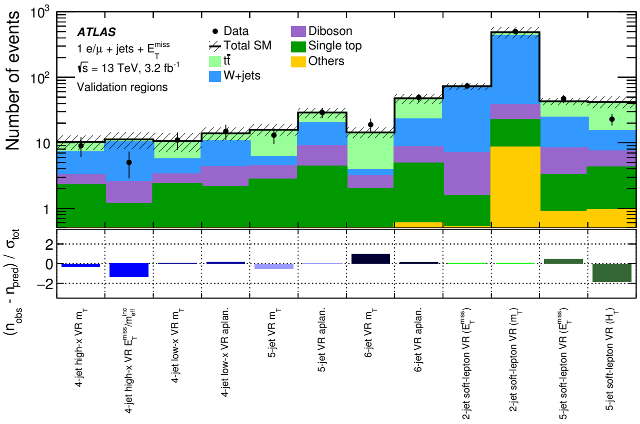


Figure 2: The observed and expected yields in all hard-lepton and soft-lepton VRs. The lower panel shows the difference in standard deviations between the observed and expected yields [2].

3. Two leptons on-Z and jets

The two leptons on-Z and jets analysis [3] targets SUSY scenarios that may produce Z bosons via the cascade decays of squarks and gluinos, where the Z boson subsequently decays leptonically (electrons or muons). An example of such a decay is shown in Figure 1b. The targetted final state in this search, $Z+\text{jets}+E_{\text{T}}^{\text{miss}}$, had an excess of 3 standard deviations above the SM expectation in Run 1 [4]. As a result, the kinematic selection was kept close to the one used in Run 1 to check the observed excess. The selection for this analysis consists of events with a pair of same-flavour opposite-sign leptons originating from a Z-boson decay, at least two jets, $E_{\text{T}}^{\text{miss}} > 225$ GeV, and $H_{\text{T}} > 600$ GeV (H_{T} is the sum of lepton and jet p_{T}). The main backgrounds in the SR are due to $t\bar{t}$, WW, and Wt production processes in which the branching fraction to $ee:\mu\mu:e\mu$ follows an expected $1:1:2$ ratio. This type of background is commonly referred to as the “flavour-symmetric” background. It is estimated by using data events in $e\mu$ control sample to determine the expected event yields in the same flavor channels and cross-checked with a fit of MC simulation to data in the Z mass sidebands window. The results from both methods are validated in dedicated VRs. Another background is due to $Z \to \ell\ell$ ($\ell = e, \mu$) that enters the SR if large $E_{\text{T}}^{\text{miss}}$ is present which may come from instrumental effects leading to “fake” $E_{\text{T}}^{\text{miss}}$or from neutrinos in jet fragmentation. Since γ+jets and Z/γ^{*}+jets processes have similar event topologies, γ+jets data events are used to model the $E_{\text{T}}^{\text{miss}}$distribution of Z/γ^{*}+jets. The remaining backgrounds such as dibosons production (WZ/ZZ) and other rare processes are taken from pure MC simulation with dedicated VRs. The estimates are consistent with the observations in all validation regions as can be seen from the results shown in Figure 3. In the SR, 21 events were observed almost evenly distributed in ee and

$\mu\mu$ channels with 10.3 ± 2.3 expected with a significance of 2.2 standard deviations. It is necessary to revisit this excess with more data during 2016.

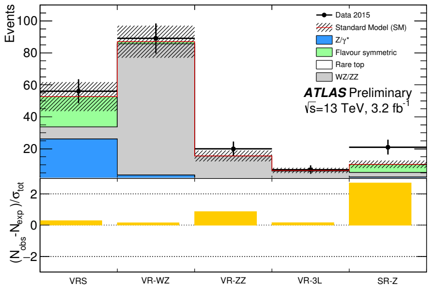


Figure 3: The observed and expected yields in the VRs and SR. The lower panel shows the difference in standard deviations between the observed and expected yields. A slight excess of events is observed in the SR [3].

4. Two same-sign leptons or three leptons and jets

In this analysis [5], 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) are used to look for gluinos and squarks. This analysis uses the fact that gluinos are Majorana fermions which can produce equally same-sign or opposite sign leptons via the decay chain of gluino pair production or produce multiple leptons via the cascade decays. This search has a low SM background which allows it to use looser kinematic requirements than other beyond the SM searches and thus increasing the sensitivity to scenarios with small mass differences between SUSY particles (compressed scenarios). The SS or 3L final state is sensitive to a variety of supersymmetric models, particulary in decays involving massive gauge bosons, sleptons, or top quarks. Four simplified models are considered to represent these processes, as shown in Figure 4, and a SR was optimized to target each one of the processes.

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 associated production of a top quark pair 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 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 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. For illustration, Figure 5 shows distributions after requiring the SS/3L selection that demonstrate the good modeling of the charge flip background and one of the VRs used to check the MC modeling of the WZ process.

5. Results

Apart from the two leptons on-Z analysis SR with a mild excess of 2.2 standard deviations, all the other SRs defined in the leptonic searches described show no significant excess over the

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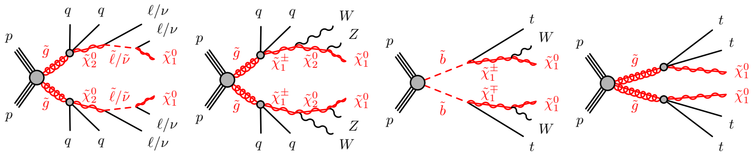

Figure 4: SUSY processes featuring gluino (a, b, d) or bottom squark (c) pair production considered in the SS/3L analysis [5].

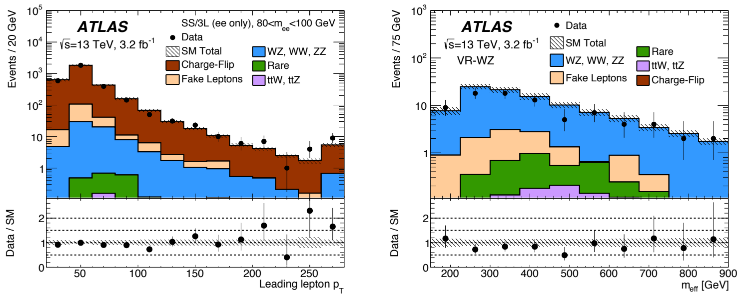

Figure 5: Distributions of kinematic variables after a SS/3L selection used to validate the background estimates of (left) the charge-flip background and (right) the WZ background. The lower panels of the plots show the ratio of the observed data to the total SM background expected from simulations. The uncertainty bands include all statistical and systematic uncertainties on simulation [5].

predicted SM background. As a result, upper limits on possible beyond the SM contributions to the SRs are computed where gluino masses $m_{\tilde{g}} \lesssim 1.1$–$1.6$ TeV for $m_{\tilde{\chi}_1^0} \lesssim 300$–$850$ GeV and bottom squark mass $m_{\tilde{b}_1} \lesssim 540$ GeV are excluded at 95% confidence level depending on the model parameters [2, 3, 5].

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