PROCEEDINGS OF SCIENCE

SUSY searches at $\sqrt{s}$ = 13 TeV with two same-sign leptons or three leptons, jets and $E_{\mathrm{T}}^{\mathrm{miss}}$ at the ATLAS detector - Background estimation and latest analysis results.

Peter Tornambe[*] [†]
Albert-Ludwigs-Universitaet Freiburg (DE)
E-mail: peter.tornambe@cern.ch

This proceeding summarizes a search for supersymmetric phenomena in final states with two leptons (electrons or muons) of the same electric charge or three leptons, jets and missing transverse energy. While the same-sign or three leptons signature is present in many SUSY scenarios, SM processes leading to such events have very small cross-sections. Therefore, this analysis benefits from a small SM background in the signal regions leading to a good sensitivity especially in SUSY scenarios with compressed mass spectra or in which the R-parity is not conserved. The search was performed with the full dataset recorded with the ATLAS detector at the Large Hadron Collider during the year 2015 and 2016 corresponding to a total integrated luminosity of 36.1 fb^{-1}. No significant excess above the Standard Model expectations is observed. The results are interpreted in several simplified supersymmetric models featuring R-parity conservation or R-parity violation, extending the exclusion limits from previous searches.

The European Physical Society Conference on High Energy Physics
5-12 July
Venice, Italy

[*]Speaker.
[†]on behalf of the ATLAS Collaboration

PoS(EPS-HEP2017)721

1. Introduction and Motivation

Supersymmetry (SUSY) is one of the most studied theories to extend the Standard Model (SM) beyond the electroweak scale. If R-parity is conserved, SUSY particles are produced in pairs and the lightest supersymmetric particle (LSP) which is typically the lightest neutralino $\tilde{\chi}_1^0$ is stable. In many models, the LSP can be a dark-matter candidate and produce signatures with large missing transverse momentum. If instead R-parity is violated (RPV), the LSP decay can generate events with high jet and lepton multiplicity. Both RPC and RPV scenarios can produce the final-state signatures considered. A search for supersymmetric phenomena in final states with two leptons (electrons or muons) of the same electric charge, referred to as same-sign (SS) leptons, or three leptons (3L), jets and in some cases also missing transverse energy $E_{\mathrm{T}}^{\mathrm{miss}}$ with proton-proton collision at $\sqrt{s}$ = 13 TeV [1] collected by ATLAS [2] at LHC is presented . The analysed data-sample corresponds to an integrated luminosity of 36.1 fb^{-1} and has been collected in 2015 and 2016. The results shown are an extension of an earlier search performed by the ATLAS experiment with $\sqrt{s}$ = 13 TeV data.
While the same-sign leptons signature is present in many supersymmetric scenarios, SM processes leading to such events have very small cross-sections. Therefore, this analysis benefits from a small SM background in the signal regions leading to a good sensitivity especially in compressed regions of the SUSY phase-space and in R-parity violated scenarios. Except from the prompt production of same-sign lepton pairs, the main sources for SM processes contaminating the signal regions are fake-leptons and leptons with a charge mis-identification. This allows to use relatively loose kinematic requirements on $E_{\mathrm{T}}^{\mathrm{miss}}$ increasing the sensitivity to several different scenarios with small mass splitting between SUSY particles (compressed scenarios) or where R-parity is violated.

2. Signatures with strong production

The fact that this analysis is sensitive to a wide range of BSM physics processes is illustrated by the interpretation of the results in the context of twelve different SUSY simplified models that may lead to same-sign or three-lepton signatures. For RPC models, the first scenarios studied focus on gluino pair production with decays into on-shell or off-shell top quarks, as well as on-shell light quarks. While the other two RPC scenarios target the direct production of third-generation squark pairs with subsequent electroweakino-mediated decay. Moreover, a full SUSY model with low fine-tuning, the non-universal Higgs model with two extra parameters (NUHM2) [3] is also considered. In the case of non-zero RPV couplings in the baryonic sector (λ''_{ijk}) as proposed in scenarios with minimal flavour violation; gluinos and squarks may decay directly to top quarks or to a neutralino LSP that further decays to SM particles via a non-zero RPV coupling in the leptonic sector.

3. Signal Regions

The signal regions are defined after an optimisation study based on simulated events for the signal models proposed. Events with two leptons with the same charge sign and p_{T} > [20,20] GeV or three lepton with p_{T} > [20,20,10] GeV are selected.
Different kinematic variables are used to define the Signal Regions: $E_{\mathrm{T}}^{\mathrm{miss}}$, jets ($p_{\mathrm{T}}$ > 25 GeV) and

b-jet multiplicities (p_{T} > 20 GeV) and effective mass m_{eff} computed from all signal leptons and selected jets as $m_{\mathrm{eff}} = E_{\mathrm{T}}^{\mathrm{miss}} + \sum p_{\mathrm{T}}^{l} + \sum p_{\mathrm{T}}^{jet}$
In the end 19 different Signal Regions have been designed to target the twelve different SUSY scenarios considered.

4. Background estimation

Searches in SS and 3L are characterized by low background yields. There are three different sources of background: (1) prompt multi-leptons, (2) "fake" leptons, when hadrons are misidentified as leptons or are coming from heavy-flavour decays, and (3) charge mis-measured leptons from photon conversion, this background is negligible for muons.

4.1 Prompt lepton background

Standard Model processes with same-sign leptons or three leptons in the final states have a small cross section. The irreducible background from events with two same-sign prompt leptons or at least three prompt leptons is estimated using the MC simulation samples. Since diboson and $t\bar{t}$V events are the main irreducible backgrounds in the signal regions, dedicated validation regions (VR) with an enhanced contribution from these processes, and small signal contamination, are defined to verify the background predictions from the simulation. All VR have a good agreement between data and predictions.

4.2 Fake lepton background

The fake lepton background is produced by processes where hadrons are mis-identified as leptons, or leptons are originating from heavy-flavour decays and electrons from photon conversion. Two data-driven methods are used to estimate the Fake Non-Prompt (FNP) lepton background, referred to as the matrix method and the MC template method. The estimates from these methods are combined in a weighted average to give the final estimate. The first estimation of the FNP lepton background is performed with a matrix method similar to that described in [4], if the ratio of signal leptons to loose leptons ε_1,ε_2,ζ_1,ζ_2 is known separately for prompt/fake leptons, the number of events with at least one fake lepton can be predicted. The second method for FNP lepton estimation is the MC template method described in details in [5]. It relies on the correct modelling of the kinematic distributions of the FNP leptons and charge-flipped electron processes in $t\bar{t}$V and V+jets samples.

4.3 Charge mis-measurement background

The most relevant background for same sign signal regions is the mis-measurement of the charge of a lepton in a process with two opposite-sign leptons in the final state. Charge misidentification is mainly due to the radiation of a hard photon from an electron followed by a conversion in $e^{+}e^{-}$ pair in the material, where the electron with the opposite charge has the larger p_{T}. The charge-flip background is dominated by dilepton $t\bar{t}$ events and is significant only for electrons pair. The probability of mis-identifying the charge of a muon is determined in simulation to be negligible in the kinematic range relevant to this analysis.

PoS(EPS-HEP2017)721

For charge-flip electrons (negligible for muons), the charge-flip rate is measured with a likelihood fit in a $Z/\gamma^{*} \to e^{+}e^{-}$ sample. The yields of this background in the signal regions are obtained by applying the measured rate to data regions similar to signal regions but with OS leptons.

5. Results and Interpretations

Figure 1 shows the event yields for data and the expected background contributions in all signal regions. In all 19 SRs the number of observed data events is consistent with the expected background within the uncertainties

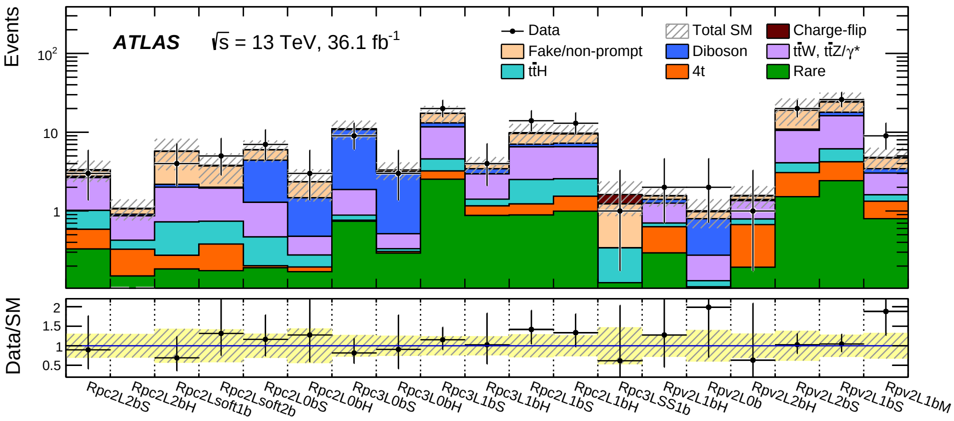


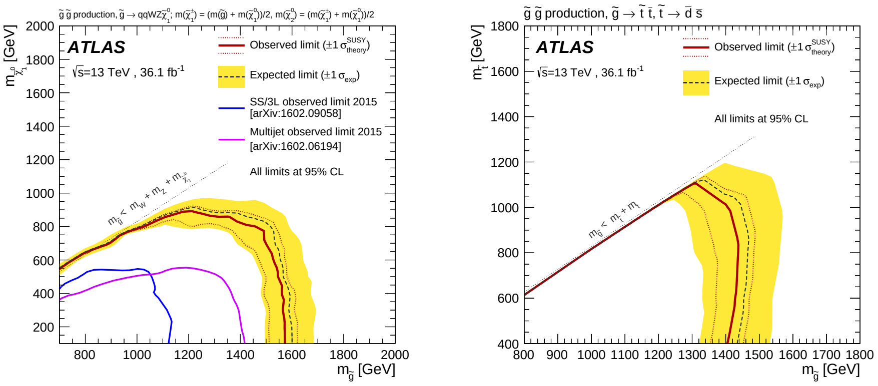
Figure 1: Comparison of (a) the observed and expected event yields in each signal region [1].

5.1 Model dependent limits

Starting from the signal models studied, an exclusion limit can be set for each one of them. The limits are calculated from asymptotic formulae with a fit to all signal regions based on the profile likelihood method. The exclusion fits are typically presented with a solid red line for the observed limit and a dashed grey line for the expected limit; in addition, two dashed red lines represent the observed limits obtained by changing the SUSY cross section by one standard deviation ($\pm\sigma^{SUSY}_{Theory}$). Statistical and systematic uncertainties (theoretical SUSY cross section uncertainty not included) are shown by a yellow band ($\pm\sigma$) around the expected limit.
In Figure 2 the limit plots for an RPC and an RPV simplified model are shown as an example for the final exclusion plots. For the RPC models, the limits set are compared with the existing limits set by other ATLAS SUSY searches.

6. Conclusions

A search for supersymmetry in events with two same-sign leptons or at least three leptons, multiple jets, b-jets and large $E_{\mathrm{T}}^{\mathrm{miss}}$ and/or large m_{eff} with proton-proton collision at $\sqrt{s}$ = 13 TeV collected by ATLAS at LHC is presented. The analysed data-sample corresponds to an integrated luminosity of 36.1fb^{-1} and has been collected in 2015 and 2016. No excess has been observed



(a) (b)

Figure 2: (a) Observed and expected exclusion limits on the $\tilde{g}$ and $\tilde{\chi}_1^0$ masses in the context of RPC SUSY scenarios with simplified mass spectra. All limits are computed at 95% CL. (b) Observed and expected exclusion limits on the $\tilde{t}$ and $\tilde{g}$ masses in the context of RPV SUSY scenarios with simplified mass spectra. All limits are computed at 95% CL [1].

in data, and exclusion limits have been set to different SUSY scenarios. In the $\tilde{g}\tilde{g}$ simplified RPC models considered, gluinos with masses up to 1.87 TeV are excluded in scenarios with a light $\tilde{\chi}_1^0$ mass. Also models with bottom squark masses below 700 GeV are also excluded in a $\tilde{b}_1\tilde{b}_1^*$ simplified model. While in the RPV scenarios, masses of down squark-rights are excluded up to $m_{\tilde{d}_R} \approx$ 500 GeV. All models with gluino masses below 1.3 TeV are excluded, improving significantly previous exclusion obtain within this search [4].

References

[1] ATLAS Collaboration, doi: 10.1007/JHEP09(2017)084, arXiv:1706.03731 [hep-ex].

[2] ATLAS Collaboration, doi: 10.1088/1748-0221/3/08/S08003, JINST 3 (2008) S08003.

[3] J. Ellis, T. Falk, K. A. Olive and Y. Santoso, doi: 10.1016/S0550-3213(02)01144-6, arXiv: hep-ph/0210205.

[4] ATLAS Collaboration, doi: 10.1007/JHEP06(2014)035, arXiv:1404.2500 [hep-ex].

[5] ATLAS Collaboration, ATLAS-CONF-2012-151, 2012, url: https://cds.cern.ch/record/1493490.