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SUPERSYMMETRY SEARCHES IN ATLAS

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Abstract. Weak scale supersymmetry remains one of the best motivated and studied Standard Model extensions. This contribution summarises recent ATLAS results for searches for supersymmetric particles with the LHC Run 1 data at $\sqrt{s} =$ 8 TeV. A sensitivity study for the $\sqrt{s} = 13$ TeV data is also briefly presented.

1 Introduction

Supersymmetry (SUSY) [1] is a generalisation of space-time symmetries that predicts new bosonic partners for the fermions and new fermionic partners for the bosons of the Standard Model (SM). The physical superpartners of the SM particles would be: scalar partners of quarks and leptons (squarks ($\tilde{q}$) and sleptons ($\tilde{\ell}$)), fermionic partners of gauge and Higgs bosons (gluinos ($\tilde{g}$), charginos and neutralinos). The charginos ($\tilde{\chi}^{\pm}$) and neutralinos ($\tilde{\chi}^{0}$) are mixtures of the bino, winos and higgsinos, collectively referred to as the electroweakinos, that are superpartners of the U(1), SU(2) gauge bosons and the Higgs bosons, respectively. Their mass eigenstates are referred to as $\tilde{\chi}^{\pm}_i$ ($i = 1, 2$) and $\tilde{\chi}^{0}_j$ ($j = 1, 2, 3, 4$) in order of increasing mass. Since no superpartners of any of the SM particles have been observed, SUSY, if realised in nature, must be a broken symmetry, therefore SUSY particles (called sparticles) must be heavier than their SM partners and could be produced in the Large Hadron Collider (LHC) [2].

Several classes of phenomenological and simplified models covering different combinations of physics objects in the final state have been studied in ATLAS [3] with the LHC Run 1 data. Here just a few examples of the rich variety of results at $\sqrt{s}$ =8 TeV, using a total integrated luminosity of about 20 fb^{-1}, will be shown giving emphasis to the most recent results.

This document is organised as follows: Section 2 will present strong production searches, Section 3 will be dedicated to 3$^{\text{rd}}$ generation squarks production and Section 4 to electroweak production. In those sections only RPC searches will be considered, leaving RPV searches for Section 5. Long-lived particles searches will not be considered in this contribution but can be found in Refs. [4, 5].

2 Strong Production Searches

This Section presents several results from inclusive searches for gluinos and first- and second-generation squarks.

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First, a simplified model with one-step decays is considered. In this case the pair-produced squarks decay via the $\tilde{\chi}_1^{\pm}$ into a W boson and the $\tilde{\chi}_1^0$. The free parameters are $m_{\tilde{q}}$ and $m_{\tilde{\chi}_1^0}$ with $m_{\tilde{\chi}_1^{\pm}} = (m_{\tilde{q}} + m_{\tilde{\chi}_1^0})/2$. This model was probed with two independent analyses: the 0-lepton (which requires the absence of isolated electrons or muons, at least two to at least six jets and significant $E_{\mathrm{T}}^{\mathrm{miss}}$) and the 1-lepton (requiring at least one isolated electron or muon, jets and high $E_{\mathrm{T}}^{\mathrm{miss}}$). The 95% CL exclusion limits obtained with the results of the two analyses separately as well as the statistical combination of both can be seen in Fig. 1. Details about the analyses and studies of other models can be seen in Ref. [6].

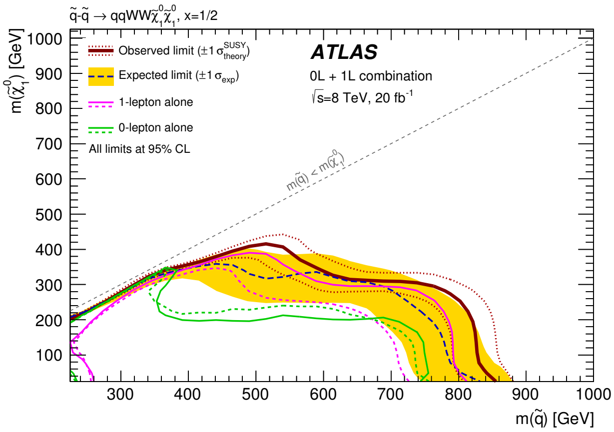

Figure 1: Observed and expected exclusion limits for simplified models of squark-pair production with one-step decays via the $\tilde{\chi}_1^{\pm}$ into a W boson and the $\tilde{\chi}_1^0$. The area below the observed limit is excluded at 95% CL. The yellow band includes all experimental uncertainties; the red dotted lines indicate the theory uncertainty on the cross-section. Taken from Ref. [6]

Another of the many interesting searches performed in the frame of the strong production searches is the Z+MET analysis [7], where events are required to contain at least two same-flavoured leptons (electrons or muons), with opposite charge, coming from the decay of a Z boson, at least two jets and high $E_{\mathrm{T}}^{\mathrm{miss}}$. After using data-driven methods to estimate all major backgrounds, which are thoroughly cross-checked with other methods (including data-driven, semi data-driven and MC), the total background estimation is 10.6 ± 3.2 events, whereas the observed number of events is 29. This corresponds to a significance of 3.0 σ. Figure 2 shows the number of observed events contrasted with the estimated background for all the regions considered in the analysis. This plot is especially interesting because it shows that the excess is not an effect of the incorrect estimation of any backgrounds. As it can be seen, in all the regions but the Signal Region (SR) the observed and estimated number of events are in very good agreement. The question if this excess is a hint of new physics or

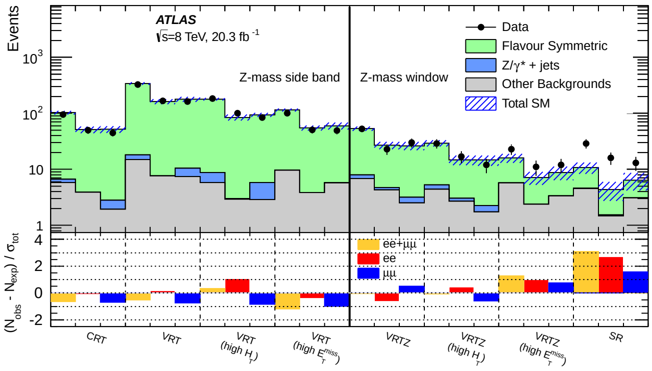

Figure 2: Summary of the agreement between data and prediction in the regions included in the Z+MET analysis. The detailed definition of all the regions can be found in Ref. [7]

a statistical fluctuation remains to be answered by the LHC Run 2 data. These results have been interpreted in a General Gauge Mediated (GGM) model and exclusion limits have been set [7].

3 Searches for Direct Pair Production of 3$^{\rm rd}$ Generation Squarks

Several searches targeting specific stop and sbottom final-state topologies can be found in Ref. [8]. Here an example will be shown where a series of simplified models is considered. It includes direct stop pair production as the only SUSY production process, and assumes that no supersymmetric particle other than the $\tilde{t}_1$ itself and the LSP, taken to be the lightest neutralino $\tilde{\chi}_1^0$, is involved in the decay. Under this assumption, there is little model dependence left in the stop phenomenology. The stop decay modes are defined mainly by the mass separation $\Delta m(\tilde{t}_1, \tilde{\chi}_1^0)$ between the stop and the neutralino. Figure 3 shows the 95% CL exclusion limits obtained in the $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0})$ plane by the relevant analyses listed in Ref. [8].

4 Electroweak Production Searches

The ATLAS results for electroweakino searches at 8 TeV in the framework of simplified models are summarised in Fig. 4 in the (m($\tilde{\chi}_1^{\pm}$,$\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)) plane. Each of the $\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0/\tilde{\chi}_3^0$ decays considered in the plot is assumed to have 100% branching fraction, and the production cross-section is for pure wino $\tilde{\chi}_1^+\tilde{\chi}_1^-$ and $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$, and pure higgsino $\tilde{\chi}_2^0\tilde{\chi}_3^0$. The limits for $\tilde{\chi}_1^+\tilde{\chi}_1^-$ and $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production with SM boson mediated decays are summarised in Fig. 4 (left). The limits for $\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ and $\tilde{\chi}_2^0\tilde{\chi}_3^0$ production with $\tilde{\ell}$-mediated decays are summarised in Fig. 4 (right). More details about the analyses that derived to these limits can

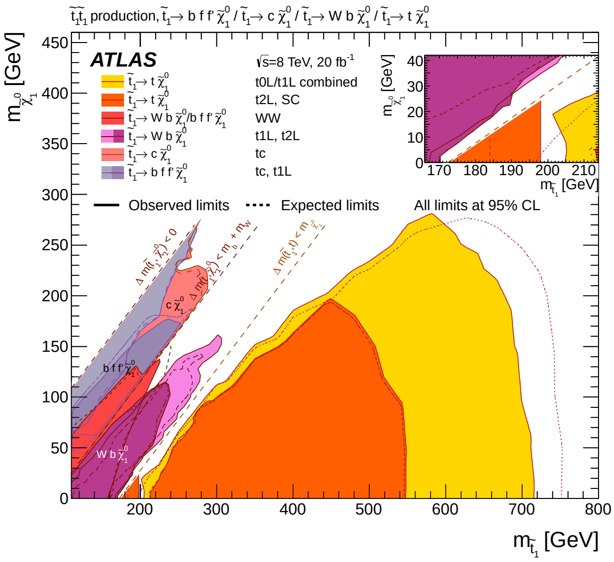

Figure 3: Summary of searches for direct stop pair production in models where no supersymmetric particle other than the $\tilde{t}_1$ and the $\tilde{\chi}_1^0$ is involved in the $\tilde{t}_1$ decay. The 95% CL exclusion limits are shown in the $(m_{\tilde{t}_1}, m_{\tilde{\chi}_1^0})$ mass plane. The dashed and solid lines show the expected and observed limits respectively, including all uncertainties except the theoretical signal cross-section uncertainty (PDF and scale). Four decay modes are considered separately with a branching ratio of 100%. Taken from Ref. [8]

be found in Ref. [9].

5 R-parity-violating Searches

Introducing RPV [10] into supersymmetric models can significantly weaken mass and cross-section limits from collider experiments and also provide a rich phenomenology. Most relevant is the fact that the lightest supersymmetric particle (LSP) is unstable and decays to SM particles rather than escaping unseen as predicted by models that conserve R-parity. This contribution shows the phenomenological minimal supersymmetric Standard Model (pMSSM) with R-parity violation through bilinear terms (bRPV).

The 95% CL lower limits obtained on the μ (the higgsino mass parameter) and $m_{\tilde{q}_{L},L}$ (the mass parameter for left-handed top and bottom squarks) parameters in natural SUSY with bRPV [10] are shown in Fig. 5.

6 Run1 SUSY Searches in Summary

This section summarises the combined sensitivity and constraints from 22 separate ATLAS analyses of the Run 1 LHC dataset. The interpretation of those

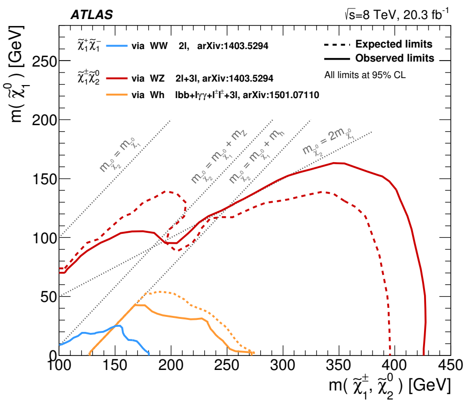

Figure 4: The 95% CL exclusion limits on $\tilde{\chi}_1^+\tilde{\chi}_2^-$, $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ and $\tilde{\chi}_2^0\tilde{\chi}_3^0$ production with (left) SM-boson-mediated decays and (right) $\tilde{\ell}$-mediated decays as a function of the $\tilde{\chi}_1^\pm$, $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^0$ masses. The production cross-section is for pure wino $\tilde{\chi}_1^+\tilde{\chi}_2^-$ and $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$, and pure higgsino $\tilde{\chi}_2^0\tilde{\chi}_3^0$. Taken from Ref. [9]

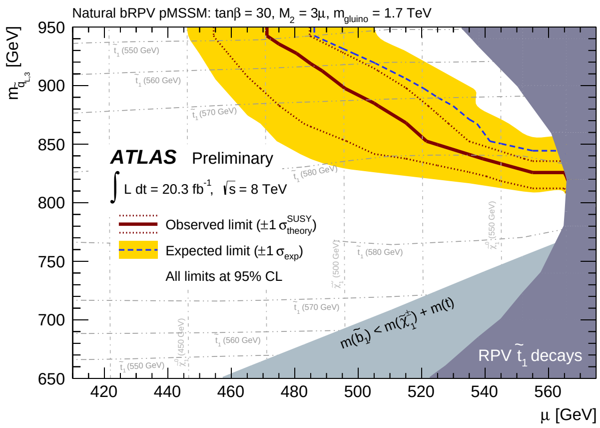

Figure 5: Observed (solid) and expected (dashed) 95% CL exclusion limit contours for the natural bRPV model. The region below and to the left of the solid line is excluded. The yellow band shows the effect of varying the experimental systematic uncertainties by $\pm 1\sigma$, while the dotted lines show the effect of the theoretical cross-section uncertainty. The other shaded areas at high μ are not explored in this analysis, see Ref. [10] for details.

results is done here within the wider framework of the pMSSM, where the over a hundred parameters of the MSSM are reduced to 19 applying a series of assumptions motivated by either experimental constraints or general features of possible SUSY breaking mechanisms. In this section the model is assumed to conserve R-parity and the LSP is required to be the lightest neutralino. A total of 310,327 model points are selected, each of which satisfies constraints from previous collider searches, precision measurements, cold dark matter energy density measurements and direct dark matter searches. More details about this study can be found in Ref. [11].

The impact of the ATLAS Run 1 searches on this model space is presented in Fig. 6, showing their overall effect in constraining such supersymmetric models. The plot shows the fraction of model points excluded for each sparticle as a function of the sparticle mass.

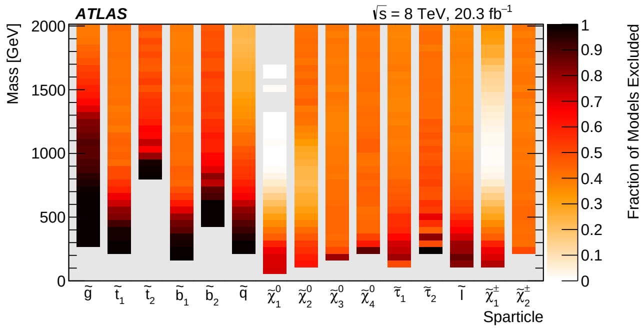

Figure 6: Each vertical bar is a 1D projection of the fraction of model points excluded, with colour coding representing the fraction of model points excluded for each sparticle. Taken from Ref. [11].

7 What's next?

This section describes the study of the expected sensitivity to pair-produced gluinos in final states with exactly one isolated lepton (an electron or a muon) and large missing transverse momentum. The sensitivity measure is the signal significance calculated based on the discovery p_0 values from the background-only hypothesis test for a counting experiment. The uncertainty on the SM background expectation is taken to be at the same level as the one observed in Run 1 (25%). Various assumptions on the integrated luminosity are evaluated. More details on this study and several others can be found in Ref. [12].

Figure 7 shows the best p_0-value obtained in the optimisation for the simplified model with gluino pair production and decay via a $\tilde{\chi}_1^{\pm}$ and two quarks to a $\tilde{\chi}_1^0$ and a W boson [12].

The LHC Run 2 has already started and several performance checks in preparation for SUSY searches have been made with an integrated luminosity about 78 pb^{-1} and $\sqrt{s} = 13$ TeV. These studies show good agreement between data and MC simulations.

8 Conclusion

Many SUSY searches have been performed, with Run 1 data, targeting different production processes and covering a wide range of final states. No significant

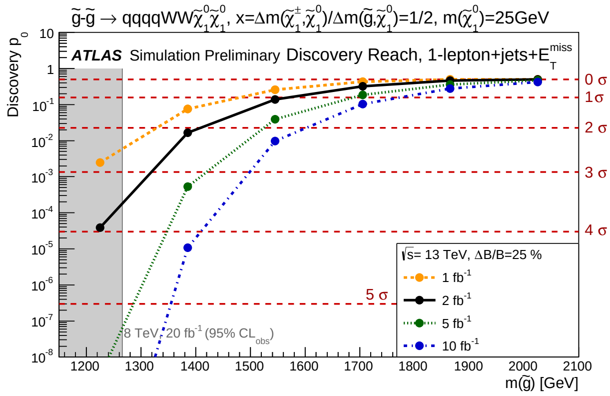

Figure 7: The best p_0-value obtained in the optimisation is shown for the simplified model with gluino pair production and decay via a chargino and two quarks to a neutralino and a W boson. Different integrated luminosities were assumed in the optimisation: 1, 2, 5 or 10 fb^{-1}. The plot assumes a total uncertainty of 25% on the background yield. Taken from Ref. [12]

excesses have been observed and 95% CL exclusion limits have been set for a large variety of models. However, an interesting 3 σ excess has been observed in the Z+MET [7] analysis, which will be further investigated with Run 2 data.

The LHC Run 2, which has already started, presents great potential for the discovery of new Physics due to its higher center-of-mass energy and luminosity.

Acknowledgments

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