Search for R-parity violating SUSY signatures with the ATLAS detector

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Searches for supersymmetry at the LHC also cover signatures from R-parity violating processes. These can be final states with resonant or non-resonant lepton flavour violation or multiple leptons. The talk presents recent results from searches for R-parity violation in events containing leptons based on data recorded in 2011 by the ATLAS detector.

1 Introduction

In general supersymmetry can lead to a large variety of signatures [1]. If R-parity is not conserved, the lightest supersymmetric particle (LSP) can decay further into standard model particles via R-parity violating Yukawa couplings. These new Yukawa couplings can either violate lepton number conservation (λ,λ') or baryon number conservation (λ") [2]. The results presented here show searches for R-parity violating supersymmetry in different final states containing leptons with the ATLAS detector using data recorded in 2011 [3]. In none of the searches an excess of data above the standard model background is observed and limits were set on the masses of new particles, the R-parity violating couplings itself and the parameter space of certain R-parity violating SUSY models.

2 Searches for heavy neutral particles in the eμ final state

A lot of standard model extensions predict new short-lived, heavy particles that can decay into two oppositely signed leptons of different flavours. In R-parity violating supersymmetry a heavy tau sneutrino can undergo this decay. The search for a heavy neutral particle decaying into an electron and a muon based on 1.07 fb^{-1} [4] is an update of the same analysis performed on 35 pb^{-1} presented in [5]. A single lepton trigger is used to collect the data sample analyzed in this search. The trigger efficiency is measured to be 100% with a precision of 1% for all $e\mu$ candidates that pass the offline selection. Electrons are required to have a transverse momentum of larger than 25 GeV, with a pseudorapidity of $|\eta| < 1.37$ or $1.52 < |\eta| < 2.47$. Quality criteria based on shower shapes, track quality, track matching with the calorimeter cluster and calorimeter isolation are imposed. Muons are reconstructed using the inner detector and the muon system. The transverse momentum must be larger than 25 GeV with a pseudorapidity of $|\eta| < 2.4$. Track isolation is imposed to reduce the background from non isolated muons. Each event is required to have exactly one electron and one muon passing the listed selection criteria. The invariant mass of the electron and muon - as the final discriminant - is examined for the presence

of a heavy tau sneutrino. The distribution is divided into 11 search regions, which depend on the simulated mass resolution defined as ($m_{\tilde{\nu}_\tau}$ + 3σ,$m_{\tilde{\nu}_\tau}$ - 3σ), where σ is the expected $m_{e\mu}$ resolution. In each search region, the number of observed and simulated background and signal events is used to calculate upper limits on $\sigma(\mathrm{pp} \longrightarrow \tilde{\nu}_\tau) \times BR(\tilde{\nu}_\tau \longrightarrow \mathrm{e}\mu)$, probing assumed $m_{\tilde{\nu}_\tau}$ in the range between 100 GeV up to 2 TeV. Figure 1 shows the 95% CL limits on $\sigma \times$ BR(eμ) as a function of the tau sneutrino mass. For R-parity violating couplings λ'$_{311}$ = 0.11 (0.1) and λ_{312} = 0.07 (0.05) tau sneutrinos with masses up to 1.32 (1.45) TeV are excluded. Figure 2 shows the 95 % C.L. upper limit on λ'$_{311}$ for different values of λ_{312} as a function of $m_{\tilde{\nu}_\tau}$.

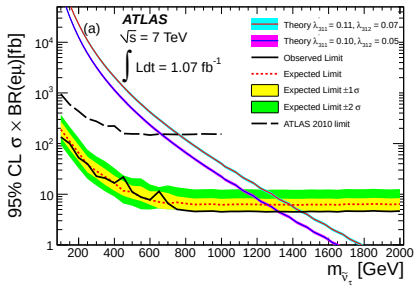

Figure 1: 95% C.L. upper limits on $\sigma \times$ BR(eμ) as a function of the tau sneutrino mass [4]. Also shown are the $\pm$1 and $\pm$2 standard deviation uncertainty bands and the previous ATLAS result from 2010

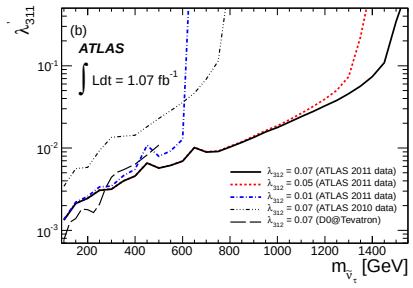

Figure 2: 95% C.L. upper limits on λ'$_{311}$ as a function of the tau sneutrino mass for three different values of λ_{312} [4]. Also shown are the exclusion regions obtained from the D0 experiment and the previously published ATLAS analysis

3 Constraining R-parity violating mSUGRA in a four lepton final state

Events with a high multiplicity of leptons can occur in a large variety of standard model extensions. The search presented in [6] is based on 2.06 fb^{-1} and targets a R-parity violating

mSUGRA model with a $\tilde{\tau}_1$ as the lightest supersymmetric particle undergoing a four body decay into a tau, a neutrino and two charged leptons. This search is a reinterpretation of the previously performed search for supersymmetry in four lepton final states [7] aiming at R-parity violating decays. The RPV coupling $\lambda_{121} = 0.032$ at the grand unification scale is small enough that SUSY particle pair production still dominates leading to final states with at least 4 charged leptons and missing transverse momentum. Single lepton triggers are used to collect the data and the simulated events are weighted by the trigger efficiencies measured on data. In order to obtain a high and stable trigger efficiency, an electron (muon) with a transverse momentum of 25 GeV (20 GeV) must be present in the event. Electrons are required to have a transverse energy of at least 10 GeV, with a pseudorapidity of $|\eta| < 2.47$. In the barrel/endcap region the cut on the transverse energy is tightened to 15 GeV. A track isolation is imposed to reduce the background from non prompt electrons. Muons are required to have a transverse momentum of at least 10 GeV with a pseudorapidity of $|\eta| < 2.4$. Again a track isolation requirement is introduced to reduce the background arising from non prompt muons. A signal region is examined for the presence of a SUSY signal. Events with at least four electrons or muons passing the listed selection criteria and $E_T^{miss} > 50$ GeV are selected. An additional Z boson veto of 10 GeV around the Z boson mass is imposed for each opposite sign-same flavour lepton pair. No data event is observed with a background expectation of 0.7 ± 0.8. Figure 3 shows the 95% C.L. exclusion in the $m_{1/2}$ $\tan(\beta)$ plane. The region for $m_{1/2} < 800$ GeV is excluded except for high values of $\tan(\beta) > 40$, where the LSP lifetime rapidly increases and the four body branching ratio rapidly decreases.

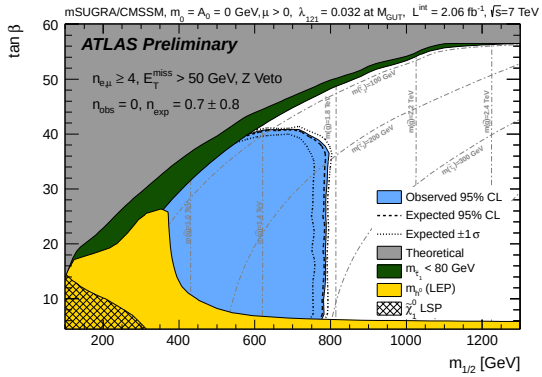

Figure 3: 95 % C.L. exclusion in the $m_{1/2}$ $\tan(\beta)$ plane [6]. Also shown are previous limits from LEP

4 Constraining bilinear R-parity violation in a one lepton final state

The analysis presented in [8] is based on 1.04 fb^{-1} and aims at bilinear R-parity violation in final states with jets, missing transverse momentum and exactly one charged and isolated muon [9]. Tight cuts on the jet transverse momenta, the missing energy and the transverse mass are applied in order to enhance the signal and suppress the background. Backgrounds were

estimated in dedicated control regions and extrapolated into the signal region with transfer factors derived from the Monte Carlo. After applying all selection criteria, 7 events were observed with a background expectation of 6 ± 2.7. 95% C.L. limits were set in the m_0 $m_{1/2}$ plane as shown in figure 4.

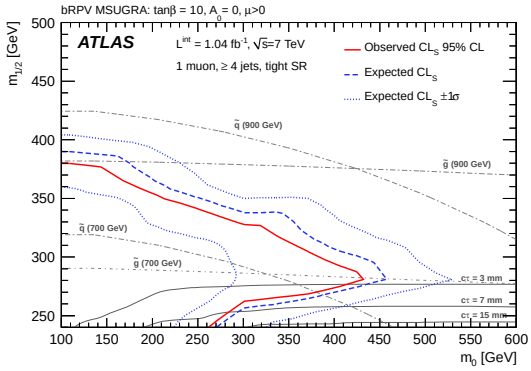

Figure 4: 95 % C.L. exclusion in the m_0 $m_{1/2}$ plane. The region below $m_{1/2} = 240$ GeV, where the LSP lifetime exceeds $c\tau > 15$ mm is not shown. [8]

5 Conclusion

Three searches for R-parity violating supersymmetry in different final states using ATLAS data collected in 2011 were presented. All analyses show good agreement between observed data and standard model predictions. Limits on SUSY particle masses and R-parity violating couplings were strongly improved compared to previous ATLAS and TeVatron limits.

References

[1] "A Supersymmetry Primer" S. Martin http://arxiv.org/abs/hep-ph/9709356

[2] "About R-parity and the Supersymmetric Standard Model" P. Fayet arXiv:hep-ph/9912413v1

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

[4] ATLAS Collaboration EPJC 71 (2011) 1809

[5] ATLAS Collaboration PRL 106 (2011) 251801

[6] ATLAS collaboration "Constraining R-parity violating Minimal Supergravity with stau$_1$ LSP in a four lepton final state with missing transverse momentum" ATLAS-CONF-2012-035 https://cdsweb.cern.ch/record/1432202

[7] ATLAS collaboration "Search for supersymmetry in events with four or more leptons and missing transverse momentum in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector" ATLAS-CONF-2012-001 https://cdsweb.cern.ch/record/1418920

[8] ATLAS Collaboration "Search for supersymmetry in final states with jets, missing transverse momentum and one isolated lepton in $\sqrt{s} = 7$ TeV pp collisions using 1fb^{-1} of ATLAS data" PRD 85 (2012) 012006

[9] W. Porod, M. Hirsch, J. Romao, and J. W. F. Valle, "Testing neutrino mixing at future collider experiments" Phys. Rev. D63 (2001) 115004, arXiv:hep-ph/0011248