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Searches for supersymmetry in resonance production and R-parity violating prompt signatures with the ATLAS and CMS detectors

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Abstract

In R-parity violating supersymmetric scenarios sparticles can be produced individually or in pairs with rates that are detectable at the LHC. Recent results from searches for resonant production and R-parity violating prompt signatures in multi-lepton and multi-jet final states in the data sample recorded by the ATLAS and CMS detectors are presented. New exclusion limits are obtained on the existence of different R-parity violating scenarios.

Keywords: ATLAS, CMS, SUSY, Exotics, RPV

1. Introduction

Supersymmetry (SUSY) [1, 2] is a space-time symmetry that postulates the existence of new SUSY particles, called "sparticles", that differ by one-half unit with respect to their Standard Model (SM) partners. It provides a solution of the hierarchy problem and a mechanism for unifying particle interactions. Assigning R-parity as $R_p = (-1)^{3B+L+2s}$, where B and L are the baryon and lepton numbers, and s is the particle spin, all the SM particles have $R_p = +1$ while all the superpartner fields have $R_p = -1$. In models where R_p is conserved, superpartners can only be produced in pairs in a collider, and the lightest supersymmetric particle (LSP) is stable and a candidate for a dark matter particle. In addition, R_p conservation ensures proton stability.

However, models with R-parity-violating (RPV) interactions conserving either B or L in addition to s can avoid direct contradiction with the proton-lifetime upper limits [3]. The most general gauge-invariant and renormalizable superpotential consists of the R-parity conserving (RPC) main part, and may also contain extra RPV terms:

$$W_{\mathrm{RPV}} = \mu_i H_u L_i + \frac{1}{2}\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \frac{1}{2}\lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k, \tag{1}$$

where i, j and k are generation indices, L and Q are the lepton and quark $SU(2)_L$ doublet superfields and $\bar{E}$, $\bar{D}$ and $\bar{U}$ are the charged lepton, down-like quark and up-like quark $SU(2)_L$ singlet superfields. The first, second and third terms violate lepton-number conservation, while the fourth term violates baryon-number conservation. The analysis presented in this proceeding consider R-parity violating interactions in order to probe the different RPV λ_{ijk}, λ'_{ijk} and λ''_{ijk} trilinear couplings introduced in Eq. 1.

2. Lepton number violation models

This section presents analyses aiming to probe different lepton number violating models, i.e. models for which any of the second or the third terms in Eq. 1 are different from zero.

2.1. Multi-lepton searches

These searches are performed by the ATLAS [4] and CMS [5] experiments, using $20.3\,\mathrm{fb}^{-1}$ and $19.5\,\mathrm{fb}^{-1}$ of

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integrated luminosity, respectively, at a center of mass energy of $\sqrt{s}$ = 8 TeV [6, 7]. If the RPV couplings are small, the dynamics of SUSY production is driven by the RPC part. The cascade decays of SUSY particles in the event are also driven by the R-parity conserving part, until a pair of LSPs remains in the end. The RPV component then determines the decay of the LSP into non-SUSY particles. In the RPV simplified models used in these analyses, a bino-like $\tilde{\chi}_1^0$ (considered the LSP) is assumed to decay into two charged leptons and a neutrino via the λ_{ijk} term in Eq. 1. Different event topologies are tested, resulting from different choices of the next-to-lightest SUSY particles (NLSPs): a chargino NSLP, slepton NLSPs, sneutrino NSLPs, gluino NLSPs and squark NLSPs.

RPV decays via the λ_{ijk} couplings give rise to high lepton multiplicities and substantial $E_{\mathrm{T}}^{\mathrm{miss}}$ due to the presence of neutrinos. For this reason, in the analysis performed by ATLAS the signal regions require four or more leptons, and are classified depending on the number of light leptons required. A Z boson veto is also required to optimize them for RPV searches. On the other hand, the CMS signal regions are required to have exactly four isolated leptons, containing at least one opposite sign, same flavor (OSSF) lepton pair. Furthermore, conditions applied to the invariant masses of the pair of leptons are used to define the regions where the signal is enhanced.

The irreducible background in both analyses is composed of those processes containing four prompt leptons, and it is estimated using Monte-Carlo (MC), normalized to the cross sections of such processes. The reducible background is composed of those processes containing one or more "fake" leptons, either from semileptonic b or c decays, photon conversions, or jet misidentifications. For these processes data-driven methods specified in detail in Refs. [6, 7] are used for their estimation.

After careful study of the systematic uncertainties in each signal regions, the agreement between the data and the MC simulation of the SM processes can be translated to exclusion contours in terms of the NLSP mass versus the LSP mass for the different models considered. As an example, Figure 1 shows the observed and expected 95% CL exclusion limit contours for the RPV gluino NLSP simplified model. Exclusions for the other models considered can be found in the Ref. [6].

The exclusion contours show strongest constraints for the $\lambda_{121} \neq 0$ and $\lambda_{122} \neq 0$ cases, while for the tau-righ decays via λ_{133} and λ_{233} the limits are less stringent. The limits are in many cases nearly insensitive to the $\tilde{\chi}_1^0$

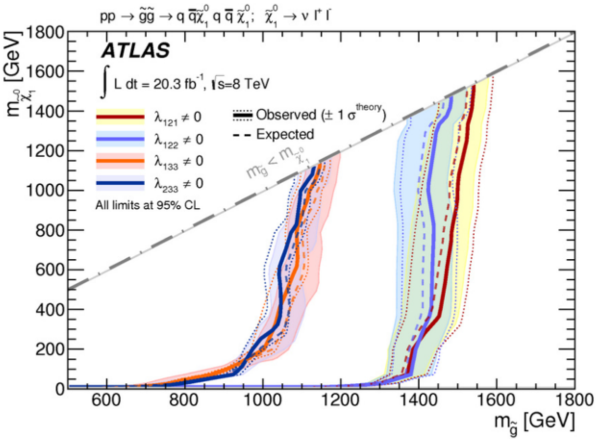

Figure 1: The observed (solid) and expected (dashed) 95% CL exclusion limit contours for the RPV gluino NLSP simplified models, assuming a promptly decaying LSP. The exclusion limits include all uncertainties except the theoretical cross-section uncertainty for the signal, the effect of which is indicated by the dotted lines either side of the observed exclusion limit contours. The shaded bands aorund each expected exclusion limit curve show the $\pm 1\sigma$ results [6].

mass, except where the $\tilde{\chi}_1^0$ is significantly less massive than the NLSP.

2.2. Multi-lepton + b-jets searches

The search for anomalous production of events with three or more isolated leptons in pp collisions at $\sqrt{s}$ = 8 TeV is performed by the CMS experiment and it is described in detail in Ref. [8]. In this analysis, R-parity violating interactions are considered in which one of the couplings is non-zero while the rest are set to zero. In particular, the analysis presented in this subsection focusses on the second and third terms from Eq. 1, i.e. the λ_{ijk} and λ'_{ijk} trilinear couplings. At least three isolated leptons with at most one hadronic tau lepton are required in the signal regions. The events are then further classified in terms of number of OSSF dilepton pairs, b-tags, number of tau leptons, the scalar sum of the p_{T} of the jets (H_T), or the scalar sum of $E_{\mathrm{T}}^{\mathrm{miss}}$, H_T and the p_{T} of all the isolated leptons (also known as S_T).

The lepton fake contributions are estimated using data driven methods described in [8], while the contributions from $t\bar{t}$, dibosons and rare processes can be estimated from simulation and validated in validation regions, defined with cuts such that the different background processes of interest are enhanced. All in all, the agreement between the data and the MC simulation of the SM processes is interpreted in the context of light RPV stops or first and second generation squarks