PROCEEDINGS OF SCIENCE

Searches for RPV SUSY in ATLAS, CMS and LHCb

Saikat Karmakar *On behalf of* ATLAS, CMS *and* LHCb *collaborations*[a,*]

[a] *Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai, India*

E-mail: saikat.karmakar@cern.ch

The traditional way of SUSY searches generally involve high missing transverse momentum because of the presence of the lightest supersymmetric particle (LSP), which is stable and remains undetected. This kind of SUSY models are called R-parity conserving SUSY. But there is also alternative scenario, where the LSP is not stable any more and can decays to Standard Model particles. This is possible in R-parity violating SUSY models. In this report three such SUSY searches have been presented. From CMS, search for top squark pair production in events with two top quark and additional jets are reported. In this analysis Top squark masses up to 670 (870) GeV are excluded at 95% confidence level for the RPV (stealth) scenario. From ATLAS, a search for R-parity-violating supersymmetry in final states characterized by high jet multiplicity, at least one isolated light lepton and either zero or at least three b-tagged jets is presented. No significant excess over the Standard Model expectation is observed and exclusion limits at the 95% confidence level are extracted, reaching as high as 2.4 TeV in gluino mass, 1.35 TeV in top-squark mass, and 320 (365) GeV in higgsino (wino) mass. From LHCb, a search is performed for massive long-lived particles (LLP) decaying semileptonically into a muon and two quarks. No evidence of these long-lived states has been observed, and upper limits on the production cross-section times branching ratio have been set for each model considered.

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*Speaker

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1. Introduction

Supersymmetry (SUSY) [4, 5] is one of the most promising beyond standard model (BSM) theories that can explain the shortcomings of the Standard Model (SM). The traditional strategy of SUSY searches have been to look for final states with large missing transverse energy (p_T^{miss}) as the lightest supersymmetric particle (LSP) is assumed to be stable due to the conservation of R-parity. This LSP escapes undetected, giving rise to large p_T^{miss}. But these kind of searches are not sensitive to the well motivated SUSY models,such as GMSB [6] or hidden valley [7] that predicts final state with low-p_T^{miss}. R-parity violating (RPV) SUSY models predicts low-p_T^{miss} SUSY signatures by allowing the LSP to decay to SM quarks. In this report we describe three such search results in the following sections.

2. Search for top squark in final states with two top quarks and several light-flavor jets in proton-proton collisions at $\sqrt{s}$ = 13 TeV

CMS performed the search [10] based on two SUSY models: RPV SUSY and Stealth SUSY. In the first model, the top squark ($\tilde{t}$) decays to the lightest neutralino ($\tilde{\chi}_1$) and the top quark (t) with the subsequent decay of the neutralino to three first or second generation SM quarks. For the stealth SUSY scenario, a "stealth" sector of light particles is introduced. The benchmark stealth SUSY model (stealth SY$\overline{\text{Y}}$) [8] used in the interpretation of the search results assumes a minimal stealth sector containing only one scalar particle S with even R-parity and its superpartner $\widetilde{S}$. The top squark decays to a $\widetilde{S}$, top quark and a gluon, with $\widetilde{S}$ decaying to a gravitino ($\widetilde{G}$) and S and then S decaying to a pair of gluons. Both the models give rise to the similar final states of two top quarks and very high jet multiplicity.

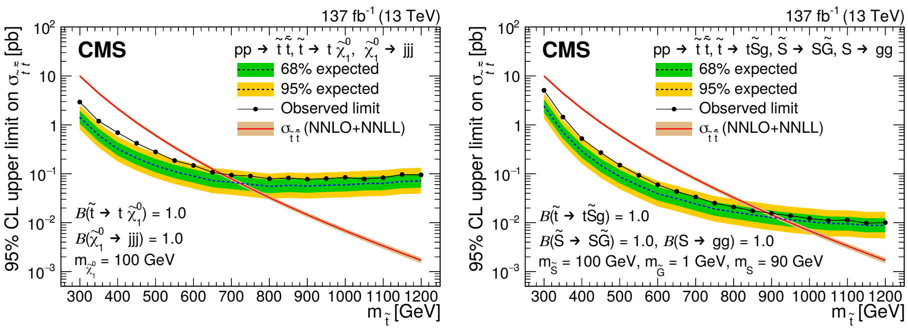

Figure 1: Expected and observed 95% CL upper limit on the top squark pair production cross section as a function of the top squark mass for the RPV (left) and stealth SY$\overline{\text{Y}}$ (right) SUSY models [10].

Event selection involves one isolated leptons, at least one b-tagged jet and several light flavor quark or gluon jets with the invariant mass of the lepton and b-jet system to be within the window 50 to 250 GeV. The signal is distinguished from the dominant and irreducible t$\bar{\text{t}}$ background by means of a neural network (NN). The crux of the analysis is to estimate the dominant t$\bar{\text{t}}$ background in four bins of the neural network output S_{NN} and six bins of jet multiplicity N_{jets} and constrain the t$\bar{\text{t}}$ N_{jets} shape to be the same in all S_{NN} categories using a simultaneous binned maximum-likelihood fit. Jet

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multiplicity is hard to model at high multiplicity, so it is modelled by fitting the N_{jets} distribution in data.
No Significance excess of data is observed over the SM background predictions. Top squark masses up to 670 GeV are excluded for the RPV model and up to 870 GeV are excluded for the stealth supersymmetry model at 95% confidence level [10] as shown in Fig. 1.

3. Search for R-parity-violating supersymmetry in a final state containing leptons and many jets with the ATLAS experiment using $\sqrt{s}$ = 13 TeV proton–proton collision data

The ATLAS experiment has performed the search for pair production od SUSY particles in RPV scenario [11]. The SUSY particles that are considered here are gluino, top squark and electroweakino. The events are selected with at least one isolated lepton and several jets. The events are selected in two main categories. 1 lepton (1ℓ) and 2-lepton with same charge ($2\ell^{\text{sc}}$). These two categories are further subdivided depending on the jet multiplicity. The sensitivity of electroweakino search is improved by adding another subcategory in the 1ℓ category only, where a separate neural network discriminant is trained in each jet slice with eight or fewer jets, to discriminate the higgsino signal from the $t\bar{t}$ background.
There is no significance excess of data over SM background and gluino masses up to 2.4 TeV are

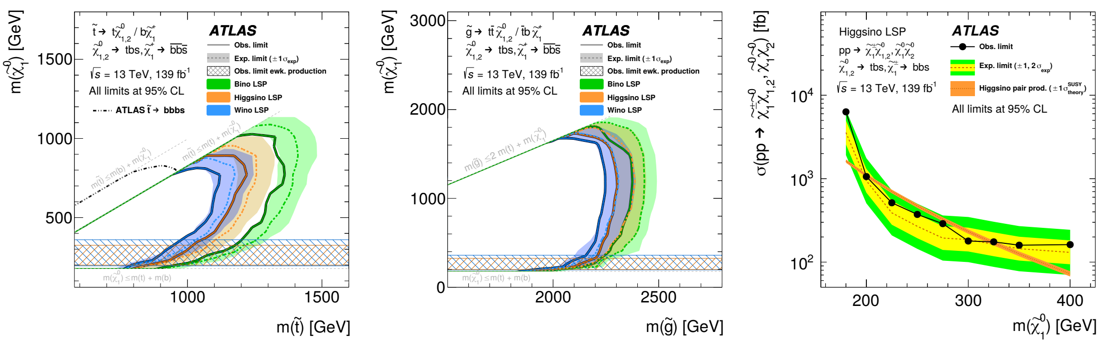

Figure 2: Observed and expected exclusion contours at 95% CL on the top squark pair production (left) and gluino pair production (middle) in the $m_{\tilde{t}} - m_{\tilde{\chi}_1}$ plane and $m_{\tilde{g}} - m_{\tilde{\chi}_1}$ respectively and electroweakino pair production cross section as a function of electroweakino mass (right) [11].

excluded for high LSP masses, and up to 2 TeV for low LSP masses. Stop masses are excluded up to $1 - 1.3$ TeV, depending on the LSP mass. Whereas for the higgsino like electroweakino, masses between 200 and 320 GeV are excluded and for the wino like case, masses between 197 ans 365 GeV are excluded. The exclusion plots are shown in Figure 2.

4. Search for massive long-lived particles decaying semileptonically at $\sqrt{s}$ = 13 TeV

The LHCb search [12] is based on the theoretical framework of mSUGRA with RPV [9]. In such model the lightest neutralino or the LSP can decay into a muon and two quarks. Here two production mechanism of LSP is considered. In the first process a Higgs boson like particle h^0,

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produced in gluon fusion process, decays to a pair of LSP. The analysis covers h^0 masses from 30 to 200 GeV, LLP lifetimes from 5 to 200 ps and LLP mass values from 10 GeV up to about one half the h^0 mass. In the second process, A pair of LSP is produced directly from the annihilation of a quark and an anti-quark. LHCb is a very forward detector and provides much lower trigger threshold for muons. As a result in LHCb it possible to explore regions of the theoretical parameter space where CMS or ATLAS experiments are limited by their low efficiency to reconstruct highly boosted LLPs.
The signal selection requires an isolated muon with transverse momentum > 12 GeV, originating from a vertex which is displaced from any primary vertex (PV) and muon impact parameter with respect to any PV > 0.25 mm. There should be at least 3 tracks to form an LLP candidate with invariant mass > 4.5 GeV. A multivariate analysis (MVA) based on a boosted decision tree is used to further purify the data sample. The signal yield is determined by a fit to the LLP reconstructed mass with a signal shape inferred from the theoretical models. The results for all theoretical models considered are compatible with the background- only hypothesis.

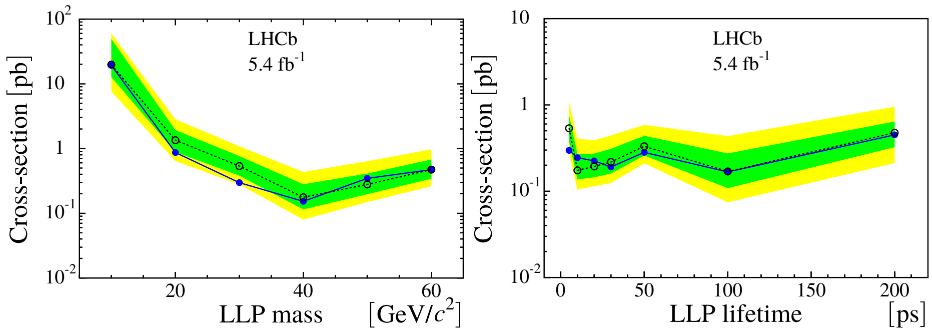

Figure 3: Expected (open dots and 1σ and 2σ bands) and observed (full dots) cross-section times branching fraction upper limits (95% CL) as a function of LSP mass (left) and LSP life time (right) for the resonant production processes with m_{h^0} = 125 GeV [10].

The upper limits at 95% CL set on the cross-section times branching fractions are mostly of O(0.1 pb). The expected and observed upper limits on cross-section times branching fraction as a function of LSP mass (left) and LSP life time (right) for the resonant production processes with m m_{h^0} = 125 GeV is shown in Figure 3.

5. conclusion

Three RPV SUSY search results are presented in this report one from each CMS, ATLAS and LHCb experiment. All the searches are consistent with the background-only hypothesis. The CMS result is interpreted in terms of RPV and stealth SUSY scenarios. Top squark masses up to 670 GeV and 870 GeV are excluded with 95% confidence level for RPV and stealth SUSY scenario respectively. ATLAS interpreted their result in terms of RPV SUSY and gluino masses up to 2.25 TeV, top quark masses up to 1.36 TeV are excluded. For the higgsino like electroweakino, masses between 200 and 320 GeV are excluded where as for the wino like cases masses between 197 and 365 GeV are excluded. The LHCb experiment also looked for massive LLP. The upper limits at 95% CL set on the cross-section times branching fractions are mostly of O(0.1 pb).

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