Search for multijet resonances of stops with RPV couplings

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1 Search for multijet resonances of stop production via RPV couplings with ATLAS

Supersymmetry (SUSY) is one of the most promising extensions of the Standard Model (SM) because, if experimental evidence supporting SUSY is found, it could explain many of the currently observed discrepancies between theoretical expectations and experimental results. This search considers scenarios with non-zero R-parity violating (RPV) couplings and will explore the transition from pair production to resonant production of the SM top quark's SUSY partners, particularly the lightest variant ($\tilde{t}_1$), and in the process search for evidence for the existence of SUSY particles in a production process that is, to this day, entirely unexplored at the LHC experiments and LHC energies. One of the main challenges in the search for and study of these processes lies in the complex topology of the final state, in addition to presumably large backgrounds.

As a first step, we investigate which part of the parameter space for stop production with RPV couplings is the most promising and interesting. For this, we are considering different combinations of parameters (stop mass and coupling stregth). In addition, we wanted to determine which process (direct quark decay to two quarks vs. cascade decay via neutralino or chargino to four quarks) presents the most promising in terms of branching ratios and signal-to-background ratio. To achieve this, we initially generated phenomenological results using the MADGRAPH event generator.

Concretely, we are working in the minimally supersymmetric model (MSSM), which postulates the minimum of necessary extensions to the SM such that the SM part of the full extended theory remains intact in its current form. This constraint is necessary because of the great accuracy of SM theory predictions for nearly all applications. MADGRAPH also employs the MSSM.

An important quantity in SUSY models is R-parity,

$$P_{\mathrm{R}} = (-1)^{3(B-L)+2s}\,, \tag{1}$$

where B is the baryon number of the particle, L is the lepton number, and s the spin. In most models this quantity is conserved, since broken R-parity without stringent upper bounds for the coupling strengths would lead to proton instability. It is however conceivable that such couplings are only significantly non-zero for certain quark generations, which would leave protons effectively entirely stable.

The field operator that breaks R-parity for baryons is defined as

$$W_{\mathrm{BRPV}} = \frac{\lambda''_{ijk}}{2}\bar{U}_i\bar{D}_j\bar{D}_k\,, \tag{2}$$

where the indices i, j, and k number the generation of quarks, λ''_{ijk} is the coupling strength for the specific generations of quarks, and $\bar{U}$ and $\bar{D}$ refer to up-type and down-type quark fields respectively.

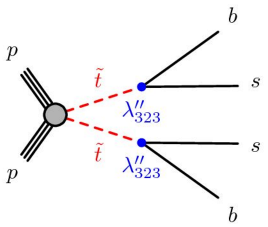
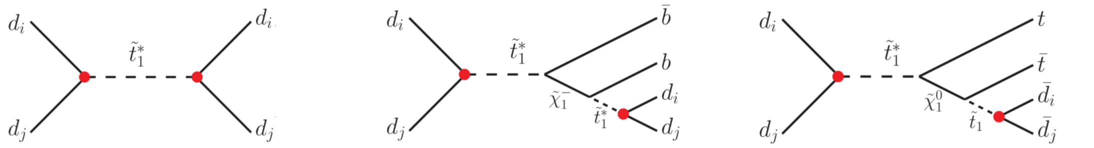


Figure 1: Production of stop pair from QCD in proton-proton collision. In this case, the stops decay under RPV individually to strange+bottom each, since coupling λ''_{323} is non-zero.



(a) Direct decay into two quarks in the final state

(b) Cascade decay with at least two bottom quarks in the final state

(c) Cascade decay with two top quarks in the final state

Figure 2: Resonant production of a single stop from the two down-type quarks d_i and d_j, where i and j number the species of the quark. The three possible decay channels are shown, where, qualitatively, larger couplings λ''_{3ij} result in suppression of the decay channels with 4-quark final states (shown in **(b)** and **(c)**), and larger stop masses result in slight kinematic enhancement of the process with the top pair in the final state (shown in **(c)**).

Pair production conserves R-parity, while resonant production from SM particles inherently breaks it. This results in the fact that the pair production cross section is independent of the actual coupling strength, while the cross section for resonant production is affected strongly by it. This fact is also illustrated in Fig. 3.

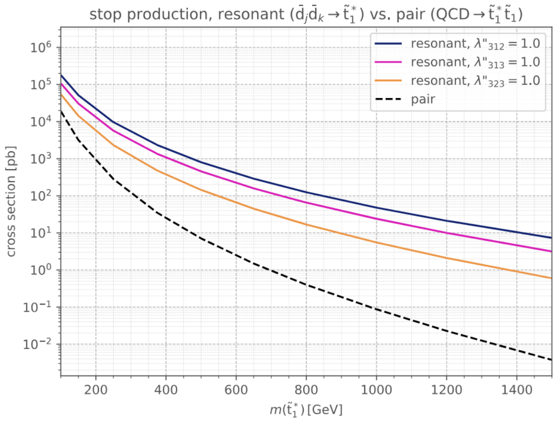


Figure 3: Production cross sections. The cross section for resonant production, which is dependent on the coupling strength λ''_{ijk}, scales with ${\lambda''_{ihk}}^2$ and is shown for $\lambda''_{ijk} = 1$.