Novel Higgs decay signals in R-parity violating models

D. Aristizabal Sierra[a], W. Porod[b], D. Restrepo[c], Carlos E. Yaguna[d]

[a] *INFN, Laboratori Nazionali di Frascati,C.P. 13, I00044 Frascati, Italy.*

[b] *Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany .*

[c] *Instituto de Física, Universidad de Antioquia, A.A. 1226, Medellín, Colombia.*

[d] *Departamento de Física Teórica C-XI, Universidad Autónoma de Madrid, Cantoblanco, E-28049 Madrid, Spain .*

Abstract

In supersymmetric models the lightest Higgs boson may decay with a sizable branching ratio into a pair of light neutralinos. We analyze such decays within the context of the minimal supersymmetric standard model with R-parity violation, where the neutralino itself is unstable and decays into Standard Model fermions. We show that the R-parity violating couplings induce novel Higgs decay signals that might facilitate the discovery of the Higgs boson at colliders. At the LHC, the Higgs may be observed, for instance, through its decay -via two neutralinos- into final states containing missing energy and isolated charged leptons such as $\ell^\pm\ell^\mp, \ell^\pm\ell^\pm, 3\ell$, and 4ℓ. Another promising possibility is the search for the displaced vertices associated with the neutralino decay. We also point out that Higgs searches at the LHC might additionally provide the first evidence of R-parity violation.

1 Introduction

The discovery of the Higgs boson is probably the most important goal of the LHC. In the Standard Model, the Higgs branching ratios depend only on the unknown Higgs mass, which is constrained to be larger than 114 GeV. In the minimal supersymmetric Standard Model (MSSM) the Higgs sector is more involved, as it includes two Higgs doublets [1]. Yet, the mass of the lightest Higgs is very restricted, typically below 135 GeV. Another remarkable feature of the MSSM Higgs is that it may decay into two light neutralinos. Besides being *invisible*, such a decay causes a suppression of all other branching ratios of the Higgs boson, rendering more difficult its observation. In R-parity violating models, however, a new twist occurs. There, the neutralino is unstable and may decay within the detector into Standard Model fermions. Thus, the decay $h \to \chi\chi$, with χ subsequently decaying into light particles, becomes *visible* and new signals for Higgs decays at colliders appear. That is exactly the situation we aim to study in this paper.

The most general supersymmetric version of the Standard Model is phenomenologically inconsistent, for it includes lepton and baryon number violating operators that would induce fast proton decay. In the MSSM, an *ad hoc* discrete symmetry known as R-parity is imposed to prevent the decay of the proton. R-parity additionally implies the conservation of lepton and baryon number as well as the stability of the lightest supersymmetric particle –the LSP. Assuming R-parity, however, is not the only way of preventing proton decay. Lepton parity and baryon triality [2] are among the alternative discrete symmetries that forbid proton decay but allow for R-parity violation and, respectively, baryon or lepton number breaking couplings. R-parity, therefore, is not an essential ingredient of low energy supersymmetry.

Supersymmetric models with broken R-parity are well motivated extensions of the Standard Model and have been amply considered in the literature. They feature a rich phenomenology, markedly different from that of the MSSM. The LSP, for instance, is unstable and consequently it is no longer bound to be a neutralino; any supersymmetric particle can be the LSP [3]. And since the LSP decays into Standard Model fermions, distinctive decay patterns and collider signals are expected [4, 5, 6]. R-parity violation might also be at the origin of neutrino masses and mixing [7]. The bilinear R-parity violating model, in particular, not only accounts for the observed values of neutrino masses and mixing angles [8, 9] but it also predicts simple correlations between them and the LSP decay branching ratios [10, 11, 4, 5, 6]. These unique signals of R-parity violating models may soon be tested at the LHC as well as at future colliders.

The mass of the lightest neutralino is not constrained by accelerator searches or precision experiments [12, 13]. If the GUT relation between gaugino masses is assumed, then the LEP limit on the chargino mass, $m_{\chi^\pm} \gtrsim 100$ GeV [14], translates into a lower bound on the neutralino mass: $M_1 \sim m_\chi \gtrsim 50$ GeV[14]. If the assumption of gaugino mass unification is not made, however, there is no general limit on the mass of the lightest neutralino. Thus, neutralinos with masses below 50 GeV, light neutralinos, are perfectly compatible with present experiments.

For the MSSM, the implications of such light neutralinos in Higgs boson decays were recently studied in [15]. There, after examining the dependence of the $h \to \chi\chi$ branching ratio with the relevant supersymmetric parameters, it was shown that the decay into two neutralinos can even be the dominant decay mode of the Higgs boson, with a branching

Coupling	Upper bound
λ''_{112}	10^{-7}
λ''_{113}	10^{-5}
λ'_{111}	10^{-4}
λ'_{i33}	10^{-4}
λ_{i33}	10^{-3}

Table 1: Strongest bounds on the R-parity violating couplings.

ratio as large as 80%. Here, we extend such an analysis to supersymmetric models with R-parity violation. The R-parity violating couplings may cause the decay of the neutralino within the detector, transforming the former *invisible* decay $h \to \chi\chi$ into a *visible* one.

We will consider both bilinear and trilinear R-parity violating operators and study the different 3-body neutralino decays they induce. These decays give rise to novel Higgs decay signals that could be searched for at colliders. The most interesting searches are final states containing missing energy and isolated charged leptons such as $\ell^\pm\ell^\mp, \ell^\pm\ell^\pm, 3\ell$, and 4ℓ. In addition to these standard searches, the neutralino decay length can be long enough to leave a displaced vertex in the detector [4, 16, 17]. These searches may facilitate the discovery of the Higgs boson at the LHC and at the same time provide direct evidence of R-parity violation.

The rest of this paper is organized as follows: In section 2 we discuss briefly the model considered as well as the constraints on the R-parity violating couplings. Section 3 is devoted to neutralino decays and presents our main results. The decay length is studied and several scenarios, in which different neutralino final states are present, are analyzed. Finally in section 4 we present our conclusions.

2 The R-parity violating model

The most general supersymmetric version of the Standard Model has a renormalizable superpotential given by

$$\begin{aligned} W &= W_{\rm MSSM} + \varepsilon_{ab}\left[\frac{1}{2}\lambda_{ijk}\widehat{L}_i^a\widehat{L}_j^b\widehat{E}_k + \lambda'_{ijk}\widehat{L}_i^a\widehat{Q}_j^b\widehat{D}_k + \epsilon_i\widehat{L}_i^a\widehat{H}_u^b\right] \\ &\quad +\varepsilon_{\alpha\beta\sigma}\frac{1}{2}\lambda''_{ijk}\widehat{U}_i^\alpha\widehat{D}_j^\beta\widehat{D}_k^\sigma \ , \end{aligned} \tag{1}$$

where $W_{\rm MSSM}$ is the lepton and baryon number conserving superpotential. In eq. (1), i, j, k run over the fermion generations, a, b are $SU(2)$ indices, and α, β, σ are color indices. The bilinear couplings ϵ_i, $i = 1, 2, 3$, have mass dimension one and break lepton number. λ and λ' are dimensionless trilinear couplings that also break lepton number. There are 27 independent λ'_{ijk} but only 9 λ_{ijk} –they are antisymmetric in i, j. Baryon number is broken by the dimensionless couplings λ''_{ijk}, 9 of which are independent. In all, therefore, the R-parity violating superpotential contains 48 additional parameters. In addition there are the corresponding soft SUSY breaking terms.

To prevent proton decay, in the MSSM all the operators in (1) are forbidden by assuming the discrete symmetry known as R-parity. From a phenomenological point of view, however, the stability of the proton only requires that baryon and lepton number violating operators not be simultaneously allowed. And R-parity is not the only discrete symmetry able to ensure that. Baryon-triality and lepton-parity [2], for instance, are two well motivated symmetries that allow for *either* lepton or baryon number violating couplings, breaking R-parity but keeping the proton stable.

Once R-parity is broken, the stability of the LSP is no longer guaranteed. The R-parity breaking terms in eq. (1) in fact induce the decay of the neutralino -mediated by a gauge boson or a scalar- to three Standard Model fermions. Such a decay constitutes the main difference between the MSSM and the R-parity violating model.

Low energy data put a strong bound on some of the R-parity violating couplings in (1). For the bilinear couplings ϵ_i, the most stringent constraint comes from neutrino physics. The atmospheric mass scale can be generated at tree level if $\sum_i(\epsilon_i v_d + \mu v_i)^2/\mathrm{Det}(m_\chi) \sim m_\nu/M_2$ where $\mathrm{Det}(m_\chi)$ is the determinant of the MSSM neutralino mass matrix, M_2 the $SU(2)$ gaugino mass, v_i and v_d are the sneutrinos and H_d vacuum expectations values. The solar mass scale, on the other hand, is induced only at the loop level and constrains the ratio $|\epsilon_i/\mu| \lesssim 10^{-3}$. For the trilinear couplings the strongest bounds come from double nucleon decay [18], neutron oscillations [18, 19], neutrino masses [20, 21], and neutrinoless double beta decay [22]. A complete and detailed list of the different constraints on the trilinear couplings can be found in [23, 24]. The most important ones are summarized, for further use, in Table 1. Note here, that in principle one can rotate the "four vector" $(\hat{H}_d, \hat{L}_i)$ such that the bilinear terms are absent in the superpotential eq. (1) on the expense of changing the values of λ_{ijk} and λ'_{ijk} (see e.g. [6]). The bounds in this table have to be understood in this particular basis.

3 Neutralino decays

The branching ratio $h \to \chi\chi$ depends mainly on μ, $\tan\beta$, and m_χ [15], whereas the subsequent neutralino decay is determined by m_χ, the R_p violating couplings and gauge bosons or scalar masses. To study the decay of neutralinos originating in Higgs decays, we will consider a generic class of supersymmetric models featuring a non-negligible $\mathrm{BR}(h \to \chi\chi)$ where all the parameters but the slepton and the squark masses are kept fixed. We take

$$\begin{aligned} &M_1 = 35\ \mathrm{GeV}, \mu = 300\ \mathrm{GeV}, \tan\beta = 5\,, \\ &M_2 = M_3 = M_A = 1\ \mathrm{TeV}\,, \\ &A_t = -1.7\ \mathrm{TeV}\,, \\ &m_{\tilde{q}} > 800\ \mathrm{GeV}\,, \\ &m_{\tilde{l}} > 200\ \mathrm{GeV}. \end{aligned} \tag{2}$$

The supersymmetric spectra thus obtained, illustrated in figure 3, satisfy the constraints from accelerator searches [14], the Higgs mass [25], $(g-2)_\mu$ [14, 26], and $b \to s\gamma$ [27]. To compute the spectrum and to evaluate the Higgs mass and other observables we use the `FeynHiggs` program [28]. According to it, lighter squarks -with all other parameters fixed- are not compatible with the LEP bound on the Higgs mass.

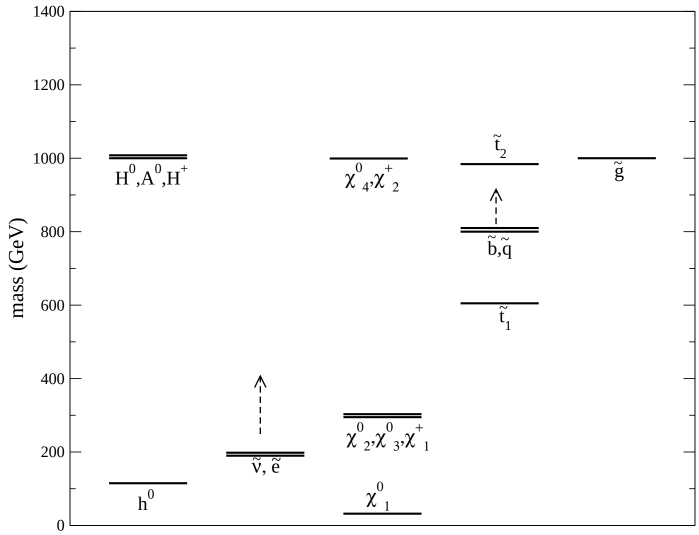

Figure 1: The typical supersymmetric spectrum we consider.

Notice that for simplicity we assumed common soft-breaking masses for sleptons and squarks [1] as well as a typical value of 1 TeV for M_2, M_3 and M_A. Since $M_A \gg M_Z$ we are in fact working in the decoupling limit, where the interactions of the lightest Higgs boson become SM-like.

Regarding $\tan\beta$, μ, and M_1, they were chosen so as to be in a region where BR($h \to \chi\chi$) is non-negligible, and their values are rather typical within that region. Specifically, we get BR($h \to \chi\chi$)= 21%, being $b\bar{b}$ the dominant decay mode with BR($h \to b\bar{b}$)= 59%. As $M_1 \ll M_2, \mu$, the lightest neutralino is dominantly a bino, but it has a small higgsino component that generates the non-zero $h\chi\chi$ coupling.

If the neutralino decays outside the detector no new collider signals due to R-parity violating couplings are expected, as we would essentially be back to the MSSM case, where the decay $h \to \chi\chi$ is invisible. We must, therefore, ensure that a significant number of neutralinos decays inside the detector. At the LHC, the Higgs is mainly produced through gluon fusion and its production cross section is huge –about 45 pb for our model. So, the neutralino decay length could be large and still yield a significant number of neutralino decays within the detector. This fact is illustrated in figure 2, where we quantify the fraction of neutralinos that decay inside a typical detector as a function of the decay length. This figure was generated with the `PYTHIA` program, version 6.414 [29], by taking into account only the production of the lightest CP-even Higgs. The MSSM parameters were varied according to eq. (2) whereas a specific R-parity violating coupling was varied in the range [10^{-4},10^{-1}]. The points were selected by imposing the condition that the neutralino decays take place inside a cylinder of 3 m in the z direction and 0.9 m of radius, e.g. well inside the inner ATLAS or the inner CMS detector. From the figure we see, for instance, that if the proper neutralino lifetime is 10 m, about 7% of the decays will occur within the detector. Notice therefore that the predicted number of events will depend on the value of the R-parity

[1]The observed splitting between the two stop mass eigenstates is due to the non-zero value of the parameter A_t

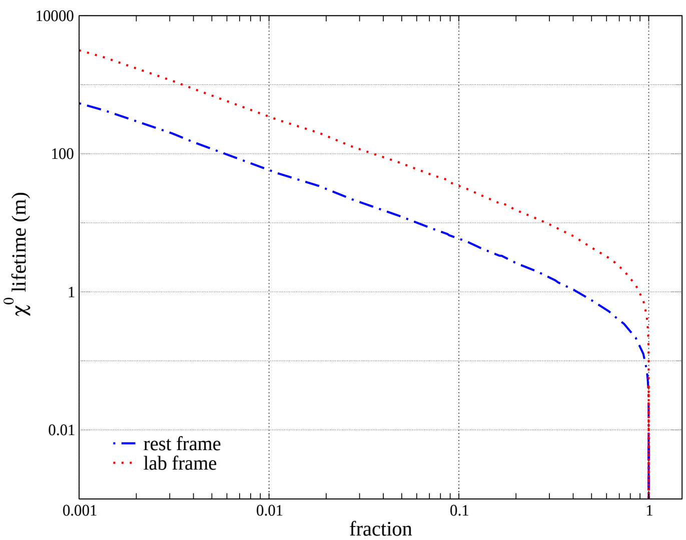

Figure 2: The relation between the fraction of neutralinos that decay within the detector and the neutralino decay length considering only neutralinos from Higgs decays.

violating couplings.

In what follows we will discuss the non-standard decays [13] of the Higgs boson that are induced by the R-parity violating couplings.

3.1 Decays induced by bilinear terms

Bilinear broken R-parity models are theoretically well motivated scenarios. They provide a simple framework that accounts for the observed values of neutrino parameters and that, in contrast with the seesaw mechanism, can be tested, through the decay properties of the LSP, in accelerator experiments. These models contain six lepton number violating parameters [30, 31]: ϵ_i, and their corresponding soft-breaking terms. These parameters are not entirely free, they are constrained by neutrino oscillation data. At present, the experimental data on neutrino oscillations indicates that [32, 33]:

$$\begin{array}{c} \tan^2\theta_{12} = 0.47 \pm 0.05, \qquad \tan^2\theta_{23} = 0.83^{+0.35}_{-0.17}, \qquad \sin^2\theta_{13} < 0.019 \\ \Delta m^2_{21} = 7.67^{+0.22}_{-0.21} \times 10^{-5}\,\mathrm{eV}^2, \qquad \Delta m^2_{31} = 2.46 \pm 0.15 \times 10^{-3}\,\mathrm{eV}^2. \end{array} \tag{3}$$

In our analysis, we will demand compatibility at the 1σ level between these data and the six bilinear parameters.

Neutralino decays in bilinear broken R-parity models are due to the mixing between neutralinos and neutrinos. The bilinear soft breaking terms, indeed, induce non-zero vevs for the sneutrinos that give rise to a mixing between leptons and gauginos and between sleptons and higgses. Such mixing allows the neutralino to decay -via a Z^0, $W^{\pm}$, sfermion or Higgs exchange- into the final states $\nu_i\nu_j\nu_k$, $\nu_i q\bar{q}$, $\nu_i l^+_j l^-_k$ or $l^{\pm}qq'$.

Apart from these contributions induced by the mixing, there are additional ones due to the *effective* trilinear couplings [6] $\lambda_{233} = h_\tau\epsilon_2/\mu$ and $\lambda'_{333} = h_b\epsilon_3/\mu$. These new contribu-

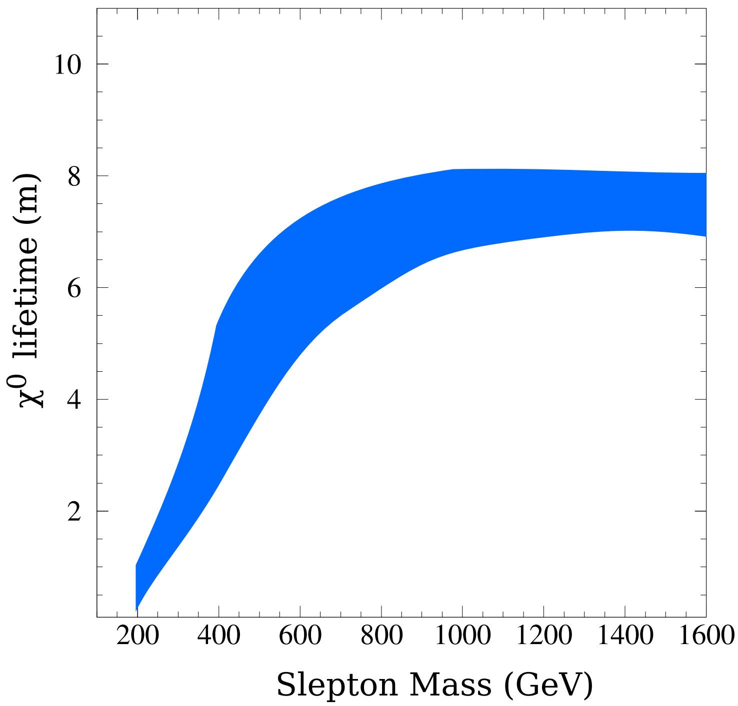

Figure 3: The neutralino lifetime as a function of the slepton mass for different values of the bilinear R-parity violating couplings consistent with neutrino oscillation data at 1 σ level.

tions, mediated by slepton and squarks, give rise to neutralino decays into the final states $\nu\tau\tau$, $\nu\mu\tau$, and $\nu b\bar{b}$.

Figure 3 shows the neutralino lifetime as a function of the slepton mass for models with bilinear R-parity violation. The supersymmetric spectrum was chosen according to equation (2) and the figure was generated with a private version of `SPheno`[2] [34] that includes bilinear R-parity violation. For any given value of the slepton mass, there is a spread in the neutralino lifetime that is due to the uncertainty on neutrino parameters. From the figure we see that the neutralino decay length has an upper bound of roughly 8 meters and that it is always larger than about 50cm. That means that, according to figure 2, between 7% and 40% of neutralino decays will occur within the detector.

Two different regions can be easily distinguished from figure 3. For low slepton masses, $m_{\tilde{\ell}} \lesssim 800$GeV, the neutralino lifetime increases with the slepton mass. Neutralino decays in this region are thus mediated by sleptons and induced by the effective trilinear couplings. For larger slepton masses, instead, the neutralino lifetime becomes essentially independent of $m_{\tilde{\ell}}$. In this region neutralino decays are mediated by gauge bosons and induced directly by the mixing. This picture is confirmed by figure 4, where we show the corresponding neutralino branching ratios as a function of the slepton mass. As expected, the dominant decay modes at low slepton masses are $\tau^\pm\tau^\mp\nu$ and $\tau^\pm l^\mp\nu$ $(l = e, \mu)$ whereas for large slepton masses several final states have sizeable branching ratios.

[2]This version can be obtained from W.P.

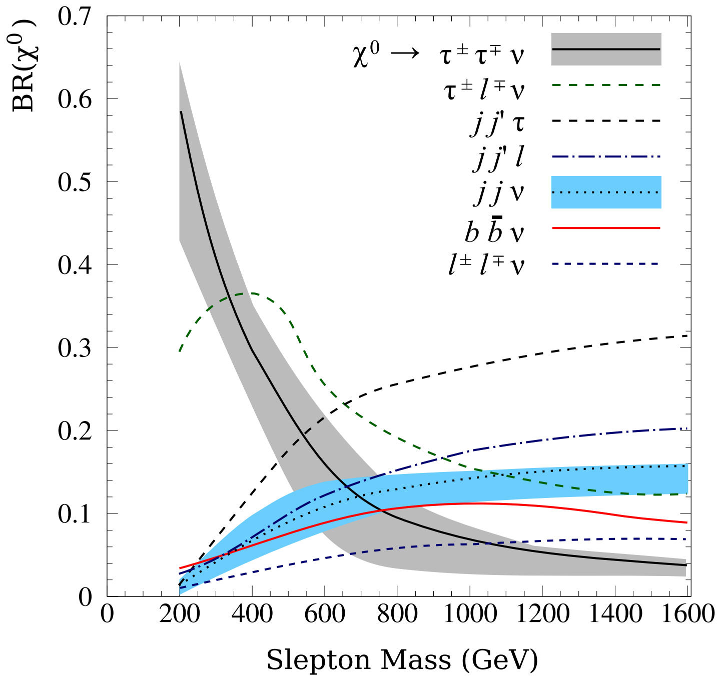

Figure 4: Neutralino decay branching ratios as a function of the slepton mass. The bilinear R-parity violating couplings are consistent with neutrino oscillation data at 1 σ level.

Models with bilinear R-parity violation have thus two remarkable features. On the one hand, the neutralino lifetime can be predicted with certain confidence. It lies between 50 cm and about 8 meters; so it is rather large but it has a known upper bound. On the other hand, the neutralino decay products are rather uncertain and strongly depend on the sfermion masses. However, certain rations of branching ratios are predicted in terms of neutrino mixing angles [4]. In general, several final states with sizable branching ratios are expected.

3.2 Decays induced by trilinear terms

The R-parity violating couplings $\lambda, \lambda', \lambda''$ induce 3-body neutralino decays into Standard Model particles. To study such decays, we assume that, in turn, only one of the couplings, say λ_{122}, dominates and all others are negligible. First we consider the baryon number violating couplings λ''_{ijk}, and then the lepton number violating λ'_{ijk} and λ_{ijk}. For each case we compute the neutralino lifetime, τ_χ, as a function of the couplings and the sfermion masses. With that information, we determine the range of R-parity violating parameters that lead to neutralino decays inside the detector, find the new Higgs decay signals they induce, and briefly analyze the possibility of observing them at colliders.

For simplicity, we work in the approximation where all final state fermions are massless[3]. This approximation breaks down only if there is a top quark in the final state. Such a decay,

[3] We have checked that even taking m_b properly into account changes the total width only slightly.

however, is not kinematically allowed. The neutralino decay width, then, has the generic form

$$\Gamma_\chi = \frac{c_f g^2 \{\lambda, \lambda', \lambda''\}^2 m_\chi^5}{1536\pi^3} f(m_{\tilde{f}}), \tag{4}$$

where c_f is the color factor, $\{\ \}$ denotes one of the couplings, and $f(m_{\tilde{f}})$ is a function of dimension m^{-4} that depends on the masses of the intermediate sfermions [35].

3.2.1 Decays induced by λ''

The trilinear coupling λ''_{ijk} may induce the decay of neutralinos into 3-quark final states, such as $\bar{u}\bar{d}\bar{s}$ and csb, leading to a Higgs boson that decays into a six-quark final state. Such decays were previously considered in [36], albeit in a different scenario. Indeed, it was assumed in [36] that the Higgs boson had a mass around 100 GeV and had been missed by LEP searches because of its dominant decay into six quarks. Such a situation, however, is only possible in a very restricted portion of the viable parameter space. We, instead, consider a more generic framework where the Higgs is compatible with the usual LEP bound and has a non-dominant BR($h \to \chi\chi$).

Three different diagrams, respectively mediated by $\tilde{u}_i$, $\tilde{d}_j$, and $\tilde{d}_k$, contribute to the neutralino decay induced by a given λ''_{ijk}. The possible final states are $u_i d_j d_k$ ($j \neq k$) and its conjugate $\bar{u}_i\bar{d}_j\bar{d}_k$. Hence, the total decay width is simply given by $\Gamma_\chi = 2\Gamma(\chi \to u_i d_j d_k)$. Besides λ'', Γ_χ will only depend on the squark masses. Figure 5 shows the neutralino lifetime as a function of the squark mass for $\lambda'' = 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}$. The resulting neutralino lifetime varies, for $m_{\tilde{q}} < 1.6$ TeV, approximately between 100 μm and 1 km.

Notice that the decays induced by the couplings λ''_{3jk} are kinematically forbidden, as they give rise to final states containing a top quark. Moreover, due to the strong constraint that exist on λ''_{112} and λ''_{113}, see Table 1, neutralino decays into uds and udb are very suppressed and take place outside the detector.

The unique signal from Higgs decays in this case is then a six-quark final state. But it is not known whether such signal could be observed over the QCD background. An interesting possibility, put forward in [37], is the search -at LHCb- for the displaced vertices associated with the neutralino decay. As observed in figure 5, the neutralino decay length may be larger than 100μm, leaving a displaced vertex; and the LHCb detector, in contrast to ATLAS and CMS, is well suited to study such events.

3.2.2 Decays induced by λ'

Neutralino decays induced by the trilinear coupling λ' contain leptons in the final state and are, therefore, easier to observe. An analysis related to ours was presented several years ago in [38]. They considered the special case of Higgs production through vector boson fusion and studied the Higgs signals induced by only certain trilinear couplings λ and λ' assuming gaugino mass unification.

The coupling λ'_{ijk} gives rise to two different final states (plus their conjugates):

$$\chi \to e_i u_j \bar{d}_k\,, \tag{5}$$

$$\chi \to \nu_i d_j \bar{d}_k. \tag{6}$$

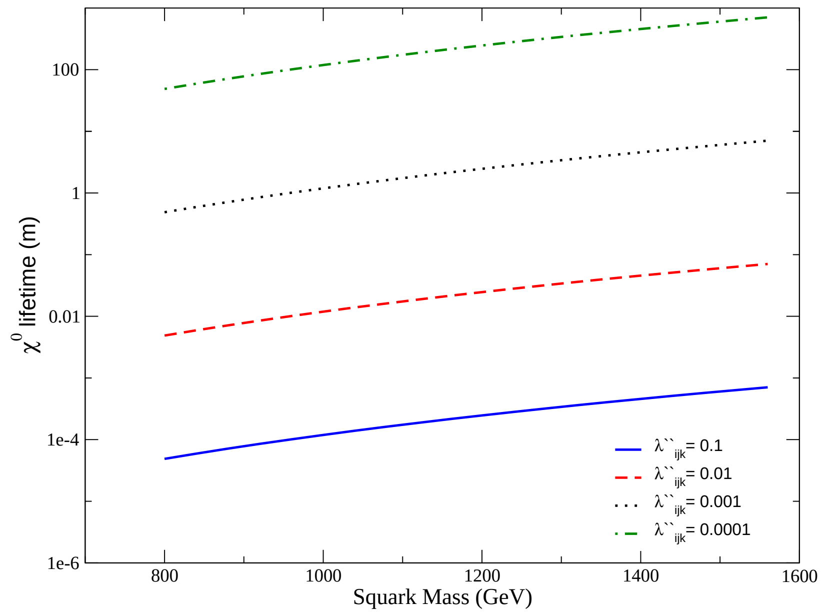

Figure 5: The neutralino lifetime as a function of the squark mass for different values of the R-parity violating couplings λ''.

And each of them receives contributions from three different diagrams. The decay (5) may have $\tilde{e}_i$, $\tilde{u}_j$, and $\tilde{d}_k$ as intermediate particles while $\tilde{\nu}_i$, $\tilde{d}_j$ and $\tilde{d}_k$ mediate the process (6). The total neutralino decay width is then given by

$$\Gamma_\chi = 2(\Gamma(\chi \to e_i u_j \bar{d}_k) + \Gamma(\chi \to \nu_i d_j \bar{d}_k)). \tag{7}$$

In this case the neutralino decay width depends on λ', the squark masses, and the slepton masses. We show, in figure 6, the neutralino decay length as a function of the slepton mass for $\lambda' = 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}$ and $m_{\tilde{q}} = 800$ GeV. Notice that for large slepton masses, the diagrams mediated by squarks tend to dominate over those mediated by sleptons and consequently the curve becomes rather flat. From the figure we see that the neutralino lifetime varies, for $m_{\tilde{\ell}} < 1.6$ TeV, between 0.1μm and 100m. Given that the final state $e_i t \bar{d}_k$ is not kinematically allowed, the couplings λ'_{i3k} induce neutralino decays only into $\nu_i b \bar{d}_k$. For those couplings, therefore, the neutralino lifetime is actually a factor of two larger than shown in figure 6.

The possible signatures of the decay of the Higgs boson due to the coupling λ' are:

1. *Zero lepton, jets, and missing energy.*
2. *One lepton, jets, and missing energy.*
3. *Opposite sign lepton pair and jets.*
4. *Same sign lepton pair and jets.*

Since standard searches for supersymmetry at colliders usually rely on missing energy signals, events with no missing energy, such as $2\ell+$ jets, might simply be rejected at the

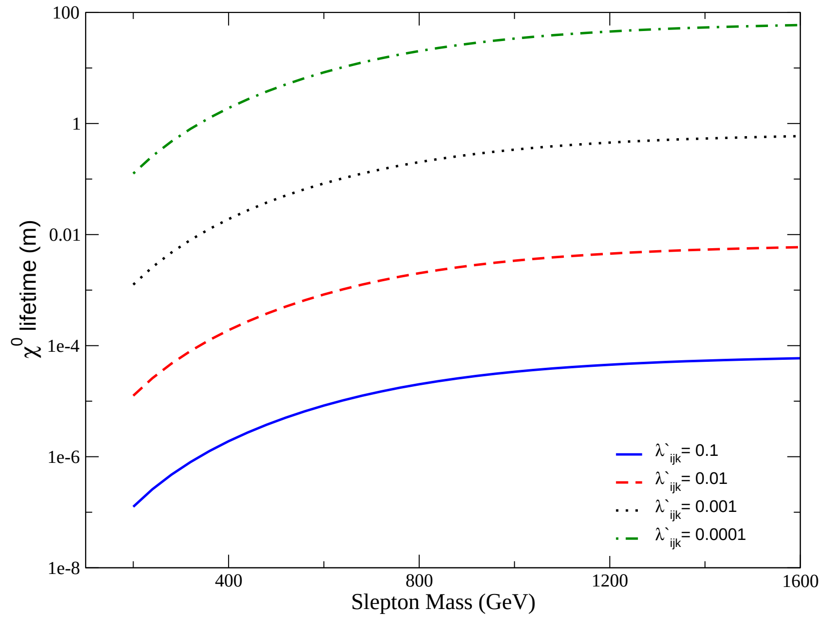

Figure 6: The neutralino lifetime as a function of the slepton mass for different values of the R-parity violating couplings λ'. The common squark mass was set to 800 GeV.

trigger level and never be available to study. They will, however, give rise to a displaced vertex provided that $\lambda' \lesssim 0.01$. The decays induced by the couplings λ'_{i3k} always give rise to jets plus missing energy signals. Even after the degrading in missing energy compared with the case of stable neutralino, the signal with jets and neutrinos, which has at least a 50% branching, has good potential to be discovered at the LHC [17]. A generic expectation of this scenario is that the Higgs should be discovered at LHCb [37].

3.2.3 Decays induced by λ

The couplings λ_{ijk} induce neutralino decays into final states containing two charged leptons and one neutrino. A given λ_{ijk} might lead to two different final states (plus their conjugates):

$$\chi \rightarrow e_i \nu_j \bar{e}_k \tag{8}$$

$$\chi \rightarrow \nu_i e_j \bar{e}_k. \tag{9}$$

Hence, a neutrino is always present in the final state. As before, three different diagrams contribute to each final state and the resulting decay width simply scales as $1/m^4_{\tilde{\ell}}$. Figure 7 shows the neutralino decay length as a function of the common slepton mass for different values of the coupling λ.

The two signatures with missing energy we mentioned in 3.2.2 -numerals 1 and 2- will also be present in this case, though the jets come from the hadronic decay of the tau lepton and not from final state quarks. Additionally, the λ couplings also give rise to new signatures with two or more leptons. They are

1. *Opposite sign lepton pair, jets, and missing energy.*

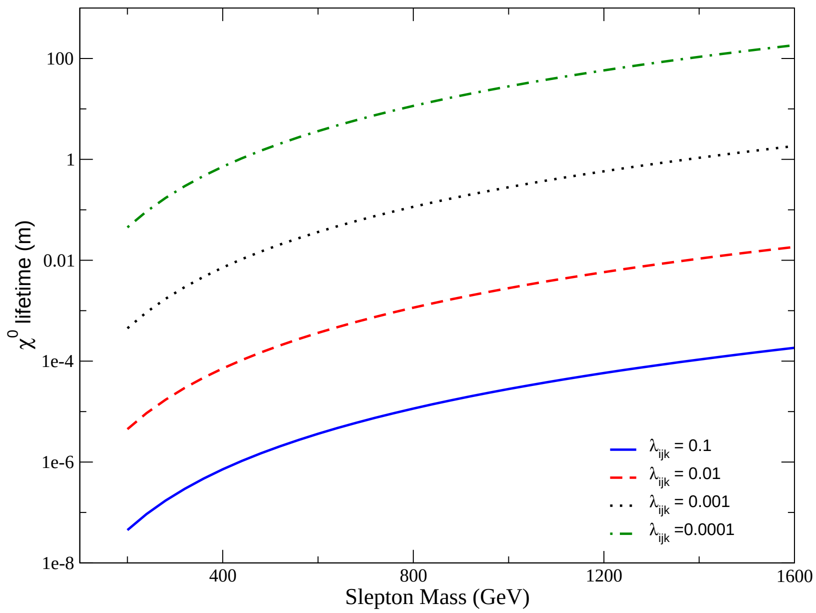

Figure 7: The neutralino lifetime as a function of the slepton mass for different values of the R-parity violating couplings λ.

2. *Same sign lepton pair, jets, and missing energy.*
3. *3 leptons + jets + missing energy.*
4. *4 leptons + missing energy.*

Notice that the decays induced by λ, in contrast with those due to λ', always lead to missing energy –from the final state neutrino. These new signatures with two or more leptons are particularly significant because thanks to their low backgrounds they have good chances to be discovered at LHC [17, 39].

4 Conclusions

We studied the decay of the Higgs boson into Standard Model particles within the context of the MSSM with R-parity violation. The decay proceeds via $h \to \chi\chi$ followed by the R-parity violating neutralino decay into light fermions. We pointed out that neutralino decays induced by the trilinear R-parity violating couplings may occur inside the detector and, as a result, give rise to novel Higgs decay signatures that may facilitate the discovery of the Higgs boson at the LHC. Particularly appealing -because of their low backgrounds- are the decays into final states containing three or four leptons and missing energy. Such decays are caused by the lepton-number violating couplings λ_{ijk} and could be easily observed at the LHC. Another promising possibility is the observation of displaced vertices associated with the neutralino decay. Thus, the discovery of the Higgs boson at the LHC might also provide direct evidence of R-parity violation.

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