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R-Parity Violating Signals at Existing Colliders[1]

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Abstract

Formation of the s-channel slepton resonances at LEP2 or Tevatron at current energies is an exciting possibility in R-parity violating SUSY models. Existing LEP2 and Tevatron data can be exploited to look for sleptons, or to derive bounds on the Yukawa couplings of sleptons to quark and lepton pairs.

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1 Introduction

Recently there was an increase of interest in the R-parity violating supersymmetric model (RPV SUSY). It has been triggered at the beginning of 1997 by observations at HERA of a number of events at high Q^2, high x in e^+p scattering [1] above the Standard Model (SM) expectations. Soon in a number of theoretical papers the supersymmetry with broken R-parity has been put forward as a possible explanation of these events [2]. It has been speculated that the events are due to the s-channel squark production. Although the great expectations of observing a genuine signal of "new physics" have not been confirmed by the data collected during the 1997 run of HERA [3], experimental situation still remains unsettled since the excess of "anomalous events" is not yet washed out by the SM background.

The analyses of the RPV SUSY models in the light of HERA data have reached interesting conclusions. First, they demonstrated that the limits on combinations of RPV Yukawa couplings and masses of relevant supersymmetric particles that have been derived from rare processes[2] are very tight. Second, that comparable limits for some of the couplings/masses could be obtained directly from LEP and/or Tevatron data to verify the theoretical attempts to explain HERA data. By now the results of LEP and Tevatron experiments [4, 5] put additional constraints for a consistent squark interpretation of HERA events.

If squarks are too heavy to be produced at HERA, LEP or Tevatron, great surprises nevertheless still might be ahead of us. Since in SUSY GUT scenarios sleptons are generally expected to be lighter than squarks, sleptons may show up at LEP2 and/or Tevatron even if squarks are beyond the kinematical reach. Indirect effects due to t/u-channel exchanges of sfermions in collisions of leptons and hadrons might be observed although they are expected to be rather small given the tight limits on the RPV couplings. Pair production of sleptons via R-parity conserving mechanisms could also be closed kinematically. However, the direct formation of sfermion resonances in the s-channel processes can produce remarkable events. Sleptons could be produced as s-channel resonances in lepton-lepton and hadron-hadron collisions, and could decay to leptonic or hadronic final states in addition to R-parity conserving modes. Therefore in my talk I will concentrate on possible effects of s-channel slepton resonance production on four-fermion processes in

[2]Note that these limits are derived with simplifying assumptions that one (or at most two) RPV couplings are different from zero at a time.

e^+e^- collisions

$$e^+e^- \to \tilde{\nu} \to \ell^+\ell^- \tag{1}$$
$$e^+e^- \to \tilde{\nu} \to q\bar{q} \tag{2}$$

and in $p\bar{p}$ collisions

$$p\bar{p} \to \tilde{\nu} \to \ell^+\ell^- \tag{3}$$
$$p\bar{p} \to \tilde{\ell}^+ \to \ell^+\nu \tag{4}$$

The results presented here have been obtained in collaboration with H. Spiesberger, R. Rückl and P. Zerwas [6, 7].

2 SUSY with R-parity violation

The minimal R-parity conserving supersymmetric extension (MSSM) of the Standard Model is defined by the superpotential

$$W_R = Y^e_{ij} L_i H_1 E^c_j + Y^d_{ij} Q_i H_1 D^c_j + Y^u_{ij} Q_i H_2 U^c_j + \mu H_1 H_2 \tag{5}$$

where standard notation is used for the left-handed doublets of leptons (L_i) and quarks (Q_i), the right-handed singlets of charged leptons (E_i), up- (U_i) and down-type quarks (D_i), and for the Higgs doublets which couple to the down (H_1) and up quarks (H_2); the indices i, j denote the generations and a summation is understood, Y^f_{ij} are Yukawa couplings and μ is the Higgs mixing mass parameter.

The superpotential W_R respects a discrete multiplicative symmetry under R-parity, which can be defined as [8]

$$R_p = (-1)^{3B+L+2S} \tag{6}$$

where B, L and S denote the baryon and lepton number, and the spin of the particle: all Higgs particles and SM fermions and bosons have $R_p = +1$, and their superpartners have $R_p = -1$. The R_p conservation implies that the interaction Lagrangian derived from W_R contains terms in which the supersymmetric partners appear only in pairs. As a result, the lightest supersymmetric particle (LSP) is stable and superpartners can be produced only in pairs in collisions and decays of particles.

In the SM the $SU(2) \times U(1)$ gauge symmetry and Lorentz invariance imply accidental B and L number conservation. Due to the larger Lorentz structure, supersymmetric

versions of the SM allow renormalizable B and L violating operators involving scalars with non-zero B and L charges. For example, the Higgs superfield H_1 can replace any of the L_i in eq. (5) since it has the same quantum numbers as lepton superfields L_i. In general, the gauge and Lorentz symmetries allow us to add the following terms to the superpotential

$$W_{\not R} = \lambda_{ijk} L_i L_j E^c_k + \lambda'_{ijk} L_i Q_j D^c_k + \lambda''_{ijk} U^c_i D^c_j D^c_k + \epsilon_i L_i H_2 \tag{7}$$

which break explicitly the R-parity [9]. If the Yukawa couplings λ, λ', λ'' and/or dimensionful mass parameters ϵ are present, the model has distinct features: superpartners can be produced singly and the LSP is not stable. Note that at least two different generations of fermions are coupled in the purely leptonic or purely hadronic operators.[3]

From the theoretical point of view, both types of models, R_p-conserving or violating, have been constructed with no preference for either of the two [10]. Since they lead to very different phenomenology, both models should be searched for experimentally.

The λ, λ' and ϵ terms violate lepton number and lepton flavor, whereas λ'' violate baryon number and baryon flavor, and thus can possibly lead to fast proton decay if both types of couplings are present. Therefore, additional symmetries are required to enforce proton stability and to suppress B and L violating transitions. In the usual formulation of the MSSM they are forbidden by R_p and the proton is stable. However, there is no theoretical motivation for imposing R-parity. Other discrete symmetries can stabilize the proton without requiring the R_p to be conserved. For example, baryon-parity (defined as -1 for quarks, and $+1$ for leptons and Higgs bosons) implies $\lambda'' = 0$. In this case only lepton number (and lepton flavor) is broken, which suffices to ensure proton stability. Lepton-number violating operators can also provide new ways to generate neutrino masses. Although in general the ϵ terms cannot be rotated away [11], here we will restrict the discussion to the MSSM with broken R_p with the most general trilinear terms in eq. (7) that violate L but conserve B.

The Lagrangian for λ and λ' parts of the Yukawa interactions have the following form:

$$\begin{aligned}
\mathcal{L}_{\not R} &= \lambda_{ijk} \Big[\tilde{\nu}^j_L \bar{e}^k_R e^i_L + \bar{\tilde{e}}^k_R (\bar{e}^i_L)^c \nu^j_L + \tilde{e}^i_L \bar{e}^k_R \nu^j_L \\
&\qquad - \tilde{\nu}^i_L \bar{e}^k_R e^j_L - \bar{\tilde{e}}^k_R (\bar{e}^j_L)^c \nu^i_L - \tilde{e}^j_L \bar{e}^k_R \nu^i_L \Big] + h.c. \\
&+ \lambda'_{ijk} \Big[(\tilde{u}^j_L \bar{d}^k_R e^i_L + \bar{\tilde{d}}^k_R (\bar{e}^i_L)^c u^j_L + \tilde{e}^i_L \bar{d}^k_R u^j_L)
\end{aligned}$$

[3]Because of anti-commutativity of the superfields, λ_{ijk} can be chosen to be non-vanishing only for $i < j$ and λ''_{ijk} for $j < k$. Therefore for three generations of fermions, $W_{\not R}$ contains additional 48 new parameters beyond those in eq. (5).

$$- (\tilde{\nu}^i_L \bar{d}^k_R d^j_L + \tilde{d}^j_L \bar{d}^k_R \nu^i_L + \overline{\tilde{d}}^k_R (\bar{\nu}^i_L)^c d^j_L) \Big] + h.c. \quad (8)$$

The notation is standard: u_i and d_i denote u- and d-type quarks, e_i and ν_i – the charged leptons and neutrinos of the i-th generation, respectively. The scalar partners are denoted by a tilde and the superscript c is for charge conjugated states. In the λ' terms, the up (s)quarks in the eud terms and/or down (s)quarks in the νdd may be Cabibbo rotated in the mass-eigenstate basis. As we will discuss mainly sneutrino induced processes, we will assume the basis in which only the up sector is mixed, *i.e.* the νdd is diagonal.

If some of the λ and λ' couplings are non-zero, many interesting processes might be expected at current and future colliders in which this scenario could be explored. For example, the $\lambda'_{ijk} E_i Q_j D^c_k$ operator could be responsible for the s-channel production of squarks in e^+p collisions at HERA (for $i = 1$), or sleptons in $p\bar{p}$ (for $j = k = 1$ in valence quark) collisions. The operator $\lambda_{1j1} L_1 L_j E^c_1$, on the other hand, can lead to the s-channel sneutrino formation at LEP.

3 Indirect limits on λ and λ' couplings

At energies much lower than sparticle masses, R-parity breaking interactions can be formulated as effective four-fermion contact terms which in general mediate L-violating and FCNC processes. Since the existing data are consistent with the SM, stringent constraints on the Yukawa couplings and sparticle masses can be derived. If, however, only some of the terms with a particular generation structure are present in eq. (8), then the effective four-fermion Lagrangian is not strongly constrained. The couplings can also be arranged in such a way that there are no other sources of FCNC than CKM mixing in the quark sector.

To illustrate how such constraints can be derived, let us consider a specific example for which our group [6] contributed in strengthening the experimental bounds denoted by [b] in Table 1. The operator $\lambda_{131} L_1 L_3 E^c_1$ can contribute to the τ leptonic decay process $\tau \to e\nu\bar{\nu}$ via the diagrams in Fig. 1. After Fierz transformation the selectron exchange diagram has the same structure as the SM W-boson exchange and thus leads to an apparent shift in the Fermi constant for tau decays. The ratio $R_\tau \equiv \Gamma(\tau \to e\nu\bar{\nu})/\Gamma(\tau \to \mu\nu\bar{\nu})$ relative to the SM contribution is then modified [12]

$$R_\tau = R_\tau(SM) \left[1 + 2 \frac{M^2_W}{g^2} \left(\frac{|\lambda_{131}|^2}{\tilde{m}^2(\tilde{e}_R)} \right) \right]. \quad (9)$$

Using the experimental value [13] we obtain [6] the bound

$$|\lambda_{131}| < 0.04 \left(\frac{\tilde{m}(\tilde{e}_R)}{100 \text{ GeV}}\right) \tag{10}$$

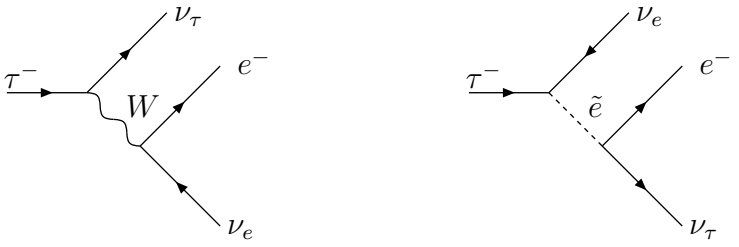

Figure 1: Tau decay via the SM W-boson exchange, and via the $\tilde{e}$ due to the $L_1 L_3 E_1^c$ operator.

The Table 1 summarizes the strictest bounds on λ and λ' couplings assuming that one RPV coupling at a time is dominant while the others are neglected; bounds on products of two couplings are not included. The bounds are given for sparticle masses $\tilde{m} = 100$ GeV. Those marked with * are based on a further assumption about the absolute mixing in the quark sector. For more details, discussion of physical processes from which they have been obtained, and references we refer to [10, 14] from where most of the entries of Table 1 have been taken.

ijk	λ_{ijk}	ijk	λ'_{ijk}	ijk	λ'_{ijk}	ijk	λ'_{ijk}
121	0.05	111	0.00035	211	0.09	311	0.10
122	0.05	112	0.02	212	0.09	312	0.10
123	0.05	113	0.02	213	0.09	313	0.10
131	0.04^b	121	0.035	221	0.18	321	0.20^*
132	0.04^b	122	0.02	222	0.18	322	0.20^*
133	0.004	123	0.20^*	223	0.18	323	0.20^*
231	0.04^b	131	0.035	231	0.22	331	0.26
232	0.04^b	132	0.33	232	0.39	332	0.26
233	0.04^b	133	0.001	233	0.39	333	0.26

Table 1: Bounds on RPV Yukawa couplings for $\tilde{m} = 100$ GeV.

In the discussions to follow we will consider two specific scenarios:
(i) one single Yukawa coupling is large, all the other couplings are small and thus neglected;
(ii) two Yukawa couplings which violate *one and the same* lepton flavor are large, all the others are neglected.

First we shortly recapitulate the situation concerning the HERA data, *i.e.* the effects that can be generated by $L_1Q_jD_k^c$ operator. Then we will discuss slepton production at LEP and Tevatron. In this context we will concentrate on possible effects generated by $\tilde{\tau}$ and $\tilde{\nu}_\tau$, (*i.e.* λ_{i3i} and λ'_{3jk} couplings) since the third-generation sfermions are usually expected to be the lightest and, due to large top quark mass, the violation of the third-generation lepton-flavor might be expected maximal. In these cases low-energy experiments are not very restrictive, see Table 1, and typically allow couplings to be of the order 0.1 for the mass scale 200 GeV of the sparticles participating in the process.

4 $L_1Q_jD_k^c$ operator

In e^+p collisions at HERA the operator $L_1Q_jD_k^c$ could be responsible for squark resonance production via

$$e^+d_R^k \to \tilde{u}_L^j \qquad (\tilde{u}^j = \tilde{u}, \tilde{c}, \tilde{t}), \tag{11}$$

$$e^+\bar{u}_L^j \to \overline{\tilde{d}}_R^k \qquad (\tilde{d}^k = \tilde{d}, \tilde{s}, \tilde{b}). \tag{12}$$

Given the bounds in Table 1, charm or top squarks can be produced off the d quarks via eq. (11). Since the excess of events was only observed in e^+p, not in e^-p scattering, the process induced by $\bar{u}$ sea in eq. (12) is unlikely. For the production off other sea quarks, where the coupling strength $\simeq e$ is required, only stop production off strange sea is still compatible with the existing bounds. In short, three possible explanations of the HERA anomaly have been identified [2]

$$e^+d \to \tilde{c} \;\; (\lambda'_{121}), \tag{13}$$

$$e^+d \to \tilde{t} \;\; (\lambda'_{131}), \tag{14}$$

$$e^+s \to \tilde{t} \;\; (\lambda'_{132}). \tag{15}$$

Within the limits on λ' in Table 1, branching ratios B_{eq} for $\tilde{c}, \tilde{t} \to e^+d$ should fall below 0.7 in order to avoid the D0/CDF mass bounds [5]. It has been shown in [15] that one can indeed find solutions in the supersymmetry parameter space in which $B_{eq} < 0.7$, although the allowed region for a consistent squark interpretation of the HERA anomaly and LEP

and D0/CDF bounds is very limited. RPV SUSY may also provide a reasonable solution [16] of the difficulty to interpret the excess of events as a single-resonance effect: mixing in the stop sector may lead to two mass eigenstates with a small but pronounced mass difference, mimicking a continuum effect.

The NC events from $\tilde{t}, \tilde{c} \to e^+ d$ have the same visible final states as the standard DIS-NC events. This is not the case for CC events since the left squarks produced in processes (13–15) do not couple to neutrinos and quarks, see eq. (8). CC-like events could only originate from cascade decays of squarks with some jets in the final state either invisible or overlapping. The H1 events with isolated muons and missing transverse momentum [17] are difficult to explain.

The $L_1 Q_j D^c_k$ operator could also contribute to processes at LEP via t- or u-channel exchange of sparticles, although the effects are expected to be small [18] for the couplings listed in Table 1. In contrast, in $p\bar{p}$ collisions sleptons can be produced in the s channel via the LQD^c operator with appreciable cross section. In hadronic environment, however, the decay modes induced by either R_p-conserving gauge or R_p-violating Yukawa λ' couplings might be quite difficult. On the other hand, if LLE^c operators are present, the leptonic decay modes can be easily detected, as discussed in the next section.

5 $L_i L_j E^c_k$ operator

In e^+e^- scattering at LEP sleptons can be produced singly in the s-channel via LLE^c and in $p\bar{p}$ at Tevatron via LQD^c operators leading to a number of different signatures depending on the assumed scenario.[4] Once produced, they can decay via either the R_p-violating Yukawa or the R_p-conserving gauge couplings. In the latter case the decay proceeds in a cascade process which involves standard and supersymmetric particles in the intermediate states and with the R_p-violating coupling appearing at the end of the cascade. Such decay processes lead in general to multibody final states and depend on many unknown SUSY parameters. In the former case, the final state is a two-body state (with two visible particles, eqs. (1)-(3), or one visible particle and a missing momentum, eq. (4)) which depends only on a limited number of parameters and which is very easy to analyze experimentally. Therefore we will consider sleptons that are produced and decay via λ and/or λ' couplings, namely their effects on four-fermion processes at LEP and Tevatron.

[4]Sleptons can be also exchanged in the t or u channels, see below.

The general expressions for a generic two-body process[5] $f\bar{f}' \to F\bar{F}'$, including the exchanges of sparticles in s, t and/or u channels, can be found in [7, 19]. For the energy close to the mass of the sparticle $\tilde{p}$ exchanged in the s channel, the cross section is well approximated by the Breit-Wigner formula

$$\sigma(f\bar{f}' \to \tilde{p} \to F\bar{F}') = \frac{4\pi s}{m_{\tilde{p}}^2} \frac{\Gamma(\tilde{p} \to f\bar{f}')\Gamma(\tilde{p} \to F\bar{F}')}{(s - m_{\tilde{p}}^2)^2 + m_{\tilde{p}}^2\Gamma_{\tilde{p}}^2} \tag{16}$$

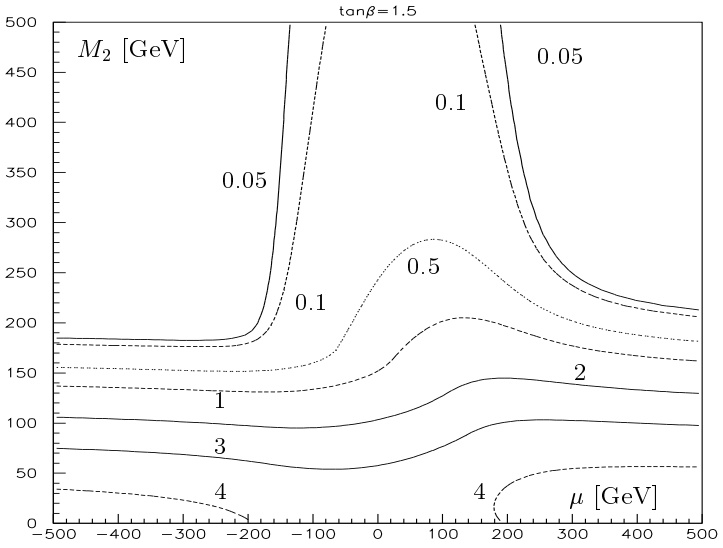

Figure 2: Contour lines for the sneutrino total decay width (in GeV) as a function of gaugino mass M_2 (gaugino unification assumed) and Higgs mixing parameter μ. The sneutrino mass $m_{\tilde{\nu}} = 200$ GeV and R_p violating couplings $\lambda = \lambda' = 0.08$ are assumed, and $\tan\beta = 1.5$.

The partial width for R_p-violating decay $\Gamma(\tilde{p} \to f\bar{f}') = \lambda^2 m_{\tilde{p}}/16\pi$ is very small for Yukawa couplings consistent with Table 1. However, the total decay width $\Gamma_{\tilde{p}}$ can be much larger since sparticles can also decay via R-parity conserving gauge couplings. As an example we will consider sneutrinos. They can decay to $\nu\chi^0$ and $l^{\pm}\chi^{\mp}$ pairs with subsequent χ^0 and $\chi^{\pm}$ decays and via R-parity violating λ' couplings to $q\bar{q}$, or via λ couplings

[5] $f, \bar{f}', F$ and $\bar{F}'$ are SM fermions.

to lepton pairs. The partial decay widths for these channels depend on the specific choice of the supersymmetry breaking parameters. In large regions of the supersymmetry parameter space, the total decay width of sneutrinos can be as large as 1 GeV, as illustrated in Fig. 2. It means that at LEP2 the sneutrino total decay width can be significantly larger than the beam energy spread. Therefore the interference with the background Standard Model process must be taken into account.

5.1 Sneutrinos in e^+e^- Scattering

As discussed earlier we consider the couplings that violate 3rd generation flavor number, λ_{131}, λ_{232} and λ'_{3jk}. Several processes can be affected in such a scenario:

(a) *Bhabha scattering:* For $\lambda_{131} \neq 0$, the tau sneutrino $\tilde{\nu}_\tau$ can contribute to Bhabha scattering via s- and t-channel exchanges. Note that the s-channel (t-) sneutrino exchange interferes with the t-channel (s-) γ, Z exchanges.

(b) *Muon-pair production:* This process can be mediated by the s-channel $\tilde{\nu}_\tau$ resonance, $e^+e^- \to \mu^+\mu^-$, if in addition $\lambda_{232} \neq 0$. Since the t-channel γ, Z and $\tilde{\nu}_\tau$ exchanges are absent, the s-channel sneutrino exchange does not interfere with the SM processes.

(c) *Tau-pair production:* This process can receive only the t-channel exchange of $\tilde{\nu}_e$ which will interfere with the SM γ, Z s-channel processes.

(d) *Neutrino-pair production:* Electron (tau) neutrinos can receive additional contributions only via t/u-channel exchanges of $\tilde{\tau}$ ($\tilde{e}$), which will interfere with the SM Z-exchange process.

(e) e^+e^- *annihilation to hadrons:* The up-type quark-pair production is not affected by sneutrino processes, as can be easily seen from the general structure of couplings in eq. (8). For the down-type quark-pair[6] production, $e^+e^- \to d_k\bar{d}_k$, the situation is similar to the muon-pair production process: there is no interference between s-channel $\tilde{\nu}_\tau$ exchange and the SM γ, Z processes. The unequal-flavor down-type quark-pair production process, $e^+e^- \to d_j\bar{d}_k$, could be generated only by s-channel sneutrino with $\lambda_{131}\lambda'_{3jk} \neq 0$.

In general, the effect of t- or u-channel exchange of sleptons is very small (typically below 1%) for the slepton masses and couplings consistent with low-energy data. On the other hand, in processes with s-channel exchanges, and not too far from the resonance, the effect of sneutrino can be quite spectacular. This is illustrated in Fig. 3, where the impact of the exchange of tau sneutrino with $m_{\tilde{\nu}_\tau} = 200$ GeV and $\Gamma_{\tilde{\nu}_\tau} = 1$ GeV

[6]The possibility of $\tilde{\nu}_\tau \to b\bar{b}$ has been discussed in the context of $e^+e^- \to b\bar{b}$ at LEP1 [20].

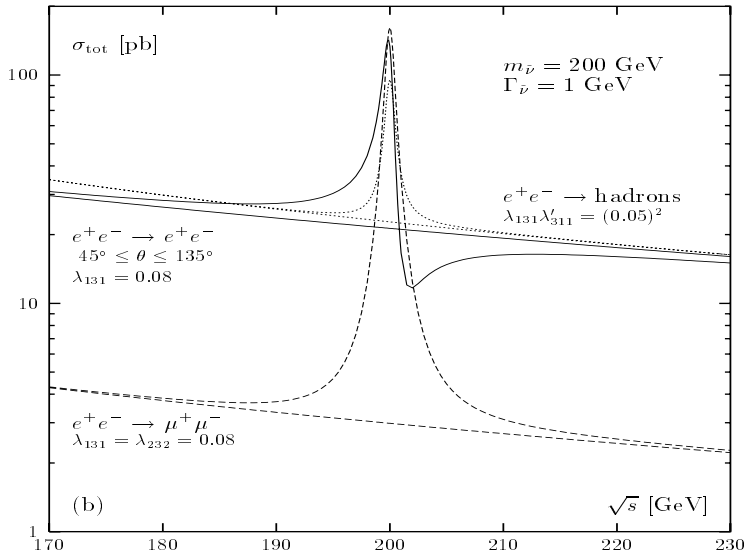

Figure 3: Cross section for Bhabha scattering (solid lines), $\mu^+\mu^-$ (dashed lines) and hadron production (dotted lines) in the SM, and including $\tilde{\nu}_\tau$ sneutrino resonance formation as a function of the e^+e^- energy.

on processes (a), (b) and (e) at LEP2 is shown. Note the difference due to different interference pattern between Bhabha scattering on one hand, and muon-pair and quark-pair production processes on the other: Bhabha is more sensitive to heavy sneutrinos. The peak cross section for Bhabha scattering is given by the unitarity limit $\sigma_{peak} = 8\pi B_e^2/m^2_{\tilde{\nu}_\tau}$ with sneutrino and anti-sneutrino production added up, where B_e is the branching ration for the sneutrino decay to e^+e^-. The cross section in the peak region is therefore very large. Another important feature of the sneutrino resonance is the change in the angular distribution of leptons and quark jets: the distribution is nearly isotropic with the strong forward-backward asymmetry in the Standard Model continuum reduced to ~ 0.03. In addition to $\ell^+\ell^-$ and $q\bar{q}$ final states one should expect many other final states generated in R-parity conserving $\tilde{\nu}$ decays to $\nu\chi^0$ and $\ell^\pm\chi^\mp$ pairs with subsequent χ^0 and $\chi^\pm$ decays [21].

An interesting situation may occur if sneutrinos mix and mass eigenstates are split by a few GeV [22]. Then one may expect two separated peaks with reduced maximum cross sections in the energy dependence in Fig. 3 for processes (a), (b) and/or (d). If

the mass splitting is below the energy resolution, one may nevertheless resolve sneutrino mass eigenstates by measuring CP-even and CP-odd spin asymmetry of final states leptons [23]. From the experimental point of view such measurements can be done only for τ pairs using spin self-analyzing decay modes. In the scenarios considered so far, however, τ-pair production is not affected by s-channel $\tilde{\nu}_\tau$ process. If instead of τ-flavor the muon-flavor is violated via $\lambda_{121}\lambda_{233} \neq 0$, then the asymmetries in $e^+e^- \to \tilde{\nu}_\mu \to \tau^+\tau^-$ can be measured with high statistical significance, as shown in Fig. 4 taken from Ref. [23].

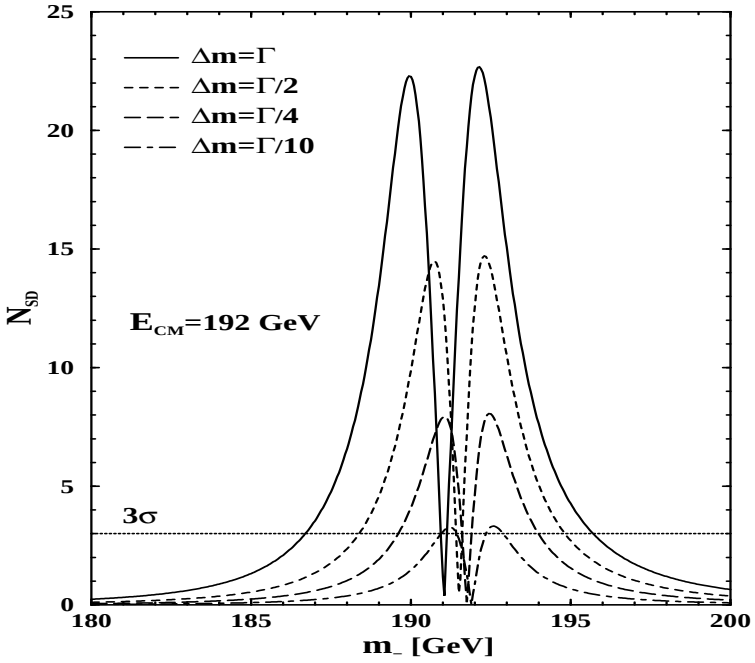

Figure 4: The statistical significance, N_{SD}, attainable at LEP2 for spin asymmetries A_{xy} and B as a function of the lighter muon sneutrino mass for several values of the mass splitting. Figure taken from Ref. [22] to which we refer for details.

5.2 Sleptons at Tevatron

For $p\bar{p}$ scattering the case λ'_{311} is the most interesting since it allows $\tilde{\nu}_\tau$ and $\tilde{\tau}$ resonance formation in valence quark collisions. As their decays to quark jets can be very difficult to observe in hadronic environment, we will consider leptonic decays of sleptons via λ_{i3i} couplings. To be specific, we take λ_{131} and discuss e^+e^- and $e^+\nu_e$ production in $p\bar{p}$

collisions; the same results hold for $\mu^+\mu^-$ and $\mu^+\nu_\mu$ production if λ_{232} is assumed. The differential cross sections for $p\bar{p} \to e^+e^-$ and $e^+\nu_e$ processes are obtained by combining the luminosity spectra for quark-antiquark annihilation with partonic cross sections for

(a) *electron-pair production:* the s-channel sneutrino $\tilde{\nu}_\tau$ exchange contributes only to $d\bar{d} \to e^+e^-$ which does not interfere with the SM s-channel γ, Z processes;

(b) *electron + missing energy:* only the process $u\bar{d} \to e^+\nu_e$ receives the s-channel $\tilde{\tau}$ slepton exchange which does not interfere with the s-channel W-boson exchange.

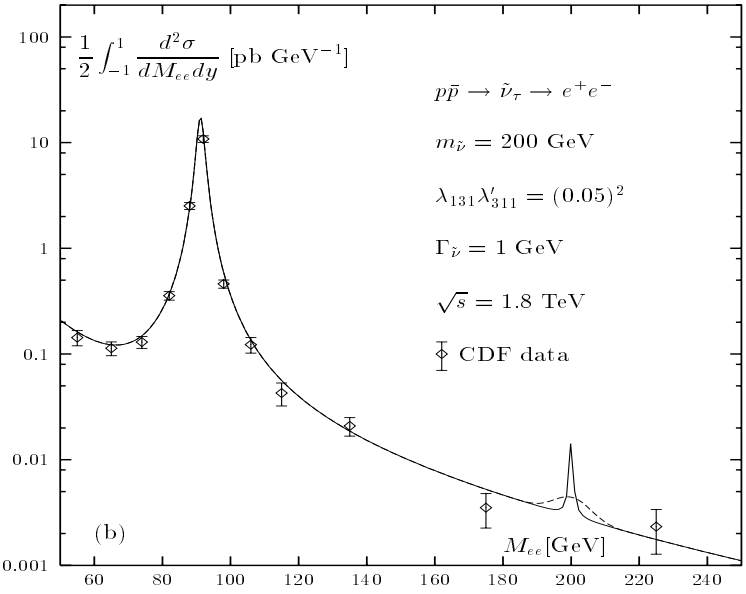

Figure 5: The e^+e^- invariant mass distribution including the s-channel sneutrino in the channel $d\bar{d} \to e^+e^-$ is compared with the CDF data; solid line: ideal detector, dashed line: sneutrino resonance smeared by a Gaussian width 5 GeV. The CTEQ3L structure functions have been used.

In numerical calculations the total decay widths of sleptons have been set to a typical value of 1 GeV, corresponding to the branching ratios for leptonic decays of order 1%. The resulting di-electron invariant mass distribution is compared to the CDF data in Fig. 5. Following CDF procedure [24], the prediction for $\frac{1}{2}\int_{-1}^{1} \mathrm{d}^2\sigma/\mathrm{d}M_{ee}\mathrm{d}y$ is shown. The solid line is for an ideal detector, while the dashed line is for the distribution after the smearing of the peak by experimental resolution characterized by a Gaussian width of 5

GeV. The CTEQ3L parametrization [25] is used together with a multiplicative K factor for higher order QCD corrections to the SM Drell-Yan pair production.

6 Summary

The R-parity violating formulation of supersymmetric extension of the SM offers a distinct phenomenology and therefore deserves detailed studies. Even if the squarks are beyond the kinematical reach of HERA, sleptons might be light enough to be produced as s-channel resonances with spectacular signatures at LEP2 and/or Tevatron. We discussed the scenario with lepton number violation, and we enumerated a number of processes in which sleptons might play an important role. We concentrated only on four-fermion processes in which sleptons are produced and decay via R_p-violating couplings. On the other hand, if no deviations from the SM expectations are observed, stringent bounds on individual couplings can be derived experimentally in a direct way. For example, if the total cross section for e^+e^- annihilation to hadrons at 192 GeV can be measured to an accuracy of 1%, the Yukawa couplings for a 200 GeV sneutrino can be bounded to $\lambda_{131}\lambda'_{311} \lesssim (0.045)^2$ [7]. Similarly, assuming the sneutrino contribution to di-electron production at Tevatron be smaller than the experimental errors, we estimate that the bound $\lambda_{131}\lambda'_{311} \lesssim (0.08)^2\tilde{\Gamma}^{1/2}$ can be established [7], where $\tilde{\Gamma}$ denotes the sneutrino width in units of GeV.

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