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Search for pair production of supersymmetric particles with R-parity violating LL$\bar{\text{E}}$ couplings at $\sqrt{s} = 192$ GeV to 202 GeV

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Abstract

The search for pair production of gauginos and sleptons under the assumption that R-parity is not conserved is presented, using data recorded by the DELPHI detector in 1999 in e^+e^- collisions at centre-of-mass energy from 192 GeV to 202 GeV. Only one R-parity violating LL$\bar{\text{E}}$ coupling, which couples scalar leptons to leptons, is considered to be dominant at a time. The results, in agreement with Standard Model expectations, are used to constrain MSSM parameter values and to derive limits on the mass of supersymmetric particles.

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1 Introduction

In the Minimal Supersymmetric Standard Model (MSSM) [1] scenario with R-parity violation ($\not{R}_p$) due to the trilinear terms [2], the supersymmetric particles are allowed to decay into standard particles through one $\not{R}_p$ coupling. Via the $\lambda_{ijk}\mathrm{L}_i\mathrm{L}_j\bar{\mathrm{E}}_k$ term, the sleptons are coupled to the leptons. In four-component Dirac notation, the Yukawa interactions of the $\mathrm{LL\bar{E}}$ R-parity violation term are [3]:

$$\lambda_{ijk}(\tilde{\nu}_{iL}\bar{\ell}_{kR}\ell_{jL} + \tilde{\ell}_{jL}\bar{\ell}_{kR}\nu_{iL} + \tilde{\ell}^{*}_{kR}(\overline{\nu}_{iL})^c\tilde{\ell}_{jL} - i \leftrightarrow j) + c.h.$$

Considering the above expression, it is evident that the $\not{R}_p$ decay of a sfermion of a particular family will be possible only with specific indices i, j, k of the coupling considered to be dominant. The possible channels from $\not{R}_p$ direct decays of sfermions are given by:

$$\begin{array}{lllllll}
\tilde{\nu}_{iL} & \rightarrow & \ell^{+}_{jL}\ell^{-}_{kR} & & \tilde{\nu}_{jL} & \rightarrow & \ell^{+}_{iL}\ell^{-}_{kR} \\
\tilde{\ell}^{-}_{iL} & \rightarrow & \bar{\nu}_{jL}\ell^{-}_{kR} & & \tilde{\ell}^{-}_{jL} & \rightarrow & \bar{\nu}_{iL}\ell^{-}_{kR} \\
\tilde{\ell}^{-}_{kR} & \rightarrow & \nu_{iL}\ell^{-}_{jL} \ , \ \ell^{-}_{iL}\nu_{jL} & & & & \\
\tilde{\chi}^{0} & \rightarrow & \ell^{+}_{i}\bar{\nu}_{j}\ell^{-}_{k} \ , \ \ell^{-}_{i}\nu_{j}\ell^{+}_{k}, & \bar{\nu}_{i}\ell^{+}_{j}\ell^{-}_{k} \ , \ \nu_{i}\ell^{-}_{j}\ell^{+}_{k} & & &
\end{array}$$

Two types of supersymmetric particle decays are considered. First, the *direct decay*, corresponding to the slepton $\not{R}_p$ decay into two leptons. Second, the *indirect decay* corresponding to the slepton cascade decay through R–parity conserving vertices to on-shell sparticles down to the lighter supersymmetric particle decaying via one $\mathrm{LL\bar{E}}$ coupling.

In all searches for R-parity violation, the LSP lifetime is a crucial parameter, since the analyses performed are mainly sensitive only if the LSP has a negligible lifetime. Considering the upper limits on the λ_{ijk} derived from the Standard Model constraints [3, 4, 5] and the dependence of the lifetime on the LSP mass and on the coupling strength, the analyses are sensitive in case of a LSP mass greater than 10 GeV/c^2, and a λ_{ijk} value above 10^{-5} – 10^{-4}. If it is not the case, the LSP decay vertex is displaced from its production vertex (by a few centimetres or tenths of centimetres, or even outside the detector giving a final state similar to the one obtained when R-parity is conserved).

The searches are performed in the MSSM framework, with the assumption that the gaugino masses are unified at the GUT scale. So the relevant MSSM parameters used to interpret the results of the $\not{R}_p$ searches are μ, tanβ, M_2 and m_0. In the slepton search, the no-mixing scenario is considered. In case of pair production of supersymmetric particles, R_p is conserved at the production vertex; the production cross-section does not depend on the $\not{R}_p$ couplings. Neutralinos and charginos are produced in pair via the exchange in the s-channel of a γ or a Z, or in the t-channel, via a selectron for the neutralinos, or a sneutrino for the charginos, if the slepton masses are low enough. Sleptons can be produced via s-channel Z or γ exchange, and the production cross-section depends on the slepton mass. The $\tilde{\nu}_{\mathrm{e}}$ ($\tilde{\mathrm{e}}$) can also be produced via the exchange of a chargino (neutralino) in the t-channel, provided that the gaugino component of the chargino (neutralino) is the dominant one. The t-channel contributes if the chargino (neutralino) mass is sufficiently low, and then the cross-section depends also on the $\tilde{\chi}^{\pm}$ ($\tilde{\chi}^{0}$) mass and field composition and thereby on the relevant MSSM parameters.

Gaugino decays

In case of a dominant λ_{ijk} coupling, the gauginos decay into charged leptons and neutrinos. The direct decay of a pair of lightest neutralinos leads to two neutrinos and four charged leptons. The heavier neutralinos and the charginos, depending on their mass difference with $\tilde{\chi}^0_1$, either decay directly into three leptons or decay to $\tilde{\chi}^0_1$, via virtual Z or W. In case of an indirect decay of a pair of charginos or heavier neutralinos the final state may contain some jets or leptons added to the four leptons and the missing energy from the $\tilde{\chi}^0_1\tilde{\chi}^0_1$ $\not{R}_p$ decay (Table 1).

processes	final states with λ_{ikk}
$\tilde{\chi}^0_a\tilde{\chi}^0_b$ (direct decay)	$\ell_i\ell_k\ell_i\ell_k(25\%) \oplus \ell_i\ell_k\ell_k\ell_k(50\%) \oplus \ell_k\ell_k\ell_k\ell_k(25\%)$ + $\not{E}$
$\tilde{\chi}^+_c\tilde{\chi}^-_d$ $\tilde{\chi}^0_a\tilde{\chi}^0_b$ a or $b > 1$ (indirect decays)	$\ell_i\ell_k\ell_i\ell_k(25\%) \oplus \ell_i\ell_k\ell_k\ell_k(50\%) \oplus \ell_k\ell_k\ell_k\ell_k(25\%)$ + $\not{E}$ $(+n\ell)$ $(+m$ qq')

Table 1: Gaugino pair production final states with λ_{ikk} couplings.

Sneutrino direct decays

The direct decay of a pair of sneutrinos gives four charged lepton final states, and the six possibilities are listed in Table 2.

final states	processes and couplings		
	$\tilde{\nu}_e\bar{\tilde{\nu}}_e$	$\tilde{\nu}_\mu\bar{\tilde{\nu}}_\mu$	$\tilde{\nu}_\tau\bar{\tilde{\nu}}_\tau$
eeee		λ_{121}	λ_{131}
ee$\mu\mu$	λ_{121}	λ_{122}	$\lambda_{132}, \lambda_{231}$
ee$\tau\tau$	λ_{131}	$\lambda_{123}, \lambda_{231}$	λ_{133}
$\mu\mu\mu\mu$	λ_{122}		λ_{232}
$\mu\mu\tau\tau$	$\lambda_{123}, \lambda_{132}$	λ_{232}	λ_{233}
$\tau\tau\tau\tau$	λ_{133}	λ_{233}	

Table 2: Four lepton final states produced by the direct decay via a LL$\bar{\rm E}$ term of a sneutrino pair.

Sneutrino and charged slepton indirect decays

The most general slepton indirect decay studied is the indirect decay into the lightest

$\tilde{\nu}\bar{\tilde{\nu}}$	$\ell_i\ell_k\ell_i\ell_k(25\%) \oplus \ell_i\ell_k\ell_k\ell_k(50\%) \oplus \ell_k\ell_k\ell_k\ell_k(25\%)$ + $\not{E}$
$\tilde{\ell}^+_m\tilde{\ell}^-_m$	$\ell^+_m\ell^-_m$ + $\ell_i\ell_k\ell_i\ell_k(25\%) \oplus \ell_i\ell_k\ell_k\ell_k(50\%) \oplus \ell_k\ell_k\ell_k\ell_k(25\%)$ + $\not{E}$

Table 3: Sfermion pair production final states in case of indirect decays when the LSP is the lightest neutralino decaying via λ_{ikk} coupling.

neutralino considered as the LSP ($\tilde{\nu} \to \nu\ \tilde{\chi}^0_1$, $\tilde{\ell} \to \ell\ \tilde{\chi}^0_1$). The indirect decay into a chargino is not taken into account: the gaugino searches lead to a chargino mass limit close to the kinematical one, and then pair production of sleptons heavier than charginos is suppressed. The final states are composed by two fermions plus the decay products of the $R\!\!\!/_p$ decay of the neutralinos. The possible final states are summarized in Table 3.

2 Data samples

The data recorded in 1999 with the DELPHI detector [6] at centre-of-mass energies from $\sqrt{s}$ = 192 GeV to 202 GeV (Table 4), corresponding to a total integrated luminosity of 226.3 pb^{-1}, have been analysed. To evaluate background contaminations, different

centre-of-mass energy (GeV)	192	196	200	202
integrated luminosity (pb^{-1})	25.9	76.4	83.4	40.6

Table 4: Data collected by DELPHI in 1999

contributions coming from the Standard Model processes were considered. The $\gamma\gamma$ events were generated with the programs `BDK` [9] for $\gamma\gamma \to \ell^+\ell^-$ processes, and `TWOGAM` [10] for $\gamma\gamma \to$ hadron processes. The Bhabha scattering events were produced with `BHWIDE` [12]. The `KORALZ` [13] generator was used to produce $e^+e^- \to \mu^+\mu^-(\gamma)$ and $e^+e^- \to \tau^+\tau^-(\gamma)$ events, and `PYTHIA` [14] to produce $e^+e^- \to q\bar{q}(\gamma)$ events. The `EXCALIBUR` [15] and `GRC4F` [16] programs were used to generate all types of four fermion processes.

The signal events have been simulated using the `SUSYGEN3 program` [17, 18], followed by the full DELPHI simulation and reconstruction program (`DELSIM`). The $\tilde{\chi}^0_i$ and $\tilde{\chi}^\pm$ pair production were considered for different values of tanβ (from 1 to 30), m_0 (between 90 GeV/c^2 and 500 GeV/c^2), μ (between –200 GeV/c^2 and 200 GeV/c^2) and M_2 (between 5 and 400 GeV/c^2), for both λ_{122} and λ_{133} searches. In case of sneutrino direct decay (Br($\tilde{\nu} \to \ell^+\ell^-$) = 100%), the processes $\tilde{\nu}_e\bar{\tilde{\nu}}_e \to 4\mu$ (λ_{122}), $\tilde{\nu}_e\bar{\tilde{\nu}}_e \to 4\tau$ (λ_{133}), $\tilde{\nu}_\mu\bar{\tilde{\nu}}_\mu \to 4\tau$ (λ_{233}) and $\tilde{\nu}_\tau\bar{\tilde{\nu}}_\tau \to 2e2\tau$ (λ_{133}) have been generated for different values of sneutrino mass up to 98 GeV/c^2, with tanβ and μ fixed at 1.5 and –150 GeV/c^2 respectively. In order to be sure that all final states were covered, signals obtained for other λ_{ijk} couplings and for sneutrino mass around 85 GeV/c^2 were also generated. Events with sneutrino (slepton) indirect decay (Br($\tilde{\nu}$ ($\tilde{\ell}$) $\to \tilde{\chi}^0_1\nu$ (ℓ)) = 100%) were also simulated with λ_{122} and λ_{133} couplings, for different $\tilde{\nu}$ ($\tilde{\ell}$) and $\tilde{\chi}^0_1$ masses, in order to cover several ranges of mass difference between sneutrinos (sleptons) and neutralinos. Furthermore, in case of slepton indirect decays, selectron, smuon and stau pair production have been simulated, since the efficiencies depend also on the slepton flavor.

3 Analyses descriptions

For all the analyses presented in this paper, it was assumed that only one λ_{ijk} is dominant at a time. Two types of analyses have been performed:

- the first one assumes that λ_{122} is dominant (i.e the charged leptons coming from $R\!\!\!/_p$ decay are muons and electrons). This is the most efficient and selective case since the selection criteria are based on e and μ identification;

- the second search assumes that λ_{133} is dominant, meaning that the leptons from $\not{R}_p$ decay are mainly taus and electrons. This is the case with the lowest efficiency and the lowest rejection power due to the presence of several taus in the final state.

Any of the possible topologies should be covered by one of the two analysis types, to be sure that any type of $\not{R}_p$ via LLE coupling signal could be discovered. Two different λ_{ijk} can lead to the same final state, and therefore the same efficiency ranges. This allows to apply the first type of analysis to signals produced via λ_{2j2}. In most cases, the analyses of the second type are applied to signals generated with other λ_{ijk}, and the efficiencies are either of the same order or higher than for λ_{133} signals.

The applied selections were based on the criteria already presented in [7, 8], using mainly missing quantities, lepton identification and kinematic properties, and jet characteristics. The lepton identification is based on standard DELPHI algorithms.

- The electron identification is provided by the `REMCLU` [19] package: a particle is a well identified electron if it verifies the tight conditions from `REMCLU`, if its momentum is greater than 5 GeV/c and if there is no other charged in a 2^o cone.
- A particule is a well identified muon if its momentum is greater than 5 GeV/c and if it is tagged as a standard or tight muon candidate by the DELPHI algorithm [6].

As already mentioned, indirect decays of gaugino pairs can give two or more jets in the final state, beside leptons and missing energy. Moreover, in the case of the λ_{133} coupling, thin jets can be produced in the τ decays. The jets were reconstructed with the `DURHAM` [20] algorithm. In order to cover the different topologies, the jet number was not fixed, and the jet charged multiplicity could be low (thin jets with one charged particle for instance). In the following, the transition value of the Y_{cut} in the `DURHAM` algorithm at which the event changes from a n-jet to a $(n-1)$-jet configuration is noted $Y_{(n-1)n}$.

3.1 Neutralino and chargino search

3.1.1 Common preselection

In the search for neutralino and chargino pair production in case of a dominant λ_{122} or λ_{133} coupling, the preselection requirements described in [8] were used. As for last year, a condition requiring at least two charged particles detected in the barrel (polar angle between 40° and 140°) was added. A criterion has been added, completing the preselection stage: the thrust axis has been asked not to be parallel to the beam pipe, i.e. $|\cos\theta_{\rm th}|$ less than 0.9.

This was efficient to suppress 99.9% of the backgrounds coming from bhabha scattering and two-photon processes while removing 97.5% of the $f\bar{f}\gamma$ contribution. The preselection also reduced by 75% the four-fermion contamination. 4053 real data remained after the preselection, for 3583 ± 36 events expected from Standard Model processes; the agreement between the number of observed and expected events at the preselection level was satisfactory.

3.1.2 Analyses with λ_{122} as dominant coupling

Concerning the neutralino and chargino searches with a dominant λ_{122} coupling, the selection procedure has been adapted from the sequential analysis performed at 189 GeV. The signature of the final states with this coupling selected by this analysis are four to eight leptons (e/μ), up to six jets and missing energy. The discriminant variables used in this analysis are displayed on Figure 1. Events satisfying the following criteria were selected:

- the number of charged particles had to be greater than the number of neutrals;
- lower limit on missing energy was applied, i.e. E_{miss} greater than $0.18\times\sqrt{s}$;
- at least one well identified muon was required, eliminating all the remaining background from bhabha scattering;
- no charged track was allowed in a 7^o isolation cone around identified leptons;
- to further reject the 4-fermions processes, at least two leading tracks had to be identified as a lepton (e/μ);
- finally, from jet characteristics, the variable $E^j_{min} \times \theta^{j_a j_b}_{min}$ was required to be greater than 4 GeV.rad, where E^j_{min} is the energy of the less energetic jet, and $\theta^{j_a j_b}_{min}$ is the angle between the two closest jets.

The applied criteria and their effects are listed in Table 5.

The number of observed data and the details of the background composition are given in the second column of Table 7. A fairly good agreement between the number of observed and expected events from the Standard Model was obtained and no excess has been seen in data. No event remained in the data, compared to 1.4 ± 0.1 expected from Standard Model background processes (0.6 from W^+W^- events and the rest from other four-fermion processes).

Using the events produced with `DELSIM`, selection efficiencies have been studied on $\tilde{\chi}^0_1\tilde{\chi}^0_1$ and $\tilde{\chi}^+_1\tilde{\chi}^-_1$ signals. All gaugino pair production processes which contribute significantly have been simulated altogether for each MSSM studied point, using `SUSYGEN`. A global event selection efficiency has then been determined at each point.
The selection efficiencies were in the range 28–52% for the neutralino pair production and 41–65% for the chargino pair production.

3.1.3 Analyses with λ_{133} as dominant coupling

The analysis applied to 1999 data was an update of the analysis used for 1998 data. The selection criteria were studied to be efficient for both low and high multiplicity cases.
First, a refined preselection was done after the common preselection: lower limit on missing energy was applied, i.e. E_{miss} greater than $0.3\times\sqrt{s}$ and the acollinearity had to be greater than 7° for events with more than 6 charged tracks. The distributions of the number of charged particles and of the energy of the most energetic lepton obtained at this preselection stage are shown in Figure 2.

For events with a charged particle multiplicity from four to six, corresponding to neutralino or chargino direct decays, the following criteria were applied:

- the energy of the most energetic lepton had to be between 2 and 70 GeV;

- there should be no other charged particle in a 20° (6°) half cone around any identified lepton for a charged particle multiplicity equal to 4 (5 or 6);
- an upper cut was imposed on the number of neutral particles: it has to be less than 11.

For events with a charged particle multiplicity greater than six, the previous criteria became:

- the energy of the most energetic lepton had to be between 5 and 60 GeV;
- if there was only one identified lepton, there should be no other charged particle in a 6° half cone around it, if there were more than one identified lepton there should be no other charged particle in a 10° half cone around at least two of them;
- the number of neutral particles had to be less than 15;
- at least one electron (loose identification) was required.

In all cases, the polar angle of at least one lepton had to be between 40° and 140°. These criteria removed 95% of $\mathrm{f\bar{f}}\gamma$, ZZ and $\mathrm{W^+W^-}$ events.

The selection based on the jet characteristics and topologies was then applied. First, constrains have been imposed to $\mathrm{Y}_{(n-1)n}$ values; this criterion eliminated 99% of the remaining $\mathrm{f\bar{f}}\gamma$ contribution. In events with more than six charged particles, at least one jet with low charged particle multiplicity was demanded. In four- or five-jet configurations, a minimum number of charged jets was required. In case of a four-jet topology, a cut was applied on the value of $\mathrm{E}^j_{\mathrm{min}} \times \theta^{j_a j_b}_{\mathrm{min}}$ where $\mathrm{E}^j_{\mathrm{min}}$ is the energy of the less energetic jet, and $\theta^{j_a j_b}_{\mathrm{min}}$ is the angle between the two closest jets. These requirements reduced to 1% the background from 4-fermions processes.

The number of remaining real and simulated data events after the selection are reported in Table 6. The number of observed data and the details of the background composition are given in Table 7. A good agreement between the number of observed and expected events was obtained, and no excess was observed in data: 15 candidates remained in the data, compared to 14.0 ± 1.1 expected from Standard Model background processes (11.8 from $\mathrm{W^+W^-}$ events and the rest from other four-fermion processes).

The selection efficiencies were computed from simulated samples for different points of the MSSM parameters space. A global event selection efficiency has been determined at each point. It was in the range 17–37% for the neutralino pair production and 21-33% for the chargino pair production.

3.2 Slepton search

Contrary to the gaugino search, in the slepton search it was not possible to define a common preselection for λ_{122} and λ_{133} analyses.

3.2.1 Analyses when λ_{122} coupling is dominant

These analyses were designed to cover three main topologies:

- 4μ and $2\mu 2\mathrm{e}$ (no missing energy), from the direct decay of $\tilde{\nu}_\mathrm{e}$ and $\tilde{\nu}_\mu$, respectively;
- 4 leptons and missing energy, with at least 2 muons, from the indirect decay of any sneutrino pair;

- 6 leptons and missing energy, with at least 4 muons, from the indirect decay of $\tilde{\mu}_R^+\tilde{\mu}_R^-$.

Events with a number of charged particles greater than or equal to four and greater than the number of neutral particles were selected. At least one identified lepton and another charged particle should both be in the barrel (i.e. with a polar angle between 40° and 140°). When neutrinos are produced in the decays, as in indirect decays, a minimum value of 5 GeV/c for the missing transverse momentum $\not{p}_t$ was required, and the polar angle of the missing momentum should be between 27° and 153°. But these could not be applied to the 4μ or $2e2\mu$ final states. In this particular case, a minimum value of 2 GeV/c was required for $\not{p}_t$, and to compensate the loss in selectivity, a lower limit to the total energy from the charged particles was applied and at least one identified muon was demanded, which eliminated Bhabha scattering events at the preselection stage. Requiring the thrust axis to be not parallel to the beam pipe, i.e. $|\cos\theta_{\rm th}|$ less than 0.9, completed the preselection stage, and after it, a vast majority of the Bhabha scattering (all in case of 4μ channel) and $\gamma\gamma$ events were eliminated (see Fig 3).

After the preselection, the main background sources were the $\mathrm{f\bar{f}}(\gamma)$ and the four fermion events. Lower or upper cut on missing energy was applied, depending on the type of final state. An additional criteria on the energy of the most energetic photon was used to select the 4μ final states. Several criteria concerning the identified leptons were applied: the number of well identified muons, the isolation angle between each identified lepton and the closest charged particle, and eventually the energy of the most energetic lepton. All these criteria helped to reduce the remaining $\mathrm{f\bar{f}}(\gamma)$ and four fermion events.

The applied criteria and their effects are listed in Tables 8 and 10. At the end, the number of remaining and expected events were:

- 1 candidate, 1.1±0.1 expected, with a typical efficiency of 50% for the direct decay of $\tilde{\nu}_e$ or $\tilde{\nu}_\mu$ (see Table 9);
- 0 candidate, 1.8±0.1 expected, with a typical efficiency of 60% for the indirect decay of any sneutrino pair;
- 0 candidate, 1.1±0.2 expected, with a typical efficiency of 70%, for the indirect decay of $\tilde{\mu}_R^+\tilde{\mu}_R^-$.

The details of the background composition are given in Table 14.

3.2.2 Analyses when λ_{133} coupling is dominant

With this type of coupling, mainly taus are produced in the final states. Then there are always neutrinos coming from the τ decay, eventually with additional neutrinos which could be produced at the $\not{R}_p$ vertex.

The analyses were designed to cover two main topologies:

- the $2\tau 2e$ final states (missing energy coming from the tau decay only), from the direct decay of $\tilde{\nu}_\tau$;
- the 4 or 6 leptons and missing energy final states, with at least 2 taus, from the indirect decay of any sneutrino pair; and from the indirect decay of a slepton pair.

A same preselection procedure can be settled for the two analyses.

Preselection

In the preselection step, it was required:

- the number of charged particles greater than three, and at least two of them with a polar angle between 40° and 140°;
- at least one "tightly" identified lepton;
- the total energy greater than $0.10\times\sqrt{s}$
- the missing p_t greater than 5 GeV/c;
- the thrust axis to be not parallel to the beam axis ($|\cos\theta_{\rm th}| < 0.9$);
- the polar angle of the missing momentum between 27° and 153°;
- the acollinearity had to be greater than 2° and greater than 7° if there were more than six charged tracks.

This was efficient to suppress the background coming from Bhabha scattering and two-photon processes, and to remove a large part of the $\rm f\bar{f}(\gamma)$ contribution. After this preselection stage, 1272 events were selected for 1214 ± 7 expected from the background sources. The distribution of the energy from the charged particles obtained before the requirement on the acollinearity, and the distribution of the missing energy at the preselection stage are shown in Figure 4.

Channel with high amount of missing energy

One analysis was performed in order to study three different cases:

- the channel $\tilde{\nu}_{\rm e}\bar{\tilde{\nu}}_{\rm e} \rightarrow 4\tau$ (direct decay of $\tilde{\nu}_{\rm e}$);
- the channel $\tilde{\nu}\bar{\tilde{\nu}} \rightarrow \nu\tilde{\chi}^0_1\nu\tilde{\chi}^0_1$ (indirect decay of sneutrinos);
- the channel $\tilde{\ell}^+_R\tilde{\ell}^-_R \rightarrow \ell\tilde{\chi}^0_1\ell\tilde{\chi}^0_1$ (indirect decay of scalar leptons).

In all cases, the final state has a large amount of missing energy, and mainly taus. The criteria were very similar to those described in [8]; they are listed in Table 11. The distributions of the number of neutral particles, and of the largest lepton isolation angle obtained after the requirement on the missing energy are shown in the top of Figure 5; the distributions of the number of leptons in the barrel and of the Durham variable $\rm Y_{23}$, obtained after the requirement on the lepton isolation are shown in the bottom of Figure 5. All these variables were used in the selection. At the end, 3 events remained in the data compared to 4.1 ± 0.25 expected from the Standard Model processes. The background was mainly composed of four fermion events, in particular from the W pair production, as can be seen in Table 14.

In case of direct decay of $\tilde{\nu}_{\rm e}$, the analysis efficiency was between 29% and 39%, depending on the sneutrino mass (see Table 12). It laid in the same range for the sneutrino indirect decay, depending also on the neutralino mass, but not on the sneutrino flavour. The efficiencies were higher for final states obtained in indirect decay of slepton pairs, due to the presence of two additional leptons. They ranged from 31% to 45% for stau pairs, and were 5% to 8% higher for selectron and smuon pairs (in this case indeed the two additional leptons are either electrons or muons).

Channel with low $\mathbf{E_{\rm miss}}$ (ee$\tau\tau$)

Compared to the previous selection procedure, the major change was the suppression of the criterion on the missing energy, and the introduction of the requirement to have at least one well identified electron. Beside this, some other criteria were slightly modified, such as the number of charged particles (from 4 to 7), the energy of the most energetic lepton (between 25 and 80 GeV). After these requirements, 22 events were obtained compared to 19.4 ± 1.6 from the Standard Model processes. Then, criteria on jet properties were applied (see Table 13). The agreement between the behaviour of the data and of the Standard Model background is fairly good (see Figure 6). At the end of the selection, 4 candidates were obtained for 4.5 ± 0.8 expected (see Table 14). The efficiencies varied with the $\tilde{\nu}_\tau$ mass and ranged from 45% to 51%.

4 Interpretation of analysis results

By performing the analyses described in the previous sections at centre-of-mass energies from 192 to 202 GeV, no excess of events was found in the data with respect to the Standard Model expectation, and limits on the MSSM parameters can be updated compared to those obtained with the analyses of the 1998 data collected in DELPHI [8].

In all the pair production processes studied, the most conservative limits were derived from the results of the λ_{133} analyses. These are hence valid for any λ_{ijk} coupling.

4.1 Results from gaugino search

The number of expected events corresponding to gauginos pair production in each point of the explored MSSM parameter space was obtained by:

$$\mathrm{N_{exp}} = \epsilon_g \times \{\sum_{E_{cm}=192}^{E_{cm}=202} \mathcal{L}_{E_{cm}} \times \{\sum_{i,j=1}^{4} \sigma(\mathrm{e^+e^-} \to \tilde{\chi}_i^0 \tilde{\chi}_j^0) + \sum_{k,l=1}^{2} \sigma(\mathrm{e^+e^-} \to \tilde{\chi}_k^+ \tilde{\chi}_l^-)\}\}$$

where ϵ_g is the global efficiency determined as explained in section 3.1. This number has been compared to the number of signal events, $\mathrm{N_{95}}$, expected at a confidence level of 95% in presence of background, determined following the Bayesian method [21]. All points which satisfied $\mathrm{N_{exp}} > \mathrm{N_{95}}$ were excluded at 95% C.L. The analysis performed considering the λ_{133} coupling as the dominant one provided the most conservative constrains on the MSSM parameter values. The corresponding excluded area in μ, $\mathrm{M_2}$ planes obtained with the present searches are extended as shown in Fig. 7, for $\mathrm{m_0} = 90$, 500 GeV/c^2 and $\tan\beta = 1.5$, 30.

For each $\tan\beta$, the highest value of neutralino mass which can be excluded has been determined in the μ, $\mathrm{M_2}$ plane (-200 GeV/$c^2 \leq \mu \leq 200$ GeV/c^2, $5 < \mathrm{M_2} \leq 400$ GeV/c^2) for several $\mathrm{m_0}$ values from 90 to 500 GeV/c^2; the most conservative mass limit was obtained for high $\mathrm{m_0}$ values. The corresponding limit on neutralino mass as a function of $\tan\beta$ is plotted in Figure 8.
The same procedure has been applied to determine the most conservative lower limit on the chargino mass. The result is less dependent on $\tan\beta$, allowing to almost reach the kinematical limit for any value of $\tan\beta$.

4.2 Results from slepton search

The results of the searches for 4μ, $2e2\mu$ and $2e2\tau$ final states were used to obtain the number of signal events expected at a confidence level of 95% in presence of background taking into account the efficiencies determined when varying the sneutrino mass. It was compared to the number of expected signal events determined with the $\tilde{\nu}_\mathrm{e}$, $\tilde{\nu}_\mu$, $\tilde{\nu}_\tau$ pair production cross-sections and the integrated luminosities at the different centre-of-mass energies (see Fig. 9). From this comparison, limits on sneutrino mass were derived. The results from the 4τ search were used to derive limits on $\tilde{\nu}_e$ (λ_{133}) and on $\tilde{\nu}_\mu$ (λ_{233}), those from the $2e2\tau$ to derive limits on $\tilde{\nu}_\tau$ (λ_{133}).

For the $\tilde{\nu}$ indirect decay in $\nu\tilde{\chi}^0_1$ with the $\not{R}_p$ decay of the neutralino via λ_{133}, the efficiencies depend on the sneutrino and neutralino masses. The results of the λ_{133} analysis were used to exclude an area in the $m_{\tilde{\chi}^0}$ versus $m_{\tilde{\nu}}$ plane, as shown in Fig. 10. This exclusion area is also valid for the other couplings.

The same procedure has been followed for the charged slepton indirect decays, and the area excluded in the $m_{\tilde{\chi}^0}$ versus $m_{\tilde{\ell}_R}$ plane is plotted in Fig. 11. The region where $m_{\tilde{\ell}_R}$ - $m_{\tilde{\chi}^0}$ is less than 2–3 GeV/c^2 is not covered by the present analysis, since then the direct decay becomes the dominant mode, leading to two leptons and missing energy signature. Since the selection of indirect decay of a $\tilde{\tau}_R$ pair into two taus and two neutralinos is less efficient than for the $\tilde{e}_R$ or $\tilde{\mu}_R$ pair, the exclusion plot derived from the analysis results of the $\tilde{\tau}_R$ indirect decay with a dominant λ_{133} is valid for any slepton flavour in the hypothesis of a branching fraction $\tilde{\ell}_R \rightarrow \ell\tilde{\chi}^0_1$ equal to 1.

5 Conclusions

Searches for $\not{R}_p$ effects in e^+e^- collisions at $\sqrt{s}$ = 192 GeV to 202 GeV have been performed with the DELPHI detector. The pair production of neutralinos, charginos and sleptons have been studied under the assumption that the $LL\bar{E}$ term is responsible for the supersymmetric particle decays into standard particles. No evidence for R–parity violation has been observed, allowing to update the limits previously obtained at $\sqrt{s}$ =189 GeV. A neutralino mass lower than 35.5 GeV/c^2 and a chargino mass lower than 99 GeV/c^2 are excluded at 95% C.L

If the sneutrino is the LSP, the present limits are, with $\tan\beta$ =1.5:

- $m_{\tilde{\nu}_e} > 96$ GeV/c^2 for $\mu = -150$ GeV/$c^2$and $M_2 = 200$ GeV/c^2;
- $m_{\tilde{\nu}_\mu} > 84$ GeV/c^2;
- $m_{\tilde{\nu}_\tau} > 86$ GeV/c^2;

If $\tilde{\chi}^0_1$ is the LSP and the branching fraction $\tilde{\nu}(\tilde{\ell}) \rightarrow \nu$ (ℓ) $\tilde{\chi}^0_1$ is equal to 1, taking into account the limit on the neutralino mass at 35.5 GeV/c^2, sneutrinos with mass lower than 83 GeV/c^2 and right-handed sleptons with mass lower than 87 GeV/c^2 were excluded at 95% C.L.

References

[1] For reviews, see e.g. H.P. Nilles, *Phys. Rep.***110** (1984) 1; H.E. Haber and G.L. Kane, *Phys. Rep.* **117** (1985) 75.

[2] G. Farrar and P. Fayet, *Phys. Lett.* **B76** (1978) 575;
L.J. Hall, M. Suzuki, *Nucl. Phys.* **B231** (1984) 419.

[3] V. Barger, G.F. Guidice and T. Han, *Phys. Rev.* **D40** (1989) 2987.

[4] B. C. Allanach, A. Dedes and H. K. Dreiner, *Phys. Rev.* **D60** (1999) 075014 [hep-ph/9906209].

[5] R. Barbier et al., *Report of the group on the R–parity violation*, hep-ph/9810232.

[6] P. Abreu et al., *Nucl. Instr. Meth.* **378** (1996) 57.

[7] DELPHI Collaboration, CERN EP/99–49, submitted to Eur. Phys. J. **C**.

[8] N. Benekos, C. Berat, F. Ledroit-Guillon, R. López-Fernandéz, Th. Papadopoulou, DELPHI note 99-79 CONF 266.

[9] F.A. Berends, P.H. Daverveldt, R. Kleiss, *Computer Phys. Comm.* **40** (1986) 271,285 and 309.

[10] S. Nova, A. Olshevski, T. Todorov, DELPHI note 90-53(1990).

[11] F.A. Berends, W. Hollik, R. Kleiss, *Nucl. Phys.* **B304** (1988) 712.

[12] S. Jadach, W. Placzek, B.F.L. Ward, *Phys. Lett.* **B390** (1997) 298.

[13] S. Jadach, Z. Was, *Computer Phys. Comm.* **79** (1994) 503.

[14] T. Sjostrand, *Computer Phys. Comm.* **82** (1994) 74.

[15] F.A. Berends, R. Kleiss, R. Pittau, *Computer Phys. Comm.* **85** (1995) 437.

[16] J. Fujimoto *et al.*, *Computer Phys. Comm.* **100** (1997) 128.

[17] S. Katsanevas, P. Morawitz, *Computer Phys. Comm.* **112** (1998) 227.

[18] N. Ghodbane, hep-ph/9909499.

[19] F. Cossutti, M. Elsing, M. Espirito-Santo, C. Parkes, T. Spassoff, A. Tonazzo, C. Weiser, K. Beloous, V. Hedberg, F. Mazzucato, DELPHI note 99-175 PROG 239.

[20] S. Catani et al., *Phys. Lett.* **B269** (1991) 432.

[21] R.M. Barnett et al., *Phys. Rev.* **D54** (1996) 1.

Selection criteria for λ_{122}	Data	Monte Carlo S.M.	Signal effi.
Preselection + No. of charged / No. of tracks $\geq$ 0.5 + Missing energy $\geq$ 20 % $\sqrt{s}$	1983	1698 ± 11	56%
No of standard or tight μ $\geq$ 2	52	42.1 ± 2.0	56%
Selection on lepton characteristics: (remove $Z\gamma$ and four-fermion final states) E(most energetic lepton) $\geq$ 10 % $\sqrt{s}$ Angle between lept. and next charged $\geq$ 7^o	30	25.6 ± 1.1	55%
Final selection to remove: **remaining four-fermions**: No jets with a lepton as lead. particle $\geq$ 2 $\theta_{min}^{j_a j_b} \times E_{min}^{j}$ $\geq$ 4GeV.rad,	0	1.42 ± 0.12	47%

Table 5: Selection criteria used in the search for neutralino and chargino decay via λ_{122}. The number of data and Standard Model background selected events are reported, as well as the efficiencies obtained for a signal generated for $\tan\beta = 1.5$, $m_0 = 90$ GeV/c^2, $\mu = 190$ GeV/c^2 and $M_2 = 170$ GeV/c^2 (at this point, $\tilde{\chi}_1^0\tilde{\chi}_1^0$ is the dominant process).

Selection criteria for λ_{133}	$4 \leq \mathrm{N_{charged}} \leq 6$	$\mathrm{N_{charged}} \geq 7$	Data events	MC S.M.	Signal effi.
Preselection + Acolin + E_{miss}	 - $> 30\% \sqrt{s}$	 $> 7^o$ $> 30\% \sqrt{s}$	1109	1164±9	53%
$\mathrm{E^{30^o}_{cone}}$	$\leq 50\%$ $\mathrm{E_{total}}$	$\leq 40\%$ $\mathrm{E_{total}}$	881	797±7	51%
$\mathrm{N_{lepton}}$ in the barrel $\mathrm{E^{l}_{max}}$	 ≥ 1 [2 GeV, 70 GeV]	 ≥ 1 [5 GeV, 60 GeV]	490	481±4	46%
Isolation	$\Theta^{\mathrm{min}}_{\mathrm{lepton-track}} \geq 20^o$ if $\mathrm{N_{charged}} = 4$ $\Theta^{\mathrm{min}}_{\mathrm{lepton-track}} \geq 6^o$ if $\mathrm{N_{charged}} = 5, 6$	$\Theta^{\mathrm{max}}_{\mathrm{lepton-track}} \geq 6^o$ $\Theta^{\mathrm{max-1}}_{\mathrm{lepton-track}} \geq 10^o$ if $\mathrm{N_{lepton}} \geq 2$	235	263±3	43%
$\mathrm{N_{neutral}} <$	11	15	198	225±3	42%
$\mathrm{N_{electron}}$		≥ 1	103	120±2	42%
$\log_{10}(\mathrm{Y_{23}})$ $\log_{10}(\mathrm{Y_{34}})$ $\log_{10}(\mathrm{Y_{45}})$	≥ -2.7 ≥ -4	≥ -1.8 ≥ -2.3 ≥ -3	20	21.0±1.3	39%
4 jets $\mathrm{E^{j}_{min}} \times \theta^{j1,j2}_{\mathrm{min}}$	 ≥ 1 GeV.rad	 ≥ 5 GeV.rad	19	19.0±1.2	37%
	4 charged jets if 4j or 5j	at least 1 jet with 1 or 2 charged part. 4 charged jets if 4j 4 or 5 charged j if 5j	15	14.0±1.1	33%

Table 6: Selection criteria used in the search for neutralino and chargino decay via λ_{133}. nj means n-jet topology, and a charged jet means a jet with at least one charged particle. The number of data and Standard Model background events are reported, as well as the efficiencies obtained for a signal generated for $\tan\beta = 1.5$, $\mathrm{m_0} = 90$ GeV/c^2, $\mu = 190$ GeV/c^2 and $\mathrm{M_2} = 170$ GeV/c^2 (at this point, $\tilde{\chi}^0_1\tilde{\chi}^0_1$ is the dominant process).

Coupling	λ_{122}	λ_{133}
Data	0	15
MC S.M.	1.42±0.12	14.0±1.1
WW-like	0.61 ± 0.10	11.80 ± 0.46
ee$\tau\tau$	0.	0.40 ± 0.04
ee$\mu\mu$, eeqq	0.23 ± 0.05	0.
$\mu\mu$qq	0.34 ± 0.03	0.
$\tau\tau$qq	0.	0.13 ± 0.01
$\ell\ell\ell\ell$ ($\ell = \mu, \tau$)	0.21 ± 0.02	0.30 ± 0.02

Table 7: Background contributions from Standard Model processes in the gaugino pair production analyses with λ_{122} and λ_{133}.

Selection criteria (λ_{122}, $\tilde{\nu}_e$ direct decay)	data	MC
$N_{charged} \geq 4$, $\geq 0.5 \times N_{total}$, $N_{muon} \geq 1$ at least 2 charged particles in the barrel at least one well identified lepton in the barrel missing $p_t > 2$ GeV/c, $\mid \cos\theta_{thrust} \mid \leq 0.9$ $E_{ch} \geq 50\% \sqrt{s}$	1034	916±7
$E_{miss} \leq 15\% \sqrt{s}$ $E_{\gamma}^{max} \leq 30$ GeV	342	324±4
event charge Q_{ev}=0	67	65.4±1.9
$N_{charged} = 4$, at least one well identified muon minimum lepton isolation angle $\geq 20°$	1	1.1±0.1

Table 8: Selection criteria applied in the analysis of the 4μ and $2e2\mu$ final states from sneutrino pair direct decay via λ_{122}.

$\tilde{\nu}_e$ mass (GeV/c^2)	75	80	85	90	95
Efficiency (%)	53	52	50	50	48

Table 9: Selection efficiencies obtained in the analysis of the 4μ final state from sneutrino pair direct decay via λ_{122}, for several values of $\tilde{\nu}_e$ mass.

Selection criteria (λ_{122}, indirect decays)	data	MC
$N_{charged} \geq 4$, $\geq 0.5\times N_{total}$, $N_{lepton} \geq 1$ at least 2 charged particles in the barrel at least one well identified lepton in the barrel missing $p_t > 5$ GeV/c, $\mid \cos\theta_{thrust} \mid\leq 0.9$ $27^o \leq \theta_{miss} \leq 153^o$	3464	3322±14
sneutrino indirect decay		
$E^{max}_{lepton} \geq 20$ GeV	2109	2047±11
minimum lepton isolation angle $\geq 10°$	530	552±4
at least two well identified muons	7	6.9±0.6
$E_{miss} \geq 20\%\sqrt{s}$	0	1.8±0.1
smuon indirect decay		
at least three well identified muons	1	1.4±0.2
$E_{miss} \geq 5\%\sqrt{s}$	1	1.1±0.2

Table 10: Selection criteria applied in the analysis of $2\mu + 2\ell + \not{E}$ final states (sneutrino indirect decay via λ_{122} coupling) and in the analysis of $4\mu + 2\ell + \not{E}$ final states (smuon indirect decay via λ_{122} coupling).

Selection criteria (λ_{133}, large amount of missing energy)	data	MC	efficiency direct decay
Preselection stage	1272	1214±7	48%
$E_{cone}^{30^o} \leq 40\%$ E_{total}	1141	1115±6	47%
$E_{miss} > 30\%\sqrt{s}$	644	620±5	43%
$N_{charged} \leq 8$			
$N_{neutral} \leq 10$	79	75.0±2.8	41%
$2 \leq E_{max}^{l} \leq 70$ GeV	64	63.6±2.3	41%
at least one isolated lepton 10^o	59	57.0±2.1	40%
at least 1 lepton in the barrel	49	47.4±1.7	37%
$\log_{10}(Y_{23}) \geq -2.7$			
$\log_{10}(Y_{34}) \geq -4$	7	7.9±0.6	34%
case of 4 jets:			
$\theta_{min}^{j1,j2} \geq 20^o$	4	4.4 ±0.3	32%
Energy of the most energetic photon $\leq 20\%\sqrt{s}$	3	4.1±0.3	32%

Table 11: Selection criteria applied to select slepton pair decays via λ_{133} with a large missing energy in the final state. The number of data and Standard Model background events are reported, as well as the efficiencies obtained for a $\tilde{\nu}_e\bar{\tilde{\nu}}_e$ signal generated with $m_{\tilde{\nu}_e} = 80$ GeV/c^2.

$\tilde{\nu}_e$ mass (GeV/c^2)	65	75	80	85	90	95	97	98
Efficiency (%)	37	33	32	33	29	32	37	39

Table 12: Selection efficiencies obtained in the analysis of sneutrino direct decay via λ_{133}coupling (4τ final state) for several values of $\tilde{\nu}_e$ mass.

Selection criteria λ_{133}	data	MC	efficiency direct decay
Preselection stage	1272	1214±7	69%
$E^{30^o}_{cone} \leq 50\%$ E_{total}	1144	1111±6	68%
at least one tight electron	587	556±5	68%
25 $\leq E^{l}_{max} \leq$ 80 GeV			
at least one isolated lepton 10^o	336	364±3	62%
at least 1 lepton in the barrel			
$N_{charged} \leq 7$, $N_{neutral} \leq 10$	22	19.4±1.6	59%
$\log_{10}(Y_{23}) \geq -2.7$	12	12.5±1.4	59%
case of 4 jets:			
$\theta^{j1,j2}_{min} \geq 20^o$	4	4.5±0.8	52%

Table 13: Selection criteria applied to select2e2τ final state. The number of data and Standard Model background events are reported, as well as the efficiencies obtained for a $\tilde{\nu}_\tau\tilde{\bar{\nu}}_\tau$ signal generated with $m_{\tilde{\nu}_\tau}$ = 85 GeV/c^2.

Coupling	λ_{122}			λ_{133}	
Channel	**$4\mu/2\mu 2e$**	**$2\mu 2\ell + E_{miss}$**	**$4\mu 2\ell + E_{miss}$**	**4τ (+2ℓ) (+$\not{E}$)**	**$2e2\tau$**
Data	1	0	0	3	4
MC S.M.	1.06 ± 0.11	1.77 ± 0.15	1.15 ± 0.18	4.13 ± 0.25	4.54 ± 0.82
Bhabha	0.	0.	0.	0.	0.29 ± 0.29
$\gamma\gamma \rightarrow \ell^+\ell^-$	0.	0.	0.	0.	1.06 ± 0.75
$\mu\mu\gamma$, $\tau\tau\gamma$	0.	0.06 ± 0.06	0.	0.24 ± 0.08	0.27 ± 0.09
$q\bar{q}\gamma$	0.	0.	0.29 ± 0.17	0.	0.
ee$\tau\tau$, ee$\mu\mu$	0.71 ± 0.11	0.32 ± 0.06	0.	0.48 ± 0.05	1.38 ± 0.10
$\ell\ell\ell\ell$ ($\ell = \mu, \tau$)	0.34 ± 0.03	0.48 ± 0.03	0.27 ± 0.02	0.35 ± 0.03	0.16 ± 0.02
$\ell\ell$qq ($\ell = \mu, \tau$)	0.01 ± 0.01	0.36 ± 0.08	0.49 ± 0.03	0.12 ± 0.02	0.12 ± 0.03
WW-like	0.	0.55 ± 0.10	0.10 ± 0.04	2.94 ± 0.23	1.23 ± 0.15

Table 14: Background contributions from Standard Model processes in the three analyses in case of dominant λ_{122}, and the λ_{133} two analyses of final state with a large amount of missing energy (4τ (+ 2ℓ) (+ $\not{E}$)) and with a low amount of missing energy (2e2τ).

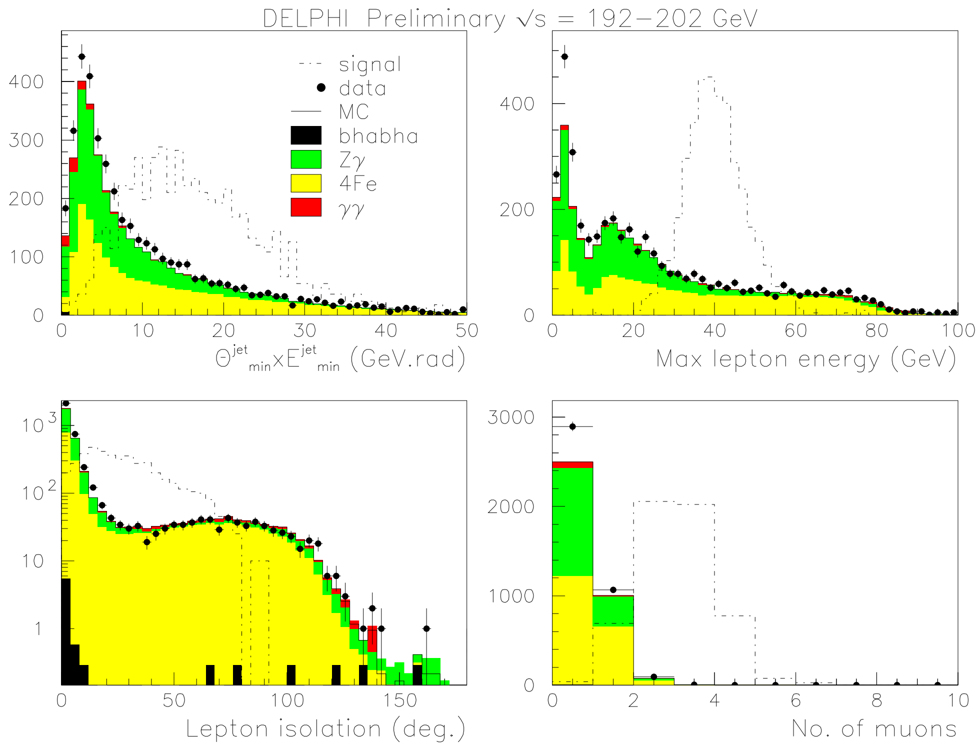

Figure 1: Neutralino and chargino search with the λ_{122} coupling: distributions at the preselection level of the missing energy, the product of the minimum jet angle times the minimum jet energy, the maximum lepton energy, the lepton isolation angle and the number of well identified muons. The black dots represent real data, shaded histograms the expected backgrounds from Standard Model processes normalised to the luminosity of the data and the dot-dashed line the signal with an arbitrary normalisation.

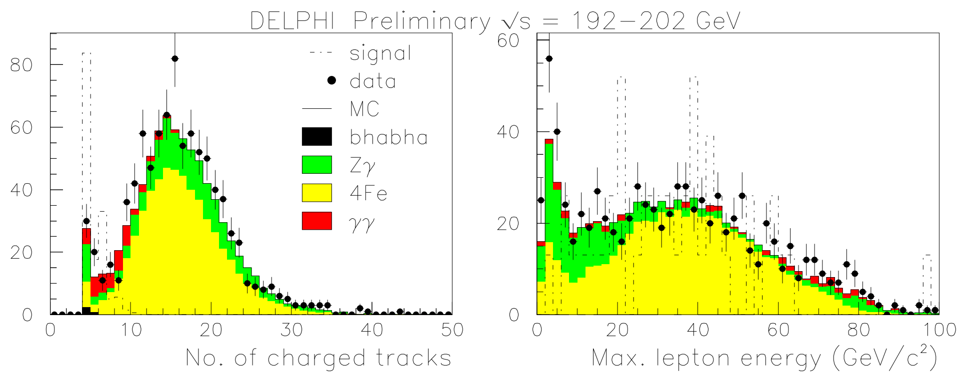

Figure 2: Neutralino and chargino search with the λ_{133} coupling: distributions at the preselection level of the number of charged particles and the energy of the most energetic lepton. The black dots represent real data, shaded histograms the expected backgrounds from Standard Model processes normalised to the luminosity of the data and the dot-dashed line the signal with an arbitrary normalisation.

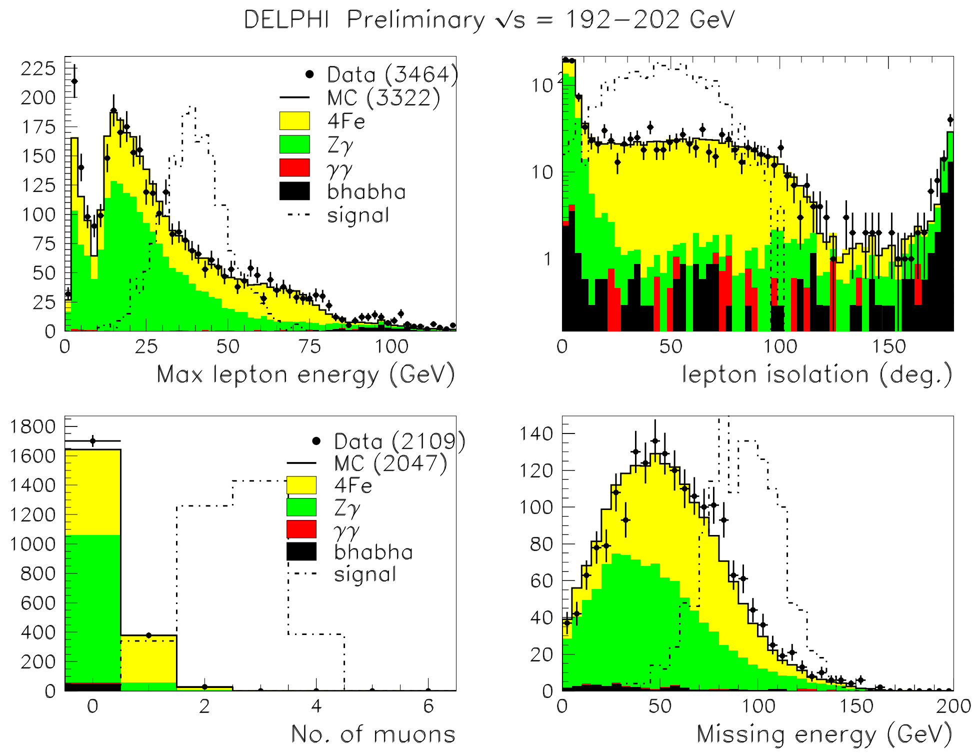

Figure 3: Slepton search with the λ_{122} coupling: the distributions of the energy of the most energetic lepton (top left) and the lepton isolation angle (top right) are shown at the preselection level; the number of well identified muons in the event (bottom left) and the missing energy distribution (bottom right) are shown after the requirement on the energy of the most energetic lepton. The black dots show the real data distributions, the shaded histograms the expected background from Standard Model processes and the dot-dashed line the signal with an arbitrary normalisation.

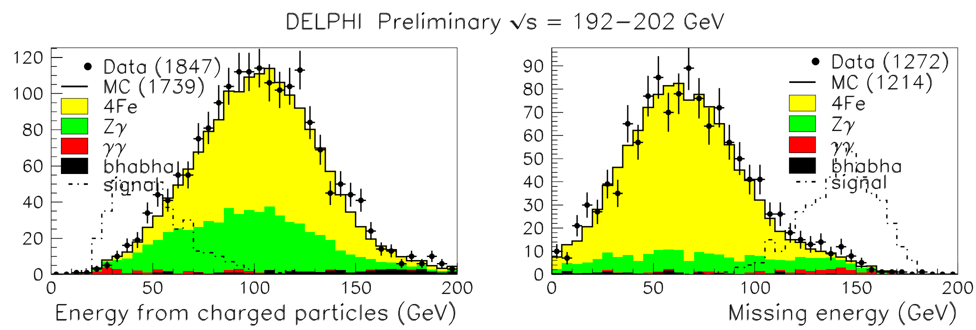

Figure 4: Slepton search with the λ_{133} coupling: event variable distributions in the preselection. The energy from charged particles (left) and the missing energy (right) distributions are shown. The black dots show the real data distributions, the shaded histograms the expected background from Standard Model processes and the dot-dashed line the signal with an arbitrary normalisation.

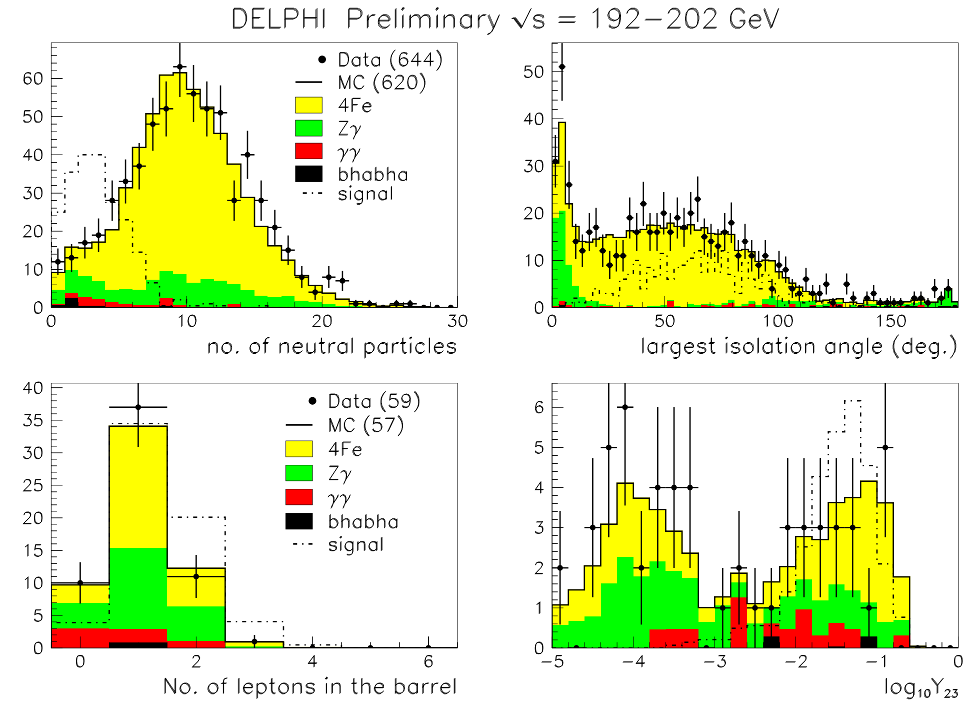

Figure 5: Slepton search with the λ_{133} coupling: event variable distributions in selection of final state with missing energy. The black dots show the real data distributions, the shaded histograms the expected background from Standard Model processes and the dot-dashed line the signal with an arbitrary normalisation.

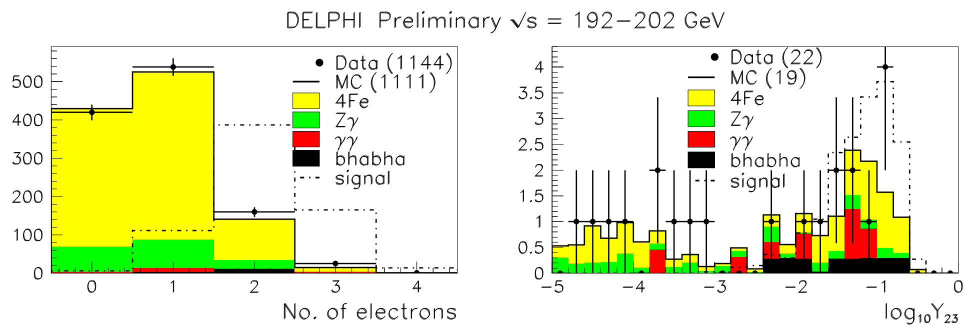

Figure 6: Slepton search with the λ_{133} coupling: event variable distributions in selection of final state with small amount of missing energy. The black dots show the real data distributions, the shaded histograms the expected background from Standard Model processes and the dot-dashed line the signal with an arbitrary normalisation.

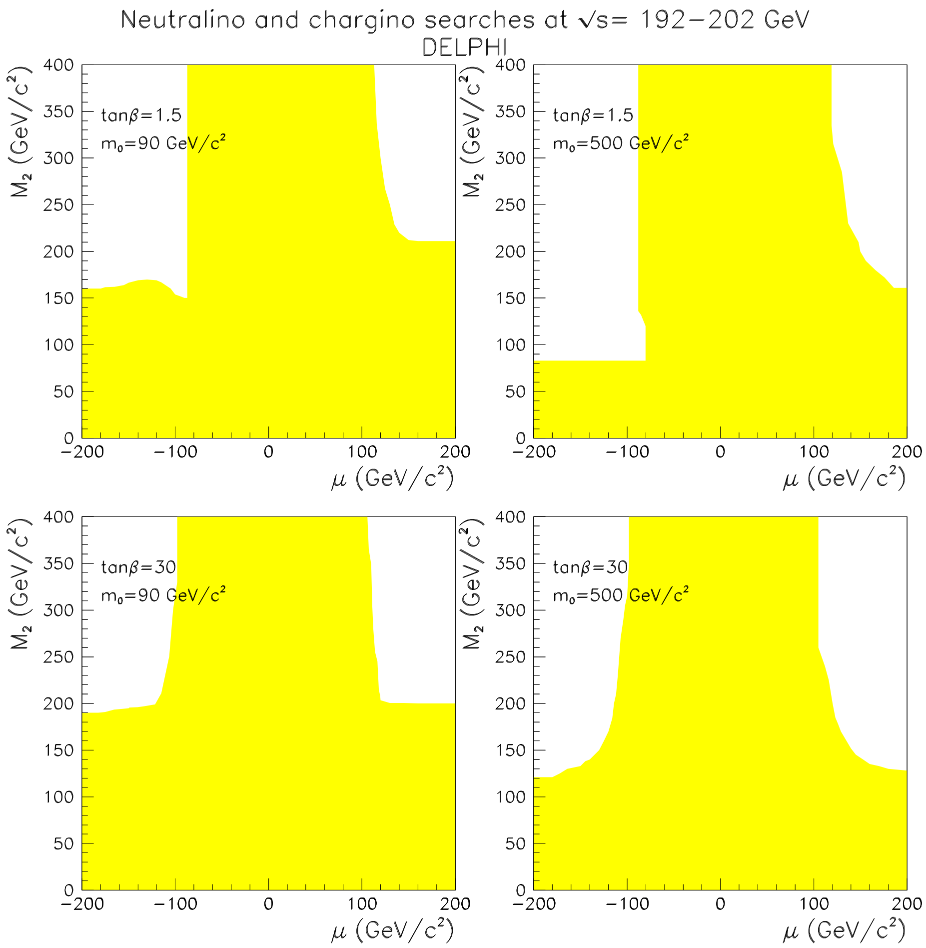

Figure 7: Neutralino and chargino searches in DELPHI data at 192 to 202 GeV with a dominant λ coupling: regions in μ, M_2 parameter space excluded at 95 % C.L. for two values of tanβ and two values of m_0. The exclusion area obtained from the λ_{133} search are shown in grey.

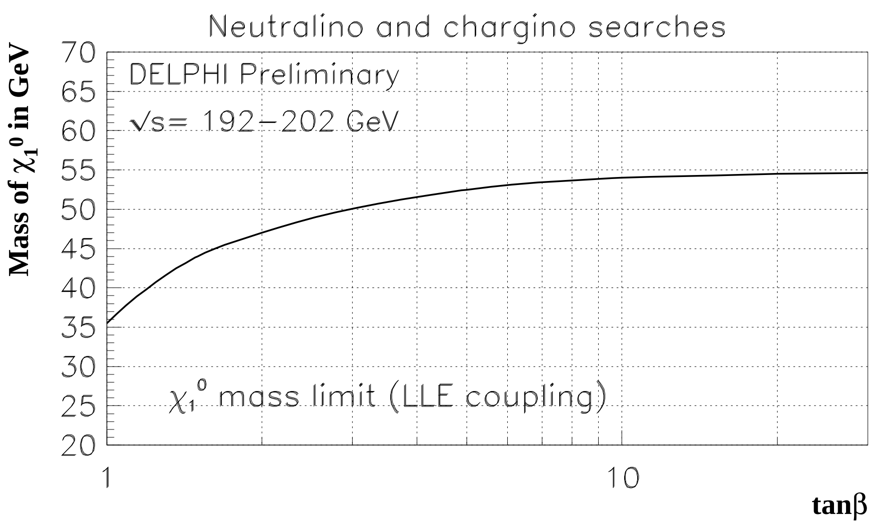

Figure 8: The excluded lightest neutralino mass as a function of tanβ at 95 % confidence level. This limit is valid for all generation indices i,j,k of the λ_{ijk} coupling and all values of m_0.

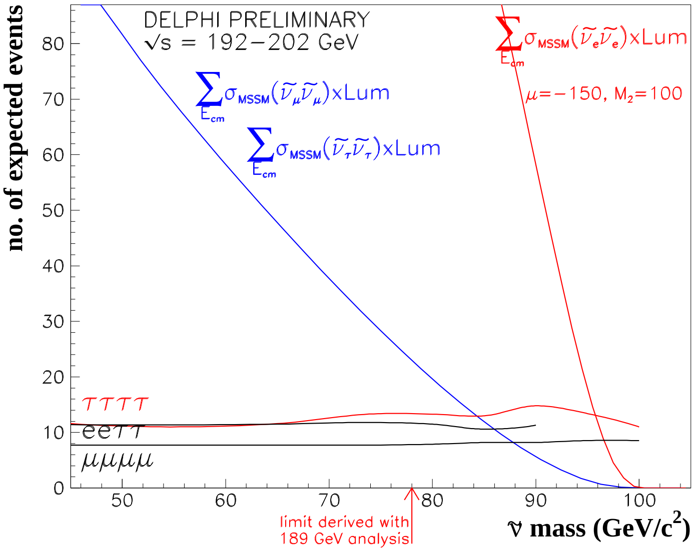

Figure 9: Sneutrino direct decay: limit on the number of $\tilde{\nu}\bar{\tilde{\nu}}$ events as a function of the mass for three different final states. The curves giving the number of expected events from the MSSM cross-sections and the luminosities at the four centre-of-mass energy values as a function of the sneutrino mass are reported in order to derive a limit on the sneutrino mass in the case of direct $\not{R}_p$ decay. The dashed lower curve corresponds to the $\tilde{\nu}_\mu\bar{\tilde{\nu}}_\mu$ and $\tilde{\nu}_\tau\bar{\tilde{\nu}}_\tau$ production, and the dashed upper curve corresponds to the $\tilde{\nu}_e\bar{\tilde{\nu}}_e$ production obtained for $\mu = -150$ GeV$/c^2$ and $M_2 = 100$ GeV$/c^2$.

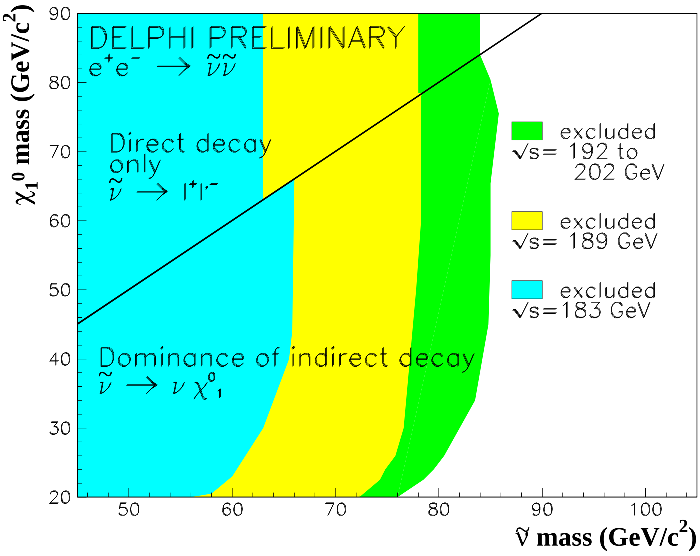

Figure 10: Excluded region at 95 % C.L. in $m_{\tilde{\chi}^0}$, $m_{\tilde{\nu}}$ parameter space by $\tilde{\nu}$ pair production for direct and indirect decays. The grey area on the left shows the part excluded by the searches at 183 GeV, the light grey area the one excluded by the analysis performed at 189 GeV, the grey area on the right the one excluded by the present analysis.

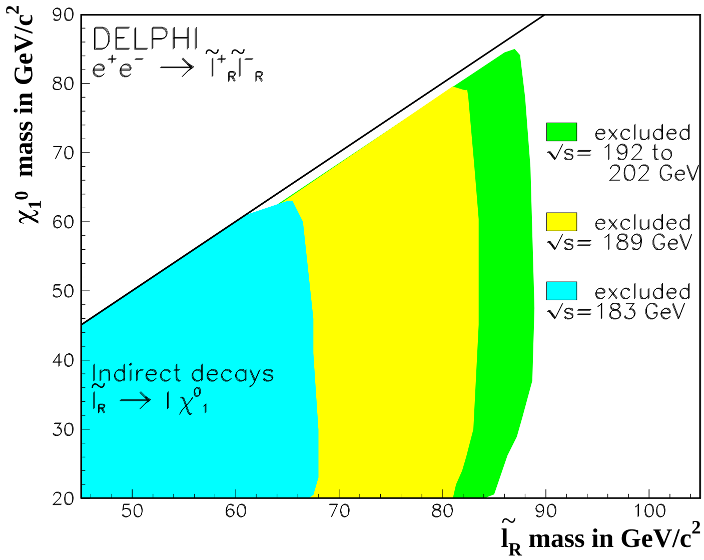

Figure 11: Charged slepton indirect decay with λ_{133} coupling: excluded region at 95 % C.L. in $m_{\tilde{\chi}^0}$, $m_{\tilde{\ell}_R}$ parameter space by $\tilde{\ell}_R$ pair production. The grey area on the left shows the part excluded by the searches at 183 GeV, the light grey area the one excluded by the analysis performed at 189 GeV, the grey area on the right the one excluded by the present analysis.