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Search for R-parity violation with a $LL\bar{E}$ coupling at $\sqrt{s} = 183$ GeV

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Abstract

Search for pair production of gauginos in e^+e^- collisions at center of mass energy of 183 GeV has been performed on DELPHI data under the assumptions that R-parity is not conserved and that the dominant R-parity violating coupling couples sleptons to standard leptons. The results are in agreement with Standard Model expectation and are used to constrain domains of the MSSM parameter space and to derive limits on the mass of supersymmetric particles. Out of this search, a neutralino with mass lower than 27 GeV/c^2 and a chargino with mass lower than 89 GeV/c^2 are excluded at 95 % confidence level.

1 Introduction

In the Minimal Supersymmetric extension of the Standard Model (MSSM) [1], the interactions are consistent with a $B-L$ conservation (B = baryon number, L = lepton number). As a consequence, the MSSM possesses a multiplicative R-parity invariance, where $R=(-1)^{3B+L+2S}$ for a particle with spin S [2]. Standard particles have even R-parity, and the corresponding superpartners have odd R-parity.

One approach to go *beyond the MSSM* is to retain the minimal particle content of the MSSM, but remove the assumption of R-parity invariance. In this scenario, new interactions violating B or L conservation appear, which can be introduced in the superpotential as [3]:

$$\lambda_{ijk}L_iL_j\bar{E}_k+\lambda'_{ijk}L_iQ_j\bar{D}_k+\lambda''_{ijk}\bar{U}_i\bar{D}_j\bar{D}_k$$

where i, j and k are the generation indices; L and E denote the lepton superfields and Q, U, D the quark superfields; λ_{ijk}, λ'_{ijk} and λ''_{ijk} are the new Yukawa couplings. The two first terms violate L conservation, and the third one B conservation. Since $\lambda_{ijk}=-\lambda_{jik}$, $\lambda''_{ijk}=-\lambda''_{ikj}$, there are 9 λ_{ijk}, 27 λ'_{ijk}, 9 λ''_{ikj} leading to 45 new couplings. But all R-parity violating ($\not{R}_p$) terms cannot be simultaneously present, otherwise the proton would decay very rapidly [4, 5].

One major phenomenological consequence of $\not{R}_p$ is the allowed decay of the Lightest Supersymmetric Particle (LSP) in standard fermions, which modifies the signatures of the supersymmetric particle production compared to the expected signatures in case of R-parity conservation. Moreover, the single sparticle production is possible. In this note, the search for pair produced gauginos ($\tilde{\chi}^0_i$, $\tilde{\chi}^{\pm}$) is performed in the hypothesis of R-parity violation with a dominant λ coupling.

In case of pair production of supersymmetric particles, R_p is conserved at the production vertex; the cross section does not depend on the $\not{R}_p$ couplings. On the contrary, the $\not{R}_p$ decay width depends on the λ coupling strength, which then determines the mean decay length of the LSP. If the LSP is a gaugino, the mean decay length is given by [6, 7]:

$$L(cm)=0.3\ (\beta\gamma)\left(\frac{m_{\tilde{l}}}{100\mathrm{GeV/c^2}}\right)^4\left(\frac{1\mathrm{GeV/c^2}}{\mathrm{m}_{\tilde{\chi}}}\right)^5\frac{1}{\lambda^2} \quad (1)$$

with $\beta\gamma=P_{\tilde{\chi}}/m_{\tilde{\chi}}$. The LSP decays within the detector if $L \lessapprox 1$ m; for typical values considered in this study, this condition implies a lower limit in sensitivity on the λ coupling in the order of $10^{-5}-10^{-6}$ in case of gauginos.

Upper limits on the lambda couplings can be derived from Standard Model processes [8, 9], mainly charged-current universality, lepton universality, $\nu_\mu - e$ scattering, forward-backward asymmetry in e^+e^- collisions, and bounds on ν_e-majorana mass. The most stringent upper bound exists for λ_{133} and comes from the last case [10]:

$$\lambda_{133}<0.003\frac{M_{\tilde{l}}}{100\mathrm{GeV/c^2}}.$$

The present indirect limits on the other λ couplings are in the range of 10^{-2} to 10^{-1}.

- **Pair production of gauginos**

Since in the $\not{R}_p$ scenario the MSSM spectrum is still valid, the masses and mixing angles of the neutralinos and the charginos are completly determined by the values of the four parameters M_1, M_2, the U(1) and SU(2) gaugino mass parameters at the electroweak scale, μ, the mixing mass term of the Higgs doublets at the electroweak scale and $tan\beta$, the ratio of the vacuum expectation values of the two Higgs doublets; assuming that gaugino masses unify at the GUT scale implies $M_1(M_Z) = \frac{5}{3}\tan^2\theta_W M_2(M_Z) \simeq \frac{1}{2}M_2(M_Z)$.

Pair production of neutralinos and charginos are considered. They are produced 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 (figure 1). So the production cross section depend also on m_0, the scalar common mass at the GUT scale, which defines the sneutrino and slepton masses. When the selectron mass is sufficiently small ($\lessapprox$ 100 GeV/c^2), the neutralino production is enhanced, as the t-channel $\tilde{e}$ exchange dominates the s-channel Z exchange. On the contrary, if the $\tilde{\nu}_e$ mass is in the same range, the chargino cross section can decrease due to destructive interference between the s- and t-channel amplitudes. If the dominant component of neutralinos and charginos is the higgsino ($|\mu| \ll M_2$), the production cross sections are large and insensitive to slepton masses. The appropriate MSSM parameters to consider in this study are then M_2, μ, $tan\beta$ and m_0. Depending on the values of the different parameters, the cross sections at $\sqrt{s}$ = 184 GeV vary typically from 0.1 to 10 pb.

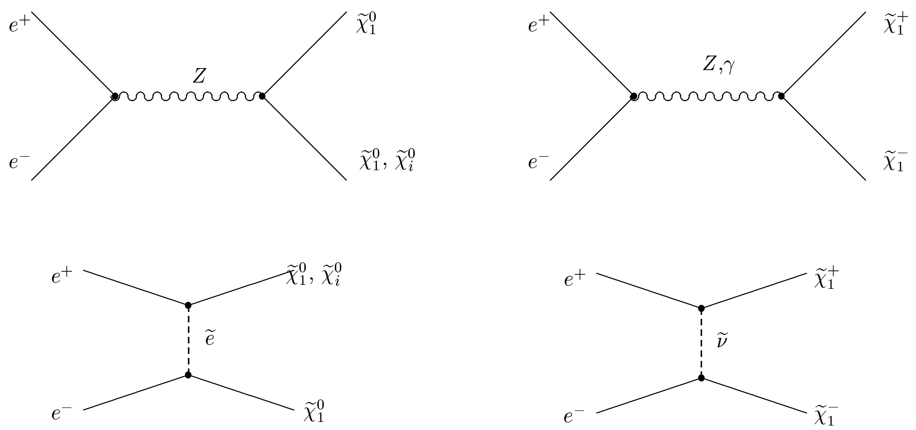

Figure 1: Gaugino pair production diagrams in the s and t channels.

In gaugino pair production several processes leading to similar final states have a non negligeable cross sections. In figure 2, the area where the $\tilde{\chi}_1^0\tilde{\chi}_1^0$, $\tilde{\chi}_2^0\tilde{\chi}_1^0$ and $\tilde{\chi}_1^+\tilde{\chi}_1^-$ cross sections are above 0.3 pb are presented in the (μ, M_2) plane for $tan\beta$ = 1.5 and m_0 = 90 GeV/c^2. As we can observe from this plot, regions where the $\tilde{\chi}_1^0\tilde{\chi}_1^0$ cross section is too low can be excluded considering the $\tilde{\chi}_1^+\tilde{\chi}_1^-$ or/and $\tilde{\chi}_2^0\tilde{\chi}_1^0$ processes, provided their cross sections are high enough.

- **Direct and indirect decays of gauginos**

In case of a dominant λ_{ijk} coupling, the sleptons couple to the leptons, and the produced gauginos decay into charged leptons and neutrinos. The decay of the lightest neutralino leads to one neutrino and two charged leptons. The heavier neutralinos and the charginos, depending on their mass difference with $\tilde{\chi}_1^0$, can either decay directly into 3 standard fermions, or decay to $\tilde{\chi}_1^0$, via for example virtual Z or W, as illustrated on

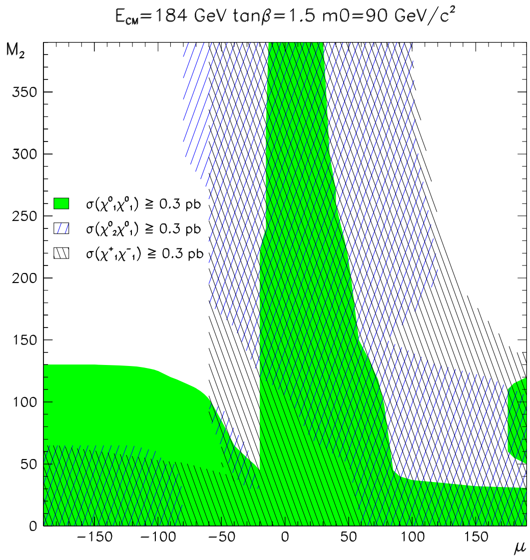

Figure 2: Gaugino cross sections for $tan\beta = 1.5$ and $\mathrm{m}_0 = 90$ GeV/c^2, in the M_2, μ plane; in the dark grey area $\sigma(e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0) > 0.3$ pb, in the hatched area $\sigma(e^+e^- \rightarrow \tilde{\chi}_2^0\tilde{\chi}_1^0) > 0.3$ pb and/or $\sigma(e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^-) > 0.3$ pb.

figure 3. Note that, even if the λ couplings lead to purely leptonic decay mode of the lightest neutralino, in case of chargino and heavier neutralinos, the final state may contain some hadronic activity.

direct decay	$\tilde{\chi}_1^0 \rightarrow \nu l^+ l^-$	$\tilde{\chi}_2^0 \rightarrow \nu l^+ l^-$	$\tilde{\chi}_1^+ \rightarrow \nu\nu l^+,\ l^+l^-l^+$
indirect decay		$\tilde{\chi}_2^0 \rightarrow Z^*\ \tilde{\chi}_1^0,\quad Z^* \rightarrow f\bar{f}$ $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 l^+l^-,\ \tilde{\chi}_1^0\gamma$	$\tilde{\chi}_1^+ \rightarrow W^{*+}\ \tilde{\chi}_1^0,\ W^{*+} \rightarrow f\bar{f}'$ $\tilde{\chi}_1^+ \rightarrow \tilde{\chi}_1^0\nu_l l^+$

Table 1: Possible decays of neutralinos and charginos.

The decay types and the branching ratios depend on the set of MSSM parameters and the value of the considered λ_{ijk} coupling; all the decay channels listed in table 1 are then possible. In order to cover both the direct and indirect decays of gauginos, the analysis has to be sensitive to the final states listed in table 2.

From equation 1, one can see that if the LSP is a gaugino with a low mass, and then with a high boost, it can escape the detection before decaying. So the assumption of a negligible LSP lifetime restricts the sensitivity of this analysis to $M_{\chi_{LSP}} \gtrsim$ 10 GeV/c^2, when considering the lowest upper bound on the λ_{ijk} coupling.

In the present analysis it was assumed that only one λ_{ijk} is dominant. Two searches have been performed:

- the first assuming that λ_{122} is dominant. In this case, the leptons coming from $\not{R}_p$ decay are muons and electrons. $\tilde{\chi}_1^0$ can decay into $e\nu_\mu\mu$ ($\approx 50\%$), or $\mu\nu_e\mu$ ($\approx$ 50 %);

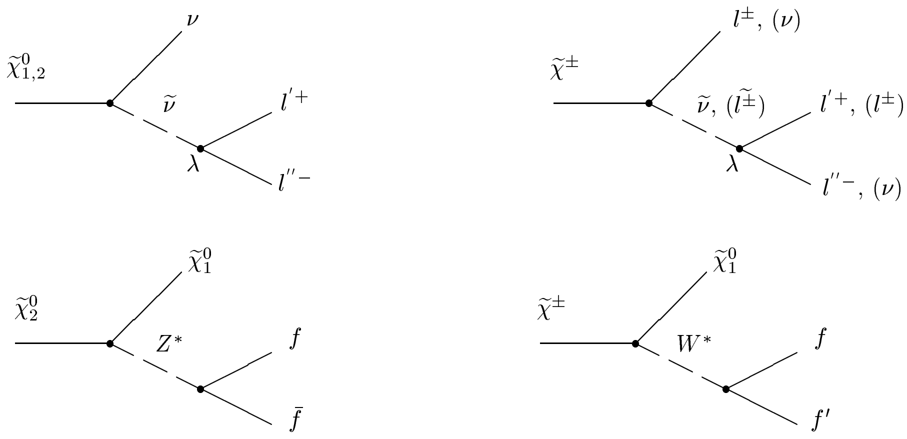

Figure 3: Gaugino direct (upper part) and indirect (lower part) decay diagrams.

final states	direct decay of	indirect decay of
$2l+ \not{E}$	$\tilde{\chi}^+_1\tilde{\chi}^-_1$	
$4l+ \not{E}$	$\tilde{\chi}^0_1\tilde{\chi}^0_1$, $\tilde{\chi}^+_1\tilde{\chi}^-_1$	$\tilde{\chi}^0_2\tilde{\chi}^0_1$
$6l$	$\tilde{\chi}^+_1\tilde{\chi}^-_1$	
$6l+ \not{E}$		$\tilde{\chi}^+_1\tilde{\chi}^-_1$, $\tilde{\chi}^0_2\tilde{\chi}^0_1$
$4l + 2$ jets $+ \not{E}$		$\tilde{\chi}^0_2\tilde{\chi}^0_1$
$4l + 4$ jets $+ \not{E}$		$\tilde{\chi}^+_1\tilde{\chi}^-_1$
$5l + 2$ jets $+ \not{E}$		$\tilde{\chi}^+_1\tilde{\chi}^-_1$

Table 2: Final states in gaugino pair production when a $LL\bar{E}$ coupling is dominant.

then the corresponding final state for $\tilde{\chi}^0_1$ pair production is: missing energy, coming from the undetected neutrinos, plus $2e2\mu$ ($\approx$ 25%) or $1e3\mu$ ($\approx$ 50%) or 4μ ($\approx$ 25%). This case should have the best efficiency since selection depends on e and μ identification.

- the second assuming that λ_{133} is dominant, meaning that the leptons from $\not{R}_p$ decay are mainly taus, and electrons. This case should have the worst efficiency due to the presence of several τ in the final state.

The other λ_{ijk} couplings lie between these two extreme cases.

2 Data samples

The data corresponding to an integrated luminosity of 54 pb^{-1} collected during 1997 by the DELPHI detector [11] at center of mass energies around 183 GeV were analysed.

Concerning the background, the different contributions coming from the Standard Model processes: $e^+e^- \to Z\gamma$, $\gamma\gamma$, e^+e^-, $We\nu_e$, Ze^+e^-, W^+W^-, ZZ were considered. For the study of four fermion final states, the PYTHIA [12] generator was used; a cross check was performed using the four-fermion final states generated with EXCALIBUR [13]. The two-photon ($\gamma\gamma$) interactions leading to leptonic final states were generated with the BDK program [14]; the $\gamma\gamma\to$ hadrons were generated using TWOGAM [15]. The event samples produced by PYTHIA, KORALZ [16] and DYMU3 [17] were used to study Z$\gamma\to$ hadrons, $\tau^+\tau^-$ and $\mu^+\mu^-$ respectively. For processes such as bhabha scattering and two-photons interactions, biased samples were used. In table 3 the visible cross sections of the simulated processes, with the equivalent luminosity derived from the number of processed MC events, are listed.

Standard Model process	σ (pb) at 184 GeV	equivalent luminosity
$\gamma\gamma(+\gamma)$QED	11.5	800
$e^+e^- + \gamma$(compton)	55.97	530
e^+e^-(bhabha)	1260.7	610
Zγ, Z$\to$ q$\bar{\text{q}}$(PYTHIA)	100.3	290
Zγ, Z$\to$ q$\bar{\text{q}}$(KORALZ)	106.	220
Zγ, Z$\to \mu^+\mu^-$	9.91	1060
Zγ, Z$\to \tau^+\tau^-$	8.74	800
ZZ(PYTHIA)	1.338	4790
Ze^+e^- "	6.81	370
W^+W^- "	15.44	2770
W$e\nu_e$ "	0.60	14960
W^+W^-(EXCALIBUR)	16.51	2990
$\gamma\gamma\to e^+e^-$(BDK)	683.3	690
$\gamma\gamma\to \mu^+\mu^-$(BDKRC)	527.8	720
$\gamma\gamma\to \tau^+\tau^-$(BDKRC)	436.3	1040
$\gamma\gamma\to$ had (VDM)	550.	740
$\gamma\gamma\to$ had (QCD-GS)	374.	300
$\gamma\gamma\to$ had (QPM)	122.7	730

Table 3: List of studied MC backgrounds; the third column gives the equivalent luminosity, i.e. the number of processed MC events divided by the corresponding cross section, to be compared to the integrated luminosity of 54 pb^{-1}.

To evaluate signal efficiencies, sparticle production was generated using SUSYGEN 2.17 [18]. Neutralino and chargino pair productions were considered in several points in the MSSM parameter space, corresponding to different values of $tan\beta$ (from 1 to 30), m_0 (between 20 GeV/c^2 and 500 GeV/c^2), μ (between -200 GeV/c^2 and 200 GeV/c^2) and M_2 (between 0 and 400 GeV/c^2), for both λ couplings. The λ parameters have been set to their present experimental upper limits: $\lambda_{122} = 0.04$ and $\lambda_{133} = 0.003$. All generated signal events were processed with DELSIM to simulate the events in the DELPHI detector.

3 Direct and indirect decays of neutralinos and charginos

As already mentionned, the indirect decays of gauginos can give two or more jets in the final state. Moreover, in case of the λ_{133} coupling, the τ decays give isolated leptons or thin jets. The DURHAM algorithm is used to reconstruct the jets. In order to cover the different topologies, the jet number is not fixed, and the jet charged multiplicity can be low (thin jets with one track are possible), or can be 0 in case of neutral jets. For each event, DURHAM is applied to reconstruct from 2 to 8 jets, and the corresponding jet parameters are stored.

3.1 λ_{122} case

Events are selected if they satisfy the following criteria:

- The charged multiplicity has to be greater than 3.
- The missing p_t is greater than 5 GeV/c and the polar angle of the missing momentum is between 20 and 160 degrees.
- At least two well identified (standard or tight)[11] muons are required.
- The energy of the most energetic identified lepton must be greater than 20 GeV.
- An isolation criterium is imposed for the identified leptons (no other charged particle in a cone of 7 degrees around the lepton).
- At least two of the identified leptons must be leading particles in the jets.
- The polar angle of the jets in case of 4, 5 or 6 jet topologies must be between 20 and 160 degrees.
- The missing energy is at least $20\%\sqrt{s}$.

After the cuts, no event remains, consistent with the 0.7 events expected from Standard Model processes, most of which comes from WW process. For $\tilde{\chi}^0_1$ pair produced, selection efficiencies are in the range 45-60 %, for $\tilde{\chi}^+_1\tilde{\chi}^-_1$: 20-50%, and for $\tilde{\chi}^0_2\tilde{\chi}^0_1$: 25-40%, for all the considered (μ, M_2) planes (see table 6).

3.2 λ_{133} case

The τ decay gives isolated leptons or thin jets, plus neutrinos. In this case the missing energy is expected to be higher than in the λ_{122} case due to the presence of neutrinos, coming not only from gaugino $\not{R}_p$ decay, but also from τ decay.

Events are pre-selected if they satisfy the following criteria:

- at least one (loose) lepton is identified;
- the number of charged tracks must be greater than 3, since the minimum number of charged tracks expected in any final states (except $2l + \not{E}$) is 4;
- the total and charged energy must be greater than $0.18\sqrt{s}$ and $0.16\sqrt{s}$ respectively.

These cuts remove around 99% of two-photons events.

Several criteria are based on the missing quantities:

- the missing p_t is greater than 5 GeV/c;
- the polar angle of the missing momentum is between 27 and 153 degrees;
- the missing energy is at least $0.30\sqrt{s}$.

These cuts are efficient to suppress the background coming from bhabha, two-photons and $Z\gamma$ events.

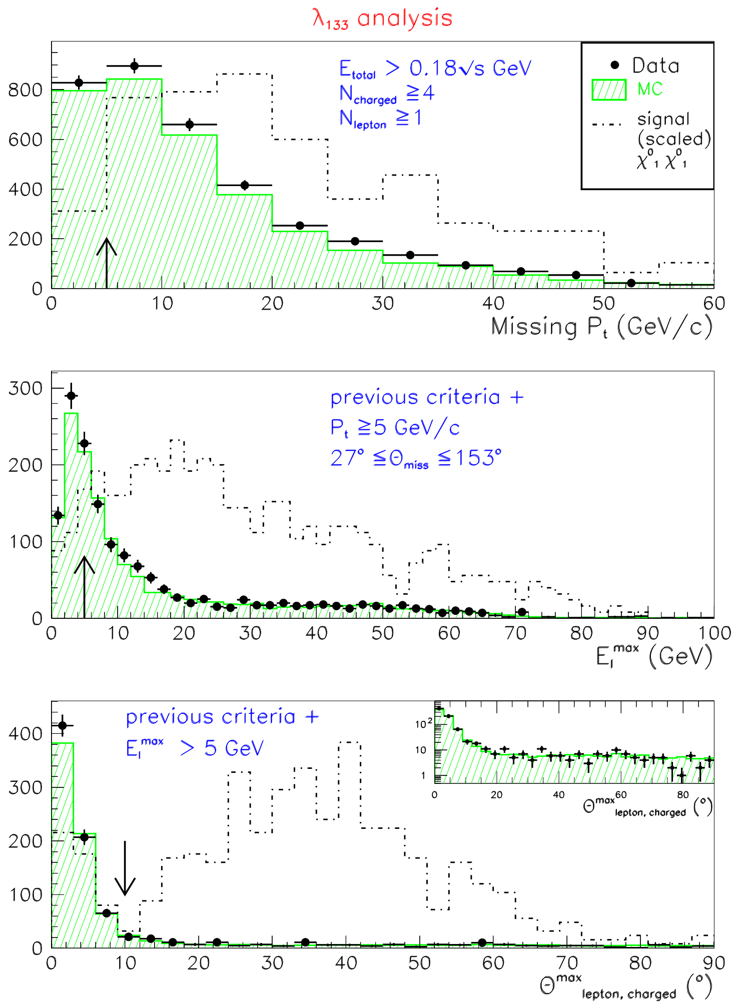

Figure 4: Missing transverse momentum, energy of the most energetic lepton and isolation angle distributions for real data (black dots), expected SM background (hatched) and $\tilde{\chi}^0_1\tilde{\chi}^0_1$ signal (dotted line). The signal distribution has been scaled (see text). The arrows show the applied cuts.

For the events with less than 8 charged particles, at least one loose lepton is required, whereas events with 8 or more charged particles must have at least two loose leptons. In both cases, the energy of the most energetic lepton must be greater than 5 GeV, and there should be no other charged track in a 10 degree cone around the identified lepton(s). These latter criteria remove $Z\gamma$, and hadronic ZZ and W^+W^- events. In figure 4 are presented the distributions of the missing p_t, the energy of the most energetic lepton, and the minimum angle between the lepton and the nearest charged particle, for real data and simulated background events. The agreement between real data and simulated background is fairly good. The distribution for simulated signal ($\tilde{\chi}^0_1\tilde{\chi}^0_1$) is also plotted; it is scaled by a factor of ~ 10 to show its distibution shape compared to MC distribution.

Selection criteria for λ_{133}coupling	data	MC
at least one loose lepton $N_{charged} \geq 4$ $E_{tot} \geq 18\%\sqrt{s}$, $E_{charged} \geq 16\%\ \sqrt{s}$ missing $p_t > 5$ GeV/c $27^o \leq \Theta_{miss} \leq 153^o$	1551	1479
$E^l_{max} \geq 5$ GeV	996	965
$\Theta^{min}_{lepton-track} \geq 10^o$	293	286
E_{miss} >30%$\sqrt{s}$	174	166
if $N_{charged} \geq 8, N_{lepton} \geq 2$	70	69.2
$Y_{34} \geq 0.001$	33	29.5
in case of 4 or 5 jets: at least 4 charged jets	14	17.9
case of 4 jets: $E^j_{min} * \theta^{j1,j2}_{min} \geq 0.5$GeV.rad, $E^j_{min} * \theta^{j1,j2}_{min} \geq 5$ GeV.rad if $N_{charged} > 8$ $E^{30^o}_{cone} \leq 50\%\ E_{total}$ $20^o \leq \theta_{jet} \leq 160^o$	3	3.3

Table 4: List of selection criteria for λ_{133} case.

data	MC	bhabha	$\gamma\gamma$	$Z\gamma$	$We\nu$	Zee	WW	ZZ
3	3.3	0	0	0.13	0.	0.14	2.73	0.31

Table 5: SM background contributions.

The final selection is based on the jet characteristics and topologies. First, the Y_{34}[1] value must be greater than 10^{-3}, which reduces the Zγ contribution (figure 5). In case of 4 or 5 jet topologies, 4 charged jets are required. In case of a 4 jet topology, a cut is applied on the value of $E^j_{min} \times \theta^{j_aj_b}_{min}$ where E^j_{min} is the energy of the less energetic jet, and $\theta^{j_aj_b}_{min}$ is the minimum angle between 2 jets. These requirements significantly reduce Zγ, $\gamma\gamma$, W$^+$W$^-$ events. The number of remaining

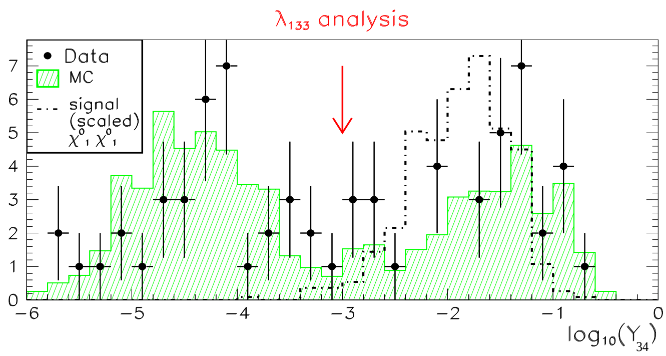

Figure 5: $log_{10}(Y_{34})$ distribution for real (black dots) and expected SM background (hatched histogram). A scaled (see text) signal distribution is also plotted to show that the applied cut removes less than 1% of the signal, and half of the background.

[1]The Y_{34} is the transition value of the "Y_{cut}" Durham distance in which the event flips from 4 to 3 jet configuration.

real and simulated data events after these cuts are reported in table 4.

For $\tilde{\chi}_1^0$ pair produced, selection efficiencies are in the range 22-34 %, for $\tilde{\chi}_1^+\tilde{\chi}_1^-$: 20-37%, and for $\tilde{\chi}_2^0\tilde{\chi}_1^0$: 20-25%, for all the considered (M_2, μ) planes. 3 events remain after the selection procedure with 3.3 expected from standard background processes. The background is mainly due to W^+W^- events (table 5). Among the 3 selected data events, one is compatible to a $4\tau + \not{E}$ topology (low charged multiplicity, see figure 6). It has been also selected by an analysis made to select $4\tau + \not{E}$ events in a search for $\tilde{\chi}_1^0$ decaying to a $\tilde{\tau}\ \tau$ in light gravitino scenario [20].

The results obtained with both the λ_{122} and λ_{133} coupling are summarized in table 6.

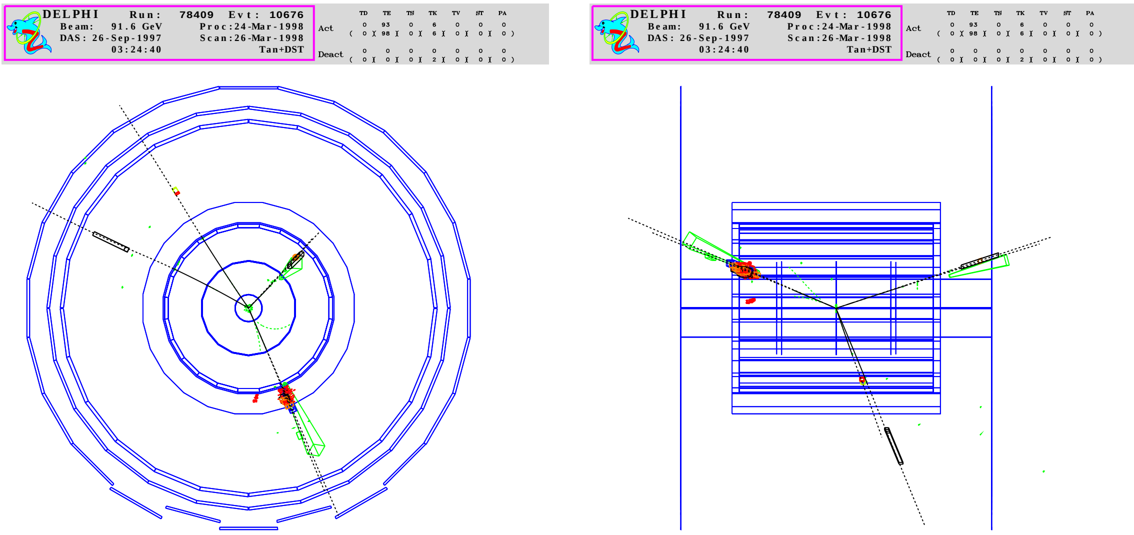

Figure 6: Selected event - right: X-Y view; left: X-Z view. This event has 4 selected charged tracks, 1 identified μ with P=18.6 GeV/c; the missing energy is $\not{E}$ = 88.0 GeV, and the transverse missing momentum is p_t = 8.6 GeV/c.

Coupling	Efficiency		Selected events	
	process	range in %	data	MC
λ_{122}	$\tilde{\chi}_1^0\tilde{\chi}_1^0$	45-60	0	0.7
	$\tilde{\chi}_2^0\tilde{\chi}_1^0$	25-40		
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$	20-50		
λ_{133}	$\tilde{\chi}_1^0\tilde{\chi}_1^0$	22-34	3	3.3
	$\tilde{\chi}_2^0\tilde{\chi}_1^0$	20-25		
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$	20-37		

Table 6: Gaugino analyses: efficiency ranges for pair production processes, and data and Monte-Carlo events selected for each studied coupling.

4 Results

By performing the analysis described in sections 3.1 and 3.2 at $\sqrt{s} = 183$ GeV, no excess of events was found in the data with respect to the Standard Model expectation. As a consequence, limits on the production and mass of the charginos and neutralinos can be set. Both direct and indirect decays of pair production of charginos and neutralinos are combined to give the exclusion contours at 95% C.L. in the μ, M_2 plane.

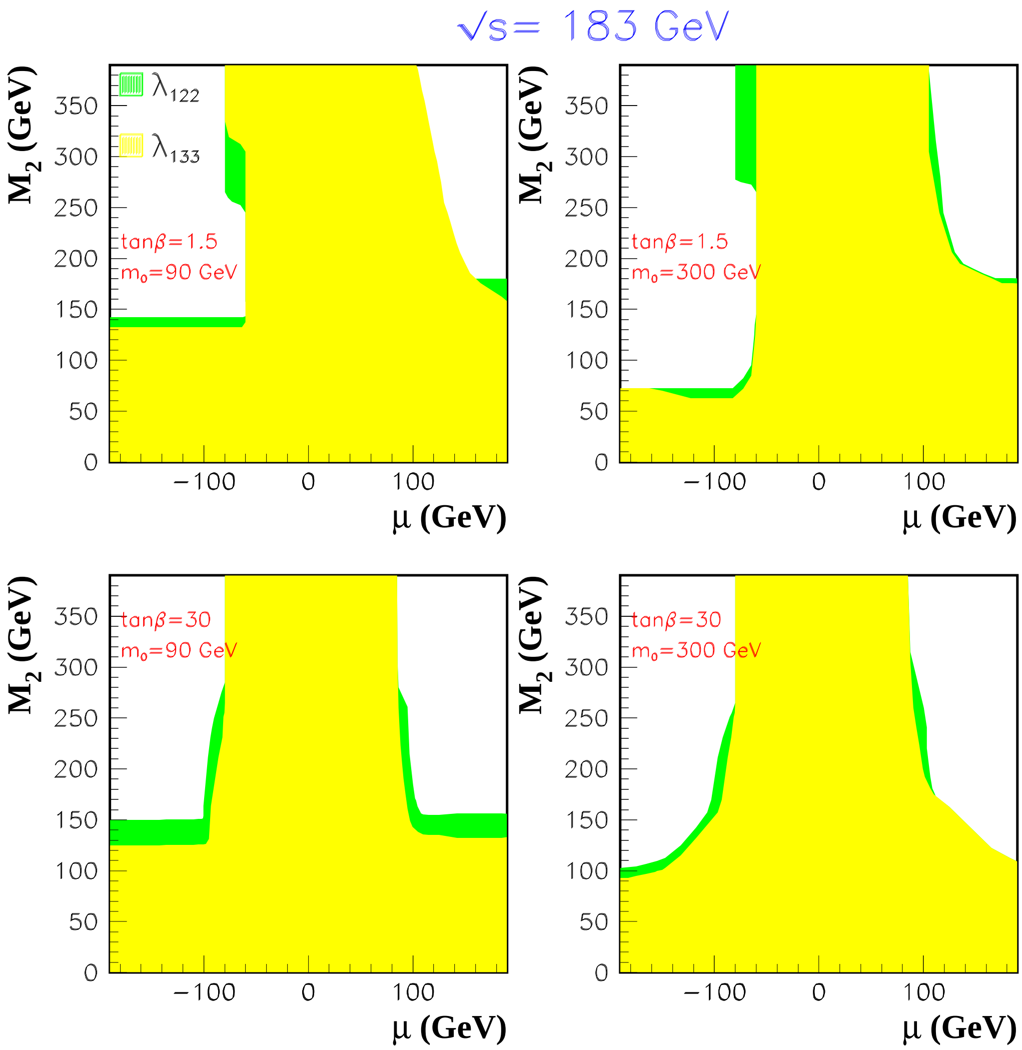

Figure 7: Regions in μ, M_2 parameter space excluded at 95 % C.L. for two values of $tan\beta$ and two values of m_0. The exclusion area obtained from the λ_{133} search is shown in light grey and the corresponding area for the λ_{122} search is shown in dark grey. The second exclusion area includes the first. The data collected at $E_{CM} = 183$ GeV are used.

For each coupling, the analysis is sensitive to most of the possible decay channels of gauginos produced in the three considered processes ($\tilde{\chi}_1^0\tilde{\chi}_1^0$, $\tilde{\chi}_2^0\tilde{\chi}_1^0$, $\tilde{\chi}_1^+\tilde{\chi}_1^-$). Then, the number of expected events N_{exp}, for a given set of MSSM parameters is

$$N_{exp} = \mathcal{L} \times \sum_{i=1}^{i=3} \epsilon_i \sigma_i$$

where ϵ_i gives the efficiency for each process, σ_i the corresponding cross section and $\mathcal{L}$ the integrated luminosity. The maximum number of signal events N^{95} in presence of background is given by the standard formula [19]. All the points in the μ, M_2 plane which satisfy the condition $N_{exp} > N^{95}$ are excluded at 95% C.L. The exclusion contours for two values of $tan\beta$ and m_0 are shown on figure 7. The light grey area shows the region excluded by the λ_{133} search and the dark grey area, the region excluded by the λ_{122} search which, having a better efficiency, includes and extends the excluded region. One can consider these two searches as the most and the least sensitive cases. The other couplings have a sensitivity lying in between these two extremes. This result can be translated into a lower limit on neutralino mass as shown in the figure 8, which was obtained by scanning over m_0 values for each $tan\beta$ in order to set a limit independantly of the choice of m_0. With this search, neutralinos with masses less than 27 GeV/c^2 are excluded at 95 % C.L. whereas the corresponding limit for charginos is 89 GeV/c^2.

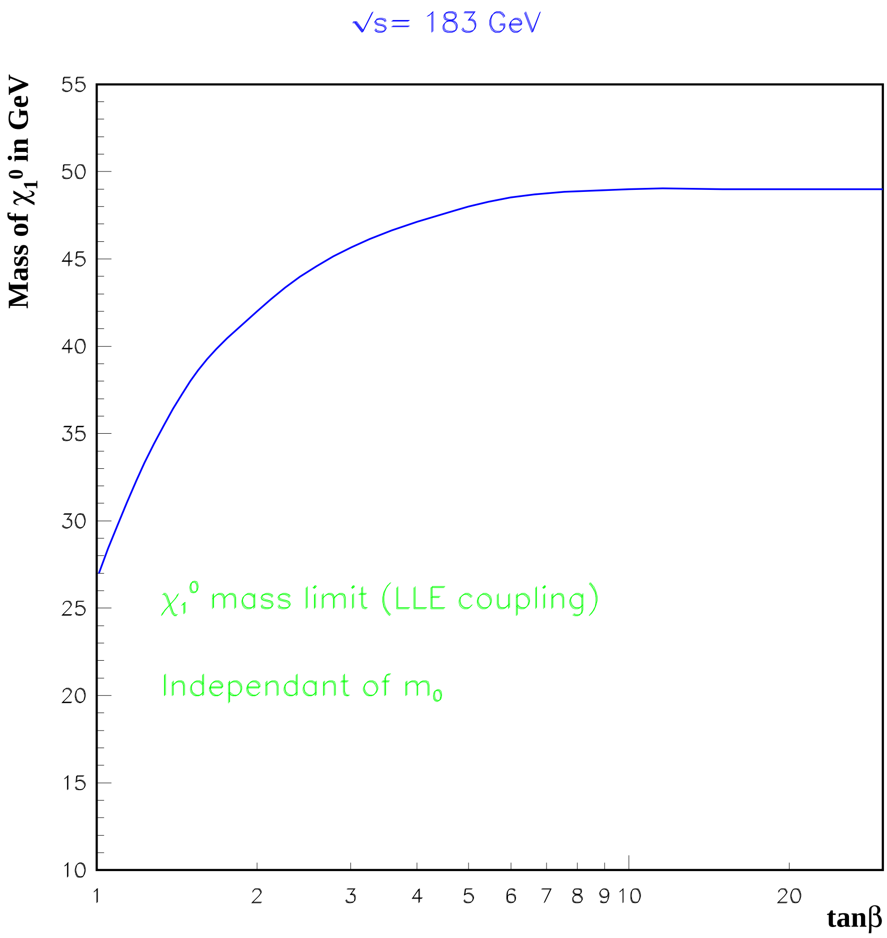

Figure 8: The lightest neutralino mass as a function of $tan\beta$ at 95 % confidence level. This limit is independent of the choice of m_0 and the generation indices i,j,k of the λ_{ijk} coupling.

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