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PRELIMINARY

LSP Mass Limit with a single dominant $LL\bar{E}$, $LQ\bar{D}$ or $\bar{U}\bar{D}\bar{D}$ R-Parity Violating Coupling in e^+e^- collisions at centre-of-mass energies between $\sqrt{s} = 189 - 208\,\mathrm{GeV}$

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Abstract

A limit is set on the LSP mass under the assumption that R-parity is violated via a single dominant $LL\bar{E}$, $LQ\bar{D}$ or $\bar{U}\bar{D}\bar{D}$ coupling. The limit is valid over the whole parameter space of the MSSM. Data collected by the ALEPH detector at LEP with centre-of-mass energies from 189 GeV to 208 GeV are used. Searches for direct or indirect decays of pair produced neutralinos and charginos are used to constrain the MSSM parameter space. Constraints from the Γ_Z measurement, slepton, squark and Higgs searches are also used to exclude parameter space.The lower mass limits at 95% confidence on the LSP are $60.2\,\mathrm{GeV}/c^2$, $44.2\,\mathrm{GeV}/c^2$ and $42.2\,\mathrm{GeV}/c^2$ for $LL\bar{E}$, $LQ\bar{D}$ and $\bar{U}\bar{D}\bar{D}$ coupling respectively. The limits are vaild for all values of μ, tanβ, m_0 and m_2

1 Introduction

In the Minimal supersymmetric extensions of the Standard Model(MSSM) [1], the SM particle content is doubled and an extra Higgs $SU(2)_L$ doublet is added. The most general interactions of these particles invariant under the $SU(3)_C \times SU(2)_L \times U(1)_Y$ gauge symmetry are those of the MSSM plus additional superpotential terms.

$$W_{\not R_p} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k, \tag{1}$$

where $\bar{D}, \bar{U}$ ($\bar{E}$) are the down-like and up-like quark (lepton) singlet superfields, and Q (L) is the quark (lepton) doublet superfield respectively; λ, λ' and λ'' are Yukawa couplings and $i, j, k = 1, 2, 3$ are generation indices. It has been found that the simultaneous presence of the last two terms in (1) leads to rapid proton decay. This problem is solved in the MSSM by imposing the conservation of a discrete multiplicative number called R-parity [2], where R-parity has the value: ($R_p = -1^{3B+L+2S}$) , and results in the exclusion of all terms where B denotes the baryon number, L the lepton number and S the spin of a field. This solution is not unique and it turns out that a number of phenomenological models [3] predict only a subset of the terms in (1) hence protecting the proton from decay.

The consequence of R-parity being violated is that the lightest supersymmetric particle(LSP) is no longer stable and decays to SM particles. In the MSSM the LSP can be either the lightest neutralino or a slepton.

The following assumptions are made throughout this analysis:

- All three terms in Equation (1) are addressed, however only one term for a specific set of indices (i, j and k) is considered non zero. Unless otherwise stated the derived limits correspond to the choice of indices for the coupling giving the worst limit.
- The lifetime of the LSP is negligible i.e the mean path of flight is less than 1cm. The lightest neutralino can have a decay length of more than 1cm when $M_\chi \leq 10\,\mathrm{GeV}/c^2$ for couplings which are not already excluded by low energy constraints. This analysis does not consider long-lived sparticles, hence regions in parameter space with $M_\chi < 10\,\mathrm{GeV}/c^2$ are ignored [4].
- Results are interpreted within the framework of the MSSM. Gaugino mass unification at the electroweak scale is assumed, giving the condition $M_1 = \frac{5}{3} M_2 \tan^2 \theta_W$.

Decays in which the sparticle decays directly to SM particles are called *direct* decays, while decays in which it first decays, conserving R-parity, to the lightest neutralino are referred to as *indirect* decays. Only processes involving neutralino/chargino decays are treated here. The search results reported here used data collected by the ALEPH collaboration in 1998, 1999 and 2000 from e^+e^- collisions at centre-of-mass energies between $189\,\mathrm{GeV}/c^2$ and $208\,\mathrm{GeV}/c^2$. The total integrated recorded luminosity of data collected during this period was $628.3\,\mathrm{pb}^{-1}$. The results shown complement previously reported ALEPH R-parity violating SUSY analysis [4, 5].

In this paper all three couplings $LL\bar{E}$, $LQ\bar{D}$ and $\bar{U}\bar{D}\bar{D}$ are considered. A global limit is set for the lightest neutralino by scanning over the MSSM space.

2 Monte Carlo Samples

The signal topologies were simulated using the `SUSYGEN` Monte Carlo program [9] modified as described in [10]. The events were subsequently passed through either a full simulation or a faster simplified simulation of the ALEPH detector. Where the fast simulation was used a subselection of these were also passed through the full simulation to verify the accuracy of the fast simulation.

Samples of all major backgrounds were generated and passed through the full simulation. The `PYTHIA` generator [11] was used to produce $q\bar{q}$ events and four-fermion final states from $We\nu$, ZZ and Zee. Pairs of W bosons were generated with `KORALW` [12]. Pair production of leptons was simulated with `BHWIDE` [13] (electrons) and `KORALZ` [14] (muons and taus). The $\gamma\gamma \to f\bar{f}$ processes were generated with `PHOT02` [15].

The selections were optimised to give the minimum expected 95% C.L. excluded cross section in the absence of a signal for masses close to the high end of the expected sensitivity. Selection efficiencies were determined as a function of the SUSY particle masses and the generation structure of the R-parity violating couplings λ_{ijk}.

The cross section limits were evaluated at the highest centre-of-mass energy. Data taken at lower centre-of-mass energies also contributed to the limits with a reduced weight. The weight was calculated from the expected evolution of the cross-section with $\sqrt{s}$.

The systematic uncertainties on the selection efficiencies are of order of 4–5% and are dominated by the statistical uncertainty of the Monte Carlo signal samples, with small additional contributions from lepton identification and energy flow reconstruction. They were taken into account by reducing the selection efficiencies by one standard deviation.

When setting the limits, background subtraction was performed for two- and four-fermion final states according to the prescription given in [16]. No background is subtracted for the $\gamma\gamma \to f\bar{f}$ processes.

For selections which have been optimised, the changes are noted in section 3.4.

3 Decay modes

The chargino and the 3 heavier flavours of neutralino can decay either directly or indirectly while the lightest neutralino flavour can only decay directly. Direct decays involve the decay of the gauginos into sfermions which in turn decay via R-parity violating coupling to fermions. In indirect decays, the gaugino decays first into the lightest neutralino and two fermions via a W^* or $(Z/\gamma)^*$ for the chargino and neutralino respectively. The flavour of the decay products depends on the flavour structure of the Yukawa coupling λ_{ijk}. This analysis considers direct decays of the lightest neutralino pairs ($\tilde{\chi}_1^0\ \tilde{\chi}_1^0$), the lightest and next lightest neutralino pair ($\tilde{\chi}_1^0\ \tilde{\chi}_2^0$), as well as the indirect decay of $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ and the lightest chargino pair ($\tilde{\chi}_1^+\ \tilde{\chi}_1^-$) .

3.1 Decays via a dominant $LL\bar{E}$ coupling

For decays via this coupling mode, $\tilde{\chi}_1^0\ \tilde{\chi}_1^0$ and $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ decay directly to give rise to a topology of **4Leptons+$\not\!\!E$** only. Indirect decays of $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ and $\tilde{\chi}_1^+\ \tilde{\chi}_1^-$ give rise to topologies of **6Leptons+$\not\!\!E$** and **Leptons+Hadrons**. In this analysis, the **4Leptons+$\not\!\!E$**, the **6Leptons+$\not\!\!E$** and the **Leptons+Hadrons** topologies were considered. Results on searches for **4Leptons+$\not\!\!E$** were obtained by combining limits from $\tilde{\chi}_1^0\ \tilde{\chi}_1^0$ and $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ searches. $\tilde{\chi}_1^0\ \tilde{\chi}_1^0$ searches from [17] were improved by introducing limits from slepton/squark searches [6]. The result was incorporated into the scan of $\sigma_{\tilde{\chi}_1^0\ \tilde{\chi}_2^0}$ as a function of the mass of the lightest neutralino. See Fig 1a. For $\tilde{\chi}_1^+\ \tilde{\chi}_1^-$ decays, the **Leptons+Hadrons** selection was inclusively combined with the **6Leptons+$\not\!\!E$** selection (see Table 1).
Limits are set by considering decays via the coupling λ_{133} as these lead to the lowest selection efficiency. This is due to the presence of taus in the final state which are difficult to identify.

3.2 Decays via a dominant $LQ\bar{D}$ coupling

The indirect decays of $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ and $\tilde{\chi}_1^+\ \tilde{\chi}_1^-$ give rise to topologies of **Multijets+Leptons**, **Multijets+$\not\!\!E$** and a mix of both. In this analysis, only the **Multijet+Lepton** topologies were considered. With respect to $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ decays, the selection for the **Multijet+Lepton** topology, was obtained from [5] and optimized (see section 3.4). This was done to allow for the fact that in regions where the neutralino mass is low, the resultant boost on final state particles will result in a broad jet rather than distinct jets. For $\tilde{\chi}_1^+\ \tilde{\chi}_1^-$ decays, the **Multijet+Lepton** selection was obtained from [5] and renamed **Multijet(soft)+Lepton** to reflect the fact that at high $m_{\tilde{\chi}_1^\pm}$, the jets are soft.
Limits are set by considering decays via the coupling λ'_{311} as these lead to the lowest selection efficiency. This is due to the presence of taus in the final state which are difficult to identify.

3.3 Decays via a dominant $\bar{U}\bar{D}\bar{D}$ coupling

Indirect decays of $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ and $\tilde{\chi}_1^+\ \tilde{\chi}_1^-$ result in topologies of **6jets+Leptons**, **Multijets** and **Multijets+$\not\!\!E$**. In this analysis, only the **Multijets** ($\tilde{\chi}_1^+\ \tilde{\chi}_1^-$) and **6Jets+Leptons** ($\tilde{\chi}_1^0\ \tilde{\chi}_2^0$) topologies were considered. The **6Jets+Leptons** topology was obtained by reoptimizing the **4j+2τ** selection [5]. For the **Multijets** topology, selections were designed to cluster the jets into 6jets i.e to look for a **6Jet** topology.
Limits are set by considering decays via the coupling λ''_{223}. The selection efficiencies are

found to have only a weak dependence on the choice of λ''_{ijk} coupling, with the worst case given by λ''_{223}.

3.4 Chargino/Neutralino decay selections

For regions of $m_0 \geq 200\,\mathrm{GeV}/c^2$, the production cross sections of the lightest neutralino pairs were too low to be excluded. Charginos searches were carried out in these regions. All Variables are defined in [5] and references therein. The selections used for neutralino direct/indirect searches at low $m0$ were:

- $LL\bar{E}$ - **4L+$\not{E}$**: Taken from **4L+$\not{E}$** selection of [5]
- $LQ\bar{D}$ - **Multijet+Leptons**: Taken from the **Multijet+Leptons** selection of [5] and optimized by requiring that $E_{10}^{iso} < 2\,\mathrm{GeV}$. Also, due to the fact that low neutralino masses are involved, the boost from $\sqrt{s}$ will result in broad jets rather than distinct jets. Hence it is required that $y_1 > 0.03$ and $y_2 > 0.01$.
- $\bar{U}\bar{D}\bar{D}$ - **6Jets+Leptons**: Taken from **4J+2τ** [5] and reoptimized by requiring at least 15 tracks and $60\%\sqrt{s} < M_{vis} < 97\%\sqrt{s}$. Also required is that $M_W > 90\,\mathrm{GeV}/c^2$.

The selections used for indirect decay chargino searches at high m_0 were:

- $LL\bar{E}$ - **Leptons+Hadrons** .OR. **6L+$\not{E}$** from [5]
- $LQ\bar{D}$ - **Multijet(soft)+Lepton**: Taken from **Multijet+Leptons** selection of [5]
- $\bar{U}\bar{D}\bar{D}$ - **6Jets**: There must be at least 20 charged tracks - a minimum of 10 in both hemishpheres. The total energy of the jets must be at least $50\%\sqrt{s}$ - a minimum of $25\%\sqrt{s}$ in both hemispheres. It is required also that the total minimum mass of the jets must be at least $28\%\sqrt{s}$ - a minimum of $14\%\sqrt{s}$ in each both hemispheres. To ensure that far-forward i.e low-angle events are removed, all events within a 14° cone around the thrust axis are rejected. To remove low-energy events it is required that all events with a recorded energy deposit of greater than 1 GeV within a 12° cone around the interaction point be removed, i.e. $E_{12} < 1\,\mathrm{GeV}$. The inverse boost must satisfy $InvB > 0.55$, where $InvB = (\sqrt{\frac{1}{2}(\gamma_1^{-2} + \gamma_2^{-2})})$ and $\gamma_i = E_i/m_i$. It is also required that $\phi_{acop} < 170$, $P_t > 2.5\%\sqrt{s}$, $E_{jet}^{em} < 90\% E_{jet}$ and finally $y_4 > 0.001$ and $y_6 > 0.002$

4 Methodology

A scan of the MSSM parameter space was done to cover regions of $\mu, \tan\beta, m_0, m_2$, as shown in Table 2. At each point, the masses and cross section values for the MSSM particles were

	$LL\bar{E}$				$LQ\bar{D}$				$\bar{U}\bar{D}\bar{D}$			
	$\sqrt{s} < 199.5$ (GeV)		$\sqrt{s} > 199.5$ (GeV)		$\sqrt{s} < 199.5$ (GeV)		$\sqrt{s} > 199.5$ (GeV)		$\sqrt{s} < 199.5$ (GeV)		$\sqrt{s} > 199.5$ (GeV)	
Selections	SM	Data	SM	Data	SM	Data	SM	Data	SM	Data	SM	Data
$4L + \not{E}$	6.6	6	7.8	10	-	-	-	-	-	-	-	-
$multiJ + L$	-	-	-	-	63.2	72	78.0	64	-	-	-	-
$6J + L$	-	-	-	-	-	-	-	-	19.5	27	23.5	25
$L + H$												
$.or.$												
$6L + \not{E}$	13.1	15	15.0	18	-	-	-	-	-	-	-	-
$multiJ + L$												
$(soft)$	-	-	-	-	9.1	18	11.2	14	-	-	-	-
$6J$	-	-	-	-	-	-	-	-	62.2	66	76.4	75

Table 1: The selections, the number of background events expected and the number of candidate events selected in the data - where J=jets, L=leptons and H=hadrons. Backgrounds for events decaying via $LL\bar{E}$ are dominated by WW and ZZ processes. In the case of $LQ\bar{D}$ and $\bar{U}\bar{D}\bar{D}$ couplings, the background is dominated by WW and qq processes.

$\tan\beta$ (step size)	m_0 (step size) GeV/c^2	μ GeV/c^2	m_2 GeV/c^2
2 - 4(1)	0 - 50(10)	-200 : +200	0 - 500
2 - 4(1)	60 - 100(10)	-200 : +200	0 - 500
2 - 4(1)	200 - 500(100)	-200 : +200	0 - 500
5 - 7(1)	0 - 50(10)	-200 : +200	0 - 500
5 - 7(1)	60 - 100(10)	-200 : +200	0 - 500
5 - 7(1)	200 - 100(100)	-200 : +200	0 - 500
8 - 10(1)	0 - 50(10)	-200 : +200	0 - 500
8 - 10(1)	60 - 100(10)	-200 : +200	0 - 500
8 - 10(1)	200 - 100(100)	-200 : +200	0 - 500
20 - 50(1)	0 - 50(10)	-200 : +200	0 - 500
20 - 50(1)	60 - 100(10)	-200 : +200	0 - 500
20 - 50(1)	200 - 100(100)	-200 : +200	0 - 500

Table 2: Region of the MSSM parameter space scanned. The scan consisted of $\approx$ 400000 points.

calculated. The regions of parameter space scanned were split into sections to observe areas of interest.

Once this was done, the following steps were carried out:

- A universal cut on all MSSM particles - sleptons, squarks and gauginos that could result in the production of and from the decay of the lightest neutralino was applied. The cut is set using the limit of the combined contribution of the sfermions and gauginos to Γ_Z. This limit is $6\,\mathrm{MeV/c^2}$ and is obtained from a combination of SM predictions and experimental observations [8]. It results in the exclusion of all regions of parameter space of the MSSM for which the combined contribution of the sfermions and gauginos to $\Gamma_Z > 6\,\mathrm{GeV}/c^2$.

- Constraints from Higgs searches [7] have shown that the neutral CP-even higgs(m_h) and the neutral CP-odd(m_A) are both excluded for masses less than $89.6\,\mathrm{GeV}/c^2$ and $90.0\,\mathrm{GeV}/c^2$ at 95% confidence level respectively. These limits were translated into parameter space with the result that all points in parameter space were excluded for $tan\beta$ between 0.7 and 2.3. To be conservative, the lower limit of $\tan\beta$ was set at 2 for this analysis.

- Limits from slepton and squark searches [6] were implemented. This results in the exclusion of all points in parameter space in which slepton and squark particles have masses lower than $\approx 100\,\mathrm{GeV}/c^2$. The sleptons, neutralino and gauginos masses were compared at each point in parameter space to determine which particle is the LSP.

- Plots of the production cross section of the lightest neutralino as a function of it's mass were obtained and a fine scan was done to locate which areas of parameter space would result in the lowest cross sectional values as a function of the mass (Fig 1a). This would mean that any point excluded would automatically exclude all other points for a given mass. MC signal events with neutralino pair production were then generated at all of the points selected.

- In regions for which $m_0 \geq 200\,\mathrm{GeV}/c^2$, the production cross section of the neutralino was too low to be sensitive to signal. Chargino searches were carried out in these regions for **4Leptons+$\not{E}$** ($LL\bar{E}$), **multijet(soft)+leptons** ($LQ\bar{D}$) and **6jets** ($\bar{U}\bar{D}\bar{D}$), in a manner analogous to the neutralino searches (Fig 1b). Bounds were set on $m_{\tilde{\chi}_1^0}$. See Table 4.

All selections were applied to MC signal [4], data and background, see Table 1. The upper limit on the cross section at 95% confidence limit, σ_{95} was compared to the production cross section and used to set exclusion zones and hence a mass limit, see Fig.2 and Fig 3. This was done for all regions of parameter space covered (Table 2).

tanβ	$\mathbf{m_0}$ (GeV/c^2)	$LL\bar{E}$ **eff** (%)	$LL\bar{E}$ **limit** $\tilde{\chi}_1^0$(GeV/c^2)	$LQ\bar{D}$ **eff** (%)	$LQ\bar{D}$ **limit** $\tilde{\chi}_1^0$(GeV/c^2)	$\bar{U}\bar{D}\bar{D}$ **eff** (%)	$\bar{U}\bar{D}\bar{D}$ **limit** $\tilde{\chi}_1^0$(GeV/c^2)
2 - 4	0 - 50	49 - 57	73.5	10 - 28	48.8	10 - 24	49.5
2 - 4	60 - 100	41 - 53	60.2	9 - 27	44.2	10 - 27	42.2
5 - 7	0 - 50	47 - 48	63.4	20 - 40	60.5	14 - 28	55.5
5 - 7	60 - 100	49 - 51	62.9	16 - 28	48.5	19 - 23	51.8
8 - 10	0 - 50	47 - 50	65.7	32 - 33	61.4	10 - 24	54.3
8 - 10	60 - 100	51 - 53	64.1	22 - 25	51.0	15 - 20	50.4
20 - 50	0 - 50	51 - 52	68.1	32 - 33	61.4	12 - 22	57.0
20 - 50	60 - 100	50 - 51	67.8	22 - 32	54.3	22 - 27	54.8

Table 3: Mass limit obtained for different regions of parameter space. The figures were obtained from direct searches for the lightest neutralino decaying via the couplings λ_{133} ($LL\bar{E}$), λ'_{311} ($LQ\bar{D}$) and λ''_{223} ($\bar{U}\bar{D}\bar{D}$) respectively. The efficiency figures correspond to points that were selected after doing a fine scan (Fig 1a). The absolute mass limits of $60.2\,\mathrm{GeV}/c^2$ ($LL\bar{E}$), $44.2\,\mathrm{GeV}/c^2$ ($LQ\bar{D}$) and $42.2\,\mathrm{GeV}/c^2$ ($\bar{U}\bar{D}\bar{D}$) respectively are obtained in the region with the lowest efficiency range i.e. tanβ: 2 — 4, m_0: 60 — $100\,\mathrm{GeV}/c^2$.

	tanβ	$\mathbf{m_0}$ (GeV/c^2)	**eff** (%)	**limit** $\tilde{\chi}_1^+$(GeV/c^2)	**bound** $\tilde{\chi}_1^0$(GeV/c^2)
$LL\bar{E}$	2 - 4	200 - 500	54.4 - 55.6	102.7	50.9
	5 - 7	200 - 500	50.6 - 53.8	103.5	50.9
	8 - 10	200 - 500	53.6 - 56.6	103.1	50.9
	20 - 50	200 - 500	52.4 - 55.2	102.9	50.9
$LQ\bar{D}$	2 - 4	200 - 500	31.6 - 32.4	102.3	50.9
	5 - 7	200 - 500	44.8 - 46.8	102.9	50.9
	8 - 10	200 - 500	39.8 - 44.8	102.8	50.9
	20 - 50	200 - 500	41.4 - 44.4	102.8	50.9
$\bar{U}\bar{D}\bar{D}$	2 - 4	200 - 500	22.6 - 24	101.9	50.9
	5 - 7	200 - 500	22.2 - 30.6	102.4	50.9
	8 - 10	200 - 500	24.8 - 29.6	102.2	50.9
	20 - 50	200 - 500	24.4 - 24.6	102.2	50.9

Table 4: Results obtained from indirect searches for the lightest chargino decaying via the λ_{133} ($LL\bar{E}$), λ'_{311} ($LQ\bar{D}$) and λ''_{223} ($\bar{U}\bar{D}\bar{D}$) couplings respectively. Bounds indicate limits on the neutralino mass obtained by excluding chargino masses. The efficiency figures correspond to points that were selected after doing a fine scan (Fig 1b).

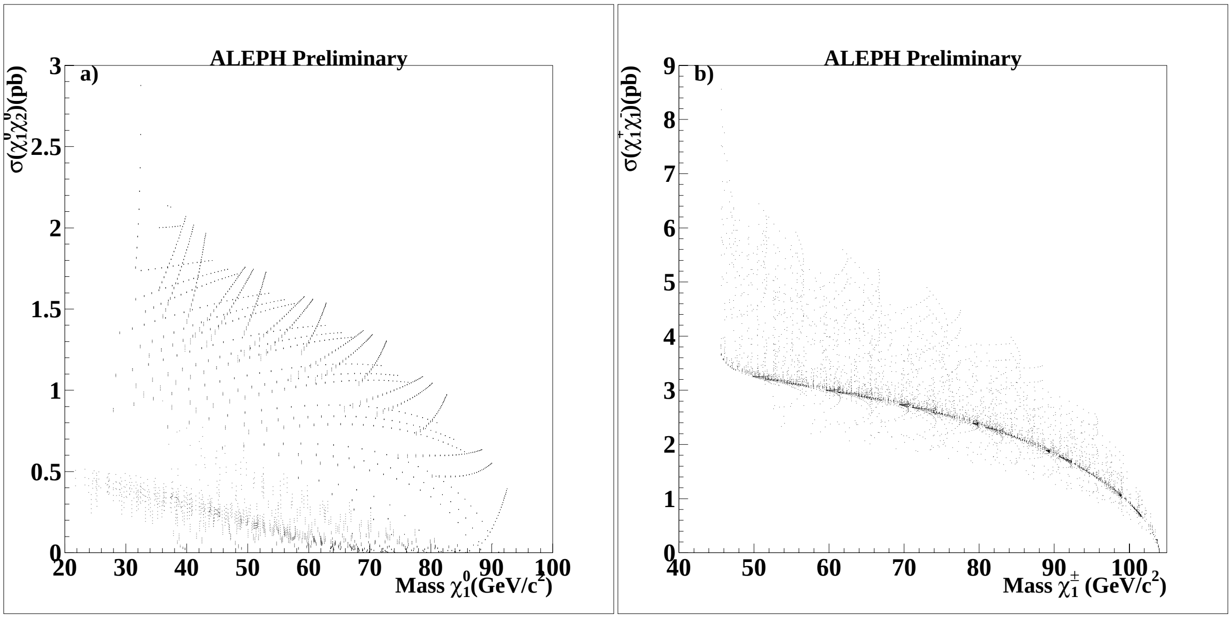

Figure 1: (a) The production cross section of the lightest neutralino as a function of it's mass which was used for $LL\bar{E}$, $LQ\bar{D}$ and $\bar{U}\bar{D}\bar{D}$ analysis in the region: μ from -200 — $+200\,\mathrm{GeV}/c^2$, m_2 from 0 — $500\,\mathrm{GeV}/c^2$, tanβ from 2 — 4 and m_0 from 60 — $100\,\mathrm{GeV}/c^2$. (b) The production cross section of the lightest chargino as a function of it's mass which was used for $LL\bar{E}$, $LQ\bar{D}$ and $\bar{U}\bar{D}\bar{D}$ analysis in the region: μ from -200 — $+200\,\mathrm{GeV}/c^2$, m_2 from 0 — $500\,\mathrm{GeV}/c^2$, tanβ from 2 — 4 and m_0 from 200 — $500\,\mathrm{GeV}/c^2$. A fine scan was done to select points with the lowest production cross section as a function of mass.

5 Summary

The searches used were designed to select R-parity violating decay topologies for pair production of SUSY particles. It is assumed that only one λ_{ijk} coupling is non-zero. The LSP is also assumed to have a negligible lifetime. All limits were set within the framework of the MSSM. No evidence for R-parity violating supersymmetry was found in the data collected at $\sqrt{s} = 189 - 208\,\mathrm{GeV}$. The limits obtained for the direct/indirect decay of neutralinos were $60.2\,\mathrm{GeV}/c^2$ ($LL\bar{E}$), $44.2\,\mathrm{GeV}/c^2$ ($LQ\bar{D}$) and $42.2\,\mathrm{GeV}/c^2$ ($\bar{U}\bar{D}\bar{D}$) respectively and are valid for all μ, tanβ, m_0 and m_2. Fig 4 and Fig 5 show the translation of the respective mass limits unto the (μ, m_2) plane in the region: μ from -200 — $+200\,\mathrm{GeV}/c^2$, m_2 from 0 — $500\,\mathrm{GeV}/c^2$, tan$\beta = 2$ and $m_0 = 60\,\mathrm{GeV}/c^2$ and $100\,\mathrm{GeV}/c^2$ respectively. At high m_0, the chargino mass limit is approximately equal to the kinematic limit irrespective of the R-parity violating operator.

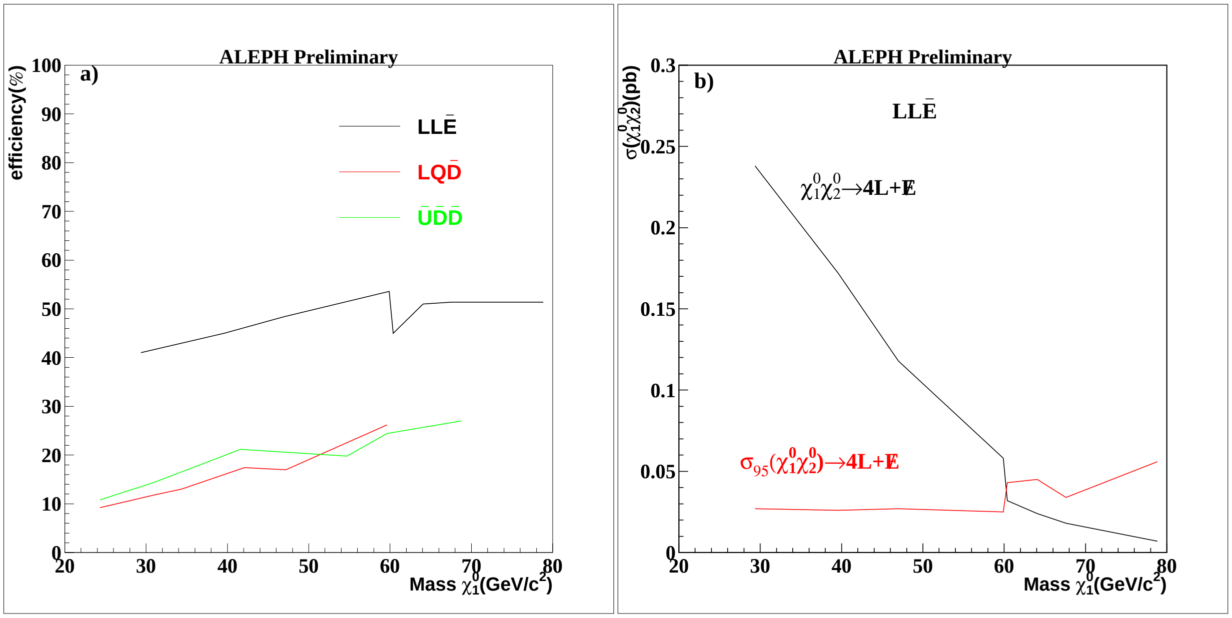

Figure 2: (a) The efficiency as a function of mass for all points selected from Fig 1a. (b) shows $\sigma_{95}(\tilde{\chi}_1^0\ \tilde{\chi}_2^0)$ superimposed over the production cross section$(\tilde{\chi}_1^0\ \tilde{\chi}_2^0)$ to obtain mass limits at $60.2\,\mathrm{GeV}/c^2$ $(LL\bar{E})$.

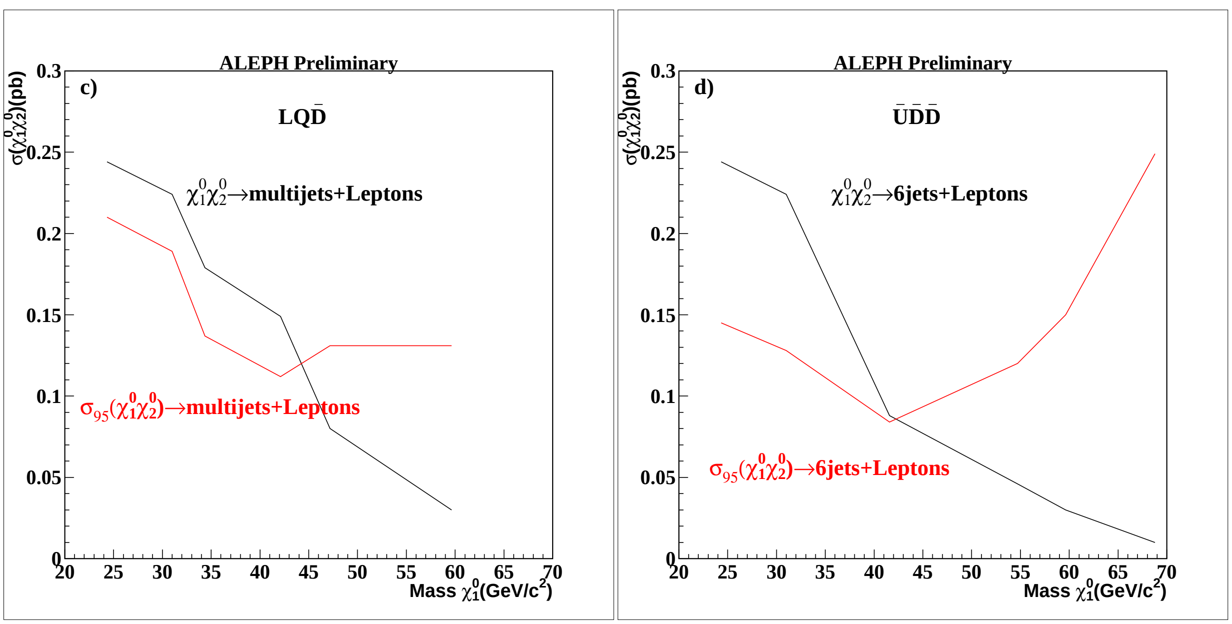

Figure 3: (c) and (d) show $\sigma_{95}(\tilde{\chi}_1^0\ \tilde{\chi}_2^0)$ superimposed over the production cross section$(\tilde{\chi}_1^0\ \tilde{\chi}_2^0)$ to obtain mass limits at $44.2\,\mathrm{GeV}/c^2$ $(LQ\bar{D})$ and $42.2\,\mathrm{GeV}/c^2$ $(\bar{U}\bar{D}\bar{D})$ respectively .

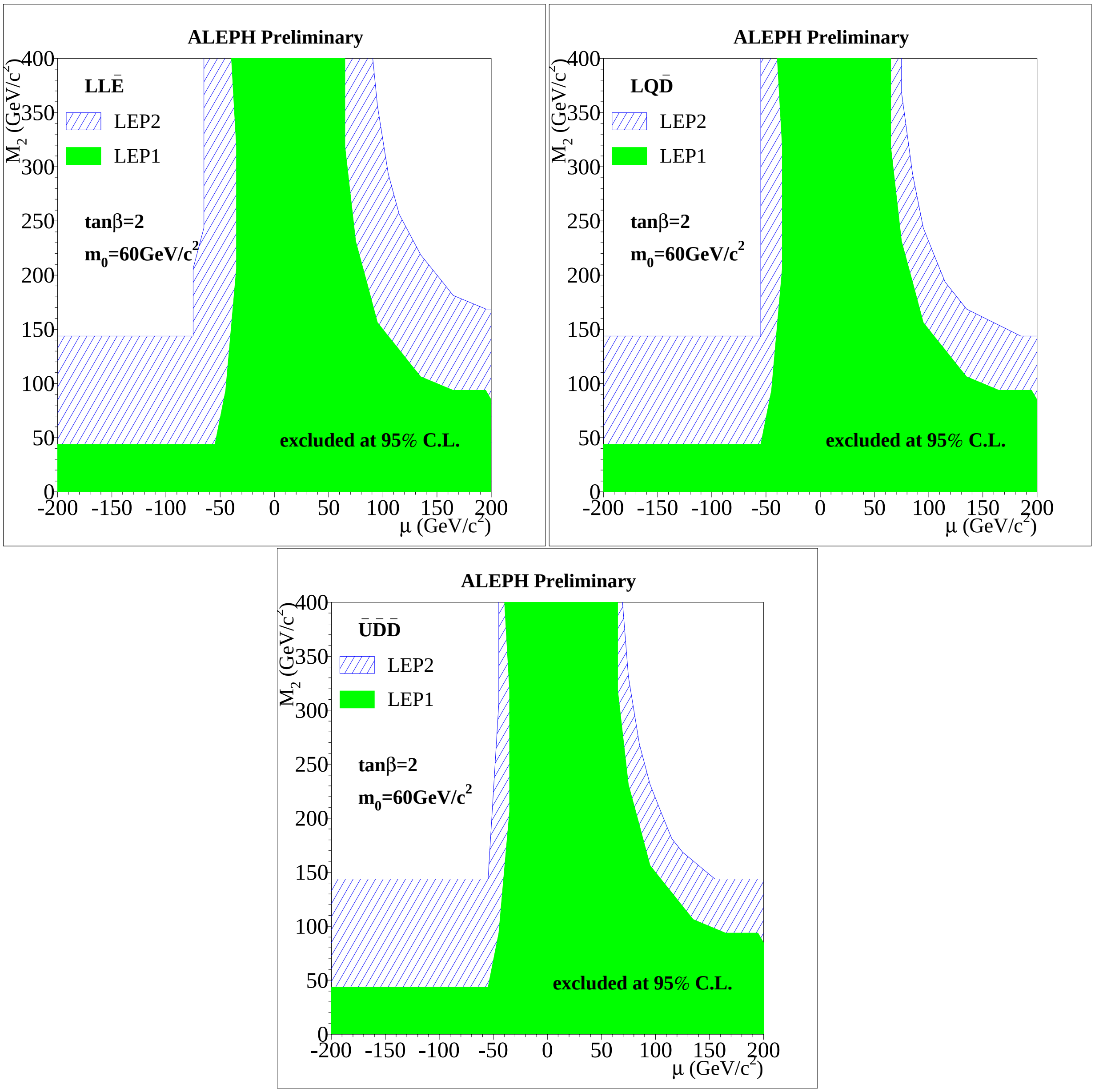

Figure 4: Shows the regions in the $(\mu,\ m_2)$ plane excluded at 95% C.L. at tan$\beta = 2$ and $m_0 = 60\,\mathrm{GeV}/c^2$ for each of the three R-Parity violating operators.

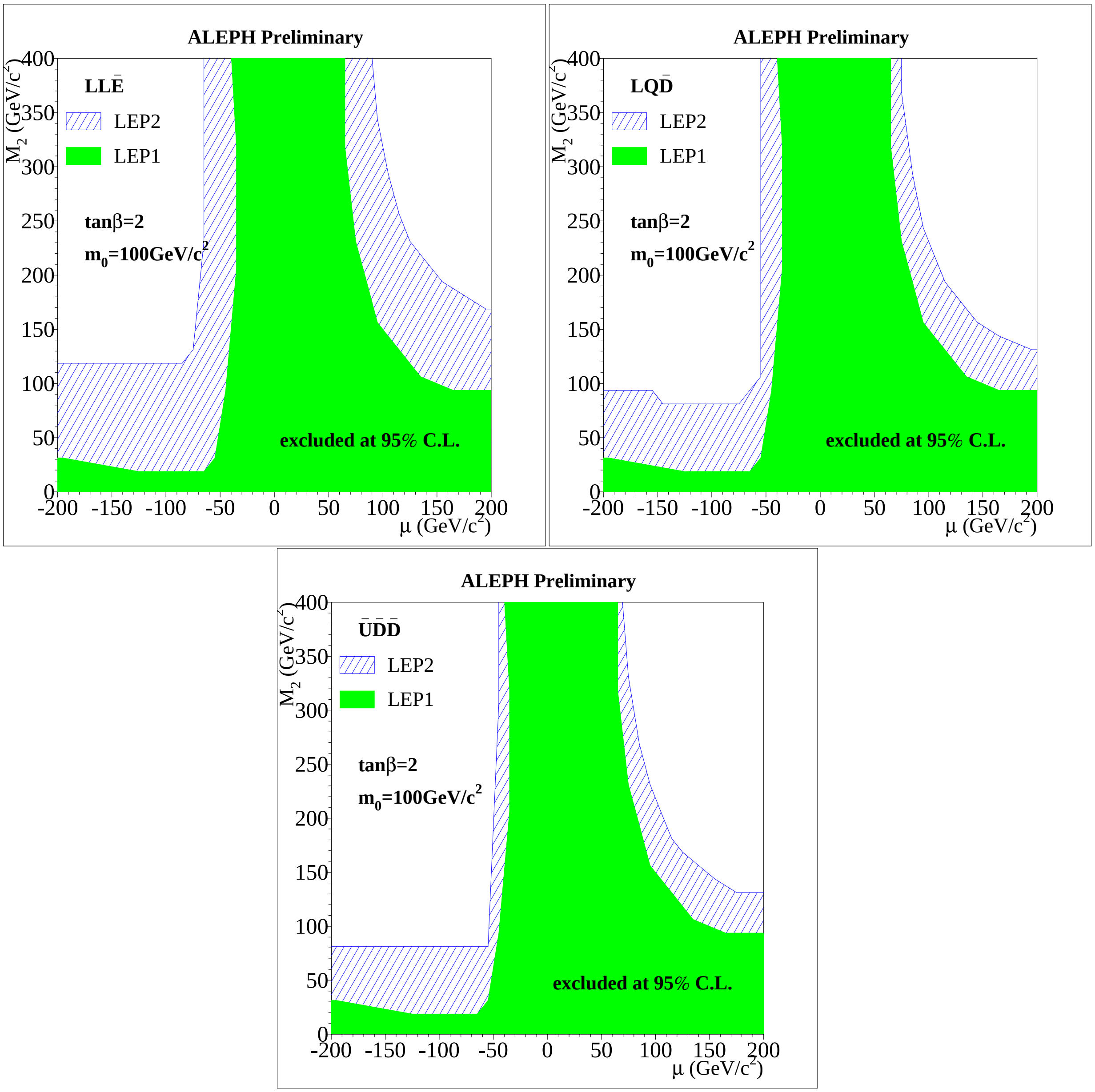

Figure 5: Shows the regions in the (μ, m_2) plane excluded at 95% C.L. at tanβ = 2 and $m_0 = 100\,\mathrm{GeV}/c^2$ for each of the three R-Parity violating operators .

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