DELPHI Collaboration

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Search for SUSY with spontaneously broken R-Parity at $\sqrt{s} = 183$ GeV

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Abstract

Searches for R-parity violating signals in e^+e^- collisions at center-of-mass energy of 183 GeV have been performed in 1997 DELPHI data. The observations are in agreement with Standard Model predictions and a chargino mass limit was derived.

Note for the Moriond Conference,
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1 Introduction

This paper presents the search for R-parity spontaneously violation in 1997 DELPHI data with center-of-mass energy of 183 GeV.

1.1 R-Parity Spontaneously Violating Lagrangian

In the Minimal Supersymmetric Standard Model (MSSM) the R-parity symmetry, related to the particle spin (S), lepton number (L) and barion number (B) through $R = (-1)^{3B+L+2S}$, is assumed to be conserved and therefore supersymmetric particles can only be produced in pairs.

One attractive way to go beyond the MSSM is considering the R-parity an exact Lagrangian symmetry, broken spontaneously through non zero vacuum expectation values (VEVs) for scalar neutrinos. In this case there are two main scenarios depending whether lepton number is a gauge symmetry or not. In the absence of an additional gauge symmetry, there is a physical massless Nambu-Goldstone boson, called Majoron. In this model [1] the Majoron is the Lightest Supersymmetry Particle (LSP), remains massles and therefore stable. The superpotential, which conserves total lepton number, is given by

$$\begin{aligned} W = \quad & h_u u^c Q H_u + h_d d^c Q H_d + h_e e^c L H_d + (h_0 H_u H_d - \epsilon^2)\Phi + \\ & h_\nu \nu^c L H_u + h \Phi \nu^c S + h.c. \quad , \end{aligned} \tag{1}$$

where the couplings h_u, h_d, h_e, h_ν, h_0, h are arbitrary matrices in generation space. The additional chiral superfields (Φ, ν_i^c, S_i) are singlets under $SU(2) \bigotimes U(1)$ and carry a conserved lepton number assigned as (0,-1,1), respectively. The superfields ν^c, S [2] and Φ [3] are required to drive the spontaneously violation of R-parity in an acceptable way, so that the Majoron is mostly a singlet [4].

By construction, neutrinos are massless before breaking of R-parity and, as a result, all R-parity violating observables are directly correlated to the neutrino mass [1], with the magnitude of this correlation depending upon the choice of the R-parity SUSY parameters.

1.2 Chargino Decay Modes

In this model, the chargino can be pair produced via

$$e^+e^- \rightarrow \gamma, Z, \tilde{\nu} \rightarrow \tilde{\chi}^+\tilde{\chi}^- \tag{2}$$

and in addition to the conventional chargino decay mode there is a new two-body decay mode, showed in figure 1. As the magnitude of R-parity violation increases, the $\tilde{\chi}^+ \rightarrow \tau^+ + J$ decay mode becames dominant. For this analysis the effective violation parameter value was fixed in 3 in order to have the $\tilde{\chi}^+ \rightarrow \tau^+ + J$ decay mode most probable, as can be observed in figure 2.

In the present analysis we considered typical values for SUSY parameters (μ, M_2) that can be covered by chargino production at LEP II and we assumed that the sneutrinos are heavy enough ($m_{\tilde{\nu}} > 300\,\mathrm{GeV/c^2}$), therefore, only the γ and Z s-channels contribute to the cross section.

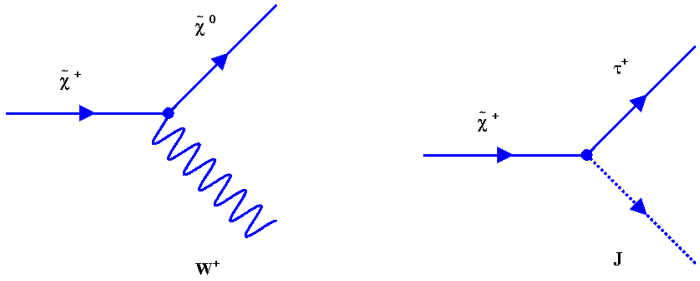


Figure 1: Chargino decay modes diagrams: $\tilde{\chi}^+ \to W^+ + \tilde{\chi}^0$ and $\tilde{\chi}^+ \to \tau^+ + J$.

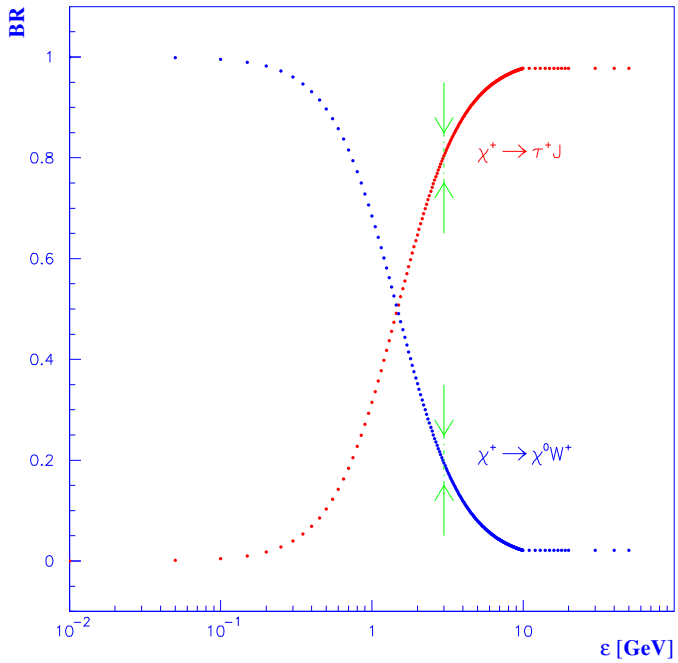


Figure 2: Chargino decays branching ratios as a function of the effective violation parameter ϵ for $\mu = 200\,\mathrm{GeV}$, $M_2 = 70\,\mathrm{GeV}$ and $\tan\beta = 2$.

2 Data Samples

The data corresponding to an integrated luminosity of $53\,\mathrm{pb}^{-1}$ collected during 1997 by the DELPHI detector [5] at $\sqrt{s} \sim 183\,\mathrm{GeV}$ have been analysed.

The program RP-generator II was used to generate chargino events and to calculate cross sections and branching ratios.

To evaluate background contaminations, different contributions comes from the Standard Model processes were considered. The background processes $e^+e^- \rightarrow f\bar{f}(n\gamma)$, $(Z^0/\gamma)^*(Z^0/\gamma)$, $W^{+*}W^{-*}$, $We\nu_e$ and $Z^0e^+e^-$ were generated using PYTHIA. The Berends and Kleis model was used to simulate Bhabha scattering. Two-photon interactions leading to hadronic final states were generated with TWOGAM and BDKRC for the Quark Parton Model contribution.

3 Event Selection

Events with a signature of two acoplanar taus with high missing energy were selected if they satisfy the following criteria:

- there were exactly two groups of well reconstructed charged and neutral particles with invariant mass below $5.5\,\mathrm{GeV/c^2}$,
- the acoplanarity, showed in figure 3, was between 4° and 175°,
- the total number of reconstructed tracks was less than 7,
- the energy of the most energetic, isolated photon was bellow 5 GeV,
- there was no calorimetric energy in a 30° cone around the beam-axis,
- at least 2 tracks with momentum above $1\,\mathrm{GeV/c}$ in the events, and at least one track with momentum above $5\,\mathrm{GeV/c}$,
- the square of transverse momentum with respect to the thrust axis above $0.75\,(\mathrm{GeV/c})^2$.

The events passed in the cuts above were then classified in four groups, according to the momentum of the most energetic charged particle in the event (figure 4). If it had a momentum below $10\,\mathrm{GeV/c}$, the event was classified as a $\gamma\gamma$-class. If the momentum was above $60\,\mathrm{GeV/c}$, the event was regarded as $Z/\gamma \rightarrow \mu^+\mu^-$-class. Events with momentum between these limits and acoplanarity below 15° were then classified as $Z/\gamma \rightarrow \tau^+\tau^-$-class, otherwise as WW-class. We reduced these backgrounds by requiring that:

- the missing transverse momentum was above $10.5\,\mathrm{GeV/c}$ for the $\gamma\gamma$-class,
- the vectorial sum of momenta was at an angle above 30° to the beam, for the $Z/\gamma \rightarrow \tau^+\tau^-$-class,
- the momentum of the most energetic lepton was below $23.5\,\mathrm{GeV/c}$ and the vectorial sum of momenta was at an angle above 34.5°, for the WW-class.

The $Z/\gamma \rightarrow \mu^+\mu^-$-class contains almost no signal events and was not considered in this analysis.

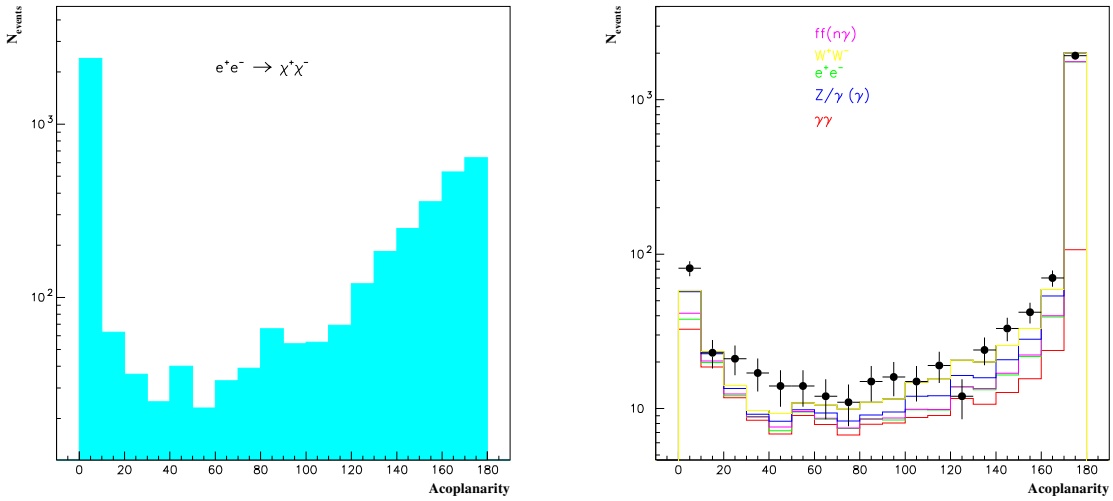


Figure 3: Acoplanarity distribution for generated signal (left) and simulated background (right). The points with error bars show the real data and the histograms show the simulated events.

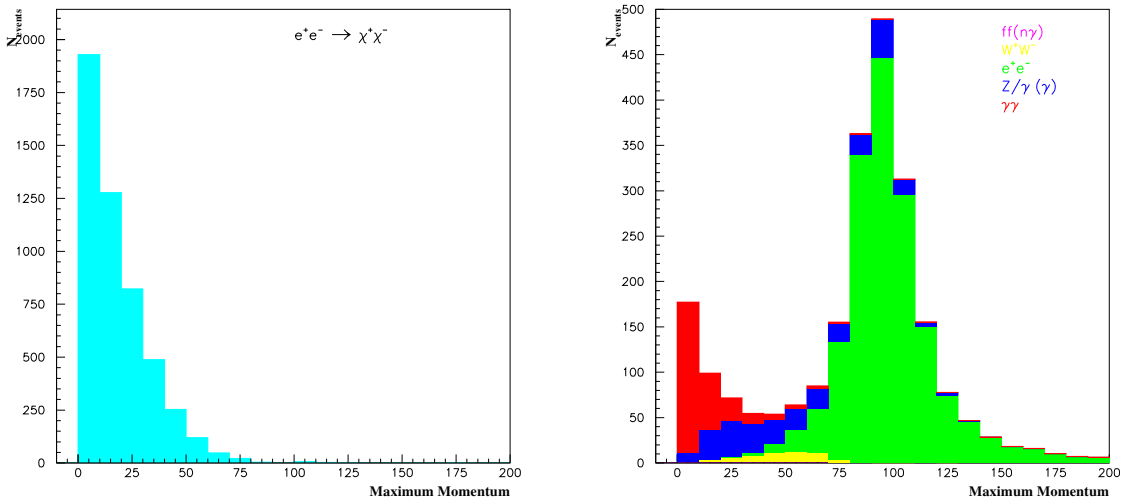


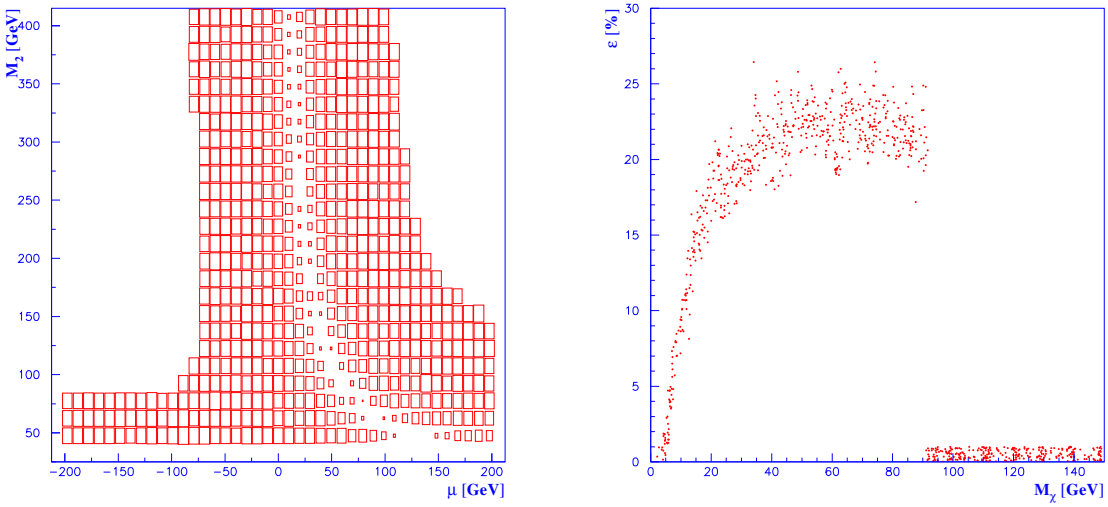
Figure 4: Momentum of the most energetic charged particle in the event for generated signal (left) and simulated background (right).

4 Results

As a result of the described selection procedure, 8 candidates for the decay $\tilde{\chi}^{\pm} \rightarrow \tau^{\pm} + J$ were found. Table 1 summarises the number of events selected in the data and the expected number of backgrounds events. The allowed SUSY parameters region and the selection efficiency are showed in figure 5.

Observed events	**8**
Total background	**6.67 ± 0.42**
$Z^{\circ}/\gamma \rightarrow (ee, \mu\mu, \tau\tau)(n\gamma)$	0.99 ± 0.25
4-fermion events	0.65 ± 0.05
$\gamma\gamma \rightarrow ee, \mu\mu, \tau\tau$	0.28 ± 0.13
$W^{+}W^{-}$	4.59 ± 0.29
$e^{+}e^{-} \rightarrow e^{+}e^{-}$	0.16 ± 0.09

Table 1: Chargino candidates with the total number of background expected and the contributions from major background sources.



(a) (b)

Figure 5: (a) Allowed parameters region in the (μ, M_2) plane for $\tan\beta = 2$ and (b) selection efficiency as a function of the chargino mass.

5 Conclusion

Searches for R-parity violating signals were perfomed in a data sample of about $53\,\mathrm{pb}^{-1}$ collected by the DELPHI detector at center-of-mass energy of 183 GeV. No evidence for R-parity spontaneously breaking has been observed. For a sneutrino mass above 300 GeV and an effective violation parameter below 3, the lower limit on the chargino mass at 95% confidence level is $90.6\,\mathrm{GeV/c^2}$, as shown in figure 6. shows the expected cross section versus the chargino mass.

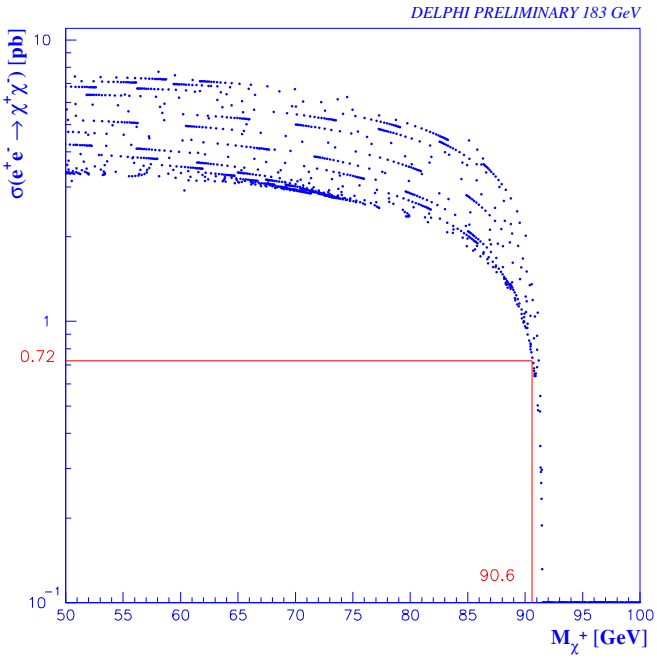


Figure 6: Expected $e^+e- \rightarrow \tilde{\chi}^+\tilde{\chi}^-$ cross section at 183 GeV (dots) as a function of chargino mass. The indicated cross section is the minimal one in the excluded mass region.

References

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