OTHER SEARCHES AT LEP

S. BRAIBANT
CERN, EP Division, CH-1211 Geneva 23, Switzerland

During the year 2000, LEP has been operated at centre-of-mass energies up to $\sqrt{s} = 209$ GeV. New particle searches have been performed using these data samples. Model independent limits on the production cross-sections and mass limits in the context of the Minimal Supersymmetric Standard Model (MSSM) assuming R-parity violation and in the context of gauge-mediated supersymmetry breaking theories (GMSB) are presented. Searches for technicolor, excited leptons and leptoquarks are also reviewed.

1 Introduction

In the year 2000, the LEP e^+e^- collider has been operated at centre-of-mass energies up to 209 GeV. In this year, each of the four LEP experiments, ALEPH, DELPHI, L3 and OPAL, has collected an integrated luminosity of about 220 pb^{-1}. Using all data collected between 1995-2000, the total luminosity per experiment is about 650–700 pb^{-1}.

With these data samples, searches for R-parity violating decays of supersymmetric (SUSY) particles or searches in the context of gauge-mediated supersymmetry breaking theories are performed and are here described. Searches for technicolor, excited leptons and leptoquarks are also briefly reviewed. A full description of the results presented here can be found in [1]. All results described here are preliminary and constitute a representative selection of results from each collaboration. In most of the searches, some candidates are selected by the analyses but their number is compatible with the expected background from Standard Model (SM) processes. Therefore, 95% confidence level (C.L.) upper limits on the production cross-section are computed and mass limits are derived.

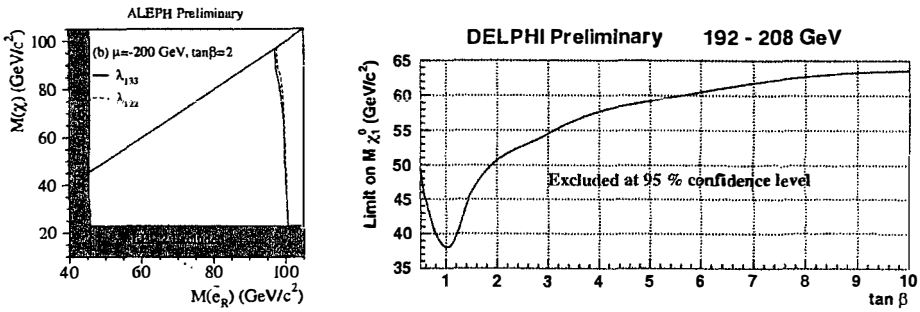

Figure 1: Left plot: 95% C.L. lower mass limits for a right-handed selectron using $\tan\beta = 2$ and $\mu = -200$ GeV from the ALEPH Collaboration. The exclusions are shown for λ_{133} (solid line) and for λ_{122} (dashed line). Right plot: 95% C.L. limits on the $\tilde{\chi}_1^0$ (LSP) mass as a function of $\tan\beta$ using $m_0 = 500$ GeV from the DELPHI Collaboration.

2 Searches for R-parity Violation Decays of Supersymmetric Particles

In this section, a few examples of searches for R-parity ($R = -1^{(2S+3B+L)}$) violating decays of supersymmetric particles are presented. When R-parity is not conserved, the lightest SUSY particle (LSP) will decay and the topologies differ significantly from the ones with conserved R-parity.

With the MSSM particle content, R-parity violating interactions are parametrised with a gauge-invariant super-potential that includes the following Yukawa coupling terms:

$$W_{RPV} = \lambda_{ijk} L_i L_j \overline{E}_k + \lambda'_{ijk} L_i Q_j \overline{D}_k + \lambda''_{ijk} \overline{U}_i \overline{D}_j \overline{D}_k, \quad (1)$$

where i, j, k are the generation indices of the super-fields L, Q, E, D and U. L and Q are lepton and quark left-handed doublets, respectively. $\overline{E}$, $\overline{D}$ and $\overline{U}$ are right-handed singlet charge-conjugate super-fields for the charged leptons and down- and up-type quarks, respectively. This makes a total of 45 parameters in addition to those of the R-parity conserving MSSM.

Pair-production of gauginos (charginos and neutralinos) and sfermions (scalar fermions) is usually assumed but searches for single resonant production via the exchange of a sneutrino are also performed. Two different scenarios are probed. In the first scenario, the decays of sparticles via the lightest neutralino, $\tilde{\chi}_1^0$, are considered, where $\tilde{\chi}_1^0$ is treated as the LSP and assumed to decay via R-parity violation. These are denoted as "indirect decays". In the second case, "direct" decays of sparticles to SM particles are investigated. In this case, the sparticle considered is assumed to be the LSP, such that R-parity conserving decay modes do not contribute.

As an example, Fig. 1 (left plot) shows the 95% C.L. lower mass limits for right-handed selectron using a λ coupling, while the right plot shows the 95% C.L. limits for a λ' coupling on the $\tilde{\chi}_1^0$ (LSP) mass as a function of $\tan\beta$ using $m_0 = 500$ GeV. A complete set of results regarding all λ-like couplings for gauginos and sfermions can be found in [1]. In all cases, no evidence for supersymmetry with R-parity violation is found and limits are placed on the production cross-sections, on the sparticle masses and on the MSSM parameter space.

3 Searches for Gauge Mediated Supersymmetry Breaking Signatures

In this section, searches in the context of a model called Gauge Mediated Supersymmetry Breaking (GMSB) are presented. In this model, supersymmetry is broken via the usual gauge interactions in a hidden sector, which couples to the visible sector of the SM and SUSY particles

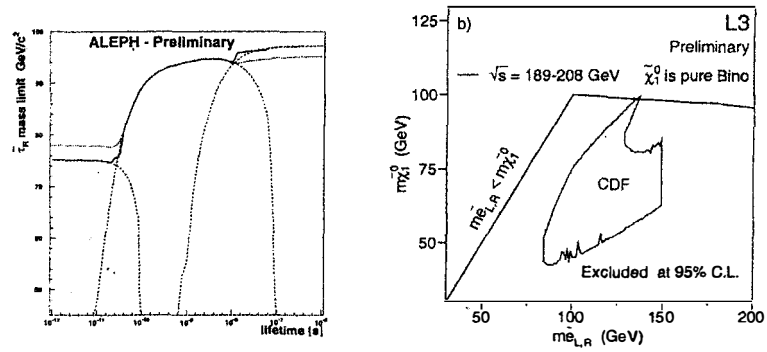

Figure 2: Left plot: 95% C.L. excluded mass regions for right-handed staus (NLSP) as a function of the NLSP lifetime from the ALEPH Collaboration and combining three different searches. Right plot: 95% C.L. excluded region in the $(m_{\tilde{e}_R}, m_{\tilde{\chi}_1^0})$ mass plane assuming a $\tilde{\chi}_1^0$ NLSP from the L3 Collaboration; this limit is derived from the search for acoplanar photons assuming a zero lifetime NLSP.

via a messenger sector. In this GMSB model, the supersymmetric partner of the graviton, the gravitino $\tilde{G}$ is assumed to be the LSP and the next-to-LSP (NLSP) can either be the lightest neutralino, $\tilde{\chi}_1^0$, or a right-handed slepton, $\tilde{l}_R$. The NLSP decay length is unconstrained and all possible decay lengths between zero and infinity have to be considered, suggesting to explore many different final state topologies. No significant excesses with respect to SM background are observed. Therefore, model independent limits on the production cross-sections and mass limits within the context of GMSB are derived. As an example, Fig. 2 (left plot) shows the 95% C.L. excluded $\tilde{\tau}_R$ mass (GeV) as a function of the lifetime (s), assuming a $\tilde{\tau}_R$ NLSP and combining searches exploring various regions of the NLSP lifetime. The very short lifetime range is covered by the search for events with a pair of acoplanar leptons; the intermediate lifetime range is covered by the searches for events containing tracks with large impact parameters and kinks; and the long lifetime range is covered by the search for heavy stable charged particles. Fig. 2 (right plot) shows the 95% C.L. excluded region in the $(\tilde{e}_R, \tilde{\chi}_1^0)$ mass plane assuming a $\tilde{\chi}_1^0$ NLSP; this limit is derived from the search for events with acoplanar photons and assuming a zero lifetime NLSP.

4 Technicolor, Excited Leptons and Leptoquarks

Technicolor is a viable alternative to the Higgs mechanisms for generating gauge boson masses. DELPHI has searched for many different channels such as $e^+e^- \to \rho_T \to f\bar{f}$ (below the W^+W^- threshold), $e^+e^- \to \rho_T \to W^+W^-$ (above the W^+W^- threshold) or $e^+e^- \to \rho_T \to \pi_T^+\pi_T^-$, followed by $\pi_T^+ \to \bar{b}c, \bar{b}u$. Good agreement is observed with the SM expectation in all channels studied. This is translated into an excluded region at the 95% C.L. level in the (m_{π_T}, m_{ρ_T}) plane as shown in the left plot of Fig. 3. The ρ_T production is excluded for $m_{\rho_T} < 202$ GeV.

Another interesting topic consists in the search for charged excited leptons with photonic decays as performed by the OPAL Collaboration. In the pair production channel, $\ell^{*+}\ell^{*-} \to \ell^+\ell^-\gamma\gamma$, no excess of events above the expected background is observed and limits on the mass of the excited leptons are inferred with the coupling assumption $f = f'$ (for the photonic branching ratio), as shown in Table 1.

A search for events with pair production of leptoquarks is also performed. The search is done assuming that leptoquarks are produced via couplings to the photon and the Z^0 and promptly

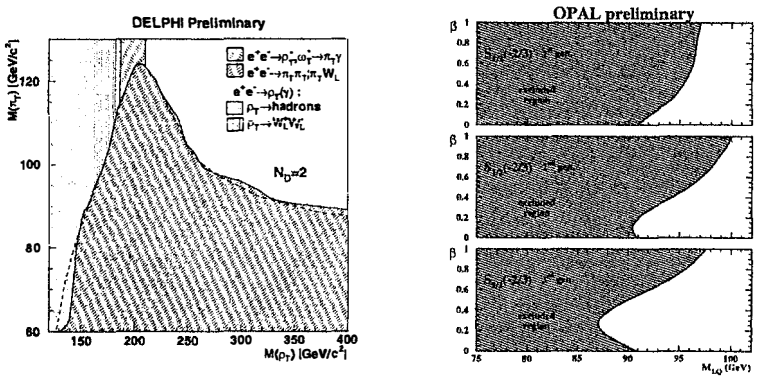

Figure 3: Left plot: 95% C.L. excluded mass regions in the (m_{π_T}, m_{ρ_T}) from the DELPHI Collaboration. Right plot: regions of the plane β *vs* M_{LQ} excluded at 95% C.L. for the scalar state $S_{1/2}(-2/3)$, with possible values of β in the range between 0 and 1 from the OPAL Collaboration.

Table 1: 95% confidence level lower mass limits on excited leptons extracted from pair production searches performed by the OPAL Collaboration. The limits are calculated assuming $f = f'$.

Flavour	Mass limit (GeV)
e*	102.9
μ^*	102.9
τ^*	102.8

decay into a lepton and quark. Moreover the simplifying assumption is made that only couplings within a single generation of leptons exist. This leads to final states characterized by high multiplicities and by the presence of isolated and energetic charged leptons or missing energy if neutrinos are present. No significant evidence for leptoquark pair production is observed in the data and lower limits on the leptoquark masses are derived as a function of the branching ratio, β, of decay into a charged lepton and a quark. As an example, Fig. 3 (right plot) shows the regions of the plane β *vs* M_{LQ} excluded at 95% C.L. for the scalar state $S_{1/2}(-2/3)$, with possible values of β in the range between 0 and 1.

5 Conclusions

LEP has been a great success until its very end allowing a multitude of searches for new particles. These searches have been performed using a total integrated luminosity of about 650–700 pb^{-1}, collected by experiment, at centre-of-mass energies up to 209 GeV. A number of preliminary updates of these searches for new particles have been performed and interpreted in various models. No significant evidence for new physics is observed.

References

1. http : //alephwww.cern.ch/ALPUB/oldconf/oldconf_01.html;
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