PHOTONIC AND GRAVITINO SEARCHES AT LEP

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The four LEP experiments have updated searches within the framework of Gauge Mediated Supersymmetry Breaking models. No deviations from the expectations from Standard Model sources were observed in the data recorded during 1999 and new cross section limits and exclusion plots have been produced.

1 Introduction

In Gauge Mediated Supersymmetry Breaking (GMSB) models[1] the Gravitino ($\tilde{G}$) is predicted to be the Lightest SUSY Particle (LSP) and the Next-to-Lightest SUSY Particle (NLSP) is typically either a slepton, decaying to a lepton and a gravitino, or a neutralino decaying to a photon and a gravitino. The gravitinos are stable and neutral and can be observed only as missing energy by the experiments.

The mass of the gravitino ($m_{\tilde{G}}$) is proportional to the square of the SUSY breaking scale and a typical scale of something like 10-10,000 TeV corresponds to a gravitino mass within the range 0.02 eV-20 keV. The decay lengths of the NLSP (i.e. the slepton or the neutralino) in turn depends on the square of the gravitino mass and so the scale, the gravitino mass and the NLSP decay length are all related.

The experiments usually do different searches depending on the assumed decay length of the NLSP. If it is very short one is looking mainly for events with acoplanar lepton- or photon-pairs, if the decay length is of the same size as the experiment one can search for leptons and photons that do not point to the Interaction Point (IP) and finally if the decay length is larger than the size of the experiment one can (in the slepton-NLSP case) look for heavy stable particles.

None of the four LEP experiments has reported an excess in any of the GMSB search channels using the 1999 LEP data. The results from these searches is therefore pre-

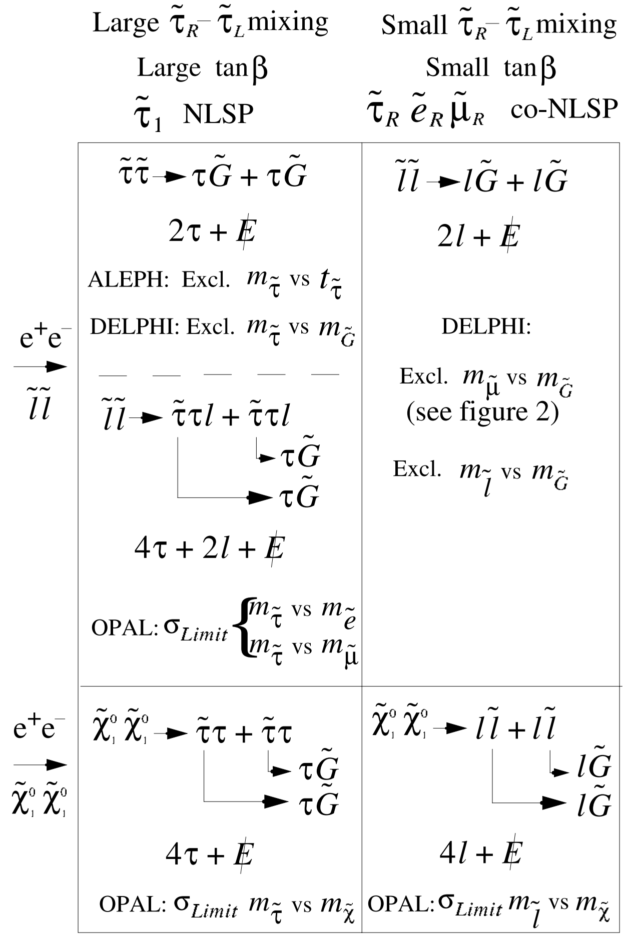

Figure 1. Slepton NLSP search scenarios and event topologies. Searches with data up to 202 GeV, where new exclusion plots or cross section limits have been produced, are indicated.

sented as cross section limits and exclusion plots. Only results including data up to 202 GeV center-of-mass energy will be presented.

2 Slepton NLSP

In the slepton-NLSP scenario the experiments are usually doing the searches under the assumption that either the stau is the NLSP (i.e. large tanβ and large mixing in the stau sector) or that the NLSP is

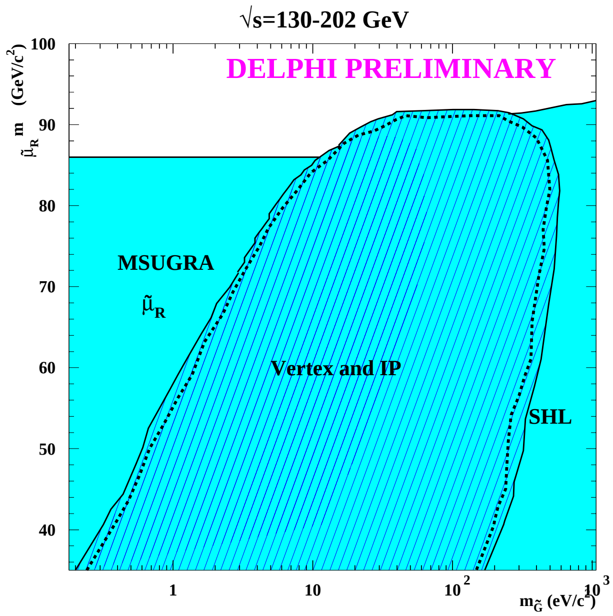

Figure 2. Exclusion plot in the $m_{\tilde{\mu}}$- $m_{\tilde{G}}$ plane by DELPHI using all data up to 202 GeV. The dashed line shows the expected limits.

a mass-degenerate state in which case also smuon and selectron searches become relevant. Searches have been made both for the case of direct slepton production and for the case of cascade decays in which first a pair of neutralinos are produced which then decays into sleptons and leptons.

Figure 1 summarizes the different search channels and the different event topologies studied by ALEPH[2], DELPHI[3] and OPAL[4]. The figure also indicates in which search channels the three collaborations have produced new exclusion plots or cross section limits using the 1999 data. One of these plots is shown in Figure 2 which illustrates a search for smuon pairs by DELPHI. Three different search analysis have been combined in this exclusion plot. For small gravitino masses ($m_{\tilde{G}}$<10 eV), i.e. a short slepton decay length, a MSUGRA search for $e^+e^- \rightarrow \tilde{\mu}\tilde{\mu} \rightarrow \tilde{\chi}_1^0\mu\tilde{\chi}_1^0\mu$ has been used to set a limit on $e^+e^- \rightarrow \tilde{\mu}\tilde{\mu} \rightarrow \tilde{G}\mu\tilde{G}\mu$ by using the MSUGRA-limit at $m_{\tilde{\chi}}$=0. This analysis gives a limit on the smuon mass of 86 GeV. In an intermediate gravitino mass region, for which the smuon is expected to decay inside the experiment, a search for muon-pair events where the muon tracks have kinks or do not

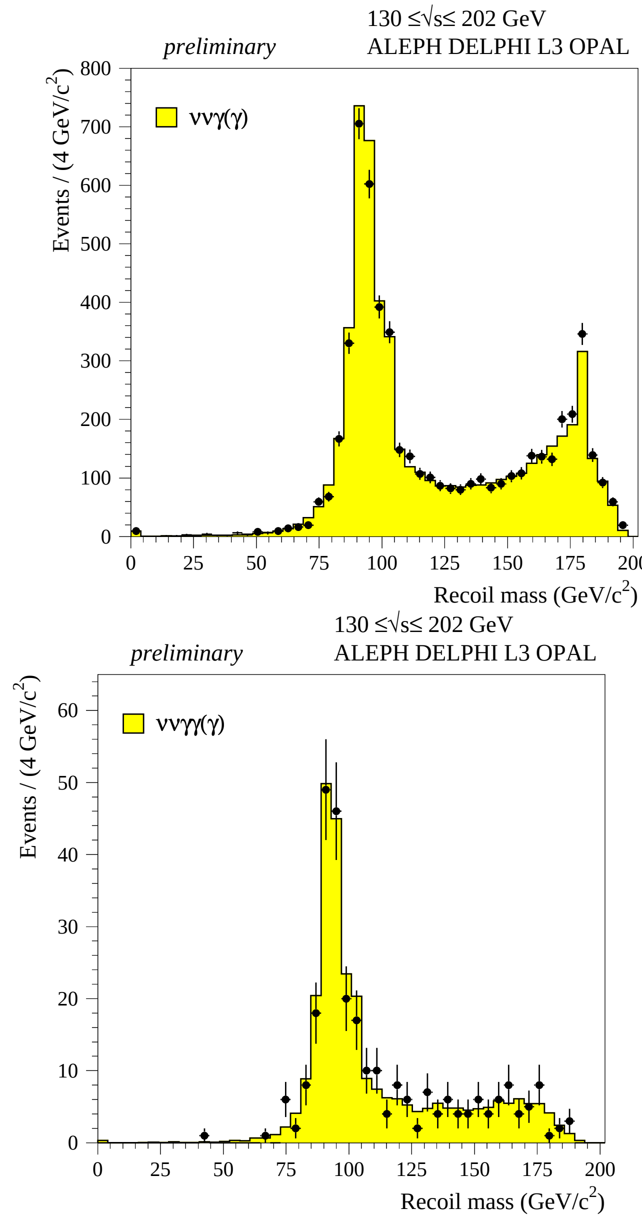

Figure 3. Recoil (or missing) mass distribution for single photon events (top) and two photon events (bottom) from all four LEP experiments[5].

point to the IP has been done. This gives a limit on the smuon mass which is between 86 and 91 GeV. For gravitino masses above a few hundred eV, searches for heavy stable particles (i.e. the smuon directly) by using dE/dx and the RICH gives an even higher limit which is between 91 and 93 GeV.

3 Neutralino NLSP

GMSB models predict that if the neutralino is the NLSP, events with one or two photons + missing energy can be important discovery topologies. Figure 3 shows the recoil

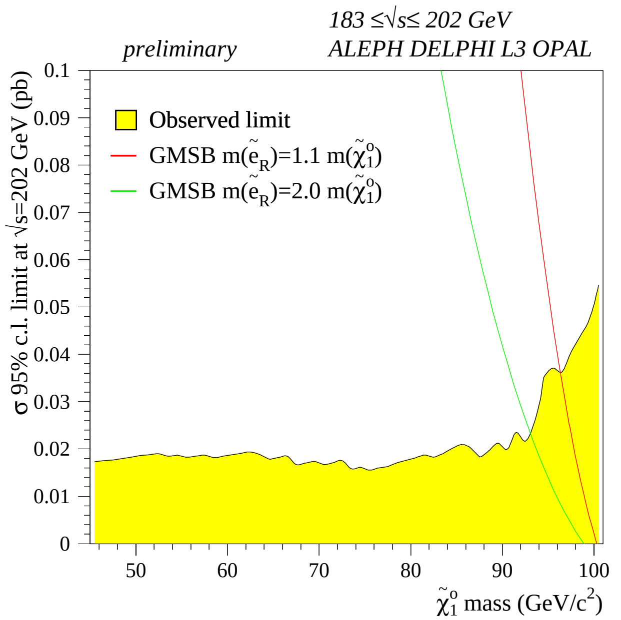

Figure 4. Cross section limit at $\sqrt{s}$ =202 GeV of the process $e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma\tilde{G}\gamma$ as a function of $m_{\tilde{\chi}}$[5].

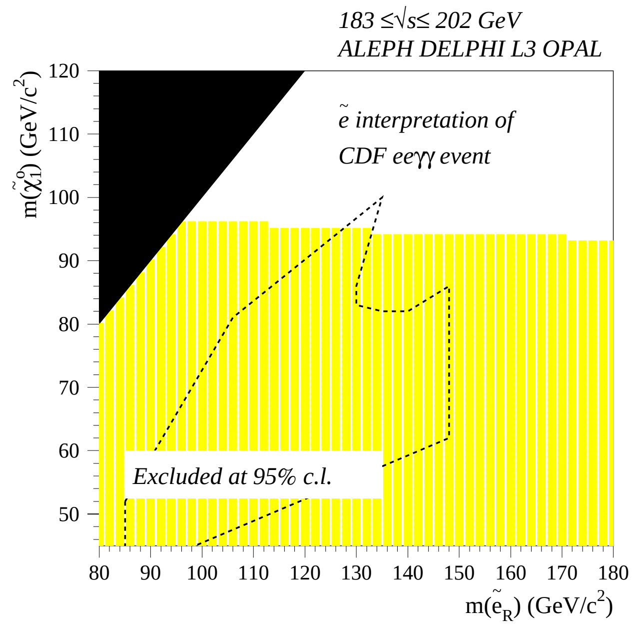

Figure 5. The shaded area shows the exclusion region in the $m_{\tilde{\chi}}$ versus $m_{\tilde{e}_R}$ plane[5].

mass (or missing mass) distribution for one and two photon events after combining the data from all four LEP experiments[5]. Neutrino pair production, $e^+e^- \rightarrow \nu\bar{\nu}\gamma(\gamma)$, is the only Standard Model process that can produce single and two photon events. None of the experiments claim to see a significant excess of events above SM expectations.

The $e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma\tilde{G}\gamma$ process is the main GMSB search channel with the neutralino as the NLSP. Figure 4 shows the cross section limit versus neutralino mass for this process (after combining the data from all four LEP experiments[5]). The corresponding exclusion plot in the neutralino-selectron mass plane is shown in Figure 5. The limits in Figure 4 and 5 assumes a short decay length i.e. a low gravitino mass. Updated cross section limits have also been calculated by ALEPH[6] and DELPHI[7] under the assumption that the neutralinos decay inside the experiment and that the photons do not point towards the IP. In this case non-pointing single photon event are searched for since the probability is low that both photons decay inside the experiment.

The cross section for the process $e^+e^- \rightarrow \tilde{G}\tilde{\chi}_1^0 \rightarrow \tilde{G}\tilde{G}\gamma$, which produces true single photon events, is only large for very light gravitinos in the mass range $10^{-4} - 10^{-5}$ eV and the experiments are therefore in this case only looking for prompt photon production. DELPHI[7] and L3[8] have produced new cross section limits as a function of neutralino mass from the single photon events and DELPHI[7] and ALEPH[6] have calculated new limits for the gravitino mass under the assumption that all SUSY particles except the gravitino is too heavy to be produced. The results are $m_{\tilde{G}} > 1.1 \cdot 10^{-5}$ eV for ALEPH[6] and $m_{\tilde{G}} > 1.2 \cdot 10^{-5}$ eV for DELPHI[7].

References

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