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Search for scalar leptons in e^+e^- collisions at centre-of-mass energies up to 208 GeV

The ALEPH Collaboration

Abstract

Search for pair production of sleptons have been performed using the data collected by the ALEPH detector at LEP in the year 2000. The centre-of-mass energy ranges from 204 to 209 GeV, corresponding to an integrated luminosity of 207.3 pb^{-1}. No evidence for the production of these particles was found. The number of candidates observed is consistent with the background expected from four-fermion processes and $\gamma\gamma$ interactions. Improved mass limits at 95 % C.L. are reported.

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1 Introduction

This note describes preliminary results of searches for sleptons ($\tilde{\ell}$) obtained using the data collected by the ALEPH detector at LEP during the year 2000, at centre-of-mass energies ranging from 204 to 209 GeV. The data were divided into three energy bins. The corresponding luminosities are given in Table 1.

The theoretical framework is the Minimal Supersymmetric Model (MSSM), with R-parity conservation and the assumption that the lightest neutralino is the Lightest Supersymmetric Particle (LSP).

Scalar leptons are pair produced at LEP through s-channel exchange of Z^0 or γ and give rise to the reactions $e^+e^- \rightarrow \tilde{\ell}_L\tilde{\ell}_L$ or $\tilde{\ell}_R\tilde{\ell}_R$. Selectrons can also be produced through the t-channel exchange of a neutralino, which yields in addition the $e^+e^- \rightarrow \tilde{e}_L\tilde{e}_R$ process. The sleptons search is based on their detection via the decay mode $\tilde{\ell}^\pm \rightarrow \ell^\pm\tilde{\chi}^0_1$. The experimental signature is a final state with two leptons of the same family and missing energy, due to the presence of two undetected neutralinos.

Cross sections and branching ratios are calculated in the framework of the MSSM with the program SUSYGEN [1]. The only dependence of the cross section for smuon and stau production on supersymmetric parameters is through the slepton mass matrix, whereas the selectron cross section depends on the selectron mass and, via the t-channel, on the MSSM parameters μ, M_2 and $\tan\beta$. The off-diagonal elements of slepton mass matrix are proportional to the lepton mass. Left and right handed sleptons can therefor mix to form mass eigenstates. The mixing is expected to be negligible for smuons and selectrons due to the small masses of their partner leptons.

Energy bin (GeV)	Luminosity (pb^{-1})
204 - 206	75.30
206 - 207	122.56
> 207	9.39

Table 1: Luminosities for the 2000 data collected by the ALEPH detector, for three energy bins.

2 Selection criteria

Slepton pair production leads to a final state characterized by two leptons of identical flavour. The twp leptons are acoplanar, due to the missing energy and momentum carried by the neutralinos. The selection criteria depend on the flavour of the leptons and on the mass difference between the slepton and the neutralino ($\Delta M = m_{\tilde{\ell}} - m_{\tilde{\chi}^0}$). The main background for large ΔM are the W pair production, four-fermion processes and dilepton production, whereas for small ΔM the dominant background comes from two-photon processes with lepton in the final state. Therefore two different sets of selection are optimized for small and large ΔM. The various selections are identical to those described in Ref. [2] for a e^+e^- centre-of-mass energy up to 202 GeV, with cut values suitably rescaled to take into account the beam energy increase.

A comparison between data and expected backgrounds from standard model processes is presented in figure 1 when using a pre-selected sample which consists in removing the criteria against the four-fermion backgrounds. The figures 1a and 1b show the distributions of the total mass and lepton momenta, in case of selectron and smuon. The figures 1c and 1d show distributions of the total mass and of the momenta of identified lepton in the tau jet, in case of stau. At the pre-selection level, good agreement is observed between data and expected backgrounds (the main contribution to the backgrounds is from W pair production).

For small ΔM the efficiency for the $\tilde{e}_R\tilde{e}_R$ selection decreases. In this region, t-channel $\tilde{e}_L\tilde{e}_R$ production leads to a final state characterised by a pair of one high and one low momentum electron. Two selections are performed, depending on the momentum of the electron stemming from the $\tilde{e}_R$ decay.

The high ΔM selection for acoplanar electrons, described above, is applied with sliding cuts adapted to the kinematical range allowed for $\tilde{e}_L\tilde{e}_R$ production. For very small ΔM the single electron selection, described in [2], is used, based on a well identified electron with high transversal momentum. Disjunction from acoplanar electron selections is obtained by a cut on the transversal momentum of the second electron.

3 Candidate events and backgrounds

The number of candidate events and expected backgrounds are given in table 2 for selectron and smuon searches and in table 3 for stau searches. Partial background substraction is performed following the procedure of Ref. [2].

Energy (GeV)	$\tilde{e}$				$\tilde{\mu}$			
	small ΔM		high ΔM		small ΔM		high ΔM	
	N_{obs}	N_{bkg}	N_{obs}	N_{bkg}	N_{obs}	N_{bkg}	N_{obs}	N_{bkg}
205.2	0	0.118	15	14.0	0	0.122	8	12.5
206.6	0	0.194	24	22.9	0	0.201	28	20.6
208.0	0	0.016	0	1.76	0	0.167	3	1.59

Table 2: Number of candidate events (N_{obs}) and background events expected from standard model processes (N_{bkg}), for selectron and smuon searches.

Energy (GeV)	$\tilde{\tau}$					
	small ΔM		high ΔM		small or high ΔM	
	N_{obs}	N_{bkg}	N_{obs}	N_{bkg}	N_{obs}	N_{bkg}
205.2	5	6.6	4	7.3	8	9.9
206.6	12	10.9	13	11.9	17	16.2
208.0	2	0.82	0	0.90	2	1.23

Table 3: Number of candidate events (N_{obs}) and background events expected from standard model processes (N_{bkg}), for stau searches.

The search for sleptons is performed as a function of both slepton and neutralino masses. A sliding cut is then applied requiring that the lepton momenta fall into the range kinematically

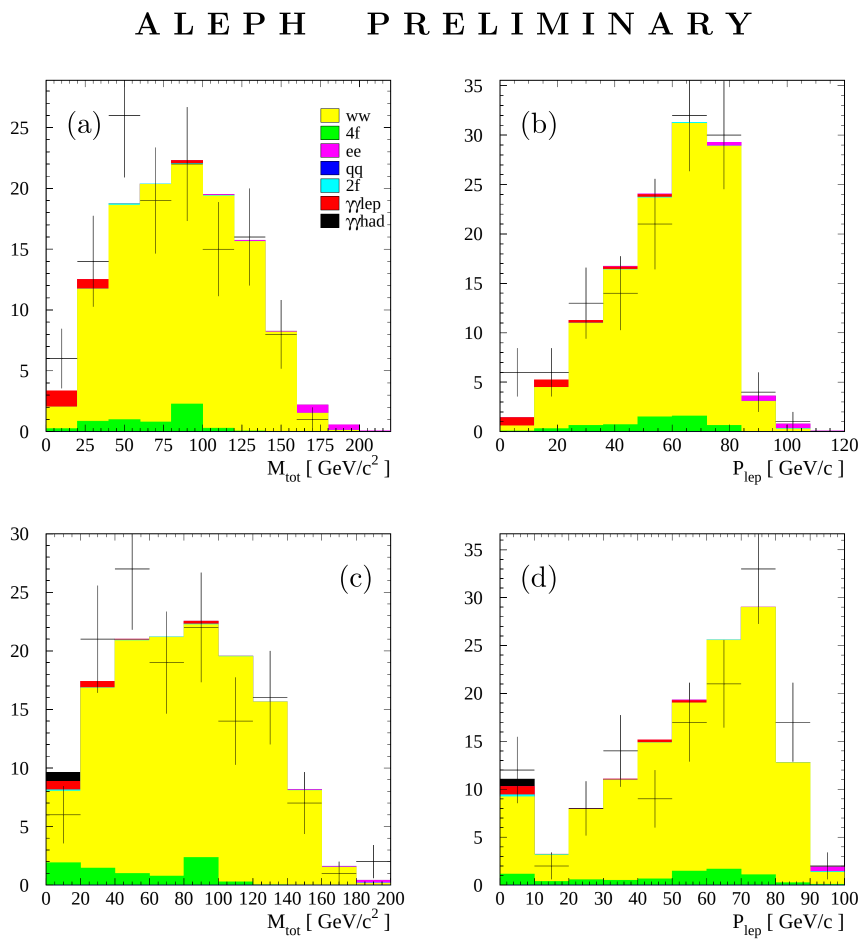

Figure 1: Comparison between data (crosses) and expected backgrounds (histograms) in case of pre-selected selectron and smuon sample: (a) total mass (M_{tot}) and (b) momentum of the leading lepton (P_{lep}); in case of the pre-selected stau sample: (c) total mass (M_{tot}) and (d) momentum of the leading lepton identified in the tau jet (P_{lep}).

allowed for a signal with the considered values of slepton and neutralino masses. For the selectron, smuon and stau searches, the number of candidate events and expected background events are displayed in figure 2 as a function of the slepton and the $\tilde{\chi}^0_1$ masses, after the sliding cuts.

The background for the single electron selection is dominated by $We\nu$ and Zee events. Reduced by the systematical error, these processes are subtracted. This amount corresponds to 80.3 % of the total background. Candidate events and expected backgrounds for the three energy bins are shown in table 4. There is no evidence for selectrons with small ΔM.

4 Interpretation in the MSSM

The non-observation of any excess of candidates can be interpreted as lower limits on the masses of the particles searched for. Unless stated otherwise, limits are derived under the assumption that only $\tilde{\ell}_R\tilde{\ell}_R$ production contributes. This assumption is conservative because of the smaller

Energy (GeV)	N_{obs}	N_{bkg}
205.2	5	7.7
206.6	7	13.8
208.0	0	1.0

Table 4: Number of candidate events (N_{obs}) and background events expected from standard model processes (N_{bkg}), for the single electron selection.

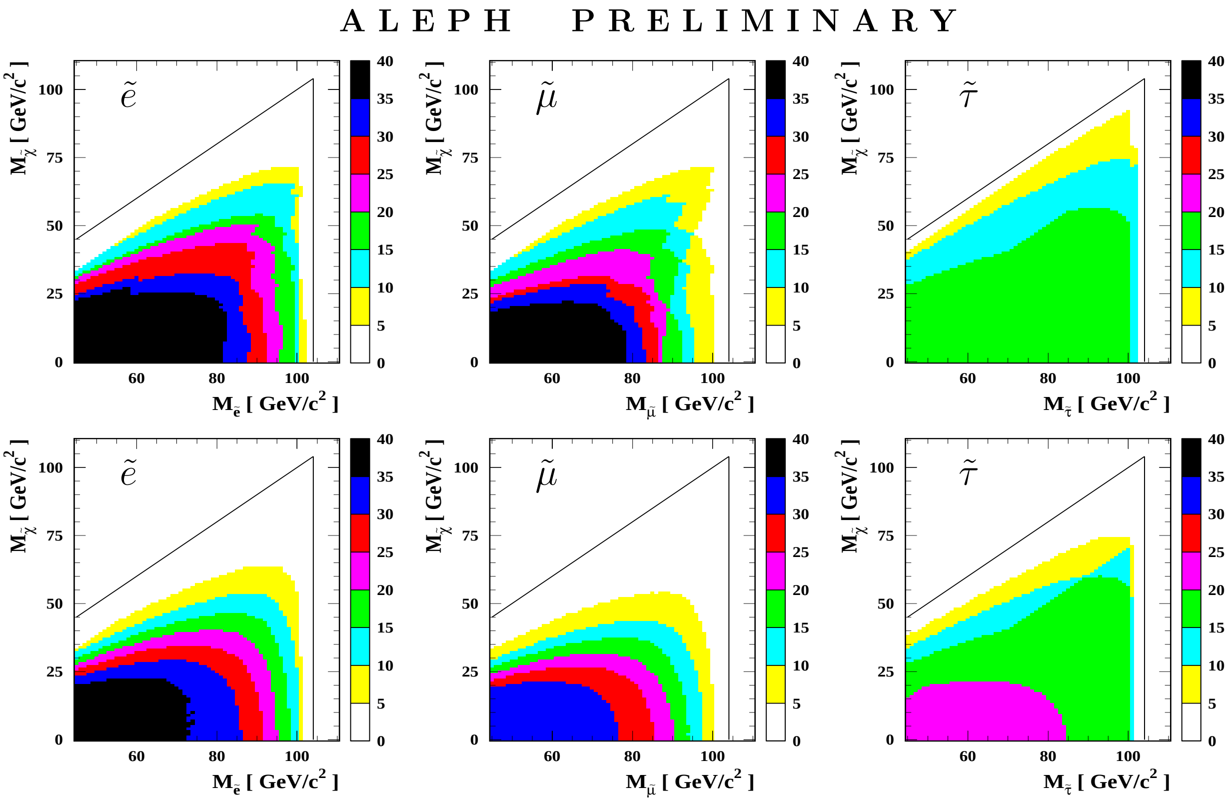

Figure 2: Number of selected events (upper figures) and expected background events from standard model processes (lower figures) in the search for selectrons, smuons and staus. The shading densities reflect the number of events as indicated on the vertical bar. The kinematically accessible region at 208 GeV is indicated by the full lines.

cross section for the production of right-handed sleptons compared to left-handed sleptons for pure s-channel production.

Mixing is expected to be negligible for all sleptons except for staus, since the tau is much heavier than the other leptons. Therefore limits are calculated for stau in mixed and unmixed scenarios. Assuming the mixing effect to be negligible, the most conservative limits are set by considering pair production of $\tilde{\tau}_R$. In the case where $\tilde{\tau}_L$ and $\tilde{\tau}_R$ mix, limits are set on the mass of the lightest stau $\tilde{\tau}_1$, choosing the mixing angle such that $\tilde{\tau}_1$ completely decouples from the Z^0 boson (corresponding to $\theta_{\tilde{\tau}} \simeq 52°$).

The unification of gaugino masses is assumed for the computation of the slepton branching ratios and of the selectron cross section. Branching ratios for the $\tilde{\ell}_R$ decay are calculated for

Channel	$M(\tilde{\ell}) >$ obtained	$M(\tilde{\ell}) >$ expected
$\tilde{e}_R$	94 GeV	96 GeV
$\tilde{\mu}_R$	86 GeV	86 GeV
$\tilde{\tau}_R$	75 GeV	78 GeV
$\tilde{\tau}$(min)	73 GeV	76 GeV

Table 5: Values of slepton masses excluded at 95% C.L. for the production of right states, for $\Delta M > 15$ GeV, with the hypothesis of BR($\tilde{\ell}^{\pm} \to l^{\pm}\tilde{\chi}_1^0$)=1. For stau, the bound corresponding to the minimum cross section is also given. In case of selectron, the values $\mu = -200$ GeV/c^2 and $\tan\beta = 2$ are used for the cross section computation.

$\mu = -200$ GeV/c^2 and $\tan\beta = 2$. The branching ratio ($\tilde{\ell}^{\pm} \to \ell^{\pm}\tilde{\chi}_1^0$) is dominant except when the decay $\tilde{\ell}_R \to \ell\tilde{\chi}_2^0$ is kinematically allowed.

The 95% C.L. bounds on the mass for selectrons, smuons and staus as function of the neutralino mass are displayed in figure 3. In the exclusion plots for the selectron and smuon searches, the dashed lines show the limits computed under the conservative assumption that the selection efficiency for decay channels other than $\tilde{\ell}^{\pm} \to \ell^{\pm}\tilde{\chi}_1^0$ is zero.

The expected and the observed bounds are both drawn in the figure and are in good agreement with each other for the selectron search. For the smuon search at high ΔM (stau search), the expected limit is below (above) the observed one, because of a small deficit (excess) of events observed, compared to the background expectation. For selectrons and smuons, the effect of cascade decays for $\mu = -200$ GeV/c^2 and $\tan\beta = 2$, assuming no efficiency for the cascade decays is shown in the figure. The limit obtained for a stau mixing angle $\theta_{\tilde{\tau}} \simeq 52°$, is given as well.

The 95% C.L. bounds on the slepton masses for $\Delta M > 15$ GeV are summarized in table 5, (the values $\mu = -200$ GeV/c^2 and $\tan\beta = 2$ are used in case of selectrons), with the hypothesis of BR($\tilde{\ell}^{\pm} \to l^{\pm}\tilde{\chi}_1^0$)=1.

Observed and expected 95% C.L. bounds in the $m_{\tilde{e}_R}$ versus $m_{\tilde{\chi}^0}$ plane, obtained by the combination of all selectron selections are shown in figure 3d. They are calculated for tanβ=2.0 and μ=-200. The limit given by the $\tilde{e}_L\tilde{e}_R$-selections depends on the mass of the lefthanded selectron. The expected limit is below the observed one because of the deficit of events observed, compared to the background expectation.

The $\tilde{e}_L\tilde{e}_R$ selection yields a 95% C.L. bound on the selectron mass, independent of ΔM for tanβ=2.0 and μ=-200 of 75 GeV (74 GeV expected).

References

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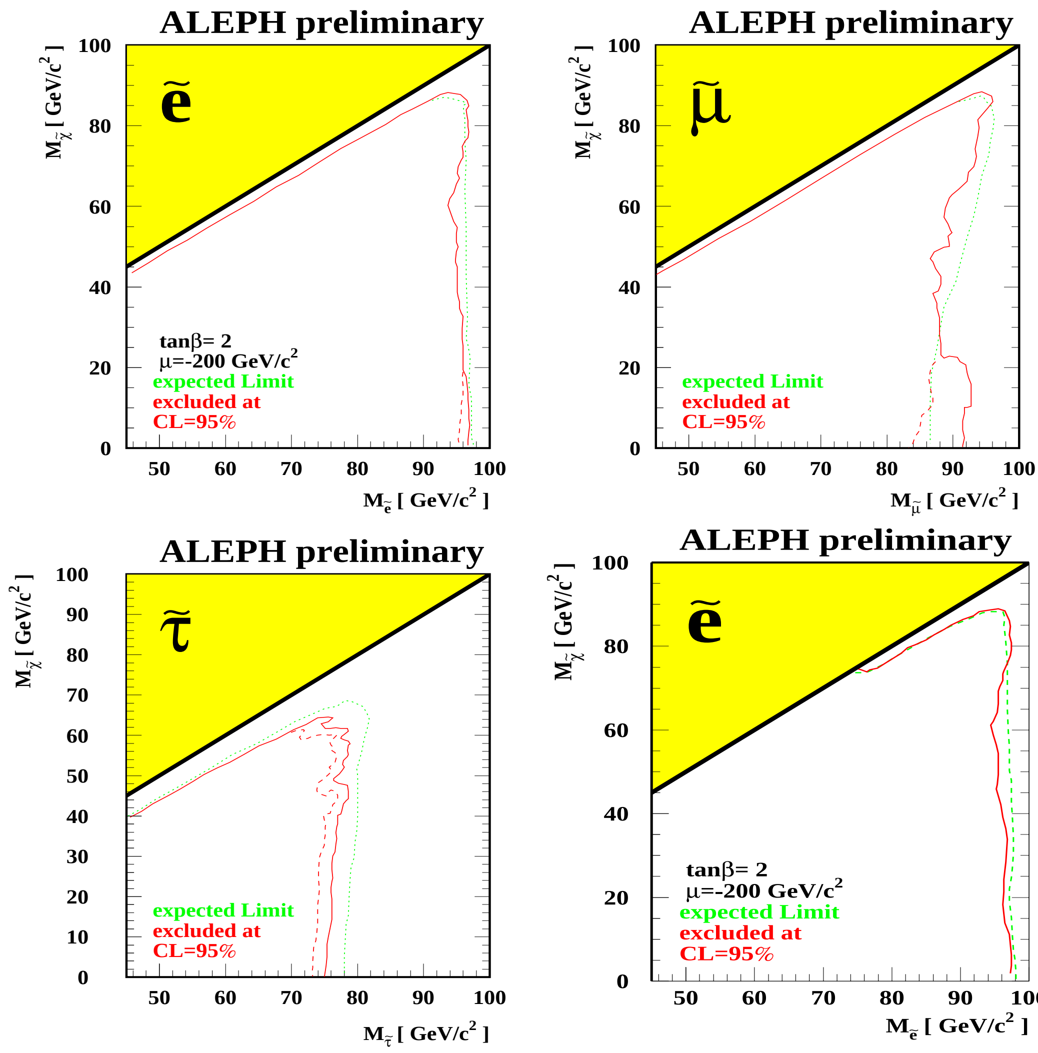

Figure 3: Excluded regions at 95% C.L. in the $m_{\tilde{\ell}_R}$ versus $m_{\tilde{\chi}_1^0}$ plane from slepton searches. The observed (full lines) and the expected (dotted lines) limits are given. For selectrons and smuons, the dashed lines give the limits in case of cascade decay of the slepton, using the hypothesis $\mu = -200$ GeV$/c^2$ and $\tan\beta = 2$. For the staus, the dashed line gives the limit obtained for a stau mixing angle $\theta_{\tilde{\tau}} \simeq 52°$. For the slepton exclusion plot (d) the $\tilde{e}_L\tilde{e}_R$ production for $\mu = -200$ GeV$/c^2$ and $\tan\beta = 2$ is included.