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Lower Mass Limit for the MSSM - selectron with the ALEPH detector

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PRELIMINARY

Abstract

The negative results of the searches for selectron, chargino and neutralino production, performed using data collected up to 201.6 GeV, are interpreted in the framework of the minimal supersymmetric model with R-parity conservation. Assuming gaugino mass unification, scalar mass unification, no slepton mixing and negligible squark mixing, a lower limit of the selectron is set at 72 GeV/c^2 at 95% confidence level.

(ALEPH contribution to the 2000 Summer Conferences)

1 Introduction

For the present note, the negative results of the searches for selectron, chargino and neutralino production, performed using data collected up to 201.6 GeV [1], are interpreted in the framework of the minimal supersymmetric model with R-parity conservation. Assuming gaugino mass unification, scalar mass unification, no slepton mixing and negligible squark mixing, a scan on the four remaining parameters m_0, M_2, μ and $\tan\beta$ was made for $1 \leq \tan\beta \leq 35$ and $1000 \geq \mu \geq -1000$ to derive a lower limit on the mass of the selectron. A similar study was performed by L3 [2].

The same notations and conventions as in ref.[1] are used for the MSSM parameters. Masses and couplings of the relevant supersymmetric particles are calculated at tree level. For charginos and neutralinos they are entirely determined by the parameters M_2, μ and $\tan\beta$. The slepton masses are determined using the renormalization group equations with the addition of the parameter m_0 representing a common SUSY breaking mass for all sleptons at the grand unification scale. As a reminder, the masses for sleptons can be given as

$$m^2_{\tilde{l}_R} = m_0^2 + 0.22M_2^2 - M_Z^2 \cos 2\beta \sin^2\theta_W \quad (1)$$

$$m^2_{\tilde{l}_L} = m_0^2 + 0.75M_2^2 - M_Z^2 \cos 2\beta \,(\frac{1}{2} - \sin^2\theta_W) \quad (2)$$

$$m^2_{\tilde{\nu}} = m_0^2 + 0.75M_2^2 + M_Z^2 \cos 2\beta \frac{1}{2}\,. \quad (3)$$

2 Impact of direct searches for selectrons

The results for the direct search for pair produced selectrons of equal and of different masses are given in [1]. The basic idea of these analyses [3, 4] is briefly described here. It is assumed that each selectron decays directly into a $\tilde{\chi}^0_1$ and an electron. No efficiency for cascade decays is assumed. This leads to a topology of two acoplanar electrons. The minimal and maximal momenta of the electrons are a function of the mass hypothesis ($m_{\tilde{\chi}^0}$, $m_{\tilde{e}}$), and therefore a sliding cut on the electron momenta is performed.

Combinations of SUSY-parameters where the mass difference (Δm) between the neutralino $\tilde{\chi}^0_1$ and the right handed selectron $\tilde{e}_R$ is small are not accessible by direct search for pair produced selectrons of equal masses. This is because the efficiency for a pair of right handed selectrons is vanishing due to the vanishing momenta of the produced electrons and left handed selectrons are too heavy to be produced in pairs. These regions can be covered by direct search for pair produced selectrons with different masses (left-right production). This leads to asymmetric acoplanar topologies, and, for very small Δm , to an effective single electron topology, since the electron coming from the right handed selectron has a too small energy to be seen.

The main background for the acoplanar selection is WW-production, which is the sole subtracted background. The main background for the single electron topology coming from $We\nu$ and Zee processes is subtracted in deriving limits.

3 Impact of direct searches for charginos

Combinations of SUSY-parameters where selectrons decay in cascades usually imply a light chargino. The analyses of the direct search for chargino pair-production are described in [1, 5]. If the chargino decays into the neutralino (called three-body decay), three different topologies are possible: hadronic (4 jet and missing p_{t}), semileptonic (2 jets, 1 lepton and missing p_{t}), or fully leptonic (two acoplanar leptons). Sliding cuts as a function of the mass difference between $\tilde{\chi}^{\pm}$ and $\tilde{\chi}^{0}$ are applied. The decay of the chargino into the sneutrino (called two-body decay) also leads to an acoplanar leptons topology similar to the selectron-pair-production, but different lepton flavours in the final state are possible.

For low mass differences between chargino and sneutrino, the search for charginos decaying in sneutrino and lepton is insensitive because of a nearly invisible final state due to low lepton momenta. If the branching ratio into the neutralino is not high enough at such a point, this point cannot be excluded by chargino searches. This is called "corridor between three- and two-body charginos". The main background for the chargino searches is WW-production, which is subtracted.

4 Dedicated searches for neutralinos

In a small region at low $\tan\beta$ ($\tan\beta < 1.5$) and low $|\mu|$ ($|\mu| < 60$), charginos are not able to cover a region of cascade decays of the selectrons because of the corridor between three- and two-body charginos. This region can be divided into two parts, one with $m_{\tilde{e}_{\mathrm{R}}} < m_{\tilde{\chi}_2^0}$, the other with $m_{\tilde{e}_{\mathrm{R}}} > m_{\tilde{\chi}_2^0}$. An example for this is shown in figure 1.

The first part contains only points with a very small mass difference between the right handed selectron and the lightest neutralino. Other points are covered by the acoplanar electrons analysis decribed in section 2. This first part is excluded by a dedicated analysis described in section 4.4.

In the second part of this region the $\tilde{\chi}_2^0$ decays mainly into $\tilde{\chi}_1^0$ and two leptons or into $\tilde{\chi}_1^0$ and a photon. This region is excluded with at least one of the analyses presented in section 4.1, 4.2 and 4.3.

4.1 search for neutralinos with leptonic final states

This analysis addresses final states mode of acoplanar electrons or muons in a general way and is based on the acoplanar lepton analysis used for the leptonic chargino decays. It is introduced in [1]. A sliding cut on the sum of the two lepton energies is made depending on the mass difference of the neutralino decay cascade that produces the lepton pair. The main background of this is WW-production.

4.2 search for $\tilde{\nu}\tilde{\nu} \to \tilde{\chi}_1^0\tilde{\chi}_2^0$

The crosssection σ_{Prod} for $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ - production vanishes in the region which is treated within this paper. However, $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ - production is possible in an indirect way by producing $\tilde{\nu}\tilde{\nu} \to \tilde{\chi}_1^0\tilde{\chi}_2^0\nu\nu$. The $\tilde{\chi}_2^0$ decays into two leptons: $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0$ll. To search for this, an analysis based on the acoplanar lepton analysis, which is used for chargino and slepton searches, has been developed. The analysis has been reoptimized for the fact that, in contrast to chargino and slepton searches, both visible leptons come from the same SUSY-Particle. The $\bar{N}_{95}$ prescription [6] was used for this optimization. A list of all cuts can be found in table 1. Some of these cuts are a function of the mass difference between $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$, $\Delta M = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$. Background expectation and number of candidates found in $\int L\,dt$ =173.6pb^{-1} at $\sqrt{s}$ =189 GeV taken with the ALEPH-detector are shown as a function of ΔM in figure 2. The efficiency for this analysis is obtained by producing $\tilde{\nu}\ \tilde{\nu}$ - Monte Carlo in every interesting point and depends mostly on ΔM.

4.3 search for radiative cascade decays of selectrons

This analysis is developed for the search for $\mathrm{e^+e^-} \to \tilde{\mathrm{e}}_\mathrm{R}\tilde{\mathrm{e}}_\mathrm{R}$ with $\tilde{\mathrm{e}}_\mathrm{R} \to \tilde{\chi}_2^0\,\mathrm{e}$ and $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\,\gamma$, described in detail in [7]. The acoplanar selectron analysis [4] is modified in the following way: two isolated photons are additionally demanded, no neutral veto is made and the cut onto the lepton momenta is tightened to 40% $\sqrt{s}$ against background from bhabha events. No candidate was found in the data taken by the ALEPH detector at $\sqrt{s}$ = 188.6 GeV with a luminosity of $\int L\,dt$ = 173.6 pb^{-1} while a background of 0.36 events was expected. The efficiency is larger than 25% for $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} > 0.5\,\mathrm{GeV}/c^2$. Lower mass differences are covered by the normal acoplanar electron analysis.

4.4 search for $\tilde{\chi}_1^0\ \tilde{\chi}_3^0$ production with low $m_{\tilde{\mathrm{e}}_\mathrm{R}}$ -$m_{\tilde{\chi}^0}$

A special analysis is required for the search of $\tilde{\chi}_1^0\tilde{\chi}_3^0$ with low $m_{\tilde{\mathrm{e}}_\mathrm{R}} - m_{\tilde{\chi}_1^0} = \Delta m$ in the interesting region since the $\tilde{\chi}_3^0$ decays mainly as $\tilde{\chi}_3^0 \to \tilde{\mathrm{l}}_R l$ and the $\tilde{\mathrm{l}}_R$ decays into a low momentum lepton and $\tilde{\chi}_1^0$. This leads to a asymmetric acoplanar lepton topology very similar to the one presumed in the case of $\tilde{\mathrm{e}}_{\mathrm{R}}$ $\tilde{\mathrm{e}}_{\mathrm{L}}$ - production (see section 2).

For $\Delta m > 0.7$ GeV/c^2 , the momentum of the boosted second lepton is high enough (in average 1 GeV) to be well identified. For these points the standard acoplanar lepton analysis which requires two lepton tracks is adapted to the $\tilde{\chi}_1^0\tilde{\chi}_3^0$ topology by an additional cut on the second lepton: its momentum is required to be lower than 0.75 time the maximum allowed momentum for signal decays. in order to reduce the remaining background consisting mainly of WW production, bhabha and $\gamma\gamma$ events. When applying this cut, for $\Delta m = 3.6$ GeV/c^2 in $\int L\,dt$ =173.6pb^{-1} at $\sqrt{s}$ =189 GeV 37.8 background events are expected, 41 candidates are seen.

For $\Delta m < 0.7$ GeV/c^2 the momentum of the second lepton is lower than 2 GeV. This leads to a reduced efficiency of the acoplanar lepton selection. The single electron analysis [4] is more efficient for these points. It requires a high energetic electron and no second charged track with transverse momentum larger than 0.5% $\sqrt{s}$.

Figure 3 shows $\bar{N}_{95}$ values [6] for both selections at $\sqrt{s}$ = 189 GeV obtained for $\tan\beta = 1.1$, $\mu = -50$ and different M_2 and m_0. The efficiency for this analysis is obtained by producing $\tilde{\chi}_1^0$ $\tilde{\chi}_3^0$ - Monte Carlo for every interesting point. The expected background for WW production is substracted in the modified acoplanar lepton selection, while in case of the single track analysis the expected Zee and Weν background is substracted.

5 Results

As it turns out the limit on $m_{\tilde{\mathrm{e}}_{\mathrm{R}}}$ coming from direct searches for $\tilde{\mathrm{e}}_{\mathrm{R}}$ $\tilde{\mathrm{e}}_{\mathrm{R}}$ (see section 2) is nearly constant over the scanned SUSY-parameter if the mass difference between $\tilde{\mathrm{e}}_{\mathrm{R}}$ and $\tilde{\chi}^0$ is large enough and no cascade decay occures. This is because σ_{Prod} depends mainly on $m_{\tilde{\chi}^0}$ and $m_{\tilde{\mathrm{e}}}$ and the background expectation is also mainly a function of $m_{\tilde{\chi}^0}$ for a given $m_{\tilde{\mathrm{e}}}$ in such a way that both dependencies are canceling each other for a given $m_{\tilde{\mathrm{e}}_{\mathrm{R}}}$. At low mass differences, the limit comes usually from the search for $\tilde{\mathrm{e}}_{\mathrm{R}}$ $\tilde{\mathrm{e}}_{\mathrm{L}}$, which is also nearly constant unless there are cascade decays.

The only effect which can cause a breakdown of the limit at a certain SUSY-point are cascade decays of either the right-handed selectron in general or the left-handed selectron at low mass differences. This may happen if $\tilde{\chi}_2^0$ becomes lighter than the selectrons. In this case, charginos are also light and so this region is usually excluded by chargino searches (see section 3).

Points where the chargino analyses fail to cover cascade decays of the selectrons due to the corridor between 2- and 3-body charginos are covered by dedicated analyses described in section 4.

Since the right-handed selectron is always lighter than the left-handed one for $\tan\beta > 1$ (see eqn.(1) and (2)), and there is no mixing between right handed and left handed selectron, the absolute limit on the selectron mass is given by the absolute limit on the right-handed selectron mass. In figure 4, the limit on the mass of the right-handed selectrons is shown as a function of $\tan\beta$. Each point is representing the result of a loop over μ, M_2 and m_0 . For low $\tan\beta$, the limit comes from searches for $\tilde{e}_R\ \tilde{e}_L$, because low mass differences between $\tilde{e}_R$ and $m_{\tilde{\chi}^0}$ are allowed and the kinematic limit for this process is at lower masses of the right-handed selectron. For high $\tan\beta$, the limit is given by direct searches for $\tilde{e}_R\ \tilde{e}_R$, because low mass differences are theoretically forbidden (negative squared masses of the scalars at GUT-scale m_0^2). The overall limit of $m_{\tilde{e}} > 72\,\mathrm{GeV}/c^2$ is found at $tanb = 1.5$ and $\mu = -80.0$.

6 Conclusion

Assuming gaugino and scalar mass unification, no slepton mixing and negligible squark mixing, a scan in the 4 fundamental parameter of the minimal supersymmetric model with R-parity conservation, $\tan\beta, \mu, M_2$ and m_0 is performed to achieve a limit on the selectron mass independent of these four parameters. Regions where the direct searches for selectron-pair production are not efficient were excluded by searches for charginos and dedicated searches for neutralinos.

For this document the negative results of the searches for selectron, chargino and neutralino production, are interpreted which were performed using data collected up to 201.6 GeV.

A lower limit of 72 GeV/c^2 at 95% C.L. on the mass of the selectron in this scenario can be set for $1 \leq \tan\beta \leq 35$ and $1000 \geq \mu \geq -1000$.

References

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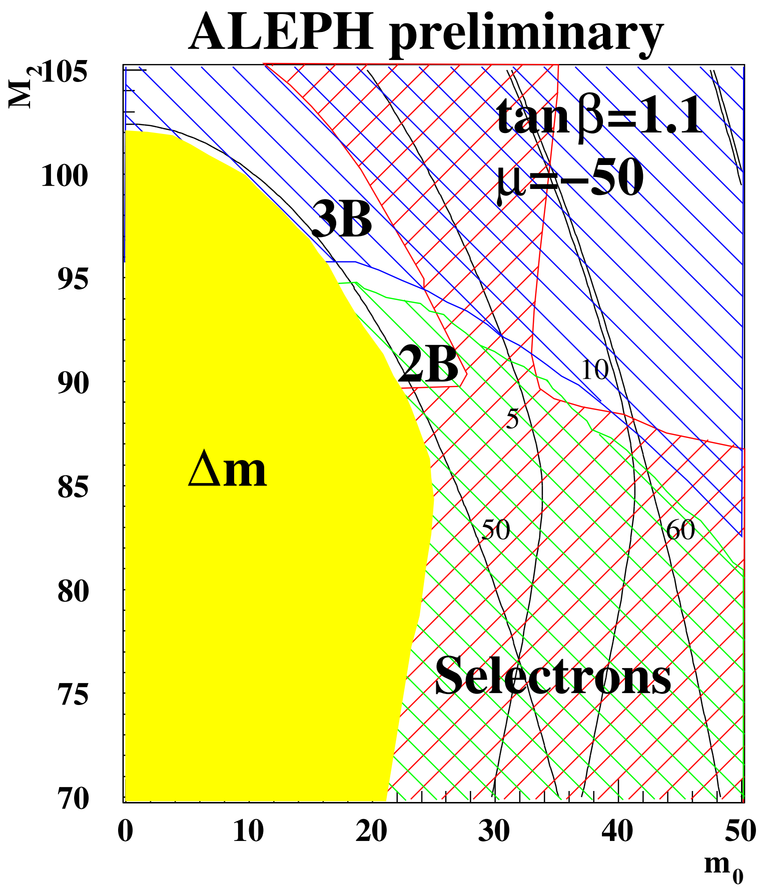

Figure 1: Exclusion domains for 2-body and 3-body charginos (hatched downwards) and selectrons (hatched upwards) in the M_2 -m_0 -plane (in GeV/c^2) for $\tan\beta$ =1.1 and μ =-50 GeV/c^2 . The thin lines show $m_{\tilde{e}_R} = 50, 60$ and $\Delta m = 5, 10$ (in GeV/c^2). The light shaded region is theoretically forbidden (the selectron is the LSP). One can clearly recognize the corridor between 2- and 3-body-charginos, divided into two parts by the selectron-exclusion-conture.

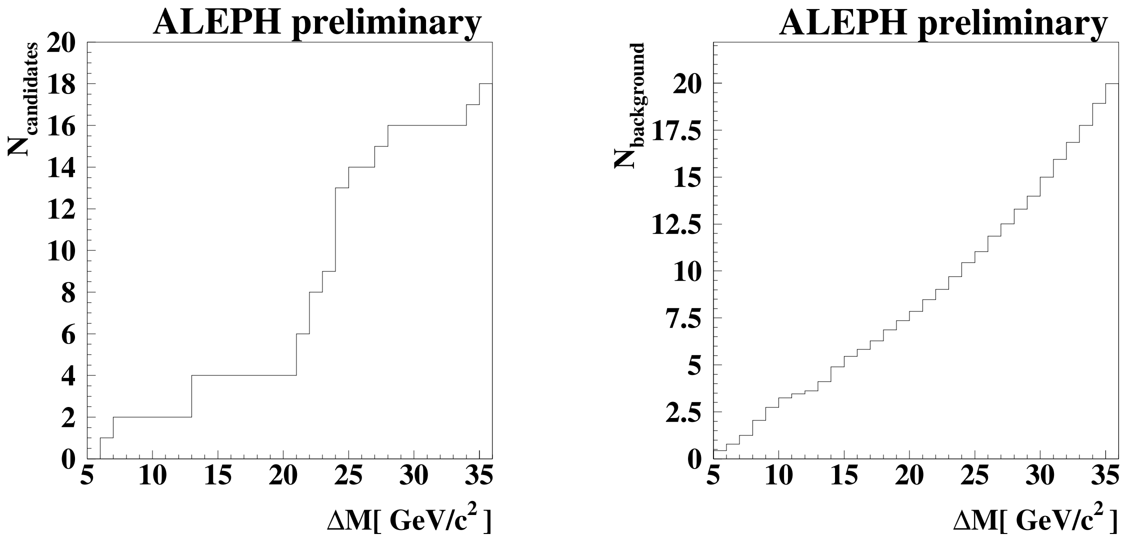

Figure 2: Candidates found in $\int L\,dt$ =173.6pb^{-1} at $\sqrt{s}$ =189 GeV and expected background of the $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ - analysis as a function of Δm

	$\Delta M < 10\,\mathrm{GeV}/c^2$	$\Delta M \geq 10\,\mathrm{GeV}/c^2$
charged tracks	2 identified leptons	
visible mass	$M_{\mathrm{vis}} > 4\ \mathrm{GeV}/c^2$	
neutral veto	$\surd$	
energy in 12°	$E_{12^\circ} = 0$	
acoplanarity	$\phi_{\mathrm{Ako}} < 170^\circ$	
acollinearity	$\alpha > 2^\circ$	
missing transversal momentum	$p_{\mathrm{T}}^{\mathrm{miss}} > 3\%\sqrt{s}$	
ρ	$\rho > 2\ \mathrm{GeV}/c$	
lepton momentum	$p_1, p_2 < 46.5\%\sqrt{s}$	
visible mass	≤ 10	$\leq \Delta M$
total energy	$\leq \Delta\mathrm{M} \cdot 4$	$\leq (\Delta M - 10)\cdot\ 0.8 + 40$
energy of leading lepton	$\leq \Delta\mathrm{M} \cdot 2.5$	$\leq (\Delta M - 10)\cdot\ 0.7 + 25$
energy of second lepton	$\leq \Delta\mathrm{M} \cdot 1.5$	$\leq (\Delta M - 10)\cdot\ 0.44 + 15$
acoplanarity	$\leq \Delta\mathrm{M} \cdot 14^\circ$	$\leq (\Delta M - 10)\cdot 0.7^\circ + 140^\circ$
acollinearity	$\leq \Delta\mathrm{M} \cdot 13^\circ$	$\leq (\Delta M - 10)\cdot 0.9^\circ + 130^\circ$

Table 1: Cuts of the $\tilde{\chi}_1^0\ \tilde{\chi}_2^0$ - analysis. Energies are given in GeV, masses in GeV/c^2 .

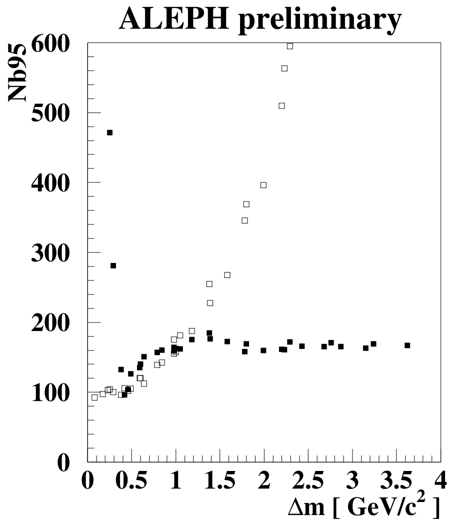

Figure 3: $\bar{N}_{95}$ as a function of Δm for single track analysis (empty boxes) and acoplanar lepton analysis (filled boxes) for $\tilde{\chi}^0_1\ \tilde{\chi}^0_3$ production at small Δm . Expected signal: N = 243. [$\tan\beta = 1.1$, $\mu = -50$]

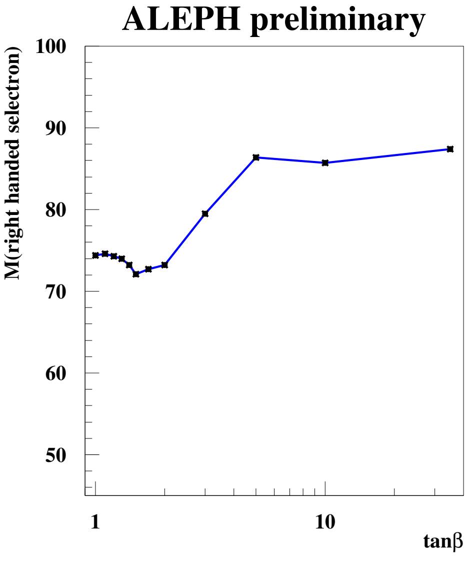

Figure 4: Limit on the mass of the selectron as a function of $\tan\beta$. Each point represents the minimum of all scanned values of μ , M_2 and m_0 .