Search for Charginos and Neutralinos with the ALEPH experiment at LEP II

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Abstract: The search for charginos and neutralinos performed with the data collected by the ALEPH detector at centre-of-mass energies from 188.6 GeV to 201.6 GeV is presented. No signal from supersymmetry has been found. This negative result, together with negative results coming from sfermion searches, is translated into exculsion in the CMSSM model parameter space and allows to set a lower limit on the mass of the neutralino at 37 GeV/c^2 at 95 % C.L., independently of $tan\beta$ and of the sfermions masses. Additional bounds on the neutralino mass, coming from the results of the Higgs search are given.

1. Introduction

Supersymmetric extensions of the Standard Model result in additional fields which are supersymmetric partners of the Standard Model fields. Two doublets of complex scalar fields are introduced to give masses to the up-like and down-like fermions via the Higgs mechanism. The ratio of the two vacuum expectation values is denoted tanβ and the Higgs mass term is μ. The mass of the susy partners are driven by the SUSY breaking terms : Gaugino masses M1, M2 and M3 associated to the U(1), SU(2) and SU(3) gauge group respectively, sfermion mass terms m_i and trilinear couplings A_i (i=1,2 or 3). The gaugino and the higgsinos mix to form the charginos and the neutralinos.

The results presented in this proceeding are given in the CMSSM framework. In this framework, the number of additional fields is minimal and some constraints on the above parameters are imposed:

The gaugino masses are assumed to unify at the GUT scale, leading at the electroweak scale to the relation : $M_1 = \frac{5}{3}tan^2\theta_W M_2$. The masses of the sfermions unify at GUT scale with the value m_0 as well as the trilinear coupling with the value A_0.

Another restriction concern the R-parity: This multiplicative symmetry, which allows to distinguish standard particle from their superpartner, is assumed to be conserved. This assumption ensure that there is no lepton nor baryon number violation. As a consequence, the lightest supersymmetric particle (neutralino), called the LSP, is stable and sparticles are produced by pairs.

Charginos (neutralinos) are produced by pair via virtual photon or Z exchange in the s-channel and neutrino (selectron) exchange in the t-channel (respectively). For the chargino the interference between s and t is generally constructive while it is destructive for neutralinos. As a consequence, cross sections are higher (lower) if sneutrino (selectron) are light (respectively).

Chargino decays to a neutralino and lepton-neutrino or quark-antiquark pair.

For large m_0 (large sfermion masses), the decays proceed mainly through the exchange of a virtual W. The dominant topologies are then hadronic events with missing energy called four jets topology (4J) or events with hadrons, an isolated lepton and missing energy (2JL) or acoplanar jets (AJ).

*on behalf of the ALEPH collaboration.

Sample	1998	1999	1999	1999	1999
$\sqrt{s}$ (GeV)	188.6	191.6	195.6	199.6	201.6
Lumi (pb-1)	173.7	28.9	79.8	86.3	42.0

Table 1: Details of the analysed data sample

Selection	1998		1999	
	Data	Bkg	Data	Bkg
Chargino (heavy sfermions)	10	8.3	9	12.7
Chargino (light sfermions)	25	23.0	24	33.9
Neutralino (heavy sfermions)	4	3.0	6	4.5
Neutralino (light sfermions)	59	60.0	76	79.8

Table 2: Number of data candidates selected and background events expected from Standard Model processes for the charginos and neutralinos selections

The selections are optimized for various ΔM ranges, where ΔM is the mass difference between the lightest neutralino ($\tilde{\chi}$) and the chargino ($\tilde{\chi}^{\pm}$) or second lightest neutralino ($\tilde{\chi}^{'}$).

The background is coming from many different two fermion and four fermion final states having missing energy. The dominant Standard Model background vary significantly with the ΔM range considered.

The selections used are identical to those presented in Ref [2] except for the exact position of the cuts which have been reoptimized to give the best sensitivity with the new energy range of the data sample.

2. Results

The search has been performed with the data collected by the ALEPH detector during 1998 and 1999 at centre-of-mass energies ranging from 188.6 GeV to 201.6 GeV. Details about the data sample are given in table 1.

The numbers of events observed and expected from Standard Model processes, after the various selections are applied, are reported in table 2.

The numbers of candidate events are consistent with the expected background from Standard Model. This negative result is then used to derive an exclusion in the the CMSSM parameter space.

3. Limits

For large m_0, the negative search result can be expressed in the (μ,M_2) plane of the CMSSM as shown in Fig 1 for $tan\beta = \sqrt{2}$.

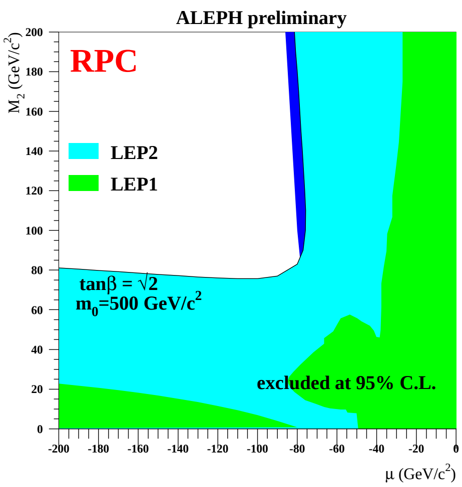

Figure 1: Limits in the (μ,M_2) plane from chargino and neutralino search, for $m_0 = 500$ GeV/c^2 and $tan\beta = \sqrt{2}$. The dark grey region corresponds to LEP 1 exclusion, the light grey is the exclusion from chargino search and the black region is the additional exclusion coming from neutralino search.

This result can also be interpreted to set a lower limit on the chargino mass as shown in Fig 2.

In the negative μ region, the chargino search can exclude masses close to the kinematical limit (in the direct production mode) except in the deep higgsino region (high M_2). In this region, the ΔM value is very small with consequent low

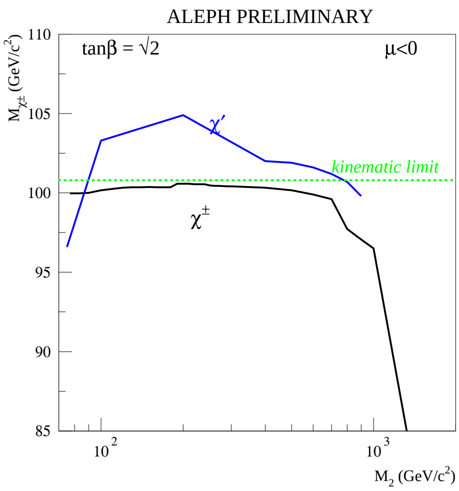

Figure 2: Mass limits on chargino using direct search ($\tilde{\chi}^{\pm}$) or using neutralino search ($\tilde{\chi}^{'}$), as functiun of the M_2 gaugino mass parameter.

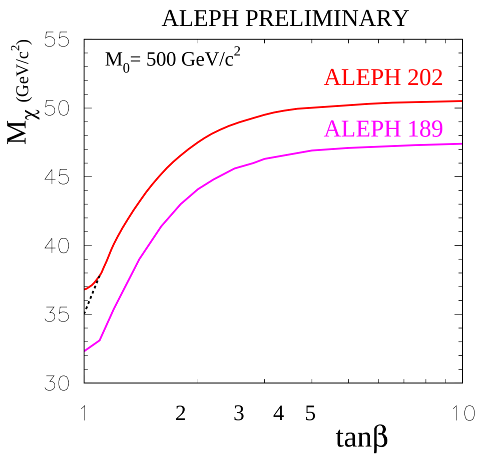

Figure 3: Mass limits on the neutralino as function of $tan\beta$ and for high m_0, using chargino and neutralino searches. The dotted line corresponds to the limit obtained using only chargino search.

efficiency for the selection.

As shown in Fig 2, the neutralino search can extend the mass limit from the direct chargino search beyond its kinematical limit in almost all the M_2 range.

The exclusion in the (μ,M_2) space allows to set a limit on the neutralino mass as function of $tan\beta$ (Fig 3). The neutralino mass limit, for high m_0, is found to be $m_{\tilde{\chi}} > 37$ GeV/c^2.

This $\tilde{\chi}$ mass limit is no longer valid if m_0 is low. In such a case, a corridor is open in the (μ, M_2) plane when there is a degeneracy between $m_{\tilde{\nu}}$, $m^{\pm}_{\tilde{\chi}}$ and $m_{\tilde{\chi}'}$. For such a case, the decays $\tilde{\chi}^{\pm} \rightarrow \tilde{\nu}l^{\pm}$ or $\tilde{\chi}^{'} \rightarrow \tilde{\nu}\nu$ are almost invisible and the selection efficiencies are too low to set an exclusion.

To extend the neutralino mass limit for the low m_0 range, it is possible to use the limit coming from the slepton and Higgs searches. This is discussed in the next session.

4. Overview of sfermions and Higgs searches

The selection and search strategies are presented in Refs [1],[3]. The number of candidate events and background for the 1999 data are reported in table 3.

Selection	1999	
	Data	Bkg
$\tilde{e}$	42	48.1
$\tilde{\mu}$	39	43.4
$\tilde{\tau}$	46	32.7
$\tilde{t} \rightarrow c\tilde{\chi}$ $(low\Delta M)$	2	1.9
$\tilde{t} \rightarrow c\tilde{\chi}$ $(high\Delta M)$	8	6.5
$\tilde{b} \rightarrow b\tilde{\chi}$ $(low\Delta M)$	1	0.9
$\tilde{b} \rightarrow b\tilde{\chi}$ $(high\Delta M)$	1	1.8
$\tilde{t} \rightarrow bl\nu$ $(low\Delta M)$	3	1.8
$\tilde{t} \rightarrow bl\nu$ $(high\Delta M)$	2	1.3

Table 3: Number of data candidates and background events expected from Standard Model processes

The data and expectation from Standard Model are in good agreement. A slight excess is observed in the acoplanar tau search. The probability that this excess comes from an upward fluctuation of the background is 1.6%.

The corresponding exclusion plots can be found in Fig 4 to 6.

The MSSM higgs search allows to set limits in the $(M_h, tan\beta)$ plane and exclude a $tan\beta$ range around [0.8 - 1.2] as shown in Fig 7.

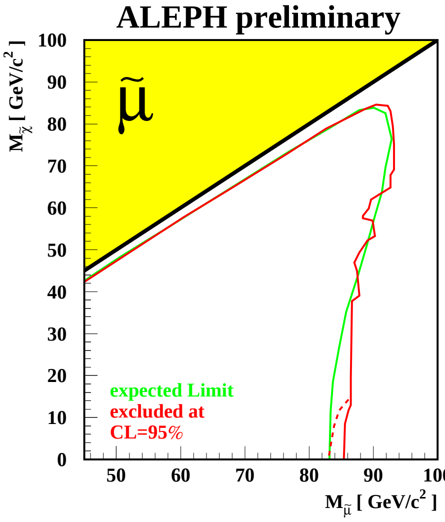

Figure 4: Exclusion in the $(M_{\tilde{\chi}}, M_{\tilde{\mu}})$ plane, from direct $\tilde{\mu}$ search.

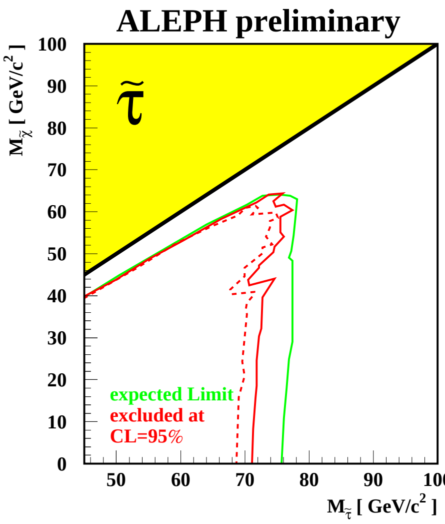

Figure 5: Exclusion in the $(M_{\tilde{\chi}}, M_{\tilde{\tau}})$ plane, from direct $\tilde{\tau}$ search.

5. Improved neutralino mass limit

Using the slepton search, the corridor in the (μ, M_2) plane found for low m_0 and discussed in section 3, can be excluded. As a consequence, a limit on the neutralino mass can be set for any m_0. The result is that the limit set at high m_0 remains

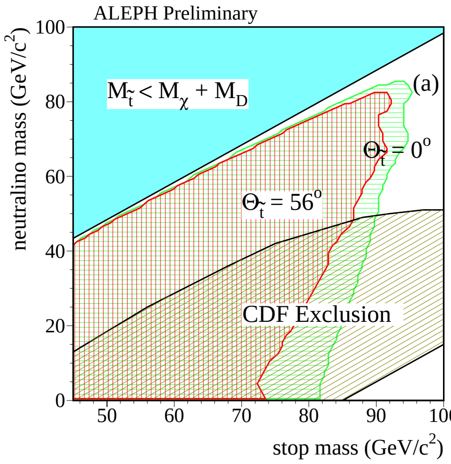

Figure 6: Exclusion in the $(M_{\tilde{\chi}}, M_{\tilde{t}})$ plane, from direct $\tilde{t}$ search.

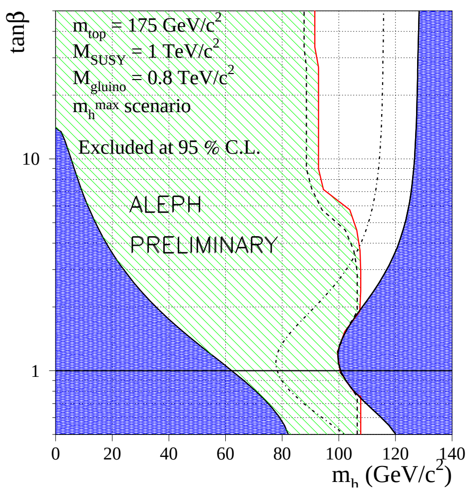

Figure 7: Exclusion in the $(tan\beta, M_h)$ plane. The dark regions are theoretically forbidden.

valid at low m_0: $m_{\tilde{\chi}} > 37$ GeV$/c^2$.

It is also possible to use the limit coming from the Higgs search to extend further the neutralino mass limit, as described in Ref [4]. These different improvements are shown in Fig 8.

The limits are then : $m_{\tilde{\chi}} > 45$ GeV$/c^2$ for $tan\beta < 3$ and $m_{\tilde{\chi}} > 38$ GeV$/c^2$ for any $tan\beta$. (This result assume $m_t = 175$ GeV$/c^2$ and $m_0 < 1$ TeV/c^2).

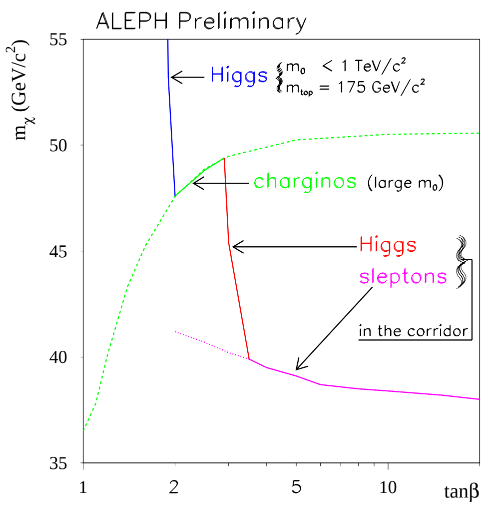

Figure 8: Neutralino mass limit as function of $tan\beta$

6. Conclusion

Searches for charginos and neutralinos with the ALEPH detector indicates no signal from supersymmetry.

This allows to set limit on the masses of the charginos and neutralinos, under certain assumptions. For $M_2 < 400$ GeV, $m_{\tilde{\chi}^\pm} > 100$ GeV.

By including searches for sfermions and Higgs, it is possible to set a limit on the neutralino independent of m_0 and $tan\beta$: $m_{\tilde{\chi}} > 38$ GeV/c^2 and a limit as strong as $m_{\tilde{\chi}} > 45$ GeV/c^2 for $tan\beta < 3$.

Acknowledgments

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References

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[3] ALEPH Coll., "Search for neutral Higgs bosons in e^+e^- collisions at centre-of-mass energies from 192 to 202 GeV", ALEPH contribution to 2000 conferences, ALEPH 2000-006/CONF 2000-003, ICHEP-2000 abstract 258.

[4] ALEPH Coll., "LSP Mass Limit in the MSSM with Higgs Search Constraints", ALEPH contribution to 2000 conferences, ALEPH 2000-019/CONF 2000-016.