SUPERSYMMETRIC DARK MATTER IN THE LIGHT OF LEP

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Abstract

The negative outcome of searches for supersymmetry performed at LEP have been used to derive indirect constraints on the parameters of the most plausible models for cold dark matter based on supersymmetric extensions of the Standard Model. The main results are summarized.

Introduction. The sensitivity of accelerators searches for new particles to possible solutions for the *Cold Dark Matter* (CDM) problem has been pointed out in Ref. [1]a. In the following we will enumerate the achievements which can be ascribed to the interpretation of the LEP results. A discussion of the experimental problematics can be found in Ref. [2]. We assume the reader being familiar with the naming scheme and the basic concepts intervening in supersymmetric models of elementary particles.

Supersymmetric CDM candidates. We consider two models: a generic Minimal Supersymmetric extensions of the Standard Model (MSSM, see [3]), with R-parity conservation and unification of gaugino and scalar masses at unification scale, and a more constrained version of it (CMSSM or mSUGRA) in which the electroweak vacuum is required to be consistent with the unification relation, and the Higgs boson masses and the scalar trilinear couplings to unify at grand scale. There are two possible situations in which the Lightest Supersymmetric Particle (LSP) is a interesting CDM candidate [1]: *i)* the LSP is a *sneutrino*, $\tilde{\nu}$, with mass in the ranges $M_{\tilde{\nu}} \sim$few GeV/c^2 or $M_{\tilde{\nu}}$ in [550,2300] GeV/c^2 ([4]); the latter range is excluded by direct searches ([5]); *ii)* the LSP is the *lightest neutralino*, χ_1^0 (a flexible candidate: see, for instance, Ref. [1]b and references therein).

The first LEP result. The agreement with the predictions of the most recent determination of the Z widths ([6]) sets 95% confidence level upper limits of 6.2 and 1.7 MeV on new contributions to the total and invisible Z widths, respectively. Consequently, *sneutrinos masses up to about 40 GeV/c^2 are excluded definitely ruling out the sneutrino as supersymmetric candidate for CDM*; this is a good example of complementarity between indirect and direct searches.

The second LEP result. The interplay of the most recent results of LEP searches for supersymmetric particles (charginos, neutralinos, sleptons, squarks) is discussed in Ref. [7]. The absence of any convincing evidence for a signal so far has allowed only to derive constraints on the parameter space. Interpreted as an absolute lower limit on $m_{\chi_1^0}$, these look like in Figure 1a (from Ref. [8]): in the MSSM, *neutralino masses smaller than* $\sim$*40 GeV/c^2 are disfavoured.*

The third LEP result. Figure 1b shows the exclusion bounds as a function of the *higgsino* content [2] p of the χ_1^0 in the MSSM *the neutralino LSP cannot be predominantly higgsino* (see Ref. [1]b). This is in agreement with the predictions of the CMSSM.

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[1] Additional CDM contributions could come also from the gravitino; however, the impact of the LEP results on gravitino cosmology is marginal.

[2] Here $p = \sqrt{1 - c_\gamma^2 - c_z^2}$ with c_γ (c_z) the photino (zino) component.

The forth LEP result. The large radiative corrections to Higgs masses establish, in the CMSSM, a strong relation between the Higgs sector and the gaugino masses. Taking into account the cosmology constraint [3], the lower limit on the Higgs boson mass can be translated into a lower limit on the common gaugino mass $m_{1/2}$ as shown in Figure 1c. In the CMSSM, *tanβ value smaller than* ~ 5 *and neutralino masses smaller than* $\sim$*85 GeV/c*^{2} *are disfavoured* (see Ref. [1]c) [4].

Conclusions. The extensive searches performed at LEP for new phenomena have ruled out a large fraction of the MSSM parameter space interesting for CDM, basically limited only by the available centre-of-mass energy. In a CMSSM folded with the cosmology constraint, the LEP results are compatible with the excess observed in the measurement of the muon anomalous magnetic moment ([10]) only for μ positive and for a small region of the parameter space (Figure 1d, from Ref. [1]d). If confirmed, this excess may be seen as the first evidence for supersymmetry. A definite answer requires both a sizeable reduction of the uncertainty on hadronic contribution to the vacuum polarization ([10]) and *sparticle* detection at the LHC or at a TeV Linear Collider ([1]d).

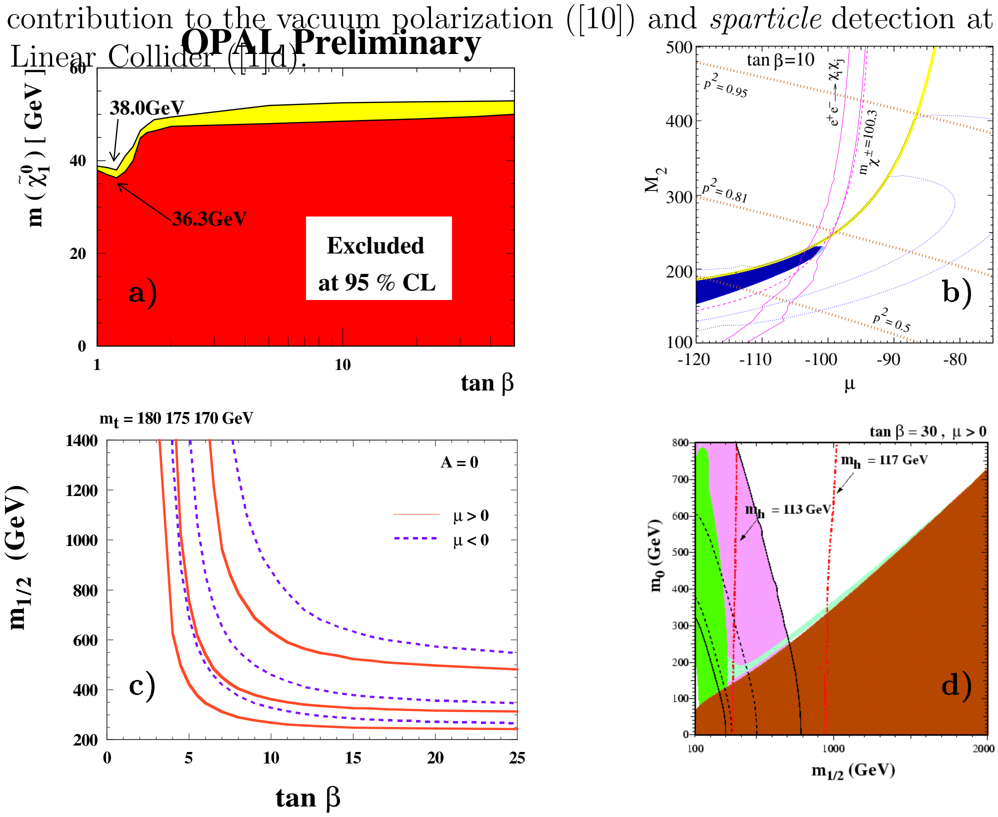

Figure 1: **a)** *Absolute limit on the* χ_1^0 *mass obtained by the OPAL collaboration in the MSSM using all the data sample; from Ref. [8].* **b)** *Allowed regions (dark gray domains) in the higgsino corner of the* μ, M_2 *plane for* $\tan\beta$ *=10; from Ref. [1]b.* **c)** *Lower bounds on* $m_{1/2}$ *from the Higgs search in the CMSSM for different model parameters; from Ref. [1]c.* **d)** *Consistency of LEP Higgs "signal" (vertical dash-dotted lines) with new measurement of (g-2)*$_\mu$ *(medium-light gray, dashed, full lines) in the CMSSM for* $\tan\beta$*=30 and* $\mu>0$*; from Ref. [1]d.*

[3] The requirement that the χ_1^0 relic density is in the right range.

[4] If the LEP "signal" [9] is confirmed, an upper limit can also be set.

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