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The status of supersymmetry phenomenology

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Abstract. In this brief review the following topics are discussed:

Direct searches for SUSY in mSUGRA: a brief review of the relevant mass limits, the clean trilepton signal, the hunt for the third generation of sfermions,
Direct searches beyond mSUGRA: search prospects in models with nonuniversal gaugino masses, search prospects in models with nonuniversal scalar masses,
Indirect searches for SUSY: precision electroweak observables and SUSY, ϵ'/ϵ and SUSY.

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1. Introduction

The searches for supersymmetry (SUSY) [1], an appealing alternative to the Standard Model (SM), have been enthusiastically carried out at all the leading high energy colliders in recent times. The negative results, in particular the ones obtained from various phases of LEP and Tevatron (Run-I), implied stringent lower limits on the sparticle masses [2]. The prospect of SUSY searches at the upgraded Tevatron (Run-II) [3] and at the large hadron collider (LHC) has also been studied in great detail [4]. The estimated sparticle mass reach of these colliders in various channels indicate that if such masses are indeed in the few TeV region, as is required by the SUSY solution of the hierarchy problem [1], then they are very likely to be discovered within the forseeable future.

In addition to the above direct searches, collecting indirect or circumstantial evidences in favour of SUSY have also attained wide attention. They arise due to production of virtual sparticles through one loop effects.

The purpose of this talk is to review some topics of current interest in direct and indirect SUSY searches.

In the first section we shall briefly summarise the existing direct limits on sparticle masses assuming a popular model (mSUGRA) based on $N = 1$ supergravity [5]. Next we shall focus our attention on SUSY searches beyond mSUGRA.

The indirect search for SUSY through the precision measurements of electroweak observables at LEP [6] is the next topic in our list. A recent fit reveals that these observables favour scenarios with relatively light gauginos and heavy sfermions, although the statistical significance of this result is rather modest [7].

It has now been conclusively established that direct CP violation in the kaon sector as revealed by a nonvanishing value of ϵ'/ϵ [8], is a fact of life. It is worth noting that the SM prediction for this quantity appear to be significantly below the central value of the data [9], although the large theoretical uncertainties in the calculations call for a cautious approach. It has also been pointed out by several groups that a relatively large ϵ'/ϵ can indeed be accommodated in a class of SUSY models [10]. This will be reviewed as the last topic.

2. Direct searches for SUSY in the conventional scenario

Unfortunately the most general [1] softly broken SUSY model (the minimal supersymmetric extension of the Standard Model (MSSM)), has too many free parameters. As a result most of the analyses of the direct search results are carried out by invoking additional theoretical assumptions, which restricts the number of parameters. In particular a model of soft SUSY breaking due to $N = 1$ supergravity [5], hereafter referred to as the conventional scenario or mSUGRA has been used most extensively.

In the conventional scenario it is assumed that all the scalars in the model, i.e. the left and right handed squarks ($\tilde{q}_L$ and $\tilde{q}_R$), the left and right handed sleptons ($\tilde{l}_L$ and $\tilde{l}_R$) and the Higgs bosons, have a common soft breaking mass (m_0) at the GUT scale (M_G). Moreover the gaugino masses and the trilinear soft breaking terms are also assigned common values, $m_{1/2}$ and A_0 respectively, at M_G. The parameters at the energy scale of interest ($\sim$ few hundred GeV) is determined by the usual renormalization group (RG) running [1].

The number of free parameters is further reduced by requiring radiative SU(2) $\times$ U(1) breaking at the electroweak scale [11]. This fixes the magnitude of the Higgsino mass parameter (μ). Thus m_0, $m_{1/2}$, A_0 along with the sign of μ and tanβ (the ratio of the vaccum expectation values of the two neutral Higgs bosons) define the model completely.

2.1 *A brief review of the relevant mass limits*

The strongest limits on the sparticle masses in the conventional scenario having bearings on the search prospects at Tevatron Run II are presented below.

The limit $M_{\widetilde{\chi}_1^\pm} > 95$ GeV [2] on the mass of the lighter chargino ($\widetilde{\chi}_1^\pm$) from LEP 2 is of special importance. This limit, in conjunction with the above assumption of gaugino mass unification [1], implies that the gluino ($\tilde{g}$) must be rather heavy with $m_{\tilde{g}} \geq 300$ GeV [12].

The limit on $M_{\widetilde{\chi}_1^\pm}$ becomes weaker if the $\widetilde{\chi}_1^\pm$ happens to be approximately degenerate with one of its decay products, either the lightest supersymmetric particle (LSP) assumed to be the lightest neutralino ($\widetilde{\chi}_1^0$), or with a sneutrino ($\tilde{\nu}$). In both the cases the $\widetilde{\chi}_1^\pm$ decays into nearly invisible soft particles. The first possibility is strongly disfavored in models with gaugino mass unification and radiative electroweak symmetry breaking. The second possibility occurs in mSUGRA models [1] for small values of m_0. However, a recent result from the DØ collaboration [12] ruled out $m_{\tilde{g}} < 300$ GeV for small m_0 from direct squark ($\tilde{q}$) and gluino ($\tilde{g}$) searches in the multi-jet + missing E_T channel.

If this is the case, gluino searches even after the main injector upgrade of the Tevatron (Tevatron Run II), with an estimated integrated luminosity of 2 fb^{-1} at $\sqrt{s}$ = 2 TeV, is not likely to improve the indirect limit on the gluino mass from LEP2 searches. This is especially so if the squarks happen to be much heavier than the gluinos ($m_{\tilde{q}} >> m_{\tilde{g}}$) (see §4.1). A further luminosity upgrade, amounting to an integrated luminosity $\sim$ 25 fb^{-1} at $\sqrt{s}$ = 2 TeV (hereafter referred to as TeV33), could reach somewhat higher but not dramatically different masses [3].

Under these circumstances it might be profitable to look for pair production of lighter electroweak gauginos [13]. Normally such processes have cross sections much smaller than that of gluino pair production via strong interaction. But when the latter process is kinematically suppressed the former indeed becomes the dominant one.

2.2 *The clean trilepton signal*

The production of $\widetilde{\chi}_1^{\pm} - \widetilde{\chi}_2^0$ (second lightest neutralino) pairs followed by their leptonic decays into e and μ, leads to the clean (jet free) trilepton + $\not\!\!E_T$ signature. Many groups have recently reemphasized this channel as the most promising one for SUSY searches at the upgraded Tevatron [14]. Some of the recent developments are summarized below.

The signal cross section in the next to leading order in QCD has been computed [15]. Typically the cross section is larger than the leading order cross section by 30%. Thus the mass reach in this channel may indeed be larger than the conservative estimates based mostly on leading order calculations [14]. The effect of the decay matrix elements on the computation of the lepton momenta have also been included in some recent modifications of the event generators (see the second paper of [14]).

Some groups have advertised the advantage of utilising the decays of the $\widetilde{\chi}_1^{\pm} - \widetilde{\chi}_2^0$ pairs into τ leptons [16] as well. This may significantly enhance the sensitivity of this channel. One can detect the τs either through their one prong or three prong hadronic decays. One can even exploit the leptonic decays of the τ by adopting softer p_T cuts on the final state leptons.

The inclusion of the τs in the trilepton signal is very crucial in certain variations of the conventional scenario with large tan β leading to relatively large b and τ Yukawa couplings. Due to RG running driven by this coupling the staus may happen to be the lightest among the sleptons. As a result stau mediated gaugino decays into τs may indeed be the dominant decay process.

A recent and rather unexpected development [17] has undermined the position of the trilepton signal as the most promising channel for SUSY search at the upgraded Tevatron. It has been pointed out that a very serious background coming from W$-\gamma^*/Z^*$ production has not been taken into account in the earlier works [14]. This background when properly calculated dwarfs all the previously estimated backgrounds. For example, subject to the standard cuts implemented hitherto this background yields 2.7 fb, while all other channels combined together give a total background of $\mathcal{O}(2\,\mathrm{fb})$.

One can, however, exploit the fact that the dileptons coming from the γ^* tend to have rather low invariant masses. Thus an invariant mass cut $m_{l\bar{l}} > X$, where X has to be optimized for each choice of m_0 and $m_{1/2}$ may keep the new background at a manageable level.

Several recent works have revised earlier estimates taking the new background into account [14,17]. It turns out that the region of the $m_0 - m_{1/2}$ plane accessible to this channel, though somewhat different from the earlier works, is still reasonably large. However, a part of the region presented in [14,17] corresponding to rather low values of m_0 has already been ruled out by direct slepton searches at LEP [2].

2.3 *The hunt for the third generation of sfermions*

It is well known that even in the conventional scenario, the left and right handed stop squarks ($\tilde{t}_L$ and $\tilde{t}_R$) could be considerably lighter than the other up type squarks. This is due to RG running below M_G driven by the rather large top Yukawa coupling. The stop mass eigenstates ($\tilde{t}_1, \tilde{t}_2$) may be even lighter due to mixing in the stop mass matrix [1].

Above the weak scale the left handed sbottom squark ($\tilde{b}_L$) mass is in any case degenerate with $\tilde{t}_L$ due to SU(2) symmetry. In the large tan β scenario the relatively large bottom Yukawa coupling may also lead to suppression of the $\tilde{b}_R$ mass or of one of the mass eigenstates.

It is therefore quite conceivable that the third generation squarks are considerably lighter than the other sfermions and are the only sparticles accessible to Tevatron Run II. Special attention should therefore be devoted to the search prospects of these species. Moreover, if this fact is confirmed by upcoming experiments, one may obtain important insights into GUT scale/Planck scale physics. Here we shall restrict ourselves to stop searches only.

The limits on the lighter stop ($\tilde{t}_1$) mass ($m_{\tilde{t}_1}$) is very sensitive on the assumed BR of $\tilde{t}_1$. If $\tilde{t}_1$ happens to be the next lightest super sparticle (NLSP), then the only available mode is the loop induced decay $\tilde{t}_1 \to c\widetilde{\chi}_1^0$.

Under this assumption the stop signal at the Tevatron is a function of $m_{\tilde{t}_1}$ only, since the stop pair production via strong interaction is independent of the stop mixing angle (θ). However, the mass limit is quite sensitive to the assumed LSP mass ($m_{\widetilde{\chi}_1^0}$). For example, with $m_{\widetilde{\chi}_1^0} = 40$ GeV, the current limit from Tevatron is $m_{\tilde{t}_1} \geq 119$ GeV [18]. For other choices of $m_{\widetilde{\chi}_1^0}$, the limit is somewhat degraded.

Limits on $m_{\tilde{t}_1}$ from LEP on the other hand depends on θ which influences the electroweak production of $\tilde{t}_1$, but is fairly independent of $m_{\widetilde{\chi}_1^0}$, unless $m_{\tilde{t}_1} - m_{\widetilde{\chi}_1^0}$ is $\mathcal{O}$ (1 GeV). Numerically the limit is much weaker than the Tevatron limit [2].

The prospect of discovering $\tilde{t}_1$ via this channel at the upgraded Tevatron has been investigated in [19]. Mass limits comparable to or slightly better than the current ones can be obtained for higher LSP masses.

In view of the chargino mass limit from LEP, the decay channel $\tilde{t}_1 \to b\widetilde{\chi}_1^{\pm}$ is kinematically allowed only for $m_{\tilde{t}_1} \geq 100$ GeV. This tree level decay, if kinematically allowed, overwhelms the loop decay. Such a stop is beyond the striking range of LEP.

Assuming 100 % BR for this channel, $M_{\widetilde{\chi}_1^{\pm}}$ = 90 GeV and $m_{\widetilde{\chi}_1^0}$ = 40 GeV, the CDF collaboration has excluded the stop pair production cross section as a function of $m_{\tilde{t}_1}$. Unfortunately even the next to leading order theoretical cross section is too small compared to the experimental limit. No useful stop mass limit can, therefore, be obtained from RUN I [18].

According to [19], $m_{\tilde{t}_1} \leq$ 225 GeV can be probed at TeV33 for $M_{\widetilde{\chi}_1^{\pm}}$ = 100 GeV or so, provided the integrated luminosity accumulates to at least 20 fb^{-1}.

If the above decay is kinematically forbidden, the dominant decay of the stop could be through the three body mode $\tilde{t}_1 \to b\tilde{l}_L\nu$ or $\tilde{t}_1 \to b\tilde{\nu}l$. Since the limit on $m_{\tilde{\nu}}$ is rather weak, this channel could be open for $\tilde{t}_1$ as light as 50 GeV. It has recently been emphasised that the signal could be large enough to be probed at Tevatron Run I [20].

The recent CDF excluded region is 85 GeV $\leq m_{\tilde{t}_1} \leq$ 122 GeV, for $m_{\tilde{\nu}}$ = 45 GeV [21]. Unfortunately the limit disappears for $m_{\tilde{\nu}} \geq$ 50 GeV. A somewhat weaker limit comes from ALEPH: $m_{\tilde{t}_1} \geq$ 90 GeV, which however, is valid for a wider range of $m_{\tilde{\nu}}$ ($m_{\tilde{\nu}} \leq$ 70 GeV) [22]. The analysis of [19] shows that significantly larger range of $m_{\tilde{t}_1}$: $m_{\tilde{t}_1} \leq \mathcal{O}$ (250 GeV) can be probed at the upgraded Tevatron for $m_{\tilde{\nu}} \leq$ 80 GeV.

The most significant development in stop physics in recent times, however, is the observation that the four body decay [23], e.g.,

$$\tilde{t}_1 \to b\tilde{\chi}_1^{\pm} * \to b\tilde{\chi}_1^0 f\bar{f}',$$

where f and f' are ordinary fermions, can indeed compete with the loop decay and for certain favourable choices of the parameters can even overwhelm the latter. The same final state can be reached through several other virtual sparticles in the intermediate state, provided they are not too heavy. In fact [23] has identified the dominant diagrams. The importance of this channel has been illustrated in a general MSSM without any assumption about the soft breaking terms, as well as in the conventional scenario.

Of course the particle content of this final state will be the same as that in $\tilde{t}_1 \to b\widetilde{\chi}_1^{\pm}$, followed by $\widetilde{\chi}_1^{\pm}$ decay. However, the kinematics of the final state may be significantly different. Yet the procedure for stop search in the above two body channel can be easily extended to the present mode.

Also the limits from $\tilde{t}_1 \to c\widetilde{\chi}_1^0$ may require revision due to a reduced branching ratio. Moreover, the Tevatron limit will no longer be a function of $m_{\tilde{t}_1}$ and $m_{\widetilde{\chi}_1^0}$ only. Since many Feynman diagrams involving several virtual sparticles contribute to the four body decay, the mixing angle θ along with other parameters will influence the relevant branching ratios.

3. Direct searches for SUSY beyond the conventional scenario

The conventional scenario with assumptions about physics at high scales, although economical and attractive, may ultimately prove wrong. It is therefore important to reexamine the search prospects at the Tevatron and its various upgrades if some or all of these assumptions are relaxed. If accompanied by suitable theoretical guidelines, this can be accomplished while still avoiding an unmanageable proliferation in the number of unknown parameters. Moreover, such an analysis indicates the feasibility of obtaining glimpses of the SUSY breaking pattern at a high scale using the Tevatron data. Finally, and most importantly, such analyses are needed to assess the robustness of the SUSY search strategies currently employed by Tevatron experiments.

One possible avenue would be to relax the gaugino mass unification condition. This has been attempted by several groups [24] and will be reviewed in the next subsection.

However, at least in the framework of SUSY GUT's, the assumption of gaugino mass unification appears quite natural, since it simply follows if the GUT symmetry is respected by the SUSY breaking mechanism at a high scale, irrespective of the specific choice of the GUT group.

The assumption that all soft breaking masses for the scalars have a universal value m_0 at scale M_G is more model dependent. Even the popular $N = 1$ SUGRA GUT models [5] guarantee degenerate scalars at some scale Λ at which SUSY breaking is transmitted from the hidden sector to the visible sector. By taking sfermions to be degenerate at scale M_G one therefore implicitly makes the assumption that $\Lambda \simeq M_G \simeq 2 \cdot 10^{16}$ GeV. However, from the supergravity point of view, it is more natural to chose Λ to be near the Planck scale $M_P \simeq 2.4 \cdot 10^{18}$ GeV. Non-universality in scalar masses at scale M_G can then arise due to several reasons.

i) The running of scalar masses between M_P and M_G [25] may lead to non-universality at M_G. This running, however, preserves the degeneracy of different members of the same GUT multiplet.
ii) It has been known for some time that if the rank of a GUT group (or some symmetry group broken at an intermediate scale) is reduced by spontaneous symmetry breaking, one may obtain D-term contributions to scalar masses [26,27]. These will in general differ for different members of the same GUT multiplet, leading to non-universal squark and slepton masses at the symmetry breaking scale. The size of these new contributions can be comparable to m_0. Note that these nonuniversal terms are generation-independent, so that no additional problems due to flavor changing neutral currents arise. The phenomenology of SO(10) breaking D-terms will be taken up in the second subsection.

3.1 *Search prospects in models with nonuniversal gaugino masses*

In a class of models, gaugino masses are generated by a chiral super field Φ that appears linearly in the gauge kinetic function, and whose auxiliary F-component develop an intermediate scale vev [1].

In the context of a SU(5) SUSY GUT both Φ and F should belong to an SU(5) irreducible representation which appears in the symmetric product of two adjoints. There are four candidate representations **1**, **24**, **75**, **200**, out of which only **1** leads to the conventional scenario with a universal gaugino mass at M_G. In the remaining models the SU(3), SU(2) and U(1) gaugino masses respectively denoted by M_3, M_2 and M_1, develop a hierarchy already at the GUT scale. For example, in the **200** model, M_3/M_2= $1/2$ at M_G, leading to M_3/M_2= $3/2$ at the weak scale. The LEP lower bound on $M_{\tilde{\chi}_1^\pm}$, therefore, does not necessarily imply $m_{\tilde{g}} \geq$ 300 GeV in the nonuniversal models. Thus gluino production may not be kinematically suppressed at the upgraded Tevatron as is anticipated in the conventional scenario.

The reach of the upgraded Tevatron for the **24**, **75** and **200** models has been studied in [28]. The main results can be summarized as follows. (i) In the **24** model, the large splitting between the two lightest neutralinos allows the decay $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z$. This in turn opens up the signal $Z+$ jets $+\not{E}_T$ which is rather uncommon in the conventional scenario. This happens over a reasonable region of the $M_3 - m_0$ parameter space. (ii) On the other hand only jets $+\not{E}_T$ signal is predicted to be observable over a large region of the parameter space in **75** and **200** models. This point underscores the importance of this signal as the most model independent tool of SUSY search.

3.2 *Search prospects in models with nonuniversal sfermion masses*

It has already been emphasized in [29] that right-handed down-type squarks ($\tilde{d}_R,\ \tilde{s}_R,\ \tilde{b}_R$, which are degenerate in mass) may be considerably lighter than other species of squarks

($\tilde{u}_L, \tilde{d}_L$ or $\tilde{u}_R$) due to the D term mechanism. A specific model in which this may happen is a SO(10) SUSY GUT, breaking down to the SM either directly or via the Pati–Salam group [30] at an intermediate scale [27]. In addition, the L-type (left-handed) or R-type (right-handed) sleptons may also turn out to be considerably lighter, which may yield many novel experimental signatures [29,31]. The phenomenological consequences of D terms at high scales have also been studied in the first paper of [24].

In [32] SUSY signals were studied within the framework of a SO(10) SUSY GUT breaking down to the SM directly. In this model nonuniversality in the squark and slepton masses at the high scale can be parametrized by only one extra parameter D (compared to the conventional scenario) [27]. Some of the novel features of this model are: (i) it can easily accommodate a higgsino like LSP since the magnitude of μ as determined by the radiative electroweak symmetry breaking could be considerably smaller that in the conventional scenario [27]. (ii) For positive values of the D parameter the $\tilde{\nu}$, $\tilde{l}_L$ and $\tilde{d}_R$ may happen to be considerably lighter than the other sfermions. (iii) If this parameter happens to be negative, then $\tilde{u}_L, \tilde{d}_L, \tilde{u}_R$ and $\tilde{l}_R$ may turn out to be relatively light.

The phenomenology of this model with small or moderately large tan β and, in particular, the search prospects at the upgraded Tevatron has been considered in great details in [32]. A typical spectrum is presented in the following table ($D = 0$ corresponds to the conventional scenario):

The key features are: (i) the cascade decays of the $\tilde{g}$ can be suppressed in general due to the presence of the relatively light $\tilde{d}_R$ ($D > 0$), which directly decays into the LSP. In particular if $m_{\tilde{g}} > m_{\tilde{d}_R}$, then the dilepton + jets + $\not{E}_T$ signal is completely depleted. However, the jets + $\not{E}_T$ and the clean trilepton signals may be enhanced due to light $\tilde{d}_R$ production and light $\tilde{l}_L$ respectively. This combination of signals is unattainable in the conventional scenario. (ii) For $D < 0$, the light $\tilde{b}_L$ signal may be observable in the near future. (iii) In general the relative magnitudes of the jets + $\not{E}_T$, dileptons + jets + $\not{E}_T$ and the clean trilepton signal could be very different from that in the conventional scenario.

In SO(10) models with a minimal Higgs sector the t, b and τ Yukawa couplings are expected to be unified at M_G. This unification requires a rather large value of tan β in the range 45–55. At such high values of tan β, however, the usual mechanism of radiative electroweak symmetry breaking does not work [33].

It has been shown in [34,35] that the modification of the universal scalar masses due to the D term mechanism may lead to successful radiative electroweak symmetry breaking at the weak scale. Several representative sparticle spectra consistent with this scenario have also been computed [35]. This model may accommodate relatively light b squarks

Table 1. Squark and slepton masses in GeV at the weak scale for different values of D with $m_0 = 600$ GeV and $m_{1/2} = 105$ GeV.

D	0	0.4	0.6	−0.75	−1.25
$m_{\tilde{u}_L}$	646.7	702.4	728.6	526.6	428.3
$m_{\tilde{u}_R}$	644.3	700.2	726.5	523.7	424.6
$m_{\tilde{d}_R}$	645.1	436.7	279.3	915.8	1058.5
$m_{\tilde{b}_L}$	525.6	592.7	623.6	367.9	203.5
$m_{\tilde{e}_L}$	606.1	376.7	170.9	888.8	1035.2
$m_{\tilde{e}_R}$	602.6	662.1	689.8	471.5	358.3

while all other squarks are heavy. A dedicated search for b-squarks at $p-\bar{p}$ and e^+-e^- colliders may provide a test of this model.

4. Indirect searches for SUSY

4.1 *Precision electroweak observables and SUSY*

In [7] SUSY contributions to several electroweak observables were studied with references to the earlier works. First sparticle contributions to the universal gauge boson propagator corrections parametrized by the three oblique parameters [36] were analysed.

Including the contributions from squarks, sleptons, gauginos and Higgs bosons separately, it was found that light squarks or sleptons just allowed by the current lower limits from direct searches, always make the fit to 22 data points (Z width and partial widths, various asymmetries etc) worse than that of the SM. The Higgs sector contribution is rather small. On the other hand relatively light charginos and neutralinos improve the fit although the statistical significance of the improvement is rather modest. Inclusion of the vertex or box graphs do not change the conclusion.

Similar conclusions pertaining to the squark sector were obtained in [37]. However, it was also noted that even for comparatively light sbottoms and small mass of one of the stops, special values of $\tilde{t}_L-\tilde{t}_R$ mixing can make the fit as good as that in the SM.

4.2 ϵ'/ϵ *and SUSY*

The measurement of ϵ'/ϵ by the KTeV and NA48 [8] collaborations reveal that this measure of direct CP violation in the kaon sector is indeed nonvanishing ($\mathcal{O}$ $(2\cdot\times 10^{-3})$). The estimates within the SM are generally well below the data [9]. However, in view of the theoretical uncertainties in the hadronic matrix elements, evaluated by nonperturbative techniques, this discrepancy cannot be interpretated as a solid evidence for new physics.

Yet the current situation calls for a reexamination of ϵ'/ϵ within the framework of SUSY [10,38]. It is, however, well-known that the SUSY contribution to ϵ'/ϵ is rather small [39] in the conventional scenario. Indeed if the Yukawa couplings are the only sources of flavour violation in the MSSM, no significantly large flavour violating effect is anticipated in the physics of the first two generations. Thus even allowing for arbitrarily large CP violating phases in the SUSY sector it is hard to generate a large ϵ'/ϵ.

In SUSY models ϵ'/ϵ is usually computed in the mass insertion approximation [40]. In the kaon sector the mass insertion parameter $(\delta_{12})_{AB}$, $A,B=L,R$, plays an important role. Treating this parameter phenomenologically, it has been shown in [10] that $\text{Im}(\delta_{12})_{LR}\sim 0.000065$ can reproduce ϵ'/ϵ at the currently observed level without affecting ϵ or the K_L-K_S mass difference. In contrast other relevant mass insertion parameters can yield ϵ'/ϵ in the interesting range only at the cost of making the other observables too large. Constructing a model with this structure of mass insertion parameters, however, is a challenge for the model builders.

In a related development it was shown in [41] that the same SUSY induced effective operators which may enhance ϵ'/ϵ also contribute to various rare kaon decays like $K_L\to\pi^0\nu\bar{\nu}$, $K^+\to\pi^+\nu\bar{\nu}$, $K_L\to\pi^0e^+e^-$ and $K_L\to\mu^+\mu^-$. In many cases the branching ratios of these decays are enhanced to levels which are likely to be observable in the near future.

5. Conclusions

In conclusion we reiterate that the clean trilepton channel or the production and decay of the third generation of squarks are the most likely channels for the discovery of SUSY at the upgraded Tevatron within the mSUGRA scenario.

The SUSY signals beyond the mSUGRA scenario also look promising over a reasonable region of the parameter space. A particular scenario may be deciphered if signals are seen in several channels.

A fit to the precision electroweak observable favours light gauginos while light scalars are disfavoured. In the first case the statistical significance of the signal is, however, modest.

If the so called discrepancy between the SM and the observed value of ϵ'/ϵ is firmly established, then SUSY beyond mSUGRA may provide a viable alternative. However, constructing a specific SUSY model for this purpose still remains a real challenge for the model builders. A confirmation of the hypothesis of SUSY induced ϵ'/ϵ may come from corresponding enhancements in certain rare K-decays, which should be observable in the near future.

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References

[1] For reviews see, for example, H P Nilles, *Phys. Rep.* **110**, 1 (1984)
P Nath, R Arnowitt and A Chamseddine, *Applied $N = 1$ Supergravity*, ICTP Series in *Theor. Phys.*, vol. I (World Scientific, 1984)
H E Haber and G L Kane, *Phys. Rep.* **117**, 75 (1985)
S P Misra, *Introduction to Supersymmetry and Supergravity* (Wiley Eastern, New Delhi, 1992)
M Drees, hep-ph/9611409

[2] For the recent limits from LEP see, e.g., the article by Grivaz in this proceedings. The limits from Tevatron relevant for this talk will be presented below

[3] S Mrenna, G Kane, G Kribs and J Wells, *Phys. Rev.* **D53**, 1168 (1996)
H Baer, C-H Chen, F Paige and X Tata, *Phys. Rev.* **D54**, 5866 (1996)

[4] H Baer *et al*, *Phys. Rev.* **D52**, 2746 (1995); *Phys. Rev.* **D53**, 6241 (1996); *Phys. Rev.* **D59**, 055014 (1999)
I Hinchcliffe *et al*, *Phys. Rev.* **D55**, 5520 (1997)
CMS collaboration: S Abdullin *et al*, hep-ph/9806366

[5] R Arnowitt, A H Chamseddine and P Nath, *Phys. Rev. Lett.* **49**, 970 (1982)
R Barbieri, S Ferrara and C A Savoy, *Phys. Lett.* **B119**, 343 (1982)

L J Hall, J Lykken and S Weinberg, *Phys. Rev.* **D27**, 2359 (1983)
[6] The LEP Electroweak Working Group and the SLD Heavy Flavour Group, CERN-EP/99-15
[7] G-C Cho and K Hagiwara, hep-ph/9912260
[8] KTeV collaboration: A Alavi-Harati *et al*, *Phys. Rev. Lett.* **83**, 22 (1999)
NA48 collaboration: V Fanti *et al*, *Phys. Lett.* **B465**, 335 (1999)
[9] S Bosch *et al*, hep-ph/9904408
T Hambye *et al*, hep-ph/9906434
M Ciuchini, *Nucl. Phys.* **B59**, 149 (1997)
S Bertolini, M Fabbrichesi and J O Eeg, hep-ph/9802405
[10] See, e.g., A Masiero and H Murayama, *Phys. Rev. Lett.* **83**, 907 (1999)
[11] L Ibáñez and G Ross, *Phys. Lett.* **B110**, 215 (1982)
L Ibáñez, *Phys. Lett.* **B118**, 73 (1982)
J Ellis, D Nanopoulos and K Tamvakis, *Phys. Lett.* **B121**, 123 (1983)
L Alvarez-Gaumé, J Polchinski and M Wise, *Nucl. Phys.* **B221**, 495 (1983)
[12] DØ Collab.: B Abbott *et al*, hep-ex/9902013
[13] V Barger *et al*, *Phys. Lett.* **B131**, 372 (1983)
H Baer, K Hagiwara and X Tata, *Phys. Rev. Lett.* **57**, 294 (1986)
P Nath and R Arnowitt, *Mod. Phys. Lett.* **A2**, 331 (1987)
R Barbieri *et al*, *Nucl. Phys.* **B367**, 28 (1991)
[14] V Barger and C Kao, hep-ph/9811489
H Baer *et al*, hep-ph/9906233
[15] W Beenakker *et al*, *Phys. Rev. Lett.* **83**, 3780(1999)
[16] H Baer *et al*, *Phys. Rev.* **D58**, 075008 (1998)
J D Wells, *Mod. Phys. Lett.* **A13**, 1923 (1998)
J D Lykken and K T Matchev, *Phys. Rev.* **D61**, 015001 (2000)
V Barger, C Kao and T-J Li, *Phys. Lett.* **B433**, 328 (1998)
[17] K T Matchev and D M Pierce, *Phys. Lett.* **B467**, 225 (1999)
[18] CDF collaboration: C Holck, hep-ex/990360
[19] R Demina, J D Lykken and K T Matchev hep-ph/ 9910275
[20] Asesh K Datta, M Guchhait and K K Jeong, *IJMP* **A14**, 2239 (1999)
[21] CDF collaboration: hep-ex/ 9912018
[22] See [2] for details
[23] C Boehm, A Djouadi and Y Mambrini, *Phys. Rev.* **D61**, 095006 (2000)
[24] J Amundson *et al*, Report of the Snowmass theory working group, hep-ph/609374
C-H Chen, M Drees and J F Gunion, *Phys. Rev. Lett.* **76**, 2002 (1996); *Phys. Rev.* **D55**, 330 (1997)
[25] P Moxhay and K Yamamoto, *Nucl. Phys.* **B256**, 130 (1985)
B Gato, *Nucl. Phys.* **B278**, 189 (1986)
N Polonsky and A Pomarol, *Phys. Rev.* **D51**, 6532 (1995)
[26] M Drees, *Phys. Lett.* **B181**, 279 (1986)
[27] Y Kawamura, H Murayama and M Yamaguchi, *Phys. Rev.* **D51**, 1337 (1995)
[28] G Anderson, H Baer, C-H Chen and X Tata, hep-ph/9903370
[29] Amitava Datta, Aseshkrishna Datta and M K Parida, *Phys. Lett.* **B431**, 347 (1998)
[30] J C Pati and A Salam, *Phys. Rev. Lett.* **31**, 661 (1973)
[31] A Datta, M Guchait and N Parua, *Phys. Lett.* **B395**, 54 (1997)
[32] Amitava Datta, Aseshkrishna Datta, Manuel Drees and D P Roy, *Phys. Rev.* **D61**, 055003 (2000)
[33] For a brief review and references to the earlier works see, e.g, H Baer *et al*, in ref. [35]
[34] H Murayama, M Olechowski and S Pokorski, *Phys. Lett.* **B371**, 57 (1996)
[35] H Baer *et al*, hep-ph/9907211
[36] M E Peskin and T Takeuchi, *Phys. Rev. Lett.* **65**, 964 (1990)

G Altarelli and R Barbieri, *Phys. Lett.* **B253**, 161 (1991)
[37] I V Gaidaenko *et al*, *Phys. Rep.* **320**, 119 (1999)
[38] K S Babu, B Dutta and R N Mohapatra, hep-ph/9905464
S Khalil and T Kobayashi, hep-ph/ 9906374
E Accomando, R Arnowitt and B Dutta, hep-ph/9907446
S Baeck *et al*, hep-ph/9907572
R Barbieri, R Contino and A Strumia, hep-ph/9908255
[39] For a review see, e.g., Y Nir, hep-ph/9810520
[40] L J Hall, V A Kostelecki and S Raby, *Nucl. Phys.* **B267**, 415 (1986)
[41] A J Buras *et al*, hep-ph/9908371