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LHC/LC interplay in the MSSM Higgs sector

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Abstract: The interplay of prospective experimental information from both the Large Hadron Collider (LHC) and the Linear Collider (LC) in the investigation of the MSSM Higgs sector is analyzed in the SPS 1a and SPS 1b benchmark scenarios. Combining LHC information on the heavy Higgs states of the MSSM with precise measurements of the mass and branching ratios of the lightest CP-even Higgs boson at the LC provides a sensitive consistency test of the MSSM. This allows to set bounds on the trilinear coupling A_t. In a scenario where LHC and LC only detect one light Higgs boson, the prospects for an indirect determination of M_A are investigated. In particular, the impact of the experimental errors of the other SUSY parameters is analyzed in detail. We find that a precision of about 20% (30%) can be achieved for $M_A = 600(800)$ GeV.

Keywords: e+-e- Experiments.

Contents

1. Introduction

The prediction of a firm upper bound on the mass of the lightest Higgs boson is one of the most striking predictions of Supersymmetric (SUSY) theories whose couplings stay in the perturbative regime up to a high energy scale. Disentangling the structure of the Higgs sector and establishing possible deviations from the Standard Model (SM) will be one of the main goals at the next generation of colliders.

In order to implement electroweak symmetry breaking consistently into the Minimal Supersymmetric Standard Model (MSSM), two Higgs doublets are needed. This results in eight degrees of freedom, three of which are absorbed via the Higgs mechanism to give masses to the $W^\pm$ and Z bosons. The remaining five physical states are the neutral CP-even Higgs bosons h and H, the neutral CP-odd state A, and the two charged Higgs bosons $H^\pm$. At the lowest order, the Higgs sector of the MSSM is described by only two parameters in addition to the gauge couplings, conventionally chosen as M_A and $\tan\beta$, where the latter is the ratio of the vacuum expectation values of the two Higgs doublets.

The Higgs-boson sector of the MSSM is affected, however, by large radiative corrections which arise in particular from the top and scalar top sector and for large values of $\tan\beta$ also from the bottom and scalar bottom sector. Thus, the tree-level upper bound on the mass of the lightest CP-even Higgs boson, $m_h < M_Z$ in the MSSM, arising from the gauge structure of the theory, receives large radiative corrections from the Yukawa sector of the theory [1]. Taking corrections up to two-loop order into account, the mass is shifted by about 50%, establishing an upper bound of $m_h \lesssim 136\,\mathrm{GeV}$ [2, 3].

An e^+e^- Linear Collider (LC) will provide precision measurements of the properties of all Higgs bosons that are within its kinematic reach [4]–[6]. Provided that a Higgs boson couples to the Z boson, the LC will observe it independently of its decay characteristics.

At the Large Hadron Collider (LHC), Higgs boson detection can occur in various channels, see e.g. ref. [7]. In many cases complementary information from more than one channel will be accessible at the LHC. In particular, the LHC has a high potential for detecting heavy Higgs states which might be beyond the kinematic reach of the LC. Furthermore, experimental information on the parameters entering via large radiative corrections will be crucial for SUSY Higgs phenomenology. This refers in particular to a precise knowledge of the top-quark mass, m_t, from the LC [4]–[6] and [8, 9] and information about the SUSY spectrum from both LHC and LC [10].

In the following, two examples of a possible interplay between LHC and LC results in SUSY Higgs physics [10] are investigated. They are based on the benchmark scenarios SPS 1a and SPS 1b [11]. In section 2 a scenario is analyzed where the LHC can detect the heavy Higgs states of the MSSM (see e.g. ref. [12]). This provides experimental information on both tree-level parameters of the MSSM Higgs sector, M_A and $\tan\beta$. Therefore, in principle the phenomenology of the light CP-even Higgs boson can be predicted on the basis of the experimental information on M_A and $\tan\beta$. The LC, on the other hand, provides precise information on the branching ratios of the light Higgs boson, which can be compared with the theory prediction. A realistic analysis, however, requires to take into account radiative corrections. In this way additional parameters become relevant for predicting the properties of the light CP-even Higgs boson. Comparing these predictions with experimental results on the light CP-even Higgs boson provides a sensitive consistency test of the MSSM at the quantum level. This allows in particular to obtain indirect information on the mixing in the scalar top sector, which is very important for fits of the SUSY Lagrangian to (prospective) experimental data [13]. Deviations between the indirect predictions and the experimental results may reveal physics beyond the MSSM.

In section 3 another scenario is analyzed where no heavy Higgs bosons can be detected at LHC and LC. The combined information about the SUSY spectrum from the LHC and LC and of Higgs-boson branching ratio measurements at the LC is used to obtain bounds on the mass of the CP-odd Higgs boson, M_A, in the unconstrained MSSM (for such analyses within mSUGRA-like scenarios, see refs. [14, 15]). Since a realistic analysis requires the inclusion of radiative corrections, the achievable sensitivity to M_A depends on the experimental precision of the additional input parameters and the theoretical uncertainties from unknown higher-order corrections. This means in particular that observed deviations in the properties of the light CP-even Higgs boson compared to the SM case cannot be attributed to the single parameter M_A. We analyze in detail the impact of the experimental and theory errors on the precision of the M_A determination. Our analysis considerably differs from existing studies of Higgs boson branching ratios in the literature [16]. In these previous analyses, all parameters except for the one under investigation (i.e. M_A) have been kept fixed and the effect of an assumed deviation between the MSSM and the SM has solely been attributed to this single free parameter. This would correspond to a situation with a complete knowledge of all SUSY parameters without any experimental or theoretical uncertainty, which obviously leads to an unrealistic enhancement of the sensitivity to the investigated parameter.

Section 4 contains our conclusions.

2. Scenario where LHC information on heavy Higgs states is available

In this section we analyze a scenario where experimental results at the LHC are used as input for confronting the predictions for the branching ratios of the light CP-even Higgs boson with precision measurements at the LC. We consider the SPS 1b benchmark scenario [11], which is a 'typical' mSUGRA scenario with a relatively large value of $\tan\beta$. In particular, this scenario yields an M_A value of about 550 GeV, $\tan\beta = 30$, and stop and sbottom masses in the range of 600–800 GeV. More details about the mass spectrum can be found in the appendix and in ref. [11].

We assume the following experimental information from the LHC and the LC:

- $\Delta M_A = 10\%$
  This prospective accuracy on M_A is rather conservative. The assumption about the experimental accuracy on M_A is not crucial in the context of our analysis, however, since for $M_A \gg M_Z$ the phenomenology of the light CP-even Higgs boson depends only weakly on M_A.

- $\tan\beta > 15$
  The observation of heavy Higgs states at the LHC in channels like $b\bar{b}H/A, H/A \to \tau^+\tau^-, \mu^+\mu^-$ will be possible in the MSSM if $\tan\beta$ is relatively large [12]. An attempted determination of $\tan\beta$ from the comparison of the measured cross section with the theoretical prediction will suffer from sizable QCD uncertainties, from the experimental errors of the SUSY parameters entering the theoretical prediction, and from the experimental error of the measured cross section. Nevertheless, the detection of heavy Higgs states at the LHC will at least allow to establish a lower bound on $\tan\beta$. On the other hand, if $\tan\beta \lesssim 10$ the LC will provide a precise determination from measurements in the chargino and neutralino sector. Thus, assuming a lower bound of $\tan\beta > 15$ seems to be reasonable in the scenario we are analyzing.

- $\Delta m_{\tilde{t}}, \Delta m_{\tilde{b}} = 5\%$
  We assume that the LHC will measure the masses of the scalar top and bottom quarks with 5% accuracy. This could be possible if precise measurements of parameters in the neutralino and chargino sector are available from the LC, see ref. [10]. On the other hand, the measurements at the LHC (combined with LC input) will only loosely constrain the mixing angles in the scalar top and bottom sectors. Therefore we have not made any assumption about their values, but have scanned over the whole possible parameter space (taking into account the SU(2) relation that connects the scalar top and bottom sector). It should be noted that for the prospective accuracy on the scalar top and bottom reconstruction at the LHC we have taken the results of studies at lower values of $\tan\beta$ ($\tan\beta = 10$). While the stop reconstruction should not suffer from the higher $\tan\beta$ value assumed in the present study, sbottom reconstruction is more involved, see ref. [10]. We assume that the reconstruction of hadronic τ's from the decay $\chi^0_2 \to \tau^+\tau^-\chi^0_1$ will be possible and the di-tau mass spectrum can be used for a mass measurement of the scalar bottom quarks at the 5% level. This still has to be verified by experimental simulation.

In the scenario we are studying here the scalar top and bottom quarks are outside the kinematic limit of the LC.

- $\Delta m_t = 0.1\,\mathrm{GeV}$
  The top-quark mass (according to an appropriate short-distance mass definition) can be determined from LC measurements at the $t\bar{t}$ threshold with an accuracy of $\Delta m_t \lesssim 0.1\,\mathrm{GeV}$ [4, 5, 6, 8]. It should be kept in mind that the experimental error at the LHC, $\Delta m_t^{\mathrm{LHC}} \lesssim 1$–$2\,\mathrm{GeV}$, would induce a parametric uncertainty in the m_h prediction of $\Delta m_h^{m_t} \approx 1$–$2\,\mathrm{GeV}$.

- $\Delta m_h = 0.5\,\mathrm{GeV}$
  At the LC the mass of the light Higgs boson can be measured with an accuracy of 50 MeV (whereas at the LHC a precision of 200–300 MeV seems to be feasible). In order to account for theoretical uncertainties from unknown higher-order corrections we assume an accuracy of $\Delta m_h = 0.5\,\mathrm{GeV}$ in this study (which dominates over the experimental resolution at the LHC and/or LC). This assumes that a considerable reduction of the present uncertainty of about 3 GeV [3] will be achieved until the LC goes into operation.

The experimental information from the heavy Higgs and scalar quark sectors that we have assumed above can be used to predict the branching ratios of the light Higgs boson. Within the MSSM, the knowledge of these experimental input quantities will significantly narrow down the possible values of the light Higgs branching ratios. Comparing this prediction with the precise measurements of the branching ratios carried out at the LC will provide a very sensitive consistency test of the MSSM.

This is shown in figure 1 for the branching ratios $\mathrm{BR}(h \to b\bar{b})$ and $\mathrm{BR}(h \to WW^*)$. The light shaded (yellow) region indicates the full parameter space allowed for the two branching ratios within the MSSM. The medium shaded (light blue) region corresponds to the range of predictions in the MSSM being compatible with the assumed experimental information from the LHC as discussed above, i.e. $\Delta M_A = 10\%$, $\tan\beta > 15$, $\Delta m_{\tilde{t}}, \Delta m_{\tilde{b}} = 5\%$. The shape and size of this region is mainly determined by the experimental uncertainties on the top-quark mass and the scalar quark masses; with the LC accuracy on m_t, the dominant uncertainty arises from the scalar quark sector. The dark shaded (dark blue) region arises if furthermore a measurement of the light CP-even Higgs mass of $m_h = 116\,\mathrm{GeV}$, including a theory uncertainty of $\Delta m_h = 0.5\,\mathrm{GeV}$, is assumed. The predictions are compared with the prospective experimental accuracies for $\mathrm{BR}(h \to b\bar{b})$ and $\mathrm{BR}(h \to WW^*)$ at the LC of about 2.5% and 5%, respectively [4]–[6] and [17].

Agreement between the branching ratios measured at the LC and the theoretical prediction would constitute a highly non-trivial confirmation of the MSSM at the quantum level. In order to understand the physical significance of the two dark-shaded regions in figure 1 it is useful to investigate the prediction for m_h as a function of the trilinear coupling A_t (see also ref. [9]). If the masses of the scalar top and bottom quarks have been measured at the LHC (using LC input), a precise measurement of m_h will allow an indirect determination of A_t up to a sign ambiguity. It should be noted that for this determina-

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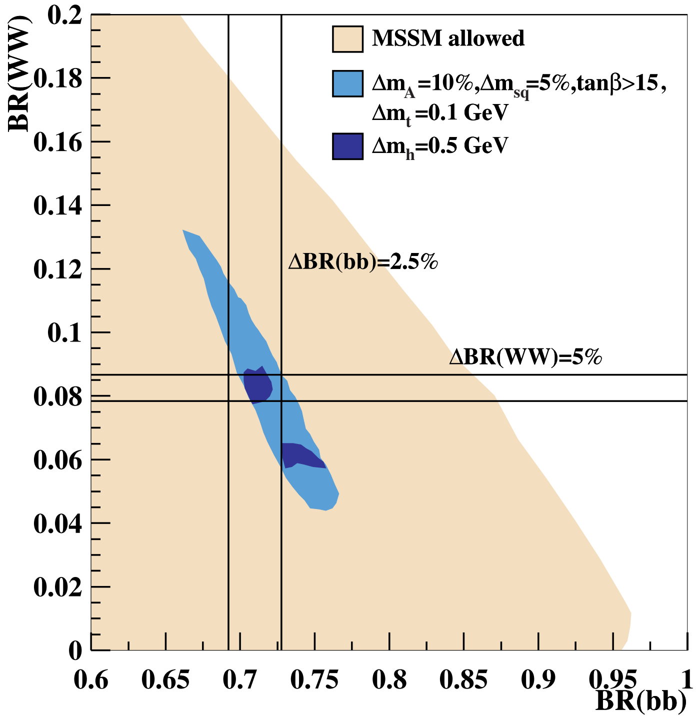

Figure 1: The experimental accuracies for the branching ratios $\mathrm{BR}(h \to b\bar{b})$ and $\mathrm{BR}(h \to WW^*)$ at the LC of about 2.5% and 5%, indicated by a vertical and horizontal band, respectively, are compared with the theoretical prediction in the MSSM. The light shaded (yellow) region indicates the full allowed parameter space. The medium shaded (light blue) region indicates the range of predictions in the MSSM being compatible with the assumed experimental information from LHC and LC, $\Delta M_A = 10\%$, $\tan\beta > 15$, $\Delta m_{\tilde{t}}, \Delta m_{\tilde{b}} = 5\%$, $\Delta m_t = 0.1\,\mathrm{GeV}$. The dark shaded (dark blue) region arises if furthermore a measurement of the light CP-even Higgs mass, including a theory uncertainty of $\Delta m_h = 0.5\,\mathrm{GeV}$, is assumed.

tion of A_t the precise measurement of m_t at the LC is essential, see [9, figure 3].[1] It also relies on a precise theoretical prediction for m_h, which requires a considerable reduction of the theoretical uncertainties from unknown higher-order corrections as compared to the present situation [3], as discussed above. Making use of a prospective measurement of m_h for predicting $\mathrm{BR}(h \to b\bar{b})$ and $\mathrm{BR}(h \to WW^*)$, on the other hand, is less critical in this respect, since the kinematic effect of the Higgs mass in the prediction for the branching ratios is not affected by the theoretical uncertainties.

Figure 1 shows that the LC measurements of the branching ratios of the light CP-even Higgs boson allow to discriminate between the two dark-shaded regions. From the discussion above, these two regions can be identified as corresponding to the two possible signs of the parameter A_t. This is illustrated in figure 2, where $\mathrm{BR}(h \to WW^*)$ is shown as a function of A_t. It is demonstrated that the sign ambiguity of A_t can be resolved with the branching ratio measurement. The determination of A_t in this way will be crucial in

[1] In ref. [9] it was shown that going from $\Delta m_t = 2(1)\,\mathrm{GeV}$ to $\Delta m_t = 0.1\,\mathrm{GeV}$ results in an improvement in the A_t determination by a factor of 3 (2).

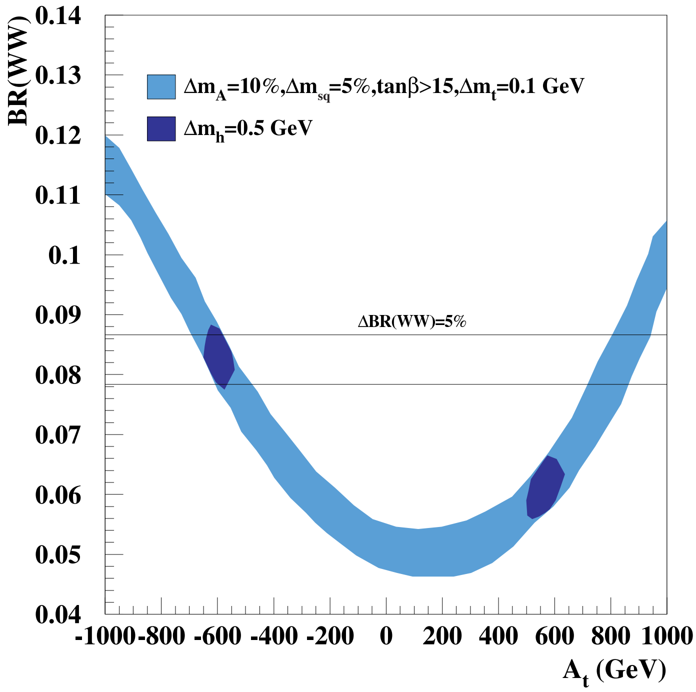

Figure 2: The branching ratio for $h \to WW^*$ is shown as a function of the trilinear coupling A_t. The light shaded (light blue) region indicates the range of predictions in the MSSM being compatible with the assumed experimental information, $\Delta M_A = 10\%$, $\tan\beta > 15$, $\Delta m_{\tilde{t}}, \Delta m_{\tilde{b}} = 5\%$, $\Delta m_t = 0.1\,\text{GeV}$. The dark shaded (dark blue) region arises if furthermore a measurement of the light CP-even Higgs mass, including a theory uncertainty of $\Delta m_h = 0.5\,\text{GeV}$, is assumed. The experimental accuracy for BR($h \to WW^*$) at the LC of about 5% is indicated by an horizontal band.

global fits of the SUSY parameters to all available data [13]. As it is clear from figure 2, this method of determining the value and the sign of A_t gets worse for small values of $|A_t|$.

3. Indirect constraints on M_A from LHC and LC measurements

In the following, we analyze an SPS 1a based scenario [11], where we keep M_A as a free parameter. We study in particular the situation where the LHC only detects one light Higgs boson. For the parameters of the SPS 1a scenario this corresponds to the region $M_A \gtrsim 400\,\text{GeV}$ (see also the appendix).

The precise measurements of Higgs branching ratios at the LC together with accurate determinations of (parts of) the SUSY spectrum at the LHC and the LC (see ref. [10]) will allow in this case to obtain indirect information on M_A (for a discussion of indirect constraints on M_A from electroweak precision observables, see ref. [18]). When investigating the sensitivity to M_A it is crucial to take into account realistic experimental errors of the other SUSY parameters that enter the prediction of the Higgs branching ratios. Therefore we have varied all the SUSY parameters according to error estimates for the measurements at LHC and LC in this scenario. The sbottom masses and the gluino mass can be obtained

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from mass reconstructions at the LHC with LC input, see ref. [10]. We have assumed a precision of $\Delta m_{\tilde{g}} = \pm 8\,\text{GeV}$ and $\Delta m_{\tilde{b}_{1,2}} \approx \pm 7.5\,\text{GeV}$. We furthermore assume that the lighter stop (which in the SPS 1a scenario has a mass of about 400 GeV, see ref. [11]) will be accessible at the LC, leading to an accuracy of about $\Delta m_{\tilde{t}_1} = \pm 2\,\text{GeV}$. The impact of the LC information on the stop mixing angle, $\theta_{\tilde{t}}$, will be discussed below. For $\tan\beta$ we have used an uncertainty of $\Delta\tan\beta = 10\%$ (this accuracy can be expected from measurements at the LC in the gaugino sector for the SPS 1a value of $\tan\beta = 10$ [19]). As before, we have assumed an error of $\Delta m_t = \pm 0.1\,\text{GeV}$ from the LC, so that the parametric uncertainties on the m_h predictions become negligible. As above, we have assumed a LC measurement of m_h, but included a theory error from unknown higher-order corrections of $\pm 0.5\,\text{GeV}$ [3].

In our analysis we compare the theoretical prediction [20] for the ratio of branching ratios

$$r \equiv \frac{\left[\text{BR}(h \to b\bar{b})/\text{BR}(h \to WW^*)\right]_{\text{MSSM}}}{\left[\text{BR}(h \to b\bar{b})/\text{BR}(h \to WW^*)\right]_{\text{SM}}} \tag{3.1}$$

with its prospective experimental measurement. Even though the experimental error on the ratio of the two BR's is larger than that of the individual ones, the quantity r has a stronger sensitivity to M_A than any single branching ratio.

In figure 3 the theoretical prediction for r is shown as a function of M_A, where the scatter points result from the variation of all relevant SUSY parameters within the 3 σ ranges of their experimental errors. The constraint on the SUSY parameter space from the knowledge of m_h is taken into account, where the precision is limited by the theory uncertainty from unknown higher-order corrections. The experimental information on m_h gives rise in particular to indirect constraints on the heavier stop mass and the stop mixing angle.[2] Without assuming any further experimental information, two distinct intervals for the heavier stop mass (corresponding also to different intervals for $\theta_{\tilde{t}}$) are allowed. This can be seen from the upper plot of figure 3. The interval with lower values of $m_{\tilde{t}_2}$ corresponds to the SPS 1a scenario, while the interval with higher $m_{\tilde{t}_2}$ values can only be realized in the unconstrained MSSM. In the lower plot the projection onto the M_A–r plane is shown, giving rise to two bands with different slopes. Since the lighter stop mass is accessible at the LC in this scenario, it can be expected that the stop mixing angle will be determined with sufficient accuracy to distinguish between the two bands. This has an important impact on the indirect determination of M_A.

The central value of r obtained from the band which is realized in the SPS 1a scenario is shown as a function of M_A in figure 4. The plot shows a non-decoupling behavior of r, i.e. r does not go to 1 for $M_A \to \infty$. This is due to the fact that the SUSY masses are kept fixed in the SPS 1a scenario. In order to find complete decoupling, however, both M_A and the mass scale of the SUSY particles have to become large, see e.g. ref. [21]. It should be noted that the sensitivity of r to M_A is not driven by this non-decoupling effect. In fact,

[2]Without the reduction of the intrinsic m_h uncertainty and without a precise determination of m_t the constraint on the SUSY parameter space would be much weaker, which would drastically decrease the sensitivity to M_A.

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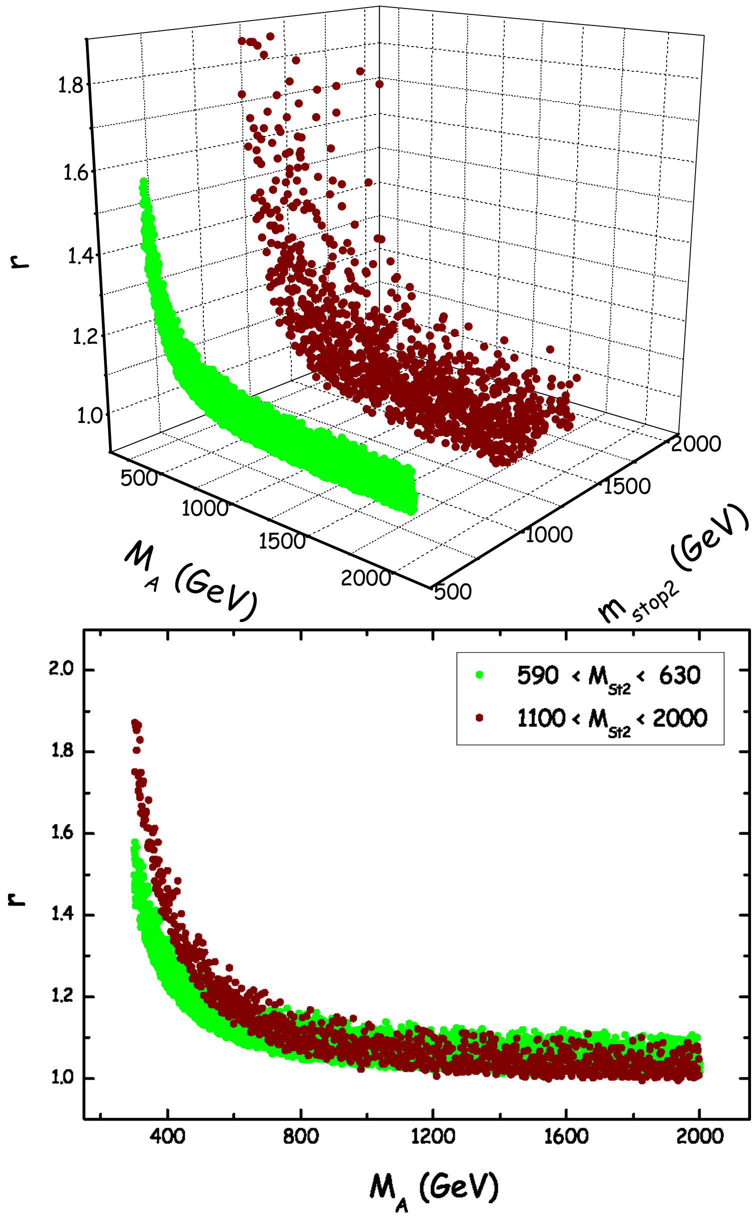

Figure 3: The ratio of branching ratios r, see eq. (3.1), is shown as a function of M_A in the SPS 1a scenario. The other SUSY parameters have been varied within the 3 σ intervals of their experimental errors (see text). The upper plot shows the three-dimensional M_A–$m_{\tilde{t}_2}$–r parameter space, while the lower plot shows the projection onto the M_A–r plane.

for larger values of the SUSY masses the slope of $r(M_A)$ even increases (one example being the second band depicted in figure 3). Thus, even stronger indirect bounds on M_A could be obtained in this case.

The relation between r and M_A shown in figure 4 corresponds to an idealized situation where the experimental errors of all input parameters in the prediction for r (besides M_A) and the uncertainties from unknown higher-order corrections were negligibly small. The comparison of the theoretical prediction for r (including realistic uncertainties) with the

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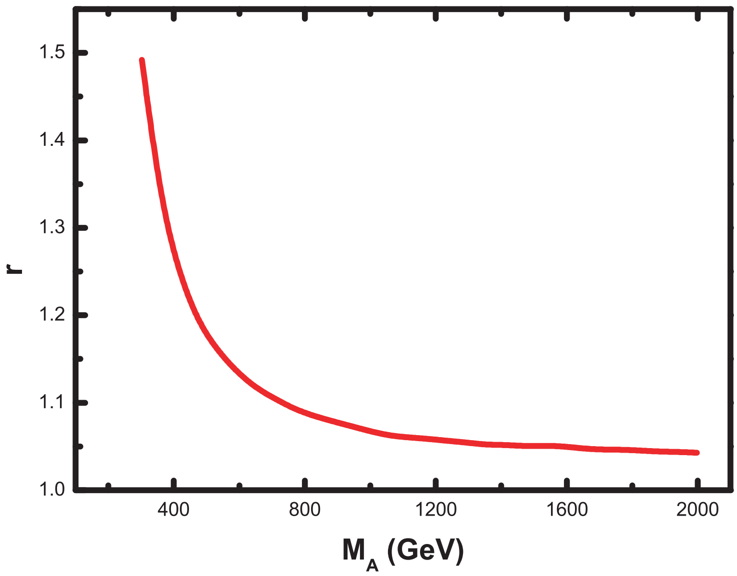

Figure 4: The central value of M_A corresponding to the central value of a prospective r measurement is shown for the SPS 1a scenario. This relation between r and M_A would be obtained if all experimental and theoretical uncertainties were negligible (see text).

experimental result at the LC allows to set indirect bounds on the heavy Higgs-boson mass M_A. Assuming a certain precision of r, figure 4 therefore allows to read off the best possible indirect bounds on M_A as a function of M_A, resulting from neglecting all other sources of uncertainties. This idealized case is compared with a more realistic situation based on the SPS 1a scenario in figure 5.

For the experimental accuracy of r we consider two different values: a 4% accuracy resulting from a first phase of LC running with $\sqrt{s} \lesssim 500\,\text{GeV}$ [4]–[6] and [17], and a 1.5% accuracy which can be achieved from LC running at $\sqrt{s} \approx 1\,\text{TeV}$ [22]. In figure 5 the resulting 1 σ bounds on M_A are shown (the corresponding value of r can be read off from figure 4) for the experimental precisions of r of 4% and 1.5%, respectively, where the estimated experimental errors on the parameters $\tan\beta, m_{\tilde{b}_{1,2}}, m_{\tilde{t}_1}, m_{\tilde{g}}, m_h$, and m_t based on the SPS 1a scenario are taken into account. Also shown is the 1 σ error for $\Delta r/r =$ 1.5% which would be obtained if all SUSY parameters (except M_A) were precisely known, corresponding to the idealized situation of figure 4.

Figure 5 shows that a 4% accuracy on r allows to establish an indirect upper bound on M_A for M_A values up to $M_A \lesssim 800\,\text{GeV}$ (corresponding to an r measurement of $r \gtrsim 1.1$). With an accuracy of 1.5%, on the other hand, a precision on $\Delta M_A/M_A$ of approximately 20% (30%) can be achieved for $M_A = 600(800)\,\text{GeV}$. The indirect sensitivity extends to even higher values of M_A. The comparison with the idealized situation where all SUSY parameters (except M_A) were precisely known (as assumed in ref. [16]) illustrates the importance of taking into account the parametric errors as well as the theory errors from unknown higher-order corrections. Detailed experimental information on the SUSY spectrum and a precision measurement of m_t are clearly indispensable for exploiting the experimental precision on r.

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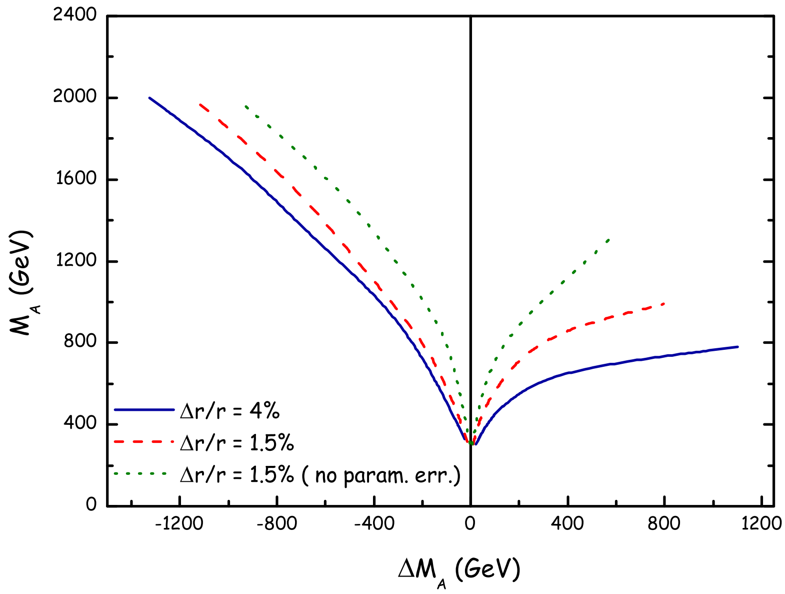

Figure 5: The 1 σ bound on M_A, ΔM_A, versus M_A obtained from a comparison of the precision measurement of r (see text) at the LC with the MSSM prediction. The results for ΔM_A are shown for a 4% accuracy of r (full line) and a 1.5% accuracy of r (dashed line). The parametric uncertainties in the prediction of r resulting from LHC/LC measurement errors on $\tan\beta, m_{\tilde{b}_{1,2}}, m_{\tilde{t}_1}, m_{\tilde{g}}, m_h$, and m_t are taken into account. Also shown is the accuracy on M_A which would be obtained if these uncertainties were neglected (dotted line).

4. Conclusions

We have investigated indirect constraints on the MSSM Higgs and scalar top sectors from measurements at LHC and LC in the SPS 1a and SPS 1b benchmark scenarios. In a situation where the LHC detects heavy Higgs bosons (SPS 1b) the combination of the LHC information on the heavy Higgs states with precise measurements of the mass and branching ratios of the lightest CP-even Higgs boson at the LC gives rise to a sensitive consistency test of the MSSM. In this way an indirect determination of the trilinear coupling A_t becomes possible. The measurement of m_h alone allows to determine A_t up to a sign ambiguity, provided that a precise measurement of the top-quark mass from the LC is available. With the measurements of the branching ratios $\mathrm{BR}(h \to b\bar{b})$ and $\mathrm{BR}(h \to WW^*)$ at the LC the sign ambiguity can be resolved and the accuracy on A_t can be further enhanced.

In a scenario where LHC and LC only detect one light Higgs boson (SPS 1a, where M_A is taken as a free parameter), indirect constraints on M_A can be established from combined LHC and LC data. Taking all experimental and theoretical uncertainties into account, an indirect determination of M_A with an accuracy of about 20% (30%) seems to be feasible for $M_A = 600(800)$ GeV. In order to achieve this, a precise measurement of the branching ratios $\mathrm{BR}(h \to b\bar{b})$ and $\mathrm{BR}(h \to WW^*)$ at the LC and information on the parameters of the scalar top and bottom sector from combined LHC / LC analyses will be crucial.

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A. Benchmark parameters

Our numerical evaluation is based on the SPS 1a and 1b benchmark scenarios that have been defined in ref. [11]. The relevant parameters of the two benchmark scenarios are given below (more details can be found in ref. [11]). They are given in the $\overline{\mathrm{DR}}$ scheme at the top squark mass scale. $m_{\tilde{t}_{L,R}}$ and $m_{\tilde{b}_{L,R}}$ denote the diagonal soft SUSY-breaking parameters in the $\tilde{t}$ and $\tilde{b}$ mass matrices, respectively.

- SPS 1a

$$\begin{aligned} m_{\tilde{t}_L} &= 495.9\,\mathrm{GeV}\,, & m_{\tilde{t}_R} &= 424.8\,\mathrm{GeV}\,, & A_t &= -510.0\,\mathrm{GeV}\,, \\ m_{\tilde{b}_L} &= m_{\tilde{t}_L}\,, & m_{\tilde{b}_R} &= 516.9\,\mathrm{GeV}\,, & A_b &= -772.7\,\mathrm{GeV}\,, \\ m_{\tilde{g}} &= 595.2\,\mathrm{GeV}\,, & M_2 &= 192.7\,\mathrm{GeV}\,, & M_1 &= 99.1\,\mathrm{GeV}\,, \\ \mu &= 352.4\,\mathrm{GeV}\,, & M_A &= 393.6\,\mathrm{GeV}\,, & \tan\beta &= 10. \end{aligned} \tag{A.1}$$

- SPS 1b

$$\begin{aligned} m_{\tilde{t}_L} &= 762.5\,\mathrm{GeV}\,, & m_{\tilde{t}_R} &= 670.7\,\mathrm{GeV}\,, & A_t &= -729.3\,\mathrm{GeV}\,, \\ m_{\tilde{b}_L} &= m_{\tilde{t}_L}\,, & m_{\tilde{b}_R} &= 780.3\,\mathrm{GeV}\,, & A_b &= -987.4\,\mathrm{GeV}\,, \\ m_{\tilde{g}} &= 916.1\,\mathrm{GeV}\,, & M_2 &= 310.9\,\mathrm{GeV}\,, & M_1 &= 162.8\,\mathrm{GeV}\,, \\ \mu &= 495.6\,\mathrm{GeV}\,, & M_A &= 525.5\,\mathrm{GeV}\,, & \tan\beta &= 30. \end{aligned} \tag{A.2}$$

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