Eur. Phys. J. C 7, 107–111 (1999)
DOI 10.1007/s100529800992

THE EUROPEAN
PHYSICAL JOURNAL C

Neutral Higgs boson mass constraints in the minimal supersymmetric standard model from searches in e^+e^- collisions

André Sopczak

Institut für Experimentelle Kernphysik, Universität Karlsruhe, D-76128 Karlsruhe, Germany

Received: 23 June 1998 / Published online: 3 December 1998

Abstract. Unexcluded mass regions are revealed by an analysis of Higgs boson searches at LEP2 in the framework of the MSSM. Previous interpretations of the LEP2 data for Higgs boson searches are based on only a few combinations of supersymmetric parameters. An independent variation of the relevant supersymmetric parameters is performed. Cancellation effects of production cross sections can occur and thus some parameter regions are not excluded in this more general framework. The combined luminosity from the four LEP experiments is required to exclude most of the critical parameter combinations. The sensitivity reach for the 1997 LEP data-taking at 183 GeV is studied.

1 Introduction

The search for Higgs particles is one of the most challenging problems of experimental particle physics. At present, no Higgs bosons have been found and lower bounds on Higgs boson masses are established from direct searches. The most stringent bounds come from the LEP collider, which ran at $\sqrt{s} \approx 183$ GeV in 1997. In the Minimal Standard Model (MSM) one Higgs boson is predicted. Particular attention is given to the search for the Higgs bosons with properties predicted by the Minimal Supersymmetric Standard Model (MSSM). The Higgs sector of the MSSM contains five physical Higgs bosons, one neutral CP-odd scalar, A, two neutral CP-even scalars, h and H, and two charged scalars, $H^{\pm}$. At least one of them, the lighter CP-even scalar h, is expected to be relatively light ($m_h \leq 130$–140 GeV) and its discovery could be the first signal for supersymmetry. Consequently, this study focuses on the interpretation of searches for the neutral Higgs bosons within the MSSM.

After six years of data-taking at the Z resonance (LEP1), the LEP machine energy was increased (LEP2), first to 130 GeV in fall 1995, and successively to 172 GeV in 1996 and then to 183 GeV in 1997. This article focuses on the data collected at $\sqrt{s} = 161$ to 172 GeV with a total luminosity of about 21 pb^{-1} for each LEP experiment, and at 183 GeV with a total luminosity of about 55 pb^{-1}. Recent results of searches for Higgs bosons are reported from the LEP experiments ALEPH [1], DELPHI [2], L3 [3], and OPAL [4]. For example, initial LEP2 results were summarized in [5–8], and final results from LEP1 were reviewed in [9].

A realistic analysis of the phenomenology of the MSSM Higgs sector has to include radiative corrections [10–16]. At the tree level, the Higgs sector of the MSSM can be effectively parameterized in terms of two free variables, for example, the masses of two Higgs bosons. After the 1-loop corrections are included, Higgs boson masses and couplings depend also on the top quark mass and the additional unknown parameters of the MSSM. Throughout the paper, these unknown parameters are referred to as SUSY parameters. Several approaches have been developed to compute radiative corrections to the tree-level approximation, the Effective Potential Approach (EPA) [11], the Renormalization Group Equations (RGE) approach [12,13], and the Full 1-loop Diagrammatic Calculations (FDC) in the on-shell renormalization scheme [14,15]. Full analytic 1-loop corrections are calculated in the EPA and good agreement with the FDC of neutral Higgs bosons masses is found [17]. A simple approximation scheme for radiative corrections to the neutral Higgs boson masses gives very good precision [18].

While the Higgs boson masses are approximated well, for the cross sections only FDC take into account the virtual effects of all possible MSSM particles, such as gauge sector contributions, momentum-dependent effects in 2- and 3-point Green's functions, and genuine 1-loop corrections to 3-point functions. A detailed description of the FDC is given in [14]. The importance of a complete parameter scan with FDC has already been pointed out [19]. Although the numerical evaluations with the FDC method are time consuming, this method is chosen for this study.

For the 1996 data, the LEP experiments [1,2] have given limits for two or three sets of SUSY parameters, proposed as a benchmark test [20], varying basically the mixing parameter in the scalar top sector. Experimental searches should rely as little as possible on theoretical assumptions. Therefore, a less constrained parameter space compared to previous analysis of Higgs boson searches at LEP2 is considered. Using the FDC allows the exploration of the dependence of the masses and couplings of the Higgs bosons on all soft breaking parameters in the MSSM Lagrangian. Some relations and simplifications are applied in order to decrease the number of free parameters, after checking that the results in the Higgs sector are not sensitive to those assumptions. Three cases of the neutral MSSM Higgs boson searches are studied and the sensitivity of one experiment [2] is assumed to be valid for the four experiments:

– The mass regions excluded from the LEP2 data are determined for the center-of-mass energies of $\sqrt{s} = 161$ to 172 GeV and the luminosity of 21 pb^{-1}.
– The excluded regions are compared for one experiment and four experiments combined.
– The discovery or exclusion potential from the four LEP experiments with a total luminosity of about 200 pb^{-1} and $\sqrt{s} = 183$ GeV is determined.

2 Parameter space of the MSSM

The most general version of the MSSM Lagrangian contains a large number of free parameters. Most of the SUSY parameters have little impact on the Higgs sector. Using numerical simulations, important parameters for the Higgs boson phenomenology are identified. These parameters have been varied independently:

– (m_h,m_A) – the investigated Higgs boson mass combinations.
– m_sq – the common mass parameter for all squarks. The assumption of the same mass parameters for the three squark generations has a small effect. Results depend mostly on the stop mass parameter and only weakly on the masses of other sfermions.
– m_g – the gaugino mass. The commonly used GUT relation for the SU(2) and U(1) gaugino masses is assumed: $m_{\text{U}(1)} = \frac{5}{3}\tan^2\theta_\text{W} m_{\text{SU}(2)}$, $m_{\text{SU}(2)} = m_\text{g}$. This assumption has little impact on the results.
– μ – the mixing parameter of the Higgs doublets in the superpotential.
– A – the mixing parameter in the sfermion sector. As for m_sq only one universal mixing parameter is considered for all squark generations. The mixing term is defined as $Am_\text{sq} + \mu/\tan\beta$.

The CDF and D0 collaborations reported direct evidence for the top quark, compatible with a mass of 175.6 ± 5.5 GeV [21]. Throughout this study, the top quark mass is fixed at $m_\text{t} = 175$ GeV. In order to study the effect of the variation of the SUSY parameters described above they are scanned in the ranges given in Table 1. The change of the limits shown in Table 1 has only a small effect on the results discussed in the following sections. Further uncertainties on the results are due to 2-loop corrections for the MSSM Higgs boson masses. The maximal value of the h mass is reduced when 2-loop corrections are included [22–24]. The leading 2-loop terms have not been calculated for the FDC, but it is expected that they improve the 1-loop results in the same way as in the EPA and RGE approach [25]. No significant effects on cross section reductions in the FDC are expected, unless the kinematic production limit is reached.

Table 1. Ranges of SUSY parameters used for independent variation in the study of the MSSM neutral Higgs boson searches

Parameter	m_sq (GeV)	m_g (GeV)	μ (GeV)	A
Range	200–1000	200–1000	−500–500	−1–1

The parameters shown in Table 1 are the input parameters for the calculations of the physical sfermion, chargino, and neutralino masses. Some parameter combinations can be unphysical (e.g. negative squark masses) or experimentally excluded. Such cases are removed by imposing conservative constraints on stop and chargino masses. For the LEP1 limit, the neutralino was required to be heavy (or weakly coupled) in agreement with the bound on contributions to the Z width beyond the MSM [26]. No theoretical constraints on the MSSM are assumed.

An additional constraint is applied on $\tan\beta$, defined as the ratio of the vacuum expectation values of the Higgs doublets. Although at the 1-loop level $\tan\beta$ is renormalization-scheme-dependent, this dependence is rather weak [14]. Tree-level experimental bounds on $\tan\beta$ are assumed to hold approximately, and its value is constrained to $0.5 \le \tan\beta \le 50$. The lower bound is described, for example, in [27]. The variation of the upper bound has no significant effect on the results. In this approach $\tan\beta$ is a function of m_h, m_A and the SUSY parameters listed in Table 1. The lower bound on $\tan\beta$ affects the theoretically allowed regions in the (m_h,m_A) planes. The change of $\tan\beta > 1$ to $\tan\beta > 0.5$ extends the theoretically allowed region for the h mass by about $\Delta m_\text{h} = 20$ GeV for $m_\text{h} > m_\text{A}$.

3 Excluded mass regions at LEP

In order to derive bounds on h and A masses, the limits on the Higgs boson production rates given in [2] have been used. In the mass plane (m_h,m_A), each point with a step size of 1 GeV up to Higgs boson masses of 120 GeV has been analyzed separately. For each mass combination, the production cross sections of the reactions $\text{e}^+\text{e}^- \to \text{hZ}, \text{HZ}$, $\text{e}^+\text{e}^- \to \text{hA}, \text{HA}$, and the branching ratios for h and A decays have been computed as a function of the parameters described in Table 1. The cross section limits from the following channels [2] are taken into account:

1) h production in bremsstrahlung processes:

$$\text{e}^+\text{e}^- \to \text{hZ}^\star \to \ \text{he}^+\text{e}^- \ , \ \text{h}\mu^+\mu^- \ , \ \text{h}\bar{\nu}\nu \ , \ \text{hq}\bar{\text{q}} \ .$$

2) hA pair-production processes:

$$\text{e}^+\text{e}^- \to \text{hA} \to \tau^+\tau^-\bar{\text{b}}\text{b} \ , \ \bar{\text{b}}\text{b}\bar{\text{b}}\text{b} \ .$$

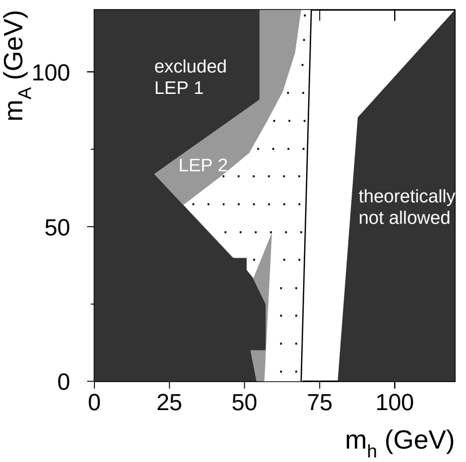

Fig. 1. MSSM exclusion for $\sqrt{s} = 161$ to $172\,\mathrm{GeV}$ and $\mathcal{L} = 21\,\mathrm{pb}^{-1}$. The region excluded by LEP1 (*black*), the newly 95% CL excluded region at LEP2 (*grey*), the region where the exclusion depends on the SUSY parameter set (*dotted space*), the region with no sensitivity (*white*), and the theoretically not allowed region (*black*) are shown

For $m_\mathrm{h} > 2m_\mathrm{A}$:

$$\mathrm{e^+e^-} \to \mathrm{hA} \to \mathrm{AAA} \to \mathrm{b\bar{b}b\bar{b}b\bar{b}}\ .$$

The parameter regions $m_\mathrm{A} < 10\,\mathrm{GeV}$ or $\tan\beta < 1$, where experimental sensitivity cannot rely on $\mathrm{b\bar{b}}$ signatures, require additional experimental attention. In this case study, the same cross-section limits are assumed to be approximately valid in these regions. The LEP1 limits from a previous study [19], which performed a scan over the SUSY parameters, are implemented.

A given (m_h,m_A) combination is excluded if for all SUSY parameter sets (from the ranges defined in Table 1 and for fixed $m_\mathrm{t} = 175$ GeV) the expected cross sections are larger than the limits in at least one of the production reactions.

For fixed (m_h,m_A), the parameter combinations are identified for which the cross section for a given production process is particularly low. It is unlikely that the cross sections are very low in all processes simultaneously, owing to the well-known complementarity of the cross sections of $\mathrm{e^+e^-} \to \mathrm{hZ}$ and $\mathrm{e^+e^-} \to \mathrm{hA}$ reactions. This complementarity holds approximately even after the inclusion of non-leading vertex corrections. Figure 1 shows five regions in the (m_h,m_A) plane:

(A) the region excluded by LEP1 (black),
(B) the newly 95% CL excluded region (grey),
(C) the region where the exclusion depends on the SUSY parameter set (dotted space),
(D) the region with no sensitivity (white), and
(E) the theoretically not allowed region (black).

The full scan over the SUSY parameter space gives no limit on the pseudoscalar mass, and a weaker limit on the scalar mass compared to the limits given in [1,2] where only two or three sets of SUSY parameters were considered.

The existence of newly unexcluded regions can be understood in the following way: The unexcluded region begins just above the $m_\mathrm{h}+m_\mathrm{A} = m_\mathrm{Z}$ limit for $m_\mathrm{h} < 60$ GeV. In this range the bremsstrahlung cross section $\mathrm{e^+e^-} \to \mathrm{hZ}$ can be small for some SUSY parameters. The complementary process $\mathrm{e^+e^-} \to \mathrm{hA}$ is reduced kinematically, thus no signal can be observed. Low unexcluded m_h values are obtained for low physical stop masses of the order of $\mathcal{O}(200$ GeV) and large mixing in the sfermion sector ($A = \pm 1$, large μ). In such cases the splitting between the left and right stop masses is large. Low unexcluded m_A values are found for small $\tan\beta$ values. Examples of unexcluded SUSY parameter combinations leading to suppressed bremsstrahlung cross sections and large m_h and m_A mass differences are given in Table 2[1]. A comparison of these cross sections with calculations based on [24] leads to the observation that the examples are unexcluded due to the parameter scan, and not due to FDC effects.

With increasing m_A, the cross section for the $\mathrm{e^+e^-} \to \mathrm{hZ}$ reaction becomes less sensitive to the SUSY parameters and similar to the $\mathrm{e^+e^-} \to \mathrm{H_{MSM}Z}$ cross section (calculated at $m_\mathrm{h} = m_{\mathrm{H_{MSM}}}$) because of the known decoupling effect [13]. The difference between cross sections calculated in the MSSM and MSM decreases as $1/m_\mathrm{A}^4$. Above $m_\mathrm{A} \approx 100$ GeV the bremsstrahlung production of h is sufficient to establish, independent of the SUSY parameters, the MSM Higgs mass bound of about 66 GeV [2].

In order to determine in a first approximation the exclusion reach of the four LEP experiments combined, the same variation is repeated with four times the luminosity and constant efficiency. Figure 2 shows that the mass region where the sensitivity depends on the set of SUSY parameters is largely covered at the 95% CL when the data of the four LEP experiments are combined. A lower mass limit of about 60 GeV on the CP-even Higgs boson is set, while no mass limit on the CP-odd Higgs boson exists (for small m_A values, unexcluded parameter combinations exist for $0.5 < \tan\beta < 1$). For large m_A, the combined LEP mass limit [28] on the MSM Higgs of 77.5 GeV is recovered.

4 Outlook for 183 GeV data

In the previous study [19], which applied a parameter scan as performed in this work, the production reactions relevant for LEP2 $\mathrm{e^+e^-} \to \mathrm{hZ}, \mathrm{hA}$ and $\mathrm{e^+e^-} \to \mathrm{HZ}, \mathrm{HA}$ were investigated based on sensitivities given in [29]. Each point in the (m_h,m_A) plane was analyzed separately with a step size of 1 GeV. For each fixed mass combination (m_h,m_A), the production cross sections of all the four reactions were calculated for $\sqrt{s} = 175$, 190, and 210 GeV with 500 pb^{-1} as a function of the parameters listed in Table 1.

[1] Other definitions in the literature are $m_g = M_2 \leftrightarrow 0.5M_2$, and $\mu \leftrightarrow -\mu$. For the two examples, the chargino and neutralino masses are: 1) $m_{\tilde{\chi}^+} = 199$, 513 GeV, $m_{\tilde{\chi}^0} = 94$, 199, 508, 509 GeV, and 2) $m_{\tilde{\chi}^+} = 208$, 510 GeV, $m_{\tilde{\chi}^0} = 96$, 208, 501, 512 GeV

Table 2. Examples of unexcluded parameter combinations in the MSSM. Cross sections for Higgs boson bremsstrahlung and pair-production are given for $\sqrt{s} = 161$ and $172\,\mathrm{GeV}$. All masses are given in GeV and cross sections in pb

m_h	m_A	m_t	m_sq	m_g	μ	A	$\tan\beta$	$m_{\tilde{t}1}$	$m_{\tilde{t}2}$	σ_hZ^{161}	σ_hA^{161}	σ_hZ^{172}	σ_hA^{172}
52.7	63	175	200	100	−500	1	6	220	299	0.46	0.24	0.41	0.23
74.5	12	175	1000	100	−500	0	0.66	948	1079	0.0	0.11	0.57	0.10

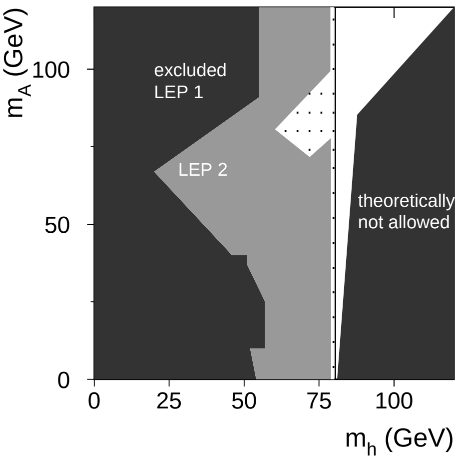

Fig. 2. MSSM exclusion for $\sqrt{s} = 161$ to $172\,\mathrm{GeV}$ and $\mathcal{L} = 84\,\mathrm{pb}^{-1}$ corresponding to the data of the four LEP experiments. The region excluded by LEP1 (*black*), the newly 95% CL excluded region at LEP2 (*grey*), the region where the exclusion depends on the SUSY parameter set (*dotted space*), the region with no sensitivity (*white*), and the theoretically not allowed region (*black*) are shown

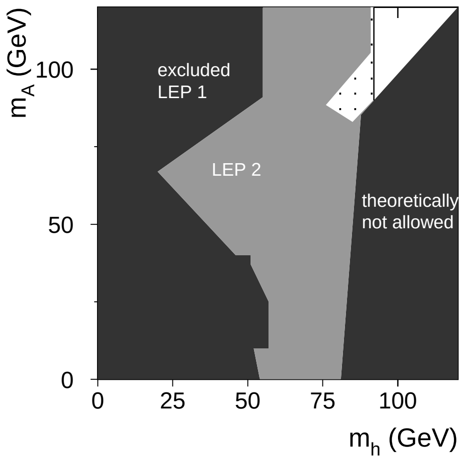

Fig. 3. MSSM prospects for $\sqrt{s} = 183\,\mathrm{GeV}$ and $\mathcal{L} = 200\,\mathrm{pb}^{-1}$. The region excluded by LEP1 (*black*), the 95% CL sensitivity or exclusion region at LEP2 (*grey*), the region where the sensitivity or exclusion depends on the SUSY parameter set (*dotted space*), the region with no sensitivity (*white*), and the theoretically not allowed region (*black*) are shown

While all the simulations were based on the LEP2 planning, in 1997, first high-energy data were recorded: $\sqrt{s} = 183$ GeV with about 200 pb^{-1}. After the luminosity and center-of-mass energy are known, much more precise predictions than in the earlier study can be made. Each point in the (m_h,m_A) plane has been analyzed separately with a step size of 1 GeV.

For Higgs boson bremsstrahlung and pair-production, the same detection sensitivities as achieved at the 172 GeV data-taking [2] are assumed. Figure 3 shows five regions in the (m_h,m_A) plane:

(A) the region excluded by LEP1 (black),
(B) the 95% CL sensitivity or exclusion region (grey),
(C) the region where the sensitivity or exclusion depends on the SUSY parameter set (dotted space),
(D) the region with no sensitivity (white), and
(E) the theoretically not allowed region (black).

For large m_A the limit on m_h is equal to the limit on the MSM Higgs boson. Independent of the SUSY parameter choice, lower mass limits on CP-even and CP-odd Higgs bosons could be set. For the combined data of the four LEP experiments, these limits are about $m_\mathrm{h} > 76\,\mathrm{GeV}$ and $m_\mathrm{A} > 83\,\mathrm{GeV}$.

5 Conclusions

Current mass limits from searches for Higgs bosons at LEP2 are studied by using a large scan over the MSSM parameter space. Full 1-loop diagrammatic calculations of radiative corrections to the Higgs particle production are applied. The dependence of the results on all important model parameters is investigated. Weaker mass limits on scalar and pseudoscalar Higgs bosons are set in comparison with previous studies. The combined luminosity of four LEP experiments significantly reduces the large parameter region where the exclusion depends on the SUSY parameters.

For the data of the 1997 LEP2 run, detailed studies for non-minimal Higgs bosons are presented and, even for unfavorable SUSY parameter combinations, large (m_h,m_A) parameter regions are covered.

Acknowledgement. It is my pleasure to thank Marcela Carena, Piotr Chankowski, Howard Haber, Janusz Rosiek, Michael Spira and Carlos Wagner for discussions on theoretical aspects and Wim de Boer and François Richard for advice on the manuscript.

Note added in proof: The results in this paper have been presented previously [8]. Since then the OPAL collaboration has performed a similar scan for their data corresponding to the total luminosity used in Fig. 1, and comes to similar conclusions [30].

References

1. ALEPH Collaboration, R. Barate et al., Phys. Lett. B **412**, 155 (1997); Phys. Lett. B **412**, 173 (1997); Phys. Lett. B **418**, 419 (1998)
2. DELPHI Collaboration, P. Abreu et al., Eur. Phys. J. C2 (1998) 1; Phys. Lett. B **420**, 140 (1998)
3. L3 Collaboration, M. Acciarri et al., Phys. Lett. B **411**, 373 (1997)
4. OPAL Collaboration, K. Ackerstaff et al., E. Phys. J. C2 (1998) 1; CERN-PPE/97-168, to be published in Phys. Lett. B
5. E. Gross, *Search for New Physics at LEP 2 (ECM = 130–172 GeV)*, talk at the Moriond Conference 1997, to be published in the proceedings
6. W. Murray, *Search for the Standard Model Higgs boson at LEP*, talk at the HEP'97 Conference, Jerusalem, Aug. 19–26, 1997, to be published in the proceedings
7. P. Janot, *Searches for New Particles*, talk at the HEP'97 Conference, Jerusalem, Aug. 19–26, 1997, to be published in the proceedings
8. A. Sopczak, *Searches for Higgs Bosons at LEP2*, talk at the 1st Int. Workshop on Non-Accelerator Physics, Dubna, July 1997, hep-ph/9712283, to be published in the proceedings
9. A. Sopczak, *Higgs Bosons Searches at LEP*, DESY97-129, ISSN 0418-9833, Proc. XII Int. Symposium on High Energy Physics, Gauhati, India, Dec. 1996 – Jan. 1997
10. J. Ellis, G. Ridolfi, F. Zwirner, Phys. Lett. B **257**, 83 (1991); H.E. Haber, R. Hempfling, Phys. Rev. Lett. **66**, 1815 (1991); Y. Okada, M. Yamaguchi, T. Yanagida, Phys. Lett. B **262**, 54 (1991); R. Barbieri, M. Frigeni, M. Caravaglios, Phys. Lett. B **258**, 167 (1991)
11. J. Ellis, G. Ridolfi, F. Zwirner, Phys. Lett. B **262**, 477 (1991); R. Barbieri, M. Frigeni, Phys. Lett. B **258**, 395 (1991); A. Brignole, J. Ellis, G. Ridolfi, F. Zwirner Phys. Lett. B **271**, 123 (1991)
12. M. Carena, K. Sasaki, C.E.M. Wagner, Nucl. Phys. B **381**, 66 (1992); R. Hempfling, Phys. Lett. B **296**, 121 (1992); H.E. Haber, R. Hempfling, Phys. Rev. D **48**, 4280 (1993)
13. P.H. Chankowski, S. Pokorski, J. Rosiek, Phys. Lett. B **281**, 100 (1992)
14. P.H. Chankowski, S. Pokorski, J. Rosiek, Phys. Lett. B **274**, 191 (1992); B **286**, 307 (1992); Nucl. Phys. B **423**, 437 (1994); B **423**, 497 (1994)
15. A. Brignole, Phys. Lett. B **281**, 284 (1992)
16. Z. Kunszt, F. Zwirner, Nucl. Phys. B **385**, 3 (1992)
17. A.V. Gladyshev et al., Nucl. Phys. B **498**, 3 (1997)
18. H.E. Haber, R. Hempfling, A.H. Hoang, Z. Phys. C **75**, 539 (1997)
19. J. Rosiek, A. Sopczak, Phys. Lett. B **341**, 419 (1995)
20. E. Accomando et al., *Higgs Physics*, in: Physics at LEP2, CERN 96-01 (1996) p. 351
21. CDF Collaboration, J. Lys, *Top Mass Measurements at CDF*, Proc. ICHEP96, Warsaw, 25-31 July 1996, (World Scientific) (1997) p. 1196; D0 Collaboration, S. Abachi et al., Phys. Rev. Lett. **79**, 1197 (1997)
22. J.R. Espinosa, M. Quirós, Phys. Lett. B **266**, 389 (1991); J. Kodaira, Y. Yasui, K. Sasaki, Phys. Rev. D **50**, 7035 (1994); R. Hempfling, A.H. Hoang, Phys. Lett. B **331**, 99 (1994)
23. J.A. Casas, J.R. Espinosa, M. Quiros, A. Riotto, Nucl. Phys. B **436**, 3 (1995), Erratum: Nucl. Phys. B **439**, 466 (1995)
24. M. Carena, J.R. Espinosa, M. Quiros, C.E.M. Wagner, Phys. Lett. B **355**, 209 (1995); M. Carena, M. Quiros, C.E.M. Wagner, Nucl. Phys. B **461**, 407 (1996)
25. W. Hollik, *Diagrammatic Approach to Radiative Corrections in the Higgs Sector of the MSSM*, talk at the Int. Workshop on Quantum Effects in the MSSM, Barcelona, 9–13 Sep. 1997; Preprint KA-TP-26-1997, to be published in the proceedings; W. Hollik, Proc. Ringberg Workshop, ed. B.A. Kniehl, (World Scientific) (1997), p. 165
26. A. Sopczak, Mod. Phys. Lett. A **10**, 1057 (1995)
27. B. Grządkowski, J.F. Gunion, Phys. Lett. B **243**, 301 (1990)
28. ALEPH, DELPHI, L3 and OPAL Collaborations, and the LEP Working Group for Higgs Boson Searches, *Lower bounds for the SM Higgs Boson mass: combined result from the four LEP experiments*, CERN/LEPC 97-11, Nov. 3, 1997
29. A. Sopczak, Int. J. Mod. Phys. A **9**, 1747 (1994)
30. OPAL Collaboration, K. Ackerstaff et al., CERN-EP/98-29, to be published in Eur. Phys. J. C.