HIGGS SEARCH AT LEP

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The search for Higgs bosons at the LEP collider is summarised. So far no direct evidence for the existence of Higgs bosons has been found. Higgs boson masses up to 89.3 GeV are excluded at 95% CL in the Standard Model. Limits on neutral and charged Higgs bosons in extensions of the Standard Model are also given.

1 Introduction

The Standard Model would not be the Standard Model without the existence of a physical Higgs particle. To confirm the Standard Model, it is therefore of prime importance to discover this Higgs boson. In supersymmetric extensions of the Standard Model, such as the Minimal Supersymmetric Standard Model (MSSM), the Higgs particle is the single most testable prediction that can confirm as well as defy the model.

Despite intensive searches for a Higgs boson, there is yet no direct evidence for its existence. However, there are indirect hints at its existence from higher order corrections to electroweak (EW) quantities that are precisely measured in Z^0 decays and $p\bar{p}$ collisions at high energy. The current best knowledge from these EW measurements indicates a most likely Standard Model Higgs mass of 74 GeV, but there is still a large range of uncertainty, which is moreover asymmetric due to the logarithmic dependence of the EW corrections on the Higgs mass.[1] In the MSSM, the lightest Higgs must have a mass below about 135 GeV, and even when this model is extended the lightest Higgs mass must remain below about 200 GeV.[2]

At this time, the most promising place to discover the Higgs particle is at the LEP e^+e^- collider. In the LEP2 programme, the centre-of-mass energy of this collider is upgraded in steps from m_Z to about 200 GeV.[3] The mass reach of LEP for the lightest Higgs boson overlaps for a large part with the current expectations from EW measurements and MSSM theory.

2 Phenomenology of Higgs production and decay

At LEP, the Standard Model Higgs particle is predominantly produced by the Higgs-strahlung process $e^+e^- \rightarrow Z^{0*} \rightarrow Z^0 H^0_{SM}$. According to the Z^0 and H^0_{SM} decay, the following final state topologies are distinguished:

four-jet channel: $(Z^0 \rightarrow q\bar{q})$ $(H^0_{SM} \rightarrow b\bar{b})$
neutrino channel: $(Z^0 \rightarrow \nu\bar{\nu})$ $(H^0_{SM} \rightarrow b\bar{b})$
electron channel: $(Z^0 \rightarrow e^+e^-)$ $(H^0_{SM} \rightarrow b\bar{b})$
muon channel: $(Z^0 \rightarrow \mu^+\mu^-)(H^0_{SM} \rightarrow b\bar{b})$
tau channel: $(Z^0 \rightarrow \tau^+\tau^-)(H^0_{SM} \rightarrow b\bar{b})$ or $(Z^0 \rightarrow q\bar{q})$ $(H^0_{SM} \rightarrow \tau^+\tau^-)$

The electron and muon channels are sometimes collectively called lepton channel. Near the kinematic boundary t-channel W and Z fusion diagrams start to contribute in a non-negligible way to the neutrino and electron channel respectively. In the Standard Model all production cross sections and decay rates are accurately known once the Higgs mass is given.

In type II two Higgs field doublet models (2HDM), one Higgs doublet couples to "up"-type fermions (u, c, t-quarks), while the other Higgs doublet couples to "down"-type fermions (d, s, b-quarks and charged leptons.) In these models five physical Higgs particles exist: two neutral CP-even bosons, h^0 and H^0, one neutral CP-odd boson A^0, and two charged bosons $H^{\pm}$. The two neutral CP-even bosons are mixed states and h^0 and H^0 indicate the light and heavy mass eigenstate, respectively. The mixing angle between these two neutral scalars is α. The ratio of vacuum expectation values of the two Higgs doublets is given as $\tan\beta$. For neutral Higgs production, there are two relevant processes in the 2HDM: Higgs strahlung identical to the SM process, and the $Z^0 \to h^0A^0$ process. The cross sections for these two processes can be given as: as:

$$e^+e^- \to h^0Z^0 : \quad \sigma_{hZ} = \sin^2(\beta-\alpha)\ \sigma_{HZ}^{SM}, \tag{1}$$

$$e^+e^- \to h^0A^0 : \quad \sigma_{hA} = \cos^2(\beta-\alpha)\ \bar{\lambda}\ \sigma_{\nu\bar{\nu}}^{SM}, \tag{2}$$

where σ_{HZ}^{SM} and $\sigma_{\nu\bar{\nu}}^{SM}$ are the cross-sections for the SM processes $e^+e^- \to H^0_{SM}Z^0$ and $e^+e^- \to \nu\bar{\nu}$, and $\bar{\lambda}$ is a kinematic factor, depending on m_h, m_A and $\sqrt{s}$, typically having values between 0.5 and 0.7 for LEP centre-of-mass energies. The two production processes depend on the angle $\beta-\alpha$ in a complementary manner. When in addition to the two Higgs doublets only Standard Model particles are considered, the h^0 and A^0 decay predominantly into fermion pairs for the masses that LEP is sensitive to. An additional complication is the possible decay $h^0 \to A^0A^0$ when $m_h > 2m_A$. The MSSM is a 2HDM with a considerable number of extra particles in addition to the Standard Model, namely all supersymmetric partners of the Standard Model particles. This leads to additional loop corrections to the production mechanisms, which turn out to be small in general. However, depending on the mass spectrum of the supersymmetric partners, there can be decay channels for the Higgs bosons in addition to those of the SM, e.g. invisible decay into pairs of lightest neutralinos. Charged Higgs bosons are coupled to the Z^0 with gauge couplings and therefore their production rate is usually not sensitive to model parameters. Their decay is predominantly sensitive to $\tan\beta$, which determines the branching ratios into $\tau\nu$ and $c\bar{s}$.

The background to Higgs signal events can be subdivided in three classes:

Two-photon processes, where both the electron and positron emit a (nearly) on-shell photon and these two photons have an interaction. The final state from two-photon interactions is normally characterised by a low momentum transverse to the beam direction and relatively high activity in the forward region of the detector. Despite a high production rate of two-photon interactions, they are easy to eliminate to a negligible level by simple cuts on the momentum transverse to the beam direction, final state multiplicity, and activity in the forward detectors.

Two-fermion processes, where the electron and positron annihilate into an off-shell Z^0 boson or photon. The Z^* or γ^* subsequently decays into a fermion pair, and in the case these are quarks, final state gluon emission can lead to multi-jet final states. Often, the Z^0 is produced on-shell through the emission of one or more photons by the initial state electron and positron (ISR).

Four-fermion processes, where four fermions are produced in the final state at "tree level". There is an overlap with the previous two processes, which can, in some cases, also lead to four-fermion final states. In addition, there are the hard four-fermion final states from W^+W^- and Z^0Z^0 production. The latter class of four-fermion events are the dominant background to many of the Higgs searches.

In Fig. 1 some important two-fermion and four-fermion process cross sections are given as a

Figure 1: Cross section of some important two-fermion and four-fermion background processes along with signal production cross sections for some Higgs masses, all as a function of e^+e^- centre-of-mass energy.

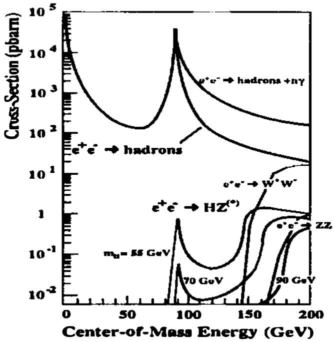
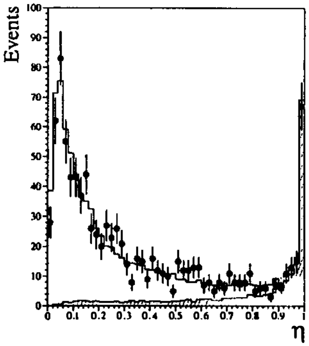


Figure 2: Artificial Neural Net b-tagging discriminant used by ALEPH.[4]



function of e^+e^- centre-of-mass energy. In the same figure the production cross section for SM Higgs bosons is indicated for several Higgs masses.

3 Results for the SM

The general search strategy for SM Higgs boson searches is to first select the correct topology, depending on the Z^0 and H^0_{SM} decay in the Higgsstrahlung final state in the following way (the details are of course somewhat different for the different collaborations):

Four-jet channel: The event must have a large charged and/or neutral particle multiplicity. A clear four-jet topology is selected by clustering the event into jets with a jet-finder, e.g. in the Durham scheme.[5] Usually the events are forced into four jets, but the clustering parameter is demanded to be within an acceptable range. Out of the four jets, at least one pair should have an invariant mass consistent with m_Z. The minimum angle between jets should be large enough to suppress two-fermion events with soft gluon radiation. The "Higgs mass" for selected events is usually obtained from a kinematic fit where the total momentum is constrained to zero and the total energy to the centre-of-mass energy. The jet-pair that forms the Higgs candidate mass is chosen to *not* be the pair that is most compatible with the Z^0 decay.

Neutrino channel: A large missing momentum is required that points away from the beam direction. The missing mass must be compatible with m_Z. The visible part of the event must have a clear two-jet structure. A minimum charged and/or neutral particle multiplicity is imposed either on the event or on the individual jets. The visible mass is identified with the "Higgs mass".

Lepton channel: Two identified leptons of the same flavour (either both electrons or both muons) are required. The invariant mass of the leptons must be compatible with m_Z. The leptons must be isolated from other nearby activity in the detector and they must be of opposite charge. The rest of the event, without the two leptons, is required to exhibit a clear two-jet topology. In the case of ALEPH these jets can even consist of one charged track each. The other experiments impose a large particle multiplicity on the event or the two individual jets in the rest of the event. The "Higgs mass" is determined from the lepton-pair recoil mass.

Tau channel: Isolated τ-leptons are identified, usually either as leptonic τ, one-prong hadronic, or three-prong hadronic τ decays. The event must have two τ candidates with opposite charge. The rest of the event, without the τ leptons, must be compatible with two jets. Now two cases

Table 1: Preliminary results for the SM Higgs search at LEP. Limits at 95% CL.

Experiment	background events expected	events selected	expected limit	observed limit
ALEPH	4.6	3	83 GeV	88 GeV
DELPHI	7.8	9	86.3 GeV	84.4 GeV
L3	8.5	11	86.7 GeV	87.6 GeV
OPAL	11.4	8	86.5 GeV	84.2 GeV
DELPHI+L3+OPAL	28	28	89.7 GeV	89.3 GeV

have to be distinguished: either the τ-pair invariant mass must be compatible with m_Z, or then jet-pair invariant mass must be compatible with m_Z.

After the topological selection of events b-quark tagging is applied. The hard four-fermion processes produce exactly the same final state topologies as Higgs signal events. However, the number of b-quarks produced in these events is limited. In W^+W^- events b-quarks production at all is highly suppressed and in hadronic Z^0Z^0 events the average number of b-quarks produced is about 0.8, while in $Z^0H^0_{SM}$ events this is about 2.2. Therefore, all the LEP collaborations have made sure to have a microvertex detector with a very good angular acceptance. In addition, much effort is put into optimally using tracking and other information to distinguish events with b-flavour from other events. The basic discrimination is made, using the b-flavoured hadron lifetime and its decay multiplicity. This is done through the use of track impact parameters and reconstructed secondary decay vertices. But also leptons from semi-leptonic b-quark decay, boosted sphericity and a number of other shape variables are used. As an example, the b-tagging discriminant that is used by ALEPH is plotted in Fig. 2. This is the output of an artificial neural net that uses as inputs: Impact parameters, vertex fit χ^2, boosted sphericity, jet multiplicity, and the sum of transverse momentum with respect to the jet-axis. A neural net output of $\eta = 1$ is very b-like, while $\eta = 0$ indicates very non-b-like.

The preliminary results of the Higgs search for the four LEP experiments are listed in Table 1. They are based on an integrated luminosity of about 55 pb^{1-} at $\sqrt{s} = 183$ GeV. The number of selected events are compared to the number of events expected from SM background processes and the number of expected Higgs signal events as a function of the Higgs mass. This comparison results in a confidence level (CL) for each Higgs mass that the observed number of

Figure 3: Preliminary mass distribution for Higgs candidates. The points are the combined DELPHI+L3+OPAL data. The shaded histograms are the SM backgrounds. The open histogram is the additional signal expectation for a 80 GeV Higgs boson mass.

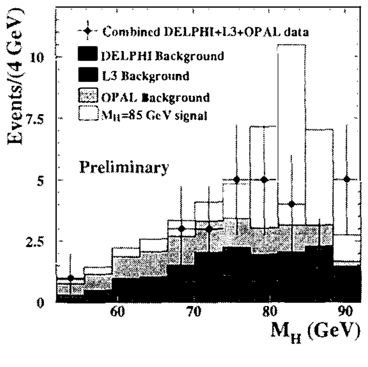


Figure 4: Preliminary confidence levels for the observation to be more signal-plus-background than background-only like for DELPHI+L3+OPAL combined. The grey curve is the average expected CL for background only experiments. The black curve is the observed CL.

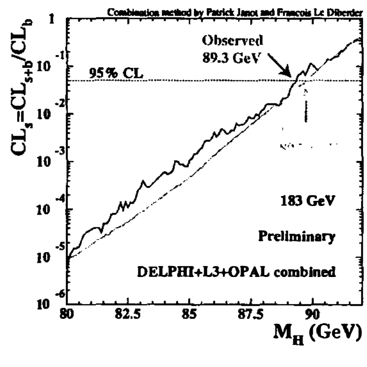
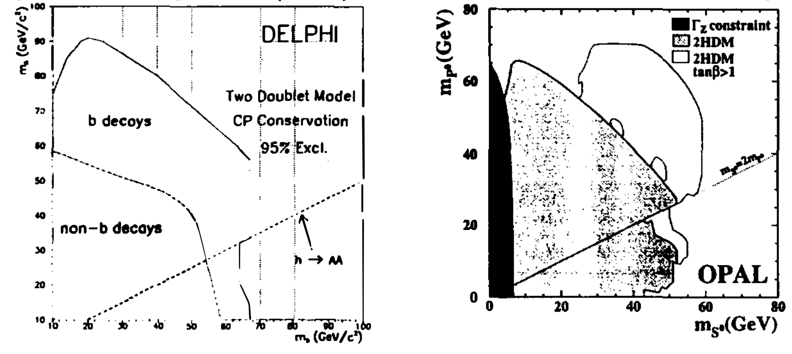


Figure 5: Excluded regions in the (m_h, m_A) plane for the 2HDM. DELPHI[8] left and OPAL[9] right.



events is more signal-plus-background than background-only like. The lowest Higgs mass that corresponds to 95% CL is the lower limit. The expected limit is the average limit that would be obtained when there is no signal and selected events are due to the background only.

The LEP Higgs working group has investigated four different methods to combine exclusion limits for the SM Higgs.[6] The combined lower Higgs boson mass limit for the data up to centre-of-mass energies of 172 GeV is 77.5 GeV. The results of the methods are not expected to be identical, but the differences in the final answer are found to less than 200 MeV. For the Preliminary DELPHI, L3 and OPAL results information was made available to combine them with one of the methods.[7] The combination is listed in the last line in Table 1. The Higgs candidate mass spectrum for data, background and signal+background Monte Carlo is shown in Fig. 3. The combined confidence levels are shown in Fig. 4. The best preliminary lower limit on the Higgs boson mass is derived to be 89.3 GeV at 95% CL, while the expected limit is 89.7 GeV.

4 Results for neutral Higgs bosons in 2HDM and MSSM

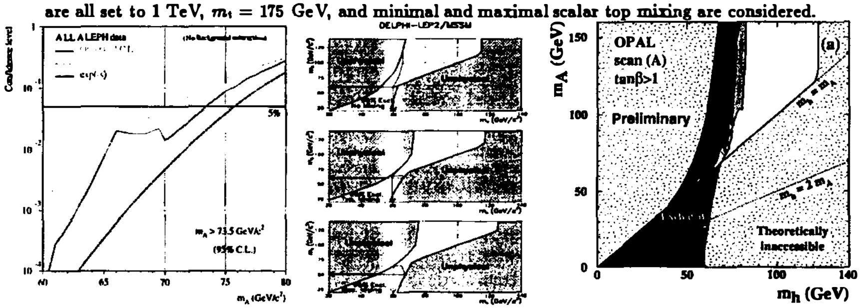
The search for the h^0 boson in Z^0h^0 production in the 2HDM and MSSM proceeds as presented in the previous section for the H^0_{SM}. The search for h^0A^0 is done for the $b\bar{b}b\bar{b}$ and $\tau^+\tau^-b\bar{b}$ final states. An added complication can be the decay $h^0 \to A^0A^0$ when $m_h > 2m_A$. For Z^0h^0 production followed by $h^0 \to A^0A^0$, the Standard Model analyses for the Z^0h^0 case turn out to be efficient also. For $h^0A^0 \to A^0A^0A^0$ a dedicated search is performed by OPAL for the $b\bar{b}b\bar{b}b\bar{b}$ final state.

The results for the Z^0h^0 and h^0A^0 searches can be combined using the complementarity of the production rate of the two processes (cf. Eq. 1 and 2.) In the 2HDM this leads to the excluded regions shown in Fig. 5. In this figure the black and dark grey area is excluded in any 2HDM. When $\tan\beta > 1$ and the decay $h^0 \to b\bar{b}$ is dominant, also the light grey area can be excluded.

The MSSM interpretation for neutral Higgs bosons is given in Fig. 6. In this figure the soft SUSY breaking masses (M_{SUSY}) are all taken to be about 1 TeV and the μ and A parameters of the MSSM are fixed by the minimal and maximal mixing conditions given in [10]. This leaves only two free parameters, e.g. m_h and $\tan\beta$. For $\tan\beta = 10$ the masses m_h and m_A are equal and the best lower limit on m_h and m_A for this situation is 75.2 GeV at 95% CL, attained by DELPHI.

The OPAL collaboration has performed a general scan of the MSSM parameter space in which all relevant soft SUSY breaking masses and the μ and A parameter are varied over a wide

Figure 6: Preliminary excluded regions in the (m_h, m_A) plane for the MSSM from left to right for ALEPH, DELPHI and OPAL. For ALEPH only the case $\tan\beta = 10$ $(m_h = m_A)$ is shown, for DELPHI the $(m_h, \tan\beta)$ projection of the excluded area is shown and for OPAL the (m_h, m_A) projection. The soft SUSY breaking masses are all set to 1 TeV, $m_t = 175$ GeV, and minimal and maximal scalar top mixing are considered.



range that is still allowed by other experimental results, e.g. from direct SUSY partner searches. The results are given in Fig. 7. In this general scan large areas that can be excluded when the soft SUSY breaking masses, μ and A parameter are fixed to certain values can no longer be excluded. A particular remarkable feature is that for any $(m_h, \tan\beta)$ pair a combination of other parameters can be found such that $\sin^2(\beta-\alpha) \approx 0$ and simultaneously $m_h + m_A > \sqrt{s}$. In this case both Z^0h^0 and h^0A^0 production are impossible and this parameter set can therefore not be excluded. However, not all parameter combinations in the MSSM give rise to physical models. In particular the vacuum can correspond to a stop field with a vacuum expectation value, which leads to a charge and colour breaking (CCB) vacuum. A full fledged calculation to determine which MSSM parameter sets are physical is not yet available. Two approximate criteria for CCB can be parametrised through the same inequality: $A^2 + 3\mu^2 < x({m_{\tilde{t}_L}}^2 + {m_{\tilde{t}_R}}^2)$, where $x \approx 3$ for a more stringent criterion,[11] but may be modified to $x \approx 7.5$ when tunneling from the EW minimum to a lower lying CCB minimum is taken into account.[12] The effect of applying this CCB criterion for the two variants is indicated in Fig. 7.

5 Results for invisibly decaying Higgs bosons

Invisibly decaying Higgs particles are searched for by looking for two fermions, either two hadron jets or two leptons of the same flavour, which should have m_Z as invariant mass. The recoil mass is then assumed to be the mass of the invisibly decaying Higgs. In Fig. 8 limits on the ratio of production cross sections for an invisibly decaying Higgs and the SM Higgs are given. If the Higgs is produced with the SM cross section this ratio can also be interpreted as the branching ratio of the Higgs into an invisible final state. For BR($h^0 \to$invisible)=100% m_h should be at least 71.3 GeV at 95% CL, if the production cross section is as for the SM Higgs, according to a preliminary result from ALEPH.

Figure 7: OPAL results for a general scan over MSSM parameters.[9] From left to right the (m_h, m_A), $(m_h, \tan\beta)$ and $(m_A, \tan\beta)$ projection are shown. The black area is always excluded. The grey areas are also excluded depending on the charge and colour breaking criteria that is applied.

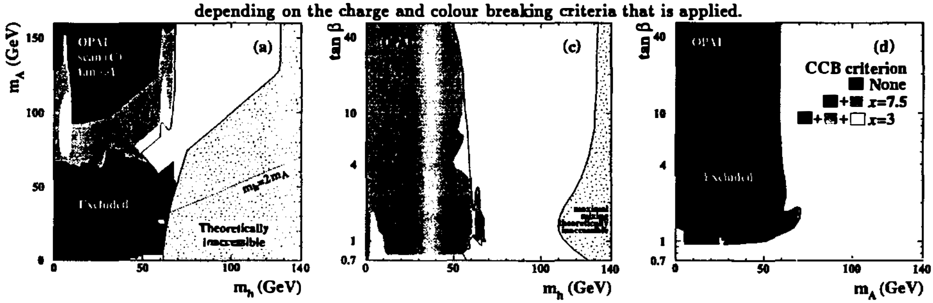
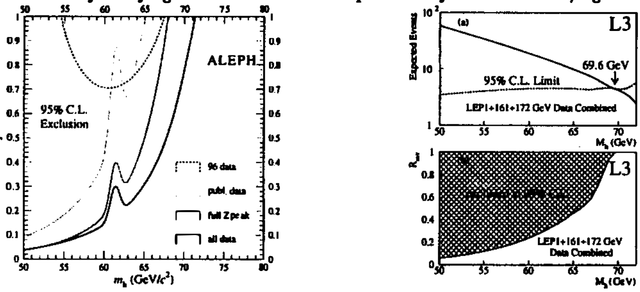


Figure 8: Limits on invisibly decaying h^0 bosons. Left is the preliminary ALEPH result, right the L3 result.[13]



6 Results for charged Higgs bosons

The charged Higgs search is done for three topologies: Hadronic channel, where both H^+ and H^- decay into a cs-quark pair. Semi-leptonic channel, where one of the H^+ or H^- decay into $\tau\nu$ and the other into a cs-quark pair. Leptonic channel, where both H^+ and H^- decay into a $\tau\nu$.

The results are presented as a function of the leptonic (or hadronic) branching ratio of the $H^\pm$ in Fig. 9. The best limit is attained by the DELPHI collaboration, who are the only to include $\sqrt{s}$ = 183 GeV data into their preliminary result. This best limit is $m_{H^\pm}$ > 56.7 GeV at 95% CL assuming that the $H^\pm$ decay is either into $\tau\nu$ or cs-quark pairs.

7 Higgs and photons

Models exist in which the lightest CP even Higgs does not couple to fermions.[16] They can still be produced in association with a Z^0 as in the SM, but their decay, for the mass range of interest at LEP, will result in two photons. An OPAL analysis identifies photons pairs recoiling against two jets, two leptons, or against missing momentum. No excess is seen over the expectation from SM background and the limits on BR($h^0 \to \gamma\gamma$) are shown in Fig. 10. For a SM production rate and BR($h^0 \to \gamma\gamma$)=100% the mass limit on the Higgs is m_h > 76.5 GeV at 95% CL.

For $h^0\gamma$ final states a DELPHI analysis find isolated single photons and studies their recoil mass. Without any further cuts this gives the Z^0 radiative return peak in the mass distribution. To increase sensitivity in the Z^0-mass region a b-tag is applied to the hadronic final states that recoil from the photon. The resulting limit on the production cross section times Higgs to $b\bar{b}$ branching ratio is shown in Fig. 11. Due to the fact that the production of the Higgs is in this case not in association with a Z^0, the excluded cross section times branching ratio is flat up to Higgs mass of about 160 GeV.

Figure 9: Limits on the charged Higgs mass at 95% CL, as a function of the leptonic (or hadronic) branching fraction. From left to right the ALEPH,[14] preliminary DELPHI, and OPAL [15] results are shown.

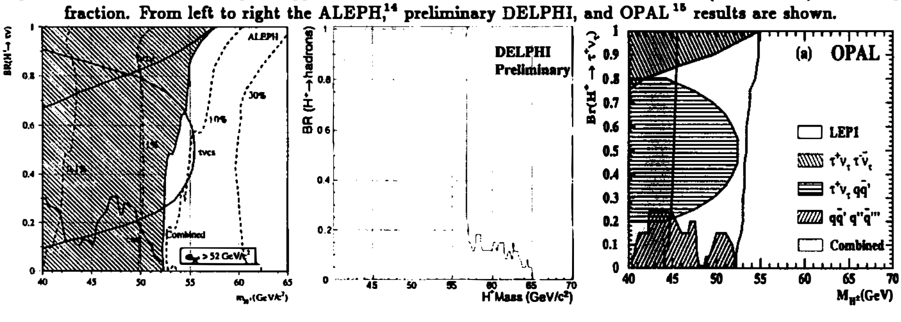


Figure 10: OPAL result on $BR(h^0 \rightarrow \gamma\gamma)$ for h^0 bosons produced in Z^0h^0 final states with SM production rates.[17]

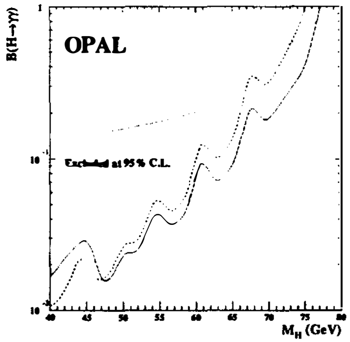
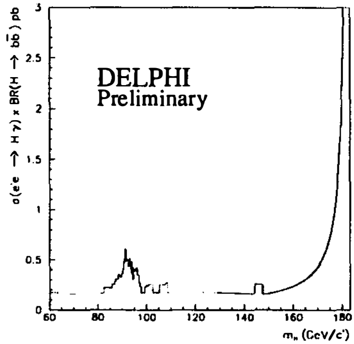


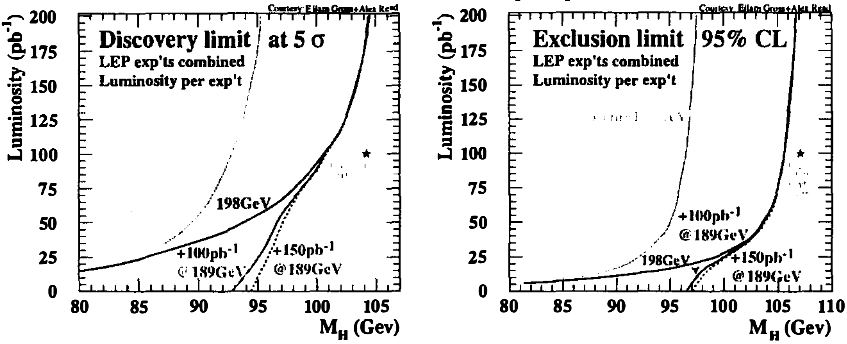
Figure 11: Preliminary DELPHI result for $h^0\gamma$ production cross section times $BR(h^0 \rightarrow b\bar{b})$ exclusion limits.



8 Outlook for LEP

Recently a new study was performed to assess the potential of LEP2 for Higgs discovery or exclusion based on the experience with the data taken so far at centre-of-mass energies up to 184 GeV.[18] In 1998 LEP is expected to run at $\sqrt{s}$ = 189 GeV and collect of the order of 150 pb^{-1}. In 1999 and 2000, new cryogenics equipment will become available that allows the energy to go up to $\sqrt{s}$ = 198 − 200 GeV. [3] In Fig. 12 the grey lines for E_{CM} = 189 GeV indicate the expected limits for discovery or exclusion as a function of integrated luminosity for data taken at $\sqrt{s}$ = 189 GeV only. The black line is for data taken at $\sqrt{s}$ = 198 GeV only. The results when data of $\sqrt{s}$ = 198 GeV is added to 100 pb^{-1} or 150 pb^{-1} data already taken at $\sqrt{s}$ = 189 GeV is also indicated. When taking 100 pb^{-1} at $\sqrt{s}$ = 198 GeV and 50 pb^{-1} at $\sqrt{s}$ = 200 GeV the exclusion limit improves marginally, compared to taking 200 pb^{-1} at $\sqrt{s}$ = 198 GeV, while the discovery limit does not change. If this trade off has to be made, higher luminosity is preferable for MSSM neutral and charged Higgs searches. For reasonable assumptions about energy and luminosity a SM Higgs up to 105 GeV is likely to be discovered at LEP and in case nothing is found the SM Higgs can be excluded for masses up to 108 GeV.

Figure 12: Expected limits on discovery (left) and exclusion (right) for different scenarios for running the LEP collider. The indicated luminosities are per experiment.



9 Conclusion

Since the start of LEP2 much data has been collected at the highest centre-of-mass energies for e^+e^- colliders. These data have been searched for all kinds of Higgs bosons with highly sophisticated data analysis techniques. Despite all this effort, no Higgs boson has been observed yet. Substantial effort was put into developing sophisticated and precise procedures to set limits. The best limit for the SM Higgs is $m_H > 89.3$ GeV at 95% CL. In the MSSM limits are set in a number of projection planes of MSSM parameter space. For example for $\tan\beta = 10$ and $M_{SUSY} = 1$ TeV a best limit of $m_h = m_A > 75.2$ GeV at 95% CL is set. A mass limit for charged Higgs bosons is set at $m_{H^\pm} > 56.7$ GeV at 95% CL. In addition a number of more exotic possibilities for Higgs boson production and decay were searched for with negative results.
The LEP2 programme is not yet over and further increases of energy and luminosity paired with indications for the existence of a light Higgs from precision Z^0 decay data make the coming few years exciting times for Higgs boson searches at LEP with mass reaches for the SM Higgs above 105 GeV.

Acknowledgements

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References

1. D. Reid, *Status of EW measurements at LEP*, these proceedings.
2. R. Munoz-Tapia, *Limits on the mass of the lightest Higgs in Susy*, these proceedings.
3. D. Brandt, *Performance and energy reach of LEP2*, these proceedings.
4. ALEPH Collab., R. Barate *et al.*, Phys. Lett. **B412** (1997) 173.
5. N. Brown and W.J. Stirling, Phys. Lett. **B252** (1990) 657;
   S. Bethke, Z. Kunszt, D. Soper and W.J. Stirling, Nucl. Phys. **B370** (1992) 310;
   S. Catani *et al.*, Phys. Lett. **B269** (1991) 432;
   N. Brown and W.J. Stirling, Z. Phys. **C53** (1992) 629.
6. ALEPH, DELPHI, L3 and OPAL Collaborations, *Lower bound for the Standard Model Higgs boson mass from combining the results of the four LEP experiments*, CERN-EP/98-046.
7. P. Janot and F. Le Diberder, *Optimally Combined Confidence Limits*, CERN-PPE/97-053, LPNHE 97-01, to be published in Nucl. Instr. Meth. A.
8. DELPHI Collab., P. Abreu *et al.*, E. Phys. J. **C2** (1998) 1.
9. OPAL Collab., K. Ackerstaff *et al.*, *A Search for Neutral Higgs Bosons in the MSSM and Models with Two Scalar Field Doublets*, CERN-EP/98-029.
10. E. Accomando *et al.*, *Higgs Physics* in *Physics at LEP2*, Editors: G. Altarelli, T. Sjöstrand and F. Zwirner, CERN 96–01 (1996).
11. J.M. Frère, D.R.T. Jones and S. Raby, Nucl. Phys. **B222** (1983) 11;
    L. Alvarez-Gaumé, J. Polchinski and M. Wise, Nucl. Phys. **B221** (1983) 495;
    J.P. Derendinger and C.A. Savoy, Nucl. Phys. **B237** (1984) 307;
    C. Kounnas, A.B. Lahanas, D.V. Nanopoulos and M. Quirós, Nucl. Phys. **B236** (1986) 438;
    J.A. Casas, A. Lleyda and C. Muñoz, Nucl. Phys. **B471** (1996) 3.

12. A. Kusenko, P. Langacker and G. Segre, Phys. Rev. **D54** (1996) 5824.
13. L3 Collab., M. Acciarri *et al.*, Phys. Lett. **B418** (1998) 389.
14. ALEPH Collab., R. Barate *et al.*, *Search for charged Higgs bosons in e+e- collisions at centre-of-mass energies from 130 to 172 GeV* , CERN PPE/97-129, Submitted to Phys. Lett. B.
15. OPAL Collaboration, K. Ackerstaff *et al.*, Phys. Lett. **B426** (1998) 180.
16. A. G. Akeroyd, Phys. Lett. **B368** (1996) 89;
A. G. Akeroyd, Phys. Lett. **B353** (1995) 519;
J. F. Gunion, R. Vega and J. Wudka, Phys. Rev. **D42** (1990) 1691.
17. OPAL Collaboration, K. Ackerstaff *et al.*, E. Phys. J. **C1** (1998) 31.
18. E. Gross and A. L. Read, *Prospects of Higgs search at LEP 200*, invited talk to appear in proceedings of the 12th Les Rencontres de Physique de la Vallée d'Aoste, La Thuile, 1-7 March 1998.