AC

ETHZ-IPR-94-11

September 5, 1994

Prospects for Higgs detection at LEP2

M. Felcini¹

Labor für Hochenergiephysik, ETH, Zürich, Switzerland

¹ *Mailing address:*

CERN, PPE Division, CH-1211 Geneva 23, Switzerland

Abstract

The experiments at the LEP2 collider will continue the search for Higgs particles, in the mass range up to 100–110 GeV, depending on the LEP2 center of mass energy and luminosity. In this paper I describe the experimental strategy designed to search for Higgs particles produced either via the Bjorken process ($e^+e^- \rightarrow h Z$) or in pair ($e^+e^- \rightarrow h A$). I summarize then the results for the expected mass regions explorable at LEP2, as function of the center of mass energy and the luminosity provided to the experiments.

*Review talk given at the
Zeuthen Workshop on Elementary Particle Theory
“Physics at LEP200 and beyond”
Teupitz, Germany, 10–15 April 1994*

5w 3446

Prospects for Higgs detection at LEP2

M. Felcini ^{a *}

^aLabor für Hochenergiephysik, ETH, Zürich, Switzerland

The experiments at the LEP2 collider will continue the search for Higgs particles, in the mass range up to 100–110 GeV, depending on the LEP2 center of mass energy and luminosity. In this paper I describe the experimental strategy designed to search for Higgs particles produced either via the Bjorken process ($e^+e^- \rightarrow h Z$) or in pair ($e^+e^- \rightarrow h A$). I summarize then the results for the expected mass regions explorable at LEP2, as function of the center of mass energy and the luminosity provided to the experiments.

1. Introduction

The Higgs sector is the only part of the otherwise well established electroweak theory that has yet to be fully understood. The theory, in its minimal version, predicts the existence of a physical scalar particle, the Higgs boson. To date there has been no observation of such a particle to confirm the Higgs mechanism. This may be because the centre of mass energy of today's colliders is insufficient to produce it. Combining the results of the experimental Higgs searches at LEP1 gives a 95% CL lower limit on the SM Higgs mass of 64.5 GeV [1]. The theory does not specify the mass of the Higgs boson, but, under certain assumption, it is possible to derive a lower limit on the Higgs mass, which is clearly of great interest and guide for the experimental search. In the framework of the Standard Model (SM) a lower limit on the Higgs mass m_H can be derived as function of the top mass m_t . There are indications that the top is rather heavy. Recently the CDF Collaboration has reported evidence for top production with a mass $m_t = 174 + 10^{+13}_{-12}$ GeV [2]. From precision measurements of the SM parameters at LEP and SLC, it is found $m_t = 178^{+11}_{-11} {}^{+18}_{-19}$ GeV [3]. As a consequence of such a large top mass, the lower limit on the SM Higgs mass is also a large value, typically above 130 GeV [4].

In theories beyond the Standard Model, where more Higgs field are present, this limit is not valid

anymore. Among the many possible extensions, the Minimal Supersymmetric Standard Model is the most popular because of its predictive power, which serves as reference guide in the experimental search for physics beyond the Standard Model. In this model, for $m_t \sim 170-180$ GeV, the lightest Higgs must have a mass below 130 GeV (see *e.g.* Ref.[5]).

The Higgs search at LEP1 is approaching its intrinsic limit, and it is unlikely that the lower limit on the Higgs mass will be extended beyond 70 GeV. However, the forthcoming upgrade to LEP2 will allow the search to be extended to higher masses. The plan is to increase the center of mass energy up to 180 GeV by 1996. The LEP magnetic limit could allow energies up to 240 GeV.

The LEP2 collider, depending on the center of mass energy and the luminosity, could explore the Higgs mass range up to 100–110 GeV, a very demanding region for the experiments at LHC. Most important, if a relatively light Higgs ($m_h \lesssim 100$ GeV) is found at LEP2, this could be a first signal that there is an extended Higgs sector and physics beyond the Standard Model.

In this paper I report about the prospects for detecting Higgs particles at LEP2.

2. Energy and luminosity for discovery

The upper limit of the Higgs mass range explorable at LEP2 depends on the center of mass (CM) energy of the machine and the luminosity delivered to the experiments. The CM energy de-

*Mailing address: CERN, PPE Division, CH-1211 Geneva 23, Switzerland

defines the kinematical limit for Higgs production. The CM energy depends on the number of superconducting cavities which will instrument the LEP tunnel. The present plan is to have the machine running at a CM energy of 176–180 GeV by 1996 with $\mathcal{L} = 2(4) \times 10^{31} \text{cm}^{-2} \text{s}^{-1}$ average instantaneous luminosity, in the 4(8) bunches-per-beam running mode. The energy increase can be achieved by installing in the LEP tunnel 192 superconducting (SC) cavities delivering an accelerating gradient of 6 MV/m, in addition to the copper cavities presently operating in the LEP tunnel. The replacement of half of the copper cavities (which limit the beam current) with SC cavities in 1997 should allow to obtain an average instantaneous luminosity of $\mathcal{L} = 6 \times 10^{31} \text{cm}^{-2} \text{s}^{-1}$, corresponding to about 140 pb^{-1} delivered per year to each experiment.

With additional 64 cavities a CM energy of 190 GeV could be obtained. Filling completely the LEP tunnel with SC cavities (about 390) would allow to reach a CM energy of 210 GeV [6]. In Fig.1[7] the number of SC cavities is shown as function of the beam energy, for an accelerating gradient of 6 MV/m. On the right-hand side of Fig. 1 the corresponding RF power needed to operate the cavities is also shown. Cavities deliver-

Figure 1. the number of superconducting cavities is shown as function of the LEP beam energy, for an accelerating field of 6 MV/m. On the right-hand side shown is also the corresponding RF power needed to operate the cavities.

ing higher accelerating field would allow to reach the magnetic limit of the LEP ring, which is about 240 GeV [8].

Even though the CM energy could be enough to produce Higgs particles, in addition one needs enough luminosity to see a signal, that is a statistically significant excess of events over the expected background. If one defines signal significance the ratio $R = S/\sqrt{B}$, being S and B the total number of signal (S) and background (B) events, after cuts, then one can also define the minimum luminosity required for discovery as:

$$L_{min} = R_{min}^2 \frac{\sigma_B \epsilon_B}{\sigma_S^2 \epsilon_S^2}$$

where σ_S (σ_B) and ϵ_S (ϵ_B) are the overall signal (background) cross-section and detection efficiency, respectively. R_{min} is the minimum signal significance required for discovery. Conventionally it is required $R_{min} = 5$, that is one defines signal an excess of events at least 5 times larger than the background standard deviation $\sigma = \sqrt{B}$. In the above expression, one observes that the minimum luminosity (or time) for discovery increases linearly with the background efficiency and decreases quadratically with the signal efficiency. Thus it is important to optimize the detector and the data analysis to have the maximum signal efficiency. The minimum luminosity for discovery is also a sensitive measure of how good an experiment is in detecting a signal and it can be used to compare the detection capabilities of different experiments. A better experiment requires less luminosity (time) to see a signal. Several studies have been done by the LEP experiments to define and optimize the Higgs search strategy at LEP2. In the following I will describe the main characteristics of the search. The result of the analysis is given in terms of the minimum luminosity required to see a signal as function of the Higgs mass at a given CM energy. Three cases have been studied in detail. $\sqrt{s} = 175, 190$ and 210 GeV, corresponding to three possible phases of the LEP2 enterprise.

3. Experimental search strategy

At LEP2 a Higgs particle is expected to be produced via the Bjorken process:

$e^+e^- \rightarrow Z^* \rightarrow H Z$. As shown in Fig.2 [9], a Higgs of mass m_H is produced efficiently via the $e^+e^- \rightarrow H Z$ process only if the CM energy is enough to produce a real Z together with the Higgs, that is if $\sqrt{s} \gtrsim m_H + m_Z$. One also ob-

Figure 2. Cross section for the SM Higgs production process $e^+e^- \rightarrow H f\bar{f}$ as a function of the CM energy for several Higgs masses.

serves that the peak value of the cross section is obtained for $\sqrt{s} \simeq m_H + m_Z + \sim 10$ GeV.

If more Higgs bosons exist, as expected for example in the MSSM, then Higgs particles could also be produced in pairs via the process $e^+e^- \rightarrow Z^* \rightarrow h A$. Within the Higgs mass range of interest at LEP2 ($60 \lesssim m_H \lesssim 100$ GeV), the Higgs is expected to decay mainly (about 90% of the cases) into $b\bar{b}$. The Z decays 10 % and 20 % of the times into charged leptons and neutrinos respectively. Its main decay is into $q\bar{q}$ pairs (70% of all decays), among which $b\bar{b}$ pairs, with 15% branching ratio. Thus there are three typical signatures which would be characteristic of Higgs production at LEP 2:

- ($\geq$) two jets plus a charged lepton pair,
- ($\geq$) two jets plus missing energy and momentum,

- ($\geq$) four jets.

The four jets signature would also be characteristic of hA production, so the search in the four jet channel can be sensitive both to the hZ as well as to the hA production.

Unfortunately there are several other known physics processes which could produce same signatures as the Higgs and fake a signal. The most dangerous ones are: WW , $Ze^+e^- \rightarrow$, $We\nu$ and ZZ production. Their cross-sections as function of the CM energy are shown in Fig. 3 [10]. It is

Figure 3. Cross sections for background processes compared to the ZH cross sections as function of the CM energy.

clear from the production cross sections that we need to reject the background by at least a factor of 100 to detect a Higgs in the 60–110 GeV mass range. Topological cuts can be used to reduce this background. The general strategy in the ZH search is first to single out events in which there is one identified Z decay. This is done by selecting events with at least two energetic jets. In addition it is required that there is either a charged lepton pair, or missing momentum, or a pair of jets with an invariant mass close to the Z mass. In these

events then the invariant mass distribution of the remaining jets (recoiling mass) is searched for a peak produced by the Higgs decay.

In Tab.1 the main search strategy in the three above mentioned channels is summarized together with the relative event rates and signal efficiencies in the different channels.

Main Search Strategy

Event topology	BR _{ZH}	BKGD Reduction	Signal EFF
~ 64.4%	$M_{JJ}^{(1)} \simeq M_Z$ $M_{JJ}^{(2)} + b - \text{tagging}$	~ 15-20%
~ 18.4%	$M_{miss} \simeq M_Z$ $M_{JJ} + b - \text{tagging}$	~ 30%
~ 9.3%	$M_{l+l} \simeq M_Z$ $M_{JJ} + b - \text{tagging}$	~ 50%

Table 1

Expected topologies for Higgs events at LEP2, with relative event rates, background reduction cuts and detection efficiencies.

The cleanest channel for the HZ search is the jets + lepton pair channel. A HZ event, with the Z decaying into a muon pair and H into b-jets, as it could be recorded in the L3 detector, is shown in Fig. 4. In the jets+lepton pair channel, the WW, $Ze^+e^- \rightarrow$, $We\nu$ backgrounds are negligible (due to the requirement of the charged lepton pair with invariant mass close to the Z mass). The only relevant background comes from events $e^+e^- \rightarrow ZZ$ where one Z decays into a lepton pair and the other Z decays into hadrons. In this case the invariant mass of the jets recoiling against the lepton pair peaks at the Z mass, leading to a clear discrimination of the signal from the background, for Higgs masses not very close to 90 GeV. The recoil mass M_{jj} is calculated from the measured energy, $E_{\ell\ell}$, and momentum, $p_{\ell\ell}$, of the lepton pair, imposing energy and momentum conservation:

$$M_{jj} = \sqrt{(\sqrt{s} - E_{\ell\ell})^2 - p_{\ell\ell}^2}.$$

Figure 4. A HZ event, with the Z decaying into a muon pair and H into b-jets, as it could be recorded in the L3 detector.

Since the CM energy of LEP is known with practically negligible error, the (systematic) error on the jet-jet recoil mass measurement is dominated by the error on the lepton energy and momentum measurements. All the LEP experiments measure lepton energy and momentum with high precision. This is quite helpful to separate the Higgs peak from the Z peak (for Higgs masses not too close to the Z mass), thus allowing efficient background reduction and Higgs detection. As an example, for the L3 experiment, a resolution in the recoil mass distribution of less than 2% is obtained, as shown in Fig. 5, where the recoil mass distribution is shown for events simulated in the L3 detector at $\sqrt{s} = 175$ GeV and Higgs mass 70 GeV and 80 GeV. The residual ZZ^* background is also shown. The Higgs signal is clearly visible and the systematic error on the Higgs mass is less than 2%. Such a good resolution could also be helpful for the Higgs mass measurement. However the total error on the Higgs mass measurement is given by

$$\Delta M_H/M_H = \sqrt{1/N + (\Delta M_{\ell\ell}/M_{\ell\ell})^2}. \quad (1)$$

being N the number of Higgs events in the mass peak and $\Delta M_{\ell\ell}/M_{\ell\ell}$ the lepton pair mass resolution. Unfortunately, the number of Higgs events expected at LEP2 in the jets+lepton pair channel is not very large, due to the relatively small

Figure 5. The recoil mass distribution in the jets+lepton pair channel, for events simulated in the L3 detector at CM energy of 175 GeV and Higgs mass 70 GeV and 80 GeV.

branching ratio of the Z decay into leptons. As an example, even at $\sqrt{s} = 175$ GeV, where the ZZ background is very small, with 500 pb^{-1} , 18 (8) Higgs events are left after cuts for a 70 (80) GeV Higgs mass [17]. The statistical error ($1/\sqrt{N}$) dominates completely the Higgs mass measurement, if N is not at least of the order of 1000 (which would require of the order of 30 fb^{-1} for the 70 GeV mass). So the mass measurement could be difficult, but it is reasonable to think that if the Higgs mass is 80 GeV or less, the Higgs discovery could be done in the lepton channel where few clean events could be recorded in a relatively short time.

If the Higgs mass is above 80 GeV, the HZ cross section is too small at $\sqrt{s} = 175$ GeV to allow Higgs discovery in a reasonable amount of running time at LEP2. So, the next phase of the collider at $\sqrt{s} = 190$ GeV would be needed. The main problem at this energy is that the ZZ background is not negligible. For Higgs mass above 80 GeV the number of HZ events after cuts in the jets+lepton pair channel is relatively small (9 events for the 90 GeV Higgs with 500 pb^{-1} and a detection efficiency of 50%) with a background of similar size. So for Higgs discovery it is necessary to search for a signal also in the 4 jets channel and the 2 jet+missing energy channel, which have larger rate, but also larger background, than the jets+lepton pair channel. A possibility to enhance the signal to background ratio, after the topological cuts have been applied, is offered by the fact that the Higgs decays into $b\bar{b}$ with a rate about 6 times larger than the Z and that the W to b -quark decay rate is negligible. Thus, the most powerful way to reduce the background, from standard production of W and Z bosons, is the identification of jets produced by the fragmentation of heavy hadrons (B and D mesons), hereafter referred to as b -jets.

Several B -tagging methods have been successfully developed and used to study heavy quark physics at LEP, with impressive new results in this field. These methods are based on the fact that B - and D -hadrons have a long lifetime as compared to hadrons from lighter quarks. Thus a characteristic signature of a B -decay is a jet with a large number of tracks coming from secondary

vertices and with a large average impact parameter. The possibility of identifying secondary vertices and measuring very precisely the track impact parameter is offered by microvertex detectors, with which all the four LEP experiments have been equipped. In Fig. 6 a multijet event

Figure 6. Multijet event with displayed secondary vertices as recorded by the microvertexed detector of the DELPHI experiment.

recorded by the DELPHI detector is shown. The special feature of this event is that many jets with several tracks coming from secondary vertices are visible, indicating that the jets have been probably produced by B hadrons. This event is a nice example of how an HZ or hA event could look like.

The usefulness of b-tagging in the search for a Higgs of more than 80 GeV at LEP2 is shown in Fig. 7 [10] where the distribution of the jet-jet invariant mass recoiling against the jet pair identified as coming from the Z decay is shown before

Figure 7. Distribution of the jet-jet invariant mass recoiling against the jet pair identified as coming from the Z decay shown before and after applying b-tagging for a 90 GeV Higgs signal and for the sum of the backgrounds for the DELPHI experiment.

and after applying b-tagging for a 90 GeV Higgs signal and for the sum of the backgrounds. Depending on the cuts, different b-tagging efficiencies and purities can be achieved. The choice of the b-tagging cuts should be optimized for each specific channel. For example, in the 4 jets channel the number of Higgs signal events after topological cuts is relatively large, so one can afford to require high purity, but small efficiency, to largely reduced the background. In the jets+missing energy channel, where the signal, but also the background, is smaller than in the 4 jets channel, one can release the requirement for higher purity, allowing for a more efficient b-tagging.

Three experiments (ALEPH, DELPHI and OPAL) are going to replace their present microvertex detector with a longer one to extend the coverage in θ and with thinner layers to reduce the multiple scattering, which deteriorates the space resolution. ALEPH will extend the azimuthal angle coverage from 49° to 29° [11], DELPHI from 45° to 25° [12], OPAL from 40° to 27° [13]. The L3 microvertex detector has already a coverage down to 22° [14].

The improvement in tagging efficiency due to a longer and thinner microvertex detector is shown, for example, in Fig. 8 [13] where one observes that with the upgraded microvertex detector higher purity can be obtained for same values of b-tagging efficiency. This improvement is directly reflected into the reduction of the luminosity needed to detect a 5 standard deviation excess over the background, as shown in Fig. 9. For example, the detection of a 90 GeV Higgs signal at $\sqrt{s} = 190$ GeV would require 25% less luminosity with the upgraded microvertex detector (360 pb^{-1}) as compared to the present configuration (490 pb^{-1}). Similar values are obtained by the other experiments. Fig. 10 [16] shows the results for the ALEPH experiment and Fig. 11 [17] shows the results for the L3 experiment. One sees that the explorable Higgs mass range at LEP2 is $m_H \lesssim \sqrt{s} - 100 \text{ GeV}$. If the Higgs is relatively light (around or below 80 GeV), it could be detected by the 4 LEP experiments in the first year of LEP2 running (assuming a delivered luminosity per year of about 150 pb^{-1}).

Figure 8. B-tagging purity versus efficiency of the microvertexed detector of the OPAL experiment for the present configuration and the one (longer and thinner) being built for LEP2.

Figure 9. The luminosity required by the OPAL experiment to detect a 5 standard deviation Higgs signal with the microvertexed detector in the present configuration and with the upgraded microvertex (longer and thinner) one for LEP2.

Figure 10. The luminosity required by the ALEPH experiment to detect a 5 standard deviation Higgs signal for three different CM energies.

Figure 11. The luminosity required by the L3 experiment to detect a 5 standard deviation Higgs signal for three different CM energies.

4. Expectations for detection of MSSM Higgs particles

The rate of the Bjorken process in the MSSM compared to the Standard Model is suppressed by a factor $\sin^2(\beta - \alpha)$. The rate of the pair production process in the MSSM is proportional to $\cos^2(\beta - \alpha)$ and so it is complementary to the Bjorken process.

Shown in Fig. 12 are contours of constant $\sin^2(\beta - \alpha)$, m_h and m_H [15] in the m_A - $\tan\beta$ plane for 170 GeV top mass. One observes that for this top mass value the upper value of m_h is 126 GeV. This limit increases with the top mass, from about 111 GeV when $m_t = 140$ GeV to about 130 GeV when $m_t = 180$ GeV. Fig.12 shows that for $m_A \gtrsim 150$ GeV $\sin^2(\beta - \alpha)$ is very close to unity, so the MSSM lightest Higgs has the same production cross section as the SM one. One also sees that the heavier Higgs H is inaccessible at LEP2.

The number of events expected for each reaction over the running time of LEP2 (integrated luminosity assumed 500 pb^{-1}) can be calculated. They are shown in Figures 13 as contour plots in the m_A - $\tan\beta$ plane for various values of the CM energy.

The hA search is done in the 4 jets channel looking for an excess of events over the expected background in a small region of the M_{12} -vs- M_{34} scatter plot, being M_{12} and M_{34} the invariant masses of the 3 possible 2×2 jet pairing combinations in the 4 jets event. Again, b-tagging is quite helpful in reducing the background. With b-tagging cuts similar to those used for the hZ search a signal efficiency almost twice that for hZ signal can be expected, given the larger average number of tracks coming from secondary vertices in events with 4 B hadrons, as compared to the Zh events, where in most of the cases only 2 B hadrons are produced (from the Higgs decay).

Combining the results of the hZ and hA searches it is possible to know the regions of the $\tan\beta$ - m_A parameter space which will be explorable at LEP2 depending on the CM energy and the luminosity. They are shown in Fig.15 where one can see that the region covered by the hA search, on the left of $m_A \sim 80$ GeV,

Figure 12. Contours of constant $\sin^2(\beta - \alpha)$ (a), m_h (b) and m_H (c).

Figure 13. Number of expected events at LEP2, for $m_t = 170$ GeV with 500 pb^{-1} and $\sqrt{s} = 175, 190, 210$ GeV. Solid contours are for Bjorken process ($h Z$), dashed contours for pair ($h A$) production

Figure 14. Regions of the $\tan \beta$ m_A plane where a 5σ signal can be detected with 500 pb^{-1} , for three possible values of the LEP2 CM energy and $m_t = 170$ GeV.

is practically independent of the CM energy. At $\sqrt{s} = 175$ GeV, most of the accessible region is covered by the hA search, because in this region the hZ cross section is rather suppressed, as compared to the SM one. If no signal is detected, it would not be possible to set a limit on $\tan\beta$. At $\sqrt{s} = 190$ GeV, the region for $\tan\beta \lesssim 1.5$ could be explored. At $\sqrt{s} = 210$ GeV the search could be extended to the region for $\tan\beta \lesssim 3$. The reduction in the explorable region of the parameter space, as a consequence of the large top mass is evident comparing Fig.14 with earlier results, shown in Fig.15 (from P. Janot reported in Ref. [6]), for which $m_t = 140$ GeV was used.

5. Conclusions

I have reviewed the strategy for Higgs search at LEP2. The detector requirements for an efficient search at LEP2 are:

- good electron and muon momentum measurement will be important for efficient Higgs detection in the low mass region, about or below 80 GeV;
- hermeticity, for good missing energy and momentum imbalance measurements, for the search in the jets+missing energy channel.
- good jet energy and direction resolution, for invariant mass reconstruction, to discriminate between signal and WW and ZZ background, for the search in the four jets channel;
- efficient b-tagging capability is mandatory for Higgs masses in the range $\sim m_Z \pm 10$ GeV, whilst, for lower Higgs masses, though not mandatory, it is very helpful in reducing background, and thus running time for discovery.

At a given $\sqrt{s}$, the Higgs mass range explorable at LEP2 with about 500 pb^{-1} , is given by

$$m_H \lesssim \sqrt{s} - 100 \text{ GeV}$$

If the Higgs is relatively light (around or below 80 GeV), it could be detected by the 4 LEP experiments in the first year of LEP2 running.

Figure 15. Regions of the $\tan\beta$ vs m_A plane accessible by with 500 pb^{-1} for two possible LEP2 energies and $m_t = 140$ GeV.

In the context of the MSSM, a 5σ signal can be detected, with about 500 pb^{-1} , if: $m_A \lesssim 80 \text{ GeV}$, independent of $\tan\beta$ and almost independent of the CM energy, and $\tan\beta \lesssim 3(1.5) \text{ GeV}$ for $\sqrt{s} = 210(190) \text{ GeV}$, independently of m_A . No limit on $\tan\beta$ can be set at $\sqrt{s} = 175 \text{ GeV}$.

As a consequence of the large top mass, the Standard Model Higgs might be beyond the reach of LEP2. However, it is still very important to search for Higgs particles at LEP2, because the detection of a light Higgs particles could be the first signal of an extended Higgs sector and physics beyond the Standard Model.

REFERENCES

1. M. Pohl, "Search for New Particles and New Interactions", Plenary talk at the ICHEP-94 Conference, Glasgow, July 20-27 1994, to be published in the conference proceedings.
2. CDF Collaboration, Phys. Rev. Lett. **73** (1994) 225.
3. D.Schaile, "Precision tests of the electroweak theory", Plenary talk at the ICHEP-94 Conference, Glasgow, July 20-27 1994, to be published in the conference proceedings; LEP Electroweak Working Group, paper in preparation.
4. G. Altarelli and G. Isidori, "Lower limit on the Higgs mass in the Standard Model: an update", Preprint CERN-TH.7351/94, July 1994.
5. J.A. Casas, J.R. Espinosa, M. Quiros and A. Riotto,, "The lightest Higgs boson mass in the Minimal Supersymmetric Standard Model", Preprint CERN-TH.7334/94, July 1994.
6. D. Treille, "The LEP200 program". Preprint CERN-PPE/93-54-REV, March 1993.
7. C. Wyss, "LEP 200 Programme", Talk given at the LEP Experiments Review Committee Meeting, CERN, Geneva, November 2-4 1992.
8. C. Rubbia, "Future facilities for particle physics", Proc. LP-HEP 1991, Geneva (World Scientific, Singapore), p.441.
9. E. Gross and P. Yepes, Int. J. Mod. Phys. **A8** (1993) 407.
10. S. Katsanevas *et al.*, "Report from the working group on LEP200 Physics", DELPHI Note DELPHI 92-166 Phys 250, December 1992.
11. ALEPH Collaboration, "Proposal for a new vertex detector for OPAL", Note CERN-LEPC/93-8, May 1993.
12. DELPHI Collaboration, "Proposal for the upgrade of DELPHI in the forward region", Note CERN-LEPC/92-13, September 1992.
13. OPAL Collaboration, "Proposal for a new silicon microvertex detector for OPAL", Note CERN-LEPC/93-13, September 1993.
14. L3 Collaboration, "Proposal for a Silicon Microvertex Detector for L3", Note CERN-LEPC/91-5, May 1991.
15. These contour plots are based on the calculations reported in Z. Kunszt and F. Zwirner, Nucl. Phys. **B385** (1992) 3.
I wish to thank Fabio Zwirner for kindly providing the computer program for the calculation of MSSM Higgs masses and couplings.
16. P. Janot, "Will a Higgs boson be found at future $e^+e^- \rightarrow$ colliders?", Preprint LAL 92-20, May 1992, published in the Proceedings of the 27th Rencontres de Moriond, 1993.
17. J. Alcaraz, M. Felcini, M. Pieri, B. Zhou, "Higgs Discovery Potential of the L3 Detector at LEP200", Preprint CERN-PPE/93-28, Contribution to the LEP Experiments Review Committee Meeting, CERN, Geneva, November 2-4 1992.