

Flavour Independent Search for Hadronically Decaying Neutral Higgs Bosons at LEP

The LEP Working Group for Higgs Boson Searches

Abstract

Hadronic decays of Higgs bosons, not necessarily into b -quarks, have been searched for using data collected at LEP-2. Such searches are complementary to the usual Standard Model Higgs searches and lead to more model-independence. Preliminary results obtained by the four LEP collaborations are presented for the hZ production mechanism (using the $q\bar{q}q\bar{q}$, $q\bar{q}\nu\bar{\nu}$ and $q\bar{q}l^+l^-$ channels) and combined for the first time.

ALL RESULTS QUOTED IN THIS NOTE ARE PRELIMINARY
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1 Introduction

There are extensions of the Standard Model in which Higgs bosons have suppressed couplings into b -quarks. This can occur for specific parameters of the Two Higgs Doublet Model [1], or of the Minimal SuperSymmetric Model [2], as well as for some composite models [3]. Standard Model Higgs searches [4] would have a reduced sensitivity in such cases, because of their strong reliance on the identification of the b -quarks from the Higgs boson decay to maximize the separating power. It is important to also cover such scenarios experimentally with dedicated searches in which the information from the flavour of the quarks in the Higgs boson decay is not exploited, so that the model-dependence of our final Higgs results can be reduced.

All four LEP collaborations have pursued such *flavour independent* searches in recent years [5, 6, 7, 8], analysing the four-jet ($q\bar{q}q\bar{q}$), missing energy ($q\bar{q}\nu\bar{\nu}$) and leptonic ($q\bar{q}l^+l^-$) topologies. None has found evidence for any signal. In this note, the first combination of the results obtained is presented, for the $e^+e^- \rightarrow Z^* \rightarrow hZ$ production mechanism, in terms of upper limits on the corresponding cross-section as a function of the Higgs boson mass, and of a lower mass limit in the assumption of production cross-sections equal to those in the Standard Model and a Higgs boson decaying into hadrons with a 100 % branching fraction. Higgs mass assumptions from 60 to 115 GeV were tested.

Some systematic effects have been studied by individual experiments, but were not considered nor included in the evaluation presented here. All results are preliminary.

2 Experimental Analyses

The analyses used by the four collaborations to search for hZ production in the flavour independent hypothesis were to a large extent adaptations of existing LEP-2 searches or measurements. In all channels except four-jets, events were selected exactly, or almost exactly, as in the corresponding Standard Model Higgs search, removing the b -tagging from the final selection. In the four-jet channel, on the other hand, all collaborations have used dedicated test-mass dependent selections, to exploit maximally the kinematic features available and the mass reconstruction. This was necessary to enable reducing as much as possible the dominant backgrounds from WW and ZZ production and from QCD processes $qqgg$, in the absence of b -tagging.

Because the searches performed by the four collaborations have been developed relatively, or in some cases very, recently, they are less optimised, slightly less comprehensive, and have used more simplifying assumptions to extract the results than the corresponding searches for the Standard Model Higgs boson.

In the ALEPH search [5], the data collected in 1998, 1999 and 2000 were used, clustering the data from the last year in seven energy bins. All the topologies corresponding to possible decay products of the Z boson were investigated. In the four-jet channel, a dedicated search based on a neural network method was developed. The compatibility of the data with the signal hypothesis was tested in the Higgs boson mass range from 60 up to 115 GeV/ c^2 , with 5 GeV/ c^2 steps, interpolating the final discriminant variable to test intermediate values.

In the DELPHI search [6], only the data collected in 1999 and 2000 were used, clustering the data from the last year in two energy bins. All the topologies corresponding to

possible decay products of the Z boson were investigated, except the $q\bar{q}\tau^+\tau^-$ final state. The compatibility of the data with the signal hypothesis was tested in the Higgs boson mass range from 50 up to 110 GeV/c², with 5 GeV/c² steps. A small degradation of the performance was introduced in the final evaluation, between each test mass, to account for mass resolution effects.

In the L3 search [7], only the data collected in 1999 and 2000 were used, clustering the data from the last year in five energy bins. All the topologies corresponding to possible decay products of the Z boson were investigated. The compatibility of the data with the signal hypothesis was tested in the Higgs boson mass range from 60 up to 115 GeV/c², with 1 GeV/c² steps.

In the OPAL search [8], the data collected in 1998, 1999 and 2000 were used, clustering the data from the last year in a single energy bin. Dedicated analyses were conducted for all the topologies corresponding to possible decay products of the Z boson. For the four-jet channel the test-masses were chosen in the Higgs boson mass range from 60 up to 115 GeV/c², with 1 GeV/c² steps.

Finally, in spite of not taking advantage of the b -tagging of the jets from the Higgs boson decay, every experiment has found small but still significant differences in performance between the different possible decay products of the Higgs boson, arising from slight differences in mass resolution and jet structure. In particular, Higgs boson decays into gluon pairs have larger multiplicities, but at the same time coarser dijet mass resolution, than decays into light quarks. In order to enable quoting genuine flavour independent results, the samples used for the final evaluation were conservatively chosen as those which gave the weakest expected performance in each channel, and for each value of the Higgs boson mass.

3 Results

The common evaluation of the results used the standard statistical procedures based on the likelihood ratio technique, as applied in the other combinations performed by the LEP working group for Higgs boson searches [9, 4].

Results were first obtained for each of the four collaborations, with two independent implementations of the combination software [11, 10], and compared with the results obtained within each collaboration. Although some slight differences were found, the general shapes and features of the observed and expected confidence levels for the signal, CL_s and background-only, CL_b hypotheses were very consistent.

The calculations of the observed and expected 95% CL lower limits on the mass of the Higgs boson, assuming production cross-sections equal to those in the Standard Model and $\text{BR}(h \rightarrow \text{hadrons}) = 1.0$, all agreed within a few hundred MeV, or better. The values¹ from one of the implementations [11] are shown in Table 1, together with the combined results using the data from all four collaborations. The combined observed and median expected limits were 112.9 and 113.0 GeV/c², respectively.

The confidence levels CL_s and CL_b obtained from the full combination in the signal and background-only hypotheses are shown as a function of the mass in Figure 1.a and 1.b,

¹Because the evaluations performed did not include systematic uncertainties, the values obtained differ in some cases from those quoted by the individual collaborations which included them in their evaluations. This is most notably the case for the OPAL results [8].

respectively. Good overall agreement can be seen between the observation and expectation in the absence of a signal. The slightly depressed values for $1 - CL_b$ for masses below 80 GeV/c², witnessing excesses of data in this region, may be the results of some statistical or systematic effect, and should be investigated further. A 5 sigma discovery corresponds to a value of $5.7 \cdot 10^{-7}$, as indicated by the horizontal line. The maximal sensitivity for such a discovery is reached for an assumed Higgs boson mass of 107 GeV/c², when this line is intersected by the expected median confidence in the background-only hypothesis.

Collaboration	Obs. limit (GeV/c ²)	Exp. median limit (GeV/c ²)
ALEPH	109.3	108.4
DELPHI	109.6	108.8
L3	111.6	109.3
OPAL	109.4	108.5
LEP	112.9	113.0

Table 1: Flavour independent observed and expected 95% CL lower limits on the mass of the Higgs boson, assuming production cross-sections equal to those in the Standard Model and BR(h → hadrons) = 1.0. The evaluation was performed using the likelihood ratio technique [11]. Systematic uncertainties were not included.

Upper limits on the production cross-section as a function of mass were also determined for each individual collaboration, and combined using the data from all four collaborations. Typically, cross-sections larger than about 10-60 % of the expected Standard Model value were excluded at 95% CL in the mass range 60-100 GeV/c², by each collaboration alone. The combined exclusion from the four collaborations is shown as a function of the mass in Figure 2. In the same mass range, it is possible to exclude cross-sections larger than about a few to 30 % of the expected Standard Model value with the full LEP-2 data set. Good overall agreement between the observation and expectation can be seen also here, except in the lower mass range, where the weaker observed limit is resulting from some excesses of data in this region, as was already noted.

Acknowledgements

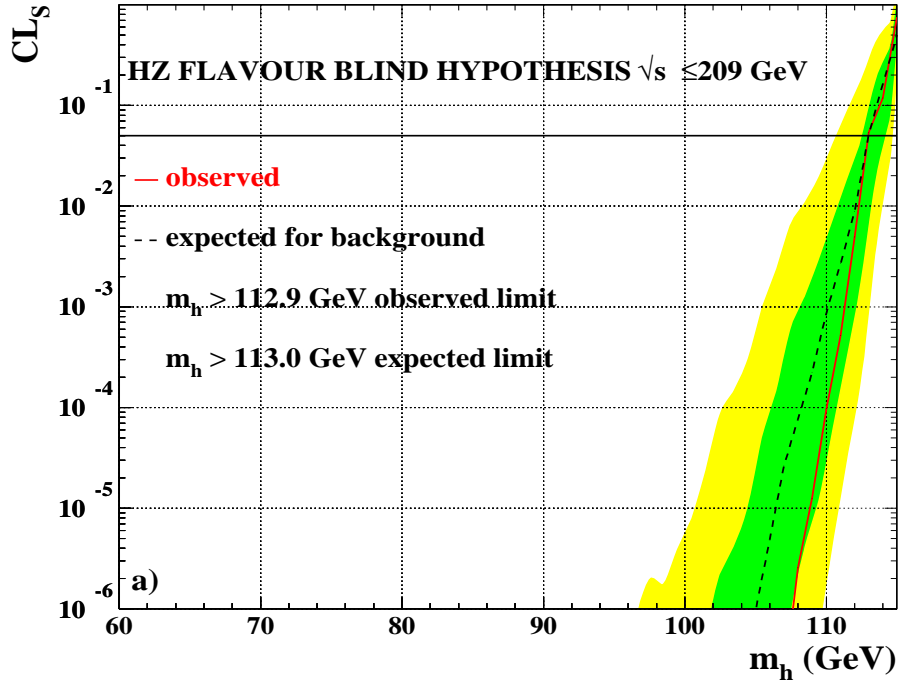
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LEP PRELIMINARY



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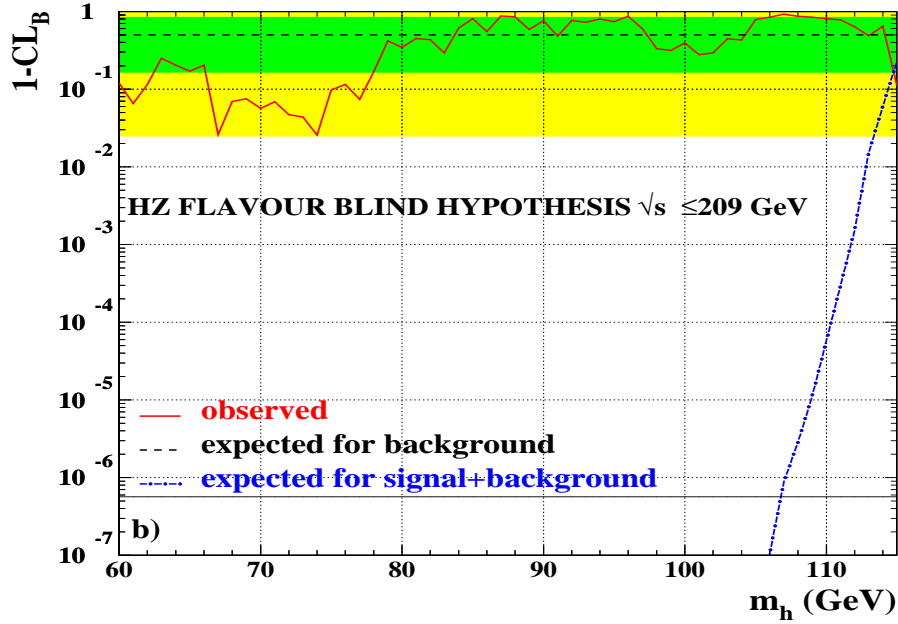


Figure 1: Combined LEP confidence levels as a function of the Higgs boson mass in the flavour independent hypothesis, computed with the likelihood ratio technique [11], assuming production cross-sections equal to those in the Standard Model and $\text{BR}(h \rightarrow \text{hadrons}) = 1.0$. The confidence levels for the signal and background-only hypotheses are shown in the upper (a) and lower (b) plots, respectively. The curves are the observed (solid) and expected median (dashed) confidences from background-only experiments, and the bands are the corresponding 68.3 % and 95 % confidence intervals. In the lower plot, the dot-dashed line shows the expected median confidence from experiments including an expected signal of mass given in abscissa.

LEP PRELIMINARY

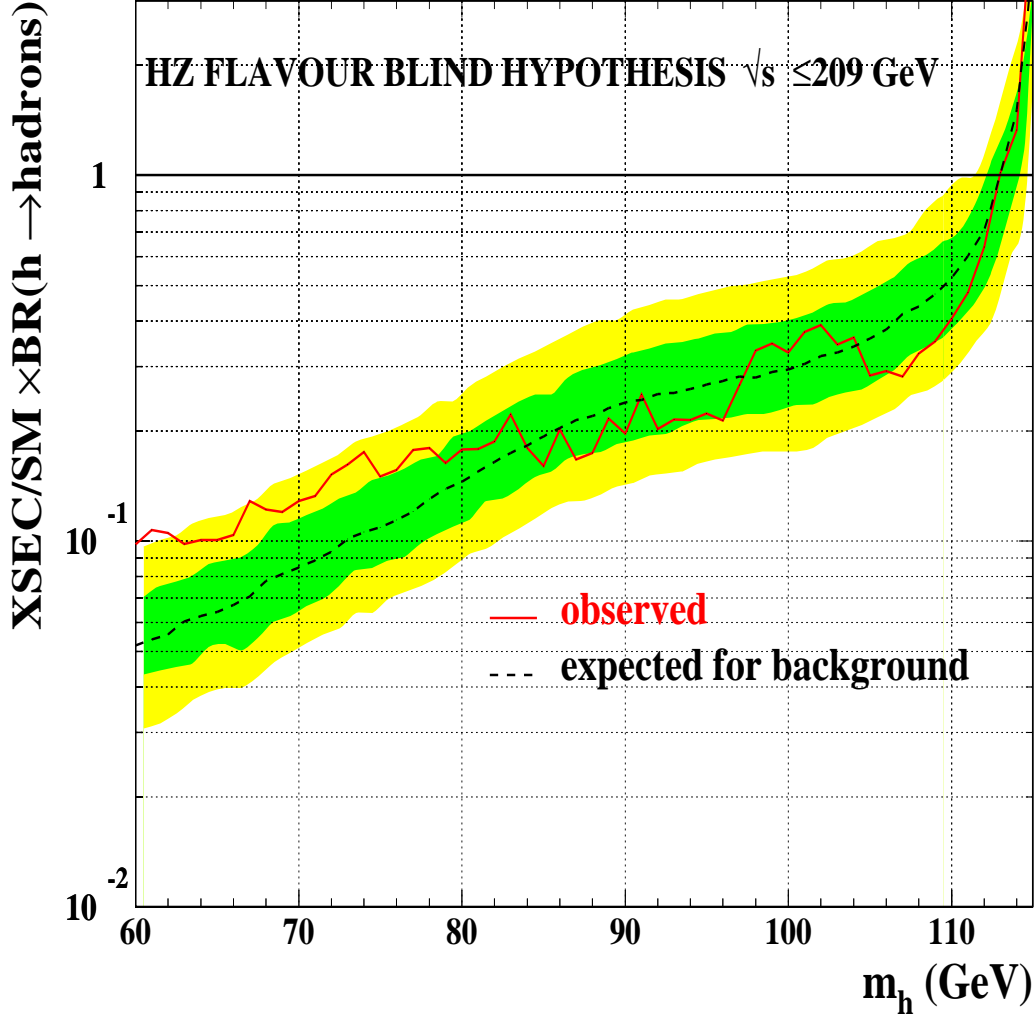


Figure 2: Combined flavour independent LEP observed and expected 95 % CL upper limits on the production cross-section as a function of the Higgs boson mass, normalised to the expected Standard Model values, computed assuming $\text{BR}(h \rightarrow \text{hadrons}) = 1.0$. The computation was done with the likelihood ratio technique [11]. The curves are the observed (solid) and expected median (dashed) excluded ratios, and the bands correspond to 68.3 % and 95 % confidence intervals from the background-only experiments.