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Search for an invisibly decaying Higgs boson at LEP at centre-of-mass energies up to 209 GeV

The ALEPH Collaboration

PRELIMINARY

Abstract

An update of the search for an invisibly decaying Higgs boson with the 215.6 pb^{-1} of data collected in 2000 at centre-of-mass energies up to 209 GeV is presented and combined with previous results obtained with data collected from 189 GeV upwards. A Higgs boson with completely invisible decays and with a production cross section equal to that of the standard model is excluded at 95 % C.L. for masses below 114.1 GeV/c^2.

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Introduction

In various theories beyond the standard model, Higgs bosons can decay into stable weakly interacting neutral particles and therefore escape undetected in the reaction $e^+e^- \to HZ$. The signatures of the aforementioned process at LEP correspond to the subsequent decays of the Z boson into a pair of leptons (e or μ) or quarks. In this note an update of the searches for these topologies with the 215.6 pb^{-1} of data collected at centre-of-mass energies up to 209 GeV in the year 2000 is reported.

The two leptons channel

The search for two acoplanar leptons is identical to the previously published version [1, 2]. A total of seven events is observed, in agreement with 6.7 events expected from standard model processes. The fitted mass distribution is displayed in Fig. 1a.

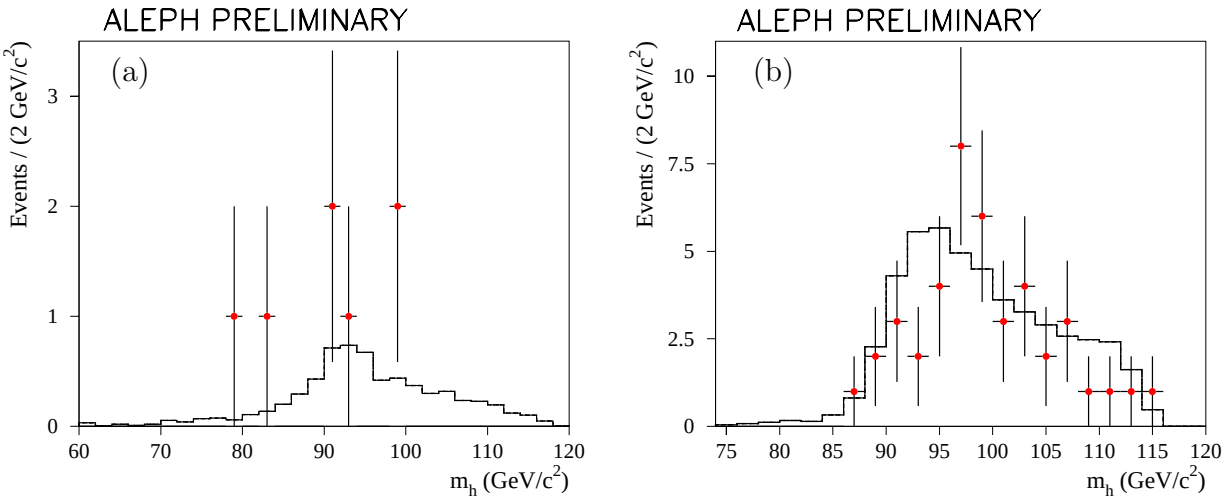

Figure 1: Distribution of the reconstructed Higgs boson mass in the data (dots with error bars) and the expected background (histogram) in the leptonic (a) and hadronic (b) channels.

The hadronic channel

In the hadronic final state, the preselection was tightened to improve the monojet events rejection. The energy of the least energetic hemisphere, formerly required to be non-zero, is now requested to be in excess of 5% of the centre-of-mass energy.

The analysis of the data taken in 1999 led to a set of three sliding neural networks (NN) each optimized for the three centre-of-mass energies 196, 200 and 202 GeV. For the data taken above 202 GeV, the NNs are neither re-trained nor re-optimized, but the sliding analysis used at $\sqrt{s} = 202$ GeV is re-expressed with the distance to threshold $d_{thrd} = \sqrt{s} - m_h - m_Z$ as sliding parameter instead of the Higgs boson mass hypothesis m_h. The same analysis can be applied at any centre-of-mass energy with nearly optimal neural network trainings and selection criteria at each mass hypothesis. Since most of

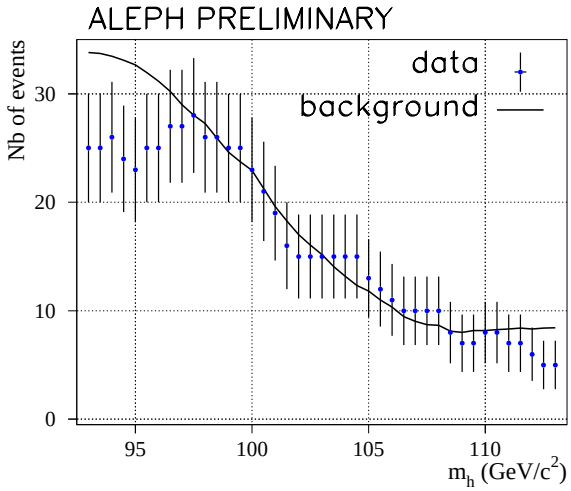

Figure 2: Number of events expected (solid line) and number of events observed (points with error bars) as a function of the Higgs boson mass.

the 2000 data has been collected at two centre-of-mass energies around 205 and 207 GeV, only two sets of sliding analyses are derived from the $\sqrt{s} = 202$ GeV one. One (NN_{205}) is applied to all data taken with $\sqrt{s} < 205.5$ GeV and the other (NN_{207}) is used for the higher energy data. The two analysis are subsequently treated as two independent channels. The correspondence between the NN trained at a given mass to analyse the 202 GeV data and the NN used to analyse the year 2000 data is shown in Table 1.

d_{thrd} (GeV/c^2)		21	16	11	8	6	3
NN_{202}	$\sqrt{s} = 202$ GeV	90	95	100	103	105	108
NN_{205}	$\sqrt{s} = 205$ GeV	93	98	103	106	108	111
NN_{207}	$\sqrt{s} = 207$ GeV	95	100	105	108	110	113

Table 1: Summary of the masses (GeV/c^2) used to train neural networks at $\sqrt{s} = 202$ GeV and the corresponding mass hypotheses with *optimal analysis* at $\sqrt{s} = 205$ and 207 GeV.

Altogether, 42 candidate events were selected in the data, compatible with the 48.6 events expected from standard model processes. The reconstructed mass distributions for the data and the simulation are displayed in Fig. 1b. The slight deficit of events observed is mostly located in the mass region dominated by the $e^+e^- \to ZZ$ background. The evolution of the expected number of background events and the number of candidate events as a function of the Higgs boson mass hypothesis is shown in Fig. 2. The overall agreement is fair, although the aforementioned slight deficit is observed at low mass hypotheses.

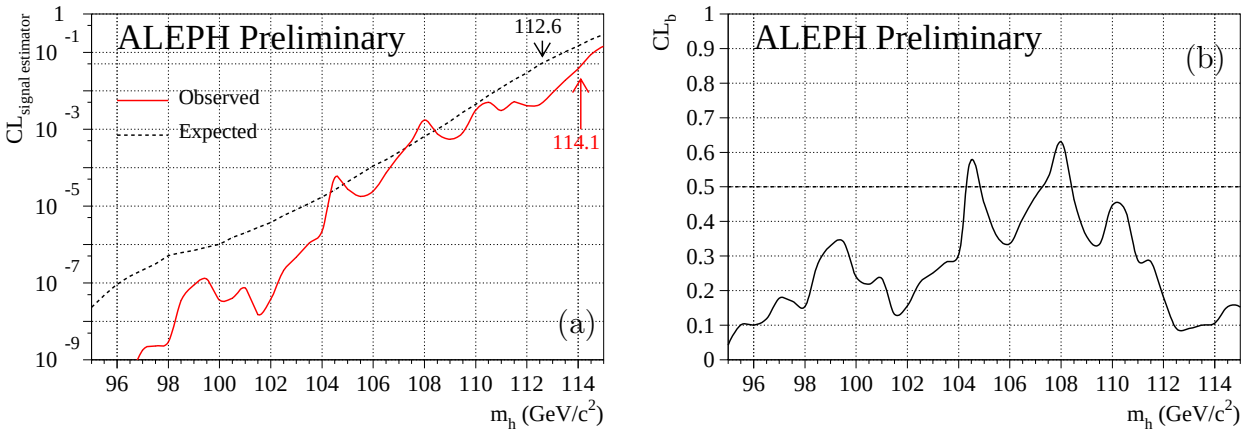

Figure 3: (a): Expected (dashed) and observed (full) confidence levels for the combination of the leptonic and hadronic channels; (b) background confidence levels.

Combined results

No excess with respect to the standard model is observed in the data. A lower limit on the mass of an invisibly decaying Higgs boson can therefore be set. To cope with the numerous centre-of-mass energies, results are effectively derived independently in five energy ranges: below 204.5, three 1 GeV intervals centred respectivelly on 205, 206 and 207 GeV, and above 207.5 GeV. In the hadronic channel, the NN_{205} analysis is applied on the first two intervals and the NN_{207} analysis on the three at higher centre-of-mass energies. The combined observed and expected confidence levels with full background subtraction are shown in Fig. 3 for the signal (a) and the background (b) hypotheses.

Alternatively, these analyses can be interpreted as an excluded region in the (m_{h},ξ^2) plane, where ξ^2 is a model-dependent parameter defined as the ratio of the $\mathrm{e^+e^-} \rightarrow \mathrm{H}_{inv}\mathrm{Z}$ cross section to the $\mathrm{e^+e^-} \rightarrow \mathrm{HZ}$ standard model cross section, as illustrated in Fig. 4. For $\xi^2 = 1$, the expected 95 % C.L. lower limit is 112.6 GeV/c^2. The observed mass lower limit is 114.1 GeV/c^2.

References

[1] ALEPH Collaboration, *Search for an invisibly decaying Higgs boson in e^+e^- collisions at 189 GeV*, *Phys. Lett.* **B466** (1999) 50.

[2] ALEPH Collaboration, *Searches for neutral Higgs bosons in e^+e^- collisions at centre-of-mass energies from 192 to 202 GeV*, *Phys. Lett.* **B499** (2001) 53.

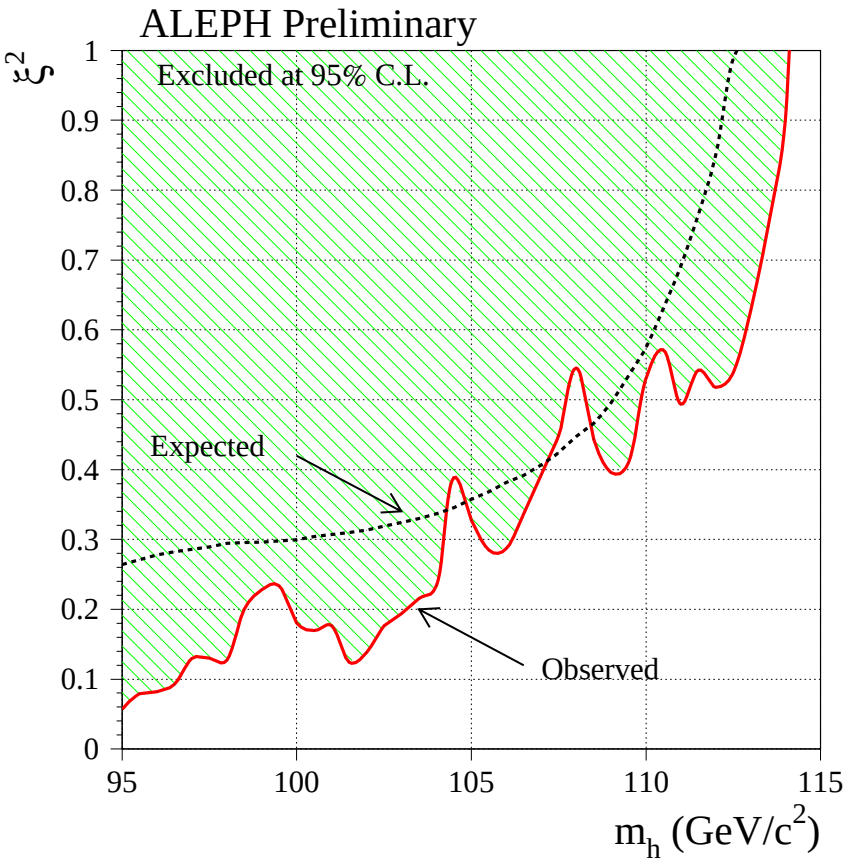

Figure 4: Excluded region at the 95 % C.L. in the (m_{h}, ξ^2) plane