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Search for $\gamma\gamma$ decays of a Higgs boson in e^+e^- collisions at $\sqrt{s}$ up to 209 GeV

The ALEPH Collaboration*)

Abstract

A search for events with a photon pair arising from the decay of a Higgs boson produced in association with a fermion pair, is performed in 893 pb^{-1} of data recorded by the ALEPH detector at LEP at centre-of-mass energies up to 209 GeV. No excess of such events is found over the expected background. An upper limit is derived on the product of the $e^+e^- \rightarrow$ HZ cross section and the $H \rightarrow \gamma\gamma$ branching fraction as a function of the Higgs boson mass. A fermiophobic Higgs boson produced with the Standard Model cross section is excluded at 95% confidence level for all masses below 105.4 GeV/c^2.

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1 Introduction

In the Standard Model (SM), the Higgs boson couples to photons through loops of charged particles. The branching ratio into $\gamma\gamma$ is therefore small ($\sim 10^{-3}$ for $m_{\mathrm{H}} = 90$ GeV/c^2). In models with at least two Higgs multiplets [1], one of the Higgs physical states may couple only to gauge bosons and is therefore called *fermiophobic*. In such models, the branching ratio into $\gamma\gamma$ would be dominant for masses accessible at LEP energies. The couplings to gauge bosons may also be enhanced either with anomalous couplings [2] or in supersymmetric extensions of the Standard Model via additional light, charged particles which enter the loops that couple Higgs bosons and photons.

In this letter, the ALEPH search [3] for the Higgs-strahlung process $\mathrm{e^+e^-} \rightarrow \mathrm{HZ}$ with $\mathrm{H} \rightarrow \gamma\gamma$ is updated by including the data collected in the year 2000, corresponding to an integrated luminosity of 220.8 pb^{-1} at centre-of-mass energies ranging from 202 to 209 GeV.

The different topologies arising from $\mathrm{e^+e^-} \rightarrow \mathrm{HZ}$ are selected according to the charged particle multiplicity of the final state: *(i)* acoplanar photons with missing energy and no charged particles for $\mathrm{e^+e^-} \rightarrow \mathrm{H}\nu\bar{\nu}$; *(ii)* photon pairs with exactly two charged particles for $\mathrm{e^+e^-} \rightarrow \mathrm{H}\ell^+\ell^-$; *(iii)* photon pairs accompanied by three or four charged particles clustered into two low-multiplicity jets for $\mathrm{e^+e^-} \rightarrow \mathrm{H}\tau^+\tau^-$; and *(iv)* photon pairs with at least five charged particles for $\mathrm{e^+e^-} \rightarrow \mathrm{Hq\bar{q}}$.

The details of the analyses are described in Ref. [3]. Only a brief account is recalled in this letter. In Section 2, a short description of the ALEPH detector is given. The selections are reviewed in Sections 3, and final results, combined with the previous ALEPH limits at lower energies [3], are presented in Section 4.

2 The ALEPH detector

The ALEPH detector and its performance are described in Refs. [4, 5]. The silicon vertex detector, the inner tracking chamber and the time projection chamber (TPC) provide efficient reconstruction of charged particles in the angular range $|\cos\theta| < 0.96$. A 1.5 T axial magnetic field delivered by a superconducting solenoidal coil allows a momentum resolution $\sigma_{1/p_\perp} = 6 \times 10^{-4} \bigoplus 5 \times 10^{-3}/p_\perp$, with $p_\perp$ in GeV/c, to be achieved.

Photons are identified with the electromagnetic calorimeter (ECAL) located between the TPC and the coil. The ECAL is a lead/wire-plane sampling calorimeter covering the angular range $|\cos\theta| < 0.98$. Cathode pads associated with each wire layer are connected to form projective towers of approximately 0.9° by 0.9°, read out in three segments in depth ("storeys"). Photon candidates are identified with a topological search [5] for energy deposits in neighbouring storeys isolated from the extrapolation of any charged particle track to the ECAL. Photon candidates close to a boundary between ECAL modules or pointing towards an uninstrumented region of the TPC are not considered in this analysis. The energy resolution for photons is $\sigma_E/E = 0.25/\sqrt{E} + 0.009$, with E in GeV.

The iron return yoke is instrumented with streamer tubes and acts as a hadron calorimeter (HCAL). The luminosity monitors extend the calorimetric coverage down to 34 mrad from the beam axis. The information from the tracking detectors and the calorimeters are combined into objects classified as charged particles, photons and neutral hadrons with the energy flow algorithm described in Ref. [5].

3 Event selection

In a preselection, two isolated energetic photons well contained in the apparatus and in time with the beam crossing are required, as described in Ref. [3].

An isolated photon is defined by requiring that the total charged energy in a cone of half-angle 14° around its direction be smaller than 2 GeV, and that the invariant mass between the photon and any charged particle be in excess of 1 GeV/c^2. The photon polar angle must satisfy $|\cos\theta_\gamma| < 0.9$. Photons belonging to a pair with an invariant mass less than 1 GeV/c^2 are rejected. In each event, only the most energetic remaining two photons are considered. They are required to have energies in the range 0.2–0.75 E_{beam}. The sum of the absolute values of the cosines of the two photon polar angles must be smaller than 1.4. The cosines of the Higgs boson production and thrust axis polar angles, $\theta_{\gamma\gamma}$ and θ_{thrust}, must be within ± 0.95. Events with more than 2 GeV detected within 14° from the beam axis are rejected. The mass recoiling against the photonic system m_{rec} is required to be consistent with the Z mass, $|m_{\mathrm{rec}} - m_{\mathrm{Z}}| < 15$ GeV/c^2.

Events passing the above preselection are classified in the four signal topologies according to their charged particle multiplicity, n_{ch}.

Events with at least two charged particle tracks are forced to form four jets with the Durham clustering algorithm [6]. The consistency of such events with a four-body final-state hypothesis is verified by requiring that each of the four jet energies, computed from their directions to satisfy energy-momentum conservation, be positive. The two jets with the smallest electromagnetic energy fraction are called *fermionic jets*.

The selection is based on that of Ref. [3], modified to search for a heavy Higgs boson produced near threshold. For each event topology, cuts were optimized for a Higgs boson mass of 105 GeV/c^2 and a centre-of-mass energy of 206 GeV, by means of the $\bar{N}_{95}$ prescription [7].

For the $\mathrm{H}\nu\bar{\nu}$ topology, it is required that the missing momentum be less than 0.46 E_{beam}, to reject events with radiative return to the Z resonance. The photon energies are required to be greater than 0.3 E_{beam}.

In the two-charged-particle topology it is required that the invariant mass of the fermion pair be greater than 1 GeV/c^2 and that the transverse momentum of each charged particle track with respect to each photon, $p^{\gamma}_{\perp_{\mathrm{ch}}}$, be greater than 10 GeV/c.

For the final state with three or four charged particles, no further cuts are applied.

Finally, events with at least five charged particles are selected by requiring that *(i)* the polar angle of each photon satisfy $|\cos\theta_{\gamma_i}| < 0.6$; *(ii)* the transverse momentum of each photon with respect to the closest fermionic jet, $p^{\rm f}_{\perp_\gamma}$, be greater than $0.2\,E_{\rm beam}$; *(iii)* the sum of the four minimum inter-jet angles, $\theta^{\rm min}_{4-\rm jets}$, be greater than 360°.

The total signal efficiency at $\sqrt{s}$=206 GeV is shown in Fig. 1a as a function of the Higgs boson mass. For $\rm m_H$=105 GeV/c^2, it amounts to 31%. The signal efficiency for the various topologies, including the cross contamination between the Z decay channels, the expected Standard Model backgrounds and the numbers of events observed are shown in Table 1. Signal efficiencies and background levels were estimated using the same generators as in Ref. [3]. The systematic uncertainties on signal efficiencies were evaluated as in Ref. [3], and are summarized in Table 2.

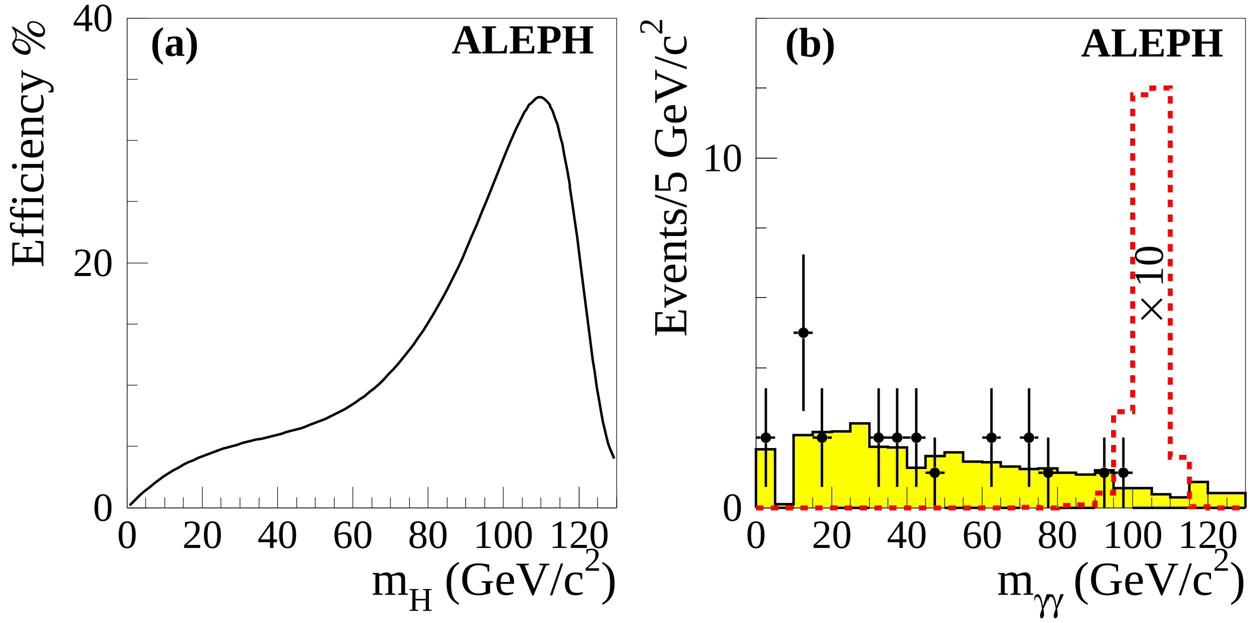

Figure 1: (a) Signal efficiency as a function of $\rm m_H$ at $\sqrt{s}$=206 GeV. (b) Di-photon invariant mass distribution for all data taken since 1991 (dots with error bars), for the expected background distributions (shaded histogram) and for a 105 GeV/c^2 fermiophobic Higgs boson signal (dashed histogram).

Table 1: Efficiencies for the different Z decay channels for a 105 GeV/c^2 Higgs boson mass at $\sqrt{s}$=206 GeV and numbers of expected background and observed events for the year 2000 data.

$n_{\rm ch}$	$\epsilon_{{\rm H}\nu\bar\nu}$	$\epsilon_{{\rm H}\ell^+\ell^-}$	$\epsilon_{{\rm H}\tau^+\tau^-}$	$\epsilon_{{\rm Hq\bar q}}$	$N_{\rm exp}$	$N_{\rm obs}$
0	50.2%	0.3%	—	—	1.2	0
2	—	40.5%	20.1%	—	0.8	1
3–4	—	0.5%	18.9%	—	0.1	0
≥5	—	—	1.8%	24.3%	0.7	0
Total	50.2%	41.3%	40.8%	24.3%	2.8	1

Table 2: Systematic uncertainties on the signal efficiency

Sources	Relative uncertainty in %
Photon identification	4.0
γ energy calibration	0.8
γ angular resolution	0.2
Photon isolation	1.6
$\cos\theta_{\mathrm{thrust}}$	0.2
p_{miss}	0.6
$p^{\mathrm{f}}_{\perp_\gamma}, p^{\gamma}_{\perp_{\mathrm{ch}}}$	0.7
$\theta^{\mathrm{min}}_{4-\mathrm{jets}}$	0.8
Model dependence	2.7
Total in quadrature	5.3

4 Results

One event, displayed in Fig. 2, is selected in the year 2000 data, compared with an expectation of 2.8 ± 0.2 events from SM background processes. In the full data sample recorded by ALEPH since 1991, corresponding to a total integrated luminosity of $893\,\mathrm{pb}^{-1}$ recorded at centre-of-mass energies ranging from 88 to 209 GeV, 23 events are selected, compared with an expectation of 31 events from SM background processes. The di-photon invariant mass distribution of these events is shown, for both data and simulation, in Fig. 1b. No evidence for a resonance decaying to $\gamma\gamma$ is observed.

From the full data sample, a 95% C.L. upper limit on the number of signal events at a given di-photon invariant mass is derived following the method of Ref. [9]. The resulting 95% C.L. upper limit on $\mathcal{B}(\mathrm{H} \to \gamma\gamma)\sigma(\mathrm{e}^+\mathrm{e}^- \to \mathrm{Hf\bar{f}})/\sigma^{\mathrm{SM}}(\mathrm{e}^+\mathrm{e}^- \to \mathrm{Hf\bar{f}})$ is shown in Fig. 3. It is assumed that the production cross section has the same $\sqrt{s}$ and m_{H} dependence as in the SM.

For the case of a Higgs boson produced at the SM rate, the smallest upper limit on the branching ratio (4.7×10^{-3} at 95% C.L.) is obtained for Higgs boson masses around 20 GeV/c^2. A Higgs boson decaying exclusively to two photons is excluded up to 113.1 GeV/c^2 at 95% C.L. A fermiophobic Higgs boson is excluded at 95% C.L. for any mass up to 105.4 GeV/c^2. The present analysis extends the reach of similar analyses performed by the other LEP collaborations [10–12].

5 Conclusion

With a data sample of $893\,\mathrm{pb}^{-1}$ recorded by ALEPH at centre-of-mass energies from 88 to 209 GeV, a search for two-photon decays of Higgs bosons produced in association with a fermion pair has been performed. No evidence for resonant production of photon pairs has been observed. For Higgs bosons with SM couplings to gauge bosons, a 95% C.L. upper limit on the Higgs boson branching ratio to two photons has been obtained for masses up to 113.1 GeV/c^2. In the fermiophobic case, a 95% C.L. lower limit on the Higgs boson mass has been set at 105.4 GeV/c^2.

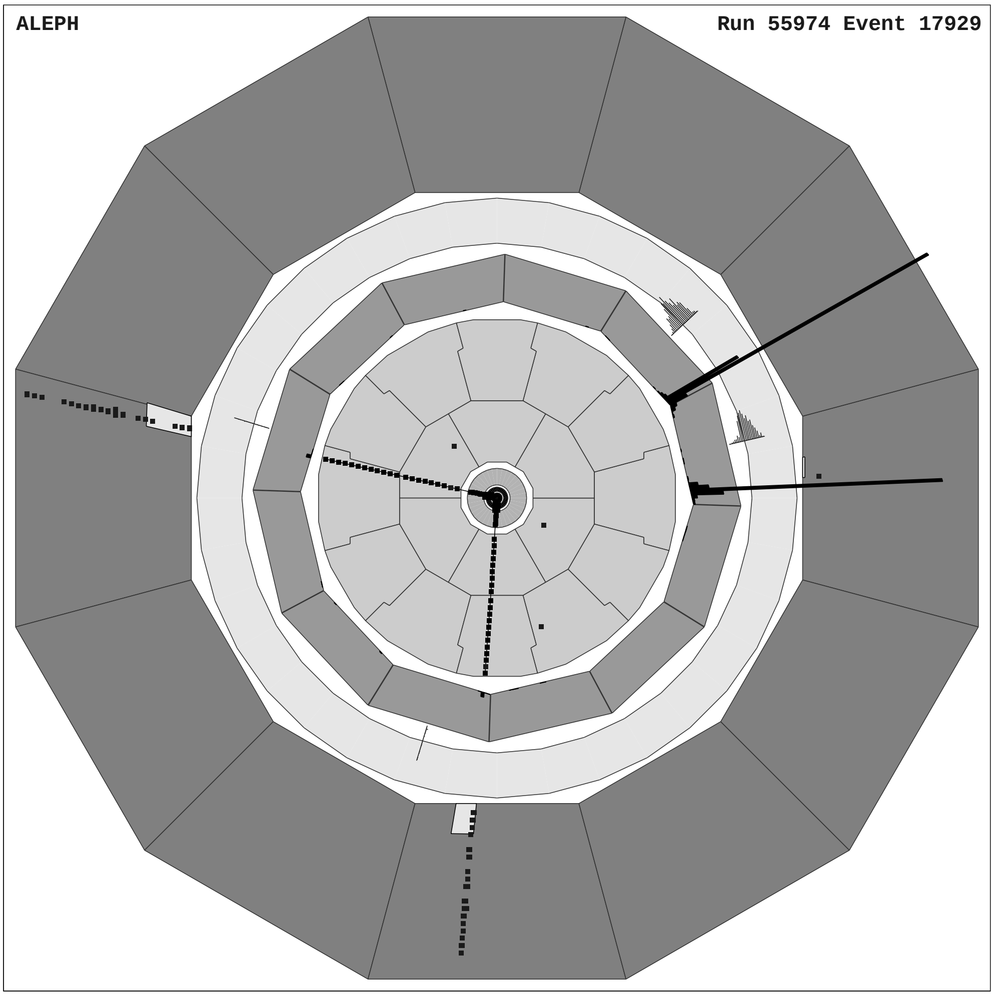

Figure 2: The candidate event observed in 2000.

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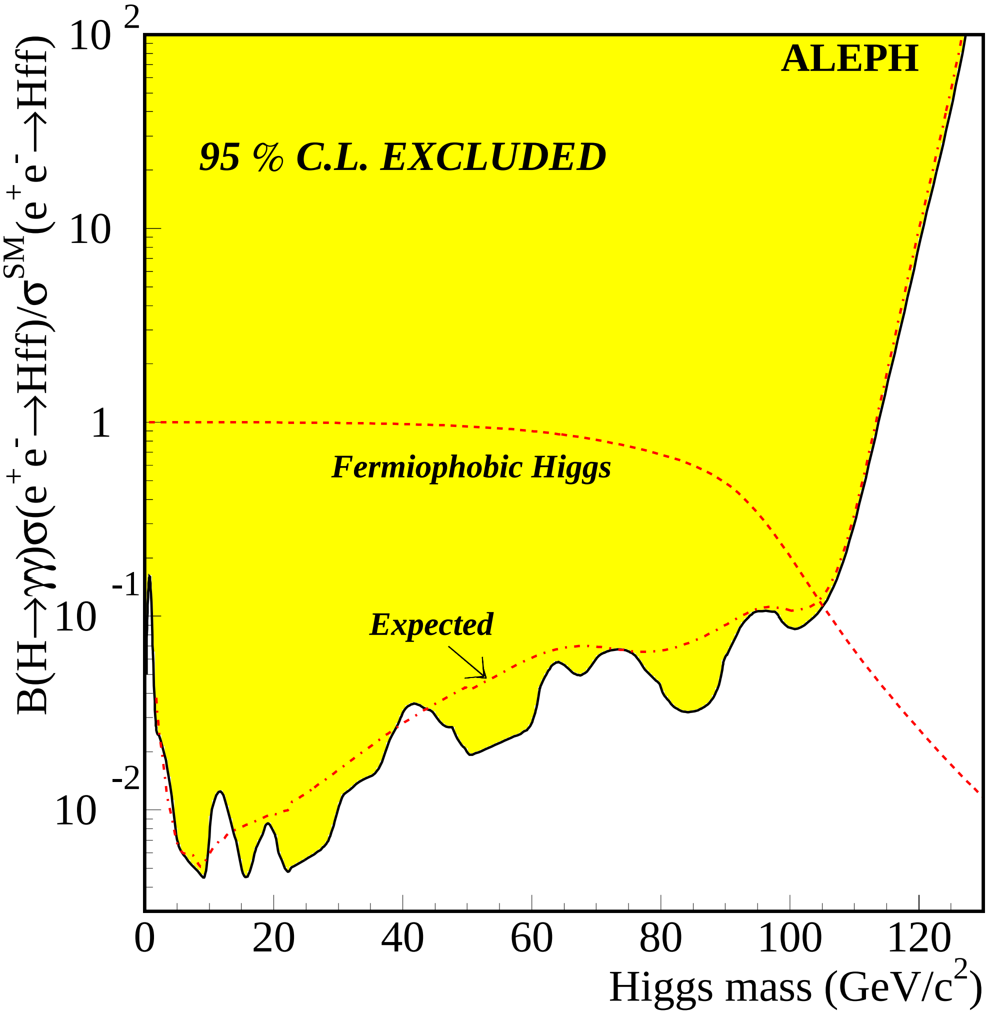

Figure 3: Measured (full curve) and expected (dash-dotted curve) 95% C.L. upper limit on $\mathcal{B}(\mathrm{H} \to \gamma\gamma)\sigma(\mathrm{e^+e^-} \to \mathrm{Hf\bar{f}})/\sigma^{\mathrm{SM}}(\mathrm{e^+e^-} \to \mathrm{Hf\bar{f}})$ using all data taken since 1991. The dashed curve is the prediction for a fermiophobic Higgs boson.

References

[1] A. G. Akeroyd, *"Fermiophobic Higgs Bosons at the Tevatron."*, Phys. Lett. **B368** (1996) 89;
H. Haber, G. Kane and T. Sterling, *"The Fermion Mass Scale and Possible Effects of Higgs Bosons on Experimental Observables"*, Nucl. Phys. **B161** (1979) 493.

[2] K. Hagiwara, R. Szalapki and D. Zeppenfeld, *"Anomalous Higgs Boson Production and Decay"*, Phys. Lett. **B318** (1993) 155.

[3] ALEPH Collaboration, *"Search for $\gamma\gamma$ decays of a Higgs boson produced in association with a fermion pair in e^+e^- collisions at LEP"*, Phys. Lett. **B487** (2000) 234.

[4] ALEPH Collaboration, *"ALEPH: A detector for Electron-Positron Annihilations at LEP"*, Nucl. Instrum. and Methods **A294** (1990) 121.

[5] ALEPH Collaboration, *"Performance of the ALEPH Detector at LEP"*, Nucl. Instrum. and Methods **A360** (1995) 481.

[6] W.J. Stirling, *"Hard QCD Working Group: Theory Summary"*, J. Phys. **G17** (1991) 1567.

[7] J.F. Grivaz and F. Le Diberder, *"Complementary analyses and acceptance optimisation in new particle searches"*, LAL-92-37;
ALEPH Collaboration, *"Search for the standard model Higgs boson"*, Phys. Lett. **B313** (1993) 299

[8] F. A. Berends and R. Kleiss, *"Distributions For Electron - Positron Annihilation Into Two And Three Photons"*, Nucl. Phys. **B186** (1981) 22.

[9] P. Janot, F. Le Diberder, *"Optimally combined confidence limits"* , Nucl. Instrum. and Methods **A411** (1998) 449;
ALEPH Collaboration, *"Search for the standard model Higgs boson in e^+e^- collisions at $\sqrt{s} = 161\,GeV$, $170\,GeV$ and $172\,GeV$"*, Phys. Lett. **B412** (1997) 155.

[10] DELPHI Collaboration, *"Search for a fermiophobic Higgs at LEP 2"*, Phys. Lett. **B507** (2001) 89.

[11] L3 Collaboration, *"Search for a Higgs Boson Decaying into Two Photons at LEP"*, Phys. Lett. **B 534** (2002) 28.

[12] OPAL Collaboration, *"Search for Higgs Boson and Other Massive States Decaying into Two Photons in e^+e^- Collisions at $189\,GeV$"*, Phys. Lett. **B 464** (1999) 311.