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at \sqrt{s} up to 209 GeV**

A. Heister, S. Schael, R. Barate, R. Bruneliere, I. de Bonis, D. Decamp, C.
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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 $105.4\text{ GeV}/c^2$.

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*) See next pages for the list of authors

The ALEPH Collaboration

A. Heister, S. Schael

Physikalisches Institut das RWTH-Aachen, D-52056 Aachen, Germany

R. Barate, R. Brunelière, I. De Bonis, D. Decamp, C. Goy, S. Jezequel, J.-P. Lees, F. Martin, E. Merle, M.-N. Minard, B. Pietrzyk, B. Trocme

Laboratoire de Physique des Particules (LAPP), IN²P³-CNRS, F-74019 Annecy-le-Vieux Cedex, France

G. Boix,²⁵ S. Bravo, M.P. Casado, M. Chmeissani, J.M. Crespo, E. Fernandez, M. Fernandez-Bosman, Ll. Garrido,¹⁵ E. Graugés, J. Lopez, M. Martinez, G. Merino, A. Pacheco, D. Paneque, H. Ruiz

Institut de Física d'Altes Energies, Universitat Autònoma de Barcelona, E-08193 Bellaterra (Barcelona), Spain⁷

A. Colaleo, D. Creanza, N. De Filippis, M. de Palma, G. Iaselli, G. Maggi, M. Maggi, S. Nuzzo, A. Ranieri, G. Raso,²⁴ F. Ruggieri, G. Selvaggi, L. Silvestris, P. Tempesta, A. Tricomi,³ G. Zito

Dipartimento di Fisica, INFN Sezione di Bari, I-70126 Bari, Italy

X. Huang, J. Lin, Q. Ouyang, T. Wang, Y. Xie, R. Xu, S. Xue, J. Zhang, L. Zhang, W. Zhao

Institute of High Energy Physics, Academia Sinica, Beijing, The People's Republic of China⁸

D. Abbaneo, P. Azzurri, T. Barklow,³⁰ O. Buchmüller,³⁰ M. Cattaneo, F. Cerutti, B. Clerbaux,²³ H. Drevermann, R.W. Forty, M. Frank, F. Gianotti, T.C. Greening,²⁶ J.B. Hansen, J. Harvey, D.E. Hutchcroft, P. Janot, B. Jost, M. Kado,² P. Mato, A. Moutoussi, F. Ranjard, L. Rolandi, D. Schlatter, G. Sguazzoni, W. Tejessy, F. Teubert, A. Valassi, I. Videau, J.J. Ward

European Laboratory for Particle Physics (CERN), CH-1211 Geneva 23, Switzerland

F. Badaud, S. Dessagne, A. Falvard,²⁰ D. Fayolle, P. Gay, J. Jousset, B. Michel, S. Monteil, D. Pallin, J.M. Pascolo, P. Perret

Laboratoire de Physique Corpusculaire, Université Blaise Pascal, IN²P³-CNRS, Clermont-Ferrand, F-63177 Aubière, France

J.D. Hansen, J.R. Hansen, P.H. Hansen, B.S. Nilsson

Niels Bohr Institute, 2100 Copenhagen, DK-Denmark⁹

A. Kyriakis, C. Markou, E. Simopoulou, A. Vayaki, K. Zachariadou

Nuclear Research Center Demokritos (NRCD), GR-15310 Attiki, Greece

A. Blondel,¹² J.-C. Brient, F. Machefert, A. Rougé, M. Swynghedauw, R. Tanaka H. Videau

Laoratoire Leprince-Ringuet, Ecole Polytechnique, IN²P³-CNRS, F-91128 Palaiseau Cedex, France

V. Ciulli, E. Focardi, G. Parrini

Dipartimento di Fisica, Università di Firenze, INFN Sezione di Firenze, I-50125 Firenze, Italy

A. Antonelli, M. Antonelli, G. Bencivenni, F. Bossi, G. Capon, V. Chiarella, P. Laurelli, G. Mannocchi,⁵ G.P. Murtas, L. Passalacqua

Laboratori Nazionali dell'INFN (LNF-INFN), I-00044 Frascati, Italy

J. Kennedy, J.G. Lynch, P. Negus, V. O'Shea, A.S. Thompson

Department of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, United Kingdom¹⁰

S. Wasserbaech

Department of Physics, Haverford College, Haverford, PA 19041-1392, U.S.A.

R. Cavanaugh,⁴ S. Dhamotharan,²¹ C. Geweniger, P. Hanke, V. Hepp, E.E. Kluge, G. Leibenguth, A. Putzer, H. Stenzel, K. Tittel, M. Wunsch¹⁹

Kirchhoff-Institut für Physik, Universität Heidelberg, D-69120 Heidelberg, Germany¹⁶

R. Beuselinck, W. Cameron, G. Davies, P.J. Dornan, M. Girone,¹ R.D. Hill, N. Marinelli, J. Nowell, S.A. Rutherford, J.K. Sedgbeer, J.C. Thompson,¹⁴ R. White

Department of Physics, Imperial College, London SW7 2BZ, United Kingdom¹⁰

V.M. Ghete, P. Girtler, E. Kneringer, D. Kuhn, G. Rudolph

Institut für Experimentalphysik, Universität Innsbruck, A-6020 Innsbruck, Austria¹⁸

E. Bouhova-Thacker, C.K. Bowdery, D.P. Clarke, G. Ellis, A.J. Finch, F. Foster, G. Hughes, R.W.L. Jones, M.R. Pearson, N.A. Robertson, M. Smizanska

Department of Physics, University of Lancaster, Lancaster LA1 4YB, United Kingdom¹⁰

O. van der Aa, C. Delaere, V. Lemaitre

Institut de Physique Nucléaire, Département de Physique, Université Catholique de Louvain, 1348 Louvain-la-Neuve, Belgium

U. Blumenschein, F. Hölldorfer, K. Jakobs, F. Kayser, K. Kleinknecht, A.-S. Müller, G. Quast,⁶ B. Renk, H.-G. Sander, S. Schmeling, H. Wachsmuth, C. Zeitnitz, T. Ziegler

Institut für Physik, Universität Mainz, D-55099 Mainz, Germany¹⁶

A. Bonissent, P. Coyle, C. Curtil, A. Ealet, D. Fouchez, P. Payre, A. Tilquin

Centre de Physique des Particules de Marseille, Univ Méditerranée, IN²P³-CNRS, F-13288 Marseille, France

F. Ragusa

Dipartimento di Fisica, Università di Milano e INFN Sezione di Milano, I-20133 Milano, Italy.

A. David, H. Dietl, G. Ganis,²⁷ K. Hüttmann, G. Lütjens, W. Männer, H.-G. Moser, R. Settles, G. Wolf

Max-Planck-Institut für Physik, Werner-Heisenberg-Institut, D-80805 München, Germany

J. Boucrot, O. Callot, M. Davier, L. Duflot, J.-F. Grivaz, Ph. Heusse, A. Jacholkowska,³² L. Serin, J.-J. Veillet, J.-B. de Vivie de Régie,²⁸ C. Yuan

Laboratoire de l'Accélérateur Linéaire, Université de Paris-Sud, IN²P³-CNRS, F-91898 Orsay Cedex, France

G. Bagliesi, T. Boccali, L. Foà, A. Giammanco, A. Giassi, F. Ligabue, A. Messineo, F. Palla, G. Sanguinetti, A. Sciabà, R. Tenchini,¹ A. Venturi,¹ P.G. Verdini

Dipartimento di Fisica dell'Università, INFN Sezione di Pisa, e Scuola Normale Superiore, I-56010 Pisa, Italy

O. Awunor, G.A. Blair, G. Cowan, A. Garcia-Bellido, M.G. Green, L.T. Jones, T. Medcalf, A. Misiejuk, J.A. Strong, P. Teixeira-Dias

Department of Physics, Royal Holloway & Bedford New College, University of London, Egham, Surrey TW20 OEX, United Kingdom¹⁰

R.W. Clift, T.R. Edgecock, P.R. Norton, I.R. Tomalin

Particle Physics Dept., Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX, United Kingdom¹⁰

B. Bloch-Devauux, D. Boumediene, P. Colas, B. Fabbro, E. Lançon, M.-C. Lemaire, E. Locci, P. Perez, J. Rander, B. Tuchming, B. Vallage

CEA, DAPNIA/Service de Physique des Particules, CE-Saclay, F-91191 Gif-sur-Yvette Cedex, France¹⁷

N. Konstantinidis, A.M. Litke, G. Taylor

Institute for Particle Physics, University of California at Santa Cruz, Santa Cruz, CA 95064, USA²²

C.N. Booth, S. Cartwright, F. Combley,³¹ P.N. Hodgson, M. Lehto, L.F. Thompson

Department of Physics, University of Sheffield, Sheffield S3 7RH, United Kingdom¹⁰

A. Böhrer, S. Brandt, C. Grupen, J. Hess, A. Ngac, G. Prange, U. Sieler

Fachbereich Physik, Universität Siegen, D-57068 Siegen, Germany¹⁶

C. Borean, G. Giannini

Dipartimento di Fisica, Università di Trieste e INFN Sezione di Trieste, I-34127 Trieste, Italy

H. He, J. Putz, J. Rothberg

Experimental Elementary Particle Physics, University of Washington, Seattle, WA 98195 U.S.A.

S.R. Armstrong, K. Berkelman, K. Cranmer, D.P.S. Ferguson, Y. Gao,²⁹ S. González, O.J. Hayes, H. Hu, S. Jin, J. Kile, P.A. McNamara III, J. Nielsen, Y.B. Pan, J.H. von Wimmersperg-Toeller, W. Wiedenmann, J. Wu, Sau Lan Wu, X. Wu, G. Zobernig

Department of Physics, University of Wisconsin, Madison, WI 53706, USA¹¹

G. Dissertori

Institute for Particle Physics, ETH Höggerberg, 8093 Zürich, Switzerland.

*Also at CERN, 1211 Geneva 23, Switzerland.

†Now at Fermilab, PO Box 500, MS 352, Batavia, IL 60510, USA

‡Also at Dipartimento di Fisica di Catania and INFN Sezione di Catania, 95129 Catania, Italy.

§Now at University of Florida, Department of Physics, Gainesville, Florida 32611-8440, USA

¶Also Istituto di Cosmo-Geofisica del C.N.R., Torino, Italy.

||Now at Institut für Experimentelle Kernphysik, Universität Karlsruhe, 76128 Karlsruhe, Germany.

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††Supported by the National Science Foundation of China.

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Supported by the UK Particle Physics and Astronomy Research Council.

Supported by the US Department of Energy, grant DE-FG0295-ER40896.

Now at Departement de Physique Corpusculaire, Université de Genève, 1211 Genève 4, Switzerland.

Supported by the Commission of the European Communities, contract ERBFMBICT982874.

Supported by the Leverhulme Trust.

Permanent address: Universitat de Barcelona, 08208 Barcelona, Spain.

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Supported by the Direction des Sciences de la Matière, C.E.A.

Supported by the Austrian Ministry for Science and Transport.

Now at SAP AG, 69185 Walldorf, Germany

Now at Groupe d' Astroparticules de Montpellier, Université de Montpellier II, 34095 Montpellier, France.

Now at BNP Paribas, 60325 Frankfurt am Mainz, Germany

Supported by the US Department of Energy, grant DE-FG03-92ER40689.

Now at Institut Inter-universitaire des hautes Energies (IIHE), CP 230, Université Libre de Bruxelles, 1050 Bruxelles, Belgique

Also at Dipartimento di Fisica e Tecnologia Relative, Università di Palermo, Palermo, Italy.

Now at McKinsey and Compagny, Avenue Louis Casal 18, 1203 Geneva, Switzerland.

Now at Honeywell, Phoenix AZ, U.S.A.

Now at INFN Sezione di Roma II, Dipartimento di Fisica, Università di Roma Tor Vergata, 00133 Roma, Italy.

Now at Centre de Physique des Particules de Marseille, Univ Méditerranée, F-13288 Marseille, France.

Also at Department of Physics, Tsinghua University, Beijing, The People's Republic of China.

Now at SLAC, Stanford, CA 94309, U.S.A.

Deceased.

Also at Groupe d' Astroparticules de Montpellier, Université de Montpellier II, 34095 Montpellier, France.

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 $m_H = 90 \text{ GeV}/c^2$). 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 $e^+e^- \rightarrow HZ$ with $H \rightarrow \gamma\gamma$ 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 $e^+e^- \rightarrow HZ$ are selected according to the charged particle multiplicity of the final state: (*i*) acoplanar photons with missing energy and no charged particles for $e^+e^- \rightarrow H\nu\bar{\nu}$; (*ii*) photon pairs with exactly two charged particles for $e^+e^- \rightarrow H\ell^+\ell^-$; (*iii*) photon pairs accompanied by three or four charged particles clustered into two low-multiplicity jets for $e^+e^- \rightarrow H\tau^+\tau^-$; and (*iv*) photon pairs with at least five charged particles for $e^+e^- \rightarrow Hq\bar{q}$.

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 $\sigma_{1/p_\perp} = 6 \times 10^{-4} \oplus 5 \times 10^{-3}/p_\perp$, 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, $|m_{\text{rec}} - m_Z| < 15 \text{ GeV}/c^2$.

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 $H\nu\bar{\nu}$ 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, $p_{\perp\text{ch}}^\gamma$, 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_{\perp}^f , be greater than $0.2 E_{\text{beam}}$; (iii) the sum of the four minimum inter-jet angles, $\theta_{4\text{-jets}}^{\text{min}}$, 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 $m_{\text{H}}=105$ 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.

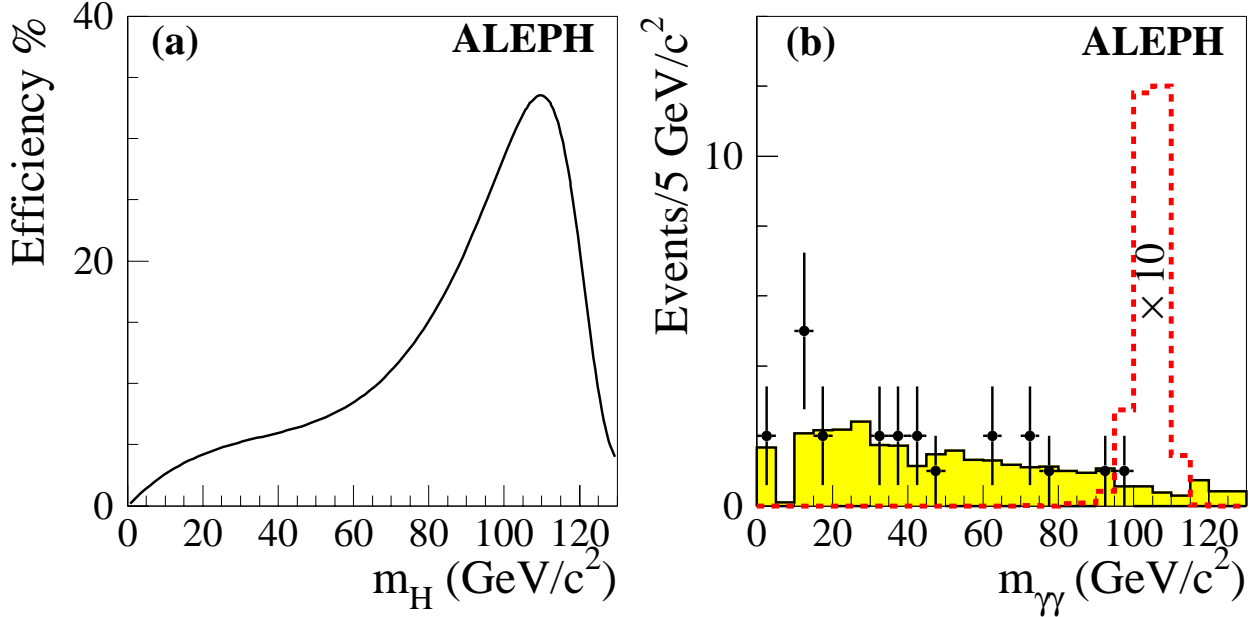


Figure 1: (a) Signal efficiency as a function of m_{H} at $\sqrt{s}=206$ GeV. (b) Di-photon invariant mass distribution for all data taken since 1991 (dots with error bars), for the expected background distributions (shaded histogram) and for a 105 GeV/c^2 fermiophobic Higgs boson signal (dashed histogram).

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_{ch}	$\epsilon_{\text{H}\nu\bar{\nu}}$	$\epsilon_{\text{H}\ell+\ell^-}$	$\epsilon_{\text{H}\tau+\tau^-}$	$\epsilon_{\text{H}q\bar{q}}$	N_{exp}	N_{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
$\cos \theta_{\text{thrust}}$	0.2
p_{miss}	0.6
$p_{\perp\gamma}^f, p_{\perp\text{ch}}^\gamma$	0.7
$\theta_{4\text{-jets}}^{\text{min}}$	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 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 $\mathcal{B}(\text{H} \rightarrow \gamma\gamma)\sigma(\text{e}^+\text{e}^- \rightarrow \text{Hff})/\sigma^{\text{SM}}(\text{e}^+\text{e}^- \rightarrow \text{Hff})$ 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 $20 \text{ GeV}/c^2$. A Higgs boson decaying exclusively to two photons is excluded up to $113.1 \text{ GeV}/c^2$ at 95% C.L. A fermiophobic Higgs boson is excluded at 95% C.L. for any mass up to $105.4 \text{ GeV}/c^2$. 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 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 $113.1 \text{ GeV}/c^2$. In the fermiophobic case, a 95% C.L. lower limit on the Higgs boson mass has been set at $105.4 \text{ GeV}/c^2$.

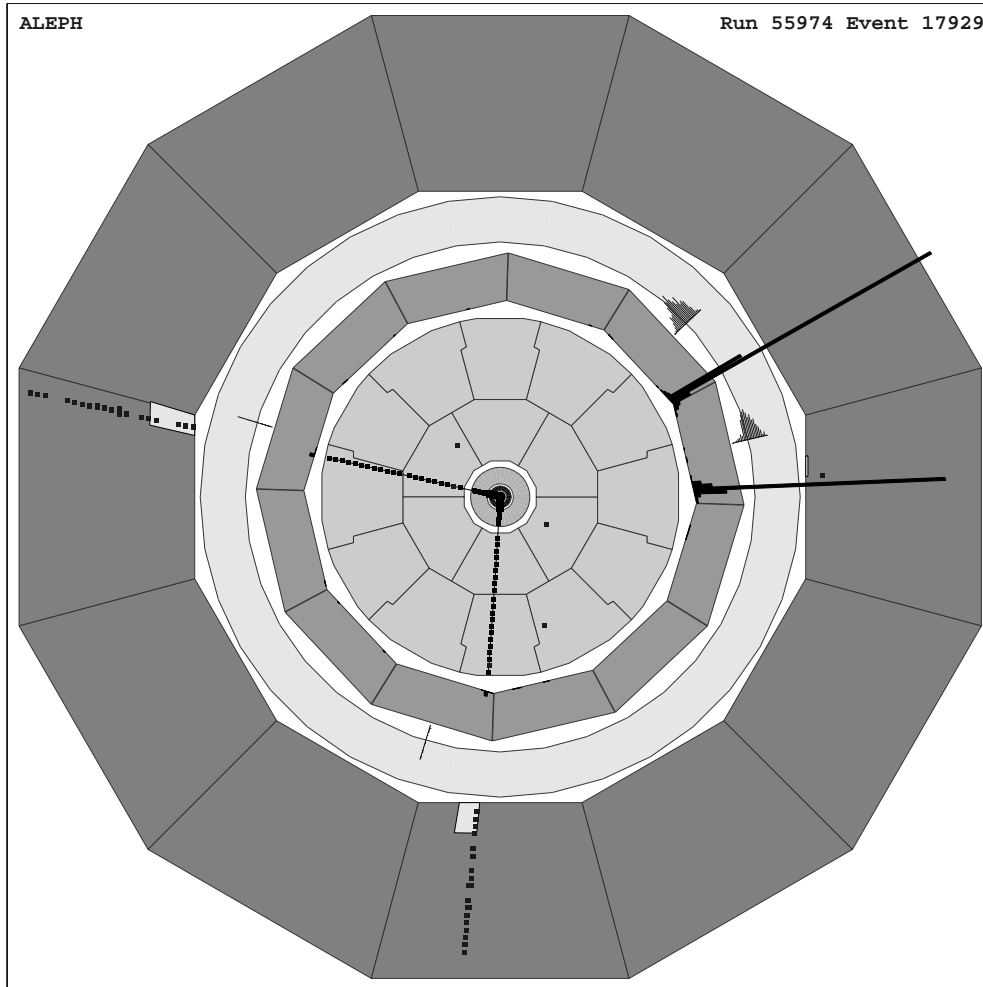


Figure 2: The candidate event observed in 2000.

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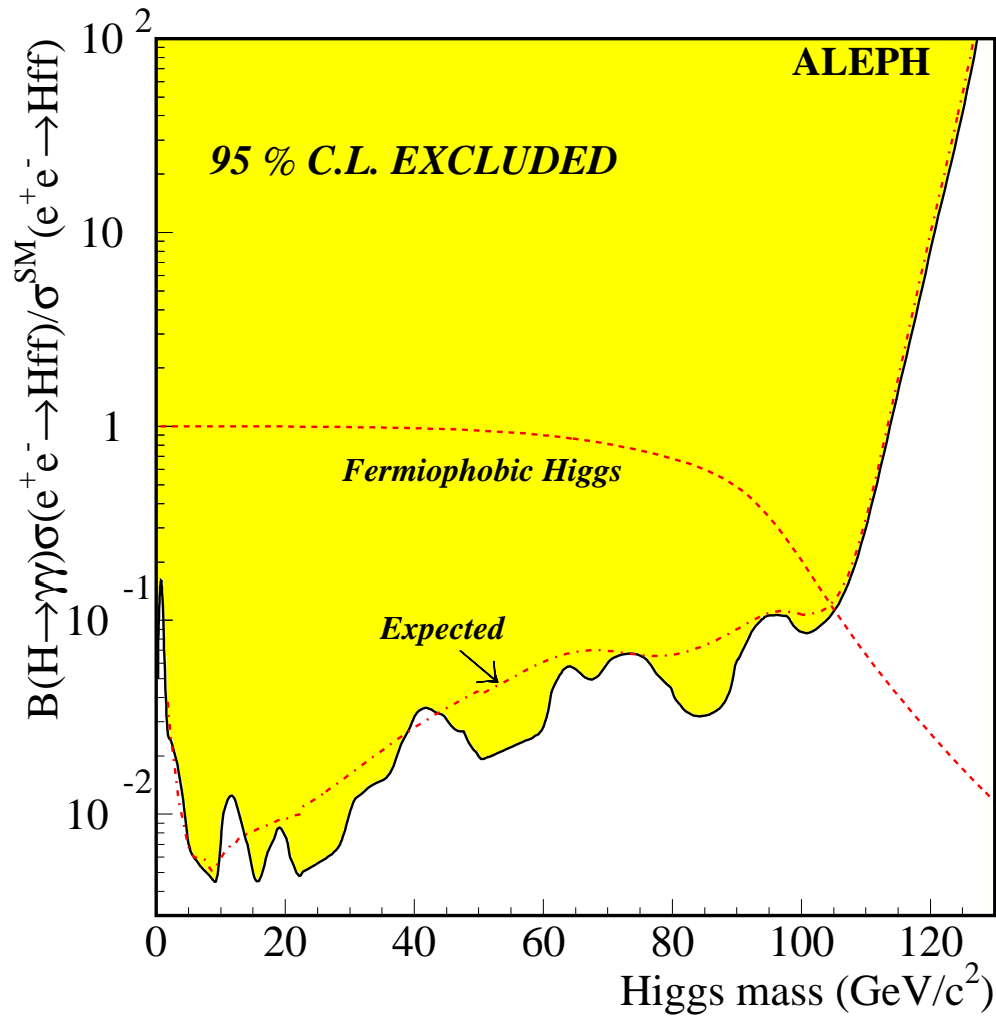


Figure 3: Measured (full curve) and expected (dash-dotted curve) 95% C.L. upper limit on $\mathcal{B}(H \rightarrow \gamma\gamma)\sigma(e^+e^- \rightarrow Hf\bar{f})/\sigma^{\text{SM}}(e^+e^- \rightarrow Hf\bar{f})$ using all data taken since 1991. The dashed curve is the prediction for a fermiophobic 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 $\sqrt{s} = 161\text{ GeV}$, 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.