Search for excited taus from Z^0 decays

L3 Collaboration

B. Adeva [a], O. Adriani [b], M. Aguilar-Benitez [c], H. Akbari [d], J. Alcaraz [c], A. Aloisio [e], G. Alverson [f], M.G. Alviggi [e], Q. An [g], H. Anderhub [h], A.L. Anderson [i], V.P. Andreev [j], T. Angelov [i], L. Antonov [k], D. Antreasyan [ℓ], P. Arce [c], A. Arefiev [m], T. Azemoon [n], T. Aziz [o], P.V.K.S. Baba [g], P. Bagnaia [p], J.A. Bakken [q], L. Baksay [r], R.C. Ball [n], S. Banerjee [o, g], J. Bao [d], L. Barone [p], A. Bay [s], U. Becker [i], J. Behrens [h], S. Beingessner [t], Gy.L. Bencze [u], J. Berdugo [c], P. Berges [i], B. Bertucci [p], B.L. Betev [k], A. Biland [h], R. Bizzarri [p], J.J. Blaising [t], P. Blömeke [v], B. Blumenfeld [d], G.J. Bobbink [w], M. Bocciolini [b], W. Böhlen [x], A. Böhm [v], T. Böhringer [y], B. Borgia [p], D. Bourilkov [k], M. Bourquin [s], D. Boutigny [t], J.G. Branson [z], I.C. Brock [aa], F. Bruyant [a], C. Buisson [ab], A. Bujak [ac], J.D. Burger [i], J.P. Burq [ab], J. Busenitz [ad], X.D. Cai [g], C. Camps [v], M. Capell [n], F. Carbonara [e], F. Carminati [b], A.M. Cartacci [b], M. Cerrada [c], F. Cesaroni [p], Y.H. Chang [i], U.K. Chaturvedi [g], M. Chemarin [ab], A. Chen [ae], C. Chen [af], G.M. Chen [af], H.F. Chen [ag], H.S. Chen [af], M. Chen [i], M.C. Chen [ah], M.L. Chen [n], G. Chiefari [e], C.Y. Chien [d], C. Civinini [b], I. Clare [i], R. Clare [i], G. Coignet [t], N. Colino [a], V. Commichau [v], G. Conforto [b], A. Contin [a], F. Crijns [w], X.Y. Cui [g], T.S. Dai [i], R. D'Alessandro [b], R. de Asmundis [e], A. Degré [a, t], K. Deiters [a, ai], E. Dénes [u], P. Denes [q], F. De Notaristefani [p], M. Dhina [h], D. DiBitonto [ad], M. Diemoz [p], F. Diez-Hedo [a], H.R. Dimitrov [k], C. Dionisi [p], F. Dittus [ah], R. Dolin [i], E. Drago [e], T. Driever [w], D. Duchesneau [s], P. Duinker [w, a], I. Duran [a, c], H. El Mamouni [ab], A. Engler [aa], F.J. Eppling [i], F.C. Erné [w], P. Extermann [s], R. Fabbretti [h], G. Faber [i], S. Falciano [p], Q. Fan [g, af], S.J. Fan [aj], M. Fabre [h], J. Fay [ab], J. Fehlmann [h], H. Fenker [f], T. Ferguson [aa], G. Fernandez [c], F. Ferroni [p, a], H. Fesefeldt [v], J. Field [s], G. Finocchiaro [p], P.H. Fisher [d], G. Forconi [s], T. Foreman [w], K. Freudenreich [h], W. Friebel [ai], M. Fukushima [i], M. Gailloud [y], Yu. Galaktionov [m], E. Gallo [b], S.N. Ganguli [o], P. Garcia-Abia [c], S.S. Gau [ae], S. Gentile [p], M. Glaubman [f], S. Goldfarb [n], Z.F. Gong [g, ag], E. Gonzalez [c], A. Gordeev [m], P. Göttlicher [v], D. Goujon [s], G. Gratta [ah], C. Grinnell [i], M. Gruenewald [ah], M. Guanziroli [g], A. Gurtu [o], H.R. Gustafson [n], L.J. Gutay [ac], H. Haan [v], S. Hancke [v], K. Hangarter [v], M. Harris [a], A. Hasan [g], C.F. He [aj], T. Hebbeker [v], M. Hebert [z], G. Herten [i], U. Herten [v], A. Hervé [a], K. Hilgers [v], H. Hofer [h], H. Hoorani [g], L.S. Hsu [ae], G. Hu [g], G.Q. Hu [aj], B. Ille [ab], M.M. Ilyas [g], V. Innocente [e, a], E. Isiksal [h], E. Jagel [g], B.N. Jin [af], L.W. Jones [n], R.A. Khan [g], Yu. Kamyshkov [m], Y. Karyotakis [t, a], M. Kaur [g], S. Khokhar [g], V. Khoze [j], D. Kirkby [ah], W. Kittel [w], A. Klimentov [m], A.C. König [w], O. Kornadt [v], V. Koutsenko [m], R.W. Kraemer [aa], T. Kramer [i], V.R. Krastev [k], W. Krenz [v], J. Krizmanic [d], A. Kuhn [x], K.S. Kumar [ak], V. Kumar [g], A. Kunin [m], A.van Laak [v], V. Lalieu [s], G. Landi [b], K. Lanius [a], D. Lanske [v], S. Lanzano [e], P. Lebrun [ab], P. Lecomte [h], P. Lecoq [a], P.Le Coultre [h], I. Leedom [f], J.M. Le Goff [a], L. Leistam [a], R. Leiste [ai], M. Lenti [b], J. Lettry [h], P.M. Levchenko [j], X. Leytens [w], C. Li [ag], H.T. Li [af], J.F. Li [g], L. Li [h], P.J. Li [aj], Q. Li [g], X.G. Li [af], J.Y. Liao [aj], Z.Y. Lin [ag], F.L. Linde [aa], D. Linnhofer [a], R. Liu [g], Y. Liu [g], W. Lohmann [ai], S. Lökös [r], E. Longo [p], Y.S. Lu [af], J.M. Lubbers [w], K. Lübelsmeyer [v], C. Luci [a], D. Luckey [ℓ, i], L. Ludovici [p], X. Lue [h], L. Luminari [p], W.G. Ma [ag], M. MacDermott [h], R. Magahiz [r], M. Maire [t], P.K. Malhotra [o], R. Malik [g], A. Malinin [m], C. Maña [c], D.N. Mao [n], Y.F. Mao [af], M. Maolinbay [h], P. Marchesini [g], A. Marchionni [b], J.P. Martin [ab], L. Martinez [a], F. Marzano [p], G.G.G. Massaro [w], T. Matsuda [i],

0370-2693/90/$ 03.50 © 1990 – Elsevier Science Publishers B.V. (North-Holland)

K. Mazumdar [o], P. McBride [ak], T. McMahon [ac], D. McNally [h], Th. Meinholz [v], M. Merk [w], L. Merola [e], M. Meschini [b], W.J. Metzger [w], Y. Mi [g], M. Micke [v], U. Micke [v], G.B. Mills [n], Y. Mir [g], G. Mirabelli [p], J. Mnich [v], M. Möller [v], B. Monteleoni [b], G. Morand [s], R. Morand [t], S. Morganti [p], V. Morgunov [m], R. Mount [ah], E. Nagy [u], M. Napolitano [e], H. Newman [ah], M.A. Niaz [g], L. Niessen [v], D. Pandoulas [v], G. Passaleva [b], G. Paternoster [e], S. Patricelli [e], Y.J. Pei [v], D. Perret-Gallix [t], J. Perrier [s], A. Pevsner [d], M. Pieri [b], P.A. Piroué [q], V. Plyaskin [m], M. Pohl [h], V. Pojidaev [m], N. Produit [s], J.M. Qian [i, g], K.N. Qureshi [g], R. Raghavan [o], G. Rahal-Callot [h], P. Razis [h], K. Read [q], D. Ren [h], Z. Ren [g], S. Reucroft [f], O. Rind [n], C. Rippich [aa], H.A. Rizvi [g], B.P. Roe [n], M. Röhner [v], S. Röhner [v], U. Roeser [ai], Th. Rombach [v], L. Romero [c], J. Rose [v], S. Rosier-Lees [t], R. Rosmalen [w], Ph. Rosselet [y], J.A. Rubio [a, c], W. Ruckstuhl [s], H. Rykaczewski [h], M. Sachwitz [ai], J. Salicio [a, c], J.M. Salicio [c], G. Sartorelli [ℓ, g], G. Sauvage [t], A. Savin [m], V. Schegelsky [j], D. Schmitz [v], P. Schmitz [v], M. Schneegans [t], M. Schöntag [v], H. Schopper [aℓ], D.J. Schotanus [w], H.J. Schreiber [ai], R. Schulte [v], S. Schulte [v], K. Schultze [v], J. Schütte [ak], J. Schwenke [v], G. Schwering [v], C. Sciacca [e], I. Scott [ak], R. Sehgal [g], P.G. Seiler [h], J.C. Sens [w], I. Sheer [z], V. Shevchenko [m], S. Shevchenko [m], X.R. Shi [aa], K. Shmakov [m], V. Shoutko [m], E. Shumilov [m], N. Smirnov [j], A. Sopczak [ah, z], C. Spartiotis [d], T. Spickermann [v], B. Spiess [x], P. Spillantini [b], R. Starosta [v], M. Steuer [ℓ, i], D.P. Stickland [q], B. Stöhr [h], H. Stone [s], K. Strauch [ak], B.C. Stringfellow [ac], K. Sudhakar [o, v], G. Sultanov [a], R.L. Sumner [q], L.Z. Sun [ag], H. Suter [h], R.B. Sutton [aa], J.D. Swain [g], A.A. Syed [g], X.W. Tang [af], E. Tarkovsky [m], L. Taylor [f], E. Thomas [g], C. Timmermans [w], Samuel C.C. Ting [i], S.M. Ting [i], Y.P. Tong [ae], F. Tonisch [ai], M. Tonutti [v], S.C. Tonwar [o], J. Tòth [u], G. Trowitzsch [ai], K.L. Tung [af], J. Ulbricht [x], L. Urbàn [u], U. Uwer [v], E. Valente [p], R.T. Van de Walle [w], H. van der Graaf [w], I. Vetlitsky [m], G. Viertel [h], P. Vikas [g], U. Vikas [g], M. Vivargent [t, i], H. Vogel [aa], H. Vogt [ai], M. Vollmar [v], G. Von Dardel [a], I. Vorobiev [m], A.A. Vorobyov [j], An.A. Vorobyov [j], L. Vuilleumier [y], M. Wadhwa [g], W. Wallraff [v], C.R. Wang [ag], G.H. Wang [aa], J.H. Wang [af], Q.F. Wang [ak], X.L. Wang [ag], Y.F. Wang [b], Z. Wang [g], Z.M. Wang [g, ag], J. Weber [h], R. Weill [y], T.J. Wenaus [i], J. Wenninger [s], M. White [i], R. Wilhelm [w], C. Willmott [c], F. Wittgenstein [a], D. Wright [q], R.J. Wu [af], S.L. Wu [g], S.X. Wu [g], Y.G. Wu [af], B. Wysłouch [i], Y.D. Xu [af], Z.Z. Xu [ag], Z.L. Xue [aj], D.S. Yan [aj], B.Z. Yang [ag], C.G. Yang [af], G. Yang [g], K.S. Yang [af], Q.Y. Yang [af], Z.Q. Yang [aj], C.H. Ye [g], J.B. Ye [h], Q. Ye [g], S.C. Yeh [ae], Z.W. Yin [aj], J.M. You [g], C. Zaccardelli [ah], L. Zehnder [h], M. Zeng [g], Y. Zeng [v], D. Zhang [z], D.H. Zhang [w], Z.P. Zhang [ag], J.F. Zhou [v], R.Y. Zhu [ah], H.L. Zhuang [af] and A. Zichichi [a, g]

[a] *European Laboratory for Particle Physics, CERN, CH-1211 Geneva 23, Switzerland*
[b] *INFN – Sezione di Firenze and University of Firenze, I-50125 Florence, Italy*
[c] *Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas, CIEMAT, E-28040 Madrid, Spain*
[d] *Johns Hopkins University, Baltimore, MD 21218, USA*
[e] *INFN – Sezione di Napoli and University of Naples, I-80125 Naples, Italy*
[f] *Northeastern University, Boston, MA 02115, USA*
[g] *World Laboratory, FBLJA Project, CH-1211 Geneva, Switzerland*
[h] *Eidgenössische Technische Hochschule, ETH Zürich, CH-8093 Zurich, Switzerland*
[i] *Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[j] *Leningrad Nuclear Physics Institute, SU-188 350 Gatchina, USSR*
[k] *Central Laboratory of Automation and Instrumentation, CLANP, Sofia, Bulgaria*
[ℓ] *INFN – Sezione di Bologna, I-40126 Bologna, Italy*
[m] *Institute of Theoretical and Experimental Physics, ITEP, SU-117 259 Moscow, USSR*
[n] *University of Michigan, Ann Arbor, MI 48109, USA*
[o] *Tata Institute of Fundamental Research, Bombay 400 005, India*
[p] *INFN – Sezione di Roma and University of Rome "La Sapienza", I-00185 Rome, Italy*
[q] *Princeton University, Princeton, NJ 08544, USA*
[r] *Union College, Schenectady, NY 12308, USA*
[s] *University of Geneva, CH-1211 Geneva 4, Switzerland*

[t] *Laboratoire de Physique des Particules, LAPP, F-74519 Annecy-le-Vieux, France*
[u] *Central Research Institute for Physics of the Hungarian Academy of Sciences, H-1525 Budapest 114, Hungary*
[v] *I. Physikalisches Institut, RWTH, D-5100 Aachen, FRG*[1]
and III. Physikalisches Institut, RWTH, D-5100 Aachen, FRG[1]
[w] *National Institute for High Energy Physics, NIKHEF, NL-1009 DB Amsterdam, The Netherlands*
and NIKHEF-H and University of Nijmegen, NL-6525 ED Nijmegen, The Netherlands
[x] *Paul Scherrer Institut (PSI), Würenlingen, Switzerland*
[y] *University of Lausanne, CH-1015 Lausanne, Switzerland*
[z] *University of California, San Diego, CA 92182, USA*
[aa] *Carnegie Mellon University, Pittsburgh, PA 15213, USA*
[ab] *Institut de Physique Nucléaire de Lyon, IN2P3-CNRS/Université Claude Bernard, F-69622 Villeurbanne Cedex, France*
[ac] *Purdue University, West Lafayette, IN 47907, USA*
[ad] *University of Alabama, Tuscaloosa, AL 35486, USA*
[ae] *High Energy Physics Group, Taiwan, ROC*
[af] *Institute of High Energy Physics, IHEP, Beijing, P.R. China*
[ag] *Chinese University of Science and Technology, USTC, Hefei, Anhui 230 029, P.R. China*
[ah] *California Institute of Technology, Pasadena, CA 91125, USA*
[ai] *High Energy Physics Institute, DDR-1615 Zeuthen-Berlin, GDR*
[aj] *Shanghai Institute of Ceramics, SIC, Shanghai, P.R. China*
[ak] *Harvard University, Cambridge, MA 02139, USA*
[aℓ] *University of Hamburg, D-2000 Hamburg, FRG*

Received 7 August 1990

We have searched for excited taus from Z^0 decay in the channels $e^+e^- \to \tau^{*+}\tau^{*-} \to \tau^+\tau^-\gamma\gamma$ and $e^+e^- \to \tau\tau^* \to \tau^+\tau^-\gamma$, using the L3 detector at LEP. Using the τ^* pair production channel, we can exclude a τ^* up to a mass of 45.5 GeV at 95% confidence level. We have also determined upper limits on the $\tau\tau^*Z^0$ and $\tau\tau^*\gamma$ couplings as a function of m_{τ^*} up to 89.3 GeV.

1. Introduction

The standard model [1] has been very successful in describing data on electroweak interactions; however, it leaves many fundamental questions unexplained such as the lepton–quark spectrum, mass generation, the Higgs mechanism, and the large number of arbitrary parameters. One possibility, which would explain the number of families and make the fermion masses and weak mixing angles calculable, would be to assume that quarks, leptons and gauge bosons are all composite [2] with an associated energy scale Λ. One natural consequence of compositeness models is the existence of excited states, ℓ^*, of the known leptons ℓ.

In this paper we describe a search for excited states of the heaviest known lepton, the tau, using the L3 detector at LEP. The excited tau, τ^*, is assumed to have spin $\frac{1}{2}$ and to decay into an ordinary tau and a photon with a 100% branching ratio.

The e^+e^- collider, LEP, is ideal for the search of excited leptons [3-5] because the initial state consists of pointlike particles with known energy and the final state leptons and photons can be clearly identified. in e^+e^- collisions excited taus can be produced in pairs ($e^+e^- \to \tau^{*+}\tau^{*-}$) or singly ($e^+e^- \to \tau\tau^*$). In the first process obviously only τ^* masses smaller than the beam energy can be explored. The signature is an acollinear tau pair and two hard photons. For the single τ^* production mass limits close to the center of mass energy can be reached. The signature for this process is an acollinear tau pair with one hard photon.

2. τ^* Production models

In this analysis we assume that the Z^0 and γ couple to spin $\frac{1}{2}$ excited tau pairs the same as the standard tau pairs. The lowest order pair-production cross section can be found in refs. [6,7].

[1] Supported by the German Bundesministerium für Forschung und Technologie.

For the single production the effective lagrangian [7] is written as:

$$L_{\text{eff}} = \sum_{V=\gamma,Z} \frac{e}{\Lambda} \bar{\Psi}_{\tau*} \sigma^{\mu\nu} (C_V - D_V \gamma_5) \Psi_\tau \partial_\mu V_\nu + \text{h.c.} ,$$

where Λ is the composite mass scale and C_V and D_V the couplings constants. Assuming lepton universality, from precise $g-2$ measurements it follows that $|C_V| = |D_V|$. The coupling constants can be written as $C_\gamma = -\frac{1}{4}(f+f')$ and $C_{Z^0} = -\frac{1}{4}(f \cot\theta_w - f' \tan\theta_w)$, where f and f' are respectively the free parameters for SU(2) and U(1). In this study we assume $f=f'$, so that the only free parameter in the lagrangian is $f/\Lambda = \sqrt{2}\lambda/m_{\tau*}$ [8]. The differential and total cross section formulae can be found in refs. [4,7].

For the generation of pair produced excited taus we have made a Monte Carlo program using the differential cross section as given in ref. [7]. We simulate the single production of excited taus with the Monte Carlo generator [9]. The subsequent decay of τ-leptons is simulated with the Monte Carlo program [10]. Both for the single and pair production processes the effect of initial state radiations is taken into account in our calculations. All generated events have been passed through the L3 detector simulation [11] #1 which includes the effects of energy loss, multiple scattering, interactions and decays in the detector and the beam pipe.

3. Data

The L3 detector and its performance in the detection of muons, electrons and photons is described in detail elsewhere [13]. It consists of a central tracking and vertex chamber (TEC), a BGO electromagnetic calorimeter, a ring of plastic scintillation counters, a hadron calorimeter made of uranium and proportional wire chambers and a high precision muon chamber system. These detectors are installed inside a 12 m inner diameter magnet which provides a uniform field of of 0.5 T along the beam direction. The luminosity is measured by detecting small angle Bhabha events. The BGO covers the polar angle from 42.3° to 137.7°, the muon chamber from 36° to 144°, and the hadron calorimeter from 5.5° to 174.5°.

The data used in these searches were taken with the L3 detector at LEP in 1990 during an energy scan of the Z^0 resonance at center of mass energies between 88.3 and 94.3 GeV. The integrated luminosity used in this analysis is 2.2 pb^{-1}.

The trigger for this analysis requires a total energy in the electromagnetic and hadronic calorimeters of at least 15 GeV in the central region ($|\cos\theta| < 0.74$), or 20 GeV in the entire calorimeter, or at least one muon reconstructed in the muon chamber with momentum larger than 2 GeV.

Our analysis uses a cluster algorithm which groups neighbouring calorimeter energy depositions. The algorithm normally reconstructs one cluster for a single electron, photon, muon, jet or high energy tau. Photons are identified as energy clusters in the BGO calorimeter with an electromagnetic shower profile and which do not match tracks from the vertex chamber. The requirement on the shower profile is that the energy sum of 9 crystals divided by the energy sum of 25 crystals (centered around the shower maximum) is larger than 0.95.

We search for excited taus by requiring the following cuts:

(1) The total energy in the calorimeters must be larger than 22 GeV. No total energy requirement is made if the event contains a reconstructed muon with momentum larger than 2 GeV.

(2) The measured energy in the BGO calorimeter alone must be larger than 2 GeV and smaller than 80 GeV; this requirement rejects $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to e^+e^-$ events.

(3) There must be less than 16 shower peaks with $E > 100$ MeV in the BGO calorimeter. This cut rejects hadron events.

(4) There must be at least one and at most eight reconstructed charged particle tracks in the vertex chamber with momentum larger than 100 MeV. This cut also rejects hadron events.

(5) There must be exactly two clusters with energies larger than 2 GeV, which are not compatible with photons.

(6) Each identified electron or muon must have an energy smaller than 35 GeV. An electron is identified as an electromagnetic shower profile with a matched track in the vertex chamber within 5° in the

#1 The GHEISHA program [12] is used to simulate hadronic events.

r–ϕ plane. This cut rejects $e^+e^- \to e^+e^-$ and $e^+e^- \to \mu^+\mu^-$ events.

After appling the above selection cuts, 1357 events remain. They are predominantly $\tau^+\tau^-$ events and are used to search for excited taus. The trigger efficiency, which exceeds 99.5%, has been checked using redundant triggers.

4. Search for $ee^- \to \tau^{*+}\tau^{*-}$

From our previous measurement of Γ_{Z^0} and the standard model prediction [14], we can set a limit on τ^* pair production which translate into m_{τ^*} greater than 27 GeV at 95% confidence level (CL). This is comparable with the limits from other experiments using direct searches [15]. In the following, we will do the direct search starting from this mass limit.

For the selection of $e^+e^- \to \tau^{*+}\tau^{*-}$ we require, in addition to the above cuts (1)–(6), the following criteria to be satisfied:

(a) There must be two identified photons with energies larger than 5 GeV. They must be separated from any other BGO calorimeter cluster by more than 10°.

(b) The opening angle between the two reconstructed clusters as defined in (5) must be smaller than 170°.

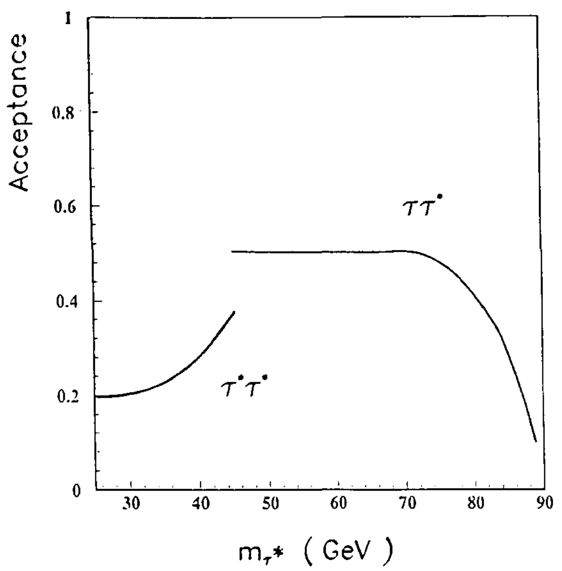

Fig. 1. The acceptance for τ^* events both for single and pair production.

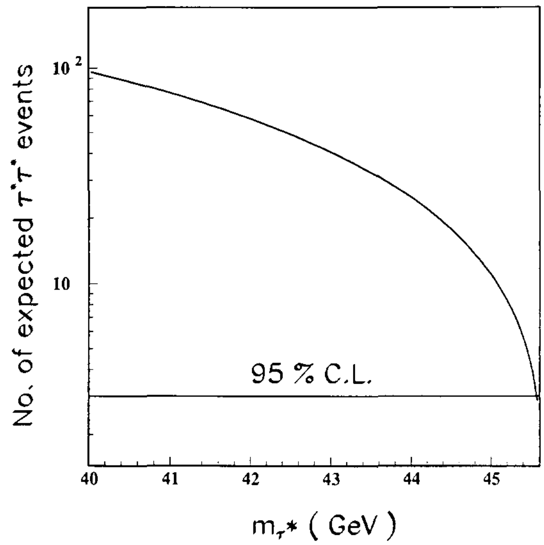

Fig. 2. Number of expected $\tau^*\tau^*$ events from pair production.

No events satisfy the above criteria. The background from radiative $\tau^+\tau^-$ events has been found to be negligible from a Monte Carlo simulation [10]. The acceptance for $\tau^*\tau^*$ events as a function of τ^* mass is shown in fig. 1. The acceptance increases with the τ^* mass because the photon becomes less collinear with the τ. Fig. 2 shows the expected number of events from $e^+e^- \to \tau^*\tau^*$ as a function of the excited tau mass. From this measurement we can exclude at 95% CL an excited tau for masses $m_{\tau^*} < 45.5$ GeV.

5. Search for $e^+e^- \to \tau\tau^*$

For the selection of $e^+e^- \to \tau\tau^*$ we require, in addition to the above cuts (1)–(6), the following criteria to be satisfied:

(a) There must be only one identified photon with energy larger than 5 GeV. The photon must be isolated as mentioned before.

(b) The opening angle between the two reconstructed clusters as defined in cut (5) must be smaller than 170°.

Fig. 3 shows the photon energy distribution after cuts (1)–(6) compared with Monte Carlo simulations for $e^+e^- \to \tau^+\tau^-$ and $e^+e^- \to \tau\tau^*$ for a τ^* mass of

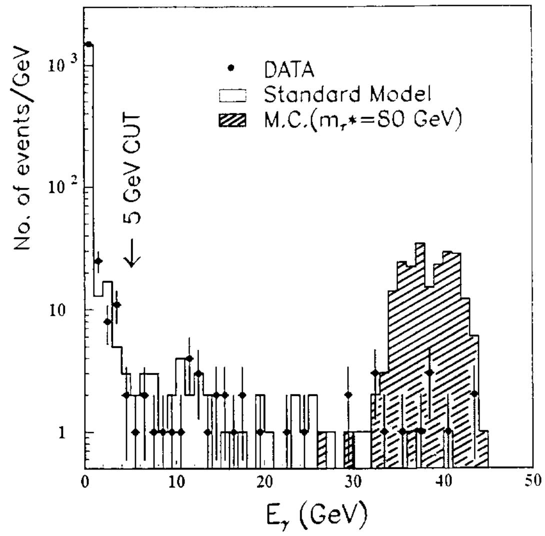

Fig.3. The measured photon energy spectrum compared with Monte Carlo. The unshaded area is the Monte Carlo prediction of standard model for $\tau^+\tau^-$. The shaded area is an example of the Monte Carlo prediction for $\tau\tau^*$ with $m_{\tau^*}=80$ GeV and $\lambda=0.5$.

80 GeV as an example. The acceptance for $\tau\tau^*$ events for different τ^* masses is shown in fig. 1.

After appling cuts (a) and (b), a total of 24 events fulfill the above cuts. From a simulation [10] of the process $e^+e^-\to\tau^+\tau^-\gamma$, 22.3 ± 4.2 events are expected. Since it is not possible to reconstruct correctly the $\tau\gamma$ invariant mass due to the undetected neutrinos from the τ decay, we conservatively assume that all 24 events are seen at each value of τ^* mass, with 22.3 background events expected. An excess of 12.5 events constitutes the 95% confidence level upper limit. For the cross section we use the analytic expression [4,7] including initial state radiative corrections. Fig. 4 shows the 95% CL upper limit of the coupling constant λ/m_{τ^*} as a function of m_{τ^*} together with results from other LEP experiments [5]. The beam energy and the energy cut for clusters limits our investigation to an m_{τ^*} mass below 89.3 GeV.

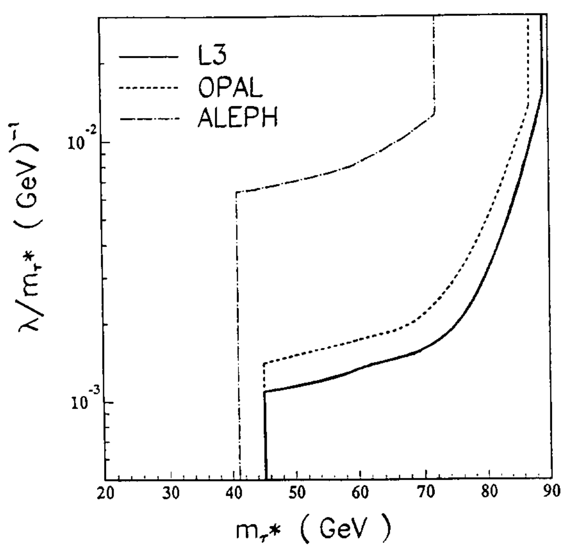

Fig. 4. The upper limit of the coupling constant λ/m_{τ^*} at 95% CL as a function of m_{τ^*}. The excluded region is above and left of the curves.

Acknowledgement

We wish to thank CERN for its hospitality and help. We want particularly to express our gratitude to the LEP division: it is their excellent achievements which made this experiment possible. We acknowledge the support of all the funding agencies which contributed to this experiment.

References

[1] S.L. Glashow, Nucl. Phys. 22 (1961) 579;
S. Weinberg, Phys. Rev. Lett. 19 (1967) 1264;
A. Salam, Elementary particle theory, ed. N. Svartholm (Almquist and Wiksell, Stockholm, 1968) p. 367.
[2] F. Boudjema et al., Z. Physics at LEP 1, Vol. 2, eds. J. Ellis and R. Peccei, CERN Report CERN 89-08 (1989) 188, and references therein.
[3] L3 Collab., B. Adeva et al., Phys. Lett. B 247 (1990) 177; B 250 (1990) 199.
[4] Y.F. Wang, Search for excited muons, L3 internal note K718 (February 1990), unpublished.
[5] ALEPH Collab., D. Decamp et al., Phys. lett. B 236 (1990) 501;
OPAL Collab., M.Z. Akrawy et al., Phys. lett. B 244 (1990) 135.
[6] H. Baer et al., Physics at LEP, Vol. 1, eds. J. Ellis and R. Peccei, CERN Report CERN 86-02 (1986) 297.
[7] K. Hagiwara et al., Z. Phys. C 29 (1985) 115.
[8] H. Terazawa et al., Phys. Lett. B 112 (1982) 387.
[9] F.A. Berends and P.H. Daverveldt, MMSTR, Nucl. Phys. B 272 (1986) 131.

[10] S. Jadach et al., KORALZ, Proc. workshop on Z physics at LEP, eds. G. Altarelli, R. Kleiss and C. Verzegnassi, CERN Report CERN 89-08, Vol. 3, p. 69.
[11] GEANT Version 3.13 (September 1989), see R. Brun et al., GEANT 3, CERN DD/EE/84-1 (revised), September 1987.
[12] H. Fesefeldt, RWTH, Aachen preprint PITHA 85/02 (1985).
[13] L3 Collab., B. Adeva et al., Nucl. Instrum. Methods A 289 (1990) 35.
[14] L3 Collab., B. Adeva et al., Phys. Lett. B 249 (1990) 341.
[15] CELLO Collab. H.-J. Behrend et al., Phys. Lett. B 168 (1986) 420;
TOPAZ Collab., I. Adachi et al., Phys. Lett. B 228 (1989) 553.