RECENT RESULTS OF THE L3 COLLABORATION (CERN)

V.A.Andreev, A.S.Denisov, O.L.Fedin, A.V.Jelamkov, P.M.Levtchenko, A.V.Nadtochi, D.A.Prokofiev, V.A.Schegelsky, I.B.Vodopianov, An.A.Vorobyov, A.Yu.Zalite, Yu.K.Zalite

1. Introduction

Twelve exciting years of research at the high energy frontier are the legacy of the Large Electron-Positron collider at CERN. During its runs at the centre-of-mass energies of m_Z (LEP1) and 130–209 GeV (LEP2), this machine has allowed for the collection of an unprecedented amount of data. About 1 fb^{-1} of integrated luminosity has been delivered per experiment. During the LEP era the Standard Model of particle physics has undergone a stringent scrutiny of its most fine details.

During LEP1 phase $\sim 4 \cdot 10^6$ Z bosons were detected. The most important results of L3 experiment have been already reported [1]:

- Z-boson mass has been measured with very high precision: $m_Z = 91.1893 \pm 0.0030$ MeV.
- The probability of the decay $Z \to \nu\bar{\nu}\gamma$ has been determined, and the number of generation of massless neutrino is $N_\nu = 2.978 \pm 0.014$.
- The Standard Model (SM) predictions have been confirmed, and Weinberg angle has been estimated with a high accuracy $\sin^2\bar{\theta}_W = 0.23093 \pm 0.00066$.
- The top-quark mass has been predicted in the frame of SM from higher order weak radiative corrections: $m_t = 197^{+30}_{-16}$ GeV. Later on m_t was directly measured with the FNAL collider.
- No trace of new physics or deviation from SM was found.

In the year 2001, main efforts were largely focused on the search for Higgs bosons and on precise measurements of the properties of the W bosons. Detailed studies of resonance formation in two-photon interactions were also continued. In the following, the recent results obtained by the L3 Collaboration are briefly reported.

2. Physics of the *W* bosons

One of the main motivations to double the LEP energy was to study the W-boson properties as well as the characteristics of the W-pair production process, such as the total cross section, the angular distributions and the helicity structure. The measurement of the W-decay branching ratios provides a test of lepton universality for charged current interactions. The W mass is one of the fundamental parameters of the Standard Model. Its actual value depends *via* radiative corrections on unknown parameters like the mass of the Higgs boson, or on the presence of physics beyond the Standard Model.

First direct measurements of m_W were derived by the L3 collaboration from total cross section measurements, mainly at the kinematics threshold of the reaction

$$e^+e^- \to W^+W^-, \tag{1}$$

$\sqrt{s} = 161$ GeV, where the dependence of the W-pair cross section on the W-boson mass is largest. At centre-of-mass energies well above the kinematics threshold, the mass and also the total width of the W boson are determined by analyzing the invariant mass of W-boson decay products.

The W-boson decays into a quark-antiquark pair, such as $W^- \to \bar{u}d$ or $\bar{c}s$, or a lepton-antilepton pair, $W^- \to l^-\bar{\nu}_l$ ($l = e, \mu, \tau$), in the following denoted as qq, $l\nu$ for both W^+ and W^- decays. Four-fermion final states expected in W-pair production are $l\nu l\nu$, $qql\nu$ and $qqqq$.

The mass and the width of the W boson are determined [2] by comparing samples of Monte Carlo events to the data. A reweighting procedure is applied to construct Monte Carlo samples corresponding to different mass and width values. The fitting procedure uses the maximum likelihood method to extract values and errors of the W boson mass m_W and the total width Γ_W.

The observed invariant mass distribution for 2000 data in the $qql\nu$ and $qqqq$ final states is shown in Fig. 1. Combining the results from 2000 data with the ones determined at lower

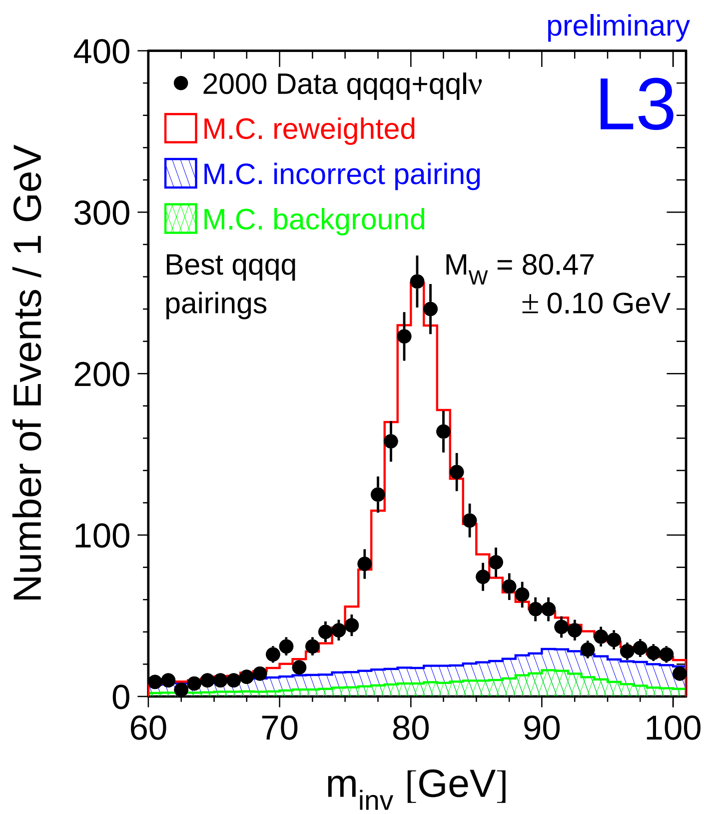

Fig. 1. Distribution of reconstructed invariant mass for all W-pair events selected in the 205–208 GeV data. For $qqqq$ events, the two best pairings are included. The solid line shows the result of the fit of m_W. The quoted error combines statistical and systematic errors in quadrature

centre-of-mass energies of 161–202 GeV yields:

$$m_W = 80.398 \pm 0.048(\text{stat}) \pm 0.050(\text{syst})\ \text{GeV}, \quad (2)$$

$$\Gamma_W = 2.24 \pm 0.11(\text{stat}) \pm 0.15(\text{syst})\ \text{GeV}. \quad (3)$$

The cross section of the process (1) as a function of the centre-of-mass energy [3] is shown in Fig. 2. The results are compared to the predictions of the Standard Model using the YFSWW3

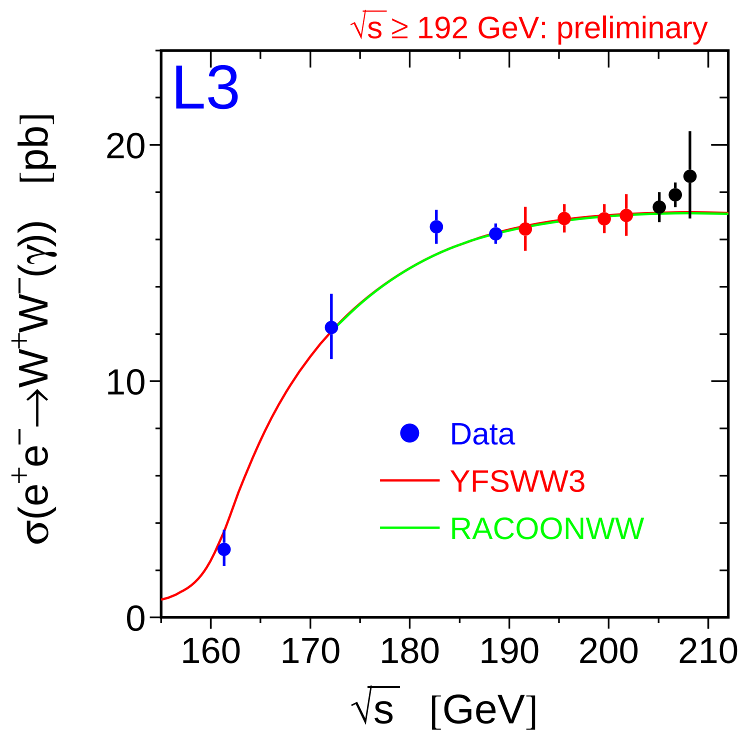

Fig. 2. The cross section, $\sigma_W W$, of the process $e^+e^- \to W^+W^-(\gamma)$ as a function of the centre-of-mass energy, $\sqrt{s}$. The measurements of $\sigma_W W$ are shown as dots with error bars, combining statistical and systematic errors in quadrature. The overlapping solid curves show the Standard Model expectation as calculated with YFSWW3 in the whole energy range and RacoonWW for $\sqrt{s} \geq 170$ GeV

and RacoonWW programs. The two predictions are consistent and have a theoretical uncertainty of 2.0% in the threshold region going down to 0.5% for $\sqrt{s} \geq 170$ GeV. The resulting W-decay branching ratios including statistical and systematic errors are listed in Table. The branching fractions are determined both with and without the assumption of charged-current lepton universality in W decays.

Precision measurements of the trilinear gauge boson couplings constitute critical tests of the Standard Model. Extensive studies of the anomalous W couplings have been carried out by experiments at the Tevatron and at LEP. These studies focused so far on pair production of vector gauge bosons – WW, WZ and $W\gamma$. The L3 collaboration explored for the first time another approach for studying the anomalous electromagnetic couplings of the W bosons by

Table

W-decay branching ratios, BR, derived with and without the assumption of charged-current lepton universality. Also shown are the W-decay branching ratios as expected in the Standard Model

Parameter	Lepton Non-Universality	Lepton Universality	Standard Model
$BR(W \to e\nu)$	$10.40 \pm 0.26 \pm 0.14$	–	
$BR(W \to \mu\nu)$	$9.72 \pm 0.27 \pm 0.15$	–	
$BR(W \to \tau\nu)$	$11.78 \pm 0.38 \pm 0.21$	–	
$BR(W \to l\nu)$	–	$10.55 \pm 0.13 \pm 0.11$	10.83
$BR(W \to qq)$	$68.10 \pm 0.41 \pm 0.33$	$68.34 \pm 0.40 \pm 0.33$	67.51

measuring the cross section of single W production

$$e^+e^- \to e^+\nu_e W^- \ . \tag{4}$$

This process is a clean test of the $WW\gamma$ vertex. The cross section of the process (4) depends only on the k_γ and λ_γ gauge coupling parameters. Any deviation from the coupling values $k_\gamma = 1$ and $\lambda_\gamma = 0$ predicted by the Standard Model would indicate that the W boson has an internal structure.

The cross section of the process (4) is small at LEP2 energies – of the order 0.5 pb. However, despite the low statistics, this process is a sensitive probe of new physics beyond the Standard Model. A specific feature of single W-boson production is a final state positron (electron) produced at very low polar angle and therefore not detected. Thus the signature of this process is a single energetic lepton, if the W-boson decays into lepton and neutrino, or two hadronic jets in the case of hadronic W decay.

The cross section of process (4) measured by the L3 collaboration at centre-of-mass energies $\sqrt{s}$ = 130–202 GeV are found to be consistent with the Standard model expectation. The $WW\gamma$ gauge couplings k_γ and λ_γ are determined to be

$$k_\gamma = 1.10^{+0.10}_{-0.11} \pm 0.08, \tag{5}$$

$$\lambda_\gamma = -0.10^{+0.41}_{-0.22} \pm 0.11. \tag{6}$$

This result is consistent with the absence of anomalous contribution to $WW\gamma$ couplings.

The new results on the W helicity fractions and the WW spin correlations are obtained using the data collected with the L3 detector at centre-of-mass energies between $\sqrt{s}$ = 183–208 GeV. At an average centre-of-mass energy of 206.6 GeV, the fractions of the different W helicity states, –1, +1 and 0 are measured to be $64.7 \pm 6.6\%$, $13.7 \pm 3.4\%$ and $21.6 \pm 5.3\%$, respectively. The results agree well with the Standard Model expectation for the three W helicity states of 62.3%, 15.7% and 22.0%. Within the Standard Model, CP is conserved in the reaction (1) and the helicity fractions (+1, –1 and 0) for the W^+ are expected to be identical with (–1, +1 and 0) for the W^- respectively. One can thus test the CP invariance by measuring separately the helicity fractions for W^+ and W^-. The measured helicity fractions agree within the statistical errors and provide the first direct test of CP invariance in the reaction (1). The W helicity fractions are also studied as a function of the W^- polar scattering angle with respect to the e^--beam direction. Strong variations of the W helicity compositions are clearly seen, and the results are in agreement with the Standard Model expectations.

Spin correlations of massive vector bosons have not been observed so far. Spin correlations between the W^+ and W^- produced in the reaction $e^+e^- \to W^+W^- \to l\nu q\bar{q}$ would mean that the helicity fractions measured with the leptonically decaying W bosons depend on the helicity of the hadronically decaying W. Another possible manifestation of WW spin correlations would show a non-uniform distribution of the angle between the W^+ and W^- decay planes. Combining all L3 data, WW spin correlations are seen with a significance of 3.6 standard deviations.

3. Search for Higgs bosons

The Higgs mechanism plays a central role in the unification of the electromagnetic and weak interactions by providing mass to the intermediate vector bosons, W and Z, without violating local gauge invariance. Within the Standard Model, the Higgs mechanism predicts a single neutral scalar particle, the Higgs boson. The mass of this boson, m_H, is not predicted by the theory. The experimental observation of the Higgs boson would be of great importance for the understanding of the spontaneous breaking of electroweak symmetry.

The L3 experiment has carried out the search for the Higgs boson at LEP in very large data samples collected at the Z resonance and at ever increasing centre-of-mass energies and luminosities greatly extending the Higgs mass range investigated. A fit that includes L3 electroweak precision measurements results in an upper limit on m_H of 133 GeV at the 95% confidence level. Previous L3 direct searches for the Standard Model Higgs boson excluded the mass range up to 107 GeV.

The Standard Model Higgs boson is produced at LEP mainly *via* the Higgs-strahlung process

$$e^+e^- \to Z^* \to HZ. \quad (7)$$

The processes of W^+W^- and ZZ fusion contribute, with smaller rate, to the Higgs production in the $H\nu\bar{\nu}$ and He^+e^- channels, respectively. The largest sources of background are four-fermion final states from W and Z pair production, as well as quark pair production $e^+e^- \to q\bar{q}(\gamma)$.

In the following, the final results of the Standard Model Higgs search performed on the data collected by L3 at a centre-of-mass energy, $\sqrt{s}$, up to 209 GeV are presented [4]. The search is based on the study of four distinct event topologies: $HZ \to q\bar{q}q\bar{q}$, $HZ \to q\bar{q}\nu\bar{\nu}$, $HZ \to q\bar{q}l^+l^-(l = e, \mu, \tau)$ and $HZ \to \tau^+\tau^-q\bar{q}$. With the exception of the $HZ \to \tau^+\tau^-q\bar{q}$ decay mode, all the analyses are optimized for the $H \to b\bar{b}$ decay. This mode represents about 80% of the Higgs branching fraction in the mass range of interest.

A lower limit on the mass of the Standard Model Higgs boson of 112.0 GeV is set at the 95% confidence level. An excess of events above background is found, which is compatible with a Standard Model Higgs boson of mass 114.5 GeV. High-weight events are seen in different decay channels – $q\bar{q}\nu\bar{\nu}$ and $q\bar{q}q\bar{q}$ – which are characteristic of Higgs production together with a Z boson. By combining all the search channels, the confidence level is computed for the data to be compatible with signal plus background or background only. For an assumed Higgs boson of this mass, the confidence level to be consistent with a background only hypothesis is calculated to be 0.09, equivalent to 1.7 standard deviations from the background expectation. The confidence level to be consistent with signal plus background is 0.62. These data from L3, together with those of other LEP experiments can be interpreted as the first observation of the Higgs boson.

In the Standard Model, the Higgs mechanism requires one doublet of complex scalar fields. The Minimal Supersymmetric Standard Model (MSSM) predicts the existence of two doublets of complex scalar fields, with a total of eight degrees of freedom. As in the Standard Model, three degrees of freedom appear as the longitudinal polarization states of the gauge bosons W^+, W^- and Z. The remaining five degrees of freedom are manifested in five physical scalar Higgs states. Under the assumption that Higgs sector of the MSSM conserves CP, the physical Higgs bosons are CP-even h and H, the CP-odd A, and the charged bosons H^+ and H^-. The quartic self-coupling of the Higgs fields is determined by the gauge couplings, which limits the mass of the lighter of the two CP-even Higgs bosons to be less than the mass of the Z at tree level. Radiative corrections, particularly from loops containing the top quark, allow the lightest Higgs boson mass to range up to approximately 135 GeV. This constraint on the mass of the h suggests that the h may be light enough to be produced at LEP.

The two most important production mechanisms of the Higgs bosons h and A are

$$e^+e^- \to Z^* \to hZ, \tag{8}$$

$$e^+e^- \to Z^* \to hA. \tag{9}$$

The cross section of the process (8) is smaller than that for the similar production of the Higgs boson in the Standard Model. This process is dominant at low values of $\tan\beta$ ($\tan\beta < 5$), where $\tan\beta$ is the ratio of the two Higgs vacuum expectation values. The pair production of Higgs bosons (9) takes over at high values of $\tan\beta$.

The L3 collaboration performed a search for the Higgs bosons h and A using data collected in the year 2000 at centre-of-mass energies 200–209 GeV [5]. For the hA production, the search is based on the study of the following decay modes: $hA \to b\bar{b}b\bar{b}$, $hA \to b\bar{b}\tau^+\tau^-$ and $hA \to \tau^+\tau^-b\bar{b}$. In the case of hZ, four event topologies covering approximately 98% of possible final states, are considered: $q\bar{q}q\bar{q}$, $q\bar{q}\nu\bar{\nu}$, $q\bar{q}l^+l^-$ ($l = \mathrm{e}, \mu, \tau$) and $\tau^+\tau^-q\bar{q}$. The searches in channels with hadronic decays of the h boson are optimized for the dominant $h \to b\bar{b}$ decay channel. No signal is observed and lower mass limits are obtained as a function of $\tan\beta$. For $\tan\beta > 0.8$ they are $m_h > 83.2$ GeV and $m_A > 83.9$ GeV at the 95% confidence level.

A search for pair-produced charged Higgs bosons

$$e^+e^- \to H^+H^- \tag{10}$$

is performed in the three decay channels: $H^+H^- \to \tau^+\nu_\tau\tau^-\bar{\nu}_\tau$, $H^+H^- \to c\bar{s}\tau^-\bar{\nu}_\tau$ and $H^+H^- \to c\bar{s}\bar{c}s$. An excess of events in the $H^+H^- \to c\bar{s}\bar{c}s$ and $c\bar{s}\tau^-\bar{\nu}_\tau$ channels is observed in the mass region around 68 GeV, which is most significant at low values of the $H^\pm \to \tau\nu$ branching ratio. Including data taken at lower centre-of-mass energies, the excess is compatible with a 4.2σ fluctuation in the background. Interpreting this excess as a statistical fluctuation in the background, lower limits on the charged Higgs mass are derived at the 95% confidence level. They vary from 66.9 to 82.7 GeV as a function of the $H^\pm \to \tau\nu$ branching ratio.

4. Study of resonance production in two-photon collisions

Electron-positron colliders are a good laboratory to investigate the behaviour of two-photon interactions *via* the process

$$e^+e^- \to e^+e^-\gamma^*\gamma^* \to e^+e^-X, \tag{11}$$

where γ^* is a virtual photon. The outgoing electron and positron carry nearly the full beam energy, and their transverse momenta are usually so small that they are not detected. This kind of events is characterized by an initial state $e^+e^-\gamma^*\gamma^*$, calculable by QED, and a low multiplicity final state. Process (11) is particularly useful in the study of the properties of hadron resonances.

The cross section for the formation of a resonance R is proportional to the two-photon partial width $\Gamma_{\gamma\gamma}(R)$ of the resonance:

$$\sigma(e^+e^- \to e^+e^-R) = K \cdot \Gamma_{\gamma\gamma}(R). \tag{12}$$

The proportionality factor K can be evaluated by a Monte Carlo calculation. The quantum numbers of the resonance R must be compatible with the initial state of the two virtual photons. A neutral, unflavoured meson with even charge conjugation and helicity zero ($\lambda = 0$) or two ($\lambda = 2$) can be formed. The two-photon width, $\Gamma_{\gamma\gamma}(R)$, is related to the flavour content of $q\bar{q}$ states. The measurement of form factors provides an important information about the wave function of the quarks inside the meson. Small values of $\Gamma_{\gamma\gamma}(R)$ are indication for the presence of a glueball or hybrid components in the state.

An extensive study of the formation of hadron resonances and of their properties is carried out by the L3 collaboration. The PNPI group takes an active part in these investigations. In the following, the main results of the analysis of $K^0_sK^\pm\pi^\mp$, $\eta\pi^+\pi^-$, $K^0_sK^0_s$ and $\pi^+\pi^-\pi^+\pi^-$ final states are presented. The analysis is performed using data collected at centre-of-mass energies from 183 GeV up to 209 GeV for an integrated luminosity of 665 pb^{-1}.

The mass region between 1200 MeV and 1500 MeV is expected to contain several resonance states. For the pseudoscalar sector ($J^{PC} = 0^{-+}$), the $\eta(1440)$ meson was observed in hadron collisions and in radiative J decay, but not in two-photon collisions, and only upper limits of its two-photon width of the order of 1 keV existed. Therefore, the $\eta(1440)$ may be interpreted as a prominent glueball candidate due to its strong production in a gluon-rich environment. There are, possibly, two pseudoscalars in the 1440 MeV mass region: one at lower mass, η_L, which decays into $a_0\pi$ or directly into $\eta\pi\pi$, and another at higher mass, η_H, decaying to K^*K. Axial vector mesons ($J^{PC} = 1^{++}$) are also present in the 1440 MeV mass region. The $f_1(1420)$ was observed in two-photon collisions in the $K\bar{K}\pi$ decay channel, and $f_1(1285)$ was seen in the $\eta\pi^+\pi^-$ decay channel.

In the analysis of $K^0_sK^\pm\pi^\mp$ and $\eta\pi^+\pi^-$ final states L3 collaboration [6] makes use of the dependence of the signal yield on the total transverse momentum $P_T^2 = (\sum \overrightarrow{p}_T)^2$, where the sum runs over all the observed particles. To a good approximation $P_T^2 = Q^2$, where Q^2 is the maximum virtuality of the two photons. For real photons ($Q^2 \simeq 0$), the production of a spin 0 state is allowed while that of a spin 1 state is suppressed. In contrast, for virtual photons ($Q^2 > 0$), the production of a spin 1 state is allowed while that of a spin 0 state diminishes. Such behaviour is described by effective

The pseudoscalar meson $\eta(1440)$ is observed (Fig. 3) for the first time in $\gamma\gamma$ collisions. The two-photon width of the $\eta(1440)$ is determined using only the events with $P_T^2 < 0.02$ GeV^2,

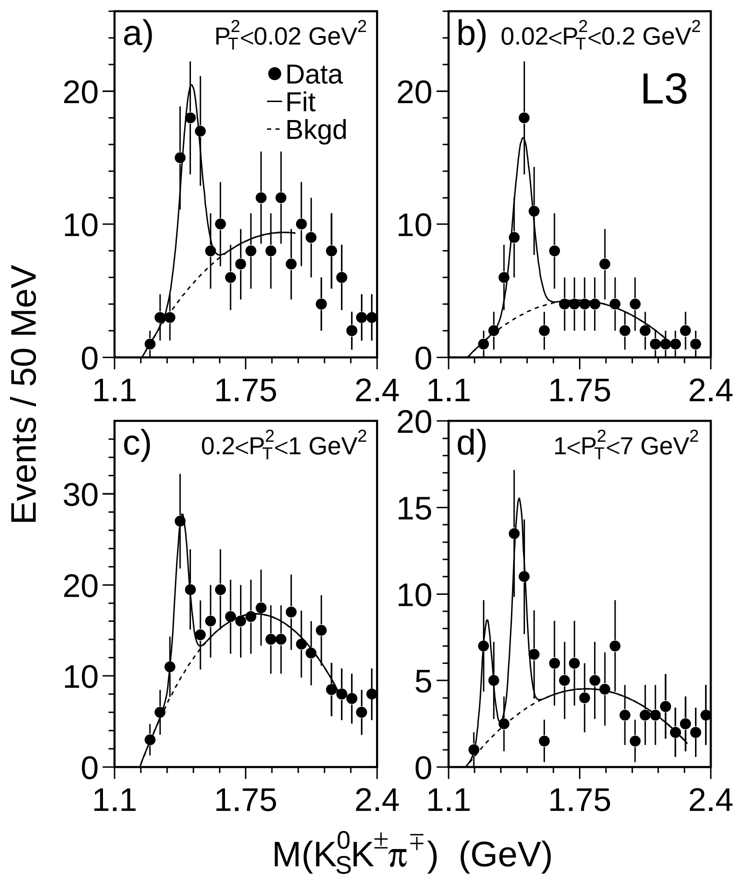

Fig. 3. The peak of the $\eta(1440)$ in $K_s^0K^{\pm}\pi^{\mp}$ spectra for different P_T^2 bins. The fits of a Gaussian plus polynomial background are superimposed on the data. In the highest P_T^2 bin, also the peak of the $f_1(1285)$ is present and the fit includes two Gaussians

shown in Fig. 3a. This cut selects events produced by quasi-real photons, dominated by the spin 0 state. Taking into account the corresponding branching ratio values, the two-photon width for the $K\bar{K}\pi$ decay channel is

$$\Gamma_{\gamma\gamma}(\eta(1440)) \cdot BR(\eta(1440) \to K\bar{K}\pi) = 212 \pm 50(\text{stat}) \pm 23(\text{syst})\ \text{eV}. \tag{13}$$

The mass and width of the $\eta(1440)$ as well as the observation of a dominant $K^*(892)K$ decay are compatible with the characteristics of the η_H. The measured two-photon width is consistent with the value expected for a first radial excitation of the pseudoscalar nonet. At the same time, tests designed to establish the gluon content of a resonance point to a strong gluonium admixture.

No positive signal is observed for the η_L state, either in the $K_s^0K^{\pm}\pi^{\mp}$ channel, where there is no clear evidence for an $a_0(980)\pi$ decay, or in the $\eta\pi^+\pi^-$ channel. Upper limits for the two-photon width of the $\eta(1440)$ and the $\eta(1295)$ in the decay channel $\eta\pi^+\pi^-$ are determined.

The high Q^2 events show clear evidence for the formation of the axial vector mesons $f_1(1420)$ in the decay channel $K_s^0K^{\pm}\pi^{\mp}$ and for the formation of $f_1(1285)$ in both $K_s^0K^{\pm}\pi^{\mp}$ and $\eta\pi^+\pi^-$ channels.

In the decay channel $\eta\pi^+\pi^-$ the differential cross section of the $f_1(1285)$ production is measured as a function of Q^2 and compared to different form factor models. The gamma-gamma coupling parameter is precisely determined for the first time:

$$\tilde{\Gamma}_{\gamma\gamma} = 3.3 \pm 0.6(\text{stat}) \pm 1.1(\text{syst})\ \text{keV}. \tag{14}$$

In order to decay into $K_s^0 K_s^0$, a resonance must have $J^{PC} = (\text{even})^{++}$. For the 2^{++}, 1^3P_2 tensor meson nonet, the $f_2(1270)$, the $a_2^0(1320)$ and the $f_2'(1525)$ can be formed. Gluonium states cannot be formed directly by the collision of two photons and the two-photon width of a glueball is expected to be very small. A state that is observed in a gluon-rich environment but not in two-photon fusion has the typical signature of a glueball.

The $K_s^0 K_s^0$ mass spectrum [7] is presented in Fig. 4 showing three distinct peaks over a low background. Despite their large two-photon widths, the $f_2(1270)$ and the $a_2^0(1320)$ tensor mesons produce a small signal in the $K_s^0 K_s^0$ final state due to their destructive interference. The spectrum is dominated by the formation of the $f_2'(1525)$ tensor meson. A signal in the mass region of the $f_J(1710)$ is observed.

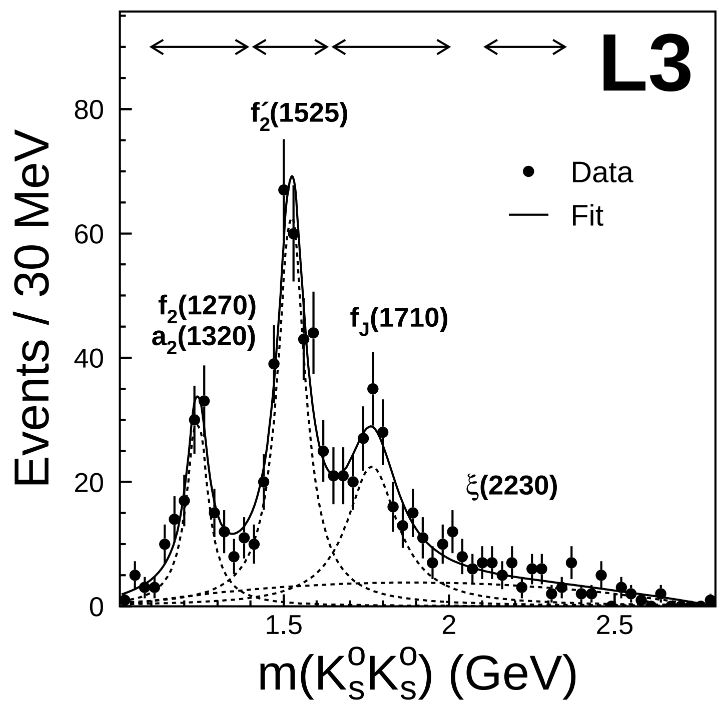

Fig. 4. The $K_s^0 K_s^0$ mass spectrum. The solid line corresponds to the maximum likelihood fit. The background is fitted by a second order polynomial and the three peaks by Breit-Wigner functions (dashed lines). The arrows correspond to the $f_2(1270)$–$a_2^0(1320)$, the $f_2'(1525)$, the $f_J(1710)$ and the $\xi(2230)$ mass regions

To determine the spin and the helicity composition in the $f_2'(1525)$ mass region between 1400 and 1640 MeV, the experimental polar angle distribution is compared with the normalized Monte Carlo expectations for the $J = 0$; $J = 2$, $\lambda = 0$ and $J = 2$, $\lambda = 2$ states. The confidence levels for the $J = 0$ and $J = 2$, $\lambda = 0$ hypotheses are less than 10^{-6}. For the $J = 2$, $\lambda = 2$ hypothesis, a confidence level of 99.9% is obtained. The two-photon width times the branching ratio into $K\bar{K}$ is determined from the cross section under the hypothesis of a pure $J = 2$, $\lambda = 2$ state:

$$\Gamma_{\gamma\gamma}(f_2'(1525)) \cdot BR(f_2'(1525) \to K\bar{K}) = 76 \pm 6(\text{stat}) \pm 11(\text{syst})\ \text{eV}. \tag{15}$$

The spin-two helicity-two state is found dominant in the mass region around 1750 MeV. No signal is observed in the mass region of the $\xi(2230)$. The upper limit of

$$\Gamma_{\gamma\gamma}(\xi(2230)) \cdot BR(\xi(2230) \to K_s^0 K_s^0) < 1.4\ \text{eV} \tag{16}$$

at the 95% confidence level supports the interpretation of the $\xi(2230)$ as the tensor glueball.

The process $\gamma\gamma \to \pi^+\pi^-\pi^+\pi^-$ is dominated by $\rho^0\rho^0$ production. A spin-parity analysis of the $\rho^0\rho^0$ system [8] for $W_{\gamma\gamma} < 3$ GeV shows a dominance of $J^P = 2^+$ and helicity 2. A contribution of $J^P = 0^+$ is also observed whereas contributions of negative parity states are found to be negligible. The $\pi^+\pi^-$ mass spectrum after subtraction of combinatorial background shows that for $W_{\gamma\gamma} > 3$ GeV there is still a strong production of ρ^0 meson but the $f_2(1270)$ meson is also seen.

Analysis of the LEP data is not yet completed. PNPI group will continue the study of exclusive multihadronic final states in two-photon interactions, especially with high masses, in the search for resonances with hidden charm and beauty quarks.

References

[1] A.A.Vorobyov, A.G.Krivchitch, and V.A.Schegelsky, PNPI Main Scientific Activities 1971–1996, Gatchina, 1998, p. 65.

[2] L3 Collaboration, L3 Note 2637, 2001, 18 p.

[3] L3 Collaboration, L3 Note 2638, 2001, 20 p.

[4] L3 Collaboration, Phys. Lett. **B517**, 319 (2001).

[5] L3 Collaboration, L3 Note 2692, 2001, 13 p.

[6] L3 Collaboration, Phys. Lett. **B501**, 1 (2001).

[7] L3 Collaboration, Phys. Lett. **B501**, 173 (2001).

[8] O.Fedin, Acta Physica Polonica **B31**, 2381 (2000).