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FORMATION OF LIGHT RESONANCES IN $K^0_S K^{\pm}\pi^{\mp}$ AND $\eta\pi^+\pi^-$ CHANNELS IN $\gamma\gamma$ COLLISIONS AT LEP*

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The $K^0_S K^{\pm}\pi^{\mp}$ and $\eta\pi^+\pi^-$ final states in two-photon collisions are studied with the L3 detector at LEP using data collected at centre of mass energies from 183 to 202 GeV. The mass spectrum of the $K^0_S K^{\pm}\pi^{\mp}$ final state shows an enhancement around 1470 MeV, which is identified with the pseudoscalar $\eta\,(1440)$. This state is observed in the $\gamma\gamma$ collisions for the first time and the value of its two-photon width is obtained. In the $\eta\pi^+\pi^-$ channel only the $f_1(1285)$ is observed, upper limits for the formation of $\eta\,(1440)$ and $\eta\,(1295)$ are given.

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1. Introduction

Resonance formation in two-photon interactions offers a clean environment to study the spectrum of hadronic final states. In this paper we study the reaction $\gamma\gamma \to K^0_S K^{\pm}\pi^{\mp}$ and $\gamma\gamma \to \eta\,\pi^+\pi^-$ using data collected by the L3 detector at LEP at $\sqrt{s} = 183$–202 GeV for a total integrated luminosity of 449 pb^{-1}.

The mass region between 1200 MeV and 1600 MeV is expected to contain several resonances [1]. Two are pseudoscalars ($J^{PC} = 0^{-+}$)$\eta\,(1440)$ and $\eta\,(1295)$, and three are axial vector mesons ($J^{PC} = 1^{++}$) $f_1(1285)$, $f_1(1420)$ and $f_1(1510)$. At present most of measurements were performed in hadron collisions and by studying the radiative decay of the J/ψ. In two-photon collisions only the $f_1(1285)$ [2,3] and $f_1(1420)$ [3,4] were observed in tagged events. For the $\eta\,(1440)$ and $\eta\,(1295)$ upper limits for their two-photon width were given [4,5]. The $\eta\,(1440)$ was therefore considered a glueball candidate.

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2. The $K^0_S K^{\pm}\pi^{\mp}$ channel

Events are selected by requiring four tracks in the L3 central tracker associated to two vertices: $K^{\pm}\pi^{\mp}$, associated to the primary vertex, and a K^0_S decaying into $\pi^+\pi^-$ at a secondary vertex. Candidates for $K^0_S K^0_S$ events and events with photons are excluded. The dE/dx measurement is used for particle identification. This selection results in the $K^0_S\ K^{\pm}\pi^{\mp}$ mass spectrum shown in Fig. 1. The fit of a Gaussian signal over a polynomial background gives the parameters: $M = 1473 \pm 8$ MeV and $\sigma = 46 \pm 7$ MeV, consistent with $\eta(1440)$ and $f_1(1420)$ [1].

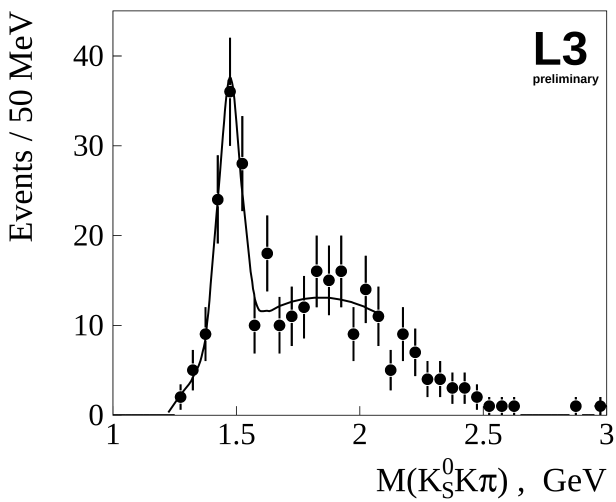

Fig. 1. The $K^0_S K^{\pm}\pi^{\mp}$ mass spectrum for $P^2_T < 0.2\text{GeV}^2$. The total number of events is 290. A Gaussian fit of the peak gives: (66±11) events, $M = 1473 \pm 8$ MeV and $\sigma = 46 \pm 7$ MeV.

TABLE I

Peak parameters for the P^2_T bins given in Fig. 2

subfigure	P^2_T, GeV^2			N_{EVENT}	M, MeV	σ, MeV
a	0	–	0.02	37 ± 9	1481 ± 12	48 ± 9
b	0.02	–	0.2	28 ± 7	1473 ± 11	37 ± 8
c	0.2	–	1	29 ± 9	1435 ± 10	32 ± 10
d	1	–	7	21 ± 6	1452 ± 11	35 ± 10
d	1	–	7	10 ± 4	1290 ± 12	29 ± 10

Spin-zero production is suppressed when a photon has a high virtuality, high four-momentum transfer squared Q^2, contrary to spin-one production, suppressed at low Q^2. Therefore we analyse the Q^2 dependence of the peak yield. The maximum Q^2 of the two virtual photons is close to the total transverse momentum of the event, $P_{\rm T}^2 = (\sum \overrightarrow{p_{\rm T}})^2$. Fig. 2 presents the $K_{\rm S}^0 K^{\pm}\pi^{\mp}$ spectra for different $P_{\rm T}^2$ ranges. The peak parameters obtained by the fit are given in the Table I.

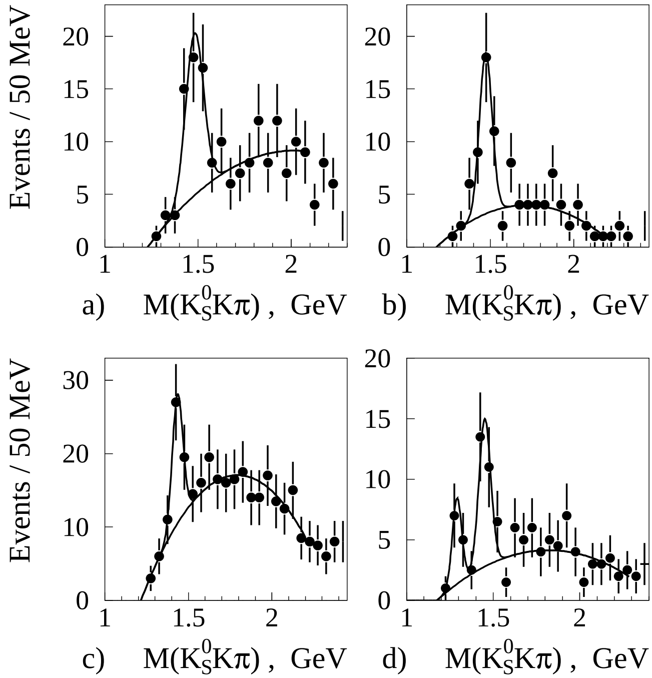

Fig. 2. $K_{\rm S}^0 K^{\pm}\pi^{\mp}$ spectra for four $P_{\rm T}^2$ ranges: (a) 0–0.02 GeV^2, (b) 0.02–0.2 GeV^2, (c) 0.2–1 GeV ^{2} and d) 1–7 GeV ^{2}. In the last $P_{\rm T}^2$ bin the $f_1(1420)$ peak is also seen.

The differential cross section $d\sigma/dP_{\rm T}^2$ (Fig. 3) is analysed using simulation for the pseudoscalar and the axial vector meson production. The Monte Carlo program GaGaRes [6] is used to reproduce all Q^2 dependences of resonance production. When comparing $d\sigma/dP_{\rm T}^2$ with Monte Carlo a compatibility test gives a confidence level CL$<10^{-4}$ for pure $J^P = 0^-$ ($\eta\,(1440)$) or pure $J^P = 1^+$ ($f_1(1420)$) hypotheses. Fitting a combination of $J^P = 0^-$ and $J^P = 1^+$ waves to the data (with a free normalisation) one gets CL$=$ 30%. Thus both waves are required to reproduce the data. The numbers of events for the spin-zero and spin-one components, estimated by the fit, are 68$\pm$10 and 49$\pm$9 respectively.

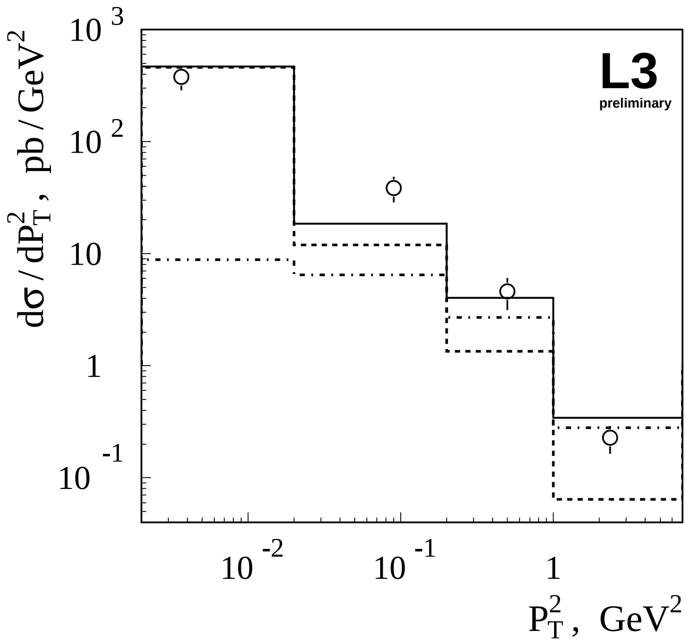

Fig. 3. Differential cross sections $d\sigma/dP_{\rm T}^2$ as function of $P_{\rm T}^2$ for the peak observed in the $K_{\rm S}^0 K^{\pm}\pi^{\mp}$ channel. The data are indicated by points with error bars. The solid line is the sum of spin-zero and spin-one simulations fitted to data. The pseudoscalar (dashed line) and the axial vector (dashed-dotted line) contributions are also shown.

The two–photon width of the $\eta\,(1440)$ is evaluated for $P_{\rm T}^2 < 0.02$ GeV^2 (Fig. 2(a)). The Monte Carlo gives an efficiency $\varepsilon = 0.74\%$. The contribution of the spin-one component to this $P_{\rm T}^2$ bin is 2%. We obtain:

$$\Gamma_{\gamma\gamma}\,(\eta\,(1440))\,{\rm BR}(\eta\,(1440) \to K\bar{K}\pi) = (234 \pm 55_{\rm stat} \pm 17_{\rm syst})\ {\rm eV}\,.$$

This value is in agreement with the upper limit of 1.2 keV reported by the CELLO Collaboration [4]. (The branching ratio BR for decay $\eta\,(1440) \to K\bar{K}\pi$ is not known.)

3. The $\eta\pi^+\pi^-$ channel

This channel is selected by taking into account only the events with two charged particles and two photons. A kinematical constraint fit for the η mass is used.

Fig. 4 shows the $\eta\pi^+\pi^-$ invariant mass spectra for different $P_{\rm T}^2$ ranges. The spectra are dominated by the $\eta'(958)$ resonance. For high $P_{\rm T}^2$ (Fig. 4(c))

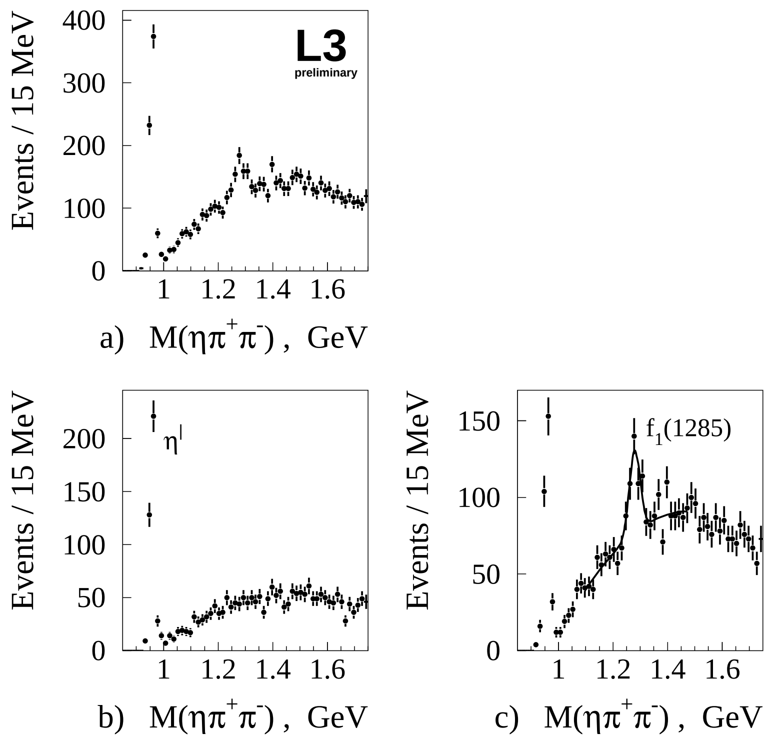

Fig. 4. $\eta\pi^+\pi^-$ mass spectrum for different $P_{\rm T}^2$ ranges: (a) total spectrum, (b) $P_{\rm T}^2 < 0.02$ GeV^2 and (c) $P_{\rm T}^2 > 0.02$ GeV^2.

we observe a significant signal which we identify with the $f_1(1285)$. A Gaussian fit gives $M = 1280 \pm 4$ MeV and $\sigma = 20 \pm 3$ MeV. There is no peak in the region 1200–1500 MeV in the low $P_{\rm T}^2$ events (Fig. 4(b)). The efficiency is $\varepsilon = 2.0\%$ for these masses. The absence of a signal leads to upper limits:

$$\Gamma_{\gamma\gamma}(\eta\,(1440))\,{\rm BR}(\eta\,(1440) \to \eta\pi\pi) \;<\; 88 \text{ eV with CL} = 90\% \quad \text{and}$$
$$\Gamma_{\gamma\gamma}(\eta\,(1295))\,{\rm BR}(\eta\,(1295) \to \eta\pi\pi) \;<\; 61 \text{ eV with CL} = 90\%$$

These values are lower than the upper limit of 300 eV reported by the Crystal Ball Collaboration [5].

4. Conclusions

The pseudoscalar meson $\eta\,(1440)$ is observed for the first time in untagged $\gamma\gamma$ collisions in the $K_{\rm S}^0\,K^\pm\pi^\mp$ decay channel. The presence of both spin zero $\eta\,(1440)$ and spin one $f_1(1420)$ components is required by the $d\sigma/dP_{\rm T}^2$ distribution. For $\eta\,(1440)$ the two-photon width times Branching Ratio is determined.

Neither $\eta\,(1440)$ nor $\eta\,(1295)$ are observed in the decay channel $\eta\,\pi^+\pi^-$. The upper limits for their two–photon widths are determined.

The $f_1(1285)$ is observed in both $K^0_{\rm S}\,K^{\pm}\pi^{\mp}$ and $\eta\pi^+\pi^-$ channels. For the $K^0_{\rm S}\,K^{\pm}\pi^{\mp}$ channel it is the first observation in $\gamma\gamma$ collisions.

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REFERENCES

[1] Particle Data Group, C. Caso *et al.*, *Eur. J. Phys.* **C3**, 1 (1998).

[2] Mark II collaboration, G. Gidal *et al.*, *Phys. Rev. Lett.* **59**, 2012 (1987); *Phys. Rev. Lett.* **59**, 2016 (1987).

[3] TPC-2γ collaboration, H. Aihara *et al.*, *Phys. Rev.* **D38**, 1 (1988); *Phys. Lett.* **B 209**, 107 (1988).

[4] CELLO collaboration, H.J. Behrend *et al.*, *Z. Phys.* **C42**, 367 (1989).

[5] Crystal Ball collaboration, D. Antreasyan *et al.*, *Phys. Rev.* **D36**, 2633 (1987).

[6] R. van Gulik, *Nucl. Phys.* **B82** (Proc. Suppl.), 311 (2000); G.A. Schuler, F.A. Berends, R. van Gulik, *Nucl. Phys.* **B523**, 423 (1998).