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Study of the reaction $\pi^- p \to \omega\omega n$ at $p_{\pi^-} = 36$ GeV/c.

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Abstract

Bityukov S.I. et al. Study of the reaction $\pi^- p \to \omega\omega n$ at $p_{\pi^-} = 36$ GeV/c.: IHEP Preprint 91-156. — Protvino, 1991. — p. 8, figs. 3, tables 1, refs.: 4.

The $\omega\omega$ system produced in the reaction $\pi^- p \to \omega\omega n$ at $p_{\pi^-} = 36$ GeV/c has been studied at the IHEP VErtex Spectrometer (VES). PWA has been performed and characteristics of objects in the waves $J^{PC} = 2^{++}$ and 4^{++} have been determined.

Аннотация

Битюков С.И. и др. Изучение реакции $\pi^- p \to \omega\omega n$ при импульсе π^- = 36 Гэв/с. : Препринт ИФВЭ 91-156. — Протвино, 1991. — 8 с., 3 рис., 1 табл., библиогр.: 4.

Изучение системы $\omega\omega$, образующейся в реакции $\pi^- p \to \omega\omega n$, было проведено на широкоапертурном ВЕршинном Спектрометре ИФВЭ при импульсе $p_{\pi^-} = 36$ Гэв/с. Проведен PWA этой системы и определены характеристики объектов, наблюдаемых в волнах $J^{PC} = 2^{++}$ и 4^{++}.

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Introduction

The results of studying the $\omega\omega$-system produced in the charge exchange reaction $\pi^- p \to \omega\omega n$ at $p_{\pi^-} = 36$ GeV/c are presented.

The $\omega\omega$ system was previously studied in the $\gamma\gamma$-interactions [1], the J/ψ radiative decays (the review in [2]) and the charge exchange reaction $\pi^- p \to \omega\omega n$ [3]. In all this reactions the enhancements have been observed near the $\omega\omega$ threshold.

In particular, in the experiment of GAMS collaboration [3] two structures having $J^{PC} = 2^{++}$ with masses $\sim$ 1640 and 1920 MeV and a broad enhancement with $J^{PC} = 4^{++}$ and mass $\sim$ 2050 MeV have been observed, where the last object is interpreted as the signal from the $f_4(2050)$-meson. In this experiment the ω-mesons were detected in $\omega \to \pi^0\gamma$ mode.

The new study of the reaction $\pi^- p \to \omega\omega n$ presented here has been performed at the VErtex Spectrometer (VES) of IHEP, but the ω-s were identified through their decay into the $\pi^+\pi^-\pi^0$, other than through the $\pi^0\gamma$. This made it possible to have somewhat higher statistics with the better background conditions.

The main elements of the VES setup are a large aperture magnet spectrometer, a multicell lead-glass electromagnetic calorimeter and an active target of organic scintillator surrounded by a veto system. The details of the VES layout are published elsewhere [4].

Selection of the $\omega\omega$-system

The $\omega\omega$-system has been selected from the sample of events with 4 charged tracks and 4 γ in the final state using the following selection criteria:

- 2 negative and 2 positive charged particles are detected by the tracking system;
- at least 4 showers not associated with the charged tracks are detected in the γ-detector;
- the effective masses of two $\gamma\gamma$-pairs lie within the π^0 mass interval

$$104 < M_{\gamma\gamma} < 164\ MeV$$

- the total energy of the remaining clusters in the γ-detector not associated with the charged tracks, doesn't exceed 0.8 GeV;
- the total energy of 6 π-mesons lies withing the interval

$$33 < \sum \left(E^{ch} + E^{\gamma}\right) < 38\ GeV$$

- the effective masses of the two $\pi^+\pi^-\pi^0$ subsystems satisfy the following condition:

$$\sqrt{\left(M^{(1)}_{\pi^+\pi^-\pi^0} - M_\omega\right)^2 + \left(M^{(2)}_{\pi^+\pi^-\pi^0} - M_\omega\right)^2} < 36\ MeV.$$

To improve the resolution in the $M_{\pi^+\pi^-\pi^0}$, the constraint $M_{\gamma\gamma} = M_{\pi^0}$ was imposed on both $\gamma\gamma$ pairs (C-fit).

About 3500 events which satisfy all these cuts were retained for further processing. The quality of the $\omega\omega$-system selection is illustrated in fig.1a,b,c,d. The background in the $\omega\omega$ peak is $\sim 15\%$.

Physical analysis

The $\omega\omega$ mass spectrum after the background subtraction is presented in fig.2b. The peaks in the region 1.6 and 1.9 GeV are clearly seen. The t-distributions for events from these two regions (fig.2c,d) give evidence for OPE dominance in the production of these objects.

The efficiency of the $\omega\omega$-system detection was Monte-Carlo calculated, using experimental t-distribution. It is about 40% over the whole mass range.

The amplitudes for the $\omega\omega$-system states were constructed using Zemach tensor formalism. In our analysis only the waves with zero ($M = 0$) spin J projection onto the Gottfried-Jackson axis were taken into account, because we assume OPE in the production of these objects. The symmetry of the $\omega\omega$-system sets additional restrictions, so only the states with $J^{PC} = 0^{++}, 2^{++}, 4^{++}, 6^{++}, \ldots$ are possible.

The set of waves with $J \leq 4$ includes:

- 2 waves 0^{++} (0^{++}S0, 0^{++}D2);
- 4 waves 2^{++} (2^{++}S2 , 2^{++}D0 , 2^{++}D2 , 2^{++}G2),
- 3 waves 4^{++} (4^{++}D2 ,4^{++}G0 ,4^{++}G2),
- FLAT — the wave representing the phase space for the $\omega\omega$-system, which doesn't interfere with any other wave.

We made the event by event fits with and without background subtraction, using the maximum likelyhood method with the likelyhood function chosen in the form

$$F = f_{\omega\omega} + W_b f_b, \qquad f = \sum_{n=1}^{N_{ev}} \ln\left(\sum_{i,j} \rho_{ij} \frac{A_{in}}{\sqrt{I_{ii}}} \frac{A^*_{jn}}{\sqrt{I_{jj}}}\right) - N_{ev} \sum_{i,j} \rho_{ij} \frac{I^{\varepsilon}_{ij}}{\sqrt{I_{ii}}\sqrt{I_{jj}}}.$$

where $f_{\omega\omega}$ is the function f calculated for the $\omega\omega$ events, and f_b is the same but for the background events; W_b is the weight of the background events, which is equal to $-1/3$ for the fit with the background subtraction and 0 — without the background subtraction. The background events are those satisfying the condition

$$36 < \sqrt{\left(M^{(1)}_{\pi^+\pi^-\pi^0} - M_\omega\right)^2 + \left(M^{(2)}_{\pi^+\pi^-\pi^0} - M_\omega\right)^2} < 72\ MeV.$$

The matrix ρ_{ij} is hermitian positive definite density matrix, A_{in} is an amplitude of the wave i for n-th event, I_{ij} is an integral of $A_i \cdot A^*_j$ over the phase space (the superscript ε means the geometrical efficiency account).

The main difference between these two fits is the sufficient FLAT wave decrease in the case of the background subtraction. There were no significant changes in other waves when compared with the fit without background subtraction, but the fit convergency is worse. The PWA for the background events themselves has been made and no significant signals have been detected in the waves other than the FLAT.

In the final fit we have used only significant waves. The waves $2^{++}S2$ and $4^{++}D2$ and their relative phase are presented in fig.3

Results

The two peaks in the wave $2^{++}S2$ are clearly seen. Their parameters have been determined by fitting the distributions with Breit-Wigner function. These parameters are given in table 1. The parameters of the peak

Table 1. Resonance parameters.

$J^{PC}ls$	Mass (GeV)	Width (GeV)
$2^{++}S2$	1.59 ± 0.03	0.10 ± 0.02
	1.92 ± 0.01	0.09 ± 0.02
$4^{++}D2$		
one resonance	1.97 ± 0.03	0.30 ± 0.05
$4^{++}D2$		
two resonances	1.88 ± 0.02	0.07 ± 0.04
	2.04 ± 0.04	0.24 ± 0.06

near the $\omega\omega$ threshold seems to be rather dependent on the form of Breit-Wigner parametrization used. This leads to the large systematic errors as shown in table 1.

The results are very similar to those of GAMS collaboration [3]. Some difference in the mass of the lightest tensor state should be mentioned.

One should notice that our method of analysis is sufficiently different from that of [3], where the quantum numbers of the X(1640) were extracted from its production cross section in the charge exchange reaction.

The object with the mass $m = 1.59$ GeV that we see, has no natural place among the $q\bar{q}$ mesons. It can be considered as the molecule of the two ω-mesons. In this model one can understand why its mass is so close to the $\omega\omega$ threshold and why the probability of its decay into the $\omega\omega$ channel is large.

The object X(1920) seen in the wave $2^{++}S2$, may be interpreted as the usual $q\bar{q}$-meson, because the three tensor mesons are expected in this mass interval — $f_2(2P), f_2'(2P), f_2(1F)$.

The broad enhancement in the $4^{++}D2$ wave can contain more than one peak. The results of fitting this spectrum by one and two non-interfering resonances are given in table 1. In the last case the right peak has the same parameters as $f_4(2050)$ meson. The variation of the relative phase in fig.3b in the mass region $1.8 < M_{\omega\omega} < 1.9$ GeV, which is in agreement with that expected for two relatively narrow resonances in $2^{++}S2$ and $4^{++}D2$ waves, can also testify to the two resonances in the $4^{++}D2$ wave hypothesis. Nevertheless, at a given statistics we cannot give preference to any of these models.

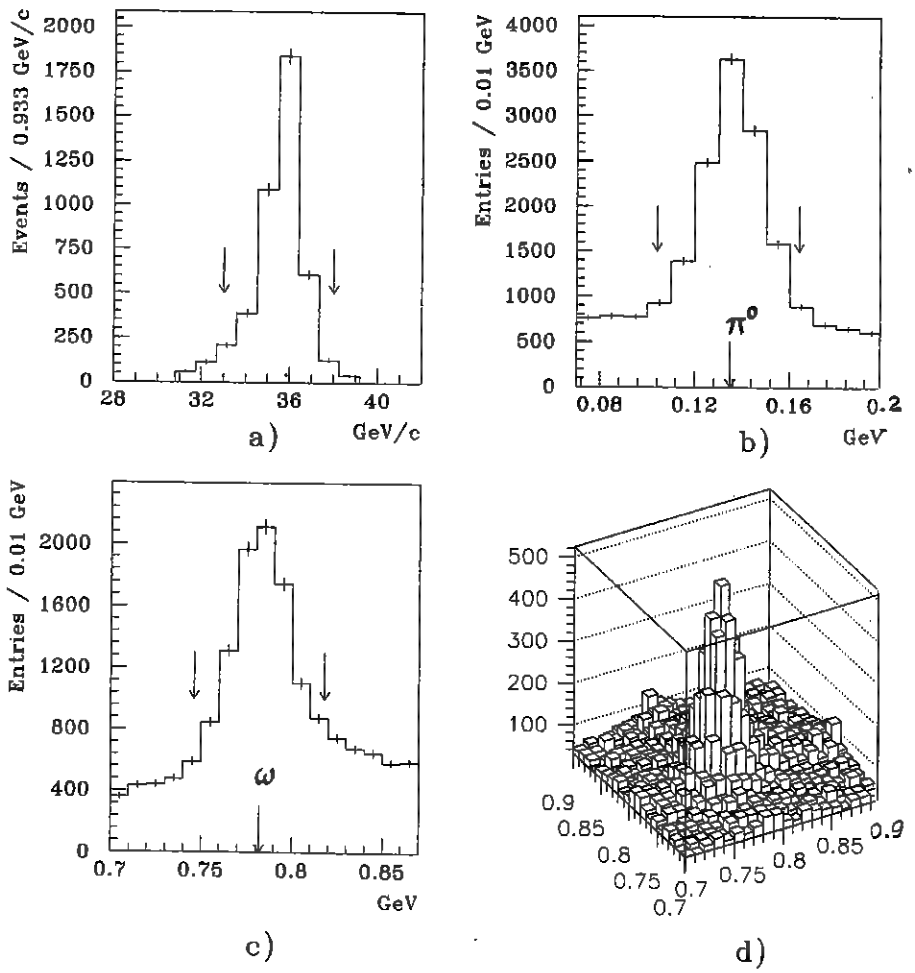

Figure 1. $\omega\omega$ system selection: a) Total momentum of 6 π-mesons; b) Effective mass of $\gamma\gamma$-pair; c) Effective mass of $\pi^+\pi^-\pi^0$; d) $M_{3\pi}$–$M_{3\pi}$ biplot.

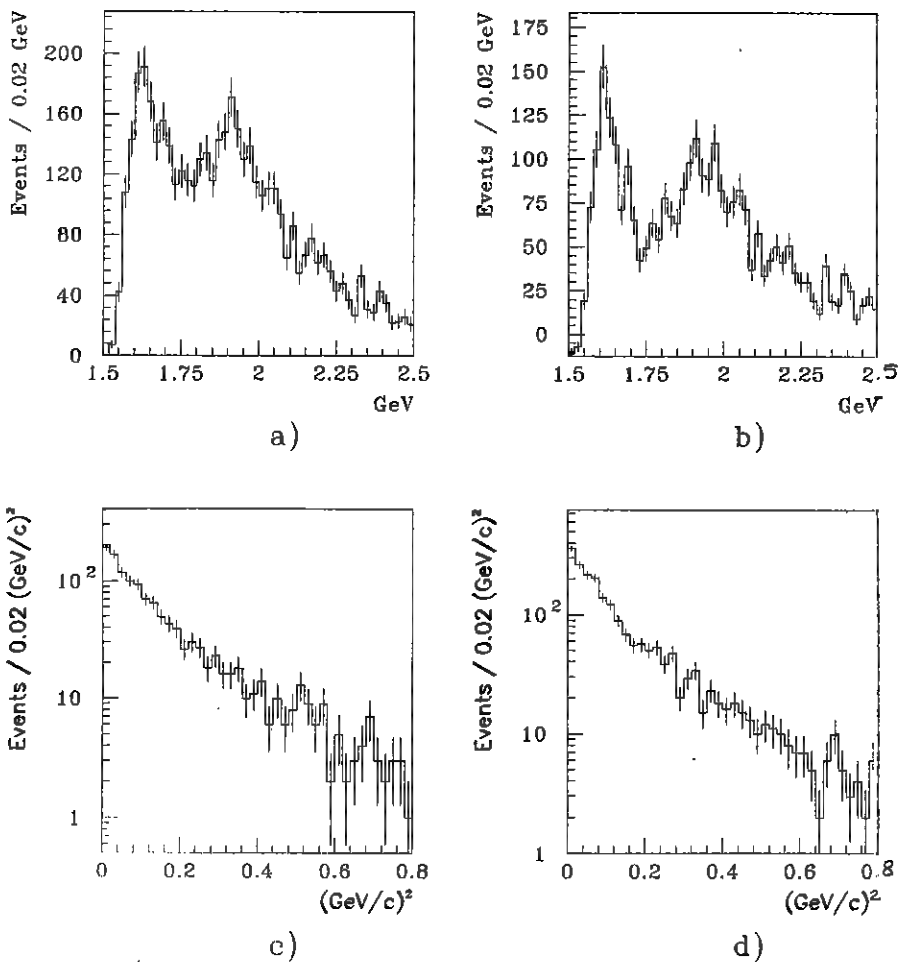

Figure 2. $\omega\omega$ distributions: a) $\omega\omega$ mass spectrum; b) $\omega\omega$ mass spectrum with subtracted background; c),d) trasfer momentum squared distributions for 1.6 and 1.9 GeV regions.

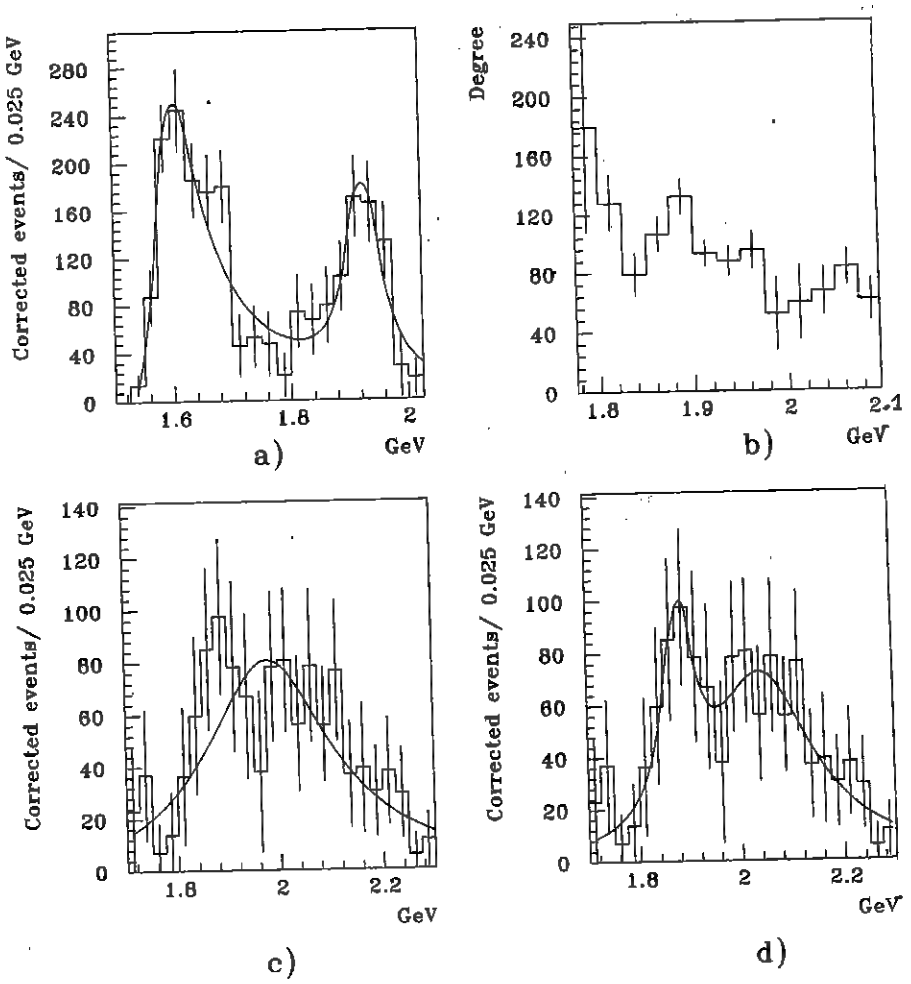

Figure 3. $\omega\omega$ waves: a) $2^{++}S2$ wave; b) relative phase of the two waves; c),d) $4^{++}D2$ wave fitted with one and two noninterfering Breit-Wigners.

Conclusions

The $\omega\omega$ system produced in the reaction $\pi^- p \to \omega\omega n$ at $p_{\pi^-} =$ 36 GeV/c has been studied at the VErtex Spectrometer. The Partial Wave Analysis of the $\omega\omega$ system has been performed. The two objects with $J^{PC} = 2^{++}$ and masses $\sim$ 1.59 and 1.92 GeV and a broad enhancement with $J^{PC} = 4^{++}$ and mass $\sim$ 2 GeV have been observed. The lightest tensor meson is considered to be non-$q\bar{q}$ candidate, while the other may be some excitation of one of the known mesons. The object with $J^{PC} = 4^{++}$ is probably the signal from the $f_4(2050)$ meson.

In conclusion we want to thank Yu.D. Prokoshkin for useful discussions.

References

[1] Phys.Lett. 198B (1987) 577

[2] L. Köpke and N. Wermes, CERN-EP/88-93, August 1988.

[3] D. Alde et al., Phys.Lett. B205, 451 (1988),
D. Alde et al., Phys.Lett. B241, 600 (1990).

[4] S.I.Bityukov et al, Preprint IHEP 91-26.

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