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Study of the reaction $\pi^- p \to \eta'\eta' n$.

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Abstract

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The reaction $\pi^- p \to \eta'\eta' n$ has been studied at $p_{\pi^-} = 37\ GeV/c$. Total of 14 events of this reaction have been selected. It has been shown that in the effective mass spectrum of the $\eta'\eta'$ system the events are concentrated mainly near the reaction threshold, which might be caused by the decay $X(1910) \to \eta'\eta'$. The reaction cross-section has been evaluated: $\sigma(\pi^- p \to \eta'\eta' n) = 110 \pm 40\ nb$.

Аннотация

Бердников Е.Б. и др. Изучение реакции $\pi^- p \to \eta'\eta' n$.: Препринт ИФВЭ 92-62. — Протвино, 1992. — 6 с., 3 рис., библиогр.: 9.

Изучена реакция $\pi^- p \to \eta'\eta' n$ при $p_{\pi^-} = 37\ ГэВ/c$. Выделено 14 событий данной реакции. Показано, что спектр эффективных масс $\eta'\eta'$ имеет ярко выраженную концентрацию событий у порога реакции, что может быть обусловлено распадом $X(1910) \to \eta'\eta'$. Получена оценка сечения реакции: $\sigma(\pi^- p \to \eta'\eta' n) = 110 \pm 40\ нб$.

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1. Introduction.

The observation of a peak in the $\eta'\eta$ mass spectrum of the reaction $\pi^- p \to \eta'\eta n$ with $M = (1910 \pm 10)\ MeV$, $\Gamma = (90 \pm 35) MeV$ was reported in the recent articles by GAMS collaboration [1,2]. This object, named $X(1910)$, has some unusual properties — it is not seen in the decay channels of $\eta\eta$, $\pi\pi$, KK; it is observed in $\eta'\eta$ channel with small production cross-section and high momentum transfer squared. To explain these properties the hypothesis of exotic quantum numbers for $X(1910)$ $J^{PC} = 1^{-+}$ has been used in [2,4]; otherwise, in [5] this object has been considered within the framework of hybrid model, in which $X(1910)$ is considered to be the member of $J^{PC} = 0^{++}$ hybrid nonet, as well as $f_0(1590)$.

To clear up the nature of $X(1910)$ the study of its decay to $\eta'\eta'$ seems to be important, because in the first model with $J^{PC} = 1^{-+}$ this decay is forbidden, while in the latter one it must be significant.

2. Experimental results.

The reaction

$$\pi^- p \to \eta'\eta' n \tag{1}$$

has been studied at the VES setup of IHEP 70-GeV synchrotron at the incident beam momentum of $p_{\pi^-} = 37$ GeV/c. The setup is a large aperture magnetic spectrometer including proportional and drift chambers and a lead-glass electromagnetic calorimeter. The description of the VES setup is published in [7].

Reaction (1) has been studied in the mode when both η'-mesons decay into $\pi^+\pi^-\eta_{\hookrightarrow\gamma\gamma}$. The following criteria have been used for the selection of $\eta'\eta'$ in the final state:

- the event contains four charged tracks (two positive and two negative ones) and four gammas;
- the total energy of the final state lies within the interval of $32 < E_{tot} < 40\ GeV$;
- charged particles are not electrons (this can be determined using the energy deposition of the particle in the electromagnetic calorimeter);
- four gammas cannot be interpreted as $\pi^0\pi^0$, i.e. the event is rejected if the effective masses of both $\gamma\gamma$-pairs for some combination lie within the interval $105 < m_{\gamma\gamma} < 165\ MeV$;
- four gammas can be interpreted as $\eta\eta$, i.e. a combination exists in which the effective masses of both $\gamma\gamma$-pairs lie within the interval $480 < m_{\gamma\gamma} < 620\ MeV$. When calculating the momenta of η-mesons the constraint $m_{\gamma\gamma} = m_\eta$ has been imposed on each $\gamma\gamma$-pair (2C-fit).
- a combination exists for which the effective masses of both $\pi^+\pi^-\eta$ subsystems meet the following condition:

$$\sqrt{(M^{(1)}_{\pi^+\pi^-\eta} - M_{\eta'})^2 + (M^{(2)}_{\pi^+\pi^-\eta} - M_{\eta'})^2} < 25\ MeV. \qquad (2)$$

The effective mass distribution for $\pi^+\pi^-\eta$ subsystem under the condition that the effective mass of the remaining $\pi^+\pi^-\eta$ lies in the interval of η':

$$|M^{(2)}_{\pi^+\pi^-\eta} - M_{\eta'}| < 25MeV$$

is shown in fig.1a. The peak is seen at the mass of $M_{\pi^+\pi^-\eta} \simeq M_{\eta'}$ which corresponds to the $\eta'\eta'$ final state. The biplot of the effective masses for two subsystems $\pi^+\pi^-\eta$ is shown in fig.1b for all combinations of particles. There is a cluster of $\eta'\eta'$ events in the point of $(M_{\eta'}, M_{\eta'})$ which is well separated from the background. It testifies to the reliability of reaction (1) selection.

The background events are selected using the condition

$$35 < \sqrt{(M^{(1)}_{\pi^+\pi^-\eta} - M_{\eta'})^2 + (M^{(2)}_{\pi^+\pi^-\eta} - M_{\eta'})^2} < 43\ MeV; \qquad (3)$$

the limits are chosen so that the area of the $(M_{\pi^+\pi^-\eta}, M_{\pi^+\pi^-\eta})$ biplot defined by inequality (3) is equal to that defined by (2). In accordance with the aforementioned conditions 14 $\eta'\eta'$ events and 2 background events have been selected; in the further analysis the histograms for the background events are formally subtracted from the histograms for $\eta'\eta'$ events.

The effective mass distribution for $\eta'\eta'$ system is shown in fig.2a; the value (in arbitrary units) of the phase space for $\eta'\eta'$ system multiplied by the acceptance is shown by the dashed line in the same picture. It is worth mentioning that the

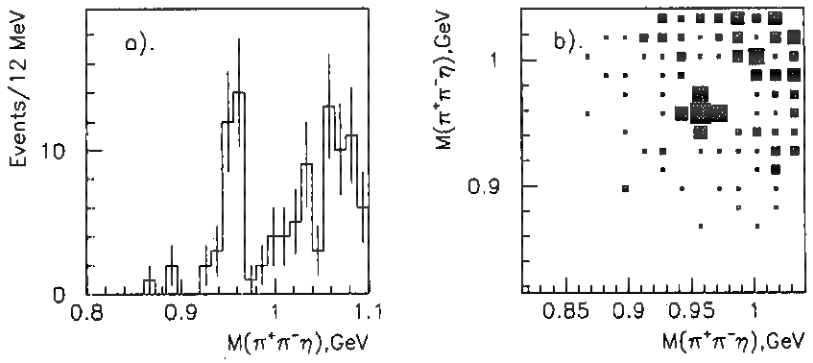

Figure 1. One-dimensional (a) and two-dimensional (b) distributions of the effective masses for $\pi^+\pi^-\eta$ subsystems.

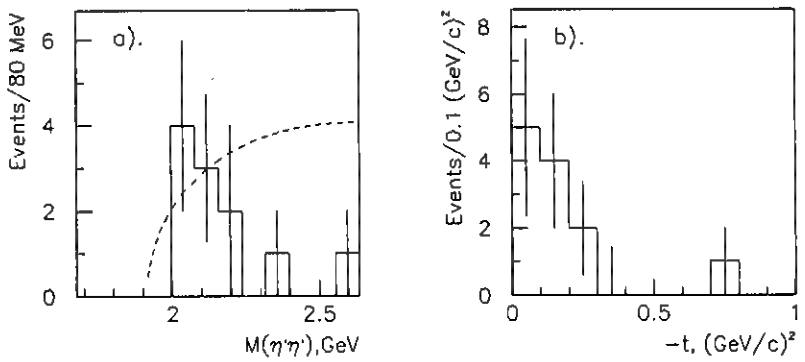

Figure 2. a). The effective mass distribution for $\eta'\eta'$ system; the dashed line is the curve of the $\eta'\eta'$ phase space multiplied by the acceptance; b). t-distribution for the events of the reaction $\pi^- p \to \eta'\eta' n$.

experimental events are concentrated near the reaction threshold rather than distributed according to the phase space curve.

The t-distribution of $\eta'\eta'$ events is shown in fig. 2b. The average value of $< t >= 0.23 \pm 0.08\ (GeV/c)^2$ is obtained, which corresponds to the slope parameter of $b = 4.5 \pm 1.5\ (GeV/c)^{-2}$. Thus, the t-distribution of $\eta'\eta'$ events is broader than that for the π-exchange.

3. Discussion.

The concentration of $\eta'\eta'$ events near the threshold and broad t-distribution allow us to suppose that the observed events are caused by the decay $X(1910) \to \eta'\eta'$. It casts doubt on the hypothesis that quantum numbers of $X(1910)$ are $J^{PC} = 1^{-+}$. Moreover, it is unlikely also that its quantum numbers are $J^{PC} = 2^{++}$, because the concentration of events near the reaction threshold might not be observed in this case due to centrifugal effect (suppression factor of $\sim (p^{c.m.}_{\eta'})^5$). Thus most probable quantum numbers of $X(1910)$ are $J^{PC} = 0^{++}$.

The cross-section of reaction (1) has been evaluated to be $110 \pm 40nb$, while in [2]

$$\sigma(\pi^- p \to X(1910)n) * BR(X(1910) \to \eta\eta') \simeq 15nb,$$

which gives evidence of much stronger coupling of $X(1910)$-meson to $\eta'\eta'$ channel than to $\eta'\eta$ (the cross-section has been calculated using the reaction $\pi^- p \to \omega\omega n$, which had been studied earlier in both GAMS [3] and VES [8] experiments).

In fig.3 one can see both $\eta'\eta'$ effective mass distribution from this work and $\eta'\eta$ mass spectrum from [2] in the region of $X(1910)$-meson (hatched histogram); y-scale is in nanobarns. Smooth curves show an example of combined description of these spectra in the coupled channels model [6] assuming that quantum numbers of $X(1910)$ are $J^{PC} = 0^{++}$ (the narrow resonance in $\eta'\eta$ mass spectrum is shown taking into account the GAMS setup mass resolution which is equal to 70 MeV (see [2]). The ratio of the coupling constants squared

$$\frac{|g[X(1910) \to \eta'\eta']|^2}{|g[X(1910) \to \eta'\eta]|^2} = 17$$

has been used in this description.

It should be noticed that experimentally observed hierarchy of the coupling constants for $X(1910)$

$$g^2(\eta'\eta') \gg g^2(\eta'\eta) \gg \begin{cases} g^2(\eta\eta) \\ g^2(\pi\pi) \\ g^2(KK) \end{cases}$$

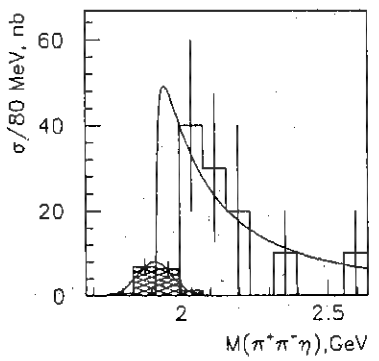

Figure 3. An example of the combined description of both $\eta'\eta'$ (this work) and $\eta'\eta$ ([2]) mass spectra in the coupled channels model.

cannot be explained in simple quark models (for example quark-line rules). On the other hand, such a hierarchy can get a natural explanation in the hybrid ([5]) or four-quark ([9]) model. This can be an indication of the exotic (non-$q\widetilde{q}$) nature of $X(1910)$-meson.

4. Conclusions.

Total of 14 events of reaction (1) have been selected. The concentration of the events near the reaction threshold is observed in the effective mass spectrum of $\eta'\eta'$. It might be explained by the decay $X(1910) \to \eta'\eta'$, assuming the quantum numbers of $X(1910)$ to be $J^{PC} = 0^{++}$. The cross-section of reaction (1) has been evaluated to be $110 \pm 40nb$, which is much higher than the value of $\sigma(\pi^- p \to Xn) * BR(X \to \eta\eta') \simeq 15nb$, obtained in [2]. This fact, when taking into account that $X(1910)$ is not observed in $\eta\eta$, $\pi\pi$, KK decay channels, might indicate the exotic nature of $X(1910)$-meson.

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