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OBSERVATION OF THE DECAY $a_2^-(1320) \to \pi^- \eta'$.

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Abstract

Bityukov S.I. et al. Observation of the decay $a_2^-(1320) \to \pi^-\eta'$: IHEP Preprint 91-95. — Protvino, 1991. — p. 7, figs. 8, refs.: 6.

The reaction $\pi^- C \to \pi^-\eta' C$ has been studied at 36 GeV/c. A clear signal for the decay $a_2^-(1320) \to \pi^-\eta'$ is observed in the $\pi^-\eta'$ mass spectrum. The measured ratio of branchings is $BR(a_2^- \to \pi^-\eta')/BR(a_2^- \to \pi^-\eta) = (3.4 \pm 0.8 \pm 0.5) \cdot 10^{-2}$.

Аннотация

Битюков С.И. и др. Наблюдение распада $a_2^-(1320) \to \pi^-\eta'$: Препринт ИФВЭ 91-95. — Протвино, 1991. — 7 с., 8 рис., библиогр.: 6.

Изучена реакция $\pi^- C \to \pi^-\eta' C$ на ядре углерода при импульсе пучка $p_\pi = 36$ *ГэВ/с*. В спектре масс $\pi^-\eta'$ выделен сигнал, отвечающий распаду $a_2^-(1320) \to \pi^-\eta'$. Найдено отношение вероятностей распадов $BR(a_2^- \to \pi^-\eta')/BR(a_2^- \to \pi^-\eta) = (3,4 \pm 0,8 \pm 0,5) \cdot 10^{-2}$.

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In this paper we report the results on the observation of the rare $a_2^-(1320)$-meson decay

$$a_2^- \to \pi^- \eta' \tag{1}$$

obtained from the data of the IHEP VES spectrometer analysis. This is the first observation of the decay $a_2 \to \pi\eta'$, the earlier searches being published in [1 ÷ 3]. The $a_2^-(1320)$-mesons were produced in the reaction $\pi^- C \to a_2^- C$ on carbon nuclei at the incident beam momentum of 36 GeV/c. The well-studied decay

$$a_2^- \to \pi^- \eta \tag{2}$$

has been used to determine the ratio of the branchings:

$$R = \frac{BR(a_2^- \to \pi^- \eta')}{BR(a_2^- \to \pi^- \eta)}, \tag{3}$$

which is interesting because of its substantional dependence on the pseudoscalar nonet mixing angle [4,5].

The VES setup is a wide aperture magnetic spectrometer which includes an active target with veto system, proportional and drift chambers, lead glass electromagnetic calorimeter and multicell Cerenkov counter. Details of the setup and run conditions are given in [6].

Decay modes $\eta' \to \pi^+\pi^-\eta \hookrightarrow \gamma\gamma$ and $\eta \to \pi^+\pi^-\pi^o \hookrightarrow \gamma\gamma$ have been used for the selection of processes (1) and (2), respectively. The simultaneous measurement of two decay channels with the same topology of the final state reduces systematic errors in the ratio R. Processes (1) and (2) have been selected from the sample of events with 3 tracks and 2 gammas in the final state. The $\gamma\gamma$ effective mass spectra are shown in figs.1a,b. The cuts $105 < m_{\gamma\gamma} < 165\ MeV$ and $480 < m_{\gamma\gamma} < 620\ MeV$ have been used for π^o and η selection. To improve $\pi^+\pi^-\gamma\gamma$ mass resolution the constraints $m_{\gamma\gamma} = m_{\pi^o}$ and $m_{\gamma\gamma} = m_\eta$ have been imposed. The effective mass spectra for $\pi^+\pi^-\pi^o$ and

$\pi^+\pi^-\eta$ are shown in figs.2a,b, where one can see η and η' peaks with the background of about 25%. For the final selection of processes (1) and (2) the cuts $938 < M_{\pi^+\pi^-\eta} < 978\ MeV$ and $529 < M_{\pi^+\pi^-\pi^o} < 569\ MeV$ have been used. These selection criteria have resulted in 1600 $\pi^-\eta'$ events and 9200 $\pi^-\eta$ events.

The $\pi^-\eta$ effective mass distribution is shown in fig.3a, where the peak with $a_2^-(1320)$-meson parameters is clearly seen. The angular distributions of π^--meson in the Gottfried-Jackson frame for a_2^- mass interval ($1270 < M_{\pi^-\eta} < 1370\ MeV$) are presented in figs.3b,c. They correspond to D_+ wave with $J^P = 2^+$ and positive exchange naturality ($|D_+(\theta,\phi)|^2 \sim cos^2\theta \cdot sin^2\theta \cdot sin^2\phi$). The number of $a_2^- \to \pi_-\eta$ events determined from a fit of the mass spectrum of fig.3a is $N(a_2^- \to \pi^-\eta) = 5810 \pm 32$.

In the $\pi_-\eta'$ mass spectrum (fig.4a) the peak in the $a_2^-(1320)$ mass region is seen with significant background corresponding to the nonresonant production of $\pi^-\eta'$ system. The angular distributions for the $a_2^-(1320)$-meson mass region shown in figs.4b,c demonstrate the presence of the same D_+-wave structure specific for $a_2^-(1320)$-meson.

For the nonresonant production of $\pi^-\eta'$ system, π^--meson is supposed to be leading and going in the forward direction mainly in the Gottfried-Jackson frame. As an example, the $cos\theta_{GJ}$ distribution for the mass interval $1520 < M_{\pi^-\eta'} < 1600 MeV$ (outside the a_2^- region) is shown in fig.5. Hence the background under a_2^--peak can be reduced by the selection of the events with the π^- going backward. The $\pi^-\eta'$ effective mass spectra for two selection criteria:

$$p_{\pi^-} < 7\ GeV, \tag{4a}$$

and

$$cos\theta_{GJ} < -0.2, \tag{4b}$$

are shown in figs.6a,b, respectively[1]. The a_2^--meson peak is clearly seen in both of these spectra. But nevertheless they cannot be used to determine the total number of $a_2^- \to \pi^-\eta'$ events, because the height of this peak is strongly influenced by the interference of resonant ($a_2^- \to \pi^-\eta'$) and nonresonant $\pi^-\eta'$ production processes in the defined by (4a) and (4b) regions of the phase space, the nonresonant production amplitude being unknown.

The most correct procedure to define the total number of $a_2^- \to \pi^-\eta'$ events would be the partial-wave analysis, but the number of $\pi^-\eta'$ events is insufficient for it. We have defined this number by fitting the overall $\pi^-\eta'$ mass spectrum.

[1]These mass spectra are obtained with the subtraction of the background under η'-meson, i.e. from the histogram for the events with $938 < m_{\pi^+\pi^-\eta} < 978\ MeV$ the histogram for the events with $908 < m_{\pi^+\pi^-\eta} < 928\ MeV$ or $988 < m_{\pi^+\pi^-\eta} < 1008\ MeV$ has been subtracted.

The geometrical acceptance of spectrometer is almost independent of the angles in Gottfried- Jackson frame (see fig.7), and the peak in this case is only affected by the interference with the D_+ component of the nonresonant production amplitude, which is supposed to be small in a_2^- mass region due to threshold suppression ($\sim p^{*5}$).

The part of the $\pi^-\eta'$ mass spectrum after the background subtraction is shown in fig.8. The background subtraction has been carried out as follows. The effective mass spectrum of $\pi^+\pi^-\eta$ system has been obtained for each $\pi^+\pi^-\pi^-\eta$ mass bin. The number of $\pi^-\eta'$ events in a given bin has been obtained by fitting the corresponding spectrum with the sum of Gaussian distribution for η'-meson and a polynomial for the background. The result of the fit of $\pi^-\eta'$ mass spectrum with Breit-Wigner function with a fixed width $\Gamma = 115\ MeV$, obtained from $\pi^-\eta$ mass spectrum fit, and polynomial background is shown in the same figure. The a_2^- peak contains $167 \pm 39(stat.) \pm 25(syst.)$ events. The systematic error is determined by the dependence of this number on the choice of background parametrisation and limits of histogram for fitting. After being corrected for detection efficiency of processes (1) and (2) and decay branchings of $\eta \to \pi^+\pi^-\pi^o$, $\eta' \to \pi^+\pi^-\eta$, $\eta \to \gamma\gamma$, we find the ratio of branchings to be

$$R = \frac{(a_2^- \to \pi^-\eta')}{BR(a_2^- \to \pi^-\eta)} = (3.4 \pm 0.8(stat.) \pm 0.5(syst.)) \cdot 10^{-2}. \qquad (5)$$

This value does not contradict the quark model predictions [4,5].

In conclusion, we express our thanks to Yu.D.Prokoshkin, S.S.Gershtein and G.L.Landsberg for useful discussions.

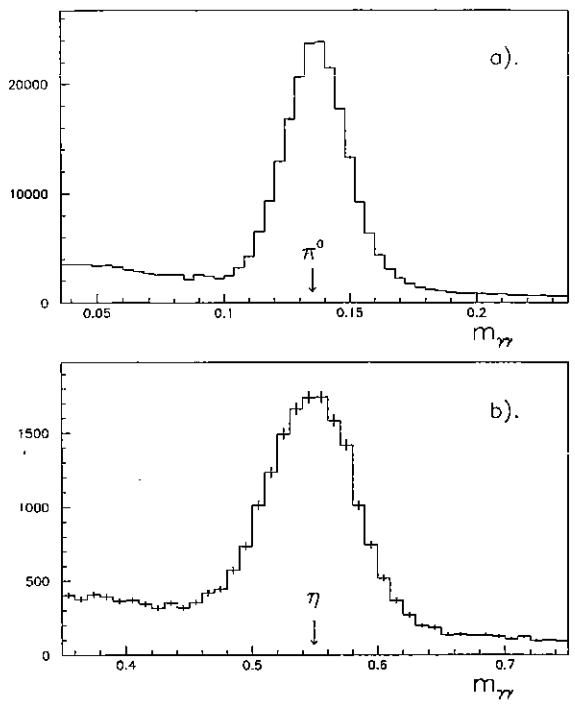

Figure 1. Effective mass spectra of $\gamma\gamma$ for π^0-meson (a) and η-meson (b) mass regions.

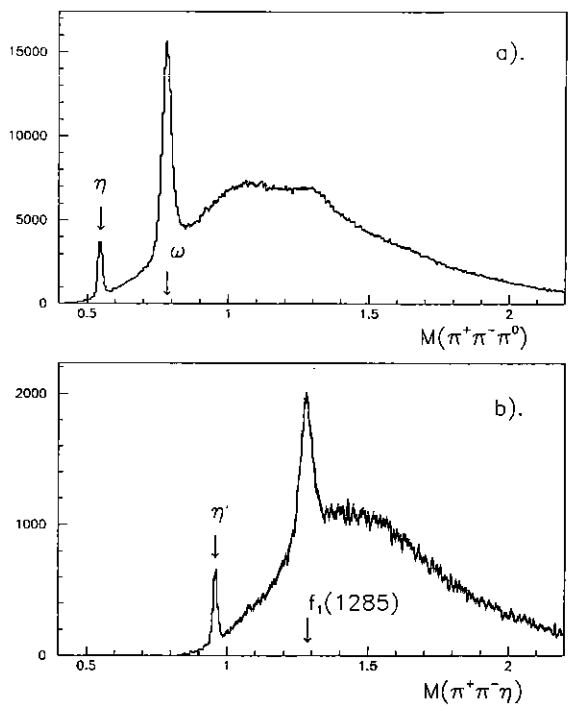

Figure 2. Effective mass spectra of $\pi^+\pi^-\pi^o$ (a) and $\pi^+\pi^-\eta$ (b) systems.

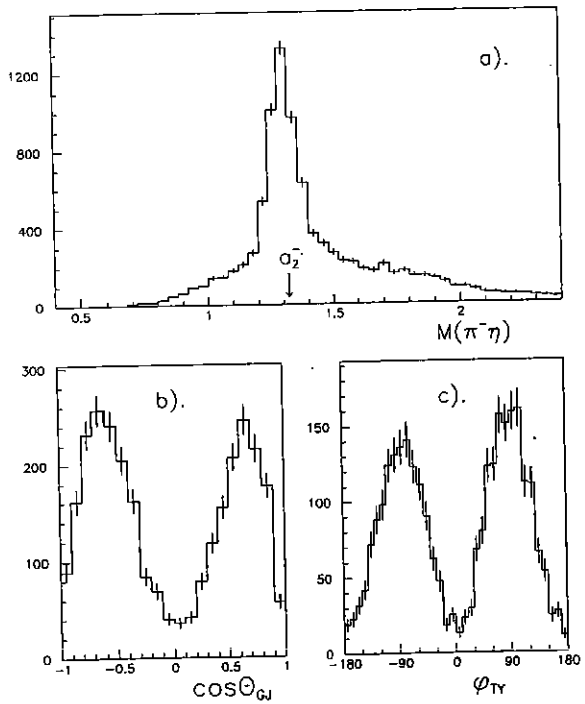

Figure 3. The $\pi^-\eta$ system: effective mass spectrum (a), polar (b) and azimuthal (c) angle distributions in Gottfried-Jackson frame for $a_2^-(1320)$-meson mass region. Angles are defined with respect to the π^- direction.

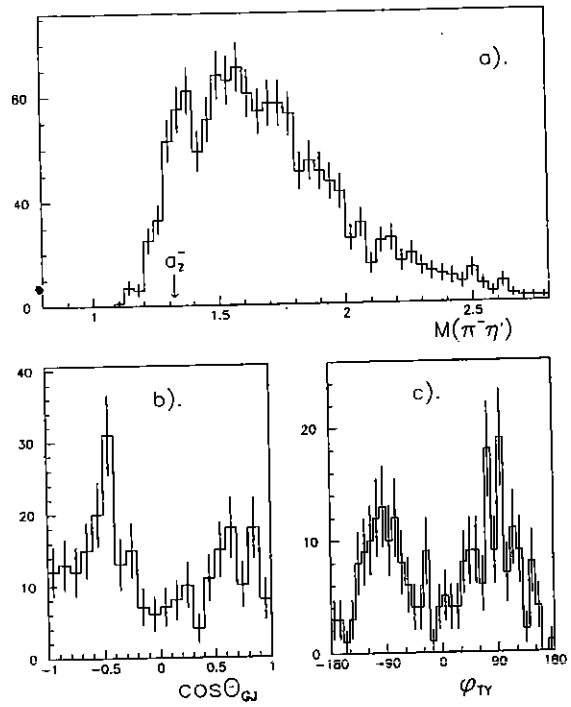

Figure 4. The same as in fig.3 for $\pi^-\eta'$ system.

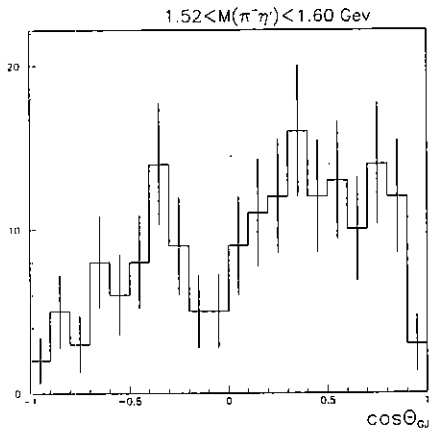

Figure 5. The $cos\theta_{GJ}$ distribution for $\pi^-\eta'$ system outside a_2^- peak ($1520 < M_{\pi^-\eta'} < 1600\ MeV$).

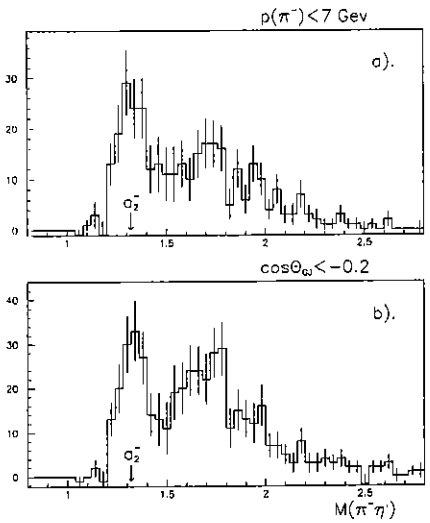

Figure 6. The effective mass spectra of $\pi^-\eta'$ system with $p_{\pi^-} < 7\ GeV$ (a) and $cos\theta_{GJ} < 0.2$ (b) conditions imposed.

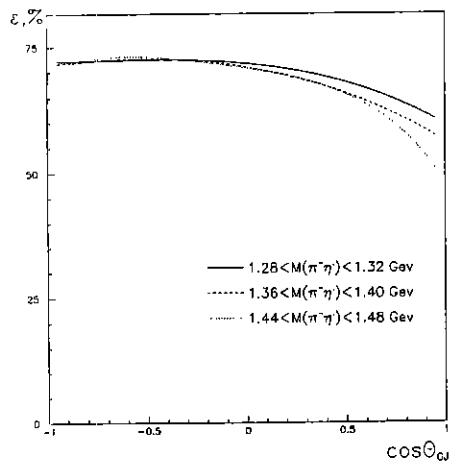

Figure 7. Angular dependence of the acceptance for different $\pi^-\eta'$ masses.

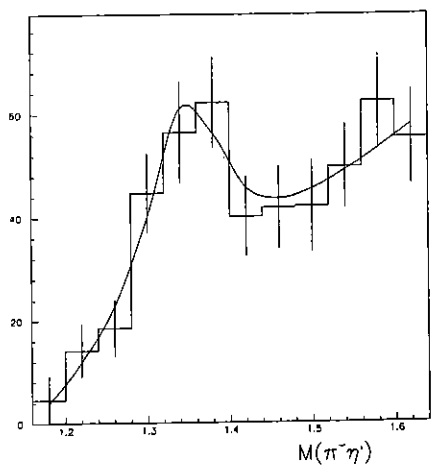

Figure 8. Part of $\pi^-\eta'$ mass spectrum after background subtraction. The solid curve represents the result of fitting with Breit-Wigner function + polynomial.

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