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NARROW RESONANCES IN THE SYSTEM OF TWO π^--MESONS

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The study of the production of exotic 4-quark resonances with isotopic spin $I = 2$ in the $\pi^-\pi^-$-systems from the reaction $np \to pp\pi^+\pi^-\pi^-$ was carries out using the data obtained in the irradiation of 1m H_2 bubble chambers of LHE, JINR by neutrons at the momentum $P_n = 5.20 \pm 0.13$ GeV/c. A number of enhancements were found at the masses of 0.330; 0.354; 0.397; 0.447; 0.510; 0.569; 0.650; 0.736; 0.822, and 0.920 GeV/c^2. Experimental widths of resonances are comparable with the resolution that is linearly increasing from 1.4 to 15.0 MeV/c^2 (σ_{res}) under alteration of masses from the sum of masses of pions to $\approx$1 GeV/c^2. An attempt was made to determine the spins of resonances. For the resonances at the mass of 0.397 GeV/c^2, the most probable value of spin was proved to be equal to $J \geq 6$.

The investigation has been performed at the Laboratory of High Energies, JINR.

УЗКИЕ РЕЗОНАНСЫ В СИСТЕМЕ ДВУХ π^--МЕЗОНОВ

Ю.А.Троян и др.

В реакции $np \to pp\pi^+\pi^-\pi^-$, выделенной на материалах облучения 1 м жидководородной пузырьковой камеры ЛВЭ ОИЯИ нейтронами с импульсом $P_n = 5{,}20 \pm 0{,}13$ ГэВ/с, исследовано образование экзотических четырехкварковых резонансов с изотопическим спином $I = 2$ в системе двух π^--мезонов. Обнаружен ряд особенностей с массами 0,330; 0,354; 0,397; 0,447; 0,510; 0,569; 0,650; 0,736; 0,822 и 0,920 ГэВ/с^2. Экспериментальные ширины резонансов определяются экспериментальным разрешением по массам, которое линейно растет от 1,4 до 15,0 МэВ/с^2 (σ_{res}) при измерении масс от суммы масс двух π^--мезонов до $\approx$1 ГэВ/с^2. Сделана попытка определения спинов резонансов. Для резонанса с массой 0,397 ГэВ/с^2 наиболее вероятное значение спина оказалось равным $J \geq 6$.

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The first results of the study of resonances in $\pi^-\pi^-$-system from the reaction $np \to pp\pi^+\pi^-\pi^-\pi^0$ (5712 events) at $P_n = 5.20 \pm 0.13\,\mathrm{GeV/c}$ were reported at the X International Seminar on Problems of High Energy Physics [1]. The data were obtained in an exposure of 1 m H_2 bubble chamber of LHE JINR by monochromatic neutrons. The beam parameters, the methods of identification of reaction channels, the values of cross sections, etc., were published in paper [2].

In this report, we present the results of the study of two π^--mesons system from the reaction (1) at the same neutron momentum (total, 8394 events of reaction (1) were identified).

$$np \to pp\pi^+\pi^-\pi^-. \qquad (1)$$

The distribution of the effective masses of $\pi^-\pi^-$-combinations from the reactions (1) is shown in Fig.1. The distribution is approximated by an incoherent sum of the background curve taken in the form of a superposition of Legendre polynomials of up to fourth power inclusive (coefficient of higher power polynomials are negligible), and by ten Breit — Wigner resonance curves. The part of the background is equal to 91%. The background

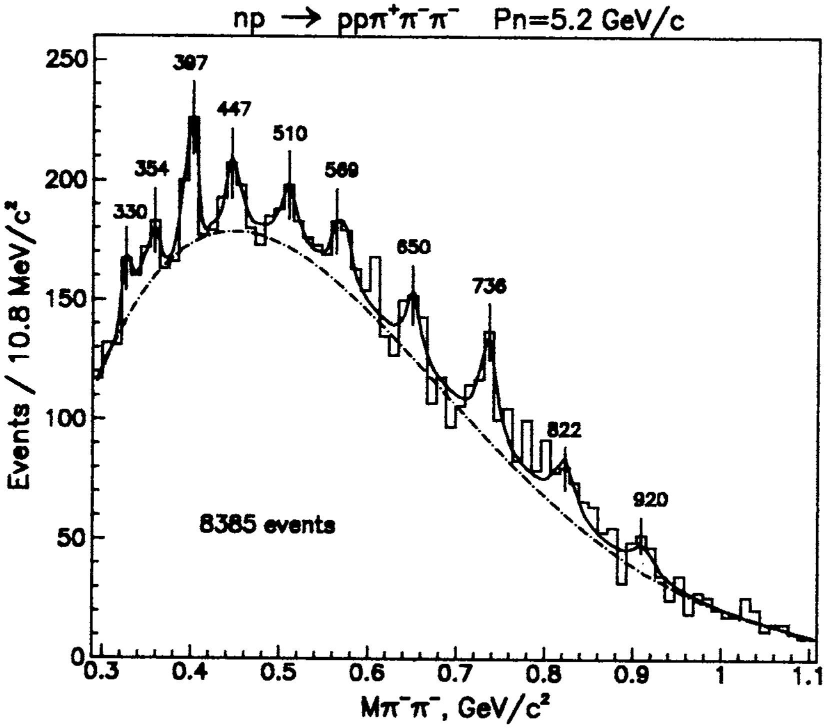

Fig.1. The effective mass distribution of $\pi^-\pi^-$-combinations at $P_n = 5.2$ GeV/c

describes the region outside the resonances with $\chi^2 = 1.01 \pm 0.14$; $\sqrt{D} = 1.37 \pm 0.10$, that is very close to the pure statistical distribution ($\chi^2 = 1$; $\sqrt{D} = 1.41$).

The obtained data are presented in the Table.

Table

$M_e \pm \Delta M_e$ MeV/c^2	$\Gamma_e \pm \Delta\Gamma_e$ MeV/c^2	$\Gamma_R \pm \Delta\Gamma_R$ MeV/c^2	$\sigma \pm \Delta\sigma$ μb	S.D.	P
330 ± 6	$12.1^{-2.8}_{+5.8}$	$11.1^{-2.8}_{+5.8}$	2.5 ± 1.2	2.2	$8.4\cdot10^{-1}$
354 ± 6	$12.1^{-2.7}_{+5.3}$	$10.5^{-2.7}_{+5.3}$	2.7 ± 1.3	2.3	$7.6\cdot10^{-1}$
397 ± 6	$12.1^{-1.7}_{+2.5}$	$9.3^{-1.7}_{+2.5}$	5.4 ± 1.4	4.4	$1.6\cdot10^{-4}$
447 ± 7	$17.6^{-9.4}_{+31.3}$	$14.6^{-9.4}_{+31.3}$	4.2 ± 1.7	2.7	$9.0\cdot10^{-2}$
510 ± 7	$21.6^{-8.8}_{+25.7}$	$17.6^{-8.8}_{+25.7}$	4.2 ± 1.9	2.4	$1.9\cdot10^{-1}$
569 ± 7	$22.0^{-10.2}_{+27.9}$	$16.1^{-10.2}_{+27.9}$	4.2 ± 1.6	2.9	$4.6\cdot10^{-2}$
650 ± 8	$19.3^{-10.4}_{+45.3}$	$5.9^{-5.9}_{+45.3}$	4.5 ± 1.4	3.4	$7.1\cdot10^{-3}$
736 ± 6	$22.8^{-7.4}_{+13.7}$	$6.0^{-6.0}_{+13.7}$	7.8 ± 1.7	5.4	$1.8\cdot10^{-9}$
822 ± 9	$27.2^{-8.6}_{+15.7}$	$9.2^{-8.6}_{+15.7}$	5.8 ± 1.4	3.7	$2.2\cdot10^{-3}$
920 ± 7	$30.5^{-18.0}_{+108.7}$	$6.9^{-6.9}_{+108.7}$	2.4 ± 0.8	3.5	$5.4\cdot10^{-3}$

The first column contains the central value of the resonance mass; the second one, the experimental full width of the resonance; the third one, the true resonance width, obtained by quadratic subtraction of the width of the resolution function for the masses of $\pi^-\pi^-$-combinations from the experimental widths. In the fourth colum, the cross section of the resonance production in reaction (1) is given (see [2]); in the fifth column, number of standard deviations above the background; in the sixth column, probability (multiplied by the number of bins) that observed enhancements is due to background fluctuations.

The experimental resolution for the masses $\sigma_{res}(M)$ is well approximated by formula (2):

$$\sigma_{res} = 2.1 \cdot [(M - M_0)/0.1] + 1.4, \tag{2}$$

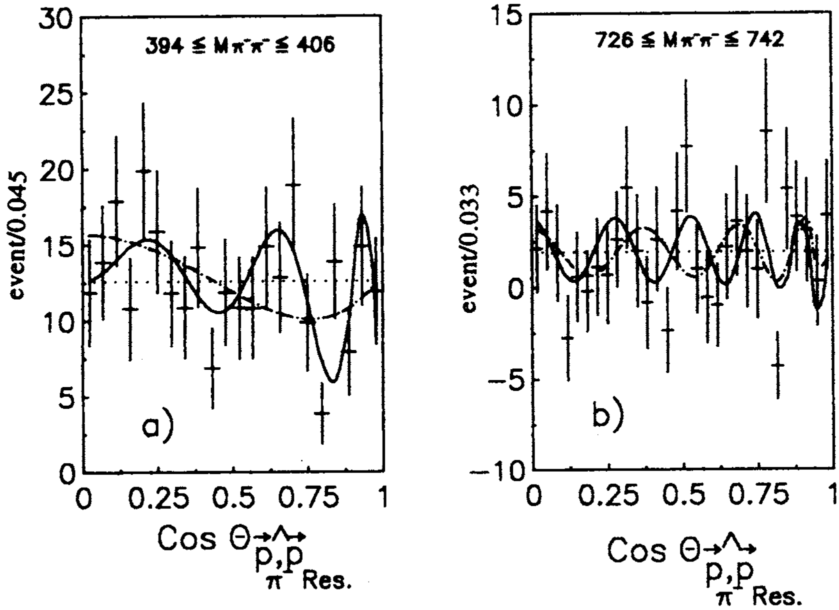

Fig.2. a) The distribution of cos $\Theta_{\widehat{P_{\pi^-},P_{Res}}}$ for resonance at the mass of 397 MeV/c^2 and b) for resonance at the mass of 736 MeV/c^2

where M is effective mass of a resonance (in GeV/c^2); M_0, the mass of two π^--mesons (in GeV/c^2). The result for σ_{res} is given in MeV/c^2. On can see from formula (2) that the mass resolution is linearly increasing from 1.4 to 15.0 MeV/c^2 under alteration of masses from the sum of masses of two pions to $\approx$1 GeV/c^2.

To determine the spins of resonances there is analysed the distribution of cos $\Theta_{\widehat{P_{\pi^-},P_{Res}}}$ — the angle between the direction of motion of π^--meson from the resonance decay ($\mathbf{P}_{\pi^-}$) and the direction of resonance motion ($\mathbf{P}_{Res}$) in general c.m.s.. All quantities are taken in resonance c.m.s. (helicity coordinate system). It is known for strong decays that such distributions can be described by a sum of Legendre polynomials of an even power with the maximum powers of $2J$, where J is the resonance spin [3].

The distributions of cos $\Theta_{\widehat{P_{\pi^-},P_{Res}}}$ are shown in Fig.2a for the resonance at the mass of 397 MeV/c^2: dotted line is isotropic distribution; dash-dot line is the description by Legende polynomials of up to the fourth power inclusive; solid line, description by Legendre polynomials of up to 12 power inclusive. The corresponding confidence levels are equal to 2.5%; 8.3%, and 45.3%, respectively. Hence, one can conclude the spin of the resonance in $\pi^-\pi^-$-system at the mass of 397 MeV/c^2 $J \geq 6$. In this procedure, the

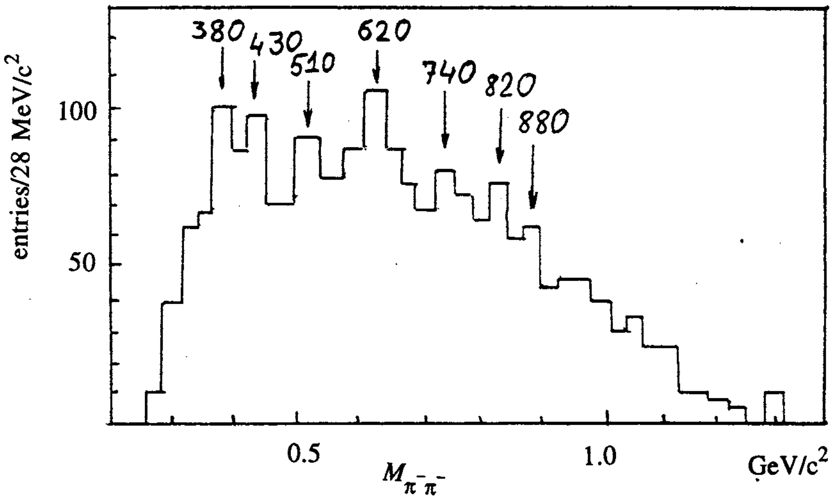

Fig.3. The effective mass distribution of $\pi^-\pi^-$-combinations from the reaction $\bar{p}d \rightarrow 2\pi^-2\pi^+n$ [6]

background from the left and from the right is not subtracted, because it is essentially isotropic.

The distributions of $\cos\Theta_{\widehat{P_{\pi^-},P_{Res}}}$ are shown in Fig.2b for the resonance at the mass of 736 MeV/c^2: dotted line is the isotopic distribution; dash-dot line, description by Legendre polynomials of up 16 power inclusive; solid line, description by Legendre polynomials of up to 22 power inclusive. The corresponding confidence levels are equal to 19.4%; 32.5%, and 55.8%, respectively. Hence, one can conclude the spin of the resonance in $\pi^-\pi^-$-system at the mass of 736 MeV/c^2 $J > 11$. In this procedure, the background from the left and from the right is subtracted.

We refer to survey article [4] devoted to theoretical discussion of the problem of 4-quark resonances and present experimental situation. There are few experimental data in literature concerned with a study of similar resonances in this region of effective masses (from $2m_\pi$ to ≈1 GeV/c^2) [5,6].

It needs to note the results obtained by OBELIX collaboration [6]. Figure 3 shows the effective mass distribution of $\pi^-\pi^-$-combinations from the reaction $\bar{p}d \rightarrow 2\pi^-2\pi^+n$. The arrows mark the following peculiarities in the effective masses spectrum: 0.38; 0.43; 0.51; 0.62; 0.74; 0.82; 0.88 GeV/c^2. One can see a good coincidence (taking into account errors) between these peculiarities and our narrow resonance structures in the effective masses spectrum of $\pi^-\pi^-$-combinations from the reaction (1). The author of the paper [6] did not pay attention to these peculiarities in the distribution presented in Fig.3. It is necessary to note this distribution is plotted using a little statistics and by larger bins (28 MeV/c^2) than in Fig.1.

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References

1. Troyan Yu.A. et al. — Proc. of Seminar on High Energy Phys. Probl. Relat. Nucl. Phys. and Quantum Chromodynamics, Dubna, September, 1990, p.149; IPNO-DRE 91-18.
2. Besliu C. et al. — Yad. Fiz., 1986, vol.43, p.888.
3. Baldin A.M. et al. — Kinematics of Nuclear Reactions. Atomizdat, M., 1968.
4. Achasov N.N., Shestakov G.N. — UFN, 1991, vol.161, p.53.
5. Albrecht H. et al. — Phys. Lett., 1991, vol.B260, pp.259—264.
6. Ableev V.G. et al. — Nucl. Phys., 1995, vol.A585, pp.577—617.

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