Study of the reaction $\pi^- Be \to \omega\pi^-\pi^0 Be$

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Abstract

The results of partial wave analysis of the $\omega\pi^-\pi^0$-system, produced in the reaction $\pi^- Be \to \pi^+ 2\pi^- 2\pi^0 Be$ at beam momentum of $37\,GeV$ are presented. An indication of the resonant type structure with mass $M \approx 1.74\,GeV$ and $J^P M^\eta = 0^- 0^+$ in the $\omega\rho^-$-system was found. The decay branching ratio of $a_2(1320)^-$ to $\omega\pi^-\pi^0$ was measured. A wave with $J^P M^\eta = 2^+ 1^+$ shows a broad bump at mass $M \approx 1.7\,GeV$. The decays $\pi_2(1670)^- \to \omega\rho^-$ and $a_4(2040)^- \to \omega\rho^-$ were observed for the first time. The bump in the $b_1(1235)\pi$ wave with exotic quantum numbers $J^{PC} = 1^{-+}$ at $M \approx 1.7\,GeV$ was observed.

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1 Introduction

The results of partial wave analysis (PWA) of the $\omega\pi^-\pi^0$-system, produced in the reaction $\pi^- Be \to \omega\pi^-\pi^0 Be$ by pion beam with momentum $P_\pi = 37\,GeV$ are presented in this article. These results were partially reported at the conferences [1], [2].

The study of this reaction is an interesting subject for several reasons. The quark model predicts many meson resonances with masses in the region of $1.5-2.5\,GeV$. The exotic mesons with the same masses may exist apart from the ordinary $q\bar{q}$ states. The hybrids, four-quark mesons, hadron molecules can be in the isovector state. Practically all of them should decay to $\omega\pi^-\pi^0$, where the $\omega\rho^-, b_1\pi, \rho_3(1670)\pi$ should be the main chanels. There exist in several cases definite predictions for probabilities of the decay of different objects into these chanels, namely $\omega\rho^-$. Study of these decays can play important role in determination of the nature of states under study, e.g. the results of the model calculations for decay widths of the $\pi(1800)$ [3],[4]. That state can be a hybrid or a radial excitation of the π-meson, 3^1S_0. The difference in the decay widths into $\omega\rho^-$ [5] predicted by the $^3P_0$ model makes it possible to distinguish between these alternatives. Similar predictions were made [5] for the $a_1(1700)$ state [3], which can be a hybrid or a 2^3P_1 radial excitation state. The predictions for the $\pi_2(1670)$ and for more heavy states with $J^PM^\eta = 2^-0^+$ [5] are worth mentioning.

The system composed of two vector mesons has been previously studied in the $\gamma-\gamma$ interactions [6], in the J/ψ radiative decays[7], in the nucleon-antinucleon annihilation [8], in the charge exchange processes [9], in the central [10] and diffractive production[1]. The relatively small probability of the production processes and/or the high multiplicity of the final states did not let them to take the experimental data sample sufficient for making detailed PWA. Nevertheless, the indications to the existence of isoscalar resonances with quantum numbers 2^{++} in the $\rho\rho$ and $\omega\omega$ systems were obtained.

The experimental information about isovector mesons is even scarcer. The diffractive productions of the isovector resonances with $J^P = 0^-, 1^+, 2^-...$ is especially suitable, for the production cross sections are large and the physical backgrounds are small. The waves with quantum numbers $J^P = 2^+, 4^+$ become important at relatively large momentum transfer.

2 Set-up description

The measurements were carried out using VES spectrometer exposed to the negatively charged pions with momentum $37\,GeV$. VES is a wide aperture spectrometer of charged particles and photons. The beam part is composed of the threshold Cerenkov counters and a system of propotional chambers. The vertex part consists of a 4cm thick Be target and a guard system surrounding it to veto events with particles moving backward to the beam in the event centre of mass system. The spectrometer of charged particles consists of a tracking system, a wide aperture magnet(kick momentum $0.7\,GeV$) and a multichanel threshold Cerenkov counter. A fine grained electromagnetic calorimeter (1600 cells) measures γ energy and position. A triggering system, which consists of a hodoscope, scincillation counters and a guard system selects events of beam interaction with the target and at least two tracks in the forward spectrometer. The data sample used for presented analysis included $\sim 6 \cdot 10^7$ reconstructed events, corresponding to the integrated luminosity of $\sim 100\,\mu b^{-1}$. The acceptance for events with several charged and neutral pions is rather high ($\epsilon \approx 0.6$ for $\omega(\pi^+\pi^-\pi^0)\pi^-\pi^0$ at $M_{\omega\pi^-\pi^0} = 1.5\,GeV$) and is a smooth function of kinematical variables. The measured width of the π^0 meson in the $\gamma\gamma$ invariant mass spectrum charactirises the experimental resolution of calorimeter and is equal to $\sim 20\,MeV$. The measured width of the ω-meson $\Gamma \sim 30\,MeV$ includes the resolution of the tracking part of set-up.

3 Event selection and main features of the reaction $\pi^- Be \to \omega\pi^-\pi^0 Be$

At first, the events of the process $\pi^- Be \to \pi^+ 2\pi^- 2\pi^0 Be$ were selected for further analysis of the $\omega\pi^-\pi^0$ system using the following criteria for reconstructed events:

- Two negative and a positive track originated in the target region.
- At least four energy clusters in the calorimeter not associated with tracks. A cluster is assumed to be a γ-shower, if it satisfied the criterion on the transverse form of the shower. Events with the pairs of photons with invariant mass nearest to the PDG value and within $60\,MeV$ range for π^0 and $156\,MeV$ for η were selected.
- Some $\sim 10\%$ of events with electrons were rejected using the ratio of the energy deposited in calorimeter and the momentum measured by magnetic spectrometer.
- The Cerenkov counter responce to passed track was applied for charged K-meson identification. Some 3.4% of events were rejected as having kaons.
- Events with two π^0 and, possibly free soft photons ($E_\gamma \leq 1\,GeV$), and the total forward final state particles energy in the range $34\,GeV \leq \sum E_i \leq 39\,GeV$ were classified as those of type $\pi^- Be \to \pi^+ 2\pi^- 2\pi^0 Be$.

A 1C-fit was done on the mass of π^0. The invariant mass distribution of the $\pi^+\pi^-\pi^0$ system with additionaly produced $\pi^-\pi^0$ is presented in fig. 1. Clear peaks corresponding to the η and ω-meson production with large backgound are evident. The ω-meson peak has a non-gaussian form. Its parameters were determined by the fit with the sum of two gaussian functions in the range from $0.6\,GeV$ to $0.9\,GeV$. The mass of the narrow part was $M_\omega = 783.37 \pm 0.06\,MeV$,

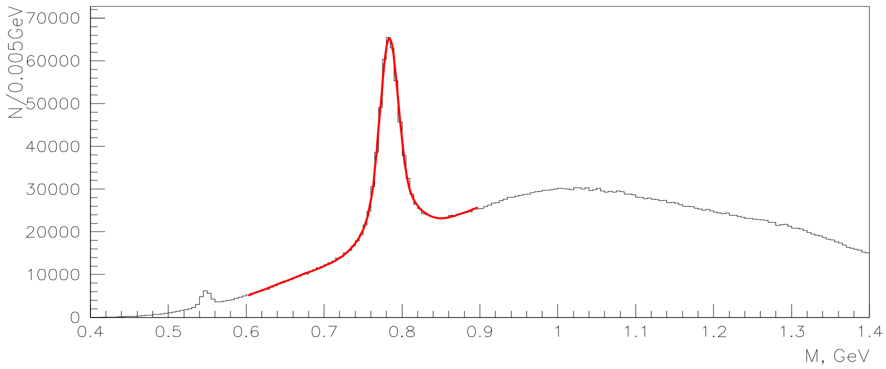

Figure 1: The invariant mass of the $\pi^+\pi^-\pi^0$ for events of $\pi^+ 2\pi^- 2\pi^0$ production.

where the systematic error was estimated to be $\sigma_{M_\omega} = 1\, MeV$. The width was: $\Gamma_\omega = 26.2 \pm 0.2\, MeV$ and the number of events with ω production turned out to be $(361 \pm 1) \cdot 10^3$. The fraction of background events at the point of the peak maximum was estimated to be $\sim 30\%$.

To make various distributions describing the production and decay of the $\omega\pi^-\pi^0$ system the background was estimated by the neighbouring to the ω peak bands and was subtracted. Application of this method assumes smooth behaiviour of the background. The drawback is the difference of the phase spaces for those bands, where the background was estimated, and for the signal ones.

Another method of background subtraction was applied for cross checking. The matrix element of the $\omega \to \pi^+\pi^-\pi^0$ decay is propotional to:

$$\lambda = \frac{4 \cdot [\vec{p}_{\pi^+} \times \vec{p}_{\pi^-}]^2}{(M_{3\pi}^2 - 9m_\pi^2)^2} \tag{1}$$

where:

$\vec{p}_{\pi^+}$ - momentum vector of π^+ in the $\pi^+\pi^-\pi^0$ centre of mass,
$\vec{p}_{\pi^-}$ - momentum vector of π^- in the $\pi^+\pi^-\pi^0$ centre of mass,
$M_{3\pi}$ - $\pi^+\pi^-\pi^0$ invariant mass,
m_π - π meson mass.

If the distribution of λ for background events is sufficiently uniform, then by weigthing events having $\lambda < 0.5$ with -1 and those having $\lambda \geq 0.5$ with +1 we effectively subtract background. But the efficient number of signal events filtered this way is twice smaller than that in the initial sample.

Both methods resulted in statistically compatible distributions of variables characterizing the $\omega\pi^-\pi^0$ decay and production. The results of the subtraction procedure by the former method is presented in fig. 2. Two slopes are clearly seen in the momentum transfer squared distribution ($t' = t - t_{min}$) in fig. 2b. It is useful to divide the experimental event sample into two parts in the variable t': type LT (low t') $-t' < 0.08\, GeV^2$ and HT (high t') $0.08 \leq -t' < 0.7\, GeV^2$.

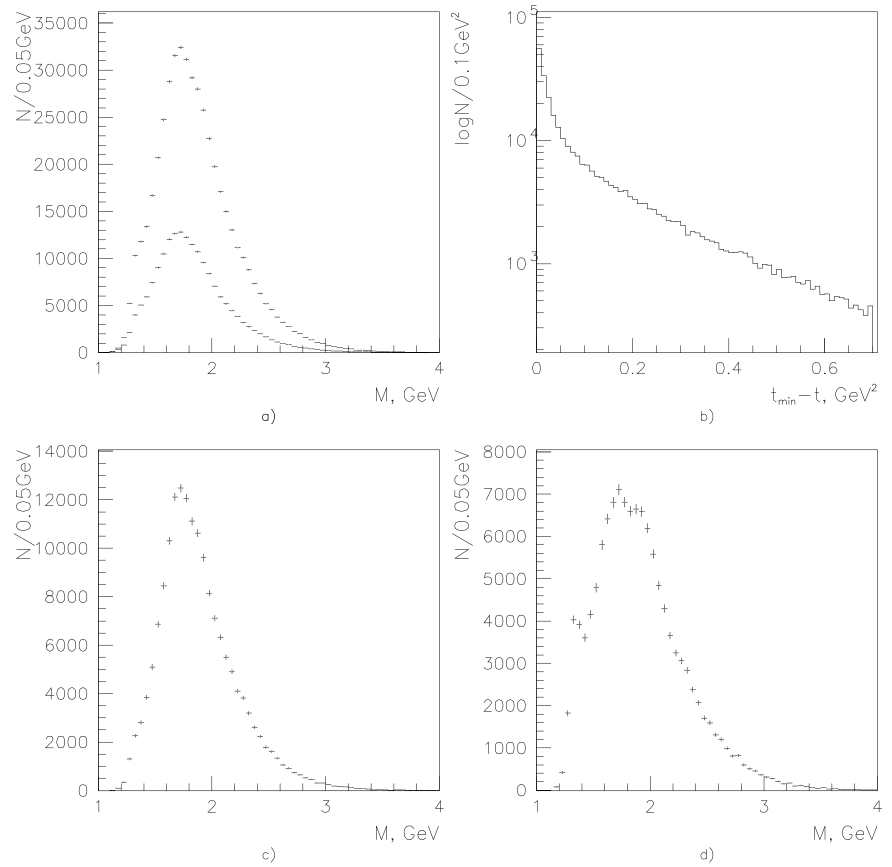

Figure 2: a) Mass of the $\pi^+ 2\pi^- 2\pi^0$-system with $-t' < 0.7\,GeV^2$ from the band $0.7577 \le M_{\pi^+\pi^-\pi^0} < 0.8077\,GeV$ with superimposed distribution from the control bands. b) Momentum transfer t' for reaction $\pi^- Be \to \omega\pi^-\pi^0 Be$. Mass of the $\omega\pi^-\pi^0$ system for: LT - c) and HT - d).

The ρ-meson peak dominates in the $\pi^-\pi^0$ invariant mass spectrum (fig. 3a). The $b_1(1235)$ isobar of the $\omega\pi$-system is more evident in the high mass region of $\pi^+2\pi^-2\pi^0$ (fig. 3b). The $\omega\pi^-\pi^0$ invariant mass spectrum of the LT type (fig. 2c) has its maximum at $1.72\,GeV$ and a weakly pronounced shoulder in the region around $2\,GeV$. The distribution of HT type events (fig. 2d) is wider and has a shoulder in the region of $2\,GeV$. A peak cooresponding to the $a_2(1320)$ meson production is clearly seen in the low mass region. The PWA method was applied to study this complicated structure. Further the event sample, where the mass of at least one of the $\pi^+\pi^-\pi^0$ combination satisfies the relation $|M_{\pi^+\pi^-\pi^0} - 0.7827| < 0.060\,GeV$, were analysed.

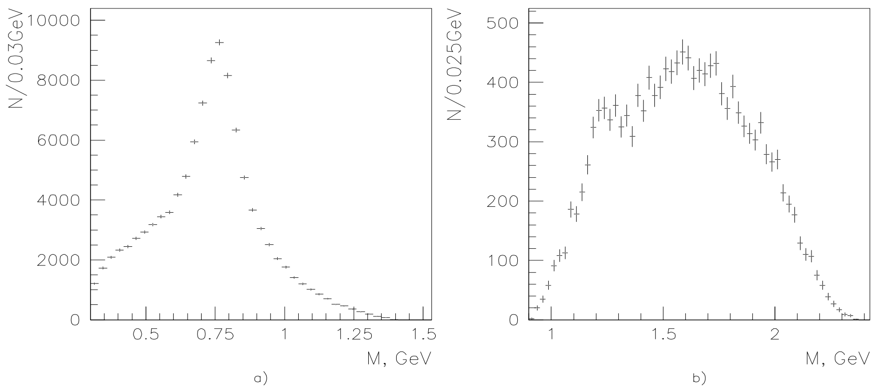

Figure 3: a) Mass of $\pi^-\pi^0$ with $-t' < 0.08\,GeV^2$, $1.65\,GeV \leq M(\pi^+2\pi^-2\pi^0) < 2.15\,GeV$. b) Mass of $\pi^+2\pi^-\pi^0$ with $-t' < 0.08\,GeV^2$, $2.15\,GeV \leq M(\pi^+2\pi^-2\pi^0) < 2.45\,GeV$.

4 Procedure of the partial wave analysis

The goal of this method is the determination of intensities and relative phases of different states as a function of $M_{\omega\pi^-\pi^0}$ and t'. This method is based on the approach realised in Illinois PWA program [11].

The full amplitude of each decay channel is written in the form of the product of production and decay amplitudes. The produced system decay process is assumed to be a chain of sequential two body decays into the isobar and a bachelor meson.

The $\omega\pi^-\pi^0$-system state is described at fixed $M_{\omega\pi^-\pi^0}$ and t' by the following set of quantum numbers: the total angular momentum J of $\omega\pi^-\pi^0$ system, the parity P, the projection of total angular momentum onto the Gottffried-Jackson reference frame z-axis M, the isobar orbital momentum in the $\omega\pi^-\pi^0$ decay L and the total spin S. It is convinient to change the basis of states having $M = \pm 1$ to the basis of their linear combinations, which are the eigenvalues of a reflection operation in the production plane. The quantum number which characterises the behaviour of the system with respect to reflecton is called a naturality, $\eta = \pm 1$. As a result any partial wave is described by the following set of numbers: $J^P M^\eta L[S](isobar)$ with $M \geq 0$.

A decay amplitude into the state with a definite orbital angular momentum L and a total spin S was written in the frame of a non-relativistic tensor Zemach formalism [12]. The isobar mass dependence of the decay amplitude was assumed in the relativistic Breit-Wigner form with the Blatt-Weisskopf form-factors [13].

Integrals of the amplitude products were calculated by the Monte-Carlo method using the set-up model.

The selected events were divided into two parts in t': the LT and HT, each of which, in turn, was divided into the $50\,MeV$ and $100\,MeV$ bins in $M_{5\pi}$, beginning from $M_{5\pi} = 1.2\,GeV$. The process of the beam diffraction dominates in the region of small momentum transfer, and this fact dictates the selected wave set with $M^\eta = 0^+$ and $J^P = 0^-, 1^+, 2^-$,... The waves with $M^\eta = 1^+$ and $J^P = 2^+, 4^+$ become dominant in the region of high momentum transfer. This is proved by the $a_2(1320)$ peak in the $M_{5\pi}$ spectrum for events from the HT sample. These facts determined the wave set used in the PWA. The following isobars were included: the ρ^- in the $\pi^-\pi^0$ chanel, the b_1, and ρ_1, and $\rho_3(1690)$ in the $\omega\pi$ chanel. The $1^-1^+S(b_1^0)$ wave with indefinite isospin was included for the description of the visible b_1^0 prevailing over b_1^-. The incoherent wave FLAT, uniformly distributed over the 5π phase space with one of the $\pi^+\pi^-\pi^0$ combination from the ω region, was included to take the non $\omega\pi^-\pi^0$ background into account.

The resultant wave set looked as following:

FLAT				
$\mathbf{0^-}$	$0^-0^+\ P1(\rho)$			
$\mathbf{1^+}$	$1^+0^+\ S1(\rho)$		$1^+0^+\ P1(b_1)$	
$\mathbf{1^+}$	$1^+0^+\ D1(\rho)$	$1^+0^+\ D2(\rho)$		$1^+0^+\ S1(\rho_1)$
$\mathbf{2^-}$	$2^-0^+\ P1(\rho)$	$2^-0^+\ P2(\rho)$	$2^-0^+\ P1(b_1)$	$2^-0^+\ P1(\rho_1)$
$\mathbf{3^+}$	$3^+0^+\ D1(\rho)$	$3^+0^+\ D2(\rho)$	$3^+0^+\ P1(b_1)$	$3^+0^+\ D1(\rho_1)$
$\mathbf{3^+}$	$3^+0^+\ S3(\rho_3)$			
$\mathbf{1^+}$	$1^+1^+\ S1(\rho)$	$1^+1^+\ D1(\rho)$		
$\mathbf{2^+}$	$2^+1^+\ S2(\rho)$			
$\mathbf{3^+}$	$3^+1^+\ D1(\rho)$	$3^+1^+\ D2(\rho)$		
$\mathbf{4^+}$	$4^+1^+\ D2(\rho)$			
$\mathbf{1^-}$			$1^-1^+\ S1(b_1)$	
$\mathbf{1^-}$			$1^-1^+\ S1(b_1^0)$	

The real and imaginary parts of the density matrix are the parameters to be defined by the extended maximum likelihood method [14]. The fits with density matrix of different ranks showed that the matrix of the rank 3 is sufficient for the experimental data description. The quality of description is illustrated in fig 4, where some angular and invariant mass distributions for events from one of the $M_{\omega\pi^-\pi^0}$ interval are plotted. The presented wave set was found to describe the data sufficiently well up to the mass $M_{\omega\pi^-\pi^0} < 2.1\,GeV$. The background model used in the PWA turned out to be good and the wave FLAT was smooth and its intensity was equal to the background in the ω peak region. The application of another PWA method with the background subtraction by the variable λ, mentioned above, proved the results of the PWA without subtraction. The results of the PWA of the $50\,MeV$ and $100\,MeV$ binned data were consistent.

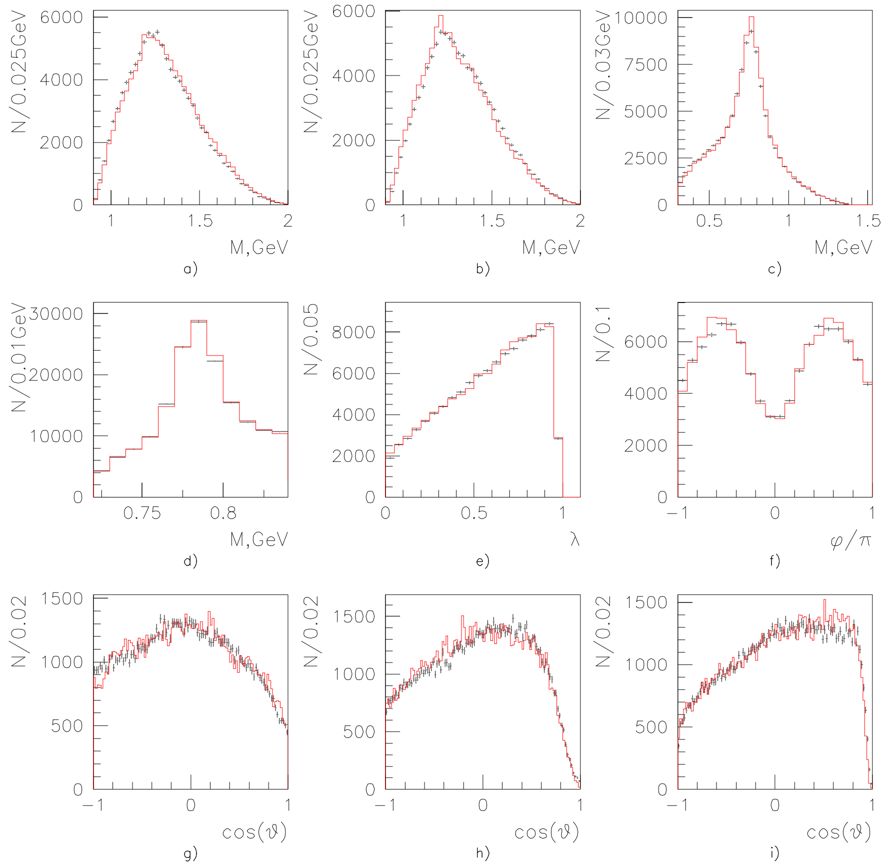

Figure 4: Comparison of the experimental data with events generated by the Monte-Carlo with the PWA model for $-t' < 0.08\,GeV^2$, $1.65\,GeV \leq M(\pi^+2\pi^-2\pi^0) < 2.15\,GeV$. a) and g) $\pi^+\pi^-2\pi^0$, b) and h)$\pi^+2\pi^-\pi^0$, c) and i) $\pi^-\pi^0$. d) Mass of $\pi^+\pi^-\pi^0$. f) Azimuthal angle of the π^--meson in the $\pi^-\pi^0$ centre of mass helicity reference frame.

5 The results of the patial wave analysis

The results of the PWA are presented in fig. 5 and 6.

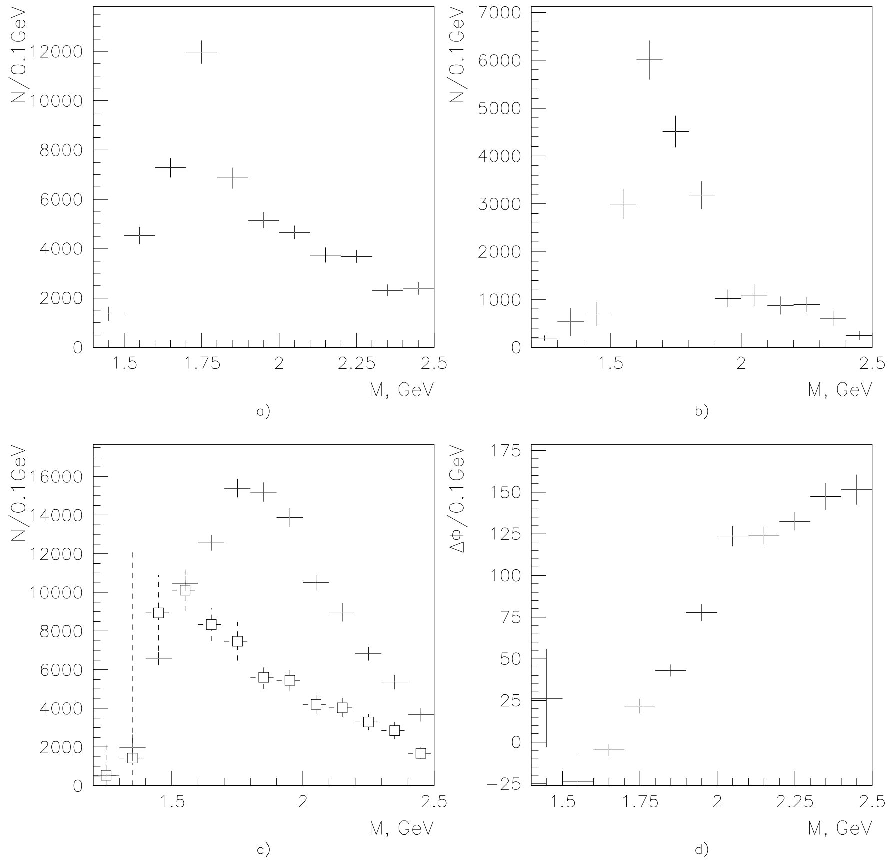

Figure 5: The PWA results for events with $-t' < 0.08\,GeV^2$. Wave intensities of: a) $0^-0^+P1(\rho)$, b) $2^-0^+P2(\rho)$, c) combined 1^+0^+. Combined intensity of the $1^+0^+P(b_1)$ and $1^+0^+S1(\rho)$ is drawn in squares. d) Phase of the $0^-0^+P1(\rho)$ wave with respect to the $1^+0^+P(b_1)$ wave.

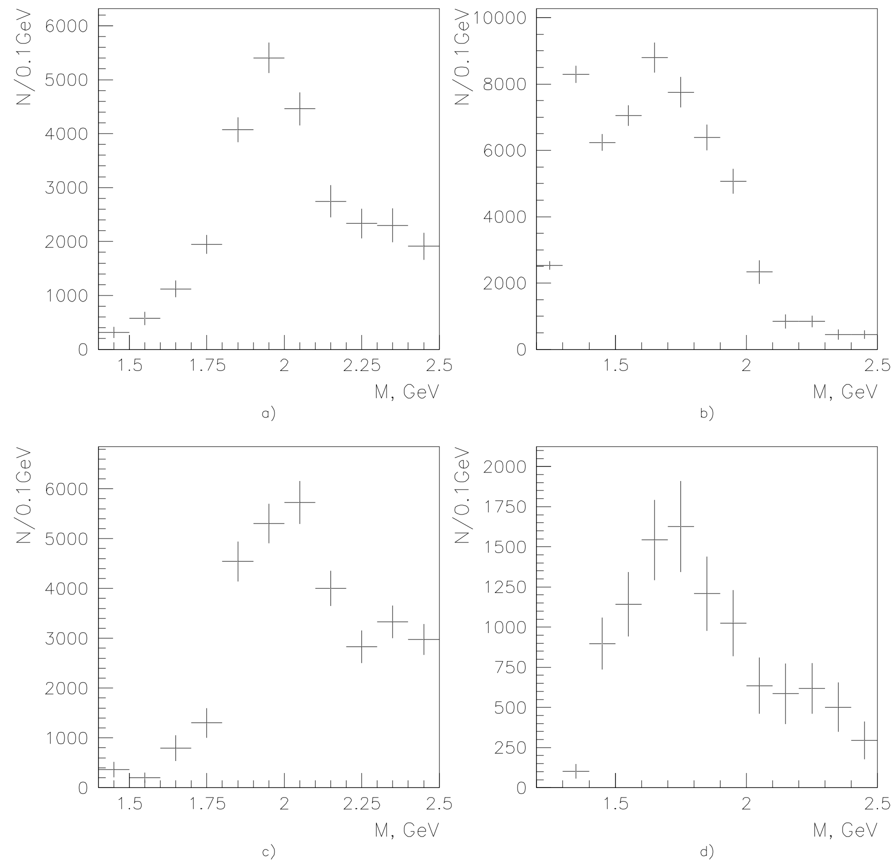

Figure 6: Wave intensities of: a) $3^+0^+S(\rho_3)$, b) $2^+1^+S2(\rho)$, c) $4^+1^+D2(\rho)$, d) $1^-1^+S(b_1)$.

$\underline{J^P M^\eta = 0^-0^+}$: A peak in the region of $1.74\,GeV$ with the flat background dominates in the wave $0^-0^+P(\rho)$ in the LT data sample (fig. 5a). The same structure is less visible in the $0^-0^+P(\rho)$ wave intensity for events from the HT sample. The phase of these waves with respect to the smooth waves $1^+0^+P(b_1)$, $1^+0^+S(\rho_1)$ exhibits resonant behaviour (fig. 5d). This fact makes it possible to assume the existence of a resonant state in the 0^-0^+ wave.

The resonance parameters were determined by the fit of the wave intensity with the incoherent sum of a relativistic Breit-Wigner function and a cubic polynomial. The parameter estimates are robust to the fit with a coherent sum and to the changes of the fit region. The mass was found to be $M = 1.737 \pm 0.005 \pm 0.015\,GeV$ and the width $\Gamma = 0.259 \pm 0.019 \pm 0.06\,GeV$. The number of resonance decays observed in the current experiment was estimated as $N(\pi^-(1740) \to \omega\rho^-) = (230 \pm 12 \pm 82) \cdot 10^3$. The mass and width of this resonance differ from that for $\pi(1800)$. The reason for this is unknown. It is possible to suggest the existence of two objects of different nature: a hybrid $\pi(1800)$ and a 3^1S_0 $q\bar{q}$ state decaying into $\omega\rho$.

$\underline{J^P M^\eta = 1^+0^+}$: The intensity of the sum of all 1^+0^+ waves has its maximum at $1.75\,GeV$. Some structure can be seen at $\sim 1.5\,GeV$ (fig. 5c). This total wave is a result of the combination of strongly interfering waves: $1^+0^+P(b_1)$, $1^+0^+S1(\rho)$, $1^+0^+S(\rho_1)$, $1^+0^+D1(\rho)$ and $1^+0^+D2(\rho)$. The data do not allow one to state that the phase of some wave has a resonant behaviour in the region of $\sim 1.5\,GeV$ or $1.75\,GeV$.

$\underline{J^P M^\eta = 2^-0^+}$: A clear peak is observed in the region of mass $1.67\,GeV$ with width $\sim 0.2\,GeV$ (fig. 5b). The resonant phase behaviour of the $2^-0^+P1(\rho)$ and $2^-0^+P2(\rho)$ waves with respect to the $1^+0^+P(b_1)$ wave makes it possible to conclude the observation of a resonance decaying into $\omega\rho$. This signal is nearly absent in the $b_1\pi$ system. The resonance parameters of the $2^-0^+P2(\rho)$ peak were estimated in the same way as for $\pi(1740)$: $M = 1.687 \pm 0.009 \pm 0.015\,GeV$ and $\Gamma = 0.168 \pm 0.043 \pm 0.053\,GeV$. We identify this phenomenon as the decay of $\pi_2(1670)$ into $\omega\rho$.

The partial branching ratio was found by normalization to the decay $\pi_2(1670) \to f_2(1270)\pi$ [3], observed in the current experiment decay:

$$Br(\pi_2(1670)^- \to \omega\rho^- S = 2) = 0.019 \pm 0.004 \pm 0.010$$
$$Br(\pi_2(1670)^- \to \omega\rho^- S = 1) = 0.009 \pm 0.002 \pm 0.003$$

The error of the normalization to the $f_2\pi$ decay is sufficiently large due to the Deck effect[15]. The upper limits of the partial branching ratios of the decays $\pi_2(1670) \to \pi\rho_1, \rho_1 \to \omega\pi$ and $\pi_2(1670) \to b_1\pi$ at the 2σ confidence level were set:

$$Br(\pi_2(1670) \to \rho_1\pi) < 0.0036,$$
$$Br(\pi_2(1670) \to b_1\pi) < 0.0019.$$

It is worth mentioning that a relatively large probability of the $\pi_2(1670) \to \omega\rho$ decay is in agreement with the model dependent calculations of [5].

$\underline{J^P M^\eta = 3^+0^+}$: A peak at $M_{5\pi} \sim 2\,GeV$ of the width $\sim 0.35\,GeV$ is clearly seen in the $3^+0^+S(\rho_3(1690))$ wave for events with low t'(LT) (fig. 6a). The resonant phase motion was not observed. Such wave behaviour can be attributed to the Deck effect process, characterized by the near threshold bump in the S-wave. A 3^+0^+ state of the $\omega\rho$ system is ~ 3 times smaller at the intensity maximum.

$\underline{J^P M^\eta = 1^+1^+}$: This wave in the $\omega\rho^-$ is non-significant and does not have narrow structures of the width $\Gamma \sim 0.2\,GeV$.

$\underline{J^P M^\eta = 2^+1^+}$: This wave dominates at high t'(HT sample). The intensive production and decay of the $a_2(1320)$ is the main process at low masses (fig. 6b). Due to the strong interefence of the $b_1\pi$ and $\omega\rho^-$ states in the region of their thresholds only the partial branching fraction of the $a_2(1320) \to \omega\pi^-\pi^0$ was determined relative to the well-known $a_2(1320)$ decay modes into $\eta\pi$ and $\rho\pi$. This probability was found to be $Br(a_2(1320) \to \omega\pi^-\pi^0) = (5 \pm 1)\%$. There exists some arbitrariness in the question of what should be called the $a_2(1320)$ due to the complicated form of the $\omega\pi^-\pi^0$ spectrum in the 2^+1^+ state. For possible misleading we define the $a_2(1320)$ partial width as that of a Breit-Wigner function with the S-wave $\omega\pi^-\pi^0$ background. This decay was previously observed in the low statistics experiments [16].

The nature of the $1.7\,GeV$ mass structure is unknown. The simple suggestion is that this peak is due to the existence of a resonance with a mass $M \approx 1.6\,GeV$ and a width $\Gamma \approx 0.3\,GeV$. The radial excitation of the $a_2(1320)$ meson should exist in this region. Nevertheless, it is worth saying that even in the absence of such a resonance the mass specrtum of the $2^+1^+S\ \omega\pi^-\pi^0$ wave should have a complicated two bump shape due to the opening of $\omega\rho$ chanel [17]. Sufficiently good description of this two bump spectrum was obtained in the model of one resonance. These possibilities are different in the phase motion. The phase motion was measured in this experiment with large uncertainty and did not allow us to make a definite conclusion. The fraction of the $b_1\pi$ production in the same state in the band $1.6 < M_{5\pi} < 2\,GeV$ is negligible.

$\underline{J^P M^\eta = 4^+1^+}$: There is a peak in the mass spectrum of $\omega\rho^-$ system with the spin 2 and orbital momentum 2 at $\approx 2\,GeV$ (fig. 6c). The phase shows resonant behaviour. This signal can be identified as $a_4(2040)$. The $a_4(2040)$ parameters were estimated by the mass spectrum fit with the incoherent sum of a D-wave relativistic Breit-Wigner functon and a polynomial background. They were found to be: $M = 1.944 \pm 0.008 \pm 0.050\,GeV$ and $\Gamma = 0.324 \pm 0.026 \pm 0.075\,GeV$. The t' dependence of $a_4(2040)$ is identical to that of $a_2(1320)$.

$\underline{J^P M^\eta = 1^-1^+}$: This exotic wave has quantum numbers which are forbidden for $q\bar{q}$ states. The intensity of the $1^-1^+S(b_1)$ wave is very small for the LT sample events. That for high t' shows a wide bump with the maximum at $M \sim 1.6 \div 1.7\,GeV$. The signal in the intensity of the $J^P M^\eta = 1^-1^+$ wave of the $\eta'\pi$-system with close parameters was observed earlier in [18]. All these facts indicate to the possibility of the existence of a wide resonance ($\Gamma \sim 0.5\,GeV$) with mass $M \approx 1.6\,GeV$. The maximum intensity of this wave does not exceed

15% of the $2^+1^+S2(\rho)$ wave intensity (fig. 6d). Similar waves in the $\omega\rho^-$ are also small.

6 Conclusions

The PWA of the $\omega\pi^-\pi^0$-system produced in the reaction $\pi^- Be \to \pi^+ 2\pi^- 2\pi^0 Be$ with beam momentum $P_\pi = 37\,GeV$ was performed.

A resonance structure with $M = 1.737 \pm 0.005 \pm 0.015\,GeV$ and $\Gamma = 0.259 \pm 0.019 \pm 0.06\,GeV$ was observed in the $J^P M^\eta = 0^- 0^+$ wave. These parameters differ from that of $\pi(1800)$ seen in the $2\pi^-\pi^+$ system. This fact may point out to the existence of two different objects with close masses.

The $a_2(1320)^- \to \omega\pi^-\pi^0$ decay in the wave $J^P M^\eta = 2^+1^+$ was found to have relative probability $Br(a_2(1320)^- \to \omega\pi^-\pi^0) = (5 \pm 1)\%$.

A wide bump of unknown nature at $M \approx 1.7\,GeV$ was observed in this wave.

The $\pi_2(1670) \to \omega\rho$ decay was observed in the $J^P M^\eta = 2^- 0^+$ wave. The partial decay fraction was found to be:

$$Br(\pi_2(1670)^- \to \omega\rho^-) = 0.027 \pm 0.004 \pm 0.01$$

The $a_4(2040) \to \omega\rho$ decay was observed in $J^P M^\eta = 4^+1^+$ wave. We measured the $a_4(2040)$ resonance parameters : $M = 1.944 \pm 0.008 \pm 0.050\,GeV$ and $\Gamma = 0.324 \pm 0.026 \pm 0.075\,GeV$.

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