Evidence for a scalar meson resonance in the π−p→nω reaction

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Citation: AIP Conf. Proc. **1257**, 262 (2010); doi: 10.1063/1.3483329
View online: http://dx.doi.org/10.1063/1.3483329
View Table of Contents: http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=1257&Issue=1
Published by the American Institute of Physics.

Evidence for a scalar meson resonance in the $\pi^- p \to n\omega\phi$ reaction.

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Abstract. The charge-exchange reaction $\pi^- p \to n\omega(780)\phi(1020)$ is studied with the VES setup. The $(\omega\phi)$ system is observed at relatively low background. Its invariant mass distribution peaks near threshold. The two-particles partial wave analyses shows that the $J^{PC} = 0^{++}$ state dominates. This wave is compared with 0^{++} component in the $(\omega\omega)$ system at the comparable mass, which was measured earlier.

PACS: 14.40.Cs 13.25.Jx 12.39.Fe

A SCALAR OBJECT NEAR THE $(\omega\phi)$ THRESHOLD.

An interesting scalar object near the $(\omega\phi)$ threshold has been reported by BES Collaboration [1]. A search for a similar object at VES experiment was undertaken. Preliminary results of this study were presented at Meson-2008 conference [2]. This study is based on the statistics acquired in interactions of a π^- beam at the momentum of 27 GeV/c and 36.6 GeV/c on a *Be* target, in reaction

$$\pi^- p \to K^+ K^- \pi^+ \pi^- \pi^0 n. \quad (1)$$

The π^0 mesons were detected in the $\gamma\gamma$ mode. Identification of charged kaons was provided by a wide-aperture Cherenkov detector. The following selection criteria have been applied for the selection of the $(K^+K^-\pi^+\pi^-\pi^0)$ events. Events with two positive and two negative tracks and two unassociated showers in the electromagnetic calorimeter were selected. The effective mass of the two photon pair was requested in the range $(0.105, 0.165)$ GeV/c^2. Accepted pairs were subjected to $1C$ kinematic fit to the π^0 mass, and fitted π^0 parameters were used in the analysis. The total event energy was required to be greater than 25 GeV or greater than 34 GeV at beam momenta of 27 and 36.6 GeV/c, respectively. Events with identified e^+/e^- were excluded. Both K^+ and K^- were identified in Cherenkov detector. The invariant mass of (K^+K^-) pair is shown in Fig.1a, clear $\phi(1018)$ signal is seen. Two remaining charged tracks were considered as pions and taken together with the π^0. Invariant mass of the $(\pi^+\pi^-\pi^0)$ system is shown in Fig. 1b, clear $\omega(782)$ signal seen, it becomes more clean if the $m(K^+K^-)$ close to the $m(\phi)$ is requested (Fig.1c). If requirements on both $m(K^+K^-)$ and $m(\pi^+\pi^-\pi^0)$ are imposed, then accumulation of events near the $(\omega\phi)$ threshold is observed(Fig.1d).

Properties of the $(\omega\phi)$ system are demonstrated in Fig.2a. Events at $m(\omega\phi) < 1.975$ GeV/c^2 were selected. There are 380 events in this mass region. The t-distribution is shown in Fig.2a. The t-slope was estimated from an exponential fit, it is -6.45 ± 0.50 GeV^{-2}. This value is close to the expectation for the pion exchange.

Angular distributions, which are shown in Fig.2b and 2c, show that the expected angular dependencies for decays of vector resonances are observed. The *cosine* of the angle between the ω and ϕ analysers is shown in Fig.2d. It supports the hypothesis, that two vector resonances are produced from decay of a scalar system. However, a possibility of spin-parity 2^+ is not completely excluded.

CP1257, *Hadron 2009, Proceedings of the XIII International Conference*
edited by V. Crede, P. Eugenio, and A. Ostrovidov

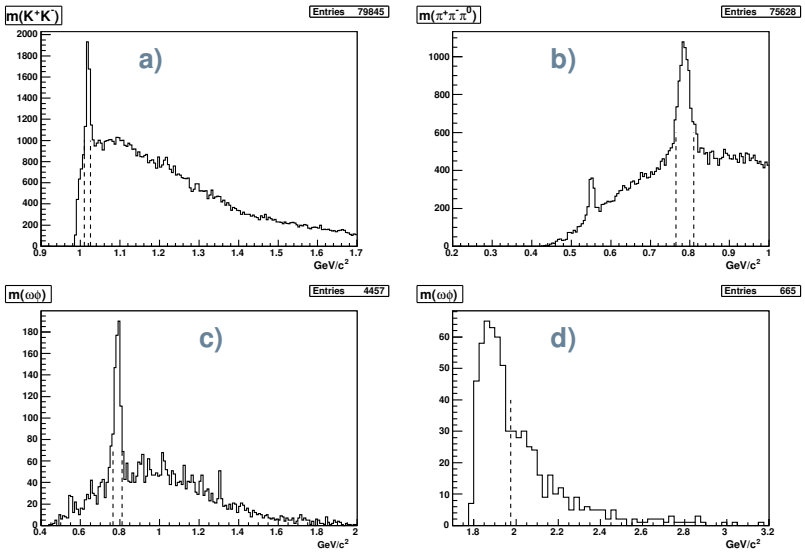

FIGURE 1. Invariant masses for $(K^+K^-\pi^+\pi^-\pi^0)$ system: a) $m((K^+K^-)$; b) $m(\pi^+\pi^-\pi^0)$; c) $m(\pi^+\pi^-\pi^0)$, selected events at $1.10 < m(K^+K^-) < 1.025$; d) $m((K^+K^-\pi^+\pi^-\pi^0)$ for selected events at $1.010 < m(K^+K^-) < 1.025$ and $0.765 < m(\pi^+\pi^-\pi^0) < 0.805\ GeV/c^2$.

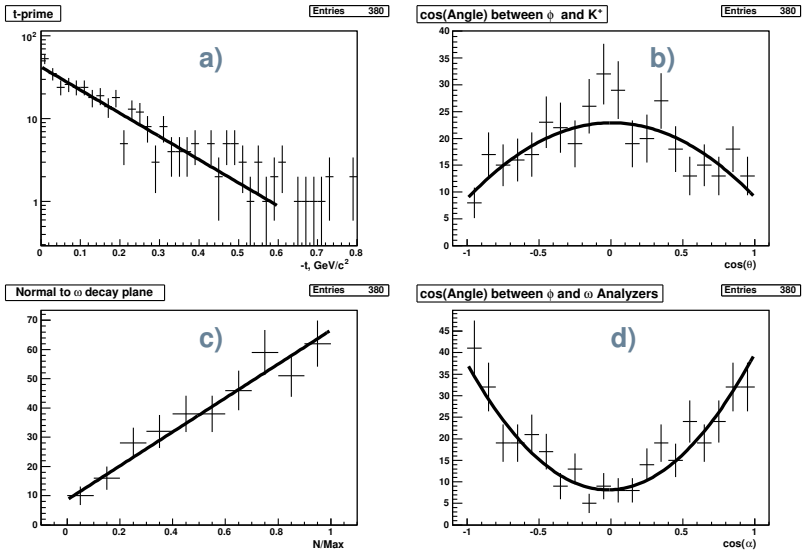

FIGURE 2. Distributions for the $(\omega\phi)$ system at $m(\omega\phi) < 1.975\ GeV/c^2$ a) $|t|$ distribution; b) $cos(\theta)$, θ is angle between direction of ϕ and the K^+ momentum in the ϕ rest frame; c) vector product of $p(\pi^+)$ by $p(\pi^-)$ in the ω rest frame; normalized to the maximum value; d) $cos(\alpha)$, α is angle between K^+ direction in ϕ rest frame and the normal to ω decay plane in the ω rest frame.

PARTIAL WAVE ANALYSIS.

Available statistics is sufficient for two-body partial wave analysis (PWA) with few waves:

- FLAT
- $J^P = 0^+, 2^+, 0^-$

PWA results are presented in Fig.3. One can see that the scalar wave dominates near the $(\omega\phi)$ threshold.

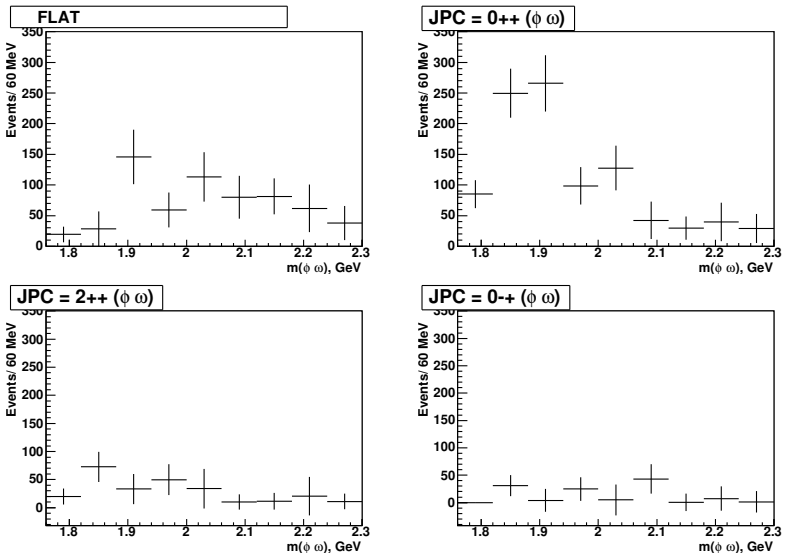

FIGURE 3. Intensities of partial waves in $(\omega\phi)$ system.

A similar system with two isosinglet vector mesons, namely the $(\omega\omega)$ system, has been analysed in VES experiment at the beam momentum of 27 GeV/c [3]. This system was subjected to Partial Wave Analysis.

The following 17 waves were included (η denotes the reflectivity):

	$(J^{PC})M^{\eta}$ JLS		$(J^{PC})M^{\eta}$ JLS
1.	$(0^{++})0^{-}$ 000	11.	$(0^{-+})0^{+}$ 011
2.	$(2^{++})0^{-}$ 202	12.	$(2^{-+})0^{+}$ 211
3.	$(2^{++})0^{-}$ 220	13.	$(1^{++})0^{+}$ 122
4.	$(2^{++})0^{-}$ 222	14.	$(3^{++})0^{-}$ 322
5.	$(2^{++})1^{-}$ 202	15.	$(2^{++})1^{+}$ 202
6.	$(4^{++})0^{-}$ 422	16.	$(4^{++})1^{+}$ 422
7.	$(4^{++})0^{-}$ 440	17.	FLAT
8.	$(4^{++})0^{-}$ 442		
9.	$(4^{++})0^{-}$ 422		
10.	$(6^{++})0^{-}$ 642		

PWA results for $(\omega\omega)$ system are presented in Fig.4.

Now we can compare intensities of scalar waves in $(\omega\phi)$ and $(\omega\omega)$ systems. The ratio of those intensities is presented in Fig.5. One can see, that the ratio of the number of events in scalar waves in $1.82 < m(\omega\phi) < 2.0$ GeV mass range is $N_{scalar}(\omega\phi)/N_{scalar}(\omega\omega) = 0.65 \pm 0.1$. This is a large value. For example

- similar ratio for $J^P = 2^+$ waves is 0.045 ± 0.01
- $\sigma(\pi^- p \to \phi n)/\sigma(\pi^- p \to \omega n) \approx 0.01$ at our beam energy region [4].

So we see strong violation of OZI rule in production of $(\omega\phi)$ scalar wave.

It worth mentioning that the violation of the OZI rule in decays of scalar mesons was predicted theoretically [5].

CONCLUSIONS.

With higher statistics and in another production process we confirm the observation of a resonance-like bump near the $(\omega\phi)$ threshold. Partial wave analysis confirms the scalar quantum numbers of this object.

Having the PWA results for the $\omega\phi$ and $(\omega\omega)$ systems at the beam momentum of 27 GeV/c, we compared the intensities of scalar waves in $(\omega\phi)$ and $(\omega\omega)$ channels. This comparison shows that OZI suppression is not observed.

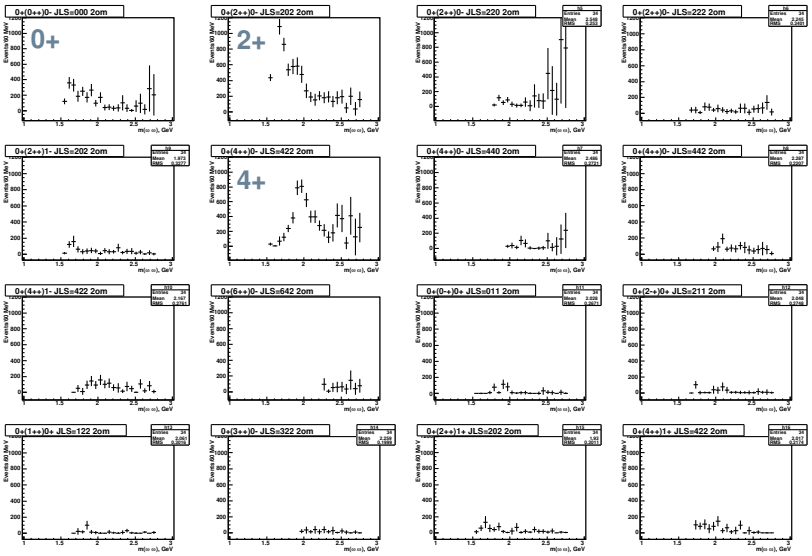

FIGURE 4. Intensities of partial waves in $(\omega\omega)$ system.

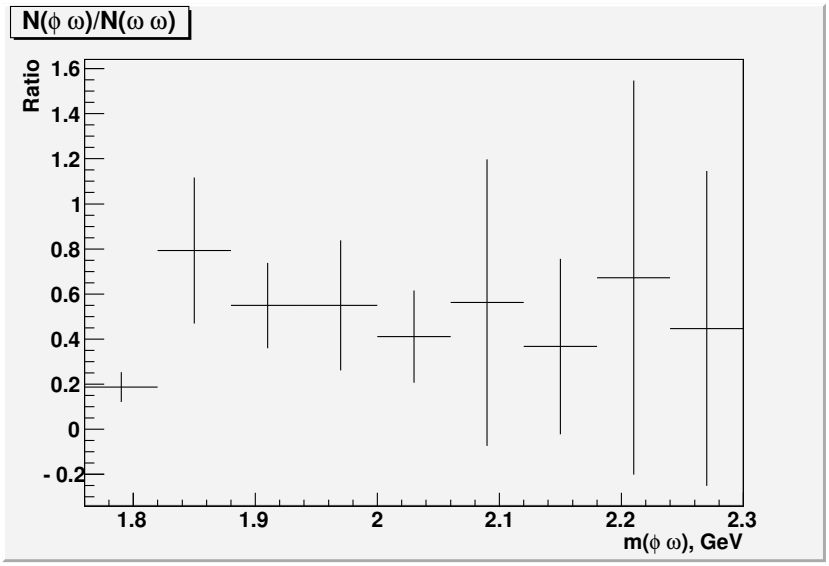

FIGURE 5. Ratio of the number of events in scalar waves, $N_{scalar}(\omega\phi)/N_{scalar}(\omega\omega)$. Differences in acceptances, luminosities and the branching ratio $BR(\phi \to K^+K^-)/BR(\omega \to \pi^+\pi^-\pi^0)$ are taken into account.

ACKNOWLEDGMENTS

This work is supported in part by the Russian Foundation of Basic Research grants RFBR 07-02-00631.

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