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PARTIAL WAVE ANALYSIS OF THE $K^+\overline{K}^o\pi^-$ SYSTEM PRODUCED IN THE REACTION $\pi^-p \to K^+\overline{K}^o\pi^-n$ AT 8 GeV/c*

S. Blessing, R. Crittenden, A. Dzierba, T. Marshall, S. Teige,† D. Zieminska
Physics Department, Indiana University, Bloomington, Indiana 47405

A. Birman,* S.U. Chung, D. Peaslee,‡ R. Fernow,
H. Kirk, S.D. Protopopescu, D. Weygand, H.J. Willutzki
Physics Dept., Brookhaven National Laboratory, Upton, New York 11973

A. Boehnlein, D. Boehnlein, J.H. Goldman, V. Hagopian, D. Reeves♮
Physics Department, Florida State University, Tallahassee, Florida 32306

Z. Bar-Yam, J. Dowd, W. Kern, E. King, H. Rudnicka, P. Rulon 3
Physics Department, Southeastern Massachusetts University, North Dartmouth, Massachusetts 02747

ABSTRACT

We have performed a partial wave analysis of the $K^+K^0_S\pi^-$ system produced in the reaction $\pi^-p \to K^+\overline{K}^o\pi^-n$ at 8 GeV/c. We present the results of the analysis of 30,740 events in the mass range 1.24 - 1.60 GeV/c^2, with $0.0 \leq -t < 1.0$ GeV^2/c^2. In the 1.28 GeV/c^2 mass region, we see evidence for a J^{PG}=0^{-+} resonance in addition to the resonant 1^{++} wave. We observe a 0^{-+} resonance and possibly a small 1^{++} resonance in the 1.42 GeV/c^2 region. We also observe a 1^{++} state near 1.5 GeV/c^2.

The 1.4 - 1.5 GeV/c^2 region of nonstrange mesons is a subject of great controversy. Various experiments studying the $K\overline{K}\pi$ and $\eta\pi\pi$ final states in hadronic reactions, hadronic J/ψ decay, and two-photon interactions have reported a state near 1.42 GeV/c^2 with J^{PC} determined alternatively as 0^{-+}[1,2] or 1^{++}.[3] The $K\overline{K}\pi$ spectrum observed in radiative J/ψ decay[4] and in one experiment studying hadronic interactions[5] is dominated by a

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† Present address: Department of Physics and Astronomy, Rutgers-The State University of New Jersey, Piscataway, NJ 08854

* Permanent address: Physics Department, Technion, Haifa 32000 Israel

‡ Permanent address: Physics Department, University of Maryland, College Park, MD 20742

♮ Present address: Fermilab, P.O. Box 500, Batavia, IL 60510

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broad structure near 1.45 GeV/c^2 with $J^{PC} = 0^{-+}$ sometimes interpreted as a glueball with a small admixture of quarks [6]. Our present experiment reveals the complicated structure of the $K\overline{K}\pi$ system in the mass range from 1.24 to 1.6 GeV/c^2.

We present results of a partial wave analysis of the $K^+K^0_S\pi^-$ system produced in the reaction $\pi^-p \rightarrow K^+\overline{K}^0\pi^-n$ at 8 GeV/c. A total of 30,740 events in the mass range 1.24 to 1.60 GeV/c^2 with $0.0 \leq -t < 1.0$ GeV^2/c^2 was collected using the BNL Multiparticle Spectrometer facility. The trigger required an increase in the number of charged particles from two to four, a forward going charged particle with momentum greater than 1.5 GeV/c^2 which was not a pion, and no signal from a lead-scintillator box surrounding the target to veto slow charged particles. Further experimental details can be found in Reference 7.

The observed $K^+K^0_S\pi^-$ mass spectrum is shown in Figure 1. The distribution is dominated by two peaks at 1.28 GeV/c^2 and 1.42 GeV/c^2. A smaller peak is also seen near 1.51 GeV/c^2. A fit of three Breit-Wigner functions and a polynomial background gives the following mass, width and number of events for each peak:

Mass (MeV/c^2)	Width (MeV/c^2)	Number of Events
1285±1	22±2	4750±100
1419±1	66±2	8800±200
1512±4	35±15	600±200

The $K^+\overline{K}^0\pi^-$ system was described as a superposition of states characterized by spin, parity and G-parity, J^{PG}, absolute value of the projection of spin on the quantization axis, M, and reflectivity (naturality of the exchanged particle), η. We applied the parametrization of the spin density matrix of Chung and Trueman [8] which ensures that the conditions of positivity, parity conservation, and rank two are automatically satisfied with the minimum number of parameters.

We assumed that the final three meson system is produced in a two step process involving two isobars: $K^*(890)$ and $a_0(980)$ [was $\delta(980)$]. For a given $K^+\overline{K}^0\pi^-$ mass, the state is fully specified by five variables: the isobar mass and the polar and azimuthal angles for the primary and secondary decays $\{m, \theta, \phi, \alpha, \beta\}$.

The intensity distribution is described by

$$I(\tau) = \sum_{a} \rho_{aa'} A_a(\tau) A^*_{a'}(\tau)$$

where $a = \{J^{PG}M^{\eta}(\text{isobar})\}$ and $\tau = \{\mathrm{m}, \theta, \phi, \alpha, \beta\}$. The A_a are decay amplitudes calculated from the data which contain Breit-Wigner functions for the secondary decays. The spin-density matrix is given by

$$\rho_{aa'} = \sum_{k=1}^{2} V_{ak} V^{*}_{a'k}$$

where the V_{ak} are complex parameters obtained in the fit and are related to production amplitudes; k allows for spin flip and spin non-flip of the nucleon.

The following waves were needed to fit the data: $J^{PG}= 0^{-+}$, 1^{++}, 1^{+-}, and 1^{--} with all possible values of M and $J^{PG}M^{\eta}=1^{-+}0^{-}$. For $J^{PG}=0^{-+}$ and 1^{++} both decay channels, $a_0\pi$ and K^*K, were allowed. However, we found that the waves $1^{++}(a_0)$ and $1^{++}(K^*)$ were too much alike to distinguish between them below the K^*K threshold and only one of them could be included at a time. We also found that in the region $1.40 < M(K^+\overline{K}^{\circ}\pi^-) < 1.60$ GeV/c^2, where both $1^{++}(a_0)$ and $1^{++}(K^*)$ could be included in the fit, $1^{++}(a_0)$ was small. The best choice was to allow $1^{++}(a_0)$ for $M(K^+\overline{K}^{\circ}\pi^-) < 1.34$ GeV/c^2 and $1^{++}(K^*)$ for $M(K^+\overline{K}^{\circ}\pi^-) > 1.34$ GeV/c^2. The waves $0^{-+}(a_0)$ and $0^{-+}(K^*)$ were varied simultaneously with an arbitrary degree of coherence between them.

The analysis was done for $1.24 \leq M(K^+\overline{K}^{\circ}\pi^-) < 1.60$ GeV/c^2 in 20 MeV/c^2 mass bins and three t bins: $0.0 \leq -t < 0.2$ GeV^2/c^2, $0.2 \leq -t < 0.45$ GeV^2/c^2, and $0.45 \leq -t < 1.0$ GeV^2/c^2.

Figure 2 shows the comparison between the data and the PWA fit for $1.40 \leq M(K^+\overline{K}^{\circ}\pi^-) < 1.42$ GeV/c^2 and $0.2 \leq -t < 0.45$ GeV^2/c^2. Our PWA fit reproduces the data very well.

Figure 3 shows the major spin-parity components of the $K^+\overline{K}^{\circ}\pi^-$ system in terms of the effective number of events attributed to each spin-parity state. The observed peak in the $K^+\overline{K}^{\circ}\pi^-$ mass spectrum at ~ 1.42 GeV/c^2 has contributions from the 0^{-+}, 1^{++}, and 1^{+-} waves. Figure 4 shows the contribution of the $0^{-+}(a_0)$ and $0^{-+}(K^*)$ waves. There is a small peak in $0^{-+}(a_0)$ at ~ 1280 MeV/c^2 along with the larger peak at ~ 1.40 GeV/c^2 in both $0^{-+}(a_0)$ and $0^{-+}(K^*)$. The main peaks in $0^{-+}(a_0)$ and $0^{-+}(K^*)$ are offset by ~ 50 MeV/c^2.

The phases of $0^{-+}(a_0)$ and $0^{-+}(K^*)$ with respect to $1^{++}0^{+}(K^*)$, for the three t regions discussed, are shown in Figure 5. For all three t regions, the waves $0^{-+}(a_0)$ and $1^{++}0^{+}(K^*)$ are highly coherent and their relative phase is well measured. For $0.2 \leq -t < 0.45$ GeV^2/c^2 and $0.45 \leq -t < 1.0$ GeV^2/c^2, the phase of $0^{-+}(a_0)$ is rising through about 300 degrees in the mass range 1.35 to 1.50 GeV/c^2, and then begins to fall. This phase variation is evidence of a resonant $0^{-+}(a_0)$ wave and predominantly nonresonant $1^{++}0^{+}(K^*)$ wave at $-t$ above 0.2 GeV^2/c^2. Both the phase motion and the intensity distribution of the $0^{-+}(a_0)$ wave are consistent with the presence of one resonance near 1.40 GeV/c^2 or two resonances between 1.40 and 1.50 GeV/c^2. Contrary to the two larger $-t$ regions, for the low $-t$ region ($0.0 \leq -t < 0.2$ GeV^2/c^2) the phase of $0^{-+}(a_0)$ relative to $1^{++}0^{+}(K^*)$ is almost constant. Therefore, the possibility of a resonance in 1^{++} at $-t$ below 0.2 GeV^2/c^2 cannot be ruled out. The phase of $0^{-+}(K^*)$ for $0.2 \leq -t < 0.45$ GeV^2/c^2 and $0.45 \leq -t < 1.0$ GeV^2/c^2 seems to be similiar to the phase of $0^{-+}(a_0)$, although not as well measured.

In the 1200 - 1350 MeV/c^2 $K^+\overline{K}^0\pi^-$ mass region, we see a 1^{++} resonance at $\sim$ 1285 MeV/c^2 which is identified as the $f_1(1285)$ [was $D(1285)$] along with a 0^{-+} resonance at $\sim$ 1280 MeV/c^2, the $\eta(1275)$.

In the 1350 - 1500 MeV/c^2 region, the 0^{-+} resonance composes $\sim$ 50 % of the observed peak. (The possibility of two resonances is not excluded. It is unclear whether $a_0\pi$ and K^*K are different decay modes of the same resonance(s) or different resonances.) A 1^{+-} resonance composes $\sim$ 20% of the observed peak and a 1^{++} resonance is seen only at $0.0 \leq -t < 0.2$ GeV^2/c^2 and composes $\sim$ 10 % of the observed peak. The balance of the observed peak is non-resonant 1^{++} K^*K threshold effect and small amounts of 1^{-+} and 1^{--}.

Above 1500 MeV/c^2, we see a 1^{++} resonance at $\sim$ 1560 MeV/c^2, the $f_1(1530)$ [was $D'(1530)$].

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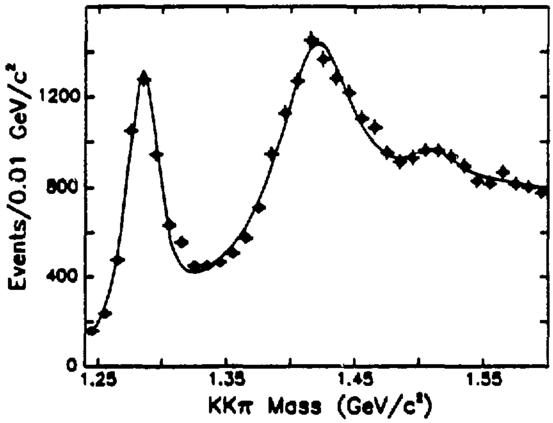

Figure 1. Observed $K^+K^0_S\pi^-$ mass spectrum, $0.0 \leq -t < 1.0$ GeV^2/c^2.

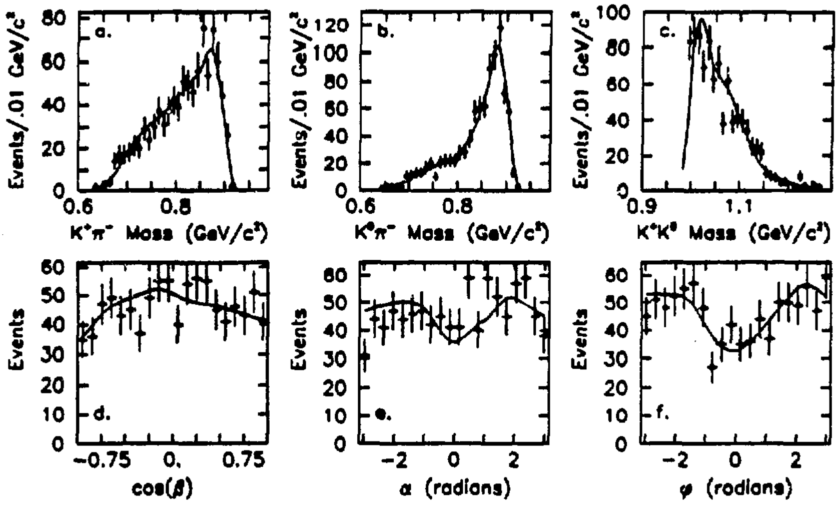

Figure 2. Comparison between data and the PWA fit of two-body masses and angular distributions of $K^+\pi^-$ for $1.40 \leq M(K\overline{K}\pi) < 1.42$ GeV/c^2, $0.2 \leq -t < 0.45$ GeV^2/c^2.

a. $K^+\pi^-$ mass b. $\overline{K^*}\pi^-$ mass

c. $K^+\overline{K}^0$ mass d. Polar angle of primary decay

e. Azimuthal angle of primary decay f. Azimuthal angle of secondary decay

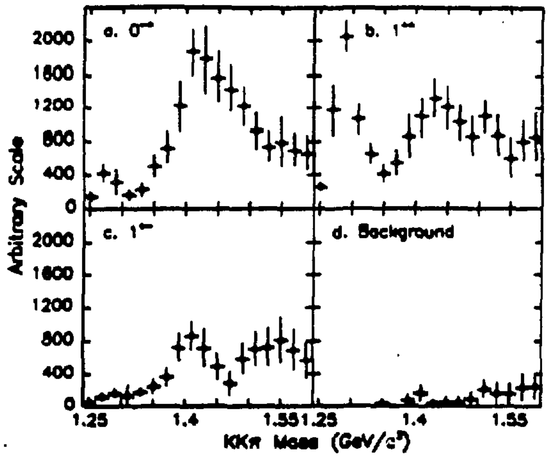

Figure 3. Major spin-parity components of the $K^+\overline{K}^*\pi^-$ system, $0.0 \leq -t < 1.0$ GeV^2/c^2.
a. 0^{-+} (a_0) and (K^*)
b. 1^{++} (a_0) and (K^*)
c. 1^{+-}(K^*)
d. Background

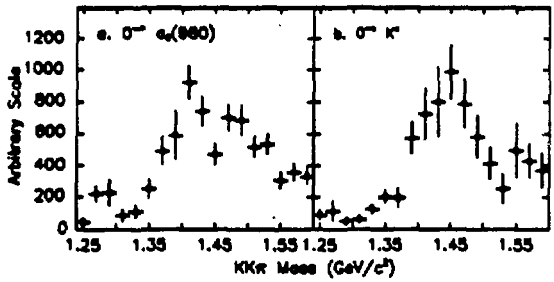

Figure 4. Contribution of 0^{-+} waves, $0.0 \leq -t < 1.0$ GeV^2/c^2.
a. 0^{-+}(a_0)
b. 0^{-+}(K^*)

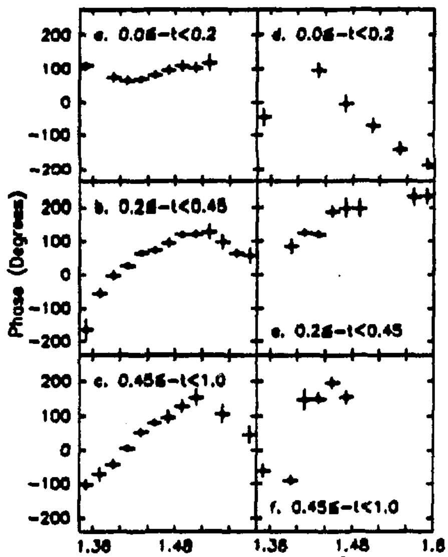

Figure 5. Phases with respect to $1^{++}0^+(K^*)$ for the three t regions discussed in the text. If the density matrix element is within two standard deviations of zero, the corresponding phase is not shown.
a-c. $0^{-+}(a_0)$
d-f. $0^{-+}(K^*)$

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