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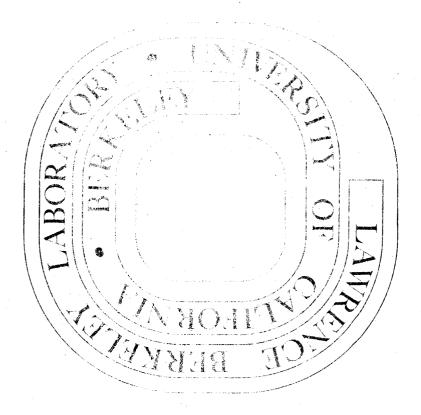
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PRODUCTION AND DECAY OF BOSON RESONANT STATES IN π^- + p INTERACTIONS AT 3.2 GeV/c

Richard I. Hess, Suh Urk Chung, Orin I. Dahl Lyndon M. Hardy, Janos Kirz, and Donald H. Miller

July 3, 1964

PRODUCTION AND DECAY OF BOSON RESONANT STATES IN $\pi^2 + p$ INTERACTIONS AT 3.2 GeV/c*

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(Presented by Donald H. Miller)

July 3, 1964

ABSTRACT

Production and decay correlations for the $\pi\omega$ resonance at 1220 MeV (B meson), the $\pi\rho$ state at 1090 MeV (A₁ meson), and the $\pi\rho$ state at 1310 MeV (A₂ meson) have been studied in detail. Interpretations are presented in terms of possible quantum number assignments. In addition, evidence for the existence of other decay modes for the A₂ meson state, i.e., A₂ + $K\overline{K}$ and A₂ + $\pi\eta$ are discussed.

^{*}Work sponsored by the U. S. Atomic Energy Commission.

In a continuing study of the interactions of π^- mesons at 1.5 to 4.2 GeV/c, we have investigated production and decay of strangeness S=0 boson resonant systems. We discuss the significant results obtained to date.

I.
$$\pi^{2}p \rightarrow \pi^{4}\pi^{0}\pi^{7}\pi^{7}p$$

The effective-mass distributions were plotted for all pion combinations at 3.2 and 4.2 GeV/c. Marked structure was observed only in the $M(\pi^{+}\pi^{-}\pi^{0})$ distributions shown in Fig 1, a and b. The ω meson is produced copiously, although the intermediate-state ω N*(1238) does not contribute strongly as in the analogous $\pi^{+}p \rightarrow \omega \pi^{+}p$ reaction. As reported earlier, ¹ the possibility for a resonant $\pi\omega$ interaction was investigated by plotting separately the $M(\pi^{+}\pi^{-}\pi^{0}\pi^{-})$ distributions for events with either of the two $M(\pi^{+}\pi^{-}\pi^{0})$ combinations in the ω interval (750 to 810 MeV). The results are given in Fig. 1, c and d. At 3.2 GeV/c, a large peak is observed at 1220 MeV with full-width $\Gamma = 180\pm30$ MeV; at 4.2 GeV/c, the effect has essentially disappeared. To illustrate that this peak, called the B meson, ² is associated with ω events, a detailed plot of the data is shown in Fig. 2, c, d, and e for several intervals in $M(\pi^{+}\pi^{-}\pi^{0})$.

General studies of the production and decay correlations for the $\pi\omega$ peak have revealed no convincing evidence for a unique J^P assignment. A, Several groups have looked for $\pi^{\pm}\pi^{0}$ enhancements at 1220 MeV in the reactions $\pi^{\pm}p \to \pi^{\pm}\pi^{0}p$, but observed none. The decay $B \to K\overline{K}$ is more difficult to detect than $B \to \pi\omega$ (see discussion below); no evidence for the decay $B \to K\overline{K}$ has been obtained. Neither decay is forbidden by G or A parity alone, so that if the B enhancement represents a pure state, such decays are likely forbidden by conservation of J^{PG} . Since the neutral $\pi\omega$ system has C = -1, decay into $\pi\pi$ and $K\overline{K}$ would be allowed for $J^{P} = 1^{-}$, 3 etc; in addition, decay of a 0^{+}

state into $\pi\omega$ is forbidden. Consequently, comparison of the observed internal correlations with the predictions for $J^P=0^-$, 1^+ , 2^- , and 2^+ are particularly interesting. The predicted correlations for the simplest forms for decay matrix elements are summarized in Table I, where θ is the angle between the normal to the ω decay plane and the momentum of the recoil pion evaluated in the ω rest frame.

Table I. Internal correlations for several J^P assignments for the B meson

State	Angular Correlation
0	cos ² 0
1+	Ą
1	$\sin^2 \theta$
2+	sin ² 0
2	a + b cos ² 0

The data are shown in Fig. 3 for several intervals of $\pi\omega$ mass. In each case the $M(\pi^{+}\pi^{-}\pi^{0})$ combination closest to 784 MeV was arbitrarily considered as the ω ; however, the result is insensitive to this choice. As a crude correction for background, the average of the distributions for the two adjacent intervals was subtracted. The remaining events give poor fits to either the $\sin^{2}\theta$ or $\cos^{2}\theta$ distributions.

For completeness, the $\pi\eta$ mass distribution is shown in Fig. 2, a and b together with a control region. Although a slight enhancement appears near 1300 MeV, the data suggest that the observed $\pi\eta$ events do not result primarily from decay of an unstable boson.

π̄p → π[†]π̄π̄p

The effective-mass distributions for $\pi^{\pm}p$ and $\pi^{\pm}\pi^{-}$ combinations indicate that most $\pi^{\dagger}\pi^{-}\pi^{-}p$ events in the 3- to 4.2-GeV/c region are produced through the intermediate states $\pi^{-}\pi^{-}N^{*++}$ (1238) and $\rho^{0}\pi^{-}p$. In a study of $\pi^{\dagger}p \rightarrow \pi^{\dagger}\pi^{\dagger}\pi^{\dagger}p$ final states at 3.65 GeV/c, Goldhaber et al. 5 demonstrated the existence of a strong $\pi\rho$ interaction (the A enhancement) in the interval 4.0 to 4.4 GeV, and suggested that it might represent two unresolved peaks. The $\pi^{-}\rho^{-}$ mass distribution for the 3.2-GeV/c events is plotted in Fig. 4, where two clearly resolved peaks are apparent. The lower peak (A_A) occurs at 1030 \pm 10 MeV with $\Gamma\approx$ 100 MeV, and the upper (A₂) at 1310 MeV with $\Gamma\approx$ 30 MeV. Since the peaks are decreased little when events with $\Delta^{2}(p) \leq 0.86 (\text{GeV/c})^{2}$ are plotted separately, we assume they are produced in peripheral collisions involving ρ exchange.

The Dalitz plots associated with these events have been discussed elsewhere. Since the JP assignment for the 1310-MeV state may be determined independently (see below), we comment only on the 1080-MeV enhancement. Based on selection criteria which eliminated (a) the N in the final states and (b) events with $\Delta^2(p) > 0.8 (\text{GeV/c})^2$, the Dalitz plot appeared consistent with JP=0, under the assumption that the 1080-MeV peak represented a pure state. However, subsequent study indicates that the distribution in P₀ Q (where Q is the normal to the $\pi\rho$ decay plane, and P₀ the momentum of the incident pion in the $\pi\rho$ c.m. system) contains a significant admixture of $\sin^2\theta$, in contradiction with a 0 assignment. In addition, contamination from events associated with the high-energy tail of the N tends to populate the edges of the Dalitz plot so that its significance is obscure. We conclude that the present data provide no convincing support for any particular JP assignment.

A study of those features of the Dalitz plot common to both $\pi^+ p$ and $\pi^- p$ production of the 1080-MeV peak would be useful.

III. $\pi p \rightarrow K\overline{K}N$

Because of the strong selection rules governing decay of unstable bosons into $K\overline{K}$, the K_4K_4n and K^*K_4p events are especially important. The $\overline{K}N$ and KK mass distributions at 3.2 GeV/c are given in Fig. 5, a, b, c, and d. In addition to RN peaks corresponding to decay of the intermediate state $K^{9}Y_{1}^{*}$ (1520), strong peaks are observed in the $K_{1}K_{1}$ and $K^{T}K_{1}$ systems at 1310 MeV. Since (a) these peaks correspond closely in position and width to the 1340-MeV mp peak and (b) the distribution in nucleon momentum-transfer (not shown) are also similar, it appears reasonable to assume that they represent alternative decay modes of the same unstable boson. The only assignments consistent with both $K^{T}K_{4}$ and $K_{4}K_{4}$ decays are $J^{P}=0^{+}, 2^{+}, 4^{+}$, etc; since 3π decay of a $J^{P} = 0^{+}$ state is forbidden, the lowest allowed assignment is JPG = 2+-. The Dalitz plot for the 1310-MeV peak is consistent with this assignment. 6 A rough estimate of the relative path lengths measured for the $\pi^- \rho$ and $K^- K_{\rho}$ events leads to $(A_2^- \to K \overline{K})/(A_2^- \to \pi \rho) = 30 \pm 7\%$. About half of the π^- path length has been studied at 4.2 GeV/c; consequently, the KR peak at 1310-MeV in Fig. 5f indicates that the production cross section for this state has decreased by a factor of about three.

Despite the large peak at 1310 MeV, we have looked for the decays $f_0(1250 \text{ MeV}) \rightarrow K_1K_1$ and $B(1220 \text{ MeV}) \rightarrow K^*K_1$. No shoulder is apparent on the low-mass side of the 1310-MeV peak either in the distributions for all events in Fig. 5, b and d or when the low momentum-transfer events are plotted separately. From this we estimate that $(B \rightarrow K^*K^0)/(B \rightarrow \pi\omega)$ is less

than 10%. Since we have not measured two prongs at 3.2 GeV/c, a similar estimate for the f is not possible.

IV.
$$\pi^- p + K \overline{K} \pi N$$

The effective-mass distributions for all pairs in this final state demonstrate that many events represent decay of the intermediate states $K\pi Y_0^*$ (1520) and $NK\overline{K}^*$ or $N\overline{K}K^*$. No evidence for production of the 1310-MeV boson (A2) was observed in the $K\overline{K}$ distributions.

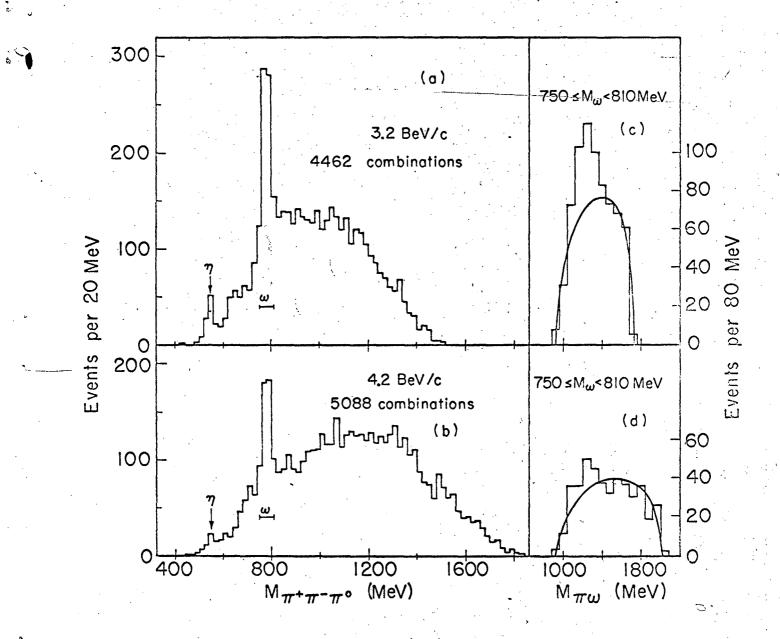
To search for bosons whose decay into $K\overline{K}$ might be forbidden, we divided the events into $(K\overline{K}\pi)^0$ and $(K\overline{K}\pi)^-$ and plotted these group separately in Figs. 6a, b. The mass distribution for the neutral combinations tends to peak strongly at 1430 MeV, producing a marked deviation from the phase-space prediction. The same effect persists in the low-momentum-transfer average, $\Delta^2(n) \leq 1.2$ (GeV/c)². This enhancement cannot be a kinematic reflection of the $K^*Y^*_0$ (1520), since the Y^*_0 (1520) is observed primarily in the pK $(K\pi)^2$ events. If it were associated with the K^* production mechanism, it is likely that a similar peak would appear in the $(K\overline{K}\pi)^-$ system. We conclude that the peak at 1430 MeV with $\Gamma\approx$ 80 MeV probably represents a valid $K\overline{K}\pi$ effect. In a study of $p\overline{p}$ annihilations at rest, Armenteros et al. 7 observed a $(K\overline{K}\pi)^0$ peak at 1440 MeV with $\Gamma\approx$ 60 MeV. It is likely that both peaks represent the same effect. If they result from decay of an unstable boson, the absence of any enhancement in $(K\overline{K}\pi)^-$ suggests the assignment $\Gamma=0$.

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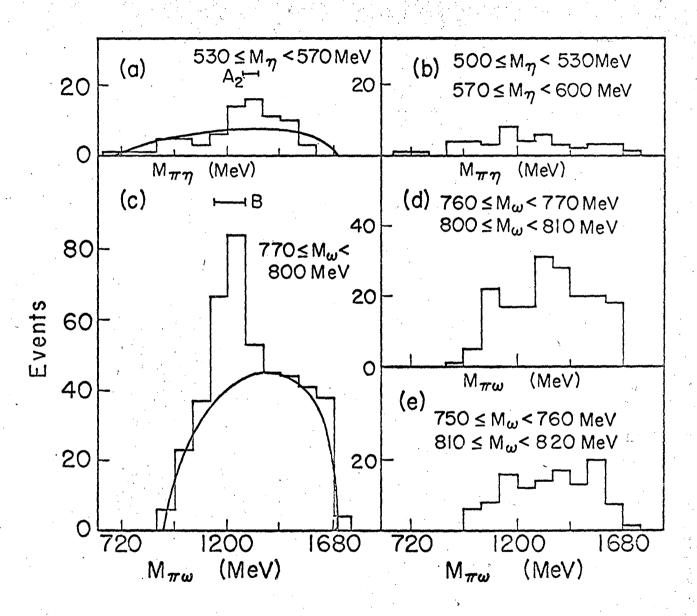
FIGURE LEGENDS

- Fig. 4. Effective-mass distributions for $\pi^{\dagger}\pi^{-\pi^{0}}$ combinations at (a) 3.2 GeV/c and (b) 4.2 GeV/c. The $\pi\omega$ effective masses are also plotted assuming that all $\pi^{\dagger}\pi^{-\pi^{0}}$ masses in the 750 to 810-MeV interval are possible ω mesons.
- Fig. 2. Effective-mass distributions for (a, b) πη combinations and (c, d, e) πω combinations at 3.2 GeV/c.
- Fig. 3. Distribution in $\cos\theta$ for 3.2 GeV/c events with several intervals in $\pi\omega$ mass, and $770 \le M_{\odot} < 800$ MeV.
- Fig. 4. Effective-mass distributions for $\pi^-\rho^0$ events at 3.2 GeV/c with $600 \le M_{\rho} < 850$ MeV. Events with $M(\pi^+p)$ in N^{*++} interval have been eliminated.
- Fig. 5. Effective-mass distributions for NR and KR combinations in KRN final states at 3.2 and 4.2 GeV/c.
- Fig. 6. Effective-mass distributions for $K\overline{K}\pi$ combinations in $K\overline{K}\pi N$ final states at 3.2 GeV/c.

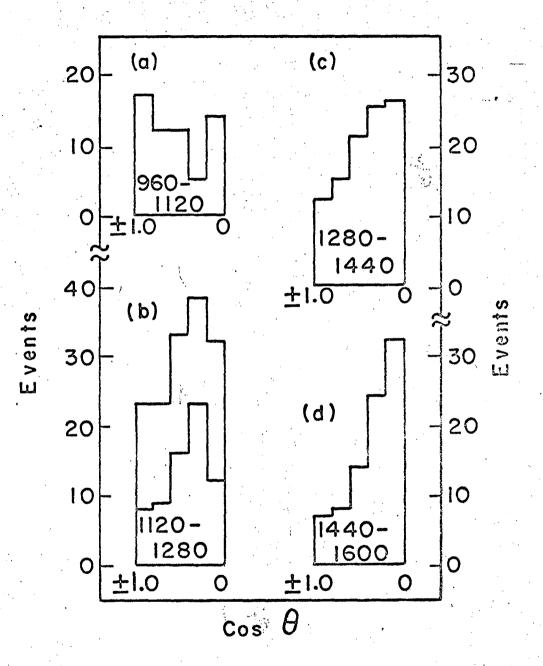


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Fig. 1

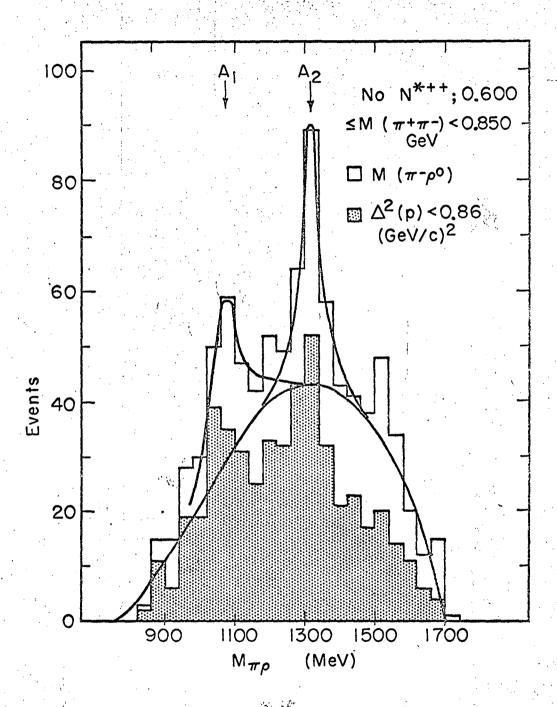


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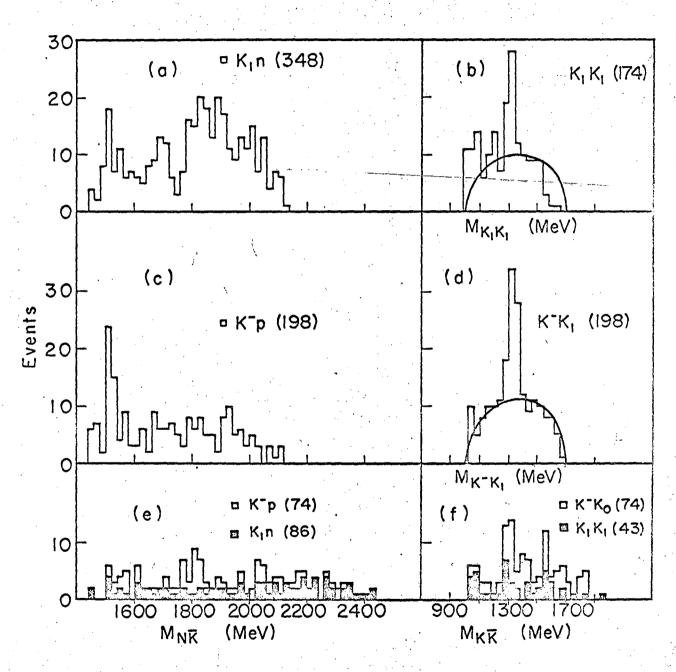
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Fig. 3



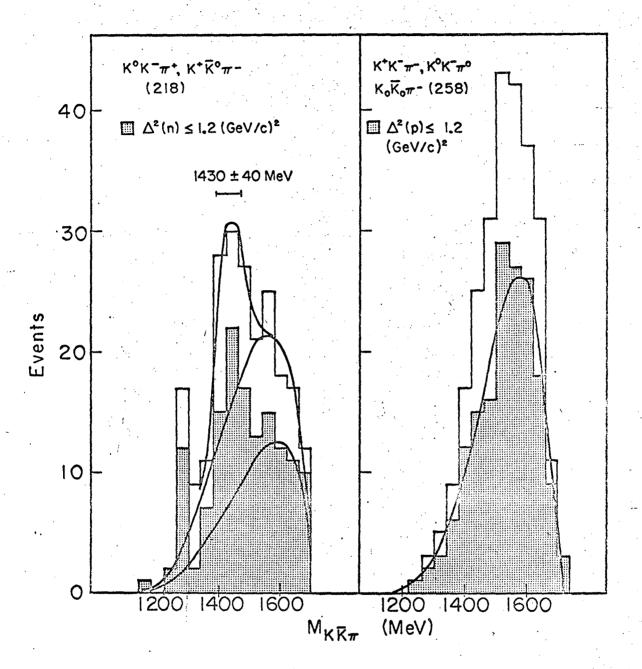
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Fig. 4



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Fig. 5



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