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Proceedings of the International Conference on
High Energy Physics - Dubna, USSR, 1964.

UCRL-11443

UNIVERSITY OF CALIFORNIA

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Berkeley, California

AEC Contract No. W-7405-eng-48

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

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(Presented by Donald H. Miller)

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ABSTRACT

Production and decay correlations for the $\pi\omega$ resonance at 1220 MeV (B meson), the $\pi\rho$ state at 1090 MeV (A_1 meson), and the $\pi\rho$ state at 1310 MeV (A_2 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 A_2 meson state, i.e., $A_2 \to K\bar{K}$ and $A_2 \to \pi\eta$ 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. $\pi^- p \rightarrow \pi^+ \pi^0 \pi^- \pi^- p$

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 $\omega N^*(1238)$ 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 $\Gamma = 180 \pm 30$ 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.[1,3] Several groups have looked for $\pi^\pm\pi^0$ enhancements at 1220 MeV in the reactions $\pi^\pm p \rightarrow \pi^\pm \pi^0 p$, but observed none. The decay $B \rightarrow K\bar{K}$ is more difficult to detect than $B \rightarrow \pi\omega$ (see discussion below); no evidence for the decay $B \rightarrow K\bar{K}$ has been obtained. Neither decay is forbidden by G or A parity[4] 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 $K\bar{K}$ 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^-	$\cos^2\theta$
1^+	1
1^-	$\sin^2\theta$
2^+	$\sin^2\theta$
2^-	$a + b\cos^2\theta$

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.

II. $\pi^- p \to \pi^+\pi^-\pi^- p$

The effective-mass distributions for $\pi^\pm p$ and $\pi^\pm\pi^-$ combinations indicate that most $\pi^+\pi^-\pi^- p$ 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 $\pi^+ p \to \pi^+\pi^+\pi^+\pi^- p$ 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 1.0 to 1.4 GeV, and suggested that it might represent two unresolved peaks. The $\pi^-\rho^0$ 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_1) occurs at 1080 ± 10 MeV with $\Gamma \approx 100$ MeV, and the upper (A_2) at 1310 MeV with $\Gamma \approx 80$ MeV. Since the peaks are decreased little when events with $\Delta^2(p) \leq 0.86 (\mathrm{GeV}/c)^2$ 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.[6] Since the J^P 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 $N^{*++}\pi^-\pi^-$ final states and (b) events with $\Delta^2(p) > 0.8 (\mathrm{GeV}/c)^2$, the Dalitz plot appeared consistent with $J^P = 0^-$, under the assumption that the 1080-MeV peak represented a pure state. However, subsequent study indicates that the distribution in $\underset{\sim}{p}_0 \cdot \underset{\sim}{q}$ (where $\underset{\sim}{q}$ is the normal to the $\pi\rho$ decay plane, and $\underset{\sim}{p}_0$ 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 J^P 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. $\pi^- p \rightarrow K\bar{K}N$

Because of the strong selection rules governing decay of unstable bosons into $K\bar{K}$, the K_1K_1n and K^-K_1p events are especially important. The $\bar{K}N$ and $K\bar{K}$ mass distributions at 3.2 GeV/c are given in Fig. 5, a, b, c, and d. In addition to $\bar{K}N$ peaks corresponding to decay of the intermediate state $K^0Y_0^*(1520)$, strong peaks are observed in the K_1K_1 and K^-K_1 systems at 1310 MeV. Since (a) these peaks correspond closely in position and width to the 1310-MeV $\pi\rho$ 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^-K_1 and K_1K_1 decays are $J^P = 0^+, 2^+, 4^+$, etc; since 3π decay of a $J^P = 0^+$ state is forbidden, the lowest allowed assignment is $J^{PG} = 2^{+-}$. 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_0 events leads to $(A_2^- \rightarrow K\bar{K})/(A_2^- \rightarrow \pi\rho) = 30 \pm 7\%$. About half of the π^- path length has been studied at 4.2 GeV/c; consequently, the $K\bar{K}$ 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_0 is not possible.

IV. $\pi^- p \to K\bar{K}\pi N$

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 $NK\bar{K}^*$ or $N\bar{K}K^*$. No evidence for production of the 1310-MeV boson (A_2) was observed in the $K\bar{K}$ distributions.

To search for bosons whose decay into $K\bar{K}$ might be forbidden, we divided the events into $(K\bar{K}\pi)^0$ and $(K\bar{K}\pi)^-$ 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 events, $\Delta^2(n) \leq 1.2\ (\mathrm{GeV}/c)^2$. This enhancement cannot be a kinematic reflection of the $K^*Y_0^*(1520)$, since the $Y_0^*(1520)$ is observed primarily in the $pK^-(K\pi)^0$ events. If it were associated with the K^* production mechanism, it is likely that a similar peak would appear in the $(K\bar{K}\pi)^-$ system. We conclude that the peak at 1430 MeV with $\Gamma \approx 80$ MeV probably represents a valid $K\bar{K}\pi$ effect. In a study of $p\bar{p}$ annihilations at rest, Armenteros et al.[7] observed a $(K\bar{K}\pi)^0$ peak at 1410 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 $(KK\pi)^-$ suggests the assignment $I = 0$.

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FIGURE LEGENDS

Fig. 1. Effective-mass distributions for $\pi^+\pi^-\pi^0$ combinations at (a) 3.2 GeV/c and (b) 4.2 GeV/c. The $\pi\omega$ effective masses are also plotted assuming that all $\pi^+\pi^-\pi^0$ masses in the 750 to 810-MeV interval are possible ω mesons.

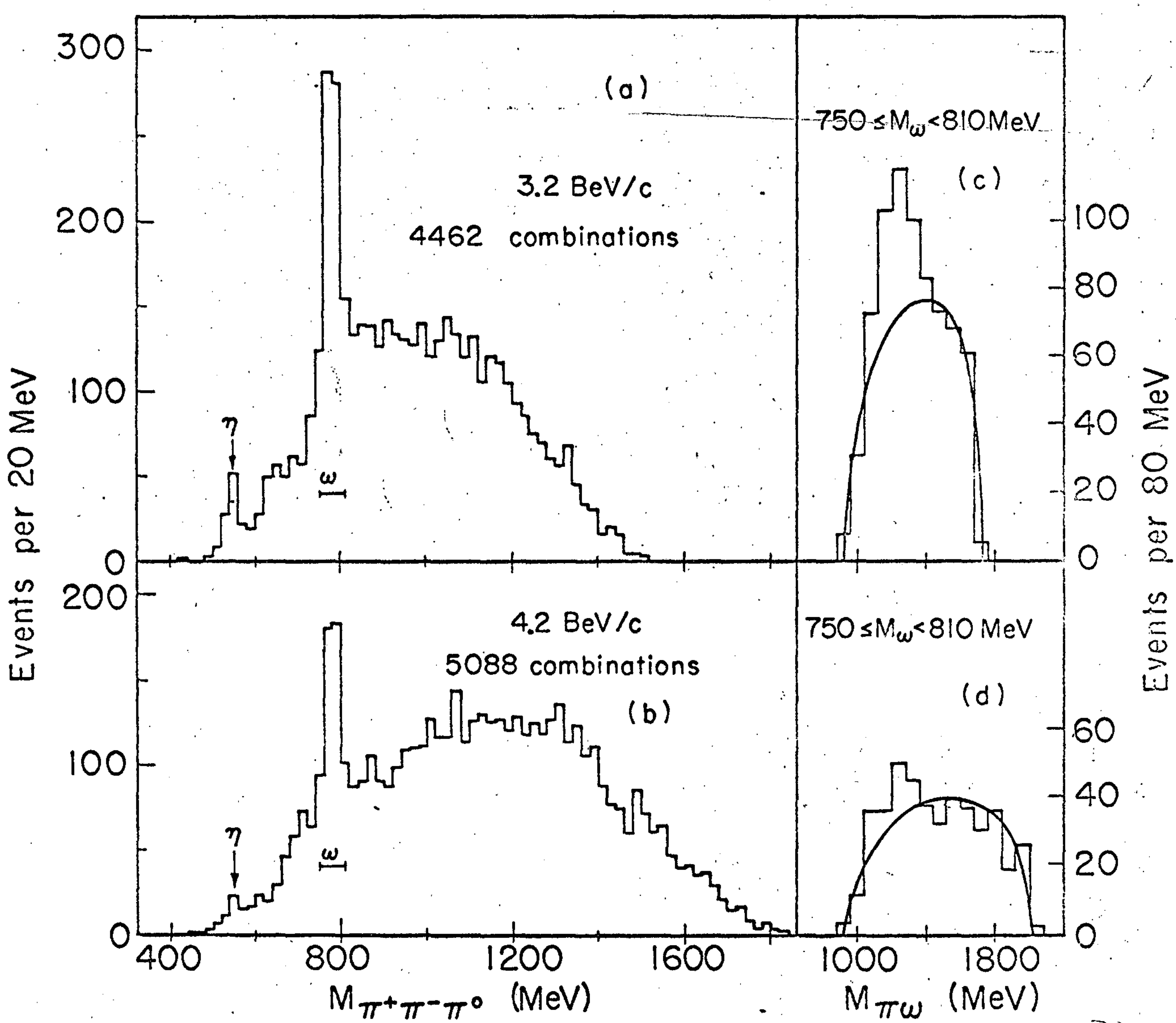
Fig. 2. Effective-mass distributions for (a, b) $\pi\eta$ combinations and (c, d, e) $\pi\omega$ combinations at 3.2 GeV/c.

Fig. 3. Distribution in $\cos\theta$ for 3.2 GeV/c events with several intervals in $\pi\omega$ mass, and $770 \leq M_\omega < 800$ MeV.

Fig. 4. Effective-mass distributions for $\pi^-\rho^0$ events at 3.2 GeV/c with $600 \leq M_\rho < 850$ MeV. Events with $M(\pi^+ p)$ in N^{*++} interval have been eliminated.

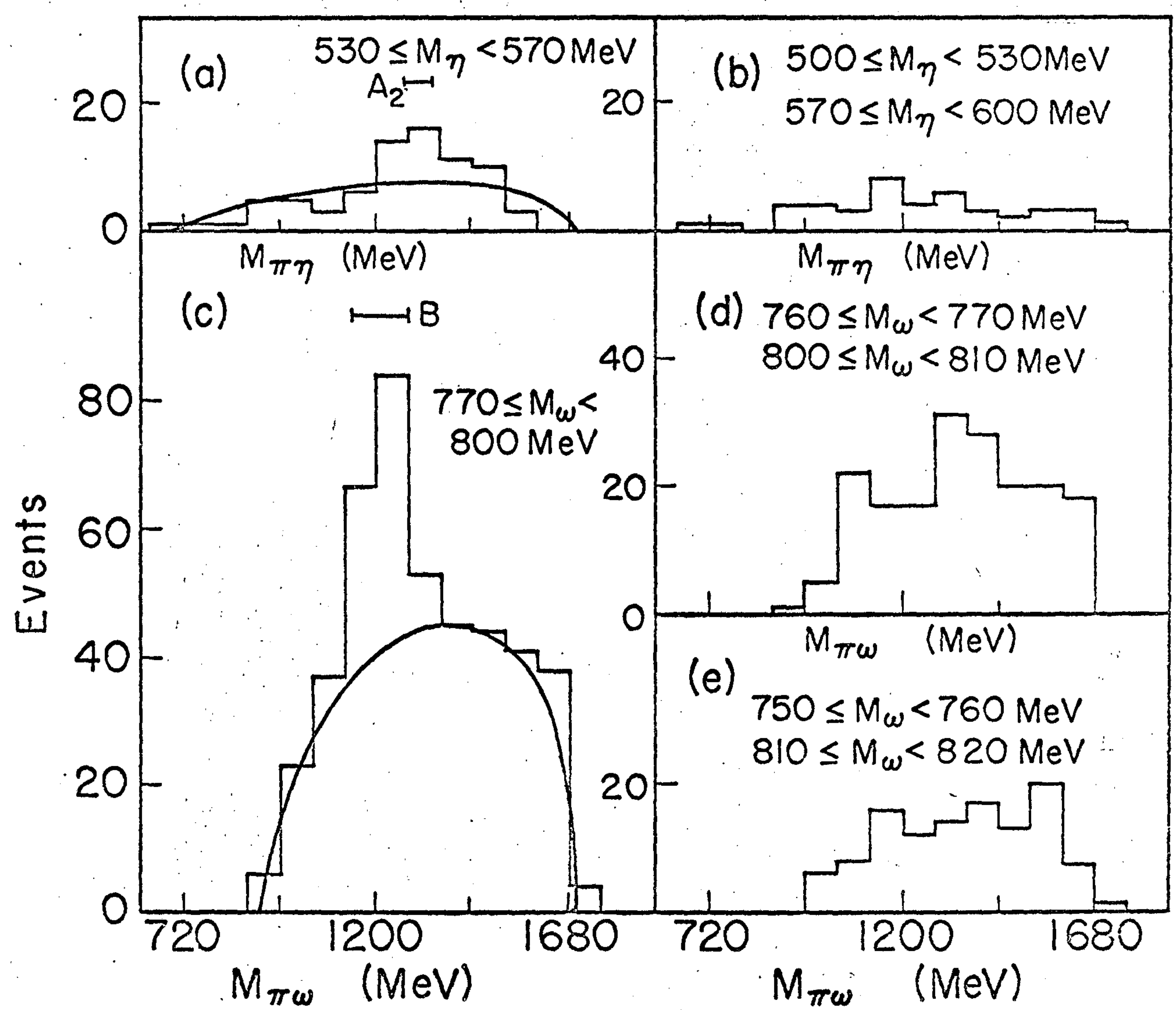
Fig. 5. Effective-mass distributions for $N\bar{K}$ and $K\bar{K}$ combinations in $K\bar{K}N$ final states at 3.2 and 4.2 GeV/c.

Fig. 6. Effective-mass distributions for $K\bar{K}\pi$ combinations in $K\bar{K}\pi N$ final states at 3.2 GeV/c.



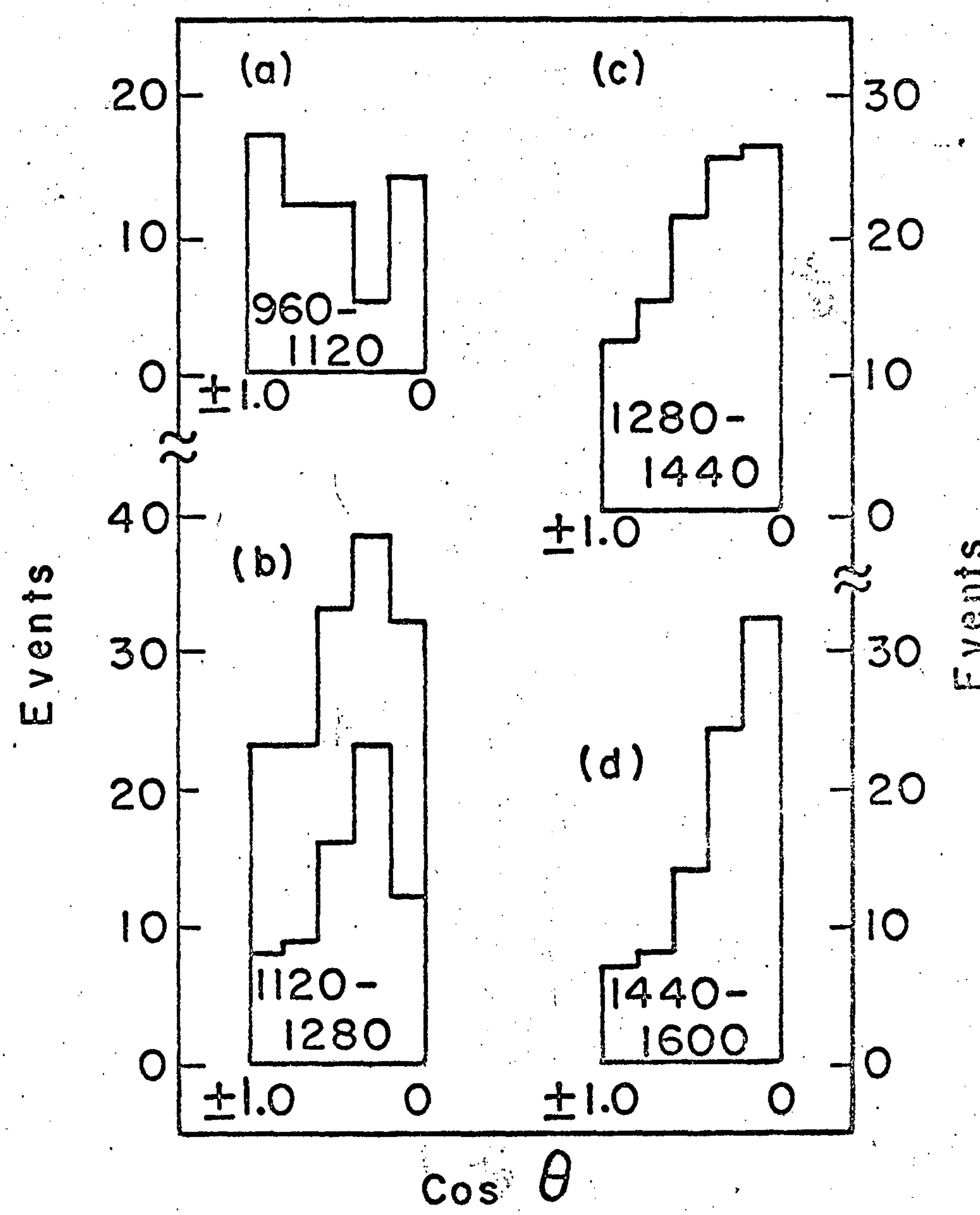
MUB-3222

Fig. 1



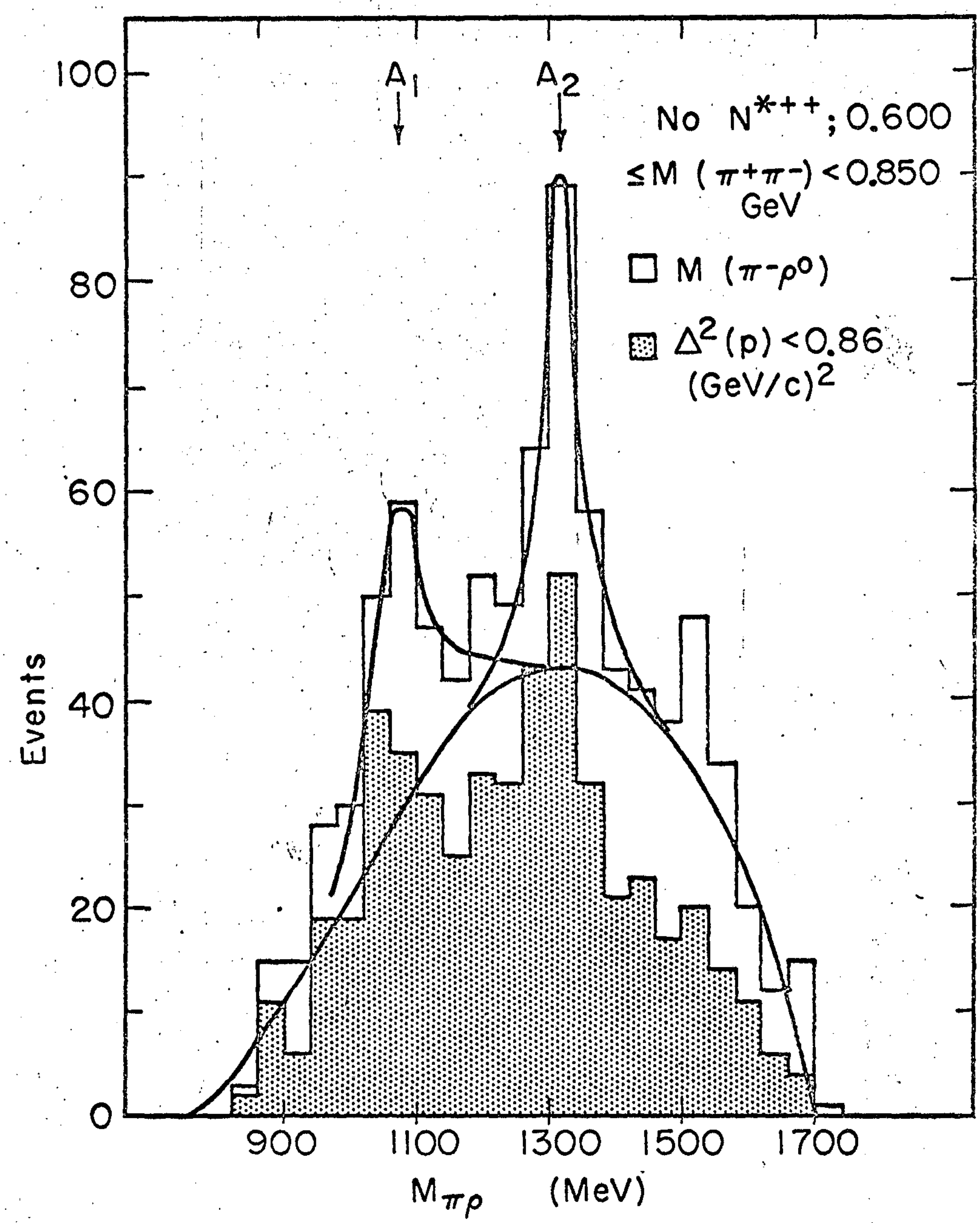
MUB-3196

Fig. 2



MUB-3223

Fig. 3



MUB-3194

Fig. 4

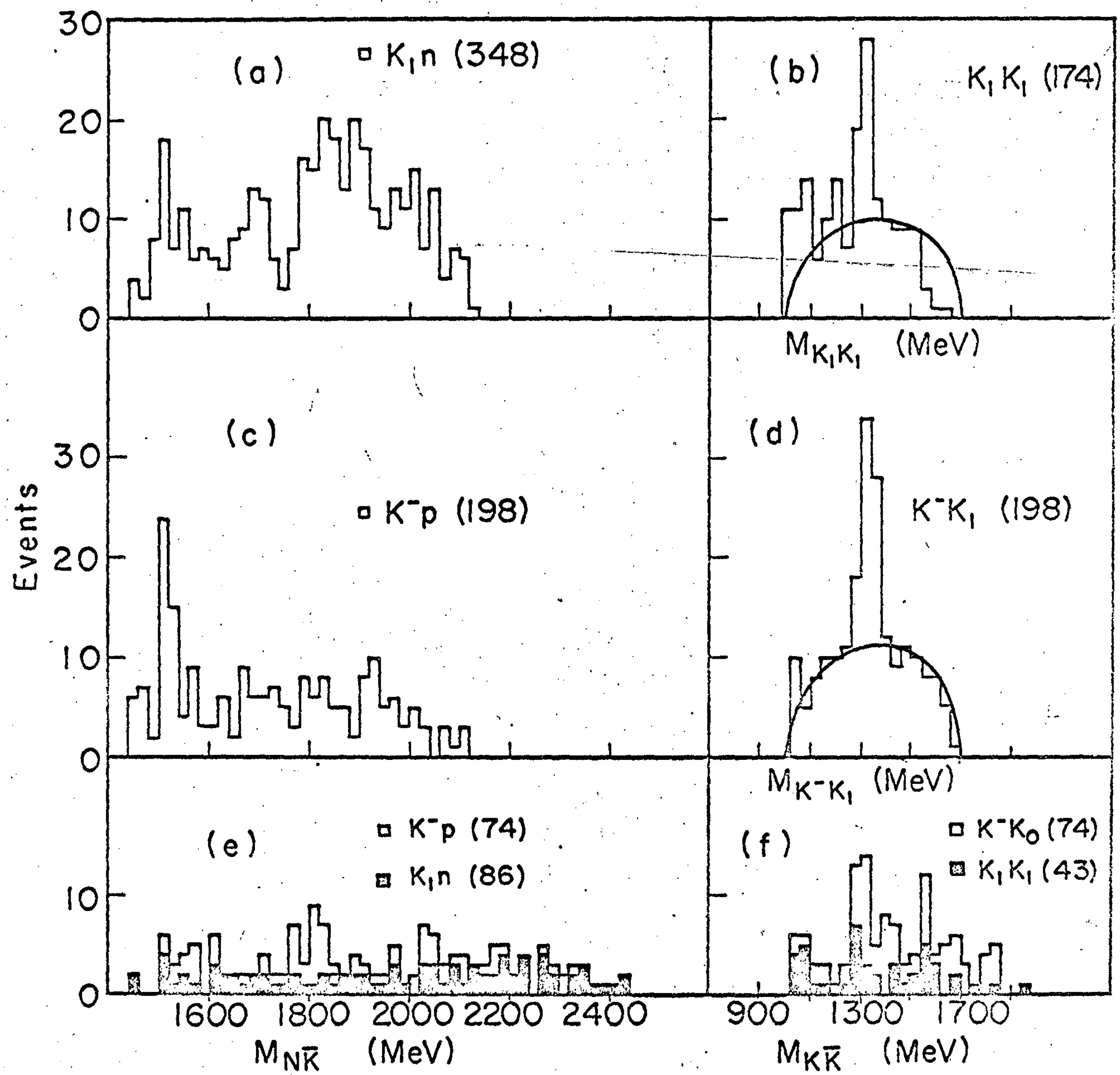


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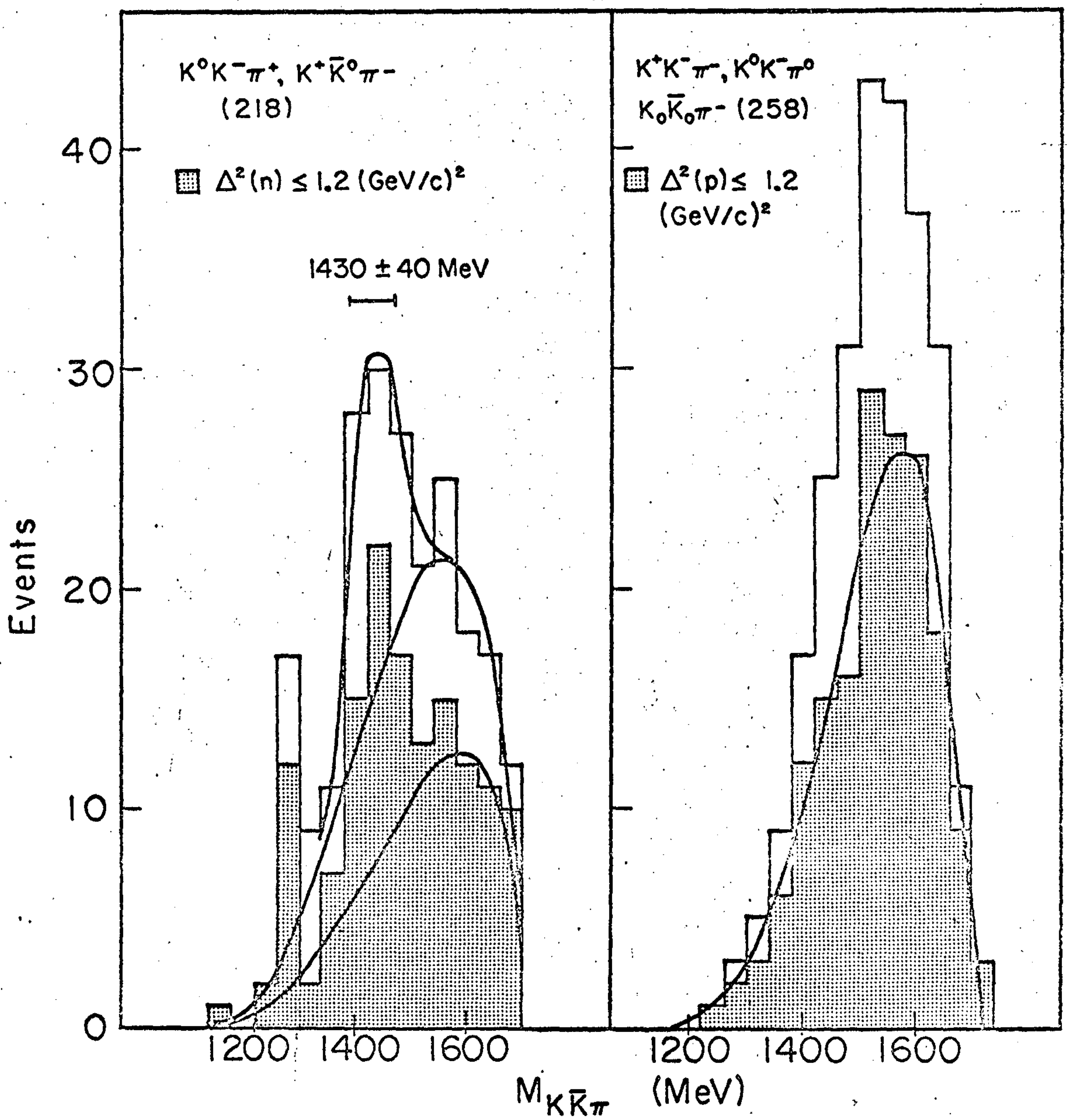
Fig. 5


K°K⁻π⁺, K⁺K̄°π⁻
(218)
Δ²(n) ≤ 1.2 (GeV/c)²
1430 ± 40 MeV
K⁺K⁻π⁻, K°K⁻π°
K₀K̄₀π⁻ (258)
Δ²(p) ≤ 1.2
(GeV/c)²
Events
40
30
20
10
0
1200
1400
1600
M_KK̄π (MeV)

MUB-3193