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In a continuation of the study of the interaction of 1.15-Bev/c K^- mesons in hydrogen by means of the Lawrence Radiation Laboratory 15-inch hydrogen bubble chamber, we now report a study of the reaction

$$K^- + p \rightarrow \bar{K}^0 + \pi^- + p. \qquad \text{(A)}$$

Examples of this reaction were easily identified in those cases in which the $\bar{K}^0$ decayed into charged pions and appeared in the chamber as a two-prong interaction associated with a V. A kinematic analysis isolated 48 events of reaction (A) from other events with similar topology.[1] In only one case was the identification not unique. Correcting for neutral decays of the $\bar{K}^0$ and for escape from the chamber, we find a total cross section of 2.0 ± 0.3 mb for Reaction (A).

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The events are shown on a Dalitz plot in Fig. 1. If the reaction were entirely dominated by phase space, the Dalitz plot would be uniformly populated. Instead, a strong clumping around proton kinetic energy of 20 Mev is observed. This effect cannot be explained by an interaction matrix element that increases monotonically with decreasing proton energy. Whereas an extrapolation from the region 15 Mev $\leq T_p \leq$ 25 Mev would lead one to expect a minimum of 16 events in the region $T_p \leq$ 15 Mev, only three are found there. No experimental bias against very-low-energy protons in the K-p center-of-mass system can exist, since such protons have laboratory-system momenta of approx 600 Mev/c, and are easily identified. The observed distribution can best be explained by a quasi-two-body reaction of the type

$$K^- + p \rightarrow K^{*-} + p, \qquad \text{(B)}$$

followed by a decay,

$$K^{*-} \rightarrow \bar{K}^0 + \pi^-. \qquad \text{(C)}$$

The 3-3 resonance of the pion nucleon system would show itself on the Dalitz plot as a concentration of points along the diagonal line drawn through Fig. 1. The absence of any evidence for this resonance in our data can be explained if Reaction (A) proceeds primarily through the I = 0 channel, which cannot produce a p-π^- system in the I = 3/2 state. Further, even in the I = 1 channel, the 3-3 resonance favors $(n + \pi^0) + \bar{K}^0$ over $(p + \pi^-) + \bar{K}^0$, and hence provides additional suppression of this resonance.

The mass distribution of the K^{*-} is shown in Fig. 2. The mean value is 885 ± 3 Mev. After removing the number of background events estimated from the phase-space distribution and unfolding the experimental error on each of the remaining 22 events (typically 3 to 4 Mev), we obtained a full width at half maximum of 16 Mev, corresponding to a lifetime of 4×10^{-23} seconds.

The angular distribution for Reaction (B) is consistent with isotropy. Assuming that the K^{*-} system is produced predominantly in the s state (which appears likely both because of the closeness to the threshold and because of

the isotropic distribution), we can obtain an upper limit of the $\bar{K}^*$ spin S. If S = 0, then the reaction can be produced only through the $p_{1/2}$ ingoing channel; if S = 1, through $s_{1/2}$ and $d_{3/2}$, etc. In any case the decay angular distribution[2] is given by

$$I(\theta) = |a\, Y_{S,0}(\theta,\phi)|^2 + |b\, Y_{S,1}(\theta,\phi)|^2, \qquad (1)$$

with $|a|^2 + |b|^2 = 1$, where a = 1 for S = 0. Here θ is the angle of the $\bar{K}^0$ in the K^{*-} rest system with respect to the incoming K^- direction. The mean value of $\cos^2\theta$, based on the distribution function (1), is

$$\left\langle \cos^2\theta \right\rangle = \frac{(2S^2 + 2S - 3) + 2|a|^2}{4S^2 + 4S - 3} \quad . \qquad (2)$$

Experimentally, $\left\langle \cos^2\theta \right\rangle$ for the 21 events lying in the K^{*-} mass range between 870 and 900 Mev is 0.275. Using S = 2 in Eq. (2), we find the expected value of $\left\langle \cos^2\theta \right\rangle \geq 0.429$, with a standard deviation of 0.051. The experimental result thus deviates from the range of values expected for S = 2 by three standard deviations. For S > 2 the discrepancy is even greater. On the other hand, the experimental result is consistent (within errors) with S = 0 or S = 1. It is worth noting that an isotropic decay distribution is obtained both for S = 0 and for S = 1 if the $d_{3/2}$ input channel does not contribute. For this reason, for S = 0, experiments at several momenta will be required to settle this problem.

Assuming that the K^- and $\bar{K}^0$ are an I-spin doublet, and I = 1/2 for the K^{*-} I spin, the branching ratio $R = (K^{*-} \to K^- + \pi^0)/(K^{*-} \to \bar{K}^0 + \pi^-)$ equals 1/2; for I = 3/2, R = 2. In either case another charge state of $\bar{K}^*$, namely $\bar{K}^{*0}$, should exist and decay into $K^- + \pi^+$ or $\bar{K}^0 + \pi^0$. The value of this branching ratio, also, depends on the isotopic spin of the $\bar{K}^*$.

To investigate the isotopic spin properties of the $\bar{K}^*$ we searched for examples of the following two reactions

$$K^- + p \to K^- + \pi^0 + p, \qquad (D)$$

$$K^- + p \to K^- + \pi^+ + n. \qquad (E)$$

These events appear as two-prong interactions and are much more difficult to identify than the events already discussed, since there are usually several possible interpretations for each inelastic two-prong event. In particular there was a pion contamination of about 10% in our incident K^- beam, and the inelastic pion interactions are kinematically very similar to Reactions (D) and (E). Both the kinematic fits and the ionization of the tracks were used to identify the events, but these criteria were not always sufficient to distinguish between various hypotheses. At present we have processed only about 2/3 of our two-prong interactions, but we feel that the data obtained are reasonably unbiased.

In both Reactions (D) and (E) there are peaks in the nucleon kinetic energy distribution in the $\bar{K}^*$ resonance region. On the basis of the number of events in the proton peak of Reaction (D), our present data allow us to make a crude estimate of the branching ratio: $R = 0.75 \pm 0.35$. The data thus strongly favor the $I = 1/2$ state.

The experimental production ratio of $\bar{K}^*$ via Reactions (A) and (E) is about 1, and is thus consistent with the production of the $\bar{K}^*$ through a pure isotopic spin state.

An $I = 1/2$ particle, called the K', with negative parity with respect to the K meson, has been invoked by Tiomno to explain the backward Λ peaking in associated production.[3] Gell-Mann postulated the existence of such a particle to permit the construction of a strangeness-violating weak-interaction axial current.[4] The K^* that we have observed has properties consistent with those postulated for the K', but, as discussed above, the K^* spin and parity remain to be established.

As in our previous communication, we acknowledge gratefully the assistance of the many people who helped us to obtain and analyze these data. One of us (PE) is grateful to the Philippe's Foundation, Inc., and to the Commisariat a l'Energè Atomique for a fellowship.

FOOTNOTES

1. M. Alston, L. W. Alvarez, P. Eberhard, M. L. Good, W. Graziano, H. K. Ticho, and S. Wojcicki, Phys. Rev. Letters 5, 520 (1960).
2. Richard Spitzer and Henry P. Stapp, Polarization and Angular Correlation in the Production and Decay of Particles of Spin 1/2 and Spin 3/2, University of California Radiation Laboratory Report, UCRL-3796 (Rev.), July 1957 (unpublished); also Henry P. Stapp (Lawrence Radiation Laboratory), private communication. We are grateful to Dr. Stapp for several illuminating discussions on this subject.
3. Jayme Tiomno, in Proceedings of the 1960 Rochester Conference, p. 466; also J. Tiomno, A. L. L. Videira, and N. Zogury, Phys. Rev. Letters (to be published).
4. M. Gell-Mann, in Proceedings of the 1960 Rochester Conference, p. 508.

FIGURE CAPTIONS

Fig. 1. Phase-space plot of the 48 examples of $K^- + p \rightarrow \bar{K}^0 + \pi + p$ reactions.

Fig. 2. Mass spectrum of the $\bar{K}^0$-π^- system. The solid line represents the phase space curve normalized to background events.

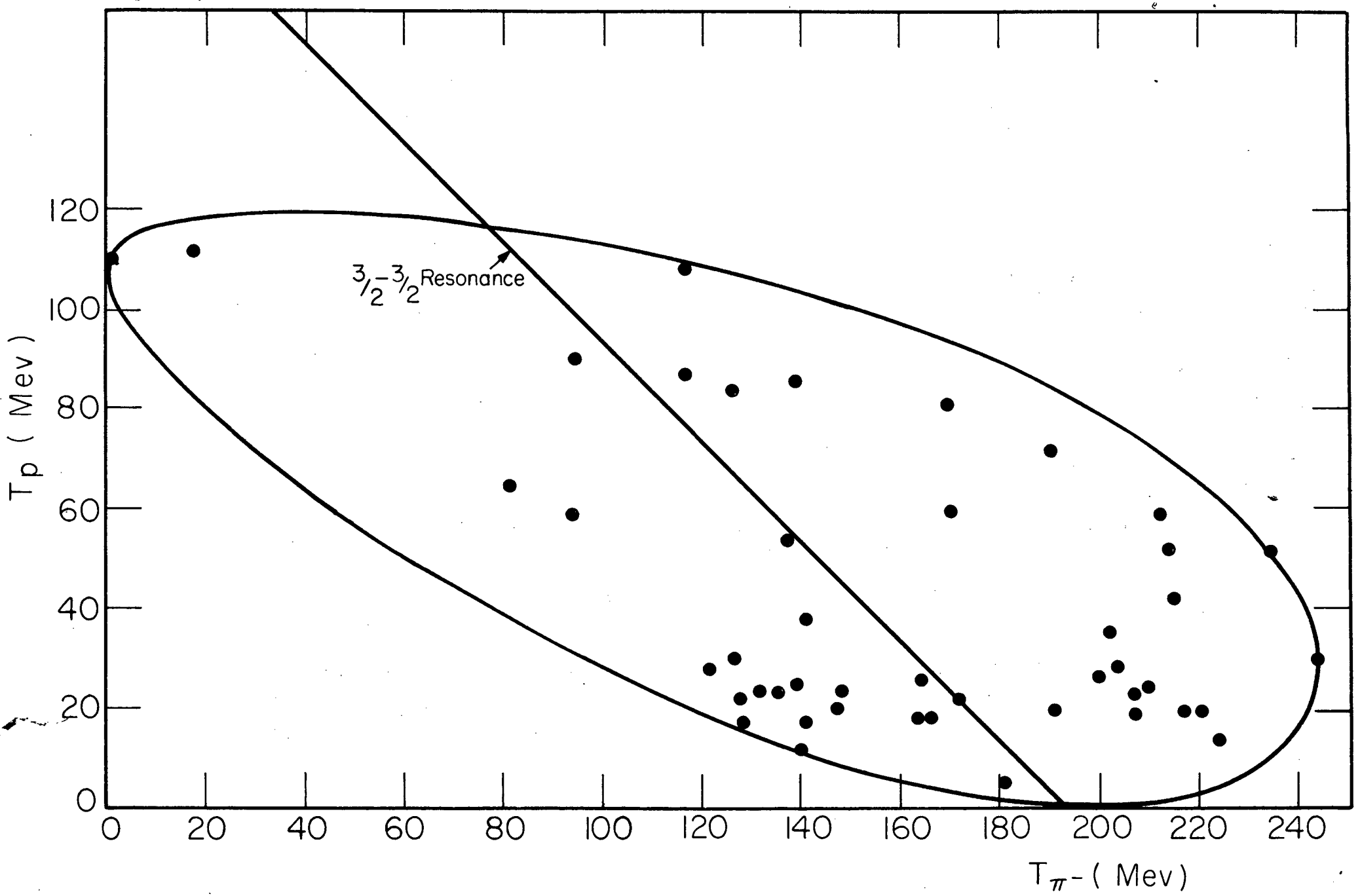
$^3/_2$–$^3/_2$ Resonance
T_p (Mev)
T_{π^-} (Mev)
0
20
40
60
80
100
120
140
160
180
200
220
240

Fig 1

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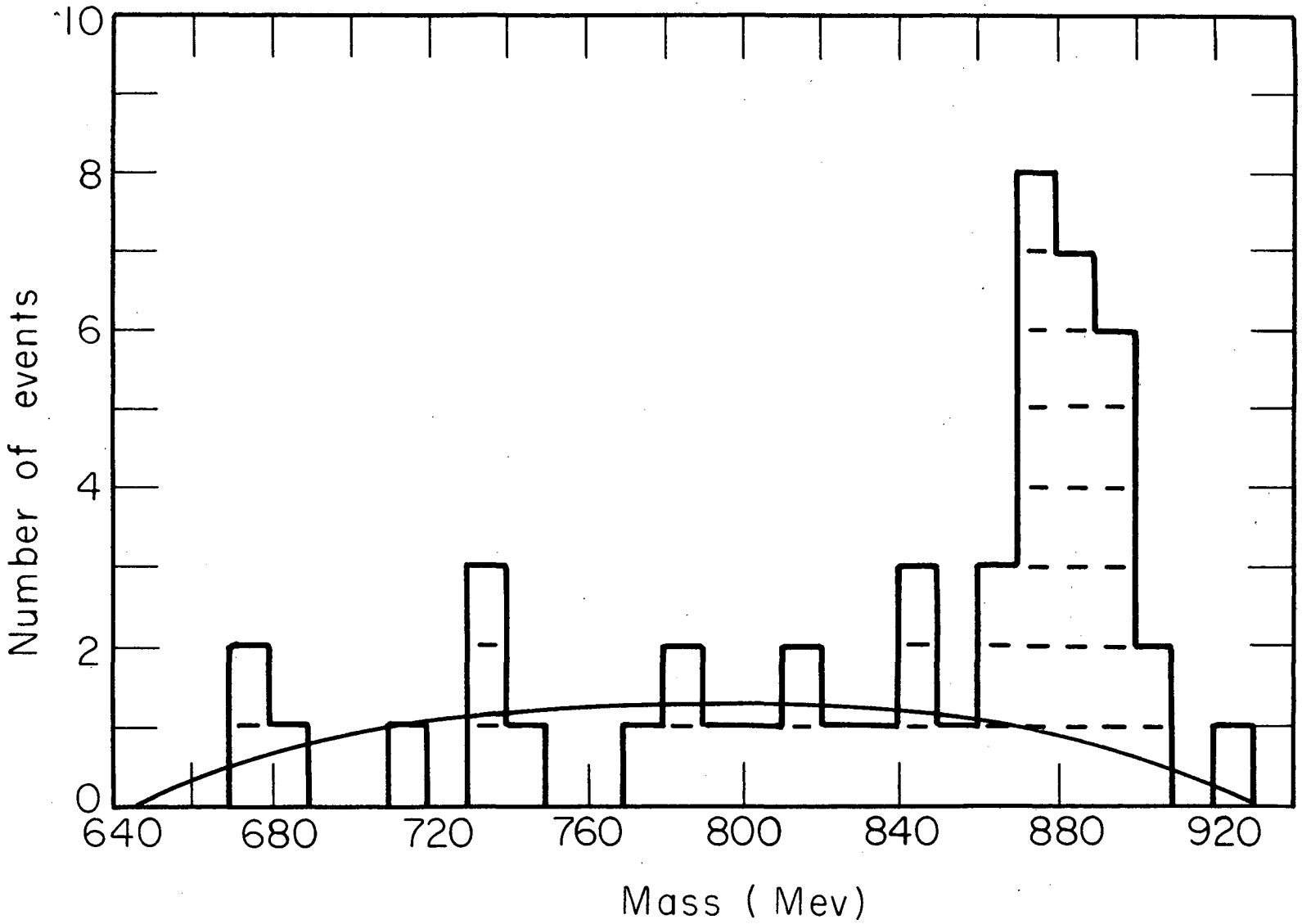
Number of events
0
2
4
6
8
10
640
680
720
760
800
840
880
920
Mass (Mev)

Fig. 2

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