STUDY OF STRANGE-PARTICLE RESONANT STATES PRODUCED IN 1.89-2.24 GeV/c π^-+p INTERACTIONS (*)

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(presented by A. H. Rosenfeld)

INTRODUCTION

A study of the effective mass distributions for the three-body final states indicates that the three resonances, Y_1^* (1385 MeV), Y_0^* (1405 MeV), and Y_0^* (1525 MeV) are produced strongly at 1.89 and 2.04 GeV/c. However, at 2.16 and 2.24 GeV/c essentially no enhancement due to the presence of the two $I=0$ resonances is observed, although some Y_1^* persists. In addition, the data for the $Y\pi$ systems at the two higher momenta show enhancement in the region $M_{Y\pi}=1685$ MeV. Since there are $\Lambda^0\pi$ events in this peak, the enhancement is attributed to the $I=1$ $Y\pi$ system. Two $K\pi$ resonant states, K^* (885 MeV) and K^* (730 MeV) are observed, the former at all momenta, the latter can only be observed at 1.89 and 2.04 GeV/c.

EXPERIMENTAL PROCEDURE

The data were obtained during an extensive exposure of the LRL 72-inch hydrogen bubble chamber to a π^- beam which was varied in momentum between 1.55 and 2.35 GeV/c. In this report we discuss preliminary results obtained in a study of the higher momentum portion of the film. All interactions leading to the production of a visible hyperon were measured on the LRL " Frankenstein " and kinematically fitted with computer programs that adjusted the measured variables to satisfy the energy-momentum conservation constraints at both the production and decay vertices simultaneously. In general, little difficulty was encountered in obtaining a unique interpretation for each event in the kinematic fitting. A significant exception occurred in the ambiguity between $\pi^-+p\to\Sigma^-\pi^+K^0$ and $\Sigma^-\pi^0K^+$ for those events in which no K^0 was observed. A comparison of the actual track ionization with the values expected from the calculated fits resolved the ambiguity for the majority of cases. The remaining ambiguous events were assigned to the fit with the lower χ^2. The events used in our analysis are summarized in Table I.

TABLE I

Distribution of numbers of observed events

	1.89-2.04 (GeV/c) $\mu=2.145$ (GeV)	2.16-2.24 (GeV/c) $\mu=2.240$ (GeV)	Incident pion momentum cms energy
Final state			*Total*
1. $\Lambda^0K^+\pi^-$	117	110	227
2. $\Lambda^0K^0\pi^0$	32	13	45
3. $\Sigma^0K^+\pi^-$	37	60	97
4. $\Sigma^+K^0\pi^-$	32	46	78
5. $\Sigma^-K^0\pi^+$	206	126	332
6. $\Sigma^-K^+\pi^0$	116	51	167
			946

A detailed examination of the data indicates that most distributions at 1.89 and 2.04 GeV/c are qualitatively similar and distinct from those at 2.16 and

(*) This work was done under the auspices of the U.S. Atomic Energy Commission.

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2.24 GeV/c. For this reason, the data have been combined into two groups (1.89, 2.04 and 2.16, 2.24 GeV/c) in the following discussions.

RESULTS

The distributions in effective-mass squared for the two-body systems comprising the $\Lambda^0\pi K$ events are given in Fig. 1. We observe a strong enhancement in the $\Lambda^0\pi$ effective mass at 1385 MeV, associated with the production of the Y_1^* resonant state. In accordance with the tentative assignment of $J = 3/2$ to this state by Ely *et al.* [1], an adequate fit to the data is obtained by a p-wave resonance curve with full width $\Gamma \approx 60$ MeV. The $K\pi$ mass distribution for these events peaks at 885 MeV, indicating the production of the K^* resonant state. In contrast to the full width of $\Gamma = 16$ MeV reported by Alston *et al.*[2] for this state, our data require $\Gamma = 60 \pm 5$ MeV. Of particular interest is the reversal of the dominant production mechanisms in the two momentum intervals; at 1.86 and 2.04 GeV/c we obtain for the ratio $Y_1^*/K^* \approx 2.0$, while at 2.16 and 2.24 GeV/c we obtain ≈ 0.5 for the same ratio. Examination of the mass distributions shows no statistically significant evidence for the resonant states at $M_{\Lambda K} = 1650$ MeV suggested recently by Baz *et al.*[3], and Bertanza *et al.*[4]

The data for the $\Sigma\pi K$ events are given in Figs. 2 and 3. At 1.89 and 2.04 GeV/c the $\Sigma\pi$ effective mass distribution in the $\Sigma^{\pm}\pi^{\mp}$ systems shows two strong peaks. The first occurs at $M_{\Sigma\pi} = 1405$ MeV and corroborates the preliminary evidence for the existence of a resonant state at this mass reported by Alston *et al.*[5]. Consistent with their assignment of $I = 0$ to this state, no corresponding peak is observed in the $\Sigma^0\pi^-$ or $\Sigma^-\pi^0$ systems. The second peak occurs at $M_{\Sigma\pi} = 1525$ MeV and may be identified with the $I = 0$, $D^{\frac{3}{2}}$ resonant state studied by Ferro-Luzzi *et al.*[6]. The fitted curve has $\Gamma = 30$ MeV. As in the case of Y_1^* production, an abrupt disappearance of the $\Sigma\pi$ resonant states is observed when the beam

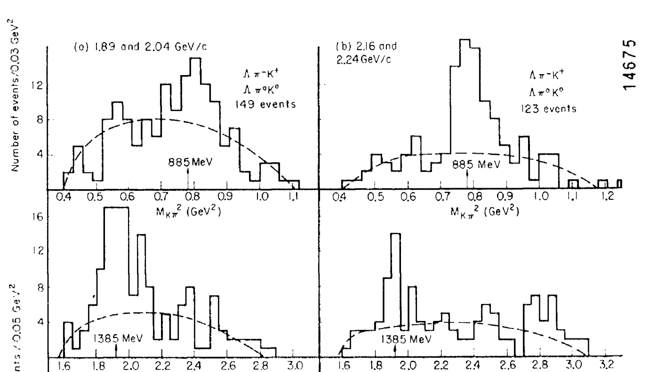

Fig. 1 Λ events. Distribution in $M_{K\pi}{}^2$, $M_{\Lambda\pi}{}^2$ and $M_{\Lambda K}{}^2$ at (a) 1.89 and 2.04 GeV/c ($\mu = 2145$ MeV), and (b) 2.16 and 2.24 GeV/c ($\mu = 2240$ MeV). The dashed curves are reasonable estimates of background where effects of the Y_1^* (1385 MeV) and K^* (885 MeV) have been taken into account in the appropriate distribution.

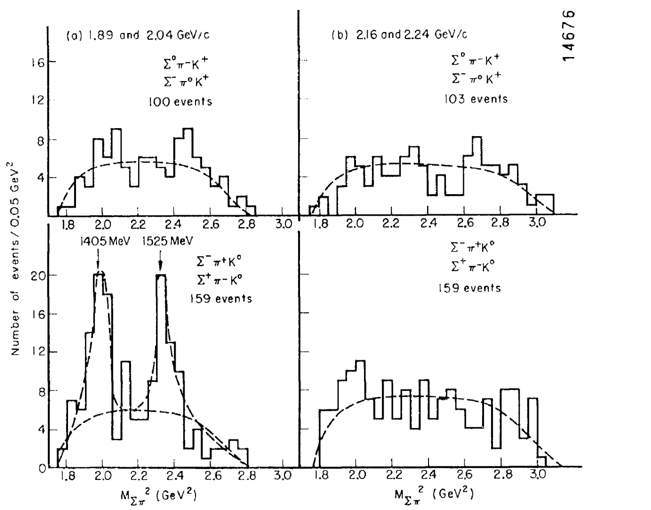

Fig. 2 Σ events. Distribution in $M_{(\Sigma\pi)^0}{}^2$ and $M_{(\Sigma\pi)^-}{}^2$ at (a) 1.89 and 2.04 GeV/c ($\mu = 2145$ MeV), and (b) 2.16 and 2.24 GeV/c ($\mu = 2240$ MeV). Background curves include effects of the K^* (885 MeV). The upper curve represents a fit to the data in the vicinity of 1405 MeV, using a model in which the Y_0^* (1405 MeV) is interpreted as a resonance associated with a bound $S^{1/2}$ state of the $\bar{K}N$ system.

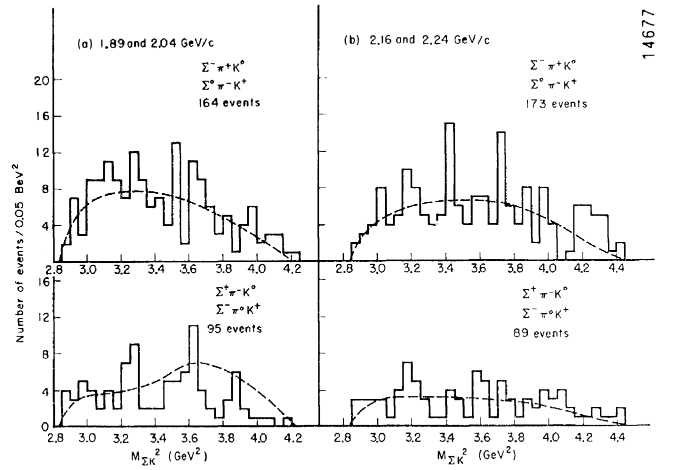

Fig. 3 Distribution in $M_{\Sigma K}{}^2$ at (a) 1.89 and 2.04 GeV/c ($\mu = 2145$ MeV), and (b) 2.16 and 2.24 GeV/c ($\mu = 2240$ MeV). Phase-space curves include effects of the Y_0^* (1405, 1525 MeV) and K^* (885 MeV) when appropriate.

momentum is increased. The ΣK mass distributions have been combined into the two groups in which either the $I = 1/2$ or $I = 3/2$ state of the ΣK system dominates. Neither group shows evidence for the existence of a resonant state.

SPIN OF Y_0^*

The most frequently discussed possibilities for the spin of the Y_0^* (1405 MeV), i.e., $S^{\frac{1}{2}}$ and $P^{\frac{3}{2}}$, can lead to significant differences in the shapes expected for the effective mass distributions. In the case of a $P^{\frac{3}{2}}$ resonance, it may be expected that (a) on the Dalitz plot the density of events will tend to zero as p^2 tends to zero (where p is the c.m. momentum in the $Y\pi$ system), and (b) the distribution will fall off gradually on the high momentum side of the peak showing no correlation with the KN threshold. In particular, the effective mass distribution in Fig. 1 for the Y_1^* events shows these general features. This behaviour may be contrasted with that of the $\Sigma^{\pm}\pi^{\mp}$ events at 1.89 and 2.04 GeV/c shown on the Dalitz plot in Fig. 4. Within the statistical limitations of the data, a rapid attenuation of events appears as the KN threshold is approached from below. The effect may be understood if the Y_0^* is interpreted as a resonance associated with a bound $S^{1/2}$ state of the KN system. The possibility for resonant states of this type was first pointed out by Dalitz and Tuan [7]. The curve on the 1405-MeV peak in Fig. 2 represents a fit to the data using this model.

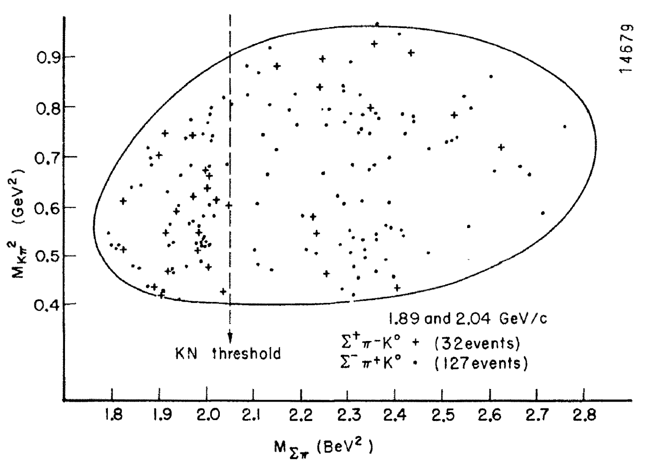

Fig. 4 Dalitz plot of $M_{K\pi}{}^2$ versus $M_{(\Sigma\pi)^0}{}^2$ at 1.89 and 2.04 GeV/c ($\mu = 2145$ MeV).

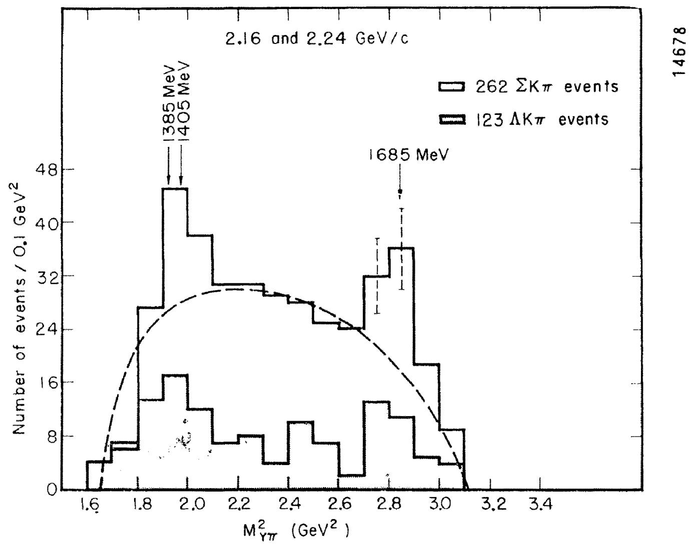

Fig. 5 Combined distribution in $M_{Y\pi}$ for $\Lambda K\pi$ and $\Sigma K\pi$ events at 2.16 and 2.24 GeV/c ($\mu = 2240$ MeV).

ENHANCEMENT AT $M_{Y\pi} = 1685$ MeV

Several of the effective mass plots at 2.16 and 2.24 GeV/c suggest an enhancement in the region $M_{Y\pi}^2 \approx 2.8$ GeV^2. To emphasize the effect, we give in Fig. 5 the $Y\pi$ mass distribution for all events at the higher momentum. A comparison with the expected phase-space distribution (appropriately modified for K^* production) shows a total enhancement of at least 25 events above a background of about 49. The effect is particularly striking because of the rapid decrease in available phase-space in this region. If we attribute the enhancement to a resonant state, we find $M_{Y\pi} \approx 1685$ MeV with $\Gamma \approx 45$-50 MeV. However, considerable uncertainty must be associated with these values because of statistical limitations and possible distortions introduced by the rapidly varying phase space. Since the $\Lambda^0\pi$ events contribute significantly to the peak, the $Y\pi$ state must have $I = 1$.

K–π MASS DISTRIBUTIONS

In a previous communication dealing with the production of strange-particle resonant states by 2.1 GeV/c π^- mesons, we presented evidence for the existence of a K-π resonance of mass 730 MeV in the reactions $\pi^- + p \rightarrow \Sigma^- K^0 \pi^+$, $\Sigma^- K^+ \pi^0$, and $\Sigma^0 K^+ \pi^-$ [7]. No statement was made on the isotopic spin assignment of this possible resonant state, although the lack of an enhancement in the reaction $\pi^- + p \to \Sigma^+ K^0 \pi^-$ suggested $I = 1/2$. We present a continuation of this analysis based on an enlarged sample of events. In addition, interesting and at present unexplained energy-dependent features of this resonance are observed.

The K-π mass squared distributions for the two momentum groups are given in Figs. 6 and 7, respectively. Figs. 6a and 7a show the $\Sigma^+ K^0 \pi^-$ distributions, where the K-π system is always in an $I = 3/2$ state. Figs. 6b and 7b give the combined Σ^-, Σ^0, and Λ^0 events, and in these cases the K-π system is a mixture of $I = 1/2$ and $I = 3/2$. The dashed curves in the $\Sigma^+ K^0 \pi^-$ data are background estimates that include effects of the Y_0^* (1405 MeV) resonance [1, 2, 3] combined with non-resonant phase space as dictated by the Σ-π mass distributions for the same events.

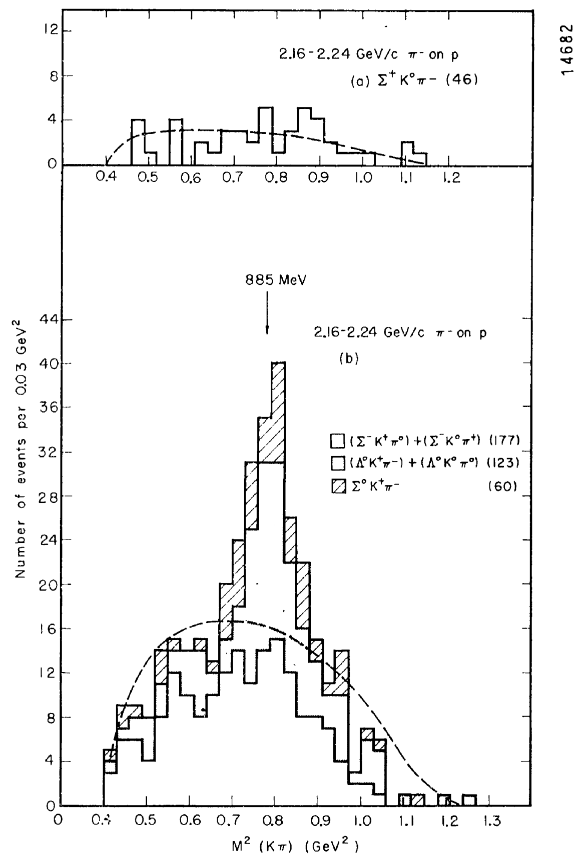

Fig. 7 K-π mass-squared distributions for (a) $\Sigma^+ K^0 \pi^-$, and (b) Σ^-, Σ^0, Λ^0 events at incident-pion momenta of 2.16 through 2.24 GeV/c (μ = 2240 MeV). The dashed curves are background estimates which take the Y^* resonances into account.

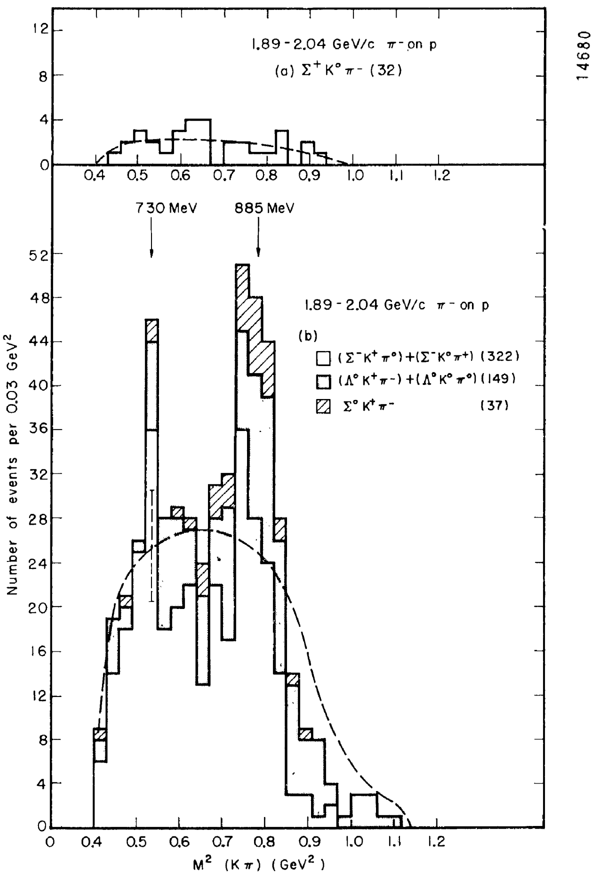

Fig. 6 K-π mass-squared distributions for (a) $\Sigma^+ K^0 \pi^-$, and (b) Σ^-, Σ^0, Λ^0 events at incident-pion momenta of 1.89 through 2.04 GeV/c (μ = 2145 MeV). The dashed curves are background estimates which take the Y^* resonances into account.

The Y_0^* (1525 MeV) resonance [6] makes no appreciable contribution to the $\Sigma^+ K^0 \pi^-$ data. The data of Figs. 1a and 2a are consistent with these background curves.

The dashed background curves of Figs. 6b and 7b include effects of the Y_1^* (1385 MeV) [5], Y_0^* (1405 MeV), and Y_0^* (1525 MeV) resonances. A striking feature of the data is the pronounced and very sharp peak in the lower momenta data shown in Fig. 6b at mass 730 MeV. In order to estimate the statistical significance of this peak above the background G. Lynch ran for us 450 Monte Carlo versions of this experiment. Among these a few showed equally striking peaks in one or more bins so we conclude that there is about a 1% probability that this effect is just a statistical accident [(*)]. The width is estimated at $\Gamma \lesssim 20$ MeV with the experimental uncertainty in measurement being $\lesssim 10$ MeV. There is no evidence for

(*) In any particular *a priori* selected bin the probability of finding 46 events when one expects only 26 is only one in 4000; but these odds become much less striking when one takes into account the fact that no previous experiment or theory suggested that we look at 730 MeV. Fluctuations could produce " resonances " in any one or more of the ten bins between 630 MeV and the lower edge of the K^* (885) peak.

such an enhancement in the data for the higher momenta shown in Fig. 2 b. The $K^*_{\frac{1}{2}}$ (885 MeV) resonance[2,7] is produced strongly at all energies studied; its width is $\Gamma \approx 60 \pm 5$ MeV.

The lack of enhancement in the 730-MeV region in the $\Sigma^+ K^0 \pi^-$ events still suggests that K^* (730 MeV) has isotopic spin $I = \frac{1}{2}$, although we do not rule out completely the possibility that accidental interference effects in the initial state of $\pi^- + p$ could simulate our data. In addition, the branching ratio $\Sigma^- K^0 \pi^+ / \Sigma^- K^+ \pi^0$ should permit an unambiguous determination of its isotopic spin. Our data do not permit a statistically significant determination of the isotopic spin from this branching ratio.

DISCUSSION

We have shown that the production rates for various strange-particle resonant states are strongly dependent upon momentum in the interval studied. This may reflect a rapid variation in the dominant state of the initial $\pi^- + p$ system. However, anomalous production rates have been observed for several systems immediately above their energetic thresholds. It appears reasonable that some part of the present result may represent a similar situation, since the threshold for Y_0^* (1525 MeV) is 1.70 GeV/c and the threshold for production of the possible Y_1^* resonant state at 1685 MeV is 2.09 GeV/c.

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