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STUDY OF STRANGE-PARTICLE RESONANT STATES PRODUCED IN 1.89-2.24 GeV/c π^{-}+p INTERACTIONS

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

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(To be presented by Arthur 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 and the latter only at 1.89 and 2.04 GeV/c.

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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 leaking 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 $\pi^- + p \rightarrow \Sigma^- \pi^+ K^0$ and $\Sigma^- \pi^0 K^+$ 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. Summary of fitted events used in the analysis.

Final State	Incident Pion Momentum (GeV/c)	
	1.89 and 2.04[a]	2.16 and 2.24[a]
1. $\Lambda^0 \pi^0 K^0$	32 (144)	13 (59)
2. $\Lambda^0 \pi^- K^+$	117 (175)	110 (165)
3. $\Sigma^0 \pi^- K^+$	37 (56)	60 (90)
4. $\Sigma^+ \pi^- K^0$	32	46
5. $\Sigma^- \pi^0 K^+$	63	43
6. $\Sigma^- \pi^+ K^0$	127	113

[a] In parentheses are the numbers of events corrected for loss from neutral decay modes.

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 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 $\Lambda^0\pi^{\overline{0}}$ 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 1.86 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, $D^{3/2}$ resonant state studied by Ferro-Luzzi et al.[6] The fitted curve has Γ = 30 MeV. As in the case of Y_1^* production, an abrupt disappearance of the $\Sigma\pi$ resonant states is observed when the beam 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. The $K\pi$ mass distributions for these events are discussed elsewhere.[7]

SPIN OF Y_0^*

The most frequently discussed possibilities for the spin of the Y_0^* (1405 MeV), i.e., $S^{1/2}$ and $P^{3/2}$, can lead to significant differences in the shapes expected for the effective mass distributions. In the case of a $P^{3/2}$ 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 behavior 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.[8] The curve on the 1405-MeV peak in Fig. 2. represents a fit to the data using this model.

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 $\Lambda^0 \pi^0$ events contribute significantly to the peak, the $Y\pi$ state must have $I = 1$.

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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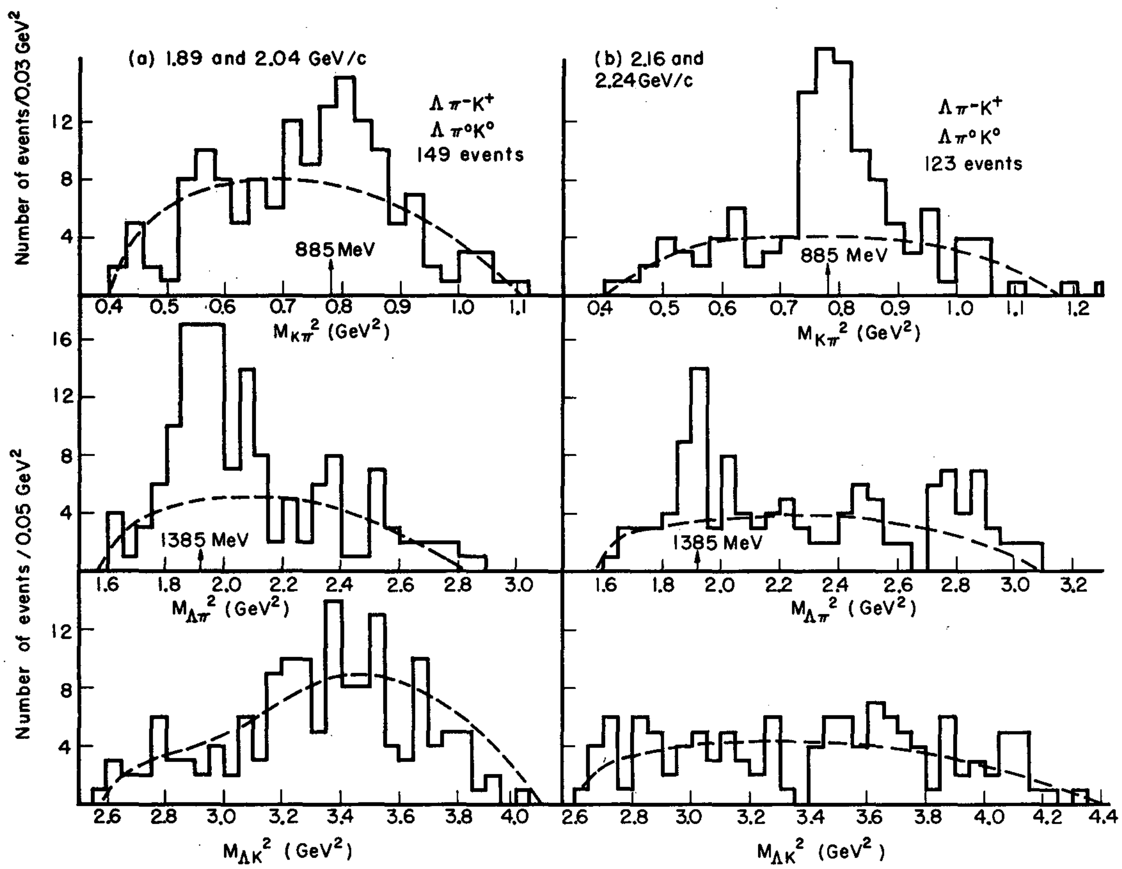

Fig. 1. Distribution in $M_{K\pi}{}^2$, $M_{\Lambda\pi}{}^2$ and $M_{\Lambda K}{}^2$ at (a) 1.89 and 2.04 GeV/c, and (b) 2.16 and 2.24 GeV/c. The dashed curves are reasonable estimates of background where effects of the Y_1^* (1385 MeV) and K^*(885 MeV) have been taken into account in the appropriate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

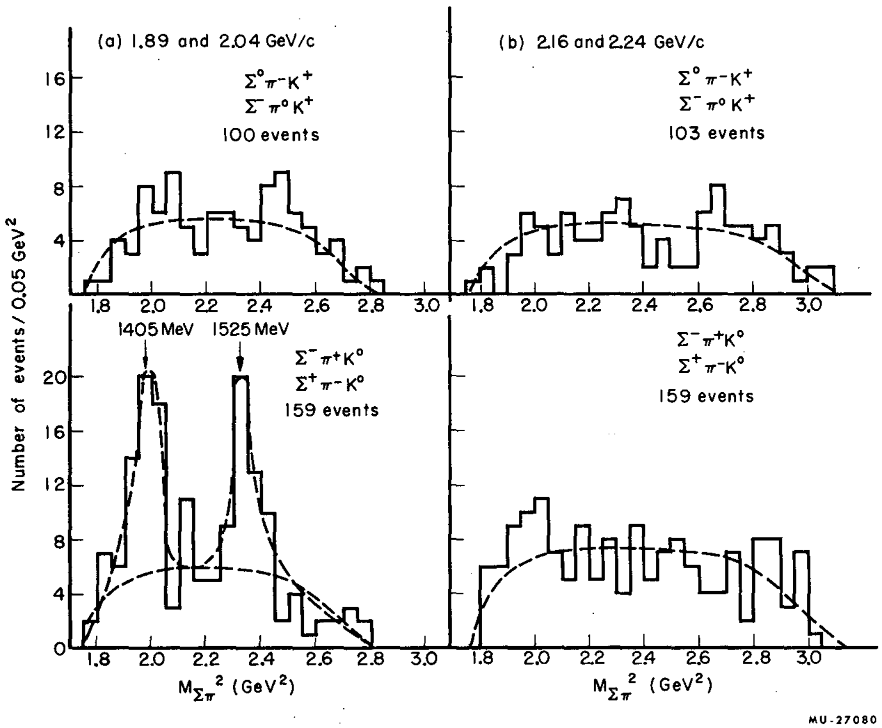

Fig. 2. Distribution in $M_{(\Sigma\pi)^0}{}^2$ and $M_{(\Sigma\pi)^-}{}^2$ at (a) 1.89 and 2.04 GeV/c and (b) 2.16 and 2.24 GeV/c. Background curves include effects of the K^*(885 MeV). The upper curve represents a fit to the data in the vicinity of 1405 MeV, using a model in which the Y_0^* (1405 MeV)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

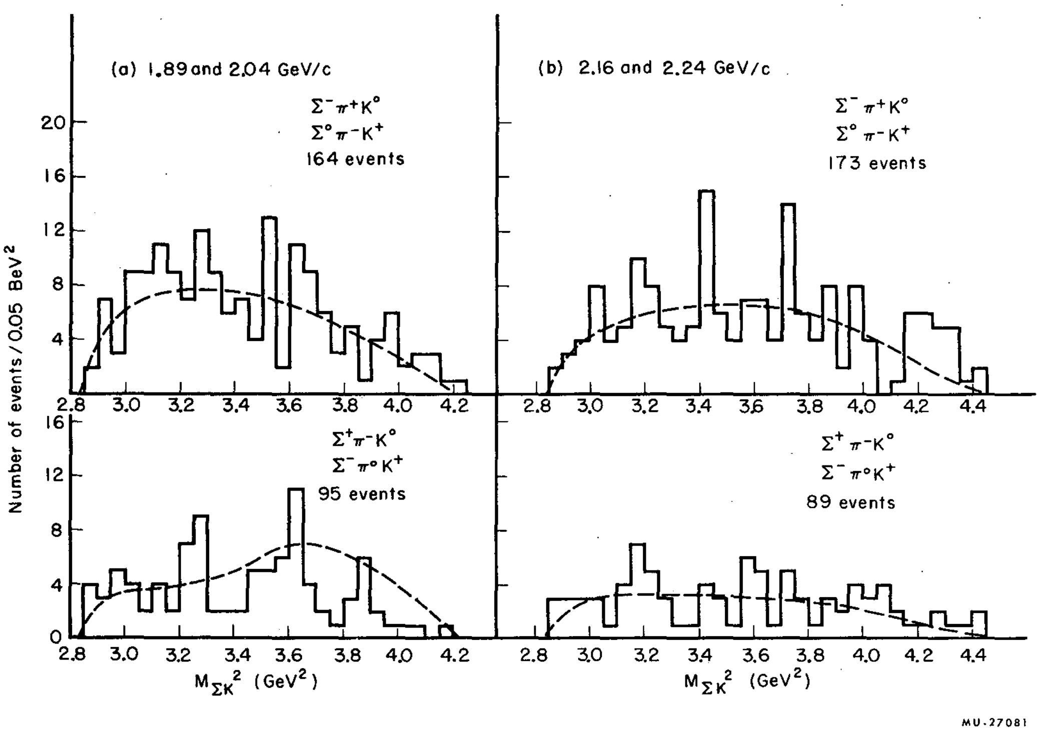

Fig. 3. Distribution in $M_{\Sigma K}^2$ at (a) 1.89 and 2.04 GeV/c, and (b) 2.16 and 2.24 GeV/c. Phase-space curves include effects of the Y_0^* (1405, 1525 MeV) and K^* (885 MeV) when appropriate.

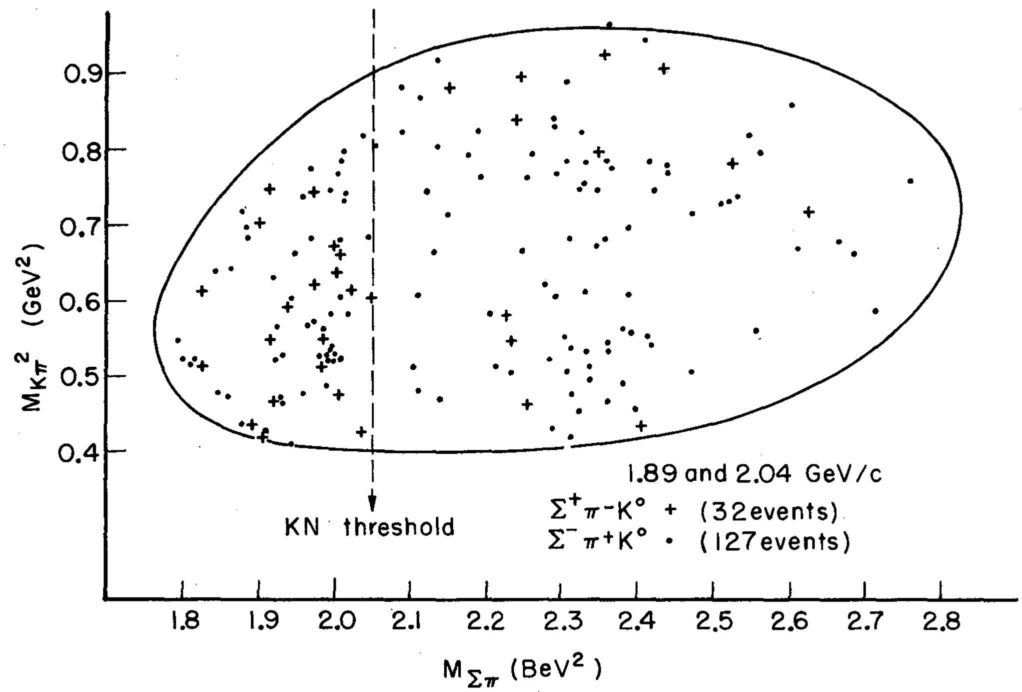

Fig. 4. Dalitz plot of $M_{K\pi}^{\ 2}$ versus $M_{(\Sigma\pi)^0}^{\ 2}$ at 1.89 and 2.04 GeV/c.

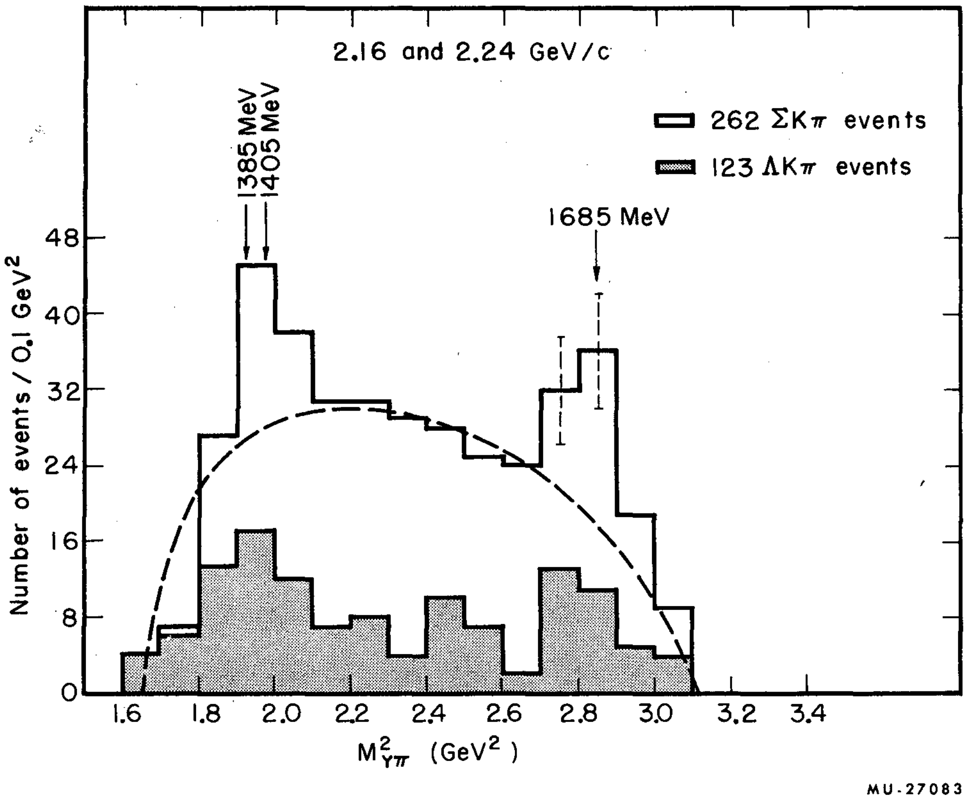

Fig. 5. Combined distribution in $M_{Y\pi}$ for $\Lambda K\pi$ and $\Sigma K\pi$ events at 2.16 and 2.24 GeV/c.