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[18]A. Pais has pointed out to us that if the $Y_1{}^*$ should turn out to be the resonance predicted by global symmetry, the question arises whether the existence of $Y_0{}^*$ could have anything to do with the global symmetry as well. This is certainly not the case because, if the $Y_0{}^*$ is related to the global symmetry hypothesis, then there should be a corresponding $T=\frac{1}{2}$ π-N resonance with $Q\sim 160$ Mev. Thus the existence of a $Y_0{}^*$ may indicate that the assumption of global symmetry is wrong. However, another possibility is that this symmetry could be valid in the P-wave but not the S-wave pion-baryon interaction.

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SIGMA DECAY MODES OF PION-HYPERON RESONANCES*

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During a study of K^-p interactions in the Lawrence Radiation Laboratory 15-inch hydrogen bubble chamber, we have analyzed a total of 249 three-body reactions of the type

$$K^-+p\rightarrow\Sigma^++\pi^-+\pi^0, \qquad (1)$$

and

$$K^-+p\rightarrow\Sigma^-+\pi^++\pi^0, \qquad (2)$$

at incident K^- momenta of 760 and 850 Mev/c. Reactions (1) and (2) are interesting in view of the existence of the resonant pion-hyperon state $Y_1{}^*$,[1] which is now known to influence strongly reactions such as

$$K^-+p\rightarrow\Lambda+\pi^++\pi^-. \qquad (3)$$

It is of interest to compare the $\Sigma^\pm$ production via reactions (1) and (2) with the Λ production via (3) to obtain the Σ/Λ branching fraction R for $Y_1{}^*$.

Another interesting feature of reactions (1) and (2) is related to the fact that the dominant decay mode $Y_1{}^*\rightarrow\Lambda+\pi$ is accessible only to the $Y_1{}^*$ of isotopic spin 1. However, pion-hyperon resonances in other isotopic spin states such as $Y_0{}^*$ and $Y_2{}^*$ can decay into $\Sigma+\pi$. Alston et al. have already reported evidence for a singlet resonance $Y_0{}^*$, and we present more $Y_0{}^*$ data in the second half of this Letter. Additional data on $Y^{*0}\rightarrow\Sigma^\pm+\pi^\mp$ have also been reported by Eisenberg et al.[3]

On the subject of the branching ratio of $Y_1{}^*$, both current theories agree in predicting values of R largely undetermined but generally "small."[4,5] In particular, global symmetry favors R of the order of a few percent with an upper limit of 25%,[4] while

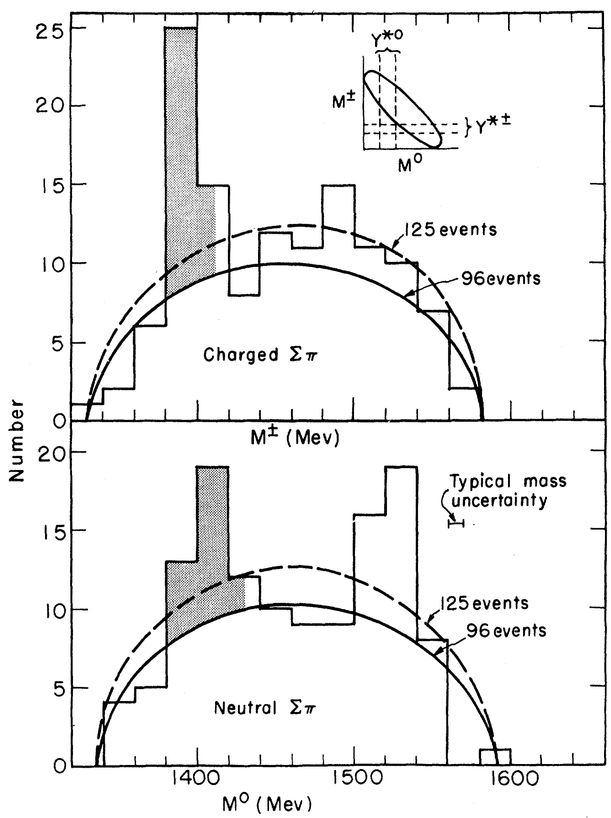

FIG. 1. Upper histogram: Sum of the mass spectrum for the $\Sigma^+\pi^0$ and $\Sigma^-\pi^0$ systems based on 49 reactions (1) and 76 reactions (2) at $P_K = 850$ Mev/c. Lower histogram: Sum of $\Sigma^+\pi^-$ and $\Sigma^-\pi^+$ masses from the same reactions. The dashed curve represents phase space normalized to all 125 events. The solid curve allows for the subtraction of the shaded areas in the Y^* peaks. For clarity, only the phase space for reaction (2) is shown; the difference from that for reaction (1) is negligible. The shaded area for charged $\Sigma\pi$ ranges from 1380 to 1410 Mev, which are the limits seen experimentally in the $Y_1^{*\pm}\to\Lambda+\pi^\pm$ mass distribution[1]; the neutral shading runs from 1380 to 1430, as suggested by Alston et al.[2] for the Y_0^*.

the $\bar{K}N$ "bound-state" model yields generally larger values of R,[5] even if no real lower limit exists because of the present uncertainty concerning the $\Lambda\Sigma$ parity and the validity of the zero-effective-range theory 50 Mev below the $\bar{K}N$ threshold.

Our kinematics program, "Kick," easily separates the three-body reactions (1) and (2) from the topologically similar two-body reactions $K^- + p \to \Sigma^\pm + \pi^\mp$, and from the four-body reactions $K^- + p \to \Sigma^\pm + \pi^\mp + \pi^0 + \pi^0$. A Dalitz plot of the 125 fitted three-body events produced at 850 Mev/c shows the now familiar highly populated bands corresponding to a mass of 1385 Mev for the $\Sigma\pi$ system. Figure 1 shows the mass histograms of these events. A small sketch at the upper right represents the scatter diagram in mass space, from which these histograms were projected. The shaded area in the conspicuous $M^\pm$ peak is easily attributed to the decay mode $Y^{*\pm}\to\Sigma^\pm+\pi^0$. (In fact, as we shall discuss below, we are forced to conclude that it is only a statistical fluctuation.) From the same hopeful point of view one can explain the broader peak at the right of the $M^\pm$ histogram as the $Y^{*0}\to\Sigma^\pm+\pi^\mp$ band projected sideways (see sketch). The dashed lines in Fig. 1 represent phase space, normalized to the total number of events. They are seen to be a rather poor fit to the histograms, thus displaying more quantitatively the extra population in the Y^* bands. In the neutral histogram of Fig. 1 some suggestion of a peak appears at 1500 to 1540 Mev, which is where Y_2^* is expected. However, this is not supported either by our data at 760 Mev/c or by the data for reactions (1) and (2) of Alston et al. at 1150 Mev/c,[2] nor is it borne out by the configuration of events on any of the Dalitz plots. For the rest of this Letter, we shall discuss only the peaks near 1385 Mev and assume that they can be explained in terms of Y_1^* and perhaps the singlet Y_0^* which, according to Alston et al., shows up in the mass region of 1380 to 1430 Mev, partly overlapping Y_1^*.[2] Note that the charged peak can come from $Y_1^{*\pm}$ only, whereas the neutral peak is the sum of contributions from Y_1^{*0} and Y_0^*. We shall discuss the unique charged peak first and determine from it the Y_1^* branching fraction, R.

In the 850-Mev/c column of Table I, the number of events in the shaded area have been used to compute $R^\pm$, which is defined as

$$R^\pm = \frac{n(Y^{*+}\to\Sigma^+\pi^0)+n(Y^{*-}\to\Sigma^-\pi^0)}{n(Y^{*+}\to\Lambda\pi^+)+n(Y^{*-}\to\Lambda\pi^-)}.$$

Charge symmetry requires

$$R^\pm = R^0 = \frac{n(Y^{*+}\to\Sigma^0\pi^+)+n(Y^{*-}\to\Sigma^0\pi^-)}{n(Y^{*+}\to\Lambda\pi^+)+n(Y^{*-}\to\Lambda\pi^-)}.$$

Values of R^0 derived at various momenta[1,2] from the study of the reaction $K^- + p \to \Sigma^0 + \pi^+ + \pi^-$ are also given in row E of Table I. The 124 events at 760 Mev/c have been treated in the same way and are displayed in Fig. 2. At this momentum neither the Dalitz plot nor the histograms show such a convincing peak structure; the solid lines in Fig. 2 represent phase space and are seen to fit the data adequately. Nevertheless some real peaking may be present, particularly because at

Table I. Data from $K^- + p \to \Sigma^\pm + \pi^\mp + \pi^0$.

	P_K(lab) (Mev/c)	760	850	1150[a]
A.	Total number of events	124	125	111
B.	$\sigma(\Sigma^-\pi^+\pi^0) + \sigma(\Sigma^+\pi^-\pi^0)$ (mb)	0.9 ±0.2	1.7 ±0.3	1.8 ±0.2
$Y_1^{*\pm} \to \Sigma^\pm + \pi^0$				
C.	Events in shaded area	6 ±7	20 ±7	−3 ±5
D.	$R^\pm$ (%)	2 ±2	15 ±6	−2 ±3
E.	R^0(from $\Sigma^0\pi^+\pi^-$) (%)	1 ±5	−5 ±5	unreliable[b]
$Y^{*0} \to \Sigma^\pm + \pi^\mp$				
F.	Events in shaded area	17 ±8	16 ±8	9 ±10
G.	$\sigma(K^- + p \to Y^{*0} + \pi^0)$ (mb)	0.12 ±0.06	0.22 ±0.11	0.15 ±0.17
H.	$\sigma(K^- + p \to Y_1^{*\pm} + \pi^\mp)$ (mb)	2.4 ±0.15	1.9 ±0.2	3.1 ±0.4

[a] From Alston et al., reference 2.
[b] The data of row E are plagued with the difficulty of Λ vs Σ^0 separation; the fraction of ambiguous events increases quickly with beam momentum, and at 1150 Mev/c only an upper limit $R^0 < 8\%$ can be stated.

760 Mev/c the Y^* bands in the mass scatter diagram are less well separated, so that they are

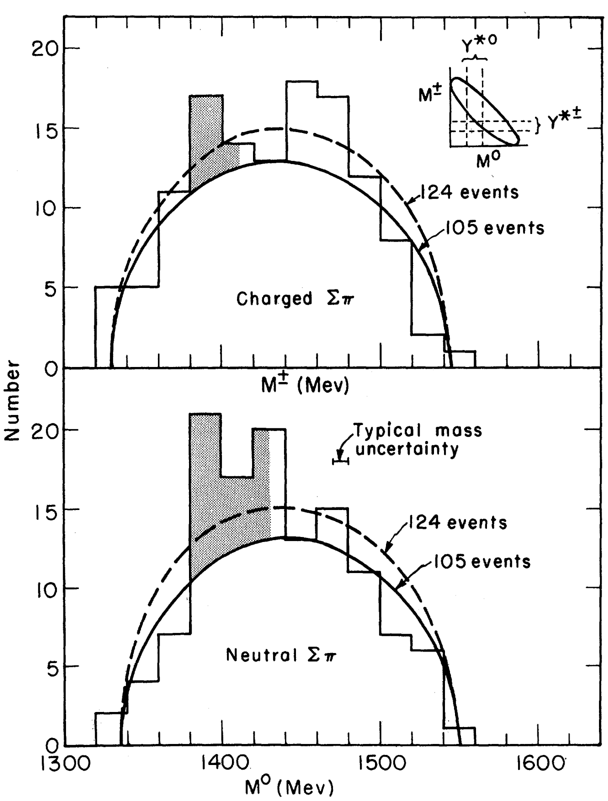

FIG. 2. Data from 55 reactions (1) and 69 reactions (2) at $P_K = 760$ Mev/c. The same considerations as for Fig. 1 apply here.

less easily resolved and are also subject to the interference effects already well known to occur in reaction (3) at the same beam momentum.[6]

The five values of the branching fraction R shown in rows D and E of Table I can now be combined to give an average of $(2 \pm 2)\%$. This average must be used with some reservation, since the five input data are not very consistent; their χ^2 value is 8 (its average expected value is 4), and the probability for this fluctuation is only about 10%. However, it is consistent with the value $\approx(6 \pm 2)\%$ observed from the reaction $K^- + d \to \Sigma^- + \pi^0 + p$ by Levine et al.[7] Therefore, we are inclined to believe that there is substantial evidence that R is less than a few percent and conclude that the 850-Mev/c charged peak is a fluctuation. If R only is a few percent, we can show now that very few of the events in the neutral peak can be attributed to Y_1^{*0}. The argument is as follows: In the production reaction $K^- + p \to Y^* + \pi$, the $I = 1$ channel cannot produce any Y_1^{*0}, and the $I = 0$ channel gives equal numbers of Y_1^{*0}, Y_1^{*+}, and Y_1^{*-}. From this it can easily be shown that in order to explain the neutral peaks as $Y_1^{*0} \to \Sigma^\pm + \pi^\mp$, we must assume that the production is dominantly in the $I = 0$ channel and $R \sim 10\%$. However, Dalitz and Miller have given good arguments in favor of the predominance of the $I = 1$ channel,[6] and furthermore we have just concluded that R is only a few percent.

We then interpret the neutral peaks either as a statistical fluctuation or as evidence for the sing-

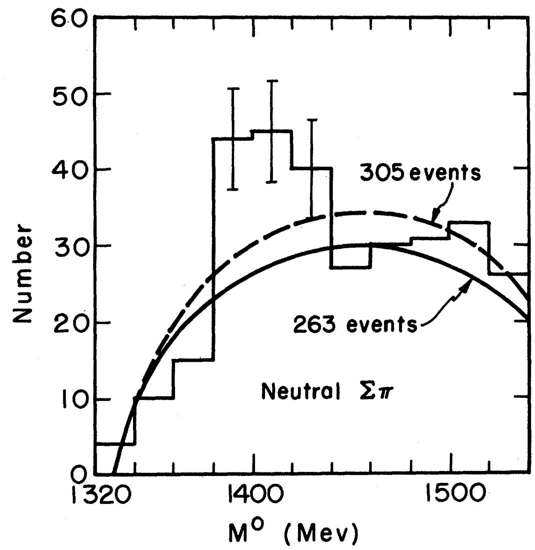

FIG. 3. Combined histogram of 305 $\Sigma^{\pm}\pi^{\mp}$ pairs at 760, 850, and 1150 Mev/c. The neutral pairs from Figs. 1 and 2 have been added to those in Fig. 1(c) of Alston et al. (1150 Mev/c).[2] The dashed curve is the sum of the dashed phase-space curves of our Figs. 1 and 2 and Fig. 1(c) of Alston et al.[2] The solid curve is the sum of our solid curves (in which we assume the existence of a neutral peak containing 17 events at 760 Mev/c and 16 at 850 Mev/c) and a corresponding curve that assumes 9 events at 1150 Mev/c, as shown in Table I.

let Y_0^* reported by Alston et al.[2] The excess events in the neutral peaks at each of the three momenta are listed in row F of Table I. The a priori probability for this fluctuation is actually quite small; however, such probabilities can give illusory results, so we prefer to illustrate the situation through Fig. 3, which is a combined mass histogram of all the currently available $\Sigma^{\pm}\pi^{\mp}\pi^0$ data. It does seem to constitute mild support for Y_0^*. In this connection two disconcerting facts should be noted: (a) The Y_0^* production cross section $\sigma(Y_0^*)$ (row G of Table I) is rather small in comparison with that of Y_1^* (row H). (b) If Y_0^* shows up so strongly in the two small-statistics, four-body final states reported by Alston et al.,[2] it is disappointing that the larger three-body samples do not confirm it more strongly.

This work is part of a study of low-energy K^-p interactions carried out in collaboration with J. P. Berge, O. Dahl, J. Kirz, D. H. Miller, J. J. Murray, R. D. Tripp, and M. Watson. We thank L. W. Alvarez and many members of his group for their help. In particular, we want to acknowledge close collaboration with the group who ran the 1150-Mev/c experiment: M. H. Alston, L. W. Alvarez, P. Eberhart, M. L. Good, W. Graziano, H. K. Ticho, and S. G. Wojcicki.

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