Strange-Particle Production by 1.95-BeV/c π^+ in Hydrogen*

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Strange-particle production has been studied in 30 000 pictures taken in the BNL 20-in. hydrogen bubble chamber exposed to a 1.95-BeV/c separated π^+ beam. Cross sections are presented and the production of resonant states is discussed. The three-particle final states are dominated by $Y_1^*(1385)$, $K^*(892)$, and $N_{1/2}^*(1688)$. The angular distribution of Σ^+ in the Σ^+K^+ final state is presented, and comparison with a resonance-exchange model is discussed.

INTRODUCTION

REACTIONS involving strange-particle production have been studied[1] in 30 000 pictures taken in the Brookhaven 20-in. hydrogen bubble chamber exposed to a separated π^+ beam with 1.95-BeV/c incident momentum from the AGS.

EXPERIMENTAL PROCEDURE

The film was scanned for all two- and four-prong interactions associated with at least either a kink or a vee. The measurements were accomplished with two Hermes Jr. machines working on line with a DDP-24 computer.[2] The geometrical reconstruction and kinematic fitting were done by the Yale system (YAP and YAK) at the New York University and at the Computer Science Center at the University of Maryland, using IBM 7094 machines. The classification of processed events and the final analysis were done at Duke on the DDP-24.

Most of the ambiguities between different production modes were resolved by examination of bubble density of the tracks. Ambiguities between $\Lambda K^+\pi^+$ and $\Sigma^0K^+\pi^+$ type two-prong and one-vee events were resolved in favor of $\Lambda K^+\pi^+$, if there was a good four-constraint fit at the primary vertex.

CROSS SECTIONS

The raw numbers of accepted events in various production modes are given in Table I. The uncertainties appearing there are due to ambiguities only. Because of scanning bias on Σ^+ resulting from a small angle between Σ^+ and its decay daughter particle, and because of short Σ^+ track length, it is necessary that cuts be made in these variables. Accepted events have $\theta > 5°$, and (Σ length)>0.4 cm. Both of these criteria are applied in the primary scanning view rather than in real space. A weight is then assigned to each Σ^+ event by the inverse probability that the event should fall below the cutoff. The average value of the weighting factor is 1.38 ± 0.15.

Five percent of the events were lost because of bad measurements. The muon contamination in the beam was taken to be 0.076.[3] The scanning efficiency used in our cross-section calculations was 0.78 ± 0.09.

The cross section for different production modes is also given in Table I. Data of other experiments with beam momentum close to ours are shown for comparison.[4]

THREE-BODY FINAL STATES

All three-body final states were searched for resonant states and it was found that they proceeded predominantly via quasi-two-body channels.

In the $\Lambda K^+\pi^+$ channel there are only two known resonant states, the $Y_1^*(1385)$ and the $N^*_{1/2}(1688)$. The Dalitz plot (Fig. 1) shows strong concentration of events around both. A fraction 0.76 ± 0.08 of these events is in the channel $Y_1^*(1385)$ plus K and 0.24 ± 0.08 is in the $N_{1/2}^*(1688)$ plus pion.

In the $\Sigma^+K^0\pi^+$ channel, $K^*(892)$ and the $N_{3/2}^*(1920)$ are accessible. The Dalitz plot (Fig. 2) shows definite K^* production; however, the $N_{3/2}^*(1920)$ is not seen.

The same resonant states, plus $Y_1^*(1385)$ are possible for the $\Sigma^+K^+\pi^0$ final state. The Dalitz plot for the $\Sigma\pi$ versus $K\pi$ systems is compared to the same plot for $\Sigma^+K^0\pi^+$ production (Fig. 3). The presence of points in the $Y_1^*(1385)$ region for $\Sigma^+K^+\pi^0$ and the absence of points in the same region for $\Sigma^+K^0\pi^+$ indicates Y_1^*-(1385) production.

In the $\Sigma^0K^+\pi^+$ final state, only the $Y_1^*(1385)$ is expected. [Note that the $N_{3/2}^*(1920)$ was not seen in $\Sigma^+K^0\pi^+$ channel.] There are not enough unambiguous events for us to draw any conclusions about this production mode.

The branching ratio of $K^*(892)$ was found to be

$$K^{*+}(892) \to K^0\pi^+ \quad 0.69\pm0.12$$
$$\to K^+\pi^0 \quad 0.31\pm0.12\,,$$

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[4] Horst W. J. Foelsche, A. Lopez-Cepero, C. Y. Chien, and H. L. Kraybill (unpublished).

TABLE I. Strange-particle production in π^+p interaction.

Reaction product	Uncorrected number of events in this experiment[a]	Cross section in millibarns for different production modes Beam momentum: 1.76 BeV/c[b]	1.95 BeV/c This expt.	2.08 BeV/c[b]
Σ^+K^+	99	0.38 ±0.05	0.31 ±0.04	0.29 ±0.04
$\Sigma^+K^+\pi^0$	26	0.07 ±0.02	0.07 ±0.02	0.17 ±0.03
$\Sigma^+K^0\pi^+$	33	0.03 ±0.01	0.12 ±0.03	0.11 ±0.03
$\Sigma^0K^+\pi^+$	10_{-4}^{+0}	0.04 ±0.02	0.03 ±0.015	0.04 ±0.02
$\Lambda K^+\pi^+$	43_{-0}^{+1}	0.19 ±0.04	0.14 ±0.03	0.12 ±0.03
$\Lambda K^0\pi^+\pi^+$, $\Sigma^0K^0\pi^+\pi^+$	5_{-0}^{+2}	0.005±0.005	0.015±0.011	0.01 ±0.01
$\Lambda K^+\pi^+\pi^0$	2_{-0}^{+1}	<0.01	0.01 ±0.01	0.015±0.011
$PK^+\bar{K}^0$	0	0.03 ±0.02	<0.01	0.05 ±0.025
All types of strange-particle products	218	0.75 ±0.07	0.70 ±0.08	0.80 ±0.07
$Y_1^{*+}(1385)K^+$	41±5	0.19 ±0.04	0.14 ±0.03	0.08 ±0.03
$\Sigma^+K^{*+}(892)$	34±3		0.14 ±0.03	
$N_{1/2}^{*+}(1688)\pi^+ \searrow K^+\Lambda$	10		0.03 ±0.01	

[a] The uncertainties are due to ambiguity only.
[b] See Ref. 4.

which is in agreement with the expected 2:1 ratio from Clebsch-Gordan coefficients.

For the $Y_1^*(1385)$ we have

$$Y_1^{*+}(1385) \rightarrow \Lambda\pi \quad 0.77\pm0.15$$
$$\rightarrow \Sigma\pi \quad 0.23\pm0.15\,,$$

which is consistent with the values found in previous experiments: 0.91±0.03 and 0.09±0.03, respectively.[5]

The cross sections for production of various resonant states for all three-body final states are presented on the bottom of Table I.

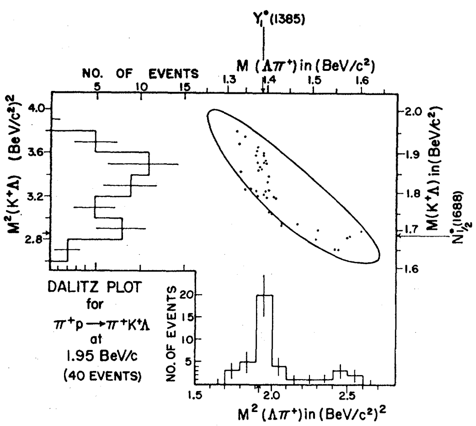

FIG. 1. Dalitz plot for $\Lambda K^+\pi^+$ production mode.

Σ^+K^+ PRODUCTION

The angular distribution of Σ^+ from the Σ^+K^+ production mode is presented together with other experi-

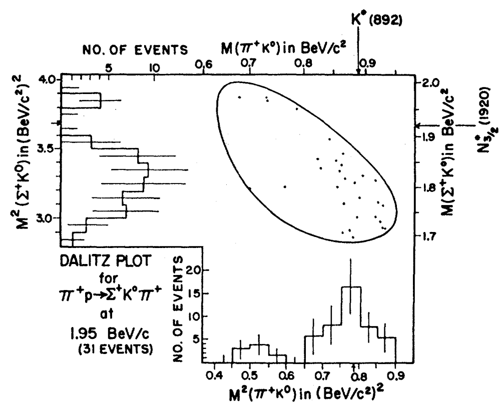

FIG. 2. Dalitz plot for $\Sigma^+K^0\pi^+$ production mode. The histograms showing the projections of the plot have been corrected for scanning losses and cuts.

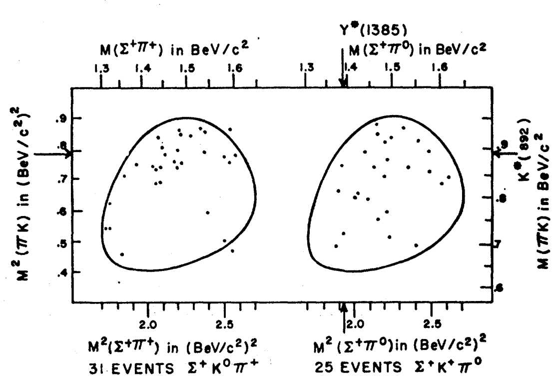

FIG. 3. Dalitz plot for $\Sigma^+K^0\pi^+$ and $\Sigma^+K^+\pi^0$ production modes.

[5] A. H. Rosenfeld, A. Barbaro-Galtieri, W. J. Podolsky, L. R. Price, P. Soding, C. G. Wohl, M. Roos, and W. J. Willis, Rev. Mod. Phys. 39, 1 (1967).

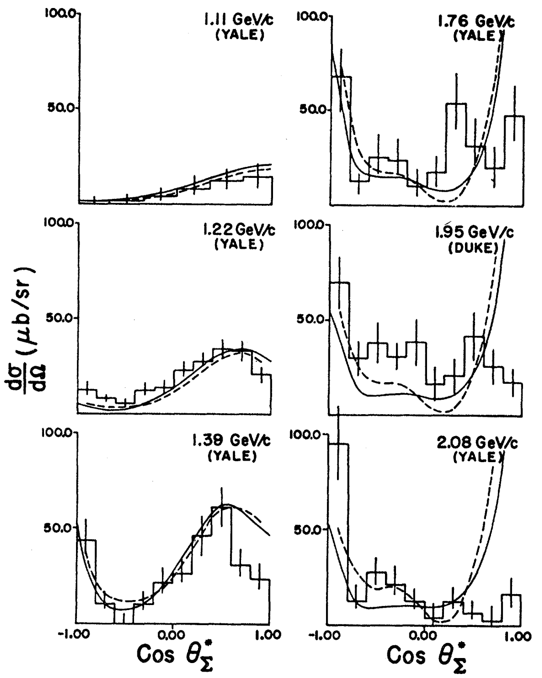

FIG. 4. Angular distributions on Σ^+ in the c.m. system. The curves are due to the resonance exchange model (see footnote 7). The smooth curve represents the original set of parameters and the dashed-line curve is obtained with our choice of parameters. The data for 1.11 and 1.22 BeV/c are from Ref. 6. The data for 1.39, 1.76, and 2.08 BeV/c are from Ref. 4.

mental results[6] for different beam momenta in Fig. 4. Comparison is made with the prediction of a simple resonance model.[7] The model consists of K^* and hyperon (Λ and Σ^0) exchanges without form factor and the contributions due to the two resonances in the $p\pi^+$ system, namely the $N_{3/2}^*(1236)$ and the $N_{3/2}^*(1920)$. The theory fits the experimental results well for pion momenta below $N_{3/2}^*(1920)$. formation threshold, but deviates at higher momenta, rather markedly.

An attempt has been made to improve the theoretical prediction in the framework of the model by adding new interaction diagrams and adjusting the free parameters (one for each diagram). The $p\pi^+$ resonance with mass 2420 MeV/c^2 and width 250 MeV/c^2 has been introduced. The two different but possible spin-parity assumptions, $J^P=\frac{9}{2}^-$ and $\frac{11}{2}^+$ are used separately in the attempt. The $\frac{9}{2}^-$ assumption for the resonance enhances the disagreement with the experiment, but the $\frac{11}{2}^+$ improves the fitting at higher momenta by raising the peak near $\cos\theta_\Sigma=-0.3$ in the Σ^+ differential cross section (Fig. 4). An attempt has also been made to use $\kappa(725)$ exchange diagram instead of that of $K^*(892)$ and to introduce the $N_{3/2}^*(1670)$ resonance, but the results do not justify the change. It is not possible to find a set of parameters satisfactory for all momenta. We give in Table II the set of parameters which seem to be a compromise. The major disagreement in Σ^+ production is in the forward direction where no peak is observed experimentally. In the model, the main contributor to this peak is the hyperon exchange. By drastically reducing the absolute magnitude of the hyperon-exchange coupling constant, the model can make predictions reasonably agreeable to our experiment; but at the same time, this upsets agreements with experiments at energies below $N_{3/2}^*(1920)$ formation threshold.[8]

TABLE II. Coupling parameters (using the same notation as Ref. 7).

	Ref. 7	This work
G_K	−0.722	−0.81
G_Λ	−10.8	−9.73
C_3	0.195	0.219
C_7	0.253	0.284
C_{11}	···	0.243

CONCLUSION

The cross sections in different strange-particle production channels are in good agreement with those found in other experiments in neighboring energies. The three-body final states are dominated by quasi-two-body final states including the resonances: $Y_1^*(1385)$, $N_{1/2}^*(1688)$, and $K^*(892)$. There is no simple explanation for the behavior of the Σ^+ angular distribution in the Σ^+K^+ final state. It is possible, however, that introducing a yet unknown N^* resonance with isospin $\frac{3}{2}$ could give a better agreement with the experiment. It will also be interesting to include the absorption effect in the theory.

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[6] C. Baltay, H. Courant, W. J. Fickinger, E. C. Fowler, H. L. Kraybill, J. Sandweiss, J. R. Sanford, D. L. Stonehill, and H. D. Taft, Rev. Mod. Phys. **33**, 374 (1961).

[7] L. E. Evans and J. M. Knight, Phys. Rev. **137**, B1232 (1965).

[8] We have also compared the theoretical prediction with results by the Purdue group [N. L. Carayannopoulos, G. W. Tautfest, and R. B. Willmann, Phys. Rev. **138**, B433 (1965)] at 1.111-, 1.206-, and 1.265-BeV/c π^+ momentum. They have more events than the Yale experiments at corresponding momenta, and the agreement with the theoretical prediction is comparable.