TO BE SUBMITTED TO PHYSICS LETTERS

CERN/TC/PHYSICS 66-12
7.6.1966

PRODUCTION OF STRANGE PARTICLES IN 8 GeV/c π^+-PROTON INTERACTIONS

II. $K\bar{K}$ production and ΛK and $K\bar{K}$ cross sections.

S. Brandt, V.T. Cocconi, O. Czyzewski, P.F. Dalpiaz, H. Hromadnik, G. Kellner and D.R.O. Morrison, - CERN, Geneva.

J. Bartke, A. Eskreys, J. Łoskiewicz and W. Zieliński - Institute for Nuclear Research, Cracow.

M. Bardadin-Otwinowska, T. Hofmokl, S. Otwinowski, H. Piotrowska, R. Sosnowski, M. Szeptycka and A. Wróblewski - University of Warsaw and Institute for Nuclear Research, Warsaw.

In this letter are presented data on the reactions :

$$\pi^+ + p \rightarrow p + \bar{K}^0 + K^+ \qquad (1)$$

$$\pi^+ + p \rightarrow p + \bar{K}^0 + K^0 + \pi^+ \qquad (2)$$

$$\pi^+ + p \rightarrow p + \bar{K}^0 + K^+ + \pi^0 \qquad (3)$$

$$\pi^+ + p \rightarrow n + \bar{K}^0 + K^+ + \pi^+ \qquad (4)$$

studied in 140.000 pictures of $\pi^+ p$ interactions at (8.04 ± 0.06) GeV/c, taken in the 81 cm Saclay bubble chamber exposed at the CERN proton synchrotron. Details of the experiment have been reported in Part I of this communication[1], concerning ΛK production.

Table I gives the cross sections, corrected for unobserved decays, for each of the reactions listed[2].

TABLE I

Reaction	Number of events	Cross section in μb
(1)	17	34 ± 8
(2)	59 + 25 x 0.5	88 ± 16
(3)	27 + 25 x 0.5	69 ± 17
(4)	22 + 21 x 0.5	63 ± 18

In reaction (2) the partial cross-sections for $pK_1^oK_1^o\pi^+$ and $pK_1^oK_2^o\pi^+$ are $(29 \pm 7)\mu b$ and $(30 \pm 12)\mu b$, respectively. These numbers were deduced from the number of events with one or two observed K^o decays. The total cross-section for $p\bar{K}^oK^o\pi^+$ was taken as $2\sigma_{K_1K_1} + \sigma_{K_1K_2}$.

For reaction (1) the distribution of the effective mass of the $\bar{K}^oK^+$ system was presented in another paper[3], where it was used to investigate the existence of a rare decay mode of the A_2-meson into $K\bar{K}$. As reported there, the branching ratio $(A_2 \to K\bar{K}) / (A_2 \to \pi\rho)$ was estimated to be 0.03 ± 0.02.

Here we discuss in detail reaction (2) for which we have the largest number of events. In Figs. 1a and 1b are shown the scatter plots of the effective mass of the systems $(p\pi^+)$ and $(K^o\pi^+)$ versus the squared four momentum transfer, $|t|$, relative to the system considered. The histograms in Figs. 1c and 1d are the corresponding projections on the effective mass axis. It can be seen that there is an appreciable production of the $N^{*++}(1238)$ isobar and of $K^{*+}(890)$, and that the points in the N^* and K^* bands tend to cluster towards small $|t|$ values. In Fig. 1c the shaded histogram corresponds to the events in which the π^+ does not form a K^*.

The shaded area in Fig. 1d corresponds to the events in which the π^+ does not form an N^{*} nor is combined with the other K^o meson to form a second K^{*}. It is interesting to note that this selection procedure removes most of the events with a low $K\pi$ mass, largely within a band near the kappa (720) mass range, whereas the $K^{*}(890)$ peak remains present.

In the $K^o\bar{K}^o$ and $K_1^oK_1^o$ effective mass distributions for reaction (2) no distinct peaks are visible. From these distributions, it is however possible to establish an upper limit for the production cross section of the ϕ and f'-mesons, as well as for the branching ratio $(f^o \to K\bar{K}) / (f^o \to \pi\pi)$ for the f^o-meson. In each case, the upper limit of the cross section is defined as twice the square root of the number of events in the mass region of the resonance considered (which corresponds to about 95 o/o confidence limit). The results are in Table II.

TABLE II

Reaction	Mass range used (GeV)	Upper limit of cross section
$\pi^+p \to p\pi^+\phi$	$1.00 < M(\phi) < 1.05$	8μb
$\to N^{*++}\phi$	$1.00 < M(\phi) < 1.05$	4μb
$\to p\pi^+f'$	$1.40 < M(f') < 1.60$	18μb

These results show that the production of ϕ and f' in π^+p interactions at 8 GeV/c is very low. Our upper limits are consistent with the small cross sections reported at lower incoming pion momenta[4]. The upper limit for the branching ratio $(f^o \to K\bar{K}) / (f^o \to \pi\pi)$ is 0.06. This number was calculated using the data of the Aachen, Berlin, CERN collaboration for the process $\pi^+p \to p\pi^+f^o$, and taking for the f^o the mass band 1.13 to 1.38 GeV.

/5494/rmn

Reactions (3) and (4) show less production of $K^{*}(890)$ and $N^{*}(1238)$ resonances than observed in reaction (2).

From the total number of events with strange particles, the cross sections $\sigma_{K\bar{K}}$ for all $K\bar{K}$ production reactions and σ_{YK} for all reactions producing a hyperon and a kaon have been calculated, after correcting for unobserved decay modes and for the reactions with 5, 6.... body final states. The results are

$$\sigma_{K\bar{K}} = (1.55 \pm 0.20) \text{ mb}$$

and $$\sigma_{YK} = (1.55 \pm 0.20) \text{ mb} .$$

The total cross section for strange particle production by 8 GeV/c positive pions on protons is therefore :

$$\sigma_{\text{strange particle}} = (3.10 \pm 0.30) \text{ mb} ,$$

which represents about 12 o/o of the total cross section for $\pi^{+}p$ interactions. This may be compared with the ratio $\sigma_{\text{strange particle}}/\sigma_{\text{tot}} = 4.3/39 = 11$ o/o obtained for 24 GeV pp collisions[5].

Our results are plotted in Fig. 2 along with other data on strange particle production by pions, reported in the literature[6 to 15]. The cross sections for $K\bar{K}$ and YK production, as well as their sum, i.e., the total cross section for strange particle production, are plotted as functions of the momentum of the incoming pion, for both $\pi^{+}p$ and $\pi^{-}p$ interactions. It may be noted that the π^{+} and π^{-} cross sections are similar at all momenta. The associated production of hyperon-kaon pairs which has the lower threshold and rises very steeply, is the main process of strange particle production below 6-7 GeV/c. At higher momenta the YK cross section levels off, while the production of kaon-antikaon pairs becomes predominant.

In the energy region studied here, the $K\bar{K}$ cross section appears not to have yet reached a plateau value.

As has been previously shown for 10 GeV/c π^-p interactions[13,16], the $K\bar{K}$ pairs tend to be emitted forwards in the c.m. system, while in the case of YK production the hyperons are produced predominantly backwards and the kaon predominantly forwards. If the production of strange particle pairs is pictured as an exchange process, these facts may be interpreted as meaning that the $K\bar{K}$ pair is produced at the mesonic vertex, while in YK production, the hyperon is produced at the baryon vertex, and hence the enchange of a strangeness quantum number is required. This might be a reason for the YK cross section to be smaller than the $K\bar{K}$ cross section at energies appreciably above threshold.

We are deeply indebted to the operating crews of the CERN proton synchrotron, of the 81 cm Saclay bubble chamber and of the 02 beam. We would like to thank the scanning, measuring and computing staffs at each of our laboratories. We are pleased to acknowledge helpful discussions with Dr. R. Armenteros, Prof. M. Danysz and Prof. Ch. Peyrou.

References

1. CERN-Cracow-Warsaw collaboration, S. Brandt et al., submitted for publication in Physics Letters.

2. The reaction $\pi^+ + p \rightarrow p + K^+ + K^- + \pi^+$ is not investigated as the events studied are two and four-prong interactions with one or more associated V^0 decays. A correction for this channel is of course included in the determination of the total cross section for kaon-anti-kaon pairs given later in this paper.

3. Aachen-Berlin-CERN collaboration, M. Deutschmann et al., Physics Letters 20 (1966) 82.

4. G.H. Trilling, J.L. Brown, G. Goldhaber, S. Goldhaber, J.A. Kadyk, J. Scanio, UCRL - 16294 (1965).

5. J. Bartke, W.A. Cooper, B. Czapp, H. Filthuth, Y. Goldschmidt-Clermont, L. Montanet, D.R.O. Morrison, S. Nilsson, Ch. Peyrou and R. Sosnowski, Nuovo Cimento 29 (1963) 8.

6. J.L. Brown, D.A. Glaser, M.L. Perl, Phys. Rev. 108 (1957) 1036.

7. L.B. Leipuner and R.K. Adair, Phys. Rev. 109 (1958) 1358.

8. F. Eisler, R. Plano, A. Prodell, N. Samios, M. Schwartz, J. Steinberger, P. Bassi, V. Borelli, G. Puppi, H. Tanaka, P. Waloschek, V. Zoboli, M. Conversi, P. Franzini, I. Mannelli, R. Santangelo and V. Silvestrini, Nuovo Cimento 10 (1958) 468.

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

10. A. Berthelot, A. Daudin, O. Goussu, F. Grard, M.A. Jabiol, F. Lévy, C. Lewin, A. Rogozinski, J. Laberrigue-Frolow, C. Ouannès and L. Vigneron, Nuovo Cimento 21 (1961) 693.

11. Saclay-Orsay-Bari-Bologna collaboration, Proceedings of 1961 Aix-en-Provence Int. Conf. on Elementary particles, p.375.

12. F.S. Crawford Jr., F. Grard and G.A. Smith, Phys. Rev. 128 (1962) 368.

13. A. Bigi, S. Brandt, A. de Marco-Trabucco, Ch. Peyrou, R. Sosnowski, A. Wroblewski, Nuovo Cimento 33 (1964) 1249.

14. Aachen-Hamburg-London (I.C.) - München collaboration, J. Bartsch, L. Bondar, R. Speth, G. Hotop, G. Knies, F. Storim, J.M. Brownlee, N.N. Biswas, D. Lüers, N. Schmitz, R. Seelinger, G.P. Wolf, preprint.

15. P. Daronian, A. Daudin, M.A. Jabiol, C. Lewin, C. Kochowski, B. Ghidini, S. Mongelli, V. Picciarelli, Saclay preprint, to be published in Nuovo Cimento.

16. A. Bigi, S. Brandt, R. Carrara, W.A. Cooper, A. de Marco, G.R. MacLeod, Ch. Peyrou, R. Sosnowski and A. Wroblewski, Proceedings of the 1962 Int. Conference on High Energy Physics at CERN, p. 247.

Figure Captions

Fig. 1. 1a) and 1b) : Scatter plot of the effective mass of the $(p\pi^+)$ and $(K^o\pi^+)$ system, respectively, versus the squared four momentum transfer, $|t|$, for the reaction $\pi^+ p \rightarrow p\bar{K}^o K^o \pi^+$.

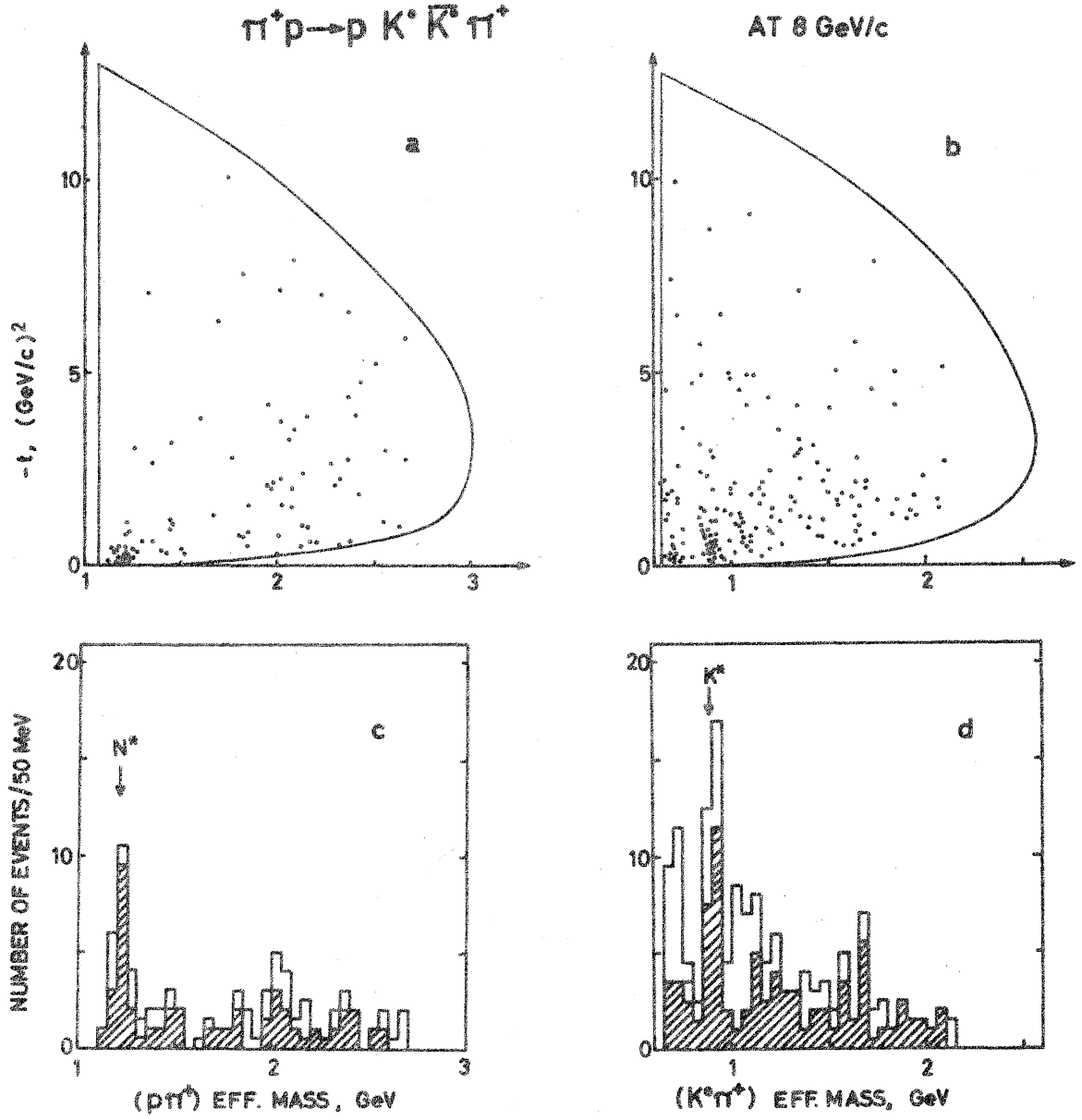
1c) and 1d) : Effective mass distributions for $(p\pi^+)$ and (K^oK^+), respectively. The shaded area in 1c) corresponds to the events in which a $K^*(890)$ is not observed. The shaded area in 1d) corresponds to the events in which the π^+ does not form a N^* isobar nor a K^* in combination with the other K^o.

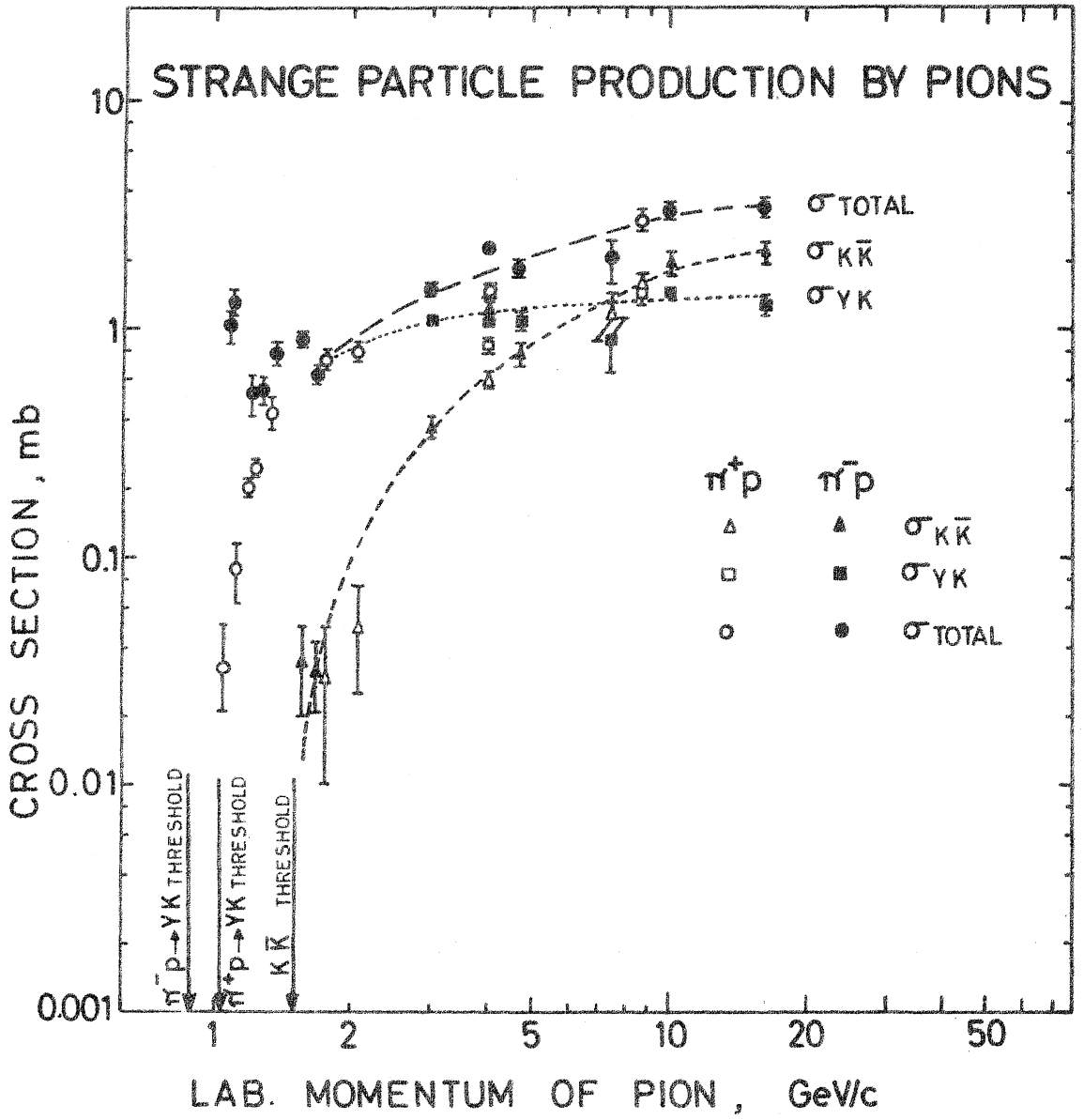
Fig. 2. Total cross section for production of strange particles and partial cross sections for $K\bar{K}$ and YK production in $\pi^{\pm} p$ interactions, as functions of the laboratory momentum of the incident pion. The curves are hand-drawn fits to the data. Near the YK thresholds no curve is drawn as the cross sections are influenced by isobar production.

Captions for Tables

TABLE I Cross sections, corrected for unobserved decay modes, for reactions (1) to (4).

TABLE II Upper limits for the indicated reactions of ϕ and f' production, as determined from the $K\bar{K}$ mass distribution in reaction $\pi^+ p \rightarrow pK^o\bar{K}^o\pi^+$.


π⁺p→p K° K̄° π⁺
AT 8 GeV/c
a
b
c
d
-t, (GeV/c)²
NUMBER OF EVENTS/50 MeV
N*
K*
(pπ⁺) EFF. MASS, GeV
(K°π⁺) EFF. MASS, GeV


STRANGE PARTICLE PRODUCTION BY PIONS
CROSS SECTION, mb
LAB. MOMENTUM OF PION, GeV/c
10
1
0.1
0.01
0.001
1
2
5
10
20
50
σ TOTAL
σ KK̄
σ YK
π⁺p
π⁻p
σ KK̄
σ YK
σ TOTAL
π⁻p → YK THRESHOLD
π⁺p → YK THRESHOLD
KK̄ THRESHOLD