Title
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Authors
Whitehead, Marian
Lanou, Robert E.
Birge, Robert W.
et al.

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ABSTRACT

The reactions $K^+ + n \rightarrow K^o + p$, $K^o \rightarrow \pi^+ + \pi^-$ have been observed in the Lawrence Radiation Laboratory 30-in. propane chamber. A beam of 200-Mev K^+ was incident on the chamber. The measured cross section, for the two events found, is 0.6 mb per carbon neutron.

II. K^+ CHARGE EXCHANGE PRODUCTION OF K^0 MESONS BY CHARGE EXCHANGE OF K^+ IN PROPANE

C_3H_8

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I. Introduction

The disappearance of K^+ meson tracks in nuclear emulsion have been reported by many observers.[1] In accordance with conservation of "strangeness" in strong interactions,[1,2] the reaction is $K^+ + n \rightarrow K^0 + p$. The K^0 will decay by either the short-lived K_1^0 or long-lived K_2^0 mode. The K_1^0 decays with a mean life of about 10^{-10} sec by either of two alternate modes:

or $$K_1^0 \rightarrow \pi^+ + \pi^-$$

$$K_1^0 \rightarrow \pi^0 + \pi^0, \qquad (1)$$

with a branching ratio[3] $(\pi^0 + \pi^0)/(\pi^+ + \pi^-) \approx \frac{1}{2}$.

The long half-life (10^{-7} sec) of the K_2^0 makes it substantially unobservable in this experiment. In nuclear emulsion, the decay of neither mode is observed. The observation of the complete process, including the decay products of the K^0, is of interest to confirm that the conservation rule is satisfied.

In another paper,[4] some of us report an attempt to observe the charge-exchange process in a counter-triggered multiplate cloud chamber at the Bevatron. No K^o decays were observed when calculations based on cross sections obtained from emulsion data indicated that 10 should be seen. The interpretation was ambiguous, because there was no way to determine whether the cross-section value, the ratio of the long-lived to short-lived decay mode of the K^o, or the experimental results were in error. Shortly after the close of that experiment the 30-in. propane bubble chamber at the Lawrence Radiation Laboratory[5] was completed and placed in a 200-Mev separated K^+ beam for a combined engineering test and experiment. This beam was modified from one designed by Dr. D. H. Stork and Dr. John Mulvey of the University of California, Los Angeles for emulsion exposures.[6] The existence of Reaction (1) has been confirmed in this experiment, and an approximate cross-section value for carbon is calculated.

II. Experimental Method

A. Beam

A diagram of the beam is shown in Fig. 1. The energy of the beam in the chamber, calculated from the known magnetic fields and absorbers, is 180 ± 37 Mev. To reach the visible portion of the chamber, the K^+ must pass through 1 in. of oil and 1/4 in. of steel. The scanning was done in the center 30 cm of the chamber. The K^+ energy half-way through the chamber was 105 ± 25 Mev; the change in the median energy over the area scanned was 60 to 130 Mev.

The range of the K^+ was approximately the length of the visible region of the chamber. Therefore, during part of the run enough additional absorber was placed in the beam to stop a median energy K^+ in the center of the chamber. In this way the calculated energies were confirmed by range measurements, and the relative number of all beam tracks (π^+, protons, and K^+) to K^+ was found. The average number was 25 ± 5 tracks for one K^+. It was not considered worthwhile to determine this number more accurately.

B. Scanning

The film was scanned twice. The first was a quick scan looking for K^o decays. In this scan, a source of background confusion became obvious. A number of π mesons enter the chamber from the side (having scattered from the magnet iron) and scatter on the carbon in the propane. These simulate K_1^o decays, which have wide opening angles at these energies.

In the second scan the observers looked for disappearing beam tracks. When one was seen, the body of the chamber was then examined for a K^o decay. Two definite cases of K^o decay were found. In one case the incoming K^+ makes a visible charged recoil in the charge-exchange reaction.

The data on these tracks are given in Table I. It should be noticed that these events cannot be coincidental π^+ scatters, since the curvatures are such that the π^+ would have to gain energy in the scatter. Event 41192 had a black prong at the charge-exchange point, which, if a proton, had an energy of 12 Mev. The observation of these events confirms the charge-exchange hypothesis based on emulsion data.

Table I.

Kinematics of K_o decays

Event No.	Momentum of Decay Products P^+ (Mev/c)	P^- (Mev/c)	Opening Angle (Deg.)	Mass of Particle: Neutral Particle (Mev)	At Disappearance $P(K^+)$	At Decay $P(K^o)$	Angle of Production (Deg.)
17257	300±31	175±18	116	484±27	350±36	312±31	38
41192	368±41	(202)[a]	109	527±29	400±41	398±44	91

[a] Calculated from tranverse momentum balance.

III. Experimental Results

A. Calculation of Cross Section

To calculate the cross section for the charge exchange of a K^+ into a visible short-lived K^o based on the two K^o decays found, we write

$$N_K = \sigma_o \frac{N_\pi}{R} \frac{lP}{A} N_0 N_n = 2,$$

where

N_K = number of K^o decays resulting from charge exchange,

N_π = total number of beam tracks in picture area scanned (8.7×10^4),

R = ratio of beam tracks to K^+ (25),

l = length of area scanned (30 centimeters),

P = density of propane (0.415 gms cm^{-2}),

A = molecular weight of propane (44 gm),

and

N_o = Avogadro's number (6.025×10^{23} mol. wgt.).

These data gives $\sigma_o = 0.2\times10^{-27}$ cm^2 per neutron. If we assume that one-half the charge exchanges led to unobserved K_2^o and also use the fact that one-third of the K_1^o decay by the two π^o mode,[3] we can calculate a total cross section for charge exchange, σ_{CE}:

$$\sigma_{CE} = 2\times\frac{3}{2}\ \sigma_o = 0.6 \text{ mb/neutron}.$$

B. Discussion

At present the charge-exchange cross section in this energy region has been measured by several emulsion groups. Their combined results give a value for σ_{CE} = 1.3±0.3 mb/neutron as an average over the energy region 40 to 150 Mev.[7,8,9] It is hard to reasonably compare this value for the cross section with ours, because ours is based on only two events and has not been corrected for scanning efficiency, which is believed to be about 80%. Furthermore, in carbon the lowest-energy process for charge exchange is

$$K^+ + C^{12} \rightarrow K^o + N^{12},$$

and C^{12} and N^{12} have a 17-Mev mass difference. If we assume that the charge exchange is with a single neutron in the carbon nucleus, the K^o must be produced at an angle large enough so that the recoil proton can have 17 Mev. The forward angles will therefore be suppressed. In addition, the analyses of the Padua and UCLA groups suggest an angular distribution of the K^o that is peaked forward. This angular distribution would cause an even more pronounced suppression of the cross section for charge exchange in carbon. Under these conditions the charge exchange of a 100-Mev incident K^+ from a static neutron must be 40^o, corresponding to a reduction of ~30% in the measured total cross section.

IV. Acknowledgments

The authors would like to acknowledge the generous assistance of many people: Dr. Joseph Lanutti for his assistance in the modification of the K^+ beam and during the experiment proper; Dr. Warren Chupp for valuable assistance throughout the experiment; Edith Goodwin, Beverly Jerome, Marilyn McLaren, Irene Bringe, and Robert Fry for the difficult task of diligently and competently scanning for and finding rare events; the bubble chamber crew who operated the complex 30-in.-chamber on its maiden voyage; and Dr. Edward J. Lofgren and the staff of the Bevatron who provided the experiment with a reliable beam.

FIGURE LEGEND

Fig. 1. Plan view of beam.

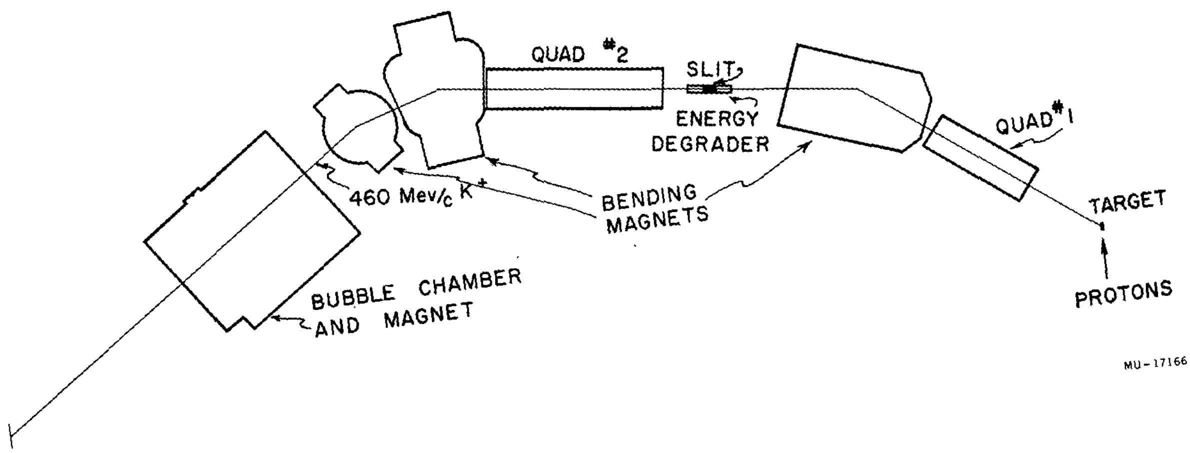
QUAD #2
SLIT
ENERGY
DEGRADER
QUAD #1
460 Mev/c K+
BENDING
MAGNETS
TARGET
PROTONS
BUBBLE CHAMBER
AND MAGNET
MU-17166

Fig. 1

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