Analysis of K-Meson Production by $\bar{p}$ Annihilation*

T. F. HOANG†
Lawrence Radiation Laboratory, University of California, Berkeley, California

(Received August 22, 1960; revised manuscript received November 17, 1960)

K-meson production by $\bar{p}$ annihilation has been investigated using an isobar model. A comparison of the predictions of this model with the experimental data excludes the assumption of an isobar state of $(\pi\pi)$ having a mass greater than three pion masses.

In a previous work on K-meson production by $\bar{p}$ annihilation, a modification of the Fermi model has been proposed by introducing an interaction volume Ω_K in addition to the customary π-meson interaction volume Ω_π of the original model. This modified model gives a satisfactory interpretation of experimental results with Ω_π equal to eight to ten times $\Omega_0=[4\pi(\hbar/\mu c)^3]/3$ and with $\Omega_K/\Omega_\pi\simeq 0.3$, μ being the π mass. The results of the analysis have been presented elsewhere.[1]

The high-momentum $\bar{p}$-annihilation data used in this work were selected from "hydrogen-like" events of a propane-bubble-chamber experiment of the Goldhaber group at Berkeley.[2] Since then, some of the problems previously treated in reference 1 have also been investigated by Goldhaber *et al.*,[2] who used a different method to select experimental data.[3] A comparison of their results with those discussed in reference 1 indicates no significant discrepancy within statistical and experimental errors. As regards their momentum spectra of the K meson and the associated π meson, there seems to be a noticeable smearing, which may reflect the effect due to the Fermi momentum and the nuclear scattering of the carbon events. Consequently a comparison of their results with the spectrum predicted by the statistical model is probably subject to more uncertainties than one using only the "hydrogen-like" events.

In this paper we present another analysis of K-meson production by $\bar{p}$ annihilation according to the isobar model.[4] Since the average number of π mesons associated with a K meson exceeds two, it is interesting to investigate if two of these π mesons are produced in a resonant state corresponding to $J=1$ and $I=1$. Let $(\pi\pi)$ designate this resonant state. Then for reactions involving two or more associated π mesons, we have to consider the following processes:

$$\bar{p}+p\rightarrow K+\bar{K}+\underset{\searrow 2\pi}{(\pi\pi)}+(n-2)\pi.$$

We have investigated two cases for assumed isobar

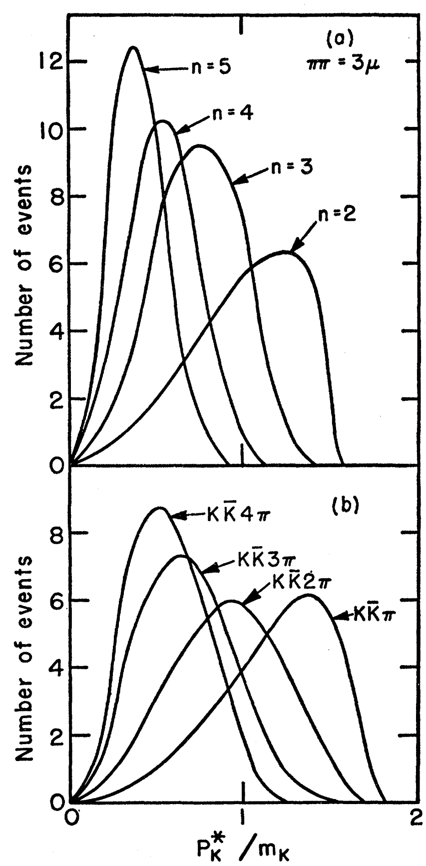

FIG. 1. Momentum spectrum for K mesons in the $\bar{p}-p$ c.m. system. The curves represent spectra computed according to the covariant phase-space factor and are normalized to the same area. (a) Curves for the isobar model corresponding to the reactions $\bar{p}+p\rightarrow K+\bar{K}+\underset{\searrow 2\pi}{(\pi\pi)}+(n-2)\pi$, with $n\geqslant 2$ and mass $(\pi\pi)=3\mu$. (b) Curves for the Fermi model corresponding to the reaction $\bar{p}+p\rightarrow K+\bar{K}+n\pi$.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† Now at Laboratoire de Physique, Ecole Polytechnique, Paris, France.
[1] T. F. Hoang, W. B. Fowler, and W. M. Powell, Lawrence Radiation Laboratory Report UCRL-8994, January, 1960 (unpublished).
[2] S. Goldhaber, G. Goldhaber, W. M. Powell, and R. Silberberg, following paper [Phys. Rev. 121, 1525 (1961)].
[3] At this point we would like to note that the scanning procedure used in reference 1 is slightly different, namely the fiducial volume for scanning was set 10 cm ahead of that used in reference 2. Consequently about 20% of events were not included in reference 2, and the average $\bar{p}$ momentum was ~15 Mev/c higher than the value quoted in other works dealing with the same experiment. As regards our charged K mesons, 10% of our $K^\pm$ do not end inside the chamber; they are identified as such by curvature and gap counting (compared to some well-identified track of the same event).
[4] The author is indebted to Professor G. Chew for suggesting this problem and drawing his attention to the paper by F. Cerrulus in Nuovo cimento 14, 827 (1959).

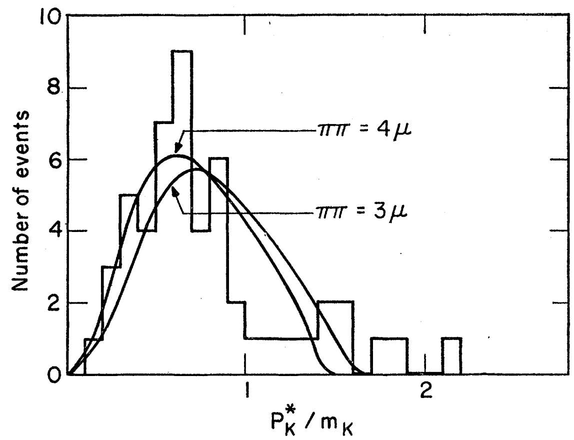

FIG. 2. Comparison of the observed K-meson momentum spectrum with theory. The histogram shows the observed K-meson momentum spectrum. The solid curves are those calculated from the isobar model assuming a mass of the $(\pi\pi)$ isobar equal to 3μ and 4μ.

masses $(\pi\pi)=3\mu$ and 4μ and have computed the K-meson momentum spectrum in the $\bar{p}$-p c.m. system according to the covariant phase-space factor for a total energy equal to 15.15μ.[5]

Figure 1 (a) shows the results for $(\pi\pi)=3\mu$. Each of these spectra has been normalized to the same area. For comparison, we have reproduced in Fig. 1 (b) the K-meson momentum spectra of reference 1 computed according to the Fermi model with no isobar state. Figure 2 shows a histogram representing the experimental data presented in reference 1 and the resultant K-meson momentum spectrum. To deduce this spectrum from the isobar model, we combine the normalized spectra of the isobar model according to the percentages of the above reactions for $n=2$, 3, and 4 as estimated from the experimental data on the multiplicity distribution of the associated π meson (see reference 1) and add the appropriate contribution from the case of one single associated π meson computed from the simple statistical model [curve $K\bar{K}\pi$ of Fig. 1 (b)].

Because of meager statistics, the difference between the two fits with $(\pi\pi)=3\mu$ and 4μ is not significant, nor do these fits differ appreciably from that derived from the ordinary statistical model. Nonetheless, if we compare the K production by $\bar{p}$ annihilation at the energy of the experiment described by Goldhaber *et al.*[2] with that at rest, we should expect an increase by a factor of more than 4 if we assume an isobar mass $(\pi\pi)=3\mu$. This seems inconsistent with the present experimental ratio, which is about 2. The disagreement is even worse if we consider the case of $(\pi\pi)=4\mu$.

Consequently, the assumption of an isobar model of two resonant π mesons of mass $(\pi\pi)\geqslant 3\mu$ seems to be ruled out. However, if the isobar mass turns out to be not much greater than two pion masses, then the results of this model will not differ appreciably from those of the Fermi model. In this case, the difficulty of too large an interaction volume Ω_π encountered in the Fermi model can be solved by the isobar model.

ACKNOWLEDGMENTS

The author is grateful to Dr. E. J. Lofgren for the hospitality at the Lawrence Radiation Laboratory and to Dr. G. Goldhaber, Dr. S. Goldhaber, and Dr. W. M. Powell for the opportunity to work with their experimental facilities.

[5] For details of the calculation, refer to T. F. Hoang and J. Young, Lawrence Radiation Laboratory Report UCRL-9050, January, 1960 (unpublished).