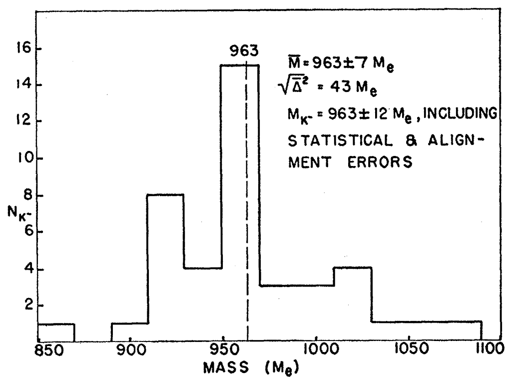

FIG. 4. Mass histogram of the negative K mesons (assuming $M_{K^+}=M_{\tau^+}=965.4\ m_e$).

The mass of the K^-, if we assume $M_{K^+}=M_\tau=965.4\ m_e$, is

$$M_{K^-}=963\pm 12\ m_e.$$

The above mass determination corresponds to the mass of K mesons present, after a time of flight of 1.4×10^{-8} sec in the proper system of the K mesons.

We are greatly indebted to Dr. E. J. Lofgren and the Bevatron crew for their assistance in carrying out the exposures. We also wish to thank Mr. H. H. Bayona, G. M. Wike, and Mrs. C. Toche for their help in scanning the emulsions.

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Heavy Meson Fluxes at the Cosmotron*

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A MOMENTUM-analyzed K-meson beam was obtained at the Brookhaven Cosmotron using a combination of two strong-focusing magnetic quadrupoles followed by a deflecting magnet, as shown in Fig. 1. The quadrupoles were of 6-inch aperture by 12-inch length with a minimum possible spacing of 15 inches. The deflecting magnet had a 3-inch gap with 9×18 inch polefaces, giving a maximum possible deflection of 32° for 290 Mev/c. With the system at 60° to the beam direction the following beam fluxes were obtained from 5.6×10^{12} protons of 2.9 Bev incident on a $\frac{1}{8}\times\frac{1}{8}\times\frac{1}{2}$ inch copper target: 3.6×10^5 protons/cm², 1.7×10^5 light tracks (mainly pions)/cm², and 280±40 K_L-mesons/cm². This particular exposure took 15 minutes of beam.

In the 114-Mev Bevatron K-meson beam,[1] the proper time between target and emulsion is 1.27×10^{-8} sec. In this experiment the proper time is 1.9×10^{-8} sec. The π/K ratio in our emulsions was (600±90) as compared to (70±7) in similar-type Bevatron exposures to 6.2-Bev protons. Assuming a K-meson lifetime of 10^{-8} sec and correcting the observed π/K ratios for decay in flight only, the π/K ratio at the Bevatron target is then about 20 compared to about 90 for the Cosmotron at the respective laboratory energies and angles.

Scanning was by means of following gray tracks picked up at a heavy meson residual range of 2 cm. A total of 328 heavy mesons was found; of these 304 had a single lightly ionizing secondary (in 19 cases the secondary could not be found, so the primary had to be determined by grain-counting), 21 were taus, and 3 had a secondary heavier than ~1.7 times minimum. The latter three were all alternate taus and none were $K_{\mu 3}$. In spite of the handicap of large π/K ratio, by restricting ourselves to certain angle, grain density, and visual scattering criteria, 80% of the tracks followed turned out to be heavy mesons. About 35% of the heavy mesons were missed when this fast scanning was used, but this does not affect the relative frequencies. Scanning rates of 18 heavy mesons per 8-hour day were achieved. Our K to tau ratio (304:21) is the same within statistics as that obtained in the Bevatron K-beams which are at 90° from a copper target bombarded by 6.2-Bev protons.[2,3]

According to the Bevatron ratios, we should have found about 4 alternate taus and about 2 $K_{\mu 3}$'s. Our results of 3 and 0, respectively, are not inconsistent with mean values of 4 and 2. Lifetime measurements

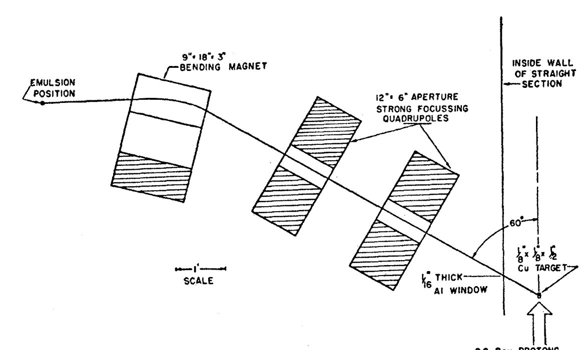

FIG. 1. Experimental setup for 80-Mev K-meson beam at the Cosmotron.

made at flight times of $\sim 10^{-8}$ sec from the target yield the same lifetime, within statistical errors, for the $K_{\pi 2}$, $K_{\mu 2}$, and τ mesons.[2,4] These facts, together with the fact that the tau should not decay into two pions,[5] suggest either that there is a single kind of K-meson with lifetime $\sim 10^{-8}$ sec which decays to L-mesons and has a significant branching ratio for gamma decay to a slightly lighter K-meson of shorter lifetime,[6] or that there are two or more kinds of K-mesons with lifetimes $\sim 10^{-8}$ sec but such that the ratio of the number decaying into 3 pions to the sum of the number decaying into 2 pions and $(\mu+\nu)$ is fairly constant. The agreement between our results and those at Berkeley on the relative frequencies of the K-mesons is very striking and taken together with the well-known similarities of lifetimes and masses, probably is indicative of some close relationship between the various K-mesons.[7]

We wish to thank Mrs. Enid Bierman for helping to develop and carry out the fast scanning. We are grateful to Professor J. Rainwater for loan of the strong focusing magnets. We are indebted to the Cosmotron staff and in particular to Dr. Wm. Moore, Dr. R. Madey, and Dr. V. Fitch for helping to set up and develop this preliminary K-meson beam.

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[7] *Note added in proof.*—T. D. Lee and C. N. Yang [Phys. Rev. (to be published)] have proposed that strong reactions be invariant with respect to a parity conjugation operator which operates only on particles of odd strangeness. In this scheme the production ratio of the τ and θ must be a constant under all conditions.

Heavy-Meson Decays and the Selection Rule $|\Delta I| \leqslant 1/2$

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THE validity of the selection rules,[1]

$$\Delta I_z = 0 \text{ for fast transitions,}$$
$$\Delta I_z = \pm\tfrac{1}{2} \text{ for slow transitions,}$$

is well established in the domain of hyperon and heavy-meson physics. Whether there exists an independent selection rule for the *total* isotopic spin I, *viz.*,

$$\begin{aligned} &\Delta I = 0 \text{ for fast transitions,} \\ &\Delta I = \pm\tfrac{1}{2} \text{ for slow transitions,} \end{aligned} \tag{1}$$

is still debatable. We want to point out that various features of the θ and τ meson decays may be interpreted as favoring the rule (1).

Takeda[2] has already shown that the branching ratio R of the θ^0, decaying into $\pi^0+\pi^0$ or $\pi^++\pi^-$ respectively, should be $\frac{1}{2}$ or 0, for even or odd parity of the θ, if (1) is valid. The explanation is simply that, for a θ of isotopic spin $\frac{1}{2}$, the final two-pion states cannot have $I=2$, according to (1). Then, for a θ of even [odd] parity, only $I=0$ [1] is possible; therefore the θ^0 decays as though it were a particle of isotopic spin 0 [1]. This leads immediately to Takeda's R-values.

With regard to the θ^+ which decays into $\pi^++\pi^0$, we observe that, because of the charge $+1$, the final states can only be $I=1$ or 2, the latter value being forbidden by (1). It follows that the decay rates of θ^+ and θ^0 should be roughly equal if the θ parity is odd [$I=1$], whereas an even θ^+ can disintegrate only in violation of the rule (1). The fact that the lifetime of θ^+ is about 100 times that of θ^0 may be cited as evidence in favor of the second alternative, *viz.*, even parity of the θ, and validity of (1).

A stronger argument results from the study of the τ disintegrations:

$$\tau^+ \rightarrow \begin{cases} 2\pi^+ + \pi^- & (\text{“}\tau \text{ decay”}) \\ 2\pi^0 + \pi^+ & (\text{“}\tau' \text{ decay”}). \end{cases}$$

The branching ratio τ/τ' has been observed to be as large as 4 (average values 4.1 and 4.6 are quoted in the literature[3]). Dalitz[4] has shown that, if the final three-pion state is an eigenstate of I, the branching ratio τ/τ' is $\frac{1}{4}$ for $I=3$, and 1 for $I=2$, whereas

$$1 \leqslant \tau/\tau' \leqslant 4 \quad \text{for } I=1. \tag{2}$$

Thus, the only single I value compatible with the observations is $I=1$. This may either mean that the τ meson has isotopic spin 1 and decays with isotopic spin conservation[4]; but this interpretation would reopen the question why the lifetime of the τ is so long. It is much more natural today to assume that the τ has isotopic spin $\frac{1}{2}$ and that the selection rule (1) is effective, leading to the same limitation for the branching ratio, *viz.* (2).

We observe further that the upper limit 4 for $\tau/\tau'[I=1]$ is obtained only if the state function of the three pions has a particularly simple symmetry property: it has the form $u(\mathbf{p}_1\mathbf{p}_2\mathbf{p}_3)\chi(i_{1z}i_{2z}i_{3z})$ where each factor is totally symmetric in the three particles, namely u with respect to the three momentum vectors, and χ with respect to the three charge numbers. Specifically:

$$\chi = (15)^{-\frac{1}{2}}\{2[(\bar{1}11)+(1\bar{1}1)+(11\bar{1})] - [(100)+(010)+(001)]\}$$

(writing $\bar{1}$ for -1).