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ABSTRACT

Our recent program on the measurement of the K-particle masses has yielded some information concerning the relative production of the different types of K particles and the relative yield of K particles with respect to the other secondary particles from a Ta target struck by 4.8-Bev protons.

The particles observed were emitted at 90° to the bombarding beam and had a nominal momentum of 375 Mev/c. The observed percentage of K particles in this secondary beam was $0.036 \pm 0.002\%$.

The ratio of K mesons to τ mesons was 9.1 ± 1.6. The ratio of the $K_{\mu 2}$ to $K_{\pi 2}$ mode was 3.0 ± 0.9. The ratio of τ ($\tau \rightarrow 2\pi^{+} + \pi^{-}$) to τ' ($\tau' \rightarrow 2\pi^{0} + \pi^{+}$) was 4.1 ± 1.9.

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INTRODUCTION

It is possible that important features of K-particle production may be deduced from the relative production of the different decay modes as a function of the bombarding energy and from the yield of K particles relative to that of the other secondary particles. We were able to obtain some information on relative yields in connection with our program, recently completed, on the measurement of the K-particle masses.[1]

In this study the bombarding beam consisted of 4.8-Bev protons. The secondary particles were emitted from a Ta target at 90° to the bombarding beam direction. Comparison of our data with those obtained at lower and higher energies should reveal trends in the ratios, if they exist.

Although absolute yield cross sections would be desirable, it is unlikely that they can be obtained accurately at present. Since the K-particle threshold is high compared with the other components observed in the secondary beam, ratio determinations probably will be the most valuable in the immediate future.

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1 H. H. Heckman, F. M. Smith and W. H. Barkas, "The Masses of Positive K Particles," UCRL-3156, Nuovo Cimento 3, 85 (1956).

EXPERIMENTAL SETUP

The secondary beam from the target passed out of the Bevatron through a 0.090-inch Al window. The particles then passed through the aperture of a strong-focusing magnetic lens, through a 0.25-inch collimator defined by 6-inch Pb walls, and into a bending magnet. The air between the collimator and detecting emulsion was replaced by an atmosphere of He to lessen gas scattering and to reduce the energy loss. The particles with momenta between 410 and 340 Mev/c (a nominal value of 375 Mev/c) were bent into a block of nuclear track emulsion.[2]

ANALYSIS OF THE SECONDARY BEAM

An analysis of the relative particle populations in the beam that entered the stack is shown in Table I(a). The particles other than π^+, K^+, and e^+ were identified by their ranges in the emulsion. The deuterons and He^3 have nearly the same range in emulsion at this momentum; therefore, they were separated by means of a gap count of the tracks. Separation of the π^+ and e^+ components was difficult because both types of particles at this momentum leave tracks that are nearly minimum in grain density upon entering the stack. The data shown in Fig. 1 enabled us to make a separation. Counts were made of the number of minimum tracks crossing lines parallel to the entrance edge of the emulsion stack at the indicated distances from the edge. Estimates from shower theory suggest that the confusable electron component is negligible after 10 to 12 cm., i.e., between 3 and 4 times the depth of the peak. The observed tracks beyond this depth are then those of pions. Using 26 cm as the mean free path for the pions and estimating their attenuation due to diffusion (scattering out of the stack[3]) leads one to expect attenuation of the pions as shown by the dashed line. This indicates that about 20% of the incoming tracks are positrons, and that at a depth of 3 cm nearly one-half of the minimum tracks are electrons.

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[2] This arrangement, except for the 0.25-inch collimator and the He atmosphere, was essentially that developed by Kerth and Stork. (R. W. Birge et al, Phys. Rev. 99, 329 (1955).

[3] B. Rossi, High Energy Particles, p. 71 New York, Prentice-Hall, 1952.

Table I

Analysis of secondary particles from a Bevatron target. Bombarding energy: 4.8 Bev. Target: Ta. Detected at 90° to the primary proton beam and at ≈ 10 ft from the target. Particle momentum: ≈ 375 Mev/c

(a) Composition of the secondary-particle flux detected in the emulsion.

(b) Relative frequencies of the decay modes of the K component. The figures are based on a total of 400 K particles.

(a) Classification of the secondary particles.

Type	Percentage of total
p	87.31 ± 2.10
d	5.13 ± 1.12
π^+	3.84 ± 0.18
H^3	1.22 ± 0.17
He^3	0.97 ± 0.49
He^4	0.75 ± 0.44
e^+	0.75 ± 0.25
K^+	0.036 ± 0.002

(b) Constituents of the K^+ component.

Type	Percentage of total	Ratios of types
$K_{\mu 2}$	65.2 ± 10.3	$K_{\mu 2}/K_{\pi 2} = 3.0 \pm 0.9$
$K_{\pi 2}$	21.4 ± 5.6	
τ	7.8 ± 1.4	$K_L/\tau_{tot} = 9.1 \pm 1.6$
K_β	$2.6 {}^{+2.2}_{-1.7}$	
τ'	1.9 ± 0.8	$\tau/\tau' = 4.1 \pm 1.9$
$K_{\mu 3}$	1.1 ± 0.7	

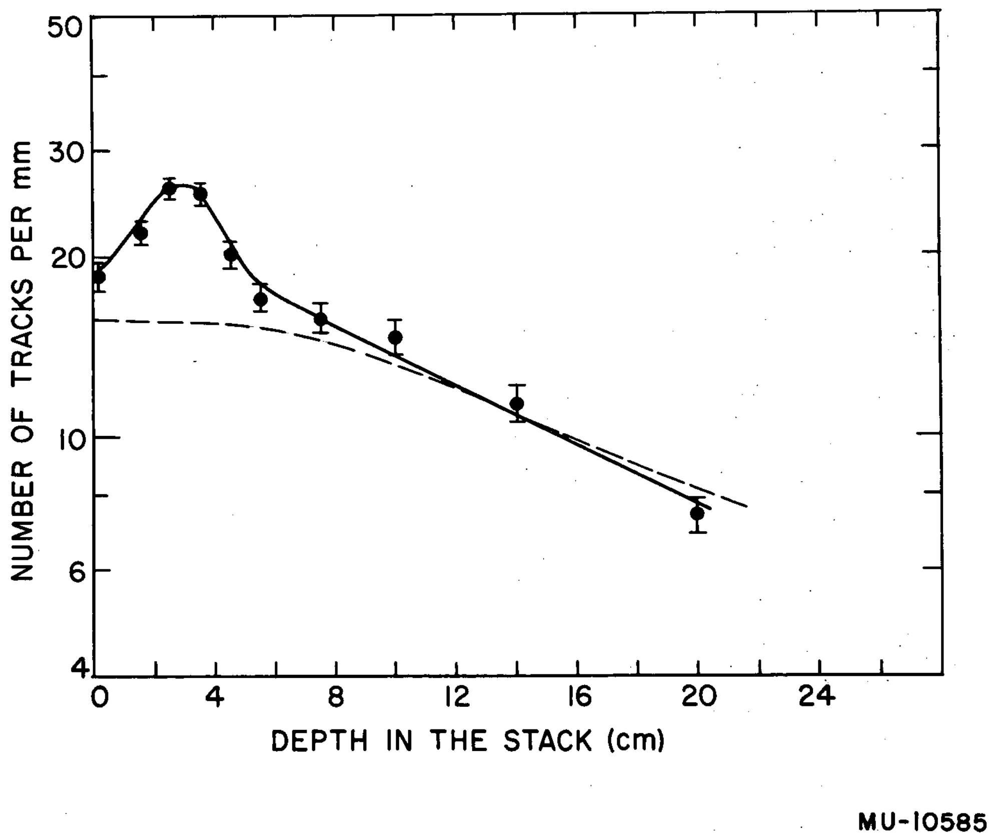

Fig. 1. Density of near-minimum tracks observed at various depths in the stack. The tracks counted were nearly parallel and each maintained its direction over an observed distance of at least 0.8 mm. They were, therefore, either tracks of pions or of electrons with comparable momentum.

IDENTIFICATION OF K PARTICLES AND THE RELATIVE FREQUENCIES OF THE MODES OF DECAY

Table I(b) shows the relative populations of the constituents of the K-particle component of the beam. The nomenclature of Table I(b) is based on the decay mode of the particle, i.e.,

$$K_{\mu 2} \rightarrow \mu^+ + \nu,$$

$$K_{\pi 2} \rightarrow \pi^+ + \pi^0,$$

$$\tau \rightarrow \pi^- + 2\pi^+,$$

$$\tau' \rightarrow \pi^+ + 2\pi^0,$$

$$K_{\mu 3} \rightarrow \mu^+ + \pi^0 + \nu,^{4}$$

$$K_\beta \rightarrow \beta^+ \text{(continous spectrum)} + \text{unknown number of neutrals.}$$

The symbol K_L is used to indicate K particles with a single charged secondary whose track is near minimum in grain density. The τ mesons are easily identified from the three charged pions emitted at the decay point. The τ' and $K_{\mu 3}$ particles included in the study were identified by following the secondary to the end of its range. The grain density at the beginning of the $K_{\mu 2}$ secondary is about 1.05 minimum, whereas that of the $K_{\pi 2}$ is about 1.21 minimum. A reasonable separation between these two modes was obtained by blob-counting those K_L secondary tracks which had dip angles in the emulsion less than 15^o. Figure 2(a) shows this separation. About 400 blobs were counted in each track. One has a further means of identifying the secondary in its multiple scattering. The mean lateral deflection per 300 μ (here called the second difference) of the track was the measure of the scattering. Second differences were taken on the tracks that had dip angles up to 10^o. Figure 2(b) shows the separation resulting from measuring the scattering of the tracks. The K_β secondary indicated was identified from the multiple scattering at several points along the track. Its initial energy was 100 ± 15 Mev. Figure 2(c) shows the complete separation obtained when the information from the blob count and the scattering was combined as a product. The ratio of $K_{\mu 2}$ to $K_{\pi 2}$ found from this analysis was assumed to hold for the remaining 75% of the K_L's (those with secondaries over 15^o in dip angle). The statistical error quoted, however, is based solely on the 25% actually identified. All the individual errors quoted in Tables I(a) and I(b) are the statistical errors based on the number of particles of the particular type found.

One of the $K_{\mu 2}$ secondaries stopped in the stack. Its range (measured along the track) was 19.74 cm, and the emulsion density was 3.84 g/cm^3. The ending of another of the $K_{\mu 2}$ tracks had associated with it a low-energy electron pair. A possible explanation lies in radiative decay.[5]

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[4] G. Yekutieli et al., Phys. Rev. 101, 506 (1956).

[5] S. Bludman and M. Ruderman, Phys. Rev. (in press), 1956.

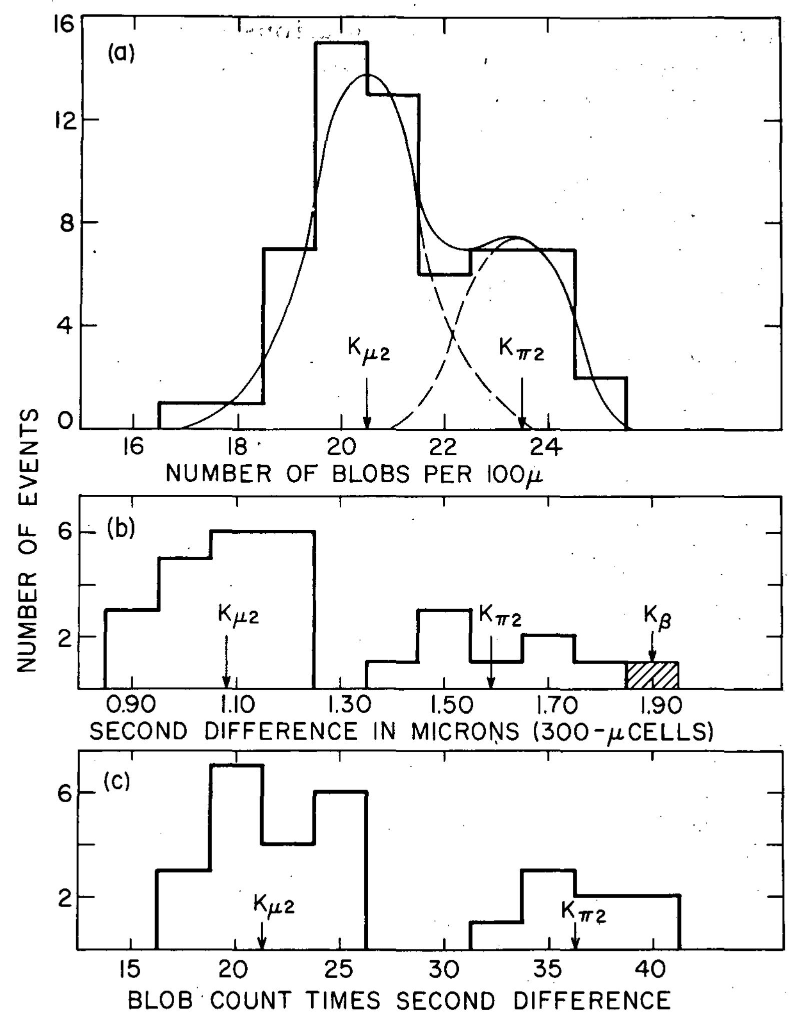

Fig. 2. Separation of the $K_{\pi 2}$ and $K_{\mu 2}$ modes by identification of the secondaries. (a) Identification of secondaries by "blob" count. About 400 blobs were counted in each secondary track. All tracks counted had dip angles $< 15^{\circ}$. (b) Secondary tracks identified by multiple scattering. The tracks scattered had dip angle $< 10^{\circ}$. The mean second difference of the $K_{\mu 2}$ secondaries is $1.08 \pm 0.03\,\mu$ and that of the $K_{\pi 2}$ secondaries is $1.59 \pm 0.05\,\mu$. The corresponding values of $p\beta$ are 215 Mev/c and 150 Mev/c respectively. (c) Complete separation between the $K_{\mu 2}$ and $K_{\pi 2}$ secondaries obtained from multiplying the blob count by the second difference for each track. The mean of this product for $K_{\mu 2}$ secondaries is 21.6 ± 0.6 while for the secondaries of $K_{\pi 2}$ it is 36.7 ± 0.9.

Table II lists the ranges--as measured along the track--and energies of several τ'* and $K_{\mu 3}$ secondaries. The ending of that τ' whose range was 2.206 cm had associated with it an electron pair of about 60 Mev.

Table II

Observed ranges and corresponding energies of τ' and $K_{\mu 3}$ secondaries.

τ'		$K_{\mu 3}$	
R(cm)	E(Mev)	R(cm)	E(Mev)
2.206	37.5	3.676	46.0
1.541	29.7	2.765	38.5
0.515	15.8	1.244	23.5
0.418	14.0		
0.352	12.5		
0.084	5.7		
0.047	4.1		
0.039	3.7		

SCANNING TECHNIQUE AND EFFICIENCY

The technique for finding K particles consisted of scanning across each plate of the stack at a distance from the entrance edge about 1.5 cm less than the calculated range of a τ meson in the stack. This method of scanning for events eliminated bias in finding the endings of tracks. Tracks with a blob density intermediate between that calculated for pions and protons and going in the forward direction were followed to the end of their range. Six hundred and twenty-two such tracks were found. Of these tracks, 240 had no apparent secondary. One hundred and three of the "no secondary" tracks were examined in detail. Forty-three of them were obviously proton tracks; the identities of the other 60 remained ambiguous until opacity measurements were made on them at a distance of 1 cm from the terminus. Eight of the 60 tracks had opacities that indicated they were made by K particles; the remaining 52 were those of protons. The track endings of the eight particles were then examined closely, and secondary tracks were observed in seven cases. The spacing between grains at the beginning of the tracks was such (about 15μ on the average) that the tracks tended to merge with the random background. There was no preferred direction or dip angle for the missed secondaries. The track for which no secondary was found ended near the emulsion surface. This information indicates that of the 240 "no secondary" tracks, 19 were probably those of K_L particles. Since 339 K_L tracks were observed during the scanning, the efficiency for K_L detection was about 95%. A further check of efficiency was made by looking for positron tracks from $\mu^+ \rightarrow e^+$ decays. Of 100 such decays examined, only two had no visible e^+ track. In both cases the terminus of the μ^+ track was near the emulsion surface.

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* Three of the τ' secondaries measured were found in a stack not used in the mass determination.

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