and almost nothing more. The estimates given in this paper and in Ref. 1 indicate, however, that to achieve even semiquantitative accuracy in the dynamics it will be necessary to employ Regge potentials together with the Mandelstam iteration or the equivalent thereto.

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Measurement of the K^+ Branching Ratio into the τ Mode

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A determination of the K^+ decay branching ratio into the mode $K^+ \to \pi^+\pi^+\pi^-$ is obtained in a H_2 bubble chamber with a beam of stopping K^+. With a total τ^+ count of 2186, the branching ratio obtained is $(5.71 \pm 0.15)\%$. The estimated world average is $(5.54 \pm 0.075)\%$.

INTRODUCTION

THE precise determination of the τ branching ratio is very important, since this information is used in most $K^\pm$ experiments to establish the $K^\pm$ flux. Many values have been obtained in the past years, not always compatible within the errors. In Table I we have collected the most significant ones.

We present here a new determination of the τ branching ratio obtained in the 81 cm Saclay-CERN hydrogen bubble chamber exposed to a beam of stopping K^+. The statistical accuracy of our determination is comparable with those of Refs. 1 and 2. However, the use of the H_2 chamber allows, in our opinion, a more certain reduction of the background.

EXPERIMENTAL DETAILS

The entire analysis was carried out at the scan table with visual separation between decays into the τ mode and all other K^+ decays. Two kinds of scans have been done. In the first scan (scan A) all the tracks entering

Table I. Published values of the τ branching ratio.

References	Technique	No. of τ	Branching ratio into τ mode
G stack coll.[a]	emulsion (cosmic rays)	30	$(8.5 \pm 1.6)\%$
Ritson *et al.*[b]	emulsion	58	$(7.6 \pm 1)\%$
Brussard *et al.*[c]	emulsion	30	$(7.1 \pm 1)\%$
Hoang *et al.*[d]	emulsion	9	$(5.2 \pm 2)\%$
Birge *et al.*[e]	emulsion	171	$(5.6 \pm 0.4)\%$
Alexander *et al.* (see Ref. 6)	emulsion	226	$(6.8 \pm 0.4)\%$
Taylor *et al.*[f]	emulsion	263	$(5.2 \pm 0.3)\%$
Roe *et al.*[g]	xenon bubble chamber	359	$(5.7 \pm 0.3)\%$
Bøggild *et al.* (see Ref. 7)	emulsion	98	$(7.7 \pm 0.8)\%$
Shaklee *et al.* (see Ref. 1)	xenon bubble chamber	540	$(5.1 \pm 0.2)\%$
Callahan *et al.* (see Ref. 2)	Freon bubble chamber	2332	$(5.54 \pm 0.12)\%$
Present experiment: scan A		504	$(5.65 \pm 0.26)\%$
Present experiment: scan B	hydrogen bubble chamber	1682	$(5.74 \pm 0.18)\%$
Present experiment: total			$(5.71 \pm 0.15)\%$
Weighted mean			$(5.54 \pm 0.075)\%$

[a] J. H. Davies *et al.*, Nuovo Cimento 2, 1063 (1955).
[b] D. M. Ritson *et al.*, Phys. Rev. 101, 1085 (1956).
[c] J. Crussard *et al.*, Nuovo Cimento 3, 731 (1956); 4, 1195 (1956).
[d] T. F. Hoang, M. F. Kaplon, and G. Yekutieli, Phys. Rev. 102, 1185 (1956).
[e] R. W. Birge *et al.*, Nuovo Cimento 4, 834 (1956).
[f] S. Taylor, *et al.*, Phys. Rev. 114, 359 (1959).
[g] B. P. Roe *et al.*, Phys. Rev. Letters 7, 346 (1961).

[1] F. S. Shaklee, G. L. Jensen, B. P. Roe, and D. Sinclair, Phys. Rev. 136, B1423 (1964).
[2] A. Callahan, R. March, and R. Stark, Phys. Rev. 136, B1463 (1964).

a given fiducial volume defined in the central view were followed until they decayed or left the volume. In scan B all τ decays were recorded while the one-prong K^+ decays ($K_1{}^+$) were counted every tenth frame. The decays were recorded if:

(a) The projected curvature of the last part of the decaying track[3] was between 20 and 55 cm, which in the average magnetic field of 16 kG corresponds to 100 to 275 MeV/c.

(b) the ionization of the track was compatible with that expected for a K^+ of the measured curvature.

Criterion (a) includes a fraction of decays in flight. This fact, however, does not affect the branching ratio because this criterion was applied in the same way to the τ and $K_1{}^+$ decays. In Fig. 1, the projected radii of τ and $K_1{}^+$ are compared.

There are some possible sources of systematic errors:

(1) Pion background in the beam: In the accepted curvature interval, the ionization allows one to easily distinguish between a flat K^+ and π^+ track. Thus the background of scatters or decays of flat π^+ is negligible in this experiment. A steep π^+, which enters the acceptance volume and scatters or decays in flight, could occasionally simulate a K^+ decay. To determine this background we counted the number of interactions of K^+ or π^+ on protons in which the recoil proton was visible. From this scan (one steep π^+ was found among 4000 $K_1{}^+$) and from the known differential cross sections of π^+ in the accepted momentum interval we estimate that the background of the π^+ scatters or decays in flight included in the $K_1{}^+$ decays sample is 0.1%. Of the same order is the probability that a K^+ scatters without giving a visible recoil and that the dip or length of the re-emitted K^+ is such that the scatter could have been considered a decay.

(2) Inclusion, among the τ decays, of $K_1{}^+$ decays with an associated Dalitz pair: This effect is negligible since, to be considered a τ decay, a Dalitz pair must have a large opening angle and must have none of the electron tracks recognized. The number of identified decays found associated with a Dalitz pair in scan A was 36; the number expected, on the basis of the published K^+ decay ratios[1] and of the Dalitz-pair frequency,[4] is 34.5 ± 1.

(3) Loss of decays near the walls of the chamber: To check this loss we divided the volume of the chamber, as seen in the central view, in 4×5 zones and determined the branching ratio in each zone. The resulting values give a 60% χ^2 probability for the hypothesis of no undetected loss, and the border zones especially show no systematic effects. There remains the possibility of having lost events near the top or the bottom of the chamber, or events with a dipping secondary. If there is such a loss, it should affect the $K_1{}^+$ more than the τ decays. Each $K_1{}^+$ track leaving the chamber through the top or the bottom was checked in the three views to ascertain the exit point and the possible presence of short secondaries. Besides, for each one-prong decay with a secondary leaving the chamber through the top or the bottom, we recorded the projected chord of the secondary in the central view. The same was done for the tracks of the τ decays. We then used the depth distribution of 511 and 2730 $K_1{}^+$ decay points, measured in previous experiments,[5] to calculate the expected distribution of the projected chords for the $K_1{}^+$ decays. This distribution is compared with the experimental one for one-prong decays in Fig. 2. Upon normalizing the two distributions in the 2- to 6-cm projected chord interval we find a loss of $K_1{}^+$ with chord <2 cm equal to $(0.14\pm0.14)\%$. In Fig. 2 also the distribution of

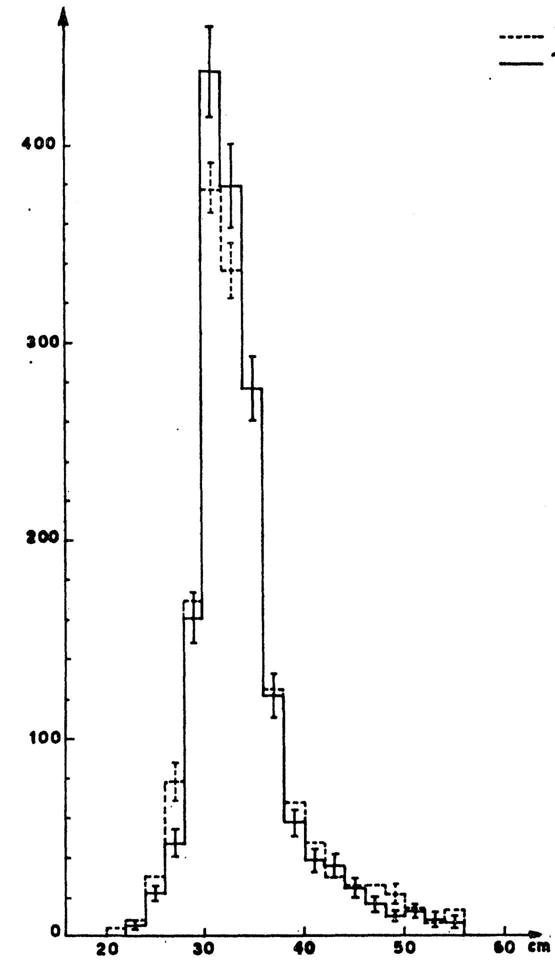

FIG. 1. Distribution of the projected radii of 3130 one-prong K^+ decays (dashed line) and of 1657 τ (full line) normalized to the same number of events.

[3] The chosen fiducial volume was such that the K^+ track was at least 10 cm long. If the K^+ interacted within 5 cm from the decay point, the curvature was measured before the interaction.

[4] N. P. Samios, Phys. Rev. **121**, 275 (1961).

[5] V. Bisi *et al.*, Phys. Rev. Letters **12**, 490 (1964).

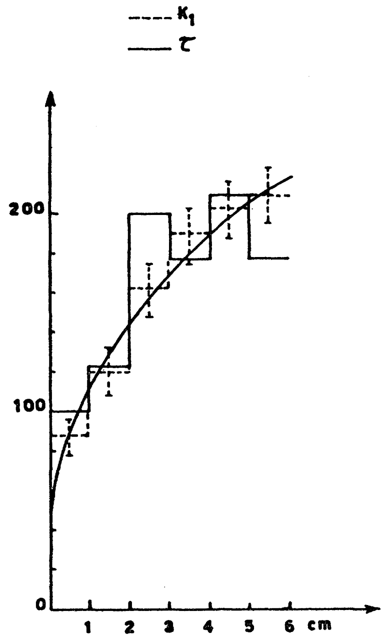

FIG. 2. Distribution of the secondary projected chords in the central view. The continuous line represents the calculated distribution, the full-line histogram the one-prong K^+ decays, and the dashed line the π^+ tracks of the τ decays. The normalization is based on the same number of events between 2 and 6 cm.

tracks of τ decays, normalized in the same interval, is shown as a further check.

(4) Background due to τ-like topology decays ($K^+ \to \pi^+\pi^-\mu^+\nu$) is negligible.

In scan A the total accepted number of decays was 8852, of which 504 were τ. A rescan based on 2697 K^+ showed that the efficiency for the τ was practically 100%, while for K_1^+ it was $(99.2\pm0.3)\%$. After this correction the branching ratio was $(5.65\pm0.26)\%$.

In scan B the track scan efficiency was checked on 820 K_1^+ and was found equal, within errors, to the efficiency in scan A. The τ-scan efficiency was practically 100% since all the film was rescanned for τ decays, each time with about 97% efficiency. The number of K_1^+ accepted was 2896; the number of τ, 1682. The branching ratio was $(5.74\pm0.18)\%$. The contribution to the statistical error of the K_1^+ count includes the effect of the beam-intensity fluctuations in every tenth frame.

CONCLUSION

Our two values of the branching ratio, $(5.65\pm0.26)\%$ and $(5.74\pm0.18)\%$, agree within errors. The combined value is $(5.71\pm0.15)\%$. This result is compatible with the value of Ref. 2 and is slightly higher than the value in Ref. 1. The weighted average of the values of Table I, excluding those values which remain more than two standard deviations away (Refs. 6 and 7) is $(5.54\pm0.075)\%$.

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[6] G. Alexander, R. H. W. Johnston, and C. O'Ceallaigh, Nuovo Cimento 6, 478 (1957).

[7] J. K. Bøggild *et al.*, Nuovo Cimento **19**, 621 (1961).