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MEASUREMENT OF THE BRANCHING RATIOS FOR $K^+_{\mu 2}$, $K^+_{\pi 2}$, $K^+_{\mu 3}$ AND K^+_{e3} DECAYS USING A MAGNETIC SPECTROMETER WITH STREAMER CHAMBERS

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The momenta of ~30 000 charged particles from K^+ decays were measured using a magnetic spectrometer with streamer chambers. The ratio $R = \Gamma(K^+_{\pi 2})/\Gamma(K^+_{\mu 2}) = 0.3355 \pm 0.0057$ was obtained. Our values for the branching ratios are:

$(63.18 \pm 0.43)\%$ for $K^+_{\mu 2}$, $(21.18 \pm 0.33)\%$ for $K^+_{\pi 2}$,
$(3.33 \pm 0.51)\%$ for $K^+_{\mu 3}$, $(4.99 \pm 0{,}54)\%$ for K^+_{e3} .

1. Introduction

The purpose of this paper is to measure the momentum of charged secondary particles from K^+ decays and to determine the branching ratios for the K^+ decay modes $K^+_{\mu 2}$, $K^+_{\pi 2}$, $K^+_{\mu 3}$ and K^+_{e3}. The simultaneous measurements of these constants is dealt with in [1], but it seemed to us that the possibility of performing corresponding measurements with a new method and under low background conditions was worth attention. We used a magnetic spectrometer with streamer chambers and an unseparated kaon beam.

2. Experimental arrangement

The magnetic canal for the kaon beam with momentum $p = 615 \pm 15$ MeV/c and the spectrometer are described in papers [2,3]; in the present paper we shall give only the main parameters of the beam and the apparatus.

At the accelerator intensity i.e.: 3×10^{11} p/pulse, the number of K^+ mesons in the beam (in the target of the spectrometer) was ~1000 K^+/pulse and the pion-to-kaon ratio was about 300 : 1. The thickness of counter C_5 being 3 G/cm^2 and with $\Delta p/p$ given above we had about 250–300 identified stopped kaons per pulse of the accelerator. The experimental set-up is given in fig. 1. K^+ mesons were identified by the C_1 Čerenkov differential counter with a solid radiator, the amplitude discrimination of the pulses in two of the three scintillation counters C_2, C_3, C_4 of the beam, the C_5 counter-target and the C_6 anticoincidence counter. The resulting suppression in our system was better than 10^4. To diminish the background from the interac-

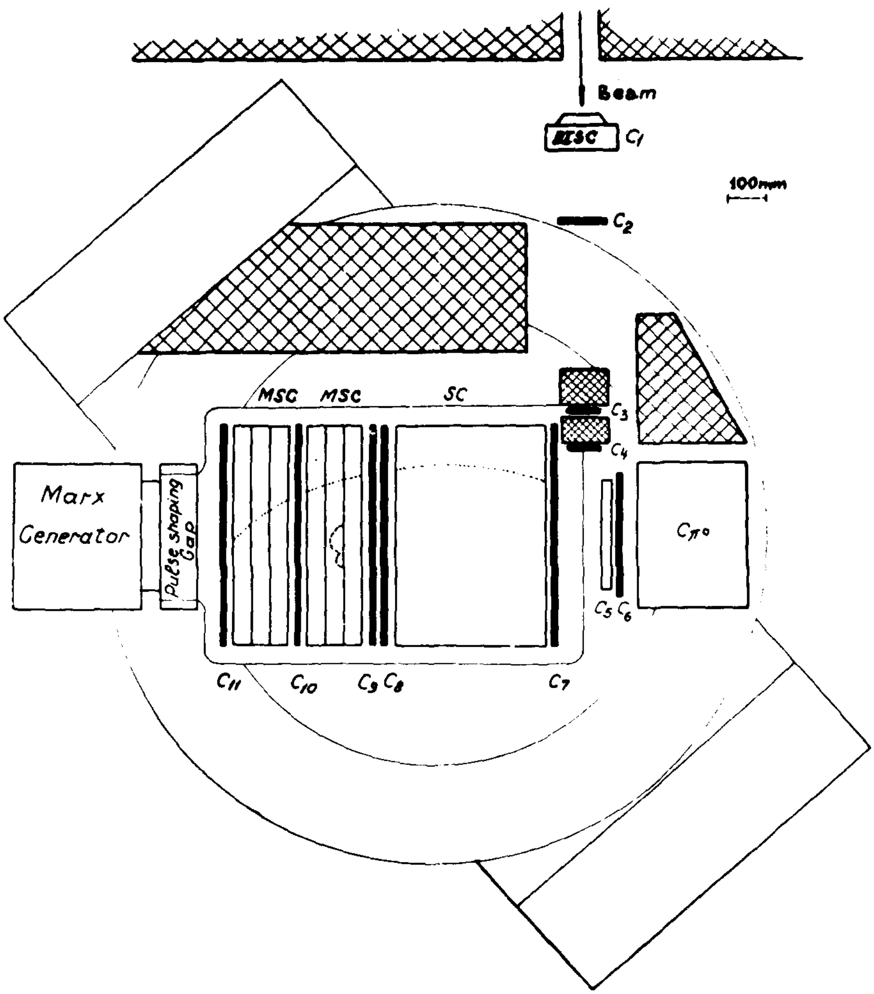

Fig. 1. The spectrometer set-up with streamer chambers.

tion of pions in counter C_5 the delay of the stopped kaon signal $C_1C_2C_3C_4C_5\bar{C}_6$ (the "gate") was 6 nsec. This 25 nsec wide "gate" was plased in coincidence with the signal $C_7C_8C_9$ obtained from detecting decay products. The signal $C_1C_2C_3C_4C_5C_6 + C_7C_8C_9$ triggered the streamer chamber. The magnetic field of the spectrometer was vertical and occupied a 140 cm diameter circular region about 50 cm high. The streamer chamber (SC) and the multiplate streamer chamber (MSC) were placed in the magnetic field which varied by a total of about 5% over the useful volume. The former chamber was to measure the momentum of the charged secondaries, the latter, to identify the secondaries. The details of the MSC construction, their parameters and the identification efficiency of the positrons were studied in a separate experiment and described earlier [2,4].

3. Measurement of the relative rate $K^+_{\mu 3}/K^+_{e3}$ and $K^+_{\pi 2}/K^+_{\mu 2}$

Fig. 2 represents the momentum spectrum of 31 419 charged secondary particles from K^+ decay in target C_5. In this spectrum two lines corresponding to the decays $K^+ \to \pi^+\pi^0$ and $K^+ \to \mu^+\nu_\mu$ are clearly seen. The events in the momentum range 130–190 MeV/c correspond mainly to the total spectrum of the positrons and muons from K^+_{e3} and $K^+_{\mu 3}$ decays. The background was defined from events with momentum $p > 280$ MeV/c and amounted to 1.14 events per 1 MeV/c. The analysis of the background events and corrections to the ionization loss of particles until they reach SC have been described in detail in [3]. The solid curve in fig. 2. shows the normalized descriptions of the experimental histogram with two normal distributions corresponding to the $K^+_{\pi 2}$ and $K^+_{\mu 2}$ decay modess and to the total theoretical spectra of positrons and muons from K^+_{e3} and $K^+_{\mu 3}$ decays, assuming a vector spectra with constant form factors.

3.1. Measurement of $R_{\mu e} = \Gamma(K^+_{\mu 3})/\Gamma(K^+_{e3})$

The positrons and muons from K^+_{e3} and $K^+_{\mu 3}$ decays were identified by analysing their interactions in the MSC. The positrons were identified by showers or large energy losses in the MSC [2,4]. For its identification it was necessary for the particle to pass four plates and not to leave the chamberrs until the middle of the fourth gap. The efficiency of the positron identification was (84 ± 5)%. The muons with $p \leqslant 150$ MeV/c were identified from the measurement of the momentum in the SC and by their range in the MSC. The following corrections were introduced into the measured spectra of the positrons and muons.

(a) Particle registration efficiency in the MSC; $\eta_e = 0.84$, $\eta_\mu = 1.04$ (the non-100% MSC efficiency of positron registration overestimated the number of muons).

(b) The relative spectrometer angular acceptances taking into account its momentum dependence; $\kappa_e = 0.264$; $\kappa_\mu = 0.129$.

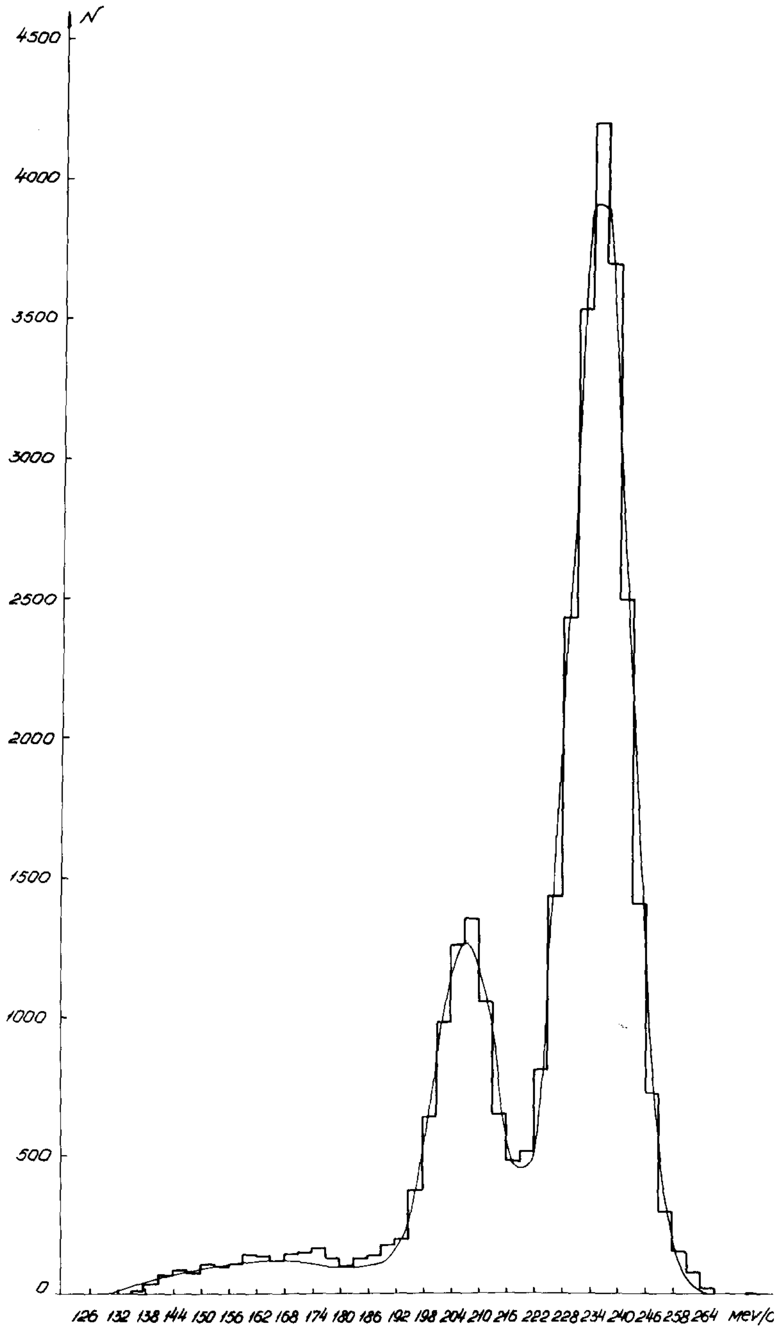

Fig. 2. The momentum spectrum of secondaries from K^+ decay.

(c) The contribution to the muon spectrum from muons due to the decay in flight of pions from $K^+_{\pi 2}$ decays; $\eta_\pi = 0.94$.

A single experiment, in which under similar conditions the spectrum of positrons and muons from K^+_{e3} and $K^+_{\mu 3}$ decays is measured, makes it possible to calculate the ratio of the K^+ decay rate in these channels:

$$R_{\mu e} = \frac{\Gamma(K^+_{\mu 3})}{\Gamma(K^+_{e3})} = \frac{N(K^+_{\mu 3})\eta_\pi}{\eta_\mu \kappa_\pi} \Big/ \frac{N(K^+_{e3})}{\eta_e \kappa_e} = 0.67 \pm 0.12 \; .$$

This result is in agreement with the summary of the world experimental data $R_{\mu e} = 0.664 \pm 0.020$ [6].

3.2. *Measurement of* $R_{\pi\mu} = \Gamma(K^+_{\pi 2})/\Gamma(K^+_{\mu 2})$

To determine the ratios of $K^+_{\pi 2}$ and $K^+_{\mu 2}$ decay rates it is necessary to exclude from the momentum spectrum the events due to $K^+_{\mu 3}$ and K^+_{e3} decays. The excluding procedure was as follows: the theoretical spectra of leptons obtained from $K^+_{\ell 3}$ decays assuming that $\lambda_+ = 0$ and $\xi(0) = 0$ were added, another assumption being that the ratio of $K^+_{\mu 3}$ and K^+_{e3} decay rates is $R_{\mu e} = 0.664$. Then the total theoretical spectrum was multiplied for each exposition by its angular acceptances [2]. The spectra thus obtained were added in accordance with the statistical weight of each exposition. The total spectrum was renormalized to the experimental histogram in the 150 – 180 MeV/c momentum range. The spectrum obtained after subtraction has only two lines: the pion one from $K^+ \to \pi^+\pi^0$ decay, and the muon one from $K^+ \to \mu^+\nu_\mu$ decay. The ratio of the number of events in these lines is $R_m = N_\pi/N_\mu = 0.3084 \pm 0.0043$ ($\chi^2 = 21$ at 16 degrees of freedom).

The value of the ratio R_m should be corrected for:

(a) the difference in angular acceptances for the momenta corresponding to the pion and muon lines of both $K^+_{\pi 2}$ and $K^+_{\mu 2}$ decays ($\eta_{a.a.} = 0.990 \pm 0.002$);

(b) nuclear interaction of pions in the target, in counter C_7 and in the entrance glass of the chamber ($\eta_{n.i.} = 1.064 \pm 0.010$);

(c) radiative $K^+_{\mu\nu\gamma}$ decay ($\eta_{K_{\mu\nu\gamma}} = 0.994$);

(d) pion-in-flight decay ($\eta_{\pi\to\mu} = 1.040 \pm 0.003$).

Introducing all these correction into R_m, yields:

$$R_{exp} = \Gamma(K^+_{\pi 2})/\Gamma(K^+_{\mu 2}) = R_m \eta_{a.a.} \eta_{n.i.} \eta_{K\mu\nu\gamma} = R_m \overline{\eta} = 0.3355 \pm 0.0057 \; ,$$

where the error accounts for the uncertainty in the coefficient η as well.

The result obtained is in reasonable agreement with the tabulated value. The papers [2,5] cited 0.328 ± 0.005 as the preliminary value of this ratio where only statistical errors were given and pion-in-flight decays were not taken into account.

4. Definition of the branching ratios for $K^+_{\mu 2}$, $K^+_{\pi 2}$, $K^+_{\mu 3}$ and K^+_{e3} decays

Using the probabilities of τ and τ' decays comprising in sum total 7.32% for normalisation, the branching ratios for $K^+_{\mu 2}$, $K^+_{\mu 3}$ and K^+_{e3} decays obtained in this paper will be, (%):

$$(K^+_{\mu 2}) = 63.18 \pm 0.43 \,,$$

$$(K^+_{\pi 2}) = 21.18 \pm 0.33 \,,$$

$$(K^+_{\mu 3}) = 3.33 \pm 0.51 \,,$$

$$(K^+_{e3}) = 4.99 \pm 0.54 \,.$$

These results coincide, within the errors, with the results of the analysis of the world data [6] and are among the three of most accurate experimental studies on simultaneous definition of the K^+ decay rate in the four main channels.

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