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PROPOSAL FOR A NEW EXPERIMENT ON K_{e4} DECAY

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Introduction

The main interest of the K_{e4} decay

$$K^{\pm} \rightarrow \pi^{+} \pi^{-} e^{\pm} \nu$$

is the possibility to study low energy $\pi\pi$ interaction in the absence of other hadrons. From the distributions in momentum and angle of the decay products one can extract the phase shift $\delta_s - \delta_p$ of the $\pi\pi$ system for a centre of mass energy ranging from 280 to about 400 MeV.

In addition, investigation of this decay yields information concerning several other aspects of the weak interaction. These include T invariance, locality (1), $\Delta S = \Delta Q$, $\Delta I = \frac{1}{2}$, and the relation between the form factors describing K_{e2}, K_{e3}, and K_{e4} decay channels as given by current algebra (2).

Until recently only about 300 K_{e4} events had been observed in a bubble chamber experiment (3). This sample was to small to distinguish between several solutions for the form factors and the pion phase shifts. Likewise, it was not possible to use the elegant method proposed by Pais and Treiman (1) to extract the $\pi\pi$ phase shifts.

In a first counter experiment (CERN experiment S68) our group increased the number of observed K_{e4} decays to about 2000 (4). We were able to extract a single set of form factors and pion phase shifts. Moreover, the method of Pais and Treiman provides an~~d~~ independent verification of the phase shifts.

To obtain the energy dependence of the form factors and of the phase shifts it appears that more statistics are necessary. We should emphasize that 5 kinematic variables are needed to describe the decay. This implies that we have to study a 5-dimensional distribution to take into account possible correlations between those variables. At the same time higher statistics and better spectrometer resolution increase our sensitivity to violation of those aspects of weak interaction mentioned above. In particular, the upper limit for a violation of the $\Delta S = \Delta Q$ rule in the case of pure axial current can be improved by an order of magnitude.

For these reasons we propose a new K_{e4} experiment to observe 20,000 K_{e4} decays.

Apparatus

The detector is quite similar to our first experiment. We observe the $K^{\pm}$ decay in flight with a magnetic spectrometer measuring the angles and the momenta of three charged particles ($\pi^+\pi^-e^{\pm}$).

We improve the acceptance of the spectrometer in three ways : 1) The distance between the decay zone and the magnet is decreased. 2) The magnet gap is increased from 40 cm to 60 cm. 3) The incident beam momentum is increased from 2.2 to about 2.8 GeV/c. A K beam of this momentum with good separation (π/K = 2 to 3) is feasible in a modified m_7 beam with one more separator.

The spectrometer (see Fig. 1) consists of three multiwire proportional chambers (PC1-PC3) and four magnetostrictive wire chambers (SC1-SC4) in front of the analyzing magnet, and five wire chambers (SC5-SC9) behind it.

A fast trigger is formed by a coincidence between an incident kaon signal, three scintillation hodoscopes (H1-H3) requiring that three charged particles pass through the spectrometer, and two threshold Cerenkov counters labeling the electron. Scintillation counters $\overline{\gamma}$ and A in anticoincidence reject triggers which include a γ at a large angle or a particle swept out of the spectrometer by the analyzing magnet.

Spectrometer Resolution

The new spectrometer will increase the precision of the vertex reconstruction by a factor 2 at least. An important improvement will be the use of proportional chambers (PC) near the decay region.

PC1 and PC2 give the direction of the incident kaon for K decays downstream of PC2. For those decays upstream of PC2, this chamber registers the three decay products ($\pi^+\pi^-e^\pm$). In either case the vertex determination of the decay is improved. PC3 requires that three particles enter the spectrometer.

The field integral of the magnet will also be increased by a factor 2.

Rate of K_{e4} events

The number of K_{e4} events per hour, n, is given by

$$n = N_K \, m \, \delta \, (B.R.) \, \alpha \, \eta_1 \, \eta_2$$

where N_K is the number of K^+ per PS burst, m the number of bursts per hour, δ the fraction of K^+ decaying in the decay volume, B.R. the branching ratio, α the geometrical acceptance of the spectrometer, η_1 the hardware efficiency and η_2 the analysis efficiency.

Studies of our first experiment and a Monte Carlo calculation for the acceptance of the new spectrometer yield the values presented in Table I. The net acquisition rate for K_{e4} is about 50 events per hour.

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Taking into account the down time for periodic calibrations of the spectrometer with $K_{\pi 3}$ and $K_{\pi 2}$ Dalitz decays, we expect about 3000 K_{e4} events per PS week.

Background

Background events are mainly those decay channels which include in the final state three charged particles which can trigger the hodoscopes and one or more electrons which can fire the Cerenkov counter. The most important are $K_{\pi 3}$ decays triggering the Cerenkov by a knock-on electron and kaon decays with $\pi^0 \rightarrow e^+ e^- \gamma$ ($K_{\pi 2}$, τ', K_{e3}, $K_{\mu 3}$).

In our previous experiment the background was eliminated by scanning the pictures of the optical shower chambers and by kinematically constraining the reconstructed events to fit a K_{e4} hypothesis. We find experimentally that the contamination of our final sample is less than 4 %.

In order to substantially decrease the background in the trigger, our new scheme replaces the shower chamber by a second Čerenkov counter.

From our previous experiment we know the probability for a $K_{\pi 3}$ to trigger a counter of this type is $4 \cdot 10^{-3}$. This figure will be somewhat reduced by pulse height analysis. Since a δ-ray produced in Čerenkov 1 cannot reach Čerenkov 2 because of the magnetic

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field, the probability for a $K_{\pi 3}$ to trigger both counters will be down to at least 10^{-5}. We expect the $K_{\pi 3}$ contamination to be 10 % in the trigger and less than 0.4 % in the final sample after kinematical fits.

Since the Dalitz pairs have a very small opening angle in the lab they are often so close together that they give only one signal in the proportion~~n~~al chamber PC3 or in the hodoscope H1 and therefore are not accepted by the trigger. Furthermore they produce twice as much light as a single electron in Čerenkov 1 and we shall set an upper cut-off on the pulse height spectrum. Finally, because of their opposite charges the 2 electrons hit 2 different regions in Čerenkov 2. The fiducial volume of this last counter will be imaged on an array of about 24 multipliers, and signal configurations corresponding to 2 incoming electrons will be rejected.

Kinematical cuts on the missing mass of the π^0 in the case of $K_{\pi 2}$ and on the effective mass of the 2 electrons for the other mode will further reduce this contamination.

We expect about 2 triggers on "2e" events for one K_{e4} trigger The contamination of the final sample will be less than 2 %.

Conclusion

Our first experiment increased the number of observed K_{e4} by a factor of 6 and yields a single solution fitting the data. This analysis showed us the wealth of information that can be extracted from K_{e4} decay and the necessity to carry on this study. The performance of experiment S68 makes us quite confident in the new scheme.

We ask the EEC to schedule this experiment for summer 1972. The PS time we need is 8 weeks for production plus setting up time, in the m_7 beam.

References

1) A. Pais and S.B. Treiman
Phys. Rev. 168, 1858 (1968)

2) S. Weinberg
Phys. Rev. Letters 17, 616 (1966)
Phys. Rev. Letters 17, 336 (1966)
Phys. Rev. Letters 18, 1178 (E) (1967)

T.D. Lee and C.S. Wu
Ann. Rev. Nucl. Sci. 16, 533 (1966)

3) R.W. Birge, R.P. Ely, Jr., G. Gidal, G.E. Kalmus, A. Kernan, W.M. Powell, U. Camerini, D. Cline, W.F. Fry, J.G. Gaidos, D. Murphree, and C.T. Murphy
Phys. Rev. 139, B 1600 (1965)

R.P. Ely, Jr., G. Gidal, V. Hagopian, G.E. Kalmus, K. Billing, F.W. Bullock, M.J. Esten, M. Govan, C. Henderson, W.L. Knight, R.R. Stannard, O. Treutler, U. Camerini, D. Cline, W.F. Fry, H. Haggerty, R.H. March, and W.J. Singleton
Phys. Rev. 180, 1319 (1969)

4) The results of experiment S68 are presently being prepared for publication in a few weeks.

5) N. Cabibbo and A. Maksymowicz
Phys. Rev. 137, B 438 (1965).

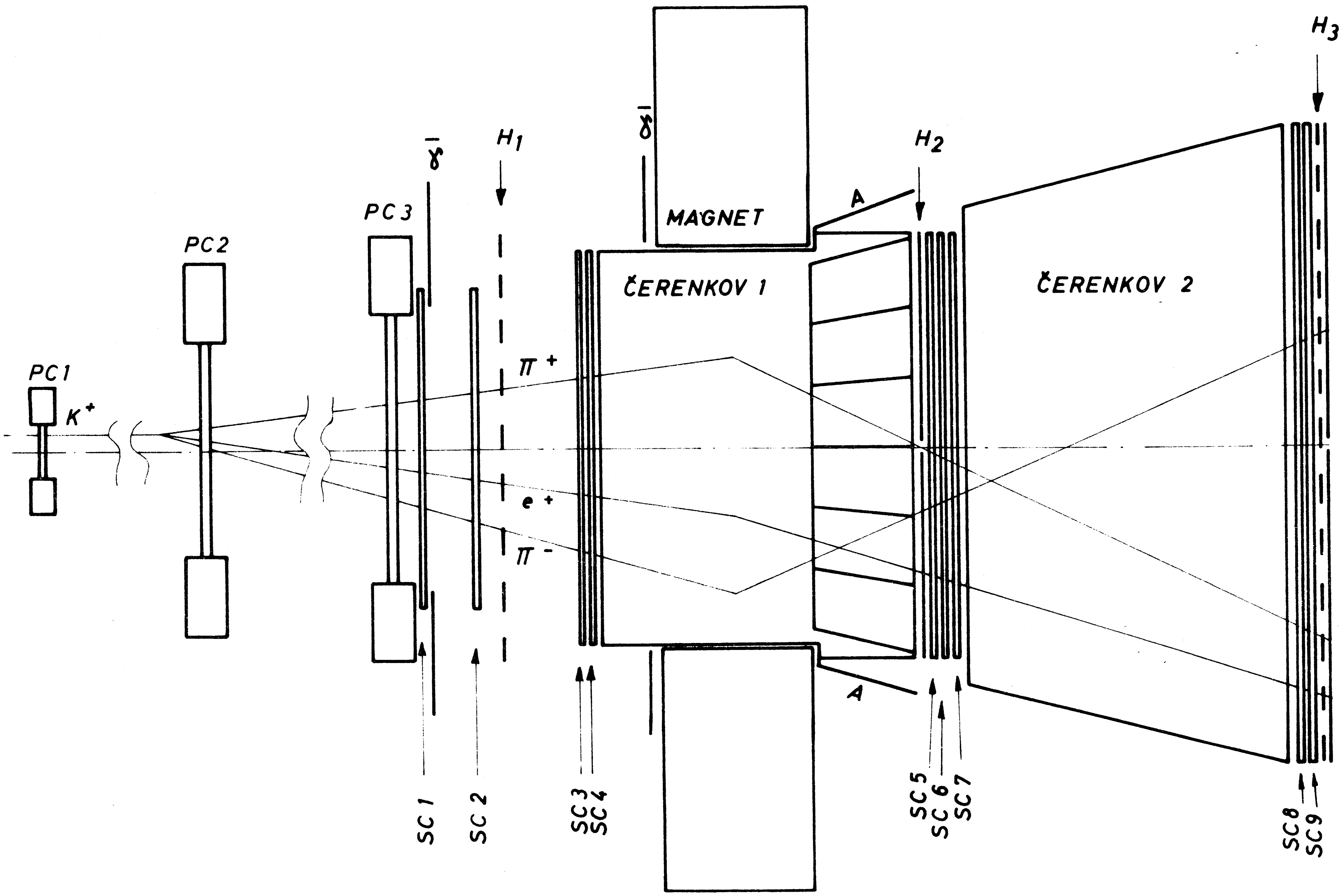
PC1
K$^+$
PC2
PC3
$\bar{\gamma}$
H$_1$
$\bar{\gamma}$
MAGNET
H$_2$
H$_3$
A
ČERENKOV 1
ČERENKOV 2
π^+
e^+
π^-
A
SC 1
SC 2
SC 3
SC 4
SC 5
SC 6
SC 7
SC 8
SC 9

Fig. 1.

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Table I. Event trigger rates and K_{e4} contaminations

Decay Mode	K_{e4}	$K_{\pi 3}$ knock-on	$K_{\pi 2}$ Dalitz	$K_{\pi 3}$ Dalitz	$K_{\mu 3}$ Dalitz	K_{e3} Dalitz
Branching ratio B.R.	$3.3 \cdot 10^{-5}$	$5.6 \cdot 10^{-2}$	$2.4 \cdot 10^{-3}$	$4 \cdot 10^{-4}$	$3.7 \cdot 10^{-4}$	$5.7 \cdot 10^{-4}$
Geometric acceptance α	0.16	0.48	$2.3 \quad 10^{-2}$	$3.7 . 10^{-2}$	$2.7 . 10^{-2}$	$1.5 . 10^{-2}$
Hardware efficiency η_1	0.70	$0.7 \cdot 10^{-5}$	$9 \cdot 10^{-2}$	$3.5 \cdot 10^{-2}$	$9 \cdot 10^{-2}$	$3 \cdot 10^{-2}$
Trigger rate per hour	44	3	60	7	11	3
Analysis efficiency η_2	0.68	$4.6 \cdot 10^{-2}$	$1.6 \cdot 10^{-3}$	$2.7 \cdot 10^{-2}$	$1.7 \cdot 10^{-2}$	$2.6 \cdot 10^{-2}$
Acquisition rate per hour n	30					
Contamination in K_{e4} sample (%)		0.35	0.32	0.56	0.62	0.27

Constants : $N_K = 6 \cdot 10^4$ K^+/burst $\quad m = 1.5 \cdot 10^3$ bursts/hour $\quad \delta = 0.133$ K^+ decay/decay volume