To : E.E.C. April 10th, 1967

PROPOSAL FOR AN EXPERIMENT ON K_{e4} DECAY

M. Bourquin, J.-P. Boymond, P. Extermann, R. Mermod,
P. Basile, B. Thévenet, R. Turlay, A. Zylberstein.

Geneva University - D. Ph. P. E. Saclay

****

Introduction

The interest of the rare decay

$$K \longrightarrow \pi \pi e \nu$$

is twofold : a) it is a good way to verify the $\Delta Q = \Delta S$ rule for axial vector current b) it provides a measurement of $\pi \pi$ phase shifts.

This decay has been observed [1-4] in the charge state

$$K^+ \longrightarrow \pi^+ \pi^- e^+ \nu \text{ with } \Delta Q = \Delta S \quad (1)$$

with a branching ratio of $(3.8 \pm 0.8)\ 10^{-5*}$ while no events of the type :

$$K^+ \longrightarrow \pi^+ \pi^+ e^- \bar{\nu} \text{ with } \Delta Q = - \Delta S \quad (2)$$

were detected. This gives an upper limit for the ratio of $\frac{\Delta Q = -\Delta S}{\Delta Q = \Delta S}$ amplitudes $X < 0.13$ for about 200 decays of type (1) observed [4]. In the decay (2) the 2 π's are in a pure isospin state $I = 2$ and so have to be in even angular momentum state, this means that the hadron current is pure axial vector assuming V-A theory.

* a better value should be available soon

The investigation of $\pi\pi$ interaction in reaction (1) has been studied by Cabibbo and Maksymowicz [5]; the 2 π's, in this reaction can be in an I = 0,1,2 isospin state which means that we have $\pi\pi$ interactions in S and P states. The difference of the phase shifts of these states can be measured looking at the fore-aft asymmetry in the angle of the pion in the dipion rest system and at the up-down asymmetry of the positron with respect to the dipion plane. With enough statistics it is possible to determine the phase shift in function of the dipion invariant mass. Finally, the mass spectrum of the dipion will give information on the existence of a $\pi\pi$ resonance with a mass below 440 Mev.

Experimental method

The K_{e4} decay will be observed in flight using a separated K^+ beam in the momentum range of 2 to 3 GeV/C. The procedure is to measure the momenta of the 3 charged particles from the decay and to identify the electron. As the K^+ momentum is known we have a one constraint kinematical fit for a further identification of the event.

The apparatus is sketched in fig. 1 and is mainly a spectrometer consisting of 4 spark chambers SC1 to SC4 and a bending magnet of 150 x 30 cm^2 aperture (Saclay). Two hodoscopes H1 and H2 made of crossed scintillators are connected to a fast logic requiring the signature of 3 charged particles. An array of 5 gas threshold Cerenkov counters C placed side by side identify the electron. A shower spark chamber gives a further identification of the electron. All spark chambers are triggered by a coincidence between an identified K^+ in the beam, 3 charged particles in the hodoscopes and an electron in the Cerenkov counter.

Event rate K_{e4}

The number of K_{e4} events per day is given by

$$n = N(K^+) \cdot b \cdot \delta \cdot R \cdot \alpha \cdot (1-\varepsilon) \cdot \eta$$

Where

$N(K^+)$	number of K^+ per burst (in the momentum bite)
b	number of bursts per day
δ	fraction of K^+ decaying in the decay zone
R	branching ratio of K_{e4} decay
α	acceptance of the detection system integrated over the decay zone
ε	loss of events due to pion decay in flight
η	efficiency of detection and analysis

The acceptance of the magnet aperture only was calculated by a Monte-Carlo calculation as a function of the distance from the center of the magnet, for K^+ momenta of 2 and 3 GeV/c. (see fig. 2). The decay zone observed by the spectrometer extends from 3.80 to 1.80 m from the magnet center. An integration over this length yields a mean acceptance of 2.9% at 2 GeV/c and of 9.6% at 3 GeV/c.

The Cerenkov counters were introduced in the Monte-Carlo calculation. It turns out that about 20% of the electrons cross an intermediate wall between two counters before passing through the magnet and are unlikely to trigger either counter.

The net acceptance α of the system is taken as the magnet acceptance reduced by 20%.

We have introduced a factor η to take into account the losses of good events due to additional tracks in the chambers and to the inefficiency of the Cerenkov counters. (The Cerenkov will be calibrated before the experiment).

With the information currently available one obtains :

$N(K^+) = 5\ 10^4$

$b = 3\ 10^4$

$R = 3.8\ 10^{-5}$

$\eta = 0.4$

For $p(K^+) = 2$ GeV/c

$\delta = 0.125$

$\alpha = 2.32\ 10^{-2}$

$\varepsilon = 0.25$

Event rate: n = 50 events per day

For $p(K^+) = 3$ GeV/c

$\delta = 0.085$

$\alpha = 7.68\ 10^{-2}$

$\varepsilon = 0.17$

Event rate: n = 120 events per day

Further studies of the resolution of the spectrometer and of the beam available will be necessary to determine the optimum K^+ momentum.

Background

The main contribution to the background is expected from the Dalitz electrons from the following decay modes :

			branching ratio
$K^+\to$	1)	$\pi^+\pi^0 \longrightarrow \pi^+ e^+ e^- \gamma$	$2.5\ 10^{-3}$
	2)	$\pi^+\pi^0\pi^0 \longrightarrow \pi^+ e^+ e^- \gamma\gamma\gamma$	$2\ 10^{-4}$
	3)	$\mu^+\pi^0\nu \longrightarrow \mu^+ e^+ e^- \gamma\nu$	$4\ 10^{-4}$
	4)	$e^+\pi^0\nu \longrightarrow e^+ e^+ e^- \gamma\nu$	$5.6\ 10^{-4}$
			$36.6\ 10^{-4}$

This contribution has to be compared with the branching ratio for K_{e4} events $(3.8 \cdot 10^{-5})$.

A large fraction of this background will be suppressed by the hodoscope H1 (the Dalitz electrons being emitted at small angle with respect to each other will hit only one cell of H1 and will not trigger the system).

The rest of this background will be eliminated by the detection of 2 electron showers in the last chamber and by kinematical criteria in the analysis.

These criteria will be to analyze each event in the assumption of the decay mode 1. which gives a one constraint fit, and to apply a lower cut-off on the angle between the electron and a particule of opposite charge.

A detailed Monte-Carlo calculation is in progress, but we feel confident that the remaining background will be small enough to allow a substantial improvement of the upper limit for the $\Delta S = - \Delta Q$ amplitude and to be neglected in the analysis of the $\Delta S = \Delta Q$ events.

Running time

According to the event rate given above we require for 5000 K_{e4} events a running time between

6 new Ps weeks with a K^+ momentum of 3 GeV/c
and 14 " " " " of 2 GeV/c.

References

1) E.L. Koller, S. Taylor, T. Huetter, P. Stamer
Phys. Rev. Letters 9, 328, 1962.

2) R.W. Birge, et al.
Phys. Rev. Letters 11, 35, 1963.

3) R.W. Birge, et al.
Phys. Rev. 139 B 1600 1965

4) R.W. Birge, et al.
UCRL 17088

5) N. Cabibbo, A. Maksimowicz
Phys. Rev. 137 B 1605 1965

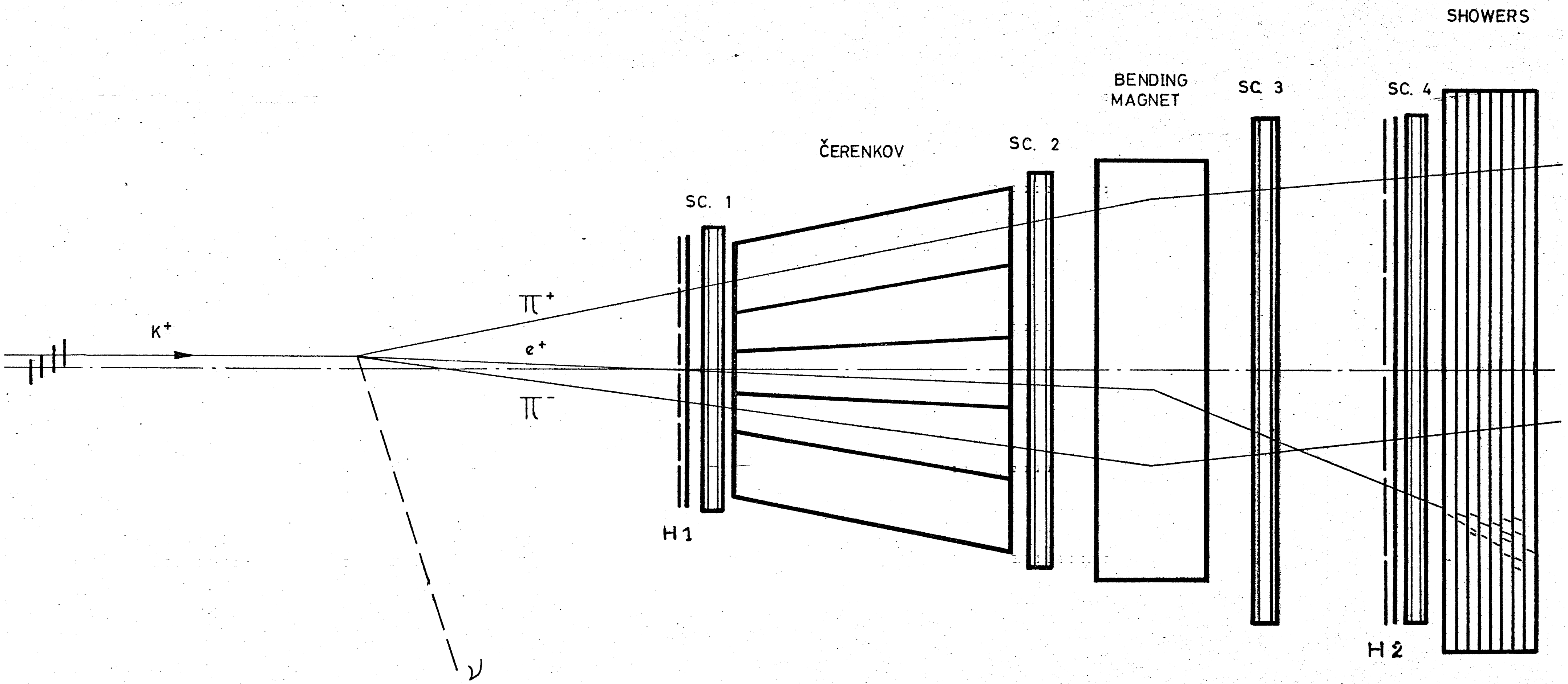

FIG.1

FIG. 2

Acceptance of the magnet as a function of the distance from magnet center.