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PROPOSAL FOR AN EXPERIMENT TO STUDY INTERFERENCES IN THE TWO-PION DECAY OF A BEAM OF K_2 MESONS WHICH HAS TRAVERSED SOME MATTER

R. Friedberg, J.M. Gaillard, C. Rubbia,

J. Steinberger and M. Tannenbaum

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I. INTRODUCTION

We propose to study the possible interference between the long-lived (K_2) and short-lived (K_1) decays of the K^0 into two pions. To this purpose we propose to insert a regenerator, probably carbon of the order of 10 g/cm^2 thick, into a neutral beam extracted at about 5 - 8° to the circulating protons and detect the $K^0 \to 2\pi$ decays as a function of position in a region extending from the target about eight K_1° mean-lives downstream. The detector will be described below.

The detection efficiency as a function of the distance can be measured in several ways, in particular either by removing the regenerator, or by placing a regenerator in several positions along the sensitive region, and recording the intense regenerated flux within one K_1 lifetime. The distance distribution can be converted into a time distribution with the help of the momentum, which is determined for each event. The expected time distribution has the form:

$$R^2 e^{-t} + \epsilon^2 + 2R\epsilon\, e^{-t/2} \cos(\Delta m t + \Phi) \qquad (1)$$

where R is the absolute value of the regenerated amplitude, ϵ^2 is the absolute value of the ratio of the decay rates, $\Gamma_{K_2 \to 2\pi}/\Gamma_{K_1 \to 2\pi}$, Φ is the sum

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p/mw

of the phases of R and ϵ, Δm is the K_1-K_2 mass difference, and the time t is in units of the K_1 lifetime. According to Fitch, ϵ is 2×10^{-3}. (1) is shown for a particular value of R ($R = 10^{-3}$) and for several values of Φ in Fig. 1.

The interference effect is large, easily studied with substantial accuracy, and must be expected if the two pions are the only particles emitted in the $K_2 \to 2\pi$ decay. It affords a new and better means of measuring the K_1-K_2 mass difference.

The purpose of the experiment is then:

1) To observe the expected interference and to measure the phase of K_1 relative to K_2 in the two-pion decay.

2) To measure the absolute value of the K_1-K_2 mass difference.

3) Incidentally, the apparatus offers the possibility of searching for the decay $K_2 \to e^+ + e^-$ and $K_2 \to \mu^+ + \mu^-$ with a sensitivity of one such decay in $10^6 - 10^7$ decays, about $10^3 - 10^4$ times more sensitive than published results. These decays, even with present accuracy, offer the most sensitive test for the presence of neutral currents in the weak interaction.

II. DETECTOR

The proposed detector is sketched in Fig. 2. The regenerator is followed by an anticoincidence counter, and then by the decay region, about 1.2 m long. This in turn is followed by a scintillation counter in coincidence, and a conventional arrangement of four spark chambers and a magnet to determine the momenta of the two charged tracks.

It is a property of the kinematics of the decay that the projections of the two prongs onto the magnet plane can be made nearly parallel to the beam over a large part of the solid angle of the K^0 decay, after traversing a magnetic field which has constant $\int Hdl$ along the direction perpendicular to the beam. We take advantage of this fact to reject the dominant leptonic decays to a level of about one per cent of their total.

The requirement of parallelism is imposed either by a system of venetian blind scintillators in anticoincidence (see Fig. 2), or by two Charpak wire mesh chambers and some simple logic. This is followed by a sandwich of lead plates and spark chambers to allow the identification of electrons, and by a 600 g/cm^2 Fe absorber followed by a scintillation counter in anticoincidence to reject muons.

The acceptance solid angle of the decay in the K^0 c.m. is $\Delta\Omega/4\pi \simeq 0.04$ about four per cent of 4π.

The momentum acceptance is about two to four GeV. The rate of successful K_2 events with a beam 35 m long at 7° to the target is expected to be about 600, with 10^{11} p on target and a beam cross-section of 200 cm^2 at the converter. The rate would be better in a shorter beam and with a higher proton flux, however 35 m seems possible without substantial dislocations, and the parasitic intensity should make it possible to obtain data over a considerable period of time. We would hope to get several thousand events for each of two or three geometries.

III. DISCUSSION

There is little doubt that this experiment is feasible and that it can answer the question of the interference of the two decays. If no interference is found then there can be only two alternatives:

a) in the decay now identified as $K_2^0 \to 2\pi$ other particles are emitted as well, or the "pions" are misidentified.

b) the mass difference is substantially smaller than the lowest value yet reported, and $\Phi \cong \pm \pi/2$.

If, as must be expected, the interference is found, this offers a new way to measure the mass difference with high sensitivity.

The relative phase of the two interfering amplitudes, aside from that due to the mass difference, is the sum of a) the phase of regeneration of the K_1, and b) the relative phase of 2π decay for K_1 and K_2. The phase b) is a constant which is of interest to anyone attempting a theory of this process and will be determined in this experiment provided a) can be determined. The regeneration phase a) is given by the phase of the amplitude $f(0) - \bar{f}(0)$ where $f(0)$ and $\bar{f}(0)$ are the forward elastic scattering amplitudes of K^0 and $\bar{K}^0$, respectively, in carbon, which we propose to use as regenerator. To find $f(0)$ and $\bar{f}(0)$ it is necessary to measure the total cross-sections and forward elastic cross-sections of K^+ and K^- mesons in carbon over the energy range in which this experiment is sensitive (2 - 4 GeV). We propose to make these auxiliary measurements, which are not difficult.

IV. APPARATUS AND TIME SCHEDULE

The K^0 beam should be extracted at $\sim 7^\circ$ and requires one sweeping magnet. It is conventional and simple.

The detector employs conventional scintillation counters and spark chambers, and these should offer no difficulty nor incur large expense.

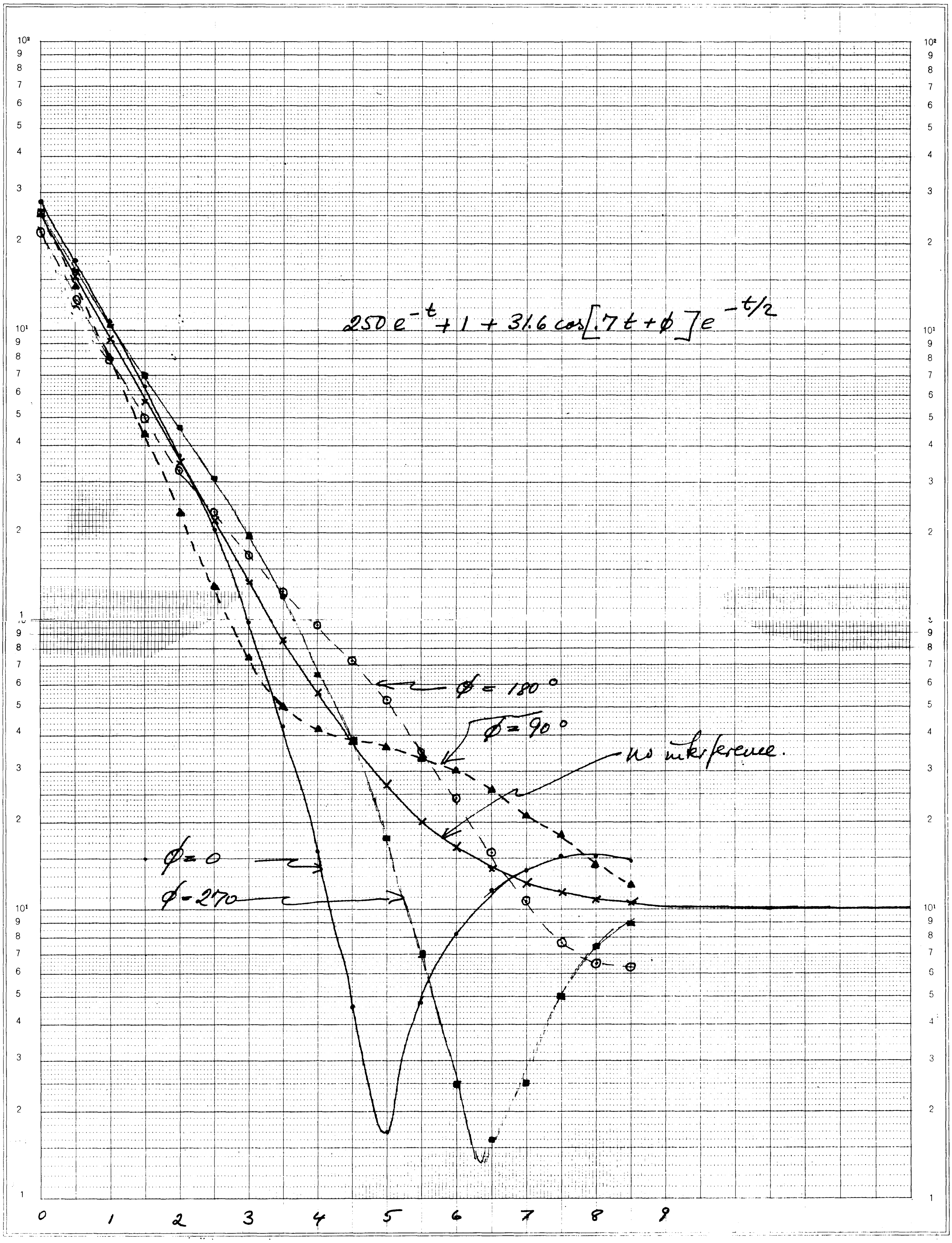
We do require modification of a 1 m bending magnet such that the return yoke is at 90° to the normal position. We expect that all equipment can be ready at the end of the present planned shut-down, July 15, without special effort, except perhaps on the magnet.

In the period immediately following the shut-down, we would hope to be able to run parasitically for ~ 4 weeks to get substantial data with, at least, two different converter thicknesses, without converter, and with the detector sensitive to $\mu^+ + \mu^-$ and $e^+ + e^-$ decays.

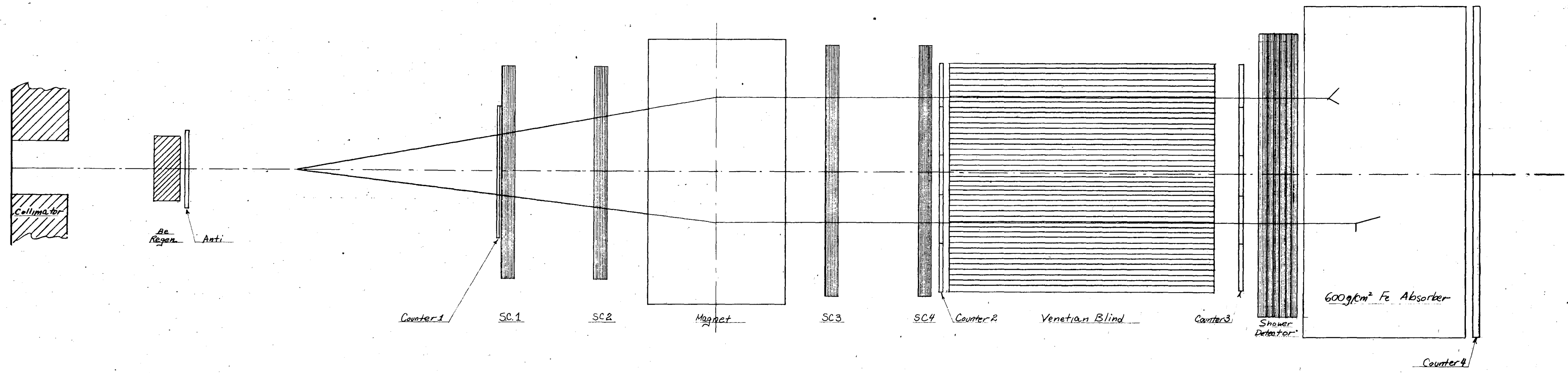
Figure captions:

Fig. 1 : The expected time distribution of $K \to 2\pi$ decays following a regenerator of given regeneration intensity, for four different values of the relative phase of K_1 and K_2 two-pion decay. It is assumed that $\Delta m = 0.7$.

Fig. 2 : Top view of proposed detector.



$250e^{-t} + 1 + 31.6\cos[.7t + \phi]e^{-t/2}$
$\phi = 180°$
$\phi = 90°$
no interference.
$\phi = 0$
$\phi = 270$
0 1 2 3 4 5 6 7 8 9


Collimator
Be Regen.
Anti
Counter 1
SC 1
SC 2
Magnet
SC3
SC4
Counter 2
Venetian Blind
Counter 3
Shower Detector
600 g/cm² Fe Absorber
Counter 4