Memorandum

To: The members of the EEC

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Subject: Request for machine time to perform a K° regeneration
experiment with the setup of S74.

Data taking for the experiments S74, i.e. K°→πνν and K°→πνννν will
be terminated in January 1971. The apparatus of these experi-
ments as shown in fig.1 and the m_7 beam are both very well suited
to perform an additional experiment which we want to describe here.
The time requested for this experiment is two weeks, and we would
like to run during the South Hall period following the January/Fe-
bruary period. Short tests have already been undertaken, and more
extensive tests could follow in January.

Coherent regeneration of K_S° states out of K_S° states in solid
matter is a well known phenomenon 1). Together with the phenomenon
of CP violation in K_L° decays it leads to interference patterns in
the time distribution of many decay modes, e.g. in the νννν mode 2).
A most remarkable decay time pattern can be reached from the inter-
ference between K_S° states produced in a charge exchange process and
K_S° states regenerated in a block of matter behind the charge exchange
target as shown in fig.2. The charge exchange process K°→K°νννν and
its detection in the cylindrical spark chambers (CCH in fig.1) per-
mit to know the production point and the state \( \gamma = \frac{1}{12} (3+L) \) of

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the neutral kaon. After passage through the regenerator between
time \( \tau_1 \) and \( \tau_2 \), the state at \( \tau_2 \) transforms into
\[
\psi(\tau_2) = \frac{e^{-\mathcal{N} \xi T}}{\mathcal{V}_2} \left[ \sum c_i e^{i \phi_i (\tau_2 - \tau_1)} \left( \xi \pm e^{i \phi_i (\tau_2 - \tau_1)} \right) + \mathcal{L} \left( \xi \pm e^{i \phi_i (\tau_2 - \tau_1)} \right) \right],
\]
where the term with \( \xi \) describes the absorption, \( \phi = (m_L - m_S) T \), \( T \)
is the \( K_S \) mean life and \( \xi \) the regeneration amplitude.

The \( \pi^+ \pi^- \) intensity integrated over all \( \tau_2 \) can be written as
\[
N = N(\tau_2) \propto \xi(\tau_2) \left[ e^{-T_1 / T_3} + |\xi|^2 + 2 |\xi|^2 e^{-T_1 / T_3} \cos (\Delta m \tau_1 - \psi_S) \right]
\]
where \( \xi(\tau_2) \) is the production point dependent acceptance of the
detector, see fig.3, and CP violating \( \pi^+ \pi^- \) decays from the \( K_L \) component
have been neglected.

W.A.W.Meephis et al \( \textsuperscript{3} \) used this pattern with about 300 events
to determine the sign of the mass difference \( \Delta m = m_L - m_S \). We estimate
to reach about 3000 events and we propose as one of our aims
to constrain the values of \( T_3 \) and \( \Delta m \) to their world averages and
to determine only \( |\xi| \) and \( \psi_S \). We would run at a \( K^0 \) momentum of about
2.0 GeV/c with a copper regenerator.

The CERN group of J.C.Chollet et al \( \textsuperscript{4} \) has measured the CP
violating parameter \( \gamma_{90} = A(K_L \rightarrow \pi^0 \pi^0) / A(K_S \rightarrow \pi^0 \pi^0) \) relative to \( \phi_{K_S} \) at this
momentum, and a determination of \( |\xi| \) with \( \pm 15\% \) or better would be de-
sirable.

The hydrogen target of our setup has an effective length of
43 cm, thus giving \( N(\tau_2) \) in a life time range of \( \Delta T = 4.5 \) from one fixed
regenerator position. We propose to take the majority of the data
with a 13 cm thick regenerator, positioning its exit face 35 cm be-
hind the target, and with a thin anticounter immediately behind the
regenerator. The Monte Carlo calculated acceptance \( \xi(\tau_1) \) at these
conditions is also shown in fig.3. In order to reach results which
are highly independent of Monte Carlo calculations we want to run
about 30\% of the time without regenerator but with anticounter to
maintain the \( \tau_2 \geq \tau_1 \) condition. The time dependence
\[
N_{\text{free}}(\tau_1) \propto \xi(\tau_1) e^{-\tau_1 / T_3}
\]
contains exactly the same acceptance as the one with regenerator.

Regenerator and anticounter are the only necessary modifica-
tions to the setup of S74. Also the existing reconstruction programs can be widely used, an important exception being the cinematical fit routine. $K^0_S$ states from production may scatter elastically at copper nuclei, and $K^0_L$ states may transform into $K^0_S$ by diffractive regeneration. Therefore, the fit has to determine $\Theta_2$ and $\Theta_3$, the horizontal and vertical scattering angle of the kaon in the regenerator central plane. The number of constraints is thus reduced to 3 for two pion decays with momentum analysis for both pions and to 2 for decays with one momentum measurement. The angular resolution of the apparatus is on average 15 mrad, whereas the angular distribution of single nuclear scattering has a width of about 30 mrad. Separation of the diffractive events from the transmission events should thus be possible. The time dependence $N_{\text{diff}}(\tau_i)$ of the diffractive events has been calculated including all multiple scattering and interference effects. The influence of diffractive events with $\Theta<15$ mrad on the precision of $|s|$ and $\psi_s$ is weak.

References


FIG. 1 Plane view of the apparatus.
Regenerator (Cu) of length l

Anticounter

Charge exchange target (liq H₂)

Fig. 2
\[ p(K^0) = 2.0 \text{ GeV/c} \]
\[ L = 13 \text{ cm} \]
\[ \frac{(f-f)}{k} = 26.0 \text{ mb} \]
\[ \phi(f-f) = -48^\circ \]
\[ \delta = 0.467 \]