SEARCH FOR THE DECAY $K_L^0 \rightarrow \pi^0 e^+e^-$

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Results are presented of a recent search by AGS Experiment 845 for the CP violating decay $K_L^0 \rightarrow \pi^0 e^+e^-$. The 90% C.L. limit $B(K_L^0 \rightarrow \pi^0 e^+e^-) < 5.5 \times 10^{-9}$ was obtained. The background to the $\pi^0 e^+e^-$ search, $K_L^0 \rightarrow e^+e^-\gamma$ with an internal bremsstrahlung is discussed.

1. INTRODUCTION

The decay $K^0 \rightarrow \pi^0 e^+e^-$ proceeds through an effective strangeness changing neutral current and is suppressed by the GIM mechanism. If the $e^+e^-$ pair originates from a $\gamma$ or $Z^0$, then the final state has even CP and the decay $K_L^0 \rightarrow \pi^0 e^+e^-$ violates CP. The decay can also proceed through a two photon intermediate state which conserves CP. Estimates of the total rate [1] in the context of the CKM Standard Model are $3 \times 10^{-12} < BR(K_L^0 \rightarrow \pi^0 e^+e^-) < 10^{-10}$. The pre-1990 experimental limit [2] is $BR(K_L^0 \rightarrow \pi^0 e^+e^-) < 4 \times 10^{-8}$ (90% confidence level). This decay mode is thus an excellent probe of CP violation from nonstandard models [1,3] where branching ratios as high as the experimental limit are possible. Furthermore, the $K_L^0$ decay to a $\pi^0$ and a scalar particle (which then decays to $e^+e^-$) conserves CP and could also occur at the experimental limit.

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2. EXPERIMENTAL APPARATUS AND PROCEDURE

Experiment 845 was performed at the Brookhaven AGS during 1989. The detector is described in ref. 4. Briefly, four drift chambers measured the electron positions and angles before and after the trajectories were altered by a 114 MeV/c magnetic field. An atmospheric pressure Cerenkov counter provided particle identification. Electron and photon energies were measured in a lead glass array. The energy resolution was \( \sigma/E = 7%/\sqrt{E} + 1.6% \) (E in GeV). At the running intensity, the highest rate blocks sustained radiation damage such that the light transmission decreased by about 15%/week. Exposure to a high intensity mercury vapor lamp every three weeks almost completely cured the damage. Veto counters downstream of 3 radiation lengths of lead framed the acceptance. There was a hole for the neutral beam through the lead glass (5" x 15"'), however, the drift chambers were sensitive over the full 1m² area in order to veto extra particles.

An "e⁺e⁻" and a "minimum bias" trigger were used. The e⁺e⁻ trigger required two charged particles, two Cerenkov quads, and at least 800 MeV in two lead glass quads. The minimum bias trigger simply required two charged particles, and was prescaled by a factor of 10,000. The minimum bias triggers were dominated by K decays. The e⁺e⁻ trigger was dominated by photon conversions in the final neutral beam collimator and \( K^e3 \) decays where the pion was above the Cerenkov threshold of 8 GeV/c. These backgrounds were easily rejected offline by requiring the vertex to be downstream of the last collimator and the electron momentum to be below the pion Cerenkov threshold. \( 10^8 \) events were written to tape during approximately 1000 hours of data collection.

Backgrounds studied while designing the experiment included:

1) \( K^0_L \rightarrow \pi^0 + \pi^0 \)
   \[ e^+e^-\gamma \text{ or } e^+e^- \]

2) \( K^0_L \rightarrow \pi^0 + \pi^0 + \pi^0 \)
   \[ e^+e^-\gamma \]
   \[ e^+e^-\gamma \]

3) \( K^0_L \rightarrow \pi e\nu \) with accidental \( \gamma\gamma \)
   \[ \rightarrow \pi e\nu\gamma \) with accidental \( \gamma \)

Background 1 is very serious at our level of sensitivity. This background is eliminated by the requirement \( m(e^+e^-) > 145 MeV/c^2 \). Background 2 is reduced to an acceptable level by vetoing on extra particles. Background 3 is reduced by requiring good electron particle ID:
\[ 1 \text{GeV/c} < p_e < 8 \text{GeV/c} \]
\[ 0.75 < E_{LG}/p_e < 1.25 \]
\[ \sum E_{LG} \left[ (x_{LG} - x_{DC})^2 + (y_{LG} - y_{DC})^2 \right] / \sum E_{LG} < 32 \text{cm}^2. \]

and good photon timing:
\[ |t_\gamma - t_e| < 5 \text{ nsec}. \]

3. RESULTS

If the \( \gamma \gamma \) effective mass was within 34 MeV/c^2 of the \( \pi^0 \) mass, the photons were constrained to the \( \pi^0 \) mass. The reconstructed K momentum vector was required to point back to the target within three standard deviations: \( \Theta_K^2 < 12 \text{mrad}^2 \). The resultant \( \pi^0 e^+ e^- \) effective mass distribution is shown in Fig. 1. There are four events within 3\( \sigma \) of the K mass.

In all four events one of the photons is clearly due to bremsstrahlung. Apparently these events are due to \( K_L^0 \rightarrow e^+ e^- \gamma \) with internal or external radiation. Subsequent Monte Carlo simulations of this background predicted a number of events consistent with the number observed. Those events which have the electron-photon opening angle greater than 7 mrad are shaded. The measurement error is approximately 2.5 mrad. No events which pass the bremsstrahlung cut have an effective mass within 3 \( \sigma \) of the K mass.

![Figure 3.1: Distribution of \( \pi^0 e^+ e^- \) effective mass (MeV/c^2). Shaded events have \( \theta_{e\gamma} > 7 \text{mrad} \). The K mass with three standard deviation bounds is also shown.](image)
The sensitivity of the experiment [4] was determined through an accounting of the \( \pi^+\pi^0 \) events in the minimum bias trigger. With the use of Monte Carlo techniques to determine the acceptance to the decay modes \( \pi^+\pi^-\pi^0 \) and \( \pi^0\overline{\nu}e^+e^- \), it was determined that the single event sensitivity was \( 2.4 \times 10^{-9} \). The 90% confidence level limit is then \( BR(K_L^0 \rightarrow \pi^0 e^+e^-) < 5.5 \times 10^{-9} \). This result is consistent with the recent Fermilab E731 result [5] \( BR(K_L^0 \rightarrow \pi^0 e^+e^-) < 7.5 \times 10^{-9} \), and constrains nonstandard models of CP violation.

REFERENCES


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