AN UPPER LIMIT ON THE $K_S^0 \rightarrow \mu^- \mu^+$ DECAY RATE

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ABSTRACT

From an experiment, studying μ pair and π pair production under similar experimental conditions in $\pi^- p$ collisions at 11 GeV/c beam momentum, we derive an upper limit for the decay mode $K_S^0 \rightarrow \mu^- \mu^+$. We find the branching ratio $\Gamma(K_S^0 \rightarrow \mu^- \mu^+)/\Gamma(K_S^0 \rightarrow \text{all}) \leq 7.3 \times 10^{-6}$ at 90% confidence.

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We present here a determination of an upper limit on the branching ratio B

$$B = \frac{\Gamma(K_S^0 \rightarrow \mu^- \mu^+)}{\Gamma(K_S^0 \rightarrow \text{all})} \quad (1)$$

obtained from a measurement of the reactions (2) and (3)

$$\pi^- p \rightarrow \mu^- \mu^+ + (1 \text{ or more particles}) \quad (2)$$

$$\pi^- p \rightarrow \pi^- \pi^+ + (1 \text{ or more particles}) \quad (3)$$

at 11 GeV/c π^- meson momentum.

A detailed description of the experiment measuring reaction (2) is given in an earlier publication¹⁾.

The measurement of reaction (3) was done with an apparatus similar to that used in the μ pair experiment. Details on the experimental arrangement, the film measurement and the event reconstruction can be obtained from paragraphs 2 and 3 of a previous publication²⁾. Only the target position and the trigger condition in this experiment were different from that described in Ref. 2. Here the target was in the same position as in the μ pair experiment, and in the trigger not only a neutron, but also more than one particle accompanying the π pair were admitted. About 45,000 photographs were recorded attempting to select reaction (3). Among these 6,396 were found to be π pair events of this type.

Figure 1 shows the π pair invariant mass distribution from reaction (3). A clear signal of about 130 K_S^0 events, with $M = 497$ MeV, is seen

above a smooth background. We may obtain an upper limit to B using these data for K_S^0 production and the μ pair invariant mass spectrum from reaction (2).

However, the sensitivity of this experiment is improved if we make use of the fact that the K_S^0 decay vertex is not coincident with the beam trajectory. Our π pair data show, that the K_S^0 have a mean transverse momentum of 300 MeV/c and thus the average distance from the decay vertex to the beam trajectory is 15 mm for a K_S^0 with 10 GeV/c momentum.

To determine the beam vertex distance d we applied the same measurement procedure to μ pairs and π pairs. Figures 2a and 2b show the distribution of d for all μ pairs and π pairs respectively, with an energy of the pair ≥ 10.0 GeV. The invariant mass spectrum of those events, which have $d \geq 10$ mm, is depicted in Fig. 2c for μ pairs and Fig. 3d for π pairs. No enhancement is seen in the K_S^0 mass region of the μ pair distribution, whereas in the π pair distribution a sharp K_S^0 peak on top of practically no background is visible. Normalizing these two mass distributions to each other, we can give an upper limit for the branching ratio B.

A K_S^0 interval $I_{K_S^0}$ of ± 20 MeV around the K_S^0 mass is chosen, which contains more than 70% of all possible $K_S^0 \rightarrow \mu^- \mu^+$ decays [the μ pair mass resolution is $\Delta M = \pm 17$ MeV²)]. The number of events observed in this interval is $n = 1$. The number of background events $\bar{b}$, expected in $I_{K_S^0}$, is determined from two 40 MeV wide test intervals on both sides of $I_{K_S^0}$, assuming a uniform distribution for the background in these intervals. From Fig. 2c one finds $\bar{b} = 2$.

The number of observed background events b and signal events s , are individually samples from Poisson distributions with means $\bar{b}$ and $\bar{s}$, and therefore also their sum $n = b + s$ is a sample from a Poisson distribution with mean $\bar{n} = \bar{b} + \bar{s}$.

On the basis of the one sample point $n = 1$, which we have available from the over-all distribution, we can calculate the upper limit $\bar{s}_0$ on the mean $\bar{s}$ to be

$$\bar{s} \leq \bar{s}_0 = 1.9 \quad \text{at 90\% confidence .}$$

This number is obtained by solving Eq. (4) for $\bar{n}_0$

$$\sum_{k=0}^1 \frac{\bar{n}_0^k}{k!} e^{-\bar{n}_0} = 0.1, \quad (4)$$

which gives $\bar{n}_0 = 3.9$ or $\bar{s}_0 = \bar{n}_0 - \bar{b} = 1.9$.

Normalizing to the number of incoming beam particles and correcting for the differences in electronics efficiency, analysis efficiency and acceptance between the μ pair and π pair experiments, one finds an upper limit for the branching ratio

$$B \leq B_0 = 7.3 \times 10^{-6} \quad \text{at 90\% confidence.} \quad (5)$$

This value is an improvement of one order of magnitude with respect to the present upper limit $B \leq 7.3 \times 10^{-5}$ ³⁾.

The branching ratio B expected from a weak x electromagnetic transition with a Feynman diagram shown in Fig. 3 is expected to be $B \lesssim 5 \times 10^{-9}$ ⁴⁻⁷⁾. The appearance of a branching ratio considerably higher than 5×10^{-9} would thus be evidence for the existence of neutral leptonic currents coupling to strangeness changing hadronic currents. Our limit B_0 provides an upper limit on coupling constants occurring in models on neutral leptonic currents ⁸⁻¹⁰⁾.

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Figure captions

- Fig. 1 : Invariant mass spectrum of all π pairs from the reaction $\pi^- p \rightarrow \pi^- \pi^+ + (1 \text{ or more particles})$. Unweighted data.
- Fig. 2 : Distribution of beam vertex distance for μ pair events (a) and π pair events (b), respectively, with $E_{\mu\mu}(E_{\pi\pi}) \geq 10.0$ GeV. The invariant mass of all events, which lie at the right side of the dotted line drawn in (a) and (b) is shown in (c) and (d) for μ pairs and π pairs, respectively.
- Fig. 3 : Feynman Diagram for the weak x electromagnetic transition $K_S^0 \rightarrow \mu^- \mu^+$.

Fig. 1

Fig. 2

Fig. 3