New results from NA48 on rare neutral kaon decays *

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NA48 has searched for rare neutral kaon decays in data collected in 1998 and 1999. Preliminary results for the decays $K_L \to \pi^0\gamma\gamma$ and $K_S, K_L \to \pi^+\pi^-e^+e^-$ are presented.

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The NA48 experiment is designed to measure direct CP-violation effects in neutral kaon decays to two pions. The experimental layout, described in detail elsewhere [1], includes a spectrometer (drift chambers and dipole magnet); an electromagnetic calorimeter; arrangements of scintillators for vetoing photons outside the calorimeter acceptance.

The decay $K_L \to \pi^0\gamma\gamma$ is studied with the aim of understanding low-energy hadron dynamics in the context of chiral perturbation theory [2]. The rate for this decay can be expressed in terms of two independent Lorentz invariant amplitudes, representing two-photon states with J=0 and J=2. Vector-meson exchange contributions to the amplitudes are parametrized in terms of an effective coupling constant, a_V. A non-zero value for a_V gives a sizeable low-mass tail in the distribution of the invariant mass of the decay photons. Data on $K_L \to \pi^0\gamma\gamma$ can also be used to constrain the CP-conserving amplitude of the decay $K_L \to \pi^0e^+e^-$.

In NA48, the decays $K_L \to \pi^0\gamma\gamma$ and $K_L \to \pi^0\pi^0$, the latter a normalization channel, are accepted by the same neutral trigger [1]. The two decays

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are selected in the offline analysis by taking events with four clusters in the electromagnetic calorimeter and no hits in the drift chambers. The main background comes from $K_L \to \pi^0\pi^0\pi^0$ decays where photons are outside the experiment's acceptance or give overlaping clusters in the calorimeter. In these cases, because of missing photon energy, the reconstucted kaon-decay vertex usually lies downstream of the true decay position. Most of the background events are rejected by requiring that the decay occur in the first ~ 20 m after the end of the beam collimator. Remaining background events are eliminated by cutting on the difference between the reconstructed positions of the kaon and pion decays, taking into account all scenarios of shower overlap, and by requiring that each cluster have a width consistent with a single electromagnetic shower. A χ^2 variable, based on the invariant masses of the two-photon combinations, is used to distinguish between $K_L \to \pi^0\gamma\gamma$ and $K_L \to \pi^0\pi^0$.

Using a fraction of the 1998 data and all of the 1999 data, a signal of 1397 $K_L \to \pi^0\gamma\gamma$ decays has been identified above a background of about 30 events (see Fig. 1). Acceptance has been determined from a simulation in which events were generated with $a_V = -0.45$. A preliminary measurement of the branching fraction gives $\mathrm{B}(K_L \to \pi^0\gamma\gamma) = (1.51 \pm 0.05(stat) \pm 0.20(sys)) \times 10^{-6}$. A clear signal is also visible for non-π^0 photons of low invariant mass ($m_{\gamma\gamma} < 240$ MeV/c^2, see Fig. 1 and Fig. 2).

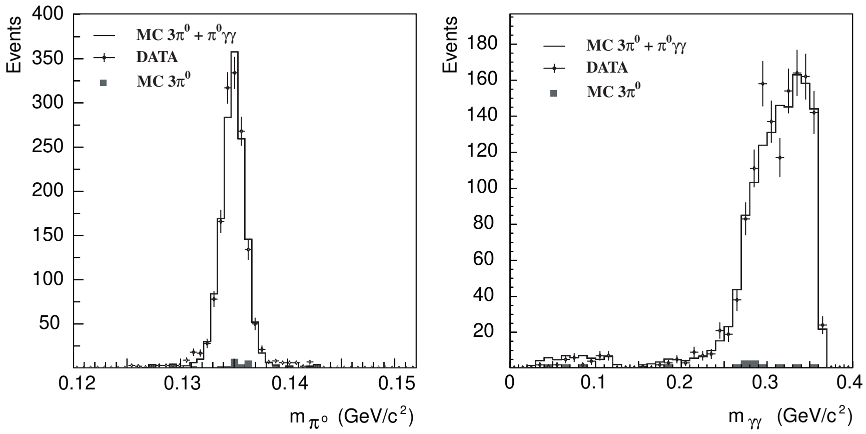

Fig. 1. Distributions of (left) m_{π^0} and (right) $m_{\gamma\gamma}$ for the $K_L \to \pi^0\gamma\gamma$ sample.

The decay $K_L \to \pi^+\pi^-e^+e^-$ is expected to involve an intermediate state with a virtual photon: $K_L \to \pi^+\pi^-\gamma^* \to \pi^+\pi^-e^+e^-$. The amplitude has two components: one from CP-conserving direct emission; the other from the CP-violating decay $K_L \to \pi^+\pi^-$, with inner bremsstrahlung. The interference of the two amplitudes causes the virtual photon to have a circular polarization, leading to an asymmetry in the angle, ϕ, between $\pi^+\pi^-$ plane and e^+e^- plane in the kaon centre-of-mass frame [3]. Only the CP-conserving inner-bremsstrahlung process contributes to $K_S \to \pi^+\pi^-e^+e^-$, and so no asymmetry is expected.

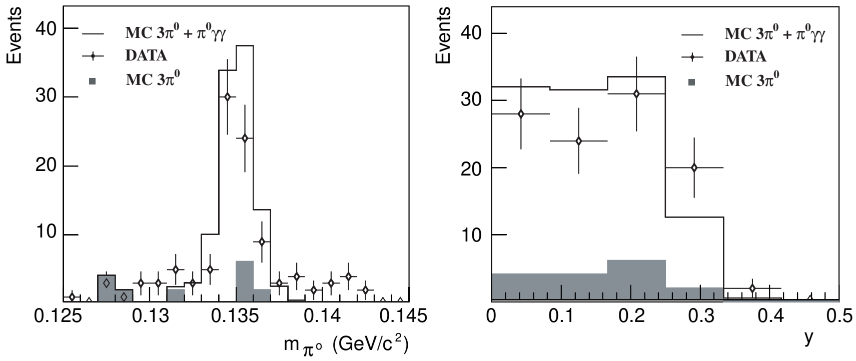

Fig. 2. Distributions of (left) m_{π^0} and (right) the rapidity $y = |E_{\gamma_1} - E_{\gamma_2}|/m_K$ for $K_L \to \pi^0\gamma\gamma$ events with $m_{\gamma\gamma} < 240$ MeV/c^2.

Kaon decays to $\pi^+\pi^-e^+e^-$ are selected, with an efficiency of about 97 %, by a trigger requiring the presence of four tracks. An event to be accepted for offline analysis is required to contain two positive and two negative tracks; a vertex reconstructed within the fiducial region and near the beam axis; two tracks identified as electrons (from E/p). It is also required that the event's trasverse momentum be small. Three main sources of background need to be eliminated: a decay $K_L \to \pi^+\pi^-\gamma$ followed by a γ conversion is rejected by requiring that all two-track vertices be outside of the material of the detector; overlaid decays of $K \to \pi e\nu$ are rejected by time constraints; a decay $K_L \to \pi^+\pi^-\pi^0_D$ is rejected from the invariant mass of the $ee\gamma$ system being consistent with the m_{π^0} mass when the photon is inside the calorimeter acceptance, or is otherwise rejected by a kinematical cut [4].

For the 1998 data, 458 $K_L \to \pi^+\pi^-e^+e^-$ decays are found, with a signal-over-background ratio of about 37 (see Fig. 3). A preliminary measurement gives the branching fraction B($K_L \to \pi^+\pi^-e^+e^-$) to be $(2.90 \pm 015(stat)) \times 10^{-7}$. The data indicate an asymmetry in good agreement with the theoretical expectations (see Fig. 3). Using the 1998 data, 58 $K_S \to \pi^+\pi^-e^+e^-$ decays are selected and a branching fraction of about 4×10^{-5} is deduced. From data taken in 1999 during a short period with a high-intensity K_S beam, 731 $K_S \to \pi^+\pi^-e^+e^-$ decays are identified (see Fig. 4). As expected, the angular asymmetry is consistent with zero to within the experimental uncertainty.

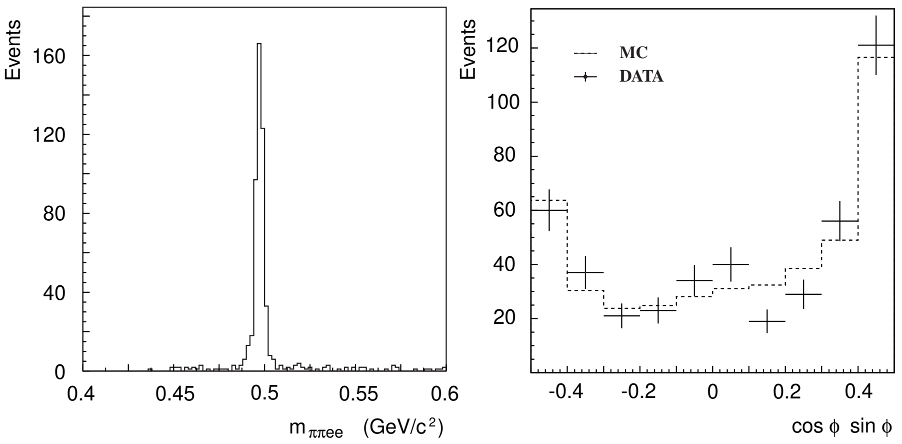

Fig. 3. Distributions showing (left) signal for $\pi^+\pi^-e^+e^-$ and (right) angular asymmetry.

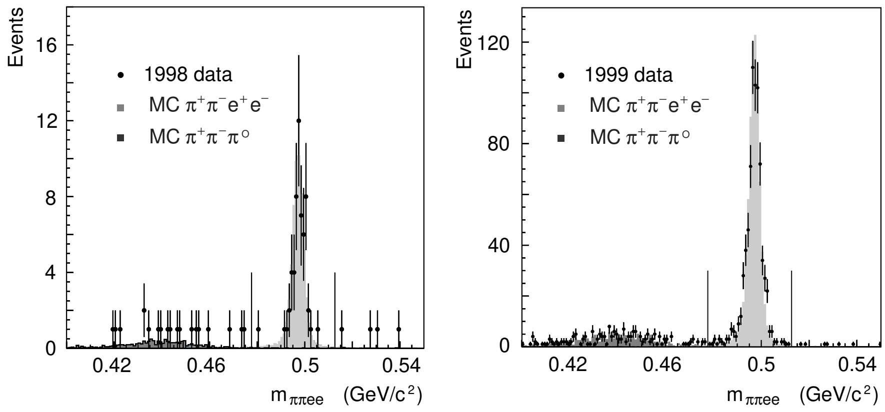

Fig. 4. Signal for $K_S \to \pi^+\pi^-e^+e^-$: (left) using 1998 data (first evidence for decay); (right) using 1999 data for high-intensity K_S beam.

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