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NA48 results on neutral kaon and hyperon rare decays

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Abstract. The NA48 Collaboration has performed an extensive program of kaon and hyperon rare decays using the data collected during the period 1997–2001. This program includes new tests of chiral perturbation theory, new measurements of the η mass and K_S lifetime and the possibility to measure the Cabibbo angle using Ξ beta decays.

1. Introduction

The NA48 experiment, over the period 1997–2000, measured the value of $\mathrm{Re}(\epsilon'/\epsilon)$, i.e., the ratio of direct over indirect CP violation in the kaon sector [1,2]. The data taken during this period, together with additional dedicated high-intensity kaon runs, have also been used to perform a variety of kaon and hyperon rare decay studies. The 2001 run has been completely dedicated to this kind of studies.

In the years 1997–2000 the NA48 experiment used a double beam technique, with a K_S and a K_L beam present at all times, while in 2001 only the K_S beam was used (with a much higher intensity) (figure 1a). A schematic of the detector is shown in figure 1b.

2. Chiral perturbation theory

Chiral perturbation theory (ChPT) has been proven as an extremely successful effective theory for low-energy hadron dynamics but the knowledge of higher order effect is rather scarce. The decays $K_S \to \gamma\gamma$ and $K_L \to \pi^0\gamma\gamma$ have been used to test these higher order loop effects since at first order ($O(p^2)$) they vanish [3] and at the following order ($O(p^4)$) they have been precisely calculated, for example [4]: the difference between the theoretical results and the measurements can be attributed to higher order effects.

2.1 *Study of the decay $K_L \to \pi^0\gamma\gamma$*

The decay rate predictions at $O(p^4)$ order are a factor of 2–3 too small [5]. The calculation at the $O(p^6)$ order has been performed, for example [6], and it includes a contribution from meson exchange, indicated by the parameter a_v, which dominates the low $m_{\gamma\gamma}$ region. The value of the parameter a_v has to be measured experimentally. Moreover, the measurement of the decay, $K_L \to \pi^0\gamma\gamma$, can be used to constrain the CP conserving part of the decay, $K_L \to \pi^0 e^+e^-$ which has a direct CP violating part. Experimentally one has to remove several sources of background. The decay, $K_L \to \pi^0\pi^0$, is suppressed by requiring that if the invariant mass of a pair of photons is within 3 MeV of the π^0 mass then the invariant mass of the other two photons should not be in the interval 110–160 MeV. The decay $K_L \to \pi^0\pi^0\pi^0$ with missing or overlapping photons (so that only for electromagnetic clusters are present in the detector) is rejected using a combination of cuts including a vertex cut and a shower width cut. The number of events passing all cuts was found to be 2500. Fitting the $M_{\gamma\gamma}$ distribution the value:

$$a_v = -0.46 \pm 0.03_{\mathrm{stat}} \pm 0.03_{\mathrm{sys}} \pm 0.02_{\mathrm{th}}$$

was found. From this value of a_v the branching ratio was found to be

$$\mathrm{BR}(K_L \to \pi^0\gamma\gamma) = (1.36 \pm 0.03_{\mathrm{stat}} \pm 0.03_{\mathrm{sys}} \pm 0.03_{\mathrm{norm}} \cdot 10^{-6})$$

and the CP conserving part of $K_L \to \pi^0 e^+e^-$:

$$\mathrm{BR}(K_L \to \pi^0 e^+e^-)_{\mathrm{CPC}} = (4.7 \pm 2.2) \cdot 10^{-13}.$$

2.2 *Study of the decay $K_S \to \gamma\gamma$*

The study of this decay channel is complicated by the presence of an irreducible background due to $K_L \to \gamma\gamma$: in the K_S beam there is a component of K_L which will decay in $\gamma\gamma$ with of course the same topology as the signal. In order to minimize this problem $\mathrm{BR}(K_L \to \gamma\gamma)$ has been measured separately using a K_L beam and using the decay $K_L \to 3\pi^0$ as a normalization channel:

$$\frac{\Gamma(K_L \to \gamma\gamma)}{\Gamma(K_L \to 3\pi^0)} = (2.81 \pm 0.01_{\mathrm{stat}} \pm 0.02_{\mathrm{sys}}) \cdot 10^{-3}.$$

In addition to this decay other sources of background were the decay $K_S \to \pi^0\pi^0$ with lost and/or overlapping photons, accidentally overlapping events and hadronic events generated in the scattering at the collimators. Figure 2a shows the vertex distribution for the signal and some background channels. The measured branching ratio for $K_S \to \gamma\gamma$ was measured to be (figure 2b)

$$\mathrm{BR}(K_S \to \gamma\gamma) = (2.78 \pm 0.06_{\mathrm{stat}} \pm 0.04_{\mathrm{sys}}) \cdot 10^{-6}$$

which clearly indicates the need for the $O(p^6)$ term in the expansion.

3. The NA48/I high-intensity K_S run

During the 2001 data taking NA48 has used a single high-intensity neutral beam. The goal is to measure several important quantities: $K_S \to \pi^0 e^+e^-, K_S \to \pi^0\mu^+\mu^-$

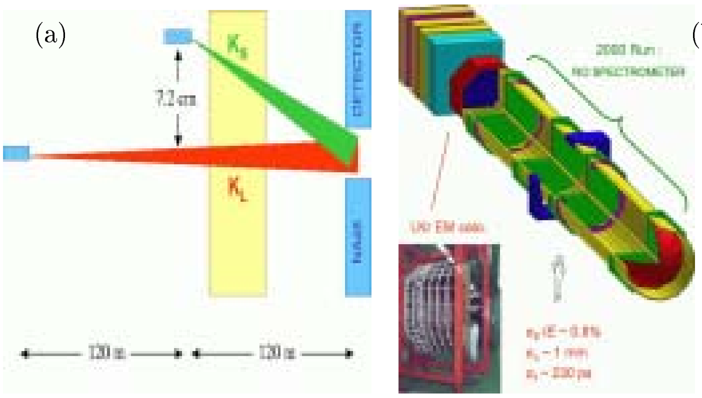

Figure 1. (**a**) The double beam technique used by the NA48 experiment. (**b**) A schematic of the NA48 detector.

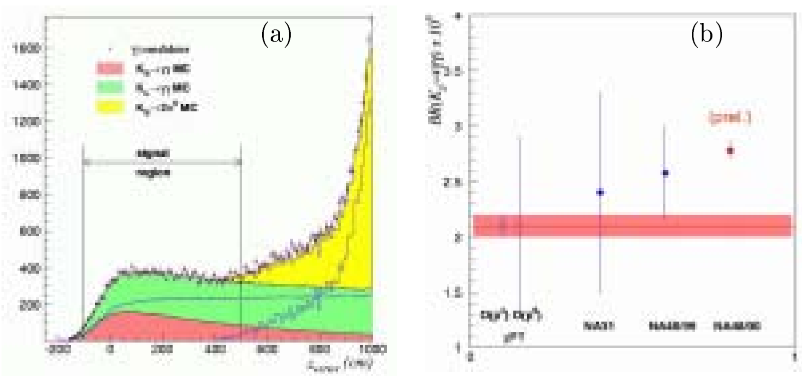

Figure 2. (**a**) Vertex distribution for the decay $K_S \to \gamma\gamma$ and some background channels. (**b**) The result from NA48 compared to previous results and to the prediction of chiral perturbation theory at $O(p^4)$ order.

to bound indirect CP violation in the corresponding K_L decays; additional chiral perturbation studies, hyperon physics: Ξ beta decays, $\Delta S = 2$ processes, radiative decays.

References

[1] V Fanti *et al*, *Phys. Lett.* **B465**, 335 (1999)
[2] A Lai *et al*, *Euro. Phys. J.* **C22**, 231 (2001)
[3] M K Gaillard and B W Lee, *Phys. Rev. Lett.* **33**, 108 (1974)
[4] G D'Ambrosio and D Espriu, *Phys. Lett.* **B175**, 237 (1986)
[5] A Lai *et al*, *Phys. Lett.* **B536**, 229 (2002)
[6] G Ecker, A Pich and E De Rafael, *Phys. Lett.* **B189**, 363 (1987)