Future prospects for K experiments

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Abstract: The study of K decays still attracts considerable experimental interest. This paper reviews ongoing programs and future projects and summarizes the physics issues addressed by them. Only programs not covered in individual contributions to this conference are addressed

Kaon decays have provided in the past invaluable information for the understanding of fundamental interactions in their most subtle aspects. With the refinement of experimental techniques, these physics potentialities can be exploited to a further level.

One example is the precision study of rare decays occurring via flavor changing neutral currents. In the standard model these processess are mediated by loop diagrams suppressed by the GIM mechanism and therefore they provide enhanced sensitivity to possible new physics. The emphasis is on measurements that can be related, with negligible theoretical uncertainty, to the parameters of the CKM matrix, describing the generation mixing in the standard model. Together with similarly clean measurement from the B system, they will overconstrain the flavor structure of the standard model. Inconsistencies in the values of the parameters derived, would be inequivocable evidence of new physics.

With the exception of few 'golden' channels, the extraction of short distance information requires the understanding of non perturbative QCD effects in the decays. Chiral perturbation theory (ChPT) provides a workable theoretical framework for this purpose. Also in this field precision studies of rare decays of kaons play a role, in that they allow to test the ChPT approach and constrain the values of its free parameters.

Finally kaons remain a unique system where tests of discrete symmetries can be performed at unequalled levels of precision. Here the interest is twofold. On one side, new CP or T violating observables can be studied with increased experimental sensitivity, in some cases close to the expectations of the standard model, so that new physics could show up as unexpectedly large effects. On the other side the already stringent limits on possible effects of CPT violation can be further refined with new experimental information.

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1. Flavor changing neutral current decays

The decays $K_L^0 \to \pi^0 \nu\overline{\nu}$ and $K^+ \to \pi^+ \nu\overline{\nu}$ are the theoretically cleanest cases. Long distance effects are negligible and the effective hamiltonian is dominated by a single operator whose matrix elements can be related to the form factors of the K_{e3} decay. The first channel is CP violating and, in the calculation of Wilson coefficients, top quark exchange dominates and QCD corrections can be computed reliably. The branching ratio is thus proportional to $|\Im(V_{ts}^* V_{td})|^2$ through a factor computed with theoretical uncertainties estimated of the order of 2%. In terms of the popular Wolfenstein parametrization of the CKM matrix, this measures η^2. In the case of $K^+ \to \pi^+ \nu\overline{\nu}$ there is a remaining non negligible contribution from charm quark exchange and a slightly larger theoretical uncertainty (5%) is estimated. Again, in terms of the Wolfenstein parametrization, the branching ratio is proportional to $[(1.4-\rho)^2+\eta^2]$. Since ρ and η can be separately determined by these two measurements in the K sector, a non trivial relation with quantities measured in B decays, like, e.g., $sin(2\beta)$, ensues.

Two more decay channels, $K_L^0 \to \mu^+\mu^-$ and $K_L^0 \to \pi^0 e^+ e^-$ are indicated as a potential source of information on CKM matrix and direct CP violation. They are mentioned here not because they are in the agenda of forthcoming experiments [1] but because they motivate measurements of other decay channels that can be used to constrain their theoretical interpretation.

For $K_L^0 \to \mu^+\mu^-$ the celebrated box diagram could be a valuable source of information on second order weak interactions. However the measured branching ratio of $(7.18 \pm 0.17) \times 10^{-9}$ has been shown to be dominated by a more mundane absorptive contribution from the $\gamma\gamma$ channel, estimated to be $(7.09 \pm 0.17) \times 10^{-9}$. In addition long range dispersive contribution from virtual photon intermediate states are expected. Precision studies of K_L^0 decays to photons or lepton pairs have been indicated as necessary experimental input for constraining these long range contributions and will be in the agenda of future high rate experiments on K_L^0 decays.

$K_L^0 \to \pi^0 e^+ e^-$ has been pointed out as a channel with potentially large contributions from direct CP violation. However this contribution has to be disentangled from two competing contributions: a CP conserving contribution mediated by two photon exchange and a contribution of indirect CP violation, occurring through the small CP even component of the K_L^0 . Both contributions can be related to experimental measurements, in the first case of the decay channel $K_L^0 \to \pi^0\gamma\gamma$, in the second of the decay $K_L^0 \to \pi^0 e^+ e^-$

2. CPT tests

K^0 $\overline{K}^0$ mixing provides an extremely high sensitivity to possible CPT violation effects showing up as a difference of mass and/or lifetime between K^0 and $\overline{K}^0$. These effects are characterized by the complex parameter

[1]In the first case a remarkably precise measurement of the branching ratio exists, in the second case the measurement requires the suppression of an overwhelming physical background from the channel $K_L^0 \to \gamma\gamma e^+ e^-$

$$\Delta = \frac{\Lambda_{\overline{K}^0\overline{K}^0} - \Lambda_{K^0K^0}}{2(\lambda_L - \lambda_S)}$$

. For $\Re(\Delta)$ the best measurement is from CPLEAR, through a direct comparison of the time evolution of flavor tagged K^0 and $\overline{K}^0$

$$Re(\Delta) = \frac{P[\overline{K}^0 \to \overline{K}^0(t)] - P[K^0 \to K^0(t)]}{P[\overline{K}^0 \to \overline{K}^0(t)] + P[K^0 \to K^0(t)]}$$

The measurement of the phases of the CP violating parameters η_{+-} and η_{00} yields the most stringent limit on $\Delta_\perp$, the component of the complex number Δ perpendicular to the "superweak" direction identified by the angle $\phi_{SW} = atan(\frac{2\Delta m_{S,L}}{\Delta\gamma_{S,L}})$, but only if the simplifying assumption to neglect CPT violation in $\pi\pi$ decay is made.

A limit on $\Im(\Delta)$ independent of assumptions on CPT conservation in the decay amplitudes is obtained from the Bell-Steinberger sum rule, a statement of the conservation of probability in the decay of K^0's , that relates the elements of the K^0 $\overline{K}^0$ mass matrix with a combination of products of K_L^0 and K_S^0 decay amplitudes. With this technique $\Im(\Delta)$ is presently known to be compatible with zero with a precision of 5×10^{-5}, limited by the measurement of η_{000} , the CP violation parameter characterizing the $K_S^0 \to 3\pi^0$ decay.

3. Kloe

The experiment Kloe will study tagged K_L^0 and K_S^0 decays produced in Φ decays at the Frascati $Da\Phi ne$ e^+e^- colliding ring.

The peak luminosity achieved at the time of the conference falls short of the design luminosity of $5 \times 10^{32} cm^{-2}s^{-1}$ by about a factor 20. Although this does not allow yet significant measurements of direct CP violation in K_L^0 decays, interesting measurements can be made with tagged K_S^0 and K_L^0 decays. Absolute branching ratios can be measured and, for some rare K_S^0 decays, tagging provides unique advantages with respect to data from hadron machines where K_S^0 beams have a large component of K_L^0's.

Tagged K_S^0	0.6×10^8
$K_S^0 \to \pi^+\pi^-$	2×10^7
$K_S^0 \to \pi^0\pi^0$	1×10^7
$K_S^0 \to \pi^+ e\nu$	6700
$K_S^0 \to \gamma\gamma$	70
Tagged K_L^0	0.9×10^8
$K_L^0 \to \pi^+\pi^-$	2.7×10^4
$K_L^0 \to \pi^0\pi^0$	1.0×10^4
$K_L^0 \to \gamma\gamma$	0.5×10^4

Table 1:
KLOE expected data yield for $200pb^{-1}$

The experiment is running with the goal of collecting an integrated luminosity of $200pb^{-1}$. Examples of the statistics expected for some channels of interest is shown in table .

The possibilities of the experiment are demonstrated by preliminary data on the $K_S^0 \to \pi e\nu$ decay presented at the. In $11.5pb^{-1}$ analyzed 283 events of this channel have been identified. This is about 4 times the present world statistics dominated by 75 events collected in the experiment CMD-2.

The CERN experiment NA48, designed for a precision measurement of the $\Re(\epsilon'/\epsilon)$ parameter characterizing direct CP violation in $K^0 \to \pi\pi$, will conclude this program in the present year. The apparatus will be used for two extensions already approved. The first one is devoted to a study of rare decays of the K^0_S and will take data in 2002.