RECENT RESULTS FROM NA48

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Abstract

Recent results from the experiments NA48, NA48/1 and NA48/2 are presented, including: direct CP-violation and Dalitz plot slopes measurements for $K^{\pm} \to 3\pi$ decays; $\pi\pi$ scattering effects in $K^{\pm} \to \pi^{\pm}\pi^{0}\pi^{0}$ and K_{e4}^{+-} decays, as well as $K_{e4}^{\pm}$ form factors and branching fraction; measurements on radiative charged kaons and hyperon decays, semileptonic decays of neutral and charged kaons; $K_L \to \pi^+\pi^-$ branching ratio and $|\eta_{+-}|$ measurement; lepton universality check with $K_{l2}^{\pm}$ decays.

1 Introduction

The series of experiments NA48, having a multipurpose large samples of neutral and charged kaon decays, continues to provide new results in the field of Kaon physics. In this paper briefly are described some of the recent measurements from all three stages of the experimental program: NA48, NA48/1 and NA48/2. The experiment NA48 (1997-2000) was dedicated to the measurement of direct CP-violation in K^0 decays. The next stage, NA48/1 (2002), was orientated mainly to the study of rare K_S decays. The final stage, NA48/2 (2003-2004), was designed to search for direct CP-violation in $K^{\pm}$ decays (see section 3). Besides these central topics, many other analyses were performed.

2 Experimental setup

The NA48 beam line was designed to produce and transport both K_L and K_S beams simultaneously. A description of the beam line, as well as of the NA48 detectors, can be found in [1]. Two of the measurements presented in this paper are performed during a dedicated 1999 NA48 run. The K_L beam was produced by SPS 450 GeV/c proton beam on a beryllium target. The beginning of the decay volume was defined by the last of three collimators, located 126 m downstream of the target.

For the NA48/1 experiment the K_L beam was removed and the proton flux on the K_S target was greatly increased. A 24 mm platinum absorber was placed after the Be target to reduce the photon flux in the neutral beam. A beam of long-lived neutral particles (γ, n, K^0, Λ and Ξ^0) was selected by the sweeping magnet, installed across the 5.2 m long collimator.

The neutral beams were replaced by simultaneous K^+ and K^- beams for the NA48/2 experiment. The momentum (60 ± 3) GeV/c was formed symmetrically for K^+ and K^- in the first achromat (see Fig. 1), in which the two beams were split in the vertical plane. In the second achromat were placed two of the three stations of the Kaon beam spectrometer (KABES). The beams followed the same path in the decay volume, comprised in a 114 m long cylindrical vacuum tank. The beam axes coincided to 1 mm, while their lateral size is about 1 cm.

The NA48 detectors, used in the presented analyses, are:

- a magnetic spectrometer for charged particles reconstruction, with 4 drift chambers; the momentum resolution is $\sigma_p/p = (1.02 \oplus 0.044p)\%$, where p is in GeV/c;
- a charged hodoscope, with good time resolution, which sends fast trigger signals;

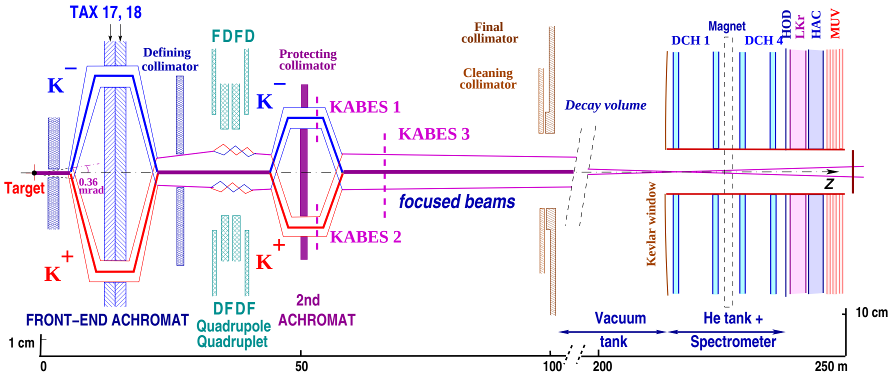


Figure 1: *Schematic side view of the NA48/2 beam line (TAX17,18: motorized beam dump/collimators used to select the momentum of the* K^+ *and* K^- *beams; FDFD/DFDF: focusing quadrupoles, KABES1–3: kaon beam spectrometer stations), decay volume and detector (DCH1–4: drift chambers, HOD: hodoscope, LKr: EM calorimeter, HAC: hadron calorimeter, MUV: muon veto). Thick lines indicate beam axes, narrow ones the projection of their envelopes. Note that the vertical scales are different in the two parts of the figure.*

- calorimeter with an active volume of 10 m^3 liquid krypton (LKr) with energy resolution of $\sigma_E/E = 0.032/\sqrt{E} \oplus 0.09/E \oplus 0.0042$ and space resolution of $\sigma_x = \sigma_y = 0.42/\sqrt{E} \oplus 0.06$ cm, where the energy E is in GeV;
- a muon detector.

3 Search for direct CP-violation in $K^\pm \to 3\pi$ decays

One of the most promising observables for direct CP-violation in Kaon physics is the asymmetry between K^+ and K^- decaying to three pions. Usually, the matrix element of $K^\pm \to 3\pi$ decays is parameterized in the following form:

$$|M(u,v)|^2 \sim 1 + gu + hu^2 + kv^2 + ..., \qquad (1)$$

where g, h and k are the slope parameters. The Dalitz-variables are defined as $u = (s_3 - s_0)/m_\pi^2$ and $v = (s_1 - s_2)/m_\pi^2$, where m_π is the charged pion mass, $s_i = (p_K - p_i)^2$, $s_0 = \sum s_i/3$ $(i = 1,2,3)$, p_K and p_i are kaon and i-th pion four-momenta respectively. The index $i = 3$ corresponds to the odd pion, i.e. the pion with a charge different from the other two. The parameter of direct CP-violation is usually defined as

$$A_g = \frac{g^+ - g^-}{g^+ + g^-},$$

where g^+ and g^- are the linear coefficients in (1) for K^+ and K^- respectively. The experimental precision for such asymmetry for both modes, $K^\pm \to \pi^\pm\pi^+\pi^-$ and $K^\pm \to \pi^\pm\pi^0\pi^0$, is at the level of 10^{-3}. The Standard Model (SM) predictions are below few 10^{-5} [2], however some theoretical calculations involving processes beyond the SM do not exclude enhancements of the asymmetry [3]. The main goal of NA48/2 experiment was a search for direct CP-violation at the level of $2 \cdot 10^{-4}$ in both 3π decay modes.

The method of such a high precision asymmetry measurement is based on direct comparison of the u-ratios for K^+ and K^- decays in which the main possible systematic effects cancel due to the presence of simultaneous K^+ and K^- beams and the frequent alternation of the magnet polarities in the beam optics and in the magnetic spectrometer. In the $K^\pm \to \pi^\pm\pi^+\pi^-$ selection, only the magnetic spectrometer was involved in the reconstruction of the events, while the analysis in $K^\pm \to \pi^\pm\pi^0\pi^0$ mode was based mainly on the information from a charge blinded detector — LKr.

In total ~ 3.1 billion $K^\pm \to \pi^\pm\pi^+\pi^-$ and ~ 91 million $K^\pm \to \pi^\pm\pi^0\pi^0$ decays were collected during 2003 and 2004 runs and the final result on asymmetries A_g^c and A_g^n, respectively, yields:

$$A_g^c = (-1.5 \pm 1.5_{stat} \pm 0.9_{trig} \pm 1.1_{syst}) \cdot 10^{-4},$$

$$A_g^n = (1.8 \pm 1.7_{stat} \pm 0.5_{syst}) \cdot 10^{-4}.$$

Both measurements are limited by the statistics and are one order of magnitude more accurate than the previous experiments. The observed results are compatible with the SM predictions. The method of measurement, selection of the events and the studies of main systematic contributions are described in more details in [4] and [5].

4 Dalitz plot slopes measurement in $K^\pm \to \pi^\pm\pi^+\pi^-$

The last measurements of the Dalitz slopes g, h and k in (1) for $K^\pm \to \pi^\pm\pi^+\pi^-$ decay mode are 30 years old. NA48/2 performed a new high precision measurement in order to verify the validity of the parameterization (1).

Approximately $4.7 \cdot 10^8$ $K^\pm \to \pi^\pm\pi^+\pi^-$ decays were selected for the analysis. The measurement method is based on fitting of the binned reconstructed $(u, |v|)$ data distribution with a sum of four MC components generated according to the four terms in the polynomial expansion. The free parameters in the fitting procedure are the slopes g, h and k, and the overall normalization parameter.

The obtained results, ignoring radiative effects (apart from Coulomb factor) and strong rescaterring effects, are:

$$g = (-21.134 \pm 0.014)\%, \quad h = (1.848 \pm 0.039)\%, \quad k = (-0.463 \pm 0.012)\%.$$

The values are with precision one order of magnitude better, than the previous experiments and are in agreement with the world averages. This is the first measurement of non-zero value of h. The quality of the fit of $(u, |v|)$ distribution ($\chi^2/n.d.f. = 1669/1585$, yielding a satisfactory probability of 7.0%) shows that the polynomial parameterization (1) is still acceptable at an improved level of precision (the rescaterring effects are much weaker than in $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ mode). No significant higher order slope parameters were found. More information on this analysis can be found in [6].

5 $\pi\pi$ scattering effects

The single-flavour quark condensate $\langle 0|\bar{q}q|0\rangle$ is a fundamental parameter of χPT, which determines the relative size of mass and momentum terms in the perturbative expansion. It is a free parameter in the theory and must be determined experimentally. The relation between $\langle 0|\bar{q}q|0\rangle$ and S-wave $\pi\pi$ scattering lengths a_0^0 and a_0^2 in isospin states $I = 0$ and $I = 2$, correspondingly, are known with precision of $\sim 2\%$ [7], so the experimental measurement of a_0^0 and a_0^2 provides an important constraints for χPT Lagrangian parameters. In the framework of NA48/2, the scattering lengths can be measured from $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ and $K^{\pm} \to \pi^+\pi^- e\nu$ (K_{e4}^{+-}) decays.

5.1 Rescattering effects in $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$

During the analysis of ~ 23 million $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ decays, taken in 2003, a sudden "cusp" like structure was found in the spectra of $\pi^0\pi^0$ invariant mass at $M_{00}^2 = 4m_{\pi^{\pm}}^2$ (see fig. 2, *a*). A fit to the data with the parameterization (1) (see fig. 2, *b*) yielded an unacceptable probability of $\chi^2/n.d.f. = 9225/149$, while the area above the "cusp" was well described ($\chi^2/n.d.f. = 133/110$).

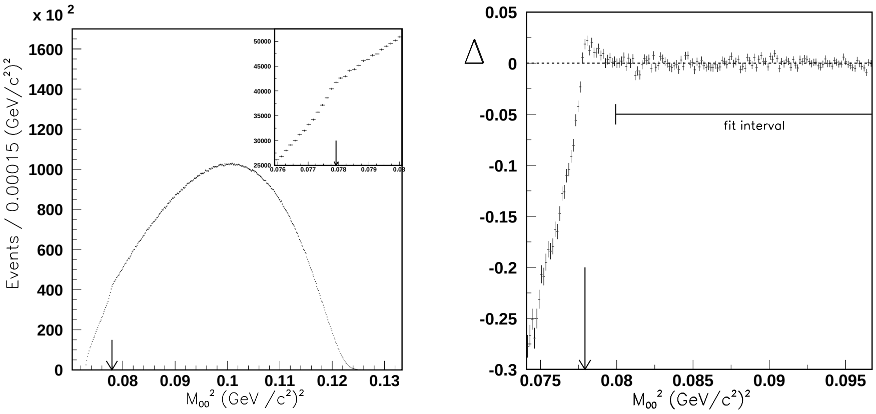
A model at one loop was developed [8] in order to explain the effect. The "cusp" effect is explained as a result of destructive interference below the threshold between the two amplitudes: the direct emission amplitude $M_0 \sim 1 + gu/2 + h'u^2/2 + k'v^2/2$ and the amplitude M_1, which describes the charge exchange $\pi^+\pi^- \to \pi^0\pi^0$ in final state of $K^{\pm} \to \pi^{\pm}\pi^+\pi^-$. A more complete formulation of the model, which includes all rescattering processes at one loop and two loop levels with precision $\sim 5\%$ [9], has been used to extract the NA48/2 result:

$$g = 0.645 \pm 0.004_{stat} \pm 0.009_{syst}$$

$$h' = -0.047 \pm 0.012_{stat} \pm 0.011_{syst}$$

$$a_0^2 = -0.041 \pm 0.022_{stat} \pm 0.014_{syst}$$

$$a_0^0 - a_0^2 = 0.268 \pm 0.010_{stat} \pm 0.004_{syst} \pm 0.013_{ext},$$



a *b*

Figure 2: *The observed "cusp"-like effect, a, and the fit result by using the parameterization (1), b.*

assuming $k' = 0$. The values for the scattering lengths are in good agreement with the theory [10) 11)]. More details about this analysis can be found in [12)].

Currently, there are two measurements of k in (1), which contradicts to each other [13)]. Taking k' as a free parameter in the fit far from "cusp", a nonzero preliminary value was obtained

$$k' = 0.0097 \pm 0.0003_{stat} \pm 0.0008_{syst}$$

and no change of a_0^0 and a_0^2 was observed.

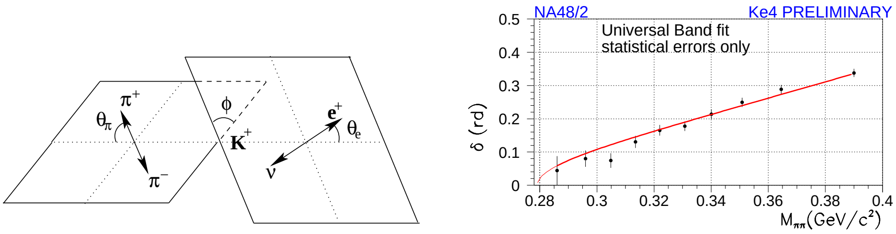
5.2 K_{e4} decays form-factors

The form factors of K_{e4}^{+-} decay can be parameterized as a function of five kinematic variables: the invariant masses $M_{\pi\pi}$ and $M_{e\nu}$, and the angles θ_π, θ_e and ϕ (see Fig. 3). The hadronic part in the matrix element can be described in terms of two axial (F and G) and one vector (H) form factors [14)]. Their expansion into partial s and p waves (neglecting d waves) and into a Taylor series in $q^2 = M_{\pi\pi}^2/4m_{\pi^\pm}^2 - 1$ allows a measurement of the form factor parameters from the experimental data [15) 16)]:

$$F = F_s e^{i\delta_s} + F_p \cos\theta_\pi e^{i\delta_p}, \quad G = G_p e^{i\delta_g}, \quad H = H_p e^{i\delta_h},$$

where

$$F_s = f_s + f_s' q^2 + f_s'' q^4, \quad F_p = f_p + f_p' q^2 + ...,$$



a *b*

Figure 3: *a) Definition of the angle kinematic variables, describing K_{e4} decays; b) $\delta(M_{\pi\pi})$ distribution, fitted to obtain a_0^0.*

$$G_p = g_p + g_p' q^2 + ..., \quad H_p = h_p e + h_p' q^2 + ...$$

Analysing part of 2003 data, $3.7 \cdot 10^5$ K_{e4}^{+-} decays were selected with background of 0.5%, mainly from 3π decays with $\pi \to e\mu$ or pion mis-identification.

The following method was used to extract the form factor parameters: In a first step, in ($M_{\pi\pi}$,$M_{e\nu}$,$\cos\theta_\pi$,$\cos\theta_e$,ϕ) space were defined 10x5x5x5x12 iso-populated bins. For each bin in $M_{\pi\pi}$, comparing data and MC, ten independent five-parameter ($F_s, F_p, G_p, H_p, \delta = \delta_s - \delta_p$) fits were performed. In the second step a fit of the distributions in $M_{\pi\pi}$ was performed to extract the form factor parameters. The $\delta(M_{\pi\pi})$ distribution was fitted with a one-parameter function given by the numerical solution of the Roy equations [17)], in order to determine a_0^0, while a_0^2 was constrained to lie on the centre of the universal band. The following preliminary results were obtained:

$$f_s'/f_s = 0.169 \pm 0.009_{stat} \pm 0.034_{syst}$$

$$f_s''/f_s = -0.091 \pm 0.009_{stat} \pm 0.031_{syst}$$

$$f_p/f_s = -0.047 \pm 0.006_{stat} \pm 0.008_{syst}$$

$$g_p/f_s = 0.891 \pm 0.019_{stat} \pm 0.020_{syst}$$

$$g_p'/f_s = 0.111 \pm 0.031_{stat} \pm 0.032_{syst}$$

$$h_p/f_s = -0.411 \pm 0.027_{stat} \pm 0.038_{syst}$$

$$a_0^0 = 0.256 \pm 0.008_{stat} \pm 0.007_{syst} \pm 0.018_{theor},$$

where the systematic uncertainty was determined by comparing two independent analyses and taking into account the effect of the reconstruction method, acceptance, fit method, uncertainty on background estimate, electron identification efficiency, radiative corrections and bias due to the neglected $M_{e\nu}$ dependence. The form factors are measured relative to f_s, which is related to the decay rate. The obtained value for a_0^0 is compatible with the χPT prediction [18] and with previous experiments [19].

The form factors were measured also for $K^\pm \to \pi^0\pi^0 e\nu$ (K_{e4}^{00}) decays, on $\sim 10^4$ selected events from 2003 run and $\sim 3 \cdot 10^4$ events from 2004 run, using the same formalism. Due to symmetry of $\pi^0\pi^0$ system, the P-wave is not present and only two parameter are left:

$$f_s'/f_s = 0.129 \pm 0.036_{stat} \pm 0.020_{syst}$$

$$f_s''/f_s = -0.040 \pm 0.034_{stat} \pm 0.020_{syst}.$$

The preliminary result is compatible with K_{e4}^{+-}.

In addition, the branching fraction of K_{e4}^{00} was measured by using only 2003 data, normalising to $K^\pm \to \pi^\pm\pi^0\pi^0$:

$$BR(K_{e4}^{00}) = (2.587 \pm 0.026_{stat} \pm 0.019_{syst} \pm 0.029_{ext}) \cdot 10^{-5},$$

where the systematic uncertainty takes into account the effect of acceptance, trigger efficiency and energy measurement of the calorimeter, while the external uncertainty is due to the uncertainty on the $K^\pm \to \pi^\pm\pi^0\pi^0$ branching fraction. The result is ~ 8 times more precise than the previous measurement.

6 New measurements on kaon and hyperon radiative decays

6.1 $K^\pm \to \pi^\pm\pi^0\gamma$ measurements

A measurement of Direct photon Emission (DE) with respect to Inner Bremsstrahlung (IB) and the interference (INT) between these two amplitudes was performed on a subsample of NA48/2 collected during 2003 run. The $K^\pm \to \pi^\pm\pi^0\gamma$ are described in terms of two kinematic variables: the energy of charged pion in kaon center of mass system (T_π^*), and $W^2 = (p_K p_\gamma)(p_\pi p_\gamma)/m_\pi^2 m_K^2$, where p_K, p_π and p_γ are the four-momenta of the kaon, charged pion and the odd gamma. About $124 \cdot 10^3$ events were selected in the ranges $T_\pi^* < 80$ MeV and $0.2 < W < 0.9$. In the previous measurements a lower cut $T^* > 55$ MeV was introduced in order to suppress $K^\pm \to \pi^\pm\pi^0\pi^0$ and $K^\pm \to \pi^\pm\pi^0$ background. In NA48/2 measurement these backgrounds are avoided with an application of a special algorithm, which detects overlapping gamma in the detector and a maximum allowed deviation of reconstructed K mass ± 10 MeV from its nominal value. The upper cut on T_π^* rejects $K^\pm \to \pi^\pm\pi^0$ decays. The background in the selected sample is kept under 10^{-4}. The photon mistagging (i.e., choice of wrong odd photon) is estimated to be less than 0.1%.

The preliminary results:

$$\mathrm{Frac(DE)} = (3.35 \pm 0.35_{\mathrm{stat}} \pm 0.25_{\mathrm{syst}})\%$$

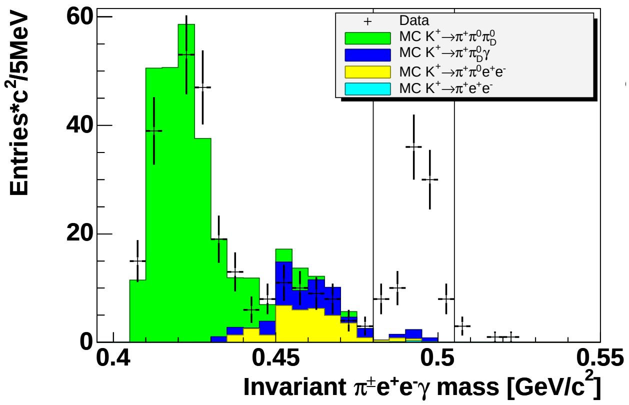


Figure 4: *The invariant mass of* $\pi^{\pm}e^{+}e^{-}\gamma$*, together with the simulated background.*

$$\mathrm{Frac(INT)} = (-2.67 \pm 0.81_{\mathrm{stat}} \pm 0.73_{\mathrm{syst}})\%$$

are obtained by using extended maximum likelihood method: the experimental W distribution is fitted with proportionally simulated IB, DE and INT distributions. The systematic error is dominated by the trigger efficiency.

This is the first observation of non zero INT component.

6.2 First observation of $K^{\pm} \to \pi^{\pm}\gamma e^{+}e^{-}$

NA48/2 experiment observed for the first time the radiative decay $K^{\pm} \to \pi^{\pm}\gamma e^{+}e^{-}$. 92 candidates were selected, with 1 ± 1 accidental background and 5.1 ± 1.7 misidentification background (Fig. 4). By using $K^{\pm} \to \pi^{\pm}\pi^{0}$ as normalization channel the branching ratio preliminary was estimated to be

$$BR(K^{\pm} \to \pi^{\pm}\gamma e^{+}e^{-}) = (1.27 \pm 0.14_{stat} \pm 0.05_{syst}) \cdot 10^{-8}.$$

6.3 First observation of $\Xi^{0} \to \Lambda^{0}e^{+}e^{-}$

In the 2002 NA48/1 run the weak radiative decay $\Xi^{0} \to \Lambda^{0}e^{+}e^{-}$ was detected for the first time [20]. 412 candidates were selected with 15 background events (Fig. 5). The obtained branching fraction

$$BR(\Xi^{0} \to \Lambda^{0}e^{+}e^{-}) = (7.7 \pm 0.5_{stat} \pm 0.4_{syst}) \cdot 10^{-6}$$

is consistent with inner bremsstrahlung-like $e^{+}e^{-}$ production mechanism.

The decay parameter $\alpha_{\Xi\Lambda ee}$ can be measured from the angular distribution

$$dN/d\cos\theta_{p\Xi} = \frac{N}{2}(1 - \alpha_{\Xi\Lambda ee}\alpha_{-}\cos\theta_{p\Xi}),$$

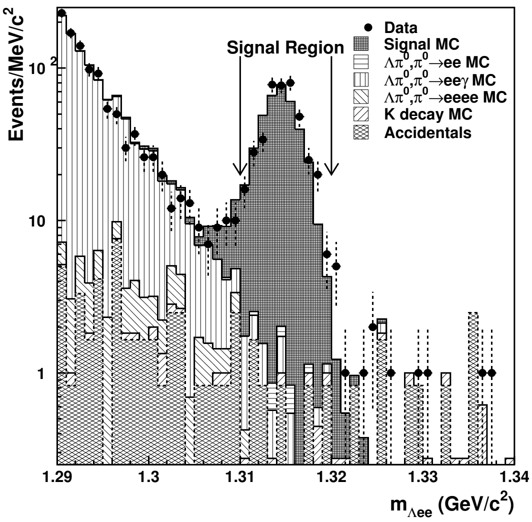


Figure 5: *The invariant mass of* Λe^+e^-, *together with the simulated background.*

where $\theta_{p\Xi}$ is the angle between the proton from $\Lambda \to p\pi$ decay relative to the Ξ^0 line of flight in the Λ rest frame. The obtained value

$$\alpha_{\Xi\Lambda ee} = -0.8 \pm 0.2$$

is consistent with the latest published value of the decay asymmetry parameter for $\Xi \to \Lambda\gamma$.

7 New measurements of K_L decays

In 1999 a dedicated NA48 run employed a minimum bias trigger to collect semileptonic decays of K_L. Two new measurements from this run are presented.

7.1 $K_{L\mu3}$ form factors

K_{l3} decays provide the cleanest way to extract $|V_{us}|$ element in the CKM matrix. Recent calculations in the framework of χPT show how the vector form factor at zero momentum transfer, $f_+(0)$, can be constrained experimentally from the slope and curvature of the scalar form factor f_0 of the $K_{\mu3}$ decay. In addition, these form factors are needed to calculate the phase space integrals, which are used in $|V_{us}|$ determination.

Approximately $2.6 \cdot 10^6$ $K_{\mu3}$ decays were selected from the 1999 minimum bias run. By studying the Dalitz plot density, the following slopes for the vector

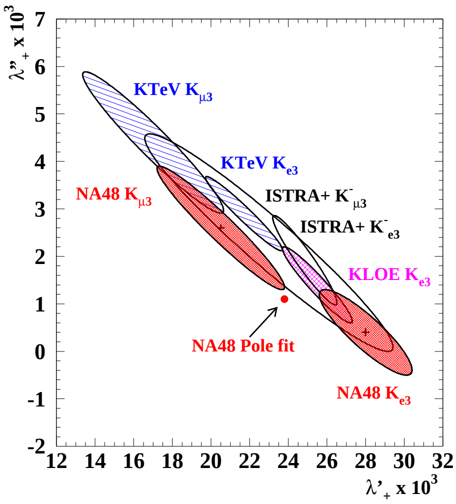


Figure 6: *Comparison between recent results on K_{Ll3} form factors measurements.*

and the scalar form factors were obtained

$$\lambda'_+ = (20.5 \pm 2.2_{stat} \pm 2.4_{syst}) \cdot 10^{-3}$$

$$\lambda''_+ = (2.6 \pm 0.9_{stat} \pm 1.0_{syst}) \cdot 10^{-3}$$

$$\lambda_0 = (9.5 \pm 1.1_{stat} \pm 0.8_{syst}.$$

The results show a presence of quadratic term in the expansion of the vector form factor in agreement with other recent measurements. A comparison between the results of the quadratic fits as reported by the recent experiments is presented in Fig. 6.

The results obtained with linear fit are

$$\lambda_+ = (26.7 \pm 0.6_{stat} \pm 0.8_{syst}) \cdot 10^{-3}$$

$$\lambda_0 = (11.7 \pm 0.7_{stat} \pm 1.0_{syst}) \cdot 10^{-3}.$$

The value for λ_+ is well compatible with the recent KTeV measurement, while λ_0 is shifted towards lower values. Details on NA48 $K_{\mu 3}$ measurement can be found in [21].

7.2 $\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_{Le3})$ ratio and $|\eta_{+-}|$ measurements

The recent results on $\Gamma(K_L \to \pi^+\pi^-)$ and the CP-violation parameter $|\eta_{+-}|$, performed by the experiments KTeV and KLOE, and the measurement of the ratio $\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_{Le3})$ by KTeV disagree with 2004 edition of PDG [22] by 10% and 5% respectively (or more than four standard deviations). Additional information could clarify the situation.

During the dedicated 1999 NA48 run $\sim 47 \cdot 10^3$ $K_L \to \pi^+\pi^-$ and $\sim 5 \cdot 10^6$ K_{Le3} decays were collected. The ratio $\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_{Le3})$ is measured to be

$$\frac{\Gamma(K_L \to \pi^+\pi^-)}{\Gamma(K_{Le3})} = (4.835 \pm 0.022_{stat} \pm 0.016_{syst}) \cdot 10^{-3}.$$

For $BR(K_L \to \pi^+\pi^-)$ and $|\eta_{+-}|$ calculation the CP-conserving direct emission $K_L \to \pi^+\pi^-\gamma$ contribution to the $K_{2\pi}$ signal was estimated and subtracted. The branching fraction of $K_{2\pi}$, including only the inner bremsstrahlung radiative component was measured to be

$$BR(K_L \to \pi^+\pi^- + \pi^+\pi^-\gamma(IB)) = (1.941 \pm 0.019) \cdot 10^{-3}.$$

Using this result and the most precise single measurements of τ_{K_S} (by NA48), τ_{K_L} and $BR(K_S \to \pi^+\pi^-)$ (by KLOE), the CP-violation parameter $|\eta_{+-}|$ is calculated:

$$|\eta_{+-}| = \sqrt{\frac{\tau_{K_S} BR(K_L \to \pi^+\pi^-)}{\tau_{K_L} BR(K_S \to \pi^+\pi^-)}} = (2.223 \pm 0.012) \cdot 10^{-3}.$$

All the presented results are in agreement with the recent KTeV and KLOE results. Details on the analysis can be found in [23].

8 Results from K^{+-} semileptonic decays

The branching ratios of semileptonic kaon decays are needed to determine $|V_{us}|$ element in the CKM matrix. In addition $\Gamma(K_{e3})/\Gamma(K_{\mu 3})$ is a function of the slope parameters of the form factors, which can be used for consistency check under the assumption of $\mu - e$ universality.

During 2003 data taking of NA48/2 a special run was dedicated to collect semileptonic decays. Approximately 56000 K^+_{e3}, 31000 K^-_{e3}, 49000 $K^+_{\mu 3}$, 28000 $K^-_{\mu 3}$, 462000 $K^+_{2\pi}$ and 256000 $K^-_{2\pi}$ decays were selected for the measurement. The ratios of decay widths, combined for K^+ and K^-, are:

$$\Gamma(K_{e3})/\Gamma(K_{2\pi}) = 0.2496 \pm 0.0009_{stat} \pm 0.0004_{syst}$$

$$\Gamma(K_{\mu 3})/\Gamma(K_{2\pi}) = 0.1637 \pm 0.0006_{stat} \pm 0.0003_{syst}$$

$$\Gamma(K_{\mu 3})/\Gamma(K_{e3}) = 0.656 \pm 0.003_{stat} \pm 0.001_{syst}$$

Taking the PDG value for the $K_{2\pi}$ branching fraction, 0.2092 ± 0.0012, the branching fractions for the semileptonic decays are found to be:

$$BR(K_{e3}) = (5.221 \pm 0.019_{stat} \pm 0.008_{syst} \pm 0.030_{norm})\%$$

$$BR(K_{\mu 3}) = (3.425 \pm 0.013_{stat} \pm 0.006_{syst} \pm 0.020_{norm})\%$$

The uncertainty is dominated by the existing data for the $BR(K_{2\pi})$. The branching fractions are higher than PDG values for both K_{e3} and $K_{\mu 3}$, confirming the K_{e3} results reported by the BNL-E865 collaboration.

By using the measured values for the vector and the scalar form factors [13], and assuming $e - \mu$ universality, a value 0.6682 ± 0.0017 for the ratio $\Gamma(K_{\mu 3})/\Gamma(K_{e3})$ can be estimated. The NA48/2 result suggests a lower value for λ_0 than the current world average for $K^{\pm}$, as found in recent measurements from K_L decays.

The product $|V_{us}|f_{+}(0)$ can be calculated by using both K_{e3} and $K_{\mu 3}$ measured branching ratios:

$$\mathrm{From\ K_{e3}:}\quad |\mathrm{V_{us}}|\mathrm{f_{+}}(0) = 0.2204 \pm 0.0012$$

$$\mathrm{From\ K_{\mu 3}:}\quad |\mathrm{V_{us}}|\mathrm{f_{+}}(0) = 0.2177 \pm 0.0013$$

The errors are dominated by the uncertainties of the external quantities needed for the calculation. Combining the results, assuming lepton universality and taking the value of $f_{+}(0)$ for neutral kaons, the obtained $|V_{us}|$ element is

$$|V_{us}| = 0.2289 \pm 0.0023,$$

which is consistent with CKM matrix unitarity predictions. For detailed description of the analysis see [24].

9 $\Gamma(K^{\pm}_{e2})/\Gamma(K^{\pm}_{\mu 2})$ measurement

The ratio $R_K = \Gamma(K^{\pm}_{e2})/\Gamma(K^{\pm}_{\mu 2})$ is a test for lepton universality and $V - A$ coupling. The SM prediction is $R_K = (2.472 \pm 0.001) \cdot 10^{-5}$, while the current PDG average is $R_K = (2.45 \pm 0.11) \cdot 10^{-5}$. Recently a new important physical motivation for a precise measurement of this ratio was added [25]: SUSY lepton flavour violating contributions could shift R_K by a relative amount of 2-3%.

The NA48/2 analysis exploits the similarity between both decays to cancel most of the possible systematic effects. In 2003 run 5239 K_{e2} were selected with $\sim 14\%$ background mainly from $K_{\mu 2}$. The obtained preliminary result is

$$R_K = (2.416 \pm 0.043_{stat} \pm 0.024_{syst}) \cdot 10^{-5}.$$

The estimations yield that the combined 2003 and 2004 result will not be sufficient to obtain a total error smaller than 1%. A dedicated 2007 run is in preparation. The conservative estimation for the error, which will be reached in R_K measurement is 0.7%. The experiment P326 could reach a per mill uncertainty, adding a new item to its physics program.

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