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NA48/2 Final results on charged semileptonic kaon decays and $|V_{us}|$; NA48 Measurements of $K\mu3$ form factors from K_L decays

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Measured ratios of decay rates for $\mathscr{R}_{Ke3/K2\pi}$, $\mathscr{R}_{K\mu3/K2\pi}$ and $\mathscr{R}_{K\mu3/Ke3}$ are presented, based on $K^{\pm}$ decays collected in a dedicated run in 2003 by the NA48/2 experiment at CERN. The results obtained are $\mathscr{R}_{Ke3/K2\pi} = 0.2470 \pm 0.0009(stat) \pm 0.0004(syst)$ and $\mathscr{R}_{K\mu3/K2\pi} = 0.1637 \pm 0.0006(stat) \pm 0.0003(syst)$. Using the PDG average for the $K^{\pm} \to \pi^{\pm}\pi^{0}$ normalisation mode, both values are found to be larger than the current values given by the Particle Data Book [1] and lead to a larger magnitude of the $|V_{us}|$ element in the Cabibbo-Kobayashi-Maskawa (CKM) matrix than previously accepted. When combined with the latest Particle Data Book value of $|V_{ud}|$ [1], the result is in agreement with unitarity of the CKM matrix. In addition, a new measured value of $\mathscr{R}_{K\mu3/K2\pi} = 0.663 \pm 0.003(stat) \pm 0.001(syst)$ is compared to the semi-empirical predictions based on the latest form factor measurements.

The $K\mu3$ form factors have been measured from a sample of K_L decays in a dedicated run in 1999 by the NA48 experiment at CERN. Studying the Dalitz plot density, using the linear form factor approximation, a measurement was made of $\lambda_{+} = (26.7 \pm 0.6_{stat} \pm 0.8_{sys}) \times 10^{-3}$ and $\lambda_0 = (11.7 \pm 0.7_{stat} \pm 1.0_{sys}) \times 10^{-3}$. Measurements were also made using the quadratic parameterisation, the pole parameterisation and the dispersive parameterisation. The results of all parameterisations will be presented.

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1. Introduction

The NA48 experiments, at the CERN SPS, continue to provide new results in the field of strange quark physics based on large samples of charged and neutral kaon decays and also hyperon decays collected during the period from 1999 to 2004.

The charged semileptonic kaon decay measurements presented here, $K^{\pm} \rightarrow \pi^0 e^{\pm} \nu$ (K_{e3}) and $K^{\pm} \rightarrow \pi^0 \mu^{\pm} \nu$ ($K_{\mu 3}$), are based on $K^{\pm}$ decays collected in a special run in 2003 by the NA48/2 Collaboration. The measured ratios [2] are:

$$\mathscr{R}_{Ke3/K2\pi} \equiv \frac{\Gamma(K^{\pm} \rightarrow \pi^0 e^{\pm} \nu)}{\Gamma(K^{\pm} \rightarrow \pi^{\pm} \pi^0)}, \qquad \mathscr{R}_{K\mu 3/K2\pi} \equiv \frac{\Gamma(K^{\pm} \rightarrow \pi^0 \mu^{\pm} \nu)}{\Gamma(K^{\pm} \rightarrow \pi^{\pm} \pi^0)} \tag{1.1}$$

and

$$\mathscr{R}_{K\mu 3/Ke3} \equiv \frac{\Gamma(K^{\pm} \rightarrow \pi^0 \mu^{\pm} \nu)}{\Gamma(K^{\pm} \rightarrow \pi^0 e^{\pm} \nu)}. \tag{1.2}$$

In both the numerator and denominator, the decays contain a charged track and at least two photons originating from a π^0 decay, thus leading to a partial cancellation in the acceptance and reconstruction uncertainties. Contributions from internal bremsstrahlung are included for all three decay modes. The general reconstruction methods are the same for all three measurements but the event selection varies because different particle identification criteria are applied.

The main interest in measuring these quantities is to extract: (1) the individual semileptonic decay widths needed to determine the V_{us} element in the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix; and (2) the ratio $\Gamma(K_{\mu 3})/\Gamma(K_{e3})$ which is a function of the slope parameters of the form factors. On the assumption of $\mu - e$ universality this ratio provides a consistency check between measurements of the form factors and of the partial decay widths.

In addition to the charged semileptonic kaon decay measurements, the neutral semimuonic kaon decay form factor measurements [3] are presented based on K_L decays collected in 1999 by the NA48 collaboration. The evaluation of the form factor slopes is necessary in order to evaluate the phase space integrals in the K_{l3} decay rate, and hence extract the V_{us} element in the CKM quark mixing matrix.

This paper is organized as follows. Section 2 outlines the phenomenological description of semileptonic decays. The charged kaon measurements are presented in Section 3 and the measurements of the neutral kaon form factors are presented in Section 4.

2. Decay rates for semileptonic decays

The decay rate for charged semileptonic decays can be written as follows [4]:

$$\Gamma(K_{\ell 3}) = \frac{G_F^2}{384\pi^3} m_K^5 S_{EW} |V_{us}|^2 |f_+(0)|^2 I_K^{\ell}[f_+(t), f_0(t)](1+\delta_K^{\ell}) \ , \tag{2.1}$$

where ℓ refers to either e or μ, G_F is the Fermi constant, m_K is the kaon mass, S_{EW} is the short-distance radiative correction, $(1+\delta_K) \simeq (1+\delta^{\ell}_{SU(2)}+\delta^{\ell}_{EM})^2$ is the model-dependent long-distance correction with contributions due to isospin breaking in strong ($SU(2)$) and electromagnetic (EM) interactions, $f_+(0)$ is the form factor at zero momentum transfer ($t=0$) for the $\ell\nu$ system. The remaining term, I_K^ℓ, is the result of the phase space integration after factoring out $f_+(0)$ [4]. The two form factors correspond to the angular momentum configuration of the $K-\pi$ system, with $f_+(t)$ representing the vector form factor, while $f_0(t)$ is the scalar form factor. The t dependence of the form factors can be described using a quadratic (linear) approximation for the vector (scalar) term:

$$f_+(t) = f_+(0)\left(1+\lambda'_+\frac{t}{m^2_{\pi^\pm}}+\frac{1}{2}\lambda''_+\frac{t^2}{m^4_{\pi^\pm}}\right) \text{ and } f_0(t) = f_+(0)\left(1+\lambda_0\frac{t}{m^2_{\pi^\pm}}\right), \tag{2.2}$$

where $f_+(0)$ is obtained from theory, and λ'_+, λ''_+ and λ_0 are measured [1]. The second term in I_K^ℓ shows that $K_{\mu3}$ decays are more sensitive to the scalar form factor than K_{e3}, because its contribution to the decay probability is supressed by the factor $(\frac{m_e}{m_K})^2$ of about 10^{-6}.

Assuming $\mu-e$ universality, the $\Gamma(K_{\mu3})/\Gamma(K_{e3})$ ratio is predicted to be [5]:

$$\mathscr{R}_{K\mu3/Ke3} \equiv \Gamma(K_{\mu3})/\Gamma(K_{e3}) = \frac{0.645+2.087\lambda_+ +1.464\lambda_0+3.375\lambda_+^2+2.573\lambda_0^2}{1+3.457\lambda_+ +4.783\lambda_+^2}. \tag{2.3}$$

This semi-empirical formula assumes a linear approximation for the form factors, $f_{+,0}(t) = f_+(0)(1+\lambda_{+,0}\frac{t}{m^2_{\pi^\pm}})$.

If the assumption of $\mu-e$ universality is removed, Eq. (2.1) implies that:

$$\mathscr{R}_{K\mu3/Ke3} = [g_\mu f_+^\mu(0)/g_e f_+^e(0)]^2 \times (I_K^\mu(1+\delta_K^\mu))/(I_K^e(1+\delta_K^e)). \tag{2.4}$$

where g is the weak coupling constant for the lepton current. The $(1+\delta_K^e)/(1+\delta_K^\mu)$ ratio for charged kaons is very close to unity because the δ_K^ℓ's are dominated by the few percent $SU(2)$ correction that is in common between the electron and the muon channel. The EM corrections are at the per mille level and compatible with zero within errors [6, 7, 8]. This is not necessarily true for neutral kaons because there is no $SU(2)$ correction and also the electromagnetic correction for the muons is larger.

3. Charged kaon semileptonic decay branching ratio measurements

3.1 NA48/2 Experimental Setup

The experiment uses simultaneous K^+ and K^- beams produced by 400 GeV protons impinging on a Be target. The beam has particles of opposite charge with a central momentum of 60 GeV/c and a momentum band of $\pm3.8\%$ produced at zero angle. Both beams are selected by a system of dipole magnets forming an achromat, along with focusing quadrupoles, muon sweepers and collimators. The spill length is about 4.5 s out of a 16.8 s cycle time, and the proton intensity is fairly constant during the spill with a mean of 5×10^{10} protons per spill. The positive (negative) kaon flux at the entrance of the decay volume is $3.2\times10^6(1.8\times10^6)$ particles per spill.

For the measurements presented here, the proton beam intensity is reduced from its nominal value so that the data-acquisition system can handle the rate of the minimum bias trigger. The $K^+/K^- \simeq 1.78$ flux ratio is given by their production rate at the Be-target.

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Decay type	Raw number of events (N_i)	Acceptance × particle ID ($Acc_i \times \varepsilon_{track_{ID}}$)	Backgrounds/Signal (Δ_i)	Trigger Efficiency ($Trig_i$)
K_{e3}^{+}	56,196	0.0698 ± 0.0001	$(0.0200 \pm 0.0008)\%$	0.9990 ± 0.0005
K_{e3}^{-}	30,898	0.0694 ± 0.0001	$(0.0209 \pm 0.0010)\%$	0.9982 ± 0.0008
$K_{\mu3}^{+}$	49,364	0.0927 ± 0.0001	$(0.2215 \pm 0.0079)\%$	0.9986 ± 0.0006
$K_{\mu3}^{-}$	27,525	0.0925 ± 0.0001	$(0.2175 \pm 0.0077)\%$	0.9988 ± 0.0007
$K_{2\pi}^{+}$	461,837	0.1418 ± 0.0001	$(0.2893 \pm 0.0058)\%$	0.9987 ± 0.0002
$K_{2\pi}^{-}$	256,619	0.1412 ± 0.0001	$(0.2896 \pm 0.0058)\%$	0.9990 ± 0.0002

Table 1: Summary of information used to extract the branching ratio, where $track = e^{\pm}, \mu^{\pm}, \pi^{\pm}$ for $i = K_{e3}^{\pm}, K_{\mu3}^{\pm}, K_{2\pi}^{\pm}$.

A detailed description of the NA48 detector can be found elsewhere [9]. The most relevant components are a high resolution liquid–krypton electromagnetic calorimeter (LKr) and a magnetic spectrometer consisting of 4 drift chambers and a dipole magnet located inside a helium tank. Other components are a hodoscope for precise track time determination, a hadronic calorimeter and a muon counter (MUC). The minimum bias trigger is defined by at least one hit in each of the horizontal and vertical planes of the hodoscope, within the same quadrant. The efficiency of the trigger, for events containing one track, is calculated from events requiring at least three hit wires, in at least three views of the upstream chamber, recorded within 200ns. The trigger efficiency is found to be greater than 99.8% and independent of the decay mode and the type of kaon beamline.

3.2 Analysis Strategy

The basic selection of all the three modes, namely $\mathrm{K}_{e3}^{\pm}, \mathrm{K}_{2\pi}^{\pm}$ and $\mathrm{K}_{\mu3}^{\pm}$, was common and was based on the presence of only one track in the spectrometer and at least two clusters (photons) in the LKr that were consistent with a π^0 decay. Further kinematical and particle id requirements were applied to separate the three decays. The kinematical selection criteria exploited both missing energy and decay topology, and the particle id requirements differentiated the type of charge track. The invariant mass for $\mathrm{K}_{2\pi}^{\pm}$ candidates was required to be within three sigma of the reconstructed kaon mass, that is: 472.2 MeV/c$^2 < m_{\pi^{\pm}\pi^0} <$ 510.2 MeV/c^2 while for $K_{\ell3}^{\pm}$ candidates it had to be outside this range. In order to separate two from three body decays, cuts were applied to the squared missing mass (m_{ν}^2), assuming the decaying kaon to have an energy of 60 GeV and a direction along the beam line axis. To distinguish electrons from pions a cut was imposed on the ratio E/p, between the energy deposited by the track in the LKr and its momentum measured by the spectrometer. $\mathrm{K}_{e3}^{\pm}$ ($\mathrm{K}_{2\pi}^{\pm}$) events were identified requiring this ratio to be greater (smaller) than 0.95. The identification of $\mathrm{K}_{\mu3}^{\pm}$ events instead was based on the association, in space and time, of the extrapolation of the track and a hit in the MUC. The selected samples were practically background free, see Table 1, and amounted to about 87000 $\mathrm{K}_{e3}^{\pm}$, 77000 $\mathrm{K}_{\mu3}^{\pm}$ and 718000 $\mathrm{K}_{2\pi}^{\pm}$ events.

3.3 Result

Table 1 lists all quantities needed to evaluate $\mathscr{R}_{K_i/K_j}$:

$$\mathscr{R}_{K_i/K_j} = \frac{Acc_{K_j} \times \varepsilon_{track_{ID_j}} \times Trig_{K_j} \times N_{K_i} \times (1+\Delta_{K_j})}{Acc_{K_i} \times \varepsilon_{track_{ID_i}} \times Trig_{K_i} \times N_{K_j} \times (1+\Delta_{K_i})}, \quad (3.1)$$

where $i, j = \ell 3, 2\pi$. The correction to K_{e3} due to particle identification efficiency ($\varepsilon_{track_{ID}}$) amounts to a few percent, while the background correction $(1+\Delta_{K_i})$ is negligible. $K_{\mu 3}$ and $K_{2\pi}$ require a particle identification correction that is below the percent level, and a correction for background correction that is only a few per mille.

The results for K^+ and K^- combined are:

$$\mathscr{R}_{Ke3/K2\pi} = 0.2470 \pm 0.0009(stat) \pm 0.0004(syst), \quad (3.2)$$

$$\mathscr{R}_{K\mu3/K2\pi} = 0.1637 \pm 0.0006(stat) \pm 0.0003(syst), \quad (3.3)$$

$$\mathscr{R}_{K\mu3/Ke3} = 0.663 \pm 0.003(stat) \pm 0.001(syst). \quad (3.4)$$

The sources of systematic uncertainties are due to the measured acceptance from monte carlo simulation, the knowledge of the particle identification efficiency, and the dependence on the result due to changes in the form factor model and parameters used.

The ratios are found to be insensitive to the photon reconstruction and track-finding. Analysis of these ratios as a function of their basic distributions show stability.

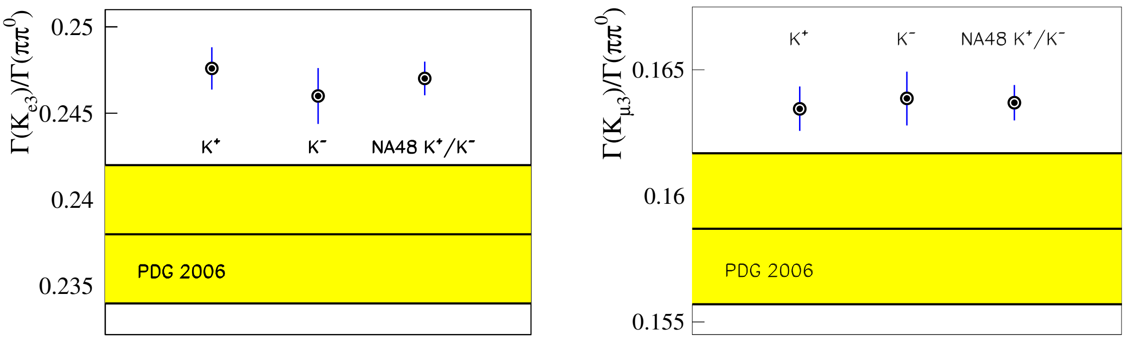

Figure 1: $\mathscr{R}_{Ke3/K2\pi}$ and $\mathscr{R}_{K\mu3/K2\pi}$ results compared to the corresponding PDG value [1].

The final results are shown in Fig. 1 for $\mathscr{R}_{Ke3/K2\pi}$ and $\mathscr{R}_{K\mu3/K2\pi}$, and in Fig. 2 (a) for $\mathscr{R}_{K\mu3/Ke3}$. These can be compared to the current PDG values of $\mathscr{R}_{Ke3/K2\pi} = 0.238 \pm 0.004$ [1], $\mathscr{R}_{K\mu3/K2\pi} = 0.159 \pm 0.003$ [11] and $\mathscr{R}_{K\mu3/Ke3} = 0.668 \pm 0.008$ [1]. Taking the current PDG value for the $K_{2\pi}$ branching fraction, 0.2092 ± 0.0012 [1], the branching fractions for the semileptonic decays are found to be:

$$Br(K_{e3}) = 0.05168 \pm 0.00019(stat) \pm 0.00008(syst) \pm 0.00030(norm), \quad (3.5)$$

$$Br(K_{\mu3}) = 0.03425 \pm 0.00013(stat) \pm 0.00006(syst) \pm 0.00020(norm). \quad (3.6)$$

The uncertainty is dominated by the existing data for the $K_{2\pi}$ branching fraction. Recall the corresponding PDG values [1] are $Br(K_{e3}) = 0.0498 \pm 0.0007$ and $Br(K_{\mu3}) = 0.0332 \pm 0.0006$. Higher

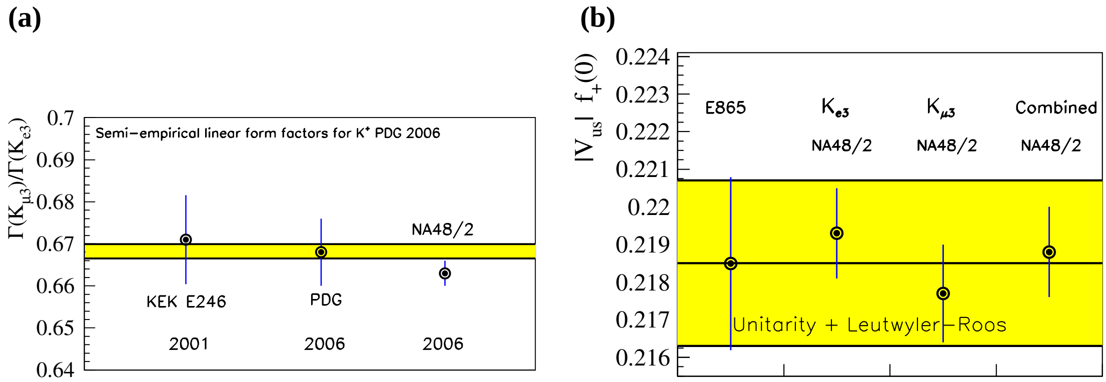

Figure 2: (a) $\mathscr{R}_{K\mu3/Ke3}$ results compared to KEK-246 results [16], the corresponding PDG value of 2006 [1] and to the predictions assuming $\mu - e$ universality, Eq. (2.3), with the λ_+ and λ_0 values given for $K^\pm$ in the PDG of 2006 [1]. **(b)** Comparison of the NA48 measurement of $|V_{us}|f_+(0)$ from K_{e3} and $K_{\mu3}$ data, and the K_{e3} BNL-E865 result [12]. The theoretical prediction shown is obtained assuming unitarity of the CKM matrix V_{ud}, using the PDG values for V_{ud} and V_{ub} as input, and using the choice of $f_+(0)$ as described in the text.

Decay Channel	Branching Fraction Br	Phase Space Integral I_K^ℓ	Radiative Correction[6, 7, 8] $\delta^\ell_{SU(2)}(\%)$	Radiative Correction[6, 7, 8] $\delta^\ell_{EM}(\%)$	$\lvert V_{us}\rvert f_+(0)$
K_{e3}	0.0517 ± 0.0004	0.1591 ± 0.0012	2.31 ± 0.22	0.03 ± 0.10	0.2193 ± 0.0012
$K_{\mu3}$	0.0343 ± 0.0002	0.1066 ± 0.0008	2.31 ± 0.22	0.20 ± 0.20	0.2177 ± 0.0013

Table 2: Inputs to Eq. (2.1) and results for $|V_{us}|f_+(0)$. By assuming unitarity, the prediction of $|V_{us}|f_+(0)$ for charged kaons is 0.2185 ± 0.0022.

branching fractions are found for both K_{e3} and $K_{\mu3}$, confirming the K_{e3} results reported by the BNL-E865 collaboration [12].

Using the newly measured branching fractions given in Eqs. (3.5)-(3.6), the $K^\pm$ lifetime $\tau^{PDG}_{K^+} = (1.2385 \pm 0.0024) \times 10^{-8}\,s$ [1], $G_F = (1.16637 \pm 0.00001) \times 10^{-5}$ GeV^{-2} [13], $m_K = 0.493677 \pm 0.000016$ GeV/c^2 [1], $S_{EW} = 1.0230 \pm 0.0003$ [14], and the full phase space integrals and long-distance corrections as given in Table 2, the $|V_{us}|$ matrix element times the vector form factor $f_+(0)$ is found to be (see Eq. (2.1)):

$$
\begin{aligned}
|V_{us}|f_+(0) &= 0.2193 \pm 0.0012\,, \qquad [K_{e3}] && (3.7)\\
&= 0.21928 \pm 0.00039(stat) \pm 0.00016(syst) \pm 0.00062(norm) \pm 0.00095(ext),\\
&= 0.2177 \pm 0.0013\,, \qquad [K_{\mu3}] && (3.8)\\
&= 0.21774 \pm 0.00041(stat) \pm 0.00019(syst) \pm 0.00064(norm) \pm 0.00103(ext),
\end{aligned}
$$

from K_{e3} and $K_{\mu3}$, respectively. 53% (60%) of the external (ext) error is due to the sum of the long-distance corrections, $SU(2)$ and EM corrections, taken from [6, 7, 8] for K_{e3} and $K_{\mu3}$, respectively. The phase space integral is evaluated using the quadratic approximation, Eq. (2.2), and gives the next largest contribution to the external error. The last significant uncertainty comes from the error in the $K^{\pm}$ lifetime. Combining these $|V_{us}|f_+(0)$ values by assuming $\mu - e$ universality, we obtain:

$$\begin{aligned} |V_{us}|f_+(0) &= 0.2188 \pm 0.0012\,, \\ |V_{us}| &= 0.2277 \pm 0.0013\,(other) \pm 0.0019\,(theo)\,, \end{aligned} \tag{3.9}$$

where "$theo$" refers to the theoretical uncertainty due to $f_+(0)$, and "$other$" refers to all the uncertainties already included in Eqs. (3.7)-(3.8) and their correlation. To extract $|V_{us}|$, it is assumed that the value of $f_+(0)$ is 0.961 ± 0.008 [4] as calculated for neutral kaons. There is no need to make a distinction between charged and neutral kaons in $f_+(0)$ because the $SU(2)$ correction is applied directly, see Eq. (2.1) and Table 2.

The consistency between the width ratio for the semileptonic decays already presented in Eq. (3.4) and the world average for the linear form factors parameters, λ_+ and λ_0 [1], can be tested. The band in Fig. 2 (a) corresponds to the predictions for $\mathscr{R}_{K\mu3/Ke3}$ assuming $\mu - e$ universality, Eq. (2.3), with the λ_+ and λ_0 values given for $K^{\pm}$ in the PDG of 2006 [1].

$\mu - e$ universality can be tested using the $\mathscr{R}_{K\mu3/Ke3}$ ratio and Eq. (2.4). The result shown in Eq. (3.4) implies that $g_\mu f_+^\mu(0)/g_e f_+^e(0)$ is 0.99 ± 0.01, which is consistent with unity within the experimental error.

4. $K_L \to \pi^{\pm}\mu^{\mp}\nu$ ($K_{\mu3}$) form factor measurement

As shown in Eq. (2.1) the form factors of the $K_{\ell3}$ decays are an input (through the phase space integrals) in the evaluation of V_{us}. It is customary to expand the form factors up to a linear or a quadratic term in t, as shown in Eq. (2.2). According to the pole model instead, the t dependence can be related to the exchange of K^* resonances:

$$f_{+,0}(t) = f_+(0)\,\frac{m_{V,S}^2}{m_{V,S}^2 - t} \tag{4.1}$$

Recently new parameterizations, based on dispersion techniques, have been proposed [17]:

$$\begin{aligned} f_+(t) &= f_+(0)\exp\Big[\frac{t}{m_\pi^2}(\Lambda_+ + H(t))\Big], \\ f_0(t) &= f_+(0)\exp\Big[\frac{t}{(m_K^2 - m_\pi^2)}(\ln C - G(t))\Big]. \end{aligned} \tag{4.2}$$

The parameter $\ln C = \ln[f_0(m_K^2 - m_\pi^2)]$ is the logarithm of the value of the scalar form factor at the Callan–Treiman point. This value can be used to test the existence of right handed quark currents (RHCs) coupled to the standard W boson.

The measurement of the $K_{\mu3}$ form factors is based on data taken in a dedicated two–day run in 1999 by the NA48 experiment. Throughout this run only the K_L beam was present. The event was triggered by the presence of two particles in the charged hodoscope system and of a vertex of two tracks in the spectrometer. The details of the selection procedure for the $K_{\mu3}$ events is discussed in detail in [3], and the final data sample consisted of about 2.3×10^6 $K_{\mu3}$ events. The determination of the form factor parameters is done studying the Dalitz plot density. To extract the form factors the data Dalitz plot is fit after correction for acceptance, migration of events due to the wrong choice of the kaon energy, backgrounds and radiative effects. Various t dependences of the form factors were considered: linear, quadratic, pole and dispersive. The fit results are listed in Table 3.

Linear ($\times 10^{-3}$) λ_+	λ_0		χ^2/ndf
26.7±0.6±0.8	11.7±0.7±1.0		604.0/582
Quadratic ($\times 10^{-3}$) λ'_+	λ''_+	λ_0	χ^2/ndf
20.5±2.2±2.4	2.6±0.9±1.0	9.5±1.1±0.8	595.9/581
Pole (MeV/c^2) m_V	m_S		χ^2/ndf
905±9±17	1400±46±53		596.7/582
Dispersive ($\times 10^{-3}$) Λ_+	$\ln C$		χ^2/ndf
23.3±0.5±0.8	143.8±8.0±11.2		595.0/582

Table 3: Form factors fit results for linear, quadratic pole and dispersive parameterizations. The first error is the statistical one, the second the systematic one.

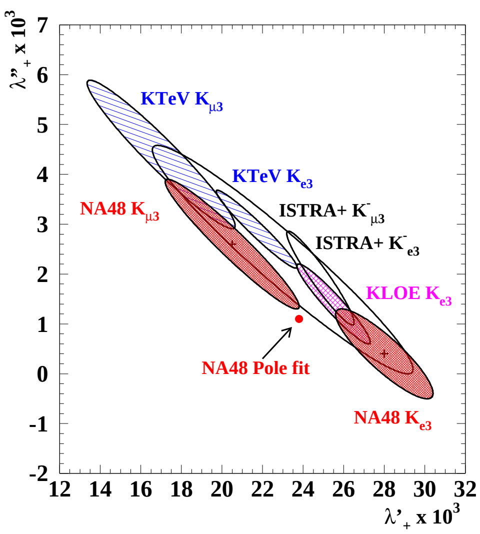

Figure 3: 1 σ contour plots in the plane λ'_+–λ''_+ showing the NA48 results together with those of [18, 20, 19, 21, 22] for the quadratic fits of the K$_{\mu3}$ and K$_{e3}$ decays.

The result indicates the presence of a quadratic term in the expansion of the vector form factor in agreement with other recent analyses of kaon semileptonic decay measurements, see Figure 3, and a value for λ_0 that is shifted towards lower values compared to other experiments [18, 20, 22].

According to the model proposed in [17] the value of $\ln C$ can be used to test the existence of RHCs by comparing it with the Standard Model predictions. We obtain for a combination of the RHCs couplings and the Callan–Treiman discrepancy ($\tilde{\Delta}_{CT}$) the value: $2(\varepsilon_S - \varepsilon_{NS}) + \tilde{\Delta}_{CT} = -0.071 \pm 0.014_{NA48} \pm 0.002_{theo} \pm 0.005_{ext}$, where the first error is the combination in quadrature of the to the uncertainties related to the approximations used to replace the dispersion integrals and the last one is due to the external experimental input.

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