RECENT RESULT OF THE NA48 EXPERIMENT

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Recent results from different phases of the NA48 experiment will be reported. From the 2003-04 data taking NA48/2 the measurements of the CP asymmetry in $K^{\pm} \rightarrow \pi^{\pm}\pi^{\mp}\pi^{\pm}$ and $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$, the first measurement of direct emission and interference term in $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\gamma$ and the first observation of $K^{\pm} \rightarrow \pi^{\pm}e^{+}e^{-}\gamma$ will be described. In addition the extraction of V_{US} from semileptonic decays, and a test of lepton universality using $K^{\pm} \rightarrow e^{\pm}\nu$ and $K^{\pm} \rightarrow \mu^{\pm}\nu$ will be addressed. Concerning NA48 and NA48/1 a measurement of the $K_L \rightarrow \pi^{\pm}\mu^{\mp}\nu$ form factor slope and the BR of $\Xi^0 \rightarrow \Lambda e^{+}e^{-}$ will be described.

1 Introduction

During 10 years of data taking NA48 has explored many topics in the charged and neutral Kaon physics, and continues to provide new results in both fields. In this paper will be discussed some of the most recent measurements produced by all three stages of the experimental program: NA48, NA48/1 and NA48/2. NA48 was devoted to the measurements of the CP violation in the neutral Kaon system through the parameter ε'/ε. The measurement has been performed during 3 years of data taking between 1997 and 2000 together with many studies of rare decays of both K_L and K_S. The next stage NA48/1 in 2002 has been aimed to measure very rare K_S decays $K_S \rightarrow \pi^0 e^+ e^-$ $K_S \rightarrow \pi^0 \mu^+ \mu^-$, and has produced also results in Hyperon physics. Finally the last stage NA48/2 has devoted his activity to the study of the CP violation in the charged Kaon sector. Together with the asymmetry measurements many other results in semileptonic and rare decays have been achieved.

2 Detector and beam line

The NA48 detector, used in all the described results, has been designed to measure with high precision momenta of both charged and neutral particles. The charged particle reconstruction is

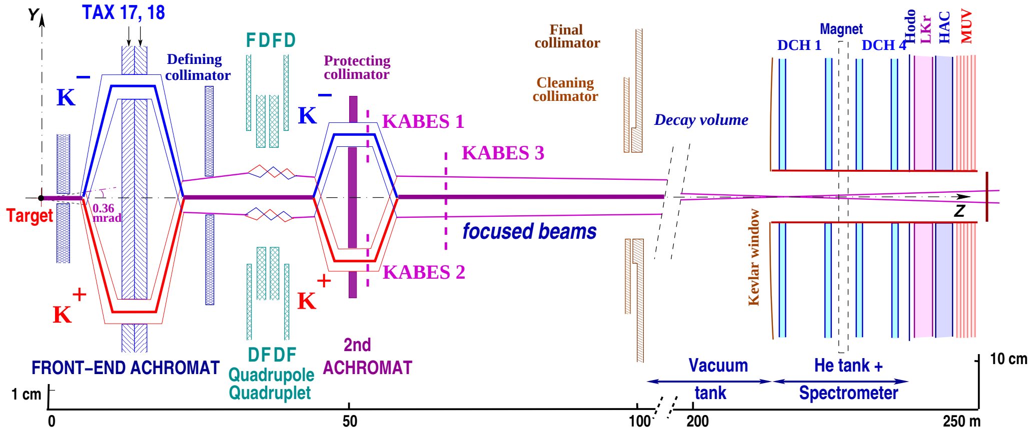

Figure 1: Schematic view on the NA48/2 beam line and detector.

provided by a magnetic spectrometer, with 4 drift chambers and a magnet, with a momentum resolution of $\sigma(P)/P = (1.02 \oplus 0.044p)\%$, where P is in GeV/c; a charged hodoscope, with good time resolution, sends fast trigger signals representing the number of charged particles. The reconstruction of photon energy, direction, time, and position is given by a the LKr calorimeter. The calorimeter has an active volume of 10 m^3 and an energy resolution of $\sigma(E)/E = 3.2\%/\sqrt{E} \oplus 9\%/E \oplus 0.42\%$. Moreover it provides the position of the impinging photons with a precision of $(0.42/\sqrt{(E)} \oplus 0.06)$ cm. To identify muons from pions an hadronic calorimeter muon counter have been also constructed. Details on the detectors can be found in[1].

The measurements presented in this paper have been obtained using different beam line configurations. The NA48 beam line was designed to produce and transport both K_L and K_S beams simultaneously[1]. The K_L beam was produced by SPS 450 GeV/c proton beam impinging 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. The measurement $K_L \to \pi^{\pm}\mu^{\mp}\nu$ form factors uses this beam configuration. 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. Using this beam line, together with the rare K_S, NA48/1 produced many Hyperons decays results from which the first measurement of $\Xi^0 \to \Lambda e^+ e^-$ will be discussed. Since 2003 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 results on charged 3π asymmetry, $K^{\pm} \to \pi^{\pm}\pi^0\gamma$, $K^{\pm} \to \pi^{\pm}e^+e^-\gamma$, semileptonic decays, and $K^{\pm} \to e^{\pm}\nu/K^{\pm} \to \mu^{\pm}\nu$ exploit this last beam configuration.

3 Charge asymmetry in $K^{\pm} \to \pi^{\pm}\pi^{\mp}\pi^{\pm}$ and $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$

The standard phenomenological description of $K_{3\pi}$ decays is made in terms of the bi-dimensional Dalitz plot variables u and v, related respectively to the energy sharing to the "odd" pion (charge opposite with respect to the other two) and among the two "even" pions:

$$u = \frac{s_3 - s_0}{m_\pi^2} \qquad v = \frac{s_2 - s_1}{m_\pi^2} \tag{1}$$

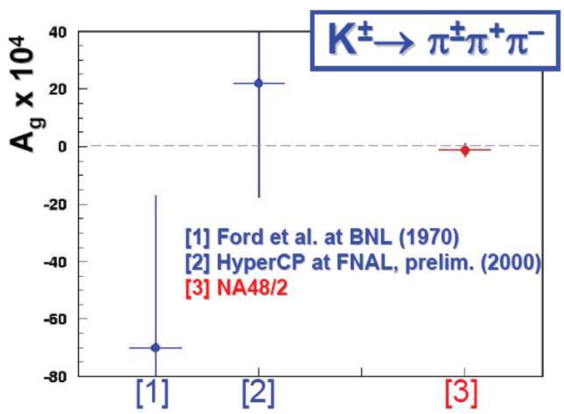

Figure 2: Experimental status of asymmetry in K charged in $3\pi^c$.

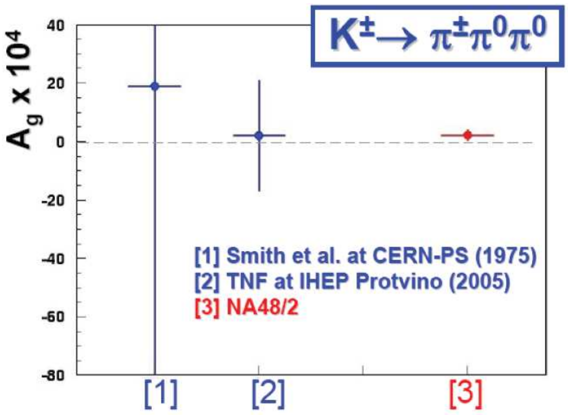

Figure 3: Experimental status of asymmetry in K charged in $3\pi^n$.

where $s_i = (P_K - P_{\pi i})^2$, i = 1,2,3, $s_0 = (s_1 + s_2 + s_3)/3$ being P_K and $P_{\pi i}$ the Kaon and Pion four-momenta, the indexes i=1,2 correspond to the two identical pions and the index i=3 to the pion of opposite charge. Using those two variables the matrix element can be parametrized as a polynomial expansion with slopes to be measured in experiments:

$$|M(u,v|^2 = 1 + gu + hu^2 + kv^2 \tag{2}$$

where $g(\pi^\pm\pi^+\pi^-) = 0.2154 \pm 0.0035$, $g(\pi^\pm\pi^0\pi^0) = 0.638 \pm 0.020$ and $|h|$, $|k| \ll |g|$. Any difference in the slopes parameters g^+ and g^- for positive and negative kaon, is a clear manifestation of direct CP violation. Usually the asymmetry parameter is defined by the corresponding slope asymmetry:

$$A_g = \frac{g^+ - g^-}{g^+ + g^-} \approx \frac{\Delta g}{2g} \tag{3}$$

SM predictions for that asymmetry vary between few 10^{-6} to few 10^{-5} while in models beyond the SM it can be enhanced up to the low 10^{-4} region. The parameter Δg can be extracted experimentally by comparing the reconstructed u spectra of K^+ and K^- decays ($N^+(u)$ and $N^-(u)$): in the $K^\pm \to \pi^\pm\pi^\mp\pi^\pm$ case the ratio $R(u) = N^+(u)/N^-(u)$ is in good approximation proportional to $(1 + \Delta g \cdot u)$, so Δg can be extracted from a linear fit. In the past years, several experiments have searched for the CP violating slope asymmetry in both $K^\pm \to \pi^\pm\pi^\mp\pi^\pm$ and $K^\pm \to \pi^\pm\pi^0\pi^0$ decay modes by collecting samples of K^+ and K^- decays. These measurements set upper limits on A_g at the level of a few 10^{-3}, limited by systematic uncertainties.

In NA48/2 using simultaneous and collinear K^+ and K^- beams and reversing all the magnets polarities during the data taking allows a charge symmetrization of the experimental conditions lowering the systematic uncertainties to few in 10^{-4}. Data collected over a period with all the four possible magnets setup configurations represent a "SuperSample", which is treated as an independent and self-consistent set of data for asymmetry measurement. To measure the charge asymmetry the following "quadruple ratio" composed as a product of four $R(u) = N^+(u)/N^-(u)$ ratios with opposite kaon sign, is used: $R4(u) = R_{US}(u) \cdot R_{UJ}(u) \cdot R_{DS}(u) \cdot R_{DJ}(u)$ where the indices U (D) denote the beam line polarities corresponding to K^+ passing along the Upper (Lower) path in the achromats, respectively, while the indices S (J) represent spectrometer magnet polarities corresponding to the "even" pions being deflected to negative (positive) x, i.e. towards the Salve (Jura) mountains, respectively.

3.1 $K^{\pm} \to \pi^{\pm}\pi^{\mp}\pi^{\pm}$ *asymmetry final result*

A very simple selection based on the measured momenta of the three charged track requires the compatibility of vertexes computed tracking back the direction of couples of tracks, reconstructed Kaon momentum compatible with the beam momentum, and the kaon reconstructed mass being in the range $M_K(PDG) \pm 9$ MeV. Using the full 2003-2004 data sample the selection leaves a practically background free sample of $3.82 \cdot 10^9$ as $K^{\pm} \to \pi^{\pm}\pi^{\mp}\pi^{\pm}$ is the dominant three-track decay mode.

Many sources of systematic effects were investigated such as the fine alignment of the spectrometer, the geometrical acceptance seen by the two beams, the dependence on the way the u variable is calculated or the fitting limits, effects due to uncertainty on the knowledge of the magnetic fields, pile-up effects, inhomogeneities in the spectrometer alignment and trigger efficiencies. After applying the above corrections, A_g is extracted by fitting the quadruple ratio of the u spectra for each SuperSample.

The difference in $K^{\pm} \to \pi^{\pm}\pi^{\mp}\pi^{\pm}$ Dalitz plot slope parameter is found to be:

$$\Delta g^c = (0.7 \pm 0.7_{stat} \pm 0.4_{trig} \pm 0.5_{syst}) \cdot 10^{-4} \tag{4}$$

. Converted to the direct CP violating charge asymmetry using the value of the Dalitz plot slope $g^c = -0.21134 \pm 0.00017$ recently measured by the NA48/2 [3]:

$$A_g^c = (-1.5 \pm 1.5_{stat} \pm 0.9_{trig} \pm 1.1_{syst}) \cdot 10^{-4} = (-1.5 \pm 2.1) \cdot 10^{-4} \tag{5}$$

which shows no CP violation in agreement with the SM prediction. The result has ~ 20 times better precision than the best measurement before NA48/2, see Fig. 2 and the precision is still limited mainly by the available statistics.

3.2 $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ *asymmetry final result*

The event selection requires 1 charged track and at least 4 in time photon clusters fulfilling geometrical and quality requirements. For each selected event, the decay is reconstructed as follows. Assuming that each pair i, k of LKr clusters (i, k =1,2,3,4) originates from a pi^0 decay, the distance D_{ik} between the pi^0 decay vertex position along the z axis and the front plane of the LKr is calculated. Among all photon pairs, the two with the smallest D_{ik} difference are selected as the best combination consistent with the hypothesis of two pi^0 mesons originating from $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ decay. Using the mean of the two vertex positions the kaon mass and momenta are reconstructed. Further event selection requires the $\pi^{\pm}\pi^0\pi^0$ invariant mass to differ from the nominal K^{pm} mass by less than $6MeV/c^2$, and the reconstructed kaon momentum to be between 54 and 66 GeV/c.

The above requirements applied to the full 2003 and 2004 data sample lead to the final sample of $9.13 \cdot 10^7$ events. The background is negligible for the applied mass cut. It can be seen that the kinematic variable u can be computed using only the $\pi^0\pi^0$ invariant mass. Thus a measurement of u uses the information from the LKr only, not involving the DCH data. This provides a certain charge symmetry of the procedure, as the LKr is a charge blind detector, except for effects of small differences between π^+ and π^- interaction characteristics.

The difference in the linear slope parameters of K^+ and K^- decays into $\pi^{\pm}\pi 0\pi 0$ was measured to be

$$\Delta g^n = (2.2 \pm 2.1_{stat} \pm 0.6_{syst}) \cdot 10^{-4} \tag{6}$$

. The corresponding direct CP violating asymmetry obtained using the nominal value of the linear slope parameter $g^n = 0.626 \pm 0.007$ [2] is

$$A_g^n = (1.8 \pm 1.7_{stat} \pm 0.5_{syst}) \cdot 10^{-4} = (1.8 \pm 1.8) \cdot 10^{-4} \tag{7}$$

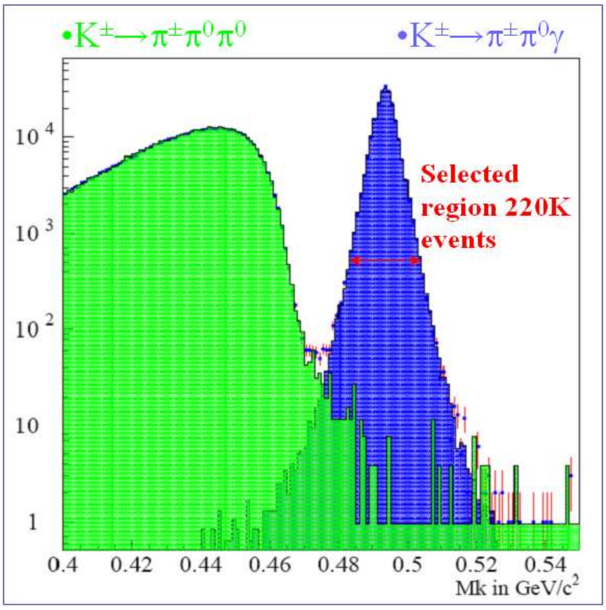

Figure 4: Data-mc comparison of M_K spectrum. Dots represent data points, green distribution the $K^{\pm} \to \pi^{\pm}\pi^0\pi^0$ MC background and the blue one the simulated signal.

As for $K^{\pm} \to \pi^{\pm}\pi^{\mp}\pi^{\pm}$ an order of magnitude improvements has been achieved with respect to previous measurements, see Fig. 3, and no CP violation has been observed according to current standard model predictions.

4 The radiative decay $K^{\pm} \to \pi^{\pm}\pi^0\gamma$

The decay channel $K^{\pm} \to \pi^{\pm}\pi^0\gamma$ is one of the most interesting and important channels for studying the low energy structure of the QCD, in fact it has been shown to be one of the most sensitive check for the Chiral Anomaly. The total amplitude of $K^{\pm} \to \pi^{\pm}\pi^0\gamma$ decay is the sum of two terms: the inner bremsstrahlung (IB) associated with the decay $K^{\pm} \to \pi^{\pm}\pi^0$ in which the photon is emitted from the outgoing charged pion, and the direct emission (DE) in which the photon is emitted from one of the intermediate states of the decay itself. Although, due to the dominant IB, the DE component is very difficult to observe it can be isolated kinematically. As the $K^{\pm} \to \pi^{\pm}\pi^0$ decay is suppressed by the $\Delta I = 1/2$ rule, also the IB will similarly suppressed. This feature could then enhance the DE. The DE term can occur through both electric (E) and magnetic (M) dipole transitions. While the magnetic part, can be evaluated using the Wess-Zumino-Witten functional, describing the reducible anomaly, there is no definite prediction from ChPT on the electric transition, whose amplitude depends on undetermined constants. The electric contribution is extremely interesting since it interferes (INT) with the IB amplitude therefore it may be distinguished from the magnetic, which does not.

In the $K^{\pm} \to \pi^{\pm}\pi^0\gamma$ decay IB, INT, and DE components can be separated kinematically using the Lorentz invariant variable W which is defined as follows:

$$W^2 = \frac{(P^*_K \cdot P^*_\gamma)(P^*_\pi \cdot P^*_\gamma)}{(m_K m_\pi)^2} \tag{8}$$

with P^*_x the 4-momentum of the x particle and γ the radiative one. The decay rate depends only on T^*_π, energy of the pion in the Kaon rest frame, and W. Integrating over T^*_π an expression that splits the different contributions into terms with different powers of W can be obtained:

$$\frac{d\Gamma^{\pm}}{dW} \simeq \left(\frac{d\Gamma^{\pm}}{dW}\right)_{IB}\left[1+2\left(\frac{m_\pi}{m_K}\right)^2 W^2|E|cos((\delta_1-\delta_0)\pm\phi)+\left(\frac{m_\pi}{m_K}\right)^4 W^4(|E|^2+|M|^2)\right] \quad (9)$$

where $|E|$ an $|M|$ represent electric and magnetic transitions, while ϕ is an unknown phase responsible for CP violation. The three terms represent IB, INT and DE contribution respectively. Recent paper by D'Ambrosio and Cappiello [10] suggest the presence of a form factor in the DE term, not yet included in the present analysis, that complicates a little bit the very simple parametrization in Eq. 9.

The IB component has been measured since the seventies by Abrams et al.[4] achieving a good agreement with solid QED theoretical predictions. The experimental measurement of the fractions of DE and INT is affected by very dangerous BG sources, such as $K^\pm \to \pi^\pm\pi^0$ and $K^\pm \to \pi^\pm\pi^0\pi^0$ decays, suppressed in a kinematically BG free region, T^*_π in the range 55-90 MeV. Moreover a good measurement requires a very good reconstruction of both charged and neutral particles 4-momenta. The present experimental knowledge about the decay is limited to the DE component while the INT has been never observed. The most recent results are summarized in Tab. 1. All of them have been obtained in the T^*_π region 55-90 MeV and setting INT=0 in the fitting procedure.

exp.	year	#events	$BR(DE)\cdot 10^{-6}$
E787 [5]	2000	20K	$4.7 \pm 0.8 \pm 0.3$
E470 [6]	2003	4.5K	$3.2 \pm 1.3 \pm 1.0$
E787 [7]	2005	20K	$3.5 \pm 0.6 \pm 0.35$
E470 [8]	2005	10K	$3.8 \pm 0.8 \pm 0.7$
ISTRA+ [9]	2006	930	$3.7 \pm 3.9 \pm 1.0$

Table 1: The $K^\pm \to \pi^\pm\pi^0\gamma$ experimental results

The errors on the measurements are quite high and the agreement in not so good. Moreover the assumption of vanishing interference term, known to exist by theory, is based on the following measurements by both E787 [5] and E470 [6]

$$INT = (-0.4 \pm 1.6)\% \qquad E787 \quad (10)$$
$$INT = (-0.58^{+0.91}_{-0.83})\% \qquad E470 \quad (11)$$

providing very weak constraints on the true value of the INT term.

The main BG sources are $K^\pm \to \pi^\pm\pi^0$ and $K^\pm \to \pi^\pm\pi^0\pi^0$. The first decay needs an accidental photon or an hadronic extra cluster to mimic the signal final state, while the second a lost or 2 fused gamma. The selection aims to suppress the contribution of them both to less than 1% of the DE component. The rejection of $K^\pm \to \pi^\pm\pi^0$ relays on the T^*_π cut. The request T^*_π lower than 80 MeV allows to reject $K^\pm \to \pi^\pm\pi^0$ and a part of the IB spectrum of $K^\pm \to \pi^\pm\pi^0\gamma$ only, including region 0-55 MeV very rich of DE and INT events. The upper cut at 80 MeV is due to trigger reasons. To suppress $K^\pm \to \pi^\pm\pi^0\pi^0$ BG the very good kaon mass resolution, (2.2 MeV), and the identification of fused gamma events constraints have been used. In Fig. 4 the data kaon mass spectrum is compared with the sum of $K^\pm \to \pi^\pm\pi^0\gamma$ and $K^\pm \to \pi^\pm\pi^0\pi^0$ MC. The figure shows that the background contribution is very low and that can be explained in term of $K^\pm \to \pi^\pm\pi^0\pi^0$ only.

A very important issue in the measurement of DE and INT is to identify the radiative γ among the 3 available. A dedicated set of cuts, based on the agreement of the vertex evaluated using the pion and kaon tracks, and the one evaluated pairing the γ's to form a π^0, has been

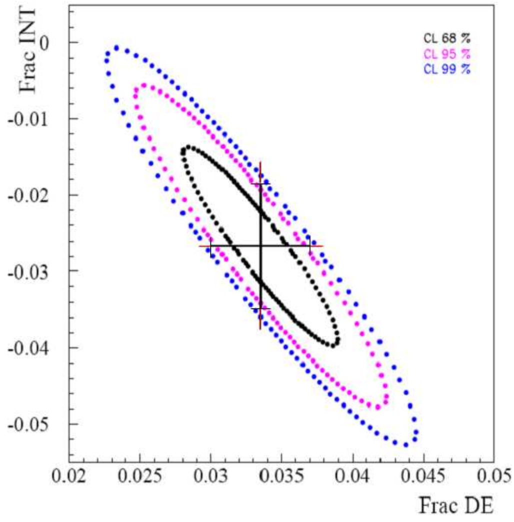

Figure 5: Contour plot for DE and INT components

implemented. Using this cuts a misidentification probabilities, computed using MC simulation, of the order of the permille for all the components has been achieved. A total of $\sim$ 220000 candidate events survived all selection cuts in the region of T^*_π 0-80 MeV using only the first 3 super sample of the 2003 data set.

The extraction of the fractions of DE and INT relies on the fact that different components show quite different W distributions. An extended maximum likelihood technique, assigning weights to MC W distributions of the 3 components to reproduce data spectrum, has been employed to get the fractions. Many checks to verify the result were made concerning the γ energies reconstructed in the calorimeter, trigger efficiencies and BG contribution. The systematic uncertainties are dominated by the trigger.

To extract the fractions the fit has been performed in the interval 0.2-0.9 in the W variable and with a minimum gamma energy of 5 GeV using only 124K events from the total sample. After correcting for different acceptances we get, in the region $0 < T^*_\pi < 80MeV$, the following preliminary values for the fractions of DE and INT with respect to IB:

$$Frac(DE) = (3.35 \pm 0.35_{stat} \pm 0.25_{syst})\% \quad (12)$$

$$Frac(INT) = (-2.67 \pm 0.81_{stat} \pm 0.73_{syst})\% \quad (13)$$

This is the first measurement of a non vanishing interference term in the $K^\pm \to \pi^\pm\pi^0\gamma$ decay. The contour plot in Fig. 5 shows the very high correlation of the two contributions $\rho = -0.92$. Major improvements in the size of the data sample are foreseen using the full 2003-2004 data set.

5 First observation of the decay $K^\pm \to \pi^\pm e^+e^-\gamma$

The decay $K^\pm \to \pi^\pm e^+e^-\gamma$ has a kinematic very similar to the corresponding $K \to \pi^\pm\gamma\gamma$. One of the photons internally converts into a pair of electrons. The branching ratio can be naively estimated using the following relation:

$$BR(K^\pm \to \pi^\pm e^+e^-\gamma) = K \to \pi^\pm\gamma\gamma \cdot 2\alpha = 1.6 \cdot 10^{-8} \quad (14)$$

Both decays are described by chiral perturbation theory. Their lowest order terms are $O(p^4)$, leading to a characteristic signature in the e^+e^- mass of the decay. Model dependent theoretical

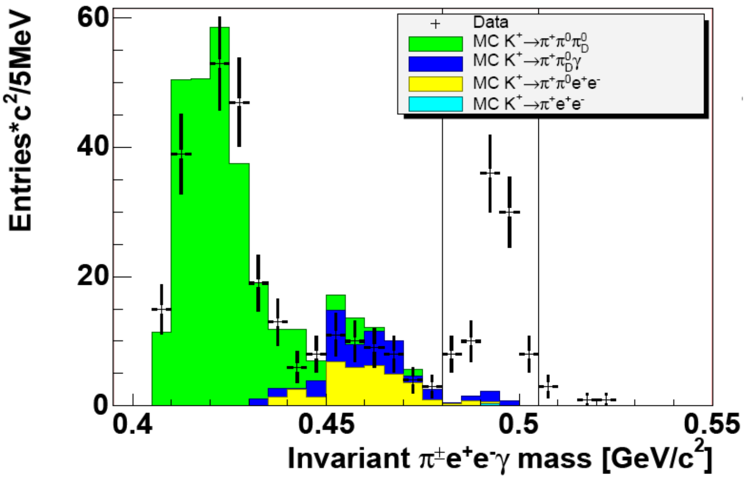

Figure 6: Mass distribution for $K^\pm \to \pi^\pm e^+e^-\gamma$ events. Black crosses represent data distribution.

estimates based on chiral perturbation theory predicts the BR to be in the range [11]:

$$BR(K^\pm \to \pi^\pm e^+e^-\gamma) = (0.9 - 1.6) \cdot 10^{-8} \tag{15}$$

In the paper the differential distribution on $m_{ee\gamma}$, very similar to the $K^\pm \to \pi^\pm\gamma\gamma$ one, is also given in term of the same $\hat{c}$ parameter.

NA48/2 experiment observed for the first time the radiative decay $K^\pm \to \pi^\pm e^+e^-\gamma$. 92 candidates were selected, with 1 ± 1 accidental background and 5.1 ± 1.7 misidentification background. The main source of BG is the $K \to \pi^\pm\pi^0_D\gamma$ with a lost γ. In Fig. 6 the reconstructed Kaon invariant mass is shown. The crosses represent data while the filled distributions represent different simulated background contribution.

By using $K^\pm \to \pi^\pm\pi^0$ as normalization channel the branching ratio was preliminary estimated to be

$$BR(K^\pm \to \pi^\pm e^+e^-\gamma) = (1.27 \pm 0.14_{stat} \pm 0.05_{syst}) \cdot 10^{-8} \tag{16}$$

Unfortunately due to lack of statistics the value of $\hat{c}$ is not accessible to this analysis.

6 Semileptonic Decays results

The branching ratios of semileptonic kaon decays are needed to determine $|V_{US}|$ element in the CKM matrix. In addition $\Gamma(Ke3)/\Gamma(K\mu3)$ is a function of the slope parameters of the form factors, which can be used for consistency check under the assumption of lepton universality.

A special run dedicated to collect semileptonic decays has been performed during 2003 data taking of NA48/2. Approximately 56000 K^+_{e3}, 31000 K^-_{e3}, 49000 $K^+_{\mu3}$, 28000 $K^-_{\mu3}$, 462000 K^+_{2pi} and 256000 $K^-_{2\pi}$ decays were selected for the measurement. The ratios of decay widths, combining K^+ and K^-, are:

$$\Gamma(K_{e3})/\Gamma(K_{2\pi}) = 0.2470 \pm 0.0009_{stat} \pm 0.0004_{syst} \tag{17}$$

$$\Gamma(K_{\mu3})/\Gamma(K_{2\pi}) = 0.1637 \pm 0.0006_{stat} \pm 0.0003_{syst} \tag{18}$$

$$\Gamma(K_{\mu3})/\Gamma(K_{e3}) = 0.663 \pm 0.003_{stat} \pm 0.001_{syst} \tag{19}$$

Using the PDG '06 [2] value for the $K_{2\pi}$ branching fraction, 0.2092 ± 0.0012, those for the semileptonic decays have been computed to be:

$$BR(Ke3) = (5.167 \pm 0.019_{stat} \pm 0.008_{syst} \pm 0.030_{norm})\% \tag{20}$$

$$BR(K\mu3) = (3.425 \pm 0.013_{stat} \pm 0.006_{syst} \pm 0.020_{norm})\% \tag{21}$$

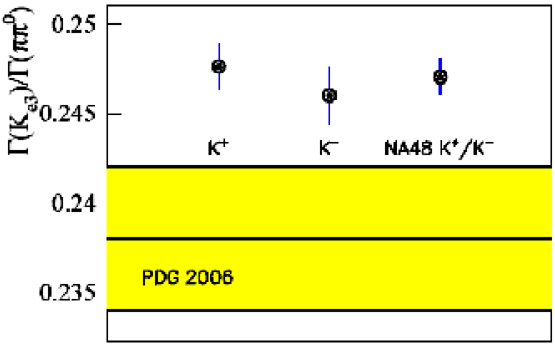

Figure 7: $K^{\pm} \to e^{\pm}\nu 3/K^{\pm} \to \pi^{\pm}\pi^0$ in NA48/2

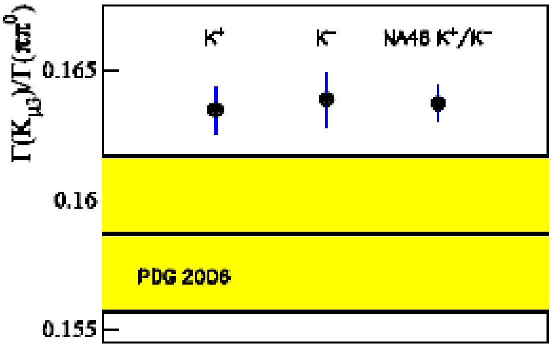

Figure 8: $K^{\pm} \to e^{\pm}\nu 3/K^{\pm} \to \pi^{\pm}\pi^0$ in NA48/2

The uncertainty is dominated by the existing data for the BR($K_{2\pi}$) used as normalization. By using the measured values for the vector and the scalar form factors, and assuming e-μ universality, the ratio $\Gamma(Ke3)/\Gamma(K\mu 3)$ can be expressed as:

$$\Gamma(Ke3)/\Gamma(K\mu 3) = \frac{0.645 + 2.087\lambda_+ + 1.464\lambda_0 + 3.375\lambda_+^2 + 2.573\lambda_0^2}{1 + 3.457\lambda^+ + 4.783\lambda_+^2} \quad (22)$$

This relationship can be used to crosscheck the form factors measurements. The value measured by NA48/2 for the ratio $0.663 \pm 0.003_{stat} \pm 0.001_{syst}$ is consistent with KEK E246 and PDG '06. Given the values of the semileptonic decays BRs the product $|V_{US}|f_+(0)$ can be extracted using the following formula:

$$\frac{BR(K_{l3})}{\tau_K} = \frac{C_K^2 G_F^2 m_K^5}{192\pi^3} S_{EW}|V_{US}|^2|f_+(0)|^2 I_K^l(\lambda_{+0})(1 + \delta^l_{SU(2)} + \delta^l_{EM}) \quad (23)$$

we get:

$$From \quad Ke3 \quad : \quad |V_{US}|f_+(0) = 0.2193 \pm 0.0012 \quad (24)$$
$$From \quad K_{\mu 3} \quad : \quad |V_{US}|f_+(0) = 0.2177 \pm 0.0013 \quad (25)$$

in which the errors are dominated by the uncertainties of the external inputs needed for the calculation in Eq. 23. Combining the results form both modes, assuming lepton universality and taking the value of $f_+(0)$ for neutral kaons, the obtained $|V_{US}|$ element is:

$$|V_{US}| = 0.2185 \pm 0.0023 \quad (26)$$

which is consistent with CKM matrix unitarity predictions. For detailed description of the analysis see [12].

7 The ratio $K^{\pm} \to e^{\pm}\nu/K^{\pm} \to \mu^{\pm}\nu$

The measurement of the ratio $R_K = K^{\pm} \to e^{\pm}\nu/K^{\pm} \to \mu^{\pm}\nu$ between the decay rates of $K^{\pm} \to e^{\pm}\nu$ and $K^{\pm} \to \mu^{\pm}\nu$ is a sensitive test of lepton universality and of V-A structure of the weak interactions. In fact, while in the BRs of $K \to l\nu$ the theoretical uncertainties are at the percent level, due to f_K, in the ratio of the electronic and muonic decay modes, the hadronic uncertainties cancel to a very large extent. As a result, the SM predictions for R_K is known with excellent accuracy and this makes it possible to fully exploit the great experimental resolutions in the ratio to constrain new physics effects. In the standard model R_K is given by:

$$R_K = \frac{\Gamma(K \to e\nu(\gamma))}{\Gamma(K \to \mu\nu(\gamma))} = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 (1 + \delta R_K) = (0.2472 \pm 0.001) \cdot 10^{-5} \quad (27)$$

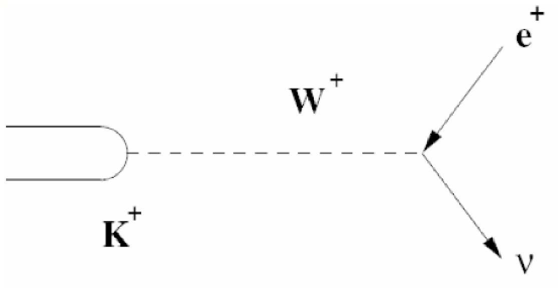

Figure 9: Main contribution to $K^{\pm} \to ll$ in the SM.

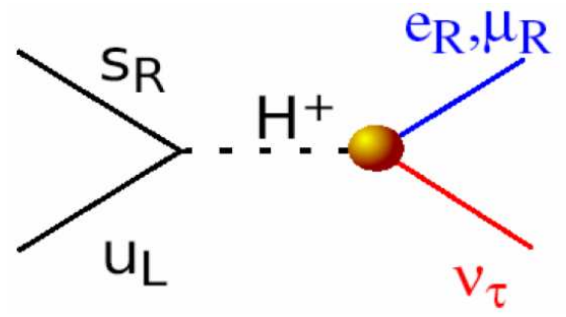

Figure 10: SUSY contribution to $K^{\pm} \to ll$.

where δR_K is due to the difference in the radiative corrections. The experimental value given by PDG [2] is $R_K = (0.245 \pm 0.11) \cdot 10^{-5}$ less precise by far.

Recent paper by Masiero, Paradisi, and Petronzio[13] studies possible contribution of Lepton Flavor Violation (LFV) mechanisms introduced by SUSY models to the value of R_K. The one involved in the calculation arise from a charged Higgs exchange through the diagram in Fig. 10.

The result of the calculation give the above enhancement for the R_K:

$$R_K^{LFV} \simeq R_K^{SM} \cdot \left[1 + \left(\frac{m_K^4}{M_H^4}\right)\left(\frac{m_\tau^2}{m_e^2}\right)|\Delta_R^{31}|^2 tan^6\beta\right] \tag{28}$$

In the large $tan\beta$ regime ($\simeq 40$) and with a relatively heavy $H^{\pm}$ ($M_H = 500$ GeV), it is possible to reach deviations from SM R_K at the percent level, thanks to LFV enhancements arising in the SUSY model.

Na48/2 has collected the world largest sample of $K^{\pm} \to e^{\pm}\nu$ and is therefore able to perform a very precise measurement of R_K. The measurement of the ratio allows the cancelation of acceptance and trigger effects common to both type of events. The selection is very similar except for the particle identification part, based on the reconstruction of the ratio E/P. In the 2003 run 5239 $K^{\pm} \to e^{\pm}\nu$ were selected, by a downscaled trigger, with $> 14\%$ background mainly from $K^{\pm} \to \mu^{\pm}\nu$. In fact in cases in which the μ produces a very high energy bremsstrahlung photon, the value of E/P is very near to one, and the event is misidentified as a electron type events. Even if the BG from this source is subtracted in the ratio calculation it is still the major source of systematic uncertainties. The preliminary result obtained with the 2003 data set only is:

$$R_K = (2.416 \pm 0.043_{stat} \pm 0.024_{syst}) \cdot 10^{-5} \tag{29}$$

The estimations yield that the combined 2003 and 2004 result will not be enough to obtain a total error smaller than 1%. A dedicated 2007 run will be performed during upcoming summer. The conservative estimation for the error, which will be reached in R_K measurement is 0.7%. In the future experiment P326 a per mill uncertainty could be reached, due to better particle identification provided by the RICH detector.

8 First observation of $\Xi^0 \to \Lambda e^+e^-$

In the 2002 NA48/1 run the weak radiative decay $\Xi^0 \to \Lambda e^+e^-$ was detected for the first time. 412 candidates were selected with 15 background events Fig. 11. The obtained branching fraction is:

$$BR(\Xi^0 \to \Lambda e^+e^-) = (7.7 \pm 0.5_{stat} \pm 0.4_{syst}) \cdot 10^{-6} \tag{30}$$

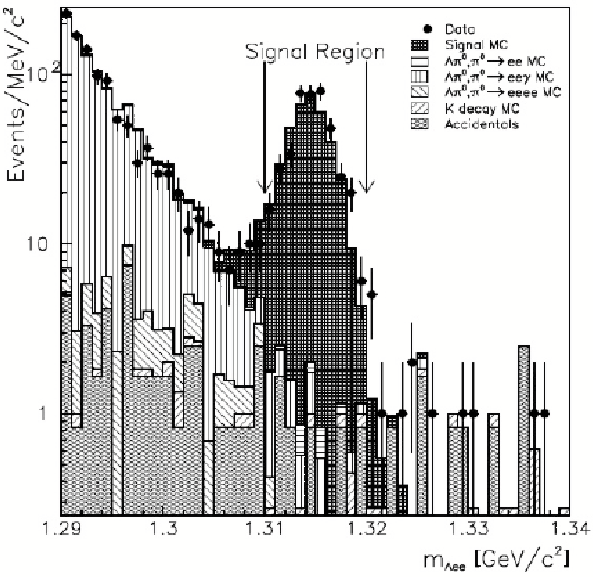

Figure 11: Signal and backgrounds in $\Xi^0 \to \Lambda e^+e^-0$ data sample.

is consistent with inner bremsstrahlung-like e^+e^- production mechanism. The decay parameter $\alpha_{\Xi\lambda ee}$ can be measured from the angular distribution:

$$\frac{dN}{d\cos\theta p\Xi} = \frac{N}{2}(1 - \alpha_{\Xi\lambda ee}\alpha_- \cos\theta p\Xi) \tag{31}$$

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 and where α_- is the asymmetry parameter for the decay $\Lambda \to p\pi^-$. 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 $\Xi \to \Lambda\gamma$. Detail on the analysis can be found in [14].

9 $K_L \to \pi^\pm\mu^\mp\nu$ form factors

Kl3 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 $K_L \to \pi^\pm\mu^\mp\nu$ decay. In addition, these form factors are needed to calculate the phase space integrals, which are used in $|V_{US}|$ determination. Approximately $2.6 \cdot 10^6$ $K_{L\mu3}$ decays were selected from a dedicated 1999 minimum bias run of NA48. By studying the Dalitz plot density, the following slopes for the vector and the scalar form factors were obtained:

$$\lambda'_+ = (20.5 \pm 2.2_{stat} \pm 2.4_{syst}) \cdot 10^{-3} \tag{32}$$

$$\lambda''_+ = (2.6 \pm 0.9_{stat} \pm 1.0_{syst}) \cdot 10^{-3} \tag{33}$$

$$\lambda_0 = (9.5 \pm 1.1_{stat} \pm 0.8_{syst}) \cdot 10^{-3} \tag{34}$$

The results show the presence of a 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. 12. The results obtained with linear fit are

$$\lambda_+ = (26.7 \pm 0.6_{stat} \pm 0.8_{syst}) \cdot 10^{-3} \tag{35}$$

$$\lambda_0 = (11.7 \pm 0.7_{stat} \pm 1.0_{syst}) \cdot 10^{-3} \tag{36}$$

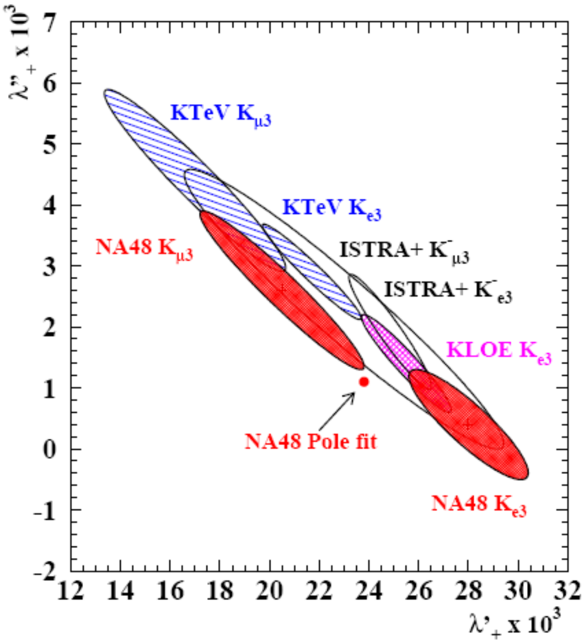

Figure 12:

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[15].

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