Probing the lepton universality with $K^{\pm}l2$ decays

V. Kozhuharov[a*]

[a]Atomic Physics Dep., Faculty of Physics, University of Sofia, 5 J. Bourchier Str, 1164 Sofia, Bulgaria; JINR Dubna, 141980, Dubna, Moscow Region, Russia

The ratio of the decay rates $R_K = \Gamma(K^{\pm} \to e^{\pm}\nu)/\Gamma(K^{\pm} \to \mu^{\pm}\nu)$ provides a powerful probe for the weak interaction structure. Recent calculations show its sensitivity to possible presence of New Physics. The value of R_K is calculated with very high precision within the Standard Model, however the achieved accuracy by the previous experiments is two orders of magnitude lower due to the lack of statistics. During two years of data taking at the CERN SPS accelerator, the NA48/2 experiment has collected more than four times the World statistics sample of $K^{\pm} \to e^{\pm}\nu$ decays allowing to perform a precision measurement of the ratio R_K and to test the theoretical predictions. The preliminary result $R_K = (2.416 \pm 0.043_{stat} \pm 0.024_{syst}) * 10^{-5}$ is presented.

1. Introduction

Decays of the light mesons into lepton and neutrino are described as tree level processes within the Standard Model (SM). In the ratio of the electron and muon mode of $M^{\pm} \to l^{\pm}\nu$ ($Ml2$) decay rates the theoretical uncertainties due to the hadronic matrix element cancel to a very high accuracy and the value of $R_M = \Gamma(Me2)/\Gamma(M\mu2)$ is given by [1]

$$R_M = \frac{m_e^2}{m_\mu^2}\left(\frac{m_M^2 - m_e^2}{m_M^2 - m_\mu^2}\right)(1 + \delta R_M) \qquad (1)$$

where the term δR_M arises from the radiative corrections ($M = \pi^{\pm}, K^{\pm}$) . In the kaon case $\delta R_K = -(3.78 \pm 0.04)\%$ leading to the theoretical prediction $R_K = (2.472 \pm 0.001) * 10^{-5}$.

Considering different extensions of the SM (like models with Lepton Flavour Violation, different SUSY scenarios) a constructive or destructive contribution to R_K as high as 3% could be achieved [2].

The value of R_K has been measured by three experiments in the 70s [3] but the precision of the combined result ($R_K = (2.45 \pm 0.11) * 10^{-5}$) doesn't allow to perform a significant test of the lepton universality within the SM.

2. NA48/2 experiment

The NA48/2 experiment was primarily designed to measure the charge asymmetry in the $K \to 3\pi$ decays in order to probe for CP violation in the charged kaon system [4]. Data were taken in 2003 and 2004, providing approximately $4 * 10^9$ $K^{\pm} \to \pi^{\pm}\pi^{+}\pi^{-}$ decays. The huge statistics allows to study rare kaon decays with high precision. For the measurement of R_K described bellow only the data taken during 2003 run was used.

Kaons at the NA48/2 experiment are produced by a 400GeV primary proton beam from the CERN SPS hitting a beryllium target. A system of collimators and achromats selects particles with mean momentum of 60GeV both with positive and negative polarity. The momentum of the particles is measured by a beam spectrometer. The simultaneous $K^{\pm}$ beams enter a 114m long evacuated decay region closed by a Kevlar window. The products of the decays are detected by the NA48 detector complex including:

- Magnetic spectrometer: Composed by four drift chambers and a dipole magnet deflecting the charged particles in horizontal direction. The resulting resolution on the momentum measurement is $\delta p/p = 1\% \oplus 0.044 * p$ [GeV/c].

- Charged hodoscope (HOD): Fast scintillator detector with time resolution of 150ps used

*On behalf of the NA48/2 collaboration

in the trigger system.

- Electromagnetic Calorimeter (LKR): A Liquid Krypton calorimeter of 27 radiation lengths used to measure the energy of the electrons and photons with resolution of $\delta E/E = 3.2\%/\sqrt{E} \oplus 9\%/E \oplus 0.42\%$ [GeV].

The Z axis of the experiment is defined as the mean beam axis.

3. Data analysis

3.1. Event selection

The online selection of the $Ke2$ events was based on a two level trigger system. The first level requirement was a signal from the HOD compatible with one charge track and energy deposition in the LKR higher than 10GeV. The second level incorporated online reconstruction of the kinematics and required that the event was not compatible with $K^{\pm} \to \pi^{\pm}\pi^{0}$ ($K2\pi$) decay. $K\mu2$ events were collected based only on the signal from the HOD. Both triggers were downscaled.

Offline the selection criteria were kept as similar as possible for both decay modes:

- Reconstructed track momentum $15GeV/c < P_{Trk} < 55GeV/c$

- Decay vertex was required to be $2000cm < Z_{vtx} < 8500cm$. Decay region starts at -1800cm.

- No extra tracks reconstructed, no extra clusters with energy greater than 1.5 GeV

Particle identification was done using the variable E/pc where E is the energy reconstructed in the LKR and p is the momentum measured by the magnetic spectrometer. Since E/pc peaks at 1 for electrons a cut of $0.95 < E/pc < 1.05$ was used for $Ke2$. Further a missing mass $|M_{miss}| < 0.02(GeV/c^2)^2$ was required calculated using 60 GeV for the kaon momentum and the track momentum under electron or muon hypothesis for Ke2 or $K\mu2$ events correspondingly.

The reconstructed $Ke2$ candidates are shown on Figure 1.

The background contribution in the $K\mu2$ sample is negligible (at the order of 10^{-3} mainly from $K^{\pm} \to \pi^{\pm}\pi^{0}$ events) but it is 14% in the $Ke2$ sample. The main contribution are $K\mu2$ events with muons releasing almost all their energy in the LKR. The background in Ke2 sample was

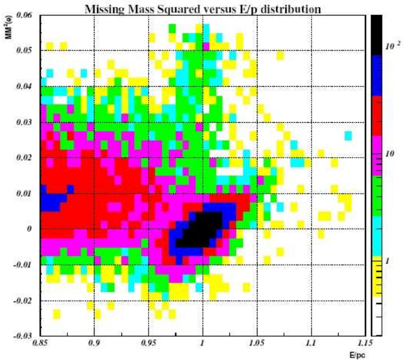

Figure 1. Missing mass versus the E/pc distribution for the $Ke2$ candidates before M_{miss} and E/pc cuts. A logarithmic scale is used for the event density in order to see the background contribution

estimated from fit of the E/pc distribution for events satisfying the missing mass cut as shown on Figure 2. The dependence of the muon E/pc distribution for $E/pc > 0.85$ was assumed to consist of two straight lines with different slopes. The point where the background changes slope is given by the parameter P3 and is close to 1 as expected.

3.2. Simulation

A full GEANT3 [5] based simulation of the detector response was used only for calculation of the acceptance for both decay modes. The radiative corrections were taken into account according to [6] and [1]. The agreement between the data and monte carlo was very good as shown on Figure 3.

4. Results and conclusions

With the presented selections a sample of 5329 Ke2 candidates were selected with a background contribution of 659 events leading to $4670 \pm 77_{stat}\ {}^{+29}_{-8(syst)}$ Ke2 events. 585 events were taken with a trigger downscaled by a factor of 40 and 4085 by a factor of 20.

The number of the reconstructed $K\mu2$ events

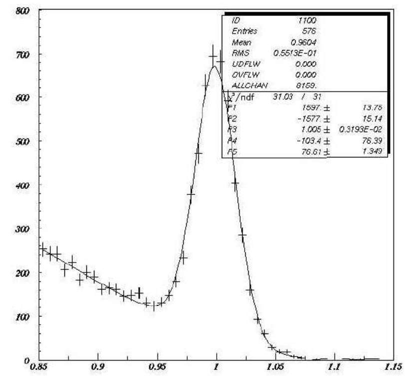

Figure 2. Fit of the E/pc distribution for events with $|M_{miss}| < 0.02(GeV/c^2)^2$ under the electron hypothesis.

was 619179 with a trigger downscaled by a factor of 10000. The raw value for R_K was

$$R_{K raw} = (1.697 \pm 0.028_{(stat)} \ {}^{+0.011}_{-0.003(syst)}) * 10^{-5} \quad (2)$$

Most of the systematics cancel in the ratio of the partial widths. After applying

Cut acceptance	$1.144 \pm 0.007_{syst}$
Trigger efficiency	$1.169 \pm 0.008_{stat}$
Radiative corrections	$1.063 \pm 0.005_{syst}$

the preliminary result is

$$R_K = (2.416 \pm 0.043_{stat} \pm 0.024_{syst}) * 10^{-5} \quad (3)$$

The uncertainty is dominated by the statistics of the $Ke2$ sample and the total error is two times smaller than the combined result from the previous experiments.

During the 2004 data a special run was dedicated to the kaon semileptonics decays and the data is being analyzed. The Ke2 sample collected was of similar statistics but the trigger logic was simpler and highly efficient. The analysis is very advanced and the results are expected to be published soon.

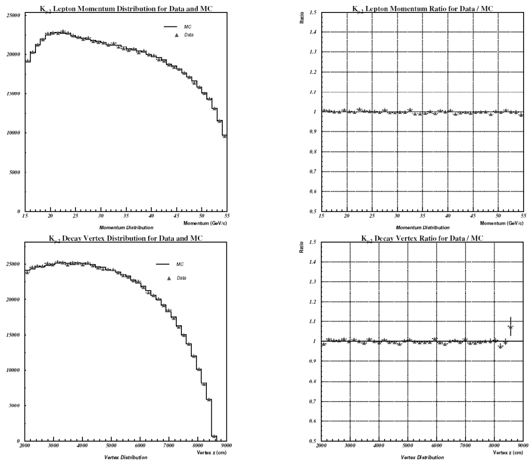

Figure 3. $K\mu2$ events Data and MC distributions and the ratio between them for the track momentum (upper) and Zvtx (lower).

Currently the NA48/2 collaboration is planning to measure R_K at the sub-percent level in a dedicated run in 2007. Such measurement will provide a sensible test of the Standard Model and will allow to probe regions in the parameter space of some of its extensions. This program is seen as a part of the preparation of a new experiment, P326 [7], aiming to collect O(100) $K^+ \rightarrow \pi\nu\nu$ events.

REFERENCES

1. M. Finkemeier, Phys. Lett. B387 (1996), 391
2. A. Masiero et al., Phys. Rev. D74 (2006), 011701
3. J. Heintze et al., Phys. Lett. 60 B (1976), 302; K.S. Heard et al., Phys. Lett. 55B (1975), 327; A.R. Clark et al., Phys. Rev. Lett 29 (1972), 1274
4. J.R.Batley et al., CERN/SPSC 2000-003 (2000)
5. CERN Program Library Long Write-up W5013 (1993.)
6. J Bijnens et al., Nucl. Phys B396 (1993), 81
7. G. Anelli *et al.*, CERN-SPSC-2005-013