Measurement of BR($Ke2$)/BR($K\mu2$) with NA62

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The NA62 experiment at CERN SPS collected, during 2007 run, the world largest sample of $K^{\pm}$ leptonic decays in order to test lepton universality, by measuring the ratio:

$$R_K = \Gamma(K^{\pm} \to e^{\pm}\nu)/\Gamma(K^{\pm} \to \mu^{\pm}\nu) = \Gamma(Ke2)/\Gamma(K\mu 2) \tag{1}$$

Being helicity suppressed, due to V-A structure of the charged weak current, R_K is sensitive to non-SM effects.
The preliminary result of the analysis based on 51089 $K^{\pm} \to e^{\pm}\nu$ candidates, extracted from a sub-sample of the data set, is:
$R_K = (2.500 \pm 0.016) \cdot 10^{-5}$, consistent with Standard Model predictions.

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1. Introduction

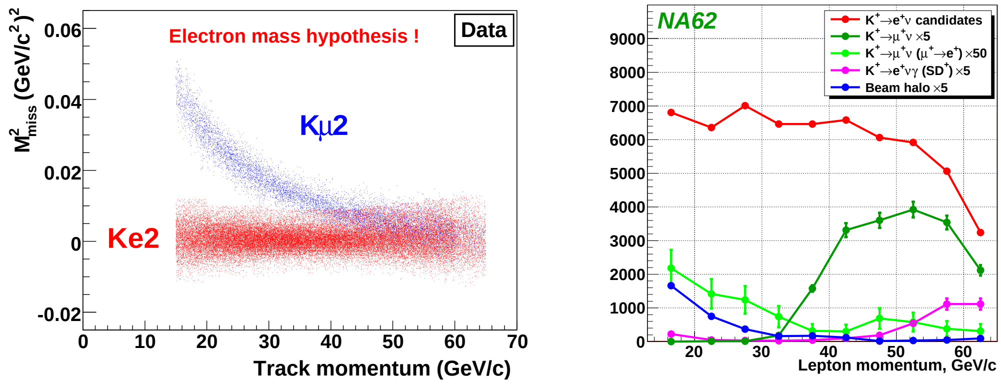
The ratio of kaon leptonic decay rates $R_K = \Gamma(K^\pm \to e^\pm \nu)/\Gamma(K^\pm \to \mu^\pm \nu)$, due to cancelation of the hadronic effects, can be computed in the Standard Model (SM) with excellent precision : $R_K^{SM} = (m_e/m_\mu)^2 \left(\frac{m_K^2-m_e^2}{m_K^2-m_\mu^2}\right)^2 (1+\delta_{RQED}) = (2.477 \pm 0.001) \cdot 10^{-5}$ [1], where $\delta_{RQED} = (-3.78 \pm 0.04)\%$ is a correction due to the inner bremsstrahlung (IB) $K_{l2(\gamma)}$ process which is included by definition into R_K. Being helicity suppressed due to V-A structure of the charged weak current, R_K is sensitive to non-SM effects. In particular in MSSM it is possible non-vanishing e-τ mixing, mediated via H^+, which can lead to order percent enhancement of R_K [2]. The present world average of $R_K = (2.467 \pm 0.024) \cdot 10^{-5}$ [3] is based on three measurements dating back to 1970s and the very recent KLOE final result [4], which pushed the precision down to $\sim 1\%$. The NA62 experiment collected data during 2007 and 2008 aiming to reach accuracy of $\sim 0.4\%$. The preliminary result on partial data set is presented here.

2. NA62 Experimental setup

The NA62 experiment utilized the NA48/2 beam line [5] and detector setup [6] with optimizations for $Ke2$ data collection. The beam line of NA48/2 experiment is designed to deliver simultaneously K^+ and K^-, produced on a beryllium target from SPS primary protons. The beams of (74 ± 2) GeV/c, after being momentum selected and focused by magnetic elements, enter 114 m long vacuum decay volume. The momenta of the charged decay products are measured by a magnetic spectrometer consisting of four drift chambers (DCHs) and a dipole magnet. The resolution of the spectrometer is $\sigma(p)/p = 1.0\% \oplus 0.044\% p$ (p in GeV/c). A scintillator hodoscope (HOD), located after the spectrometer, sends fast trigger signals from charged particles and measures their time with a resolution of 150 ps. The electromagnetic energy deposit of particles is measured by a liquid krypton calorimeter (LKr) with a resolution of $\sigma(E)/E = 3.2\%/\sqrt{E} \oplus 9\%/E \oplus 0.42\%$. A beam pipe traversing the centers of the detectors allows undecayed beam particles and muons from decays of beam pions to continue their path in vacuum. The $Ke2$ decays are selected by trigger requiring coincidence of hits in the HOD planes (Q1 signal) together with sizable energy deposit (> 10 GeV) in LKr. The $K\mu2$ events are selected by Q1 signal, downscaled by a factor 150.

3. Data selection and analysis strategy

Due to the topological similarity of $Ke2$ and $K\mu2$ final states large part of the selection conditions are common. The presence of a single reconstructed charged track with momentum 15 GeV/c<p<65 GeV/c, within the geometrical acceptances of DCH, LKr and HOD, and with a CDA between the charged track and the nominal kaon beam less than 1.5 cm, is required. In order to suppress the background from other kaon decays the events are rejected if a cluster in the LKr with energy larger than 2 GeV and not associated with track is found. For low track momenta, a kinematical separation between $Ke2$ and $K\mu2$ is possible, based on the reconstructed missing mass $M^2_{miss(l)} = (P_K - P_l)^2$, assuming the lepton mass to be that of an electron or a muon (see Fig. 1(a)). NA62 is not able to directly measure the kaon four-momentum P_K in each event, nevertheless its average is monitored in each SPS spill using $K^\pm \to \pi^\pm\pi^+\pi^-$ decays. A cut $|M^2_{miss}(e)| < M_0^2$ is



(a) (b)

Figure 1: (a) $M^2_{miss}(e)$ for $Ke2$ and $K\mu2$ decays. (b) Signal and BG lepton momentum distributions

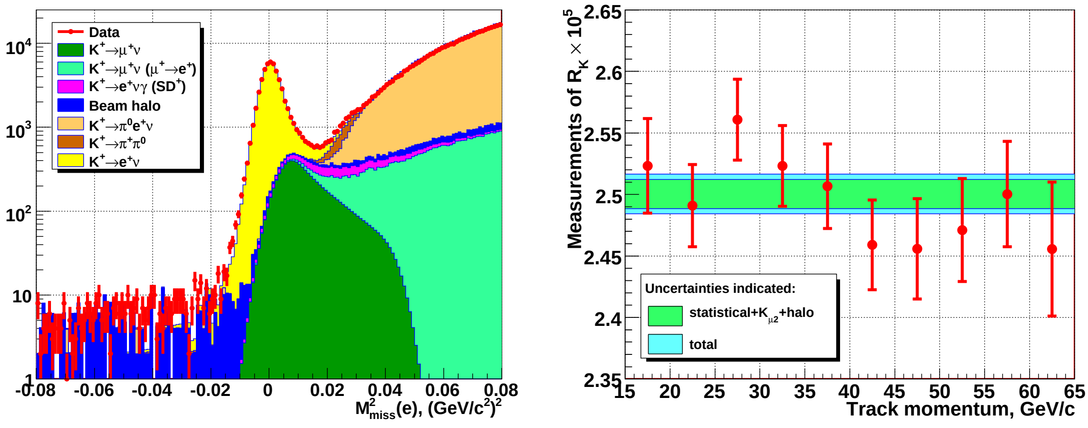
applied to select $Ke2$ candidates, and $|M^2_{miss}(\mu)| < M^2_0$ for $K\mu2$ ones, where M^2_0 varies from 0.009 to 0.013 $(GeV/c^2)^2$ for different track momenta, following M_{miss} resolution. Particle identification is based on the ratio E/p of track energy deposit in the LKr to its momentum measured by the spectrometer. Particles with 0.95 < E/p < 1.1 are identified as electrons, while particles with E/p < 0.85 as muons. The analysis is based on counting the number of reconstructed $Ke2$ and $K\mu2$ candidates with the selection described in previous section. Since the decays are collected simultaneously, the result does not depend on kaon flux measurement and the systematic effects due to the detector efficiency cancel to first order. To take into account the momentum dependence of signal acceptance and background level, shown in Fig. 1(b), the measurement is performed independently in bins of reconstructed lepton momentum. The ratio R_K in each bin is computed as:

$$R_K = \frac{1}{D}\frac{N(Ke2) - NB(Ke2)}{N(K\mu2) - NB(K\mu2)}\frac{f_\mu \cdot A(K\mu2)\cdot \varepsilon(K\mu2)}{f_e \cdot A(Ke2)\cdot \varepsilon(Ke2)}\frac{1}{f_{LKr}} \qquad (3.1)$$

where N(Kl2) are the numbers of selected Kl2 candidates (l = e,μ), NB(Kl2) are numbers of background events, f_l are the identification criteria efficiencies for electron and muon , A(Kl2) are geometrical acceptances, $\varepsilon(Kl2)$ are trigger efficiencies, f_{LKr} is the global efficiency of the LKr readout, and D=150 is the downscaling factor of the $K\mu2$ trigger. In order to compute A(Kl2), a detailed Geant3-based Monte-Carlo simulation is employed. It includes full detector geometry and material description, stray magnetic fields, local DCH inefficiencies, misalignment, detailed simulation of beam line, and time variations of the above throughout the running periods.

4. Background studies

NB(Ke2) in 3.1 is dominated by $K\mu2$ events with the muon misidentified as electron, mainly in case of high energetic bremsstrahlung after the magnetic spectrometer. In particular cases, the photon can take up to more than 95% of muon's energy. The probability for such process is measured directly by sample of $K\mu2$ with the muon passing $\sim 10X_0$ of lead before hitting the LKr. Those events have been collected during dedicated data taking periods in which a lead wall was installed in front of the LKr calorimeter. A Geant4 simulation is used to evaluate the correction



(a) **(b)**

Figure 2: (a) $M^2_{miss}(e)$ distributions for $Ke2$ events and backgrounds. (b) R_K in track momentum bins.

to the probability for muon to give E/p>0.95 due to the presence of the Pb which is induced by: 1) muon energy loss in Pb by ionization, dominating at low momenta; 2) bremsstrahlung in the last radiation lengths of Pb increasing the probability for high track momenta. The background contribution is evaluated to be (6.28 ± 0.17)%.

Since the incoming kaon is not tracked and the signature of Kl2 decays is a single reconstructed track, the background from beam halo should be considered. The performance of muon sweeping system results in lower background in K^+_{e2} sample (~ 1%) with respect to K^-_{e2} sample (~ 20%), therefore ~ 90% of data were collected with the K^+ beam only. Small fractions were recorded with simultaneous $K^{\pm}$ beams and K^- beam only. The halo background in K^+_{e2} was measured to be (1.45 ± 0.04)% directly form data, collected when no K^+ beam was present. The other relevant background sources are:

$K\mu 2$ with subsequent $\mu \to e$ decay: (0.23 ± 0.01)%

$Ke2\gamma(SD)$: (1.02 ± 0.15)% (recent KLOE measurement not included in the error computation)

$Ke3$ and $K2\pi$: 0.03% for both decays

Before background subtraction, the number of $Ke2$ collected candidates is 51089. The $M^2_{miss(e)}$ distribution for data events, red points, and simulated backgrounds are presented in Fig. 2(a).

5. Systematic uncertainties and results

The electron identification efficiency is measured directly as a function of track momentum and its impact point at LKr using electrons from $Ke3$ decays. The average fe is (99.20 ± 0.05)% (f_μ is negligible). The geometric acceptance correction A($K\mu 2$)/A($Ke2$) depends on the radiative $Ke2\gamma(IB)$ decays, which are simulated in one-photon approximation [1] without re-summing leading logarithms [7]. The trigger efficiency correction $\varepsilon(Ke2)/\varepsilon(K\mu 2) \sim 99.9$% accounts for the difference in the trigger conditions, namely the requirement of E>10 GeV energy deposited in LKr, applied to $Ke2$ only. A conservative systematic uncertainty of 0.3% is ascribed due to effects of trigger dead time. LKr global readout efficiency is measured to be (99.80 ± 0.01)% using independent LKr readout. The systematic uncertainties on R_K result are summarized in Table 1.

Source	Error	Source	Error
Statistics	0.012	Geometrical acceptance	0.002
$K\mu 2$ background	0.004	Electron ID	0.001
$Ke2\gamma$ background	0.004	IB simulation	0.007
Beam halo background	0.001	Trigger dead time	0.007

Table 1: Summary of the R_K uncertainties in units of 10^{-5}.

The independent measurements of R_K in track momentum bins are presented in Fig. 2(b). The preliminary NA62 result is $R_K = (2.500 \pm 0.012_{stat} \pm 0.011_{syst}) \cdot 10^5 = (2.500 \pm 0.016) \cdot 10^5$, consistent with SM expectation [1]. The precision has been improved to 0.6% to be compared to the 1% of present PDG average. The analysis on the whole data set will allow us to reach uncertainty of 0.4%. The combined new world average is $(2.498 \pm 0.014) \cdot 10^5$.

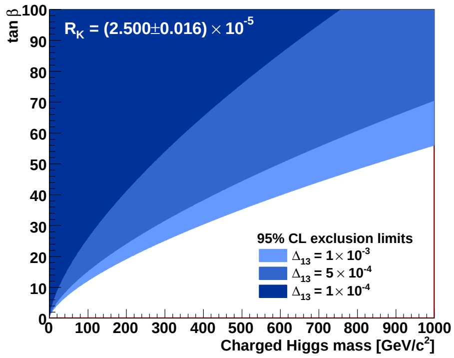


Figure 3: Exclusion plot in the plane M_{H+} vs $tan(\beta)$ using NA62 R_K measurement.

In the framework of MSSM, with lepton-flavor violating couplings (Δ_{13}), [2] found:

$$R_K^{LFV} \approx R_K^{SM}\left[1+\left(\frac{m_K^4}{M_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{M_e^2}\right)|\Delta_{13}|^2 tan^6\beta\right] \tag{5.1}$$

where Δ_{13} is the effective e-τ coupling constant depending on MSSM parameters. The regions excluded at 95% C.L. in the plane M_{H^+}-$tan(\beta)$ are shown in Fig. 3 for different values of the effective LFV coupling Δ_{13}.

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