

## Results and prospects on kaon physics with the NA62 experiment at CERN

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**Summary.** — The measurement of the ratio of the rates of leptonic kaon decays performed by NA48/2 and NA62 ( $R_K$  phase) experiments is presented, together with the description of the NA62 experiment that will start collecting data in 2015 at the CERN SPS with the main goal of measuring the branching ratio(BR) of the rare decay  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$  with a precision of 10%.

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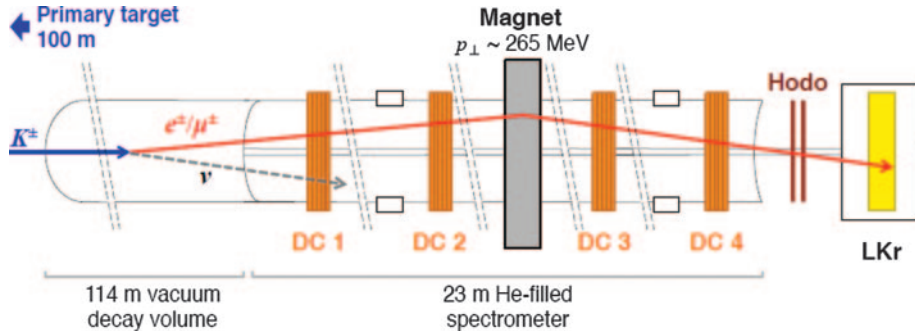


Fig. 1. – NA48 and NA62 ( $R_K$  phase) experimental layout.

### 1. – NA48/2 and NA62 ( $R_K$ phase) beams and detector

In 2003-04 the NA48/2 experiment at the CERN SPS collected the world largest sample of charged kaon decays, with the main goal of studying direct CP violation [1]. In 2007-08 the NA62 experiment ( $R_K$  phase) collected data with the same beam line and experimental setup but different data taking conditions, with the main goal of measuring the ratio of the rates of leptonic kaon decays [2]. An unseparated charged kaon beam was used, produced by the 400 GeV/c primary proton beam from SPS hitting a beryllium target. A 100 m long beam line selected the momentum of the secondary beam to  $(75 \pm 3)$  GeV/c and the beam entered a decay volume, housed in a 100 m long vacuum tank. The detector (see fig. 1) was designed to detect particles from the kaon decays in the vacuum region. In order to track the charged particle from the  $K^+$  decays, a magnetic spectrometer, consisting of 4 drift chambers separated by a dipole magnet, was used. It provided a transverse momentum kick of 265 MeV/c, corresponding to a momentum resolution of  $\sigma_p/p = (0.48 \oplus 0.009 \times p)\%$  ( $p$  in GeV/c). A scintillator hodoscope gave the main trigger for the event topologies including charged particles and set the time reference for the other detectors. A quasi-homogeneous electromagnetic calorimeter with liquid krypton as active material (LKr) was used mainly for particle identification. The measured energy resolution was  $\sigma(E)/E = 0.032/\sqrt{E} \oplus 0.09/E \oplus 0.0042(E$  in GeV).

### 2. – NA62 results on $R_K$

The decays of pseudoscalar mesons to light leptons are helicity suppressed in the Standard Model (SM) due to the  $V - A$  structure of the electroweak charged current coupling. Because of the decay constant  $f_P$ , the SM predictions for leptonic decay rates are affected by hadronic uncertainties; however ratios of decay rates of the same parent meson do not depend on  $f_P$  and can be computed very precisely. In particular, the SM prediction for  $R_K = \Gamma(K^\pm \rightarrow e^\pm \nu_e)/\Gamma(K^\pm \rightarrow \mu^\pm \nu_\mu)$ , inclusive of internal bremsstrahlung (IB) radiation, is [3]

$$(1) \quad R_K^{SM} = \left(\frac{M_e}{M_\mu}\right)^2 \left(\frac{M_K^2 - M_e^2}{M_K^2 - M_\mu^2}\right)^2 (1 + \delta R_{QED}) = (2.477 \pm 0.001) \times 10^{-5},$$

where  $\delta R_{QED} = (-3.79 \pm 0.04)\%$  is the electromagnetic correction. Within extensions of the SM involving two Higgs doublets,  $R_K$  is sensitive to lepton flavour violating effects induced by loop processes with the charged Higgs boson exchange [4].

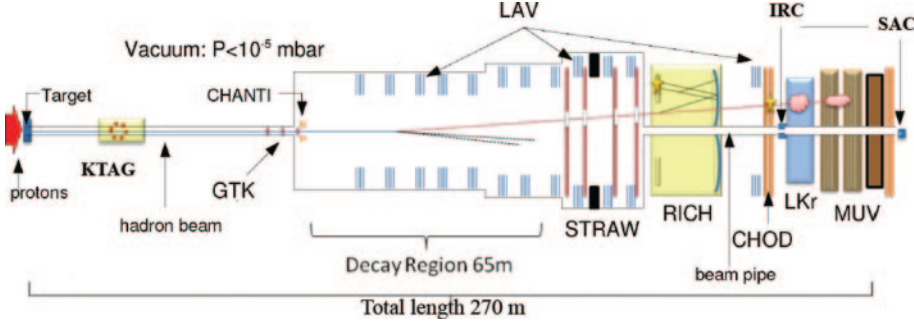


Fig. 2. – NA62 experimental layout.

About 65% of data were taken with the  $K^+$  beam only, 8% with the  $K^-$  only and the rest with simultaneous  $K^\pm$ . Dedicated data taking were performed in order to validate with data the background estimation. In particular 55% of data were collected with a lead bar in front of the LKr) to measure directly on data the  $\mu$ -electron misidentification probability. The selection criteria and the analysis strategy including the treatment of all systematic effects are described in [2]. A sample of 145958  $K \rightarrow e\nu$  candidates, with an estimated background of  $(10.95 \pm 0.27)\%$ , was collected providing a final result with an overall uncertainty of 0.4%:

$$(2) \quad R_K = (2.488 \pm 0.007_{stat} \pm 0.007_{syst}) \times 10^{-5}.$$

### 3. – NA62 for $K^+ \rightarrow \pi^+\nu\bar{\nu}$ and other rare decays: strategy and prospects

The NA62 experiment will start its data taking in 2015 with a new generation detector [5], optimized for the experiment goal: the measurement of the BR of the ultra-rare kaon decay  $K^+ \rightarrow \pi^+\nu\bar{\nu}$  with uncertainty less than 10%, collecting  $\sim 100$  events in 3 years of data taking according to the SM branching fraction. This is a flavor changing neutral current (FCNC) process strongly suppressed in the SM, that predicts a BR of  $(7.81 \pm 0.75 \pm 0.29) \times 10^{-11}$  [6], and is dominated by top-quark loop contributions. Because of the excellent precision in the theoretical prediction even relatively small difference with respect to the SM could be a clear signal of new physics. In addition the precise measurement of  $K^+ \rightarrow \pi^+\nu\bar{\nu}$  will be an alternative measurement of  $V_{td}$  with respect to the B decays. Experimentally 7 candidates of the  $K^+ \rightarrow \pi^+\nu\bar{\nu}$  decay have been observed by the BNL E787/E949 experiments with a BR of  $1.73^{+1.15}_{-1.05} \times 10^{-10}$  [7].

The layout of the NA62 experiment is shown in fig. 2. A high intensity and high energy kaon beam is exploited to provide kaon decays in flight over a long decay region. It is part of an unseparated hadron beam obtained, like for NA62  $R_K$  phase, by the primary 400 GeV/c proton beam from the SPS accelerator impinging on a beryllium target. About 6% of the total amount of particles in the secondary 75 GeV/c beam are kaons; the rest are mainly pions ( $\sim 70\%$ ) and protons ( $\sim 23\%$ ). The identification of the kaons in the beam is done by a differential hydrogen Čerenkov counter (KTAG). A silicon pixel beam spectrometer (Gigatracker) placed on the hadron beam, measures the momentum and the direction of the particles working at a rate of 750 MHz. A CHarged ANTI-counter (CHANTI) follows, which is required in order to reduce the critical background induced by inelastic interaction of the beam with the collimator and the Gigatracker stations. The decay region is housed in a  $\sim 80$  m long  $\sim 2.5$  m diameter evacuated tube



Apart from the  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$  process, the high kaon fluxes (accompanied by  $2 \times 10^{12} \pi^0$  decays from  $K \rightarrow \pi \pi^0$ ), the excellent particle identification capabilities and the precise kinematical reconstruction of the events will open several possibilities to improve the experimental knowledge on many rare or forbidden kaon decays. The measurement of  $R_K$  will be improved, pushing the experimental accuracy to a level closer to the theoretical one. Studies of the prospects for searches for lepton-flavor (LF) or lepton-number (LN) violating and other forbidden decays with NA62 are underway. Preliminary estimates of the single-event sensitivities (defined as the reciprocal of the product of the number of accepted decays) give results at the level of  $10^{12}$  for  $K^+$  decays to states such as  $\pi^+ \mu^\pm e^\mp$  (LFV),  $\pi^- \mu^+ e^+$  (LFNV), and  $\pi^- e^+ e^+$  or  $\pi^- \mu^+ \mu^+$  (LNV), and at the level of  $10^{11}$  for  $\pi^0$  decays to  $\mu^\pm e^\mp$  [8].

#### 4. – Conclusion

The most precise measurement of  $R_K$  has been performed from a sample of about  $150 \times 10^3 K \rightarrow e \nu$  candidates collected by the NA48/2 and NA62 ( $R_K$  phase) experiments. The result is  $R_K = (2.488 \pm 0.010) \times 10^{-5}$ , consistent with the earlier measurements and with the SM prediction. The experimental uncertainty on  $R_K$  is still an order of magnitude larger than the one on the SM expectation. The NA62 experiment at the CERN SPS will start collecting data in 2015. The main goal of the experiment will be the measurement of BR of  $K^+ \rightarrow \pi^+ \nu \bar{\nu}$  decay, predicted by the SM with high precision. A discrepancy at level of  $\sim 20\%$  with respect to the predicted value will be a clear signal of physics beyond the SM. With  $10^{13} K^+$  in its fiducial volume in three years of data taking, the NA62 experiment will have a single event sensitivity of  $10^{12}(10^{11})$  for a number of  $K^+(\pi^0)$  LFV decays, as well as the potential to improve the upper limits for several searches for effects and particles not foreseen in the SM.

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