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KAON SEMILEPTONIC DECAYS AT KLOE

The KLOE Collaboration*
presented by Claudio Gatti
Università di Roma "La Sapienza" - INFN
claudio.gatti@lnf.infn.it

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* A. Aloisio, F. Ambrosino, A. Antonelli, M. Antonelli, C. Bacci, M. Barva, G. Bencivenni, S. Bertolucci, C. Bini, C. Bloise, V. Bocci, F. Bossi, P. Branchini, S. A. Bulychjov, R. Caloi, P. Campana, G. Capon, T. Capussela, G. Carboni, F. Ceradini, F. Cervelli, F. Cevenini, G. Chiefari, P. Ciambrone, S. Conetti, E. De Lucia, A. De Santis, P. De Simone, G. De Zorzi, S. Dell'Agnello, A. Denig, A. Di Domenico, C. Di Donato, S. Di Falco, B. Di Micco, A. Doria, M. Dreucci, O. Erriquez, A. Farilla, G. Felici, A. Ferrari, M. L. Ferrer, G. Finocchiaro, C. Forti, P. Franzini, C. Gatti, P. Gauzzi, S. Giovannella, E. Gorini, E. Graziani, M. Incagli, W. Kluge, V. Kulikov, F. Lacava, G. Lanfranchi, J. Lee-Franzini, D. Leone, F. Lu, M. Martemianov, M. Martini, M. Matsyuk, W. Mei, L. Merola, R. Messi, S. Miscetti, M. Moulson, S. Müller, F. Murtas , M. Napolitano, F. Nguyen, M. Palutan, E. Pasqualucci, L. Passalacqua, A. Passeri, V. Patera, F. Perfetto, E. Petrolo, L. Pontecorvo, M. Primavera, P. Santangelo, E. Santovetti, G. Saracino, R. D. Schamberger, B. Sciascia, A. Sciubba, F. Scuri, I. Sfiligoi, A. Sibidanov, T. Spadaro, E. Spiriti, M. Tabidze, M. Testa, L. Tortora, P. Valente, B. Valeriani, G. Venanzoni,

ABSTRACT

KLOE has collected $\sim 450\mathrm{pb}^{-1}$ in the previous two years of data taking. The analyses on the semileptonic decays of charged and neutral kaons performed with this data is discussed in this paper. Preliminary results are shown on the branching ratio and charge asymmetry of the $K_S \to \pi e \nu$ decay.

1 Introduction

The measurement of semileptonic kaon decay widths provides several tests of fundamental aspects of the standard model. The matrix element V_{us} is extracted from semileptonic kaon decays, both charged and neutral. Its value is used to test the unitarity of CKM matrix at per-mil level.

The validity of the rule $\Delta S = \Delta Q$ can be tested through the quantity

$$\mathrm{Re}(\mathrm{x}_+) \equiv \frac{1}{2}\left[\frac{\langle \mathrm{e}^+\pi^-\nu|\,\mathrm{T}\,|\bar{\mathrm{K}}^0\rangle}{\langle \mathrm{e}^+\pi^-\nu|\,\mathrm{T}\,|\mathrm{K}^0\rangle} + \frac{\langle \mathrm{e}^-\pi^+\bar{\nu}|\,\mathrm{T}\,|\mathrm{K}^0\rangle^*}{\langle \mathrm{e}^-\pi^+\bar{\nu}|\,\mathrm{T}\,|\bar{\mathrm{K}}^0\rangle^*}\right], \tag{1}$$

which can be measured from the relative difference of K_S and K_L decay widths into $\pi e \nu$:

$$\mathrm{Re}(\mathrm{x}_+) = \frac{1}{2}\frac{\Gamma(\mathrm{K_S} \to \pi \mathrm{e}\nu) - \Gamma(\mathrm{K_L} \to \pi \mathrm{e}\nu)}{\Gamma(\mathrm{K_S} \to \pi \mathrm{e}\nu) + \Gamma(\mathrm{K_L} \to \pi \mathrm{e}\nu)}. \tag{2}$$

$\mathrm{Re}(\mathrm{x}_+)$ is expected to be of the order $G_F m_\pi^2 \sim 10^{-7}$ in the Standard Model.

Finally, discrete symmetries are tested through the measurement of the charge asymmetries

$$\mathrm{A_{L,S}} = \frac{\Gamma(\mathrm{K_{L,S}} \to \pi^-\mathrm{e}^+\nu) - \Gamma(\mathrm{K_{L,S}} \to \pi^+\mathrm{e}^-\overline{\nu})}{\Gamma(\mathrm{K_{L,S}} \to \pi^-\mathrm{e}^+\nu) + \Gamma(\mathrm{K_{L,S}} \to \pi^+\mathrm{e}^-\overline{\nu})}. \tag{3}$$

We took into account the presence of a photon in the final state of the decays into charged particles, by introducing a complete Monte Carlo (MC) simulation of the process for each decay [1)].

2 $K_S \to \pi^\mp e^\pm \nu(\overline{\nu})$

We select a pure K_S-beam by identifying the K_L interactions inside the calorimeter. The K_S decays close to the interaction point (IP) with a decay length of

S. Veneziano, A. Ventura, R. Versaci, I. Villella, G. Xu

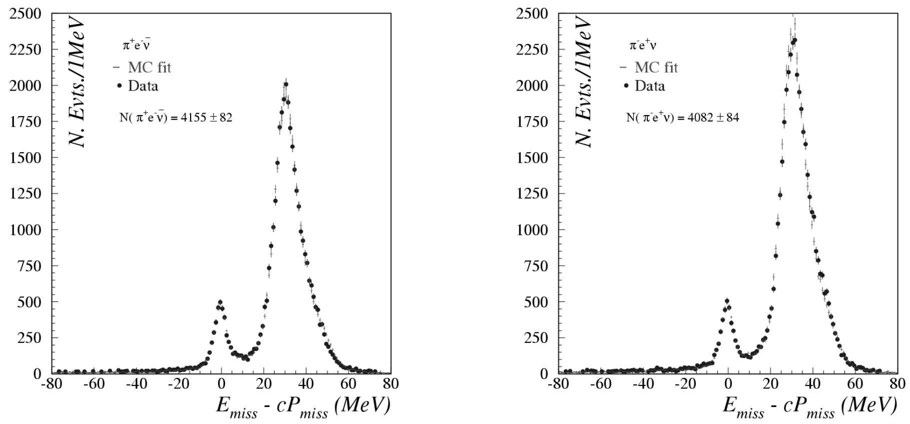

Figure 1: *Fit to the $E_{miss} - p_{miss}$ distributions for $K_S \to \pi^+ e^- \overline{\nu}$ (Left) and $K_S \to \pi^- e^+ \nu$ (Right) decays, for the data collected during the year 2001. The dots represent data while the crosses represent MC after the fit.*

~ 0.6 cm. We select events with two tracks forming a vertex close to the IP, and with two energy clusters associated. Pions and electrons are recognized using a time of flight technique. Using the K_S momentum estimated from the K_L-cluster position ($\sigma_p \sim 2$ MeV), and the particle momenta, we calculate the difference between missing energy and momentum $E_{miss} - p_{miss}$. The signal peaks at zero due to the missing neutrino as shown in Fig. 1. The background is due to $K_S \to \pi^+\pi^-$ decays where one of the pions decays before entering the drift chamber or where the tracks are not well reconstructed. We count the signal events by fitting the $E_{miss} - p_{miss}$ spectrum with the MC distributions for signal and background. The fit is performed independently for the two charge states $K_S \to \pi^+ e^- \overline{\nu}$ and $K_S \to \pi^- e^+ \nu$. We obtain $\sim 23\,000$ events in the whole data set. The $K_S \to \pi^\mp e^\pm \nu(\overline{\nu})$ branching ratio is obtained by normalizing the number of signal events to the number of $K_S \to \pi^+\pi^-$ decays collected in the same data set, correcting for the selection efficiencies, and using the present experimental value of $\mathrm{BR}(\mathrm{K_S} \to \pi^+\pi^-)$:

$$\mathrm{BR}(\pi \mathrm{e} \nu) = \frac{\mathrm{N}(\pi \mathrm{e} \nu)}{\mathrm{N}(\pi\pi)} \times \frac{\varepsilon^{\pi\pi}_{\mathrm{tot}}}{\varepsilon^{\pi \mathrm{e} \nu}_{\mathrm{tot}}} \times \mathrm{BR}(\pi\pi). \tag{4}$$

we obtain:

$$\begin{aligned}
\mathrm{BR}(\mathrm{K_S} \to \pi^- \mathrm{e}^+ \nu) &= (3.54 \pm 0.05_{\mathrm{stat}} \pm 0.05_{\mathrm{syst}}), \\
\mathrm{BR}(\mathrm{K_S} \to \pi^+ \mathrm{e}^- \overline{\nu}) &= (3.54 \pm 0.05_{\mathrm{stat}} \pm 0.04_{\mathrm{syst}}), \\
\mathrm{BR}(\mathrm{K_S} \to \pi \mathrm{e} \nu) &= (7.09 \pm 0.07_{\mathrm{stat}} \pm 0.08_{\mathrm{syst}}).
\end{aligned}$$

The charge asymmetry is equal to:

$$\mathrm{A_S} = (-2 \pm 9_{\mathrm{stat}} \pm 6_{\mathrm{syst}}). \tag{5}$$

We can extract the parameter $\mathrm{Re(x_+)}$, defined in Eq. 1, using the experimental values for the K_L branching ratio and lifetime. Using the PDG value for the branching ratio we obtain:

$$\mathrm{Re(x_+)} = (12.6 \pm 3.1_{\mathrm{stat}} \pm 2.9_{\mathrm{syst}}) \times 10^{-3}, \tag{6}$$

while using the recent value obtained from the KTeV Collaboration [2]:

$$\mathrm{Re(x_+)} = (0.9 \pm 2.9_{\mathrm{stat}} \pm 2.9_{\mathrm{syst}}) \times 10^{-3}. \tag{7}$$

The most precise published measurement of $\mathrm{Re(x_+)}$ is from the CPLEAR Collaboration [3]:

$$\mathrm{Re(x_+)} = (-1.8 \pm 4.1_{\mathrm{stat}} \pm 4.5_{\mathrm{syst}}) \times 10^{-3}. \tag{8}$$

Finally, following the prescription in [4] we extract the value of $f_+^{K^0\pi^-} \times V_{us}$

$$f_+^{K^0\pi^-} \times V_{us} = 0.2157 \pm 0.0018 \tag{9}$$

which is compatible with the unitarity of the CKM matrix.

3 Measurement of τ_L

The K_L lifetime has been measured in 1972. Its uncertainty dominates the error on the estimate of V_{us} from K_L decays. In KLOE we observe K_L decays for a large fraction ($\sim$ 50%) of its decay length ($\sim$ 340 cm). Furthermore, the momentum of the kaon is well known. We select $K_L \to \pi^0\pi^0\pi^0$ decays starting from an event with a $K_S \to \pi^+\pi^-$ decay. The decay vertex of the K_L is obtained through the measurement of the photon time of flight and

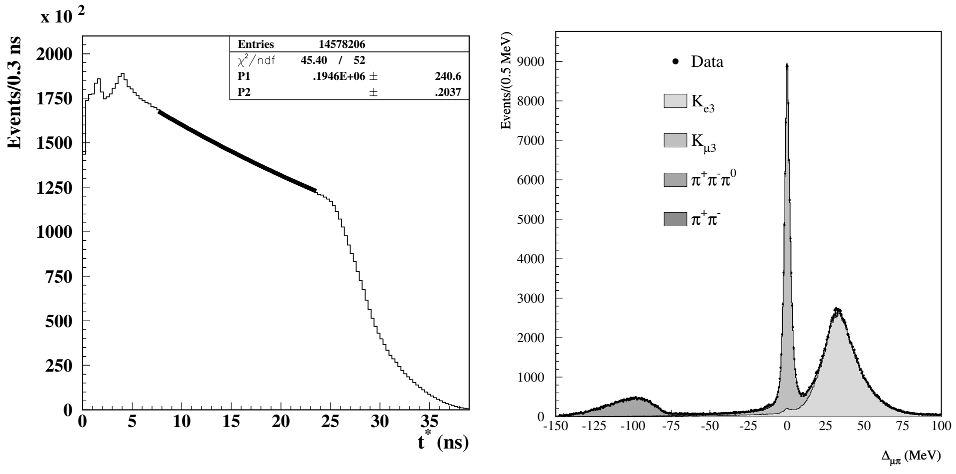

Figure 2: *Left: K_L proper time distribution. The fit is superimposed. Right: Fit to the $E_{miss} - p_{miss}$, in the $\pi\mu$ hypothesis, for charged decays of the K_L.*

position. The time scale calibration is checked at the per-mil level measuring the DAΦNE bunch crossing period with $\gamma\gamma$ events. The fit to the K_L proper time distribution is shown in Fig. 2 (Left panel). We reach a precision of $\sim 0.4\%$ with $\sim 15 \times 10^6$ K_L decays. The systematic is $\sim 0.6\%$, at present limited by the MC statistics.

4 Measurement of the dominant K_L branching ratios

$K_S \to \pi^+\pi^-$ decays are used as a tag for K_L decays. $K_L \to \pi^0\pi^0\pi^0$ are selected as described in the previous section, while all the events with a vertex reconstructed from two tracks in the drift chamber are retained as $K_L \to$ *charged* events. For these events the distribution $E_{miss} - p_{miss}$, in the $\pi\mu$ hypothesis, is shown if Fig. 2 (Right panel). A fit to this distribution is performed using MC spectra for the different decays. With 2×10^7 selected events inside a fiducial volume, we reach a statistical precision of $\sim 0.1\%$.

5 $K^\pm \to \pi^0 e^\pm \nu$

$K^\pm \to \mu^\pm \nu$ decays are used as a tag for charged kaon events. Starting from these events, $K^\pm \to \pi^0 e^\pm \nu$ are selected with few kinematic cuts and by mea-

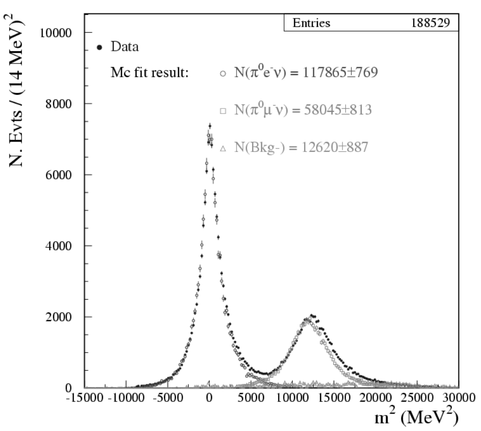

Figure 3: m^2 *spectrum (see text). The fit performed using MC distributions is superimposed.*

suring the charged particle mass through the measurement of the time of flight, T_{tof}, and momentum, p:

$$m^2 = p^2 \times \left[\left(\frac{cT_{tof}}{L} \right)^2 - 1 \right], \tag{10}$$

where L is the track length. We count the number of semileptonic events by performing a fit using MC distributions, as shown in Fig. 3. With the data collected in the years 2001 and 2002 we find $\sim$ 200000 $K^{\pm} \to \pi^0 e^{\pm} \nu$ events, reaching a statistical precision of $\sim 0.2\%$.

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