PROCEEDINGS OF SCIENCE

KLOE measurements of the charged Kaon lifetime and BR(K$^+ \rightarrow \pi^+ \; \pi^0 \; (\gamma)$)

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The preliminary results on the charged kaon lifetime $\tau^{\pm}$ and on the absolute branching ratio of the decay $K^+ \rightarrow \pi^+\pi^0(\gamma)$, obtained by the KLOE experiment operating at the DAΦNE Frascati ϕ-factory, are presented.

Kaon International Conference
May 21-25, 2007
Laboratori Nazionali di Frascati dell'INFN

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PoS(KAON)017

1. DAΦNE and KLOE

The DAΦNE e$^+$e$^-$ collider operates at a total energy $W = 1020$ MeV, the mass of the ϕ(1020)-meson. Since 2001, the KLOE experiment has collected an integrated luminosity of about 2.5 fb^{-1}. Results presented below are based on an integrated luminosity of about 250 pb^{-1}. The KLOE detector consists of a large cylindrical drift chamber, DC, surrounded by a lead/scintillating-fiber electromagnetic calorimeter, EMC. The drift chamber [1] is 4 m in diameter and 3.3 m long, has full stereo geometry and operates with a 90% helium - 10% isobutane gas mixture. The momentum resolution is $\sigma(p_T)/p_T \sim 0.4\%$. Two track vertices are reconstructed with $\sim$ 3 mm resolution. The calorimeter [2], composed of a barrel and two endcaps, covers 98% of the solid angle. Energy and time resolution are $\sigma(E)/E = 5.7\%/\sqrt{E(\mathrm{GeV})}$ and $\sigma(t) = 57\mathrm{ps}/\sqrt{E(\mathrm{GeV})} \oplus 100\mathrm{ps}$. A superconducting coil surrounds the detector and provides a solenoidal field of 0.52 T. The KLOE trigger [3], uses calorimeter and drift chamber information. For the present analysis, only events triggered by the calorimeter have been used.

2. The tag mechanism

The ϕ-meson decays most of the times into $K\bar{K}$ pairs; these are quasi anti-collinear in the laboratory due to the small crossing angle of the e$^+$e$^-$ beams. Therefore the detection of a $K(\bar{K})$ guaranties the presence of a $\bar{K}(K)$ of given momentum and direction. Therefore identified $K^\mp$ decays tag a $K^\pm$ beam and provide the normalization sample for signal count. This procedure is a unique feature of a ϕ-factory and gives the possibility of measuring absolute branching ratios. Charged kaons are tagged using their two-body decays, $K^\pm \to \mu^\pm \nu_\mu$ and $K^\pm \to \pi^\pm \pi^0$, accounting for $\sim$85% of the total decay width. We have about 1.5×10^6 K^+K^- events/pb^{-1}. The two-body decays are identified as peaks in the momentum spectrum of the charged decay particle evaluated in the kaon rest frame and assuming the pion mass.

3. Measurement of the charged kaon lifetime

The measurement is performed using 230 pb^{-1} collected at ϕ peak. The data sample has been split in two uncorrelated subsamples, 150 pb^{-1} have been used for the measurement, the remaining 80 pb^{-1} have been used to evaluate the efficiencies. $K_{\mu 2}$ tags of both charges have been used. There are two methods developed for the measurement based on the kaon decay length and the kaon decay time, respectively. The two methods allow cross checks and studies of systematics; their resolutions are comparable. The method relying on the measurement of the charged kaon decay length requires first the reconstruction of the kaon decay vertex in the fiducial volume using only DC information: the signal is given by a $K^\pm$, moving outwards in the DC with momentum $70 < p_K < 130$ MeV/c and having point of closest approach to the interaction point (IP) with $0 < \sqrt{x_{PCA}^2 + y_{PCA}^2} < 10$ cm and $|z_{PCA}| < 20$ cm. The kaon decay vertex in the DC fiducial volume ($40 < \sqrt{x_V^2 + y_V^2} < 150$ cm, $|z_V| < 150$ cm) is required. Once the decay vertex has been identified the kaon track is extrapolated backward to the interaction point into 2 mm steps, taking into account the ionization energy loss

dE/dx to evaluate its velocity βc. Then the proper time is obtained from:

$$t^* = \sum_i \Delta t_i = \sum_i \frac{\sqrt{1-\beta_i^2}}{\beta_i} \Delta l_i \tag{3.1}$$

The efficiency has been evaluated directly from data. The control sample has been selected using calorimetric information only, selecting for a neutral vertex: two clusters in time fired by the photons coming from the π^0 decay. The proper time distribution is fitted between 16 and 30 ns correcting for the efficiency. Resolution effects have been taken into account. The preliminary result we have obtained, which is the weighted mean between the K^+ and the K^- lifetimes, is:

$$\tau^{\pm} = (12.367 \pm 0.044 \pm 0.065)\ ns \tag{3.2}$$

The evaluation of systematic uncertainties is still preliminary.

The second method relies on the measurement of the kaon decay time. We consider only events with a π^0 in the final state:

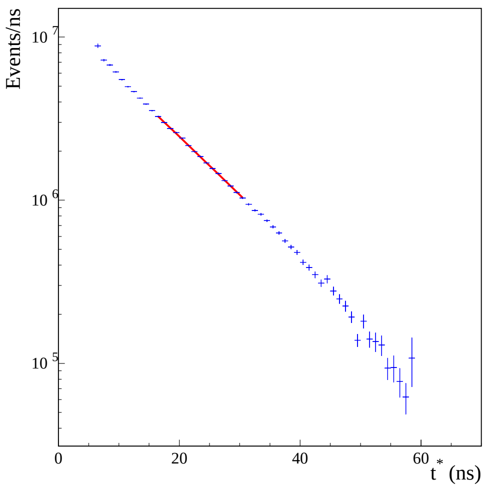

Figure 1: Charged kaon proper time distribution, obtained with the first method, fitted (red line) with a convolution of an exponential and a resolution function

$$K^{\pm} \to X + \pi^0 \to X + \gamma\gamma \tag{3.3}$$

We can obtain the kaon time of flight using the time ot the EMC clusters of the photons from the π^0 decay. We require the backward extrapolation to the interaction point of the tagging kaon track and the forward extrapolation of the helix of the other kaon on the signal side. Stepping along the helix we look for the $\pi^0 \to \gamma\gamma$ decay vertex without looking at the real kaon track. For each photon it is possible to measure the kaon proper decay time

$$t^* = (t_\gamma - \frac{r_\gamma}{c} - t_\phi) \cdot \sqrt{1-\beta_K^2} \tag{3.4}$$

The efficiency has been evaluated directly from data. The control sample has been selected using drift chamber information only, selecting the kaon decay vertex in the fiducial volume. The proper time distribution is fitted between 13 and 42 ns correcting for the efficiency. Resolution effects have been taken into account. The weighted mean between the K^+ and the K^- lifetimes gives as preliminary result:

$$\tau^{\pm} = (12.391 \pm 0.049 \pm 0.025)\ ns \tag{3.5}$$

The evaluation of systematic uncertainties is still preliminary.

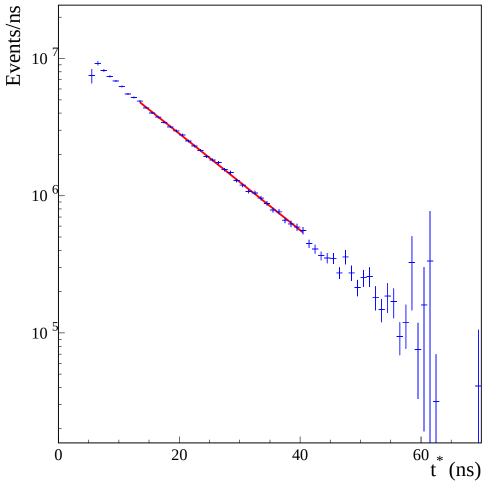

Figure 2: Charged kaon proper time distribution, obtained with the second method, fitted (red line) with a convolution of an exponential and a resolution function

In order to evaluate the statistical correlation between the two methods we divide the data sample into five subsamples. For each subsample, and for each method, we evaluate the proper time distribution and its efficiency. The value of the correlation is

$$\rho = .338 \tag{3.6}$$

The weighted mean between the two charges and between the two methods is

$$\tau^{\pm} = (12.384 \pm 0.048)\ ns \tag{3.7}$$

4. Measurement of the absolute branching ratio of the $K^+ \to \pi^+\pi^0(\gamma)$ decay.

The measurement of the branching ratio (BR) is performed using 250 pb^{-1} collected at ϕ peak. The normalization sample is given by $K^- \to \mu^-\overline{\nu}(\gamma)$ tagged events, providing a pure K^+ beam for signal search. In order to minimize the impact of the trigger efficiency on the reconstruction of the signal decay channel, we require the tagging kaon alone to satisfy the EMC trigger request, hereafter *self-triggering tag*. Nevertheless a residual dependency of the tagging criteria on the decay mode of the signal kaon is still present and it is accounted for in the final branching ratio measurement.The decision of using K^- to tag and K^+ for signal search has been taken to neglect corrections to the BR from nuclear interactions (NI) of the kaon ($\sigma_{NI}(K^+) \sim \sigma_{NI}(K^-)/10^2$). The choice of $K^-_{\mu 2}$ decays for tagging purposes allows us to separate as much as possible the tag hemisphere from the signal hemisphere, minimizing possible interference in track reconstruction and cluster association.

The signal selection of $K^+ \to \pi^+\pi^0(\gamma)$ decays uses DC information only. The K^+ is identified by a positive track moving outwards in the DC with momentum $70 < p_K < 130$ MeV/c and having point of closest approach (PCA) to the interaction point with $\sqrt{x^2_{PCA} + y^2_{PCA}} < 10$ cm and $|z_{PCA}| < 20$ cm. Decay vertices (V) in the drift chamber fiducial volume are selected, $40 < \sqrt{x^2_V + y^2_V} < 150$ cm, with the momentum difference between the kaon and the secondary $-320 < \Delta p = |\vec{p}_K| - |\vec{p}_{sec}| < -50$ MeV/c and the charged decay particle momentum in the kaon rest frame in pion mass hypothesis $50 < p^* < 370$ MeV/c.

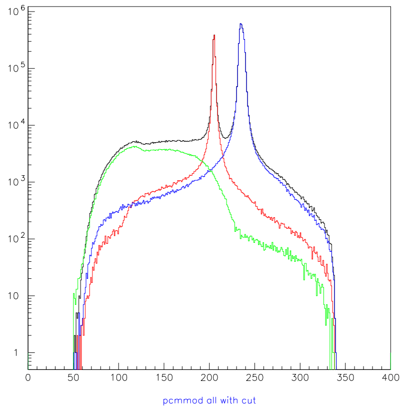

Figure 3: Spectra of the charged secondary momentum in the kaon mass rest frame assuming the pion mass obtained from MonteCarlo simulation. Two peaks are visible, the $K_{\pi 2}$ *peak* at 205 MeV and the $K_{\mu 2}$ *peak* at 236 MeV. Blue corresponds to $K^+ \to \mu^+\nu$, red to $K^+ \to \pi^+\pi^0$ and green to $three-body$ decays.

After this selection, the $K^+ \to \pi^+\pi^0(\gamma)$ signal count is extracted from the fit of the p^* distribution in the window starting from p^*_{cut}=180 MeV/c (see figure 3). This spectrum exhibits two peaks, the first at about 236 MeV/c from $K^+ \to \mu^+\nu$ decays, $K_{\mu 2}$ *peak*, and the second at about 205 MeV/c from $K^+ \to \pi^+\pi^0$ decays, $K_{\pi 2}$ *peak*; lower p^* values are due to three-body decays. The momenta of the charged secondaries produced in the kaon decay have been evaluated in the kaon rest frame using the pion mass hypothesis. Therefore the $K_{\pi 2}$ *peak*, evaluated using the correct mass hypothesis, appears to be symmetric while the $K_{\mu 2}$ *peak* is asymmetric do to the incorrect mass hypothesis used (pion instead of muon).

The fit to the p^* distribution is done using the following three contributions:

1. $K_{\mu 2}$ *peak*: this contribution accounts for $K^+ \to \mu^+\nu(\gamma)$ decays and it is taken directly from

a data control sample selected using calorimetric information only;

2. $K_{\pi 2}$ *peak*: this contribution accounts for $K^+ \to \pi^+\pi^0(\gamma)$ decays and it is taken directly from a data control sample selected using calorimetric information only;

3. $three - body$ decays: this contribution accounts for $three - body$ decays and it is taken from MC simulation.

Figure 4 shows the result of the fit of the p^* distribution performed on the selected data sample. Different colours indicate the different contributions: green for $K^+ \to \pi^+\pi^0(\gamma)$ decays, red for $K^+ \to \mu^+\nu(\gamma)$ decays and light blue for $three - body$ decays.

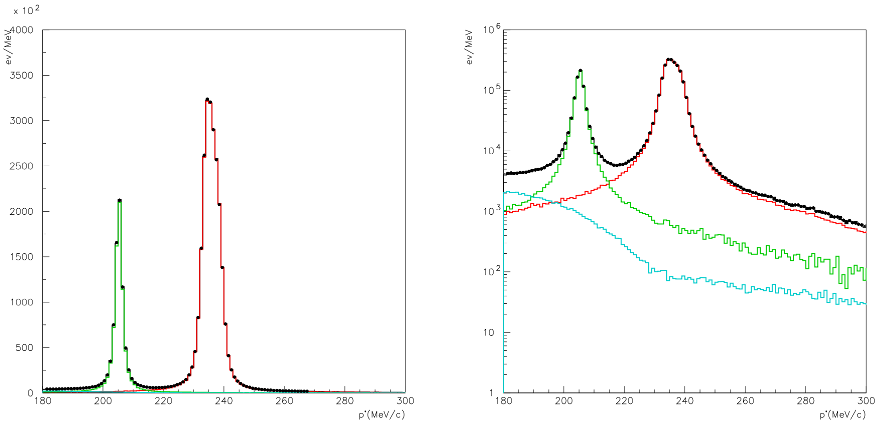

Figure 4: Fit of the p^* distribution: black dots are data to be fit and solid black line is the fit output. The three contributions used to fit the data are: $K_{\mu 2}$ peak (red), $K_{\pi 2}$ peak (green) and $three - body$ decays (light blue).

The efficiency has been evaluated directly on data from a control sample selected using calorimetric information only, to avoid correlation with the DC-driven sample selection. Given the tag by $K^- \to \mu^-\overline{\nu}(\gamma)$ decays, the control sample selection for the evaluation of this efficiency is given by $K^+ \to X^+\pi^0$ decays identified via the reconstruction of $\pi^0 \to \gamma\gamma$ decay vertices. Corrections to the efficiency accounting for possible distortions induced by the control sample selection have been evaluated using MC simulation.

From preliminary studies we are confident we are able to perform the measurement of the absolute branching ratio of the $K^+ \to \pi^+\pi^0(\gamma)$ decay at the few permil level of precision.

References

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