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Charged kaon lifetime at KLOE

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Abstract

Preliminary result on the charged kaon lifetime $\tau^\pm$, obtained by the KLOE experiment operating at DAΦNE, the Frascati ϕ-factory, is presented.

1. DAΦNE and KLOE

The DAΦNE e^+e^- collider operates at a total energy W = 1020 MeV, the mass of the $\phi(1020)$-meson. Approximately 3×10^6 ϕ -mesons are produced for each integradet luminosity of 1 pb^{-1}. Since 2001, KLOE has collected an integrated luminosity of about 2.5 fb^{-1}. Results presented below are based on 2001-02 data for about 450 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. The momentum resolution is $\sigma(p_T)/p_T \sim 0.4\%$. Two track vertices are reconstructed with a spatial resolution of ~ 3 mm. 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 around the detector provides a 0.52 T magnetic field. The KLOE trigger [3], uses calorimeter and drift chamber information. For the present analysis only the electromagnetic calorimeter (EMC) signals have been used. Two local energy deposits above threshold, $E_{\mathrm{th}} > 50$ MeV for the barrel and $E_{\mathrm{th}} > 150$ MeV for the endcaps, are required.

2. The tag mechanism

Most of the case in its center of mass ϕ-mesons decay into anti-collinear $K\bar{K}$ pairs. In the laboratory this remains approximately true because of the small crossing angle of the e^+ and e^- beams. Therefore the detection of a $K(\bar{K})$ tags the presence of a $\bar{K}(K)$ of given momentum and direction. The decay products of the $K^\pm$ pair define two spatially well separated regions called the tag and the signal hemispeheres. Identified $K^\mp$ decays tag a $K^\pm$ beam and provide sample count, using the total number of tags as normalization. This procedure is a unique feature of a ϕ-factory and provides the means for measuring absolute branching ratios. Charged kaons are tagged using the two body decays $K^\pm \to \mu^\pm \overset{(-)}{\nu}_\mu$ and $K^\pm \to \pi^\pm \pi^0$. Since the two body decays correspond to about 85% of the charged kaon decays [4] and since $BR(\phi \to K^+K^-) \simeq 49\%$ [4], there are about $1.5 \times 10^6 K^+K^-$ events/pb^{-1}. The two body decays are identified as peaks in the momentum spectrum of the secondary tracks in the kaon rest frame and computed assuming m_π for the particle (Fig. 1). In order to minimize the impact of the trigger efficiency, the taging kaon must provide the EMC trigger of the event, so called self-triggering tags. $N_{\mathrm{selftrg\ tag}} \approx 2 \times 10^5$ per pb^{-1}.

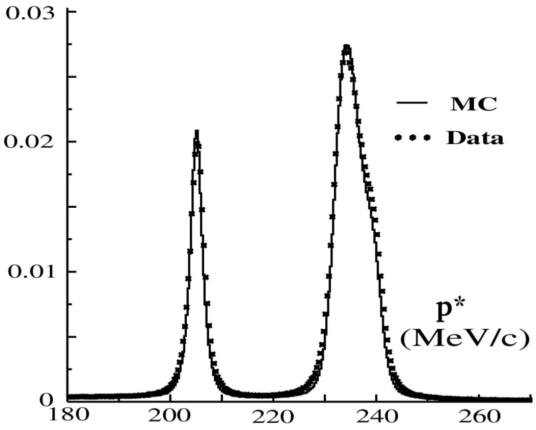

Figure 1. Momentum spectrum in the kaon rest frame of the negative charged decay particle, assuming the particle has the pion mass for data (dots) and MC (lines).The distribution are normalized to unity. The two peaks correspond to pions and muons from $K^- \to \pi^-\pi^0$ (205 MeV/c) and $K^- \to \mu^-\nu_\mu$ (236 MeV/c). The muon peak is broadened by the use of the incorrect 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 available for the measurement: the kaon decay length and the kaon decay time. 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 $0 < \sqrt{x^2_{PCA} + y^2_{PCA}} < 10$ cm and $|z_{PCA}| < 20$ cm. The kaon decay vertex in the DC fiducial volume ($40 < \sqrt{x^2_V + y^2_V} < 150$ 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:

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

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 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:

$$\tau^\pm = (12.367 \pm 0.044 \pm 0.065)\ ns \tag{2}$$

The evaluation of systematic uncertainties is sill preliminary, final numbers will be presented at the conference.

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

$$K^\pm \to X + \pi^0 \to X + \gamma\gamma \tag{3}$$

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

$$t^* = (t_\gamma - \frac{r_\gamma}{c} - t_\phi) \cdot \sqrt{1-\beta_K^2} \tag{4}$$

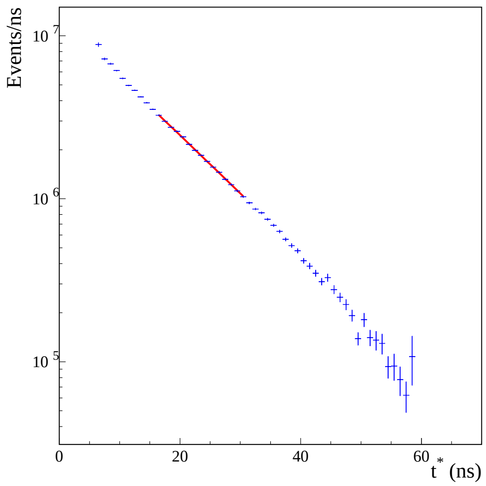

Figure 2. Charged kaon proper time distribution, obtained with the first method, fitted (red line) with a convolution of an exponential and a resolution function

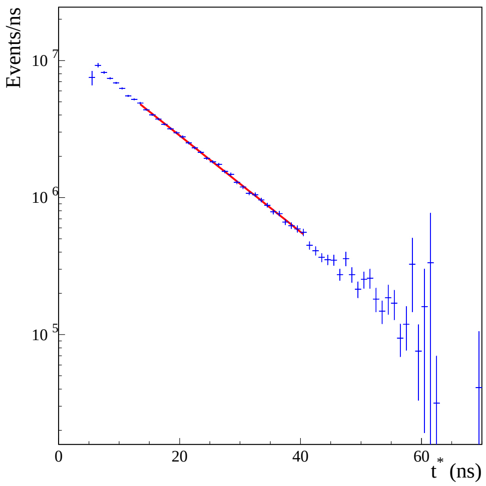

Figure 3. Charged kaon proper time distribution, obtained with the second method, fitted (red line) with a convolution of an exponential and a resolution function

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 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:

$$\tau^{\pm} = (12.391 \pm 0.049 \pm 0.025)\ ns \tag{5}$$

The evaluation of systematic uncertainties is sill preliminary, final numbers will be presented at the conference. 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

$$\rho = .338 \tag{6}$$

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

$$\tau^{\pm} = (12.384 \pm 0.048)\ ns \tag{7}$$

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