RECENT RESULTS ON KAON DECAYS FROM KLOE AT DAΦNE

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The analysis of the full data sample of about 2.5 fb^{-1} collected by the KLOE experiment at DAΦNE is in progress. New results on $K_S \to e^+e^-$, $K_S \to \gamma\gamma$, $K_L \to \pi e \nu \gamma$, and $K_{L\mu 3}$ form factor are presented. The most recent KLOE results on V_{us}, CPT invariance and QM tests are reviewed.

1 The KLOE experiment at DAΦNE

The Frascati ϕ-factory, DAΦNE, is an e^+e^- collider working at a center of mass energy of $\sqrt{s} \sim 1020$ MeV, corresponding to the peak of the ϕ resonance. The ϕ production cross section is $\sim 3\mu$b, and the $\phi \to K^0\bar{K}^0$ decay has a branching fraction of 34%. The beams collide at the interaction point (IP) with a crossing angle $\theta_x \simeq 25$ mrad, therefore ϕ's are produced with a small momentum of ~ 12.5 MeV in the horizontal plane. The typical sizes of the beam are: $\sigma_x = 0.2\,\mathrm{cm}; \sigma_y = 20\,\mu\mathrm{m}; \sigma_z = 3\,\mathrm{cm}$.

The KLOE detector consists mainly of a large volume drift chamber surrounded by an electromagnetic calorimeter. A superconducting coil provides a 0.52 T solenoidal magnetic field.

The fine sampling lead-scintillating fiber calorimeter [1] (EmC) consists of a barrel and two end-caps, and has solid angle coverage of 98%. Photon energies and arrival times are measured with resolutions $\sigma_E/E = 5.7\%/\sqrt{E(\mathrm{GeV})}$ and $\sigma_t = 54\mathrm{ps}/\sqrt{E(\mathrm{GeV})} \oplus 50\mathrm{ps}$, respectively. Photon entry points are determined with an accuracy $\sigma_z \sim 1$ cm$/\sqrt{E(\mathrm{GeV})}$ along the fibers and $\sigma_\perp \sim 1$ cm in the transverse direction.

The tracking detector is a 4 m diameter and 3.3 m long cylindrical drift chamber [2] (DCH) with a total of ~ 52000 wires, of which ~ 12000 are sense wires. In order to minimize multiple scattering and K_L regeneration and to maximize detection efficiency of low energy photons, the chamber works with a helium based gas mixture and its walls are made of light materials (mostly

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carbon fiber composites). The momentum resolution for tracks produced at large polar angle is $\sigma_p/p \leq 0.4\%$. Vertices are reconstructed with a resolution of ~ 3 mm.

At a ϕ-factory the $\phi \to K^0\bar{K}^0$ decay produces the neutral kaon pair in a coherent quantum state with $J^{PC} = 1^{--}$:

$$|i\rangle = \frac{1}{\sqrt{2}}\{|K^0\rangle|\bar{K}^0\rangle - |\bar{K}^0\rangle|K^0\rangle\} = \frac{N}{\sqrt{2}}\{|K_S\rangle|K_L\rangle - |K_L\rangle|K_S\rangle\} \quad (1)$$

where $N = (1+|\epsilon|^2)/(1-\epsilon^2) \simeq 1$ is a normalization factor.

The detection of a kaon at large (small) times *tags* a K_S (K_L) in the opposite direction. At KLOE a K_S is tagged by identifying the interaction of the K_L in the calorimeter (K_L-crash). In fact about 50% of the produced K_L's in $\phi \to K_S K_L$ events reach the calorimeter before decaying; their associated interactions are identified by a high energy, neutral and delayed deposit in the calorimeter, i.e. not associated to any charged track in the event, and delayed of ~ 30 ns (as at KLOE K_L's have a velocity $\beta \sim 0.22$) with respect to a photon coming from the interaction region. Pure K_S samples have been selected exploiting this tagging technique.
A K_L is tagged by detecting a $K_S \to \pi^+\pi^-$ decay near the IP; the invariant mass from the momenta of the two pion tracks is reconstructed with a resolution of ~ 1 GeV, thus allowing the selection of a clean K_L sample.

KLOE completed the data taking in March 2006 with a total integrated luminosity of $\sim$ 2.5 fb^{-1}, corresponding to $\sim 7.5 \times 10^{-9}$ ϕ-mesons produced.

2 New KLOE results on neutral kaon decays

2.1 $K_S \to e^+e^-$

The SM prediction of the branching ratio of $K_S \to e^+e^-$ decay is rather low (BR$= 1.6 \times 10^{-15}$), but quite precise [3], leaving room for possible new physics effects to be detected. A data sample corresponding to 1.3 fb^{-1} has been analyzed; events are selected requiring the presence of a K_S decay, tagged by the detection of a K_L-crash, and two charged tracks coming from the IP, with an invariant mass (in the e^+e^- hypothesis) M_{inv} greater than 420 MeV. A χ^2-like variable is built, based on the measured time of flights of the two particles, E/p, and the transverse distance between the track impact point on the calorimeter and the closest calorimeter cluster. The search for the signal is performed inside a *signal* box in the χ^2-M_{inv} plane, whose definition is optimized with a Monte Carlo (MC) simulation study: $492 \leq M_{inv} \leq 504$ MeV and $\chi^2 \leq 20$. These cuts reject almost all the events due to the background processes $K_S \to \pi^+\pi^- \to \mu\pi$, $K_S \to \pi^+\pi^-$, and $\phi \to \pi^+\pi^-\pi^0$, while retaining 55.8% of the signal. The selection is inclusive for radiated photons with energy in the kaon rest frame $E^*_\gamma < 6$ MeV. We observe $N = 3$ events inside the box, with an expected background of 7.1 ± 3.6 events, corresponding to an upper limit of 4.3 events at 90% c.l.; after normalization to $K_S \to \pi^+\pi^-$ events, we obtain a preliminary result for the branching fraction:

$$\mathrm{BR}(K_S \to e^+e^-(\gamma); E^*_\gamma < 6 \text{ MeV}) < 2.1 \times 10^{-8}$$

at 90% c.l., improving the previous limit [4] by almost an order of magnitude.

2.2 $K_S \to \gamma\gamma$

The measurement of BR($K_S \to \gamma\gamma$) is an important test of chiral perturbation theory, as discussed in Ref.[5]. A data sample corresponding to 1.6 fb^{-1} has been analyzed; events are selected requiring the presence of a K_S decay, tagged by the detection of a K_L-crash, and two and only two photons with an energy greater than 7 MeV, back-to-back in the center of mass system of K_S ($\cos(\theta^{\star}_{\gamma\gamma}) \leq -0.95$), and coming from the IP ($T_\gamma - R/c \simeq 0$). A kinematic fit constrains the time, momentum, and invariant mass $M_{\gamma\gamma}$ of the two photons. In order to further reduce the copious background due to $K_S \to 2\pi^0$ with two undetected photons, a veto on the signal of two small calorimeters surrounding the focusing quadrupoles near the IP is applied. The background due to $K_L \to \gamma\gamma$ decays is absent due to the high purity of the K_S sample. The overall efficiency on the signal is $\sim 52\%$. Finally, the signal counts are obtained by fitting the $M_{\gamma\gamma}$ and $\cos(\theta^{\star}_{\gamma\gamma})$ bi-dimensional distribution with signal and background distributions obtained from MC. The reconstructed energy scale is well kept under control by comparing data samples of $K_S \to 2\pi^0$ and $K_L \to \gamma\gamma$ events with MC. The preliminary result is

$$\mathrm{BR}(K_S \to \gamma\gamma) = (2.35 \pm 0.14) \times 10^{-6}$$

in agreement with $\mathcal{O}(p^4)$ chiral perturbation theory calculation, and not confirming the discrepancy of $\sim 30\%$ found by the NA48 collaboration [6].

2.3 $K_L \to \pi e \nu \gamma$

Radiative effects play an important role in kaon semileptonic decays. Both inner bremsstrahlung (IB) and structure dependent (SD) amplitudes contribute to the $K_L \to \pi e \nu \gamma$ process, as discussed in Ref. [7]. A data sample corresponding to ~ 330 pb^{-1} has been analyzed; inclusive selection of $K_L \to \pi e \nu(\gamma)$ events requires a K_L of known momentum and direction, tagged by $K_S \to \pi^+\pi^-$ decay near the IP. In a fiducial volume extending for $\sim 0.4\lambda_L$, two-track decay vertices are selected around the K_L line of flight; the vast majority of the background due to $K_L \to \pi\mu\nu$, and $\pi^+\pi^-\pi^0$ is rejected by cutting on the $E_{miss} - P_{miss}$ distribution, where P_{miss} and E_{miss} are the missing momentum and missing energy evaluated in the hypothesis of pion and muon daughter particles. A time of flight technique is used to identify electron and pion tracks. The radiative events are selected by further requiring the detection of a photon with a time of flight compatible with the decay vertex; the cluster position is used to close the kinematics $p_\nu^2 = 0 = (p_K - p_\pi - p_e - p_\gamma)^2$, and evaluate the energy E_γ of the photon. A control sample of $K_L \to \pi^+\pi^-\pi^0$ decays is used to check the photon efficiency, energy and vertex resolutions. Finally, the signal counts are obtained by fitting the $E^{\star}_\gamma$ and $\theta^{\star}_{e-\gamma}$ bi-dimensional distribution, where $\theta^{\star}_{e-\gamma}$ is the angle between the electron and the photon [b], with signal and background distributions obtained from MC.

The preliminary result for the ratio $R = \mathrm{BR}(K_L \to \pi e \nu \gamma)/\mathrm{BR}(K_L \to \pi e \nu(\gamma))$, with the cuts for the exclusive channel $E^{\star}_\gamma > 30$ MeV, and $\theta^{\star}_{e-\gamma} > 20°$, is:

$$R = (0.92 \pm 0.02_{\mathrm{stat}} \pm 0.02_{\mathrm{syst}})\% \ .$$

By using the SD spectrum shape evaluated in Ref. [7], we are also able to measure the SD contribution:

$$\mathrm{BR_{SD}}(K_L \to \pi e \nu \gamma) = (-3.1 \pm 3.0) \times 10^{-5} \ ; \qquad \mathrm{BR_{SD}} \leq 2.5 \times 10^{-5} \ @ \ 90\% \ \mathrm{c.l.} \ ,$$

in agreement with theoretical predictions based on chiral perturbation theory calculation [7].

The accuracy of the KLOE result on R is not sufficient to shed light on the discrepancy between previous measurements by KTeV and NA48 collaborations [8,9]. However the analysis of the full KLOE data sample (statistics $\times 5$) will improve the accuracy on both R and $\mathrm{BR_{SD}}$ results.

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[b] The symbol $\star$ indicates quantities evaluated in the kaon rest frame

2.4 $K_{L\mu3}$ form factor slope λ_0

The knowledge of the K_L scalar form factor $f_0(t)$, where t is the momentum transfer, is relevant for the determination of V_{us} and to test e/μ universality; typically a linear parametrization is used $f_0(t) \propto 1+\lambda_0(t/m^2_{\pi^+})$, where the slope λ_0 is a parameter to be experimentally determined. A data sample corresponding to $\sim$ 330 pb^{-1} has been analyzed; $K_{L\mu3}$ events are selected requiring a K_L of known momentum and direction, tagged by $K_S \to \pi^+\pi^-$ decay near the IP. In a fiducial volume extending for $\sim 0.4\lambda_L$, two-track decay vertices are selected around the K_L line of flight; the background due to $K_L \to \pi e\nu$, $\pi^+\pi^-\pi^0$, and $\pi^+\pi^-$ is rejected by cutting on different combinations of E_{miss} and P_{miss} variables, where E_{miss} is evaluated in different masses hypothesis for the daughter particles. The same variables are used to select the signal. A further reduction of the background at the level of $\sim 1.5\%$ is obtained using neural network and time of flight techniques. The analysis of $K_{L\mu3}$ decays for the measurement of the slope parameter λ_0 is more complicated than for K_{Le3} decays [11] because pure and efficient $\pi - \mu$ separation is much more difficult to achieve. In order to overcome this problem, the analysis aims at measuring λ_0 through a fit to the distribution of the neutrino energy E_ν, which can be evaluated through a Lorentz transformation of the missing momentum $\vec{P}_{miss}$ in the K_L rest frame. As a consequence the sensitivity on form factor slope λ_0 is slightly reduced with respect to that achieved from a fit on the t distribution. A combined fit of the neutrino energy spectrum with K_{Le3} results for the vector form factor slopes λ'_+, λ''_+ [11] yields the following preliminary result:

$$\lambda_0 = (15.6 \pm 1.8_{\rm stat} \pm 1.9_{\rm syst}) \times 10^{-3}$$

with an accuracy similar to other measurements [12]. The relative statistical accuracy will be in the range $5 - 10\%$ with the analysis of the full KLOE data sample.

3 KLOE summary on V_{us}

The most precise test of the unitarity of the CKM matrix can be performed from its first row. Defining $\Delta = |V_{\rm ud}|^2 + |V_{\rm us}|^2 + |V_{ub}|^2 - 1$, an accuracy of few parts in 10^{-4} on Δ can be reached. The contribution of $|V_{ub}|^2$ is negligible [12]; the determination of $|V_{\rm ud}|$ form super-allowed nuclear beta decays gives an uncertainty of 5×10^{-4} on Δ [13]. A similar accuracy can be reached extracting $|V_{\rm us}|$ from the rates of semileptonic kaon decays:

$$\Gamma^i(K_{e3(\gamma),\mu3(\gamma)}) = \frac{C_i^2 G^2 M^5}{128\pi^3} S_{\rm EW}|V_{\rm us}|^2|f_+(0)|^2 I^i_{e3,\mu3}(1+\delta^i_{e3,\mu3}) \quad (2)$$

where the index i refers to $K^0 \to \pi^-$ or $K^+ \to \pi^0$ transitions for which $C_i^2 = 1$ or $1/2$, respectively, G is the Fermi constant, M is the appropriate kaon mass, and $S_{\rm EW}$ is a universal short-distance electroweak correction [14]. The δ^i term accounts for long-distance radiative corrections depending on the meson charges and lepton masses and, for $K^\pm$, for isospin-breaking effects. The $f_+(0)$ form factor parametrizes the vector-current transition $K^0 \to \pi^-$ at zero momentum transfer t, while the dependence of vector and scalar form factors on t enters into the determination of the integrals $I_{e3,\mu3}$ of the Dalitz-plot density over the physical region.

The experimental inputs in Eq.(2) are the semileptonic decay widths, evaluated from the γ-inclusive BR's and from the kaon lifetimes, and the parameters describing the t-dependence of the vector and scalar form factors. The KLOE experiment provides measurements for all these quantities [c] with the only exception of the K_S lifetime; taking the τ_S from Ref. [12], the values of $|V_{\rm us}|f_+(0)$ are obtained from KLOE measurements for different decay modes, as listed in Table 1. The best accuracy, $\sim 0.3\%$, is obtained from K_{Le3} mode, with the error dominated

[c] For the recent KLOE measurement of $\tau_\pm$ see Ref. [15].

Table 1: Summary of KLOE measurements of $|V_{\rm us}|f_+(0)$.

Mode	$\lvert V_{\rm us}\rvert f_+(0)$
K_{Le3}	0.2156(7)
$K_{L\mu3}$	0.2163(10)
K_{Se3}	0.2154(14)
$K^{\pm}_{e3}$	0.2168(22)
$K^{\pm}_{\mu3}$	0.2151(30)
Average	0.2158(6)

by the knowledge of τ_L. Using the value of $f_+(0) = 0.961(8)$ evaluated by Leutwyler and Roos [16], the value of $V_{\rm us} = 0.2246(20)$ from KLOE average for $K_{\ell 3}$ modes is obtained; using the world average [13] value of $V_{\rm ud} = 0.97377(27)$, we get $\Delta = (-13 \pm 10) \times 10^{-4}$. A combined analysis of all available experimental results in order to extract $|V_{\rm us}|$ is discussed in detail elsewhere [17].

The values of $V_{\rm us}$ obtained from K_{e3} and $K_{\mu3}$ decays can also be used to test the universality of e and μ couplings to the W boson. KLOE results are compatible with a ratio of effective Fermi constants equal to unity:

$$[G(\mu3)/G(e3)]^2 = 1.0065(98) \qquad \text{for } K_L$$

$$[G(\mu3)/G(e3)]^2 = 0.984(25) \qquad \text{for } K^{\pm} \quad .$$

From the measured ratio $\Gamma(K \to \mu\nu)/\Gamma(\pi \to \mu\nu)$ of radiation-inclusive kaon and pion widths for $\mu\nu$ decays, the ratio $|V_{\rm us}/V_{\rm ud}|$ can be extracted, using as theoretical inputs the form factor ratio f_K/f_π from lattice calculation [19], and a radiative correction factor from Ref.[18]. From the precise KLOE measurement [20] $\mathrm{BR}(K^+ \to \mu^+\nu) = 0.6366 \pm 0.0009_{\rm stat} \pm 0.0015_{\rm syst}$, and using PDG values [12] for the other experimental inputs, we get:

$$|V_{\rm us}/V_{\rm ud}| = 0.2286 \left({}^{+27}_{-15}\right) \quad .$$

This result can be fit togheter with the values of $V_{\rm us}$ from KLOE average and $V_{\rm ud}$ from Ref.[13], yielding the result $V_{\rm us} = 0.2239(16)$ and $\Delta = (16 \pm 12) \times 10^{-4}$ with a χ^2 probability of 56%, demonstrating the consistency of KLOE measurements, and giving no indication of any violation of CKM unitarity.

4 CPT Test from Bell-Steinberger Relation

The Bell-Steinberger relation (BSR) [21] relates a possible violation of CPT invariance ($m_{K^0} \neq m_{\bar{K}^0}$ and/or $\Gamma_{K^0} \neq \Gamma_{\bar{K}^0}$) in the time-evolution of the K^0–$\bar{K}^0$ system to the observable CP-violating interference of K_L and K_S decays into the same final state f. The BSR relation can be written in the following form :

$$\left(\frac{\Gamma_S + \Gamma_L}{\Gamma_S - \Gamma_L} + i \tan\phi_{SW}\right)\left(\frac{\Re(\epsilon)}{1+|\epsilon|^2} - i\Im(\delta)\right) = \frac{1}{\Gamma_S - \Gamma_L}\sum_f \mathcal{A}^*_S(f)\mathcal{A}_L(f) \tag{3}$$

without approximations, and phase-convention independent in the exact CPT limit [22], where ϵ and δ are the usual T and CPT violating parameters in the kaon mixing, respectively, ϕ_{SW} is the superweak phase, and $\mathcal{A}_{S,L}(f)$ are the decay amplitudes of $K_{S,L}$ into the final state f. The solution of Eq. 3 is given by:

$$\begin{pmatrix} \dfrac{\Re(\epsilon)}{1+|\epsilon|^2} \\ \Im(\delta) \end{pmatrix} = \frac{1}{N}\begin{pmatrix} 1+\kappa(1-2b) & (1-\kappa)\tan\phi_{\rm SW} \\ (1-\kappa)\tan\phi_{\rm SW} & -(1+\kappa) \end{pmatrix}\begin{pmatrix} \Sigma_f \Re(\alpha_f) \\ \Sigma_f \Im(\alpha_f) \end{pmatrix}, \tag{4}$$

where on the r.h.s. there are all measurable quantities; the α_f parameters are conveniently defined as follows for the main final states:

$$\alpha_{\pi\pi} \equiv \frac{1}{\Gamma_S} \langle \mathcal{A}_L(f)\mathcal{A}_S^*(f)\rangle = \eta_f \ \mathrm{BR}(K_S \to f) \ , \qquad f = \pi^0\pi^0 \ , \ \pi^+\pi^-(\gamma), \tag{5}$$

$$\alpha_{\pi\pi\pi} \equiv \frac{1}{\Gamma_S}\langle \mathcal{A}_L(f)\mathcal{A}_S^*(f)\rangle = \frac{\tau_{K_S}}{\tau_{K_L}}\eta_f^* \ \mathrm{BR}(K_L \to f), \qquad f = 3\pi^0 \ , \ \pi^0\pi^+\pi^-(\gamma). \tag{6}$$

$$\begin{aligned}\alpha_{\pi\ell\nu} &\equiv \frac{1}{\Gamma_S}\sum_{\pi\ell\nu}\langle \mathcal{A}_L(\pi\ell\nu)\mathcal{A}_S^*(\pi\ell\nu)\rangle + 2i\frac{\tau_{K_S}}{\tau_{K_L}} \mathrm{BR}(K_L \to \pi\ell\nu)\Im(\delta) \\ &= 2\frac{\tau_{K_S}}{\tau_{K_L}} \mathrm{BR}(K_L \to \pi\ell\nu)\left((A_S + A_L)/4 - i\Im(x_+)\right),\end{aligned} \tag{7}$$

with $\eta_i = \mathcal{A}_L(i)/\mathcal{A}_S(i)$, $A_{S,L}$ is the semileptonic charge asymmetry for $K_{S,L}$, $\Im(x_+)$ is the $\Delta S = \Delta Q$ violating and CPT conserving parameter for semileptonic decay amplitudes, and $\kappa = \tau_{K_S}/\tau_{K_L}$, $b = \mathrm{BR}(K_L \to \pi\ell\nu)$, $N = (1+\kappa)^2 + (1-\kappa)^2\tan^2\phi_{\mathrm{SW}} - 2\,b\,\kappa(1+\kappa)$.

After having provided all the experimental inputs to Eq.(4) by using KLOE measurements, PDG values, and a combined fit of KLOE and CPLEAR data in order to improve the precision on $\Im(x_+)$, we obtain [d]:

$$\Re(\epsilon) = (159.6 \pm 1.3) \times 10^{-5} \ , \qquad \Im(\delta) = (0.4 \pm 2.1) \times 10^{-5}$$

improving by almost a factor three the previous best limit on $\Im(\delta)$ from CPLEAR [23]. The main limiting factor of the present result is the uncertainty on the phase of $\eta_{\pi^+\pi^-}$ parameter entering in $\alpha_{\pi^+\pi^-}$. In fact, using the KLOE upper limit on $\mathrm{BR}(K_S \to 3\pi^0)$ [24] and the A_S measurement [25], $\alpha_{\pi^0\pi^0\pi^0}$ and $\alpha_{\pi l\nu}$ do not limit anymore the test sensitivity.

The limits on $\Im(\delta)$ and $\Re(\delta)$ [26] can be used to constrain the mass and width difference between K^0 and $\bar{K}^0$. Since the total decay widths are dominated by long-distance dynamics, in models where CPT invariance is a pure short-distance phenomenon, it is useful to consider the limit $\Gamma_{K^0} = \Gamma_{\bar{K}^0}$. In this limit we obtain the following bound on the neutral kaon mass difference:

$$-5.3 \times 10^{-19}\ \mathrm{GeV} < \Delta M < 6.3 \times 10^{-19}\ \mathrm{GeV} \quad \text{at 95 \% CL}.$$

5 Decoherence and CPT Tests Using Kaon Interferometry

The quantum interference between the two kaon decays in the CP violating channel $\phi \to K_S K_L \to \pi^+\pi^-\pi^+\pi^-$ has been observed for the first time by KLOE [27]. A data sample corresponding to $\sim 330\ \mathrm{pb}^{-1}$ has been analysed; the selection of the signal requires two vertices, each with two opposite curvature tracks inside the drift chamber, with an invariant mass and total momentum compatible with the two neutral kaon decays. The experimental resolution on the time difference $\Delta t = |t_1 - t_2|$ in the case of $\pi^+\pi^-$ decays can be improved exploiting the good momentum resolution of the KLOE detector and the closed kinematics of the event. After a kinematic fit, a resolution $\sigma_{\Delta t} \sim 0.9\tau_S$ is obtained. The measured Δt distribution can be fitted with the expression:

$$I(\pi^+\pi^-,\pi^+\pi^-;\Delta t) \propto e^{-\Gamma_L\Delta t} + e^{-\Gamma_S\Delta t} - 2(1-\zeta_{SL})e^{-\frac{(\Gamma_S+\Gamma_L)}{2}\Delta t}\cos(\Delta m\Delta t)$$

where the quantum mechanical expression in the $\{K_S, K_L\}$ basis has been modified with the introduction of a decoherence parameter ζ_{SL}, and a factor $(1-\zeta_{SL})$ multiplying the interference

[d] See Ref. [22] for a detailed discussion on the fit procedure.

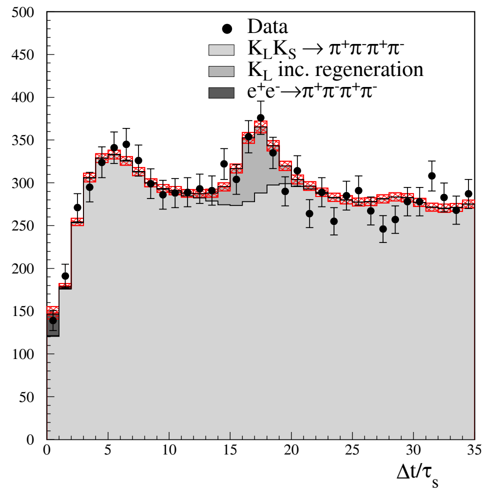

Figure 1: Δt distribution from the fit used to determine ζ_{SL}. The black points with errors are data and the solid histogram is the fit result. The uncertainty arising from the efficiency correction is shown as the hatched area.

term. Analogously, a $\zeta_{0\bar{0}}$ parameter can be defined in the $\{K^0, \bar{K}^0\}$ basis[28]. After having included resolution and detection efficiency effects, having taken into account the background due to coherent and incoherent K_S-regeneration on the beam pipe wall, the small contamination of non-resonant $e^+e^- \to \pi^+\pi^-\pi^+\pi^-$ events, and keeping fixed in the fit Δm, Γ_S and Γ_L to the PDG values, a fit is performed on the Δt distribution, as shown in Fig.1. The fit results are:

$$\begin{aligned} \zeta_{SL} &= 0.018 \pm 0.040_{\text{stat}} \pm 0.007_{\text{syst}} \\ \zeta_{0\bar{0}} &= (1.0 \pm 2.1_{\text{stat}} \pm 0.4_{\text{syst}}) \times 10^{-6} \end{aligned}$$

compatible with the quantum mechanics prediction, i.e. $\zeta_{SL} = \zeta_{0\bar{0}} = 0$, and no decoherence effects. In particular the result on $\zeta_{0\bar{0}}$ has a high accuracy, $\mathcal{O}(10^{-6})$, due to the CP suppression present in the specific decay channel; it improves of five orders of magnitude the previous limit obtained by Bertlmann and co-workers [28] in a re-analysis of CPLEAR data. This result can also be compared to a similar one recently obtained in the B meson system [29], where an accuracy $\mathcal{O}(10^{-2})$ can be reached.

It has been pointed out [30,31] that in the context of a hypothetical quantum gravity, CPT violation effects might occur in correlated neutral kaon states, where the resulting loss of particle-antiparticle identity could induce a breakdown of the correlation of state (1) imposed by Bose statistics. As a result the initial state (1) can be parametrized in general as:

$$|i\rangle = \frac{1}{\sqrt{2}} \left[|K^0\rangle|\bar{K}^0\rangle - |\bar{K}^0\rangle|K^0\rangle + \omega \left(|K^0\rangle|\bar{K}^0\rangle + |\bar{K}^0\rangle|K^0\rangle \right) \right] \ , \tag{8}$$

where ω is a complex parameter describing a completely novel CPT violation phenomenon, not included in previous analyses. Its order of magnitude could be at most

$$|\omega| \sim \left[(m_K^2 / M_{\text{Planck}}) / \Delta\Gamma \right]^{1/2} \sim 10^{-3}$$

with $\Delta\Gamma = \Gamma_S - \Gamma_L$. A similar analysis performed on the same data as before, including in the fit of the Δt distribution the modified initial state Eq.(8), yields the first measurement of the complex parameter ω [27]:

$$\Re(\omega) = \left(1.1^{+8.7}_{-5.3} \pm 0.9 \right) \times 10^{-4} \qquad \Im(\omega) = \left(3.4^{+4.8}_{-5.0} \pm 0.6 \right) \times 10^{-4} \ ;$$

with an accuracy that already reaches the interesting Planck's scale region. Other interesting results related to possible decoherence and CPT violation in the quantum gravity framework are discussed in Ref. [27].

Conclusions

New preliminary results on $K_S \to e^+e^-$, $K_S \to \gamma\gamma$, $K_L \to \pi e \nu \gamma$, and $K_{L\mu 3}$ form factor have been presented, and some recent results on V_{us}, CPT invariance and QM tests reviewed. The analysis of the full data sample of about 2.5 fb^{-1} is in progress, and new or improved results will be available in the next future. In the meanwhile the possibility to continue the KLOE physics program at DAΦNE with an improved luminosity at the ϕ peak up to $\sim 10^{33}$cm^{-2}s^{-1} is strongly considered.

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