Test of CPT symmetry with the KLOE detector

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KLOE and KLOE-2

The ϕ-factory DAΦNE is localized in the National Laboratory in Frascati (LNF-INFN, Italy). This collider operates at the peak of ϕ resonance ($\sqrt{s} = m_\phi \approx 1019\ MeV$) and it is the natural place for kaon physics studies, since a ϕ meson decays mostly into kaon pairs (49% into K^+K^- and 34% into K_SK_L). The KLOE detector collected 2.5 fb^{-1} of integrated luminosity [1] from 2001 to 2006. The KLOE-2 data-taking started in 2014 and finished this year resulting in 5.5 fb^{-1} of integrated luminosity. Together, KLOE and KLOE-2 provide the largest sample of $e^+e^- \to \phi$ events.

The main components of the detector are a cylindrical drift chamber [2] and an electromagnetic calorimeter [3] surrounded by a superconducting coil which produces an axial magnetic field parallel to the beam axis. From the point of view of kaon physics the crucial modification for KLOE-2 system was installation of a light-material Inner Tracker detector. It is based on the Cylindrical GEM technology to improve charged vertex reconstruction and to increase the acceptance for low transverse momentum tracks [4–6].

Reconstruction of the $K_S \to \pi^+\pi^-$ (BR=69%) decay close to interaction region allows to tag a K_L presence which makes KLOE an excellent place for K_L decay measurements. A study of pure K_S beams is also possible via detection of the K_L hit in the calorimeter module, which is a unique property of KLOE system. Since both kaons are produced in a pure quantum state ($J^{PC} = 1^{--}$), it is possible to study e.g. quantum interference effects. Details about whole KLOE-2 physics program can be found in Ref. [7].

CPT symmetry test via measurement of charge asymmetry of K_S

The charge asymmetry for semileptonic decays of neutral kaons can be defined as follows:

$$A_{S,L} = \frac{\Gamma(K_{S,L} \to \pi^- e^+ \nu) - \Gamma(K_{S,L} \to \pi^+ e^- \bar{\nu})}{\Gamma(K_{S,L} \to \pi^- e^+ \nu) + \Gamma(K_{S,L} \to \pi^+ e^- \bar{\nu})} = 2\left[Re\left(\epsilon_{S,L}\right) - Re(y) \pm Re(x_-)\right] \quad (1)$$

to the first order in parameters ϵ_S, ϵ_L which can be expressed in terms of the CP and CPT violation parameters ϵ_K and δ_K, respectively:

$$\epsilon_{L/S} = \epsilon_K \mp \delta_K. \quad (2)$$

Sum and difference of the A_S and A_L allow to search for the CPT symmetry violation, either in the decay amplitudes through the parameter y or in the mass matrix through the parameter δ_K:

$$\begin{aligned} A_S + A_L &= 4Re(\epsilon) - 4Re\left(y\right), \\ A_S - A_L &= 4Re(\delta_K) + 4Re\left(x_-\right). \end{aligned} \quad (3)$$

The charge asymmetry was measured by the KTeV experiment for long-lived kaon [8] and by the KLOE - for the short-lived one [9]:

$$\begin{aligned} A_L &= (3.322 \pm 0.058_{stat} \pm 0.047_{syst}) \times 10^{-3}, \\ A_S &= (1.5 \pm 9.6_{stat} \pm 2.9_{syst}) \times 10^{-3}. \end{aligned} \quad (4)$$

Presently the additional KLOE data set of 1.7 fb^{-1} was analyzed. The best separation between the signal and background components is obtained with the variable:

$$M^2(e) = \left[E_{K_S} - E(\pi) - E_\nu\right]^2 - p^2(e), \quad (5)$$

where $E_\nu = |\vec{p}_{K_S} - \vec{p}(e) - \vec{p}(\pi)|$ (FIG. 1). The result is [10]:

$$A_S = (-4.9 \pm 5.7_{stat} \pm 2.6_{syst}) \times 10^{-3}, \quad (6)$$

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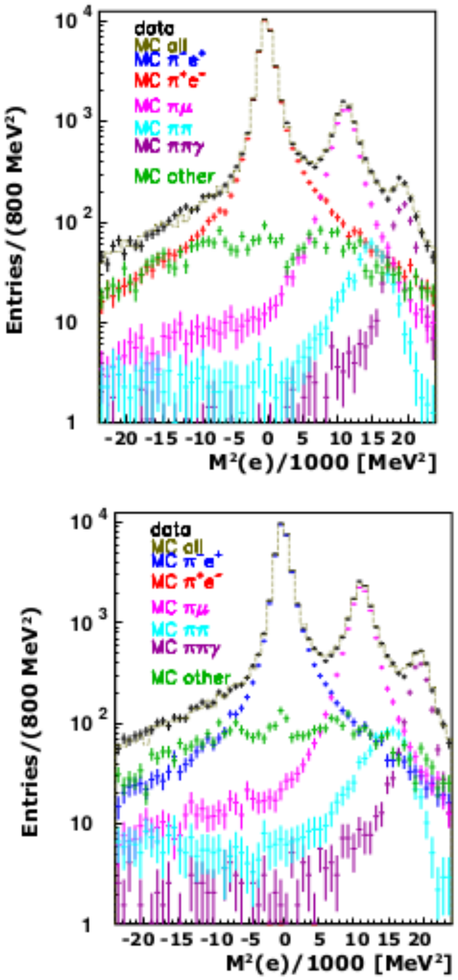

FIG. 1: $M^2(e)$ distribution for data (black points) and MC simulation (dotted histogram) for both final charge states (π^+e^- – upper panel, π^-e^+ – bottom panel).

while the combined result of both KLOE measurements is:

$$A_S = (-3.8 \pm 5.0_{stat} \pm 2.6_{syst}) \times 10^{-3} \quad (7)$$

The extracted CPT violating parameters $Re(x_-)$ and $Re(y)$:

$$Re(x_-) = (-2.0 \pm 1.4) \times 10^{-3}, \quad (8)$$

$$Re(y) = (1.7 \pm 1.4) \times 10^{-3}, \quad (9)$$

are consistent with CPT invariance.

Based on the KLOE-2 data sample a measurement of A_S with a statistical uncertainty at the level of 3×10^{-3} is possible.

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