Test of CPT symmetry with the KLOE detector

E. Czerwiński[1] on behalf of the KLOE-2 Collaboration*
[1] *Jagiellonian University, Faculty of Physics, Astronomy and Applied Computer Science, Institute of Physics, Kraków, Poland*

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].

*Electronic address: `eryk.czerwinski@uj.edu.pl`

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:

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

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:

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

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

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

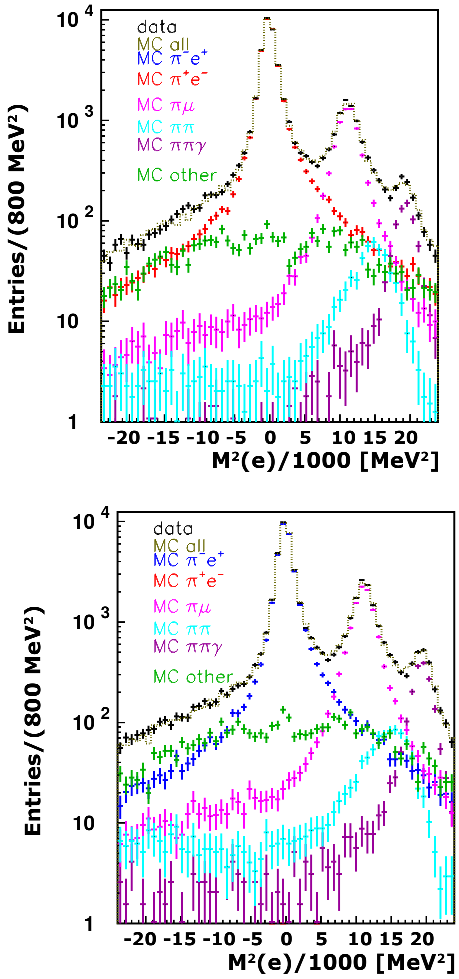

FIG. 1: $M^2(e)$ distribution for data (black points) and MC simulation (dotted histogram) for both final charge states (π^+e^- – upper panel, π^-e^+ – bottom panel).

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.

Acknowledgments

We warmly thank our former KLOE colleagues for the access to the data collected during the KLOE data taking campaign. We thank the DANE team for their efforts in maintaining low background running conditions and their collaboration during all data taking. We want to thank our technical staff: G.F. Fortugno and F. Sborzacchi for their dedication in ensuring efficient operation of the KLOE computing facilities; M. Anelli for his continuous attention to the gas system and detector safety; A. Balla, M. Gatta, G. Corradi and G. Papalino for electronics maintenance; C. Piscitelli for his help during major maintenance periods. This work was supported in part by the Polish National Science Centre through the Grants No. 2013/11/B/ST2/04245, 2014/14/E/ST2/00262,2014/12/S/ST2/00459, 2016/21/N/ST2/01727,2016/23/N/ST2/01293, 2017/26/M/ST2/00697.

References

[1] F. Bossi *et al.*, Rivista del Nuovo Cimento Vol.31 (2008) N.10

[2] M. Adinolfi *et al.*, Nucl. Instrum. Meth. A **461** (2001) 25

[3] M. Adinolfi *et al.*, Nucl. Instrum. Meth. A **482** (2002) 364

[4] M. Alfonsi *et al.*, *Nucl. Instr. & Meth. A* **617** (2010) 151

[5] A. Balla *et al.*, Nucl. Instrum. Meth. A **845** (2017) 266

[6] A. Balla *et al.*, Nucl. Instr. & Meth. A **604** (2009) 23

[7] G. Amelino-Camelia *et al.*, Eur. Phys. J. C **68** (2010) 619

[8] A. Alavi-Harati *et al.*, Phys. Rev. Lett. 88 (2002) 181601

[9] F. Ambrosino *et al.*, Phys. Lett. B636 (2006) 173

[10] A. Anastasi *et al.*,JHEP **1809** (2018) 021