1 Goal of the research

The goal of the proposed project is conducting a direct test of the fundamental symmetry under reversal in time with the quantum-entangled system of neutral K mesons. The direct test is possible by means of a comparison of probabilities of a physical process and its inverse under time reversal, obtained through an exchange of an initial and final state of the process. In the proposed test, transitions of neutral K mesons between their strangeness-definite states and eigenstates of the CP operator. For each such transition it is possible to obtain its time-inversed transition and their recording is made possible by quantum entanglement of neutral kaon pairs produced in decays of the ϕ meson. A direct T symmetry test defined in this manner is free of the influence of CP symmetry violation in the neutral kaon system.

The proposed project will be the second test of the T symmetry in the world performed in a direct manner independent of CP violation, as well as the first such measurement in the neutral K meson system (the first one utilized the B mesons).

2 Methodology

The research will be conducted by analyzing the decays of ϕ mesons i.a. into neutral kaon pairs recorded in the years 2004-2005 by the KLOE detector located in the Italian laboratory Laboratori Nazionali di Frascati. The integrated luminosity of the available data amounts to 1.9 fb^{-1}, which corresponds to about 10^{10} of ϕ meson decays. The KLOE experiment is the only setup worldwide, in which neutral K meson pairs are available in a quantum-entangled state, which is an inevitable requirement of the proposed T symmetry test.

The test will be based on a comparison of probabilities of neutral kaon transitions, whose experimental measure will be the distributions of numbers of events in which both neutral kaons of the entangled pair undergo specific decays identifying their states in the strangeness basis or the basis of CP operator eigenstates. The determined distributions will be dependent on the difference of decay times of both kaons which will be reconstructed with a resolution at the level of $\mathcal{O}(1\tau_S)$.

Particular compared transitions will be identified by two classes of processes: $\phi \to \mathrm{K_S K_L} \to \pi^{\pm}\ell^{\mp}\nu\ 3\pi^0$ and $\phi \to \mathrm{K_S K_L} \to \pi^+\pi^-\ \pi^{\mp}\ell^{\pm}\nu$. Reconstruction of the former will use a technique of reconstruction of the $\mathrm{K_L} \to 3\pi^0$ decay devised by the main investigator of the proposed project.

3 Influence of the expected results on the development of science, civilization and society

The result of the performed measurement of the level of time reversal symmetry violation will contribute to deepening of the knowledge on fundamental symmetries and interactions, as well as allow to verify the presently existing theoretical models in which T symmetry violation is an effect expected on the basis of CPT symmetry conservation and CP violation observed already multiple times. Moreover, as the second measurement of this type worldwide, this result will be essential for a verification or confirmation of the only direct observation of T symmetry violation to date, made in the neutral B meson system.