A search for directional violations of the Lorentz invariance through the study of a possible asymmetry of particle lifetimes

M. De Maria*, M. Antonelli†, A. De Angelis‡, and M. Dreucci*
on behalf of the KLOE Collaboration

Possible violations of the Lorentz invariance have been recently suggested to explain anomalies in the propagation of cosmic rays and the transparency of the Universe to gamma rays [1, 2, 3]. Violations of the Lorentz invariance might in particular imply the existence of a preferred reference frame. A global anisotropy might explain a possible different behavior of photon propagation for different high energy gamma sources.

The Cosmic Microwave Background (CMB) dipole anisotropy, interpreted as a Doppler effect, indicates the motion of the Local Group in the direction $(\ell, b)_{\rm CMB} = (264°, 48°)$ in galactic coordinates, with a speed of $V = (369 \pm 1)$ km/s [4], i.e., $V/c = (1.231 \pm 0.003) \times 10^{-3}$. The CMB is a unique rest frame: even if this fact does not imply by itself any anisotropy of the physical laws, the existence of such a natural rest frame provides a rational framework for the interpretation of any asymmetry that might possibly be discovered.

Many experiments measuring particle lifetimes [5] give evidence for a time dilation in accordance with the Lorentz transformations, predicted by Special Relativity. Such experimental verifications do not rule out however that the lifetime of the particles depends on their direction of motion; present isotropy tests are less accurate [6].

Collider detectors with 4π acceptance, like KLOE at the DAFNE accelerator in Frascati, can be used as a probe for detecting asymmetries in the Universe [6]: the Earth's rotation provides in the different seasons and hours of the day different orientations of the symmetry axes with respect to arbitrary directions that allow averaging detector effects. A test of the isotropy of K_S^0 lifetime has been done [7] by comparing the lifetimes of K_S^0 measured by KLOE parallel and antiparallel with respect to the direction of motion of the particles with respect to the CMB system.

Selected data on K_S^0 decays into charged pion pairs have been used from the data collected by KLOE in 2004 and 2005. After a severe quality selection, a total sample of about 62.3 million well reconstructed decays has been used. The K_S^0 momentum has been transformed from local-KLOE into galactic coordinates [7]. We retained only events inside a cone with an opening angle of 30°, parallel (*up*) and antiparallel (*down*) to the direction of motion with respect to the CMB, and in each cone we fit the K_S^0 lifetime, τ. We define the asymmetry A_{cone} as $A_{cone} = (\tau_{up} - \tau_{down})/(\tau_{up} + \tau_{down})$, founding $A = (0.13 \pm 0.40) \times 10^{-3}$, consistent with zero. As a cross check, the asymmetry has been measured in two directions perpendicular to the direction of motion with respect to the CMB, and found again to be consistent with zero. The present result on the asymmetry with respect to a cone translates in an upper limit at 95% CL referred to the direction of motion with respect to the CMB:

$$|A|_{\rm CMB} = \frac{|\tau_{+CMB} - \tau_{-CMB}|}{\tau_{+CMB} + \tau_{-CMB}} < 0.98 \times 10^{-3}\,(95\%\,{\rm CL})\,.$$

This result sets limits to non-relativistic theories, and to possible anisotropical interactions of neutral kaons with the matter in the universe, in an unexplored domain, improving by one order of magnitude the results in [6]. The present upper limit on the asymmetry is smaller than the relative velocity, in natural units, of the Solar System with respect to the CMB.

References

[1] S. Coleman and S.L. Glashow 1997, Phys. Lett. B405, 249

[2] T. Kifune 1999, Astrophys. J. 518, L21

[3] F. Stecker, invited talk at SCINEGHE 2009, Perugia

[4] K. Nakamura et al. (Particle Data Group) 2010, J. Phys. G37, 075021

[5] For a review of the test of time dilation see Y.Z. Zhang 1997, "Special Relativity and Its Experimental Foundations", World Scientific (Singapore)

[6] A. De Angelis and B. Smalska 1996, "Search for Intrinsic Anisotropies of Time Dilation", CERN DELPHI 1996 141 PHYS 640 (Geneva)

[7] M. De Maria 2010, "Searching for Intrinsic Anisotropies of the Universe through the Study of Kaon Liferimes", PhD Thesis at the University of Udine (see http://www.infn.it); KLOE Collaboration, to appear.

*Università IUAV di Venezia and INFN Trieste, Italy
†Laboratori Nazionali di Frascati dell'INFN, Frascati, Italy
‡Università di Udine and INFN Trieste, Italy