On Estimating the Loss Rate of Ultracold Neutrons in Material Traps

P.D. Grigoriev[1,2*], V.D. Kochev[2,1]

[1]*L.D. Landau Institute for Theoretical Physics RAS, Chernogolovka, 142432, Russia*
[2]*National University of Science and Technology «MISIS», Moscow, 119049 Russia*
**E-mail: grigorev@itp.ac.ru*

The accurate estimate of loss rate of ultracold neutrons (UCN) by the absorption inside the walls of material traps is important for precise measurements of neutron lifetime and for other UCN experiments. The typical difference between the measured UCN storage time τ_{st} and the neutron beta-decay time τ_n exceeds 20 seconds, while the systematic error of τ_n measurements is less than 1 second. Such a high precision is achieved by the accurate estimate of UCN loss rate using the geometry and temperature extrapolation. The standard geometry extrapolation to extract the neutron lifetime from the measured storage time is complicated by the energy dependence of the effective collision frequency and by the effect of Earth gravity field. The latter is, usually, taken into account via the dependence of neutron kinetic energy on its height above the trap bottom, with a subsequent integration over the trap surface.

However, the gravity field changes not only the neutron kinetic energy but also its angular velocity distribution, because only the vertical velocity component is affected by gravity. The assumption of uniform angular distribution of UCN velocity is no more valid. This changes the UCN absorption rate inside trap walls, because the latter depends on the normal-to-wall component of neutron velocity, i.e. on the incidence angle of neutrons reflected from the wall in addition to its kinetic energy. Usually, this change of UCN angular distribution is disregarded, but it may modify the estimates of UCN losses in material traps and shift the measured τ_n.

We analyze how the change of angular distribution of UCN velocity by gravity affects the UCN loss rate from the absorption inside trap walls and the accuracy of τ_n measurements.

The work is supported by the Russian Science Foundation grant No. 23-22-00312.