Neutron and Neutrino oscillations in the framework of IFMIF/ELAMAT facility

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Why is there more matter than anti-matter in the universe?
What is the character of the neutrino?

These two fundamental questions can be addressed using very intense neutron sources.

The observed predominance of matter over antimatter in the universe cannot be explained based on the symmetries of the Standard Model (SM) of particle physics. A violation of the baryon number (B) conservation is one of the conditions require to explain such asymmetry [1]. Such violation is included in various grand unified theories, wherein B-violation occurs through the exchange of massive ($M >> M_{WEAK}$) particles. In the SM, the baryon (B) and lepton (L) numbers are accidentally conserved at the renormalizable level, but both are broken by non-perturbative effects [2], with only the combination B-L conserved. If neutrinos masses are of the Majorana types (neutrino is its own anti-particle) they provide evidence for B-L violation, via ΔL=2 operator. The conservation can be restored if B-violation occurs by two units (ΔB=2). One experimental test for such ΔB=2 violation is the search for the existence of neutron-antineutron oscillation ($n \rightarrow \bar{n}$). The present limit on $n \rightarrow \bar{n}$ transition is slightly above 10^8 s and was obtained for bound neutrons in the super Kamiokande detector [3]. The best limit for free neutrons was obtained in the 90's at the ILL research reactor with a value slightly below 10^8 s [4]. Regarding the latter experiment two parameters can nowadays been improved to increase the sensitivity of the experiment: the neutron flux and the propagation time of the neutron in quasi-free conditions (without interaction). With the availability of intense accelerator-based neutron sources we could expect a real improvement of neutron-antineutron oscillation measurement playing on these two parameters.

Neutrino oscillation experiments have clearly established the existence of a non-vanishing neutrino mass. The PMNS matrix relating flavor eigenstates to mass eigenstates is now well constrained with the latter results from Daya-Bay, Double-Chooz and Reno [5]. Despite such high-statistic measurements some incoherency exists between predictions and measurements that could be attributed to the existence of light sterile states. An important research effort is now devoted to search for new oscillations at short distances [5]. With the availability of intense accelerator-based neutron sources it is possible to envisage intense sources of decay-at-rest neutrinos for oscillation measurements at very short distance (few meters). These sources can be obtained by moderating neutrons and adding for example a lithium blanket to favor the $Li^8 \rightarrow Be^8 + e^- + \bar{\nu}_e$ reaction.

In this presentation I will discuss these two topics in the framework of the IFMIF/ELAMAT project.

[1]. A.D. Sakharov, Prisma Zh. Eksp. Teor. Fiz. 5 (1967) 32.
[2] F.R. Klinkhaner and N.S. Manton, Phys. Rev. D30 (1984) 2212.
[3] K. Abe et al. ((Super-Kamiokande Collaboration)), Phys. Rev. D 91 (2015) 072006.
[4] M. Baldo-Ceolin et al., Z. Phys. C 63 (1994) 409-416.

[5] For a recent review see for instance the 51st Rencontres de Moriond EW 2016 conference site: https://indico.in2p3.fr/event/12279/