PROGRAM OF RESEARCH INTO FUNDAMENTAL INTERACTIONS BY PIK REACTOR – PART II: SEARCH FOR NEUTRON EDM

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With help of ultra cold neutrons produced by a neutron source with superfluid helium on the output beam of cold neutrons of GEK-4 channel, we are planning to make an experiment on search for a neutron electric dipole moment (EDM). The article discussed the theoretical motivations for neutron EDM measurements and current situation as well as future opportunities in the experiment

Key words: neutron EDM, CP-violation

In 1967 A.D. Sakharov, for the first time, claimed that for interpretation of baryon asymmetry of the Universe, it was necessary to assume that there was an interaction, firstly, non conserving a baryon number and, secondly, violating *CP*-invariance.

Such interactions are not available in the SM, therefore, an interpretation of a baryon asymmetry of the Universe is outside the scope of SM. In a number of modern Grand unified theories (unified models of strong, weak and electromagnetic interactions), as well as in super symmetry theories, allowance is made for violence of baryon and lepton numbers and, consequently, for a proton decay and neutron-antineutron oscillations. *CP*-symmetry violation (as well as *T*-symmetry, according to CPT theorem) was discovered in decays of neutral *K*-mesons as far back as over 40 years ago. In summer of 2004, two large international collaborations, Belle and BaBar, working in Japan and USA, reported the observation of *CP*-violation in decays of neutral *B*-mesons containing heavy quarks, as well. SM is capable of accounting for *CP*-symmetry violation in *K*- and *B*-mesons, however, in this case, baryon asymmetry is predicted at the level of 10^{-25}, while observations provide evidence for the level of $6 \cdot 10^{-10}$. Thus, search for a mechanism responsible for *CP*-symmetry violation and

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interpreting a baryon asymmetry of the Universe is regarded as one of the corner stones of modern physics.

The presence of neutron EDM requires a simultaneous violation of invariance with respect to inversion of space (*P*) and time (*T*), and hence, *CP*-invariance violation as well. The detected *CP*-symmetry violation in decays of *K*- and *B*-mesons, taken into account within SM, results in the value of neutron EDM at the level of $\sim 10^{-31}$–10^{-33} e·cm, which is far beyond the limits of modern experimental facilities for making measurements.

However, in models, interpreting baryon asymmetry of the Universe, neutron EDM proves to be at the level of $\sim 10^{-26}$–10^{-28} e·cm, and its detection would be a direct evidence for validity of the models, combining different interactions, i.e. super symmetric and Grand unification models. At present, preparation for a few experiments on search for neutron EDM at this level of precision is under way in the world. Thus, increase of estimation accuracy in neutron physics makes it possible to obtain the results quite compatible in their significance with those obtained with super colliders of high cost, and could essentially supplement them. Detection of neutron EDM, in particular, would be evidence for presence of super symmetric particles.

Magnetic resonance spectrometer on ultra cold neutrons (UCN) for measuring neutron EDM was made at PNPI. In making measurements of neutron EDM with a universal channel of WWR-M reactor, a limit $1 \cdot 10^{-25}$ e·cm (90 %) [1, 2] was set. In subsequent measurements in ILL (Fig. 1) the limit was improved up to $0.55 \cdot 10^{-25}$ e·cm (90 %) [3].

At present, with the aim of enhancing sensitivity, a new type of spectrometer traps has been designed. After trial of a new version and conducting new measurements, a spectrometer will be transferred to the PIK reactor from ILL. We are planning to obtain UCN density 100 times higher on the PIK reactor than at ILL, and to increase measurement precision to the level of predictions made by some modern theoretical models. Fig. 2 presents the history of neutron EDM measurements and plans for enhancing precision at the ILL and PIK reactor.

An experiment on search for neutron EDM is one of the most precise experiments in physics and can be treated as the result of experimenters' efforts for the last 50 years. Nevertheless, increase of sensitivity of EDM experiment is at present as urgent as ever. Many of the suggested theories of *CP*-violation have been discarded by the present limit on neutron EDM, however, a new class of models is available nowadays, predicting neutron EDM within sensitivity of new experiments.

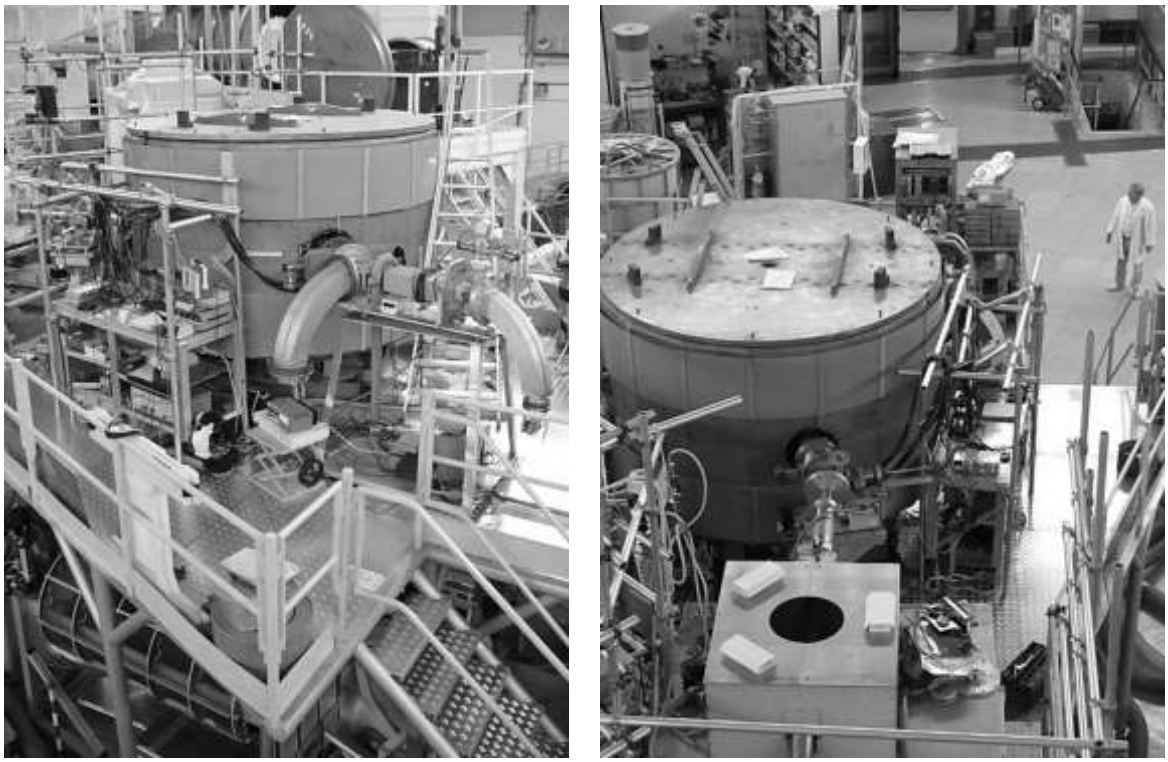

Fig. 1. The installation of PNPI NRC KI for measuring neutron EDM at ILL.

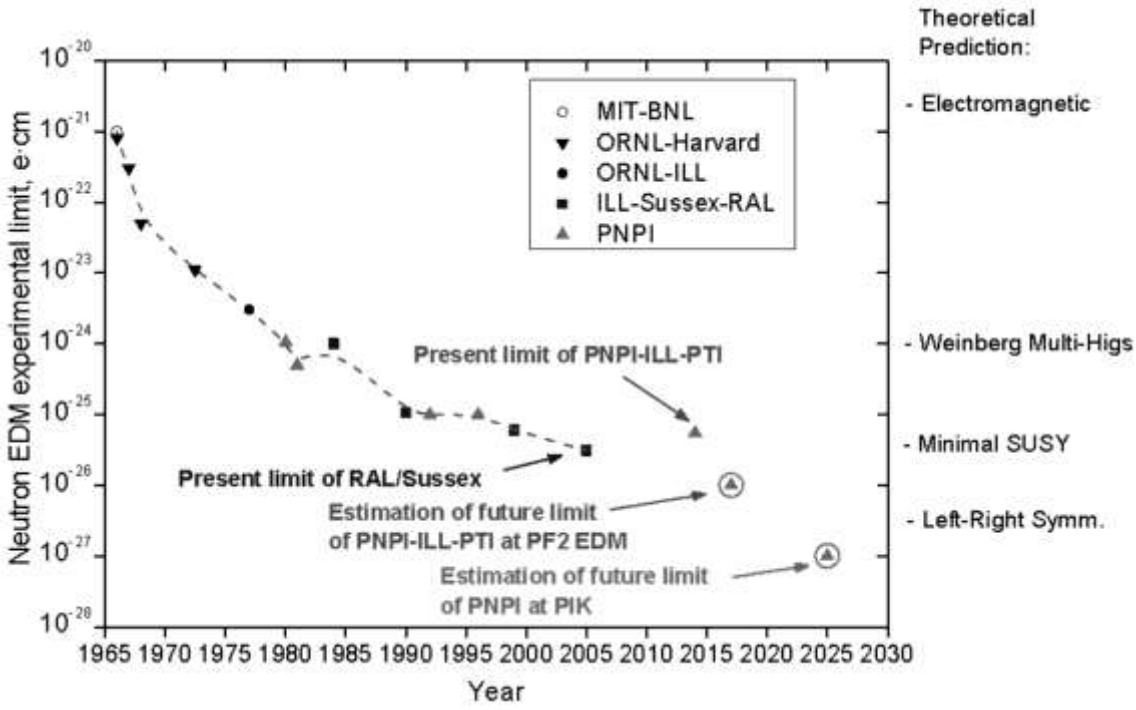

Fig. 2. The neutron EDM measurement history and plans for enhancing accuracy at ILL and at the PIK reactor.

Conclusion

Summing up this article, the authors would like to emphasize that the precision research methods, those of search for small deviations from Standard physical laws make it possible to obtain information on fundamental interactions and successfully compete with investigations conducted at colliders. Realization of the experiment on search for neutron EDM with accuracy of 10^{-27} e·cm, is of principal significance for physics of fundamental interactions.

In conclusion, the authors would like to express their gratitude to numerous co-workers involved in the investigations presented here. First of all, it is worth mentioning that it is V.M. Lobashev who initiated the research with UCN in PNPI. The authors of the article highly appreciate V.A. Nazarenko's support in these investigations.

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