PROGRAM OF RESEARCH INTO FUNDAMENTAL INTERACTIONS BY PIK REACTOR – PART I: A GENERAL SCHEME

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The research program on fundamental interactions with ultra cold and polarized cold neutrons on GEK-4-4' channel of the PIK reactor is presented. An experimental complex scheme comprises: a source of cold neutrons in deuterium reflector of the reactor, a source of ultra cold neutrons (UCN) on superfluid He on the output beam of cold neutrons of GEK-4 channel and a number of experimental installations on neutron beams. Using a UCN beam, we are planning to make an experiment on search for a neutron electric dipole moment (EDM) as well as an experiment on a neutron lifetime measurement with a big gravitation trap. An experiment on measuring asymmetry of neutron decay with a superconducting solenoid will be performed on the beam of cold polarized neutrons of GEK-4' channel. The second UCN source and an experiment on measuring a neutron lifetime with a magnetic trap are to be put into being on a neutron guide system of GEK-3 channel. An experiment on search for sterile neutrino is elaborated along the lines of neutrino physics. The article focuses on the state of things relevant to preparation of an experimental apparatus for the program concerned.

Key words: ultra cold neutrons, superfluid He, neutron EDM, neutron lifetime, sterile neutrino

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Introduction

Precision investigations in neutron physics open opportunity for research into fundamental interactions. One of the most significant problems in physics is the time invariance violation primarily concerned with the origin of the Universe. Experiments on search for neutron electric dipole moment, other than zero, are regarded as a time invariance violation test, while an ultra cold neutron method provides a very high accuracy. Precision measurements of a neutron lifetime with ultra cold neutrons are extremely significant for testing the model of the Universe formation on its early stage. Investigations on asymmetry of the neutron decay and lifetime are considered as Standard Model (SM) testing and at the same time as search for possible deviations at high precision measurements [1].

Preparation for conducting research into physics of fundamental interactions by the PIK reactor was started at the WWR-M reactor. In view of this, a universal channel of polarized cold and ultra cold neutrons was installed at the WWR-M reactor [2].

Located on this channel was a complex of installations for the neutron decay investigations and measurements of a neutron electric dipole moment (Fig.1). Essentially, it was a prototype of an experimental complex to be constructed on GEK-4-4' channel.

Though significant results have been already achieved in research on the WWR-M reactor, the urgency of the formulated physical tasks is still increasing in recent years. The latest investigations on the PIK reactor have provided new possibilities for enhancement of measurement precision owing to increase of neutron intensity and elaboration of upgraded installations.

1. General scheme of a complex of experimental installations for conducting investigations of fundamental interactions at the PIK reactor

Channel GEK-4-4' is basis for a complex of experimental installations for investigations of fundamental interactions at the PIK reactor. The channel is passing through the reactor core and has outputs with both sides, with a source of cold neutrons being placed approximately in the center of it (Fig. 2). A UCN source with superfluid He is located on the output beam of cold neutrons of GEK 4 channel (Fig. 3). A polarizer and a neutron beam chopper are installed on GEK-4' channel. Both channels are provided with uncooling bismuth filters comprising valve devices of channels. On the beam of cold polarized neutrons of GEK-4' channel, an experiment is to be made on measuring a neutron decay asymmetry with a superconducting solenoid. On UCN beam, we are planning to carry out an experiment on search for electric dipole moment, and another one on measuring neutron lifetime with a big gravitational trap.

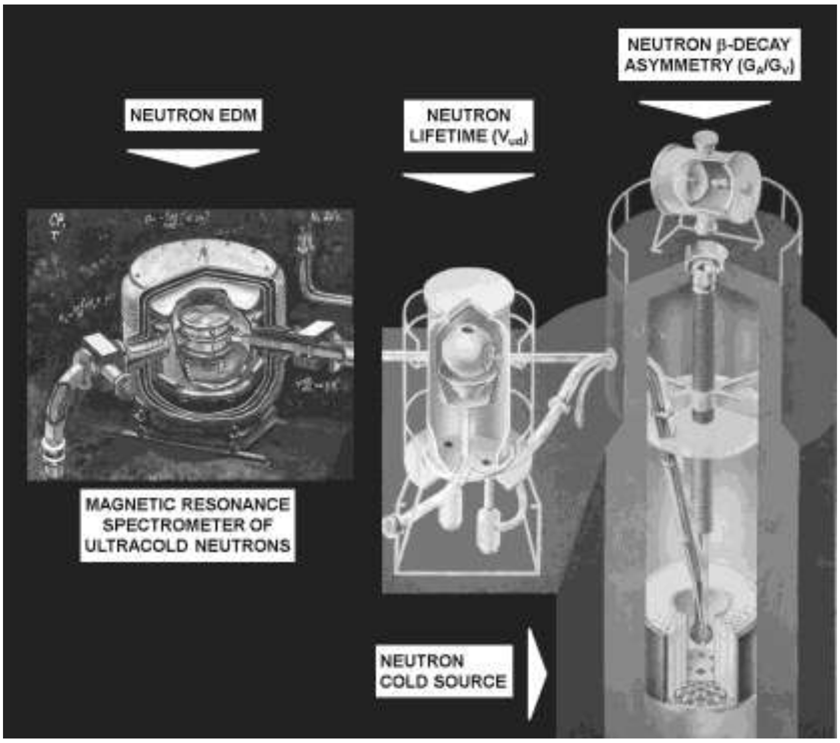

Figure 1. Complex of installations on the WWR-M reactor for investigating fundamental interactions: a) a magnetic resonance spectrometer for search of neutron EDM, b) universal source of polarized cold and ultracold neutrons and installations for investigating a neutron decay – lifetime and a decay asymmetry.

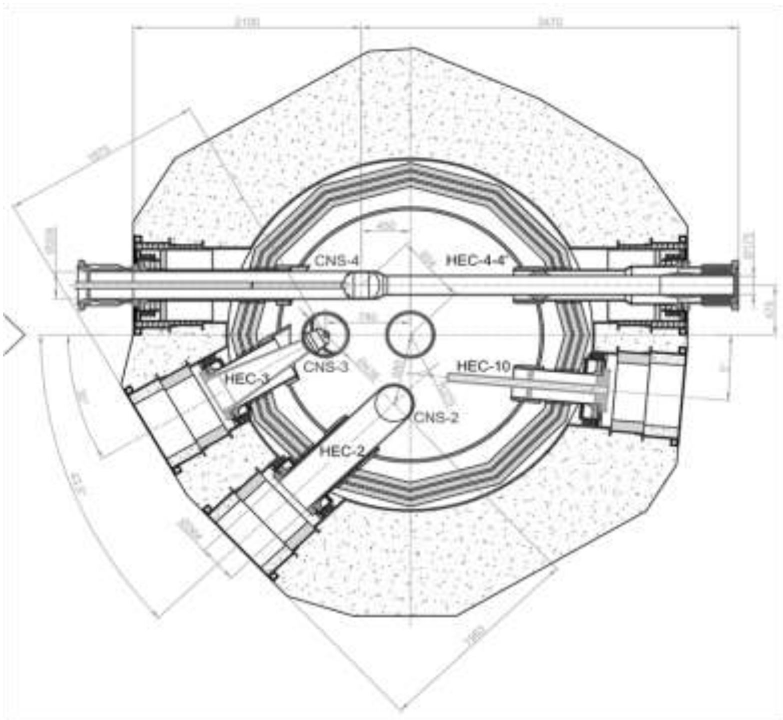

Figure 2. A layout of horizontal channels of the PIK reactor. A source of cold neutrons is situated in the GEK-4-4' channel.

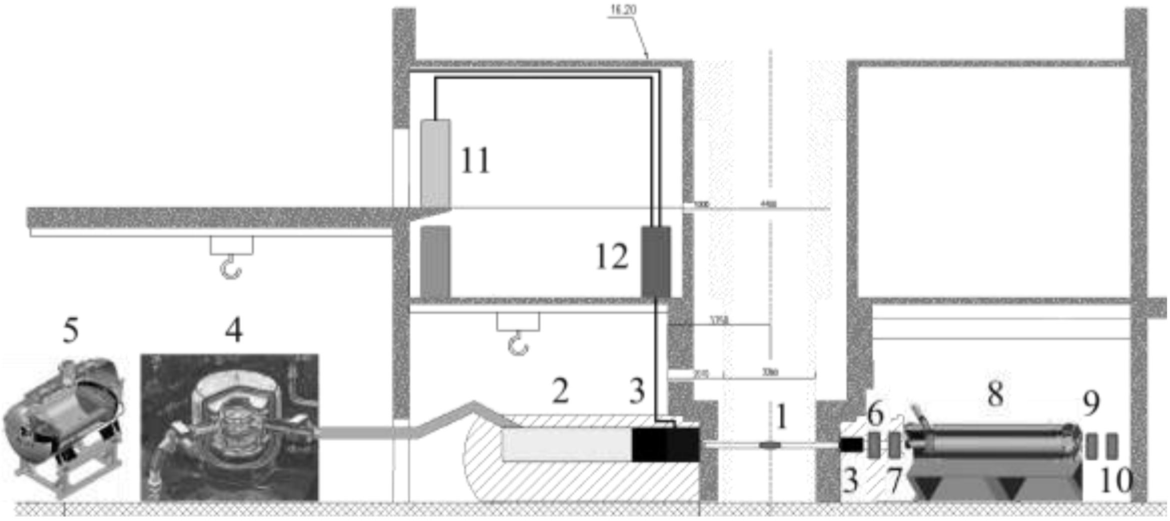

Figure 3. A vertical outlay of the channel GEK-4-4'**:** 1 – a source of cold neutrons, 2 – UCN source on superfluid He is located on the output beam of cold neutrons, 3 – uncooling bismuth filters comprising valve devices of channels, 4 – EDM spectrometer, 5 – a gravitational trap for measuring a neutron lifetime, 6 – a chopper of cold neutrons beam, 7 – a polarizer of neutron beam on polarized ^{3}He, 8 – an installation for measuring asymmetry of a neutron decay with a superconducting solenoid, 9 – a polarization analyzer, 10 – a detector, 11 – He refrigeration unit for a cold neutron source, 12 – a liquid deuterium capacitor for a cold neutron source.

Fig. 4 shows a layout of experimental installations on channel GEK-4, as well as on a neutron guide channel GEK-3.

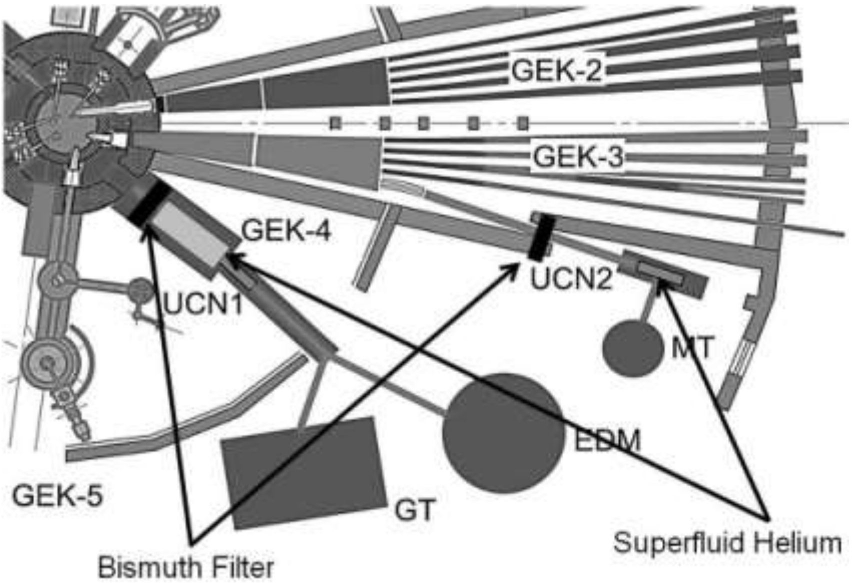

Fig. 4. A layout of UCN source with superfluid He and experimental installations on channels GEK-3 and GEK-4 of the PIK reactor: UCN1 – UCN source on channel GEK-4, UCN2 – UCN source on channel GEK-3, EDM – installation for measuring a neutron EDM, GT – installation for measuring a neutron lifetime with UCN gravitational trap, MT – an installation for measuring a neutron lifetime with UCN magnetic trap.

Due to application of polycrystalline bismuth filter, it has become possible to solve the problem of reducing a heat gain towards super fluid He up to the level of 0.5 W. In this connection, a project for a technological complex has been elaborated to remove thermal power of 1 W at temperature 1 K from super fluid He for UCN source on the PIK reactor. The complex includes UCN source, a cryogenic block, a system of pumping out He vapors, a compressor system of storage and allocation of helium gas. The parameters and operating modes of equipment are matched. Fig. 5 illustrates a project for such a complex.

The maximum possible density of UCN in the source volume 150 l can reach 10^5cm^{-3} with total production rate 10^7UCN/s.

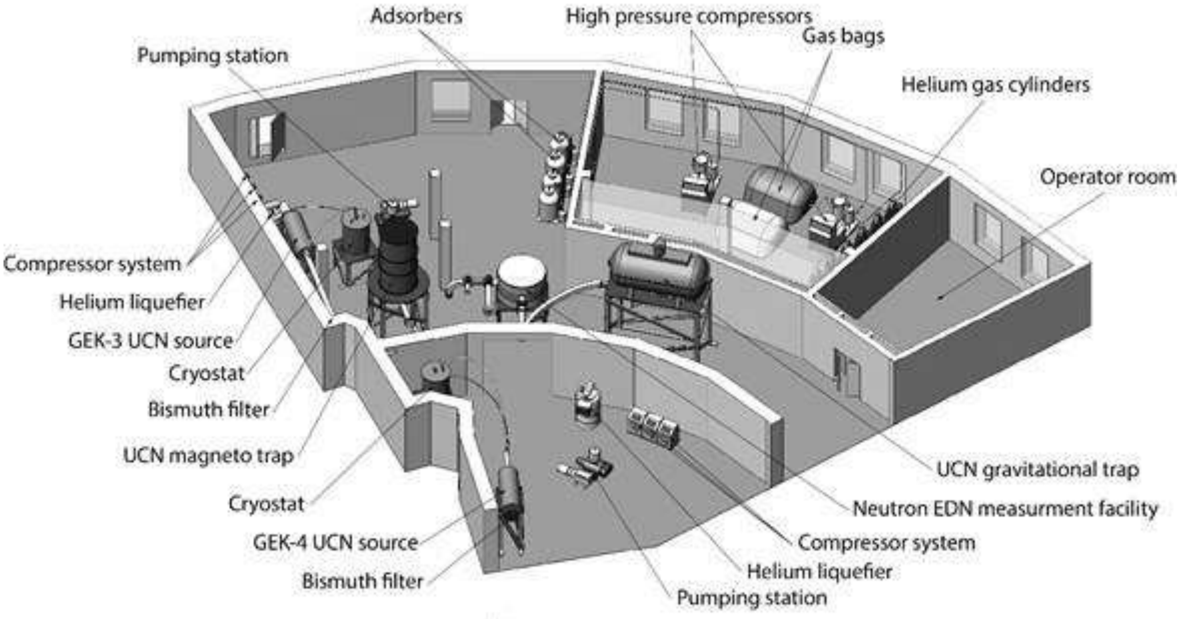

Fig. 5. General layout of a scientific station of UCN source on the PIK reactor

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. Examples of such investigations are presented in this article. Realization of the experiment on search for neutron EDM with accuracy of 10^{-27} e·cm, and for the reactor neutrino oscillations with a few percent accuracy at a distance of 6 – 12 m from the reactor active zone, is of principal significance for physics of fundamental interactions. The presented research program on physics of fundamental interactions is an important integral part of a joint scientific program of the PIK reactor research.

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 at PNPI. The authors of the article highly appreciate V.A. Nazarenko's support in these investigations.

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