PROGRAM OF RESEARCH INTO FUNDAMENTAL INTERACTIONS BY PIK REACTOR – PART V: SEARCH FOR THE REACTOR ANTINEUTRINO OSCILLATIONS AT SHORT DISTANCES

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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.

Key words: sterile neutrino

At present, the possible existence of a sterile neutrino having a significantly smaller cross-section of interaction with a substance than, for example, electron antineutrinos from a reactor, is being widely discussed. It has been suggested that due to transition of a reactor antineutrino into a sterile state, one can observe both the oscillation effect at short range distances from the reactor and deficiency of the reactor antineutrino flux at large range distances [1,2] (Fig. 1). In addition, sterile neutrinos are considered as candidates for dark matter [3].

The ratio of experimentally observed neutrino flux to the predicted one is estimated as 0.927±0.023 [1]. This effect comprises 3 standard deviations. It is still insufficient to confirm the existence of reactor antineutrino anomaly. The method of comparison of the measured antineutrino flux with the expected one from the reactor is unsatisfactory, because of the problem of an accurate estimation of the reactor antineutrino flux and efficiency of the antineutrino detector.

The idea of oscillations can be tested by direct measurements of the effect of flux variation and the spectrum of antineutrino at short range distances from the reactor. The detector should be movable and spectral-sensitive. Our experiment sets the task of either confirming or disproving the possibility of a sterile neutrino existence at certain accuracy level.

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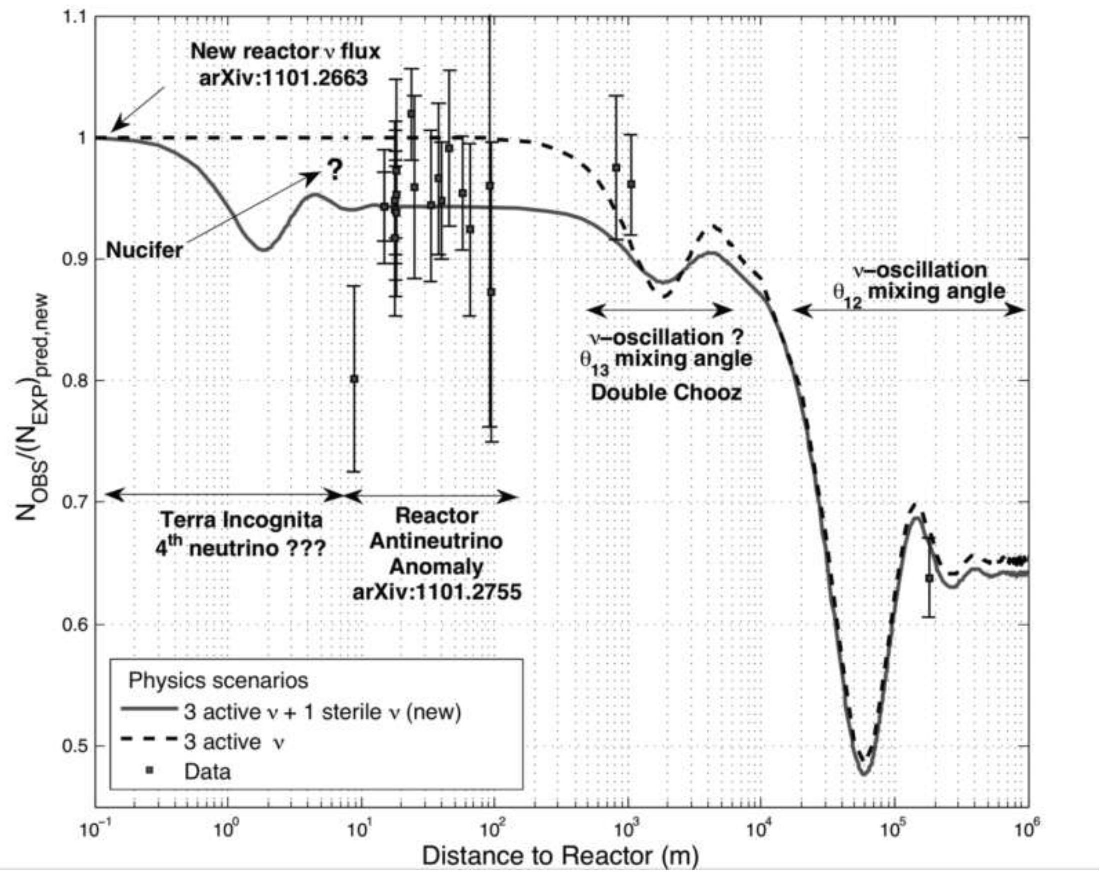

Fig. 1. Neutron anomaly in oscillations of the reactor antineutrino. The dotted line curve shows modern theoretical predictions, the solid curve shows predictions with regard to sterile neutrino emergence.

In search for oscillations into a sterile neutrino, it is necessary to register a variation of the reactor antineutrino flux. If such a process does exist, it can be described by an equation of oscillation:

$$P(\tilde{\nu}_e \to \tilde{\nu}_e) = 1 - \sin^2 2\theta_{14}\ \sin^2(1.27\frac{\Delta m^2_{14}[eV^2]L[m]}{E_{\tilde{\nu}}[MeV]}) \ , \quad (1)$$

where $E_{\tilde{\nu}}$ is antineutrino energy, with unknown values being oscillation parameters Δm^2_{14} and $\sin^2 2\theta_{14}$. For conducting an experiment, one needs to make measurements of an antineutrino flux and spectra at short range distances, for example, 6-12 m from a practically point-like source of antineutrino. With this purpose one can employ compact active cores of the research reactors of SM-3 and PIK, the latter is preparing to be put into operation. Similar detectors have never been mounted at such a short range distance, nor have they ever been located in a reactor hall with high radiation and neutron fields.

Installation «Neutrino-4»

The detector is based on using the reaction of a reverse beta-decay $\tilde{\nu}_e + p \rightarrow e^+ + n$. The detector will register two sequential signals from a positron and a neutron. At annihilation of a stopped positron the two 511 keV gamma-rays, ejected into opposite directions, are formed. Neutrons emerging in this reaction are absorbed by Gd to produce a cascade of gamma quanta with the total energy of about 8 MeV. The detector has a duplex structure and can be moved to measure dependence of flux and spectrum of the antineutrinos in dependence of the distance to the active core of a reactor. The antineutrino energy spectrum will be reconstructed from the positron energy spectrum. The detector must be surrounded by a passive and active shield to suppress the background from the reactor hall and cosmic radiation. The detector will be located in the hall for model testing (building 029) of the PIK reactor (Fig.2).

An experimental task is to find out deviation from the $1/R^2$ law in registering antineutrino. Preparation of the experiment has been started at the WWR-M reactor and being continued at the SM-3 reactor [4-6]. When the PIK reactor will be put into operation, the main measurements are planned to be carried at it. The scheme of a duplex structure detector for an antineutrino is presented in Fig. 3.

The expected count rate of antineutrino events for the detector with volume of a cubic meter, at a distance of 8 m from the PIK reactor active zone, is to be ~$0.4 \cdot 10^3$ per day, and correspondingly, $1.7 \cdot 10^2$ per day at a distance of 12 m.

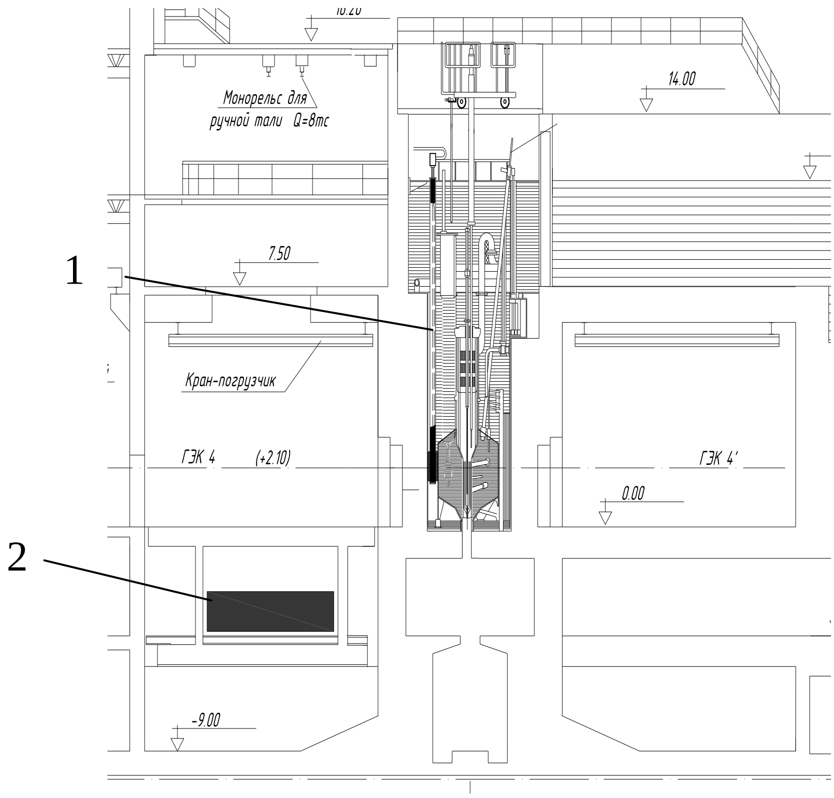

Fig. 2. A scheme of location of an antineutrino detector at the PIK reactor. 1 – an active core of the PIK reactor, 2 – an area of antineutrino detector moving is 8 – 12 meters from the core of the PIK reactor.

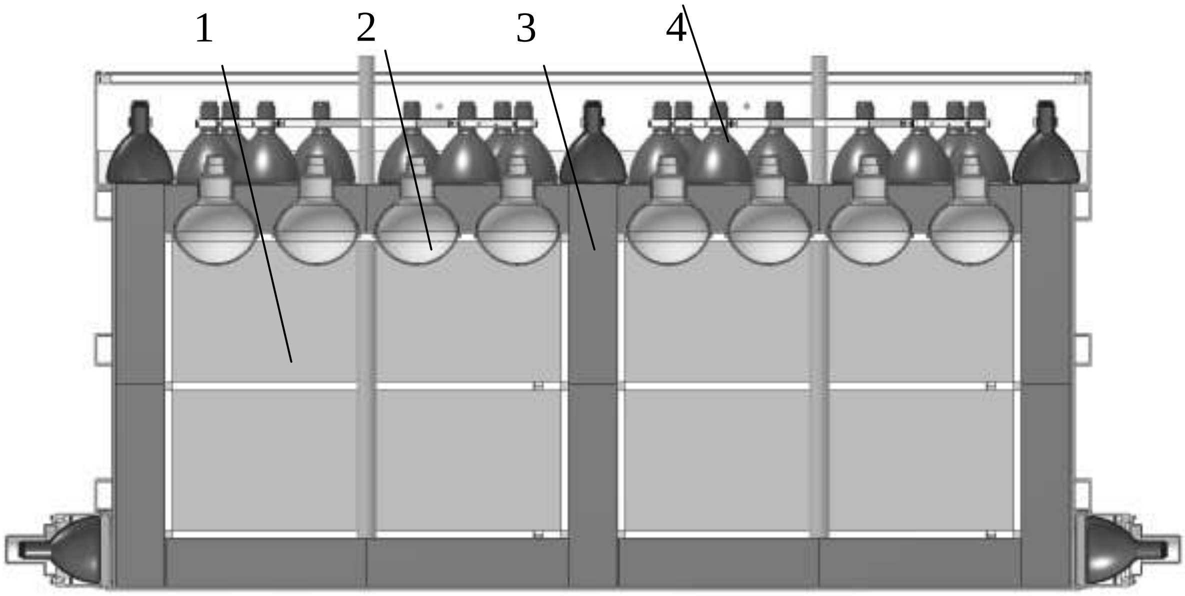

Fig. 3. A scheme of a duplex structure antineutrino detector. 1 – a section of the reactor antineutrino detector, 2 – PMT 9354, 3 – active protection, 4 – PMT-49B.

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 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.

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