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First measeurements in search for keV-sterile neutrino in tritium beta-decay by Troitsk nu-mass experiment

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Neutrino studies nowadays belong to the most active and promising research domain in particle physics. Neutrinos are massive and this property cannot be accommodated in the Standard model. Therefore, studies of the neutrino mass matrix give us unique opportunity to probe a new physics in the laboratory directly. The simplest mechanism to provide neutrino with the mass assumes the existence of new particles – right handed (or "sterile") neutrinos. Their number, masses and mixing angles with left handed ("active") neutrinos, apart from the existing observational restrictions, are free parameters of the theory, for the review see [1].

It is important that sterile neutrino in the keV mass range is one of the best motivated [1] dark matter particle candidates. Therefore, sterile neutrino searches in this mass range are of particular interest.

Sterile neutrinos do not have Standard Model interactions (hence the name "sterile"). However, since sterile neutrinos mix with active neutrinos, they are emitted with small probability in every process where active neutrinos can be born. In particular, in the presence of sterile neutrino the spectrum of tritium β-decay is modified in the following way:

$$S(E) = U_{e4}^2 S(E, m_4^2) + (1 - U_{e4}^2) S(E, m_1), \qquad (1)$$

where $S(E,m)$ is standard β-spectrum with single neutrino if it has mass m; U_{e4} is relevant element of the neutrino mixing matrix; mass states m_4 and m_1 practically coincide with sterile and electron neutrino correspondingly, if mixing is small. Sterile neutrinos can be searched for by looking for such small β-spectrum distortions.

In this Letter we present the first results of precision measurements of tritium β-decay spectrum in the electron energy range 16–18.6 keV by the Troitsk nu-mass experiment. The goal is to find distortions which may be caused by the existence of sterile neutrinos in a keV mass range. A signature would correspond to a kink in the spectrum with characteristic shape and end point shifted by the value of a heavy neutrino mass.

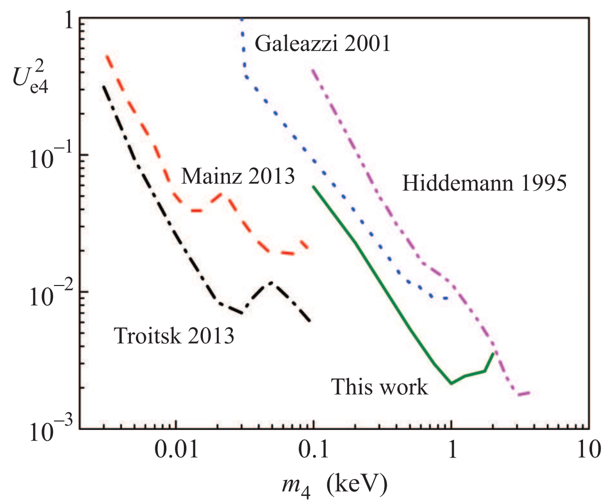

Fig. 1. (Color online) Upper limits on U_{e4}^2 at 95 % confidence level. Our result is shown by the solid curve. Published data are from [5–9]

Troitsk nu-mass experiment, which had been designed for the active neutrino mass measurements, and where the strongest direct limit on it [2, 3] has been obtained so far, is well suited for the keV sterile neutrino searches. Detailed description of Troitsk nu-mass experiment, hardware, procedures and important systematic errors inherent to the spectrum measurements on this apparatus, can be found in Ref. [4]. Moreover, currently, it is the only installation in operation which is capable for the sterile neutrino searches in the keV mass

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range. We have started corresponding research program recently.

This Letter also reports on the first physical results and restrictions obtained in searches for sterile neutrinos in the mass range up to a few keV. Our resulting upper limits for allowed U_{e4}^2 are shown in Fig. 1 as a function of sterile neutrino mass. In the same figure we also present the existing published limits [5–9]. We have improved the existing limits on their mixing with electron neutrinos by the factor of 2 to 5, depending upon m_x, in the mass range 0.1–2 keV.

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