Pis'ma v ZhETF, vol. 110, iss. 2, pp. 81 – 82

Direct search for keV-sterile neutrino in nuclear decay. Troitsk nu-mass (Mini-review)

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Submitted 21 May 2019
Resubmitted 21 May 2019
Accepted 27 May 2019

DOI: 10.1134/S0370274X19140017

The discovery of mixing in the lepton sector of elementary particles and non-zero neutrino mass generates several fundamental questions. One of them is: are there more than three neutrinos? Can there be any neutral fermionic states besides active neutrinos? For example, there is an extension of Standard Model (SM) to a set of right handed neutrinos. New fermions do not necessarily couple to SM particles and are usually referred to as *sterile* neutrinos. Sterile neutrinos mix with active neutrinos, and thus neutrino mixing matrix may have more parameters and more oscillation frequencies. If the sterile neutrino mass is in the scale of a few keV, such a particle can be considered a good candidate for the Warm Dark Matter [1]. While there is still only a hypothesis of the sterile neutrino existence, many experiments are currently investigating or planning to investigate this new particle.

The best result for active electron neutrino mass has been obtained in Tritium β-decay. The same process could shed light on the existence of sterile neutrinos. In 1980 R. E. Shrock proposed to search for possible neutrino mass states m_i in β-spectra [2]. For non-zero m_i there will be an additional component with a kink in the spectrum at the energy $E_0 - m_i$, where E_0 is the endpoint in the electron spectrum. Another technique to search for the sterile neutrino is based on the internal electron capture experiments. The idea is to use spectrum of the recoil nucleus, like ^{163}Ho in ECHo experiment [3] and some other nuclei to measure the spectrum end point. Low temperature calorimeters are used in such experiments.

We present a brief review of experimental status in searching for hypothetical sterile neutrino in nuclear decay in laboratory testing. The advantages and problems arising in the precise measurements of β- spectrum are demonstrated on the basis of the "Troitsk nu-mass" experiment. The experiment has two major subsystems: an integrating electrostatic spectrometer with adiabatic magnetic collimation and a windowless gaseous tritium source (WGTS) as a volume for β-decays. The spectrometer resolution is about 1.5 eV. We measured an integrated electron spectrum in the region of the last 4–5 keV from the spectrum endpoint (18575 eV) by varying the electrostatic potential V on the spectrometer electrode. All details of the experimental setup, data taking, analysis, corrections and estimation of systematic error are published in [4]. The major contribution to the systematic error budget comes from the dead time and pileup uncertainty and events under the detection threshold. The last uncertainty appears because of back-scattering from the detector, some electrons do not release the full energy, so the signal amplitude for these electrons falls below the threshold (about 6 keV electrons in the current configuration). The number of electrons falling below the threshold can be about 4 % for retarding potential of 16 kV and up to 10 % for a retarding potential of 14 kV.

Other corrections are electron trapping effect in WGTS, spectrometer transmission function, energy loss in WGTS, correction for the excited states of daughter molecule after tritium decay, instability of of high voltage system (about ± 0.3 V). Results on the upper limit at 95 % C.L. for the additional neutrino mass eigenstate, m_4, for data above 16 kV are presented in Fig. 1. These data were taken in the period 2016–2017. We improve the existing limits by 5–10 times, the result was considered among the major achievements in physics division of RAS in 2018. Analysis of tritium data in the β-spectrum range 14–18.5 keV is undergoing.

Nearest future of searching for sterile neutrino in nucleus decay. There is a proposal to combine cryogenic microcalorimetry and a penning trap spectrometer for electron capture decay of different isotopes to probe sterile neutrino with masses in the range

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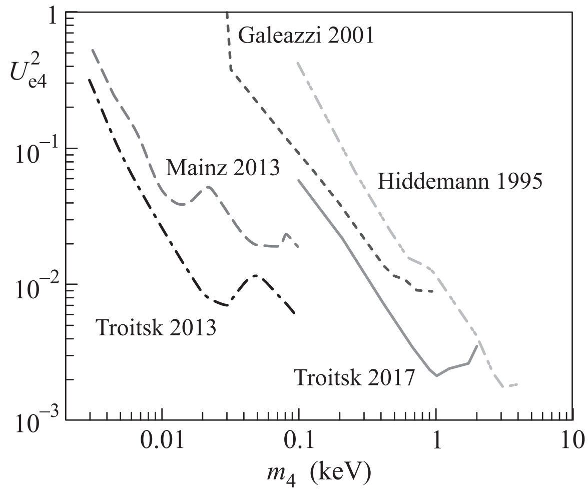

Fig. 1. (Color online) The results from our work published in [5] compared to other experiments

0.5–100 keV at the level of 1 % [6]. The KATRIN experiment has plans to start searching for a keV-sterile neutrino in the Tritium beta decay [7]. For this purpose design and manufacture detector and electronics started in the frame of the new secondary project TRISTAN. We plan to use opportunity of scientific collaboration with group working on TRISTAN project. One sample of TRISTAN detector prototype 40 mm by 40 mm with 166 channels will nicely fits our system. A few first tests with a new type of pixel detector were already held in Troitsk in 2017–2018 [8].

The current analysis was supported by Russian Foundation for Basic Research under grant number 17-02-00361. We also would like to thank our colleagues of "Troitsk nu-mass" experiment for their valuable contribution to experiment preparation and data taking.

Full text of the paper is published in JETP Letters journal. DOI: 10.1134/S0021364019140042

1. M. Drewes, T. Lasserre, A. Merle et al. (Collaboration), JCAP **1701**, 025 (2017).
2. R. E. Shrock, Phys. Lett. B **96**, 159 (1980).
3. L. Gastaldo, K. Blaum, K. Chrysalidis et al. (Collaboration), Eur. Phys. J. ST **226**, 1623 (2017).
4. D. N. Abdurashitov, A. I. Belesev, A. I. Berlev et al. (Collaboration), JINST **10**, T10005 (2015).
5. D. N. Abdurashitov, A. I. Belesev, V. G. Chernov, E. V. Geraskin, A. A. Golubev, P. V. Grigorieva, G. A. Koroteev, N. A. Likhovid, A. A. Nozik, V. S. Pantuev, V. I. Parfenov, A. K. Skasyrskaya, I. I. Tkachen, an S. N. Zadorozhny, Pisma v ZhETF **105**(12), 723 (2017) [JETP Lett. **105**(12), 753 (2017)].
6. P. E. Filianin, K. Blaum, S. A. Eliseev, L. Gastaldo, Yu. N. Novikov, V. M. Shabaev, I. I. Tupitsyn, and J. Vergados, J. Phys. G **41**, 095004 (2014).
7. S. Mertens, T. Lasserre, S. Groh, G. Drexlin, F. Glueck, A. Huber, A. W. P. Poon, M. Steidl, N. Steinbrink, and C. Weinheimer, JCAP **1502**, 020 (2015).
8. K. Altenmüller, T. Bode, T. Brunst, V. Chernov, O. Gevin, A. Huber, M. Korzeczeck, Th. Lasserre, O. Limousin, D. Maier, S. Mertens, A. Nozik, V. Pantuev, A. Skasyrskaya, and M. Slezak, Nucl. Instrum. Meth. A **912**, 333 (2018).