ФИЗИКА ЭЛЕМЕНТАРНЫХ ЧАСТИЦ И АТОМНОГО ЯДРА
2015. Т. 46. ВЫП. 2

CURRENT STATUS OF NEW SAGE PROJECT WITH ^{51}Cr NEUTRINO SOURCE

V. Gavrin [a,*], *B. Cleveland* [b], *S. Danshin* [a], *S. Elliott* [c], *V. Gorbachev* [a], *T. Ibragimova* [a], *A. Kalikhov* [a], *T. Knodel* [a], *Yu. Kozlova* [a], *Yu. Malyshkin* [a], *V. Matveev* [a,d], *I. Mirmov* [a], *J. Nico* [e], *R. G. H. Robertson* [f], *A. Shikhin* [a], *D. Sinclair* [g], *E. Veretenkin* [a], *J. Wilkerson* [h]

[a] Institute for Nuclear Research of the Russian Academy of Sciences, Moscow

[b] SNOLAB, Lively, Ontario, P3Y 1N2, Canada

[c] Los Alamos National Laboratory, Los Alamos, NM, USA

[d] Joint Institute for Nuclear Research, Dubna

[e] National Institute of Standards and Technology, Gaithersburg, Maryland, USA

[f] Center for Experimental Nuclear Physics and Astrophysics, University of Washington, WA, USA

[g] Department of Physics, Carleton University, Ottawa, Ontario, Canada

[h] Department of Physics, University of North Carolina, Chapel Hill, NC, USA

A very short-baseline neutrino oscillation experiment with an intense ^{51}Cr neutrino source is currently under construction at the Baksan Neutrino Observatory of the Institute for Nuclear Research RAS (BNO). The experiment, which is based on the existing SAGE experiment, will use an upgraded Gallium–Germanium Neutrino Telescope (GGNT) and an artificial ^{51}Cr neutrino source with activity of ~ 3 MCi to search for transitions of active neutrinos to sterile states with $\Delta m^2 \sim 1$ eV^2. The neutrino source will be placed in the center of a target of liquid Ga metal that is divided into two concentric zones, internal and external. The average path length of neutrinos in each zone will be the same, and the neutrino capture rate will be measured separately in each zone. The oscillation signature, which comes from the ratio of events in the near and far gallium volumes, will be largely free of systematic errors, such as may occur from cross section and source strength uncertainties, and will provide a clean signal of electron neutrino disappearance into a sterile state at baselines of about 0.6 and 2.0 m. The sensitivity to the disappearance of electron neutrinos is expected to be a few percent. Construction of this set of new facilities, including a two-zone tank for irradiation of 50 t of Ga metal with the intense ^{51}Cr source, as well as additional modules of the GGNT counting and extraction systems,

*E-mail: gavrin@inr.ru

is close to completion. To check the new facilities, they will first be used for SAGE solar neutrino measurements.

PACS: 14.60.Pq

INTRODUCTION

The concept of neutrino oscillations was introduced by B. M. Pontecorvo long ago [1]. But it took more than 30 years before definite experimental results in favor of oscillations appeared from solar, atmospheric, and long-baseline reactor and accelerator experiments. The discovery of neutrino oscillations has provided a direct challenge to the completeness of the Standard Model of particle physics. For many years, all direct experimental data fit well into a scheme with three active neutrinos [2] which contained two nonzero differences of neutrino masses squared and two large and one small mixing angle. The only exception was the LSND experiment, which was interpreted to show oscillations between muon and electron antineutrinos at $\Delta m^2 \sim 1$ eV^2 [3]. This result did not fit into the standard pattern of three neutrinos, and suggested at least one light sterile neutrino needed to be added to the theory.

More recently, the MiniBooNE experiment, which was designed to test LSND, has presented oscillation results in both neutrino mode and antineutrino mode. The results obtained in neutrino mode [4] disfavor most of the parameter space preferred by LSND, but the antineutrino data [5] are consistent with the LSND signal. Combining both results, MiniBooNE observes a 3.8σ excess of events in the 200–1250 MeV oscillation energy range that is consistent with the LSND signal and consistent with oscillations at Δm^2 about 1 eV^2 [6].

Additional evidence for neutrino disappearance at baselines of less than 100 m has recently appeared [7]. This occurred as a result of reanalysis of the global short-baseline reactor antineutrino experimental data combined with an updated calculation of the reactor neutrino flux. A possible physical explanation for this effect may be the existence of mixing with $\Delta m^2 \sim 1$ eV^2 between the electron antineutrino and a new, 4th neutrino type which does not interact through the Standard Model weak interactions. It may well be that the same physics is also responsible for the discrepancy between the result of the calibration experiments of SAGE and GALLEX with artificial sources of neutrinos [8,9] and their theoretical predictions.

B. M. Pontecorvo also suggested the possibility of transitions between active neutrinos and particles "that are, from the point of view of the ordinary weak interactions, sterile, i.e., practically unobservable" [1]. Recently there have been indications from experiments directly studying neutrino oscillations and there have been hints from cosmology that transitions into one or more sterile components may occur. Consequently, the search for sterile neutrinos is now a field of very active investigation. To hasten the resolution of this intriguing problem, multiple approaches to its experimental solution should be investigated.

The goal of the experiment considered here — named **BEST** for **B**aksan **E**xperiment on **S**terile **T**ransitions — is to search for transitions of active to sterile neutrinos at two baselines by using neutrinos from an intense compact artificial source which interact with nuclei of gallium in the GGNT.

1. LABORATORY OF THE GALLIUM–GERMANIUM NEUTRINO TELESCOPE

The GGNT is situated in a dedicated deep-underground laboratory of the Baksan Neutrino Observatory INR (Russia) in the Northern Caucasus Mountains, with a vertical rock overburden of approximately 4700 meters water equivalent (m.w.e.). The measured muon flux at the location of the GGNT is $(3.03 \pm 0.10) \cdot 10^{-9}$ cm$^{-2} \cdot$ s^{-1}. The GGNT with 50 t of metallic gallium has been successfully operated for more than 20 years in the solar neutrino experiment SAGE [10–13]. The research team at the telescope has good experience with powerful artificial sources of neutrinos, and Russia has unique experience and technical capabilities of their manufacture.

2. Ga EXPERIMENTS WITH ARTIFICIAL NEUTRINO SOURCES

The first solar neutrino measurements with gallium, which started in the 1990s in SAGE [14] and GALLEX [15], showed a flux of neutrinos that was considerably less than what was expected in the framework of the Standard Solar Model (SSM). Because of the importance of the conclusions based on these results, many ancillary experiments were conducted to prove that the efficiencies of these neutrino detectors were known correctly.

As a further check on all experimental procedures, including neutrino cross sections, chemical extraction procedures, counting of ^{71}Ge, and the analysis technique, SAGE and GALLEX used very intense artificial neutrino sources. Two independent experiments with artificial sources of electron neutrinos with activity close to 1 MCi were performed on each of the detectors. In SAGE, approximately 25% of the target was irradiated with sources made from the isotopes ^{51}Cr [16] and ^{37}Ar [17] and GALLEX twice used a ^{51}Cr source to irradiate their entire target [18, 19]. Both of these sources emit practically monoenergetic neutrinos with energy 0.75 MeV for ^{51}Cr and 0.81 MeV for ^{37}Ar.

The weighted-average result of these experiments, expressed as the ratio R of the measured neutrino capture rate to the expected rate, based on the measured source intensity and the known neutrino capture cross section calculated by J. Bahcall [20], gave $R = 0.87 \pm 0.05$, more than two standard deviations less than unity.

Possible explanations of such a low result are considered in detail in [12]. One of the hypotheses considered in that article — that the cross section for neutrino capture to the two lowest excited levels in ^{71}Ge [21] was overestimated — was not confirmed. On our initiative, measurements of the charge-exchange reaction ^{71}Ga(^{3}He, t)^{71}Ge were carried out at the RCNP (Osaka, Japan) which determined with high precision the contribution of excited levels in ^{71}Ge to the cross section of neutrino capture by the ^{71}Ga nucleus [22]. These measurements showed that the contribution of these levels to the cross section agrees well with the value calculated by J. Bahcall [20]. Also the first direct Q-value measurement of the ^{71}Ga(ν, e^{-})^{71}Ge reaction was performed using the TITAN mass-measurement facility at ISAC/TRIUMF (Canada) [23]. The value obtained was very similar to previous measurements and did not appreciably change the calculated ^{51}Cr ν cross section. Taken together these experiments show that there are no further uncertainties in the nuclear structure which could remove the discrepancy between the measured neutrino capture rate in the Ga calibration experiments and the theoretically calculated rate.

The remaining reasons for the deficit of neutrinos in the Ga calibration experiments are 1) a statistical fluctuation, the probability of which is small, about 5%, or 2) a real physical effect, possibly the transition of active neutrinos into sterile states at very short baselines with large Δm^2 [9]. The region of allowable oscillation parameters, obtained from the results of all four Ga source experiments, under the assumption that transitions to sterile states occur, is shown in Fig. 1.

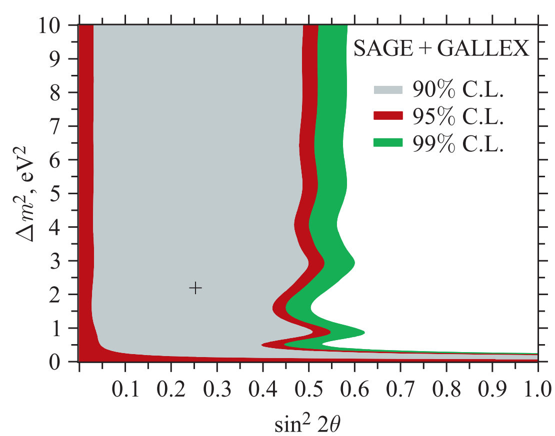

Fig. 1. Region of allowed mixing parameters inferred from gallium source experiments assuming oscillations to a sterile neutrino. The plus sign at $\Delta m^2 = 2.15$ eV^2 and $\sin^2 2\theta = 0.24$ indicates the best-fit point

3. THE BEST EXPERIMENT

We propose the BEST experiment to search for the disappearance of electron neutrinos at short baselines from a radioactive source. The scheme of BEST to search for transitions of active neutrinos to sterile states is shown in Fig. 2.

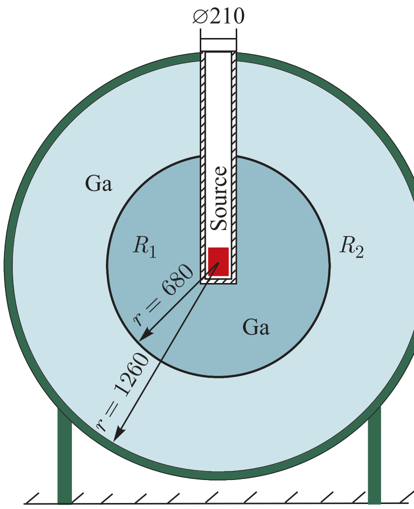

Fig. 2. Schematic drawing of the proposed experiment. R_1 and R_2 are the ratios of measured capture rate to predicted rate in the inner and outer zones, respectively. Outer radii r of the two zones and diameter of source re-entrant tube are given in mm

An intense 3-MCi ^{51}Cr source will be placed at the center of a 50-t target of liquid Ga metal that is divided into independent inner and outer zones and the neutrino capture rates in each zone are measured simultaneously. The zones are specially constructed so that the neutrino path lengths in each zone are nearly the same with the result that the neutrino capture rate in each zone is also nearly the same if neutrino oscillations do not occur.

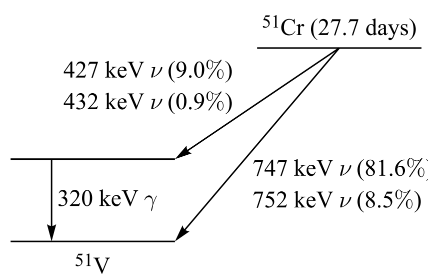

Fig. 3. Decay scheme of ^{51}Cr to ^{51}V through electron capture

3.1. ^{51}Cr Source. The decay of ^{51}Cr is by electron capture to ^{51}V with a half-life of 27.7 days. The decay scheme is illustrated in Fig. 3. There is a 90% branch that decays directly to the ground state of ^{51}V and a 10% branch that decays to the lowest excited state of ^{51}V, which then promptly decays to the ground state with the emission of a 320-keV gamma ray.

Taking into account the atomic levels to which the transitions can occur, the source will radiate neutrinos with energies 752 keV (8%), 747 keV (82%), 432 keV (1%), and 427 keV (9%). Since 90% of the decays give ~ 0.75-MeV neutrinos, the source can be considered with good approximation as monochromatic.

^{51}Cr will be produced by the capture of thermal neutrons on the stable isotope ^{50}Cr, whose content in natural Cr is 4.35%. To make the volume of the final source as small as possible, the first step in source production will be to use centrifuge technology to produce 3.5 kg of ^{50}Cr with enrichment up to 97% in the form of highly-purified chromium trioxide.

The isotopically enriched Cr will be converted to metal by electrolysis and pressed into 81 metallic Cr rods with diameter 9.3 mm and length 95 mm whose total mass is 3015 g. For neutron irradiation, these ^{50}Cr rods will be placed in cells in the central neutron trap of the reactor SM-3 (Dmitrovgrad, Russia). Immediately following irradiation, the activity of ^{51}Cr should be not less than 3.2 MCi. The total time to assemble the source at RIAR, to transport it to BNO, and to insert it in the detector should be no more than 60 hours (2.5 days). As a result, when exposure of the BEST two-zone detector begins, the activity of the source should be 3.0 MCi.

Precise determination of the absolute activity of the source at $\sim 1\%$ level will further enhance the sensitivity of the measurement. The source activity will be measured after each exposure by calorimetry and by gamma spectroscopy with high-purity germanium detectors (HPGe). A 3-MCi source emits about 650 W of heat and a special calorimeter will be built to measure its absolute activity.

3.2. Design and Construction of a Two-Zone Tank for Ga Target. A concentric tank design has been chosen to optimize the search for the disappearance of electron neutrinos from the radioactive source at two short baselines. The inner tank is a sphere with a radius of 660 mm to which is attached a cylindrical re-entrant tube with a diameter of 203 mm and a height of 1196 mm. This geometry places the source at the center of the target and gives a neutrino path length of 55 cm. This zone will contain 7.5 t of Ga.

Because manufacture of a large sphere is expensive, the outer zone is approximated as a cylinder with a dished bottom (see Fig. 4). This results in only a 2% reduction of the neutrino capture rate and almost negligibly changes the sensitivity of the experiment to oscillations. The outer cylindrical zone (diameter of 2192 mm and height of 2192 mm) contains 42.5 t of Ga.

The chemical technology and electrical schemes of the 2-zone experiment have been completely developed and designed, including the choice of auxiliary equipment. Furthermore, the same Ge extraction technology and counting equipment that is used in SAGE to measure the solar neutrino flux will be used in this source experiment.

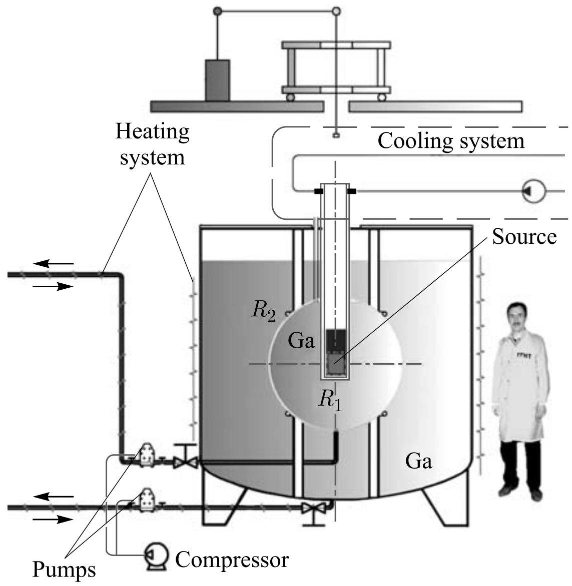

Fig. 4. Layout of the 2-zone facility

3.3. Exposure Schedule, Statistics and Uncertainties. The geometry of the tanks ensures that the average neutrino path length through the two Ga zones is equal, and has the value $\langle L \rangle \sim 550$ mm. Both zones will be irradiated simultaneously, and in the absence of oscillations the predicted number of ^{71}Ge atoms generated in each zone will be the same. When a ^{51}Cr source with initial activity of 3 MCi is placed at the center of the concentric tanks, a mean of 65 atoms of ^{71}Ge will be produced by the source per day in each zone at the beginning of irradiation.

After an exposure period of 9 days, the Ga in each zone is transferred to reaction vessels and the ^{71}Ge atoms produced by neutrino capture are extracted. These steps are the same as have been used in our prior source experiments [16, 17] and are all well tested. Finally, the Ge atoms are placed in proportional counters and their number is determined by counting the Auger electrons released in the transition back to ^{71}Ga, which occurs with a half-life of 11.4 days. Ten such exposures will be made, each of 9 days duration, with one day for extraction. The ^{71}Ge atoms extracted from each zone will be measured in individual counters.

With this schedule, ~ 1647 ^{71}Ge atoms are predicted to be in each zone of the target at the end of source irradiation. Taking into account the total efficiency of extraction and the efficiency of counting, which have a combined value of 53%

(see [17]), the total number of ^{71}Ge decay pulses that will be detected in the counters should be ~ 873.

These extraction and counting procedures have been used in the SAGE experiment for the last 20 years [12] and are all very well understood. A Monte Carlo simulation of the entire experiment — ten extractions each with a 9-day exposure — that uses typical values of extraction efficiency, counter efficiency, counter background rates, and includes the known solar neutrino rate, indicates that the rate can be measured with a statistical uncertainty of $\pm 3.7\%$ in each zone and $\pm 2.6\%$ in the entire target.

From our prior experience in measurement of the solar neutrino flux, we expect a systematic uncertainty of $\pm 2.6\%$, leading to a total uncertainty, statistical plus systematic, of $\pm 4.5\%$ for each zone and $\pm 3.7\%$ for the total target.

Including the theoretical uncertainty of the cross section for neutrino capture from the ^{51}Cr source, which is $+3.6/-2.8\%$ [20], the total uncertainty of the experiment should be $\pm 5.5\%$ for each zone and $\pm 4.8\%$ for the entire target.

3.4. Sensitivity and Prospects. If oscillations to sterile neutrinos occur, the neutrino wave function which describes a pure ν_e state at the source will contain an amplitude which oscillates into sterile neutrinos as the distance from the source increases. In a model with just the electron neutrino and one sterile neutrino, the probability that a neutrino with energy E will survive after passing the distance L from the source, i.e., the survival probability, is described by the expression: $P_{ee} = 1 - \sin^2(2\theta)\sin^2\left[1.27\Delta m^2(\mathrm{eV}^2)\dfrac{L(\mathrm{m})}{E_\nu(\mathrm{MeV})}\right]$, where Δm^2 is the squared mass difference of neutrino eigenstates and θ is the mixing angle. The apparatus shown in Fig. 2 is sensitive to this type of oscillation as the two gallium regions are at different distances from the source.

The probability of interaction of the neutrinos in each region, for the specific case of $\sin^2 2\theta = 0.3$, is shown in Fig. 5 together with the ratio of event rates.

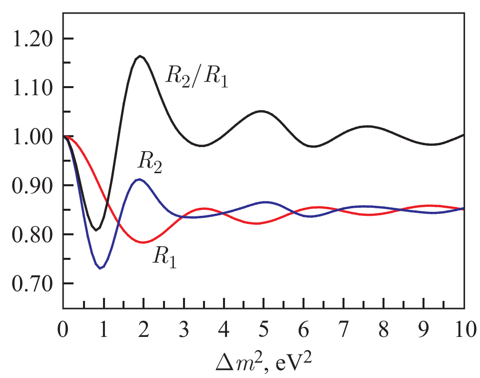

Fig. 5. Ratio of measured capture rate to predicted rate in the inner (R_1) and outer (R_2) zones and their ratio R_2/R_1 as a function of Δm^2 for mixing angle $\sin^2 2\theta = 0.3$

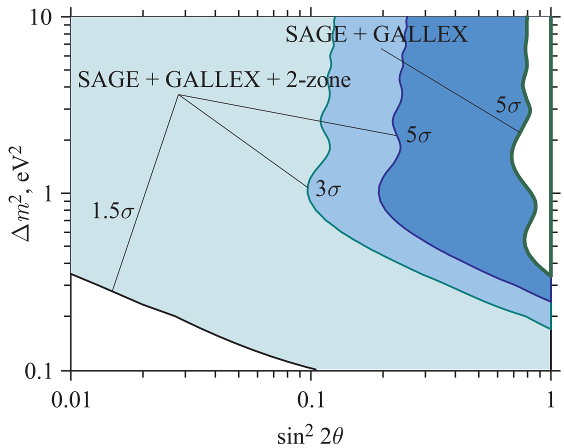

Fig. 6. Region of mixing parameters to which the BEST experiment, in combination with previous source experiments, is sensitive with various levels of confidence. The white region in the upper-right corner has been already excluded with 5σ confidence by previous SAGE and GALLEX source experiments. As indicated, the BEST experiment has the capability to greatly expand this exclusion region with high confidence

The ratio is particularly sensitive to any oscillation because it is independent of both the source strength and the cross section, thus eliminating the major systematic errors.

A statistically significant departure of either of the rates, R_1 or R_2, or their ratio, would provide direct evidence of nonstandard properties of the neutrino. The obtained ratio of the rates would provide guidance to new neutrino properties and these can be further constrained by including the results of the earlier gallium experiments. The sensitivity region of the new 2-zone Ga experiment with a 3-MCi ^{51}Cr source, combined with the previous Ga experiments, would provide the constraints indicated in Fig. 6.

The proposed experiment BEST has significant advantages in comparison to other projects. These advantages come from the use of a compact nearly monochromatic neutrino source with well-known activity, the use of a dense metallic Ga target that provides a high interaction rate, the special geometry of the target which gives the possibility of measuring the neutrino capture rate at two baselines, and the use of the well-established procedure of measurement of the neutrino capture rate on gallium that has been developed in SAGE.

Other advantages of this experiment are the significant value of the signal/background ratio and the simplicity of interpretation of the results. The main contribution to the background will in fact be neutrinos from the Sun, whose flux is known well from many years of measurement by the telescope. Because of the strong activity of the source the rate of interactions in the detector will be many times higher than the rate produced by the Sun.

The simplicity of interpretation of results is assured by the use of the ^{51}Cr source that emits nearly monochromatic neutrino flux, and the absence of systematic uncertainties connected with inaccurate knowledge of the neutrino spectrum and cross section.

CONCLUSIONS

The BEST experiment on electron neutrino disappearance with an intense artificial source of electron neutrinos and an optimized geometry gives an opportunity to search for transitions of active neutrinos to sterile states with $\Delta m^2 > 0.5$ eV^2 with a sensitivity to disappearance of electron neutrinos of a few percent. We plan to complete modernization of GGNT and begin to use the 2-zone tank for solar neutrino measurements in 2014 (see Appendix, Figs. 7, 8, 9).

This work was supported in part by the Program of Basic Research "Fundamental Properties of Matter and Astrophysics" of the Presidium RAS, by the Russian Foundation for Basic Research grants 11-02-00806-a, 11-02-12130-ofi-m-2011, 13-02-12075-ofi-m-2013, and by the grant of the President of the Russian Federation NS-871.2012.2.

APPENDIX

THE STAGES OF ASSEMBLING OF THE 2-ZONE TANK IN THE GGNT LABORATORY

Fig. 7. The inner and the outer tanks delivered to the GGNT laboratory

Fig. 8. The outer tank is completely prepared for the installation of the inner sphere

Fig. 9. The inner sphere is placed into the outer cylinder

REFERENCES

1. *Pontecorvo B. M.* Neutrino Experiments and the Problem of Conservation of Leptonic Charge // J. Exp. Theor. Phys. 1967. V. 53. P. 1717.
2. *Beringer J. et al. (Particle Data Group).* Review of Particle Physics // Phys. Rev. D. 2012. V. 86. P. 010001.
3. *Aguilar A. et. al. (LSND Collab.).* Evidence for Neutrino Oscillations from the Observation of Antineutrino (Electron) Appearance in an Antineutrino (Muon) Beam // Phys. Rev. D. 2002. V. 64. P. 112007.
4. *Aguilar-Arevalo A. A. et al. (MiniBooNE Collab.).* A Search for Electron Neutrino Appearance at the $\Delta m^2 \sim 1$ eV^2 Scale // Phys. Rev. Lett. 2007. V. 98. P. 231801; *Aguilar-Arevalo A. A. et al. (MiniBooNE Collab.).* Unexplained Excess of Electron-Like Events from a 1-GeV Neutrino Beam // Phys. Rev. Lett. 2009. V. 102. P. 101802.
5. *Aguilar-Arevalo A. A. et al. (MiniBooNE Collab.).* Improved Search for $\bar{\nu}_\mu \to \bar{\nu}_e$ Oscillations in the MiniBooNE Experiment. arXiv:1303.2588v1 [hep-ex].

6. *Aguilar-Arevalo A. A. et al. (MiniBooNE Collab.).* Improved Search for $\bar{\nu}_\mu \to \bar{\nu}_e$ Oscillations in the MiniBooNE Experiment // Phys. Rev. Lett. 2013. V. 110. P. 161801.
7. *Mention G. et al.* The Reactor Antineutrino Anomaly // Phys. Rev. D. 2011. V. 83. P. 073006.
8. *Acero M. A., Giunti C., Laveder M.* Limits on ν_e and $\bar{\nu}_e$ Disappearance from Gallium and Reactor Experiments // Phys. Rev. D. 2008. V. 78. P. 073009;
   Giunti C., Laveder M. Short-Baseline Electron Neutrino Disappearance, Tritium Beta Decay and Neutrinoless Double-Beta Decay // Phys. Rev. D. 2010. V. 82. P. 053005.
9. *Abazajian K. N. et al.* Light Sterile Neutrinos: A White Paper. arXiv:1204.5379v1 [hep-ph];
   Gavrin V. N. et al. Gallium Experiments with Artificial Neutrino Sources as a Tool for Investigation of Transition to Sterile States. arXiv:1006.2103 [nucl-ex].
10. *Abdurashitov J. N. et al. (SAGE Collab.).* Measurement of the Solar Neutrino Capture Rate with Gallium Metal // Phys. Rev. C. 1999. V. 60. P. 055801.
11. *Abdurashitov J. N. et al. (SAGE Collab.).* Solar Neutrino Flux Measurements by the Soviet–American Gallium Experiment (SAGE) for Half the 22-Year Solar Cycle // Zh. Eksp. Teor. Fiz. 2002. V. 122. P. 211.
12. *Abdurashitov J. N. et al. (SAGE Collab.).* Measurement of the Solar Neutrino Capture Rate with Gallium Metal. III. Results for the 2002–2007 Data-Taking Period // Phys. Rev. C. 2009. V. 80. P. 015807.
13. *Gavrin V. N.* The Russian–American Gallium Experiment SAGE // Usp. Fiz. Nauk. 2011. V. 0181. P. 0975.
14. *Abazov A. I. et al. (SAGE Collab.).* Search for Neutrinos from Sun Using the Reaction $^{71}\mathrm{Ga}(ne, e^-)^{71}\mathrm{Ge}$ // Phys. Rev. Lett. 1991. V. 67. P. 3332.
15. *Anselmann P. et al. (GALLEX Collab.).* Solar Neutrinos Observed by GALLEX at Gran Sasso // Phys. Lett. B. 1992. V. 285. P. 376.
16. *Abdurashitov J. N. et al. (SAGE Collab.)* // Phys. Rev. C. 1999. V. 59. P. 2246.
17. *Abdurashitov J. N. et al. (SAGE Collab.)* // Phys. Rev. C. 2006. V. 73. P. 045805.
18. *Hampel W. et al. (GALLEX Collab.).* Final Results of the Cr-51 Neutrino Source Experiments in GALLEX // Phys. Lett. B. 1998. V. 420. P. 114.
19. *Kaether F. et al. (GALLEX Collab.).* Reanalysis of the GALLEX Solar Neutrino Flux and Source Experiments // Phys. Lett. B. 2010. V. 685. P. 47.
20. *Bahcall J. N.* Gallium Solar Neutrino Experiments: Absorption Cross Sections, Neutrino Spectra, and Predicted Event Rates // Phys. Rev. C. 1997. V. 56. P. 3391.
21. *Hata N., Haxton W.* Implications of the GALLEX Source Experiment for the Solar Neutrino Problem // Phys. Lett. B. 1995. V. 353. P. 422.
22. *Frekers D. et al.* The ^{71}Ga (^{3}He, t) Reaction and the Low-Energy Neutrino Response // Phys. Lett. B. 2011. V. 706. P. 134.
23. *Frekers D. et al.* Penning-Trap Q-Value Determination of the $^{71}\mathrm{Ga}(\nu, e)^{71}\mathrm{Ge}$ Reaction Using Threshold Charge Breeding of On-Line Produced Isotopes // Phys. Lett. B. 2013. V. 722. P. 233.