Background-free search for neutrinoless double-β decay of ^{76}Ge with GERDA

K.N. Gusev, I.V. Zhitnikov, D.R. Zinatulina, A.A. Klimenko, A.V. Lubashevskiy, N.S. Rumyantseva, A.A. Smolnikov, M.V. Fomina, E.A. Shevchik, M.V. Shirchenko

The **GERDA** collaboration searches for neutrinoless double beta (0νββ) decay of ^{76}Ge. The discovery of this process, which violates the lepton number, would mean that neutrino is a Majorana particle and prove the existence of New Physics beyond Standard Model. The experimental facility is located at the Laboratori Nazionali del Gran Sasso in Italy. GERDA uses high purity germanium detectors enriched in ^{76}Ge (about 40 kg of ^{76}Ge in total), which are arranged in seven strings inside a cryostat filled with 64 m^3 of liquid argon. The liquid argon acts both as cooling and passive and active shielding medium. Thanks to it and to the excellent pulse shape discrimination capability of Ge detectors, GERDA has achieved the unique background level of 0,5 × 10^{-4} counts/(keV kg yr). Thus, an average background less than 1 count expected in the ROI up to the design exposure of 100 kg yr. This implies that GERDA is the first background-free 0νββ experiment. The data taking in the GERDA experiment has been completed and the transition phase to the next generation project LEGEND has been started.

With a total exposure of 127.2 kg yr (103.7 kg yr in Phase II), we observed no 0νββ signal and derived a world best lower half-life limit of $T^{0\nu}_{1/2}$ > 1.8 × 10^{26} yr (90% C.L.) at the unprecedented median sensitivity of 1.8 × 10^{26} yr. The linear increase of sensitivity with exposure, achieved by GERDA, proves that we were taking data in background free regime. This fact opens very promising future for the background-free tone-scale germanium experiment.

JINR scientists are playing significant roles in all key parts of the project. DLNP JINR was responsible for design, production, testing and installation of plastic muon veto system. JINR specialists actively participated the development of liquid argon instrumentation first in the R&D of argon scintillations registration principles and then in the design and production of the initial liquid argon veto system for the experiment (in 2015). In 2018 the modified argon veto system with improved light collection was produced, tested and installed in GERDA by common TUM and JINR group. Our scientists have been developed the original method of mitigation of ^{42}Ar background. Specially made low background nylon mini-shrouds, covered with a wavelength shifter, have been mounted on every detector string and allowed to suppress this background significantly. Physicists from our institute were strongly involved in the analysis of GERDA data and were responsible for all operations with bare enriched germanium detectors starting from confirmation of their functionality in cryogenic liquids at the beginning of the project and then for the integration of all of them in the GERDA cryostat in both phases of the experiment.

GERDA results were presented at many conferences as well as many papers were published. However, we have chosen 8 papers for this nomination. Two of them describe the GERDA experimental facility, one is dedicated to the ^{42}Ar mitigation and other five are devoted to the stepwise improvement of the half-life limit for 0νββ decay of ^{76}Ge up to the final achievement in 2020 – the world best limit for this process. All of them were published in refereed journals, including Nature and Science.

The main results are:

1. Experimental confirmation of the robustness and efficiency of the novel approach of using Ge detectors (bare Ge detectors are directly immersed in cryogenic liquid).
2. R&D, construction and commissioning of the GERDA experimental facility (Phase I and II) and its successful upgrade in 2018.
3. R&D of different background suppression methods (active muon and argon veto systems, pulse shape discrimination with Ge detectors, ^{42}Ar mitigation system). Thanks to them GERDA has achieved the unprecedented background index of 0,5 × 10^{-4} counts/(keV kg yr). All these methods are going to be used in the next generation experiment searching for 0νββ decay of ^{76}Ge.
4. Confirmation of background free regime of data taking – the linear increase of sensitivity with exposure.
5. Achievement of the world best lower half-life limit on 0νββ decay of ^{76}Ge of $T^{0\nu}_{1/2}$ > 1.8 × 10^{26} yr (90% C.L.).

List of publications

1. K.-H. Ackermann et al., The GERDA experiment for the search of 0νββ decay in ^{76}Ge, **Eur. Phys. J. C 73 (2013) 2330**, DOI: 10.1140/epjc/s10052-013-2330-0

2. M. Agostini et al., Results on Neutrinoless Double-β Decay of ^{76}Ge from Phase I of the GERDA Experiment, **Phys. Rev. Lett 111 (2013) 122503**, DOI: 10.1103/PhysRevLett.111.122503
3. GERDA collaboration, Background-free search for neutrinoless double-β decay of ^{76}Ge with GERDA, **Nature 544 (2017) 47**, DOI: 10.1038/nature21717
4. A. Lubashevskiy et al., Mitigation of $^{42}Ar/^{42}K$ background for the GERDA Phase II experiment, **Eur. Phys. J. C 78 (2018) 15**, DOI: 10.1140/epjc/s10052-017-5499-9
5. GERDA collaboration, Upgrade for Phase II of the GERDA experiment, **Eur. Phys. J. C 78 (2018) 388**, DOI: 10.1140/epjc/s10052-018-5812-2
6. GERDA collaboration, Improved Limit on Neutrinoless Double-β Decay of ^{76}Ge from GERDA Phase II, **Phys. Rev. Lett. 120 (2018) 132503**, DOI: 10.1103/PhysRevLett.120.132503
7. M. Agostini, Probing Majorana neutrinos with double-β decay, **Science 365 (2019) 1445**, DOI: 10.1126/science.aav8613
8. GERDA collaboration, Final Results of GERDA on the Search for Neutrinoless Double-β Decay, submitted to Phys. Rev. Lett. (2020), arXiv: 2009.06079