Referee report of GERDA (“G&M”) project

The goal of the GERDA (GErmanium Detector Array) experiment is to search for neutrinoless double beta decay (0νββ) of ^{76}Ge. The 0νββ decay is one of the most sensitive probes of still unknown neutrino properties such as neutrino type and their mass scale. Neutrinos are under extensive experimental study now and the knowledge about their properties has advanced our understanding of weak interactions significantly. Still unanswered, however, is the very fundamental question whether the neutrino is a Majorana particle. If the neutrinoless double beta decay occurs then their Majorana nature is proven. The potential of this method has increased considerably during the last years since a non-zero mass of the neutrinos has been established by the observation of neutrino flavor oscillation. The observation of 0νββ decay would not only establish the Majorana nature of the neutrino but also provide a measurement of its effective mass $<m_{ee}>$ as well as fix the hierarchy of neutrino spectrum.

GERDA operates with bare germanium detectors (enriched in ^{76}Ge) situated in liquid argon (LAr) for shielding against external radiation. This concept is based on the observation that the background signals are largely dominated by external radiation. By removing most of the cladding materials and immersing the crystals in an ultra-pure environment, which is used also as active veto, one can reduce detector background dramatically. It’s proven that GERDA reached the designed background of 10^{-3} cts/(keV·kg·yr), which makes it first background free experiment in the 0νββ field.

Construction of the main experimental GERDA infrastructure was completed in 2010. A stainless steel cryostat with internal Cu shield contains 100 tons of LAr. The cryostat is situated inside a water tank. The ultra-pure water buffer serves as a gamma and neutron shield and, instrumented with photomultipliers, as Cherenkov detector for efficiently vetoing cosmic muons. Plastic scintillator panels on top of the detector will tag muons which enter the dewar through the neck. The Ge detector array is made up of individual detector strings. Cleanroom and radon tight locks on top of the vessel assembly allow inserting and removing individual detector strings without contaminating the cryogenic volume. The experimental set up is located in the underground laboratory of LNGS (Italy).

The experimental GERDA strategy is based on at least two phases, in each incrementing the target mass. In the Phase I the 8 existing enriched detectors (18 kg of ^{76}Ge in total) from the previous Heidelberg-Moscow (HdM) and IGEX experiments were employed, in the Phase II the new modern BEGe-detectors made from recently produced enriched material were added. To reach the background level required for the Phase II ($<10^{-3}$ cts/keV·kg·yr) new methods have been developed to suppress the intrinsic background of the detectors.

After about 1.5 years of the Phase I data taking, corresponding to an exposure of 20 kg·yr with the very low background level 10^{-2} counts/ keV·kg·yr, GERDA refuted the claimed observation of 0νββ decay (H. Klapdor’s et al. (KKGH) claim $T_{1/2} = 1.2 \times 10^{25}$ y or $<m_\nu> = 0.44$ eV) at the high statistical level without problems with uncertainties in nuclear matrix elements (NME) and establishes the new limit on the half-life $T_{1/2} > 2.1 \times 10^{25}$ years, translated into an effective neutrino mass, $m_\nu < 0.2 – 0.4$ eV, depending on NME used.

In GERDA Phase II about 20 kg of new enriched BEGe detectors were added, which gives the total mass of about 40 kg. Data taking in Phase II has started in December 2015. The analysis of data collected so far showed that the desired background index of 10^{-3} counts/keV·kg·yr has been successfully achieved. Thus, less than 1 count in ROI expected up to design exposure of 100 kg·yr and GERDA will stay background free until the end of data taking. By now the GERDA experiment reached the half-life sensitivity of 5.8×10^{25} years and the limit $> 8.0 \times 10^{25}$ years, which means in terms of effective neutrino mass $m_{\nu} < 0.12 – 0.26$ eV. The projected sensitivity of 10^{26} years can be achieved already next year. When GERDA will reach the design exposure of 100 kg·yr, the sensitivity should be above 1.4×10^{25} years.

As the next step of GERDA and Majorana projects a common ton scale ^{76}Ge experiment (LEGEND) is going to be build. The ultimate goal of the new experiment is to reach the exposure of 10 t yr with further background reduction to $< 10^{-4}$counts/keV·kg·yr. This will allow to achieve the half-life sensitivity of $> 10^{28}$ years or, in terms of effective neutrino mass, $<m_{\nu}> = 0.01$ eV and thus to cover the inverted neutrino mass hierarchy region. Close contacts between the Majorana and GERDA collaborations have been already established in order to provide a large transparency between the collaborations and to coordinate the R&D work. The achieved background indices are similar in both projects. The LEGEND experiment will select the best technologies from GERDA and Majorana as well as contributions from other groups and experiments.

The GERDA collaboration consists of about 110 physicists from 16 institutions coming from 6 countries.

The JINR team participating in the GERDA project has a serious experience in low background physics, including double-beta decay experiments (such as NEMO-3 and TGV). The team members are experts in production and operation of semiconductor detectors, on active (scintillation) veto technic, in construction and operation of underground facilities and in data analysis.

Scientists from JINR participate in the most main parts of the collaboration tasks which include, in particular, simulation of the main background contributions aimed to clarify the main conceptual design of the set up; modification of existing enriched Ge detectors and testing them in liquid argon for long term operation; development and production of the effective veto shields on the base of plastic scintillators; development of new methods of background reduction including active LAr scintillation veto and pulse shape discrimination; design and construction of the test facility LArGe containing 1 ton of liquid argon; measurements of radioactive contamination of a large fraction of the construction materials by using low-background Ge gamma-spectrometers.

GERDA (“G&M”) looks like one of the more advanced ongoing and near future experiments for neutrinoless double beta decay search in the world. The expected (in the following few years) results will improve the present knowledge about nature of neutrino leading to physics beyond the Standard Model. In case of successful realization of the tonne-scale LEGEND project the expected sensitivity can reach the region of the effective Majorana neutrino mass of about 0.01 eV and the inverted hierarchy region will be covered. I have no doubts that the GERDA (“G&M”) project will be realized and the claimed goals are reachable in the near future.

The role of the JINR team in realization of the project seems to be considerable and very important.

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