Referee report of GERDA (LEGEND) project

The goal of the Large Enriched Germanium Experiment for Neutrinoless double beta Decay (LEGEND) experiment, which is the successor of the GERDA and Majorana experiments, is to search for neutrinoless double beta decay ($0\nu\beta\beta$) of ^{76}Ge. The $0\nu\beta\beta$ 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 $0\nu\beta\beta$ 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.

LEGEND is going to operate with bare germanium detectors (enriched in ^{76}Ge) situated in liquid argon (LAr) for shielding against external radiation. This concept 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. This concept was successfully proven by the predecessor GERDA project which managed to reach the unique background index of 5×10^{-4} cts/(keV·kg·yr). This achievement made GERDA the first background free experiment in the $0\nu\beta\beta$ field.

The experimental LEGEND strategy is based on at least two phases, in each incrementing the target mass. In the first phase (LEGEND-200) up to 200 kg of enriched Ge is going to be employed. This includes the existing enriched Ge detectors from the GERDA and Majorana experiments as well as the new detectors which are being produced now. The goal is to reach the half-life sensitivity $> 10^{27}$ years. The ultimate phase (LEGEND-1000) will use up to 1000 kg of ^{76}Ge in order to achieve the half-life sensitivity of $> 10^{28}$ years or, in terms of effective neutrino mass, $<m_{\beta\beta}> \sim 0.01$ eV and thus to cover the inverted neutrino mass hierarchy region.

The LEGEND-200 experiment is going to reuse the GERDA experimental infrastructure located in the underground laboratory of LNGS (Italy). 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 tag muons which enter the cryostat through the neck. The Ge detector array will be made from individual detector strings. The LAr instrumentation will surround the detector array to readout of scintillation light creating an effective active LAr veto system. Cleanroom and radon tight locks on top of the vessel assembly allow inserting and removing the Ge detector array and LAr veto without contaminating the cryogenic volume. The LEGEND-200 experiment is selecting the best technologies from GERDA and Majorana as well as contributions from other groups and experiments. LEGEND plans to start data taking within the next few years.

It worth to note here the final result of the GERDA experiment which was recently stopped data taking after reaching the desired exposure of 100 kg yr. The analysis of the full data set of 127.2 kg yr (103.7 kg yr was collected in Phase II and 23.5 kg yr – in Phase I) allowed GERDA to set the new, the best in the world, half-life limit on $0\nu\beta\beta$ decay of ^{76}Ge > 1.8 x 10^{26} years at the sensitivity of 1.8 x 10^{26} years. This unprecedented result indicates that the ambitious goals of the LEGEND experiment could be achieved as well.

The LEGEND collaboration consists of about consists of 240 members from 47 institutions worldwide.

The JINR team participated in the GERDA project since the very beginning and now plays the important role in the LEGEND project. The team members are experts in production and operation of semiconductor detectors, in active (scintillation) veto technics, in construction and operation of underground facilities and in the data analysis.

Scientists from JINR participate in the most main parts of the collaboration tasks which include, in particular, handling of the enriched germanium detectors; integration of the experiment; development of new background reduction technics including active LAr scintillation veto and pulse shape discrimination; development and production of the nylon mini-shrouds which will be used mitigate one of the most dangerous source of the background for LEGEND-200 – ^{42}Ar; development and production of the new liquid argon instrumentation; measurements of radioactive contamination of a large fraction of the construction materials by using low-background Ge gamma-spectrometers.

GERDA (LEGEND) looks like one of the most 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 tone-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 (LEGEND) 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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