

# Status of the GERDA experiment

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## **Abstract.**

The GERmanium Detector Array GERDA is designed to search for neutrinoless double beta decay of  $^{76}\text{Ge}$ . This search is necessary to establish the nature of the neutrino (Dirac or Majorana) and is emphasized by the evidence of a non-zero neutrino mass from flavour oscillations and by the claim for a positive signal based on data of the Heidelberg-Moscow experiment. GERDA will be installed in the Gran Sasso underground laboratory of INFN/Italy. The experiment is designed to collect at the end of phase II an exposure of about 100 kg·y quasi background free. This leads to a requirement of a background index of the order of  $10^{-3}$  counts/(kg·keV·y) at the  $Q_{\beta\beta}$ -value of 2039 keV.

## **1. Introduction**

The GERmanium Detector Array GERDA [1] is a new double beta decay experiment using  $^{76}\text{Ge}$ . To achieve better sensitivity a significant reduction of background compared to previous experiments is required. The main concept for background suppression followed by GERDA is the operation of bare Ge-diodes enriched in  $^{76}\text{Ge}$  in ultrapure liquid argon. Liquid argon acts as passive shield and cooling medium for the diodes. It is contained in a stainless steel vacuum cryostat. Additional shield against external neutrons and gamma-rays is provided by pure water surrounding the cryostat. The water tank is equipped with photo multiplier tubes and operated as a Cherenkov detector to reject residual cosmic muons. Enriched  $^{76}\text{Ge}$ -diodes will be prepared in a cleanroom and inserted into a lock system from where they are lowered inside the cryostat.

## **2. Sensitivity**

The GERDA experiment is performed in different phases: In phase I 17.9 kg of existing  $^{76}\text{Ge}$  diodes from the previous Heidelberg-Moscow and IGEX experiments will be re-used. At the expected background rate of  $10^{-2}$  counts/(kg·keV·y) around the Q-value of the  $^{76}\text{Ge}$  decay (2039 keV) the resulting sensitivity for the half-life of the neutrinoless double beta decay is  $2 \cdot 10^{25}$  y after 1 year of exposure. This is sufficient to scrutinize the existing claim for a positive signal [2]. In phase II new diodes will be added to increase the active mass up to 40 kg. A major progress in sensitivity can only be obtained if the background can be suppressed to  $10^{-3}$  counts/(kg·keV·y). This will be achieved by segmented detector readout, minimization of cosmic ray exposure, pulse shape discrimination and careful selection of construction materials. The expected sensitivity lies around 130 meV for the effective neutrino mass at an exposure of 100 kg·y. A third phase aiming to the inverted neutrino mass hierarchy regime would require about 1 ton of  $^{76}\text{Ge}$  target material as well as a further reduction of background.

### 3. Status of selected sub-projects

#### 3.1. Liquid argon purity

Liquid argon will be in direct contact to the Germanium diodes. Thus, it has to fulfill stringent purity requirements. The most worrisome radio-active contamination in argon is  $^{222}\text{Rn}$  and in particular its progeny  $^{214}\text{Bi}$ . Radon can be removed from argon by cryogenic adsorption on activated carbons. In a series of measurements it was found that a concentration reduction of more than a factor 2500 can be achieved with 1 kg of activated carbon if the purification happens in gas phase. For liquid phase purification which is relevant for GERDA the efficiency is about one order of magnitude worse. However, due to the relatively short half-life of  $^{222}\text{Rn}$  a reduction can also be obtained by storing liquid argon in a clean storage tank. For this reason the  $^{222}\text{Rn}$  emanation rate of cryogenic storage tanks was investigated. Although many tanks had rather high  $^{222}\text{Rn}$  emanation rates a few sufficiently clean tanks could be identified. One of them with a volume of  $6.3\text{ m}^3$  and a  $^{222}\text{Rn}$  activity of  $(3.5 \pm 0.2)\text{ mBq}$  in saturation might be available for the GERDA experiment.

#### 3.2. Cryostat

To achieve the ambitious background goals also the GERDA stainless steel cryostat must fulfill stringent radio-purity requirements. In particular, the high energy gamma lines from  $^{208}\text{Tl}$  and  $^{214}\text{Bi}$  from U/Th contaminations must be suppressed sufficiently. This is achieved by a careful selection of radio-pure stainless steel and the installation of copper plates inside the inner wall of the cryostat. More than 10 batches of stainless steel type 1.4571 were screened with low background Germanium spectrometers. The activities found for  $^{226}\text{Ra}/^{228}\text{Th}$  lie in most cases below  $1\text{ mBq/kg}$  [3]. This is significantly lower than what was expected from results of previous stainless steel screening campaigns [4]. As a consequence the required amount of copper could be reduced by more than a factor 2 which relaxed mechanical constraints and costs significantly. The cryostat is under construction now and is planned to be delivered to Gran Sasso beginning of 2008.

#### 3.3. GERDA detector laboratory

The GERDA detector laboratory is located in close neighborhood to the main GERDA site in hall A of the Gran Sasso underground laboratory. It is a facility offering all equipment for handling and manipulations of bare Germanium diodes like a chemical hood and clean benches. One of the clean benches is air tight so that a  $^{222}\text{Rn}$ -free atmosphere can be provided. Diodes mounted there can directly be tested in an attached liquid argon test stand without being exposed to air. The GERDA detector laboratory also hosts a larger ( $1\text{ m}^3$ ) liquid argon test stand called LArGe. Besides detector testing it will be used for liquid argon scintillation light studies. LArGe is under construction and will be operational in 2008.

#### 3.4. Preparation of existing diodes

For phase I of GERDA existing Germanium diodes enriched in  $^{76}\text{Ge}$  from previous experiments are used. Altogether 8 diodes with a mass of  $17.9\text{ kg}$  are available corresponding to  $\sim 15\text{ kg}$  of pure  $^{76}\text{Ge}$ . After a careful characterization of the diodes they have been removed from their cryostats. Then their dimensions were measured and they were stored in an underground location (HADES) in Belgium. Together with Canberra / Olen in Belgium they were prepared for the operation without vacuum cryostat. A refurbishment including a loss of a few grams of  $^{76}\text{Ge}$  was tolerated for some of the diodes which had a different contact scheme. Now all diodes have the same well tested and well understood contact scheme which increases the confidence of safe operations in liquid argon.

### 3.5. Prototype testing for phase I

For the last 2 years intensive tests with a phase I prototype crystal have been performed. It is mounted in a low mass ( $\sim 80$  g) support structure made out of copper and PTFE. Both materials were screened by gamma ray spectroscopy and only upper limits for U/Th contaminations were found (in the range of  $20 \mu\text{Bq/kg}$  for copper and  $100 \mu\text{Bq/kg}$  for PTFE). Monte Carlo-simulations have shown that the background from the material of the detector holder fulfills the requirements for phase I. Handling of bare diodes is very delicate, because the passivation layer is very sensitive. In particular, it is important to be able to warm up and cool down the diodes without damaging them. Meanwhile, more than 40 cooling and warming cycles have been performed and the passivation layer had to be renewed only twice. This shows that the detector handling process is well under control. Also the response of the diode's leakage current to irradiation with gamma ray sources was investigated. A reversible increase of the leakage current was observed which was strongest when the passivation layer was irradiated directly. Covering this side of the diode with a PTFE/Cu/PTFE sandwich disk solved the problem. A several months lasting long-term test showed only a negligible increase of leakage current. Further improvements are under development.

### 3.6. Preparations for phase II

In 2005 37.5 kg of enriched  $^{76}\text{Ge}$  was produced for the phase II diodes. Currently, techniques are being optimized to reach the chemical purity necessary for crystal pulling and to improve the yield and thus to minimize the loss of enriched Germanium. In parallel different options for crystal pulling are investigated. Until the preparation of the next steps is finished the material is stored in an underground location to avoid cosmogenic activation. The phase II detectors will be n-type detectors with segmented readout electrodes. The background suppression by segmented detectors is currently tested with several test setups. Promising results were obtained with the chosen segmentation scheme of 3x6 segments (3 along z-coordinate and 6 azimuthal segments).

## 4. Outlook

The GERDA experiment will become operational in 2009. After 1 year of data taking with the existing diodes the claim by [2] for a  $0\nu\beta\beta$ -decay will be checked unambiguously. If it would not be confirmed even after phase II the goal must be to do a  $\sim 1$  ton experiment to access the range of inverted neutrino mass hierarchy. Since this can only be afforded in a world-wide collaboration a close contact with the Majorana project has already been established aiming to a common large-scale experiment in the future.

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