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GERDA: a germanium detector array to search for neutrinoless double beta decay

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Abstract. The GERDA, a new experiment to search for the double beta decay of ^{76}Ge , is being installed at Laboratori Nazionali del Gran Sasso. The potentialities of this experiment as well the status of the project are reviewed.

1. Introduction

The physics motivations to search for $0\nu\beta\beta$ decay have been discussed in many theoretical and experimental papers, also at this same Conference. In this paper GERDA [1], a new experiment based on the use of a large amount of ^{76}Ge , is presented. Ge diodes are excellent devices to search for neutrinoless $\beta\beta$ decay. The germanium acts as source and detection medium; the transition energy is reasonably high (2038.5 keV) and the energy resolution is better than 4 keV at this energy. All materials used are carefully selected. In addition, recently developed techniques - diode segmentation and pulse shape discrimination – are applied. All this combined, it is possible to greatly reduce the background.

Two collaborations have recently provided new data on ^{76}Ge : the IGEX Coll. [2] provided a limit on the $0\nu\beta\beta$ decay half-life of $1.57 \cdot 10^{25}$ y; the Heidelberg-Moscow (HdM) Collaboration at Gran Sasso obtained a similar; Klapdor-Kleingrothaus and coll. [3], using the full statistics of the HdM experiment (72 kg.y) found a positive signal of 29 counts above a background of 60. This signal corresponds to a half-life $(1.19^{+0.37}_{-0.23}) \cdot 10^{25}$ y; the GERDA experiment is designed to clarify the situation and extend the ranges of accessible life-times.

2. The baseline design of GERDA

The baseline design of GERDA is shown in the artistic view of the figure (figure 1). The diodes are directly immersed in liquid nitrogen (LN) which has two functions: to cool down and to shield the diodes from external radioactivity. The cryostat will be built out of high purity copper (an alternative design based on the use of steel has also been studied) and it will be immersed in a tank filled with high purity water tank to further reduce the n 's and γ 's fluxes. Suspension wires and electronics cable will pass through the long neck on top of the cryostat. The water will be instrumented with PMT's to veto the muons entering in the set-up. Special counters will be located on the top of the entire structure to complete the muon veto. On the top of the water tank, a building will house a clean room, the electronics and the needed infrastructures. GERDA will be located in the Hall A of the underground Gran Sasso laboratories of LNGS.

^{a)} The Members of GERDA collaboration are reported in <http://www.mpi-hd.mpg.de/GERDA>

3. Ge diodes and read out electronics

GERDA will proceed by phases: in Phase I the crystals from IGEX and HdM will be installed, after an appropriate refurbishing. At present, the HdM detectors have been characterized, while the IGEX detectors will arrive at Gran Sasso in November.

In Phase II, new detectors will be installed. The more significant steps in the production of the new enriched detectors are: the *procurement of enriched material* - 37.5 kg of enriched (86% in ^{76}Ge) germanium have been produced by ECP Company (Zelenogorsk – Russian Federation); *chemical purification*- typically this step has a yield of 70% only; R&D on the purification has led to an efficiency of more than 85%; *transport and storage* - special care have been taken in order to reduce as possible the cosmogenic production of background inducing isotopes; *crystal production* - the first stages of the crystal production are the purification of Germanium by polyzone and consecutive monozone refinement; definition of these steps is under discussions with companies specialized in crystal production; *segmentation* - crystals will be truly coaxial type and segmented 6-fold in Φ and 3-fold along the core axis. Coincidence among different crystals and segments of the same crystal will allow a good background rejection, as shown by many Monte Carlo simulations.

Old and new diodes will be mounted in a modular, scalable arrangement of strings. The suspension system will be constructed out of Teflon and copper; a prototype is under test.

Read out and signal processing. For the front end three possibilities have been investigated: i) AGATA hybrid preamplifier [4] plus BF862FET, ii) IPA4 [5], an integrated preamplifier originally developed for Lar and Kr calorimetry and iii) AMPTEK250 + SK152 [6]; moreover a new CMOS ASIC circuit which is being developed by the Collaboration. For the signal processing, two possible solutions are MD²S [7] system, developed by the GERDA Padua group in the framework of the AGATA project and the commercial VME cards SIS 3301 produced by Struck.

4. Background evaluation

The different sources of background are discussed in details in the GERDA proposal. The goal is to achieve a background of 10^{-3} count/ (kg·y·keV) at 2 MeV.

The flux of 2.6 MeV γ from ^{208}Tl has been remeasured in the Hall A of the Laboratory, where GERDA will be located. The measured flux is $(0.031 \pm 0.09) \gamma/(\text{s} \cdot \text{cm}^2)$; the thickness of the shield was adjusted to this with a safety margin of two. The shield is a hybrid construction with a cryogenic and a water layer (see fig.1). All the materials that will be used in the construction have been screened to select those with the lowest content of radionuclides.

A substantial contribution to the background comes from cosmogenically produced ^{60}Co and ^{68}Ge . This background will be different in the detectors of phase I and II, because the new detectors will be constructed minimizing the exposure time to cosmic rays. The relevant background reactions have photons in the final state which deposit energy at multiple sites. The signal electrons typically deposit energy locally. Therefore, an analysis using anticoincidence strongly reduce the background. A careful investigation of the background induced by muons crossing the set-up has been carried out by the MAGE group (Majorana-GERDA group). The suppression due to the rejection of events by the muon veto and a crystal-based anti-coincidence analysis are taken into account. The predicted background is more than one order of magnitude below the goal as stated above. In conclusion, we expect a background of 10^{-2} and of 10^{-3} counts/(kg·y·keV) for crystals of Phase I and II respectively.

5. Potentialities of GERDA

Assuming the energy resolution and the background index quoted above, it is straightforward to compute the expected number of events for different values of the half life. The phase I detectors with a mass of approximately 19kg (corresponding to more than 200 moles of ^{76}Ge) will yield about ten events per year, if the half-life is 10^{25} y. The number of background events is expected to be one. A similar exposure of phase II detectors is expected to be background free. Consider first the Phase I detectors. For a half life of 10^{25} years, we expect, in one year of data taking, 8.3 events of signal and 0.7 events of background. The same signal is expected for Phase II detectors, while their background is negligible. Assuming two years of data taking with old detectors and one year with new diodes

(which will be installed later) a signal of 25 events is expected, against 1.5 background events. Therefore the central value of the signal observed by Klapdor-Kleingrothaus and coll. will be confirmed or disproved with a high statistical significance. Should no signal be observed, a limit of 10^{26} y can be achieved in about three years.

6. Status of the project and conclusions

The project is approved and funded. The needed space is allocated at LNGS. The infrastructure, including water tank and cryostat are under final design.

The works on old and new diodes and the definition of the read-out and DAQ electronics is progressing.

Construction will commence in 2006.

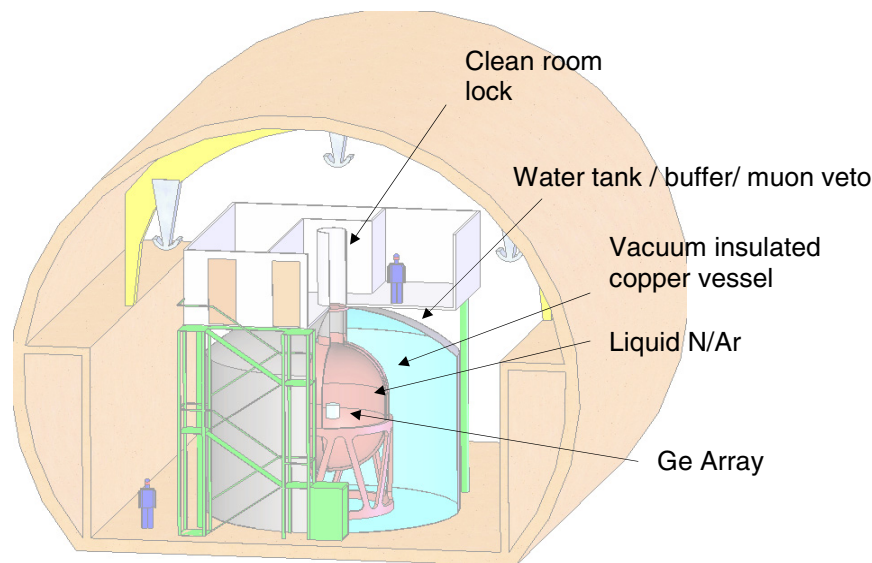


Figure 1. Artistic view of the GERDA setup.

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