The neutrinoless double beta decay in ^{76}Ge at GERDA

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Abstract

The neutrinoless double beta decay in ^{76}Ge will be investigated at a background level below 10^{-3} counts/(kg keV y) in order to determine the nature of the neutrinos. To this aim the GERmanium Detector Array GERDA is designed and is presently being installed at the INFN Gran Sasso National Laboratory, employing the novel feature of immersing the bare Ge diodes into the cryo liquid. In a first phase the existing enriched detectors from Heidelberg-Moscow and IGEX are employed (ca. 18 kg); in a second phase they will be amended by about 20 kg of segmented diodes made from recently purchased material.

Key words: neutrinoless double beta decay, ^{76}Ge
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1. Introduction

Research on neutrino flavor oscillations during the last decades firmly establishes that the neutrinos have finite mass. Already their non-zero mass leads towards physics beyond the standard model. If the neutrinos happens to be their own anti-particles is still an open question. For 10 nuclei, amongst them ^{76}Ge, the beta decay is energetically forbidden, however, a change of two neutrons into two protons is allowed. This second order weak process is accompanied by the emission of two anti-neutrinos – and this $2\beta 2\nu$ process does not violate any number conservation. However, if the neutrinos are of Majorana type, then the very rare process of neutrinoless double beta decay ($2\beta 0\nu$) can occur. The $2\beta 0\nu$ process violates the lepton number conservation by 2. It is the aim of the GERDA collaboration to search for neutrinoless double beta decay in ^{76}Ge.

The detection of extremely rare events requires the use of enriched material and high resolution detectors, a careful selection of proper materials for the construction, and low

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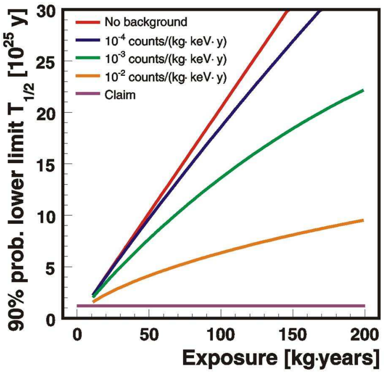

Fig. 1. The sensitivity in dependence on exposure for various background scenarios ; taken from Ref. [1]

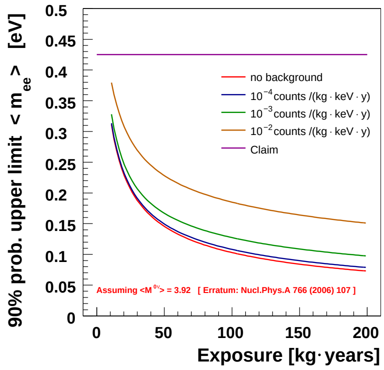

Fig. 2. The effective neutrino mass m_{ee} in dependence on exposure for various background scenarios; adapted from Refs. [1,2] with $\langle M^{0\nu}\rangle$=3,92.

background rates; possibly longer data taking periods. Fig. 1 demonstrates the sensitivity on the background when plotting the expected 90 % probability lower limit of the $2\beta 0\nu$ half-life for versus exposure. The half-life for the claimed observation for neutrinoless double beta decay of ^{76}Ge [3] is also shown. Already with an exposure of 15 (kg y) and a background index of 10^{-2} counts/(kg keV y) the disputed claim [3] can be checked.

The Gerda experiment will proceed in three phases with increasing mass. For phase II a reduced background index at a level of less than 10^{-3} counts/(kg keV y) is envisaged for an exposure of about 100 (kg y). Fig. 2 converts the half life into the effective Majorana neutrino mass using the corrected matrix elements by Rodin *et al.* [2]. The expected 90 % probability upper limit on the effective Majorana neutrino mass is plotted versus the exposure for the same background conditions as in Fig. 1. The Gerda and Majorana collaborations forsee a common phase III experiment.

2. The experimental setup

The Gerda experiment [4,5] will employ the calorimetric approach towards the search for the neutrinoless double beta decay in ^{76}Ge, in contrast to others (see contribution by E. Fiorini [6]). The Ge diodes are source and detector at the same time, where the superior energy resolution permits a setting of very narrow regions of interest and thus low background contributions.

To reduce the flux of cosmic particles the experiment will be set up at the LNGS laboratory which has an overburden of 3800 mwe. Following the suggestion of G. Heusser [7] the diodes will be immersed into liquid argon. By this, the low-Z material reduces background from cosmogenic radiation; in addition we perform R&D for further background suppression through the scintillation light. For technical and safety reasons the pure copper cryostat has been replaced by a stainless steel tank of reasonable high radio-purity ($\sim$ 1 mBq/kg) with copper liners in the center (Fig. 3). The cryostat is surrounded by a water tank of 10 m in diameter which serves as passive shield and which will be instrumented by 66 photomultipliers for a cosmic muon veto (Figs. 3, 4).

The enriched detectors of the former IGEX and Heidelberg-Moscow experiments have been tested for resolution and stability in the old casing. Presently they have been dis-

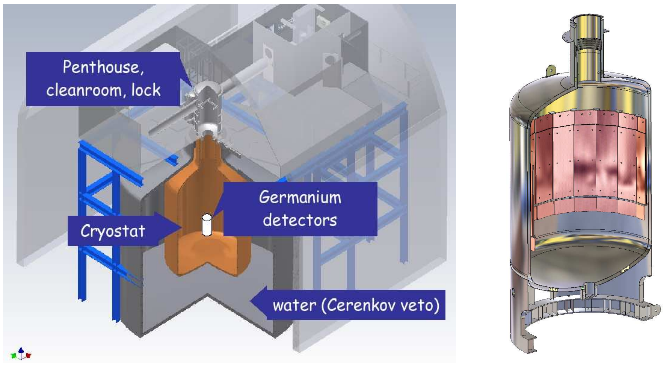

Fig. 3. Schematic view of the GERDA experimental setup at LNGS and a sketch of the stainless steel cryostat with Cu lining.

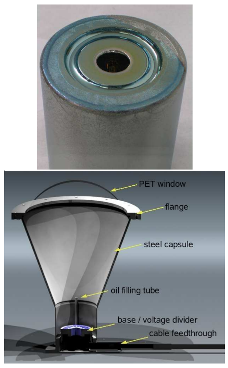

Fig. 4. A bare Ge diode (top) and the PMT encapsulation.

mantled and are being refurbished for use in the new GERDA setup. Extensive tests of non-enriched detectors, prototypes of segmented diodes and enriched detectors are ongoing. Proper procedures are being developed which permit several cooling cycles without loss of performance. R&D on the cold preamplifiers procured two models which are to be tested in the final configuration. We investigate n-capture on ^{76}Ge at the reactor in Munich, to understand possible background contributions.

3. Status

The GERDA collaboration has submitted the Letter of Intent [4] and the Proposal [5] in 2004. LNGS has approved the modified construction and safety concept. The foundation plate of the water tank is already laid out in Hall A of LNGS; the construction of the water tank will be resumed when the cryostat is erected. The vessel heads of the cryostat have been delivered and the welding is under way.

The 8 existing enriched Germanium diodes of HdM and IGEX have been tested and the same energy resolutions as previously were obtained. They are being refurbished for mounting in the cryo liquid. 35 kg of enriched material has been procured from Krasnojarsk for phase II detectors. The material is stored underground to prevent cosmogenic activation. Depleted material is available for testing the purification and production processes. Non-enriched and 18-fold segmented detectors have successfully been tested for resolution and pulse shape analysis. The commissioning of the completed setup of GERDA and the start of data taking (phase I) is scheduled for 2008.

References

[1] A. Caldwell and K. Kröninger, Phys. Rev D **74** (2006) 092003.
[2] V. Rodin *et al.*, Nucl. Phys. A **766** (2006) 107; and correction: arXiv:0704.4304.
[3] H.V. Klapdor-Kleingrothaus *et al.*, Phys. Lett B **586** (2004) 198.
[4] The GERDA Collaboration, Letter of Intent, 2004, hep-ex/0404039
[5] The GERDA Collaboration, Proposal 2004; `http://www.mpi-hd.mpg.de/ge76/`
[6] E. Fiorini, contribution to this conference, P9.
[7] G. Heusser, Ann. Rev. Nucl. Part. Sci.**45** (1995) 543.