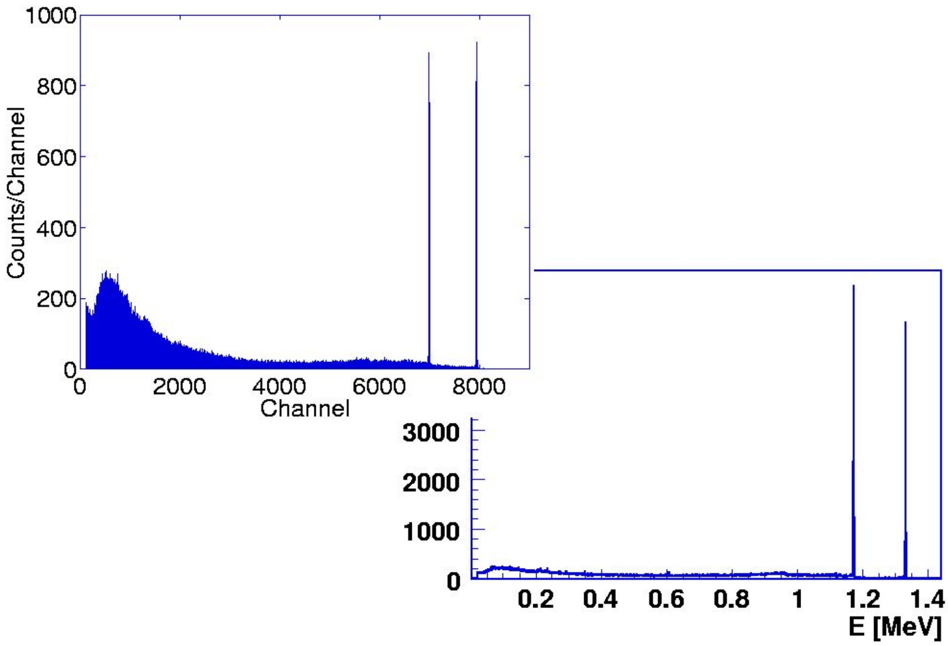
Gerda

Progress Report to the LNGS Scientific Committee

LNGS-EXP 33/05 add. 2/06



March 2006

I. Abt [j], M. Altmann [j], A.M. Bakalyarov [i], I. Barabanov [g], C. Bauer [c], M. Bauer [l], E. Bellotti [f], S. Belogurov [g,h], S.T. Belyaev [i], A. Bettini [k], L. Bezrukov [g], V. Brudanin [b], V.P. Bolotsky [h], A. Caldwell [j], C. Cattadori [a,f], M.V. Chirchenko [i], O. Chkvorets [c], E. Demidova [h], A. Di Vacri [a], J. Eberth [d], V. Egorov [b], E. Farnea [k], A. Gangapshev [g], J. Gasparro [m], P. Grabmayr [l], G.Y. Grigoriev [i], V. Gurentsov [g], K. Gusev [b], W. Hampel [c], G. Heusser [c], M. Heisel [c], W. Hofmann [c], M. Hult [m], L.V. Inzhechik [i], J. Jochum [l], M. Junker [a], S. Katulina [b], J. Kiko [c], I.V. Kirpichnikov [h], A. Klimenko [b,g], M. Knapp [l], K.T. Knöpfle [c], O. Kochetov [b], V.N. Kornoukhov [g,h], K. Kröninger [j], V. Kusminov [g], M. Laubenstein [a], V.I. Lebedev [i], X. Liu [j], B. Majorovits [j], G. Marissens [m], I. Nemchenok [b], L. Pandola [a], P. Peiffer [c], A. Pullia [f], C. Rossi Alvarez [k], V. Sandukovsky [b], S. Schönert [c], S. Scholl [l], J. Schreiner [c], U. Schwan [c], B. Schwingenheuer [c], H. Simgen [c], A. Smolnikov [b,g], F. Stelzer [j], A.V. Tikhomirov [i], C. Tomei [a], C.A. Ur [k], A.A. Vasenko [h], S. Vasiliev [b,g], D. Weißhaar [d], M. Wojcik [e], E. Yanovich [g], J. Yurkowski [b], S.V. Zhukov [i], F. Zocca [f], G. Zuzel [c]

[a] INFN Laboratori Nazionali del Gran Sasso, Assergi, Italy
[b] Joint Institute for Nuclear Research, Dubna, Russia
[c] Max-Planck-Institut für Kernphysik, Heidelberg, Germany
[d] Institut für Kernphysik, Universität Köln, Germany
[e] Jagiellonian University, Cracow, Poland
[f] Università di Milano Bicocca e INFN Milano, Milano, Italy
[g] Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
[h] Institute for Theoretical and Experimental Physics, Moscow, Russia
[i] Russian Research Center Kurchatov Institute, Moscow, Russia
[j] Max-Planck-Institut für Physik, München, Germany
[k] Dipartimento di Fisica dell'Università di Padova e INFN Padova, Padova, Italy
[l] Physikalisches Institut, Universität Tübingen, Germany
[m] Institute for Reference Materials and Measurements, Geel, Belgium

Spokesperson: S. Schönert,
(Stefan.Schoenert@mpi-hd.mpg.de)
Co-Spokesperson: C. Cattadori
(Carla.Cattadori@lngs.infn.it)
Technical Coordinator: K.T. Knöpfle
(Karl-Tasso.Knoepfle@mpi-hd.mpg.de)

URL: http://www.mpi-hd.mpg.de/GERDA/

Contents

1 Executive Summary

This document summarizes the progress of the GERDA experiment accomplished since the last LNGS SC meeting in October 2005. It is less comprehensive as the past reports given the short lead time available for its preparation. Most relevant issues and major recent achievements are highlighted below:

- **Enriched detectors:** With the transportation of three enriched IGEX detectors from the Canfranc laboratory last November, there are now 17.9 kg of HP-Ge detectors enriched in ^{76}Ge available at LNGS. All detectors are working according to their specifications after careful reconditioning. A prototype p–type detector with natural isotopic abundance was assembled in the foreseen Phase I detector mount and successfully operated in liquid nitrogen with an energy resolution of 2.2 keV FHWM at 1.332 MeV. 'True-coaxial' segmented prototype detectors for Phase II are available. A 6–fold–ϕ p–type and a 18-fold segmented n–type detector, 6-fold in ϕ and 3-fold in height, are under test. The energy resolution of the latter at 1.332 MeV measured in a standard cryostat is 2 keV and 3.5 keV FWHM for the core and a segment respectively. Mechanical prototypes of Phase II detector assemblies are available. 37.5 kg of enriched germanium will be transported from Siberia to Europe during the next weeks.

- **Front-End electronics:** CMOS ASIC integrated front-end circuits have been designed and submitted for production. A first version of the semi-integrated circuit has been tested and gave promising results in terms of noise, bandwidth and power consumption. A second version, which has the feed-back components integrated into the circuit, will be available within the next months for testing. An ASIC front-end circuit will be already available most likely for Phase I.

- **Material Screening:** Special sintered polytetrafluorethylen (PTFE) has been measured with GEMPI low-level gamma spectrometer. Limits of approximately 100 μBq/kg for ^{228}Th and ^{226}Ra have been achieved qualifying the material as suitable insulating and support material for Phase I/II detectors. The value is an improvement of about a factor five with respect to our earlier measurements. Super-insulation material is currently measured with GEMPI. Preliminary results indicate that the sensitivity of 1 mBq/kg ^{228}Th and ^{226}Ra can be reached.

- **Cryostat and 3rd wall:** The baseline design of the cryostat is a super-insulated device manufactured from radio-pure OFE copper. The fall-back solution is a super-insulated stainless steel cryostat with an internal copper or lead shield. An additional, structural independent containment, called 3rd wall, has been requested by the LNGS to minimize the risk of mixing cryogenic liquid and water. Preparations for the fabrication of cryostat and 3rd wall have commenced after the electron beam welding certifications. At the beginning of February 2006, a detailed plan for the assembly and welding of the cryostat from its individual pieces became available. The quote for the cryostat (excluding the 3rd wall) received by March 1, 2006 totals to about three times the amount of money detailed in a project study by the same company in September, 2004. The absolute sum is clearly beyond the budget available for the cryostat - even disregarding the fact that the price for the raw copper material has almost doubled since the GERDA Letter of Intent. Our present activities focus on possibilities to reduce the cost for the fabrication of the copper cryostat. In parallel, we study in more detail back-up solutions, in particular that described in the Technical Proposal, a stainless steel cryostat with internal copper or lead shield.

- **Other infrastructures:** The Water tank tender has been published in December 2005. The contract with the winning company will be issued end of May. Underground construction work will commence in autumn this year. Infrastructure requests to the LNGS, including the super-structure, have been reviewed by an independent commission appointed by the INFN. Funds for the super-structure and other main infrastructures have been requested by LNGS to the INFN management. They should be available in May to start the tendering procedure. The clean room on top of the tank is ready for tendering. The opening date will be tuned to the actual construction time schedule of the cryostat, the water tank, and the super-structure.

- **Funding and Schedule:** The full implications for the time schedule of the cost increase of the copper cryostat, and the addition of a third wall, have not yet been completely worked out. While we will continue to push on the schedule, the chances for the delivery of a cryostat in late 2006 now seem small. The collaboration is currently evaluating the possible options based on the available technical solutions, including producing a stainless steel cryostat based on the copper cryostat design. The physics performance, available funds, and the overall time schedule will be considered for the different options. A special collaboration meeting has been called for next week where these options will be discussed and the path to a solution will be defined.

2 Phase I Detectors

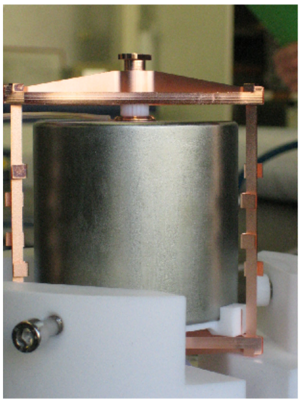
With the support of the former members of the IGEX collaboration from Spain and US, the IGEX detectors have been transported from the Canfranc to the Gran Sasso underground laboratory by van in November 2005. Upon arrival, the detectors had been unloaded and stored underground. The overall exposure to cosmic rays during the transportation could be minimized to 18 hours. Cosmogenic isotope production has therefore been negligible. Subsequently, the detectors were carefully conditioned in the underground detector laboratory (LARGE-FACILITY) during November and December. Following several pump and heating cycles, as well as minor detector maintenance, the original detector performance could be restored. Comprehensive measurements of the detector parameters such as energy resolution, leakage currents and relative efficiencies have been performed as a function of the HV settings for all detectors. All IGEX detectors are now operating stable and show an energy resolution similar to the values measured during the IGEX experiment at Homestake and Canfranc. Similar tests were carried out with the HDM detectors. All major detector tests which were planned within work package two (WP2) for the HDM and the IGEX detectors are now completed. Germanium detectors enriched in ^{76}Ge, with a total mass of 17.9 kg, are now ready for transformation for Phase I of GERDA. Table 1 summarizes the energy resolution of the the enriched germanium detectors as measured in the underground detector laboratory.

	ANG1	ANG2	ANG3	ANG4	ANG5	RG1	RG2	RG3
FWHM [keV]	2.54	2.29	2.93	2.47	2.59	2.21	2.31	2.26
Mass [kg]	0.980	2.906	2.446	2.400	2.781	2.150	2.194	2.121

Table 1: Energy resolution (FWHM at 1.332 MeV) of the enriched HDM and IGEX detectors as measured in the underground detector laboratory and the nominal masses of the crystals. The total mass of enriched detectors is 17.9 kg.

After final commissioning and cleanup, the underground detector laboratory (WP1) is now operational. Technical aspects of the low-mass detector support and contacts (WP3) have been described already in the last report to the LNGS Scientific Committee (SC). The spectroscopic performance of a complete detector assembly has been tested with a 1.6 kg natural germanium crystal. Measurements have been carried out in collaboration with the detector company with which we plan to cooperate during the refurbishment of the enriched detectors. In addition, a full reprocessing cycle of a faulty diode has been carried out to study this part of the detector transformation for Phase I. The achieved energy resolution of this diode mounted into the low-mass support and operated in liquid nitrogen is 2.2 keV FWHM at 1.3 MeV. This value coincides with the value measured by the company before with the diode mounted in a vacuum test cryostat. Fig. 1 displays the detector assembly and the recorded ^{60}Co energy spectrum in liquid nitrogen.

With the completion of the Phase I prototype tests, we are currently preparing the transformation of the first enriched detector. This corresponds to the first step of WP4.



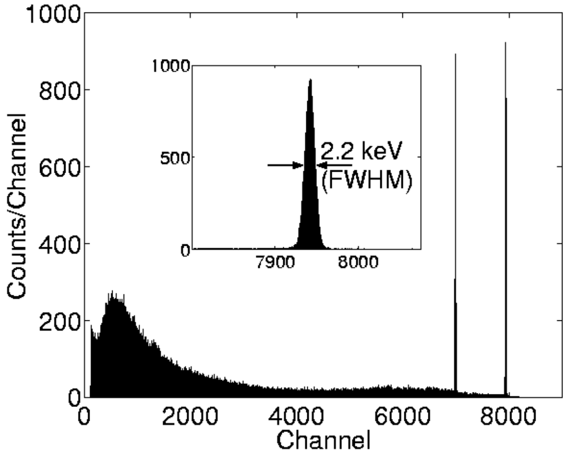


Figure 1: Left: Photo of a Phase I prototype detector assembly mounted on a transportation device. The crystal mass is 1.6 kg. Right: ^{60}Co spectrum of this assembly measured submerged in liquid nitrogen. The energy resolution (FWHM) at 1.332 MeV is 2.2 keV.

ANG1, the 1 kg enriched detector, will be dismounted in the underground detector laboratory in April. The transformation into a Phase I detector assembly might include a reprocessing step at the detector company. Details of the logistics have been worked out including underground storage at the HADES underground laboratory in order to keep the cosmic ray exposure within the tolerable limits. The transformation and testing of Phase I detectors will continue until early 2007.

3 Phase II Detectors

The enrichment of 37.5 kg of germanium is completed. The material has an abundance of ^{76}Ge of more than 86 %. It will be shipped to Munich within the next few weeks for further processing.

The development of "true-coaxial" 18–fold segmented detectors, 6–fold in ϕ and 3–fold in height, is ongoing. A 6–fold–ϕ segmented p-type and an 18–fold segmented n-type detector with natural isotopic abundance is available. As the n-type technology yields more regular electrical fields, it is preferable with respect to possible pulse-shape analysis. Fig. 2 shows a ^{60}Co spectrum as measured with the core [Left] and a segment [Right] of the 18–fold prototype. The FWHM for the 1.3 MeV peaks are 2 keV and 3.5 keV, respectively.

The development of a copper suspension system is well advanced. Prototypes are available. Stress tests with a safety factor of three were passed successfully. The tooling needed to mount crystals is under test. Fig. 3 left shows a prototype detector mounted in the copper suspension. Up to five detectors can be connected to a string. Phase II foresees up to 7 strings in an array as depicted in Fig. 3. Prototype Kapton cables are available. A back-up solution with CuFlon is being worked on.

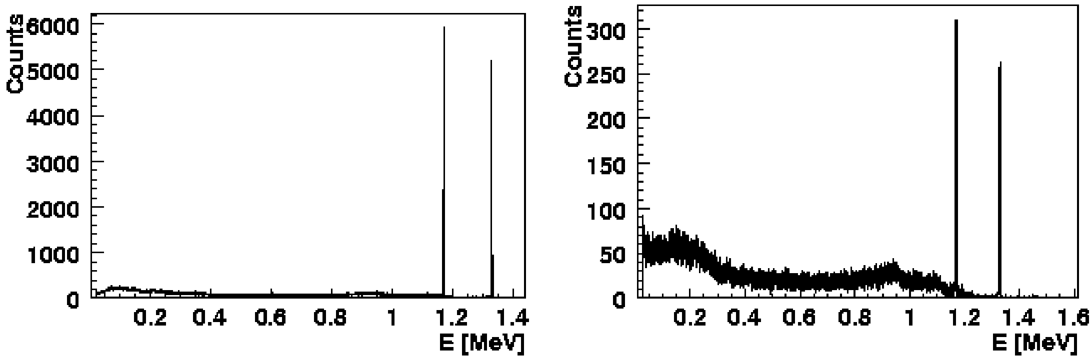


Figure 2: ^{60}Co energy spectra as measured by the core [Left] and a segment [Right] of the n-type 18–fold prototype detector.

Figure 3: Left: A prototype detector mounted in its copper suspension. Right: The design drawing of a load of 7 strings in the Phase II design with 5 detectors each including suspension and cabling.

4 Front-End Electronics

Significant results have been achieved on front-end (FE) electronics since the previous the report to the Lngs SC. Two R&D activities are ongoing in Heidelberg and in Milano to develop a suited CMOS ASIC integrated FE circuit, fitting germanium spectrometry specifications. The circuits have been designed and submitted for production to Imec-Europractive, Belgium and to X-Fab, Germany. The two projects are complementary. One approach (CMOS, 0.6 μm, 5 V technology) points to the complete integration of feed-back components, input device as well as the amplifying and output stage; the circuit has been designed and submitted in February 2006 for production at X-Fab. The second approach (CMOS, 0.8 μm, 5 V technology) is a semi-integrated one, as the feedback components and the input FET are not-integrated in the CMOS ASIC. The latter project is more advanced, as chips are already under test and first results are very promising, in terms of noise, bandwidth and power consumption which is of the order of 30 mW per channel. We are confident that we will have an integrated or quasi-integrated low power consumption FE preamplifier available already in Phase I of Gerda. The main advantage of the integrated solution comes from the background reduction due to the minimum mass of such circuits. The total activity budget of the FE electronic has been computed to be of the order of 10 μBq. The choice of FE circuits substrate, cryogenic cables to connect FE to FADC etc. are under test and screening. Other cryogenic FE working solution have been prepared, as reported in the previous report to the Lngs SC. They will be used along 2006 for prototype detector readout.

5 Cryostat and 3rd Wall

The baseline design for the Gerda cryostat is a super-insulated device manufactured predominantly from radiopure (<10μBq/kg ^{208}Tl) OFE copper; the fall-back solution is a super-insulated stainless steel cryostat with a lead or copper shield in the cold volume. Basic specifications include an earthquake tolerance of 0.6 g and a daily evaporation rate of <0.2 %. As result of the safety review, the implementation of an additional, structural independent containment, called 3rd wall in the following, has been requested by LNGS in order to further minimize the risk of mixing cryoliquid and water.

Figure 4 shows part of the almost finished production drawing of the super-insulated copper cryostat. The inner container rests on six vespel pads, while a stainless steel bellow in the neck compensates different thermal contractions of inner and outer container. Two further sets of radially pointing vespel pads at top and bottom are used to center inner and outer container. The cryostat is attached to a separate skirt which integrates the bottom and the base plate flange of the 3rd wall. The cryogenic design of the cryostat was reviewed in a meeting with a experts from CERN and cryogenic industry.

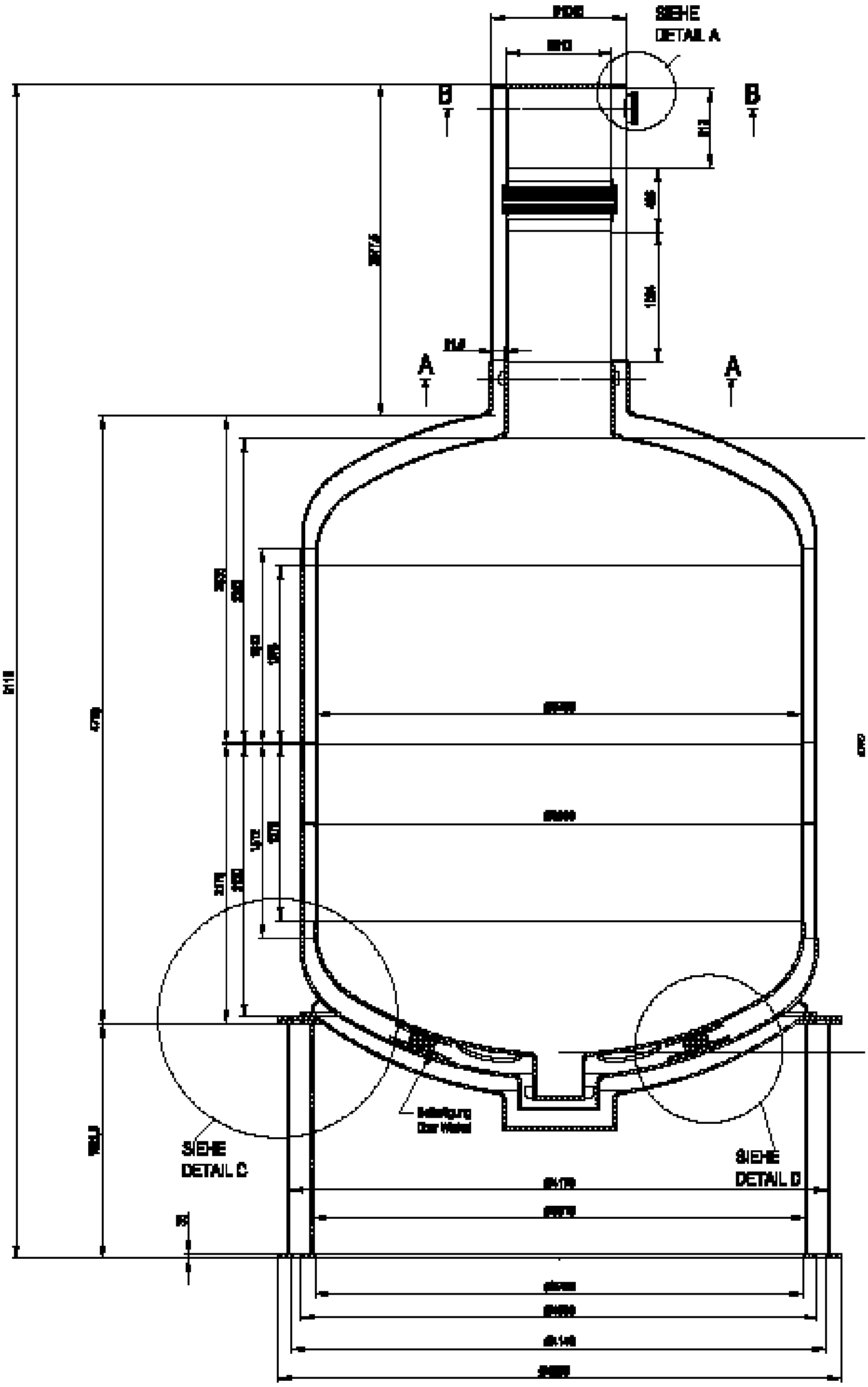


Figure 4: Layout of the super-insulated copper cryostat including skirt with integrated bottom and support for the 3rd wall.

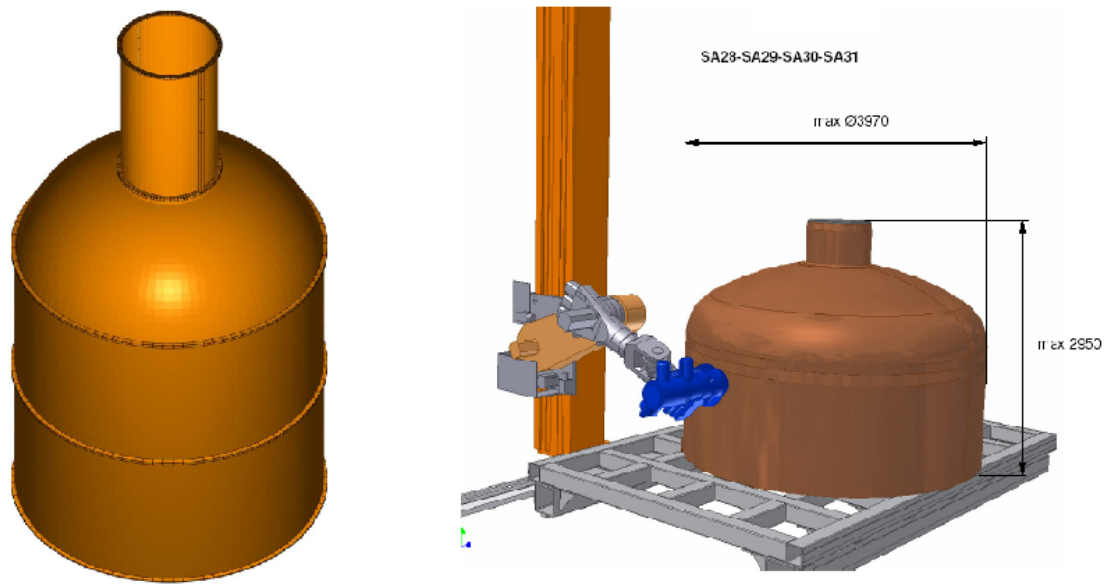


Figure 5: Left: Isometric view of the 3rd wall made from OFE copper. Right: Fabrication study for the electron beam welding of the copper cryostat.

The all copper 3rd wall follows within a distance of 10 cm or less the contour of the cryostat; it is assembled (see Fig. 5 [Left]) from two large cylinders of 4.2 m diameter, and a smaller cylinder around the cryostat's neck consisting of two half shells. The cylinders are connected by flanges; water tightness is achieved by Teflon seals. This design allows to access, in principle, the cryostat's neck and cylindrical walls after the 3rd wall's installation; this is, however, no longer possible for the bottom wall of the cryostat. Preliminary fabrication drawings of the 3rd wall are available.

Preparations for the fabrication of cryostat and 3rd wall have commenced after the electron beam welding certifications for copper - copper, copper - 1.4404 (stainless steel) and 1.4404 - 1.4404 joints with thicknesses between 8 and 20 mm have been issued by the TÜV Nord in December 2005. Measured yield and tensile strengths of the copper - 1.4404 joints corresponded to that of the pure copper material. Simultaneously, it has been established that the quality of the electron beam welds allows to fabricate the semi-elliptical vessel heads by pressing big circular copper sheets which are assembled from various smaller copper sheets by electron beam welding.

After an European-wide tendering, 75 tons of ultra pure OFRP copper have been ordered from Norddeutsche Affinerie for the production of cryostat and 3rd wall, and details for the rolling of the cast ingots into metal sheets of appropriate sizes and thicknesses have been worked out. At the beginning of February 2006, a detailed plan for the assembly and welding of the cryostat from its individual pieces became available. This plan including its graphical presentations, see Fig. 5 [Right] for an example, was used to define the jigs needed for the electron beam welding and to estimate the cost for the electron beam welding including the design and construction of the jigs. The quote for the cryostat (excluding the 3rd wall) received by March 1, 2006 totals to about three times the amount of money detailed in a project study by the same company in September, 2004. The absolute sum is clearly beyond the budget available for the cryostat - even disregarding the fact that the price for the raw copper material has almost doubled since the GERDA Letter of Intent.

Our present activities focus on possibilities to reduce the cost for the fabrication of the copper cryostat. In parallel, we study in more detail back-up solutions, in particular that described in the Technical Proposal, a stainless steel cryostat with internal copper or lead shield. With liquid nitrogen (argon), the amount of copper needed to reduce the activity of the steel by a factor of 1000 to that of copper is typically 100t (30t). While 100t of copper are very expensive, and the much cheaper lead is no real option due to a relatively larger muon-induced neutron background, the choice of LAr seems an attractive solution. More detailed Monte Carlo simulations are in progress. In addition, tests of n-type Ge-diodes will be intensified in order to find out if there is any potential problem with their operation in liquid argon.

Our activities on the definition of the cryogenic infrastructure and the super-insulation are close to be final. A concept for the active cooling of the cryoliquid has been developed in collaboration with experts from Dresden university and CERN. A relatively simple and cost effective evaporation cooler with liquid nitrogen as cooling medium is envisaged. For the super-insulation, various materials have been screened, and a promising 'blanket' candidate has been identified. The tendering for these components will start as soon as a decision on the choice of cryostat has been taken.

The full impact for the time schedule of the cost increase are not yet clear. While we will continue to push on the schedule, the chances for the delivery of a cryostat in late 2006 now seem small.

6 Water Tank

The Water Tank project is fixed since middle 2005, and has not been modified since the previous report. The tank will be made of stainless steel 304L or equivalent and the relevant dimensions are 10 m diameter, 8.9 m height. It will be filled with the ultra-pure water produced by the Borexino plant. Relevant safety devices will be installed to assure safe filling, emptying and exchange of water.

The water tank tender has been published in the Italian official bulletin on 28th December 2005 based on the project specifications ('definitive project)', which was developed by the Gerda collaboration. The winning company will be in charge to develop the executive project. Relevant milestones of the water tank project are, i) the signature of the contract with the winning company at the end of May 2006, ii) start of water tank work on-site underground in fall 2006. The water tank building procedure and timing will be tuned and coordinated with the construction schedule of other main piece of hardware, namely of the cryostat and the superstructure.

7 Underground Building and Main Infrastructures

The GERDA main building is located between the GERDA water tank and the LVD experiment, with the third level and the roof top extending over the water tank. The building offers Laboratory space for GERDA on four levels. In addition the structure provides emergency escape routes and a control room for the nearby LVD experiment. The GERDA infrastructure is being developed in close coordination with the 'Support to Experiments Service' of the LNGS. The following functional blocks are contained or associated with the building:

Functional Block	Level	Surface [m^2]
Water Systems	Ground floor	15
LVD and GERDA Control Rooms	1st floor	15
Detector Test Lab. and Muon Veto Electronics	2nd floor	15
Clean Room	3rd floor	90
HP-Ge Electronics Servicing Area	3rd floor	6
Cryogenic Infrastructures (on-tank location)	3rd floor	10
Solid Plastic Scintillator Muon Veto	roof top	25

Table 2: Locations and allocated floor space for the main infrastructures in the GERDA main building.

The total costs of the building and the associated experimental infrastructures have been evaluated by the LNGS. The total sum is approximately 750 k Euros. The evaluation has subsequently been verified by an independent commission appointed by the INFN. LNGS is now asking this amount to the INFN management. We expect that the funds required for starting the tendering procedure will become available latest in May. Opening of the tender for building and infrastructures is planned to start subsequently. The time for tendering including administrative times will be about six month. After signing the contract with the awarded company, it will take three month until the work in the underground laboratory will start. The winning company will have to elaborate the executive project, order the needed material and prepare the elements in their workshop. Another two month are estimated to erect the GERDA building to a state such that the third level is ready for the installation of the penthouse clean room. The installation of the remaining infrastructure will take an additional time of two month.

8 Infrastructures on Top of the Detector

The clean-room is ready for tendering, pending the request from other task groups to rearrange the space on top of the GERDA setup. The operational parameters are defined and the infrastructural requests to LNGS were made. The class 10000 clean-room will be constructed from stainless steel and will have radon–reduced air.

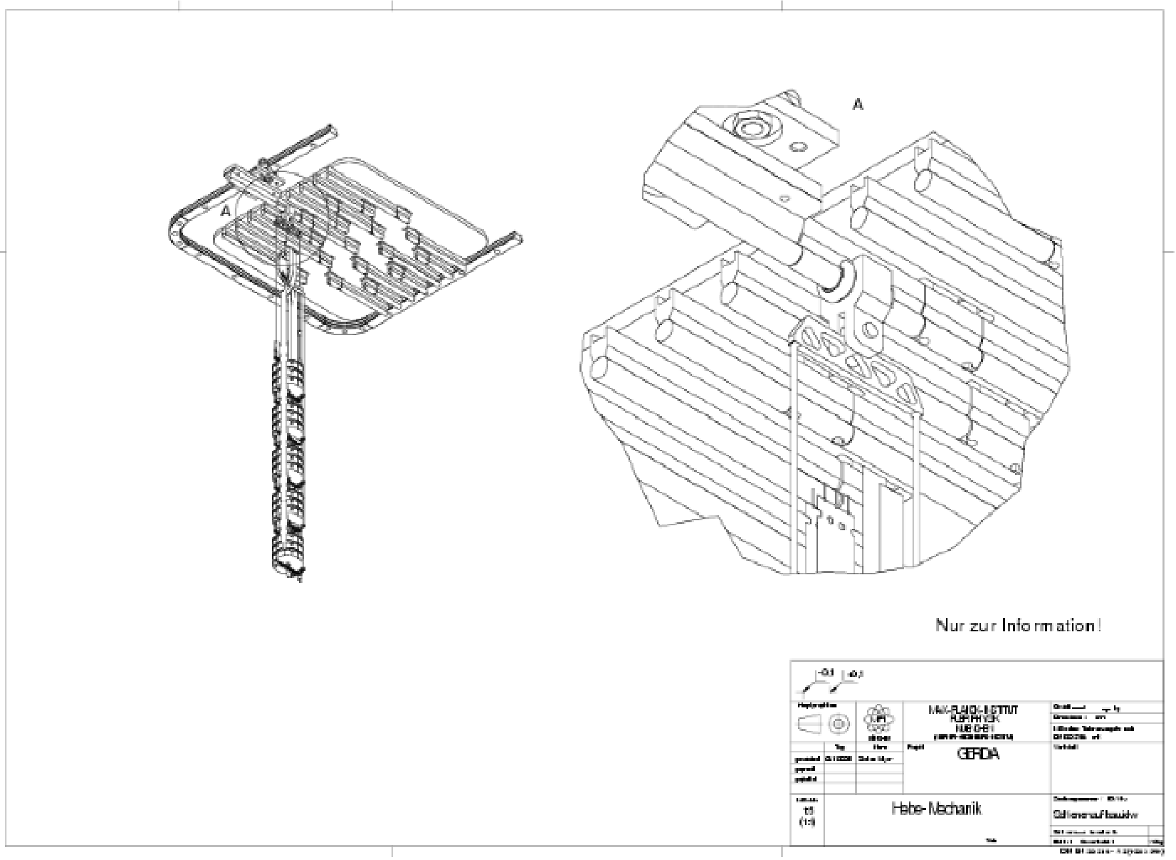


Figure 6: Left: The rail system to position and lower individual strings as seen from below. Right: Details of the rail segment where the string is locked into position before lowering.

Solutions for all technical issues regarding the lock and the internal loading systems are available. A number of materials were sent to task group 11 for radon emanation tests and gamma spectroscopy. The detailing of the various components is under way as well as the development of a construction sequence. Fig. 6 shows a preliminary design of the rails system which brings the strings to their final position and from which they are lowered. It is planned to completely assemble the lock and the loading system before shipping the system to LNGS.

9 Muon Veto

To achieve the necessary background index, particularly for Phase II of GERDA, a muon veto system will be installed. This system will actively reduce muon induced events, in particular for the case when the Ge-diodes register simultaneously an energy deposition in the energy range of $Q_{\beta\beta}$.

The veto will consist of two main parts: (i) a set of plastic scintillators on top of the penthouse covering an area of approx. 500 cm×500 cm. (ii) a water Cerenkov detector which uses the water shielding of the cryostat employing about 80 photomultiplier. The part below the cryostat is considered as a special part of the Cerenkov veto, which will be equipped with special care.

As the 3rd wall design has not been frozen yet, the finalization of the MC studies for the optimal positions of the PMTs are pending. Some structural improvements within the codes have been concluded in order to continue this work immediately after a final decision.

Photomultiplier of type ETL 9350KB/9354KB have arrived. The construction of their encapsulation follows the the Borexino muon veto design, however some modifications have been implemented. The mechanical design has been finished. In particular the mounting of the PMTs will be done via two 8 mm studs welded to the inside wall of the water tank. The base of the encapsulation holds the respective holes; thus, the mounting requires just the fastening of two nuts. Similarly, studs will be set for the reflector foils, the fastening of the cables going in vertical direction and for the cable trays at the very top. The cables exit via 4 chimneys (DN250). A total of about 600 studs will be needed. Most of the mechanical items are on order. Glass and steel samples have been forwarded for screening.

Two versions for the data acquisition are presently in discussion. One version, where each PMT is read by a FADC, would permit full flexibility in retracing delayed coincidences with the Ge-diodes.

10 Monte Carlo Simulations

The Monte Carlo task group (TG10) is actively involved in the development of the MaGe framework, a GEANT4-based Monte Carlo tool which is used for the simulations of the GERDA experiment and test stands at various institutes. Most of the simulations run by the group are based on this framework.

The main focus is on the simulation of background contributions to the $0\nu\beta\beta$ process coming from radio-impurities in the vicinity of the crystals, the cryogenic liquid and the water tank. Figure 7 shows the energy distribution for a set of Monte Carlo data expected for an exposure of 45 kg years in the range from 0-10 MeV (top) and in the region of interest (bottom). The background index is approximately 10^{-3} counts/kg/keV/y.
Furthermore, design studies for the Phase II crystals are being performed. Using the background Monte Carlo data and the obtained design parameters, the sensitivity for the Phase II is calculated using Monte Carlo ensembles. The background from primordial and muon-induced neutrons is also simulated and cross-checked with different transport codes. The μ-induced background can be divided in prompt and delayed component. The latter is due to the production of long-lived unstable isotopes decaying with Q-value larger than $Q_{\beta\beta}$. The analysis was performed for the two cryoliquid options, i.e. liquid nitrogen and liquid argon.
The background from the prompt component, including electromagnetic showers and neutron inelastic interactions, depends essentially on the efficiency of the veto system. The

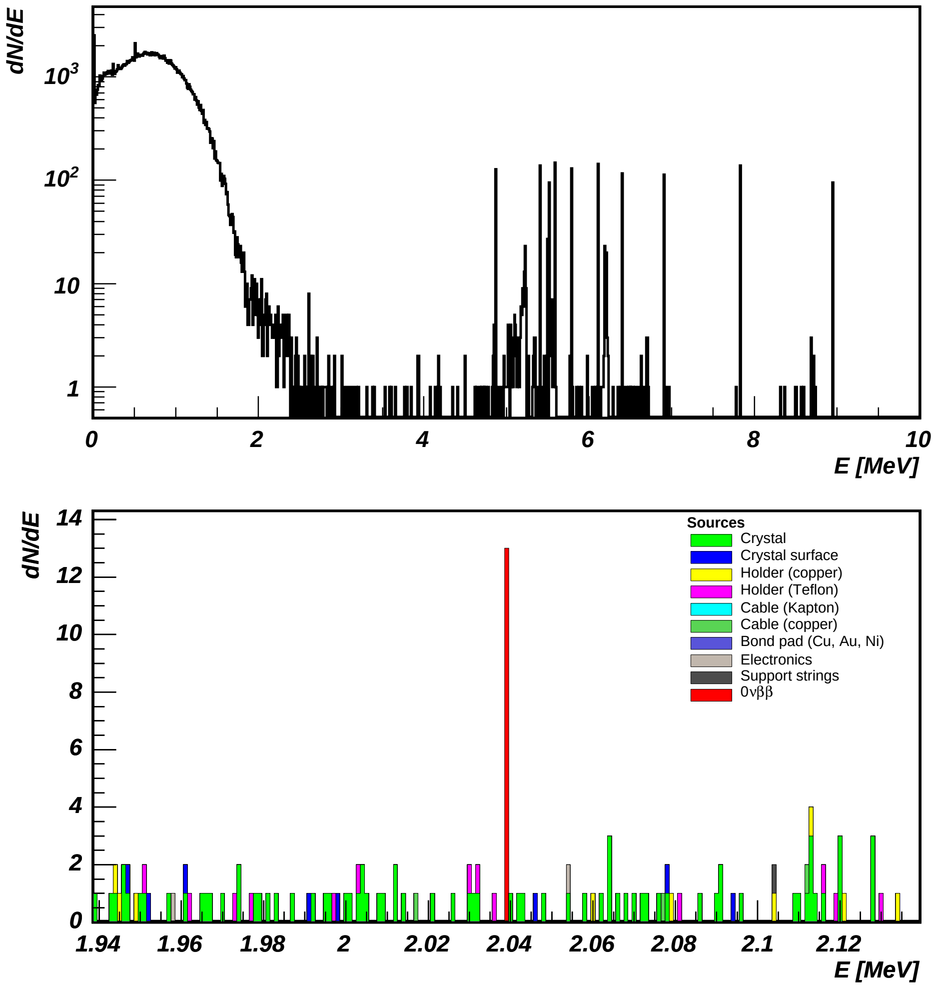


Figure 7: Energy spectra for a set of Monte Carlo data expected for an exposure of 45 kg years in the 0-10 MeV range (top) and the region of interest (bottom). The half-life of the $0\nu\beta\beta$ process was assumed to be $T_{1/2} = 1.6 \cdot 10^{25}$ years. The background index is approximately 10^{-3} counts/kg/keV/y.

contribution can be kept at the level of 10^{-4} counts/keV/kg/y, provided the efficiency of the water Cherenkov veto above 120 MeV is at least 95%. The choice of the cryogenic liquid has a minor effect. The foreseeable efficiency of the Cherenkov veto was evaluated with specific simulations where optical photons are explicitly tracked from the production point and eventually detected by the PMTs. An efficiency above 98% can be achieved using about 70 PMTs, deployed on the walls of the water tank and on the top and the bottom of the cryostat.

The delayed background, which is dominated by the production of ^{77}Ge and ^{77m}Ge by capture of thermal neutrons from ^{76}Ge, is of the order of 10^{-4} counts/keV/kg/y in the liquid argon option. It is 10 times smaller, and hence negligible, for liquid nitrogen. This is due to the facts that (1) the neutron yield from muons is smaller in nitrogen than in argon and (2) argon is a less efficient neutron absorber. Studies are underway to verify whether the ^{77}Ge/^{77m}Ge background can be suppressed by means of delayed coincidences.

11 Material Screening

The material screening by gamma spectroscopy focused on the measurement of polytetrafluorethylen (PTFE) to be used as an insulater in the detector holder of the Ge diodes, and of super-insulation foils for the cryostat. We have screened a 28 kg sample of PTFE, which has been specially produced for us by Elring-Klinger AG, with the GeMPI detector. No ^{226}Ra/^{228}Th contaminations could be identified at the 100 μBq/kg level. To our knowledge, this new limit is the lowest contamination level of ^{226}Ra and ^{228}Th measured in plastics. It is an improvement of about a factor of five with respect to our earlier measurements of a different sample. The material suffices our requirements for radio-purity.

For the super-insulation foil we could find two candidates which were clean in ^{226}Ra and ^{228}Th at the 10 mBq/kg. One of them (from Austrian Aerospace) is screened now at Gran Sasso to push the limits by at least one order of magnitude. This would be sufficient for the baseline design. Preliminary results show that the 1 mBq/kg limit can be reached.

In the reporting period we have started as well to do tests on the ^{222}Rn emanation of samples which will be used inside the lock system. Also copper surface contamination studies have been continued. Another activity concerns the procurement of ultra-pure liquid gases for GERDA. The goal is to find sufficiently pure nitrogen or argon on the market to meet the specifications for the experiment without further purification. If successful this approach allows to avoid the construction of a large-scale purification plant at Gran Sasso. The ^{222}Rn concentration in nitrogen from the Italian company SOL was investigated in the framework of BOREXINO and found to be sufficiently low. In parallel ^{222}Rn emanation studies of storage tanks for cryogenic liquids were performed, because it will determine the final purity which can be obtained without purification. The conclusion from these tests is that the initial filling of GERDA without purification seems possible. A small-scale purification plant will most likely be sufficient for the replacement of the evaporated gas.