GERDA

Progress report to the LNGS scientific committee

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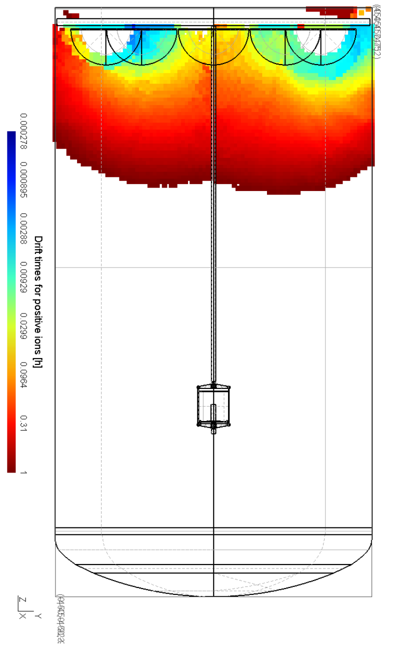
This GERDA report summarizes the progress achieved during the last six months. It is linked at:

`http://www.mpi-hd.mpg.de/GERDA/reportsLNGS/gerda-lngs-sc-apr11-shwup.pdf`.

Previous reports are available at: `http://www.mpi-hd.mpg.de/GERDA/reportsLNGS`.



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The last six months were devoted to the study of the background signals with non-enriched detectors in GERDA and in its low-background LARGE facility. A detailed report (GSTR-11-003) summarizes the operations and measurements together with the achieved results and is available to the LNGS Scientific Committee. This short write-up highlights the main achievements and gives an overview of the status of the GERDA experiment.

Background studies with non-enriched detectors in GERDA: The activities during the last six months focused on the investigation of the background signals measured with the non-enriched detectors. In particular, the ^{42}K (^{42}Ar) signal and its dependence on the electric field configuration was studied. So far, the lowest achieved background index derived from the energy region $Q_{\beta\beta} \pm 200$ keV is about 6×10^{-2} cts/(keV·kg·y), which is lower than for all previous experiments but a factor 6 larger than the background goals for GERDA Phase I.

We have investigated possible sources of these background signals: This includes long-lived cosmogenic isotopes in the germanium detectors, Compton scattered γ–radiation from uranium and thorium progenies, and β–radiation from the ^{42}Ar progeny ^{42}K as well as presumably less probable contributions from cosmic ray muons (prompt events and short lived isotopes), two-neutrino double-β decay of ^{76}Ge, and α particles.

We find that the remaining background in the $Q_{\beta\beta}$ region has contributions from Compton scattered events from decays of ^{208}Tl and ^{214}Bi external to the germanium diodes and from residual ^{42}K decays. Possibly, also degraded α–rays and long-lived cosmogenic produced isotopes contribute to the event rate. However, the limited data set does currently not allow a clear separation of these components.

Upcoming operations: The next operations encompass the installation and commissioning of the 3-string lock starting in April, adjacent to the single–string, and the deployment of the first enriched germanium diodes into GERDA. The main motivations are to increase the target mass and to avoid background sources which might be specific to the GTF detectors. The increase of mass, and therefore of exposure for a given measurement time, is essential to identify residual background sources. Moreover, the deployment of enriched detectors will allow us to study the background situation with the detectors with which we intend to perform the physics measurements. The start of Phase I physics data taking is contingent on the achieved background results.

Background studies in LARGE: The measurements carried out in the GERDA LARGE–facility during the last six months focused on the investigation of ^{42}Ar and its progeny ^{42}K. Central questions are the measurement of the distribution of the charge states of ^{42}K ions produced in the liquid argon environment via the β-decay of ^{42}Ar, their drift in the electrical fields and the impact of the convective flow of the argon. The measurements are still ongoing and no final results are yet available. In the current measurement, liquid argon which has previously been used in the WARP experiment is used. The ^{42}Ar concentration measured in a quasi-field free configuration is within its uncertainties identical with that measured in GERDA. In total, there have been measured three different liquid argon batches (one in GERDA and two in LARGE) which all give consistent ^{42}Ar concentrations.

The 1525 keV ^{42}K peak count rate could be reduced by a factor 5 with respect to the field-free configuration. According to our current understanding, the electrical field of the PMTs together with the convective liquid argon flow act as an 'ion sweeper' to collect ^{42}K ions. A 3-dimensional electrical field and the ion drift calculations have been carried out for quantitative comparisons (see figure on front page).

A secondary goal of this measurement campaign was to probe the achievable background level after application of the liquid argon scintillation veto. After 116 kg$\times$days of exposure (47.05 days) one event survived the liquid argon veto cut in the energy region of interest (here: $Q_{\beta\beta} \pm 150$ keV). The corresponding background index is $1.0 \cdot 10^{-2}$ cts/(keV·kg·y) as central value and a 90% confidence interval of $[0.12 - 4.6 \cdot 10^{-2}]$ cts/(keV·kg·y). Triggered by these results, the collaboration decided to pursue a timely development of a design for the liquid argon scintillation instrumentation for GERDA.

Phase II detectors: The planning for the production of the Phase II detectors in BEGe technology has begun. Negotiations with Canberra concerning crystal growth at the Oak Ridge facility and subsequent detector fabrication at Canberra-Olen are underway, and several iterations on the terms of the contract have taken place. The storage site for the enriched Ge near Canberra Oak Ridge has been identified, and the site is being improved with respect to security. The planning of the Germanium transport to and from the US is well advanced. In parallel, R&D on crystal production at the Leibniz Institute for Crystal Growth are continuing, and a crystal slice with impurity concentration $(2 - 4) \cdot 10^{10}\mathrm{cm}^{-3}$ will be used for diode fabrication tests. Further improvements on the process at IKZ are expected in the next months.

Front end electronics: For the readout of the enriched Ge diodes eight 3-channel PCBs of the front end circuit CC2, version 2, have been produced, tested and γ-ray screened. This new version features feedback and test capacitors that are printed on the board which allows to eliminate the corresponding physical devices. On avarage, the measured activity of one PCB is 290 μBq and 150 μBq in ^{226}Ra and ^{228}Th, respectively.

Work on the readout of BEGe diodes has started. The goal is to minimize the number of components and the space occupied close to the detector, and to exploit the very low capacitance of the BEGe detectors. The circuit consists of a cold JFET transistor and a warm remote second stage. The DC feedback path is closed using a cold diode. Only two signal cables are necessary for biasing and readout. The circuit is able to drive a terminated coaxial cable and guarantees high speed and low noise. Power dissipation is minimal thanks to the fact that only the JFET and the diode are operated in the liquid gas. The circuit has been tested with a small coaxial detector and a resolution of 2.21 keV FWHM at the 1.275 MeV ^{22}Na γ line has ben obtained.

A prototype for a low-background high-voltage capacitor for AC-read out of the diodes has been successfully tested with a bare detector in the GDL test stand.

Cryostat: Since the filling in December 2009, both cryostat and cryogenic infrastructure show a smooth and reliable performance. All major operation parameters including cryostat pressure (1.2 bar absolute), isolation vacuum (3×10^{-8} mbar), liquid argon temperature (88.50 K) and water flow through the heat exchanger (> 9 kg/s) are very stable. The active cooling with liquid nitrogen works so well that no argon needed to be refilled since more than one year.

During the last term, the PLC controlling the cryostat issued a single alarm indicating on January 27, 2011 a reduced water flow through the heat exchanger which raised the alarm level from 'green' to 'yellow'. This event was caused by the maintenance of the LNGS cooling water system and verified the functioning of the fully automatic alarm system which includes the notification of the expert crew by SMS.

Between November 2010 and January 2011, the pressure regulation showed periodic spikes with amplitudes somewhat larger, 50 mbar, than the usual pressure fluctuations of less than 10 mbar. Their origin could be traced back to a regulation valve (LCV000) in the cold box which is used for filling a cold trap with liquid nitrogen. Since this trap is needed only in case of refills with liquid argon, the regulation valve could be disabled and the spikes eliminated.

Works to be done in near future include the installation of the water pipes to the GNO pits 1 and 3, the elaboration of a service plan for all crucial components, the identification of spare parts which will help to maintain an continuous smooth operation, as well as a final description of the layout and performance of the drainage system for the water tank which is also controlled by the cryostat's PLC.

Lock systems: The infrastructure to lower three detectors into the cryostat has been installed in hall A of LNGS in March 2010. Detector strings have been inserted into the GERDA cryostat roughly 15 times since without any problem.

A second cable arm with enough space for all phase I detectors has been designed, constructed and assembled. The lock system can hold a total weight of up to 40 kg. Dummies with dimensions and weights as the phase I detectors have been attached to the lock system. The string containing all mounted dummies was moved between uppermost and lower position several times. Smooth movement of the detectors was observed. The PLC system has been upgraded for use with two different cable arms. It has been tested at MPI für Physik in Munich during the mechanical tests. The completely mounted lock system is presently waiting for delivery to LNGS. Mounting on the GERDA cryostat is foreseen in April.

The first draft of the design of the final lock system needed to house all phase II detectors is finished. The cylinder, cable arms and most other parts needed for full assembly have been machined and procured. To test the feasibility of the system, it is going to be test assembled at MPI für Physik. Installation will start once the three string lock has been sent to LNGS.

Water loop plant: The water loop is working regularly since August 2010. At the normal water flow rate of 2 m^3/h it produces very high quality water with a resistivity above 17 MΩ·cm at 25°C. The volume above the water level of about 4 m^3 is continously purged with nitrogen gas at the rate of 0.6 Nm^3/h.

Muon system: The Water Cherenkov muon veto system is operating smoothly. The capability of the Cherenkov veto in rejecting muon-induced events in the Germanium detectors was evaluated from the data themselves to be larger than 94% (at 95% credibility level). The background index of muon-induced prompt events prior to applying muon veto and anti-coincidence cuts corresponds to about 10^{-2} cts/(keV·kg·y), as predicted by Monte Carlo simulations. A part (7) of the plastic scintillator panels has been installed on the roof of the clean room and integrated into the DAQ.

DAQ and slow control system: The data taking is, since past summer, running smoothly using FADC systems. For the muon veto, the analog PMT signals are digitized with commercial FADCs which also generate trigger signals. A coincidence of hits is defined as a muon candidate. All hardware is implemented on VME boards and works reliably. For the germanium diodes a different system was built: the FADCs are on NIM boards and the digitized data are stored on PCI cards. In addition a copy of the muon DAQ is in use. The comparison of the two allows debugging and checking of both systems.

The slow control system is storing all relevant hardware information like temperatures and flow rates in a data base and provides a new web based graphical presentation of the historical data. Compared to the previous version, the new web interface has better readability with high data visualization density, an automatic update of data, and a high compatibility with different browsers. The system works reliably without any interruption and with good performance. The integration of an alarm system is close to completion.

Another web-based slow control system for LArGe is now also operational and guarantees stable operations.

Calibration source lowering system: A motorized calibration source lowering system was designed and is currently being built. After tests at the surface, three such systems will be mounted to the Gerda cryostat and will allow the calibration of the Ge diodes with ^{228}Th sources. An accurate and redundant positioning of the calibration sources via an optical system counting perforations in a steel band and a multi-turn absolute encoder mounted to the motor axis will be available. The lowering system can be controlled via a user interface at the motor control unit as well as remotely via a web-interface written in LabView. Hence calibration runs can also be performed from off-site. Two new ^{228}Th calibration sources are available and have been brought to Lngs. The iterative automated calibration routine which has been developed to perform the calibration of the single diodes for the different energy reconstruction algorithms is now used as a standard calibration routine. Weekly calibrations of the diodes show a reasonable stability in time of the energy calibration close to the Q- value of the $0\nu\beta\beta$ decay of (2039.006 ± 0.050) keV. All available calibration information is stored in a MySQL based relational database allowing a real-time access of relevant parameters for the data analysis.

Data processing and analysis infrastructures: The GERDA data analysis framework - called GELATIO (GErda LAyouT for Input/Output) - has been further developed and intensively tested. It is presently in a mature stage for being used in real data analysis. In fact, the processing and analysis of the signals recorded from the Ge detectors operated in GERDA and LArGe are now fully performed through GELATIO.
We have developed two new infrastructures for data management: (1) a MYSQL database, to store and manage the event raw information (e.g. traces) and the result of signal processing; (2) a web-based user interface, to send SQL queries to the database, to retrieve and plot the data in a friendly way, and to create reports. They are presently running on a dedicated server at LNGS, and will be further benchmarked by the Collaboration in the next months.

Simulation of Ge detector response: The integrated simulation of the Ge detector response to charged particles and γ-radiation interacting inside the crystal has been applied to coaxial detectors. The computation of the electric field inside the crystal and of the charge carries transportation towards the electrodes provided important information concerning the pulse shape dependence on the interaction position. Moreover the pulse shape correlation with the geometry parameters has been investigated. The simulation has been validated by comparison against experimental data.

Collaboration organization and management: The main part of the GERDA construction has been completed and the organizational structure reflects the transition from construction to maintenance and operations (M&O). The task groups are being revisited and will be adopted according to the requirements of M&O. As data taking and analysis has now become a central activity, Luciano Pandola has been appointed as analysis coordinator. In preparation of the next GERDA phase, Bela Majorovits has been appointed as Phase II coordinator. It has also been decided that all management positions will be appointed on a temporary basis in the future. The first turn around is the collaboration chair. Manfred Lindner will take over from Allen Caldwell in June 2011. Since November 2010, the new group of Stefan Schönert from the Technische Universität München (TUM) became member of the GERDA collaboration.