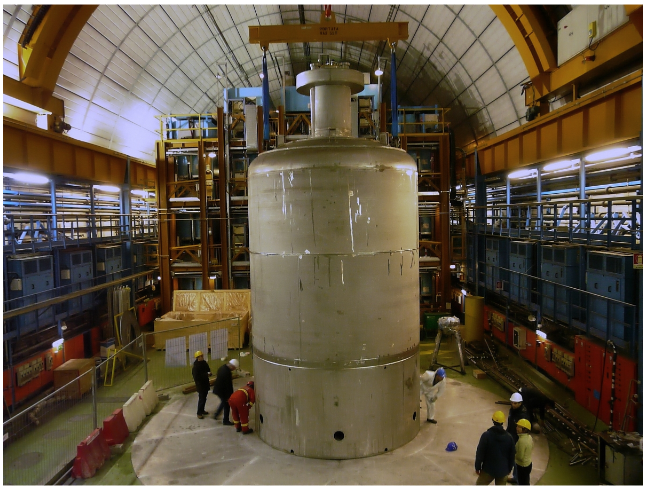
GERDA

Progress report to the LNGS scientific committee

(Short write-up)

LNGS-EXP 33/05 add. 6/08

The format of this GERDA progress report differs from our earlier ones to facilitate both fast and in-depth reading. A *short write-up* (http://www.mpi-hd.mpg.de/GERDA/reportsLNGS/gerda-lngsSC-shwup-apr08.pdf) summarizes concisely the achievements during the last six months and highlights important issues. An *appendix* to the report (http://www.mpi-hd.mpg.de/GERDA/reportsLNGS/gerda-lngsSC-appdx-apr08.pdf) provides additional technical and experimental details for follow-up reading.



April 2008

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URL: http://www.mpi-hd.mpg.de/GERDA/reportsLNGS/gerda-lngsSC-shwup-apr08.pdf

Major progress has been accomplished by the GERDA collaboration since the last meeting of the LNGS Scientific Committee (SC) in October 2007. Important milestones and results are summarized below.

Cryostat installed at LNGS: On 6 March 2008, the cryostat was delivered to LNGS and placed at the foreseen location in Hall A. Mounting of the internal copper shield was completed on March 18. The cryostat passed several acceptance tests at the manufacturer and after arrival underground. This includes pressure tests under the supervision of TÜV for certification as a pressure vessel, helium leak tests, liquid nitrogen evaporation tests and radon emanation measurements. The installation of the cryostat and its compliance with the design specifications is a major milestone for the GERDA experiment. The construction of the water tank will commence middle of April. Subsequently the GERDA building, the clean room and lock above the cryostat will be erected.

Long-term stability tests of Phase I detectors: Stability tests of the operation of (p-type) diodes in cryogenic liquids are practically completed. In total, three different non-enriched high-purity p-type prototype detectors with different passivation layer geometries have been operated successfully. The detectors are biased at or above their operational voltages and the leakage currents (LC), continuously monitored with high accuracy, are stable at a few tens of pA, as measured at the detector manufacturer. During two years of operation, we have carried out more than 50 warming and cooling cycles, defining the detector handling procedure.

As reported at the last SC meeting, gamma irradiation in liquid argon can lead to an increase in leakage current. Our data suggest that the effect is due to the extension of the passivation layer onto large areas of the n- and p-contacts and that charge collection on the surface of the insulating passivation layer is the origin of the (reversible) LC increase. The measurements with the reprocessed GTF crystals showed that the LC increase is negligible if the passivation layer is limited to the groove area only.

Front-End electronics integration: New versions of the PZ0 and PZ1 ASIC CMOS charge sensitive amplifier (CSA) had been submitted to the foundry in November 2007 and the chip production returned completed in February 2008. Testing of the CSA in liquid nitrogen with germanium detectors started recently with two new detector test stands, namely the THE SUB with a p-type detector and GERDELLA with an n-type detector. Measurements with the first version of the PZ0 mounted to THE SUB gave an energy resolution of 2.6 keV (FWHM) at 1.3 MeV. A resolution of 3.0 keV has been achieved with the CSA77, a discrete CSA, for the same configuration. The fully integrated PZ1 and the discrete IPA4 are prepared for testing. Optimization in terms of noise performance is ongoing and further improvements expected. An other successful FE integration activity concerned the test of a complete cable signal and connector path.

Phase II crystal production: The yield for the germanium purification from the delivered GeO_2 to 6N metal at PPM Pure Metal has been increased from 77% to around

90% recently. This excellent result means that most of the enriched material can be used to pull crystals. The second goal of the test was to reduce the exposure of the germanium to the cosmic radiation. The material was temporarily stored underground in a nearby mining museum. The test proved that transporting the material back and forth to the underground storage is feasible and the time above ground for the purification should not exceed two-three days.

The Institut für Kristallzüchtung (IKZ) set up the diagnostic tools (Hall-effect and PTIS) for the characterization of pulled crystals. IKZ already pulled a small crystal from the zone-refined material produced during the first purification test at PPM. The first (preliminary) Hall-effect measurement suggest that the concentration of impurities in the zone-refined material is between 10^{12} and $10^{11}/\mathrm{cm}^3$. This numbers are consistent with the one deduced from resistivity measurement mentioned in the previous Progress Report and they are far better than expected, since this Ge is rated as 6N material.

The Czochralski puller is now refurbished and is already set up to produce 2" crystals. First crystals from this device are expected soon.

Muon veto system: A batch of 10 plastic scintillator panels with dimensions of $200 \times 50 \times 3$ cm^3 has been assembled at Dubna and first tests have been performed at Dubna, Heidelberg, Tübingen and LNGS. The tests showed that the concept works, but more wavelength shifting fibers and green- extended H6780-20 photo-tubes are desirable for improved performance. The background due to gamma radiation inside the LNGS tunnel is lower by a factor two than outside. The gammas and muons give distinct signals. The PMT preproduction assembly for the water Cherenkov detector has been completed successfully by building and testing five complete PMT capsules. The full production will be completed by July 2008.

Monte-Carlo simulations: The GEANT4-based MAGE Monte-Carlo framework has been modified to be compiled optionally with the GDML libraries. GDML stands for Geometry Description Markup Language and it is designed as a standard geometry exchange format among various softwares. A geometry defined in a GDML file can be used by GEANT4, or by ROOT, or be exported from a technical drawing created by CAD tools. It is now possible to read (write) MaGe geometries from (to) GDML files and use them for the simulation. Another new tool implemented in MAGE allows to debug complex geometries. As many technical details of the Gerda setup have been finalized recently, the Gerda geometry in MaGe has been significantly updated. The most important changes are related to the geometry of the detector strings and of the cryostat. First more precise results from the expected external background contributions are available. The main goal for the upcoming months is to perform a new full Monte Carlo campaign to estimate the total background spectrum in Gerda, taking into account the most recent information about the geometry and the material radio-purity.

Material screening: The list of samples screened by gamma spectroscopy or radon emanation is constantly growing. Results for e.g. cables, resistors, electrical feedthroughs, and materials for the suspension of diodes have been obtained. The radon emanation of the cryostat has been measured twice at different stages of the production. Before the internal copper shield was installed, the emanation was approximately 14 mBq which is low compared to other vessels measured in the past. This value would correspond to a background index of 2×10^{-4} cts/(kg·keV·year) with no cuts, assuming an identical emanation rate a liquid argon temperature and uniformly mixing in the liquid argon. Another measurement with the copper in place is planned for the near future and its result will influence the final cleaning procedure of the cryostat.

Radon mobility in liquid nitrogen: The behavior of radon and its daughters in liquid nitrogen has been studied. As expected, radon stays predominantly in the liquid, i.e. the specific activity in the boil-off nitrogen is reduced by a factor of 16. The data suggest that radon and in particular its progenies ^{214}Po and ^{218}Po are attracted to steel plates if either positive or negative high voltage is applied. Measurements in argon and with germanium substrates are now under preparation. This effect, if it persists in LAr/Ge, might lead to an increase of radon concentration in the vicinity of the germanium detectors in GERDA. On the other hand, such an effect would offer the possibility to remove actively residual radon traces by implementing electrodes to sweep out radon and their progenies.

Personnel: Kai Zuber, who has accepted the chair for non-accelerator particle physics at the Technical University Dresden, joined the GERDA collaboration recently. The main responsibility of the TU Dresden group concerns the determination and characterization of impurities in germanium crystals and contributions to Phase II detectors.

The Padova group has been strengthened with the entry of three new members who took up the responsibility to develop the slow-control system for GERDA. Software developed by this group for the Opera experiment will be adopted.

Schedule: With the installation of the cryostat in hall A of LNGS a major milestones has been achieved. The successful long term operation at stable leakage currents of Phase I detectors in liquid argon is a further major step towards the start-up of GERDA. The construction of the water tank will resume in April, followed by the GERDA building which is scheduled for completion by August. Clean room construction will commence in October followed by the lock installation which will last until the end of the first quarter of 2009. In parallel, the water Cherenkov detector, the cryogenic infrastructure and other auxiliary infrastructures will be installed to be ready for commissioning when the lock is in place.

With respect to the schedule presented one year ago, the cryostat delivery has shifted by three months because of production delays at the manufacturer. This has shifted the overall schedule by the same amount, as the constructions of the main hardware installations can be carried out only sequentially. It is noteworthy that no additional delays have been accumulated and that the schedule is unchanged with respect to the one discussed at the LNGS SC meeting October 2007.

Coordination with LNGS and integration issues: An integration meeting between LNGS technical staff and members of the GERDA collaboration took place 14 January 2008 in order to prepare for a smooth and safe start-up of the GERDA experiment. A list of topics had been identified and discussed. As a consequence, the space for locating the cryogenic storage vessels is now under preparation. The explosion proof door which currently limits the access to the space still needs to be removed. LNGS assured to dismount the door timely prior to the beginning of the cryogenic infrastructure installations. A design and the dimensioning for the argon gas heat-exchanger which is required in an emergency case, has been proposed by the GERDA collaboration and discussed at the integration meeting. The LNGS staff consulted NIER engineering and came to the preliminary conclusion that a reduced version for a gas flow of 2000 m^3 per hour would be sufficient. The official feedback from LNGS which is required to start the tender process is pending. A further issue concerns the connection of the exhaust argon gas discharge into the LNGS ventilation system. Here, the specifics of the GERDA cryostat being a closed system can be taken advantage of. A design similar as the one proposed for Icarus seems less suited and more expensive while a direct connection to the cryostat appears safer and more cost efficient. An important result of the integration meeting and the follow-up work done by LNGS staff is the definition of the fast water drainage procedure in an emergency case. An additional connection pipe has to be installed in the floor of Hall A. It has as well been agreed to perform a water tank draining test in order to verify the flow rates and the time required to empty the water tank. It had been requested to LNGS to carry out this drainage test in conjunction with the hydraulic acceptance test at the end of the water tank construction. This however would require a timely completion of the tube installations. In summary, the integration meeting with the LNGS SPP and the responsible GERDA members was very productive and all efforts should be made to further strengthen the coordination between LNGS SPP and the GERDA collaboration.