Commissioning of GERDA

A.V. Lubashevskiy
on behalf of GERDA collaboration,
Max-Planck-Institut für Kernphysik,
Heidelberg
The GERmanium Detector Array (GERDA) Collaboration:  
~100 physisists  
19 institutes  
7 countries
Motivation

The GERDA experiment is an ultra-low background experiment aimed to search for $^{76}\text{Ge}$ $0\nu\beta\beta$ decay.

Searching for $0\nu\beta\beta$ helps to understand:
- Nature of $\nu$ (Dirac or Majorana)
- Neutrino mass scale
- Neutrino hierarchy
Motivation

Best limits on (0νββ)-decay half-life $1.9 \cdot 10^{25}$ y and $1.6 \cdot 10^{25}$ y, correspond to $|m_{ee}| < 0.3 - 1.1$ eV, have been obtained with HPGe detectors in the previous experiments Heidelberg-Moscow & IGEX with using Enriched Germanium (86% in $^{76}$Ge, $Q_{bb}=2038.5$ keV).

Part of H-M Collaboration, claimed evidence for 0νββ observation with the best fit $T_{1/2} = 1.2 \times 10^{25}$ y, $|m_{ee}| = 0.44$ eV.


The main goal of the GERDA experiment is searching for neutrinoless double beta decay of $^{76}$Ge. Within 1 year of data taking with considerable reduction of background GERDA will able to check claim of H-M experiment.
Phases of GERDA

Three phases of GERDA experiment has been proposed:

- **Phase I:** 8 existing enriched detectors (18 kg of $^{76}$Ge total) from the previous Heidelberg-Moscow and IGEX experiments, and 6 natural HPGe detectors (in total 15 kg of natural Ge) from the Genius Test-Facility will be deployed. Expected BI ~ 0.01 counts (kg ∙ keV ∙ year)

- **Phase II:** BEGe detectors (>20 kg of $^{76}$Ge). In total: 40 kg of $^{76}$Ge + 15 kg of natural Ge. In addition several detectors from depleted of $^{76}$Ge material will be incorporated too. Expected BI ~ 1 counts (ton ∙ keV ∙ year)

- **Phase III:** Depending on the results of phase II possible GERDA-MAJORANA collaboration aimed to cover inverted hierarchy. Planned BI ~ 0.1 counts (ton ∙ keV ∙ year)
In IGEX and H-M experiments it was shown that main part of the detector’s background is due to radioactive contamination of surrounding materials (including copper cryostat).

So, in GERDA we use “naked” Ge detectors submerged into the High-Purity liquid Ar which shields from the radiation and cools down the Ge detectors.

30g Cu, 6.3g PTFE, 1g Si per detector
Background reduction

GERDA experiment located at LNGS underground laboratory (Italy). The rock overburden is equivalent to 3400 m.w.e. This allows to reduce $\mu$ ($\sim 10^6$ times) and neutron flux induced by cosmic radiation.
Scheme of GERDA

- Clean room
- Lock system
- Detector array
- Water tank with HP water and $\mu$-veto
- Cryostat with internal Cu shield
- HP liquid Ar
Stages of installation process
Stages of installation process

History of installation:
- 12.09 cryostat has been filled with liquid Ar.
- 05.10 first submerging of the non-enriched detector into the liquid Ar.
- 06.10 start commissioning with non-enriched detectors in GERDA.
Since June 2010 commissioning of GERDA has been started. Non-enriched detectors have been used. Detectors work stable in liquid Ar.

Energy resolution of Phase I detectors is 3.6 - 6 keV (FWHM at 2.6 MeV) depending on the configuration of the detector and surrounding.

Energy resolution of Phase II detector (BEGe) is 2.8 keV (FWHM at 2.6 MeV).
Unexpected $^{42}\text{Ar}$ background

In proposal of GERDA for estimation of the $^{42}\text{Ar}$ concentration, it was taken a limit of $^{42}\text{Ar}/^{\text{nat}}\text{Ar} < 3 \times 10^{-21}$ [Barabash et al., 2002]. After deposition of the detector into GERDA we found that intensity of 1525 keV peak from $^{42}\text{K}$ (daughter of $^{42}\text{Ar}$) at least 10 times more than expected from limit [Bar02]. Beta decay of $^{42}\text{K}$ near detector could increase a background for $0\nu\beta\beta$ search. Incorrect limit or $^{42}\text{K}$ ion collection on the surface?
Creating the field to drift $^{42}$K ions

If positive or negative ions of $^{42}$K are drifting in the liquid Ar they could be attracted by the E-field of the detectors or another electrodes. To check this different electrical fields have been organized by using shroud and mini-shroud.

Detectors without mini-shroud

Detectors with mini-shroud
It was found that initial intensity of $^{42}$K peak is significantly higher than with “E-field free” configuration.

Run 1-3 (0.59 kg years)

Run 10-11 (1.0 kg years)
Rate of $^{42}$K

Since June 2010 12 commissioning runs with different electric field configuration has been performed. Count rate of the 1525 keV peak from $^{42}$K decay changes almost in 10 times depending on different E-field near the detector.

Also $^{42}$K “problem” was investigated in LArGe low-background test facility. With no field configuration $^{42}$K rate is 0.050±0.023. So we have possibilities for further suppression of background from $^{42}$K in GERDA.
Background vs. time

Run12. Exposure: 0.587 kg × year

- All events
- Muon veto
- Multiple-detector

Energy (keV)

Date
17-Feb
24-Feb
02-Mar
09-Mar
16-Mar

\(^{42}\text{K}\)

\(0\nu\beta\beta\) ROI

Alphas
Background index is significantly lower than in previous experiments but still higher than Phase I proposal (0.01 counts/(keV·kg·year)). Next steps: runs in field free configuration and with enriched germanium detectors with low cosmogenic activation.

Run12. Anti-concidence and mu veto. Exposure: 0.587 kg×year

Background rate: 0.055 counts/(keV×kg×year)

$Q_{\beta\beta} = 2039$ keV
Phase II detectors BEGe

- Dimensions: Ø 81 mm x 32 mm
- Weight: 878 g
- Contact:  
  - p⁺ contact
  - n⁺ contact

**p-type germanium**

**FWHM**
- @ 59.5 keV: 0.49 keV
- @ 1.33 MeV: 1.59 keV

**DEP:** 90%

**γ-bgd:** 11%

**228Th all events**

**0νββ-like**

**γ FE peak**
LArGe test facility

LArGe is a low background test facility, which has been created in order to investigate possibility to suppress background by using anticoincidence with liquid Ar scintillation signal detected by PMTs.
LArGe test facility

Measurements with BEGe detector inside LArGe show very good suppression of background. As an example, for $^{228}$Th inner source the suppression factor $> 5000$ has been obtained after applying LAr VETO and PSD.
Conclusion

• GERDA experimental setup has been installed and working stable. Commissioning runs with non-enriched germanium detectors has been started.

• Background rate of $^{42}$K is different with different field configuration and could be suppressed.

• BI in ROI of $0\nu\beta\beta$ is 0.05 counts /($\text{keV} \cdot \text{kg} \cdot \text{year}$), it is significantly better than in predecessor experiments.

• Possibilities of further suppression of the background have been developed (BEGe and LArGe).

• Enriched detectors will be deployed into the GERDA detector soon.
Back up slides
LArGe test facility

Estimated $^{42}\text{Ar}$ concentration is $(2.1 \pm 1.9) \cdot 10^{-21}$ [90% c.l.].
GERDA

Run12. Anti-concidence and mu veto. Exposure: 0.587 kg\times year

counts/(10 keV)

Energy (keV)

1600 1800 2000 2200 2400 2600

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
GERDA

Run12. Exposure: 0.587 kg×year

Counts/(50 keV)

Alpha candidates (single detector, no muon)

Energy (keV)

24.03.2011

DPG Spring Meeting
Activity of Tl-208, mBq/kg:
Rock, concrete \(\sim 3000\)
Stainless steel \(< 5\)
Cu(OFHC) \(< 0.02\)
Water purified \(< 0.001\)
LAr \(\sim 0\)

11.5 kg of enriched Ge detectors
71.7 kg yrs of data
0.11 Counts/(kg keV y) around 2040 keV
\(T_{1/2} \geq 1.9 \times 10^{25}\) years (90% C.L.)

Background: 0.16 counts/(keV kg year)

6.8 kg of enriched Ge detectors
8.5 kg yrs of data
0.17 Counts/(kg keV y) around 2040 keV
\(T_{1/2} \geq 1.6 \times 10^{25}\) years (90% C.L.)

Production of BEGe detectors from $^{\text{enr}}\text{Ge}$ for GERDA Phase II

After successful test of production chain with $^{\text{depl}}\text{Ge}$:

- **37.5 kg of 86% $^{\text{enr}}\text{Ge}$** (in form of GeO2) purified to **35.4 kg (94%) of 6N** (+ 1.1 kg tail = 97%);
- crystal pulling and detector fabrication under preparation