Outline

- Introduction and motivation
- Goals and design of GERDA
- Main hardware components of GERDA:
  - Cryostat and water tank
  - Cleanroom and lock system
  - GERDA detector laboratory (GDL)
- Status of subprojects:
  - Detector preparation for phase I
  - Development of phase II detectors
  - Further running R&D programs
- Schedule and summary
The GERDA collaboration

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~70 physicists
13 institutions
6 countries
GERDA – A quick overview

- Next generation $^{76}$Ge double beta decay experiment at Gran Sasso
- Significant reduction of background around $Q_{\beta\beta}$ to $\leq 10^{-3}$ cts/(kg·keV·y)
- Contamination in previous experiments mainly in cryostat / diode holder
  → Bare diodes in cryogenic liquid (LAr)
- Cryogenic liquids have very high radiopurity
Why Germanium?

- Enrichment of $^{76}\text{Ge}$ possible (natural abundance: 7.4%)
- Germanium semiconductor diodes
  - source = detector
  - excellent energy resolution
  - ultrapure material (monocrystal)
- long experience in low-level Germanium spectrometry
Previous $^{76}$Ge $0\nu\beta\beta$ experiments

**IGEX experiment:**
$T_{1/2} > 1.6 \times 10^{25}$ y (90% C.L.)

**Heidelberg-Moscow experiment:**
$T_{1/2} = (0.7 - 4.2) \times 10^{25}$ y (3\sigma range)

Scrutinize claim with same & different isotopes!
Phases of GERDA

- **Phase I:**
  - Use of existing $^{76}$Ge-diodes from Heidelberg-Moscow and IGEX-experiments
  - 17.9 kg enriched diodes $\Rightarrow$ ~15 kg $^{76}$Ge
  - Background-free probe of KKDC evidence

- **Phase II:**
  - Adding new segmented diodes (total: ~40 kg $^{76}$Ge)
  - Demonstration of bkg-level <1 count/(kg·keV·y)

If KKDC-evidence not confirmed:
- Goal: O(1 ton) experiment in worldwide collaboration (cooperation with Majorana)
GERDA sensitivity

assumed energy resolution:
$\Delta E = 4 \text{ keV}$

Background reduction!!!
GERDA sensitivity

90% prob. upper limit < m_{ee}^\wedge

Exposure [kg \cdot years]

no background
10^{-4} counts / (kg \cdot keV \cdot y)
10^{-3} counts / (kg \cdot keV \cdot y)
10^{-2} counts / (kg \cdot keV \cdot y)
Claim

\textbf{using} \\
\langle M^{0\nu} \rangle = 3.92

V.A. Rodin at al., 

\textit{Erratum:} \\
GERDA design

Cleanroom

Lock

Water tank (650 m$^3$ H$_2$O)

Cryostat (70 m$^3$ LAr)
GERDA design

Additional inner copper shield

Germanium-detectors

Liquid argon

Vacuum-insulated double wall stainless steel cryostat
Gas purification for BOREXINO

$N_2$ production rate: 100 m$^3$/h

$^{222}$Rn: <1 atom/4 m$^3$ (STP)
Argon purification from $^{222}$Rn

- Same principle as $N_2$ purification
- Initial $^{222}$Rn conc. in Ar higher than in $N_2$
- In gas phase achieved:
  
  $^{222}$Rn in Ar: $<1$ atom$/4m^3$ (STP)

- Even sufficient for GERDA phase III
- Purification works also in liquid phase
  (efficiency lower $\Rightarrow$ more activated carbon)

G. Zuzel: “Low-level techniques applied in the experiments looking for rare events”, Wed. 12.09, Solar neutrinos & low background techniques
Stainless steel (SS) cryostat

- Ordered in Dec. 2006
- 4 vessel heads produced
- Welding certification in progress
- Delivery: Beginning of 2008
Radioactivity of the SS cryostat

- SS contains U/Th/K-contaminations (and $^{60}$Co)
- Most dangerous: $^{208}$Tl ($^{214}$Bi)
- LAr (higher density than LN$_2$)
- $^{208}$Tl requirements of stainless steel (SS 1.4571) for
  - Vessel heads: <10 mBq/kg
  - Cylindrical part: <5 mBq/kg

$^{208}$Tl requirements

<10 mBq/kg

<5 mBq/kg
## Screening results of stainless steel samples (SS 1.4571)

<table>
<thead>
<tr>
<th>No.</th>
<th>Specific activity [mBq/kg]</th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$^{228}$Th</td>
<td>$^{226}$Ra</td>
</tr>
<tr>
<td>1 D</td>
<td>5.1 ± 1.0</td>
<td>2.9 ± 1.0</td>
</tr>
<tr>
<td>2 G</td>
<td>&lt; 0.27</td>
<td>&lt; 0.35</td>
</tr>
<tr>
<td>3 D</td>
<td>1.1 ± 0.4</td>
<td>&lt; 0.84</td>
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<tr>
<td>4 D</td>
<td>&lt; 2.6</td>
<td>&lt; 2.2</td>
</tr>
<tr>
<td>5 D</td>
<td>&lt; 1.1</td>
<td>&lt; 1.2</td>
</tr>
<tr>
<td>6 D</td>
<td>&lt; 0.8</td>
<td>&lt; 0.6</td>
</tr>
<tr>
<td>7 G</td>
<td>&lt; 0.20</td>
<td>&lt; 1.3</td>
</tr>
<tr>
<td>8 G</td>
<td>&lt; 0.11</td>
<td>&lt; 0.24</td>
</tr>
<tr>
<td>9 G</td>
<td>&lt; 0.41</td>
<td>&lt; 0.74</td>
</tr>
<tr>
<td>10 G</td>
<td>&lt; 1.0</td>
<td>&lt; 1.3</td>
</tr>
<tr>
<td>11 G</td>
<td>1.5 ± 0.2</td>
<td>1.0 ± 0.6</td>
</tr>
</tbody>
</table>
Water tank and muon veto

- Passive shield (reduces amount of LAr)
- Filled with ultrapure water
- Equipped with 66 PMTs: Cherenkov detector
- Plastic scintillator on top
- Construction has started (bottom plate installation)
Cleanroom on top of water vessel
The lock system
GERDA site at Gran Sasso

Gerda at LNGS
Construction in hall A started

Water tank bottom plate (August 2007)
GERDA detector lab (GDL) at Gran Sasso
Enriched diodes for phase I

- In 2006 3 IGEX diodes and 5 HdM diodes were removed from their cryostats
- Dimensions were measured
- Construction of dedicated low-mass holder for each diode
Reprocessing of enriched and non-enriched diodes for phase I

- Different design of Hd-Moscow and IGEX diodes
- Reprocessing of all diodes at manufacturer
- Underground storage in between
- 17.9 kg enriched and 15 kg non-enriched crystals under processing
Phase I prototype testing

- Low mass detector holder developed and tested
- Definition of detector handling protocol
- Optimization of thermal cyclings
  - >40 warming and cooling cycles carried out
  - Passivation layer only refurbished twice

Same performance in LN$_2$/LAr
Phase I prototype testing

- Study of leakage current (LC) with respect to
  - Detector handling procedure
  - Irradiation with $\gamma$-sources
- Prototype detector continuously operated in LAr under varying irradiation conditions since Feb 07
- Present LC similar to initial value (few tens of pA)
GERDA phase II

- September 2005: 37.5 kg $^{enr}_{\text{Ge}}$ produced
  - $\sim 87\%$ $^{76}_{\text{Ge}}$ enrichment
  - in form of GeO$_2$
  - Chemical purity: 99.95 % (not yet sufficient)
- Underground storage until further processing steps are defined
- Investigation of different options for crystal pulling
Development of true-axial segmented detectors

- $\beta\beta$-decay is single-site event, $\gamma$-background mostly multi-site event $\Rightarrow$ Discrimination by segmentation

- Available detectors for testing:
  - 6-fold $\phi$-segmented p-type crystal
  - two 18-fold ($6\phi$, 3z) segmented detectors (n- and p-type)

- 18-fold n-type preferred:
  - Segmentation easier
  - Thin outside dead layer $\Rightarrow$ little loss of active mass
Results obtained with 18-fold segmented n-type detector

- Suppression of events from external $^{60}\text{Co}$ and $^{228}\text{Th}$ source (10 cm distance).
Background reduction by LAr-scintillation

rate [hz]

0 500 1000 1500 2000 2500

Energy [keV]

$^{232}$Th-source

- Blue line: Ge signal
- Red line: Ge signal with LAr veto
- Gray area: bkgd data
- Light gray area: bkgd data with LAr veto
Liquid argon scintillation – Work in progress

- Increase of photo-electron yield:
  - by fluor coating (1100 pe/MeV achieved)
  - by Xe doping
- Characterization of $\alpha$, $\beta$, $\gamma$ and neutron interactions by pulse shape analysis
- Preparation for LArGe in GDL @ Gran Sasso:
  - Study of LAr scintillation in ultralow-background environment
  - operational beginning of 2008
LArGe in GDL @ Gran Sasso

MC example: Background suppression for contaminations located in detector support

Factor 300 reduction in ROI
LArGe @ Gran Sasso
Front-end electronics

- Requirements:
  - Low noise, low radioactivity, low power consumption, operational at 87 K
  - Monolithic JFET semi-integrated CSA currently used for prototype testing
  - 2 R&D programs for ASIC CMOS chips
  - Characterization and testing ongoing
Monte Carlo Simulations

- Joint Gerda/Majorana code “MaGe” based on GEANT4
- Extensive physics validation program (most test setups are implemented).
Muon-induced background I: Prompt background

- 75% effective muon-veto is sufficient to achieve $10^{-4}$ counts/kg/keV/y
Muon-induced background II: Delayed background

<table>
<thead>
<tr>
<th></th>
<th>Background in LAr [cts/(kg·keV·y)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{77,77m}_{\text{Ge}}$</td>
<td>$1.1 \times 10^{-4}$</td>
</tr>
<tr>
<td>Others</td>
<td>$5 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

- $^{77}_{\text{Ge}}$ produced from $^{76}_{\text{Ge}}$ by n-capture.
- Significant reduction possible by delayed coincidence cut (muon, $\gamma$-rays, $\beta$-decay).
Schedule

- June 2007: GERDA safety concept officially approved by Gran Sasso
- Water tank installation started → continued after cryostat delivery beginning of 2008
- Next: Construction of lab building, platform, cleanroom and lock (~1 year)
- Meanwhile: Prototype and enriched detector testing is going on
- Commissioning of GERDA ~14 months after cryostat delivery
Summary

- The challenge:
  - Reduction of background by ~2 orders of magnitude with respect to previous $^{76}\text{Ge}$ experiments ⇒ Using bare diodes

- The status:
  - Construction of cryostat and water-tank started
  - Good understanding of bare detector handling
  - Reprocessing of existing enriched diodes almost finished
  - New $^{76}\text{Ge}$ for phase II available
  - Different new background reduction strategies for phase II and beyond under investigation

- The future:
  - Start data taking in 2009