High Sensitive Gamma-Spectrometers of GERDA for Material Screening: Part 2

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Outline

§ basic design considerations
§ setup of the CORRADO spectrometer (15m w.e.)
§ setup of the GeMPI III spectrometer (3800m w.e.)
§ comparison of achieved background-reduction

GeMPI III:

LNGS: 3800m w.e.
Basic Design Considerations

The central question:

How to decrease the lowest detectable specific activity:

\[ A_{\text{spec}} \approx \frac{\sqrt{B}}{M \cdot \varepsilon \cdot t} \]

- optimize signal count rate (i.e. \( M \cdot \varepsilon \) is maximal)
  - use large Ge-crystal
  - use high sample masses in efficient geometry
    i.e. choose optimal sample chamber dimensions
- low background
Background Reduction Techniques

$\textbf{external background}$ (environmental radioactivity, radon & progenies, neutrons from fission and $(\alpha,n)$-reactions)
- passive shielding (Pb, Cu, polyethylene)
- air tightness, $N_2$-flushing

$\textbf{internal background}$ in detector & shielding material
- strict material selection (iterative process)
- minimize cosmogenic production in detector & shielding copper during production
- surface cleaning, machining

$\textbf{cosmic rays}$
- go underground
- active muon veto (in shallow depth)
Design of CORRADO

muon-veto:
- MWPC in anticoincidenz
- ~10^4 µ/min

sample chamber:
- large volume (25x25x33 cm³)
- can be evacuated & flushed with boil off nitrogen

passive shield:
- inside: 5cm copper
- outside: 15-20cm lead

HP Ge-crystal
- coaxial, p-type
- active mass: 0.93kg
- relative efficiency: 37%
- aluminum cap

at 15m w.e.
Assembly of CORRADO
Background Reduction of CORRADO

- based on first preliminary background spectrum:

- **passive shield**: reduction of environmental & airborne radioactivity by factor ~100

- **active shield**: suppression of muon induced background by factor ~10 (88%)

- still no background lines observable

<table>
<thead>
<tr>
<th>Energy [keV]</th>
<th>Count rate [cts/d/kg/keV]</th>
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</thead>
<tbody>
<tr>
<td>40-2700 keV</td>
<td>5600</td>
</tr>
<tr>
<td>609 keV</td>
<td>~214Bi &lt;13</td>
</tr>
<tr>
<td>1461 keV</td>
<td>~40K &lt;2.3</td>
</tr>
<tr>
<td>2615 keV</td>
<td>~208Tl &lt;2.9</td>
</tr>
</tbody>
</table>

- **coming up**: long term background measurement

**expected sensitivity:**

~1 mBq/kg
Design of GeMPI III

- steel casing
  - radon tight
  - permanently flushed with N\textsubscript{2}

- sample chamber:
  - 25x25x30 cm\textsuperscript{3}
  - flushed with N\textsubscript{2}

- HP Ge-crystal:
  - coaxial, p-type
  - mass: 2.3kg

- custom made copper cryostat:
  - strict material selection to minimize bulk contamination
  - avoid materials with high neutron activation cross section
  - cleaning by electropolishing & acid cleaning
  - roman lead as FET-shield

- at LNGS: 3800m w.e.

- airlock & glovebox for insertion of sample

- passive shield:
  - inside: 5cm copper
  - outside: 20cm lead
  - + 5cm polyethylene
Assembly of GeMPI III

assembly completed in January ´07
First Spectra of GeMPI III

- $^{222}$Rn ($^{214}$Bi) lines from air in sample chamber visible (due to provisional tightness)

- high $^{207}$Bi contamination!
  - 570 keV: $(37.8\pm1.6)$ cts/d
  - 1064 keV: $(21.2\pm1.2)$ cts/d
  - sum: $(3.0\pm0.5)$ cts/d

- from line ratio: contamination is inside of shielding

- suspecting the lead: possible production via $(p,n)$-reaction on $^{207}$Pb

- screening of candidates in progress

- from summation peak & MC: distance & direction information (in progress)
Comparison of Background Reduction

![Graph showing comparison of background countrates between GeMPI and DARIO]

<table>
<thead>
<tr>
<th>Long-lived isotopes</th>
<th>Energy (keV)</th>
<th>GeMPI</th>
<th>DARIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{226}$Ra</td>
<td>352/609</td>
<td>&lt;24/25</td>
<td>4790±590/4070±460</td>
</tr>
<tr>
<td>$^{228}$Th</td>
<td>583/2615</td>
<td>&lt;21/18±5</td>
<td>1440±330/4520±280</td>
</tr>
<tr>
<td>$^{40}$K</td>
<td>1461/2615</td>
<td>86±12</td>
<td>302±161</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>1173/1332</td>
<td>43±10/35±8</td>
<td>&lt;375/&lt;348</td>
</tr>
<tr>
<td>total</td>
<td>100-2730</td>
<td>6840±110</td>
<td>1320000±4400</td>
</tr>
</tbody>
</table>

Achieved sensitivity:
- GeMPI: $\sim 10 \mu\text{Bq/kg}$
- DARIO/CORRADO: $\sim 1 \text{mBq/kg}$
new high sensitive Ge-spectrometers are being build in order to provide sufficient screening capacity for GERDA.

with a shielding system appropriate to the depth of the detector site sensitivities of ~1mBq/kg @ 15m w.e. ~10µBq/kg @ 3800m w.e. can be achieved.

a good knowledge of the detector‘s background, it‘s geometry, as well as large sample masses at long measurement times are required.