Estimate of the Internal Gamma Background of the GERDA-Experiment

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Overview

Theory Introduction and Experimental Setup of Gerda

Typical Backgrounds and Reduction

Monte Carlo Simulation

Results and Outlook
Theory Introduction to Double Beta Decay

Second order weak process => rare

\( \text{\^{76}Ge} \) \(2\nu\beta\beta\):
\[ T_{1/2} = 1.55 \times 10^{21} \text{ a} \]

\( \text{\^{76}Ge} \) \(0\nu\beta\beta\):
\[ T_{1/2} > 1.9 \times 10^{25} \text{ a} \]

\[ \nu_L \rightarrow \nu_R \]

-allowed in SM

\[ Q_{\beta\beta}^{(76\text{Ge})} = 2039 \text{ keV} \]

\[ \frac{dN}{dE} \]

\[ \frac{dN}{dE} \] search in energy window around \( Q_{\beta\beta} \)

\[ \Delta L \neq 0 \]

- only if \( \nu = \nu \) \&\& \( m_\nu > 0 \)
Experimental Setup

LNGS

3500 m.w.e.

Phase I: 8 enriched unsegmented detectors
Phase II: 21 enriched detectors (33.9 kg)
18 fold segmented

Targeted background rate: $1 \times 10^{-3}$ cts/(kg keV y)
in ROI

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Typical Backgrounds

• **Cosmogenic production** of isotopes in germanium

• **Cosmic Muons**

• **Neutrons**
  • muon induced
  • from decays in the rock

• **Radioactive** isotopes in surrounding
  • electrons
  • alphas (on surfaces)
  • gammas
Typical Backgrounds + Means of Reduction

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minimize exposure above ground

go underground
muon veto

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Typical Backgrounds + Means of Reduction

- **Cosmogenic production** of isotopes in germanium
  - minimize exposure above ground
  - go underground
  - muon veto

- **Cosmic Muons**
  - go underground
  - muon veto

- **Neutrons**
  - muon induced
  - from decays in the rock
  - water tank

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- **Neutrons**
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  - go underground
  - muon veto
  - water tank
- **Radioactive** isotopes in surrounding
  - electrons
  - alphas (on surfaces)
  - gammas
  - choice of material close to detectors
  - shielding
  - minimize exposure above ground
  - go underground
  - muon veto
  - water tank
  - choice of material close to detectors
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Typical Backgrounds + Means of Reduction

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- Minimize exposure above ground
- Go underground
- Muon veto
- Water tank
- High purity argon
- Choice of material close to detectors
- Shielding
Typical Backgrounds + Means of Reduction

- **Cosmogenic production** of isotopes in germanium
  - minimize exposure above ground

- **Cosmic Muons**
  - go underground muon veto

- **Neutrons**
  - muon induced
  - from decays in the rock
  - go underground muon veto
  - water tank

- **Radioactive** isotopes in surrounding
  - electrons
  - alphas (on surfaces)
  - gammas
  - treat crystal in clean env high purity argon
  - choice of material close to detectors shielding
Background Reduction

~ 2MeV \textbf{gamma} deposits energy predominantly through Compton-Scattering
mean free path (Ge) : \sim 5\text{cm}

\textbf{Signal} (electrons) deposit energy very locally

\textbf{Signal:} \hspace{2cm} \textbf{Background:}

\begin{itemize}
  \item \textbf{energy cut:} $Q_{\beta\beta} \pm 10$ keV
  \item \textbf{segment anti-coincidence} cut to reduce gamma background
\end{itemize}
Monte Carlo Simulation

- Use Monte Carlo simulation framework **MaGe** (Majorana Gerda)  
  - **MaGe**: Geant4 based  
  - includes decay generators,..

Simulation takes into account:

- **natural radioactivity**:
  - $^{232}\text{Th}$
    - $^{208}\text{TI}$: 2614.5 keV  
  - $^{238}\text{U}$
    - $^{234}\text{Pa}$: 2072.2 keV  
    - $^{214}\text{Bi}$: many  
    - $^{210}\text{TI}$: several
  - $^{40}\text{K}$: 1460.8 keV

- **“man made“ radioactivity**
  - $^{137}\text{Cs}$: 661.6 keV

- **cosmogenic activation**
  - $^{60}\text{Co}$: 2158.5 keV  
  - 2505. keV
**Evaluation**: Energy cut + segment anticoincidence cut, applying measured activity

<table>
<thead>
<tr>
<th>Part</th>
<th>Background contribution [10^{-4} counts/(kg·keV·y)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector</td>
<td></td>
</tr>
<tr>
<td>68Ge</td>
<td>4.3 - after 2 years</td>
</tr>
<tr>
<td>60Co</td>
<td>0.3</td>
</tr>
<tr>
<td>Bulk</td>
<td>3.0</td>
</tr>
<tr>
<td>Surf.</td>
<td>3.5 - further reduction through PSA expected</td>
</tr>
<tr>
<td>Holder</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>1.4</td>
</tr>
<tr>
<td>Teflon</td>
<td>0.3</td>
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<tr>
<td>Cabling</td>
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</tr>
<tr>
<td>Kapton</td>
<td>1.5</td>
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<tr>
<td><strong>Electronics</strong></td>
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<tr>
<td>LAr</td>
<td>1.0</td>
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<tr>
<td>Infrastructure</td>
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<tr>
<td>Muons and neutrons</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>21.0</td>
</tr>
</tbody>
</table>
String Setup in Monte Carlo
String Setup in MC

Cable Chain:
- last meter made from copper
- above stainless steel

Cables:
- woven ribbon signal cable

41 cm above crystals
String Setup in MC

most material copper
30 cm above crystals

mass:
1.074 kg copper
0.105 kg "plastic"

murtfeldt plastic
teflon, iglidur
String Setup in MC

1.62kg Ge

31g copper holder

2.5g Kapton cable

1.34g teflon

4.79g teflon

1.44g teflon
Outlook

Finish analysis

Rerun simulation with realistic setup

Take into account other background contribution

 Produce Reference Energy Spectrum