LAr instrumentation for GERDA Phase II

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LAr scintillation veto for background suppression

How does an active LAr veto work?

**signal**

$0\nu\beta\beta$ event deposits its energy locally in the Ge-crystal → single site event

**backgrounds**

- $\gamma$ background: mainly Compton scattered events from natural decay chains ($^{228}\text{Th}$, $^{226}\text{Ra}$)
- $\alpha$ and $\beta$ decays near/on detector surface ($^{226}\text{Ra}$, $^{42}\text{K}$)

**LAr instrumentation**

- Energy deposition in LAr creates scintillation light @ $\lambda = 128 \text{ nm}$, 40000 pe/MeV
- Can be used as *anticoincidence veto*
“Hybrid” LAr veto design for **GERDA** Phase II

“hybrid” design is outcome of an extensive MC simulation campaign using photon tracking.

**Photomultipliers**
- type: 3 “ R 11065-20 MOD
- 9* top, 7* bottom

**Scintillating fibers and SiPMs**
- build the middle shroud
- type: BCF-91A coated with TPB
- light readout at both ends by SiPMs on top
“Hybrid” LAr veto design for GERDA Phase II

**Top/bottom copper shroud + reflective foil**

- Tetratex coated with TPB as wavelength shifter
- Installed on inner side of copper shrouds

**Nylon mini-shrouds**

- Around each detector string
- Transparent & WLS
- Usable together with light instrumentation
**Photomultiplier - Hardware**

<table>
<thead>
<tr>
<th>228(^{\text{Th}})</th>
<th>226(^{\text{Ra}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMT *</td>
<td>&lt; 1.94 &lt; 1.7</td>
</tr>
<tr>
<td>VD</td>
<td>&lt; 0.5 &lt; 1.14</td>
</tr>
</tbody>
</table>

* calculated from component screening peak-to-valley: 4:1

**teststand**

- test of up to 10 PMTs in LAr
  - light yield measurements with internal sources
  - gain calibration with LED
  - signal rate monitoring
  - longterm test up to 6 weeks performed

⇒ 18 PMTs classified as good enough for operation in GERDA
Fibers - Hardware

scintillating fibers coated with TPB
- fibers themselfe are WLS

Absorption  
Emission

screening results
- $^{228}$Th: 0.058 Bq/kg
- $^{226}$Ra: 0.042 Bq/kg

9 fibers per SiPM
- readout at the top
  ⇒ far from detectors

SiPMs at LN temperature
- good QE, negligible dark rate
- Ketek SiPMs in ’die’ → low background packaging
LAr veto integration in GERDA

- Integration started in summer 2014
- Finished in November 2014
LAr veto integration in GERDA
LAr veto commissioning in GERDA

November 2014: first commissioning run w/o Ge diodes
- mechanical test
- learn about noise, rates, coincidences between SiPMs and PMTs, read-out window
- apply analysis tools to real data

December 2014: first test with one working BEGe and $^{232}$Th source
- learn about veto efficiencies of LAr instrumentation

February 2015: data taking with one BEGe string and a $^{228}$Th calibration source
- learn about interplay of PSD and LAr veto
LAr veto analysis

saved traces for every trigger in a Ge-diode

Ge trace

SiPM traces

PMT traces

use as filter parameter angle
\( \alpha \cdot |\text{slope}| \) for hit identification

use simple leading edge filter

1. hit identification in whole trace

2. determine veto threshold & window for each channel

   ➤ for this analysis set by eye

   ➤ later: maximize suppression factor/random coincidence rate as function of veto window, veto threshold, multiplicity,...

3. set veto flag
First LAr veto suppression in GERDA

GERDA preliminary March 2015

228Th calibration run
- no cut
- PSD
- LAr veto
- PSD + LAr veto

Anne Wegmann (MPIK)
Summary

- LAr light instrumentation with PMTs and Fibers/SiPMs has been installed in GERDA:
  - hardware tests of individual components completed prior to the installation
- first commissioning runs have been conducted
  - PMTs & SiPMs show good signal-to-noise ratio (PMTs: peak-to-valley 4:1)
- First results (preliminary!)
  - LAr veto: SF ≈ 50 for nearby $^{228}$Th calibration source (only 6 of 15 fiber modules were working)
  - PSD + LAr veto: SF ≈ 100
- broken SiPMs exchanged & much higher suppression expected for the next runs

outlook

- optimize LAr veto algorithms with respect to the suppression factors and random coincidence rate
- perform MC simulations to verify the agreement between the measured and the expected suppression factors
- commissioning is ongoing...
Thank you for your attention!
LArGe - a test facility for GERDA
Proof of LAr-veto concept in low background environment

energy spectrum for an internal $^{228}$Th source:

<table>
<thead>
<tr>
<th>source</th>
<th>position</th>
<th>LAr veto</th>
<th>PSD</th>
<th>suppression factor</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{228}$Th</td>
<td>int</td>
<td>1180 ± 250</td>
<td>2.4 ± 0.1</td>
<td>5200 ± 1300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ext</td>
<td>25 ± 1.2</td>
<td>2.8 ± 0.1</td>
<td>129 ± 15</td>
<td></td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td>int</td>
<td>4.6 ± 0.2</td>
<td>4.1 ± 0.2</td>
<td>45 ± 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ext</td>
<td>3.2 ± 0.2</td>
<td>4.4 ± 0.4</td>
<td>18 ± 3</td>
<td></td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>int</td>
<td>27 ± 1.7</td>
<td>76 ± 8.7</td>
<td>3900 ± 1300</td>
<td></td>
</tr>
</tbody>
</table>
Physics validation of Monte Carlo using photon tracking
Comparison to LArGe data

- simple geometry
- data with various sources in different locations available
- tuning of optical properties
  - material reflectivities (Ge, Cu, VM2000, ...)
  - absorption and emission spectra
  - LAr attenuation length, light yield and triplet lifetime
- good MC description after tuning
  ⇒ can be used to design the LAr veto for GERDA

<table>
<thead>
<tr>
<th></th>
<th>bg LArGe data</th>
<th>MC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>internal</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{208}$Tl</td>
<td>1180 ± 250</td>
<td>909 ± 235</td>
</tr>
<tr>
<td>$^{214}$Bi</td>
<td>4.6 ± 0.2</td>
<td>3.8 ± 0.1</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>27 ± 2</td>
<td>16.1 ± 1.3</td>
</tr>
<tr>
<td><strong>external</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{208}$Tl</td>
<td>25 ± 1.2</td>
<td>17.2 ± 1.6</td>
</tr>
<tr>
<td>$^{214}$Bi</td>
<td>3.2 ± 0.2</td>
<td>3.2 ± 0.4</td>
</tr>
</tbody>
</table>
Fibers - Hardware

TUM cryostat
Fibers - filter algorithm

4 triggers with assigned amplitude

not found