Neutrinoless double-beta decay in the GERDA Phase II

Carla Macolino per la collaborazione GERDA

INFN, Laboratori Nazionali del Gran Sasso

Congresso Nazionale SIF
Trieste, 25.02.2013
Outline

• Science motivation for Phase II
• On the way to GERDA Phase II
• Pulse-Shape Discrimination (PSD) Analysis for BEGes
• LAr instrumentation
Science motivation

\[(T_{1/2}^{0\nu})^{-1} = G^{0\nu} |M^{0\nu}|^2 \frac{\langle m_{\beta\beta} \rangle^2}{m_e^2}\]

with \(\langle m_{\beta\beta} \rangle = \text{effective electron neutrino mass}\)

\[\langle m_{\beta\beta} \rangle \equiv |U_{e1}|^2 m_1 + |U_{e2}|^2 m_2 e^{i\phi_2} + |U_{e3}|^2 m_3 e^{i\phi_3}\]

- \(m_i = \text{masses of the neutrino mass eigenstates}\)
- \(U_{ei} = \text{elements of the neutrino mixing matrix}\)
- \(e^{i\phi_2}\) and \(e^{i\phi_2}\) the relative CP phases

→ information on the absolute mass scale!

- **Phase I result**: \(B_l \sim 10^{-2}\) cts/(keV kg yr) and \(\sim 20\) kg yr exposure
  → limit on \(\langle m_{ee} \rangle\) between 0.2 and 0.4 eV
- **Phase II goal**: \(B_l \sim 10^{-3}\) cts/(keV kg yr) and 100 kg yr exposure
  → sensitivity on \(\langle m_{ee} \rangle \sim 100\) meV
On the way to GERDA Phase II

How to get a higher sensitivity for the Phase II:

- Understand background sources and reduce radiation sources
- Improve background rejection
- Increase mass

Strategy:

- Transition currently ongoing at LNGS
- Increase mass: additional 30 enriched BEGe detectors (about 20 kg)
- Suppress background contamination by a factor of 10 w.r.t. GERDA Phase I:
  - Use BEGes with Pulse-Shape Analysis for high background recognition efficiency
  - Use LAr scintillation light for background recognition and rejection
  - Use lower background Signal and HV cables w.r.t. Phase I
  - Use lower background Very Front End electronics w.r.t. Phase I
- Minimize material around sources and special care in crystal production
- Start commissioning in Autumn 2013 - Spring 2014
Soon after the deployment. The analyses discussed here classification and PSD selection based on the pulse asymmetry selections have been performed for the semi-coaxial estimated $0^+ (0.007$ are applied for the first time in a $0^+ +0$ process the event selection for every analysis while the other two (likelihood and to correct for the observed time

Applying the PSD cut to $2^+ \cdot \epsilon$ events results in an $0^+$

SIF Trieste

Phase II BEGe detectors

Broad Energy Germanium detectors allow a highly efficient discrimination of the background:

Outer surface: n+ electrode (HV contact)

p-type Germanium

Grooves separating the contacts

p+ electrode (signal readout contact)

Discriminate between Single-site and Multi-site events

SSE: $\beta\beta$, DEP

MSE: Compton

Pulse-shape analysis

e signal: single site energy deposition

$\gamma$ signal: multiple site energy deposition
PSD on Phase II BEGe detectors

A/E parameter allows to separate SSE events from MSE, $n^+$ and $p^+$ events

D. Budjas et al, JINST 4 P10007 (2009)
M. Agostini et al., JINST 6P03005 (2011)
PSD on Phase II BEGe detectors

Most dominant background from $^{42}$K near n$^+$ contact (different pulses with low A/E)

Experimental evidence of efficient $^{42}$K rejection by PSD on GERDA Phase I data

The GERDA Collaboration, The European Physics Journal C, *in press*
Liquid Argon instrumentation for Phase II

PMT LAr instrumentation studies for Phase II in LArGe (a smaller GERDA facility)

Different possible hardware configurations:

- SiPM fiber curtain
- PMTs on top and bottom of the array
- Hybrid solution
- Meshed copper shroud around strings
- Transparent mini-shroud
- VM2000 coated mini-shroud with large area SiPMs between detectors
Background for GERDA Phase II

Background suppression measurements with PMT veto and different possible configurations

<table>
<thead>
<tr>
<th>Experimental condition</th>
<th>1540-3000 keV$^1$ cts/(kg d)</th>
<th>Suppression to bare BEGe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare BEGe, PMTs off</td>
<td>514(18)</td>
<td>1</td>
</tr>
<tr>
<td>MMS, HV = 0, PMTs off</td>
<td>552(16)</td>
<td>0.9</td>
</tr>
<tr>
<td>MMS, HV = 0, PMTs on</td>
<td>154(9)</td>
<td>3.3</td>
</tr>
<tr>
<td>MMS, HV = +4kV, PMTs on</td>
<td>58(8)</td>
<td>8.9</td>
</tr>
<tr>
<td>Nylon MS, PMTs off</td>
<td>203(10)</td>
<td>2.5</td>
</tr>
<tr>
<td>Nylon MS, PMTs on</td>
<td>64(3)</td>
<td>8.0</td>
</tr>
<tr>
<td>Nylon MS, PMTs on$^2$</td>
<td>60(6)</td>
<td>8.6</td>
</tr>
<tr>
<td>Nylon MS, PMTs off</td>
<td>58(4)</td>
<td>8.9</td>
</tr>
<tr>
<td>Foil MS + SiPM, PMTs off</td>
<td>69(4)</td>
<td>7.5</td>
</tr>
<tr>
<td>Foil MS + SiPM, PMTs off</td>
<td>61(3)</td>
<td>8.4</td>
</tr>
<tr>
<td>Foil MS + SiPM, PMTs on</td>
<td>49(4)</td>
<td>10.5</td>
</tr>
<tr>
<td>LAr refilling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foil MS + SiPM, PMTs off</td>
<td>k*81(4)</td>
<td>~ 5.8</td>
</tr>
<tr>
<td>Glued Nylon MS, PMTs off</td>
<td>K*28(2)</td>
<td>~ 17</td>
</tr>
</tbody>
</table>

Carla Macolino (LNGS)
Conclusions

- GERDA Phase I/Phase II transition currently ongoing
- On the way to improve GERDA sensitivity:
  - **Increase mass:**
    - 30 additional BEGes (∼ 20 kg)
    - already produced and completely tested in Hades (Belgium)
    - BEGe detectors already tested in the real environment in the Phase I
  - **Suppress background by a factor of 10 w.r.t. Phase I:**
    - Very efficient Pulse-Shape Discrimination for background recognition
    - Liquid Argon veto by detecting scintillation light
    - HV cable and VFE electronics with lower background
  - New lock system for the detector deployment into the cryostat
- Many important contributions from the GERDA Italian groups (Padova, Milano Bicocca and LNGS) on BEGe characterization, VFE electronics, data processing, MC simulations, data analysis
- Commissioning foreseen in **Autumn 2013 - Spring 2014**