MEASURING BACKGROUND WITH NEMO-3

The source foils contain small amounts of background radioactive isotopes which were detected with a high-purity Germanium detector. Using a number of control regions defined by different final state event topologies, the activity of these background isotopes can be directly measured with the NEMO-3 detector, and used to estimate the number of expected events in the $2\nu\beta\beta$ and $0\nu\beta\beta$ signal regions.

The most significant background to the $^{100}$Mo $0\nu\beta\beta$ decay is the irreducible $2\nu\beta\beta$ decay spectrum.

The $2\nu\beta\beta$ efficiency is 2.47% for metallic and 2.29% for composite foils. S/B is 63 for metallic, 94 for composite. Using an exposure of 34.7 kg y of $^{100}$Mo:

$$T_{1/2}^{2\nu\beta\beta} = (6.81 \pm 0.01 \pm 0.46) \times 10^{18} \text{ years}.$$

The HSD (high intermediate state) model is excluded. The SSD (single state dominant) and SSD-1 (where the contribution of the first 1+ excited state is taken into account) are favoured.

**2$\nu$\beta$\beta$ RESULTS FOR $^{100}$Mo**

<table>
<thead>
<tr>
<th>Source of uncertainty</th>
<th>Effect on $T_{1/2}^{2\nu\beta\beta}$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute normalization of $\varepsilon_0$</td>
<td>± 5</td>
</tr>
<tr>
<td>Thin source foil modelling</td>
<td>± 4</td>
</tr>
<tr>
<td>$^{100}$Mo decay model</td>
<td>± 1.8</td>
</tr>
<tr>
<td>Energy calibration</td>
<td>± 0.6</td>
</tr>
<tr>
<td>$^{100}$Mo mass</td>
<td>± 0.3</td>
</tr>
<tr>
<td>Background uncertainty</td>
<td>± 0.2</td>
</tr>
<tr>
<td>Total</td>
<td>± 6.7</td>
</tr>
</tbody>
</table>

The NEMO-3 experiment searches for neutrinoless double beta decay ($0\nu\beta\beta$). This is a hypothesized nuclear decay. Its rate is proportional to the effective neutrino mass squared:

$$\left(T_{1/2}^{0\nu\beta\beta}\right)^{-1} = G^2 \left| M^{0\nu}\right|^2 \left|m_\nu\right|^2,$$

where $G^{0\nu}$ and $M^{0\nu}$ are the theoretically calculated phase space and nuclear matrix elements, respectively. Observation of $0\nu\beta\beta$ decay would be direct evidence that neutrinos are Majorana particles and lepton number conservation is violated. Therefore, $0\nu\beta\beta$ decay is a process which is beyond the current standard model of particle physics [1].

**THE NEMO-3 EXPERIMENT**

- Located in the Modane Underground Laboratory (LSM)
- Operated from February 2003 to January 2011
- Unique detector among $2\nu\beta\beta$ and $0\nu\beta\beta$ experiments due to the separation of the isotopes from the active detector system
- Allows for direct measurements of internal and external background rates and final state kinematic variables
- 7 different isotopes investigated simultaneously for $2\nu\beta\beta$ and $0\nu\beta\beta$ [2]

**MAJORON AND EXOTIC SEARCHES**

NEMO-3 also investigated the majoron and exotic $\beta\beta$ decays for $^{100}$Mo.

In various theoretical models the neutrinoless double beta decay can occur with the emission of a single or double majoron (massless or light boson with a coupling to neutrinos). Using $^{100}$Mo, NEMO-3 provided one of the most sensitive constrain on the majoron coupling constant.

$$\sin^22\chi < 0.27 \quad (T_{1/2}^{0\nu}(90\% \ g.s.) > 1.2 \times 10^{21} \text{ y})$$

The search for the bosonic neutrino is more promising when searching the $2\nu\beta\beta$ to the first $2^+$ excited state.

The Lorentz invariance can be tested with double beta decay as its violation leads to energy spectra of emitted particles different from those in usual $2\nu\beta\beta$ process. NEMO-3 sets constrain on the Lorentz violation which can produce a positive or negative deviation of the spectrum:

$$-4.2 \times 10^{-7} \text{ GeV} < \delta_{\text{off}}^{(3)} < 3.5 \times 10^{-7} \text{ GeV}$$

**References**