Background reduction in a gamma spectrometer with an active shielding

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Introduction

In gamma spectroscopy, the minimal detectable activity is of great importance. For example, in sediment dating the samples often contain very low levels of $^{210}$Pb, that is used in the chronology. One of the determining factors in detection of low levels of gamma radiation is the background present the spectra. Background in gamma spectroscopy is due to a combination of different components [1]:

- Environmental gamma radiation
- Intrinsic radioactivity of building and detector materials
- Cosmic radiation

To reduce background, gamma spectrometers are usually passively shielded by housing them in lead castles of 10-15 cm thickness [1, 2]. This works well against environmental radiation, since the lead is several times thicker than the half value layer for most gamma energies.

Cosmic radiation

Cosmic radiation at sea level, on the other hand, consists mostly (about 75%) of muons [1]. Muons interact only very weakly with the lead shielding, because of low specific energy loss rates, but can cause several secondary effects like bremsstrahlung that increases the background continuum.

Active shielding

In the past, other groups [3, 4] have obtained good results with active shielding of the detector by surrounding the detector with scintillators in an anti-coincidence system.

Method

We use a similar setup as [3] with two plastic scintillators (50x100x5 cm$^3$ each) mounted on top of the lead castle. Shielding the top direction promises the best result, because the cosmic component of the background has a strong preference to enter the detector from the top direction, since the muons have an angular distribution in the form of cos$^2\theta$, where $\theta$ is the zenith angle.

Fig. 1: Active shielding schematic.

In order to block the background caused by cosmic radiation, the two plastic scintillator signals are summed and processed together with the timing signal from the HPGe in an anti-coincidence system.

Results

With the active shielding the overall background count rates could be reduced from 1.30 cps to 0.66 cps, which improves the minimal detectable activity. The spectra were measured for 3 days, and for comparisons an efficiency for a petri dish with $d=7$cm, $h=2$cm and $\rho=19$cm$^3$ has been used.

Table 1: Theoretical minimal detectable activity.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>MDA [Bq/$\sqrt{cp}$]</th>
<th>relative MDA [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^7$Be</td>
<td>0.066</td>
<td>0.999</td>
</tr>
<tr>
<td>$^60$K</td>
<td>0.110</td>
<td>0.178</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>0.009</td>
<td>0.013</td>
</tr>
<tr>
<td>$^{131}$I</td>
<td>0.009</td>
<td>0.014</td>
</tr>
<tr>
<td>$^{134}$Cs</td>
<td>0.008</td>
<td>0.012</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>0.010</td>
<td>0.014</td>
</tr>
<tr>
<td>$^{210}$Pb</td>
<td>0.075</td>
<td>0.110</td>
</tr>
<tr>
<td>$^{212}$Pb</td>
<td>0.017</td>
<td>0.021</td>
</tr>
</tbody>
</table>

Fig. 2: Background count rates comparison.

Fig. 3: Relative minimal detectable activity.

Conclusion

It could be shown that the tested active shielding setup is effective in reducing the background count rates. This improves the minimal detectable activity for all gamma lines to an average of 68% ± 5% of the MDA without active shielding.

References