Calibration Validation of beta-gamma coincidence detector systems

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Calibration validation steps
- Calibration measurements and calculations on-site
- Independent calculations at CTBTO
- Injection of radioactive spikes and their re-analysis at Noble Gas laboratories
- Quality assurance measurements at laboratories including participation in intercomparisons

GEANT4 model (in progress)
- Sample: 20% of xenon gas mixed in 80% Helium
- Nuclear data: DDEP & Brookhaven NDNC (Xe-135), the data set is incomplete
- Physics list: standard 6M package, incl. photoelectric effect, Compton scattering, pair production, Auger process, bremsstrahlung, ionization, multiple scattering and annihilation
- Optical photons interactions (Cherenkov, scintillation, Rayleigh scattering, absorption and boundary processes) to be completed

Beta energy and resolution calibration
- Slicing of the Cs-137 scattering distribution
- Projecting on the beta axis
- Simultaneous beta energy and resolution calibrations using the projections
- Beta energy given by the equation $E_{\beta} = E_{\gamma} - E_{\text{sc}}$

Uncertainty budget

<table>
<thead>
<tr>
<th>Uncertainty source</th>
<th>Estimate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Counting statistics</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Calibration constants</td>
<td>&lt;1.5%</td>
</tr>
<tr>
<td>Gas background</td>
<td>&lt;1.5%</td>
</tr>
<tr>
<td>Detectors background</td>
<td>&lt;1.5%</td>
</tr>
<tr>
<td>Interference factors</td>
<td>&lt;5.5%</td>
</tr>
<tr>
<td>Branching ratios</td>
<td>2.5</td>
</tr>
<tr>
<td>Half life</td>
<td>0.01 - 0.6</td>
</tr>
</tbody>
</table>

*For major interference factors, which are all Radon interference factors and ROIs 2 and ROIs 3

Beta energy and resolution calibration

<table>
<thead>
<tr>
<th>Isotope</th>
<th>ROI</th>
<th>SAUNA average</th>
<th>SIPIN</th>
<th>SIPIN-SAUNA Nal (estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xe-125</td>
<td>2</td>
<td>0.49(3)</td>
<td>0.30(2)</td>
<td>0.4</td>
</tr>
<tr>
<td>Xe-133</td>
<td>3</td>
<td>0.62(3)</td>
<td>0.41(1)</td>
<td>0.4</td>
</tr>
<tr>
<td>Xe-133m</td>
<td>4</td>
<td>0.62(3)</td>
<td>0.27(4)</td>
<td>0.3</td>
</tr>
<tr>
<td>Xe-135m</td>
<td>5</td>
<td>0.60(3)</td>
<td>0.25(1)</td>
<td>0.25</td>
</tr>
<tr>
<td>Xe-133m</td>
<td>6</td>
<td>0.60(3)</td>
<td>0.23(4)</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Conclusions
- Calibration – complex multistep process
- Calibration validation procedure is established
- Improved understanding of uncertainties
- Promising results with the increased resolution of the SIPIN detector
- Initial simulations with GEANT4

Future work:
- Simplification of calibration procedure with fewer measurements
- Study systematic uncertainties
- Complete GEANT4 modelling
- DDEP data for Xe-135 is missing, and Xe-133m is not up-to-date