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Calibrating a beta-gamma coincidence detector system for assay of Xe-127

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INTRODUCTION AND MAIN RESULTS

To calibrate a beta-gamma coincidence detector system for measurement of the ^{127}Xe, a series of laboratory measurements were conducted using radio-pure gas. A calibration scheme was devised and compared to detector models and singles gamma spectrometry measurements, demonstrating very good agreement. Several key trends were identified from the calibration measurements, showing an efficiency dependence on the xenon gas concentration for some coincidence regions of interest in the energy matrix.

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Introduction

Xenon-127 (^{127}Xe) is a neutron-deficient radionuclide produced from activation, in contrast to the fission-produced radioxenon isotopes relevant to the CTBT. This radionuclide is a useful surrogate for radioxenon measurement development and system quality assurance due to electron-photon coincidence decay signatures and 36-day half-life.

Others have explored the use of ^{127}Xe to support the QA programme at IMS Radionuclide Laboratories [1,2] however quantification of the activity using beta-gamma coincidence detector systems has proved complex and challenging.

This work focusses on the β-γ coincidence assay of ^{127}Xe and explores various regions of interest (ROIs) for use in quantifying the activity present. **Fig. 1** shows β-γ coincidence measurements of ^{127}Xe and selected ROIs.

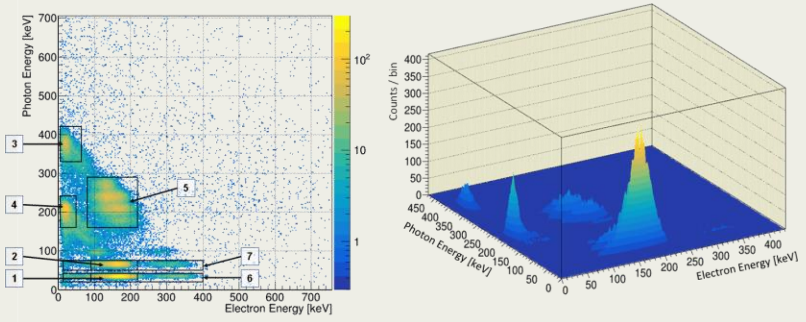

Figure 1. ^{127}Xe measurement on a SAUNA-style beta-gamma coincidence detector. **Left**: showing the regions of interest used for the analysis of ^{127}Xe in these samples and **right**: showing a 3D representation of the coincidence matrix

Methods/Data

A 30 cm^3 xenon sample containing radiopure ^{127}Xe was prepared and distributed to multiple laboratories for measurement using different systems. At AWE, a SAUNA II Lab system was used to measure the ^{127}Xe. The detector system usually operates with xenon volumes up to 5 cm^3 so the sample was siphoned and aliquots measured with volumes from 0.8-7 cm^3, with most samples <4 cm^3. The activity is calculated using pre-calibrated detector response [3].

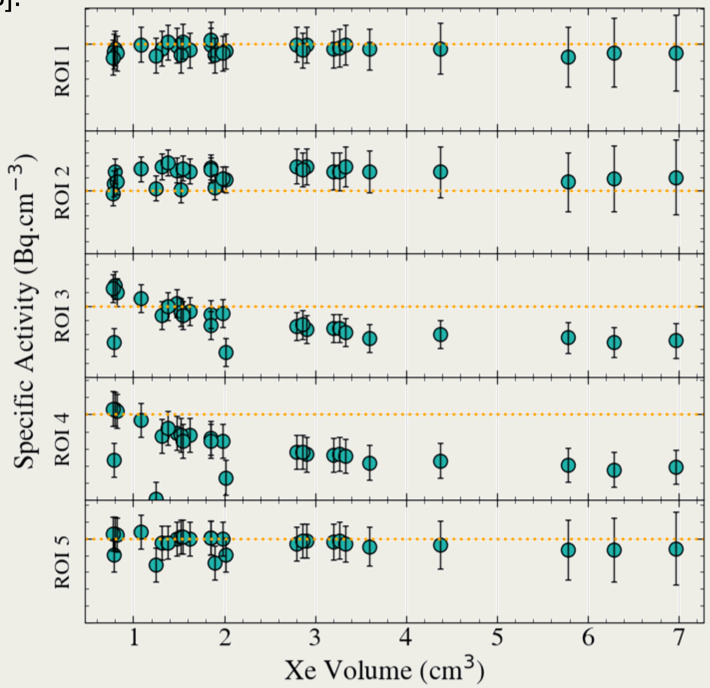

Figure 2. Specific activity of ^{127}Xe as calculated from each ROI 1-5. The dashed line represents 1 $Bq.cm^{-3}$ which is the approximate reference activity determined from high-resolution gamma spectrometry.

Laboratory Measurements

The low electron-energy ROIs (3+4) show a clear dependency on xenon volume (see **Fig. 2**), likely due to the increased self-attenuation of electrons emitted during decay. ROI 1 is the most consistent measurement showing no strong trend with increasing xenon volume.

Using this data, volume-dependent efficiency functions were derived to correct the loss in efficiency at higher volumes, ensuring that the data from all ROIs can be used. These functions are geometry specific. **Fig. 3** shows the spread in laboratory measurements once the correction function was applied.

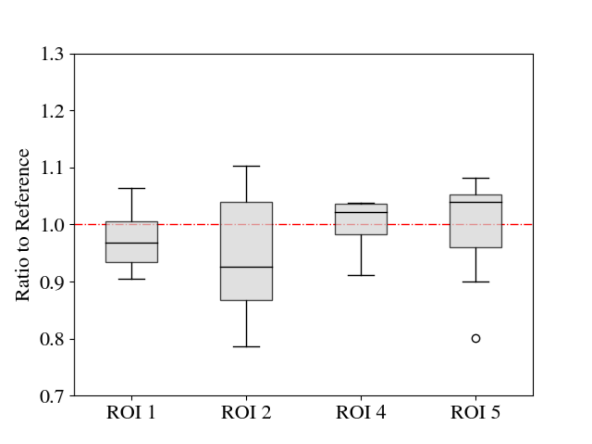

Figure 3. Comparison of quantified activities using each ROI (1,2,4,5), following measurement on a SAUNA II detector system.

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Discussion

Measuring ^{127}Xe for the purposes of Quality Assurance of IMS laboratories can provide more information than standard isotopes such as ^{133}Xe and ^{131m}Xe. Whilst this is especially useful for laboratories that use beta-gamma coincidence spectrometry, it is also useful for singles high-resolution gamma spectrometry systems, where there are multiple gamma lines available for analysis.

The intricacies of quantification of such a radionuclide through gamma and beta-gamma spectrometry can provide useful information to laboratory operators, such as self-attenuation quantification, coincidence summing, detection efficiencies across a wider range of energies and more discrete coincidence energy signatures.

Table 1 shows the summarised list of signatures used during the measurements discussed here. The ROIs selected are not the only options, but capture the most intense signatures. The table also highlights the complex nature of the decay signatures in a beta-gamma coincidence detector.

Table 1
ROI definitions and a summary of some of the main signatures. *γ0*=57 keV, *γ1*=145 keV, *γ2*=172 keV, *γ3*=202 keV, *γ4*=375 keV. X(K) refers to a K-shell X-ray. *denotes that the X-ray can be produced from either the EC decay or from internal conversion during a coincident cascading de-excitation. Coincidences can occur where a *γ*-ray is missed/not-detected but then the next de-excitation is detected. From [3].

ROI	E_e low [keV]	E_e high [keV]	E_γ low [keV]	E_γ high [keV]	Contributing signatures *[Electron signature in italics]*
1	90	220	20	42	*K(CE)*γ_1 + X(K)* *K(CE)*γ_2 + X(K)* *K(CE)*γ_3 + X(K)* Plus the above with Auger (K) electron
2	90	220	50	75	*K(CE)*γ_1+ γ_0 *K(CE)*γ_2+ γ_0 ROI 1 + X-ray sum
3	5	65	330	420	*K-Auger* + γ_4 *K-Auger* + γ_2+ γ_3
4	5	50	160	242	*K-Auger* + γ_3
5	80	220	160	275	*K(CE)*γ_2 + γ_3 *K(CE)*γ_3 + γ_2 *K(CE)*γ_2 + γ_3 + X(K)* *K(CE)*γ_3 + γ_2 + X(K)* *K(CE)*γ_2 + γ_3 + 2X(K)* *K(CE)*γ_3 + γ_2 + 2X(K)* *K(CE)*γ_3 + *K-Auger* + γ_2 + X(K)*
6	14	400	20	42	*Incl. ROI 1* *K(CE)*γ_4 + X(K) *K(CE)*γ_4 + *K-Auger* + X(K)
7	14	400	50	75	*Incl. ROI 2* *K(CE)*γ_4 + $X(K)_{x2}$

Conclusions

Noble Gas stations would benefit from further calibration work if ^{127}Xe samples could be measured at stations and quantified at IMS NG laboratories, in addition to the ^{133}Xe+^{131m}Xe spikes already performed. This would provide more information than the standard calibration spikes, covering more of the beta-gamma coincidence energy matrix and providing the PTS and laboratories with more resilience to deal with shipping delays between stations and laboratories.

The volume-dependence of ROI 3+4 may provide more useful information for efficiency calibrations and ROI 1 used here is very close to the ^{131m}Xe coincidence signature (129 keV internal conversion electron + 30 keV X-ray). ROI 5 may provide useful pseudo-calibration for ^{135}Xe (~250 keV) which is not possible to calibrate in the fielded IMS systems due to the short half-life.

References
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