Comparison of Analysis Methods to Identify Radioxenon Isotopes

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Four isotopes are of interest for radioxenon monitoring, Xe-135, Xe-133, Xe-133m, and Xe-131m. Many of the detectors in the International Monitoring System (IMS) use β-γ coincidence detection: where NaI(Tl) is the gamma detector and the plastic cell is the source container and beta detector. To characterize the source of radioxenon, ratios between the isotopes are used, which require accurate quantification of each isotope. However, the use of low resolution plastic scintillators for beta detection causes significant challenges for quantifying the metastable isotopes Xe-131m and Xe-133m, whose emissions overlap with Xe-133 emissions. This overlap makes it difficult to identify metastable isotopes when Xe-133 is present, which happens frequently. An alternative method of quantifying radioxenon is presented. In this method, the Xe-131m and Xe-133m energy spectra are evaluated through β-anti-γ detection, whereby a signal is detected via beta measurement but vetoed if a simultaneous gamma signal is detected. This exploits the nuclear emissions differences between the β- decay of Xe-133, and the internal conversion decay of the metastable isotopes; all three isotopes are still detected; but our method suppresses Xe-133 signal relative to Xe-131m and Xe-133m signals. We show new experimental and simulated data from a NaI-plastic scintillator system. Additionally, the technique was applied to a radioxenon detection system using YAP in place of the plastic scintillator.

Goals and Objectives

- Develop an alternative method to quantify meta-stable isotope activities in the presence of Xe-133.
- Compare the activity and minimum detectable activity of the alternative method to the traditional coincidence method .

Anti-coincidence Methodology

- Radioxenon decays by emitting a photon and electron in coincidence. The meta-stable isotopes emit electrons through internal conversion. Above the K-shell, the accompanying x-ray or Auger electron can not be detected due to threshold limits which results in electron-no photon events which will be referred to as anti-coincidence events.
- However, it is possible that coincidence electrons are detected without the presence of the accompanying x-ray due to escape and this scenario also must be accounted for when measuring anti-coincidence spectra.

Xe-131m electron only emissions

Emission	Branching Ratio
CE K (129 keV) + Auger K (~29 keV)	6.88%
CE L (158 keV)	28.80%
CE M (162 keV)	6.59%
CE 0 (162 keV)	0.15%

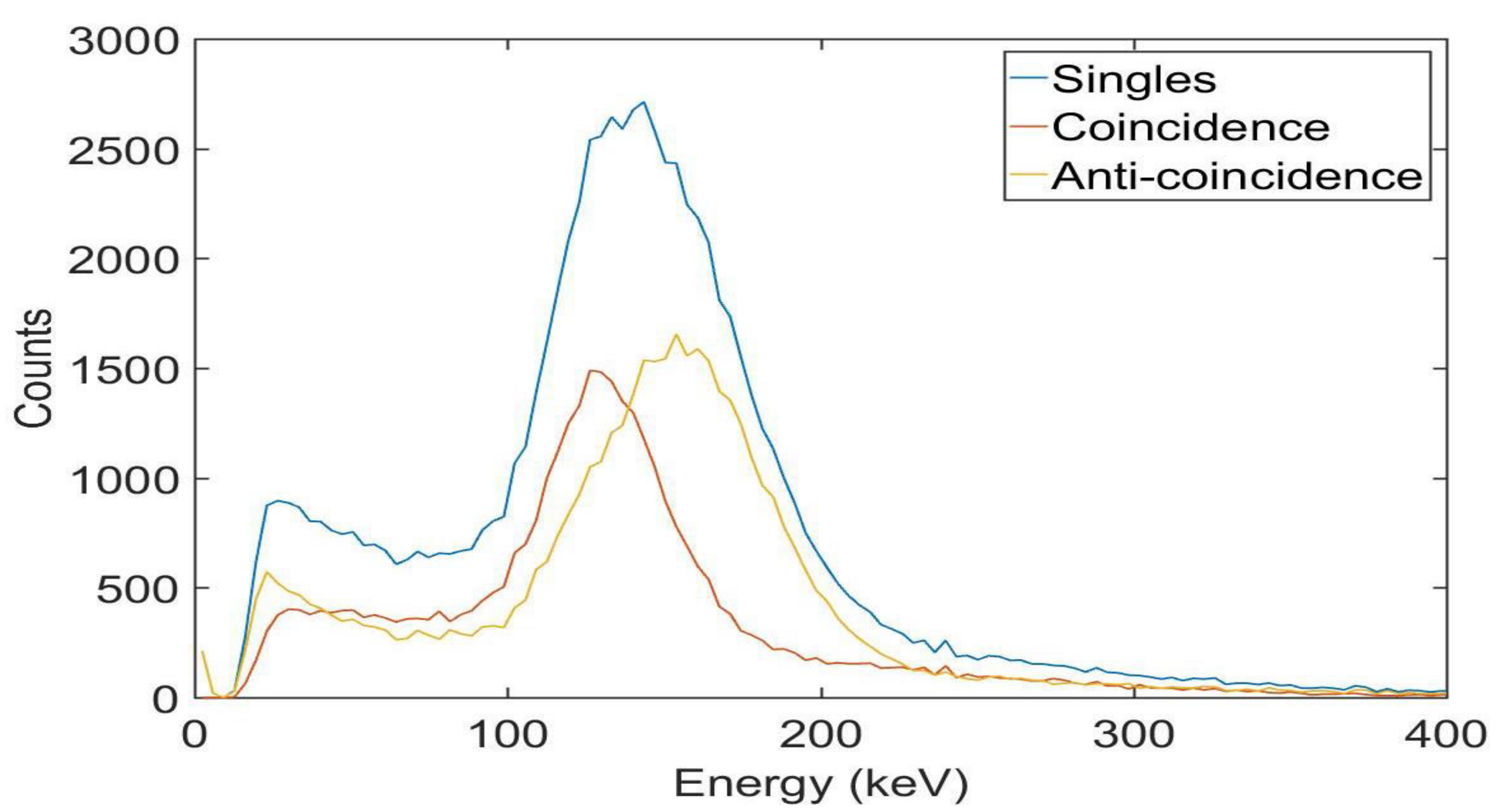

Figure 1. The plot shows the different features of each spectrum where the singles spectrum is a sum of the coincidence and anti-coincidence spectra. The coincidence spectrum emphasizes the 129 keV CE whereas the anti-coincidence spectrum emphasizes the 158 and 162 keV CE, although many 129 keV CE are shown due to detection efficiency of the 30 keV x-ray.

Analysis

- A mixed sample containing ~150 Bq of Xe-133 and ~4.50 Bq of Xe-131m was counted for about 50 days in a beta-gamma coincidence detector using plastic and NaI(Tl).
- The anti-coincidence spectrum is created by subtracting the beta coincidence spectrum from the beta singles spectrum; the three spectra are shown in Figure 1.
- The activity of the sample was calculated using a verified tool for coincidence spectrum analysis and is used to derive the constants for the anti-coincidence method [1-2]. The MDA was also calculated for both methods [3].

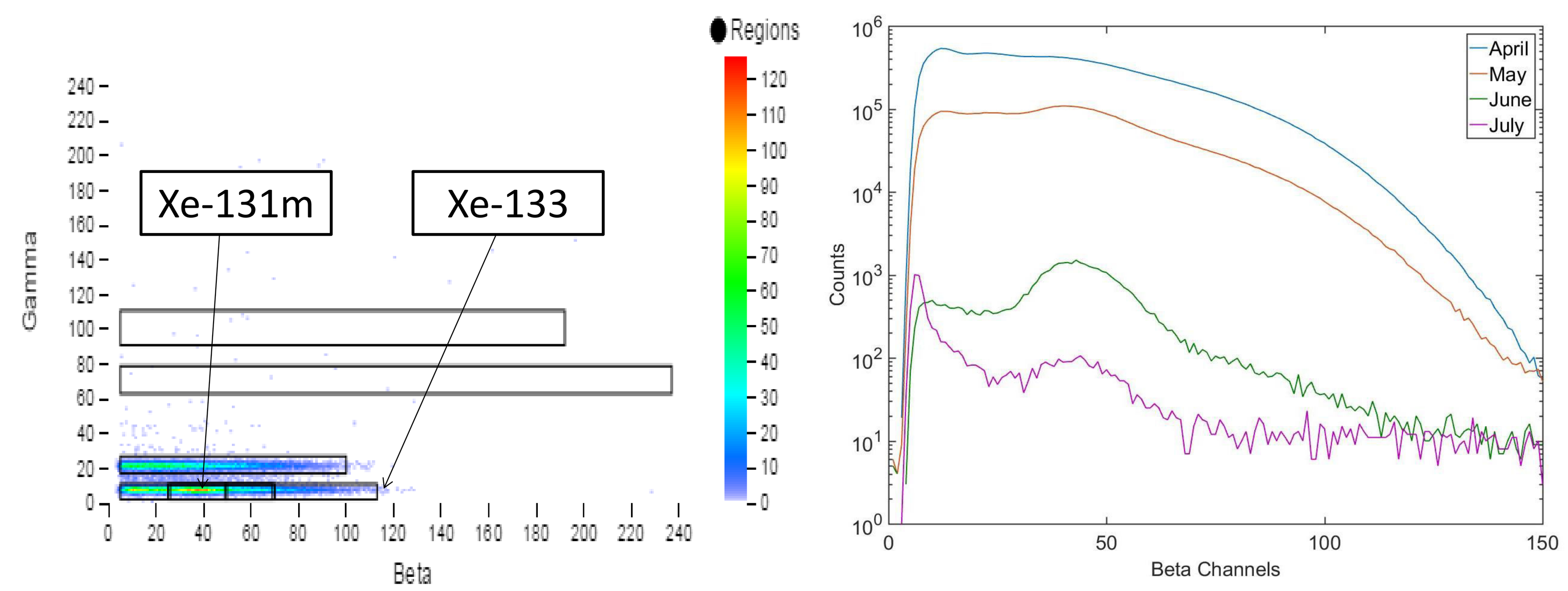

Figure 2. The plot on the left shows the 2-D coincidence spectrum where the Xe-133 region of interest overlaps with the Xe-131m region of interest. The plot on the right shows the change of the singles beta spectrum during measurement of the mixed sample. The conversion electrons from Xe-131m begin to appear as more Xe-133 decays.

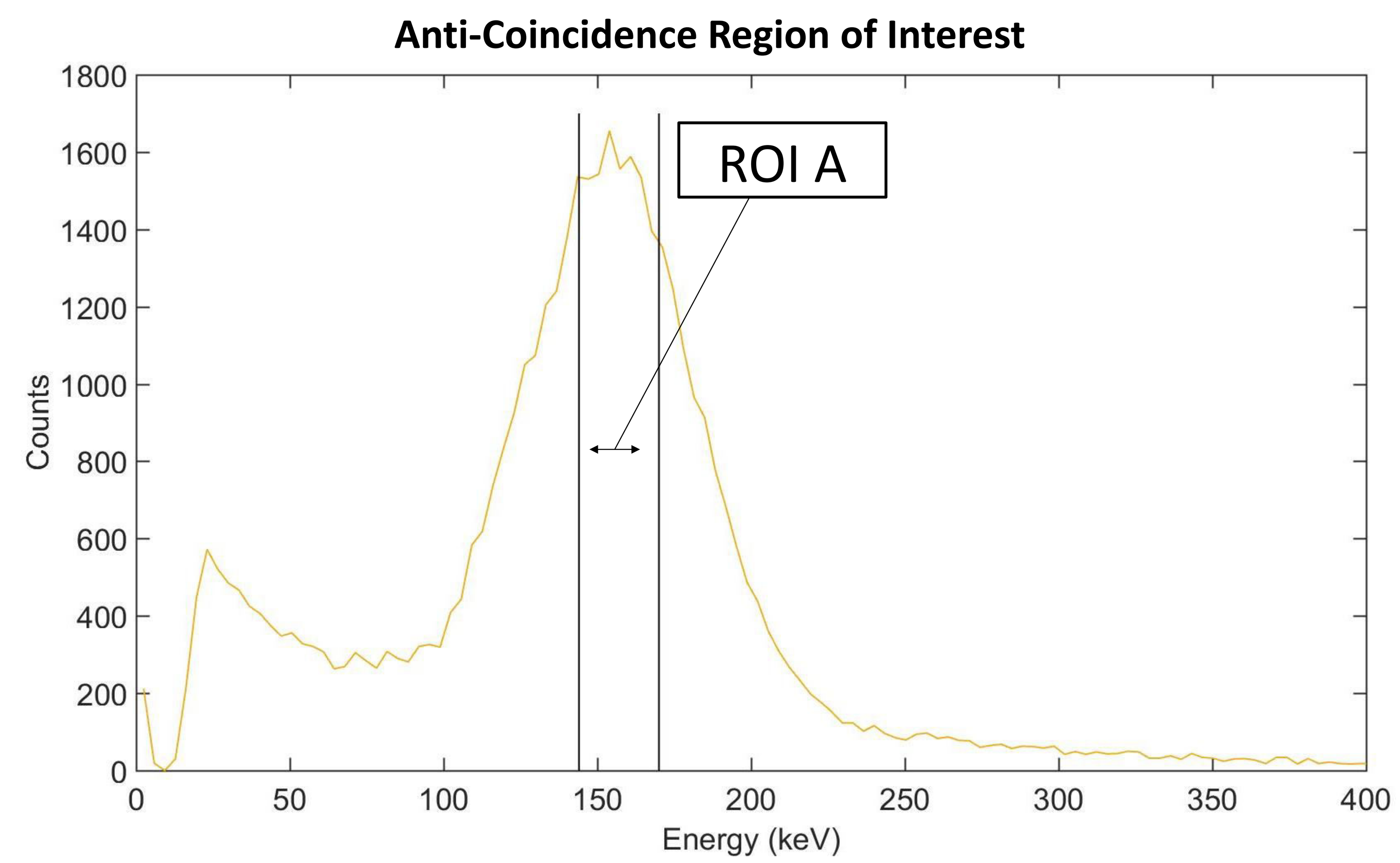

Figure 3. The region in black is used as the region of interest to quantify Xe-131m activity in the sample. This is in comparison to ROI 5 used in traditional coincidence methods. The ROI bounds were optimized for least interference from Xe-133.

Activity Comparison

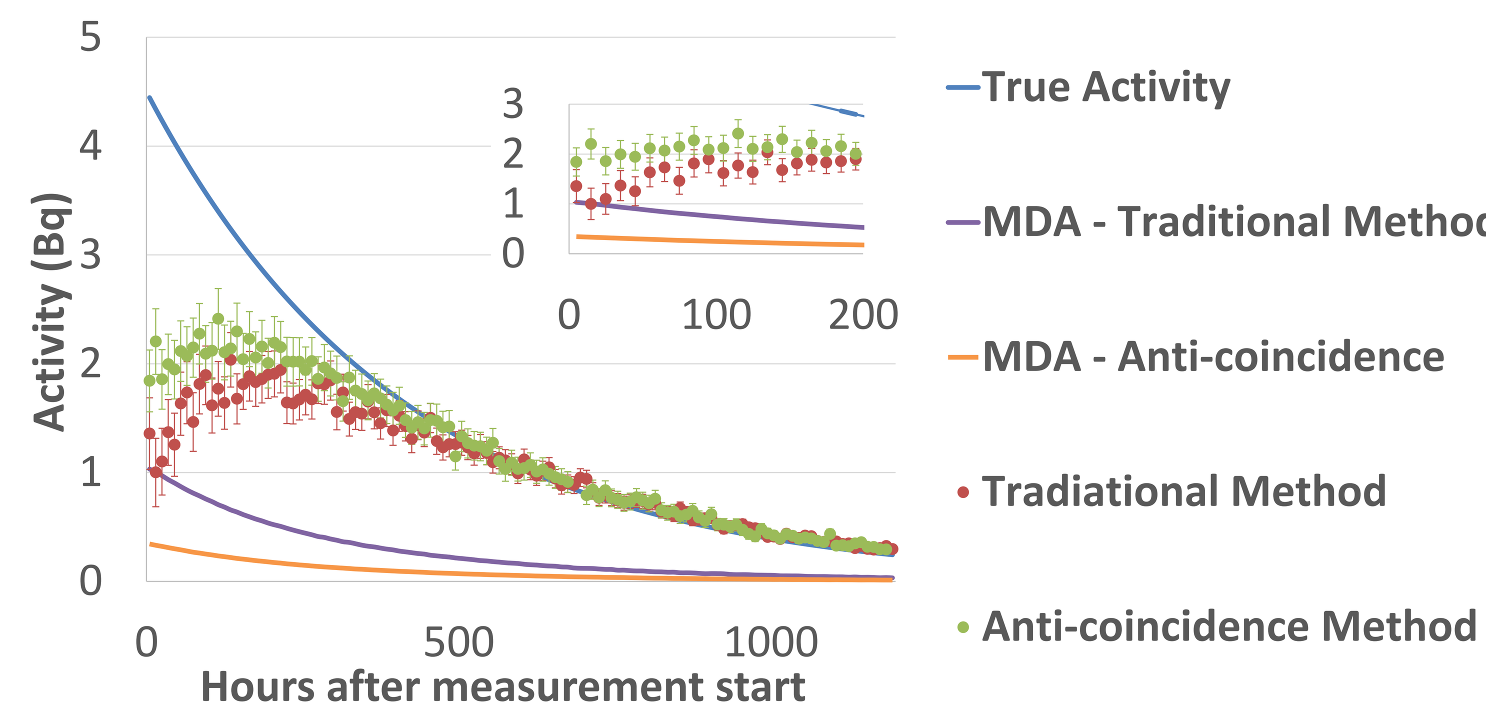

Figure 4. The plot shows the Xe-131m activity calculations for each measurement comparing the traditional and anti-coincidence methods to the true activity of the sample. At the beginning of the measurement, both calculations suffer from Xe-133 interference however, the anti-coincidence method more quickly calculates the accurate Xe-131m activity. Additionally, the MDA curve shows that the anti-coincidence method is more sensitive to identifying the isotope since the curve is lower and never intersects with the activity calculation unlike the traditional method.

Detailed Activity Comparison

Hours after measurement start	Calculated Activity	Anti-coincidence Method	Traditional Method
100	3.55	2.28 ± 0.27	1.77 ± 0.26
200	2.78	1.95 ± 0.22	1.76 ± 0.21
300	2.18	1.85 ± 0.20	1.82 ± 0.18
400	1.71	1.64 ± 0.17	1.50 ± 0.14
500	1.34	1.25 ± 0.13	1.23 ± 0.11

Conclusions and Future Work

The anti-coincidence method has been shown to be more sensitive at identifying Xe-131m. The next step will be to repeat the analysis using a mixed sample containing Xe-133m.

Acknowledgements

This work was funded in-part by the Consortium for Verification Technology under Department of Energy National Nuclear Security Administration award number DE-NA0002534. I would also like to thank my PNNL collaborators Justin McIntyre and Amanda Prinke.

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