SnT 2021
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PREPARATORY COMMISSION

Technique to mitigate effects of detector gain drifts through use of larger regions of interest

Michael F. Mayer, Matthew W. Cooper,
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P3.5-236

POSTER

BATTELLE

Pacific Northwest
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National Nuclear Security Administration

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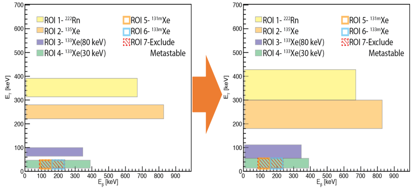
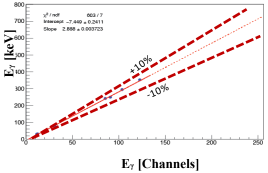
Introduction

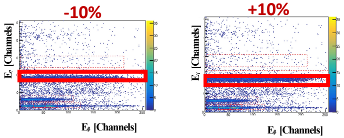
Atmospheric radioxenon measurements are a component of the International Monitoring System of the Comprehensive Nuclear-Test-Ban Treaty which detects four isotopes of xenon (^{135}Xe, ^{133}Xe, ^{133m}Xe, and ^{131m}Xe). These four isotopes are used to assess whether a detect is from a background (i.e., nuclear power plant or medical isotope production facility) or from a nuclear explosion. Measurement of the xenon from the atmosphere is performed using a beta-gamma coincidence detector. The resultant measurement is displayed on a two-dimensional energy histogram. The concentration of each isotope in the measured sample can then be determined by the net count method which uses background subtracted counts from a region-of-interest (ROI) associated with a particular isotope of xenon. The limits of these ROIs are based on the physics of the emanated radiation and the resolution of the detectors. The nuclear detectors' gain can occasionally drift, and the ROIs no longer encompass the radiation signature. One method to mitigate the impact of gain drift would be to increase the ROIs. We increased the ROI limits in the gamma energy to 3σ of the peak observed in each ROI.



Simulating Gain Drift

Since radioxenon isotopes decay relatively quickly with respect to the measurement time, it would be challenging to make multiple measurements of a single sample at different gain levels. Therefore, gain changes were simulated by adjusting the channel to energy calibration of either the gamma or beta detector to simulate gain drift to +/- 10% by increments of 1%. This was performed for both the normal ROI and larger ROI to study the impact on activity calculations and detector sensitives.





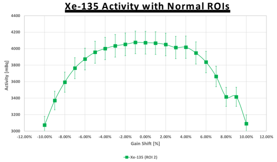
Detector Calibration

The detector needs to be calibrated for each ROI to accurately calculate the activity of a sample. The efficiencies, interference terms, and an energy calibration were determined for the detector using the absolute calibration method. This involved introducing isotopically pure spikes into the detector for each isotope of interest. Only one set of calibration spikes was needed to determine calibration parameters for both ROI limits. Increasing the size of the ROIs results in higher efficiencies and interference terms than normal ROIs due to the increased counts. The energy calibration of each detector remained the same for the calibrations.

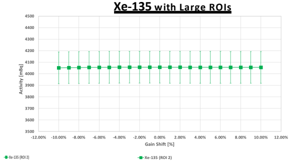
Sample Measurement – Activity with Gamma Detector Drift

A series of sample measurements were performed with multiple isotopes present in each sample. The activity of each sample was measured, and a simulated gain change was performed. The activity of the sample with the gain changes can be seen in the charts below. Detector sensitivity values for the minimum detectable activity (MDA) are also provided in the table.

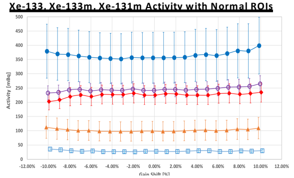
Xe-135 Activity with Normal ROIs



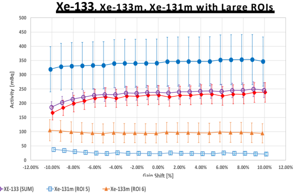
Xe-135 with Large ROIs



Xe-133, Xe-133m, Xe-131m Activity with Normal ROIs



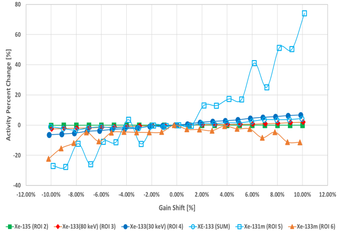
Xe-133, Xe-133m, Xe-131m with Large ROIs



Region	Isotope	MDA (mBq)		
		Normal ROI	Large ROI	Relative Change (%)
2	Xe-135	6.39	9.77	52.90
3	Xe-133(80 keV)	10.13	11.69	15.40
4	Xe-133(30 keV)	12.91	13.70	6.12
3+4-7	Xe-133 (SUM)	9.22	10.46	13.45
5	Xe-131m	10.13	10.61	4.74
6	Xe-133m	11.61	11.94	2.84

Sample Measurement – Activity with Beta Detector Drift

Samples with both Xe-131m and Xe-133m were looked at with just a beta detector drift to observe the impact to the activities. The smallest ROIs which correspond to the metastable conversion electron regions are impacted the most. The relative change from the true activity can be seen in the chart below.



Conclusion

Gain changes on the detector system do affect the measured activities of the samples for normal-sized ROIs. A drastic example of this can be seen on isotopes with higher energy ROIs, Xe-135 and Rn-222, when the gamma detector undergoes a gain change. A gain change on the beta detector only affect the metastables (Xe-131m and Xe-133m). The ROIs with lower energies are less affected as the gain of the gamma detector changes, but there are some minor effects. When a beta detector's gain changes, the ROIs associated with betas only are only impacted slightly since only the upper limit is mostly affected which is in the tail region of the beta spectrum.

The use of larger ROIs does mitigate the impact of any gain changes by allowing a buffer region for gain changes. This increases the MDA of the measurement slightly. Larger ROIs in the beta energy space would be more challenging since the conversion electrons associated with the metastables are close to one another. This should be explored for higher resolutions detectors like silicon. Activity measurements are relatively stable for beta particle measurement should gain be changed.

Technique to mitigate effects of detector gain drifts through use of larger regions of interest

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Abstract

Radioxenon measurements use the net-count method to determine the activity for the radioxenon isotopes of interest. Detected decay events are plotted on a beta-gamma coincidence histogram and events are tallied inside regions-of-interest specific to a given radioxenon isotope. The boundaries of these regions are based on both the resolution of the detector and the physics of the emitted radiation of the radioisotope. Nuclear detector gain drifts can cause the energy calibration of the detector to be incorrect and the decay events to fall outside the region, causing inaccurate activity measurements if the detector gain drifts too much. One possible method to mitigate the effect of gain drifts is to increase the size of the regions-of-interest. This presentation will demonstrate the effect gain shifts have on activity calculations, how larger regions decrease this effect, and the impact larger regions have on the sensitivity of the measurement.

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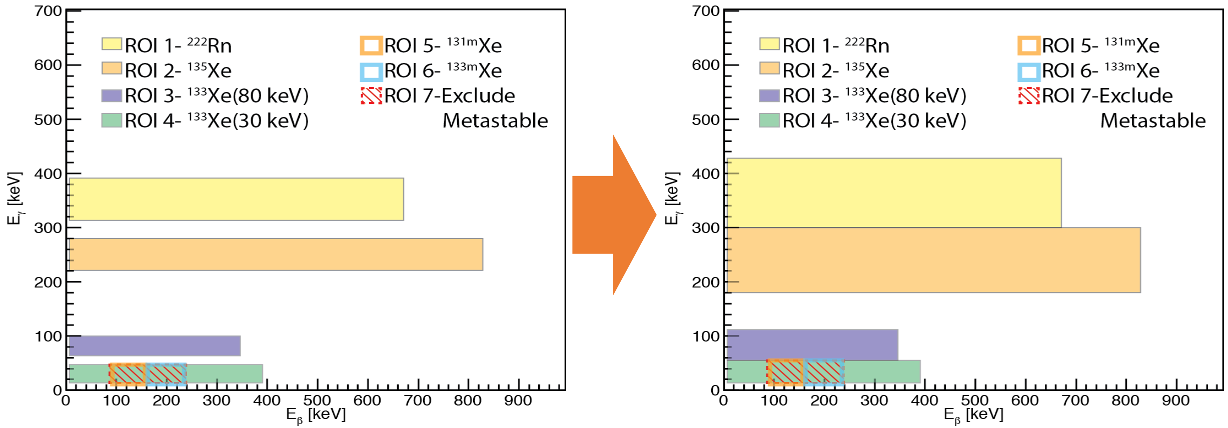

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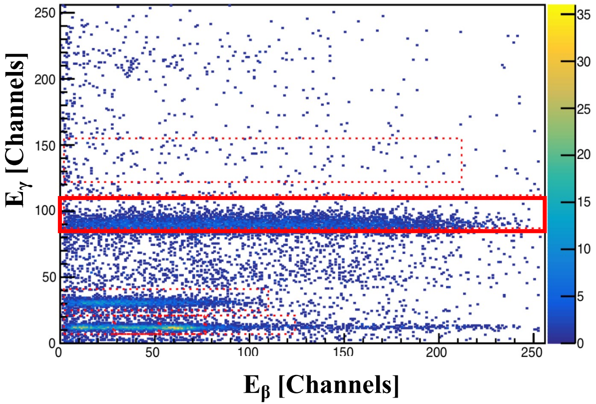
-10%



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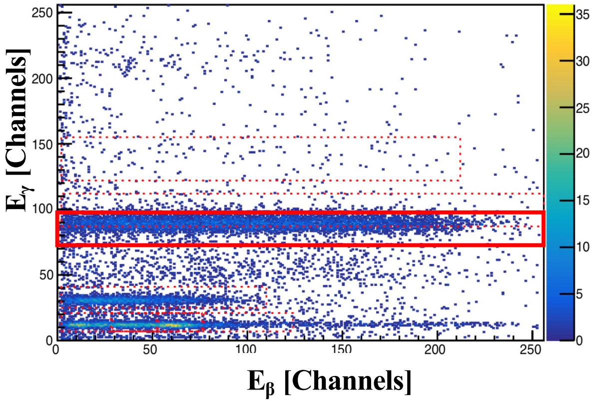

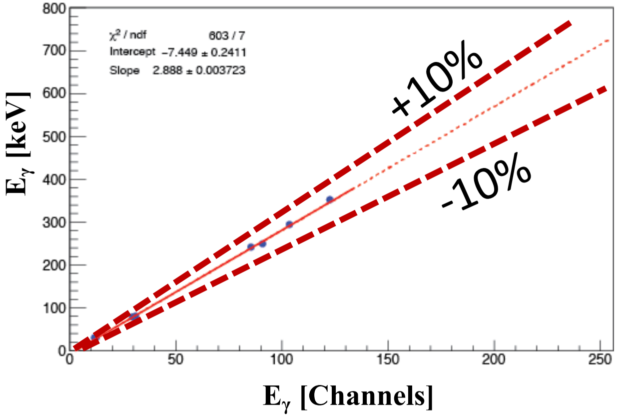

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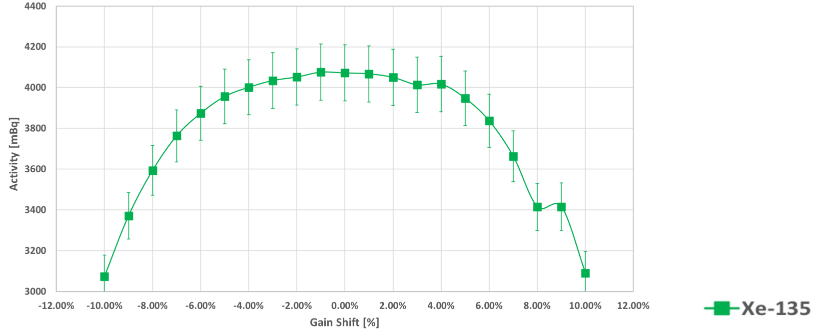

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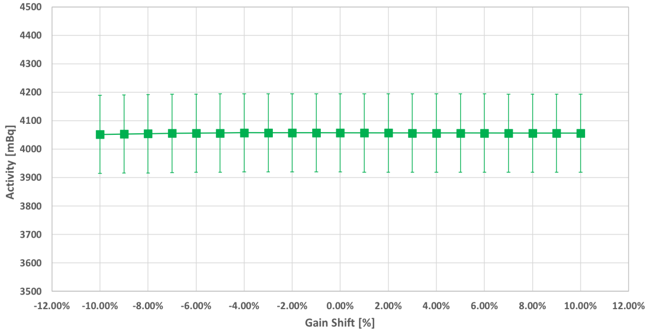

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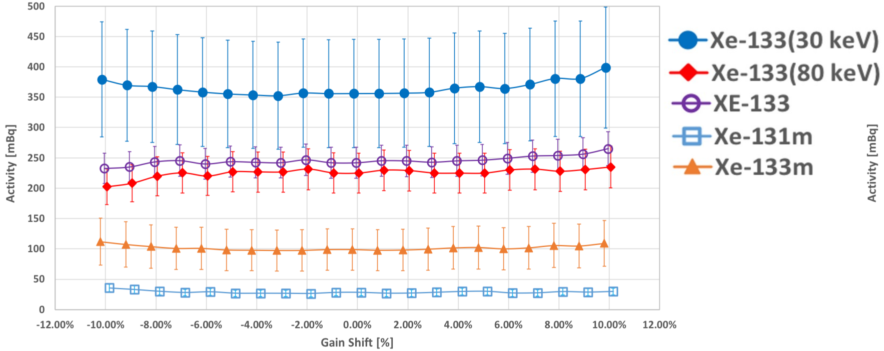

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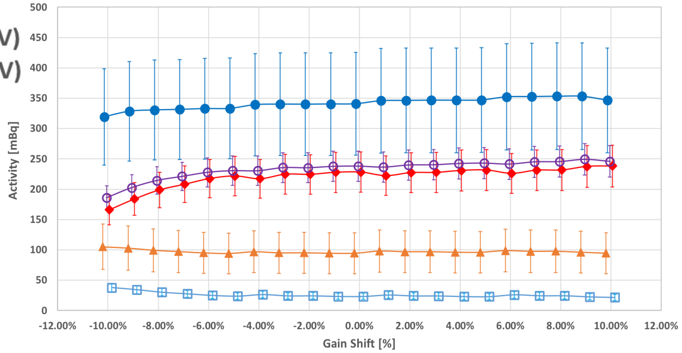

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Change in Sensitivity

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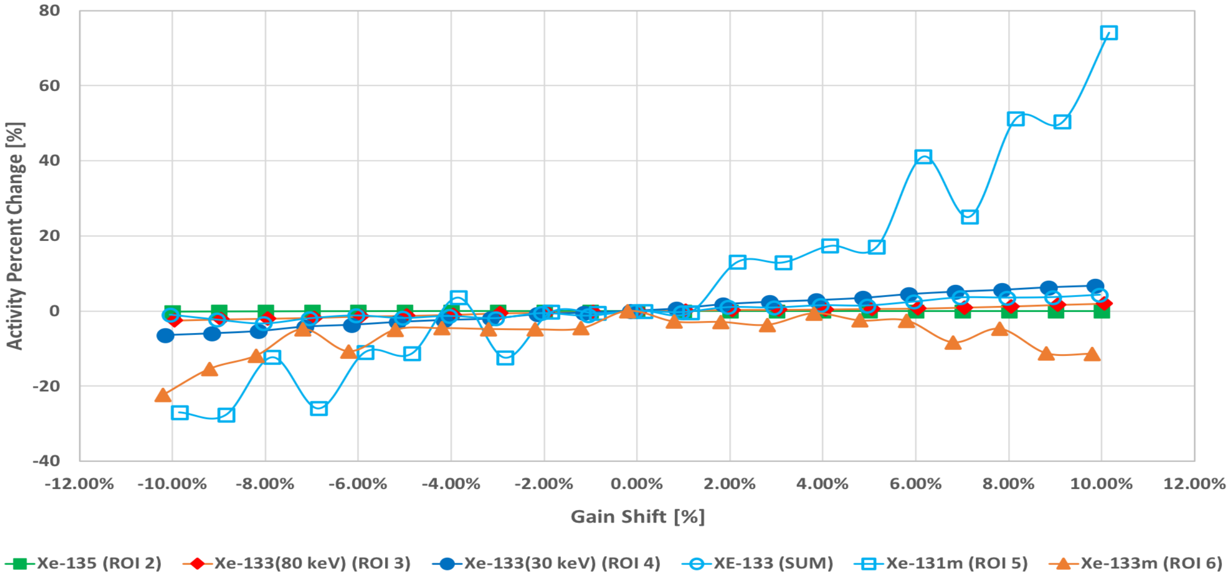

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