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Performance Monitoring of Beta-Gamma Detectors using Quality Control Data

Michael F. Mayer, Matthew W. Cooper,
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POSTER

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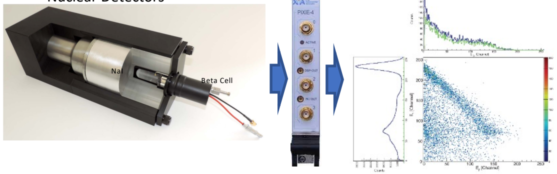
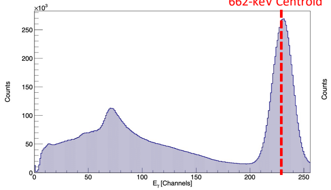
Introduction

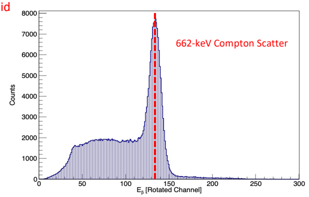
Quality Control (QC) measurements are taken to monitor and correct for gain drifts in radioxenon nuclear detectors. The measurement is performed by placing a 137Cs source near the detector and measuring the position of the 662-keV photoelectric peak in the NaI detector and determining the endpoint for the Compton scatter distribution, but there is much more information that can be gleaned from the collected spectra, which PNNL is now leveraging. This QC data set is being utilized to additionally monitor the health and performance of the nuclear detectors over time by determining the relative efficiency, resolutions, and gains with respect to the check source. Baseline determination of these detector characteristics and placement of quality control limits enables an operator to determine if an issue is happening or has happened with the detectors. This presentation will go over how we determine these QC detector characteristics and how they can be used to infer the health of the detectors.



Gain Stability

The nuclear detectors of radioxenon systems are a critical component to determining the activity concentration of radioxenon in the atmosphere. The modus operandi of monitoring this element of the system is through a quality control (QC) check with a short measurement of a check source which is typically just 137Cs. The QC measurement is used to just look at the channel to energy positioning of peaks found in the spectrum to verify there have been no gain shifts on the detectors. The times of these QC measurements are generally around 15 minutes and are taken in regular intervals; typically, before a sample measurement. The Pacific Northwest National Laboratory has developed algorithms and software in our Beta-Gamma Viewer to leverage the QC measurement to monitor the health of the nuclear detectors and Data Acquisition (DAQ) looking at parameters related to the resolution, efficiency, and gain over time to ensure quality spectral data.

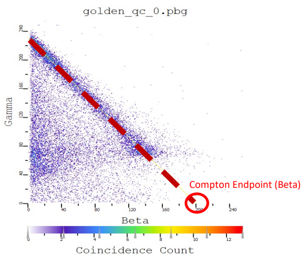




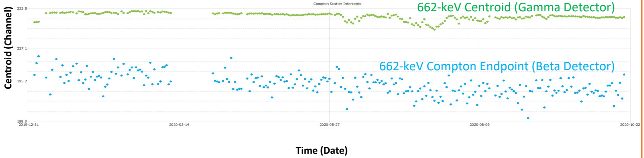
Gain Stability (continued)

The QC measurement's primary function is monitoring the gain of the detectors. This is done by first determining the position of the 662-keV gamma peak observed on the NaI detector using the singles spectrum and comparing it to the position set during the initial calibration. The typical range needed for the net count method has the 662-keV gamma peak set at channel 230. The beta detector uses a plastic scintillator which does not have a visible photopeak. Instead, the Compton scatter is used to infer an endpoint position. Using a frame-rotation method, the centroid of the Compton scatter can be determined which when rotated back will be the beta-endpoint.

Angle	Beta Intercept	Gamma Peak	Gamma Intercept
40.9021	200.412	229.64	231.345

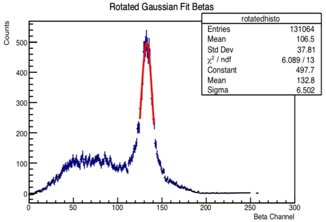


2D Histogram of 137Cs with Compton scatter line and beta endpoint



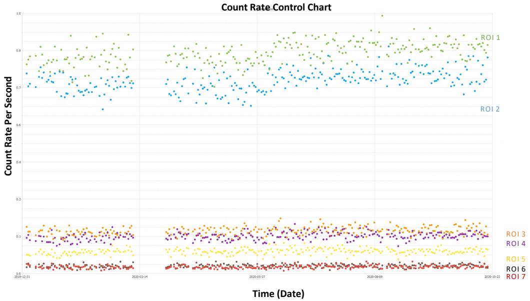
Resolution

To determine the centroid of the peaks, a Gaussian is fit to both the gamma 662-keV photopeak and the rotated Compton scatter peak. The standard deviation is determined during this fit which is used to determine the resolution of the detectors. Control charts are also generated using multiple QC measurements. Changes in the resolution can be a sign of scintillator degradation or loss of scintillation photon capture. For systems with multiple PMTs that are gain matched, degradation in resolution can be a sign of the gain matching deviating.



Efficiency

QC measurements utilize a single 137Cs source placed at the same position for the measurement. Therefore, the total counts and counts per ROI are proportional to the efficiency of the detector. A change in either the detector, source position, or detector electronics (e.g., noise) would cause a change in count rate. The Beta-Gamma Viewer's performance monitoring algorithm provides a control chart of the count rates with control limits placed at 2σ as a caution limit and 3σ as a warning limit.



Conclusion

The performance monitoring tools implemented in the Beta-Gamma software provide a means to enhance the quality control and quality assurance of a QC measurement. This is done by examining multiple facets of the QC data which have yet to be exercised. Placing the resultant data in control charts allows users and analysists to get an overall perspective on the nuclear detectors and their state-of-health. Predictive analysis could provide insight into when a detector needs to be recalibrated or replaced.

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ABSTRACT

Quality Control (QC) measurements are taken to monitor and correct for gain drifts in radioxenon nuclear detectors. The measurement is performed by placing a ^{137}Cs source near the detector and measuring the position of the 662-keV photoelectric peak in the NaI detector and determining the endpoint for the Compton scatter distribution, but there is much more information that can be gleaned from the collected spectra, which PNNL is now leveraging. This QC data set is being utilized to additionally monitor the health and performance of the nuclear detectors over time by determining the relative efficiency, resolutions, and gains with respect to the check source. Baseline determination of these detector characteristics and placement of quality control limits enables an operator to determine if an issue is happening or has happened with the detectors. This presentation will go over how we determine these QC detector characteristics and how they can be used to infer the health of the detectors.

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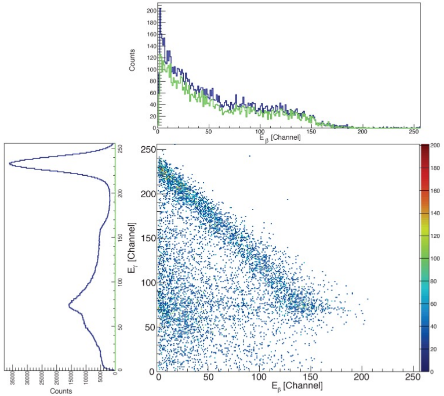
Nuclear Detectors

Data Acquisition



Spectral Data

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GAIN STABILITY

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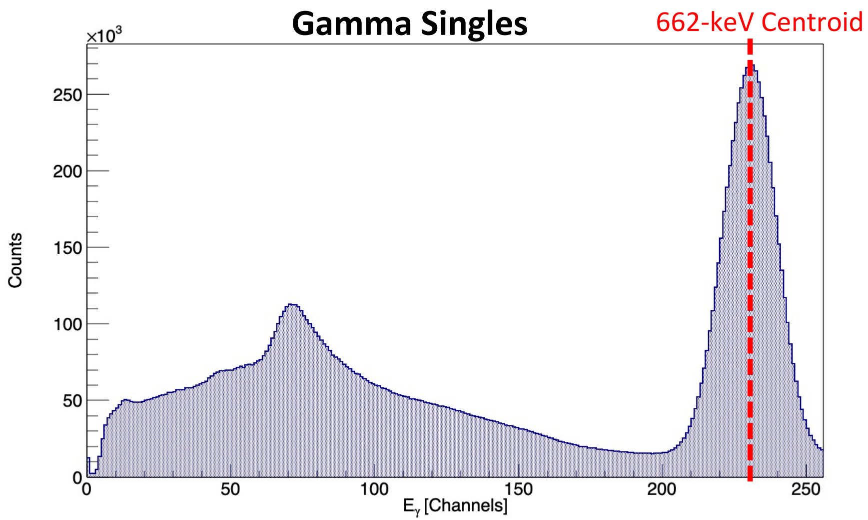

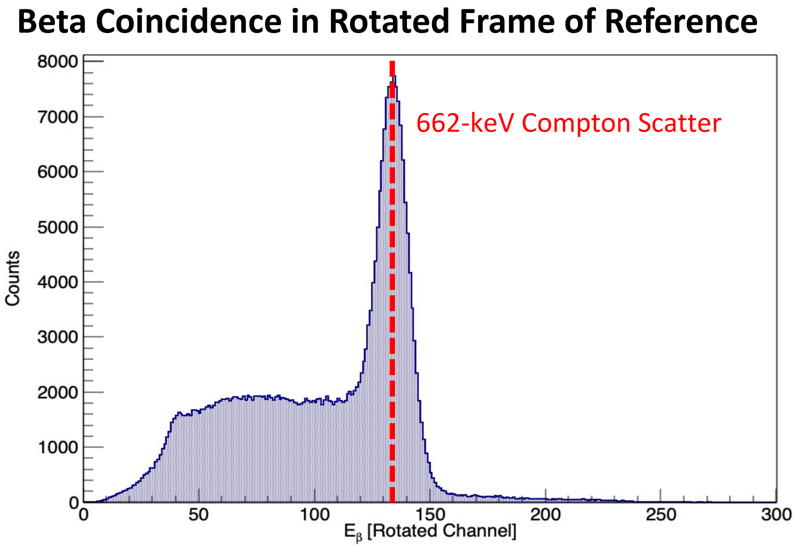

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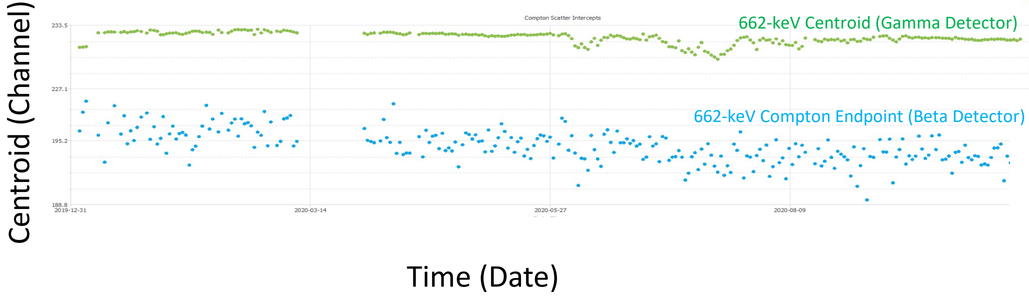
GAIN STABILITY

The position of these peaks and gain parameters can be monitored over time to ensure there is no degradation of the detector. With the use of auto gain adjustment software on systems, the peak positions should be constant. Therefore, looking at the gain parameters used to down bin the channels to the standard 256 channels is a complementary feature. Control limits are placed on the peak position to ensure that auto gain adjustment software is work. Additionally, control limits are placed on the gain parameters to ensure these values do not break into a runaway trend. Such runaway trends can be a sign of failure of the PMT or DAQ hardware.

Control chart of 662-keV peak position and Compton scatter endpoint



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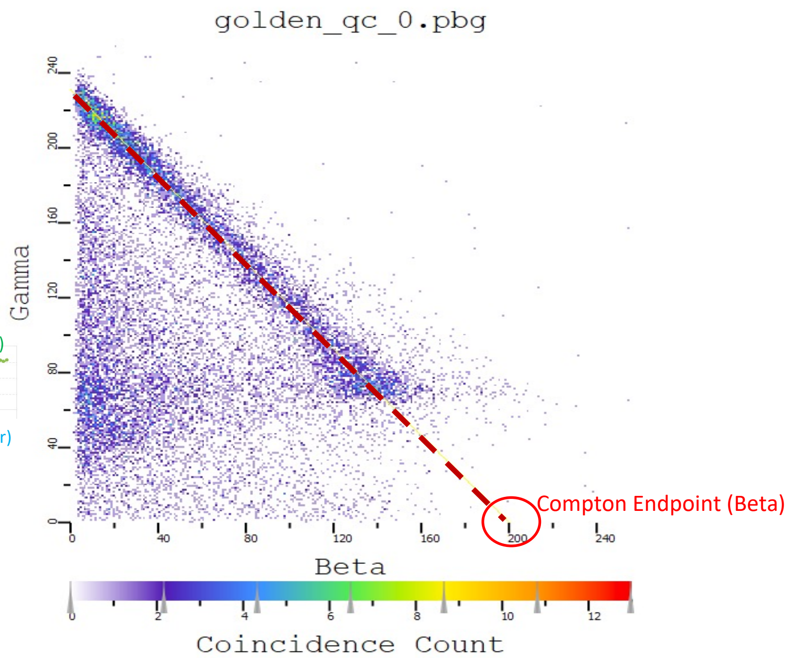

2D Histogram of ^{137}Cs with Compton scatter line and beta endpoint

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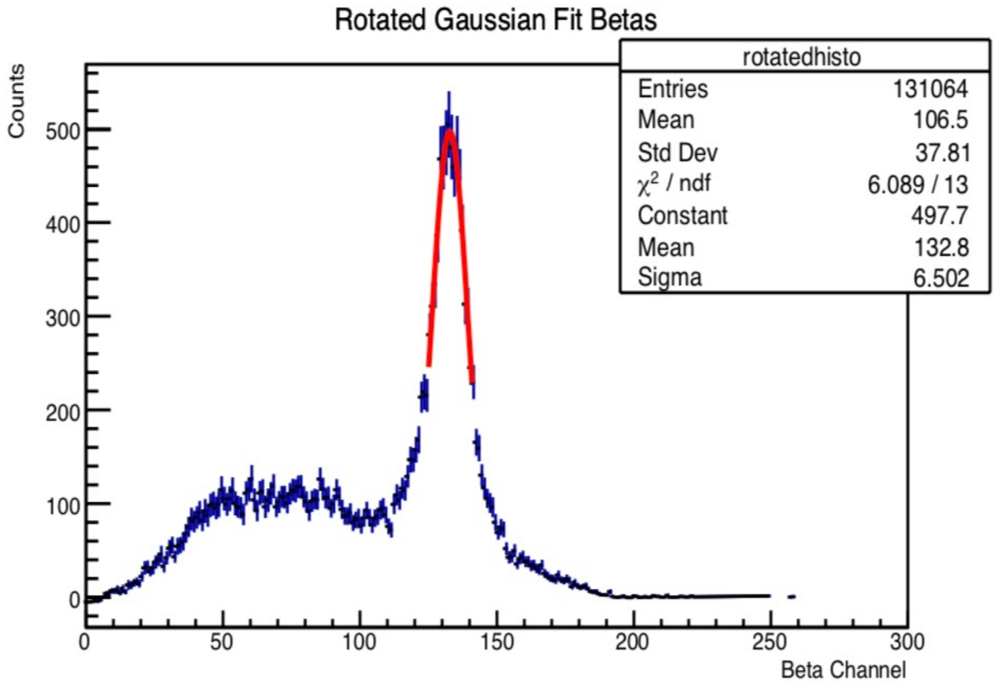
RESOLUTIONS

To determine the centroid of the peaks, a Gaussian is fit to both the gamma 662-keV photopeak and the rotated Compton scatter peak. The standard deviation is determined during this fit which is used to determine the resolution of the detectors. Control charts are also generated using multiple QC measurements. Changes in the resolution can be a sign of scintillator degradation or loss of scintillation photon capture. For systems with multiple PMTs that are gain matched, degradation in resolution can be a sign of the gain matching deviating.



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Count Rate Control Chart

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO PrepCom

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CONCLUSIONS

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