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Radioxenon Uncertainty Model

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INTRODUCTION

The latest round of radioxenon systems are more sensitive than ever before and are likely to frequently detect multiple xenon isotopes. Accurate measurement of multiple xenon needs a complete uncertainty model.

METHODS/DATA

A matrix formulation of radioxenon concentration calculation provides a framework to include all the interference terms and through matrix inversion, an elegant method to solve the systems of equations.

START

RESULTS

Numerical calculation of the uncertainty for each parameter involves varying the parameter to determine the impact to the final result.

This variation provides an uncertainty budget for every variable/parameter used in the concentration calculation.

Excellent agreement between automated matrix analysis and calculations performed through Mathematica.

CONCLUSION

Inclusion of all radioxenon interference terms into a matrix formulation provides accurate ratios.
False positives in the presence of high activity samples is reduced.
The combined uncertainty matches an expected normal distribution.

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Introduction

- New systems with better sensitivity mean radioxenon is detected more frequently
- Accurate measurements are becoming even more important
- Requires excellent uncertainty models
- Several methods to determine uncertainty, but it is important to account for sources of uncertainty
  - Empirically
  - Theoretically
  - Hybrid
- Traditionally statistical uncertainty is determined empirically; however, there are some components that cannot not readily be measured, such as some sources of systematic uncertainty.

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Objectives

- Development of concentration calculations that accurately estimates the four radioxenon isotopes.
- Reduce false positive results when high activity radioxenon are observed
- Develop a complete uncertainty model that more accurately represents the physics and includes all interference terms between the radioxenon nuclides of interest.
- Validation of matrix analysis against known results and maintain a consistent uncertainty estimate conforming to expected false positive/negative.

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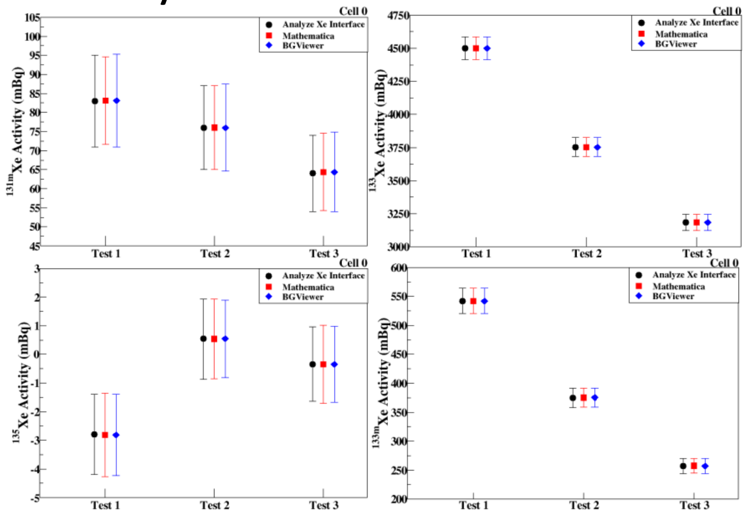
Matrix Analysis (MITER)

- In matrix analysis of 4 radioxenon, Pb-214, backgrounds, and interferences, the uncertainty is numerically calculated.

$$\text{Matrix} = \begin{bmatrix} 1 & r2142 & r2143 & r2144 & r2145 & r2146 & r2147 \\ r1351 & 1 & r1353 & r1354 & r1355 & r1356 & r1357 \\ r1331 & r1332 & 1 & r1334 & r1335 & r1336 & r1337 \\ r131m1 & r131m2 & r131m3 & r131m4 & 1 & r131m6 & r131m7 \\ r133m1 & r133m2 & r133m3 & r133m4 & r133m5 & 1 & r133m7 \end{bmatrix}$$

- Numerical calculation of the uncertainty for each parameter involves varying the parameter to determine the impact to the final result. This variation provides an uncertainty budget for every variable/parameter used in the concentration calculation.
- Excellent agreement between automated matrix analysis and calculations performed through Mathematica.

	Mathematica		BGViewer	
Xenon Isotope	Activity (mBq)	Uncertainty (2σ)	Activity (mBq)	Uncertainty (2σ)
131m	96.9	13.6	96.9	14.4
133	4929.5	93.3	4929.5	93.5
133m	643.2	25.2	643.2	25.4
135	-1.5	1.6	-1.5	1.5



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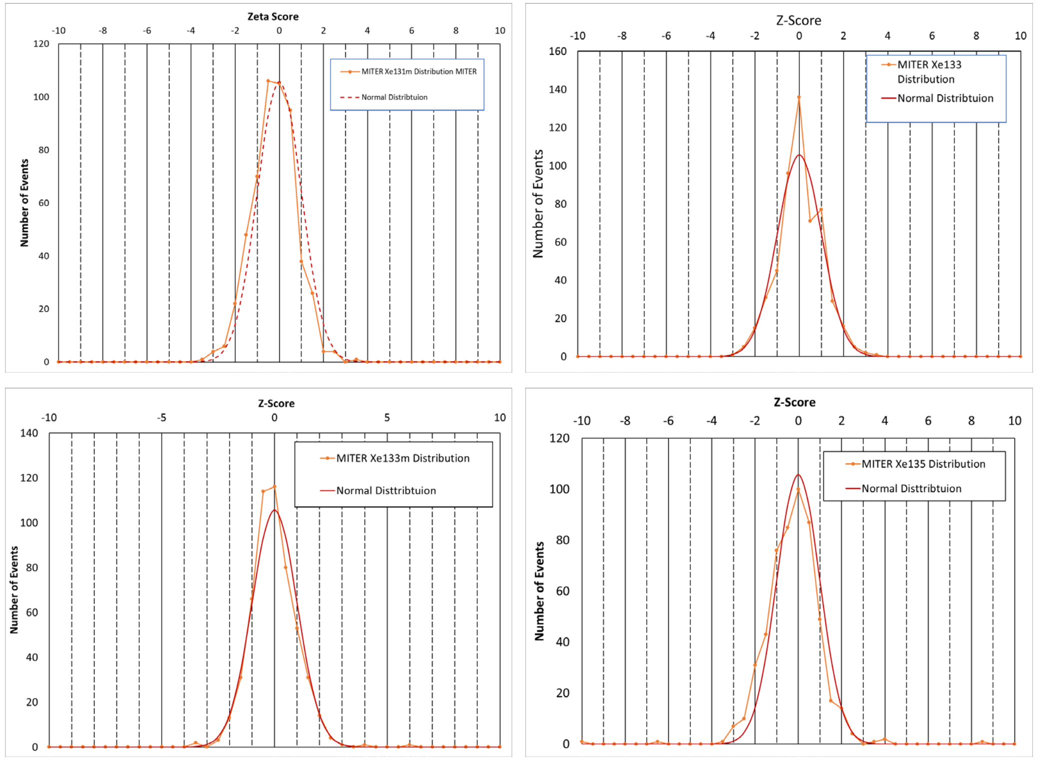
Uncertainty Model Validation

- There are 530 datasets in which either the sample isotopes were known (i.e., test spikes) or there were no expected isotopes present

$$Zeta_i = \frac{X_i - Xref_i}{\sqrt{uX_i^2 - uXref_i^2}}$$

- The expected mean for the z-score distributions is 0, with a standard deviation of 1.
- Results match well with a normal distribution,
- A few variations that are likely related one of two issues
  - Calibration inaccuracy
  - Inaccurate expected value



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Conclusion

- Matrix analysis includes all interference terms
- Uses a numerical calculation to determine uncertainty of parameters and overall combined uncertainty
- The combined uncertainty matches well with an expected normal distribution
- Software (Beta-Gamma Viewer) now has a complete combined uncertainty model using the matrix formulation