SnT 2021

CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

CTBTO

PREPARATORY COMMISSION

Accounting for radioxenon interferences

Matthew Cooper[1], Brittany Abromeit[1], James Ely[1], Daniel Keller[1], Michael Mayer[1], Justin McIntyre[1], Johnathon Slack[1], Thomas Suckow[1], Ryan Wilson[1]

[1] Pacific Northwest National Laboratory

P3.5-280

POSTER

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ABSTRACT: Radioxenon analysis is a critical part of monitoring for underground nuclear explosions. Algorithms that determine the activity concentration of a sample were developed over many years and continue to be updated as lessons are learned from automated radioxenon analysis systems. During Xenon International testing in the U.S., a large activity ^{133}Xe spike caused false positive hits for ^{133m}Xe and ^{131m}Xe, with similar false positive hits are expected when the metastable isotopes are present. The U.S. is developing algorithms that include interference terms for the four radioxenon isotopes and the radon daughters to reduce the biasing and false positives that are caused by large interference radioxenon spikes. The algorithms will use matrix inversion to solve the correlated interference terms simultaneously. The additional interference terms will provide radioxenon analysis that is more accurate under broader conditions and will reduce the number of false positive results.

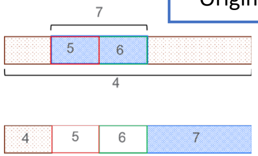
Introduction

- Algorithm for metastable interference in other ROIs
  - Specifically to account for false positives of ^{131m}Xe and ^{133m}Xe respectively
  - But, also accounts for other interferences
- Method uses interference ratios
- For all isotopes in all ROIs
- Set of linear equations; matrix is best method mathematically

Standardizing and Redefining

- ROI changes (beta spectrum in 30 keV)
  - Remove overlapping ROIs
  - Changed ROI4; now below ROI5
  - Changed ROI7; now above ROI6
- Standardizing naming convention for calibration files
- Load up files from directory with single path selection (easier loading)

Original 7-ROI



New 7-ROI

Expanded Interference Terms

- All interference ratios in file header
  - Expand interference ratio section
  - Software description block
    - Identifies which analysis module to run
- Since modifying file anyway….
  - Put b-g efficiencies in b-g_Efficiency block (consistent with IMS)
  - Additional significant figures on the interference ratio uncertainties
  - Plan: add in hardware gain settings

```
#---------------------------------------------------------------------------
# b-g_Efficiency
#---------------------------------------------------------------------------
b-gEfficiency XE-135     2          0.680116   0.002689
b-gEfficiency XE-133     3          0.652805   0.001149
b-gEfficiency XE-133     4          0.595457   0.001448
b-gEfficiency XE-131m    5          0.676982   0.016108
b-gEfficiency XE-133m    6          0.627726   0.016153
b-gEfficiency XE-133     7          0.272581   0.000854

#---------------------------------------------------------------------------
# Ratios
#---------------------------------------------------------------------------
Ratio PB214_352:242    1  2   0.437683 0.001251
Ratio PB214_352:80     1  3   0.350661 0.001086
Ratio PB214-1_352:30   1  4   0.016495 0.000204
Ratio PB214-2_352:30   1  5   0.018474 0.000216
Ratio PB214-3_352:30   1  6   0.017461 0.000210
Ratio PB214-4_352:30   1  7   0.037956 0.000313
Ratio XE135-0_250:80   2  1   0.005677 0.000113
Ratio XE135-1_250:80   2  3   0.010148 0.000149
Ratio XE135-2_250:30   2  4   0.003374 0.000086
Ratio XE135-3_250:30   2  5   0.004351 0.000097
Ratio XE135-4_250:30   2  6   0.011483 0.000157
Ratio XE135-5_250:30   2  7   0.021929 0.000219
Ratio XE133_81:352     3  1   0.000035 0.000018
Ratio XE133_81:242     3  2   0.000000 0.000032
Ratio XE133-1_81:30    3  4   0.429782 0.000966
Ratio XE133-2_81:30    3  5   0.399789 0.000922
Ratio XE133-3_81:30    3  6   0.234857 0.000664
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Ratio XE131m-2_250:80  5  2   0.000000 0.000025
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Ratio XE133m_250:240   6  1   0.000172 0.000104
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Ratio XE133m-1_250:30  6  3   0.000000 0.010372
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```

Matrix Inversion

- Matrix inversion; converts from ROI to isotope
  - 5 x 7 matrix – can't invert directly, but use a pseudo inversion (Moore-Penrose)
  - Using a numerical approach to uncertainty to better account for total uncertainty
    - Spot checked against GUM workbench and Wolfram Mathematica
- Exclusive on upper channel limit (avoids possible double counting)

$$\boldsymbol{IR} = \begin{bmatrix} 1 & R_{135:1} & R_{133:1} & R_{131m:1} & R_{133m:1} \\ R_{214:2} & 1 & R_{133:2} & R_{131m:2} & R_{133m:2} \\ R_{214:3} & R_{135:3} & 1 & R_{131m:3} & R_{133m:3} \\ R_{214:4} & R_{135:4} & R_{133:4} & R_{131m:4} & R_{133m:4} \\ R_{214:5} & R_{135:5} & R_{133:5} & 1 & R_{133m:5} \\ R_{214:6} & R_{135:6} & R_{133:6} & R_{131m:6} & 1 \\ R_{214:7} & R_{135:7} & R_{133:7} & R_{131m:7} & R_{133m:7} \end{bmatrix}$$

Metastable Interference Results

- Software developed and analysis approach implemented
  - Consistent with previous measurements
- ^{131m}Xe interference removed from ^{133m}Xe region (ROI6) – ^{133m}Xe consistent with zero
- ^{133m}Xe interference removed in ^{131m}Xe region (ROI5) – but required a calibration adjustment to reduce the ^{131m}Xe activity concentration to zero
  - Mismatch between data taken and when the detector was originally calibrated
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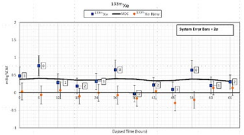

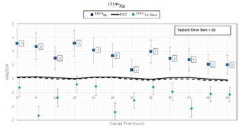

Conclusions

- Matrix inversion method has been demonstrated as capable of accounting for additional interference terms
- ROI limits, all interference ratios have been redefined
- Developed a calibration method to determine the additional interference terms

Future

- Need to recalibrate systems in order to use the new analysis
- Correct header information
- New ROI definitions need to be implemented

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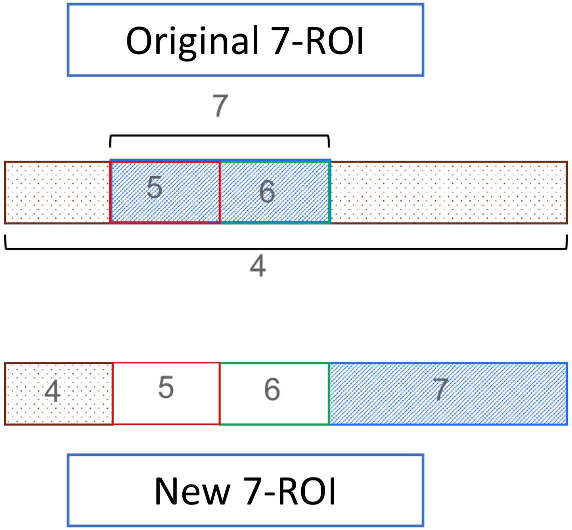

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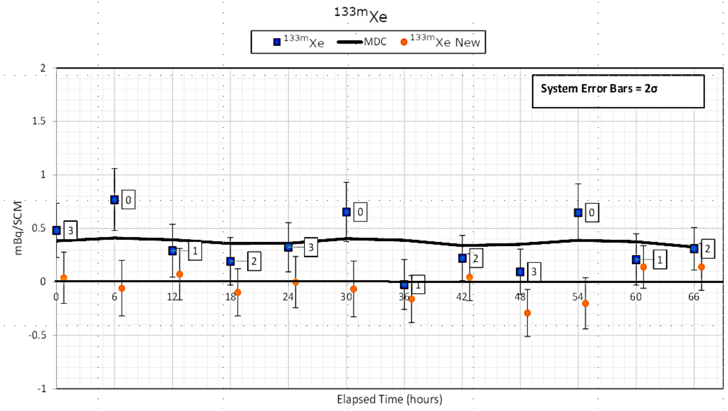

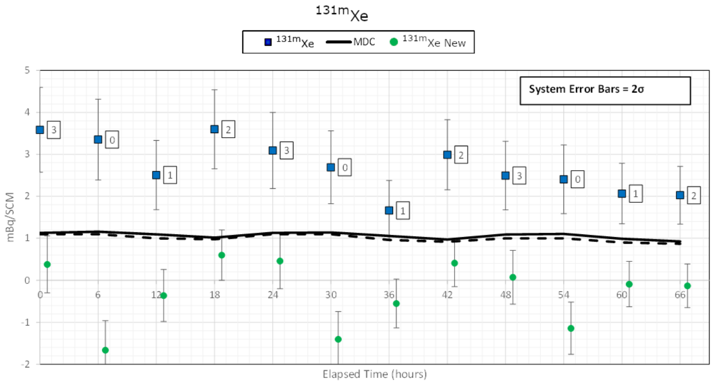

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO

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