SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

P3.2-763

Potential Improvements for a Radioxenon Laboratory Measurement System Operation

Michael Foxe, Brittany Abromeit, Ben Asher, Theodore Bowyer, Ian Cameron, Caden Carter, Matt Cooper, Jason Crosen, Thomas Hallen, James Hayes, Ricky Lavergne, Lance Lidey, Michael Mayer, Jennifer Mendez, Rose Perea, Johnathan Slack

Pacific Northwest National Laboratory

INTRODUCTION AND MAIN RESULTS

We have developed the Post-processed Radioxenon Isotope Measurement and Evaluation (PRIME) system for laboratory measurements of radioxenon.

The system has been optimized for the processing and analysis of archive containers from IMS stations.

We describe the system and validation tests performed to verify the operations.

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Introduction

- Environmental gas samples are collected to monitor for nuclear explosions. During this process, air is collected and purified to extract xenon to measure the amount of radioactive xenon present.
- Following the collection and measurement, the xenon can be stored in an archive container with a carrier gas of either nitrogen or helium. This archive bottle can then be sent to a laboratory for subsequent measurement.

Example Bottles and Collection Tube

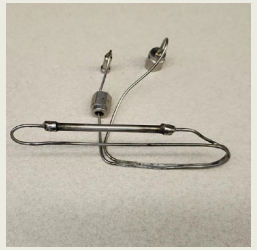
- A current laboratory system has the capability to process one archive container in approximately 2 hours but then takes 24 hours to perform the measurement and 24 hours to perform a gas background after the measurement (~50 hours per sample total).
- We have developed a new improved system for laboratory operations.

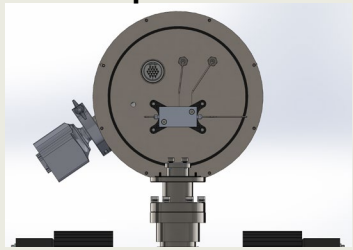
Post-processed Radioxenon Isotope Measurement and Evaluation (PRIME) system

Gas Collection and Processing Optimization

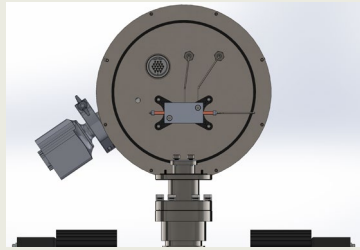
- Xenon collection and purification is performed through cryogenic trapping. Both charcoal and stainless-steel springs have been utilized for collection of the xenon.
- Charcoal offers improved xenon collection, without requiring as low of a collection temperature. However, a higher temperature is needed to elute the xenon from the charcoal.
- Small stainless-steel springs require lower collection temperatures and a larger trap volume but allow for an easier elution of the xenon.
- An additional processing step is the recollection of a sample after the nuclear measurement. For this purpose, it was determined that stainless-steel springs allow for a more effective process in reverse and better quantification of the stable xenon.
- To effectively collect the stable xenon on the stainless-steel springs, a gas flow restriction (to ~20 cc/min) is required. This allows for the residence time to be prolonged for complete collection within the trap.
- System volumes and sample quantification is possible on load with the springs, while charcoal adds uncertainty into the initial measurement.

Charcoal Trap





Stainless-Steel Spring Trap



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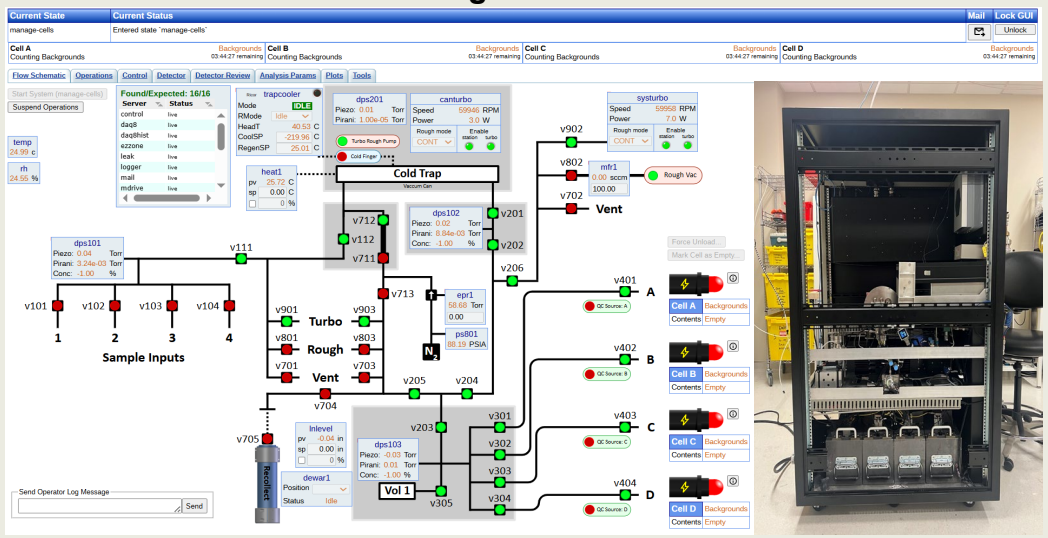
Gas Quantification and Transfer Efficiency

- To compare radioxenon activities, it is important to normalize against the amount of stable xenon collected from the air through the activity concentration.
- After the collection of the stable xenon, it is quantified with a binary gas sensor (dps102) to determine the pressure and fraction of stable xenon. Combined with the previously measured physical volume allows for a calculation of the stable xenon in the archive container.
- The collected xenon is then transferred into the beta cell and pushed with N_2 to allow for near complete transfer efficiency into the detector.

Processing Flow Schematic



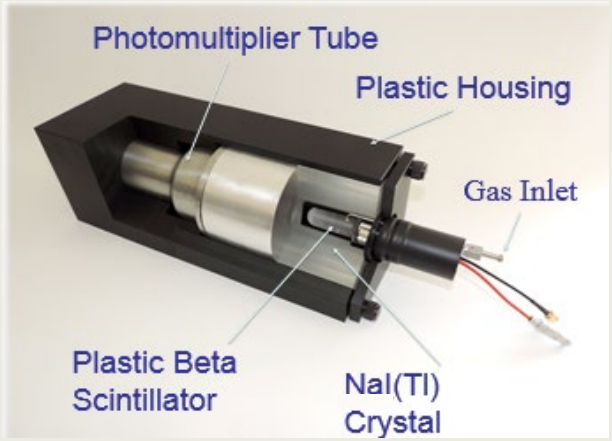
Trap Xe volume: 1.338, Uncertainty: 0.0033
Xe volume after pushes: 1.284, Uncertainty: 0.0108
Unload Xe volume: 1.254, Uncertainty: 0.0238

Radioxenon Detection and Sensitivity

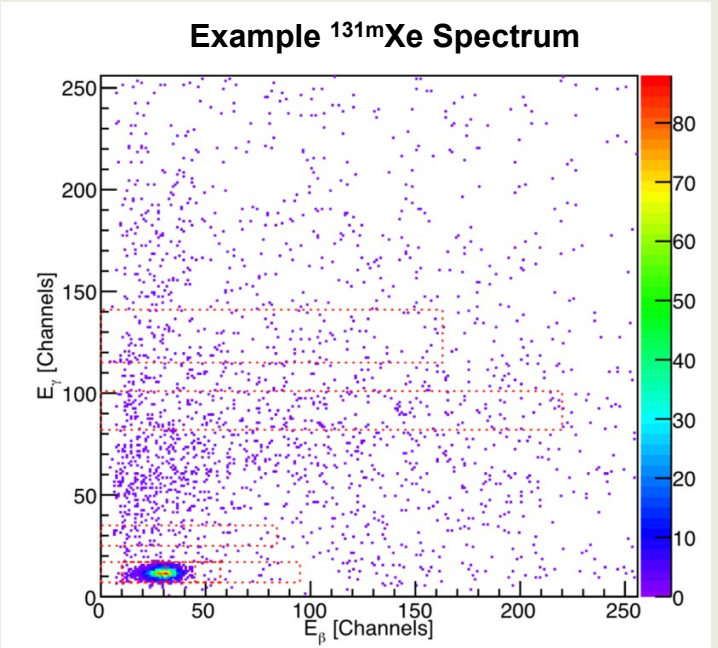
- Beta-gamma detectors are used to measure the radioactive xenon present within the gas sample.
- Al_2O_3 coating is used to prevent the absorption of Xe into the plastic scintillator beta cell.
- Detector calibration is performed with isotopically pure ^{135}Xe, ^{133}Xe, ^{131m}Xe and a $^{133m}Xe/^{133}Xe$ mixture.
- 6-day detector backgrounds and gas backgrounds were taken to calculate the minimum detectable activity (MDA)

$$MDC\left(\frac{mBq}{m^3_{air}}\right) = \frac{2.71 + 4.65\sigma_0}{\varepsilon_\gamma \varepsilon_\beta \gamma_{BR} \beta_{BR}} \frac{\lambda^2}{(1-\exp(-\lambda T_C))\exp(-\lambda T_P)(1-\exp(-\lambda T_A))} \frac{T_C * 1000}{V_{Air}}$$

Beta-Gamma Detector



Example ^{131m}Xe Spectrum



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Sample Throughput

- Four sample ports and electronic valves allows the samples to be processed continuously.
- Following a sample measurement, it can:
  - Transferred to another cell for re-measurement
  - Recollected into a sample tube
  - Recollected back into the archive bottle and backfilled with N_2
- If one sample is counting longer to improve the detection limit for a specific isotope, that cell is removed from the rotation until finished.

Next Steps

- Final validation tests are currently being performed
  - Cross-contamination between sample processing cycles
  - Memory effect across sample measurements in a single cell
  - Stable xenon quantification at high xenon volumes (for future larger xenon archive samples
- System has already been compared against the current laboratory system and performed well

Hours	00:00		04:00		08:00		12:00		16:00	20:00	24:00	28:00	32:00	36:00	40:00
Prime Cell A	QC Count	Process Sample #1	Count Sample #1									Post Sample QC	Gas Background		
Prime Cell B	Gas Background		QC Count	Process Sample #2	Count Sample #2								Post Sample QC	Gas Background	
Prime Cell C	Gas Background				QC Count	Process Sample #3	Count Sample #3							Post Sample QC	Gas Background
Prime Cell D	Gas Background						QC Count	Process Sample #4	Count Sample #4						Post Sample QC

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