



133Xe Noble Gas Mass Spectrometry Measurement for High Purity Germanium Detector Performance Verification

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133Xe Noble Gas Mass Spectrometry Measurement for High Purity Germanium Detector Performance Verification

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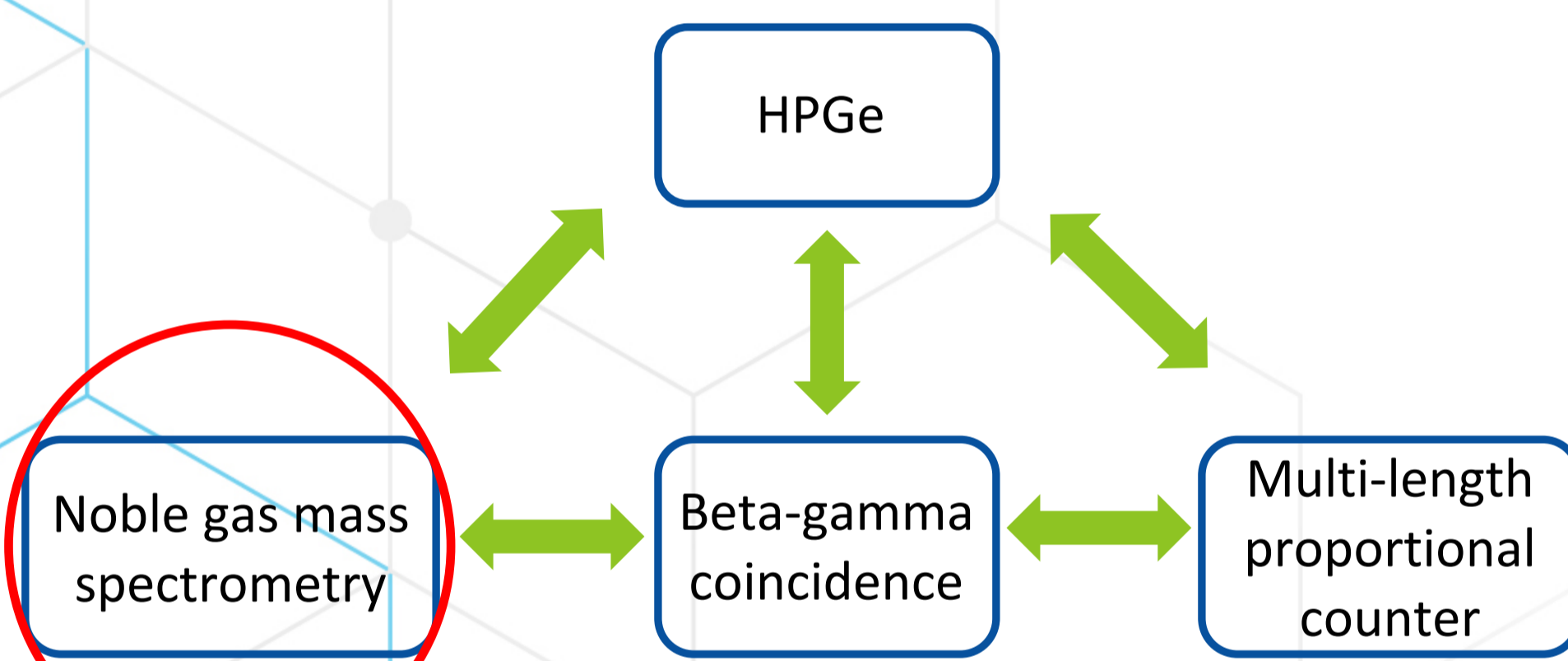
Introduction:

- Idaho National Laboratory (INL) produces quality control (QC) standards for laboratories that operate xenon (Xe) radionuclide monitoring stations
- Standards consist of fission product Xe radionuclides (^{131m}Xe, ¹³³Xe, ^{133m}Xe, and ¹³⁵Xe)
- The activity of each shipped QC standard is quantified with high purity germanium (HPGe) detectors
- PTS provided INL with measurement bias values to INL certified values

Radionuclide	PTS Bias to INL Reported Activity	
^{131m} Xe	-0.86% ± 10.6 %	
¹³³ Xe	-4.97% ± 10.2 %	After ^{133m} Xe recalibration
^{133m} Xe	-7.60% ± 15.2 %	-1.18 ± 11.2%
¹³⁵ Xe	2.40% ± 16.1 %	

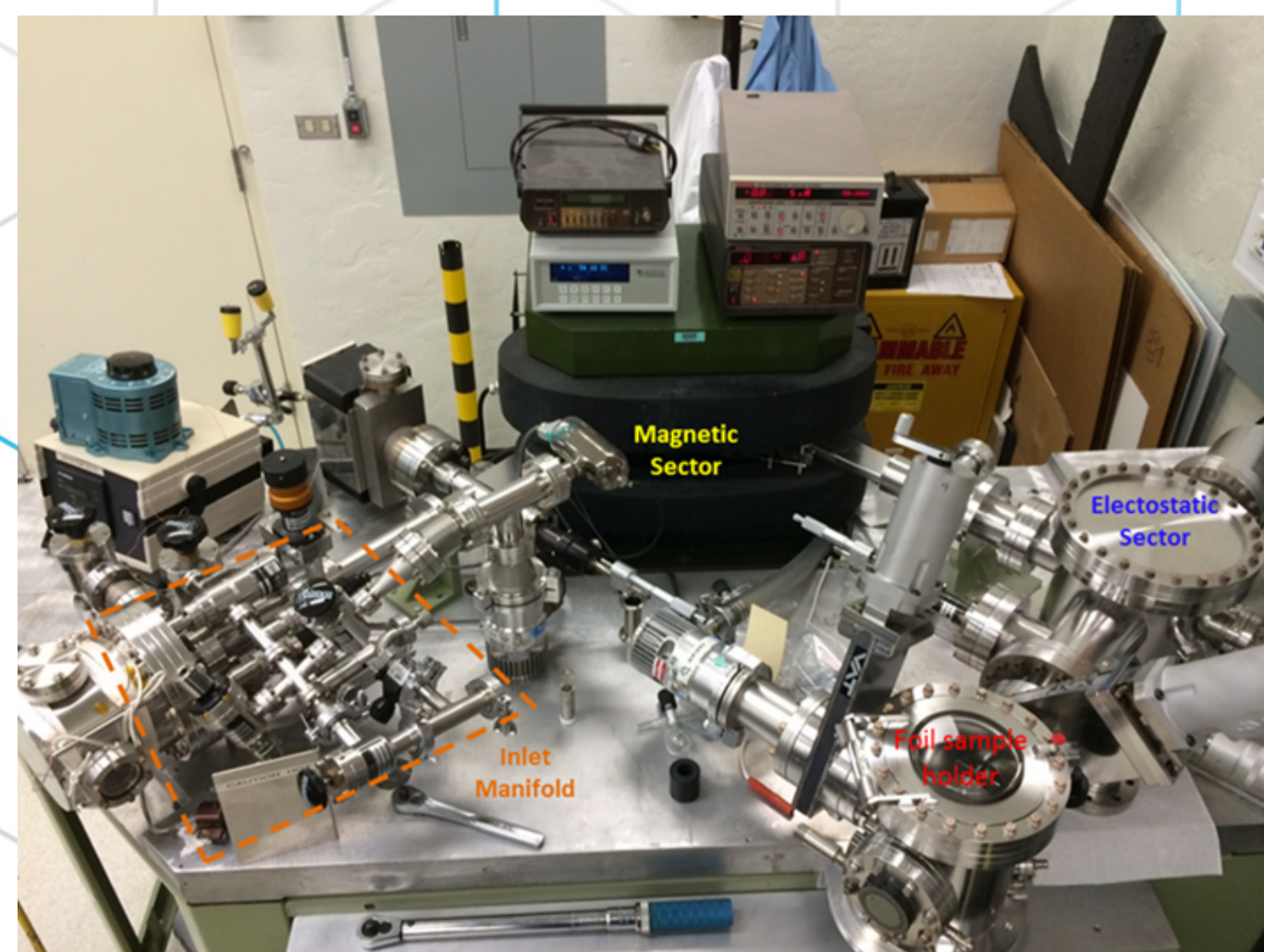
Objective:

- INL's continual mission – provide high quality standards to all customers
- Establish an in-house HPGe performance verification system that uses noble gas mass spectrometry, beta-gamma coincidence counting, and multi-length proportional counters
- This poster presents our first mass spectrometry vs HPGe comparison measurement



Isolating ¹³³Xe for Noble Gas Mass Spectrometry Measurement:

- Medical ¹³³Xe (purchased from Lantheus) was run through a mass separator¹
- ¹³³Xe was separated from all other fission Xe isotopes in the gas sample
- Mass separator implanted ¹³³Xe atoms into aluminum foil (±0.15% efficiency)



Releasing, Collecting, and Quantifying the Implanted ¹³³Xe Activity:



- HPGe measured ¹³³Xe activity = $289 \times 10^3 \pm 2\%$ Bq
- Activity was decay corrected to $t = 0$ of mass spectrometry measurement
- Measured activity was converted to number of atoms using the equation:
- Number of ¹³³Xe atoms = $189 \times 10^9 \pm 2\%$ atoms

Volumetrically Measured ¹²⁶Xe Diluent:

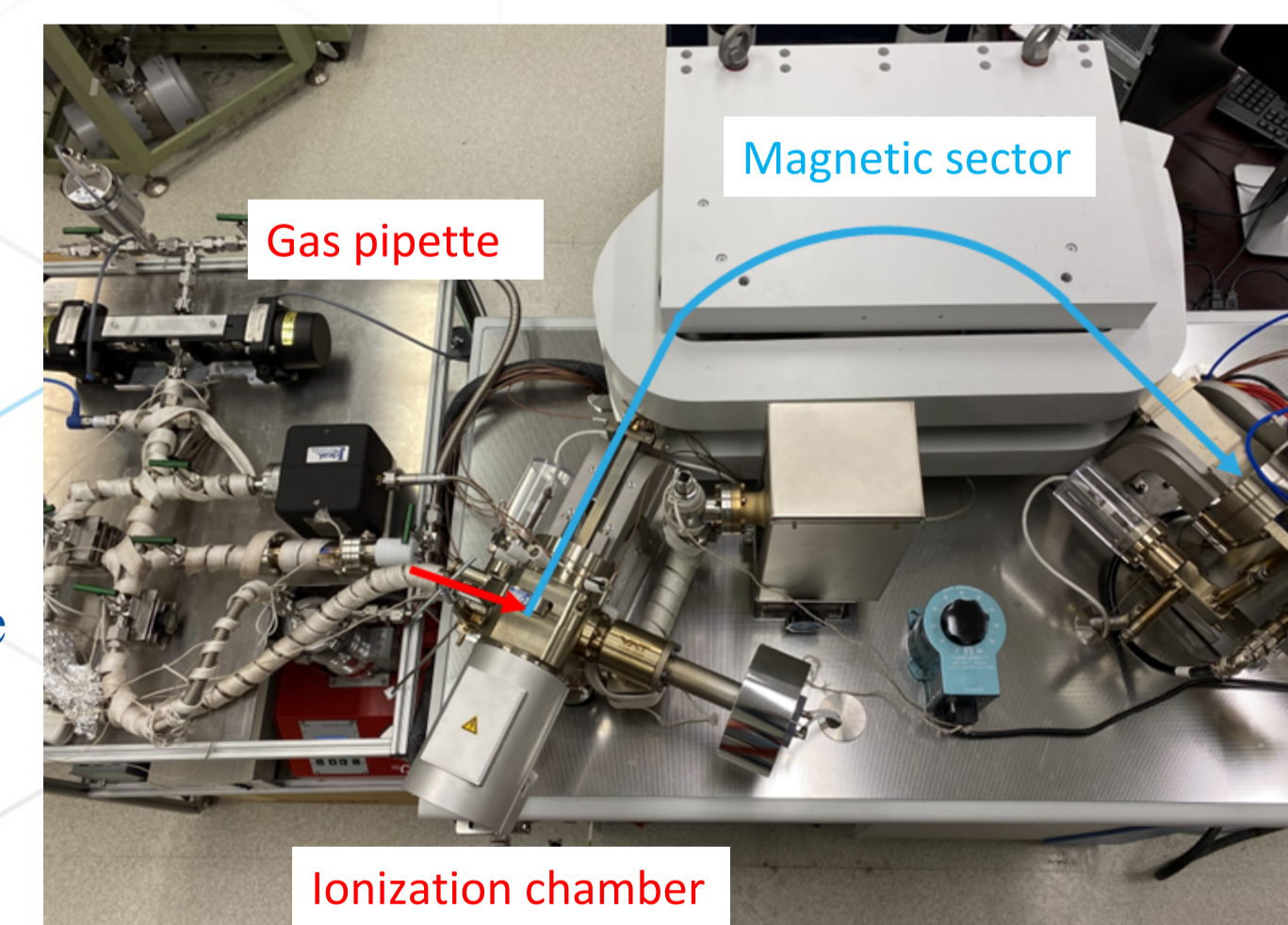
- Enriched ¹²⁶Xe gas (purchased from ISOFLEX USA) was volumetrically measured in a gas manifold with a known volume
 - Enriched ¹²⁶Xe gas composition
- | Isotope | ¹²⁴ Xe | ¹²⁶ Xe | ¹²⁸ Xe | (± ¹²⁹ Xe) |
|-------------|-------------------|-------------------|-------------------|-----------------------|
| Content (%) | 0.024 | 99.94 | 0.014 | 0.003 |
- This gas was chosen to eliminate ¹³²Xe (26.9% natural abundance) in the sample
 - Xe can form hydrides – ¹³²XeH has isobaric interference with ¹³³Xe
 - $1.64 \times 10^{15} \pm 0.6\%$ atoms ¹²⁶Xe were metered into known volume of gas manifold
 - ¹²⁶Xe gas was cryogenically transferred into a 10cc transfer cylinder

Mixing the Gas Sample:

- The glass ampule with ¹³³Xe was broken in an evacuated manifold and the gas was cryogenically transferred into the 10cc transfer cylinder
- ¹³³Xe/¹²⁶Xe atom ratio = $1.15 \times 10^{-4} \pm 2\%$ (1± uncertainty)
 - Based on ¹³³Xe HPGe measured activity and volumetrically measured ¹²⁶Xe

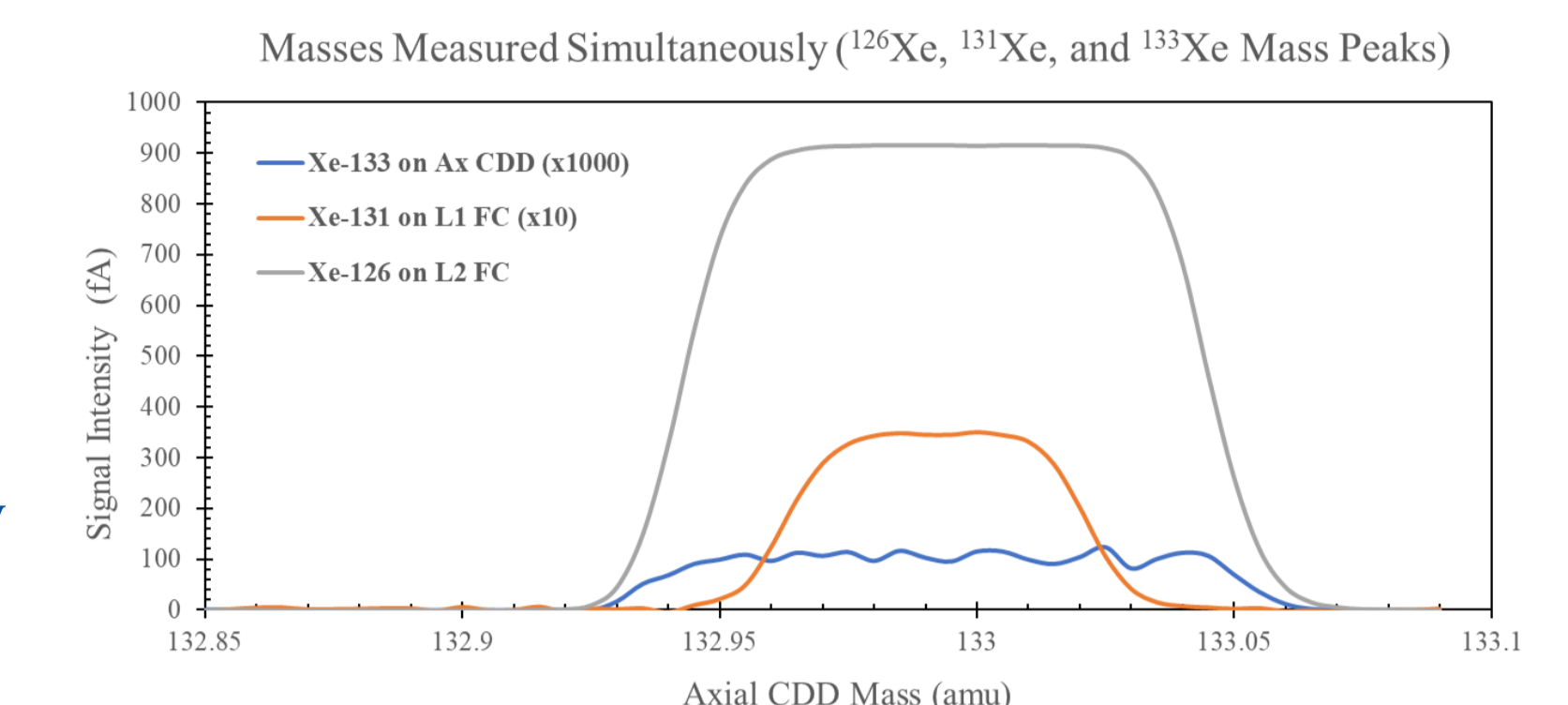
Introducing the Gas Sample Into the Helix MC Plus Noble Gas Mass Spectrometer:

- Aliquot of Xe gas mixture was taken with a 0.1cc gas pipette
- Aliquot was reduced in size through volumetric expansion from gas pipette
- Gas was cleaned with a SAES getter pump
- Gas sample was introduced into static noble gas mass spectrometer for analysis
- ~10 million ¹³³Xe atoms were introduced into mass spectrometer



Xe Mass Spectrometry Measurement:

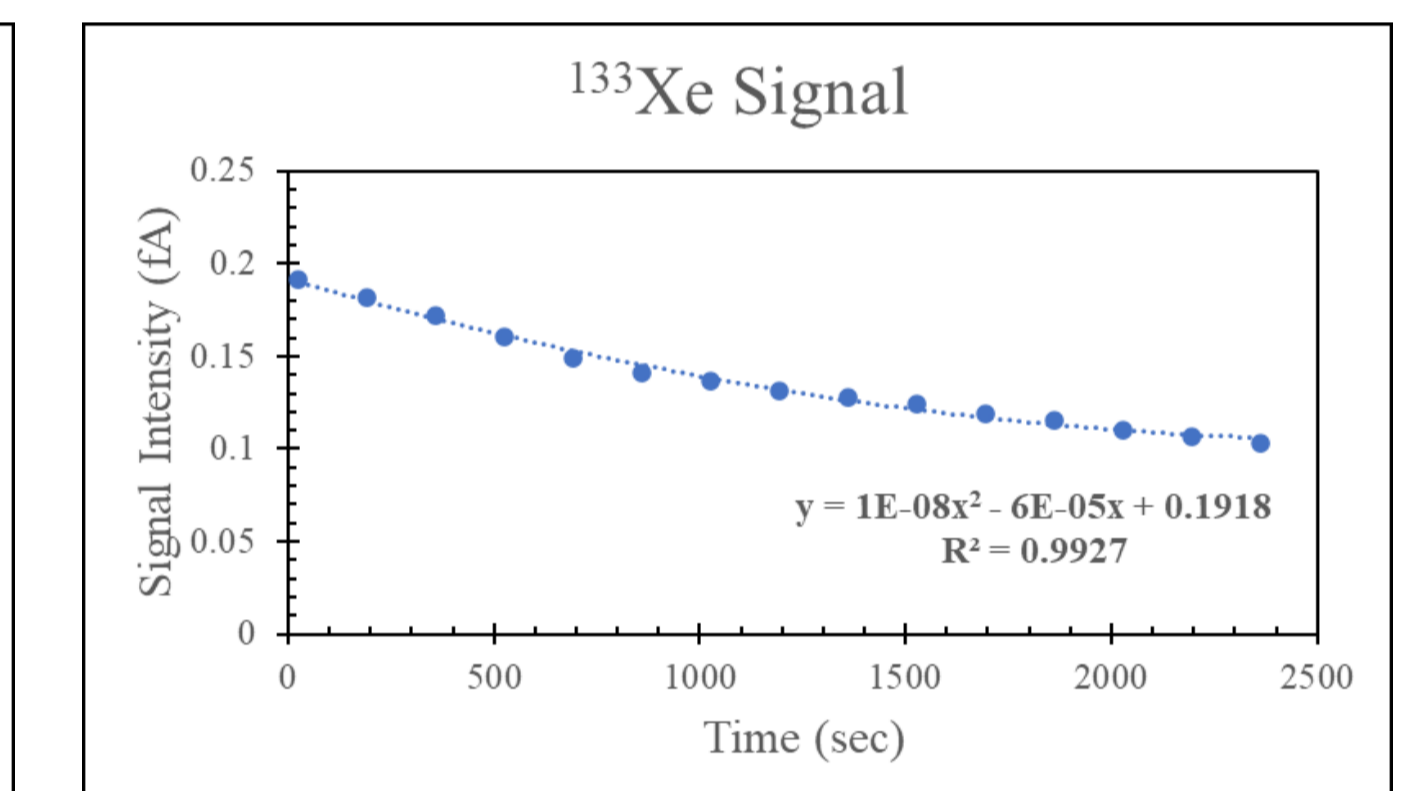
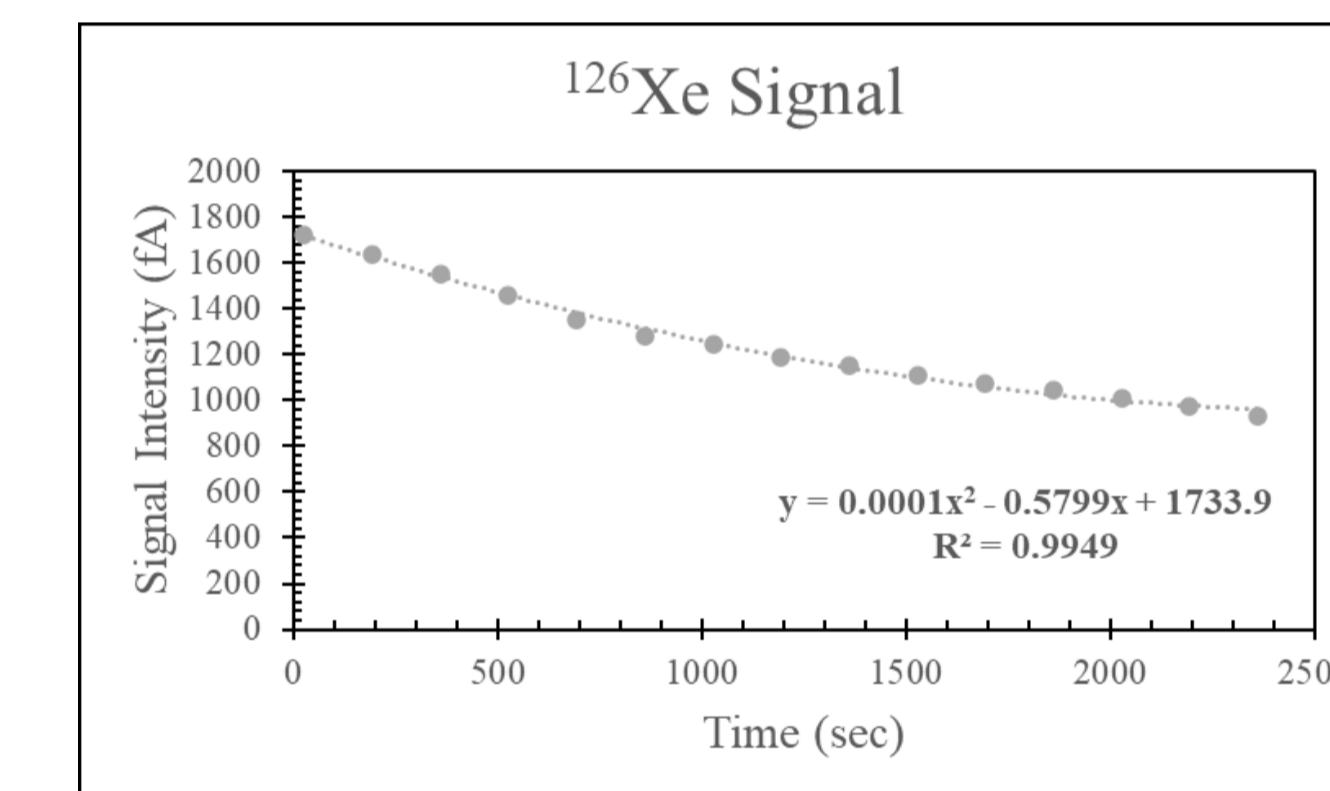
- Simultaneously measured ¹²⁶Xe, ¹³¹Xe, and ¹³³Xe
 - ¹³¹Xe signal arising from natural Xe contamination in the sample
 - Natural ¹²⁶Xe abundance (0.09%) does not significantly affect ¹²⁶Xe diluent gas signal



- Also monitored ¹²⁶XeH (mass 127) and ¹³²Xe on compact discrete dynode (CDD) multipliers
 - Measure of these signals (along with that of ¹²⁶Xe) allowed for ¹³²XeH correction

Corrections Applied to Mass Spectrometry Measurement:

- Detector cross-calibration
- Xe detector background signals
- Detector baselines
- ¹³²XeH
- Natural Xe contamination
 - Addition of ¹²⁶Xe



- ¹³³Xe/¹²⁶Xe atom ratio was determined by extrapolating corrected signals to $t = 0$
- ¹³³Xe/¹²⁶Xe atom ratio from mass spectrometry = $1.10 \times 10^{-4} \pm 2\%$ (1± uncertainty)
 - Mass spectrometry ratio is 4.3% lower than the atom ratio calculated from measured ¹³³Xe HPGe activity and volumetrically measured ¹²⁶Xe

Conclusion:

- This was our first comparison measurements between HPGe and noble gas mass spectrometry towards establishing an in-house HPGe performance verification system
- There was a -4.3% bias between the measured mass spectrometry atom ratio and the atom ratio determined from the HPGe measured ¹³³Xe activity and the volumetrically measured ¹²⁶Xe
 - This first measurement is inline with the observed PTS ¹³³Xe measurement bias

Future Measurements to Include:

- More rigorous determination of ¹²⁶Xe atom quantity
- Include beta-gamma coincidence measurement of ¹³³Xe activity

Reference:

- A. Appelhans, J. Olson, D. Dahl, M. Ward, T. Robinson, J. Delmore. Mass separator for radioactive isotopes. Journal of Radioanalytical and Nuclear Chemistry 315 (2018) 207-209.