Development of a radioxenon detector with a high-resolution beta detector

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ABSTRACT

Beta-gamma detectors are utilized extensively for the detection of radioxenon, but the beta detection is primarily performed with a plastic scintillator cell. Two areas of improvement for plastic scintillators are the sample carry-over (“memory effect”) and energy resolution. While the scintillator can be coated to remove the memory effect, the energy resolution must be improved with a different detector material. Silicon is the current leading candidate for the future beta cell material due to the much-improved energy resolution compared to plastic scintillators (factor of ~3x). PNNL is developing a silicon beta cell for use as a potential modular replacement within Xenon International (a next-generation radioxenon detection system currently undergoing acceptance testing for potential inclusion in the International Monitoring System). The beta cell utilizes four different silicon detectors to create an active volume for the radioxenon within an outer gas cell. Since there are four separate beta signals (compared to one for plastic scintillators), data acquisition modifications are required. In this presentation, we detail the design, efficiency measurements, and long-term testing of the silicon beta cell and potential improvements in isotopic discrimination. Additionally, we discuss the required data acquisition and analysis updates needed to best utilize the silicon improvements.

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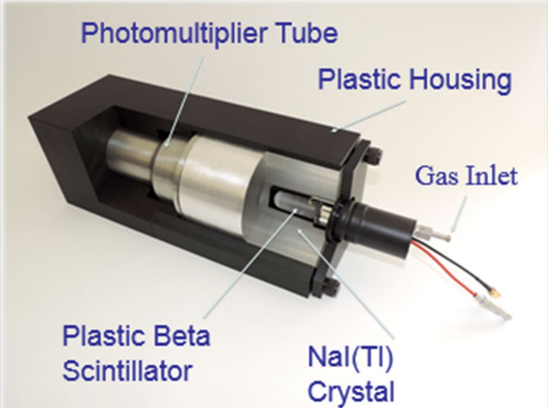
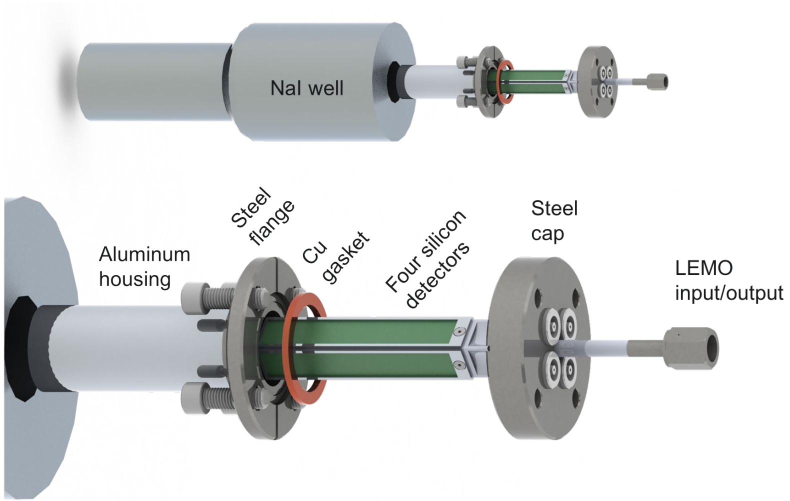
INTRODUCTION

Current photomultiplier tube-based technology conducive to be replaced with a SiPIN beta cell

- Single Gamma detector (NaI)
- Single Beta detector (Plastic (PVT) scintillator)



- Silicon is a promising alternative beta cell material
- Improved resolution
  - ~10% compared to ~30% for plastic scintillator
  - Potential for improved isotopic discrimination
- Decreased memory effect



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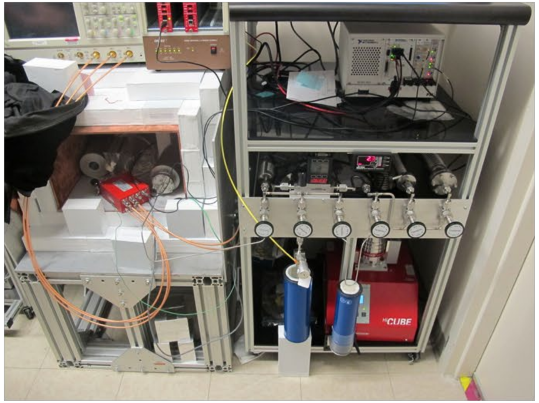
METHODS

- Prototype cells fabricated
  - Aluminum housing
  - Micron Semiconductor Ltd. fabricated Si-chips
  - Carbon fiber housing to be further studied



- Data acquisition system
  - Gas processing and injection
  - Commercial preamp
  - Commercial power supply
  - XIA system with Pixie-4 (5 Pixie-4 cards per Xenon International)

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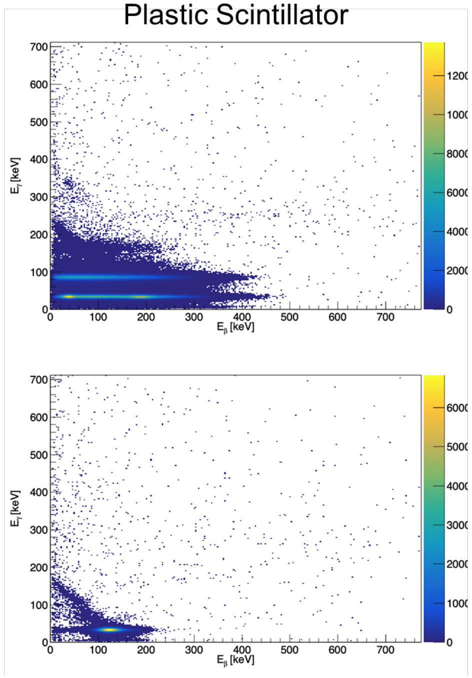
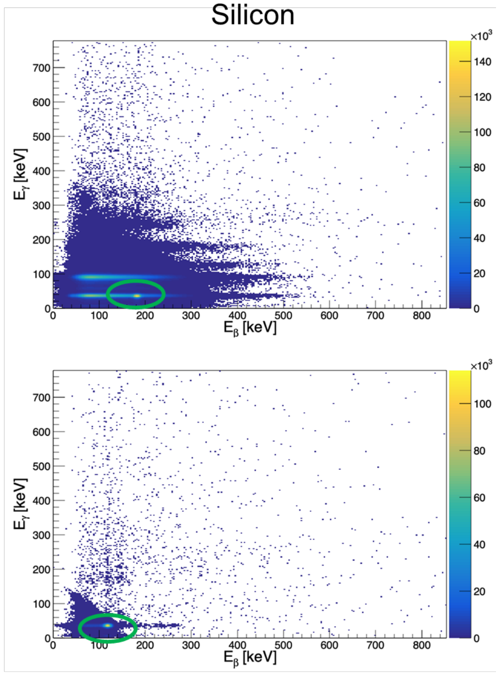
RESULTS

- There is little observable difference between the plastic and silicon when comparing the beta continuums of Xe-133 and Xe-135 (not shown here)
- The improved energy resolution for the silicon compared to the plastic results in much better metastable (Xe-133m and Xe-131m) peak identification (circled in green) while there is a Xe-133 beta continuum present.

Xe-133m

Xe-131m





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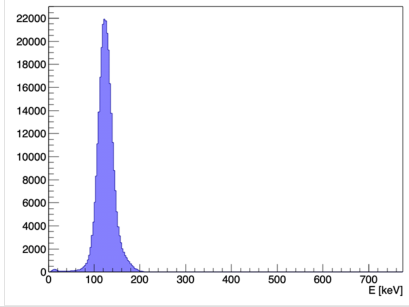
RESULTS

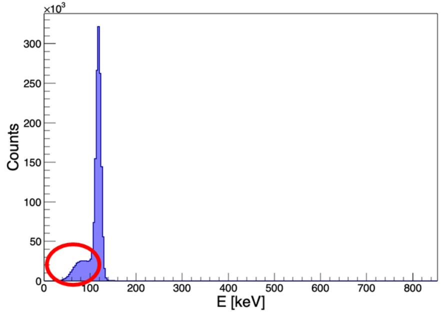
- The enhanced electron backscatter (circled in red) from the silicon will need to be included in the analysis
- Indicates the need for a ROI analysis that includes interferences between every ROI.
- With improved energy resolution, it may be possible to improve single isotope detection with the beta singles spectra.

Plastic Scintillator

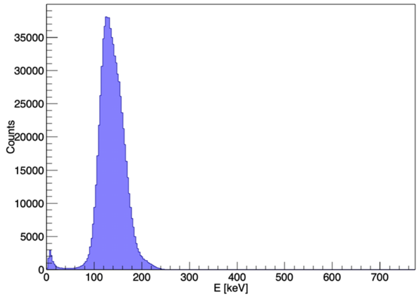
Silicon

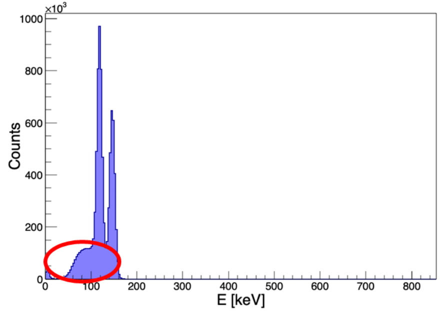
Beta Coincidence





Beta Singles





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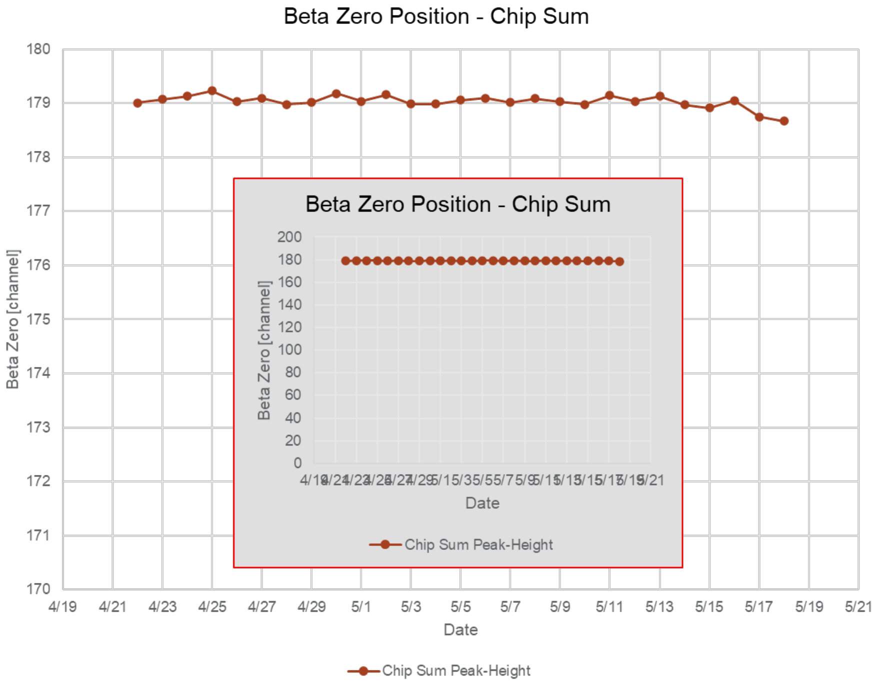
RESULTS

- Long term gain stability proves that the silicon gain is stable over a long period of time with only statistical fluctuations
- Major fluctuations correspond to moving the source position relative to the beta cell
- Had a ventilation outage in the laboratory that resulted in a temperature spike
  - Detector was stable with the temperature fluctuations (small compared to environmental conditions though)



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CONCLUSIONS

- Improved resolution over plastic
  - Low energy threshold and resolution could still be improved
- Eliminates memory effect
  - Housing design optimization and verified during calibration
- Low cost and easily manufactured
- Detector gain is stable over the course of months
- Electronics updates – Integrated pre-amplifier
  - Improve robustness to environmental noise, and further improve resolution
- Analysis updates
  - How do we fully leverage the improvements from silicon?