Simulations and Testing of a Rapid Surface Characterization Scanner

LEGEND
Large Enriched Germanium Experiment for Neutrinoless ββ Decay

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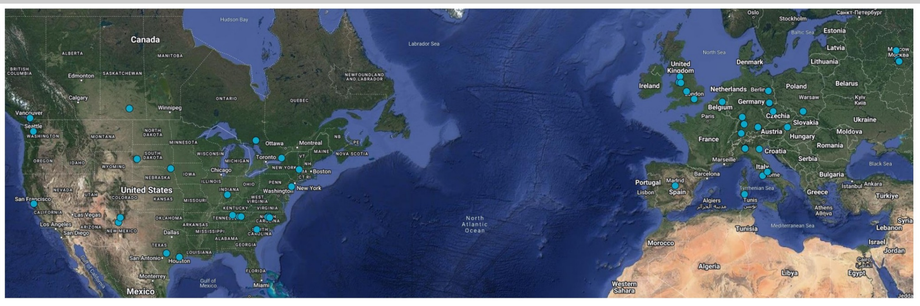

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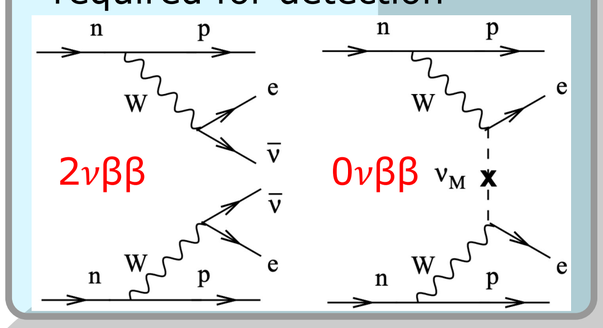
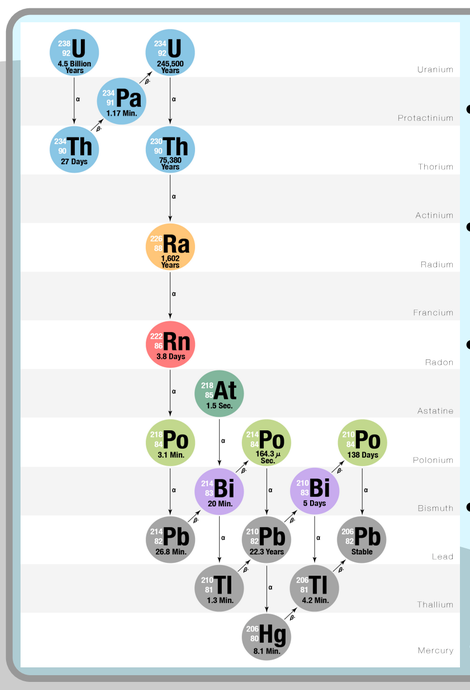
LEGEND

- Searching for $0\nu\beta\beta$ with ^{76}Ge
- Could elucidate neutrino mass ordering and origins of baryon asymmetry
- Almost zero background required for detection





^{238}U Decay Chain

Surface Scanner

- Being developed at UNC to address gaps in surface alpha event characterization
- Germanium detector surface response is complex, must be fully understood
- Alpha events from common isotopes (including ^{238}U) can have energies in the $0\nu\beta\beta$ region of interest ($Q_{\beta\beta}$ = *2039 keV)*
- Analysis of simulations compared to data from the scanner is needed to test scanner efficacy

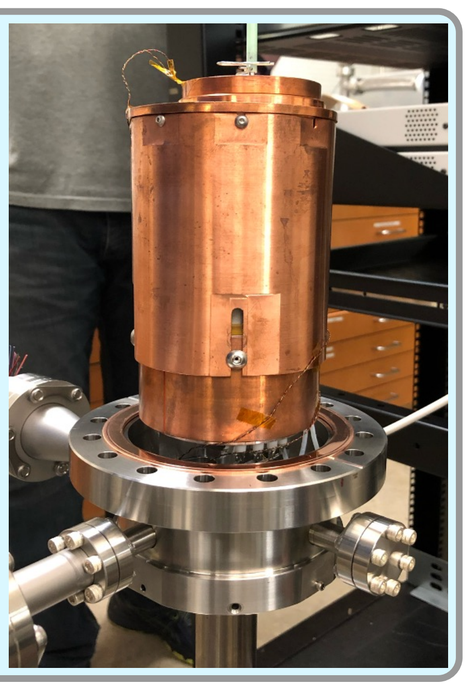
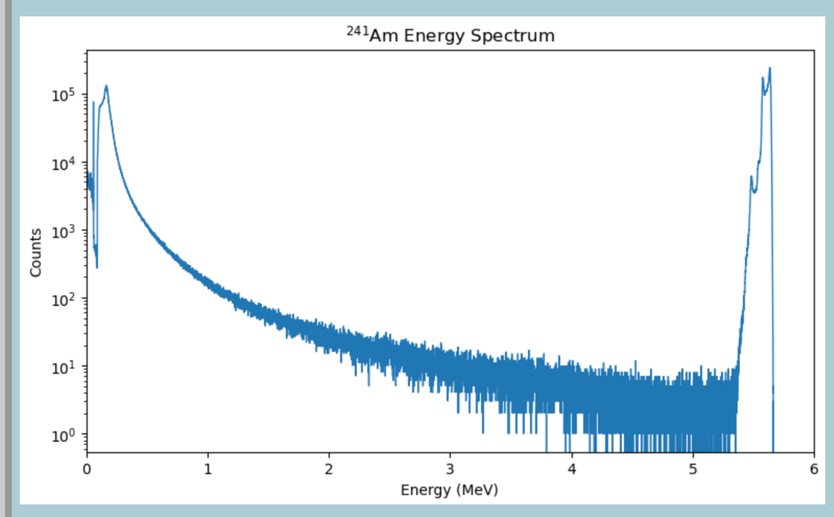
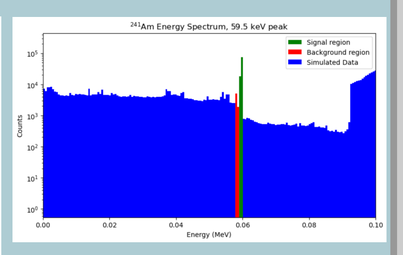


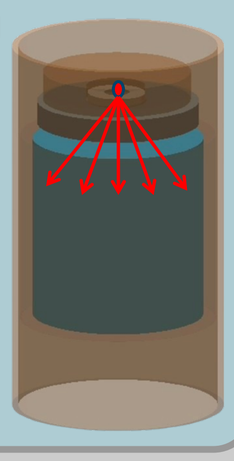
Photo of the Scanner

Simulated Data





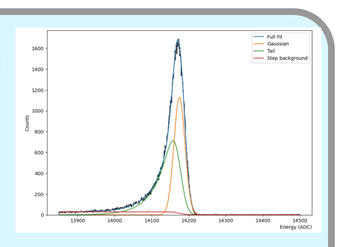
Geometry visualization of ^{241}Am source emitting from source holder into detector

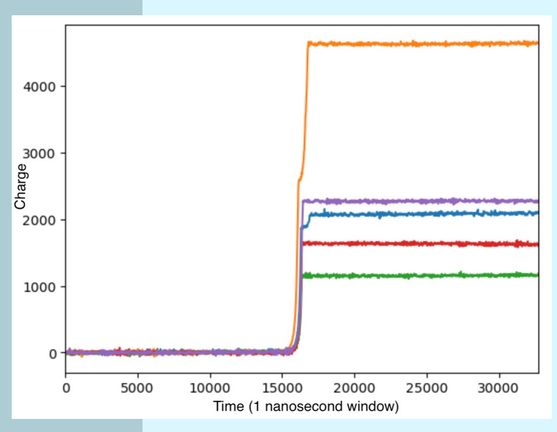


- Simulations carried out for ^{241}Am and three background isotopes (^{214}Bi, ^{208}Tl, ^{40}K)
- ^{241}Am was collimated, and the backgrounds were simulated in a concrete shell surrounding the scanner
- Post processing software used to turn simulated data into a spectrum that includes physical properties of the detector
- Used dead layer, threshold, impurity profile, and gaussian energetic smearing to make simulated energy spectra

Experimental Data

Cryogenic improvements of scanner were performed. Detector was biased and data was collected for 72 hours using ORCA software.



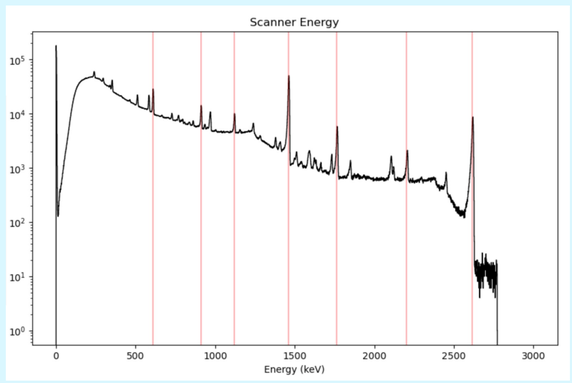


Energy Calibration

- Energy spectra initially have non-physical units of ADC
- 3-part fit performed to 7 peaks to extract calibration function
- Gives insight into the FWHM of detector at different energy ranges
- Used for activity estimates and $Q_{\beta\beta}$ energy resolution

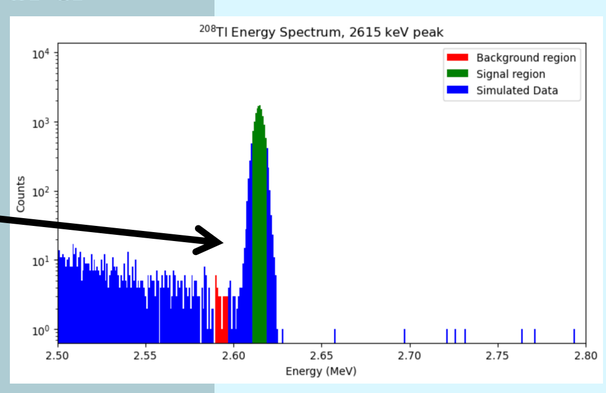
Digital Signal Processing

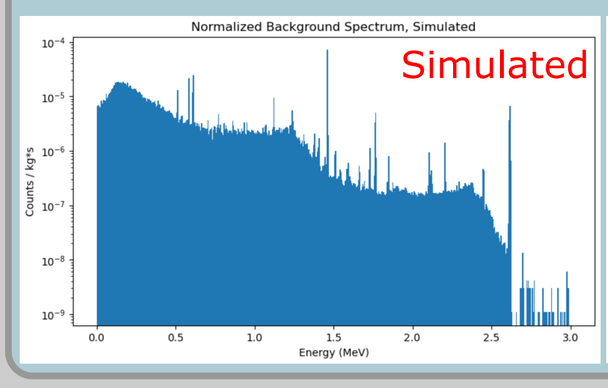
- Two main parts: pole zero (PZ) correction and trap filter
- Waveforms decay due to quasi-RC circuit behavior
- Optimization of the PZ constant makes waveforms as flat as possible
- Trap filter parameters are optimized to minimize energy uncertainty

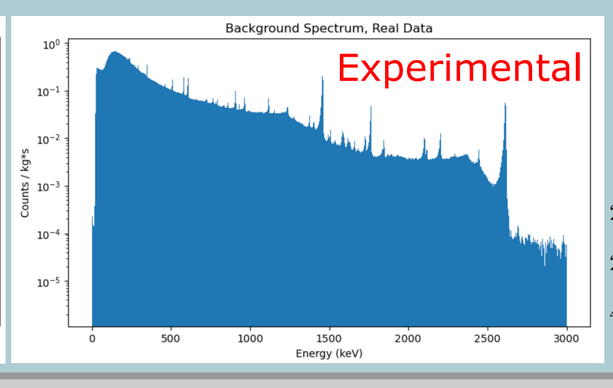


Comparing Energy Spectra

- Signal rate weighs counts of events in each spectral peak by mass, energy, and time
- Signal and background events are counted from a window sized by the FWHM of the relevant energy peak
- Low energy ^{241}Am peak at 60 keV was also studied, but the value was far from agreeing with simulations







Signal rates used to weigh the background spectrum and validate against data:

$$^{214}\mathrm{Bi},\ 2204\ \mathrm{keV\ peak}:\ 1.132 \pm 0.047 \times 10^{-7}$$
$$^{208}\mathrm{Tl},\ 2615\ \mathrm{keV\ peak}:\ 1.260 \pm 0.012 \times 10^{-6}$$
$$^{40}\mathrm{K},\ 1461\ \mathrm{keV\ peak}:\ 4.026 \pm 0.090 \times 10^{-6}$$

Further Research

- Add beta particle veto
- Statistical testing on spectrum
- Compare simulations and data for other isotopes

Acknowledgements

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