URANIUM ISOTOPE DETECTION USING GAMMA-GAMMA COINCIDENCE COUNTING TECHNIQUES

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Outline

- Background
- Method
- Setup
- Results
- Future Work

Background

- Work done through Nuclear Forensics Student Internship Program at Lawrence Livermore National Laboratory in California
- In collaboration with Dr. Tzu-Fang Wang of Lawrence Livermore National Laboratory

Background

- The ratio of ^{235}U to ^{238}U is one of the most important pieces of data in regards to nuclear forensics
- The strongest peak of ^{235}U is at 186 keV
- There are two main sources of interference at this energy level – Compton continuum and ^{226}Ra

Background – ^{226}Ra

- The strongest gamma peak of ^{226}Ra is also at 186 keV
- Because ^{226}Ra is in the decay chain of ^{238}U it is commonly found in many materials that contain ^{235}U
- Traditionally, these isotopes are separated by finding the amount of ^{226}Ra from its decay products and subtracting the interference from the 186 keV peak, leaving room for a high amount of uncertainty

Background – Compton Continuum

- When looking at a spent fuel cell or post-detonation sample, the concentration of fission products in the sample is very high

- Though most of these fission products are very short-lived (seconds or minutes) some of them have much longer half-lives (50+ years)

- These long-lived fission products can have high gamma energies, which contribute to the Compton continuum around the strongest peaks of ^{235}U

Background - ^{238}U

- ^{238}U itself does not have any strong peaks that we can detect
- The daughter of ^{238}U is ^{234}Th, which has a 24-day half-life
- The daughter of ^{234}Th is ^{234}Pa, which has a 6-hour half-life

Background - ^{238}U

- Because the 1st and 2nd generation daughters of ^{238}U have such short half lives, they all come into secular equilibrium fairly quickly
- After about 7-8 months, ^{234}Pa spontaneously decays just as often as ^{238}U
- ^{234}Pa has a strong gamma peak at 1001 keV, which is outside the Compton continuum, and thus has very little interference associated with it

Method

- We want to utilize coincident gamma rays in ^{235}U to isolate it from the interferences affecting its main peak
- There is a strong coincidence in ^{235}U between the 186 keV peak and the 202 keV peak
- Using proper electronics and timing software, we can find the ^{235}U concentration using these coincidence events

Method

- For the ^{238}U concentration, we can use the 1001 keV peak associated with ^{234}Pa
- By using standards with known concentrations, we can find an equation relating the ^{235}U coincident events and the ^{238}U daughter singlet events
- By finding this equation for any particular detector setup, one can determine the isotopic ratio of uranium in any given sample from these coincident and singlet data

Setup

- At LLNL, the experiment was performed in the Nuclear Counting Facility, which is underneath one story of soil designed to eliminate interference radiation

- In our setup, we had two coaxial HPGe detectors separated by 5 cm, with a Compton suppression system attached to the back of each respective detector

Setup

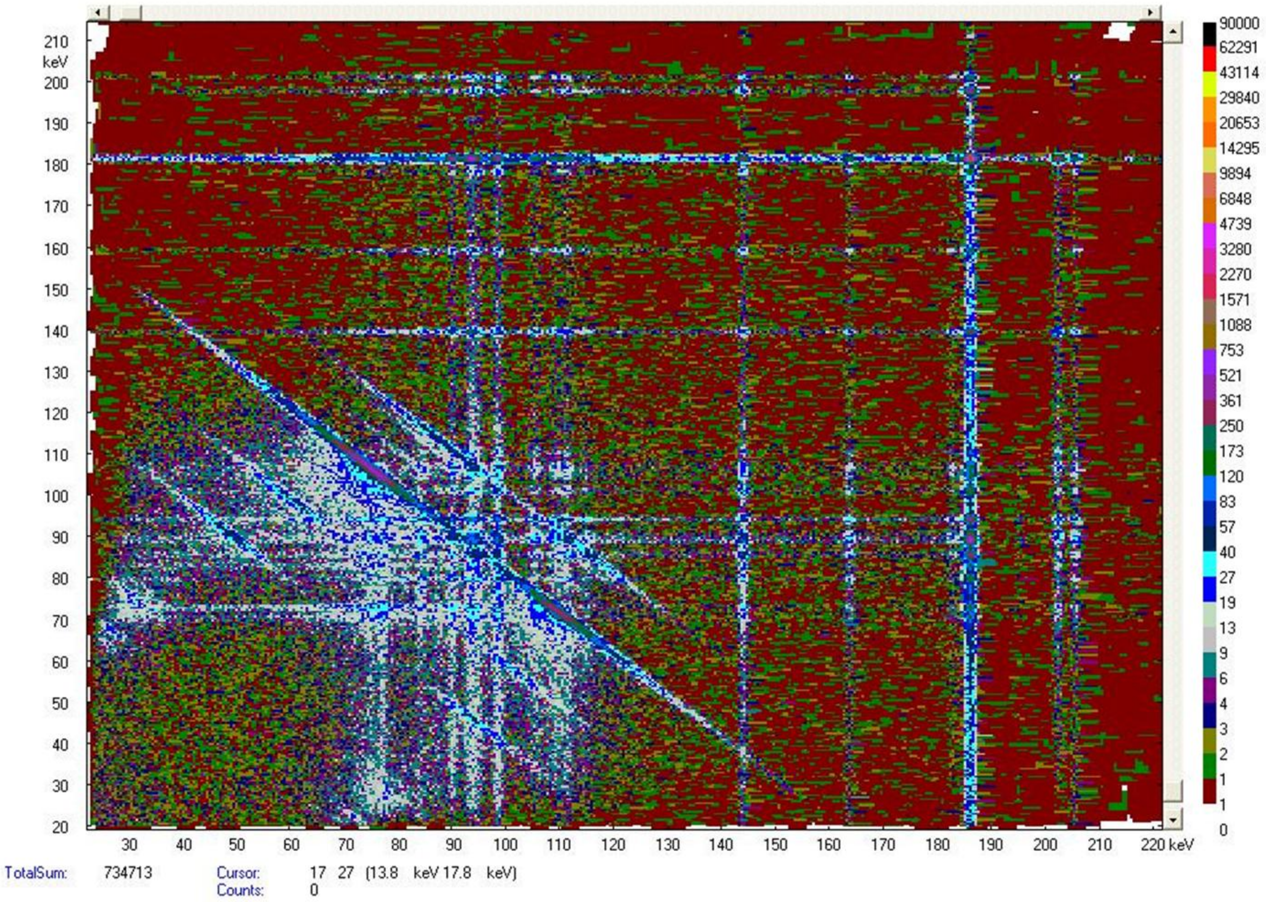
Setup

- The software we used gave single spectrum for each detector, as well as a 2-dimensional plot for the coincidence data

- Using these spectra, the number of counts due to each isotope was determined

- We counted three aged samples consisting of .5% ^{235}U, 5% ^{235}U, and 50% ^{235}U with the remaining portion of the sample being ^{238}U

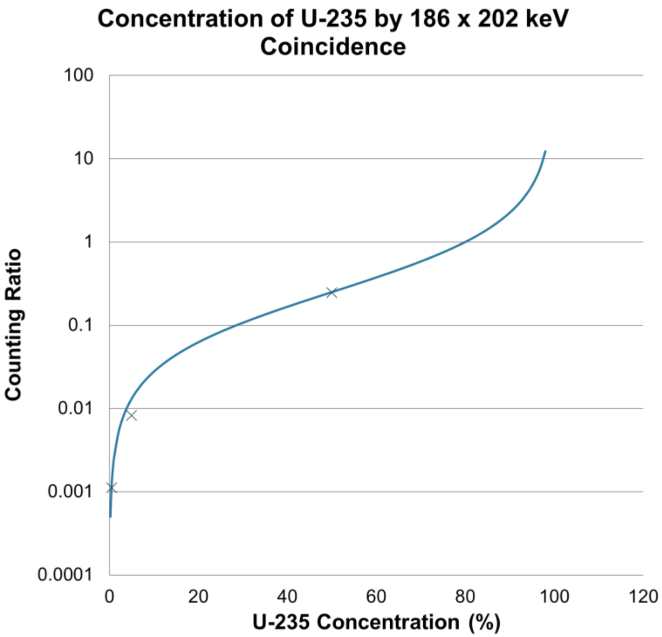
Results


210
keV
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 keV
90000
62291
43114
29840
20653
14295
9894
6848
4739
3280
2270
1571
1088
753
521
361
250
173
120
83
57
40
27
19
13
9
6
4
3
2
1
1
0
TotalSum: 734713
Cursor: 17 27 (13.8 keV 17.8 keV)
Counts: 0

Results

- From the data, we were able to obtain an equation relating the ratio of 186-202 keV coincident events to 1001 keV singlet events

U-235 Concentration	186 x 202 Coincidence :: 1001 keV Ratio
.5%	1.11e-3 ± 2.00e-4
5%	8.19e-3 ± 2.75e-4
50%	2.46e-1 ± 4.59e-3



Future Work

- More data points need to be included in order to give validity to this method, especially at higher ^{235}U concentrations

- The method needs to be tested under high background conditions, such as those that might be found in a spent fuel cell

Future Work and Conclusion

- ^{239}Pu also has several coincident gamma rays that can be utilized using a similar method

- Random coincidence subtraction methods could also be useful in gaining accuracy for this method

- This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344