Gamma-gamma coincidence measurements of naturally occuring radioactive materials

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Background

- Natural radionuclide: ^{40}K, ^{238}U and ^{232}Th series are present in earth crust, building materials, air, water, food and the human body
- These nuclides are usually measured by gamma spectrometry [1]
- ^{40}K has a single gamma-ray peak
- ^{232}Th and ^{238}U are unstable and decay by producing nuclides (daughters) which are also unstable (fig. 1 & fig. 3) [2]

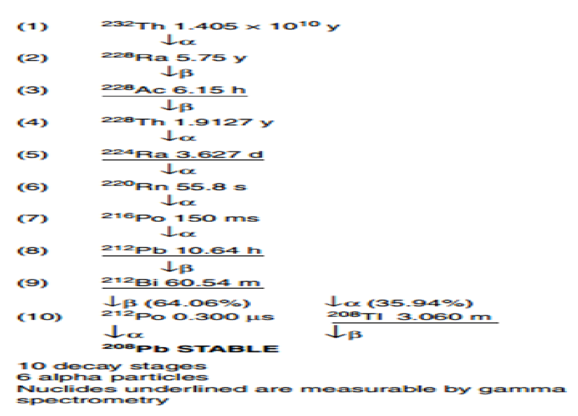

Figure 1: ^{232}Th decay series (from Gilmore [1])

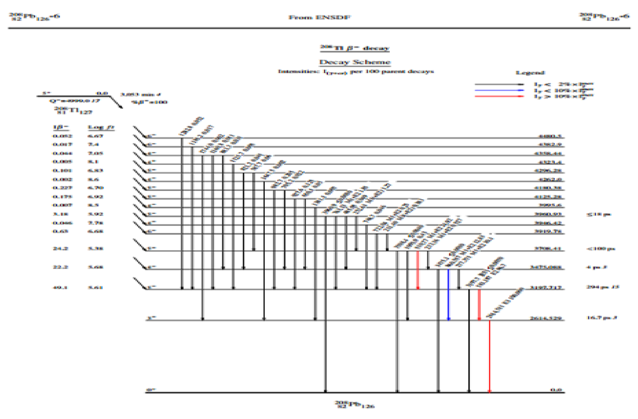

Figure 2: Decay scheme of ^{208}Tl (from ENSDF)

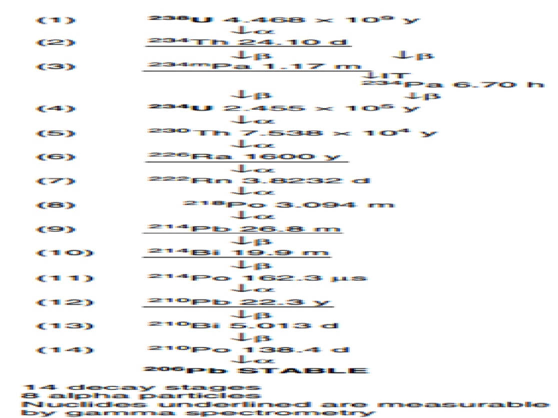

Figure 3: ^{238}U decay series (from Gilmore [1])

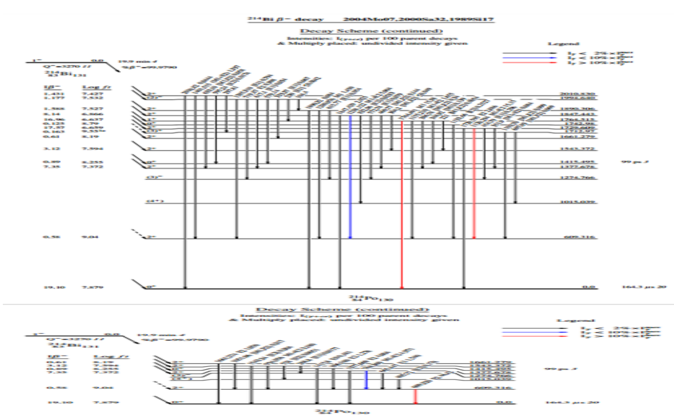

Figure 4: Decay scheme of ^{214}Bi (from ENSDF)

Motivation

- Measurements of natural radioactivity concentration using gamma - gamma coincidence method has advantage of minimizing spectrum background over single measurement [3]
- Detection limits can be improved by eliminating the internal activity in LaBr$_3$:Ce scintillator through gamma - gamma coincidence condition [4]

Detectors setup and Method

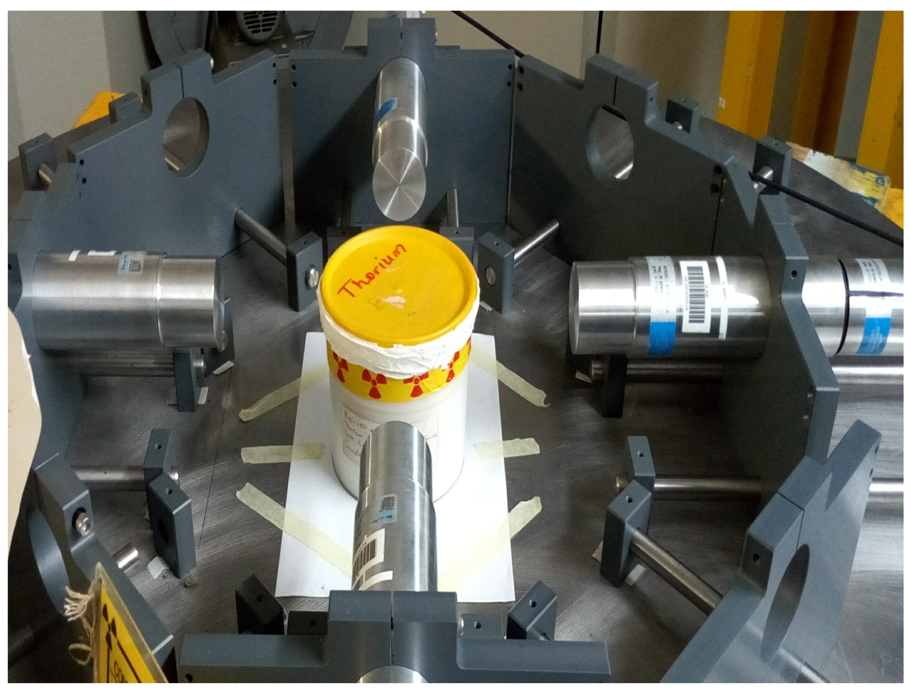

Figure 5: Experimental geometry

- An array of four LaBr$_3$:Ce (2" by 2") detectors connected to a Digital Signal Processing system (XIA PIXIE) were used for measurement of natural occuring radioactive materials (NORM) as shown in fig. 5
- Detector to sample distance was 10 cm
- Thorium (Th) ore and Uranium (U) ore from IAEA in 1L Marinelli beakers were each measured for 48 hours
- Background measurements was also taken using empty Marinelli beaker

Analysis

- For singles background spectrum was subtracted from both Th and U spectra
- Gamma - gamma coincident spectra were generated by setting software time gates tb1, tb2 & tf (fig. 6) offline
- The gamma-gamma of time tb1 + tb2 (fig. 8) which is compton continuum background was normalized to the time tf and subtracted from the gamma-gamma of time tf (fig. 7) to obtain fig. 10 for Th and the same was done for U to obtain fig. 12
- ^{208}Tl peaks (fig. 2) was used for ^{232}Th and ^{214}Bi (fig. 4) for ^{238}U
- Energy gates were set on $\gamma - \gamma$ matrices associated with the ^{208}Tl (583 keV and 2614 keV) (fig. 10) and ^{214}Bi (609 keV and 1120 keV) (fig. 12) respectively.

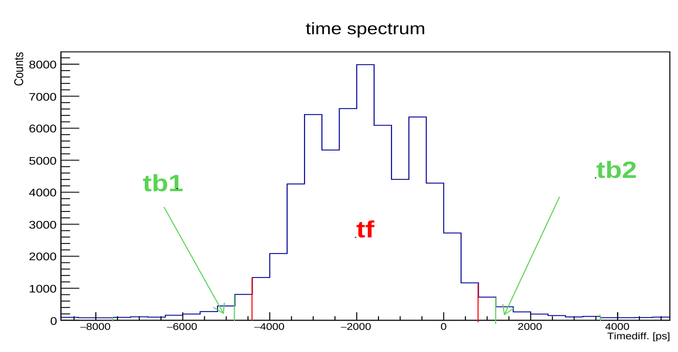

Figure 6: Time spectrum for thorium

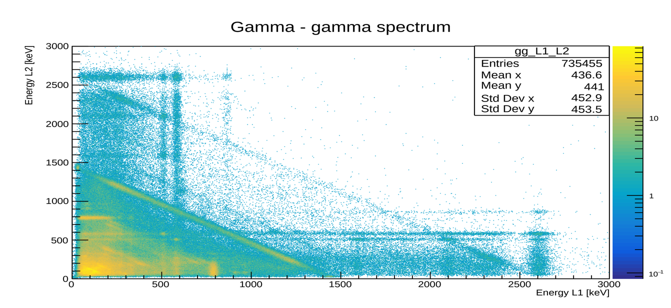

Figure 7: Gamma-gamma for thorium using time gate tf

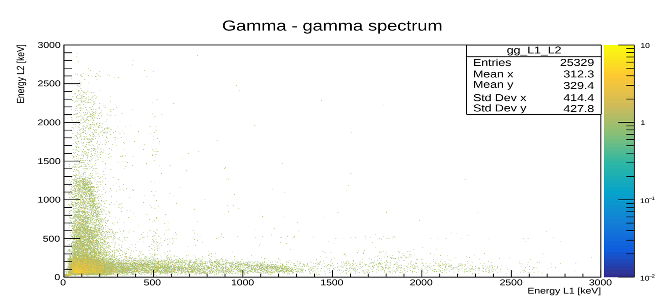

Figure 8: Gamma-gamma for thorium using time gate tb1 + tb2

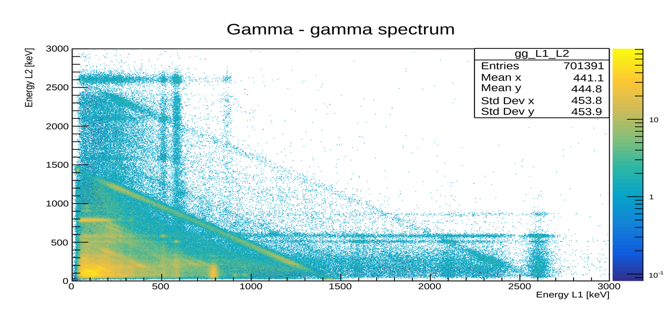

Figure 9: Gamma-gamma for thorium after subtraction of gamma-gamma of time gate tb1 + tb2 from that of time gate tf

Preliminary results

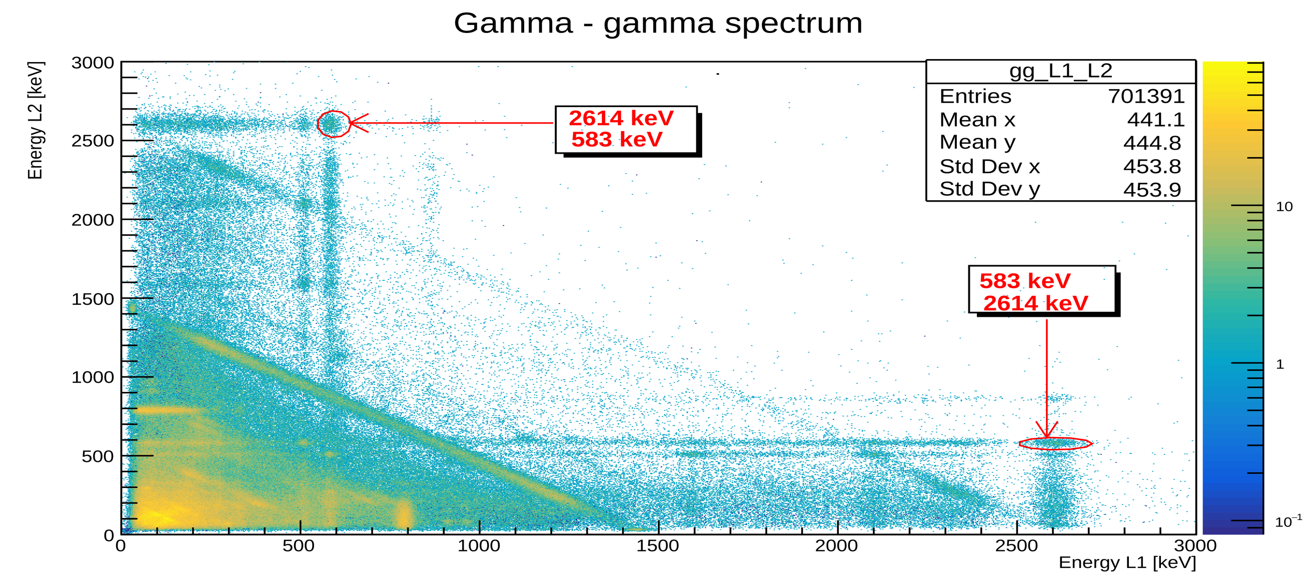

Figure 10: Gamma-gamma coincidence for Thorium

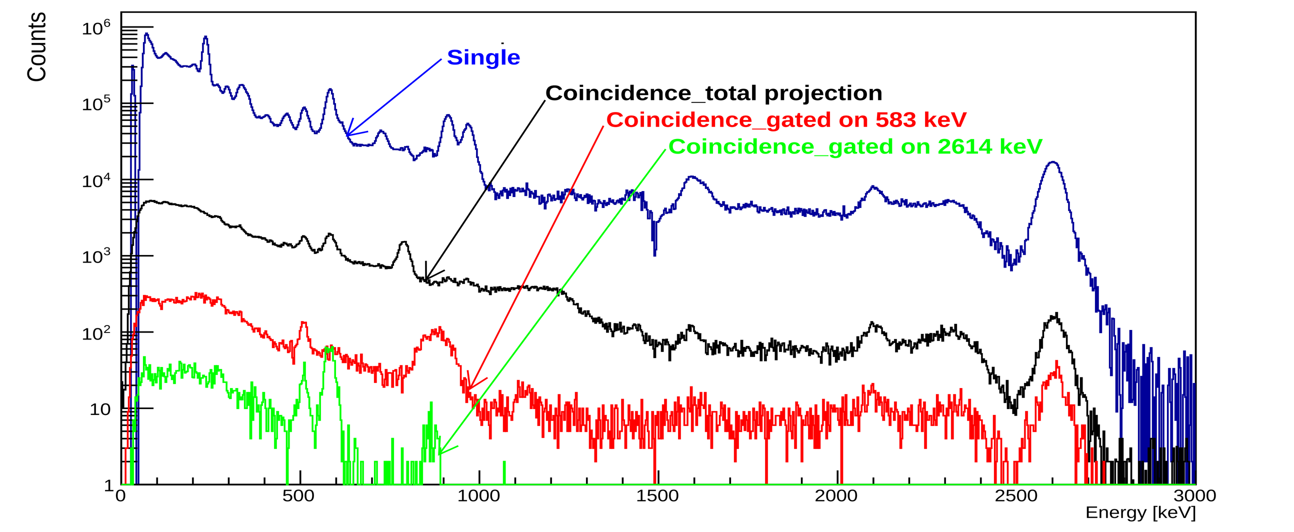

Figure 11: Single spectrum and Coincidence spectra (total projection, gated on 583 keV and 2614 keV) for Thorium

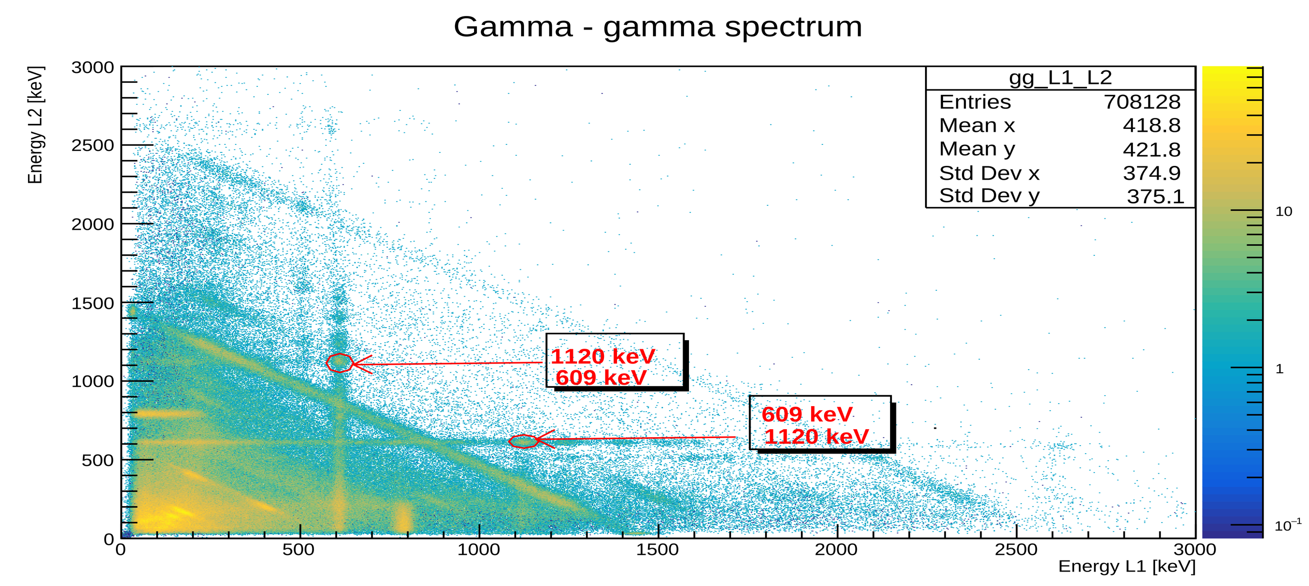

Figure 12: Gamma-gamma coincidence for Uranium

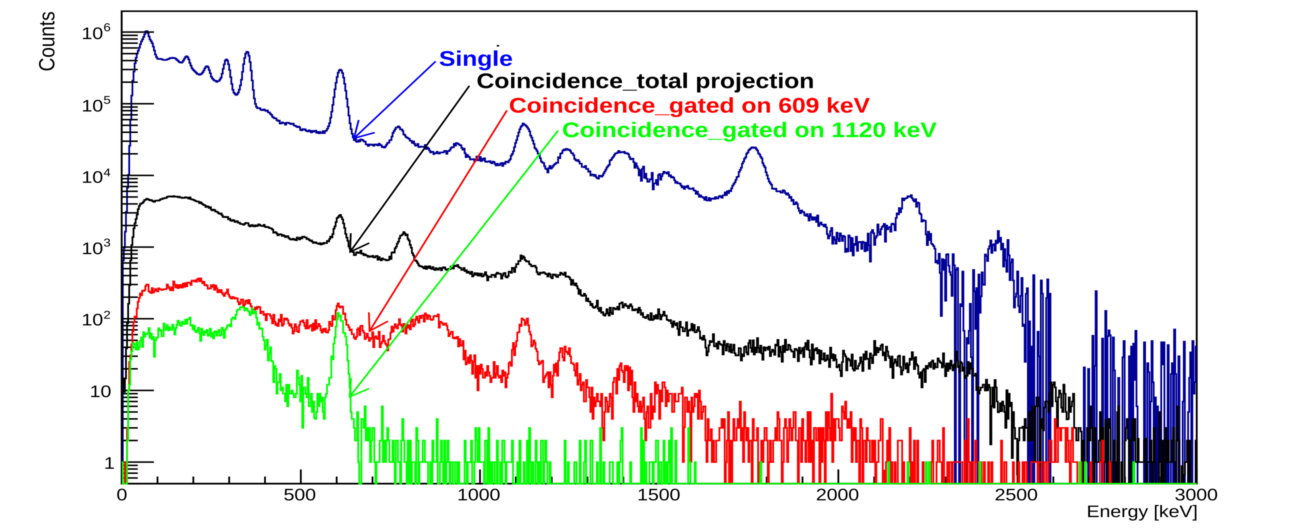

Figure 13: Single spectrum and Coincidence spectra (total projection, gated on 583 keV and 2614 keV) for Uranium

Conclusion and Outlook

- As seen in fig. 11 & 13 the compton continuum in the coincidence spectrum is less compared to the single, thereby reducing the spectrum background
- Counts in each peak of interest will be extracted
- peak-to-total ratios will be calculated for both singles and coincidence
- Detection efficiency will be determined
- Activity concentration will be calculated for singles and coincidence using the formular suggested by Kai [5]
- Lifetime of the levels will also be verified

References

[1] Gilmore G.; 2008. Practical Gamma-Ray Spectrometry, second ed. John Wiley & Sons, Ltd., West Sussex, England, ISBN 978-0-470-86196-7

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[4] A. Drescher *et al.*, Gamma-gamma coincidence performance of LaBr3:Ce scintillation detectors vs HPGe detectors in high count-rate scenarios, Applied Radiation Isotope, vol. 122, pp. 116-120, 2017.

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