Shape-factor analysis of real-time, in-situ photon-depth spectra for land quality β^--emitter assay

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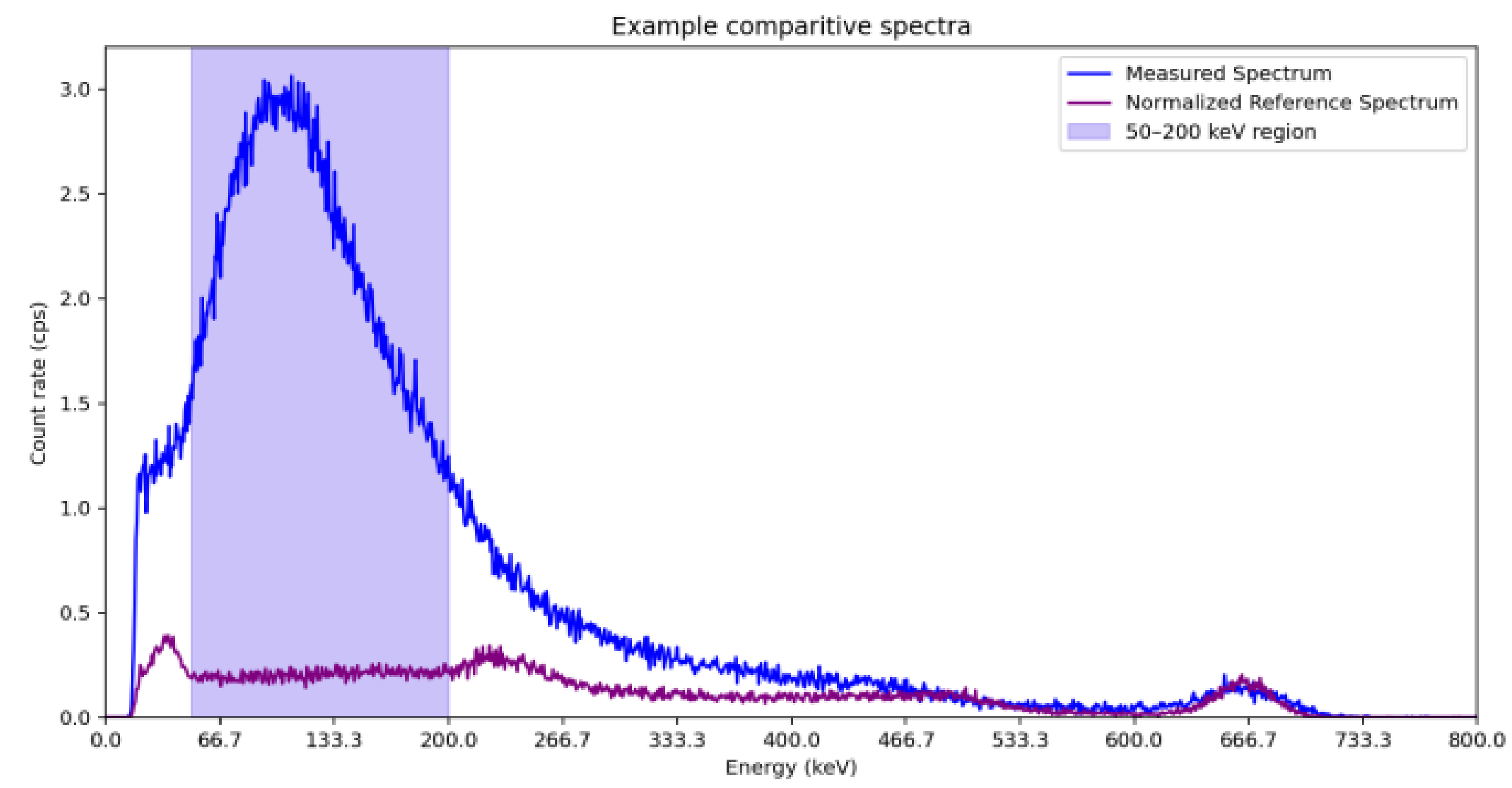
Background

There is a need for spectral discrimination between key groundwater contaminants, in particular ^{137}Cs, ^{90}Sr and ^{90}Y, as current in-situ radiometric monitoring methods of legacy leakage only output gross dose rates. Therefore, real time Sellafield photon spectra were analysed alongside lab-based ^{137}Cs spectra to identify the optimal region of interest for ^{90}Y/^{90}Sr separation, before definition of a shape factor, in order to identify at what depths ^{90}Y/^{90}Sr are present. This method was designed for in-situ implementation.

Initial results

In-situ spectral data and reference ^{137}Cs were calibrated to the respective 662 keV γ peaks[2], and the reference was normalised to each individual in-situ peak height. The two spectra were then plotted on the same axis to compare spectral differences for ROI definition. One such graph is shown below.

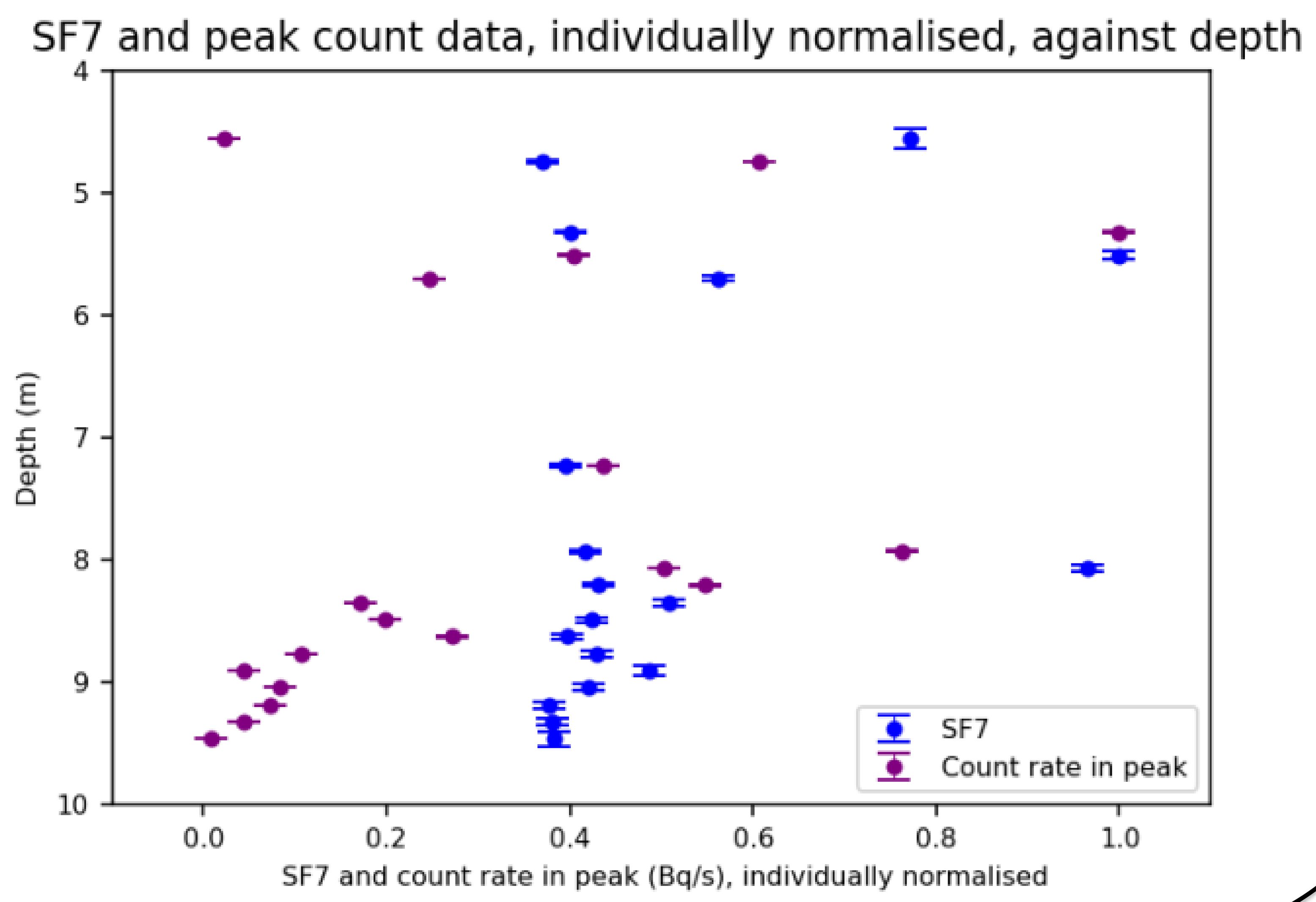


The light blue area represents the ROI chosen – 50-200 keV. This region was chosen as the reference spectra is flat here whereas the in-situ spectra peak.

The subsequent equation used to define the shape factor (SF) is as below:

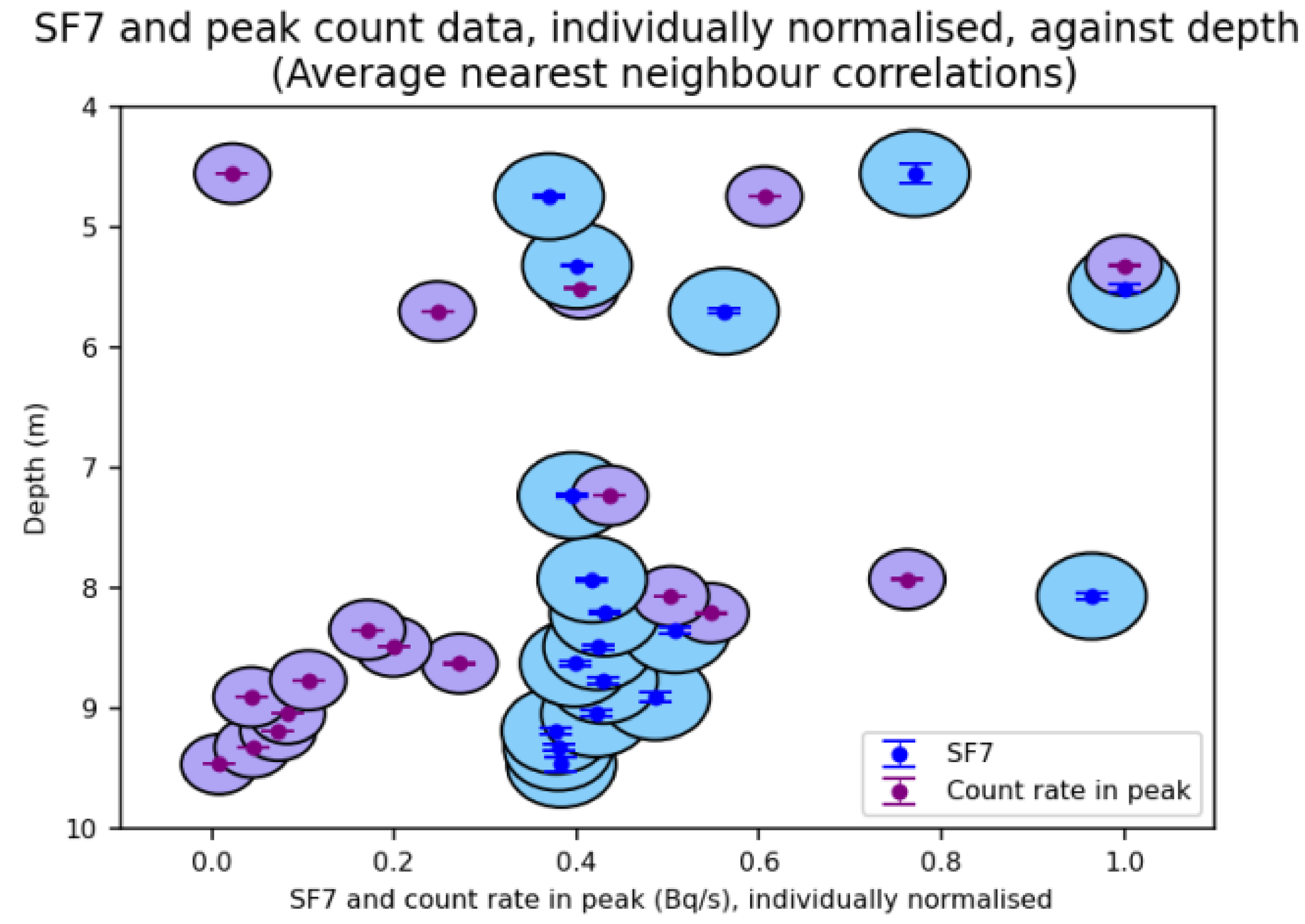
$$SF7 = \frac{\textit{spectral counts between 50 and 200 keV}}{\textit{reference counts between 50 and 200 keV}}$$

This equation was applied to the spectral data, and plotted alongside the peak count data. Peak count rate data was obtained using the peak fitting code described in (Elisio et al., 2023)[3], and both datasets were individually normalised to their maximums.



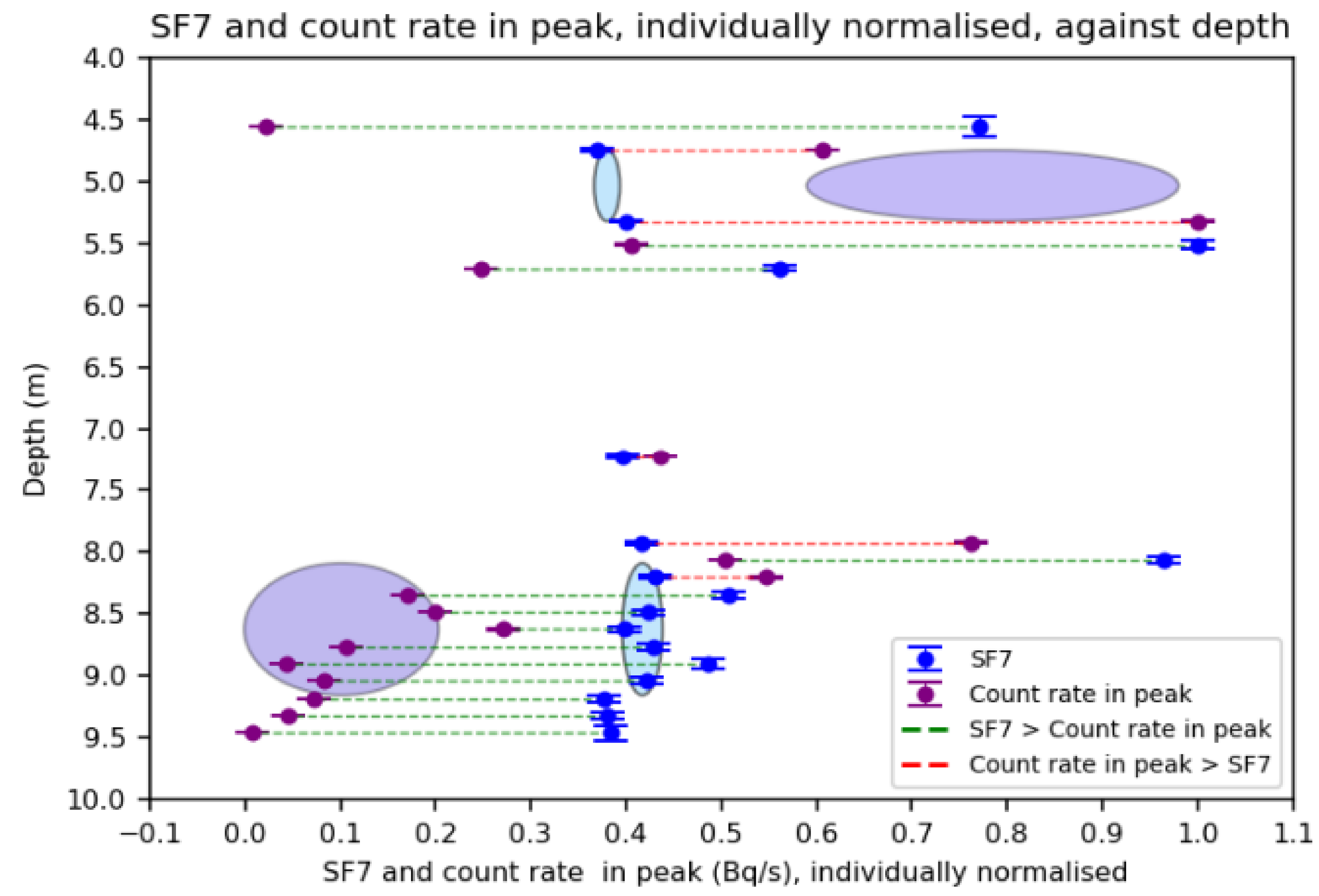
Analysis

The nearest neighbour distance for each data point was found and then an error weighted average of those distances computed and plotted as the ellipses, in order to find clusters in the data.



For the count rate in peak, there is no clustering up to a depth of around 8 after which 3 separate clusters are visible. In SF7, there are two clear clusters, one at around 5 m and one around 8-10 m. Therefore, further analysis was done solely based on the SF7 clustering as these included more of the data and spread across a larger depth range.

The loci and mean radius of the datapoints present in the SF7 cluster and equivalent in the count rate in peak were found, once again error weighted, and are represented below by the ellipses. Lines were added for greater correlation visibility between the two data sets with the colour representing which dataset was larger at that specific depth.



At shallow depths, the count rate in peak is clearly statistically higher than the SF7. However, at deeper depths (8-9.5 m), the opposite is true. This suggests that at greater depths in the borehole, ^{90}Sr is present. This conclusion concurs with knowledge of isotopic migration in the subsurface at Sellafield.

This method therefore does successfully discriminate between isotopes in real time datasets. Next steps are to test whether ^{90}Sr is responsible for this difference in the laboratory/find the most likely root cause of the higher shape factor.

References

[1]Elísio, S. C., Andrew, J., Bandala, M., Budge, E., Calverley, T., Coghill, E., Graham, J., Grievson, A., MacGregor, J., McAlister, D., O'Kane, A., Spence, J., & Joyce, M. J. (2024). Discerning β-emitting radioactivity from caesium-137 γ radiation via bremsstrahlung for in-situ groundwater monitoring. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 1068*, 169792. 10.1016/j.nima.2024.169792

[2]Data and calibration performed by Soraia Elisio

[3]Elísio, S. C., Bala, A., Bandala, M., Graham, J., Grievson, A., & Joyce, M. J. (2023). Point-Spread Analysis of γ-Ray/Depth Spectra for Borehole Monitoring Applications. *IEEE Transactions on Nuclear Science, 70*(11), 2506–2514. 10.1109/TNS.2023.3319540

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