Analysis of Gamma Ray Spectra from Reference Isotopes with Multi-Channel Analyzers

Oliver Kirkpatrick
School of Engineering, RMIT University
Email: s3725341@student.rmit.edu.au

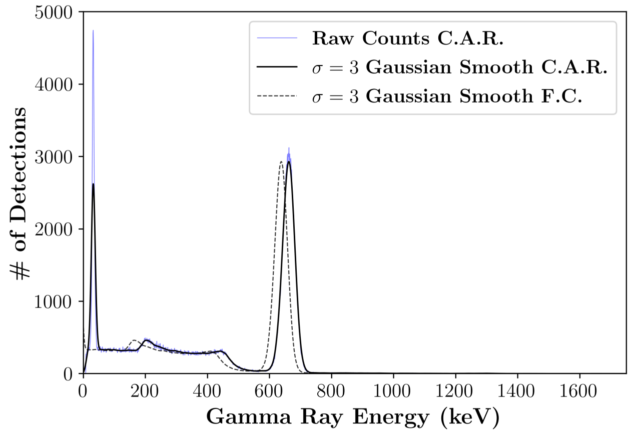
***Abstract*—The interaction of gamma rays with matter, the results are classed into three categories: photoelectric scattering, Compton Scattering, and Pair production. Which of these effects occurs is closely linked with the energy carried by the original gamma ray. Presented in this study is an investigation into gamma ray scattering and spectra using a Thallium doped Sodium Iodide (NaI(Tl)) scintillating crystal detector, and a multi-channel analyzer. Common radioactive isotopes of Cesium, Sodium, and Cobalt were utilized as reference isotopes to calibrate the equipment setup, such that an unknown material could be identified through gamma ray spectra and half life.**

I. Introduction

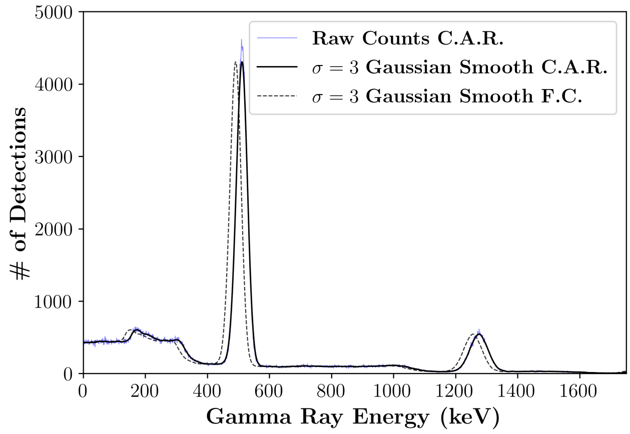
- Gamma ray scattering is a phenomenon that occurs when gamma rays interact with matter.
- The process involves the deflection of gamma rays from their original path due to interactions with atomic nuclei.
- The scattering of gamma rays is caused by the electromagnetic interaction between the gamma rays and atomic electrons.
- The probability of scattering depends on the energy of the gamma rays and the atomic number of the material being scattered.
- Scattering can occur at any angle and is described by a scattering cross-section.
- The scattering cross-section is a measure of the probability of scattering and is dependent on the energy of the gamma ray.
- Gamma ray scattering is used in many applications, including medical imaging and materials science.
- In medical imaging, gamma ray scattering is used to identify the presence and location of tumors or other abnormalities.
- Materials science researchers use gamma ray scattering to study the atomic structure of materials.
- Gamma ray scattering is also used in astrophysics to study the properties of celestial objects.
- For incident gamma rays with lower energies ($<$ 100 keV), this photoelectric effect is dominant [Kane et al., 1986], [Kane, 2005]
- The Compton effect is a type of gamma ray scattering in which a gamma ray loses energy and changes direction after interacting with an atomic electron.
- The energy lost by the gamma ray in the Compton effect is transferred to the electron, which is ejected from the atom.
- The Compton effect is the dominant mechanism for gamma ray scattering at intermediate energies.
- At high energies, gamma rays can also undergo pair production, in which a gamma ray is converted into an electron-positron pair.
- Gamma ray scattering is an important phenomenon in physics and has many practical applications in science and medicine.

II. Results and Discussion

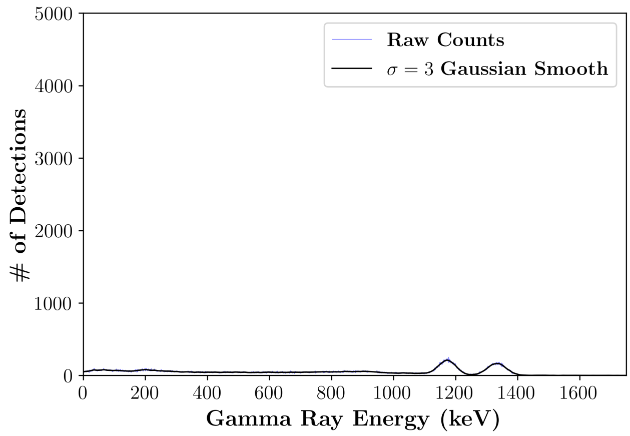
A. Calibration Process



(a) ^{137}Cs Gamma Ray Spectra



(b) ^{22}Na Gamma Ray Spectra



(c) ^{60}Co Gamma Ray Spectra

Fig. 1: Gamma ray spectra for known isotopes of Cesium (^{137}Cs), Sodium (^{22}Na), and Cobalt (^{60}Co). Cobalt was the final isotope tested, and the calibration metrics calculated for it were used for the rest of the experiment. For the Cesium and Sodium isotopes, the spectra with the calibration at recording (**C.A.R.**), is shown in solid black, and the spectra adjusted with the final calibration (**F.C.**) is shown in dashed gray. Raw counts for all isotopes are shown in blue, though these are often obscurred by the $\sigma = 3$ gaussian smoothed curves.

B. Background Radiation

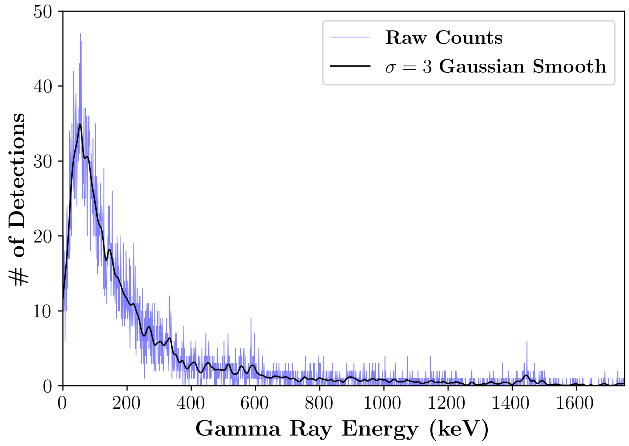
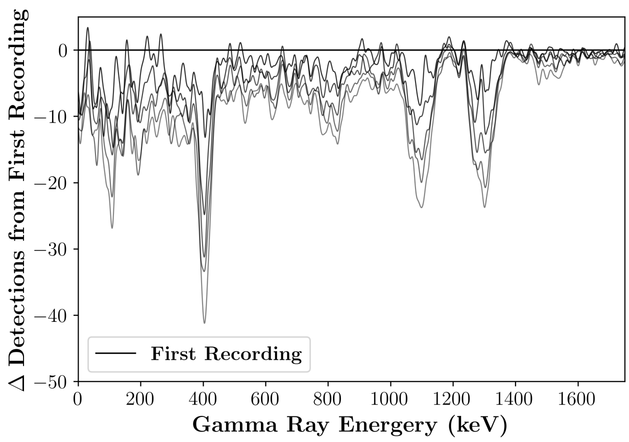


Fig. 2: Background radiation profile.

C. Analysis of Unknown Sample



References

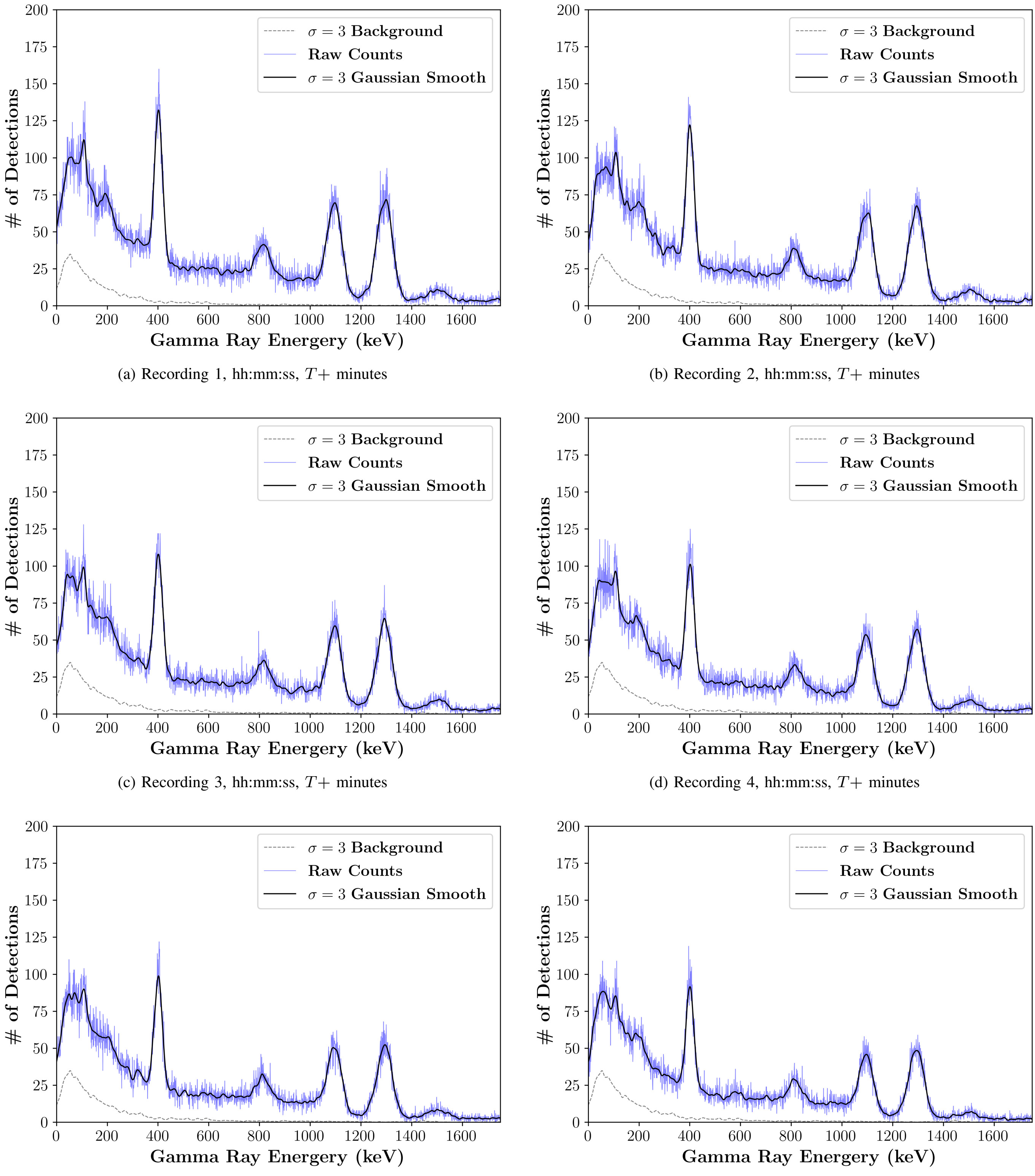
[Kane, 2005] Kane, P. (2005). Elastic scattering of gamma rays and x-rays. *Radiation Physics and Chemistry*, 74(6):402–410.

[Kane et al., 1986] Kane, P., Kissel, L., Pratt, R., and Roy, S. (1986). Elastic scattering of γ-rays and x-rays by atoms. *Physics Reports*, 140(2):75–159.

TABLE I: Total counts and peak energies with with increasing time since first measurement.

Sample Number	$T+$ **(s)**	**Total Counts**	**Peak 1 Energy**	**Peak 2 Energy**	**Peak 3 Energy**	**Peak 4 Energy**
1	0s	68493	401.24 keV	815.92 keV	1096.59 keV	1296.46 keV
2	420s	63755	400.52 keV	799.32 keV	1106.59 keV	1295.25 keV
3	819s	59850	401.25 keV	796.80 keV	1099.32 keV	1293.16 keV
4	1199s	56863	400.35 keV	759.04 keV	1097.07 keV	1295.73 keV
5	1559s	53111	401.94 keV	805.54 keV	1104.55 keV	1296.78 keV
6	1936s	50483	400.41 keV	812.17 keV	1085.92 keV	1292.84 keV

Appendix



(a) Recording 1, hh:mm:ss, $T+$ minutes

(b) Recording 2, hh:mm:ss, $T+$ minutes

(c) Recording 3, hh:mm:ss, $T+$ minutes

(d) Recording 4, hh:mm:ss, $T+$ minutes

(e) Recording 5, hh:mm:ss, $T+$ minutes

(f) Recording 6, hh:mm:ss, $T+$ minutes

Fig. 3: Raw count data for each recording of gamma rays from the unknown isotope.

ss