The system is linear! Signal from the detector is faithfully amplified by the Preamp and Pre-Amplifier (near the detector) and the Main or Linear Amplifier (in the main console).

Stated another way: Voltage at amplifier is directly proportional to keV deposited in the detector.

This allows the amplifier output to faithfully represent (be proportional to) the gamma ray energy deposited in the scintillation crystal.

The Pulse Height Analyzer looks at the amplifier output voltage and classifies the pulses by height — i.e. energy.
The Pulse Height Analyzer looks at the amplifier output voltage and classifies the pulses by height—i.e., energy. Only pulses that fall in the Window count. Others are ignored in a SCA.

By moving the Window to successively higher and lower values all the energies can be measured. This produces a spectrum of gamma ray energies.

The most prominent part of an energy spectrum is the photopeak—it corresponds to all the gamma ray energy being deposited in the detector.

A measure of quality of a counting system is the width of the photopeak—expressed as the Full Width at Half Maximum (FWHM).

\[ \%\text{FWHM} = \frac{B-A}{E_p} \times 100 \]

This broadening of the photopeak in a spectrum is due to the variation in the number of light photons created by a gamma ray and by the variation in the number of photoelectrons created at the photocathode.

A 100 keV gamma ray will produce on average 5000 light photons with a standard deviation of ±5000 because it is Poisson distributed. I.e. the efficiency of light photon productions is 0.05.

An 1000 light photons will produce on average 100 photoelectrons at the photocathode with a standard deviation of ±100 because it is Poisson distributed. I.e. the efficiency of photoelectron production is 0.1.

This leads to the spread of the photopeak. It closely approximates a Gaussian distribution.

The most dominate part of an energy spectrum is the photopeak—it corresponds to all the gamma ray energy being deposited in the detector. But there are several other features in a spectrum that are related to the photopeak.

A measure of quality of a counting system is the width of the photopeak—expressed as the Full Width at Half Maximum (FWHM).

\[ \%\text{FWHM} = \frac{B-A}{E_p} \times 100 \]

This leads to the spread of the photopeak. It closely approximates a Gaussian distribution.
It may happen that the gamma ray interacts in a Compton event and the scattered gamma ray escapes the crystal and less than full energy is deposited. The maximum energy that can remain in the crystal is for a scattering angle of 180°. This may produce a “Compton Edge”. The part of the spectrum between the CE and 0 energy is called the “Compton Plateau”.

Other Features of Spectra

- X rays – Many sources have low energy x rays that will also be detected. E.g. Tl-201 (60 keV), Tc-99m.
- X-rays from shielding or collimation – Lead and tungsten are used for shielding and may, depending upon exact geometry, contribute characteristic x-rays (about 72 and 60 keV respectively) that are detected.
- Iodine Escape peak – The iodine x-ray produced by the photoelectric interaction with NaI may escape producing a peak with Ep-28 keV. Noticeable at energies below about 100 keV when using NaI detectors. (See Saha Fig. 8.4)
- Sum or coincidence peak - if two gamma rays hit the crystal at the same time the light adds and a new (sum) peak is found in the spectrum. E.g In-111 (See Saha Fig. 8.4 and Na-24 spectra).
- Annihilation peaks – If the gamma ray energy exceeds 1.02 MeV then it can interact in the crystal by pair production and one or both of the 511 keV gamma rays may be detected or escape creating peaks at 0.511, 1.02, Ep-0.511 and Ep-1.02 MeV. (See Na-24 and Zn-65 spectra.

Detection Efficiency

\[ \text{Eff} = f_i \times f_p \times f_g \times N_i \]

- \( f_i \) is intrinsic detector efficiency
- \( f_p \) is photopeak efficiency (photofraction)
- \( f_g \) is geometric efficiency
- \( N_i \) is gamma ray abundance, photon yield (gammas per decay) efficiency

http://www.amptek.com/gamma8k.html

Probability of interaction in NaI at 30 and 76 mm thick
\( f_g \) is geometric efficiency

Detector surrounds source, e.g., liquid scintillation counter, PET camera? 4π
Detector subtends \(~1/2\) sphere, \(2\pi\) Often much less than these two case

\( f_p \) is photopeak efficiency (photofraction)

\( f_p = \frac{\text{Counts in photopeak}}{\text{Counts in whole spectrum}} \)

\( N_i \) is gamma ray abundance,

- Also called photon yield
- Also called gammas per decay

Information readily available from many sources. E.g., MIRD documents, Cherry, Sorenson and Phelps, ICRP data, websites, etc.

\[
R_t = \frac{R_o}{1 - \frac{R_o}{R_{\text{true}}}}
\]

\[
\text{max for non-paralyzing model} = \frac{1}{T} \quad \text{max for paralyzing model} = \frac{1}{e}
\]

\[
R_o = R_{\text{true}}/T \quad \text{Ro} = R_{\text{true}}/T^n
\]