EVALUATION OF GAMMA SPECTRA

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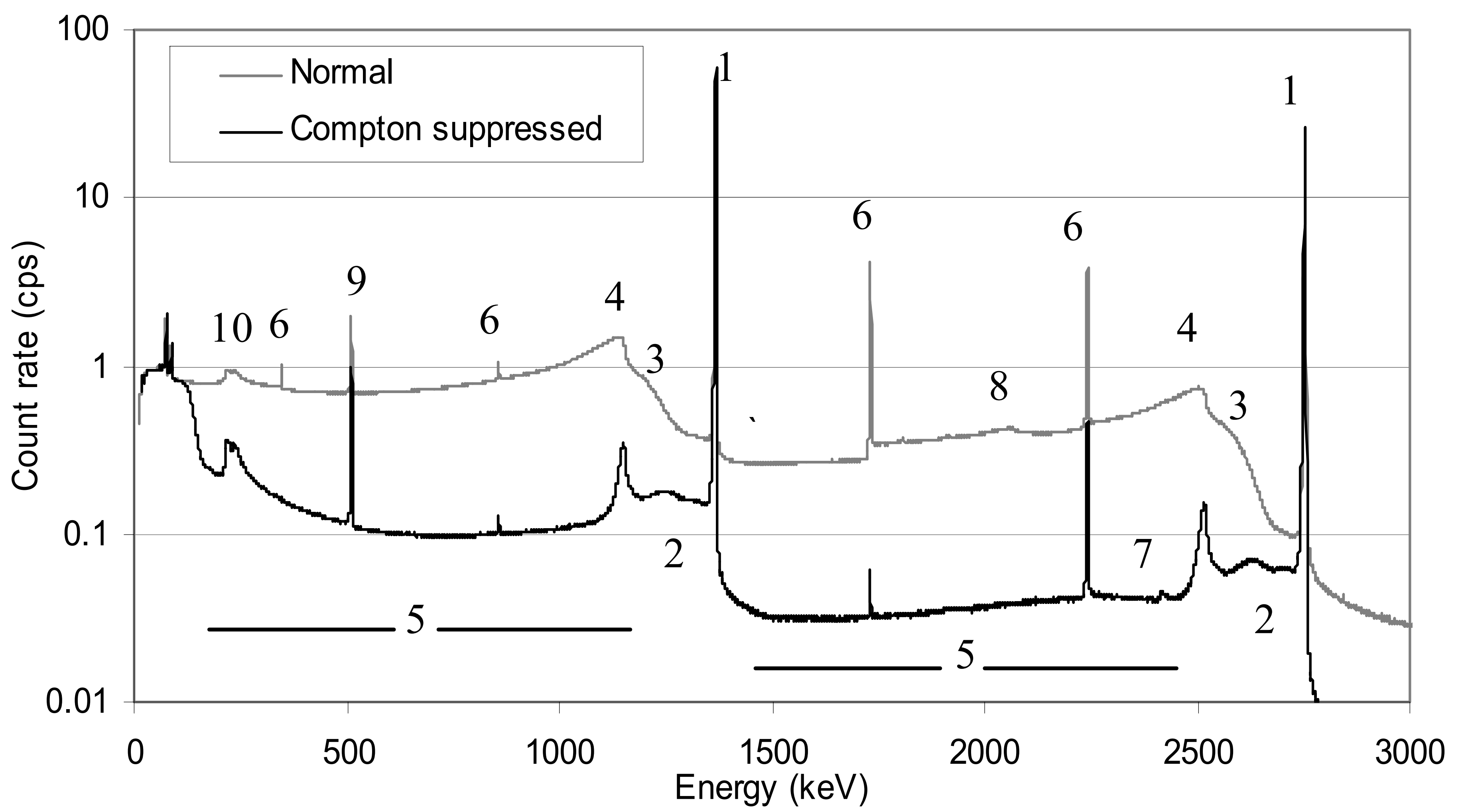
Response function of the HPGe



1. Full-energy peak (FEP), when the photon loses all its energy within the active volume of the detector.
2. Step below the full-energy peak, when the photons lose a small amount of energy in low-angle Compton scattering in the collimator or in the dead region of the detector followed by full absorption of the scattered photon.
3. Multiple Compton scattering region below the full energy peak and above the Compton edge.
4. Compton edge about 220–250 keV below the full energy peak. It is a result of a single Compton-event and corresponds to the highest energy left in the detector in a single scattering. The Compton edge is below the FEP with an energy of $E^2/(255.5 + E)$ (where E is the energy of the FEP in keV), as calculated for free electrons.
5. Compton continuum, when the Compton photon leaves the detector.
6. Single and double escape peaks are 511 and 1022 keV below the full energy peak. They are produced when one or both annihilation photons leave the detector.

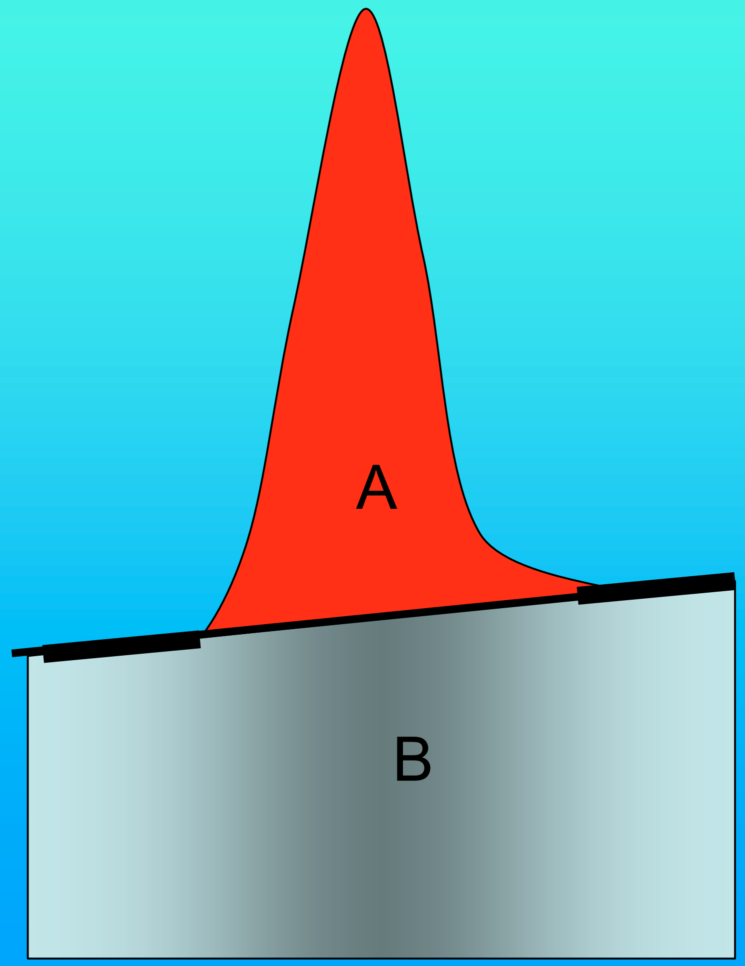
7. Between the single escape peak and the Compton edge there are events from single escape processes. The escaping 511 keV photons may produce a Compton scattering before leaving the sensitive volume. Even a peak due to back scattering of the annihilation photon from the cold finger can be identified at the energy of E – 341 keV. This component is stronger for high-energy photons, which penetrate deeper in the detector.
8. Between the single escape and double escape peaks there are events from Compton scattering of both escaping 511 keV photons, which leave the sensitive volume. Their Compton edge is 170 keV below the single escape peak. Sometimes a back scattered peak of one of the escaping 511 keV photons can be identified at 341 keV below the single escape peak.
9. Annihilation peak at 511 keV, when an annihilation radiation produced in the surrounding structural material or the sample is detected.
10. Back scattering peak at 220–250 keV is produced when back-scattered Compton-photons from the sample chamber and other structural materials in front of the detector are observed. (The exact energy is $E^2/(255.5 + E)$.) In the special case plotted in the previous there are two back scattering peaks according to the two gamma energies, while in the typical prompt gamma spectra it covers a wider region.

Simplest case

- linear background
- simmetric peak
  - Gaussian
  - (Lorentzian, Voigt-function for X-ray peaks)

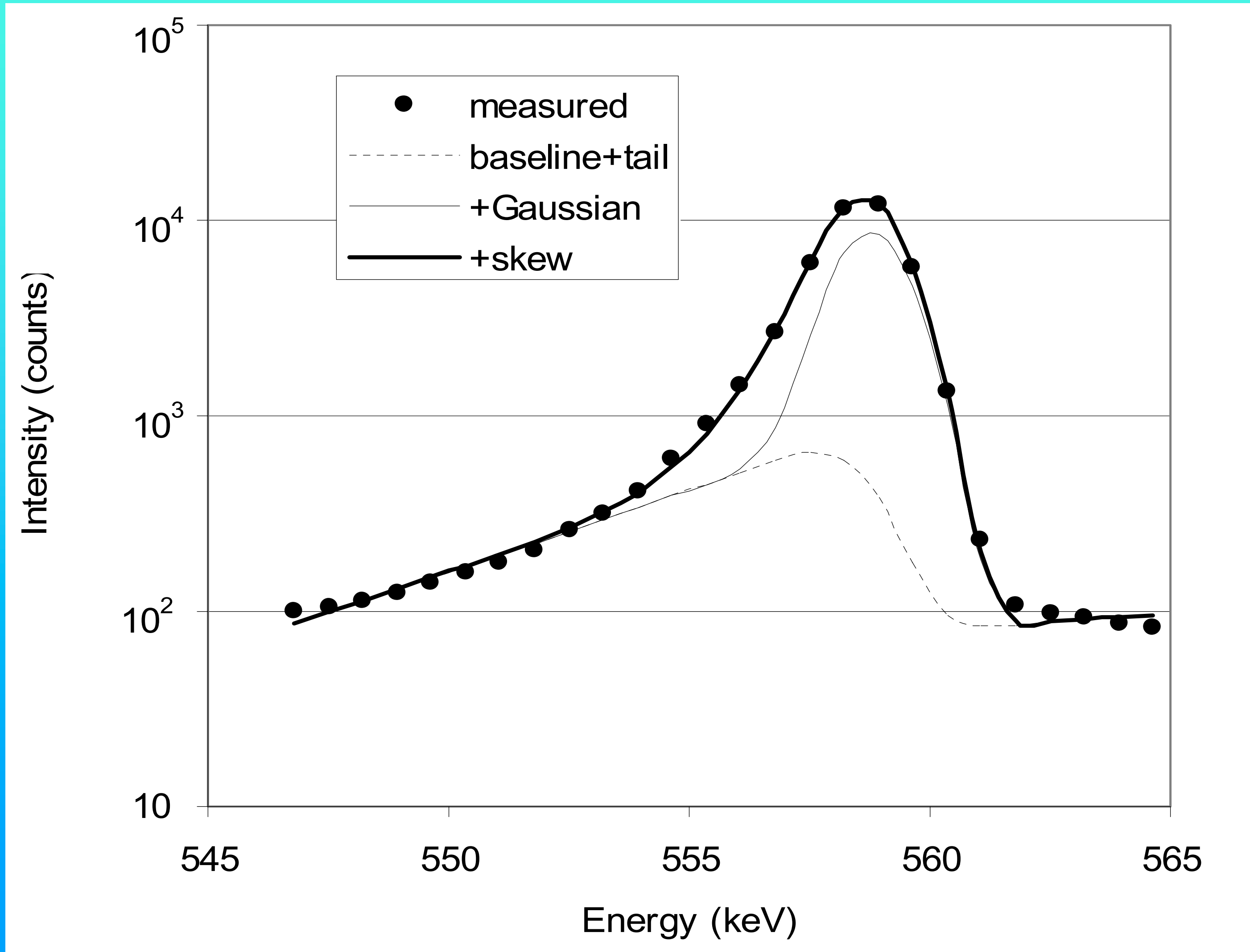
Fitting simmetric peaks on linear background

- Peak summing



$$A \pm (A + \varepsilon B)^{1/2}$$

Shape of a gamma peak in more general cases



Components of the peak shape

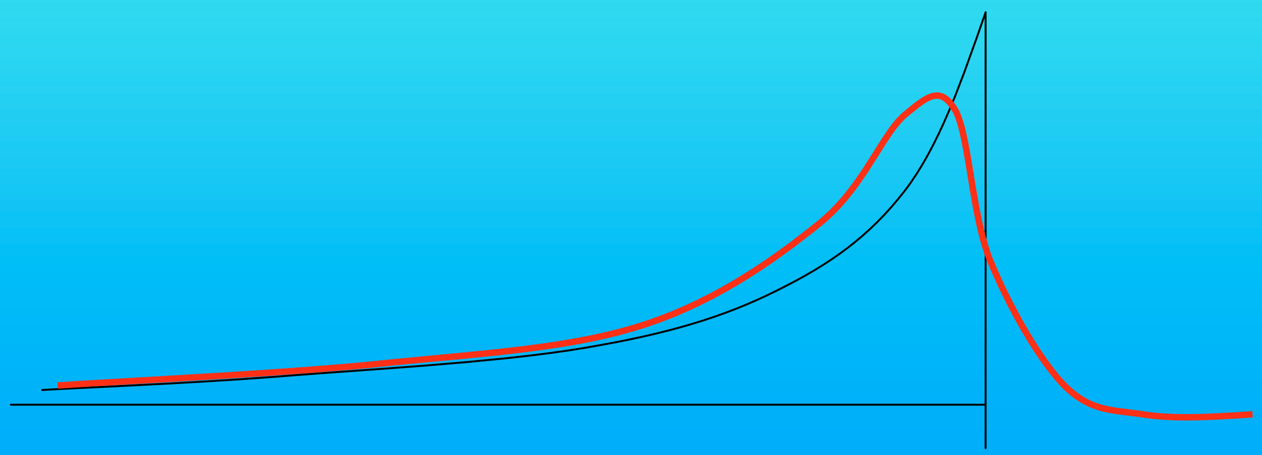
- base-line
  - linear, polinomial
- peak dependent background
  - step (collimation)
  - tail (incomplete charge collection, pile-up, Compton scattering)
- peak
  - Gaussian
  - left skew (incomplete charge collection)
  - right skew (pile-up)

Gaussian

$$g_{E_0,A,\sigma}(E) = \frac{A}{\sqrt{2\pi\sigma^2}} e^{-\frac{(E_0 - E)^2}{2\sigma^2}}$$

Exponentially Modified Gaussian

- convolution of exponential decay with a Gaussian

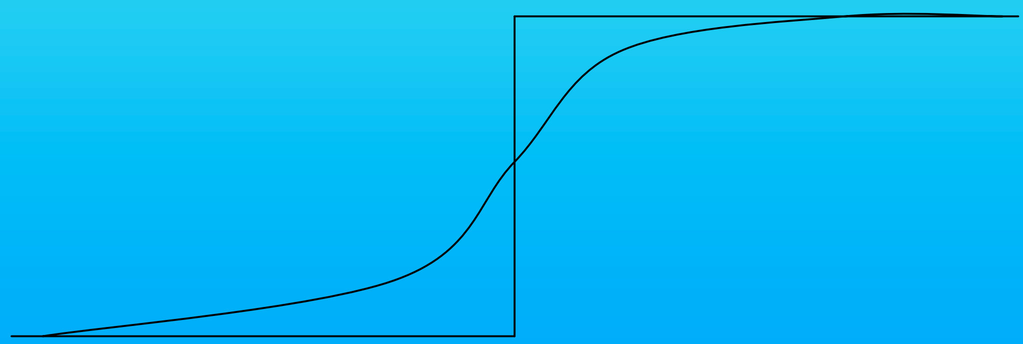


EMG

$$EMG_{E_0,\alpha,\beta,\sigma}(E) = \frac{1}{2}\alpha\, e^{-\frac{E-E_0}{\beta}} \operatorname{erfc}\left(\frac{E-E_0}{\sqrt{2}\sigma} + \frac{\sigma}{\sqrt{2}\beta}\right)$$

Smooth step

- convolution of step function with a Gaussian = erf function



Hypermet history

- 1970s for Ge(Li) detectors, Phillip & Marlow (Naval Res. Lab.)
  - for mainframe computers, in FORTRAN
- 1980s VAX version, PC version
- 1992—97, Hypermet-PC, in C++ (Béla Fazekas†, Institute of Isotopes)
  - modifications (Révay 2001)
- 1997— Hyperlab (J. Östör)

Hypermet peak shape

- 2nd order polynomial baseline
- background
  - step (erf)
  - tail (long EMG)
- peak
  - Gaussian
  - skew (short EMG)

Hypermet peak shape

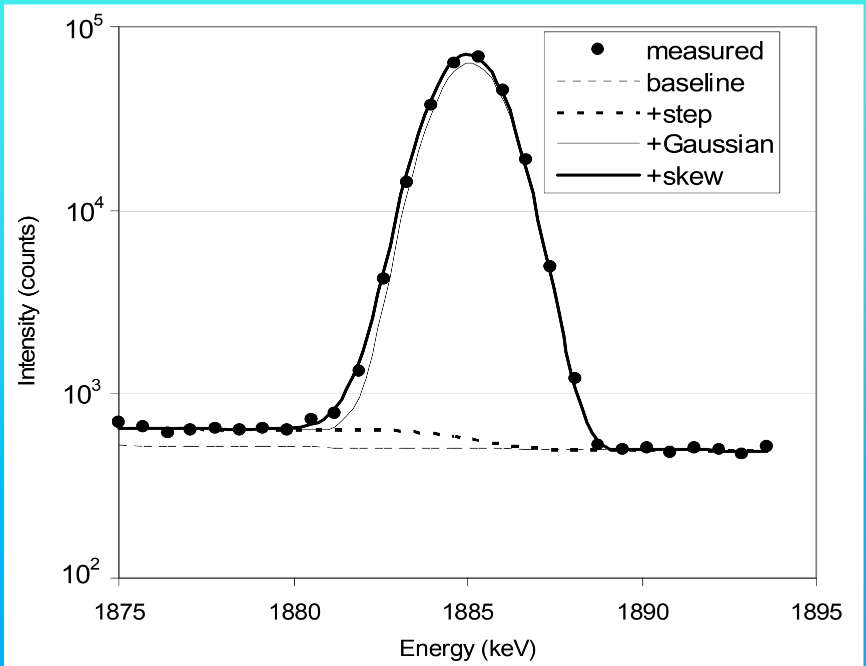
Gaussian	+	left skew	+
step	+	tail	+
baseline			

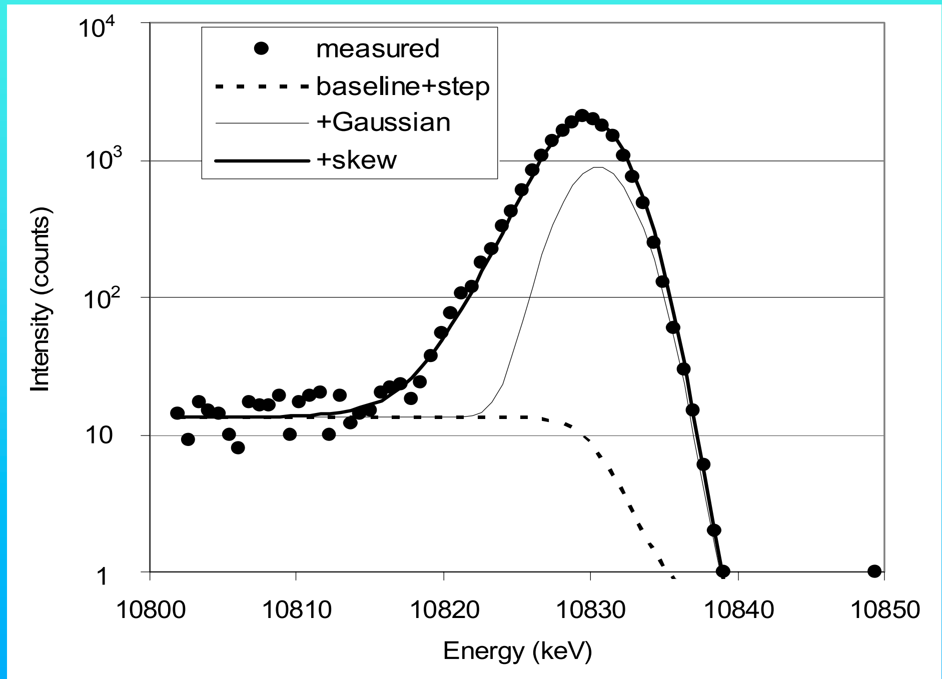
$$y(j) = \left[\Gamma_i e^{-\frac{(j-E_i)^2}{\delta^2}} \right] + \left[\frac{1}{2} \alpha_i \, e^{\frac{j-E_i}{\beta}} \operatorname{erfc}\left(\frac{j-E_i}{\delta} + \frac{\delta}{2\beta} \right) \right] +$$

$$\left[s_i \operatorname{erfc}\left(\frac{j-E_i}{\delta} \right) \right] + \left[\frac{1}{2} \sigma_i \, e^{\frac{j-E_i}{\tau}} \operatorname{erfc}\left(\frac{j-E_i}{\delta} + \frac{\delta}{2\tau} \right) \right] +$$

$$a_0 + a_1 j + a_2 j^2$$

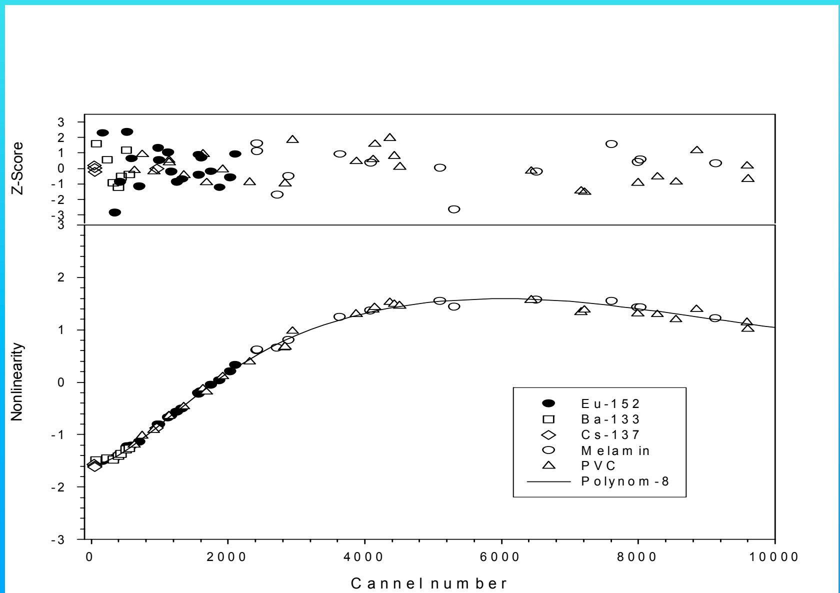
Peak fits at different energies



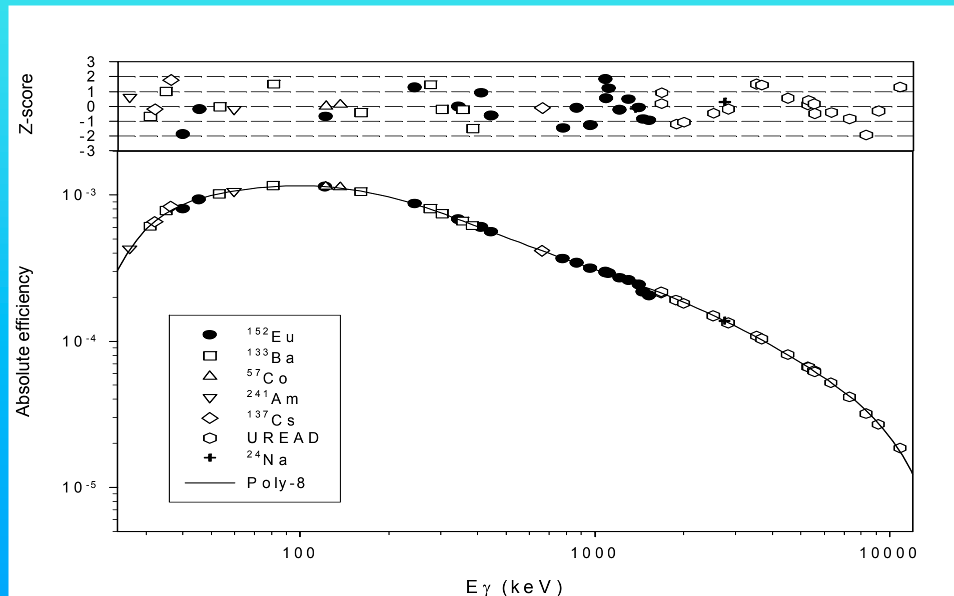


Calibration routines

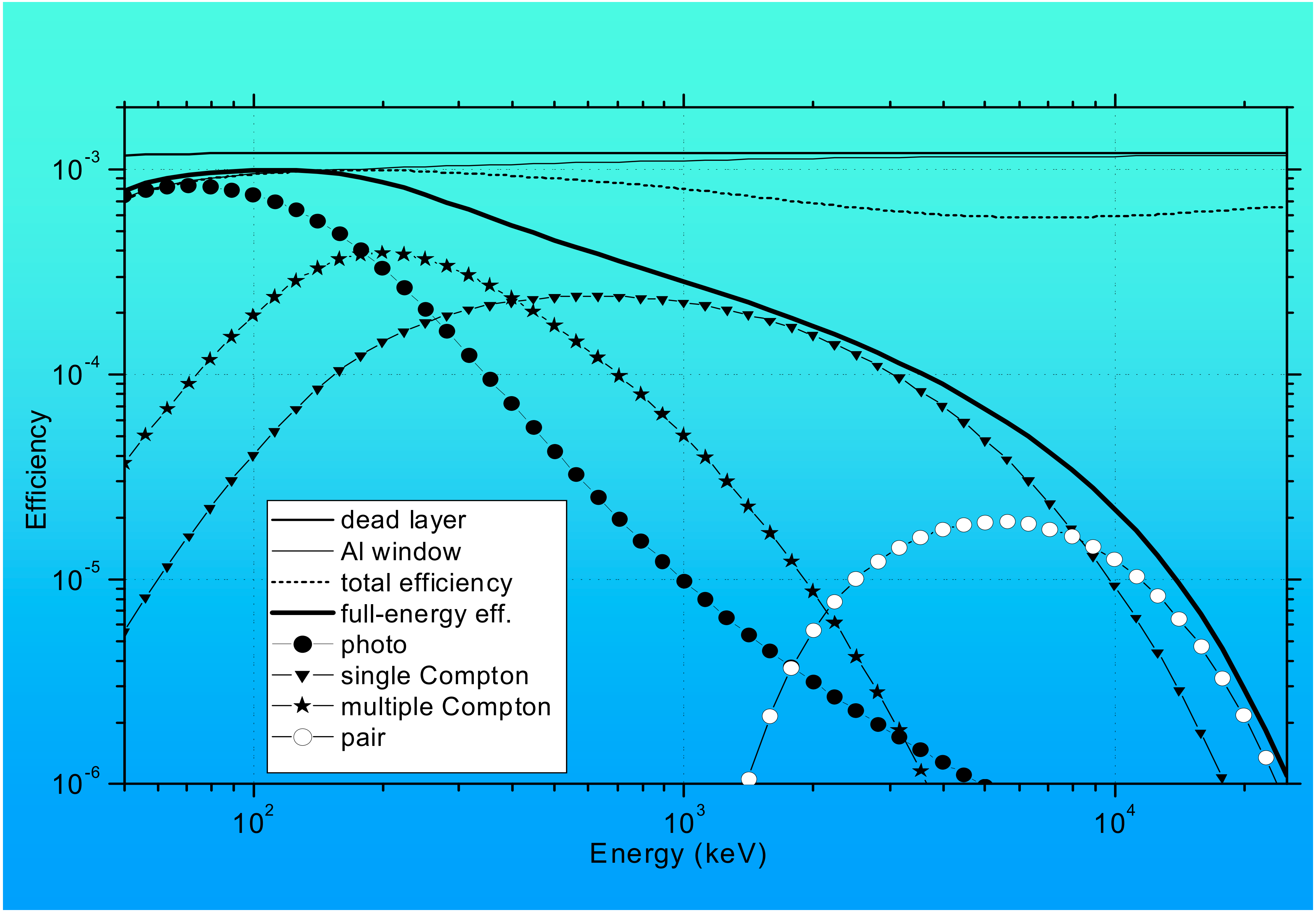
- non-linearity
- efficiency
- peak width



non-linearity



efficiency



Efficiency
Energy (keV)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{2}
10^{3}
10^{4}
dead layer
Al window
total efficiency
full-energy eff.
photo
single Compton
multiple Compton
pair