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Gamma Ray Line Shapes from Cadmium Zinc Telluride Detectors: An Interim Report

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Gamma ray detectors made of cadmium telluride and cadmium zinc telluride (CZT), operating at ambient temperatures, are potentially useful for applications in Safeguards Technology, such as assay and isotopic analysis of nuclear materials in the field[1,2]. Techniques are now becoming available for fabricating reasonable size CZT detectors with good enough resolution for such applications. Also, work is in progress to develop a portable system incorporating a CZT detector[3].

Gamma spectra obtained with CZT detectors usually have a significant tail on the low energy side of the photopeak. This is believed to be due to the unfavorable charge transport properties of the detector material itself. Thus, holes have relatively low mean free path in the material due to the low value of their mobility-lifetime product and are therefore trapped with high probability. To analyze complex gamma spectra obtained using these detectors, the gamma line shapes, including the amplitude and shape of the tail, must be understood.

Using standard gamma ray sources, we have studied the line shapes in spectra taken with a 5x5x5 mm detector made of cadmium zinc telluride in which Cd, Zn and Te had the weight fractions of 0.4, 0.1 and 0.5 respectively. This detector was made by eV Products and has a full-width-at-half-maximum (FWHM) of 2.7 keV (including the contribution from the tail) at 122 keV. The spectra were taken with the electronics setup described in Ref. 3.

We used gamma rays from ^{57}Co, ^{133}Ba, ^{137}Cs, ^{152}Eu and ^{241}Am, sources, thus covering the energy range 59 to 661 keV. After subtracting the background (as calculated by the method given in Ref. 4), the peaks were fit to a sum of a Gaussian and an exponential tail confined to the low energy side of the Gaussian. This description of the line shape is the same as that used in earlier work on Ge detectors at LLNL[4]. In the fits, there are five parameters in addition to the overall normalization: the peak energy and the width of the Gaussian, the relative amplitude and the slope of the exponential tail, and a cutoff parameter that makes the tail go smoothly to zero at the peak. Specifically, the expression used is:

$$N_i = N_0\{\exp[\alpha(\varepsilon_i-\varepsilon_0)^2] + T(\varepsilon)\}$$

where

N_i = net counts in channel ε_i,

N_0 = net counts at the peak,

α = $-(0.5/\sigma^2)$ = $-2.7726/(\text{FWHM})^2$ where
FWHM is the ull width of the peak at half maximum and
σ^2 is the variance of the Gaussian component,

ε_0 = the mean of the Gaussian, and

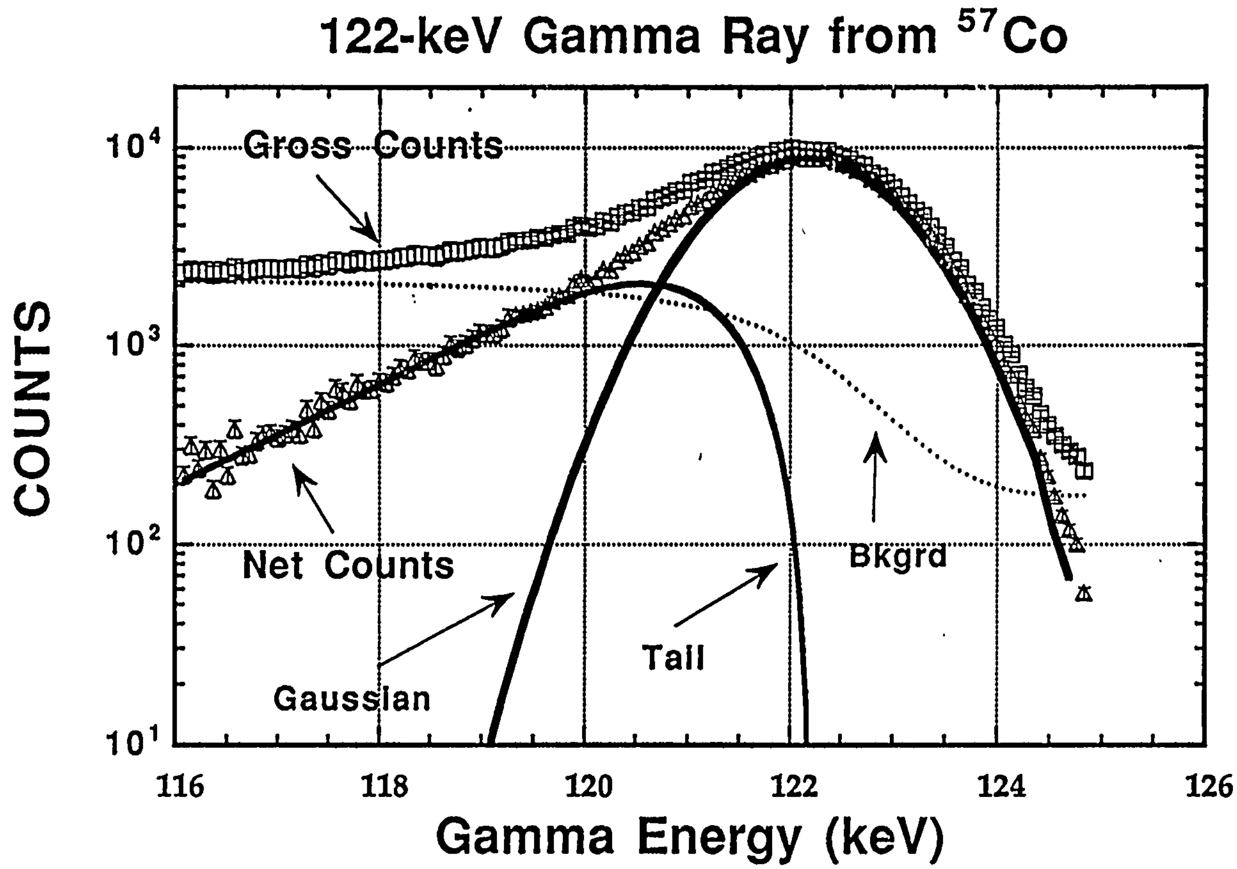
122-keV Gamma Ray from 57Co
COUNTS
10 4
10 3
10 2
10 1
Gross Counts
Net Counts
Gaussian
Tail
Bkgrd
116
118
120
122
124
126
Gamma Energy (keV)

Fig. 1

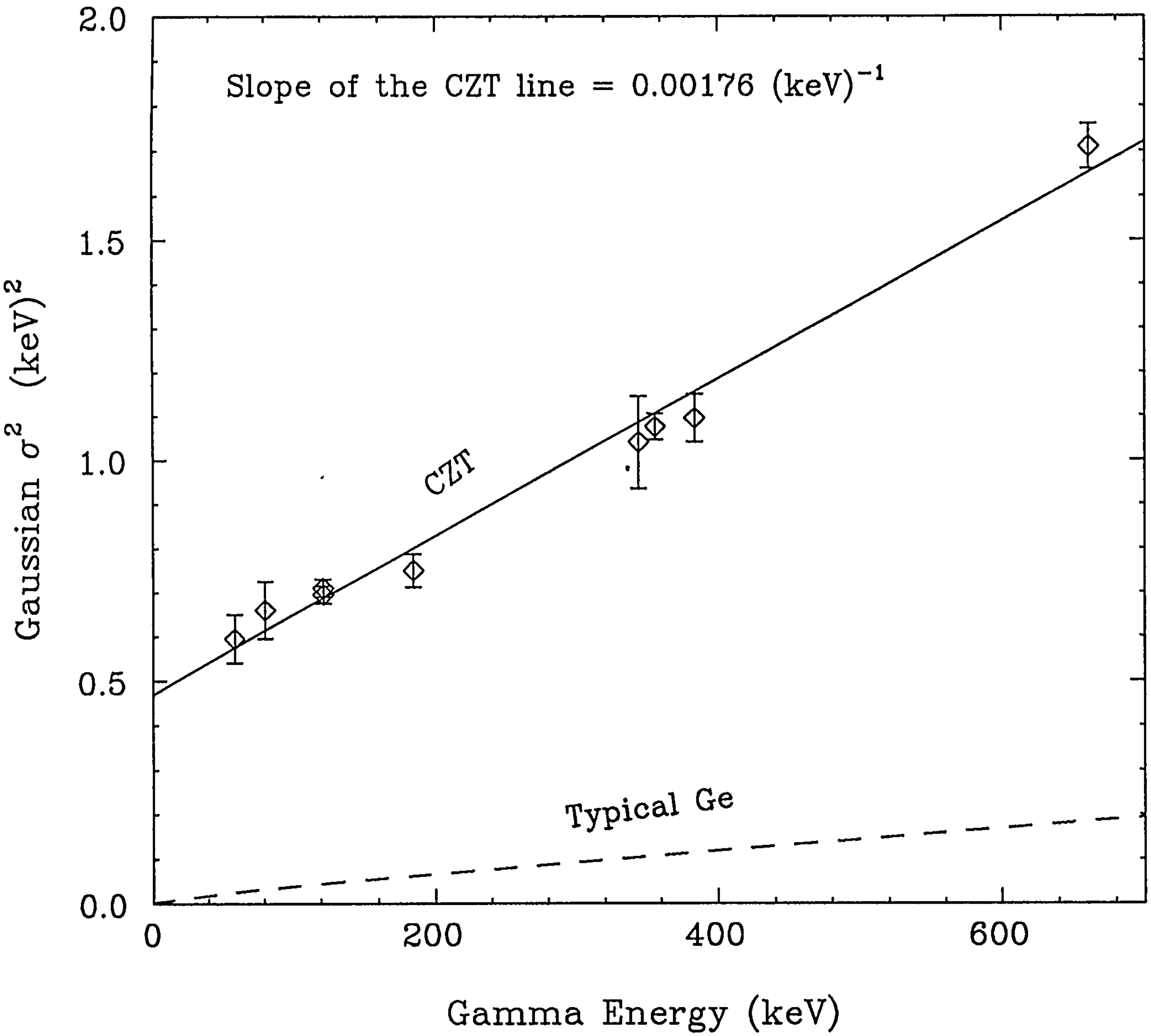
2.0
1.5
1.0
0.5
0.0
0
200
400
600
Gaussian σ² (keV)²
Gamma Energy (keV)
Slope of the CZT line = 0.00176 (keV)⁻¹
CZT
Typical Ge

Fig. 2

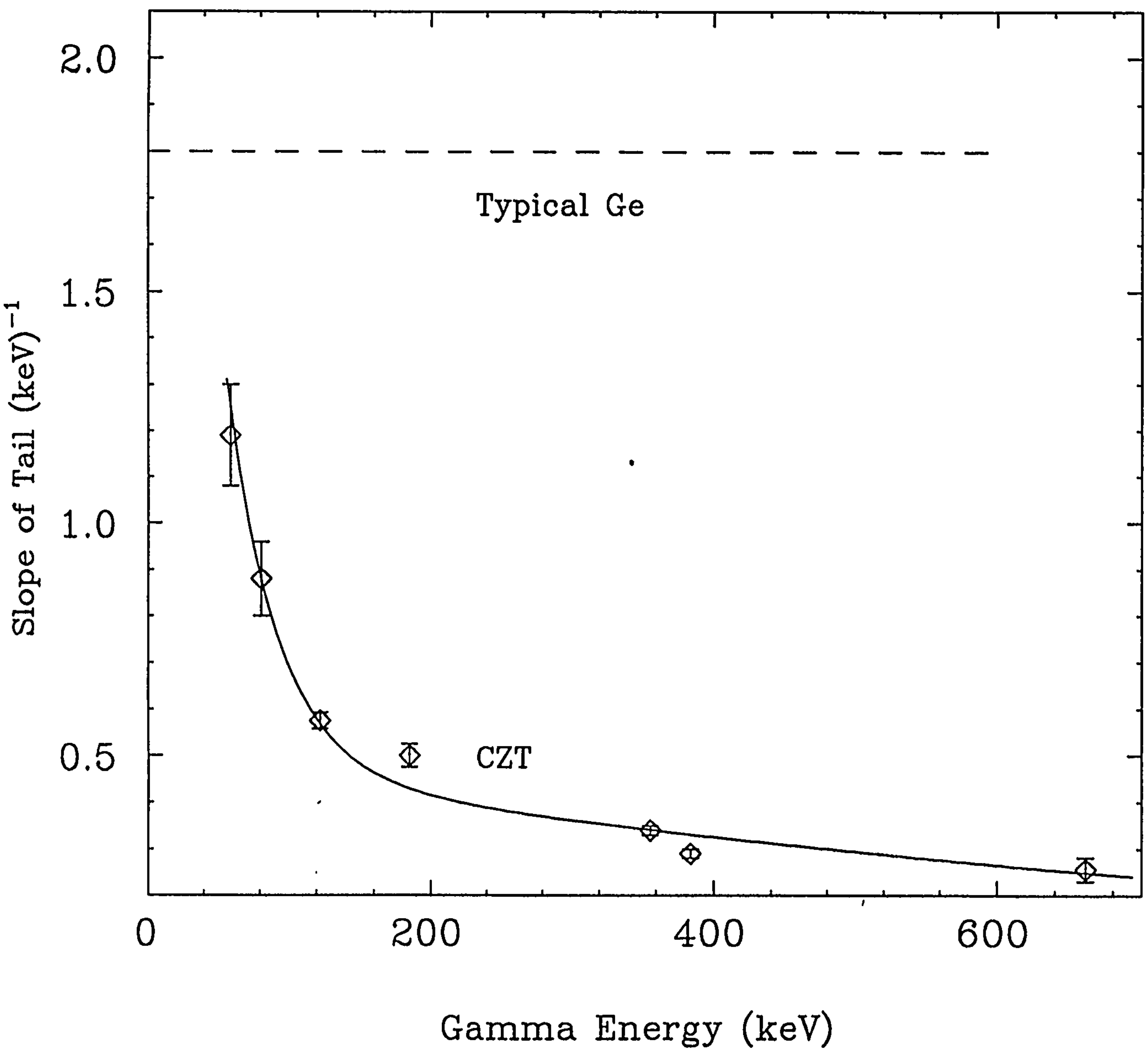
2.0
1.5
1.0
0.5
Slope of Tail (keV)$^{-1}$
Typical Ge
CZT
0
200
400
600
Gamma Energy (keV)

Fig. 3

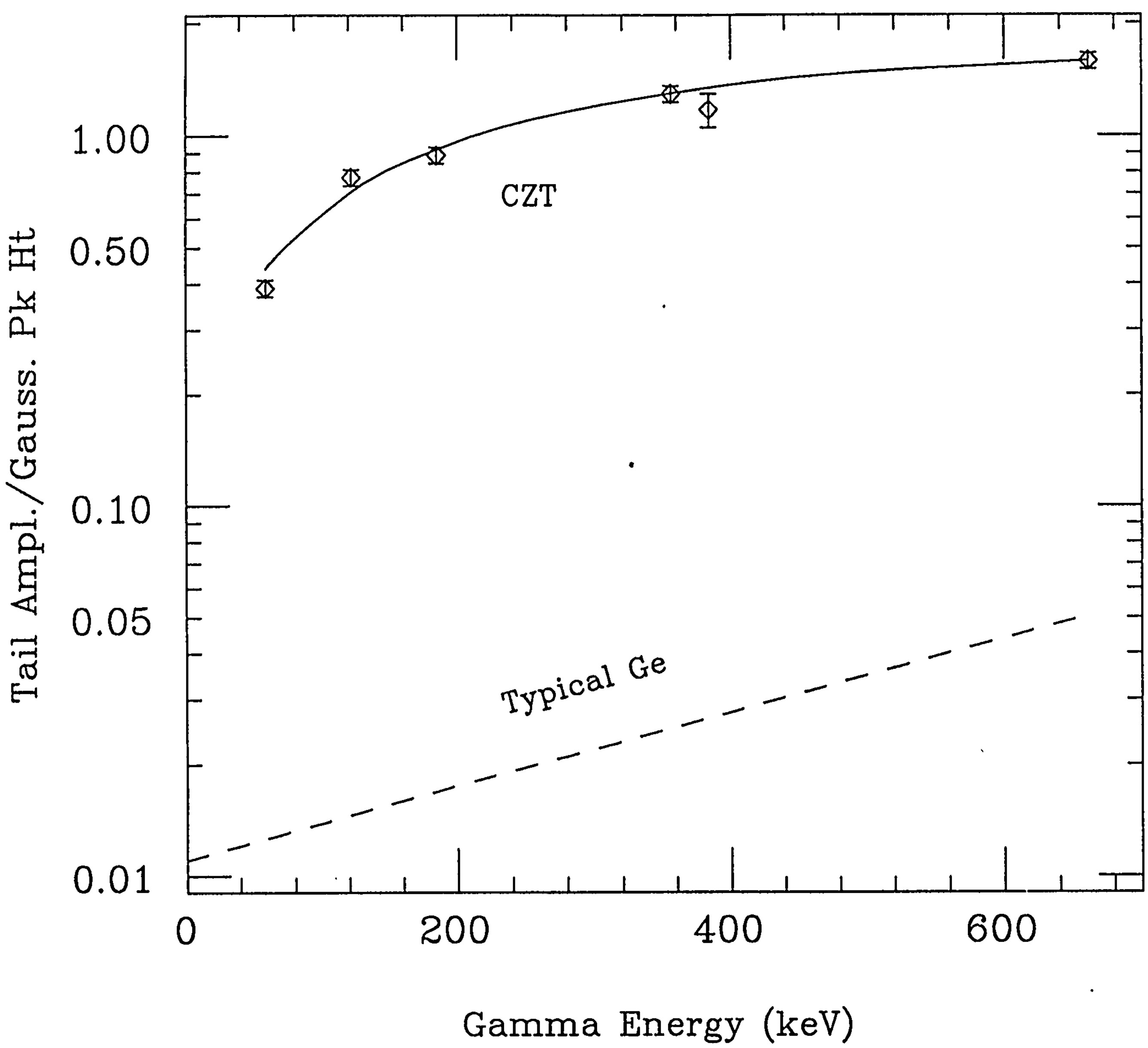
Tail Ampl./Gauss. Pk Ht
1.00
0.50
0.10
0.05
0.01
CZT
Typical Ge
0
200
400
600
Gamma Energy (keV)

Fig. 4

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