Monte Carlo response function simulations for the HEXITEC CdTe detector

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1. Introduction

High atomic number semiconductor detectors such as CdTe (Z = 50) offer the possibility to detect X-ray energies above what is possible with Silicon or Germanium sensors [1]. Furthermore, due to a large band gap, CdTe detectors exhibit less thermal charge leakage and can therefore be operated at room temperature. However, phenomena such as polarization, event pile-up and charge sharing, affect CdTe detector performance and are yet to be fully understood.

2. The HEXITEC system

High energy X-ray imaging technology (HEXITEC) is a family of spectroscopic, single photon counting, pixel detectors developed for high energy X-ray and γ-ray spectroscopy applications. The HEXITEC ASIC has previously demonstrated good spectroscopic results when coupled with a 1mm thick CdTe detector, giving an energy resolution of ~1 keV FWHM at the 59.5 keV [2] and detecting photons up to ~ 200 keV. The ASIC anode consists of an 80x80 pixel array on a 250μm pitch.

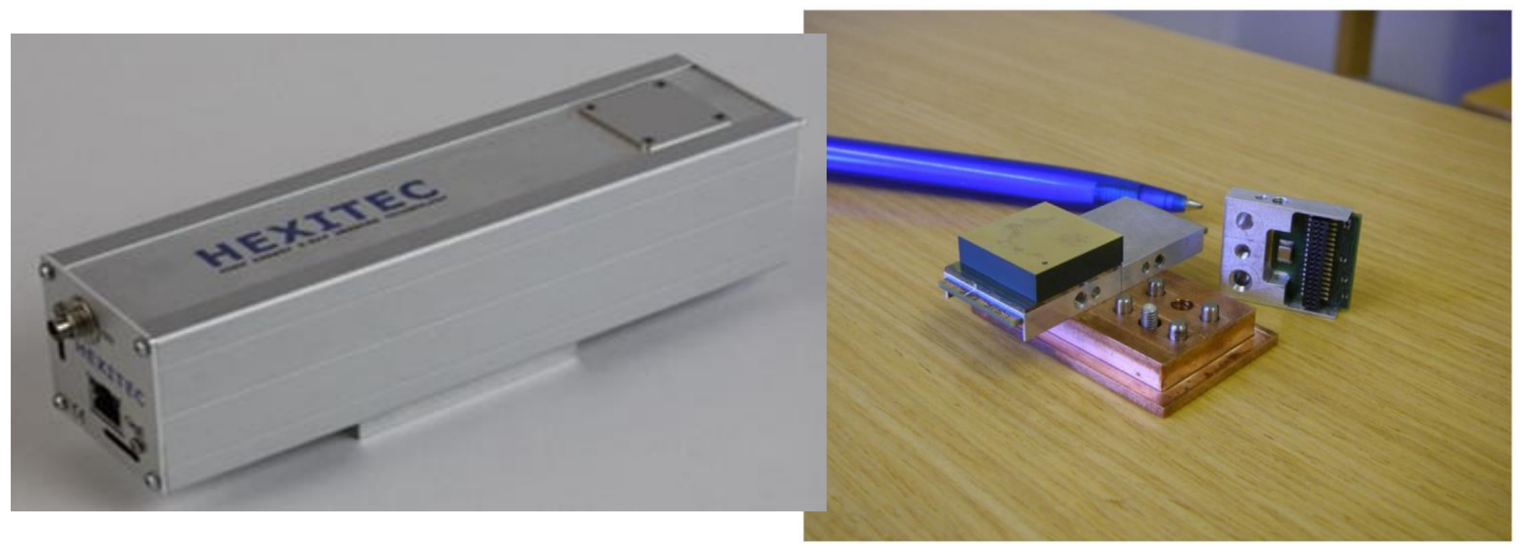

Figure 1. Left: HEXITEC, right: CZT detector [2].

3. Method

A Monte Carlo model, written in Python, has been developed. X-ray attenuation by Compton scattering, photoelectric effect and Rayleigh scattering is considered. The charge cloud size due to electron ranges, cloud diffusion during drift and charge collection efficiency (CCE) due to carrier trapping is calculated. Observations using the HEXITEC were made with radioisotopes ^{109}Cd, ^{241}Am and ^{57}Co which have primary photopeaks at 22, 59.5 and 122 keV respectively.

The HEXITEC detector benefits from the small-pixel effect; when the pixel size, *w*, is small compared to the thickness of the detector, *L*. This influences the weighting potential, shown in figure 2, which improves the CCE by favouring charge collection from the electrons over the holes. Both weighting potentials are included in the model.

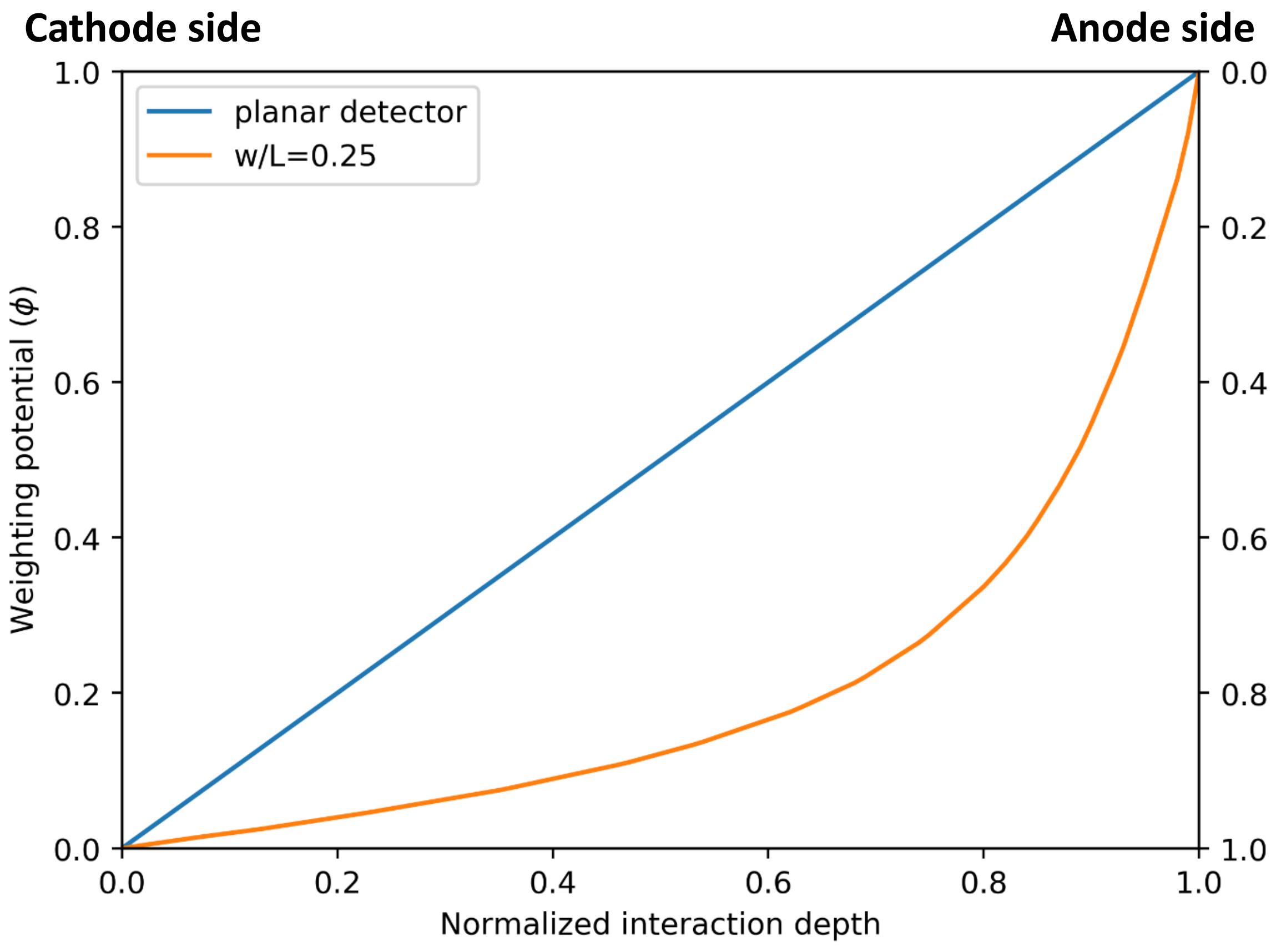

Figure 2. Weighting potential for the Hecht equation to calculate CCE for a planar detector w=L, and HEXITEC detector, w/L = 0.25, showing small pixel effect [3].

4. Results and Discussion

Figure 3 shows a ^{57}Co spectrum from the HEXITEC collected over all pixels compared with a simulated model. Both spectra are normalized to the main photopeak at 122 keV. With the exception of the Te escape peak, a good agreement for the Cd escape peak and Cd & Te XRF which are re-absorbed within the detector is seen, with a slight over-estimation from the model.

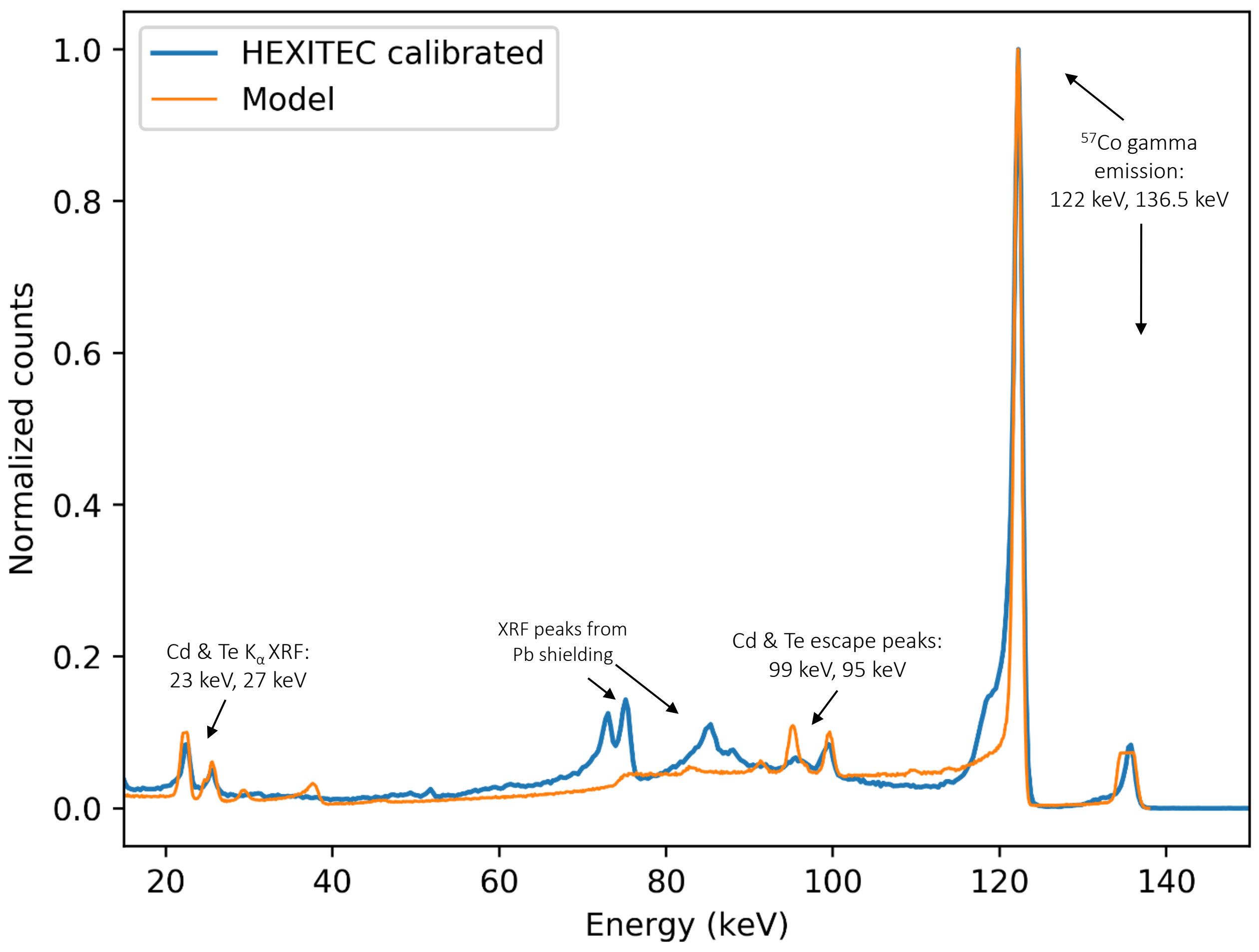

Figure 3. ^{57}Co spectrum from HEXITEC and model.

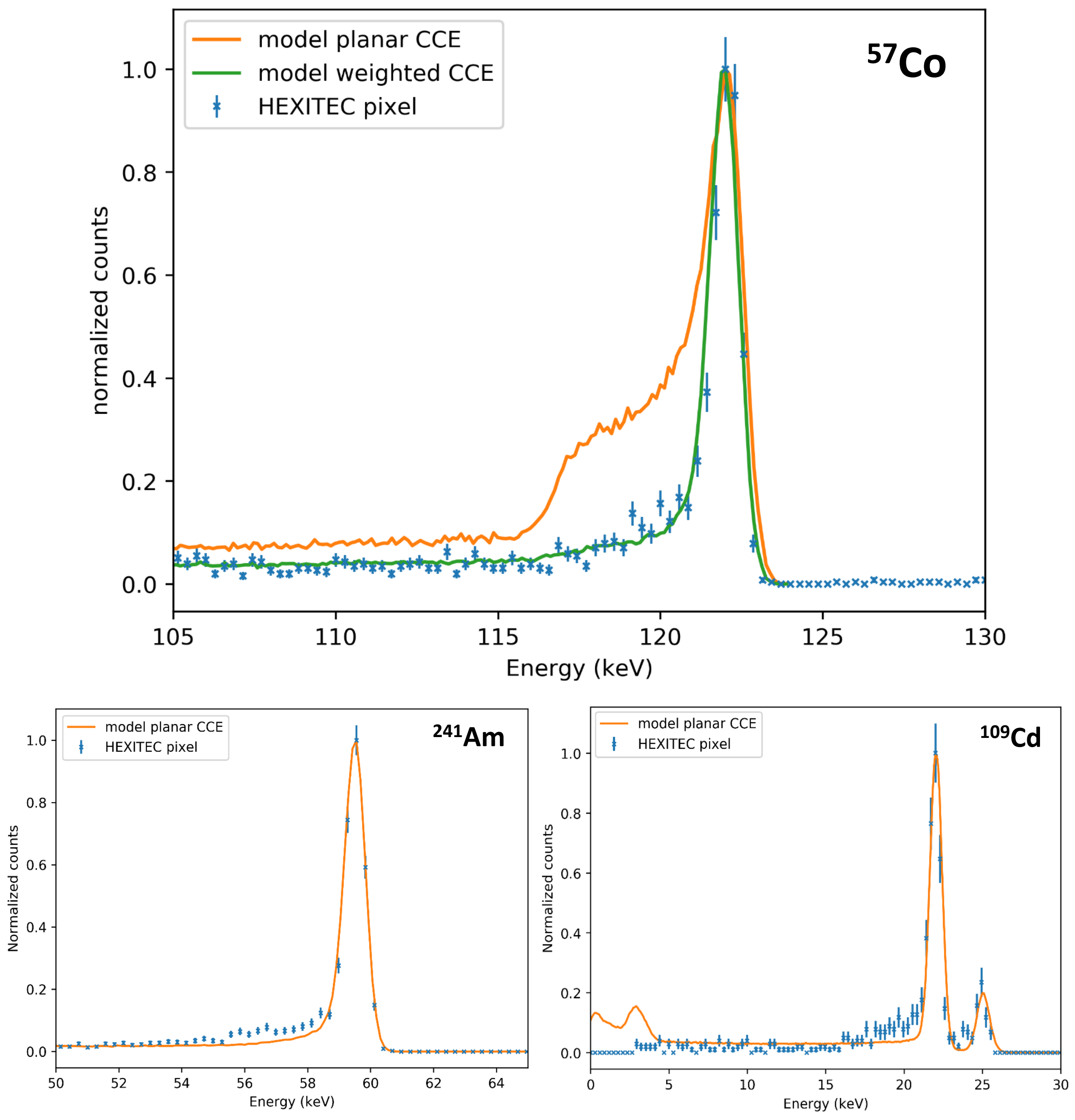

Figure 4. Model vs HEXITEC data for a single pixel, biased at -500V and 80e$^-$ noise.

Figure 4 shows the simulated model against HEXITEC data for a single pixel – the orange curves represent CCE for a planar detector (i.e. worst case scenario), and the green curve the CCE after correction by the small-pixel effect weighting. For the photopeaks at 22 and 59 keV for ^{109}Cd, ^{241}Am respectively, the 'tail' cannot be modelled using the CCE. At 122 keV for ^{57}Co, the model for the weighted CCE gives a good fit, whereas the planar CCE significantly over-corrects. Figure 5 shows charge loss between two HEXITEC pixels – a loss of up to ~5 keV can be seen.

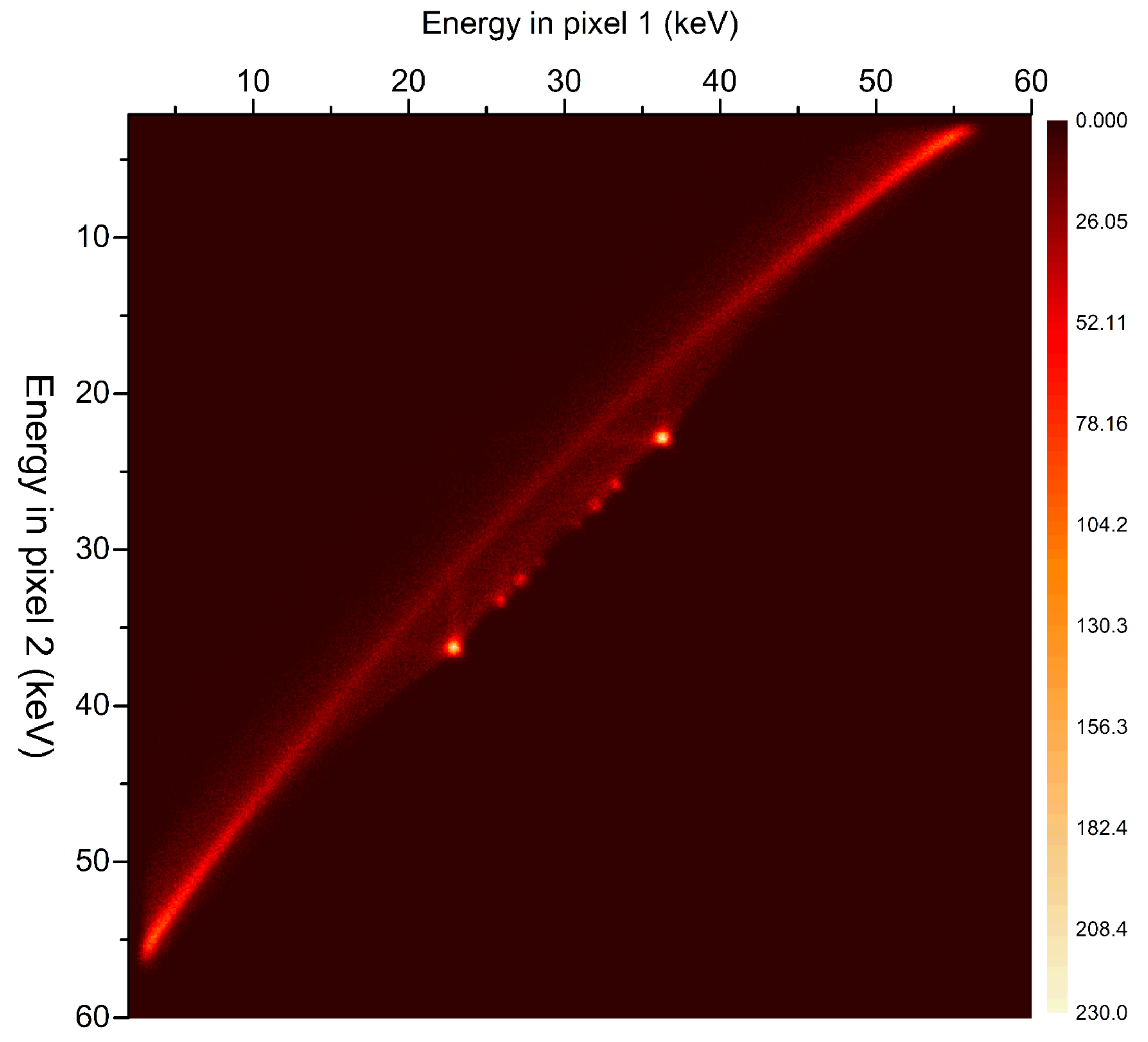

Figure 5. Charge sharing between adjacent pixels for 59 keV line from ^{241}Am source.

5. Conclusions

- The tail to the left of the photopeak at lower energies (22 and 59 keV) may not be due to charge trapping but instead result from effects such as charge sharing or polarization.
- At higher energies (122 keV) the dominant source of the tail appears to be charge trapping.

1. S. Del Sordo, Progress in the development of CdTe semiconductor radiation detectors for astrophysical and medical applications, Sensors (2009)
2. M. L. Wilson et al, A 10cm10cm CdTe Spectroscopic Imaging Detector based on the HEXITEC ASIC, JINST 10 (2015) P10011
3. D.D. Duarte, Simulation of active-edge pixelated CdTe radiaton detectors, Nuc. Inst. and Meth. In Phy. Res. A. (2015)