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Pulse Pileup Models for Spectral X-ray Imaging

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This paper reports on the development and testing of analytical models for simulating the pileup effects on photon-processing detectors. With the Medipix3RX detector and other energy-resolving photon-counting detectors, pulse pileup distorts the measurement of the photon energy. This is particularly important in photon-processing detectors that use charge summing and inter-pixel communication such as the Medipix3RX detector used in MARS scanners.

The processing time for shaping and amplifying analogue pulses within the ASIC limits the count rate capability of photon-processing detectors when performed under high photon flux rates. Pileup effects also occur in semiconductor sensors arising from the overlap of the charge clouds from different photon events. When two or more photon events occur within this processing time, they are registered as a single event with an energy different from those of original photons.

The properties of GaAs and CZT sensors bump-bonded to Medipix3RX are investigated. Measurements of the resolving time and true interaction rate are presented. Several distribution functions are used to quantify the probability of counts that are registered at different energies due to pileup effects. The predicted spectrum from our model is compared with the measurements within the energy range of 20-130 keV. There is an excellent agreement between the measurements and our model for flux rates up to ten times higher than the typical operational rate. The results show that our pileup model is capable of simulating the measurements, even when up to 37.2% of counts were lost due to pileup.

Knowing the contribution of various pileup effects to the detector measurements allows compensation for energy distortion at higher flux rates. Integrating our pileup model into the MARS material reconstruction algorithm will result in improved spectral CT image quality and classification of materials particularly when using shorter scan times.

Primary author: Dr ATHARIFARD, Ali (Mars Bioimaging Limited)

Presenter: Dr ATHARIFARD, Ali (Mars Bioimaging Limited)

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