Count Rate Linearity and Spectral Response of the Medipix3RX Chip Coupled to a 300um Silicon Sensor Under High Flux Conditions

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Abstract

For clinical X-ray imaging, the detector performance under high flux conditions is very important, with typical flux rates for modern CT systems reaching 10^9 photons s^{-1} mm^{-2} in the direct beam. In addition, for spectral imaging a good energy resolution under these conditions is needed. This poses difficulties since pulse pile up in the pixel electronics does not only affect the count rate, leading to a deviation from the otherwise linear behavior, but also degrades the spectral response of the detector.

Measurement Setup

The measurements in this study were performed at the TOPO-TOMO beam line in the ANKA synchrotron. Monoenergetic X-rays from 6keV to 15keV were used and the sensor was flood illuminated. Two detectors were investigated, one with the intrinsic 55um pixel pitch of the Medipix3RX and one with 110um pixel pitch. The sensor material was Silicon in order to provide a clean signal and investigate the ASIC rather than effects in the sensor layer. The detectors were operated both in single pixel mode (SPM) and charge summing mode (CSM). Before the measurements the detectors were equalized using test pulses to optimize the energy response but no offline alignment of the spectrum or gain correction has been done.

Low Flux Energy Resolution

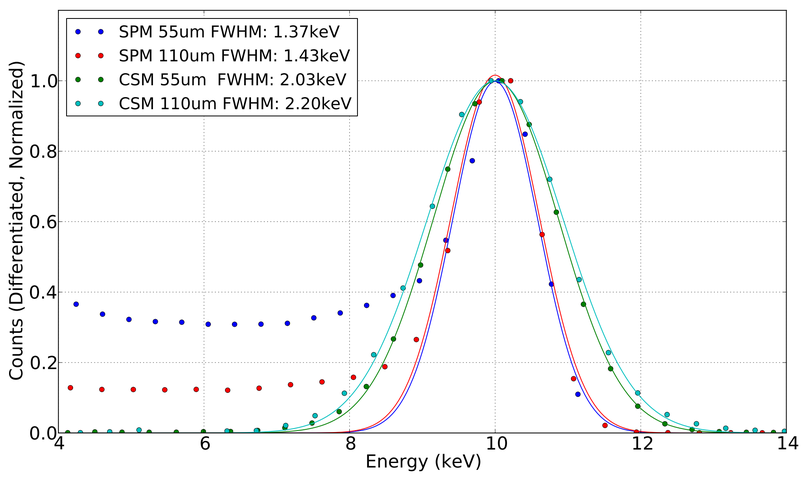

Figure 1: Measured energy resolution at 10keV under low flux

The detectors show similar energy resolution but the charge sharing is significantly lower for the 110um detector. In charge summing mode the charge sharing is fully suppressed for both detectors but the energy resolution is slightly degraded because of the added noise. It can also be seen that the Medipix3RX charge summing over an 110x110um^2 area is superior to fixed 110x110um^2 pixels due to the dynamic allocation of the summing area.

Count Rate Linearity

The readout electronics has one parameter I_{KRUM} which determines the return to zero time of the preamplifier. Changing this parameter effects the count rate linearity and the energy response.

Acknowledgements
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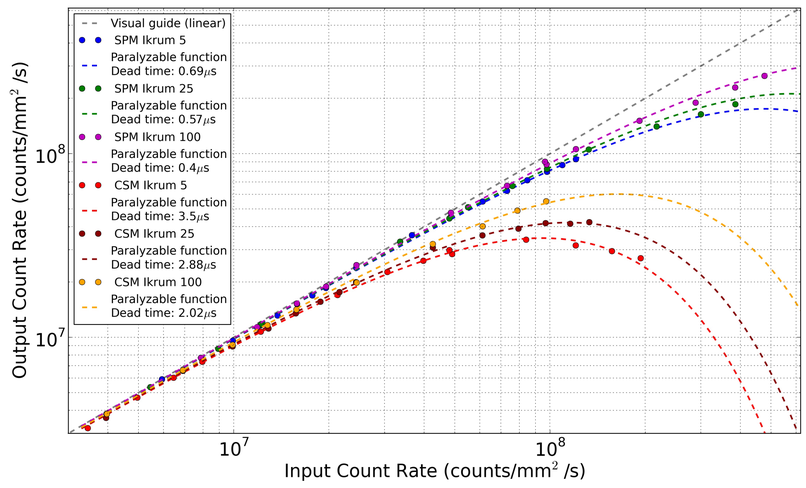
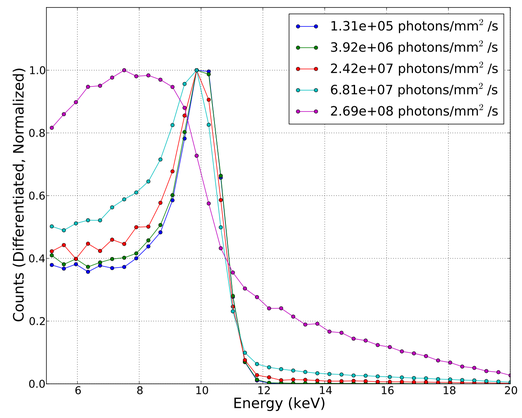


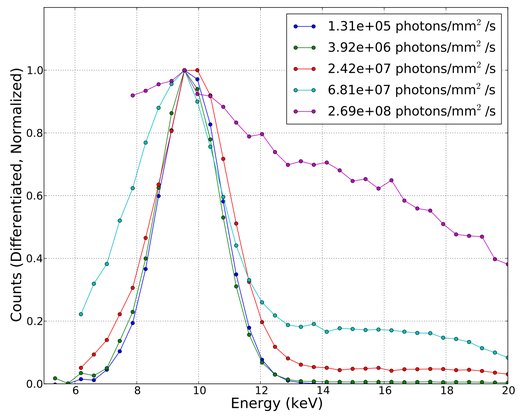
Figure 3: Output count rate as a function of input count rate for single pixel mode (SPM) and charge summing mode (CSM) at different Ikrum.

The count rate linearity was measured for various I_{KRUM} settings using 10keV photons and the threshold set at 7keV. Figure 3 shows the measurement points and the fitted dead times for the 55um detector. When compared to the 110um detector we see no difference in the count rate capability per pixel but due to the larger pixels it means that the 110um detector can handle four times less photons per unit area. As expected increasing values of I_{KRUM} imporves the count rate linearity.

Energy Response at High Flux

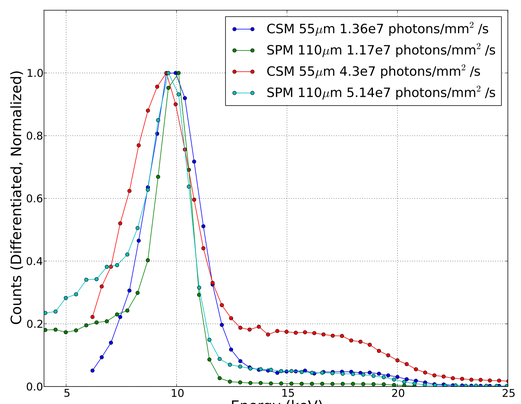


a) Single Pixel Mode (55um)
$\Phi_{0.9}$=6.1E7



b) Charge Summing Mode (55um)
$\Phi_{0.9}$=1.2E7

Figure 4:
Energy response at I_{KRUM}=25 under high flux conditions and the 90% linerity point $\Phi_{0.9}$ for a) single pixel mode and b) charge summing mode and c) comparison between 55um charge summing mode and 110um single pixel mode



c) CSM 55um and SPM 110

Conclusions

The count rate linearity and the energy response of the Medipix3RX chip has been measured for several operating points. The charge summing mode fully suppresses charge sharing in the investigated energy range but the count rate capabilities are about 4-5 times less then the single pixel mode as expected.

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