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P1.25: Experimental evaluation of signal-to-noise ratio in counting detectors under pile-up conditions

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As a follow-up of the Signal-to-Noise Ratio study presented previously [1], this work discusses the experimental results obtained for the statistical analysis of photon counting detector measurements.
A SPHIRD v1.0 ASIC [2] bump-bonded to a 50µm pitch electron collection silicon sensor 400 µm thick was used as the device under test. The ASIC analogical circuit generates a pulse of tens of nanoseconds for each hit, and its digital circuit includes the implementation of both amplitude and time-based pile-up compensation methods, being therefore an ideal candidate for this study.
The detector was illuminated with a direct beam of 15 keV monochromatic X-ray photons from the ESRF beamline BM05. Aluminium filters with thicknesses varying from 60 µm to 4 mm were used to scan the photon flux reaching the detector in a controlled manner. 500 acquisitions were taken for each filter step, and the input flux was measured simultaneously by a transmission Silicon diode in front of the detector as a reference.
To avoid experimental artefacts coming from drifts of the synchrotron ring current and beam instabilities that could affect the measurement of the statistical response, the variance of the output counts was obtained from the ratio of each two consecutive measurements at each step. The SNR conserved at the end of the detection chain was then obtained by applying the numerical method presented in [1]. In addition to standard photon counting operation, two pile-up compensation methods implemented in SPHIRD were tested: adding a second voltage discriminator at 135% of the pulse height and summing the extra counts (a method hereon called "Voltage Discrimination 1", or VDIS-1); and using an asynchronous clock pulse of 200MHz to measure the pulse length in time, later using this result to calculate the actual number of hits (method called "Fractional Photon Counting", or FPHC) [2]. The latter was also evaluated for different threshold levels.
The results were evaluated for individual pixels. The standard photon counting results reproduce the simulated behaviour, presenting a SNR2 response that peaks around 10 Mcps/pixel, and then drops to almost zero. Meanwhile, both pile-up compensation methods have presented a comparable effect on improving not only the count rate but also the statistical response of the system, for the covered count-rate range of up to 35Mcps/pixel.
The obtained results were encouraging and validate the presented methodology to obtain the SNR, also elucidating the pile-up detrimental effect on the statistical quality of the data. Further improvements on the simulation tool to accurately reproduce the charge-sensitive amplifier response of SPHIRD v1.0 and allow the precise simulation of these and other pile-up compensation methods are under development.

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