Simulation-based Investigation of Signal Processing Algorithms for Silicon Drift Detectors

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Due to their excellent energy resolution and high count rate capability silicon drift detectors (SDDs) are widely used for energy-dispersive spectroscopy in X-ray fluorescence analysis [1]. Output signals of SDDs are preamplified and evaluated in signal processing units in order to acquire X-ray energy spectra. In modern signal processing units the preamplifier output voltage is converted into a digital signal using an analog-to-digital-converter, and signal processing algorithms are applied in field-programmable-gate-arrays (FPGAs) [2]. Performance of SDD-based spectrometers strongly depends on signal processing algorithms implemented in the FPGA. Algorithms aim for optimization of spectra quality, signal throughput, detection of light elements, high-energy efficiency, and computing efficiency [3]. This work presents simulation-based investigation of signal processing algorithms using time domain signals generated by a Monte-Carlo-based model of SDDs [4]. Simulated detector data are used for computer-based investigation of signal processing, allowing algorithms to be realized in a high-level programming language without restrictions due to FPGA hardware resources and real-time capability. This method is applied for the investigation of two techniques presented in the past regarding their utilization with modern SDDs: First, findings regarding detector reset triggered by the signal processing unit after successful evaluation of an X-ray are presented [5]. Results show that efficiency at high X-ray energies can be improved up to 13 % compared to detector reset at a fixed voltage threshold when processing 30 keV X-rays with a rate of $20 \cdot 10^3$ counts per second using an energy filter peaking time of 100 ns. It will be shown how benefits of the method are decreased for high count rates, long energy filter peaking times, and low X-ray energies. Furthermore, adaptation of the energy filter's peaking time to the randomly distributed time intervals between X-rays on a pulse-to-pulse-basis is investigated [6]. Exemplary results are shown for 6 keV X-rays with a rate of 10^6 counts per second. Using an energy filter with a static peaking time of 200 ns a dead-time ratio of about 61 % and a full-width at half maximum (FWHM) energy resolution of 133 eV was found. Utilization of an energy filter with adaptive peaking times between 200 ns and 500 ns improves the FWHM energy resolution to 129 eV without suffering additional dead time. Figure 1 shows exemplary traces of simultaneous signal processing with static and adaptive energy filter. Drawbacks of adaptive energy filters like count rate dependency of energy resolution and deviation of spectrum peak shape from gaussian will be shown.

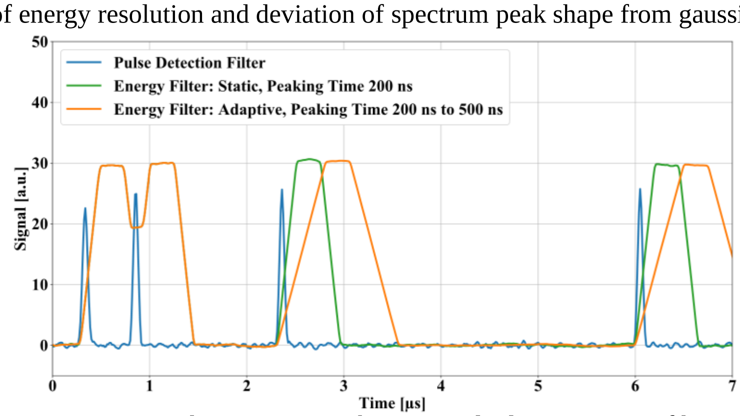

Figure 1: Signal processing with static and adaptive energy filter

[1] B. G. Lowe and R. A. Sareen, "Semiconductor X-Ray Detectors", Taylor & Francis Ltd., 2017.
[2] M. Nakhostin, "Signal Processing for Radiation Detectors", John Wiley & Sons, Inc., 2018.
[3] J. J. Friel and R. B. Mott, "Energy-Dispersive Spectrometry from Then until Now: A Chronology of Innovation", Microscopy and Microanalysis, Volume 4, Issue 6, pp. 559-566, 1998.
[4] F. Rettenmeier and L. Maurer, "Development and application of a simulation environment for the analysis of EDX signal processing algorithms", 9th World Congress on Spectroscopy & Analytical Techniques, 2019.
[5] D. A. Landis et. al., "Transistor reset preamplifier for high rate high resolution spectroscopy", IEEE Transactions on Nuclear Science, Volume NS-29, No. 1, pp. 619-624, 1982.
[6] H. Koeman, "Discussion on Optimum Filtering in Nuclear Radiation Spectrometers", Nuclear Instruments and Methods 123, pp.161-167, 1975.