# Development of digital signal processing for the readout of complex Ge(i)-detectors

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Advanced experiments, associated with the investigation of atomic processes in heavy-ion atom collisions, require application of complex solid state detectors for the detection of X-ray photons [1-3]. Very recently, particular attention has been paid to precise X-ray measurements at the ESR storage ring at GSI in Darmstadt, concentrated around the Lamb shift in hydrogen-like high-Z ions [3]. However, in order to achieve considerable advance in the field, further accuracy improvements of the measurements are required. This should be allowed in the next generation of experiments because of the application of a focusing crystal spectrometer combined with a position sensitive micro-strip detector, equipped with up to 200 strips [1]. In the X-ray energy region of interest, i.e. above 15 keV, germanium seems to be the best material for the fabrication of such detectors, foreseen for position sensitive x-ray spectroscopy [4].

A segmented germanium pixel detector (16 pixels) was successfully tested for the polarization study of radiative electron capture (REC) into the K shell of bare uranium ions [2]. To simplify fast and reliable processing of signals from segmented germanium detectors, a new flexible multi-channel read-out and data acquisition system was developed and tested. The idea comprises both hardware and software development. This digital system, based on the continuous signal sampling, is presented below.

The voltage pulses provided by the charge sensitive preamplifiers, connected directly to Ge detectors, form the inputs for the designed read-out board. The height of these pulses, for the lowest X-ray energies of interest, is in the mV range and, on average, only slightly exceeds the noise level. In the case of the weakest pulses registered, a typical signal to noise ratio is of about two. Timing parameters of the rising edge of the pulse determine the position of the X-ray interaction within the detector crystal. To extract the time and amplitude (energy) information, the noisy input signals are amplified first, without any shaping, and then digitized. Only a simple CR high-pass filter is used to reject the omnipresent 50 Hz hum (Fig. 1).

The read-out electronics is split into 16-channel boards. Each channel on the read-out board contains the input amplifier, the ADC (Analog to Digit Converter) and the FIFO (First In First Out) memory. The logic controller on the board controls the operation of the input channels and the digital data transmission to the receiving device. The structure of one input channel is presented in Fig. 1.

The boards are read sequentially. The digital data from all the boards are transmitted with one 50-way cable to the VME crate in the event by event mode. The acceptable distance between the detector and the VME crate is up to 100 meters.

The data packets will be further on-line processed in the SAM3 VME module developed at GSI Darmstadt [5], and will be accessible to the user via the VME crate controller.

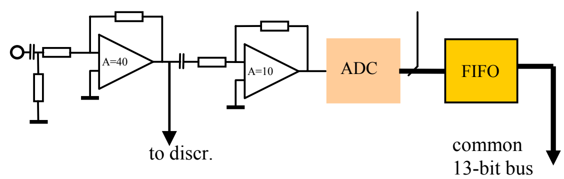


Fig.1 Structure of one input channel

The main advantages of the new read-out electronics are: reduced noise pick-up, low channel to channel cross talk, improved signal to noise ratio, high reliability, modular structure (easy to upgrade), low cost per channel, fast on-line data processing. In order to obtain information on the energy and time of the detected photon from the digitized data stream, special algorithms have been developed and prepared.

When the trigger signal appears, the pre-defined number of digital samples, taken before and after the trigger signal, is stored in the FIFO memory of each channel. The length of the time window is approximately in the range of 0.1– 4.0 μs.

A single channel planar Ge(i) detector (ORTEC GLP 16195/10-S) has been used for test purposes, utilizing $^{241}$Am and $^{133}$Ba standard calibration sources. The signal output from the read-out board were filtered and cleaned by DSP algorithms. An example spectrum of the amplitude of the signal is shown in Fig. 2. The amplitude (energy) resolution is approximately 1.3% (800eV) for the 60 keV line.

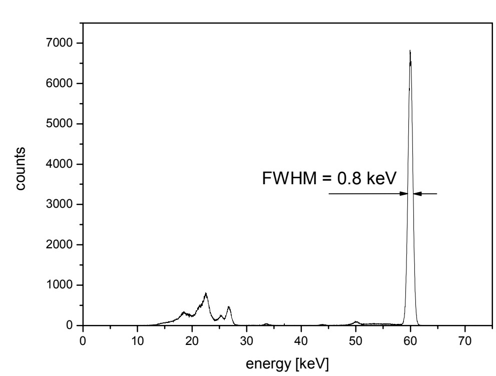


Fig 2. Energy spectrum for $^{241}$Am source registered via new read-out board.

Next, measurements of the time difference between trigger and energy signal were performed. Here, the $^{133}$Ba source was used. For a single X-ray line, the achieved time resolution is of a few ns.

The board was also used to measure the $^{241}$Am energy spectrum with a 16-fold pixel Ge(i) detector. Fig. 3 presents an example spectrum measured by one of the pixels (pixel number 14).

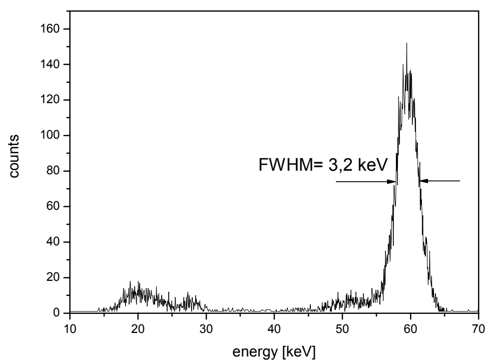


Fig. 3 $^{241}$Am energy spectrum registered by one pixel of the 16-fold detector

The designed read-out board along with the prepared software shows excellent energy and time resolution. Moreover, the results point to the possibility of improvement, particularly on the software side. This development is in progress and will be concentrated on multi-dimensional detectors which goes towards precise X-ray tracing.

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