DIGITAL DATA ACQUISITION FOR γ AND PARTICLE SPECTROSCOPY*

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The data acquisition (DAQ) system of the HPGe-detector array HORUS at the Institute for Nuclear Physics at the University of Cologne is currently being updated. Instead of using analogue DAQ techniques to obtain γ and particle spectra as well as the corresponding coincidence matrices, the 80 MHz Multichannel Digital Gamma Finder (DGF-4C Rev. F) developed by XIA, which samples the pre-amplifier signal directly, is employed. The DGF module and the new DAQ have been tested extensively and compared to the former analogue data acquisition using α and γ sources and the results of these tests are presented.

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1. Introduction

The 10 MV Tandem accelerator at the Institute for Nuclear Physics at the University of Cologne has been temporarily out of operation for the last two years to enable the installation of a new 6 MV Tandetron Accelerator at the new Accelerator Mass Spectrometer CologneAMS [1]. In the course of the overall refurbishment during this halt, a new digital data acquisition [2] for the HORUS spectrometer was set up.

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2. HORUS

The HORUS spectrometer consists of 14 HPGe detectors surrounding the target as can be seen in figure 1. This configuration will yield a photo peak efficiency of up to 5%. To reduce the Compton background, six detectors can be equipped with BGO shields. Instead of one single detector, composite detectors like clover or cluster detectors can be used, *e.g.*, to enable Compton polarimetry [3]. To prevent neutron damage to the detectors, it is possible to activate the targets 1 m downstream outside of the spectrometer. The activated target is then moved into the spectrometer and off-beam spectrometry is performed. Due to a motor-driven slide ("β"-slider), beta decay studies of short-lived ($\tau \geq 1$ s) isotopes are still feasible [4].

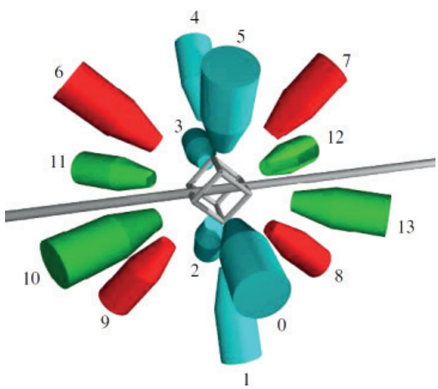

Fig. 1. Schematic view of the detector positions in the standard HORUS setup, from [4]. The detectors are positioned on the corners and faces of a cube.

3. Digital DAQ at HORUS — XIA DGF-4C Rev. F module

The former data acquisition at HORUS [5] was designed for a maximum of 16 channels. To be able to use the modularity of HORUS by adding auxiliary detectors, a new data acquisition with more channels had to be installed. Apart from being less space consuming, the higher reliability and (assumed) better performance at high count rates (*e.g.* concerning dead time) lead to replacing the former data acquisition by the commercial solution of XIA LLC, *i.e.* the DGF-4C Rev. F module [6]. In each channel of this module, a Pipeline ADC samples the pre-amplifier signal directly with a sampling rate of 80 MHz. The digitised signal is then passed on to an FPGA, that applies two moving window filters. The slow energy filter parameters (both its rise time and flat top) are used to optimise the energy resolution *versus* the throughput. An additional parameter, that corrects for the slope of the signal in the slow filter, is also crucial for obtaining the best energy resolution. The trigger threshold has to be set just above the noise level for best energy resolution. If the signal passes the pile-up rejection and externally applied gates, it is processed and stored by the DSP. When the on-board memory is full, it is read out to a computer via USB. Since the bandwidth using USB 2.0 is higher than that of the former system FERA-BUS, this is an improvement for the readout of HORUS. The most important results of the optimisation of the parameters for the detectors in the standard HORUS setup are shown and compared to analogue data below.

3.1. Energy resolution

For most of the experiments that have been and will be conducted at the accelerator in Cologne, high energy resolution is crucial to obtain high sensitivity. Since a new particle detector array will be used within the HORUS spectrometer, the resolution of silicon detectors was also investigated. A comparison of the resolutions achieved with the HPGe detectors in the standard HORUS setup (at 500 to 3 000 cps) is given in figure 2. It is clearly visible that both data acquisitions yield comparable results with the digital DAQ performing slightly better (the average difference $\langle \mathrm{FWHM}_{\mathrm{dig.}} - \mathrm{FWHM}_{\mathrm{ana.}} \rangle$ is -0.05 keV). Another comparison of HPGe detectors at different count rates and the resolution of α-energies for a PIPS Si detector are given in Table I as well as the corresponding spectra in figure 3. Obviously, the high resolution of the HPGe detector is (at least) maintained when switching from analogue to digital readout. The peak shape is

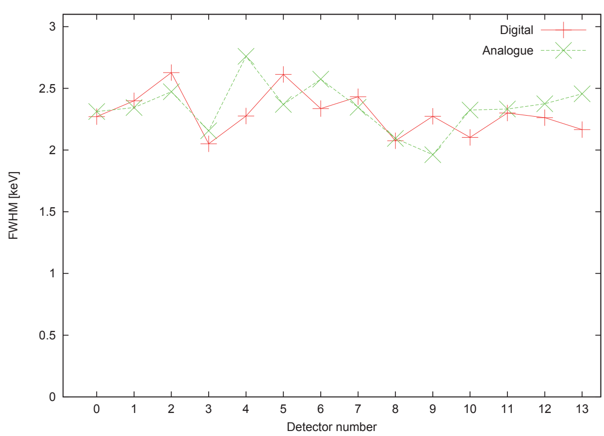

Fig. 2. Energy resolution of the HPGe detectors on HORUS, determined for the 1332 keV transition of ^{60}Co. The rise time of the DGF filter was set to 6 μs and the flat top to 1.2 μs. The analogue shaping time was set to 3 μs or 6 μs respectively (depending on the detector) to achieve an optimal analogue resolution.

also identical, which can be seen in figure 3. The energy resolution of the α-detector is somewhat worse, however the peak shape is also very similar, so it is acceptable.

TABLE I

Energy resolution of an HPGe detector in HORUS setup at two different rates and of a PIPS Si detector.

Detector	Rate [cps]	Energy [keV]	$FWHM_{ana.}$ [keV]	$FWHM_{dig.}$ [keV]
HPGe	1 000	1 332	2.08(3)	2.08(2)
HPGe	10 000	1 332	2.51(1)	2.55(1)
PIPS Si	500	5 805	20.20(7)	21.34(3)

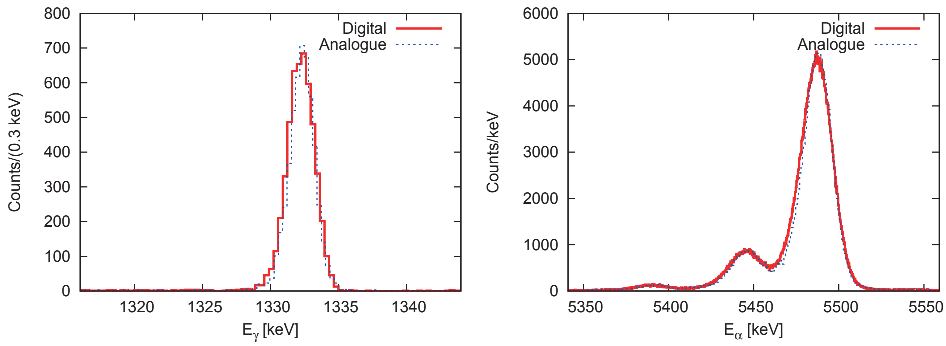

Fig. 3. Comparison of the analogue and digital spectrum of ^{60}Co recorded by an HPGe detector at 1 000 cps (left) and of ^{244}Cm recorded by a PIPS Si detector at 500 cps (right). The values for the FWHM are given in Table I.

3.2. Timing properties

The timing resolution of the digital data acquisition suffers from relying on a leading-edge trigger, which gives rise to walk effects. However, it was possible to improve the timing resolution by implementing an off-line walk correction which applies an energy-dependent time correction by an empirical function.

3.3. Dead time performance

Another important characteristic of the data acquisition system is the dead time. In the DGF module, it is mainly caused by the processing time of the DSP and the readout time. Both can be significantly reduced by applying a trigger logic, *e.g.*, on particle-γ or $\gamma\gamma$ coincidences. The individual contributions as a function of the count rate will be subject to further investigations.

3.4. Off-line analysis

Since the DGF data acquisition is fast enough to store energy and time values in an event-by-event mode, the data can be analysed off-line, which allows for much more complex algorithms. Since the off-line analysis is a demanding task, the new software SOCO has been developed which cannot only handle the format of XIA, but can be easily adapted to all event-by-event mode data [7].

4. Summary and outlook

The new digital data acquisition based on the XIA Digital Gamma Finder Rev. F has been proven to be competitive to the former analogue setup concerning energy and time resolution. The energy resolution gave the same value with both readout techniques, the timing property was in the expected range and was improved by adding an off-line walk correction. Concerning the dead time, the digital DAQ performed better than the former analogue system. Future tests will be performed in in-beam experiments, since the refurbished accelerator is expected to be operational this year. With a well-known reaction, the system as a whole will be validated; *e.g.*, concerning angular correlations. Since the new data acquisition will also provide more channels, a new target chamber consisting of eight $\Delta E - E$ detectors will be mounted inside the HORUS spectrometer, measuring the energy and angular distribution of γ rays and particles simultaneously.

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