DIGITAL PULSE PROCESSING ALGORITHMS DEVELOPED FOR FISSION FRAGMENT SPECTROSCOPY

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Introduction

Goal of this work was mass and TKE dependence of PFN distribution measurement in (n_{th}, f) reaction. We adopted the approach of C. Budtz-Jorgensen and K.-H. Knitter [1], where it can be done by measurement of mass yield versus TKE in two measurements with and without demanding coincidence between FF and PFN emission. Thanks to digital pulse processing, and PFN detection techniques we managed to modify B-K approach. In present paper we report some modifications related to software and mathematics of digital pulse processing (DPP) application to the fission reaction. Additionally we developed some automation of the data analysis process to accelerate cumbersome data analysis procedure.

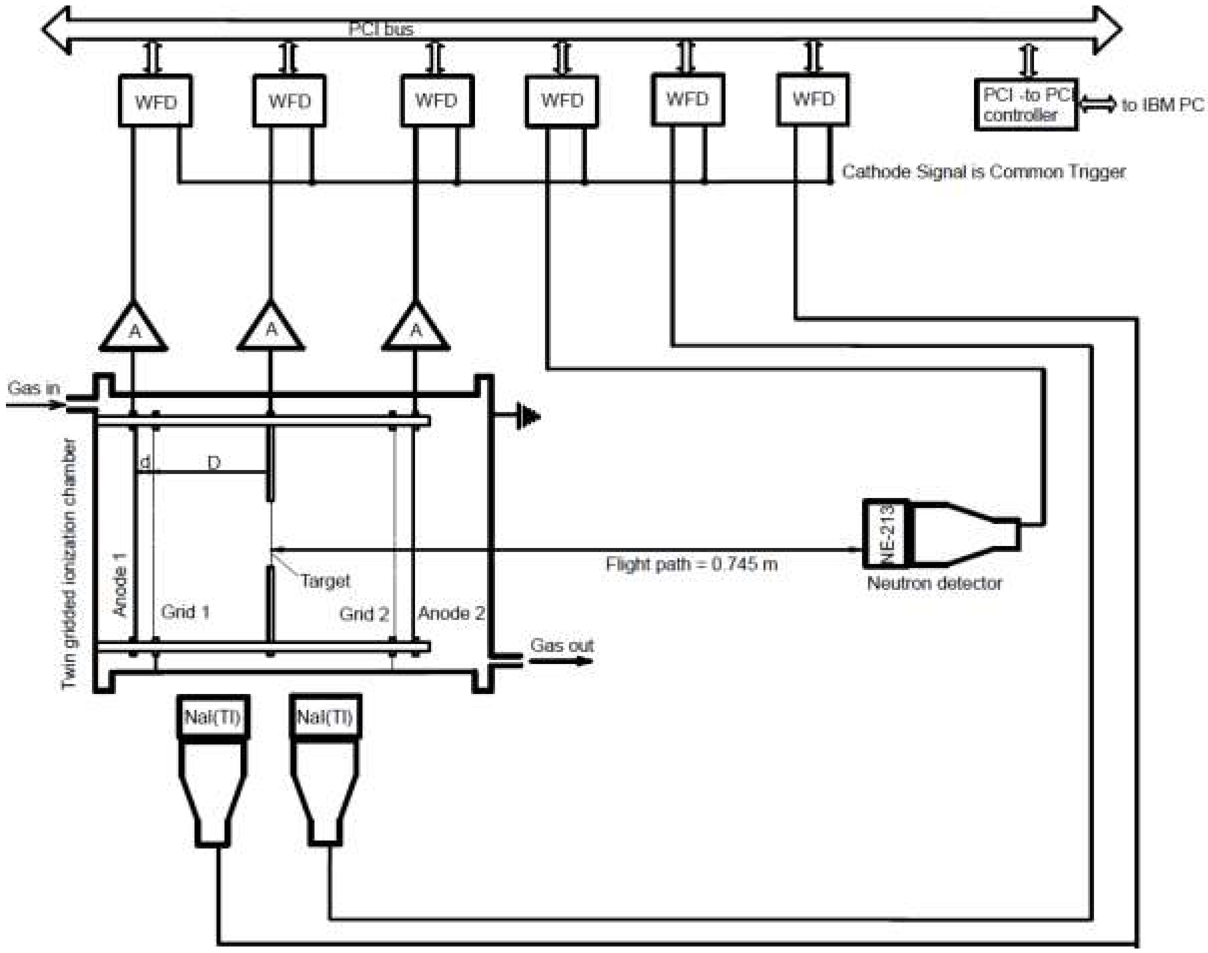

FIGURE 1. Sketch of experimental setup with digitizers.

Implementation of data analysis procedure was based on adaptation the methods of the analogue pulse processing, which was considered as a linear mathematical operators applied to the continuous signals. According to Shannon sampling theorem both representations are equivalent if the sampling of continuous signal made with high enough frequency. Then the analysis, implemented to discreet numbers, would provide the same result as in the conventional analog pulse processing (APP) procedure.

Experimental setup

A sketch of the experimental setup along with digital pulse processing electronics was shown in Fig. 1. A twin ionization chamber (TIC) was used for fission fragment mass-TKE spectroscopy along with PFN emission angle (Θ) measurement. A target with fissile material, deposited on thin organic foil, was located on the common cathode of the chamber. Fission fragments were decelerated inside sensitive volume of two independent chambers spending their kinetic energy for free electron creation. Free electrons drifted inside the chamber to respective anodes. The electric charge, induced on two anodes and common cathode were proportional to fission fragments (FF) kinetic energy, were measured by three synchronized waveform digitizers (WFD). Approximately 0.15% of fission fragment detection coincided with neutron detection by ND, which signal was digitized using fourth WFD. The common time base was achieved due to all four digitizer sampled detector pulses synchronously and the common cathode pulse was considered as an indication of a fission event. The common cathode pulse was used as a “T-zero” signal for PFN time-of-flight measurement and as one of the input pulses of coincidence unit. A neutron, detected inside the time interval of 200 ns duration after “T-zero” was considered as the PFN. In such a way two types of fission events were recorded in given experiment: with and without coincidence with ND pulse. Apparently, the intensity of fission events with coincidence with ND was proportional to conditional probability of neutron emission in a detected fission event. In experiment the following

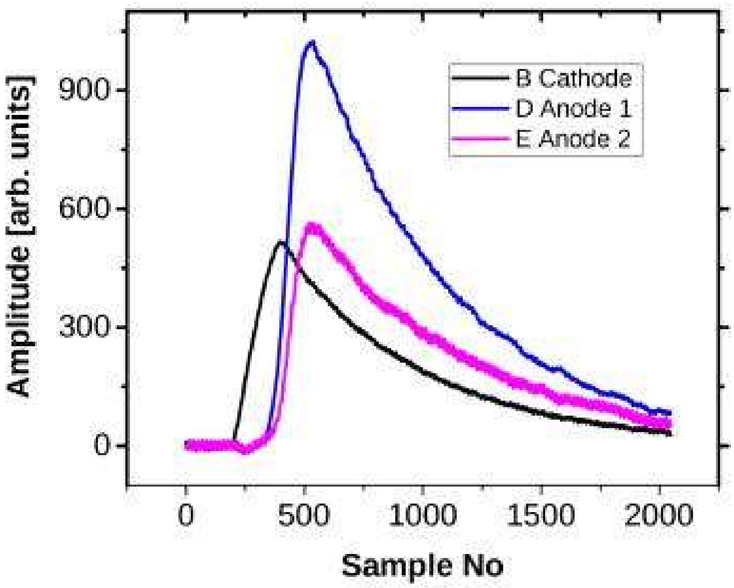

FIGURE 2. Original waveforms of the TIC cathode and anodes pulses.

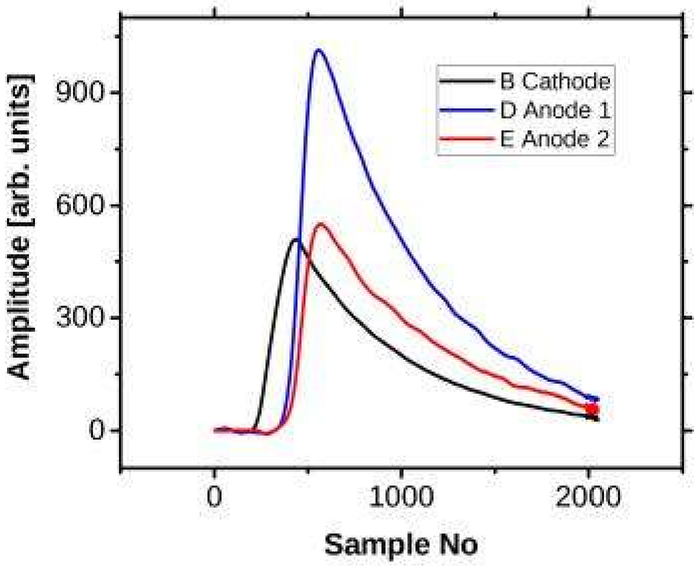

FIGURE 3. Waveforms after passage through 2nd order digital low pass filter.

parameters of fission event were required to be measured: kinetic energies of correlated FF, their angle in respect to the TIC axis, the PFN time-of-flight, the angle between FF and PFN

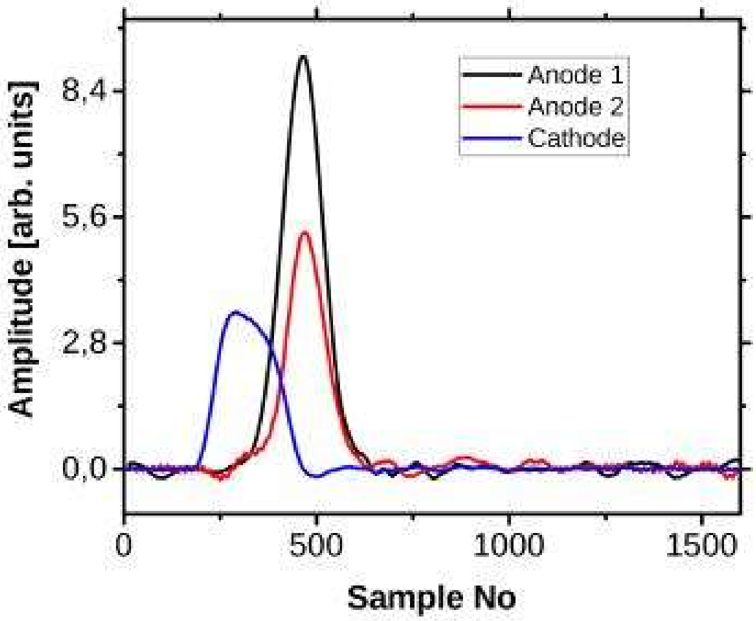

FIGURE 4. The current waveforms after obtained for the cathode and anodes signals.

(thanks to allocation of ND on the TIC axis) was the same as the Θ - angle. The information about the listed parameters was retrieved from the sampled TIC and the ND pulses using DPP algorithms. The waveform of the anode signal, being preprocessed by charge-sensitive preamplifier, was the step-like pulse with the height proportional to total charge of the electrons released during FF deceleration. The FF angle information can be obtained from the anode pulse rise time, which was proportional to the FF charge drift time from the point of origin to the respective anode. Usually waveforms might be biased, therefore, in first place the waveforms were passed through the digital differentiating filter (DDF), which was digital analog of the RC circuit as:

$$W_{out}[i+1] = \exp(-\frac{1}{RC}) \cdot (W_{out}[i] + W_{in}[i+1] - W_{in}[i]) \,, \tag{1}$$

where $W_{out}[i]$, $W_{in}[i]$ were used for the output and the input signals respectively, the RC was

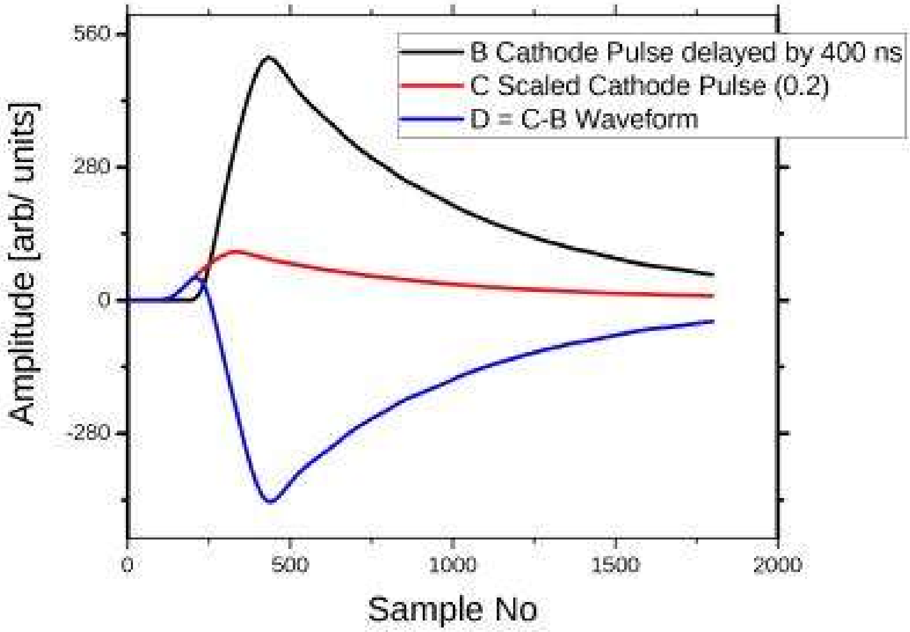

FIGURE. 5. Demonstration of the digital CFD realization. The zero crossing of the resulted bipolar signal was assigned the time mark.

chosen to be equal to 300 ns. Then the signals were passed through the digital integrating filter (DIF), which was analog of the CR circuit as:

$$W_{out}[i+1] = (W_{in}[i] + \exp(-\frac{1}{RC}) \cdot W_{out}[i]) \,. \tag{2}$$

The waveforms of the cathode and two anode waveforms after passing through DDF were presented in Fig. 2. After that the waveforms were twice passed through DIF and the result was presented in Fig.3. It should be noticed that the result of DIF implementation to the waveforms had improved their signal-to-noise ratio as it was demonstrated in Fig. 3. Using these waveforms we retrieved the current signal waveforms by rewriting Eq. 2 as follows:

$$W_{in}[i] = W_{out}[i+1] - \exp(-\frac{1}{RC}) \cdot W_{out}[i] \,. \tag{3}$$

In Fig.4 the current pulses was obtained by using Eq. 3 applied to the cathode and the anodes waveforms.

Measurement of PFN time-of-flight in present experiment was done using cathode pulse of TIC as a “T-zero” signal and the ND signal as “Stop” signal. The signals were digitized with 250 MHz sampling rate and stored during experiment for further off-line data analysis. Time difference between these two signals was analyzed implementing standard constant fraction time marking (CFTM) algorithm both to the cathode and to the ND waveforms. The realization of the algorithm demonstrated in Fig. 5 as it was applied to the cathode waveform. The copy of the original signal is delayed by approximately 0.4 of the cathode signal rise time (~1000 ns) and summed with scaled and inverted original signal. The "T-zero" time is assigned to the crossing point of resulting signal with time axis. The crossing point was calculated using parabola interpolation between two successive samples, first of which has positive and second – the negative values. The time mark for the ND signal was found in the similar way. It should be noted that to achieve the best timing resolution in CFTM realization one should convert sampled waveform to continuous form using Shannon's sampling formula [9]. Unless we do not deal with energy spectrum reconstruction, the resolution (~2.5 ns) provided in this simple implementation we found sufficient for PFN analysis. The difference between "T-zero" the "centre-of-gravity" for the anode waveform was used as measure of the average drift time for free electrons, created during FF deceleration in the working gas of TIC. The relation between the cosine of FF angle to the cathode normal provided by the formula from Ref. [2]:

$$\cos(\Theta) = \frac{T_{90} - T}{T_{90} - T_0}, \tag{4}$$

where T_{90} and T_0 were the extremes for drift time, which calculated using the following formula:

$$T = \frac{1}{M} \cdot \sum_{i=0}^{N} i \cdot W[i] - T_{ZERO}, \quad M = \sum_{i=0}^{N} W[i]. \tag{5}$$

The extremes T_{90} and T_0 were correspond to angles 90 and 0 degree respectively. T_{ZERO} was evaluated from the cathode signal as was described earlier.

References

[1] C. Budtz-Jorgensen and H.-H. Knitter, Nucl. Phys., A**490**, 307 (1988).

[2] Zeynalov Sh., Jaksybekov A., Sedyshev P., Sidorova O., Shvetsov V. XXIV International Seminar on Interaction of Neutrons with Nuclei, Dubna, May 23–27, 2016, JINR to be published.