Journal of Physics: Conference Series

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To cite this article: A S Chepurnov *et al* 2017 *J. Phys.: Conf. Ser.* **934** 012054

Study of the influence of ADC sampling rate on the efficiency of neutron-gamma discrimination by the pulse shape

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Abstract. The influence of a sampling rate of ADC on the efficiency of the pulse shape discrimination procedure (PSDP) developed for gamma-neutron discrimination was studied. Pu-Be neutron source and two types of digitizers (CAEN DT5730 and CAEN DT5743) were used. Both digitizers together with application software allow to store sequences of waveforms from a scintillation detector. The functional features of the CAEN DT5730 and CAEN DT5743 are described, and experimental characteristics of their operation are compared. Experimental values of an efficiency of neutron/gamma signal discrimination using two ADCs with different sampling frequencies are presented.

1. Introduction

There are several applications which require a parallel detection of fast neutrons and gamma radiation: 1) a monitoring of neutron and gamma background in low-background underground experiments (neutrino and Dark Matter detectors) [1], 2) a measurement of a fast neutron yield from neutron generators [2, 3], 3) a monitoring of a spent nuclear fuel , 4) an environmental monitoring on nuclear power plants.

Scintillation detectors with organic crystals, plastic and liquid scintillators are used for such a technique of a radiation detection. The shape of the output pulses from such detectors depends on the particle type. Fast ADC are used to digitize the output pulse and, than, different procedures of digital processing are used to discriminate the type of the particle. We studied and present in this paper how differs an efficiency of the same PSDP from the type of ADC with a different sampling rate and an accuracy.

2. Experimental setup

The experimental setup consists of the Pu-Be neutron source, a scintillation detector, ADCs and a personal computer with an application software for digital pulse shapes discrimination. The scintillation detector consists from an organic p-terphenyl crystal of 25x25 mm cylindrical form. Hamamatsu R6094 photomultiplier registers scintillation flashes. Output of the PMT's high voltage divider is connected directly to the digitizer input. The distance between the Pu-Be neutron source and the detector was 100 mm. USB interface embedded in to the ADCs was used to communicate with the personal computer.

We used two Desktop Waveform Digitizers alternately. One was CAEN DT5730 (ADC#1) with the following technical characteristics: 8 channels, 14 bit, 500 MS/s, bandwidth 250 MHz. The second digitizer was CAEN DT5743 (ADC#2) with the following technical characteristics: 8 channels, 12 bit, 3.2 GS/s, bandwidth 500 MHz) [4]. Both digitizers have 50 Ohm input impedance. Both digitizers together with appropriate software allow to store in to files input waveforms together with a time stamp of each sampling point relatively external or internally generated trigger. The feature when the samples are precisely time stamped is very important for such experiential tasks as neutron/gamma background monitoring near accelerators [5, 6] and a measurement of pulsed particle fluxes [7, 8]. ^{137}Cs and ^{60}Co radioactive gamma sources have been used to calibrate the scintillation detector.

3. The influence of ADC sampling rate on the efficiency of neutron-gamma discrimination

The digitizers can store different number of waveform's samples from the detector. ADC#2 stores a fixed number of the samples per event which is equal to 1024, while the number of the points per event for the ADC#1 is programmable. We used 500 samples from ADC#1 per event for the analysis. The number of samples per a pulsed waveform of a certain amplitude for the ADC#2 was six times more than for the waveform from ADC#1. This difference could influence the efficiency of gamma-neutron discrimination when these two digitizers are used.

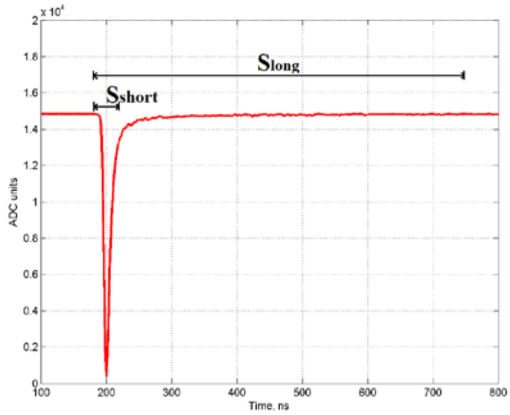

Figure 1. A waveform with indication of the short and the long gates.

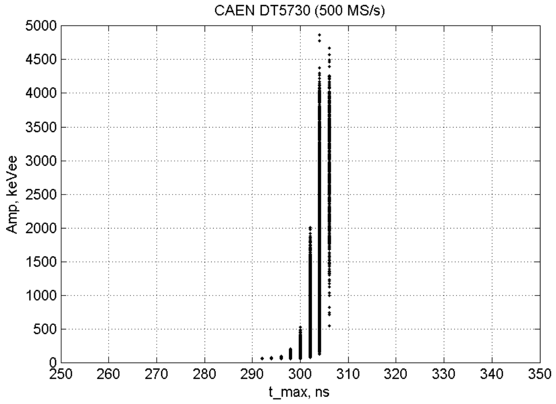

Figure 2. A distribution of a maximum position of pulses within a waveform when ADC#1 is used.

The application software was developed to discriminate gamma and neutron events according to the shape of the waveform. We calculate the area within the "short" (Sshort) and the "long" (Slong) gates separately (Figure 1). The area corresponds to the charge at the output of the detector. The length and the time position of the gates are optimized. A distribution of a maximum position of pulses within a waveform relatively the waveform start when ADC#1 is used is shown on Figure 2 and looks fixed.

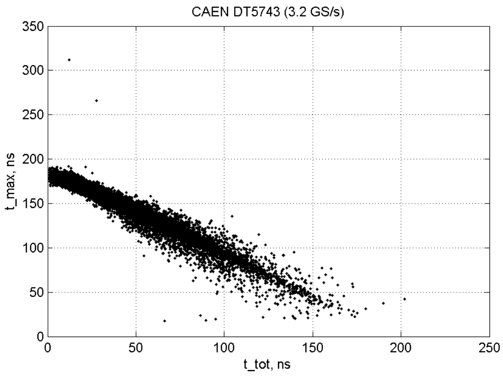

Figure 3. The distribution of the position of the maximum of the pulses within the waveform for ADC # 2.

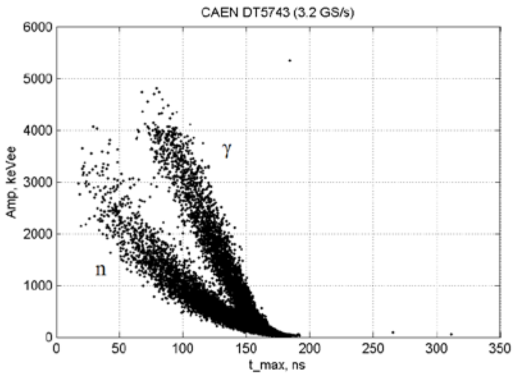

Figure 4. The dependence of pulse amplitude on the maximum position for ADC # 2 is used.

A position of the maximum of the pulses for the ADC#2 is distributed in the wide range and depends on the amplitude of the signal. It is shown on the Figure 3. The dependence of the moment of the maximum of the signal on the amplitude makes it possible to carry out a rough separation of the signals from neutrons and gamma (Figure 4).

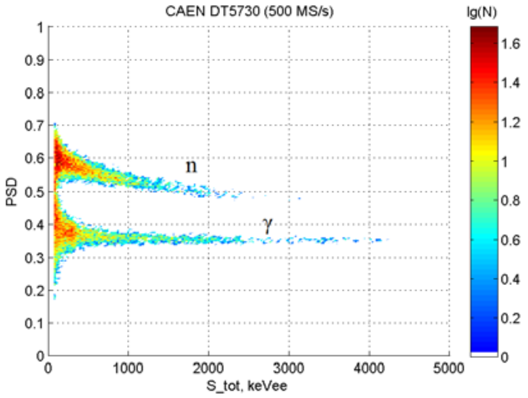

Figure 5. The dependence of the PSD parameter on the total pulse area when using ADC # 1.

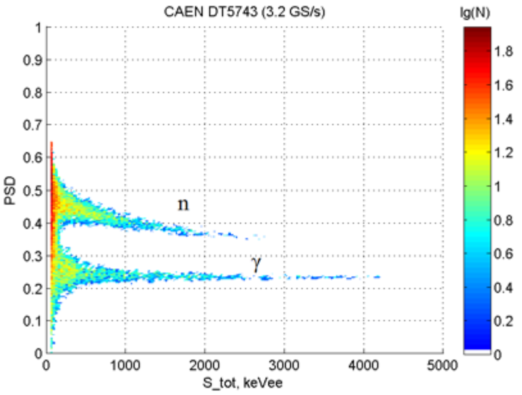

Figure 6. The dependence of the PSD parameter on the total pulse area when using ADC # 2.

PSDP as a procedure could be characterized by PSD parameter which describes numerically the discrimination process - PSD = (S_{long} - S_{short}) / S_{long}. Figure 5 and Figure 6 show the parametrized result of PSD procedure operation for gammas and neutrons when ADC#1 and ADC#2 are used.

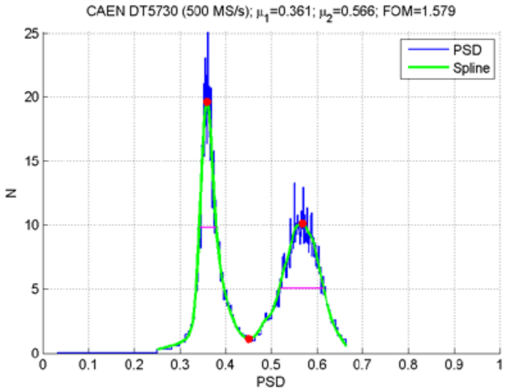

Figure 7. Discrimination of peaks from neutrons and gamma quanta using ADC # 1.

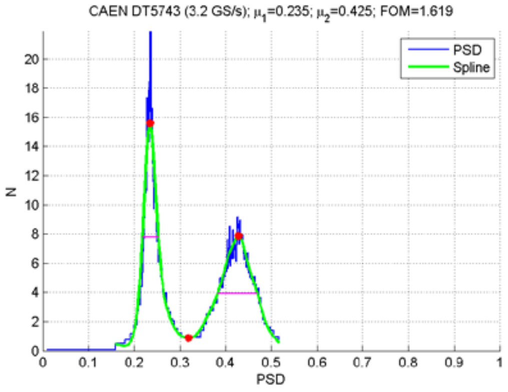

Figure 8. Discrimination of peaks from neutrons and gamma quanta using ADC # 2.

PSD parameter histograms together with corresponding spline approximations are represented on the Figure 7 and Figure 8. The quantitative criterion for the efficiency of PSDP could be defined as the value of FOM (Figure of Merit) when FOM = $(\max_n - \max_\gamma) / (FWHM_n + FWHM_\gamma)$. When ADC #1 is used the criteria FOM = 1.58, whereas when ADC #2 is used the criteria FOM =1.62.

4. Conclusion

Our experimental results show that the efficiency of the PSDP from neutrons and gamma rays is almost identical for both digitizers operating with 500Ms/s and 3.2Ms/s sampling rates. Thus, an increase in the sampling frequency of the ADC does not significantly increase the efficiency of pulse shape discrimination when detecting neutrons and gamma quanta using a scintillation detector with an organic crystal. Currently, a scintillation detector with a p-terphenyl crystal is used to measure the neutron yield in a new fast neutron generator being developed using carbon nanotubes.

Acknowledgments

The work is performed with financial support of the Ministry of Science and Education of Russia, the Project no. 14.578.21.0192 (RFMEFI57816X0192).
The authors are grateful for the equipment and software provided for the experiments by CAEN S.p.A. and TFT JSC.

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