PL9800085

Application of modular neutron spectrometer to measure neutron spectra from fission of ^{252}Cf

Z.Szefliński, S.Osuch, M. Popkiewicz, Z.Wilhelmi, Z. Żelazny.

Multi-detector systems play an important role in modern nuclear physics. Over the past few years the era of multidetectors in charged particle, γ-rays and neutron detection has begun. In heavy ion collision studies, it appeared that the neutron information is necessary to study the properties of radiation sources. Neutrons originating from a hot source carry an information on the nuclear temperature. The multiplicity of emitted neutrons grows rapidly with energy of the collision therefore simultaneous registration of many neutrons is required. The so-called Neutron Balls allow the measurement of neutron multiplicity event by event. However, these detectors do not deliver any information on energy spectra and angular distributions of the detected neutrons. In order to reach the necessary neutron information, one needs a detector system which gives simultaneous control of the energy spectra, angular distribution and multiplicity in individual detection of the event.

Our detector MONA (MOdular Neutron Array) allows the high efficiency measurement of energy spectra, angular distribution and multiplicity of neutrons in one geometrical set-up. MONA was constructed to register neutrons of intermediate energy (0.5 MeV-30 MeV). It is well known fact that the response of an organic scintillator can be observed as the sum of two components, fast and slow ones [1,2]. The intensity ratio of these two parts depends upon the rate of energy loss and allows to discriminate between the detected particles; in particular between neutrons and γ-rays. When the speed of identification is a critical parameter, special pulse shape discrimination (PSD) modules like CANBERRA 2160 are used. However these modules are relatively costly, what makes impractical its use in large arrays of detectors. Therefore we apply another PSD method, which is based on charge integration of the pulse current over two different time intervals using charge integrating QDC [3,4]. One channel of QDC is used to integrate the leading part of the anode pulse received from the scintillator and the second one to integrate the slow component of it.

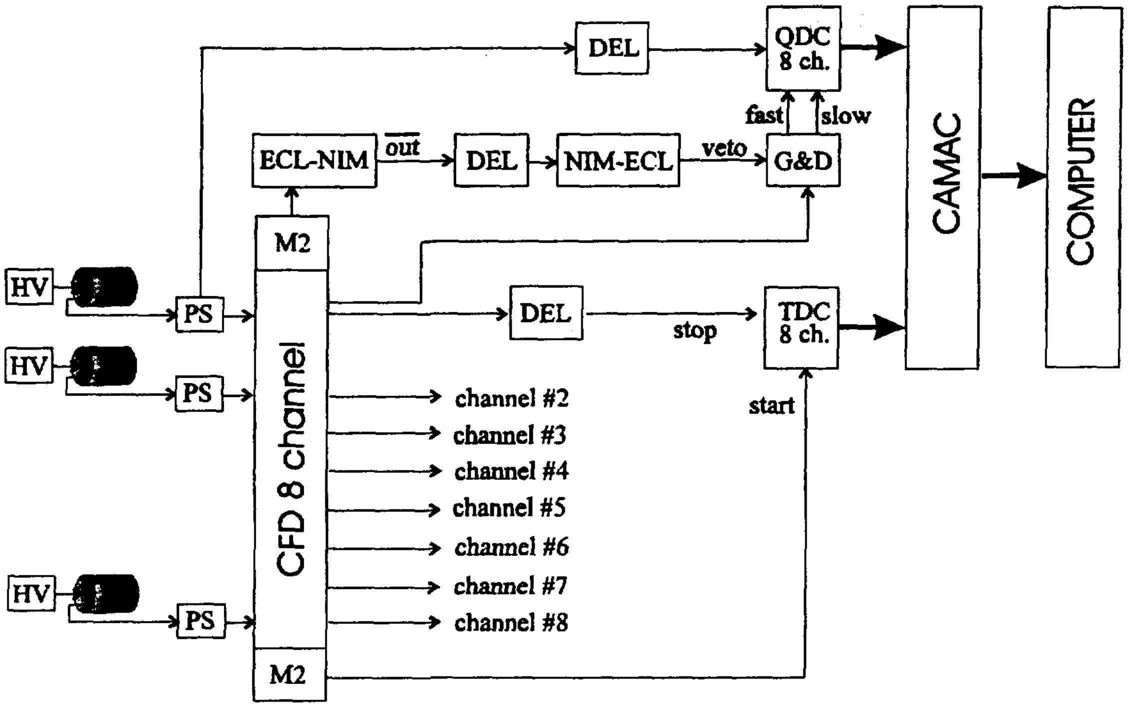

Fig. 1. Block scheme of the electronic set-up for pulse-shape-dicsrimination and time-of-flight. Identical circuits were built for all detectors. Description in the text.

Our detection system consists of eight BC-501A scintillation detectors (equivalent to NE-213), 8 channel CAMAC electronics to analyze the pulse shape, and a data acquisition system to write the results to the computer (Fig. 1). Each detector (DET) has large scintillator 4" in diameter by 2" thick with attached R-329 (HAMAMATSU) photomultiplier tube. For the purpose of PSD we have built a compact "pulse shape discriminating" system containing a multidetector array and a dual charge integrating QDC (GAN'ELEC QDC1612F)(Fig.1). For every detector one channel of QDC is used to integrate the rising part of the anode pulse received from the scintillator and the second one to integrate the slow component of it. The experimental set-up required only general purpose electronics. An anode signal from a passive splitter (PS) is delayed (DEL) and then send to the respective QDC channel input. The second signal given by the splitter is used to be analysed by the constant fraction discriminator (CFD). The output of CFD is used to trigger the delayed gate signals (G&D), which set apropriate integration gates for the QDC. In order to select high multiplicity events ($M \geq 2$), an output of G&D is vetoed until coincidence between two detectors takes place (Multiplicity $M \geq 2$ cancels veto). The QDC converters are gated by reshaped signals from G&D to integrate the fast part of the signal and that due to slow component of the scintillation pulse. The first integral is proportional to the energy loss of the particle inducing scintillation while the second one depends on the particle type. The suitable gate widths and delays are chosen to maximize the difference between the integrals for neutrons and γ-rays while minimizing the statistical spreads in those integrals. Identical circuits were built for all detectors. Appropriate settings were found empirically. The relative timing of delayed signal and gate signals is displayed in Fig.2. Both outputs from QDCs are send to multi-parametric data acquisition system.

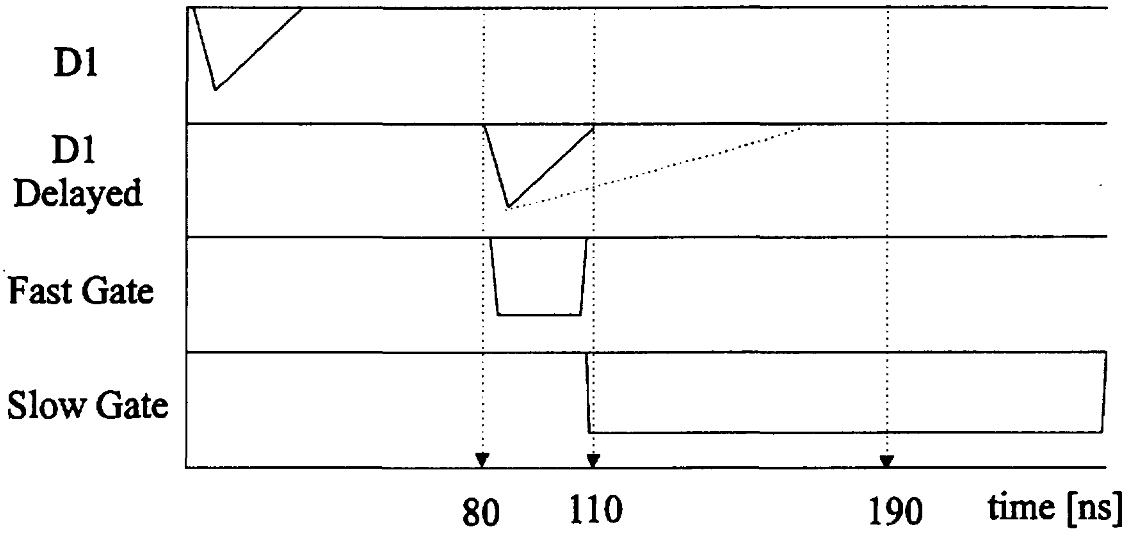

Fig.2. Display of the time relations between photomultiplier pulsesd and gates at the input of the QDC. D1 represents the anode signal, the logical signals denotes as fast gate and slow gate show the integration times.

In order to measure the neutron spectrum from spontaneous fission of ^{252}Cf time-of-flight method was applied. The velocity of the neutron was determined by measurement the difference between flight time of a photon and neutron detected in coincidence event. A relation between detector thickness and flight path gives reasonable minimum distance of 50 cm from the source to the detector. The fast trigger was generated by multiplicity signal, M=2 produced in CFD unit. Stop signals produced by CFD and sent to 8-channel TDC unit (see Fig. 2b) The delay of ~80 ns is necessary to shift STOP generated by the detection of a photon beyond START generated by the detection of a neutron . TDC and QDC outputs are stored in the computer by data acquisition system.

Some basic tests of our detectors were performed. We have tested the properties of pulse shape discrimination due to interaction of neutrons and γ-rays in the scintillator. The timing characteristics of the detector were also investigated. The pulse shape discrimination properties of single detector were studied. The response of the set-up to Cf source is given in Fig.3. Neutrons and γ-rays are seen to be well separated with from each other.

The counting efficiency of the detectors was established using a calibrated ^{252}Cf neutron source. Additionally the efficiency was calculated using an efficiency code [5]. Good agreement between calculated and experimental efficiency allows us to accept the calculated values. The calculated detector efficiency is η=0.25 at the neutron energy of 2.0 MeV.

The neutron spectra from the ^{252}Cf source were measured by the detectors placed symmetrically around the source. The distance from the source to the detector was 50 cm. Every coincidence between two detectors produces a trigger pulse for the detection system and all inputs of TDC and QDC are being readout. The outputs are stored in the computer by data acquisition system. Event by event spectra were collected and recorded on computer disc, neutron events were extracted in the off-line analysis. The set-up described above can be used as an autonomic detector for measurement of angular distributions and energy spectra of neutrons. It can also work as a part of a greater modular detector.

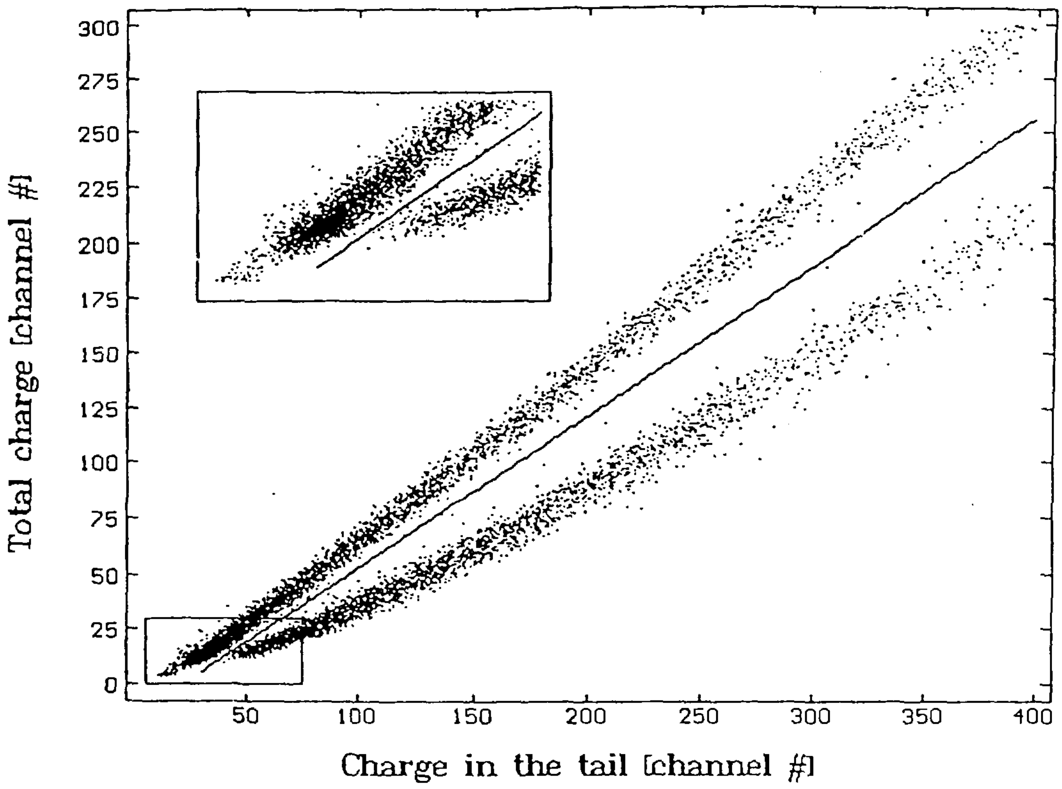

Fig.3. Two dimensional spectrum of charge in the front part of the pulse vs. the charge in the tail of the pulse taken for the ^{252}Cf source. The solid line show the separation between neutrons and γ-rays.

Acknowledgments

This work was financially supported by the Polish State Committee for Scientific Research (KBN Grant No. 2 P03B 027 08).

References

[1] Wright, Proc.Phys.Soc. B49(1956)358
[2] Sjölin, Nucl.Instr. and Meth. 37(1965)45
[3] M.Moszyński, G.J.Costa, G.Guillaume, B.Heusch, A.Huck, S.Mouatassim,Nucl. Instr. and Meth. in Phys. Research A307(1991)97
[4] J.H.Heltsley, L.Brandon, A.Galonsky, L.Heilbronn,B.A.Remington, S.Langer, Van der Molen, J.Yurkon. Nucl.Instr.Meth..A263,(1988)441.
[5] R.A.Cecil, D.B. Anderson and R.Madey, Nucl. Instr. and Meth.161(1979)439.