TEST OF MODULAR NEUTRON SPECTROMETER IN MEASUREMENT OF NEUTRON SPECTRA FROM FISSION OF ^{252}Cf * **

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An array of eight large BC-501A liquid scintillators for use in neutron time-of-flight experiments was build. Pulse-shape-discrimination method was applied to distinguish between neutrons and γ-rays. The array has been tested in the measurement of neutron spectra from spontaneous fission of ^{252}Cf. Future experiments on heavy ion beam are in preparation.

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1. Introduction

MONA (Modular Neutron Array) is a multidetector designed for studies of heavy ion induced neutron emission at intermediate energies (0.5–30 MeV). Our aim is to study the neutron decays, induced in HI collisions at the Warsaw Cyclotron and measure the neutron energy spectra by time of flight method, which in turn allows us to extract the temperature parameter. The multiplicity of emitted neutrons grows rapidly with energy of the collision and therefore simultaneous registration of many neutrons is required. In order to get 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 [1]. In order to measure the multiplicity of γ quanta originating from the decaying nucleus a multiplicity filter working as a part the experimental set-up is required. MONA's advantage is the versatility of its geometry, which can be easily adjusted to the needs of particular experiment.

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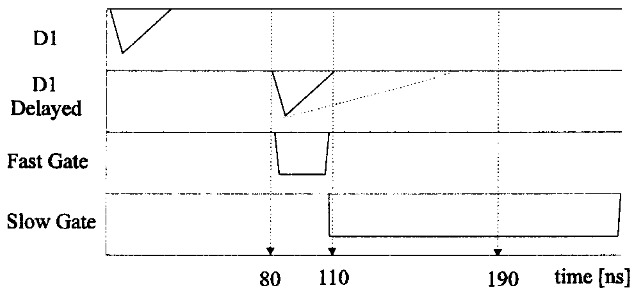

Fig. 1. Display of the time relations between photomultiplier pulses and gates at the input of the QDC. D1 represents the anode signal, the logical signals denoted as fast gate and slow gate show the integration intervals.

2. Experimental set-up

MONA allows the high efficiency measurement of energy spectra, angular distribution and multiplicity of neutrons in different geometrical arrangements. The use of BC–501A liquid scintillator gives an easy and efficient way to discriminate between incident γ's and neutrons by means of pulse shape discrimination (PSD). It is well known, that the response of an organic scintillator can be observed as the sum of two components, fast and slow ones [2, 3]. 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. We apply a PSD method, which is based on charge integration of the pulse current over two different time intervals using charge integrating QDC [4, 5]. 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.

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. Each detector has a large scintillator 4″ in diameter by 1″ thick with attached R-329 (HAMAMATSU) photomultiplier tube. For the purpose of PSD we have built a compact system containing a multidetector array and a dual charge integrating QDC (GAN'ELEC QDC1612F). 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 QDC converters are gated by reshaped signals from gate and delay generator 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. 1. Both outputs from QDCs are send to multi-parametric data acquisition system.

3. Tests and calibration

In order to test the MONA's parameters some measurements were made with the ^{252}Cf source. The velocity of neutrons was determined by measuring the difference between TOF of a photon and a neutron detected in a coincidence event. A relation between detector thickness and flight path gives reasonable minimum distance of 40 cm from the source to the detector. The fast logical trigger was generated by multiplicity signal ($M \geq 2$) produced by a CFD unit. STOP signals were produced by CFD and sent to 8-channel TDC unit. In order to assure, that the STOP signal will always appear after the START, even when the START signal is late (generated by the detection of a neutron) and the STOP signal is early (detection of a photon), STOP signals were delayed by $\tau = 80$ ns. TDC and QDC outputs were stored in the computer by the data acquisition system.

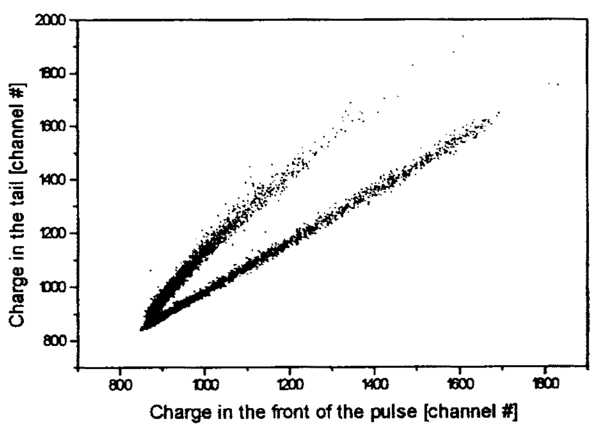

Fig. 2. Two dimensional spectrum of charge in the tail of the pulse vs. the charge in the front part of the pulse measured for the ^{252}Cf source.

We have tested the properties of pulse shape discrimination both for neutron and γ registration as well as timing characteristics. Best PSD results were achieved, when fast and slow gates were separated and integration gates widths were equal to 30 ns for the fast gate and 200 ns for the slow one. Perfect adjustment of the end of the fast gate with the start of the slow gate was not necessary, as the total energy is determined by TOF method. The results of test measurements on the ^{252}Cf source are given in Fig. 2. Neutrons and γ-rays are seen to be very well separated from each other. In order to determine the velocity and, consequently, energy of detected neutrons, only coincidence events between γ's and neutrons were taken into account. The energy spectrum, after corrections for efficiency, is in a very good agreement with previously measured data.

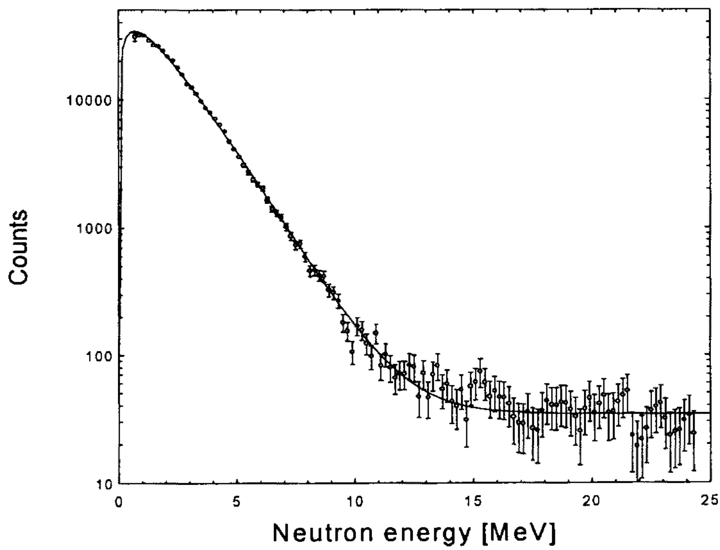

Fig. 3. Energy spectrum of fission neutrons. (Energy in the laboratory system)

The obtained spectrum, corrected for the efficiency is shown in Fig. 3. We have used an efficiency code written by Stanton and updated by Cecil *et al.* [6]. This version of code fully treats the neutron multiple scattering process inside the scintillator cell, takes into account the interaction channels contributing to the neutron detection: n+p elastic scattering, n+C elastic scattering (nondiffractive and diffractive processes), ^{12}C(n,n') and ^{12}C(n,charged particle production). Recent light response functions are taken into account, as well as relativistic kinematics and proper determination of light deposited by escaping charged particles. The calculated detector efficiency is $\varepsilon = 0.2$ at the neutron energy of 2.0 MeV. The simplest and most correct one-parameter representation of this spectrum is given by the Maxwellian distribution:

$$n(E) = C \cdot \sqrt{\frac{E}{(\pi T^3)}} \cdot \exp(-\frac{E}{T}) .$$

The obtained value of the parameter $T = (1.36 \pm 0.04)$ MeV is consistent with other experiments. The efficiency of a detector at a chosen energy can be obtained by comparing of the measured spectrum with the real, well-known ^{252}Cf spectrum. In future experiments we are going to use this method for fast and accurate determination of efficiencies of our detectors.

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