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PRECISION MONITORING OF FAST NEUTRON FLUX[1]

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Two monitors of a fast neutron flux from the reactions ^{3}H(d, n) ^{4}He and ^{2}H(d, n) ^{3}He are described. The first monitor is based on a scintillation counter with a stilbene crystal and the second on a silicon surface barrier detector. In long-term relative measurements of neutron fluxes, using both monitors, the accuracy of 0.1 % was achieved.

For many experiments with fast neutrons, for example, for the measurement of the neutron-proton scattering parameters in the energy range from 10 MeV to 30 MeV, it is necessary to perform the relative neutron flux monitoring accurately. Since these parameters must be measured with an accuracy of about 1 %, the accuracy of the relative measurement of the neutron flux is required to approximately one order of magnitude better. Taking into account this condition, we decided to design and test two types of monitors. The first is based on counting the recoil protons from the (n, p) scattering in a stilbene crystal and the second on counting the charged particles from the (n, α) and (n, p) nuclear reactions in a silicon surface barrier detector. The present paper describes in short our monitors and the results of their testing.

Description of the monitors:

The scintillation minitor

The monitor with a stilbene scintillation counter, whose simplified block diagram is shown in Fig. 1, was used because of its very high efficiency of the fast neutrons detection. Fig. 2 shows a recoil proton pulse-height spectrum for neutrons from the ^{3}H (d, n) ^{4}He reaction.

The relative measurement of the neutron flux was performed by counting the pulses whose amplitude was above some level of the integral discriminator. However, any counter with an organic scintillator is very sensitive to γ-rays and the gain stability of such a counter is not sufficient for our purpose. To suppress these unpleasant properties we designed the $n - \gamma$ discriminator [1] and the gain stabilizer [2]. The pulse-shape discrimination is performed by shaping a single dynode pulse of the photomultiplier by means of a delay line. The gain stabilizing system uses a light emitting diode as a stable reference. Changes of the gain are counteracted by varying the high photomultiplier voltage.

We used a 50 mm dia × 30 mm stilbene crystal. The distortion of the pulse height spectrum for this size of crystal is minimal for a neutron energy of 15 MeV and the efficiency of detection is about 7 % [3].

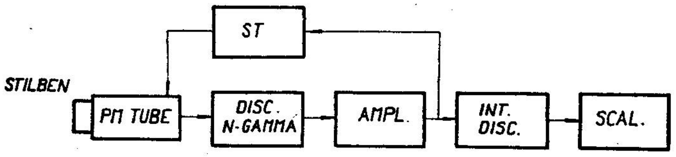

Fig. 1. Block diagram of the monitor based on a scintillation counter.

The semiconductor monitor

This monitor consists of a 200 mm^2 silicon surface barrier detector (fabrication Tesla, model PSC) with a depletion depth of ~ 500 μm, a charge-sensitive preamplifier, an amplifier, an integral discriminator and a scaler. For illustration, Fig. 3 shows the spectrum of charged particles produced by monoenergetic neutrons in a semiconductor detector. In the upper portion of the spectrum there is evident the fairly large separation of the peaks of α-particles and protons produced in the reactions ^{28}Si(n, α) ^{25}Mg and ^{28}Si(n, p) ^{28}Al. These separate peaks may be used for an accurate measurement of neutron energy [4]. The neutron flux monitoring is performed in the same manner as in the case of a scintillation counter monitor. Unlike the scintillation counter a silicon semiconductor detector is almost not sensitive to γ-rays and moreover, with a corresponding electronic equipment, we can achieve a good gain stabilization. The efficiency of the neutron detection by this monitor is about 3.5×10^{-3}. The radiation resistance of a silicon surface barrier detector to fast neutrons is sufficiently high. The changes of the parameters of this type of detector are observable beginning from the integrated neutron flux in excess of about 10^{12} cm^{-2} [5]. Under our experimental conditions these detectors could be used for long time measurements.

Experimental arrangement

For both monitors we used present-day electronics to ensure high stability of the monitor parameters in work of long duration.

In our experiments we performed neutron flux monitoring using one scintillation monitor and two semiconductor monitors simultaneously. A solid tritiated titanum or zirconium target bombarded with deuterons from a Van de Graaff or cyclotron accelera-

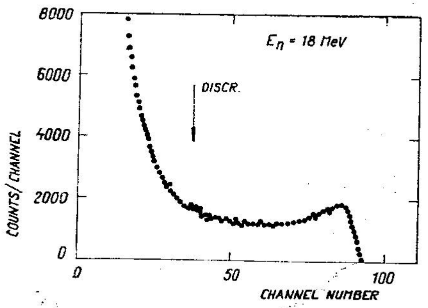

Fig. 2. A pulse height spectrum of the scintillation counter.

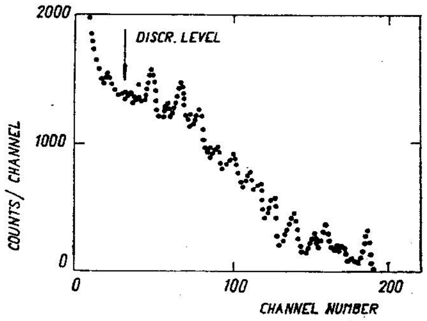

Fig. 3. Spectrum from neutron induced reactions at E_n = 14 MeV in the semiconductor detector.

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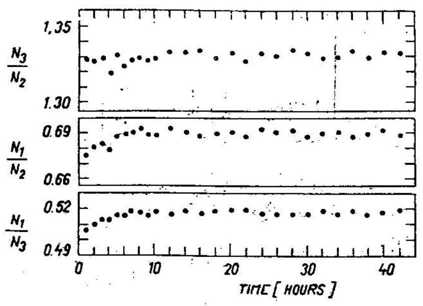

Fig. 4. The time dependence of the counting rates ratios of the monitors.

tor served as a monoenergetic neutron source in the range from 10 MeV to 30 MeV. The semiconductor detectors were located at a 120° angle with respect to the incident deuteron beam, the distance from the target being from 10 cm to 30 cm. In this place the energy of detected neutrons is practically independent on the neutron energy and the resolution of peaks in the spectrum is good. For a better resolution we put the detector side-on to the target. The average load of the detectors was such that counting losses could not influence the results of flux monitoring. The scintillation counter was put several meters from the target at a 30° angle, so that the counter was not overloaded and the energy of the detected neutrons was as hight as possible.

The monitors arranged as described above were tested many times in several days. The scintillation monitor and the two semiconductor monitors were switched on simultaneously for 1—2 hours and the values N_1, N_2 and N_3 were recorded. The accuracy of neutron flux monitoring was derived analysing the time dependence of the ratios N_1/N_2, N_1/N_3, N_3/N_2. Fig. 4 shows a typical dependence of these ratios in the first 40 hours of work. Several hours after switching on the device the working conditions are stabilized and the average values are $N_1/N_2 = 0.688 \pm 0.002$, $N_1/N_3 = 0.518 \pm \pm 0.001$, $N_3/N_2 = 1.328 \pm 0.004$. If we suppose that there is no dependence on some external disturbance, such as a temperature change, nearly identical for both types of monitors considered, we can conclude that the relative error of neutron flux monitoring by a scintillation monitor is equal to 1.3×10^{-3}, while for the semiconductor monitors we find 2.1×10^{-3} and 0.9×10^{-3}, respectively.

Finally, we should like to remark that any changes of position of the experimental devices located near the target can easy influence the neutron flux at the semiconductor monitor to such an extent that the accuracy of $\sim 0.1\%$ becomes meaningless. On the other hand, the advantage of the semiconductor monitor is its simplicity and high reliability.

By both types of monitors described the neutron energy and the absolute flux can be determined. The reliability of both monitors was verified in long-term work.

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