Features of the time dependence of the intensity of delayed neutrons in the range of 0.02 s in the ^{235}U fission by thermal and fast neutrons.

K. Mitrofanov[1], V. Piksaikin[1], A. Egorov[1], V. Mitrofanov[1], D. Gremyachkin[1], B. Samylin[1]

[1]Joint Stock Company "State Scientific Centre of the Russian Federation – Institute for Physics and Power Engineering named after A. I. Leypunsky" (JSC “SSC RF – IPPE”) , Obninsk, Russia

E-mail contact of main author: kmitrofanov@ippe.ru

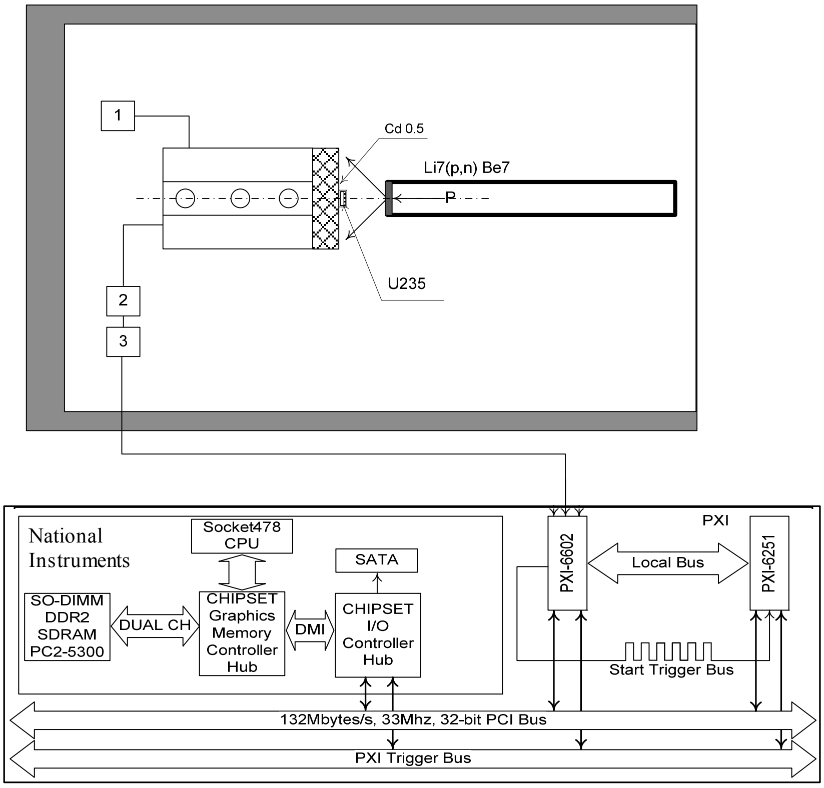
Abstract. In the present work the set-up created on the basis of the accelerator Tandetron (IPPE) for the experimental studies of the time dependence of delayed neutron activity from neutron induced fission of ^{235}U is described. Measurements were carried out with neutron beam generated by the $^{7}Li(p,n)$ reaction. The lower limit of the investigated time range was governed by the proton beam switching system that was 20 ms. The neutron detector is an assembly of three SNM-18 counters (working gas: a mixture of 97% He-3 + 3% Ar, pressure of 405 kPa) mounted in the polyethylene box. It was shown that the temporary characteristics of delayed neutrons from the fission of ^{235}U by epithermal neutrons is consistent with the time dependence which at present is recommended as a standard. In case of the fast neutron induced fission of ^{235}U the measured decay curve of delayed neutrons shows excess of counting rate in the time interval 0.01-0.2 s as compared with the decay curve corresponding to the recommended data. The microscopic approach using the data on the probability of emission of delayed neutrons and cumulative yields of fission products for 368 nuclei precursors also indicates the existence of short-lived component ($T_{1/2}$ <0.2 s) in the decay curve of activity of delayed neutrons emitted in the fission of ^{235}U.

Key Words: Tandetron, delayed neutrons, fission of ^{235}U, nuclei precursors.

1. The experimental setup

Experiment was carried out at the accelerator Tandetron (IPPE). Block diagram of the experimental setup is shown in Figure 1. The neutron detector is an assembly of three counters SNM-18 (Working gas: a mixture of 97% He-3 + 3% Ar. The pressure of 405 kPa) mounted in a polyethylene box. Signals from the counters SNM-18 received consistently to preamplifiers, amplifiers and conditioners. At the output of the last were formed TTL signals received on the adder, combined into a single digital stream of information transmitted by electronic analysis system and accumulation.

Electronic system of data collection, processing and visual process control during a session of experimental data acquisition is based on National Instruments (NI). The system includes a PXI-8104 controller and a timer-counter PXI-6602. All modules are installed in the chassis-rack PXI-1042 equipped with a bus PXI / PCI allowing to integrate the controller processor and the individual modules into a single platform. This system allows you to record the pulses spaced 12.5 ns. Therefore, the resolution time of countable channel is mainly determined by the neutron detector dead time (2.3 ms). In these measurements, the width of the channel in the time spectrum is 0.0001 seconds. Registration the number of pulses was carried out continuously including the irradiation time of the sample and the time of counting activity of the delayed neutron after an interruption of the proton beam.



1 – high voltage source; 2 – preamplifiers of signals from the counters SNM-18; 3 – summator of signals from the preamplifier of detector counters.

FIG. 1. Block diagram of the experimental setup is performed on the basis of the system of accumulation of National Instruments.

2. The energy dependence of the neutron yield from neutron target

In this work, the neutron detector was set up, in which the effect of the distortion of the counting characteristics at the initial time after irradiation session was absent. In addition, the counting characteristics of the detector is not distorted even during irradiation intense beam of neutrons generated in the lithium target under the action of protons. The neutron source was a lithium target irradiated by a proton beam. The current in the experiment was 10 μA. The proton energy was 2.6 MeV. Figure 2 shows the energy dependence of the neutron yield from neutron target.

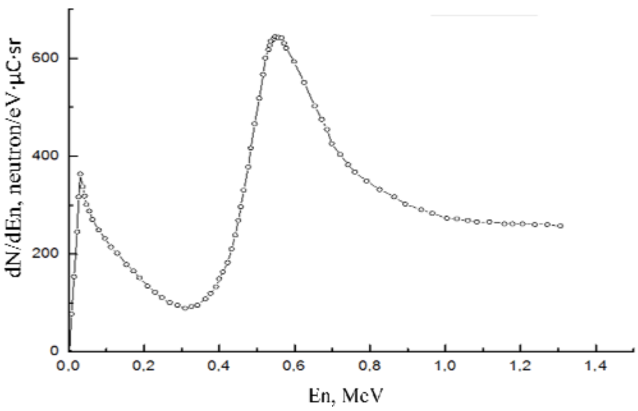


FIG.2. The energy dependence of the neutron yield from neutron target.

3. Two types of experiments

There were two types of experiments. In the first experiment, the irradiated sample was placed on a side surface of a neutron detector (FIG. 3). In a second experiment, a ^{235}U sample was placed in cadmium cover and a lead shield was placed between the detector and the sample (FIG. 4). Obviously, in the first experiment, the neutron spectrum is significantly softer than the case of experiment №2, because the direct beam of the neutrons from the target is added the neutrons scattered by the material of the neutron detector. In the second experiment, a sample of ^{235}U is at a distance of 5 cm from the detector, and the scattered neutron at the detector are intensity absorbed by cadmium filter. Lead filter is designed to protect the detector from the possible detection of delayed gamma rays from the sample ^{235}U. A sample of ^{235}U is a metal disk of 3 mm thickness and 41 mm in diameter, located in a metal shell. Measurements in the experiments were carried out for two different irradiation times – 180 s and 15 s. The experimental method used in this experiment based on the cyclic irradiation of fissile samples in a neutron flux of Li(p,n) reaction and the measurement of the time dependence of the intensity decrease of the delayed neutron [2].

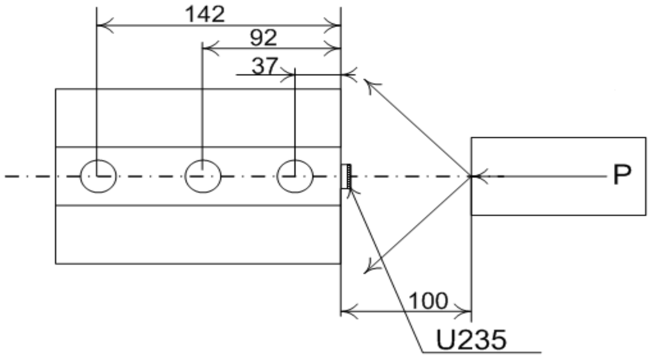


FIG.3. The first experimental scheme.

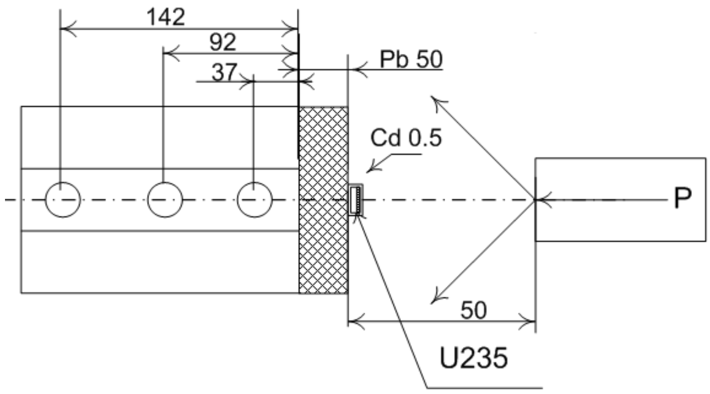


FIG.4. The first experimental scheme.

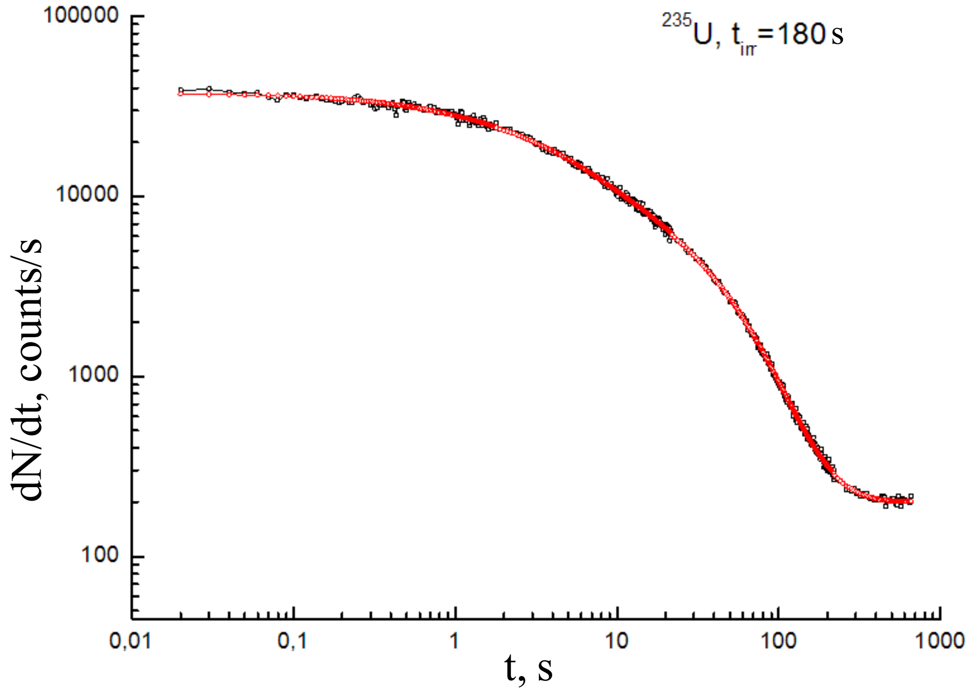


FIG. 5. Time dependence of the activity of the ^{235}U sample obtained in experiments №1 with irradiation time of the sample tirr = 180 s, presented as a count rate.

To verify the correct operation of all the experimental equipment (neutron detector with a registration tract, the electronic data storage system), the obtained data were processed to evaluate the time parameters of the delayed neutron. The estimation of parameters of the delayed neutron performed by an iterative least-squares method [3]. The evaluation was carried out as part a 6-group model of time parameters of the delayed neutron. The obtained data are presented in Table 1. The table shows the analogous data from Kipin work [5]. The value of the average half-life obtained in the present work is the same as the corresponding recommended data [4].

TABLE 1: Relative yields and periods of delayed neutrons in the fission of 235U by neutrons from the reaction 7Li (p, n).

№		1	2	3	4	5	6	$T_{1/2}$ cp
^{235}U (present work, hard spectrum)	a_i	0.03950 ± 0.00131	0.20823 ± 0.00692	0.19670 ± 0.00881	0.38126 ± 0.01501	0.14655 ± 0.00692	0.02776 ± 0.00139	8.90932 ± 0.48652
	T_i	54.12201 ± 1.01994	22.38173 ± 0.29337	6.09608 ± 0.22313	2.2432 ± 0.05674	0.45424 ± 0.02208	0.17896 ± 0.00894	
^{235}U Kipin (fast)	a_i	0.038	0.213	0.188	0.407	0.128	0.026	8.83
	T_i	54.51	21.84	6.0	2.23	0.496	0.179	

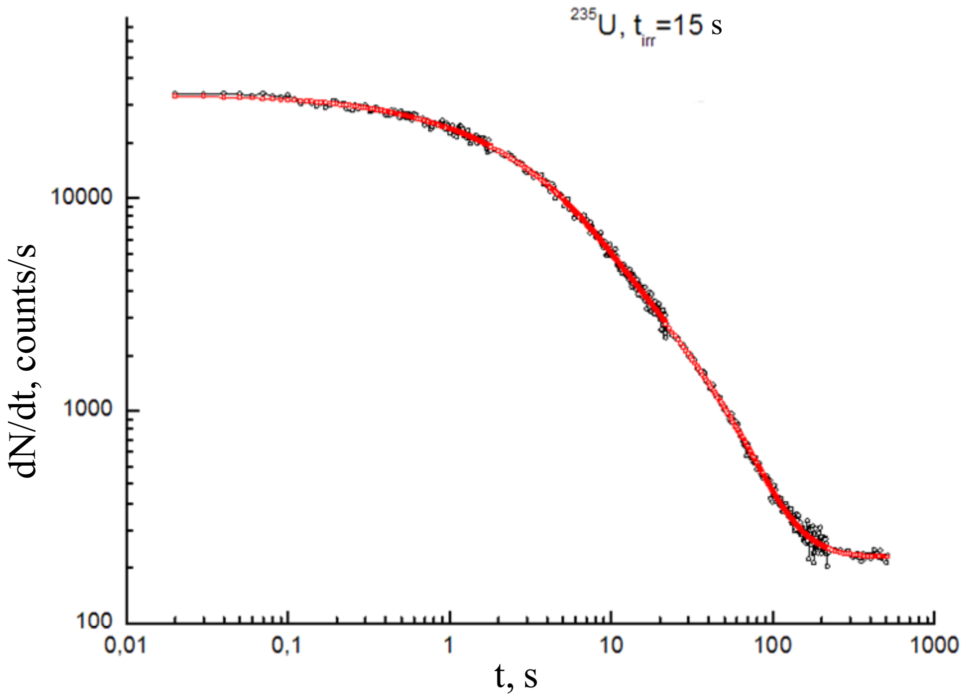


FIG. 6. Time dependence of the activity of the ^{235}U sample obtained in experiments №1 with irradiation time of the sample tirr = 15 s, presented as a count rate.

The Figures 5 and 6 show that in this configuration the experimental data for the time of irradiation tirr = 15 do not show a significant excess of delayed neutron intensity at the lower boundary of the investigated time range (0.01-0.5 s), as in the the case of long irradiation (tirr = 180).

Figure 7 shows that data of experiment №2 indicate the excess of numbers of counts in the low times in relation to the recommended data [4].

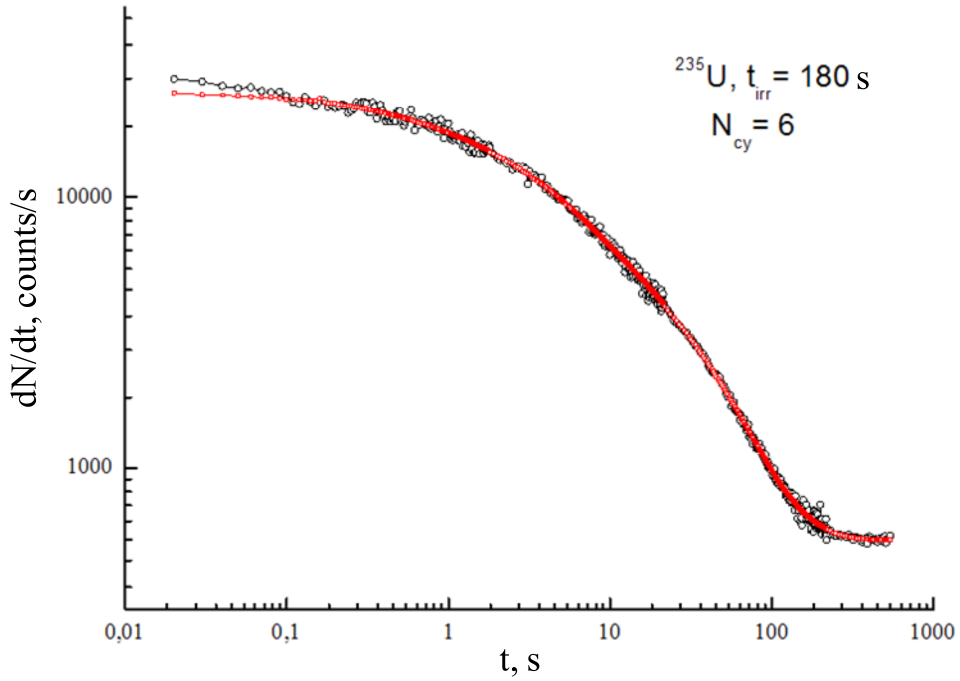


FIG. 7. Time dependence of the activity of the ^{235}U sample obtained in experiments №2 with irradiation time of the sample tirr = 180 s, presented as a count rate.

Similar results were obtained in experiments with a configuration corresponding to a fast spectrum of primary neutrons for the irradiation time of the sample tirr = 15 s. These data are presented as the count rate of pulses from a neutron detector in Figure 8. It is seen that there is an increase the count rate of delayed neutrons in the times region up to 0.12 s compared with the data obtained on the basis of the recommended data. Recommended data were measured in the time range starting from 0.1.

Thus, it was shown in the experiment that the measured dependence of delayed neutron activity of soft spectrum of primary neutrons coincides with the recommended. On the fast spectrum of primary neutrons on decay curve of activity of delayed neutrons in the time range of 0.01 - 0.2 s is observed the excess of numbers of count compared to the decay curve corresponding to the recommended data.

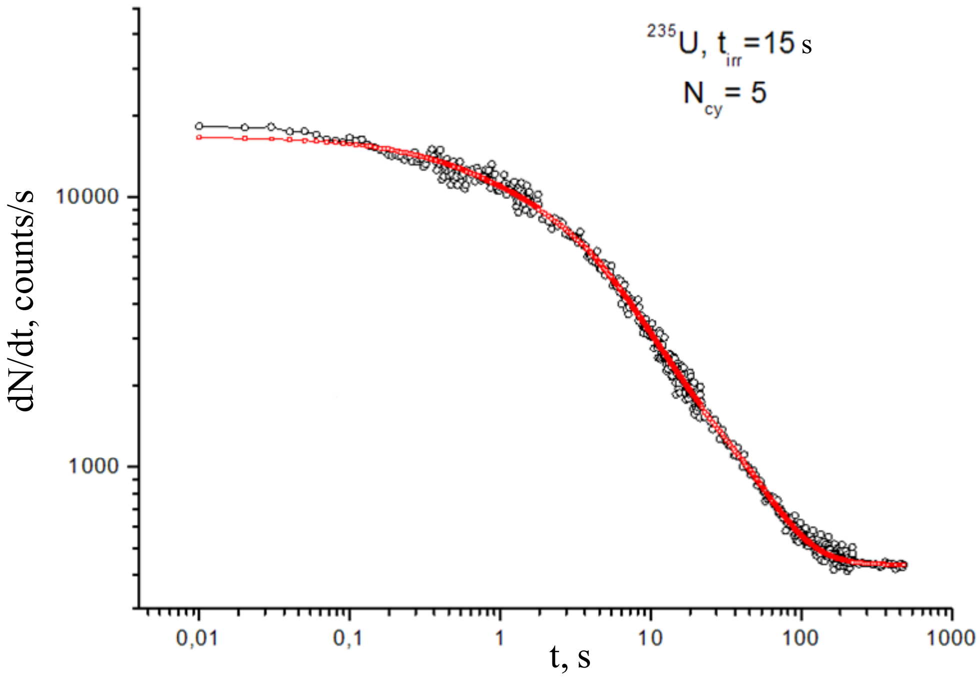


FIG. 8. Time dependence of the activity of the ^{235}U sample obtained in experiments №2 with irradiation time of the sample tirr = 15 s, presented as a count rate.

4. Conclusion

In this work, the set-up was created on the basis of the Tandetron (IPPE) allowing to measure the activity curves of delayed neutrons of fission of heavy nuclei by neutrons in the time range, which the lower limit is determined by the speed of the charged particle beam interruption. It was shown in the experiments that the measured dependence of activity curves of delayed neutrons in the fission of ^{235}U on the soft spectrum of primary neutrons coincides with the recommended. On the fast spectrum of primary neutrons the activity curves of delayed neutrons in the time range of 0.01 - 0.2 s is observed with the excess of numbers of count compared to the decay curve corresponding to the recommended data.

The microscopic approach using the data on the probability of emission of delayed neutrons and cumulative yields of fission products for 368 nuclei precursors also indicates the existence of short-lived component ($T_{1/2}$ <0.2 s) in the decay curve of activity of delayed neutrons emitted in the fission of ^{235}U.

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