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

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1. The set-up was 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.

2. Measurements were carried out with neutron beam generated by the $^7\text{Li}(\text{p},\text{n})$ reaction.

3. The lower limit of the investigated time range was governed by the proton beam switching system that was 0.02 s (20 ms).

4. It was shown that the temporary characteristics of delayed neutrons from the fission of $^{235}$U by thermal neutrons is consistent with the time dependence which at present is recommended as a standard.

5. 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 0.02-0.2 s as compared with the decay curve corresponding to the recommended data.

6. 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.
Block diagram of the experimental setup is performed on the basis of the system of accumulation of National Instruments.

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

The neutron detector is an assembly of three counters SNM-18 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.

This system allows 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). 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.
Histogram of the counts of the detector placed in a mixed neutron field from the $^{7}\text{Li} \ (p, \ n)$ reaction and the Pu-Be source. Channel width pulse time distribution was $0.001 \, s$. 

$N(t)$, counts/channel vs $t$, channel
Experiment №1 (w/o Cd & Pb)

Experiment №2 $^{235}$U in Cd cover.
Detector with shield of lead.
Apparatus time spectrum of activity of delayed neutrons in the fission of $^{235}\text{U}$ by neutrons, obtained in experiment 1.

Analyzer channel width - 0.01 s, the curve contains 50000 channel

Apparatus time spectrum of activity of delayed neutrons in the fission of $^{235}\text{U}$ by neutrons, obtained in experiment 2.

Analyzer channel width - 0.01 s, the curve contains 50000 channel
experiment 1

Time dependence of the activity of the $^{235}$U sample obtained in experiments №1 with irradiation time of the sample $t_{irr}=180$ s and 15 s, presented as a count rate.

The figures show that in this configuration the experimental data for the time of irradiation $t_{irr}=15$ s do not show a significant excess of delayed neutron intensity at the lower boundary of the investigated time range (0.02-0.2 s), as in the case of long irradiation ($t_{irr}=180$).
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 evaluation was carried out as part a 6-group model of time parameters of the delayed neutron. The table shows the analogous data from Kipin work. The value of the average half-life obtained in the present work is the same as the corresponding recommended data.

Table 1. Relative yields and periods of delayed neutrons in the fission of $^{235}$U by neutrons from the reaction $^7$Li (p,n).

<table>
<thead>
<tr>
<th>№</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>$&lt;T_{1/2}&gt;$</th>
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<tbody>
<tr>
<td>$^{235}$U (present work)</td>
<td></td>
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<tr>
<td>$a_i$</td>
<td>0,03950 ± 0,00131</td>
<td>0,20823 ± 0,00692</td>
<td>0,19670 ± 0,00881</td>
<td>0,38126 ± 0,01501</td>
<td>0,14655 ± 0,00692</td>
<td>0,02776 ± 0,00139</td>
<td>8,90932 ± 0,48652</td>
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<tr>
<td>$T_i$</td>
<td>54,1220 ± 1,01994</td>
<td>22,3817 ± 0,29337</td>
<td>6,09608 ± 0,22313</td>
<td>2,2432 ± 0,05674</td>
<td>0,45424 ± 0,02208</td>
<td>0,17896 ± 0,00894</td>
<td></td>
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<tr>
<td>$^{235}$U Kipin</td>
<td></td>
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<tr>
<td>$a_i$</td>
<td>0,038 ± 0,011</td>
<td>0,213 ± 0,037</td>
<td>0,188 ± 0,0077</td>
<td>0,407 ± 0,0084</td>
<td>0,128 ± 0,0034</td>
<td>0,026 ± 0,001</td>
<td>8,83 ± 0,324</td>
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<tr>
<td>$T_i$</td>
<td>54,51 ± 0,006</td>
<td>21,84 ± 0,008</td>
<td>6,0 ± 0,002</td>
<td>2,23 ± 0,003</td>
<td>0,496 ± 0,001</td>
<td>0,179 ± 0,002</td>
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</tr>
</tbody>
</table>
Time dependence of the activity of the $^{235}\text{U}$ sample obtained in experiments №2 with irradiation time of the sample $t_{irr} = 180$ s and 15 s, presented as a count rate.

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.
Curve of activity decay of short-lived component of delayed neutrons in the fission of $^{235}\text{U}$ by neutrons in experiment №2 with $t_{irr} = 15\text{s}$

Analysis of the data (15s) showed that the dependence is exponential with a half-life equal to $0.04565 \pm 0.00971\text{ s}$

Curve of activity decay of short-lived component of delayed neutrons in the fission of $^{235}\text{U}$ by neutrons in experiment №2 with $t_{irr} = 180\text{ s}$

Analysis of the data (180s) has shown that the dependence is exponential with a half-life equal to $0.05603 \pm 0.00649\text{ s}$
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 0.02 - 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.
Thank you for your attention!