SET-UP FOR MEASUREMENTS OF DELAYED NEUTRON CHARACTERISTICS IN INTERACTION OF HEAVY NUCLEI WITH RELATIVISTIC PROTONS OF THE SYNCHROCYCLOTRON PINP GATCHINA

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Abstracts

In present paper the method and set-up for measurements of delayed neutron characteristics in interaction of heavy nuclei with relativistic protons are described. On the basis of this method the time dependence of delayed neutron activity has been measured from interaction of ^{238}U sample with 1 GeV pulsed proton beam of the synchrocyclotron of the Petersburg Institute of Nuclear Physics, Gatchina. The measured data was analyzed in frame of 8-group precursor's model with a consistent set of half-lives. Obtained results on the fractional yields of delayed neutron precursors are compared with an appropriate data from the fast neutron induced fission of ^{238}U.

EXPERIMENTAL METHOD AND SET-UP

The measurements of delayed neutron decay from the fission of ^{238}U induced by relativistic protons were carried out on the set-up installed at the synchrocyclotron of the Petersburg Institute of Nuclear Physics, Gatchina. The synchrocyclotron is a pulsed accelerator with a 1 GeV proton beam intensity of about 10^{10} protons/cm^2·s in the location of sample. The width of proton pulses in the ^{238}U experiment was 0.008 s with the repetition time of 0.02 s

The experimental method employed in the measurements of delayed neutron decay curves is based on cyclic irradiations of the ^{238}U samples by protons followed by the registration of the time dependence of accumulated delayed neutron activity.[1]

Block diagram of the experimental setup is presented on figure 1.

The detector is shielded against the neutron background by borated polyethylene and cadmium sheets. The amplifier (A) and pulse discriminator (D) were used for two sets of counters – outer and inner as related to incident neutrons. The output signals from these electronic channels are fed to a mixing module (Σ) coupled with DAQ electronic system. The dead time of neutron detector is 2.3±0.2 μs.

The pneumatic transfer system is capable to transport the sample for the time short enough to measure the delayed neutron yields with the shortest half-lives. Two electromagnetic valves are responsible for the sample transportation route. The stainless steel tube with inner diameter of 12 mm and wall thickness of 1 mm serves as a pneumatic flight guide (3). The positions of the sample in the neutron detector and irradiation location are fixed by the plugs with adjustable central hole which provides the excessive pressure in front of the moving sample and smoothes the contact between the sample and the plug. The information on the sample location is obtained from sample position detector (6). Time of flight of the sample is about 150 ms.

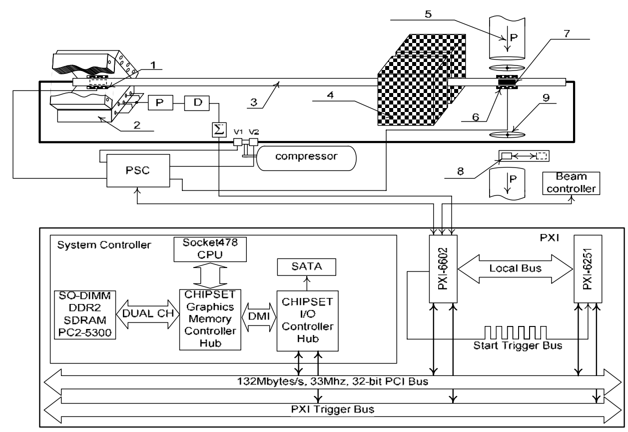

Figure 1: Block diagram of the experimental setup: 1,6-sample position detector; 2-neutron detector; 3-pneumatic transfer system; 4-neutron detector shield; 5-beam line; 7-sample of ^{238}U; 8,9 Laser positioning device; (P) preamplifier, (D) pulse discriminator; (Σ) summator; (PSC) Pneumatic System Controller; In the bottom of the fig.1 is presented Data Acquisition system by National Instruments based on Labview.

RESULTS AND DISCUSSION

Composite decay curves which were measured in interaction of 1 GeV pulsed beam of protons with ^{238}U with irradiation times 15 and 180 s is presented on fig.2. The original scale of time analyzer (0.0001 s/channel) were transformed in scale of 0.1 s/channel. The obtained data were also corrected for the degradation effect of counting response of neutron detector placed in a high intensity fields of neutrons and gamma rays during irradiation time [2].

The accumulated decay curves were analyzed in the 8-group model approximation [3] with the help of the iterative least-squares method [4]. The relative abundances for ^{238}U were obtained on the basis of experimental data which were measured with different irradiation times. In the analysis of the delayed neutron time-dependence the data with irradiation time of 180 s were used to obtain the group constants for the first, second and third group of delayed neutrons. Group constants for the fourth to the eighth groups were

ISBN 978-3-95450-170-0

obtained from the data measured in the experiment with the irradiation time of 15 s. The group constants obtained from the long time irradiation data were fixed in the analysis of short time irradiation data.

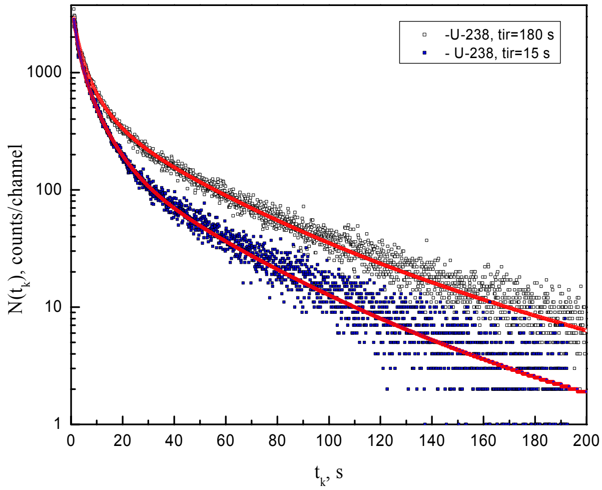

Figure 2: Composite delayed neutrons curves measured from interaction of 1 GeV pulsed beam of protons with ^{238}U with irradiation times 15 and 180 s. Solid lines – results of delayed neutron parameters estimation. Time-channel width – 0.1 s.

In the course of data processing two additional groups of delayed neutron precursors were introduced to take into consideration decay ^{16}C and ^{17}N with half-life 0.747 и 4.17 s respectively. These nuclides are produced in interaction of 1 GeV proton with ^{238}U with high probability [5]. It is allowed to take into account a contribution of the fragmentation channel in the composite delayed neutron decay curve. Thus the obtained fractional yields of delayed neutron precursors are corresponding mainly to the fission channel of the investigated interaction. The average half-life of delayed neutron precursors was obtained on the basis of the relative abundances and half-lives of their precursors according to formula $<T>=\Sigma T_j \cdot a_j$ (j=1-8). Obtained results on the fractional yields of delayed neutron precursors and their average half-life calculated on the basis of these data are presented in Table 1.

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Table 1. Fractional yields of delayed neutron precursors and their average half-life from fission of ^{238}U by 1 GeV protons.

Target, proton energy	Group number, half-life and predominant precursors of delayed neutrons								Average half-life, s $<T>=\sum_{j=1}^{8} T_j \cdot a_j$
	1 55.6 c **^{87}Br**	2 24.5 c **^{137}I**	3 16.3 c **^{88}Br**	4 5.21 c **^{138}I, ^{93}Rb, ^{89}Br**	5 2.37 c **^{94}Rb, ^{139}I, ^{85}As, ^{98m}Y**	6 1.04 c **^{93}Kr, ^{144}Cs, ^{140}I**	7 0.424 c **^{91}Rb, ^{95}Rb**	8 0.195 c **^{96}Rb, ^{97}Rb**	
^{238}U 1 GeV	0.023 ±0.004	0.139 ±0.004	0.050 ±0.001	0.365 ±0.010	0.263 ±0.010	0.102 ±0.002	0.035 ±0.001	0.023 ±0.015	8.15 ±0.25

ISBN 978-3-95450-170-0