## *NEW MEASUREMENTS OF THE NEUTRON SPECTRUM IN THE BOMBARDMENT OF Be BY 680-Mev PROTONS*

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AN investigation of the neutron spectrum obtained in the bombardment of a beryllium target by 680-Mev protons has been reported earlier;[1] in that work the measurements were performed by measuring the absorption curves for the recoil protons emitted in elastic np scattering. The energy distributions obtained in this way contained a sizeable charged-pion component (20%) in the high-energy region; these mesons are products of the reactions

$$n + p \rightarrow \pi^+ + n + n, \quad (1)$$

$$n + p \rightarrow \pi^- + p + p. \quad (2)$$

The absence of any experimental data for the spectra of charged pions formed in these reactions leaves an element of uncertainty in the reliability of the corrections which are applied to take account of this contamination.

By using a magnetic field for momentum analysis of the recoil protons in the present work, it has been possible to avoid completely any charged-pion contamination over the entire energy range investigated. The measurements carried out with the new method were performed at a neutron emission angle of 0°. Special attention was paid to the high-energy region of the spectrum, since this region is important in most of the work carried out with the neutron beam.

A diagram of the experimental arrangement is shown in Fig. 1. The neutron beam strikes either a polyethylene or a carbon target. The effect due to hydrogen is taken as the difference in the results obtained with these two targets. The scintillation counters 1, 2, 3, which record the recoil protons, are connected in coincidence. Counter 1 is very thin ($0.1\ g/cm^2$) in order to minimize multiple scattering; counters 2 and 3 are long (15 cm) in the direction perpendicular to the plane of the figure in order to detect the majority of particles which diverge in the vertical plane as a result of defocusing. The spectrometer is calibrated by the well-known method in which a current-carrying wire is used to "mark" the magnetic field. The absolute energy scale is determined with an accuracy of approximately 1%.

In computing the spectrum, corrections were made for the proton energy loss in the targets and in air and for the astigmatism of the magnetic system. Corrections for the energy dependence of the cross section for elastic np scattering were taken from work on the differential cross sections for np scattering reported in the literature.[2-8]

In Fig. 2 are shown the corrected results of these measurements. In the same figure are shown the data obtained earlier,[1] which have been adjusted (corrections < 10%) in accordance with the new measurements on the yield of charged pions in np collisions.[9] The results of the two measurements were combined in such a way as to make the integrated spectra the same between 300-Mev and the maximum energy. The errors denoted by the vertical lines in Fig. 2 are the statistical uncertainties; these do not include the errors in the n-p scattering cross sections. The latter are not important because we consider only a small energy range and need be taken into account only in comparing the far regions of the spectra. The horizontal spreads indicate the calculated resolving power of the instrument.

It should be kept in mind that the portion of the spectrum between 100 and 500 Mev contains a small admixture of protons emitted in the reaction $n + p \rightarrow \pi^0 + n + p$ and in reaction (2). This admixture is estimated as approximately 10%; this figure

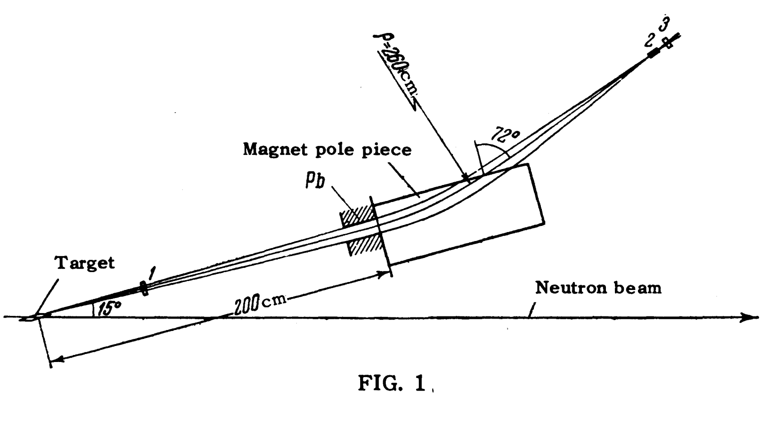


FIG. 1.

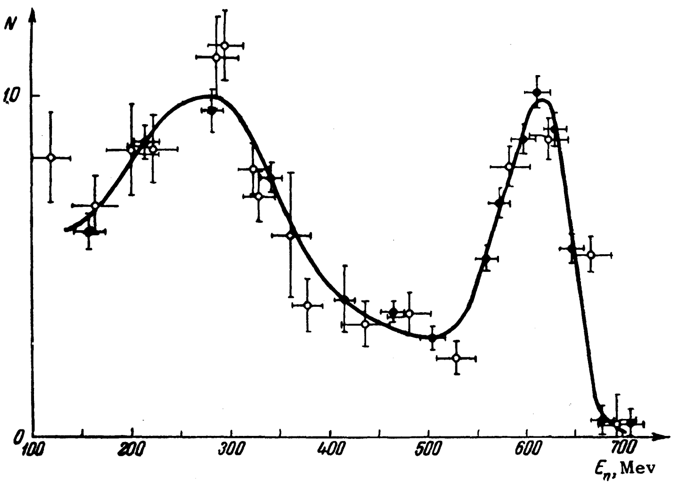


FIG. 2. Neutron energy spectrum. The black dots refer to the data of the present measurements. The circles refer to the data of reference 1 with the corrections indicated in the text.

has not been determined experimentally because of the great difficulty involved.

The present measurements, which were made with a high-resolution detector and in which there was no pion contamination, indicate that the maximum at 610-Mev has a smaller half-width (approximately 100-Mev) than that given in reference 1.

The origin of the two maxima in the neutron spectrum has been discussed in reference 1, to which the reader is referred.

In conclusion the authors wish to thank V. P. Zrelov for a number of valuable comments in connection with the present work.

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## *RELATIVE YIELDS OF DELAYED NEUTRONS IN FISSION OF* $U^{238}$, $U^{235}$ *AND* $Th^{232}$ *BY FAST NEUTRONS*

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MEASUREMENTS have been made of the relative yields of delayed neutrons in fission of natural uranium, $U^{235}$ (90% enriched) and $Th^{232}$ by neutrons with energies of 15.0 ± 0.9, 3.3 ± 0.7, and 2.4 ± 0.3 Mev.

The 15.0-Mev neutrons were obtained from a thick tritium target which was bombarded by 440-kev deuterons. The 3.3 and 2.4-Mev neutrons were obtained from the $D(d, n)He^3$ reaction. A target of heavy ice was bombarded by 920-kev deuterons.

The thermal neutrons were also recorded. The latter were obtained by slowing down fast neutrons from the $Be^9(d, n)B^{10}$ reaction in a paraffin block which surrounded the target. The number of delayed neutrons for a sample enclosed in cadmium was less than 5% of the number of the delayed neutrons without the cadmium.

In order to determine the effect of target thickness on the delayed-neutron yield ratio measurements were made using $U^{235}$ samples of different thickness in fission by 15.0-Mev neutrons. The $U^{238}$, $Th^{232}$ and $U^{235}$ samples were 35 mm in diameter and 9, 10, and 8 mm thick respectively.

The detector was a bank of four $BF_3$ counters connected in parallel and surrounded by paraffin.

The samples of fissile material were irradiated by the fast-neutron flux for a given time interval and then dropped into the counter block, located at a distance of approximately 1.5 meters below the target. When the sample was located the ion source of the accelerator and the high voltage power supply were switched off. The time required to move the sample was 0.20 to 0.30 sec.

The neutron detection circuit was switched on when the sample reached the center of the counter. The pulses from the counter bank were amplified and then recorded in a time analyzer. The channels in the time analyzer record in sequence the time required for a predetermined number of pulses.

Two series of exposures were made, 300 and 30 sec. The corresponding measurement times were 360 and 270 sec. There was essentially no background during the measurements; the background was checked by using a steel sample in place of the fissile material.