Time-of-Flight Measurement of Photoneutron Energy Spectra*†

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A TECHNIQUE has been developed for measuring photoneutron energy spectra which makes use of the time-of-flight principle and the M.I.T. linear accelerator as a pulsed source of bremsstrahlung. Electrons from the linear accelerator, analyzed to 3% in energy, impinge on a target at a repetition rate of 120/sec. The pulses have a duration $\sim 2.5\times 10^{-9}$ sec which is controlled by the conduction time of an electron gun in the Van de Graaff injector. The interval of time is measured between the passage of the bremsstrahlung through a plastic scintillator near the (γ,n) target and the detection of a neutron in another plastic scintillator (via a proton recoil) located at the end of a seven-meter flight path, 120° to the path of the bremsstrahlung beam. The elapsed-time spectrum is converted to a

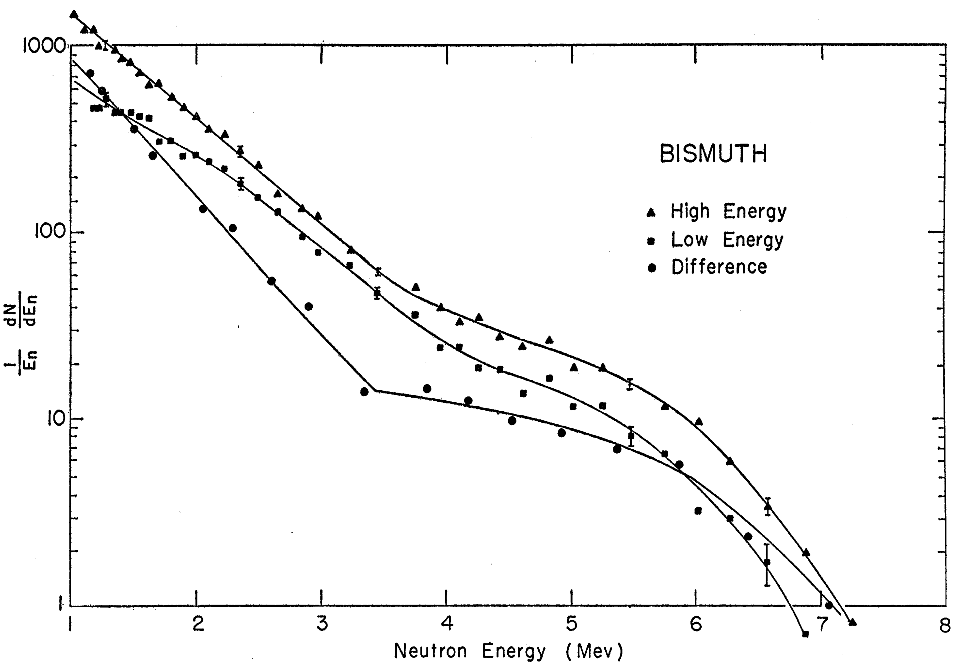

Fig. 1. Energy spectra $(1/E_n)(dN/dE_n)$ of photoneutrons from Bi for bremsstrahlung of maximum energies $\sim$14.3 Mev and $\sim$15.8 Mev, and difference spectrum.

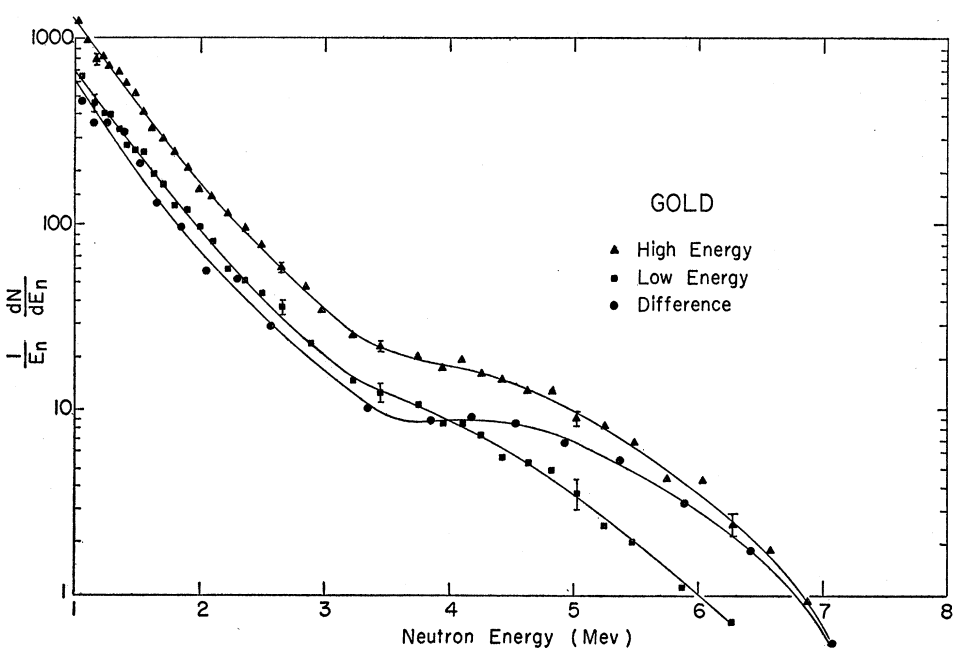

Fig. 2. Energy spectra $(1/E_n)(dN/dE_n)$ of photoneutrons from Au for bremsstrahlung of maximum energies $\sim$14.3 Mev and $\sim$15.8 Mev, and difference spectrum.

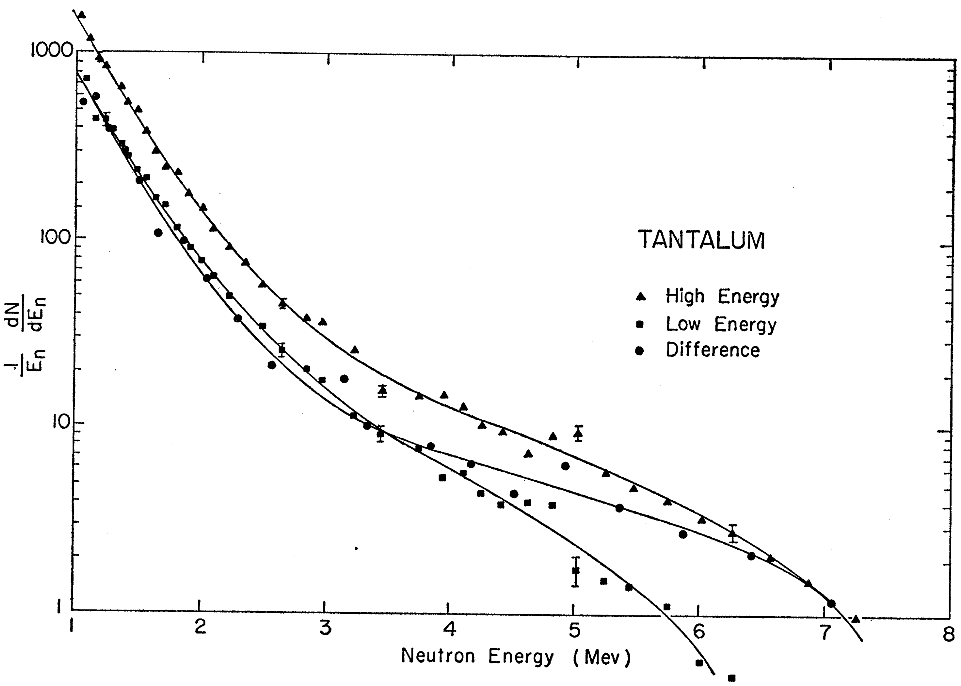

FIG. 3. Energy spectra $(1/E_n)(dN/dE_n)$ of photoneutrons from Ta for bremsstrahlung of maximum energies ~14.3 Mev and ~15.8 Mev, and difference spectrum.

pulse-height spectrum which is analyzed into 256 channels. The energy scale and resolution were tested by comparing the structure induced on a smooth (γ,n) spectrum by a transmission through carbon with that expected on the basis of the known total neutron cross section of carbon.[1] The resolution is roughly 3% in energy at 2 Mev and 6% at 9 Mev. Proton recoils of energy greater than 0.87 Mev are detected.

In Figs. 1, 2, and 3 we present data for the energy spectra $(1/E_n)(dN/dE_n)$ of photoneutrons from Bi, Au, and Ta produced by bremsstrahlung of the two maximum energies ~14.3 Mev and ~15.8 Mev. The data are normalized so as to yield equal numbers of photoneutrons from $\mathrm{D}(\gamma,n)$ with energies $E_n > 1.4$ Mev for each bremsstrahlung energy. The difference curves, obtained by subtracting the low-energy curves from the high-energy curves, can then be considered produced by a band of photons centered at about 14.5 Mev with about a 2-Mev half-width. The data at each bremsstrahlung energy are also normalized per atom. The ordinates are otherwise arbitrary.

If these spectra are due to the decay of a compound nucleus, we can obtain a measure of the relative level density of each nucleus by forming the quantities $\eta = [1/E_n\sigma_c(E_n)](dN/dE_n)$ from the experimental difference curves. This can be compared to theoretical expressions[2] for the level density of a degenerate Fermi gas that have the form $\eta(U) \sim (1/U^2)\exp[(aU)^{\frac{1}{2}}]$, where for our experiments $U \cong 14.5 - E_{\text{threshold}} - E_n$ Mev. Using reasonable assumptions for $\sigma_c(E_n)$ [$\sigma_c(E_n)$ constant and $\sigma_c(E_n)$ varying as in the report of Schrandt *et al.*[3]], we find that the theoretical expressions fail to reproduce the experimental difference curves by factors of 10 at high neutron (>3.5 Mev) energies. Although not as striking, the agreement at low neutron energies is also not good. The theoretical curves reflect the dominant $\sqrt{U}$ variation in the exponential, while the experimental curves have the character of U^n with $n \geq 1$ in the exponential. In order to obtain agreement in this low-energy region, it would be necessary for $\sigma_c(E_n)$ to decrease rapidly with increasing neutron energy, which seems an unlikely behavior.

Although the x-ray spectra in these experiments represent photon absorption over an interval >2 Mev, the neutron spectra appear to change character (from the rapidly varying low-energy group to the flat high-energy tail) in a narrow region of neutron energy ($\lesssim \frac{3}{4}$ Mev). This behavior appears to be independent of the excitation energy of the residual nucleus. This dependence on neutron energy may indicate that the absorption of a photon leads to the initial concentration of the photon energy in the motion of a single particle.[4,5]

More complete results and experimental details will be published.

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[1] *Neutron Cross Sections*, compiled by D. J. Hughes and J. A. Harvey, Brookhaven National Laboratory Report BNL-325 (Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 1955).
[2] See, for example, T. D. Newton, Can. J. Phys. **34**, 804 (1956); A. A. Ross, Phys. Rev. **108**, 720 (1957).
[3] Schrandt, Beyster, Walt, and Salmi, Los Alamos Report LA-2099, December, 1956 (unpublished).
[4] D. H. Wilkinson, Physica **22**, 1039 (1956).
[5] S. Rand, Phys. Rev. **107**, 208 (1957).