NEUTRON YIELD FROM (^{3}He,xn) REACTIONS ON THICK COPPER TARGETS

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Energy spectra and absolute yields of neutrons from a thick copper target bombarded by 270 MeV ^{3}He particles have been measured. Information about absorption of neutrons has also been obtained with the use of a shadow bar. The results of these measurements are important for estimating the neutron background which is produced in the focal plane of the K=600 magnetic spectrograph when the ^{3}He beam hits an internal Faraday cup inside the spectrograph in the (^{3}He,t) reaction at 0°.

Beams of 1 to 3 na, pulse-selected 1:2 (period 63 nsec) were directed onto a thick Cu viewer located in beam line 5. An NE102 plastic scintillator, 2.5 x 2.5 x 5.1 cm^3, served as neutron detector. It was mounted at a distance of 196 cm and at an angle of 19° with respect to the beam. A thin charged-particle veto scintillator in front of the neutron detector was used to eliminate events triggered by high-energy charged particles. The pulse height calibration of the detector used the known conversion between electron energy and proton energy[1] and the location of the Compton edges[2] for ^{22}Na, ^{137}Cs and ^{228}Th. A typical two-dimensional spectrum of pulse height versus time-of-flight is displayed in Fig. 1. Prompt gamma rays from the target appear in channel 940. Pulse-selection leak-through from the intermediate beam burst about 32 nsec after the main burst is seen near channel 100. Time-uncorrelated background at low pulse heights is due to (n,n), (n,n') and (n,n'γ) reactions in the walls and the floor.

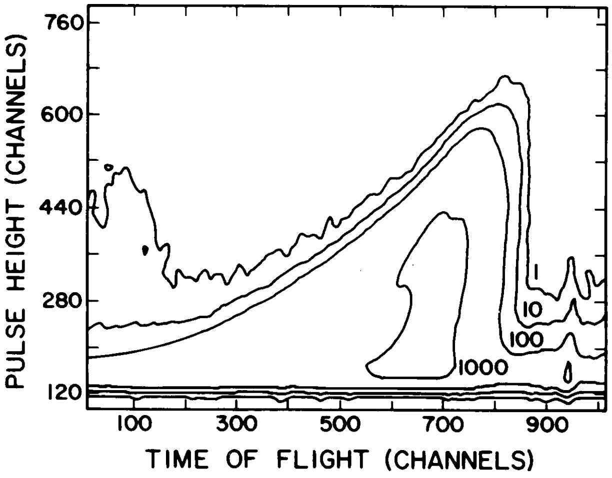

Figure 1. Two-dimensional contour plot (logarithmic) of pulse height versus time-of-flight.

Combining the pulse-height and time-of-flight calibrations with scintillator efficiency calculations using the program of Cecil, Anderson and Madey[1] makes it possible to construct consistent absolute neutron spectra. The time-independent background must be eliminated with appropriate software pulse-height thresholds. The experimental neutron spectrum so obtained is shown in Fig. 2 in units of neutrons/(MeV.sr.incident particle).

The spectrum displays a low-energy plateau of about 2 x 10^{-4} n(MeV)$^{-1}$(sr)$^{-1}$(^{3}He)$^{-1}$ extending to about 70 MeV, followed by an essentially exponential falloff over three orders of magnitude. Also shown in Fig. 2 is a calculated spectrum obtained by assuming projectile fragmentation.[3] The shape of the experimental spectrum above 80 MeV is exceptionally well reproduced, but the calculations overpredict the

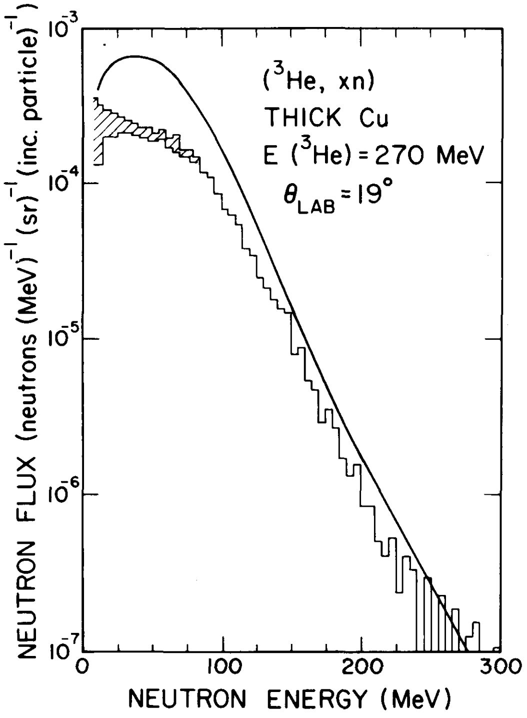

Figure 2. Experimental and calculated neutron yield at Θ = 19° from a thick Cu target bombarded by 270 MeV ^{3}He particles.

yield by a factor of two and do not completely reproduce the low-energy plateau region. Neutron spectra from 160, 200 and 450 MeV protons stopped in thick targets also display low-energy plateau regions.[4,5] Interestingly, the neutron yield from ^{3}He particles of 270 MeV and protons of about 270 x 0.4 = 110 MeV have similar neutron yields.

An internal Faraday cup to be used for the K = 600 spectrograph in (^{3}He,t) measurements at 0° will be located 3.4 m from the low-resolution exit port. The focal plane detector is shielded by 1.6 m of Fe from the neutrons emitted from the beam stop at 19° with respect to the ^{3}He beam direction. Using the procedures of Ref. 3 to estimate the absorption in Fe and the scintillator efficiency of Ref. 1 leads to a neutron background rate in the focal plane scintillators of a few events per second for a 200 MeV ^{3}He beam of 100 na. However, this estimate is probably too low, and rates of a few 100 counts/sec are more realistic. Shadow bar measurements which were intended to test the absorption calculations are not fully understood yet and are likely to require a modification of the procedures of Ref. 3. The assumption that the effective removal cross section is about 50% of the total cross section[6] seems to give a reasonable attenuation length in Fe of about 20 cm.

1) R.A. Cecil, B.D. Anderson and R. Madey, Nucl. Instr. Meth. 161, 439 (1979).

2) G. Dietze and H. Klein, Nucl. Instr. Meth. 193, 197 (1968).

3) J. Naryanaswamy et al., MSU Internal Report MSUCP-40 (1982).

4) J.W. Wachter et al., Phys. Rev. 161 (1967) 971; Phys. Rev. C 6, 1496 (1972).

5) R.G. Alsmiller, R.T. Santoro and J. Barish, Particle Accelerator 7 (1975) 1; see also H.S. Smith, IUCF Internal Report IUCF 74-6 (1974).

6) R.J. Schneider and A.M. Cormack, Nucl. Phys. A119, 197 (1968).