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AN ASSOCIATED ALPHA-PARTICLE TIME-OF-FLIGHT FACILITY

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A fast neutron time-of-flight spectrometer based on an associated alpha-particle technique has been developed. The neutron detector is a 12.7 cm diam by 5.1 cm long BC-501 liquid scintillator. The detector is housed in a heavy shielding. The alpha detector is a 0.025 mm thick NE102A scintillator. The time-of-flight system was tested by measuring differential cross-sections of 14.1 MeV neutron scattered from carbon.

I. INTRODUCTION

The secondary neutron energy and angular distributions from (n, xn') reaction on certain materials are of both theoretical and experimental interest. Information on nuclear level densities and reaction mechanisms can be extracted from an analysis of the spectral shape and differential cross section.[1-4] In addition, the cross sections are of importance for the development of fission and fusion reactor system and accelerator based applications.[5,6]

Serveral calculations[4,7] have been made to predict the angle integrated neutron energy spectrum. Attempts to determine which calculations provide correct results in any part of the spectrum have been complicated by the fact that available experimental measurements[8-12] of neutron energy spectra do not agree over the entire range of emitted neutron energies.

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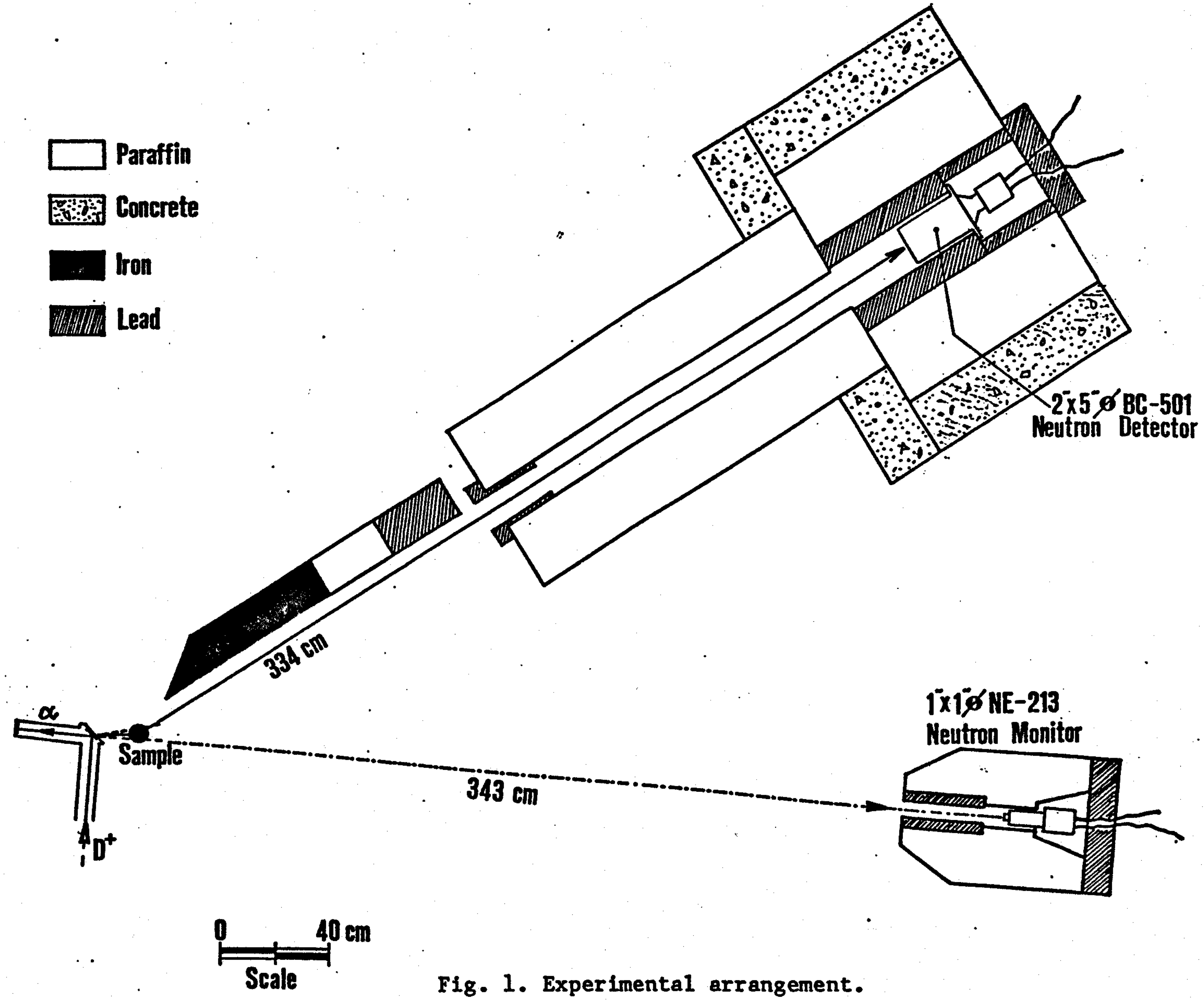

Fig. 1. Experimental arrangement.

In order to resolve discrepancies that exist among various measurement, to test the nuclear model calculations and to provide data for nuclear technology application new measurements are needed.

We have initiated a programme to set up a facility to measure neutron emission cross-sections at incident neutron energy of 14.1 MeV based on an associated alpha-particle time-of-flight (TOF) technique.

In this report we present results of the investigation on the performance of the overall TOF spectrometer by measuring differential cross-sections of neutron elastically and inelastically (4.43 MeV) scattered from carbon.

II. EXPERIMENTAL PROCEDURE

The experimental set up is shown in Fig. 1. Neutrons were produced from an AID J25 accelerator[(i)] The associated alpha detector was a 0.025 mm thick NE102A plastic scintillator viewed through a perspex light pipe by an RCA8575 photomultiplier tube (PMT); a cylindrical aluminium housing combined the light pipe, the scintillator and the photomultiplier tube into a vacuum sealed single unit as shown in Fig. 2. The path length of the detected alpha particle was 27 cm long. Neutrons were detected in a 12.7 cm diam by 5.1 cm long BC-501[(ii)] liquid cylinder which was coupled directly to RCA8575 photomultiplier tube. The relative neutron flux was monitored by a 2.54 cm diam by 2.54 cm long NE213 liquid scintillator. The yield of the $T(d,n)^4He$ neutron in this detector was used as a relative measure of the integrated neutron flux at the samples during measurements with the main detector, thus making normalization of different runs to each other possible. Pulse shape discriminators (PSD)[13)] were used in both neutron detectors to reduce the gamma-ray background. The scattering samples were 3.8 cm diam by 4.5 cm high cylindrical graphite and 4.6 cm diam by 4.5 cm high hydrocarbon. They were suspended with thin threads at a distance of about 15 cm from the neutron producing target and with the symmetry axis perpendicular to the scattering plane.

(i) Assistance Industrielle Dauphinoise (formerly SAMES) Meylan, France.

(ii) Supplied by BICRON CORP., Ohio, U.S.A.

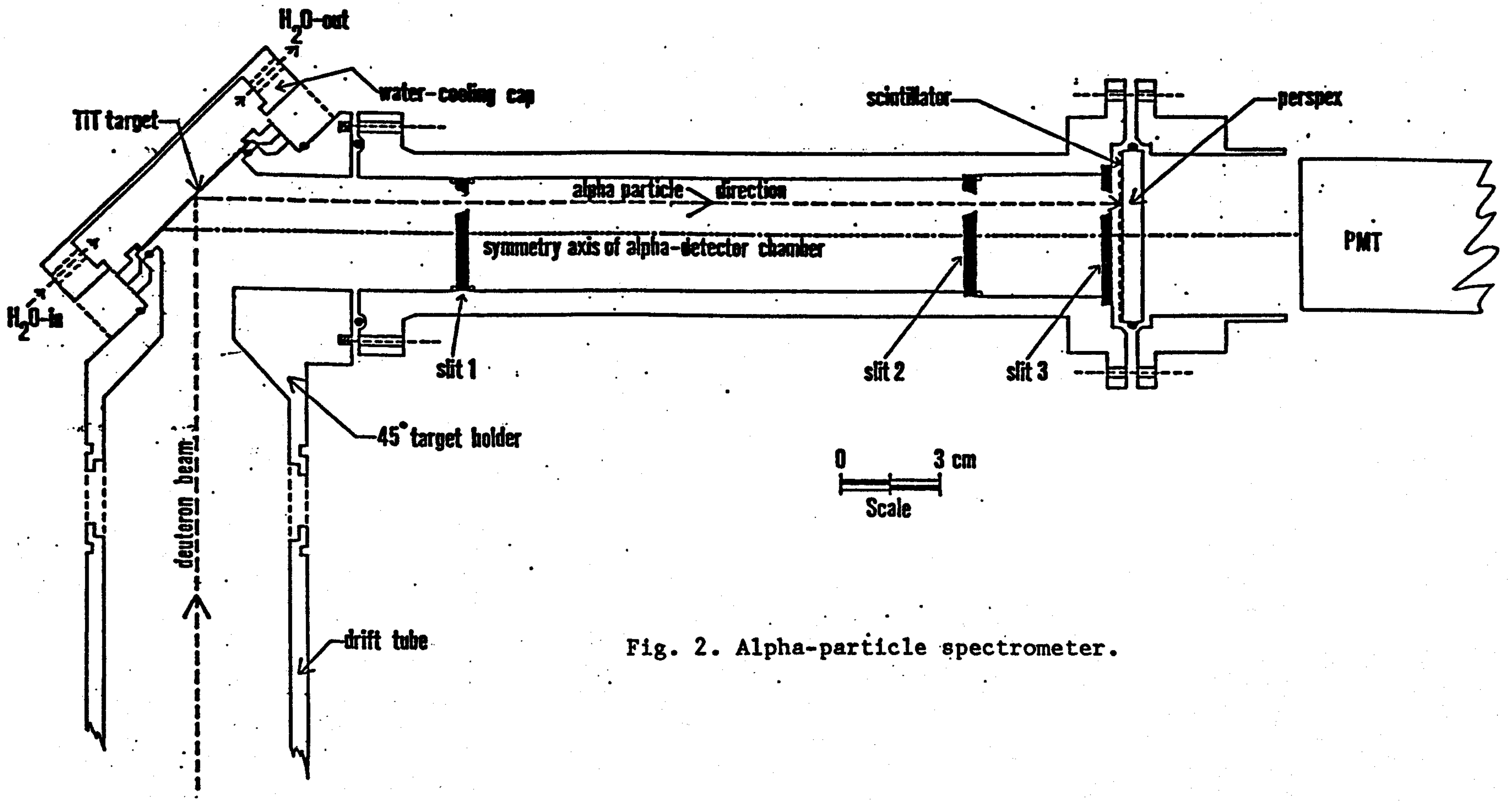

Fig. 2. Alpha-particle spectrometer.

The pulse height from each neutron counter was calibrated periodically with a series of radioactive gamma sources, namely ^{137}Cs, ^{22}Na, and ^{60}Co. The Compton peak in the gamma-ray spectrum was used as a calibrating point. We associated the peak channel with an electron energy equal to 0.95 that of the maximum Compton energy.[14] The time-to-amplitude converter for the time-of-flight spectrum was calibrated with a (Tennelec TC850) precision time calibrator. The time calibration was 180 psec per channel.

III. TIME-OF-FLIGHT MEASUREMENTS

Fresh neutron producing targets were used in this experiment to avoid contamination due to d-D reaction in the alpha detector. A typical pulse height spectrum from the alpha detector is shown in Fig. 3. One output from the neutron monitor was fed into another multichannel analyser (MCA) in an MCS made to observe variation in the primary neutron yield. A typical spectrum is shown in Fig. 4. Time-of-flight spectra were measured in the angular range from 30° to 120°. Conversion from yields to cross sections was accomplished by comparison with the n-p scattering cross section, using a hydrocarbon (nylon) scattering sample. Typical TOF spectra from a nylon and carbon target is shown in Fig. 5. In Fig. 5(a) the first peak on the right is the elastic scattering (0^+) peak whereas the second peak to the left is due to n-p scattering. Fig. 5(b) shows peaks due to carbon scattering to the ground and 2^+ excited states. The TOF spectra display time-independent (flat) backgrounds before and after region of interest. Target-out run spectrum also confirmed this time-independent nature.

IV. DATA REDUCTION

The laboratory differential cross section $d\Omega\ (\theta)/d\ \Omega$ in units of millibarn per steradian is given by the expression:

$$\frac{d\sigma(\theta)}{d\Omega} = \left(\frac{N_s}{N_H}\right) \left(\frac{M_H}{M_s}\right) \left(\frac{n_H}{n_s}\right) \left(\frac{\varepsilon_H}{\varepsilon_s}\right) \left(\frac{d\sigma}{d\Omega}\,(\theta')_H\right) \qquad (1)$$

where N_s, N_H are the carbon and hydrogen peak areas in the spectrum, M_s, M_H are the count rates from neutron monitor for carbon and hydrocarbon sample. n_H is the member of hydrogen atoms per unit volume, n_s is the number of carbon atoms per unit volume. ε_s, ε_H are

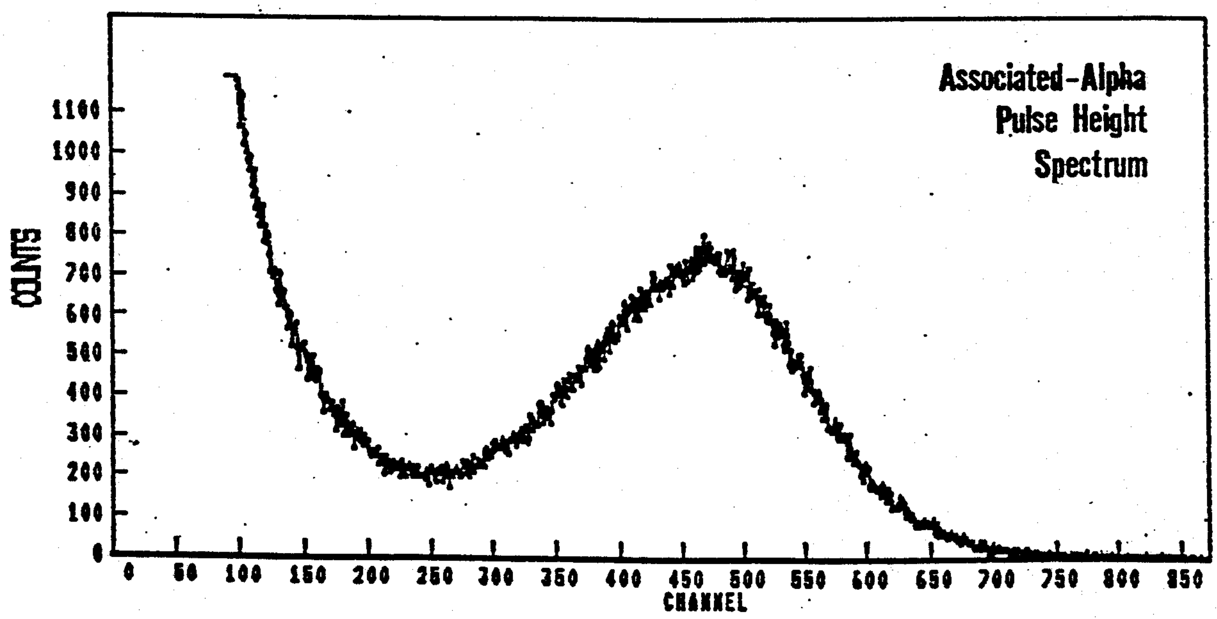

Fig. 3. Typical pulse height spectrum from the alpha detector.

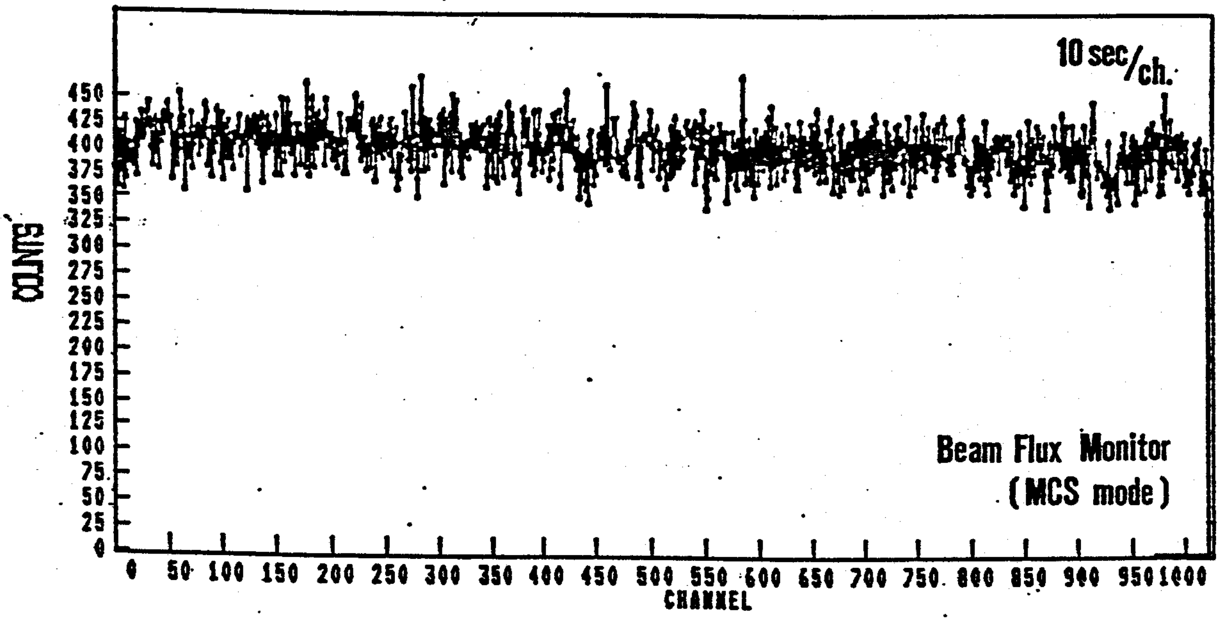

Fig. 4. Typical spectrum in an MCS mode from the neutron monitor.

the detection efficiencies of the neutron counter and $d\sigma(\Theta')H/d\Omega$ is the differential cross section of hydrogen at and angle Θ'.

The neutron detection efficiency was calculated with the Monte Carlo computer program of Cecil et al.[15] which is an improved version of the program written by Stanton.[16] The improvements include new cross section determinations for the inelastic reaction on carbon, a proper determination of the energy deposited by escaping

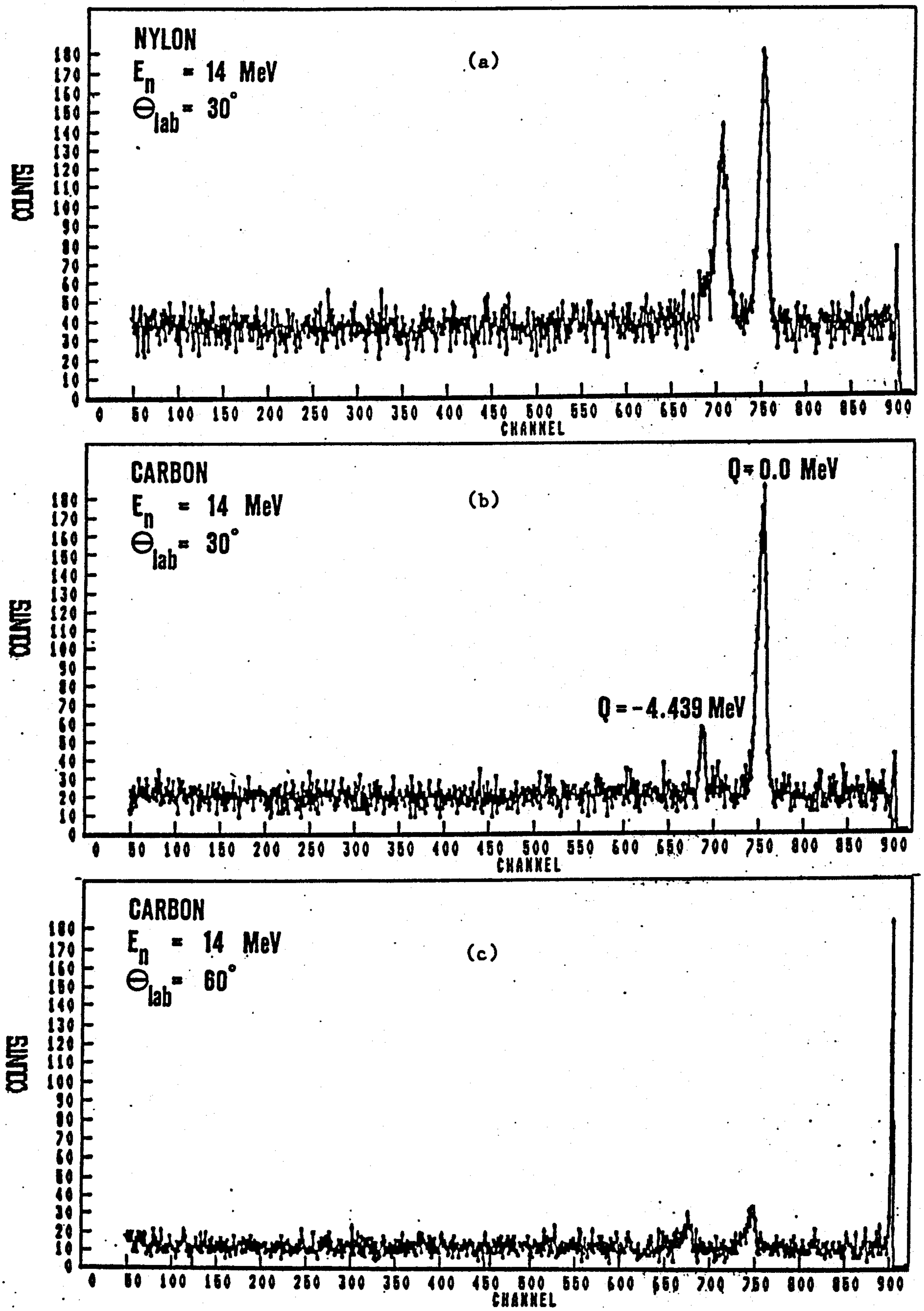

Fig. 5. Typical Time-of-flight spectra.

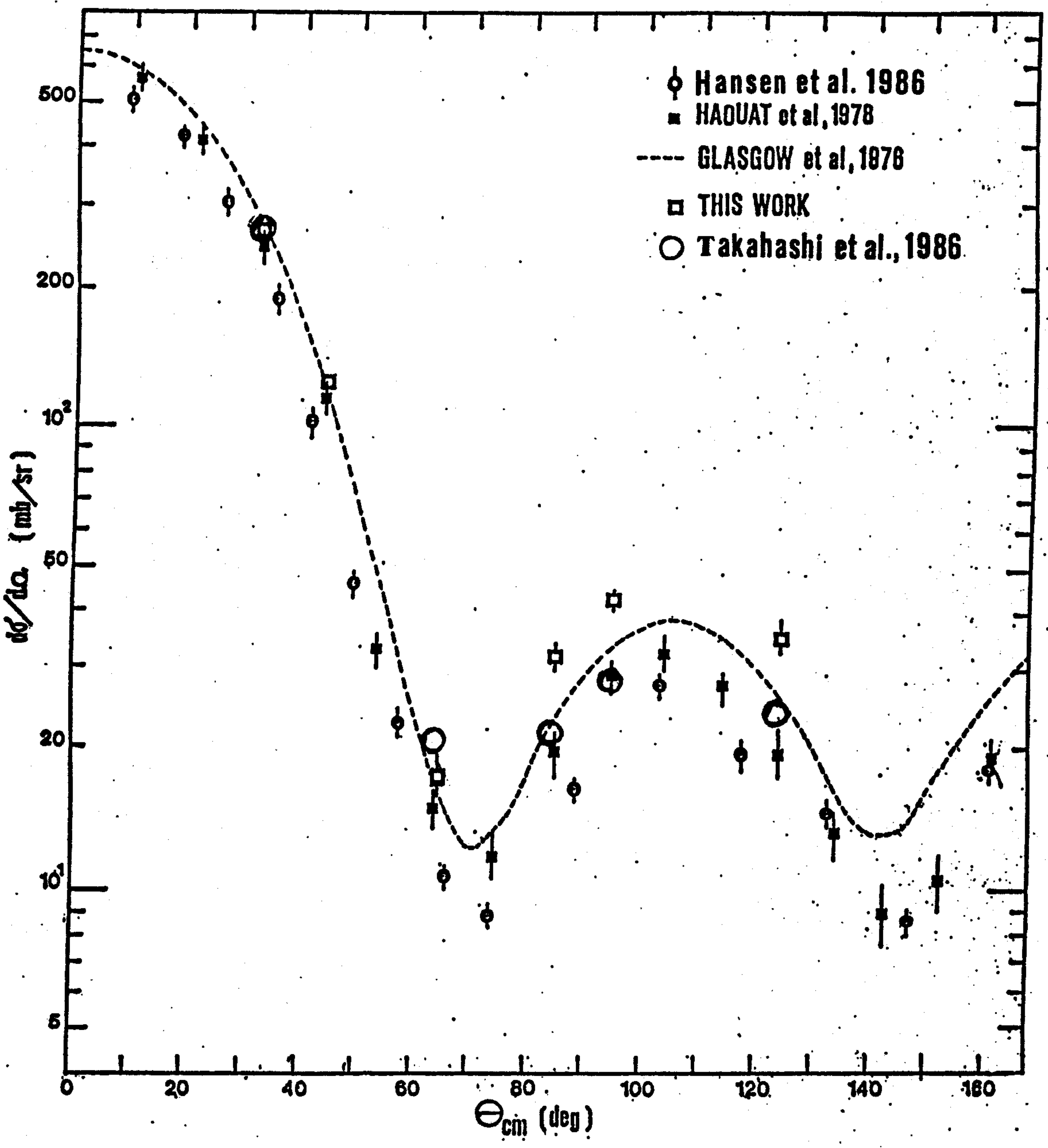

Fig. 6. Differential cross sections for 14.1 MeV neutrons elastically scattered from carbon. Errors shown in our data are statistical only. Only some representative cross sections of Takahashi's data are platted here.

charged particles, and the use of relativistic kinematics. The uncertainly in the Monte Carlo calculation including an uncertainly in the pulse height threshold is estimated to be about 5 percent. The cross sections were not corrected for attenuation and multiple scattering. Another source of systematic error could also arise from instability of the deuteron beam. This would effect count rates re-

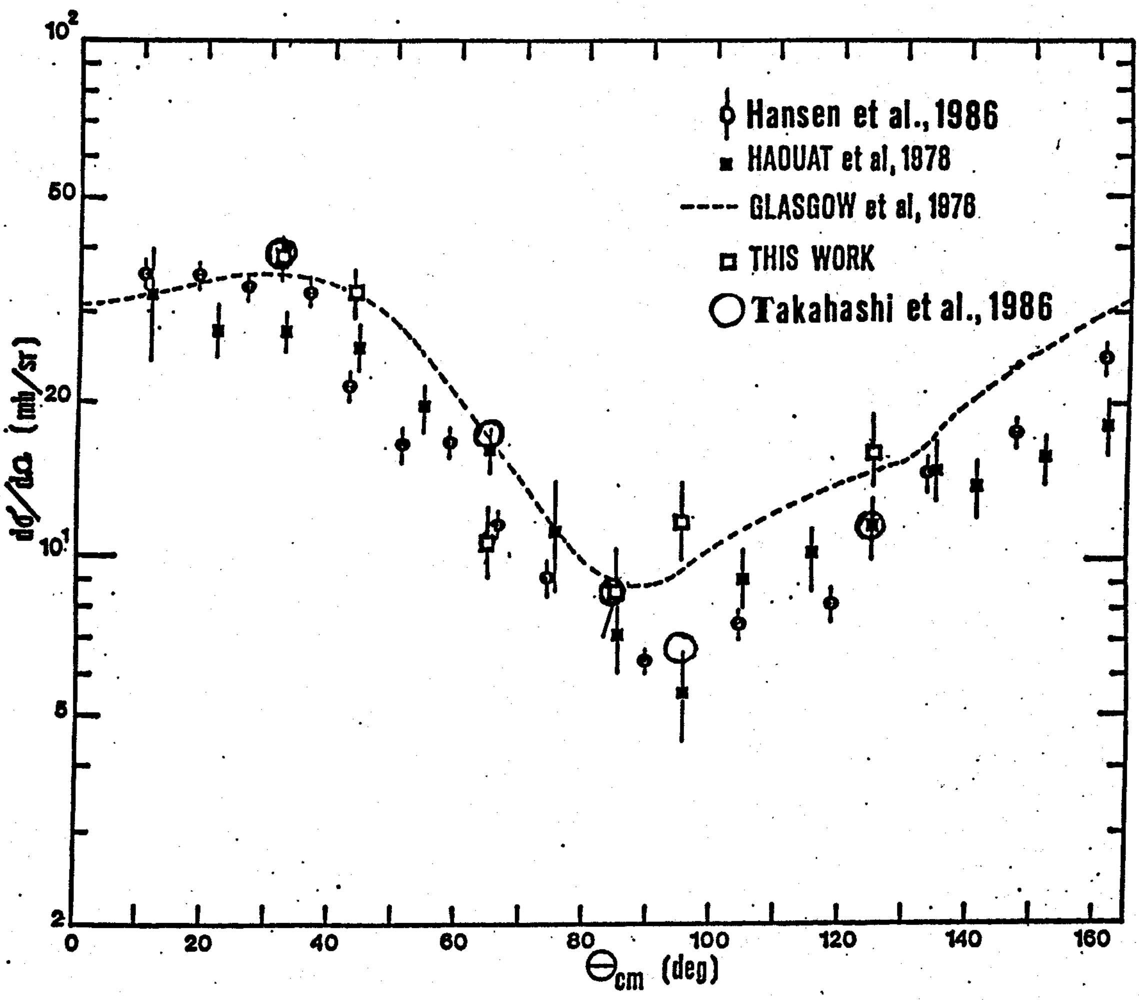

Fig. 7. Differential cross sections for 14.1 MeV neutron inelastically scattered from carbon. Errors shown in our data are statistical only. Only some representative cross sections of Takahashi's data are platted here.

gistered in the neutron monitor. We estimated an overall systematic error to be about 15 percent. The statistical uncertainly varies from ± 2 percent to ± 10 percent.

V. RESULTS AND DISCUSSION

Differential cross sections for scattering to the ground state and the 2^+ excited state are shown in Fig. 6 and Fig. 7 respectively. We also compare our measurements from carbon with those of Haouat et al.,[17] Glasgow et al.,[18] Hansen et al.,[19] and Takahashi et al.,[20]. As mentioned earlier the angular distributions have not been corrected for neutron attenuation and multiple scattering and are shown only to give an impression of the performance of our time-of-flight facility. Generally, within the limits of our estimated uncertainties, they agree with the results obtained by others indicating that our spectrometer works satisfactorily.

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REFERENCE

1. L.F. Hansen et al., Nucl.Sci.&Eng. 61, 201(1976).
2. G. Stengl et al., Nucl.Phys. A290, 109(1977).
3. B. Strohamier., Nucl.Sci.&Eng. 65, 368(1978).
4. S. Pearlstein, Nucl.Sci.&Eng. 68, 55(1978).
5. Proceeding of International Conference on "Neutron Physics and Nuclear Data for Reactors and Other Applied Purposes," Harwell, U.K., Sep. 1978.
6. Proceeding of International Conference on "Neutron Cross Section for Technology," Knoxville, U.S.A., Oct. 1979.
7. C.Y. Fu, "Development and Applications of Multi-step Hauser-Feshbach/Pre-equilibrium Theory, IAEA-SMR-69/1 (1981).
8. D. Hermsdorf et al., Zfk-277 (U) Zentralinstitute Fur Kernforshung, Dresden (1975).
9. S.C. Matheur et al., Phys.Rev. 186 1038 (1969).
10. J.L. Kammercliener, UCRL-51232 (1972).
12. A. Chalupka et al., Proc. of IXth International Symposium on the Interaction of Fast Neutrons with Nuclei, Gaussig (GDR), Nob. 1979.
13. G.G. Hoyes et al., "Instrumentation for a Fast Neutron Time-of-Flight Spectrometer," INDC(TAI)-002GI., INT(83)-1, November 1982, IAEA, Vienna.

14. H.H. Knox and T.G. Miller, Nucl.Instrum.Methods 101, 519 (1972).

15. R.A. Cecil et al., Nucl.Instrum.Methods 161, 439(1979).

16. N. Stanton, Chicago Operations Office Report-COO-1545-92, 1971.

17. G. Haouat et al., Nucl.Sci.&Eng. 65, 331(1978).

18. D.W. Glasgow et al., Nucl.Sci.&Eng. 61, 521(1976).

19. L. Hansen, private communication (1986).

20. A. Takahashi, private communication (1986).