WORKING GROUP SESSION III

APPLICATION OF THE DUAL THIN SCINTILLATOR NEUTRON FLUX MONITOR IN A $^{235}U(n,f)$ CROSS-SECTION MEASUREMENT

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Abstract

The fission cross section for ^{235}U was measured over the 1 to 6 MeV energy range using the National Bureau of Standards neutron time-of-flight facility at the NBS 100-MeV electron linac. The recently developed dual thin scintillator (DTS) neutron detector was used as the neutron flux monitor. The DTS flux monitor was placed ~ 200 m from the source. At ~ 69 m on the same flight path a well-characterized fission chamber containing ~ 100 $\mu g/cm^2$ of ^{235}U was located. The background for both detectors was reduced to negligible levels. Two parameter data (pulse height and time-of-flight) were taken for both detectors with a computer based system. Since the experiment was devised primarily to verify the accuracy of the DTS detector as an absolute neutron flux monitor, only moderate energy resolution was planned ($\Delta E/E \approx 10\%$). The cross section uncertainty obtained was ~ 2%.

INTRODUCTION

Recently a new concept in neutron flux monitors employing proton recoil scintillators has been developed at NBS. The detector, which is called the dual thin scintillator (DTS) neutron detector[1] uses a thin plastic scintillator to keep multiple scattering corrections small. A second thin plastic scintillator is used to experimentally eliminate the pulse height distortion due to proton escape.

The DTS detector has been calibrated using the time-correlated associated-particle technique and Monte Carlo simulations. To further test the DTS detector as a neutron flux monitor, it has been used for this purpose in a measurement of the ^{235}U neutron-induced fission cross section over the 1-6 MeV range. The measurement is closely related to the 0.3 to 3.0 MeV measurement using the NBS Black Detector as the neutron flux monitor.[2] For the present measurement the DTS detector was placed at the same position as the Black Detector.

Since this measurement was devised primarily to verify the accuracy of the DTS detector as an absolute flux monitor, only moderate energy resolution was planned ($\Delta E/E \approx 15\%$).

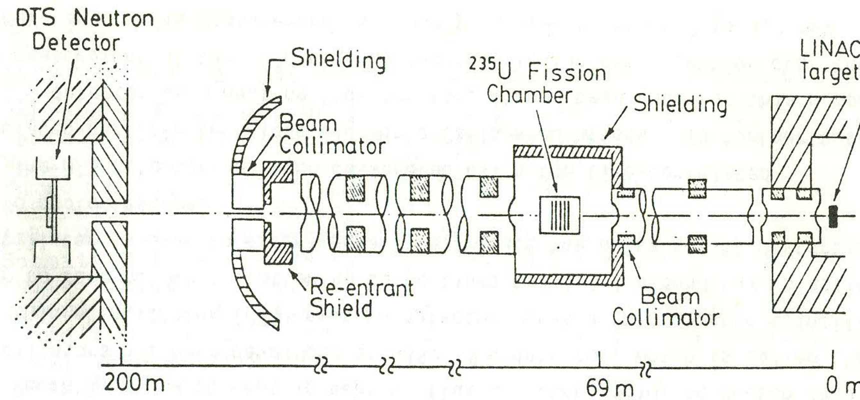
This report presents preliminary results of the measurement. These results may be subject to minor revision and should not be used until final corrections are made.

EXPERIMENTAL METHOD

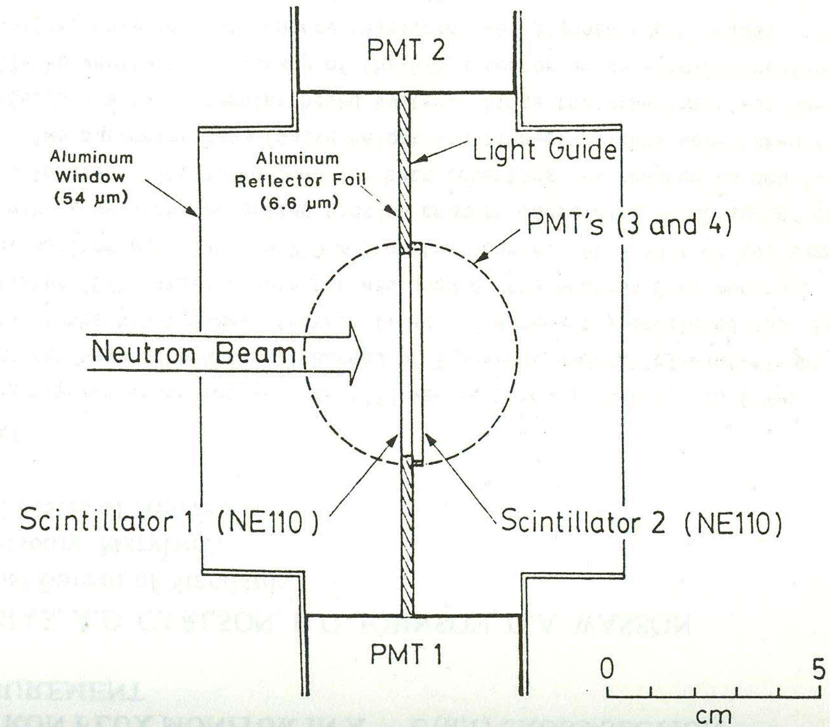
A general description of the NBS Neutron Time-of-Flight Facility has been described previously.[3] The present measurements were made at the 200-m flight path of this facility as shown in Fig. 1. The large parallel-plate ionization fission chamber[4] with 170.9 ± 2.0 mg of ^{235}U was located at 69.466 m from the neutron producing target. The absolute neutron fluence was monitored by the DTS detector located at 200.765 m. The NBS linac operated with a 30-ns pulse width, 720-Hz repetition rate, and with 1.7 kW on target.

Details on the design and calibration of the DTS detector, which is shown in Fig. 2, have been described in a recent paper.[1] A brief summary follows. The detector consists of two thin NE110 plastic scintillators optically separated from each other and independently coupled to photomultiplier tubes. The two scintillators are 0.2565 cm in thickness and 4.70 and 4.90 cm in diameter. Each scintillator is coupled to a pair of photomultipliers by a rectangular (5.3 cm by 12.0 cm) plastic light guide. The primary advantage of this detector concept is that all calculated corrections to the efficiency are kept small. For a thin scintillator multiple scattering corrections are small. Although distortion of the proton recoil spectrum due to escape of protons is large for a single thin sciintillator, the use of a second scintillator experimentally eliminates this correction.

The absolute efficiency of the DTS detector has been calculated for the 1 to 15 MeV range using Monte Carlo techniques. The efficiency was also measured at 2.44 MeV and 14.0 MeV using the time-correlated associated-particle technique at the NBS 3-MV Positive-Ion Van de Graaff. The agreement between the calculated and measured efficiencies is $\lesssim 1.7\%$.



1. Experimental geometry for the ^{235}U neutron-induced cross-section measurement.



2. Geometry of the dual thin scintillator (DTS) detector.

Shielding for the DTS detector at the 200-m flight path consisted of 20 cm of Pb and 20 cm of borated-polyethylene. The neutron beam was collimated to an area of 1.1459 cm^2 incident on the center of the scintillators. Time-independent background was measured by opening a time gate just before the next beam pulse. The largest potential source of time-dependent background was due to high-energy neutrons scattered by the detector then scattered back later in time by the shielding. This source was eliminated by opening the time gate for these high energy neutrons and operating in a one stop per start mode.

DATA ANALYSIS

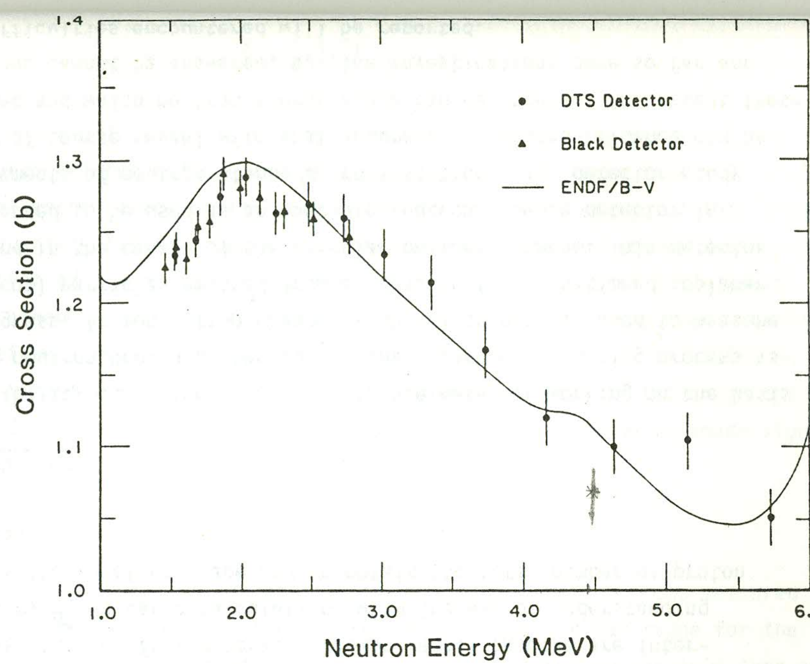
Data from both the fission chamber and the DTS detector were taken in two-parameter mode (pulse-height and time-of-flight). The data were analyzed by a comprehensive computer program that calculated the fission chamber and DTS detector yields (corrected for dead time and background). The neutron detector yields were then normalized to match the time width and flight path at the fission chamber. The neutron fluence was determined for each time-of-flight channel by correcting for detection efficiency and neutron attenuation in materials between the fission chamber and the neutron detector. The latter correction was made using cross sections from ENDF/B-V.[5] Also, the neutron yields were smeared by a Gaussian function to match the broader time resolution of the fission chamber. Ratios of the corrected fission chamber and neutron detector yields were multiplied by the appropriate scale factor to give the $^{235}U(n,f)$ cross section per time-of-flight channel together with its statistical uncertainty. The data was then grouped into the desired energy intervals.

The efficiency of the DTS neutron detector was calculated using the following interpolation formula:

$$\epsilon_B = \sigma_H \ (A_1 + A_2\sigma_C + A_3\sigma_H) \qquad (1)$$

where ϵ_B is the biased efficiency, σ_H is the hydrogen elastic cross section, σ_C is the carbon elastic plus inelastic cross section, and A_i are fitting constants. The parameters of Eq. (1) were determined by fitting the Monte Carlo calculations of the efficiency for a 30% energy bias. The calculations were in turn normalized to the associated-particle technique calibrations.

2. Geometry of the dual thin scintillator (DTS) detector.



3. $^{235}U(n,f)$ cross section in the 1-6 MeV range.
Circles - DTS detector as the neutron flux monitor.
Triangles - Black Detector as the neutron flux monitor.
Solid line - ENDF/B-V evaluation.
The error bars represent statistical uncertainties only.

RESULTS AND CONCLUSIONS

The data were grouped so that the energy resolution ΔE/E was approximately 10% throughout the energy range (1.45 to 6.00 MeV). The statistical error which is obtained with this grouping is ~ 1.0% at the lowest energy and increases to ~ 1.9% at the highest energies. At this time the systematic errors have not been fully evaluated, nevertheless, they will be dominated by the DTS detector efficiency uncertainty (approximately 1.7% at low energies decreasing to 1.1%) and by uncertainty in the ^{235}U mass (approximately 1.2%).

In Fig. 3 the preliminary results of the present experiment are presented. The error bars are statistical uncertainties only. Also shown are partial results from the NBS measurement using the Black Detector as the flux monitor and the ENDF/B-V evaluation. In the region of overlap there is good agreement between the two measurements but both results are somewhat lower than ENDF/B-V. Above ~ 2.5 MeV the present results are in reasonable agreement with ENDF/B-V.

It must be emphasized that this is a preliminary report. Systematic corrections and their uncertainties have not been finalized. Careful evaluation of these corrections can cause changes in these results by ~ 1.0 %.

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INVESTIGATION FOR A PRECISE AND EFFICIENT NEUTRON FLUENCE DETECTOR BASED ON THE n-p SCATTERING PROCESS

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Abstract

An ionization chamber with Frisch grid is used to detect the recoil protons induced by fast neutrons in an advantageous 2π-geometry. The working principles of the detector are explained. Recoil proton spectrum measurements are made at several incident neutron energies below 2 MeV using four radiator foils of different thicknesses. These measurements permit a proton energy calibration of the detector and the determination of proton stopping powers for the radiator foil material. Proton recoil spectra are interpreted by Monte Carlo calculations with the aim of understanding closely the spectrum shape and to obtain the total number of proton recoils.

INTRODUCTION

A feasibility study for a neutron fluence detector working on the basis of the neutron,proton or perhaps on the n-carbon scattering process is in progress. An ionization chamber with Frisch grid is used to measure the recoil particles emitted from a radiator foil positioned coplanar with and in the centre of the circular chamber cathode. This detector is intended to be used as an absolute neutron fluence detector in measurements of neutron standard cross sections. The detector study should of course reveal with what accuracy the neutron fluence can be measured and which neutron energy range can be covered. At present these questions cannot be answered, but the investigations done so far and the difficulties encountered will be reported.