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# 2.5 MeV NEUTRON SOURCE FOR FISSION CROSS SECTION MEASUREMENT

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Abstract: A 2.5-MeV neutron source has been established on the beamline of a 100-kV, 0.5-ma ion accelerator. The ion accelerator provides a 100-kV deuteron beam of about 200 μa into a 3-mm beam spot at the target position. The neutron source is produced by the $D(d,n)^3He$ reaction with a yield of about $10^7$ n/sec. The time-correlated associated particle method (TCAP) is utilized for the neutron fluence determination and for neutron background elimination. The $^3He$ associated particles are detected at 90 degrees behind a thin aluminum foil and the corresponding neutrons are emitted at 73.5 degrees with an energy near 2.5 MeV. Also, the protons from the competing D(d,p)T reaction are monitored at 135 degrees for normalization and diagnostic purposes. A fission chamber containing six uranium tetrafluoride deposits has been designed for use in the $^{235}U(n,f)$ cross section measurement at 2.5 MeV. The 5-cm diameter deposits range in thickness from 230-300 $\mu g/cm^2$ and are expected to have good uniformity. A description of the 2.5-MeV neutron source facility is presented along with details of the associated particle detection and neutron beam characteristics. Preparations for the fission cross section measurement are discussed.

(associated particle; $D(d,n)^3He$; 2.5-MeV neutrons; neutron fluence determinations; $^{235}U(n,f)$ cross section; TCAP)

## Introduction

The long-standing request of 1% accuracy in neutron standard cross sections throughout the energy range of interest has been achieved only at the 14-MeV and thermal spot energies. It has been recognized[1] that with the present measurement technology, the desired accuracy can be best achieved through a series of high accuracy time-correlated associated-particle (TCAP) measurements at several spot energies. Relative measurements of cross-section shape would then be normalized at the TCAP spot energies. Specifically at 2.5 MeV, TCAP measurements would offer a distinctively located normalization at an intermediate energy between 14 MeV and thermal.

The $^{235}U(n,f)$ cross section is an important standard whose measurement has been of primary interest at the National Bureau of Standards (NBS) for some time. A discrepancy continues to exist in the results of more recent measurements of the $^{235}U(n,f)$ cross section at 2.5 MeV[2-5]. A 2.5-MeV neutron source has been established at the NBS on the beamline of a 100-kV, 0.5-ma ion accelerator using the $D(d,n)^3He$ reaction and the TCAP method with a primary objective being to measure the $^{235}U(n,f)$ cross section at 2.5 MeV.

TCAP methods are utilized for neutron fluence determination and neutron background elimination. The TCAP measurement with the $D(d,n)^3He$ source requires the use of a low energy, high current deuteron beam[6]. The ability to distinguish the $^3He$ associated particles from the high yield of scattered deuterons by foil absorption can be best accomplished with lower energy beams below 150 keV. However, the lower neutron yield from the d-d source at the lower deuteron beam energies must be compensated for by increased beam currents. The low voltage, 100-kV ion accelerator can provide the needed intensity to carry out the $^{235}U(n,f)$ cross section measurement.

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The facility, consisting of the 100-kV ion accelerator and the fixed TCAP setup is dedicated solely to the production and measurement of 2.5-MeV neutrons. The stable measurement conditions, resulting partly from the stability of self-regenerating deuterium targets, should be sufficient for the careful, long term evaluation of this and other important standard cross sections at 2.5 MeV.

## Facility Description

The 2.5-MeV neutron source facility consists of a 100-kV, 0.5-ma ion accelerator, a beamline with focusing and steering elements, and a target chamber designed for TCAP measurement. This setup is illustrated in Figure 1. The deuteron beam is produced by a radio-frequency type ion source and accelerated to 100 kV. The unanalyzed beam produced is adequate because the neutron field characteristics obtained in the measurement geometry used are insensitive to variations in the deuteron beam energy. The deuteron beam is focused and steered by a magnetic quadrupole doublet and a magnetic x-y steerer through a 3-mm collimator and onto a TiD target. The 200-μa beam current into the 3-mm beam spot produces a neutron yield of about $10^7$ n/sec. The target is mounted at the end of the target chamber and is cooled by forced air. Target vacuum pumping is provided by a turbomolecular pump connected to an outlet at the bottom of the chamber and is essential for reducing the outgassing caused by the high incident beam currents. Beam currents on the beam collimator and target are monitored separately.

The target chamber shown in Figure 2 has been designed for associated particle measurement with the $D(d,n)^3He$ reaction at 90 degrees and time-correlated neutron emission at about 70 degrees. The TiD target is oriented at 45 degrees with respect to the deuteron beam axis. The geometry was chosen in order to optimize the ability to distinguish the $^3He$ associated particles from scattered deuterons and to minimize the distortion of associated particle energy and neutron beam

1 HV Terminal
2 100-kV Power Supply
3 Acceleration Tube
4 Vac Ion Main Pump
5 Magnetic Quadrupole Doublet
6 Magnetic Dipole X-Y Steerer
7 Isolation Gate Valve
8 Target Chamber
9 Turbomolecular Auxillary Pump
10 Fore Pump
11 Concrete Floor

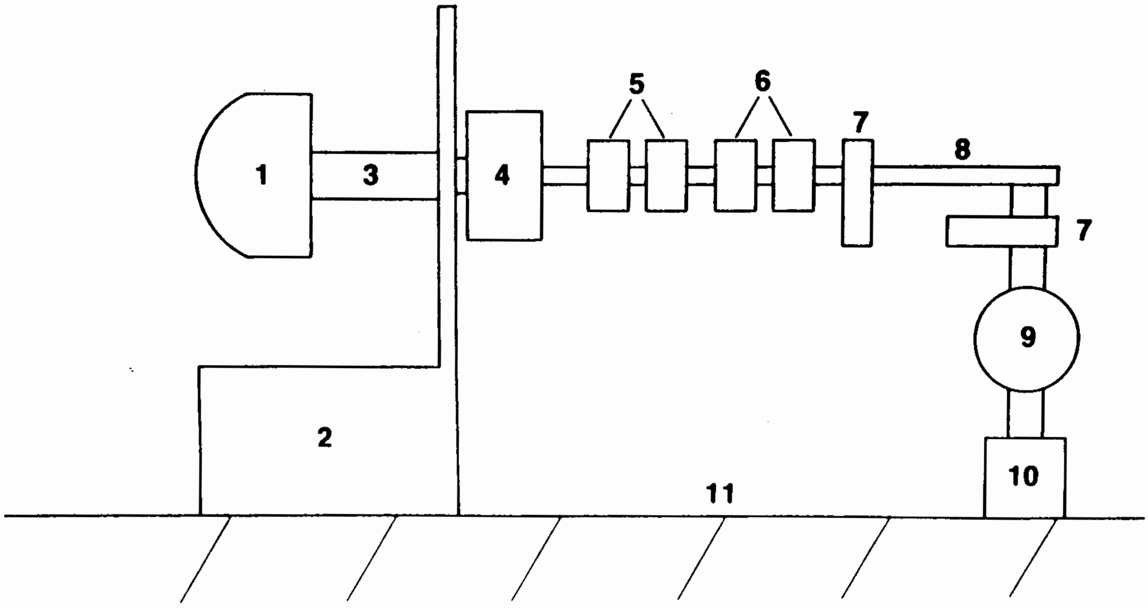


Fig. 1. Diagram of apparatus used to produce the 2.5-MeV neutron beam. The compact apparatus is 2.5 m in length and is setup in a shielded experimental hall.

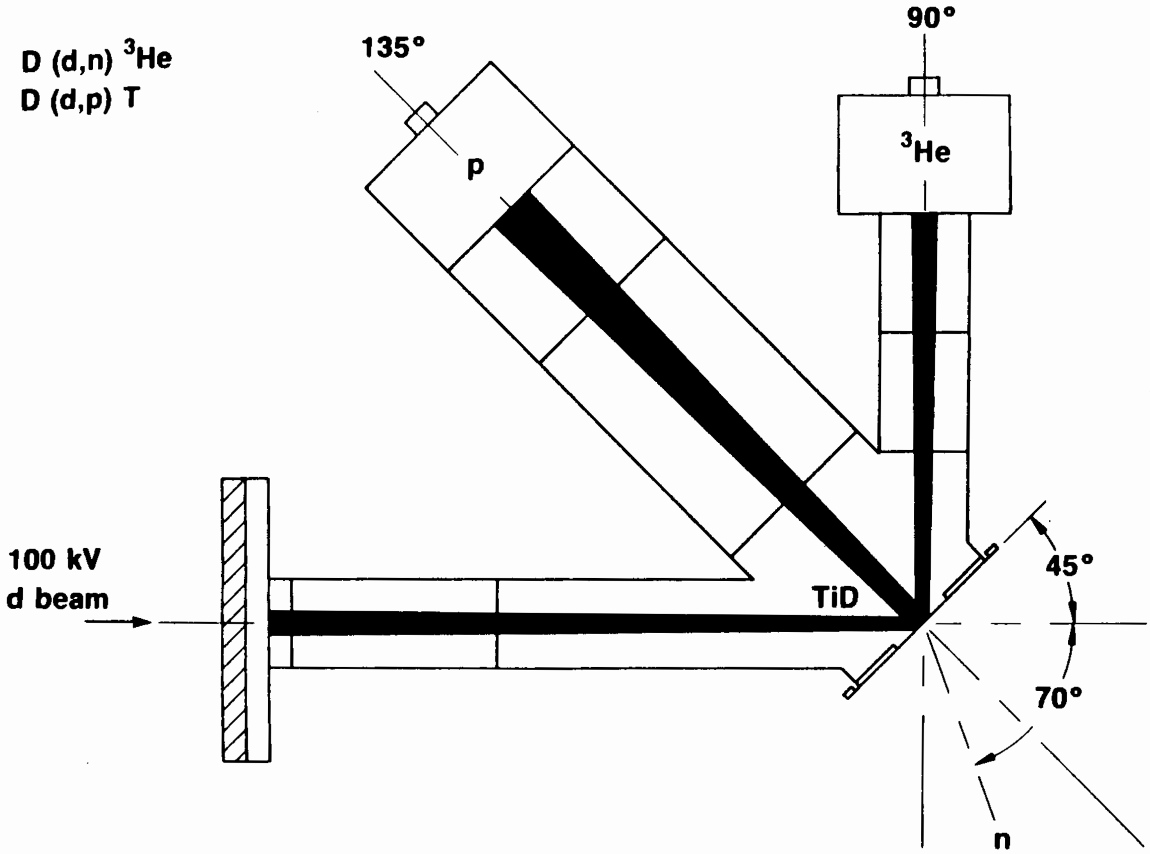


Fig. 2. Diagram of the target chamber used for TCAP measurement. The $^3$He associated particles from the D(d,n)$^3$He reaction are detected at 90 degrees and the unassociated protons from the D(d,p)T reaction at 135 degrees. The TiD target is oriented at 45 degrees with respect to the incident deuteron beam. The beam of correlated neutrons is emitted through the vacuum chamber wall consisting of 0.6-mm thick copper at about 70 degrees. The tubular construction of the chamber helped facilitate its' fabrication.

characteristics. An unassociated particle detection arm has been included in the target chamber design. The protons from the competing D(d,p)T reaction are monitored for normalization and diagnostic purposes at a back angle of 135 degrees.

## TCAP Measurement

The $^3$He associated particles are detected at 90 degrees with a silicon surface barrier detector behind a thin 0.216-mg/cm$^2$ aluminum foil. The aluminum filter gave the best results of the materials tested and was free of pin-holes. A collimator confines the associated particle detector acceptance to a full cone angle of 5.8 degrees. The detector diameter is intended to be only slightly larger than the collimator diameter in order to reduce the background in the associated particle spectrum due to neutron interactions in the silicon detector.

The associated particle spectrum shown in Figure 3 was obtained at the beam current and neutron intensity required to carry out the $^{235}$U(n,f) cross section measurement. The $^3$He pulse height events were accumulated at 5000 counts per second and are shown well separated from the pulse pile-up edge due to scattered deuterons and the triton events.

The neutrons correlated with $^3$He events within a selected pulse height window were emitted at an angle of 73.5 degrees with an energy near 2.5 MeV. A horizontal profile of the correlated neutron cone is shown in Figure 4. The full angle spread of the distribution at 50% and 10% of the peak height was 4.6 degrees and 9.4 degrees, respectively.

## Fission Chamber

Six uranium tetrafluoride deposits have been acquired for use in the $^{235}$U(n,f) cross section at 2.5 MeV. The deposits, fabricated at the Central Bureau for Nuclear Measurements, Geel, Belgium, have a combined thickness of 1627 μg/cm$^2$ and are 5 cm in diameter with good spacial uniformity.

An aluminum parallel-plate fission chamber has been built with 0.13-mm thick aluminum windows. The multiple signal ports on the chamber allow the fission events for each deposit to be recorded separately. With the chamber positioned close to the source, the stack of fission deposits sufficiently overlap the time-correlated neutron cone. The fission chamber count rate is expected to be about 100 counts per hour with the current source yield.

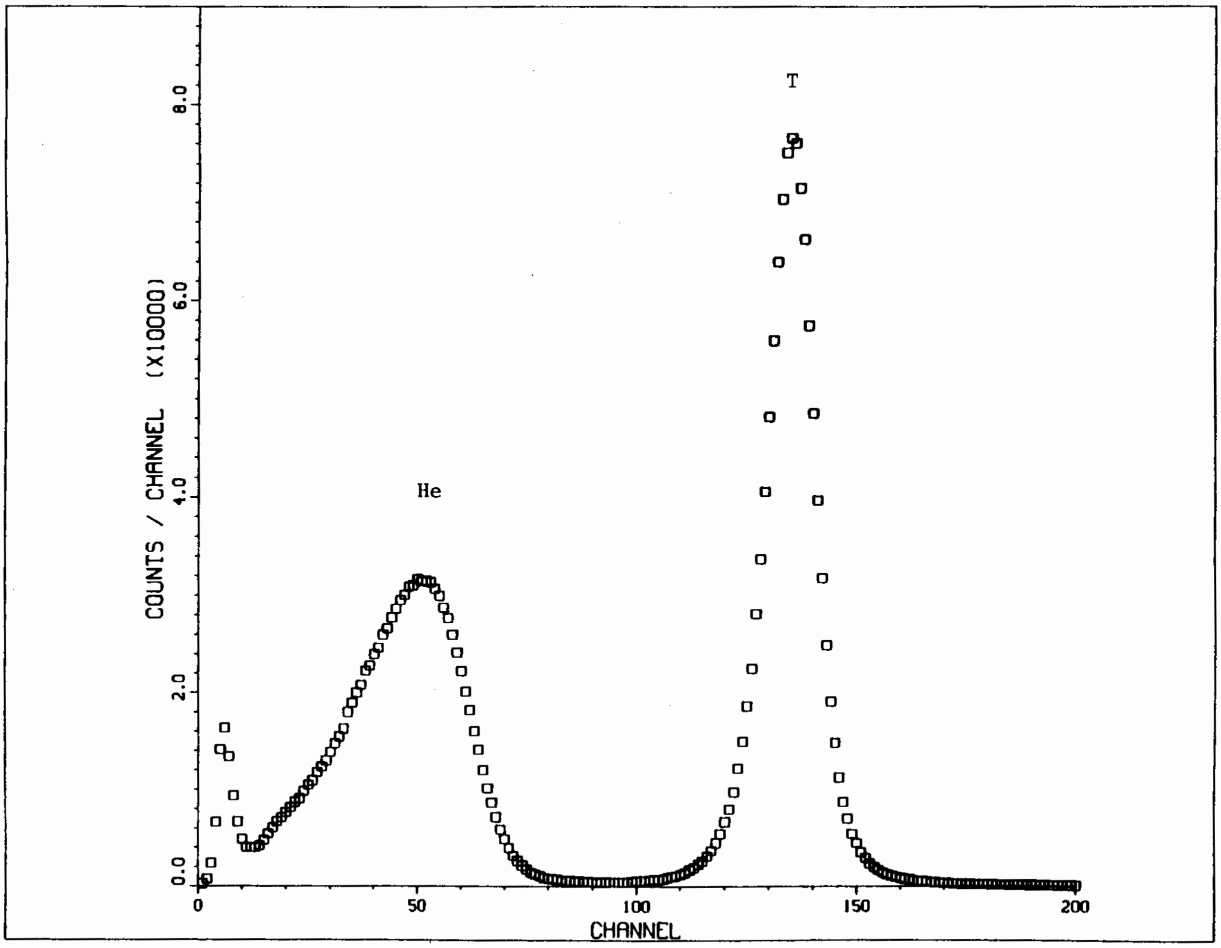


Fig. 3. Pulse-height distribution obtained with the silicon surface-barrier detector behind the 0.216-mg/cm$^2$ aluminum foil. A good separation between the $^3$He and triton peaks is observed above the pulse-pileup edge.

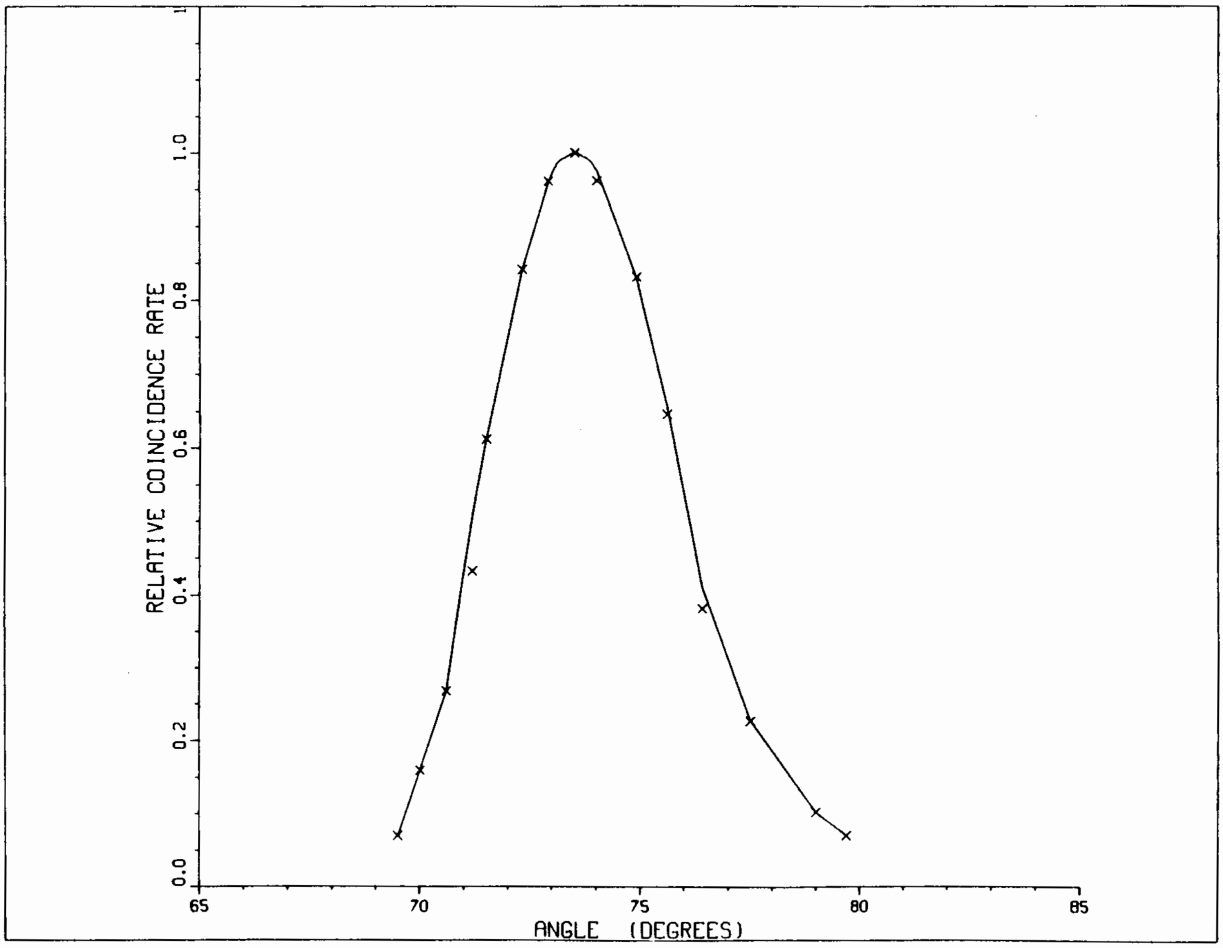


Fig. 4. Horizontal profile of the time-correlated neutron beam. The curve through the data points serves as an eye guide. The increased broadening at the larger angles is expected to result from the multiple scattering of associated particles that originate deep in the TiD target.

## Conclusion

A 100-kV, 0.5-ma ion accelerator has been used along with the $D(d,n)^3He$ reaction to produce a 2.5-MeV neutron source with sufficient intensity to carry out the $^{235}U(n,f)$ cross section measurement at 2.5 MeV. The needed intensity is obtained while maintaining the requirements necessary for accurate TCAP measurement. The facility is dedicated soley to producing 2.5-MeV neutrons in a fixed TCAP setup with good stability. Careful, long term measurement of neutron standard cross sections at 2.5 MeV should help establish the 2.5-MeV spot energy as an intermediate energy normalization point between 14 MeV and thermal.

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