

## THE NBS 14 MeV ABSOLUTE NEUTRON BEAM FACILITY

K. C. Duval and O. A. Wasson  
National Bureau of Standards  
Washington, D.C. 20234

### Summary

A 14 MeV absolute neutron beam has been established at the NBS 3 MV positive-ion Van de Graaff Accelerator Laboratory. The  $T(d,n)\alpha$  reaction is used for the production of the 14.1 MeV neutron flux with a source strength of  $10^8$  n/sec. The neutron flux is absolutely determined by the measurement of the associated alpha particle rate in a silicon surface barrier detector positioned at 84 degrees with respect to the beam axis. The facility may be used to measure the absolute response of active neutron monitoring devices with high accuracy. The neutron background contributions may be eliminated in the calibration measurements by utilizing the coincidence between the device and the solid state alpha detector. This method allows a neutron flux in a cone of 2 degree half angle to be placed at 90 degrees with respect to the beam axis.

### Introduction

A 14 MeV absolute neutron beam has been established at the NBS, 3 MV positive-ion Van de Graaff Accelerator Laboratory. The neutron production is monitored by detection of the associated  $\alpha$  particle from the  $T(d,n)\alpha$  neutron source. The facility may be used to measure the absolute efficiency of active neutron detectors for 14 MeV incident neutron flux. The measurement procedure utilizes a coincidence requirement between the associated  $\alpha$  particles and detected neutrons to eliminate background contributions to the neutron detector rate. A high accuracy for detector calibrations may be obtained by this method.

### 14 MeV Absolute Neutron Beam Facility

The NBS 3 MV positive-ion Van de Graaff Accelerator has recently been modified for low energy operation. With a large section of the resistor series connected to ground, the entire terminal voltage is applied across one-quarter of the original distance along the accelerating column. The effect is to provide better inherent beam focusing at low accelerator energy. The corona needles were also extended 7.5-cm for more stable operation.

A stable monoenergetic, 500 keV molecular deuterium beam is obtained and bent 90 degrees onto a thick tritiated-titanium target as shown in Fig. 1.

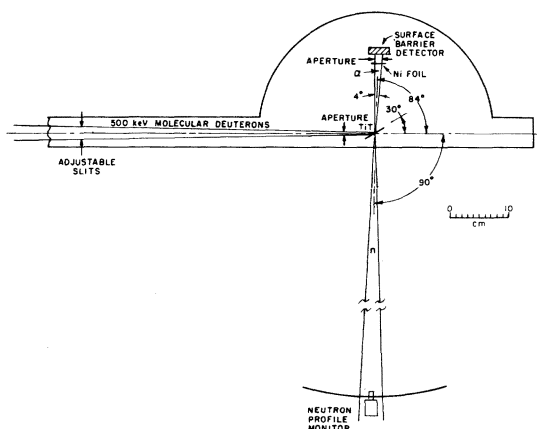


Fig. 1. Experimental geometry.

The 0.5  $\mu$ amps current is applied to the target continuously and collimated to a stable 3 mm beam spot. The deuterium molecule dissociates upon impact with the target and effectively allows a 250 keV atomic beam to interact with the target nuclei. A 3 mg/cm<sup>2</sup>, copper backed TiT target oriented at 30 degrees with respect to the beam axis is used for the generation of the 14.1 MeV neutron flux.

The neutrons are produced in the  $T(d,n)\alpha$  source reaction and monitored by the detection of the associated  $\alpha$ -particles. A silicon surface barrier detector located at 84 degrees with respect to the beam axis and a distance of 12.7 cm from the source is used for the associated particle detection. A collimator limits the detector acceptance cone angle to 2.05 degrees in half angle. The collimator is precisely machined to reduce in-scattering from the aperture wall. A thin 0.1 mil nickel foil mounted over the aperture face eliminates the large background level in the solid state detector resulting from the high yield of scattered deuterons.

A silicon surface barrier detector pulse height spectrum is shown in Fig. 2. The dominant peak observed is the 3.6 MeV  $\alpha$  particle from the  $T(d,n)\alpha$  source reaction. The continuous background contribution under the peak is less than 0.8% of the detector rate and is due to the deuteron interactions with the titanium in the target and neutron induced reactions in the silicon surface barrier detector. The background component was measured with the use of a thin aluminum absorber placed over the detector aperture. Additional background in the surface barrier detector due to charged particles from the  $^3\text{He}(d,p)^4\text{He}$  reaction<sup>1</sup> was eliminated by the use of freshly made TiT targets. Also, protons from the  $^2\text{H}(d,p)^3\text{H}$  reaction<sup>2</sup> did not contribute significantly to the detector rate.

The detector and target apparatus are mounted in a 25-cm diameter, brass semi-circular scattering chamber which is held at a vacuum pressure of about  $7 \times 10^{-6}$  mm. The neutron flux emitted at 90 degrees with respect to the beam axis passes through the thin 1 mm thick chamber wall with little attenuation.

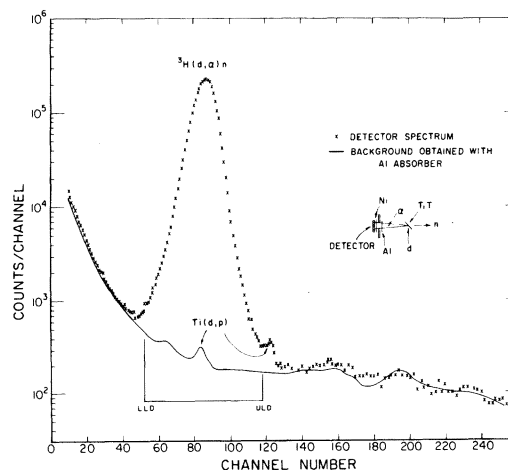


Fig. 2. Associated particle spectrum obtained with a silicon surface barrier detector. The main peak represents the detected associated particle events. A smooth curve indicating the background contribution was obtained with a thin aluminum foil over the detector aperture.

A secondary neutron monitor, positioned 169 cm from the source and constrained to movement about the source center was used to map the neutron horizontal profile. This monitor consists of a 2.5-cm diameter 7.5 cm thick Ne110 plastic scintillator mounted on an RCA 8850 photomultiplier tube. The monitor was also mounted onto a movable table for vertical scans. When this neutron monitor is operated in coincidence with the solid state associated particle detector, a neutron cone corresponding to the associated particle acceptance is mapped out.

The 14.1 MeV neutron profile is shown in Fig. 3. It is observed that 50% of the integrated flux is contained in a cone of 2.3 degree half angle and 99% in a cone of 6.0 degree half angle. It is also observed that both the shape of the neutron profile and the cone centroid varies as a function of the tritiated-titanium target life. In Fig. 3, the neutron profile of a fresh target and a used target have been plotted. Either through depletion of the target or through surface deposition, the effective mean deuteron incident energy shifts to lower values and the angle of neutron emission shifts correspondingly. The target life is about 6 hours with 0.5  $\mu$ amps beam continuously applied. During this period, the neutron cone centroid shifts approximately 1.5 degrees. The neutron cone may be monitored continuously so that corrections or adjustments can be made as required.

The rate in the associated particle solid state detector is typically 30,000 counts/sec. Pulse pile up events in the associated particle spectrum are rejected by pulse amplitude discrimination. All lost events in the associated particle spectrum are also lost in the coincidence rate and therefore corrections for deadtime are not required. The coincidence resolving time was typically 8 nsec. The coincidence rate, however, is corrected for accidental coincidence rates. Also neutron and  $\gamma$ -ray background contributions to the neutron detector rate are eliminated by the coincidence requirement. With this experimental arrangement, neutron fluences received by neutron devices operated in coincidence with the associated particle detector can be determined with accuracies of the order of a percent.

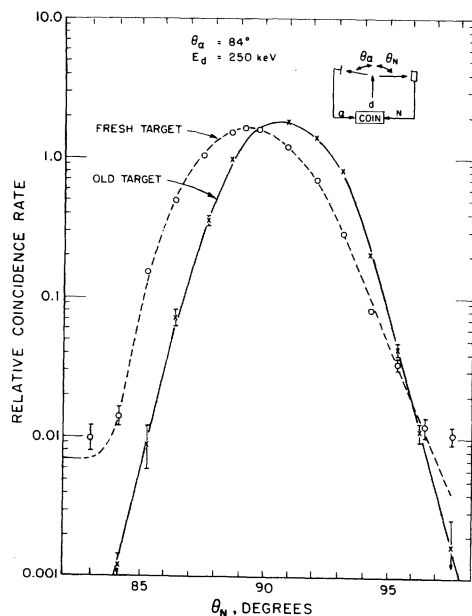


Fig. 3. Neutron beam profile obtained with 2.54 cm diameter plastic scintillator operated in coincidence with the associated particle detector at 169 cm from the source. Separate beam profiles are shown for a fresh and used TiT target.

## Calibration of Active Neutron Detectors

The 14 MeV Absolute Neutron Beam Facility may be used to measure the absolute response of active neutron detectors at 14 MeV when operated in coincidence with the associated particle detector. The procedure is to position the neutron detector in the center of the neutron cone while only sampling a small fraction of the total flux emitted into the cone. The position relative to the source is such that the detector intercepts a parallel beam. The determination of the fraction of the beam intercepted by the neutron detector is the dominant limitation to the measurement accuracy. The expression for determining the efficiency is:

$$\epsilon = \frac{\alpha_n}{\alpha} f T$$

where  $\epsilon$  is the efficiency

$\alpha, n$  is the number of coincidence events

$\alpha$  is the number of associated  $\alpha$  particles detected.

$f$  is the correction for neutron flux in the cone that is not incident on the detector.

$T$  is the correction for neutron beam attenuation through air, scattering chamber wall, and target backing material.

A 2.54-cm diameter, 7.5-cm thick Ne110 plastic scintillator neutron detector was calibrated by this method. The detector intercepted about 2% of the total flux emitted into the neutron cone. The absolute efficiency at 14 MeV was determined to be  $0.1635 \pm 0.004$  above a bias setting of 690 keV.

## Conclusion

A 14 MeV absolute neutron beam has been established at the NBS which can be used for high accuracy calibration measurements. The absolute efficiency of neutron detectors which can be operated in coincidence with an associated particle detector can be determined. Neutron detector calibration services at 14 MeV can now be provided by the NBS for the scientific and industrial community.

## References

1. J. C. Robertson and K. J. Zieba, Nucl. Inst. and Meth. 45 (1966) 179.
2. P. Kuijper and D. Spaargaren, Nucl. Instr. and Meth. 98 (1972) 173.