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TITLE: USE OF THE WNR SPALLATION NEUTRON SOURCE AT LAMPF TO DETERMINE THE ABSOLUTE EFFICIENCY OF A NEUTRON SCINTILLATION DETECTOR

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USE OF THE WNR SPALLATION NEUTRON SOURCE AT LAMPF TO DETERMINE THE ABSOLUTE EFFICIENCY OF A NEUTRON SCINTILLATION DETECTOR

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ABSTRACT

Prompt fission neutron spectrum measurements at the University of Massachusetts Lowell 5.5 MV Van de Graaff accelerator laboratory require that the neutron detector efficiency be well known over a neutron energy range of 100 keV to 20 MeV. The efficiency of the detector, has been determined for energies greater than 5.0 MeV using the Weapons Neutron Research (WNR) white neutron source at the Los Alamos Meson Physics Facility (LAMPF) in a pulsed beam, time-of-flight (TOF) experiment. Carbon matched polyethylene and graphite scatterers were used to obtain a hydrogen spectrum. The detector efficiency was determined using the well known H(n,n) scattering cross section. Results are compared to the detector efficiency calculation program SCINFUL available from the Radiation Shielding Information Center at Oak Ridge National Laboratory.[1]

(Neutrons, time-of-flight, H(n,n) standard cross section, detector efficiency, neutron sources)

I. INTRODUCTION

Prompt fission neutron spectrum measurements at the University of Massachusetts Lowell 5.5 MeV Van de Graaff accelerator laboratory require that the neutron detector efficiency be well known over the energy range from 100 keV to 20 MeV. While there are various methods for measuring neutron detector efficiencies.[2,3] An ideal situation is a "white" neutron source that varies slowly over the energy range, allowing for the efficiency to be measured over the energy range of interest in one experiment. This situation is present at the WNR white neutron source at the Los Alamos meson Physics Facility (LAMPF).[4]

The intensity of the neutron beam from the WNR neutron source makes it difficult to place the neutron detector in the beam without saturating the detector. To reduce the incident neutron beam intensity the neutron detector was placed at 23.3 degrees off beam axis. Separately, carbon-matched polyethylene, (CH_2), and graphite, (C), scatterers were used to scatter neutrons to the detector for acquisition of a time-of-flight (TOF) spectra. A ^{235}U fission chamber was used for neutron beam normalization. After subtraction of the Carbon spectra the well known H(n,n) scattering cross section was used to determine the absolute efficiency of the neutron detector.

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II. EXPERIMENTAL METHOD

Figure 1 shows the WNR experimental area. The measurements were made at the 30°, 40 m flight path of the WNR target-4 neutron TOF facility at LAMPF. The facility uses the 800 MeV pulsed proton beam from LAMPF incident on a 7.5-cm long, 3.0-cm diameter tungsten target to produce a "white" source of neutrons up to 600 MeV from a spallation reaction.[4] The proton beam consisted of 150 ps wide pulses separated by 3.6 μs with about 3×10^8 protons in each pulse. The macroscopic duty factor of LAMPF gave a rate of about 8000 of these proton pulses per second.

For this experiment, the neutron beam was collimated to a diameter of 8.3 cm, permanent magnets were used to deflect charged particles from the beam. The fission chamber with the ^{235}U fission foil was located at 43.34 m from the tungsten target, and the scattering samples were located 46.92 m from the tungsten target. The scattering samples consisted of carbon matched polyethylene (CH_2) and graphite (C) disks, 5.083 cm in diameter, the polyethylene sample contained 3.819 moles of hydrogen. The ^{235}U fission chamber was used for neutron fluence normalization and neutron beam profile measurements. The ^{235}U foil had a mass of 302.0 $\mu g/cm^2$ of ^{235}U. A mask of 5.083 cm diameter was used to block fission fragments from the foil that occurred "outside" the diameter of the scattering samples, this enabled for a quick and accurate determination of the neutron fluence through the scattering samples.

The neutron detector was a 10.82 cm diameter by 1.27 cm thick right circular cylinder filled with BC-501 liquid scintillator, and was viewed by an RCA type 8854 photomultiplier.[5,6] The neutron detector was located 1.627 m from the scattering samples at 23.3° relative to the beam axis. This location ensured that the neutron detector was outside of the main neutron beam. A thin plastic detector or "paddle" was placed between the scattering samples and the neutron detector to veto data events caused by proton recoil events in the detector.

III. RESULTS and ANALYSIS

The fission chamber data was corrected for a detection inefficiency of fission events induced by neutron energies below 14.1 MeV.[7,8] The ^{235}U fission foil was removed and the alpha activity counted to determine the mass of the foil. The results of a mass spectroscopic analysis provided by ORNL was used to identify contaminant mass contributions in cases where individual alpha particle peaks could not be resolved. Figure 2 shows the measured incident neutron spectrum at the 30° 40 m flight path. The spectrum was corrected for events due to these contaminants.[9] In addition, events due to charged particle producing reactions in the stainless steel foil backing material were taken into account during the data analysis.

The neutron detector data was analyzed off-line to subtract a time-uncorrelated background, correct for dead time and then grouped into energy bins. The polyethylene and graphite runs were normalized to equal incident neutron flux using the ^{235}U fission chamber data over the energy region from 5 to 50 MeV. Typical acquisition times for each of the measurements was approximately 24 hours. Figure 3 shows the measured hydrogen TOF spectrum, resulting from the subtraction of the graphite spectrum from the polyethylene spectrum, used to determine the energy dependent efficiency of the neutron detector.

Figure 4 shows the efficiency curve for the neutron detector. The data points show the efficiency that was measured at the WNR facility and the solid line shows the calculated efficiency using the SCINFUL[1] code. The excellent agreement between the measurement and calculation of the neutron detector efficiency, over the energy region of interest, is apparent.

IV. CONCLUSION

The reduction in neutron beam intensity provided by a simple scattering arrangement enabled the measurement of the absolute efficiency of the neutron detector used for fission neutron spectra measurements over the energy range from 5 to 50 MeV in an uncomplicated manner. The WNR target-4 neutron source provides a neutron source over an energy range not available at most laboratories and remains a valuable resource for intense neutron beams covering a large energy range for use by the nuclear physics community.

V. ACKNOWLEDGMENTS

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Figure Captions:

Figure 1. Layout of the source and flightpaths for the target-4 white neutron source at LAMPF.

Figure 2. The measured relative incident neutron spectrum at the 30° left 40 meter flightpath of target-4.

Figure 3. The measured H(n,n) spectrum at 23.3°.

Figure 4. The efficiency curve for the neutron detector. The solid line is the SCINFUL calculation.[1] The data points represent the measurement at the WNR white neutron source at LAMPF using carbon matched polyethelene and graphite scatters.

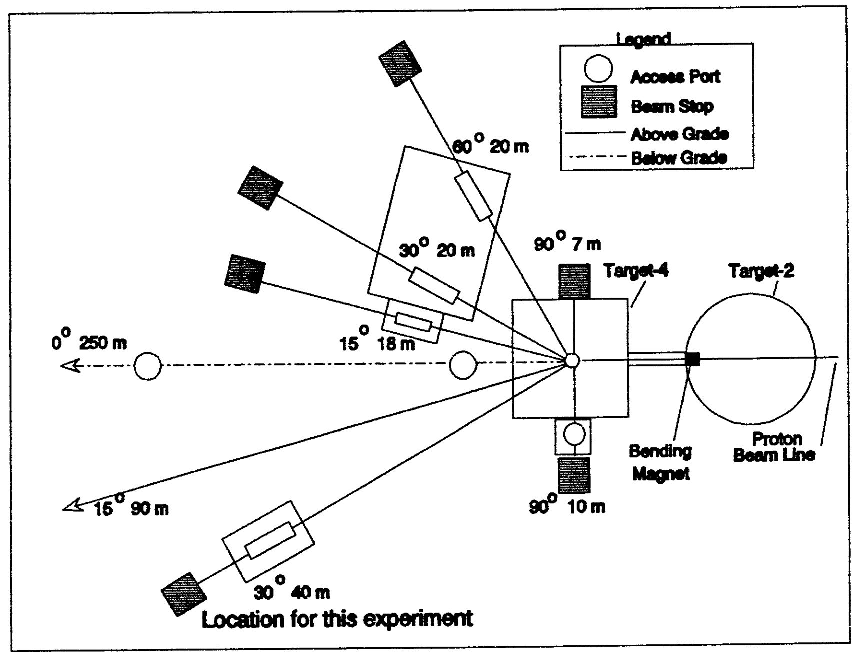
Legend
Access Port
Beam Stop
Above Grade
Below Grade
60° 20 m
30° 20 m
90° 7 m
Target-4
Target-2
15° 18 m
0° 250 m
Bending Magnet
Proton Beam Line
90° 10 m
15° 90 m
30° 40 m
Location for this experiment

FIG. 1

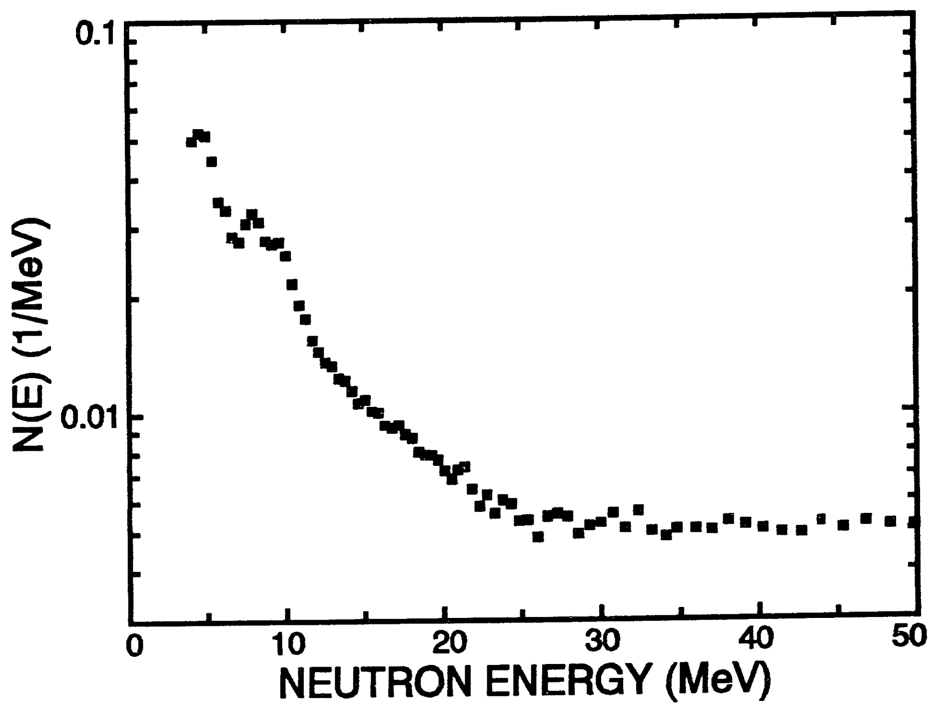

FIG. 2

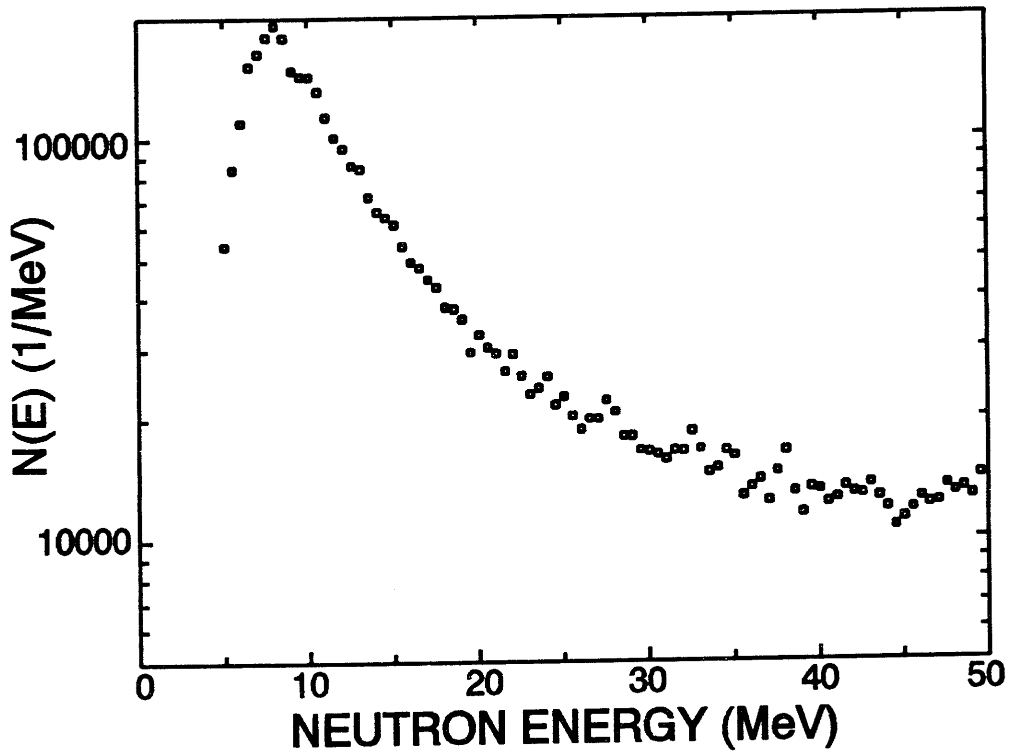

FIG. 3

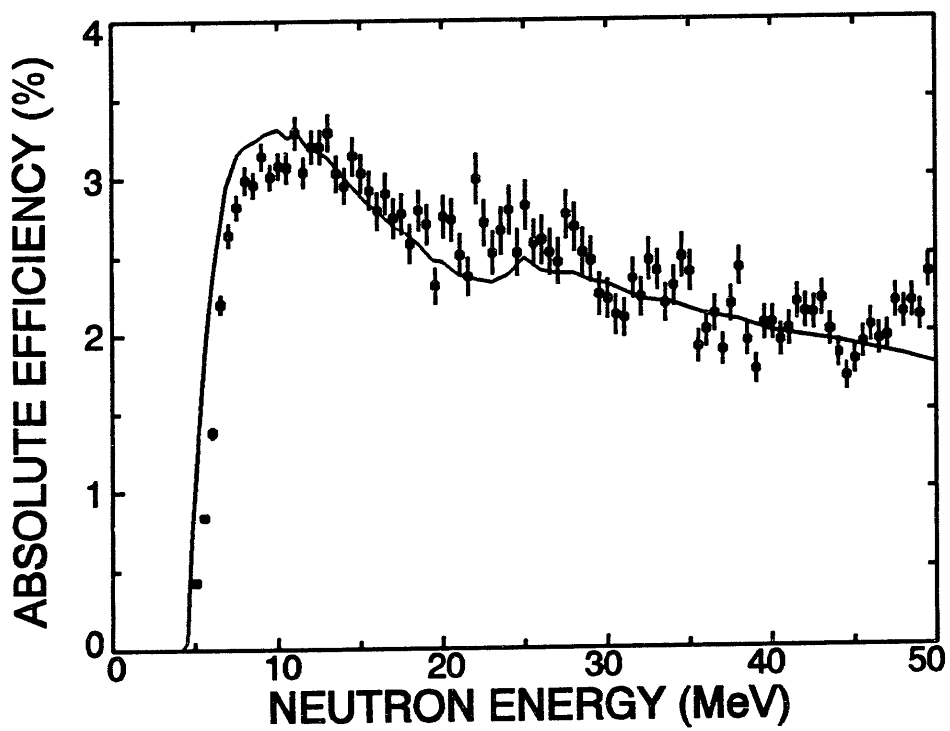
ABSOLUTE EFFICIENCY (%)
0
1
2
3
4
0
10
20
30
40
50
NEUTRON ENERGY (MeV)

FIG. 4

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