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# DETECTION EFFICIENCY OF A PLASTIC SCINTILLATOR FOR 20 TO 170 MeV NEUTRONS*

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The neutron detection efficiency of a plastic scintillator 30.5 cm long and 12.7 cm in diameter has been measured for neutron energies from 20 to 170 MeV at thresholds of 2, 4 and 16 MeV electron energy.

In connection with n-p bremsstrahlung measurements at 208 MeV, some earlier efficiency measurements[1,2]) for neutron energies between 10 and 70 MeV were extended up to 170 MeV. Included here are the corrected data[2]) and the present measurements extending up to 170 MeV.

Previously, in this energy range, the neutron detection efficiency of solid plastic scintillators has been measured for neutron energies from 4 to 76 MeV [3]) and from 20 to 130 MeV [4]). Measurements have also been made from 15 to 120 MeV with liquid scintillators[5]).

The method of measuring the efficiency was identical to that used previously[1]). Protons from n-p scattering in a liquid hydrogen-target are detected in a range telescope. A calculable fraction of the conjugate neutrons are intercepted by the neutron detector, $D_n$. From a corrected ratio of neutron to proton counts, the efficiency can be determined.

The neutron beam, produced by stripping deuterons with a Be target in the Lawrence Radiation Laboratory's 184″ cyclotron, had a mean energy of 208 MeV and a fwhm of about 45 MeV. The beam was well defined by the steel collimator 3.2 cm high and 2.6 cm wide. The liquid hydrogen target flask of 0.25 mm mylar was 7.64 cm in diameter and 15.25 cm high. The neutron detector consisted of a cylinder of NE102 plastic scintillator 30.5 cm long and 12.7 cm in diameter viewed by a magnetically shielded XP1040 PM tube. This assembly was wrapped in Al foil, sponge, and tape and housed in a soft iron cylinder of 0.65 cm wall thickness and 16.5 cm in outside diameter. A counter having an 0.8 mm plastic scintillator was placed in front of $D_n$ to veto charged particles. The proton telescope contained four 0.8 mm plastic scintillators ($S_1$, $S_2$, $S_3$ and a veto, $S_4$) viewed by 8575 PM tubes and two copper absorbers ($A_1$ and $A_2$) which in the sequence $S_1S_2A_1S_3A_2S_4$ defined a range "bite" of the scattered protons. The "Range-Energy tables" of Rich and Madey[6]) were used in determining proton energies. A $^{60}$Co source was used to set the neutron counter thresholds.

The signal $S_1S_2S_3S_4$ provided the "start" and the neutron detector the "stop" pulses for a time-to-amplitude convertor (TAC). The TAC spectra were clean with well defined peaks. Target empty background was $<5\%$ of the full rate for all but small proton angles where it increased to $\simeq 10\%$.

A computer program integrated over the beam energy spectrum (near the peak), over the defining aperture of $S_3$, and over the target volume intercepted by the beam. The result is the distribution of conjugate neutron flux in space and energy. From this, one can calculate the fraction of flux intercepted by $D_n$ and the energy spread over which $D_n$ averages. Then the average efficiency

TABLE 1

Efficiencies for various electron energy thresholds.

| Average neutron energy (MeV) | Threshold 2 MeV | 4 MeV | 16 MeV |
|---|---|---|---|
| 20.5 | 0.332 ± 0.015 | 0.222 ± 0.012 | |
| 29.5 | 0.376 ± 0.015 | 0.238 ± 0.012 | |
| 39.5 | 0.380 ± 0.016 | 0.296 ± 0.012 | |
| 50.0 | 0.376 ± 0.014 | 0.320 ± 0.012 | |
| 60.0 | 0.382 ± 0.016 | 0.313 ± 0.014 | |
| 70.0 | 0.358 ± 0.014 | 0.306 ± 0.009 | |
| 80.5 | 0.348 ± 0.009 | 0.311 ± 0.008 | |
| 90.5 | 0.326 ± 0.014 | 0.291 ± 0.012 | 0.186 ± 0.008 |
| 99.0 | 0.348 ± 0.014 | 0.297 ± 0.013 | |
| 109.5 | 0.326 ± 0.013 | 0.284 ± 0.011 | 0.194 ± 0.008 |
| 120.0 | 0.326 ± 0.013 | 0.284 ± 0.011 | 0.202 ± 0.008 |
| 130.5 | 0.330 ± 0.009 | 0.290 ± 0.007 | 0.198 ± 0.008 |
| 140.0 | 0.349 ± 0.014 | 0.332 ± 0.013 | 0.213 ± 0.008 |
| 148.5 | 0.345 ± 0.014 | 0.301 ± 0.012 | 0.212 ± 0.008 |
| 159.0 | 0.341 ± 0.014 | 0.296 ± 0.012 | 0.213 ± 0.008 |
| 168.5 | 0.329 ± 0.013 | 0.305 ± 0.012 | 0.223 ± 0.009 |

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over this energy span is obtained from the corrected ratio of neutron (TAC) to proton counts. Corrections were applied to account for the absorption of scattered neutrons in the $LH_2$ and air, the edge effects of the scintillator and its housing[4]), and the effects of a non-uniform flux over the detector cross section.

The results are given in table 1, and compared with predictions obtained from Kurz's computer code[7]) in fig. 1. The agreement is quite good overall. We seem to see a slight increase in efficiency for neutron energies around 140 MeV; otherwise, it is fairly constant for energies in the range 90 to 170 MeV.

In fig. 2 our results are compared with those of Crabb et al.[4]), whose counter was 30 cm in diameter and 28.6 cm long. The differences in efficiency can be largely accounted for by the different thresholds and detector thicknesses.

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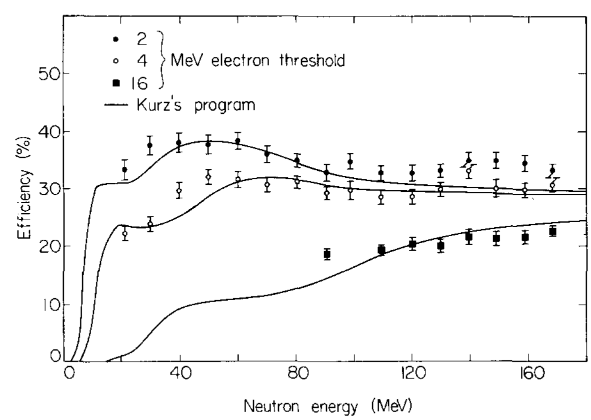


Fig. 1. The efficiency of the detector as a function of neutron energy for electron energy thresholds of 2, 4 and 16 MeV and the corresponding predictions of Kurz.

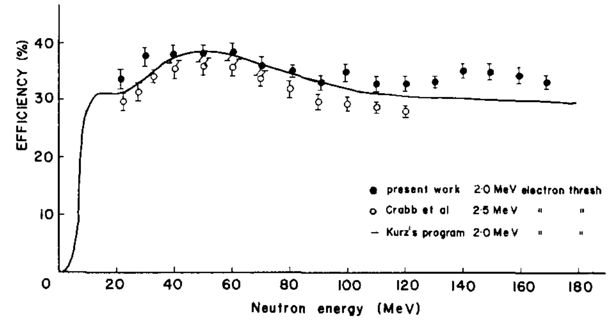


Fig. 2. Comparison between some of the present measurements and those of Crabb et al. The thresholds are in electron energy. Kurz's results are for the present case.

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