# CALIBRATION OF THE NEUTRON DETECTION EFFICIENCY OF THE COMPTEL NE213 DETECTOR

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The measured zero-degree cross section for the $^{7}Li(p,n)$ reaction to the ground and first excited states of $^{7}Be$ is the best calibrated source of neutrons for energies from 20 to 200 MeV. This cross section has been used to measure the detection efficiency of two NE213 detectors, one to be used in the COMPTEL Gamma Ray Observatory, the other an IUCF monitor.

The organic scintillant NE213 is widely used in neutron detection because it allows use of pulse-shape discrimination to distinguish pulses due to incident neutrons from those due to gamma rays, that is, between Compton electrons and recoil protons. Two experiments (refs. 1 and 2) underway at the Indiana University Cyclotron Facility (IUCF) use this scintillator at energies between 20 and 200 MeV. Although Monte Carlo calculations[3] of detection efficiency are generally reliable[4] to about 10% over this energy range, a recent measurement[5] of the efficiency of an NE213 detector strongly suggests that the calculated values may be seriously in error, particularly for high pulse-height thresholds. We have therefore used the well-known $^{7}Li(p,n)^{7}Be$ cross section to make a rough measurement of the efficiency of an NE213 scintillator over the energy from 20 to 200 MeV.

Proton beams at nominal energies of 20, 40, 80, 135 and 200 MeV were directed onto $^{7}Li$ targets using the IUCF beam swinger at an exit angle of zero degrees. Detailed listings of energies and target thicknesses are given in Table I. At 20, 40 and 80 MeV the stripper loop was used to avoid wrap-around of neutrons from different beam bursts.

The IUCF neutron monitor was a 12.7 cm diameter by 12.7 cm deep cylindrical NE213 scintillator with an RCA 8575 photomultiplier tube and an IUCF high count-rate base. The axis of the scintillator was perpendicular to the incident flux, and the flight path was 48 m. The pulse-height calibration used the conversion between electron energy and proton energy obtained by Cecil, Anderson and Madey;[1] the channels corresponding to the Compton peaks for gamma rays from $^{22}Na$ and $^{228}Th$ sources were located using the technique of Dietz and Klein.[6] These pulse-height calibrations are required in order to calculate the efficiency using the program described in ref. 3.

Neutron time-of-flight (TOF) and anode pulse-height information were stored as two-parameter displays. Dead times were typically less than 10% and have been taken into account in the final data. At 80, 135 and 200 MeV the two-dimensional spectra were corrected for time walk; all spectra were then integrated over pulse height using several different thresholds and corrected for the energy dependence of the integral efficiency by using the calculated values. The corrected yields were roughly the same for several different thresholds; the statistical errors were increased to account for any sizeable differences. At 40 and 20 MeV the target thicknesses were large enough to completely dominate the resolution contribution due to the time structure of the incident beam.

The results are summarized in Table I. The cross

TABLE I

Summary of Results

| | | | | | | |
|---|---|---|---|---|---|---|
| Beam and Target Parameters | | | | | | |
| Nominal Ep | 20 | 40 | 80 | 135 | 200 | MeV |
| Mean Ep | 20.1 | 37.3 | 78.6 | 133.7 | 199.7 | MeV |
| Energy Loss | 2.8 | 3.3 | 1.0 | 1.0 | 0.7 | MeV |
| Target thickness | 137 | 293 | 203 | 203 | 203 | $mg/cm^2$ |
| $\sigma(0°)$ (lab) | 14 | 33 | 36 | 38 | 38 | mb/sr |
| IUCF Monitor | | | | | | |
| Eff. (observed) | 0.11 | 0.035 | 0.033 | 0.036 | 0.039 | |
| Threshold | 4.3 | 13 | 26 | 27 | 27 | $MeV_{ee}$ |
| Eff. (calc) | 0.133 | 0.050 | 0.041 | 0.043 | 0.042 | |
| Eff. Ratio (o/c) | 0.82(11) | 0.70(18) | 0.80(11) | 0.84(13) | 0.93(21) | |
| COMPTEL Detectors | | | | | | |
| Eff. (observed) | 0.28 | 0.055 | 0.067 | 0.067 | 0.059 | |
| Eff. (calc) | 0.245 | 0.183 | 0.108 | 0.083 | 0.081 | |
| Eff. Ratio (o/c) | 0.88 | 0.30 | 0.62 | 0.81 | 0.73 | |

sections for the calculations were obtained from refs. 4, 7 and 8. For the IUCF detector, the measured efficiencies appear to be about 20% lower than the calculated values; the average ratio is 0.82 ± 0.11. For the COMPTEL detector, the calculations assume normal incidence on a detector 14 cm in radius and 8.5 cm in depth with a threshold at 625 $keV_{ee}$. With the exception of the measurements at 40 MeV, the agreement between the efficiencies observed with the COMPTEL and IUCF detectors is within uncertainties and suggests that calculated efficiencies for NE213 scintillant may be about 20% too high over the 20-200 MeV energy range. A similar conclusion was reached in another recent measurement of detection efficiency for an NE213 scintillator.[5]


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3) R.A. Cecil, B.D. Anderson and R. Madey, Nucl. Inst. Meth. 439, (1979).

4) J.W. Watson, B.D. Anderson and A.R. Baldwin, Nucl. Inst. Meth. 215.

5) S.D. Howe, P.W. Lisowski, G.J. Russell, N.S.P. King and H.J. Donnert, Nucl. Inst. Meth. 227, 565 (1984).

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8) C.D. Bowman et al, S.A. Wender and G.F. Auchampaugh, in Neutron-Nucleus Collissions: A Probe of Nuclear Structure, ed. J. Rapaport, R.W. Rinlay, S.M. Grimes and F.S. Dietrich, AIP Conf. Proc. 124 (1984), p. 259.