**Zeitschrift:** Helvetica Physica Acta

**Band:** 54 (1981)

**Heft:** 4

**Artikel:** The (n, d) differential elastic cross section at 2 MeV

**Autor:** Weber, J.

**DOI:** https://doi.org/10.5169/seals-115226

Helvetica Physica Acta
Vol. 54, 1981

0018-0238/81/040547-05$1.50+0.20/0
Birkhäuser Verlag Basel, 1981

# The $(n, d)$ differential elastic cross section at 2 MeV[1])

J. Weber, Institut de Physique de l'Université, 2000 Neuchâtel, Switzerland

(2. XI. 1981)

*Summary.* The $(n, d)$ differential elastic cross section at 2.016 MeV has been measured in the 104° to 180° angular range (CM) by means of the recoil energy spectrum method. The present results beyond 140° are larger than earlier data. This is discussed in view of some theoretical predictions.

## 1. Introduction

The number of available $(n, d)$ differential elastic scattering cross section data at 2 MeV is very much limited beyond 140° CM: at our knowledge, there is only one old measurement by Elwyn et al. [1] at 166° CM. Therefore it is difficult, by a phase shift analysis, to determine at this energy the relative importance of high partial waves ($l > 2$). Our aim in making this measurement was to get more data points at large angles to be used in an effective range approximation analysis of the elastic $d(\vec{n}, \vec{n})d$ scattering [2].[2])

## 2. Experimental method

The experimental method has been described in great details in Ref. 5 and 6. It will only be reminded here that it is based on the relation between the cross section in the center of mass system and the deuteron recoil energy spectrum. A deuteron beam from our 3 MeV van de Graaff accelerator, inpinging on a thin NiTiD target, produced mono-energetic neutrons through the $d(d, n)\ ^3He$ reaction. The $^3He$ particles were detected by a thin NE102 plastic scintillator. The mean neutron energy was 2.016 MeV; the half width at mid-height of the neutron energy distribution in the beam was 20 keV. The neutron scatterer was a deuterated NE213 liquid scintillator (2 cm dia., 2 cm height). For each event, the following parameters were recorded in a PDP 15/20 computer: the $^3He$ and recoil deuteron energy spectra, the neutron time-of-flight and finally the $(n, \gamma)$ discrimination spectrum.

---

[1]) Work supported in part by the Fonds National Suisse de la Recherche Scientifique.

[2]) The angular distribution of the neutron depolarization factor $D(\theta)$ [3, 4] is another influential data set that will be used in this analysis.

## 3. Data analysis

The data analysis method also has already been described in details in Ref. 6. It is sufficient to say here that the light-energy function of the scintillator and the resolution function of the apparatus have been measured in a separate experiment as explained in Ref. 5, and that the contribution of the neutron multiple scattering to the deuteron recoil energy spectrum has been taken into account through a Monte Carlo type simulation.

## 4. Results

They are listed in Table I and depicted in Fig. 1. The cross section data are 'unsmoothed' in the sense defined in Ref. 6. The corresponding standard deviations (SD) are a combination of the standard deviation computed through the data analysis procedure ($SD_{fit}$) and the standard deviation corresponding to the statistical accuracy of the measurement itself ($SD_{stat}$):

$$SD = \sqrt{(SD_{fit})^2 + (SD_{stat})^2}$$

The data have been normalized at 148 mb/sr at $\cos\theta_{CM} = -0.306$ [7] according to the method described in Ref. 6.

Table I
$n$–$d$ elastic cross section $\sigma$ (mb/sr) at $E_n = 2.016$ MeV in function of $\cos\theta_{CM}$ (unsmoothed data set, see Section 4). The figures in the SD columns are explained in Section 4. The normalization is discussed in Sections 4 and 5.

| $\cos\theta_{CM}$ | $\sigma$ | SD | $\cos\theta_{CM}$ | $\sigma$ | SD | $\cos\theta_{CM}$ | $\sigma$ | SD | $\cos\theta_{CM}$ | $\sigma$ | SD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| −0.2498 | 127.7 | 10.7 | −0.2612 | 140.1 | 10.3 | −0.2725 | 139.7 | 10.1 | −0.2837 | 143.7 | 9.9 |
| −0.2949 | 146.2 | 9.8 | −0.3060 | 145.7 | 9.7 | −0.3170 | 146.9 | 9.7 | −0.3279 | 147.7 | 9.7 |
| −0.3388 | 154.3 | 9.7 | −0.3496 | 143.4 | 9.8 | −0.3604 | 148.0 | 9.9 | −0.3711 | 135.9 | 10.0 |
| −0.3817 | 188.1 | 10.1 | −0.3923 | 175.8 | 10.2 | −0.4028 | 154.0 | 10.3 | −0.4132 | 152.7 | 10.5 |
| −0.4236 | 167.2 | 10.6 | −0.4340 | 154.9 | 10.7 | −0.4443 | 164.0 | 10.7 | −0.4545 | 167.0 | 10.8 |
| −0.4647 | 168.1 | 10.9 | −0.4748 | 164.2 | 11.0 | −0.4849 | 201.8 | 11.1 | −0.4949 | 175.4 | 11.1 |
| −0.5049 | 178.0 | 11.2 | −0.5148 | 175.2 | 11.2 | −0.5246 | 182.7 | 11.3 | −0.5345 | 190.2 | 11.4 |
| −0.5442 | 195.6 | 11.4 | −0.5540 | 191.5 | 11.5 | −0.5637 | 179.2 | 11.6 | −0.5733 | 193.3 | 11.7 |
| −0.5829 | 176.8 | 11.8 | −0.5924 | 194.8 | 11.9 | −0.6019 | 205.6 | 12.1 | −0.6114 | 185.8 | 12.2 |
| −0.6208 | 212.5 | 12.4 | −0.6302 | 215.8 | 12.6 | −0.6395 | 228.8 | 12.7 | −0.6488 | 227.6 | 13.0 |
| −0.6581 | 226.5 | 13.2 | −0.6673 | 227.8 | 13.4 | −0.6764 | 250.3 | 13.7 | −0.6856 | 216.4 | 13.9 |
| −0.6947 | 261.3 | 14.2 | −0.7037 | 258.2 | 14.5 | −0.7127 | 265.2 | 14.7 | −0.7217 | 247.1 | 15.0 |
| −0.7307 | 283.8 | 15.3 | −0.7396 | 299.1 | 15.6 | −0.7485 | 308.8 | 15.9 | −0.7573 | 316.9 | 16.2 |
| −0.7661 | 306.3 | 16.6 | −0.7749 | 344.7 | 16.9 | −0.7836 | 349.0 | 17.2 | −0.7923 | 338.3 | 17.5 |
| −0.8010 | 338.4 | 17.8 | −0.8096 | 379.7 | 18.1 | −0.8182 | 388.0 | 18.5 | −0.8268 | 391.5 | 18.8 |
| −0.8353 | 426.2 | 19.1 | −0.8439 | 441.3 | 19.5 | −0.8523 | 432.3 | 19.8 | −0.8608 | 458.5 | 20.2 |
| −0.8692 | 492.3 | 20.6 | −0.8776 | 503.4 | 21.0 | −0.8860 | 512.9 | 21.4 | −0.8943 | 519.2 | 21.9 |
| −0.9026 | 551.8 | 22.4 | −0.9108 | 555.6 | 23.0 | −0.9191 | 589.1 | 23.6 | −0.9273 | 605.2 | 24.3 |
| −0.9355 | 621.6 | 25.1 | −0.9436 | 640.9 | 26.0 | −0.9518 | 646.3 | 26.9 | −0.9599 | 685.0 | 27.9 |
| −0.9680 | 741.8 | 29.1 | −0.9760 | 754.7 | 30.3 | −0.9840 | 768.5 | 31.7 | −0.9920 | 811.7 | 33.2 |
| −1.0000 | 819.0 | 34.8 | | | | | | | | | |

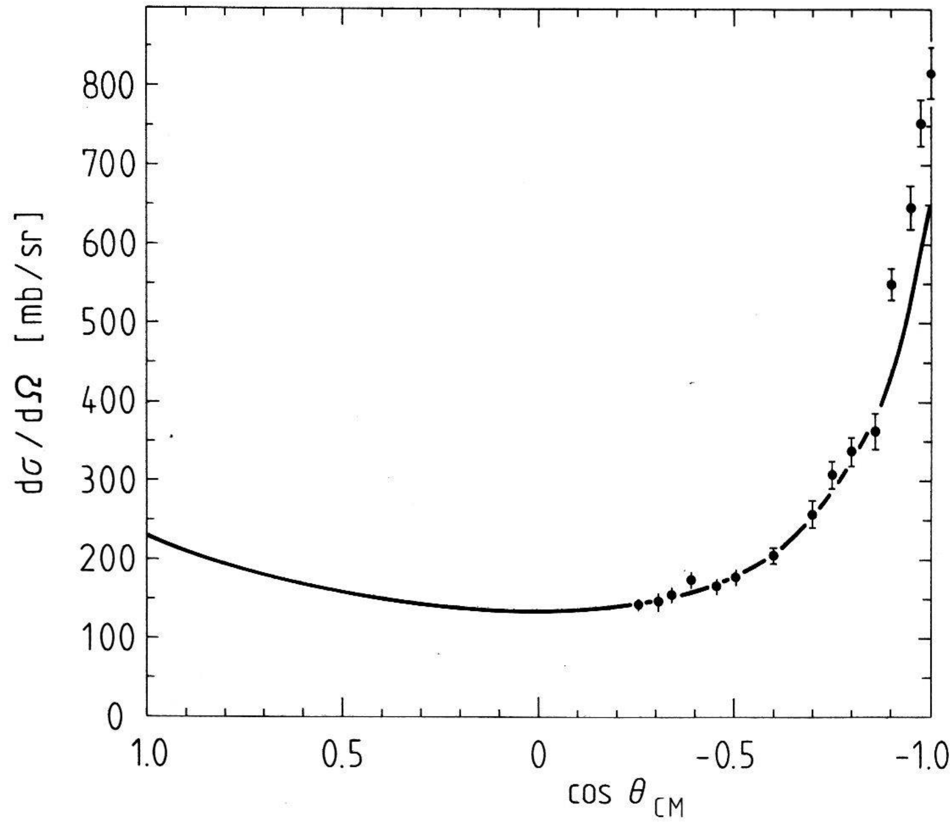


Figure 1
*n–d* elastic cross section at 2 MeV (Lab). present work (sample), normalized at 148 mb/sr at $\cos\theta_{CM} = -0.306$ [7]. — from Ref. 7.

## 5. Discussion

In Fig. 2, a few theoretical and experimental values of the cross section at 180° are plotted in function of energy. Alt and Bakker's (A–B) results [8] show a smooth variation with a maximum around 1.3 MeV. The experimental values of $\sigma$ (180°) from Ref. 7[3]) also show a smooth trend up to 2 MeV and are higher than A–B's calculations; on the contrary, the next two results (at 2.45 and 3.27 MeV) are lower. Moreover one can note that the 2.45 MeV data point of this Ref. 7 is too low to fit in any smooth trend drawn through the other data points. In this respect, the experimental results (not extrapolated) of Chatelain et al. [6] appear to be more compatible.

By comparing the result of the present work (not extrapolated) with the trend suggested by the two data points of Chatelain et al. one is induced to think that it is too large by about 10%. This could be due to the normalization of our data. To get some feeling in this problem, one can make the following remarks. When one looks at Fig. 3, one can estimate that the $\sigma$ (0°) at 1.95 MeV of Ref. 7 might well be around 300 mb/sr instead of 230 mb/sr, which is not unreasonable if one considers that the 230 mb (extrapolated) value is essentially determined by one data point only at 33° CM [1]. Then, by integration over the whole angular range,

[3]) Obtained by extrapolation of the curves shown in the figures of Ref. 7. These curves are drawn mainly through the data points of Ref. 1, 9.

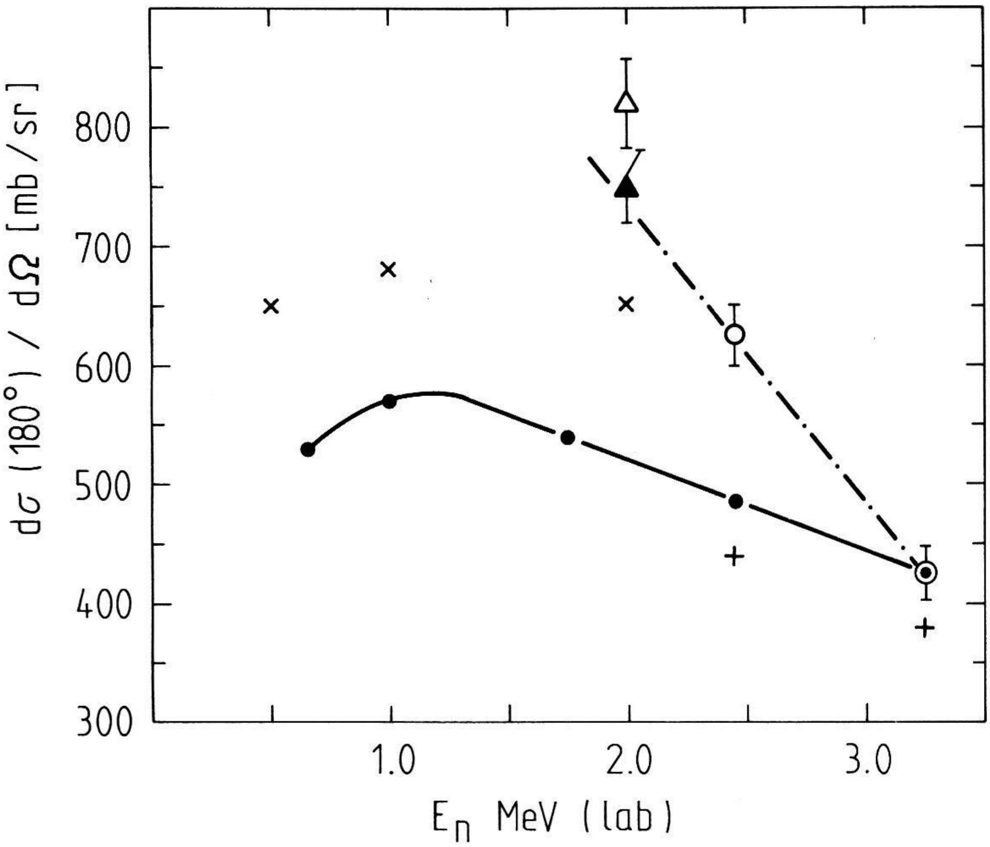


Figure 2
*n–d* elastic cross section at 180° in function of neutron eneryg. ● from Ref. 8; × and + from Ref. 7 (extrapolated values); Φ from Ref. 6; Δ present work; ▲ present work (renormalized, see section 5); — and —·—: guide lines.

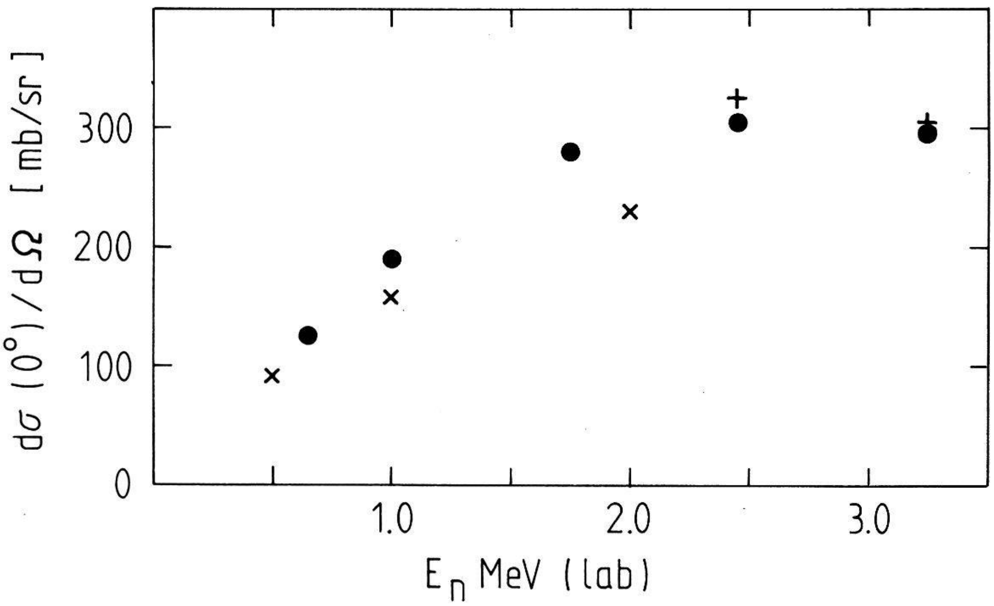


Figure 3
*n–d* elastic cross section at 0° in function of neutron energy. ● from Ref. 8; × and + from Ref. 7 (extrapolated values).

one gets an estimated value of $\sigma_t$ to be compared with the accepted value of $2.56b$ [10]. Hence a renormalization factor of approximately 0.92 is obtained. Then the renormalized value of $\sigma$ (180°) becomes 760 mb/sr which is compatible with the trend suggested by the data points of Chatelain et al.

## 6. Conclusion

This paper presents a set of $(n, d)$ elastic differential cross section data in the 104° to 180° angular range. They are normalized at 148 mb/sr at $\cos\theta_{CM} = -0.306$. Comparison of experimental results with some theoretical predictions of $d\sigma/d\Omega(180°)$ and $d\sigma/d\Omega(0°)$ suggests that this set of cross sections could be renormalized by a factor 0.92.

REFERENCES

[1] A. J. ELWYN, R. O. LANE and A. LANGSDORF, Phys. Rev. *128*, 779 (1962).
[2] R. VIENNET and J. WEBER, to be published.
[3] D. BOVET, P. CHATELAIN, Y. ONEL and J. WEBER, Progress Report to NEANDC from Switzerland, June 1979, p. 3. D. BOVET, P. CHATELAIN, R. VIENNET and J. WEBER, J. Phys. G *4*, 1313 (1978). P. CHATELAIN, Thesis, University of Neuchâtel, 1979.
[4] D. BOVET, S. JACCARD and J. WEBER, Helv. Phys. Acta. *46*, 659 (1973).
[5] P. CHATELAIN, Y. ONEL and J. WEBER, Nucl. Inst. Meth. *151*, 519 (1978).
[6] P. CHATELAIN, Y. ONEL and J. WEBER, Nucl. Phys. *A319*, 71 (1979).
[7] M. D. GOLDBERG, V. M. MAY and J. R. STEHN, BNL-400, Second Edition, Vol. I.
[8] E. O. ALT, and B. L. G. BAKKER, Z. Physik *A273*, 37 (1975), and private communication.
[9] J. D. SEAGRAVE and L. CRANBERG, Phys. Rev. *105*, 1816 (1957).
[10] J. D. SEAGRAVE, The Elastic Channel in Nucleon-Deuteron Scattering. Proceedings of the 1st Int. Conf. on the 3-Body Problem in Nuclear and Particle Physics, Birmingham 1969 (McKee and Rolph Ed.; North-Holland Pub.).