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The (n, d) differential elastic cross section at 2 MeV^1)

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(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, γ) discrimination spectrum.

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

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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 $\cos \theta_{\rm CM} = -0.306$ [7] according to the method described in Ref. 6.

Table I n-d elastic cross section σ (mb/sr) at $E_n = 2.016$ MeV in function of $\cos \theta_{\rm CM}$ (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.

$\cos \theta_{\rm CM}$	σ	SD	$\cos \theta_{\rm CM}$	σ	SD	$\cos \theta_{\rm CM}$	σ	SD	$\cos \theta_{\rm CM}$	σ	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		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				34 120-121-121-121-121-121-121-121-121-121-	10-10-11-11-11-11-11-11-11-11-11-11-11-1	w(10000001515100048			

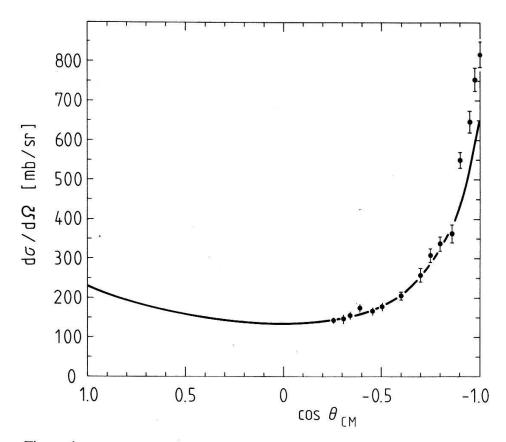


Figure 1 n-d elastic cross section at 2 MeV (Lab). $\frac{1}{4}$ present work (sample), normalized at 148 mb/sr at $\cos \theta_{\rm CM} = -0.306$ [7]. — from Ref. 7.

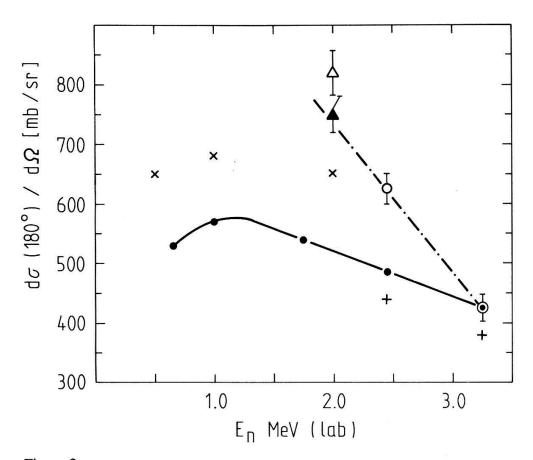
5. Discussion

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 σ (180°) from Ref. 7³) 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 σ (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,

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.

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Figure 2 n-d elastic cross section at 180° in function of neutron energy. • from Ref. 8; × and + from Ref. 7 (extrapolated values); Φ from Ref. 6; Φ present work; Φ present work (renormalized, see section 5); — and — :—: guide lines.

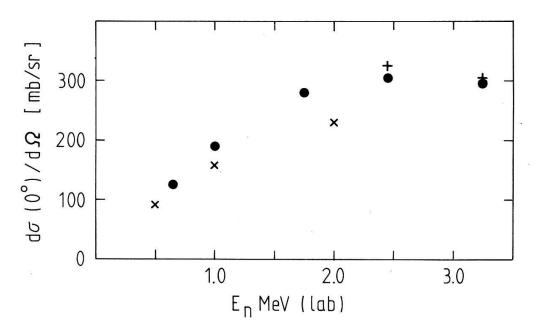


Figure 3 n-d elastic cross section at 0° in function of neutron energy. \bullet from Ref. 8; \times and + from Ref. 7 (extrapolated values).

one gets an estimated value of σ_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 σ (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 $\cos \theta_{\rm CM} = -0.306$. Comparison of experimental results with some theoretical predictions of $d\sigma/d\Omega(180^\circ)$ and $d\sigma/d\Omega(0^\circ)$ suggests that this set of cross sections could be renormalized by a factor 0.92.

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