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ELASTIC SCATTERING OF NEUTRONS FROM ^{6}Li

by

H.-H. KNITTER and M. COPPOLA

1967

Joint Nuclear Research Center
Geel Establishment - Belgium

Central Bureau for Nuclear Measurements - CBNM

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SUMMARY

Angular distributions of neutrons elastically scattered from ^{6}Li were measured in the energy region between 1.0 and 2.3 MeV using a fast neutron time-of-flight spectrometer. Flux attenuation and shape corrections were calculated and the final data are presented in the form of coefficients of Legendre polynomial expansions.

Introduction

A systematic study of neutron elastic scattering from ^{6}Li was realized as a part of a program established to provide data needed for reactor design. Some time-of-flight measurements of neutron scattering from ^{6}Li were previously accomplished (1-5), but the data are spread over a large range of energies up to 14 MeV and do not provide a consistent set of experimental results. R.O.Lane et al. (6) have measured neutron differential cross sections of ^{6}Li between 50 keV and 2.0 MeV using BF_3 counters. A complete survey of the neutron cross sections of ^{6}Li in the energy region 0.001 eV - 15 MeV existing up to July 1964 was made by E.D.Pendlebury (7). More recently R.O.Lane et al. have measured polarization and differential cross sections for neutron scattering from ^{6}Li and ^{7}Li between 0.2 and 2.0 MeV using the same technique as before.

In the energy region of the present measurements also the reaction ^{6}Li(n,dn')α with a Q-value of -1.47 MeV is energetically possible. However, since these neutrons have much longer flight times than the elastically scattered ones, they contribute to a region far from the elastic peak in the time spectra. In any case also at the highest primary neutron energy no appreciable contribution was observed from the ^{6}Li(n,dn')α reaction.

Experimental equipment

The measurements were performed at the 3 MeV Van de Graaff accelerator of CBNM using a fast neutron time-of-flight spectrometer. The experimental equipment is the same used for earlier measurements and was already described (9).

Neutrons were produced through the T(p,n)^{3}He reaction in occluded targets 1.0 and 0.6 mg/cm^{2} thick. The scattering samples were cylindrically shaped and enclosed in very thin aluminium containers. The contribution to the scattering due to the containers was experimentally subtracted using a dummy can. For best detection efficiency two different ^{6}Li samples were used at different energies.

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Sample I: Height 2,59 cm; Ø 3,67 cm; Weight (12,807 ± 0,002)g
Sample II: Height 4,98 cm; Ø 3,68 cm; Weight (24,666 ± 0,005)g.
Both samples had an isotopic composition of 95,82% ^{6}Li and 4,18% ^{7}Li.

Due to the sample-to-detector collimation two different scintillators were also used, in conjunction with the above described samples.
Detector I: Stylbene crystal 1 3/4" Ø and 1" height
Detector II: NE 102 A plastic scintillator 4" Ø and 1" height.

In the case of Detector I the crystal was directly facing the photocathode of a 56 AVP tube, while for Detector II a light-pipe of plexiglass was inserted between scintillator and photocathode. The relative efficiencies of both detectors were obtained by comparison of the measured yield of neutrons scattered from hydrogen at several angles with the known n-p differential scattering cross sections (10). Proper beam attenuation corrections in the hydrogenous sample were introduced.

Experimental results

Neutron scattering from ^{6}Li was measured at several angles between 20° and 150°, but for some of the angular distributions the maximum scattering angle was reduced to 145° because of geometry limitations.
Angular distributions of elastically scattered neutrons were measured at incident neutron energies of 1.00, 1.10, 1.20, 1.33, 1.40, 1.50, 1.60, 1.70, 1.80, 1.90, 2.00, 2.09, 2.19 and 2.30 MeV, with energy spreads, due to target thickness and finite geometry, of 62, 60, 59, 56, 54, 89, 87, 85, 83, 81, 78, 76, 75 and 74 keV respectively.
For the absolute calibration of the cross sections, at each primary energy the neutron scattering from a polyethylene sample was measured at a certain angle. Absolute values of the differential cross sections were then obtained by comparison of the angular distribution results on ^{6}Li with the H(n,n)H differential cross section values.
Corrections for finite geometry, beam attenuation and multiple scattering were calculated with the program MAGGIE (11),

and the corrected differential cross section data were then fitted with a Legendre polynomial expansion of the form

$$\frac{d\sigma}{d\Omega}(\vartheta) = \sum_{L=0}^{7} B_L\, P_L(\cos\vartheta).$$

The best fitting curves are presented in figs. 1, 2 and 3 with the corrected experimental points. The values of the B_L coefficients derived from the least squares fit procedure are presented in table I, together with the computed errors, which are only of statistical nature.
Overall errors on the absolute differential elastic cross sections are estimated to be around 5%.
Integrated elastic scattering cross sections are presented in table II and fig. 4. The agreement with the previous results of R.O.Lane (6) is good.

The theoretical interpretation of our scattering data on ^6Li and ^7Li is under study and it will be the matter of a future publication.

The authors wish to thank Dr. J.Spaepen, Director of CBNM, for supporting these measurements. The cooperation of Mr. B.Jay, Mr. C.Rousseau, the accelerator staff and the Sample Preparation Group is gratefully acknowledged.

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TABLE I

Values of the coefficients in the Legendre polynomial expansions in mb/sr

E_n (MeV)	B_o	B_1	B_2	B_3	B_4	B_5	B_6	B_7
1.00	+ 81.42±1.31	+59.89±2.36	+27.11±3.39	+2.95±4.66	+2.20±4.19	-1.19±6.92	-0.03±0.06	-0.08±0.06
1.10	+ 82.84±1.40	+66.82±3.12	+19.30±4.71	-0.66±6.03	-0.36±5.11	-3.56±8.31	-4.47±8.44	-7.29±8.81
1.20	+ 78.46±1.50	+56.09±3.16	+20.52±4.31	-8.02±5.57	+3.67±5.02	-7.80±7.31	+0.86±7.85	-8.29±8.70
1.33	+ 76.31±0.27	+47.83±0.72	+14.96±0.97	-1.54±1.06	+2.63±0.88	-0.76±1.77	+0.03±0.06	-0.05±0.10
1.40	+ 77.99±0.51	+48.56±1.21	+20.07±1.66	+3.15±2.07	+4.84±1.75	-1.05±2.92	-0.12±0.03	-0.03±0.03
1.50	+ 76.99±0.73	+39.75±2.17	+18.33±3.11	-11.70±3.97	+8.62±3.64	-12.64±4.32	+7.96±3.50	-1.25±2.95
1.60	+ 78.17±0.93	+47.09±2.64	+12.40±4.28	+1.94±5.59	+6.98±4.59	+5.47±5.58	+0.28±6.44	-0.47±6.58
1.70	+ 81.74±0.37	+47.91±0.98	+14.59±1.30	-5.30±1.56	+2.47±1.32	-3.32±2.10	-0.10±0.05	-0.02±0.06
1.80	+ 78.86±0.65	+45.75±1.55	+10.00±2.17	-4.07±2.68	+2.52±2.26	-4.42±3.65	-0.11±0.05	+0.05±0.05
1.90	+ 84.70±0.47	+48.39±1.14	+13.89±1.63	+1.88±2.10	+1.30±1.44	-1.52±3.16	-0.10±0.05	+0.02±0.06
2.00	+ 89.61±0.57	+52.83±1.27	+15.63±1.76	+8.80±2.31	-4.57±2.67	+5.91±2.79	+0.02±0.06	-0.13±0.06
2.09	+ 95.38±0.76	+60.57±2.33	+26.89±3.39	+17.80±4.53	+4.53±3.87	+12.41±4.79	+6.87±4.05	+7.28±3.98
2.19	+ 99.56±0.77	+57.36±1.94	+27.68±2.75	+12.01±3.65	+2.20±1.89	+6.91±3.70	+0.70±1.00	+0.84±1.06
2.30	+105.20±0.69	+62.38±2.17	+36.72±3.02	+15.76±4.32	+7.92±3.91	+4.61±4.50	+8.24±3.22	+2.28±3.93

TABLE II

Integrated elastic cross sections

E_n (MeV)	1.00	1.10	1.20	1.33	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.09	2.19	2.30
σ_{el} (mb)	1023	1040	985	958	980	967	982	1027	990	1064	1126	1198	1250	1321
$\Delta\sigma_{el}$ (mb)	36	36	34	33	34	34	34	36	35	37	39	42	44	46

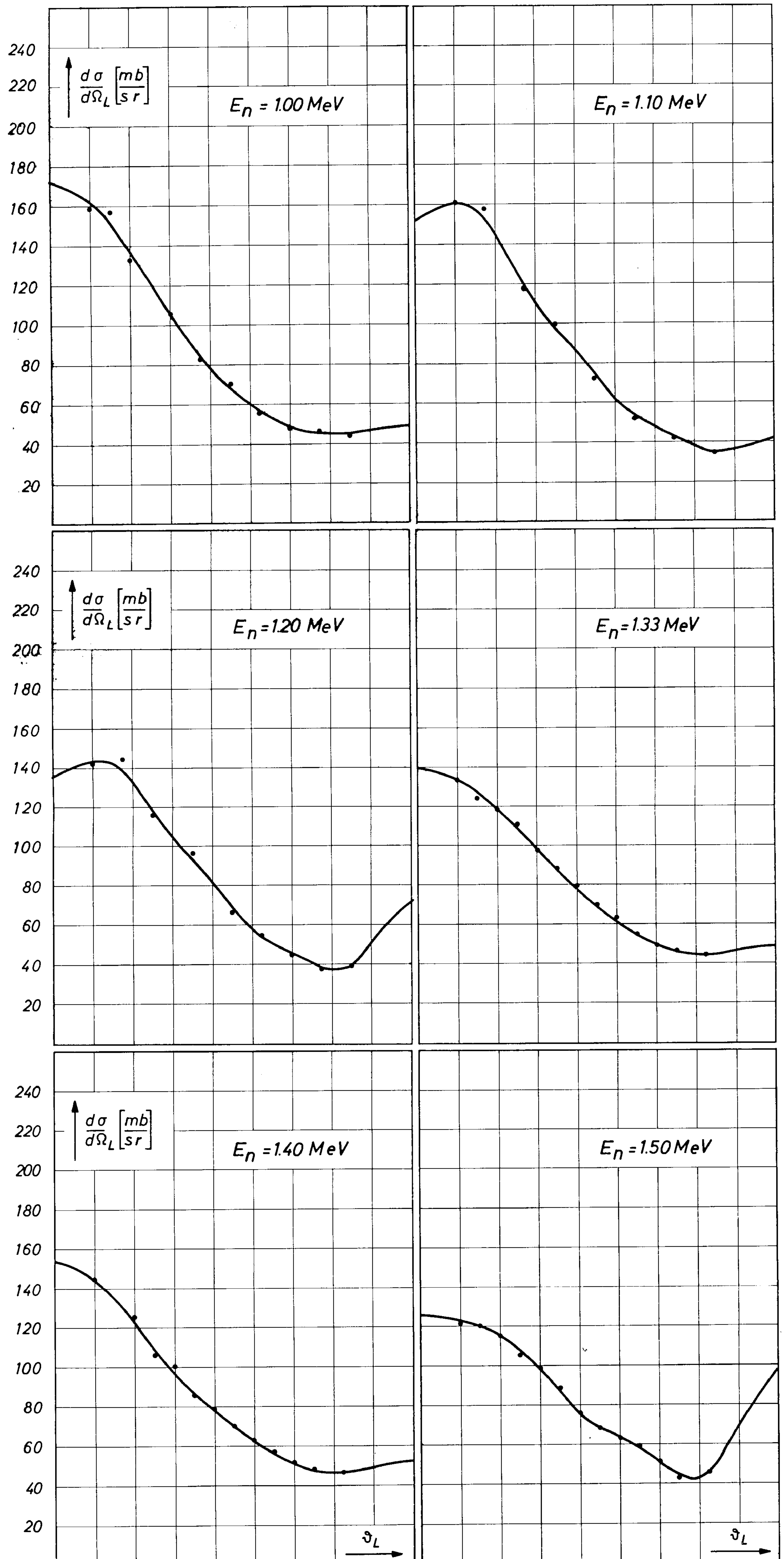

Fig.1 Elastic scattering of neutrons from ^{6}Li in the Lab system.
Solid curves are the best fits through corrected experimental points.

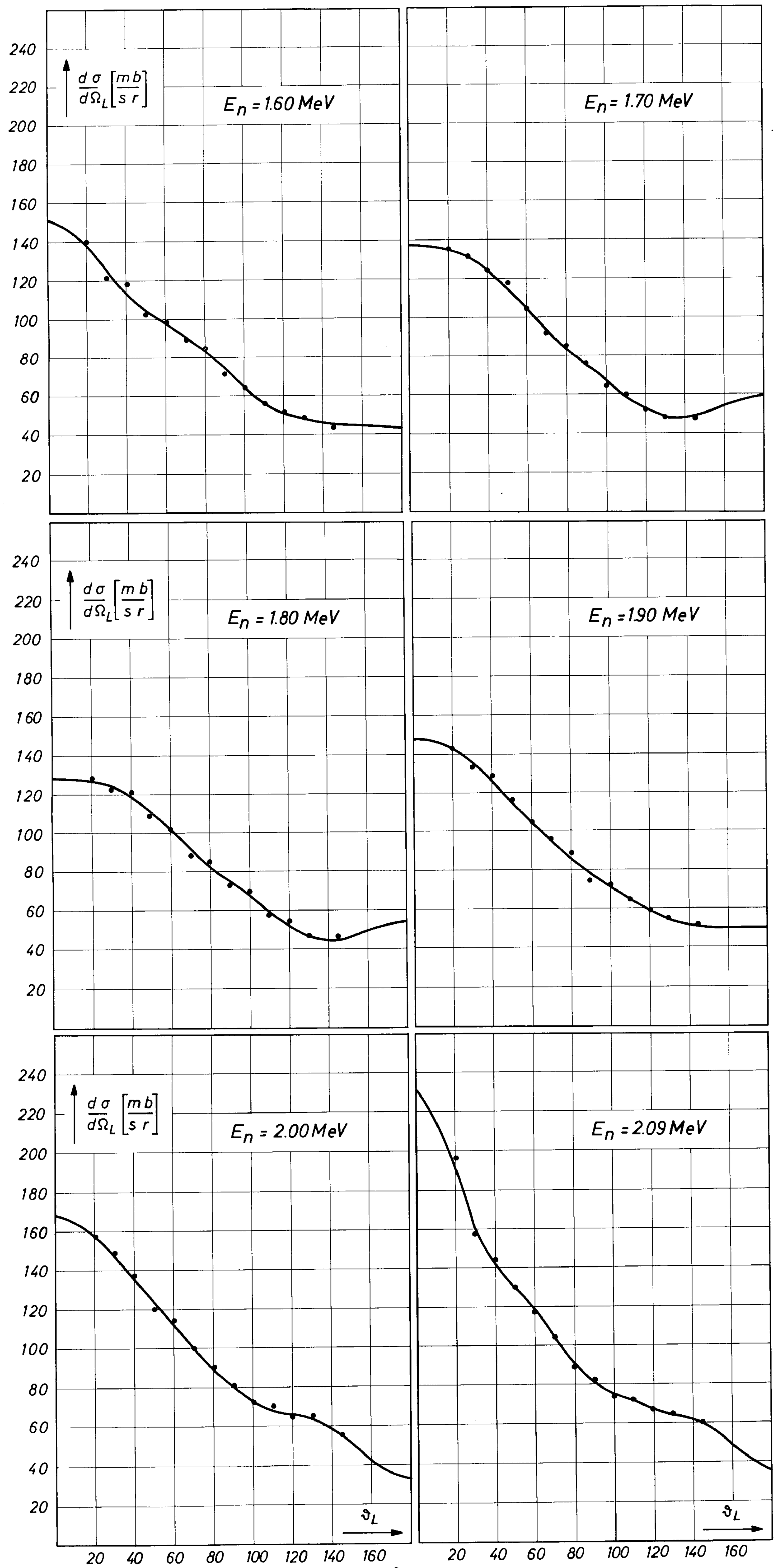

Fig. 2 Elastic scattering of neutrons from ^6Li in the Lab system.
Solid curves are the best fits through corrected experimental points.

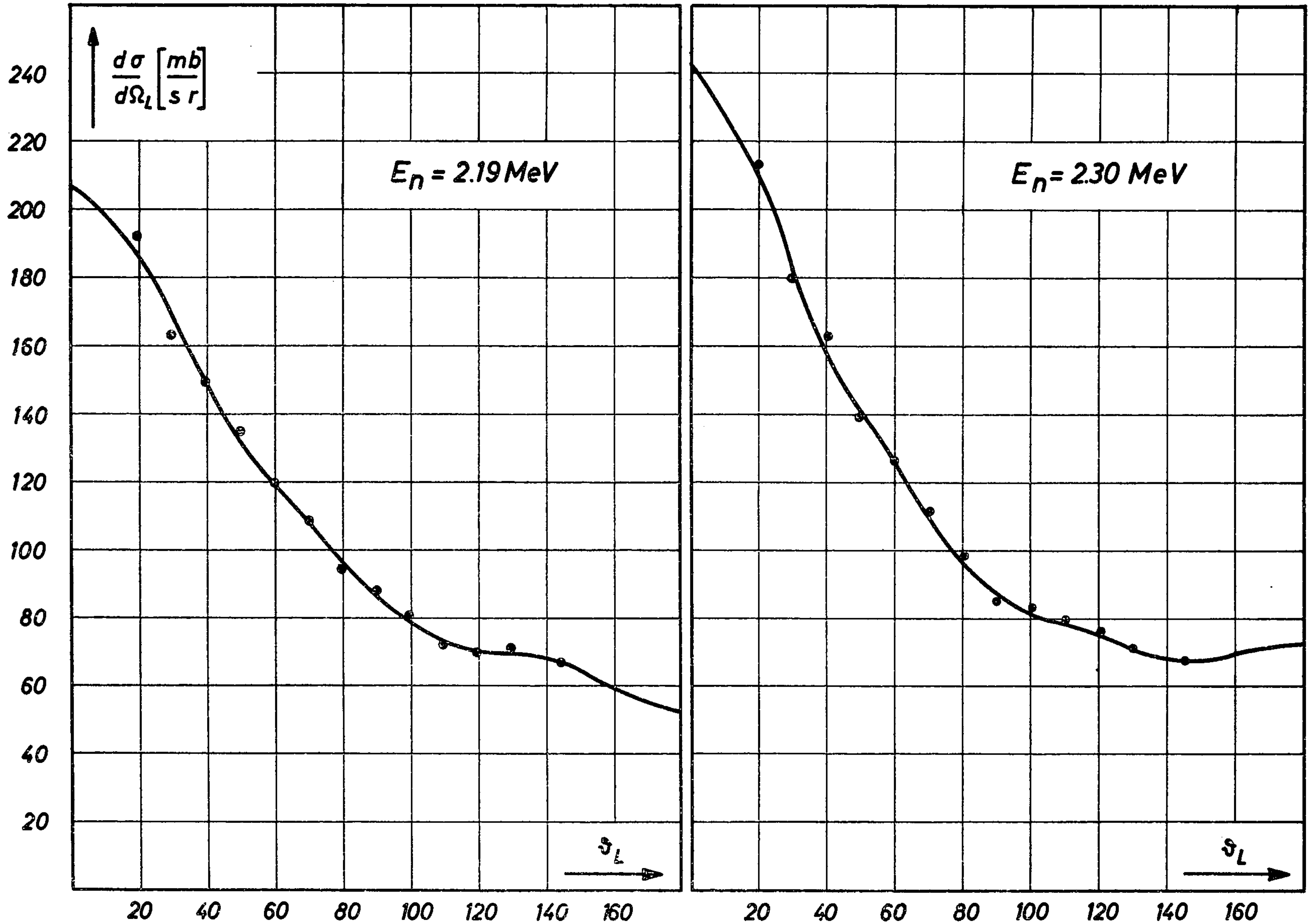

Fig. 3 Elastic scattering of neutrons from ^{6}Li in the Lab system.
Solid curves are the best fits through corrected experimental points.

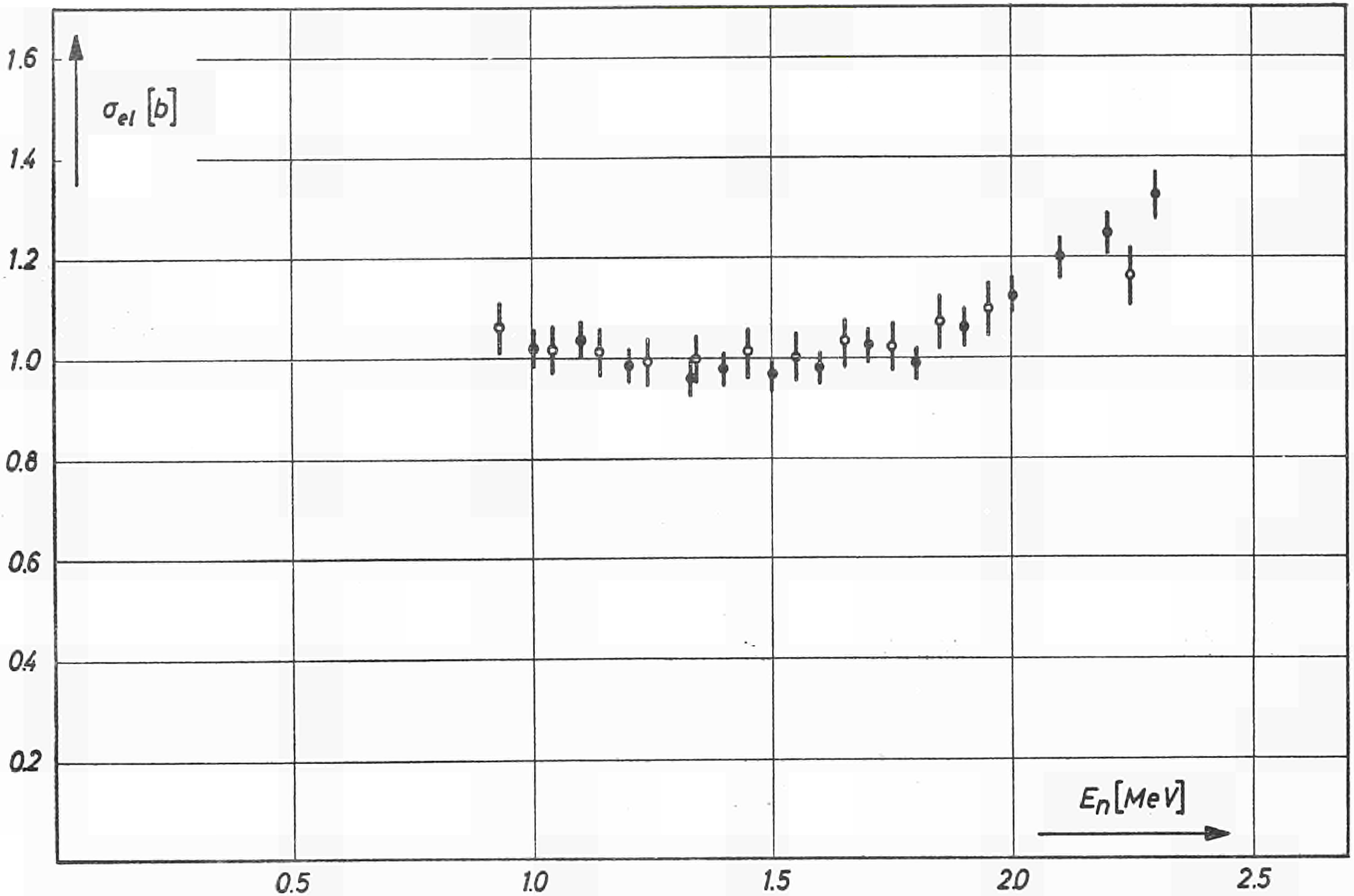

Fig. 4 Integrated elastic cross sections.
• present work
∘ Lane et al. (6)

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To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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