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AE-476

Excitation Functions for Charged Particle Induced Reactions in Light Elements at Low Projectile Energies

J. Lorenzen and D. Brune

AKTIEBOLAGET ATOMENERGI

STUDSVIK, NYKÖPING, SWEDEN 1973

ERRATA

to report AE-476

EXCITATION FUNCTIONS FOR CHARGED PARTICLE INDUCED REACTIONS IN LIGHT ELEMENTS AT LOW PROJECTILE ENERGIES

J Lorenzen and D Brune

Page 4: Line 22: Börnstein instead of Bernstein

In the following reactions the residual nucleus is left in an excited state and should be marked with (*)

Page	23	lower fig
"	30	lower fig
"	31	upper fig
"	36	
"	37	
"	38	
"	43	
"	48	b, c, d
"	50	both
"	51	both
"	53	the dashed lowest line corresponds to E_d = 5.74 MeV
"	54	
"	55	
"	58	
"	59	
"	63	upper fig
"	72	lower line
"	76	
"	77	lower fig
"	80	
"	105	lower fig
"	106	

AKTIEBOLAGET ATOMENERGI, Sweden 1973.

EXCITATION FUNCTIONS FOR CHARGED PARTICLE INDUCED REACTIONS IN LIGHT ELEMENTS AT LOW PROJECTILE ENERGIES[x)]

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SUMMARY

The present chapter has been formulated with the aim of making it useful in various fields of nuclear applications with emphasis on charged particle activation analysis.

Activation analysis of light elements using charged particles has proved to be an important tool in solving various problems in analytical chemistry, e g those associated with metal surfaces. Scientists desiring to evaluate the distribution of light elements in the surface of various matrices using charged particle reactions require accurate data on cross sections in the MeV-region.

A knowledge of cross section data and yield-functions is of great interest in many applied fields involving work with charged particles, such as radiological protection and health physics, material research, semiconductor material investigations and corrosion chemistry. The authors therefore decided to collect a limited number of data which find use in these fields. Although the compilation is far from being complete, it is expected to be of assistance in devising measurements of charged particle reactions in Van de Graaff or other low energy accelerators.

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x) To be included in a handbook of cross section data for activation analysis purposes published by I. A. E. A.

LIST OF CONTENTS

INTRODUCTION

Nuclear reactions with charged particles are, as is well-known, hindered by the repulsive Coulomb interaction with the nucleus. Thus charged particle reactions with acceptable yields occur only where low- or medium-weight nuclei are involved. Elements heavier than $Z > 12$ have therefore been omitted from this compilation. The central problem in activation analysis is the identification of a given nuclide, and a quantitative determination of its concentration in a more or less complex matrix. In this connection it is necessary to search for special reactions which exclude competitive processes. This can be done, for example, by using selected bombarding energies which lead to as few competitive reactions as possible: Use is thus made of resonances in the excitation function in order to obtain a dominant yield from the selected nuclide, or of coincidence measurements with reactions products. Consequently, inclusion has been made of differential cross sections wherever they are available as well as integral curves. Furthermore, the compilation contains various yield curves.

In some cases the emerging particle is specified with an index i. This denotes whether the light product is produced in the ground state (o) or in the i:th excited state of the product nucleus. The excited states and the corresponding gamma ray energies can be obtained for instance in:

Nuclear Data Sheets, National Academy of Science, National Research Council, Washington D C, 1962

Where the values for angular distribution are related to the centre-of-mass-system this is denoted by the index c.m. for the units of the cross section in the figures. Otherwise the figures show values in the laboratory system.

The authors suggest that a diagram showing the shape of cross sections or excitation functions provides a more rapid and useful source of information than do data from tables. For this reason only diagrams of absolute, normalized experimental values have been presented, even in those instances where tables were provided by the experimentalists. Unified symbols and units (see conventions and symbols) have been used, abbreviated references and comments have been included on the same page as the figures. The absolute errors as determined by the experimentalists are shown in the diagrams.

A reference list will be found at the end of this compilation arranged in P (number) for proton, D (number) for deuteron, A (number) for alpha and H (number) for ^{3}He-particle-induced reactions.

In some cases we found several publications concerned with the same reaction. Where the cross section was measured in different energy regions an attempt was made to fit and normalize the different results to a mean value at the point of intersection. Where identical information was presented by several authors the choice was restricted to that of the most recent origin.

In most cases the cross sections collected for this compilation will be found up to 20 MeV. In order to optimize irradiation conditions it may be necessary to know whether the cross section increases at higher energies or whether the resonance for the reaction concerned is already exceeded at low bombarding energies. Unfortunately there are only very few measurements for reactions induced by charged particles at higher energies. Therefore a request was addressed to H Münzel at Kernforschungszentrum Karlsruhe to include the systematic study made by him and his coworker on calculated and experimental cross-sections for charged particle induced reactions at higher energies. The original work is to be found in KFK 767, May 1968 (I Lange, H Münzel). A condensed part of this work is given in Appendix I. A more comprehensive compilation of this kind will be published in Landolt-Bernstein Vol III in the near future.

(p, γ) reactions exhibit several resonances in the MeV region. These resonances are of special interest in charged particle activation analysis. For calibration purposes and depth distribution studies of light elements in heavy matrices use can favourably be made of these sharp resonances. In most of the cases the shape of the resonances is not so important as the characteristic data like position (resonance energy in keV), resonance width (FWHM in keV) and height (cross section in mb). Therefore a request was addressed to I W Butler, U S Naval Research Laboratory, Washington D C, to include the systematic collection made by him on (p, γ) resonances (see Appendix II). The original report will be found in NRL-5282 from April 1959.

The cross section given is the total cross section in millibarns at the resonance peak. Where more than one primary gamma ray is emitted, the tabulated value of the cross section is the sum of all such individual primary gamma-ray cross sections. For those resonances which are too narrow for such cross section measurements, the integrated cross section, $\int \sigma dE$, has been tabulated where this measurement has been made. In these instances, the abbreviation "evb" for "electron-volt barn" has been inserted in the cross-section column.

As far as the gamma energies are concerned only the most predominant have been compiled here. A question mark means doubt about the number.

In Appendix III, finally, a collection of references concerning various data about charged particle induced reactions is given.

The authors wish to express their gratitude to the various contributors to this compilation, especially to Dr McGowan of the Data Centre at Oak Ridge, Tennessee.

CONVENTIONS AND SYMBOLS

σ	total cross section
σ_{exc}	excitation function
$\frac{d\sigma}{d\Omega}$	angular distribution
$\frac{d\sigma}{d\Omega}(0^o)$	diff cross section for 0^o
c.m.	Centre-of-Mass system
θ	lab angle of measurement in angular distributions
E	energy in lab system
p	subscripts refer to proton
d	subscripts refer to deuteron
^3He	subscripts refer to helium-3
α	subscripts refer to alpha particle
gr. st.	ground state
exc. st.	excited state
(p,p')	inelastic proton scattering

PROTON

Reaction	Cross sections and ang distr	Energy range (MeV)	Page
$^{7}Li(p,n)^{7}Be$	$\sigma(0^{o})$	3-13	11
$^{7}Li(p,\alpha)^{4}He$	$\sigma(90^{o}, 120^{o})$	0.5-2.3	12
$^{7}Be(p,\gamma)^{8}B$	σ	1-3.5	12
$^{9}Be(p,\alpha)^{6}Li$	$\frac{d\sigma}{d\Omega}$	6-8	13
$^{9}Be(p,d)^{8}Be$		5-11	13
$^{10}Be(p,\gamma)^{11}B$	$\sigma(0^{o}, 90^{o})$	0-6	16
$^{10}B(p,\gamma)^{11}C$	$\sigma(90^{o})$	3-17	16
$^{11}B(p,\gamma)^{12}C$	σ, $\frac{d\sigma}{d\Omega}(90^{o})$	1-14	17
$^{12}C(p,\gamma)^{13}N$	σ	0-2.2	19
$^{13}C(p,n)^{13}N$	σ; $\sigma(5^{o}, 40^{o})$	3-14	19
$^{14}N(p,\gamma)^{15}O$	$\sigma(90^{o})$	2-19	21
$^{15}N(p,n)^{15}O$	σ; $\sigma(5^{o}, 40^{o})$	4-14	22
$^{18}O(p,p)^{18}O$	$\sigma(0^{o})$	3.2-5.4	23
$^{18}O(p,\alpha)^{15}N$	$\sigma(0^{o})$	3.2-5.4	24
$^{19}F(p,\alpha)^{16}O$	σ; $\frac{d\sigma}{d\Omega}$	4-12	24
	$\sigma(70^{o}, 165^{o})$; $\frac{d\sigma}{d\Omega}$	9-12	25
$^{19}F(p,\alpha\gamma)^{16}O$	relative yield	0-5.6	29

DEUTERON

ALPHA

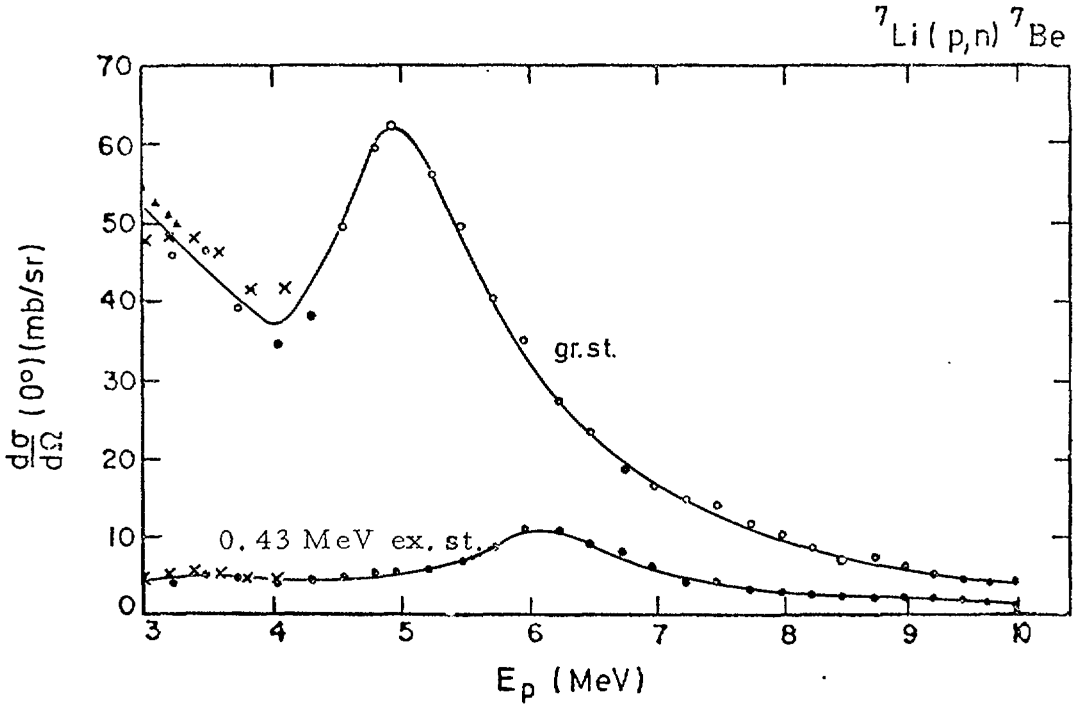
Reaction	Cross section and ang distr	Energy range (MeV)	Page
$^{6}Li+\alpha$	$\frac{d\sigma}{d\Omega}$	10; 12.5	60
$^{7}Li(\alpha,n)^{10}B$	σ; $\sigma(0^{o})$	4-8	61
	$\frac{d\sigma}{d\Omega}$	4.8-7.8	62
$^{9}Be(\alpha,n)^{12}C$	σ; $\sigma(0^{o})$	1.6-6.4	63
	$\frac{d\sigma}{d\Omega}(0^{o})$	0.34-0.7	64
	$\frac{d\sigma}{d\Omega}$	3.2-6.4	65
$^{9}Be(\alpha,2n)^{11}C$	σ	24-38	69
$^{13}C(\alpha,n)^{16}O$	σ	2-5.3	69
$^{16}O(\alpha,n)^{19}Ne$	σ	6-17.5	70
$^{20}Ne(\alpha,n)^{23}Mg$	σ	11-28	70

HELIUM 3

Reaction	Cross-section and ang distr	Energy range (MeV)	Page
$^{3}H(^{3}He,n)^{5}Li$	$\frac{d\sigma}{d\Omega}$; $\sigma(0^{o}, 40^{o})$	1-4	71
$^{7}Li(^{3}He,t)^{7}Be$	$\sigma(30^{o})$	2-4	72
	$\frac{d\sigma}{d\Omega}$	3; 3.5; 4	72
$^{7}Li(^{3}He,\alpha)^{6}Li$	$\sigma(40^{o})$	2-4	73
$^{9}Be(^{3}He,n)^{11}C$	σ	3-10	73
$^{9}Be(^{3}He,t)^{9}B$	$\sigma(40^{o})$	2.5-4	73
	$\frac{d\sigma}{d\Omega}$	3-3.8	74
$^{10}Be(^{3}He,p)^{12}C$	$\sigma(90^{o}, 150^{o})$	11-18	75
$^{10}Be(^{3}He,d)^{11}C$	$\sigma(150^{o})$	11-19	75
$^{10}Be(^{3}He,\alpha)^{9}B$	$\sigma(\theta)$	2-19	76
	$\sigma(\theta)$	9-19	77
$^{10}Be(^{3}He,n)^{12}N$	σ	1-7	78
$^{10}B(^{3}He,\alpha)^{9}B$	$\sigma(\theta)$	2-10	78
	$\frac{d\sigma}{d\Omega}$	3.4-9.8	79
$^{12}C(^{3}He,p)^{14}N$	$\frac{d\sigma}{d\Omega}$; σ	3-11	81*
$^{12}C(^{3}He,d)^{13}N$	σ	6-10	101
$^{12}C(^{3}He,d)^{13}N+$ $+^{12}C(^{3}He,pn)^{13}N$	σ_{ex}	6-30	101
$^{12}C(^{3}He,\alpha)^{11}C$	σ	1-6	102
$^{12}C(^{3}He,n)^{14}O$	σ	1.6-6; 1.6-11	102
	σ_{ex}	2-32	103
$^{14}N(^{3}He,p)^{16}O$	σ	3-12	104
$^{14}N(^{3}He,\alpha)^{13}N$	σ	4-10	104
$^{16}O(^{3}He,p)^{18}F$	σ	2-9	108
$^{16}O(^{3}He,\alpha)^{15}O$	σ	2-9	108
$^{19}F(^{3}He,\alpha)^{18}F$	σ	3-9	109
$^{19}F(^{3}He,\alpha n)^{17}F$	σ	3-9	109

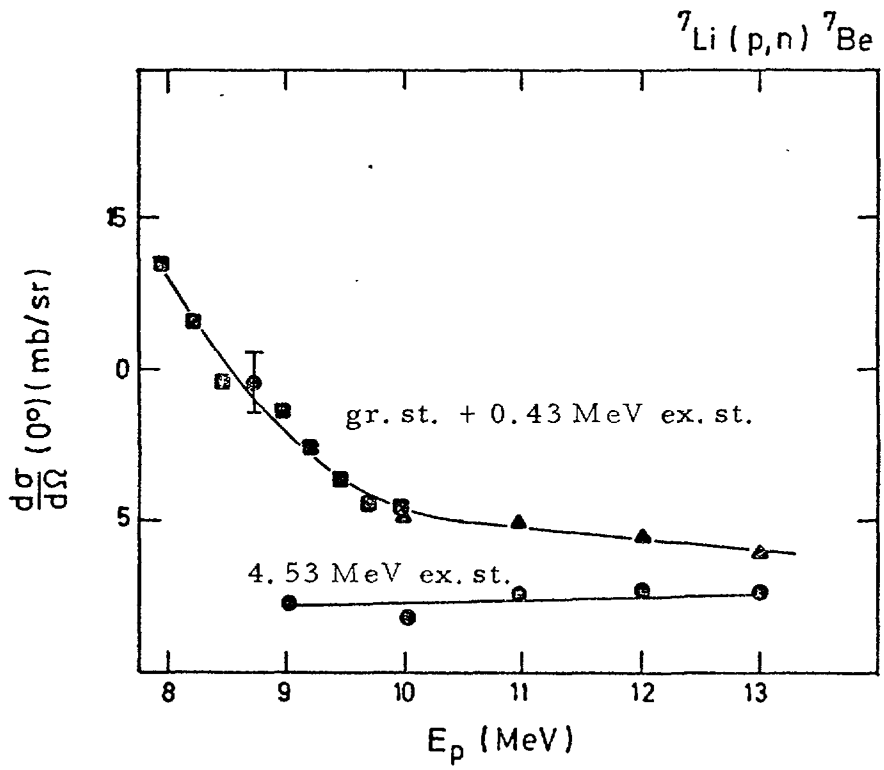
* $\theta = 172^{o}$

YIELD CURVES



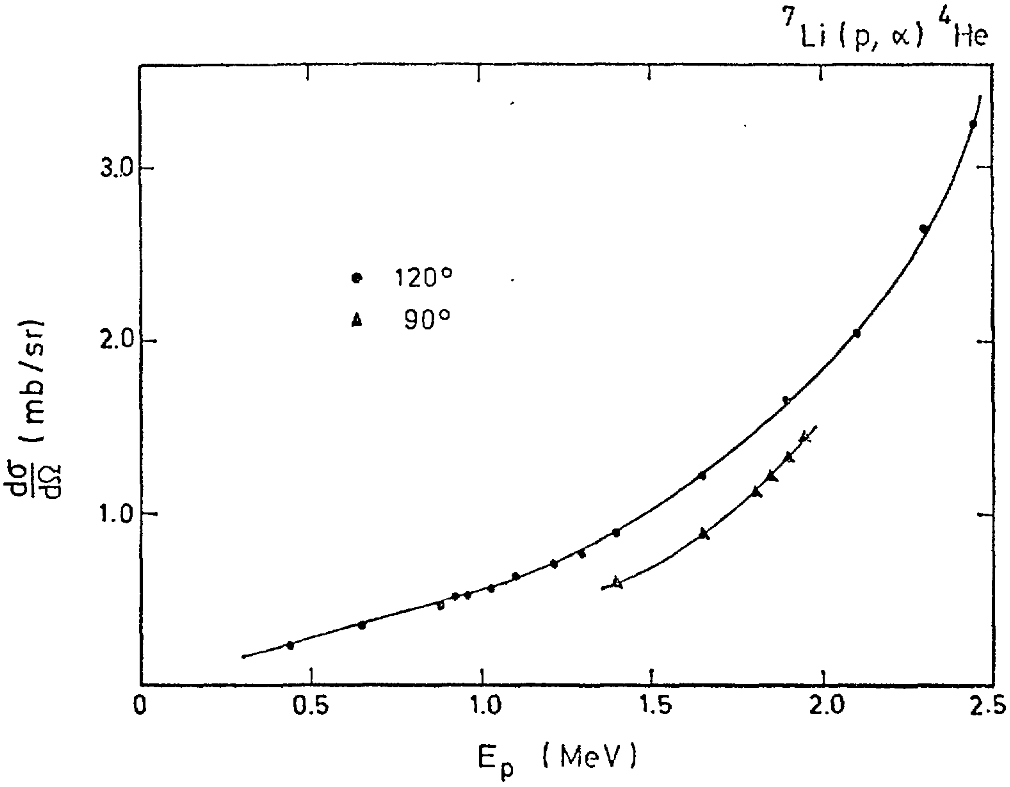
^{7}Li (p,n) ^{7}Be
gr. st.
0. 43 MeV ex. st.
$\frac{d\sigma}{d\Omega}$ (0°) (mb/sr)
E_p (MeV)

Ref P1



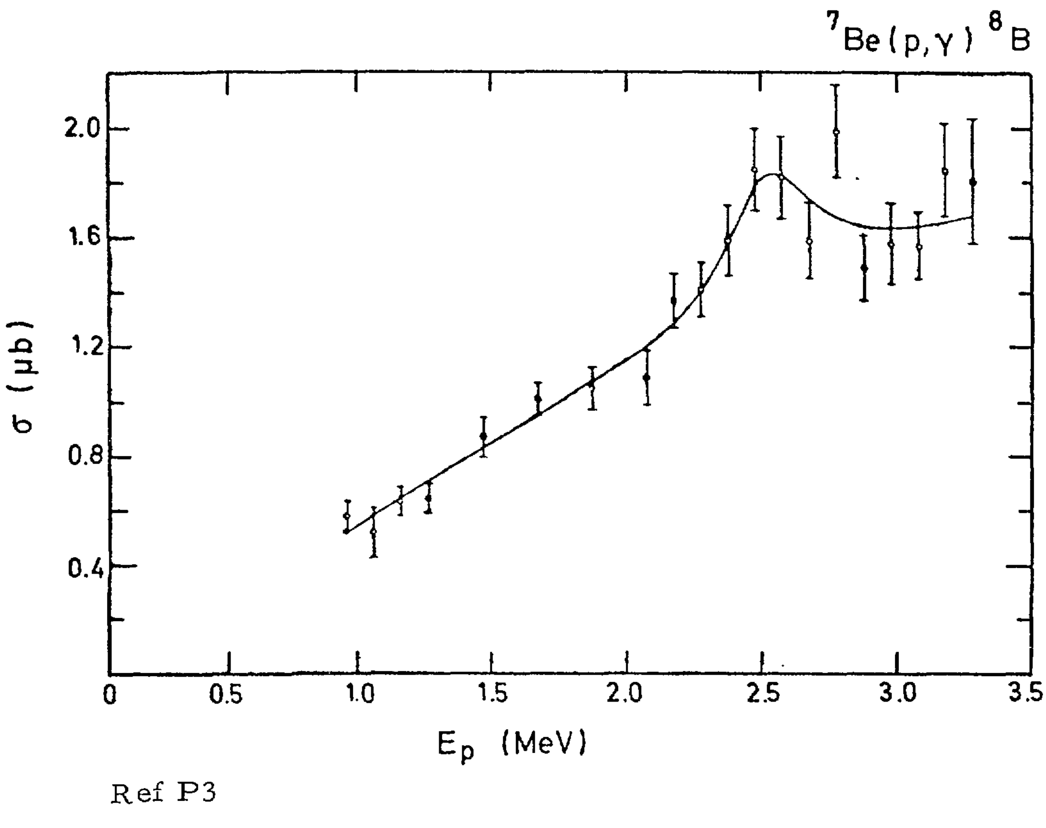
^{7}Li (p,n) ^{7}Be
gr. st. + 0. 43 MeV ex. st.
4. 53 MeV ex. st.
$\frac{d\sigma}{d\Omega}$ (0°) (mb/sr)
E_p (MeV)

Ref P1



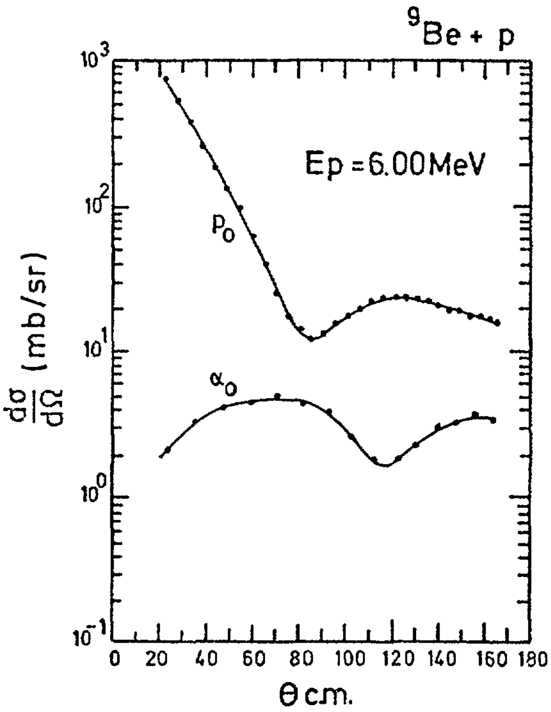
$^7Li(p,\alpha)^4He$
120°
90°
$\frac{d\sigma}{d\Omega}$ (mb/sr)
3.0
2.0
1.0
0
0.5
1.0
1.5
2.0
2.5
E_p (MeV)

Ref P2



$^7Be(p,\gamma)^8B$
σ (μb)
2.0
1.6
1.2
0.8
0.4
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
E_p (MeV)

Ref P3



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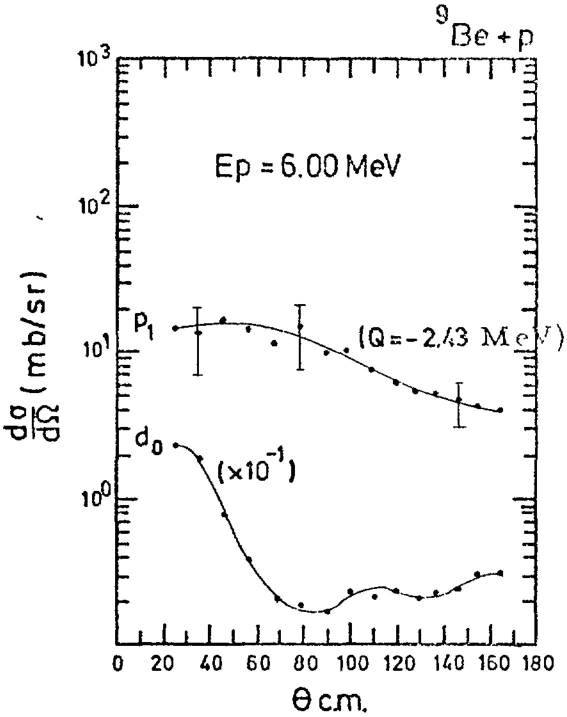

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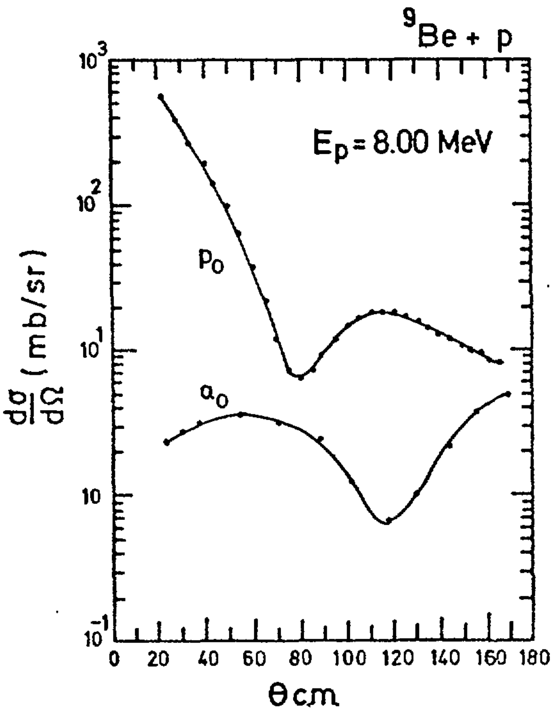

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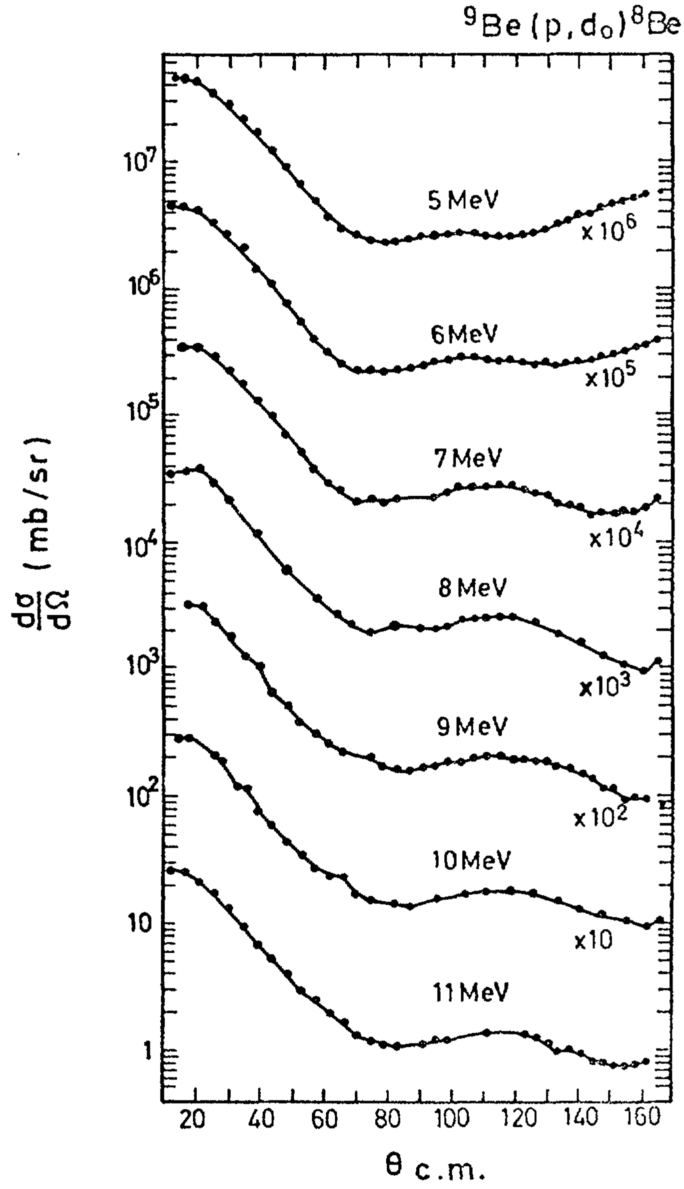
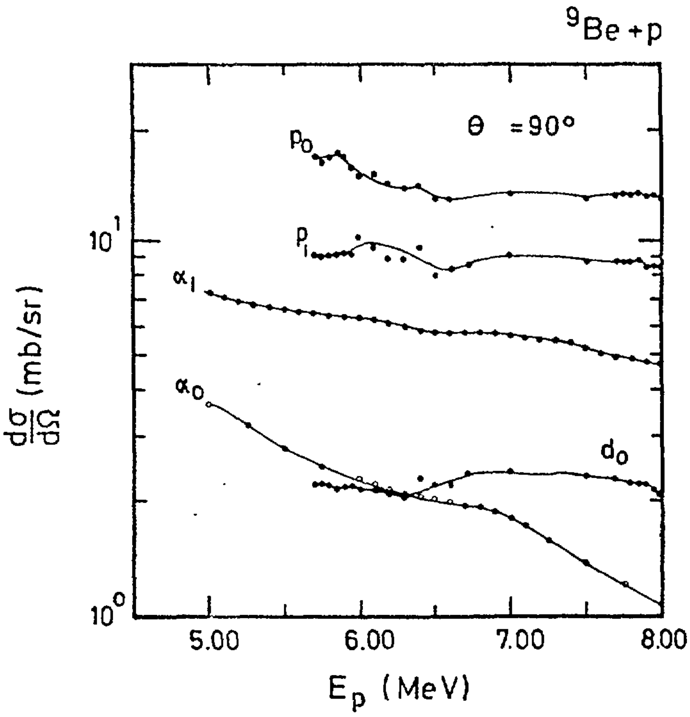
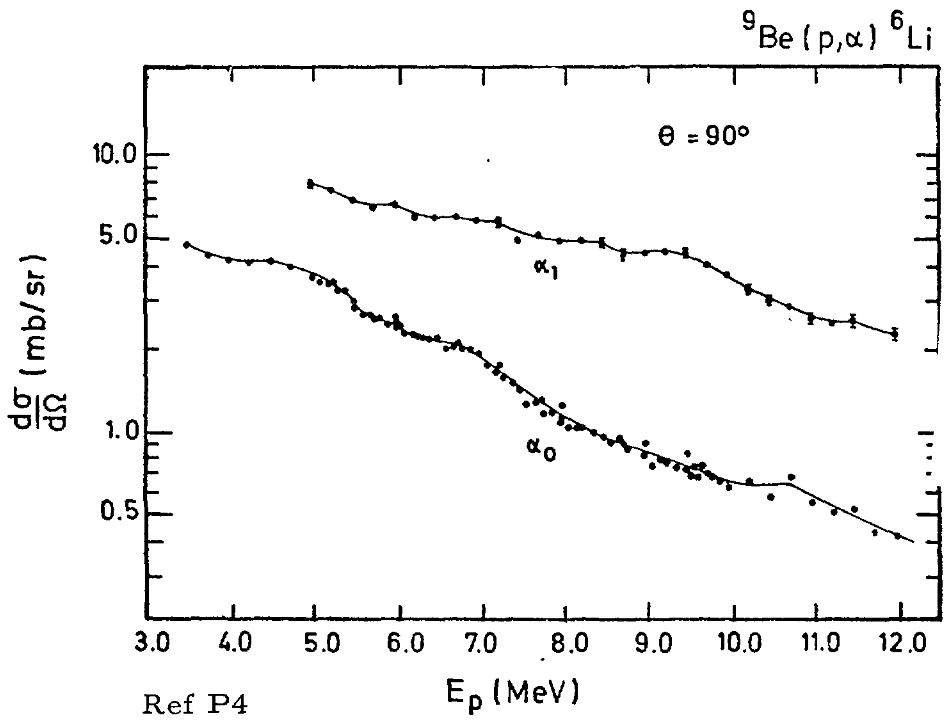




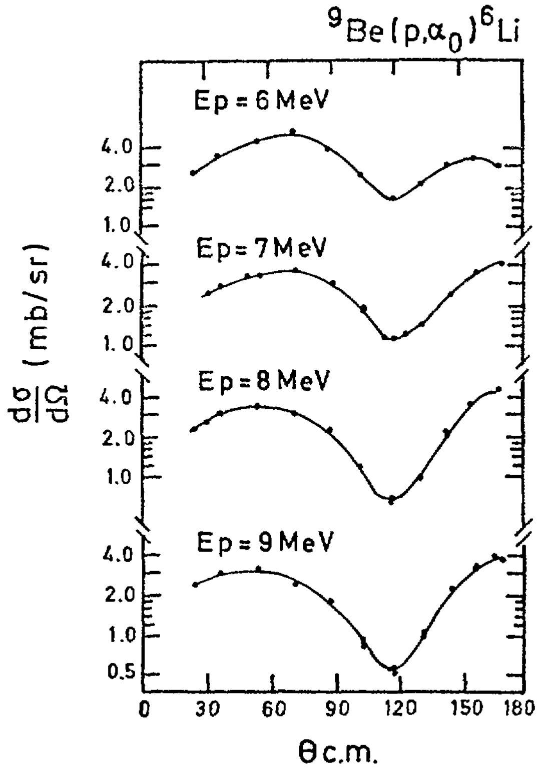
^{9}Be + p
θ = 90°
p_0
p_1
α_1
α_0
d_0
10^1
10^0
$\frac{d\sigma}{d\Omega}$ (mb/sr)
5.00
6.00
7.00
8.00
E_p (MeV)

Ref P4



^{9}Be (p,α) ^{6}Li
θ = 90°
10.0
5.0
1.0
0.5
$\frac{d\sigma}{d\Omega}$ (mb/sr)
α_1
α_0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
E_p (MeV)

Ref P4



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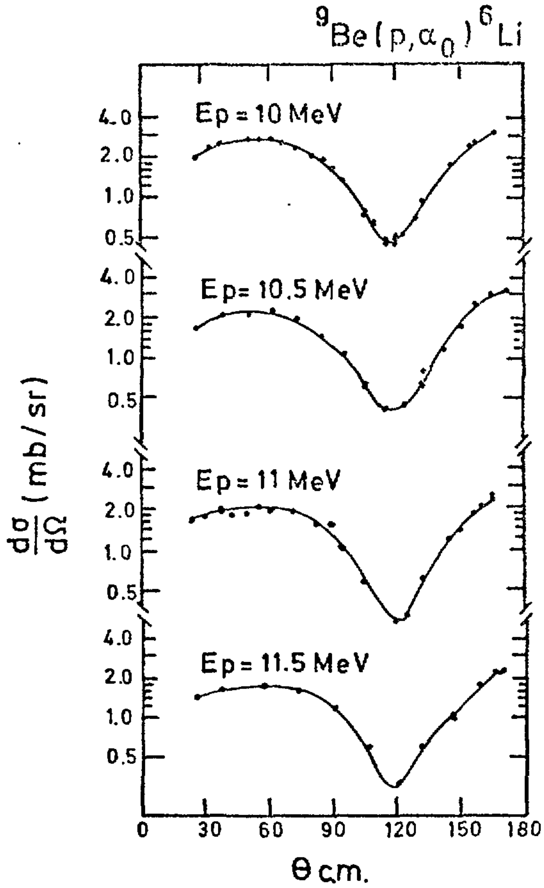

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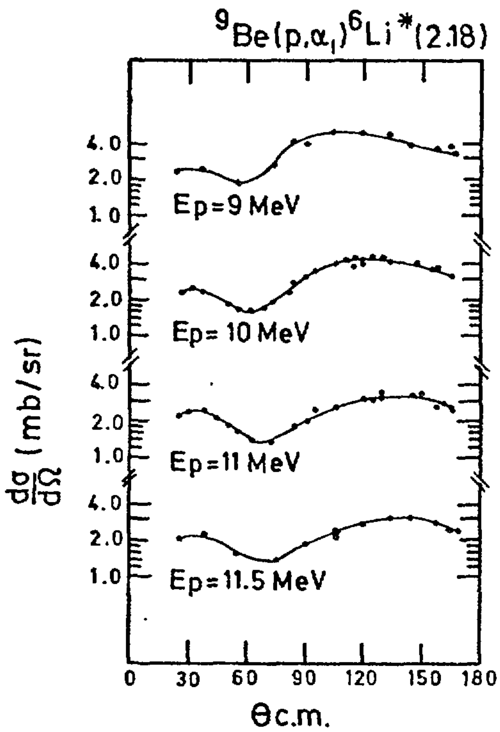

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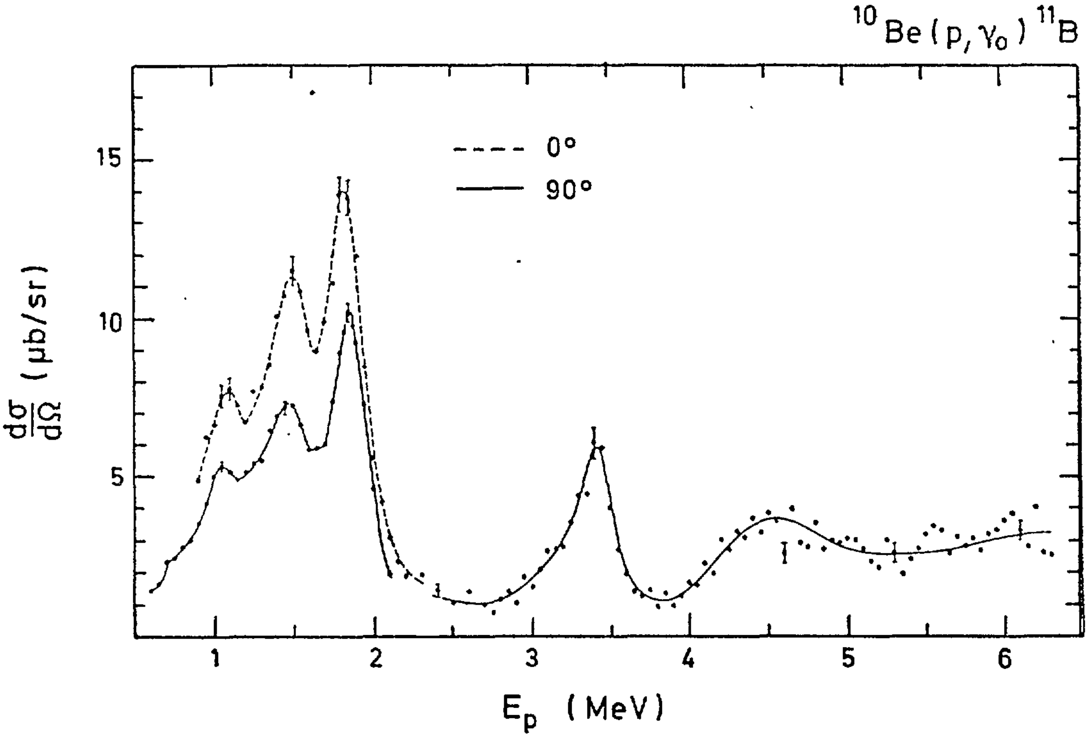
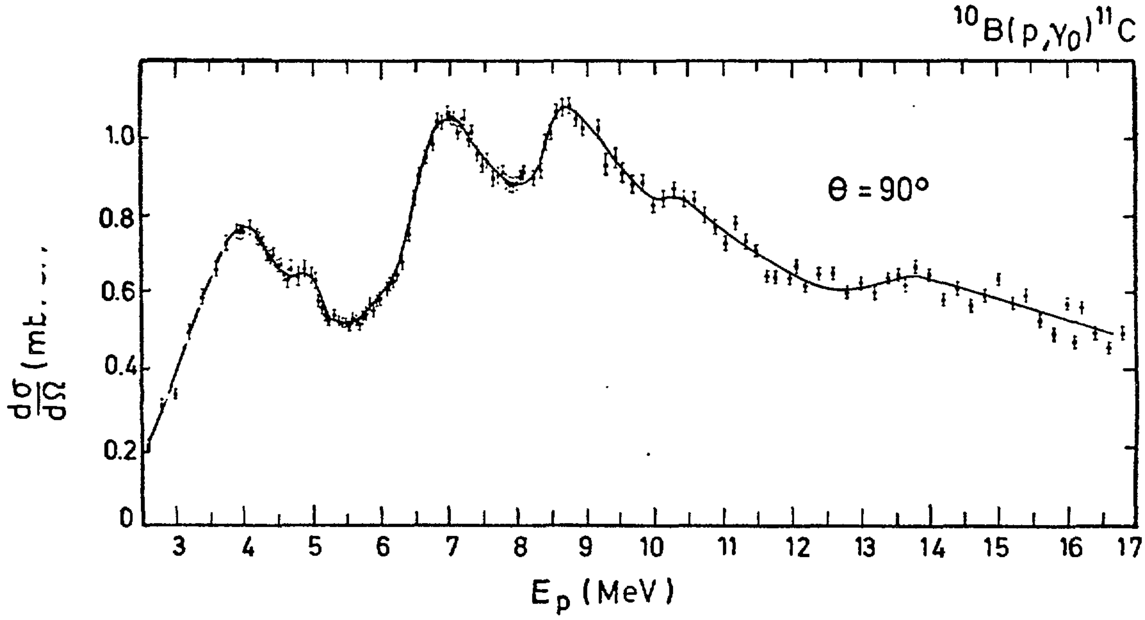


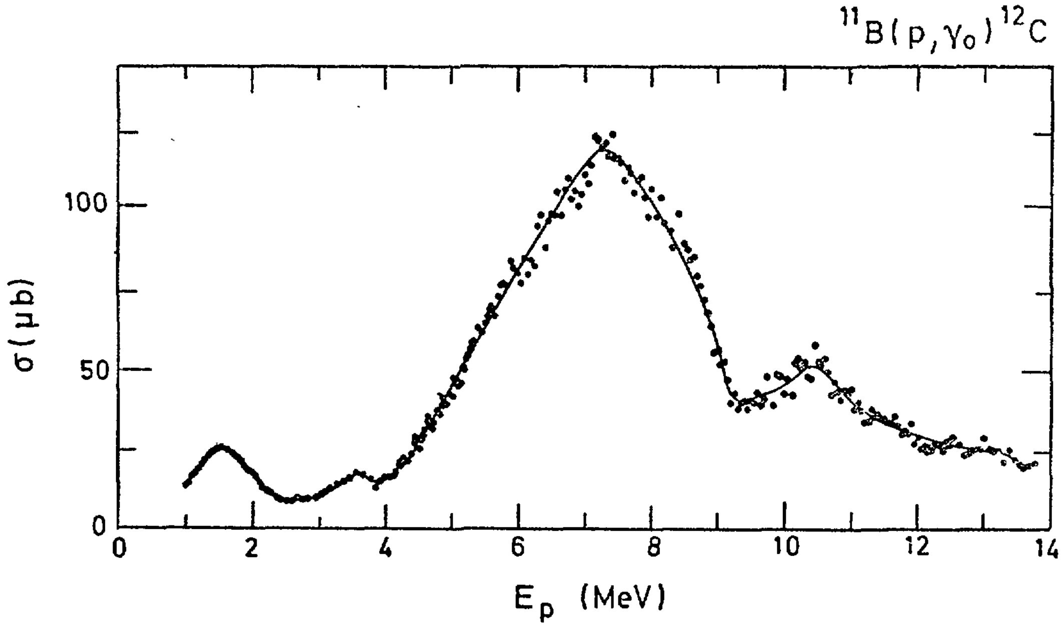
^{10}Be (p, γ_0) ^{11}B
0°
90°
15
10
5
dσ/dΩ (μb/sr)
1
2
3
4
5
6
E_p (MeV)

Ref P5



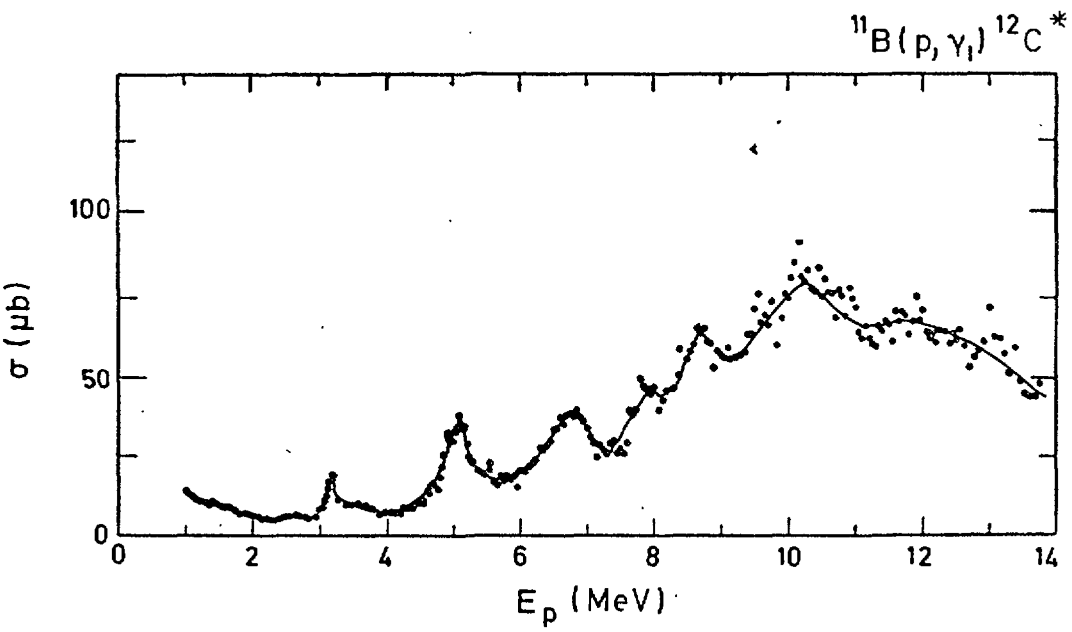
^{10}B(p,γ_0)^{11}C
θ = 90°
1.0
0.8
0.6
0.4
0.2
0
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
E_p (MeV)

Ref P6



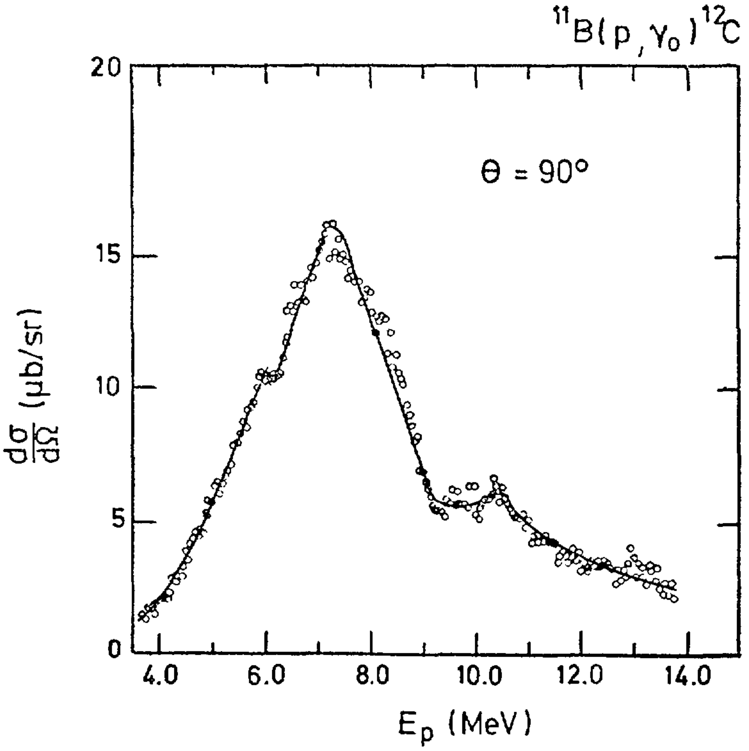
$^{11}B(p,\gamma_0)^{12}C$
σ (μb)
100
50
0
0
2
4
6
8
10
12
14
E_p (MeV)

Ref P7



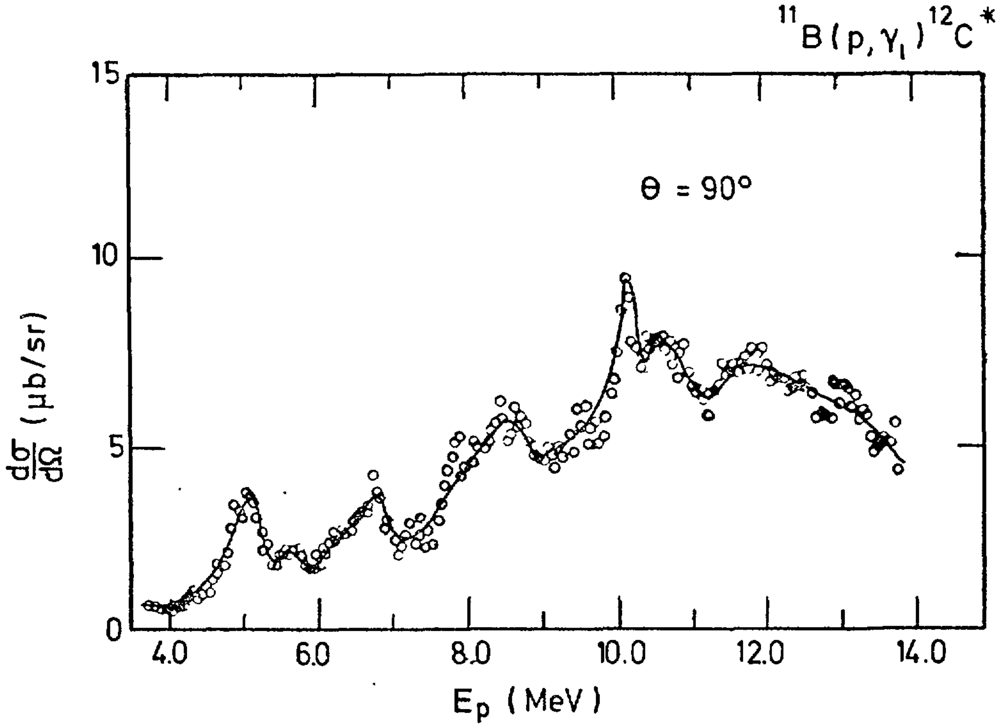
$^{11}B(p,\gamma_1)^{12}C^*$
σ (μb)
100
50
0
0
2
4
6
8
10
12
14
E_p (MeV)

Ref P7



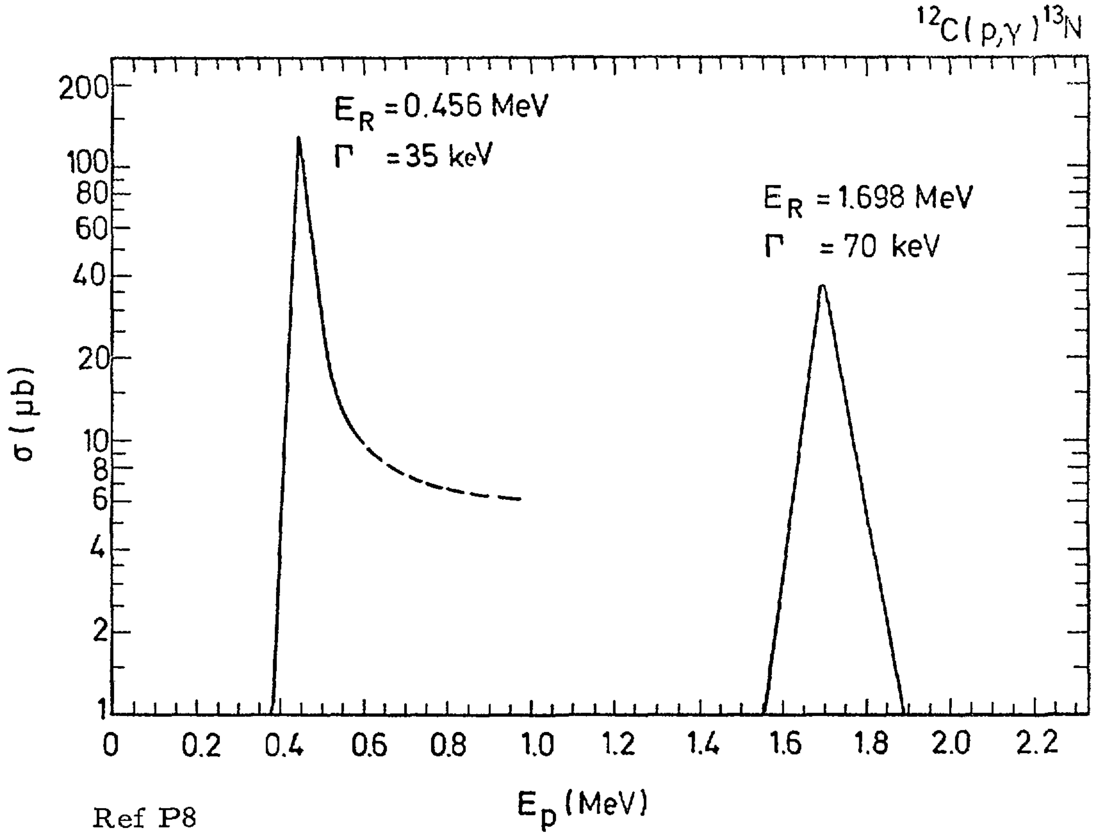
$^{11}B(p,\gamma_0)^{12}C$
20
15
10
5
0
θ = 90°
$\frac{d\sigma}{d\Omega}$ (μb/sr)
4.0
6.0
8.0
10.0
12.0
14.0
E_p (MeV)

Ref P7



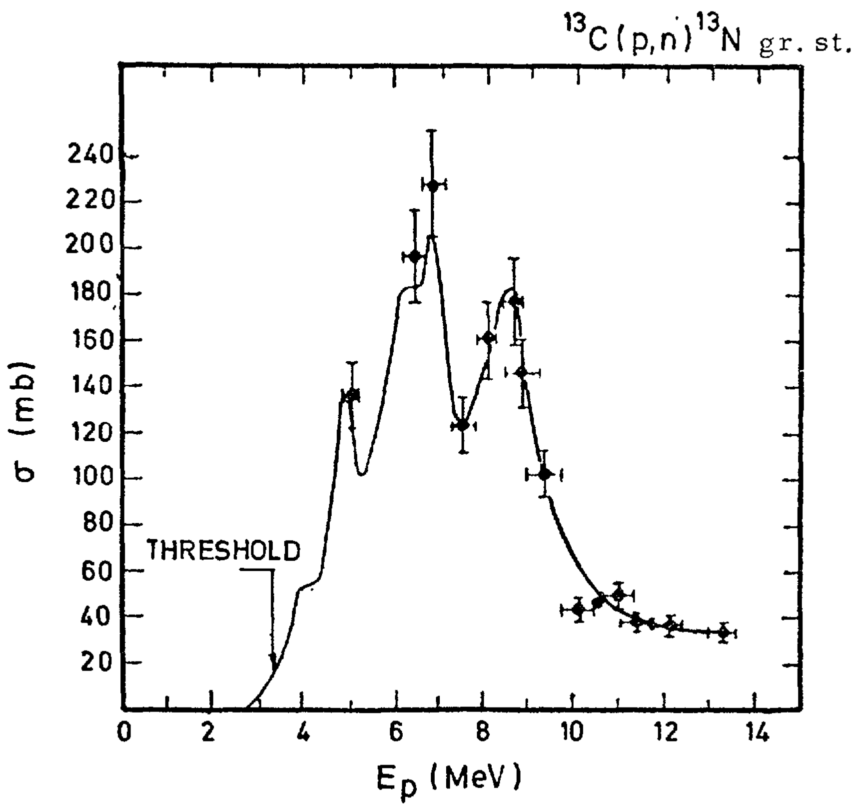
$^{11}B(p,\gamma_1)^{12}C^*$
15
10
5
0
θ = 90°
$\frac{d\sigma}{d\Omega}$ (μb/sr)
4.0
6.0
8.0
10.0
12.0
14.0
E_p (MeV)

Ref P7



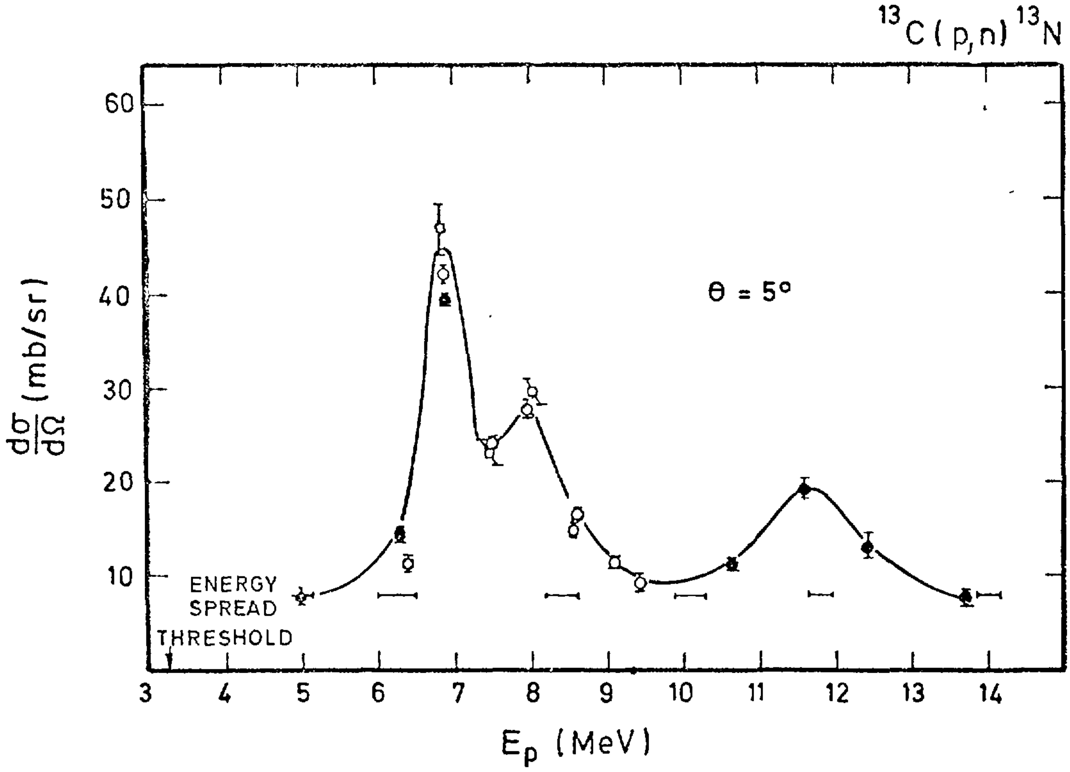
$^{12}C(p,\gamma)^{13}N$
E_R = 0.456 MeV
Γ = 35 keV
E_R = 1.698 MeV
Γ = 70 keV
σ (μb)
E_p (MeV)

Ref P8



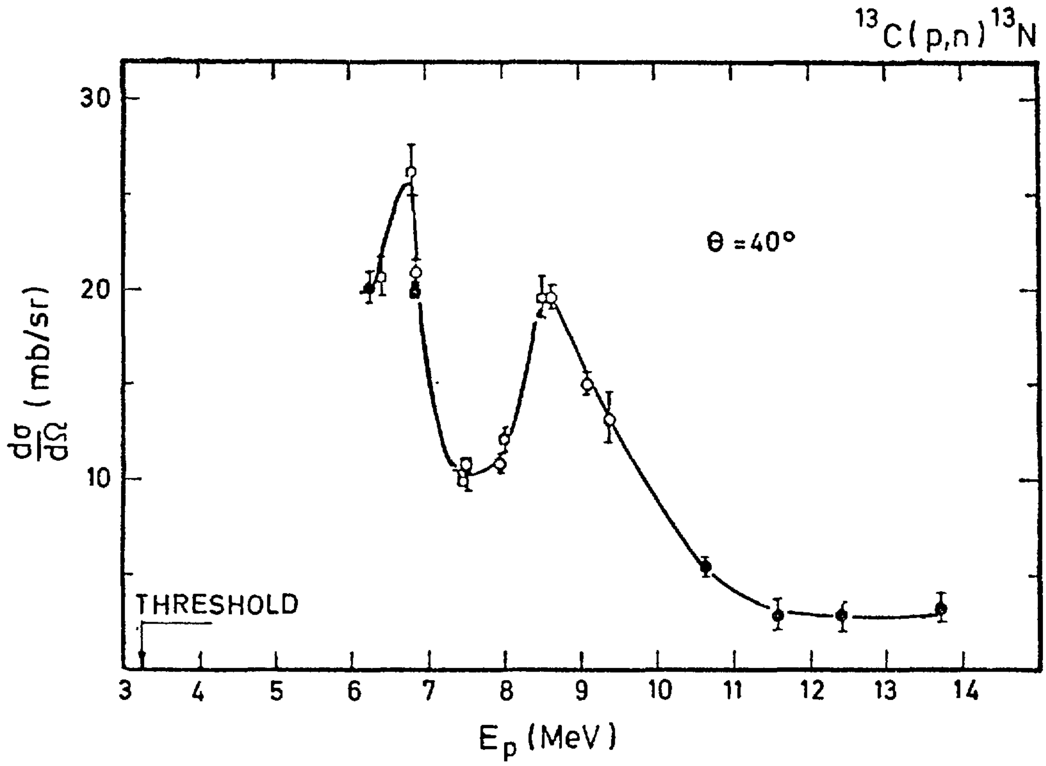
$^{13}C(p,n)^{13}N$ gr. st.
THRESHOLD
σ (mb)
E_p (MeV)

Ref P9



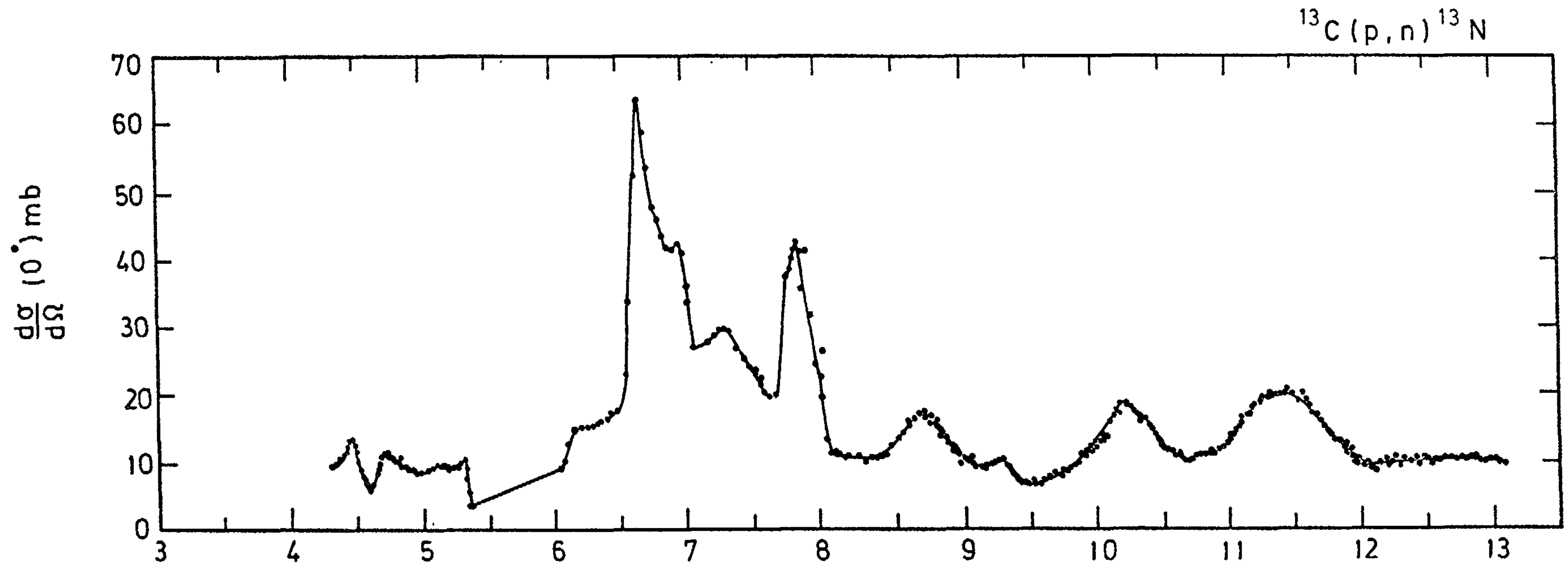
$^{13}C(p,n)^{13}N$
60
50
40
30
20
10
$\frac{d\sigma}{d\Omega}$ (mb/sr)
θ = 5°
ENERGY SPREAD
THRESHOLD
3 4 5 6 7 8 9 10 11 12 13 14
E_p (MeV)

Ref P9



$^{13}C(p,n)^{13}N$
30
20
10
$\frac{d\sigma}{d\Omega}$ (mb/sr)
θ = 40°
THRESHOLD
3 4 5 6 7 8 9 10 11 12 13 14
E_p (MeV)

Ref P9



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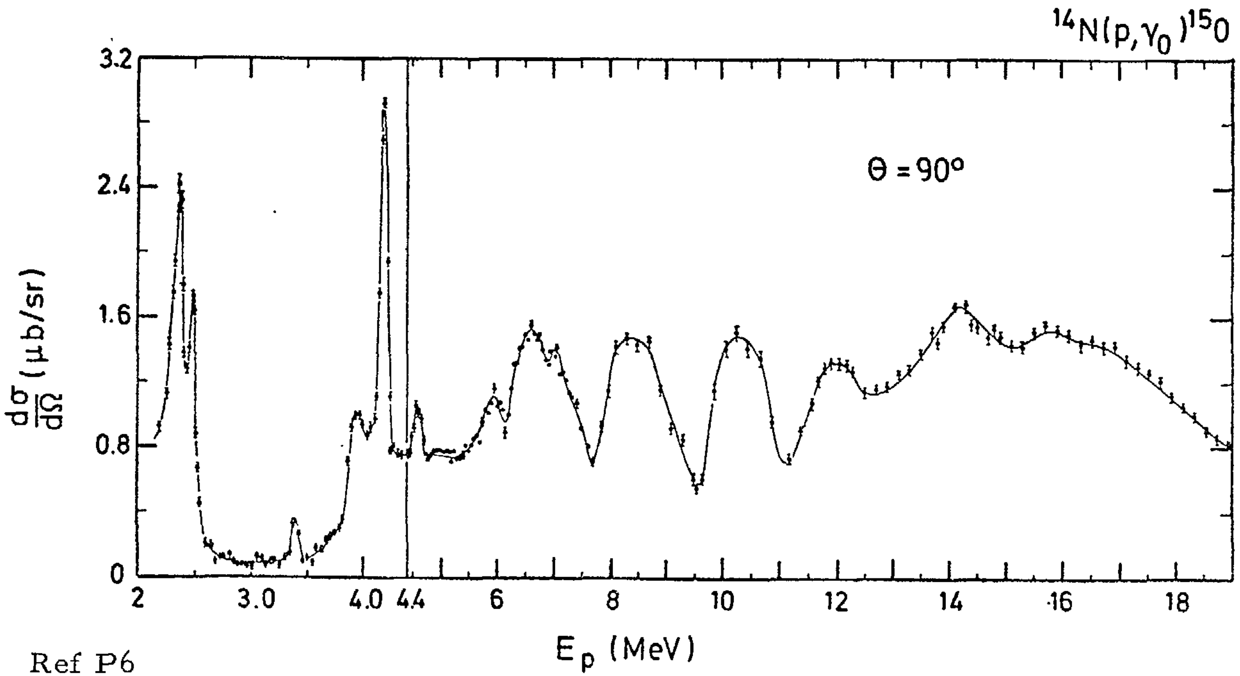

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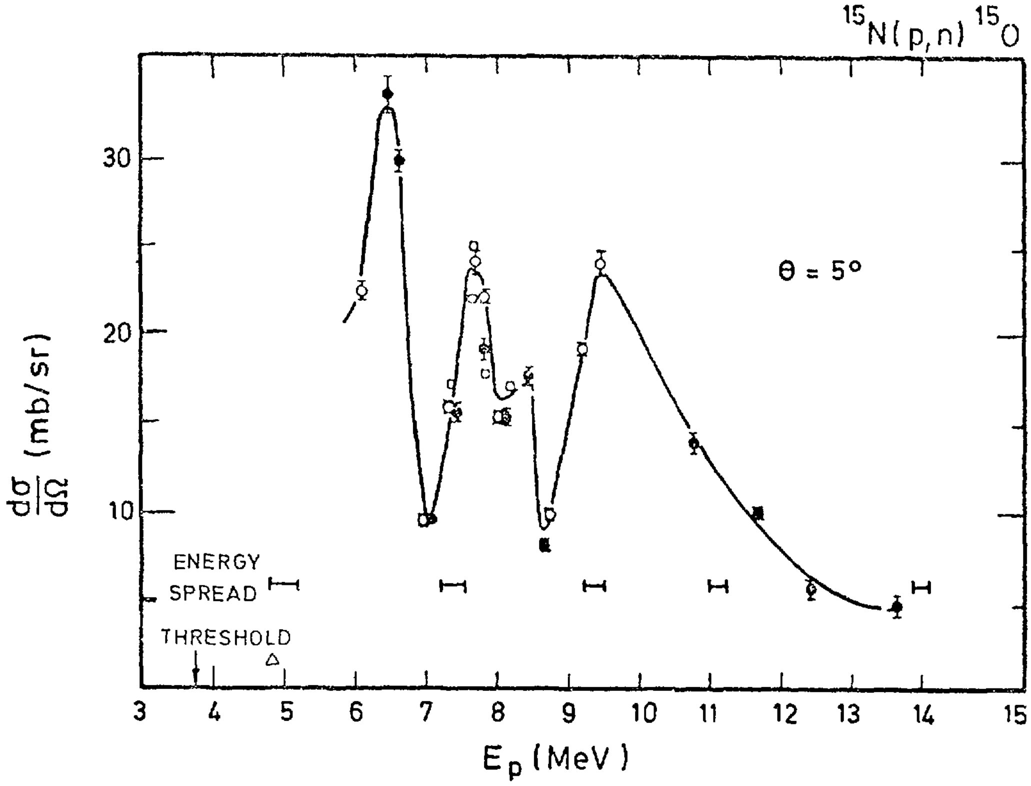
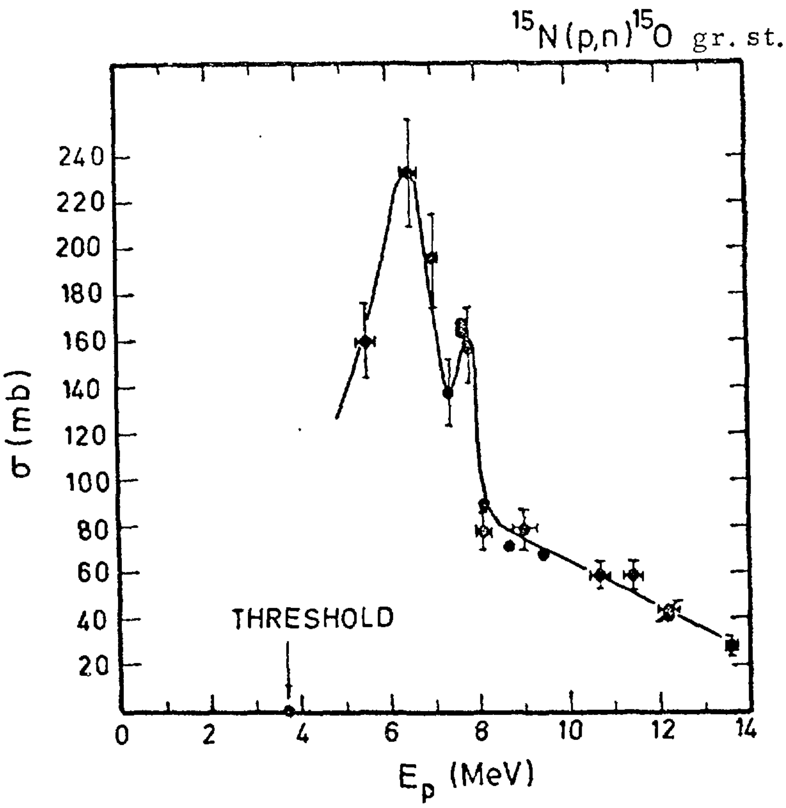


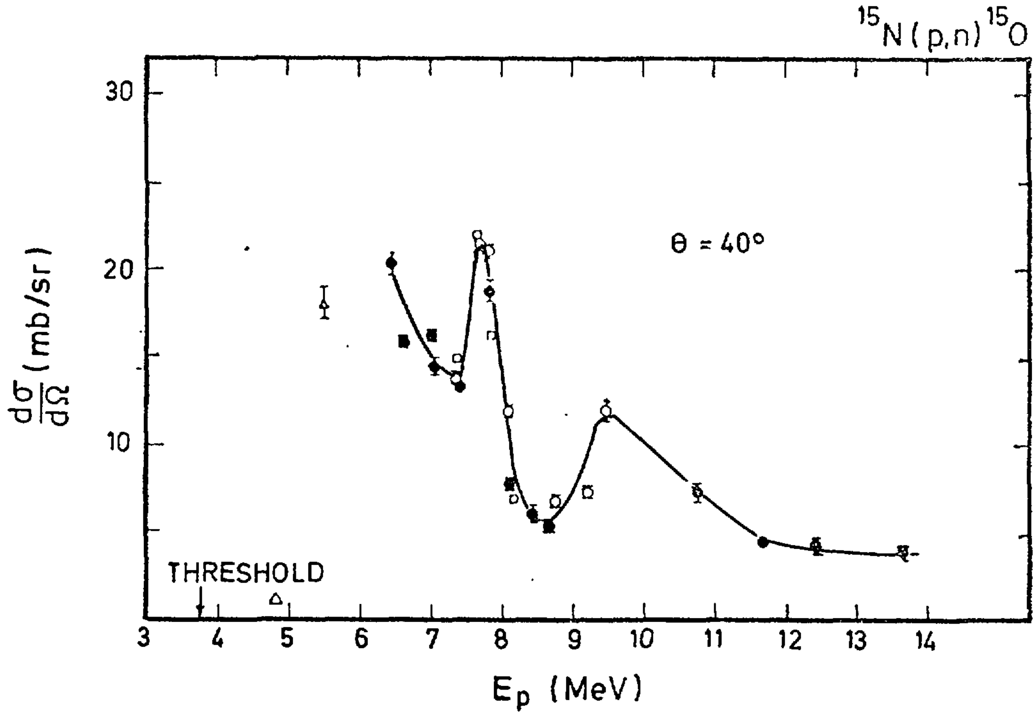
$^{15}N(p,n)^{15}O$
θ = 5°
dσ/dΩ (mb/sr)
ENERGY
SPREAD
THRESHOLD
E_p (MeV)

Ref P9



$^{15}N(p,n)^{15}O$ gr. st.
σ (mb)
THRESHOLD
E_p (MeV)

Ref P9



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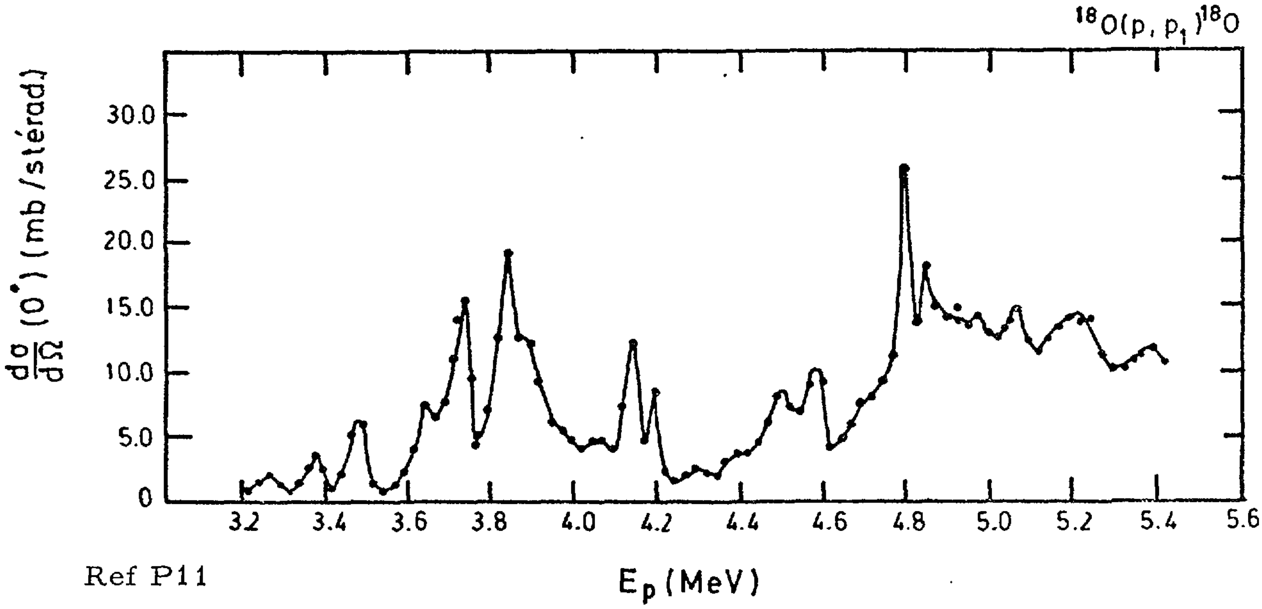
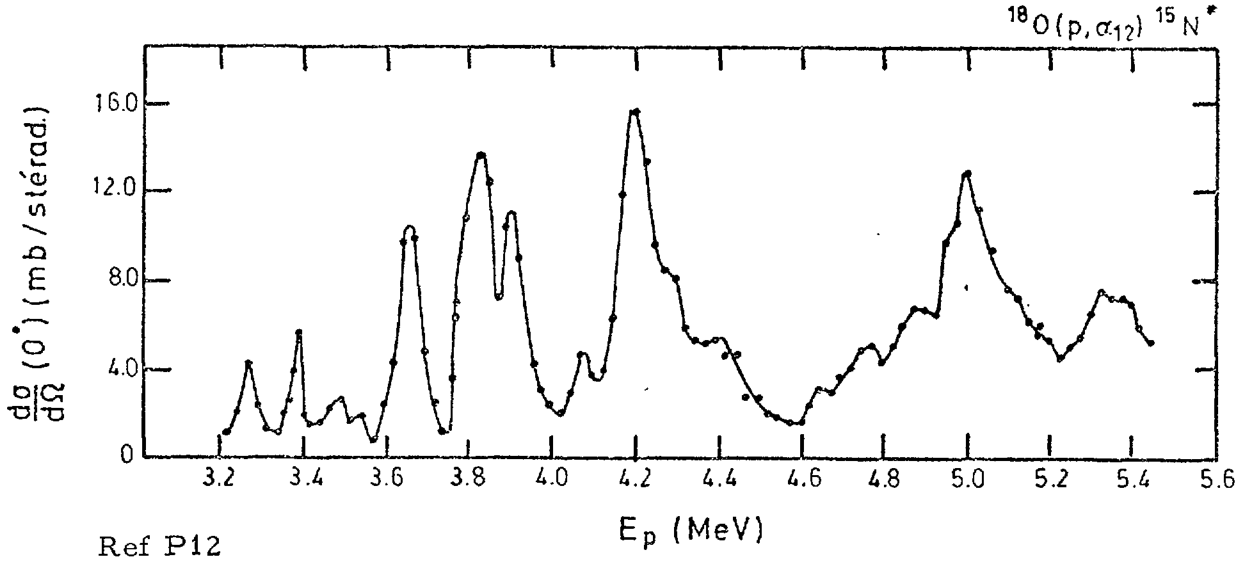
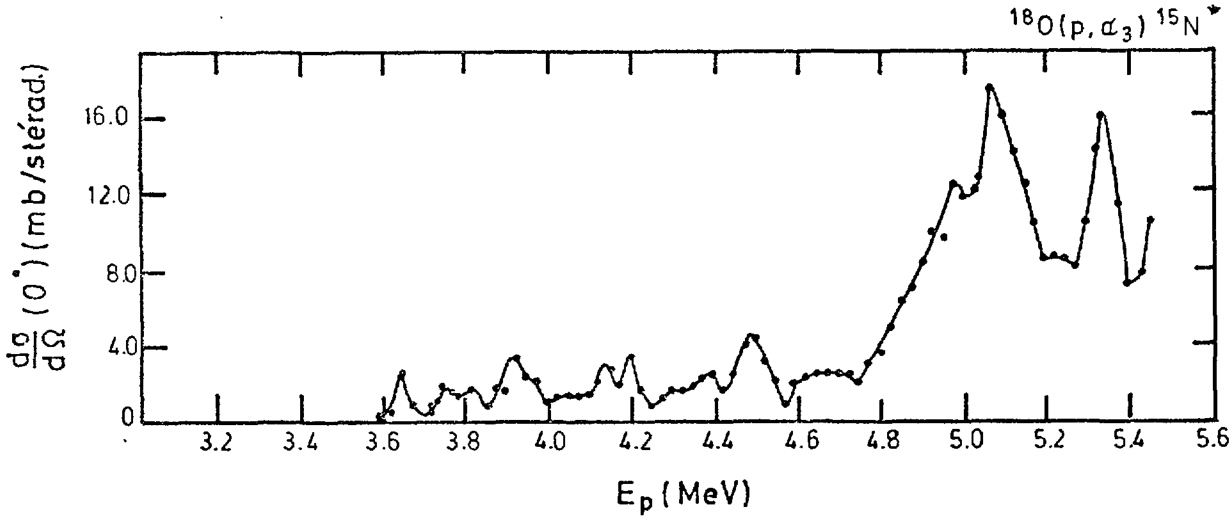


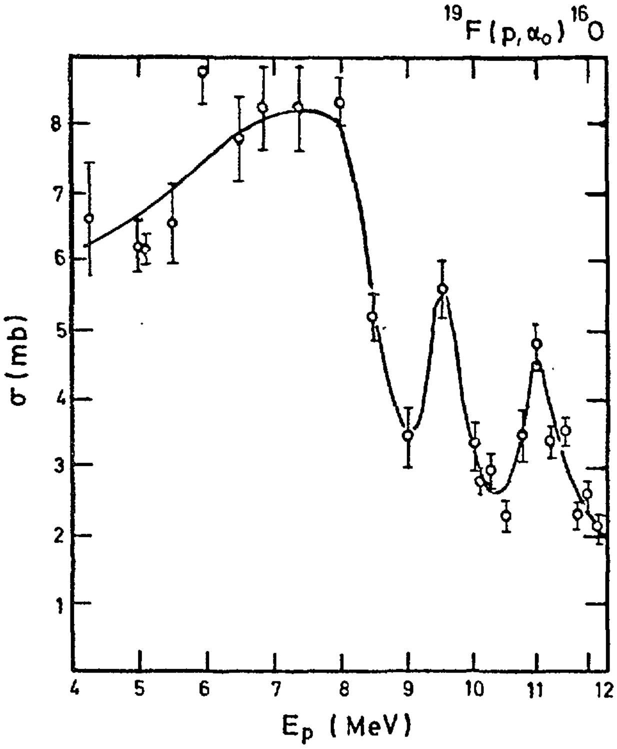
Ref P11



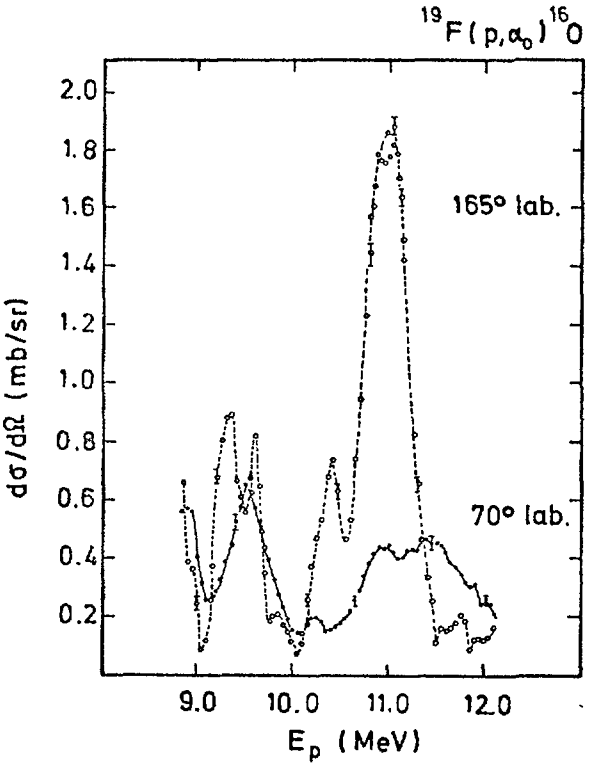
Ref P12



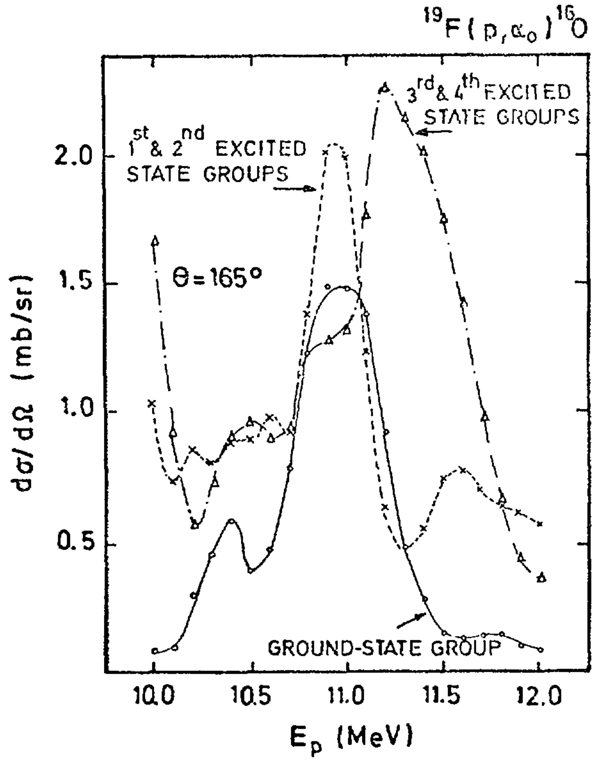
Ref P12



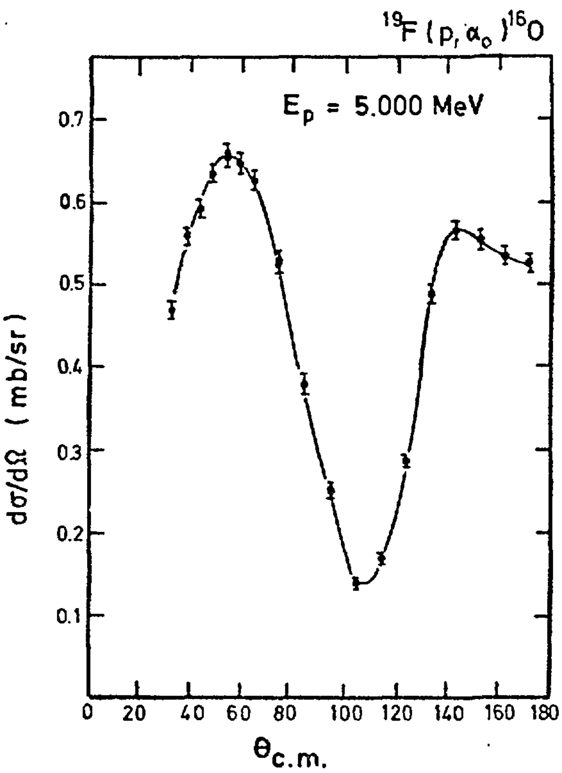
Ref P12



Ref P12



Ref P12



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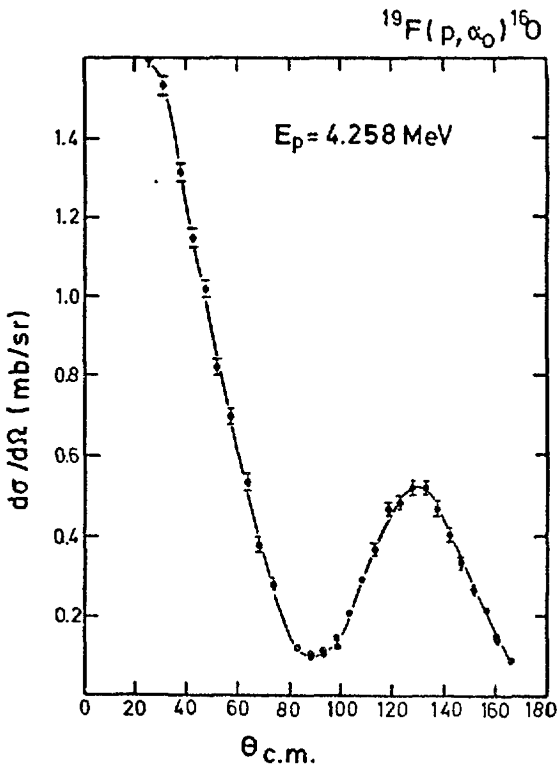
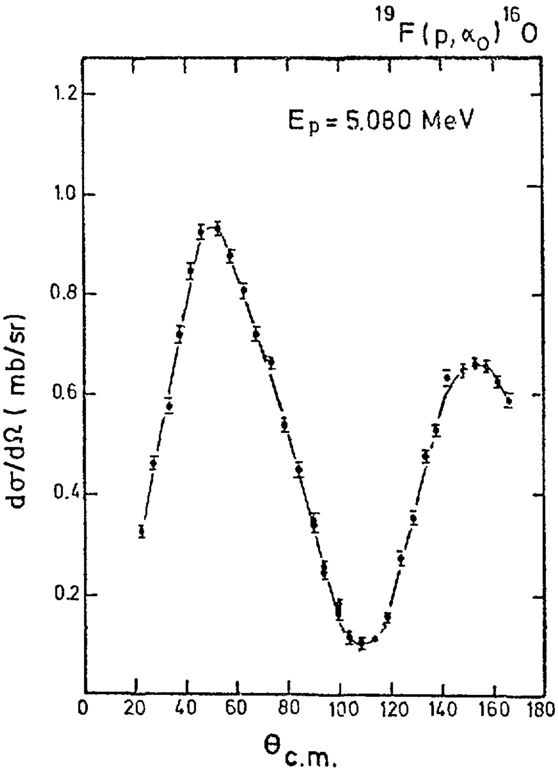
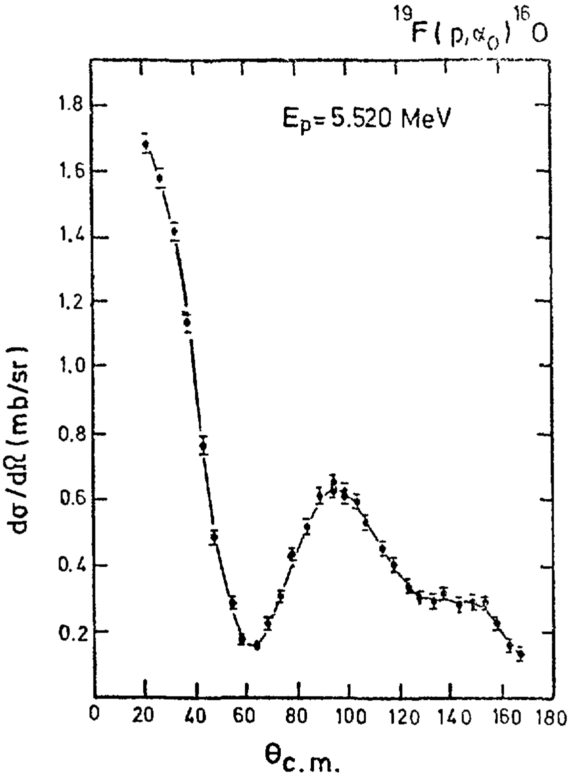


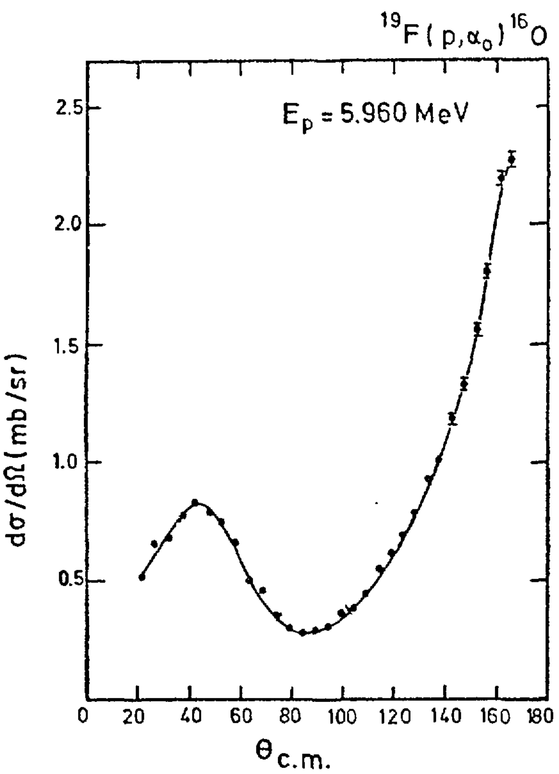
Ref P12



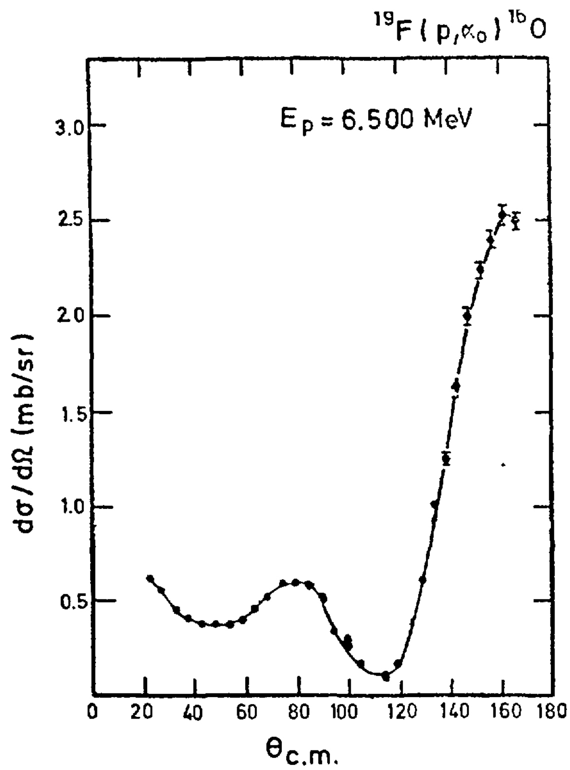
Ref P12



Ref P12



Ref P12



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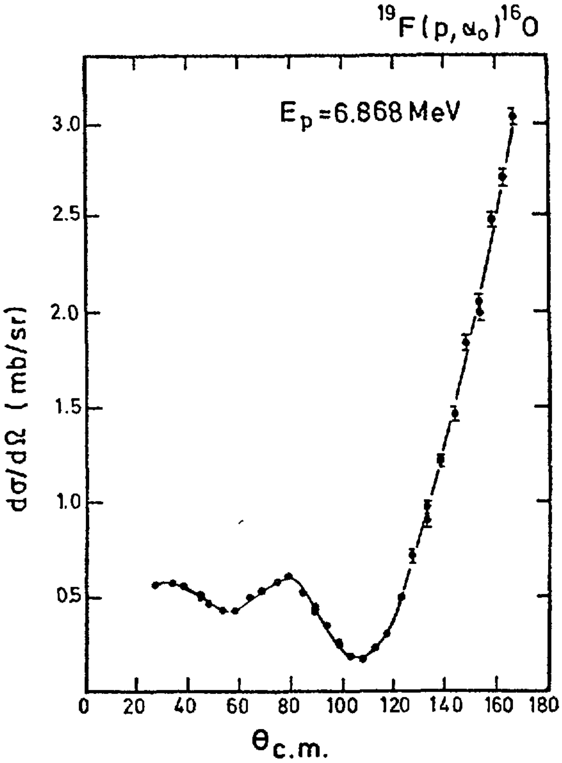

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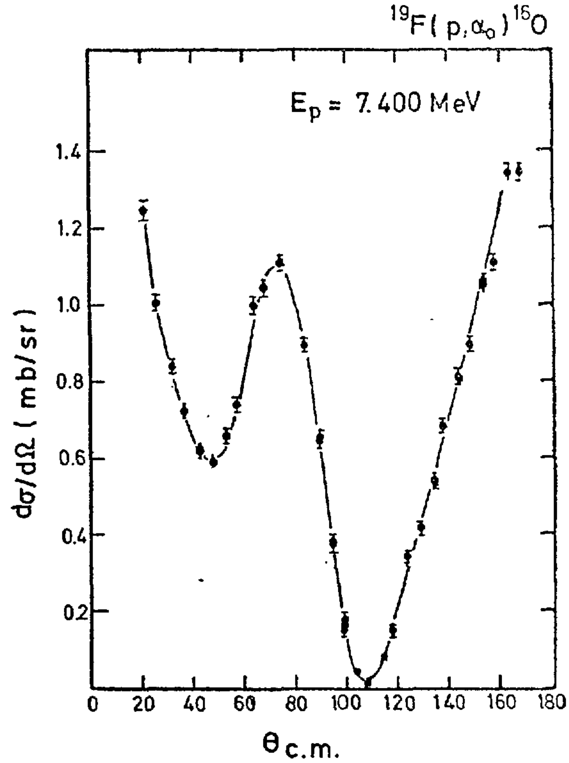

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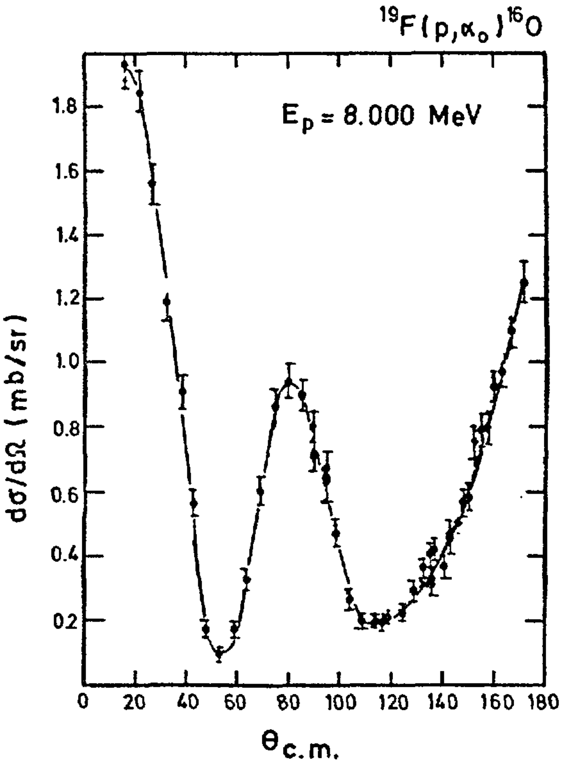
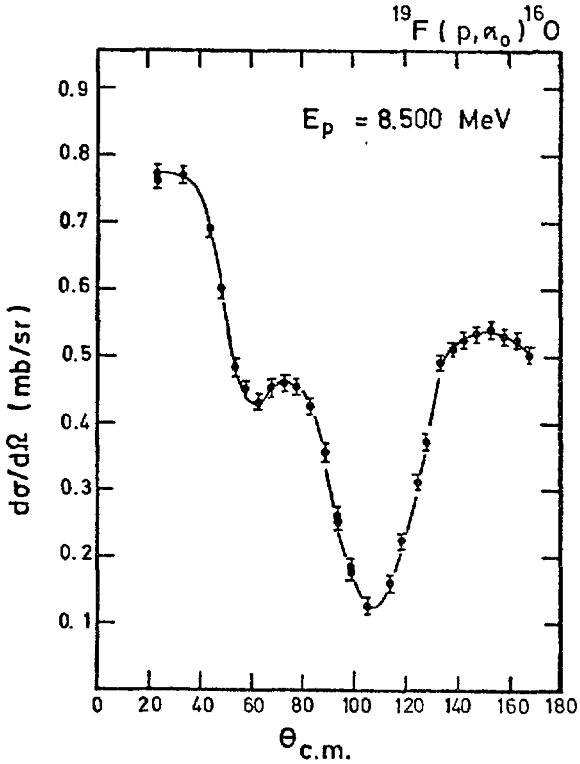


Ref P12



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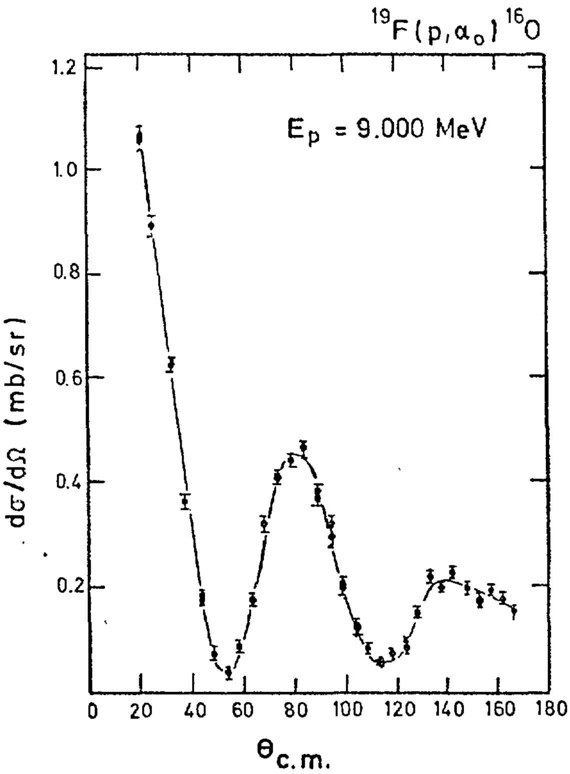
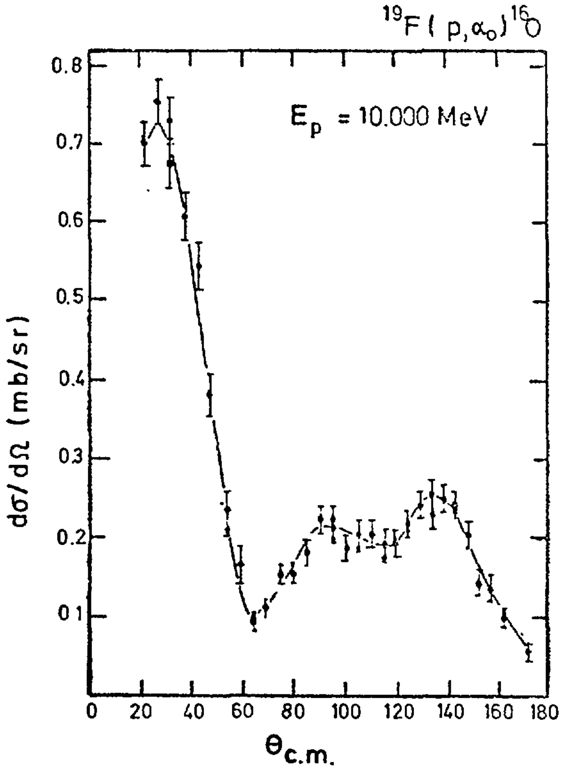
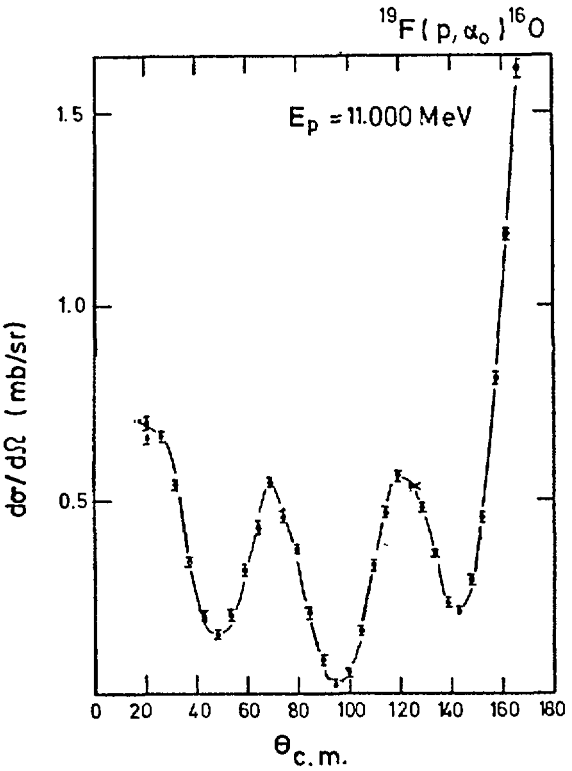


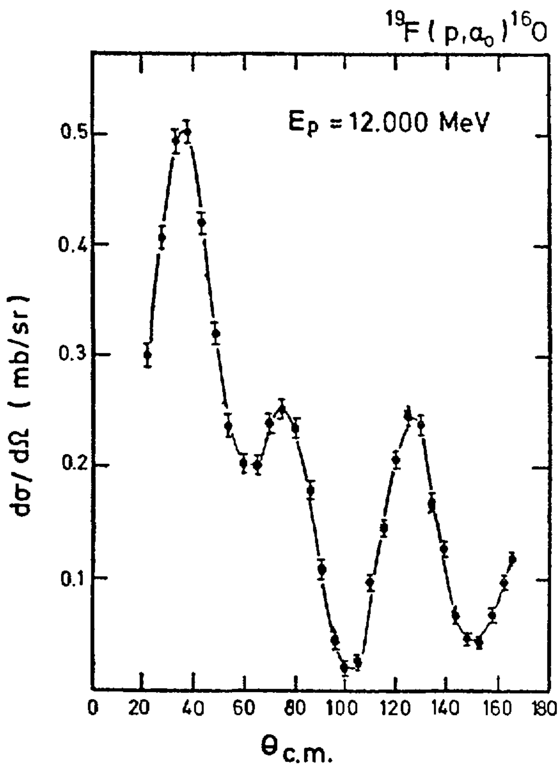
Ref P12



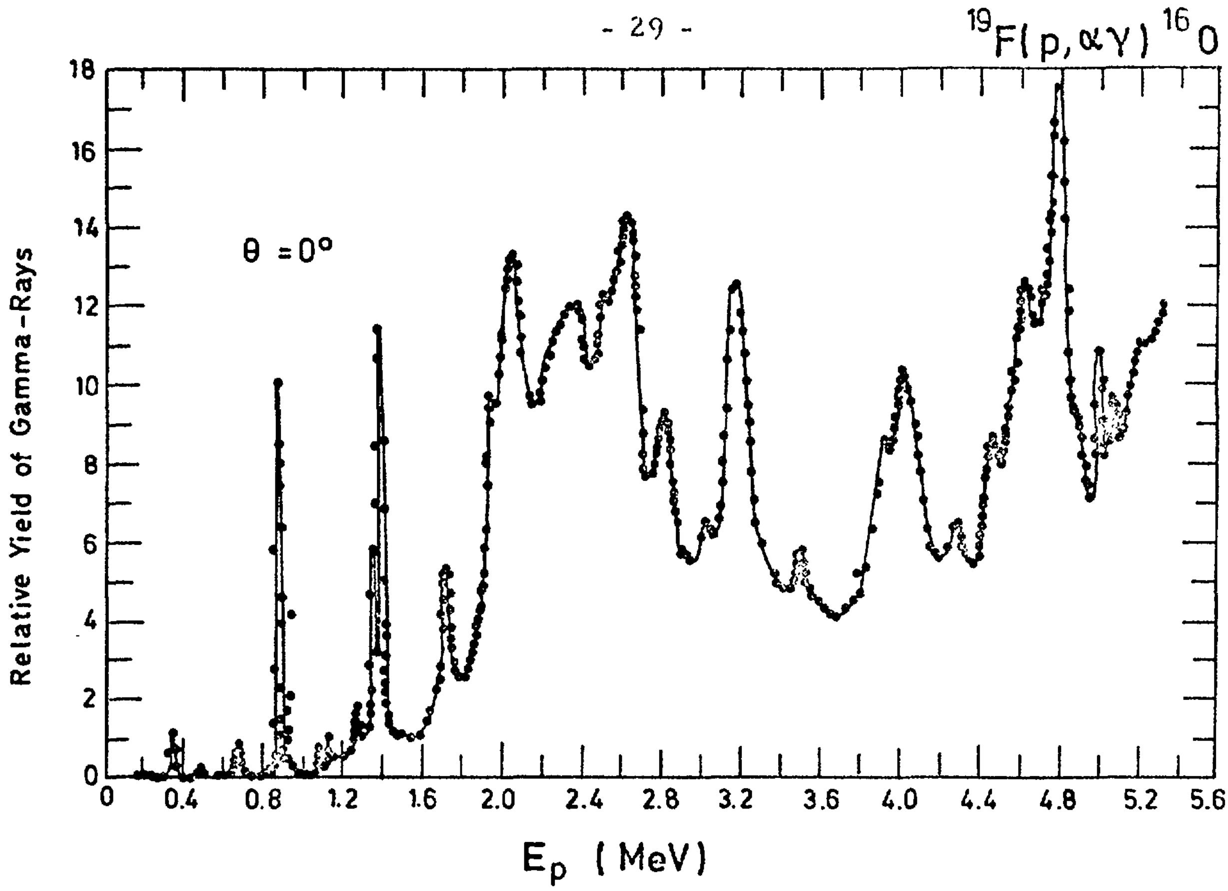
Ref P12



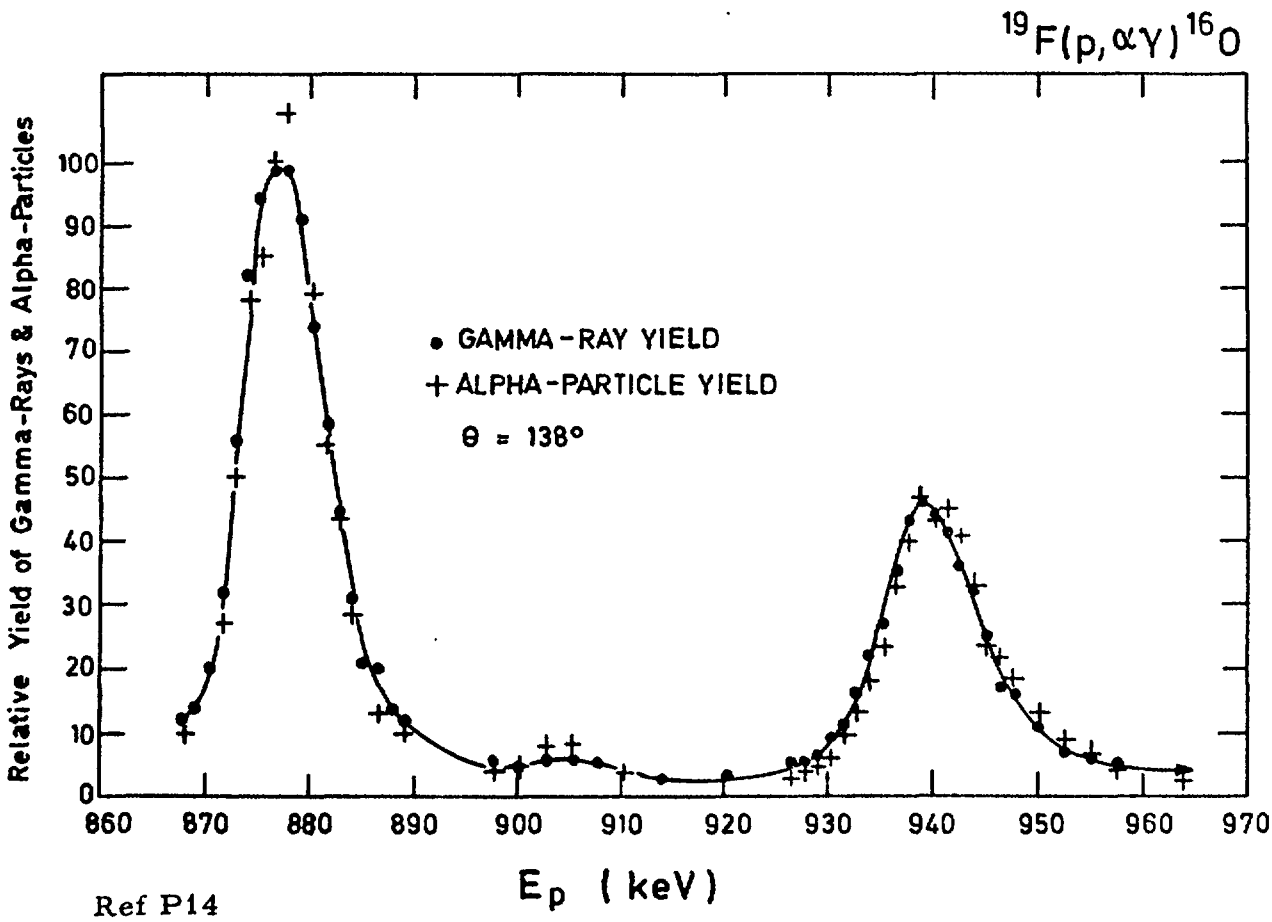
Ref P12



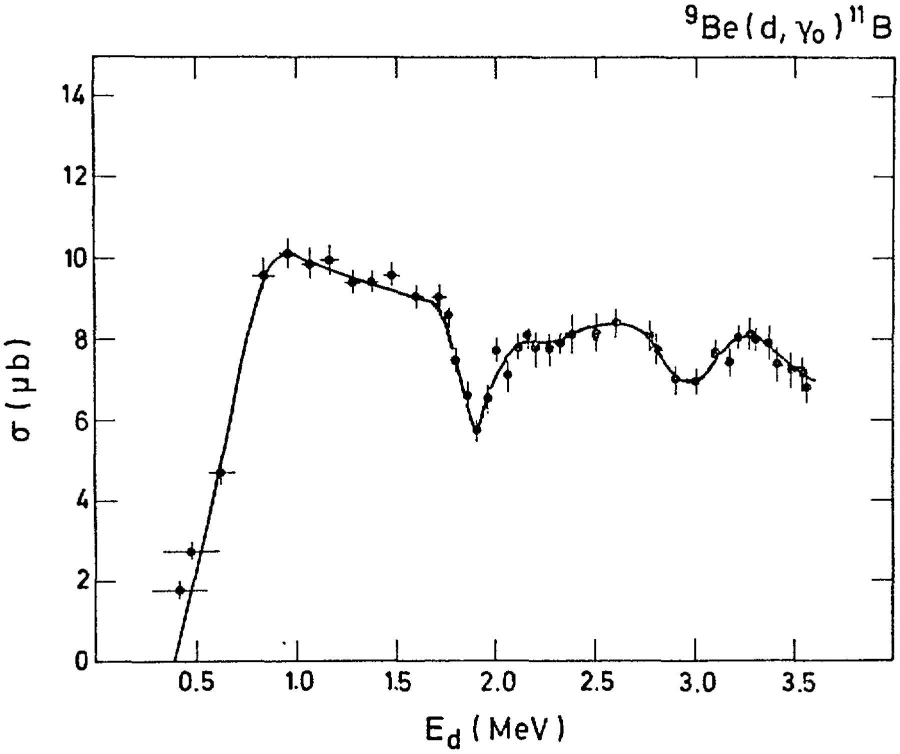
Ref P12



Ref P13

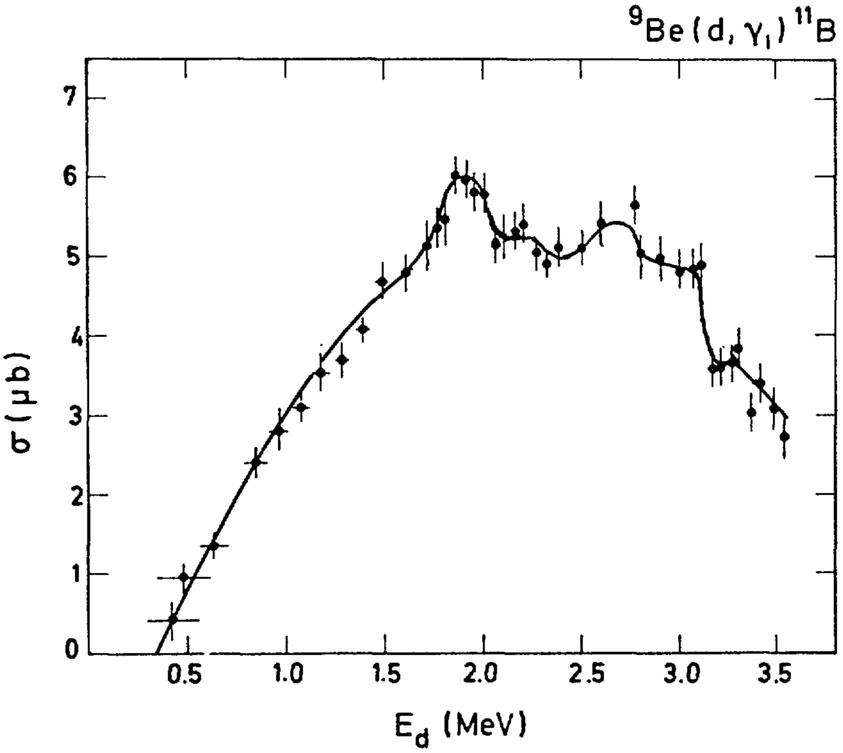


Ref P14



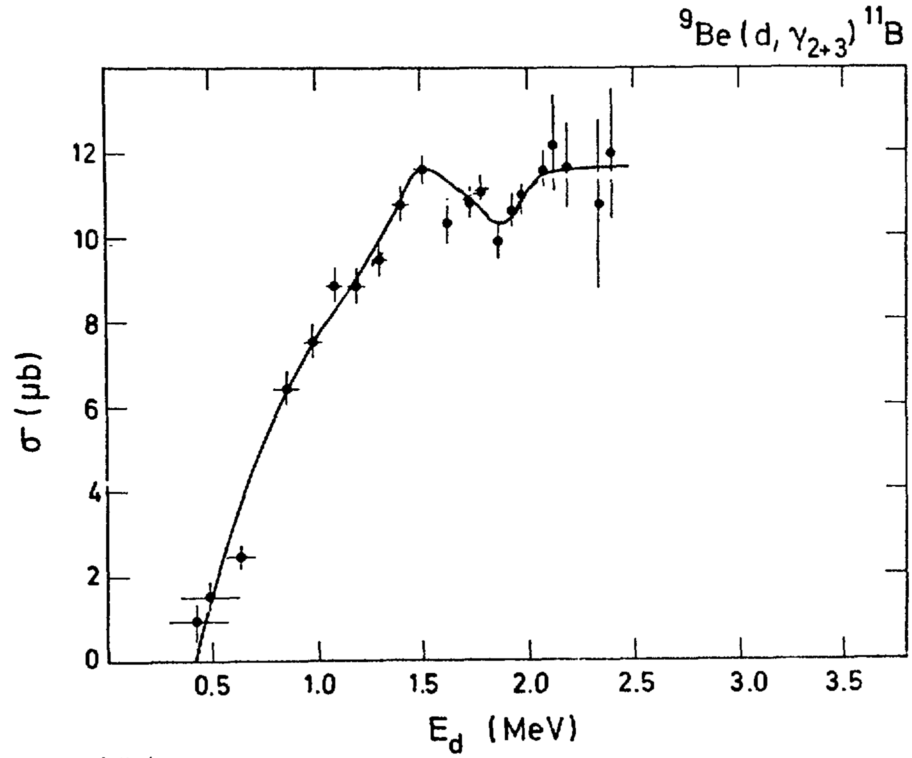
$^9Be(d,\gamma_0)^{11}B$
σ (μb)
0
2
4
6
8
10
12
14
0.5
1.0
1.5
2.0
2.5
3.0
3.5
E_d (MeV)

Ref D1



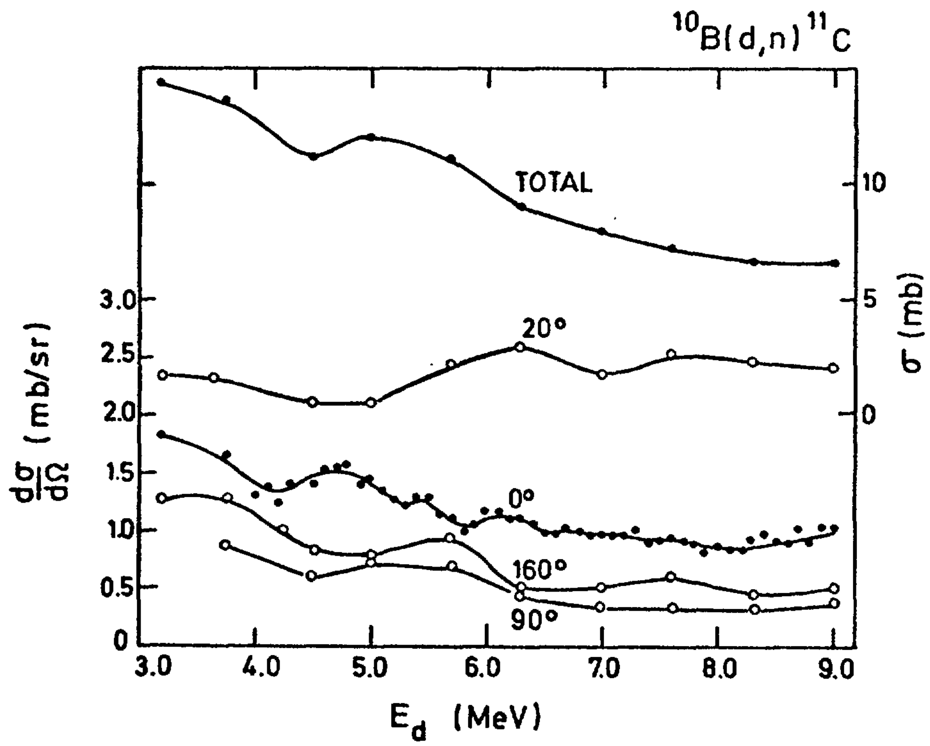
$^9Be(d,\gamma_1)^{11}B$
σ (μb)
0
1
2
3
4
5
6
7
0.5
1.0
1.5
2.0
2.5
3.0
3.5
E_d (MeV)

Ref D1



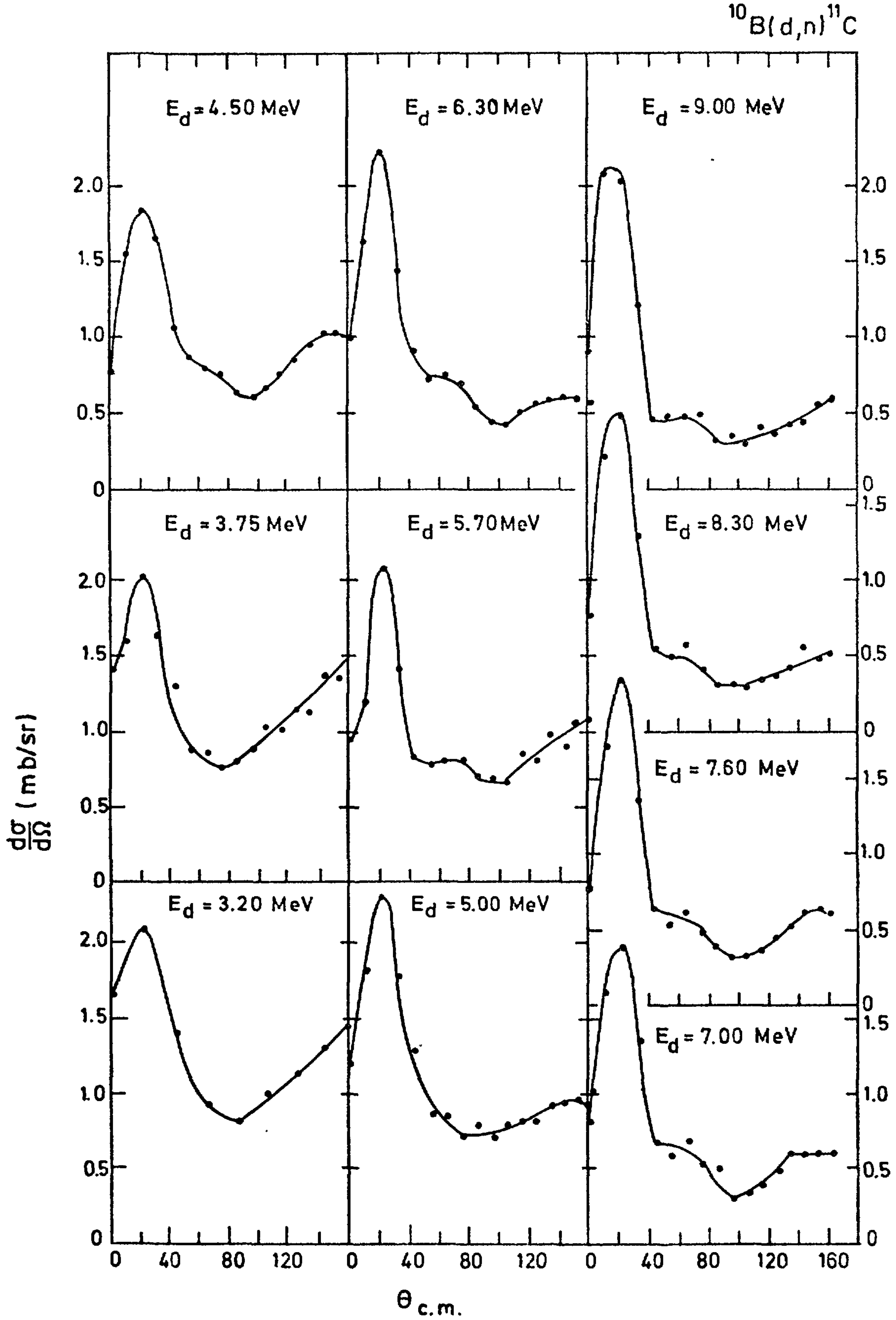
^{9}Be (d, γ_{2+3}) ^{11}B
σ (μb)
0
2
4
6
8
10
12
0.5
1.0
1.5
2.0
2.5
3.0
3.5
E_d (MeV)

Ref D1



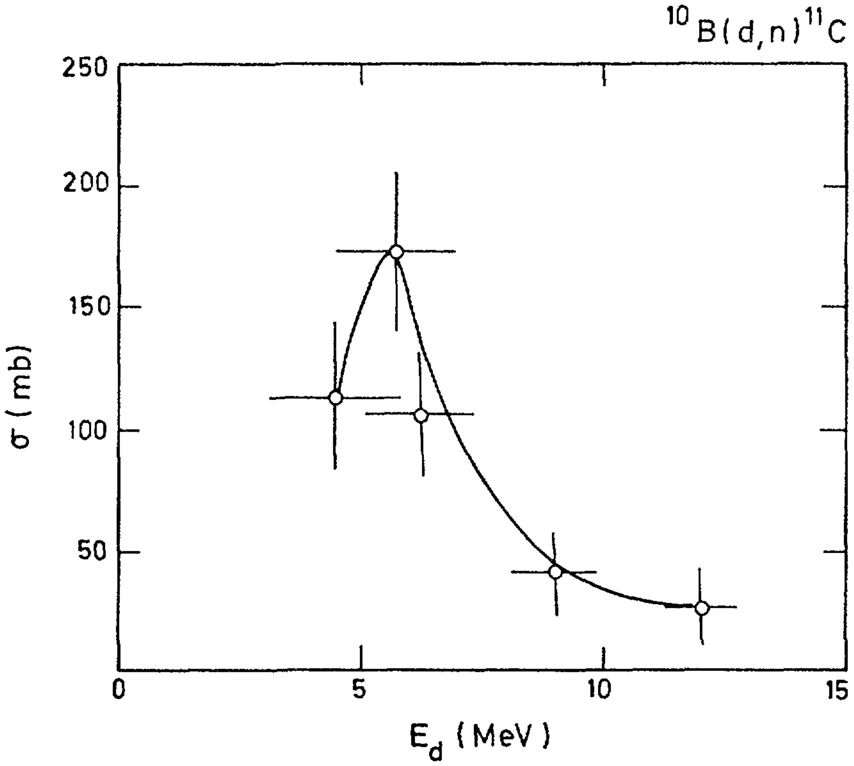
^{10}B(d,n)^{11}C
TOTAL
20°
0°
160°
90°
dσ/dΩ (mb/sr)
σ (mb)
0
0.5
1.0
1.5
2.0
2.5
3.0
5
10
3.0
4.0
5.0
6.0
7.0
8.0
9.0
E_d (MeV)

Ref D2



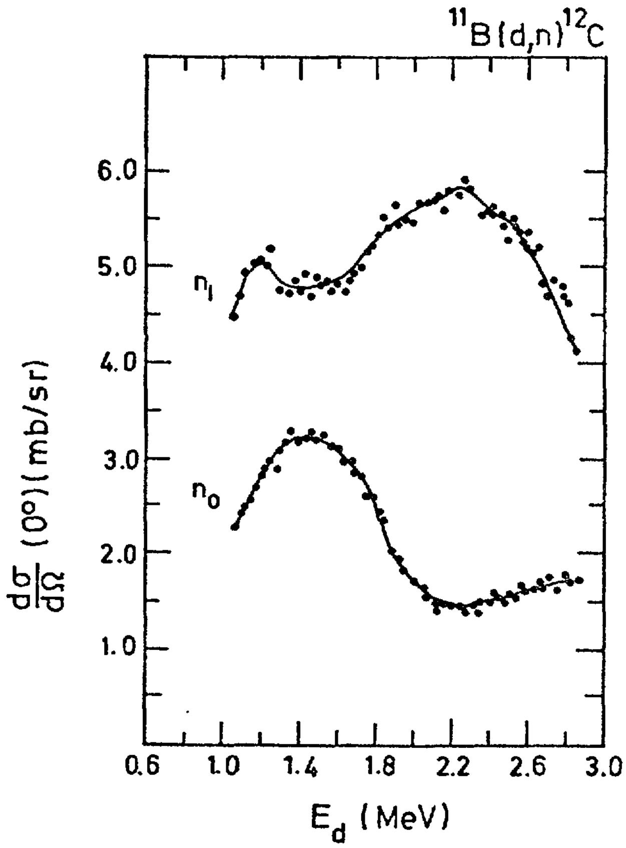
$^{10}B(d,n)^{11}C$
E_d = 4.50 MeV
E_d = 6.30 MeV
E_d = 9.00 MeV
E_d = 3.75 MeV
E_d = 5.70 MeV
E_d = 8.30 MeV
E_d = 7.60 MeV
E_d = 3.20 MeV
E_d = 5.00 MeV
E_d = 7.00 MeV
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$\theta_{c.m.}$
0
40
80
120
160
0.5
1.0
1.5
2.0

Ref D2



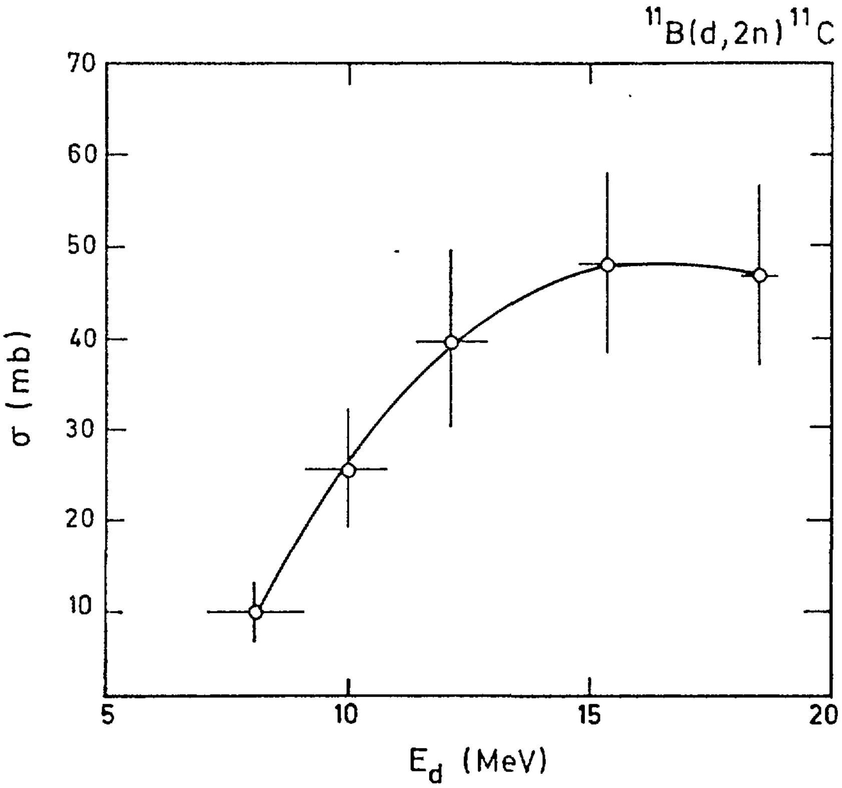
^{10}B(d,n)^{11}C
250
200
150
100
50
σ (mb)
0
5
10
15
E_d (MeV)

Ref D3

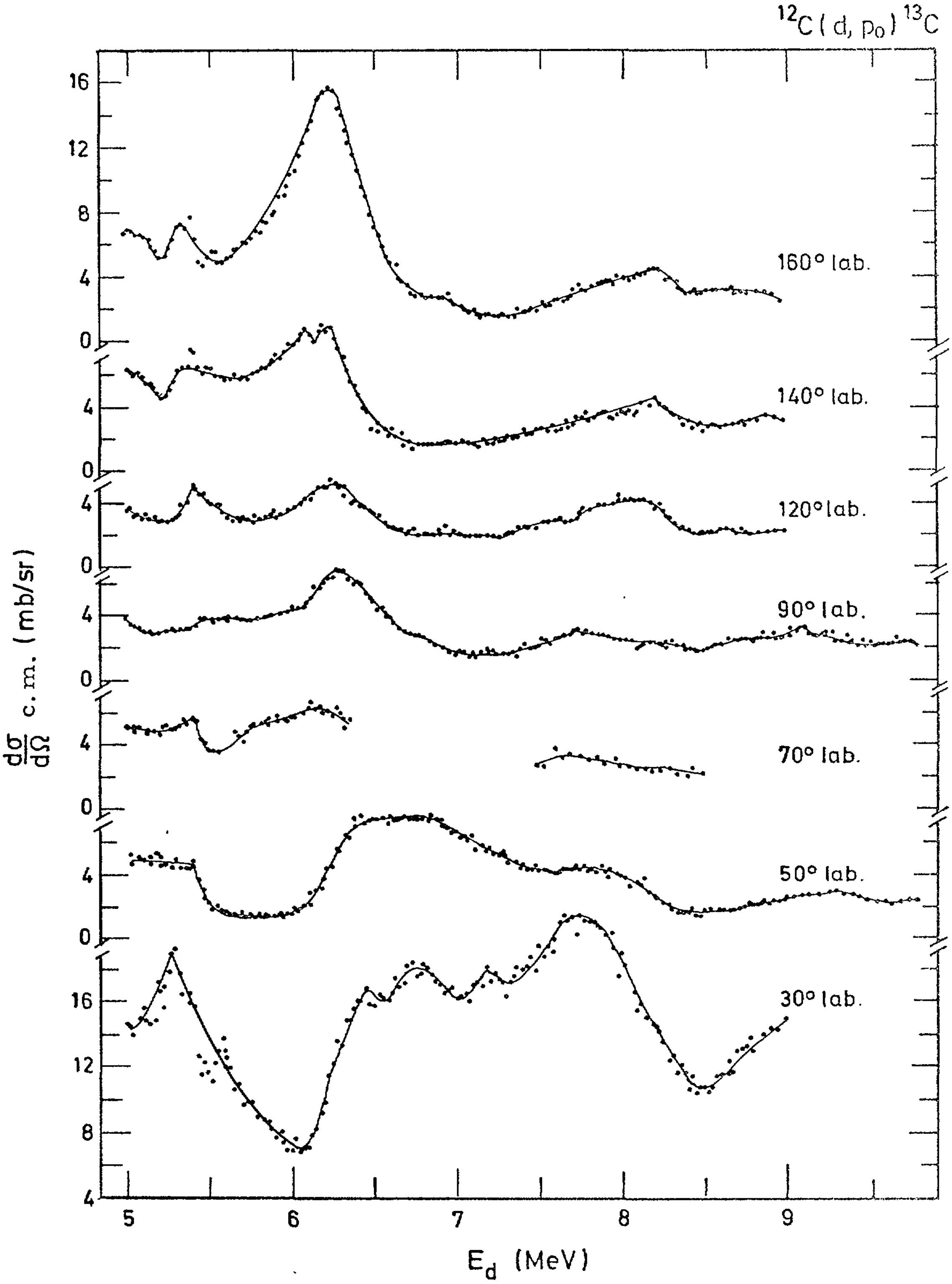


^{11}B(d,n)^{12}C
6.0
5.0
4.0
3.0
2.0
1.0
n_1
n_0
$\frac{d\sigma}{d\Omega}$ (0°) (mb/sr)
0.6
1.0
1.4
1.8
2.2
2.6
3.0
E_d (MeV)

Ref D2

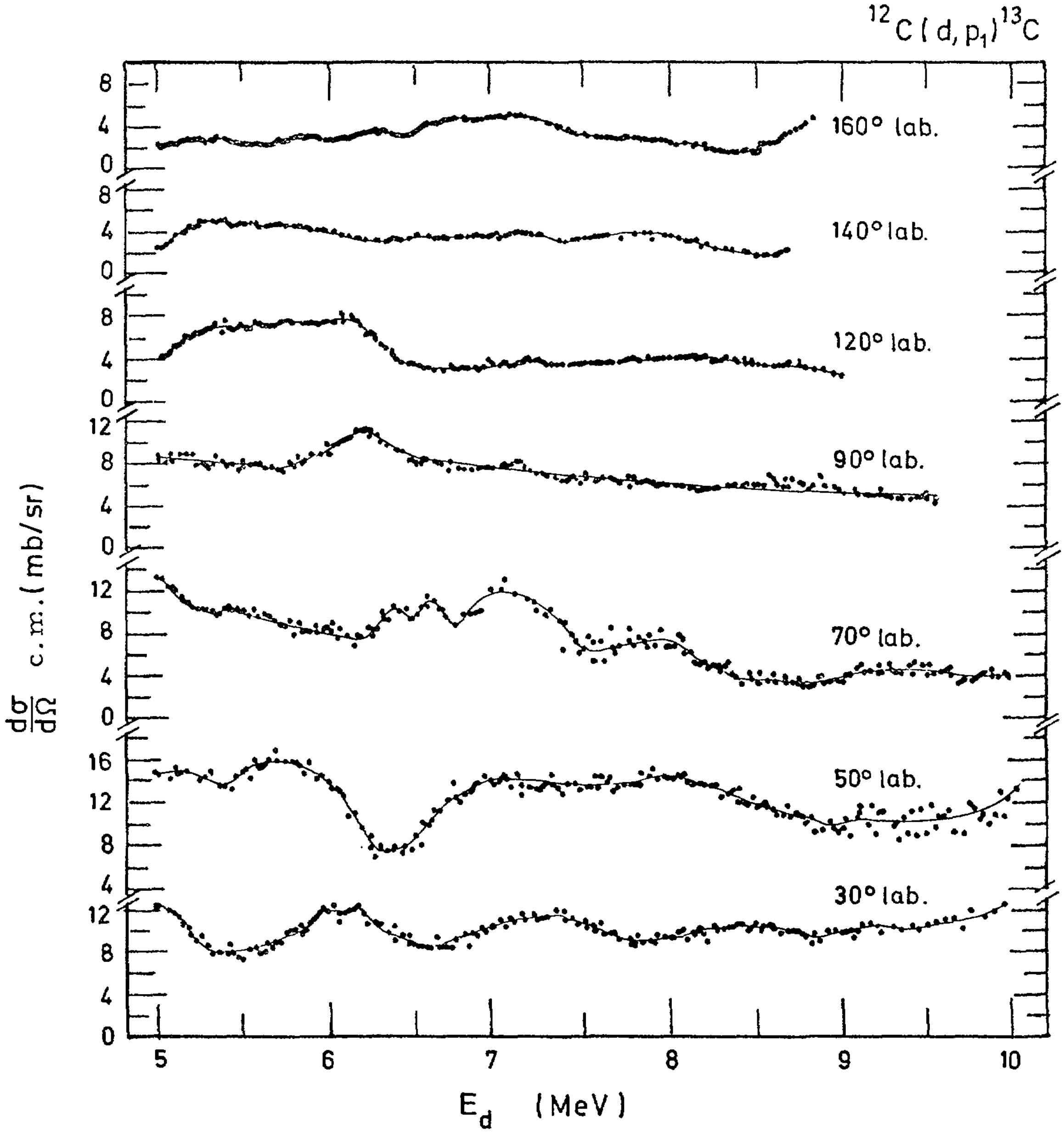


Ref D3



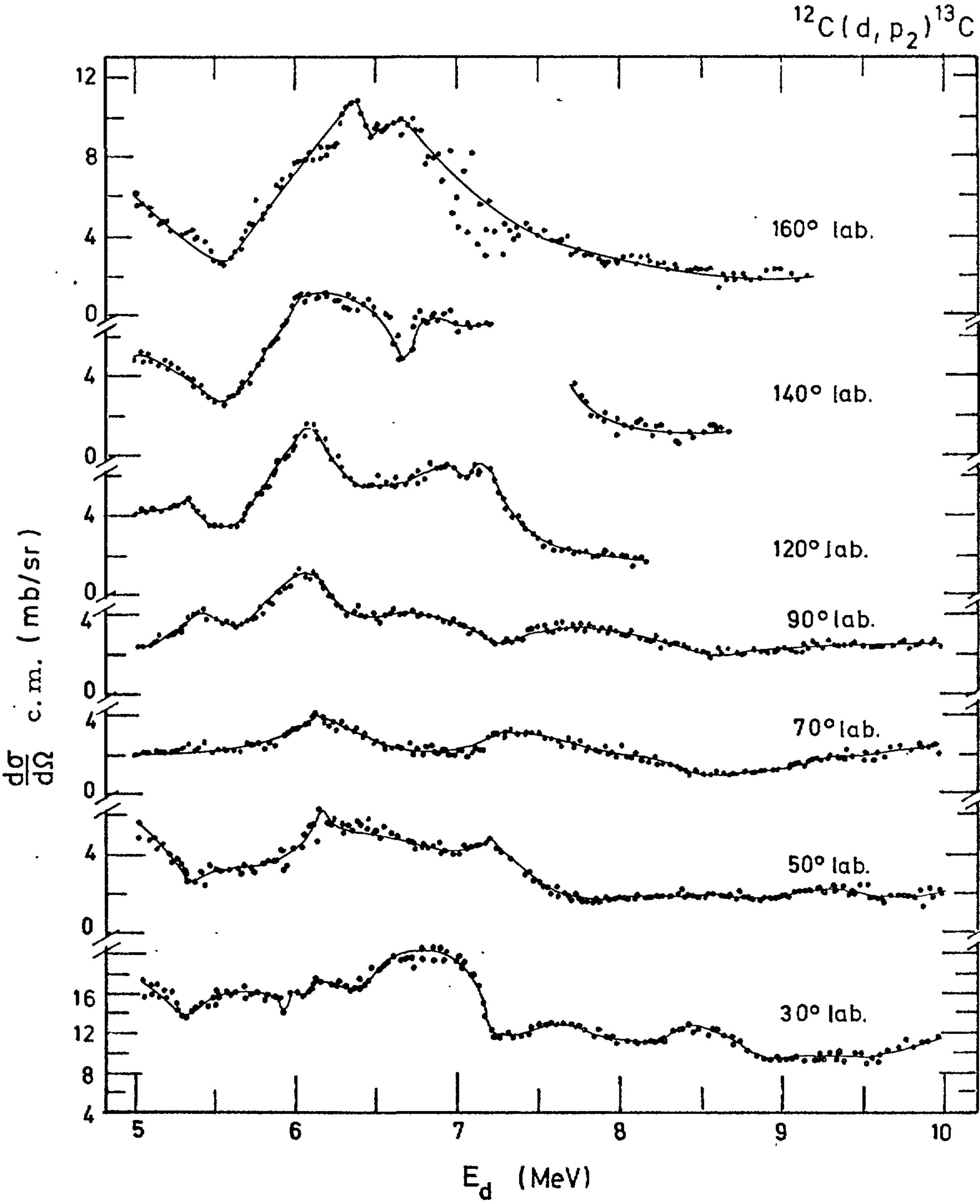
$^{12}C(d, p_0)^{13}C$
160° lab.
140° lab.
120° lab.
90° lab.
70° lab.
50° lab.
30° lab.
$\frac{d\sigma}{d\Omega}$ c.m. (mb/sr)
E_d (MeV)
5
6
7
8
9
16
12
8
4
0

Ref D4



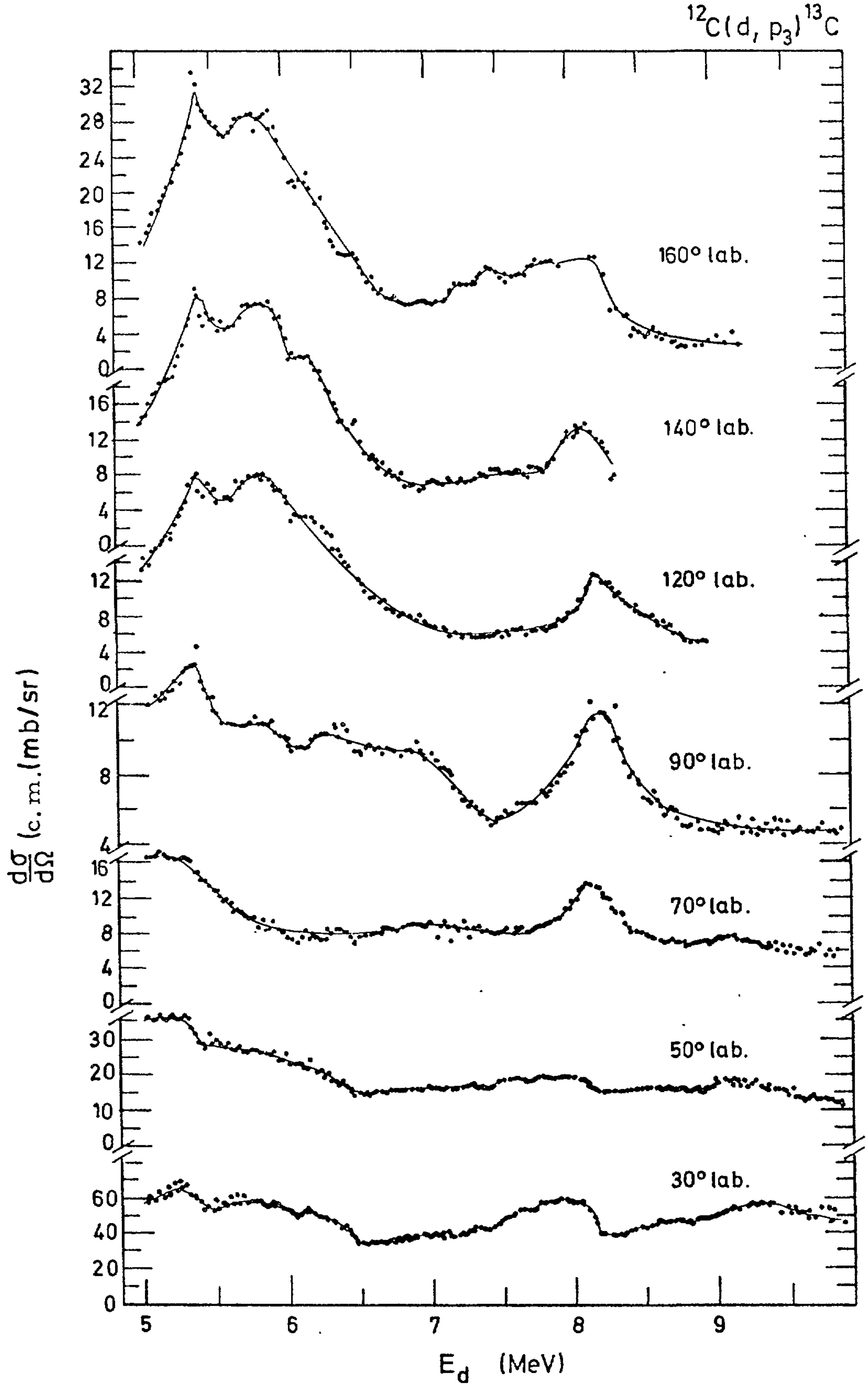
$^{12}C(d,p_1)^{13}C$
160° lab.
140° lab.
120° lab.
90° lab.
70° lab.
50° lab.
30° lab.
$\frac{d\sigma}{d\Omega}$ c.m. (mb/sr)
E_d (MeV)
5
6
7
8
9
10

Ref D4



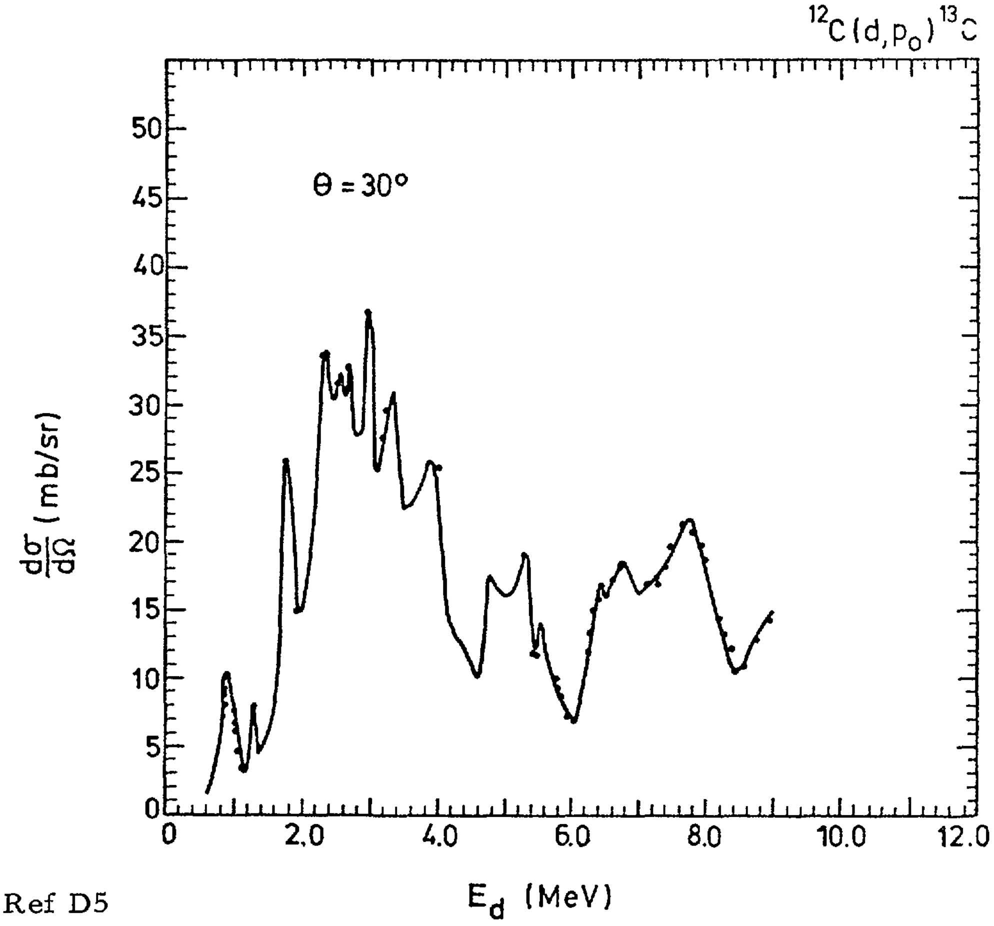
$^{12}C(d,p_2)^{13}C$
160° lab.
140° lab.
120° lab.
90° lab.
70° lab.
50° lab.
30° lab.
dσ/dΩ c.m. (mb/sr)
E_d (MeV)
12
8
4
0
16
5
6
7
8
9
10

Ref D4



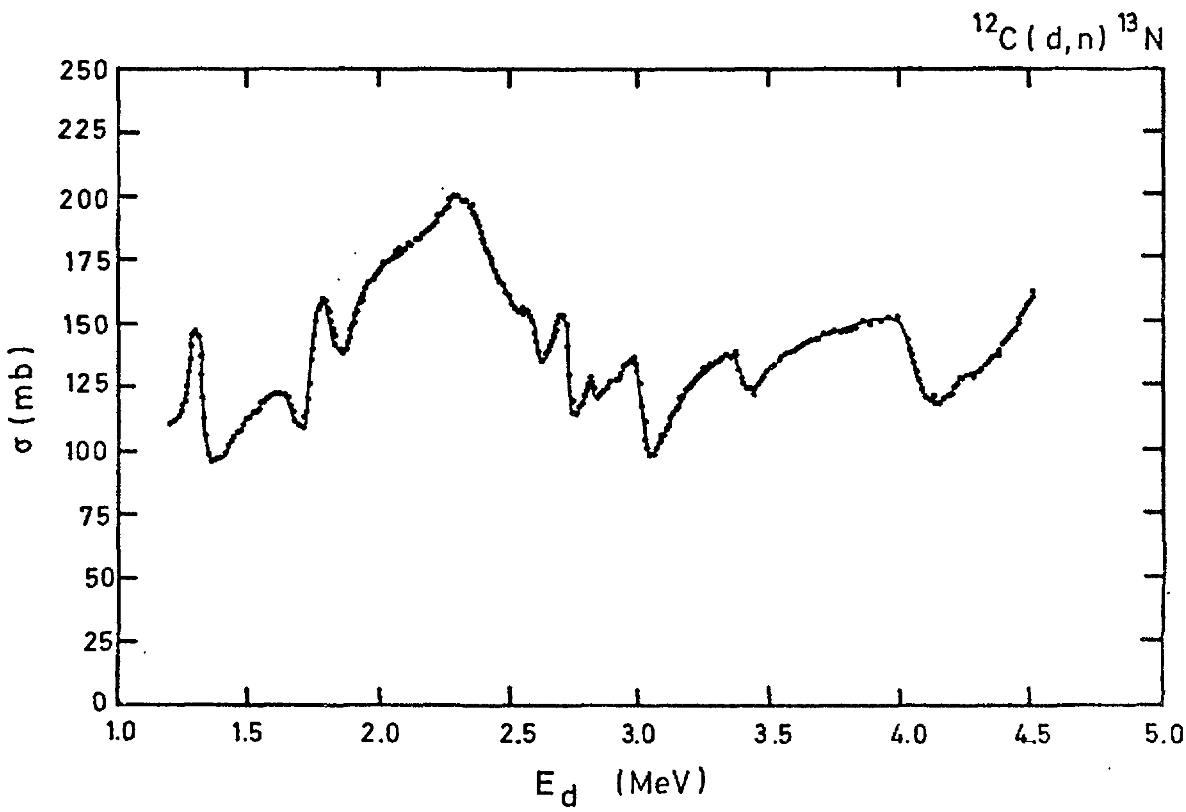
$^{12}C(d, p_3)^{13}C$
160° lab.
140° lab.
120° lab.
90° lab.
70° lab.
50° lab.
30° lab.
dσ/dΩ (c. m. (mb/sr)
E_d (MeV)

Ref D4



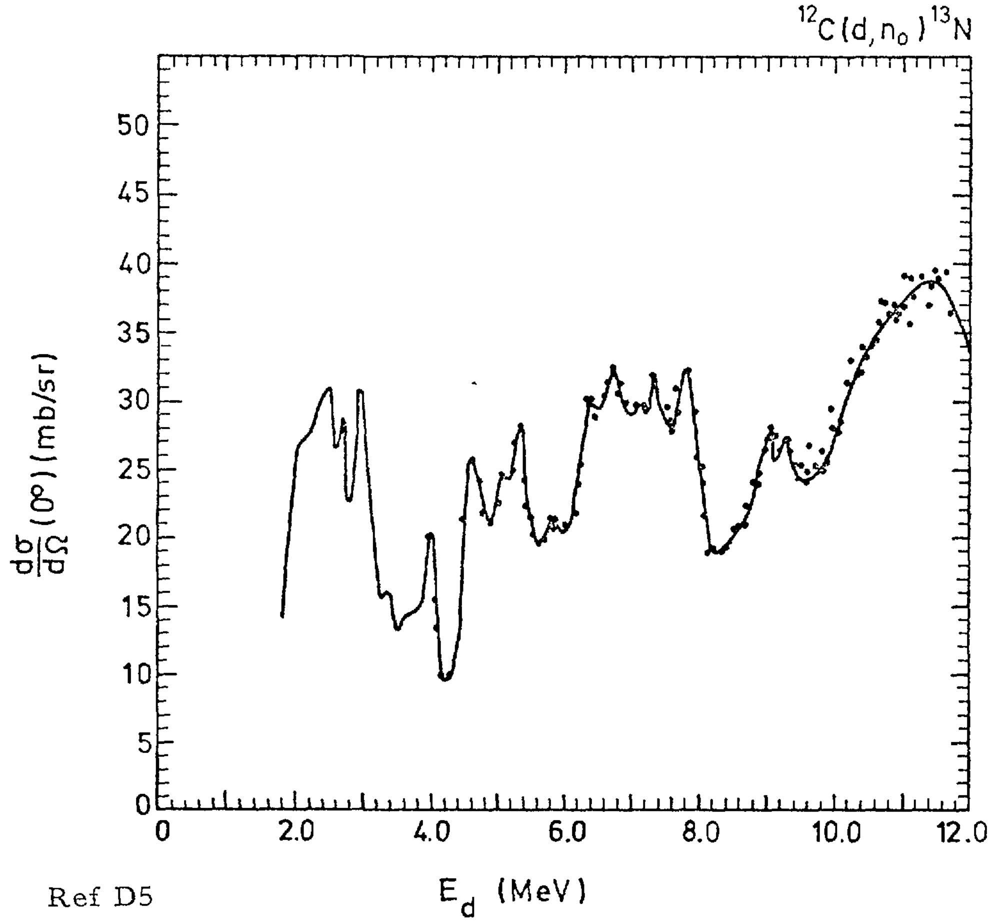
$^{12}C(d,p_o)^{13}C$
θ = 30°
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0
5
10
15
20
25
30
35
40
45
50
0
2.0
4.0
6.0
8.0
10.0
12.0
E_d (MeV)

Ref D5



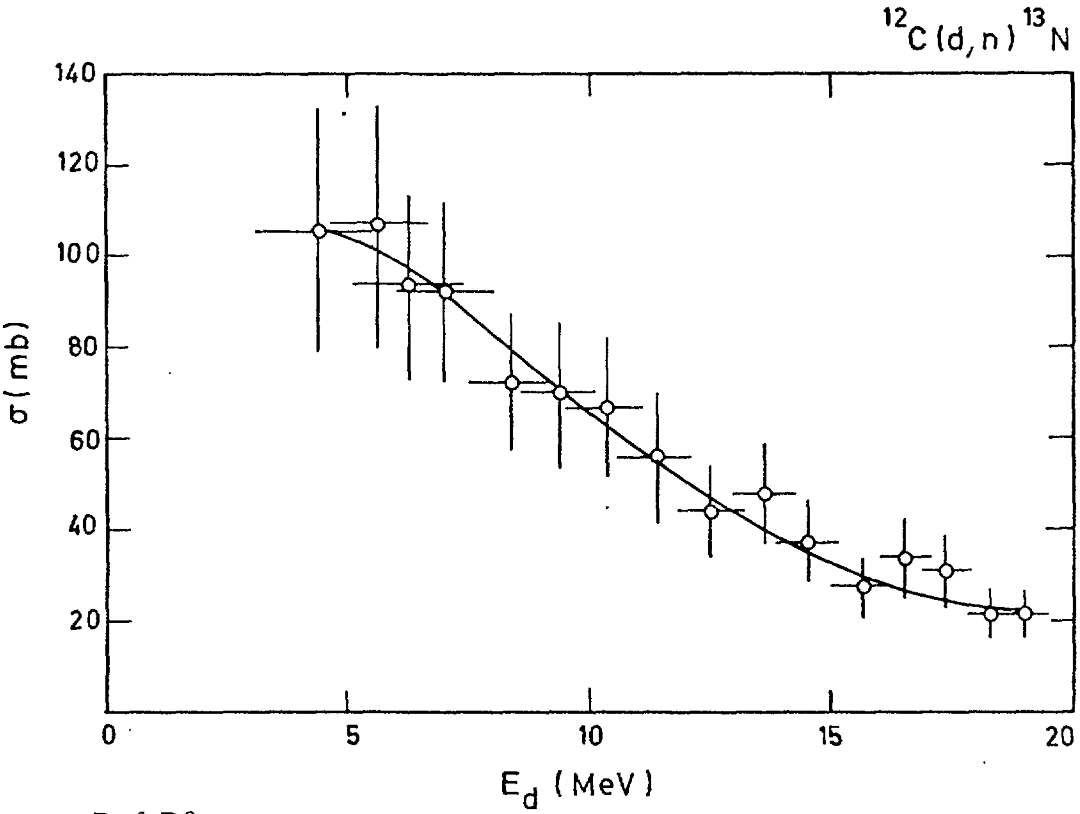
$^{12}C(d,n)^{13}N$
σ (mb)
0
25
50
75
100
125
150
175
200
225
250
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
E_d (MeV)

Ref D6



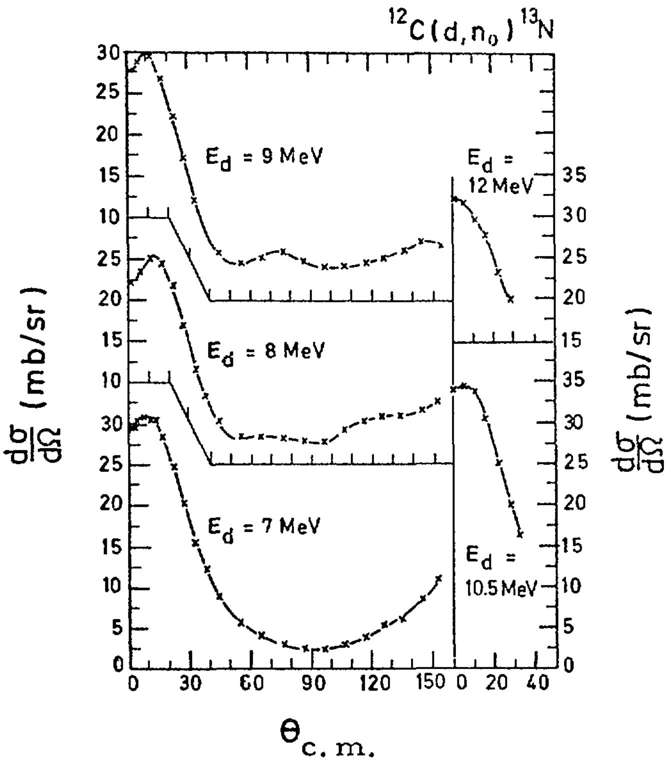
$^{12}C(d,n_0)^{13}N$
$\frac{d\sigma}{d\Omega}(0°)$ (mb/sr)
0
5
10
15
20
25
30
35
40
45
50
0
2.0
4.0
6.0
8.0
10.0
12.0
E_d (MeV)

Ref D5

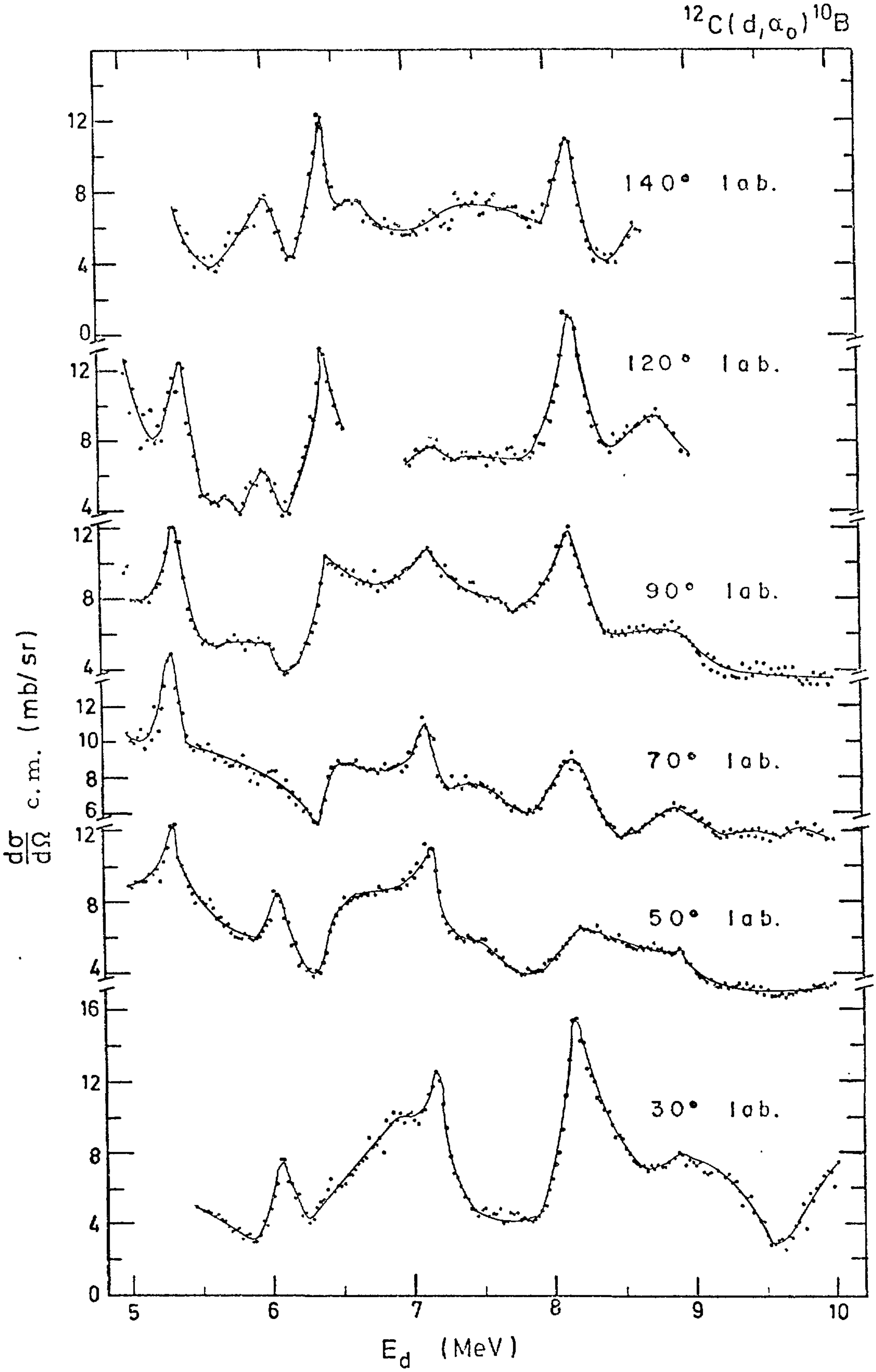


$^{12}C(d,n)^{13}N$
σ (mb)
20
40
60
80
100
120
140
0
5
10
15
20
E_d (MeV)

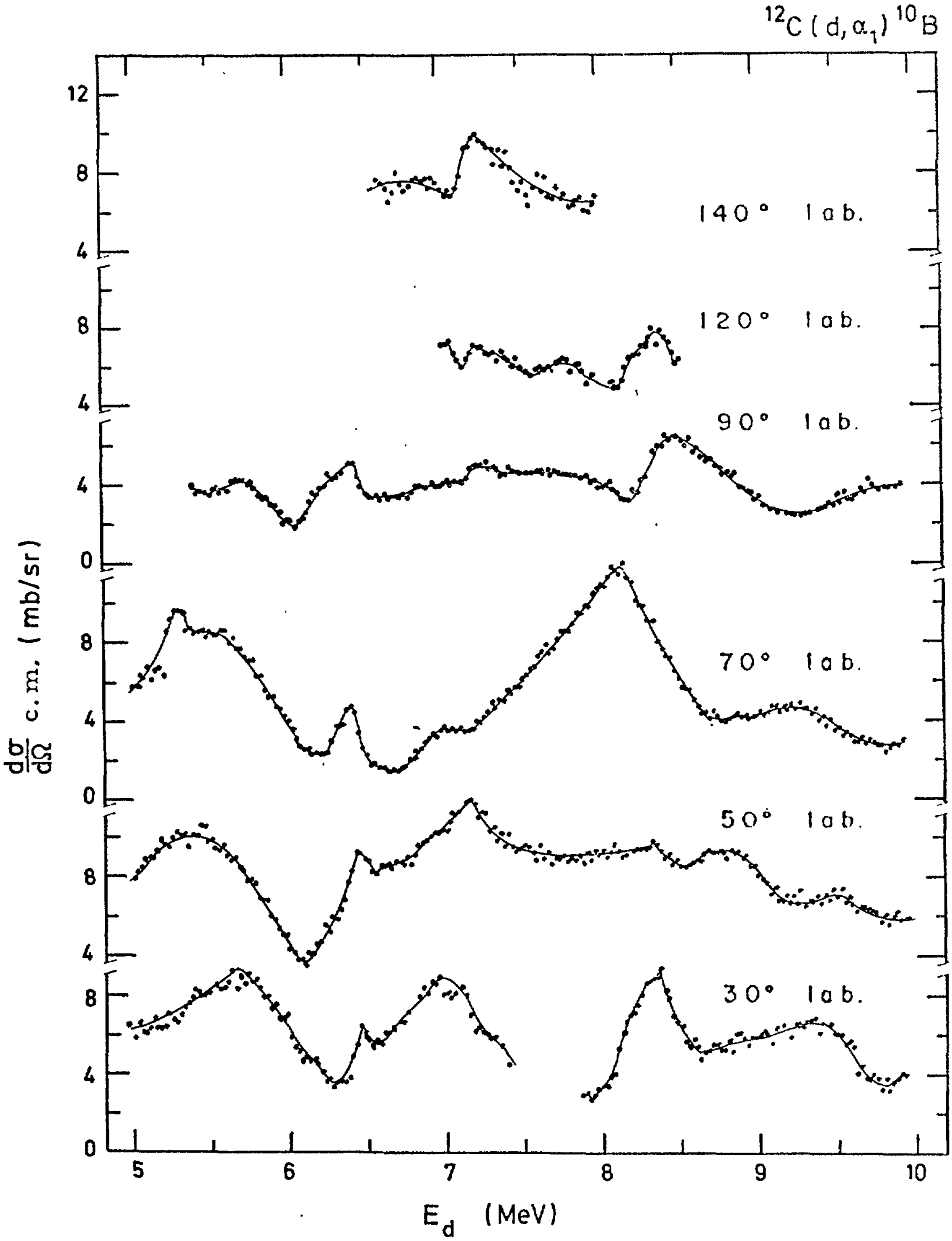
Ref D3


$^{12}C(d,n_0)^{13}N$
E_d = 9 MeV
E_d = 8 MeV
E_d = 7 MeV
E_d = 12 MeV
E_d = 10.5 MeV
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$\Theta_{c.m.}$

Ref D5

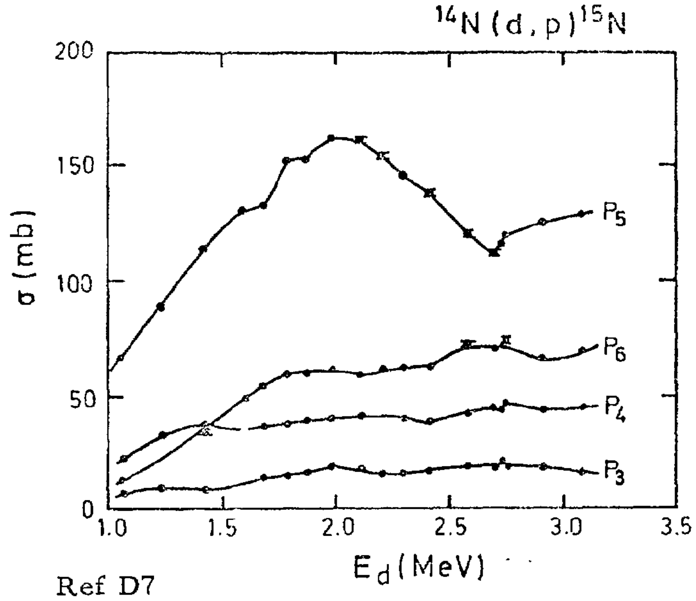

$^{12}C(d,\alpha_0)^{10}B$
140° lab.
120° lab.
90° lab.
70° lab.
50° lab.
30° lab.
$\frac{d\sigma}{d\Omega}$ c.m. (mb/sr)
E_d (MeV)
0
4
8
12
16
5
6
7
8
9
10

Ref D4

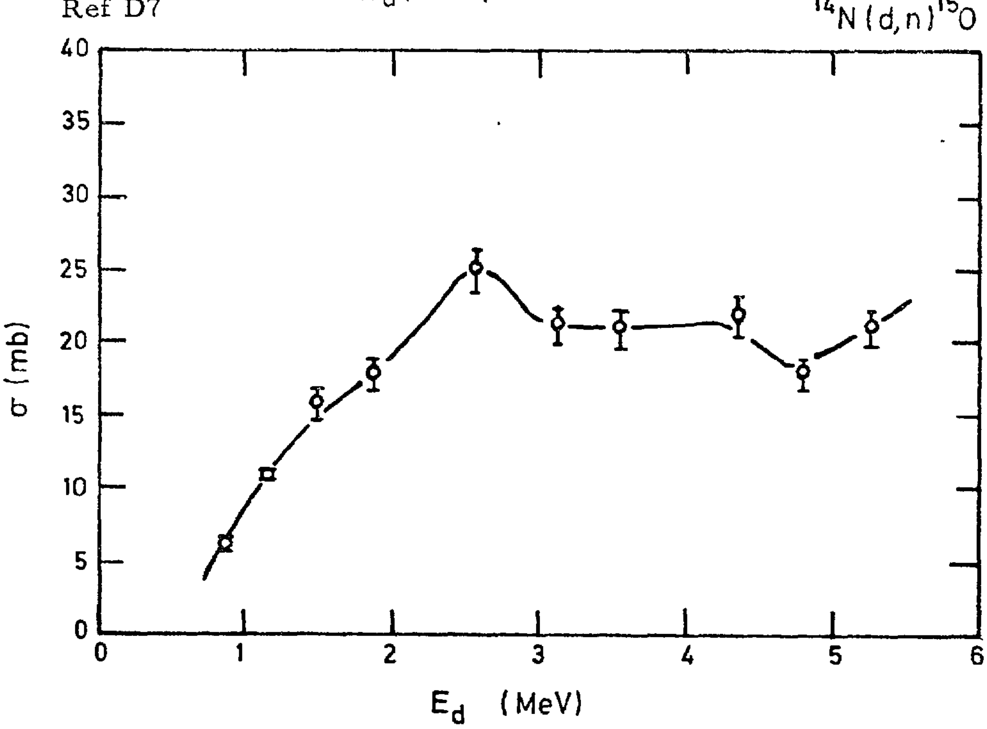


$^{12}C(d,\alpha_1)^{10}B$
140° lab.
120° lab.
90° lab.
70° lab.
50° lab.
30° lab.
$\frac{d\sigma}{d\Omega}$ c.m. (mb/sr)
E_d (MeV)

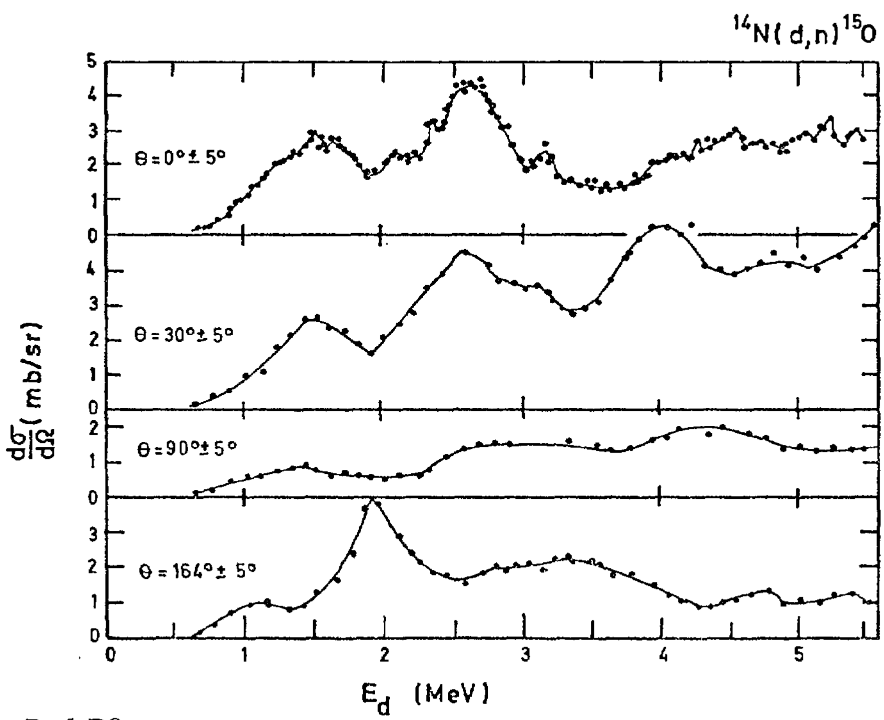
Ref D4



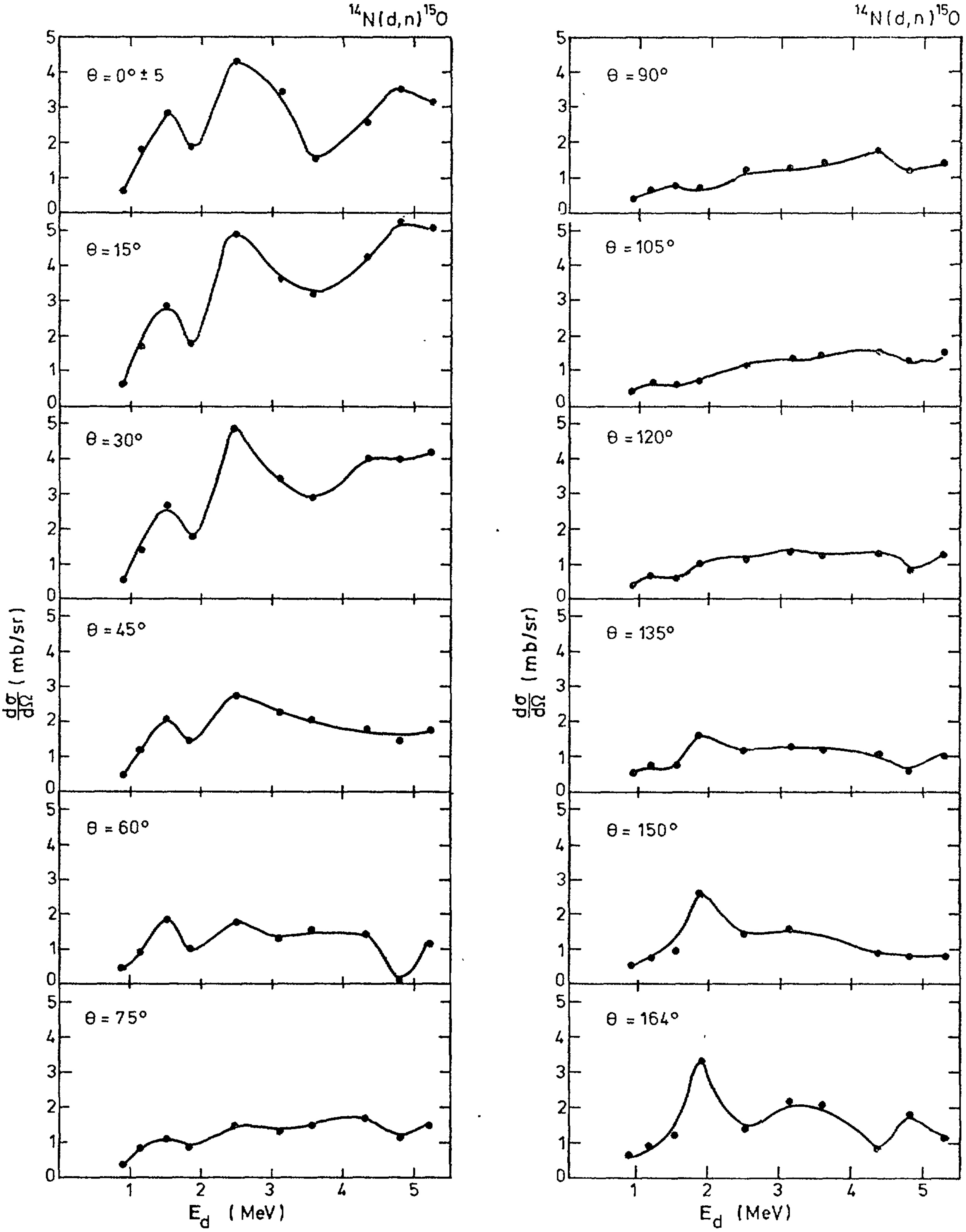
Ref D7



Ref D8

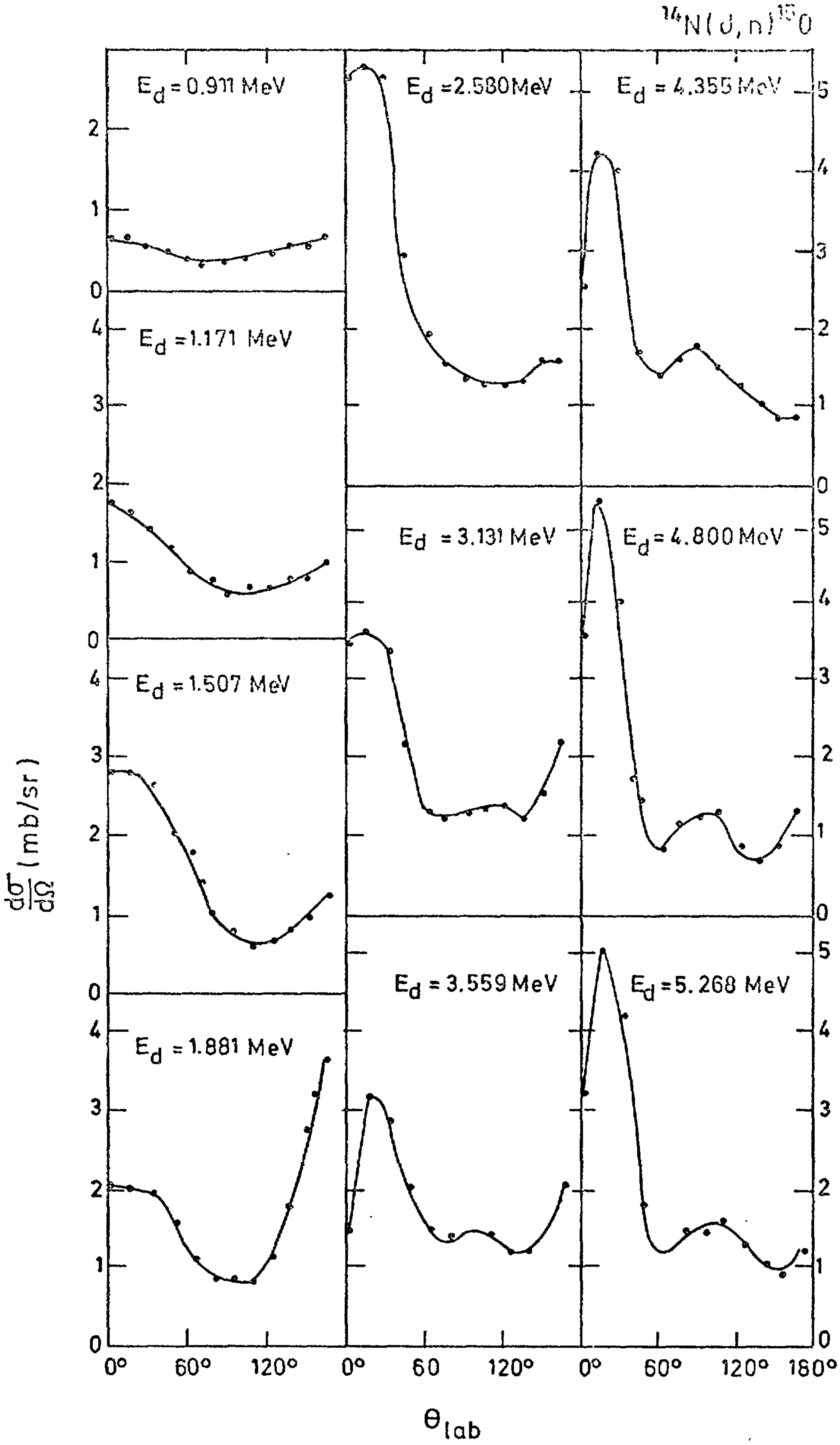


Ref D8



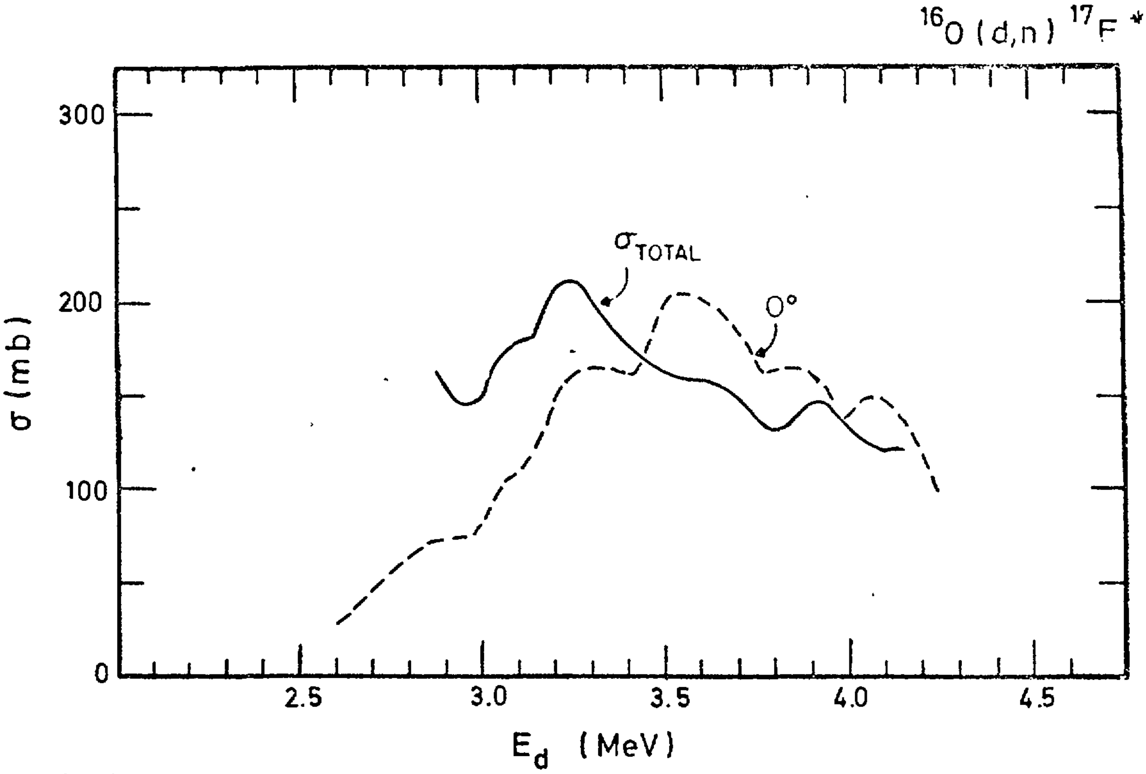
$^{14}N(d,n)^{15}O$
θ = 0° ± 5
θ = 15°
θ = 30°
θ = 45°
θ = 60°
θ = 75°
$\frac{d\sigma}{d\Omega}$ (mb/sr)
E_d (MeV)
$^{14}N(d,n)^{15}O$
θ = 90°
θ = 105°
θ = 120°
θ = 135°
θ = 150°
θ = 164°
$\frac{d\sigma}{d\Omega}$ (mb/sr)
E_d (MeV)

Ref D8

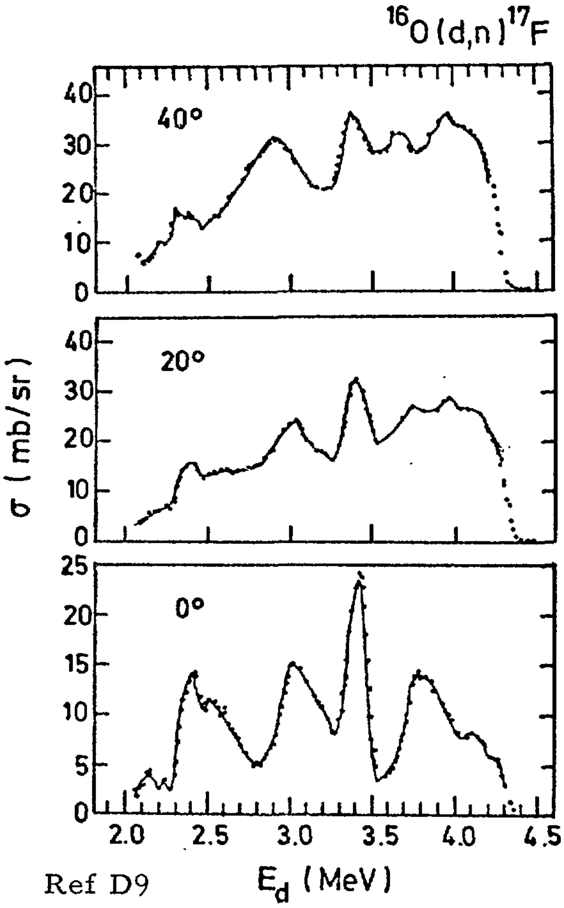


$^{14}N(d,n)^{15}O$
E_d = 0.911 MeV
E_d = 1.171 MeV
E_d = 1.507 MeV
E_d = 1.881 MeV
E_d = 2.580 MeV
E_d = 3.131 MeV
E_d = 3.559 MeV
E_d = 4.355 MeV
E_d = 4.800 MeV
E_d = 5.268 MeV
$\frac{d\sigma}{d\Omega}$ (mb/sr)
θ_{lab}

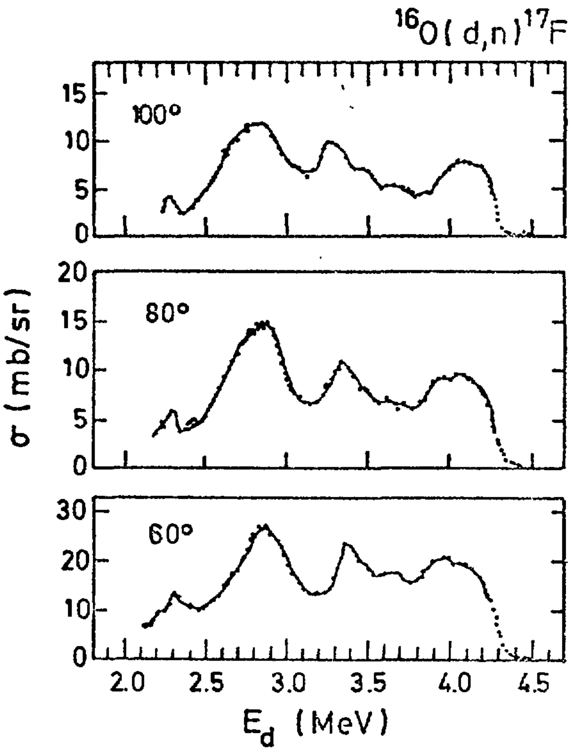
Ref D8



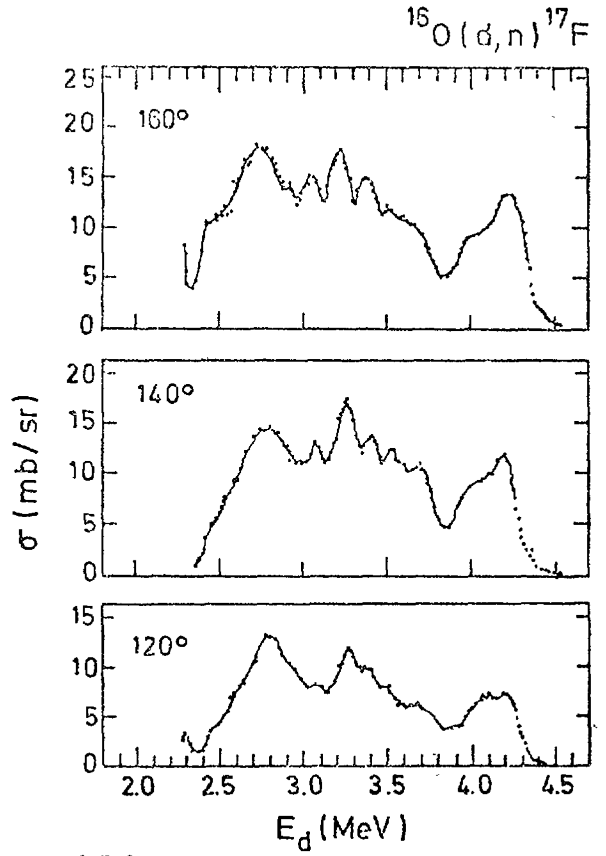
Ref D9



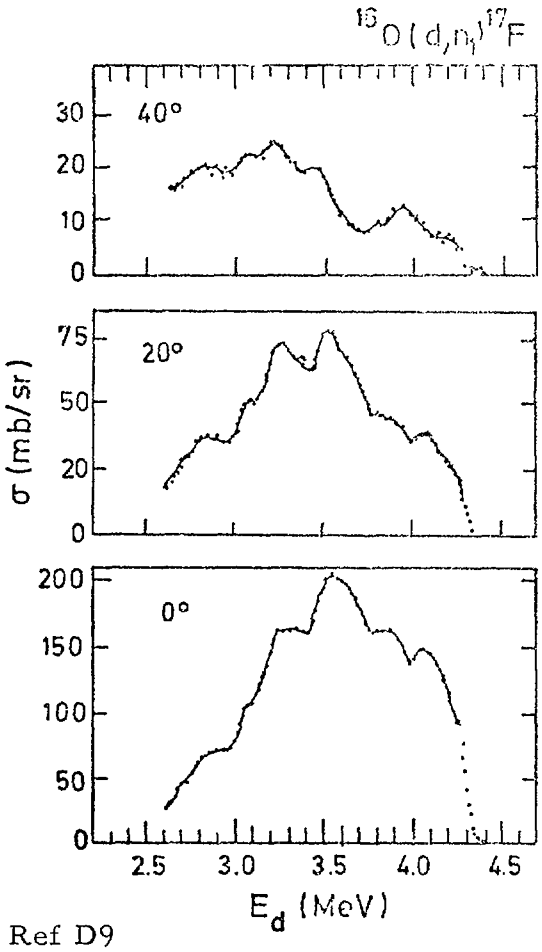
Ref D9



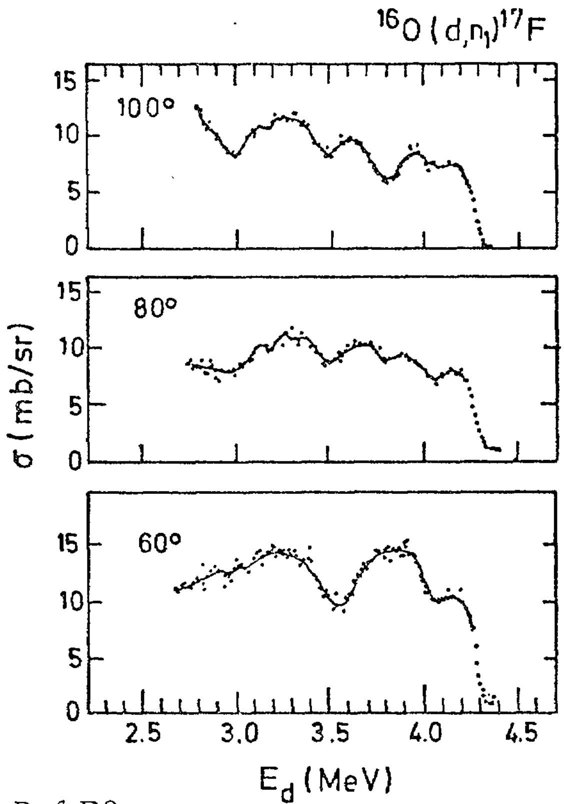
Ref D9



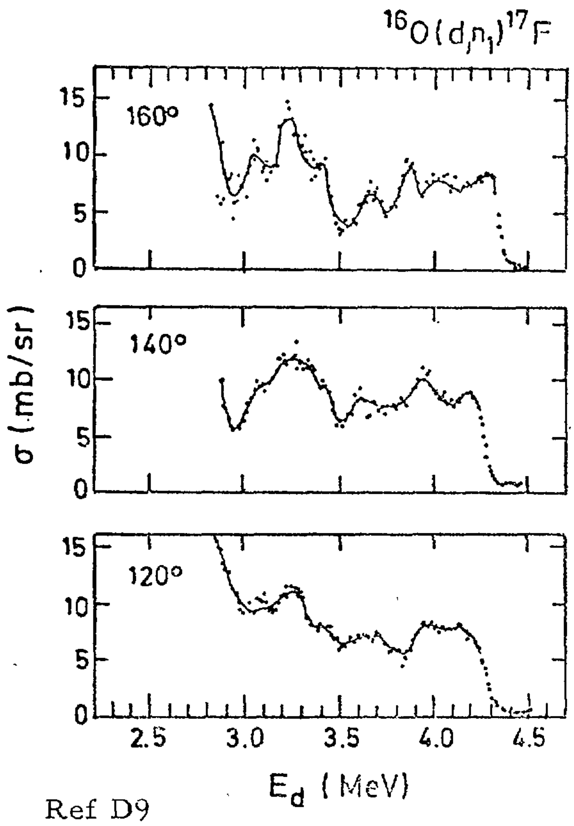
Ref D9



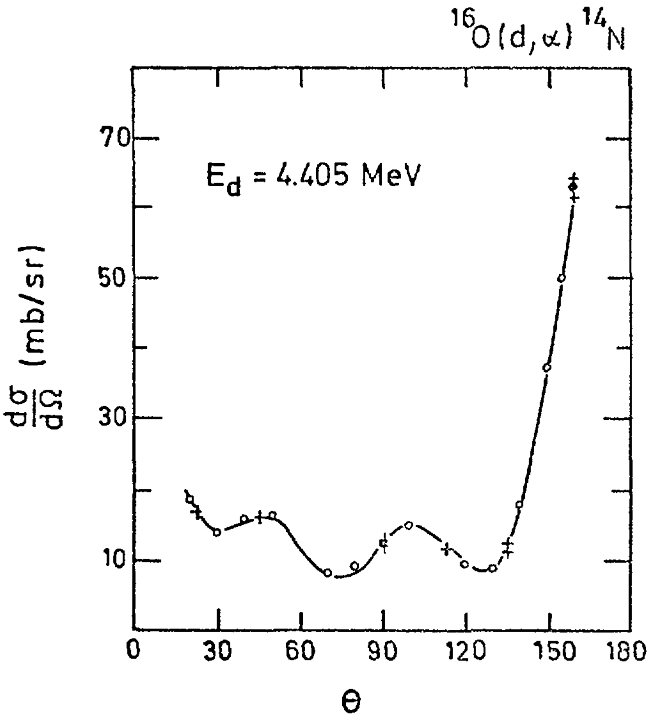
Ref D9



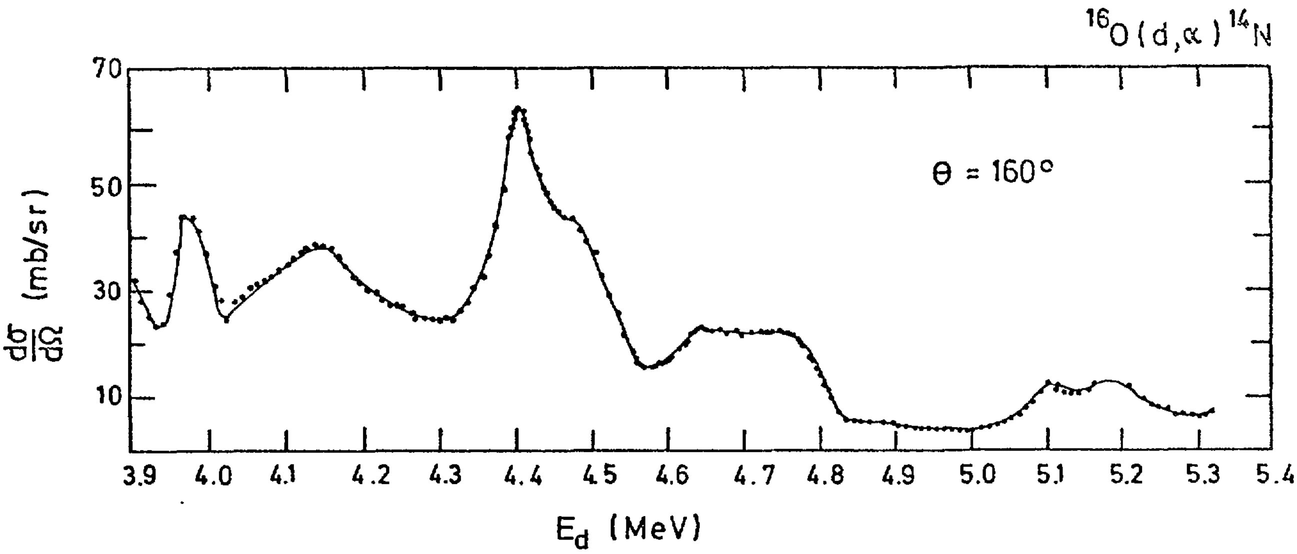
Ref D9



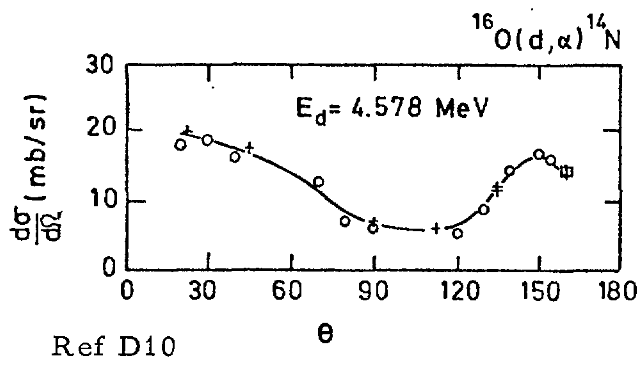
Ref D9

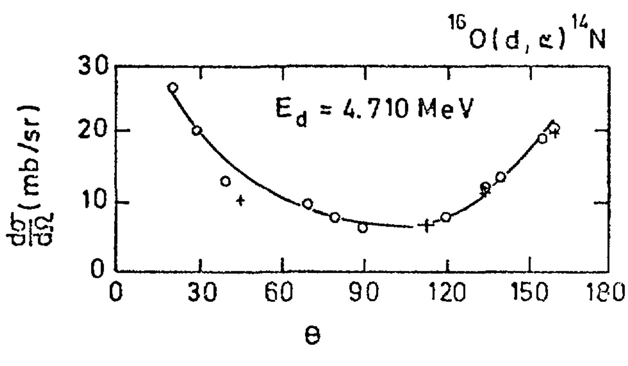


Ref D10

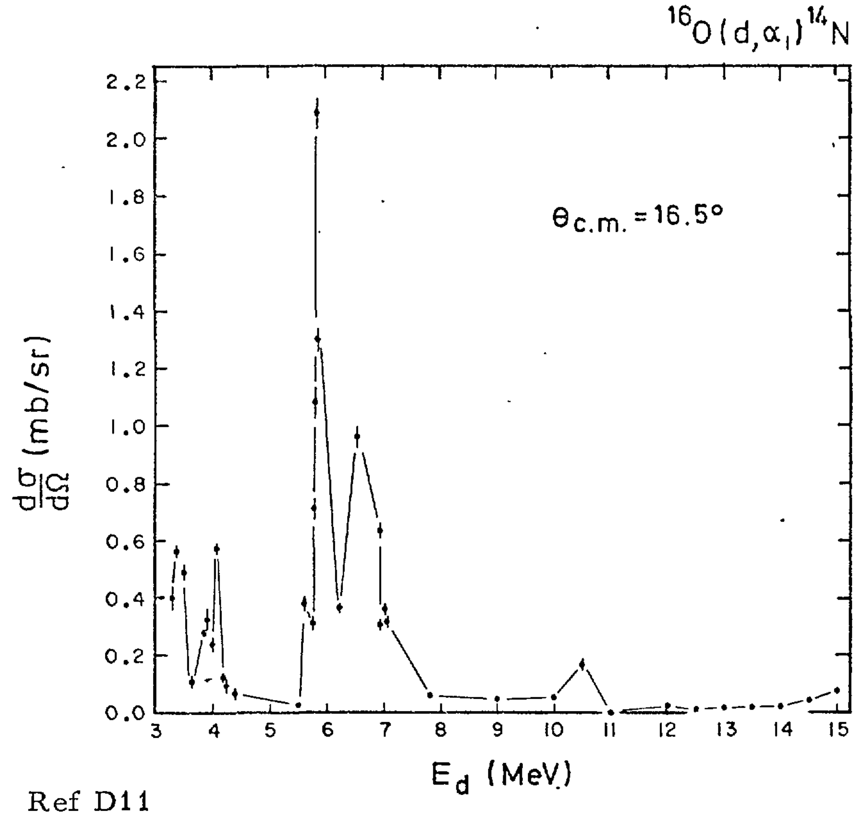


Ref D10

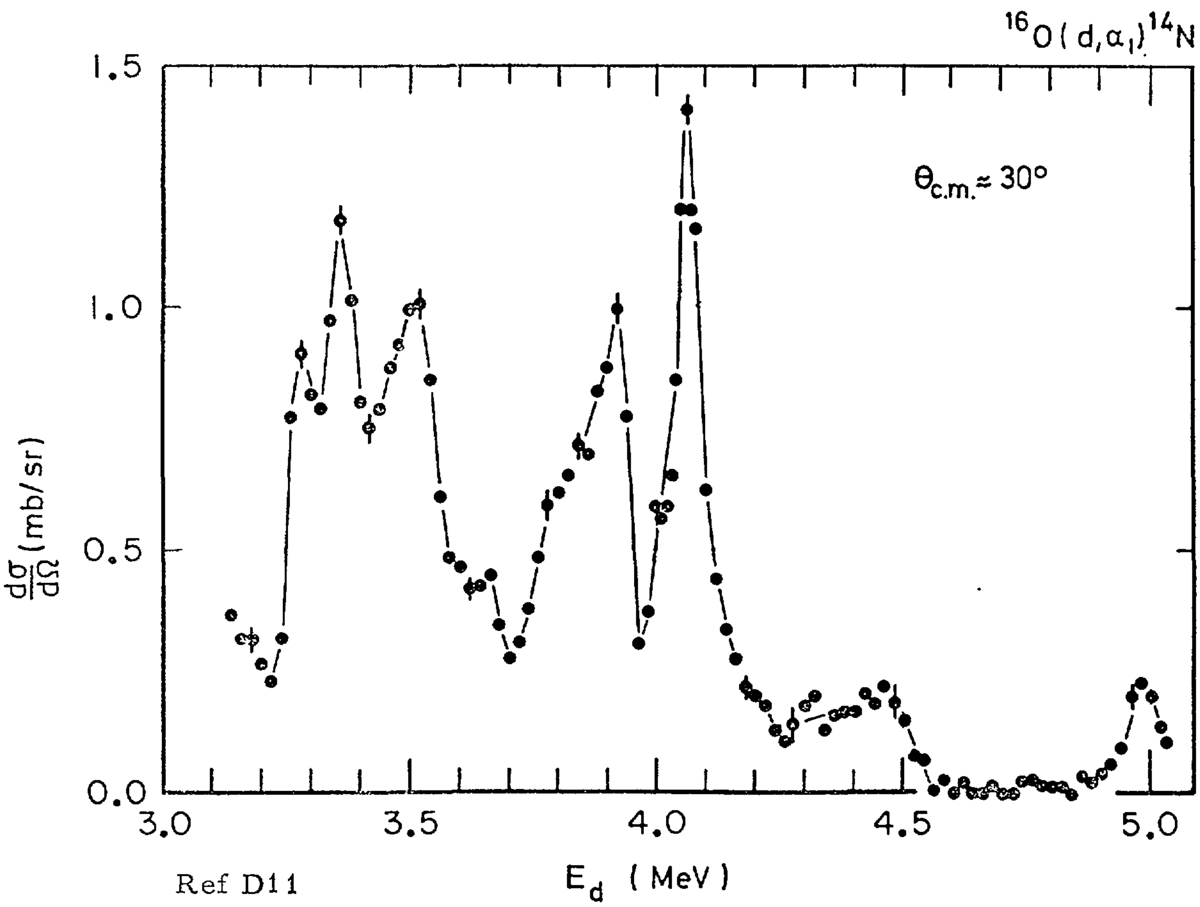




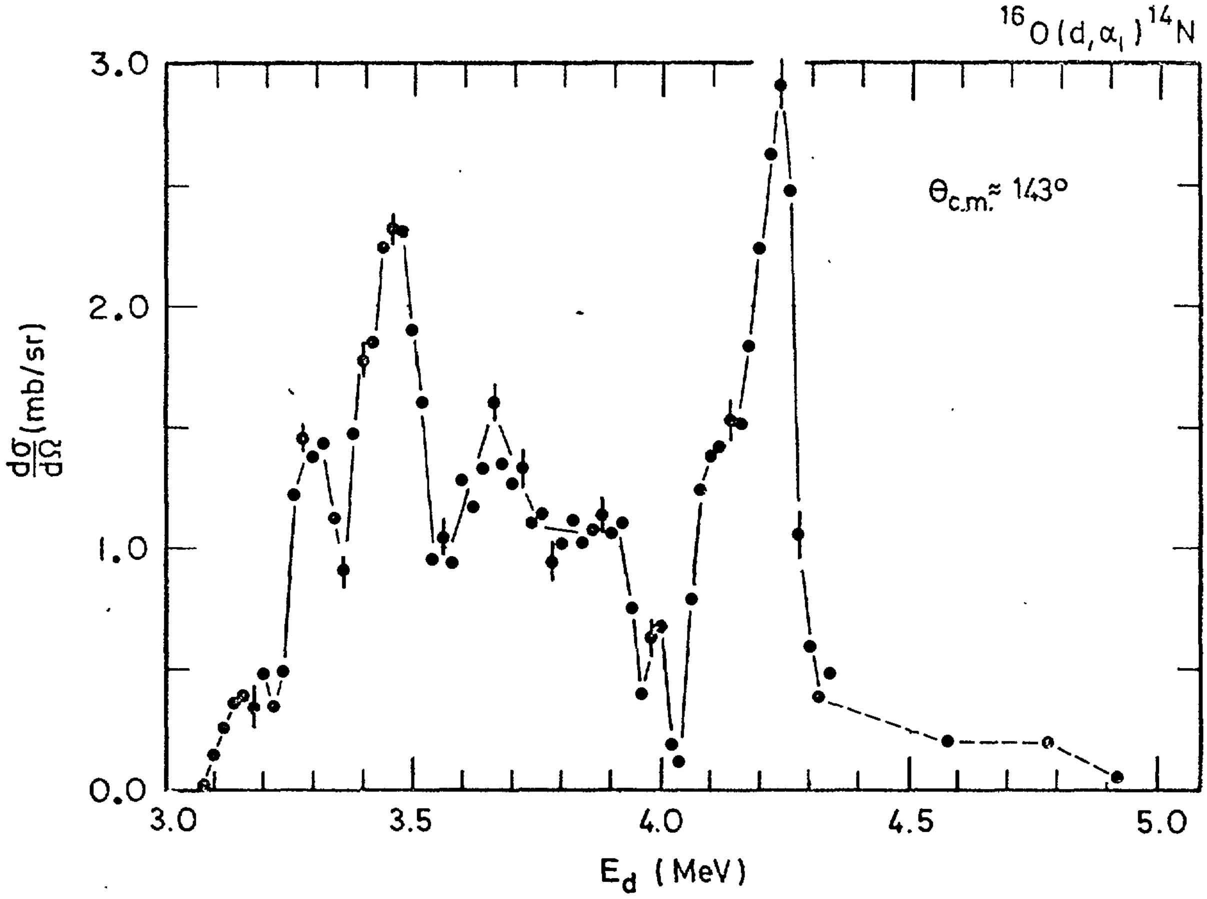
Ref D10



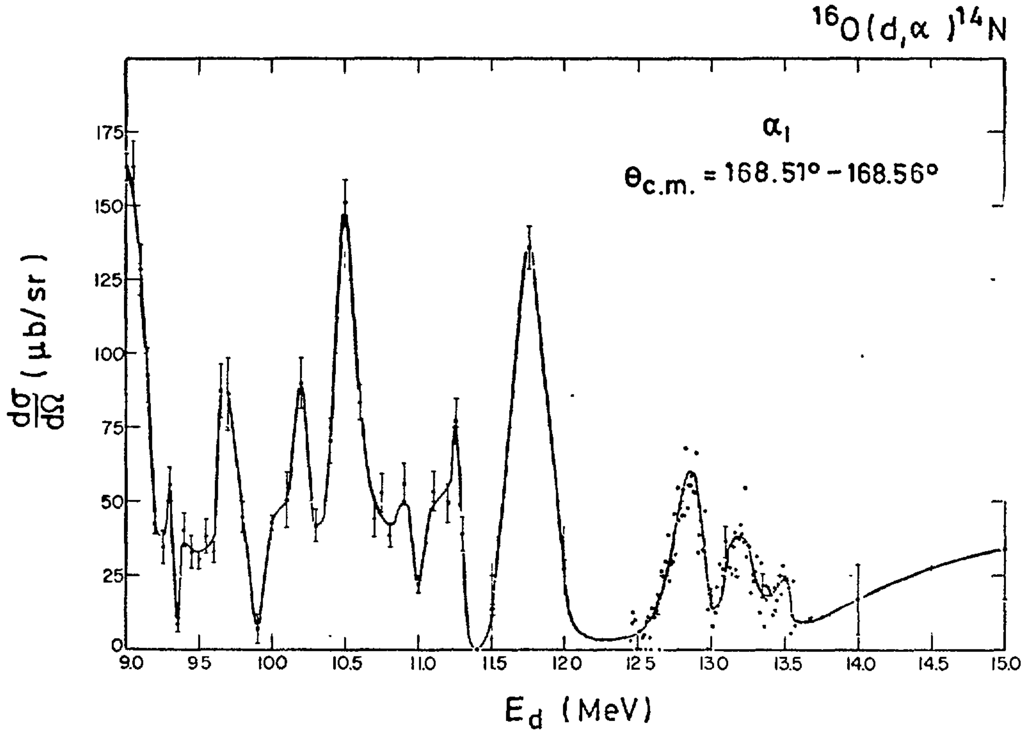
Ref D11



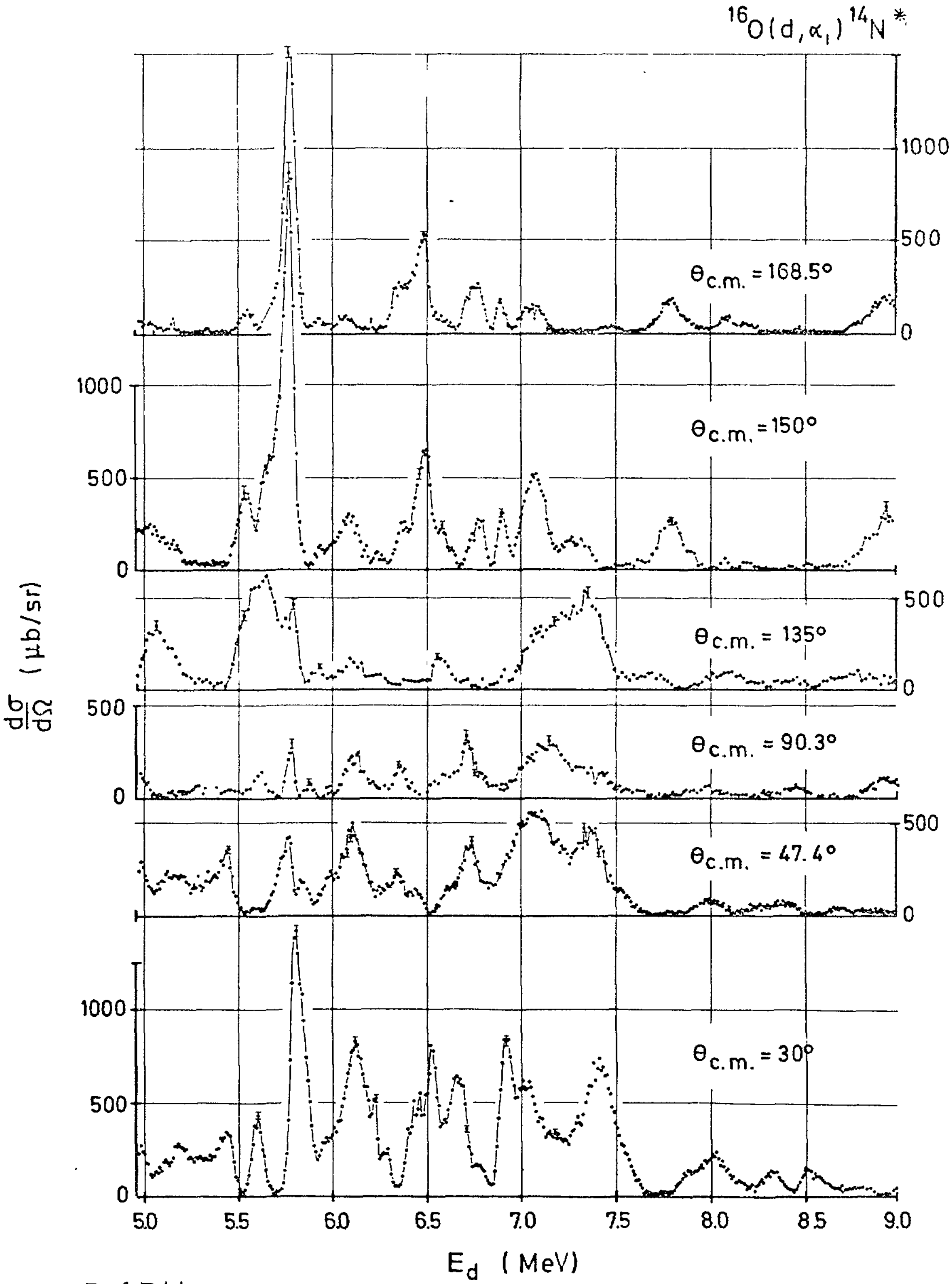
Ref D11



Ref D11

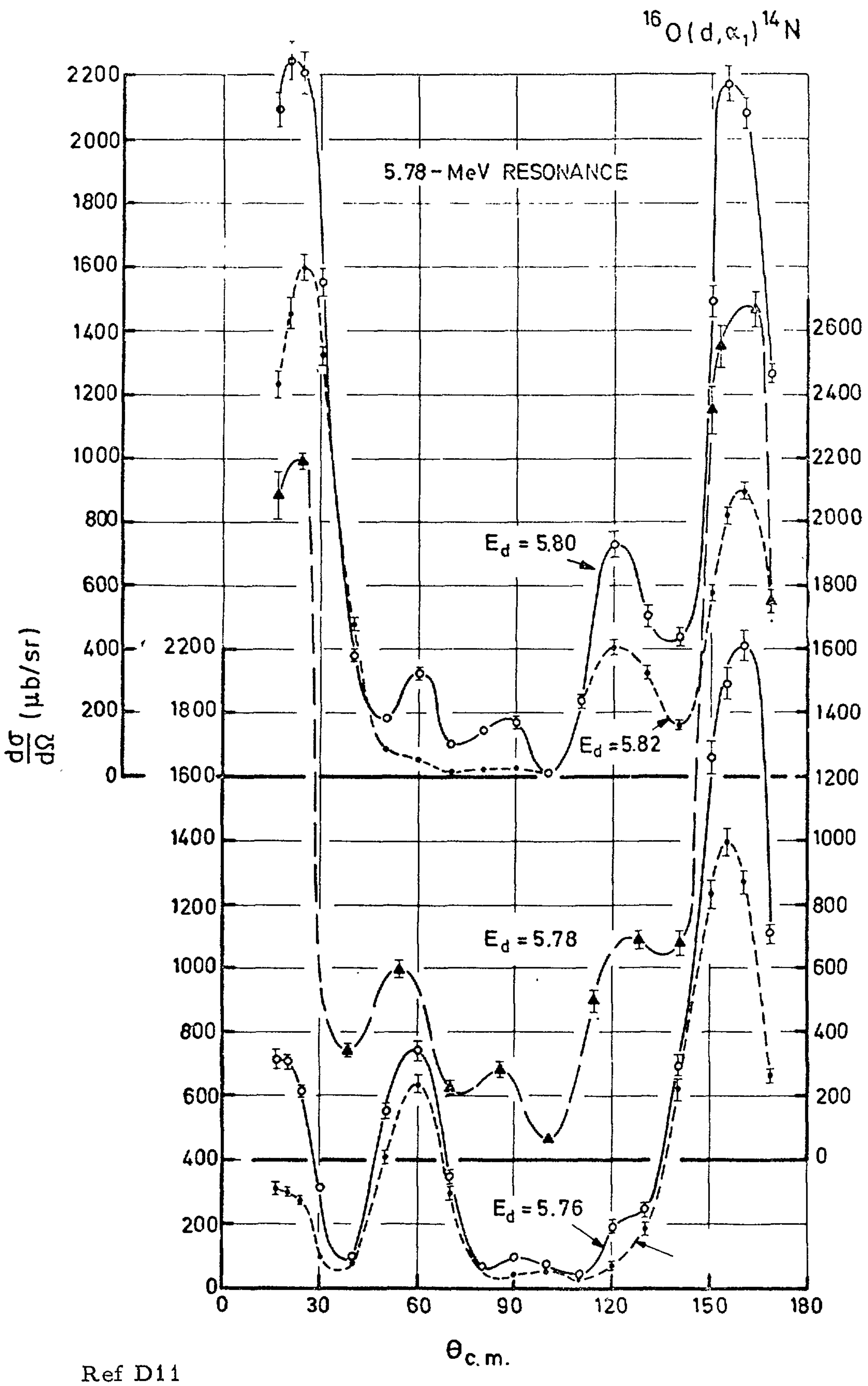


Ref D11



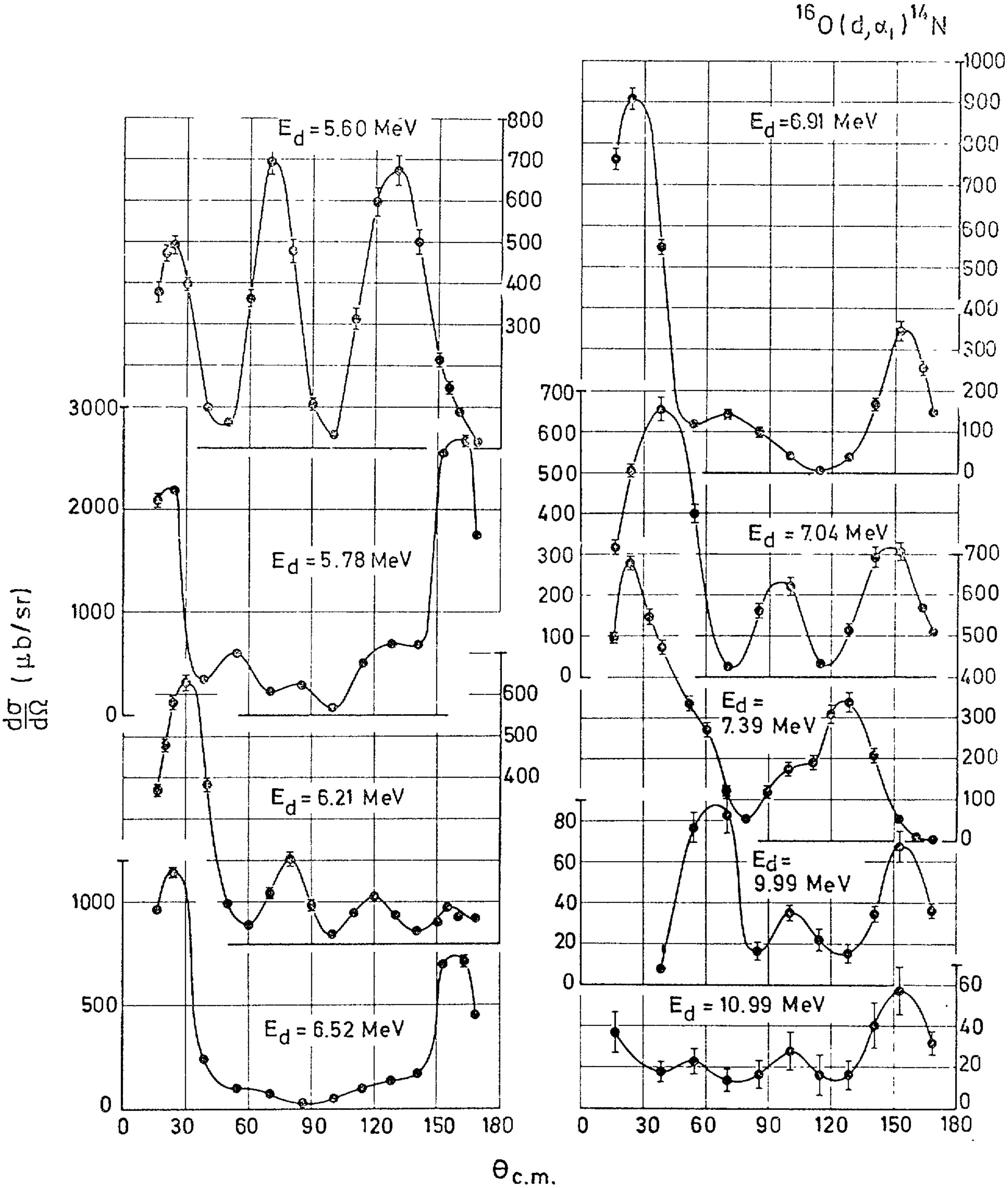
$^{16}O(d,\alpha_1)^{14}N^*$
θc.m. = 168.5°
θc.m. = 150°
θc.m. = 135°
θc.m. = 90.3°
θc.m. = 47.4°
θc.m. = 30°
dσ/dΩ (μb/sr)
E_d (MeV)
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
0
500
1000

Ref D11



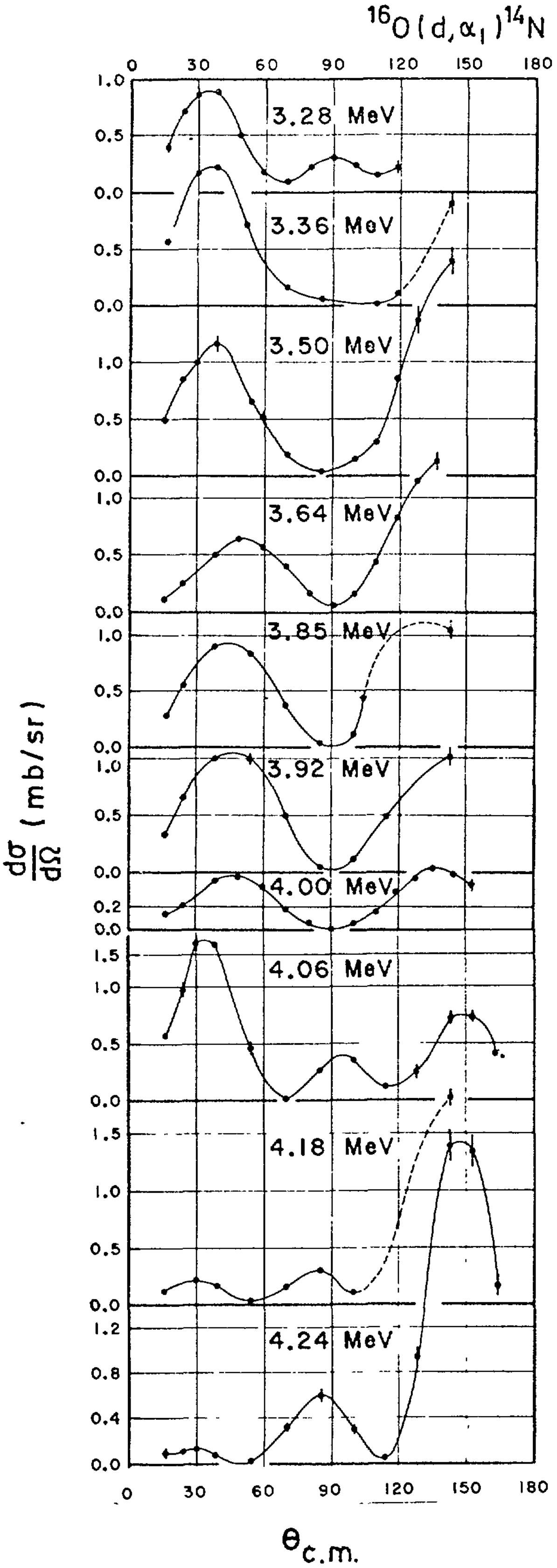
$^{16}O(d,\alpha_1)^{14}N$
5.78 - MeV RESONANCE
E_d = 5.80
E_d = 5.82
E_d = 5.78
E_d = 5.76
dσ/dΩ (μb/sr)
θc.m.
0
30
60
90
120
150
180

Ref D11

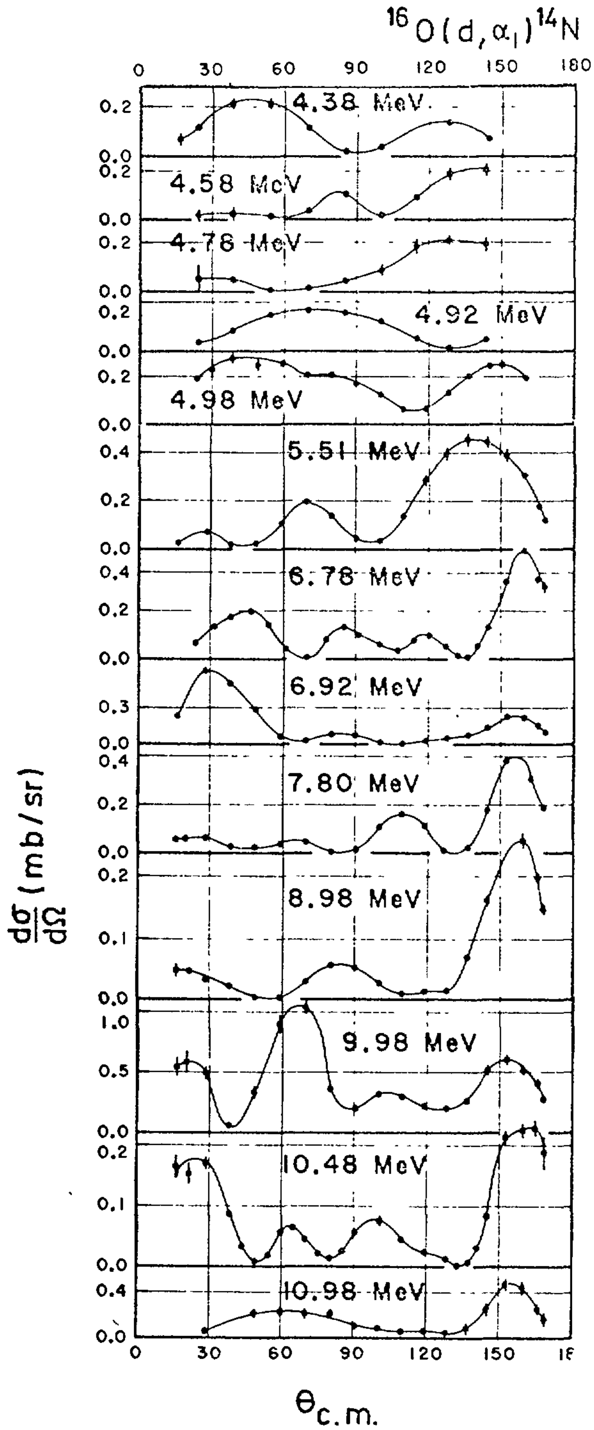


$^{16}O(d,\alpha_1)^{14}N$
Ed = 5.60 MeV
Ed = 5.78 MeV
Ed = 6.21 MeV
Ed = 6.52 MeV
Ed = 6.91 MeV
Ed = 7.04 MeV
Ed = 7.39 MeV
Ed = 9.99 MeV
Ed = 10.99 MeV
dσ/dΩ (μb/sr)
θc.m.

Ref D11

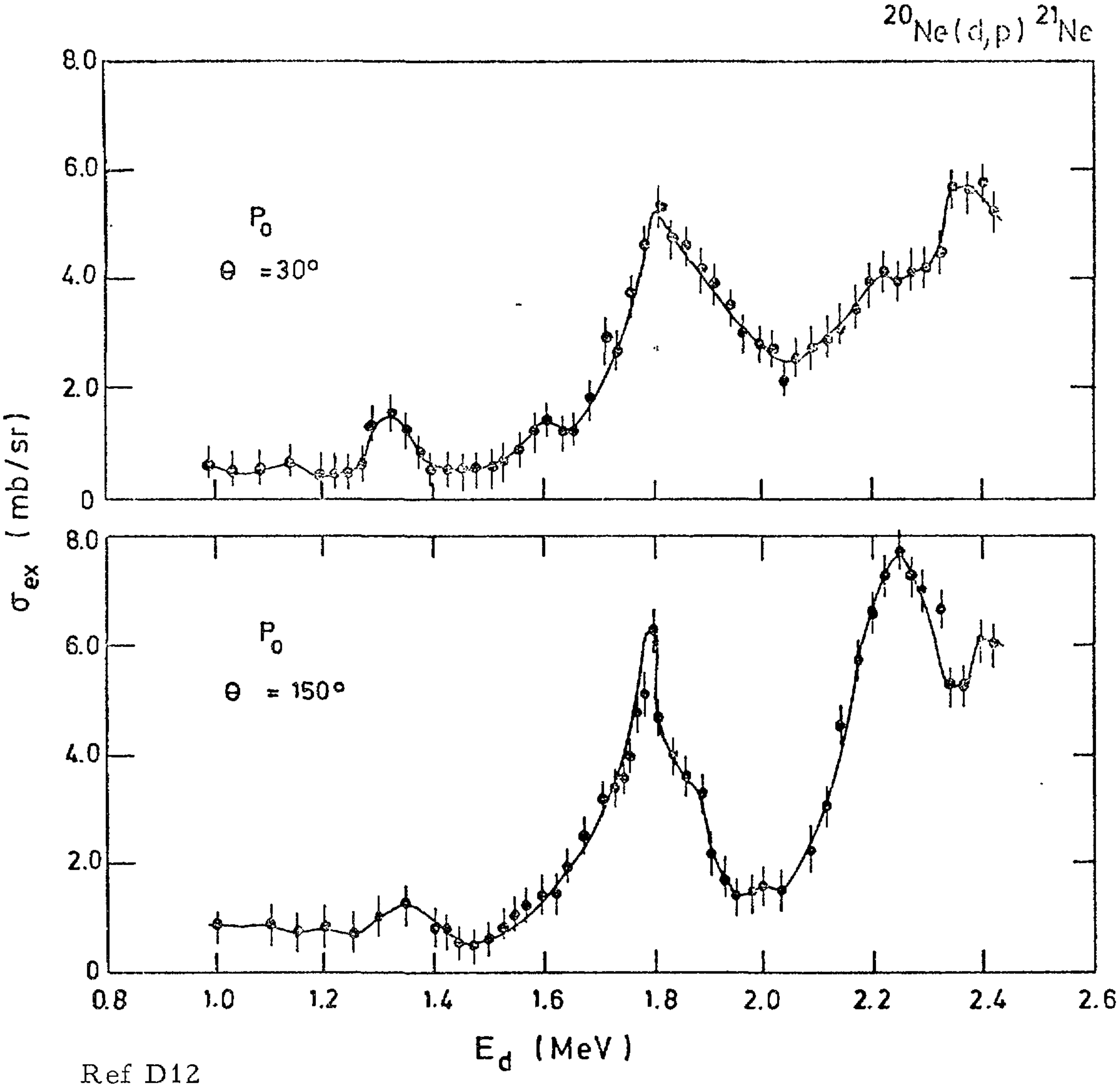


$^{16}O(d,\alpha_1)^{14}N$
3.28 MeV
3.36 MeV
3.50 MeV
3.64 MeV
3.85 MeV
3.92 MeV
4.00 MeV
4.06 MeV
4.18 MeV
4.24 MeV
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$\theta_{c.m.}$

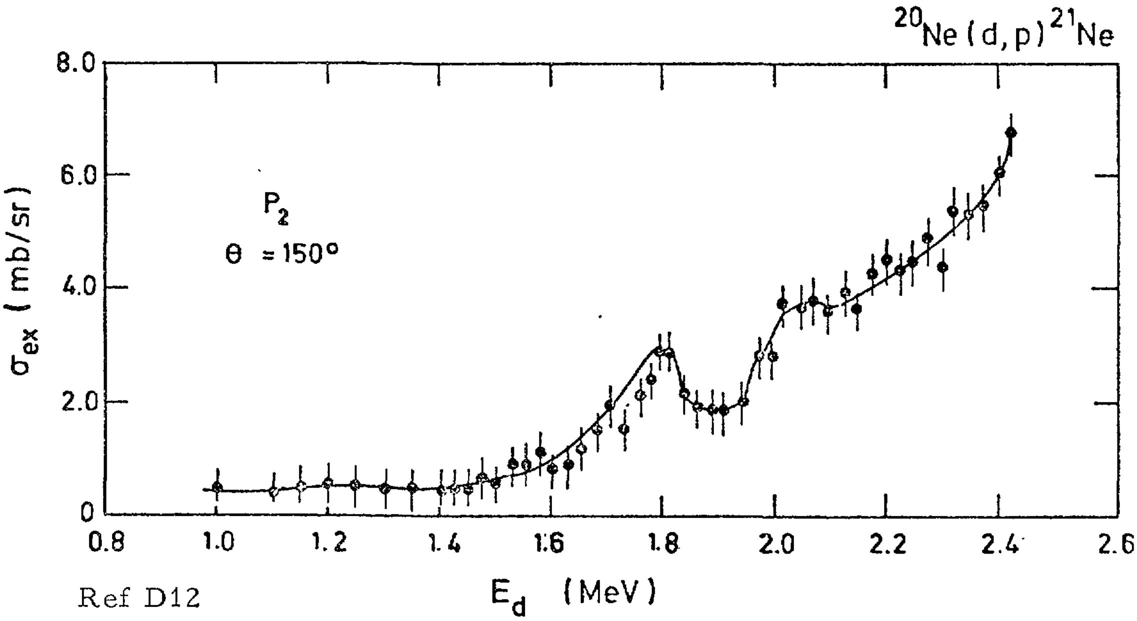


$^{16}O(d,\alpha_1)^{14}N$
4.38 MeV
4.58 MeV
4.78 MeV
4.92 MeV
4.98 MeV
5.51 MeV
6.78 MeV
6.92 MeV
7.80 MeV
8.98 MeV
9.98 MeV
10.48 MeV
10.98 MeV
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$\theta_{c.m.}$

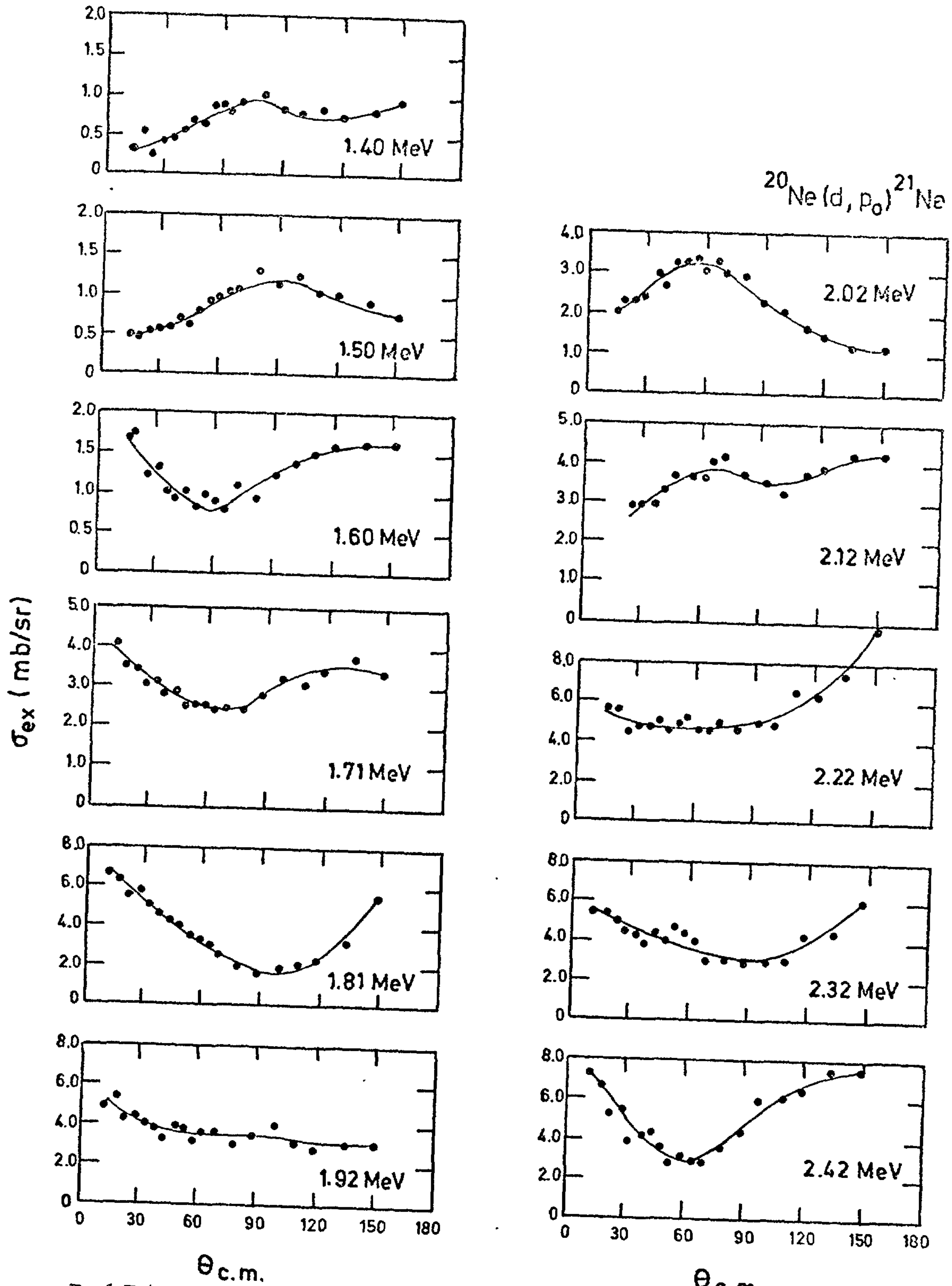
Ref D11



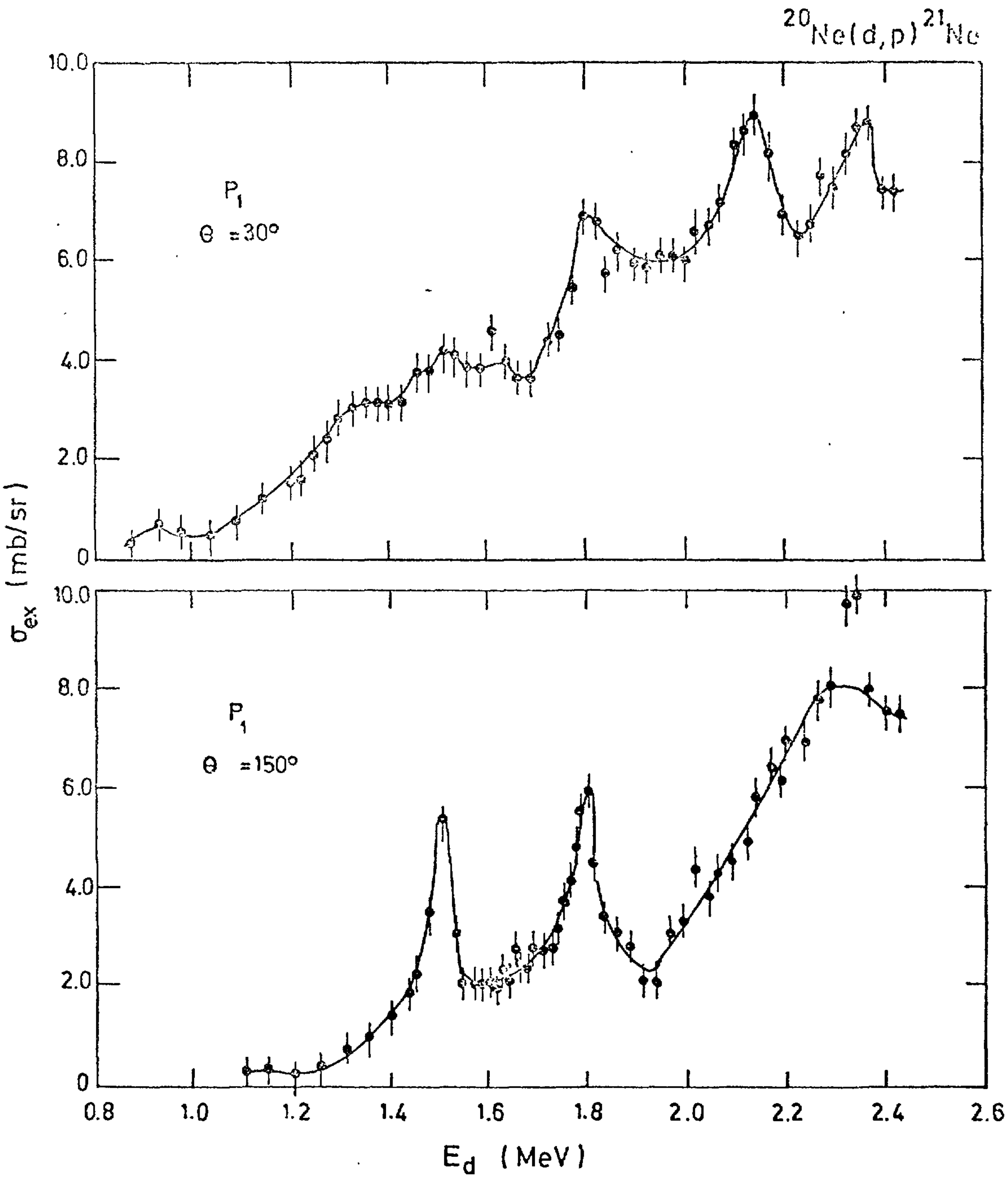
Ref D12



Ref D12

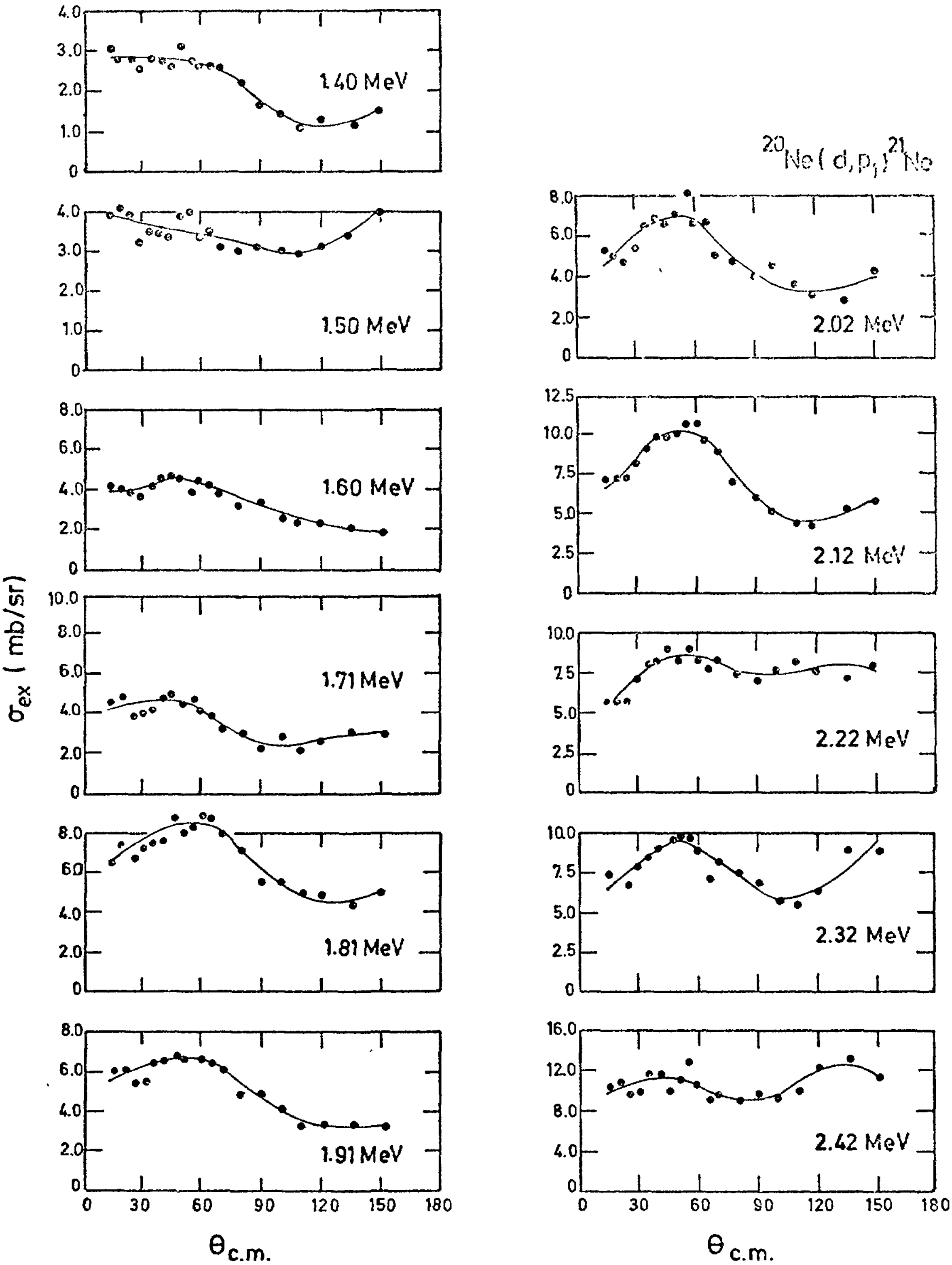

^{20}Ne (d, p_o)^{21}Ne
1.40 MeV
1.50 MeV
1.60 MeV
1.71 MeV
1.81 MeV
1.92 MeV
2.02 MeV
2.12 MeV
2.22 MeV
2.32 MeV
2.42 MeV
σ_{ex} (mb/sr)
$\theta_{c.m.}$
$\theta_{c.m.}$
0 30 60 90 120 150 180

Ref D12



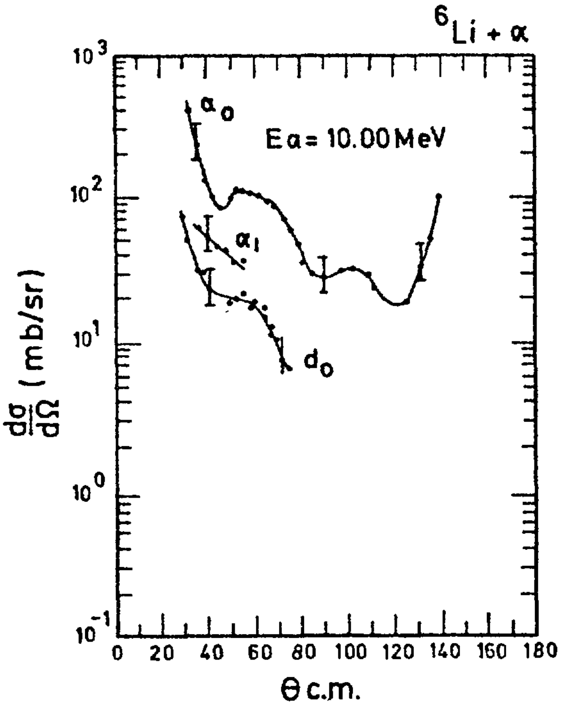
^{20}Ne(d,p)^{21}Ne
P1
θ =30°
P1
θ =150°
σex (mb/sr)
Ed (MeV)
10.0
8.0
6.0
4.0
2.0
0
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6

Ref D12



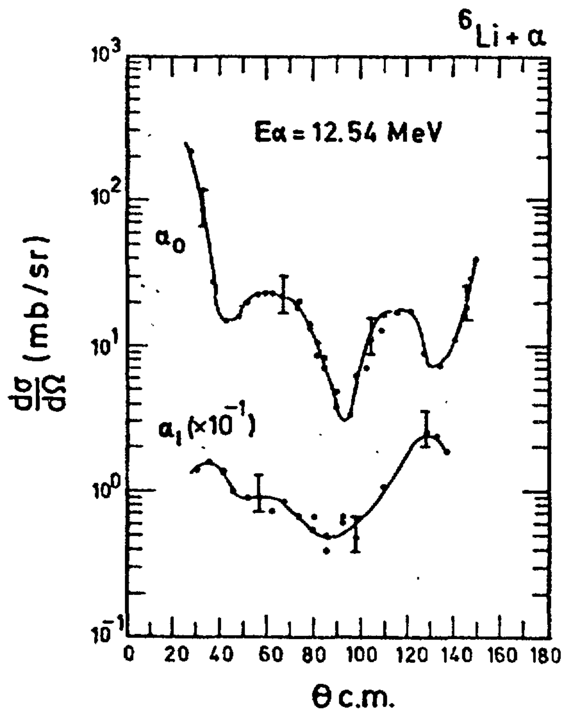
$^{20}Ne(d,p_1)^{21}Ne$
1.40 MeV
1.50 MeV
1.60 MeV
1.71 MeV
1.81 MeV
1.91 MeV
2.02 MeV
2.12 MeV
2.22 MeV
2.32 MeV
2.42 MeV
σex (mb/sr)
θc.m.
θc.m.

Ref D12



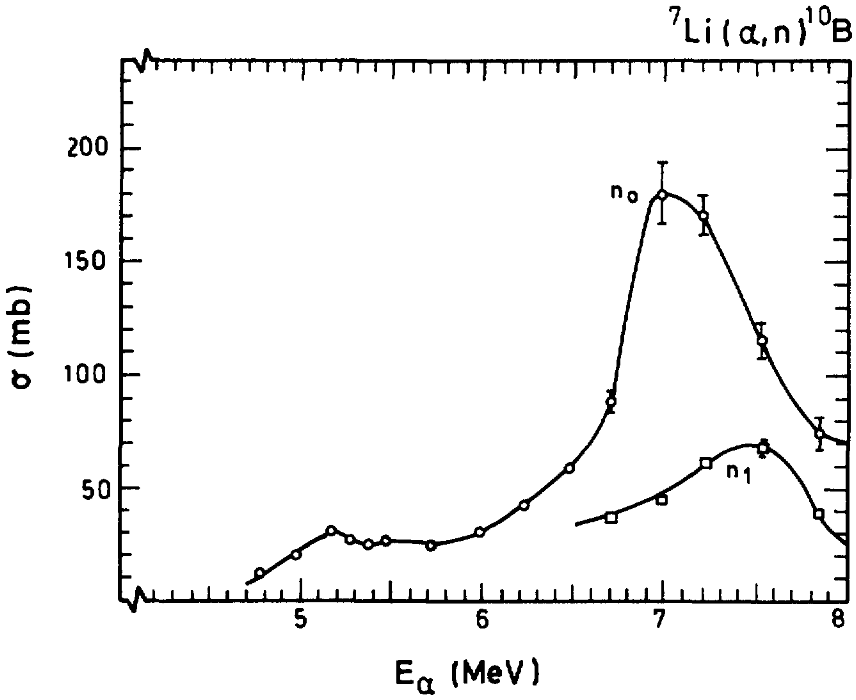
$^6Li + \alpha$
Eα = 10.00 MeV
α0
α1
d0
dσ/dΩ (mb/sr)
θ c.m.

Ref A1



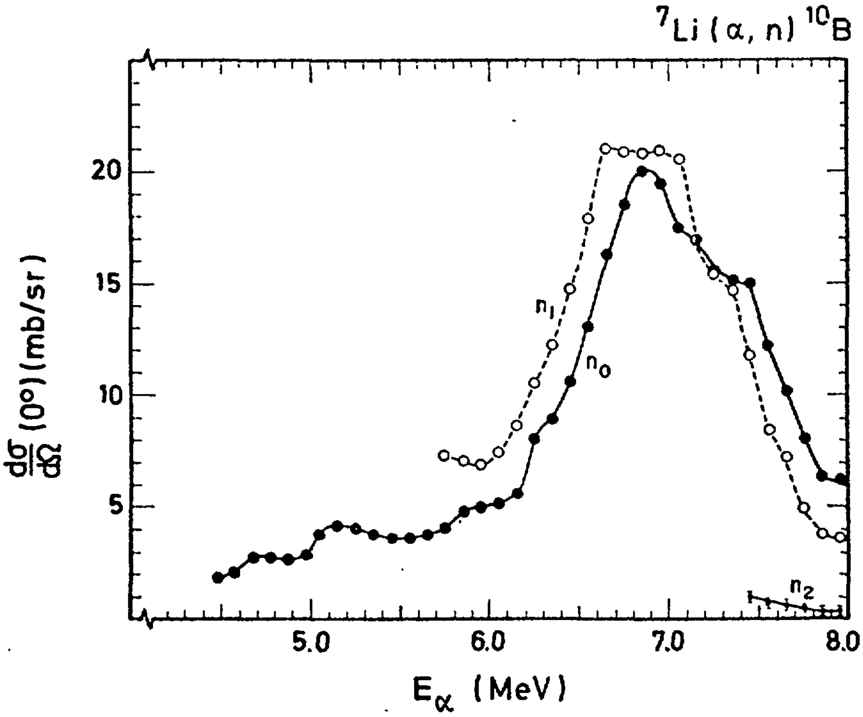
$^6Li + \alpha$
Eα = 12.54 MeV
α0
α1 (×10⁻¹)
dσ/dΩ (mb/sr)
θ c.m.

Ref A1



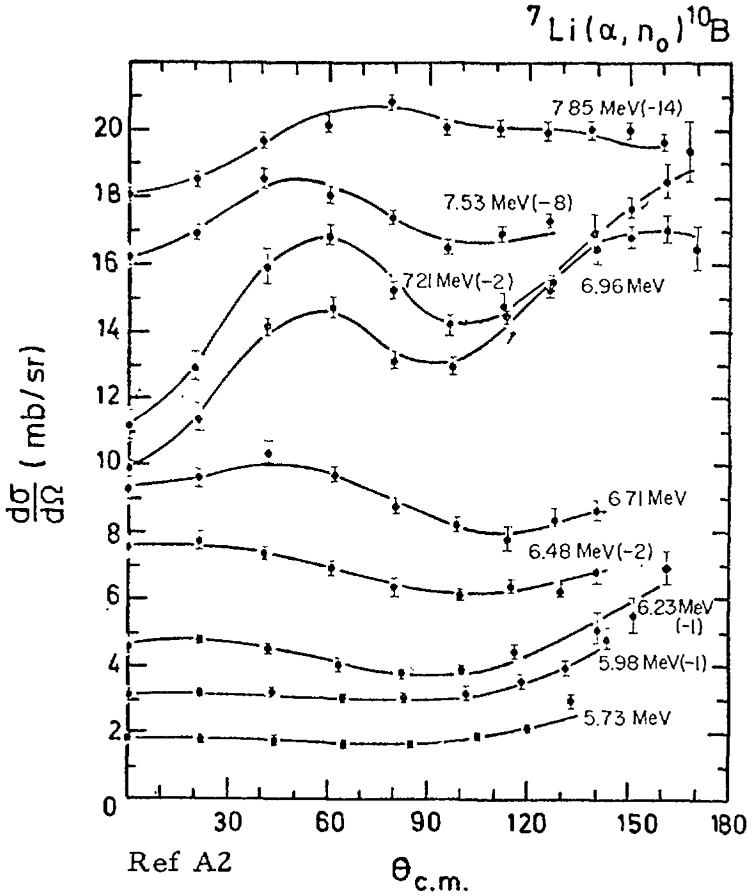
$^7Li(\alpha,n)^{10}B$
σ (mb)
200
150
100
50
n₀
n₁
5
6
7
8
E_α (MeV)

Ref A2

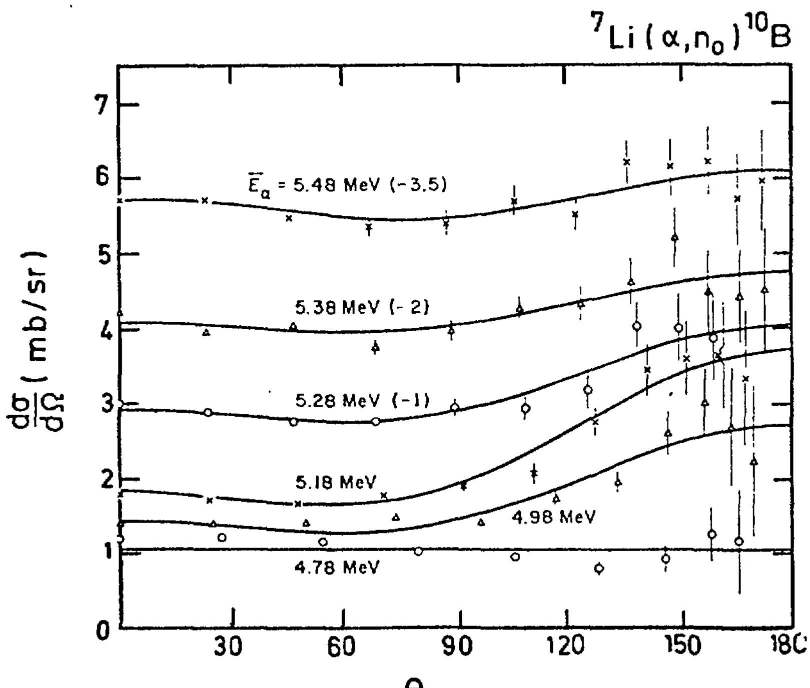


$^7Li(\alpha,n)^{10}B$
$\frac{d\sigma}{d\Omega}(0°)$ (mb/sr)
20
15
10
5
n₁
n₀
n₂
5.0
6.0
7.0
8.0
E_α (MeV)

Ref A2

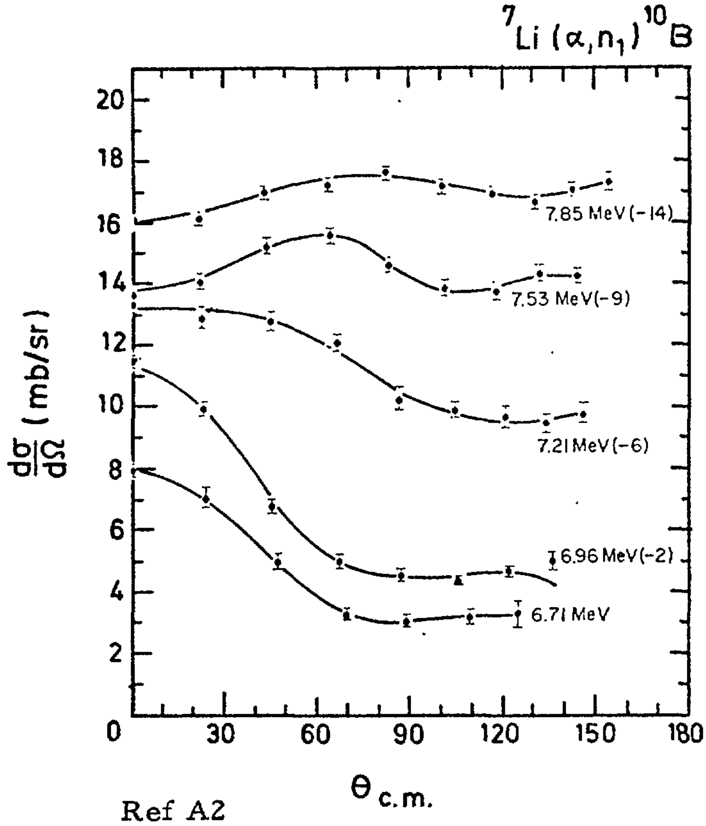


Ref A2

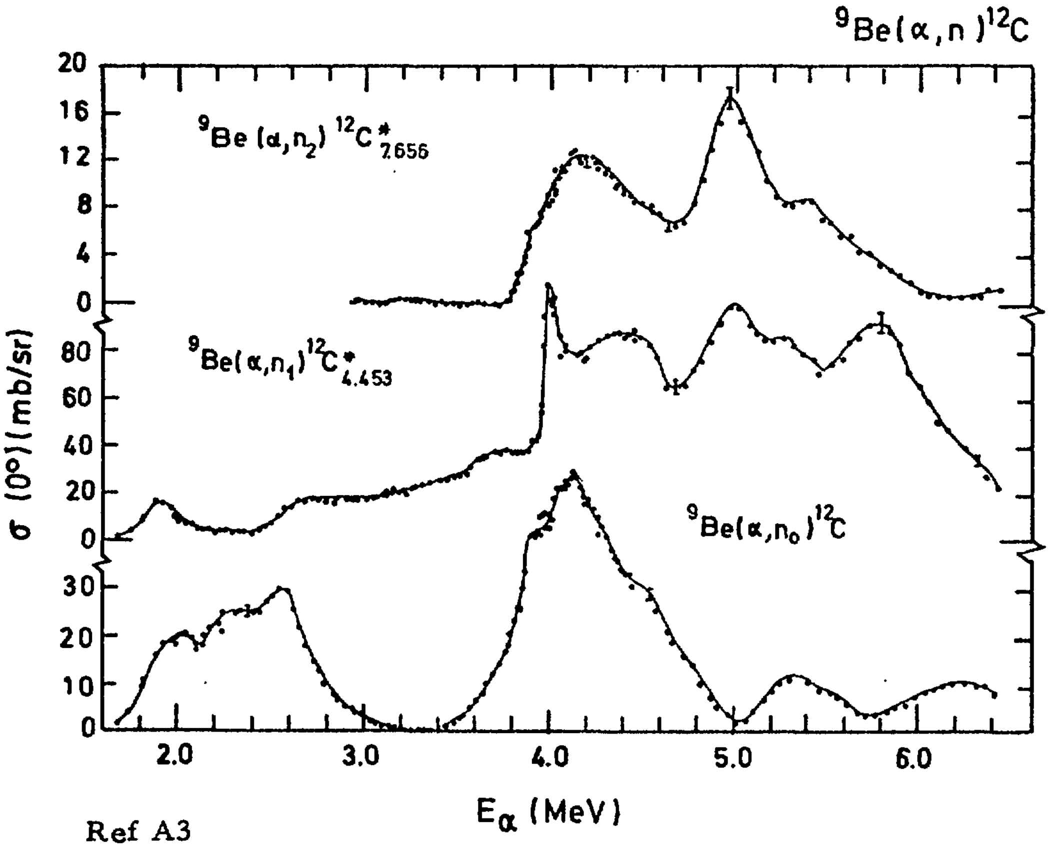


Ref A2

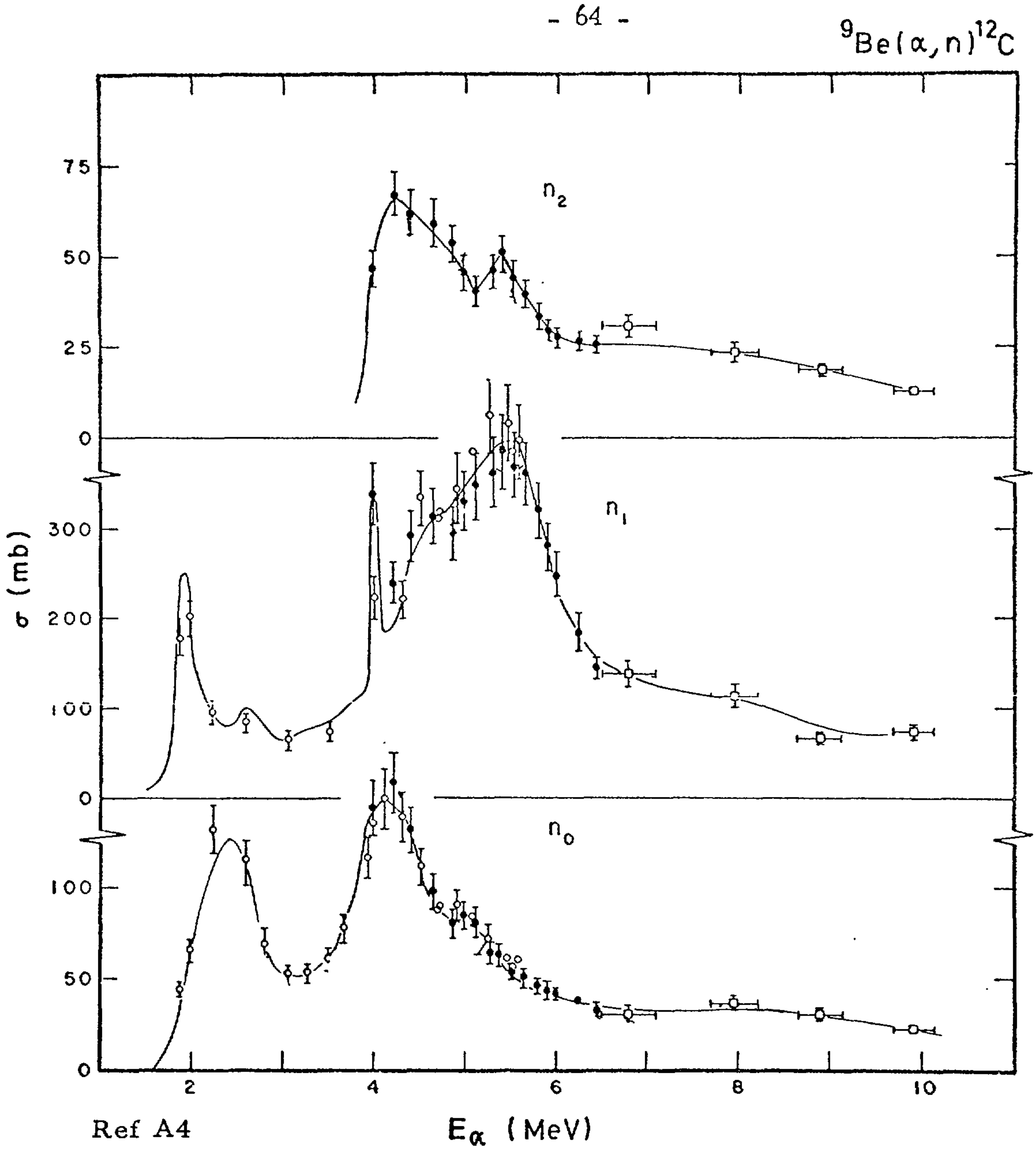
For clarity some curves have been raised by the number in mb/sr in brackets.



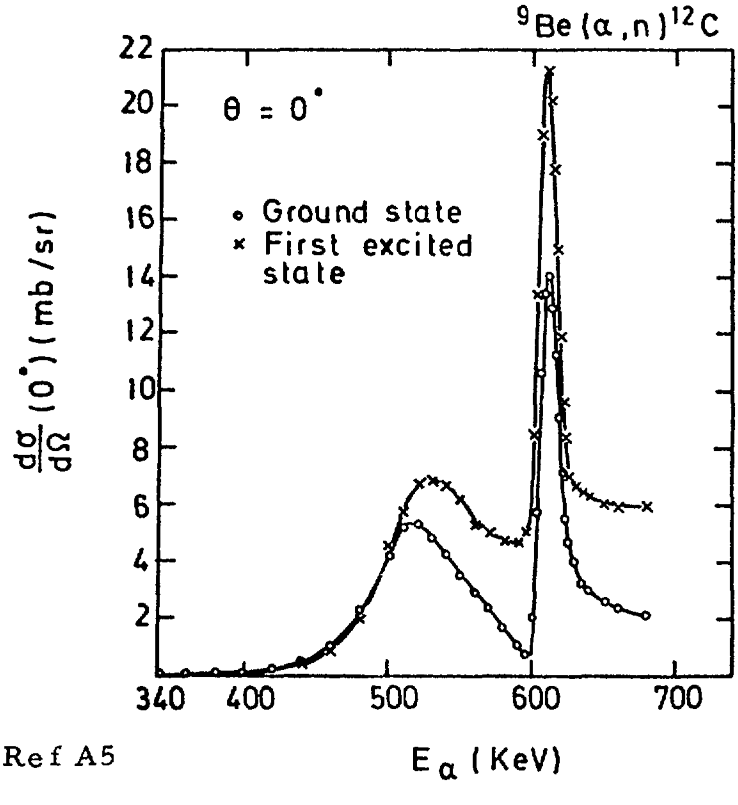
Ref A2
For clarity some curves have been raised by the number in mb/sr in brackets.



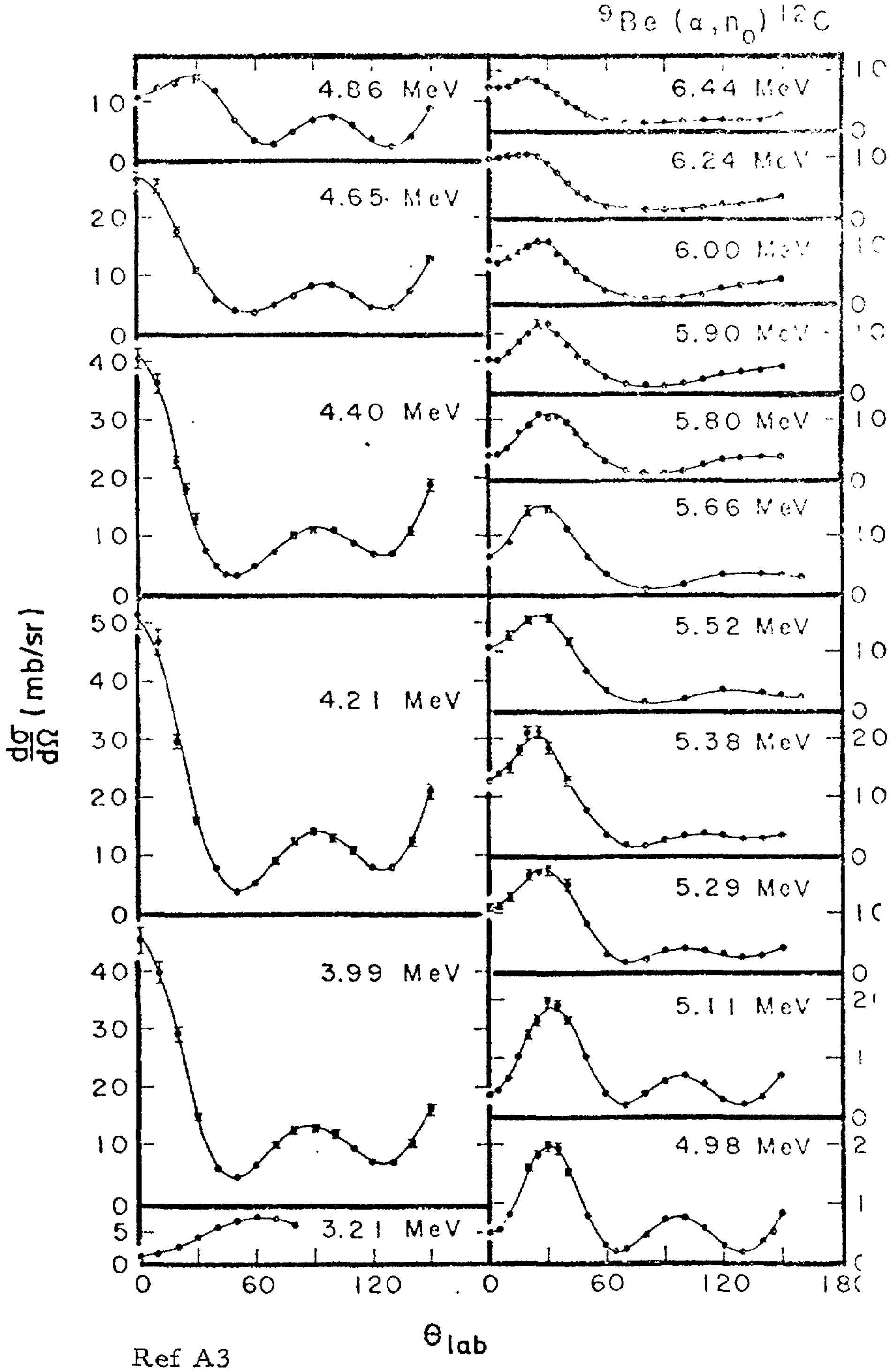
Ref A3


$^9Be(\alpha,n)^{12}C$
n_2
n_1
n_0
σ (mb)
75
50
25
0
300
200
100
0
100
50
0
2
4
6
8
10
E_α (MeV)

Ref A4

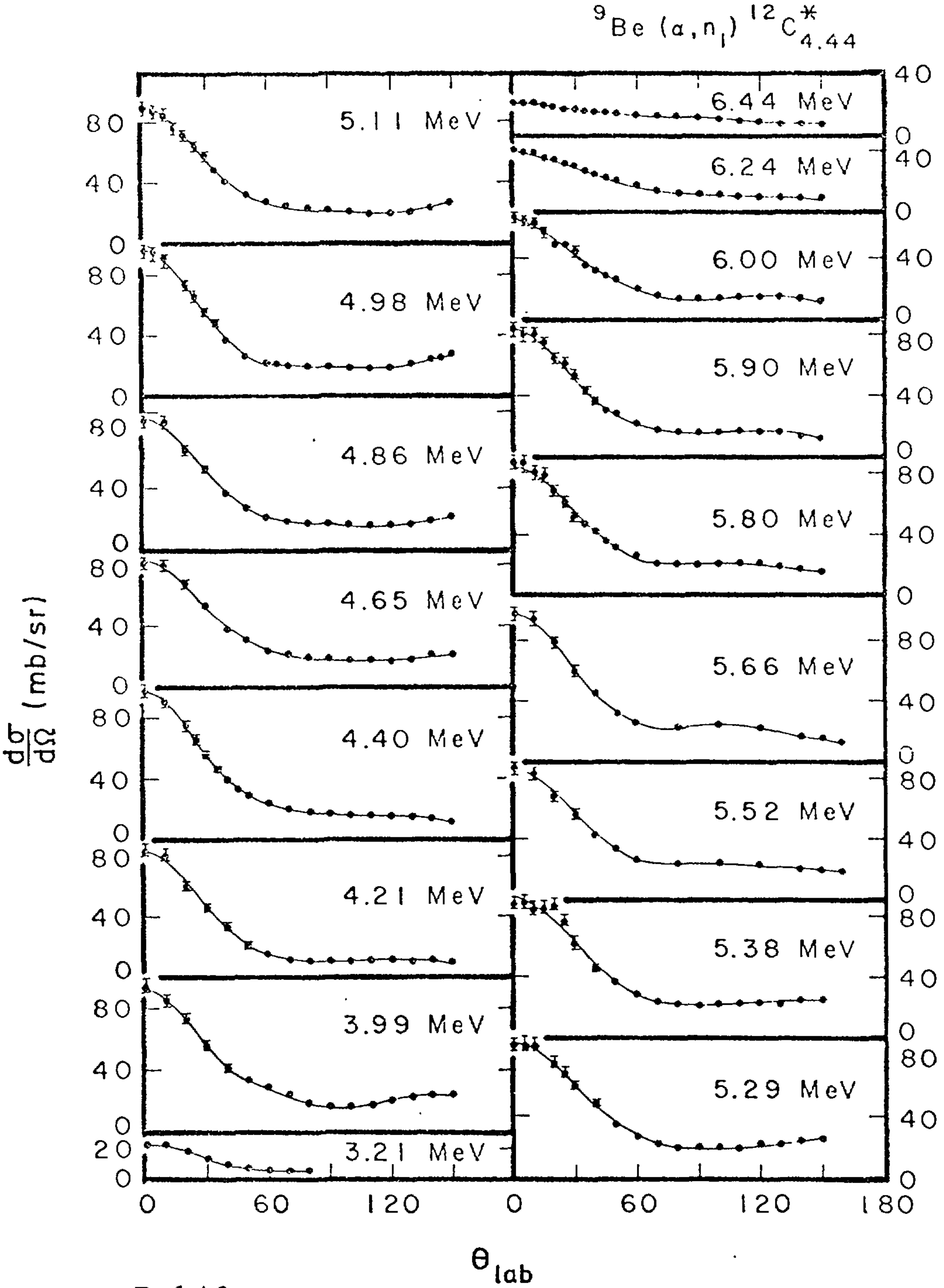

$^9Be(\alpha,n)^{12}C$
θ = 0°
∘ Ground state
× First excited state
$\frac{d\sigma}{d\Omega}(0^\circ)$ (mb/sr)
22
20
18
16
14
12
10
8
6
4
2
340
400
500
600
700
E_α (KeV)

Ref A5



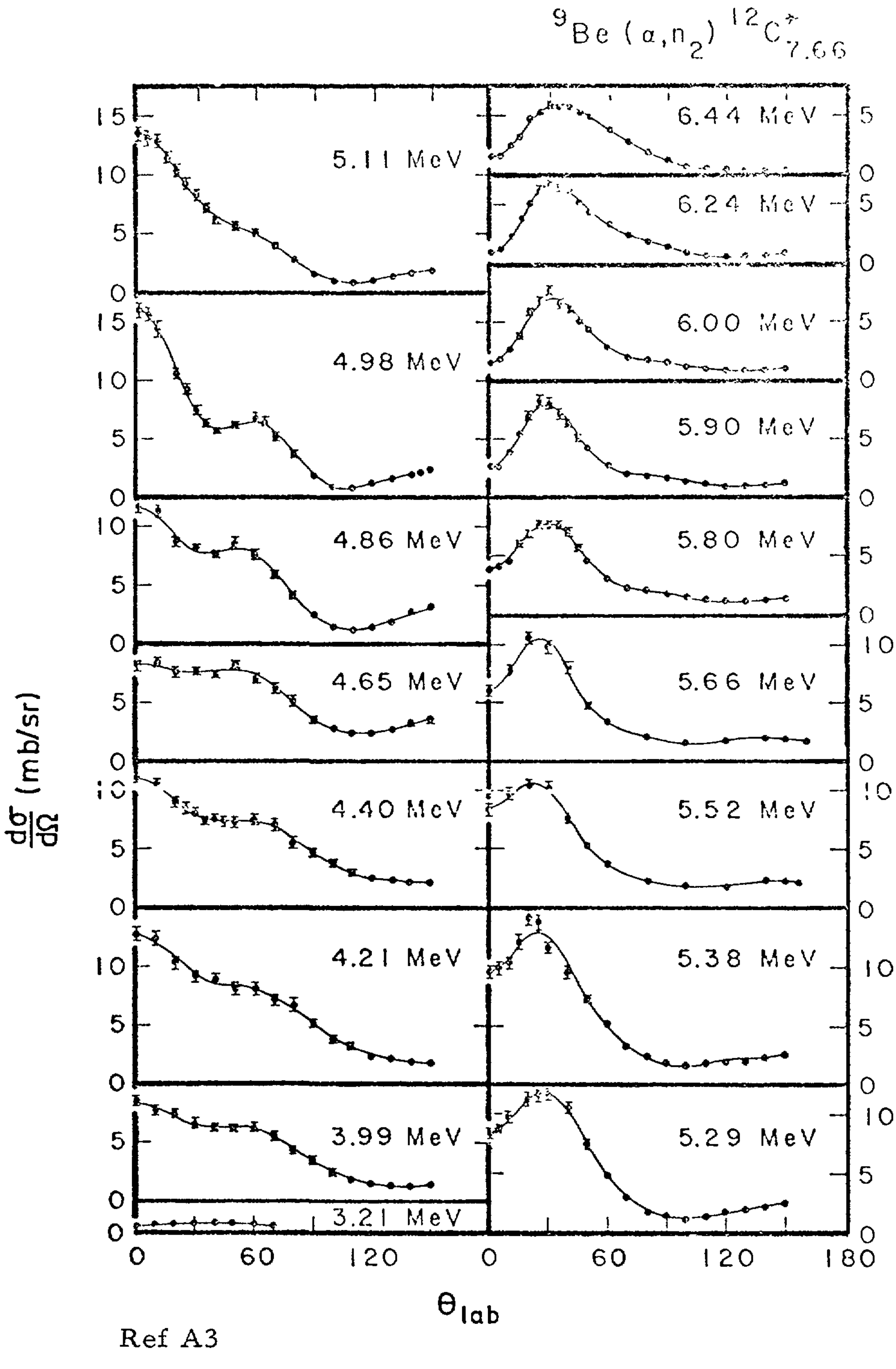
$^{9}Be(\alpha, n_0)^{12}C$
4.86 MeV
4.65 MeV
4.40 MeV
4.21 MeV
3.99 MeV
3.21 MeV
6.44 MeV
6.24 MeV
6.00 MeV
5.90 MeV
5.80 MeV
5.66 MeV
5.52 MeV
5.38 MeV
5.29 MeV
5.11 MeV
4.98 MeV
$\frac{d\sigma}{d\Omega}$ (mb/sr)
θ_{lab}

Ref A3



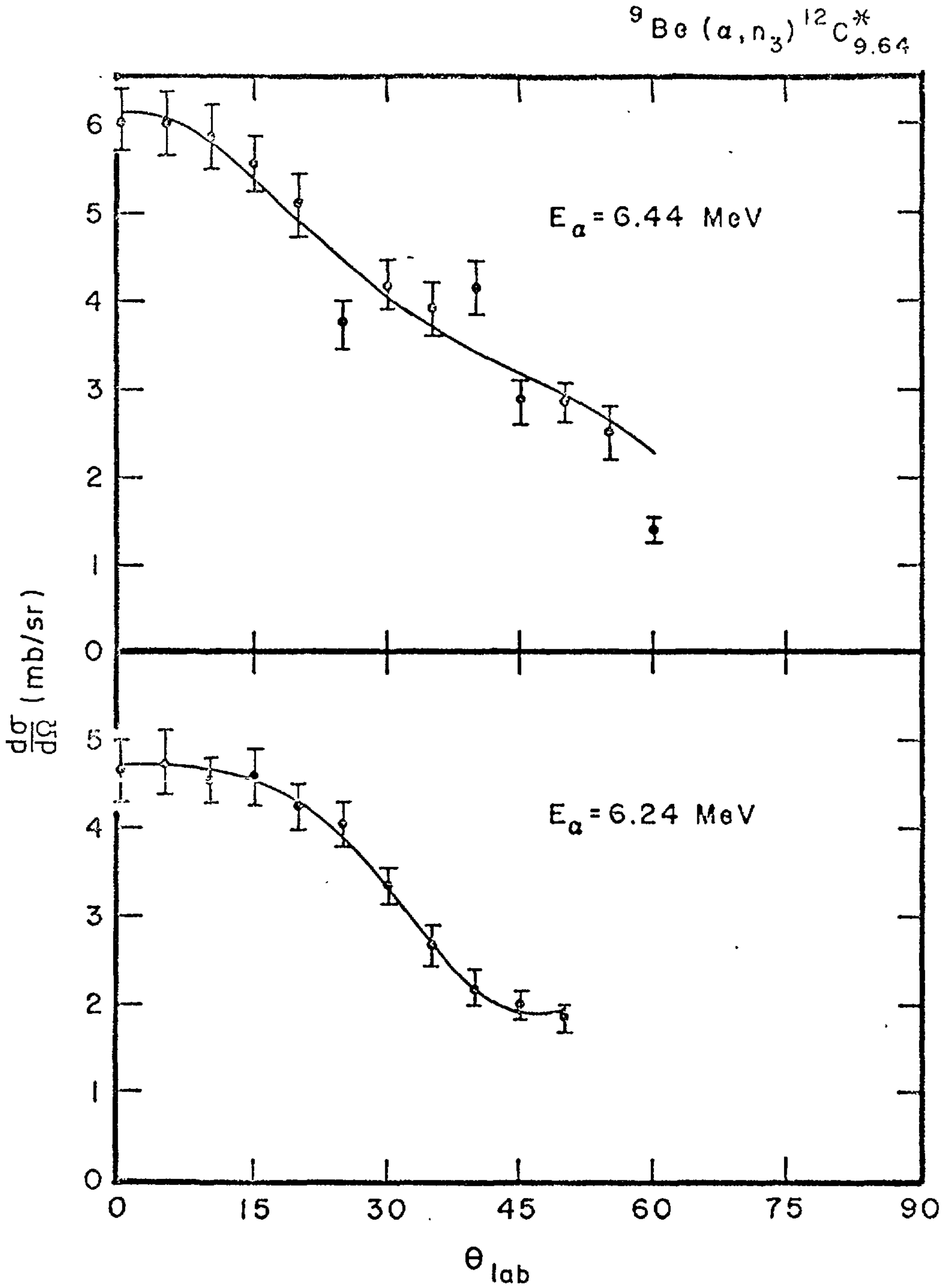
$^9Be\ (\alpha, n_1)\ ^{12}C^*_{4.44}$
6.44 MeV
6.24 MeV
6.00 MeV
5.90 MeV
5.80 MeV
5.66 MeV
5.52 MeV
5.38 MeV
5.29 MeV
5.11 MeV
4.98 MeV
4.86 MeV
4.65 MeV
4.40 MeV
4.21 MeV
3.99 MeV
3.21 MeV
dσ/dΩ (mb/sr)
θ lab

Ref A3



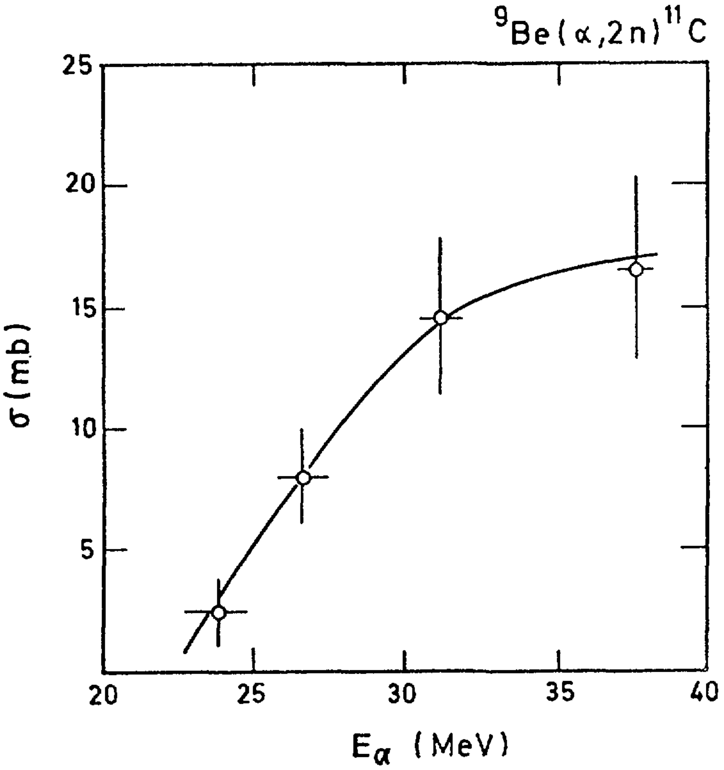
$^9Be(\alpha,n_2)^{12}C^*_{7.66}$
5.11 MeV
4.98 MeV
4.86 MeV
4.65 MeV
4.40 MeV
4.21 MeV
3.99 MeV
3.21 MeV
6.44 MeV
6.24 MeV
6.00 MeV
5.90 MeV
5.80 MeV
5.66 MeV
5.52 MeV
5.38 MeV
5.29 MeV
$\frac{d\sigma}{d\Omega}$ (mb/sr)
θ_{lab}

Ref A3



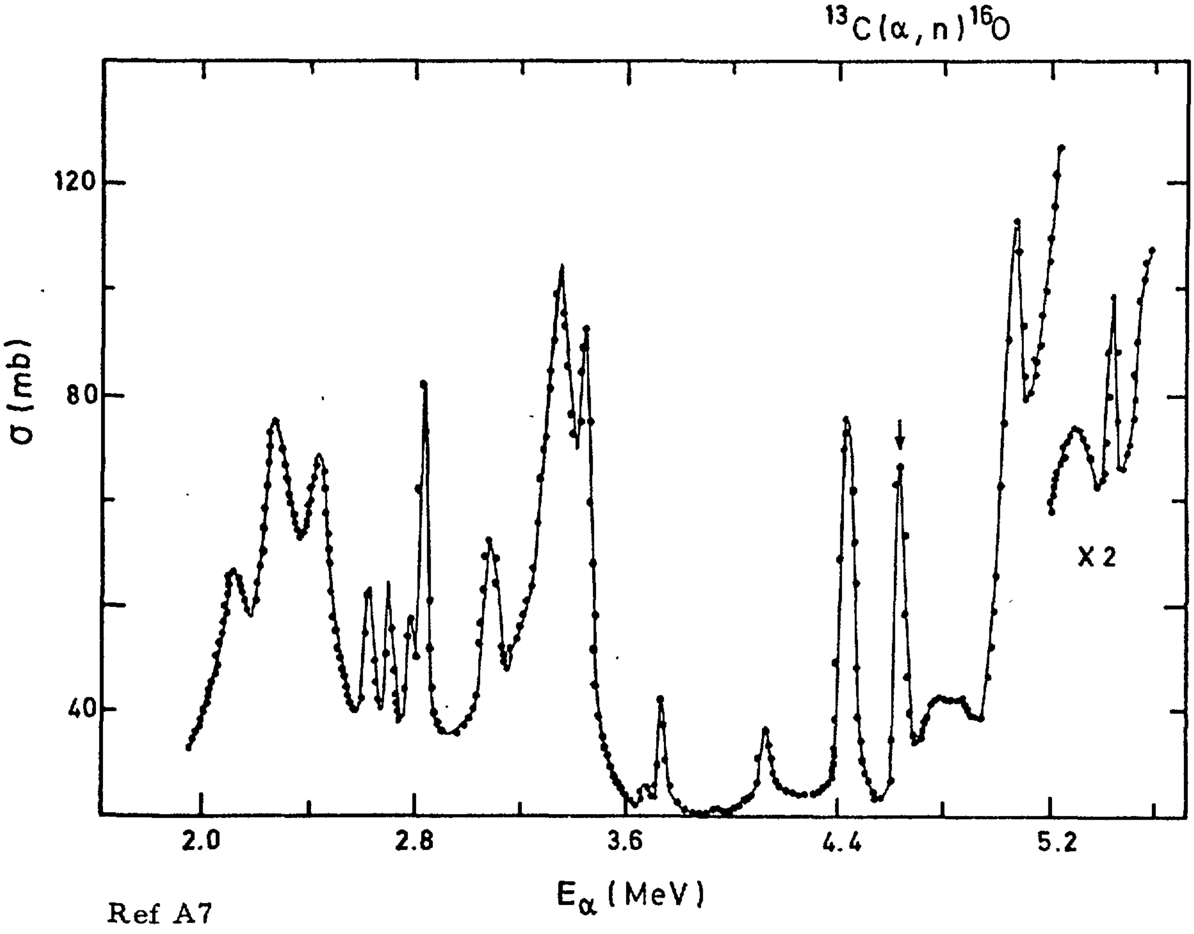
$^9Be(\alpha, n_3)^{12}C^*_{9.64}$
$E_\alpha = 6.44$ MeV
$E_\alpha = 6.24$ MeV
$\frac{d\sigma}{d\Omega}$ (mb/sr)
θ_{lab}
0
1
2
3
4
5
6
15
30
45
60
75
90

Ref A3



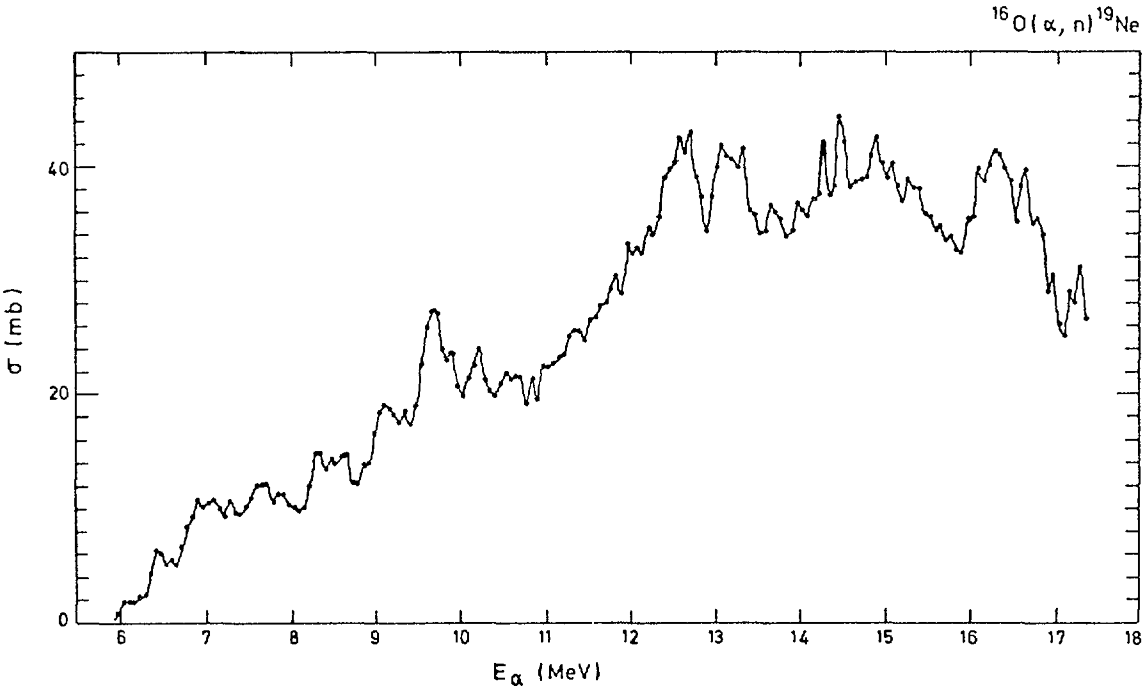
$^9Be(\alpha,2n)^{11}C$
25
20
15
10
5
σ (mb)
20
25
30
35
40
E_α (MeV)

Ref A6



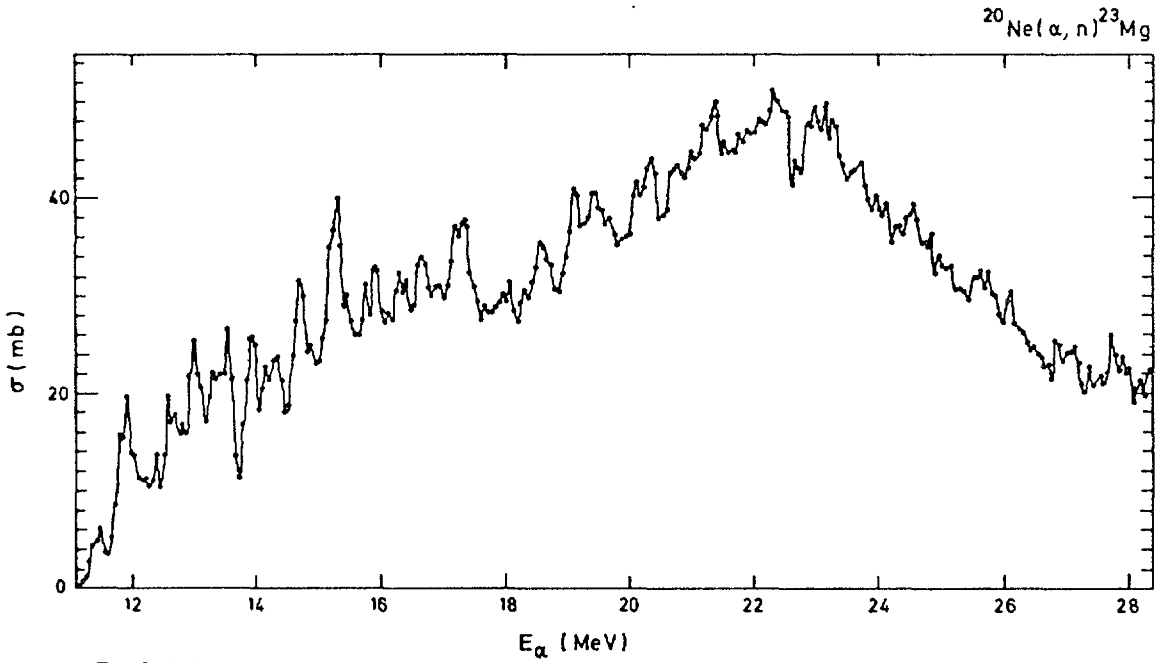
$^{13}C(\alpha,n)^{16}O$
120
80
40
σ (mb)
X 2
2.0
2.8
3.6
4.4
5.2
E_α (MeV)

Ref A7



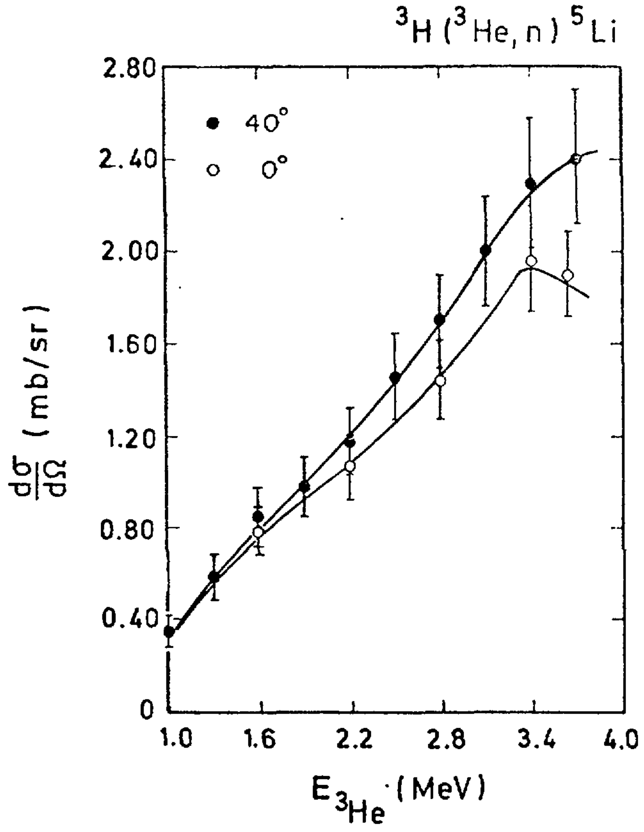
$^{16}O(\alpha, n)^{19}Ne$
σ (mb)
0
20
40
6
7
8
9
10
11
12
13
14
15
16
17
18
E_α (MeV)

Ref A8



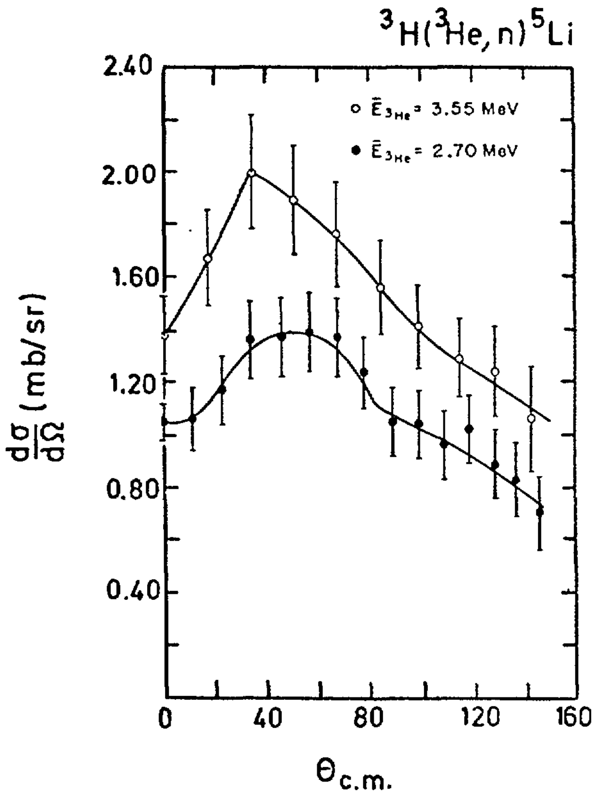
$^{20}Ne(\alpha, n)^{23}Mg$
σ (mb)
0
20
40
12
14
16
18
20
22
24
26
28
E_α (MeV)

Ref A8



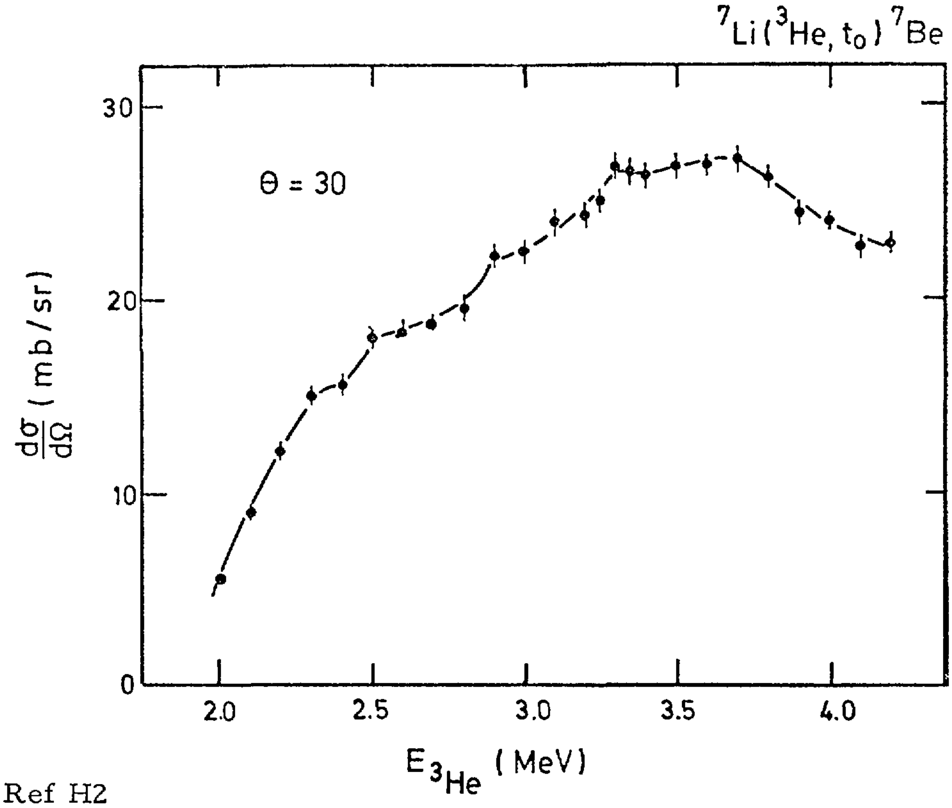
$^3H(^3He,n)^5Li$
40°
0°
2.80
2.40
2.00
1.60
1.20
0.80
0.40
0
1.0
1.6
2.2
2.8
3.4
4.0
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$E_{^3He}$ (MeV)

Ref H1

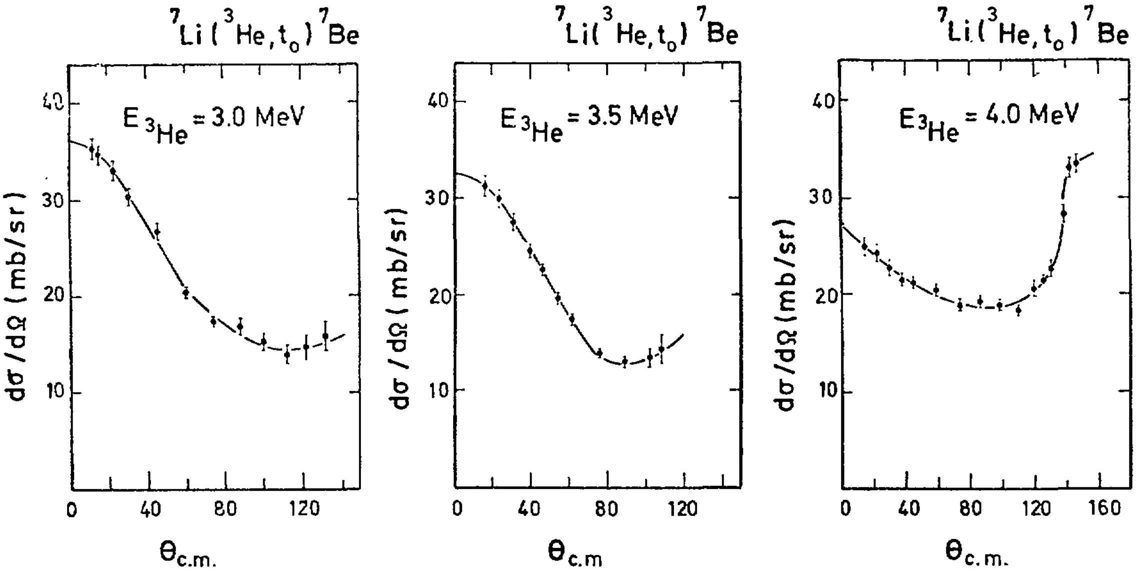


$^3H(^3He,n)^5Li$
$\bar{E}_{^3He}$ = 3.55 MeV
$\bar{E}_{^3He}$ = 2.70 MeV
2.40
2.00
1.60
1.20
0.80
0.40
0
40
80
120
160
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$\theta_{c.m.}$

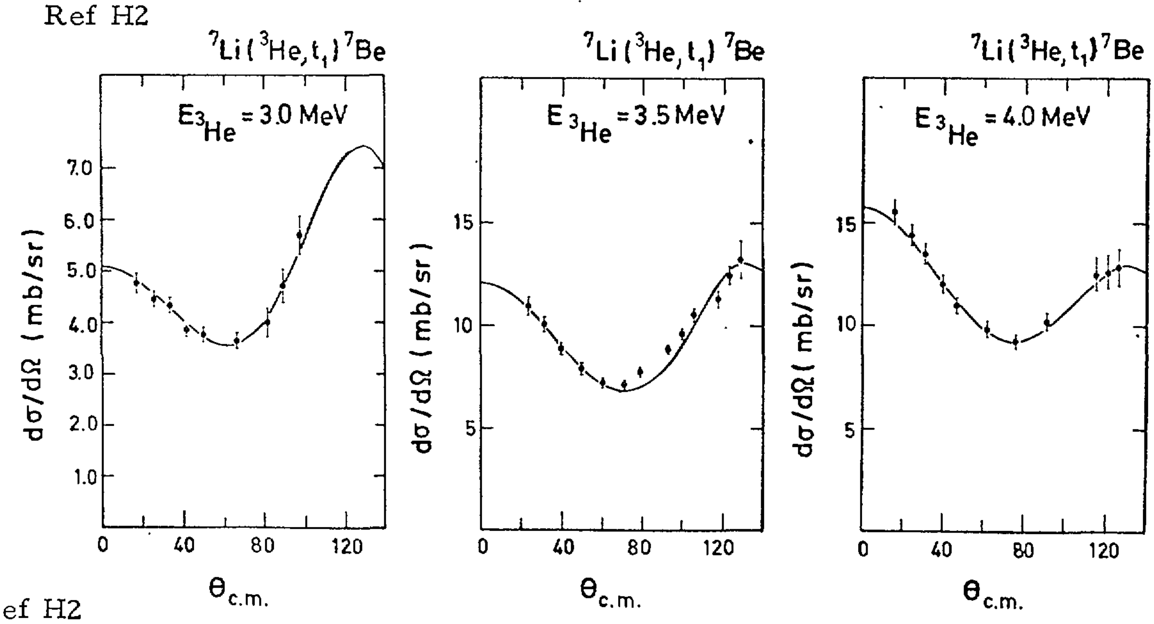
Ref H1



Ref H2

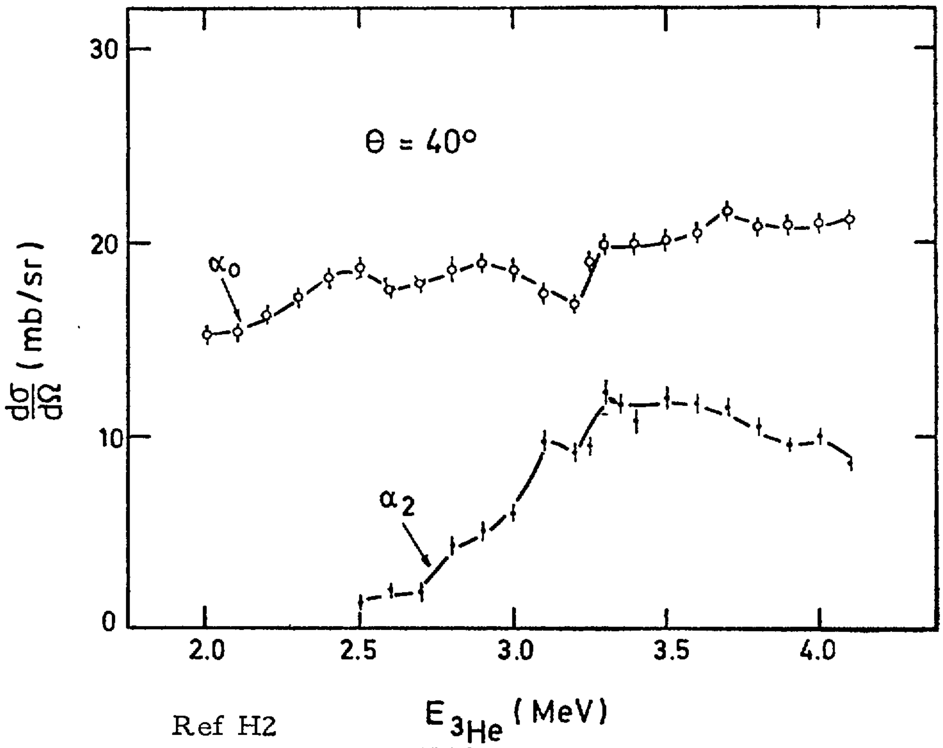


Ref H2



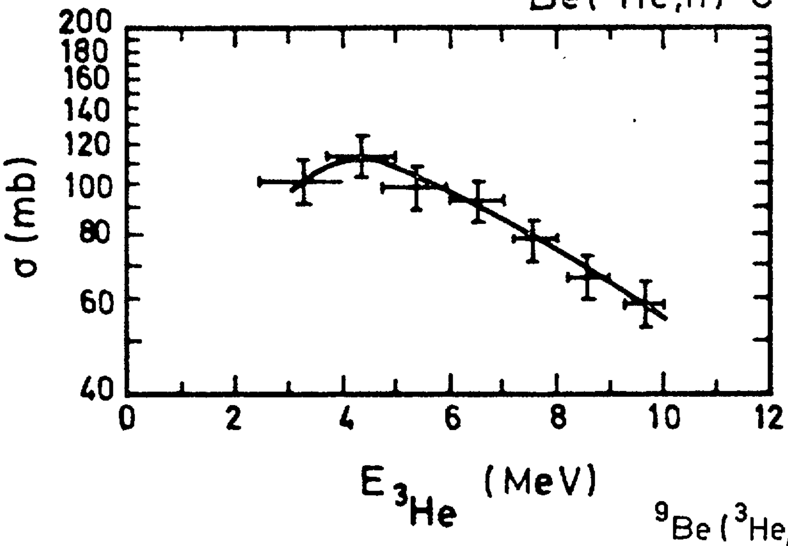
Ref H2

$^{7}Li(^{3}He,\alpha)^{6}Li$

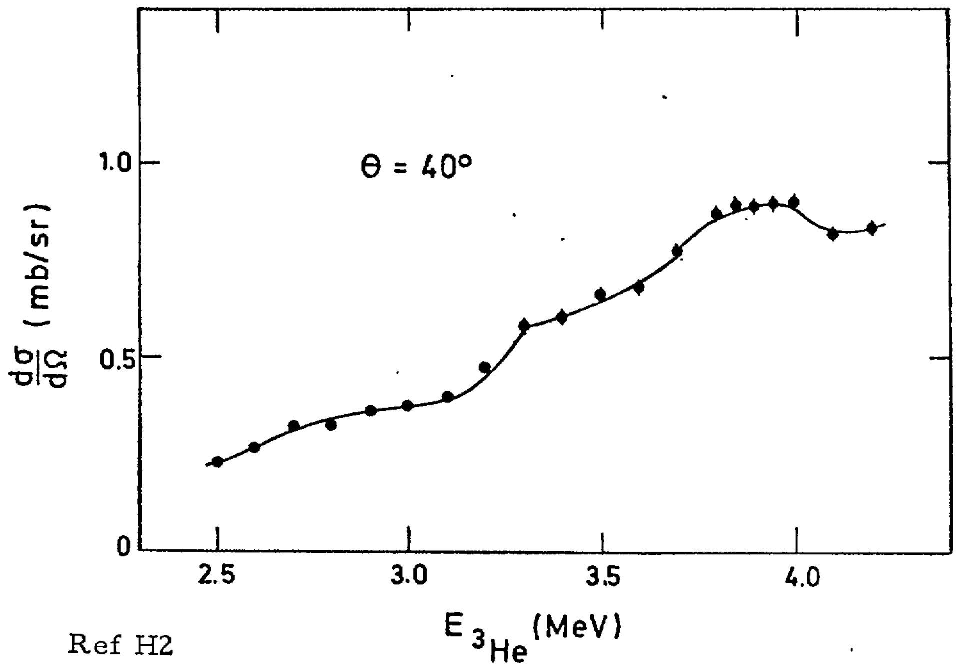


Ref H2

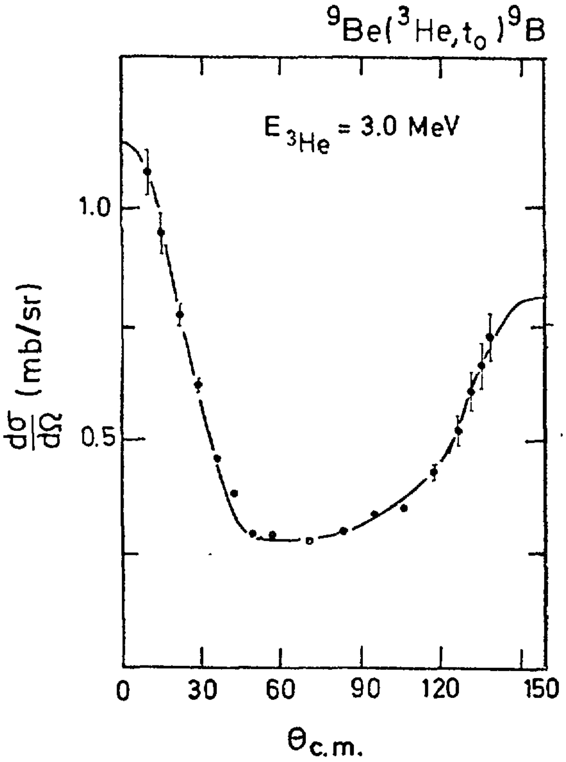
$^{9}Be(^{3}He,n)^{11}C$



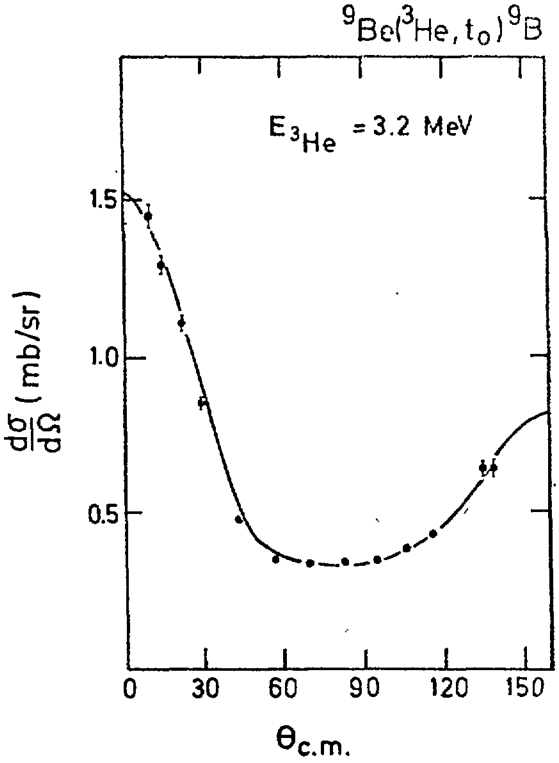
$^{9}Be(^{3}He,t_0)^{9}B$



Ref H2

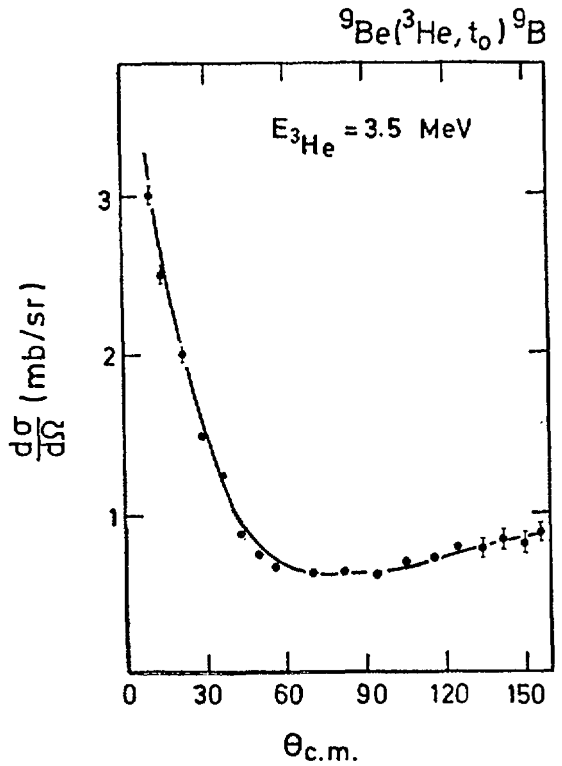


$^{9}Be(^{3}He,t_{0})^{9}B$
$E_{^3He}$ = 3.0 MeV
1.0
0.5
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0
30
60
90
120
150
$\theta_{c.m.}$

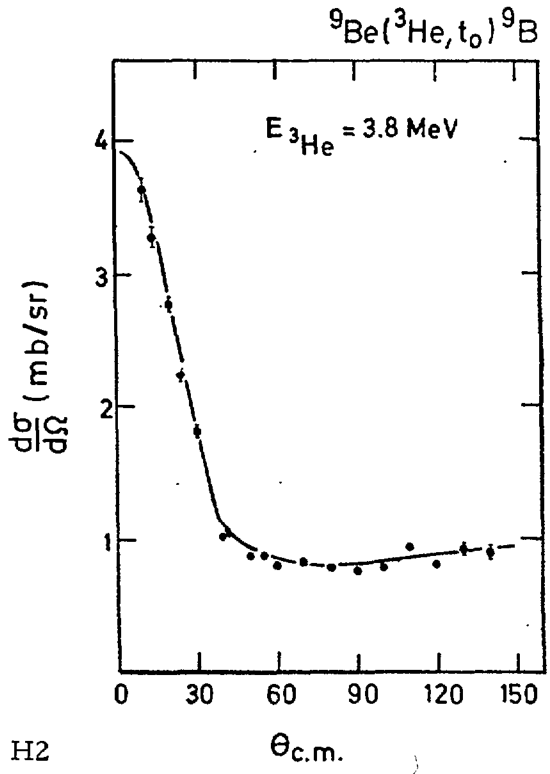


$^{9}Be(^{3}He,t_{0})^{9}B$
$E_{^3He}$ = 3.2 MeV
1.5
1.0
0.5
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0
30
60
90
120
150
$\theta_{c.m.}$

Ref H2

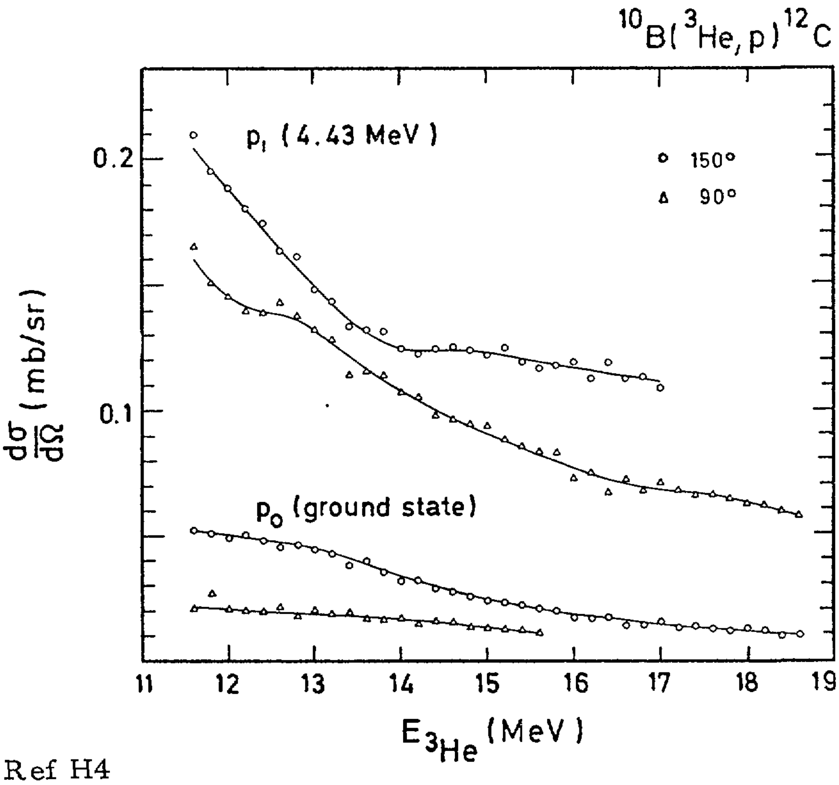


$^{9}Be(^{3}He,t_{0})^{9}B$
$E_{^3He}$ = 3.5 MeV
3
2
1
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0
30
60
90
120
150
$\theta_{c.m.}$



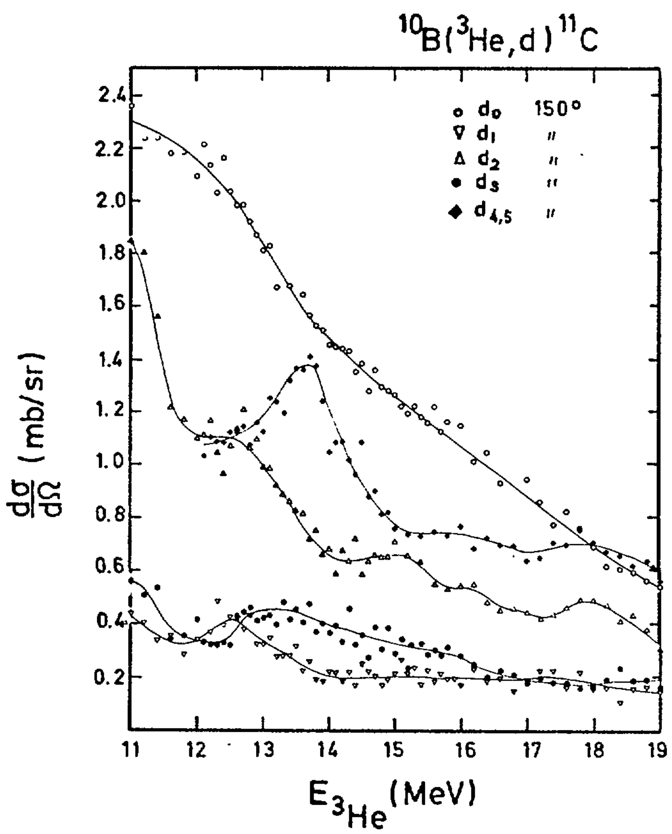
$^{9}Be(^{3}He,t_{0})^{9}B$
$E_{^3He}$ = 3.8 MeV
4
3
2
1
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0
30
60
90
120
150
$\theta_{c.m.}$

Ref H2



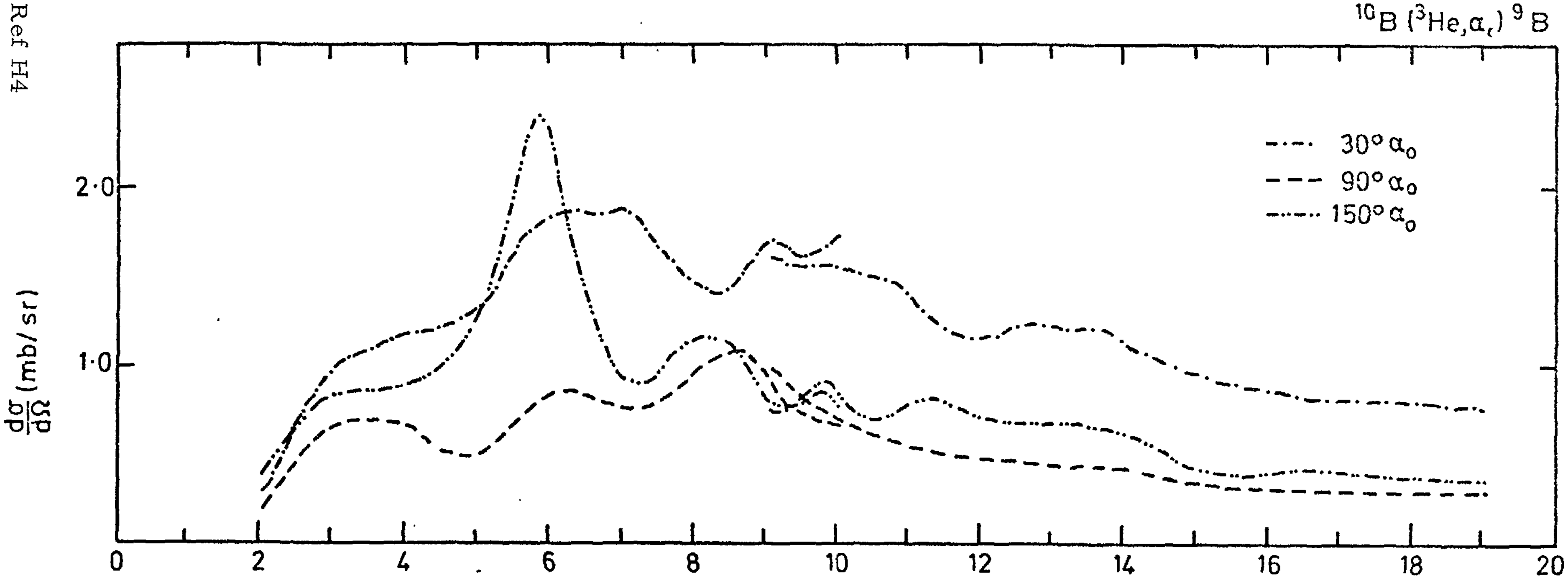
$^{10}B(^3He,p)^{12}C$
p_1 (4.43 MeV)
150°
90°
p_0 (ground state)
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0.2
0.1
11
12
13
14
15
16
17
18
19
$E_{^3He}$ (MeV)

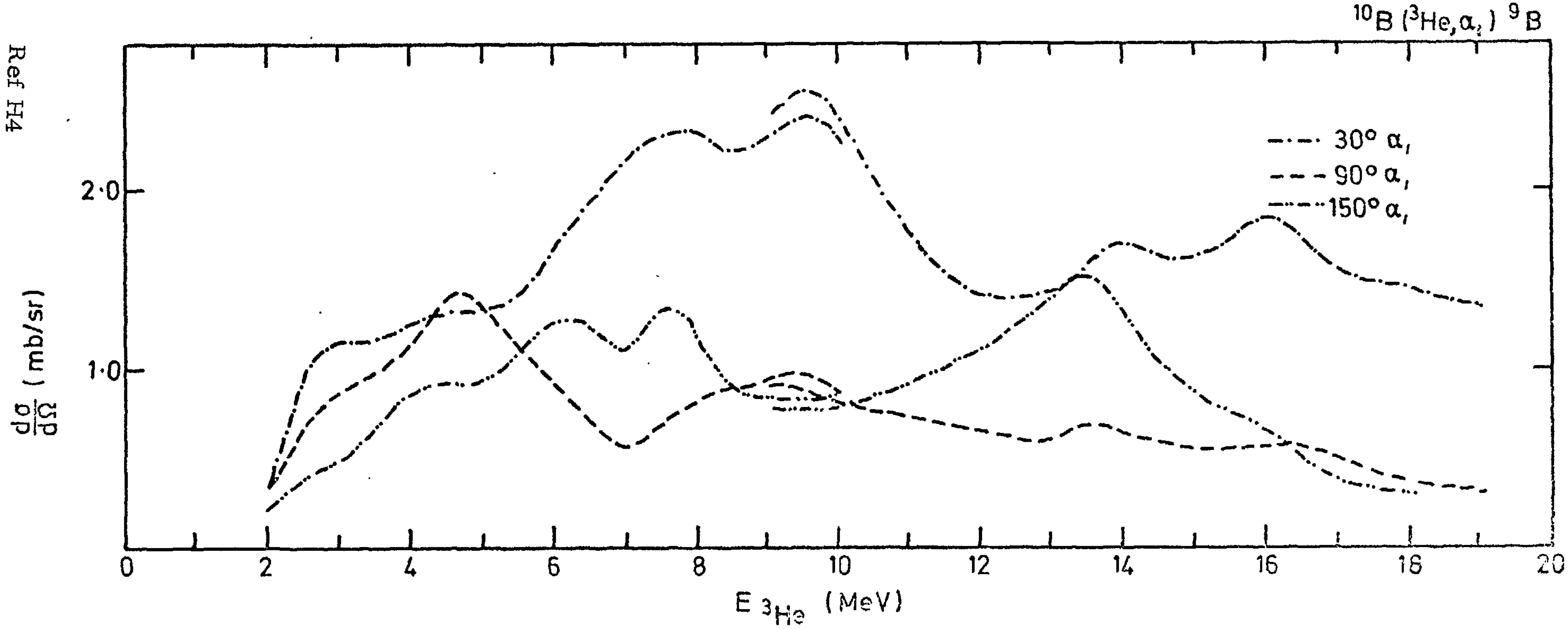
Ref H4

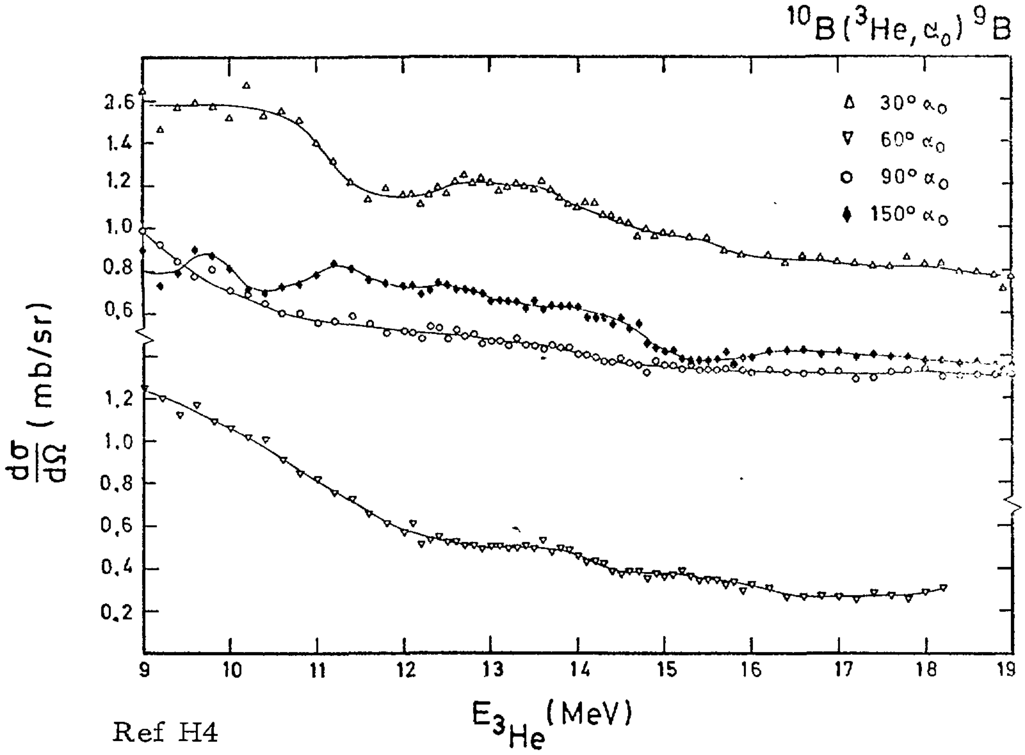


$^{10}B(^3He,d)^{11}C$
d_0 150°
d_1 "
d_2 "
d_3 "
$d_{4,5}$ "
$\frac{d\sigma}{d\Omega}$ (mb/sr)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
11
12
13
14
15
16
17
18
19
$E_{^3He}$ (MeV)

Ref H4

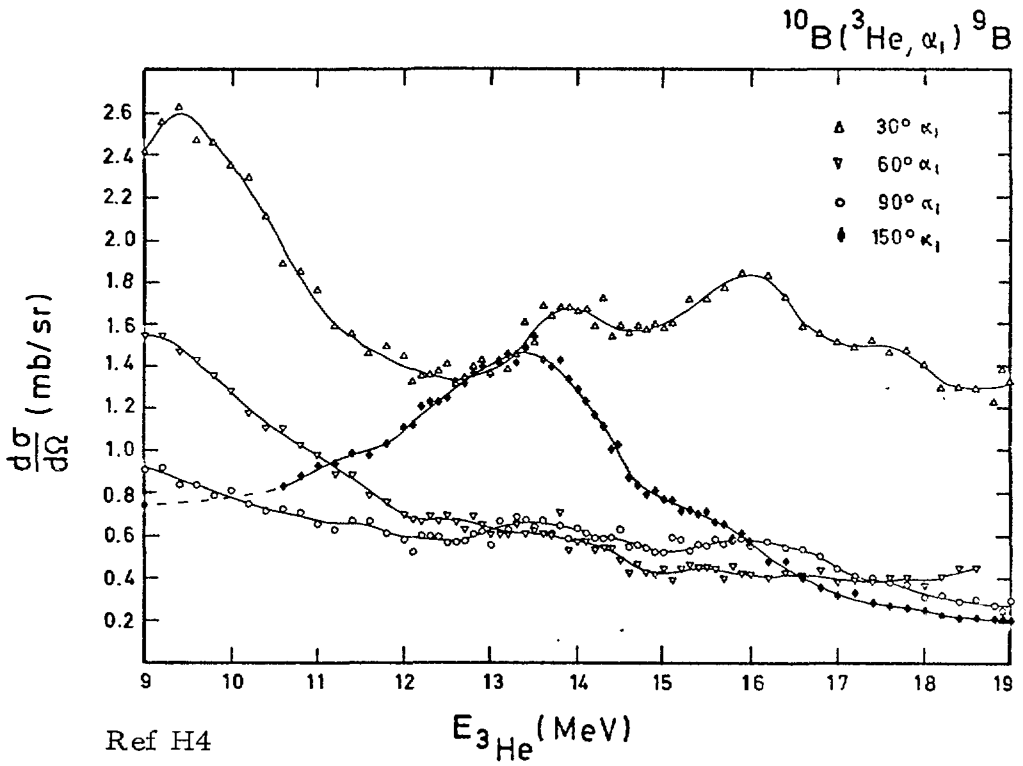

Ref H4
$^{10}B(^3He,\alpha_0)^9B$
30° α_0
90° α_0
150° α_0
$\frac{d\sigma}{d\Omega}$ (mb/sr)
2·0
1·0
0
2
4
6
8
10
12
14
16
18
20


Ref H4
$^{10}B(^3He,\alpha_1)^9B$
30° α_1
90° α_1
150° α_1
$\frac{d\sigma}{d\Omega}$ (mb/sr)
2·0
1·0
0
2
4
6
8
10
12
14
16
18
20
$E_{^3He}$ (MeV)



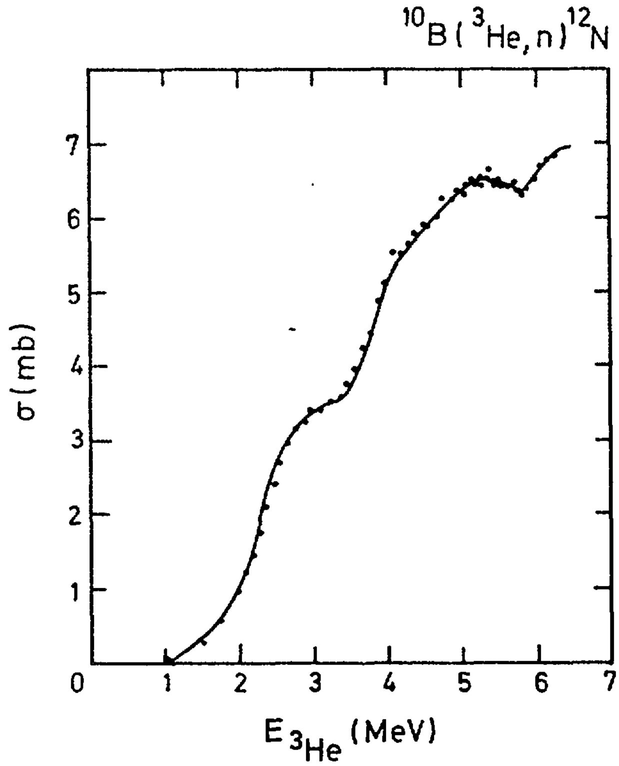
10B(3He,α0)9B
30° α0
60° α0
90° α0
150° α0
dσ/dΩ (mb/sr)
E3He (MeV)

Ref H4



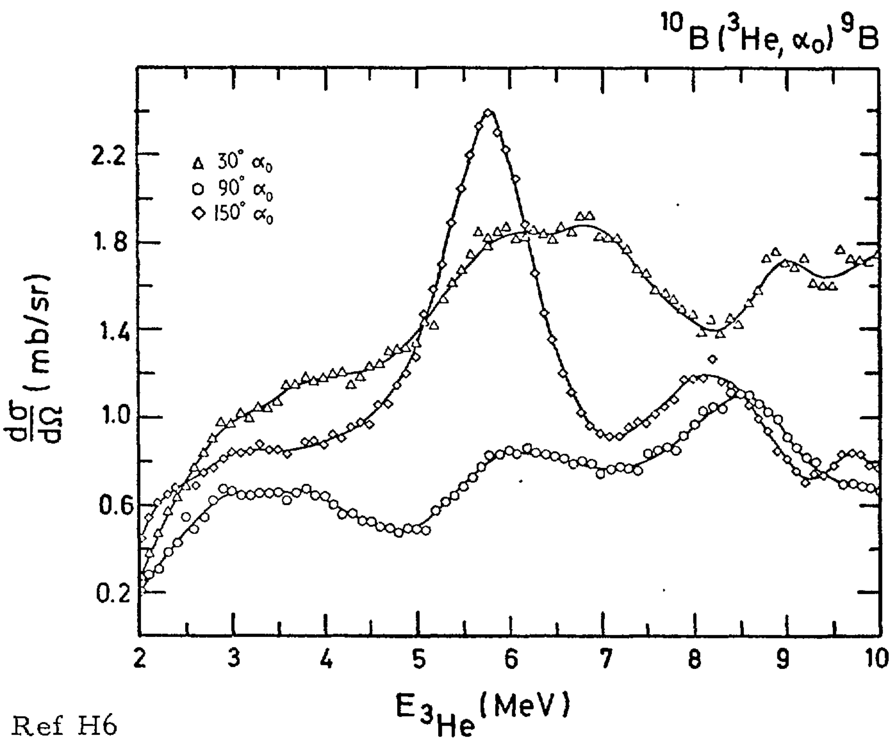
10B(3He,α1)9B
30° α1
60° α1
90° α1
150° α1
dσ/dΩ (mb/sr)
E3He (MeV)

Ref H4



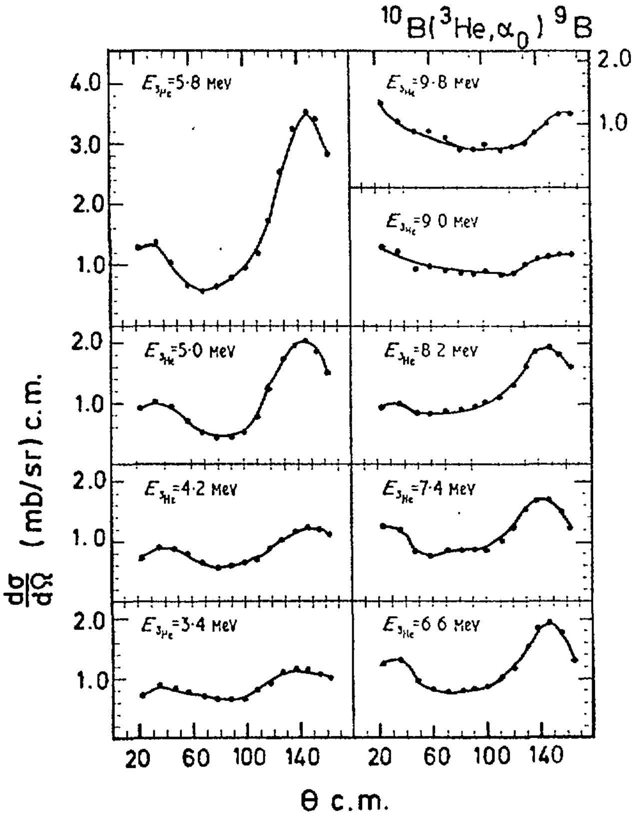
$^{10}B(^{3}He,n)^{12}N$
σ (mb)
$E_{^3He}$ (MeV)

Ref H5

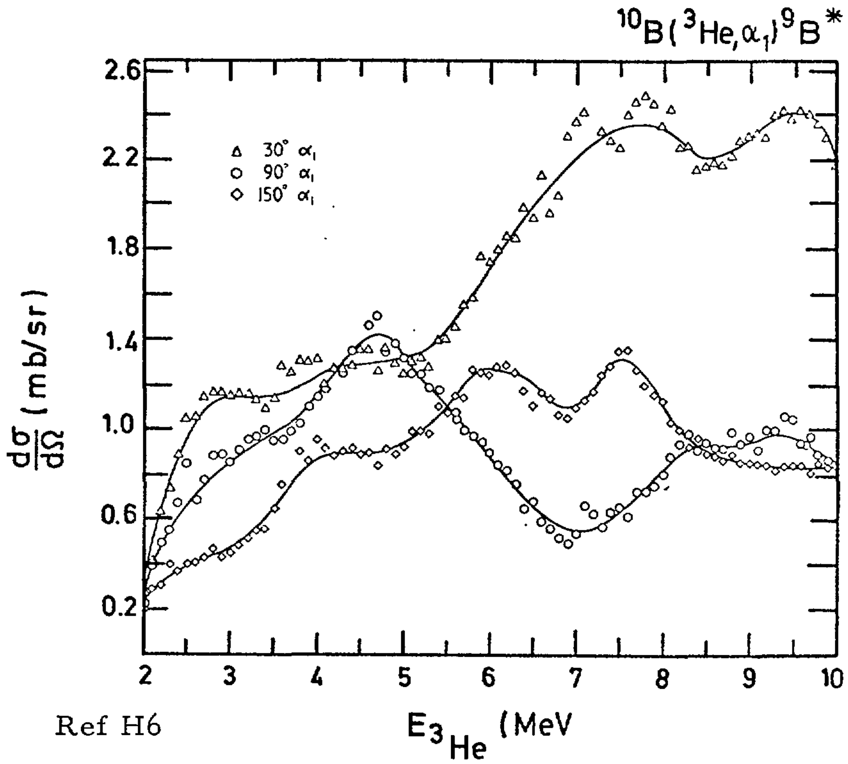


$^{10}B(^{3}He,\alpha_0)^{9}B$
△ 30° α_0
○ 90° α_0
◇ 150° α_0
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$E_{^3He}$ (MeV)

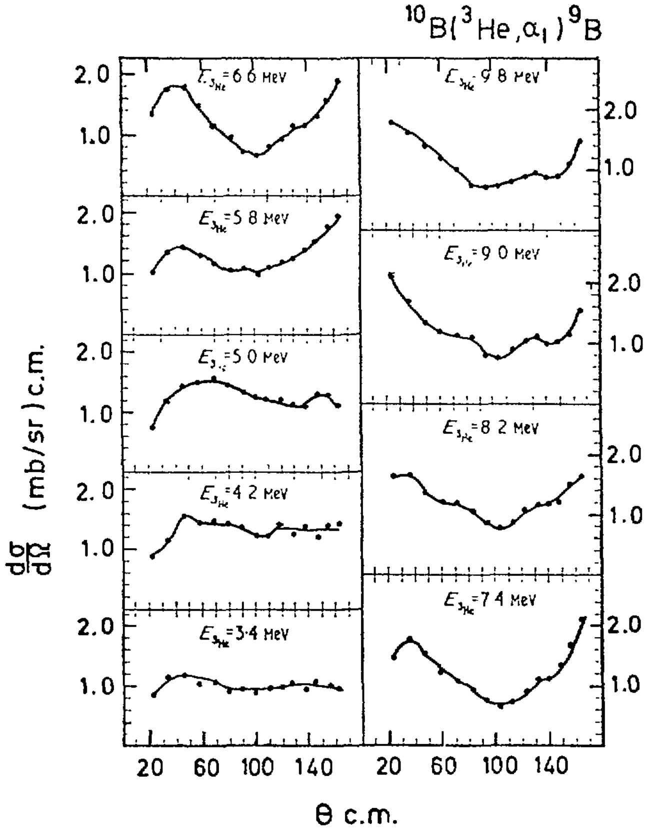
Ref H6


10B(3He,α0) 9B
E3He=5·8 MeV
E3He=9·8 MeV
E3He=9 0 MeV
E3He=5·0 MeV
E3He=8 2 MeV
E3He=4·2 MeV
E3He=7·4 MeV
E3He=3·4 MeV
E3He=6 6 MeV
dσ/dΩ (mb/sr) c.m.
θ c.m.

Ref H6

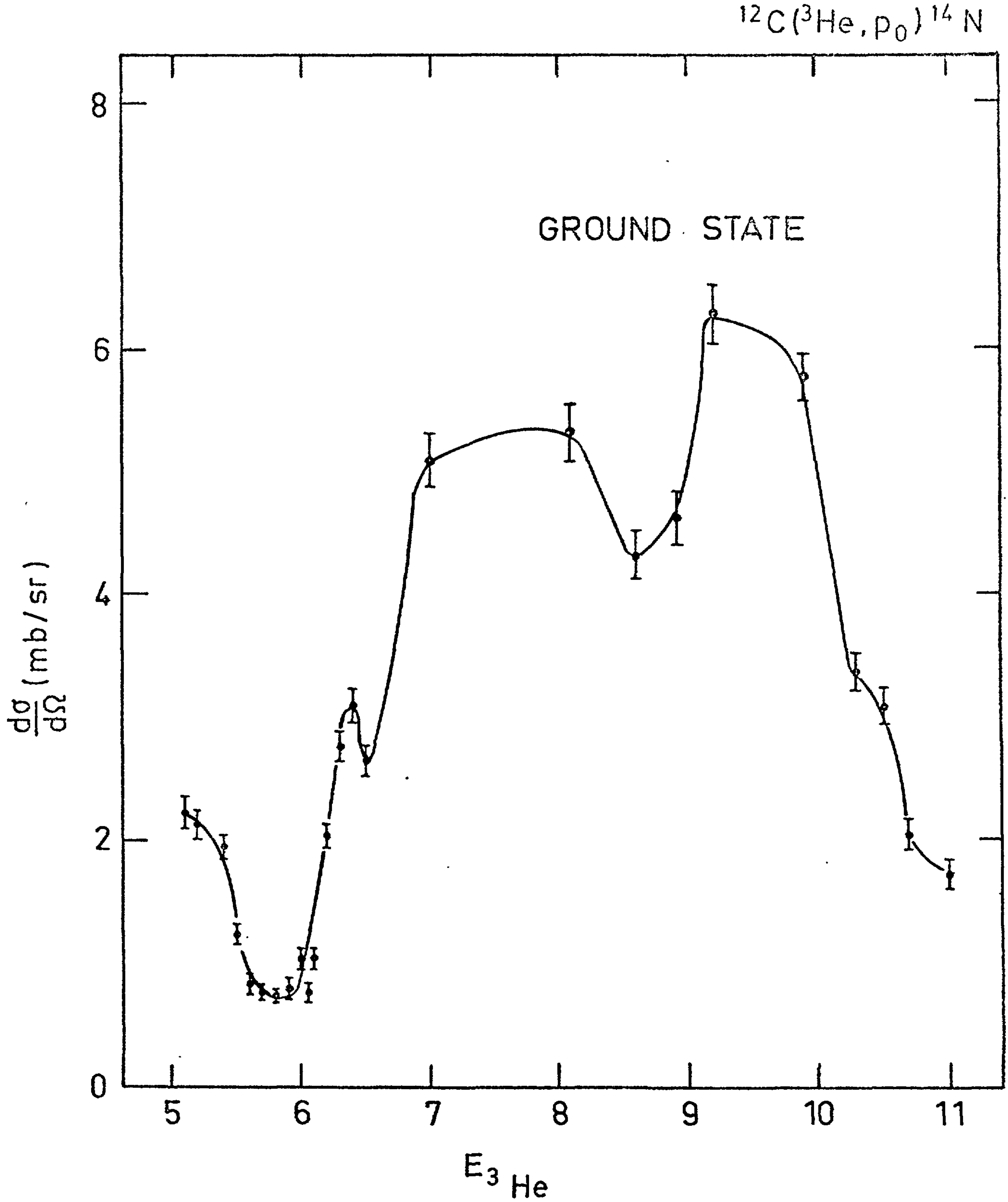

10B(3He,α1)9B*
30° α1
90° α1
150° α1
dσ/dΩ (mb/sr)
E3He (MeV

Ref H6



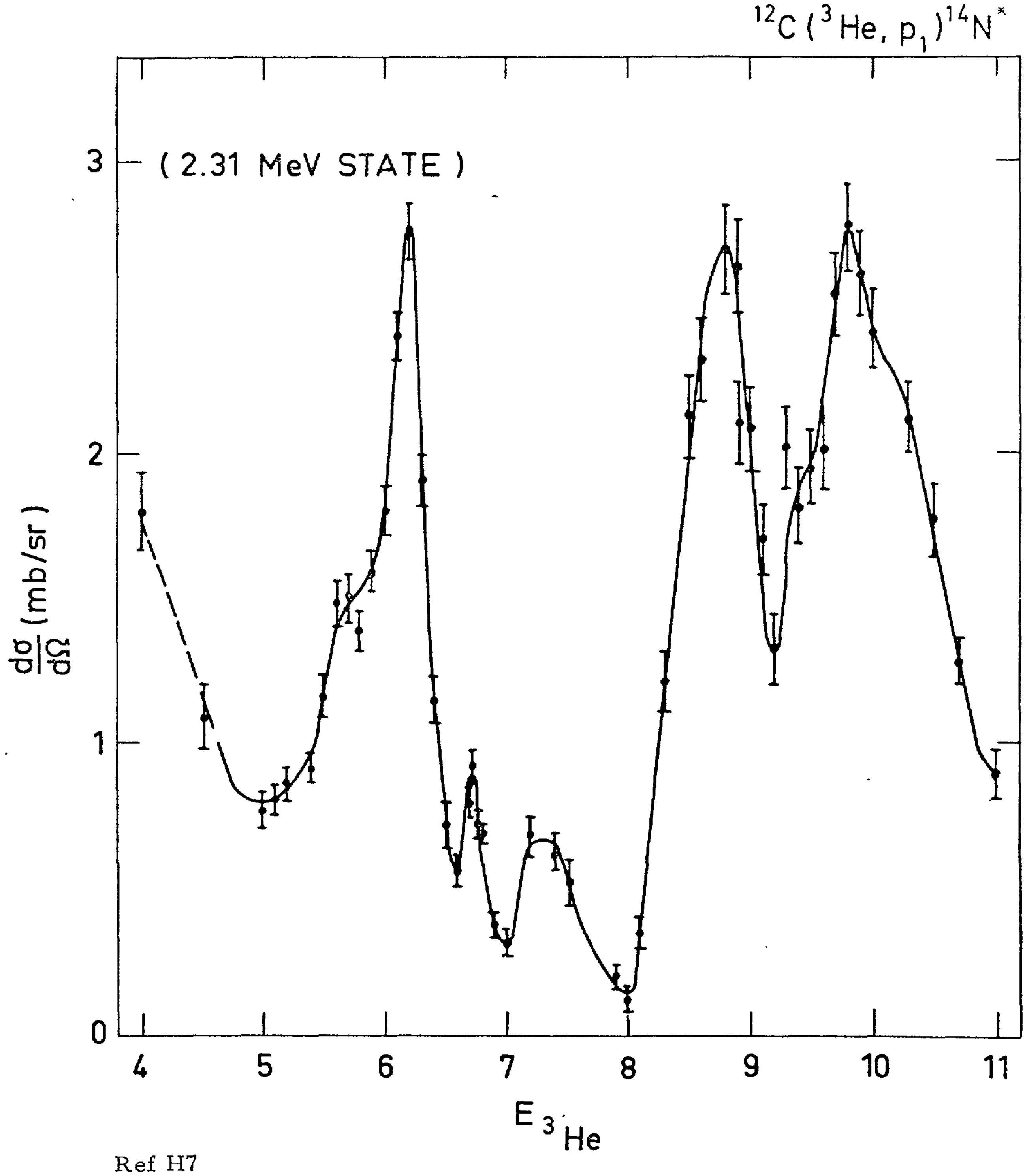
$^{10}B(^3He,\alpha_1)^9B$
$E_{^3He}$=6 0 MeV
$E_{^3He}$=5 8 MeV
$E_{^3He}$=5 0 MeV
$E_{^3He}$=4 2 MeV
$E_{^3He}$=3·4 MeV
$E_{^3He}$=9 8 MeV
$E_{^3He}$=9 0 MeV
$E_{^3He}$=8 2 MeV
$E_{^3He}$=7 4 MeV
2.0
1.0
$\frac{d\sigma}{d\Omega}$ (mb/sr) c.m.
20 60 100 140
θ c.m.

Ref H6



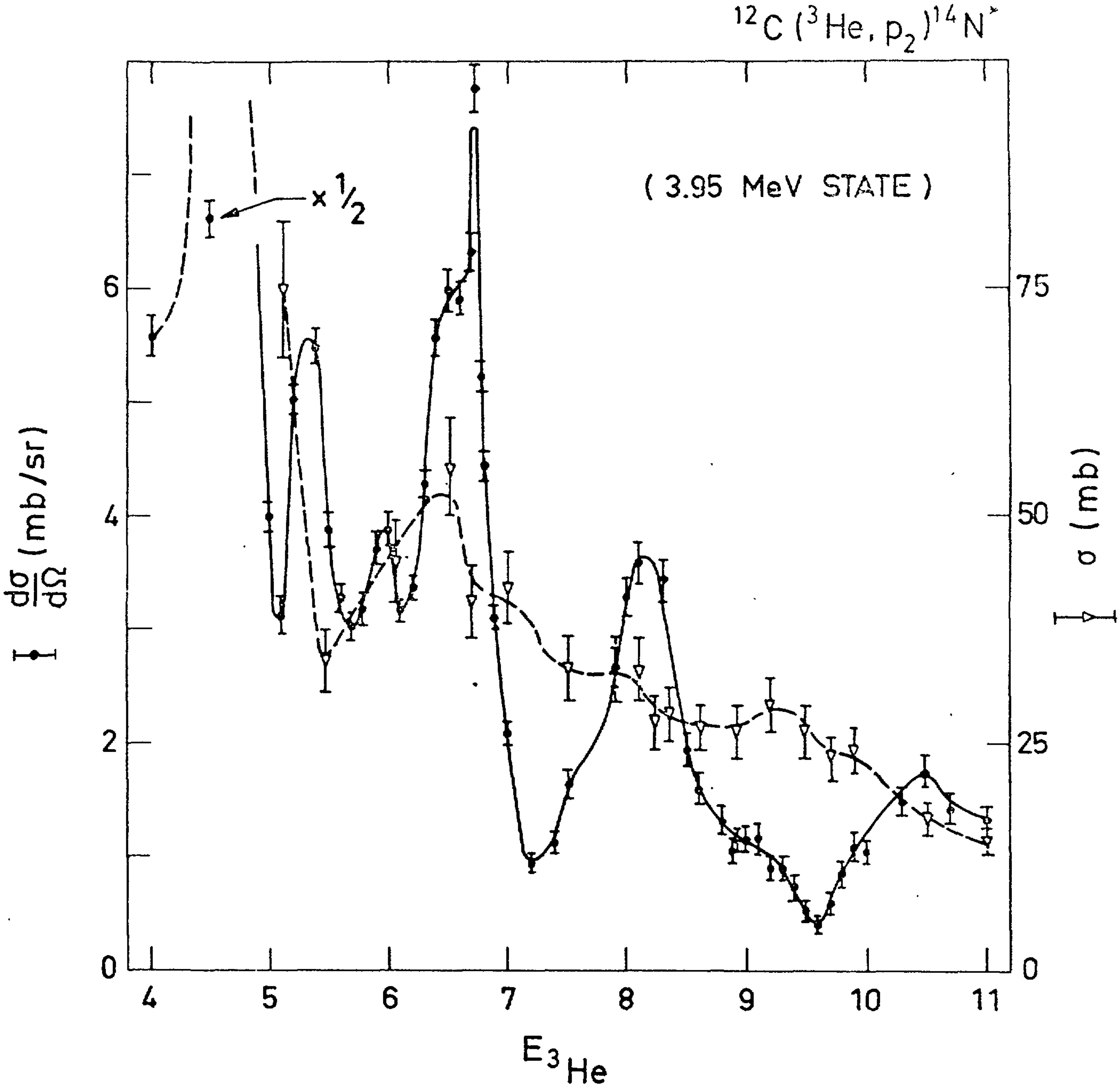
$^{12}C(^3He, p_0)^{14}N$
GROUND STATE
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0
2
4
6
8
5
6
7
8
9
10
11
$E_{^3He}$

Ref H7

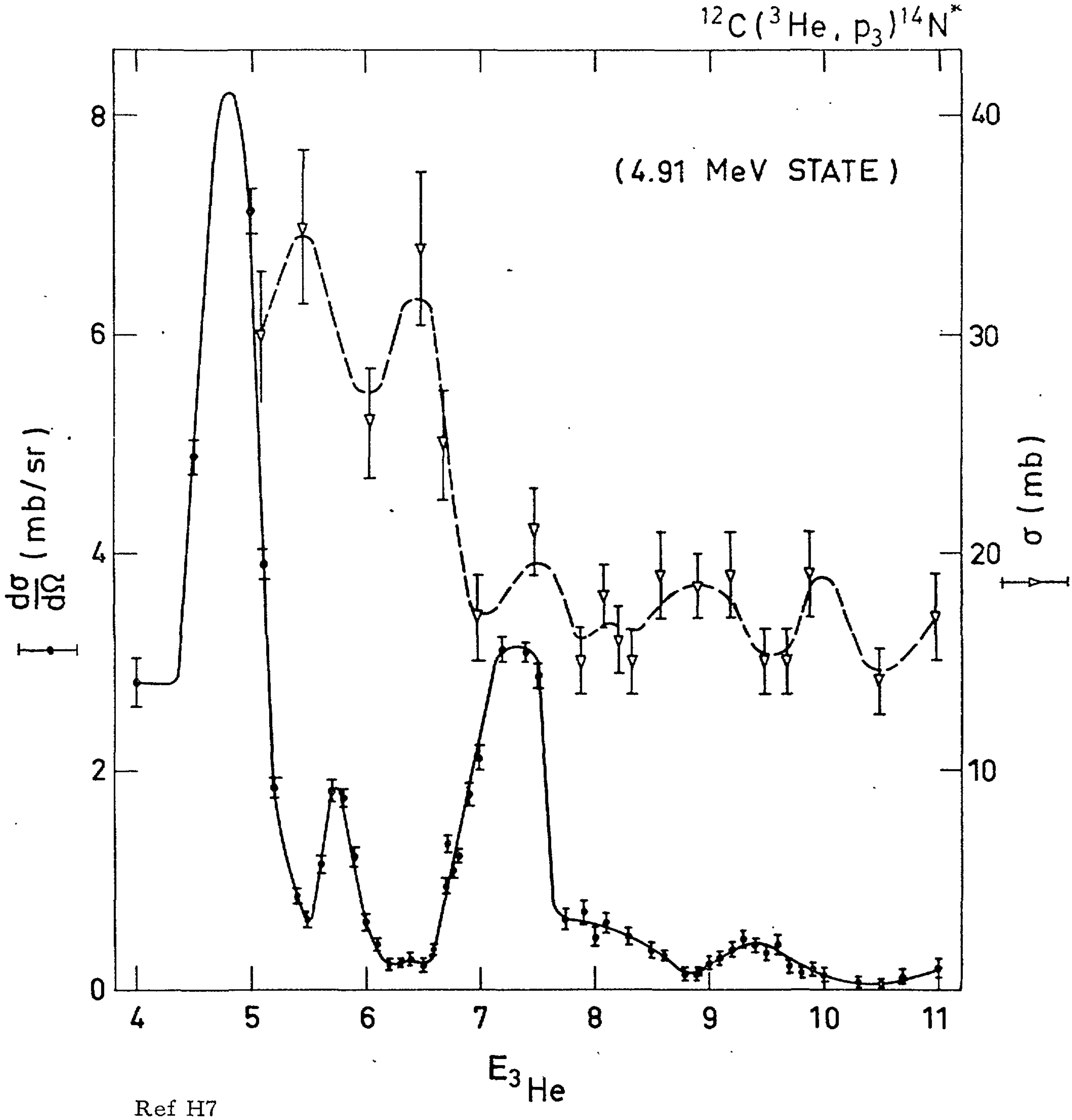


$^{12}C(^{3}He, p_1)^{14}N^*$
(2.31 MeV STATE)
$\frac{d\sigma}{d\Omega}$ (mb/sr)
$E_{^3He}$
0
1
2
3
4
5
6
7
8
9
10
11

Ref H7

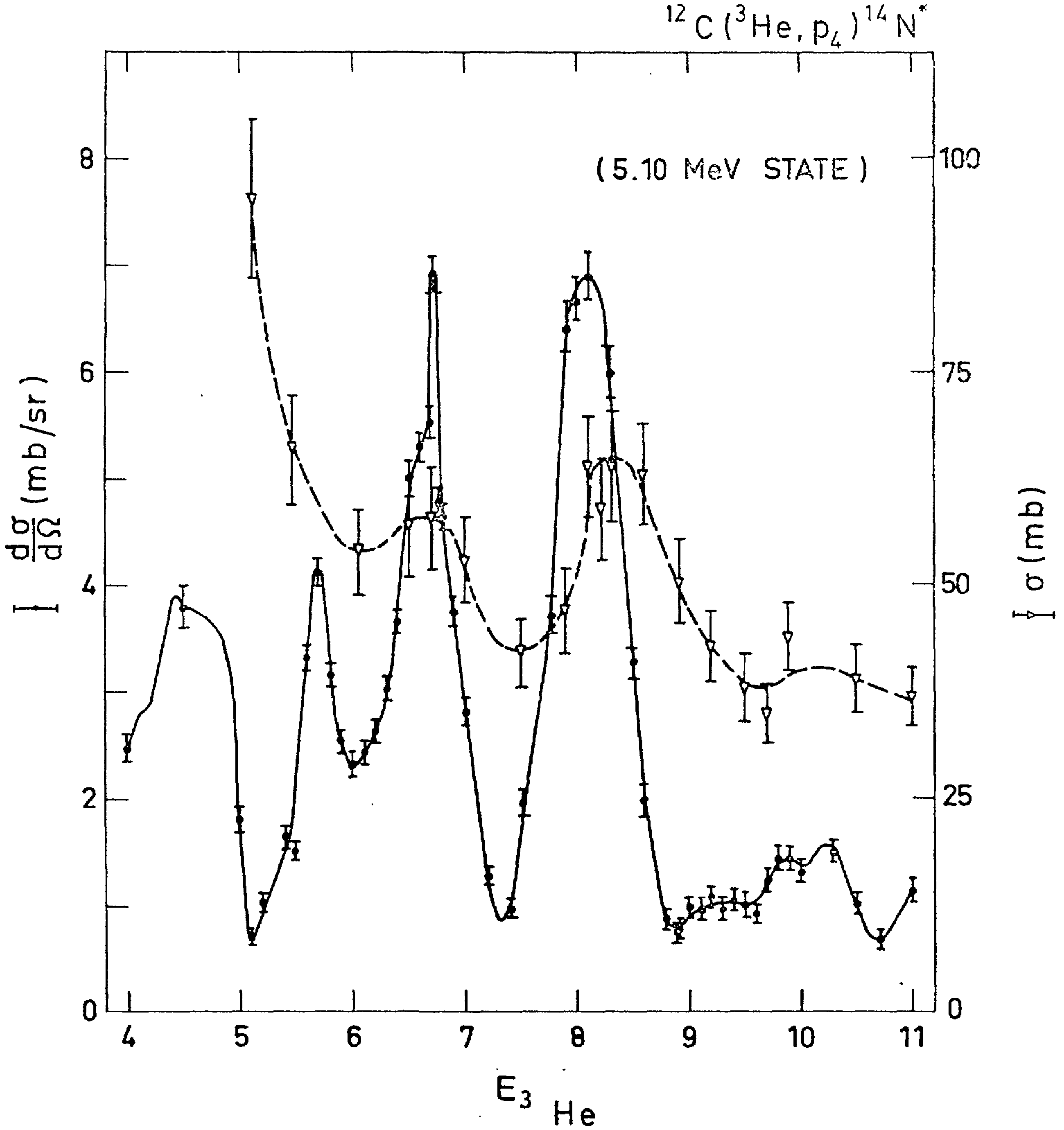

$^{12}C(^{3}He, p_2)^{14}N^*$
(3.95 MeV STATE)
x 1/2
$\frac{d\sigma}{d\Omega}$ (mb/sr)
σ (mb)
0
2
4
6
25
50
75
4
5
6
7
8
9
10
11
$E_{^3He}$

Ref H7

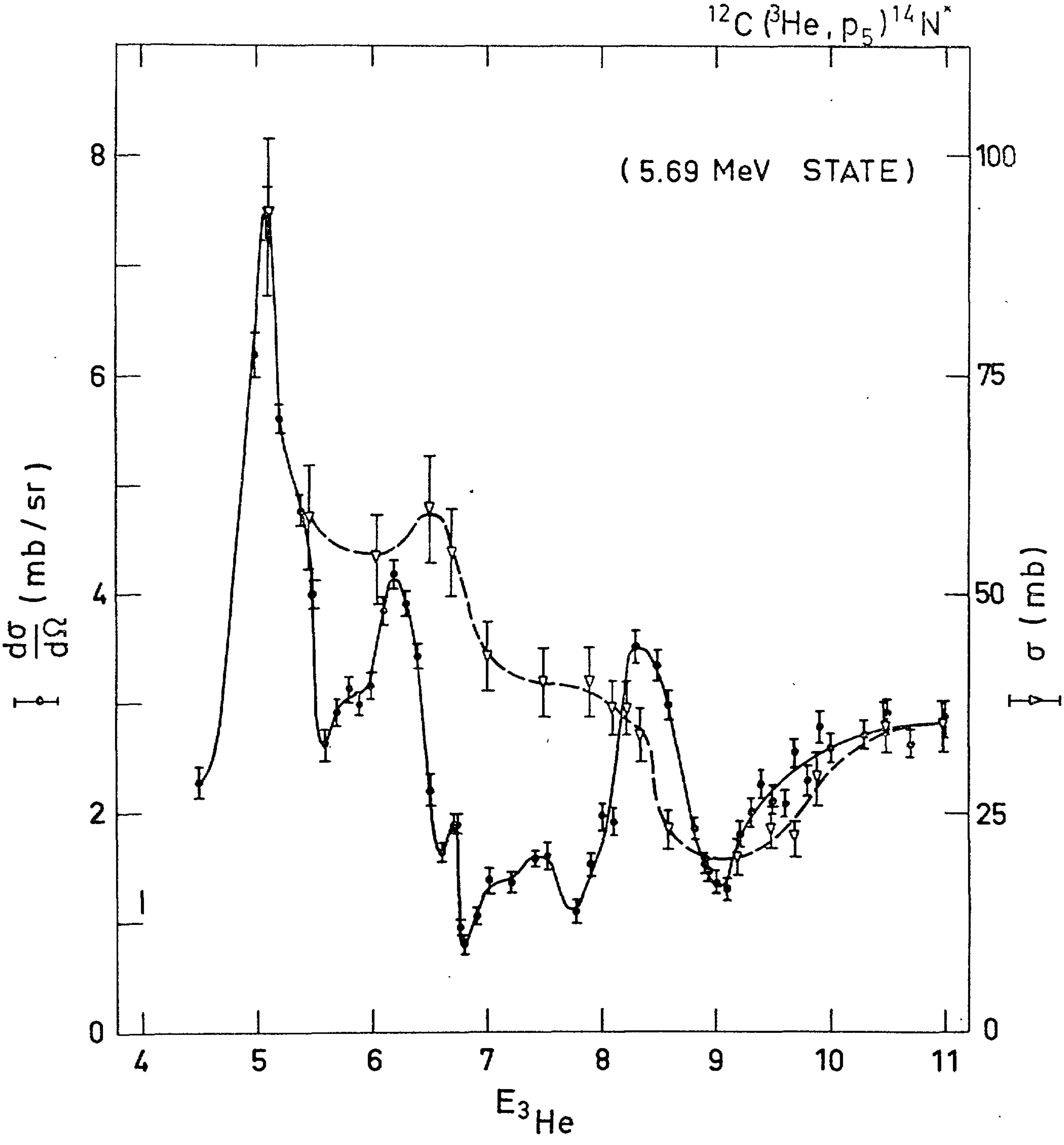


$^{12}C(^3He, p_3)^{14}N^*$
(4.91 MeV STATE)
$\frac{d\sigma}{d\Omega}$ (mb/sr)
σ (mb)
$E_{^3He}$
0
2
4
6
8
10
20
30
40
4
5
6
7
8
9
10
11

Ref H7

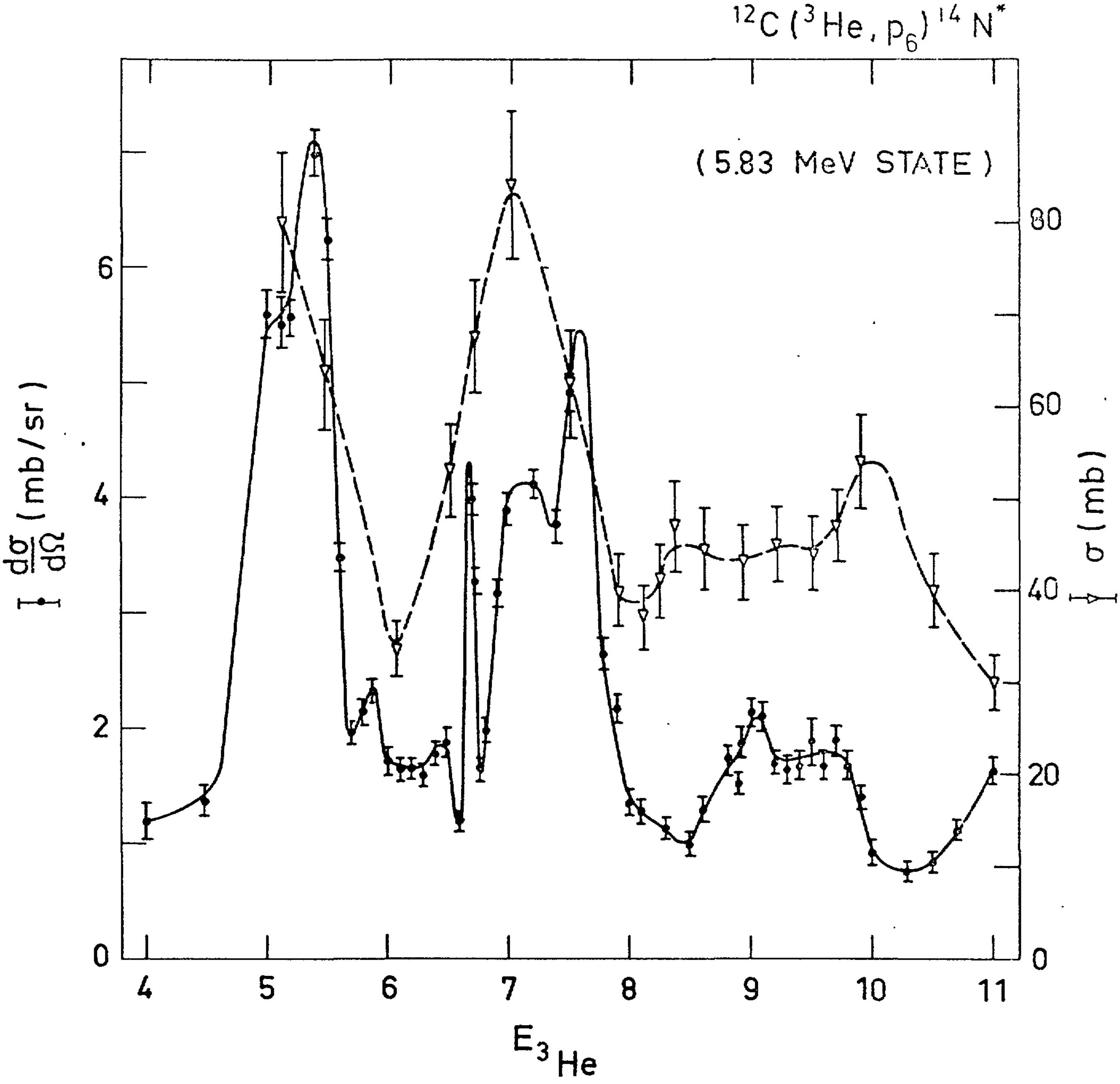

$^{12}C(^{3}He, p_{4})^{14}N^{*}$
(5.10 MeV STATE)
dσ/dΩ (mb/sr)
σ (mb)
$E_{^3He}$
0
2
4
6
8
25
50
75
100
4
5
6
7
8
9
10
11

Ref H7



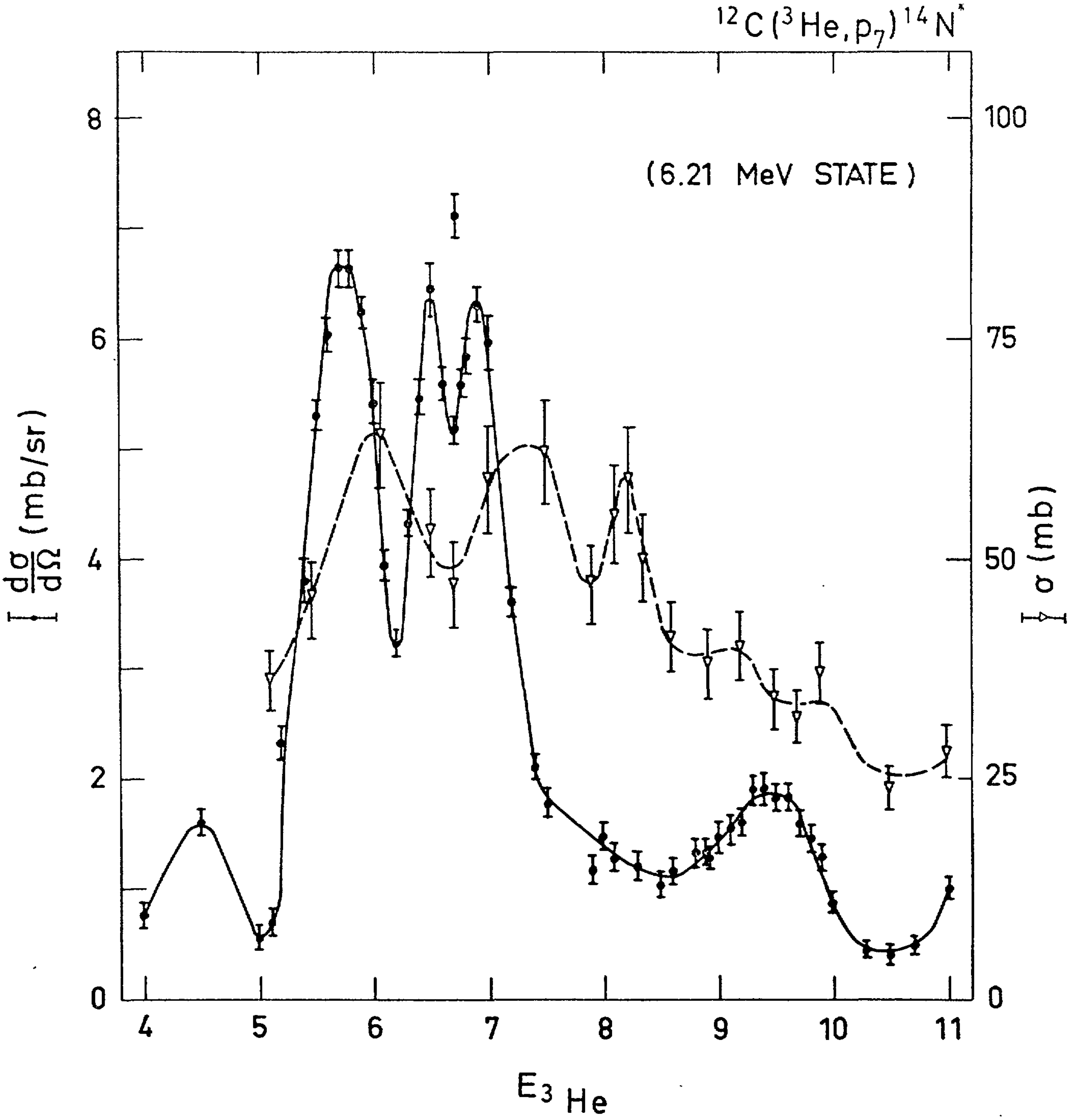
$^{12}C(^{3}He, p_5)^{14}N^*$
(5.69 MeV STATE)
$\frac{d\sigma}{d\Omega}$ (mb/sr)
σ (mb)
$E_{^3He}$
0
2
4
6
8
25
50
75
100
4
5
6
7
8
9
10
11

Ref H7



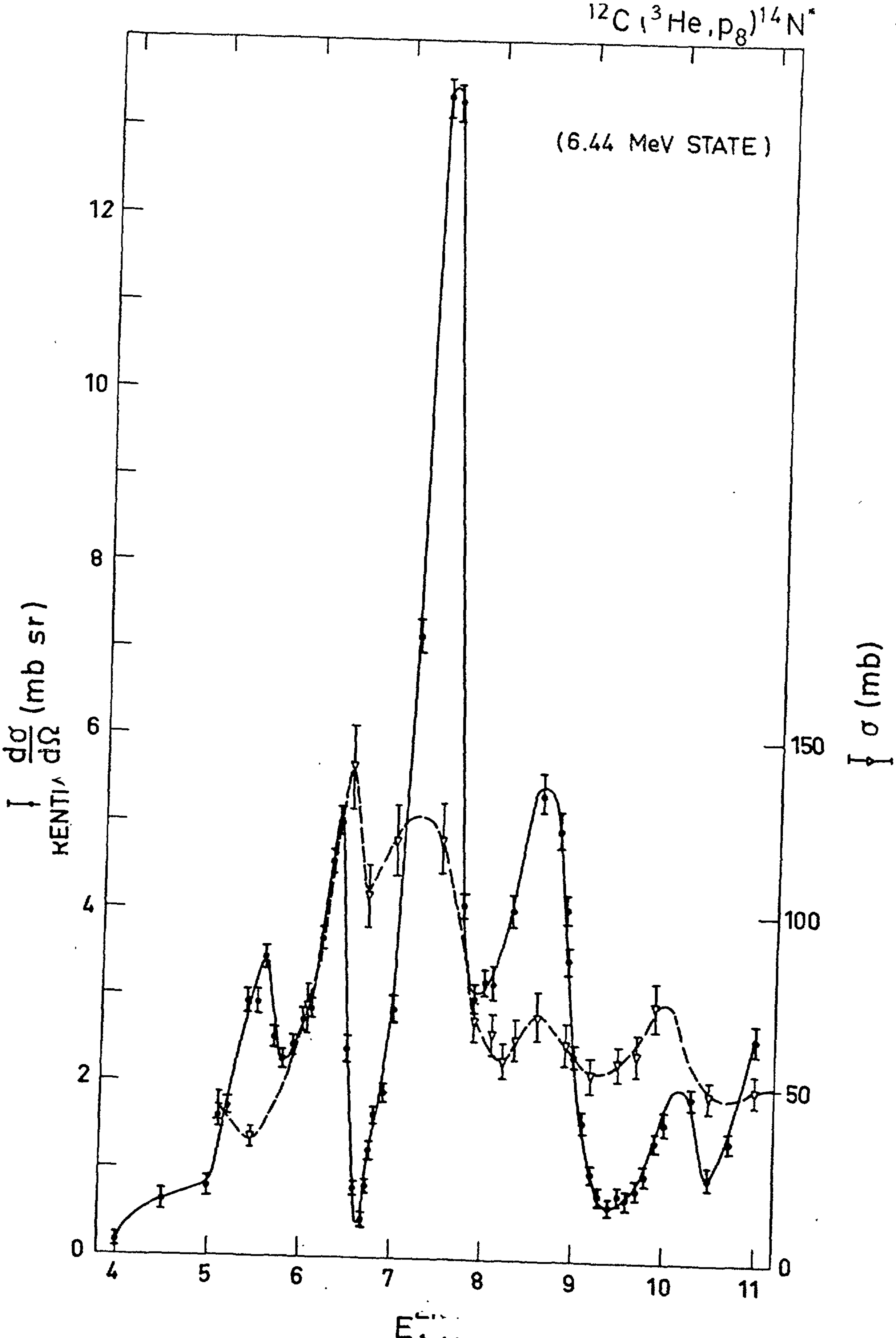
$^{12}C(^3He, p_6)^{14}N^*$
(5.83 MeV STATE)
$\frac{d\sigma}{d\Omega}$ (mb/sr)
σ (mb)
$E_{^3He}$
0
2
4
6
20
40
60
80
4
5
6
7
8
9
10
11

Ref H7



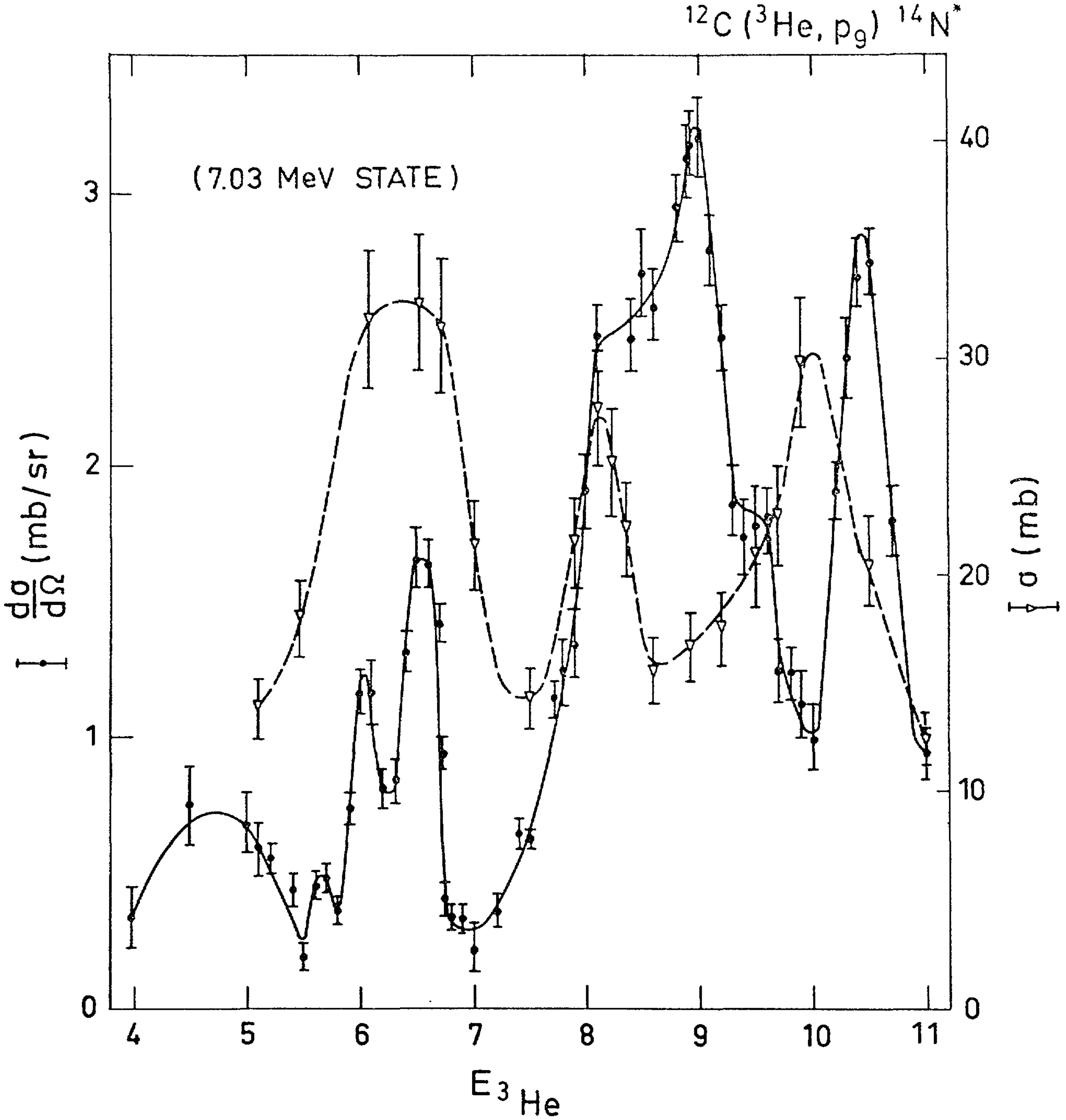
$^{12}C(^{3}He,p_{7})^{14}N^{*}$
(6.21 MeV STATE)
$\frac{d\sigma}{d\Omega}$ (mb/sr)
σ (mb)
$E_{^3He}$
0
2
4
6
8
25
50
75
100
4
5
6
7
8
9
10
11

Ref H7



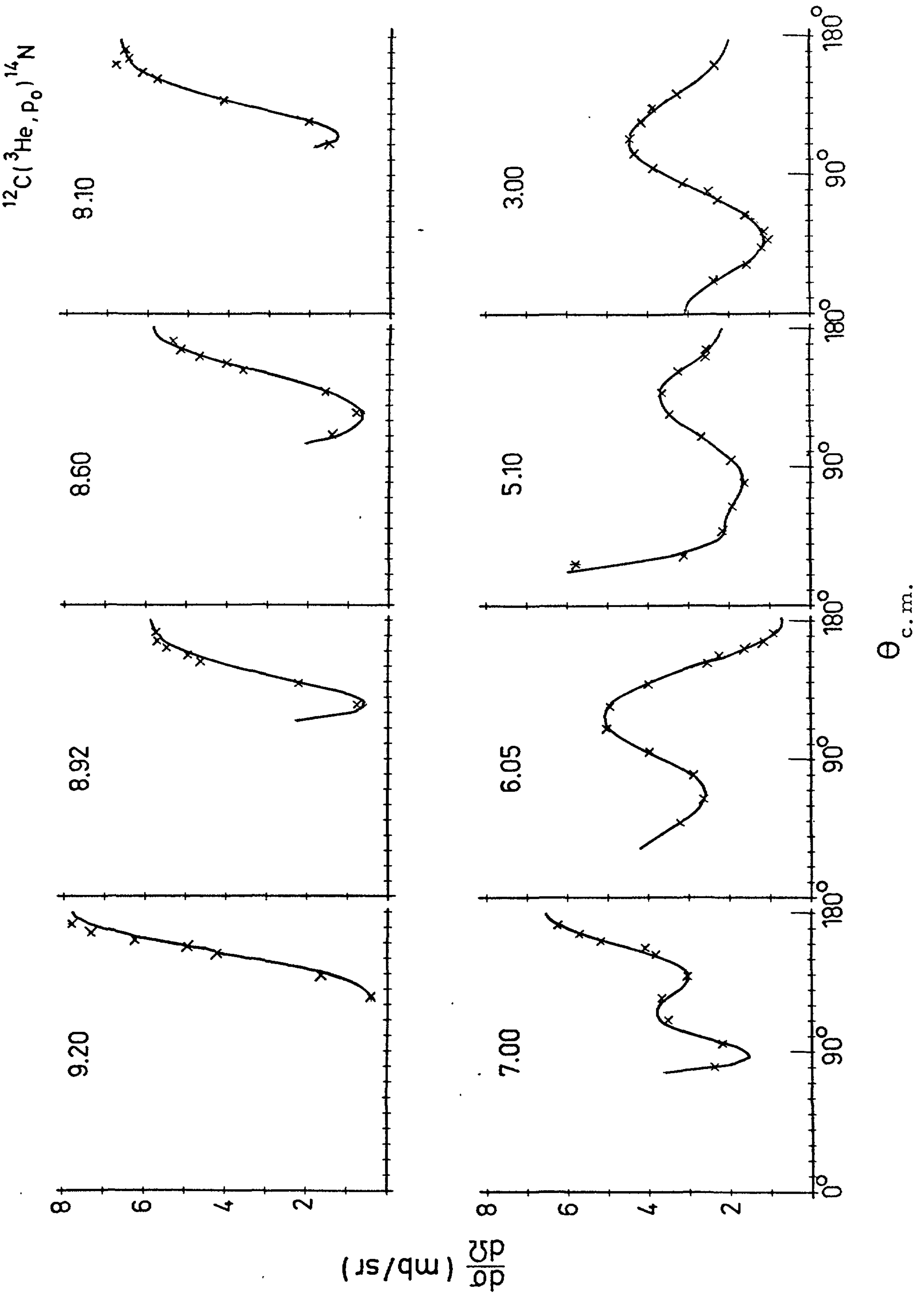
$^{12}C(^3He,p_8)^{14}N^*$
(6.44 MeV STATE)
$\frac{d\sigma}{d\Omega}$ (mb sr)
σ (mb)
0
2
4
6
8
10
12
50
100
150
4
5
6
7
8
9
10
11
$E_{^3He}$

Ref H7



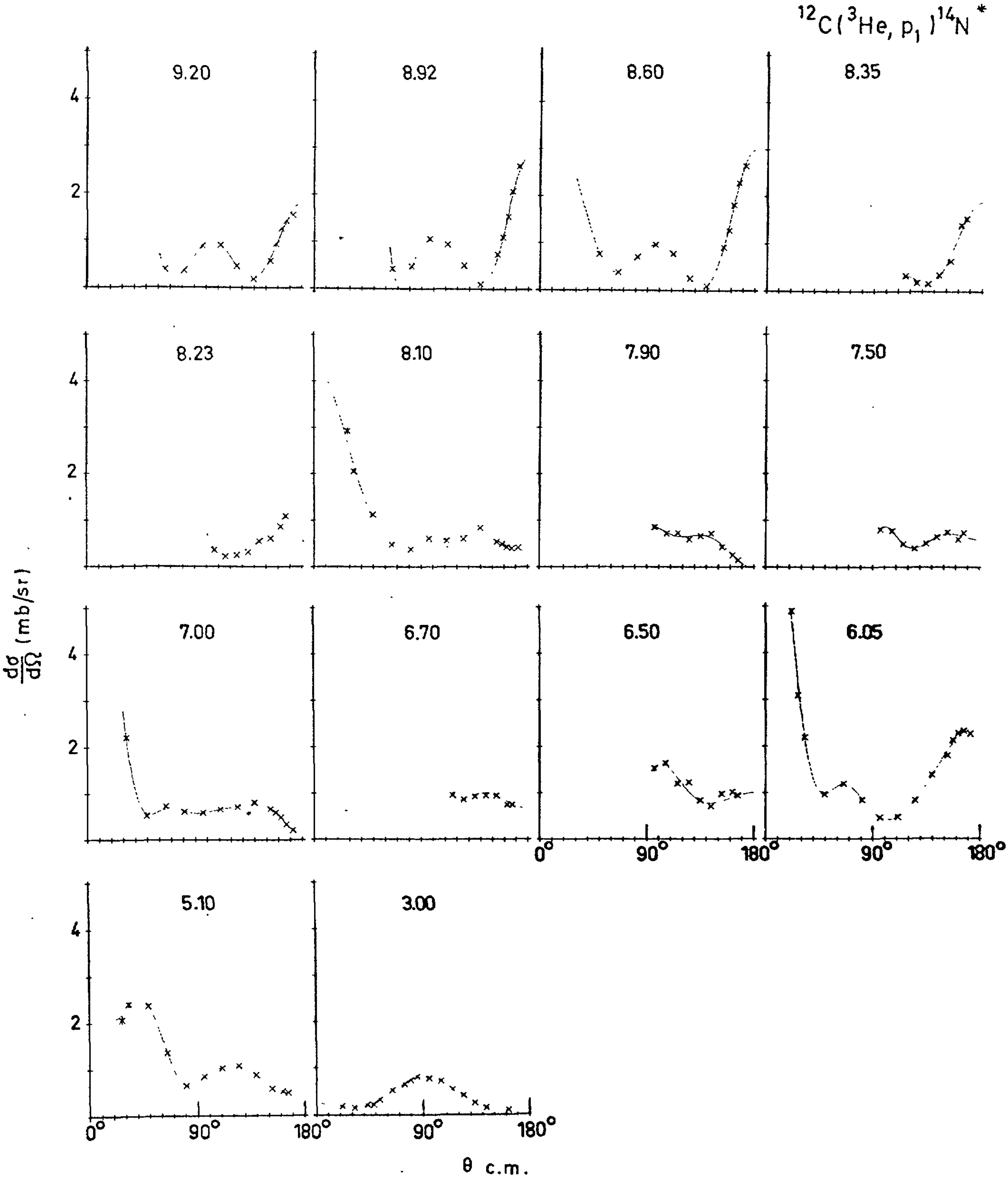
$^{12}C(^3He, p_g)\ ^{14}N^*$
(7.03 MeV STATE)
$\frac{d\sigma}{d\Omega}$ (mb/sr)
σ (mb)
$E_{^3He}$
0
1
2
3
10
20
30
40
4
5
6
7
8
9
10
11

Ref H7

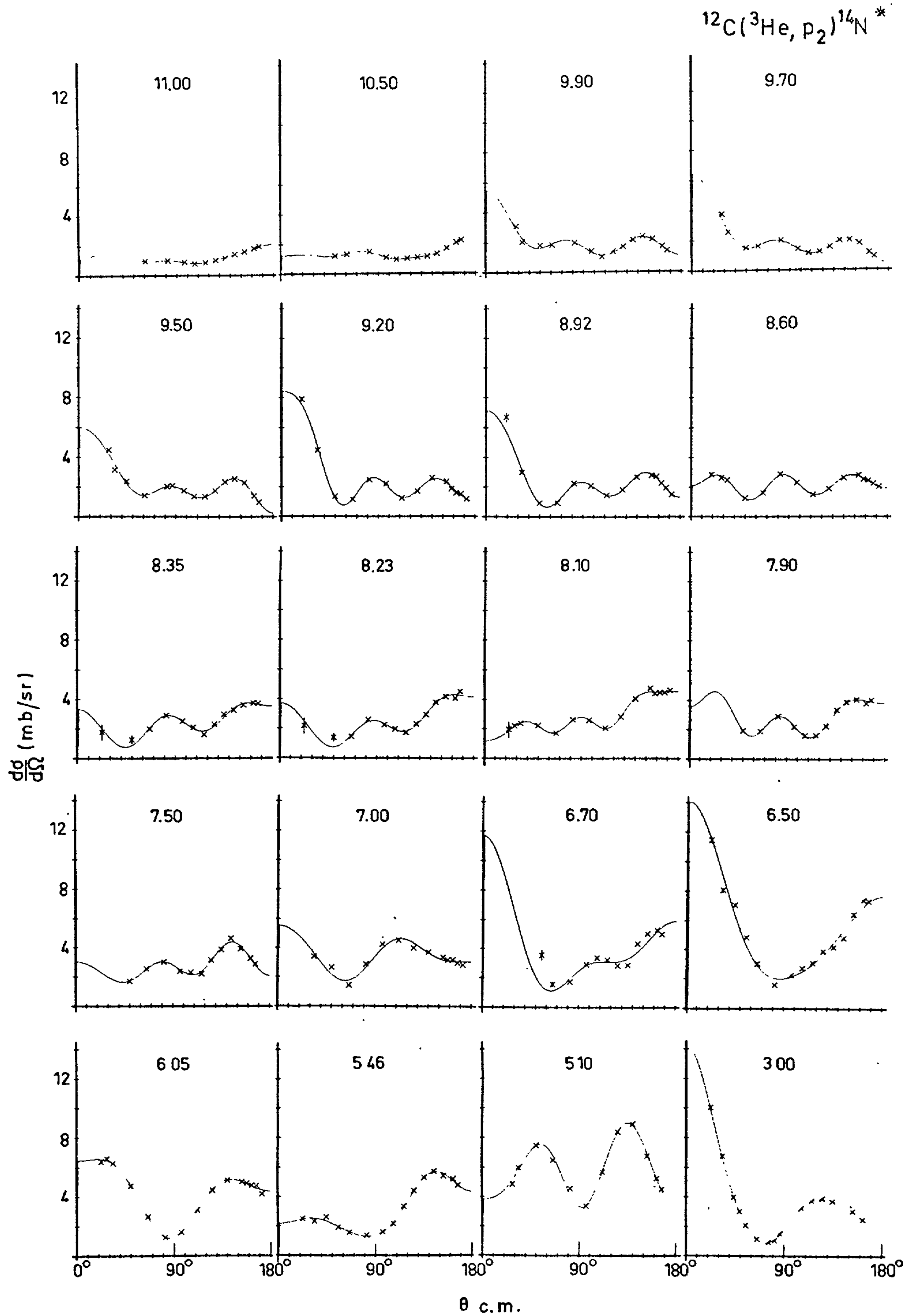


12C(3He,po)14N
9.20
8.92
8.60
8.10
7.00
6.05
5.10
3.00
dσ/dΩ (mb/sr)
Θc.m.
0°
90°
180°

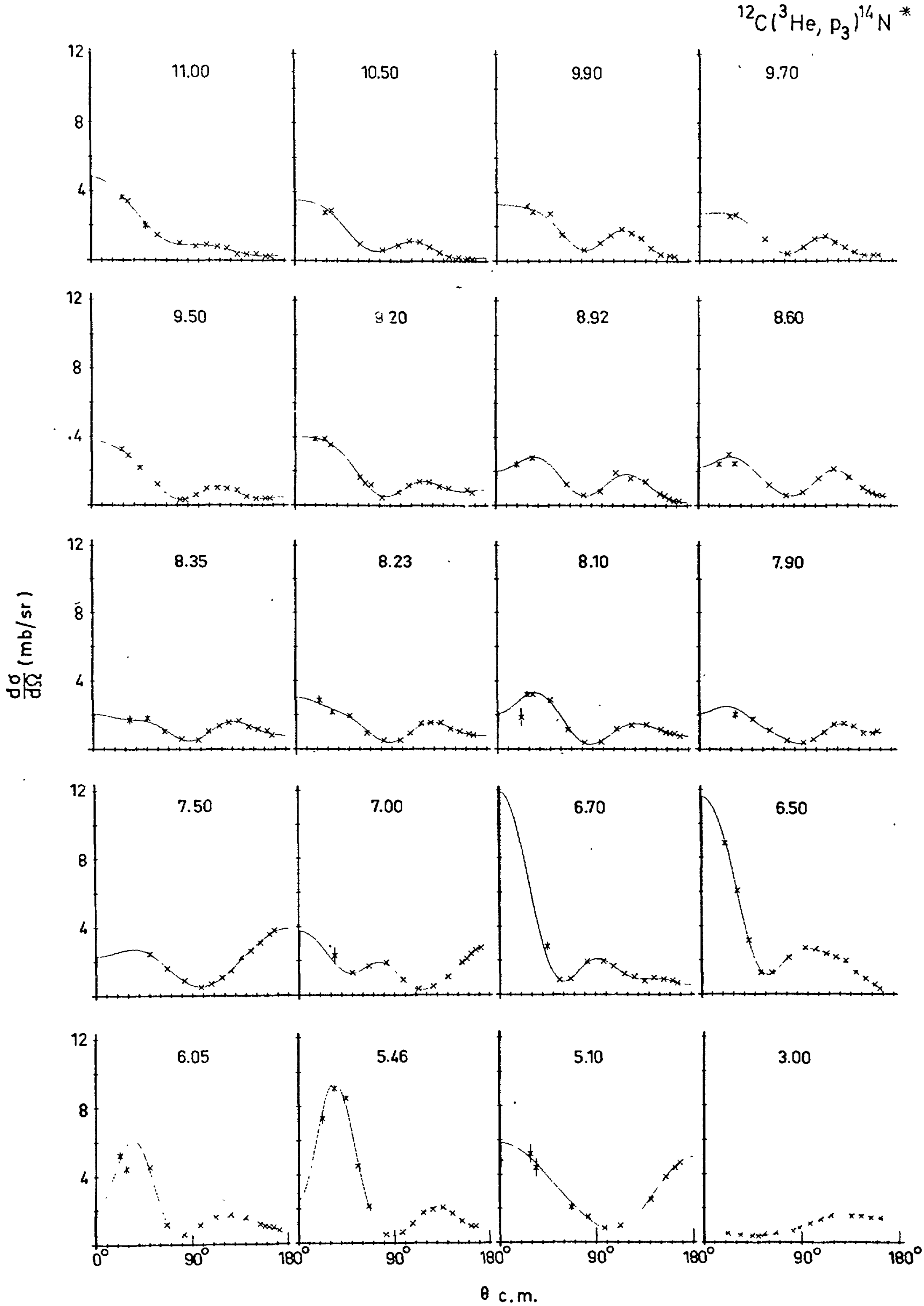
Ref H7


$^{12}C(^3He, p_1)^{14}N^*$
9.20
8.92
8.60
8.35
8.23
8.10
7.90
7.50
7.00
6.70
6.50
6.05
5.10
3.00
4
2
dσ/dΩ (mb/sr)
0°
90°
180°
θ c.m.

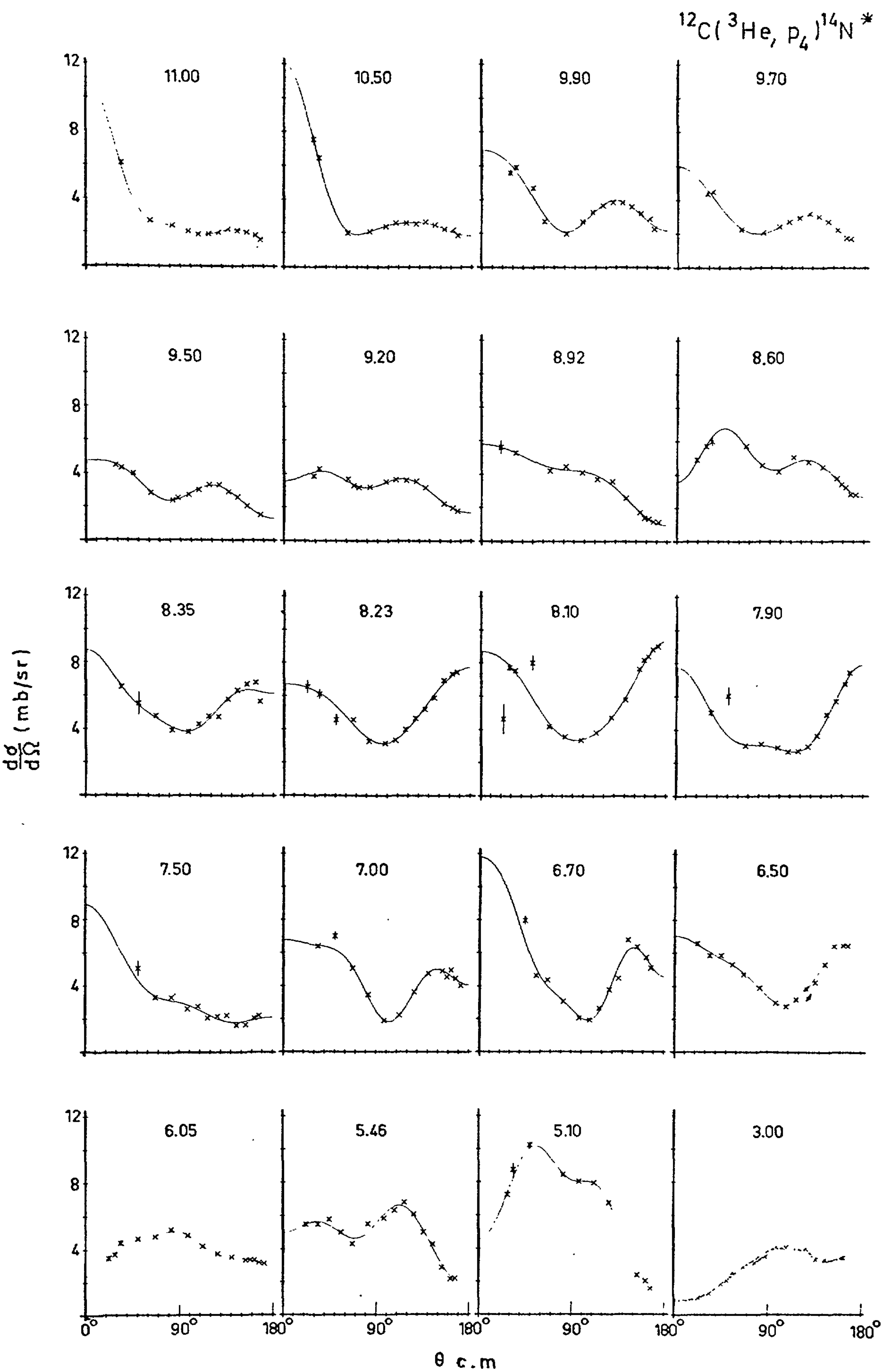
Ref H7


$^{12}C(^3He, p_2)^{14}N^*$
11.00
10.50
9.90
9.70
9.50
9.20
8.92
8.60
8.35
8.23
8.10
7.90
7.50
7.00
6.70
6.50
6 05
5 46
5 10
3 00
12
8
4
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0°
90°
180°
θ c.m.

Ref H7

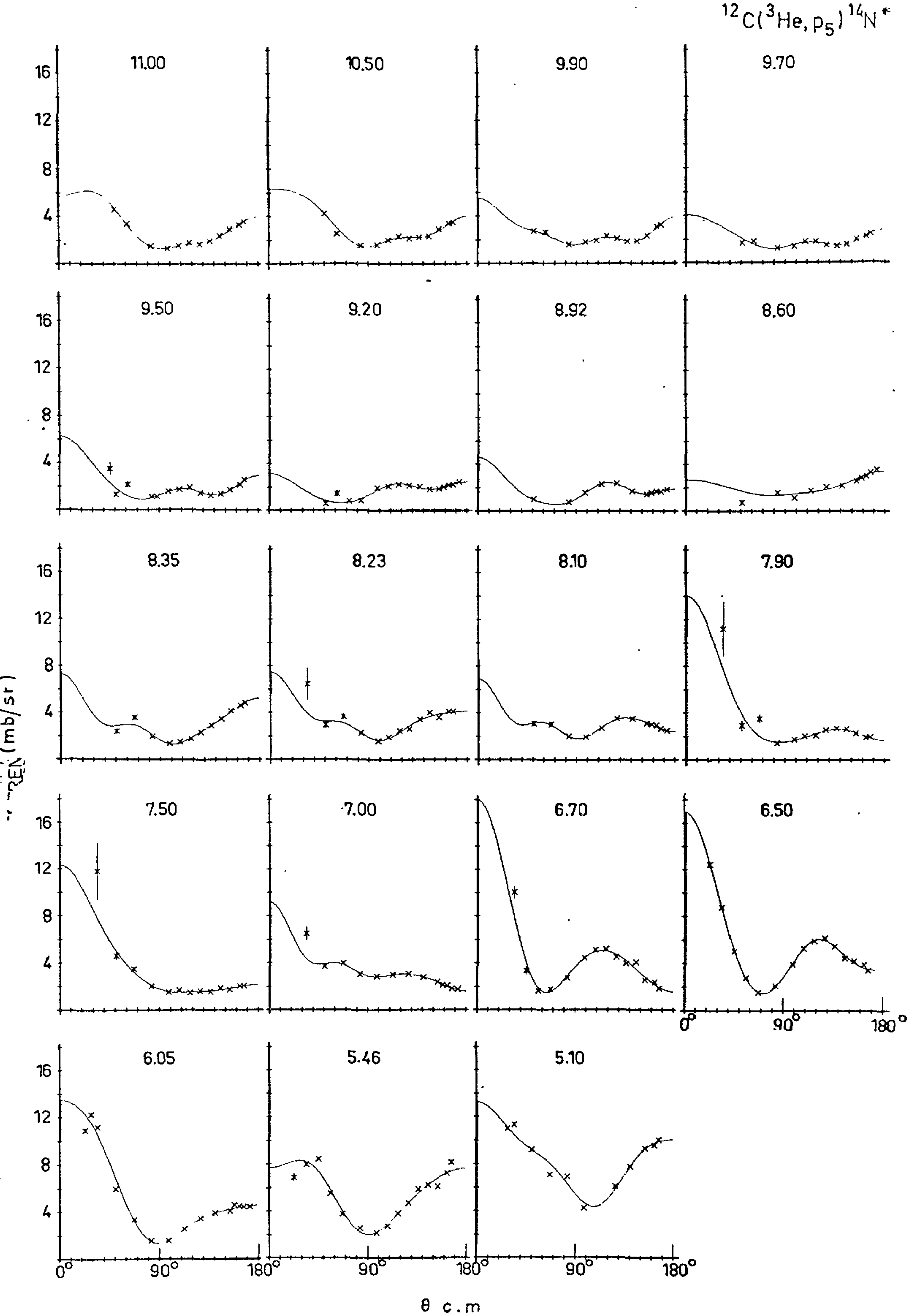

$^{12}C(^3He, p_3)^{14}N^*$
11.00
10.50
9.90
9.70
9.50
9.20
8.92
8.60
8.35
8.23
8.10
7.90
7.50
7.00
6.70
6.50
6.05
5.46
5.10
3.00
12
8
4
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0°
90°
180°
θ c.m.

Ref H7



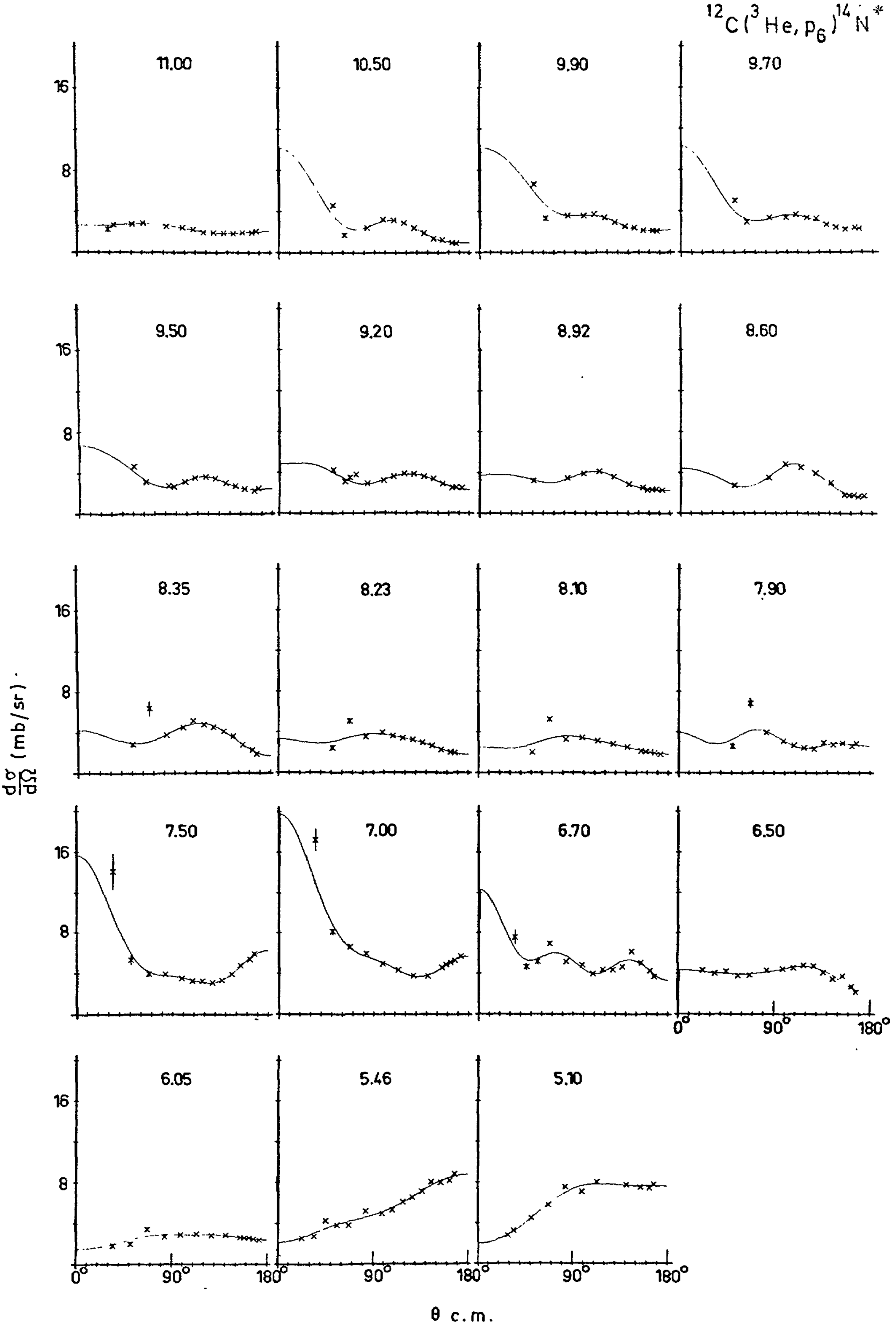
12C(3He, p4)14N*
11.00
10.50
9.90
9.70
9.50
9.20
8.92
8.60
8.35
8.23
8.10
7.90
7.50
7.00
6.70
6.50
6.05
5.46
5.10
3.00
dσ/dΩ (mb/sr)
12
8
4
0°
90°
180°
θ c.m

Ref H7



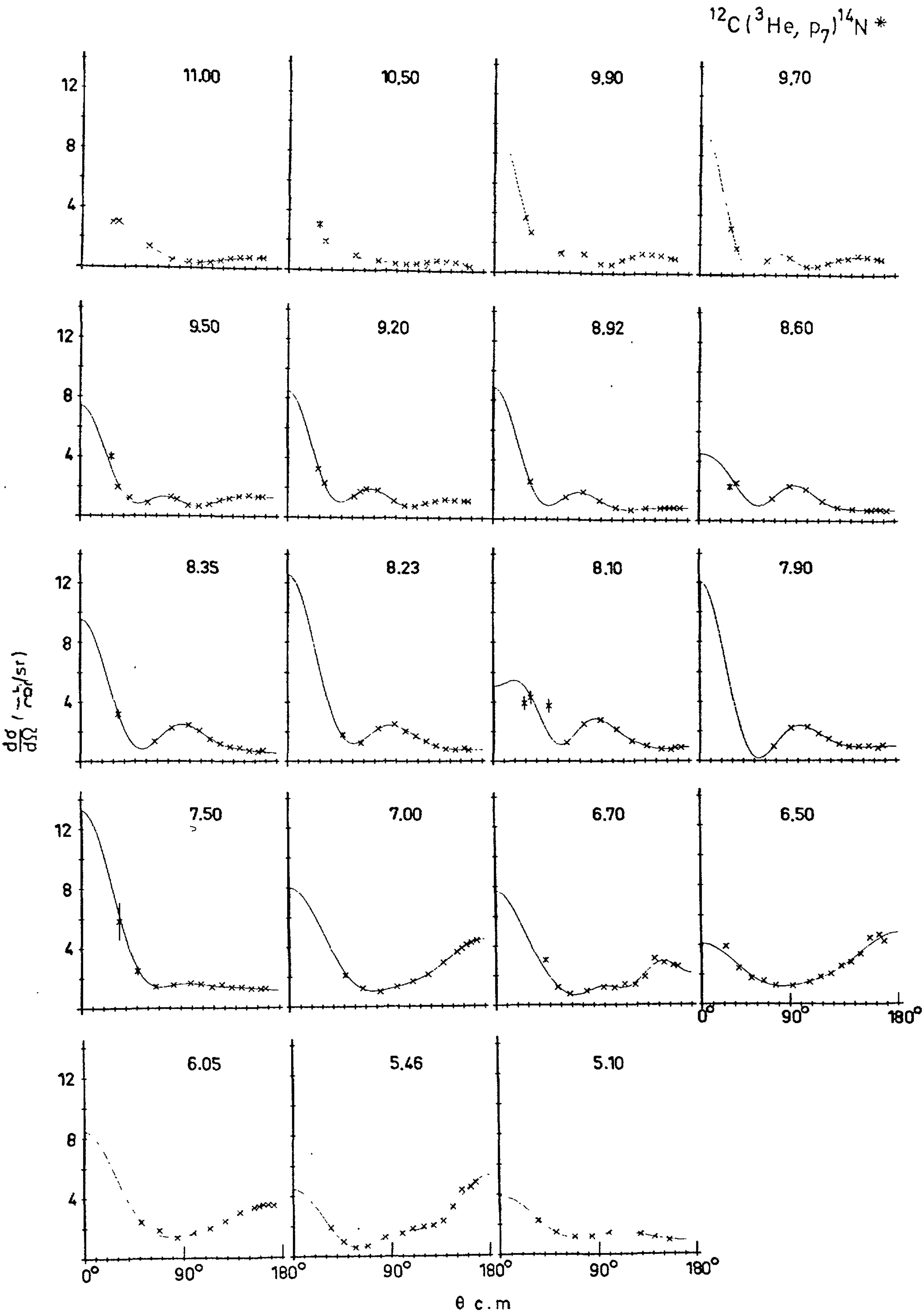
$^{12}C(^3He, p_5)^{14}N^*$
11.00
10.50
9.90
9.70
9.50
9.20
8.92
8.60
8.35
8.23
8.10
7.90
7.50
7.00
6.70
6.50
6.05
5.46
5.10
16
12
8
4
(mb/sr)
0°
90°
180°
θ c.m

Ref H7



$^{12}C(^3He, p_6)^{14}N^*$
11.00
10.50
9.90
9.70
9.50
9.20
8.92
8.60
8.35
8.23
8.10
7.90
7.50
7.00
6.70
6.50
6.05
5.46
5.10
16
8
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0°
90°
180°
θ c.m.

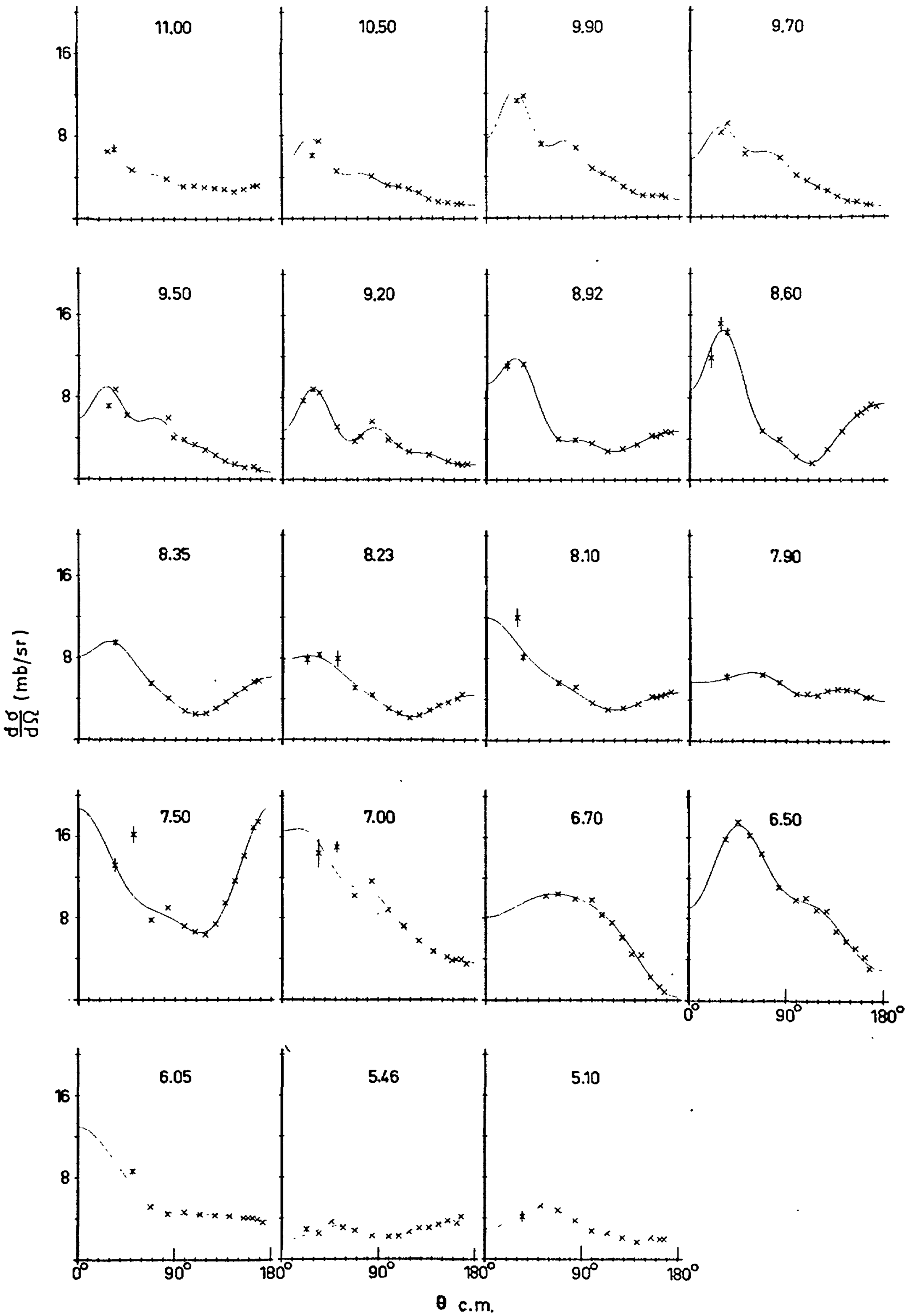
Ref H7



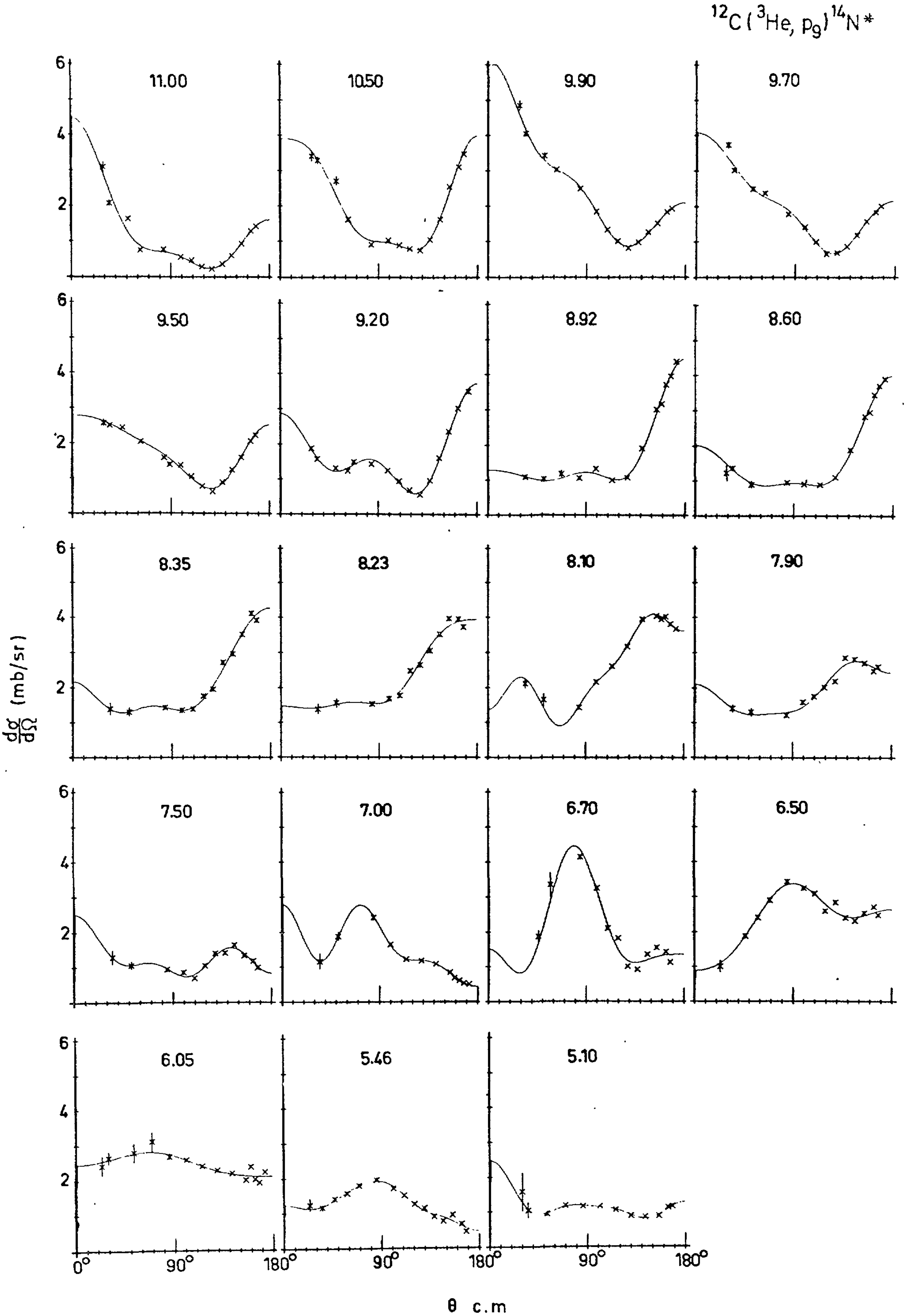
$^{12}C(^{3}He, p_7)^{14}N*$
11.00
10.50
9.90
9.70
9.50
9.20
8.92
8.60
8.35
8.23
8.10
7.90
7.50
7.00
6.70
6.50
6.05
5.46
5.10
12
8
4
$\frac{d\sigma}{d\Omega}$ (mb/sr)
0°
90°
180°
θ c.m

Ref H7

$^{12}C(^{3}He, p_8)^{14}N^*$

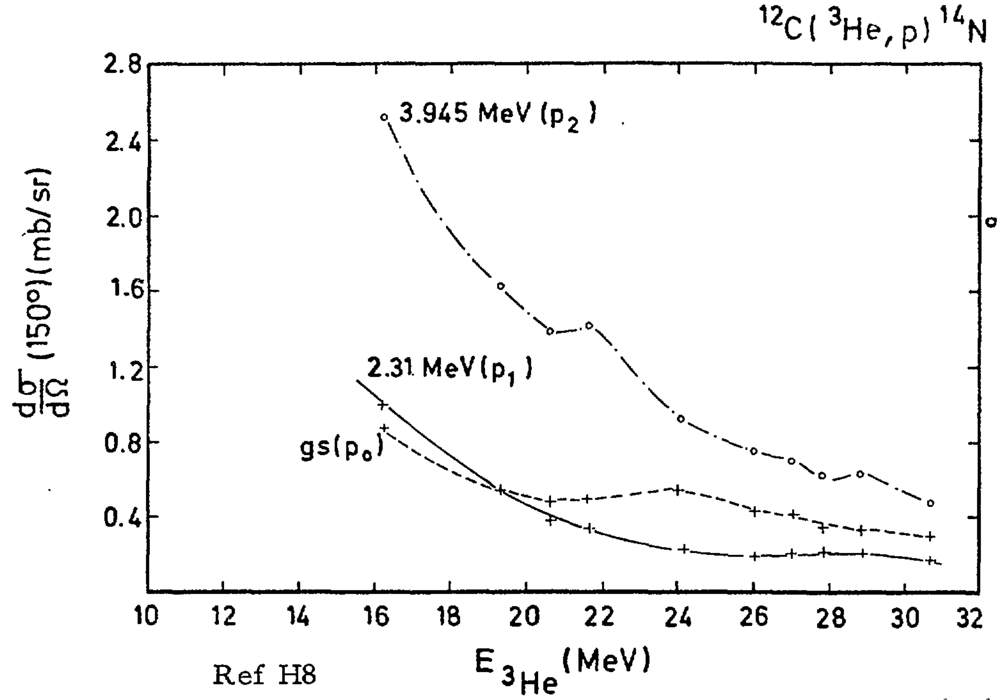


Ref H7

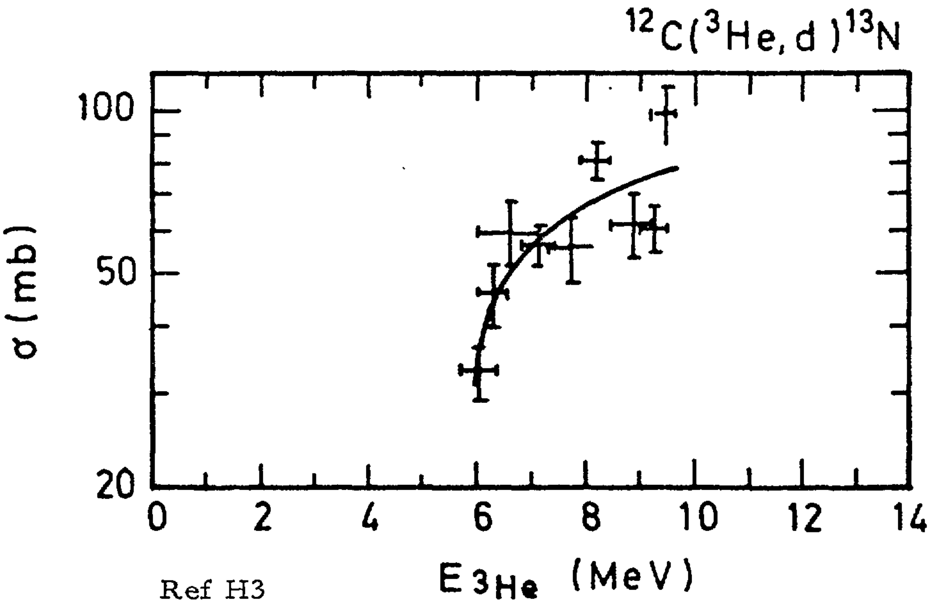


$^{12}C(^{3}He, p_{g})^{14}N*$
11.00
10.50
9.90
9.70
9.50
9.20
8.92
8.60
8.35
8.23
8.10
7.90
7.50
7.00
6.70
6.50
6.05
5.46
5.10
$\frac{d\sigma}{d\Omega}$ (mb/sr)
6
4
2
0°
90°
180°
θ c.m

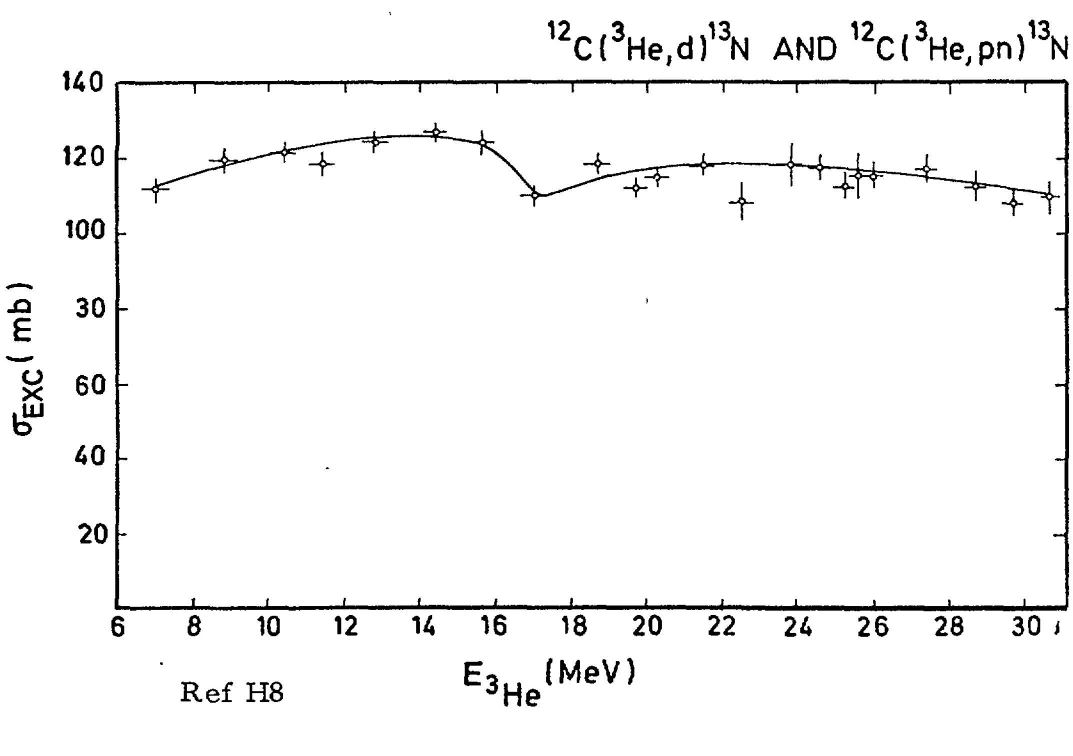
Ref H7



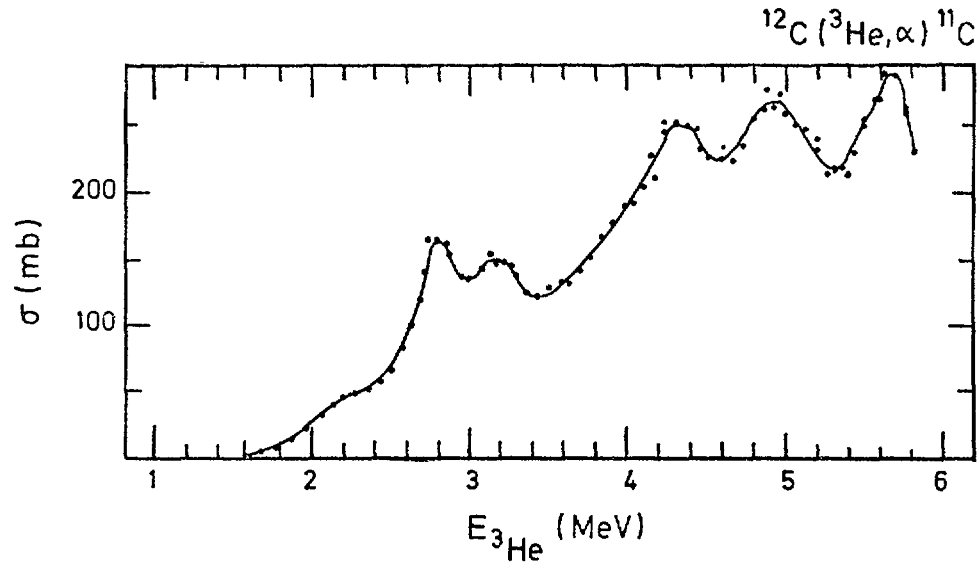
Ref H8



Ref H3

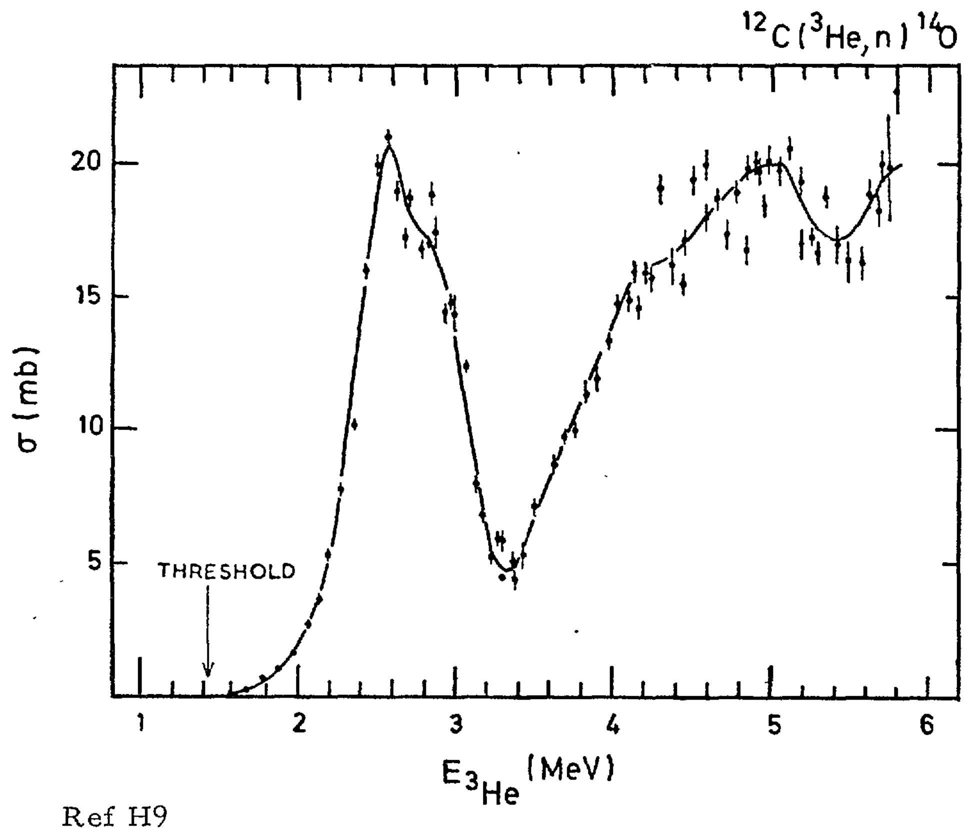


Ref H8



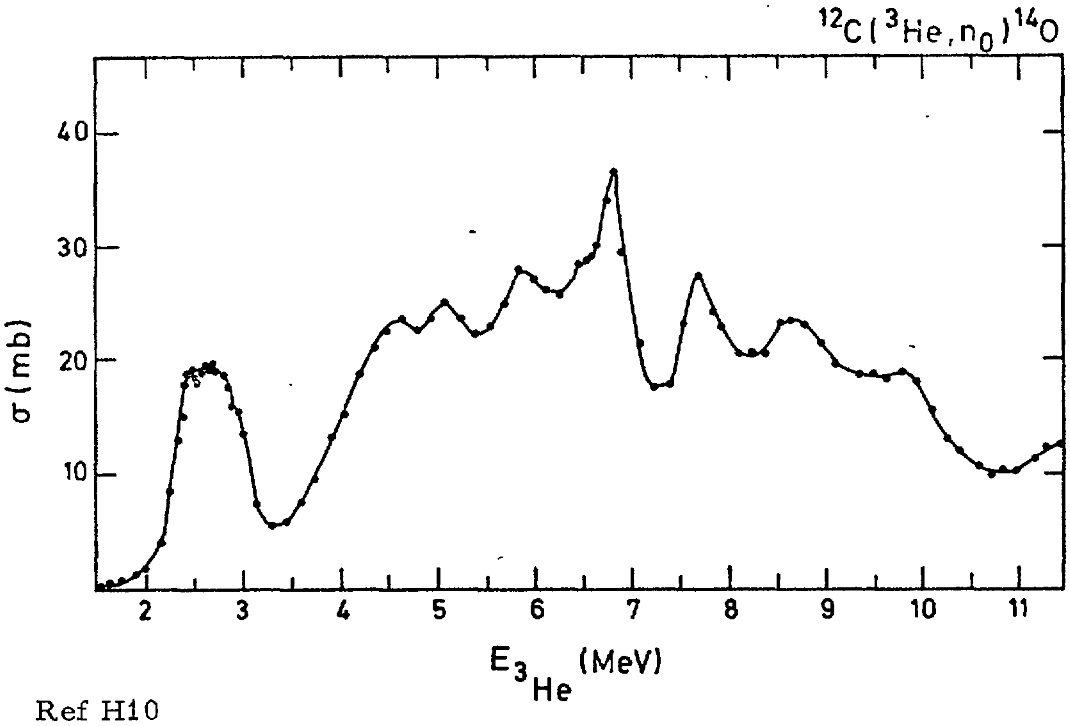
$^{12}C(^{3}He,\alpha)^{11}C$
σ (mb)
100
200
1
2
3
4
5
6
$E_{^3He}$ (MeV)

Ref H9

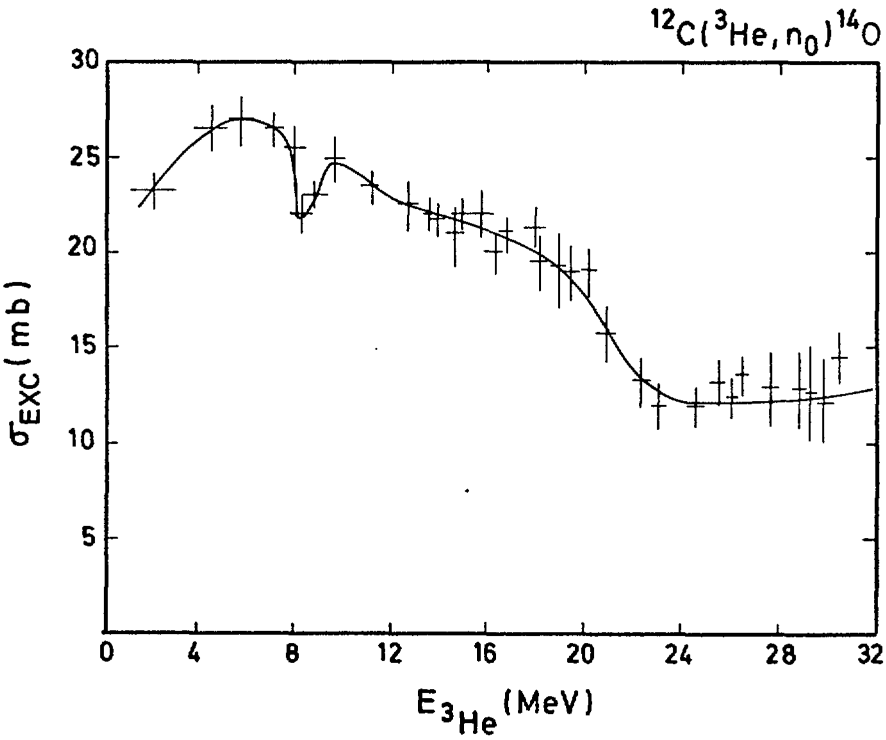


$^{12}C(^{3}He,n)^{14}O$
σ (mb)
5
10
15
20
THRESHOLD
1
2
3
4
5
6
$E_{^3He}$ (MeV)

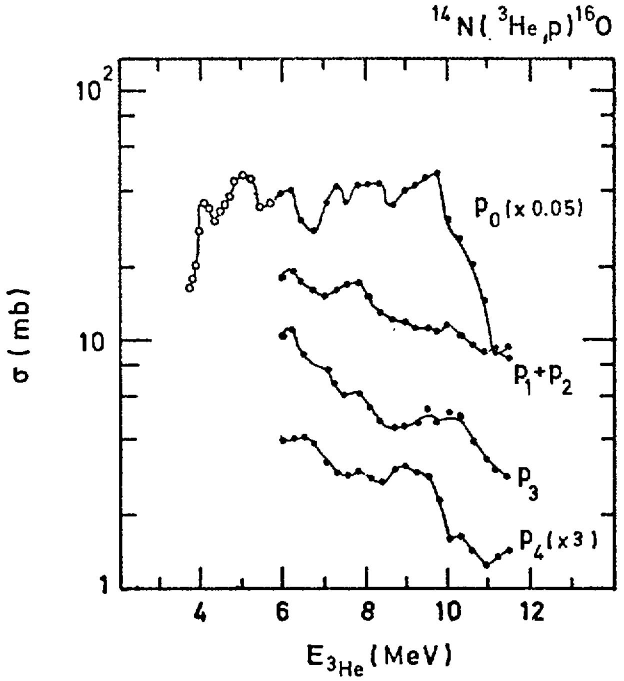
Ref H9



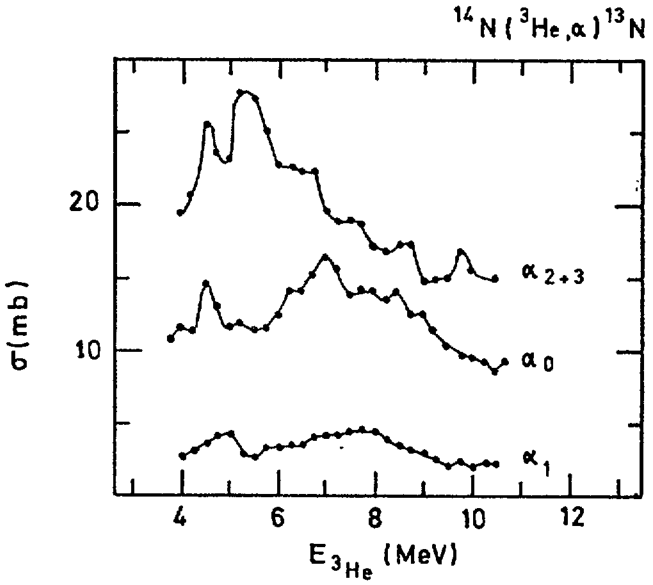
Ref H10



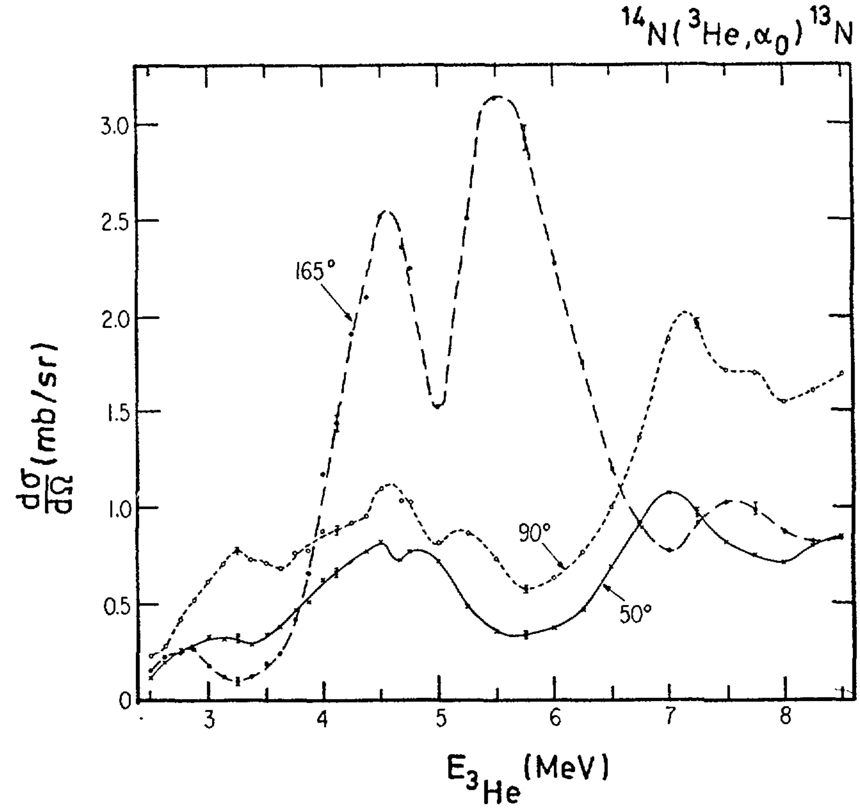
Ref H8



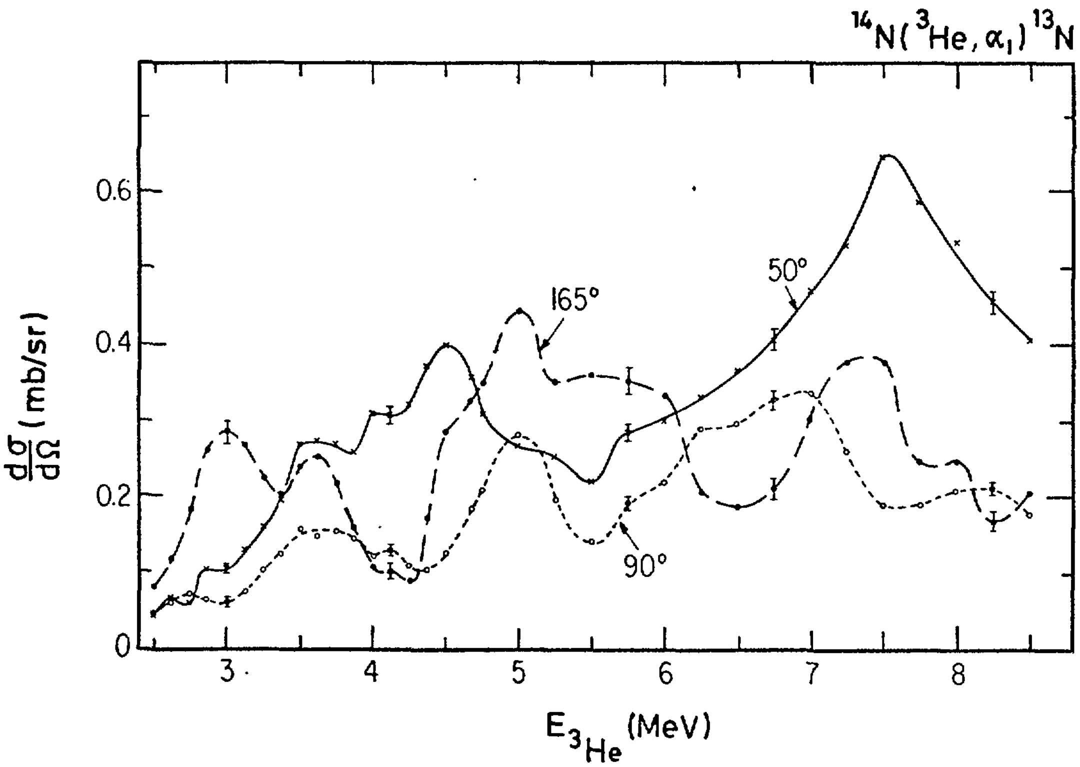
Ref H11



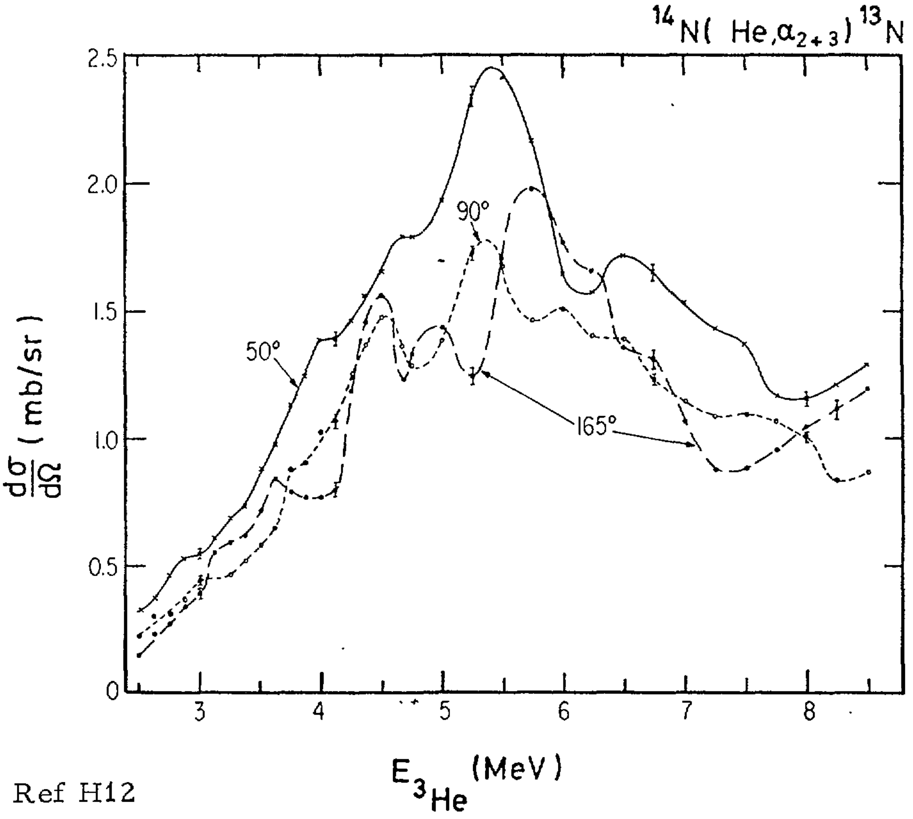
Ref H11



Ref H12

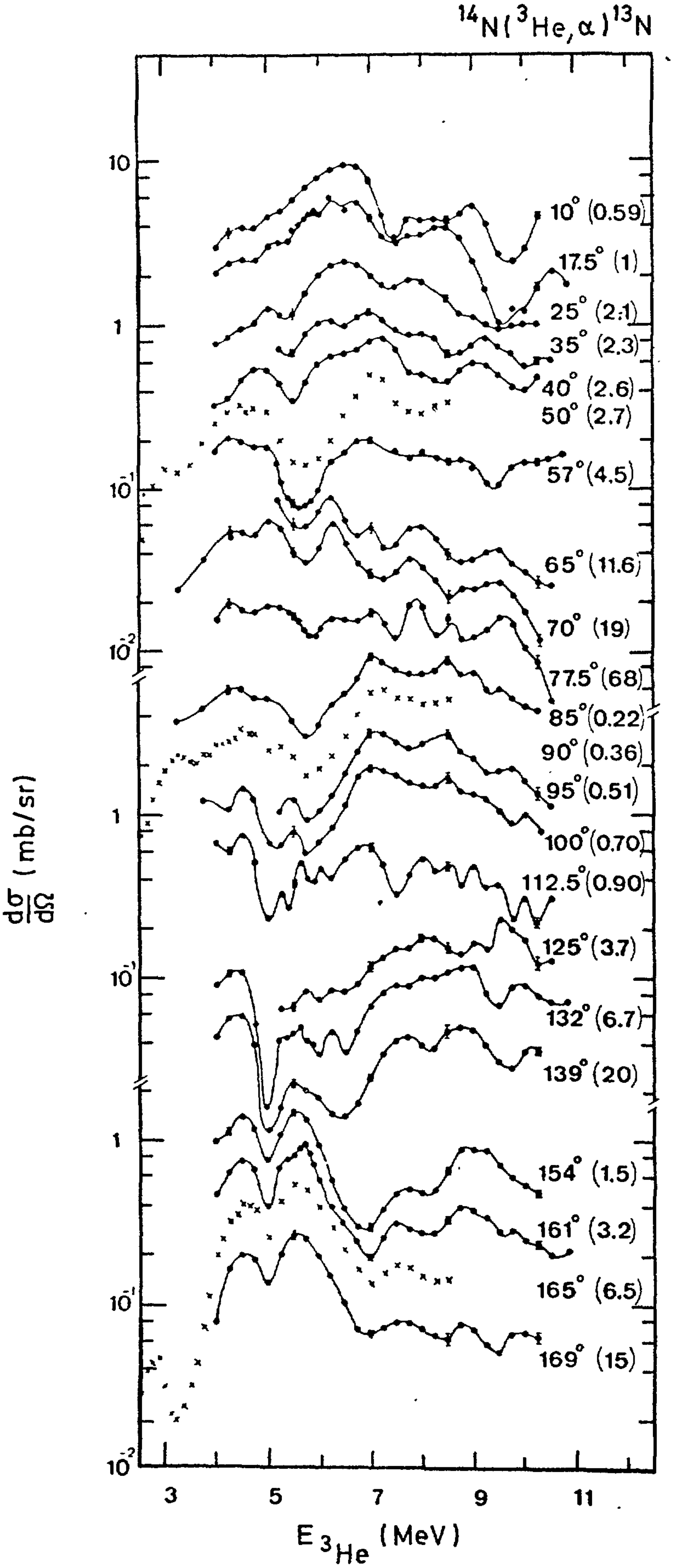


Ref H12



14N(He,α2+3) 13N
50°
90°
165°
dσ/dΩ (mb/sr)
E3He (MeV)
0
0.5
1.0
1.5
2.0
2.5
3
4
5
6
7
8

Ref H12

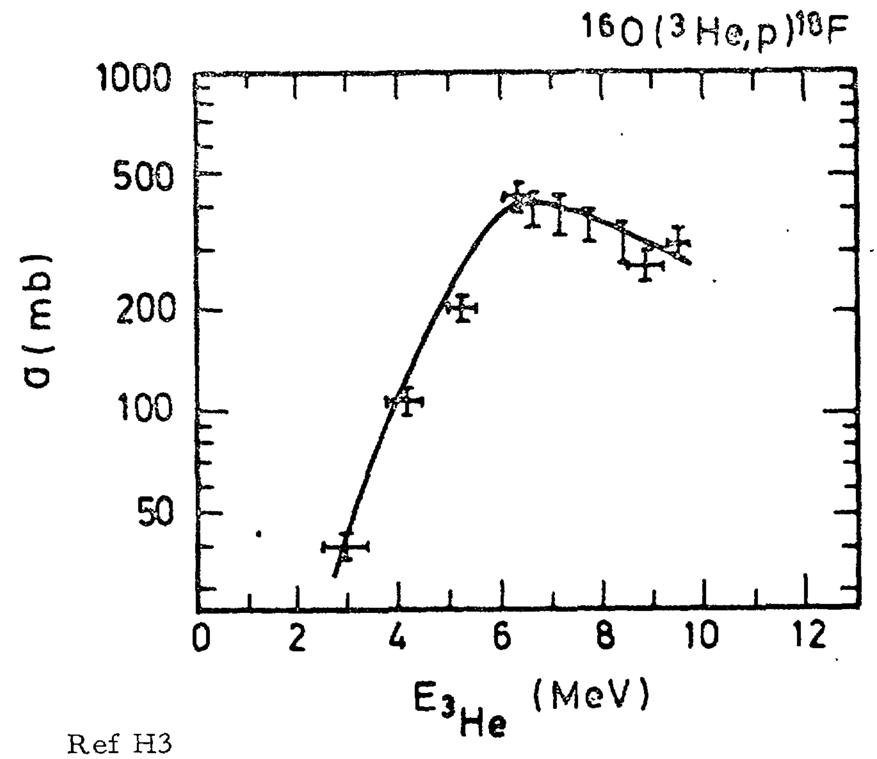


x indicates data from: KNUDSON; YOUNG.

Nucl Phys A 149, 323 (1970)

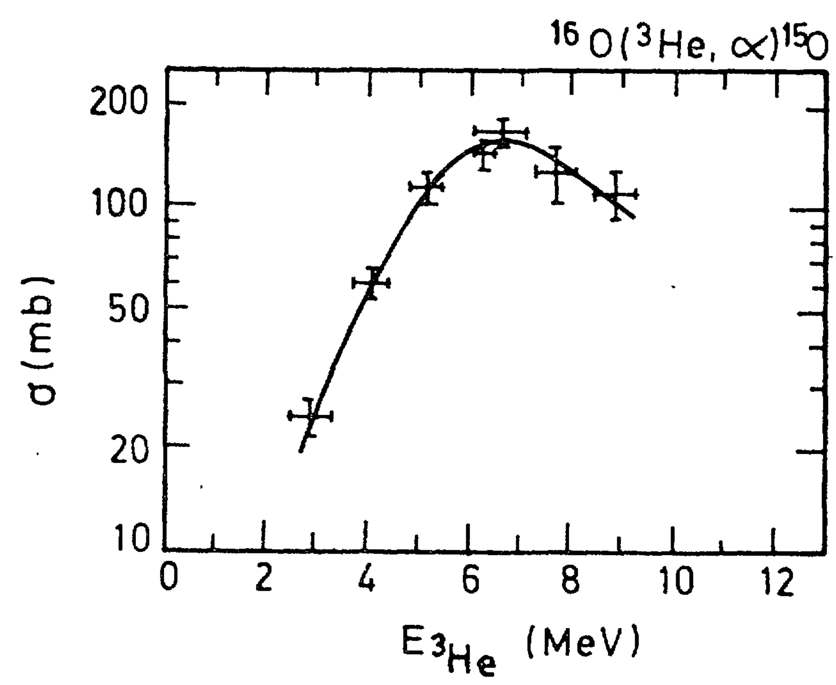
The plotted cross-section must be multiplied by the number in brackets to obtain the true cross-section.

Ref H11



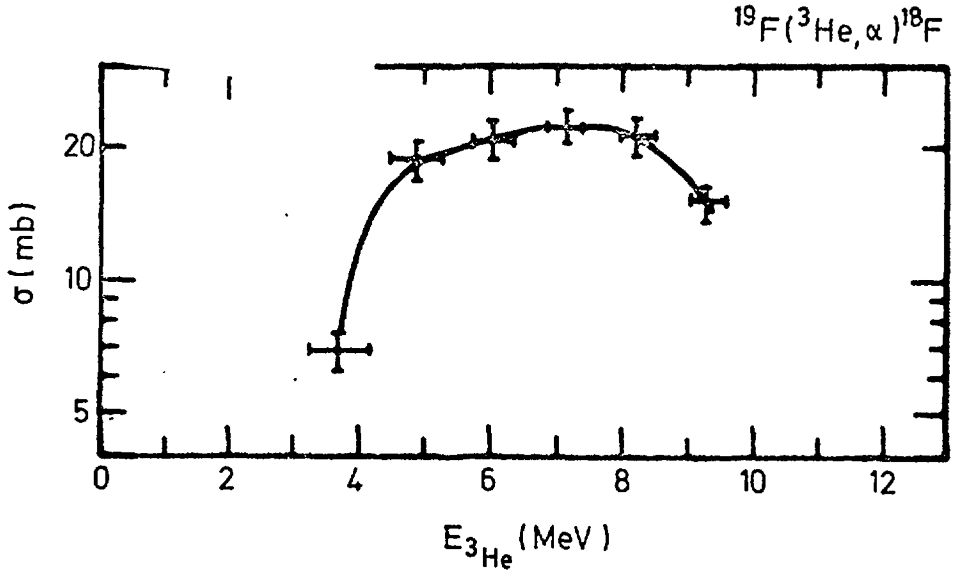
16O(3He,p)18F
1000
500
200
100
50
σ(mb)
0
2
4
6
8
10
12
E3He (MeV)

Ref H3

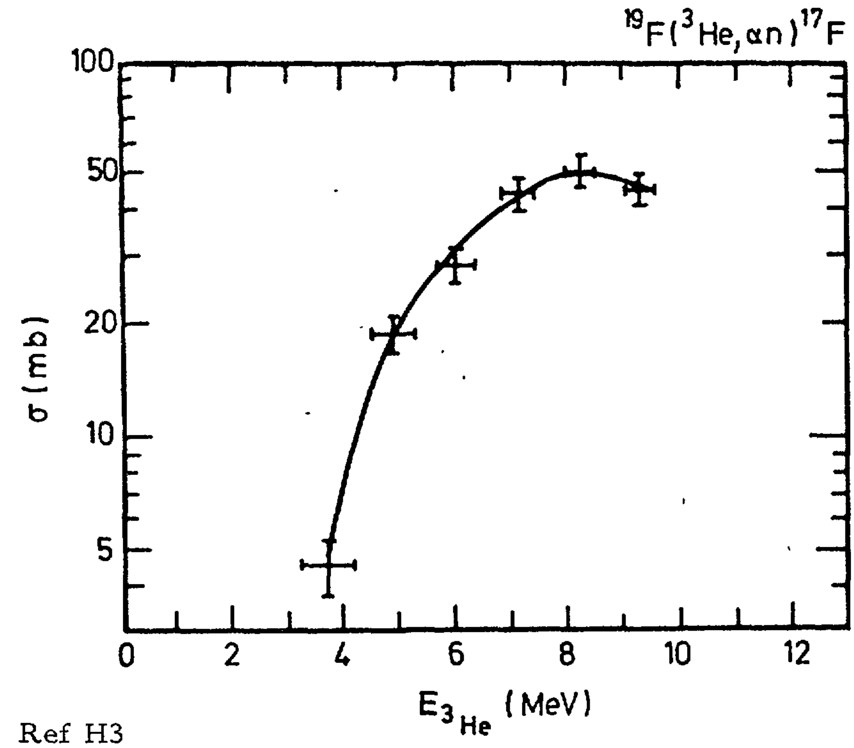


16O(3He,α)15O
200
100
50
20
10
σ(mb)
0
2
4
6
8
10
12
E3He (MeV)

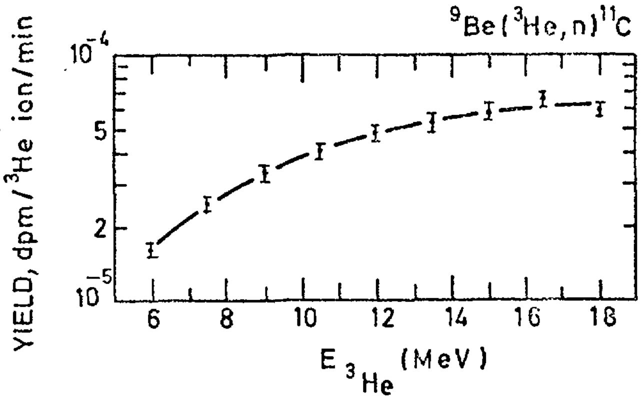
Ref H3


$^{19}F(^3He,\alpha)^{18}F$
σ (mb)
20
10
5
0
2
4
6
8
10
12
$E_{^3He}$ (MeV)

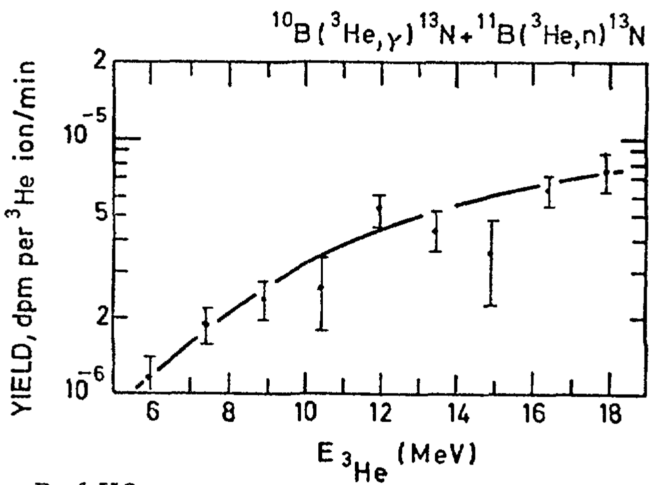
Ref H3


$^{19}F(^3He,\alpha n)^{17}F$
100
50
20
10
5
σ (mb)
0
2
4
6
8
10
12
$E_{^3He}$ (MeV)

Ref H3



Ref Y1



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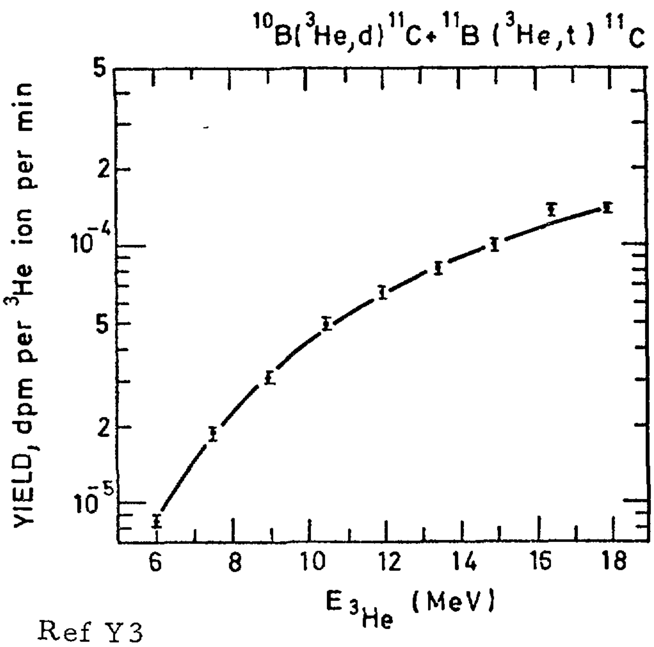
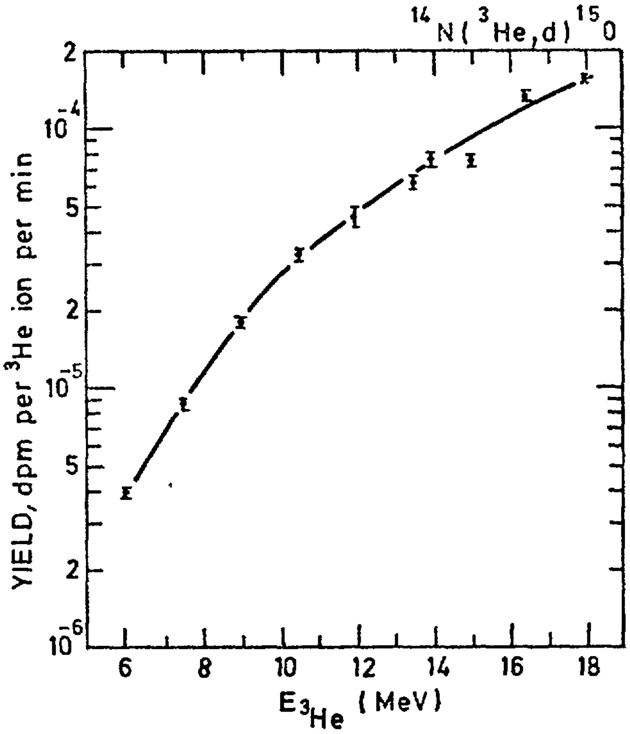
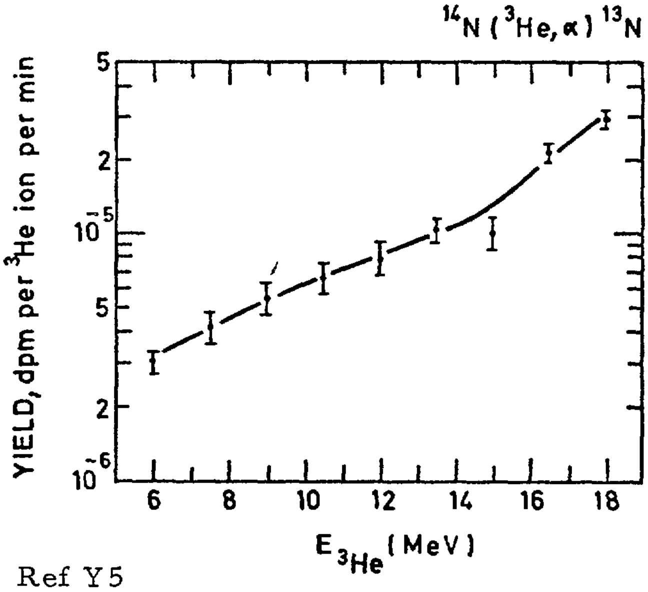


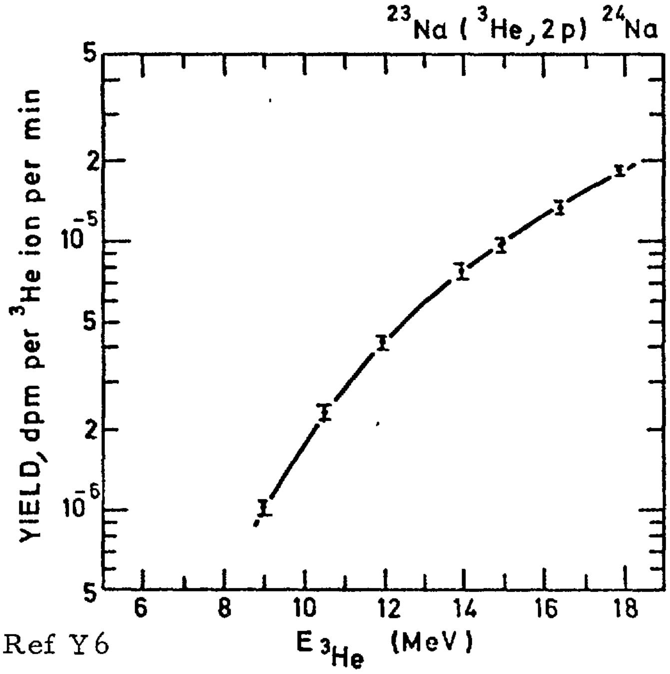
Ref Y3



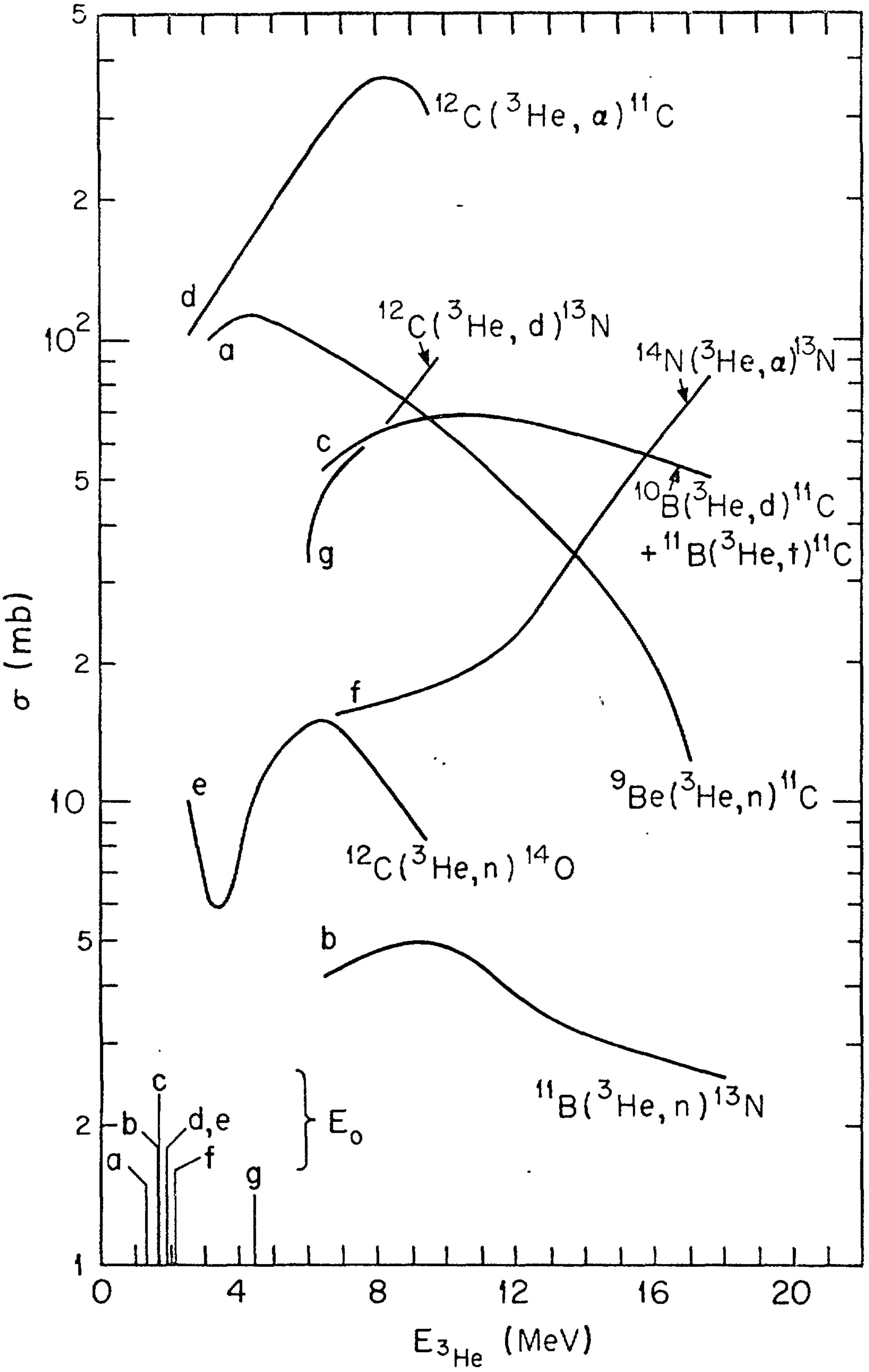
Ref Y4



Ref Y5

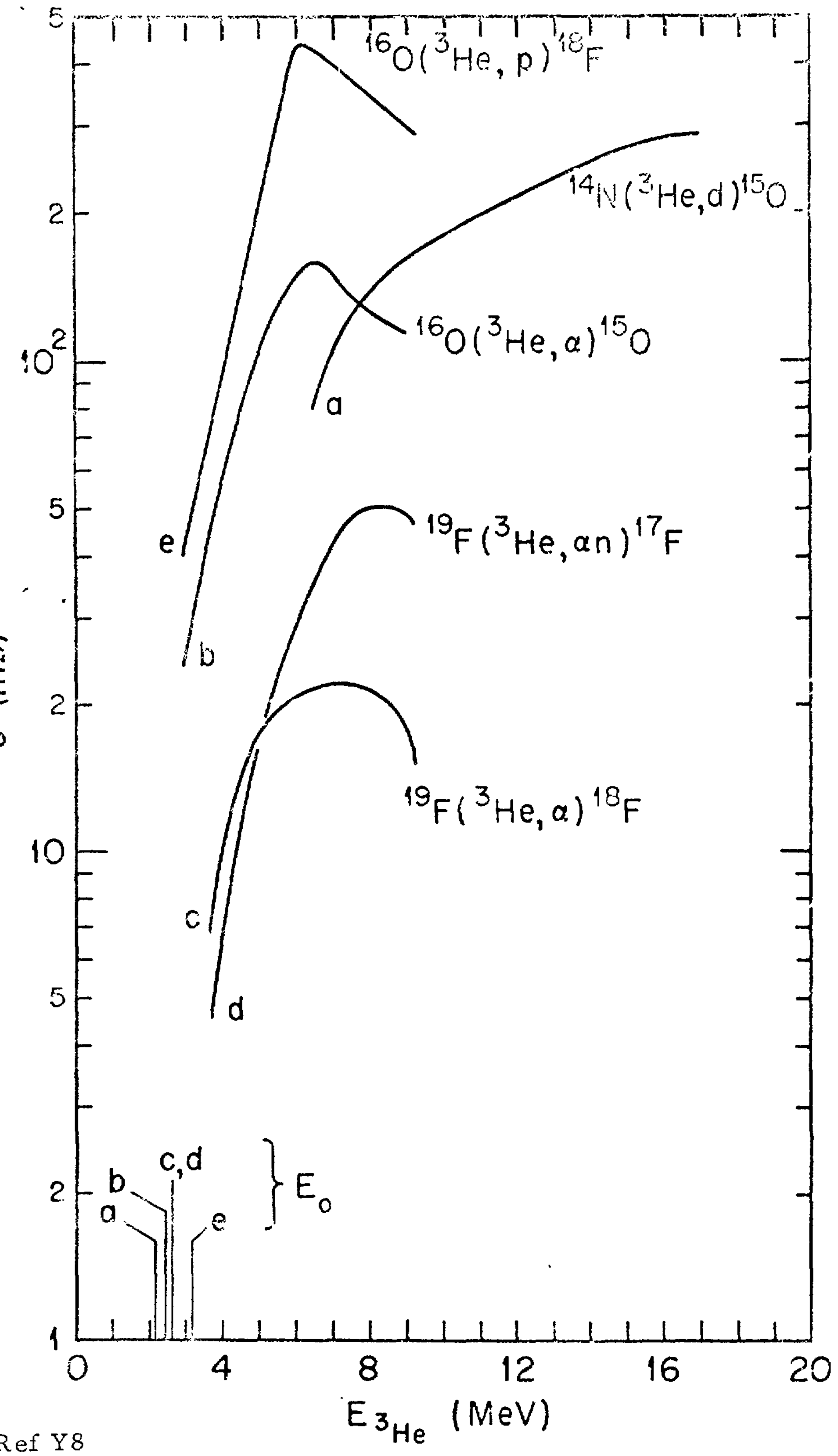


Ref Y6



5
2
10^2
5
2
10
5
2
1
σ (mb)
0
4
8
12
16
20
$E_{^3He}$ (MeV)
$^{12}C(^3He,\alpha)^{11}C$
$^{12}C(^3He,d)^{13}N$
$^{14}N(^3He,\alpha)^{13}N$
$^{10}B(^3He,d)^{11}C$
$+\,^{11}B(^3He,t)^{11}C$
$^9Be(^3He,n)^{11}C$
$^{12}C(^3He,n)^{14}O$
$^{11}B(^3He,n)^{13}N$
a
b
c
d
e
f
g
d,e
E_o

Ref Y7


16O(3He, p)18F
14N(3He,d)15O
16O(3He,α)15O
19F(3He,αn)17F
19F(3He,α)18F
a
b
c
d
e
c,d
E0
5
2
10²
5
2
10
5
2
1
0
4
8
12
16
20
σ (mb)
E3He (MeV)

Ref Y8

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APPENDIX I

Characteristic data for excitation functions of charged particle induced reactions at higher energies.

Systematics

TABLE OF THE CHARACTERISTIC DATA FOR THE EXCITATION FUNCTIONS

The five columns below list the following parameters:

1. No of excitation function in fig AI-14 to AI-21
2. Target nucleus, atomic number, chem symbol, mass number
3. Q-value of the reaction (MeV)
4. Position of the maximum with respect to the energy scale E+Q (MeV)
5. Height of the maximum (mb)

No	Target nucleus	Q-value	Position of maximum	Height of maximum
(α, n)				
1	21 Sc-45	-2.2	12.7	630
2a	25 Mn-55	-3.5	8.7	680
2b	25 Mn-55	-3.5	10.9	520
3	26 Fe-54	-5.8	10.5	190
4	27 Co-59	-5.1	-	-
5	28 Ni-60	-7.9	11.1	550
6	Ni-62	-6.5	9.7	950
7	29 Cu-63	-7.5	8.9	700
8a	Cu-65	-5.8	-	-
8b	Cu-65	-5.8	11.8	820
9a	30 Zn-64	-9.2	10.9	770
9b	30 Zn-64	-9.2	10.2	320
10	Zn-68	-5.7	-	-
11	37 Rb-85	-3.5	12.0	250
12	Rb-87	-3.8	10.0	240
13a	41 Nb-93	-7.0	9.4	470
13b	41 Nb-93	-7.0	-	-
14	42 Mo-92	-8.4	11.6	370
15	Mo-100	-4.6	9.6	760
16a	47 Ag-107	-7.6	9.2	420
16b	47 Ag-107	-7.6	10.8	340
17	Ag-109	-6.4	10.0	360
18	48 Cd-106	-10.1	10.9	670

No	Target nucleus	Q-value	Position of maximum	Height of maximum
(α, n)				
19	49 In-115	-7.2	12.1	300
20	50 Sn-112	-13.0	6.4	550
21	Sn-114	-11.1	7.0	290
22	Sn-124	-5.6	13.4	160
23a	56 Ba-138	-8.6	7.4	130
23b	56 Ba-138	-8.6	17.2	900
24a	57 La-139	-9.2	9.1	115
24b	57 La-139	-9.2	8.4	110
24c	57 La-139	-9.2	8.3	110
25a	67 Ho-165	-9.2	11.8	79
25b	67 Ho-165	-9.2	8.8	30
26	68 Er-164	-11.1	6.9	260
27	79 Au-197	-9.8	-	-
28	82 Pb-207	-12.1	10.3	110
29	Pb-208	-15.0	6.4	90
30	92 U-235	-10.9	-	-
31	94 Pu-238	-13.1	-	-
(α, 2n)				
1	21 Sc-45	-12.8	13.3	200
2a	25 Mn-55	-12.1	-	640
2b	25 Mn-55	-12.1	-	670
3	26 Fe-54	-16.0	16.3	10
4	27 Co-59	-14.0	14.4	390
5	28 Ni-60	-17.1	14.9	180
6	29 Cu-63	-16.6	14.4	260
7a	Cu-65	-14.1	13.4	650
7b	Cu-65	-14.1	-	1000
8	30 Zn-64	-19.0	13.5	86
9	32 Ge-70	-16.1	16.9	320
10	35 Br-79	-14.4	-	2300
11	37 Rb-85	-12.7	12.3	810
12	47 Ag-107	-15.6	11.4	1000

No	Target nucleus	Q-value	Position of maximum	Height of maximum
(α, 2n)				
13	Ag-109	-14.3	10.2	1050
14	48 Cd-106	-19.2	12.3	430
15	52 Te-130	-11.8	13.7	66
16	67 Ho-165	-16.2	7.3	750
17	68 Er-164	-18.0	11.0	820
18a	79 Au-197	-16.4	12.6	640
18b	79 Au-197	-16.4	13.6	800
18c	79 Au-197	-16.4	12.4	650
19	82 Pb-206	-20.0	11.0	1050
20	Pb-208	-19.5	10.5	1000
21a	83 Bi-209	-20.3	9.9	900
21b	83 Bi-209	-20.3	10.5	910
22	92 U-233	-19.1	8.9	6.5
23	U-235	-17.9	8.3	16
24	93 Np-237	-18.3	9.7	16
25	94 Pu-238	-17.8	8.2	15.5
26	Pu-239	-18.2	10.8	13
27	Pu-242	-17.2	7.8	10.5
28	98 Cf-252	-18.2	10.4	9.5
(α, 3n)				
1	25 Mn-55	-23.5	-	-
2	26 Fe-56	-26.3	17.3	16
3	30 Zn-64	-31.5	-	-
4	37 Rb-85	-24.7	15.1	600
5	47 Ag-107	-26.1	13.1	550
6a	Ag-109	-24.1	11.9	1000
6b	Ag-109	-24.1	13.9	950
7	49 In-115	-24.4	-	-
8	50 Sn-124	-21.0	15.0	1400
9	57 La-139	-24.5	11.7	1400
10	67 Ho-165	-24.7	10.1	840
11	68 Er-164	-27.5	12.9	1180

No	Target nucleus	Q-value	Position of maximum	Height of maximum
(α, 3n)				
12a	79 Au-197	-25.4	13.6	1100
12b	79 Au-197	-25.4	12.8	1400
13	82 Pb-206	-28.5	-	-
14	Pb-207	-26.8	12 8	1400
15	83 Bi-209	-28.0	-	-
16	83 Bi-209	-28.0	11.5	1200
17	92 U-233	-25.3	9.1	1
18	U-235	-23.8	9.8	8
19	93 Np-237	-25.4	13.4	14
20	94 Pu-239	-23.8	13.2	4.5
21	98 Cf-252	-25.0	12.4	3.3
(α, p)				
1	26 Fe-54	-1.8	16.2	600
2	28 Ni-58	-3.1	-	-
3	30 Zn-64	-4.0	15.0	520
4	42 Mo-92	-5.6	14.4	185
5	48 Cd-106	-5.6	17.3	245
6	50 Sn-124	-6.4	23.0	18
(α, pn)				
1a	26 Fe-54	-13.2	14.8	750
1b	26 Fe-54	-13.2	14.6	470
2a	Fe-56	-13.7	13.7	840
2b	Fe-56	-13.7	14.7	790
2c	Fe-56	-13.7	16.3	630
3	28 Ni-60	-14.6	16.4	890
4	Ni-62	-14.3	17.2	495
5	29 Cu-63	-12.6	17.4	870
6a	30 Zn-64	-16.0	-	-
6b	30 Zn-64	-16.0	16.6	790
7	Zn-66	-15.5	-	-
8	Zn-70	-13.9	17.1	88
9	32 Ge-70	-15.3	15.7	575

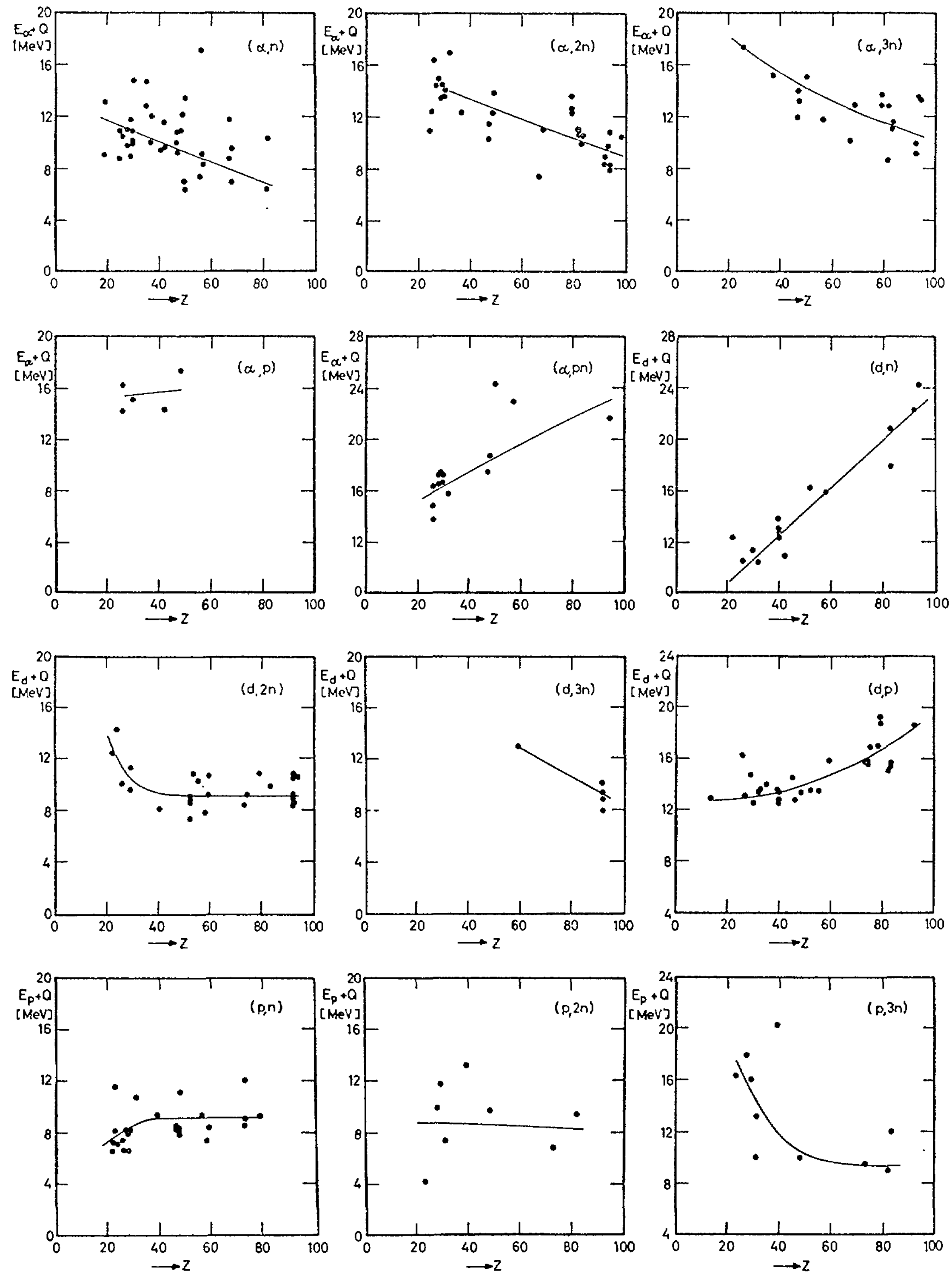
No	Target nucleus	Q-value	Position of maximum	Height of maximum
(α, pn)				
10	47 Ag-107	-13.6	17.4	91
11	48 Cd-106	-16.7	18.6	225
12	50 Sn-124	-14.8	24.2	46
13	57 La-139	-15.6	-	-
14	94 Pu-238	-18.3	20.7	15
(d, n)				
1	22 Ti-47	4.6	12.4	200
2	24 Cr-50	2.9	8.3	265
3	26 Fe-54	2.8	10.5	155
4	30 Zn-66	3.1	11.4	450
5	32 Ge-70	2.4	10.4	270
6a	40 Zr-94	4.6	13.8	120
6b	40 Zr-94	4.6	12.3	130
7a	Zr-96	5.2	12.7	85
7b	Zr-96	5.2	13.0	85
8	42 Mo-92	1.9	10.9	190
9	52 Te-130	5.2	16.2	75
10a	58 Ce-142	3.5	-	-
10b	58 Ce-142	3.5	15.9	60
11a	83 Bi-209	2.8	20.8	34
11b	83 Bi-209	2.8	-	32
12	92 U-235	2.6	22.2	10
13	94 Pu-239	2.2	24.2	14
(d, 2n)				
1	22 Ti-47	-5.9	9.5	400
2	Ti-48	-7.0	10.0	38
3a	24 Cr-52	-7.7	-	-
3b	24 Cr-52	-7.7	14.3	200
4	26 Fe-56	-7.6	10.0	310
5	29 Cu-63	-6.4	-	-
6a	Cu-65	-4.4	11.3	920
6b	Cu-65	-4.4	9.6	820
7a	30 Zn-66	-8.2	-	-

No	Target nucleus	Q-value	Position of maximum	Height of maximum
(d, 2n)				
7b	30 Zn-66	-8.2	-	-
8	Zn-68	-5.9	-	-
9	32 Ge-70	-9.2	-	-
10	34 Se-82	-3.1	-	-
11a	40 Zr-96	-2.8	-	-
11b	40 Zr-96	-2.8	8.2	1050
12	52 Te-126	-5.2	7.3	750
13	Te-128	-4.3	9.0	800
14a	Te-130	-3.4	8.8	700
14b	Te-130	-3.4	8.5	750
15	53 J-127	-3.7	10.9	700
16	55 Cs-133	-3.5	10.3	600
17a	58 Ce-142	-3.8	-	-
17b	58 Ce-142	-3.8	7.8	750
18	73 Ta-181	-3.2	8.4	660
19	74 W-184	-4.7	-	-
20	W-186	-3.6	9.2	380
21	79 Au-197	-3.8	10.8	600
22	83 Bi-209	-4.9	9.9	540
23	92 U-234	-4.8	9.2	32
24a	U-235	-3.1	8 6	19
24b	U-235	-3.1	10.8	25
25	U-236	-3.9	8.4	43
26a	U-238	-3.1	8.9	48
26b	U-238	-3.1	10.5	70
27	94 Pu-239	-3.8	10.6	28
(d, 3n)				
1	40 Zr-96	-10.0	-	-
2	53 J-127	-10.9	-	-
3	59 Pr-141	-12.7	12.9	1200
4a	83 Bi-209	-11.9	-	-
4b	83 Bi-209	-11.9	-	-
5	92 U-234	-10.9	7.9	19

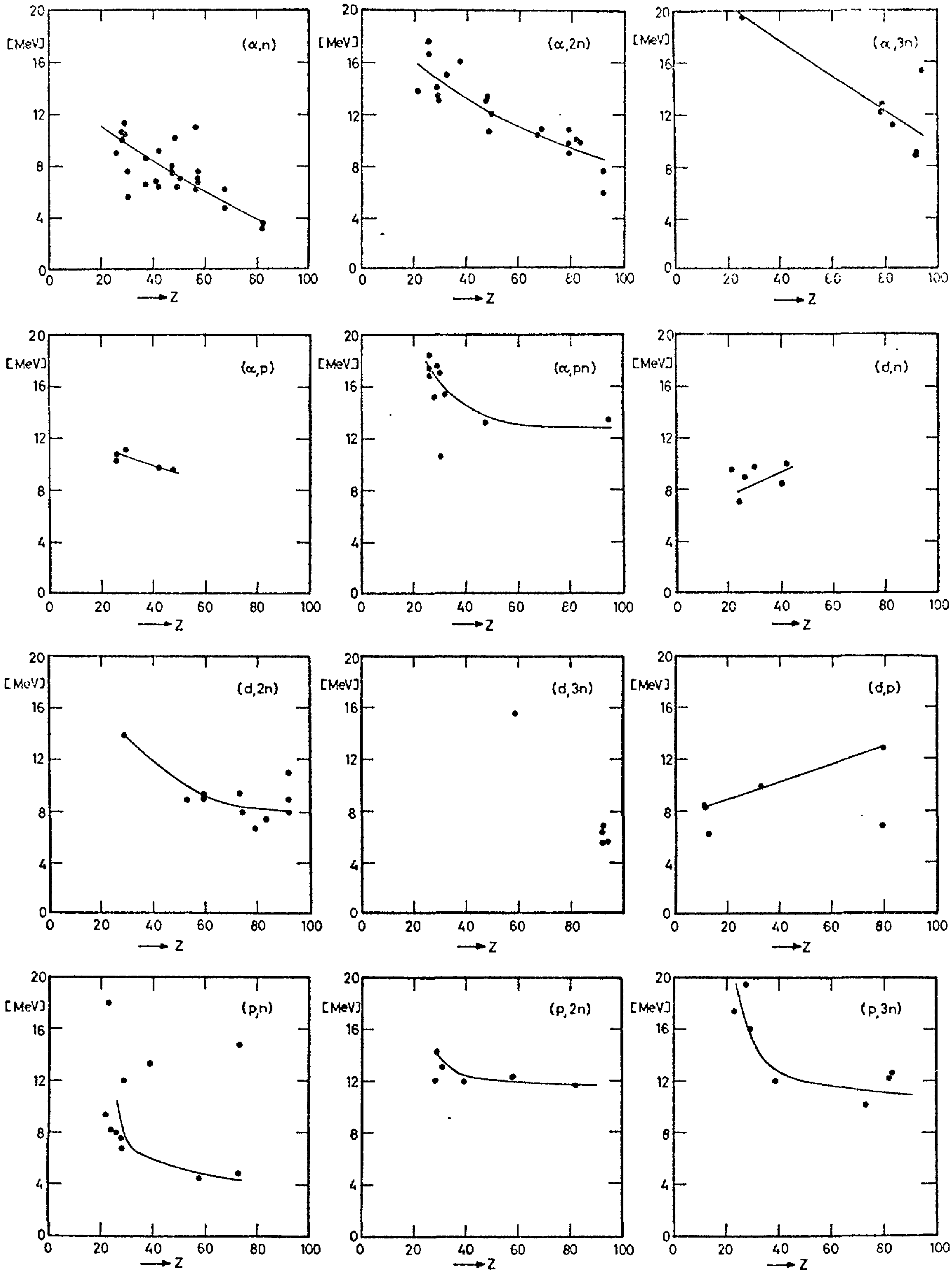
No	Target nucleus	Q-value	Position of maximum	Height of maximum
(d, 3n)				
6a	92 U-235	-10.1	10.1	26
6b	92 U-235	-10.1	8.9	24
7	U-236	-9.6	9.4	57
8	94 Pu-239	-10.9	-	-
(d, p)				
1	27 Co-59	5.3	13.1	300
2	29 Cu-63	5.7	14.7	275
3	30 Zn-68	4.3	12.5	450
4	32 Ge-70	5.2	13.4	450
5	33 As-75	5.1	13.6	250
6	35 Br-81	5.4	13.9	370
7	39 Y-89	4.6	13.6	205
8	40 Zr-94	4.2	13.4	280
9a	Zr-96	3.4	12.8	220
9b	Zr-96	3.4	12.6	300
10	45 Rh-103	4.8	14.5	200
11	46 Pd-110	3.5	12.8	285
12	48 Cd-114	3.9	13.3	265
13	52 Te-130	3.7	13.5	200
14	55 Cs-133	3.9	13.5	175
15a	58 Ce-142	2.9	-	-
15b	58 Ce-142	2.9	12.9	230
16	59 Pr-141	3.6	15.8	260
17	73 Ta-181	3.8	15.8	230
18	74 W-184	3.5	15.8	280
19	W-186	3.3	15.7	310
20	75 Re-187	3.0	17.0	210
21	78 Pt-196	3.1	-	-
22a	79 Au-197	4.3	18.8	280
22b	79 Au-197	4.3	19.3	160
23	82 Pb-208	1.7	15.1	205
24	83 Bi-209	2.4	15.4	115
25	Bi-209	2.4	15.6	110
26	92 U-238	2.6	18.6	220

No	Target nucleus	Q-value	Position of maximum	Height of maximum
(p, n)				
1	22 Ti-47	-3.7	6.5	300
2	Ti-48	-4.8	7.2	510
3a	23 V-51	-1.5	-	-
3b	23 V-51	-1.5	11.5	700
4a	24 Cr-52	-5.5	7.1	600
4b	24 Cr-52	-5.5	-	-
5	25 Mn-55	-1.0	-	-
6	26 Fe-56	-5.4	6.6	450
7	Fe-57	-1.6	7.4	400
8	27 Co-59	-1.9	8.1	500
9	28 Ni-61	-3.0	6.6	700
10	Ni-62	-4.7	-	-
11	Ni-64	-2.5	7.9	850
12	29 Cu-63	-4.2	8.2	500
13	Cu-65	-2.1	-	-
14	31 Ga-69	-2.2	-	-
15	39 Y-89	-3.6	9.4	730
16	47 Ag-107	-2.2	-	-
17	Ag-109	-1.0	8.2	360
18	48 Cd-110	-4.7	8.3	870
19a	Cd-111	-1.9	11.1	530
19b	Cd-111	-1.9	-	-
20	Cd-112	-3.4	-	-
21	Cd-114	-2.2	-	-
22	50 Sn-124	-1.4	-	-
23	57 La-139	-1.1	-	-
24	58 Ce-142	-1.6	7.4	120
25	59 Pr-141	-2.6	-	-
26a	73 Ta-181	-1.0	8.5	100
26b	73 Ta-181	-1.0	9.0	100
26c	73 Ta-181	-1.0	9.0	105
26d	73 Ta-181	-1.0	12	100
27	79 Au-197	-1.6	9.2	95

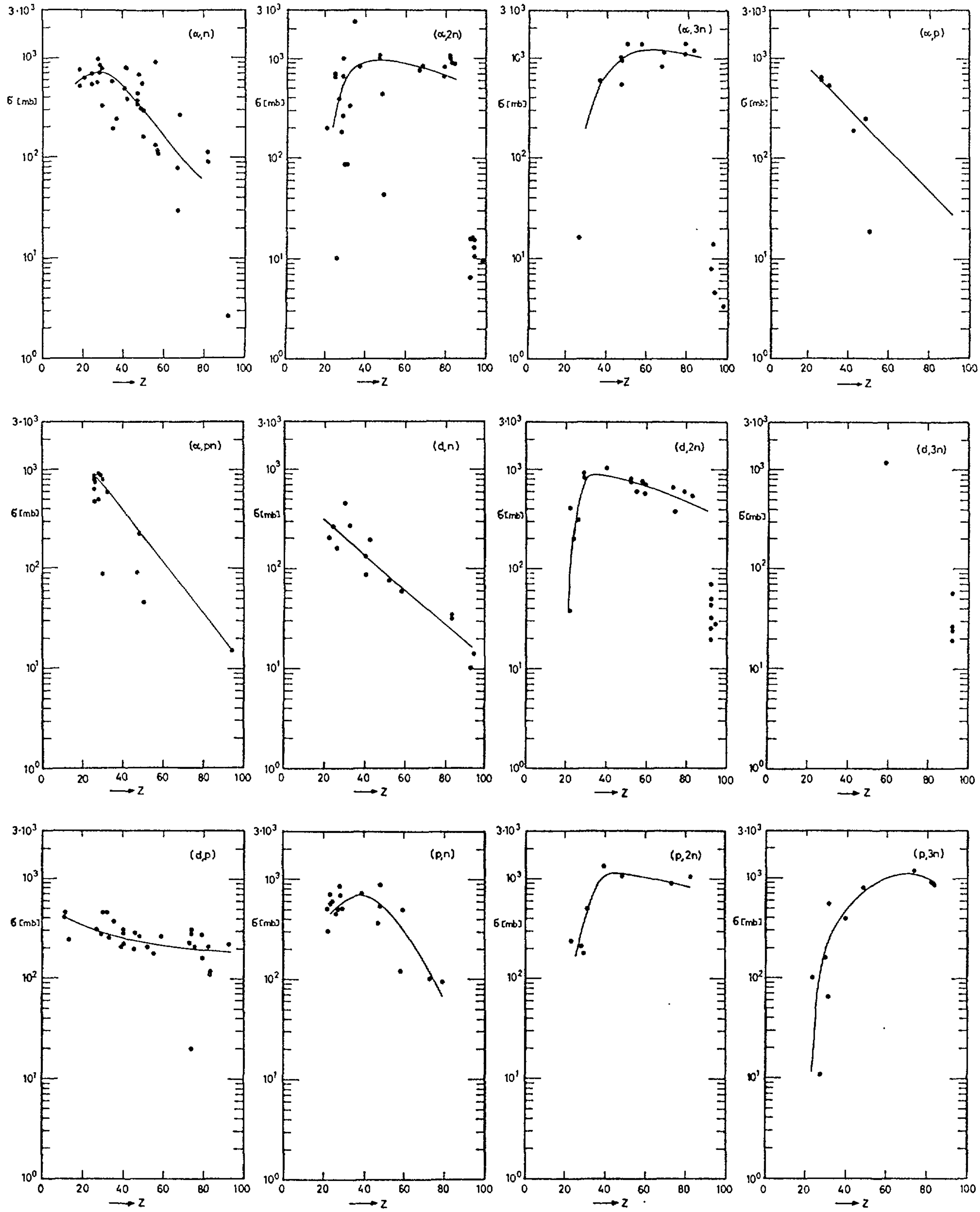
No	Target nucleus	Q-value	Position of maximum	Height of maximum
(p, 2n)				
1	23 V-51	-10.8	4.2	240
2	27 Co-59	-10.9	-	-
3	28 Ni-62	-13.6	9.9	210
4	29 Cu-63	-13.3	11.7	180
5	31 Ga-69	-11.6	7.4	500
6	39 Y-89	-12.8	13.2	1300
7	41 Nb-93	-9.3	-	-
8	47 Ag-107	-10.1	-	-
9	48 Cd-110	-12.7	-	-
10	Cd-111	-11.7	-	-
11	Cd-112	-11.3	9.7	1050
12a	73 Ta-181	-7.9	-	-
12b	73 Ta-181	-7.9	6.8	900
13a	79 Au-197	-8.2	-	-
13b	79 Au-197	-8.2	-	-
14	82 Pb-206	-11.6	9.4	1050
(p, 3n)				
1	23 V-51	-23.7	16.3	100
2	27 Co-59	-23.1	17.9	11
3	29 Cu-65	-22.0	16.0	160
4	31 Ga-69	-23.8	13.2	65
5	Ga-71	-20.0	10.0	550
6	39 Y-89	-20.8	20.2	390
7	48 Cd-112	-21.1	9.9	780
8	73 Ta-181	-15.5	9.5	1200
9	82 Pb-206	-20.0	9.0	900
10	83 Bi-209	-18.0	12.0	850



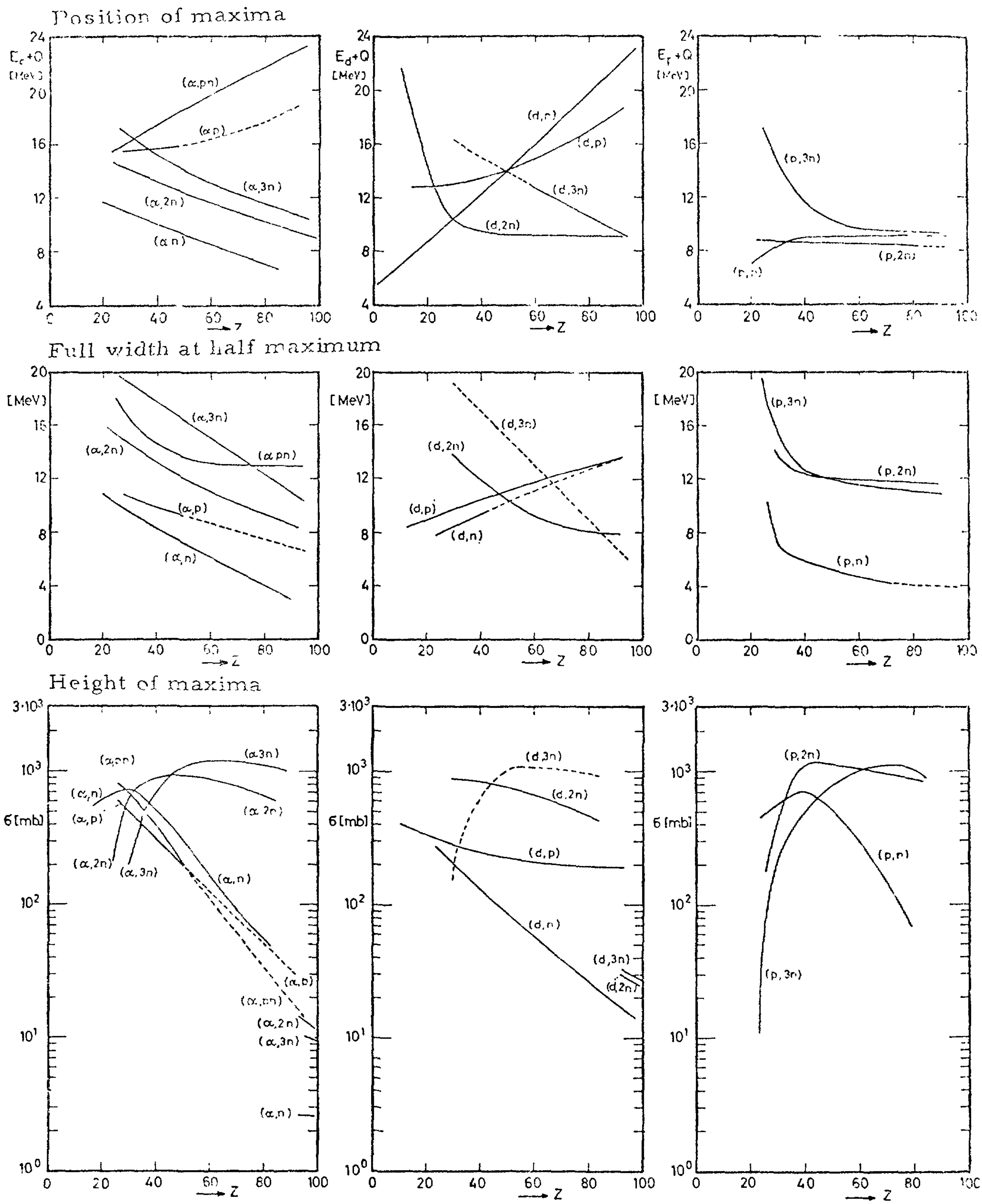
Positions of the maxima for the excitation functions dependent on the atomic number Z of the target nucleus



Full width at half maximum for the excitation functions dependent on the atomic number Z of the target nucleus



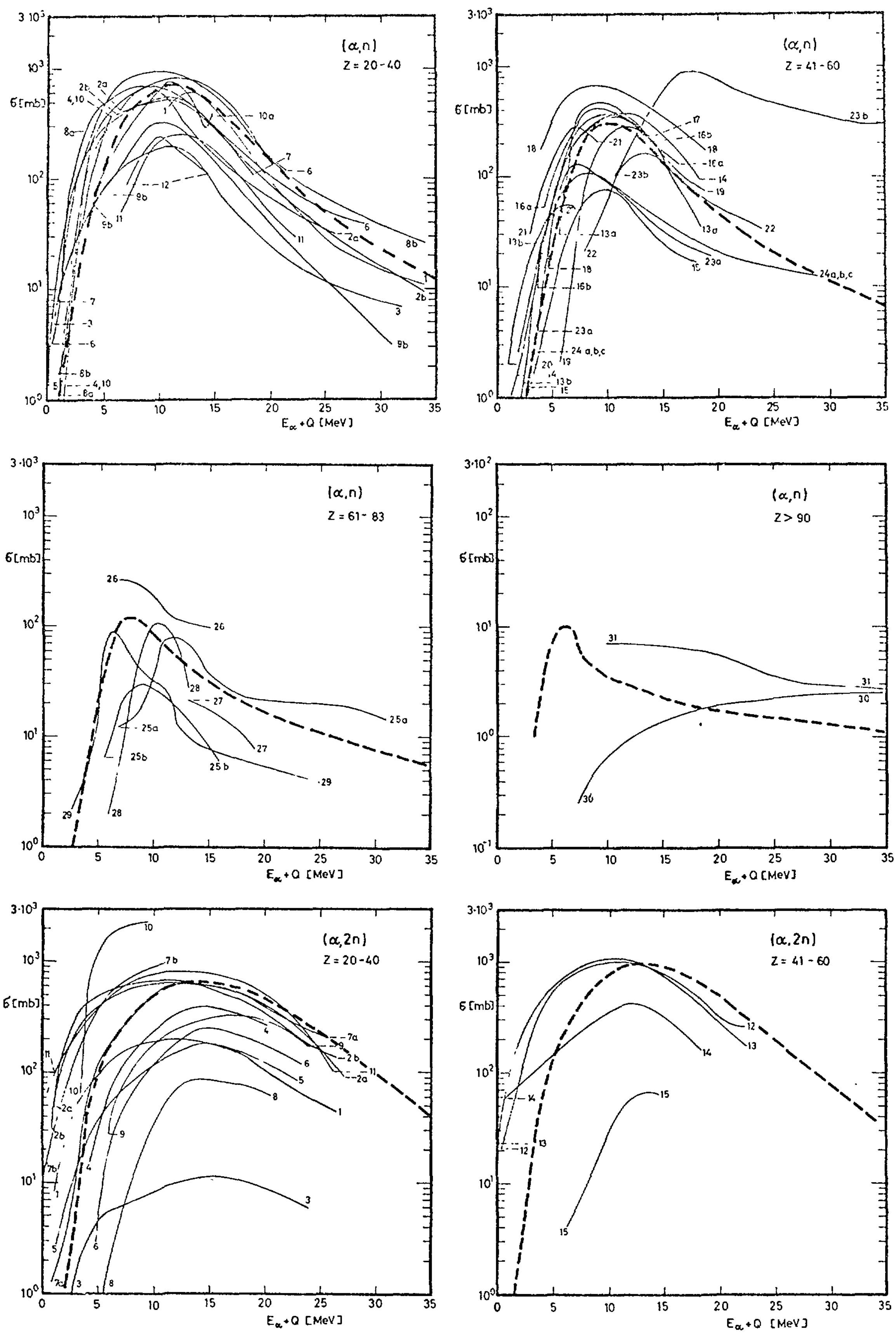
Heights of maxima for the excitation functions dependent on the atomic number Z of the target nucleus



Characteristic data of excitation functions dependent on the atomic number Z of the target nucleus

——— structure corresponding to figs AI-10-AI-12

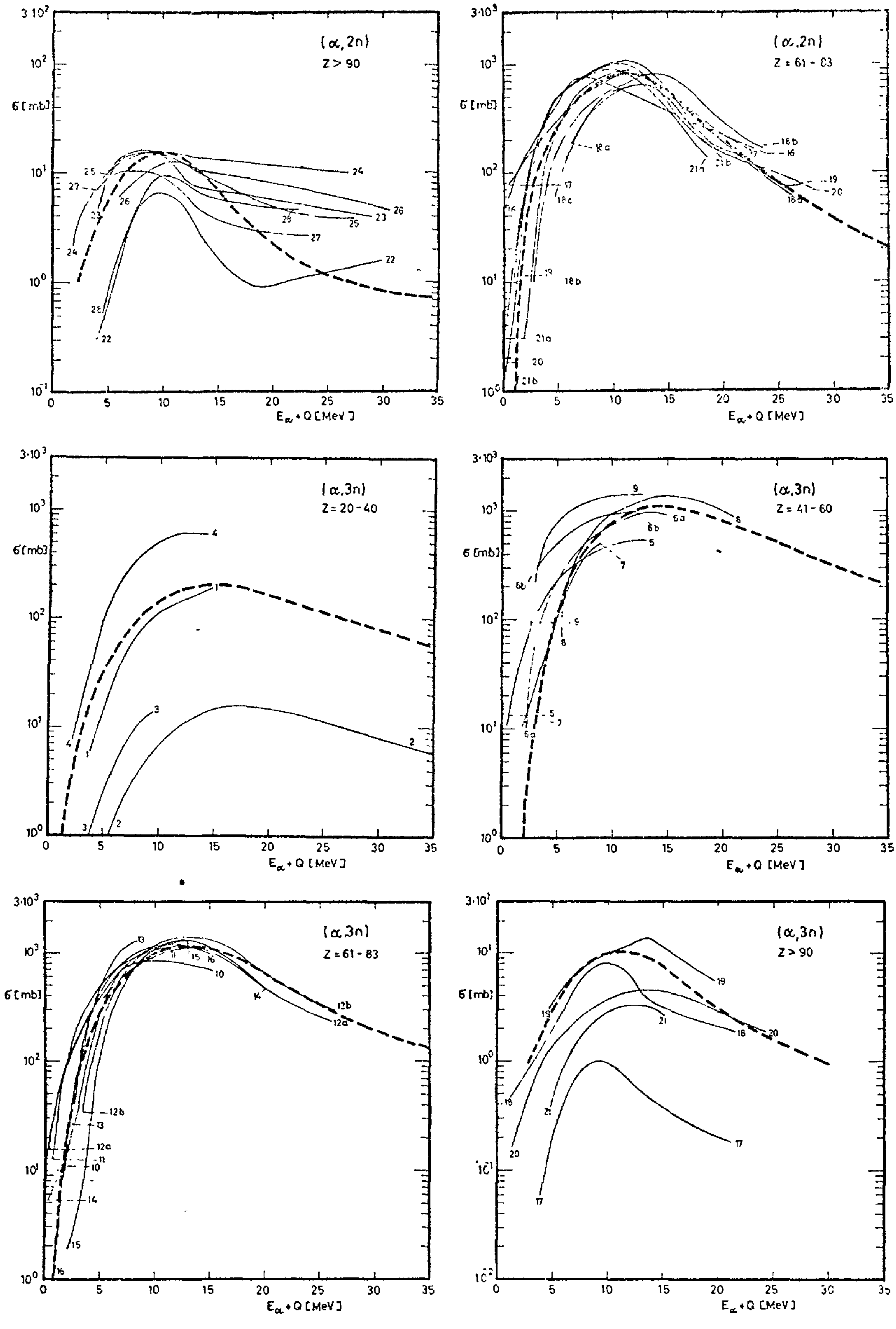
- - - - - - - structure estimated



Calculated and experimental excitation functions

——— experimental excitation functions

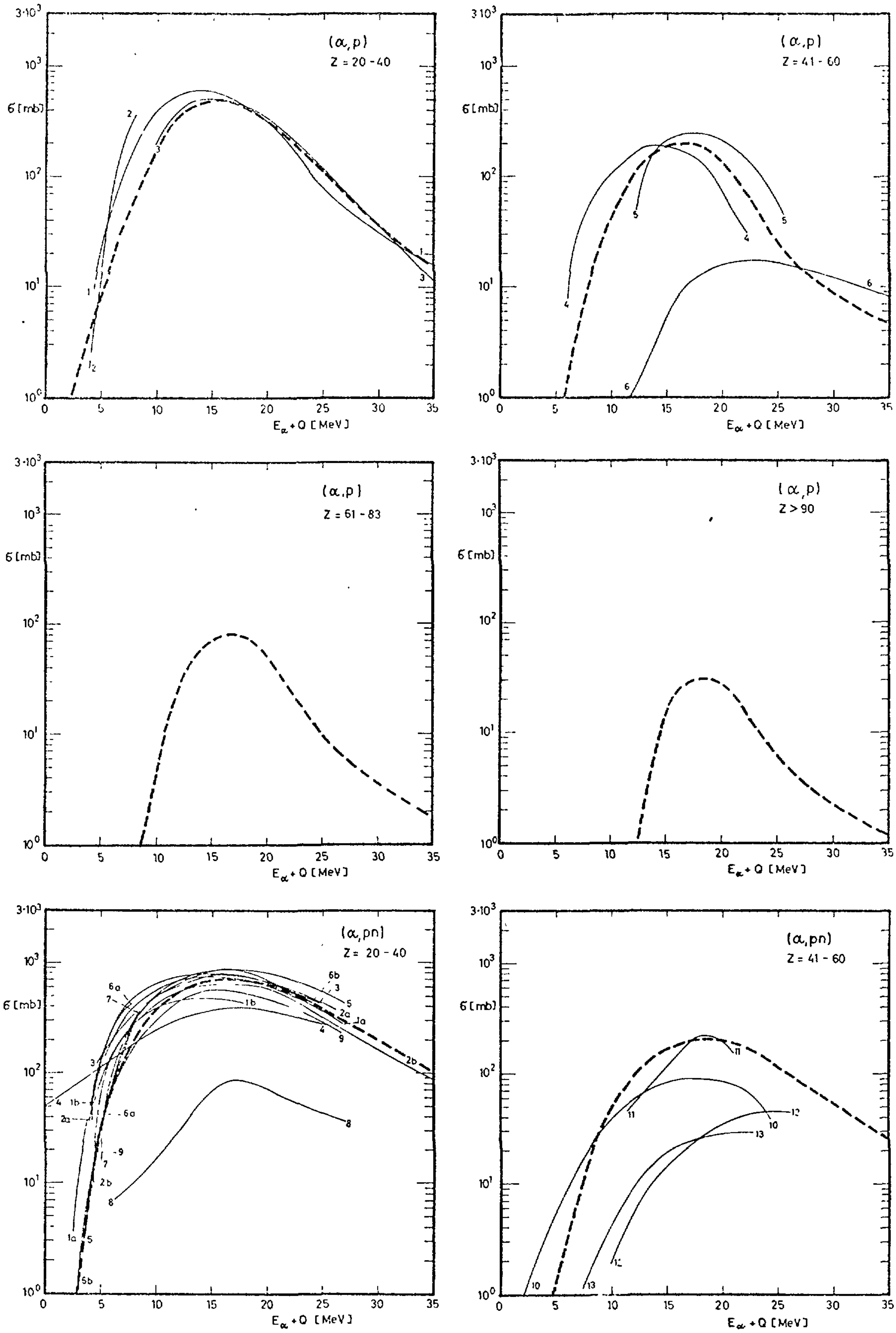
- - - - - - calculated excitation functions



Calculated and experimental excitation functions

——— experimental excitation functions

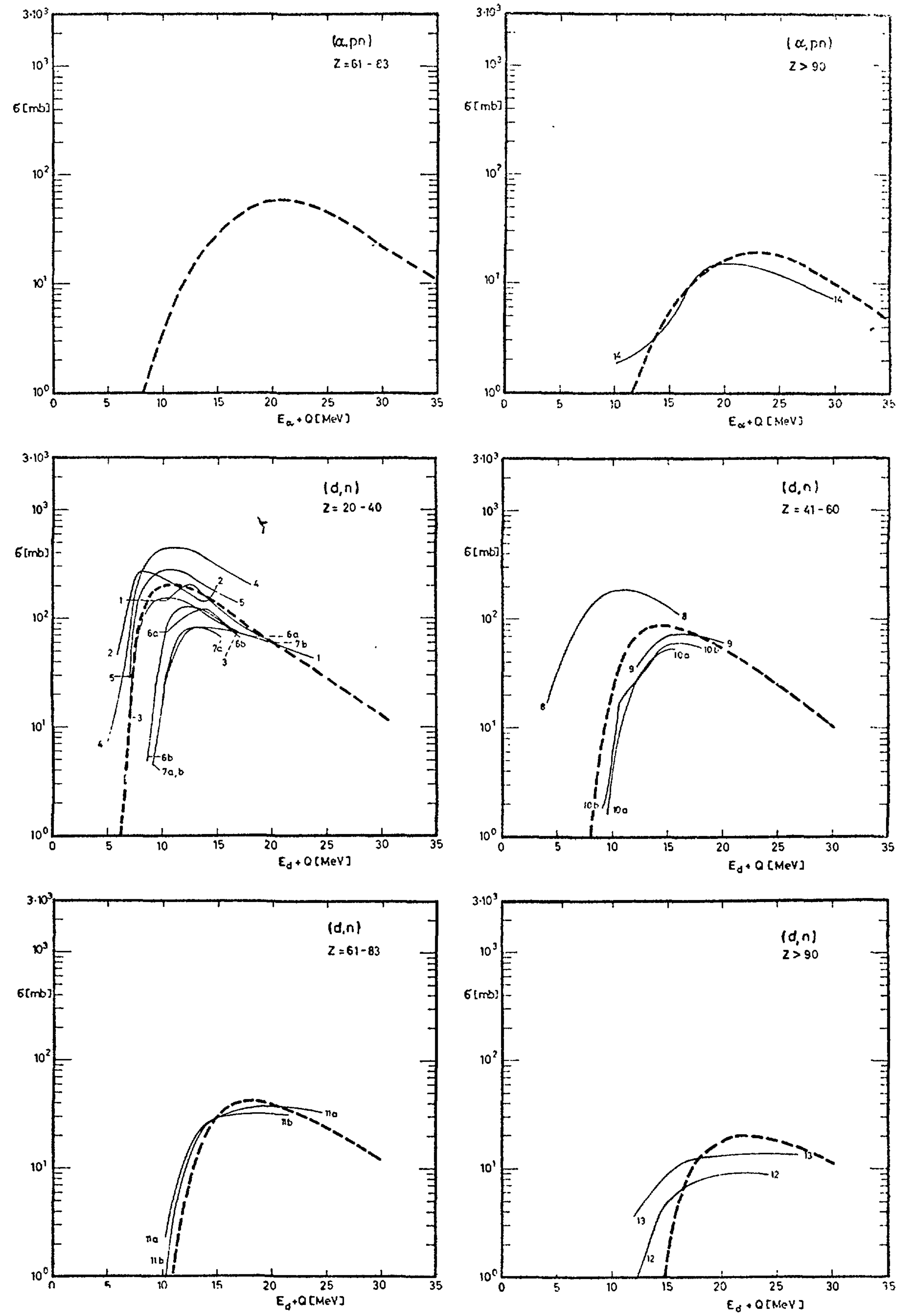
- - - - - - calculated excitation functions



Calculated and experimental excitation functions

——— experimental excitation functions

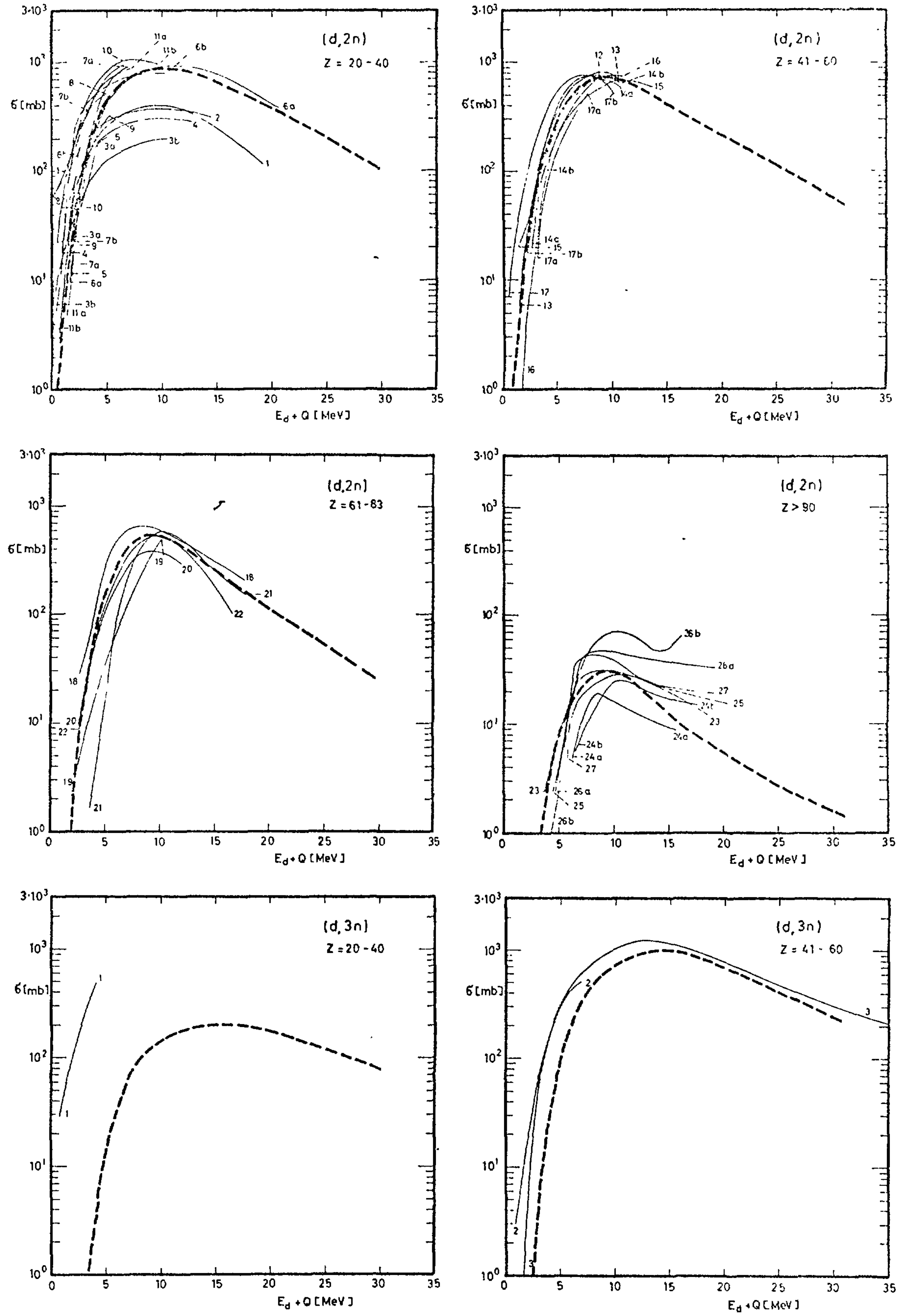
- - - - - - calculated excitation functions



Calculated and experimental excitation functions

——— experimental excitation functions

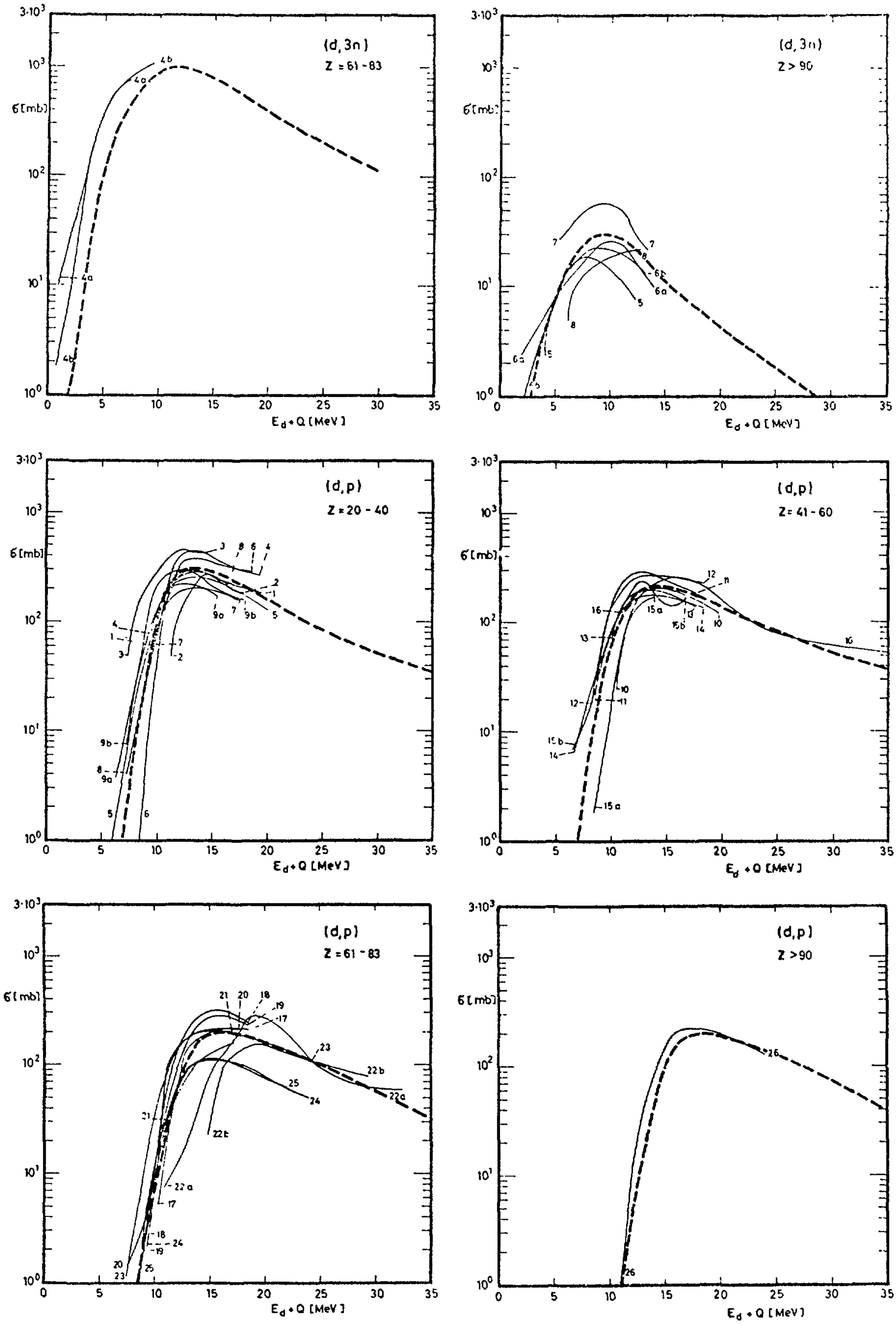
- - - - - - - calculated excitation functions



Calculated and experimental excitation functions

——— experimental excitation functions

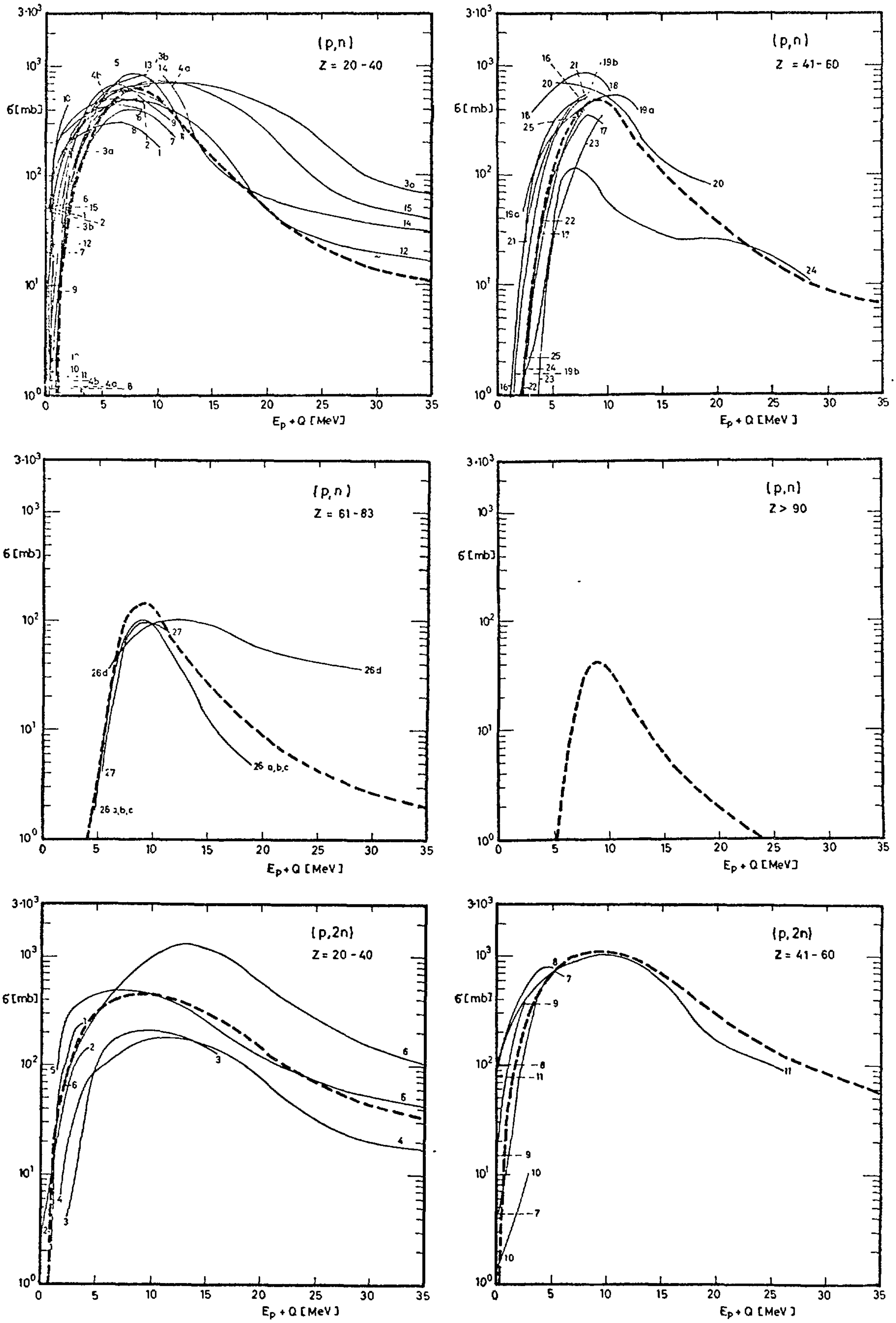
- - - - - - calculated excitation functions



Calculated and experimental excitation functions

——— experimental excitation functions

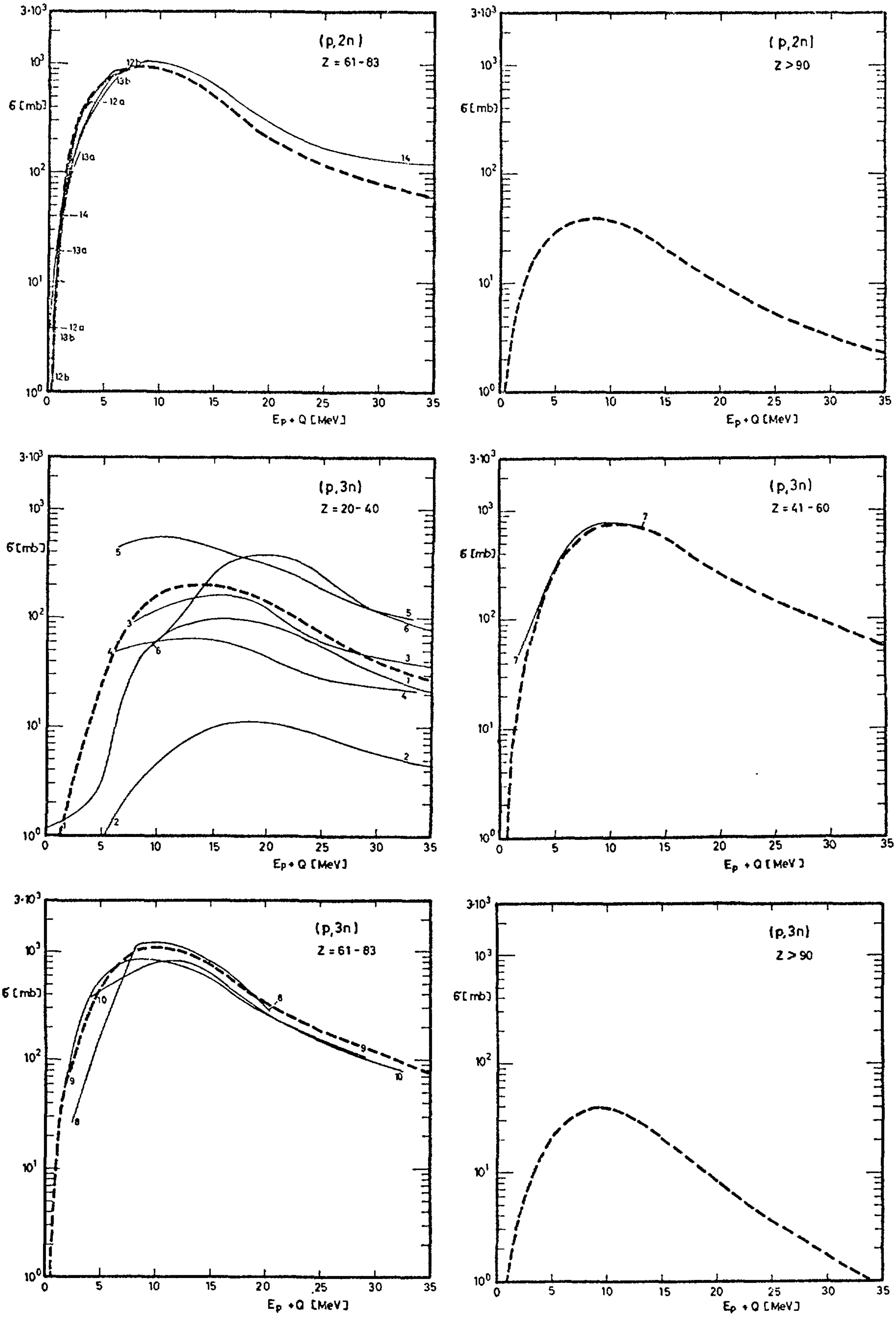
- - - - - - calculated excitation functions



Calculated and experimental excitation functions

——————— experimental excitation functions

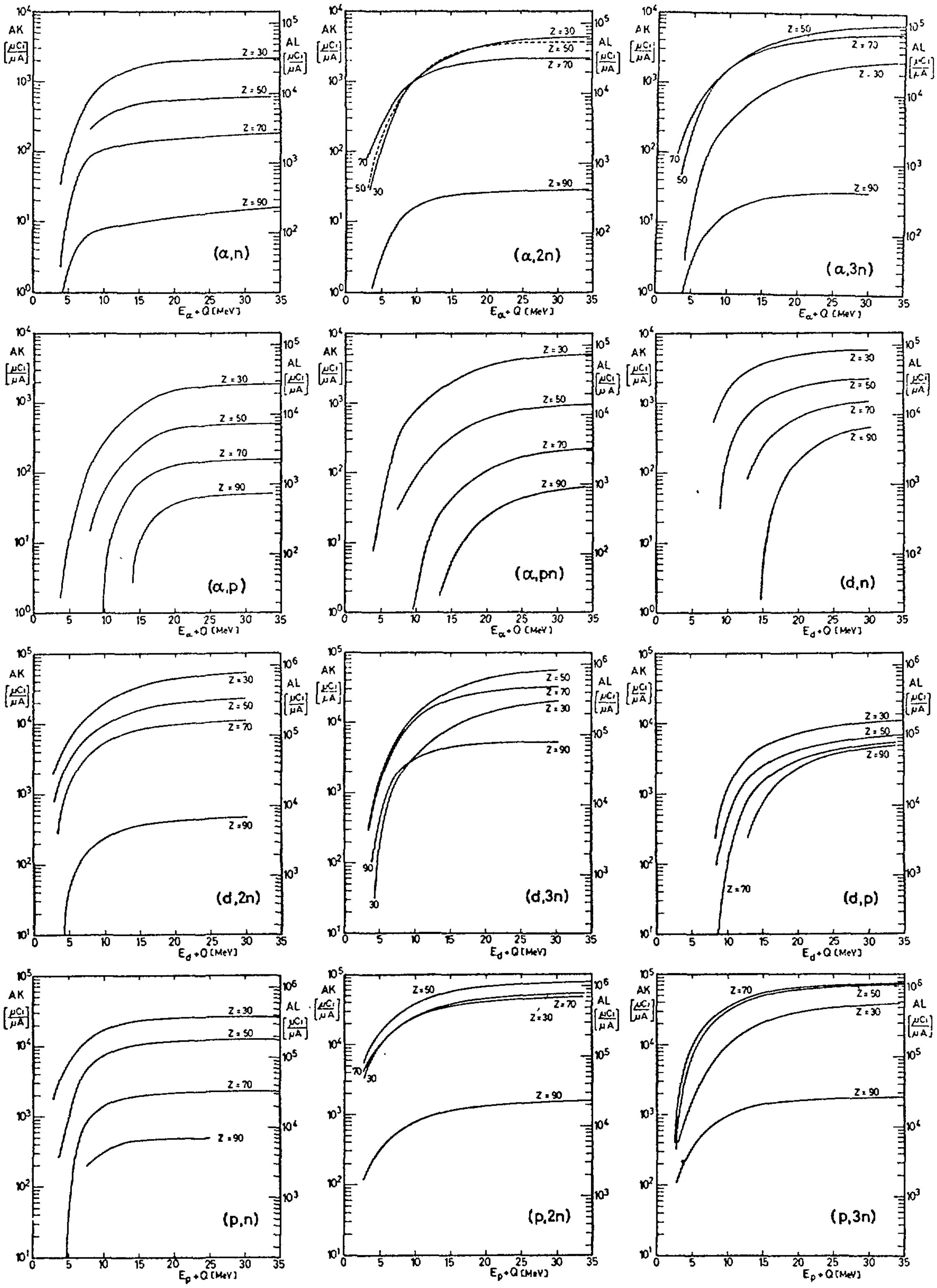
- - - - - - calculated excitation functions



Calculated and experimental excitation functions

——— experimental excitation functions

- - - - - - calculated excitation functions



Yield from thick targets

AK = yield from short irradiation times (t = 0.1 T)

AL = yield from long irradiation times (t >>T)

APPENDIX II

(p, γ)-resonances listed in respect to resonance energies from 163 keV to 3.0 MeV.

The different columns show

1. The proton energy in keV
2. The (p, γ)-reaction concerned
3. The energies of emitted gamma rays
4. The cross section in mb
5. FWHM of the resonance in keV
6. Half life and β-energy in β^+-decay (from "Chart of the nuclides" 3rd edition 1968, Bonn).

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
163	$B^{11}(p,\gamma)C^{12}$	16.11, 11.68, 4.43	0.157	7	
224	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	>0.2	1	
226	$Mg^{24}(p,\gamma)Al^{25}$	2.06, 1.56, 0.95		1 ?	7.2 s; 3.3
226	$Al^{27}(p,\gamma)Si^{28}$				
251	$Na^{23}(p,\gamma)Mg^{24}$			0.3	
261	$C^{14}(p,\gamma)N^{15}$				
278	$N^{14}(p,\gamma)O^{15}$	6.82, 6.14, 1.47		1.6	2.03 m; 1.7
294	$Al^{27}(p,\gamma)Si^{28}$			<1	
295	$Mg^{26}(p,\gamma)Al^{27}$				
308	$Na^{23}(p,\gamma)Mg^{24}$	10.6, 7.8, 6.7		0.8	
317	$Mg^{25}(p,\gamma)Al^{26}$	6.19, 4.86, 0.82		12	6.4 s; 3.2
326	$Al^{27}(p,\gamma)Si^{28}$	7.6, 7.2, 6.2		<1	
326	$Si^{29}(p,\gamma)P^{30}$	5.88, 5.17			2.50 m; 3.2
330	$Be^{9}(p,\gamma)B^{10}$	6.9, 6.2, 5.2		160	
339	$Mg^{26}(p,\gamma)Al^{27}$	7.74, 5.85, 5.61			
340	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	160	3	
355	$P^{31}(p,\gamma)S^{32}$				
356	$C^{14}(p,\gamma)N^{15}$	10.5, 7.1, 5.4			
360	$N^{15}(p,\gamma)O^{16}$	12.43, 6.37	0.007	94	
360	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	0.03	94	
374	$Na^{23}(p,\gamma)Mg^{24}$	6.26	2		
392	$Mg^{25}(p,\gamma)Al^{26}$	6.26, 4.6?, 3.5?	4	8	6.4 s; 3.2
405	$Al^{27}(p,\gamma)Si^{28}$	7.3, 5.1, 2.8			
414	$Si^{29}(p,\gamma)P^{30}$	5.25, 0.70			2.5 m; 3.2
418	$Mg^{24}(p,\gamma)Al^{25}$	2.70, 2.25, 0.89		1	7.2 s; 3.3
429	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	300	0.9	
429	$N^{15}(p,\gamma)O^{16}$	6.46	0.001	0.9	
437	$Mg^{25}(p,\gamma)Al^{26}$	6.72, 6.30, 4.66?			6.4 s; 3.2
439	$Al^{27}(p,\gamma)Si^{28}$				
440	$P^{31}(p,\gamma)S^{32}$			34	
441	$Li^{7}(p,\gamma)Be^{8}$	17.64, 14.74, 12.24	6	12	

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
444	$Na^{23}(p,\gamma)Mg^{24}$			0.8	
448	$C^{13}(p,\gamma)N^{14}$				
454	$Mg^{26}(p,\gamma)Al^{27}$	7.85, 7.68, 5.71			
457	$C^{12}(p,\gamma)N^{13}$	2.36	0.127	39.5	9.96 m; 1.2
473	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
484	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	>32	0.9	
496	$Mg^{25}(p,\gamma)Al^{26}$	6.36, 4.24, 4.21?		5	6.4 s; 3.2
500	$Si^{30}(p,\gamma)P^{31}$	7.75, 6.48, 4.62			
504	$Al^{27}(p,\gamma)Si^{28}$	12.07		<0.20	
506	$Al^{27}(p,\gamma)Si^{28}$	10.29		<0.17	
511	$Na^{23}(p,\gamma)Mg^{24}$	10.8, 8.0, 6.9		0.8	
513	$Mg^{25}(p,\gamma)Al^{26}$			3	6.4 s; 3.2
530	$Mg^{25}(p,\gamma)Al^{26}$			3	6.4 s; 3.2
532	$C^{14}(p,\gamma)N^{15}$	10.7, 5.3			
540	$P^{31}(p,\gamma)S^{32}$				
550	$C^{13}(p,\gamma)N^{14}$	8.06, 4.11	1.44	32.5	
580	$Mg^{25}(p,\gamma)Al^{26}$	6.85?, 6.43, 4.28			6.4 s; 3.2
594	$Na^{23}(p,\gamma)Mg^{24}$	10.9, 8.0, 7.0		2	
594	$S^{32}(p,\gamma)Cl^{33}$	2.86, 2.05, 0.806			2.53 s; 4.5
597	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	7.1	30	
607	$Mg^{25}(p,\gamma)Al^{26}$	6.88?, 6.46, 4.34			6.4 s; 3.2
612	$Al^{27}(p,\gamma)Si^{28}$			<1	
625	$Si^{30}(p,\gamma)P^{31}$	7.87			
630	$O^{18}(p,\gamma)F^{19}$	8.5		2.6	
632	$Al^{27}(p,\gamma)Si^{28}$	10.41, 7.59, 1.77		<0.06	
636	$Ne^{22}(p,\gamma)Na^{23}$	9.40			
640	$C^{14}(p,\gamma)N^{15}$	10.8, 5.3			
648	$P^{31}(p,\gamma)S^{32}$			17	
650	$Ca^{40}(p,\gamma)Sc^{41}$				0.596 s; 5.6
654	$Al^{27}(p,\gamma)Si^{28}$	10.43, 7.61		<0.06	
660?	$Ne^{22}(p,\gamma)Na^{23}$				
661	$Mg^{26}(p,\gamma)Al^{27}$	7.88, 6.68, 5.9			
667	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
672	$F^{19}(p,\gamma)Ne^{20}$	11.88, 1.63	0.5	6.0	
672	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	57	6.0	
675	$B^{11}(p,\gamma)C^{12}$	12.15, 4.43	0.050	322	
675	$Na^{23}(p,\gamma)Mg^{24}$	11.0, 8.1, 7.1		≤1	
675	$Mg^{25}(p,\gamma)Al^{26}$	6.55, 5.21, 3.30			6.4 s; 3.2
675	$Si^{30}(p,\gamma)P^{31}$	7.92, 6.65, 1.27			
678	$Al^{27}(p,\gamma)Si^{28}$	10.45, 7 63		<1	
693	$Si^{29}(p,\gamma)P^{30}$	6.26, 4.29, 3.51			2.5 m; 3.2
700	$N^{14}(p,\gamma)O^{15}$	8.0		100	
703?	Si(p, γ)P				2.03 m; 1.7
710	$N^{15}(p,\gamma)O^{16}$	6.72		40	
717?	Si(p, γ)P				
720	$Mg^{25}(p,\gamma)Al^{26}$	6.59, 4.93, 2.46			6.4 s; 3.2
720	$Mg^{26}(p,\gamma)Al^{27}$	6.74, 5.96, 5.28			
725	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.52	0.01 evb	<1	3.3 h; 1.2
730	$Si^{29}(p,\gamma)P^{30}$	3.33			2.5 m; 3.2
731	$Al^{27}(p,\gamma)Si^{28}$			<0.16	
736	$Al^{27}(p,\gamma)Si^{28}$			<0.09	
740	$Na^{23}(p,\gamma)Mg^{24}$	11		<3	
741	$Al^{27}(p,\gamma)Si^{28}$			<1	
744	$Na^{23}(p,\gamma)Mg^{24}$	8		<3	
759	$Al^{27}(p,\gamma)Si^{28}$			<0.06	
760	$Si^{30}(p,\gamma)P^{31}$	6.71, 4.57, 1.27			
765	$Ne^{21}(p,\gamma)Na^{22}$				2.62 y; 0.5, 1.8
766	$Al^{27}(p,\gamma)Si^{28}$			<0.08	
773	$Al^{27}(p,\gamma)Si^{28}$	12.33		0.009	
775	$Si^{30}(p,\gamma)P^{31}$	8.00, 6.73, 1.27			
777	$Mg^{25}(p,\gamma)Al^{26}$	6.65?, 4.99, 3.90			
780	$F^{19}(p,\alpha\gamma)O^{16}$			7.6	6.4 s; 3.2
800?	Si(p, γ)P				
813	$Mg^{26}(p,\gamma)Al^{27}$				
816	$P^{31}(p,\gamma)S^{32}$	7.39			
820	$Mg^{25}(p,\gamma)Al^{26}$	7.69, 5.04, 4.56			6.4 s; 3.2
825	$Mg^{24}(p,\gamma)Al^{25}$	3.09, 2.64, 2.14		1.5	
825	$P^{31}(p,\gamma)S^{32}$	9.64			7.2 s; 3.3
828	$Ne^{22}(p,\gamma)Na^{23}$				

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
835	$F^{19}(p, \alpha\gamma)O^{16}$	7.12, 6.92, 6.13	19	6.5	
840	$Mg^{26}(p, \gamma)Al^{27}$				
840	$Si^{30}(p, \gamma)P^{31}$	6.82, 4.80, 1.27			
849	$O^{18}(p, \gamma)F^{19}$	8.8		40	
854	$Ne^{22}(p, \gamma)Na^{23}$	9.61, 9.17, 5.70			
855	$Cl^{35}(p, \gamma)A^{36}$	7.2, 5.1, 4.3		≤5	
855	$Ni^{58}(p, \gamma)Cu^{59}$	≤4.26	0.007 evb	<1	81 s; 3.7
872	$F^{19}(p, \alpha\gamma)O^{16}$	7.12, 6.92, 6.13	540	4.5	
877	$Na^{23}(p, \gamma)Mg^{24}$	11		8	
883?	$K^{39}(p, \gamma)Ca^{40}$	9?			
884	$Al^{27}(p, \gamma)Si^{28}$			<1	
888	$Cl^{35}(p, \gamma)A^{36}$				
890	$Mg^{25}(p, \gamma)Al^{26}$				
892	$P^{31}(p, \gamma)S^{32}$			9	
895?	$Si(p, \gamma)P$				
895	$Ni^{60}(p, \gamma)Cu^{61}$	≤5.69	0.01 evb	<1	3.3 h; 1.2
898	$N^{15}(p, \alpha\gamma)C^{12}$	4.43	800	2.2	
900	$A^{40}(p, \gamma)K^{41}$				
901	$Ne^{22}(p, \gamma)Na^{23}$	9.66?, 9.22?			
902	$F^{19}(p, \alpha\gamma)O^{16}$	7.12, 6.92, 6.13	23	5.1	
916	$Si^{29}(p, \gamma)P^{30}$	5.74, 4.48			2.5 m; 3.2
922	$Al^{27}(p, \gamma)Si^{28}$			<0.19	
925?	$K^{39}(p, \gamma)Ca^{40}$	9?			
933	$Ne^{22}(p, \gamma)Na^{23}$	9.69?, 9.25?			
935	$F^{19}(p, \alpha\gamma)O^{16}$	7.12, 6.92, 6.13	180	8.6	
936	$Al^{27}(p, \gamma)Si^{28}$			0.34	
940	$Mg^{25}(p, \gamma)Al^{26}$	6.99, 5.15			6.4 s; 3.2
943?	$Ne^{22}(p, \gamma)Na^{23}$				
944?	$Si(p, \gamma)P$				
947	$Ni^{58}(p, \gamma)Cu^{59}$	≤4.35	0.14 evb	<1	81 s; 3.7
954	$Mg^{26}(p, \gamma)Al^{27}$				
955	$Si^{30}(p, \gamma)P^{31}$	8.19, 6.92, 1.27			
956	$Si^{29}(p, \gamma)P^{30}$	6.49, 5.04, 4.52			2.5 m; 3.2
960	$Mg^{25}(p, \gamma)Al^{26}$	5.17, 4.70, 3.57?			6.4 s; 3.2
980?	$F^{19}(p, \gamma)Ne^{20}$				

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
980	$Si^{30}(p,\gamma)P^{31}$	4.96, 4.84, 1.27			
980	$K^{39}(p,\gamma)Ca^{40}$	9?			
982	$Ne^{22}(p,\gamma)Na^{23}$				
989	$Na^{23}(p,\gamma)Mg^{24}$	9		<1	
990	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
991	$Be^{9}(p,\gamma)B^{10}$	7.5, 6.8, 5.8		89	
992	$Mg^{26}(p,\gamma)Al^{27}$				
992	$Al^{27}(p,\gamma)Si^{28}$	10.78, 7.93, 1.77		0.05	
995	$Si^{30}(p,\gamma)P^{31}$	6.98, 6.02, 1.27			
1000	$Si^{30}(p,\gamma)P^{31}$	8.25, 6.98, 5.12			
1001	$Al^{27}(p,\gamma)Si^{28}$			<1	
1002	$Ne^{22}(p,\gamma)Na^{23}$				
1006	$Ge^{74}(p,\gamma)As^{75}$			<2.5	
1010	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.41	0.007 evb	<1	81 s; 3.7
1011	$Na^{23}(p,\gamma)Mg^{24}$			≤0.5	
1015	$Mg^{26}(p,\gamma)Al^{27}$				
1022	$Na^{23}(p,\gamma)Mg^{24}$	9		6.6	
1024	$Al^{27}(p,\gamma)Si^{28}$			<0.24	
1029	$Ni^{60}(p,\gamma)Cu^{61}$	<5.82	0.02 evb	<1	3.3 h; 1.2
1030	$Li^{7}(p,\gamma)Be^{8}$	18.15, 15.25, 0.478		168	
1040	$N^{15}(p,\gamma)O^{16}$	13.09	1	130	
1040	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	15	130	
1046	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
1050	$P^{31}(p,\gamma)S^{32}$			<5	
1050	$A^{40}(p,\gamma)K^{41}$				
1056	$Mg^{26}(p,\gamma)Al^{27}$				
1059	$N^{14}(p,\gamma)O^{15}$	8.34, 5.27, 3.04		4	
1066	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.86	0.05 evb	<1	2.03 m; 1.7
1068	$P^{31}(p,\gamma)S^{32}$			6	3.3 h; 3.2
1070	$Ne^{22}(p,\gamma)Na^{23}$				
1070	$Cl^{37}(p,\gamma)Ar^{38}$	9.1, 7.5, 6.3		≤5	
1078	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.87	0.03 evb	<1	
1080	$A^{40}(p,\gamma)K^{41}$				
1084	$Be^{9}(p,\gamma)B^{10}$	6.9, 5.4, 0.7		3.8	
1086	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
1087	$Na^{23}(p,\gamma)Mg^{24}$			1.1	
1088	$Ne^{22}(p,\gamma)Na^{23}$				
1089	$Al^{27}(p,\gamma)Si^{28}$			<0.11	
1090	$F^{19}(p,\gamma)Ne^{20}$	12.28, 8.84, 1.63	>0.05	0.7	
1090	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	>13	0.7	
1090	$Cl^{37}(p,\gamma)Ar^{38}$				
1096	$Al^{27}(p,\gamma)Si^{38}$			<1	
1094	$Ge^{74}(p,\gamma)As^{75}$			9.5	
1100	$A^{40}(p,\gamma)K^{41}$				
1100	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.50	0.05 evb	<1	81 s; 3.7
1101	$P^{31}(p,\gamma)S^{32}$				
1102	$Cl^{35}(p,\gamma)Ar^{36}$				
1105	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
1106	$Ne^{22}(p,\gamma)Na^{23}$				
1117	$Al^{27}(p,\gamma)Si^{28}$			0.80	
1117	$P^{31}(p,\gamma)S^{32}$	9.92		5	
1120	$K^{39}(p,\gamma)Ca^{40}$	9.5, 6.1, 3.8		≤5	
1123?	$F^{19}(p,\alpha\gamma)O^{16}$			22	
1132	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.92	0.04 evb	<1	3.3 h; 1.2
1135	$Cl^{37}(p,\gamma)Ar^{38}$	9.1, 7.5, 6.3		<5	
1140	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	15	2.5	
1146	$B^{10}(p,\gamma)C^{11}$	9.7, 5.5?, 4.2?	0.0055	450	20.3 m; 1.0
1146	$P^{31}(p,\gamma)S^{32}$	7.71			
1160	$C^{13}(p,\gamma)N^{14}$	8.62, 4.67, 2.39	0.56	6	
1163	$C^{14}(p,\gamma)N^{15}$	11.30		12	
1165	$Ne^{20}(p,\gamma)Na^{21}$	<4			22.8 s; 2.5
1166	$Na^{23}(p,\gamma)Mg^{24}$			1.2	
1167	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.96	0.15 evb	<1	3.3 h; 1.2
1167	$Ge^{74}(p,\gamma)As^{75}$			4.5	
1169	$O^{18}(p,\gamma)F^{19}$	6.3		1	
1171	$Al^{27}(p,\gamma)Si^{28}$			0.25	
1172	$Mg^{26}(p,\gamma)Al^{27}$				
1176	$Na^{23}(p,\gamma)Mg^{24}$			2.5	
1180	$B^{10}(p,\gamma)C^{11}$	9.4	0.0075	570	20.3 m; 1.0
1182	$Al^{27}(p,\gamma)Si^{28}$			0.71	

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
1185	$Mg^{25}(p,\gamma)Al^{26}$				6.4 s; 3.2
1189	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	19	110	
1197	$Ni^{60}(p,\gamma)Cu^{61}$	≤5.99	0.13 evb	<1	3.3 h; 1.2
1198	$Al^{27}(p,\gamma)Si^{28}$			6.3	
1200	$Mg^{24}(p,\gamma)Al^{25}$	3.44, 1.83, 1.61		<10	7.2 s; 3.3
1209	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.00	0.14 evb	<1	3.3 h; 1.2
1210	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	425	22.5	
1212	$Al^{27}(p,\gamma)Si^{28}$			<0.21	
1213	$Na^{23}(p,\gamma)Mg^{24}$			0.4	
1213	$Ge^{74}(p,\gamma)As^{75}$			<2.5	
1227	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.63	0 045 evb	<1	81 s; 3.7
1235	$A^{40}(p,\gamma)K^{41}$				
1239	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.03	0.13 evb		3.3 h; 1.2
1247	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.04	0.1 evb	<1	3.3 h; 1.2
1248	$P^{31}(p,\gamma)S^{32}$	10.05, 7.80		9	
1250	$C^{13}(p,\gamma)N^{14}$	8.71	0.062	500	
1255	$Mg^{26}(p,\gamma)Al^{27}$				
1257	$Ge^{74}(p,\gamma)As^{75}$			<2.5	
1258	$Cl^{35}(p,\gamma)A^{36}$				
1261	$Al^{27}(p,\gamma)Si^{28}$			<0.20	
1262	$Ne^{23}(p,\gamma)Na^{23}$				
1273	$Na^{23}(p,\gamma)Mg^{24}$				
1274	$Al^{27}(p,\gamma)Si^{28}$			<1	
1278	$Ne^{22}(p,\gamma)Na^{23}$				
1283	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	29	19	
1295	$Mg^{26}(p,\gamma)Al^{27}$				
1300	$K^{39}(p,\gamma)Ca^{40}$	9.6, 6.3, 3.8		≤5	
1308	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.71	0.11 evb	<1	
1312	$C^{14}(p,\gamma)N^{15}$	11.43		43	
1313	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.10	0.21 evb	<1	3.3 h; 1.2
1315	$Al^{27}(p,\gamma)Si^{28}$			<0.16	
1316	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.71	0.08 evb	<1	81 s; 3.7
1319	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.11	0.25 evb	<1	3.3 h; 1.2
1321	$Na^{23}(p,\gamma)Mg^{24}$	11		2.1	
1322?	$F^{19}(p,\gamma)Ne^{20}$	12.50, 1.63	0.081	4.0	

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
1322	$Ne^{22}(p,\gamma)Na^{23}$				
1232	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.11	0.29 evb	<1	3.3 h; 1.2
1327	$Al^{27}(p,\gamma)Si^{28}$			<0.16	
1331	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.12	0.06 evb	<1	3.3 h; 1.2
1332	$Ge^{74}(p,\gamma)As^{75}$			5.0	
1338	$K^{39}(p,\gamma)Ca^{40}$	5.91, 5.74, 3.8		≤5	
1343	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.13	0.45 evb	<1	3.3 h; 1.2
1347	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.14	0.40 evb	<1	3.3 h; 1.2
1348	$F^{19}(p,\gamma)Ne^{20}$		0.1	5.6	
1348	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	89	5.6	
1350	$Ne^{22}(p,\gamma)Na^{23}$				
1362	$Al^{27}(p,\gamma)Si^{28}$			<0.12	
1370?	$S^{34}(p,\gamma)Cl^{35}$				
1371	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.16	0.15 evb	<1	3.3 h; 1.2
1375	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13	300	11	
1375	$Ne^{22}(p,\gamma)Na^{23}$				
1376	$Ni^{58}(p,\gamma)Cu^{59}$	4.77, 4.28, 3.86	0 19 evb	<1	
1380	$Al^{27}(p,\gamma)Si^{28}$			0.70	
1387	$Al^{27}(p,\gamma)Si^{28}$			0.29	
1381	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.17	0.2 evb	<1	3.3 h; 1.2
1386	$Ne^{22}(p,\gamma)Na^{23}$				
1388	$B^{11}(p,\gamma)C^{12}$	17.23, 12.80	0 053	1270	
1395	$P^{31}(p,\gamma)S^{32}$			15	
1398	$Na^{23}(p,\gamma)Mg^{24}$	8		0.5	
1399	$O^{18}(p,\gamma)F^{19}$	9.3		<15	
1408	$P^{31}(p,\gamma)S^{32}$			15	
1415	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.20	0.35 evb	<1	3.3 h; 1.2
1419	$Na^{23}(p,\gamma)Mg^{24}$	9		≤0.3	
1422	$Ge^{74}(p,\gamma)As^{75}$			<2.5	
1424	$Ni^{58}(p,\gamma)Cu^{59}$	4.82, 4.33	1.7 evb	≤0.05	
1425	$Mg^{26}(p,\gamma)Al^{27}$				
1431?	$F^{19}(p,\gamma)Ne^{20}$	12.60, 1.63	0.19	15.7	
1431	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.22	0.18 evb	<1	3.3 h; 1.2
1433	$Ne^{22}(p,\gamma)Na^{23}$				
1443	$P^{31}(p,\gamma)S^{32}$			12	

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
1451	$Ni^{60}(p,\gamma)Cu^{61}$	6.24	0.75 evb	<1	3.3 h; 1.2
1461	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.25	0.14 evb	<1	3.3 h; 1.2
1465	$Mg^{26}(p,\gamma)Al^{27}$				
1465	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.25	0.11 evb	<1	3.3 h; 1.2
1470	$C^{13}(p,\gamma)N^{14}$	5.83, 5.10, 3.07	0.074	20	
1482	$P^{31}(p,\gamma)S^{32}$			6	
1483	$Ni^{60}(p,\gamma)Cu^{61}$	<6.27	0.14 evb	<1	3.3 h; 1.2
1484	$Cl^{35}(p,\gamma)Ar^{36}$	9.9		≤5	
1490	$Mg^{24}(p,\gamma)Al^{25}$	3.72, 1.91		0.3	7.2 s; 3.3
1491	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.28	0.14 evb	<1	3.3 h; 1.2
1492	$Ne^{22}(p,\gamma)Na^{23}$				
1500	$C^{14}(p,\gamma)N^{15}$	11.61		520	
1500	$Al^{27}(p,\gamma)Si^{28}$				
1502	$Ne^{22}(p,\gamma)Na^{23}$				
1510	$Cl^{35}(p,\gamma)Ar^{36}$	9.9		≤5	
1515	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.30	0.4 evb	<1	3.3 h; 1.2
1519	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.30	0.7 evb	<1	3.3 h; 1.2
1520?	$Si(p,\gamma)P$			9.0	
1522	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.92	0.012 evb	<1	81 s; 3.7
1527	$P^{31}(p,\gamma)S^{32}$			14	
1529	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.31	0.06 evb	<1	3.3 h; 1.2
1530	$Ge^{74}(p,\gamma)As^{75}$			9.0	
1533	$Cl^{37}(p,\gamma)Ar^{38}$	9.5		≤5	
1538	$Ni^{60}(p,\gamma)Cu^{61}$	6.32	0.35 evb	<1	3.3 h; 1.2
1540	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.93	0.020 evb	<1	81 s; 3.7
1544	$N^{14}(p,\gamma)O^{15}$	8.8?		34	2.03 m; 1.7
1550	$C^{13}(p,\gamma)N^{14}$	8.99	0.037	7	
1559	$Ge^{74}(p,\gamma)As^{75}$			6.5	
1566	$K^{39}(p,\gamma)Ca^{40}$	9.9, 6.6, 6.1		≤5	
1566	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.35	0.22 evb	<1	3.3 h; 1.2
1570	$Al^{27}(p,\gamma)Si^{28}$				
1571	$P^{31}(p,\gamma)S^{32}$			7	
1577	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.36	0.35 evb	<1	3.3 h; 1.2
1580	$Cl^{35}(p,\gamma)Ar^{36}$	10		≤5	

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
1582	$Ni^{58}(p,\gamma)Cu^{59}$	≤4.98	0.066 evb	<1	81 s; 3.7
1588	$Ni^{60}(p,\gamma)Cu^{61}$	6.37, 5.90	0.9 evb	<1	3.3 h; 1.2
1598	$P^{31}(p,\gamma)S^{32}$			5	
1599	$Ni^{60}(p,\gamma)Cu^{61}$	6.38, 5.00	2.3 evb	<1	3.3 h; 1.2
1605	$Ni^{60}(p,\gamma)Cu^{61}$	6.39, 5.01	2.0 evb	<1	3.3 h; 1.2
1607	$F^{19}(p,\alpha\gamma)O^{16}$			6.0	
1610?	$S^{34}(p,\gamma)Cl^{35}$				
1618?	Si(p, γ)P				
1620	$Mg^{24}(p,\gamma)Al^{25}$	3.40, 2.90, 1.34		36	7.2 s; 3.3
1620	$Ni^{60}(p,\gamma)Cu^{61}$	6.40, 5.02	1.8 evb	<1	3.3 h; 1.2
1635?	Si(p, γ)P				
1635	Cl(p, γ)Ar				
1639	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.42	0.14 evb	<1	3.3 h; 1.2
1640	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	340	68	
1640	$Al^{27}(p,\gamma)Si^{28}$				
1643	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.43	0.35 evb	<1	3.3 h; 1.2
1643	$Ge^{74}(p,\gamma)As^{75}$			~15	
1645	Cl(p, γ)Ar				
1649	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.43	0.29 evb	<1	3.3 h; 1.2
1650	$Si^{28}(p,\gamma)P^{29}$	4.30		50	4.20 s; 4.0
1653	$Ni^{58}(p,\gamma)Cu^{59}$	≤5.05	0.045 evb	<1	81 s; 3.7
1656	$Ni^{60}(p,\gamma)Cu^{61}$	6.44, 5.97	1.0 evb	<1	3.3 h; 1.2
1659	$Al^{27}(p,\gamma)Si^{28}$				
1660	$Mg^{24}(p,\gamma)Al^{25}$	3.88, 3.43, 2.93		0.1	7.2 s; 3.3
1660	Cl(p, γ)Ar				
1663?	Si(p, γ)P				
1663	$Ni^{58}(p,\gamma)Cu^{59}$	5.06, 4.15, 3.28	0.16 evb	<1	81 s; 3.7
1665	$Ge^{74}(p,\gamma)As^{75}$			~15	
1669	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.45	0.4 evb	<1	3.3 h; 1.2
1670	Cl(p, γ)Ar				
1674	$Ni^{60}(p,\gamma)Cu^{61}$	5.50, 5.08	1.0 evb	<1	3.3 h; 1.2
1679	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.46	0.5 evb	<1	3.3 h; 1.2
1680?	Si(p, γ)P				
1680	Cl(p, γ)Ar				
1685	$O^{18}(p,\gamma)F^{19}$	9.6		15	

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
1690	$S^{34}(p,\gamma)Cl^{35}$				
1690	$Ge^{74}(p,\gamma)As^{75}$			~30	
1691	$F^{19}(p,\alpha\gamma)O^{16}$	7.12, 6.92, 6.13		35	
1694	$Ni^{60}(p,\gamma)Cu^{61}$	6.48, 5.52	1.0 evb	<1	3.3 h; 1.2
1698	$C^{12}(p,\gamma)N^{13}$	3.51, 2.37, 1.14	0.035	70	9.98 m; 1.2
1698	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.48	0.3 evb	<1	3.3 h; 1.2
1699?	$Si(p,\gamma)P$				
1700	$Al^{27}(p,\gamma)Si^{28}$				
1710	$Cl(p,\gamma)Ar$				
1711	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.49	0.23 evb	<1	3.3 h; 1.2
1716	$Ni^{58}(p,\gamma)Cu^{59}$	5.11, 4.20	0.35 evb	<1	81 s; 3.7
1721	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.50	0.11 evb	<1	3.3 h; 1.2
1725	$Cl^{37}(p,\gamma)A^{38}$	5.2, 3		≤5	
1726	$Al^{27}(p,\gamma)Si^{28}$				
1734	$Ni^{60}(p,\gamma)Cu^{61}$	6.52	0.7 evb	<1	3.3 h; 1.2
1739	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.52	0.3 evb	<1	3.3 h; 1.2
1742	$N^{14}(p,\gamma)O^{15}$	9.0?		5	2.03 m; 1.7
1748	$C^{13}(p,\gamma)N^{14}$	9.17, 6.43, 2.74	340	0.075	
1755	$Cl(p,\gamma)Ar$				
1757	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.54	0.5 evb	<1	3.3 h; 1.2
1764	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.55	0.6 evb	<1	3.3 h; 1.2
1765	$Cl(p,\gamma)Ar$				
1769	$O^{18}(p,\gamma)F^{19}$	9.6		4	
1770	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.55	0.75 evb	<1	3.3 h; 1.2
1774?	$Si(p,\gamma)P$				
1781	$Al^{27}(p,\gamma)Si^{28}$				
1783	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.56	0.55 evb	<1	3.3 h; 1.2
1797	$Ni^{60}(p,\gamma)Cu^{61}$	≤6.57	0.45 evb	<1	3.3 h; 1.2
1800?	$S^{34}(p,\gamma)Cl^{35}$				
1805	$Ge^{74}(p,\gamma)As^{75}$			20	
1810?	$Si(p,\gamma)P$				
1807	$N^{14}(p,\gamma)O^{15}$	9.0?		5	2.03 m; 1.7
1833	$Mg^{24}(p,\gamma)Al^{25}$	4.05, 2.43, 1.62			7.2 s; 3.3
1833	$Ni^{58}(p,\gamma)Cu^{59}$	≤5.22	0.063 evb	<1	81 s; 3.7
1844	$Ni^{58}(p,\gamma)Cu^{59}$	5.23	2.1 evb	≤0.1	81 s; 3.7
1849?	$Si(p,\gamma)P$				

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
1860?	$S^{34}(p,\gamma)Cl^{35}$				
1870	$Ca^{40}(p,\gamma)Sc^{41}$				0.596 s; 5.6
1879?	Si(p, γ)P				
1890	$Al^{27}(p,\gamma)Si^{28}$				
1892	$P^{31}(p,\gamma)S^{32}$	10.68		24	
1906	$Ge^{74}(p,\gamma)As^{75}$			~15	
1916	$P^{31}(p,\gamma)S^{32}$				
1926	$Ge^{74}(p,\gamma)As^{75}$			~15	
1931	$O^{18}(p,\gamma)F^{19}$	9.8		1.5	
1940	$Al^{27}(p,\gamma)Si^{28}$				
1945	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		40	
1972	$Ge^{74}(p,\gamma)As^{75}$			35	
1979	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	35	23	
1985	$P^{31}(p,\gamma)S^{32}$	10.77			
2000?	$Li^{7}(p,\gamma)Be^{8}$	19.0?, 16.1?			
2000	$C^{13}(p,\gamma)N^{14}$	5.10, 4.80		~20	
2010	$Mg^{24}(p,\gamma)Al^{25}$	3.77, 3.27		0.15	7.2 s; 3.3
2025	$C^{14}(p,\gamma)N^{15}$			18	
2026	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		120	
2026	$Al^{27}(p,\gamma)Si^{28}$				
2027	$P^{31}(p,\gamma)S^{32}$	10.81			
2074	$Ge^{74}(p,\gamma)As^{75}$			13.5	
2079	$C^{14}(p,\gamma)N^{15}$			55	
2083	$Al^{27}(p,\gamma)Si^{28}$				
2090	$Si^{28}(p,\gamma)P^{29}$	4.74		12	4.20 s; 4.0
2120	$C^{13}(p,\gamma)N^{14}$	5.10, 4.39	0.20	45	
2120	$P^{31}(p,\gamma)S^{32}$	10.90		5	
2130	$Li^{7}(p,\gamma)Be^{8}$	19.12, 16.21		400	
2135	$Ne^{20}(p,\gamma)Na^{21}$				
2161	$Ge^{74}(p,\gamma)As^{75}$			~15	22.8 s; 2.5
2180	$Al^{27}(p,\gamma)Si^{28}$				
2200	$Al^{27}(p,\gamma)Si^{28}$				
2210	$Ge^{74}(p,\gamma)As^{75}$			40	
2212	$Al^{27}(p,\gamma)Si^{28}$				
2282	$Al^{27}(p,\gamma)Si^{28}$				

Proton energy (keV)	Reaction	Gamma-ray energy (MeV)	Cross section (mb)	Width (keV)	Half life and β^+ energy (MeV)
2295	$Ge^{74}(p,\gamma)As^{75}$			27	
2315	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		85	
2320	$P^{31}(p,\gamma)S^{32}$	11.09		8	
2340	$P^{31}(p,\gamma)S^{32}$	11.11		8	
2342	$Ge^{74}(p,\gamma)As^{75}$			15	
2344	$Al^{27}(p,\gamma)Si^{28}$				
2350	$N^{14}(p,\gamma)O^{15}$	9.5?		14	2.03 m; 1.7
2400	$Mg^{24}(p,\gamma)Al^{25}$	3.65		0.3	7.2 s; 3.3
2440	$Ge^{74}(p,\gamma)As^{75}$			11	
2480	$N^{14}(p,\gamma)O^{15}$	9.7?		11	2.03 m; 1.7
2510	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		30	
2520?	$Si(p,\gamma)P$				
2528	$Ge^{74}(p,\gamma)As^{75}$			15	
2542	$Al^{27}(p,\gamma)Si^{28}$				
2543?	$Si(p,\gamma)P$				
2553?	$Si(p,\gamma)P$				
2558?	$Si(p,\gamma)P$				
2564	$Be^{9}(p,\gamma)B^{10}$	8.1, 0.7		39	
2564	$Be^{9}(p,\alpha\gamma)Li^{6}$	3.56		39	
2570?	$Si(p,\gamma)P$				
2575	$N^{14}(p,\gamma)O^{15}$	9.8?		1000	2.03 m; 1.7
2575?	$Si(p,\gamma)P$				
2593	$Ge^{74}(p,\gamma)As^{75}$			44	
2630	$B^{11}(p,\gamma)C^{12}$	13.94, 4.43, 2.14		300	
2630	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		90	
2664	$Ge^{74}(p,\gamma)As^{75}$			10	
2800	$F^{19}(p,\alpha\gamma)O^{16}$	6-7		60	
3000	$N^{15}(p,\alpha\gamma)C^{12}$	4.43	750	45	

APPENDIX III

1. Theoretical cross sections for charged particle reactions at higher energies:
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   iii. Ch Engelman
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   iv. Ch Engelman
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4. Some references to other compilations of charged particle reactions cross-sections together with references on special topics concerning charged particles:

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