Transfer of data and compilations between EXFOR and IBANDL

Valentina Semkova
Naohiko Otuka
Viktor Zerkin

Institute for Nuclear Research and Nuclear Energy, Bulgarian Academy of Sciences
Nuclear Data Section, IAEA

Content

- IBA analytical techniques and IBANDL library
- EXFOR v IBANDL format
- x4toR33
- R33tox4
- Elastic back scattering (EBS) Nuclear reaction analysis (NRA)
- Reaction Q-value; SF5=PAR
- Elastic recoil detection analysis (ERDA)
- IBANDL data calculated using Legendre coefficients - I

IBA analytical techniques and IBANDL library

Beam out	Ion beam analysis techniques
ion	Rutherford back scattering (RBS) Elastic back scattering (EBS) Nuclear reaction analysis (NRA)
target	Elastic recoil detection analysis (ERDA) Secondary ion mass spectroscopy (SIMS)
gamma-ray	Particle-induced gamma emission (PIFE)

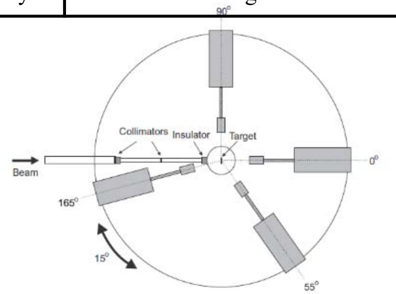


Fig. 1. The experimental setup used for the cross section measurements. After each run, the turntable was rotated by 15° counterclockwise in order to acquire data at four additional angles.

A. Lagoyannis+(2015)
Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.342, p.271

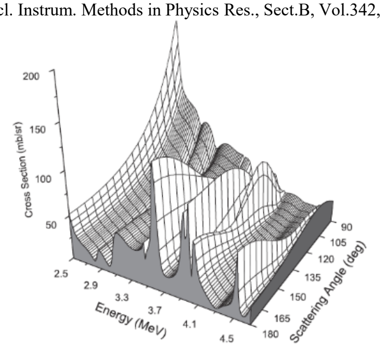
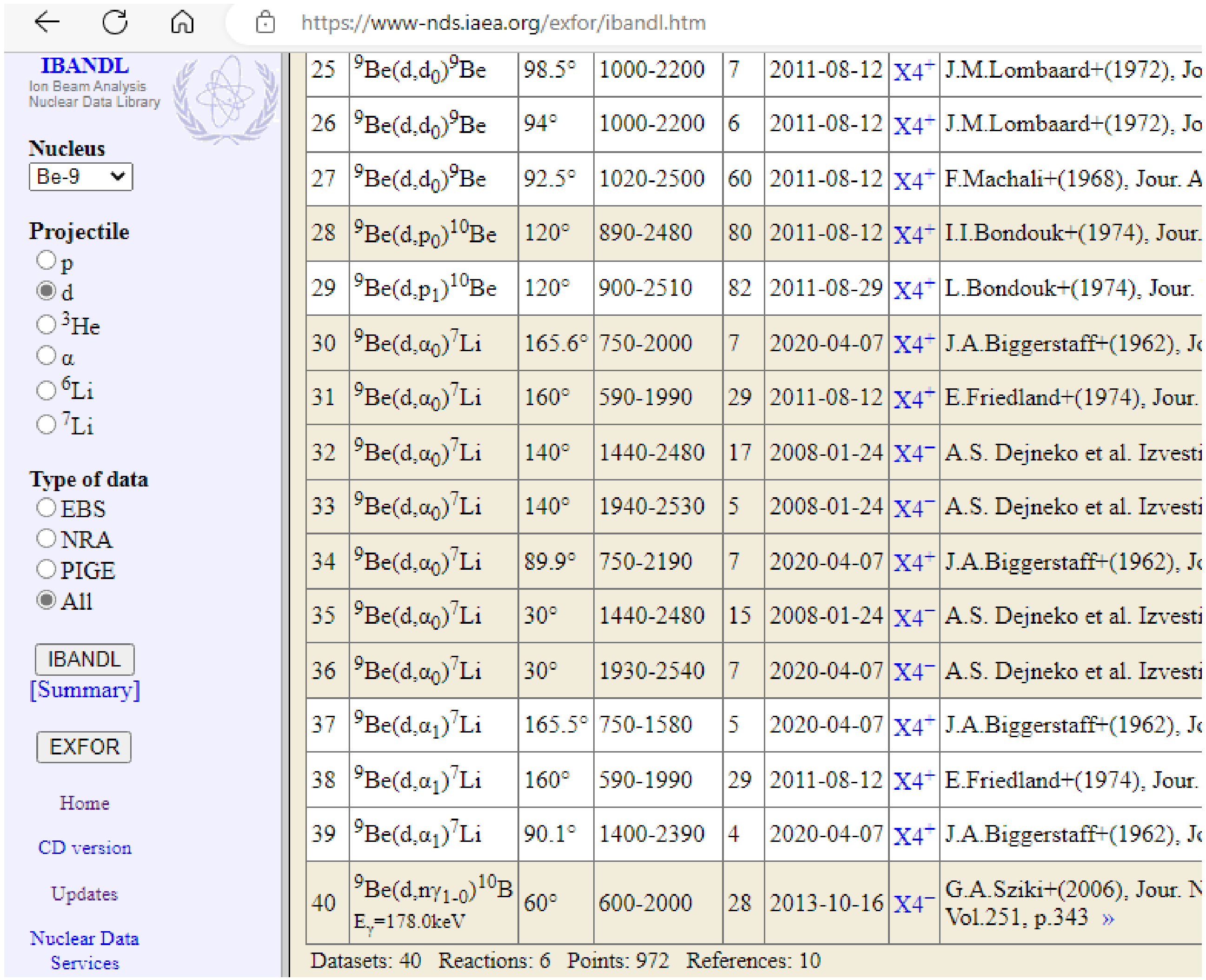


Fig. 4. Evaluated elastic scattering cross-sections for $^{14}N(\alpha,\alpha)^{14}N$ as a function of scattering angle and alpha particle energy (the narrow resonance at 2.767 MeV is omitted in the figure).

A.F.Gurbich+(2011),
Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.269, p.40



25	$^{9}Be(d,d_0)^{9}Be$	98.5°	1000-2200	7	2011-08-12	X4+	J.M.Lombaard+(1972), Jo
26	$^{9}Be(d,d_0)^{9}Be$	94°	1000-2200	6	2011-08-12	X4+	J.M.Lombaard+(1972), Jo
27	$^{9}Be(d,d_0)^{9}Be$	92.5°	1020-2500	60	2011-08-12	X4+	F.Machali+(1968), Jour. A
28	$^{9}Be(d,p_0)^{10}Be$	120°	890-2480	80	2011-08-12	X4+	I.I.Bondouk+(1974), Jour.
29	$^{9}Be(d,p_1)^{10}Be$	120°	900-2510	82	2011-08-29	X4+	L.Bondouk+(1974), Jour.
30	$^{9}Be(d,\alpha_0)^{7}Li$	165.6°	750-2000	7	2020-04-07	X4+	J.A.Biggerstaff+(1962), Jo
31	$^{9}Be(d,\alpha_0)^{7}Li$	160°	590-1990	29	2011-08-12	X4+	E.Friedland+(1974), Jour.
32	$^{9}Be(d,\alpha_0)^{7}Li$	140°	1440-2480	17	2008-01-24	X4−	A.S. Dejneko et al. Izvesti
33	$^{9}Be(d,\alpha_0)^{7}Li$	140°	1940-2530	5	2008-01-24	X4−	A.S. Dejneko et al. Izvesti
34	$^{9}Be(d,\alpha_0)^{7}Li$	89.9°	750-2190	7	2020-04-07	X4+	J.A.Biggerstaff+(1962), Jo
35	$^{9}Be(d,\alpha_0)^{7}Li$	30°	1440-2480	15	2008-01-24	X4−	A.S. Dejneko et al. Izvesti
36	$^{9}Be(d,\alpha_0)^{7}Li$	30°	1930-2540	7	2020-04-07	X4−	A.S. Dejneko et al. Izvesti
37	$^{9}Be(d,\alpha_1)^{7}Li$	165.5°	750-1580	5	2020-04-07	X4+	J.A.Biggerstaff+(1962), Jo
38	$^{9}Be(d,\alpha_1)^{7}Li$	160°	590-1990	29	2011-08-12	X4+	E.Friedland+(1974), Jour.
39	$^{9}Be(d,\alpha_1)^{7}Li$	90.1°	1400-2390	4	2020-04-07	X4+	J.A.Biggerstaff+(1962), Jo
40	$^{9}Be(d,n\gamma_{1-0})^{10}B$ E_γ=178.0keV	60°	600-2000	28	2013-10-16	X4−	G.A.Sziki+(2006), Jour. N Vol.251, p.343 »

Datasets: 40 Reactions: 6 Points: 972 References: 10

EXFOR v IBANDL format

```
SUBENT F0095001   last-updated: 2012-01-26
  BIB   #bibliographic and descriptive information
    TITLE
      Differential cross sections for (d,a) and (d,t)
      reaction in 9Be.
    AUTHOR
      (J.A.Biggerstaff, R.F.Hood, H.Scott, M.T.Mcellistrem)
    INSTITUTE
      (1USAKTY)   #exington, KY, USA
    REFERENCE
      (J,NP,36,631,1962)   #Jour: Nuclear Physics, Vol.36, p.631 (1962)
    SAMPLE
      Two type of beryllium targets. The first was prepared
      by evaporating beryllium onto 0.177 mg/cm**2 aluminium
      backing, the second was self-supporting targets of
      beryllium. Target thicknesses used varied from 25 to
      39 mu-g/cm2.
    ERR-ANALYS
      The total systematic uncertainty includes: incident
      charge collection (0.5%), target thickness (3%),
      detector solid angle (1.5%).Relative uncertainty
      includes: analyzer dead time (<1%), statistics (<4%)
      alpha discrimination for CsI(Tl) (2%).
      (ERR-DIG)
         Data digitizing error
    FACILITY
      (VDG   #Van de Graaff
      ,1USAKTY)   #exington, KY, USA
    DETECTOR
      (SCIN   #Scintillation detector
      ,SOLST)   #Solid-state detector
       Scintillation and diffused junction
      silicon detectors were mounted on the rotating arms.
      The scintillator used was a CsI(Tl) wafer, 1.6 mm thick
    METHOD
      (BCINT)   #Beam current integrated
    HISTORY
  NOCOMMON
SUBENT F0095005   last-updated: 2012-01-26
  BIB   #bibliographic and descriptive information
    REACTION
      (4-BE-9(D,A)3-LI-7,PAR,DA)
    ERR-ANALYS
    EN-SEC
    STATUS
  COMMON 4x1   #Constant parameters
    Legend
    Data
```

ANG-ERR-D	ERR-DIG	ERR-SYS	DATA-ERR1
ADEG	MB/SR	PER-CENT	PER-CENT
0.6	0.06	5.0	4.0

```
  DATA 4x219
    Legend
    Data
```

EN	E-LVL	ANG-CM	DATA-CM
MEV	MEV	ADEG	MB/SR
0.75	0.0	31.94	1.699
0.75	0.0	48.84	1.543

IBANDL
Ion Beam Analysis
Nuclear Data Library

Nucleus
Be-9

Projectile
- ○ p
- ◉ d
- ○ ^{3}He
- ○ α
- ○ ^{6}Li
- ○ ^{7}Li

Type of data
- ○ EBS
- ○ NRA
- ○ PIGE
- ◉ All

IBANDL
[Summary]

EXFOR

Home

CD version

Updates

Nuclear Data Services

```
Comment:      Automatically converted from EXFOR on 2020-04-07,17:41:02
              by the IAEA-NDS EXFOR Web-Retrieval System
              program ver-2019-12-10 (V.Zerkin).
              X4Title: "Differential cross sections for (d,a) and (d,t)
                       reaction in 9Be."
              X4Author: J.A.Biggerstaff, R.F.Hood, H.Scott, M.T.Mcellistrem
              EXFOR: F0095005    Created: 1983-08-25  Updated: 2012-07-02
              X4Reaction:4-BE-9(D,A)3-LI-7,PAR,DA; X4Points:219
              Converted from C.M. to Lab.: Sigma, Theta
              SigmaLab=SigmaCM/{1.2273586, 1.381056}
              ThetaLab=165.6 ThetaCM:167.4 [166.2, 168.7]
              ENSDF:LevelEnergy=0.00
              Theta groupping interval=3.0 deg.
              Systematic uncertainty: ErrSys=5.0%
              AME2016: M1=2.014101778 M2=9.012183066 M3=4.002603254 M4=7.016003436

Version:       R33
X4Number:      F0095005 20120702
Source:        J.A.Biggerstaff+(1962), Jour. Nuclear Physics, Vol.36, p.631
Reaction:      9Be(d,a0)7Li
Distribution:  Energy
Sigfactors:    1.00, 0.05
Enfactors:     1.00, 0.00, 0.00, 0.00
Units:         mb
Composition:
Masses:        2.0, 9.0, 4.0, 7.0
Zeds:          1, 4, 2, 3
Qvalue:        7152.15, 0.00, 0.00, 0.00, 0.00
Theta:         165.6
Data:
    750.00,      0.00,    2.4805,     0.1919
   1000.00,      0.00,    4.0418,     0.1249
   1100.00,      0.00,    4.4949,     0.1259
   1400.00,      0.00,    4.0749,      0.123
   1580.00,      0.00,    4.0066,       0.00
   1940.00,      0.00,    1.8311,       0.00
   2000.00,      0.00,    1.7704,       0.00
EndData:
```

x4toR33

Apply ⌄ Data re-normalization (for advanced users, results in: C4, TAB and Plots)

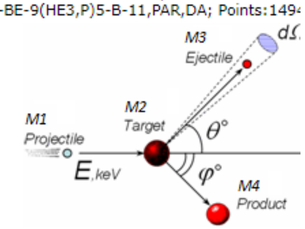
n	Display	Year	Author-1	Energy range,eV		Points	Reference	Subentry#P	NSR-Key	Info+
1)	4-BE-9(HE3,P)5-B-11,PAR,DA Q(keV)=10322.81 C4: MF=4 MT=601 Op=0						Invert data to reaction 5-B-11(P,HE3)4-BE-9,,DA (PAR:LVL=0) must be used with option Advanced plot/C5			
	Quantity: [DAP] Partial differential cross section d/dA									
1	+ i X4 X4+ X4± T4	2021	G.Provatas+	1.34e6	2.86e6	1494	[pdf]+ J,NIM/B,500-501,57,2021	D0998002 [1] R33 /30	2021PR06	An[30]=107:164
2	+ i X4 X4+ X4± T4	2020	G.Provatas+	1.28e6	2.86e6	4680	[pdf]+ J,NIM/B,472,36,2020	D0977002 [1] R33 / 80	2020PR03	An[30]=107:164 QVL[6]=3e6:1e7

Plots: dσ/dΩ(E):32/52 dσ/dΩ(θ):32/54 See: [doc] x4:σ(E,θ) Try:[θ_{CM},σ_{CM}→Lab] Try:[θ_{CM}→Lab] Show:[err-stat] Group:[3°]

1) 107.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
2) 109.5°:2466.03:52pt [Plot] [R33] [IBA] [C.M.] [Inv]
3) 112.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
4) 114.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
5) 116.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
6) 118.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
7) 120.6°:2466.03:44pt [Plot] [R33] [IBA] [C.M.] [Inv]
8) 123.0°:2466.03:18pt [Plot] [R33] [IBA] [C.M.] [Inv]
9) 125.5°:2466.03:53pt [Plot] [R33] [IBA] [C.M.] [Inv]
10) 128.0°:2466.03:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
11) 130.0°:2466.03:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
12) 132.0°:2466.03:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
13) 134.0°:2466.03:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
14) 139.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
15) 141.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
16) 143.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
17) 145.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
18) 147.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
19) 149.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
20) 151.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
21) 153.5°:2466.03:52pt [Plot] [R33] [IBA] [C.M.] [Inv]
22) 156.0°:2466.03:25pt [Plot] [R33] [IBA] [C.M.] [Inv]
23) 158.0°:2466.03:26pt [Plot] [R33] [IBA] [C.M.] [Inv]
24) 160.0°:2466.03:25pt [Plot] [R33] [IBA] [C.M.] [Inv]
25) 162.0°:2466.03:23pt [Plot] [R33] [IBA] [C.M.] [Inv]
26) 164.0°:2466.03:21pt [Plot] [R33] [IBA] [C.M.] [Inv]
27) 107.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
28) 109.5°:4778.83:54pt [Plot] [R33] [IBA] [C.M.] [Inv]
29) 112.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
30) 114.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
31) 116.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
32) 118.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
33) 120.6°:4778.83:46pt [Plot] [R33] [IBA] [C.M.] [Inv]
34) 123.0°:4778.83:19pt [Plot] [R33] [IBA] [C.M.] [Inv]
35) 125.5°:4778.83:54pt [Plot] [R33] [IBA] [C.M.] [Inv]
36) 128.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
37) 130.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
38) 132.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
39) 134.0°:4778.83:27pt [Plot] [R33] [IBA] [C.M.] [Inv]
40) 139.0°:4778.83:24pt [Plot] [R33] [IBA] [C.M.] [Inv]
41) 141.0°:4778.83:24pt [Plot] [R33] [IBA] [C.M.] [Inv]
42) 143.0°:4778.83:24pt [Plot] [R33] [IBA] [C.M.] [Inv]
43) 145.0°:4778.83:24pt [Plot] [R33] [IBA] [C.M.] [Inv]
44) 147.0°:4778.83:24pt [Plot] [R33] [IBA] [C.M.] [Inv]
45) 149.0°:4778.83:24pt [Plot] [R33] [IBA] [C.M.] [Inv]
46) 151.0°:4778.83:23pt [Plot] [R33] [IBA] [C.M.] [Inv]
47) 153.5°:4778.83:46pt [Plot] [R33] [IBA] [C.M.] [Inv]
48) 156.0°:4778.83:23pt [Plot] [R33] [IBA] [C.M.] [Inv]
49) 158.0°:4778.83:23pt [Plot] [R33] [IBA] [C.M.] [Inv]
50) 160.0°:4778.83:23pt [Plot] [R33] [IBA] [C.M.] [Inv]
51) 162.0°:4778.83:20pt [Plot] [R33] [IBA] [C.M.] [Inv]
52) 164.0°:4778.83:17pt [Plot] [R33] [IBA] [C.M.] [Inv]

Datasets:52 Points:1494 Thetas:26 Levels:2

EXFOR: D0998002 See also:C4,C5
Created: 2021-08-17 Updated: 2022-01-1
4-BE-9(HE3,P)5-B-11,PAR,DA; Points:149




```
Comment:   Automatically converted from EXFOR at 2022-12-13,21:31:37
           by the IAEA-NDS EXFOR Web-Retrieval System,
           program X4toR33 ver-2021-12-15 (V.Zerkin).
           X4Title: "Systematic study of the 12C(3He,p)14N reaction for
                    NRA applications"
           X4Author: G.Provatas,  S.Fazinic,  N.Soic,  N.Vukman,
            D.Cosic, M.Krmpotic,  L.Palada,  R.Popocovski,
            D.Dell'aquila, M.Jaksic,  M.Kokkoris,  F.Maragkos
           EXFOR: D0998002    Created: 2021-08-17  Updated: 2022-01-12
           X4Reaction:4-BE-9(HE3,P)5-B-11,PAR,DA; X4Points:1494
           X4:QVAL=2466.03  AME2020:Q0=10322.9898  Q0-QVAL=7856.9598
           ENSDF:LevelEnergy=7978.00 keV
           Theta groupping interval=1.0 deg.
           AME2020: M1=3.016029321 M2=9.012183062 M3=1.007825031 M4=11.009305166

Version:     R33
X4Number:    D0998002 20220112
Source:      G.Provatas+(2021), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.500-501, p.57
Reaction:    9Be(3He,p7)11B
Distribution: Energy
```

R33tox4 – I

IBANDL
Ion Beam Analysis
Nuclear Data Library

Nucleus
Be-9

Projectile
- ○ p
- ○ d
- ◉ ^{3}He
- ○ α
- ○ ^{6}Li
- ○ ^{7}Li

Type of data
- ○ EBS
- ○ NRA
- ○ PIGE
- ◉ All

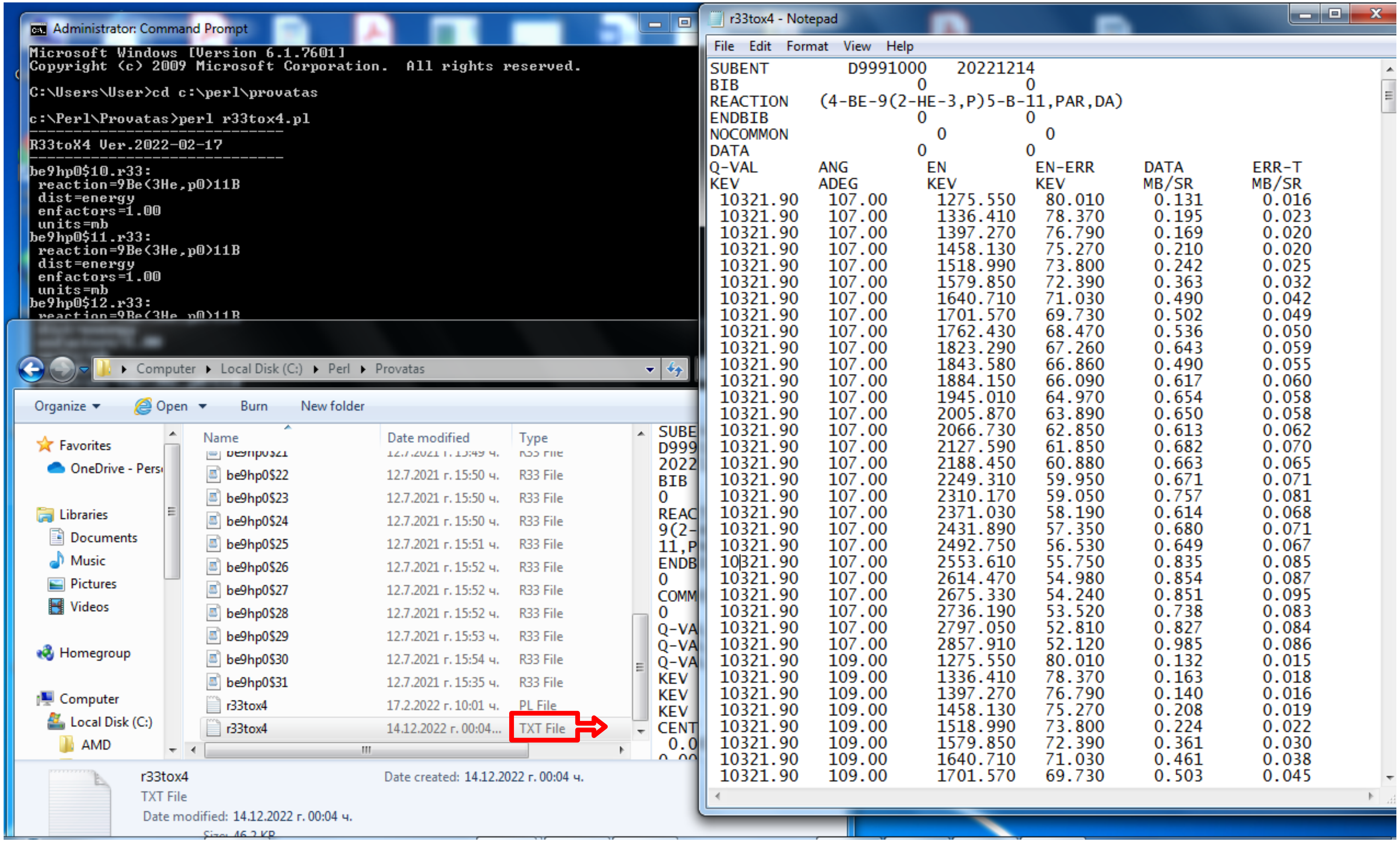
IBANDL
[Summary]

EXFOR

Home
CD version
Updates
Nuclear Data Services

							Vol.472, p.36 »			
24	^{9}Be(^{3}He,p$_0$)^{11}B	118°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
25	^{9}Be(^{3}He,p$_0$)^{11}B	116°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
26	^{9}Be(^{3}He,p$_0$)^{11}B	114°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
27	^{9}Be(^{3}He,p$_0$)^{11}B	112°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
28	^{9}Be(^{3}He,p$_0$)^{11}B	110°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
29	^{9}Be(^{3}He,p$_0$)^{11}B	109°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
30	^{9}Be(^{3}He,p$_0$)^{11}B	107°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
31	^{9}Be(^{3}He,p$_1$)^{11}B	164°	1270-2860	27	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
32	^{9}Be(^{3}He,p$_1$)^{11}B	162°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
33	^{9}Be(^{3}He,p$_1$)^{11}B	160°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
34	^{9}Be(^{3}He,p$_1$)^{11}B	158°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
35	^{9}Be(^{3}He,p$_1$)^{11}B	156°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
36	^{9}Be(^{3}He,p$_1$)^{11}B	154°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb
37	^{9}Be(^{3}He,p$_1$)^{11}B	153°	1270-2860	28	2021-07-12	X4⁻	G.Provatas+(2020), Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.472, p.36 »	View	Save	☐ mb

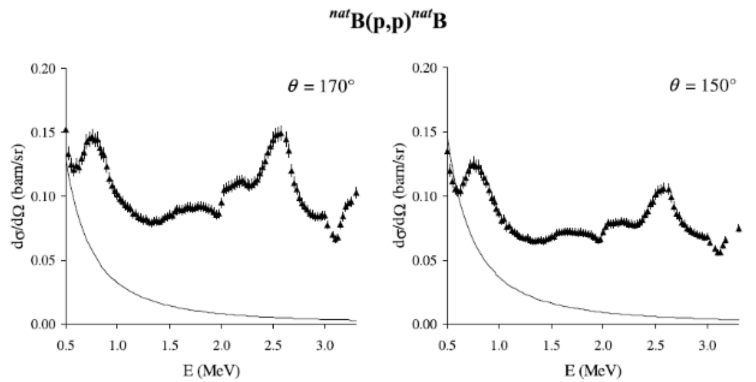
R33tox4 – II



Administrator: Command Prompt
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.
C:\Users\User>cd c:\perl\provatas
c:\Perl\Provatas>perl r33tox4.pl
R33toX4 Ver.2022-02-17
be9hp0$10.r33:
reaction=9Be(3He,p0)11B
dist=energy
enfactors=1.00
units=mb
be9hp0$11.r33:
reaction=9Be(3He,p0)11B
dist=energy
enfactors=1.00
units=mb
be9hp0$12.r33:
Computer ▸ Local Disk (C:) ▸ Perl ▸ Provatas
Organize Open Burn New folder
Favorites
OneDrive - Pers
Libraries
Documents
Music
Pictures
Videos
Homegroup
Computer
Local Disk (C:)
AMD
Name Date modified Type
be9hp0$22 12.7.2021 г. 15:50 ч. R33 File
be9hp0$23 12.7.2021 г. 15:50 ч. R33 File
be9hp0$24 12.7.2021 г. 15:50 ч. R33 File
be9hp0$25 12.7.2021 г. 15:51 ч. R33 File
be9hp0$26 12.7.2021 г. 15:52 ч. R33 File
be9hp0$27 12.7.2021 г. 15:52 ч. R33 File
be9hp0$28 12.7.2021 г. 15:52 ч. R33 File
be9hp0$29 12.7.2021 г. 15:53 ч. R33 File
be9hp0$30 12.7.2021 г. 15:54 ч. R33 File
be9hp0$31 12.7.2021 г. 15:35 ч. R33 File
r33tox4 17.2.2022 г. 10:01 ч. PL File
r33tox4 14.12.2022 г. 00:04... TXT File
r33tox4
TXT File
Date modified: 14.12.2022 г. 00:04 ч.
Date created: 14.12.2022 г. 00:04 ч.
r33tox4 - Notepad
File Edit Format View Help
SUBENT D9991000 20221214
BIB 0 0
REACTION (4-BE-9(2-HE-3,P)5-B-11,PAR,DA)
ENDBIB 0 0
NOCOMMON 0 0
DATA 0 0
Q-VAL ANG EN EN-ERR DATA ERR-T
KEV ADEG KEV KEV MB/SR MB/SR
10321.90 107.00 1275.550 80.010 0.131 0.016
10321.90 107.00 1336.410 78.370 0.195 0.023
10321.90 107.00 1397.270 76.790 0.169 0.020
10321.90 107.00 1458.130 75.270 0.210 0.020
10321.90 107.00 1518.990 73.800 0.242 0.025
10321.90 107.00 1579.850 72.390 0.363 0.032
10321.90 107.00 1640.710 71.030 0.490 0.042
10321.90 107.00 1701.570 69.730 0.502 0.049
10321.90 107.00 1762.430 68.470 0.536 0.050
10321.90 107.00 1823.290 67.260 0.643 0.059
10321.90 107.00 1843.580 66.860 0.490 0.055
10321.90 107.00 1884.150 66.090 0.617 0.060
10321.90 107.00 1945.010 64.970 0.654 0.058
10321.90 107.00 2005.870 63.890 0.650 0.058
10321.90 107.00 2066.730 62.850 0.613 0.062
10321.90 107.00 2127.590 61.850 0.682 0.070
10321.90 107.00 2188.450 60.880 0.663 0.065
10321.90 107.00 2249.310 59.950 0.671 0.071
10321.90 107.00 2310.170 59.050 0.757 0.081
10321.90 107.00 2371.030 58.190 0.614 0.068
10321.90 107.00 2431.890 57.350 0.680 0.071
10321.90 107.00 2492.750 56.530 0.649 0.067
10321.90 107.00 2553.610 55.750 0.835 0.085
10321.90 107.00 2614.470 54.980 0.854 0.087
10321.90 107.00 2675.330 54.240 0.851 0.095
10321.90 107.00 2736.190 53.520 0.738 0.083
10321.90 107.00 2797.050 52.810 0.827 0.084
10321.90 107.00 2857.910 52.120 0.985 0.086
10321.90 109.00 1275.550 80.010 0.132 0.015
10321.90 109.00 1336.410 78.370 0.163 0.018
10321.90 109.00 1397.270 76.790 0.140 0.016
10321.90 109.00 1458.130 75.270 0.208 0.019
10321.90 109.00 1518.990 73.800 0.224 0.022
10321.90 109.00 1579.850 72.390 0.361 0.030
10321.90 109.00 1640.710 71.030 0.461 0.038
10321.90 109.00 1701.570 69.730 0.503 0.045

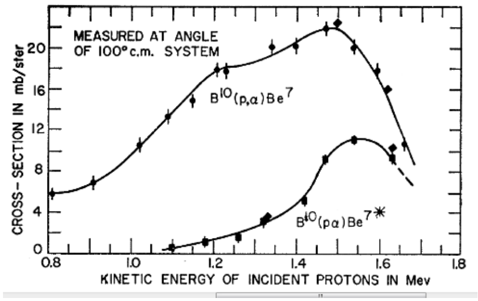
Elastic back scattering (EBS)
Nuclear reaction analysis (NRA)

Elastic Back Scattering (EBS) is the general extension of the Rutherford Back Scattering (RBS) at higher energies, where the elastic scattering cross section is no longer Rutherford

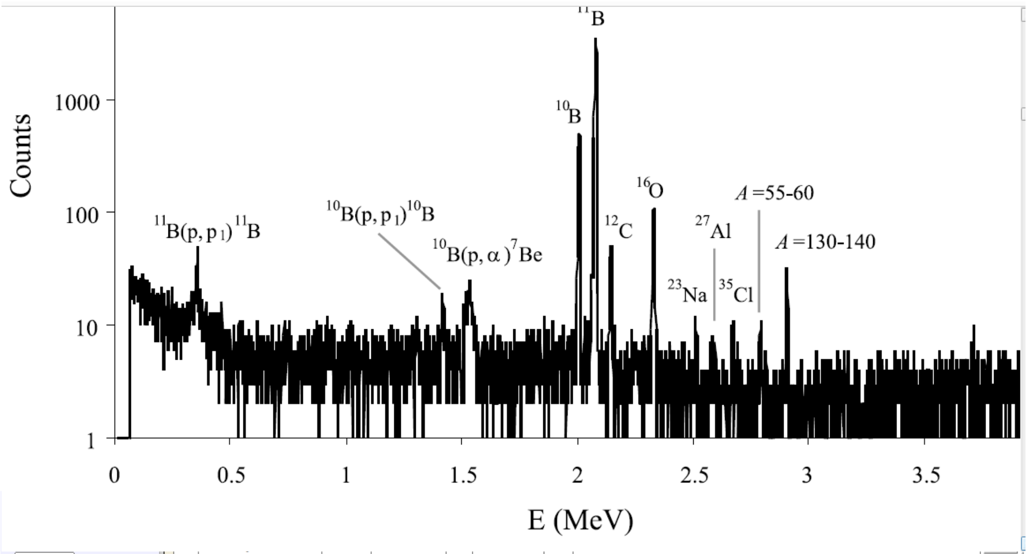


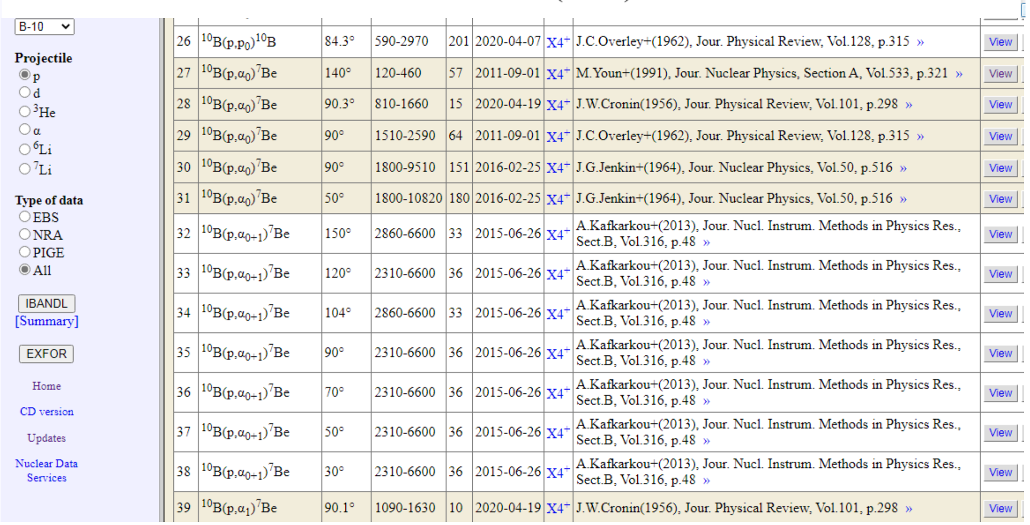
M.Chiari+(2001), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.184, p.309

Reaction:	10B(p,a)7Be
Qvalue:	1145.67 keV
7Be	
LVL-NUMBER	E-LVL KEV
1	429.08
2	4570
.	.
.	.



J.W.Cronin(1956), Jour. Physical Review, Vol.101, p.298




B-10

Projectile: p, d, 3He, α, 6Li, 7Li

Type of data: EBS, NRA, PIGE, All

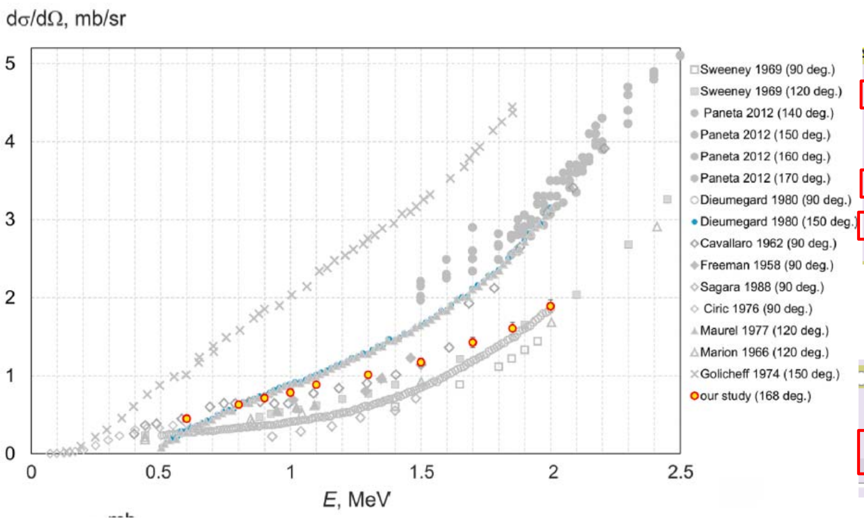
IBANDL [Summary]

EXFOR

Home · CD version · Updates · Nuclear Data Services

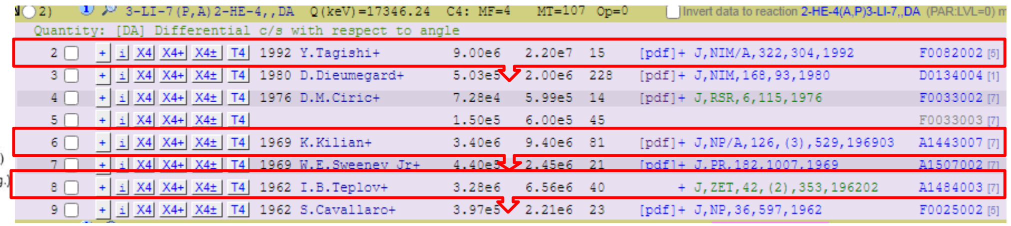
26	$^{10}B(p,p_0)^{10}B$	84.3°	590-2970	201	2020-04-07	X4+	J.C.Overley+(1962), Jour. Physical Review, Vol.128, p.315 »	View
27	$^{10}B(p,\alpha_0)^7Be$	140°	120-460	57	2011-09-01	X4+	M.Youn+(1991), Jour. Nuclear Physics, Section A, Vol.533, p.321 »	View
28	$^{10}B(p,\alpha_0)^7Be$	90.3°	810-1660	15	2020-04-19	X4+	J.W.Cronin(1956), Jour. Physical Review, Vol.101, p.298 »	View
29	$^{10}B(p,\alpha_0)^7Be$	90°	1510-2590	64	2011-09-01	X4+	J.C.Overley+(1962), Jour. Physical Review, Vol.128, p.315 »	View
30	$^{10}B(p,\alpha_0)^7Be$	90°	1800-9510	151	2016-02-25	X4+	J.G.Jenkin+(1964), Jour. Nuclear Physics, Vol.50, p.516 »	View
31	$^{10}B(p,\alpha_0)^7Be$	50°	1800-10820	180	2016-02-25	X4+	J.G.Jenkin+(1964), Jour. Nuclear Physics, Vol.50, p.516 »	View
32	$^{10}B(p,\alpha_{0+1})^7Be$	150°	2860-6600	33	2015-06-26	X4+	A.Kafkarkou+(2013), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.316, p.48 »	View
33	$^{10}B(p,\alpha_{0+1})^7Be$	120°	2310-6600	36	2015-06-26	X4+	A.Kafkarkou+(2013), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.316, p.48 »	View
34	$^{10}B(p,\alpha_{0+1})^7Be$	104°	2860-6600	33	2015-06-26	X4+	A.Kafkarkou+(2013), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.316, p.48 »	View
35	$^{10}B(p,\alpha_{0+1})^7Be$	90°	2310-6600	36	2015-06-26	X4+	A.Kafkarkou+(2013), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.316, p.48 »	View
36	$^{10}B(p,\alpha_{0+1})^7Be$	70°	2310-6600	36	2015-06-26	X4+	A.Kafkarkou+(2013), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.316, p.48 »	View
37	$^{10}B(p,\alpha_{0+1})^7Be$	50°	2310-6600	36	2015-06-26	X4+	A.Kafkarkou+(2013), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.316, p.48 »	View
38	$^{10}B(p,\alpha_{0+1})^7Be$	30°	2310-6600	36	2015-06-26	X4+	A.Kafkarkou+(2013), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.316, p.48 »	View
39	$^{10}B(p,\alpha_1)^7Be$	90.1°	1090-1630	10	2020-04-19	X4+	J.W.Cronin(1956), Jour. Physical Review, Vol.101, p.298 »	View

Reaction Q-value; SF5=PAR

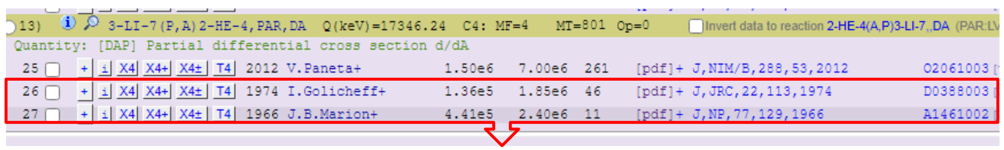


Cross-section measurement for the $^{7}Li(p,\alpha)^{4}He$ reaction at proton energies 0.6 – 2 MeV

Sergey Taskaev[a,b,*], Marina Bikchurina[a,b], Timofey Bykov[a,b], Dmitrii Kasatov[a,b], Iaroslav Kolesnikov[a,b], Aleksandr Makarov[a,b], Georgii Ostreinov[a,b], Sergey Savinov[a,b], Evgeniia Sokolova[a,b]



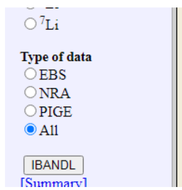
Add SF5=PAR E-LVL = 0.0 MeV



Only E-LVL=0 is possible delete SF5=PAR

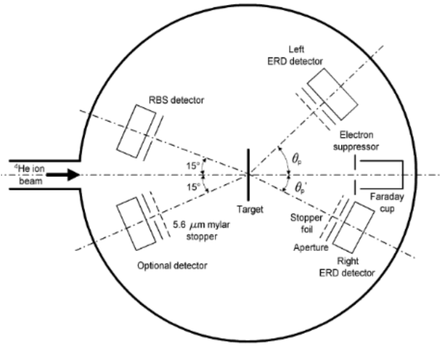
However, in IBANDL the level of the reaction product is important since it is related to the energy of the outgoing particle.

Reaction: 7Li(p,a)4He
Qvalue: 17346.244 keV
4He
LVL-NUMBER E-LVL
KEV
1 20210
2 21010
. .
. .



57	$^{7}Li(p,\alpha_0)^{4}He$	150°	500-2000	D.Dieumegard+(1980), Jour. Nuclear Instrum.and Methods in Physics Res., Vol.168, p.93
58	$^{7}Li(p,\alpha_0)^{4}He$	150°	4040-5290	N.Sarma+(1963), Jour. Nuclear Physics, Vol.44, Issue.2, p.205
59	$^{7}Li(p,\alpha_0)^{4}He$	150°	130-1850	I.Golicheff+(1974), Jour. Journal of Radioanalytical Chemistry, Vol.22, p.113
60	$^{7}Li(p,\alpha_0)^{4}He$	150°	1490-7000	V.Paneta+(2012), Jour. Nucl. Instrum. Methods in Physics Res., Sect.B, Vol.288, p.53
61	$^{7}Li(p,\alpha_0)^{4}He$	150°	500-2000	B.Maurel et al.,in Ion Beam Handbook (s. 133), ed. J.W.Mayer & E.Rimini, (1977

Elastic recoil detection analysis (ERDA)



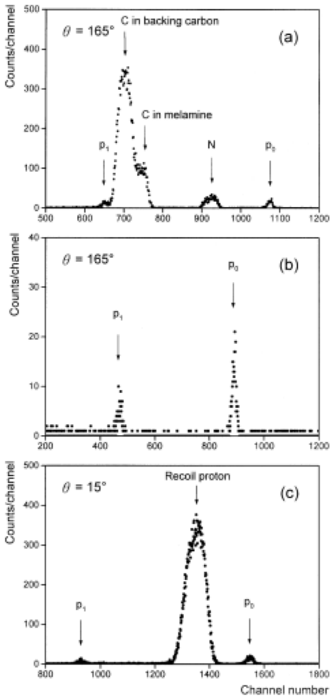


Fig. 4. A set of simultaneously accumulated spectra of ^{4}He ions at $\theta = 165°$ backscattered from the melamine and backing carbon (a), of the p_0 and p_1 proton groups at $\theta = 165°$ after passing through a 5.6 μm Mylar stopper (b) and of the elastic recoil protons at $\theta = 15°$ after passing through a 27.4 μm Mylar stopper (c) for 4.84 MeV incident ^{4}He ions.

IBANDL
Ion Beam Analysis Nuclear Data Library

Nucleus
H-1

Projectile
○ p
○ d
○ ^{3}He
◉ α
○ ^{6}Li

5	$^1H(\alpha,p)^4He$	45°	2500-4500	5	2020-10-21	X4+	I.Bogdanovic Radovic+(2001), Nucl. Instrum. Met Sect.B, Vol.174, p.25 »
6	$^1H(\alpha,p)^4He$	41.5°	2440-2980	5	2019-11-08	X4−	S.Yamaguchi et al. Nucl. Instr. & Meth. 218 (1983)
7	$^1H(\alpha,p)^4He$	41.5°	2430-2970	5	2019-11-08	X4−	S.Nagata et al. Nucl.Instrum. & Meth. v.B6(1985)
8	$^1H(\alpha,p)^4He$	40°	2500-4500	5	2020-10-21	X4+	I.Bogdanovic Radovic+(2001), Nucl. Instrum. Met Sect.B, Vol.174, p.25 »
9	$^1H(\alpha,p)^4He$	40°	600-4830	22	2011-09-08	X4+	Chang-Shuk Kim+(1999), Jour. Nucl. Instrum. Me Sect.B, Vol.155, p.229 »
10	$^1H(\alpha,p)^4He$	35°	590-4830	22	2011-09-08	X4+	Chang-Shuk Kim+(1999), Jour. Nucl. Instrum. Me

1) 1-H-1(A,EL)1-H-1,,DA,P Q=0 C4: MF=4 MT=2 Op=0
Quantity: [DA] Angular distribution of particle specified

	n	Display	Year	Author-1	Energy range,eV		Points	Reference	Subentry#P	
	1	+ i X4 X4+ X4± T4	2014	Hongliang Zhang+	1.75e6	5.95e6	19	[pdf]+ J,NIM/B,335,85,2014	S0204002 [2]	R33
	2	+ i X4 X4+ X4± T4	2004	R.Ishigami+	5.43e6	1.37e7	11	pdf + J,NST,41,(10),953,200410	E1908002 [1]	R33
	3	+ i X4 X4+ X4± T4	2001	I.Bogdanovic Radovic+	2.50e6	4.50e6	29	[pdf]+ J,NIM/B,174,25,2001	O0850002 [4]	R
	4	+ i X4 X4+ X4± T4	1999	Chang-Shuk Kim+	5.96e5	4.83e6	154	[pdf]+ J,NIM/B,155,229,1999	O0858002 [4]	R33
	5	+ i X4 X4+ X4± T4	1993	V.Quillet+	1.69e6	1.77e6	3	[pdf]+ J,NIM/B,83,47,1993	O0817005S [5]	R33
g	6	+ i X4 X4+ X4± T4	1989	E.Szilagyi+	8.20e5	3.42e6	230	[pdf]+ J,NIM/B,43,502,1989	D4380002 [1]	R33
g	7	+ i X4 X4+ X4± T4	1986	F.Paszti+	2.15e6	3.32e6	47	[pdf]+ J,NIM/B,15,486,1986	D4381002 [1]	R33
g	8	+ i X4 X4+ X4± T4			3.00e6		7		D4381003 [1]	R33

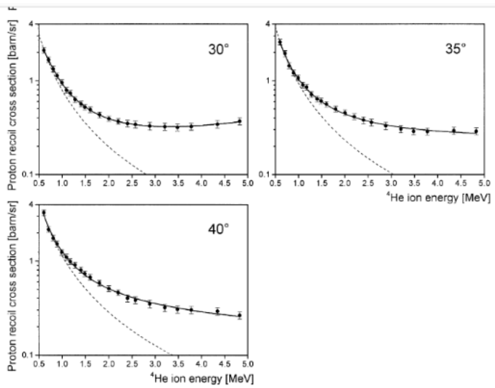


Fig. 6. Proton recoil cross sections at $\theta_p = 10°–40°$ for 0.6–5.0 MeV ^{4}He ion energies from the present work (data points). The solid lines are the polynomial fits to the data points, and the Rutherford values are shown in dashed lines.

```
Comment:     Automatically converted from EXFOR at 2022-12
             by the IAEA-NDS EXFOR Web-Retrieval System,
             program X4toR33 ver-2021-12-15 (V.Zerkin).
             X4Title: "Proton elastic recoil cross section
                       4-He ions"
             X4Author: Chang-Shuk Kim,  Suk-Kwon Kim,  Hee
             EXFOR: O0858002    Created: 2001-05-05  Updat
             X4Reaction:1-H-1(A,EL)1-H-1,,DA,P; X4Points:1
             ENSDF:LevelEnergy=0.00 keV
             Theta groupping interval=1.0 deg.
             AME2020: M1=4.002603254 M2=1.007825031 M3=4.0

Version:       R33
X4Number:      O0858002 20050926
Source:        Chang-Shuk Kim+(1999), Nucl. Instrum. Metho
Reaction:      1H(a,a0)1H
Distribution:  Energy
Sigfactors:    1.00, 0.00
Enfactors:     1.00, 0.00, 0.00, 0.00
Units:         mb
Composition:
Masses:        4.0, 1.0, 4.0, 1.0
Zeds:          2, 1, 2, 1
Qvalue:        -0.0, 0.00, 0.00, 0.00, 0.00
Theta:         10
Data:
   596.00,      0.00,   1918.00,    140.00
```

Recover Web-Retrieval System (v-2008/11/03)

IBANDL data calculated using Legendre coefficients - I

n	Display	Year Author-1	Energy range,eV		Points	Reference	Subentry#P NSR-Key	Info+
1)	4-BE-9(D,A)3-LI-7,PAR,DA Q(keV)=7152.153 C4: MF=4 MT=801 Op=0					Invert data to reaction 3-LI-7(A,D)4-BE-9,,DA (PAR:LVL=0) must be used with option Advanced plot/C5		
	Quantity: [DAP] Partial differential cross section d/dA							
1	+ i X4 X4+ X4± T4	1971 A.Saganek+	9.00e5	2.16e6	493	[pdf]+ J,APP/B,2,473,1971	F0451002 [5] R33 /0 1971SA27	An[375]=15:169 LVL[2]=0:4.8e5
2)	4-BE-9(D,A)3-LI-7,PAR,DA,,LEG/RS Q(keV)=7152.153 C4: MF=154 MT=800 Op=0							
	Quantity: [DAP] Leg.coef.fit part1.4pi/Sig d/dA=1+Sum(a(L)P(L))							
2	+ i X4 X4+ X4± T4	1971 A.Saganek+	8.90e5	2.27e6	176	[pdf]+ J,APP/B,2,473,1971	F0451004 [5] 1971SA27	LVL[2]=0:4.8e5
3)	4-BE-9(D,A)3-LI-7,PAR,SIG Q(keV)=7152.153 C4: MF=3 MT=801 Op=0					Invert data to reaction 3-LI-7(A,D)4-BE-9,,SIG (PAR:LVL=0) must be used with option Advanced plot/C5		
	Quantity: [CSP] Partial cross section							
3	+ i X4 X4+ X4± T4	1971 A.Saganek+	8.90e5	2.24e6	28	[pdf]+ J,APP/B,2,473,1971	F0451003 [5] 1971SA27	LVL[2]=0:4.8e5

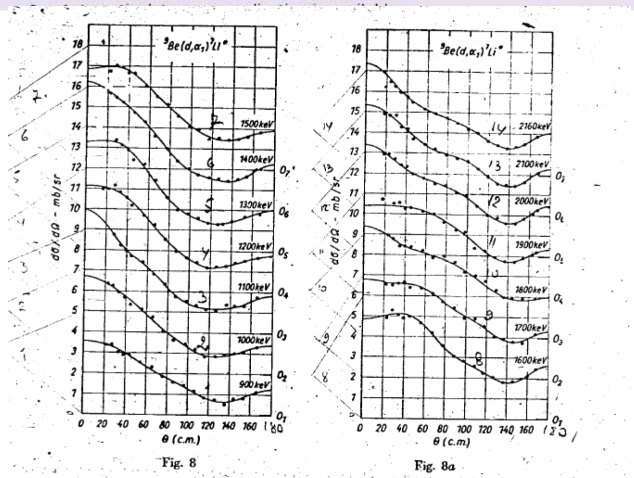


Fig. 8. Angular distributions of the ^{9}Be$(d,\alpha_1)^7$Li* (1-st exc. state) particles in the 0.9–1.5 MeV energy range. Solid lines passing through the experimental points represent the Legendre-polynomial fits.

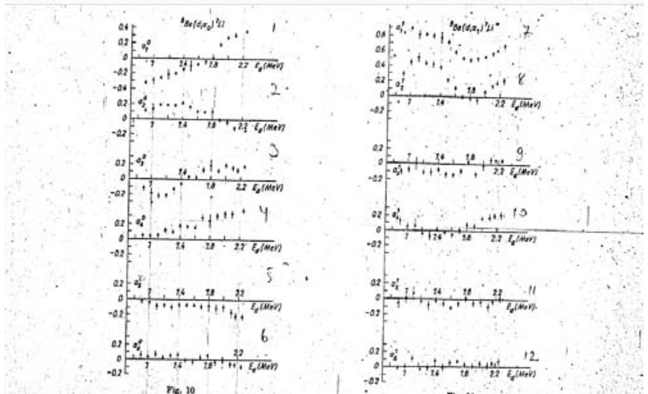


Fig. 10. Legendre polynomial coefficients for the ^{9}Be$(d,\alpha_0)^7$Li reaction as a function of incident deuteron energy. The error bars indicate the uncertainties in the coefficients due to the statistical errors in the data

Fig. 11. Legendre polynomial coefficients for the ^{9}Be$(d,\alpha_1)^7$Li* reaction as a function of incident deuteron energy. For error bars see caption to Fig. 10

```
46) 99.6°:4pt [Plot] [R33] [IBA] [C.M.] [Inv]    95) 38.6°:480:3pt [Plot] [R33] [IBA] [C.M.] [Inv]    144) 162.9°:4
47) 100.9°:4pt [Plot] [R33] [IBA] [C.M.] [Inv]   96) 40.7°:480:6pt [Plot] [R33] [IBA] [C.M.] [Inv]    145) 164.6°:4
48) 101.3°:4pt [Plot] [R33] [IBA] [C.M.] [Inv]   97) 42.0°:480:5pt [Plot] [R33] [IBA] [C.M.] [Inv]    146) 165.4°:4
49) 102.8°:2pt [Plot] [R33] [IBA] [C.M.] [Inv]   98) 48.3°:480:2pt [Plot] [R33] [IBA] [C.M.] [Inv]
Datasets:146 Points:493 Thetas:140 Levels:2

Comment:      Automatically converted from EXFOR at 2022-12-13,14:55:15
              by the IAEA-NDS EXFOR Web-Retrieval System,
              program X4toR33 ver-2021-12-15 (V.Zerkin).
              X4Title: "9Be(d,alpha0)7Li (ground state)and 9Be(d,alpha1)7Li
                       (470 keV)reactions in the 0.9 - 2.2 MeV energy range"
              X4Author: A.Saganek, I.Sledzinska, A.Turos, Z.Wilhelmi,
              B.Zwieglinski
              EXFOR: F0451002    Created: 1986-09-01  Updated: 2020-06-26
              X4Reaction:4-BE-9(D,A)3-LI-7,PAR,DA; X4Points:493
              Converted from C.M. to Lab.: Sigma, Theta
              SigmaLab=SigmaCM/{0.7658534, 0.75119716}
              ThetaLab=13.8 ThetaCM:15.9 [15.4, 16.3]
              ENSDF:LevelEnergy=0.00 keV
              Theta grouping interval=1.0 deg.
              AME2020: M1=2.014101777 M2=9.012183062 M3=4.002603254 M4=7.016003434

Version:      R33
X4Number:     F0451002 20200626
Source:       A.Saganek+(1971), Acta Physica Polonica, Part B, Vol.2, p.473
Reaction:     9Be(d,a0)7Li
Distribution: Energy
Sigfactors:   1.00, 0.00
Enfactors:    1.00, 0.00, 0.00, 0.00
Units:        mb
Composition:
Masses:       2.0, 9.0, 4.0, 7.0
Zeds:         1, 4, 2, 3
Qvalue:       7152.15, 0.00, 0.00, 0.00, 0.00
Theta:        13.8
Data:
  1800.00,      0.00,     6.1239,      0.00
  2160.00,      0.00,     5.9771,      0.00
EndData:
```

$$\frac{d\sigma}{d\Omega}(E,\theta) = a_0 + \sum_{l=1}^{n} a_l(E)\,P_l(cos\theta)$$

IBANDL data calculated using Legendre coefficients - II

$$\frac{d\sigma}{d\Omega}(E,\theta) = a_0 + \sum_{l=1}^{n} a_l(E)\, P_l(cos\theta)$$

2376 B. B. MARSH AND O. M. BILANIUK

TABLE I. Coefficients for the Legendre polynomials corresponding to $C^{13}(d,\alpha)B^{11}$ angular distributions.

E_d (MeV)	3.35	3.55	3.85	3.95	4.20
$(\chi^2/d)^{1/2}$	1.49	1.31	0.94	1.28	1.39
a_0	5.76±0.03	7.45±0.05	7.82±0.04	6.85±0.05	5.90±0.05
a_1	1.32±0.07	−0.57±0.12	0.48±0.07	1.60±0.14	2.15±0.12
a_2	4.23±0.10	2.53±0.19	3.70±0.10	0.90±0.28	3.21±0.18
a_3	4.61±0.12	2.16±0.23	0.47±0.12	0.28±0.24	1.07±0.23
a_4	5.25±0.27	5.34±0.27	4.17±0.16	2.20±0.42	4.66±0.25
a_5	2.15±0.15	0.00±0.26	−1.90±0.19	−1.53±0.29	−1.64±0.25
a_6	−0.86±0.14	−2.20±0.16	−2.15±0.16	−2.98±0.39	−1.46±0.24
a_7	−0.10±0.15	0.36±0.23	1.50±0.17	1.68±0.25	0.87±0.22

butions over an angular range of 10° to 90° at three energies. Perfect agreement prevailed in the angular range where the two sets of data overlapped.

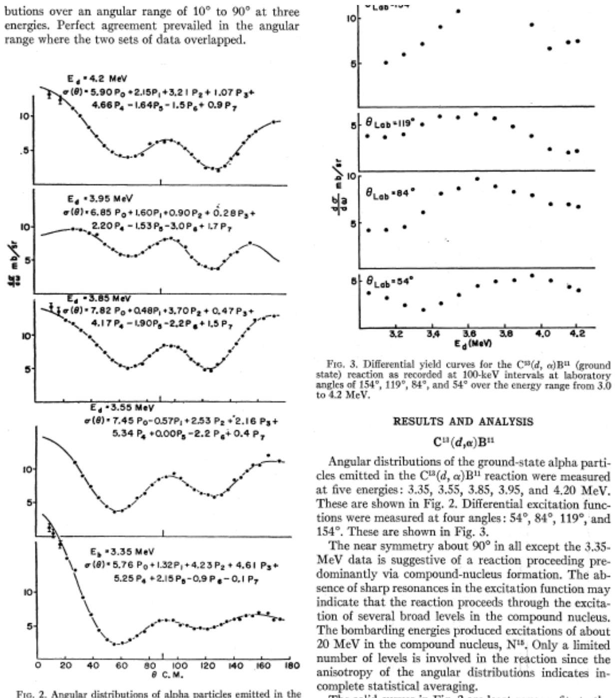


FIG. 2. Angular distributions of alpha particles emitted in the $C^{13}(d,\alpha)B^{11}$ reaction as recorded at 4.20, 3.95, 3.85, 3.55, and 3.35 MeV. The statistical errors for the data points lie within the circles except where indicated. Solid lines are least-squares Leg-

FIG. 3. Differential yield curves for the $C^{13}(d,\alpha)B^{11}$ (ground state) reaction as recorded at 100-keV intervals at laboratory angles of 154°, 119°, 84°, and 54° over the energy range from 3.0 to 4.2 MeV.

RESULTS AND ANALYSIS

$C^{13}(d,\alpha)B^{11}$

Angular distributions of the ground-state alpha particles emitted in the $C^{13}(d,\alpha)B^{11}$ reaction were measured at five energies: 3.35, 3.55, 3.85, 3.95, and 4.20 MeV. These are shown in Fig. 2. Differential excitation functions were measured at four angles: 54°, 84°, 119°, and 154°. These are shown in Fig. 3.

The near symmetry about 90° in all except the 3.35-MeV data is suggestive of a reaction proceeding predominantly via compound-nucleus formation. The absence of sharp resonances in the excitation function may indicate that the reaction proceeds through the excitation of several broad levels in the compound nucleus. The bombarding energies produced excitations of about 20 MeV in the compound nucleus, N^{15}. Only a limited number of levels is involved in the reaction since the anisotropy of the angular distributions indicates incomplete statistical averaging.

The solid curves in Fig. 2 are least-squares fits to the angular distributions, using Legendre polynomials in

angle over a continuous range without breaking vacuum.[5] This method was used to measure angular distributions over an angular range of 10° to 90° at three energies. Perfect agreement prevailed in the angular range where the two sets of data overlapped.

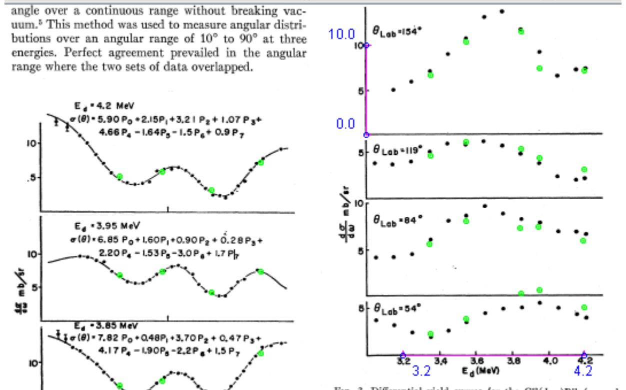


FIG. 3. Differential yield curves for the $C^{13}(d,\alpha)B^{11}$ (ground state) reaction as recorded at 100-keV intervals at laboratory angles of 154°, 119°, 84°, and 54° over the energy range from 3.0 to 4.2 MeV.

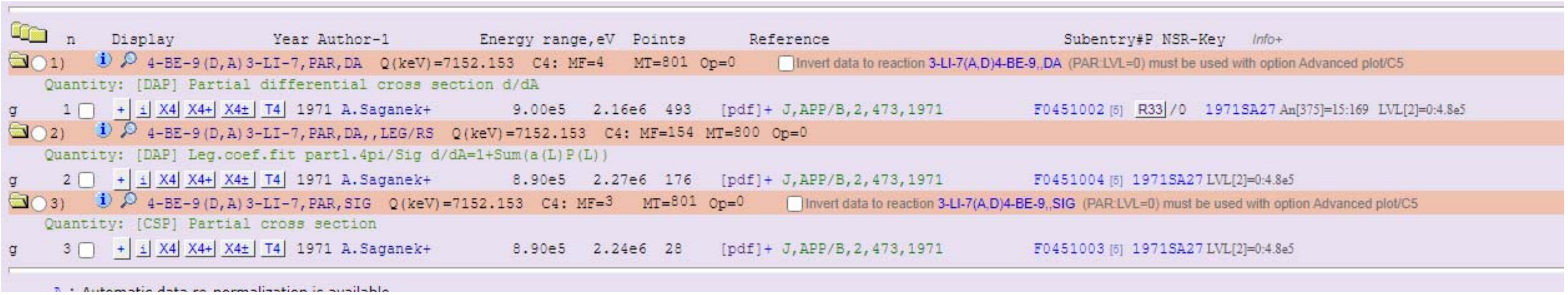
RESULTS AND ANALYSIS

$C^{13}(d,\alpha)B^{11}$

Angular distributions of the ground-state alpha particles emitted in the $C^{13}(d,\alpha)B^{11}$ reaction were measured at five energies: 3.35, 3.55, 3.85, 3.95, and 4.20 MeV. These are shown in Fig. 2. Differential excitation functions were measured at four angles: 54°, 84°, 119°, and 154°. These are shown in Fig. 3.

The near symmetry about 90° in all except the 3.35-MeV data is suggestive of a reaction proceeding predominantly via compound-nucleus formation. The absence of sharp resonances in the excitation function may indicate that the reaction proceeds through the excitation of several broad levels in the compound nucleus. The bombarding energies produced excitations of about 20 MeV in the compound nucleus, N^{15}. Only a limited number of levels is involved in the reaction since the anisotropy of the angular distributions indicates in-

IBANDL data calculated using Legendre coefficients - III



$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{\sigma}{4\pi}\left[1 + \sum_{l=1}^{n} W_l(E)P_l(cos\theta)\right]$$