JAERI-M
93-205

DATABASE FOR ^{238}U INELASTIC SCATTERING CROSS SECTION EVALUATION

October 1993

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編集兼発行　日本原子力研究所
印　　刷　いばらき印刷㈱

Database for ^{238}U Inelastic Scattering Cross Section Evaluation

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(Received September 17, 1993)

There are discrepancies among evaluated neutron inelastic scattering cross sections for ^{238}U in the evaluated nuclear data files, JENDL-3, ENDF/B-VI, JEF-2, BROND-2 and CENDL-2. Re-evaluating them is internationally being discussed to obtain the best outcome which can be accepted in common at the present by experts in the world. This report has been compiled to review the discrepancies among the evaluations in the present data files and to provide a common database for the re-evaluation work.

Keywords: U-238, Neutron Cross Section, Inelastic Scattering, Experimental Data, Evaluated Data

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^{238}U非弾性散乱断面積評価用データベース

日本原子力研究所東海研究所
シグマ研究委員会
神田　幸則*・藤川　　登*・河野　俊彦*

（1993年9月17日受理）

^{238}Uの非弾性散乱断面積の評価値は，ＪＥＮＤＬ－３，ＥＮＤＦ／Ｂ－ＶＩ，ＪＥＦ－２，ＢＲＯＮＤ－２，ＣＥＮＤＬ－２間で相違がある。現状で世界の専門家が共通に納得しうる最良値を求めるための再評価作業が，国際協力で進行中である。本報告書は，既存データファイルの評価値間の相違を比較すると共に，再評価作業のための共通のデータベースを整備するために編集されたものである。

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＊　九州大学

Contents

目　　次

1. INTRODUCTION

Accurate neutron inelastic scattering cross sections for ^{238}U are important for reactor design. However, determination of the inelastic scattering cross sections is difficult because of a complicated nuclear structure and scarce experimental data. There are considerable discrepancies among the evaluated nuclear data libraries, JENDL-3[1], ENDF/B-VI[2], JEF-2[3], BROND-2[4], and CENDL-2[5].

This report was planned as a database for the evaluation of the ^{238}U inelastic scattering cross section. This report makes comparisons of the evaluated nuclear data of ^{238}U inelastic scattering cross sections with the experimental data, and contains graphs of experimental data of the total, elastic, capture, (n,2n), and (n,3n) reactions above ~ 1 MeV. The experimental data of these reactions above ~ 1 MeV were derived from the EXFOR file. The experimental data in the plotting are identified by their ENTRY and SUBENT numbers of the EXFOR file. The information about the experimental data, such as authors, their institution and its reference, is given in the Appendix.

2. COMMENTS ON THE PLOTTING

The evaluated data files of the ^{238}U inelastic scattering cross sections and the EXFOR file were obtained from the NEA Data Bank via Nuclear Data Center in JAERI in 1992. These data are plotted with GR3 which is a data drawing program written in C-language on a personal computer with the size of about 200 kbytes.

2.1 Nuclear Structure

Discrete level data of ^{238}U are tabulated in Table 1. The excitation energy, spin, and parity of the levels assigned in Nuclear Data Sheets[6] are listed in the first column as a reference. The second column shows the excitation energies compiled in Table of Isotopes[7]. The rest four columns give the energies of levels whose excitation cross sections are given in the evaluated data files.

Shan et al.[8] give a detailed table of decomposition of the collective band level scheme of ^{238}U. Table 2 gives their level assignment.

1. INTRODUCTION

Accurate neutron inelastic scattering cross sections for ^{238}U are important for reactor design. However, determination of the inelastic scattering cross sections is difficult because of a complicated nuclear structure and scarce experimental data. There are considerable discrepancies among the evaluated nuclear data libraries, JENDL-3[1], ENDF/B-VI[2], JEF-2[3], BROND-2[4], and CENDL-2[5].

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Shan et al.[8] give a detailed table of decomposition of the collective band level scheme of ^{238}U. Table 2 gives their level assignment.

Number of levels as a function of the excitation energy is shown in Fig. 1 in order to determine the level density of ^{238}U.

2.2 Comparison of the Evaluated Data

Figures 2~5 show the inelastic scattering cross sections in the evaluated data files, ENDF/B-VI, JENDL-3, JEF-2, BROND-2, and CENDL-2. Heavy solid lines are the total inelastic scattering cross section, light dotted lines are the inelastic scattering to the first excited state, heavy dotted lines are that for the continuum region, and the other lines are that for the various discrete levels. The cross sections in JEF-2 are almost equivalent to that in JENDL-3 except the first level in the energy region below 400 keV.

Comparisons of the total inelastic scattering and the partial inelastic scattering to low-lying 2^+, 4^+, 6^+, 1^-, and 3^- levels are displayed in Figs. 6~11.

2.3 Partial Inelastic Scattering

The experimental inelastic scattering cross sections for the discrete levels are displayed in Figs. 12~32. The energies written in the drawings are the discrete level energies in Ref. 1. Some of the figures for higher energy level involve experimental data which are the sum of cross sections to adjacent levels.

2.4 Angular Distributions of Inelastically Scattered Neutrons

The angular distributions of the inelastic scattering neutrons to the first and the second excited state are shown in Figs. 33~41. JEF-2 gives the same distributions as JENDL-3.

2.5 Other Reactions

The total cross sections are displayed in Figs. 42 and 43, the capture cross sections are in Fig. 44, the (n,2n) reaction cross sections are in Fig. 45 and the (n,3n) are in Fig. 46, and the elastic scattering cross sections are in Fig. 47, respectively. The angular distributions of the elastic scattering are in Figs. 48~63.

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Table 1 Energies of the ^{238}U excited states in the evaluated files.

NDS(*1)	Jπ	TOI(*2)	JENDL-3	ENDF-VI	BROND2	CENDL2
0.0	0+	0.0	0.0	0.0	0.0	0.0
44.91	2+	44.9	44.889	44.9	45	44.9
148.41	4+	148.4	148.4	148.4	148	148.4
307.21	6+	307.2	307.2	308		307.0
518.3	8+	517.8	517.8			
680.1	1-	680.0	680.1	680	680	680
731.9	3-	731.9	731.9	732	732	731.9
775.7	10+	775.7	775.7			
826.7	5-	827.2	827.1	827		827
925.7	(0+)	927.2	927			927
930.8	(1-)	930.8			939	
950.2	(2-)	950.0	950			950
966.3	7-	965.9		965		966
967.3	2+	966.3	966.3			
993	(0+)	993	993			993
997.5	3-	997.5				997.5
		998.3			1006	998.3
1037.3	2+	1037.3	1037.3	1048		1037
1056.6	(4+)	1055			1047	1055
1059.5	(3+)	1059.7	1059.5			1060
1060.3	2+	1060.3				
1076.5	12+	1076.5	1076.5		1076	
1105.7	(3+)	1105.6			1078(*3)	
1112.6	(1-)	1107	1107			1107
1127	(4+)	1127				1127
1128.7	(2-)	1128.7	1128.9			1129
1135.8						
1150.3	9-	1150.3	1150.3			
1168.0	(4+)	1167				1167
1170.4	3-	1169.4	1169	1170		1169
		1209				
1224.2	(2+)	1223.7	1223.9			1224
1231		1231				1224
1232.6	(4-)	1243	1243	1250		
1260.9						
1269.2	(6+)	1270	1270			

*1) Nuclear Data Sheets **53**, 601(1988).

*2) Table of Isotopes 7th edition.

*3) Beginning of a continuum region.

Table 1 (continued)

NDS	Jπ	TOI	JENDL-3	ENDF-VI	BROND2	CENDL2
1278.5	(1-, 2+)		1278.5			
1285.8	(5-)	1290	1290			
1355.2	(1, 2+)					
1375		1375				
1378.4	11-	1378.4	1378.4			
1381.7	(6-)					
1413.3	(2+, 3-)					
1415.3	14+	1415.7	1415.3	1440		
1482.0	(0+)		1500			
1516.5	(4+)	1512				
1530.7	2+	1530				
1594.9	(2+, 3, 4+)			1590		
1630		1630				
1643.2	4+					
		1647				
1648.9	13-	1648.9				
1665		1665				
1672.0						
1712		1712				
1761.2	(4+)	1758		1750		
1774.7	(3-, 4, 5-)	1774				
1788.2	16+	1788.2				
1814.3	(6+)	1807		1850		
1892.2	(4+, 5-)					
1958.6	15-	1958.6		1950		
1992.6	(3-)					
2163.6				2150		
2190.7	18+	2190.7				
2305.9	17-	2305.9		2300		
				2390		
				2489.5		
2557.6	0+	2559		2492.8		
2618.7	20+	2618.7				
2687.2	19-	2687.2				
2754	(1)					
3067.2	22+	3067.2		2940		

Table 2 Level assignment by Shan, et al.

NDS	Jπ	K=0+ g.s. rot.	K=0+ β vib.	K=2+ γ vib.	K=0+ 2γ vib.	K=0- oct.	K=1- oct.	K=2- oct.
0.0	0+	0.00						
44.91	2+	44.9						
148.41	4+	148.4						
307.21	6+	307.2						
518.3	8+	517.8						
680.1	1-					680.1		
731.9	3-					731.9		
775.7	10+	775.7						
826.7	5-					827.2		
925.7	0+				927.0			
930.8	1-						930.8	
950.2	2-						950.0	
966.3	7-					966		
967.3	2+				966.3			
993	0+		993					
997.5	3-						997.5	
1037.3	2+		1037.3					
1056.6	4+				1055			
1059.5	3+							
1060.3	2+			1060.3				
1076.5	12+	1076.6						
1105.7	3+			1105.6				
1112.6	1-							
1127	4+		1127					
1128.7	2-							1128.7
1135.8								
1150.3	9-					1150		
1168.0	4+			1167.7				
1170.4	3-							1169.1
1224.2	2+							
1231								
1232.6	4-							1243?
1260.9								
1269.2	6+		1270					

Table 2 (continued)

NDS	Jπ	K=0+ g.s. rot.	K=0+ β vib.	K=2+ γ vib.	K=0+ 2γ vib.	K=0- oct.	K=1- oct.	K=2- oct.
1278.5	1-, 2+							
1285.8	5-							
1355.2	1, 2+							
1375								1375?
1378.4	11-					1378		
1381.7	6-							
1413.3	2+, 3-							
1415.3	14+	1415						
1482.3	0+							
1516.5	4+							
1530.7	2+							
1594.9	2+, 3, 4+							
1630								
1643.2	4+							
1648.9	13-					1649		
1665								
1672.0								
1712								
1761.2	4+							
1774.7	3-, 4, 5-							
1788.2	16+	1788						
1814.3	6+							
1892.2	4+, 5-							
1958.6	15-					1959		
1992.6	3-							
2163.6								
2190.7	18+	2191						
2305.9	17-					2306		
2557.6	0+							
2618.7	20+	2619						
2687.2	19-					2687		
2754	1							
3067.2	22+	3067						

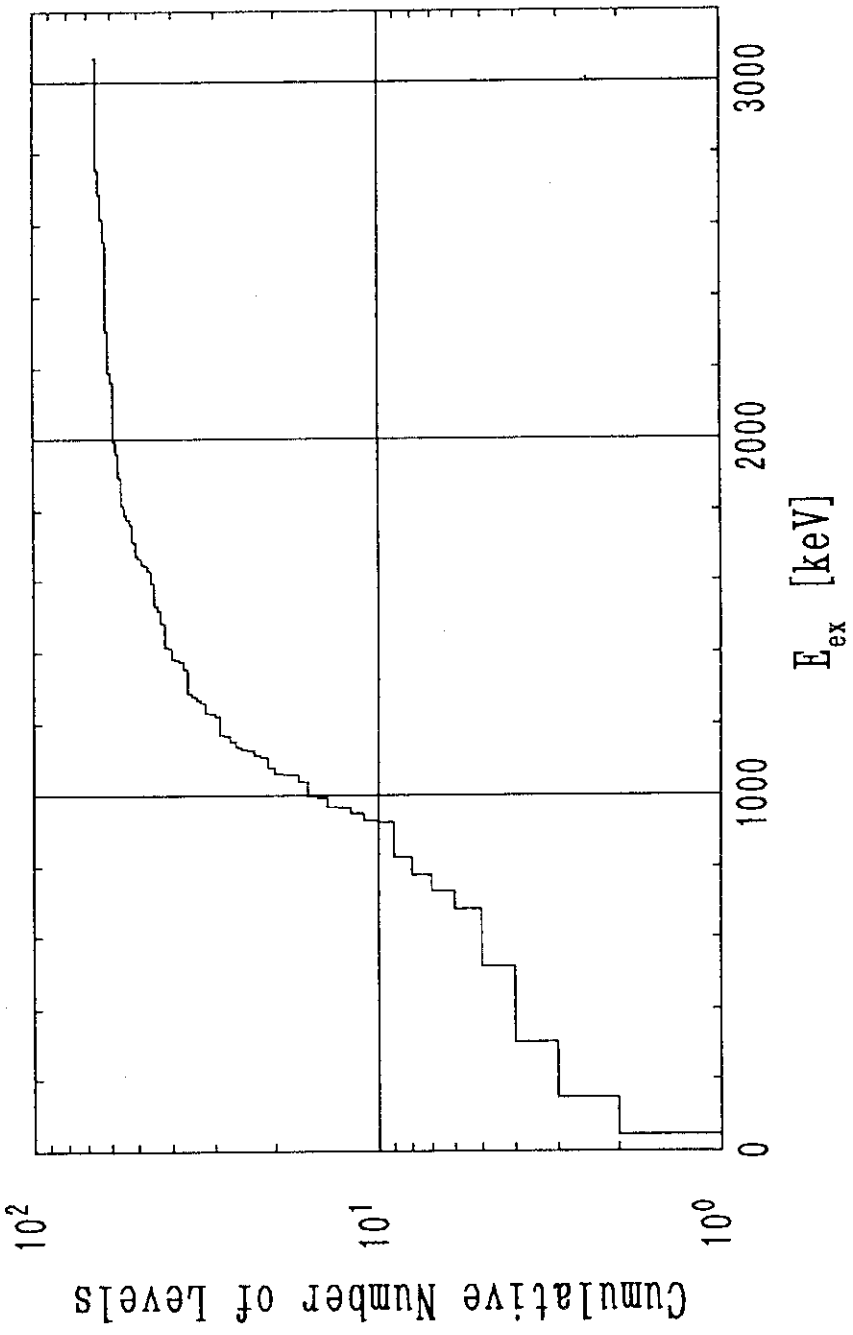


Fig. 1 Number of levels of ^{238}U up to energy E_{ex}.

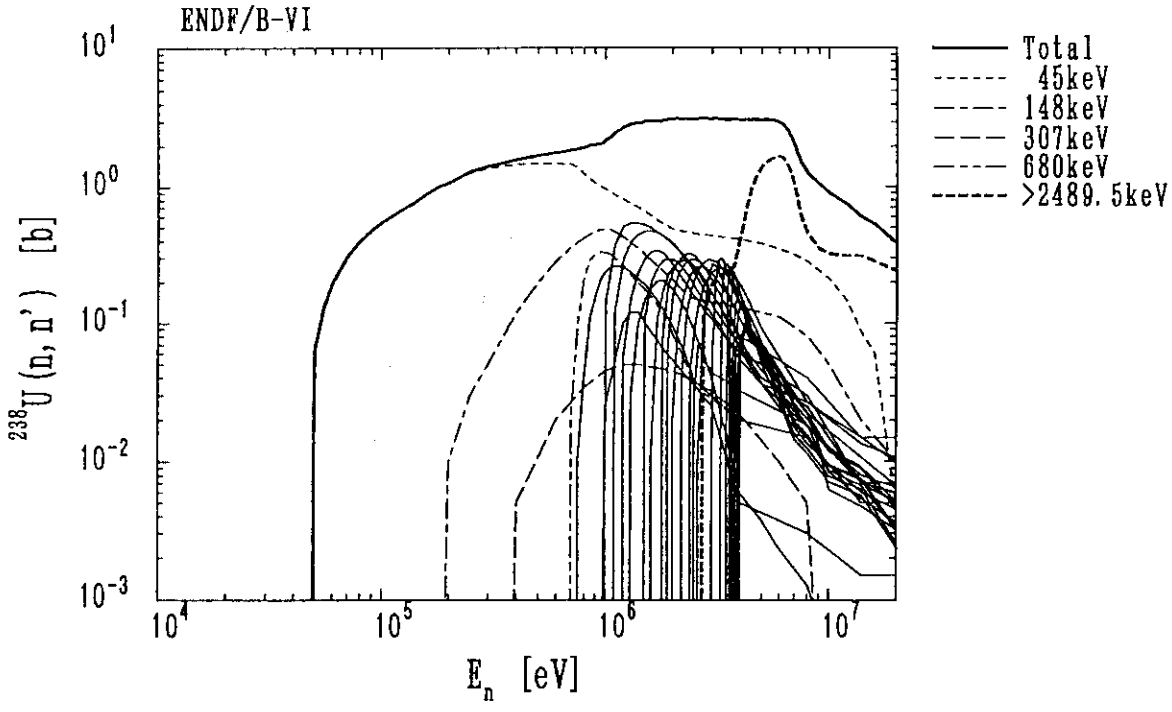


Fig. 2 ^{238}U inelastic scattering cross sections in ENDF/B-VI.

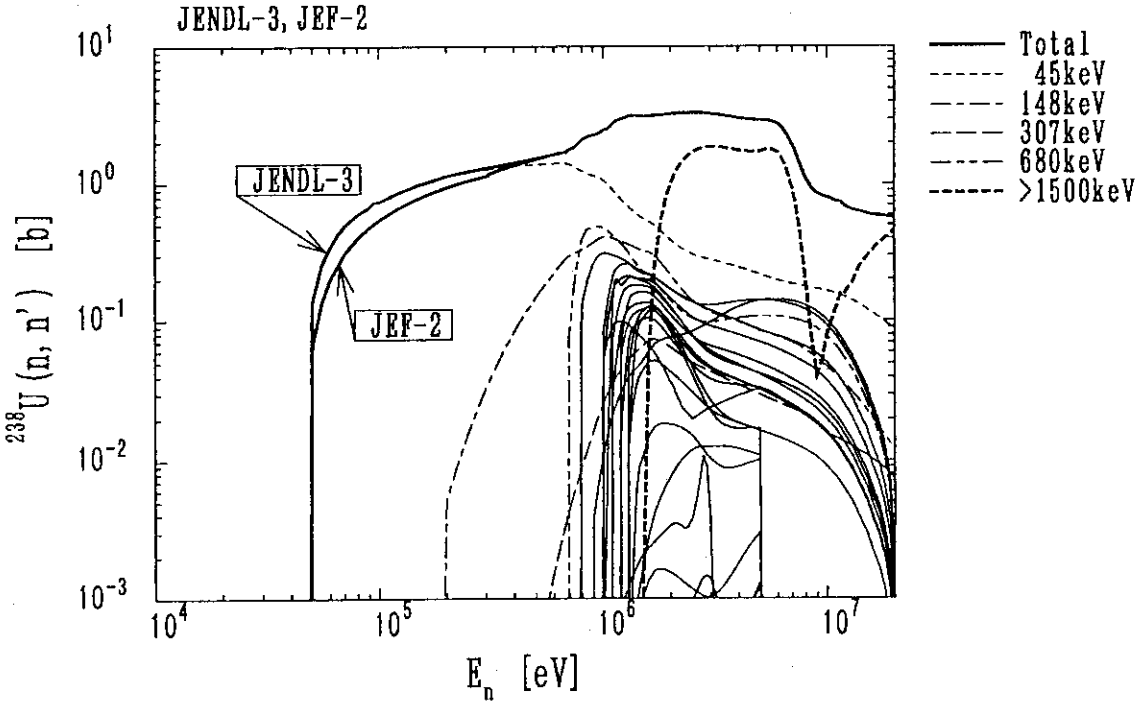


Fig. 3 ^{238}U inelastic scattering cross sections in JENDL-3 and JEF-2.

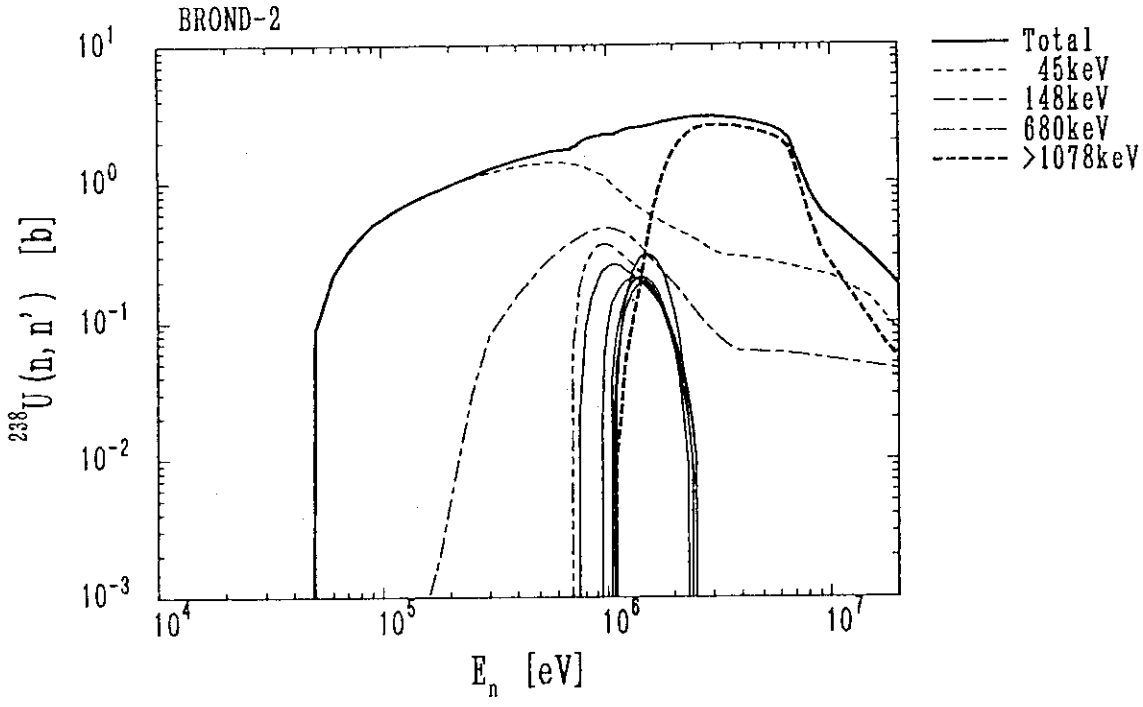


Fig. 4 ^{238}U inelastic scattering cross sections in BROND-2.

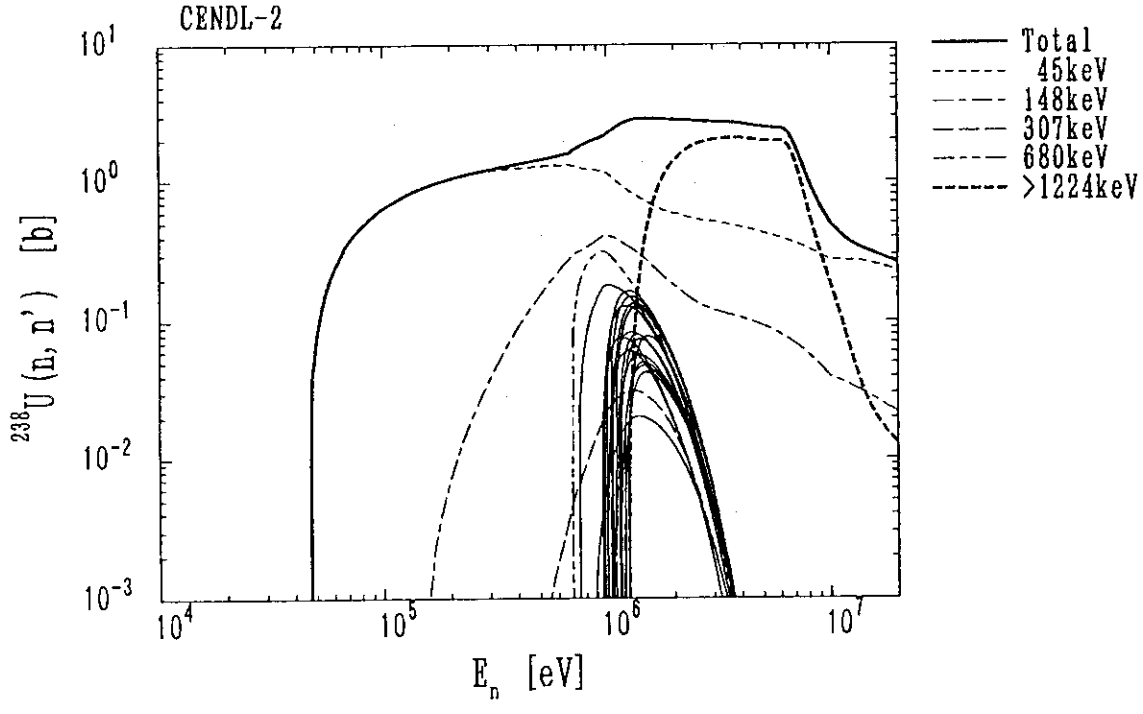


Fig. 5 ^{238}U inelastic scattering cross sections in CENDL-2.

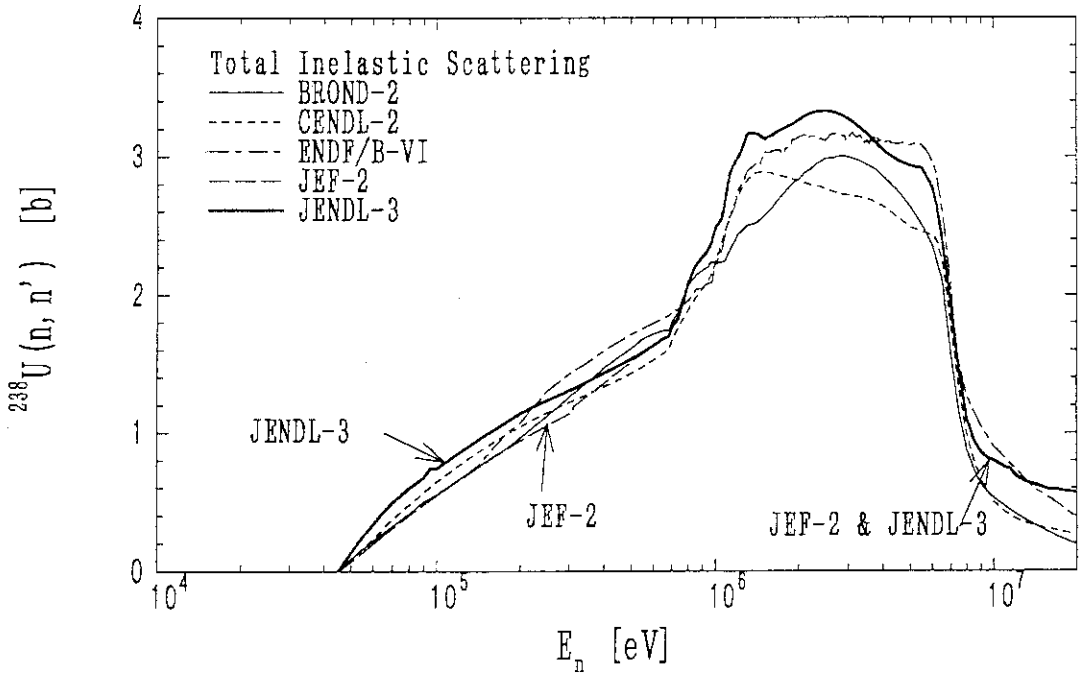


Fig. 6 Comparison of total inelastic scattering cross section.

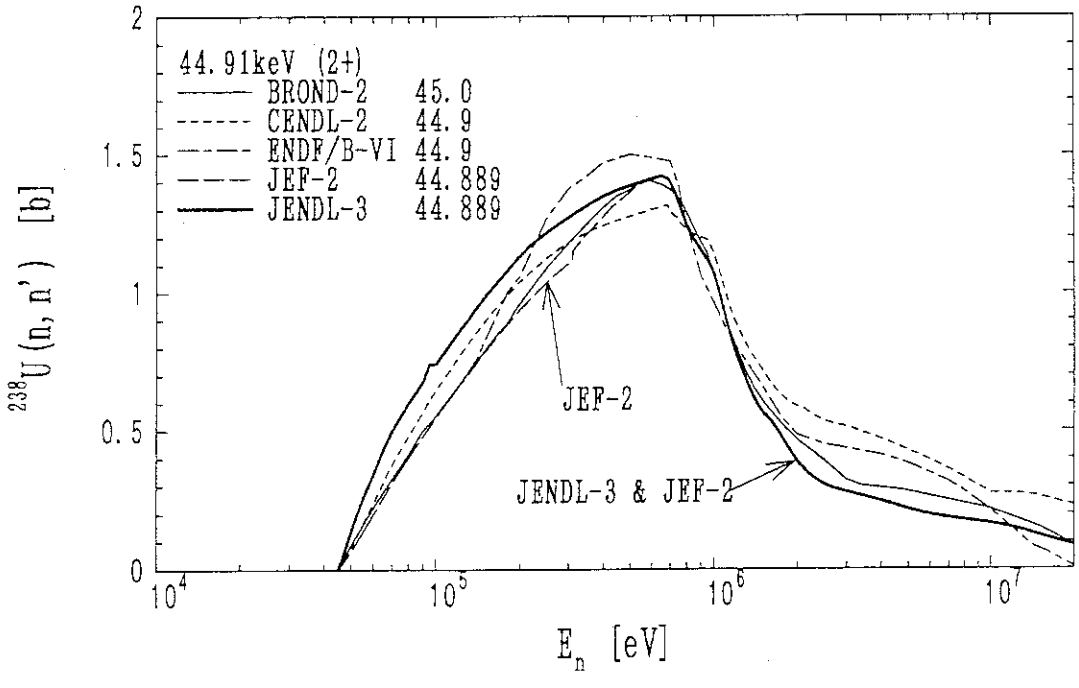


Fig. 7 Comparison of inelastic scattering cross section to 44.91 keV level.

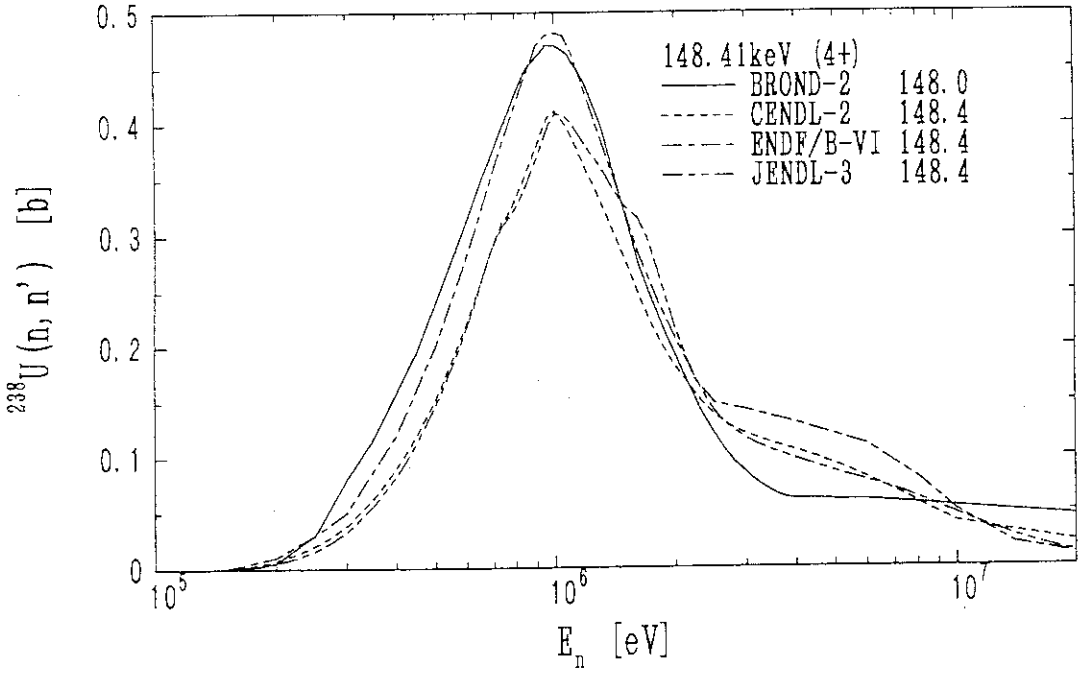


Fig. 8 Comparison of inelastic scattering cross section to 148.41 keV level.

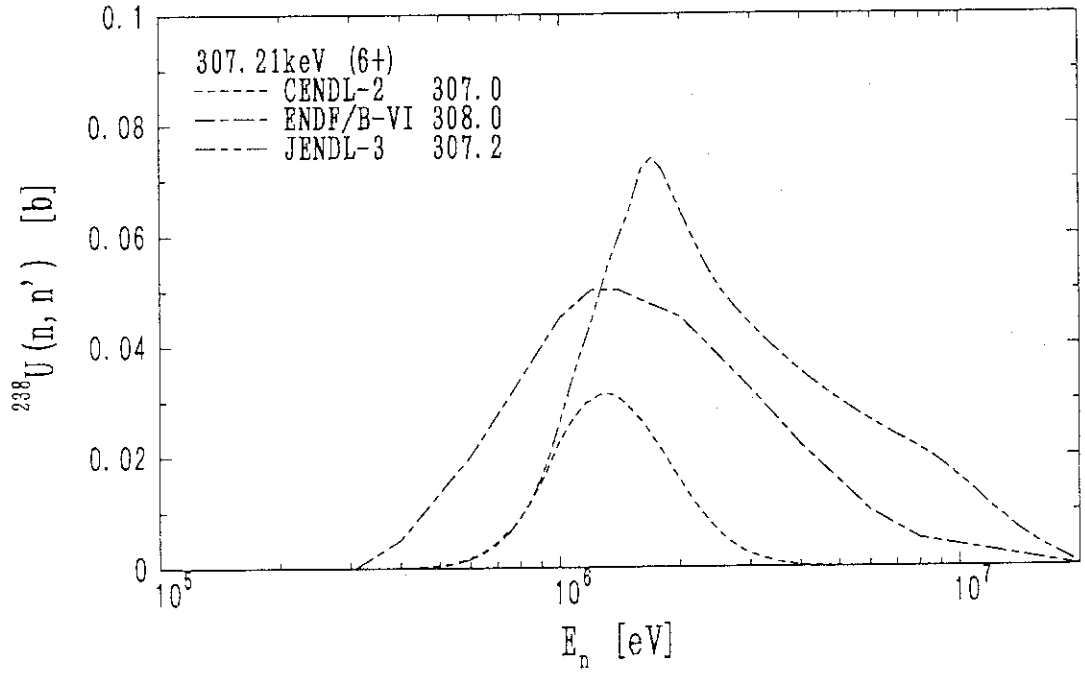


Fig. 9 Comparison of inelastic scattering cross section to 307.21 keV level.

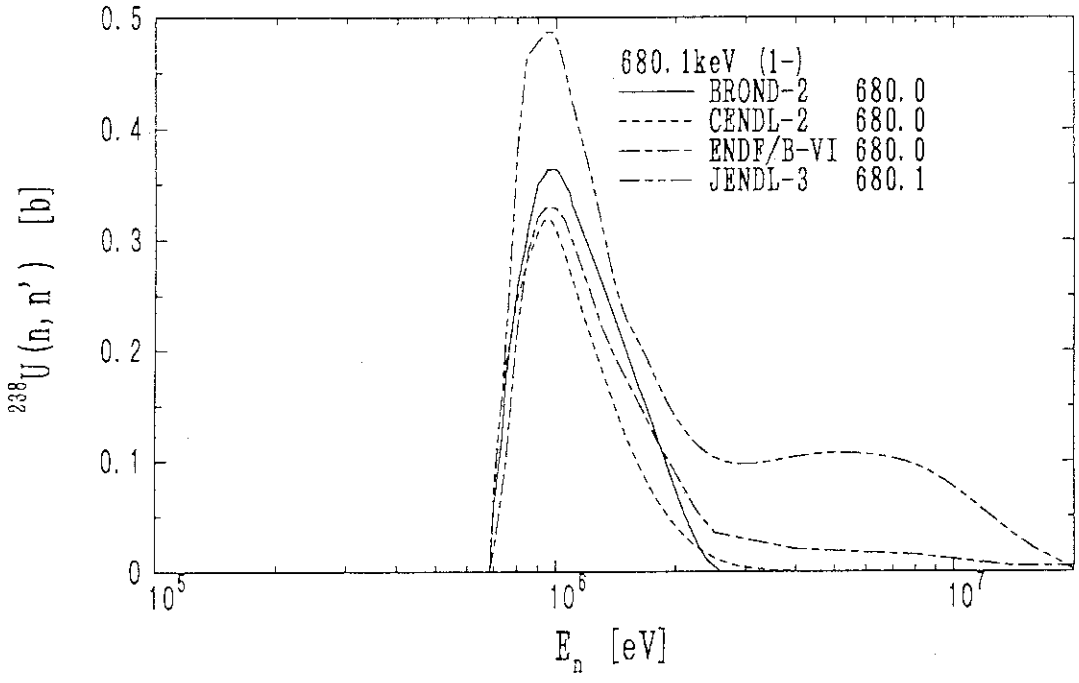


Fig. 10 Comparison of inelastic scattering cross section to 680.1 keV level.

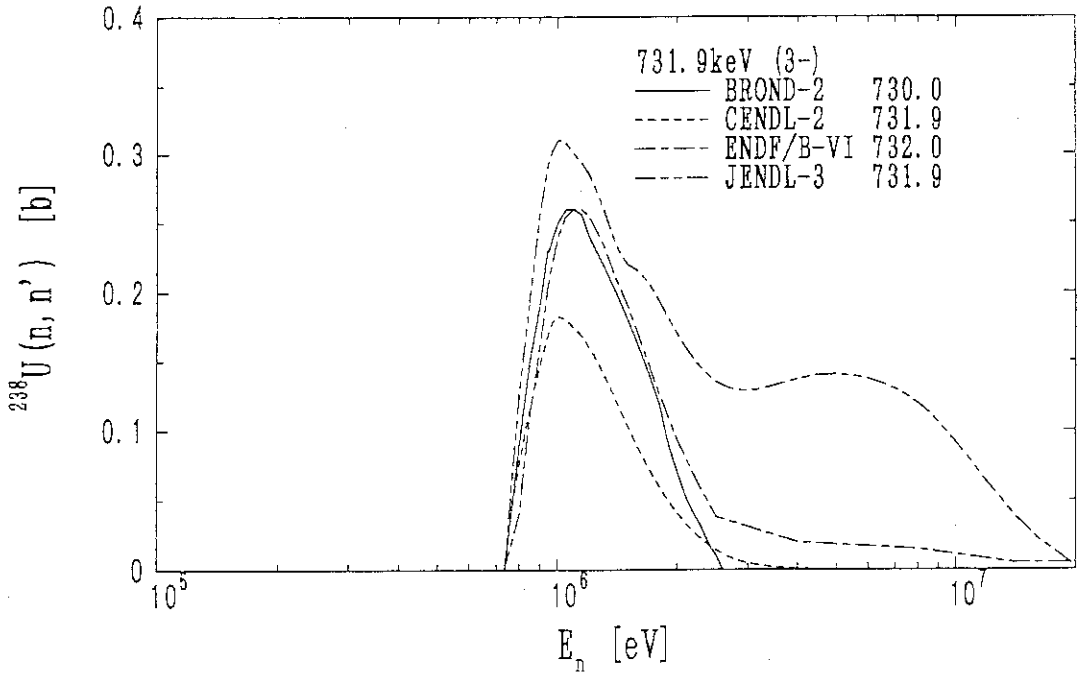


Fig. 11 Comparison of inelastic scattering cross section to 731.9 keV level.

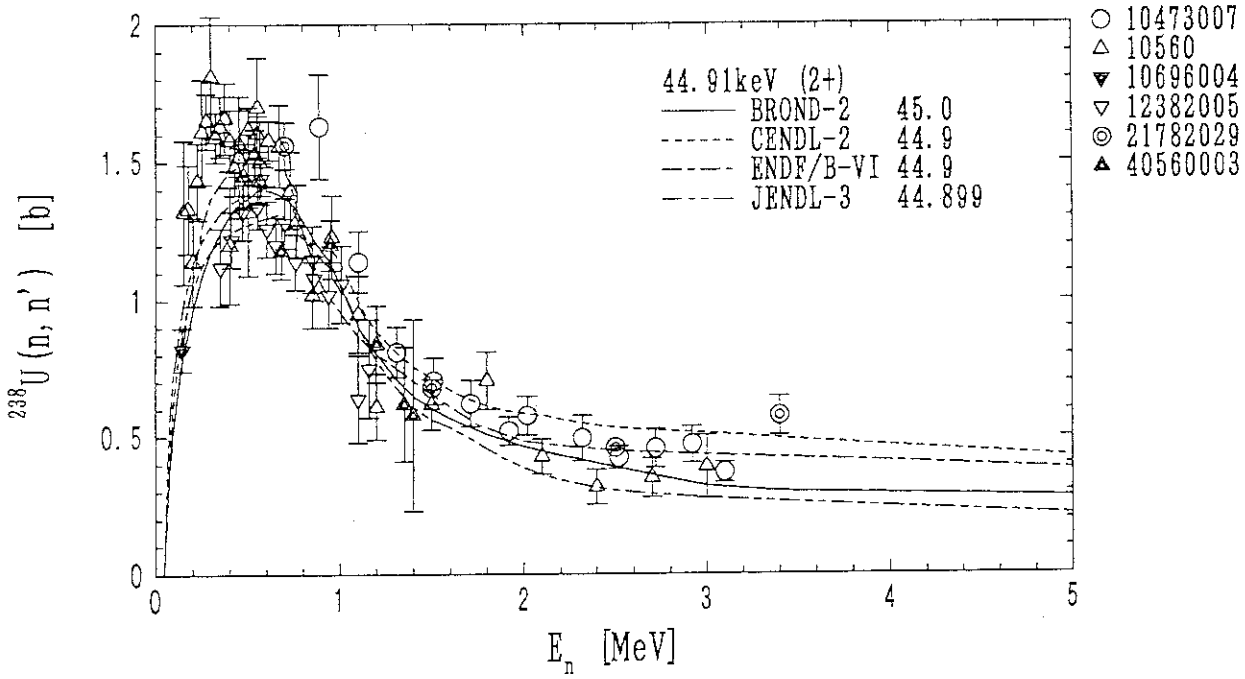


Fig. 12 Inelastic scattering cross section to 44.91 keV level.

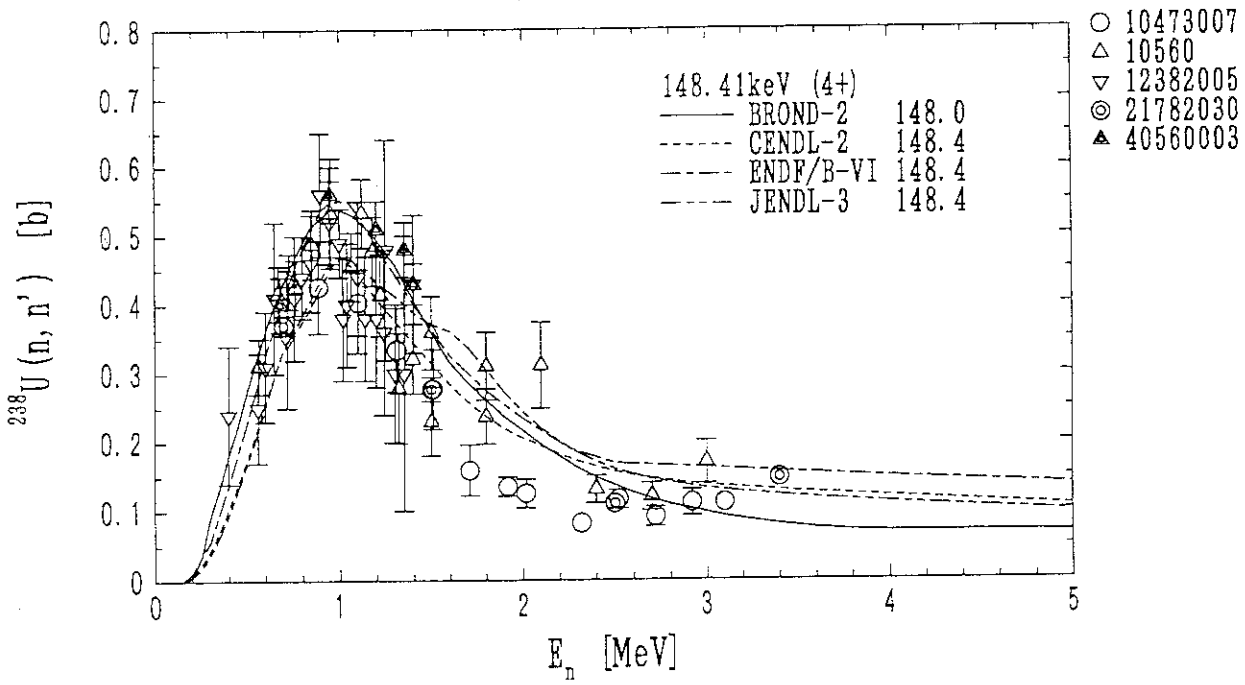


Fig. 13 Inelastic scattering cross section to 148.41 keV level.

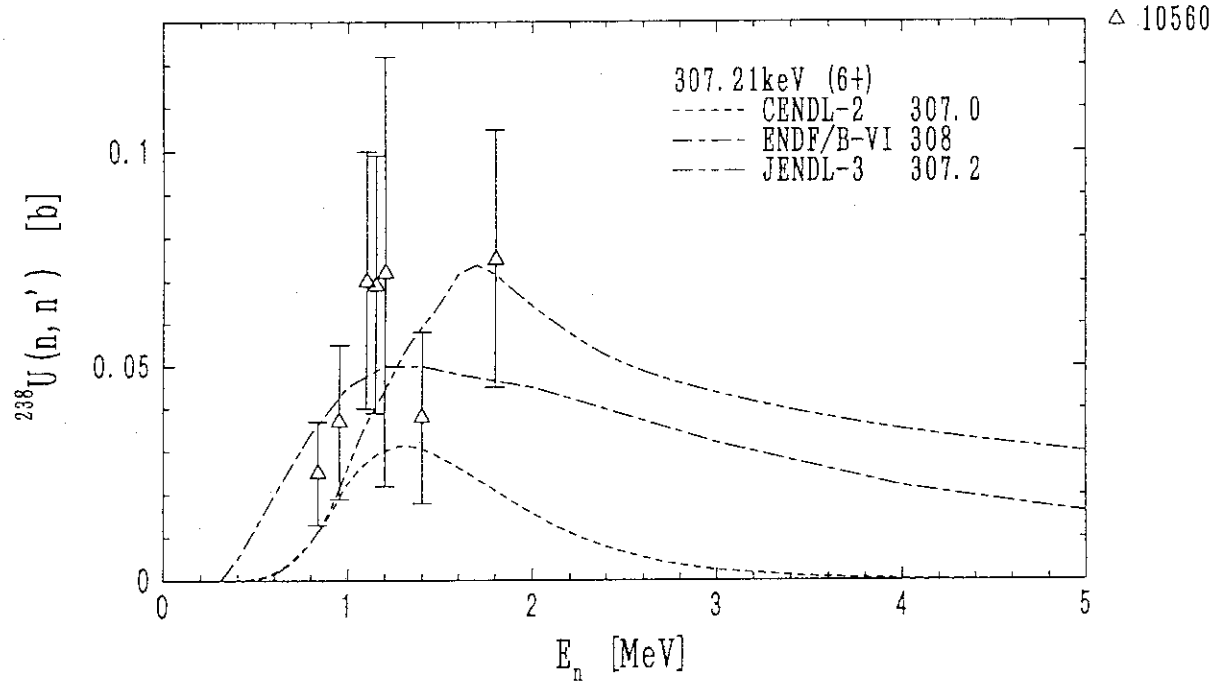


Fig. 14 Inelastic scattering cross section to 307.21 keV level.

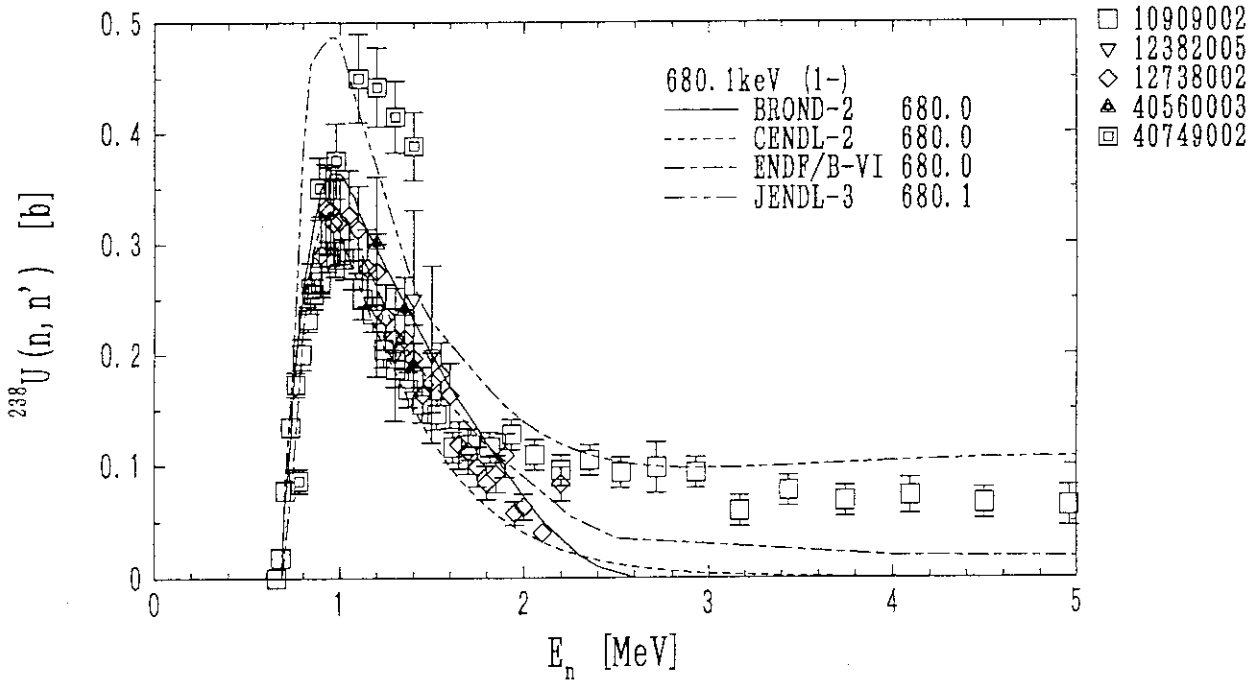


Fig. 15 Inelastic scattering cross section to 680.1 keV level.

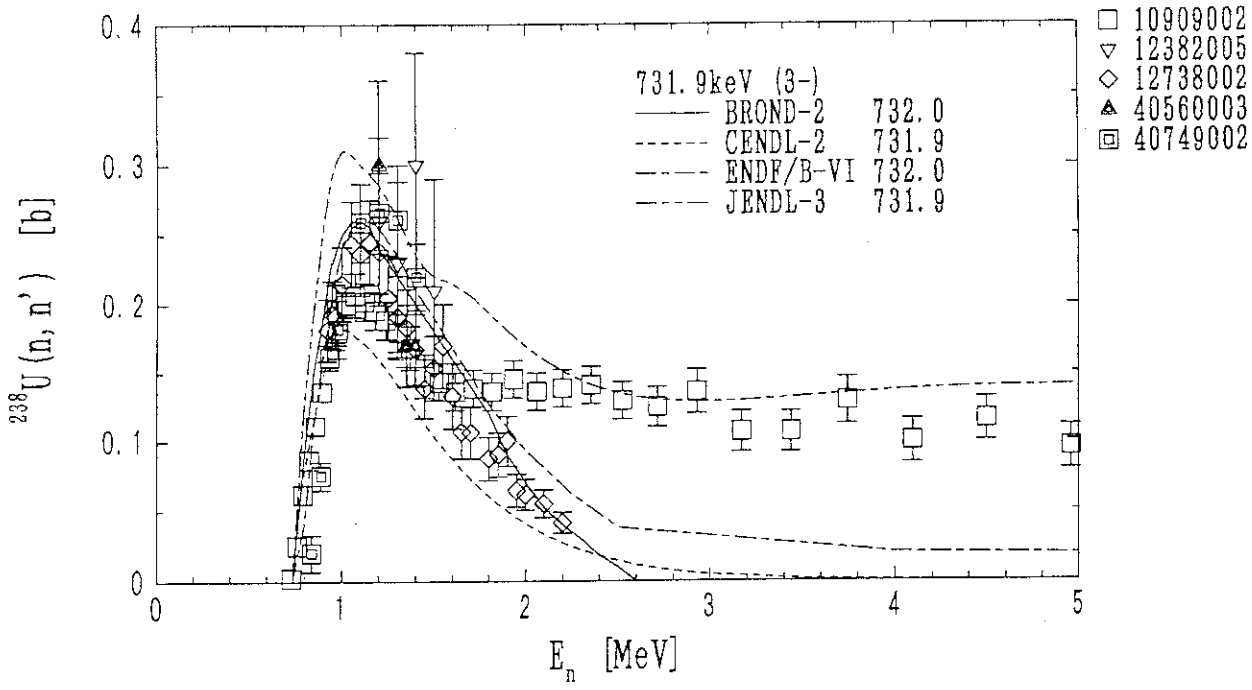


Fig. 16 Inelastic scattering cross section to 731.9 keV level.

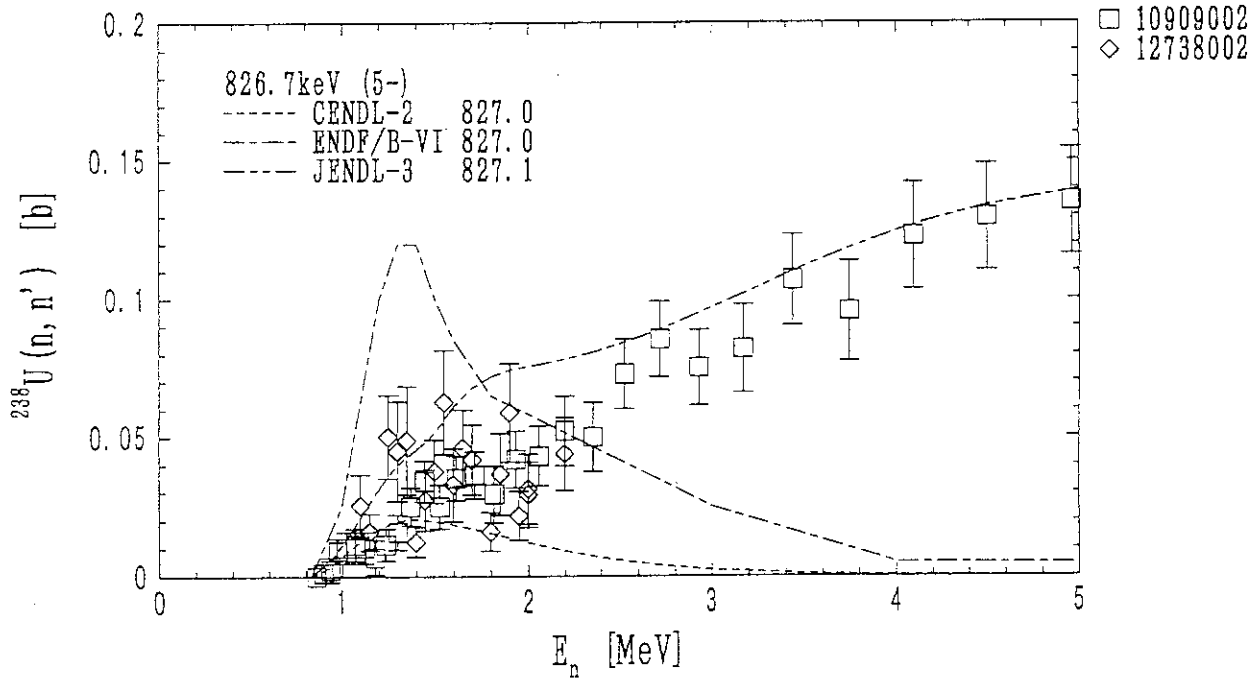


Fig. 17 Inelastic scattering cross section to 826.7 keV level.

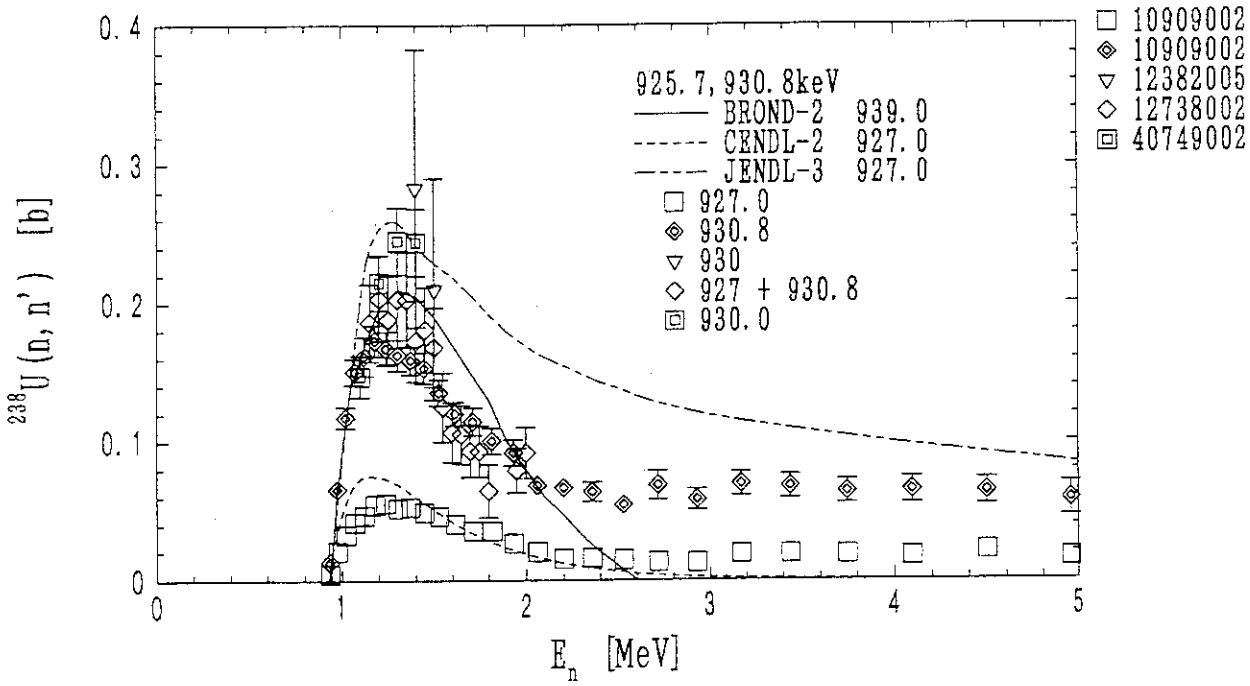


Fig. 18 Inelastic scattering cross section to 925.7 and 930.8 keV level.

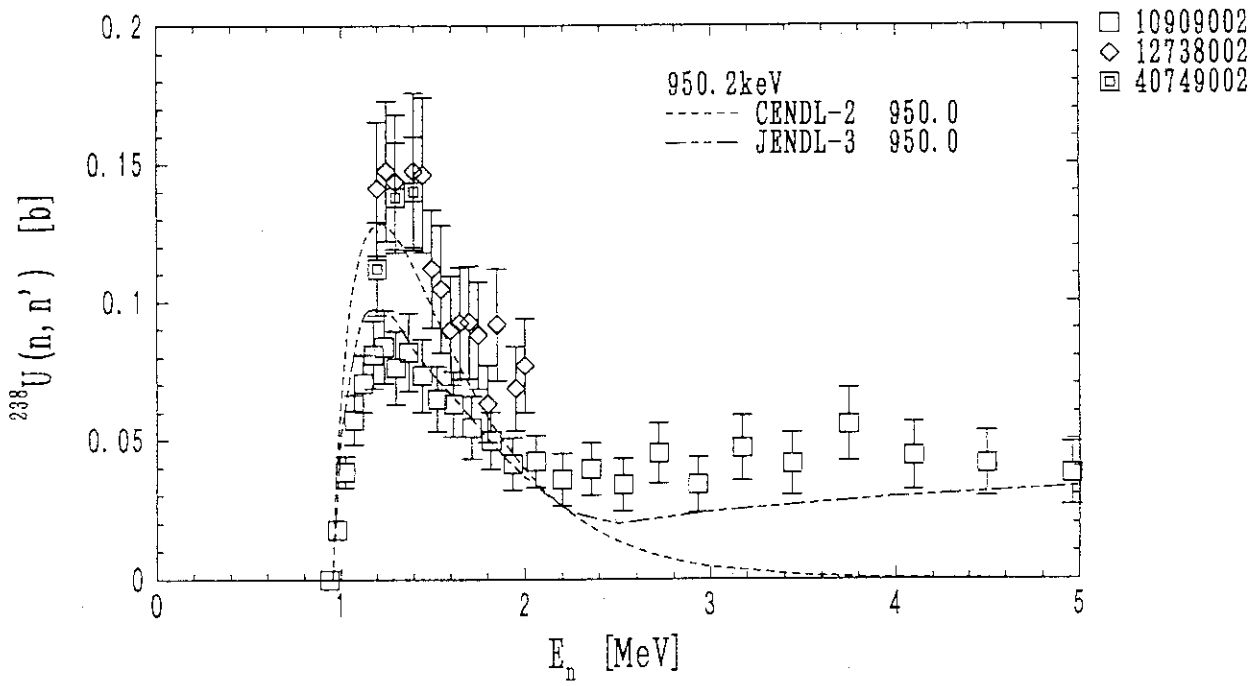


Fig. 19 Inelastic scattering cross section to 950.2 keV level.

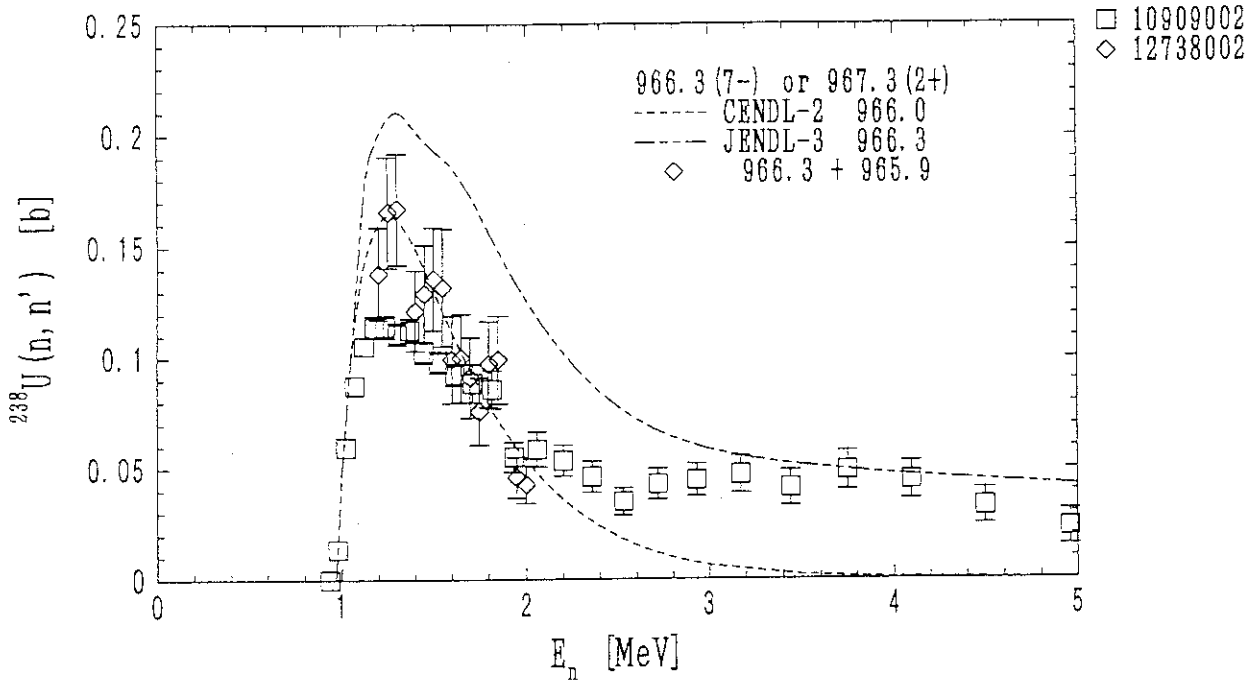


Fig. 20 Inelastic scattering cross section to 966.3 and 967.3 keV levels. In Nuclear Data Sheets 38, 277(1983), J^{π} of the 966.3 keV level was 2^{+}. However, in the Nuclear Data Sheets 50, 601(1988), the adopted J^{π} of the 966.3 keV level is 7^{-} and the energy of the 2^{+} level is changed into 967.3 keV. These experimental data and the evaluations correspond possibly to 967.3(2^{+}) level.

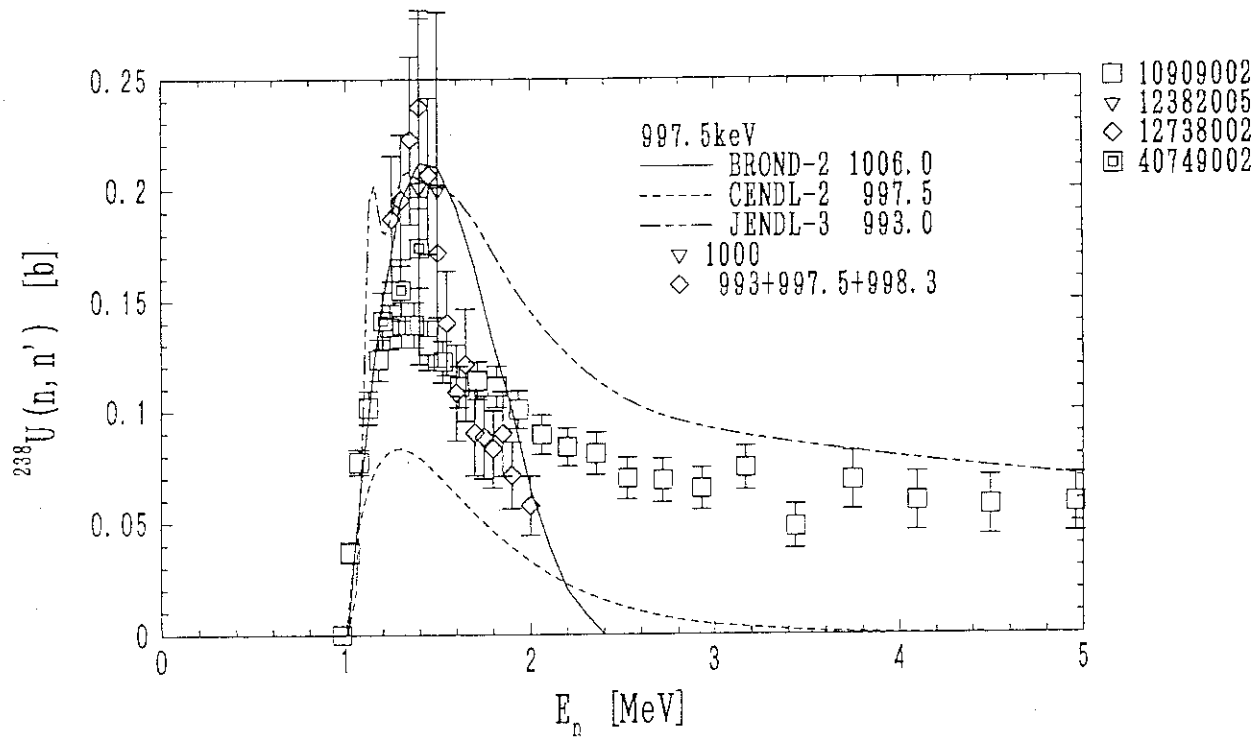


Fig. 21 Inelastic scattering cross section to 997.5 keV level.

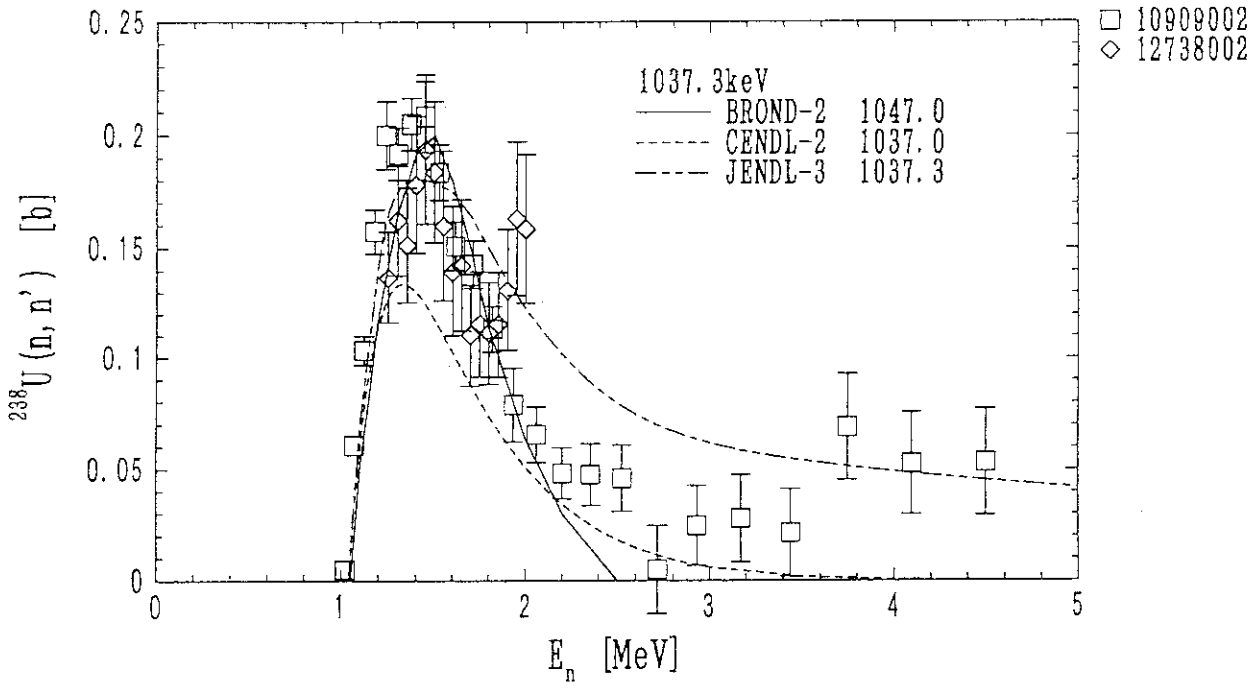


Fig. 22 Inelastic scattering cross section to 1037.3 keV level.

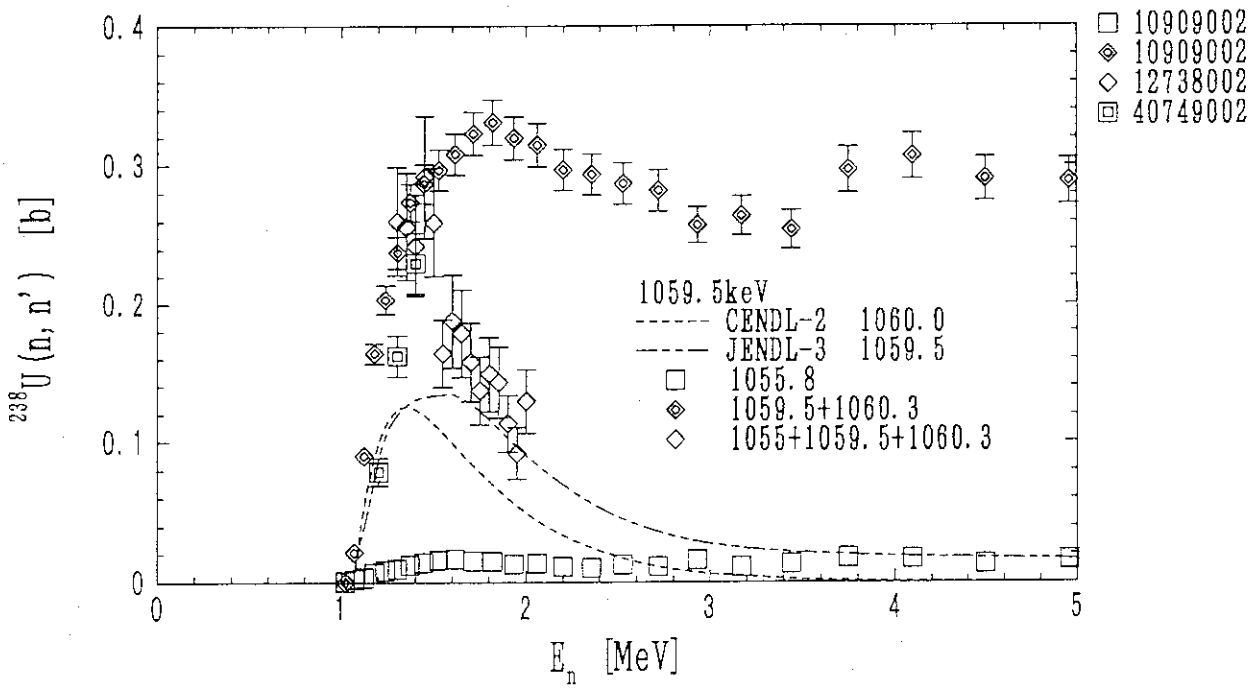


Fig. 23 Inelastic scattering cross section to 1059.5 keV level.

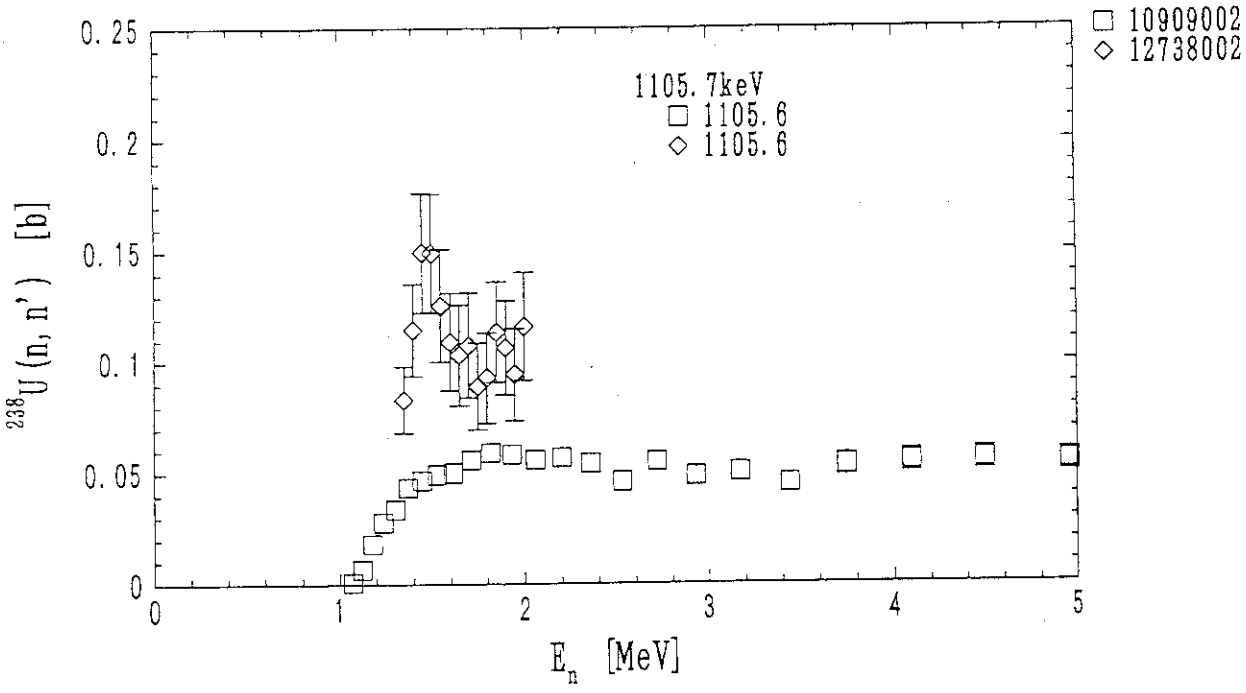


Fig. 24 Inelastic scattering cross section to 1105.7 keV level.

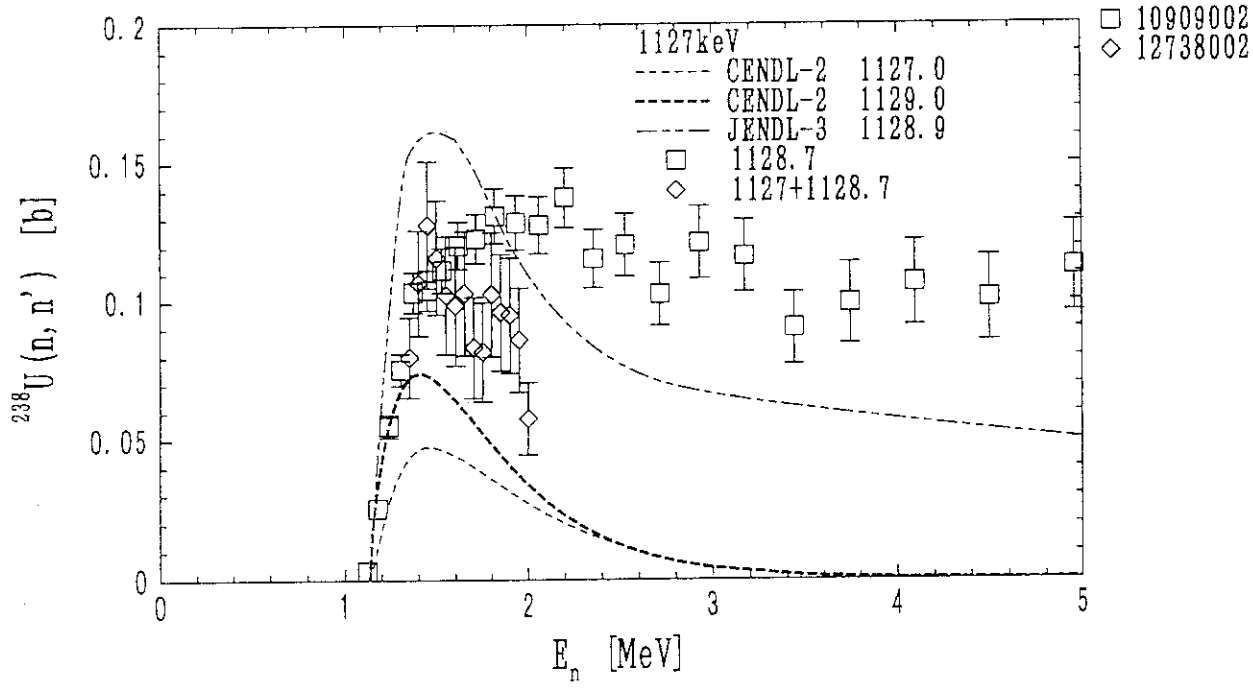


Fig. 25 Inelastic scattering cross section to 1127 keV level.

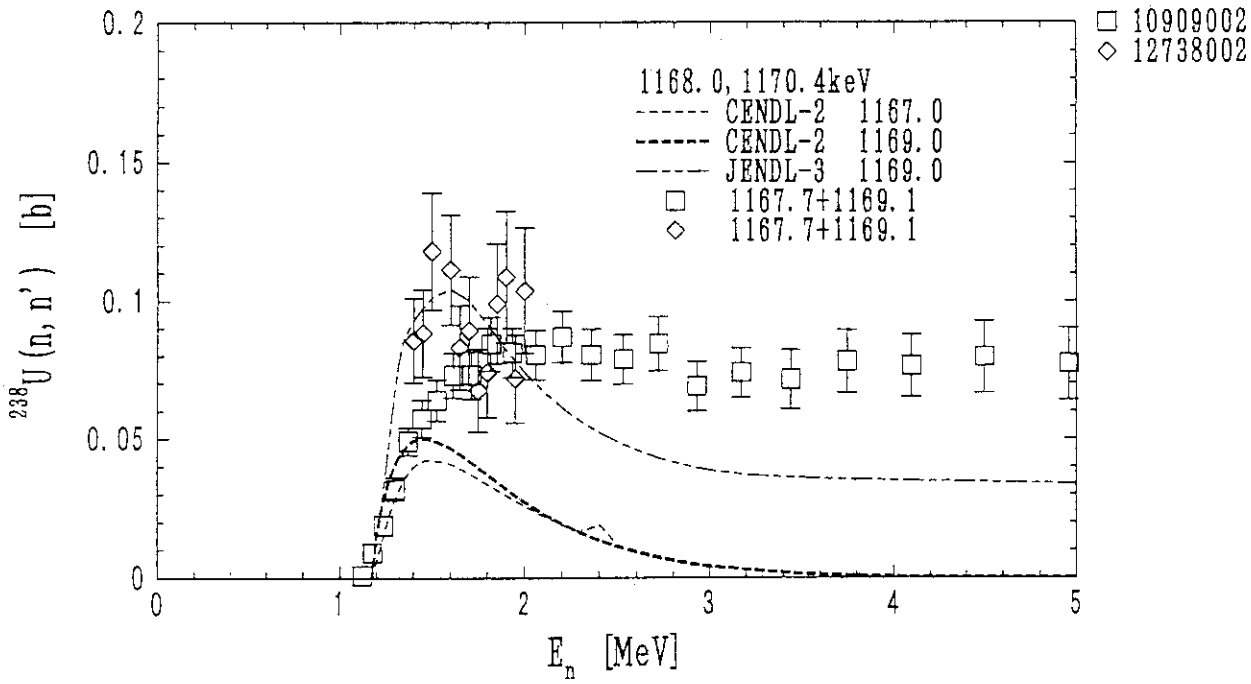


Fig. 26 Inelastic scattering cross section to 1168.0 and 1170.4 keV levels.

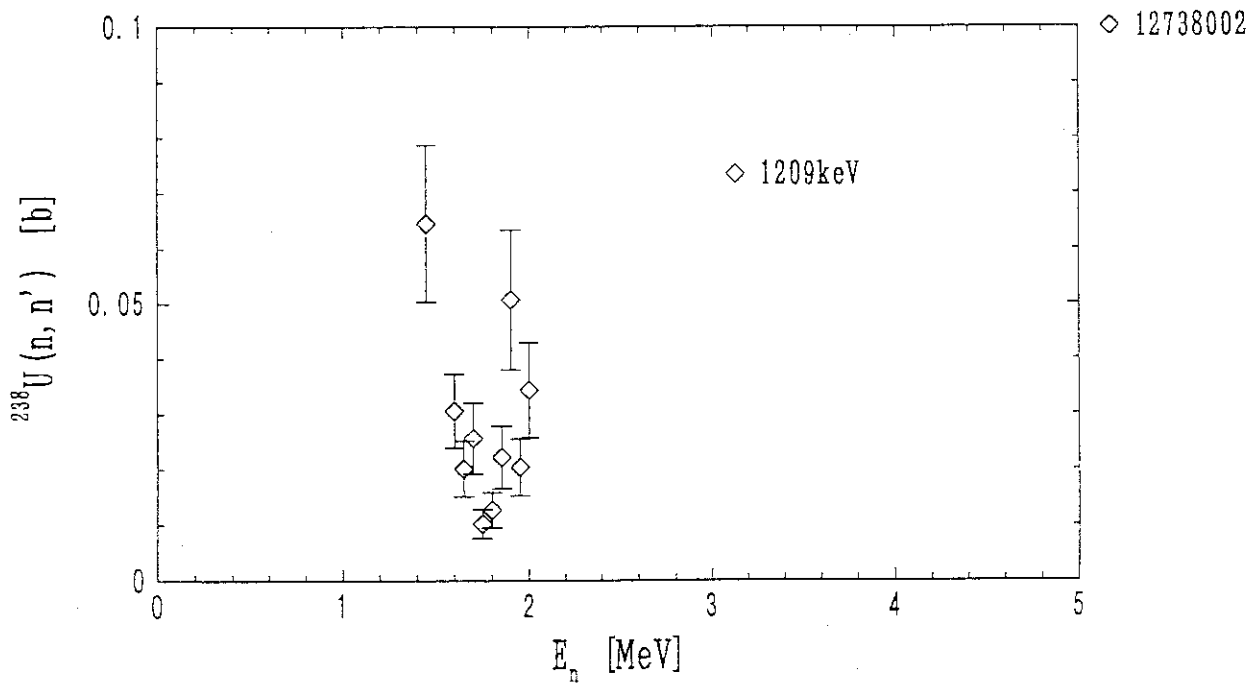


Fig. 27 Inelastic scattering cross section to 1209 keV level. This level is not found in Nuclear Data Sheets.

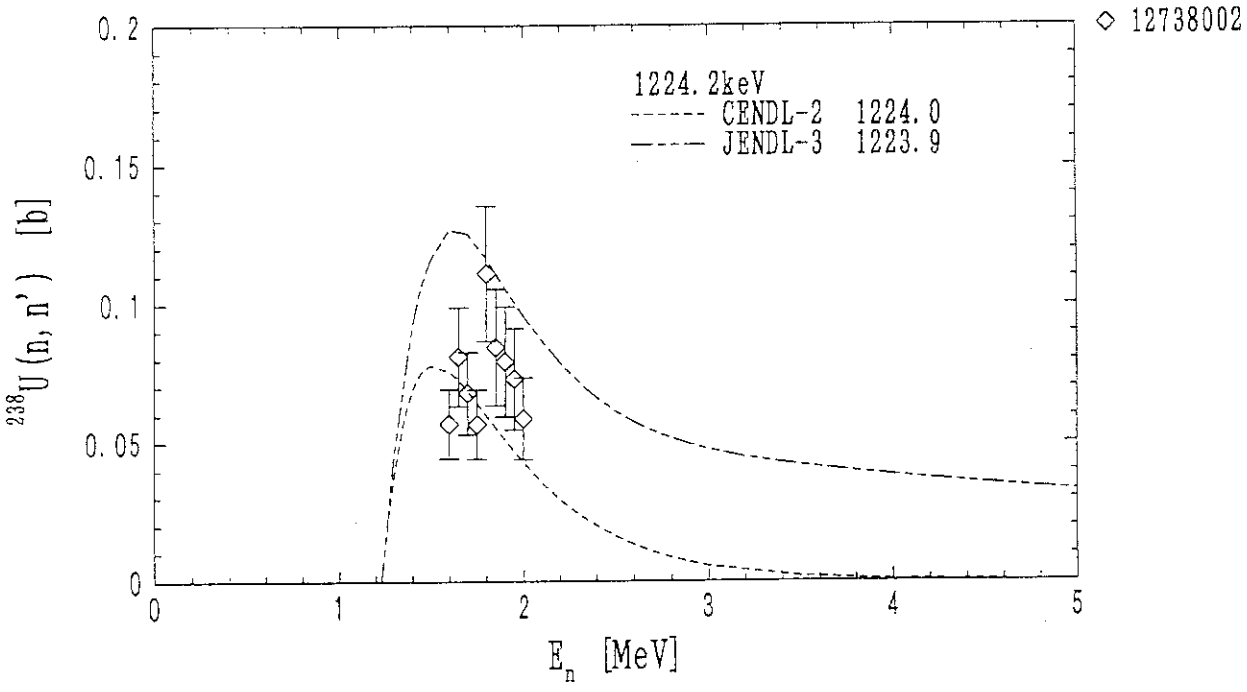


Fig. 28 Inelastic scattering cross section to 1224.2 keV level.

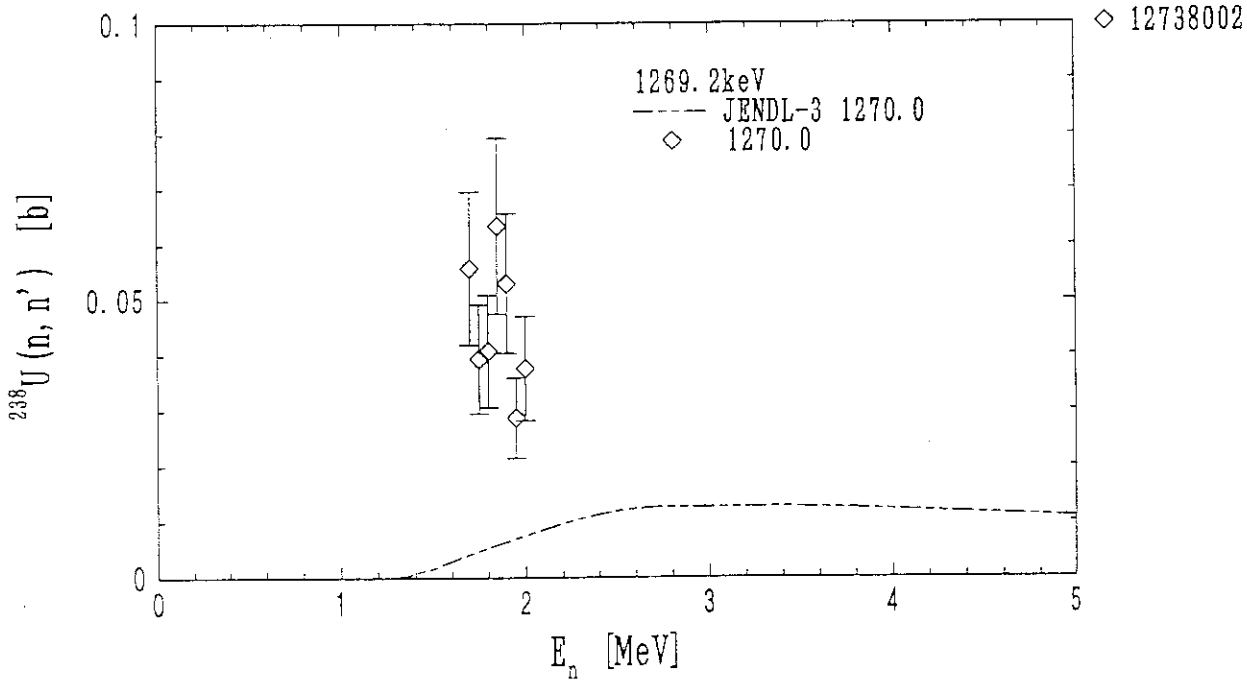


Fig. 29 Inelastic scattering cross section to 1269.2 keV level.

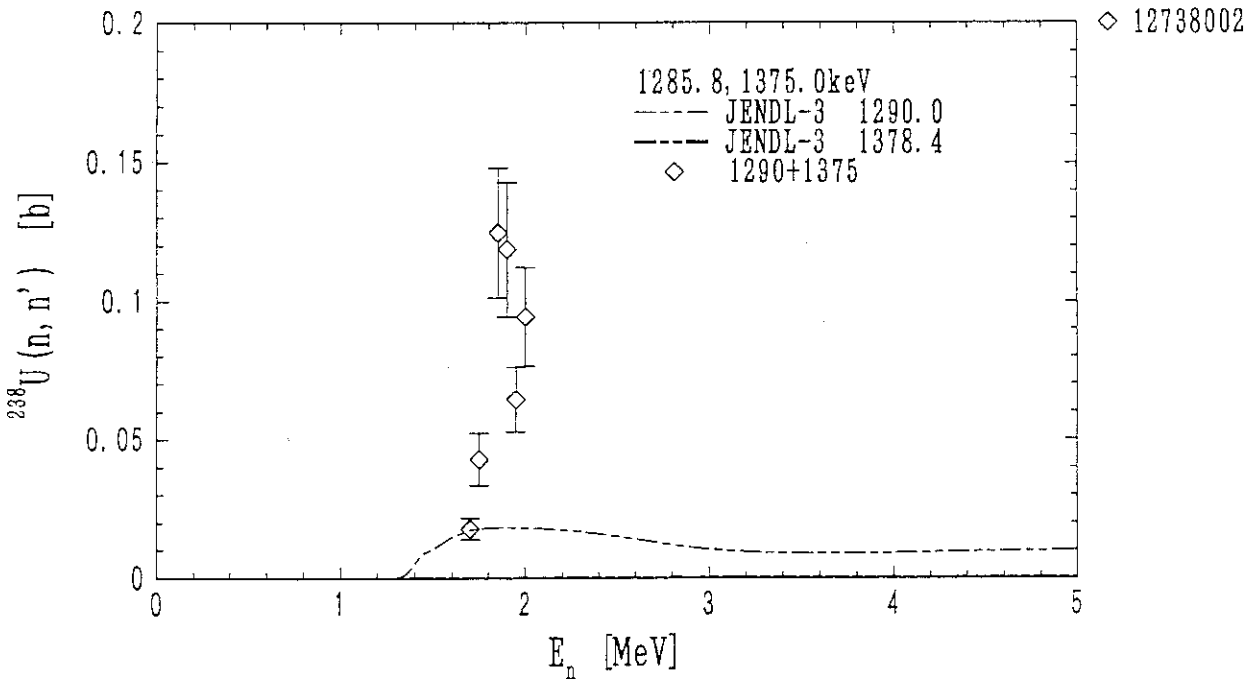


Fig. 30 Inelastic scattering cross section to 1285.8 and 1375.0 keV levels.

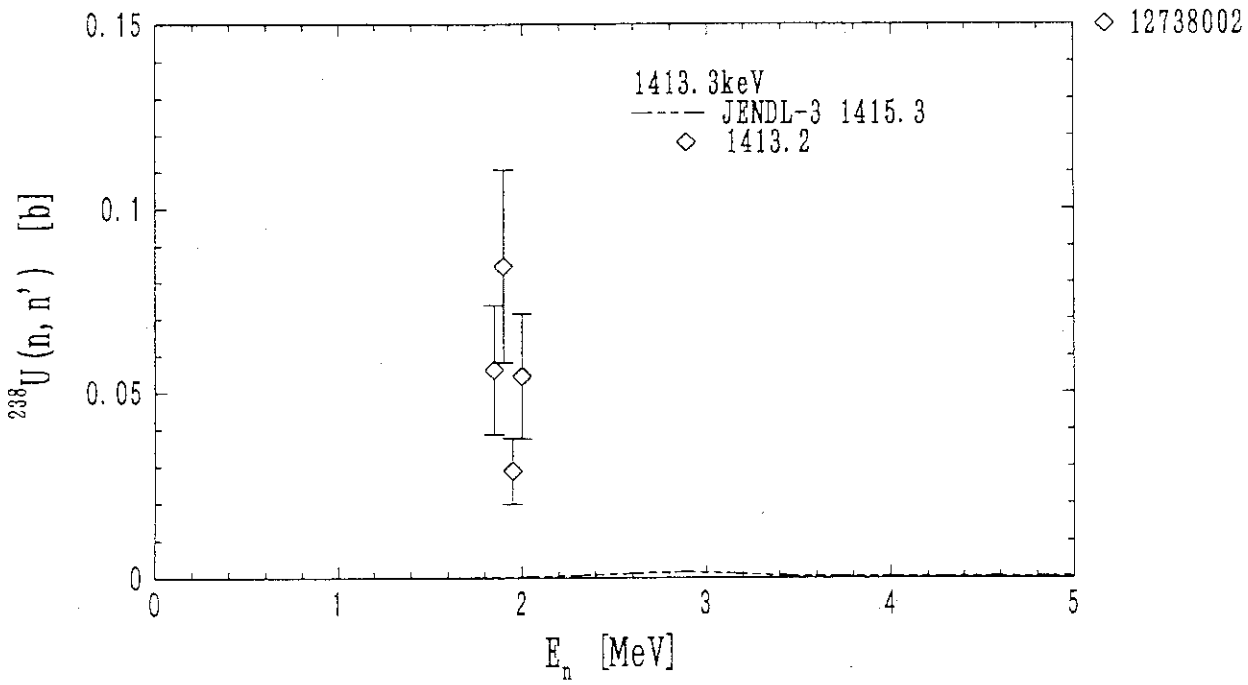


Fig. 31 Inelastic scattering cross section to 1413.3 keV level.

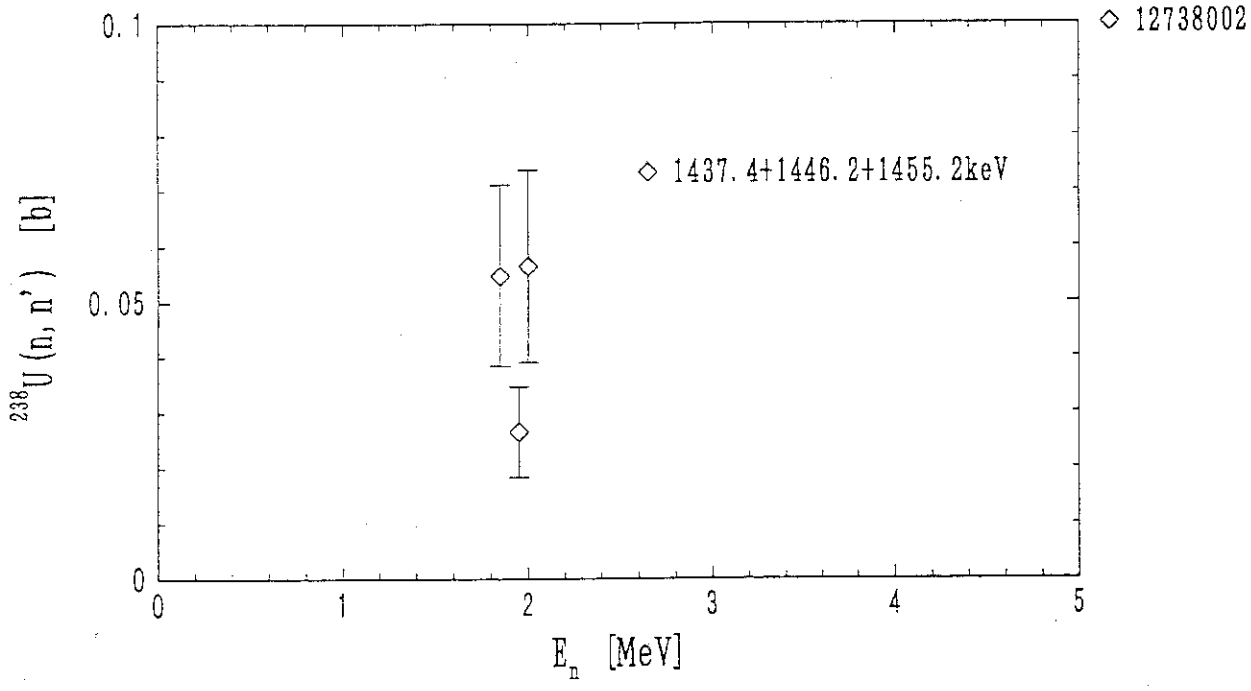


Fig. 32 Inelastic scattering cross section to 1437.4, 1446.2 and 1455.2 keV levels. These levels are not found in Nuclear Data Sheets.

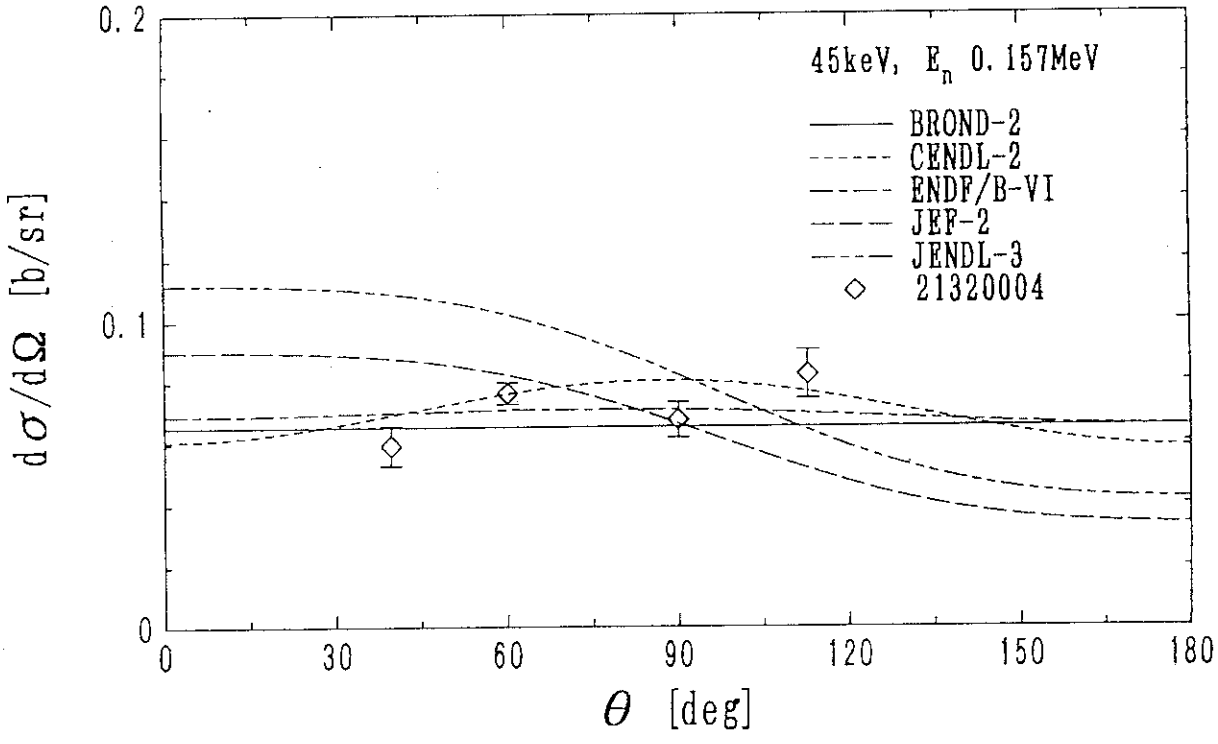
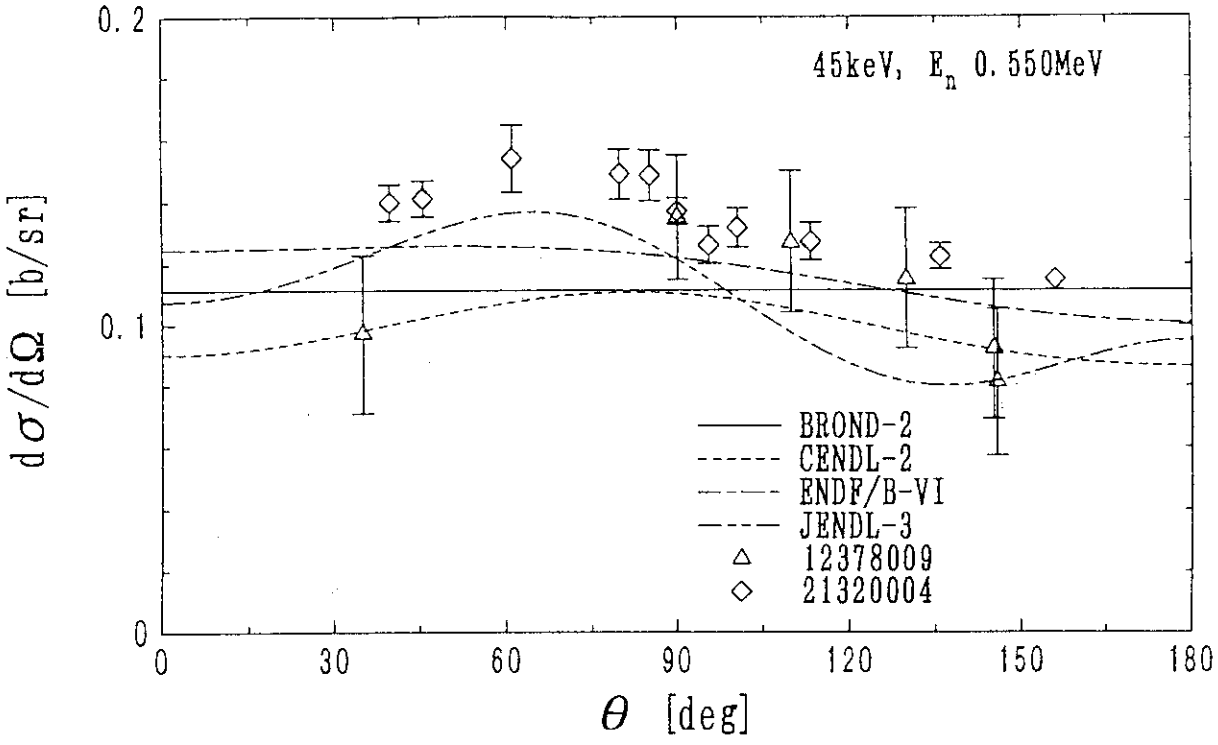


Fig. 33 Differential inelastic scattering cross section to the first excited level at E_n = 0.157 MeV.



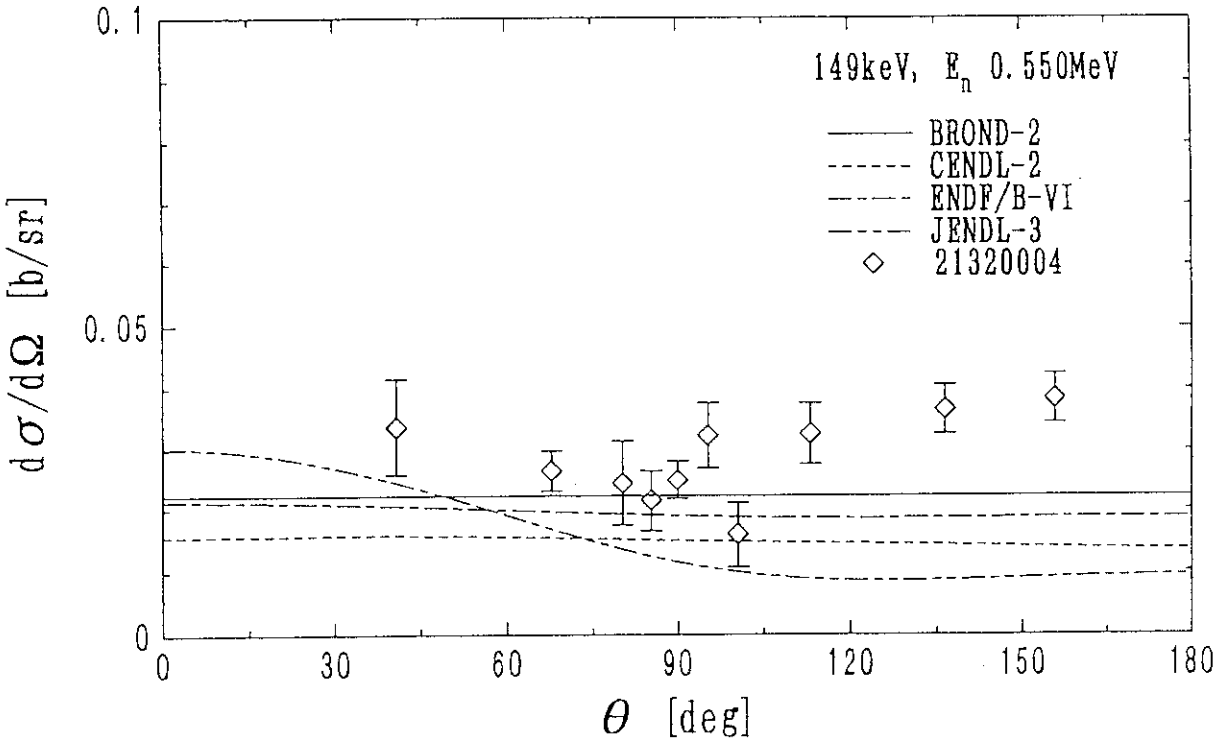
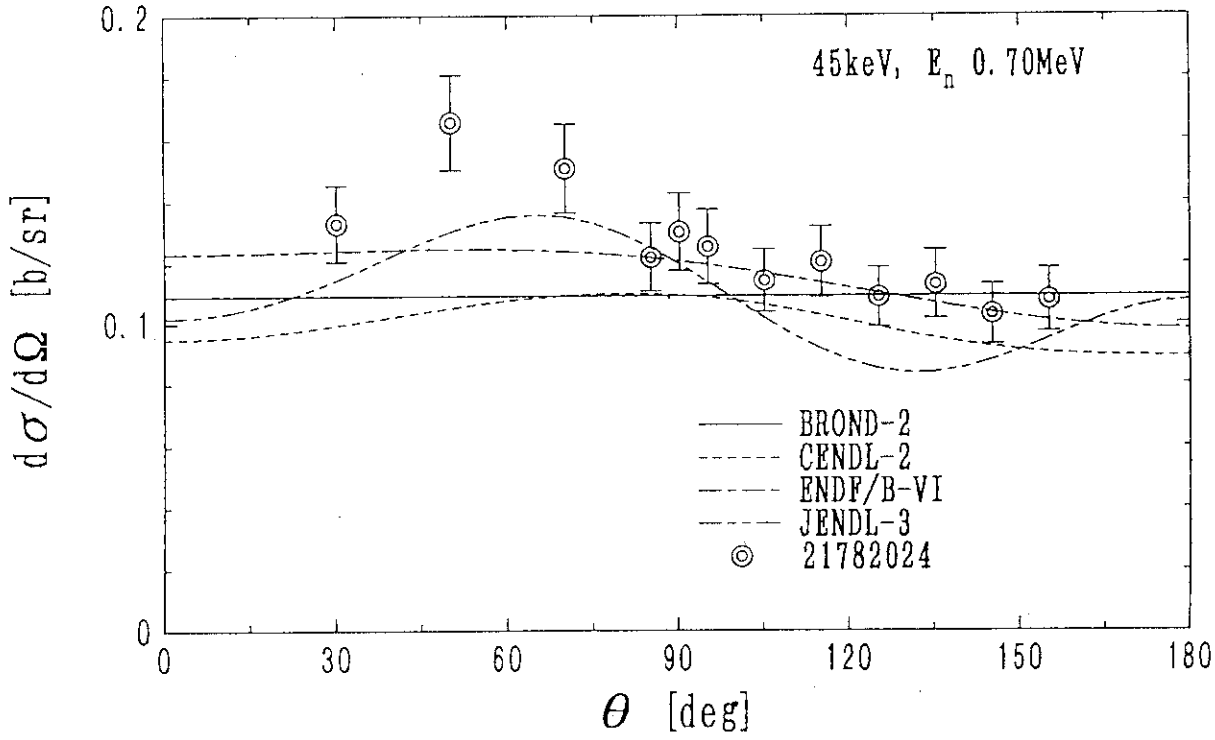


Fig. 34 Differential inelastic scattering cross section to the first and the second excited levels at E_n = 0.550 MeV.



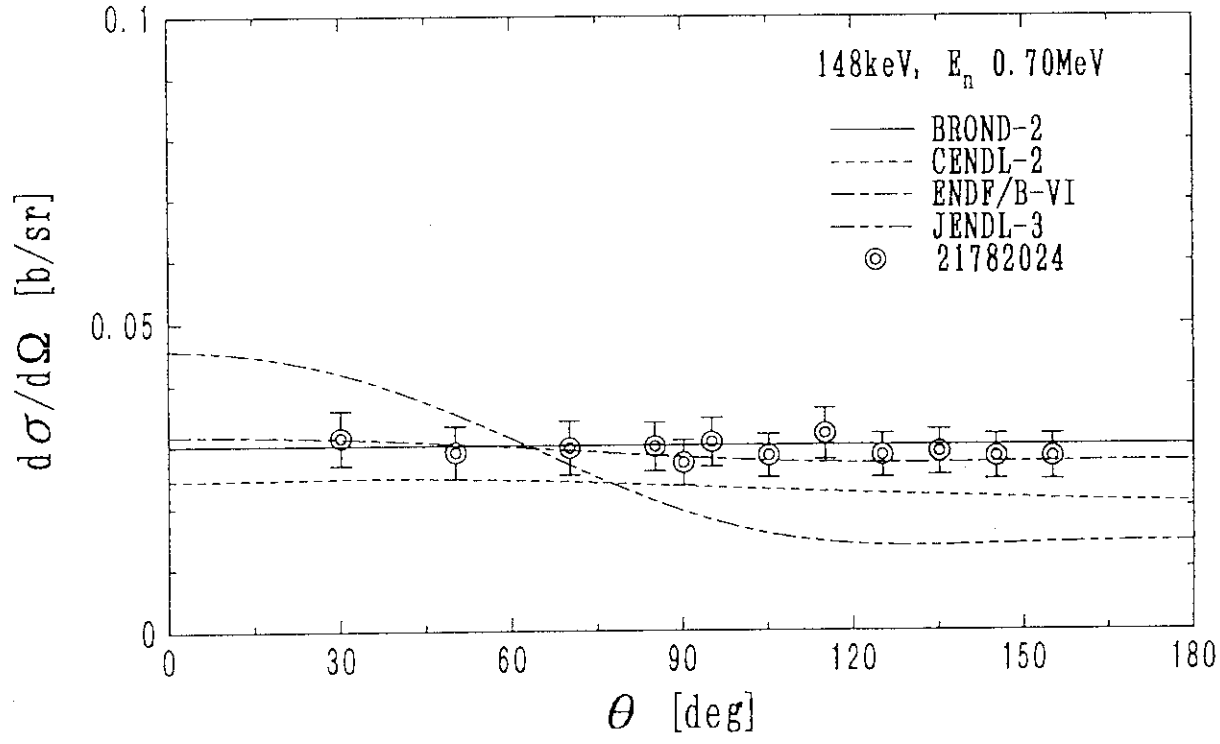
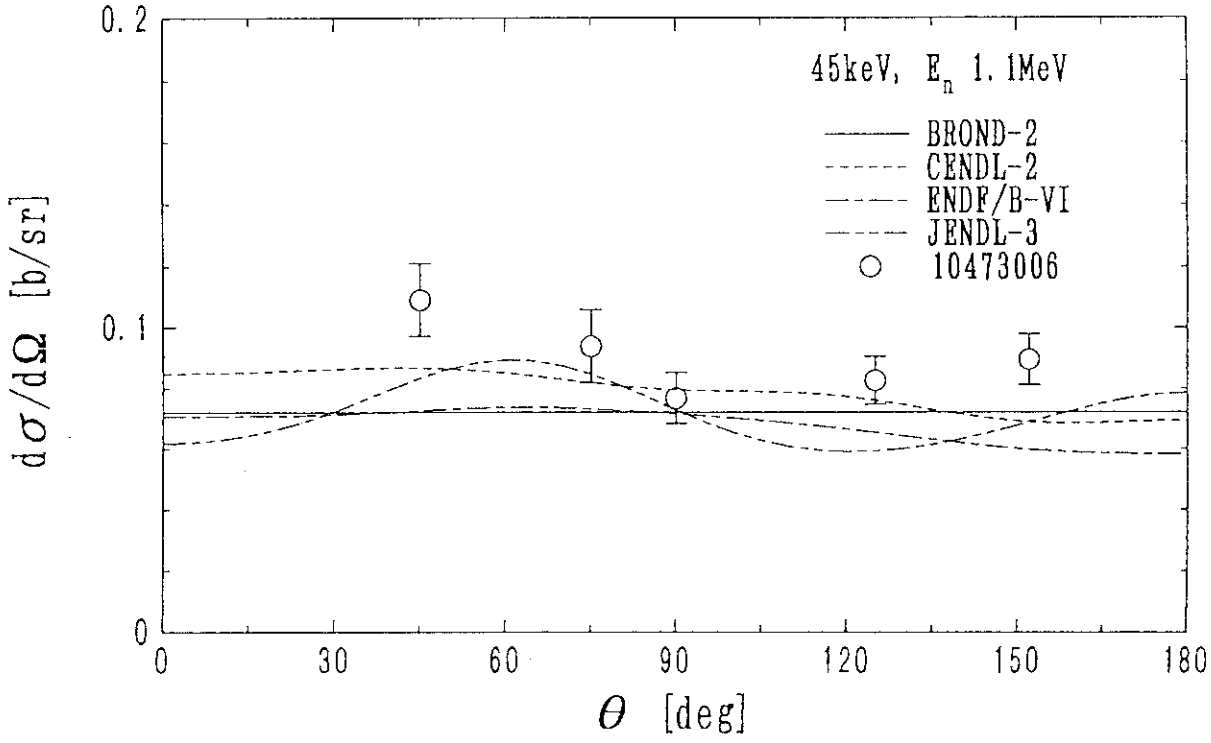


Fig. 35 Differential inelastic scattering cross section to the first and the second excited levels at E_n = 0.70 MeV.



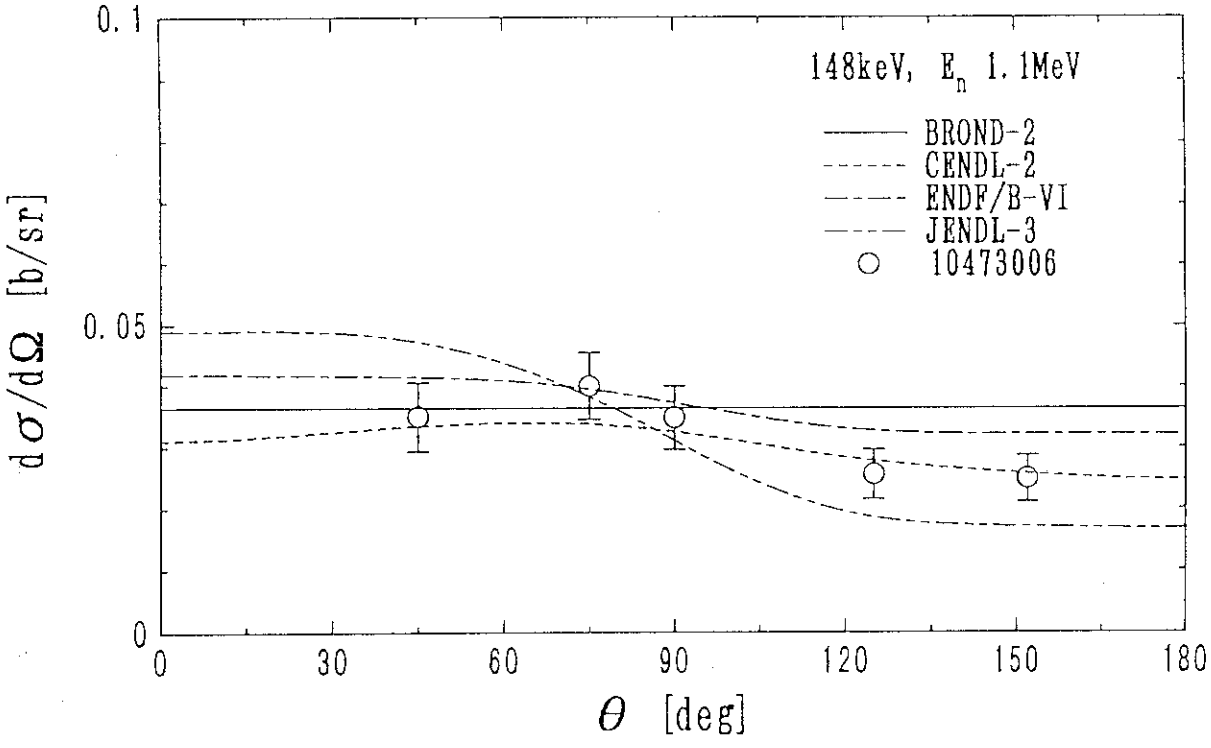


Fig. 36 Differential inelastic scattering cross section to the first and the second excited levels at E_n = 1.1 MeV.

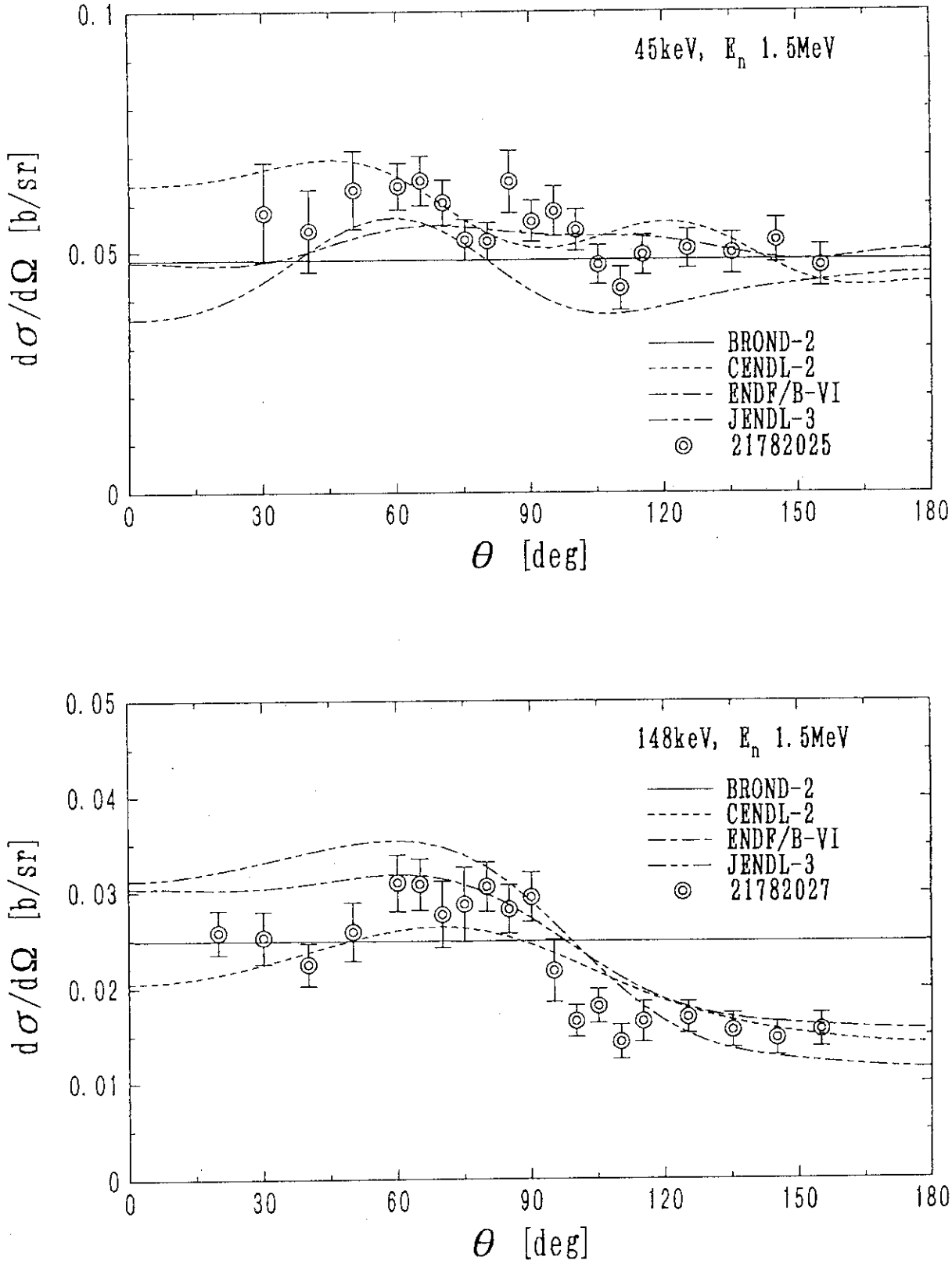
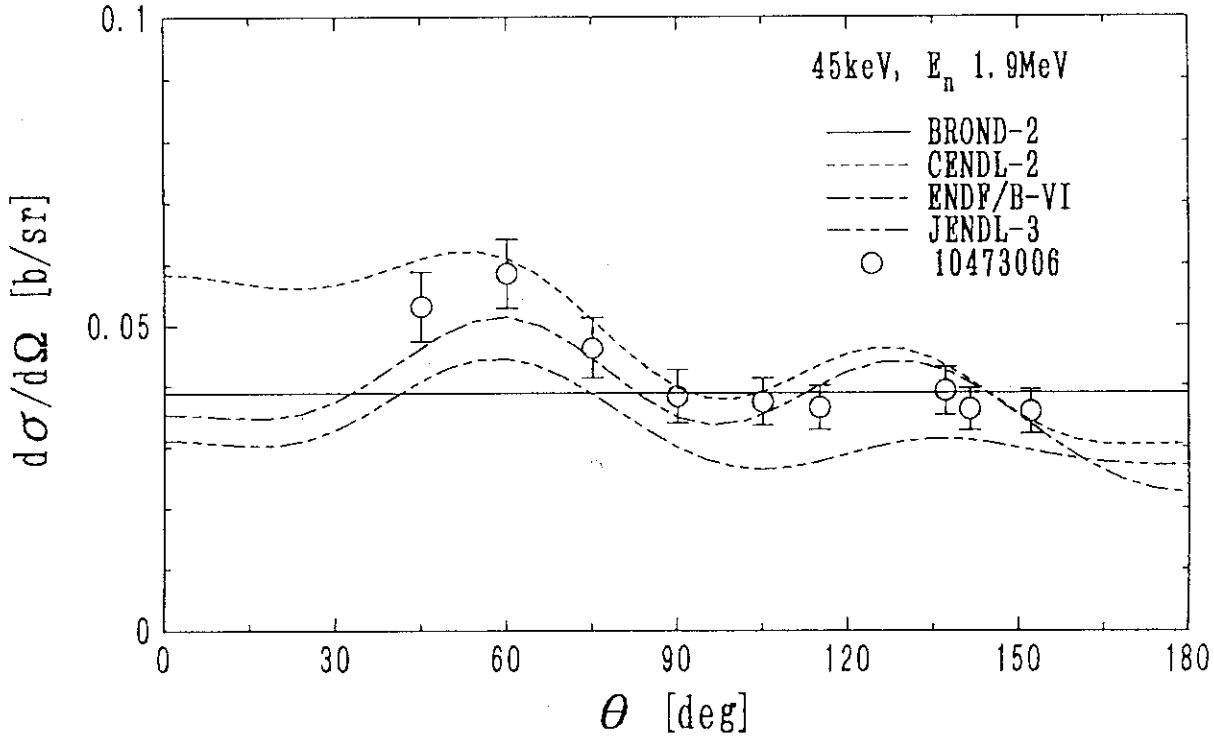


Fig. 37 Differential inelastic scattering cross section to the first and the second excited levels at E_n = 1.5 MeV.



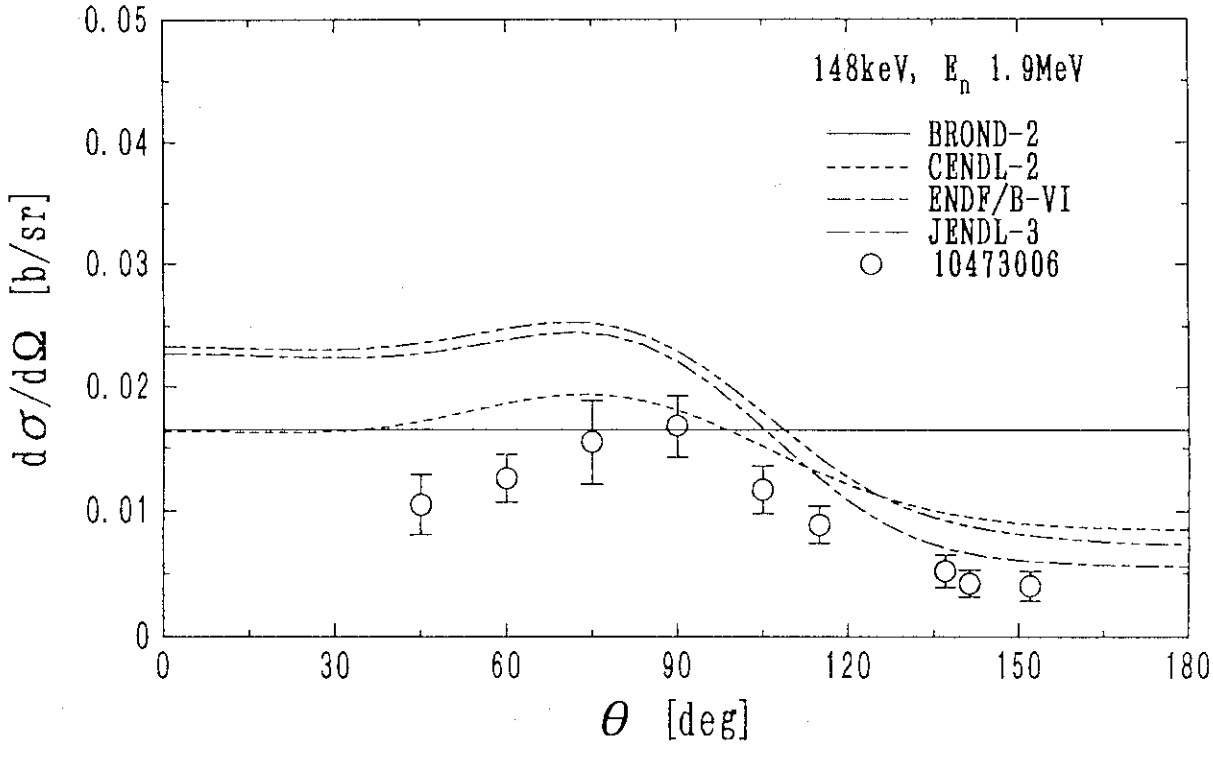
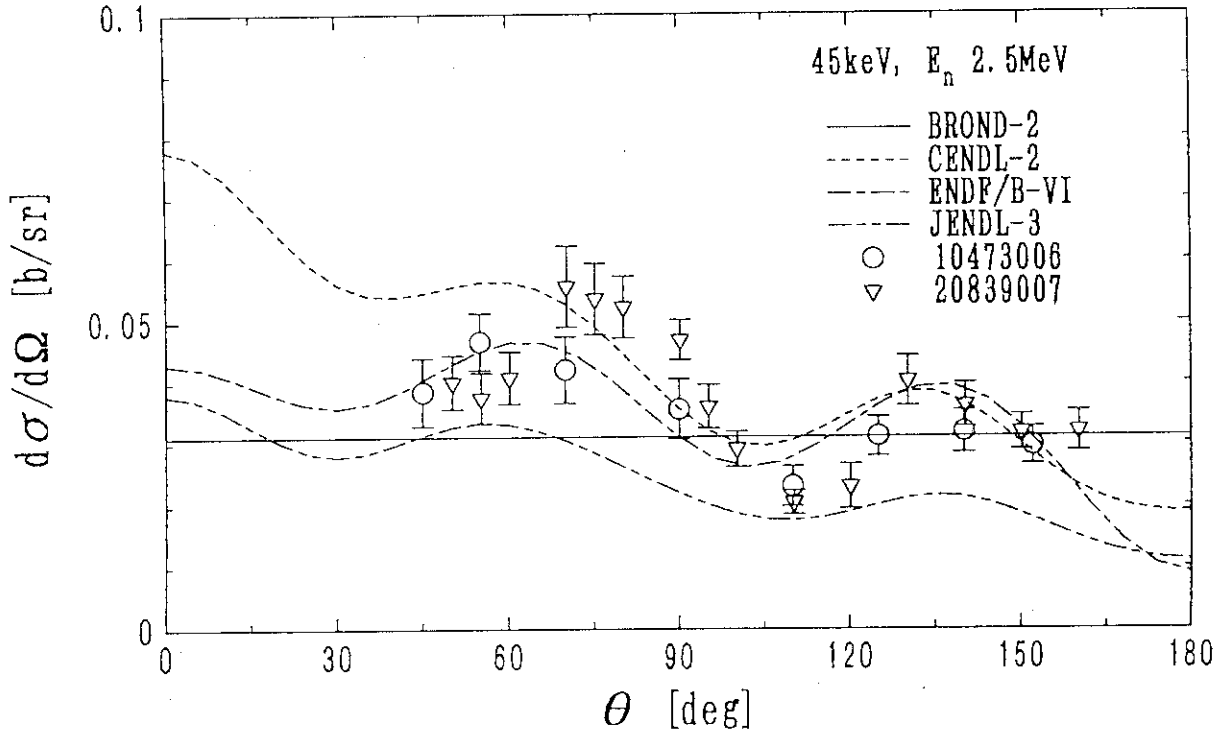


Fig. 38 Differential inelastic scattering cross section to the first and the second excited levels at E_n = 1.9 MeV.



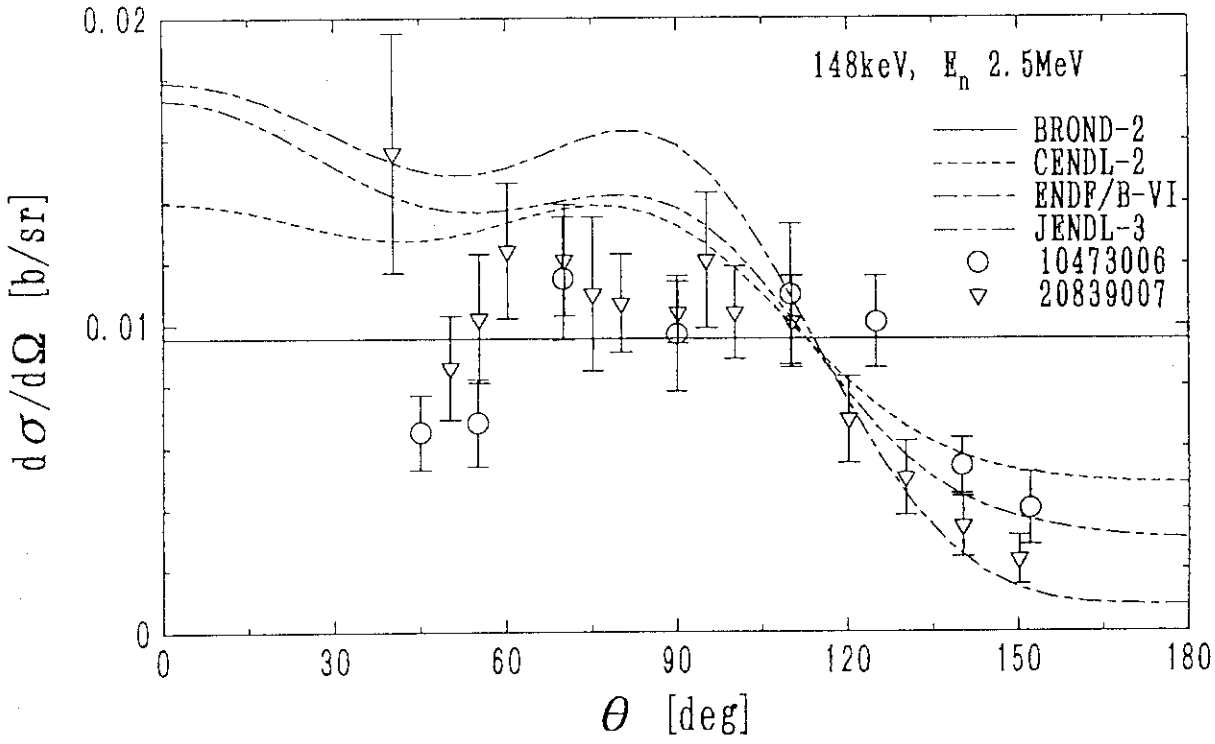


Fig. 39 Differential inelastic scattering cross section to the first and the second excited levels at E_n = 2.5 MeV.

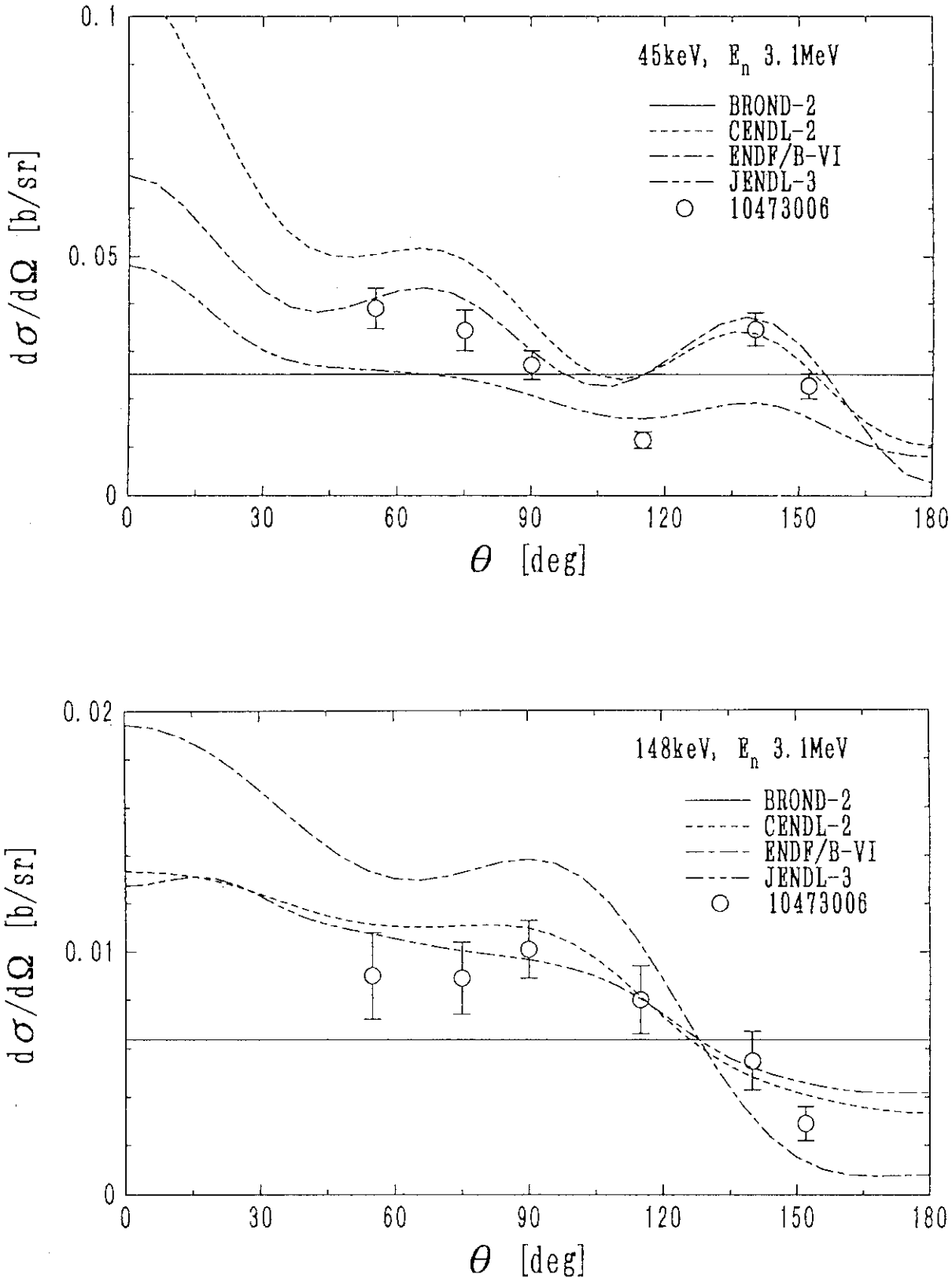
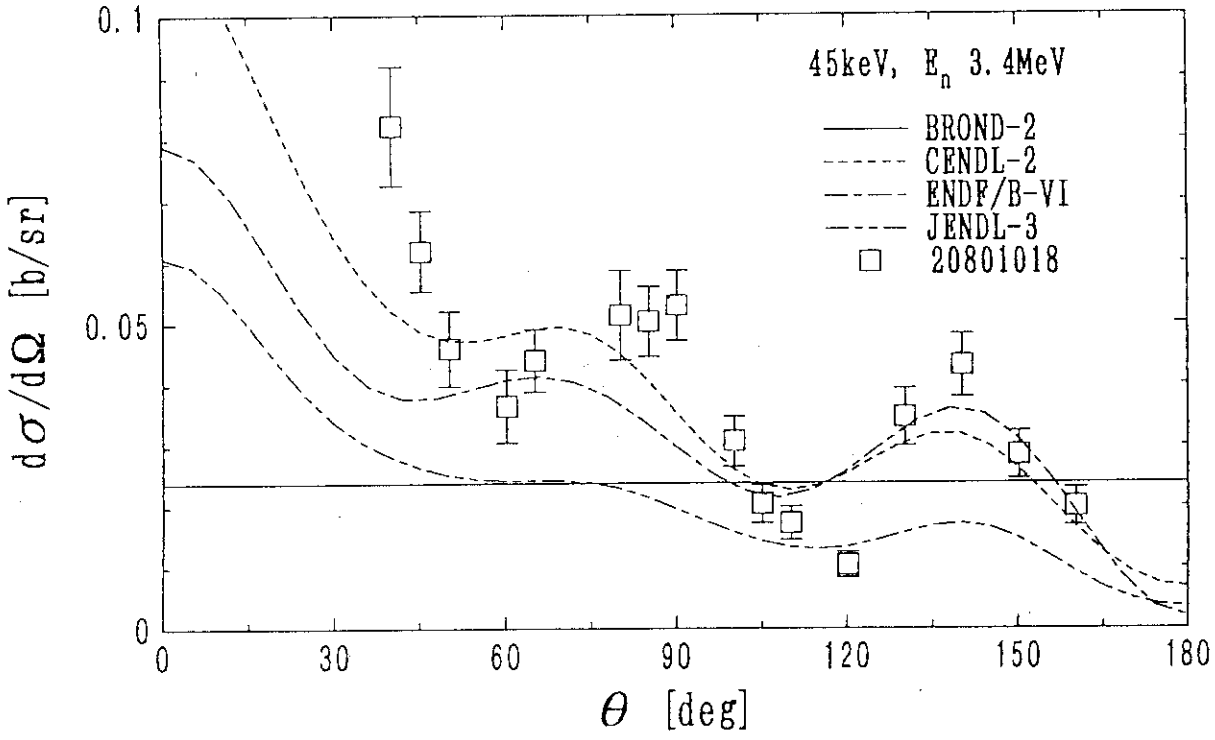


Fig. 40 Differential inelastic scattering cross section to the first and the second excited levels at E_n = 3.1 MeV.



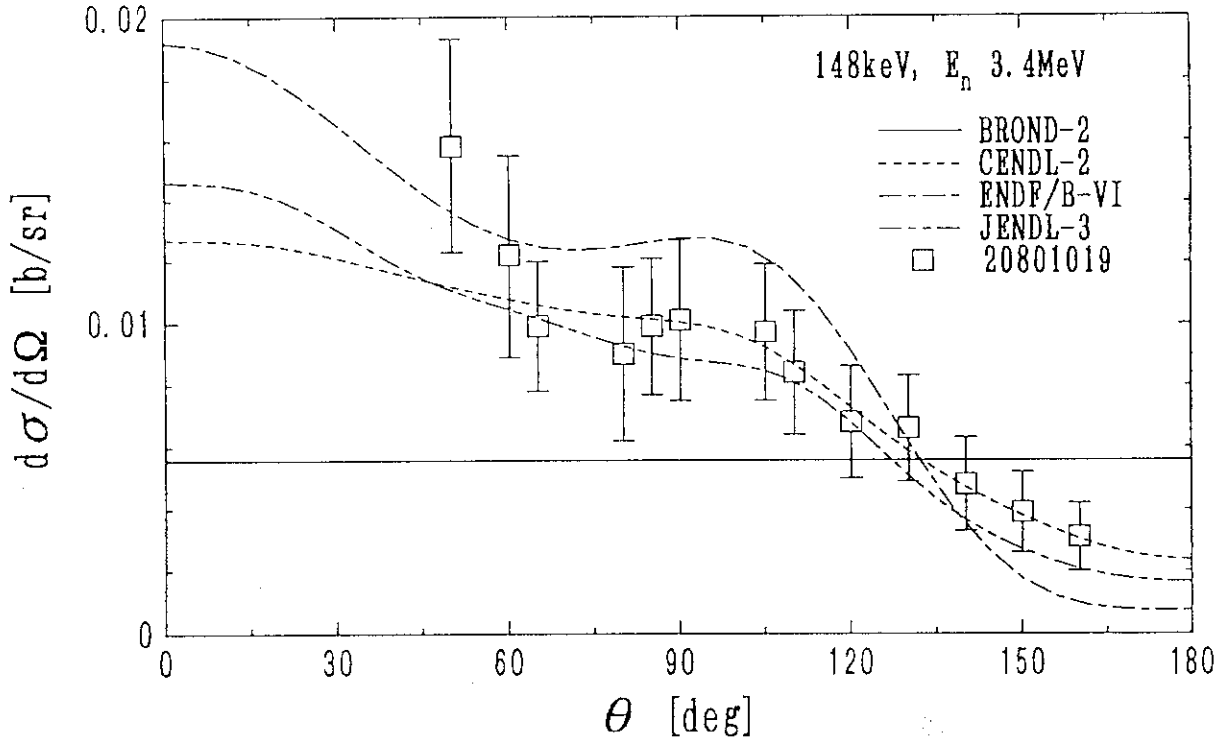


Fig. 41 Differential inelastic scattering cross section to the first and the second excited levels at E_n = 3.4 MeV.

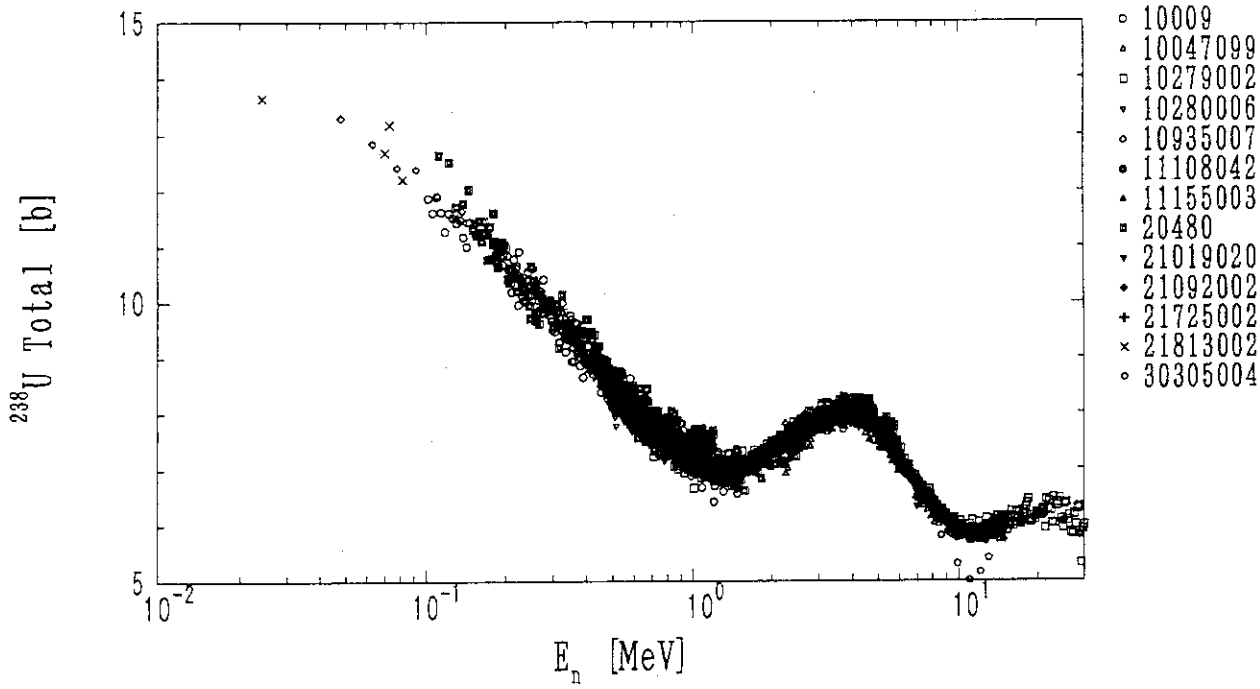


Fig. 42 ^{238}U total cross section.

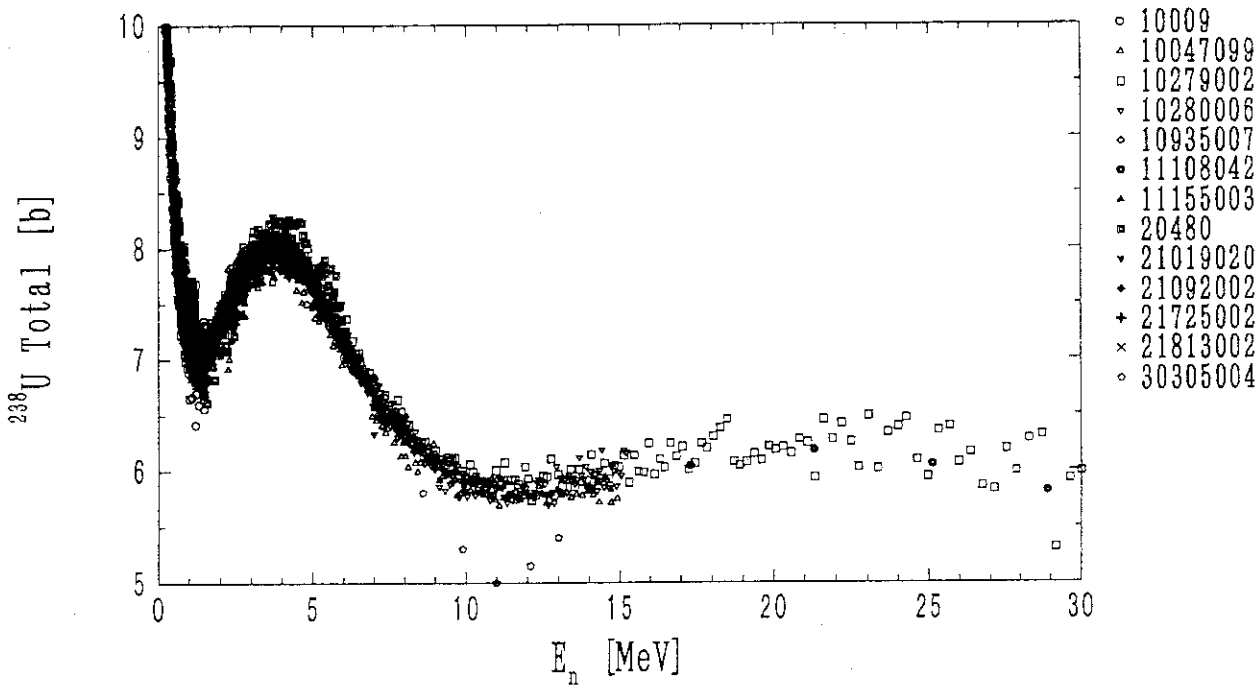


Fig. 43 ^{238}U total cross section.

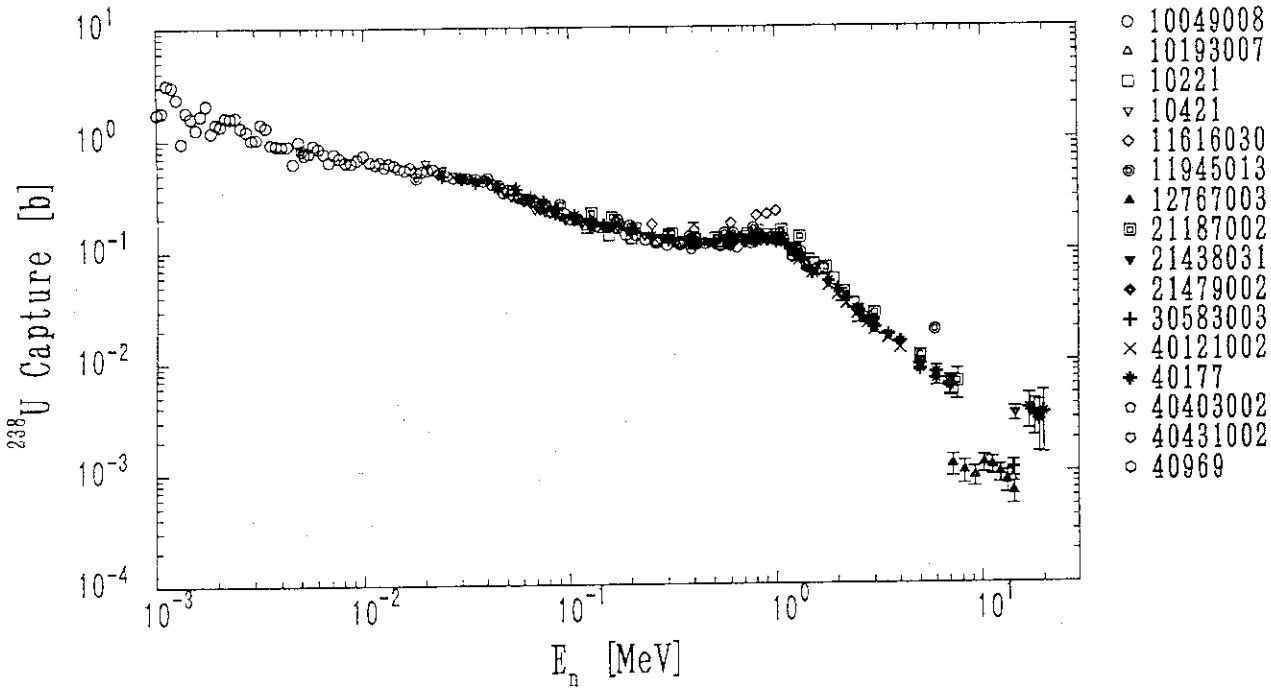


Fig. 44 ^{238}U capture cross section.

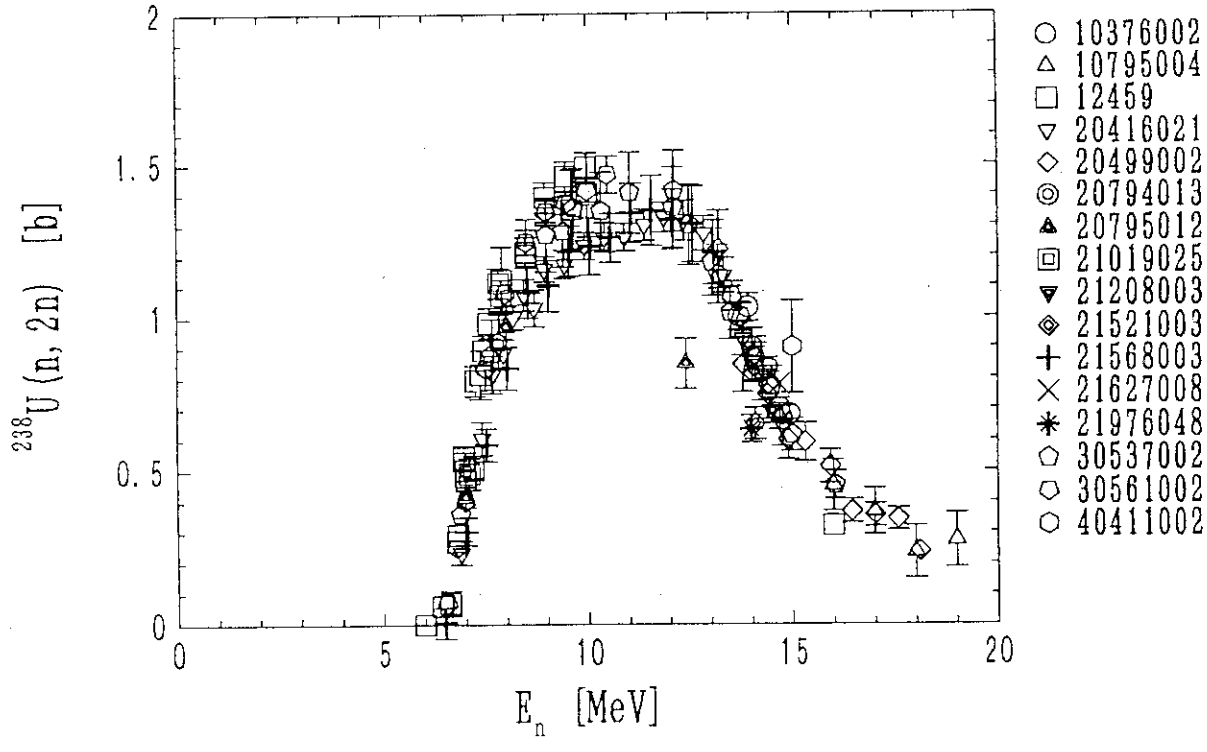


Fig. 45 ^{238}U(n,2n) reaction cross section.

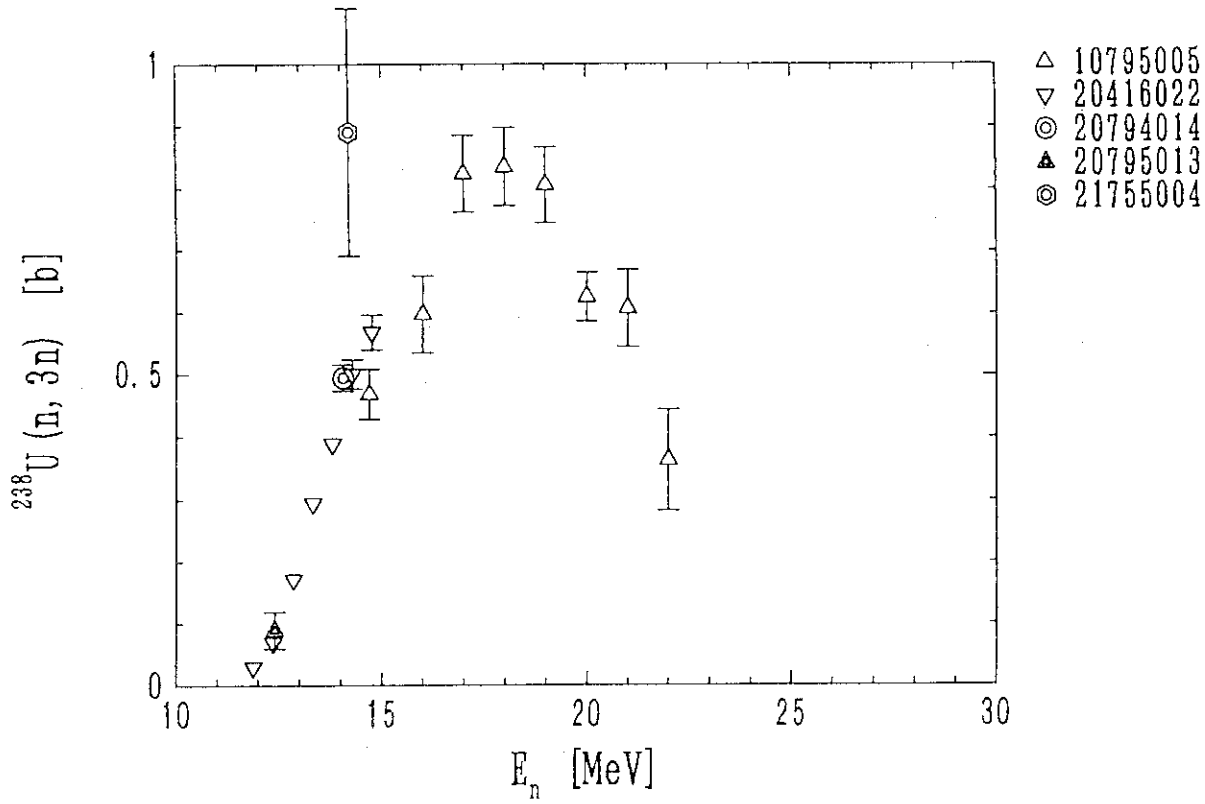


Fig. 46 ^{238}U(n,3n) reaction cross section.

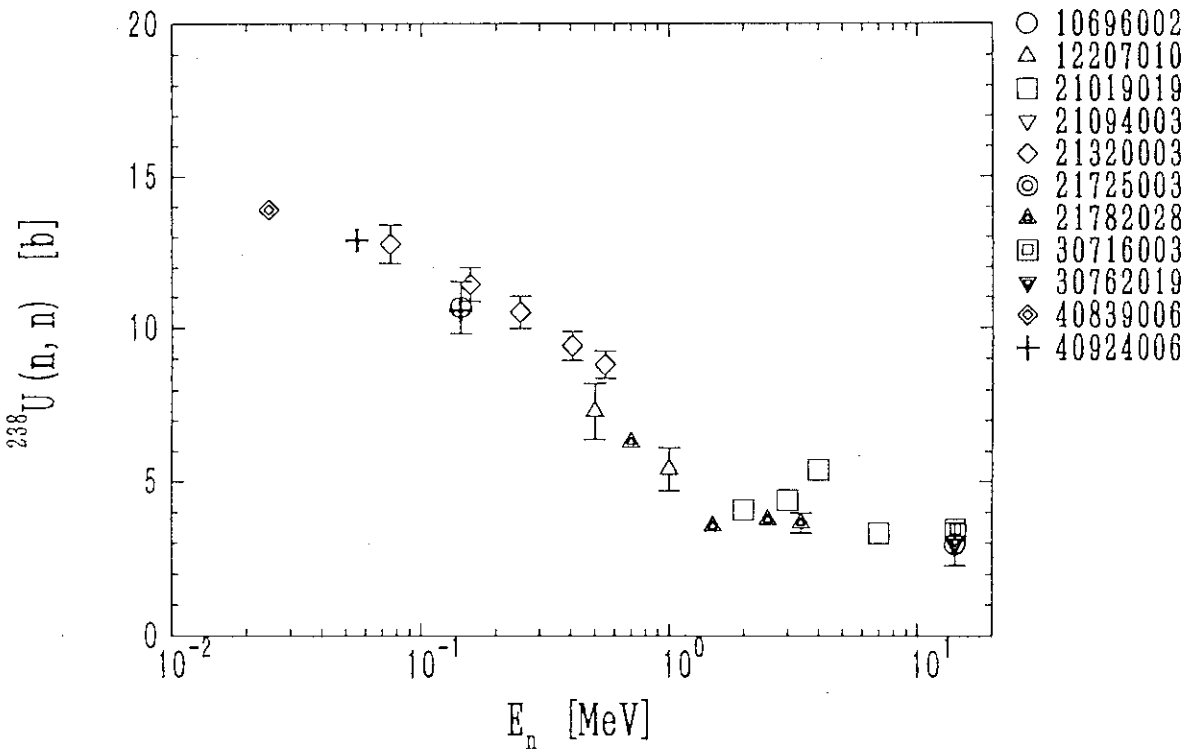


Fig. 47 ^{238}U total elastic scattering cross section.

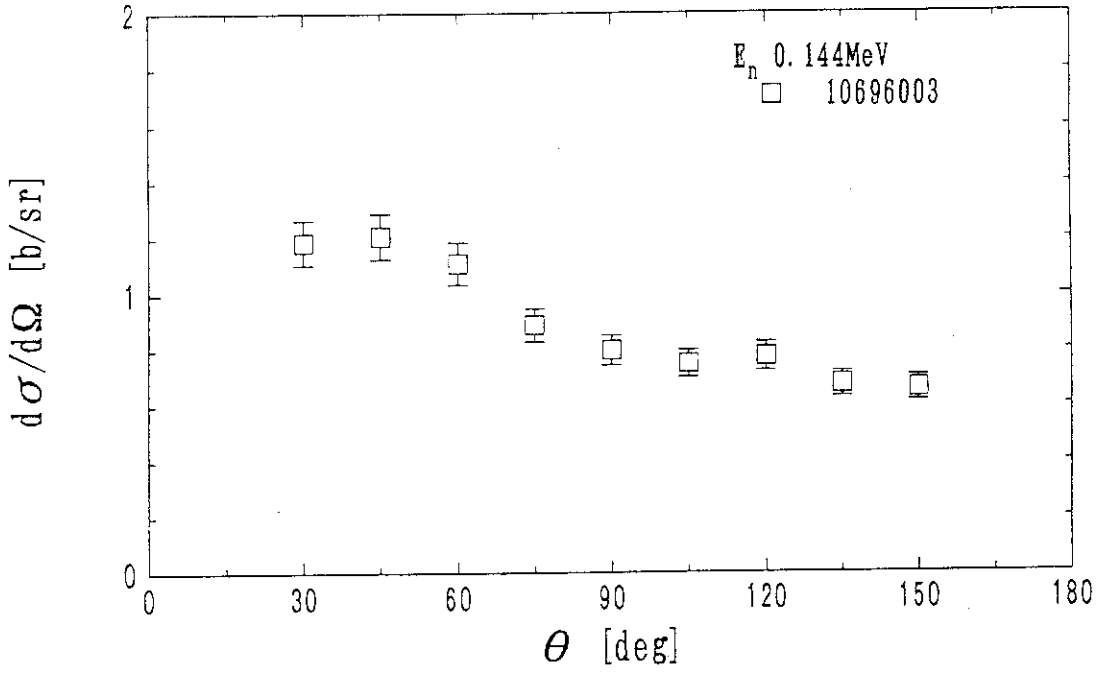


Fig. 48 Differential elastic scattering cross section at E_n = 0.144 MeV.

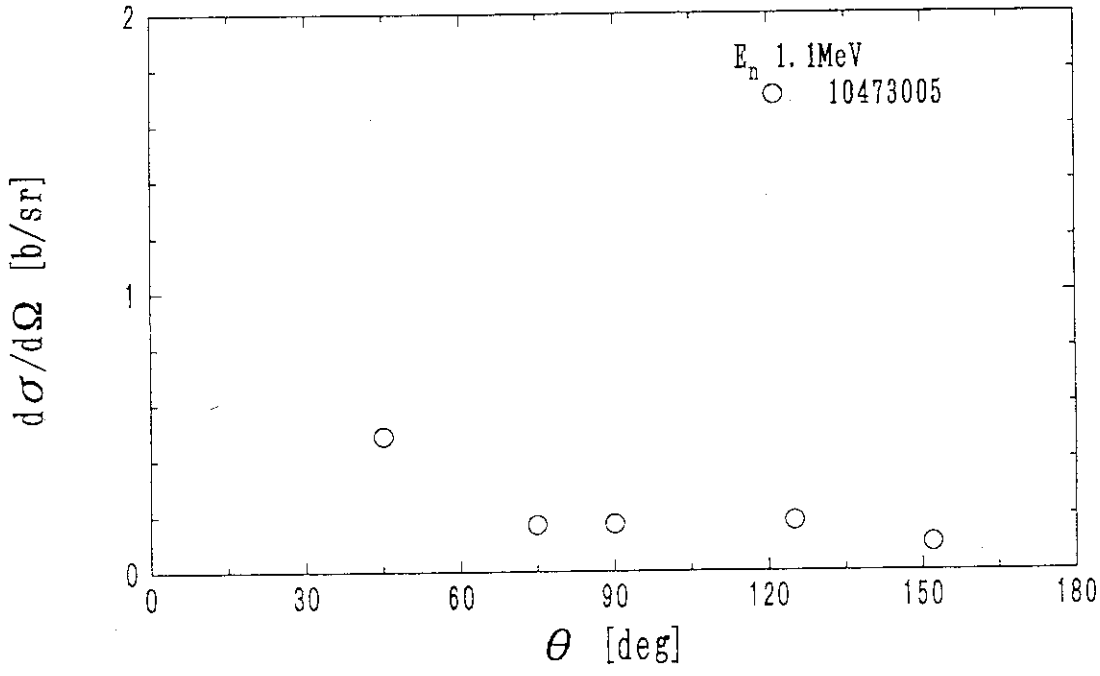


Fig. 49 Differential elastic scattering cross section at E_n = 1.1 MeV.

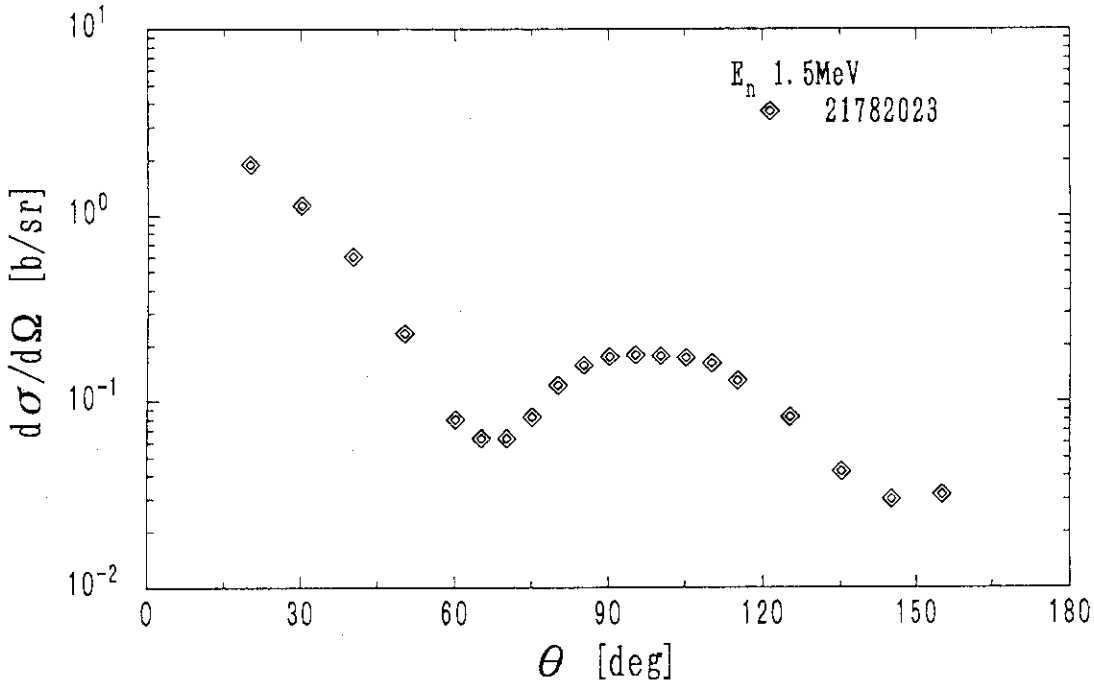


Fig. 50 Differential elastic scattering cross section at E_n = 1.5 MeV.

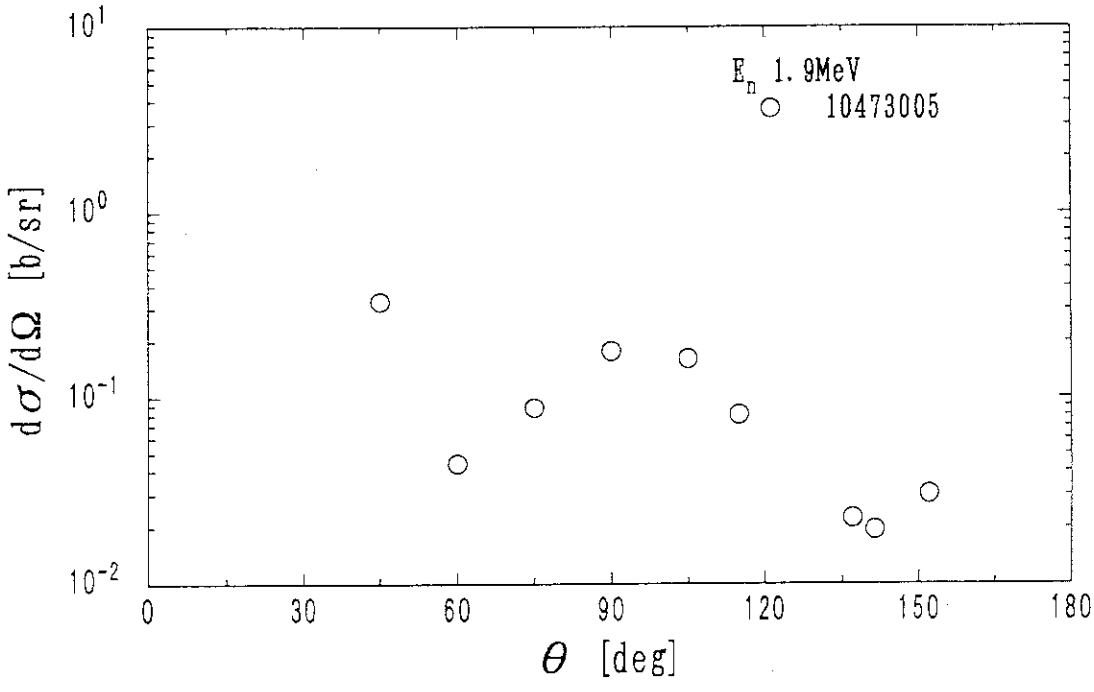


Fig. 51 Differential elastic scattering cross section at E_n = 1.9 MeV.

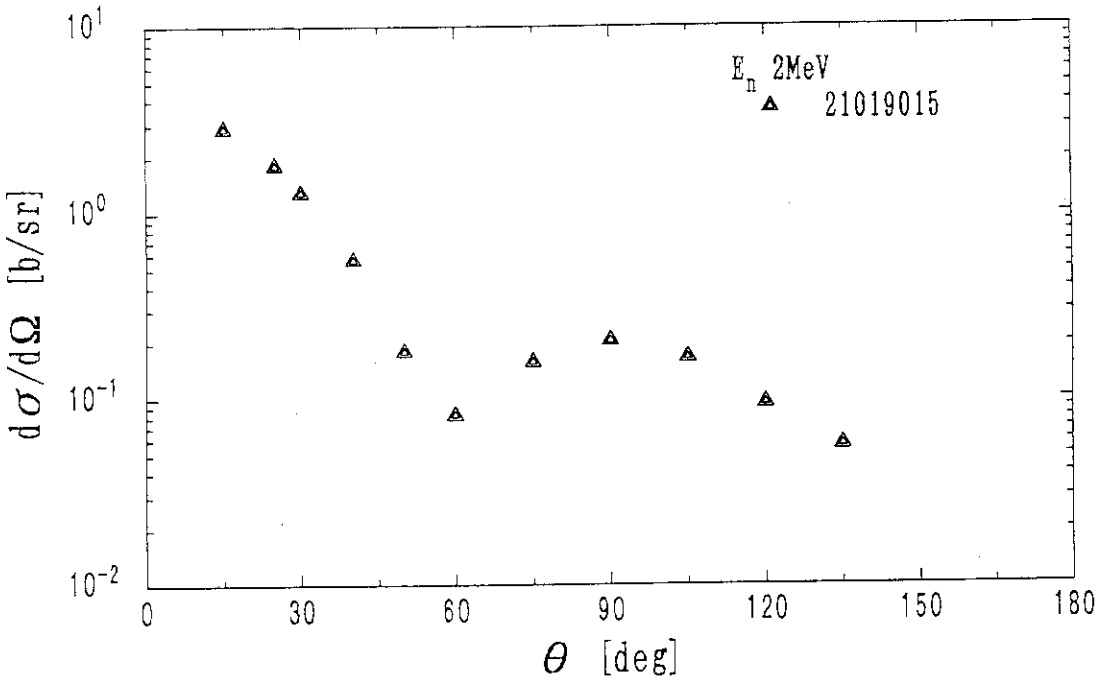


Fig. 52 Differential elastic scattering cross section at E_n = 2.0 MeV.

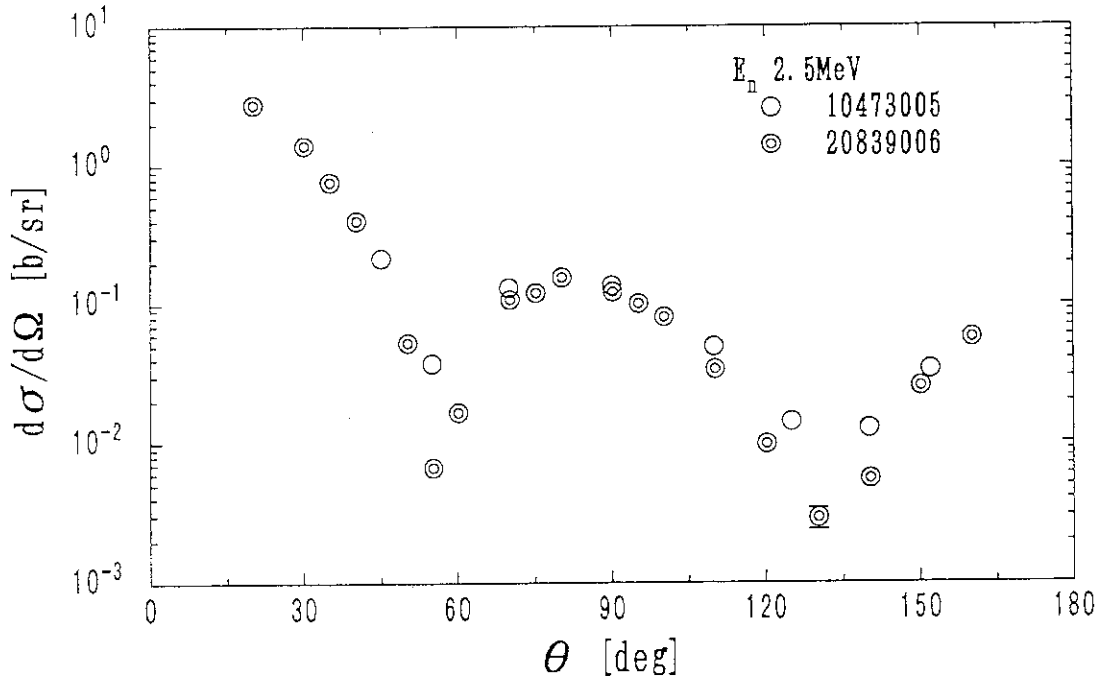


Fig. 53 Differential elastic scattering cross section at E_n = 2.5 MeV.

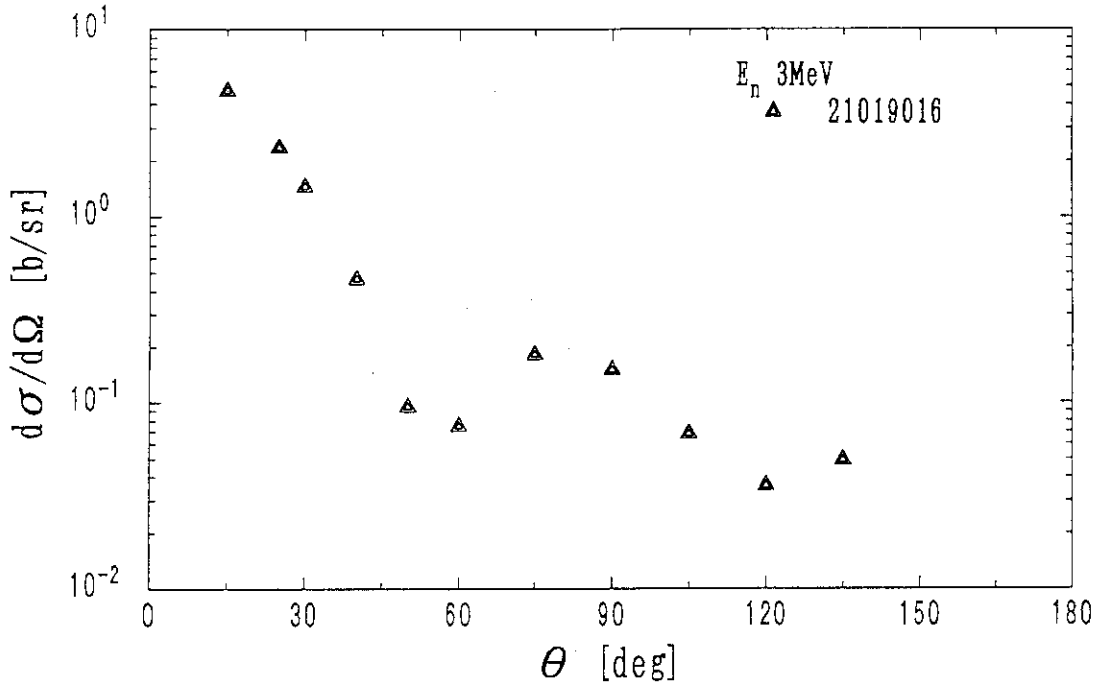


Fig. 54 Differential elastic scattering cross section at E_n = 3.0 MeV.

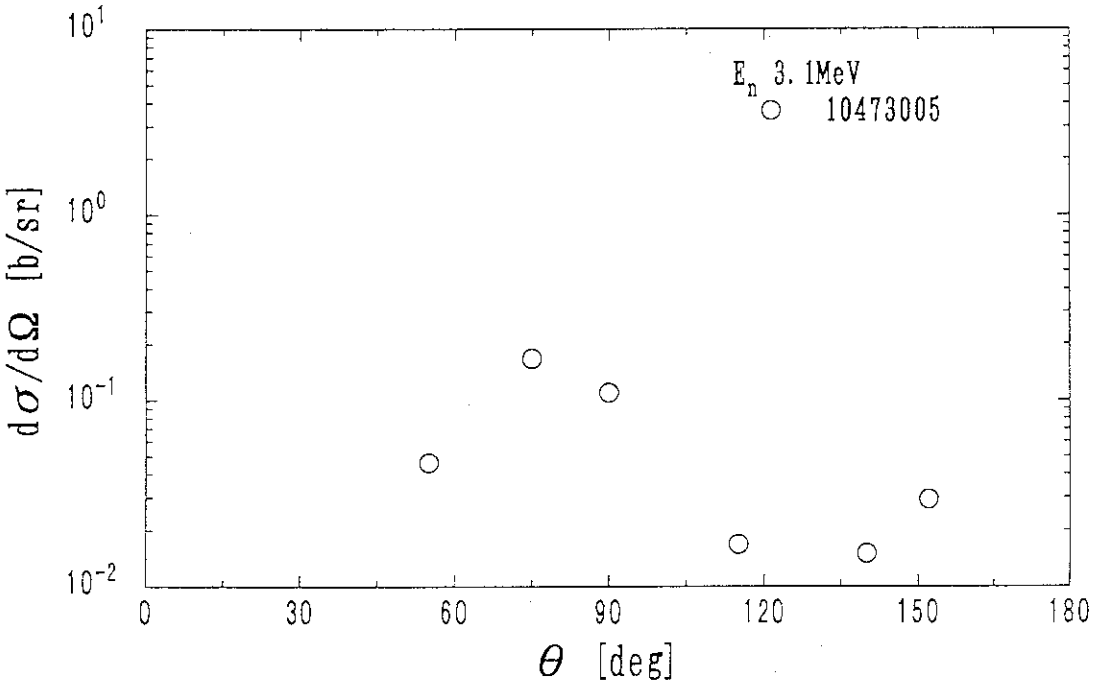


Fig. 55 Differential elastic scattering cross section at E_n = 3.1 MeV.

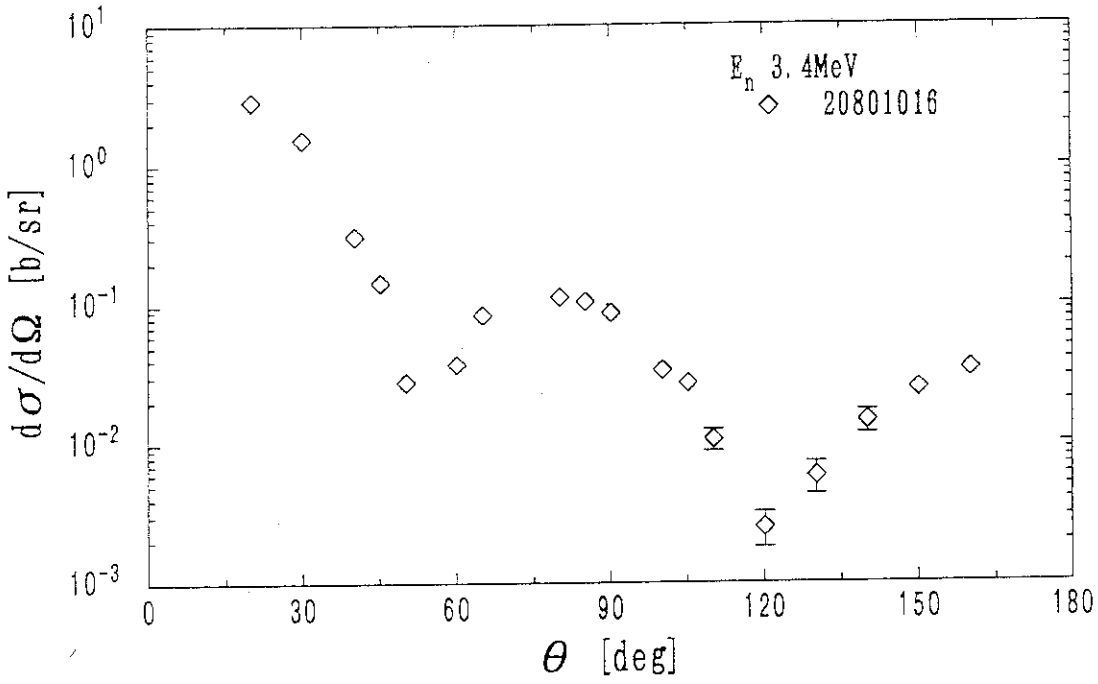


Fig. 56 Differential elastic scattering cross section at E_n = 3.4 MeV.

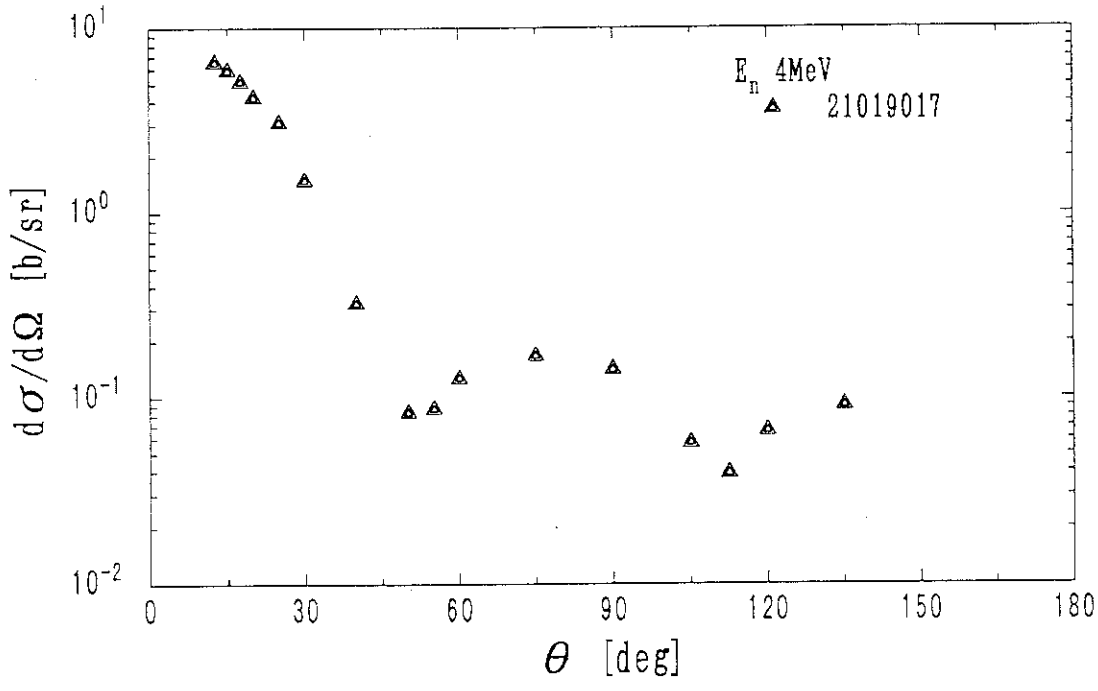


Fig. 57 Differential elastic scattering cross section at E_n = 4.0 MeV.

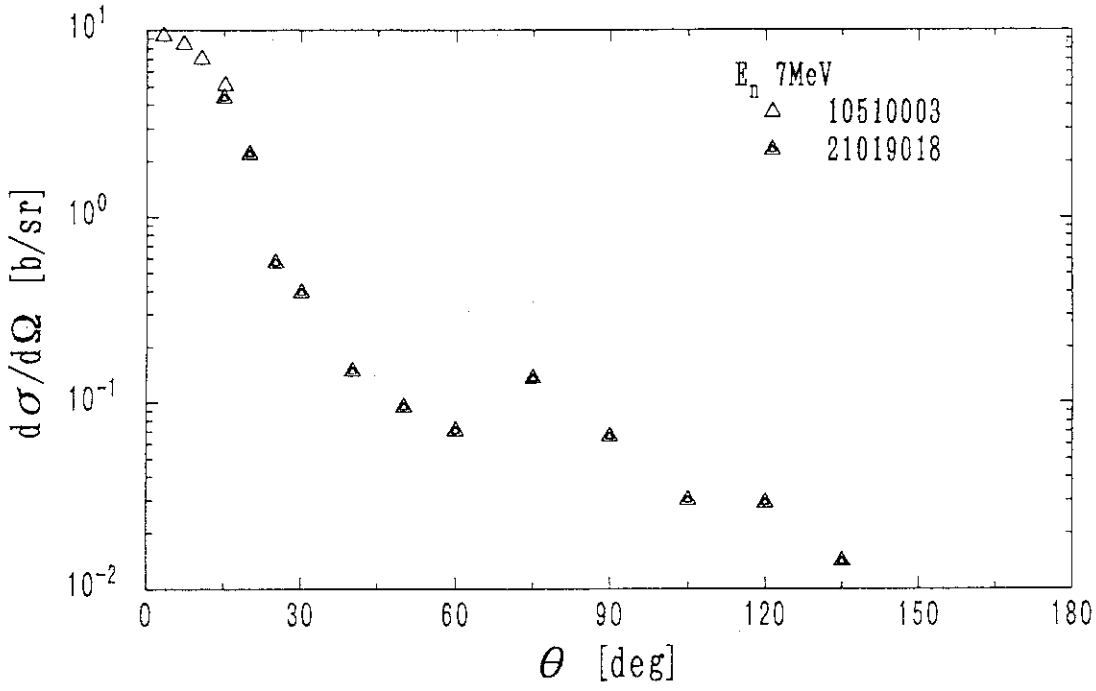


Fig. 58 Differential elastic scattering cross section at E_n = 7.0 MeV.

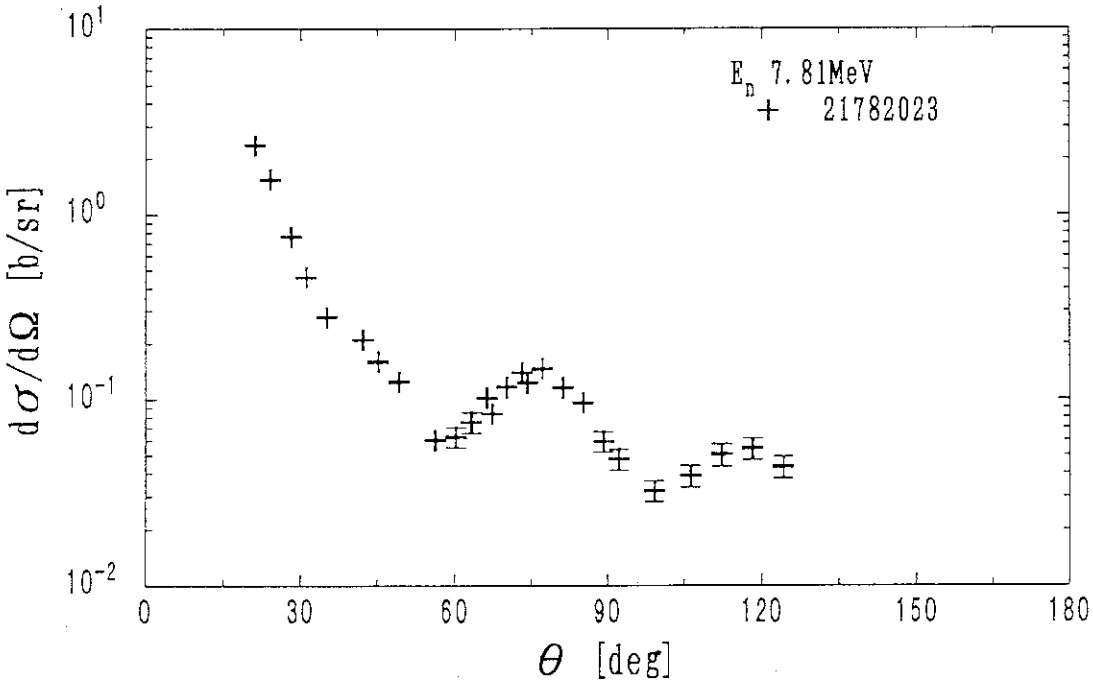


Fig. 59 Differential elastic scattering cross section at E_n = 7.81 MeV.

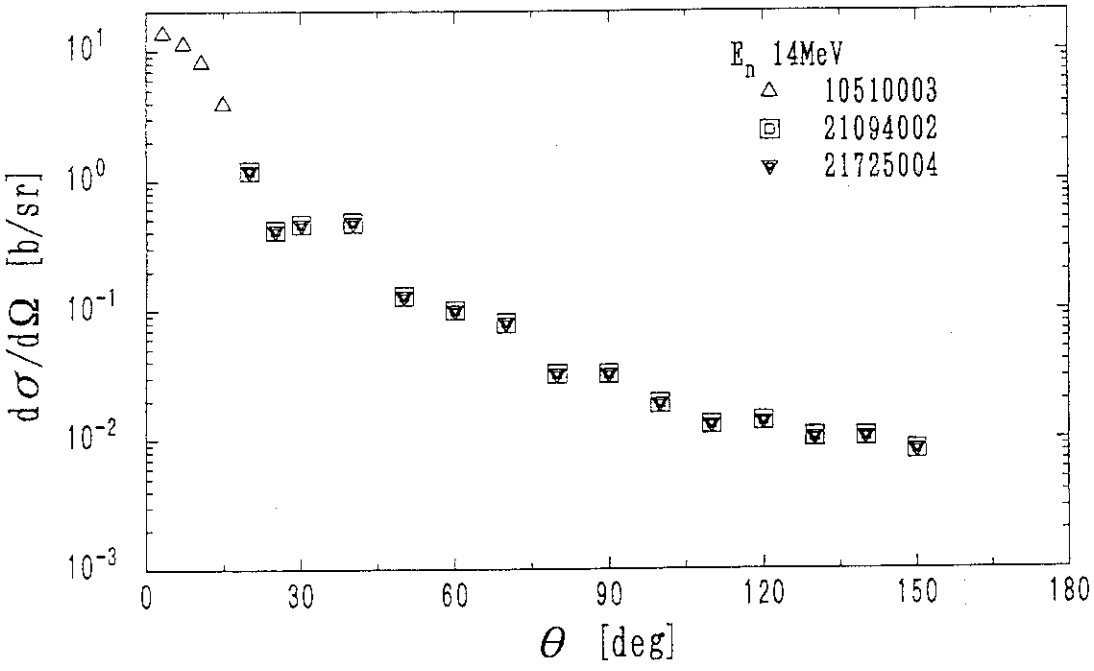


Fig. 60 Differential elastic scattering cross section at E_n = 14.0 MeV.

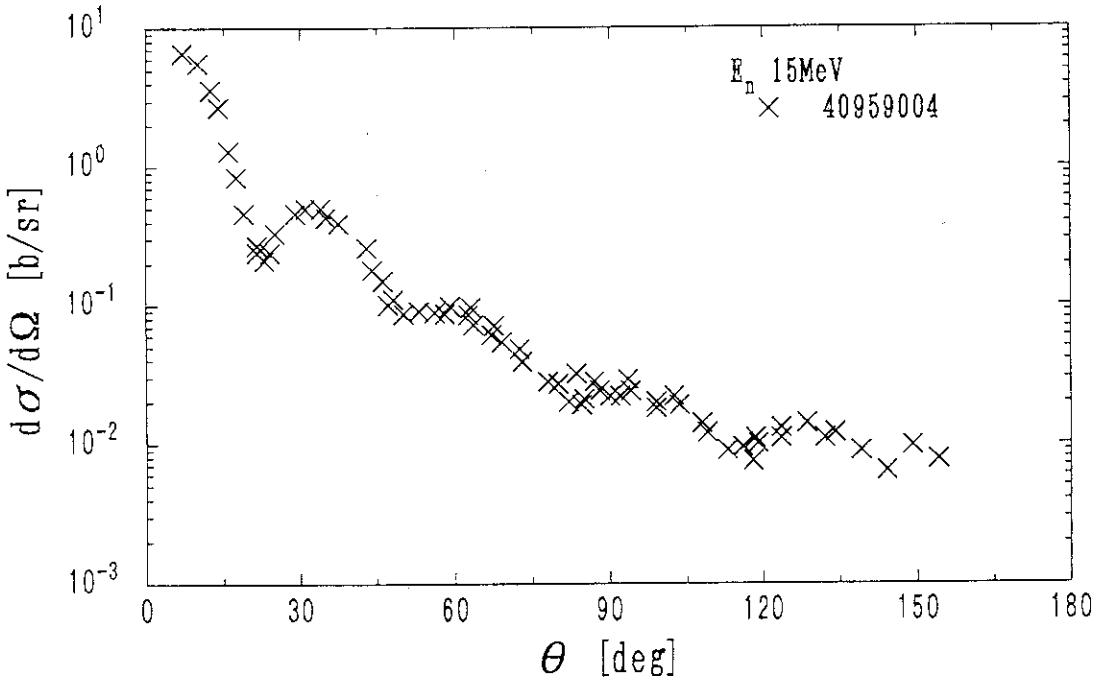


Fig. 61 Differential elastic scattering cross section at E_n = 15.0 MeV.

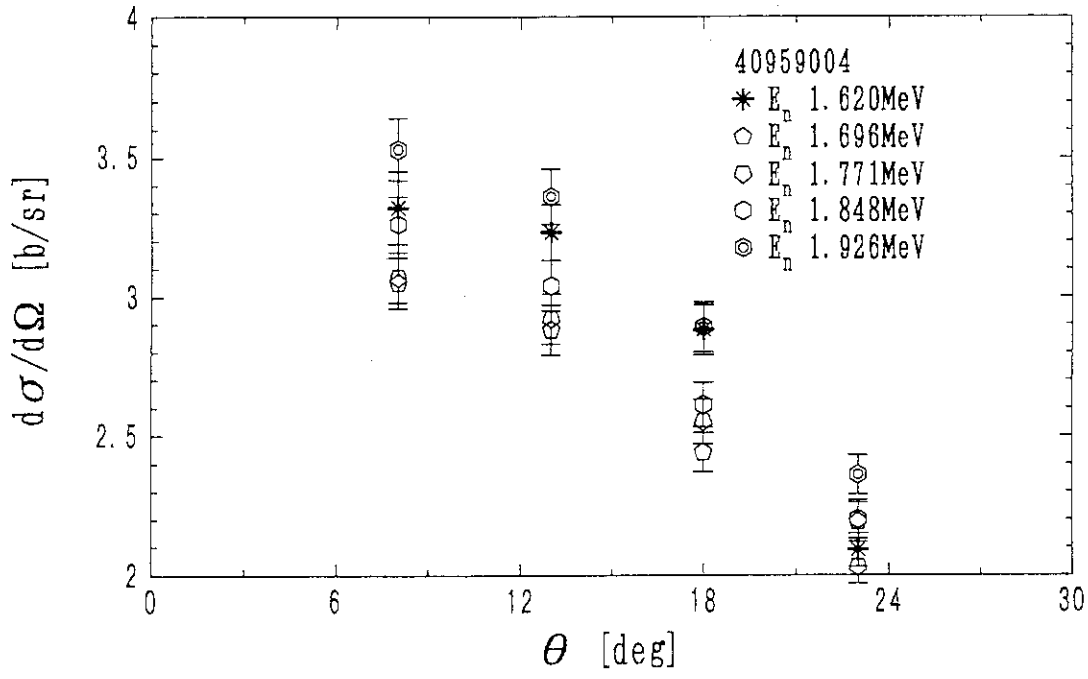


Fig. 62 Differential elastic scattering cross section for forward angles at E_n = 1.620 ~ 1.926 MeV.

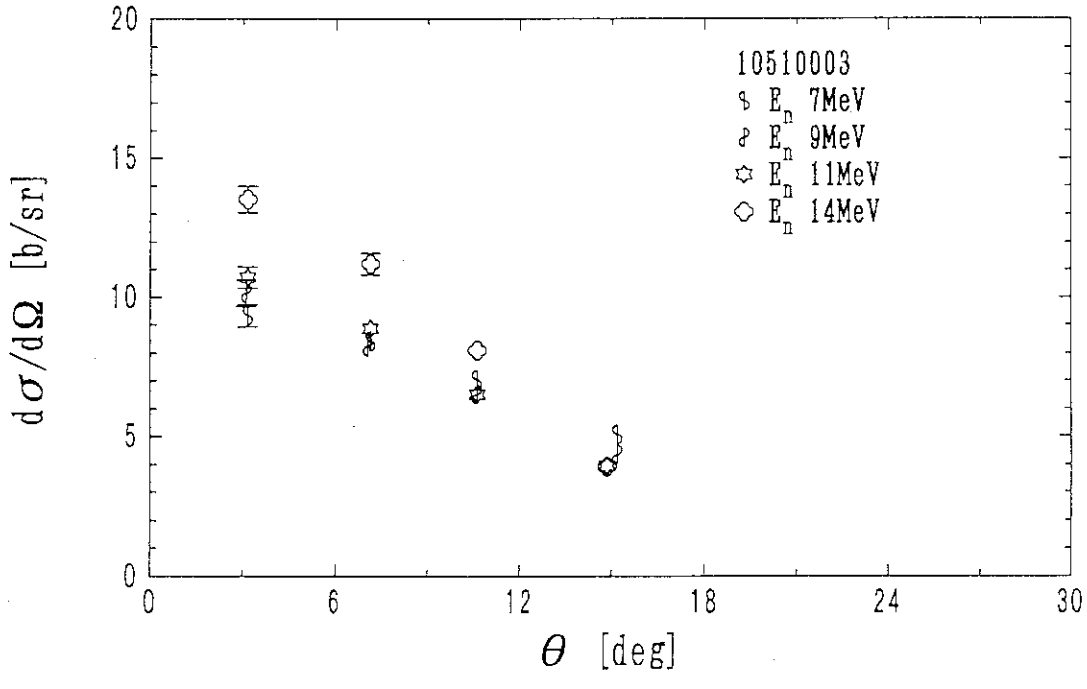


Fig. 63 Differential elastic scattering cross section for forward angles at E_n = 7 ~ 14 MeV.

APPENDIX

Literature of Experiments

EXFOR ENTRY number, author, laboratory, and reference
Abbreviations of laboratory and type of reference, see ABBR 1 and 2

ENTRY	AUTHOR	LAB.	TYPE	REFERENCE
10009	J.F.WHALEN	USAANL	P	ANL-7710,9 (1971)
	A.B.SMITH			
10047	D.G.FOSTER JR	USABNW	J	PR/C,3,576 (1971)
	D.W.GLASGOW			
10049	M.P.FRICKE	USAANL	C	71KNOX,1,252 (1971)
	W.M.LOPEZ		C	70HELSINKI,2,265(43) (1970)
	S.J.FRIESENHAHN		R	GA-10194 (1970)
	A.D.CARLSON			
	D.COSTELLO			
10193	D.DRAKE	USALAS	J	PL/B,36,557 (1971)
	I.BERGQVIST			
	D.K.MCDANIELS			
10221	M.LINDNER	USALRL	J	NSE,59,381(1976)
	R.J.NAGLE	USALAS	C	71KNOX,2,259 (1971)
	J.H.LANDRUM			
10279	S.H.HAYES	USARPI	J	NSE,50,243 (1973)
	P.STOLER			
	J.M.CLEMENT			
	C.A.GOULDING			
10280	R.B.SCHWARTZ	USANBS	J	NSE,54,322 (1974)
	R.A.SCHRACK			
	H.T.HEATON II			
10286	W.E.KINNEY	USAORL	R	ORNL-4804 (1973)
	F.G.PEREY			
10376	J.H.LANDRUM	USALRL	J	PR/C,8,1938 (1973)
	R.J.NAGEL			
	M.LINDNER			
10421	W.P.POENITZ	USAANL	J	NSE,57,300 (1975)
10473	L.E.BEGHIAN	USALTI	J	NSE,69,191 (1979)
	G.H.R.KEGEL	USABNL	J	ANS,27,871 (1977)
	T.V.MARCELLA		C	75WASH,2,950 (1975)
	B.K.BARNES			
	G.P.COUCHELL			
	J.J.EGAN			
	A.MITTLER			
	D.J.PULLEN			
	W.A.SCHIER			
10510	W.BUCHER	USABRL	C	75WASH,2,945 (1975)
	C.E.HOLLANDSWORTH		J	PRL,35,1419 (1975)
	J.E.YOUNGBLOOD		J	BAP,20,174(IB25) (1975)
			J	NIM,111,237 (1973)
10560	P.GUENTHER	USAANL	R	ANL-NDM-16 (1975)
	D.HAVEL			
	A.SMITH			
10696	F.Y.TSANG	USAMIS	J	NSE,65,70 (1978)
	R.M.BRUGGER			
10795	L.R.VEESER	USALAS	C	78HARWELL,,1054 (1978)
	E.D.ARTHUR			
10909	D.K.OLSEN	USAORL	C	79KNOX,,677 (1979)
	G.L.MORGAN			
	J.W.MCCONNELL			

ENTRY	AUTHOR	LAB.	TYPE	REFERENCE
10935	W.P.POENITZ J.F.WHALEN A.B.SMITH	USAANL	J R	NSE,78,333 (1981) ANL-NDM-80 (1983)
11108	J.M.PETERSON A.BRATENAHL J.P.STOERING	USALRL	J	PR,120,521 (1960)
11155	A.BRATENAHL J.M.PETERSON J.P.STOERING	USALRL	J	PR,110,927 (1958)
11616	B.C.DIVEN J.TERRELL A.HEMMENDINGER	USALAS	J	PR,120,556 (1960)
11945	G.A.LINENBERGER J.A.MISKEL	USALAS	R	LA-467 (1946)
12207	R.C.ALLEN R.B.WALTON R.B.PERKINS R.A.OLSON R.F.TASCHEK	USALAS	J	PR,104,731 (1956)
12378	L.CRANBERG J.S.LEVIN	USALAS	J R	PR,109,2063 (1958) LA-2177 (1959)
12382	A.B.SMITH	USAANL	J	NP,47,633 (1963)
12459	J.D.KNIGHT R.K.SMITH B. WARREN	USALAS	J	PR,112,259 (1958)
12738	J.Q.SHAO G.P.COUCHELL J.J.EGAN G.H.R.KEGEL S.Q.LI, A.MITTLER D.J.PULLEN W.A.SCHIER	USALTI	J T C	NSE,92,350 (1986) SHAO (1984) 85SANTA,,(JB37) (1985)
12767	D.K.MC DANIELS P.VARGHESE D.M.DRAKE E.ARTHUR A.LINDHOLM I.BERGQVIST J.KRUMLINDE	USALAS USAORE	J	NP/A,384,88 (1982)
20195	G.DECONNINCK A.GONZE P.MACQ J.P.MEULDERS	BLGLVN	J	JPR,22,652 (1961)
20416	J.FREHAUT A.BERTIN R.BOIS J.JARY	FR BRC	C C C R	75KIEV (1975) 75WASH,,(IB1) (1975) 75GAUSSIG (1975) CEA-R-4627 (1974)

ENTRY	AUTHOR	LAB.	TYPE	REFERENCE
20480	J.CABE	FR BRC	R	CEA-R-4524 (1973)
	M.CANCE		P	EANDC(E)-49 (1963)
			J	CR,258,1478 (1964)
			J	CR,259,4610 (1964)
			P	EANDC(E)-57 (1965)
			J	JPR,27,755 (1966)
			R	CEA-R-3279 (1967)
			J	NP/A,102,92 (1967)
			C	67BORDEAUX,1,36 (1967)
			P	EANDC(E)-89 (1968)
			P	EANDC(E)-115 (1969)
			P	EANDC(E)-127 (1970)
			J	JPR/S,31,217 (1970)
			C	70HELSINKI,2,31 (1970)
			P	EANDC(E)-140 (1971)
			P	EANDC(E)-150 (1972)
20499	H.KARIUS	GERHAM	J	JP/G,5,5,715 (1979)
	A.ACKERMANN		P	NEANDC(E)-161,113 (1974)
	W.SCOBEL			
20794	D.S.MATHER	UK ALD	R	AWRE-O-47/,69 (1969)
	L.F.PAIN		J	PR/B,133,1403 (1964)
20795	D.S.MATHER	UK ALD	R	AWRE-O-72/,72 (1972)
	P.F.BAMPTON		R	AWRE-O-47/,69 (1969)
	R.E.COLES			
	G.JAMES			
	P.J.NIND			
20801	G.HAOUAT	FR BRC	J	NSE,81,4,491 (1982)
	J.LACHKAR		R	NEANDC(E)-196 (1978)
	CH.LAGRANGE		C	78HARWELL,508 (1978)
	Y.PATIN		C	78HARWELL,136 (1978)
	J.SIGAUD,		C	76LOWELL,1330 (1976)
	R.E.SHAMU		P	CEA-N-1969,32 (1977)
			P	CEA-N-1969,39 (1977)
20839	G.HAOUAT	FR BRC	J	NSE,81,4,491 (1982)
	J.SIGAUD		R	NEANDC(E)-180L (1978)
	J.LACHKAR		C	76LOWELL,1327 (1976)
	CH.LAGRANGE		P	CEA-N-1969,32 (1977)
	B.DUCHEMIN,		C	78HARWELL,508 (1978)
	Y.PATIN			
21019	R.BATCHELOR	UK ALD	J	NP,65,236 (1965)
	W.B.GILBOY			
	J.H.TOWLE			
21092	M.BABA	JPNTOH	P	EANDC(J)-30,66 (1973)
	K.NOMOTO			
	K.KANDA			
	N.HIRAKAWA			
	J.MITSUI			
	T.MOMOTA			
21094	J.VOIGNIER	FR SAC	R	CEA-3503 (1968)
21187	J.F.BARRY	UK ALD	J	JNE,18,481 (1964)
	J.BUNCE			
	P.H.WHITE			

ENTRY	AUTHOR	LAB.	TYPE	REFERENCE
21208	J.L.PERKIN	UK ALD	J	JNE,14,69 (1961)
	R.F.COLEMAN		R	AERE-NP/R-2033 (1961)
21320	E.BARNARD	UK HAR	J	NP,80,46 (1966)
	A.T.G.FERGUSON		C	66PARIS,1,443 (1966)
	W.R.MCMURRAY		R	INDC-156 (1967)
	I.J.VAN HEERDEN		C	65ANTWERP,504 (1965)
			P	AERE-PR/NP-6 (1964)
			R	INDSWG-62 (1964)
			C	63MANCHST,4,17 (1963)
21438	J.L.PERKIN	UK ALD	J	PPS,72,505 (1958)
	L.P.O'CONNOR			
	R.F.COLEMAN			
21479	BRODA	UK CAV	R	BR-574 (1945)
21521	J.A.PHILLIPS	UK HAR	R	AERE-NP/R-2033 (1956)
21568	J.FREHAUT	FR BRC	J	NSE,74,29 (1980)
	A.BERTIN			
	R.BOIS			
21627	T.B.RYVES	UK NPL	J	JP/G,6,(6),771 (1980)
	P.KOLKOWSKI		P	NEANDC(E)-212,8,87 (1980)
			P	INDC(UK)-32L/N,8,87 (1980)
21725	J.VOIGNIER	FR VNV	R	CEA-R-3503 (1968)
			C	67BORDEAUX,24 (1967)
21755	P.H.WHITE	UK ALD	J	JNE/AB,16,261 (1962)
21782	G.HAOUAT	FR BRC	J	NSE,81,(4),491 (1982)
	J.LACHKAR			
	CH.LAGRANGE			
	J.JAY			
	J.SIGAUD			
	Y.PATIN			
21813	I.TSUBONE	JPNJAE	J	NSE,88,579 (1984)
	Y.NAKAJIMA		C	82ANTWER,,65 (1982)
	Y.FURUTA			
	Y.KANDA	JPNKYU		
21976	R.PEPELINK	GERKIG	C	85SANTA,,(JA46) (1985)
	B.ANDERS			
	B.M.BAHAL			
22121	G.SCHREDER	GERTHS	C	88MITO,,691 (1988)
	J.W.HAMMER		J	PR/C,39,1768 (1989)
	W.GRUM			
	K.-W.HOFFMANN			
	G.DAGGE,			
	M.KOCH			
	G.BULSKI			
	G.KEILBACH			
	H.POSTNER			
	G.SCHLEUSSNER			
30305	S.MUBARAKMAND	PAKNIL	J	NIM,115,345 (1974)
	M.AHMAD			
	M.ANWAR			
	M.S.CHAUDHRY			
30537	CHOU YOU-PU	CPRAEP	R	HSJ-77091 (1978)

ENTRY	AUTHOR	LAB.	TYPE	REFERENCE
30561	N.V.KORNILOV	CCPFEI	S	ZFK-410,68 (1980)
	B.V.ZHURAVLEV		P	INDC(HUN)-17,47 (1980)
	O.A.SAL'NIKOV		J	AE,49,283 (1980)
	P.RAICS	HUNKOS	J	SJA,49,772 (1981)
	S.NAGY		C	80KIEV,1,236 (1980)
	S.DAROCZY			
	K.SAILER			
	J.CSIKAI			
30583	HUANG ZHENG-DE	CPRAEP	S	LBL-11118,243 (1980)
	CAO ZHONG		C	81GRENOB,,512 (1981)
	WANG HUI-ZHU			
	LIU JI-SHI			
	DING DA-ZHAO			
30716	SHEN GUANRAN	CPRAEP	J	CNP,6,193 (1984)
	HUANG TANGZI			
	WEN SHENLIN			
	YU CHUNYING			
	LI ANLI			
	TANG HONGOING			
	SHEN QINGBIAO			
	ZHAO ZHIXINAG			
	GU FUHUA			
30762	LI JINGDE	CPRSIU	C	86HARROG,1,229 (1986)
	XIE DAQUAN			
	MA GONGGUI			
	ZOU YIMING			
	WANG SHIMING			
	CHEN SHUYING			
40121	JU.G.PANITKIN	CCPFEI	J	AE,33,782 (1972)
	V.A.TOLSTIKOV			
40177	JU.G.PANITKIN	CCPFEI	J	AE,33,825 (1972)
	V.A.TOLSTIKOV			
40403	A.N.DAVLETSHIN	CCPFEI	C	75KIEV,4,109 (1976)
	A.O.TIPUNKOV			
	V.A.TOLSTIKOV			
40411	G.P.ANTROPOV	CCPCCP	J	AE,5,456 (1958)
	YU.A.ZISIN		J	JNE,10,184 (1959)
	A.A.KOVRIZHNIKH			
	A.A.LBOV			
40431	JU.G.PANITKIN	CCPFEI	J	AE,39,17 (1975)
	L.E.SHERMAN		R	YFI-19,7 (1974)
40560	P.E.VOROTNIKOV	CCPKUR	C	77KIEV,2,119 (1977)
	V.A.VUKOLOV			
	E.A.KOLTYPIN			
	JU.D.MOLCHANOV			
	G.A.OTROSHCHENKO			
	G.B.JAN'KOV			
40643	B.YA.GUZHOVSKIY	CCPKUR	J	AE,11,(4),395 (1961)
			J	SJA,11,1041 (1962)

ENTRY	AUTHOR	LAB.	TYPE	REFERENCE
40749	B.G.KAZJULA	CCPRI	J	YK,4/39,14 (1980)
	E.M.KOZULIN			
	L.A.POBEDONOSTSEV			
	G.A.TUTIN			
	JU.A.NEMILOV			
	L.N.SYSOEVA			
	A.A.FILATENKOV			
40839	V.P.VERTEBNYJ	CCPIJI	C	80KIEV,2,249 (1980)
	N.L.GNIDAK			
	A.V.GREBNEV			
	A.L.KIRILJUK			
	G.M.NOVOSELOV			
	E.A.PAVLENKO			
	N.A.TROFIMOVA			
40924	A.V.MURZIN	CCPIJI	J	YK,(4),30 (1986)
	V.P.VERTEBNYJ		J	AE,62(3),192 (1987)
	A.L.KIRILJUK		R	KIYAI-85-35 (1986)
	V.A.LIBMAN			
	L.L.LITVINSKIJ			
	G.M.NOVOSELOV			
	V.F.RAZBUDEJ			
	C.V.SIDOROV			
	N.A.TROFIMOVA			
40959	V.M.MOROZOV	CCPKUR	J	YF,46(5),1326 (1987)
	YU.G.ZUBOV		J	PTE,(6),33 (1986)
	N.S.LEBEDEVA		J	YF,8,1086 (1968)
40969	N.N.BULEEVA	CCPFEI	J	AE,65,(6),348 (1988)
	A.N.DAVLETSHIN			
	O.A.TIPUNKOV			
	S.V.TIKHONOV			
	V.A.TOLSTIKOV			

ABBREVIATIONS

ABBR 1 Laboratories

USAANL	ARGONNE NATIONAL Lab., ARGONNE, ILLINOIS
USABNL	BROOKHAVEN NATIONAL Lab., UPTON, NEW YORK
USABNW	BATTELLE NORTHWEST, RICHLAND, WASHINGTON
USABRL	BALLISTIC RESEARCH Labs., ABERDEEN, PROVING GROUNDS, MARYLAND
USALAS	LOS ALAMOS NATIONAL Lab., NEW MEXICO
USALRL	LAWRENCE LIVERMORE NATIONAL Lab., CALIFORNIA
USALTI	Univ. of LOWELL, LOWELL, MASSACHUSETTS
USAMIS	Univ. of MISSOURI, COLUMBIA, MISSOURI
USANBS	NATIONAL BUREAU of STANDARDS, WASHINGTON,D.C.
USAORE	Univ. of OREGON, EUGENE, OREGON
USAORL	OAK RIDGE NATIONAL Lab., TENNESSEE
USARPI	RENSSELAER POLYTECH.Inst. TROY, NEW YORK
BLGLVN	Univ. of LOUVAIN, LOUVAIN
FR BRC	CEN BRUYERE LE CHATEL
FR SAC	CEN SACLAY, ESSONNE
FR VNV	CENTRE D'ETUDES DE LIMEIL, VILLENEUVE-SAINT-GEORGES
GERHAM	HAMBURG, UNIVERSITAET
GERKIG	GKSS, GEESTHACHT
GERTHS	UNIVERSITAET STUTTGART
JPNJAE	JAPAN ATOMIC ENERGY RESEARCH Inst., TOKAI
JPNKYU	KYUSHU Univ., Dept. of NUCLEAR ENGINEERING, FUKUOKA
JPNTOH	TOHOKU Univ., SENDAI
UK ALD	AWRE, ALDERMASTON, ENGLAND
UK CAV	CAVENDISH Lab., CAMBRIDGE, ENGLAND
UK HAR	AERE, HARWELL, BERKS, ENGLAND
UK NPL	NATIONAL Phys. Lab., TEDDINGTON
CRPAEP	Inst. of ATOMIC ENERGY, Acad. SINICA, PEKING
HUNKOS	KOSSUTH Univ. DEBRECEN
PAKNIL	PINSTECH, NILORE, RAWALPINDI
CCPCCP	UNION of SOVIET SOCIALIST REPUBLICS
CCPFEI	FIZIKO-ENERGETICHESKIJ Inst., OBNINSK
CCPIJI	Inst. JADERNYKH ISSLEDOVANIJ A. N. UKRAINSKOI SSR, KIEV
CCPKUR	Inst. At. En. I.V.KURCHATOVA, MOSKVA
CCPRI	KHLOPIN RADIEVYJ Inst., LENINGRAD

ABBR 2 Reference Types

C	Conference
J	Journal
P	Progress Report
R	Report other than Progress Report
S	Conference Proceedings within a Report Series
T	Thesis or Dissertation