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EVALUATION OF NEUTRON NUCLEAR DATA FOR ^{233}U IN THERMAL AND RESONANCE REGIONS

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Evaluation of Neutron Nuclear Data for ^{233}U in Thermal and Resonance Regions

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The thermal and resonance cross sections of ^{233}U were evaluated for JENDL-2. The cross sections below 1 eV are given as point-wise data and were evaluated by the use of the measured fission and capture cross sections. The resolved resonance parameters are derived up to 100 eV. The parameters were obtained by using NDES so as to reproduce the measured total and fission cross sections. The cross sections from 100 eV to 30 keV are represented by the unresolved resonance parameters. The fission and capture resonance integrals calculated from these parameters are 771 and 138 barns, respectively, which agree with the measured data within the quoted errors.

Keywords; ^{233}U, evaluation, JENDL-2, thermal cross sections, resonance parameters

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^{233}Uの熱中性子および共鳴領域核データの評価

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^{233}Uの熱中性子および共鳴断面積の評価をＪＥＮＤＬ－２のために行った。１ｅＶ以下の断面積は核分裂と捕獲断面積の実験値より評価し，ポイント・ワイズ・データとして与えた。分離共鳴パラメータは全断面積と核分裂断面積の実験値を再現するようＮＤＥＳコードシステムで評価し１００ｅＶまで与えた。１００ｅＶ－３０ｋｅＶの間は非分離共鳴パラメータを与えた。これらの共鳴パラメータから計算された核分裂および捕獲共鳴積分はそれぞれ７７１ｂと１３８ｂであり，誤差の範囲内で実験値と一致している。

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1. Introduction

In the thorium fuel cycle, ^{233}U has an essential role as a main fissile material. In spite of its importance, there still remain large uncertainties in the evaluated nuclear data of ^{233}U. For example, McNeamy and Jenkins[1] pointed out from their benchmark tests that the cross sections of ^{233}U in ENDF/B-IV had some errors in the epithermal region.

Considering such a situation, the cross sections of ^{233}U were evaluated in the full energy range for JENDL-2. As ^{233}U is expected to be used in a thermal breeder reactor because of its high η-value in the thermal energy region, the thermal and resonance cross sections, as well as the cross sections for fast neutrons, were carefully evaluated.

In the evaluation for JENDL-2, the thermal and resonance cross sections were evaluated by the present author, and the cross sections in the higher energy range were evaluated by Asano and Matsunobu. The outline of the evaluation for full energy range will be published[2] elsewhere. Hence this report describes detailed evaluation procedure and gives the numerical results in the thermal and resonance regions.

The cross sections below 1 eV, given as point-wise data, are described in Chapter 2. The cross sections are represented by the resolved resonance parameters between 1 and 100 eV and by the unresolved resonance parameters between 100 eV and 30 keV. The evaluations of both parameters are described in Chapters 3 and 4, respectively.

2. Thermal Cross Sections

The cross sections below 1 eV are given as point-wise data, for the cross section values cannot be reproduced satisfactorily with the single-level resonance parameters in this energy range because of interference effects among levels.

The fission cross section was evaluated on the basis of recently measured data by Pschenichny et al.[3], Deruytter and Wagemans[4], Weston et al.[5,6] and Cao et al.[7] The capture cross section was also evaluated on the basis of measured data by Weston et al.[5] The evaluation was made by using NDES (Neutron Data Evaluation System)[8]. In this system, numerical experimental data are displayed in a graphic form on a cathode-ray tube, and any point on the graph can be recorded in the computer memory by using a cross-hair cursor. Thus the evaluation with the eye-guide method can be made easily with this system.

The elastic scattering cross section was calculated from the resonance parameters with assuming the effective scattering radius of 9.93 fm which was obtained from analyses of the unresolved resonance parameters as will be described later. The 2200 m/s values of the evaluated cross sections agree with the values recommended by Lemmel[9] within the quoted errors. The total cross section given as a sum of the partial cross section agrees with the recent measurements[3,10,11,12] within their scatter.

The cross sections thus evaluated are given in Table 1. The evaluated cross section curves are compared with the measured data in Figs. 1 ∿ 4.

3. Resolved Resonance Parameters

3.1 Status of Measured Data

The resonance parameters measured after publication of BNL-325 2nd edition[13] were surveyed through CINDA-76/77 and CINDA-78[14]. The status of the measured data is shown in Table 2. The measured resonance parameters were stored in the REPSTOR system[15], and were compared with one another.

The measurements of the resonance cross sections were also surveyed through CINDA-76/77 and CINDA-78. The survey was restricted to data whose numerical values were available in NEUDADA file, since the energy points are very numerous in these data of the resonance cross sections. The status of the measured data is shown in Table 3.

3.2 Deduction of Complete Sets of Parameters

A total of 8 sets of the measured resonance parameters were examined. In the present work, only the parameters for the single-level Breit-Wigner formula were considered because of limitation in the processing codes. Thus the sets deduced by de Saussure et al.[18] and Cao et al.[7] were omitted. The sets by Felvinci and Melkonian[17] and by Sauter and Bergen[20] were also abandoned, because these parameters were very discrepant from the remaining ones. Finally we considered the parameter sets deduced by Nizamuddin and Blons[16], by Kolar et al.[11], by Ryabov et al.[19] and by Bergen and Silbert[21] in the present work.

All the necessary parameters were not given by the experimenters as seen in Table 2. In order to calculate the resonance cross sections, the parameters not given by the experimenters were estimated as follows:

a) Nizamuddin and Blons[16]

They gave the parameters for 169 levels, 33 of which are artificial

levels deduced to partially compensate the interfernce effects among levels. They gave Γ, Γ_f and $\sigma_0\Gamma_f$ for the real levels, and Γ and $\sigma_0\Gamma_f$ for the artificial levels. Taking account of the relation

$$\sigma_0\Gamma_f = \frac{2\pi}{\lambda\!\!\!^{-2}} g \frac{\Gamma_n\Gamma_f}{\Gamma}, \tag{1}$$

we had for the real levels

$$\Gamma_n = 2g\Gamma_n = (\sigma_0\Gamma_f) \quad \lambda\!\!\!^{-2}\Gamma/\pi\Gamma_f, \tag{2}$$

$$\Gamma_\gamma = \Gamma - \Gamma_f. \tag{3}$$

The values of Γ_γ were found to be 39 meV for all the real levels. For the artificial levels, Γ_f was obtained by assuming the same value of Γ_γ as the real levels,

$$\Gamma_f = \Gamma - \Gamma_\gamma \ (=39 \text{ meV}), \tag{4}$$

and Γ_n was obtained from Eq. (2).

b) Kolar et al.[11]

They gave Γ and $2g\Gamma_n{}^\circ$ from their transmission measurements. By assuming Γ_γ = 39 meV according to Nizamuddin and Blons, we obtained

$$\Gamma_n = 2g\Gamma_n = 2g\Gamma_n{}^\circ \sqrt{E},$$

$$\Gamma_f = \Gamma - \Gamma_n - \Gamma_\gamma.$$

c) Ryabov et al.[19]

They gave $2g\Gamma_n$ and Γ from their measurements on the total, fission and capture cross sections, but detailed information was not available. Assuming Γ_γ = 39 meV, we obtained

$$\Gamma_n = 2g\Gamma_n,$$

$$\Gamma_f = \Gamma - \Gamma_n - \Gamma_\gamma.$$

d) Bergen and Silbert[21)]

They obtained $2g\Gamma_n^\circ$ and Γ_f from the measurements of the fission and capture cross sections by using the underground nuclear detonation as a neutron source. By assuming Γ_γ = 45 meV as they assumed in their analysis, we had

$$\Gamma_n = 2g\Gamma_n = 2g\Gamma_n^\circ\sqrt{E}$$

$$\Gamma = \Gamma_f + \Gamma_\gamma + \Gamma_n.$$

3.3 Evaluation of Parameters

3.3.1 Comparison of Parameter Sets

The four sets of the parameters above mentioned were compared with one another and with the parameters of ENDF/B-IV. It is difficult, however, to compare each quantity of the parameters with one another directly, because a quantity is correlated with the others in the analysis. For example the value of Γ_n is dependent on the value of Γ_γ, when it is deduced from the transmission measurements.

In the present work, the areas of each resonance and the calculated cross sections were compared. For compaison of the fission or capture area, we calculated A_f and A_c defined as

$$A_f = 2g\frac{\Gamma_n\Gamma_f}{\Gamma}, \qquad A_c = 2g\frac{\Gamma_n\Gamma_\gamma}{\Gamma}.$$

Table 4 compares the values of A_f and A_c summed up over levels located in adequate energy ranges. The areas calculated from the parameters of Nizamuddin and Blons[16)], Kolar et al.[11)] and ENDF/B-IV agree well with one another within the error of 20 %, while the areas of Bergen and Silbert[21)] are very large and those of Ryabov et al.[19)] are extremely small.

The total, fission and capture cross sections were calculated from these 5 sets with the RESENDD code[27] and are compared with one another in Figs. 5 ∿ 7, respectively. The set of Bergen and Silbert gives the largest values for all the cross sections. Small resonances seem to be missed in the set of Ryabov et al.

3.3.2 Initial Guess Prameters

From the comparisons mentioned above, we omitted the parameter sets of Bergen and Silbert and of Ryabov et al., because Bergen and Silbert deduced parameters from the larger cross sections than the recently measured ones, and Ryabov et al. missed small resonances. As to the remaining two sets, we concluded that the set of Nizamuddin and Blons was more reliable, because their parameters were deduced not only from the high resolution measurements of the fission cross section by Blons[26] but also from the transmission measurements by Kolar et al.[11] from which the parameters of Kolar et al. were deduced. Thus the set of Nizamuddin and Blons was adopted as the initial guess parameters. In the energy range below 6 eV, where Nizamuddin and Blons did not give the parameters, the recommended data in BNL-325 3rd edition[28] were adopted as the initial guess.

3.3.3 Modification

The cross sections were calculated from the initial guess parameters with assuming the effective scattering radius of 9.93 fm. The calculated total and fission cross sections agree well with the measured data within their scatters in most of energy range. It should be noted that the calculated capture cross section agrees well with the measured data

of Weston et al.[6], though the resonance parameters were deduced without considering the capture data. This suggests applicability of the parameters of Nizamuddin and Blons.

In some energy ranges, however, agreement was not satisfactory between the calculated and measured cross sections. The resonance parameters were modified so as to reproduce the measured data in such energy ranges by displaying the calculated cross sections and the measured data on a cathode ray tube with NDES. Figures 8 and 9 show improvement of agreement in total and fission cross sections, respectively, by modification of the resonance parameters.

The parameters of the lowest five levels were further modified so as to reproduce the measured data of fission and capture resonance integrals.

3.3.4 Background Cross Section

Even after modifying the resonance parameters, the calculated fission cross section failed to reproduce the measured data in limited energy ranges particularly in valleys between resonances. This is caused by the interference among resonances and cannot be resolved even by adoption of the artificial levels. The multi-level formula is essentially required for such a fissile nuclide as ^{233}U. In the present work, however, the discrepancies were corrected by applying a positive or negative background cross section to the fission cross section. This work was made also by using NDES. No background correction was applied to the capture and elastic scattering cross sections. Figure 10 shows the fission cross sections calculated with and without the background cross section as well as the measured data in the energy range between

13 and 16 eV. The background fission cross section is tabulated in Table 5.

3.3.5 Results

The evaluated resonance parameters are listed in Table 6 with the measured data and the evaluated ones in BNL-325 2nd and 3rd edition and in ENDF/B-IV. The calculated total, fission and capture cross sections are shown with the measured data in Figs. 11 ∿ 13, respectively. Satisfactory agreement is observed in full energy range, when the background cross section is applied.

4. Unresolved Resonance Parameters

The unresolved resonance parameters were deduced by the ASREP code[29] so as to reproduce the total, fission and capture cross sections evaluated by Asano and Matsunobu[2] on the basis of measured data. The total cross section was evaluated by averaging the data of Pattenden et al.[24] and Kolar et al.[11] The fission cross section was taken from the measerements by Blons[26]. The capture cross section was evaluated on the basis of the measured data of Weston et al.[6] and of Hopkins and Diven[30] by the aid of the statistical model calculation.

First we searched for the s- and p- wave strength functions, the fission widths and the effective scattering radius so that the global trends of the total, fission and capture cross sections might be well reproduced. The observable level spacing (D_{obs}) and the radiation width (Γ_γ) were fixed to be 0.68 eV and 39 meV, respectively. The energy dependence of the level spacing was calculated with the level density parameters given by Gilbert and Cameron.[31] The ratio of the s- wave to

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p- wave strength function was fixed to be 0.79 as obtained from the optical model calculation, and the spin dependence of the fission widths was also fixed as expected[32] from the channel theory of fission. The effective scattering radius of 9.93 fm was obtained as the results of this search. The strength functions and fission widths thus determined were used as the initial guess parameters in the next step.

Then we searched for the s- and p- wave strength functions and the fission widths with fixing the other parameters so as to reproduce the total, fission and capture cross sections at each energy point. The ratios of s- wave to p- wave strength function and of the fission widths for each spin state were also fixed in this search.

The unresolved resonance parameters thus obtained are given in Table 7 with the calculated cross sections. The energy dependence of the strength functions and the fission widths are shown in Fig. 14 as the ratios to the initial guess values. The fluctuations are considerably large below 1 keV and there seem to exist tendencies to increase with increasing energy in both strength functions and the fission widths.

5. Discussion

The point-wise cross sections were calculated from the resonance parameters and the background cross sections in the energy range from 10^{-5} eV to 30 keV. The fission and capture resonance integrals were calculated from these cross sections by numerical integration, and are compared with the measured data in Table 8. The calculated values agree with the measured data within the quoted errors. This suggests applicability of the present data to thermal reactor calculations.

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in the thermal, resolved resonance and unresolved resonance regions. This suggests the consistency of the evaluation in these three energy regions.

6. Conclusions

The thermal and resonance cross sections of ^{233}U were evaluated for JENDL-2. The cross sections below 1 eV were given as point-wise data, and the resonance cross sections were represented by the resonance parameters and the background cross sections.

The resolved resonance parameters were evaluated by useing NDES where the calculated resonance cross sections could be compared immediately with the measured data in the graphical form. The background corrections were made on the fission cross section in the very restricted energy regions where the calculation could not reproduce the measured data because of the strong interference among levels. The unresolved resonance parameters were obtained up to 30 keV so as to reproduce the evaluated total, fission and capture cross sections. No background correction was applied in the unresolved resonance region.

The evaluated cross sections agree very well with the measured data, and the calculated resonance integrals reproduce the measured data within the quoted errors. Hence the presently evaluated data are expected to be applicable to the thermal reactor calculations in the thorium fuel cycle.

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Table 1 Cross sections of ^{233}U below 1 eV

Energy (eV)	Total (b)	Fission (b)	Capture (b)	Elastic scattering (b)
0.00001	29283	27000	2270	12.7
0.0001	9233	8500	720	12.7
0.001	2940	2700	227	12.7
0.01	935	850	72.0	12.7
0.02	667	603	50.8	12.7
0.0253	588	530	45.3	12.7
0.03	545	491	41.2	12.7
0.04	472	423	36.6	12.7
0.05	421	375	33.4	12.7
0.06	388	344	30.6	12.6
0.07	356	314	28.8	12.6
0.08	335	295	27.9	12.6
0.09	316	276	27.1	12.6
0.1	301	261	26.9	12.6
0.11	288	249	26.4	12.6
0.13	266	228	27.1	12.5
0.14	261	220	28.4	12.5
0.15	254	213	28.4	12.5
0.16	247	207	27.5	12.5
0.18	239	201	25.6	12.5
0.2	232	197	23.0	12.4
0.25	211	181	17.6	12.4
0.3	196	169	14.0	12.3
0.4	172	148	11.5	12.1
0.5	157	134	10.5	11.9
0.6	147	125	10.2	11.8
0.7	139	117	10.2	11.6
0.8	140	118	10.9	11.4
0.9	148	125	12.1	11.2
1.0	162	137	13.8	10.0

Interpolation law: log - log

Table 2 Status of measured resonance parameters of ^{233}U

Author	Year	Ref.	E_{min} (eV)	E_{max} (eV)	No. of levels	Formula*	Quantities	Measured
Nizamuddin	74	16	6	124	169	B - W	$E,\Gamma,\Gamma_f,\sigma_0\Gamma_f$	σ_f
Felvinci	71	17	1.55	29.54	36	B - W	E,Γ_f	fragment K.E
Kolar	70	11	2.5	53	72	B - W	$E,\Gamma,2g\Gamma_n^\circ$	σ_T
			2.5	93	85	A - A	μ,ν,G^T,H^T	
de Saussure	70	18	-2.8	64	70	A - A	μ,ν,G^f,H^f,G^c,H^c	σ_f,σ_c
Cao	70	7	-2.8	65	72	A - A	μ,ν,G^f,H^f	σ_f
Ryabov	70	19	1.8	20.6	13	B - W	$\mu,\nu,2g\Gamma_n$	$\sigma_T,\sigma_c,\sigma_f$
Sauter	68	20	1.59	30.8	30	B - W	$E,\Gamma,g\Gamma_n,g\Gamma_n\Gamma_\gamma$	σ_s,σ_c
Bergen	68	21	20.6	62.7	68	B - W	$E,2g\Gamma_n^\circ,\Gamma_f,\Gamma_\gamma$	σ_f,σ_c
			20.5	62.7	54	R - M	$E,2g\Gamma_n^\circ,\Gamma_f$**,	

* B - W: Single-level Breit-Wigner formula,
A - A: Multi-level farmula by Adler and Adler[22),
R - M: Multi-level farmula by Reich and Moore[23).

** Three fission channels were assumed.

Table 3 List of measured resonance cross sections of ^{233}U

Quantities	Author	Year	Ref.	E_{min} (eV)	E_{max} (eV)	Laboratry
Total	Kolar	70	11	0.68	750	Geel
	Brooks	66	10	0.04	11	Harwell
	Pattenden	63	24	0.07	8,800	ORNL
	Moore	60	25	0.02	20	MTR
Fission	Deruytter	74	4	1.0	30	Geel
	Blons	74	26	6.0	30,000	Saclay
	Cao	70	7	0.7	3,000	Geel
	Bergen	68	21	10	2,850,000	LASL
	Weston	68	6	0.4	2,000	ORNL, RPI
	Brooks	66	10	1.0	11	Harwell
	Moore	60	25	0.02	960	MTR
Capture	Weston	68	6	0.4	2,000	ORNL, RPI

Table 4 Fission and capture areas integrated over energy intervals

Energy Interval (eV)	*	Nizamuddin[16]	Kolar[11]	Ryabov[19]	Bergen[21]	ENDF/B-IV
2 - 5	A_f		0.61	0.40		0.54
	A_c		0.05	0.15		0.12
5 - 10	A_f	1.23	1.47	0.47		1.21
	A_c	0.30	0.30	0.14		0.29
10 - 20	A_f	9.34	8.27	6.08		7.44
	A_c	1.33	1.38	0.89		1.37
20 - 30	A_f	10.82	11.91		18.6	10.46
	A_c	1.20	1.31		2.75	1.22
30 - 40	A_f	8.87	10.51		13.4	8.18
	A_c	0.88	0.91		1.95	0.94
40 - 50	A_f	7.03	7.62		8.3	5.80
	A_c	1.14	1.13		1.73	1.33
50 - 60	A_f	14.26			19.2	12.57
	A_c	1.21			1.90	1.10

* $A_f = 2g\Gamma_n\Gamma_f/\Gamma$, $A_c = 2g\Gamma_n\Gamma_\gamma/\Gamma$

Table 5 Background fission cross section

E_n (eV)	σ_f (barns)	E_n (eV)	σ_f (barns)	E_n (eV)	σ_f (barns)
1.0	0.0	2.85	0.0	14.0	0.0
2.38	0.0	2.90	2.7	14.2	-4.94
2.41	-1.84	3.01	6.3	14.4	-8.6
2.47	-28.0	3.29	6.3	14.6	-11.23
2.50	-28.8	3.45	0.0	14.8	-14.23
2.59	-15.9	3.7	0.0	15.0	-19.37
2.70	-6.7	3.8	-5.05	15.2	0.0
2.76	-1.33	4.0	-9.52	59.0	0.0
2.80	0.0	4.19	-5.33	59.4	-2.81
		4.36	0.0	59.8	-2.65
				60.2	0.0
				100	0.0

Interpolation law: linear-linear

Table 6 Resonance parameters of ^{233}U

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH * (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS **	REFERENCE
-2.81	2.5	754.5	4.5	30.0	720.0	L = 0	JENDL-2
-2.81	2.5	725.5	4.5	1.0	720.0	L = 0	ENDF-B-4
0.17	2.5	100.0	0.0002	40.0	60.0	L = 0	JENDL-2
0.17 ± 0.02	(3)	100 ±20	A 0.0002± 0.0002	40 ±10	60 ±15	WGO= 0.0005± 0.0005	BNL325(2)
0.272	2.5	233.7	0.00462	37.7	196.0	L = 0	ENDF-B-4
0.17 ± 0.02		100 ±20	A 0.00020±0.00004	40 ±10	60 ±15	WGO= 0.00049±0.00010	BNL325(3)
1.45	2.5	530.11	0.11	30.0	500.0	L = 0	JENDL-2
1.55 ± 0.05	(2)	650 ±200	A 0.17 ± 0.01	50 ±30	600 ±200	WGO= 0.14 ± 0.01	BNL325(2)
1.451	2.5	594.76	0.1127	66.34	528.3	L = 0	ENDF-B-4
1.55 ± 0.02		600 ±50	A 0.165± 0.010	45 ±20	555 ±80	WGO= 0.133± 0.008	BNL325(3)
1.59		645				WW5= 0.00605	68SAUTER
						WGM= 0.050	
1.55		600					71FELVINCH
1.78	2.5	260.334	0.334	50.0	210.0	L = 0	JENDL-2
1.78 ± 0.01	(3)	260 ±30	A 0.31 ± 0.04	40 ±10	220 ±30	WGO= 0.23 ± 0.03	BNL325(2)
1.782	2.5	273.44	0.3467	49.29	223.8	L = 0	ENDF-B-4
1.79 ± 0.01		260 ±30	A 0.34 ± 0.04	40 ±10	220 ±30	WGO= 0.25 ± 0.03	BNL325(3)
1.74		255				WW5= 0.0259	68SAUTER
						WGM= 0.28	
1.79 ± 0.01		330 ±50	A 0.35 ± 0.04				70RYABOV
1.79		240					71FELVINCH
2.17	2.5	125.03	0.03	10.0	115.0	L = 0	JENDL-2
2.17 ± 0.01		170 ±20	A 0.072		115 ±20	WGO= 0.048	BNL325(3)
2.15		180					71FELVINCH
2.29	2.5	110.17	0.17	50.0	60.0	L = 0	JENDL-2
2.30 ± 0.01	(3)	86 ±12	A 0.18 ± 0.03	40 ±10	46 ± 7	WGO= 0.12 ± 0.02	BNL325(2)
2.279	2.5	101.82	0.1935	45.15	56.48	L = 0	ENDF-B-4
2.29 ± 0.01		75 ±10	A 0.17 ± 0.03	40 ±10	35 ± 5	WGO= 0.11 ± 0.02	BNL325(3)
2.29		95				WW5= 0.0432	68SAUTER
						WGM= 0.18	
2.30		500				WGO= 0.012	70KOLAR
2.32 ± 0.02		60 ±20	A 0.17 ± 0.04				70RYABOV
2.27		70					71FELVINCH
3.49	2.5	500.07	0.07	45.0	455.0	L = 0	JENDL-2
3.415	2.5	465.34	0.07681	0.06425	465.2	L = 0	ENDF-B-4
3.49 ± 0.07		500 ±200	A 0.07	(45)	455 ±200	WGO= 0.037	BNL325(3)
3.49		700				WGO= 0.089	70KOLAR
3.30		550					71FELVINCH
3.62	2.5	185.1	0.1	50.0	135.0	L = 0	JENDL-2
3.66 ± 0.02	(3)	230 ±30	A 0.141± 0.013	53 ±15	180 ±20	WGO= 0.074± 0.007	BNL325(2)
3.616	2.5	155.49	0.0931	45.6	109.8	L = 0	ENDF-B-4
3.66 ± 0.01		185 ±20	A 0.12 ± 0.02	50 ±15	135 ±20	WGO= 0.063± 0.011	BNL325(3)
3.61		180				WW5= 0.0156	68SAUTER
						WGM= 0.15	
3.66		130				WGO= 0.040	70KOLAR
3.68 ± 0.02		220 ±40	A 0.13 ± 0.02				70RYABOV
3.60		180					71FELVINCH
4.76	2.5	900.31	0.31	45.0	855.0	L = 0	JENDL-2
4.81 ± 0.03	(2)	900 ±200	A 0.28 ± 0.07	70 ±30	800 ±200	WGO= 0.13 ± 0.03	BNL325(2)
4.748	2.5	858.11	0.2997	28.91	828.9	L = 0	ENDF-B-4
4.76 ± 0.01	(2)	900 ±100	A 0.24 ± 0.07	(45)	855 ±100	WGO= 0.11 ± 0.03	BNL325(3)
4.72		995				WW5= 0.00874	68SAUTER
						WGM= 0.39	
4.77		1000				WGO= 0.186	70KOLAR
4.82 ± 0.03		600 ±280	A 0.25 ± 0.07				70RYABOV
4.75		900					71FELVINCH
5.89	2.5	320.133	0.13282	39.0	281.0	L = 0	JENDL-2
5.95 ± 0.07	(3)	380 ±110	A 0.15 ± 0.05	80 ±40	300 ±100	WGO= 0.06 ± 0.02	BNL325(2)
5.865	2.5	340.63	0.143	39.69	300.8	L = 0	ENDF-B-4
5.89 ± 0.02		350 ±70	A 0.17 ± 0.03	(45)	320 ±50	WGO= 0.070± 0.012	BNL325(3)
5.77		300				WW5= 0.00367	68SAUTER
5.89		350				WGO= 0.060	70KOLAR
5.86		350					71FELVINCH
5.89		320			281	GFS= 26	74NIZAMUDDIN
6.27	2.5	538.062	6.178-2	39.0	499.0	L = 0	JENDL-2
6.27		538				GFS= 12	74NIZAMUDDIN-A
6.64	2.5	500.313	0.31264	39.0	461.0	L = 0	JENDL-2
6.64		500				GFS= 57	74NIZAMUDDIN-A
6.363	2.5	757.23	0.1839	11.85	745.2	L = 0	ENDF-B-4
6.42 ± 0.02		600 ±75	A 0.22 ± 0.11	(45)	570 ±75	WGO= 0.087± 0.04	BNL325(3)
6.40		650				WGO= 0.086	70KOLAR
6.44		500					71FELVINCH
6.82	2.5	138.796	0.79645	39.0	99.0	L = 0	JENDL-2
6.82 ± 0.05	(3)	190 ±30	A 0.89 ± 0.08	53 ±15	140 ±20	WGO= 0.34 ± 0.03	BNL325(2)

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH* (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS**	REFERENCE
6.79	2.5	172.88	0.9207	43.26	128.7	L = 0	ENDF-B-4
6.81 ± 0.02		150 ±30	A 0.78 ± 0.12		108 ±20	WGO= 0.30 ± 0.05	BNL325(3)
6.77		210				WW5= 0.1338	68SAUTER
6.81		170				WGO= 0.380	70KOLAR
6.85 ± 0.04		170 ±60	A 0.61 ± 0.12				70RYABOV
6.75		150					71FELVINCH
6.82		138 ±10			99 ± 6	GFS= 110 ±12	74NIZAMUDDIN
7.5	2.5	200.028	0.028	39.0	161.0	L = 0	JENDL-2
7.60 ± 0.07	3)	200 ±50	A 0.041± 0.014	48 ±15	150 ±50	WGO= 0.015± 0.005	BNL325(2)
7.49	2.5	183.28	0.02374	35.56	147.7	L = 0	ENDF-B-4
7.48 ± 0.02		170 ±30	A 0.038± 0.007	48 ±15	120 ±30	WGO= 0.015± 0.003	BNL325(3)
7.46		135				WW5= 0.00222	68SAUTER
7.50		200				WGO= 0.014	70KOLAR
7.46		200					71FELVINCH
7.50		200			161	GFS= 5	74NIZAMUDDIN
7.80		500				WGO= 0.012	70KOLAR
8.0	2.5	2039.08	0.08	39.0	2000.0	L = 0	JENDL-2
8.33		500				WGO= 0.010	70KOLAR
8.64	2.5	339.05	0.05	39.0	300.0	L = 0	JENDL-2
8.75 ± 0.07		500 ±200	A 0.06 ± 0.03	40 ±20	500 ±200	WGO= 0.020± 0.010	BNL325(2)
8.582	2.5	421.14	0.0722	45.77	375.3	L = 0	ENDF-B-4
8.67 ± 0.02		380 ±50	A 0.038± 0.019	40 ±20	340 ±60	WGO= 0.013± 0.007	BNL325(3)
8.67		745				WW5= 0.00631	68SAUTER
8.68		390				WGO= 0.024	70KOLAR
8.64		248			209	GFS= 5	74NIZAMUDDIN
9.26	2.5	298.12	0.12	39.0	259.0	L = 0	JENDL-2
9.30 ± 0.10	3)	250 ±50	A 0.11 ± 0.03	50 ±20	200 ±50	WGO= 0.035± 0.010	BNL325(2)
9.237	2.5	334.05	0.1611	47.09	286.8	L = 0	ENDF-B-4
9.26 ± 0.02		300 ±50	A 0.13 ± 0.03	50 ±20	250 ±50	WGO= 0.043± 0.010	BNL325(3)
9.17		240				WW5= 0.00667	68SAUTER
9.25		250				WGO= 0.039	70KOLAR
9.33		360					71FELVINCH
9.26		298			259	GFS= 15	74NIZAMUDDIN
9.71	2.5	500.06	0.06	39.0	461.0	L = 0	JENDL-2
9.68 ± 0.02		600 ±50	A 0.13	(45)	555 ±50	WGO= 0.042	BNL325(3)
9.66		650				WGO= 0.041	70KOLAR
9.71		500				GFS= 4	74NIZAMUDDIN-A
10.39	2.5	316.662	1.6618	57.0	258.0	L = 0	JENDL-2
10.45 ± 0.10	3)	340 ±50	A 1.55 ± 0.13	80 ±40	260 ±30	WGO= 0.48 ± 0.04	BNL325(2)
10.35	2.5	335.38	1.731	52.35	281.3	L = 0	ENDF-B-4
10.37 ± 0.02		320 ±30	A 1.66 ± 0.08		260 ±30	WGO= 0.515± 0.025	BNL325(3)
10.30		280				WW5= 0.1182	68SAUTER
10.38		320				WGO= 0.520	70KOLAR
10.50 ± 0.06		270 ±90	A 1.5 ± 0.3				70RYABOV
10.35		350					71FELVINCH
10.39		315 ±20			258 ±16	GFS= 172 ± 2	74NIZAMUDDIN
10.86	2.5	1000.01	8.606-3	39.0	961.0	L = 0	JENDL-2
10.86 ± 0.04		350	A 0.073			WGO= 0.022	BNL325(3)
11.00		350				WGO= 0.022	70KOLAR
10.86		1000				GFS= 1	74NIZAMUDDIN-A
11.31	2.5	439.2	0.2	39.0	400.0	L = 0	JENDL-2
11.5 ± 0.2			A 0.20 ± 0.07	(45)	350 ±150	WGO= 0.06 ± 0.02	BNL325(2)
11.26	2.5	553.03	0.3067	33.42	519.3	L = 0	ENDF-B-4
11.31 ± 0.02	2)	325 ±60	A 0.20 ± 0.07		280 ±60	WGO= 0.059± 0.021	BNL325(3)
11.30		220				WW5= 0.00682	68SAUTER
11.32		350				WGO= 0.060	70KOLAR
11.20		350					71FELVINCH
11.31		218			179	GFS= 8	74NIZAMUDDIN
11.89	2.5	2000.5	0.5	39.0	1961.0	L = 0	JENDL-2
12.05 ± 0.04		900	A 0.30 ± 0.05			WGO= 0.086± 0.014	BNL325(3)
11.81		200				WW5= 0.0345	68SAUTER
12.05		900				WGO= 0.090	70KOLAR
11.69		200					71FELVINCH
11.89		2000				GFS= 129	74NIZAMUDDIN-A
12.22		500					71FELVINCH
12.79	2.5	310.446	1.4457	55.0	254.0	L = 0	JENDL-2
12.9 ± 0.1			A 1.4 ± 0.2	(45)	260 ±30	WGO= 0.40 ± 0.06	BNL325(2)
12.74	2.5	339.62	1.46	40.86	297.3	L = 0	ENDF-B-4
12.81 ± 0.03		310 ±15	A 1.4 ± 0.1		265 ±20	WGO= 0.39 ± 0.03	BNL325(3)
12.74		295				WW5= 0.0786	68SAUTER
12.81		300				WGO= 0.408	70KOLAR
12.65 ± 0.08		340 ±120	A 1.3 ± 0.4				70RYABOV
12.73		300					71FELVINCH
12.79		309 ±20			254 ±16	GFS= 122 ± 3	74NIZAMUDDIN

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH* (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS**	REFERENCE
13.45	2.5	144.056	5.619-2	39.0	105.0	L = 0	JENDL-2
13.43	2.5	900.54	0.3361	240.5	659.7	L = 0	ENDF-B-4
13.45 ± 0.06		165	A 0.055		120	WGO= 0.015	BNL325(3)
13.45		150				WGO= 0.015	70KOLAR
13.45		144 ±40			105	GFS= 4 ± 1	74NIZAMUDDIN
13.73	2.5	255.309	0.30863	39.0	216.0	L = 0	JENDL-2
13.8 ± 0.2			A 0.41 ± 0.07	(45)	320 ±40	WGO= 0.11 ± 0.02	BNL325(2)
13.73	2.5	212.29	0.1852	4.501	207.6	L = 0	ENDF-B-4
13.74 ± 0.03		320 ±40	A 0.39 ± 0.05		270 ±40	WGO= 0.11 ± 0.01	BNL325(3)
13.54		345				WWS= 0.0267	68SAUTER
13.74		300				WGO= 0.106	70KOLAR
13.9 ± 0.1		380 ±130	A 0.33 ± 0.07				70RYABOV
13.66		320					71FELVINCH
13.73		255 ±24			216	GFS= 25 ± 1	74NIZAMUDDIN
13.95		1000				GFS= 15	74NIZAMUDDIN-A
14.22		490				GFS= 2	74NIZAMUDDIN-A
15.33	2.5	122.464	0.46448	30.0	92.0	L = 0	JENDL-2
15.3	2.5	243.25	1.012	66.94	175.3	L = 0	ENDF-B-4
15.35 ± 0.03		235 ±30	A 0.47 ± 0.06	(45)	190 ±20	WGO= 0.12 ± 0.02	BNL325(3)
15.28		260				WWS= 0.155	68SAUTER
15.36		90				WGO= 0.120	70KOLAR
15.34		240					71FELVINCH
15.33		122 ±22			92 ±25	GFS= 30 ± 6	74NIZAMUDDIN
15.47	2.5	255.473	0.47292	39.0	216.0	L = 0	JENDL-2
15.47		255				GFS= 34	74NIZAMUDDIN-A
15.5 ± 0.1			A 0.90 ± 0.12	(45)	170 ±20	WGO= 0.23 ± 0.03	BNL325(2)
15.54 ± 0.03		225 ±25	A 0.425± 0.060	(45)	180 ±25	WGO= 0.11 ± 0.02	BNL325(3)
15.51		225				WGO= 0.108	70KOLAR
15.5 ± 0.1		200 ±60	A 0.84 ± 0.34				70RYABOV
15.84		250					71FELVINCH
15.82	2.5	200.02	0.02	39.0	161.0	L = 0	JENDL-2
15.82		200				GFS= 6	74NIZAMUDDIN-A
16.2	2.5	426.896	0.89638	39.0	387.0	L = 0	JENDL-2
16.4 ± 0.2			A 1.2 ± 0.3	(45)	600 ±200	WGO= 0.30 ± 0.08	BNL325(2)
16.15	2.5	530.72	1.018	36.1	493.6	L = 0	ENDF-B-4
16.29 ± 0.06	(2)	530 ±70	A 1.35 ± 0.10	(45)	485 ±70	WGO= 0.334± 0.025	BNL325(3)
16.14		395				WWS= 0.0367	68SAUTER
16.26		600				WGO= 0.334	70KOLAR
16.13		200					71FELVINCH
16.20		426			387	GFS= 66	74NIZAMUDDIN
16.56	2.5	219.706	0.70587	39.0	180.0	L = 0	JENDL-2
16.7 ± 0.2			A 0.41 ± 0.12	(45)	100 ±40	WGO= 0.10 ± 0.03	BNL325(2)
16.5	2.5	213.59	0.589	40.6	172.4	L = 0	ENDF-B-4
16.59 ± 0.03		172 ±20	A 0.48 ± 0.03	(45)	127 ±20	WGO= 0.118± 0.007	BNL325(3)
16.49		225				WWS= 0.0613	68SAUTER
16.59		150				WGO= 0.118	70KOLAR
16.6 ± 0.2		650 ±130	A 1.16 ± 0.25				70RYABOV
16.50		300					71FELVINCH
16.56		219 ±20			180	GFS= 46 ± 2	74NIZAMUDDIN
17.28		1500				GFS= 22	74NIZAMUDDIN-A
17.63		900				GFS= 5	74NIZAMUDDIN-A
17.97	2.5	208.32	0.32005	39.0	169.0	L = 0	JENDL-2
18.1 ± 0.2			A 0.30 ± 0.09	(45)	160 ±30	WGO= 0.07 ± 0.02	BNL325(2)
17.93	2.5	159.76	0.2612	30.5	129.0	L = 0	ENDF-B-4
18.01 ± 0.03		205 ±30	A 0.42 ± 0.03	(45)	160 ±30	WGO= 0.099± 0.007	BNL325(3)
17.91		160				WWS= 0.0181	68SAUTER
18.01		250				WGO= 0.099	70KOLAR
18.2 ± 0.2		200 ±50	A 0.26 ± 0.09				70RYABOV
17.93		200					71FELVINCH
17.97		208 ±20			169	GFS= 19 ± 1	74NIZAMUDDIN
18.28	2.5	379.015	0.015	39.0	340.0	L = 0	JENDL-2
18.28		379				GFS= 9	74NIZAMUDDIN-A
18.48	2.5	135.158	0.15834	39.0	96.0	L = 0	JENDL-2
18.6 ± 0.3			A 0.17 ± 0.09	(45)	120 ±60	WGO= 0.04 ± 0.02	BNL325(2)
18.46	2.5	257.0	0.1809	66.22	190.6	L = 0	ENDF-B-4
18.50 ± 0.06		225 ±30	A 0.23 ± 0.03	(45)	180 ±30	WGO= 0.054± 0.007	BNL325(3)
18.41		160				WWS= 0.0119	68SAUTER
18.50		250				WGO= 0.061	70KOLAR
18.47		250					71FELVINCH
18.48		135 ±16			96	GFS= 8 ± 4	74NIZAMUDDIN
18.96	2.5	317.754	1.7538	22.0	294.0	L = 0	JENDL-2
19.1 ± 0.2			A 1.7 ± 0.2	(45)	270 ±40	WGO= 0.39 ± 0.04	BNL325(2)

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH* (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS**	REFERENCE
18.87	2.5	310.71	1.756	44.25	264.7	L = 0	ENDF-B-4
18.98 ± 0.03		300 ±20	A 1.74 ± 0.08	(45)	253 ±20	WGO= 0.399± 0.018	BNL325(3)
18.90		325				WW5= 0.1323	68SAUTER
18.98		270				WGO= 0.406	70KOLAR
19.0 ± 0.2		300 ±130	A 1.6 ± 0.3				70RYABOV
18.91		300					71FELVINCH
18.96		316 ±20			294 ±18	GFS= 113 ± 2	74NIZAMUDDIN
19.40		500				WGO= 0.060	70KOLAR
19.63	2.5	2500.39	0.39487	39.0	2461.0	L = 0	JENDL-2
19.63		2500				GFS= 26	74NIZAMUDDIN-A
19.94		400				WGO= 0.018	70KOLAR
20.59	2.5	364.773	0.77279	39.0	325.0	L = 0	JENDL-2
20.8 ± 0.2			A 1.1 ± 0.2	(45)	420 ±50	WGO= 0.24 ± 0.04	BNL325(2)
20.53	2.5	466.62	1.078	57.94	407.6	L = 0	ENDF-B-4
20.54 ± 0.03		450 ±40	A 1.17 ± 0.08	(45)	404 ±40	WGO= 0.258± 0.018	BNL325(3)
20.58				45	360	WGO= 0.38	68BERGEN
20.57		615				WW5= 0.0748	68SAUTER
20.64		450				WGO= 0.258	70KOLAR
20.6 ± 0.2		450 ±110	A 1.3 ± 0.2				70RYABOV
20.52		400					71FELVINCH
20.59		364 ±25			325	GFS= 44 ± 1	74NIZAMUDDIN
21.47		400				WGO= 0.038	70KOLAR
21.58	2.5	2000.59	0.58669	39.0	1961.0	L = 0	JENDL-2
21.58		2000				GFS= 35	74NIZAMUDDIN-A
21.86	2.5	255.062	1.0621	39.0	215.0	L = 0	JENDL-2
22.1 ± 0.3			A 0.9 ± 0.3	(45)	180 ±50	WGO= 0.20 ± 0.06	BNL325(2)
21.83	2.5	248.75	1.094	52.46	195.2	L = 0	ENDF-B-4
21.90 ± 0.04		250 ±25	A 1.2 ± 0.3	(45)	204 ±25	WGO= 0.26 ± 0.06	BNL325(3)
21.88					200	WGO= 0.53	68BERGEN
21.81		225				WW5= 0.112	68SAUTER
21.90		250				WGO= 0.314	70KOLAR
21.75		200					71FELVINCH
21.86		254 ±20			215	GFS= 54 ± 2	74NIZAMUDDIN
22.34	2.5	415.332	3.3317	48.0	364.0	L = 0	JENDL-2
22.5 ± 0.3			A 3.3 ± 0.5	(45)	370 ±60	WGO= 0.70 ± 0.11	BNL325(2)
22.24	2.5	441.35	3.424	47.03	390.9	L = 0	ENDF-B-4
22.35 ± 0.04		450 ±50	A 3.4 ± 0.2	40	407 ±50	WGO= 0.72 ± 0.04	BNL325(3)
22.36					350	WGO= 1.51	68BERGEN
22.35		390				WW5= 0.1833	68SAUTER
22.37		350				WGO= 0.714	70KOLAR
22.28		480					71FELVINCH
22.34		412 ±30			364 ±21	GFS= 173 ± 2	74NIZAMUDDIN
22.9	2.5	692.554	0.55448	39.0	653.0	L = 0	JENDL-2
22.84	2.5	980.13	0.8837	0.04498	979.2	L = 0	ENDF-B-4
22.93 ± 0.04		730 ±50	A 0.85 ± 0.08	(45)	684	WGO= 0.18 ± 0.02	BNL325(3)
22.96					450	WGO= 0.18	68BERGEN
22.93		700				WGO= 0.178	70KOLAR
22.89		760					71FELVINCH
22.9		692			653	GFS= 30	74NIZAMUDDIN
23.75	2.5	453.554	0.55419	39.0	414.0	L = 0	JENDL-2
24.0 ± 0.3			A 1.0 ± 0.4	(45)	600 ±300	WGO= 0.20 ± 0.08	BNL325(2)
23.66	2.5	555.29	0.4704	30.62	524.2	L = 0	ENDF-B-4
23.77 ± 0.04		450 ±50	A 0.60 ± 0.15		385 ±40	WGO= 0.12 ± 0.03	BNL325(3)
23.78					390	WGO= 0.22	68BERGEN
23.62		945				WW5= 0.0334	68SAUTER
23.77		450				WGO= 0.124	70KOLAR
23.67		640					71FELVINCH
23.75		453 ±30			414	GFS= 28 ± 1	74NIZAMUDDIN
24.3	2.5	1000.52	0.51997	39.0	961.0	L = 0	JENDL-2
24.25	2.5	549.61	0.2894	40.92	508.4	L = 0	ENDF-B-4
24.26 ± 0.04		700	A 0.48 ± 0.04	(45)	654	WGO= 0.098± 0.008	BNL325(3)
24.26					530	WGO= 0.105	68BERGEN
24.28		700				WGO= 0.088	70KOLAR
24.3		1000			961	GFS= 27	74NIZAMUDDIN
24.64					200	WGO= 0.01	68BERGEN
25.26	2.5	274.74	0.73993	39.0	235.0	L = 0	JENDL-2
25.5 ± 0.3			A 1.0 ± 0.3	(45)	330 ±100	WGO= 0.20 ± 0.06	BNL325(2)
25.13	2.5	356.09	0.8086	45.68	309.6	L = 0	ENDF-B-4
25.28 ± 0.04		315 ±30	A 0.88 ± 0.09		290 ±30	WGO= 0.175± 0.018	BNL325(3)
25.27					260	WGO= 0.30	68BERGEN
25.20		270				WW5= 0.0578	68SAUTER
25.30		320				WGO= 0.174	70KOLAR
25.20		380					71FELVINCH
25.25		274 ±25			235	GFS= 33 ± 1	74NIZAMUDDIN

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH * (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS **	REFERENCE
25.78	2.5	660.522	0.52169	39.0	621.0	L = 0	JENDL-2
25.86	2.5	629.59	0.5686	43.62	585.4	L = 0	ENDF-B-4
25.85 ± 0.04		600 ±200	A 0.8 ± 0.2	(45)	554 ±200	WGO= 0.16 ± 0.04	BNL325(3)
25.75					340	WGO= 0.10	68BERGEN
25.72		75				WW5= 0.00267	68SAUTER
25.89		900				WGO= 0.152	70KOLAR
25.86		360					71FELVINCH
25.78		660			621	GFS= 25	74NIZAMUDDIN
26.08					200	WGO= 0.05	68BERGEN
26.25	2.5	495.239	0.23872	39.0	456.0	L = 0	JENDL-2
26.30 ± 0.04		150	A 0.036	45	105	WGO= 0.007	BNL325(3)
26.30					100	WGO= 0.035	68BERGEN
26.33		150				WGO= 0.007	70KOLAR
26.25		495			456	GFS= 11	74NIZAMUDDIN
26.62	2.5	260.358	0.35778	39.0	221.0	L = 0	JENDL-2
26.57	2.5	438.68	0.6029	45.48	392.6	L = 0	ENDF-B-4
26.65 ± 0.04		300	A 0.70 ± 0.18	(45)	254	WGO= 0.14 ± 0.04	BNL325(3)
26.65					300	WGO= 0.17	68BERGEN
26.53		250				WW5= 0.0404	68SAUTER
26.66		300				WGO= 0.098	70KOLAR
26.54		480					71FELVINCH
26.62		260 ±24			221	GFS= 15 ± 1	74NIZAMUDDIN
26.98	2.5	592.154	0.15398	39.0	553.0	L = 0	JENDL-2
27.00				(45)	433	WGO= 0.104	BNL325(2)
27.1	2.5	364.91	0.05224	59.96	304.9	L = 0	ENDF-B-4
27.04 ± 0.04		600 ±50	A 0.17		540 ±50	WGO= 0.033	BNL325(3)
27.05					200	WGO= 0.015	68BERGEN
27.15		600				WGO= 0.032	70KOLAR
26.98		592			553	GFS= 7	74NIZAMUDDIN
27.76	2.5	900.508	0.5083	39.0	861.0	L = 0	JENDL-2
27.84	2.5	690.75	0.1209	0.2301	690.4	L = 0	ENDF-B-4
27.74					800	WGO= 0.135	68BERGEN
27.76		900			861	GFS= 23	74NIZAMUDDIN
28.07	2.5	168.028	2.784-2	39.0	129.0	L = 0	JENDL-2
28.09 ± 0.04			A 0.027± 0.010			WGO= 0.0051± 0.0019	BNL325(3)
28.00					130	WGO= 0.007	68BERGEN
28.05		800				WGO= 0.102	70KOLAR
28.07		168			129	GFS= 1	74NIZAMUDDIN
28.28	2.5	230.233	0.23343	39.0	191.0	L = 0	JENDL-2
28.26	2.5	853.61	0.7386	54.77	598.1	L = 0	ENDF-B-4
28.38 ± 0.04			A 0.50 ± 0.15			WGO= 0.094± 0.028	BNL325(3)
28.32					250	WGO= 0.105	68BERGEN
28.38		170				WGO= 0.038	70KOLAR
28.17		220					71FELVINCH
28.28		230 ±30			191	GFS= 9 ± 1	74NIZAMUDDIN
28.85					320	WGO= 0.135	68BERGEN
29.04	2.5	541.764	1.7641	39.0	501.0	L = 0	JENDL-2
29.2 ± 0.4			A 1.6 ± 0.3	(45)	460 ±150	WGO= 0.30 ± 0.06	BNL325(2)
29.05	2.5	457.64	1.469	44.17	412.0	L = 0	ENDF-B-4
29.07 ± 0.04		530 ±40	A 1.8 ± 0.2	(45)	484 ±40	WGO= 0.33 ± 0.04	BNL325(3)
29.12					290	WGO= 0.338	68BERGEN
28.76		505				WW5= 0.0616	68SAUTER
29.11		530				WGO= 0.352	70KOLAR
29.00		540					71FELVINCH
29.04		540 ±40			501	GFS= 74 ± 1	74NIZAMUDDIN
29.58	2.5	112.138	0.13826	39.0	73.0	L = 0	JENDL-2
29.56	2.5	152.27	0.1199	33.25	118.9	L = 0	ENDF-B-4
29.61 ± 0.04		200 ±50	A 0.3 ± 0.1	(45)	155 ±50	WGO= 0.055± 0.018	BNL325(3)
29.59					150	WGO= 0.073	68BERGEN
29.65		250				WGO= 0.036	70KOLAR
29.54		160					71FELVINCH
29.58		112			73	GFS= 4	74NIZAMUDDIN
30.35	2.5	396.154	0.15384	39.0	357.0	L = 0	JENDL-2
30.36	2.5	261.06	0.1034	59.26	201.7	L = 0	ENDF-B-4
30.39 ± 0.04		400 ±50	A 0.13 ± 0.03	(45)	355 ±50	WGO= 0.024± 0.005	BNL325(3)
30.30					130	WGO= 0.02	68BERGEN
30.43		400				WGO= 0.028	70KOLAR
30.35		396			357	GFS= 6	74NIZAMUDDIN
30.72	2.5	261.627	0.62701	37.0	224.0	L = 0	JENDL-2
30.71	2.5	345.42	0.694	46.23	298.5	L = 0	ENDF-B-4
30.75 ± 0.04		260 ±30	A 0.8 ± 0.2	(45)	214 ±30	WGO= 0.14 ± 0.04	BNL325(3)
30.73					260	WGO= 0.215	68BERGEN
30.76		445				WW5= 0.0647	68SAUTER
30.79		250				WGO= 0.114	70KOLAR
30.72		261 ±21			224 ±23	GFS= 23 ± 1	74NIZAMUDDIN

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH* (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS**	REFERENCE
31.33	2.5	325.298	0.29827	39.0	286.0	L = 0	JENDL-2
31.2 ± 0.4			A 0.8 ± 0.2	(45)	400 ±150	WGO= 0.15 ± 0.04	BNL325(2)
31.39	2.5	443.33	0.5567	46.37	396.4	L = 0	ENDF-B-4
31.39 ± 0.04		450 ±70	A 0.71 ± 0.07	(45)	404 ±70	WGO= 0.127± 0.013	BNL325(3)
31.35					230	WGO= 0.10	68BERGEN
31.44		550				WGO= 0.126	70KOLAR
31.33		325			286	GFS= 11	74NIZAMUDDIN
31.69	2.5	600.465	0.46464	39.0	561.0	L = 0	JENDL-2
31.66					200	WGO= 0.075	68BERGEN
31.69		600				GFS= 18	74NIZAMUDDIN-A
32.01	2.5	217.951	0.95107	39.0	178.0	L = 0	JENDL-2
32.3 ± 0.4			A 1.1 ± 0.2		200 ±70	WGO= 0.19 ± 0.03	BNL325(2)
31.98	2.5	234.36	1.004	40.46	192.9	L = 0	ENDF-B-4
32.06 ± 0.04		330 ±50	A 1.64 ± 0.08	(45)	284 ±50	WGO= 0.290± 0.014	BNL325(3)
32.04					170	WGO= 0.30	68BERGEN
32.09		350				WGO= 0.278	70KOLAR
32.01		217 ±20			178	GFS= 32 ± 1	74NIZAMUDDIN
33.14	2.5	740.719	0.71939	39.0	701.0	L = 0	JENDL-2
33.01	2.5	796.17	1.173	42.1	752.9	L = 0	ENDF-B-4
33.14 ± 0.04		900 ±150	A 1.26 ± 0.10	(45)	853 ±150	WGO= 0.218± 0.017	BNL325(3)
33.11					750	WGO= 0.27	68BERGEN
33.18		1000				WGO= 0.218	70KOLAR
33.14		740			701	GFS= 27	74NIZAMUDDIN
33.67					500	WGO= 0.11	68BERGEN
33.95	2.5	1301.79	1.786	39.0	1261.0	L = 0	JENDL-2
34.04	2.5	572.06	0.6648	45.9	525.5	L = 0	ENDF-B-4
34.02 ± 0.04		1000	A 1.35 ± 0.14			WGO= 0.23 ± 0.02	BNL325(3)
34.06					480	WGO= 0.155	68BERGEN
34.02		1000				WGO= 0.228	70KOLAR
33.95		1300			1261	GFS= 67	74NIZAMUDDIN
34.51	2.5	648.192	1.1924	48.0	599.0	L = 0	JENDL-2
34.9 ± 0.5			A 1.7 ± 0.4		700 ±200	WGO= 0.29 ± 0.07	BNL325(2)
34.47	2.5	659.88	1.431	43.85	614.6	L = 0	ENDF-B-4
34.55 ± 0.04		630 ±50	A 2.2 ± 0.4	(45)	583 ±50	WGO= 0.37 ± 0.07	BNL325(3)
34.55					550	WGO= 0.37	68BERGEN
34.58		600				WGO= 0.206	70KOLAR
34.51		647 ±44			599 ±58	GFS= 42 ± 2	74NIZAMUDDIN
35.25	2.5	395.238	0.2383	39.0	356.0	L = 0	JENDL-2
35.17	2.5	346.61	0.07792	27.33	319.2	L = 0	ENDF-B-4
35.20 ± 0.04		500	A 0.20	(45)	455	WGO= 0.034	BNL325(3)
35.27					450	WGO= 0.114	68BERGEN
35.20		500				WGO= 0.034	70KOLAR
35.25		395			356	GFS= 8	74NIZAMUDDIN
35.62					300	WGO= 0.024	68BERGEN
35.75	2.5	900.683	0.68306	39.0	861.0	L = 0	JENDL-2
35.44	2.5	815.69	0.7456	50.74	764.2	L = 0	ENDF-B-4
35.89 ± 0.04		1100 ±400	A 1.4 ± 0.2	(45)	1100 ±400	WGO= 0.23 ± 0.03	BNL325(3)
35.96					750	WGO= 0.14	68BERGEN
35.75		1500				WGO= 0.264	70KOLAR
35.75		900			861	GFS= 24	74NIZAMUDDIN
36.53	2.5	197.798	0.79785	39.0	158.0	L = 0	JENDL-2
37.1 ± 0.5			A 0.9 ± 0.3		270 ±80	WGO= 0.15 ± 0.05	BNL325(2)
36.54	2.5	236.42	0.926	45.99	189.5	L = 0	ENDF-B-4
36.60 ± 0.04		170 ±20	A 1.07 ± 0.13		110 ±20	WGO= 0.177± 0.021	BNL325(3)
36.59					110	WGO= 0.20	68BERGEN
36.65		170				WGO= 0.156	70KOLAR
36.53		197 ±20			158	GFS= 23 ± 1	74NIZAMUDDIN
37.2	2.5	420.094	9.369-2	39.0	381.0	L = 0	JENDL-2
37.20		420				GFS= 3	74NIZAMUDDIN-A
37.48	2.5	395.697	0.69679	39.0	356.0	L = 0	JENDL-2
37.44	2.5	383.81	0.6705	42.74	340.4	L = 0	ENDF-B-4
37.50 ± 0.04		420 ±20	A 0.78 ± 0.11		380 ±20	WGO= 0.127± 0.018	BNL325(3)
37.51					380	WGO= 0.21	68BERGEN
37.55		430				WGO= 0.128	70KOLAR
37.48		395			356	GFS= 22	74NIZAMUDDIN
39.08					200	WGO= 0.055	68BERGEN
39.33	2.5	686.794	0.794	39.0	647.0	L = 0	JENDL-2
39.33	2.5	381.21	0.4117	37.5	343.3	L = 0	ENDF-B-4
39.40 ± 0.05		775 ±100	A 1.1 ± 0.2	(45)	729 ±100	WGO= 0.175± 0.032	BNL325(3)
39.32				45	250	WGO= 0.056	68BERGEN
39.42		850				WGO= 0.170	70KOLAR
39.33		686			647	GFS= 25	74NIZAMUDDIN
39.56					250	WGO= 0.055	68BERGEN

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH * (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS**	REFERENCE
39.83	2.5	445.266	0.26599	39.0	406.0	L = 0	JENDL-2
39.86	2.5	1390.8	0.6714	58.16	1332.0	L = 0	ENDF-B-4
39.94 ± 0.05		580 ±70	A 0.49 ± 0.10	(45)	535 ±70	WGO= 0.078± 0.016	BNL325(3)
39.89					600	WGO= 0.145	68BERGEN
40.00		800				WGO= 0.074	70KOLAR
39.83		445 ±10			406	GFS= 8 ± 1	74NIZAMUDDIN
40.41	2.5	901.062	1.0616	39.0	861.0	L = 0	JENDL-2
40.3	2.5	1250.1	1.173	38.95	1210.0	L = 0	ENDF-B-4
40.50 ± 0.05		650 ±70	A 0.9 ± 0.2	(45)	604 ±70	WGO= 0.14 ± 0.03	BNL325(3)
40.49					650	WGO= 0.175	68BERGEN
40.50		600				WGO= 0.112	70KOLAR
40.41		900			861	GFS= 33	74NIZAMUDDIN
41.03	2.5	175.34	0.34	39.0	136.0	L = 0	JENDL-2
41.02	2.5	165.28	0.3171	49.96	115.0	L = 0	ENDF-B-4
41.06 ± 0.05		225 ±75	A 0.59 ± 0.03	(45)	179 ±75	WGO= 0.092± 0.005	BNL325(3)
41.06					190	WGO= 0.091	68BERGEN
41.15		300				WGO= 0.094	70KOLAR
41.03		175 ±22			136	GFS= 9 ± 1	74NIZAMUDDIN
41.79	2.5	392.035	3.534-2	39.0	353.0	L = 0	JENDL-2
41.75					150	WGO= 0.009	68BERGEN
41.79		392 ±30			353	GFS= 1	74NIZAMUDDIN
42.09	2.5	592.137	0.13727	39.0	553.0	L = 0	JENDL-2
42.27	2.5	210.82	0.06233	46.46	164.3	L = 0	ENDF-B-4
42.09 ± 0.05		700 ±100	A 0.24 ± 0.02	(45)	655 ±100	WGO= 0.037± 0.003	BNL325(3)
42.16					350	WGO= 0.035	68BERGEN
42.05		800				WGO= 0.040	70KOLAR
42.09		592			553	GFS= 4	74NIZAMUDDIN
42.62	2.5	209.77	0.77	57.0	152.0	L = 0	JENDL-2
42.62	2.5	206.71	0.6792	45.93	160.1	L = 0	ENDF-B-4
42.68 ± 0.05		230 ±30	A 1.0 ± 0.2	(45)	274 ±30	WGO= 0.15 ± 0.03	BNL325(3)
42.66					140	WGO= 0.19	68BERGEN
42.72		230				WGO= 0.138	70KOLAR
42.62		209 ±27			152 ±22	GFS= 20 ± 1	74NIZAMUDDIN
43.5	2.5	341.4	0.4	20.0	321.0	L = 0	JENDL-2
43.46	2.5	333.54	0.4226	43.82	289.3	L = 0	ENDF-B-4
43.57 ± 0.05		290 ±40	A 0.52 ± 0.07	(45)	244 ±30	WGO= 0.079± 0.011	BNL325(3)
43.53					240	WGO= 0.093	68BERGEN
43.62		330				WGO= 0.072	70KOLAR
43.50		341 ±32			321 ±40	GFS= 13 ± 1	74NIZAMUDDIN
44.10		300				GFS= 2	74NIZAMUDDIN-A
44.52	2.5	519.3	0.3	19.0	500.0	L = 0	JENDL-2
44.52	2.5	501.48	0.2881	10.29	490.9	L = 0	ENDF-B-4
44.70 ± 0.10		1000 ±200	A 0.70 ± 0.07	(45)	954 ±200	WGO= 0.11 ± 0.01	BNL325(3)
44.58					660	WGO= 0.086	68BERGEN
44.75		1100				WGO= 0.114	70KOLAR
44.52		1060			1041	GFS= 28 ± 4	74NIZAMUDDIN
45.25	2.5	138.025	0.025	39.0	99.0	L = 0	JENDL-2
45.25		138				GFS= 1	74NIZAMUDDIN-A
45.45	2.5	150.025	0.025	39.0	111.0	L = 0	JENDL-2
45.38					180	WGO= 0.006	68BERGEN
45.45		150 ±15			111	GFS= 1	74NIZAMUDDIN
46.1	2.5	192.39	0.39	39.0	153.0	L = 0	JENDL-2
46.03	2.5	165.78	0.466	50.51	114.8	L = 0	ENDF-B-4
46.18 ± 0.05		210 ±40	A 0.66 ± 0.05	(45)	164 ±20	WGO= 0.097± 0.007	BNL325(3)
46.16					150	WGO= 0.105	68BERGEN
46.23		250				WGO= 0.090	70KOLAR
46.10		192 ±30			153	GFS= 11 ± 1	74NIZAMUDDIN
46.53	2.5	245.08	0.08	39.0	206.0	L = 0	JENDL-2
46.72	2.5	245.0	1.7 -5	45.0	200.0	L = 0	ENDF-B-4
46.70 ± 0.05		230 ±30	A 0.075± 0.008	(45)	185 ±30	WGO= 0.011± 0.001	BNL325(3)
46.71					200	WGO= 0.01	68BERGEN
46.73		200				WGO= 0.012	70KOLAR
46.53		245			206	GFS= 2	74NIZAMUDDIN
47.16	2.5	857.76	0.7458	53.81	803.2	L = 0	ENDF-B-4
47.05					400	WGO= 0.075	68BERGEN
47.22	2.5	507.88	0.88	39.0	468.0	L = 0	JENDL-2
47.23	2.5	308.88	0.2897	40.19	268.4	L = 0	ENDF-B-4
47.37 ± 0.05		470 ±40	A 0.98 ± 0.06	(45)	424 ±40	WGO= 0.14 ± 0.09	BNL325(3)
47.36					220	WGO= 0.13	68BERGEN
47.38		470				WGO= 0.152	70KOLAR
47.22		507 ±50			468	GFS= 27 ± 1	74NIZAMUDDIN
48.68	2.5	172.6	1.6	40.0	131.0	L = 0	JENDL-2

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH * (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS **	REFERENCE
48.66	2.5	233.38	2.566	66.81	164.0	L = 0	ENDF-B-4
48.79 ± 0.05		208 ±20	A 2.8 ± 0.3	(45)	160 ±20	WGO= 0.40 ± 0.04	BNL325(3)
48.75					175	WGO= 0.445	68BERGEN
48.83		200				WGO= 0.362	70KOLAR
48.68		171 ±22			131	GFS= 40	74NIZAMUDDIN
49.1	2.5	516.5	0.5	39.0	477.0	L = 0	JENDL-2
49.12	2.5	223.98	0.1477	11.53	212.3	L = 0	ENDF-B-4
49.32 ± 0.05		270 ±25	A 0.34 ± 0.02	(45)	225 ±25	WGO= 0.048± 0.003	BNL325(3)
49.30					200	WGO= 0.050	68BERGEN
49.35		300				WGO= 0.048	70KOLAR
49.10		516			477	GFS= 14 ± 1	74NIZAMUDDIN
50.4	2.5	1100.84	0.84	39.0	1061.0	L = 0	JENDL-2
50.32	2.5	813.01	0.6602	0.45	811.9	L = 0	ENDF-B-4
50.55 ± 0.05		996 ±50	A 1.27 ± 0.05	(45)	950 ±50	WGO= 0.179± 0.007	BNL325(3)
50.48					900	WGO= 0.184	68BERGEN
50.60		1100				WGO= 0.172	70KOLAR
50.4		1100			1061	GFS= 25	74NIZAMUDDIN
51.0	2.5	500.114	0.114	39.0	461.0	L = 0	JENDL-2
51.00		500			461	GFS= 3	74NIZAMUDDIN
51.03	2.5	441.23	0.1581	18.77	422.3	L = 0	ENDF-B-4
51.40 ± 0.10		355 ±50	A 0.14 ± 0.02	(45)	310 ±50	WGO= 0.0195± 0.003	BNL325(3)
51.23					260	WGO= 0.021	68BERGEN
51.45		400				WGO= 0.019	70KOLAR
51.85	2.5	150.021	0.021	39.0	111.0	L = 0	JENDL-2
51.85		150			111	GFS= 0.5	74NIZAMUDDIN
52.1	2.5	280.055	0.055	39.0	241.0	L = 0	JENDL-2
52.07	2.5	266.34	0.05029	32.39	233.9	L = 0	ENDF-B-4
52.11 ± 0.05		290 ±30	A 0.14 ± 0.02		245 ±30	WGO= 0.0194± 0.003	BNL325(3)
52.06					300	WGO= 0.016	68BERGEN
52.15		300				WGO= 0.023	70KOLAR
52.10		280			241	GFS= 1.5	74NIZAMUDDIN
53.03	2.5	240.47	0.47	39.0	201.0	L = 0	JENDL-2
53.04	2.5	391.27	0.8944	42.88	347.5	L = 0	ENDF-B-4
53.17 ± 0.05			A 1.39		290	WGO= 0.19	BNL325(3)
53.17					290	WGO= 0.19	68BERGEN
53.03		240			201	GFS= 12	74NIZAMUDDIN
53.32	2.5	360.44	0.44	39.0	321.0	L = 0	JENDL-2
53.54 ± 0.05			A 0.40		300	WGO= 0.055	BNL325(3)
53.54					300	WGO= 0.055	68BERGEN
53.32		360			321	GFS= 12	74NIZAMUDDIN
53.94	2.5	230.198	0.19788	39.0	191.0	L = 0	JENDL-2
53.94		230				GFS= 4 ± 2	74NIZAMUDDIN-A
54.05	2.5	501.3	1.3	39.0	461.0	L = 0	JENDL-2
54.0	2.5	411.97	1.477	41.29	369.2	L = 0	ENDF-B-4
54.15 ± 0.05			A 2.2		400	WGO= 0.30	BNL325(3)
54.15					400	WGO= 0.30	68BERGEN
54.05		500 ±100			461	GFS= 36 ± 3	74NIZAMUDDIN
54.41	2.5	295.096	9.550-2	39.0	256.0	L = 0	JENDL-2
54.41		295				GFS= 2	74NIZAMUDDIN-A
54.78	2.5	264.1	1.1	39.0	224.0	L = 0	JENDL-2
54.78	2.5	291.19	1.468	50.72	239.0	L = 0	ENDF-B-4
54.89 ± 0.05			A 2.4		320	WGO= 0.33	BNL325(3)
54.89					320	WGO= 0.33	68BERGEN
54.78		263 ±20			224	GFS= 26.5	74NIZAMUDDIN
55.2	2.5	490.137	0.13703	39.0	451.0	L = 0	JENDL-2
55.20		490				GFS= 3	74NIZAMUDDIN-A
55.95	2.5	862.678	2.6782	39.0	821.0	L = 0	JENDL-2
55.92	2.5	862.45	2.166	46.68	813.6	L = 0	ENDF-B-4
55.81 ± 0.05			A 1.7		500	WGO= 0.23	BNL325(3)
55.81					500	WGO= 0.23	68BERGEN
55.95		860 ±85			821	GFS= 60 ± 8	74NIZAMUDDIN
56.04	2.5	321.84	0.1852	52.85	268.8	L = 0	ENDF-B-4
56.18 ± 0.05			A 1.5		300	WGO= 0.20	BNL325(3)
56.18					300	WGO= 0.20	68BERGEN
56.44	2.5	374.04	1.04	42.0	331.0	L = 0	JENDL-2
56.39	2.5	501.77	1.614	55.76	444.4	L = 0	ENDF-B-4
56.58 ± 0.05			A 2.6 ± 0.2		450	WGO= 0.34 ± 0.03	BNL325(3)
56.58					450	WGO= 0.34	68BERGEN
56.44		373 ±70			331	GFS= 24 ± 6	74NIZAMUDDIN
56.88	2.5	1501.25	1.2454	39.0	1461.0	L = 0	JENDL-2

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH* (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS**	REFERENCE
56.88		1500				GFS= 28	74NIZAMUDDIN-A
57.48	2.5	782.36	2.36	49.0	731.0	L = 0	JENDL-2
57.48	2.5	1013.8	3.945	37.6	972.3	L = 0	ENDF-B-4
57.55 ± 0.05			A 5.6 ± 0.7		900	WGO= 0.74 ± 0.09	BNL325(3)
57.55					900	WGO= 0.74	68BERGEN
57.48		780 ±60			731	GFS= 53 ± 2	74NIZAMUDDIN
58.18	2.5	1301.51	1.5075	39.0	1261.0	L = 0	JENDL-2
58.18		1300				GFS= 33	74NIZAMUDDIN-A
58.52	2.5	225.56	0.56	39.0	186.0	L = 0	JENDL-2
58.5	2.5	413.3	1.086	41.11	371.1	L = 0	ENDF-B-4
58.54 ± 0.05			A 1.76		350	WGO= 0.23	BNL325(3)
58.54					350	WGO= 0.23	68BERGEN
58.52		225 ±30			186	GFS= 13 ± 1	74NIZAMUDDIN
59.35	2.5	345.0	0.00478	45.0	300.0	L = 0	ENDF-B-4
59.35 ± 0.05			A 0.069		300	WGO= 0.009	BNL325(3)
59.35					300	WGO= 0.009	68BERGEN
59.10		295			256	GFS= 1	74NIZAMUDDIN
60.38	2.5	545.38	0.2722	45.01	500.1	L = 0	ENDF-B-4
60.38 ± 0.05			A 0.35		500	WGO= 0.045	BNL325(3)
60.38					500	WGO= 0.045	68BERGEN
60.01		220			181	GFS= 0.6	74NIZAMUDDIN
60.42		1700				GFS= 4	74NIZAMUDDIN-A
60.95	2.5	940.87	0.87	39.0	901.0	L = 0	JENDL-2
61.07	2.5	334.79	0.4432	45.65	288.7	L = 0	ENDF-B-4
61.07 ± 0.05			A 0.63		280	WGO= 0.08	BNL325(3)
61.07					280	WGO= 0.08	68BERGEN
60.95		940			901	GFS= 18	74NIZAMUDDIN
61.38	2.5	401.45	1.45	39.0	361.0	L = 0	JENDL-2
61.5	2.5	509.96	1.644	51.42	456.9	L = 0	ENDF-B-4
61.50 ± 0.05			A 2.8		400	WGO= 0.36	BNL325(3)
61.50					400	WGO= 0.36	68BERGEN
61.38		400 ±40			361	GFS= 31 ± 1	74NIZAMUDDIN
62.59	2.5	213.5	1.5	52.0	160.0	L = 0	JENDL-2
62.72	2.5	400.91	0.1582	85.65	315.1	L = 0	ENDF-B-4
62.72 ± 0.05			A 2.3		165	WGO= 0.29	BNL325(3)
62.72					165	WGO= 0.29	68BERGEN
62.59		135 ±26			83	GFS= 22 ± 1	74NIZAMUDDIN
63.49	2.5	1000.2	0.2	39.0	961.0	L = 0	JENDL-2
63.49		1000				GFS= 9	74NIZAMUDDIN-A
64.03	2.5	370.763	0.76317	39.0	331.0	L = 0	JENDL-2
64.03		370 ±55			331	GFS= 14 ± 2	74NIZAMUDDIN
64.44	2.5	240.466	1.4662	39.0	200.0	L = 0	JENDL-2
64.44		239 ±43			200	GFS= 25 ± 2	74NIZAMUDDIN
65.09	2.5	238.593	0.59289	39.0	199.0	L = 0	JENDL-2
65.09		238 ±20			199	GFS= 10	74NIZAMUDDIN
65.49	2.5	630.479	0.47853	39.0	591.0	L = 0	JENDL-2
65.49		630 ±44			591	GFS= 9 ± 1	74NIZAMUDDIN
66.56	2.5	770.641	0.64077	39.0	731.0	L = 0	JENDL-2
66.56		770 ±80			731	GFS= 12 ± 1	74NIZAMUDDIN
67.3	2.5	940.396	0.39572	39.0	901.0	L = 0	JENDL-2
67.30		940			901	GFS= 7.4	74NIZAMUDDIN
67.98	2.5	333.469	0.46914	39.0	294.0	L = 0	JENDL-2
67.98		333 ±52			294	GFS= 8 ± 1	74NIZAMUDDIN
69.23	2.5	1002.3	2.3044	39.0	961.0	L = 0	JENDL-2
69.23		1000			961	GFS= 42	74NIZAMUDDIN
70.19	2.5	534.989	1.9892	46.0	487.0	L = 0	JENDL-2
70.19		533 ±35			487	GFS= 34	74NIZAMUDDIN
71.75	2.5	349.246	0.24606	39.0	310.0	L = 0	JENDL-2
71.75		349 ±74			310	GFS= 4 ± 1	74NIZAMUDDIN
72.22	2.5	800.52	0.5204	39.0	761.0	L = 0	JENDL-2
72.22		800 ±132			761	GFS= 9 ± 1	74NIZAMUDDIN
73.43	2.5	126.707	1.707	39.0	86.0	L = 0	JENDL-2
73.43		125 ±39			86	GFS= 21 ± 1	74NIZAMUDDIN
74.03	2.5	514.762	4.762	39.0	471.0	L = 0	JENDL-2

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH* (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS**	REFERENCE
74.03		510 ±50			471	GFS= 78 ± 2	74NIZAMUDDIN
75.0 75.00	2.5	258.673 258	0.67293	39.0	219.0 219	L = 0 GFS= 10	JENDL-2 74NIZAMUDDIN
75.49 75.49	2.5	293.255 290 ±30	3.255	39.0	251.0 251	L = 0 GFS= 49 ± 1	JENDL-2 74NIZAMUDDIN
76.77 76.77	2.5	872.551 872 ±200	0.55086	39.0	833.0 833	L = 0 GFS= 9	JENDL-2 74NIZAMUDDIN
78.18 78.18	2.5	571.981 570 ±44	1.9814	39.0	531.0 531	L = 0 GFS= 31 ± 1	JENDL-2 74NIZAMUDDIN
78.46 78.46	2.5	900.375 900	0.37478	39.0	861.0	L = 0 GFS= 6	JENDL-2 74NIZAMUDDIN-A
79.0 79.00	2.5	1200.68 1200	0.68408	39.0	1161.0	L = 0 GFS= 11	JENDL-2 74NIZAMUDDIN-A
79.78 79.78	2.5	598.536 596 ±60	2.5356	39.0	557.0 557	L = 0 GFS= 39 ± 2	JENDL-2 74NIZAMUDDIN
81.47 81.47	2.5	1301.6 1300	1.5992	39.0	1261.0 1261	L = 0 GFS= 25 ± 3	JENDL-2 74NIZAMUDDIN
82.35 82.35	2.5	741.721 740	1.7214	39.0	701.0 701	L = 0 GFS= 26	JENDL-2 74NIZAMUDDIN
82.78 82.78	2.5	137.128 135 ±20	2.1278	39.0	96.0 96	L = 0 GFS= 24 ± 1	JENDL-2 74NIZAMUDDIN
84.75 84.75	2.5	815.475 815 ±80	0.47454	39.0	776.0 776	L = 0 GFS= 7	JENDL-2 74NIZAMUDDIN
85.22 85.22	2.5	400.791 400 ±60	0.79108	39.0	361.0 361	L = 0 GFS= 11 ± 1	JENDL-2 74NIZAMUDDIN
85.73 85.73	2.5	590.35 590	0.34957	39.0	551.0 551	L = 0 GFS= 5	JENDL-2 74NIZAMUDDIN
86.78 86.78	2.5	295.076 295	7.616-2	39.0	256.0	L = 0 GFS= 1	JENDL-2 74NIZAMUDDIN-A
87.13 87.13	2.5	150.359 150 ±40	0.3587	39.0	111.0 111	L = 0 GFS= 4 ± 1	JENDL-2 74NIZAMUDDIN
87.7 87.7	2.5	88.012 88	1.199-2	39.0	49.0 49	L = 0 GFS= 0.1	JENDL-2 74NIZAMUDDIN
88.89 88.89	2.5	344.14 342 ±35	2.1396	39.0	303.0 303	L = 0 GFS= 26 ± 1	JENDL-2 74NIZAMUDDIN
89.76 89.76	2.5	558.588 558	0.588	39.0	519.0 519	L = 0 GFS= 8	JENDL-2 74NIZAMUDDIN
90.55 90.55	2.5	260.256 253 ±30	7.2564	39.0	214.0 214	L = 0 GFS= 89 ± 1	JENDL-2 74NIZAMUDDIN
91.72 91.72	2.5	740.59 740	0.58993	39.0	701.0 701	L = 0 GFS= 8	JENDL-2 74NIZAMUDDIN
92.67 92.67	2.5	518.298 517 ±70	1.2977	39.0	478.0 478	L = 0 GFS= 17 ± 1	JENDL-2 74NIZAMUDDIN
93.25 93.25	2.5	590.38 590	0.38024	39.0	551.0	L = 0 GFS= 5	JENDL-2 74NIZAMUDDIN-A
93.77 93.77	2.5	105.6 104 ±40	1.5997	39.0	65.0 65	L = 0 GFS= 14 ± 1	JENDL-2 74NIZAMUDDIN
95.22 95.22	2.5	102.654 101 ±40	1.6539	39.0	62.0 62	L = 0 GFS= 14 ± 1	JENDL-2 74NIZAMUDDIN
96.42 96.42	2.5	1603.31 1600	3.3119	39.0	1561.0 1561	L = 0 GFS= 44	JENDL-2 74NIZAMUDDIN
97.81 97.81	2.5	233.759 229 ±38	4.7586	39.0	190.0 190	L = 0 GFS= 53 ± 2	JENDL-2 74NIZAMUDDIN
98.58 98.58	2.5	316.971 315 ±84	1.9708	39.0	276.0 276	L = 0 GFS= 23 ± 1	JENDL-2 74NIZAMUDDIN
99.3 99.30	2.5	541.386 540 ±200	1.3858	39.0	501.0 501	L = 0 GFS= 17 ± 2	JENDL-2 74NIZAMUDDIN
99.95	2.5	542.626	2.6256	39.0	501.0	L = 0	JENDL-2

ENERGY (EV)	J	TOTAL WIDTH (MEV)	NEUTRON WIDTH * (MEV)	GAMMA WIDTH (MEV)	FISSION WIDTH (MEV)	MISCELLANEOUS**	REFERENCE
99.95		540 ±100			501	GFS= 32	74NIZAMUDDIN
101.29 101.29	2.5	1000.24 1000	0.24082	39.0	961.0 961	L = 0 GFS= 3	JENDL-2 74NIZAMUDDIN
102.89 102.89	2.5	226.517 225 ±55	1.5167	39.0	186.0 186	L = 0 GFS= 16 ± 1	JENDL-2 74NIZAMUDDIN
104.79 104.79	2.5	46140.6 500 ±60	1.5581	39.0	46100.0 461	L = 0 GFS= 18 ± 1	JENDL-2 74NIZAMUDDIN
105.23 105.23	2.5	430.088 430 ±50	8.813-2	39.0	391.0	L = 0 GFS= 1	JENDL-2 74NIZAMUDDIN-A
105.95 105.95	2.5	192.437 190 ±20	2.4368	39.0	151.0 151	L = 0 GFS= 24 ± 1	JENDL-2 74NIZAMUDDIN
106.51 106.51	2.5	273.034 270 ±30	3.0341	39.0	231.0 231	L = 0 GFS= 32 ± 1	JENDL-2 74NIZAMUDDIN
106.95 106.95	2.5	327.869 325 ±30	2.8694	39.0	286.0 286	L = 0 GFS= 31 ± 2	JENDL-2 74NIZAMUDDIN
107.83 107.83	2.5	351.479 350 ±60	1.4788	39.0	311.0 311	L = 0 GFS= 16 ± 1	JENDL-2 74NIZAMUDDIN
108.2 108.20	2.5	400.822 400	0.82178	39.0	361.0	L = 0 GFS= 9	JENDL-2 74NIZAMUDDIN-A
108.64 108.64	2.5	220.402 220 ±20	0.40228	39.0	181.0 181	L = 0 GFS= 4	JENDL-2 74NIZAMUDDIN
109.36 109.36	2.5	419.045 415 ±43	4.0449	39.0	376.0 376	L = 0 GFS= 44 ± 1	JENDL-2 74NIZAMUDDIN
109.98 109.98	2.5	520.815 520 ±50	0.81499	39.0	481.0 481	L = 0 GFS= 9	JENDL-2 74NIZAMUDDIN
110.88 110.88	2.5	409.234 404 ±49	5.2344	39.0	365.0 365	L = 0 GFS= 56 ± 1	JENDL-2 74NIZAMUDDIN
112.53 112.53	2.5	1203.37 1200	3.3662	39.0	1161.0 1161	L = 0 GFS= 38	JENDL-2 74NIZAMUDDIN
113.55 113.55	2.5	1003.78 1000	3.7796	39.0	961.0 961	L = 0 GFS= 42	JENDL-2 74NIZAMUDDIN
114.24		678				GFS= 28	74NIZAMUDDIN-A
114.56		234 ±20			195	GFS= 19	74NIZAMUDDIN
115.80		128 ±35			89	GFS= 3	74NIZAMUDDIN
117.00		745			706	GFS= 5	74NIZAMUDDIN
117.92		341 ±50			302	GFS= 66	74NIZAMUDDIN
119.45		110 ±30			71	GFS= 10	74NIZAMUDDIN
120.03		962			923	GFS= 14	74NIZAMUDDIN
121.19		405 ±50			366	GFS= 12	74NIZAMUDDIN
122.05		46			7	GFS= 5	74NIZAMUDDIN
122.67		180 ±20			141	GFS= 5	74NIZAMUDDIN
123.70		707				GFS= 6	74NIZAMUDDIN-A
124.12		260 ±50			221	GFS= 39	74NIZAMUDDIN

* Mark A denotes that the value is $2g\Gamma_n$

** Symbols in miscellaneous column

L : orbital angular momentum of incident neutrons

WG0: $2g\Gamma_n$ *

WW5: $g\Gamma_n\Gamma_\gamma/\Gamma$

WGM: $g\Gamma_n$

GFS: $\sigma_0\Gamma_f$

Table 7 Unresolved resonance parameters and calculated cross sections of ^{233}U.
Fixed parameters: R = 9.93 fm and Γ_γ = 39 meV.

E_n (keV)	S_0 ($\times 10^{-4}$)	S_1 ($\times 10^{-4}$)	$\Gamma_f(2^+)$ (meV)	$\Gamma_f(3^+)$ (meV)	$\Gamma_f(1^-)$ (meV)	$\Gamma_f(2^-)$ (meV)	$\Gamma_f(3^-)$ (meV)	$\Gamma_f(4^-)$ (meV)	D_{obs} (eV)	σ_t (barns)	σ_f (barns)	σ_c (barns)
0.1	0.79	1.00	1014	416	915	624	843	624	6.80	44.97	27.84	4.44
0.15	0.81	1.03	1186	486	1070	730	985	730	6.80	39.77	23.76	3.35
0.25	0.96	1.21	1148	471	1037	707	954	707	6.80	37.49	21.63	3.10
0.35	0.85	1.08	2263	928	2042	1393	1880	1393	6.80	31.24	17.24	1.46
0.45	0.61	0.77	2050	841	1850	1261	1703	1261	6.79	24.32	10.87	1.00
0.55	0.86	1.08	851	349	768	524	707	524	6.79	27.50	12.54	2.24
0.65	1.11	1.41	1397	573	1261	860	1161	860	6.79	30.43	15.77	1.90
0.75	0.87	1.11	1227	503	1108	755	1019	755	6.79	25.59	11.43	1.53
0.85	1.10	1.39	1477	606	1333	909	1227	909	6.79	27.95	13.67	1.57
0.95	0.87	1.10	1298	532	1171	799	1078	798	6.79	24.11	10.22	1.30
1.5	0.91	1.15	1694	695	1529	1042	1407	1042	6.78	22.14	8.74	0.895
2.5	0.95	1.20	1572	645	1419	967	1306	967	6.77	20.22	7.01	0.746
3.5	0.92	1.16	1716	704	1549	1056	1425	1056	6.76	18.79	5.83	0.573
4.5	0.93	1.18	1870	767	1688	1151	1554	1151	6.74	18.13	5.33	0.484
5.5	0.85	1.07	1761	722	1589	1084	1463	1084	6.73	17.08	4.40	0.417
6.5	0.95	1.21	2196	901	1982	1351	1824	1351	6.72	17.25	4.68	0.367
7.5	0.94	1.19	2111	866	1905	1299	1753	1299	6.70	16.85	4.33	0.347
8.5	0.99	1.25	2363	969	2133	1454	1963	1454	6.69	16.77	4.34	0.315
9.5	1.01	1.28	2379	976	2147	1464	1976	1464	6.68	16.62	4.24	0.303
10	0.95	1.20	2121	870	1914	1305	1762	1305	6.67	16.23	3.86	0.302
15	0.96	1.21	2123	871	1916	1306	1764	1306	6.61	15.50	3.35	0.253
20	0.99	1.25	2098	861	1894	1291	1743	1291	6.55	15.08	3.11	0.231
25	1.00	1.26	1821	747	1644	1121	1513	1121	6.49	14.73	2.87	0.233
30	1.00	1.27	1709	701	1542	1052	1420	1052	6.43	14.46	2.29	0.229

Table 8 Fission and capture resonance integrals(barns)

	Present	ENDF/B-IV	BNL-325[28]
Fission	771	763	764 ± 13
Capture	138	135	140 ± 6

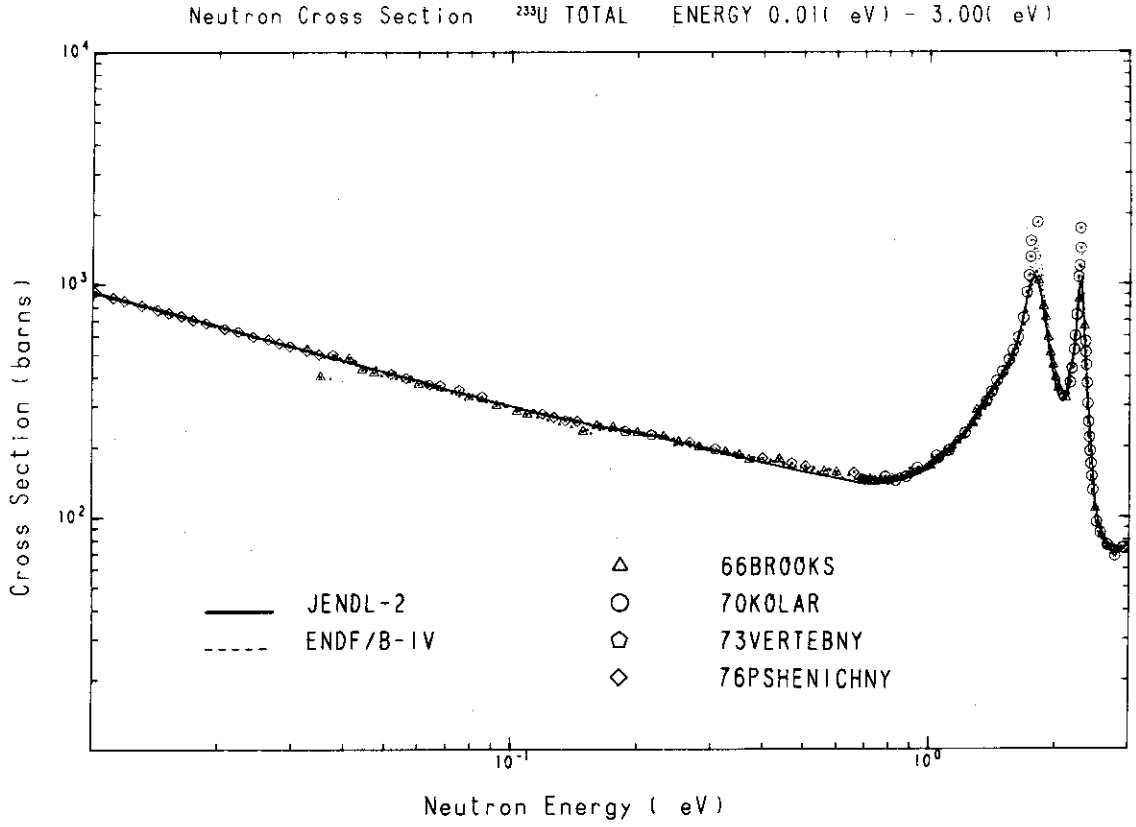


Fig.1 Total cross sections of ^{233}U in the energy range from 0.01 to 3 eV.

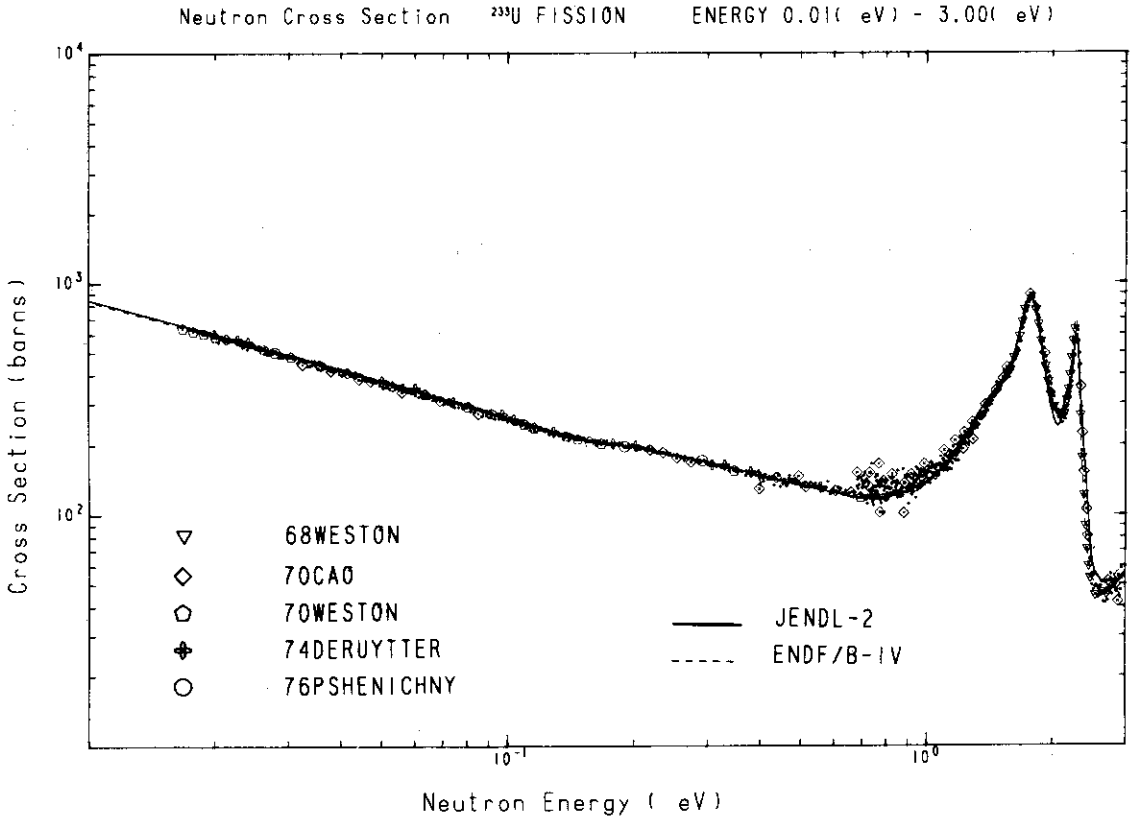


Fig.2 Fission cross sections of ^{233}U in the energy range from 0.01 to 3 eV.

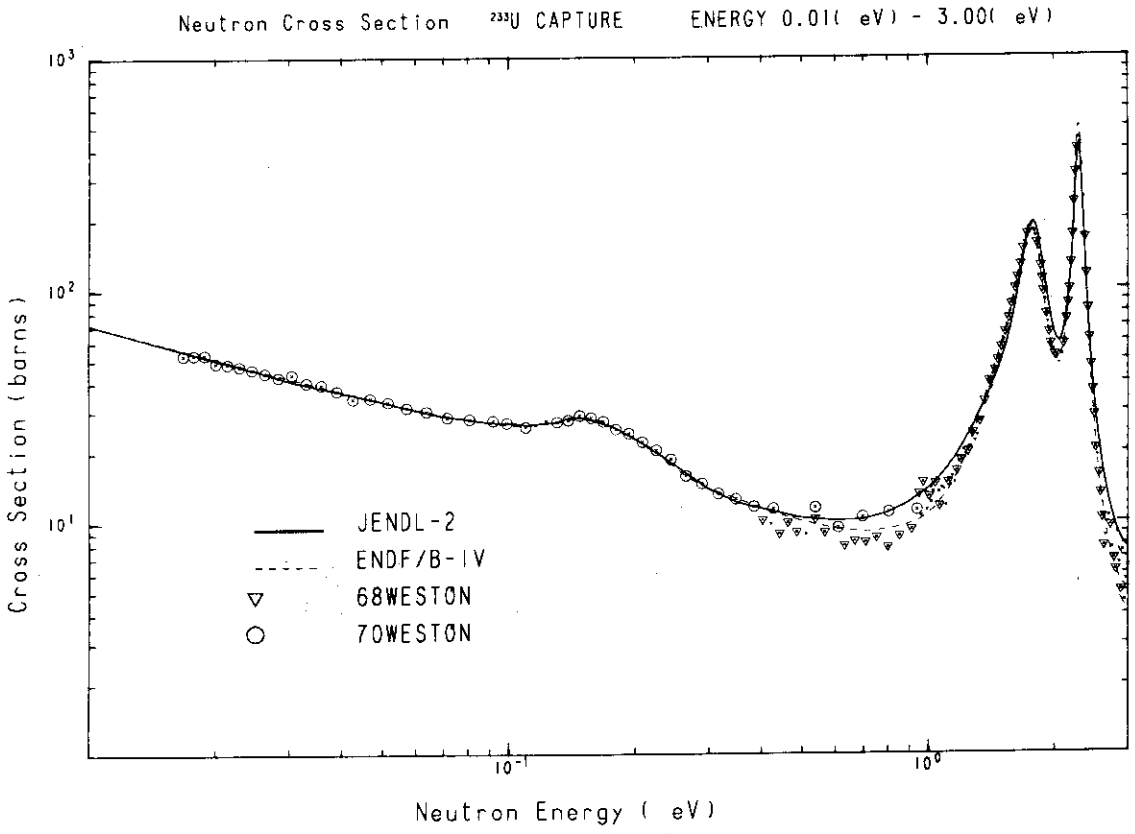


Fig.3 Capture cross sections of ^{233}U in the energy range from 0.01 to 3 eV.

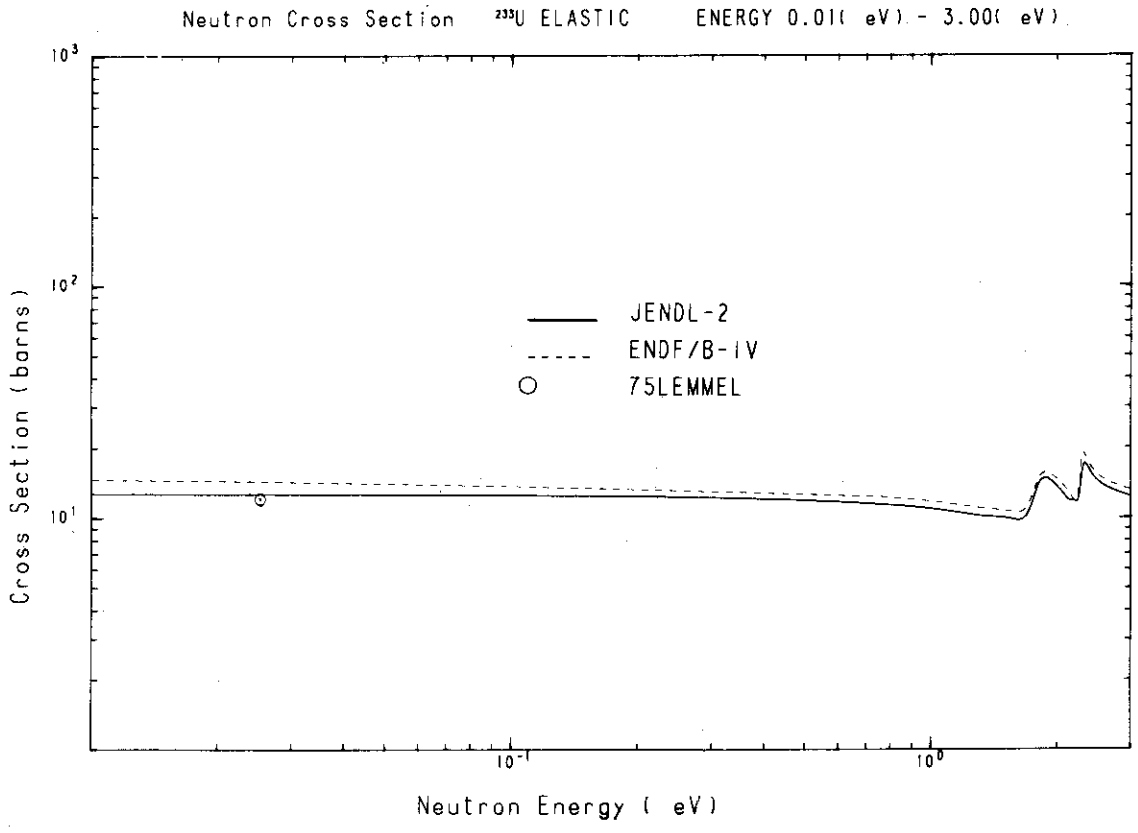
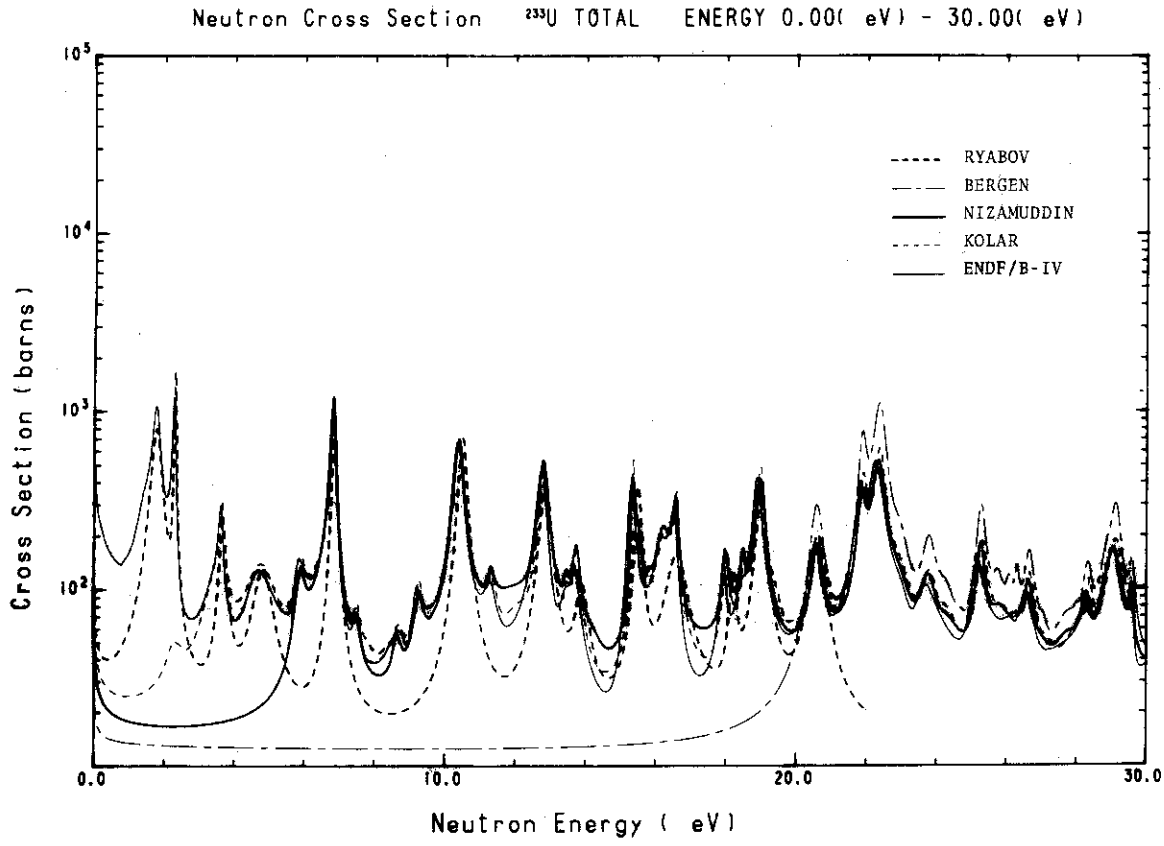
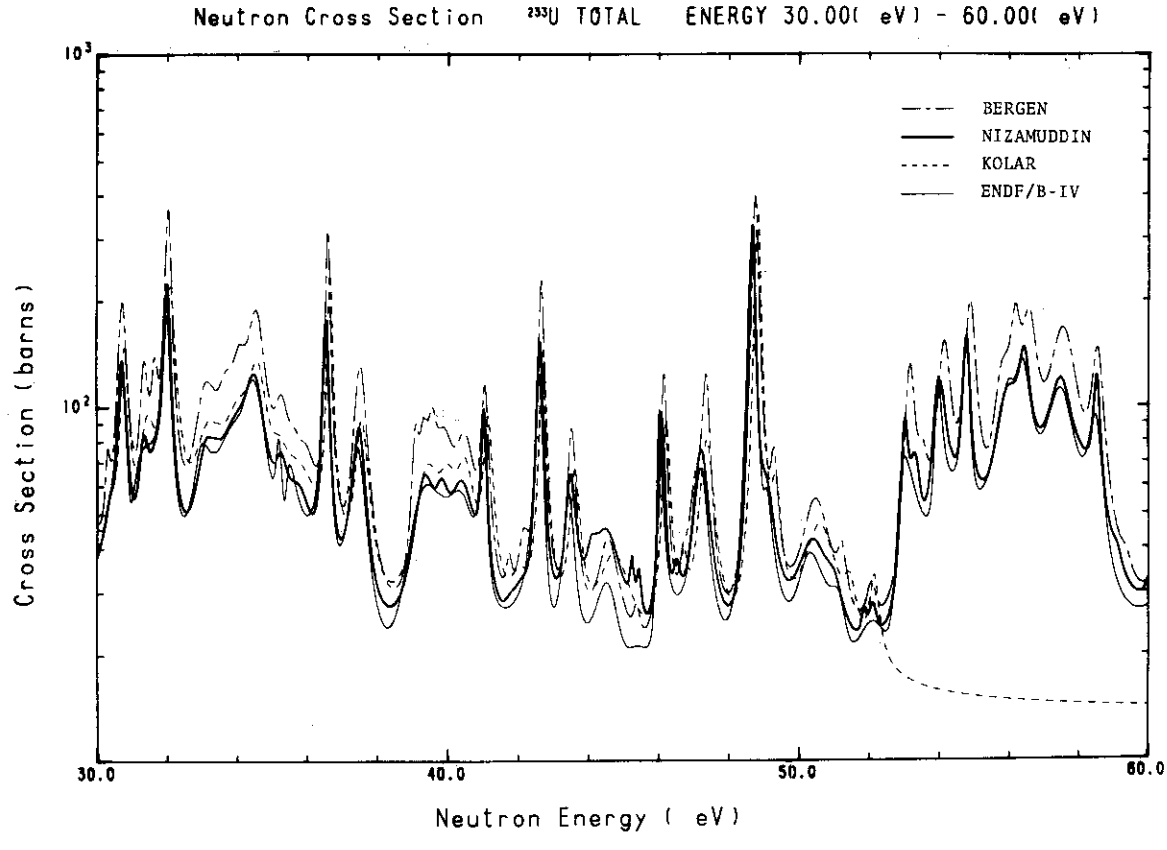


Fig.4 Elastic scattering cross sections of ^{233}U in the energy range from 0.01 to 3 eV.

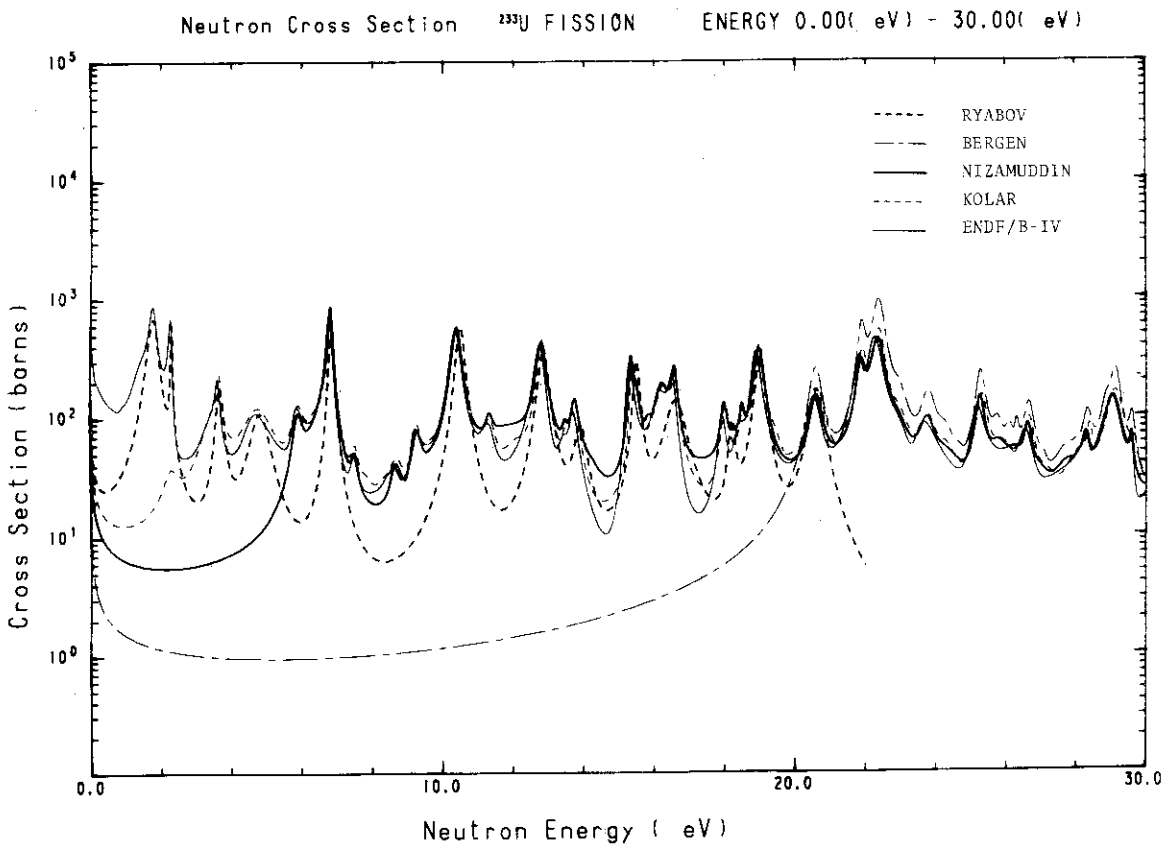


(a)

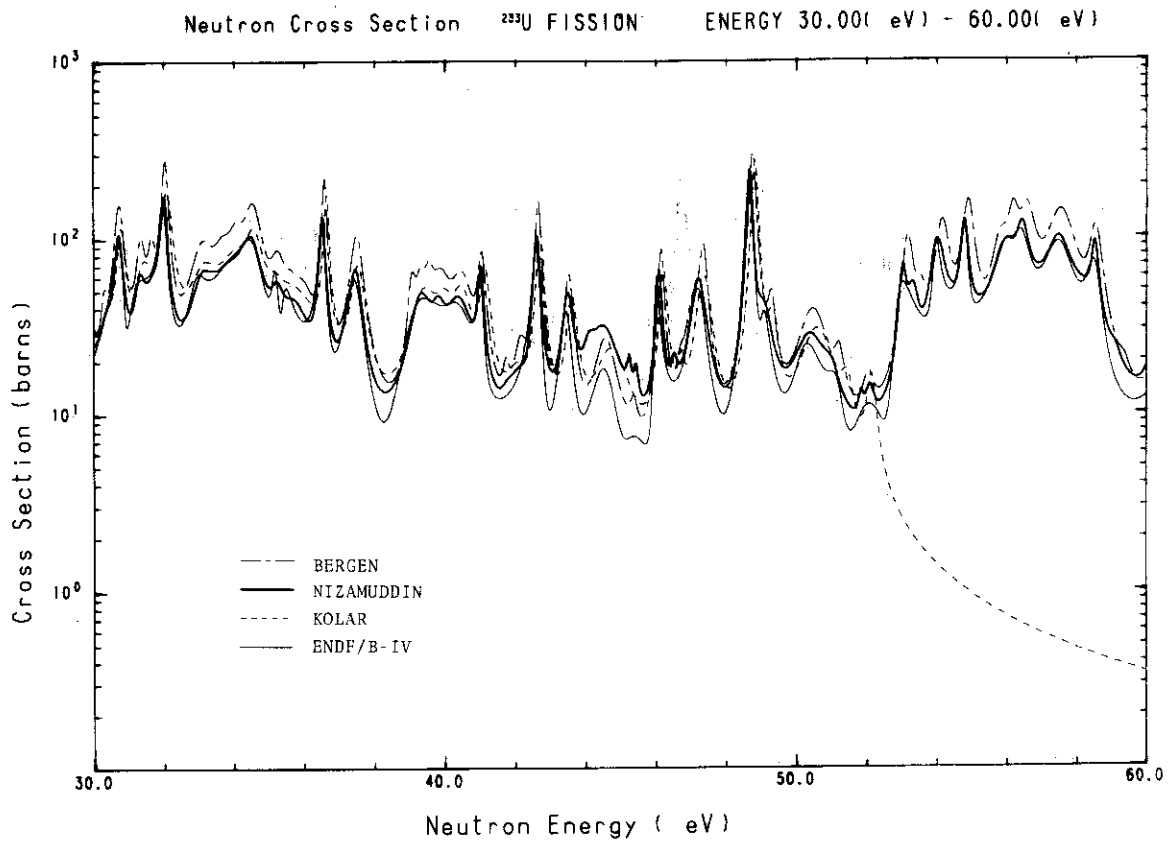


(b)

Fig.5 Comparison of total cross sections of ^{233}U calculated from various sets of resonance parameters.

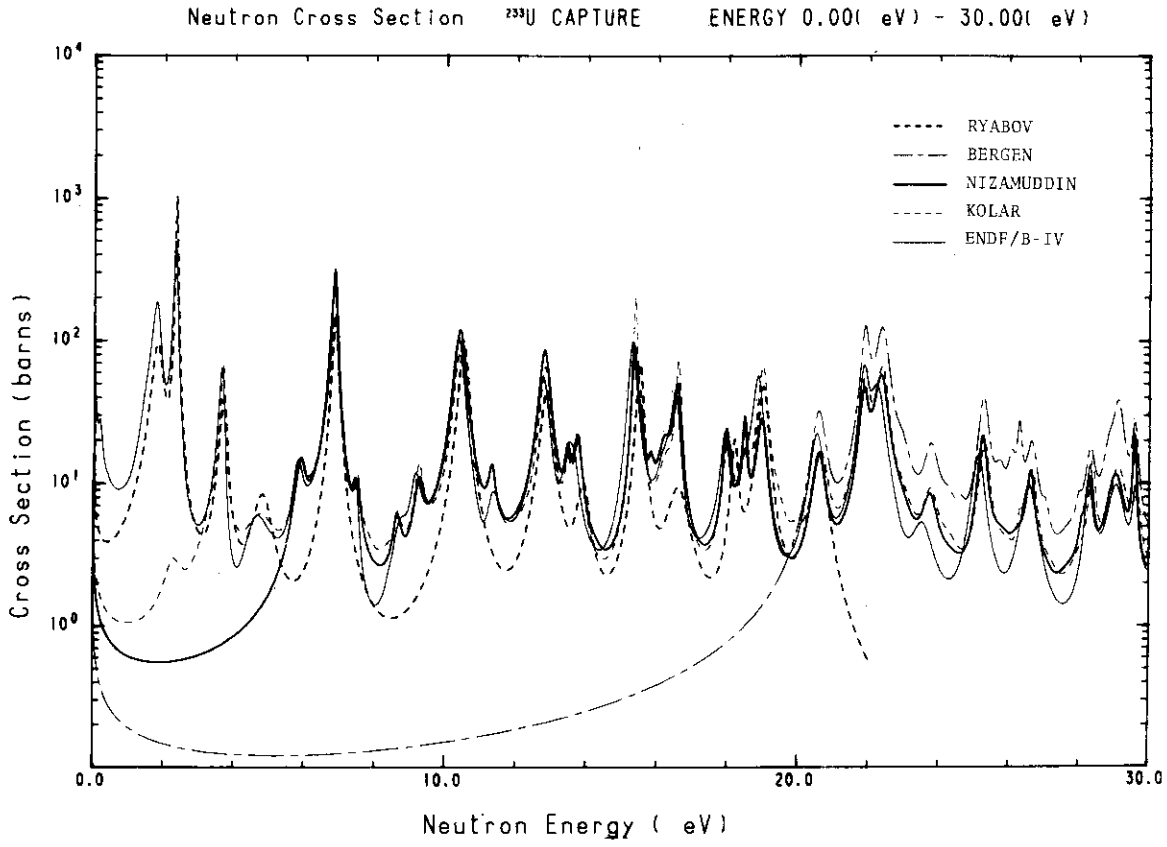


(a)

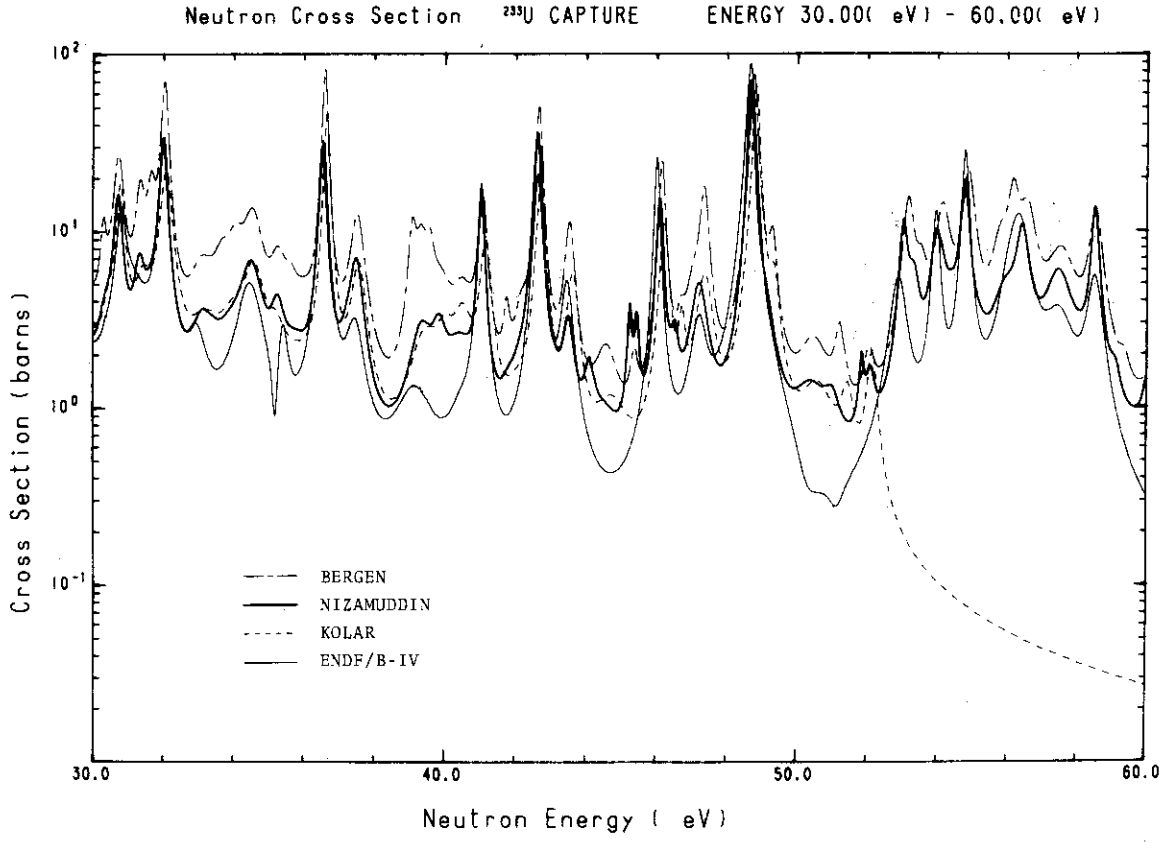


(b)

Fig.6 Comparison of fission cross sections of ^{233}U calculated from various sets of resonance parameters.



(a)



(b)

Fig.7 Comparison of capture cross sections of ^{233}U calculated from various sets of resonance parameters.

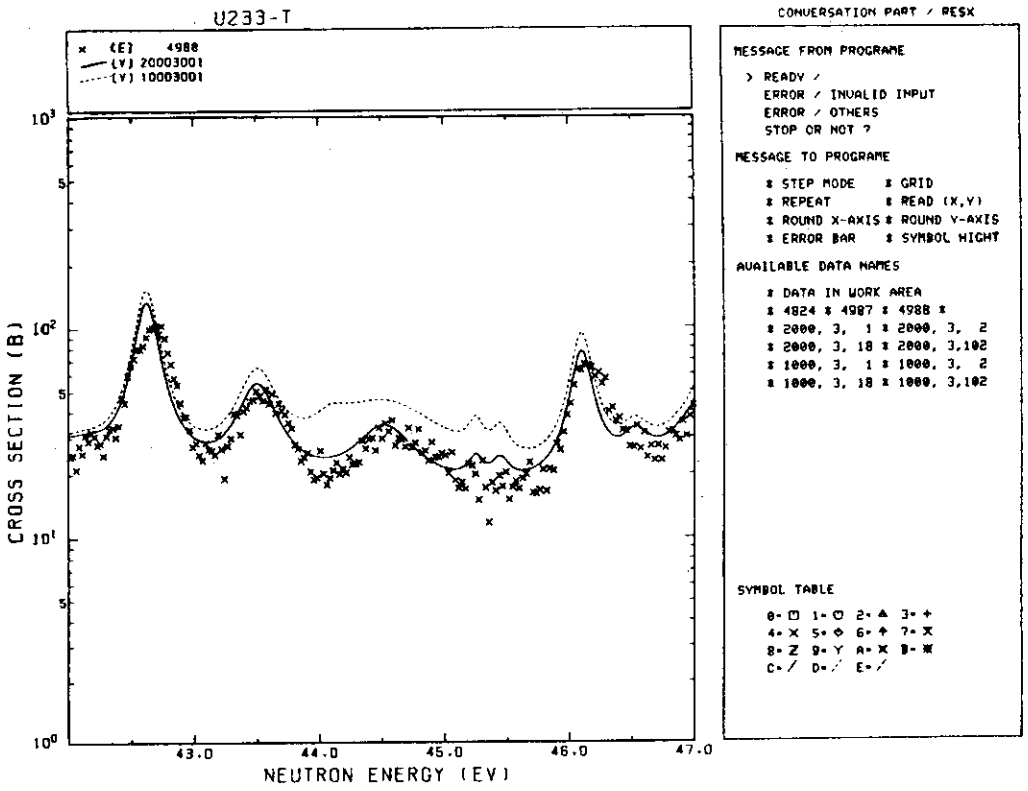


Fig.8 Example of improvement: Total cross sections of ^{233}U displayed on the cathode ray tube. The solid line is calculated from the final parameters, the dashed line from the initial guess parameters. The cross points are the measured data by Kolar et al.

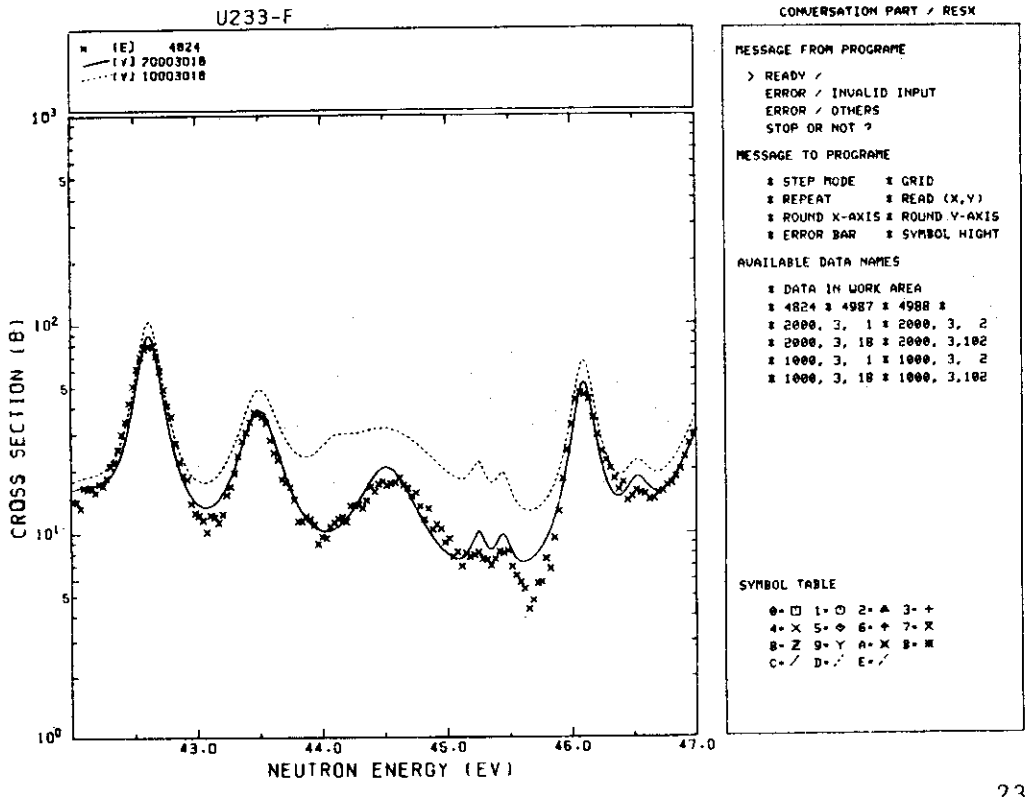


Fig.9 Example of improvement: Fission cross sections of ^{233}U displayed on the cathode ray tube. The solid line is calculated from the final parameters, the dashed line from the initial guess parameters. The cross points are the measured data by Blons.

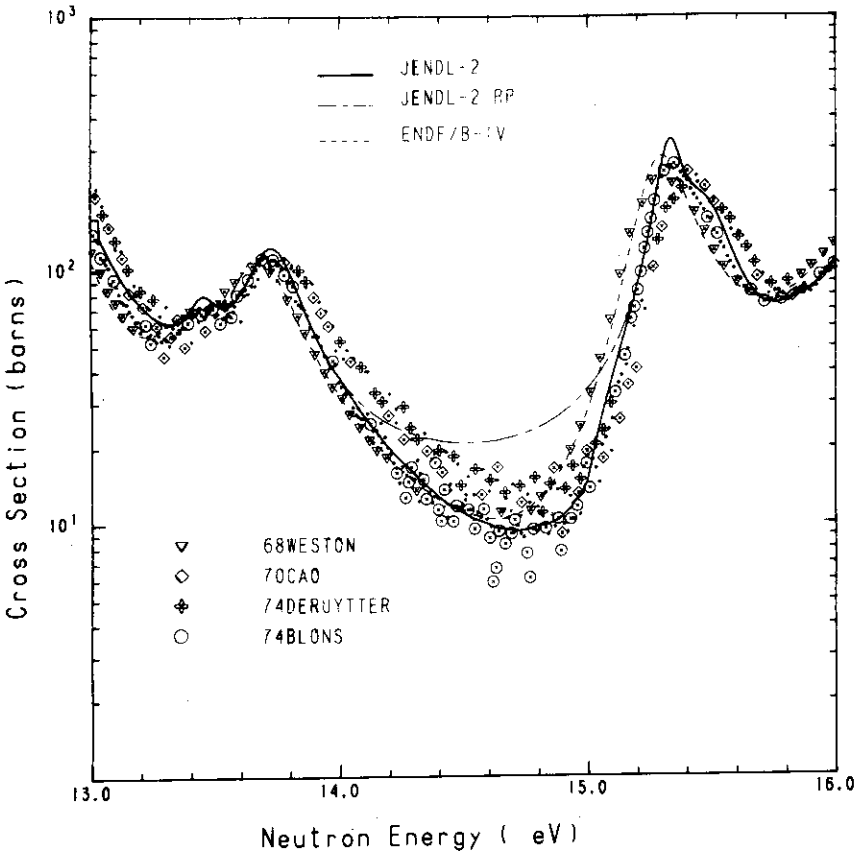
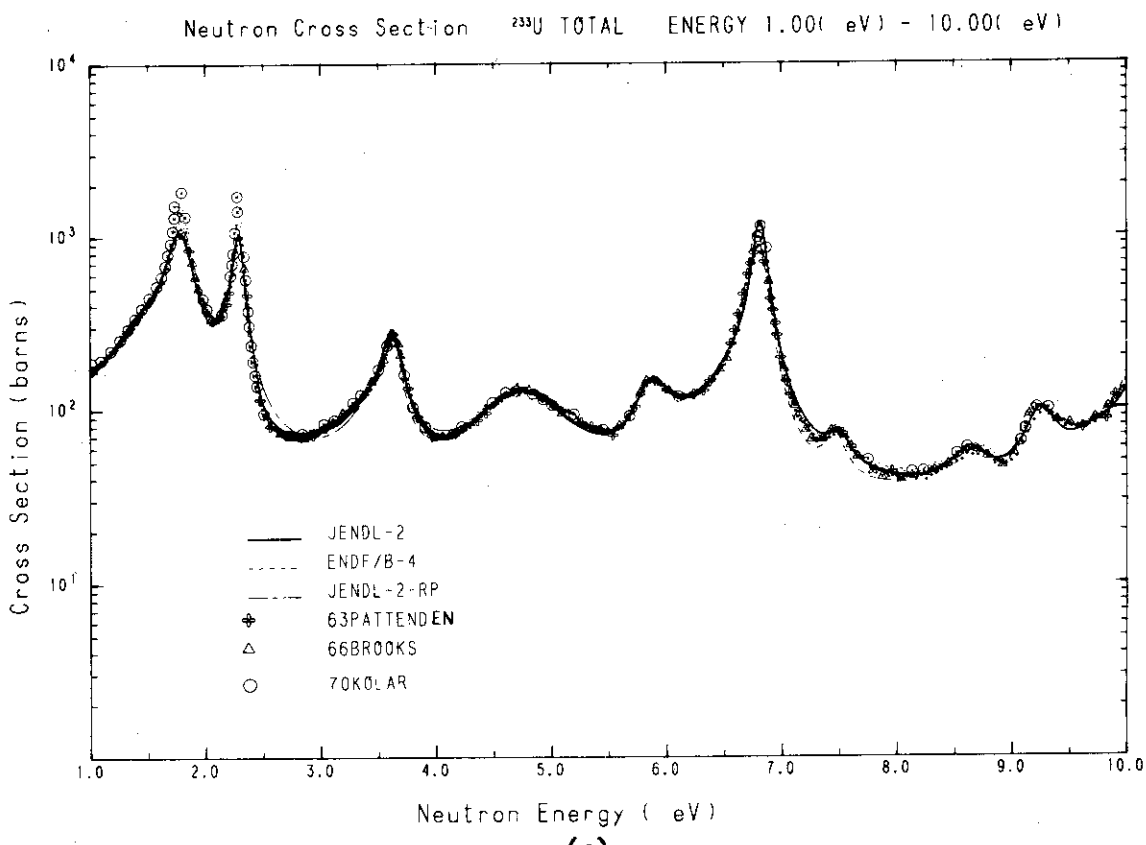
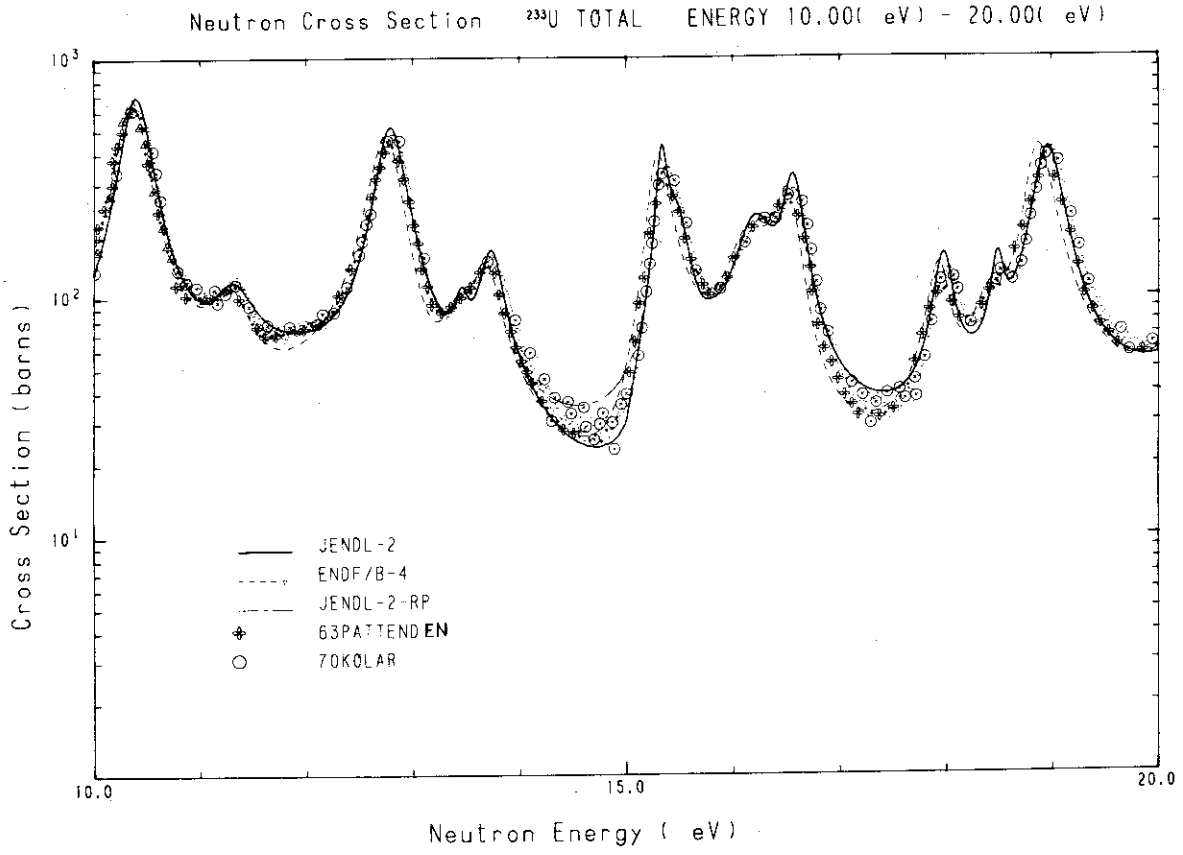


Fig.10 Fission cross sections of ^{233}U in the energy range between 13 and 16 eV. The solid and dash-dotted lines are calculated from the present resonance parameters with and without the background cross section, respectively. The dotted line represents the value of ENDF/B-IV.

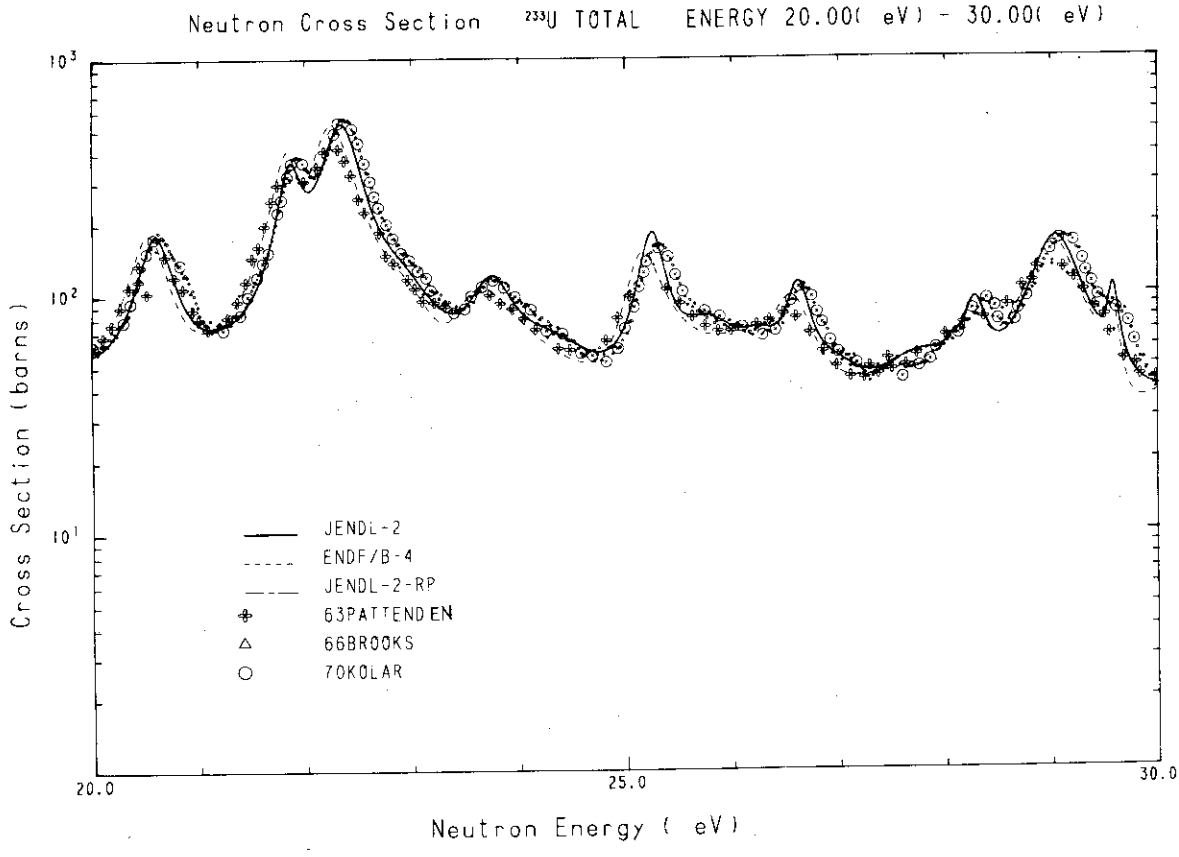


(a)

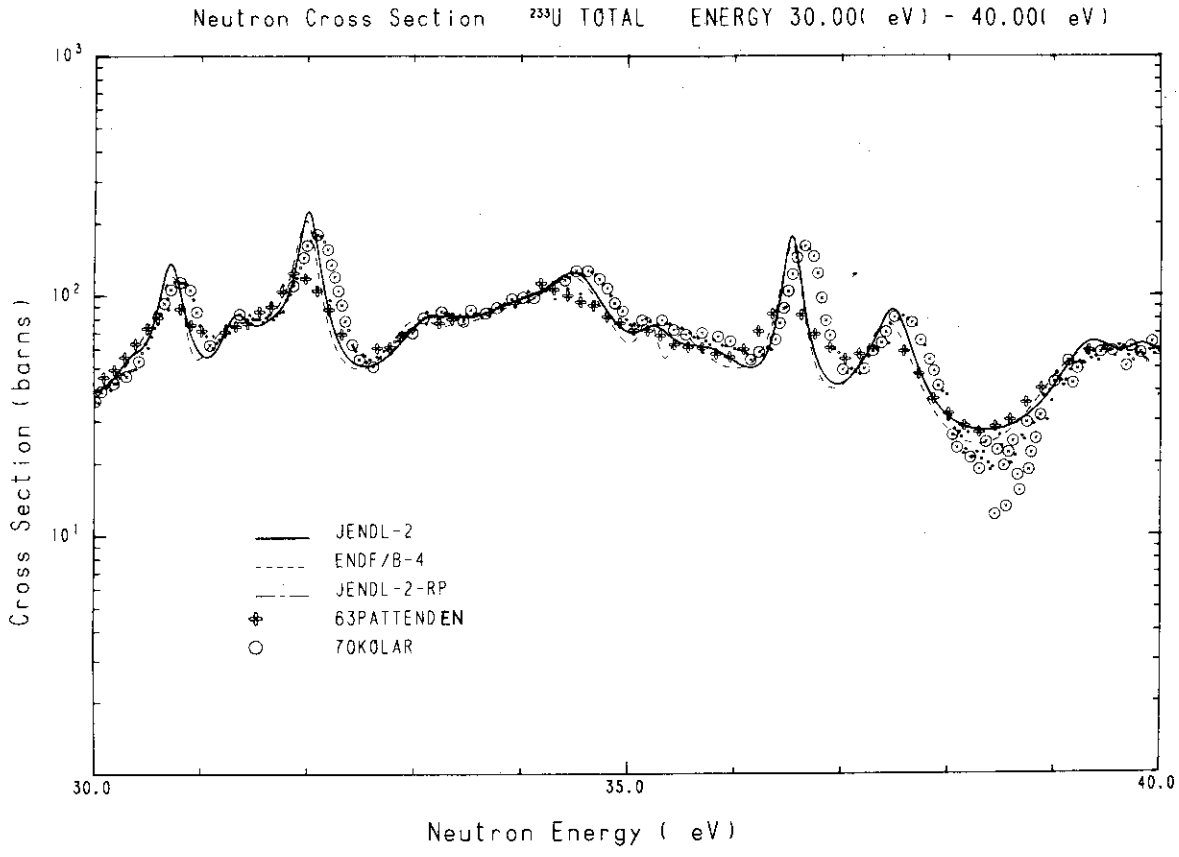
Fig.11 Total cross sections of ^{233}U. The solid and dash-dotted lines are calculated from the present resonance parameters with and without the background cross section, respectively. The dotted line represents the value of ENDF/B-IV.


Neutron Cross Section 233U TOTAL ENERGY 10.00(eV) - 20.00(eV)
Cross Section (barns)
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
63PATTENDEN
70KOLAR
10.0
15.0
20.0

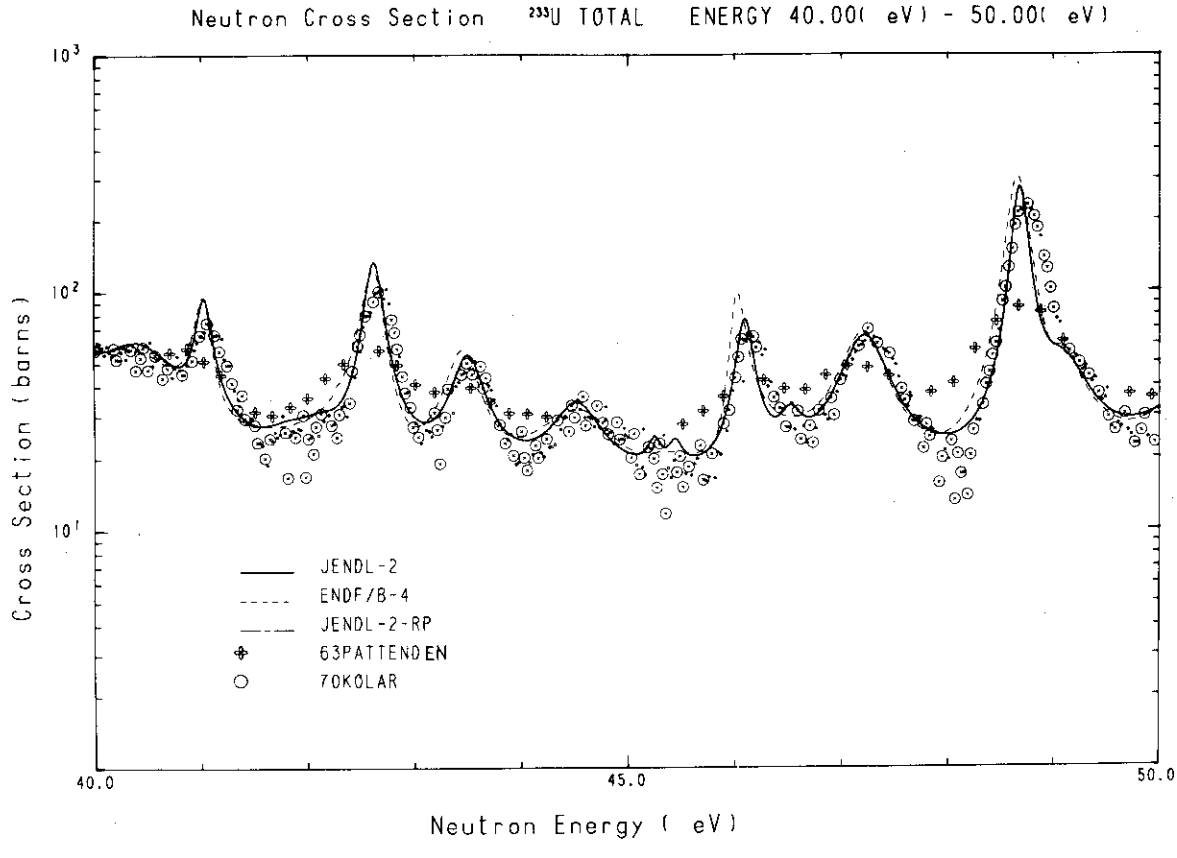
(b)


Neutron Cross Section 233U TOTAL ENERGY 20.00(eV) - 30.00(eV)
Cross Section (barns)
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
63PATTENDEN
66BROOKS
70KOLAR
20.0
25.0
30.0

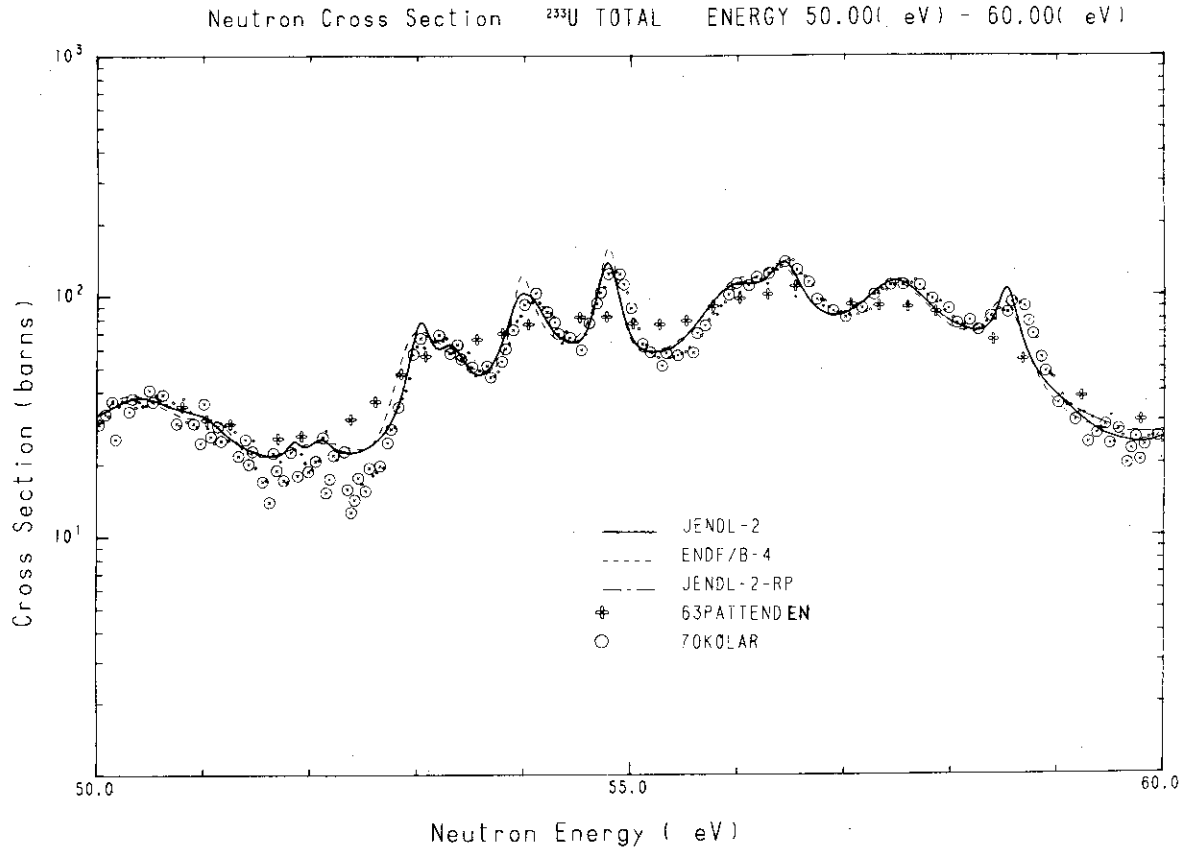
(c)


Neutron Cross Section ²³³U TOTAL ENERGY 30.00(eV) - 40.00(eV)
Cross Section (barns)
10³
10²
10¹
30.0
35.0
40.0
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
63PATTEND EN
70KOLAR

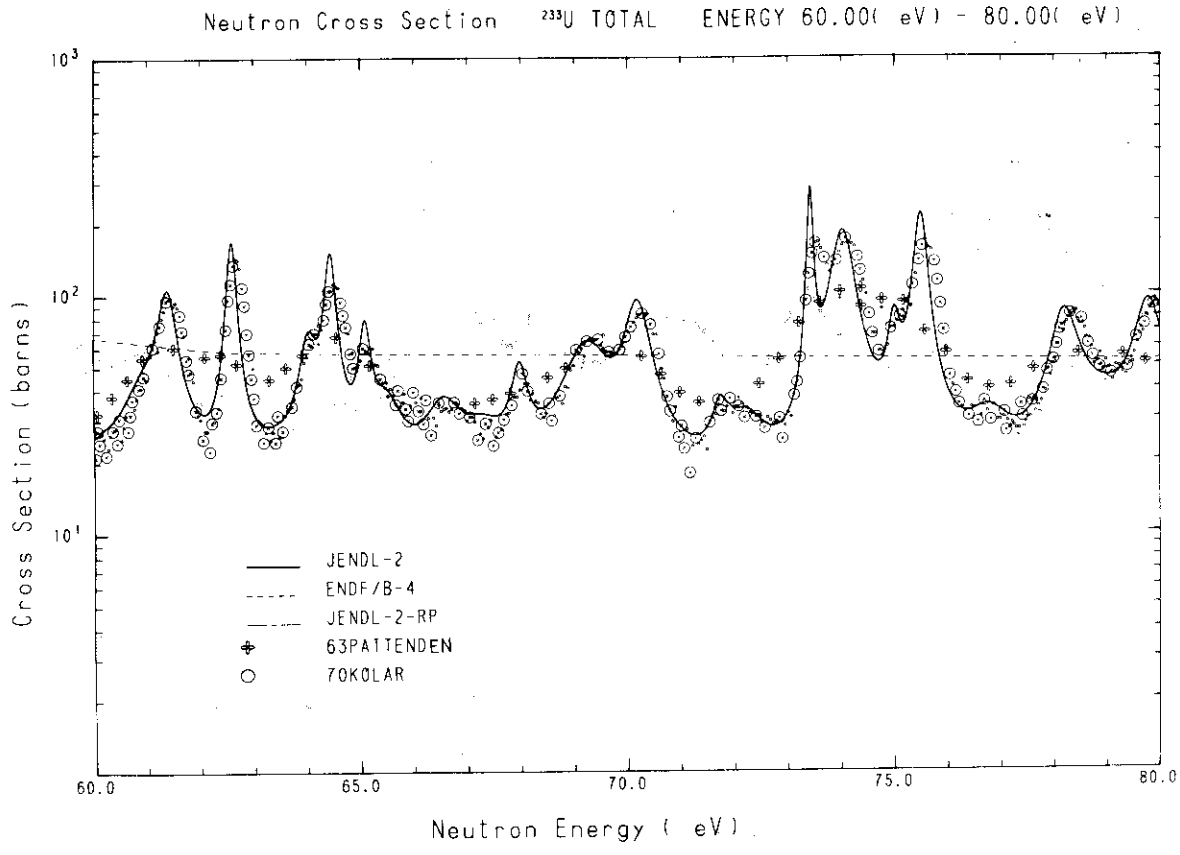
(d)


Neutron Cross Section ²³³U TOTAL ENERGY 40.00(eV) - 50.00(eV)
Cross Section (barns)
10³
10²
10¹
40.0
45.0
50.0
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
63PATTEND EN
70KOLAR

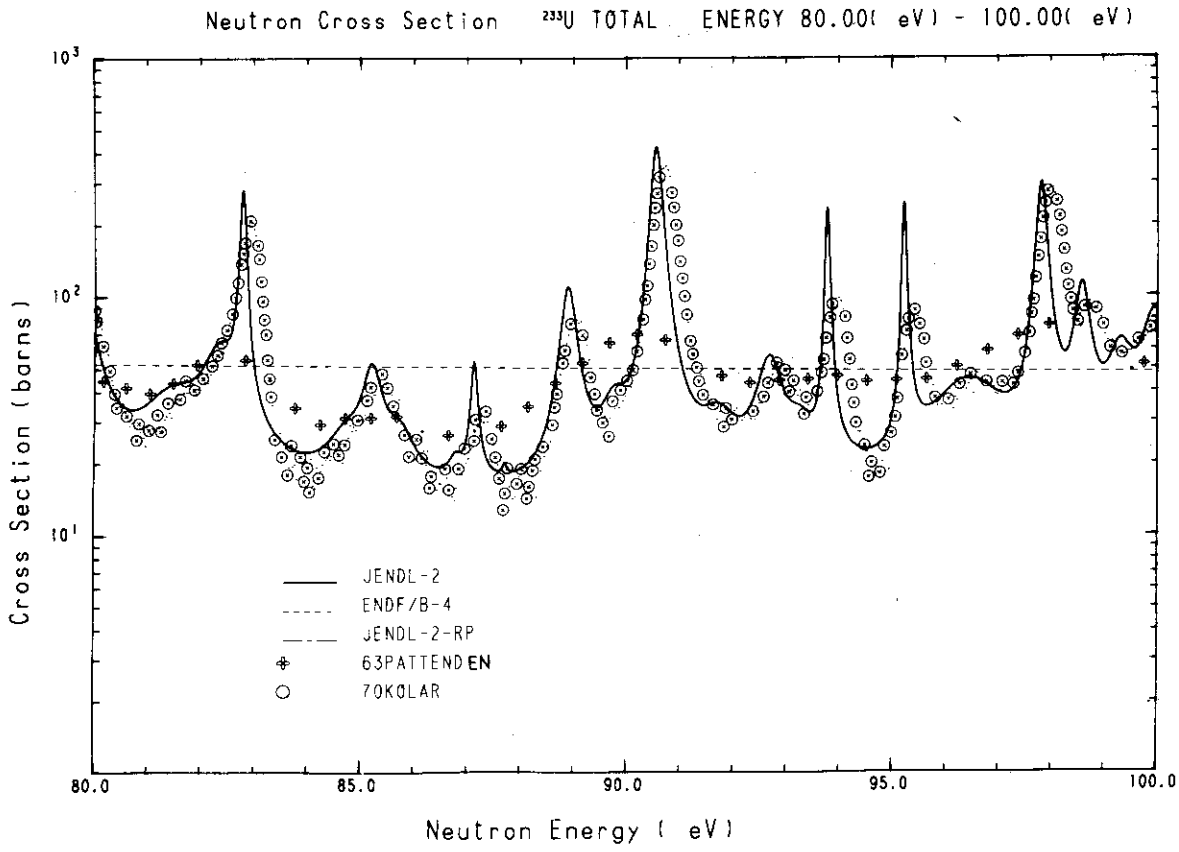
(e)


Neutron Cross Section ²³³U TOTAL ENERGY 50.00(eV) - 60.00(eV)
Cross Section (barns)
10³
10²
10¹
50.0
55.0
60.0
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
63PATTENDEN
70KOLAR

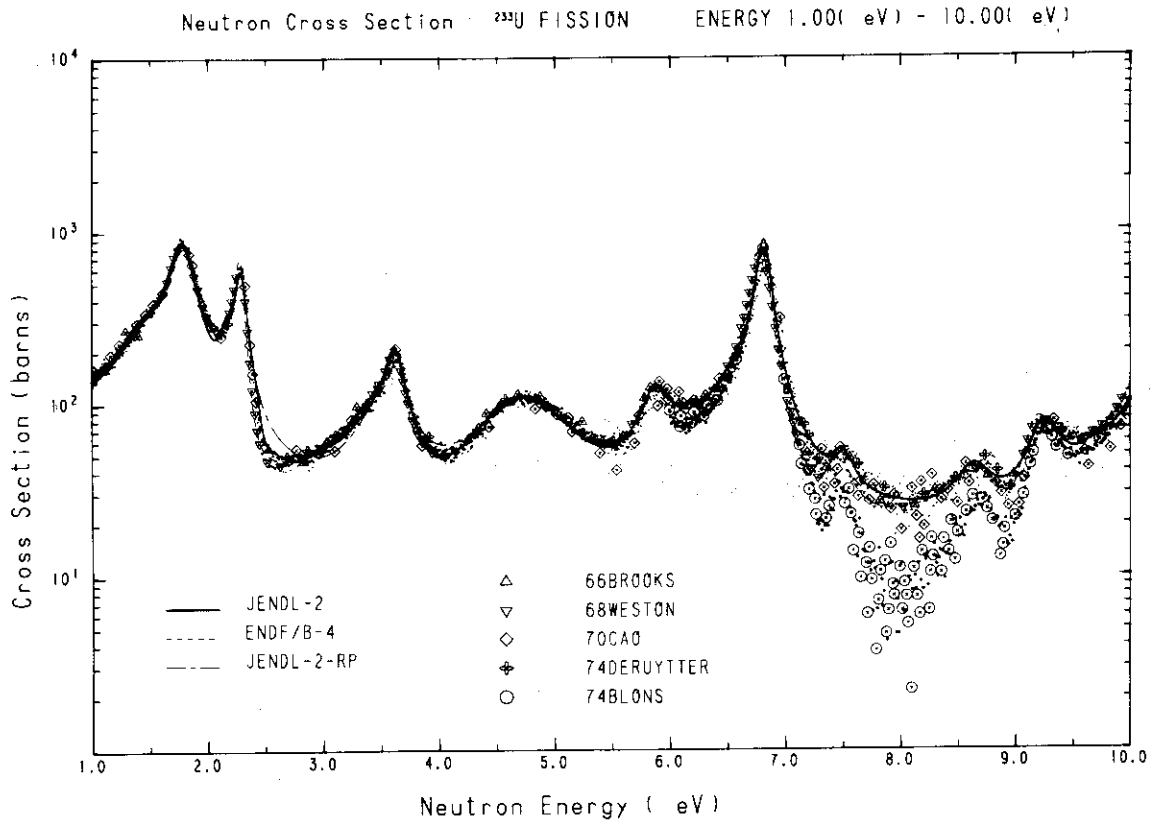
(f)


Neutron Cross Section ²³³U TOTAL ENERGY 60.00(eV) - 80.00(eV)
Cross Section (barns)
10³
10²
10¹
60.0
65.0
70.0
75.0
80.0
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
63PATTENDEN
70KOLAR

(g)

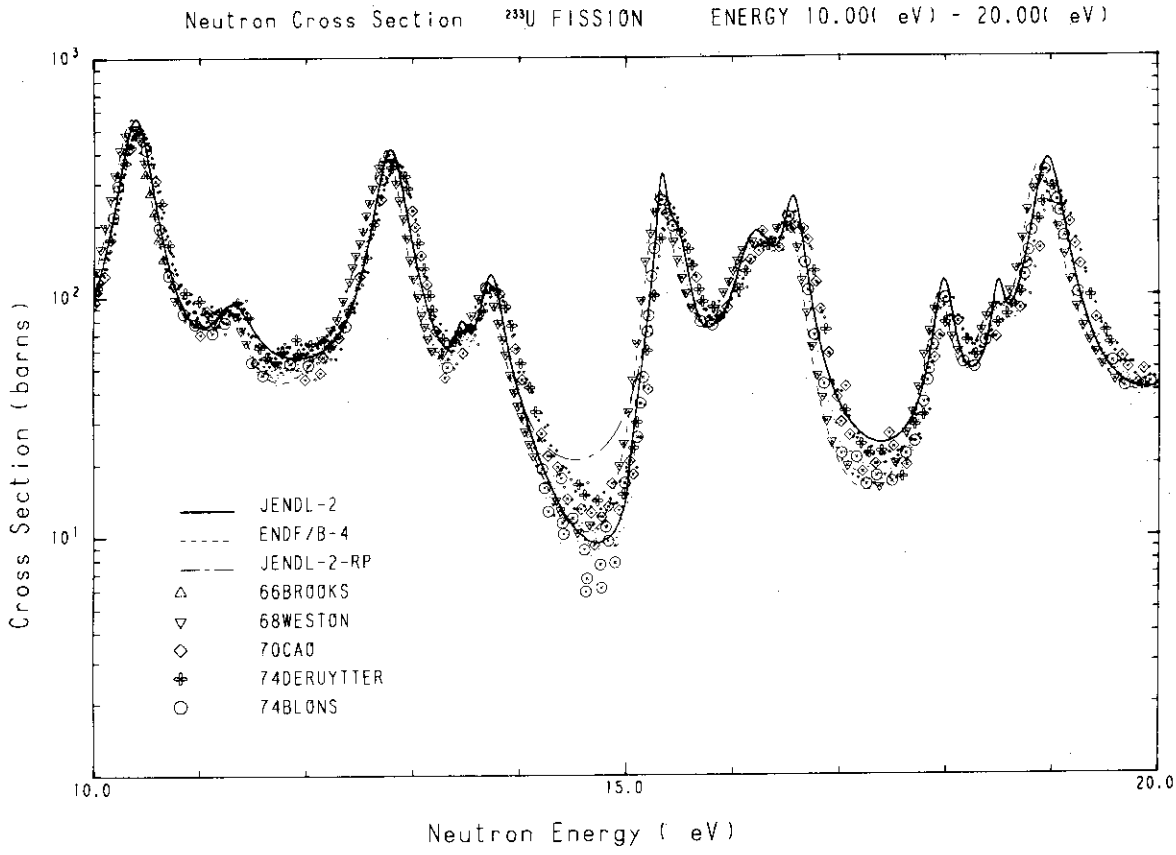


(h)

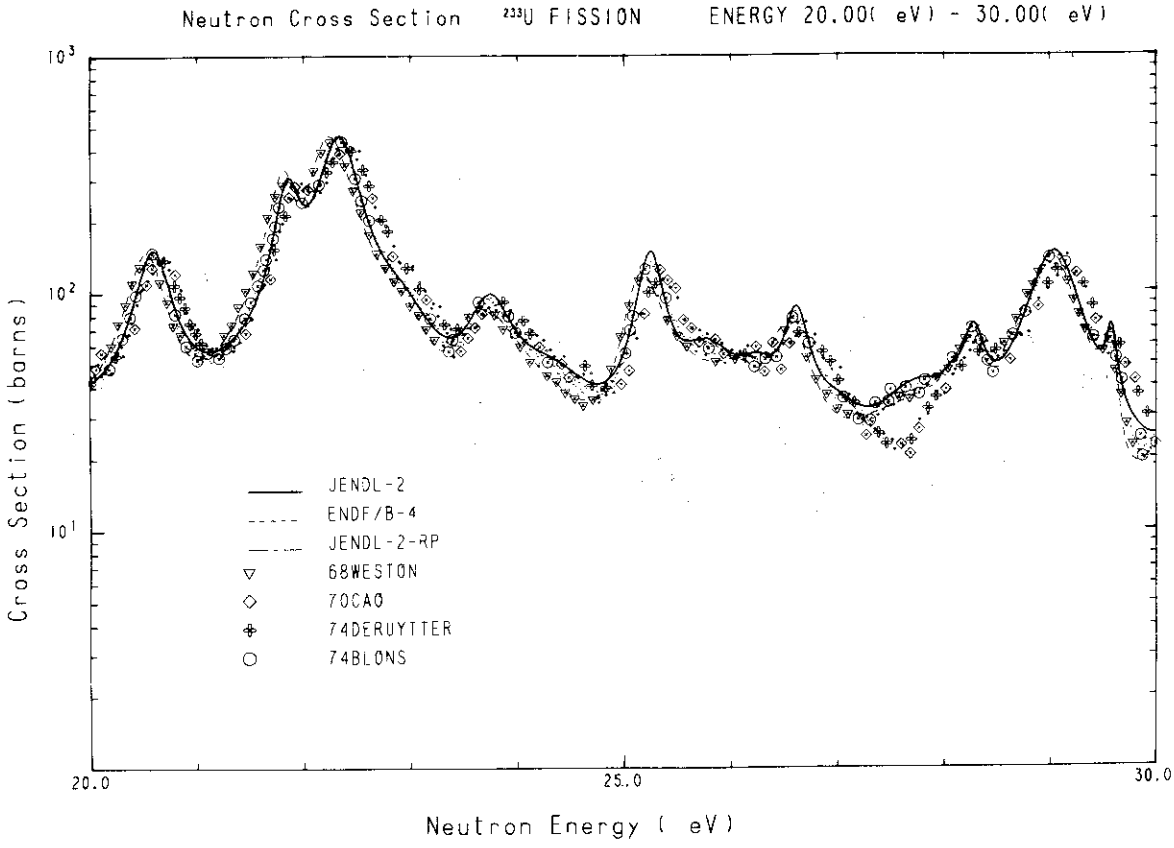


(a)

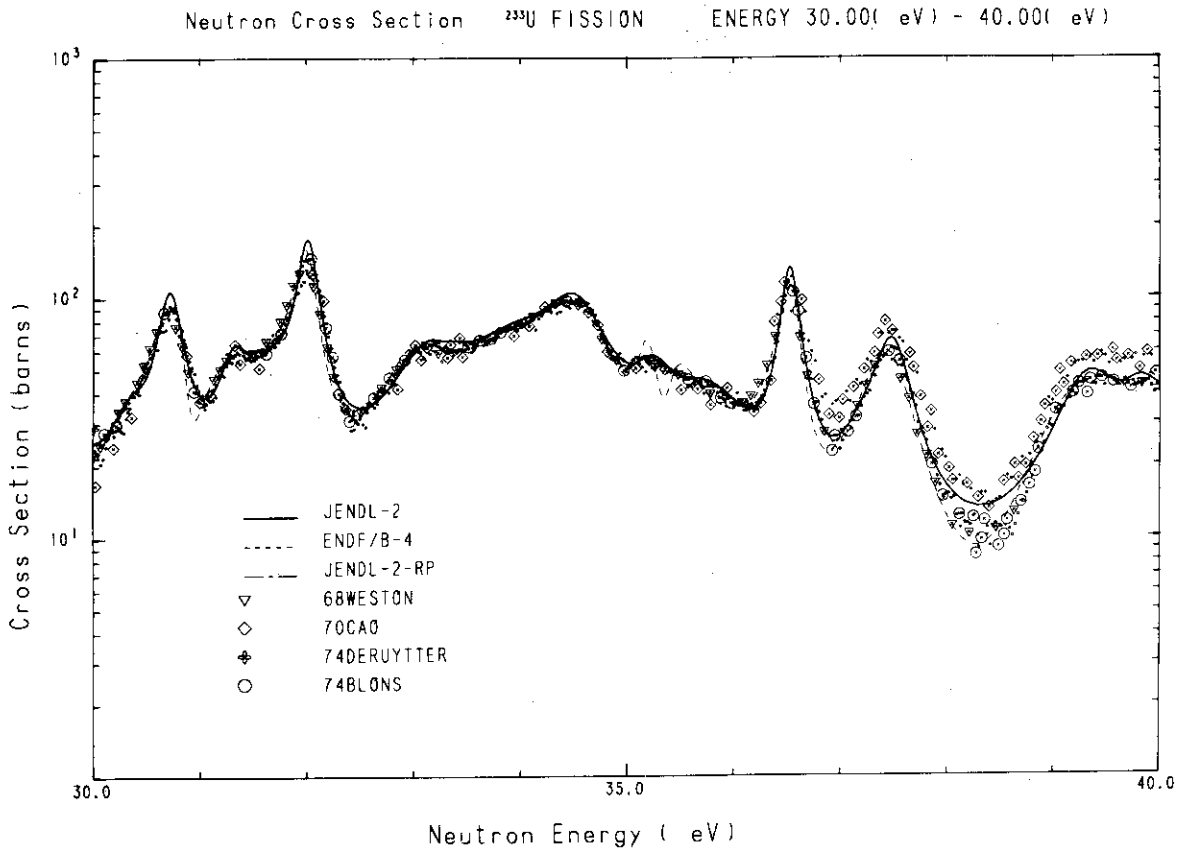
Fig.12 Fission cross sections of ^{233}U. The solid and dash-dotted lines are calculated from the present resonance parameters with and without the background cross section, respectively. The dotted line represents the value of ENDF/B-IV.


Neutron Cross Section ²³³U FISSION ENERGY 10.00(eV) - 20.00(eV)
Cross Section (barns)
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
66BROOKS
68WESTON
70CAO
74DERUYTTER
74BLONS

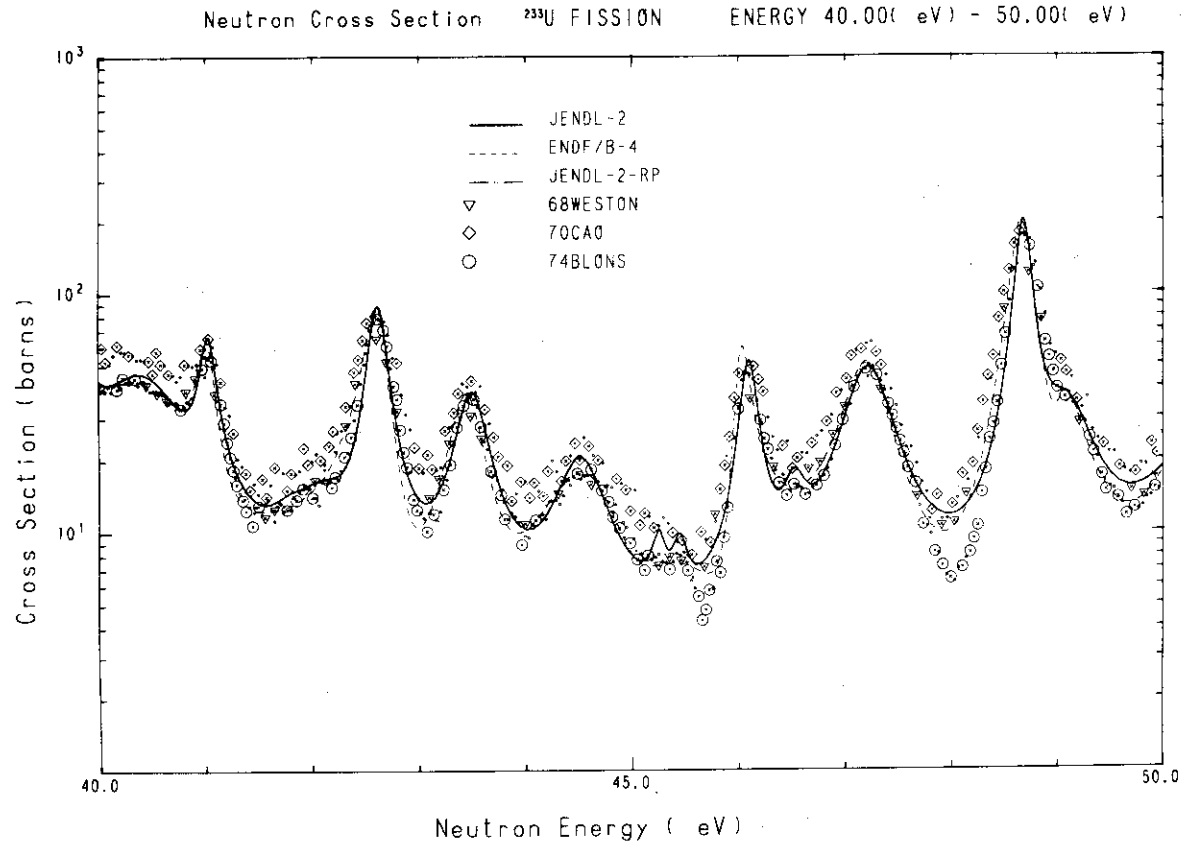
(b)


Neutron Cross Section ²³³U FISSION ENERGY 20.00(eV) - 30.00(eV)
Cross Section (barns)
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
68WESTON
70CAO
74DERUYTTER
74BLONS

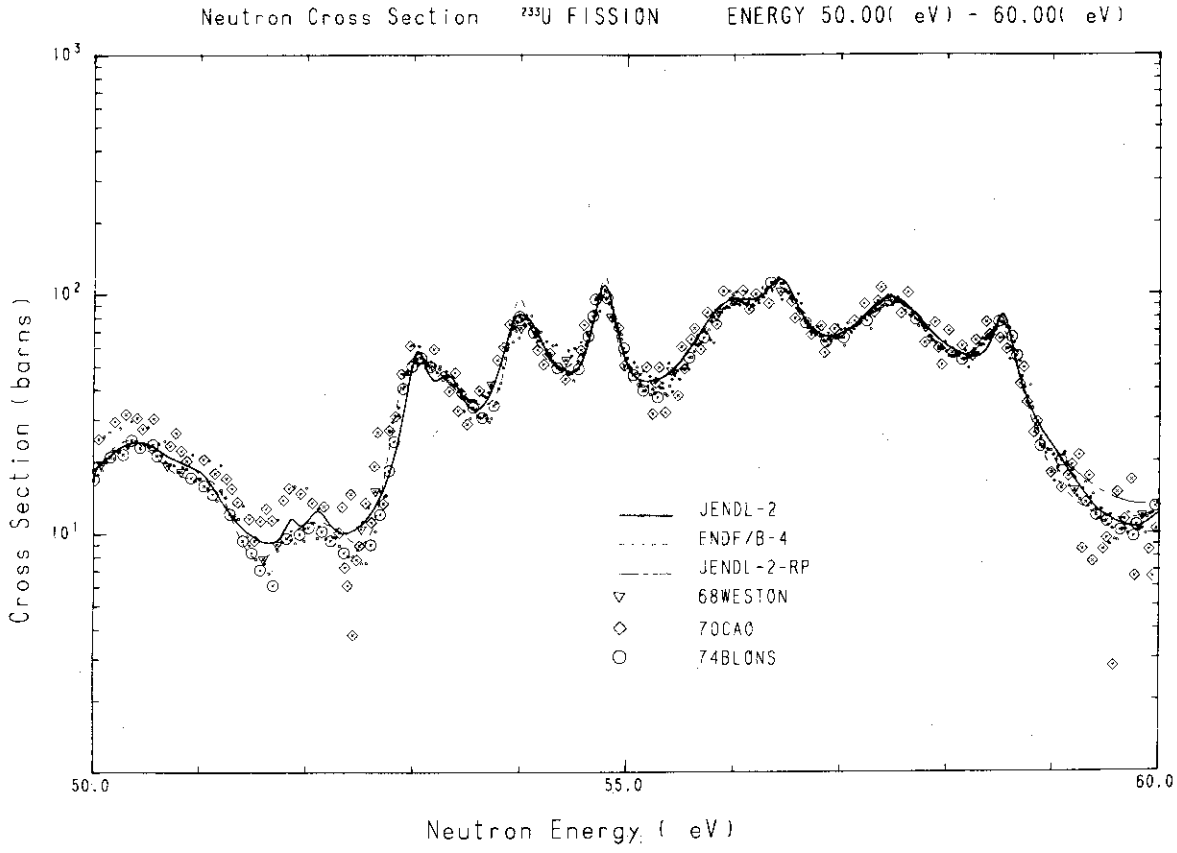
(c)


Neutron Cross Section ²³³U FISSION ENERGY 30.00(eV) - 40.00(eV)
Cross Section (barns)
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
68WESTON
70CAO
74DERUYTTER
74BLONS
30.0
35.0
40.0

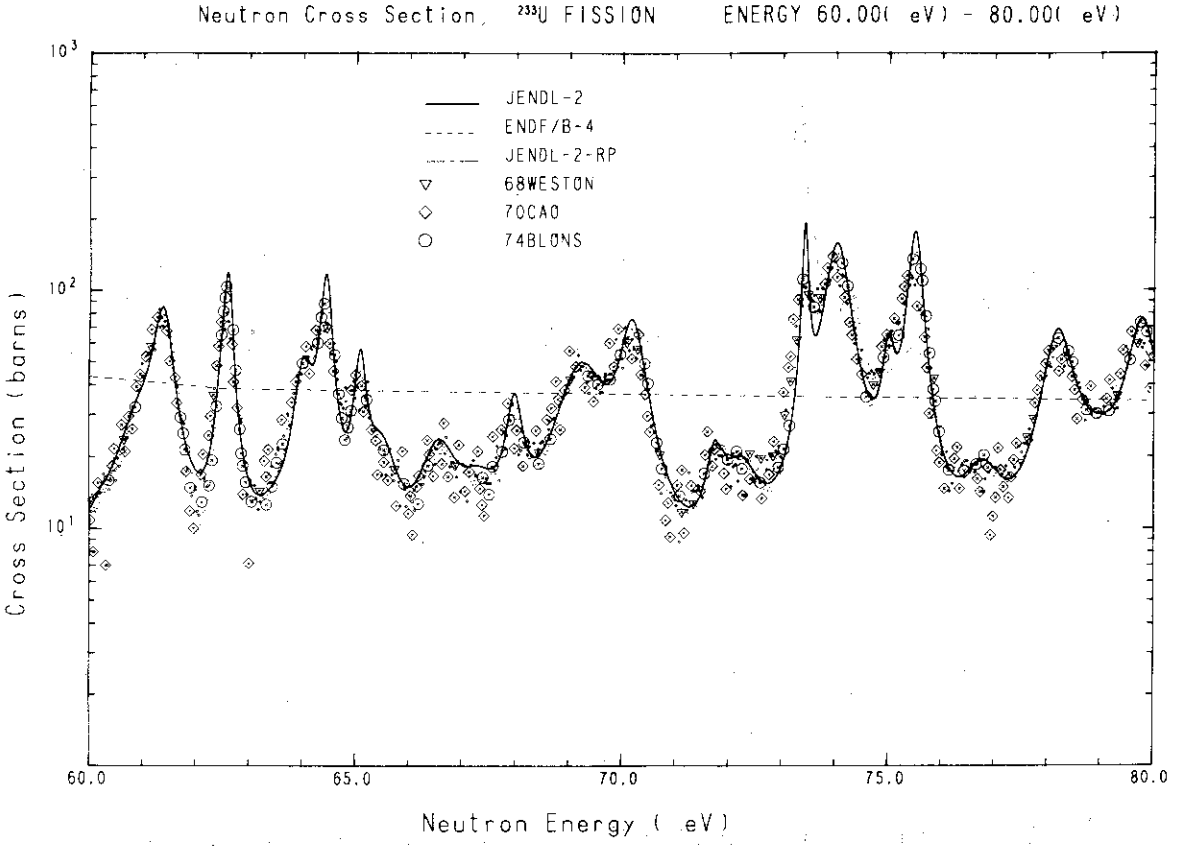
(d)


Neutron Cross Section ²³³U FISSION ENERGY 40.00(eV) - 50.00(eV)
Cross Section (barns)
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
68WESTON
70CAO
74BLONS
40.0
45.0
50.0

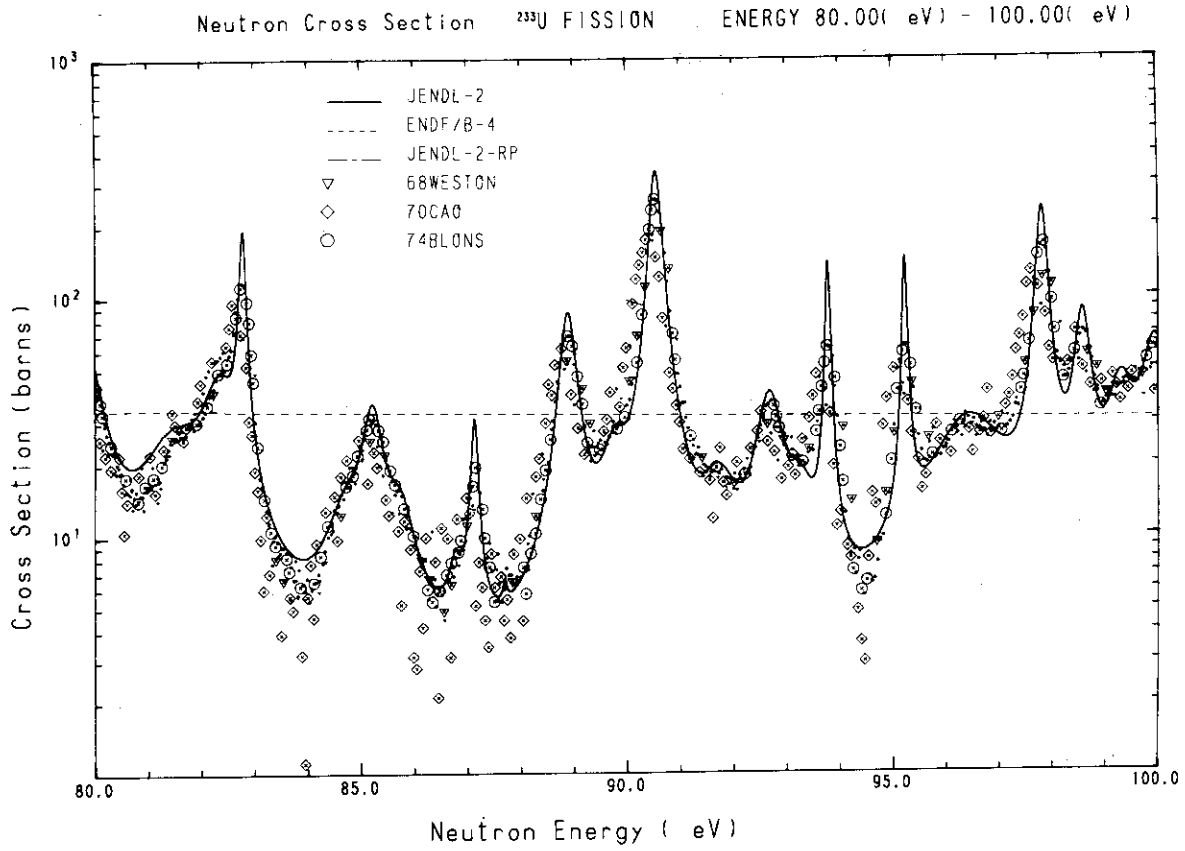
(e)


Neutron Cross Section ²³³U FISSION ENERGY 50.00(eV) - 60.00(eV)
Cross Section (barns)
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
68WESTON
70CAO
74BLONS
50.0
55.0
60.0

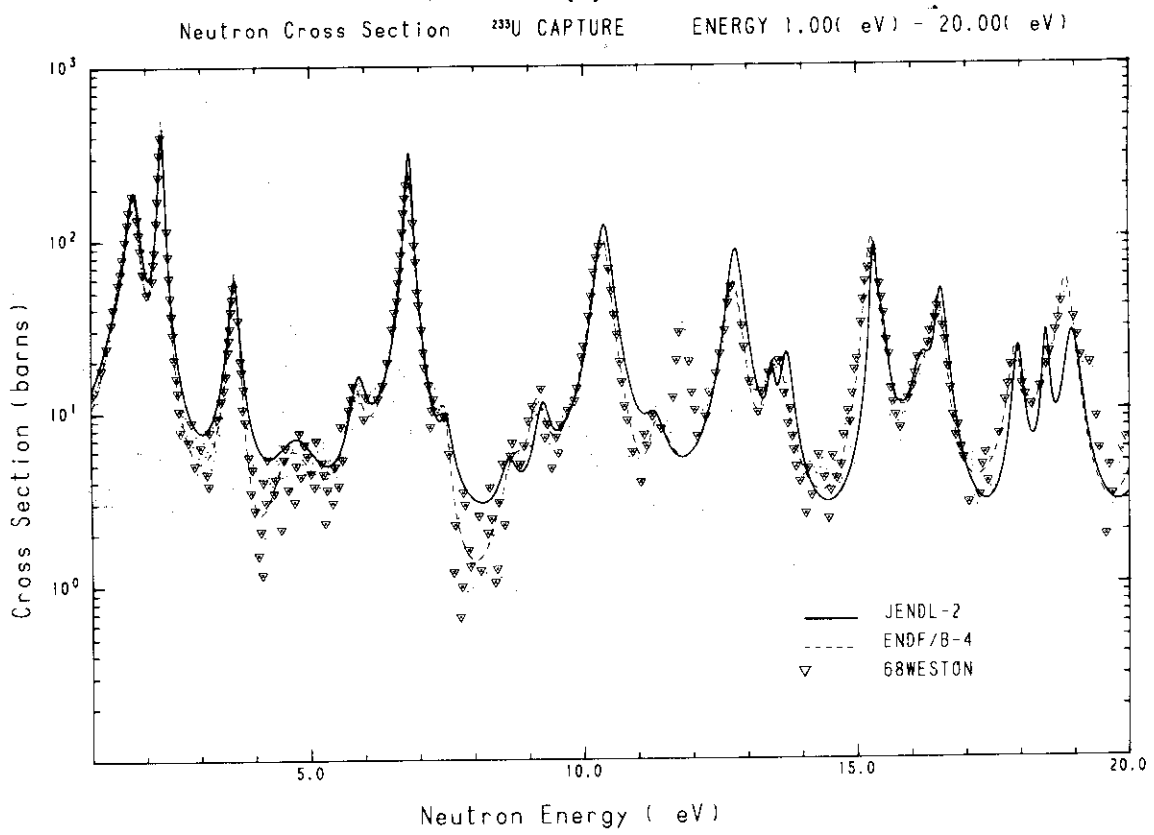
(f)


Neutron Cross Section ²³³U FISSION ENERGY 60.00(eV) - 80.00(eV)
Cross Section (barns)
Neutron Energy (eV)
JENDL-2
ENDF/B-4
JENDL-2-RP
68WESTON
70CAO
74BLONS
60.0
65.0
70.0
75.0
80.0

(g)

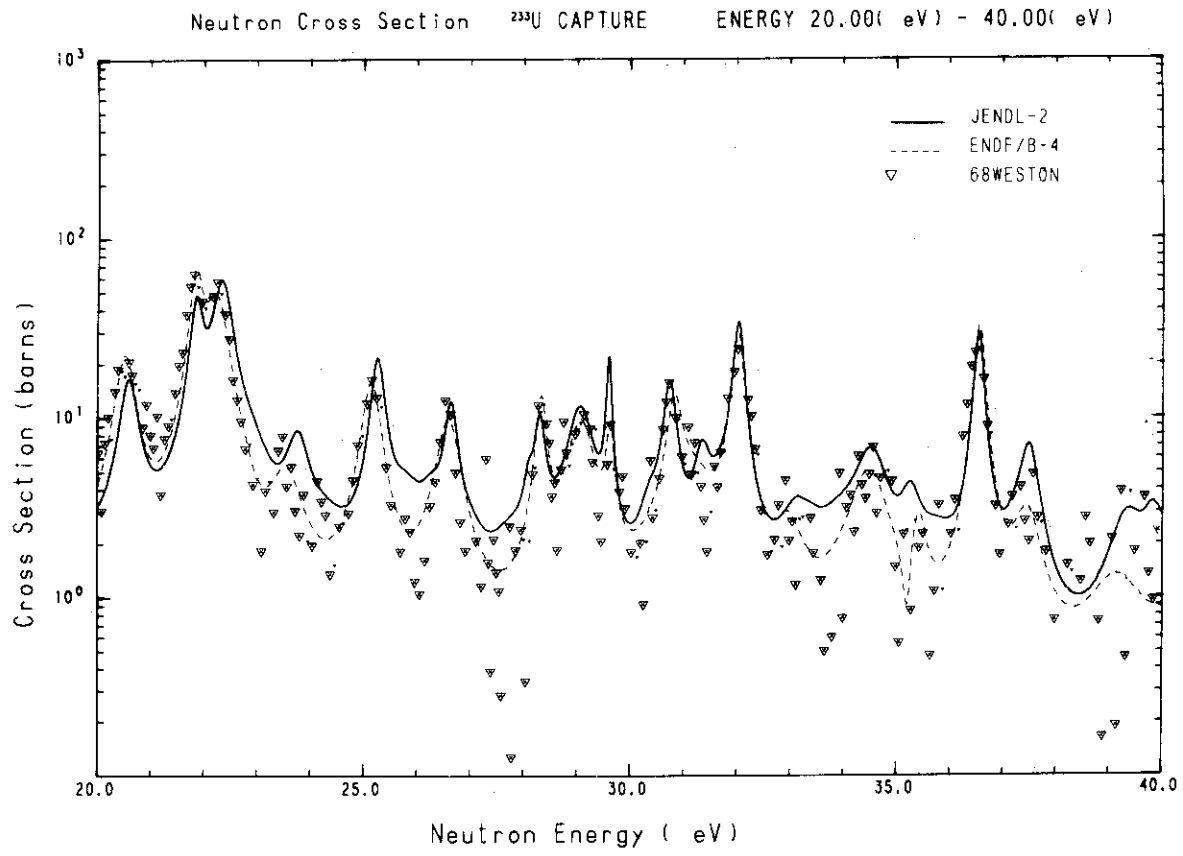


(h)

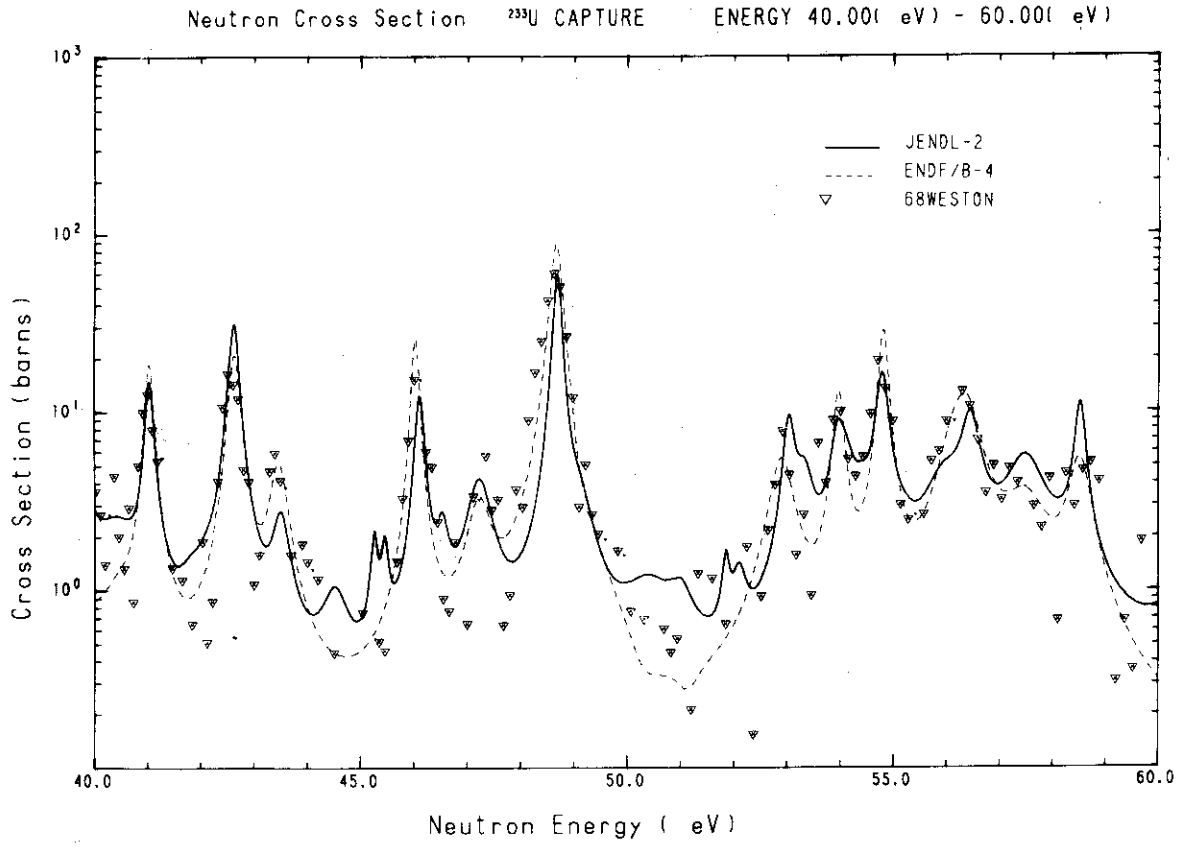


(a)

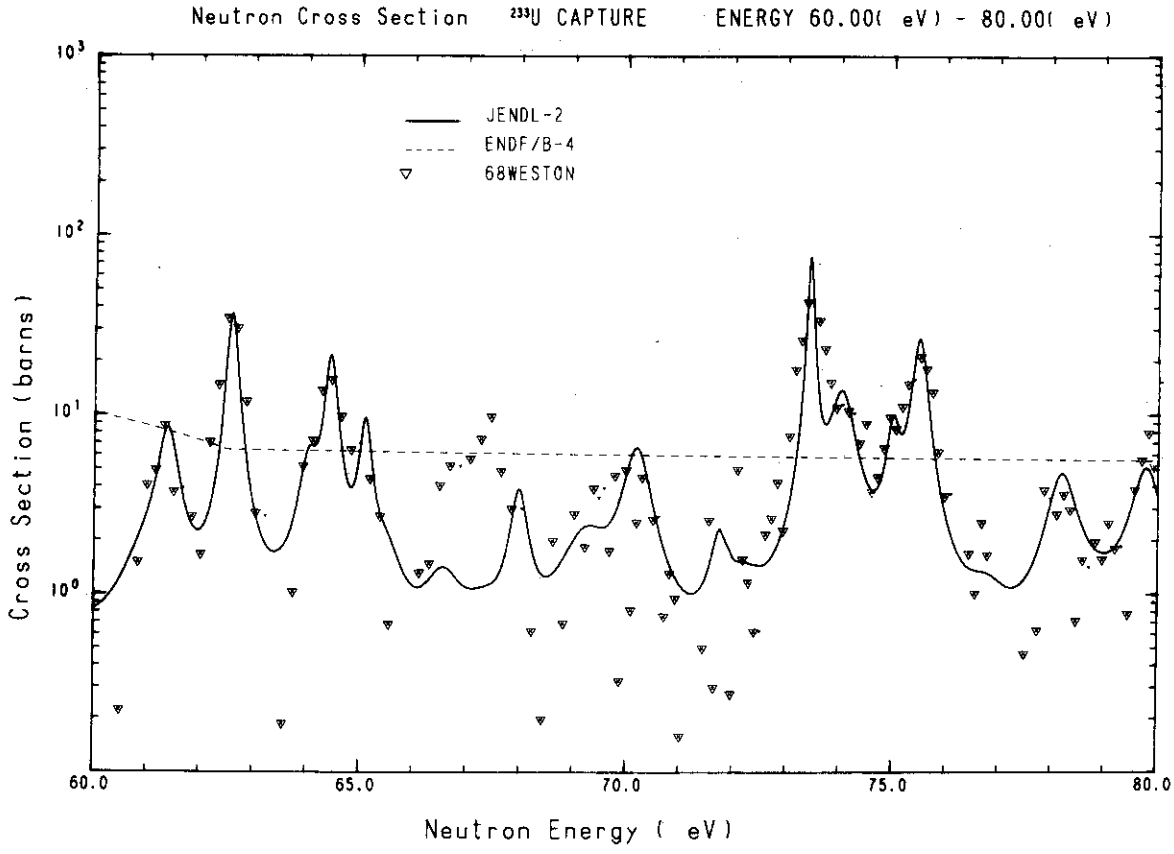
Fig.13 Capture cross sections ^{233}U. The solid and dotted lines represent the present values and those of ENDF/B-IV, respectively.


Neutron Cross Section ²³³U CAPTURE ENERGY 20.00(eV) - 40.00(eV)
JENDL-2
ENDF/B-4
68WESTON
Cross Section (barns)
Neutron Energy (eV)
20.0
25.0
30.0
35.0
40.0

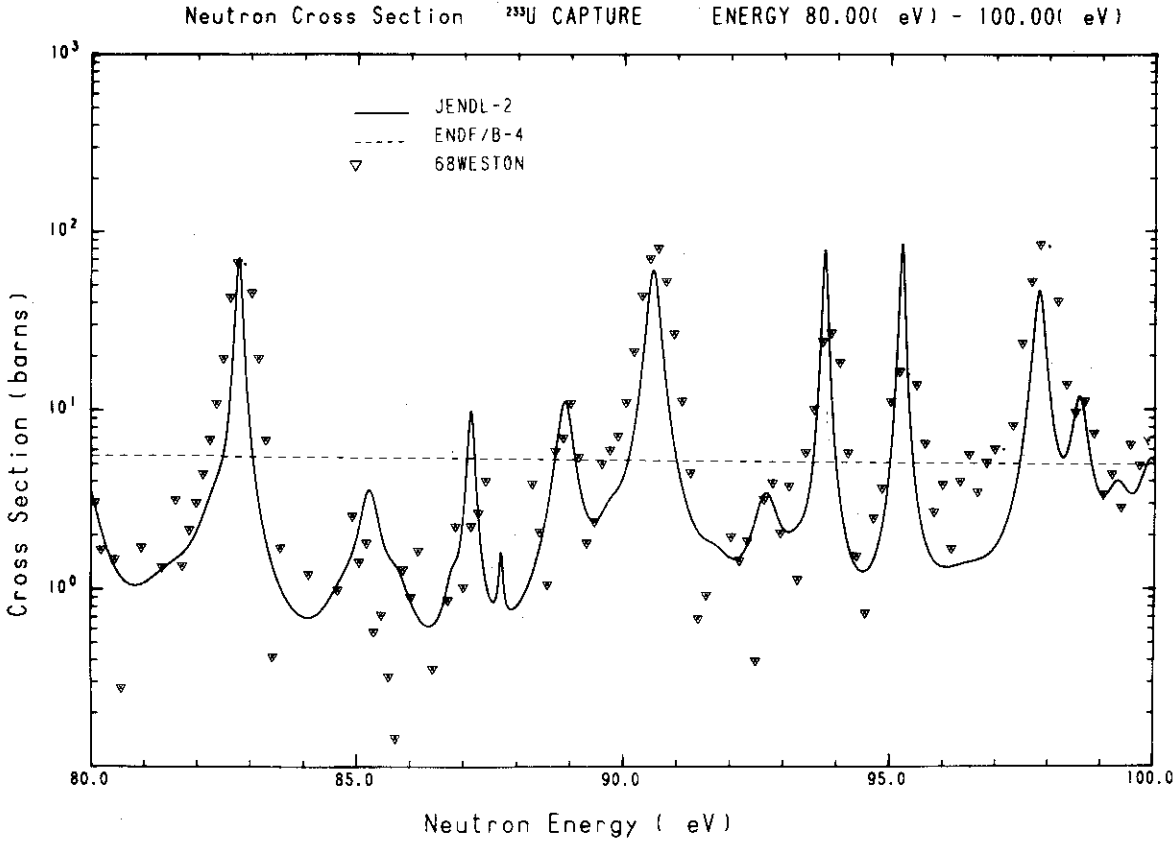
(b)


Neutron Cross Section ²³³U CAPTURE ENERGY 40.00(eV) - 60.00(eV)
JENDL-2
ENDF/B-4
68WESTON
Cross Section (barns)
Neutron Energy (eV)
40.0
45.0
50.0
55.0
60.0

(c)


Neutron Cross Section ²³³U CAPTURE ENERGY 60.00(eV) - 80.00(eV)
JENDL-2
ENDF/B-4
68WESTON
Cross Section (barns)
Neutron Energy (eV)
60.0
65.0
70.0
75.0
80.0

(d)


Neutron Cross Section ²³³U CAPTURE ENERGY 80.00(eV) - 100.00(eV)
JENDL-2
ENDF/B-4
68WESTON
Cross Section (barns)
Neutron Energy (eV)
80.0
85.0
90.0
95.0
100.0

(e)

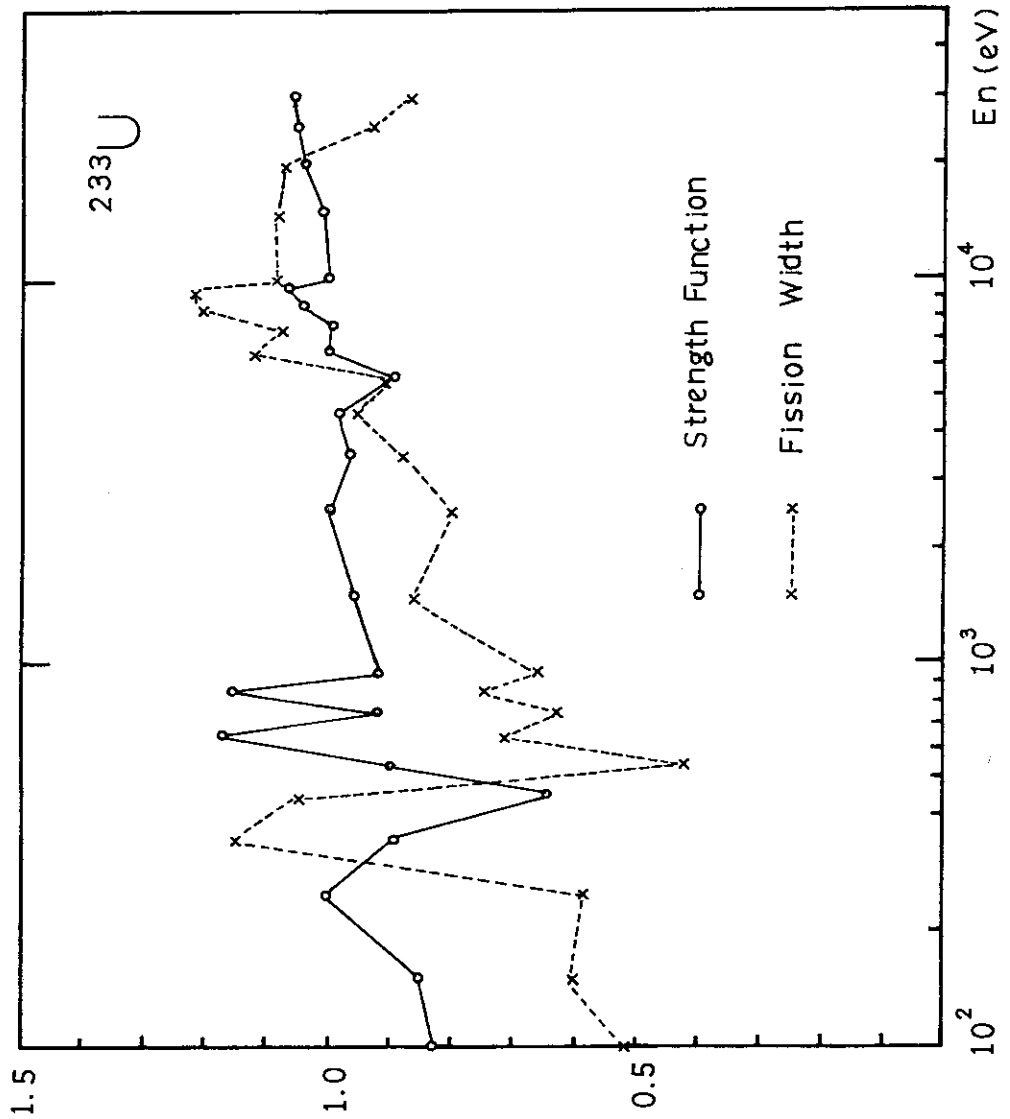


Fig.14 Energy dependence of strength function and fission width of ^{233}U in unresolved resonance region. This figure gives the ratios of the finally adopted values to the energy-independent initial guess values.