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CONSISTENCY BETWEEN DATA FROM THE ENDF/B-V DOSIMETRY FILE AND CORRESPONDING EXPERIMENTAL DATA FOR SOME FAST NEUTRON REFERENCE SPECTRA

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ABSTRACT

In this report results are given of a study on the consistency between "integral" and "differential" cross section data for four benchmark neutron spectra and 36 neutron reactions of importance for reactor neutron metrology.
The energy dependent cross section data and their uncertainty data are obtained from the ENDF/B-V dosimetry file.
The reactions have been considered with respect to the following quantities:

1) The precision of the averaged cross sections, for a specified spectrum;
2) The discrepancy between the measured and the calculated average cross section values;
3) The consistency between the measured and calculated average cross section values, described by the χ^2-parameter.

It was possible to take into account the available cross section covariance information present in the ENDF/B-V dosimetry file. Covariance information on the benchmark flux density spectra was not taken into account in this study.

KEYWORDS

NEUTRON DOSIMETRY
NEUTRON SPECTRA
FAST NEUTRONS
COMPARATIVE EVALUATIONS
EVALUATED DATA

CONTENTS

1. INTRODUCTION

This study on the consistency between spectrum averaged cross section values and energy dependent cross section data is based on the comparison of measured and calculated values of spectrum averaged cross sections.

The measured value is obtained by irradiation of an activation detector in a specified spectrum field, yielding a single averaged value (sometimes called "integral" value).

The calculated value is obtained by folding calculated numerical information on the neutron flux density spectrum with energy dependent (sometimes called "differential") cross section data.

In this study the ENDF/B-V dosimetry file has been applied together with uncertainties from the ENDF/B-V covariance files. For this reason this report can be considered as an updated version of the report "On the consistency between integral and differential cross section data" [1], which was based on the ENDF/B-IV dosimetry file and on a non-recent set of uncertainty data.

In the calculations four fast neutron flux density benchmark spectra have been used:

- the thermal fission neutron spectrum of ^{235}U [1];
- the spontaneous fission neutron spectrum of ^{252}Cf [1];
- the neutron spectrum of the ΣΣ facility in Mol, Belgium [1];
- the neutron spectrum in the CFRMF at Idaho Falls, USA [1].

The uncertainties in these reference spectra were not taken into account.

For each of these spectra the spectrum averaged cross section value and the uncertainty of this value have been calculated for the neutron detection reactions for which the measured average cross sections, the energy dependent cross sections, and the corresponding uncertainties are available. These calculations have been done using the computer program STAY'SL [2].

The spectrum averaged cross sections and their uncertainties are also calculated for a typical CTR neutron spectrum. These calculations are performed only to give an indication of the uncertainties in the calculated activities for this spectrum type. This CTR spectrum is calculated for a Tokamak and kindly made available to us by Dr. R. Dierckx [3].

2. INPUT DATA

For the calculation the Petten version of the computer program STAY'SL was used.
A complete input deck had to be supplied. For the calculations a group structure has to be chosen. It is noted that the group structures for the cross section data and the input flux density spectrum have to be the same.
Calculations have been performed with two group structures (one with the energy range from 10^{-10} to 18 MeV, covering 15 groups, and the other one for the same range, covering 98 groups).
The results for the two group structures with respect to average cross section values and the standard deviations were nearly the same.
In this report therefore results obtained with the 98 groups structure are given.
The original spectrum data were converted first to the 620 groups structure by means of the SAND-II program [4]. For the cases where spectrum data were incomplete, some extrapolations were performed to achieve a full coverage of the range from 10^{-10} to 18 MeV.
With a small special program (GROUP) the spectrum was converted to the group structure specification for STAY'SL. The conversion consisted of the calculation of the sum of the fine group flux density values for the STAY'SL groups.
The group cross sections were calculated also with this special program with as input the cross section library in 620 groups and the weighing spectrum also in 620 groups.
The cross section covariance data from the ENDF/B-V dosimetry file were converted in two steps with two small programs.
The program COVSIG converted the ENDF data to a more appropriate form [5]. This program was used previously with a 15 groups structure (as listed in table 1). The coefficients of variation, as derived from the variance values on the main diagonal of the 15×15 variance-covariance matrix, are shown in table 2.
The output of COVSIG was used as input for the other program which made the covariance data required as input for the program STAY'SL.
The remainder of the input data for STAY'SL which does not influence the results presented here was chosen in a rather arbitrary way (i.e. all input activities and their uncertainties the same, no correlations be-

tween the input activities, an arbitrary flux density covariance data set, and some extra parameters for normalization of the data set).

3. MEASURED ACTIVITIES

The measured activities and their uncertainties were in general the same as the corresponding values applied in [1], which used data from Fabry et al. [6]. Only the data for the ^{252}Cf neutron spectrum have been replaced by the evaluated measured average cross section by Mannhart and Perey [7]. Also some small changes and measured average cross sections, which were not available in the review from Fabry et al., were taken from Magurno [8].

4. TREATMENT OF STAY'SL OUTPUT

The calculated average cross section values were obtained by dividing the calculated reaction rates by the spectrum integral (i.e. the total flux density), both taken for the input spectrum. The uncertainty (in percent) can directly be read in the matrix with cross section uncertainty data in the STAY'SL output. The output data are listed and in the same listing a survey of measured values is given.
Also a table is given which is intended as a survey of the quality of the data. This table gives data for the precision of the measured average cross section, for the discrepancy of measured and calculated average cross sections, and for the consistency of measured and calculated cross sections.
As measure for the consistency the following value for χ^2 is used:

$$\chi^2 = \frac{(\alpha^m - \alpha^c)^2}{\text{var } \alpha^m + \text{var } \alpha^c}$$

with α^m = measured average cross section;
α^c = calculated average cross section;
var α^m = variance of measured value;
var α^c = variance of calculated value.

The quality of these data is indicated with a code.
The key of the code is listed below.

quality	precision	discrepancy	consistency
++	0% < v ≤ 2%	0% < Δ ≤ 2%	$\chi^2 \leq 1,5$
+	2% < v ≤ 4%	2% < Δ ≤ 4%	$1,5 < \chi^2 \leq 3$
0	4% < v ≤ 6%	4% < Δ ≤ 6%	$3 < \chi^2 \leq 4,5$
-	6% < v ≤ 8%	6% < Δ ≤ 8%	$4,5 < \chi^2 \leq 6$
--	8% < v	8% < Δ	$6 < \chi^2$

5. RESULTS AND DISCUSSION

Table 2 shows for the reactions considered the coefficients of variation for the group cross sections in a 15 groups structure. One can observe that for the reactions $^{45}Sc(n,\gamma)$ and $^{59}Co(n,\gamma)$ the coefficient of variation in the resonance energy region is remarkably higher than in the MeV region. For the other (n,γ) reactions in table 2 one sees that the coefficient of variation increases with increasing energy.
With respect to threshold reactions one may observe that very often the coefficients of variation have appreciable values in the MeV region. These values are remarkably higher than the precision of experimental spectrum averaged values, obtained for reference spectra.
In this context it should be noted that the benchmark spectra which have been considered in this study all have the character of a fast neutron spectrum. Furthermore it is emphasized that in our calculations it was assumed that the benchmark spectra were exactly known (thus neglecting all variances and covariances of group flux densities).
Table 3 gives the measured and calculated cross section data and their ratios.
The standard deviations for the data of table 3 are given in table 4, together with the χ^2-values.
Table 5 shows a survey of the quality of the data.
For the interpretation of these data it should be noted that the uncertainty data applied in these calculations are not fully representative, because we were not able to include the covariance data from ENDF/B-V file 32 at this moment, due to lack of software. For this reason we

had incomplete uncertainty data for the reactions $^{23}Na(n,\gamma)$, $^{54}Fe(n,\gamma)$, $^{63}Cu(n,\gamma)$, and $^{237}Np(n,f)$.
Furthermore the covariance data on the ENDF/B-V files which were used were not complete for the reactions $^{238}U(n,\gamma)$ and $^{239}Pu(n,f)$.
For the reaction $^{54}Fe(n,p)$ we observed a correlation coefficient larger than 1, so we suspect the presence of some error in the data.
All these effects lead to a too low value for the calculated uncertainty.

When looking at the consistency columns of table 4 one may note that in most cases small values for the χ^2 are found.
Only for the ΣΣ we observe two large values for the reactions $^{56}Fe(n,p)$ and for $^{238}U(n,\gamma)$. The latter reaction has an incomplete covariance matrix resulting in a too small variance in the calculated cross section. So the conclusion can be drawn that the ENDF/B-V cross section data are consistent with the measured data.
The situation is however less favourable when the absolute values for the discrepancies are inspected.
The good consistency is mainly due to the relatively large values of the calculated uncertainties. For the four reference spectra the calculated relative uncertainties in the average cross section are nearly spectrum independent. Only the reactions responding to low energy neutrons show deviations in the calculated uncertainties.
In table 5 also the precision of σ^c is given. This column shows that only 15 reactions can give uncertainties smaller than 6% in these spectra and only a few give uncertainties smaller than a few percent. This situation has consequences for neutron spectrum unfolding.
The detector set which is applied should in general contain reactions for which good quality data (i.e. cross section with small uncertainty values) are available and that means that only a few reactions can be used.
For the sake of unfolding it is required to reduce the uncertainties in the cross section data, so that more reactions can be used and thus reasonable information can be obtained.

6. ACKNOWLEDGEMENT

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Table 1. Energy boundaries of the 15 groups used in table 2

The 16 boundary values, expressed in MeV, are as follows:
10^{-10}; $0{,}4\times10^{-6}$; 10^{-5}; 10^{-2}; 10^{-1}; 11, 1,4 ; 2,2; 3; 4; 5; 6; 8; 11; 12; 20.

Table 2. Coefficients of variation (in %) of the group cross sections of the various reactions.

	MAT	MT															
^{23}Na(n,γ)	6311	102	2	2	4	10	2	20	20	20	20	20	25	25	25	25	25
^{27}Al(n,p)	6313	103	0	0	0	0	0	0	11	23	13	11	7	9	13	14	8
^{27}Al(n,α)	6313	107	0	0	0	0	0	0	0	0	31	22	9	7	6	4	4
^{55}Mn(n,2n)	6325	16	0	0	0	0	0	0	0	0	0	0	0	0	5	22	6
^{59}Co(n,2n)	6327	16	0	0	0	0	0	0	0	0	0	0	0	0	4	21	6
^{59}Co(n,γ)	6327	102	9	26	26	27	27	17	9	9	9	9	9	10	10	10	10
^{59}Co(n,α)	6327	107	0	0	0	0	0	0	0	0	0	0	4	6	5	5	5
^{237}Np(n,f)	6337	18	0	0	30	30	10	10	10	10	10	10	15	15	15	15	15
^{197}Au(n,γ)	6379	102	1	2	4	10	4	9	20	20	20	22	22	22	22	25	24
^{232}Th(n,f)	6390	18	0	0	0	0	0	12	6	7	6	7	7	11	11	11	11
^{232}Th(n,γ)	6390	102	3	8	11	11	11	11	21	21	21	21	21	21	21	21	21
^{235}U (n,f)	6393	18	0	2	3	3	3	3	3	3	3	4	4	4	3	4	5
^{238}U (n,f)	6398	18	25	7	4	30	19	6	2	2	2	2	3	4	2	2	5
^{238}U (n,γ)	6398	102	1	0	0	2	2	4	10	30	30	30	30	30	30	30	30
^{239}Pu(n,f)	6399	18	1	4	4	5	3	2	2	2	2	2	2	2	2	2	2
^{6}Li(n,He)	6424	207	5	5	5	5	5	7	7	7	9	10	10	10	13	15	16
^{10}B (n,He)	6425	207	15	15	15	15	15	15	15	15	18	18	13	11	14	11	10
^{45}Sc(n,γ)	6426	102	9	26	26	27	27	17	9	9	9	9	9	10	10	10	10
^{46}Ti(n,p)	6427	103	0	0	0	0	0	0	0	9	13	13	13	13	12	14	14
^{47}Ti(n,np)	6428	28	0	0	0	0	0	0	0	0	0	0	0	0	3	30	30
^{47}Ti(n,p)	6428	103	0	0	0	0	0	2	11	11	11	11	11	11	10	13	13
^{48}Ti(n,np)	6429	28	0	0	0	0	0	0	0	0	0	0	0	0	0	19	30
^{48}Ti(n,p)	6429	103	0	0	0	0	0	0	0	0	0	11	11	11	10	13	13
^{54}Fe(n,p)	6430	103	0	0	0	0	0	1	3	2	2	2	2	2	3	3	4
^{56}Fe(n,p)	6431	103	0	0	0	0	0	0	0	0	10	8	7	5	4	4	2
^{58}Fe(n,γ)	6432	102	0	0	0	0	1	2	31	31	31	31	31	31	24	5	5
^{58}Ni(n,2n)	6433	16	0	0	0	0	0	0	0	0	0	0	0	0	0	6	11
^{58}Ni(n,p)	6433	103	0	0	0	0	2	14	11	10	10	7	7	7	7	10	14
^{60}Ni(n,p)	6434	103	0	0	0	0	0	0	0	8	8	8	8	13	8	9	7
^{63}Cu(n,γ)	6435	102	2	4	6	8	20	20	20	20	20	20	20	20	20	20	20
^{63}Cu(n,ℓ)	6435	107	0	0	0	0	0	0	4	20	15	10	8	7	6	6	6
^{65}Cu(n,2n)	6436	16	0	0	0	0	0	0	0	0	0	0	0	0	6	7	5
^{115}In(n,2n)	6477	51	0	0	0	0	8	14	14	14	12	13	13	11	12	11	22
^{115}In(n,γ)	6477	102	6	6	5	9	5	4	7	7	7	13	13	13	13	13	13
^{127} I(n,2n)	6439	16	0	0	0	0	0	0	0	0	0	0	0	0	21	40	40

Table 3. Measured and calculated cross section data and their ratios for various neutron spectra

reaction	^{235}U			^{252}Cf			CFRMF			ΣΣ			CTR
	$\langle\sigma_m\rangle$	$\langle\sigma_c\rangle$	$\frac{\langle\sigma_m\rangle}{\langle\sigma_c\rangle}$	$\langle\sigma_m\rangle$	$\langle\sigma_c\rangle$	$\frac{\langle\sigma_m\rangle}{\langle\sigma_c\rangle}$	$\langle\sigma_m\rangle$	$\langle\sigma_c\rangle$	$\frac{\langle\sigma_m\rangle}{\langle\sigma_c\rangle}$	$\langle\sigma_m\rangle$	$\langle\sigma_c\rangle$	$\frac{\langle\sigma_c\rangle}{\langle\sigma_c\rangle}$	$\langle\sigma_c\rangle$
$^{6}Li(n,\alpha)$		465,1			464,7		948	914,9	1,04		859,6		888,7
^{10}B (n,α)		499,3			489,1		1814	1674,5	1,08		1466,4		1950,6
$^{23}Na(n,\gamma)$		0,282		0,335	0,271	1,24		1,520			1,111		1,941
$^{27}Al(n,p)$	3,86	4,123	0,94	5,1	5,137	0,99	0,874	0,948	0,92	0,983	0,878	1,12	21,67
$^{27}Al(n,\alpha)$	0,705	0,693	1,02	1,019	1,059	0,96	0,161	0,184	0,88	0,153	0,156	0,98	31,08
$^{45}Sc(n,\gamma)$		5,639			5,258		23,5	24,400	0,97		22,46		28,00
$^{46}Ti(n,p)$	11,8	10,82	1,09	14,12	13,47	1,05	2,61	2,476	1,05		2,268		70,44
$^{47}Ti(n,p)$	19,0	21,58	0,88	19,27	24,07	0,80	4,18	5,139	0,81		5,231		36,30
$^{47}Ti(n,np)$		0,00848			0,0207			0,00323			0,00202		13,81
$^{48}Ti(n,p)$	0,300	0,273	1,10	0,424	0,409	1,04	0,0688	0,0711	0,97		0,0611		15,94
$^{48}Ti(n,np)$		0,00136			0,00344			0,00532			0,000332		1,935
$^{54}Fe(n,p)$	79,7	77,83	1,02	86,58	88,25	0,98	17,5	17,81	0,98		17,66		113,7
$^{55}Mn(n,2n)$	0,244	0,201	1,21	0,58	0,441	1,32		0,0692			0,0457		178,0
$^{55}Mn(n,\gamma)$		3,598			3,409			45,78		36,0	34,49	1,01	63,54
$^{56}Fe(n,p)$	1,035	1,005	1,03	1,468	1,413	1,04		0,250		0,260	0,223	1,17	27,72
$^{58}Fe(n,\gamma)$		1,714			1,665		6,12	6,686	0,92		6,078		10,51
$^{58}Ni(n,2n)$	0,00577	0,00286	2,02		0,00724			0,00113			0,00684		6,541
$^{58}Ni(n,p)$	108,5	100,92	1,08	115,4	113,78	1,01	24,0	23,44	1,02	26,5	23,43	1,13	134,9
$^{59}Co(n,\alpha)$	0,143	0,145	0,99	0,20	0,217	0,92		0,0378			0,0327		7,300
$^{59}Co(n,2n)$		0,183		0,57	0,405	1,41		0,0635			0,0415		184,3
$^{59}Co(n,\gamma)$		6,283		6,97	6,032	1,16	91,6	82,20	1,11		40,79		87,20
$^{60}Ni(n,p)$		2,527			3,440			0,614			0,550		32,91
$^{63}Cu(n,\alpha)$	0,500	0,540	0,93		0,757			0,134			0,118		11,14
$^{63}Cu(n,\gamma)$	9,30	10,07	0,92	10,95	9,646	1,14	45,4	47,00	0,97	36,2	36,26	1,00	56,32
$^{65}Cu(n,2n)$		0,0306			0,650			0,102			0,0692		213,3
$^{115}In(n,n')$	189	173,4	1,09	198,3	182,0	1,09	51,0	49,74	1,03	56,0	53,54	1,05	58,99
$^{115}In(n,\gamma)$	134,5	126,6	1,06	126,0	121,3	1,04	281,5	281,8	1,00	240	262,1	0,92	281,0
^{127}I $(n,2n)$	1,05	1,186	0,89		2,310			0,371			0,267		400,1
$^{197}Au(n,\gamma)$	83,5	81,21	1,03	77,20	76,55	1,01	424	422,7	1,00	402	371,8	1,08	471,6

Table 3 (continued)

reaction	^{235}U			^{252}Cf			CFRMF			ΣΣ			CTR
	$\langle\sigma_m\rangle$	$\langle\sigma_c\rangle$	$\frac{\langle\sigma_m\rangle}{\langle\sigma_c\rangle}$	$\langle\sigma_m\rangle$	$\langle\sigma_c\rangle$	$\frac{\langle\sigma_m\rangle}{\langle\sigma_c\rangle}$	$\langle\sigma_m\rangle$	$\langle\sigma_c\rangle$	$\frac{\langle\sigma_m\rangle}{\langle\sigma_c\rangle}$	$\langle\sigma_m\rangle$	$\langle\sigma_c\rangle$	$\frac{\langle\sigma_m\rangle}{\langle\sigma_c\rangle}$	$\langle\sigma_c\rangle$
$^{232}Th(n,f)$	81	72,44	1,12	89,0	78,08	1,14		18,67			19,86		111,0
$^{232}Th(n,\gamma)$		94,19			89,65			264,3			233,8		272,8
$^{235}U(n,f)$	1203	1236,7	0,97	1203	1235,9	0,97	1557	1581,7	0,98	1512	1500,4	1,01	1901,3
$^{238}U(n,f)$	305	293,8	1,04	318,6	312,7	1,02	75,6	77,29	0,98	84,8	83,08	1,02	358,9
$^{238}U(n,\gamma)$		72,07			68,35		233	237,0	0,98	174	210,1	0,83	249,1
$^{237}Np(n,f)$	1312	1322,4	0,99	1338	1352,8	0,99	551	586,3	0,94	586,5	624,6	0,94	1008,2
$^{239}Pu(n,f)$	1811	1785,8	1,01	1799	1792,7	1,00	1783	1787,0	1,00	1764	1758,0	1,00	2060,8

Table 4. Standard deviations of measured and calculated average cross sections and χ^2 values for various neutron spectra

reaction	^{235}U			^{252}Cf			CFRMF			ΣΣ			CTR
	$s(\sigma_m)$	$s(\sigma_c)$	χ^2	$s(\sigma_m)$	$s(\sigma_c)$	χ^2	$s(\sigma_m)$	$s(\sigma_c)$	χ^2	$s(\sigma_m)$	$s(\sigma_c)$	χ^2	$s(\sigma_c)$
$^{6}Li(n,\alpha)$		4,98			4,97		4,11	5,08	0,30		5,10		4,75
$^{10}B\ (n,\alpha)$		13,05			12,73		3,30	14,86	0,30		14,85		13,67
$^{23}Na(n,\gamma)$		12,69[a]		4,48	12,96[a]	2,81		9,19[a]			8,99[a]		9,23[a]
$^{27}Al(n,p)$	6,48	5,86	0,572	9,80	5,73	0,004	3,78	5,79	1,33	10,15	5,85	0,88	8,91
$^{27}Al(n,\alpha)$	5,67	5,65	0,046	2,40	5,46	0,41	3,10	5,53	4,12	3,27	5,64	0,09	4,75
$^{45}Sc(n,\gamma)$		18,48			17,94		3,83	25,79	0,02		25,65		25,90
$^{46}Ti(n,p)$	6,36	12,66	0,394	2,60	12,59	0,14	3,83	12,62	0,17		12,65		13,53
$^{47}Ti(n,p)$	7,37	11,27	0,845	2,50	11,24	3,05	4,79	11,26	2,45		11,27		11,51
$^{47}Ti(n,p)$		29,70			29,78			29,77			29,72		30,00
$^{48}Ti(n,p)$	6,00	10,45	0,641	2,80	10,30	0,12	4,36	10,35	0,08		10,44		12,66
$^{48}Ti(n,np)$		29,60			29,69			29,68			29,65		30,00
$^{54}Fe(n,p)$	6,15	2,54[b]	0,125	2,50	2,56[b]	0,28	3,44	2,59[b]	0,17		2,59[b]		3,82[b]
$^{55}Mn(n,2n)$	6,15	13,27	1,974	10,34	12,44	2,92		12,46			13,08		7,33
$^{55}Mn(n,\gamma)$		4,22			4,22			1,92		5,56	2,02	0,06	1,91
$^{56}Fe(n,p)$	7,25	4,57	0,116	2,80	4,45	0,54		4,48		3,08	4,55	8,19	2,03
$^{58}Fe(n,\gamma)$		11,78[a]			12,91[a]		3,59	- [a]	-		- [a]		10,70[a]
$^{58}Ni(n,2n)$	5,38	10,94	43,591		10,89			10,93			10,87		11,95
$^{58}Ni(n,p)$	4,98	6,56	0,787	1,90	6,43	0,04	3,33	6,51	0,11	3,02	6,66	3,06	13,11
$^{59}Co(n,\alpha)$	6,99	4,37	0,029	5,00	4,26	1,56		4,33			4,37		5,66
$^{59}Co(n,2n)$		11,36		10,53	10,46	5,04		10,55			11,15		5,82
$^{59}Co(n,\gamma)$		13,69		4,88	13,12	1,19	3,92	26,09	0,19		25,66		26,16
$^{60}Ni(n,p)$		7,75			7,56			7,62			7,85		9,30
$^{63}Cu(n,\alpha)$	11,18	5,38	0,403		5,25			5,32			5,36		5,45
$^{63}Cu(n,\gamma)$	15,03	19,06[a]	0,105	4,66	19,25[a]	0,46	5,73	6,43[a]	0,16	5,52	8,27[a]	0,0003	3,95[a]
$^{65}Cu(n,2n)$		6,51			6,21			6,29			6,54		5,11
$^{115}In(n,n')$	4,23	11,98	0,491	2,60	11,88	0,54	5,88	12,02	0,04	2,50	12,15	0,14	11,88
$^{115}In(n,\gamma)$	4,46	4,25	0,961	3,50	4,32	0,47	3,91	3,78	0,0004	3,75	3,62	2,856	4,56
$^{127}I\ (n,2n)$	6,19	38,39	0,087		38,58			38,54			38,41		41,41
$^{197}Au(n,\gamma)$	5,99	8,04	0,078	2,70	8,45	0,01	3,30	4,18	0,0003	2,49	3,67	3,185	5,07

Table 4 (continued)

reaction	235U			252Cf			CFRMF			ΣΣ			CTR
	$s(\sigma_m)$	$s(\sigma_c)$	χ^2	$s(\sigma_m)$	$s(\sigma_c)$	χ^2	$s(\sigma_m)$	$s(\sigma_c)$	χ^2	$s(\sigma_m)$	$s(\sigma_c)$	χ^2	$s(\sigma_c)$
$^{232}Th(n,f)$	6,66	5,09	1,716	10,11	5,09	1,23		5,13			5,21		9,75
$^{232}Th(n,\gamma)$		11,56			11,75			10,73			10,66		10,87
^{235}U (n,f)	2,49	1,96	0,765	1,80	1,97	1,02	3,41	1,91	0,16	3,63	1,94	0,035	1,95
$^{238}U(n,f)$	3,29	1,11	1,127	2,50	1,08	0,47	3,96	1,30	0,29	2,95	1,32	0,397	3,47
$^{238}U(n,\gamma)$		4,63[c]			4,92[c]		4,72	0,66[c]	0,13	4,02	0,94[c]	24,669	0,79[c]
$^{237}Np(n,f)$	3,81	9,33[a]	0,006	2,60	9,19[a]	0,01	3,81	9,62[a]	0,34	3,41	9,64[a]	0,361	10,44[a]
$^{239}Pu(n,f)$	3,32	1,98[c]	0,131	2,50	1,99[c]	0,01	3,36	1,82[c]	0,003	3,69	1,84[c]	0,007	1,89[c]

a) covariance matrix not yet complete; data on the covariance file 32 not yet treated with our program COVSIG incomplete covariance data;
b) covariance matrix not trustworthy, because of correlation coefficients larger than one.
c) covariance matrix incomplete; some data in the covariance file 32 are missing.

Table 5. Survey of the quality of the data.

reaction	precision of α_m				precision of α_c	discrepancy				consistency			
	^{235}U	^{252}Cf	CFRMF	ΣΣ	for 4 reference spectra	^{235}U	^{252}Cf	CFRMF	ΣΣ	^{235}U	^{252}Cf	CFRMF	ΣΣ
$^{6}Li(n,\alpha)$			0		0			+				++	
$^{10}B\ (n,\alpha)$			+		--			-				++	
$^{23}Na(n,\gamma)$		0			--		--				+		
$^{27}Al(n,p)$	-	--	+	--	0	0	++	-	--	++	++	++	++
$^{27}Al(n,\alpha)$	0	+	+	+	0	++	0	--	++	++	++	0	++
$^{45}Sc(n,\gamma)$			+		--			+				++	
$^{46}Ti(n,p)$	-	+	+		--	--	0	0		++	++	++	
$^{47}Ti(n,p)$	-	+	0		--	--	--	--		++	0	+	
$^{47}Ti(n,np)$					--								
$^{48}Ti(n,p)$	0	+	0		--	--	+	+		++	++	++	
$^{48}Ti(n,np)$					--								
$^{54}Fe(n,p)$	-	+	+		+	++	++			++	++	++	
$^{55}Mn(n,2n)$	-	--			--	--	--			+	+		
$^{55}Mn(n,\gamma)$				0	0				++				++
$^{56}Fe(n,p)$	-	+		+	0	+	+		--	++	++		--
$^{58}Fe(n,\gamma)$			+		--			-				+	
$^{58}Ni(n,2n)$	0				--	--				--			
$^{58}Ni(n,p)$	0	++	+	+	-	-	++	++	--	++	++	++	+
$^{59}Co(n,\alpha)$	-	0			0	++	-			++	+		
$^{59}Co(n,2n)$		--			--		--				-		
$^{59}Co(n,\gamma)$		0	+		--		--	--			++	++	
$^{60}Ni(n,p)$					-								
$^{63}Cu(n,\alpha)$	--				0	-				++			
$^{63}Cu(n,\gamma)$	--	0	0	0	-(-)[a]	-	--	+	++	++	++	++	++
$^{65}Cu(n,2n)$					-								
$^{115}In(n,n')$	0	+	0	+	--	--	--	+	0	++	++	++	++
$^{115}In(n,\gamma)$	0	+	+	+	0(+)[a]	0	+	++	-	++	++	++	+
$^{127}I\ (n,2n)$	-				--	--				++			
$^{197}Au(n,\gamma)$	-	+	+	+	--(+)[a]	+	++	++	-	++	++	++	0

Table 5 (continued).

reaction	precision of α_m				precision of α_c	discrepancy				consistency			
	^{235}U	^{252}Cf	CFRMF	ΣΣ	for 4 reference spectra	^{235}U	^{252}Cf	CFRMF	ΣΣ	^{235}U	^{252}Cf	CFRMF	ΣΣ
$^{232}Th(n,f)$	-				0	--				+	++		
$^{232}Th(n,\gamma)$					--								
^{235}U (n,f)	+	++	+	+	++	+	+	++	++	++	++	++	++
^{238}U (n,f)	+	+	+	+	++	+	+	+	++	++	++	++	++
^{238}U (n,γ)			0	0	0(++)[a]			+	--			++	--
$^{237}Np(n,f)$	+	+	+	+	--	++	++	0	0	++	++	+	++
$^{239}Pu(n,f)$	+	+	+	+	++	++	++	++	++	++	++	++	++

[a] Values between ( ) refer to CFRMF and ΣΣ spectra.