GESELLSCHAFT FÜR KERNFORSCHUNG M.B.H.
KARLSRUHE

KERNFORSCHUNGSZENTRUM KARLSRUHE

KFK 1629
EANDC (E) 151 "U"

Institut für Neutronenphysik und Reaktortechnik
Projekt Schneller Brüter

Evaluation of neutron data for U-235 above the resolved resonance region for KEDAK

B. Schatz

Gesellschaft für Kernforschung mbH., Karlsruhe

Abstract

In this report an evaluation for the neutron nuclear data types of U-235 above the resolved resonance region up to 15 MeV is described. In particular the following data types were evaluated: the fission cross section, the total cross section, the capture-to-fission ratio and the mean number of secondary neutrons per fission. But also some of the other data types changed due to their dependence upon the primarily evaluated types. The presently recommended nuclear data for U-235 are contained in version 3 of the KEDAK-library which will presumably be released in the second half of 1973.

Auswertung von Neutronendaten für U-235 oberhalb des aufgelösten Resonanzbereichs für KEDAK

Zusammenfassung

Dieser Bericht beschreibt eine Auswertung der Neutronenkerndaten für U-235 oberhalb des aufgelösten Resonanzbereiches bis herauf zu 15 MeV. Im einzelnen wurden die folgenden Datentypen ausgewertet: Der Spaltquerschnitt, der totale Wirkungsquerschnitt, das Verhältnis vom Einfang- zu Spaltquerschnitt und die mittlere Anzahl der pro Spaltung frei werdenden Neutronen. Aber auch ein Teil der übrigen Datentypen hat sich geändert wegen ihrer Abhängigkeit von diesen primär ausgewerteten Typen. Die gegenwärtig für U-235 empfohlenen Kerndaten sind in Version 3 der KEDAK-Bibliothek, die voraussichtlich in der 2. Hälfte von 1973 freigegeben wird, enthalten.

Contents **Page**

I. Introduction

This report describes a re-evaluation of the following nuclear data types for U-235 on the German nuclear data file KEDAK:

$\bar{\nu}$, the mean number of secondary neutrons per fission,
σ_f , the fission cross section,
σ_T , the total cross section,
α , the capture-to-fission ratio,

in the energy region above the resolved resonance range in particular
$\bar{\nu}$: thermal - 15 MeV
σ_f, σ_T, α : 15o eV - 15 MeV

This evaluation has been started, since a number of precision measurements for these data types have been carried out in the years after 1966, the year of J.J. Schmidt's KEDAK-evaluation for this isotope. /34/ A precise knowledge of the neutron fission cross section of U-235 is of obvious importance for its use as standard and for the calculation of fast reactor properties. The $\bar{\nu}$-data needed a revision since most recent measurements for $\bar{\nu}$ (U-235) revealed considerable deviations from the so long assumed linear energy dependence which should be taken into account in fast reactor analysis.

Concerning $\bar{\nu}$ all experimental information available till September 197o, concerning σ_f till January 1971, σ_T till June 1971 and α till October 1971 has been considered here. The evaluation takes into account the most recent recommendations by the IAEA /from 1969/ for the $\bar{\nu}$-value from spontaneous fission of ^{252}Cf.

Besides, the upper energy limit of the data sets available for U-235 on KEDAK was extended for all data types up to 15 MeV.

The here recommended neutron nuclear data for U-235 are included in version 3 of the KEDAK-library which will presumably be released in 1973.

Zum Druck eingereicht am 7.5.1973.

In order to avoid misunderstandings we would like to emphasize that the U-235 data sets recommended here for KEDAK do not correspond to the microscopic data basis of the KFK INR-set for U-235. The KFK INR-set [116] was stablished on the basis of the MOXTOT-set [115] by modifying the group constants for selected data types and energy groups for some materials of paricular importance in reactor calculations, mainly for the heavy isotopes U-235, U-238 and Pu-239. These group constants sets were in general not derived from evaluated nuclear data but were obtained as eye-guide averages of experimental data in specific energy ranges selected in such a way that an improvement in the agreement between calculated and measured results for integral quantities of fast test reactors could be expected. This way of improving the nuclear data basis for reactor calculations by modifying group constants is considered in Karlsruhe only as a first and preliminery step prior to a careful re-evaluation of the data [117] , and this procedure was also applied in the case of U-235. Whereas the KFK INR-set for U-235 was generated in the beginning of 1971, the evaluation for U-235 was completed only in the second half of 1972.

The only evaluated data set for U-235 on which the KFK INR-set is based represents that for the data type $\bar{\nu}$ which is recommended in this report. The other data types: σ_f, σ_γ, α have not yet been re-evaluated for the KEDAK file at the time when the KFK INR-set was generated. In the present evaluation of these data types all experimental information has been considered, eventually selected and afterwards fitted by a smooth curve without direct relationship to integral quantities of fast reactors. The differences between the basic nuclear data of the KFK INR-set for U-235 and the corresponding new data sets for KEDAK described here are therefore mainly due to the fact that the KEDAK data sets represent evaluated data whereas the group constants of the KFK INR-set, though generally within the range of available experimental data, are biased to some extent by the aim of getting an improved accordance between calculated and measured integral quantities of fast zero power reactors. In addition in particular cases preliminary experimental data were used in generating the KFK INR group constants whereas the KEDAK evaluation could profit by the corresponding final values due to the time delay in establishing both data sets.

II. The average number of secondary neutrons per fission

a) The energy dependence of $\bar{\nu}$(U-235)

The current concept of the energy dependence of the average number of neutrons per fission $\bar{\nu}$ is based on the independence of the average kinetic energy of the fission fragments upon the excitation energy of the fissile nucleus [1]. From this it follows directly the linear increase of $\bar{\nu}$ with increasing incident neutron energy. Schuster and Howerton [2] have modified this energy dependence by taking into account the various fission modes.

For incident neutron energies below about 5 MeV there exists only one chance for fission namely the fission of the formed compound nucleus ^{236}U. At energies above about 6 MeV the excitation energy becomes high enough to permit the evaporation of a neutron prior to fission of the residual nucleus. In this range of incident neutron energies the (n, n'f) reaction occurs in addition to the (n, f) reaction and two types of nuclei are undergoing fission, namely the ^{236}U compound nucleus and the ^{235}U compound nucleus. Above about 10 - 12 MeV also fission of the ^{234}U compound nucleus takes place due to the (n, 2n'f) process in the ^{236}U target nucleus. Thus all neutrons emitted by fission of the compound nuclei ^{236}U, ^{235}U, ^{234}U formed by the three reaction types will contribute to the total number of neutrons per fission of the target nucleus ^{235}U.

The modification of the linear energy dependence of $\bar{\nu}$ in the upper energy range by the incidence of the (n, n'f) process and the (n, 2n'f) process has been confirmed by most recent precision measurements. Furthermore, most recent measurements have revealed considerable structure in $\bar{\nu}$ in the energy region below about 1,5 MeV. Previous measurements had in general not a sufficiently high resolution and were not spaced in energy dense enough to detect the variation of $\bar{\nu}$ (E). Detailed studies of these observed effects have been given by Blyumkina et al. [3]; Kuznetsov, Smironkin [4]; Strutinskii, Pavlinchuk [5], Meadows and Whalen [6]. According to Meadows and Whalen the average kinetic energy of the fission fragments is not constant with increasing neutron energy E_n, i.e. the necessary assumption for a linear variation of $\bar{\nu}$ with E_n is not valid.

The Russian groups use the channel theory of the fission process for an interpretation of the irregularities of $\bar{\nu}$. In the opinion of Blyumkina et al. those irregularities are connected with irregularities in the average kinetic energy of the fission fragments. They are based on the transition from s- to p-wave neutron fission channels with different parity which takes place with increasing incident neutron energy. At the present time, however, there is no indication for a preference of any of the hypotheses and additional studies are needed for the clarification of the process in this energy region.

b) Evaluation of $\bar{\nu}(E)$ for U-235

No evaluation has been carried out for the $\bar{\nu}$-value for ^{235}U at thermal energy. We rely here on the comprehensive study of Hanna, Westcott, Lemmel, Leonard, Story and Attree /7/ on the 2200 m/sec constants for fissile isotopes. They have considered all available experimental information up to late 1969 and have obtained the following figures:

$$\bar{\nu}_t^{\,th}\,(^{235}\mathrm{U}) = 2.4229 \pm 0.0066$$

where $\bar{\nu}_t = \bar{\nu}_p + \bar{\nu}_d$ with $\bar{\nu}_p$ as average number of prompt neutrons per fission and $\bar{\nu}_d$ as average number of delayed neutrons per fission.

The available experimental information about $\bar{\nu}_d\,(^{235}\mathrm{U})$ is given in Table I. All previous measurements indicate a considerable increase in the yield of delayed neutrons with neutron energy increasing from 3 to 14 MeV. This is contrary to theoretical predictions based on the behaviour of fission mass and change distributions /8, 9, 10/. Most recent LA-measurements of Masters, Thorpe, Smith /11/ have confirmed the theoretical expectations. They have developed a new technique for the accurate determination of absolute delayed-neutron yields fully utilizing the neutron intensities available from accelarator neutron sources.

Therefore small samples could be used so that multiplication corrections were not necessary. Masters et al. have performed an absolute measurement of $\bar{\nu}_d$ (^{235}U) at 14.9 MeV using the T (d, n) ^{4}He reaction as neutron source and a relative measurement of the 3.1 - to 14.9 - MeV yield. Essentially all systematic errors are eliminated in those relative measurements. No absolute calibrations or mass determinations are necessary; only the accelerator target is changed (from D to T). The absolute delayed-neutron yield at 3.1 MeV has then been obtained as product of the absolute yield at 14.9 MeV and the relative yield.

We have adopted the experimental results of these LA-measurements for the calculation of the total number of neutrons per fission from the measured number of prompt neutrons. We have assumed their 14.9 MeV-value to be valid in the energy range above 10 MeV and their 3.1 MeV-value to be valid in the energy range below 10 MeV and above thermal energy. At thermal energy we have chosen the result obtained in measurements of Keepin et al. [8] .

$$\bar{\nu}_d\,(^{235}\mathrm{U}) \;=\; \begin{cases} 0.0158 \pm 0.0005 & \text{thermal energy} \\ 0.018 \;\pm 0.002 & \text{below 10 MeV} \\ 0.0095 \pm 0.0008 & \text{above 10 MeV} \end{cases}$$

All recent and the majority of the earlier measurements for $\bar{\nu}$ for fissile materials have been performed relative to the mean number of prompt neutrons from spontaneous fission of ^{252}Cf. All experimental $\bar{\nu}$(^{235}U)-values have been renormalized if necessary to the value recommended by the IAEA [7]

$$\bar{\nu}_t^{\,sp} \quad (^{252}\mathrm{Cf}) \;=\; 3.765 \pm 0.012$$

with $\bar{\nu}_d^{\,sp}$ $(^{252}\mathrm{Cf}) \;=\; 0.009$ [11] it follows

$$\bar{\nu}_p^{\,sp} \quad (^{252}\mathrm{Cf}) \;=\; 3.756 \pm 0.012$$

In the evaluation of $\bar{\nu}(E)$ for ^{235}U we have taken into account the experimental information available up to September 1970. The experiments going back to years earlier than 1961 have not been considered here because all these measurements do not cover a closed energy range but have been performed only at single energy points. In addition it is often not clear whether delayed neutrons are included in the final results given by the authors or not. The available experimental information is summarized in Table II. In particular we have considered the following measurements:

Blyumkina et al.	; 1964	[3]
Butler et al.	; 1961	[19]
Colvin, Sowerby	; 1965	[20]
Condé	; 1965	[21]
Hopkins, Diven	; 1963	[22]
Kuznetsov, Smirenkin	; 1966	[18, 23]
Mather et al.	; 1964	[24]
Meadows, Whalen	; 1962, 1967	[25, 26]
Nesterov et al.	; 1970	[27]
Prokhorova, Smirenkin	; 1968	[28]
Savin et al.	; 1970	[29]
Soleilhac et al.	; 1969, 1970	[30, 31]

The experimental results of these measurements were renormalized to the most recently recommended $\bar{\nu}_p^{sp}(^{252}Cf)$-value as given above. The numerical results of the Savin measurement are not quoted in reference [29] but could be extracted from the IAEA-review which had just become available [32]. Concerning the uncertainty of the $\bar{\nu}_p$-values we have taken over the values given by the authors themselves. No additional error analysis has been carried out by ourselves.

The results of the above measurements have been fitted by a smooth curve passing through the $\bar{\nu}$-value at thermal energy as recommended by the IAEA. For this purpose the computer subroutine SMØØTH [33] has been used. The fit has been performed at once for the whole energy range from thermal up to 15 MeV. The subroutine SMØØTH determines for the description of a smooth curve through the data

$$f(x) = a_i + b_i (x-x_i) + c_i (x-x_i)^2 + d_i (x-x_i)^3$$

$$i = 1,2, \quad n-1$$
$$x_i \leq x \leq x_{i+1}$$

and that

$$\int_{x_1}^{x_n} [f''(x)]^2 \, dx = \text{Min}$$

and $$\sum_{i=1}^{n} \left(\frac{f(x_i) - Y_i}{p_i} \right)^2 \leq S$$

(x_i, Y_i) are the data points with weights p_i $i = 1,n$.

The inverse squares of the errors of the individual measured points enter in this procedure as weights of the data points. Since only one particular value for the parameter S can be used for the smooth over the whole energy range, also relative weights were assigned to the data in the various energy regions to obtain different degrees of smoothing which is necessary in order to get best fits to the different energy regions. Thus the weights p_i of the data points are products of the relative weights which are characteristic for a particular energy range and the individual weights of the data points.

The most important measurement series in the energy range above 1.5 MeV up to 15 MeV is that of Soleilhac et al. /30/ because of the good energy resolution of this measurement and the small *uncertainty of its results (see Table II). In addition this* measurement covers the whole energy range 1.5 MeV - 15 MeV in steps of approximately 0.5 MeV. In this region also Mather and Fieldhouse /24/ have performed measurements but only at several energy points and with a lesser accuracy in $\bar{\nu}$ and with a coarse energy resolution than Soleilhac. The uncertainty of the $\bar{\nu}$-data measured by Savin et al. in this energy range is larger than that of the Soleilhac-data.

This is taken into account in the fit of the data by the weighting with the inverse error-squares of the data. Thus the results of Soleilhac et al. get the greatest weight in the following procedure as far as the above energy range is concerned.

The most extensive measurements in the energy range below 1.5 MeV are those of Meadows and Whalen, of Savin et al. and of Soleilhac et al. The uncertainty in $\bar{\nu}_p$ (^{235}U) is of comparable size in the measurements of Meadows and Whalen and of Soleilhac et al. It is larger, however, by a factor of about 3 in the experiment of Savin et al.

Fig. 1 shows the experimental data for $\bar{\nu}$(^{235}U) together with the associated errors in the energy range from thermal up to 1.4 MeV and Fig. 2 the data in the energy range from 1.4 MeV up to 15 MeV. Concerning the Soleilhac measurements the so-called maximum errors, i.e. the statistical errors plus 0,5 % due to corrections inaccuracy, are plotted. As already mentioned the measured $\bar{\nu}_p$-values were renormalized to $\bar{\nu}_p^{sp}$ (^{252}Cf) = 3.756. Also the recommended curve $\bar{\nu}_{25}$(E) is given in the figures 1 and 2. Fig. 1 compares in addition our recommended $\bar{\nu}$(E)-curve with the evalution of Mather and Bampton [10]. In the energy region of Fig. 1, i.e. up to 1.5 MeV, our $\bar{\nu}_t$-values are below 1 MeV higher than those of Mather by up to 0.3 %. In the upper energy range above 1.5 MeV deviations from the evaluated curve of Mather are encountered in the regions 2.5 - 5.5 MeV, 7.5 MeV - 10 MeV, 11 MeV - 13 MeV and are there of the order of magnitude of 0.3 - 0.5 %.

Above 1.5 MeV $\bar{\nu}_{25}$ (E) can be approximated by a series of straight lines. If allowance is made for a maximum deviation of 0.1 % of the straight line functions for $\bar{\nu}$ from the recommended curve the following functions reproduce $\bar{\nu}_{25}$ (E) :

1.5 - 2.4 MeV : $\bar{\nu}(E) = 2.385 + 0.134E$ [MeV]
2.4 - 3.3 MeV : $\bar{\nu}(E) = 2.455 + 0.105E$ [MeV]
3.3 - 4.8 MeV : $\bar{\nu}(E) = 2.3555 + 0.1354E$ [MeV]
4.8 - 5.2 MeV : $\bar{\nu}(E) = 2.186 + 0.189E$ [MeV]
5.2 - 6.2 MeV : $\bar{\nu}(E) = 1.968 + 0.2124E$ [MeV]
6.0 - 7.7 MeV : $\bar{\nu}(E) = 2.1355 + 0.1848E$ [MeV]
7.7 - 10.0 MeV : $\bar{\nu}(E) = 2.500 + 0.138E$ [MeV]
10.0 - 11.0 MeV : $\bar{\nu}(E) = 2.771 + 0.110E$ [MeV]
11.0 - 11.8 MeV : $\bar{\nu}(E) = 2.601 + 0.1255E$ [MeV]
11.8 - 15.0 MeV : $\bar{\nu}(E) = 2.372 + 0.1450E$ [MeV]

According to the various fission modes the (n,f)-, the (n, n'f)- and the (n, 2n'f)- reaction an only three-segment linear fit of the evaluated smooth curve $\bar{\nu}_{25}$ (E) should be appropriate with breakpoints at the threshold energies of the (n, n'f)process at about 6 MeV and of the (n, 2n'f) process at about 11 MeV. Then good linear fits were obtained if the energy limits for the linear fits are chosen in the following manner:

1.5 - 4.8 MeV : $\bar{\nu}(E) = 2.4003 + 0.1245E$ [MeV]
7.5 - 10.5 MeV : $\bar{\nu}(E) = 2.509 + 0.136E$ [MeV]
11.5 - 15 MeV : $\bar{\nu}(E) = 2.372 + 0.145E$ [MeV]

The deviations of the first two straight line functions from the evaluated smooth curve do not exceed 0.3 % and those of the last one 0.2 %.

Below 1.5 MeV $\bar{\nu}_{25}$ (E) is given by a smooth curve which shows maximum deviations from the linear energy dependence (straight line through thermal best value and $\bar{\nu}$-values above 1.4 MeV and below 1.6 MeV)

at about 0.4 MeV of about 1.05 %

and

at about 1.05 MeV of about 1.0 %.

with their time resolution

1. Patrick et al.	[58]	2 nsec/m
2. Blons et al.	[43]	1 nsec/m
3. de Saussure et al.	[48]	100 nsec/m - 5 nsec/m
4. Michaudon et al.	[37 - 41]	10 nsec/m
5. Van - Shi - di et al.	[47]	40 nsec/m - 10 nsec/m
6. Wilbur K. Brown et al.	[50]	20 nsec/m and 1 μsec/m
7. J. H. Lemley et al.	[100]	1 nsec/m

The measurements of Cao et al. [54] cover only the energy range from 6 eV to 3 keV. Structure in σ_f, however, is observed also in the higher keV-range so that this measurement was rejected in favour of the other more extensive ones. Bowmann et al. [56] have measured with a resolution of 1 nsec/m and have detected structure in σ_f at neutron energies as high as 200 keV, but they have only determined the shape of σ_f.

We have taken into account the structure in the fission cross section of ^{235}U up to 30 keV as given by the above experiments and have selected the measurements of Blons et al. for incorporation into the KEDAK-file, since these measurements have been carried out with the best resolution and a good accuracy of the order of magnitude of 4.5 - 7 %. The experimental results of Blons et al. are based on the ^{10}B (n, α) cross section for which the authors have assumed the following energy dependence

$$\sigma\,(n,\alpha) \quad = \quad \frac{610.3}{\sqrt{E\,[eV]}} - 0.38$$

More recent measurements for the ^{10}B (n, α) cross section by Sowerby et al. [82] have shown deviations from the so far assumed $1/\sqrt{E}$ behaviour of this cross section. The differences between the more recently recommended ^{10}B (n, α) cross sections and the values assumed by Blons et al. amount at 10 keV to 1 % (below 10 keV they are less than 1 %), at 15 keV to 1.8 %, at 20 keV to 2.5 %, at

25 keV to 3 % and at 30 keV, which is the upper energy limit of the Blons experiment, to 4 %. In 1971 the original Blons data were corrected for this effect by Blons himself and we have included in the KEDAK - file these corrected σ_f - values.

For comparison purposes the results of the above measurement series in the region 1 keV - 30 keV are plotted in Fig. 3 as averages over 1 keV intervals between 10 keV and over 10 keV intervals above 10 keV up to 30 keV. These averages are also quoted in Table IV. Their numerical values were taken from the report of Blons et al. /43/ and Lemley et al. /100/ with the exception of the measurements of Patrick et al. /53/ for which we ourselves have calculated the averages. The interval values of the Blons results which we presently recommend on KEDAK are systematically lower than the averages of the Michaudon data which have been recommended previously. The same tendency show the LA-results /50, 100/ and the Harwell-measurements /55/ . They are in general also lower than the ORNL/RPI /48/ and the Russian /47/ measurements. This discrepancy is not yet resolved, but we presently recommend the Blons results since the more recent measurements tend to lower values and in addition the energy resolution was improved in this experiment in comparison to the measurements of Michaudon. The deviations between the Michaudon and the Blons results amount in the maximum to 15 % in the interval 8 keV - 9 keV. They are by far not so large in the energy range below 1 keV (in general they do not exceed there 4 %). This can be seen in the Blons report, since these authors give for this energy range a comparison of $\bar{\sigma}_f$-averages of these measurements over o.1 keV intervals.

We have taken over on KEDAK the Blons data in the whole energy range from 150 eV up to 30 keV.

The results of the Lemley et al. [100] measurements were not available at the time of this evaluation. The resolution of this measurement is comparable with that of the Blons experiment, but for the Blons data a higher accuracy is quoted. Furthermore the Lemley-data are in the region 1 - 5 KeV extremely low in comparison to all other existing measurements (s. Fig. 3).

The fluctuations observed in high-resolution fission cross section measurements are connected with similar fluctuations in the total cross section. This implies that they are due to the entrance channel rather than to the phenomenon of intermediate structure in the fission channels

Above 30 KeV the scattering experimental data points have been fitted by a smooth curve using the computer subroutine SMOOTH [53] (see also section II b)). The fit has been carried out at once for the whole energy range upwards from 30 keV up to 15 MeV. The measurements of the following authors have been taken into account either as complete data sets or partly and with reservations (see also Table III):

Melkonian et al.	[44]
Diven	[58]
Dorofeev, Dobrynin	[61]
Kalinin, Pankratov	[66]
Adams et al.	[70]
White	[72]
Knoll, Pönitz	[75]

Hansen, McGuire, Smith	/79/
Szabo et al.	/80/
Käppeler	/81/

The inverse squares of the errors of the individual measured data points were used as individual weights of the data in the following procedure. Concerning the measurements of Diven and those of Dorofeev and Dobrynin only the absolutely measured fission cross sections at 1.27 MeV and 30 keV respectively were included in the data fit.

In the energy range from 1 MeV to 3 MeV there exist only very few data points of the selected measurement series (see Fig. 6). In order to obtain here a reasonable σ_f-shape we have accepted the results of the Los Alamos bomb shot measurements by Cramer /52/ in this region. These data would otherwise be left out of consideration since they are normalized to the already evaluated σ_{f25}-data of Davey /53/ in this range. Furthermore the uncertainties of these measurements are for a number of data points very large.

In the energy range above 3 MeV the White data are in good agreement with the revised σ_f-values of Hansen, McGuire, Smith corrected for errors in the efficiency of the long counter used for flux measurements. These corrections lead to reductions in the original σ_f-values of Smith, Henkel Nobles /79/ of the order of 10 %. Highest preference was given to this data set because of its normalization to the well-known (n,p) standard. The experimental results of Kalinin and Pankratov in this energy range were also taken into account in the data fit but with less weight than the other measurement series since this data set is not in accordance with the low White value at 5.4 MeV. This discrepancy is probably due to difficulties in the accurate determination of the neutron flux. The measurements of White are characterized by a particular careful determination of the neutron flux whereas in the Russian measurements the flux determination is based on a yield curve for the p-T-reaction measured in parts 1953 and 1958.

In the upper MeV-range above about 13 MeV we have used in addition to the Hansen, McGuire, Smith results the experimental data of Adams, Batchelor, Green /70/ in order to determine the shape of the fission cross section in this range. In particular we have drawn above 14 MeV an eye-guide curve through the data of these two measurement series. We have postulated for the σ_f-curve that it passes at 14.1 MeV through the White value at this energy, although the LA-results /78/ show a tendency to lower σ_f-values around 14 MeV. But the White result at 14.1 MeV is confirmed by a measurement of Uttley and Phillips /83/ relative to σ_{f28} (see Table III) at the same energy and is also in good agreement with the measurement at Aldermaston of Adams, Batchelor, Green at 14 MeV. Thus it can be considered as very reliable. Above 17 MeV the two measurement series of Adams, Batchelor, Green and of Hansen, McGuire, Smith show strong discrepancies, but no attention was given to it since we confirm ourselves in this evaluation to an upper energy limit of 15 MeV.

In the Figs. 4, 5,6 the experimental results of the selected measurement series as well as the recommonded σ_f(E)-curve are represented together with the measurement uncertainties if assigned by the authors. The energy range from 30 keV to 270 keV is considered in Fig. 4, from 200 keV to 1.5 MeV in Fig. 5 and from 1 MeV to 15 MeV in Fig. 6. The largest diviations of the presently recommended σ_f-data from the previously recommended fission cross section values on KEDAK to the amount of 10 % are encountered in the MeV-range above about 2 MeV, where the σ_f-data from the measurements of Smith, Henkel, Nobles have been replaced by corrected values of these measurements. The deviations in the energy range from 30 keV to 2 MeV amount to maximal 3 %. A comparison with these previously recommended KEDAK-values is only given in Fig. 7, whereas a comparison with the Dewey-evaluation /53/ is given over the energy region of Fig.4, Fig. 5, Fig. 6.

The recommended σ_f(E)-curve is in accordance with theoretical expectations /84/ in so far as at about 6 MeV a new rise of the fission cross section occurs due to the incidence of the (n, n'f) process and of about 11 MeV an increase in σ_f attributable to the (n, 2n'f) reaction.

The evaluation for σ_f^{25} (E) could be summarized as follows:

Energy region	Experimental basis
150 eV - 30 kev	Blons et al. /43/
30 kev- 15 MeV	White /72/; Szabo et al. /80/; Hansen, McGuire, Smith /78/; Käppeler /81/;

The estimated accuracy of the recommended σ_f-values for ^{235}U is tabulated below:

Energy range	$\frac{\Delta\sigma_f}{\sigma_f}$ /%/	Comments
150 eV - 1 keV	± 10	Corresponds to the uncertainty of the majority of the Blons et al. /43/ results in these regions
1 - 30 keV	± 6	
30 keV - 1 MeV	± 3	Uncertainty of the White- and the Szabo et al. - results which are predominant in this range
1 MeV - 3 MeV	± 5	Average uncertainty of the results of Cramer /52/ which mainly determine the σ_f-curve in this range
3 MeV - 15 MeV	± 6	Corresponds to the average error of the revised σ_f-values of Hansen, McGuire, Smith

IV. The total cross section

The total cross section was evaluated in the energy range above the resolved resonance region i.e. above 150 eV. Since the evaluation of J. J. Schmidt in 1966 /34/ in the lower energy range precision measurements with high energy resolution have been performed which show considerable structure in σ_T. The σ_T-values recommended on KEDAK in 1966 had been obtained in this energy range as the sum of the partial cross sections σ_γ σ_f and σ_n. Therefore errors in this cross section type arose from wrong fluctuations in σ_γ (see section V) and a revision of these data was of great importance. Furthermore in the higher energy range recently a high precision measurement of Cabé et al. has become available.

In the middle of 1971, when this evaluation was started, the existing measurements and the energy range covered in these measurements were

in the lower energy range, i.e. below 30 keV, those of

Michaudon,	1964;	150 eV - 720 eV ;	/40/
Yester et al.	1957;	210 eV - 7.9 keV;	/85/
Melkonian et al.	1958;	1.2 E-2 eV - 48 keV;	/86/
Derrien	1966;	720 eV - 10 keV;	/87/
Uttley et al.	1966;	150 eV - 950 keV;	/88/
Uttley	1964;	270 eV - 76 keV;	/89/
Hibdon, Langsdorf	1954;	650 eV - 150 keV;	/90/
Böckhoff et al.	1971;	10 keV - 100 keV;	/91/

and in the higher energy range, i.e. above 30 keV, those of

Bratenahl et al.	1958;	7 MeV - 14 MeV;	/92/
Cabé et al.	1970;	100 keV - 6 MeV;	/93/

Foster et al.	1967;	2.3 MeV - 15 MeV;	/94/
Galloway	1960;	500 keV - 950 keV;	/95/
Henkel	1952;	40 keV - 7.5 MeV;	/96/
Smith et al.	1965;	810 keV - 1.5 MeV;	/97/

In this survey about available measurements the measurements of Averchenko, Veretennikov /98/ and those of Longsford do not appear. Both were rejected in advance because of their large uncertainty (up to 18 % and 11 % respectively).

From the above measurement series we have selected the following ones:

Michaudon	/40/	in the region	160 eV - 720 eV
Derrien	/87/	" " "	220 eV - 10 keV
Böckhoff et al.	/91/	" " "	10 keV - 30 keV

and in the region 30 keV - 15 MeV

Cabé et al.	/33/
Foster et al.	/94/
Galloway	/95/
Bratenahl	/92/
Uttley	/88, 89/

All these measurements have a total uncertainty of their results of about 3 %.

The measurements of Michaudon, those of Derrien and those of Böckhoff et al. are not only the most extensive measurements in the respective energy region but they have also the best resolution in comparison with other experiments done in this range, namely

t = 5 nsec/m in the Michaudon experiment,
t = 0.8 nsec/m in the Derrien experiment,
t = 0.3 nsec/m in the Böckhoff experiment.

Whereas the measurements of Michaudon and of Derrien are absolute measurements, that of Böckhoff et al. is a relative one aiming only to investigate the structure of the total cross section and does not give absolute cross section values. Its results were normalized by Böckhoff to the σ_T -values evaluated by J.J. Schmidt /34, 35/ which are based on experimental results of Uttley /89/ in this range. Since no new measurements are available in this range the above normalization still holds. But the results of the Böckhoff experiment are therefore only *in that energy region of use for us, where we take fluctuations* in the cross section types into account, i.e. up to 30 keV.

The experimental results of these high-resolution measure*ments in the lower energy range are represented in* *Fig. 7 a) - q).* The plotted points correspond in the energy region 150 eV - 720 eV (Fig. 7 a) - h)) to the Michaudon points, in the region 720 eV - 10 keV (Fig. 7 h) - p)) to the Derrien points and in the range 10 keV - 30 keV (Fig. 7 q)) to the Böckhoff results. The experimental data of Derrien /87/ have a gap between 5.43 keV and 5.97 keV.

In the higher energy range, i.e. above 30 keV, the measurement series of Smith et al. /91/, of Henkel /96/ and of Hibdon et al. /90/ were discarded because of the reasons outlined below.

The experimental results of the Smith measurements /91/ and also of the Henkel measurements /96/ in the upper energy range are too low (see Fig. 8 b)) in comparison to the very extensive and accurate measurements of Cabé et al. recently performed in this range up to 6 MeV. A comparison of the accuracy of the three data sets cannot be made, since for the Henkel and also the Smith results no uncertainties are quoted in the corresponding references /96, 97/ .

The uncertainty of the Cabé results is given in reference /93/ as less than 3 %. Higher σ_T-values are also claimed by Foster et al. /94/, although his results are lower than those of Cabé and of Bratenahl et al. /92/ who has measured only one value in this range, namely at 7.05 MeV. The measurement series of Hibdon, Langsdorf /90/ can in any case only play a role in the energy range from 30 keV - 150 keV. This measurement goes back to 1953. Furthermore no uncertainty is quoted for the experimental results and since the experimental data are considerably lower by about 5 % than the Uttley results in this range /88, 89/ and also than the Cabé results in the small overlapping region of both measurements, from 30 keV up to 150 keV preference has been given to the two measurement series of Uttley. The experimental results of the two measurement series were fitted in this energy range by a smooth curve. For the data points of the measurement of Uttley from 1964 /89/ no errors were quoted. We have here taken over the uncertainty of the data points in the corresponding energy region of the measurement from 1966 /88/ which varies between 1 and 2 %, since both measurement series cover the same energy range.

Above 150 keV up to 6 MeV the Cabé data /93/ play the predominant role because these measurements were carried out at very densely spaced energy points. In smoothing out the experimental data the results of the Uttley measurement, however, were also taken into account, at least up to 850 keV, the upper energy limit of this measurement. In the region 2.3 MeV - 6 MeV the Cabé-data and those of Bratenahl et al. /92/ were fitted by a smooth curve.

In this region also experimental data of a measurement of Foster et al. /94/ exist, but the measurement series of Foster et al. and of Cabé et al. are discrepant. The results of Foster are systematically lower than the results of Cabé by about 3 to 5 %. The measurement of Foster is neither a high precision nor a high resolution measurement. It was performed over a large energy range only to determine the energy dependence of σ_T. The energy resolution is 2.5 - 4.5 %, that means worse than that of the Cabé measurement by a factor of about 3. In the region 6 MeV up to 15 MeV we had no other choice than to take the values of Foster et al. /94/, since this is the only existing measurement which covers the whole region. Besides this measurement there are only a few data points of Bratenahl et al. /92/.

The experimental results of the measurement series for σ_T in the upper energy range from 30 keV 15 MeV are shown in Fig. 8 a) - h) together with the presently recommended σ_T(E)-curve obtained by smoothing out the selected experimental data.

A comparison between the presently recommended σ_T-values and the previously on KEDAK recommended curve is given in Fig. 9 for the energy range 30 keV - 15 MeV. In this region the previously recommended σ_T(E)-curve is lower than the presently recommended one by about 5 %. A maximum deviation of nearly 8 % is encountered at about 4 MeV. These higher σ_T-values are due to the recent experimental results of Cabé et al. /93/ which are higher than the results of Henkel /96/ on which the previous evaluation /34, H5/ is based. Concerning the lower energy range in the region 10 - 30 keV essentially no differences in comparison to the previous KEDAK σ_T-values exist, since the Böckhoff results are normalized to the σ_T-values recommended by J. J. Schmidt [34, H5]. In the range 150 eV - 10 keV maximum deviations of about 10 % are encountered in the region 1 keV - 10 keV where the previously recommended σ_T-values are lower than the presently recommended ones.

A survey about the measurements considered in the σ_T-evaluation is given below

Energy range	Experimental basis
150 eV - 720 eV	Michaudon [40]
720 eV - 10 keV	Derrien [87]
10 keV - 30 keV	Böckhoff et al. [91]
30 keV - 150 keV	Uttley [88, 89]
150 keV - 6 MeV	Cabé [93], Uttley [88], Galloway [95]
6 MeV - 15 MeV	Foster et al. [94], Bratenahl [82]

The accuracy of the recommended σ_T^{25}-values is estimated to be:

Energy range	$\frac{\Delta\sigma_T}{\sigma_T}$ [%]	Comments
150 eV - 720 eV	± 3	due to the uncertainty of the Michaudon results
720 eV - 10 keV	± 7	due to uncertainty of the Derrien results
10 keV - 30 keV	± 4	due to the spread of experimental data in this range
30 keV - 150 keV	+ 2 - 5	due to the spread of experimental data in this range and to the uncertainty of the Uttley results

Energy range	$\frac{\Delta \sigma_T}{\sigma_T}$ [%]	Comments
150 keV - 2.3 MeV	± 3	due to the uncertainty of the Cabó and Uttley results
2.3 MeV - 6 MeV	+ 3 - 5	due to discrepancy between Foster and Cabé and to the uncertainty of the Cabé results
6 MeV- 15 MeV	+ 5 - 3	due to uncertainty of the Foster results and its discrepancy with the Cabé results

V. The capture-to-fission ratio

A revision of the KEDAK-value for α was performed in the energy region above the resolved resonance region, i.e. above 150 eV. In the eV-region the results of a high resolution measurement of de Saussure et al. [48] has become available since the evaluation of J. J. Schmidt [34]. This necessitated an incorporation of these values into KEDAK, since due to the lack of an α-measurement of a resolution comparable with that of the Michaudon σ_f-measurements, incorporated 1966 into KEDAK, we had since that time wrong fluctuations in the capture cross sections. The highest resolution reached in the de Saussure experiment from 1966 is 5 nsec/m and so comparable with the resolution of the Michaudon σ_T-experiment, from which we have taken over the energy values for KEDAK.

Up to October 1971 when this evaluation was started no other measurements were available with such a good resolution. Silver, de Saussure et al. [102] have performed a new α-measurement over the same energy range and even extended up to 100 keV, whereas the high-resolution measurement of de Saussure from 1966 has an upper limit of 3 KeV. At Knoxville preliminary results of these recent measurements were reported but up to now no final results are available. We have not taken into account them therfore [114] in our evaluation and have taken over on KEDAK in the lower energy range the data of de Saussure from 1966.
The de Saussure data were normalized concerning the fission cross section by making the fission resonance integral from 0.45 to 10 MeV equal to 127.45b and concerning the capture cross sections by making the absorption resonance integral from 0.45 to 1.0 eV equal to 58.12 b. From a comparison of 100 eV interval values it follows that on the average the de Saussure data show deviations of about 15 % with regard to the previous KEDAK -values.

In the lower keV-range, i.e. above 3 keV up to some ten of keV a number of measurements are available:

		Energy region	Accuracy	Ref.
Bandl et al.	1971;	8 - 60 keV;	(12-17) %;	[103]
Czirr, Lindsey,	1970;	2.6 - 30 keV;	7 - 8 %;	[104]
Muradjan et al.	1970;	0.3 eV-5 keV;	4 -16 %;	[105]
Kurov, Ryabov,	1970;	100eV-30 keV;	9.5 -13 %;	[106]
Van-Shi-di et al.	1965;	100eV-30 keV;	below 1 keV 7 % above 1 keV 7.5-12%	[47]
Silver, de Saussure et al.	1971;	100 eV-100keV;	-	[102]

In the higher keV-range except of some very old inaccurate measurements (see reference [34, H15]) the following measurements were performed:

		Energy range	Accuracy	Ref.
de Saussure et al.,	1966	17 keV-600 keV;	8 - 16 %	[48]
Weston et al.,	1964	12 keV-690 keV;	9 - 20 %	[101]
Diven et al.,	1958	100 keV- 1 MeV;	16 %	[108]
Hopkins, Diven	1962	30 keV- 1 MeV;	7 - 11 %	[109]

Since in the lower keV-range all authors have quoted interval-averaged values, even if unfortunately not over the same intervals, we give in Fig. 10 a) and b) a comparison of the different measurements in the region up to 100 keV. For KEDAK we have taken over in this range from 3 keV - 11 keV the three values of Czirr and Lindsey over the intervals 3 keV - 4.29 keV-7.34 keV - 10.9 keV. It is difficult to decide for one of the measurements in this range. First the data of the several authors are not averaged over the same energy intervals as already mentioned. But furthermore the different sets of interval values show a different tendency with increasing energy, some data sets increase, some decrease in the same energy range. Concerning the Van-Shi-di measurements we have thought that it is a too old measurement. The α-values of this measurement show very strong fluctuations in the energy range considered here. The same it true for the measurements of Kurov, Ryabov. The experiment of Muradjan et al. covers only the energy range up to 5 keV. The results of Silver, de Saussure are only preliminary, not yet corrected for multiple scattering e.g. [114].

Then remain the Bandl et al. measurement and the Czirr, Lindsey measurement up to 1o keV (above 1o keV they have quoted only one value for the interval 23 keV - 28 keV, for the interval 11 - 23 keV no value is given) mainly because of the fact that it goes down to such low energies as 3 keV which is the upper energy limit of the high resolution de Saussure measurement from 1966 adopted for KEDAK. From the Bandl measurement results are available only above 8 keV and for joining the last de Saussure value at about 3 keV one has anyway to take the Czirr data between 3 and 8 keV. Above 1o keV one has the choice either to fit the results from the measurements at selected energies of de Saussure et al. and of Weston et al. by a smooth curve or to take over the interval values of Bandl et al. The α(E)-curve evaluated 1966 gives in this range a good mean between the Bandl results and the higher results of the point measurements if one excludes the deep minimum in the α-curve of Bandl around 25 keV. This minimum in the α(E)-curve, however, is up to now not confirmed by other experimental final results. We have therefore kept on KEDAK up to about 4o keV the α(E)-curve evaluated by J.J. Schmidt in 1966.

Between 11 keV and 15 keV we have adopted a smooth connection to the α-value recommended by J.J. Schmidt [34, H15]. In the region above 4o keV we have taken over higher α-values than J.J. Schmidt ones so following the evaluation of Alter and Dunford [11o]. Alter and Dunford took by 5 to 7 % higher α - values, but only in the region 6o - 2oo keV. According to our opinion the range with higher α- values should be extended up to 45o keV. The main reason for recommending higher α-values are the experimental data of de Saussure et al. [48] which had not been available to J.J. Schmidt. This measurement series covers the region from 17 keV-6oo keV, however. We have drawn an eye-giude curve through the there available measurements of Diven, Weston, Hopkins and Diven and de Saussure and have joined it to the previous KEDAK-evaluation of J.J. Schmidt [34,H15] at 7oo keV. The presently recommended α-values are by about 5 - 7 % higher in the region 6o keV - 45o keV. The experimental data in the range up to 1 MeV as well as the recommended curve for α(E) are given in Fig. 11.

Above 7oo keV up to 1o MeV the α(E)-curve of J.J. Schmidt from 1966 /34/ is still recommended, that means a rather close 1/E -dependence of σ_γ, since no measurements at all exist above 1 MeV and no new measurements are available between 7oo keV and 1 MeV.

Above 1o MeV up to 15 MeV we have taken over the α-values recommended by Alter and Dunford who have obtained their values by extending smoothly the α(E)-curve of J.J. Schmidt. The presently recommended α(E)-curve in the region 3o keV - 15 MeV is given in Fig. 12. A summary of the α-evaluation is given below:

Energy region	Comments
15o eV - 3 keV	de Saussure /48/- data
3 keV - 11 keV	interval values of Czirr, Lindsey /1o4/
11 keV - 15 keV	smooth connection between Czirr, Lindsey and the α (E) - curve recommended above 15 keV
15 keV - 6o keV	mean between Bandl interval values and de Saussure and Weston data
6o keV - 45o keV	eye-guide curve through data of Diven, Weston, Hopkins and Diven, de Saussure; 5 - 7 % higher α-values than previous KEDAK-evaluation
45o keV - 7oo keV	smooth joining of present and previous KEDAK-evaluation for α
7oo keV - 1o MeV	previous KEDAK-evaluation for α
1o MeV - 15 MeV	Alter , Duford evaluation: smooth continuation of previous KEDAK-evaluation

The accuracy of the recommended α_{25}-values is estimated as outlined below:

Energy region	$\frac{\Delta\alpha}{\alpha}$ [%]	Comments
150 eV - 3 keV	+ 10 - 20	estimated uncertainty of the de Saussure data
3 keV - 15 keV	+ 25 - 10	due to discrepancies between experimental α-data in comparison to the Czirr, Lindsey values
15 keV - 50 keV	+ 10 - 15	due to the spread of experimental data in this range
50 keV - 1 MeV	+ 10 - 15	due to the scattering of the experimental data around the recommended curve in particular due to the discrepancy between the high de Saussure values and the low Weston results

No accuracy estimate can be made above 1 MeV since there exist no experimental data at all.

VI. Secondary data changes

The re-evaluation for the data types σ_f, σ_T, α, $\bar{\nu}$ causes changes in the other cross section types, the so-called secondary data changes, since they are mutually dependent. The energy range in which data changes for the different cross section types of U-235 are encountered, are summarized in the table below:

KEDAK cross section type name	data type	Energy range of the changes /eV/
ALPHA +	$\alpha = \sigma_\gamma / \sigma_f$	150. - 15.E+6
ETA	$\eta = \frac{1}{1+\alpha}\bar{\nu}$	1.E-3 - 15.E+6
CHIF	χ - energy distribution of the prompt neutrons	unchanged
MUEL	$\bar{\mu}_L$-average of the cosine of the elastic scattering angle in the laboratory system	10.E+6 - 15.E+6
NUE +	$\bar{\nu}$ -average number of neutrons per fission	1.E-3 - 15.E+6
SGA	σ_a-absorption cross section	150. - 15.E+6
SGALP	σ_α-(n, α) cross section	unchanged
SGF +	σ_f-fission cross section	150. - 15.E+6
SGG	σ_γ-capture cross section	150. - 15.E+6
SGI	$\sigma_{n'}$- inelastic scattering cross section	2.4E+6 - 15.E+6
SGN	σ_n - elastic scattering cross section	150. - 15.E+6
SGP	σ_p- (n, p) cross section	unchanged
SGT +	σ_T- total cross section	150. - 15.E+6
SGTR	σ_{tr} - transport cross section	150. - 15.E+6
SG2N	σ_{2n} - (n, 2n) cross section	10.E+6 - 15.E+6
SG3N	σ_{3n} - (n, 3n) cross section	12.5E+6 - 15.E+6
SGX	σ_x- non-elastic cross section	150. - 2.4E+6; 10.E+6 - 15.E+6

+ - these data types were re-evaluated.

For the data types SG2N, SG3N, MUEL the changes consist only in an extension of the curves recommended by J. J. Schmidt /34/ up to an energy of 15 MeV.

For the non-elastic cross section, data type name SGX, no new measurements exist. In the range 10 MeV - 15 MeV we have taken over the values read from the extended σ_x(E)-curve previously recommended on KEDAK /34/. In the range below 2.4 MeV SGX was changed as obtained by the relation

$$\sigma_x = \sigma_\gamma + \sigma_f + \sigma_{n'} + \underbrace{\sigma_{2n} + \sigma_{3n}}_{= 0 \text{ below } 2.4 \text{ MeV}}$$

In the range 2.4 MeV - 10 MeV the previously recommended SGX-values remained. The changes in σ_f and σ_γ in this range and also in the range 10 MeV - 15 MeV were shifted on the inelastic scattering cross section, data type name SGI. We relied here on J. J. Schmidt's KEDAK-evaluation for U-235 from 1966 /34/ and adopted the same procedure for the determination of the SGX- and SGI-values.

The changes for the other cross section types were obtained throughout from the following relations:

SGA - absorption cross section $\sigma_a = \sigma_\gamma + \sigma_f$ since $\sigma_p = 0$, $\sigma_\alpha = 0$

SGG - capture cross section $\sigma_\gamma = \alpha \cdot \sigma_f$

SGN - elastic scattering cross section $\sigma_n = \sigma_T - \sigma_x$

SGTR - transport cross section $\sigma_{tr} = \sigma_T - \mu_L \cdot \sigma_n$

In the higher energy range above 400 keV the presently and previously on KEDAK recommended σ_n(E)-curve and σ_x(E)-curve respectively are given in Fig. 13 and Fig. 14 respectively together with the experimental data points. For both cross section types no new measurements exist. The inelastic scattering cross section $\sigma_{n'}$ in the same energy range is represented in Fig. 15. For this data type some new measurements are available, namely that of Drake et al. /111/, that of Armitage et al. /112/ and that of Batchelor and Wyld /113/. The calculated curves for $\sigma_n, \sigma_x, \sigma_{n'}$ lie fairly well between the experimental measurements.

Concerning the energy scale of the KEDAK-points all data types for U-235 except CHIF are stored at the same energy points since our program for the calculation of the mutually dependent cross sections presupposes this. Above 30 keV up to 10 MeV we have used the same energy points as stored in the previous version, only very few additional points were inserted in this scale in order to reproduce well the energy dependence of $\bar{\nu}$ and σ_f. Below 30 keV we have taken over the energy points of the high resolution σ_T-measurements of Michaudon (Δt = 5 nsec/m) in the range 150 eV - 723 eV, of Derrien (Δt = 0.8 nsec/m) in the range 724 eV - 10 keV and of Böckhoff (Δt = 0.3 nsec/m) in the range 10 keV - 30 keV and have interpolated the other cross section types at these energies or calculated the mutually dependent cross sections at these energies. Since the high resolution σ_f-measurements of Blons et al. (Δt = 1 nsec/m) and the α-measurements of de Saussure (Δt = 5 nsec/m) show sometimes a shift in the energy of their peaks and valleys in comparison to the peaks and valleys of σ_T, the above selection of the energies by taking the points of the σ_T-measurements has sometimes led to negative σ_n-values. Very probably some of these negative σ_n-values are also due to the difference in the resolution of the σ_T-measurements on one side and the σ_f- and α-measurements on the other side.

Since the number of these points, however, was very small in comparison to the total number of energy points in this range we have re-calculated the cross section values at these points deciding from case to case whether σ_T or σ_f or α as basic cross section type should be changed by a small amount.

In the KEDAK-evaluation from 1966 for U-235 the energy dependence of the average fission width $\bar{\Gamma}_f$ was determined by fitting the evaluated $\alpha(E)$-curve. A spin dependence of $\bar{\Gamma}_f$ was not considered. Since also nowadays better information about the spin- and energy-dependence not yet exists we have only repeated the fitting procedure with our changed α-values. The quantity α is best suited for this purpose because it depends only weakly on a correct value for the strength function.

$$\langle \alpha \rangle = \frac{\sum\limits_{l,J} \langle \sigma_\gamma^{lJ} \rangle}{\sum\limits_{l,J} \langle \sigma_f^{lJ} \rangle} = \frac{2\pi ƛ^2 \sum\limits_{l,J} g_J \cdot \frac{1}{D_{lJ}} \left\langle \frac{\Gamma_{nl}^J \Gamma_{\gamma l}^J}{\Gamma_l^J} \right\rangle}{2\pi ƛ^2 \sum\limits_{l,J} g_J \cdot \frac{1}{D_{lJ}} \left\langle \frac{\Gamma_{nl}^J \Gamma_{fl}^J}{\Gamma_l^J} \right\rangle}$$

$$= \frac{\sum\limits_{l,J} g_J \frac{\bar{\Gamma}_{nl}^J}{D_{lJ}} T_\gamma^{lJ}}{\sum\limits_{l,J} g_J \frac{\bar{\Gamma}_{nl}^J}{D_{lJ}} \cdot \frac{\Gamma_{fl}^J}{\bar{\Gamma}_\gamma^J} \cdot T_f^{lJ}}$$

where $$T_x^{lJ} = \frac{\bar{\Gamma}_x^J}{\bar{\Gamma}_{nl}^J \bar{\Gamma}_{xl}^J} \left\langle \frac{\Gamma_{nl}^J \Gamma_{xl}^J}{\Gamma_l^J} \right\rangle$$

with

$$\frac{\overline{\Gamma}^{J}_{nl}}{\overline{D}_{lJ}} = \frac{\overline{D}_{lJ}(E_B+E)}{\overline{D}_{lJ}(E_B)} \cdot \overline{D}_{lJ}(E_B)\, \overline{\Gamma}^{(o)J}_{nl} \sqrt{E}\, v_l$$

it follows

$$\langle \alpha \rangle = \frac{\sum\limits_{l,J} g_J S_{lJ} \dfrac{v_l}{\overline{D}_{lJ}(E_B+E)/\overline{D}_{lJ}(E_B)} \cdot T^{lJ}_{\gamma}}{\sum\limits_{l,J} g_J S_{lJ} \dfrac{v_l}{\overline{D}_{lJ}(E_B+E)/\overline{D}_{lJ}(E_B)} \dfrac{\overline{\Gamma}^{J}_{fl}}{\overline{\Gamma}^{J}_{\gamma}} T_f^{lJ}}$$

The energy dependence of $\overline{D}$ is predicted by the Fermi gas model. By using this relation one obtains that

$$\frac{\overline{D}_{lJ}(E_B+E)}{\overline{D}_{lJ}(E_B)} = \frac{(E_B+E)^2}{E_B^{\,2}} \exp\left(-2\sqrt{a(E_B+E)} + 2\sqrt{aE_B} \right)$$

is independent of l and J. Then we have

$$\langle \alpha \rangle = \frac{\sum\limits_{l,J} g_J S_{lJ} v_l \cdot T^{lJ}_{\gamma}}{\sum\limits_{l,J} g_J S_{lJ} v_l \dfrac{\overline{\Gamma}^{J}_{fl}}{\overline{\Gamma}^{J}_{\gamma}} T_f^{lJ}}$$

The used symbols have the following meaning:

Γ_n, Γ_γ, Γ_f, Γ - elastic scattering and capture and fission and total widths, respectivley
J - spin of the compound nucleus
l - angular momentum of the incident neutron
D - level spacing
S - strength function
v - barrier penetration factor

g - statistical spin factor
E - incident neutron energy
E_B - effective binding energy corrected for the pairing energy, of the last neutron in the compound nucleus
a - level density parameter

We make now the following simplifying assumptions (for reasons of justification see also KFK 120 p. D 99 - D 117):

1. $\bar{\Gamma}^{J=3}_{fl=o} = \bar{\Gamma}^{J=4}_{fl=o} = \bar{\Gamma}_f$

   and since nothing about p-wave fission is known one can set

   $\bar{\Gamma}^{J}_{f1} = \bar{\Gamma}_f$

2. $\bar{\Gamma}^{J}_{\gamma} = \bar{\Gamma}_{\gamma}$ since nothing definitive is known about the J-dependence of

3. $S_o^{J=3} = S_o^{J=4} = S_o$

   $S_o^{J=2} = \frac{1}{2} S_1^{J=3} = \frac{1}{2} S_1^{J=4} = S_1^{J=5} = S_1$

   because of the lack of any other evidence

4. $T^{oJ=3}_{\gamma,f} = T^{oJ=4}_{\gamma,f} = T^{o}_{\gamma,f}$

   That means that the statistical distributions of Γ_f and Γ_n were assumed to be the same for the two spin states J = 3 and J = 4.

With these assumptions it follows

$$\langle \alpha \rangle = \frac{\bar{\Gamma}_{\gamma}}{\bar{\Gamma}_{f}} \quad \frac{g_{o}T^{o}_{\gamma} + g_{1}\nu_{1}(g_{2}T^{1}_{\gamma J=2} + 2g_{3}T^{1}_{\gamma J=3} + 2g_{4}T^{1}_{\gamma J=4} + g_{5}\, T^{1}_{\gamma J=5})}{g_{o}T^{o}_{f} + g_{1}\nu_{1}(g_{2}T^{1}_{fJ=2} + 2g_{3}T^{1}_{fJ=3} + 2g_{4}T^{1}_{fJ=4} + g_{5}\, T^{1}_{fJ=5})}$$

$\bar{\Gamma}_{f}$ (E) was determined from this expression by fitting the evaluated α (E)-curve. The new values were incorporated into the KEDAK-file under the data type STGF.

Acknowledgements

I would like to acknowledge the valuable support I had from Dr. R. Meyer's experience in computerized handling of large data sets. I would like to thank Mrs. B. Krieg and Miss I. Langner for incorporating the evaluated data into the KEDAK-file. I am very grateful to Dr. A. Schett from the Neutron Data Compilation Centre Saclay for the prompt delivery of all the requested experimental data.

Literature references

[1] R.B. Leachman, Phys. Rev. 101 (1956) 1005 and Proc. Conf. PUAE, Geneva 1955, Vol. 2, pp. 193 and Geneva 1958, Vol. 15, pp. 331

[2] S.H. Schuster, R.J. Howerton, Journ. Nucl. En. A/B 18 (1964) 125

[3] Yu.A. Blyumkina, I.I. Bondarenko, V.F. Kuznetsov, V.G. Nesterov, V.N. Okolovitch, G.N. Smirenkin, L.N. Usachev Nucl. Phys. 52 (1964) 648

[4] V.F. Kunetsov, G.N. Smirenkin , Proc. Conf. on Nucl. Data for Reactors, Paris 1966, Vol. II, pp. 75 or English translation: ANL-tr.-808

[5] V.M. Strutinskii, V.A. Pavlinchuk, Proc. Conf. on Physics and Chemistry of Fission, Salzburg 1965, Vol. 1, pp. 127

[6] J.W. Meadows, J.F. Whalen, Journ. Nucl. En. 21 (1967) 157

[7] G.C. Hanna, C.H. Westcott, H.D. Lemmel, B.R. Leonard jr., J.S. Story, P.M. Attree, Atomic Energy Review, Vol. VII, No. 4, IAEA, Vienna 1969

[8] G.R. Keepin, T.F. Wimett, R.K. Zeigler, Journ. Nucl. En. 6 (1957/58) 1

[9] G.R. Keepin, T.F. Wimett, R.K. Zeigler, Phys. Rev. 107 (1957) 1044

[10] G.R. Keepin, The Physics of Nuclear Kinetics (Addison-Wesley, Reading, Massachusetts, 1965) Chapter 4

[11] C.F. Masters, M.M. Thorpe, D.B. Smith, Nuc. Sc. Engng. 36 (1969) 202

[12] G.S. Brunson, E.N. Pettitt, R.D. McCurdy, ANL-5480 (1955)

[13] H. Rose, R.D. Smith, Journ. Nucl. En. 4 (1957) 133

[14] W.I. McGarry, R.J. Omohundro, G.E. Holloway, Bull. Am. Phys. Soc. 5 (1960) 33

/15/ B.P. Maksyutenko, Sov. Journ. At. En. 7 (1960) 943 and Journ. Nucl. En. A 12 (1960) 140

/16/ S.A. Cox, E.E. Dowling Whiting, ANL-7410 (published 1969) 27

/17/ B.C. Diven, J.C. Hopkins, Proc. Seminar on Physics of Fast and Intermediate Reactors, Vienna 1961, Vol. 1, pp. 149

/18/ V.F. Kuznetsov, G.N. Smirenkin, Sov. Journ. At. En. 22 (1967) 500

/19/ D. Butler, S. Cox, J. Meadows, J. Roberts, A. Smith, J. Whalen, Proc. Seminar Physics of Fast and Intermediate Reactors, Vienna, Aug. 1961, Vol. 1, pp. 125

/20/ D.W. Colvin, M.G. Sowerby, Proc. Sympos. on Physics and Chemistry of Fission, Salzburg, March 1965, Vol. 2, pp. 25

/21/ H. Condé, Arckiv fcr Fysik 29 (1965) 293

/22/ J.C. Hopkins, B.C. Diven, Nucl. Phys. 48 (1963) 433

/23/ V.F. Kuznetsov, G.N. Smirenkin, Proc. Nucl. Data for Reactors, Paris, Oct. 1966, Vol. II, pp. 75

/24/ D.S. Mather, P. Fieldhouse, A. Moat, Phys. Rev. 133 B (1964) 1403

/25/ J.W. Meadows, J.F. Whalen, Phys. Rev. 126 (1962) 197

/26/ J.W. Meadows, J.F. Whalen, Journ. Nucl. En. 21 (1967) 157

/27/ V.G. Nesterov, B. Nurpeisov, L.I. Prokhorova, G.N. Smirenkin, Yu.M. Turchin, 2nd Int. Conf. Nucl. Data for Reactors, Helsinki, June 1970, p. CN-26/74 or Vol. II, pp. 167

/28/ L.I. Prokhorova, G.N. Smirenkin, Sov. Journ. Nucl. Phys. 7 (1968) 579

/29/ M.V. Savin, Yu.A. Khokhlov, Yu.S. Zamyatnin, I.N. Paramonova, 2nd Int. Conf. Nucl. Data for Reactors, Helsinki, June 1970, p. CN-26/40 or Vol. II, pp. 157

/30/ M. Soleilhac, J. Fréhaut, J. Gauriau, Journ. Nucl. En. 23 (1969) 23

/31/ M. Soleilhac, J. Fréhaut, J. Gauriau, G. Mosinski, 2nd Int. Conf. Nucl. Data for Reactors, Helsinki, June 1970, p. CN-26/67 or Vol. II, pp. 145

/32/ V.A. Konshin, F. Manero, INDC (NDS) - 19/N

/33/ H. Späth, SMOOTH, eine FORTRAN-IV-Subroutine zum Glätten von Daten bei unbekanntem Modell mit Hilfe des Splinefits; internal report

/34/ J.J. Schmidt, KFK 120 (1966) (HI) (EANDC (E)-35 "U")

/35/ I. Langner, J.J. Schmidt, J. Woll, KFK 750, (EANDC (E)-88 "U"), 1968

/36/ M.L. Yeater, P.L. Kelley, E.R. Gaerttner, KAPL-1109, 1954; KAPL-1565, Phys. Rev. 104 (1956) 479

/37/ R. Genin, R. Joly, A. Michaudon, G. Vendrys, Proc. Conf. PUAE, Geneva 1958, Vol. 16, pp. 115

/38/ A. Michaudon, R. Genin, R. Joly, G. Vendrys, CEA-963 (1958) and CEA-1093 (1959)

/39/ A. Michaudon, R. Bergère, A. Coin, R. Joly, Journ. Phys. Rad. 21 (1960) 429

/40/ A. Michaudon, CEA-R-2552 (1964)

/41/ A. Michaudon, H. Derrien, P. Ribon, M. Sanche, Nucl. Phys. 69 (1965) 545

/42/ F.J. Shore, V.L. Sailor, Phys. Rev. 112 (1958) 191

/43/ J. Blons, G. Debril, J. Fermandjian, A. Michaudon, Proc. 2nd Int. Conf. Nucl. Data for Reactors, Helsinki, June 1970, p. CN-26/60 or Vol. I, pp. 469

/44/ E. Melkonian, V. Perez-Mendez, M.L. Melkonian, W.W. Havens Jr., L.J. Rainwater, Nucl. Sc. Engng. 3 (1958) 435 and CU-163 (1957)

/45/ G.V. Gorlov, B.M. Gokhberg, V.M. Morozov, G.A. Ortoshchenko, V.A. Shigin, Sov. Journ. At. En. 6 (1960) 317; Journ. Nucl. En. A 12 (1960) 79

/46/ J.L. Perkin, P.H. White, P. Fieldhouse, E.J. Axton, P. Cross, J.C. Robertson, Journ. Nucl. En. parts A/B 19 (1965) 423

/47/ Van-Shi-di, Van Yun-Tschan, E. Dermendshiev, Y.V. Ryabov, Proc. Symposium Phys. Chem. Fission, Salzburg, 1965; Vol. 1, pp. 287 and BNL-tr-16

/48/ G. de Saussure, R. Gwin, L.W. Weston, R.W. Ingle, R.R. Fullwood, R.W. Hockenbury, A. Lottin, Proc. Conf. Nucl. Data for Reactors, Paris 1966, Vol. II, pp. 233 and ORNL-TM-1804 (1967)

/49/ C.D. Bowmann et al., Proc. Conf. Neutron Cross Section Technology, Washington, March 1966, Vol. 2, pp. 1004

/50/ Wilbur K. Brown, D.W. Bergen, J.D. Cramer, Proc. Conf. on Neutron Cross Section Technology, Washington, March 1966 (Conf.-660303), Vol. 2, pp. 971

/51/ J.D. Cramer, D.W. Bergen, LA-4285 (1969)

/52/ J.D. Cramer, published in "Fission Cross Sections from Pommard", by P.A. Seeger, LA-4420 (1970)

/53/ W.G. Davey, Nucl. Sc. Engng. 32 (1968) 35 and Nucl. Sc. Engng. 26 (1966) 149

/54/ M.G. Cao, E. Migneco, J.P. Theobald, J.A. Wartena, J. Winter, Proc. Conf. Neutron Cross Sections Technology, Washington 1968, Vol. I, pp. 481 or Journ. Nucl. En. 22 (1968) 211

/55/ B.H. Patrick, M.G. Sowerby, M.G. Schomberg, AERE-R-6350 (1970) or Journ. Nucl. En. 24 (1970) 269; private communication with B. Patrick, 1971

/56/ C.D. Bowmann, M.L. Stelts, R.J. Baglan, Proc. 2nd Int. Conf. Nucl. Data for Reactors, Helsinki 1970, p. CN-26/41 or UCRL-72472

/57/ W. Nyer, LAMS-938, 1950

/58/ B.C. Diven, Phys. Rev. 105 (1957) 1350; LA-1336 (1953)

/59/ W.D. Allen, A.T.G. Ferguson, Proc. Phys. Soc. A 70 (1957) 573

/60/ R.L. Henkel, LA-2114, LA-2122, 1957

/61/ G.A. Dorofeev, Y.P. Dobrynin, Sov. Journ. At. En. 2 (1957) 9 or Journ. Nucl. En. 5 (1957) 219

/62/ A. Moat, 1958; quoted by B. Adams et al. in /70/

[63] A.A. Berezin, G.A. Stoliarov, Y.V. Nikolskii, I.E. Chelnokov, Sov. Journ. At. En. 5 (1958) 1604 or Journ. Nucl. En. Pts. A/B 11 (1959/60) 175

[64] F. Nettor, CEA-1913, 1961

[65] D. Szteinsznaider, V. Naggiar, F. Nettor, Proc. Conf. PUAE, Geneva 1955, Vol. 4, pp. 245

[66] S.P. Kalinin, V.M. Pankratov, Proc. Conf. PUAE, Geneva 1958, Vol. 16, pp. 136

[67] V.M. Pankratov, N.A. Vlasov, P.V. Rybakov, Sov. Journ. At. En. 9 (1961) 939 or Journ. Nucl. En. Pts. A/B Reactor Sc. Techn. 16 (1962) 494

[68] V.M. Pankratov, Sov. Journ. At. En. 14 (1963) 167 or Journ. Nucl. En. 18 (1964) 215

[69] G.N. Smirenkin, V.G. Nesterov, I.I. Bondarenko, Sov. Journ. At. En. 13 (1963) 974

[70] B. Adams, R. Batchelor, T.S. Green, Journ. Nucl. En. 14 (1961) 85

[71] R.D. Albert, Phys. Rev. Letters 15 (1965) 637

[72] P.H. White, Journ. Nucl. En. 19 (1965) 325

[73] R.L. Macklin, J.H. Gibbons, Phys. Rev. Letters 16 (1966) 248

[74] W.B. Gilboy, G.F. Knoll, Phys. Rev. Letters 21 (1966) 432

[75] G.F. Knoll, W.P. Pönitz, Journ. Nucl. En. 21 (1967) 643

[76] W.P. Pönitz, Proc. Conf. Neutron Cross Section Technology Washington 1968, Vol. I, pp. 503

[77] W.P. Pönitz, Nucl. Sc. Engng. 40 (1970) 383

[78] G. Hansen, S. McGuire, R.K. Smith, private communication 1970

[79] R.K. Smith, R.L. Henkel, R.A. Nobles, Bull. Am. Phys. Soc. 2 (1957) 196

/80/ I. Szabo, J.P. Marquette, E. Fort, J.L. Leroy, Proc. 2nd Int. Conf. Nucl. Data for Reactors, Helsinki 1970, Vol. I, p. CN-26/69, pp. 229

/81/ F. Käppeler, KFK 1313, 1970; Proc. 2nd Int. Conf. Nucl. Data for Reactors, Helsinki 1970, Vol. I, pp. 221

/82/ M.G. Sowerby, B.H. Patrick, C.A. Uttley, K.M. Diment, Proc. of sympos. on neutron standards and flux normalization, Argonne, Oct. 1970, pp. 151

/83/ C.A. Uttley, J.A. Philipps, AERE - NP/R-1996, 1956

/84/ N. Bohr, Phys. Rev. 58 (1940) 864

/85/ R. Fullwood, E. Morgan, M. Yeater, KAPL-1770 (1957) 65 data referenced in CCDN-NW/11, pp. 291

/86/ E. Melkonian, V Perez-Mendez, M.L. Melkonian, W.W. Havens jr., L.J. Rainwater, Nucl. Sc. Engng. 3 (1958) 435

/87/ H. Derrien et al., unpublished 1966; data referenced in CCDN-NW/11, pp. 291

/88/ C.A. Uttley, C.M. Newstead, K.M. Diment, Proc. Conf. Nucl. Data for Reactors, Paris, Oct. 1966, Vol. I, pp. 165; data referenced in CCDN-NW/11, pp. 291

/89/ C.A. Uttley, AERE-M-1272 (1963); data referenced in CCDN-NW/11, pp. 291

/90/ C.T. Hibdon, A. Langsdorf jr., ANL-5175 (1954); data referenced in CCDN-NW/11, pp. 290

/91/ K.H. Böckhoff, A. Dufrasne, G. Rohr, H. Weigmann, private communication 1971, published in Journ. Nucl. En. 26 (1972) 91; data received from CCDN in Saclay, 1971

/92/ A. Bratenahl, J.M. Peterson, J.P. Stoering, Phys. Rev. 110 (1958) 927

/93/ J. Cabé, M. Cance, A. Adam, M. Beaufour, M. Labet, Proc. 2nd Int. Conf. Nucl. Data for Reactors, Helsinki, June 1970, p. CN-26/68 or Vol. II, pp. 31

/94/ D.W. Glasgow, D.G. Foster jr., Phys. Rev. Letters 22 (1969) 139

/95/ L.A. Galloway, quoted in TID-11005 (1960)

/96/ R.L. Henkel, LA-1493 (1952); data referenced in CCDN-NW/11, pp. 290

/97/ J.P. Whalen, A.B. Smith, J.W. Meadows, ANL-7110 (1965); data referenced in CCDN-NW/11, pp. 291

/98/ V.Y. Averchenkov, A.I. Veretennikov, Sov. Progress in Neutron Phys., Moscow 1961, pp. 191

/99/ A. Langsford, AERE-PR/NP9 (1966) 34

/100/ J.R. Lemley, G.A. Keyworth, B.C. Diven, Nucl. Sc. Engng. 43 (1971) 281

/101/ D.S. Mather, P.F. Bampton, AWRE 055/71 (=EANDC (UK) 132 AL), Aug. 1971

/102/ E.G. Silver, G. de Saussure, R.B. Perez, R.W. Ingle, Proc. 3rd Conf. Neutr. Cross Sections Technology, Knoxville, March 1971, Conf. 710301, Vol. 2, pp. 728

/103/ R.-E. Bandl, H. Miessner, F.H. Fröhner, Proc. 3rd Conf. Neutr. Cross Section Technology, Knoxville, March 1971, Vol. 1, pp. 273 and KFK 1563 (1972)

/104/ J.B. Czirr, J.S. Lindsey, UCRL-72454 (1970) and Nucl. Sc. Engng. 41 (1970) 56

/105/ G.V. Muradjan, T.A. Mostovaja, V.J. Mostovo, Yu. G. Tschepkin Proc. 2nd Int. Conf. Nucl. Data for Reactors, Helsinki, June 1970, Vol. I, pp. 357 or p. CN-26/121

/106/ M.A. Kurov, Yu.V. Ryabov, So Don Sik, N. Chikov et al., Proc. 2nd Int. Conf. Nucl. Data for Reactors, Helsinki, June 1970, p. CN-26/126

/107/ L. W. Weston, G. de Saussure, R. Gwin, Nucl. Sc. Engng. 20 (1964) 80

/108/ B.C. Diven, J. Terrell, A. Hemmendinger, Phys. Rev. 109 (1958) 144

/109/ J.C. Hopkins, B.C. Diven, Nucl. Sc. Engng. 12 (1962) 169

/110/ H. Alter, C.L. Dunford, AI-AEC-MEMO-12916 (1970)

/111/ D.M. Drake, Nucl. Phys. A 133 (1969) 108

/112/ B.H. Armitage, A.T.G. Ferguson, J.H. Montague, N. Starfelt, Proc. Conf. on Nucl. Data for Reactors, Paris, Oct. 1966, Vol. I, pp. 383

/113/ R. Batchelor, K. Wyld, AWRE-055/69 (1969)

/114/ G. de Saussure, private communication 1972

/115/ E. Kiefhaber, J.J. Schmidt KFK 969 (=EANDC(E)-118"U"), Sept. 1970

/116/ E. Kiefhaber, KFK1572, März 1972

/117/ H. Küsters et al., KFK1632 to be published

List of the tables

Table I: Available experimental information on the absolute delayed neutron yield per fission of ^{235}U

$\bar{\nu}_d$ (^{235}U)	Reference
$\frac{\bar{\nu}_d(^{235}U)\ \text{thermal}}{\bar{\nu}_d(^{235}U)_{\text{fast}}} = 1.017 \pm 11\ \%$ (fission spectrum)	Brunson et al., 1955 [12]
fission spectrum neutrons: 0.01741 0.0014	Rose, Smith, 1957 [13]
thermal: 0.0158 ± 0.0005 fission spectrum: 0.0165 ± 0.0005	Keepin et al., 1958 [8, 9, 10]
14 MeV neutrons: 0.022 ± 0.005	McGarry et al., 1960 [14]
$\bar{\nu}_d$(2.4 MeV)/ $\bar{\nu}_d$thermal = 1.03 ± 0.04 $\bar{\nu}_d$(3.3 MeV)/ $\bar{\nu}_d^{th}$ = 0.99 ± 0.04 $\bar{\nu}_d$(15 MeV)/ $\bar{\nu}_d^{th}$ = 1.86 ± 0.06	Maksyutenko, 1960 [15]
several measurements in the range 250 keV - 1.5 MeV $\bar{\nu}_d$ varies between 0.015 and 0.017; no numerical values given	Cox et al., 1967/68 [16]
14.9 MeV neutrons: 0.0095 ± 0.0008 $\frac{\bar{\nu}_d\ (3.1\ \text{MeV})}{\bar{\nu}_d(14.9\ \text{MeV})} = 1.80 \pm 0.11$	Masters et al., 1969 [11]

Table II: Available experimental information on $\bar{\nu}_{25}$ from 1961 up to late 1970

Reference	Energy region	Accuracy /%/	Standard	Comments
Blyumkina et al.; 1964 /3/	0.08 MeV - 0.99 MeV 0.08 MeV - 0.64 MeV	0.7-1.2 0.7-1.6	$\bar{\nu}^{p}_{th}(^{235}U)$ = 2.43	Scintillator measurements Thorium fission detector measured quantity $\frac{\bar{\nu}_p(E_n)}{\bar{\nu}_p(E^o_n)}$ E^o_n = 0.39 MeV
Butler et al.; 1961 /19/	0.21 MeV - 1.58 MeV	0.6-1.	$\bar{\nu}^{p}_{th}(^{235}U)=2.47$	
Colvin, Sowerby; 1965 /20/	0.101 MeV - 2.57 MeV	0.8-1.9	$\bar{\nu}^{p}_{sp}(^{252}Cf)$	in reference /20/ data for the ratio $\bar{\nu}_p(E)\ (^{235}U)/\bar{\nu}^{p}_{sp}(^{252}Cf)$ given
Condé et al.; 1965 /21/	0.06 MeV - 14.8 MeV (3 energy points)	1.	$\bar{\nu}^{p}_{sp}(^{252}Cf)=3.767$	
Hopkins, Diven; 1963 /22/	0.280 MeV - 14.5 MeV	0.9-1.6	$\bar{\nu}^{p}_{sp}(^{252}Cf)=3.771$	
Kuznetsov, Smirenkin; 1966 /18,23/	0.08 MeV - 0.70 MeV	0.7-1.	$\bar{\nu}^{p}_{th}(^{235}U)=2.43$	measured quantity $\frac{\bar{\nu}_p(E_n)}{\bar{\nu}_p(E^o_n)}$ E^o_n = 0.4 MeV
Mather, Fieldhouse, Most; 1964 /24/	0.04 MeV - 7.96 MeV	0.6-1.7	$\bar{\nu}^{p}_{sp}(^{252}Cf)=3.782$	
Meadows, Whalen; 1962 /25/ ; 1967 /26/	0.03 MeV - 1.76 MeV 0.039 MeV - 1.0 MeV	0.7-1.0 0.6-0.9	$\bar{\nu}^{p}_{sp}(^{252}Cf)=3.782$	

Table II : Continued

Reference	Energy region	Accuracy [%]	Standard	Comments
Nesterov, Kurpeisov; 1970 [27]	0. - 1.5 MeV	0.6 - 1.1	$\bar{\nu}^{p}_{sp}(^{252}Cf)=3.782$	
Prokhorova, Smirenkin; 1968 [28]	0.37 MeV - 3.25 MeV	0.7 - 1.7	$\bar{\nu}^{p}_{th}(^{235}U)=2.414$	measured quantity $\frac{\bar{\nu}_p(E_n)}{\bar{\nu}_p(E^o_n)}$ E^o_n = 0.37 MeV;
Savin et al.; 1970 [29,32]	0.65 MeV - 6.60 MeV	1.2 - 3	$\bar{\nu}^{p}_{sp}(^{252}Cf)=3.772$	
Soleilhac et al.; 1970 [31] 1969 [30]	0.21 MeV - 1.36 MeV 1.36 MeV - 14.79 MeV	0.5 - 2.2 0.3 - 0.5 (statistical) only		

values used for renormalization:

$\bar{\nu}^{p}_{sp}(^{252}Cf) = 3.756$

$\bar{\nu}^{p}_{th}(^{235}U) = 2.4071$

<u>Table III:</u> Available σ_f-measurements for ^{235}U in the energy range 1 keV - 15 MeV later than 1950

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	data fit$^+$
Yeater et al.; 1954 [36] 1956	0.7 - 43 keV 5 eV - 2 keV	± 4 - 6	Columbia absolute σ_{f25} measurements between 0.3 and 0.7 eV [37]	not considered because no absolute measurements and reference values are based on earlier measurements	-
Michaudon et al.; 1958 - 1984 [37] - [40]	<1 keV - 20 keV	± 5 - 6	$\int_{8\,eV}^{10\,eV} \sigma_f^{25}(E)dE$ from measurements of Shore, Sailor [42] normalized to $\sigma_f(0.025\ eV)$ = 582b		-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ /%/	Standard	Comments	data fit
Michaudon, Ribon et al.; /41/ 1965	2.5 eV - 20 keV	± 5 - 6	$\int_{0.4}^{1.3} \sigma_f^{25}(E)\, dE$ with data of Shore, Sailor /42/	previously recommended on KEDAK /34, 35/; presently replaced by the Blons measurements /43/: resolution: 10 nsec/m	-
Melkonian et al.; 1957 /44/	0.01 eV - 40 keV	± 4 - 6	σ_{f25} = 580b/ 0.0253 eV	relative measurements, but normalized to the well-known 2200 m/sec value for σ_{f25} and therefore taken into account	x

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	data fit
Gorlov et al.; 1959 [45]	3.5 - 800 keV	± 7	σ_{f25} = 1.30b/270 keV	rejected since relative measurements and normalized to the absolutely measured standard value	-
Perkin et al.; 1965 [46]	24 keV	σ_{f25} =(2.36 ± 0.06) b	absolute measurement	neutrons from a Sb-Be-source, calibrated in three independent ways	x
Van-Shi-di et al.; [47] 1965	0.1 keV - 30 keV	± 1 - 4	σ_{f25}=(582±6) b/ 0.025 eV	rejected because of a (10-40 nsec/m) resolution worse than the Blons experiment [43] and since the results are avail. only as energy averages, used for comparison purposes	-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
de Saussure et al. 1966 [48] 1967	0.4 eV - 30 keV	≈ 5	$\int_{0.45\,eV}^{10\,eV} \sigma_f(E)\,dE = 127.9\,b$ obtained from the measured data of Bowmann [49] which are normalized to $\sigma_{f25} = 577.1\,b/0.025\,eV$	measurements with a resolution of 100 nsec/m - 2 nsec/m; worse resolution than the Blons experiment; used for comparison purposes	-
Wilbur K. Brown, Bergen, Cramer; 1966 [50]	20 eV - 2 MeV	-	$Li(n,\alpha)T$ up to 100 keV; σ_{f25} 10 keV-2 MeV (BNL325)	relative measurements; Petrel underground explosion; used for comparison purposes	-
Cramer, Bergen; 1969 [51]	20 eV - 1 keV	± 5.5-90	$Li(n,\alpha)T$; $He(n,p)T$	underground nucl. detonation Persimmon	-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Cramer; 1970 [52]	10 eV - 2.84 MeV	± 4.5-50	Below 1 keV Li (n,α)T; above σ_{f25}-data evaluated by Davey [53] at several energy points in the range 0.672 - 3.01 MeV	Pommard underground detonation; because of the large uncertainty of this measurement only used in the range 0.9 - 3 MeV, where not sufficient experimental data points from other authors are available for the determination of the shape of $_f$ and where the uncertainty of the measured data is satisfactory and	partly x

Table III: Continuation

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ /%/	Standard	Comments	Data fit
				ranges from 4.4 - 6.6 %	
Cao et al.; 1988 /54/	6 eV - 3 keV	-	$\int_{0.45\,eV}^{10\,eV} \sigma_f(E)\,dE$ from measurements of Shore, Sailor /42/ relative to σ_{f25}=582b/0.025eV	two different detector systems: ionization chamber, liquid scintillator. Rejected since the measurements do not cover the whole energy range 1 keV - 30 keV, where structure was found	-
Patrick et al.; 1970 /55/	50 eV - 30 keV	≈ ± 5	$^{10}B(n,\alpha)$; $\eta = 1.64$ at the 56.3 eV resonance /48/	with a resolution of 2 nsec/m worse than the Blons experiment; only used for comparison purposes	-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Bowman et al.; 1970 [56]	1.5 keV - 500 keV	-	-	no absolute cross section determination; considerable structure observed up to 200 keV	-
Blons et al.; 1970 [43]	17 eV - 30 keV	± 4.5 - 7	$^{10}B(n,\alpha)$; $\int_{60\,eV}^{300\,eV} \sigma_f(E)dE$ over the measured data of Michaudon [40]	measurement with the best energy resolution amongh the σ_f-measurements which show structure in σ_f in the keV-range	x
Lemley et al.; 1971 [100]	20 eV - 100 keV	average: 8	^6Li (n, α)	data not available at the time of this evaluation; only used for comparison purposes; underground nuclear explosion	-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Nyer; 1950 [51]	14 MeV	$\sigma_{f25}=(2.16\pm0.09)$b	$\sigma_{f28}=(1.13\pm0.03)$b/ 14 MeV	single data point measured relative to the standard	-
Diven; 1953, 1957 [58]	0.403-1.62 MeV	± 3 - 6	$\sigma_{f25}=(1.27\pm0.04)$b/ 1.27 MeV measured relative to (n, p)	absolute measurement only at 1.27 MeV; this result has been considered	x partly
Uttley, Phillips; 1956 [83]	14.1 MeV	$\sigma_{f25}=(2.20\pm0.07)$b	$\sigma_{f28}=(1.14\pm0.03)$b/ 14.1 MeV	relative measurement, confirms the White result at 14.1 MeV	
Allen, Ferguson: 1957 [59]	30 keV - 3 MeV	± 1.3 - 3	(n, p)	flux determination by proportional counters filled with hydrogen.	-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ /%/	Standard	Comments	Data fit
				The data below 100 keV show strong deviations from the majority of the other measurements in particular from those of Perkin and of White. Because of this possibly systematic error the data set was excluded	
Henkel; 1957 /60/	10 keV - 3 MeV	-	σ_{f25}=1.27b/ 1.27 MeV	rejected since relative measurements which are normalized to an absolute measurement by Diven /58/ Corrections to the long counter efficiency have been applied 1957 to the 1954 results /LA-1714/	

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Dorofeev, Dobrynin; 1957 [61]	30 keV - 5 MeV	± 5.5-6.5	$\sigma_{f25}=(2.21\pm0.12)$b/ 30 keV	measurements using known strength sources; absolute σ_f-measurement only at 30keV, therefore only this value has been taken into account	x partly
Moat; 1958 [62]	14 MeV	$\sigma_{f25}=(2.13\pm0.09)$b	$\sigma_{f28}=(1.13\pm0.02)$b/ 14 MeV measured by Moat [62]	single data point, measured relative to the standard	-
Berezin et al.; 1958 [63]	14.6 MeV	$\sigma_{f25}=(2.30\pm0.15)$b	$\sigma_{f28}=(1.13\pm0.05)$b/ 14.6 MeV		-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Netter; 1961 [64, 65]	50 keV - 3.8 MeV	± 4 - 9	$\sigma_{f49}=(2.04\pm0.12)$b, 1.6 MeV	measurement of the ratio σ_f(Pu239)/ σ_f(U-235); standard measured relative to natural uranium and determined with $\sigma_{f28}=0.34$b at 1.6 MeV. Since the measurements were not absolute, they have been rejected.	-
Kalinin, Pankratov; 1958 [66]	3 - 8 MeV	≈ ± 7 no error bars for the individual data points are given	absolute measurement	considered in the data fit, but less weight was assigned to these data than to the results of Hansen, McGuire [78] since the latter measurement support the White data in this range in contrary to Pankratov	x with reservation

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Pankratov, Vlasov, Ryabov; 1961 [67]	1o - 22 MeV	≤ ± 5	σ_{f25}=2.25b/14 MeV	rejected since no absolute measurements, normalized to earlier meas.	-
Pankratov; 1963 [68]	6 - 26 MeV	≤ ± 5	σ_{f25}=1.23b/3.4MeV		-
Smirenkin et al.; [69] 1962	0.3-2.6 MeV	± 5 - 10	σ_{f28}=0.585b/ 2.5 MeV	rejected, since the data are not of high accuracy and the measurements are not absolute	-
Adams et al.; 1961 [70]	13.2-19.4 MeV	± 4.5 - 5	σ_{f28}=(1.13 ± 0.02)b/14 MeV measured by Moat 1958 [62]	relative measurement, only used for the determination of the shape of σ_{f25} passing through the White result at 14MeV	x with reservations

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Albert; 1965 [71]	0.1 - 2 MeV	$\geq \pm 5$	-	use of a nuclear explosion as neutron source; data were not taken into account, for reasons see KFK 120 pp. H11/12 [34]	-
White; 1965 [72]	40 keV - 14.1 MeV	$\pm$ 2.5 - 3	(n, p)	for flux measurements use of a proton recoil counter up to 505 keV, of a solid hydrogenous radiator at higher energies	x
Macklin, Gibbons; 1966 [73]	0.15-0.335 MeV	$\pm$ 2.5-7.5	σ_{f25}-data of White	measurements carried out for verification of the structure in σ_{f25} found by Albert [71]; results compatible with White	-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ /%/	Standard	Comments	Data fit
Gilboy, Knoll; 1966 /74/	0.38 - 0.62 MeV	± 2 statistical	^{6}Li (n, α)	rejected, since relative measurements aiming to the investigation of structure in σ_f as detected by Albert /71/;	-
Knoll, Pönitz; 1967 /75/	30 keV 64 keV	σ_{f25}=(2.19±0.06)b σ_{f25}=(1.78±0.13)b	absolute measurements	two independent methods for the determination of the neutron flux	x
Pönitz; 1968 /76/ 1970 /77/	30 keV - 1.5 MeV 130 keV - 1.5 MeV	± 5 - 12	σ_{f25}=2.19b/30 keV measured by Knoll, Pönitz /75/	"grey" neutron detector; data not compatible with the White measurements relative to the hydrogen scattering cross section, deviations of up to about 15 %. Rejected because of these unresolved discrepancies.	-

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Hansen, McGuire, Smith; 1968 [78]	2.2 - 10.5 MeV	± 5 - 7	(n, p)	neutron flux measurements with a proton recoil telescope; data originally measured by Smith, Henkel, Nobles [79]; corrected by Hansen et al. for inscattering effects.	x
Szabo, Leroy et al.; 1970 [80]	17.5 keV - 1.01 MeV	± 3	absolute measurements	three different methods for determination of the neutron flux; use of the fission chamber constructed by White; deviations between the White- and Szabo-results < 1 %.	x

Table III: Continued

Reference	Energy range	Accuracy $\frac{\Delta\sigma_f}{\sigma_f}$ [%]	Standard	Comments	Data fit
Käppeler; 1970 [81]	440 keV 530 keV	$\sigma_{f25}=(1.17\pm0.041)b$ $\sigma_{f25}=(1.17\pm0.041)b$	(n, p)	The measurements were extended over the energy range 0.1 MeV up to 1 MeV, but no final results are available.	x

\+ The sign "x" means, that the results of this measurement were taken into account in the data fit, the sign "-" means, that they have not been considered.

Table IV: σ_{f25}-averages of high resolution measurements over the energy range 1 keV - 30 keV

	$\langle \sigma_f \rangle$						
Energy internal [keV]	Michaudon et al. [27-41] Saclay	Van-Shi-di et al. [47] Dubra	de Saussure et al. [43] ORNL-RPI	Wilbur K.Brown et al. [50] Los Alamos	Blons et al. [43] Saclay	Patrick et al. [55] Harwell	Lemley et al. [100] Los Alamos
30 - 20	-	3.115	-	-	2.106	2.093	2.101
20 - 10	2.801	3.271	-	2.752	2.467	2.468	2.338
10 - 9	3.418	3.340	3.101	3.248	3.074	3.188	3.105
9 - 8	3.505	3.227	3.122	3.030	2.984	3.102	
8 - 7	3.551	3.430	3.931	3.034	3.193	3.296	
7 - 6	3.791	3.457	3.612	3.149	3.469	3.291	
6 - 5	4.274	3.831	3.910	3.459	3.948	4.273	
5 - 4	4.502	4.499	4.728	4.013	4.413	4.371	4.010
4 - 3	4.887	4.907	5.117	4.721	4.854	4.805	4.511
3 - 2	5.761	5.620	5.680	5.464	5.404	5.388	5.057
2 - 1	7.545	7.619	7.601	7.653	7.445	7.483	6.741

Figure captions

Fig. 1 : The experimental information and recommended curve for $\bar{\nu}_{25}(E)$ in the energy range from thermal up to 1.4 MeV

Fig. 2 : The experimental information and recommended curve for $\bar{\nu}_{25}(E)$ in the energy range from 1.4 MeV up to 15 MeV

Fig. 3 : σ_{f25}-averages of high resolution measurements in the energy range 1 keV - 30 keV

Fig. 4 : Selected measurement series and recommended σ_{f25}-curve in the energy range from 30 keV to 270 keV.

Fig. 5 : Selected measurement series and recommended σ_{f25}-curve in the energy range from 200 keV to 1.5 MeV.

Fig. 6 : Selected measurement series and recommended σ_{f25}-curve in the energy range from 1 MeV to 15 MeV.

Fig. 7 :
a) - q) High-resolution σ_T^{25}-measurements recommended on KEDAK in the energy range 150 eV - 30 keV.

Fig. 8 :
a) - b) Experimental data and recommended curve for σ_T^{25} in the energy range 30 keV - 15 MeV.

Fig. 9 : Comparison between the previously and presently on KEDAK recommended $\sigma_T(E)$-curve

Fig. 10: Experimental data and recommended curve for α_{25} in
a) the energy range 3 keV - 50 keV
b) the energy range 45 keV - 100 keV

Fig. 11: Experimental data and recommended curve for α_{25} in the region 50 keV - 1 MeV

Fig. 12: Presently recommended $\alpha(E)$-curve in the energy region 30 keV - 15 MeV.

Fig. 13: Experimental data and recommended curve for σ_n^{25} in the energy range 400 keV - 15 MeV.

Fig. 14: Experimental data and recommended curve for the non-elastic cross section σ_x^{25} in the region 400 keV - 15 MeV.

Fig. 15: Experimental data and recommended curve for the total inelastic scattering cross section σ_n^{25} in the energy range 15 keV - 15 MeV.

Key to the symbols used in Fig. 1

▲	Blyumkina et al.	;	1964	[18]
◈	Butler et al.	;	1961	[19]
○	Colvin, Sowerby	;	1965	[20]
▲	Condó	;	1965	[21]
◇	Hopkins, Diven	;	1963	[22]
▼	Kuznetsov, Smirenkin	;	1966	[23]
◐	Mather et al.	;	1964	[24]
+	Meadows, Whalen	;	1962, 1967	[25, 26]
◆	Nesterov et al.	;	1970	[27]
△	Prokhorova, Smirenkin	;	1968	[28]
∧	Savin et al.	;	1970	[29]
●	Soleilhac et al.	;	1969, 1970	[30, 31]
—	presently recommended			
—	Mather - evaluation			[101]

Key to the symbols used in Fig. 2

⊕	Butler et al.	;	1961	[19]
○	Colvin, Sowerby	;	1965	[20]
▲	Condó	;	1965	[21]
◇	Hopkins, Diven	;	1963	[22]
◐	Mathor et al.	;	1964	[24]
+	Meadows, Whalen	;	1962	[25]
⬘	Nesterov et al.	;	1970	[27]
△	Prokhorova, Smirenkin	;	1968	[28]
∧	Savin et al.	;	1970	[29]
●	Soleilhac et al.	;	1969	[30]
—	presently recommended			

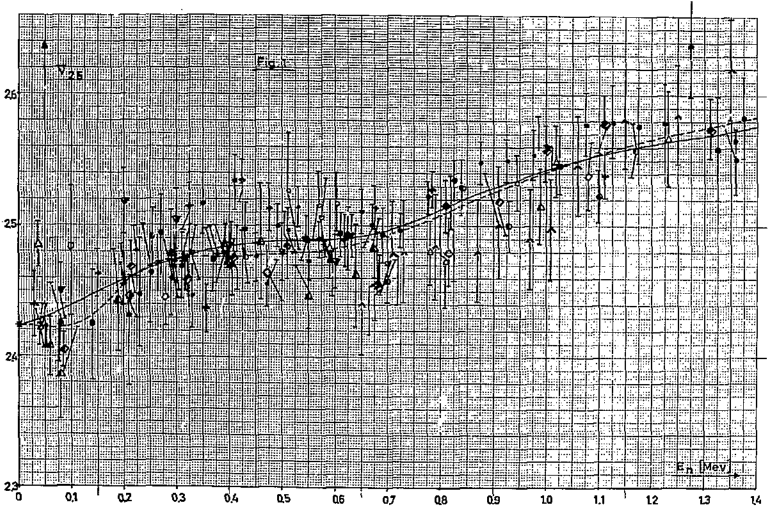
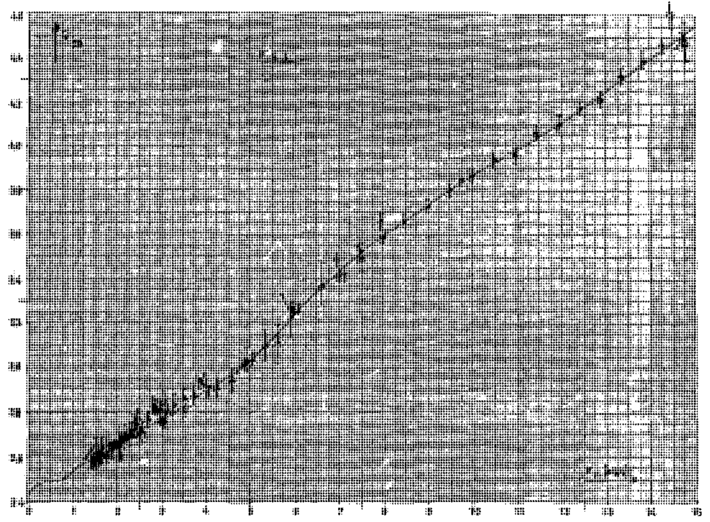


Fig. 1


0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

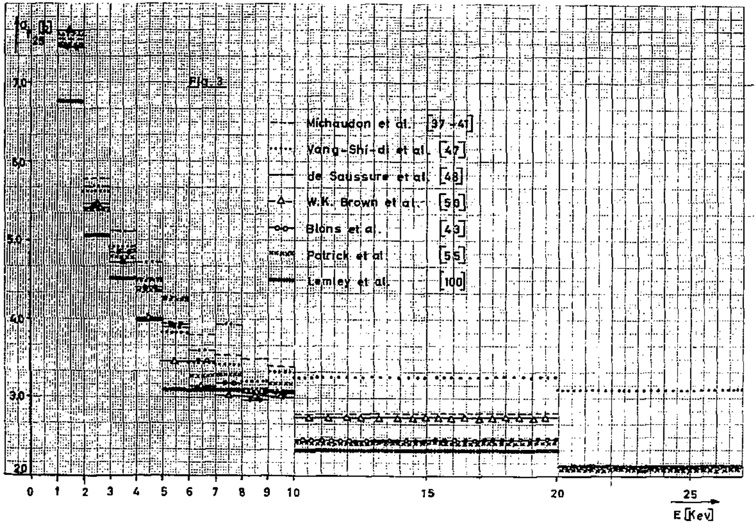


Fig. 3

σf [b]
25
7.0
6.0
5.0
4.0
3.0
2.0
Michaudon et al. [37 - 41]
Vang-Shi-di et al. [47]
de Saussure et al. [48]
W.K. Brown et al. [56]
Blons et al. [43]
Patrick et al. [55]
Lemley et al. [100]
0
1
2
3
4
5
6
7
8
9
10
15
20
25
E [Kev]

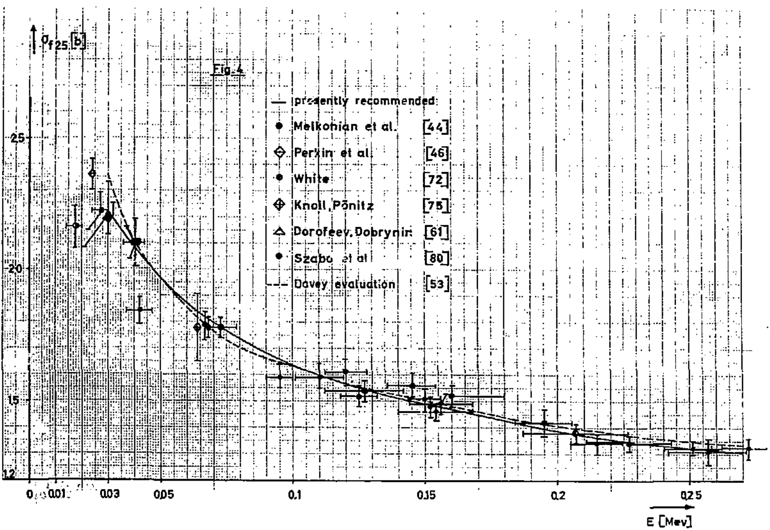


Fig. 4
σ_{f25} [b]
25
20
15
12
0
0.01
0.03
0.05
0.1
0.15
0.2
0.25
E [Mev]
— presently recommended:
● Melkonian et al. [44]
◇ Perkin et al. [46]
● White [72]
◈ Knoll, Pönitz [75]
△ Dorofeev, Dobrynin [61]
● Szabo et al [80]
--- Davey evaluation [53]

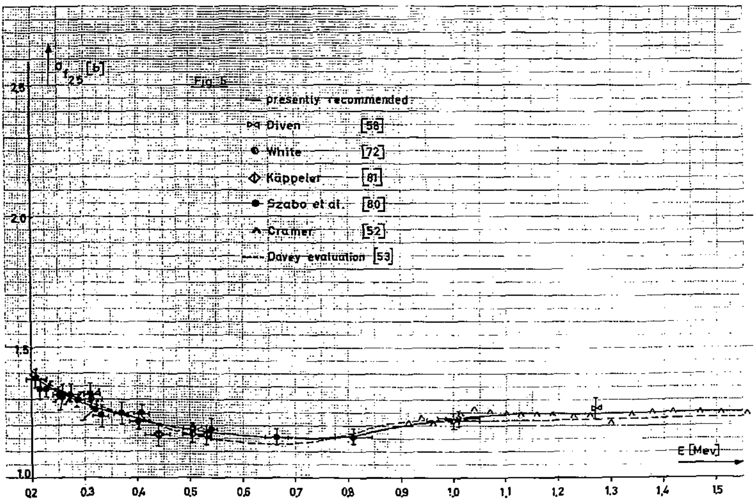


Fig. 5

$\sigma_{f_{25}}$ [b]
2,5
2,0
1,5
1,0
— presently recommended
⋈ Diven [58]
● White [72]
◇ Käppeler [81]
● Szabo et al. [80]
^ Cramer [52]
---- Davey evaluation [53]
E [Mev]
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
1,1
1,2
1,3
1,4
1,5

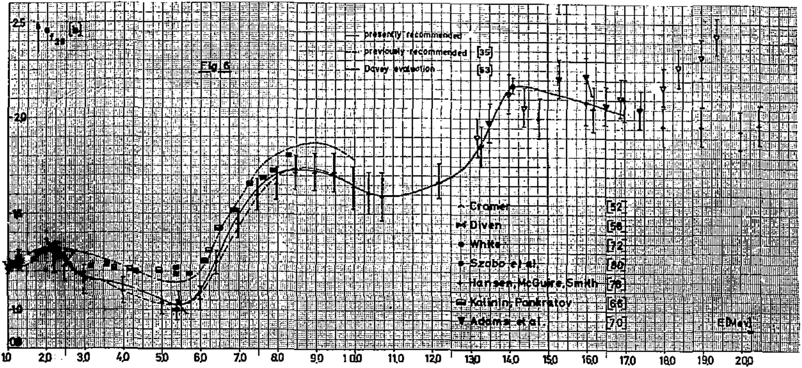


Fig. 6

σ f,28 [b]
2.5
2.0
1.5
1.0
0.5
presently recommended
previously recommended [35]
Davey evaluation [53]
Cramer [52]
Diven [56]
White [72]
Szabo et al. [80]
Hansen, McGuire, Smith [78]
Kalinin, Pankratov [66]
Adams et al. [70]
E(MeV)
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0

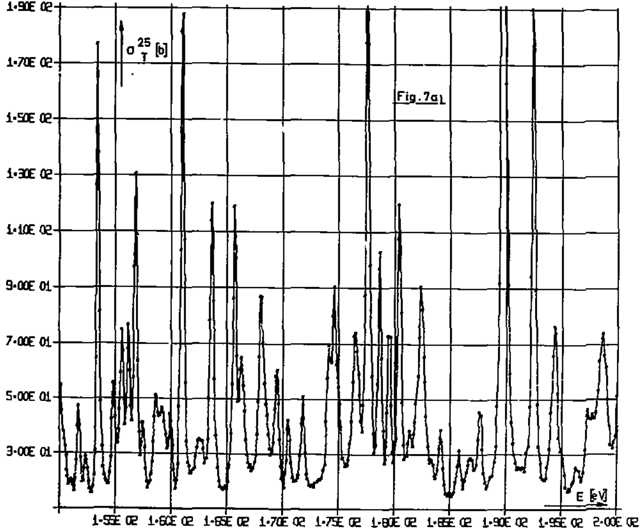


Fig.7a1

σ_T^{25} [b]
1·90E 02
1·70E 02
1·50E 02
1·30E 02
1·10E 02
9·00E 01
7·00E 01
5·00E 01
3·00E 01
E [eV]
1·55E 02
1·60E 02
1·65E 02
1·70E 02
1·75E 02
1·80E 02
1·85E 02
1·90E 02
1·95E 02
2·00E 02

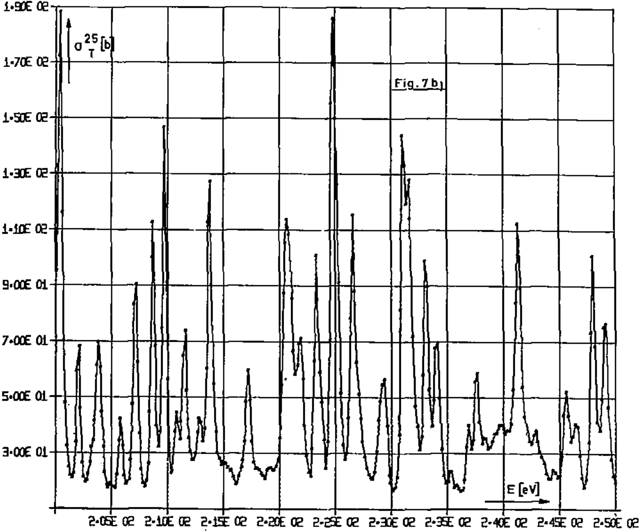


Fig. 7 b)

σ_T^{25} [b]
1·90E 02
1·70E 02
1·50E 02
1·30E 02
1·10E 02
9·00E 01
7·00E 01
5·00E 01
3·00E 01
E [eV]
2·05E 02
2·10E 02
2·15E 02
2·20E 02
2·25E 02
2·30E 02
2·35E 02
2·40E 02
2·45E 02
2·50E 02

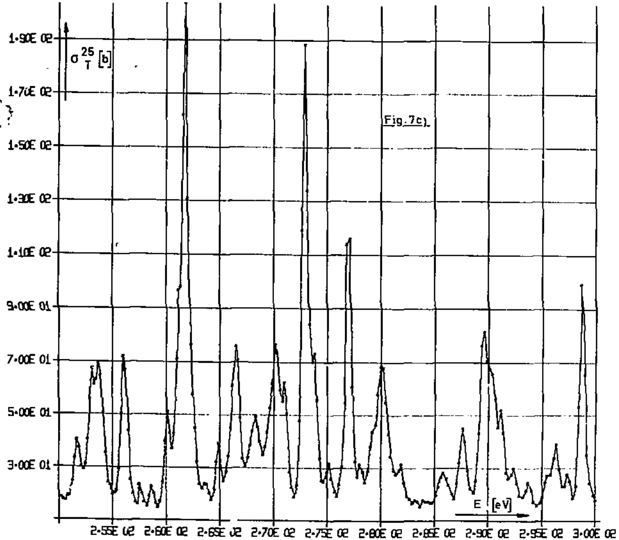
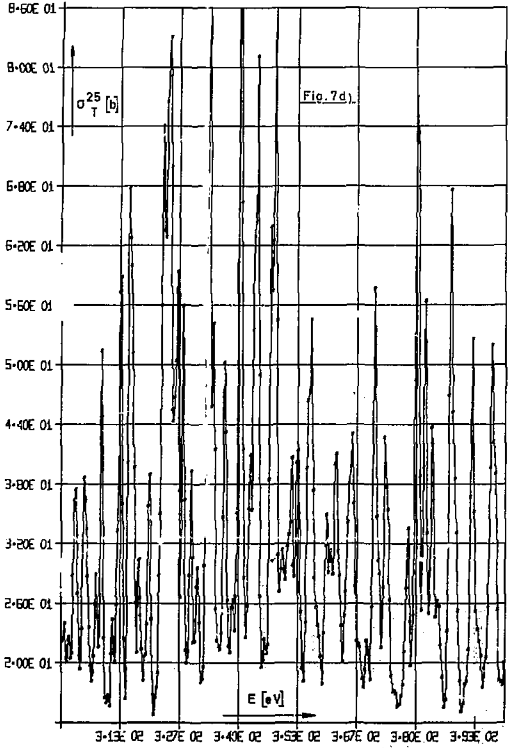


Fig. 7c)
1·90E 02
1·70E 02
1·50E 02
1·30E 02
1·10E 02
9·00E 01
7·00E 01
5·00E 01
3·00E 01
σ_T^{25} [b]
2·55E 02
2·60E 02
2·65E 02
2·70E 02
2·75E 02
2·80E 02
2·85E 02
2·90E 02
2·95E 02
3·00E 02
E [eV]



8·60E 01
8·00E 01
7·40E 01
6·80E 01
6·20E 01
5·60E 01
5·00E 01
4·40E 01
3·80E 01
3·20E 01
2·60E 01
2·00E 01
σ_T^{25} [b]
Fig. 7d)
E [eV]
3·13E 02
3·27E 02
3·40E 02
3·53E 02
3·67E 02
3·80E 02
3·93E 02

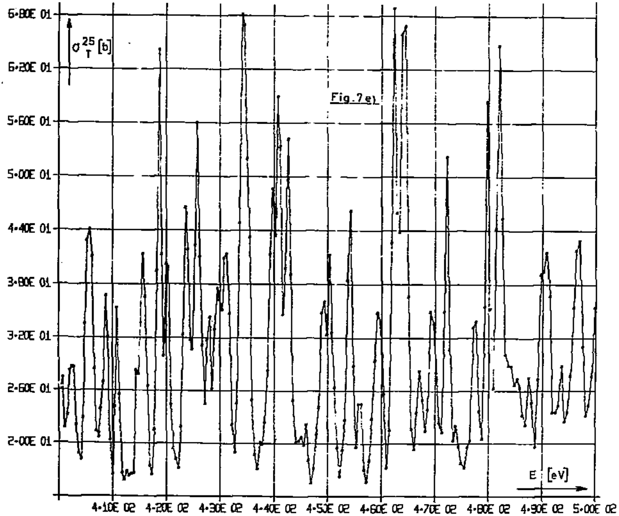


Fig.7e)

σ_T^{25} [b]
6•80E 01
6•20E 01
5•60E 01
5•00E 01
4•40E 01
3•80E 01
3•20E 01
2•60E 01
2•00E 01
4•10E 02
4•20E 02
4•30E 02
4•40E 02
4•50E 02
4•60E 02
4•70E 02
4•80E 02
4•90E 02
5•00E 02
E [eV]

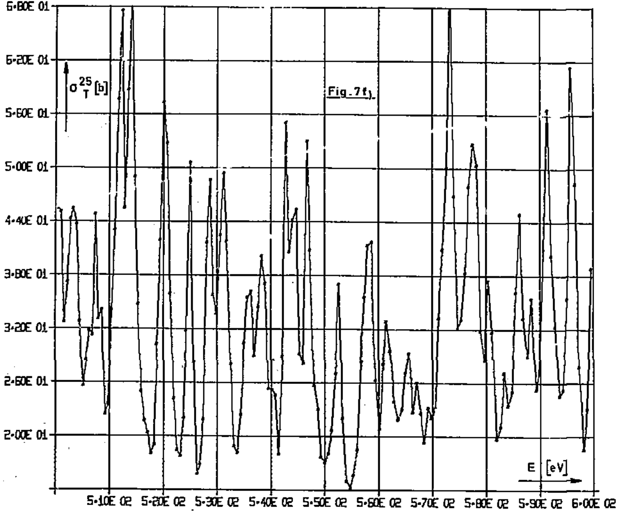


Fig. 7f).

σ_T^{25} [b]
6·80E 01
6·20E 01
5·60E 01
5·00E 01
4·40E 01
3·80E 01
3·20E 01
2·60E 01
2·00E 01
5·10E 02
5·20E 02
5·30E 02
5·40E 02
5·50E 02
5·60E 02
5·70E 02
5·80E 02
5·90E 02
6·00E 02
E [eV]

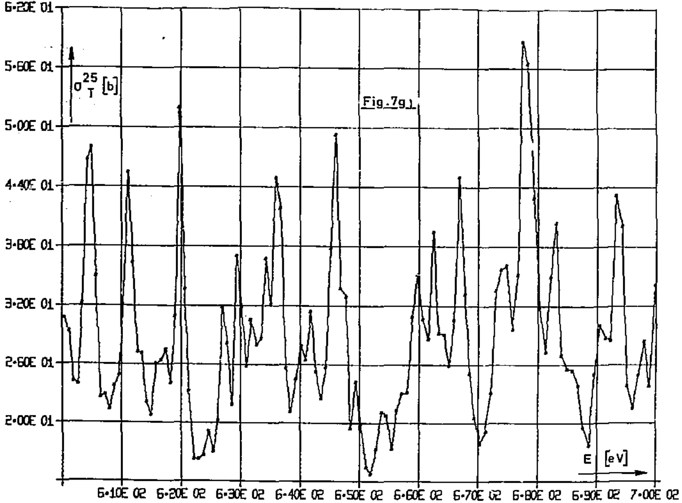
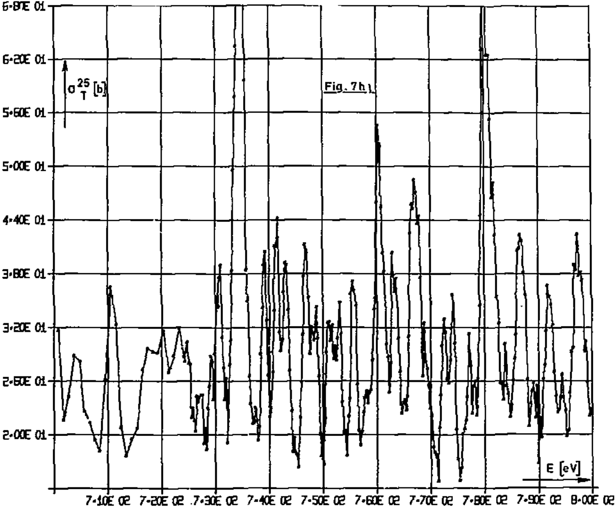


Fig. 7g1

6·20E 01
5·60E 01
5·00E 01
4·40E 01
3·80E 01
3·20E 01
2·60E 01
2·00E 01
σ 25 T [b]
E [eV]
6·10E 02
6·20E 02
6·30E 02
6·40E 02
6·50E 02
6·60E 02
6·70E 02
6·80E 02
6·90E 02
7·00E 02


6·80E 01
6·20E 01
5·60E 01
5·00E 01
4·40E 01
3·80E 01
3·20E 01
2·60E 01
2·00E 01
σ_T^{25} [b]
Fig. 7h)
E [eV]
7·10E 02
7·20E 02
7·30E 02
7·40E 02
7·50E 02
7·60E 02
7·70E 02
7·80E 02
7·90E 02
8·00E 02

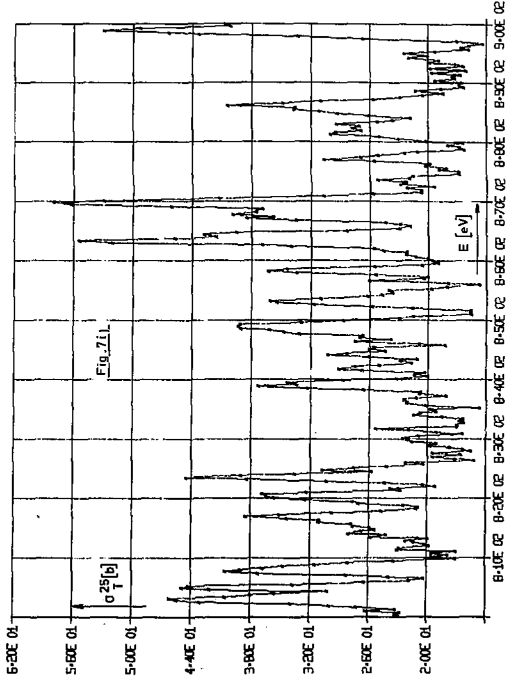

σ_T^{25}[b]
6·20E 01
5·60E 01
5·00E 01
4·40E 01
3·80E 01
3·20E 01
2·60E 01
2·00E 01
8·10E 02
8·20E 02
8·30E 02
8·40E 02
8·50E 02
8·60E 02
8·70E 02
8·80E 02
8·90E 02
9·00E 02
E [eV]

Fig. 7i)

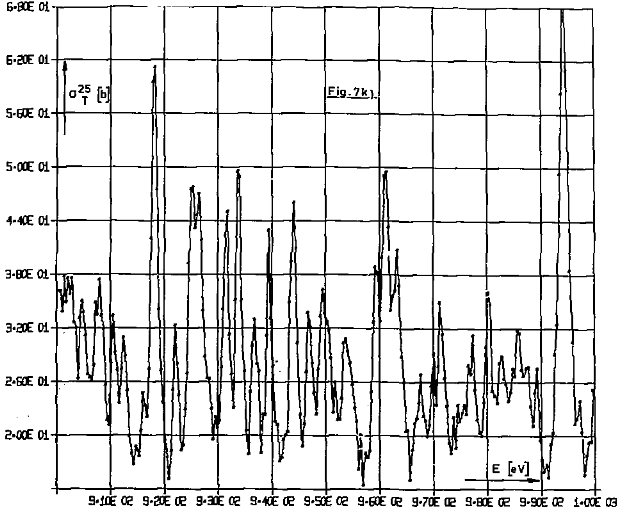


Fig. 7k).

σ_T^{25} [b]
E [eV]
6·80E 01
6·20E 01
5·60E 01
5·00E 01
4·40E 01
3·80E 01
3·20E 01
2·60E 01
2·00E 01
9·10E 02
9·20E 02
9·30E 02
9·40E 02
9·50E 02
9·60E 02
9·70E 02
9·80E 02
9·90E 02
1·00E 03

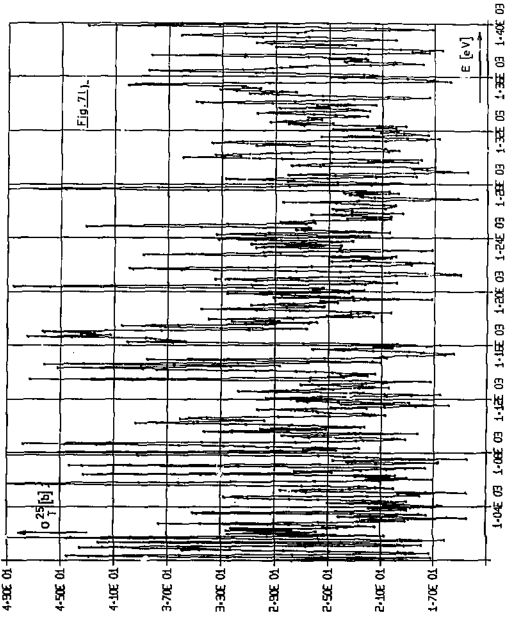


Fig.7l).

σ_T^{25} [b]
E [eV]
4·90E 01
4·50E 01
4·10E 01
3·70E 01
3·30E 01
2·90E 01
2·50E 01
2·10E 01
1·70E 01
1·04E 03
1·08E 03
1·12E 03
1·16E 03
1·20E 03
1·24E 03
1·28E 03
1·32E 03
1·36E 03
1·40E 03

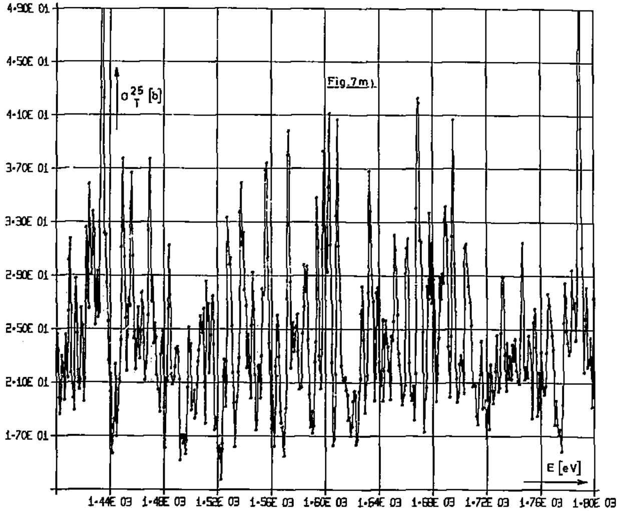


Fig.7m)

σ_T^{25} [b]
4·90E 01
4·50E 01
4·10E 01
3·70E 01
3·30E 01
2·90E 01
2·50E 01
2·10E 01
1·70E 01
1·44E 03
1·48E 03
1·52E 03
1·56E 03
1·60E 03
1·64E 03
1·68E 03
1·72E 03
1·76E 03
1·80E 03
E [eV]

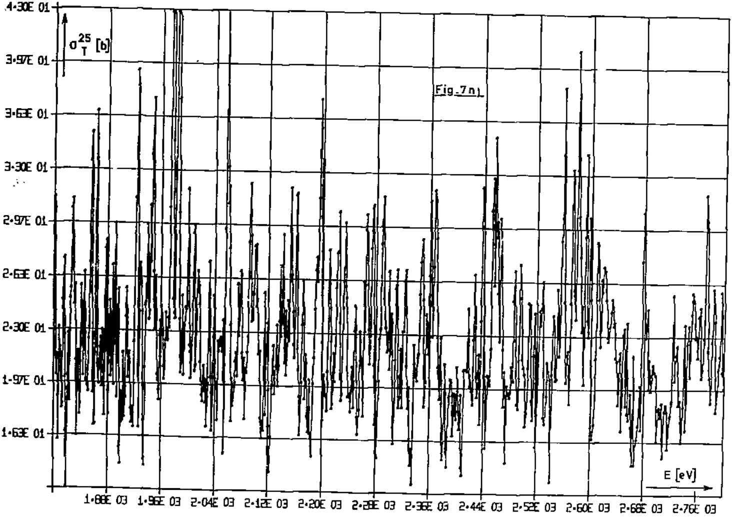


Fig. 7n)
4·30E 01
3·97E 01
3·63E 01
3·30E 01
2·97E 01
2·63E 01
2·30E 01
1·97E 01
1·63E 01
σ_T^{25} [b]
1·88E 03
1·96E 03
2·04E 03
2·12E 03
2·20E 03
2·28E 03
2·36E 03
2·44E 03
2·52E 03
2·60E 03
2·68E 03
2·76E 03
E [eV]

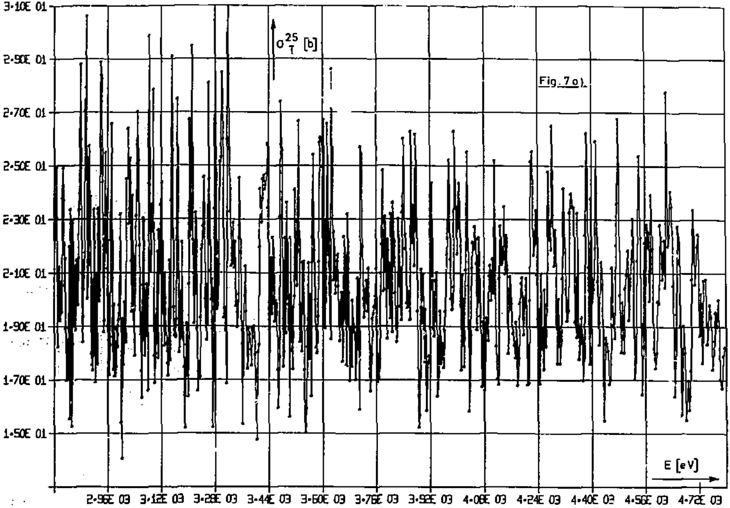
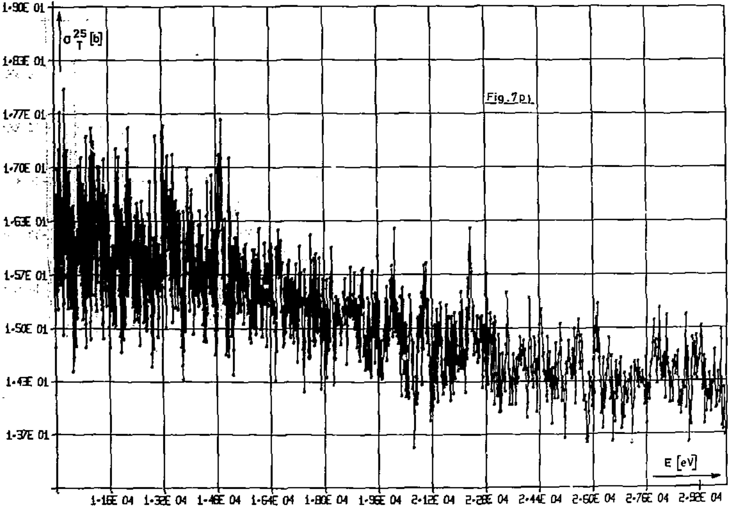
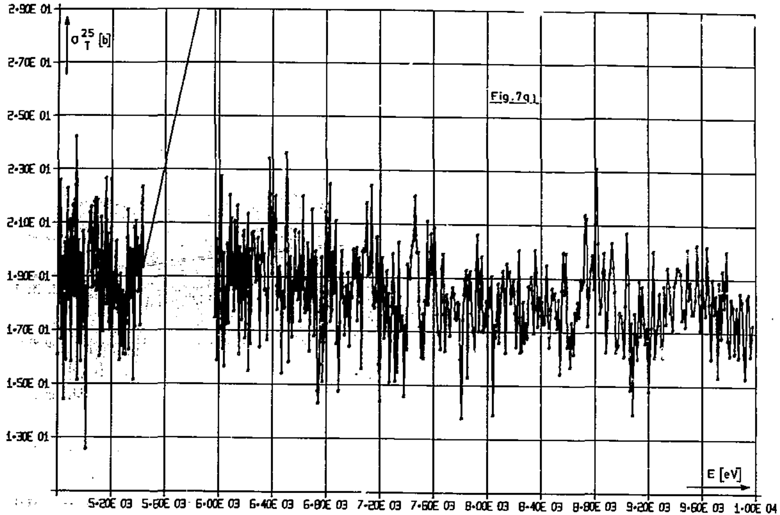

3·10E 01
2·90E 01
2·70E 01
2·50E 01
2·30E 01
2·10E 01
1·90E 01
1·70E 01
1·50E 01
σ_T^{25} [b]
2·96E 03
3·12E 03
3·28E 03
3·44E 03
3·60E 03
3·76E 03
3·92E 03
4·08E 03
4·24E 03
4·40E 03
4·56E 03
4·72E 03
E [eV]

Fig. 7a)



1·90E 01
1·83E 01
1·77E 01
1·70E 01
1·63E 01
1·57E 01
1·50E 01
1·43E 01
1·37E 01
σ_T^{25} [b]
Fig. 7p)
E [eV]
1·16E 04
1·32E 04
1·48E 04
1·64E 04
1·80E 04
1·96E 04
2·12E 04
2·28E 04
2·44E 04
2·60E 04
2·76E 04
2·92E 04


2·90E 01
2·70E 01
2·50E 01
2·30E 01
2·10E 01
1·90E 01
1·70E 01
1·50E 01
1·30E 01
σ_T^{25} [b]
Fig.7q)
E [eV]
5·20E 03
5·60E 03
6·00E 03
6·40E 03
6·80E 03
7·20E 03
7·60E 03
8·00E 03
8·40E 03
8·80E 03
9·20E 03
9·60E 03
1·00E 04

Key to the symbols used in Fig. 8 a) - b)

●	Hibdon, Langsdorf	;	1954	/90/
▽	Uttley	;	1963	/85/
⋈	Uttley	;	1966	/88/
⧖	Henkel	;	1952	/96/
○	Smith et al.	;	1965	/97/
◇	Cabé et al.	;	1970	/93/
×	Galloway	;	1960	/95/
+	Foster, Glasgow	;	1969	/94/
□	Bratenahl et al.	;	1958	/92/

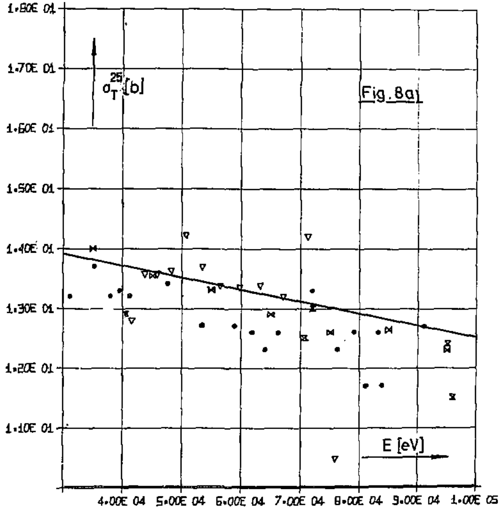

σ_T^{25} [b]
E [eV]
1.80E 01
1.70E 01
1.60E 01
1.50E 01
1.40E 01
1.30E 01
1.20E 01
1.10E 01
4.00E 04
5.00E 04
6.00E 04
7.00E 04
8.00E 04
9.00E 04
1.00E 05

Fig. 8a)

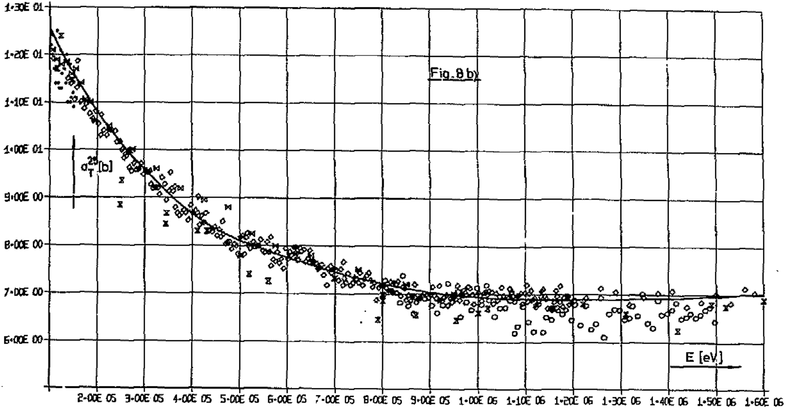

1·30E 01
1·20E 01
1·10E 01
1·00E 01
9·00E 00
8·00E 00
7·00E 00
6·00E 00
σ$_T^{25}$ [b]
2·00E 05
3·00E 05
4·00E 05
5·00E 05
6·00E 05
7·00E 05
8·00E 05
9·00E 05
1·00E 06
1·10E 06
1·20E 06
1·30E 06
1·40E 06
1·50E 06
1·60E 06
E [eV]

Fig. 8 b)

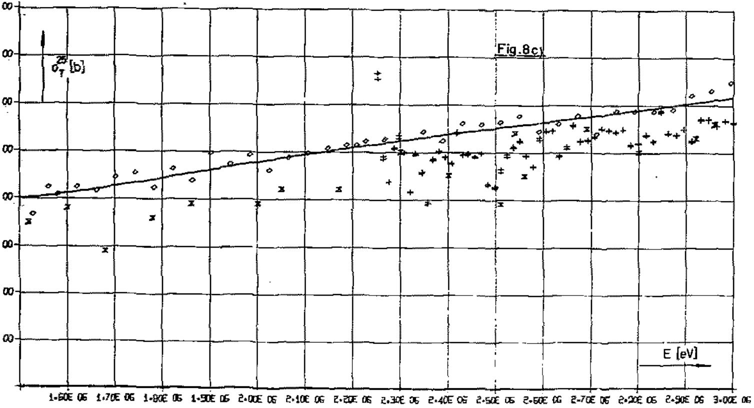


Fig.8c)

σ_T^{25} [b]
9.00E 00
8.50E 00
8.00E 00
7.50E 00
7.00E 00
6.50E 00
6.00E 00
5.50E 00
1.60E 06
1.70E 06
1.80E 06
1.90E 06
2.00E 06
2.10E 06
2.20E 06
2.30E 06
2.40E 06
2.50E 06
2.60E 06
2.70E 06
2.80E 06
2.90E 06
3.00E 06
E [eV]

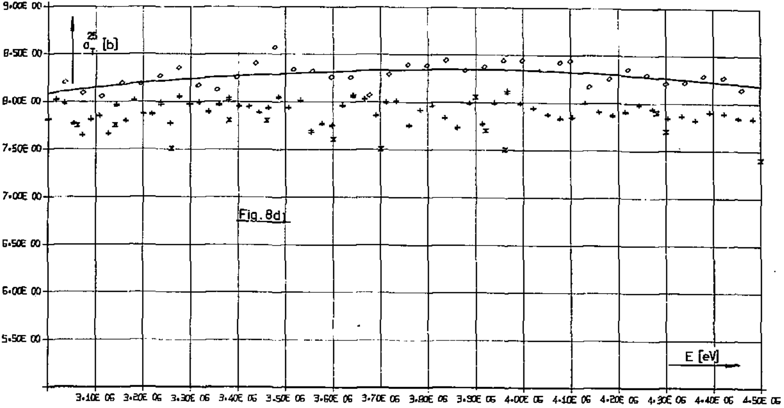
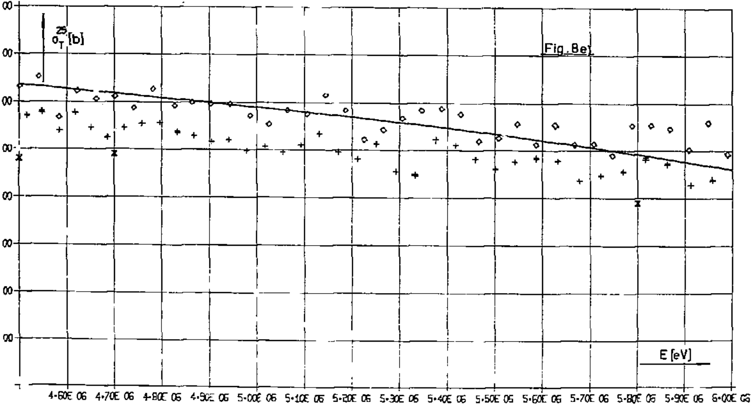


Fig. 8d)
σ_T^{25} [b]
9.00E 00
8.50E 00
8.00E 00
7.50E 00
7.00E 00
6.50E 00
6.00E 00
5.50E 00
3.10E 06
3.20E 06
3.30E 06
3.40E 06
3.50E 06
3.60E 06
3.70E 06
3.80E 06
3.90E 06
4.00E 06
4.10E 06
4.20E 06
4.30E 06
4.40E 06
4.50E 06
E [eV]


σ_T^{25} [b]
Fig. 8e)
9·00E 00
8·50E 00
8·00E 00
7·50E 00
7·00E 00
6·50E 00
6·00E 00
5·50E 00
4·60E 06
4·70E 06
4·80E 06
4·90E 06
5·00E 06
5·10E 06
5·20E 06
5·30E 06
5·40E 06
5·50E 06
5·60E 06
5·70E 06
5·80E 06
5·90E 06
6·00E 06
E [eV]

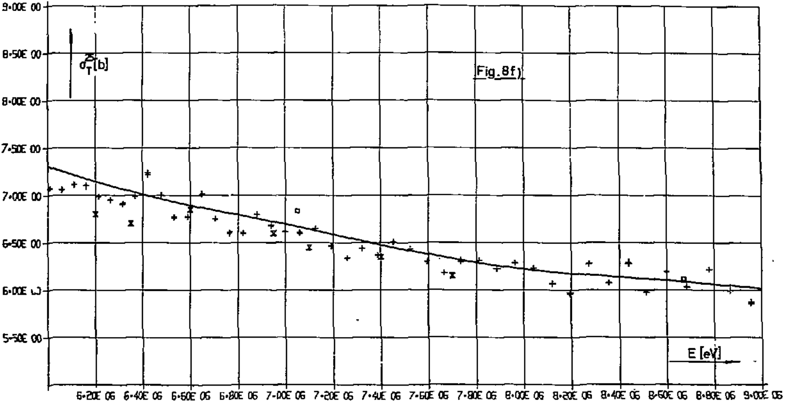


Fig. 8f)

σ_T^{ZN}[b]
9.00E 00
8.50E 00
8.00E 00
7.50E 00
7.00E 00
6.50E 00
6.00E 00
5.50E 00
6.20E 06
6.40E 06
6.60E 06
6.80E 06
7.00E 06
7.20E 06
7.40E 06
7.60E 06
7.80E 06
8.00E 06
8.20E 06
8.40E 06
8.60E 06
8.80E 06
9.00E 06
E [eV]

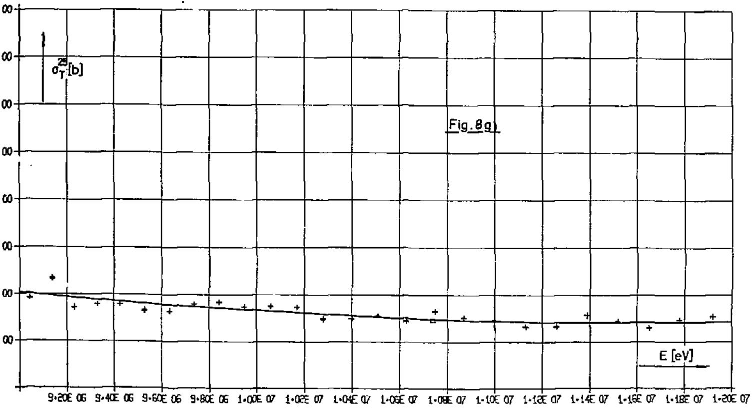

9.00E 00
8.50E 00
8.00E 00
7.50E 00
7.00E 00
6.50E 00
6.00E 00
5.50E 00
σ_T^{25}[b]
E [eV]
9.20E 06
9.40E 06
9.60E 06
9.80E 06
1.00E 07
1.02E 07
1.04E 07
1.06E 07
1.08E 07
1.10E 07
1.12E 07
1.14E 07
1.16E 07
1.18E 07
1.20E 07

Fig. 8g)

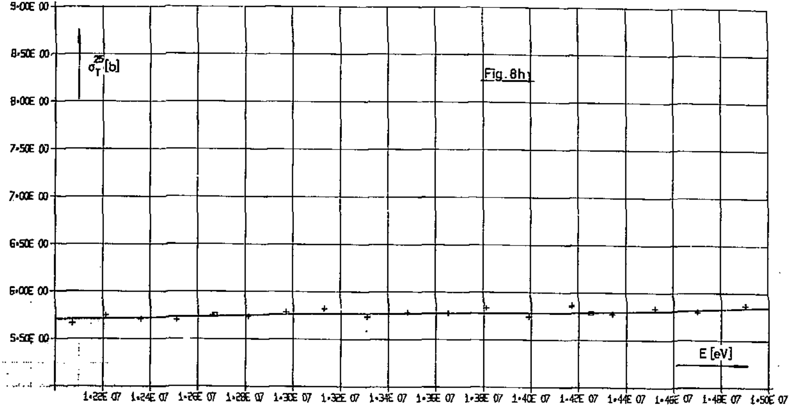


Fig. 8h)

σ_T^{25}[b]
9.00E 00
8.50E 00
8.00E 00
7.50E 00
7.00E 00
6.50E 00
6.00E 00
5.50E 00
1.22E 07
1.24E 07
1.26E 07
1.28E 07
1.30E 07
1.32E 07
1.34E 07
1.36E 07
1.38E 07
1.40E 07
1.42E 07
1.44E 07
1.46E 07
1.48E 07
1.50E 07
E [eV]

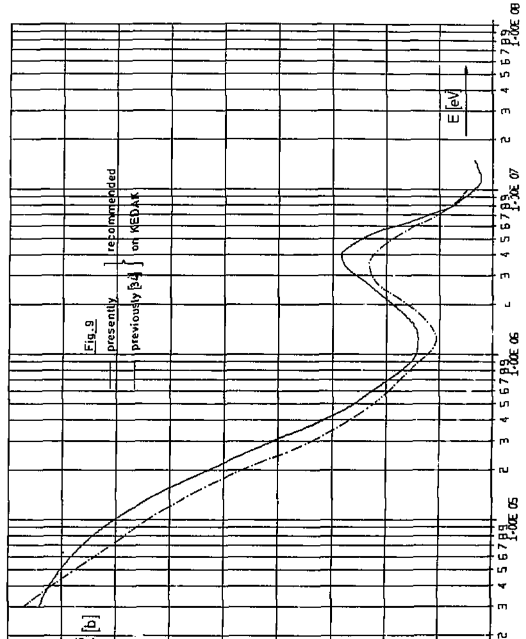


Fig. 9

presently
previously [34]
recommended
on KEDAK
σ_T^{25} [b]
E [eV]
1.45E 01
1.35E 01
1.25E 01
1.15E 01
1.05E 01
9.50E 00
8.50E 00
7.50E 00
6.50E 00
1.00E 04
2
3
4 5 6 7 8 9
1.00E 05
2
3
4 5 6 7 8 9
1.00E 06
2
3
4 5 6 7 8 9
1.00E 07
2
3
4 5 6 7 8 9
1.00E 08

Key to the symbols used in Fig. 10 and 11

———	presently recommended α (E) curve	
—·—··	previously /35/ recommended α (E) curve	
⎍	Van - Shi - di et al.	/47/
— — —	Bandl et al.	/103/
xxxxxx	Czirr, Lindsey	/104/
—·—·	Muradjan et al.	/105/
······	Kurov, Ryabov et al.	/106/
oo●●oo	Silver, de Saussure et al.	/102/
○	de Saussure et al.	/48/
●	Weston et al.	/107/
×	Diven et al.	/108/
△	Hopkins, Diven	/109/

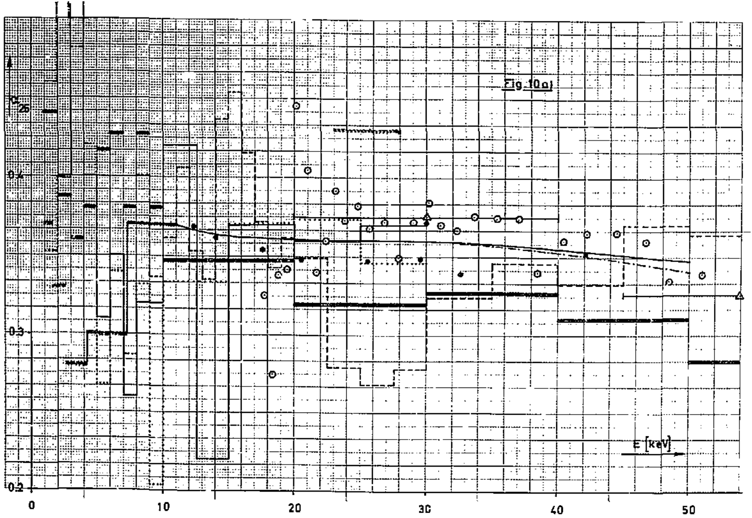


Fig. 10a)
α_{25}
0.4
0.3
0.2
0
10
20
30
40
50
E [keV]

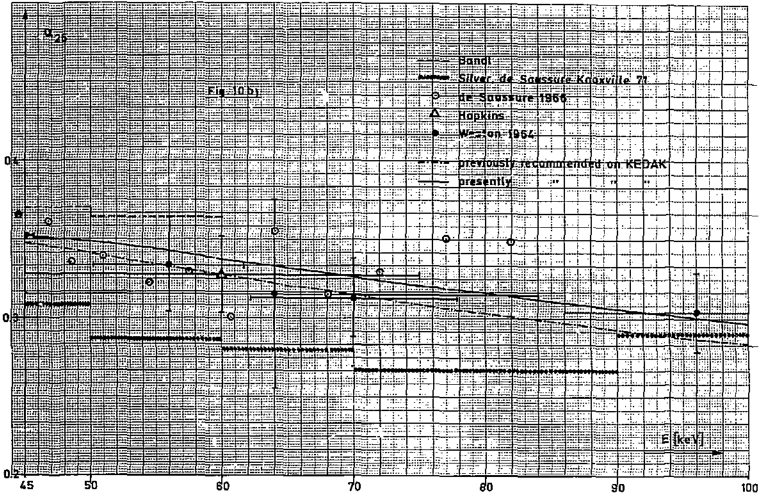


Fig 10 b)
α25
Bandl
Silver, de Saussure Knoxville 71
de Saussure 1966
Hopkins
Weston 1964
previously recommended on KEDAK
presently " " "
0.4
0.3
0.2
45
50
60
70
80
90
100
E [keV]

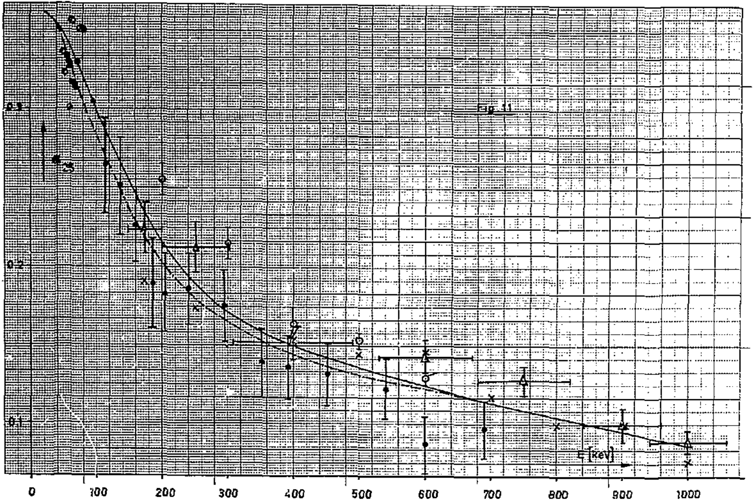
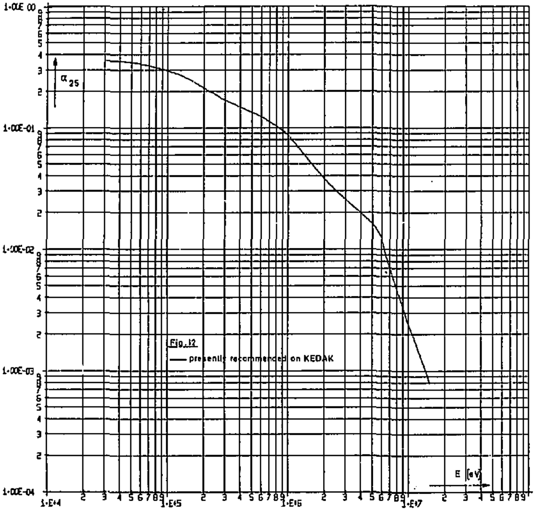


Fig. 11



1·00E 00
1·00E-01
1·00E-02
1·00E-03
1·00E-04
9
8
7
6
5
4
3
2
α_{25}
presently recommended on KEDAK
E [eV]
1·E+4
2
3
4
5
6
7
8
9
1·E+5
1·E+6
1·E+7

Fig. 12

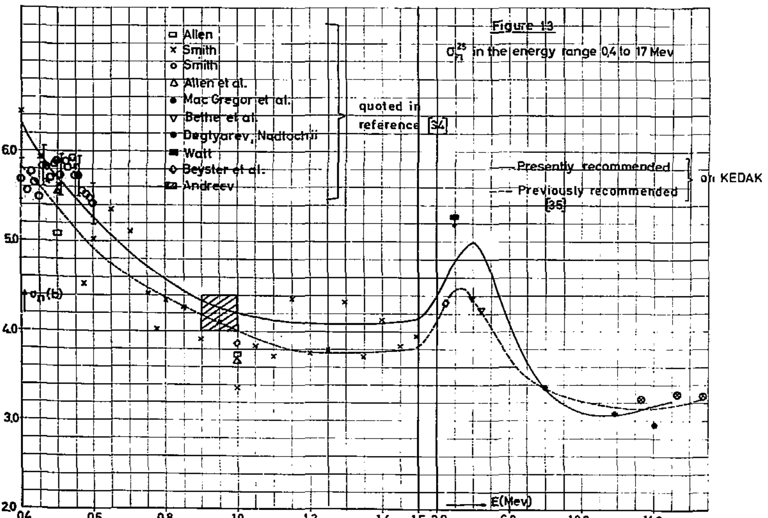


Figure 13

σ_n^{25} in the energy range 0,4 to 17 Mev

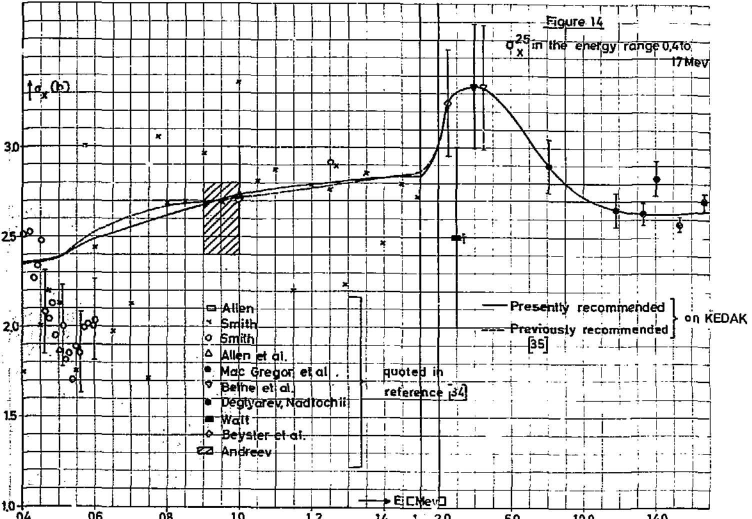


Figure 14

σ_x^{25} in the energy range 0,4 to 17 Mev

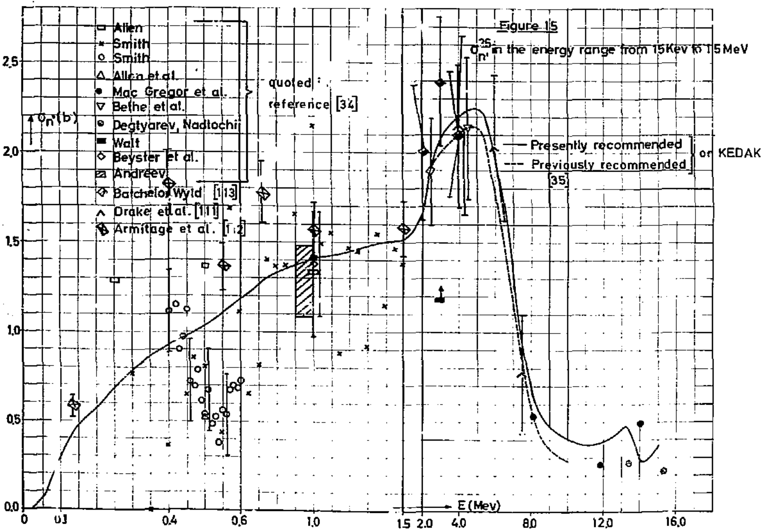


Figure 15

$\sigma_{n'}^{25}$ in the energy range from 15 Kev to 15 MeV