International Atomic Energy Agency

INDC-342

# INTERNATIONAL NUCLEAR DATA COMMITTEE

## Energy dependent $\bar{\nu}$-values for $^{235}U$, $^{239}Pu$, $^{233}U$, $^{240}Pu$, $^{241}Pu$, and the status of $\bar{\nu}$ for spontaneous fission isotopes

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Vienna, June 1970

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## 1. The status of the absolute $\bar{\nu}(^{252}Cf)$-value

All recent and the majority of the old measurements of $\bar{\nu}$-values for fissile elements were made relative to the $\bar{\nu}(^{252}Cf)$-value. In connection with it the knowledge of the absolute $\bar{\nu}(^{252}Cf)$-value is of great importance.

The experimental results available for $\bar{\nu}(^{252}Cf)$ show a spread of about 1 % due to a disagreement between the liquid scintillator measurements (higher values) and manganese bath and boron pile measurements (lower values).

The survey of $\bar{\nu}(^{252}Cf)$ measurements carried out up to 1963 was made by J.J. Schmidt [1] who gave the following value for the average number of total neutrons resulting from spontaneous fission of $^{252}Cf$: $\bar{\nu}_t(^{252}Cf) = 3{,}773$, with the number of delayed neutrons being 0,009. This $\bar{\nu}(Cf)$ value was mainly based on the boron pile measurements of Colvin et al [2] and liquid scintillator measurements [3], [4]. From that time several new measurements of $\bar{\nu}(^{252}Cf)$ have been carried out, the most recent among them are the Axton et al. measurements [5] and the De-Volpi and Forges measurements [6]. The results of Axton measurements are provisional at the present time, because they have restarted the experiment with a new larger sample of modern californium.

The present status and the evaluation of the absolute $\bar{\nu}(^{252}Cf)$-value has recently been made by G.C. Hanna, C. H. Westcott et al. [7] in their comprehensive study of the 2200 m/sec constants for fissile isotopes. They considered the absolute $^{252}Cf$ $\bar{\nu}$-measurements in relationship to the ratio of $\bar{\nu}$-values for $^{235}U$ and $^{252}Cf$, and the $\bar{\nu}$, $\eta$ and $\alpha$-values for $^{235}U$. The procedure adopted by Hanna et al. was to consider the individual data separately and first derive weighted means for the individual parameters and then to use these as input data for a fitting scheme from which a set of fitted parameters is obtained. The experimental values for $\bar{\nu}(^{252}Cf)$, which Hanna et al. used, are given in table 1.

TABLE 1

The average number of prompt neutrons per fission, $\bar{\nu}$, for $^{252}Cf$ (taken from Hanna et al.[7])

| References | Technique used | Experimental $\bar{\nu}$(Cf)-values with the corrections made by Hanna et al. |
|---|---|---|
| Asplund-Nilsson et al. [3] | liquid scintillator | 3,830 ± 0,037 |
| Hopkins and Diven [4] | liquid scintillator | 3,793 ± 0,031 |
| Colvin and Sowerby [2] | boron pile | 3,713 ± 0,015 |
| Moat et al.[8] | manganese bath | 3,727 ± 0,056 |
| Colvin et al.[9] | -"- | 3,700 ± 0,031 |
| White and Axton[10] | -"- | 3,796 ± 0,031 |
| Axton et al.[11] | -"- | 3,700 ± 0,020 |
| DeVolpi and Porges [6] (DeVolpi revised value) | -"- | 3,739 ± 0,017 (3,725 ± 0,015) |
| Hanna et al.[7] weighted mean | | 3,743 ± 0,016 |
| Fitted value | | 3,7653 ± 0,0104 |

As one can see from the table, there are two separate groups of results with the values of about 3,800and 3,700.

Hanna et al. incorporated into the experimental values for $\bar{\nu}$ the correction for the energy dependence of neutron detector efficiencies. The necessity of such a correction was due to the uncertairty in the measured fission spectra for $^{252}Cf$ and for the other fissile isotopes. This uncertainty can be one of the sources of possible systematic errors which can be reduced by considering $\bar{\nu}$-ratios for different fissile isotopes rather than considering $\bar{\nu}$-ratio to $\bar{\nu}(^{252}Cf)$ only, because the mean neutron energy value $\bar{E}$ for $^{252}Cf$ is high enough [$\bar{E}(^{252}Cf)$ = 2,35 MeV, $\bar{E}(^{235}U)$ = 2,10 MeV, $\bar{E}(^{233}U)$ = 2,14 MeV, $\bar{E}(^{239}Pu)$ = 2,24 MeV, $\bar{E}(^{240}Pu)$ = 1,93 MeV, according to [7]].

Besides, Hanna et al. made the correction to manganese bath measurements for the loss of fast neutrons by the reactions $^{16}O\ (n,\alpha)\ ^{13}C$, $^{32}S\ (n,\alpha)\ ^{29}Si$ and $^{32}S\ (n,p)\ ^{32}P$, because new results for oxygen $(n,\alpha)$-cross section became available, but this effect is quite small for the fission spectrum.

There are two more physical effects which should be taken into consideration when analysing results of absolute $\bar{\nu}$-measurements. The first one is connected with delayed $\gamma$-rays which can be detected by the liquid scintillator technique, but not a boron pile method. The respective correction is of the order of about 0,2 - 0,5 % at the thermal neutron energy for $^{235}U$ and $^{239}Pu$ and of (0,25 $\pm$ 0,12)% for $^{252}Cf$ [12]. Therefore, this effect can definitely not explain the 2 - 3 % difference between liquid scintillator and boron pile measurements.

The second physical phenomenon in which the source of discrepancies can be searched for, is chemical instability of the solutions by the Szilard-Chalmers reaction. It was noted that the $MnSO_4$ solution was getting instable during the irradiation time, and $^{56}Mn$ precipitates slowly from the solution. The value of the precipitation depends on the concentration of the solution, the amount of oxygen soluted, temperature, acidity, irradiation dose etc. This effect of precipitation can lead to a systematic error depending on the activity counting technique. De Volpi and Porges indicate that this effect was about 1 to 2 % in their measurements. The activity in a bath can be stabilized by special additives such as sulfur acid and hydrogen peroxide, but introducing additives to manganese bath complicates the determination of a very important Mn/H-ratio .

On the other hand, according to Axton [14], the chemical instability of the solution is not a reason of systematic errors in the measurements carried out in his laboratory, although this effect should be taken into account, at least for $KMnO_4$ solution.

It seems there is no single cause for the explanation of a spread in the experimental results for $\bar{\nu}(^{252}Cf)$, but probably a combination of fortuitous circumstances lead to a systematic error. Perhaps errors assigned to systematic effects have been insufficient in the various experiments.

As far as boron pile measurements are concerned it must be taken into consideration that these measurements were carried out without calibration with neutron sources, the strength of which had been determined predominantly by bath measurements. Calibration of boron pile measurements has been made by the absolute counting of photo-protons in the $^{2}H$ ($\gamma$,n) $^{1}H$-reaction. The boron pile - manganese bath comparisons were introduced at a late stage when Colvin and Sowerby were searching for possible systematic errors. The comparison of both methods was based on the radium beryllium photoneutron source, and agreement was within 0,25 percent. Other comparisons made with a Ra-Be-source and a $^{240}$Pu spontaneous fission source give agreement 0,25 % and 0,67 % respectively. We can conclude therefore that renormalization of the boron pile results is not justifiable.

Hence the available experimental results can be grouped into the following three independent categories: liquid scintillator, boron pile and manganese bath measurements. This grouping is, of course, relative because the important question about systematic errors still remains. And if two experiments are similar to each other, (a possibility of a same systematic error remains,) then those two experiments should be considered in one group. But anyway the weight of each group should be considered separately. It was done in the review of Hanna et al., who obtained the fitted value of $\bar{\nu}(^{252}Cf)$ = 3,7653, which is not so close to the weighted mean 3,743. This reflects the fact that the fitted value of $\bar{\nu}(^{252}Cf)$ is strongly dependent upon the highly accurate $\eta$ and $\alpha$-values for the fissile isotopes and the precisely measured ratios of $\bar{\nu}$ for the fissile isotopes to the $\bar{\nu}(^{252}Cf)$. For this reason, although DeVolpi and Porges have revised their results to 3,725 $\pm$ 0,015, the fitted value of $\bar{\nu}(^{252}Cf)$ should only change very slightly by the use of the revised De Volpi and Porges result. It is also confirmed by the fact that a revised weighted mean value obtained by using the revised De Volpi and Porges results is equal to 3,740 (the Hanna weighted mean is 3,743).

Therefore we shall use in this review for normalization purposes the following values for $^{252}$Cf: $\bar{\nu}_t(^{252}Cf)$ = 3,765, $\bar{\nu}_p(^{252}Cf)$ = 3,756.

2) The energy dependence of $\bar{\nu}$ for $^{235}U$

The energy-dependence of $\bar{\nu}$ for $^{235}U$ below 1,0 MeV is of great importance to fast reactor physics, since in this region the majority of the neutron fission spectrum lies. Therefore we shall consider in greater detail this energy region.

All available experimental information on $\bar{\nu}(^{235}U)$ in the energy region below 1 MeV is given in table 2. Part of these results, which were obtained up to 1965, has already been considered by J.J. Schmidt in [1]. The table 2 contains the results of all the measurements carried out up to April 1970.

We do not consider $\bar{\nu}$ values at thermal energies. Recently obtained ratios at thermal energies agree with each other with an accuracy better than 1 % [15], and the accuracy of the majority of the measurements is about 0,5 - 1%. All available information up to late 1969 has recently been evaluated carefully by Hanna, Westcott et al. [7]. They considered the absolute measurements for $\bar{\nu}(^{235}U)$ at thermal energies as well as the ratios $\bar{\nu}(^{235}U)$ to $\bar{\nu}(^{252}Cf)$ and the ratios $\bar{\nu}(^{235}U)$ to $\bar{\nu}$ for $^{233}U$, $^{239}Pu$. The fitted values for the $\bar{\nu}$-ratios $^{235}U/^{252}Cf$, $^{233}U/^{235}U$, $^{239}Pu/^{235}U$ are not close enough to the weighted means and therefore the fitted value is dependent on the accurate $\bar{\nu}$, $\alpha$ and $\eta$-values for $^{233}U$, $^{239}Pu$ and $^{252}Cf$. Hanna et al. get the following figures: $\bar{\nu}_t^{th}(^{235}U) = 2,4229 \pm 0,0066$, $\bar{\nu}_t = \bar{\nu}_p + \bar{\nu}_d$, $\bar{\nu}_p$ = average number of prompt fission neutrons, $\bar{\nu}_d$ = average number of delayed fission neutrons. Assuming for $\bar{\nu}_d$ the value 0,0158 taken from Keepin [68] we get $\bar{\nu}_p^{th}(^{235}U) = 2,4071$. We used these thermal $\bar{\nu}_p$ and $\bar{\nu}$-values for $^{235}U$ as standards in renormalizing all the experimental $\bar{\nu}$-values given in table 2. For $^{252}Cf$ used as a standard the following values were used for renormalization: $\bar{\nu}_t^{Sp}(^{252}Cf) = 3,765$, $\bar{\nu}_p^{Sp}(^{252}Cf) = 3,756$.

There was clear evidence of the non-linear dependence of $\bar{\nu}(^{235}U)$ below 1MeV in the investigations of Moat, Mather and Fieldhouse [22], and in the studies of Mather, Fieldhouse and Moat [25]. This trend has been confirmed by the works of Blyumkina, Bondarenko et al. [25], Kuznetsov, Smirenkin [29], Nadkarni and Ballal [30]. Unfortunately, the energy resolution obtained in those three works was not adequate in order to investigate the energy-dependence of $\bar{\nu}$ below 1 MeV in detail. The better energy resolution was achieved in the measurements of Meadows and Whalen [28] and in those of Soleilhac, Decarsin et al.[31].

Meadows and Whalen have measured the energy dependence of $\bar{\nu}_p$ over the incident neutron energy range 0,04 - 1,0 MeV by determining the ratio of prompt neutrons from neutron-induced fission of $^{235}U$ to those from spontaneous fission of $^{252}Cf$. They used as standard $\bar{\nu}_p(^{252}Cf) = 3,782$. The Meadows and Whalen results have been renormalized to the adopted $\bar{\nu}_p(^{252}Cf)$ value and are shown in table 2.

Soleilhac, Decarsin et al. [31] have recently determined the energy-dependence of $\bar{\nu}$ relative to $\bar{\nu}_p(^{252}Cf)$ over the energy range 210 keV to 1,36 MeV, using the time-of-flight technique. The liquid scintillator method was used to detect the neutrons. Their numerical results as well as the results of the other authors are given in table 2.

The analysis of the experimental data below 1 MeV shows the existence of a certain structure. In order to illustrate this characteristic, two sets of data were chosen for this purpose because of their better energy resolution; i.e. the data of Soleilhac et al. [32] obtained with an energy resolution of ± 10 keV below 0,7 MeV, and those of Meadows and Whalen [28], with a resolution of ± 25 - 30 keV. The data of Blyumkina et al. [25] were obtained with the energy resolution of about ± 50 keV and therefore could not be expected to show the fine structure. The data of Soleilhac et al., and those of Meadows and Whalen, have been plotted in fig. 1, having also drawn a histogram through the experimental points of the first author. The experimental errors in $\bar{\nu}$ shown in the fig. 1 are of ± 0,017 - 0,020 for the Meadows and Whalen data and ± 0,040 - 0,020 for the Soleilhac data in the energy range up to 0,4 MeV and ± 0,020 - 0,014 for both sets at the energy region 0,4 - 1,0 MeV. As is seen from fig. 1., both sets of data are in good agreement at practically all energies from 240 keV to 1 MeV, confirming particularly the structure shown at 250, 330, 400, and 500 keV. Moreover, the Soleilhac values show a periodical fine structure with an interval of about 80 keV, superposed to a broader one.

From this reality of a fine structure in $\bar{\nu}$ , the conclusion can be drawn that we need to be very careful in any interpolation of $\bar{\nu}$ from near the thermal energy region to an energy of about a hundred keV. The reality of such a structure in $\bar{\nu}$ will undoubtedly affect the data used for reactor calculations, as the difference in $\bar{\nu}$ (2,530 rather than 2,45) of about 3 % is highly significant since it is used for multiplication constant $K_{eff}$ calculations for fast reactors and might be the main reason for the inaccurate prediction of $^{235}U$ critical masses.

The energy dependence of $\bar{\nu}$ for $^{235}U$ from 1 to 15 MeV was studied by several authors; for instance, a recent evaluation of $\bar{\nu}$-energy dependence was made by Fillmore [15]. All data for $\bar{\nu}$ available up to 1966 were analyzed. The linear equation obtained by a least-squares fit of the points between 1,0 and 2,57 MeV has the form: $\bar{\nu}_t = 2,417 + 0,1146\ E$; and for the energy region $E > 2,44$ MeV - $\bar{\nu}_t = 2,324 + 0,1569\ E$ the normalization to $\bar{\nu}_p$ ($^{252}Cf$) = 3,756.

The points above 2,5 MeV show considerable scattering and the accuracy obtained from the least-squares analysis mentioned above may be not so good because of the use of many points of low accuracy around 14 MeV which may exert a strong influence on the slope. Also, in view of the scatter of the points, the possibility of systematic errors in some of them remains.

There are two latest works in which the $^{235}U$ $\bar{\nu}$-energy dependence was studied with great details in the energy region above 1 MeV - the work of Soleilhac, Frehaut and Gauriau [32] in the energy region 1,3 - 28,0 MeV and the work of Savin, Khokhlov, Zamjatnin and Paramonova [34] in the energy region 0,6 - 5,0 MeV.

The results of Soleilhac et al. were published in [32] for $\bar{\nu}$-values in the energy region 1,3 - 15,0 MeV. The published data were changed by the authors of 0,1 - 0,5 % mainly in the energy region 7 - 13 MeV. These new data up to the energy 28 MeV, sent to us by the authors, are given in table 3.
The data obtained by Soleilhac et al. are in general in agreement with the results of other measurements within the limit of the experimental errors. Their curve goes somewhat lower than the results of the other authors in the region 2 - 6 MeV and a little higher in the region 7 - 15 MeV. The Soleilhac data also shows that there is an increase of 5 % in $\frac{d\bar{\nu}}{dE}$ between 5 and 7,5 MeV.

Such an increase can be explained in the terms of (n,n'f)-reaction, but the $\bar{\nu}$-values calculated with the fission cross section ratio $\frac{\sigma(n,n'f)}{\sigma(n,f)}$ available from the literature are about 3 % less than the experimental data. Soleilhac et al. give the following least squares fit to their results for $^{235}U$:

$$\bar{\nu}(E) = 2,3729 + 0,1293E, \qquad 1,36 < E < 5,06 \text{ MeV}$$
$$\bar{\nu}(E) = 2,0284 + 0,2000E, \qquad 5,06 < E < 7,48 \text{ MeV}$$
$$\bar{\nu}(E) = 2,5204 + 0,1353E, \qquad 7,48 < E < 14,79 \text{ MeV},$$

using as standard to $\bar{\nu}_p(^{252}Cf) = 3,782$. With the renormalization to $\bar{\nu}_p(^{252}Cf) = 3,756$ the linear equations will be the following: $\bar{\nu}(E) = 2,3566 + 0,1284\ E$, $\bar{\nu}(E) = 2,0144 + 0,1986E$, $\bar{\nu}(E) = 2,5030 + 0,1344\ E$ for the respective, above mentioned energy regions.

Soleilhac et al. did not find any steps in the energy dependence of $\bar{\nu}$ in the energy region from 1 to 3 MeV. It is explained by the fact that in this energy region they measured the $\bar{\nu}$-values at four energies only, at steps of about 0,5 MeV.

Savin et al. [34] carried out the measurements of $\bar{\nu}(En)$ for 20 energy points in the region 1 – 3 MeV and extended the measurements to the energy of 6 MeV. Background conditions gave them the allowance to perform the relative measurements with an accuracy of about 1 % in the energy region 0,6 – 5,0 MeV, where the background due to scattered neutrons was 2 – 7 % of the effect. The numerical data of Savin et al., renormalized to the value of $\bar{\nu}_p(^{252}Cf) = 3,756$ are given in table 3. These data are systematically somewhat higher than those of Prokhorova, et al., [33] in the region 1–3 MeV, although coinciding with the latter within the limit error of 1 %.

The Savin data repeat the characteristic peculiarities of the energy dependence of $\bar{\nu}$ in the energy region from 1 to 3 MeV obtained by Prokhorova et al., namely, the stepped form of the energy dependence of $\bar{\nu}$ in this region. The totality of the data shows that there is an increase of $\bar{\nu}$ at about 1 MeV, and in the energy region 1,5 – 2,0 MeV the $\bar{\nu}$-value remains constant. Then, beginning from 2,5 – 3 MeV a faster increase is ascertained with $\frac{d\bar{\nu}}{dEn} \approx 0,16\ MeV^{-1}$. The derivative $\frac{d\bar{\nu}}{dEn}$ increases again with the beginning of the process (n,n'f) at the energy $En \sim 5,5 - 6$ MeV as it was measured by Soleilhac et al. [32], and an increase of $\bar{\nu}(En)$ in the energy region between 5,06 and 7,48 MeV may be fitted by the slope $\frac{d\bar{\nu}}{dEn} = 0,20\ MeV^{-1}$.

The stepped dependence of $\bar{\nu}$ is associated with the discrete energy levels of a nucleus in the transition state (so-called fission channels). The stepped form of the energy dependence of $\bar{\nu}$, as is shown in [33], is in good qualitative agreement with the conclusions of M.V. Strutinsky and Pavlinchuk [35], regarding the effect of nucleon pairing on the internal excitation spectrum of fissionable nuclei. The effect of the stepped dependence of $\bar{\nu}$ on the energy of neutrons inducing fission of the even-even compound nucleus $^{236}U$ as well as $\bar{K}^2$ – the mean square of the angular momentum projection on the nucleus axis – was explained by the stepped change of the number of excited quasiparticles with the increase of excitation energy in the interval of several $\Delta$ ( $\Delta$ is an energy gap in the $^{236}U$ inner excitation spectrum, $2\Delta = 2,5$ MeV).

In summary, the totality of all the experimental data available for $\bar{\nu}(^{235}U)$ gives evidence that the linear energy dependence of $\bar{\nu}$ exists only in the energy region above 2,5 MeV. Below this energy it is necessary to use for practical purposes of reactor calculations the experimental data themselves, shown as a histogram on Fig. 1 and 2, and given in tables 2 and 3.

Present status of the energy dependence of $\bar{\nu}$ for $^{239}$Pu

It is not necessary to emphasize the importance of an accurate knowledge of $\bar{\nu}$ for $^{239}$Pu in reactor physics, but in spite of this importance the problem has not completely been solved yet, particularly in the low energy region, below 1,5 MeV, where more accurate and precise measurements would certainly be welcomed.

We have left out in this review the subject of thermal $\bar{\nu}$ for $^{239}$Pu, because it has been considered in detail in the latest 2200 m/sec constants revision of Hanna et al. [7] and, to our knowledge, no new value has been published afterwards.

As regards the energy dependence of $\bar{\nu}$($^{239}$Pu), the present situation is as follows: a total amount of 14 different experimental sets of values are available, five of which give $\bar{\nu}$ only at one energy and are very old, and another two give $\bar{\nu}$ at two different energies only. We then have seven different sets of values with more than four points each, three of which will be released at the 2nd International IAEA Conference on Nuclear Data for Reactors at Helsinki. The remaining four sets have been published between 1963 and 1969.

The first set of data of interest to be considered is that of Hopkins and Diven [4] with a total number of six points in the energy range from 0,250 to 14,5 MeV. They used $\bar{\nu}^{p}$($^{252}$Cf) = 3,771 as standard and a gated cadmium - loaded liquid scintillation tank as a neutron detector. The efficiency of the detector was obtained by a Monte Carlo method and chequed experimentally at one energy and angle by n-p scattering on a plastic scintillator. They measured in the same experiment $\bar{\nu}$($^{233}$U) and $\bar{\nu}$($^{235}$U) and the claimed accuracy of their measurements is of the order of 1,3%. No correction was applied for the fission spectra differences of the samples and of the standard used.

The same technique was used by Mather et al. [37] to determine $\bar{\nu}$($^{239}$Pu) and $\bar{\nu}$($^{233}$U) at four energies between 1 and 4 MeV. They used $\bar{\nu}$($^{252}$Cf) = 3,782 as standard and the time-of-flight technique to determine the spectrum of incident neutrons. Their final results were corrected for spectral differences between the sample and the standard (the correction was obtained by Monte Carlo calculations supposing a Maxwellian spectrum) and for the anisotropy of fission fragment emission.

The total correction applied to the experimental values was less than 2,1% and the reported accuracy in $\bar{\nu}$ of the order of 1,7 %.

Conde et al. [44] have used also a gated scintillation tank and the time-of-flight technique to measure $\bar{\nu}$($^{239}$Pu) between 4,22 and 14,8 MeV at five different energies, but the liquid scintillator was loaded with gadolinium instead of cadmium. As standard was used $\bar{\nu}_p$($^{252}$Cf) = 3,764. In the same experiment $\bar{\nu}$($^{241}$Pu) was also determined in the same energy range. Their final values were corrected among other effects for the contribution of the spontaneous fission of $^{240}$Pu ( correction ~ 2 %), for differences in fission neutron spectra (-0,2 % at 4 MeV) and for anisotropy of the fission neutron emission. The total correction applied to the measured values was 1,2 % at 4 MeV, and the reported accuracy was better than 3 %.

Soleilhac et al. [32] have used the same type of neutron detector to determine $\bar{\nu}_p$ for $^{239}Pu$, $^{235}U$ and $^{238}U$ between 1,3 and 15 MeV. The standard was $\bar{\nu}_p(^{252}Cf)$ = 3,782 and the measurements were carried out with a multiplate ionization chamber which allowed determining simultaneously $\bar{\nu}$ for the three isotopes and for the standard. In order to minimize alpha pile-up, the total $^{239}Pu$ mass was distributed over eight outputs with 12 mg per output. The measured values were corrected, among other effects, for spectral differences (maximum correction + 0,5 %) between sample and standard. The anisotropy in fission neutron emission was not accounted for, because following Mather [37] the maximum correction would be + 0,2 % at 7 MeV, and was considered negligible.
These published $\bar{\nu}$-values have been modified slightly afterwards by the authors [31], who have also increased the reported error to include the statistical errors of the corrections for efficiency and degraded neutrons.

They have extended down also the measured energy range up to 0,2 MeV in an intent to look for structures. The measurements in this low energy region were carried out with a thick neutron target and the neutron energy was determined by flight-of-time. The total energy resolution was 20 keV below 0,7 MeV, and 50 keV above this energy. They have used the same standard that in previous measurements and in the same experiment was determined also $\bar{\nu}_p(^{235}U)$.

Other unpublished results are those of Mather et al [38], who have used a large scintillator counter to measure average values of $\bar{\nu}$ for the neutron induced fission of $^{239}Pu$ over 11 energy bands below 1,2 MeV. The energy bands were 40 - 115 keV, 115 - 285 keV, and 100 keV wide from 300 keV to 1,2 MeV. The raw data were corrected among other effects for the contribution of the $^{240}Pu$ content and for fission spectral differences between sample and standard, determined by a Monte Carlo calculation supposing a Maxwellian distribution with $\bar{E}$ deduced from the expression given by Terrell [78]. The correction was of the order of - 0,3 %. The $^{239}Pu$ results were quoted as ratios to $\bar{\nu}_p(^{252}Cf)$, which was used as standard, and the relative accuracy was 1 % being dominated by the counting statistic.

Finally, we have obtained the data of Savin et al. [34] between 0,6 and 5 MeV, with an accuracy of 1 - 3 %. They used $\bar{\nu}(^{252}Cf)$ = 3,772 as standard value, and in the same experiment $\bar{\nu}_p(^{235}U)$ and $\bar{\nu}_p(^{240}Pu)$ were also measured. They have used a large liquid scintillation tank as neutron detector. This was divided in two halves and a coincidence was established between the pulses coming from both parts. In this form they succeeded in reducing the background by two orders of magnitude, being only 2 - 7 % of the total number of counts in the energy range from 0,6 to 5 MeV. In the final $\bar{\nu}$-value was taken into account the angular correlation between incoming and fission neutrons, spectral differences between sample and standard, multiplication effects in the sample and the effects of impurities. According to the authors, their results for ($^{239}Pu$) give evidence of some structure in the region from 0,7 to 3,3 MeV in the form of two steps at En = 1,3 MeV and En = 2,5 MeV. All the reported data are listed in tables 4 and 5, together with their renormalized values considering, as in the case of $^{235}U$, the standard value $\bar{\nu}^p_{sp}$ ($^{252}Cf$) = 3,756, and were plotted as a function of the energy in figure no. 2.

An inspection of this figure shows that:
i) all the old data about 14 MeV and some old ones at lower energies deviate too much from the general trend expressed by the new ones and should be excluded in any least-square fit .

ii) There is good general agreement among the data of Hopkins et al. [4], Condé et al. [44], Soleilhac et al. [31,32] and Savin et al. [34].

iii) The old data of Mather et al. [37] – although showing the same linear dependence as the others,– present a wrong slope and should be disregarded, unless they are renormalized by pivoting them into the 1,99 MeV value, chosen as pivot because of its agreement with other measurements.

iv) The latest data of Mather et al. [38], though showing large fluctuations, agree with the mean general tendency of the other measurements.

v) Confirming the subjections of previous measurements and the theoretical analysis of Schuster and Howerton [79], there seems to be some structure in the energy dependence of $\bar{\nu}$, in the form of changes of slope, which take place at about 6,5 MeV and 12 MeV and which – like in the case of $^{235}U$ – can be related with (n,n'f) and (n,2nf) processes, but nevertheless the effect observed is very small.

vi) It seems to be some indication of a certain structure below 4 MeV, but of smaller amplitude than for $^{235}U$. This question will be considered more carefully later on.

There have been many attempts to represent the experimental data by a/ linear equation of the form $\bar{\nu}(E) = \bar{\nu}_o + AE$,– where $\bar{\nu}_o$ is the thermal value,– merely by determining the coefficients $\bar{\nu}_o$ and A by means of a least squares fit. These determinations have been listed in the following table where the coefficients $\bar{\nu}_o$ and A are given as ratios to the standard used, $\bar{\nu}_{sp}(^{252}Cf)$ in all of them, in order to give an easier comparison.

Parameters of the best fits to the experimental data on $\bar{\nu}_p(^{239}Pu)$

| Reference | | year | Energy range (MeV) | $\bar{\nu}_o/\bar{\nu}_p(^{252}Cf)$ | $A/\bar{\nu}_p(^{252}Cf)$ |
|---|---|---|---|---|---|
| Mather et al.[37] | (a) | 1963 | 0 - 4 | 0,7852±0,0063 | 0,0259±0,0029 |
| | (b) | " | 0 - 4 | 0,7639±0,0037 | 0,0346±0,0021 |
| Hopkins et al.[4] | (a) | 1965 | 0 -14 | 0,7523±0,1007 | 0,0424 |
| Filmore [15] | (b) | 1968 | 0 -14 | 0,7662 | 0,0337 |
| Condé et al.[44] | (a) | " | 4 -15 | 0,773 ±0,013 | 0,037 ±0,003 |
| | (b) | " | 0 -14 | 0,7665 | 0,0364 |
| Soleilhac et al.[32] | (a) | 1969 | 1,36 -5,06 | 0,7548±0,0025 | 0,0401±0,0007 |
| | | | 6,08–11,93 | 0,7613±0,0035 | 0,0400±0,0005 |
| | | | 12.41–14,79 | 0,7374±0,0012 | 0,0407±0,0022 |
| | | | [1,36-5,06)+(12,41–14,79] | 0,7572±0,0015 | 0,0393±0,0002 |
| | | | 1,36–14,79 | 0,7595±0,0027 | 0,0396±0,0003 |
| Mather et al.[38] | (a) | 1970 | 0,040-1,2 | 0,7660±0,0053 | 0,0396±0,0074 |
| | | " | 0,040-1,2 | 0,7664±0,0056 | 0,0389±0,0078 |
| Colvin | (c) | | 4,2 | 0,7658±0,0018 | 0,0354±0,0011 |
| Savin [34] | (a) | 1970 | | | 0,0397 |
| Hanna et al.[7] | (d) | 1969 | thermal | 0,7650±0,0022 | |

(a) least square fit to author's data

(b) " " " to all available data at that moment

(c) Quoted by Mather et al. [38]

(d) Derived from the IAEA best Values after making allowance for delayed neutrons.

Then we can see from the table above that below $\simeq$ 5 MeV the energy dependence of $\bar{\nu}$ for $^{239}Pu$ can be expressed in a first approximation, by a linear equation with a slope of 0,150 neutrons/MeV.

At the present moment it is a controversial subject if some structure exists or not in the energy dependence of $\bar{\nu}$ below $\sim$1 MeV. While some authors, as Soleilhac [31], are inclined to the existence of some structure of a similar kind to those reported for $^{235}U$ below 1 MeV, other authors, as Boldeman[80], are against the existence of it.

In order to throw some light on this subject, all available experimental data below 1,4 MeV have been plotted on figure 5. This figure shows that, in spite of the different energy resolution of the several sets of values and the large spread among them, some structure seems to be present at about 400 keV.

In order to enhance this apparent structure, we have considered the data of Soleilhac et al. [31] alone, obtained with good resolution and short spacing; and we have smoothed them by averaging at first each two and then each three subsequent points in order to suppress the statistical fluctuations. The result of this smoothing has been plotted in figure 4, together with the remaining values from the other authors. We see that the smoothing procedure has displayed the existence of a structure in the form of some steps at about 0,6 and 1 MeV. This structure seems to be confirmed by the latest results of Mather et al. [38], in spite of their much larger fluctuations, and by the measurements of Hopkins et al.[4]. Nevertheless the amplitude of the structure is extremely low, of the order of 0,6 % only, i.e. much lower than in the case of $^{235}U$, but seems to exist really.

From this analysis we conclude that:

a) the thermal value of $\bar{\nu}$ for $^{239}Pu$ is well represented by the value of the latest neutron constants revision of Hanna et al. [7]. This value is

$$\bar{\nu}_T^{Th}(^{239}Pu) = 2,8799 \pm 0,0090$$

from which we deduce

$$\bar{\nu}_p^{th} = 2,8738 \pm 0,0090$$

after subtracting $\bar{\nu}_d$ = 0,0061 taken from Keepin et al. [81]

b) This value is in good agreement with the value obtained from the intercept at zero energy of the line obtained from the least-squares fit of the energy dependent values between 1 and 5 MeV.

c) The energy dependence of $\bar{\nu}(^{239}Pu)$ between 1 and 5 MeV can be represented fairly accurately by a linear equation with a slope of 0,150 neutrons/MeV.

d) For practical purposes this linear dependence is also an adequate representation of the energy dependence of $\bar{\nu}$ below 1 MeV.

e) Superposed to a linear dependence there is a structure below 1,5 MeV with an amplitude of about 0,6% and spacing of $\sim$ 400 keV in the form of plateaux and steps, which should be taken into account in more detailed calculations.

The energy dependence of $\bar{\nu}$ for $^{233}U$.

The most recent and thorough evaluation of the $\bar{\nu}$-value for $^{233}U$ at thermal energy is that of Hanna et al. [7]. They considered experimental results both for the ratio $\bar{\nu}(^{233}U)/\bar{\nu}(^{235}U)$ and $\bar{\nu}(^{233}U)/\bar{\nu}(^{252}Cf)$. The most recent and accurate measurement of the $\bar{\nu}(^{233}U)/\bar{\nu}(^{235}U)$-ratio is the result by Feldeman and Dalton [65], on which Hanna's evaluation is heavily based. Hanna et al. give the following value for $\bar{\nu}(^{233}U)$ at thermal energy: $\bar{\nu}_t^{th}(^{233}U) = 2{,}4866 \pm 0{,}0069$.

For the energy region above thermal all experimental data available for $\bar{\nu}_p(^{233}U)$ are given in the BNL-sigma book [66] and in the report by Drake [67]. The latest measurements quoted there stem to 1965, and to the best of our knowledge there are only very few data to be added.

All the experimental data for $\bar{\nu}(^{233}U)$ available so far are given in table 6. The data were renormalized to the values indicated in the comments to the table. The average number of delayed neutrons was taken to be 0,007 [74].

As one can see from the table, there is the energy gap between 4 and 14 MeV, where no results are available. Also, similar to $^{235}U$, there is some indication of structure between 0 and 1 MeV, but this structure is not studied in great detail. The complexity of the situation is shown by the available evidence for $^{233}U$, where the measurements by Blyumkina et al. [25] and the relative $\bar{\nu}$ measurements of Kuznetsov and Smirenkin [73] show that there is a maximum for the $\bar{\nu}$-value at about 300 keV and $\bar{\nu}$ decreases in going from 300 keV and then rises in going to higher energies.

The least squares fits for $\bar{\nu}(^{233}U)$ given by Snidow [76], Keepin [77], and Boroughs, Craven and Drake [75] were mainly based on the experimental data quoted in the table 6. All of them use a linear representation of $\bar{\nu}(^{233}U)$ in the energy regions from 0 to 1 MeV and 1 to 15 MeV:

Snidow [76] : $\bar{\nu} = 2{,}504 + 0{,}028\,E$, $0 < E \leq 1{,}1$ MeV, $\bar{\nu} = 2{,}532$ at E = 1 MeV
$\bar{\nu} = 2{,}3900 + 0{,}1323\,E$, $1{,}1 < E < 15$ MeV, $\bar{\nu} = 4{,}375$ at E = 15 MeV

Keepin [77] : $\bar{\nu} = 2{,}482 + 0{,}075\,E$, $0 \leq E \leq 1$ MeV $\bar{\nu} = 2{,}557$ at E = 1 MeV,
$\bar{\nu} = 2{,}412 + 0{,}136\,E$, $E > 1$ MeV $\bar{\nu} = 4{,}452$ at E = 15MeV.

The most recent fit for $\bar{\nu}(^{233}U)$ is that of Boroughs et al. [75], who presents the $\bar{\nu}$-energy dependence by two linear segments in the form:
$\bar{\nu} = 2{,}500$ at $E = 2{,}53 \cdot 10^{-8}$ MeV,

$\bar{\nu} = 2{,}562$, E = 1 MeV

$\bar{\nu} = 4{,}360$, E = 15MeV.

We would recommend the employ of the latter fit of Boroughs et al., but it would be preferable to use the value $\bar{\nu} = 2{,}4866$ at thermal energy as given by Hanna et al.

Energy dependence of $\bar{\nu}$ for $^{240}$Pu, $^{241}$Pu

The experimental available data on $\bar{\nu}(E)$ for the plutonium heavier isotopes are very scarce. For $^{240}$Pu there is no value at thermal energy. For the energy dependence of $\bar{\nu}(^{240}Pu)$ we have only the measurements of Kuzminov [45] at 3,69 and 15 MeV, obtained using $\bar{\nu}^{p}_{th}$ ($^{239}$Pu) as standard and with an accuracy of about 5%; three points below 1,6 MeV,-due to De Vroey et al. [46], of comparable accuracy to the preceding ones,-and finally the recent measurements of Savin et al. [34] between 1 and 4 MeV with a reported accuracy of 2 - 3 %, obtained in an experiment were $\bar{\nu}_p(^{235}U)$ and $\bar{\nu}_p(^{239}Pu)$ were also determined. The standard used was $\bar{\nu}^{p}_{sp}$ ($^{252}$Cf) = 3,772.

There are also three other measurements carried out with a fission spectrum and not with monoenergetic neutrons. These are those of Sander [91], who gives $\bar{\nu}(^{240}Pu) = 3,15 \pm 0,20$ for an energy of 2,1 MeV, the value of Engle et al. [70), who give for E= 2,13 $\bar{\nu} = 3,27 \pm 0,14$ and finally the measurement of Barton et al. [92] who obtained $3,32 \pm 0,14$ for E = 2,0 MeV.

All the available experimental values, including the measurements with a fission spectrum, are plotted in figure 5. We can see there, as reported by Savin et al. [34] that there seems to be some anormalous behaviour in $\bar{\nu}$ but the relatively low statistic due to the spontaneous fission of $^{240}$Pu does not allow to deduce definite conclusions.
On the other hand we can see that the results of Kuzminov are too low compared with those of Savin and the systematic of the other measured Pu isotopes, for which $\bar{\nu} \simeq 5$ at 14 MeV.

The total value of $\bar{\nu}$ for $^{240}$Pu was obtained by adding $\bar{\nu}_d$ = 0,0057 at 14 MeV and $\bar{\nu}_d$ = 0,0088 below 5 MeV, according to the results of Keepin [81, 82].

In the case of $^{241}$Pu the situation is even worse. The thermal value is well represented by the revised value of Hanna et al. [7], who give $\bar{\nu}_T(^{241}Pu) = 2,934 \pm 0,012$. After the publication of the value of Hanna et al., a new value of $\bar{\nu}^{p}_{th}$ ($^{241}$Pu) has been reported, that of Jaffey et al. [62], who have obtained $\bar{\nu}^{p}_{th}(^{241}Pu) = 2,874 \pm 0,015$, a value too low compared to the remaining more recent measurements from which the value of Hanna was deduced. According to the own authors, apart from this discrepancy, they have not found a basis for suspecting a systematic error in the method. Indeed, other measured values for other isotopes agree with previous measurements. For the energy dependence of $\bar{\nu}(^{241}Pu)$ the only values available are those of Conde et al. [44], obtained in the same experiment in which $\bar{\nu}_p(^{239}Pu)$ was also measured, but the accuracy of the $^{241}$Pu measurements are lower. They are listed, together with the renormalized values, in table 8.
The total value of $\bar{\nu}$ was obtained by adding $\bar{\nu}_d$ = 0,0084 at 15 MeV [82] and $\bar{\nu}_d$ = 0,013 at lower energies. This late value has been deduced from the value at 15 MeV by multiplying it by 1,6, according to the results of Masters et al. [83] who have found a decrease in $\bar{\nu}_d$ with increasing energy.

The set of values of Condé et al. [44] shows clearly a linear dependence which can be represented by the equation

$$\bar{\nu}_p(E) = 2,921 + 0,1430 \, En$$

The intercept at zero energy is in good agreement with the thermal prompt value of the Hanna revision.

As for the energy dependence of $\bar{\nu}$ for heavier plutonium isotopes, as $^{242}Pu$, no experimental values are available to our knowledge.

<u>Energy dependence of the delayed neutron yield</u>

Before leaving the subject of the energy dependence of $\bar{\nu}$ for the main fissionable isotopes, it seems to be very convenient to say a few words on the status of energy dependence of the delayed neutron yield, not only because of its interest for the study of the nuclear structure, but also because of its importance in the development of kinetic response methods used in nuclear safeguards problems [93].

The first determinations of the delayed neutron yield were carried out with fission spectra of different types of reactors. [81,84-85]. The work of Keepin et al. [81] included also values of the thermal delayed neutron yield.

Some years later Shpakov et al. [86] and Maksyutenko [87] found that the neutron delayed yield increases with increasing energy in unexpected contradiction to the theoretical predictions.

This long standing discrepancy has lately been resolved. It has been reported by Masters et al. [83] et Hast et al. [82] that the yield decreases with increasing energy, the ratios being in the range 1,60 to 1,94 at 3,1 and 14,9 MeV for different fissionable isotopes. These results are in accordance with qualitative predictions based on fission systematics.

According to the latest published results we have the following absolute delayed neutron yields for the isotopes in study:

| Isotope | thermal(a) | Fast (a) (Fission spectr.) | 3,2MeV(b) | 14,9 MeV(c) |
|---|---|---|---|---|
| $^{233}U$ | 0,0066±0,0003 | 0,0070±0,0004 | 0,0077±0,0008 | 0,0043±0,0004 |
| $^{235}U$ | 0,0158±0,0005 | 0,0165±0,0005 | 0,018 ±0,002 | 0,0095±0,0008 |
| $^{239}Pu$ | 0,0061±0,0003 | 0,0063±0,0003 | 0,0069±0,0007 | 0,0043±0,0004 |
| $^{240}Pu$ | | 0,0088±0,0006 | | 0,0057±0,0007 |
| $^{241}Pu$ | | | | 0,0084±0,0012 |

(a) values of Ref. [81]

(b) values of Ref. [83]

(c) values of Refs. [82, 83]

## $\bar{\nu}$-values for Spontaneous Fission

The only isotope of which the $\bar{\nu}$ value for spontaneous fission was measured absolutely, is $^{252}Cf$. For all the other isotopes the measurements were made relative to the $\bar{\nu}$ value of another spontaneous fissionable isotope, mainly $^{252}Cf$, or the thermal $\bar{\nu}$ value of $^{235}U$. Therefore the final value for all the remaining isotopes depends strongly on the value adopted for the standards.

After $^{252}Cf$, already considered, the next closely studied isotope has been $^{240}Pu$, and in a third position $^{242}Pu$ and $^{244}Cm$. For all the remaining isotopes the knowledge of their spontaneous fission $\bar{\nu}$ values rely on the measurements carried out in two or three laboratories, some of them being very old indeed.

All available experimental values on those isotopes are listed in tables 9, 10 and 11, together with their renormalized values and the mean value obtained by averaging the renormalized experimental values with weights proportional to the inverse of the square of their standard errors.

In the case of $^{240}Pu$ the corrections applied to the measured values by the authors were almost the same in all of them. In these cases, where a liquid scintillation tank was used as neutron detector, only Boldeman [57] has taken also into account the spectral differences between sample and standard. Nevertheless we have not considered this detail when giving weights, because the value of Boldeman had already the largest weight due to its much smaller error, so that the final mean value for $\bar{\nu}_{sp}(^{240}Pu)$ is almost entirely determined by this value. The same applied also to $\bar{\nu}_{sp}$ ($^{242}Pu$).

In the case of $\bar{\nu}_{sp}$ ($^{244}Cm$) the weighted mean value is determined mainly by the data of Jaffey et al. [62]. Their $\bar{\nu}_{sp}$($^{244}Cm$) was obtained as mean value of several determinations relative to different well established standards.

In most of the cases the $\bar{\nu}$ value for the spontaneous fission of the isotopes considered was determined in an experiment, in which the $\bar{\nu}$ values of other fissionable isotopes were also measured. It seems then interesting to consider the ratios of $\bar{\nu}$ for spontaneous fission of these isotopes to the $\bar{\nu}_{sp}$ or $\bar{\nu}_{th}$ of the more important isotopes. These ratios are listed in tables 12, 13 and 14 respectively.

In such case where the ratio considered has not been measured directly, the reported error has been increased in the percentage corresponding to the error with which the now considered standard has been determined, as is shown in the tables reducing in this form its weight in an average.

From the mean values of these ratios an average of $\bar{\nu}_{sp}$ has been deduced. The error in the mean values includes also the error of the standards.

Although the average values obtained agree to those deduced by direct averaging of the renormalized values, this concordance is not significative because in both cases the final results are strongly influenced by the same best determined values.

For the sake of completeness we are listing in table 15 all available experimental data on $\bar{\nu}$ for the spontaneous fission of the remaining isotopes, and their mean values have been plotted together with $^{240}Pu$, $^{242}Pu$ and $^{244}Cm$ in figure 6, as a function of the mass number.

TABLE 2

Available experimental data on $\bar{\nu}(^{235}U)$ in the energy range 0,03 to 1 MeV.

| Reference | Energy, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| J.M. Blair [16] | 0,2 | 2,39 ± 0,15 | | 2,39 ± 0,15 | 2,39 ± 0,15 |
| J. Terrel et al. [17] | 0,7 | 1,02 ± 0,02 | $\bar{\nu}^p_{th}(U^{235}) = 1$ | 2,46 ± 0,05 | 2,48 ± 0,05 |
| B.C. Diven et al.[18] | 0,08 | 2,47 ± 0,03 | $\bar{\nu}_{th}(U^{235}) = 2,46$ | 2,43 ± 0,03 | 2,43 ± 0,03 |
| R.C. Hanna [19] | 0,74 | 2,48 ± 0,05 | $\bar{\nu}_{th}(U^{235}) = 2,47$ | 2,44 ± 0,05 | 2,44 ± 0,05 |
| | 1,3 | 2,61 ± 0,09 | -"- | 2,57 ± 0,09 | 2,57 ± 0,09 |
| L.N. Usachev et al.[20] | 0,7 | 2,52 ± 0,06 | $\bar{\nu}_{th}(U^{235}) = 2,47$ | 2,48 ± 0,06 | 2,48 ± 0,06 |
| | 1,0 | 2,84 ± 0,35 | -"- | 2,80 ± 0,35 | 2,80 ± 0,35 |
| D.Butler et al.[21] | 0,21 | 2,492± 0,016 | $\bar{\nu}_{th}(U^{235}) = 2,47$ | 2,445± 0,016 | 2,445± 0,016 |
| | 0,625 | 2,538± 0,024 | -"- | 2,490± 0,024 | 2,490± 0,024 |
| | 1,10 | 2,570± 0,020 | -"- | 2,521± 0,020 | 2,521± 0,020 |
| A. Moat et al.[22] | 0,04 | 2,384± 0,018 | $\bar{\nu}^p_{sp}(Cf^{252}) = 3,77$ | 2,375± 0,018 | 2,390± 0,018 |
| | 0,25 | 2,469± 0,021 | -"- | 2,460± 0,021 | 2,476± 0,021 |
| | 0,50 | 2,468± 0,018 | -"- | 2,459± 0,018 | 2,475± 0,018 |
| | 0,75 | 2,447± 0,014 | -"- | 2,438± 0,014 | 2,454± 0,014 |
| | 1,00 | 2,475± 0,018 | -"- | 2,466± 0,018 | 2,482± 0,018 |
| | 1,25 | 2,540± 0,019 | -"- | 2,531± 0,019 | 2,547± 0,019 |
| B.C.Diven et al.[23] | 0,325±0,093 | 2,424± 0,039 | $\bar{\nu}^p_{th}(U^{235}) = 2,414$ | 2,417± 0,039 | 2,433± 0,039 |
| | 0,475±0,075 | 2,431± 0,038 | -"- | 2,424± 0,038 | 2,440± 0,038 |
| | 0,842±0,059 | 2,458± 0,038 | -"- | 2,451± 0,038 | 2,467± 0,038 |
| | 1,106±0,052 | 2,519± 0,040 | -"- | 2,512± 0,040 | 2,528± 0,040 |

TABLE 2 (continued)

| Reference | Energy, MeV | $\bar{\nu}_{exp}$ | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| A. Moat et al.[24] | 0,075 | 2,39 ± 0,05 | $\bar{\nu}^p_{sp}$ ($Cf^{252}$) = 3,69) | 2,43 ± 0,05 | 2,59 ± 0,05 |
| J.C. Hopkins et al.[4] | 0,280± 0,090 | 2,438± 0,022 | $\bar{\nu}^p_{sp}$ ($Cf^{252}$) = 3,771) | 2,428± 0,022 | 2,444± 0,022 |
| | 0,470± 0,080 | 2,456± 0,022 | -"- | 2,446± 0,022 | 2,462± 0,022 |
| | 0,815± 0,060 | 2,471± 0,026 | -"- | 2,461± 0,026 | 2,477± 0,026 |
| | 1,08 ± 0,05 | 2,530± 0,026 | -"- | 2,520± 0,026 | 2,536± 0,026 |
| D.W.Colvin et al.[2] | 0,101± 0,060 | 2,478± 0,027 | $\bar{\nu}^p_{sp}$ ($Cf^{252}$) = 3,76 | 2,475± 0,027 | 2,491± 0,027 |
| | 0,514± 0,054 | 2,524± 0,045 | -"- | 2,521± 0,045 | 2,537± 0,016 |
| | 0,571± 0,156 | 2,511± 0,023 | -"- | 2,508± 0,023 | 2,524± 0,023 |
| | 0,572± 0,015 | 2,501± 0,029 | -"- | 2,498± 0,029 | 2,514± 0,029 |
| | 0,604± 0,053 | 2,519± 0,023 | -"- | 2,516± 0,023 | 2,534± 0,023 |
| | 0,946± 0,128 | 2,534± 0,018 | -"- | 2,531± 0,018 | 2,547± 0,018 |
| Y.A. Blyumkina et al. [25] | 0,08 ± 0,05 0,06 | 2,431± 0,030 | $\bar{\nu}^p_{th}$ ($U^{235}$) = 2,43 | 2,408± 0,030 | 2,424 ± 0,030 |
| | 0,31 ± 0,04 | 2,481± 0,025 | -"- | 2,458± 0,025 | 2,474 ± 0,025 |
| | 0,39 ± 0,05 | 2,491± 0,017 | -"- | 2,468± 0,017 | 2,484 ± 0,017 |
| | 0,55 ± 0,05 | 2,451± 0,024 | -"- | 2,428± 0,024 | 2,444 ± 0,024 |
| | 0,67 ± 0,05 | 2,488± 0,023 | -"- | 2,465± 0,023 | 2,481 ± 0,023 |
| | 0,78 ± 0,06 | 2,486± 0,025 | -"- | 2,463± 0,025 | 2,479 ± 0,025 |
| | 0,99 ± 0,06 | 2,521± 0,029 | -"- | 2,497± 0,029 | 2,513 ± 0,029 |
| | 0,08 ± 0,05 0,06 | 2,391± 0,035 | -"- | 2,369± 0,035 | 2,385 ± 0,035 |
| | 0,19 ± 0,09 | 2,448± 0,038 | -"- | 2,425± 0,038 | 2,441 ± 0,038 |
| | 0,29 ± 0,04 | 2,483± 0,034 | -"- | 2,460± 0,034 | 2,476 ± 0,034 |

TABLE 2 (continued)

| Reference | Energy, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Y.A. Blyumkina et al. [25] (cont'd) | 0,39 ± 0,05 | 2,491 ± 0,017 | $\bar{\nu}^p_{th}$ $(U^{235})$ = 2,43 | 2,468 ± 0,017 | 2,484 ± 0,017 |
| | 0,46 ± 0,05 | 2,493 ± 0,037 | -"- | 2,470 ± 0,037 | 2,486 ± 0,037 |
| | 0,64 ± 0,05 | 2,468 ± 0,038 | -"- | 2,445 ± 0,038 | 2,461 ± 0,038 |
| D.S.Mather et al.[26] | 0,04 | 2,420 ± 0,021 | $\bar{\nu}^p_{sp}$ $(Cf^{252})$ = 3,782 | 2,403 ± 0,021 | 2,419 ± 0,021 |
| | 0,14 ± 0,04 | 2,423 ± 0,045 | -"- | 2,406 ± 0,045 | 2,422 ± 0,045 |
| | 0,23 ± 0,025 | 2,490 ± 0,027 | -"- | 2,473 ± 0,027 | 2,489 ± 0,027 |
| | 0,33 ± 0,115 | 2,478 ± 0,026 | -"- | 2,461 ± 0,026 | 2,477 ± 0,026 |
| | 0,43 ± 0,115 | 2,475 ± 0,025 | -"- | 2,458 ± 0,025 | 2,474 ± 0,025 |
| | 0,70 ± 0,145 | 2,457 ± 0,022 | -"- | 2,440 ± 0,022 | 2,456 ± 0,022 |
| | 0,84 ± 0,070 | 2,529 ± 0,026 | -"- | 2,511 ± 0,026 | 2,527 ± 0,026 |
| | 0,93 ± 0,190 | 2,499 ± 0,026 | -"- | 2,482 ± 0,026 | 2,498 ± 0,026 |
| | 1,17 ± 0,175 | 2,557 ± 0,027 | -"- | 2,539 ± 0,027 | 2,555 ± 0,027 |
| H. Conde [27] | 0,06 | 2,416 ± 0,023 | $\bar{\nu}^p_{sp}$ $(Cf^{252})$ = 3,767 | 2,409 ± 0,023 | 2,424 ± 0,023 |
| J.W. Meadows et al. [28] | 0,039± 0,050 | 2,422 ± 0,017 | $\bar{\nu}^p_{sp}$ $(Cf^{252})$ = 3,782 | 2,405 ± 0,017 | 2,421 ± 0,017 |
| | 0,046± 0,050 | 2,423 ± 0,016 | -"- | 2,406 ± 0,016 | 2,422 ± 0,016 |
| | 0,150± 0,032 | 2,462 ± 0,018 | -"- | 2,445 ± 0,0018 | 2,461 ± 0,018 |
| | 0,225± 0,030 | 2,480 ± 0,018 | -"- | 2,463 ± 0,018 | 2,479 ± 0,018 |
| | 0,265± 0,028 | 2,470 ± 0,022 | -"- | 2,453 ± 0,022 | 2,469 ± 0,022 |

TABLE 2 (continued)

| Reference | Energy, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| J.W. Meadows et al. [28] cont'd. | 0,298 ± 0,027 | 2,472 ± 0,022 | $\bar{\nu}^p_{sp}(Cf^{252}) = 3,782$ | 2,455 ± 0,022 | 2,471 ± 0,022 |
| | 0,325 ± 0,027 | 2,514 ± 0,018 | -"- | 2,496 ± 0,018 | 2,512 ± 0,018 |
| | 0,358 ± 0,025 | 2,436 ± 0,018 | -"- | 2,419 ± 0,018 | 2,435 ± 0,018 |
| | 0,375 ± 0,025 | 2,477 ± 0,022 | -"- | 2,460 ± 0,022 | 2,476 ± 0,022 |
| | 0,405 ± 0,025 | 2,468 ± 0,022 | -"- | 2,451 ± 0,022 | 2,467 ± 0,022 |
| | 0,425 ± 0,025 | 2,534 ± 0,017 | -"- | 2,516 ± 0,017 | 2,532 ± 0,017 |
| | 0,476 ± 0,024 | 2,512 ± 0,019 | -"- | 2,494 ± 0,019 | 2,510 ± 0,019 |
| | 0,548 ± 0,021 | 2,489 ± 0,017 | -"- | 2,472 ± 0,017 | 2,488 ± 0,017 |
| | 0,675 ± 0,018 | 2,514 ± 0,017 | -"- | 2,496 ± 0,017 | 2,512 ± 0,017 |
| | 0,785 ± 0,021 | 2,527 ± 0,014 | -"- | 2,509 ± 0,014 | 2,525 ± 0,014 |
| | 1,000 ± 0,020 | 2,561 ± 0,016 | -"- | 2,543 ± 0,016 | 2,559 ± 0,016 |
| V.F.Kuznetsov et al. [29] | 0,08 | 0,986 ± 0,006 | $\bar{\nu}(\tilde{E}n) = 2,491 \pm 0,007$ and $\bar{\nu}^p_{th}(U\text{-}235) = 2,430$ | 2,433 ± 0,022 | 2,449 ± 0,022 |
| | 0,20 | 1,013 ± 0,007 | -"- | 2,500 ± 0,024 | 2,516 ± 0,024 |
| | 0,30 | 1,008 ± 0,006 | -"- | 2,487 ± 0,022 | 2,503 ± 0,022 |
| | 0,40 | 1,000 ± 0,000 | -"- | 2,468 ± 0,007 | 2,484 ± 0,007 |
| | 0,50 | 0,998 ± 0,005 | -"- | 2,463 ± 0,019 | 2,479 ± 0,019 |
| | 0,60 | 0,995 ± 0,005 | -"- | 2,455 ± 0,019 | 2,471 ± 0,019 |
| | 0,70 | 0,994 ± 0,005 | -"- | 2,453 ± 0,019 | 2,469 ± 0,019 |
| | 0,99 | 1,005 ± 0,009 | -"- | 2,480 ± 0,029 | 2,496 ± 0,029 |

TABLE 2 (continued)

| Reference | Energy, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| D.M. Nadkarni et al. [30] | 0,37 ± 0,15 | 2,57 ± 0,11 | ? | | |
| | 0,43 ± 0,14 | 2,53 ± 0,11 | | | |
| | 0,49 ± 0,14 | 2,49 ± 0,11 | | | |
| | 0,54 ± 0,14 | 2,49 ± 0,11 | | | |
| | 0,65 ± 0,13 | 2,37 ± 0,07 | | | |
| | 0,76 ± 0,13 | 2,50 ± 0,10 | | | |
| | 0,82 ± 0,13 | 2,60 ± 0,10 | | | |
| | 0,87 ± 0,12 | 2,65 ± 0,10 | | | |
| | 0,92 ± 0,12 | 2,64 ± 0,10 | | | |
| | 0,98 ± 0,12 | 2,62 ± 0,09 | | | |
| | 1,03 ± 0,12 | 2,59 ± 0,09 | | | |
| | 1,09 ± 0,12 | 2,56 ± 0,05 | | | |
| M.Soleilhac et al.[31] | 0,21 ± 0,01 | 2,4307± 0,0535 | $\bar{\nu}^{p}_{sp}(Cf^{252}) = 3,782$ | 2,4139± 0,0533 | 2,4300 ± 0,0533 |
| | 0,23 ± 0,01 | 2,4471± 0,0410 | -"- | 2,4302± 0,0408 | 2,4463 ± 0,0408 |
| | 0,25 ± 0,01 | 2,4635± 0,0371 | -"- | 2,4465± 0,0369 | 2,4625 ± 0,0369 |
| | 0,27 ± 0,01 | 2,4930± 0,0307 | -"- | 2,4758± 0,0305 | 2,4918 ± 0,0305 |
| | 0,29 ± 0,01 | 2,4607± 0,0292 | -"- | 2,4437± 0,0290 | 2,4597 ± 0,0290 |
| | 0,31 ± 0,01 | 2,4699± 0,0257 | -"- | 2,4529± 0,0255 | 2,4689 ± 0,0255 |
| | 0,33 ± 0,01 | 2,4455± 0,0242 | -"- | 2,4286± 0,0240 | 2,4446 ± 0,0240 |
| | 0,35 ± 0,01 | 2,5165± 0,0237 | -"- | 2,4991± 0,0235 | 2,5151 ± 0,0235 |
| | 0,37 ± 0,01 | 2,4736± 0,0232 | -"- | 2,4565± 0,0230 | 2,4725 ± 0,0230 |

TABLE 2 (continued)

| Reference | Energy, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| M.Soleilhac et al [31] | 0,39 ± 0,01 | 2,4788±0,0229 | $\bar{\nu}^p_{sp}$ ($Cf^{252}$) = 3,782 | 2,4617±0,0227 | 2,4777±0,0227 |
| | 0,41 ± 0,01 | 2,5326±0,0212 | -"- | 2,5151±0,0210 | 2,5311±0,0210 |
| | 0,43 ± 0,01 | 2,4969±0,0206 | -"- | 2,4797±0,0204 | 2,4957±0,0204 |
| | 0,45 ± 0,01 | 2,4764±0,0184 | -"- | 2,4593±0,0182 | 2,4753±0,0182 |
| | 0,47 ± 0,01 | 2,4562±0,0179 | -"- | 2,4393±0,0177 | 2,4553±0,0177 |
| | 0,49 ± 0,01 | 2,5004±0,0163 | -"- | 2,4831±0,0161 | 2,4991±0,0161 |
| | 0,51 ± 0,01 | 2,4960±0,0162 | -"- | 2,4788±0,0160 | 2,4948±0,0160 |
| | 0,53 ± 0,01 | 2,5140±0,0155 | -"- | 2,4967±0,0153 | 2,5127±0,0153 |
| | 0,55 ± 0,01 | 2,4725±0,0146 | -"- | 2,4554±0,0144 | 2,4714±0,0144 |
| | 0,57 ± 0,01 | 2,4885±0,0143 | -"- | 2,4713±0,0141 | 2,4873±0,0141 |
| | 0,59 ± 0,01 | 2,4725±0,0142 | -"- | 2,4554±0,0140 | 2,4714±0,0140 |
| | 0,61 ± 0,01 | 2,4928±0,0168 | -"- | 2,4756±0,0166 | 2,4916±0,0166 |
| | 0,63 ± 0,01 | 2,4921±0,0162 | -"- | 2,4749±0,0160 | 2,4909±0,0160 |
| | 0,65 ± 0,01 | 2,5108±0,0167 | -"- | 2,4935±0,0165 | 2,5095±0,0165 |
| | 0,670± 0,01 | 2,4998±0,0168 | -"- | 2,4826±0,0166 | 2,4986±0,0166 |
| | 0,690± 0,01 | 2,4920±0,0195 | -"- | 2,4756±0,0193 | 2,4916±0,0193 |
| | 0,725± 0,025 | 2,4958±0,0129 | -"- | 2,4786±0,0127 | 2,4946±0,0127 |
| | 0,775± 0,025 | 2,5215±0,0136 | -"- | 2,5041±0,0134 | 2,5201±0,0134 |
| | 0,825± 0,025 | 2,5347±0,0151 | -"- | 2,5172±0,0149 | 2,5332±0,0149 |
| | 0,875± 0,025 | 2,5473±0,0166 | -"- | 2,5297±0,0164 | 2,5457±0,0164 |
| | 0,925+ 0,025 | 2,5498±0,0173 | -"- | 2,5322±0,0171 | 2,5482±0,0171 |

TABLE 2 (continued)

| Reference | Energy, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| M.Scleilhac et al. [31] | 0,975 ± 0,025 | 2,5539±0,0194 | $\bar{\nu}^{p}_{sp}(Cf^{252}) = 3,782$ | 2,5363±0,0192 | 2,5523±0,0192 |
| | 1,025 ± 0,025 | 2,5471±0,0233 | -"- | 2,5295±0,0231 | 2,5455±0,0231 |
| | 1,075 ± 0,025 | 2,5782±0,0242 | -"- | 2,5604±0,0240 | 2,5764±0,0240 |
| | 1,125 ± 0,025 | 2,5786±0,0277 | -"- | 2,5608±0,0275 | 2,5768±0,0275 |
| | 1,175 ± 0,025 | 2,5769±0,0292 | -"- | 2,5559±0,0290 | 2,5719±0,0290 |
| | 1,225 ± 0,025 | 2,5779±0,0300 | -"- | 2,5601±0,0298 | 2,5701±0,0298 |
| | 1,275 ± 0,025 | 2,6378±0,0396 | -"- | 2,6196±0,0394 | 2,6356±0,0394 |
| | 1,325 ± 0,025 | 2,5588±0,0399 | -"- | 2,5411±0,0397 | 2,5571±0,0397 |
| | 1,375 ± 0,025 | 2,5826±0,0317 | -"- | 2,5648±0,0315 | 2,5808±0,0315 |
| | 1,360 ± 0,025 | 2,5650±0,0100 | -"- | 2,5473±0,0100 | 2,5633±0,0100 |
| M.V. Savin et al.[34] | 0,65 | 2,432±0,039 | $\bar{\nu}^{p}_{sp}(Cf^{252}) = 3,772$ | 2,422 ±0,039 | 2,438 ±0,039 |
| | 0,68 | 2,447±0,039 | -"- | 2,437 ±0,039 | 2,453 ±0,039 |
| | 0,71 | 2,472±0,039 | -"- | 2,461 ±0,039 | 2,477 ±0,039 |
| | 0,73 | 2,473±0,039 | -"- | 2,462 ±0,039 | 2,468 ±0,039 |
| | 0,79 | 2,478±0,039 | -"- | 2,467 ±0,039 | 2,483 ±0,039 |
| | 0,82 | 2,491±0,040 | -"- | 2,480 ±0,040 | 2,496 ±0,040 |
| | 0,87 | 2,474±0,039 | -"- | 2,463 ±0,039 | 2,479 ±0,039 |
| | 0,91 | 2,499±0,040 | -"- | 2,488 ±0,040 | 2,504 ±0,040 |
| | 0,97 | 2,484±0,039 | -"- | 2,473 ±0,039 | 2,489 ±0,039 |
| | 1,01 | 2,491±0,039 | -"- | 2,480 ±0,039 | 2,496 ±0,039 |

TABLE 3

Recent experimental data on $\bar{\nu}(U^{235})$ in the energy region 1 to 28 MeV

| Reference | En, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| M.Soleilhac et al. [32] | 1,36 | 2,565 ± 0,017 | $\bar{\nu}_p^{Sp}(Cf^{252}) = 3,782$ | 2,547 ± 0,017 | 2,563 ± 0,017 |
| | 1,87 | 2,631 ± 0,022 | -"- | 2,613 ± 0,022 | 2,629 ± 0,022 |
| | 2,45 | 2,688 ± 0,022 | -"- | 2,669 ± 0,022 | 2,685 ± 0,022 |
| | 2,98 | 2,757 ± 0,018 | -"- | 2,738 ± 0,018 | 2,754 ± 0,018 |
| | 3,50 | 2,804 ± 0,023 | -"- | 2,784 ± 0,023 | 2,800 ± 0,023 |
| | 4,03 | 2,890 ± 0,019 | -"- | 2,870 ± 0,019 | 2,886 ± 0,019 |
| | 4,54 | 2,984 ± 0,022 | -"- | 2,963 ± 0,022 | 2,979 ± 0,022 |
| | 5,06 | 3,040 ± 0,019 | -"- | 3,019 ± 0,019 | 3,035 ± 0,019 |
| | 5,57 | 3,163 ± 0,028 | -"- | 3,141 ± 0,028 | 3,159 ± 0,028 |
| | 6,08 | 3,254 ± 0,029 | -"- | 3,231 ± 0,029 | 3,247 ± 0,029 |
| | 6,97 | 3,422 ± 0,022 | -"- | 3,398 ± 0,022 | 3,414 ± 0,022 |
| | 7,09 | 3,428 ± 0,029 | -"- | 3,404 ± 0,029 | 3,420 ± 0,029 |
| | 7,48 | 3,521 ± 0,016 | -"- | 3,496 ± 0,016 | 3,512 ± 0,016 |
| | 7,99 | 3,582 ± 0,017 | -"- | 3,567 ± 0,017 | 3,573 ± 0,017 |
| | 8,49 | 3,658 ± 0,018 | -"- | 3,632 ± 0,018 | 3,648 ± 0,018 |
| | 9,00 | 3,731 ± 0,018 | -"- | 3,705 ± 0,018 | 3,721 ± 0,018 |
| | 9,49 | 3,809 ± 0,020 | -"- | 3,782 ± 0,020 | 3,798 ± 0,020 |
| | 9,74 | 3,850 ± 0,021 | -"- | 3,823 ± 0,021 | 3,839 ± 0,021 |
| | 9,98 | 3,882 ± 0,014 | -"- | 3,855 ± 0,014 | 3,871 ± 0,014 |
| | 10,47 | 3,937 ± 0,020 | -"- | 3,909 ± 0,020 | 3,925 ± 0,020 |

TABLE 3 (continued)

| Reference | En, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| M. Soleilhac et al. [32] | 10,96 | 3,972 ± 0,019 | $\bar{\nu}^{sp}_{p}(Cf^{252}) = 3,782$ | 3,944 ± 0,019 | 3,960 ± 0,019 |
| | 11,44 | 4,074 ± 0,020 | -"- | 4,045 ± 0,020 | 4,061 ± 0,020 |
| | 11,93 | 4,136 ± 0,021 | -"- | 4,107 ± 0,021 | 4,123 ± 0,021 |
| | 12,41 | 4,202 ± 0,020 | -"- | 4,172 ± 0,020 | 4,188 ± 0,020 |
| | 12,88 | 4,257 ± 0,024 | -"- | 4,227 ± 0,024 | 4,243 ± 0,024 |
| | 13,36 | 4,345 ± 0,022 | -"- | 4,315 ± 0,022 | 4,331 ± 0,022 |
| | 13,84 | 4,411 ± 0,022 | -"- | 4,380 ± 0,022 | 4,496 ± 0,022 |
| | 14,31 | 4,481 ± 0,023 | -"- | 4,450 ± 0,023 | 4,466 ± 0,023 |
| | 14,79 | 4,508 ± 0,023 | -"- | 4,476 ± 0,023 | 4,492 ± 0,023 |
| | 22,79 | 5,511 ± 0,049 | -"- | 5,472 ± 0,049 | 5,488 ± 0,049 |
| | 23,94 | 5,654 ± 0,054 | -"- | 5,614 ± 0,054 | 5,630 ± 0,054 |
| | 25,05 | 5,693 ± 0,054 | -"- | 5,653 ± 0,054 | 5,669 ± 0,054 |
| | 26,15 | 5,789 ± 0,042 | -"- | 5,748 ± 0,042 | 5,764 ± 0,042 |
| | 27,22 | 5,986 ± 0,062 | -"- | 5,944 ± 0,062 | 5,960 ± 0,062 |
| | 28,28 | 6,108 ± 0,090 | -"- | 6,065 ± 0,090 | 6,081 ± 0,090 |
| L.I. Prokhorova et al. [33] | 0,81 ± 0,09 | 2,457 ± 0,035 | $\bar{\nu}(0,39\ MeV) = 1,025 \cdot \bar{\nu}^{p}_{th}(U\text{-}235)$;<br>$\bar{\nu}^{p}_{th}(U\text{-}235) = 2,430$ | 2,434 ± 0,035 | 2,450 ± 0,035 |
| | 1,02 ± 0,08 | 2,534 ± 0,027 | -"- | 2,510 ± 0,027 | 2,526 ± 0,027 |
| | 1,23 ± 0,08 | 2,551 ± 0,037 | -"- | 2,527 ± 0,037 | 2,543 ± 0,037 |
| | 1,44 ± 0,07 | 2,555 ± 0,037 | -"- | 2,531 ± 0,037 | 2,547 ± 0,037 |

TABLE 3 (continued)

| Reference | En, MeV | $\bar{\nu}$exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| L.I.Prokhorová et al. [33] | 1,64 ± 0,07 | 2,583 ± 0,034 | $\bar{\nu}(0,39 MeV)=1,025\cdot\bar{\nu}^{p}_{th}(U-235)$; $\bar{\nu}^{p}_{th}(U-235)= 2,430$ | 2,559 ± 0,034 | 2,575 ± 0,034 |
| | 1,85 ± 0,07 | 2,610 ± 0,032 | -"- | 2,586 ± 0,032 | 2,602 ± 0,032 |
| | 2,05 ± 0,06 | 2,598 ± 0,029 | -"- | 2,574 ± 0,029 | 2,590 ± 0,029 |
| | 2,25 ± 0,06 | 2,665 ± 0,035 | -"- | 2,640 ± 0,035 | 2,556 ± 0,035 |
| | 2,46 ± 0,06 | 2,741 ± 0,038 | -"- | 2,715 ± 0,038 | 2,731 ± 0,038 |
| | 2,76 ± 0,06 | 2,795 ± 0,034 | -"- | 2,769 ± 0,034 | 2,785 ± 0,034 |
| | 3,06 ± 0,05 | 2,803 ± 0,046 | -"- | 2,777 ± 0,046 | 2,793 ± 0,046 |
| | 3,25 ± 0,05 | 2,830 ± 0,042 | -"- | 2,803 ± 0,042 | 2,819 ± 0,042 |
| M.V. Savin et al [34] | 1,06 | 2,539 ±0,038 | $\bar{\nu}^{sp}_{p}(Cf^{252}) = 3,772$ | 2,528 ± 0,038 | 2,544 ± 0,038 |
| | 1,15 | 2,575 ±0,038 | -"- | 2,564 ± 0,038 | 2,580 ± 0,038 |
| | 1,25 | 2,578 ±0,038 | -"- | 2,567 ± 0,038 | 2,583 ± 0,038 |
| | 1,35 | 2,613 ±0,039 | -"- | 2,602 ± 0,039 | 2,618 ± 0,039 |
| | 1,41 | 2,618 ±0,039 | -"- | 2,607 ± 0,039 | 2,622 ± 0,039 |
| | 1,48 | 2,636 ±0,039 | -"- | 2,625 ± 0,039 | 2,641 ± 0,039 |
| | 1,63 | 2,641 ±0,039 | -"- | 2,630 ± 0,039 | 2,646 ± 0,039 |
| | 1,80 | 2,641 ±0,039 | -"- | 2,630 ± 0,039 | 2,646 ± 0,039 |
| | 1,97 | 2,645 ±0,039 | -"- | 2,634 ± 0,039 | 2,650 ± 0,039 |
| | 2,05 | 2,661 ±0,040 | -"- | 2,650 ± 0,040 | 2,666 ± 0,040 |
| | 2,18 | 2,700 ±0,033 | -"- | 2,688 ± 0,033 | 2,704 ± 0,033 |

TABLE 3 (continued)

| Reference | En, MeV | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Savin et al. [34] | 2,26 | 2,713 ± 0,035 | $\bar{\nu}_p^{sp}$ ($^{252}$Cf) = 3,772 | 2,701 ± 0,035 | 2,717 ± 0,035 |
| | 2,39 | 2,748 ± 0,035 | -"- | 2,736 ± 0,035 | 2,752 ± 0,035 |
| | 2,55 | 2,711 ± 0,035 | -"- | 2,699 ± 0,035 | 2,715 ± 0,035 |
| | 2,68 | 2,763 ± 0,033 | -"- | 2,751 ± 0,033 | 2,767 ± 0,033 |
| | 2,85 | 2,812 ± 0,034 | -"- | 2,800 ± 0,034 | 2,816 ± 0,034 |
| | 2,94 | 2,806 ± 0,034 | -"- | 2,794 ± 0,034 | 2,810 ± 0,034 |
| | 3,06 | 2,800 ± 0,034 | -"- | 2,788 ± 0,034 | 2,804 ± 0,034 |
| | 3,28 | 2,833 ± 0,043 | -"- | 2,821 ± 0,043 | 2,837 ± 0,043 |
| | 3,71 | 2,871 ± 0,043 | -"- | 2,859 ± 0,043 | 2,875 ± 0,043 |
| | 4,23 | 2,903 ± 0,044 | -"- | 2,891 ± 0,044 | 2,907 ± 0,044 |
| | 4,57 | 2,937 ± 0,058 | -"- | 2,924 ± 0,058 | 2,940 ± 0,058 |
| | 4,90 | 3,032 ± 0,061 | -"- | 3,019 ± 0,061 | 3,035 ± 0,061 |
| | 5,32 | 3,095 ± 0,072 | -"- | 3,082 ± 0,072 | 3,098 ± 0,072 |
| | 5,60 | 3,110 ± 0,082 | -"- | 3,097 ± 0,082 | 3,113 ± 0,082 |
| | 5,94 | 3,234 ± 0,106 | -"- | 3,220 ± 0,105 | 3,236 ± 0,105 |
| | 6,60 | 3,373 ± 0,111 | -"- | 3,759 ± 0,110 | 3,775 ± 0,110 |

## TABLE 4

Available experimental data on $\bar{\nu}$(239-Pu) in the energy range 0.08 to 1.5 MeV

| Reference | Energy (MeV) | $\bar{\nu}$ exp | Standard | $\bar{\nu}_p$ (x) renormalized | $\bar{\nu}$total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Diven et al.[18] | 0,080 | 3,048 ± 0,079 | $\bar{\nu}^p_{th}(^{235}U)$=2.46 | 2,982 ± 0,078 | 2,988 ± 0,078 |
| Allen et al.[36] | 0,5 | (1.3 ± 0,2) | $\bar{\nu}_{th}(^{235}U)$=1 | | 3,156 ± 0,48 |
| | 1,0 | (1,3 ± 0,2) | -"- | | 3,156 ± 0,48 |
| Hopkins et al.[4] | 0,250 ± 0,050 | 2,931 ± 0,039 | $\bar{\nu}^p_{th}(^{252}Cf)$=3,771 | 2,920 ± 0,039 | 2,926 ± 0,039 |
| | 0,420 ± 0,110 | 2,957 ± 0,046 | -"- | 2,946 ± 0,046 | 2,952 ± 0,046 |
| | 0,610 ± 0,070 | 2,904 ± 0,041 | -"- | 2,893 ± 0,041 | 2,899 ± 0,041 |
| | 0,900 ± 0,080 | 3,004 ± 0,041 | -"- | 2,993 ± 0,041 | 2,999 ± 0,041 |
| Mather et al.[37] | 0,99 ± 0,185 | 3,103 ± 0,056 | $\bar{\nu}^p_{sp}(^{252}Cf)$=3,782 | 3,082 ± 0,053 | 3,088 ± 0,053 |
| Soleilhac et al.[31] | 0,21 ± 0,01 | 2,8969 ± 0,0941 | $\bar{\nu}^p_{sp}(^{252}Cf)$=3,782 | 2,8778 ± 0,0935 | 2,8838 ± 0,0935 |
| | 0,23 ± 0,01 | 2,9185 ± 0,0588 | -"- | 2,8992 ± 0,0584 | 2,9052 ± 0,0584 |
| | 0,25 ± 0,01 | 2,8537 ± 0,0493 | -"- | 2,8349 ± 0,0490 | 2,8409 ± 0,0490 |
| | 0,27 ± 0,01 | 2,8883 ± 0,0420 | -"- | 2,8692 ± 0,0417 | 2,8752 ± 0,0417 |
| | 0,29 ± 0,01 | 2,8795 ± 0,0359 | -"- | 2,8605 ± 0,0358 | 2,8695 ± 0,0358 |
| | 0,31 ± 0,01 | 2,9307 ± 0,0324 | -"- | 2,9113 ± 0,0324 | 2,9173 ± 0,0358 |
| | 0,33 ± 0,01 | 2,9576 ± 0,0306 | -"- | 2,9381 ± 0,0304 | 2,9441 ± 0,0304 |
| | 0,35 ± 0,01 | 2,9467 ± 0,0300 | -"- | 2,9272 ± 0,0300 | 2,9332 ± 0,0300 |
| | 0,37 ± 0,01 | 2,9367 ± 0,0295 | -"- | 2,9173 ± 0,0294 | 2,9333 ± 0,0294 |
| | 0,39 ± 0,01 | 2,9592 ± 0,0270 | -"- | 2,9397 ± 0,0269 | 2,9457 ± 0,0269 |
| | 0,41 ± 0,01 | 2,9345 ± 0,0275 | -"- | 2,9151 ± 0,0274 | 2,9211 ± 0,0274 |
| | 0,43 ± 0,01 | 2,9641 ± 0,0249 | -"- | 2,9445 ± 0,0247 | 2,9505 ± 0,0247 |
| | 0,45 ± 0,01 | 2,9366 ± 0,0228 | -"- | 2,9172 ± 0,0226 | 2,9232 ± 0,0226 |
| | 0,47 ± 0,01 | 2,9577 ± 0,0220 | -"- | 2,9382 ± 0,0219 | 2,9442 ± 0,0219 |
| | 0,49 ± 0,01 | 2,9202 ± 0,0193 | -"- | 2,9009 ± 0,0193 | 2,9069 ± 0,0193 |

| [illegible] | Energy (MeV) | $\bar{\nu}_{exp}$ | Standard | $\bar{\nu}_p$ (*) renormalized | $\bar{\nu}$ [illegible] $\bar{\nu}_p$ + [illegible] |
|---|---|---|---|---|---|
| Soleilhac et al.[31] | 0,51 ± 0,01 | 2,9683 ± 0,0176 | $\nu_{sp}^{p}(^{252}Cf) = 3,782$ | 2,9487 ± 0,0175 | 2,9547 ± 0,0175 |
| | 0,53 ± 0,01 | 2,9281 ± 0,0173 | -"- | 2,9088 ± 0,0172 | 2,9148 ± 0,0172 |
| | 0,55 ± 0,01 | 2,9600 ± 0,0169 | -"- | 2,9405 ± 0,0168 | 2,9465 ± 0,0168 |
| | 0,57 ± 0,01 | 2,9605 ± 0,0164 | -"- | 2,9410 ± 0,0164 | 2,9470 ± 0,0164 |
| | 0,59 ± 0,01 | 2,9358 ± 0,0178 | -"- | 2,9164 ± 0,0177 | 2,9254 ± 0,0177 |
| | 0,61 ± 0,01 | 2,9702 ± 0,0162 | -"- | 2,9506 ± 0,0161 | 2,9566 ± 0,0161 |
| | 0,63 ± 0,01 | 2,9686 ± 0,0181 | -"- | 2,9490 ± 0,0180 | 2,9550 ± 0,0180 |
| | 0,65 ± 0,01 | 2,9562 ± 0,0184 | -"- | 2,9367 ± 0,0183 | 2,9427 ± 0,0183 |
| | 0,67 ± 0,01 | 2,9719 ± 0,0190 | -"- | 2,9523 ± 0,0189 | 2,9583 ± 0,0189 |
| | 0,69 ± 0,01 | 2,9781 ± 0,189 | -"- | 2,9584 ± 0,0188 | 2,9644 ± 0,0188 |
| | 0,725 ± 0,025 | 2,9712 ± 0,0145 | -"- | 2,9516 ± 0,0145 | 2,9576 ± 0,0145 |
| | 0,775 ± 0,025 | 2,9912 ± 0,0153 | -"- | 2,9714 ± 0,0152 | 2,9774 ± 0,0152 |
| | 0,825 ± 0,025 | 2,9674 ± 0,0180 | -"- | 2,9478 ± 0,0179 | 2,9538 ± 0,0179 |
| | 0,875 ± 0,025 | 3,0035 ± 0,0176 | -"- | 2,9837 ± 0,0175 | 2,9897 ± 0,0175 |
| | 0,925 ± 0,025 | 2,9858 ± 0,0209 | -"- | 2,9661 ± 0,0208 | 2,9721 ± 0,0208 |
| | 0,975 ± 0,025 | 2,9885 ± 0,0206 | -"- | 2,9688 ± 0,0205 | 2,9748 ± 0,0205 |
| | 1,025 ± 0,025 | 3,0177 ± 0,0263 | -"- | 2,9978 ± 0,0261 | 3,0038 ± 0,0261 |
| | 1,075 ± 0,025 | 3,0457 ± 0,0307 | -"- | 3,0276 ± 0,0305 | 3,0336 ± 0,0305 |
| | 1,125 ± 0,025 | 3,0614 ± 0,0288 | -"- | 3,0412 ± 0,0286 | 3,0472 ± 0,0286 |
| | 1,175 ± 0,025 | 3,0310 ± 0,0343 | -"- | 3,0100 ± 0,0341 | 3,0160 ± 0,0341 |
| | 1,225 ± 0,025 | 3,0835 ± 0,0406 | -"- | 3,0631 ± 0,0404 | 3,0691 ± 0,0404 |
| | 1,275 ± 0,025 | 3,1027 ± 0,0381 | -"- | 3,0822 ± 0,0380 | 3,0882 ± 0,0380 |
| | 1,325 ± 0,025 | 3,1439 ± 0,0473 | -"- | 3,1231 ± 0,0471 | 3,1291 ± 0,0471 |
| | 1,375 ± 0,025 | 3,0446 ± 0,0421 | -"- | 3,0245 ± 0,0420 | 3,0305 ± 0,0420 |
| | 1,36 ± 0,165 | 3,0708 ± 0,0180 | -"- | 3,0505 ± 0,0180 | 3,0565 ± 0,0180 |

TABLE 4 continued

| Reference | Energy (MeV) | $\bar{\nu}_{exp}$ | Standard | $\bar{\nu}_p$ (*) renormalized | $\bar{\nu}_{total} = \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Mather et al.[38] | 0,0775 ± 0,0375 | 0,7650 ± 0,0072 | $\bar{\nu}^{p}_{sp}(^{252}Cf) = 1$ | 2,874 ± 0,027 | 2,880 ± 0,027 |
| | 0,200 ± 0,085 | 0,7754 ± 0,0077 | | 2,913 ± 0,029 | 2,919 ± 0,029 |
| | 0,350 ± 0,050 | 0,7738 ± 0,0073 | | 2,915 ± 0,027 | 2,923 ± 0,027 |
| | 0,450 ± 0,050 | 0,7933 ± 0,0077 | | 2,980 ± 0,029 | 2,986 ± 0,029 |
| | 0,550 ± 0,050 | 0,7964 ± 0,0075 | | 2,992 ± 0,028 | 2,998 ± 0,028 |
| | 0,650 ± 0,050 | 0,8023 ± 0,0076 | | 3,014 ± 0,028 | 3,020 ± 0,028 |
| | 0,750 ± 0,050 | 0,7795 ± 0,0073 | | 2,929 ± 0,027 | 2,935 ± 0,027 |
| | 0,850 ± 0,050 | 0,7969 ± 0,0078 | | 2,994 ± 0,029 | 3,000 ± 0,029 |
| | 0,950 ± 0,050 | 0,8046 ± 0,0074 | | 3,023 ± 0,028 | 3,029 ± 0,028 |
| | 1,050 ± 0,050 | 0,8070 ± 0,0075 | | 3,032 ± 0,028 | 3,038 ± 0,028 |
| | 1,150 ± 0,050 | 0,8134 ± 0,0075 | | 3,056 ± 0,028 | 3,062 ± 0,028 |
| | 0,550 ± 0,025 | 0,7889 ± 0,0101 | $\bar{\nu}^{p}_{sp}(^{252}Cf) = 1$ | 2,964 ± 0,038 | 2,970 ± 0,038 |
| | 0,600 ± 0,025 | 0,7715 ± 0,0102 | | 2,898 ± 0,038 | 2,904 ± 0,038 |
| | 0,650 ± 0,025 | 0,8158 ± 0,0120 | | 3,065 ± 0,045 | 3,071 ± 0,045 |
| | 0,700 ± 0,025 | 0,8114 ± 0,0110 | | 3,048 ± 0,038 | 3,054 ± 0,038 |
| | 0,750 ± 0,025 | 0,7917 ± 0,0122 | | 2,974 ± 0,046 | 2,980 ± 0,046 |
| | 0,800 ± 0,025 | 0,7928 ± 0,0108 | | 2,978 ± 0,041 | 2,984 ± 0,041 |
| | 0,850 ± 0,025 | 0,7874 ± 0,0106 | | 2,958 ± 0,040 | 2,964 ± 0,040 |
| Savin et al.[34] | 0,89 | 3,026 ± 0,070 | $\bar{\nu}^{p}_{sp}(^{252}Cf) = 3,772$ | 3,013 ± 0,070 | 3,019 ± 0,070 |
| | 0,96 | 3,005 ± 0,060 | | 2,442 ± 0,060 | 2,998 ± 0,060 |
| | 0,99 | 3,011 ± 0,060 | | 2,998 ± 0,060 | 3,004 ± 0,060 |
| | 1,03 | 3,049 ± 0,046 | | 3,036 ± 0,046 | 3,042 ± 0,046 |

TABLE 4 continued

| Reference | Energy (MeV) | $\bar{\nu}$ exp | Standard | $\bar{\nu}_p$ (*) renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Savin et al.[34] | 1,07 | 3,009 ± 0,046 | $\bar{\nu}^{p}_{sp}(^{252}Cf)$= 3,772 | 2,996 ± 0,046 | 3,002 ± 0,046 |
| | 1,10 | 3,053 ± 0,046 | | 3,040 ± 0,046 | 3,046 ± 0,046 |
| | 1,14 | 3,089 ± 0,047 | | 3,076 ± 0,047 | 3,082 ± 0,047 |
| | 1,17 | 3,066 ± 0,046 | | 3,053 ± 0,046 | 3,059 ± 0,046 |
| | 1,22 | 3,061 ± 0,046 | | 3,048 ± 0,046 | 3,054 ± 0,046 |
| | 1,26 | 2,984 ± 0,045 | | 2,971 ± 0,045 | 2.977 ± 0,045 |
| | 1,30 | 3,021 ± 0,045 | | 3,008 ± 0,045 | 3,014 ± 0,045 |
| | 1,34 | 3,129 ± 0,047 | | 3,116 ± 0,047 | 3,122 ± 0,047 |
| | 1,39 | 3,118 ± 0,047 | | 3,105 ± 0,047 | 3,111 ± 0,047 |
| | 1,49 | 3,138 ± 0,047 | | 3,125 ± 0,047 | 3,131 ± 0,047 |
| | 1,54 | 3,165 ± 0,047 | | 3,151 ± 0,047 | 3,157 ± 0,047 |

(*) Renormalization values

$\bar{\nu}^{p}_{sp}(^{252}Cf)$ = 3.756 ± 0,000

$\bar{\nu}^{p}_{th}(^{235}U)$ = 2,407 ± 0.000

TABLE 5

Available experimental data on $\bar{\nu}(^{239}Pu)$ above 1.0 MeV

| Reference | Energy (MeV) | $\bar{\nu}$ exp. | Standard | $\bar{\nu}_p$ (*) renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Bethe et al.[39] | 4,25 | 3,66 ± 0,40 | - | 3,66 ± 0,40 | 3,67 ± 0,40 |
| Smirenkin et al.[40] | 4, ± 0,3 | 3,43 ± 0,11 | $\bar{\nu}^p_{th}(^{239}Pu)$ = 2,91 | 3,38 ± 0,11 | 3,39 ± 0,11 |
| | 15 ± 0,5 | 4,71 ± 0,20 | -"- | 4,64 ± 0,20 | 4,65 ± 0,20 |
| Flerov et al.[41] | 14 | 4,62 ± 0,28 | - | 4,62 ± 0,28 | 4,63 ± 0,28 |
| Leroy [42] | 14,2 | 4,75 ± 0,4 | $\bar{\nu}^p_{th}(^{235}U)$ = 2,47 | 4,63 ± 0,39 | 4,64 ± 0,39 |
| Hopkins et al.[4] | 3,90± 0,29 | 3,422± 0,039 | $\bar{\nu}^p_{sp}(^{252}Cf)$ =3,771 | 3,409± 0,039 | 3,414± 0,039 |
| | 14,5 ± 1,0 | 4,942± 0,119 | -"- | 4,924± 0,119 | 4,930± 0,119 |
| Mather et al.[37] | 1,99± 0,135 | 3,170± 0,045 | $\bar{\nu}^p_{sp}(^{252}Cf)$ =3,782 | 3,149± 0,040 | 3,155± 0,040 |
| | 3,00± 0,105 | 3,243± 0,054 | -"- | 3,221± 0,049 | 3,227± 0,049 |
| | 4,02± 0,095 | 3,325± 0,054 | -"- | 3,303± 0,050 | 3,309± 0,050 |
| Johnston [43] | 14,1 | 4,85 ± 0,50 | | 4,85 ± 0,50 | 4,86 ± 0,50 |
| Condé et al.[44] | 4,22± 0,02 | 3,47 ± 0,07 | $\bar{\nu}^p_{sp}(^{252}Cf)$= 3,764 | 3,46 ± 0,07 | 3,47 ± 0,07 |
| | 5,91± 0,12 | 3,74 ± 0,07 | -"- | 3,73 ± 0,07 | 3,74 ± 0,07 |
| | 6,77± 0,10 | 3,94 ± 0,10 | -"- | 3,93 ± 0,10 | 3,94 ± 0,10 |
| | 7,51± 0,09 | 3,97 ± 0,06 | -"- | 3,96 ± 0,06 | 3,97 ± 0,06 |
| | 14,8 ± 0,20 | 4,98 ± 0,09 | -"- | 4,97 ± 0,09 | 4,98 ± 0,09 |
| Soleilhac et al.[31] | 1,025±0,025 | 3,0177±0,0263 | $\bar{\nu}^p_{sp}(^{252}Cf)$=3,782 | 2,9978±0,0261 | 3,0068±0,0261 |
| | 1,075±0,025 | 3,0457±0,0307 | -"- | 3,0276±0,0305 | 3,0336±0,0305 |
| | 1,125±0,025 | 3,0614±0,0288 | -"- | 3,0412±0,0286 | 3,0472±0,0286 |
| | 1,175±0,025 | 3,0310±0,0343 | -"- | 3,0100±0,0341 | 3,0160±0,0341 |
| | 1,225±0,025 | 3,0835±0,0406 | -"- | 3,0631±0,0404 | 3,0691±0,0404 |
| | 1,275±0,025 | 3,1027±0,0381 | -"- | 3,0822±0,0380 | 3,0882±0,0380 |
| | 1,325±0,025 | 3,1439±0,0473 | -"- | 3,1231±0,0471 | 3,1291±0,0471 |
| | 1,375±0,025 | 3,0446±0,0421 | -"- | 3,0245±0,0420 | 3,0305±0,0420 |

TABLE 5 continued

| Reference | Energy (MeV) | $\bar{\nu}_{exp}$ | Standard | $\bar{\nu}_p$ (*) renormalized | $\bar{\nu}_{total} = \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Soleilhac et al.[31] | 1,36 ± 0,165 | 3,071 ± 0,018 | $\bar{\nu}^{p}_{sp}(^{252}Cf)=3,782$ | 3,051 ± 0,018 | 3,057 ± 0,018 |
| | 1,87 ± 0,150 | 3,152 ± 0,021 | -"- | 3,131 ± 0,020 | 3,136 ± 0,020 |
| | 2,45 ± 0,125 | 3,222 ± 0,022 | -"- | 3,201 ± 0,021 | 3,207 ± 0,021 |
| | 2,98 ± 0,105 | 3,311 ± 0,016 | -"- | 3,289 ± 0,016 | 3,295 ± 0,016 |
| | 3,50 ± 0,100 | 3,372 ± 0,022 | -"- | 3,350 ± 0,021 | 3,356 ± 0,021 |
| | 4,03 ± 0,090 | 3,467 ± 0,017 | -"- | 3,444 ± 0,017 | 3,450 ± 0,017 |
| | 4,54 ± 0,080 | 3,562 ± 0,022 | -"- | 3,538 ± 0,021 | 3,544 ± 0,021 |
| | 5,06 ± 0,070 | 3,628 ± 0,017 | -"- | 3,604 ± 0,017 | 3,610 ± 0,017 |
| | 5,57 ± 0,070 | 3,688 ± 0,027 | -"- | 3,664 ± 0,026 | 3,670 ± 0,026 |
| | 6,08 ± 0,075 | 3,791 ± 0,028 | -"- | 3,766 ± 0,027 | 3,772 ± 0,027 |
| | 6,97 ± 0,170 | 3,937 ± 0,022 | -"- | 3,911 ± 0,021 | 3,917 ± 0,021 |
| | 7,09 ± 0,065 | 3,970 ± 0,029 | -"- | 3,944 ± 0,028 | 3,950 ± 0,028 |
| | 7,48 ± 0,165 | 3,998 ± 0,018 | -"- | 3,972 ± 0,018 | 3,978 ± 0,018 |
| | 7,99 ± 0,145 | 4,090 ± 0,018 | -"- | 4,063 ± 0,018 | 4,069 ± 0,018 |
| | 8,49 ± 0,130 | 4,176 ± 0,020 | -"- | 4,148 ± 0,020 | 4,154 ± 0,020 |
| | 9,00 ± 0,120 | 4,249 ± 0,020 | -"- | 4,221 ± 0,020 | 4,227 ± 0,020 |
| | 9,49 ± 0,110 | 4,324 ± 0,023 | -"- | 4,298 ± 0,022 | 4,304 ± 0,022 |
| | 9,74 ± 0,110 | 4,334 ± 0,021 | -"- | 4,305 ± 0,021 | 4,311 ± 0,021 |
| | 9,98 ± 0,100 | 4,421 ± 0,016 | -"- | 4,391 ± 0,016 | 4,397 ± 0,016 |
| | 10,47 ± 0,095 | 4,462 ± 0,022 | -"- | 4,432 ± 0,021 | 4,438 ± 0,021 |
| | 10,96 ± 0,090 | 4,542 ± 0,021 | -"- | 4,512 ± 0,020 | 4,518 ± 0,020 |
| | 11,44 ± 0,085 | 4,620 ± 0,023 | -"- | 4,589 ± 0,022 | 4,595 ± 0,022 |

TABLE 5 continued

| Reference | Energy (MeV) | $\bar{\nu}$ exp | Standard | $\bar{\nu}$p (*) renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Soleilhac et al[31] | 11,93 ± 0,080 | 4,683 ± 0,023 | $\bar{\nu}^p_{sp}(^{252}Cf)=3,782$ | 4,652 ± 0,022 | 4,658 ± 0,022 |
| | 12,41 ± 0,080 | 4,697 ± 0,024 | -"- | 4,666 ± 0,023 | 4,672 ± 0,023 |
| | 12,88 ± 0,080 | 4,804 ± 0,025 | -"- | 4,772 ± 0,024 | 4,778 ± 0,024 |
| | 13,36 ± 0,075 | 4,859 ± 0,026 | -"- | 4,827 ± 0,025 | 4,833 ± 0,025 |
| | 13,84 ± 0,075 | 4,939 ± 0,025 | -"- | 4,906 ± 0,024 | 4,912 ± 0,024 |
| | 14,31 ± 0,070 | 4,997 ± 0,029 | -"- | 4,964 ± 0,028 | 4,970 ± 0,028 |
| | 14,79 ± 0,070 | 5,048 ± 0,027 | -"- | 5,015 ± 0,026 | 5,021 ± 0,026 |
| | 22,79 ± 0,140 | 6.026 ± 0,077 | -"- | 5,986 ± 0,075 | 5,992 ± 0,075 |
| | 23,94 ± 0,115 | 6,127 ± 0,064 | -"- | 6,086 ± 0,062 | 6,092 ± 0,062 |
| | 25,05 ± 0,105 | 6,170 ± 0,086 | -"- | 6,129 ± 0,084 | 6,135 ± 0,084 |
| | 26,15 ± 0,090 | 6,296 ± 0,056 | -"- | 6,254 ± 0,054 | 6,260 ± 0,054 |
| | 27,22 ± 0,080 | 6,457 ± 0,076 | -"- | 6,414 ± 0,074 | 6,420 ± 0,074 |
| | 28,28 ± 0,075 | 6,513 ± 0,104 | -"- | 6,470 ± 0,101 | 6,476 ± 0,101 |
| Savin et al.[34] | 0,89 | 3,026 ± 0,070 | $\bar{\nu}^p_{sp}(^{252}Cf)=3,772$ | 3,013 ± 0,070 | 3,019 ± 0,070 |
| | 0,96 | 3,005 ± 0,060 | | 2,992 ± 0,060 | 2,998 ± 0,060 |
| | 0,99 | 3,011 ± 0,060 | | 2,998 ± 0,060 | 3,004 ± 0,060 |
| | 1,03 | 3,049 ± 0,046 | | 3,036 ± 0,046 | 3,042 ± 0,046 |
| | 1,07 | 3,009 ± 0,046 | | 2,996 ± 0,046 | 3,002 ± 0,046 |
| | 1,10 | 3,053 ± 0,046 | | 3,040 ± 0,046 | 3,046 ± 0,046 |
| | 1,14 | 3,089 ± 0,047 | | 3,076 ± 0,047 | 3,082 ± 0,047 |
| | 1,17 | 3,066 ± 0,046 | | 3,053 ± 0,046 | 3,059 ± 0,046 |
| | 1,22 | 3,061 ± 0,046 | | 3,048 ± 0,046 | 3,054 ± 0,046 |

TABLE 5 continued

| Reference | Energy (MeV) | $\bar{\nu}_{exp}$ | Standard | $\bar{\nu}_p$ (*) renormalized | $\bar{\nu}_{total} = \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Savin et al.[34] | 1,26 | 2,984 ± 0,045 | $\bar{\nu}^p_{sp}(^{252}Cf)$=3,772 | 2,971 ± 0,045 | 2,977 ± 0,045 |
| | 1,30 | 3,021 ± 0,045 | | 3,008 ± 0,045 | 3,014 ± 0,045 |
| | 1,34 | 3,129 ± 0,047 | | 3,116 ± 0,047 | 3,122 ± 0,047 |
| | 1,39 | 3,118 ± 0,047 | | 3,105 ± 0,047 | 3,111 ± 0,047 |
| | 1,49 | 3,138 ± 0,047 | | 3,125 ± 0,047 | 3,131 ± 0,047 |
| | 1,54 | 3,165 ± 0,047 | | 3,151 ± 0,047 | 3,157 ± 0,047 |
| | 1,60 | 3,135 ± 0,045 | | 3,122 ± 0,045 | 3,128 ± 0,045 |
| | 1,66 | 3,100 ± 0,045 | | 3,087 ± 0,045 | 3,093 ± 0,045 |
| | 1,72 | 3,142 ± 0,047 | | 3,129 ± 0,047 | 3,135 ± 0,047 |
| | 1,78 | 3,203 ± 0,048 | | 3,189 ± 0,048 | 3,195 ± 0,048 |
| | 1,85 | 3,217 ± 0,048 | | 3,203 ± 0,048 | 3,209 ± 0,048 |
| | 1,91 | 3,220 ± 0,048 | | 3,206 ± 0,048 | 3,212 ± 0,048 |
| | 1,97 | 3,243 ± 0,048 | | 3,229 ± 0,048 | 3,235 ± 0,048 |
| | 2,05 | 3,163 ± 0,047 | | 3,149 ± 0,047 | 3,155 ± 0,047 |
| | 2,14 | 3,176 ± 0,047 | | 3,162 ± 0,047 | 3,168 ± 0,047 |
| | 2,23 | 3,230 ± 0,048 | | 3,216 ± 0,048 | 3,224 ± 0,048 |
| | 2,36 | 3,227 ± 0,048 | | 3,213 ± 0,048 | 3,219 ± 0,048 |
| | 2,49 | 3,310 ± 0,049 | | 3,296 ± 0,049 | 3,302 ± 0,049 |
| | 2,59 | 3,304 ± 0,049 | | 3,290 ± 0,049 | 3,296 ± 0,049 |
| | 2,67 | 3,338 ± 0,057 | | 3,324 ± 0,057 | 3,330 ± 0,057 |
| | 2,79 | 3,320 ± 0,056 | | 3,306 ± 0,056 | 3,312 ± 0,056 |
| | 3,01 | 3,364 ± 0,057 | | 3,350 ± 0,057 | 3,356 ± 0,057 |
| | 3,21 | 3,415 ± 0,061 | | 3,400 ± 0,061 | 3,406 ± 0,061 |

TABLE 5 continued

| Reference | Energy (MeV) | $\bar{\nu}_{exp}$ | Standard | $\bar{\nu}_p$ (*) renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Savin et al.[34] | 3,34 | 3,395 ± 0,061 | $\bar{\nu}_{sp}(^{252}Cf)$=3,772 | 3,381 ± 0,061 | 3,387 ± 0,061 |
| | 3,52 | 3,387 ± 0,061 | | 3,373 ± 0,061 | 3,379 ± 0,061 |
| | 3,72 | 3,379 ± 0,067 | | 3,365 ± 0,067 | 3,371 ± 0,067 |
| | 3,94 | 3,439 ± 0,075 | | 3,424 ± 0,075 | 3,430 ± 0,075 |
| | 4,05 | 3,579 ± 0,078 | | 3,564 ± 0,078 | 3,570 ± 0,078 |
| | 4,23 | 3,558 ± 0,089 | | 3,543 ± 0,089 | 3,549 ± 0,089 |
| | 4,35 | 3,551 ± 0,089 | | 3,536 ± 0,089 | 3,542 ± 0,089 |
| | 4,49 | 3,661 ± 0,091 | | 3,645 ± 0,091 | 3,651 ± 0,091 |
| | 4,70 | 3,684 ± 0,110 | | 3,668 ± 0,109 | 3,674 ± 0,109 |

(*) Renormalization value

$\bar{\nu}^{p}_{sp}(^{252}Cf) = 3,756$

TABLE 6

Available experimental data on $\bar{\nu}(^{233}U)$

| Reference | Energy (MeV) | $\bar{\nu}$exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total = p + d |
|---|---|---|---|---|---|
| Smirenkin et al.[40] | 4,0 | 3,00 ± 0,11 | $\bar{\nu}^p_{th}(^{233}U)$= 2,55 | 2,92 ± 0,11 | 2,93 ± 0,11 |
| | 15,0 | 4,33 ± 0,16 | -"- | 4,21 ± 0,16 | 4,22 ± 0,16 |
| Kalashnikova et al. [68] | 1,8 | 2,69 ± 0,06 | p | | |
| Diven et al. [18] | 0,08 | 2,585± 0,062 | $\bar{\nu}_{th}(^{235}U)$=2,46 | 2,530± 0,062 | 2,540± 0,062 |
| Protopopov et al.[69] | 14,8 | 4,35 ± 0,40 | $\bar{\nu}^p_{th}(^{233}U)$=2,52 | 4,28 ± 0,40 | 4,29 ± 0,40 |
| Engle et al[70] | 1,45 | 2,71 ± 0,08 | | 2,71 ± 0,08 | 2,71 ± 0,08 |
| Flerov et al[41] | 14,0 | 4,23 ± 0,24 | $\sigma_{in}(^{233}U)$=2,85 barns | 4,23 ± 0,24 | 4,23 ± 0,24 |
| Vasil'ev et al[71] | 14,3 | 4,20 ± 0,30 | $\sigma_{in} - \sigma_f$= 0,2 barns | | |
| Hopkins et al [4] | 0,280±0,090 | 2,489± 0,033 | $\bar{\nu}^{sp}_p(^{252}Cf)$= 3,771 | 2,479±0,033 | 2,486±0,033 |
| | 0,440±0,080 | 2,502± 0,033 | -"- | 2,492±0,033 | 2,499±0,033 |
| | 0.980±0,050 | 2,553± 0,035 | -"- | 2,543±0,035 | 2,550±0,035 |
| | 1,080±0,050 | 2,510± 0,030 | -"- | 2,500±0,030 | 2,507±0,030 |
| | 3,930±0,290 | 2,983± 0,040 | -"- | 2,971±0,040 | 2,978±0,040 |
| Colvin et al[72] | 0,58 | 2,47 ± 0,05 | $\bar{\nu}^{sp}_p(^{252}Cf)$ = 3,780 | 2,45 ±0,05 | 2,46 ±0,05 |
| | 0,93 | 2,56 ± 0,05 | -"- | 2,54 ±0,05 | 2,55 ±0,05 |
| | 1,49 | 2,52 ± 0,10 | -"- | 2,50 ±0,10 | 2,51 ±0,10 |
| | 2,12 | 2,575± 0,050 | -"- | 2,56 ±0,05 | 2,57 ±0,05 |
| | 2,58 | 2,81 ± 0,06 | -"- | 2,79 ±0,06 | 2,80 ±0,06 |
| Mather et al[37] | 0,960±0,205 | 2,532± 0,040 | $\bar{\nu}^{sp}_p(^{252}Cf)$=3,782 | 2,515±0,040 | 2,522±0,040 |
| | 1,980±0,145 | 2,639± 0,037 | -"- | 2,621±0,037 | 2,628±0,037 |
| | 3,000±0,115 | 2,855± 0,042 | -"- | 2,835±0,042 | 2,842±0,042 |
| | 4,000±0,090 | 2,923± 0,047 | -"- | 2,903±0,047 | 2,910±0,047 |

TABLE 6 continued

| Reference | Energy (MeV) | $\bar{\nu}$ exp | Standard originally used | $\bar{\nu}$ renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Kuznetsov et al[73] | 0,08 | 2,489±0,030 | $\bar{\nu}(\tilde{E}n)(^{233}U)$=2,462 $\bar{\nu}th/(\tilde{E}n)$=1,013 | 2,481 ± 0,030 | 2,481 ± 0,030 |
| | 0,20 | 2,467±0,031 | -"- | 2,459 ± 0,031 | 2,459 ± 0,031 |
| | 0,30 | 2,442±0,027 | -"- | 2,434 ± 0,027 | 2,434 ± 0,027 |
| | 0,40 | 2,462±0,025 | -"- | 2,454 ± 0,025 | 2,454 ± 0,025 |
| | 0,50 | 2,472±0,027 | -"- | 2,464 ± 0,027 | 2,464 ± 0,027 |
| | 0,60 | 2,491±0,028 | -"- | 2,483 ± 0,028 | 2,483 ± 0,028 |
| | 0,70 | 2,516±0,029 | -"- | 2,508 ± 0,029 | 2,508 ± 0,029 |

* The following values were used for renormalization:

$\bar{\nu}_t^{th}(^{233}U) = 2,4866$, $\bar{\nu}_p^{th}(^{233}U) = 2,480$, $\bar{\nu}_t^{th}(^{235}U) = 2,4229$, $\bar{\nu}_p^{th}(^{235}U) = 2,4071$, $\bar{\nu}_t^{sp}(^{252}Cf) = 3,765$, $\bar{\nu}_p^{sp}(^{252}Cf) = 3,756$.

TABLE 7

Available experimental data on the energy dependence of $\bar{\nu}$ for $^{240}Pu$

| Reference | Energy | $\bar{\nu}$ exp | Standard | $\bar{\nu}_p$ (*) renormalized | $\bar{\nu}$ total $= \bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Kuzminov [45] | 3,69 | 3,25 ± 0,15 | $\bar{\nu}^p_{th}(^{239}Pu) = 2,90$ | 3,22 ± 0,14 | 3,23 ± 0,14 |
| | 15,0 | 4,4 ± 0,2 | -"- | 4,36 ± 0,20 | 4,37 ± 0,20 |
| De Vroey et al[46] | 0,1 | 2,89 ± 0,19 | $\bar{\nu}^p_{th}(^{235}U) = 2,414$ | 2,88 ± 0,19 | 2,89 ± 0,19 |
| | 1,0 | 2,55 ± 0,35 | -"- | 2,54 ± 0,35 | 2,55 ± 0,35 |
| | 1,6 | 3,26 ± 0,12 | -"- | 3,05 ± 0,12 | 3,06 ± 0,12 |
| Savin et al.[34] | 1,08 | 3,138± 0,156 | $\bar{\nu}^p_{sp}(^{252}Cf) = 3,772$ | 3,125± 0,155 | 3,134± 0,155 |
| | 1,15 | 3,221± 0,161 | | 3,207± 0,160 | 3,216± 0,160 |
| | 1,23 | 3,018± 0,120 | | 3,005± 0,129 | 3,014± 0,119 |
| | 1,31 | 3,038± 0,106 | | 3,025± 0,105 | 3,034± 0,105 |
| | 1,39 | 3,037± 0,106 | | 3,024± 0,105 | 3,033± 0,105 |
| | 1,46 | 3,051± 0,112 | | 3,038± 0,111 | 3,047± 0,111 |
| | 1,54 | 3,192± 0,102 | | 3,178± 0,101 | 3,187± 0,101 |
| | 1,62 | 3,260± 0,097 | | 3,246± 0,096 | 3,255± 0,096 |
| | 1,71 | 3,170± 0,095 | | 3,156± 0,095 | 3,165± 0,095 |
| | 1,81 | 3,264± 0,091 | | 3,250± 0,091 | 3,259± 0,091 |
| | 1,92 | 3,238± 0,090 | | 3,224± 0,089 | 3,233± 0,089 |
| | 2,02 | 3,175± 0,104 | | 3,161± 0,103 | 3,170± 0,103 |
| | 2,15 | 3,151± 0,104 | | 3,138± 0,103 | 3,147± 0,103 |
| | 2,29 | 3,280± 0,114 | | 3,266± 0,113 | 3,275± 0,113 |
| | 2,39 | 3,262± 0,114 | | 3,248± 0,113 | 3,257± 0,113 |
| | 2,50 | 3,435± 0,127 | | 3,420± 0,126 | 3,429± 0,126 |

TABLE 7 continued

| Reference | Energy | $\bar{\nu}$ exp | Standard | $\bar{\nu}$p (*) renormalized | $\bar{\nu}$total $=\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Savin et al.[34] | 2,62 | 3,367±0,134 | $\bar{\nu}^p_{sp}(^{252}Cf)=3.772$ | 3,353±0,133 | 3,362±0,133 |
| | 2,74 | 3,327±0,133 | | 3,313±0,132 | 3,322±0,132 |
| | 2,88 | 3,450±0,138 | | 3,435±0,137 | 3,444±0,137 |
| | 3,02 | 3,423±0,143 | | 3,408±0,142 | 3,417±0,142 |
| | 3,18 | 3,484±0,156 | | 3,469±0,155 | 3,478±0,155 |
| | 3,53 | 3,501±0,157 | | 3,486±0,156 | 3,495±0,156 |
| | 3,73 | 3,406±0,170 | | 3,391±0,169 | 3,400±0,169 |
| | 3,94 | 3,507±0,200 | | 3,492±0,199 | 3,501±0,199 |

(*) Renormalization values

$\bar{\nu}^p_{sp}(^{252}Cf) = 3,756 \pm 0,000$

$\bar{\nu}^p_{th}(^{235}U) = 3,407 \pm 0,000$

$\bar{\nu}^p_{th}(^{239}Pu) = 2,874 \pm 0,000$

TABLE 8

Available experimental data on the energy dependence of $\bar{\nu}$ for $^{241}Pu$

| Reference | Energy (MeV) | $\bar{\nu}$ exp | Standard | $\bar{\nu}$ p (*) renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|---|
| Condé et al.[44] | 0,52 ± 0,02 | 2,89 ± 0,11 | $\bar{\nu}^p_{sp}(^{252}Cf)=3,764$ | 2,88 ± 0,11 | 2,89 ± 0,11 |
| | 2,71 ± 0,01 | 3,37 ± 0,11 | | 3,36 ± 0,11 | 3,37 ± 0,11 |
| | 4,19 ± 0,02 | 3,50 ± 0,10 | | 3,49 ± 0,10 | 3,49 ± 0,10 |
| | 5,88 ± 0,12 | 3,84 ± 0,12 | | 3,83 ± 0,12 | 3,83 ± 0,12 |
| | 14,8 ± 0,2 | 5,02 ± 0,14 | | 5,01 ± 0,14 | 5,01 ± 0,14 |

(*) Renormalization value

$\bar{\nu}^p_{sp}$ ($^{252}Cf$) = 3,756 ± 0,000

TABLE 9

Available experimental data on $\bar{\nu}$ for the spontaneous fission of $^{240}Pu$

| Reference | $\bar{\nu}_{exp}$ | Standard | $\bar{\nu}^p$ renormalized | $\bar{\nu}$ total = $\bar{\nu}_p + \bar{\nu}_d$ |
|---|---|---|---|---|
| Segre [47] | 2,31 ± 0,3 | – | | |
| Barclay et al.[48] | 2,84 ± 0,26 | Ra-Be Source | | |
| Carter [49] | 2,22 ± 0,11 | – | | |
| Martin et al.[50] | 2,20 ± 0,05 | – | | |
| Sanders [51] | 0,759± 0,028 | $\bar{\nu}_{th}(^{239}Pu)$= 1 | 2,181 ± 0,080 | 2,187 ± 0,080 |
| Carter et al.[52] | 2,20 ± 0,03 | – | | |
| Kalashnikova [53] | 2,20 ± 0,09 | Calibrated n-source | | |
| Johnstone [43] | 2,21 ± 0,13 | Calibrated n-source | | |
| Crane et al.[54] | 2,09 ± 0,11 | $\bar{\nu}^p_{sp}(^{252}Cf)$ = 3,53 | 2,22 ± 0,12 | 2,229 ± 0,12 |
| Diven et al.[18] | 2,257± 0,045 | $\bar{\nu}^p_{th}(^{235}U)$ = 2,46 | 2,208± 0,044 | 2,217 ± 0,044 |
| Moat et al.[8] | 2,13 ± 0,05 | $\bar{\nu}^p_{sp}(^{252}Cf)$= 3,69 | 2,16 ± 0,05 | 2,169 ± 0,05 |
| Diven et al.[23] | 2,187± 0,036 | $\bar{\nu}^p_{th}(^{235}U)$ = 2,414 | 2,180± 0,036 | 2,189 ± 0,036 |
| Asplund-Nilson et al. [55] | 2,154± 0,028 | $\bar{\nu}^p_{sp}(^{252}Cf)$= 3,80 | 2,130± 0,028 | 2,139 ± 0,028 |
| Hopkins et al.[4] | 2,189± 0,026 | $\bar{\nu}^p_{sp}(^{252}Cf)$= 3,771 | 2,181± 0,026 | 2,190 ± 0,026 |
| Colvin et al.[2] | (0,888± 0,005) | $\bar{\nu}^p_{th}(^{235}U)$ = 1 | 2,137± 0,012 | 2,146 ± 0,012 |
| Baron et al.[56] | 2,153± 0,020 | $\bar{\nu}^p_{sp}(^{252}Cf)$= 3,782 | 2,139± 0,020 | 2,148 ± 0,020 |
| Boldeman [57] | 2,168± 0,009 | $\bar{\nu}^p_{sp}(^{252}Cf)$= 3,784 | 2,153± 0,009 | 2,162 ± 0,009 |
| | Averaged value = | | 2,150± 0,015 | 2,159 ± 0,015 |

(*) Renormalization values. See table 7

TABLE 10

Available experimental data on $\bar{\nu}$ for the spontaneous fission of $^{242}Pu$

| Reference | $\bar{\nu}$ exp | Standard | $\bar{\nu}^p$ (*) renormalized |
|---|---|---|---|
| Crane et al.[54] | 2,32 ± 0,16 | $\bar{\nu}^p_{sp}(^{252}Cf) = 3,53$ | 2,47 ± 0,17 |
| Hicks et al.[58] | 2,18 ± 0,09 | $\bar{\nu}^p_{sp}(^{240}Pu) = 2,257$ | 2,08 ± 0,09 |
| Boldeman [57] | 2,157± 0,009 | $\bar{\nu}^p_{sp}(^{252}Cf) = 3,784$ | 2,142± 0,009 |
| Prokhorova [59] | 2,13 ± 0,05 | $\bar{\nu}^p_{sp}(^{244}Cm) = 2,71$ | 2,12 ± 0,05 |
| | | Averaged value = | 2,141 ± 0,011 |

(*) Renormalization values

$\bar{\nu}^p_{sp}(^{252}Cf) = 2,756 \pm 0,000$

$\bar{\nu}^p_{sp}(^{240}Pu) = 2,150 \pm 0,000$

$\bar{\nu}^p_{sp}(^{244}Cm) = 2,691 \pm 0,000$

TABLE 11

Available experimental data on $\bar{\nu}$ for the spontaneous fission of $^{244}Cm$.

| Reference | exp | Standard | (*) renormalized |
|---|---|---|---|
| Hicks et al.[60] | 2,66 ± 0,11 | $\bar{\nu}_{sp}(^{252}Cf) = 3,53$ | 2,83 ± 0,12 |
| Hicks et al.[58] | 2,84 ± 0,09 | $\bar{\nu}_{sp}(^{240}Pu) = 2,257$ | 2,70 ± 0,08 |
| Crane et al.[54] | 2,61 ± 0,13 | Calibrated n-source | |
| Diven et al.[18] | 2,810 ± 0,059 | $\bar{\nu}^{p}_{sp}(^{240}Pu) = 2,257$ | 2,677± 0,056 |
| Bolshov et al.[61] | 2,71 ± 0,04 | $\bar{\nu}^{p}_{sp}(^{240}Pu) = 2,17$ | 2,68 ± 0,024 |
| Jaffey et al.[62] | 2,692 ± 0,024 | (a) | 2,692± 0,024 |
| Zamyatnin et al.[63] | 2,77 ± 0,08 | $\bar{\nu}^{p}_{th}(^{235}U) = 2,426$ | 2,75 ± 0,08 |
| | | averaged value = | 2,691±0,032 |

(*) Renormalization values

$\bar{\nu}^{p}_{sp}(^{252}Cf) = 3,756 \pm 0,000$

$\bar{\nu}^{p}_{sp}(^{240}Pu) = 2,150 \pm 0,000$

$\bar{\nu}^{p}_{th}(^{235}U) = 2,407 \pm 0,000$

(a) The reported value is an average of several determinations, in which the thermal $\bar{\nu}_p$ values of $^{233}U$, $^{235}U$ and $^{239}Pu$ and $\bar{\nu}^{p}_{sp}(^{252}Cf)$ were used as standards.

TABLE 12

Ratios for the prompt neutron yield in the spontaneous fission of $^{240}Pu$

| References | $\frac{\bar{\nu}_{sp}(^{240}Pu)}{\bar{\nu}_{sp}(^{252}Cf)}$ | $\frac{\bar{\nu}_{sp}(^{240}Pu)}{\bar{\nu}_{th}(^{235}U)}$ | $\frac{\bar{\nu}_{sp}(^{240}Pu)}{\bar{\nu}_{th}(^{239}Pu)}$ |
|---|---|---|---|
| Sanders [31] | | | 0,757 ± 0,028 (*) |
| Crane et al. [54] | 0,592 ± 0,031 | | |
| Diven et al. [18] | 0,5833±0,0116±0,0118 | 0,9175±0,0183 | |
| Moat et al. [8] | 0,577 ±0,019 | | |
| Asplund-Nilsson et al. [55] | 0,5668±0,0073 | | |
| Hopkins et al. [4] | 0,5805±0,0050 | 0,9027±0,0107±0,0074 | 0,7732±0,0092±0,0076 |
| Colvin et al. [2] | 0,5704±0,0032±0,0026 | 0,888 ±0,005 (*) | 0,7513±0,0042±0,0020 |
| Baron et al. [56] | 0,5693±0,053 | | |
| Boldeman [57] | 0,5729±0,0023 | 0,8700±0,0036±0,0029 | 0,7465±0,0031±0,0020 |
| Average values | 0,5730±0,0039 | 0,8838±0,0325 | 0,7495±0,0073 |
| $\bar{\nu}^{p}_{sp}(^{240}Pu)$ deduced values (**) | 2,153 ± 0,021 | 2,127 ± 0,084 | 2,154 ± 0,021 |

$\bar{\nu}^{p}_{sp}(^{240}Pu)$ weighted mean = 2,153 ± 0,023

(*) Authors' reported values

(**) For standards used see table 7

TABLE 13

Ratios for the prompt neutron yield in the spontaneous fission of $^{242}Pu$

| References | $\frac{\bar{\nu}_{sp}(^{242}Pu)}{\bar{\nu}_{sp}(^{252}Cf)}$ | $\frac{\bar{\nu}_{sp}(^{242}Pu)}{\bar{\nu}_{sp}(^{240}Pu)}$ | $\frac{\bar{\nu}_{sp}(^{242}Pu)}{\bar{\nu}_{sp}(^{244}Pu)}$ |
|---|---|---|---|
| Crane et al. [54] | 0,659 ± 0,045 | 1,1100±0,077±0,058 | |
| Hicks et al. [58] | 0,571 ± 0,023 ± 0,018 | 0,966 ±0,040 | 0,768 ± 0,032 ± 0,024 |
| Boldeman [57] | 0,5700± 0,0023 (*) | 0,9949±0,0041±0,0041 | |
| Prokhorova et al. [59] | | 0,983 ±0,020 | 0,787 ± 0,016 (*) |
| Averaged values | 0,5702± 0,0025 | 0,9926±0,0079 | 0,7864± 0,019 |
| $\bar{\nu}^{p}_{sp}$ ($^{242}Pu$) deduced values (**) | 2,142 ± 0,016 | 2,134 ±0,043 | 2,14 ± 0,12 |
| $\bar{\nu}^{p}_{sp}$ ($^{242}Pu$) weighted mean = | 2,141 ± 0,021 | | |

(*) Authors' reported values

(**) For standards used see table 10

TABLE 14

Ratios for the prompt neutron yield in the spontaneous fission of $^{244}Cm$

| References | $\frac{\bar{\nu}_{sp}(^{244}Cm)}{\bar{\nu}_{sp}(^{252}Cf)}$ | $\frac{\bar{\nu}_{sp}(^{244}Cm)}{\bar{\nu}_{th}(^{235}U)}$ | $\frac{\bar{\nu}_{sp}(^{244}Cm)}{\bar{\nu}_{sp}(^{240}Pu)}$ |
|---|---|---|---|
| Crane et al. [54] | 0,741 ± 0,037 ± 0,034 | | 1,249 ± 0,062 ± 0,066 |
| Hicks et al. [60] | 0,741 ± 0,031 (*) | | |
| Hicks et al. [58] | | | 1,245 ± 0,026 ± 0,025 |
| Diven et al. [18] | 0,7263± 0,0152±0,0147 | 1,1423 ± 0,0239 | |
| Bol'shov et al. [61] | | | 1,250 ± 0,018 (*) |
| Jaffey et al. [62] | 0,720 ± 0,020 (*) | 1,120 ± 0,010 (*) | |
| Zamyatnin et al. [63] | 0,734 ± 0,021 ± 0,016 | 1,142 ± 0,033 | |
| Averaged values | 0,728 ± 0,028 | 1,125 ± 0,013 | 1,251 ± 0,028 |
| $\bar{\nu}^{p}_{sp}$ ($^{244}Cm$) deduced values (**) | 2,735 ± 0,113 | 2,708 ± 0,038 | 2,690 ± 0,092 |
| $\bar{\nu}^{p}_{sp}$ ($^{244}Cm$) weighted mean = | | 2,708 ± 0,051 | |

(*) Author reported values

(**) For standards used see table 11

TABLE 15

Available experimental data on $\bar{\nu}$ for the spontaneous fission of the remaining heavy isotopes

| Isotope | Reference | $\bar{\nu}$ exp | Standard | $\bar{\nu}$ renormalized (*) |
|---|---|---|---|---|
| $^{232}Th$ | F.R. Barclay et al. [88] | 2,37 ± 0,14 | $\bar{\nu}_{sp}(U)$ | 2,13 ± 0,14 |
| $^{238}U$ | Kuzminov et al. [64] | 2,1 ± 0,1 | $\bar{\nu}_{sp}(^{240}Pu) = 2,26$ | 1,98 ± 0,06 |
| | Leroy [42] | 2,10 ± 0,08 | $\bar{\nu}^{p}_{th}(^{235}U) = 2,47$ | 2,05 ± 0,08 |
| | Asplund-Nilsson et al. [55] | 1,97 ± 0,07 | $\bar{\nu}^{p}_{sp}(^{252}Cf) = 3,80$ | 1,95 ± 0,07 |
| | | | Averaged value | 1,99 ± 0,07 |
| $^{236}Pu$ | Crane et al. [54] | 1,89 ± 0,20 | $\bar{\nu}^{p}_{sp}(^{252}Cf) = 3,52$ | 2,03 ± 0,21 |
| | Hicks et al. [58] | 2,30 ± 0,19 | $\bar{\nu}^{p}_{sp}(^{240}Pu) = 2,257$ | 2,19 ± 0,18 |
| | | | Averaged value = | 2,12 ± 0,19 |
| $^{238}Pu$ | Crane et al. [54] | 2,04 ± 0,13 | $\bar{\nu}^{p}_{sp}(^{252}Cf) = 3,52$ | 2,18 ± 0,014 |
| | Hicks et al. [58] | 2,33 ± 0,08 | $\bar{\nu}_{sp}(^{240}Pu) = 2,257$ | 2,22 ± 0,07 |
| | | | Averaged value = | 2,21 ± 0,09 |
| $^{242}Cm$ | Crane et al. [54] | 2,33 ± 0,11 | $\bar{\nu}^{p}_{sp}(^{252}Cf) = 3,52$ | 2,48 ± 0,12 |
| | Hicks et al. [58] | 2,65 ± 0,09 | $\bar{\nu}^{p}_{sp}(^{240}Pu) = 2,257$ | 2,52 ± 0,08 |
| | Jaffey et al. [62] | = 2.51 | $\bar{\nu}^{p}_{sp}(^{244}Cm) = 2,69$ | 2,51 |
| | | | Averaged value = | 2,51 ± 0,10 |

TABLE 15 continued

| Isotope | Reference | $\bar{\nu}$ exp | Standard | $\bar{\nu}$ renormalized (*) |
|---|---|---|---|---|
| $^{249}Bk$ | Pyle [89] | 3,67 ± 0,16 | | |
| $^{246}Cf$ | Pyle [89] | 2,88 ± 0,19 | | |
| $^{254}Cf$ | Pyle [89] | 3,90 ± 0,14 | | |
| $^{254}Fm$ | Choppin et al.[90] | 4,05 ± 0,19 | $\bar{\nu}_{sp}(^{252}Cf) = 3,82$ | 3,98 ± 0,14 |

(*)For standards used see tables 10 and 11

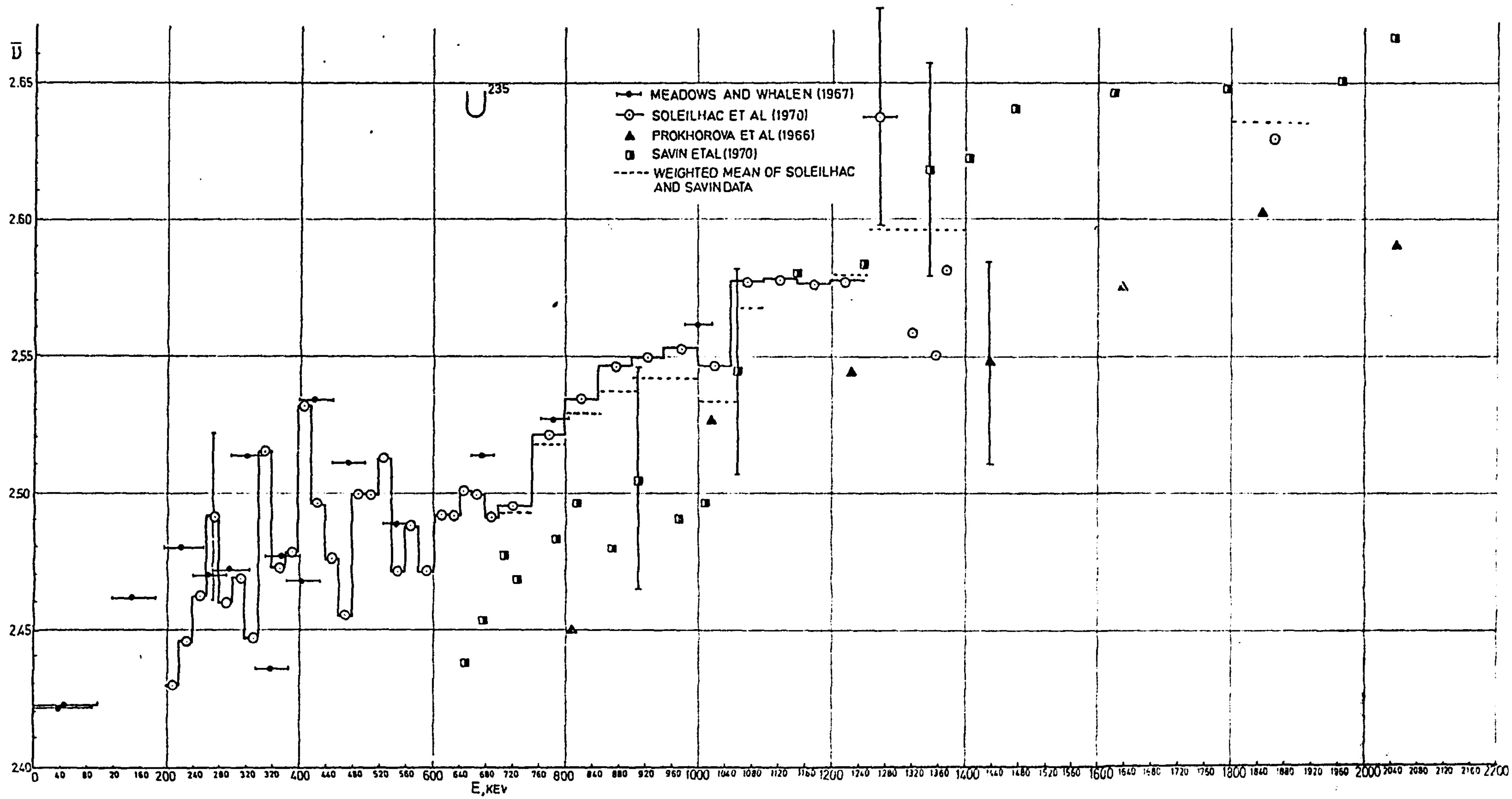

$\bar{\nu}$
$U^{235}$
MEADOWS AND WHALEN (1967)
SOLEILHAC ET AL (1970)
PROKHOROVA ET AL (1966)
SAVIN ETAL (1970)
WEIGHTED MEAN OF SOLEILHAC AND SAVIN DATA
2.65
2.60
2.55
2.50
2.45
2.40
E, KEV

Fig.1

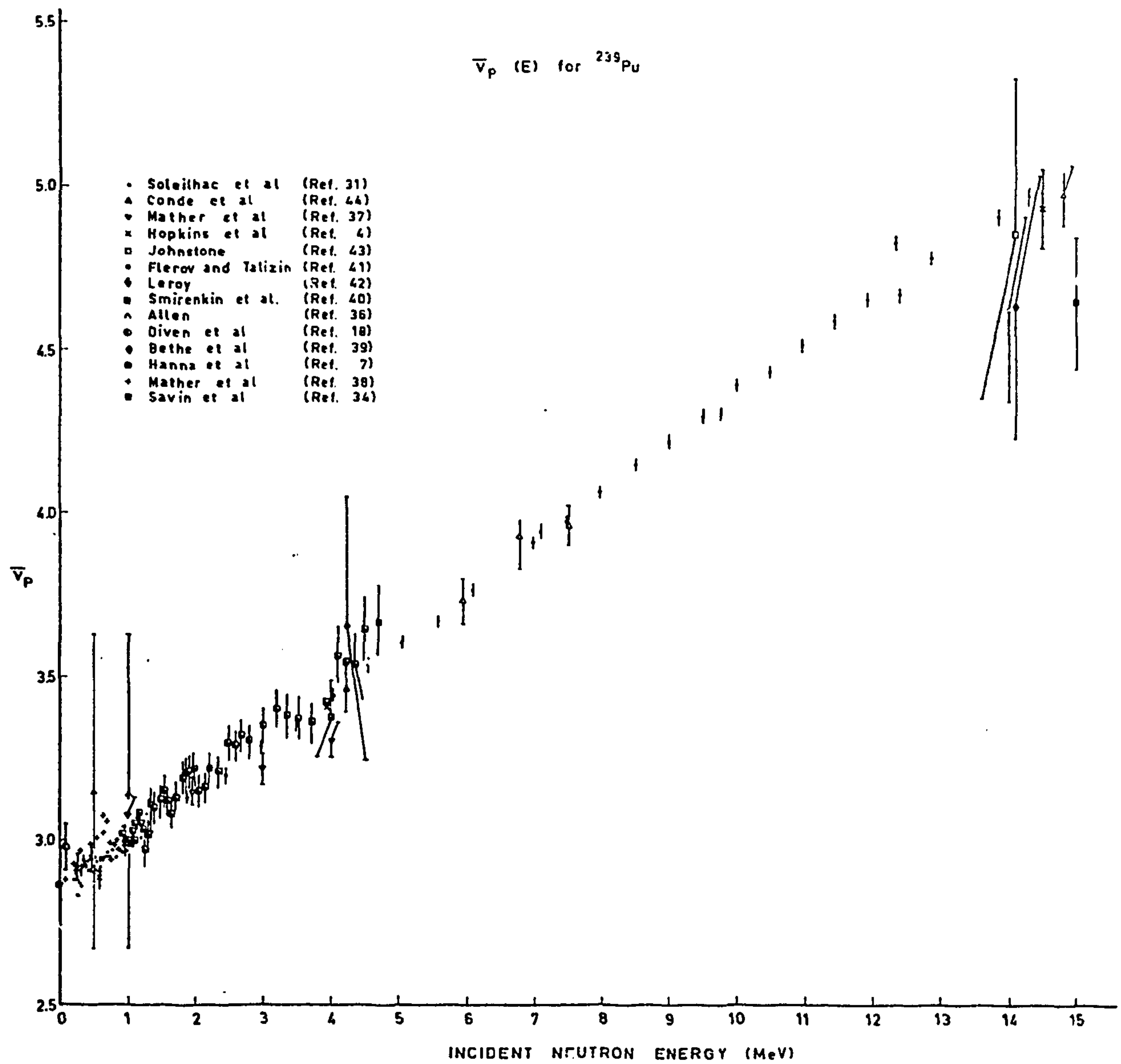
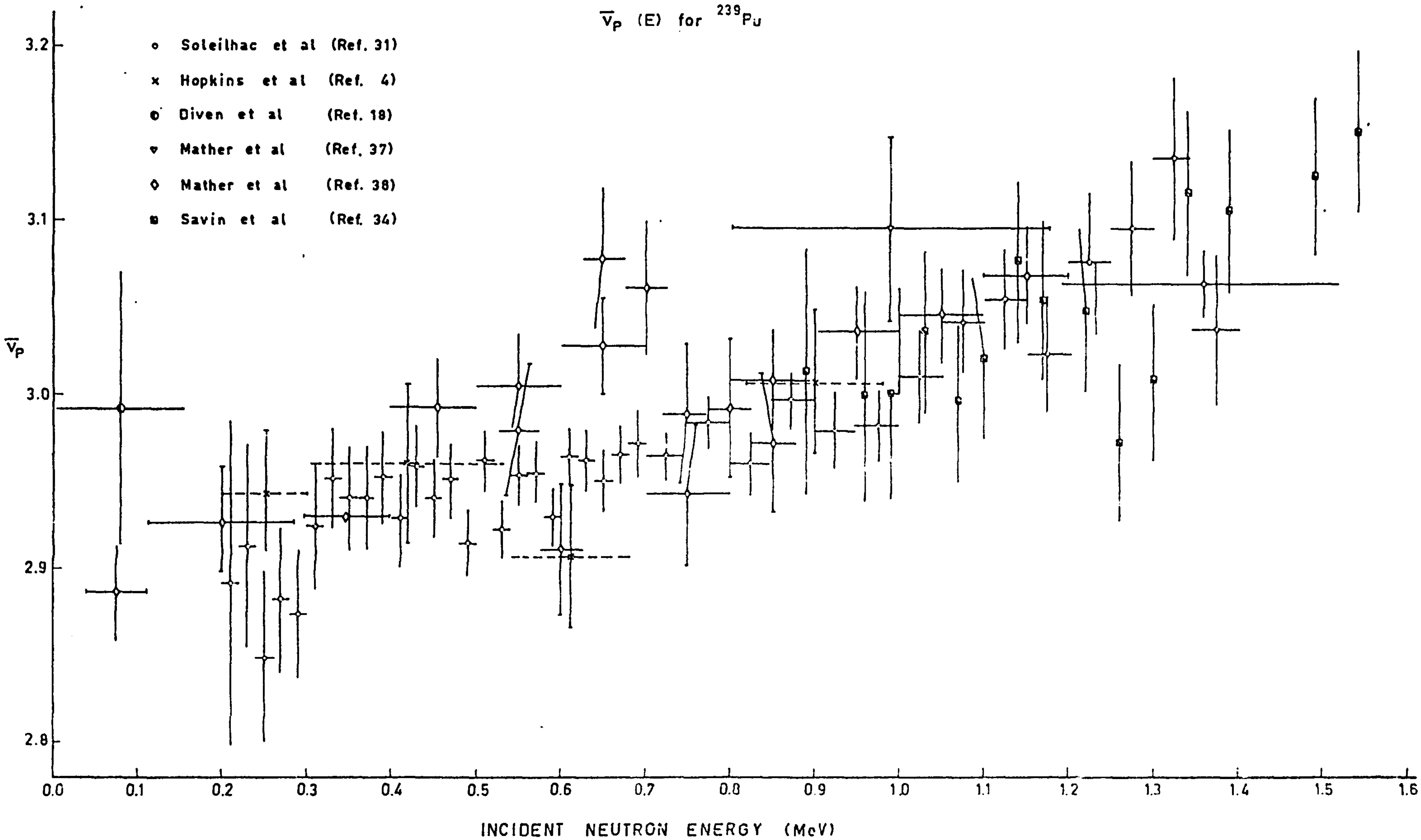

$\overline{\nu}_p$ (E) for $^{239}$Pu
Soleilhac et al (Ref. 31)
Conde et al (Ref. 44)
Mather et al (Ref. 37)
Hopkins et al (Ref. 4)
Johnstone (Ref. 43)
Flerov and Talizin (Ref. 41)
Leroy (Ref. 42)
Smirenkin et al. (Ref. 40)
Allen (Ref. 36)
Diven et al (Ref. 18)
Bethe et al (Ref. 39)
Hanna et al (Ref. 7)
Mather et al (Ref. 38)
Savin et al (Ref. 34)
$\overline{\nu}_p$
5.5
5.0
4.5
4.0
3.5
3.0
2.5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
INCIDENT NEUTRON ENERGY (MeV)

Fig. 2



$\overline{\nu}_P$ (E) for $^{239}$Pu
o Soleilhac et al (Ref. 31)
× Hopkins et al (Ref. 4)
Diven et al (Ref. 18)
Mather et al (Ref. 37)
◇ Mather et al (Ref. 38)
Savin et al (Ref. 34)
$\overline{\nu}_P$
3.2
3.1
3.0
2.9
2.8
0.0
0.1
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
1.6
INCIDENT NEUTRON ENERGY (MeV)


Fig. 3

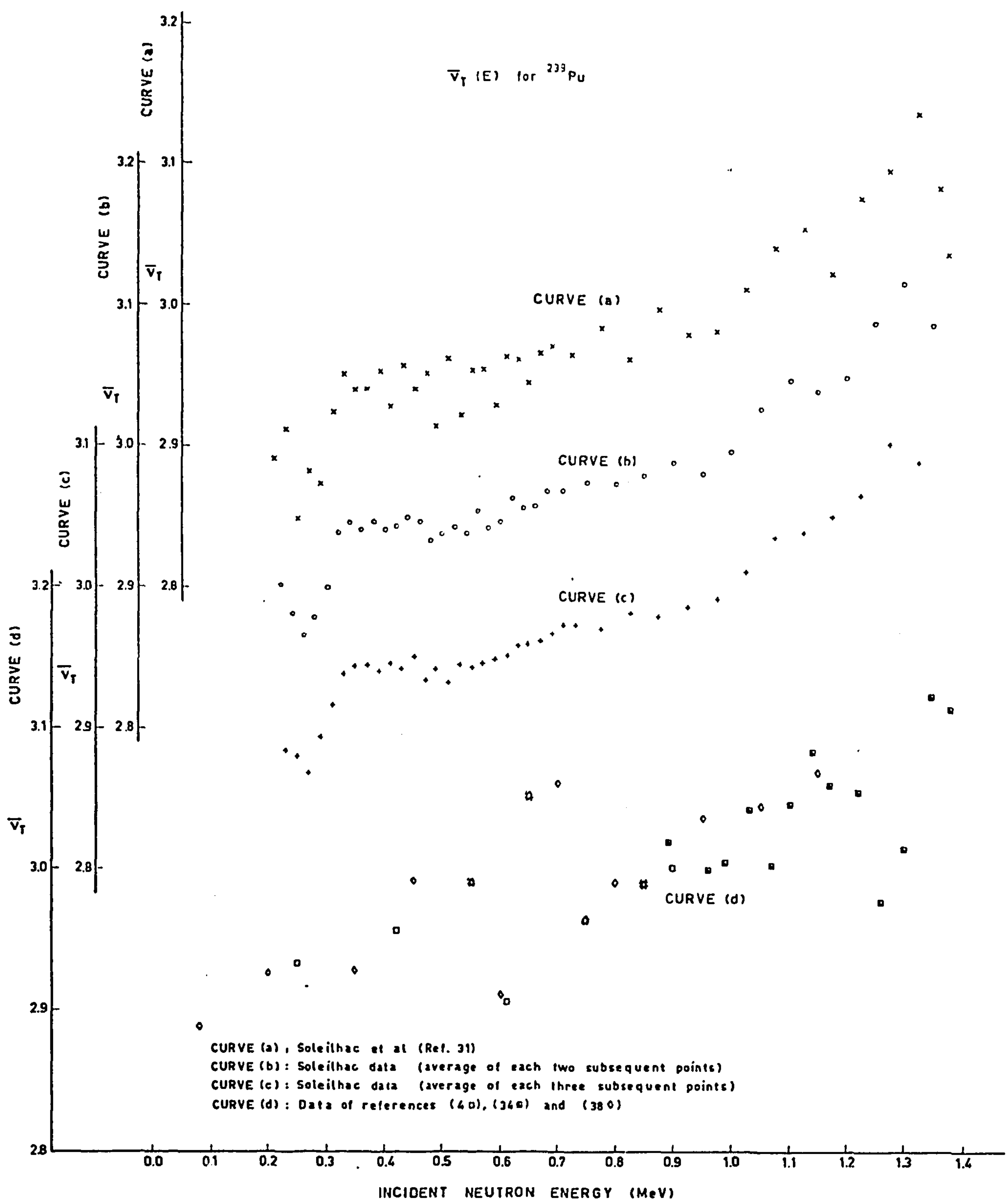

$\bar{\nu}_T$ (E) for $^{239}$Pu
CURVE (a)
CURVE (b)
CURVE (c)
CURVE (d)
$\bar{\nu}_T$
CURVE (a) , Soleilhac et al (Ref. 31)
CURVE (b) : Soleilhac data (average of each two subsequent points)
CURVE (c) : Soleilhac data (average of each three subsequent points)
CURVE (d) : Data of references (40), (34) and (38)
INCIDENT NEUTRON ENERGY (MeV)

Fig.4

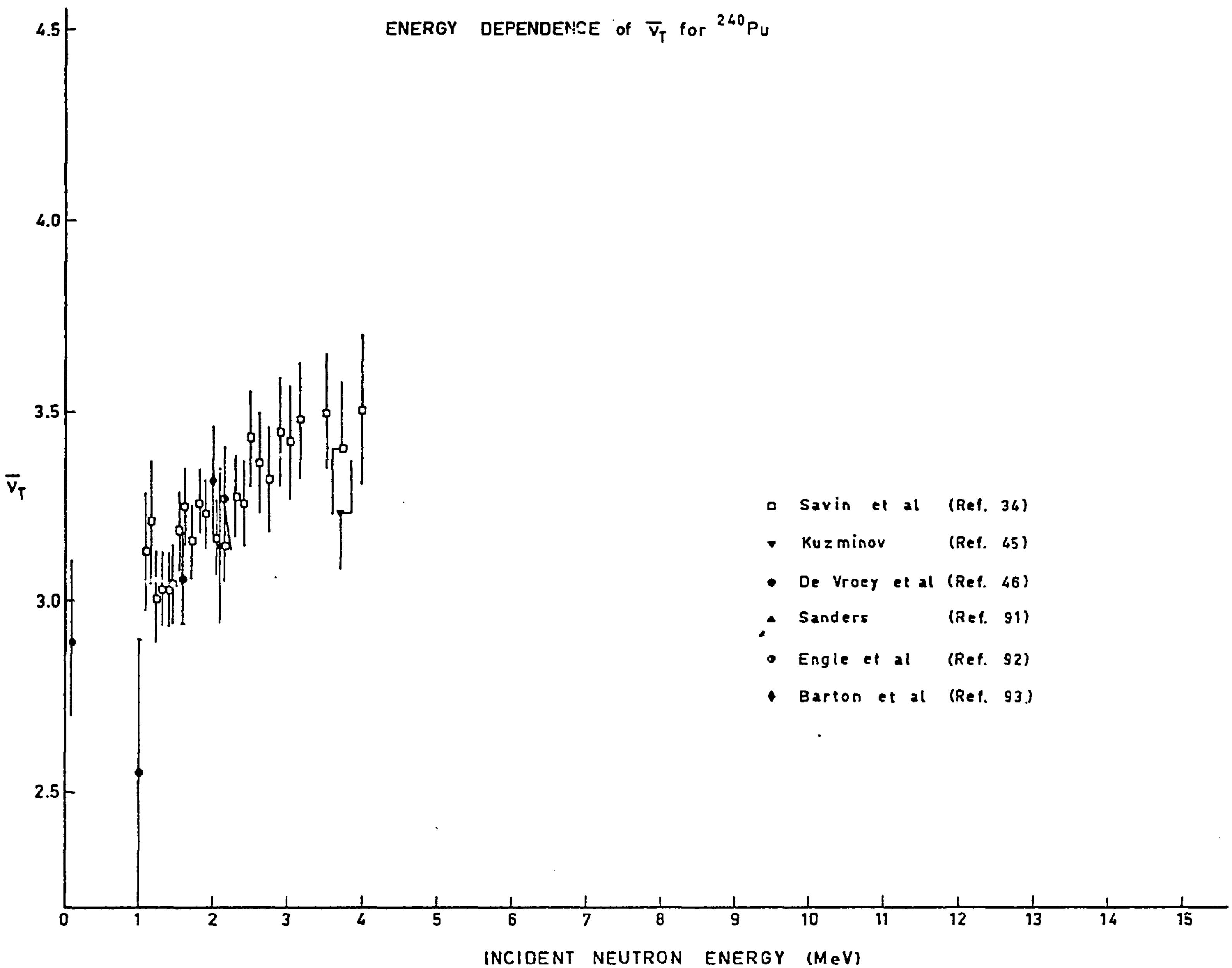
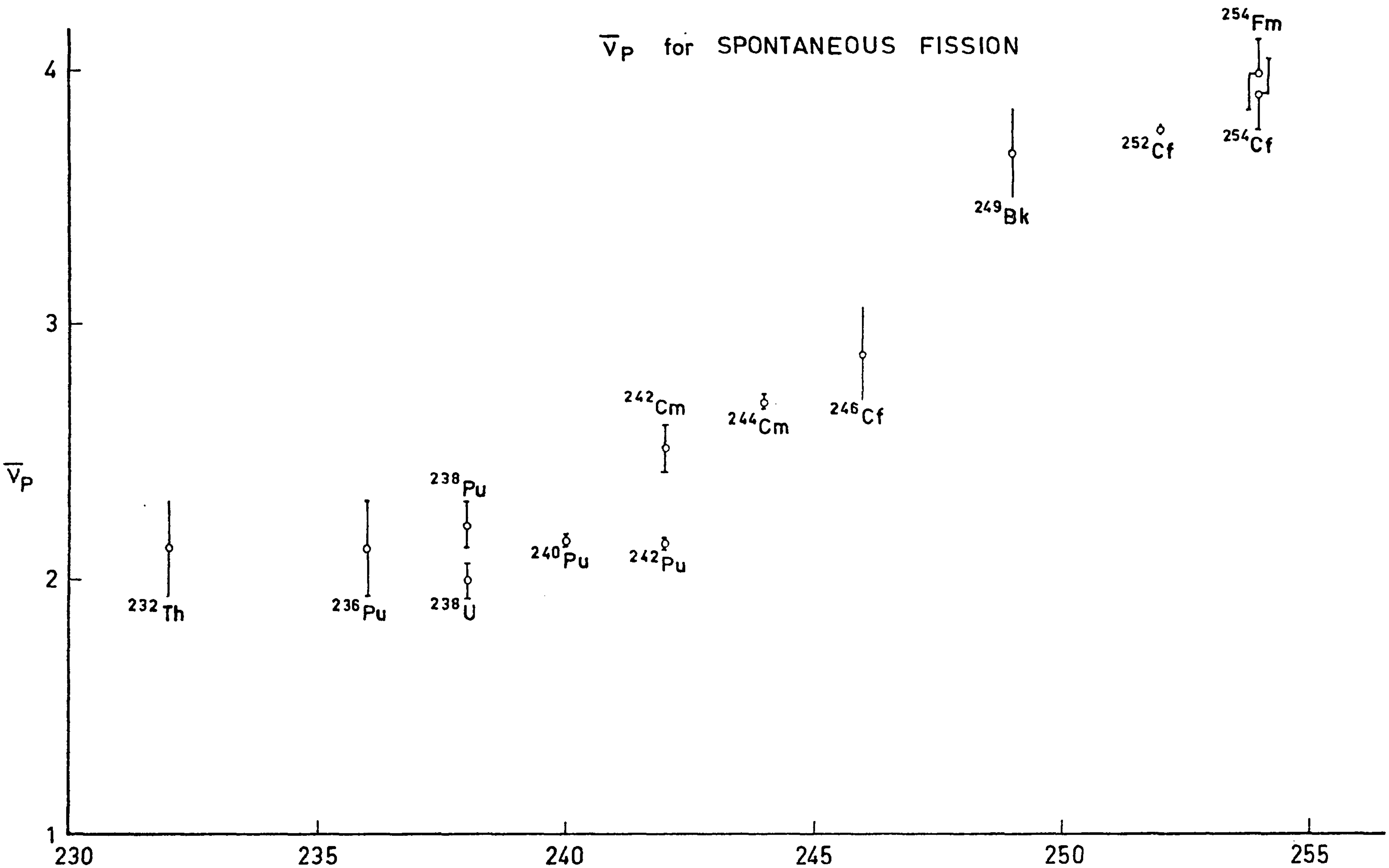

ENERGY DEPENDENCE of $\overline{\nu}_T$ for $^{240}Pu$
4.5
4.0
3.5
3.0
2.5
$\overline{\nu}_T$
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
INCIDENT NEUTRON ENERGY (MeV)
Savin et al (Ref. 34)
Kuzminov (Ref. 45)
De Vroey et al (Ref. 46)
Sanders (Ref. 91)
Engle et al (Ref. 92)
Barton et al (Ref. 93)

Fig.5.



$\overline{\nu}_P$ for SPONTANEOUS FISSION
$\overline{\nu}_P$
MASS NUMBER
1
2
3
4
230
235
240
245
250
255
$^{232}$Th
$^{236}$Pu
$^{238}$Pu
$^{238}$U
$^{240}$Pu
$^{242}$Pu
$^{242}$Cm
$^{244}$Cm
$^{246}$Cf
$^{249}$Bk
$^{252}$Cf
$^{254}$Cf
$^{254}$Fm


Fig. 6.

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