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Test of Pre-ENDF/B-VI Decay Data and Fission Yields

Los Alamos

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by

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ABSTRACT

Pre-ENDF/B-VI nuclear decay data and fission yields have been supplemented by average beta and gamma energies and Pn-values from recent experiments at Studsvik. This data base has been used for a series of summation calculations, and the results have been compared with experimental determinations of decay heat and of delayed-neutron effects. The comparisons are limited to thermal fission of ^{235}U and ^{239}Pu and to fast fission of ^{238}U. The general impression of the comparisons is that the data base does reproduce experimental results satisfactorily (with a few exceptions) within the combined limits of error of the experimental determinations and the calculation.

I. INTRODUCTION

Important input data in the calculation of the decay heat in nuclear fuel by the summation method are the average beta and gamma energies emitted per decay of the fission products. The origin of these data are:

(a) decay schemes constructed from spectroscopic investigations;

(b) direct determinations of the energies;

(c) (for nuclides with incomplete decay schemes) partial experimental information used to complement a theoretical calculation;

(d) (for nuclides without experimental information) calculations using nuclear theory.[1-4]

Apart from the average energies, the inventory of fission products, and its variation with time, must be known. This requires the knowledge of the fission yields and nuclear decay data such as half-lives, branching ratios, and Pn-values.

The aim of the present work is to test pre-ENDF/B-VI tables of fission yields and decay data, and data from other sources, by comparing calculated decay heat curves with integral determinations. The equilibrium number of delayed neutrons is also calculated and compared with experimental data. This is a sensitive test both of the Pn-values and of the fission yields, especially the odd-even effects (most of the delayed neutrons are emitted from odd-Z nuclides).

The comparisons have been limited to thermal fission of ^{235}U and ^{239}Pu and to fast fission of ^{238}U.

II. INPUT DATA

A. Average Beta Energies

Spectroscopists rarely measure complete beta spectra. Instead, beta spectra are evaluated from level schemes deduced from gamma measurements where the beta branches are obtained as differences between the gamma transitions depopulating a level and those feeding it. The resulting beta spectrum is then evaluated by summing the spectra corresponding to all the beta branches. Even if the level scheme, and thus also the beta branches, is very well known, this method has an inherent weakness. The shape of forbidden beta spectra is seldom known. The error introduced is expected to be small, but a realistic error estimate is difficult to give.

More serious errors may arise for the following reasons:

1. The level scheme may be incorrect because of erroneous placements of gamma transitions, or gamma rays not put into the decay scheme. This leads to an error of the beta energy that is very difficult to quantify. It may also be wrong because some gamma rays are missing, usually high-energy ones leading to overlooking highly excited levels. This means that low-energy beta branches to these levels will be omitted. The average beta energy will then become too high and the average gamma energy (per decay) too low.

2. If only gamma spectra have been measured, ground-to-ground state beta transitions have to be deduced from spin and energy arguments. Unless the spins are such as to effectively prevent these transitions, such estimates are often quite inaccurate.

Most of the above-mentioned difficulties are avoided if the complete beta spectrum is measured. Such an experiment has been carried out[5] giving average beta energies, which should be more accurate than those deduced from incomplete decay schemes and comparable to results for nuclides with well-known decay schemes.

For nuclides with incomplete decay schemes, the experimental information can still be used to back-up a theoretical determination of the average beta energy. If experimental information is completely lacking, we have to rely on theoretical calculations solely. Such a calculation can be carried out using the gross beta theory[1-3] or other models.[4] In the present work we use the gross theory with parameters determined, as described in Ref. 3.

B. Average Gamma Energies

If a complete set of energies and branching ratios for the gamma rays emitted in the decay of a nuclide is known, the evaluation of the average gamma energy per decay is straightforward.

The only thing to bear in mind is that there is a systematic component in the branching ratio error, *i.e.*, the absolute determination of the branching ratio of a particular gamma ray used as reference. The statistical error may well be below 1%, but the absolute branching ratio is seldom known to be better than 10% for short-lived nuclides far from stability.

For less well studied nuclides, the gamma spectrum may not be complete. Most often, high-energy gamma rays are missing. A lack of part of the gamma rays will lead to an average gamma energy per decay that is too low.

"Direct" determinations of gamma spectra and the evaluation of average gamma energies are also reported in Ref. 5. They were carried out in an attempt to avoid the difficulty with incomplete gamma spectra. The main source of error is, again, the absolute determination of a particular branching ratio.

For nuclides with only incomplete experimental information, or without any information at all, theoretical models have to be used in a way similar to that for average beta energies. Nearly half of the known radioactive products require some degree of theoretical supplement for spectra and average energies.

C. Fission Yields

The set of pre-ENDF-6 independent fission yields available for the work[6] was incomplete in the sense that the yields of about 40 isomeric states were missing. The set was therefore completed in the following way. The isotopic yield was retained but the isomeric splitting was done according to experimental results[7] or, for isomeric pairs without experimental determinations, using the model by Madland and England.[8] The nuclides corrected in this way are listed below (for the model calculation, the Jrms value 7.5 was used):

^{74m}Ga (3) - ^{74}Ga (1+):	Model split 85:15
^{78m}As:	Yield put = 0
^{79m}Ge (7/2+) - ^{79}Ge (1/2-):	Experimental split 100 (is):0 (gs)
^{79m}Kr - ^{79}Kr:	Both yields were put = 0
^{81m}Ge (1/2+) - ^{81}Ge (9/2+):	Experimental split 19:81
^{85m}Sr (1/2-) - ^{85}Sr (9/2+):	Model split 19:81
^{86m}Rb (6-) - ^{86}Rb (2-):	Model split 64:36
^{90m}Y (7+) - ^{90}Y (2-):	Model split 59:41
^{90m}Zr (5-) - ^{90}Zr (0+):	Model split 81:19
^{91m}Y (9/2+) - ^{91}Y (12):	Model split 81:19
^{93m}Y (9/2+) - ^{93}Y (1/2-):	Model split 81:19
^{97m}Y (9/2+) - ^{97}Y (1/2-):	Model split 81:19

^{100m}Y (3+) - ^{100}Y (1+):	Model split 85:15
^{102m}Nb(?) - ^{102}Nb (?):	Model split ~80:~20. Spins unknown. gs-spin extrapolated to 1+
^{104m}Nb(?) - ^{104}Nb (?):	Model split ~80:~20. Spins unknown. gs-spin extrapolated to 1 +
^{108m}Ag (6+) - ^{108}Ag (1+):	Model split 70:30
^{109m}Ru (?) - ^{109}Ru (?):	Yield split 50:50
^{109m}Ag (7/2+) - ^{109}Ag (1/2-):	Model split 87:13
^{114m}Ag (6+) - ^{114}Ag (1+):	Model split 70:30
^{117m}Sn (11/2) - ^{117}Sn (1/2+):	Model split 77:23
^{120m}Ag (6-) - ^{120}Ag (3+):	Experimental split 85:15
^{121m}Cd (11/2-) - ^{121}Cd (1/2+):	Experimental split 89:11
^{124m}In (8-;3.70s) - ^{124}In (3+; 3.09s):	Experimental split 86:14
^{126m}In (8-;1.65s) - ^{126}In (3+;1.60s):	Experimental split 42:58
^{128m}In (8-;0.72s) - ^{128}In (3+;0.84s):	Experimental split 30:70
^{129m}Sb (?) - ^{129}Sb (7/2+):	Yield split 50:50
^{129m}Xe (11/2-) - ^{129}Xe (1/2+)	Model split 77:23
^{130m}In (2 states;0.53 s) - ^{130}In (1-3;0.33s):	Experimental split 68:32
^{130m}Sn (7-) - ^{130}Sn (0+):	Experimental split 13:87
^{131m}In (1/2-) - ^{131}In (9/2+):	Experimental split 83:16
^{131m}Sn:	Yield put = 0
^{132m}I (8-) - 132I (4+):	Model split 43:57
^{133m}I (19/2-) - ^{133}I (7/2+):	Experimental split 6.6:93.4
^{134m}Sb (0-) - ^{134}Sb (7-):	Model split 30:70
^{134m}Cs (8-) - ^{134}Cs (4+):	Model split 43:57
^{135m}Cs (19/2-) - ^{135}Cs (7/2+):	Model split 38:62
^{136m}Cs (6-) - ^{136}Cs (2-):	Model split 64:36
^{136m}Ba (7-) - ^{136}Ba (0+):	Model split 70:30
^{142m}Pr (5-) - ^{142}Pr (2-):	Model split 70:30
^{146m}La (6) - ^{146}La (2-):	Experimental split 5.5:94.5 (from Ref. 9)
^{148m}Pr (4) - ^{148}Pr (1-):	Experimental split 12:88 (from Ref. 10)
^{154m}Eu (8-) - ^{154}Eu (3-):	Model split 47:53

D. Pn-Values

An extensive program for the determination of Pn-values has recently been started at Studsvik.[11] About half the program has been carried out including Pn-value determinations for almost all precursors in the mass range 79-100. Precursors in the heavy mass range will be investigated later. An analysis of the precursors around the light-mass fission peak has been carried through, and the results are listed in Appendix A. The analysis is somewhat preliminary, but great changes are not expected. Using the new results and data available in the literature,[12] a set of Pn-values has been prepared for testing. Only this particular set of evaluated measurements was used in testing.

The delayed-neutron study has also yielded a set of average neutron energies that are tabulated in Appendix B.

E. Half-Lives

The delayed-neutron experiment referred to above has led to improved half-lives for many of the precursors, and a list of "best choice" half-lives has also been prepared (Appendix C).

III. RESULTING DECAY HEAT CURVES

A. ^{235}U

When comparing decay heat curves obtained by the summation method with integral determinations, one difficulty arises in that the latter deviate appreciably from each other. Thus, we do not have a globally acceptable benchmark with which to compare. In the present work, the comparisons have been done with the three most recent integral determinations: the Tokyo experiment,[13] the Oak Ridge experiment,[14] and the Studsvik experiment.[15] Those were all done measuring beta and gamma spectra from irradiated samples. They are therefore similar to the summation calculations that are also based on beta and gamma measurements. In addition, the summation calculations have also been compared with the calorimetric measurements of the total power produced by the decaying fission products, carried out at Los Alamos by Yarnell and Bendt.[16]

In the calculations we found it interesting to trace the contributions from the different categories of nuclides listed as Groups (a)-(d) in the Introduction. These groups have therefore been flagged in the calculations in the following way:

Flag 0: Average energy obtained from decay schemes;[3]

Flag 1: Average energy "directly" measured at Studsvik;[5]

Flag 2: Average energy from gross beta theory complemented by incomplete experimental information;[3]

Flag 3: Average energy from gross beta theory.[3]

In the figures, the bottom curve corresponds to Flag 0, the next one to Flags 0+1, the third one to Flags 0+1+2, and the top one to Flags 0+1+2+3, *i.e.* to the sum of all contributions. The contribution from a particular group of nuclides is then just the difference between consecutive curves.

A list of the nuclides and their respective flags (both for average beta energy and for average gamma energy) is given in Appendix D. The actual energies used are those tabulated in Appendix C of Ref. 3, with supplements from the Studsvik measurements in Ref. 5.

The calculation also yields the uncertainty of the points. These uncertainties have not been plotted, as they would make the figures cumbersome to read. Only the errors of the integral experiments are retained. It should be mentioned, however, that the uncertainties of the summation calculation are typically around 3% and thus smaller than, or of the same order, as the integral experiment errors.

The inventory calculations were carried out using the computer code INVENT.[17] It has been shown in a benchmark experiment comparing codes[18] that this code gives results almost identical to the CINDER-10 code[19] (and also to other frequently used codes).

The comparison with the Tokyo experiment is shown in Figs. 1a-1c for the beta heat, the gamma heat, and the total heat, respectively. Fig. 1a shows a very good agreement for the beta heat. The calculated curve falls everywhere within the error limits of the experimental one. The figure also shows that the experimental basis for the calculation is very satisfactory, the curve flagged 0+1 corresponding to about 90% of the total effect. The remaining part is almost completely accounted for by Group (c)-nuclides, with experimental evidence supporting theory. Only a very minute amount corresponds to Group (d), i.e., to nuclides for which experimental information is lacking. The number of nuclides in Group (d) is large, but their contribution is relatively small.

The gamma heat (Fig. 1b) is almost as satisfactory. The calculated curve falls within the error limits of the integral determination over practically the whole range of cooling times. The Flags 0+1 curve gives a contribution of about 80% of the heat, which is somewhat less than for the beta heat. Again, nuclides without experimental information give a small contribution to the heat.

Because both the beta and gamma parts of the calculated decay heat agree with the integral determination, this must also be the case for the total heat. This is seen in Fig. 1c.

The comparisons with the Oak Ridge experiment are shown in Figs. 2a-2c. The integral measurements extend to shorter cooling times than the Tokyo experiment. Figure 2a shows a good agreement all the way down to the shortest cooling time used (2.7 s) for the beta part of the decay heat.

For the gamma part, the agreement is not as good, with deviations both at short cooling times (summation calculation is low) and in the range 100-1000 s where the summation calculation gives a higher result. It should be noted that the Tokyo and Oak Ridge experiments deviate significantly in the latter cooling-time range.

Figure 2c shows agreement between the Oak Ridge experiment and the summation calculation, within limits of error, over the entire cooling-time range measured.

The comparisons with the Studsvik results are shown in Figs. 3a-3c. The beta curves agree. The integral gamma decay heat (and also the total heat) is higher than the summation calculation at cooling times below 100 s. The discrepancy is not serious, however, and the curves agree within combined limits of error.

In order to compare with the calorimetric measurement, the summation calculation was carried out using the same irradiation time (20 000 s) as used by Yarnell and Bendt. The curves are plotted *vs* cooling time as decay heat divided by the average fission rate during the irradiation. Both logarithmic plots (Fig. 4a), and linear plots (Fig. 4b) are shown. The figures show a good agreement with a small deviation at the shortest cooling times (Fig. 4b).

A more sensitive way to compare experiment and calculation is to plot the ratio between them *vs* cooling time. This has been done for the total decay heat. The results are shown in Figs. 5a-5d for the Tokyo, the Oak Ridge, the Studsvik, and the Los Alamos experiments, respectively. The limits of error given in the figures correspond to the combined experimental error and uncertainty of the calculation.

Figures 5a-5c clearly demonstrate the agreement between the summation calculation and the spectroscopic decay heat determinations. Also, the agreement with the calorimetric measurement is satisfactory.

B. ^{239}Pu

In the case of ^{239}Pu, the experimental basis for the decay heat calculation is not so dominant as for ^{235}U, dropping from about 90% of the effect to about 80%. Thus, the theoretical treatment of the part of the nuclides with incomplete experimental decay data gets more important. The gross beta theory seems to give very satisfactory results, as seen in Fig. 6a where it is is found that the summation calculation agrees with the Tokyo experiments within limits of errors over the whole cooling-time range measured in the case of the beta part of the decay heat.

For the gamma part (Fig. 6b), the agreement is also good except for the cooling-time range 50-500 s, where the summation calculation gives results below the measured curve. This effect also shows up for the total decay heat (Fig. 6c), although to a lesser degree. In that case the curves would agree within combined limits of error.

For ^{239}Pu, the summation calculation agrees better with the Oak Ridge experiments than with the Tokyo ones (Figs. 7a-7c). The beta curve (Fig. 7a) agrees well over the entire cooling-time range measures, which extends down to 2.7 s. The gamma curve (Fig. 7b) shows a small deviation in the same range as the Tokyo experiment, but is much less pronounced, and within the combined limits of error. The same applies to the total decay heat curve (Fig. 7c).

A comparison with Studsvik results is shown in Figs. 8a-8c. The experimental curves cover the cooling-time range from 200 to 10,000 s. The beta curves agree, while the integral gamma curve (and also the total) is higher than the summation calculation for cooling times around 1000 s.

The comparison with the calorimetric experiment is shown in the same way as for ^{235}U (Figs. 9a and 9b). Here there is a significant discrepancy over a long cooling-time range--from the shortest ones measured to about 1000 s (cf. Fig. 9b). This is still a puzzle. We have good agreement for ^{235}U but not for ^{239}Pu.

In order to amplify the differences, the total heat ratios have been plotted as for ^{235}U (Figs. 10a-10d). In this case, all the spectroscopic experiments indicate a deficiency of the summation calculation in the time range 1000-10,000 s. The experimental points there are higher than the summation calculation by 5%. The calorimetric determination gives a different picture. It is consistently higher than the summation calculation by about 10% over a cooling-time range up to about 3000 s; then the curves approach each other.

For fast fission of ^{238}U, we have a set of integral beta and gamma measurements from Tokyo and, in addition, gamma measurements from Studsvik. A comparison with the Tokyo results is done in Figs. 11a-11c for the beta heat, the gamma heat, and the total heat. The nuclides with complete experimental basis correspond to between 70 and 80% of the heat for both beta and gamma.

There is agreement between the integral experiment and the summation calculation over the whole cooling-time range measured, except for a small deficiency of the summation calculation of the gamma heat around 1000 s (however, within the combined limits of error). Unfortunately, the Tokyo experiment does not cover short cooling times; it is not possible to verify whether the large beta effect at cooling times below 10 s, predicted by the summation calculation, and to a large extent caused by Flag 3 nuclides (*i.e.*, nuclides with no experimental basis), is real.

The comparison with the Studsvik results on the gamma heat is shown in Fig. 12. The Studsvik curve is higher than the summation curve for cooling times below 100 s (a tendency also apparent in the corresponding Tokyo curve).

IV. DELAYED NEUTRONS

A. Neutron Yields

The second kind of test that has been carried out is a calculation of the delayed-neutron yield at equilibrium conditions (irradiation time: 10 000 s, cooling time: 0). The new set of Pn-values referred to above was used, and the fission yield sets were the pre-6 ones completed as discussed above. The results are as follows:

^{235}U:	162.6 ± 7.5 neutrons per 10 000 fissions;
^{238}U:	365 ± 31 neutrons per 10 000 fissions;
^{239}Pu:	68.3 ± 3.0 neutrons per 10 000 fissions.

These figures should be compared with the recommended yields (based on experiments) 162 ± 5 for ^{235}U, 439 ± 10 for ^{238}U, and 63 ± 4 for ^{239}Pu.[20] The delayed-neutron yield agrees with the recommended yield within limits of error for ^{235}U and ^{239}Pu. It is low by about two standard deviations for ^{238}U.

The contributions (with uncertainties) of the various precursors to the delayed-neutron yield have been tabulated in Appendix E. It is seen that the top ten precursors contribute more than 70% of the number of delayed neutrons. It is also interesting to note that for ^{239}Pu, almost one neutron out of four originates from a single precursor--^{137}I.

B. Neutron Decay Curves

The variation of delayed neutrons with cooling time can easily be calculated. Such curves are shown for thermal fission of ^{235}U and an irradiation time of 10 000 s in Fig. 13a (decay time is shorter than 12 s) and Fig. 13b (decay time is up to 600 s). The results can also be directly compared with experimental curves. This is shown for burst fission of ^{235}U in Figs. 14a and 14b, where the comparison is done with Keepin's relative experiment.[21] The curves agree well over the whole range measured.

C. Average Neutron Energies

As the mean neutron energy is known for all important precursors, it is also possible to calculate the average delayed-neutron energy as a function of cooling time. Such a curve is shown in Fig. 15, and it is valid for ^{235}U, irradiated long enough to ensure equilibrium. The average energy is about 450 keV at equilibrium. It then decreases with cooling time to eventually reach the value for ^{87}Br: 200 keV. The decrease is not monotonic. The curve is nearly constant for the first 50 seconds before starting to fall.

V. CONCLUSIONS

The following conclusions can be drawn from the comparison between experimental measurements and summation calculations using the set of data presented or referenced above.

For ^{235}U the decay heat curves from the summation calculation agree within combined limits of error with all integral determinations used in the comparisons, *i.e.*, the Tokyo,[13] Oak Ridge,[14] and Studsvik[15] spectroscopic determinations and the Los Alamos calorimetric measurements.[16] This shows that the fission yield set and the average beta and gamma energies are well described in the data base, at least for those fission products that are the main contributors to the decay heat. The delayed-neutron comparison also shows that the set of Pn-values is acceptable.

For ^{239}Pu the situation is good for the beta part of the decay heat. However, the summation calculation does not reproduce the gamma part for cooling times around 1000 s, (clearly shown in the Tokyo and the Studsvik experiments). It is also true that the calorimetric determination of the total decay heat is significantly higher than that which the summation calculation predicts for all cooling times up to about 3000 s. The results for the gamma heat could possibly be erroneous average gamma energies (or yields) in a part of the fission product range where the yields are larger for ^{239}Pu than for ^{235}U, *i.e.*, in the mass range a few units above mass 100. The good agreement of the neutron yields indicates that the fission yields are satisfactory for the bromine, rubidium, and iodine isotopes. The seemingly systematic discrepancy between the calorimetric measurement and the summation calculation of the total heat remains unexplained.

For ^{238}U the agreement between the summation calculation and the integral measurement is acceptable, although both the Tokyo experiments and the one at Studsvik give slightly higher values for the gamma heat in the cooling-time range between 10 and 100 s than does the summation calculation. This, and the fact that the calculation of the neutron yield gives a low result, indicates that the fission yields must be regarded with some care.

Final Comment

Some readers of this document may wonder how measured results compare with the final ENDF/B-VI data. The data base used here is the closest available to the currently incomplete ENDF/B-VI, with the exception of some decay energies in Ref. 5 and Pn values in Appendix A and Ref. 12. Some, though not all, of the measured decay energies from Studsvik were already incorporated into the ENDF/B-VI library.

A subsequent document will provide final comparisons, and Ref. 3 will provide spectral comparisons based on the current ENDF/B library.

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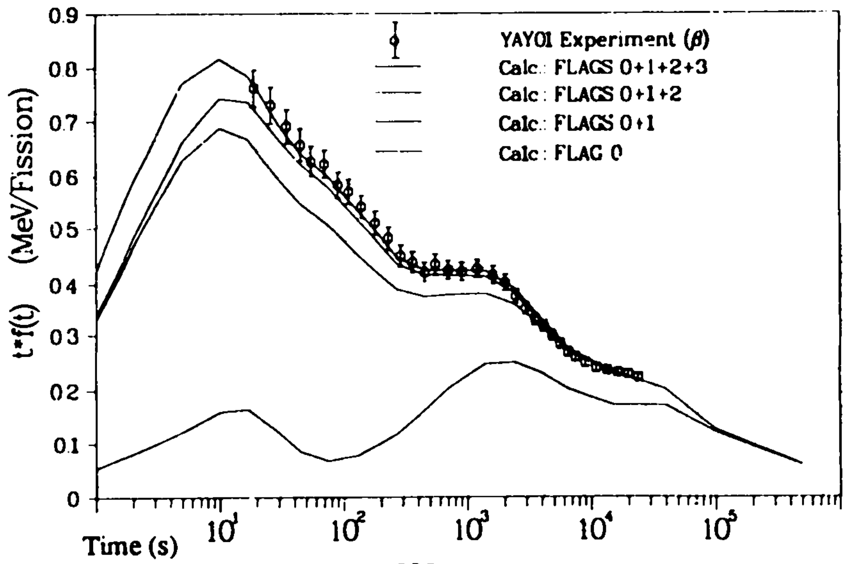

Fig. 1a. Beta decay energy after ^{235}U fission (pulse) [YAYOI experiment].

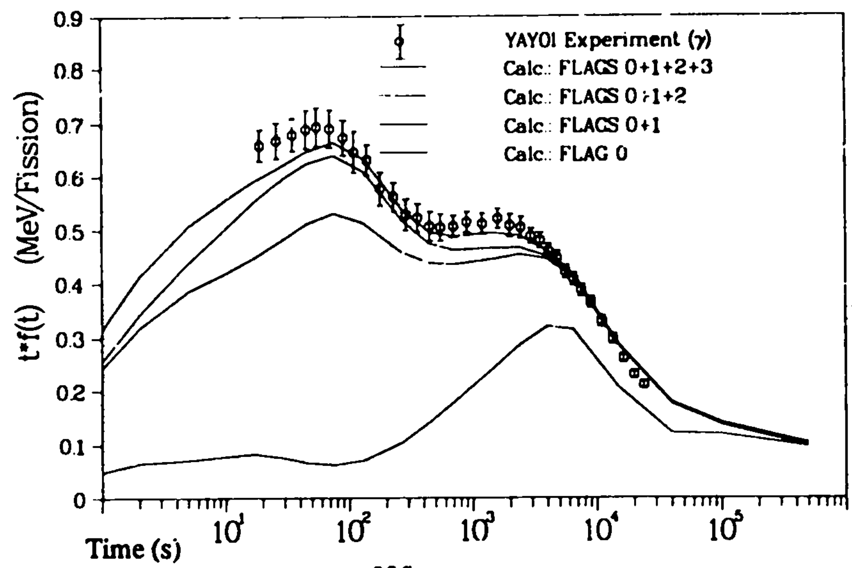

Fig. 1b. Gamma decay energy after ^{235}U fission (pulse) [YAYOI-Tokyo-experiment].

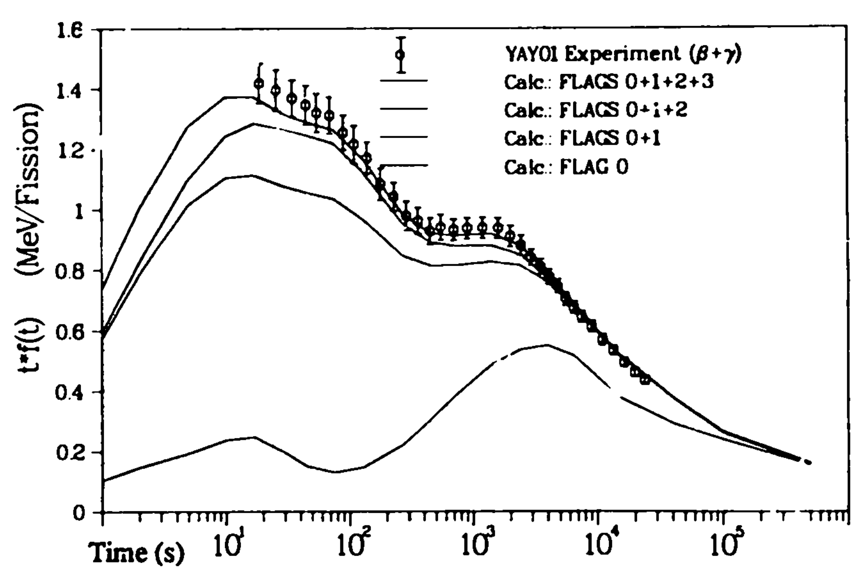

Fig. 1c. Total decay energy after ^{235}U fission (pulse) [YAYOI-Tokyo-experiment].

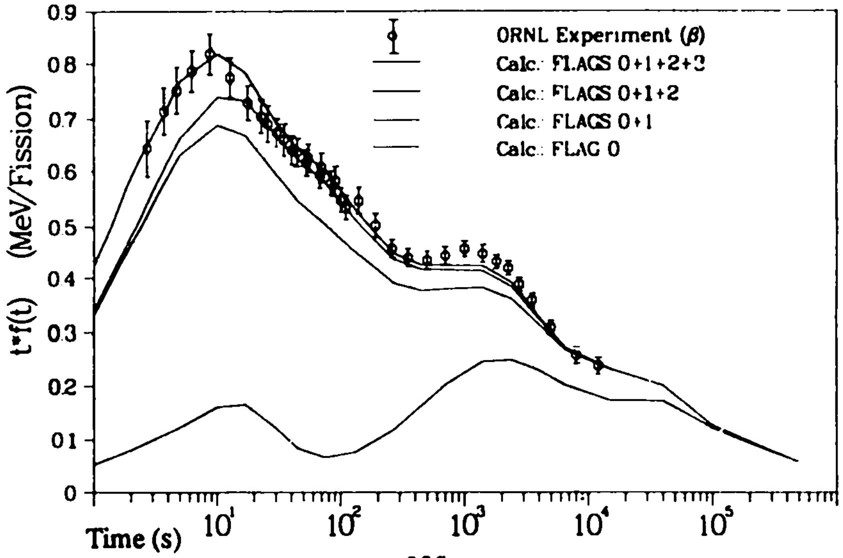

Fig. 2a. Beta decay energy after ^{235}U fission (pulse) [ORNL-experiment].

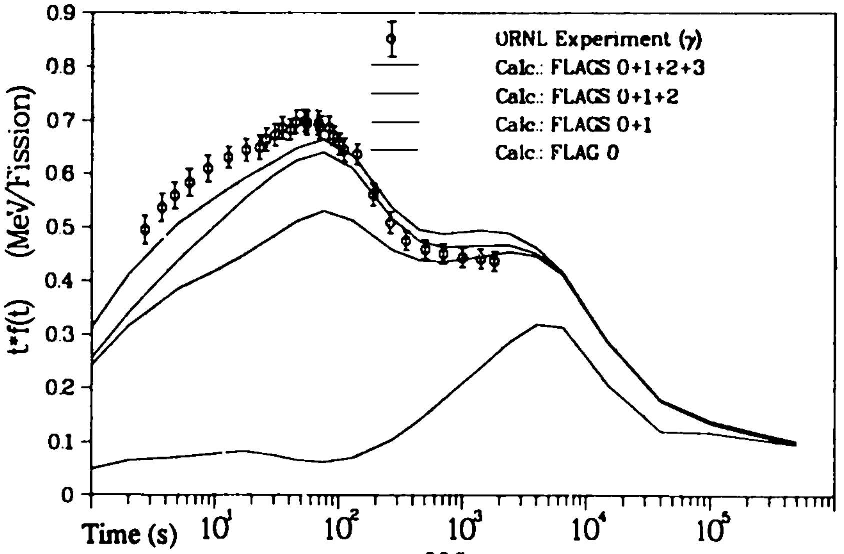

Fig. 2b. Gamma decay energy after ^{235}U fission (pulse) [ORNL-experiment].

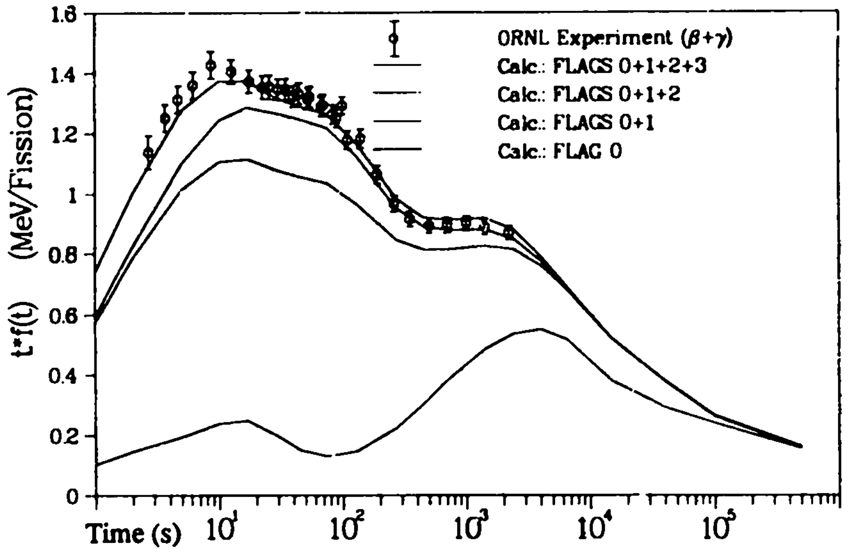

Fig. 2c. Total decay energy after ^{235}U fission (pulse) [ORNL-experiment].

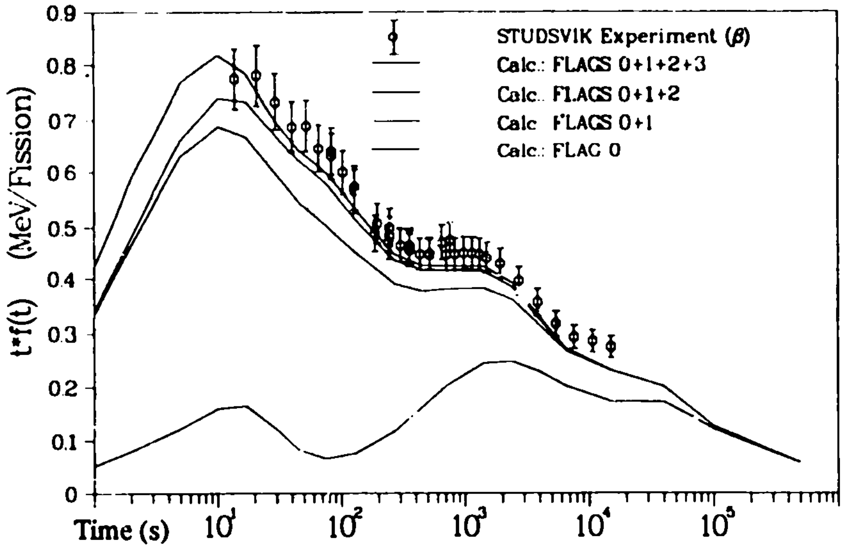

Fig. 3a. Beta decay energy after ^{235}U fission (pulse) [Studsvik-experiment].

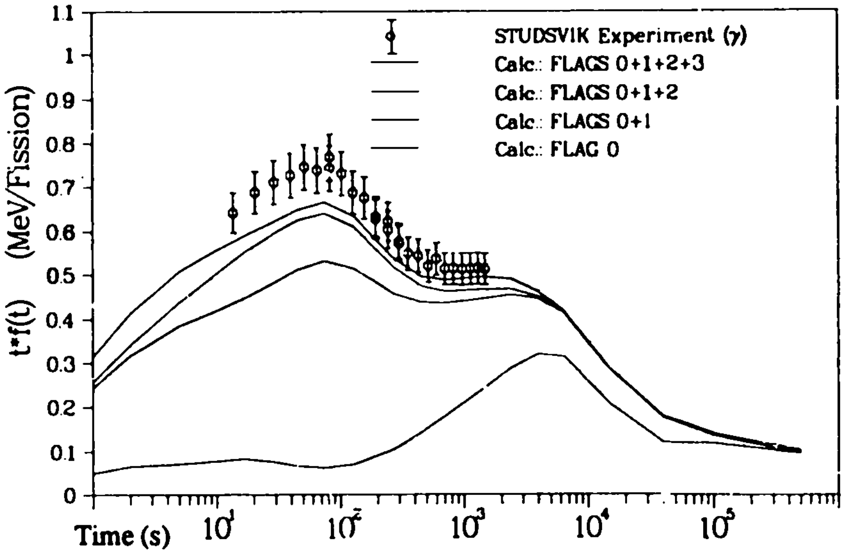

Fig. 3b. Gamma decay energy after ^{235}U fission (pulse) [Studsvik-experiment].

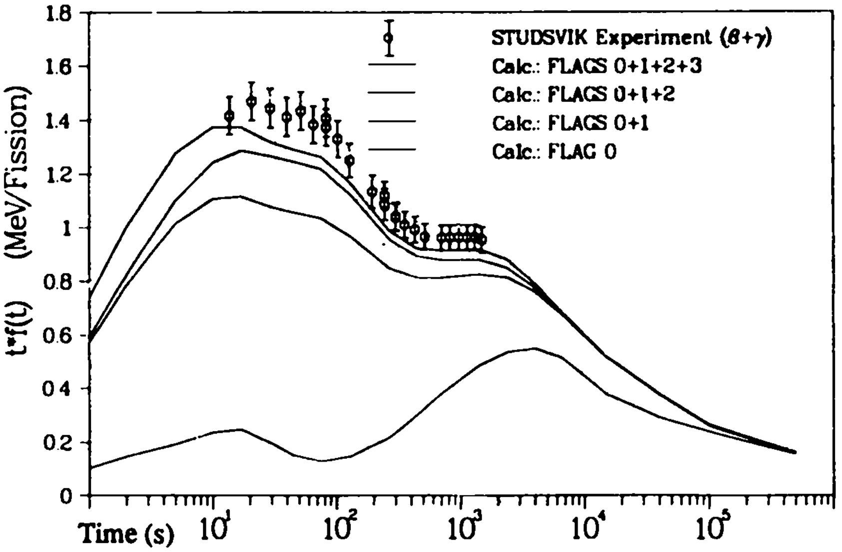

Fig. 3c. Total decay energy after ^{235}U fission (pulse) [Studsvik-experiment].

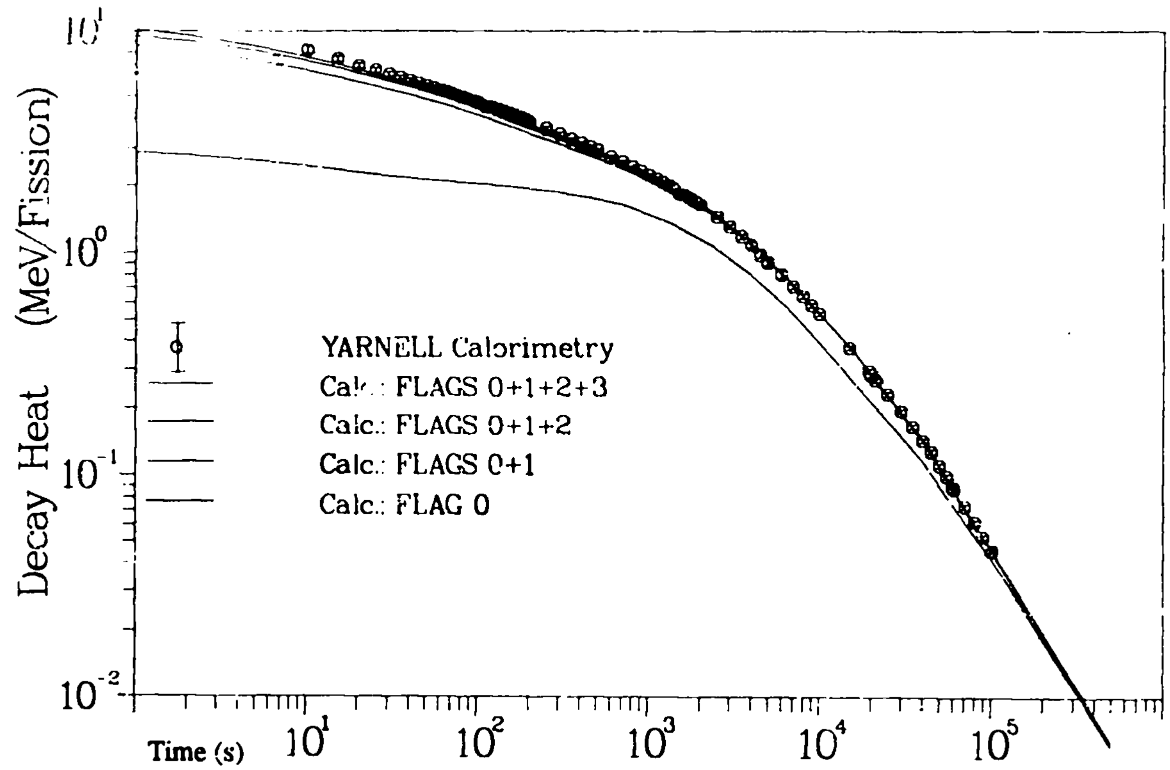

Fig. 4a. Total decay energy after ^{235}U fission (20 000 s) [log, log].

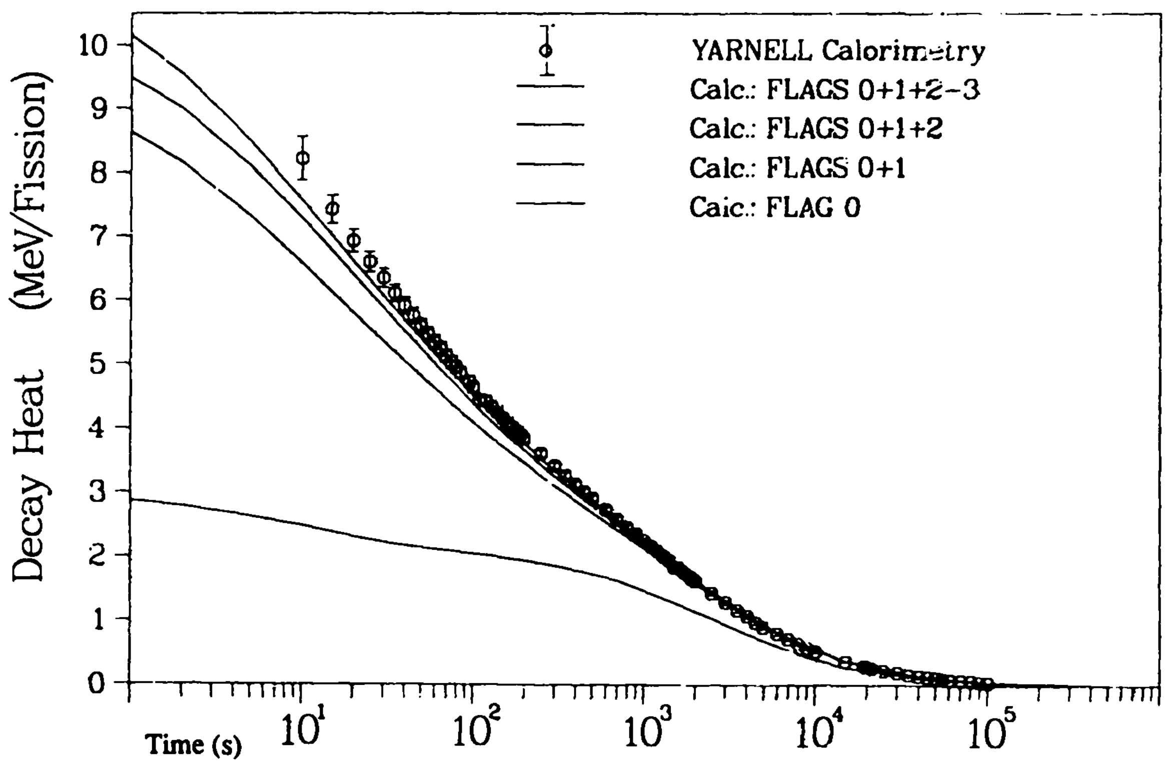

Fig. 4b. Total decay energy after ^{235}U fission (20 000 s) [lin, log].

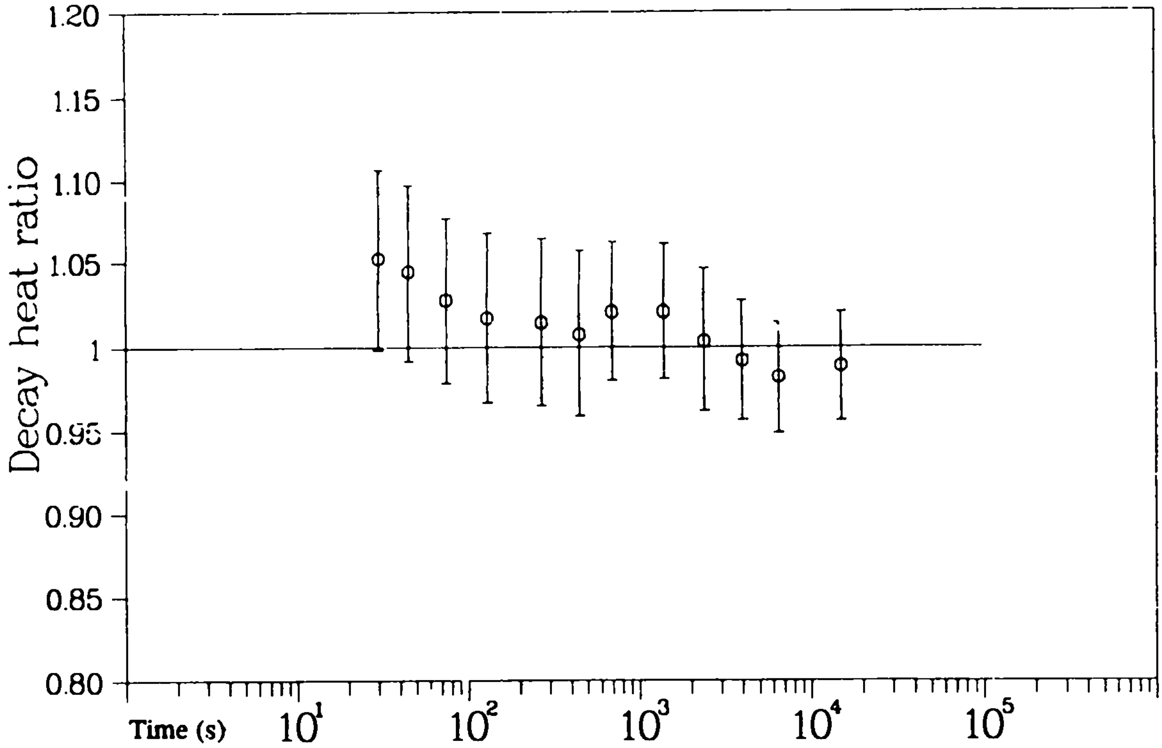

Fig.5a. Decay heat ratio after ^{235}U fission (pulse)--Tokyo total energies divided by summation calculation.

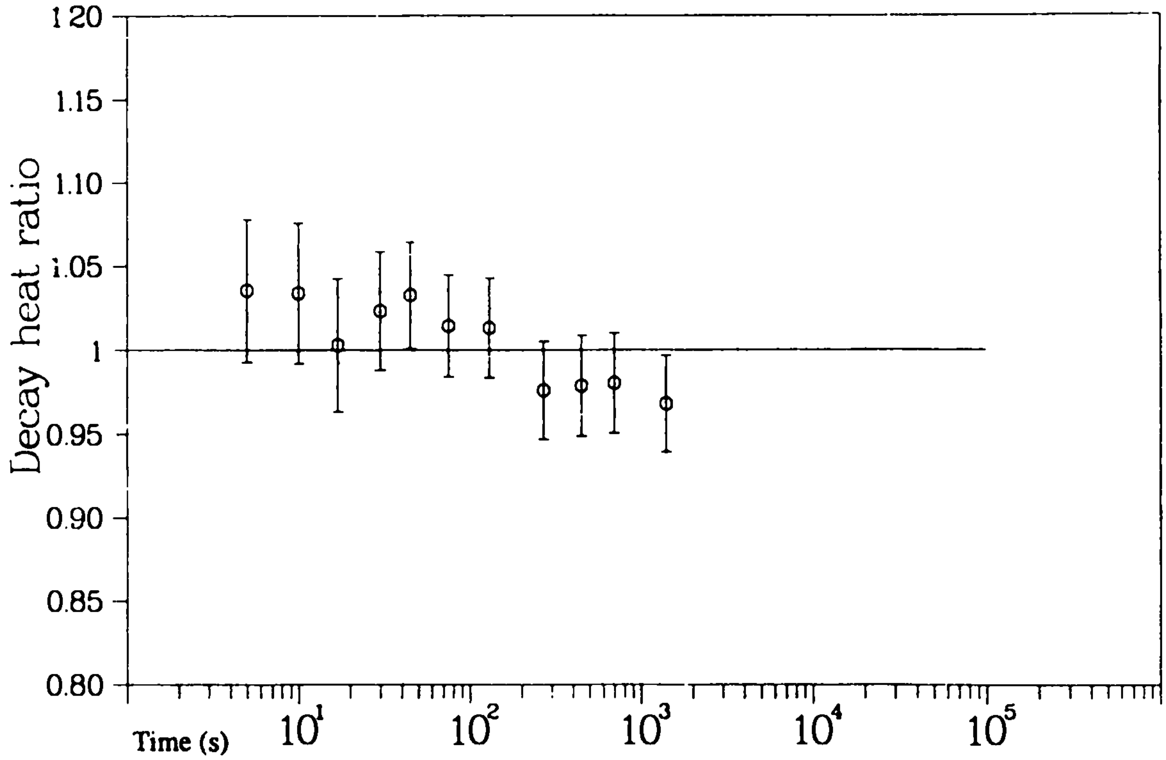

Fig. 5b. Decay heat ratio after ^{235}U fission (pulse)--ORNL total energies divided by summation calculation.

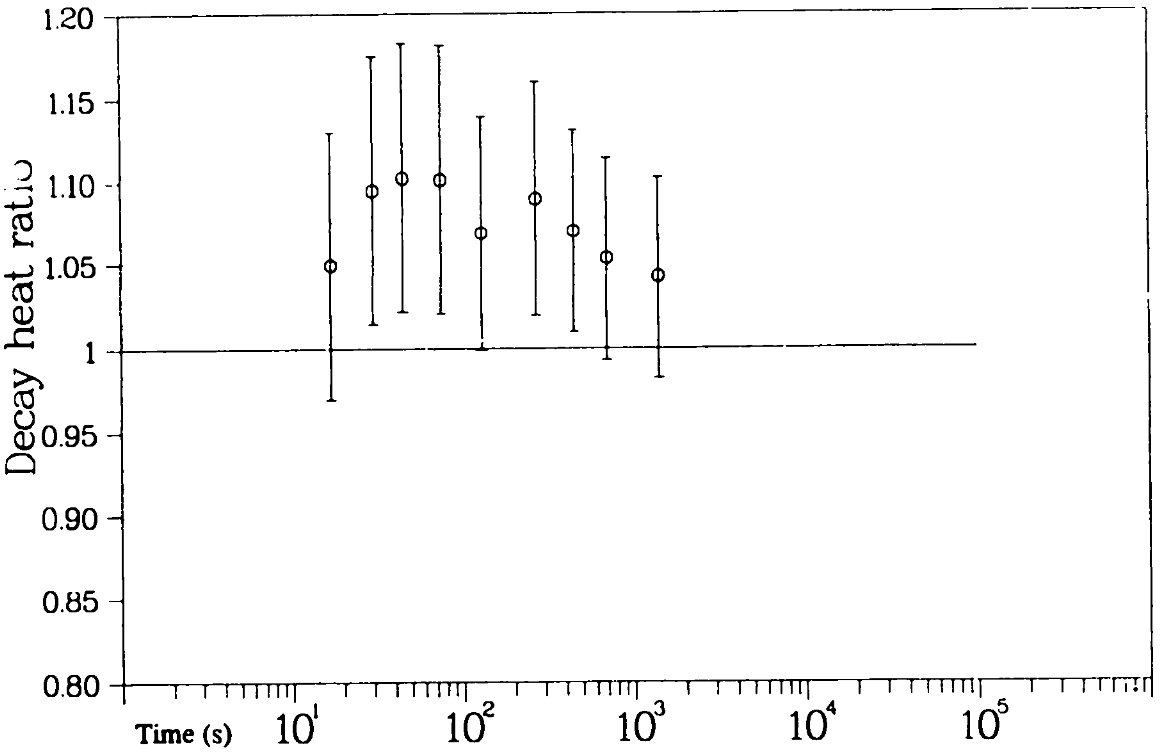

Fig. 5c. Decay heat ratio after ^{235}U fission (pulse)--Studsvik total energies divided by summation calculation.

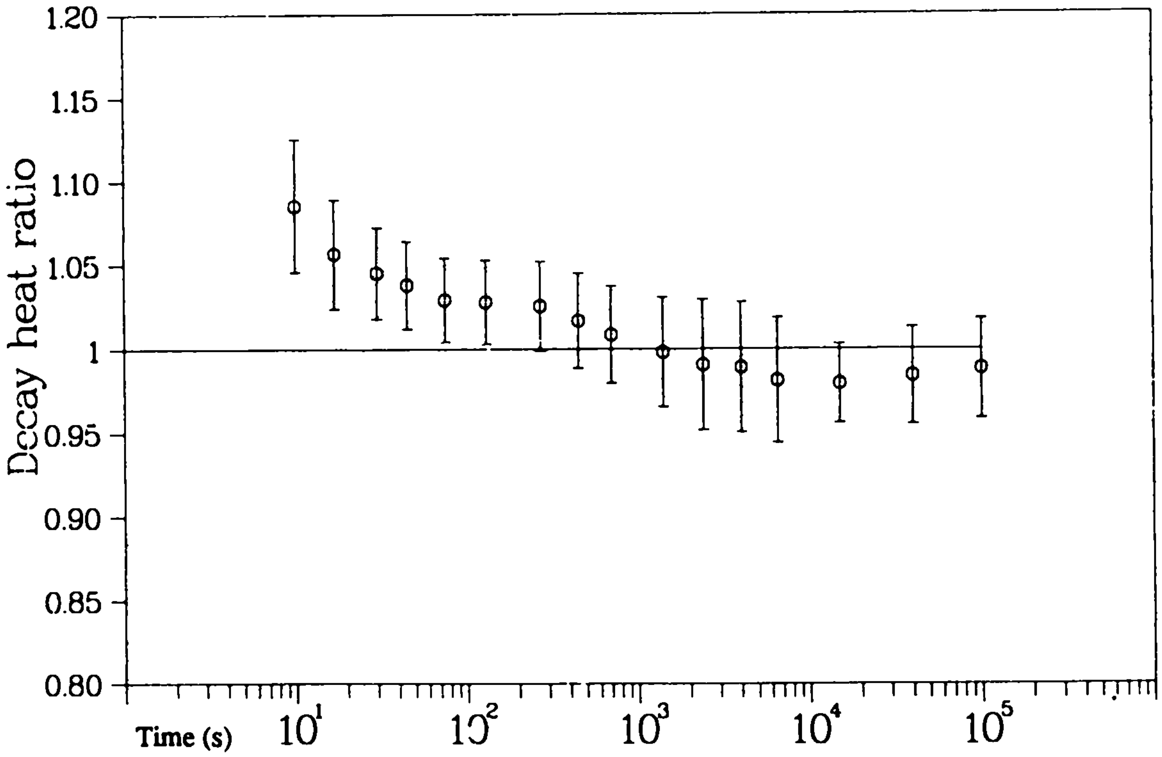

Fig. 5d. Decay heat ratio after ^{235}U fission--Los Alamos total energies divided by summation calculation.

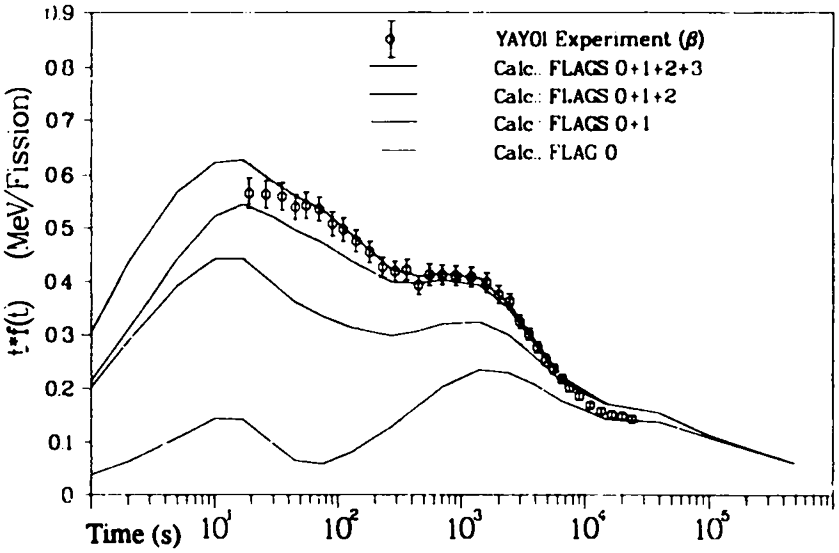

Fig. 6a. Beta decay energy after ^{239}Pu fission (pulse) [YAYOI-experiment].

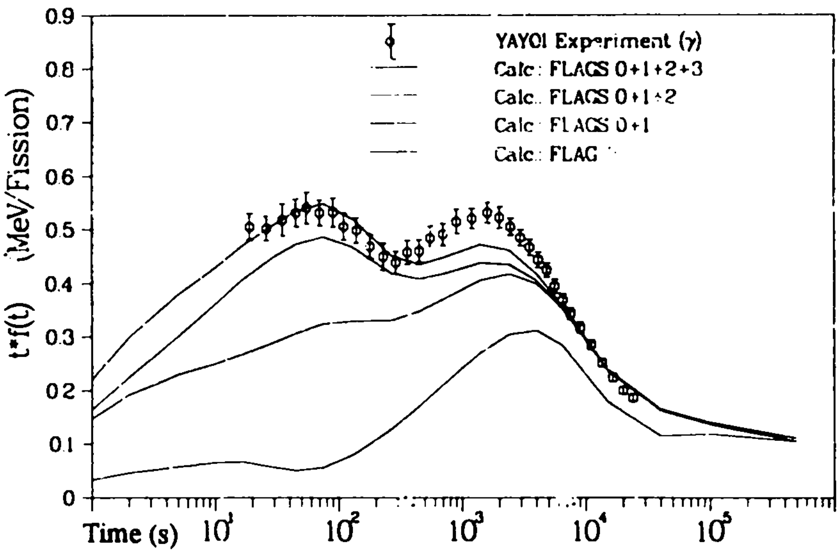

Fig. 6b. Gamma decay energy after ^{239}Pu fission (pulse) [YAYOI-experiment].

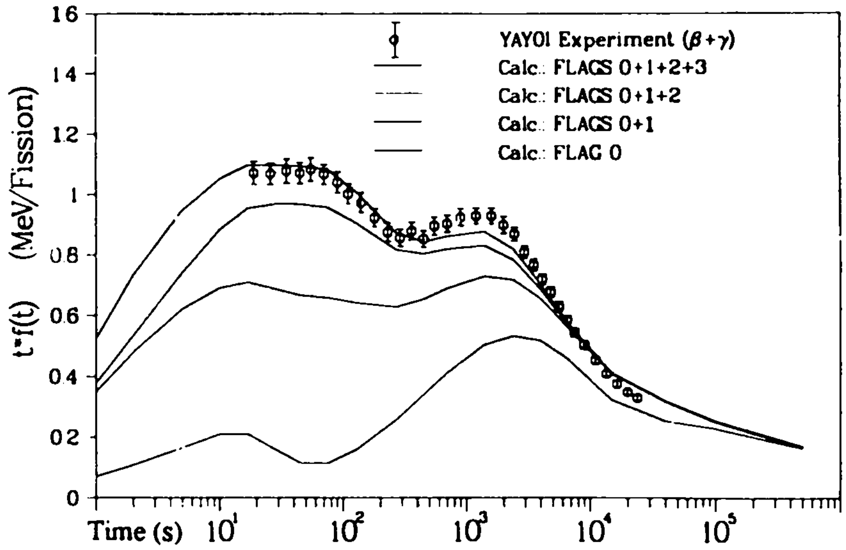

Fig. 6c. Total decay energy after ^{239}Pu fission (pulse) [YAYOI-experiment].

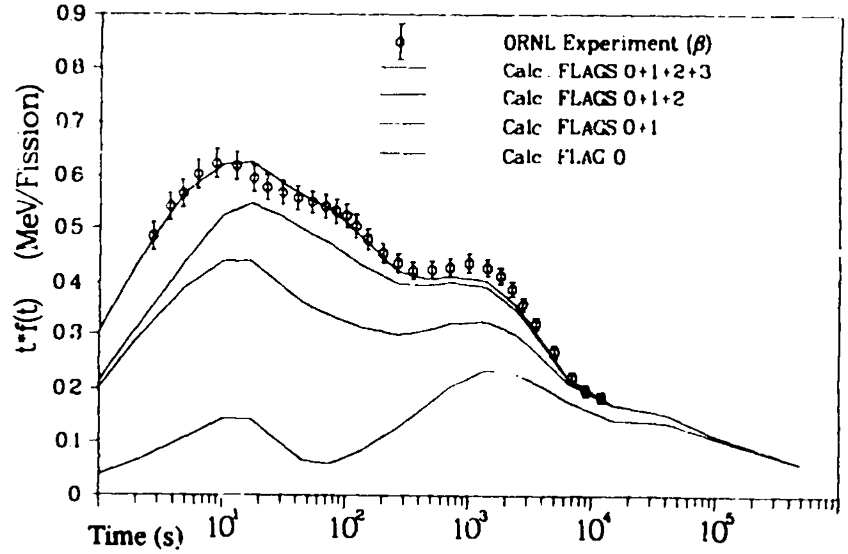

Fig. 7a. Beta decay energy after ^{235}Pu fission (pulse) [ORNL-experiment].

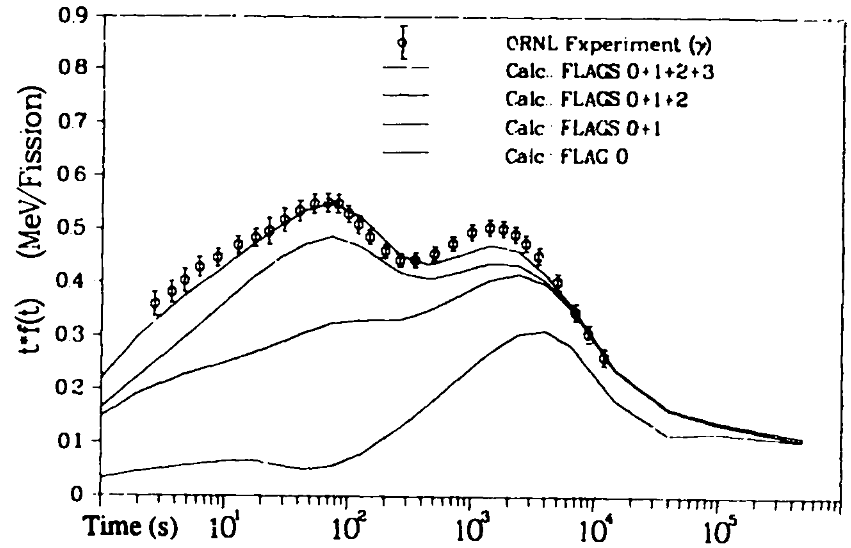

Fig. 7b. Gamma decay energy after ^{239}Pu fission (pulse) [ORNL-experiment].

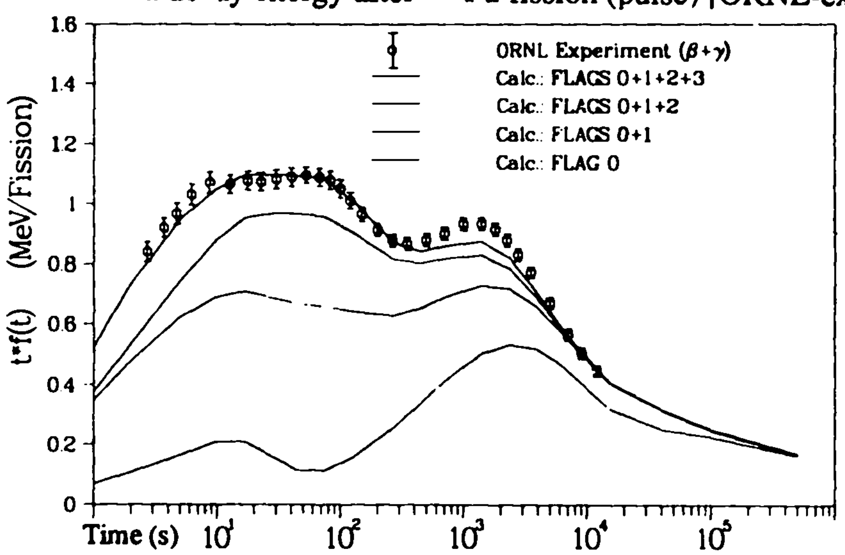

Fig. 7c. Total decay energy after ^{239}Pu fission (pulse) [ORNL-experiment].

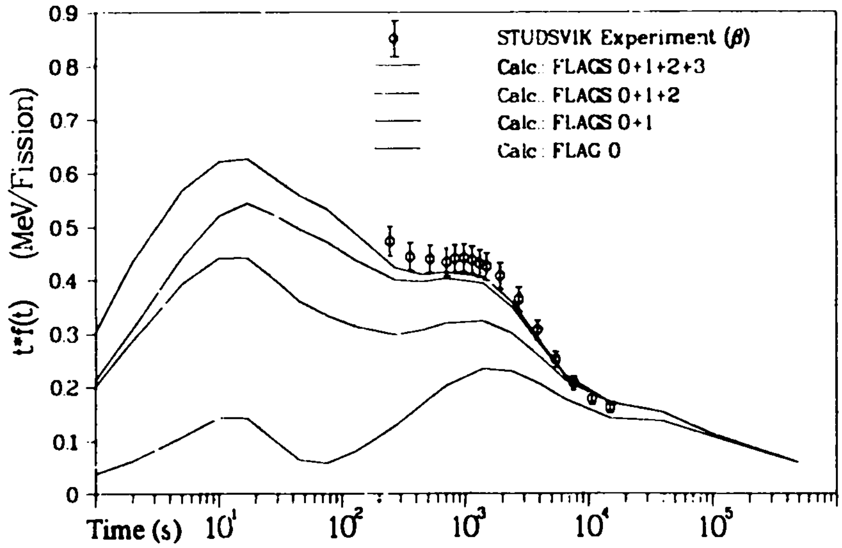

Fig. 8a. Beta decay energy after ^{239}Pu fission (pulse) [Studsvik-experiment].

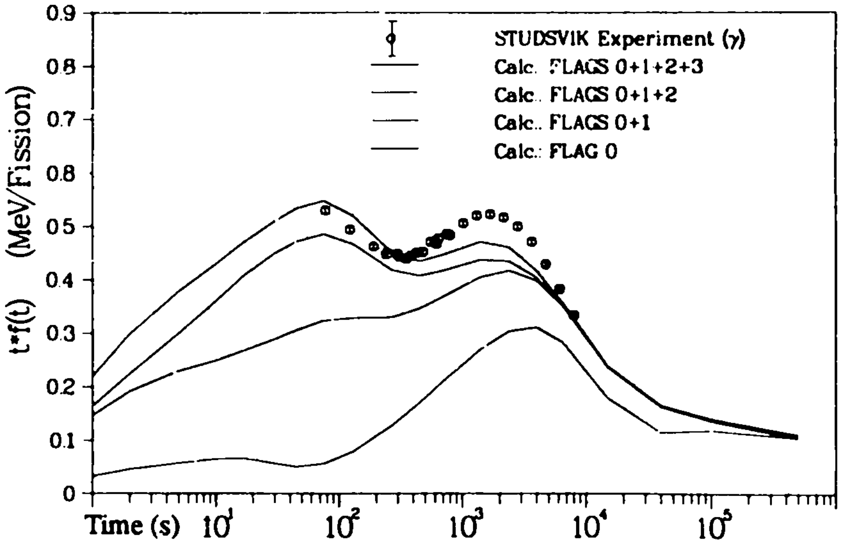

Fig. 8b. Gamma decay energy after ^{239}Pu fission (pulse) [Studsvik-experiment].

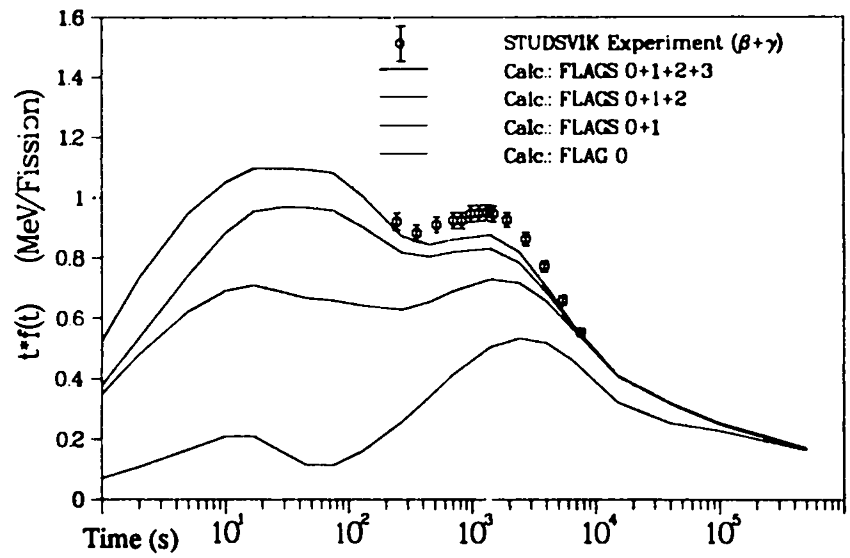

Fig. 8c. Total decay energy after ^{239}Pu fission (pulse) [Studsvik-experiment].

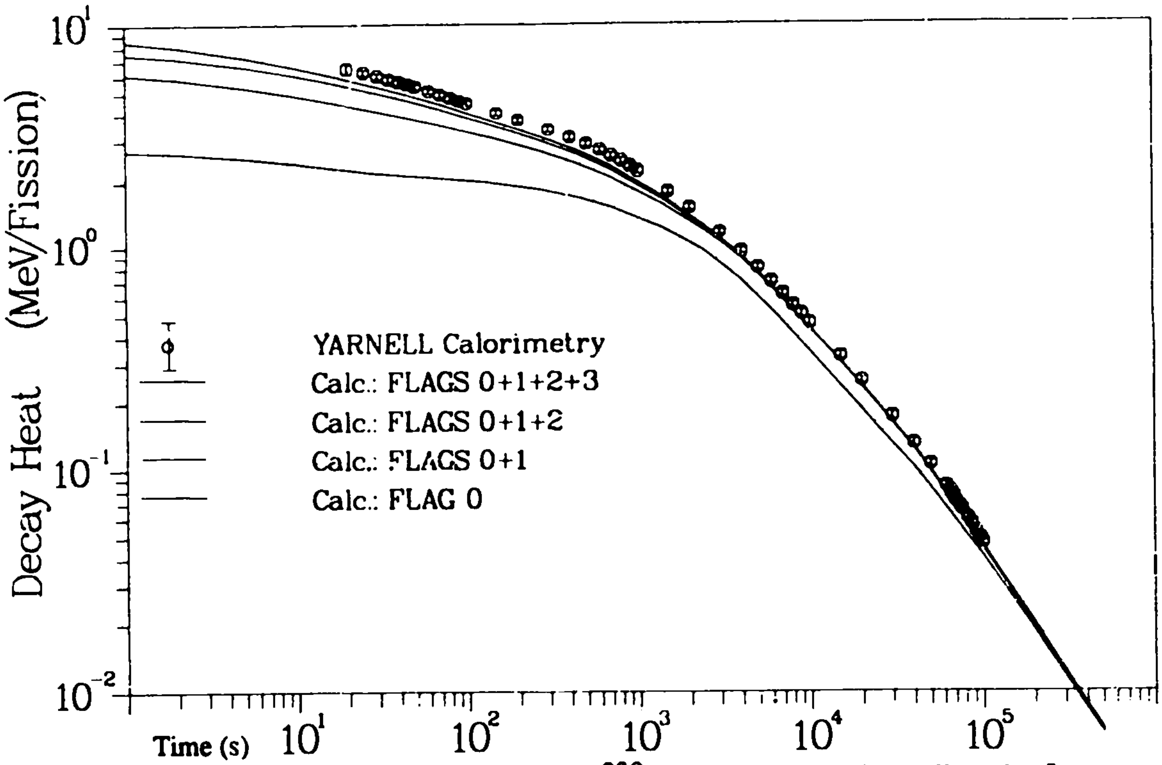

Fig. 9a. Total decay energy after ^{239}Pu fission (20 000 s) [log, log].

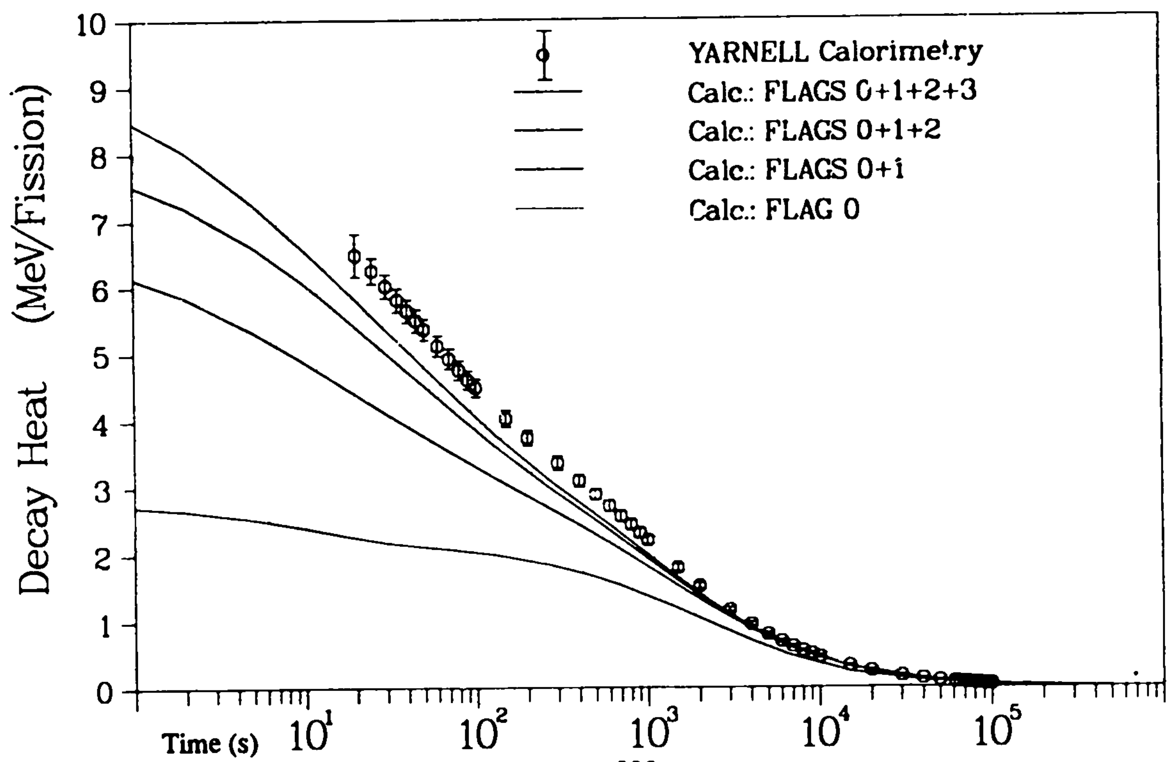

Fig. 9b. Total decay energy after ^{239}Pu fission (20 000 s) [log, lin].

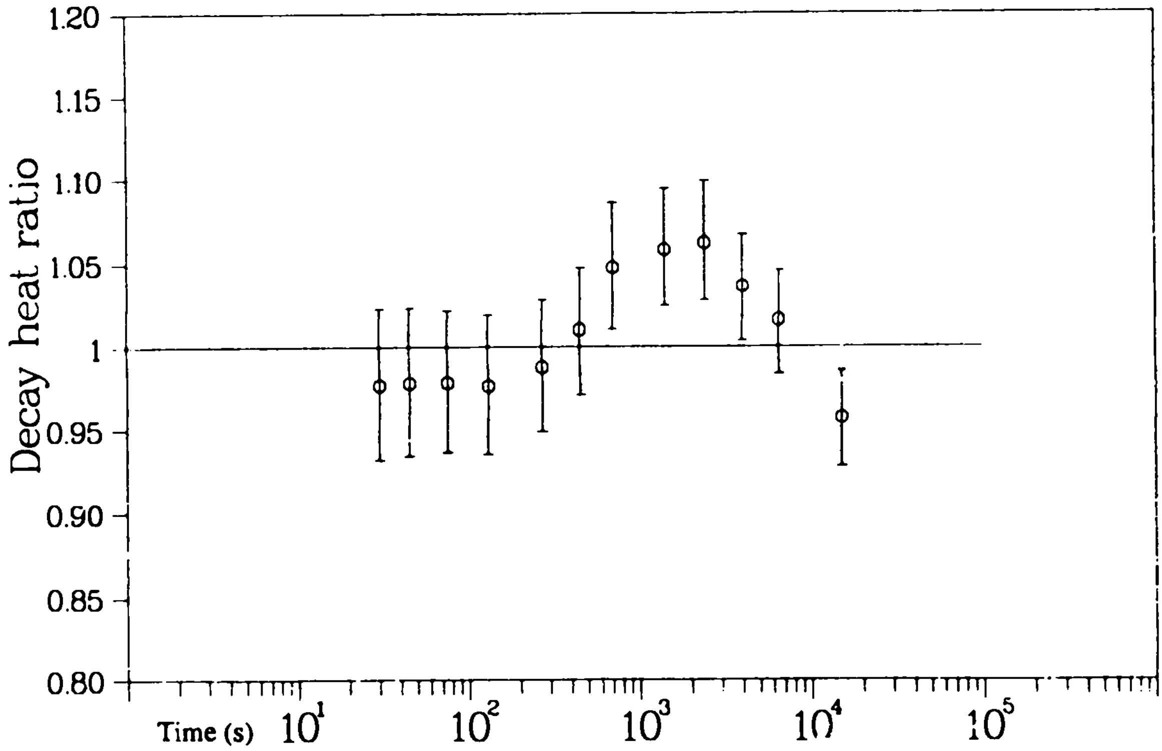

Fig. 10a. Decay heat ratio after ^{239}Pu fission (pulse)--Tokyo total energies divided by summation calculation.

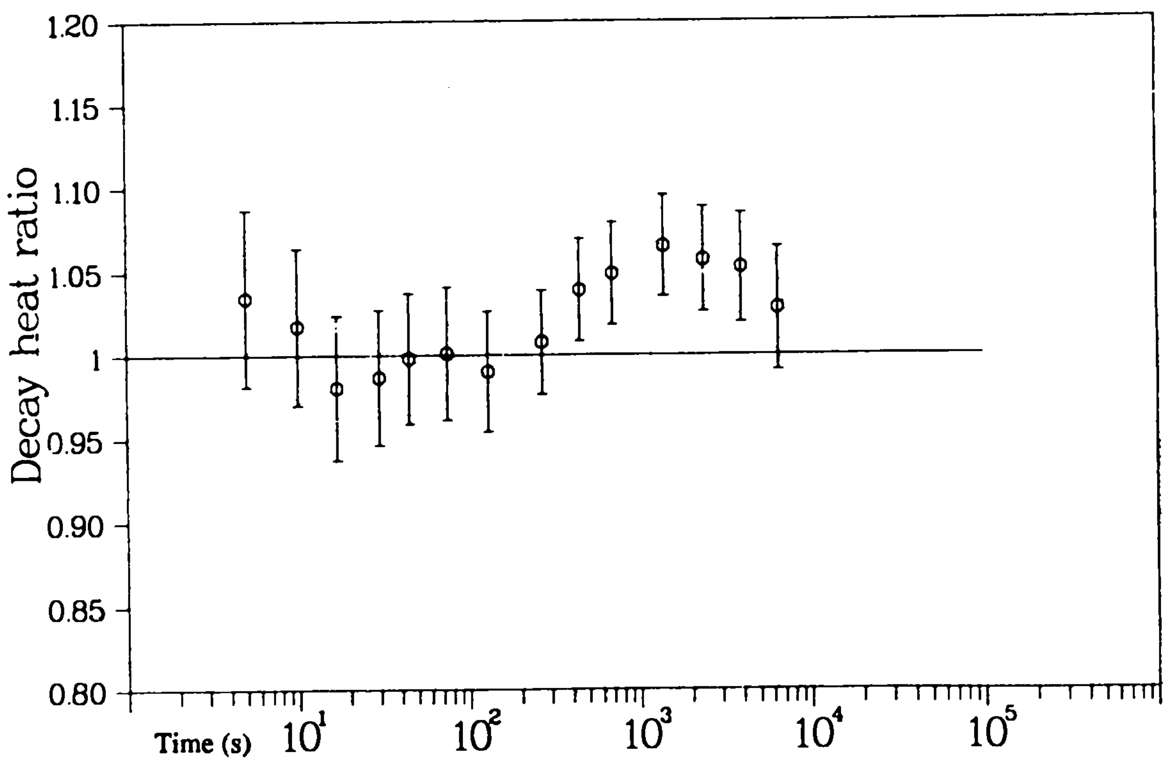

Fig. 10b. Decay heat ratio after ^{239}Pu fission (pulse)--ORNL total energies divided by summation calculation.

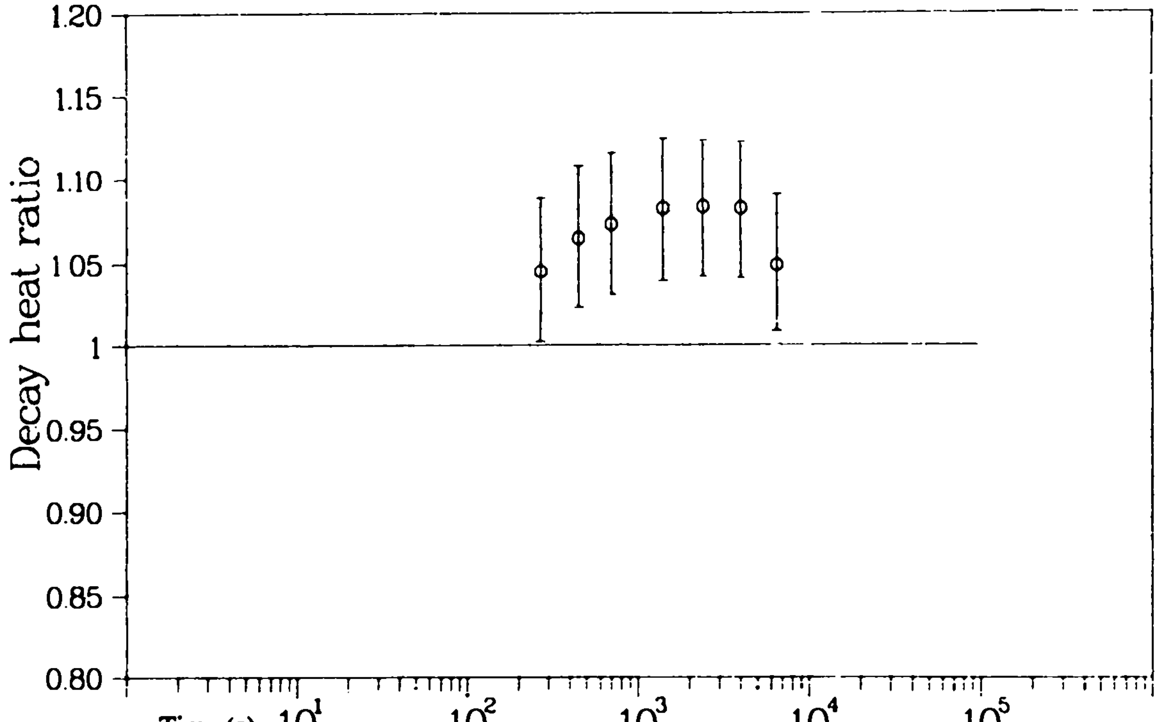

Fig. 10c. Decay heat ratio after ^{239}Pu fission (pulse)--Studsvik total energies divided by summation calculation.

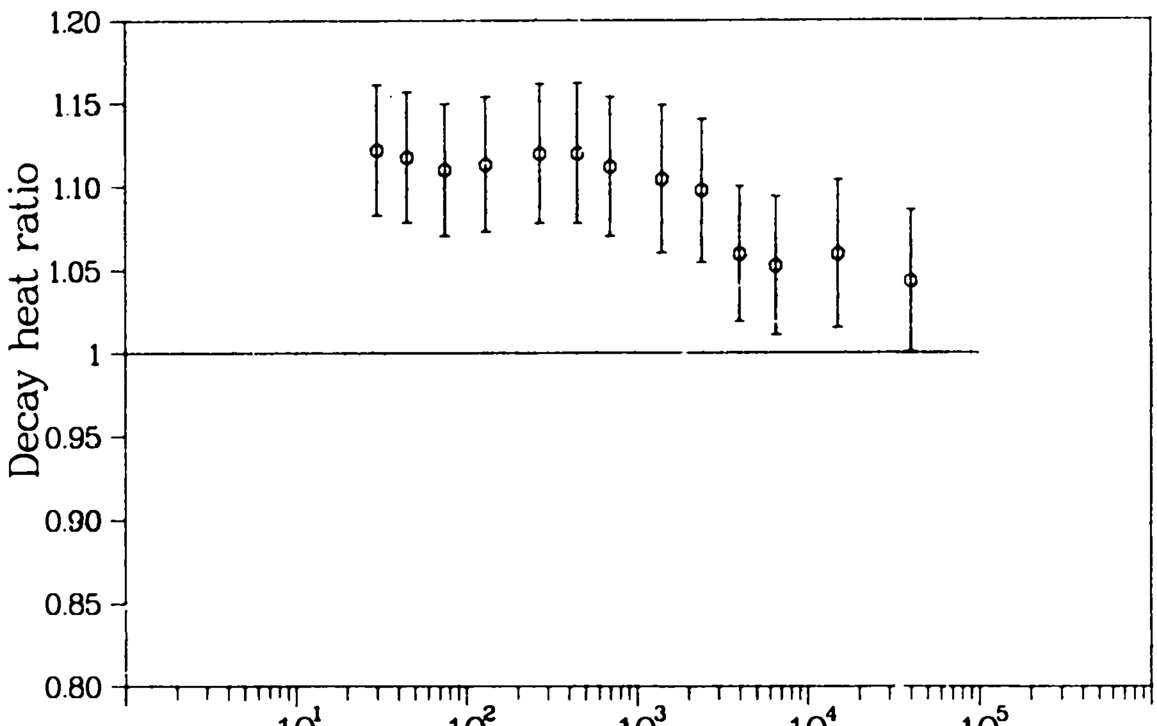

Fig. 10d. Decay heat ratio after ^{239}Pu fission--Los Alamos total energies divided by summation calculation.

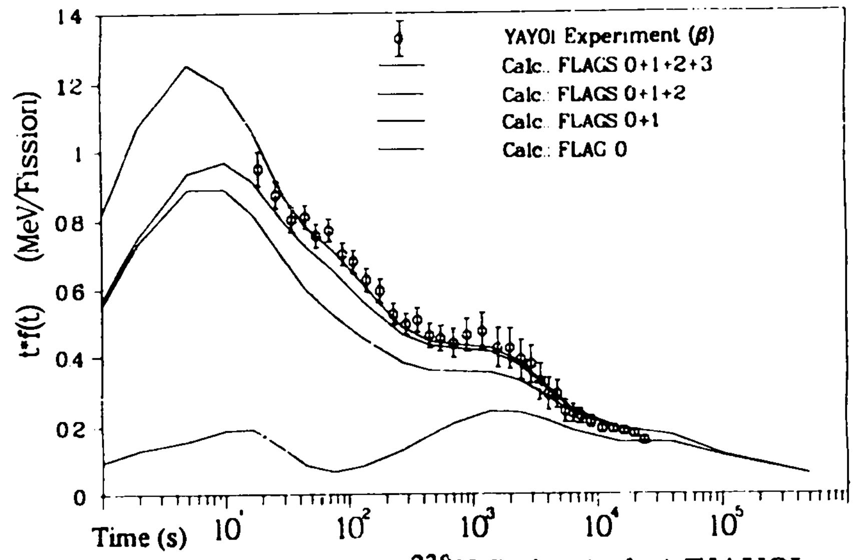

Fig. 11a. Beta decay energy after ^{238}U fission (pulse) [YAYOI-experiment].

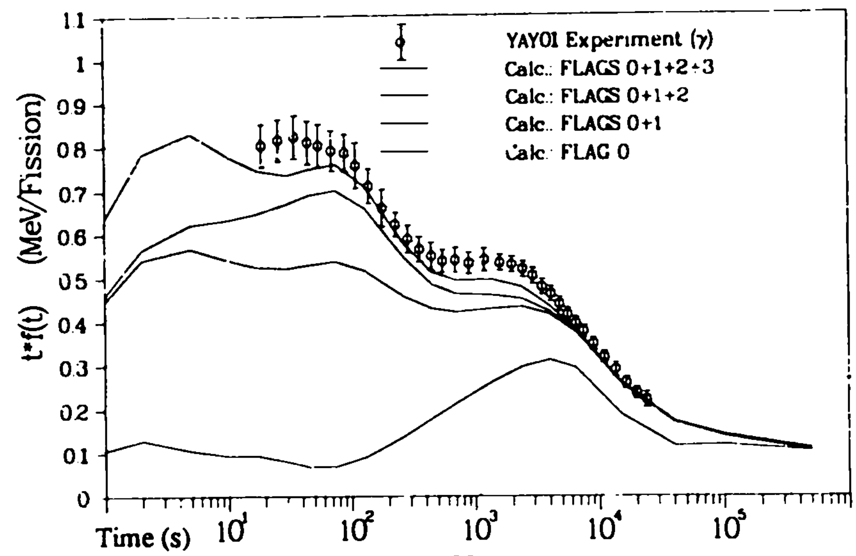

Fig. 11b. Gamma decay energy after ^{238}U fission (pulse) [YAYOI-experiment].

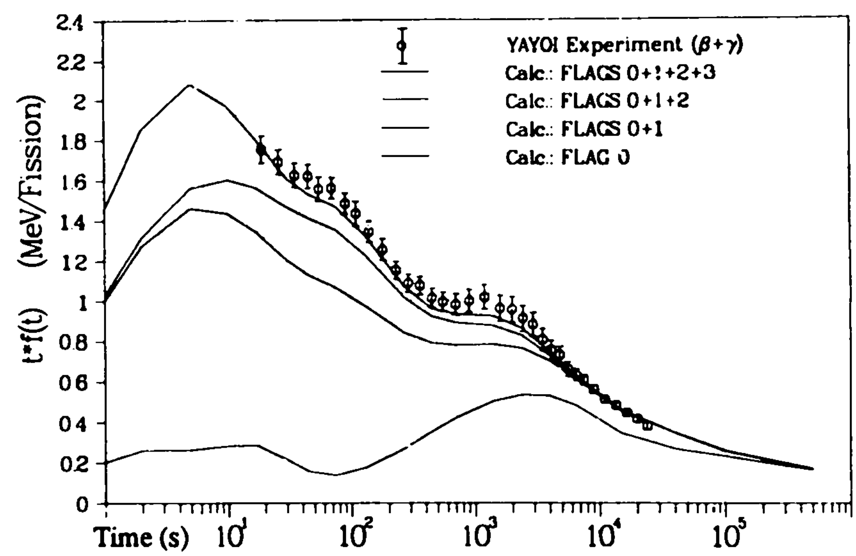

Fig. 11c. Total decay energy after ^{238}U fission (pulse) [YAYOI-experiment].

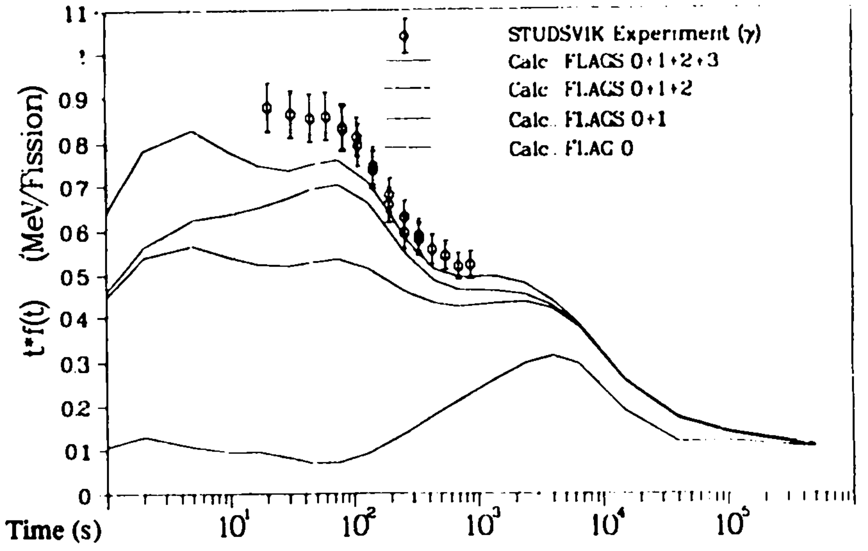

Fig. 12. Gamma decay energy after ^{238}U fast fission (pulse) [Studsvik-experiment].

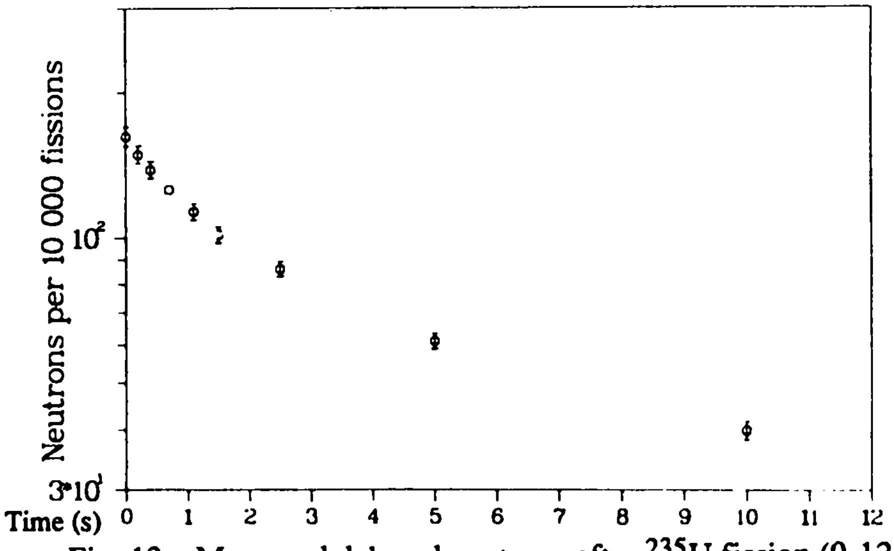

Fig. 13a. Measured delayed neutrons after ^{235}U fission (0-12 s).

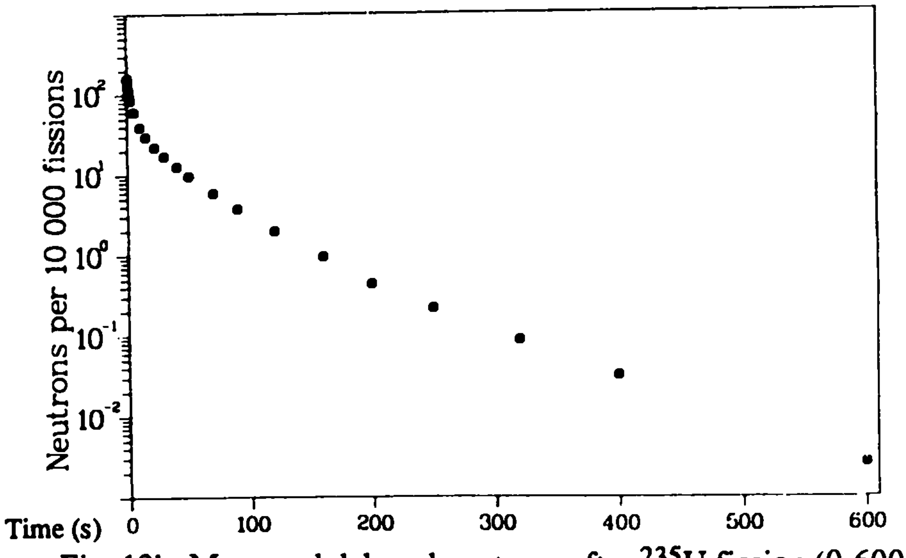

Fig. 13b. Measured delayed neutrons after ^{235}U fission (0-600 s).

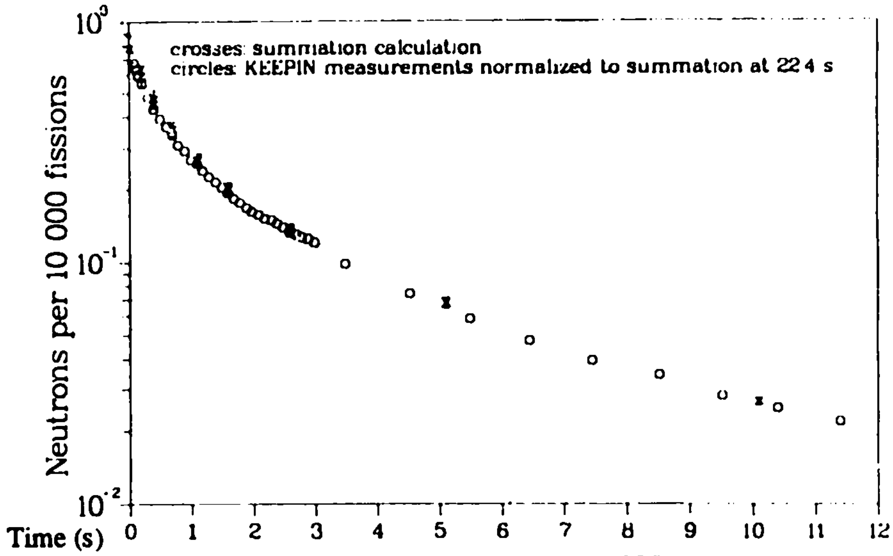

Fig. 14a. Comparison: delayed neutrons after ^{235}U fission (pulse) (0-12 s).

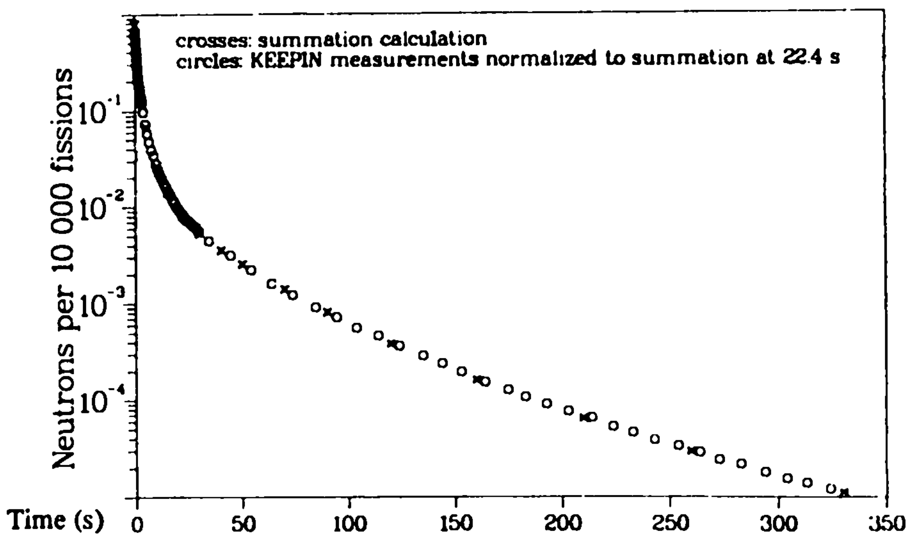

Fig. 14b. Comparison: delayed neutrons after ^{235}U fission (pulse) (0-350 s).

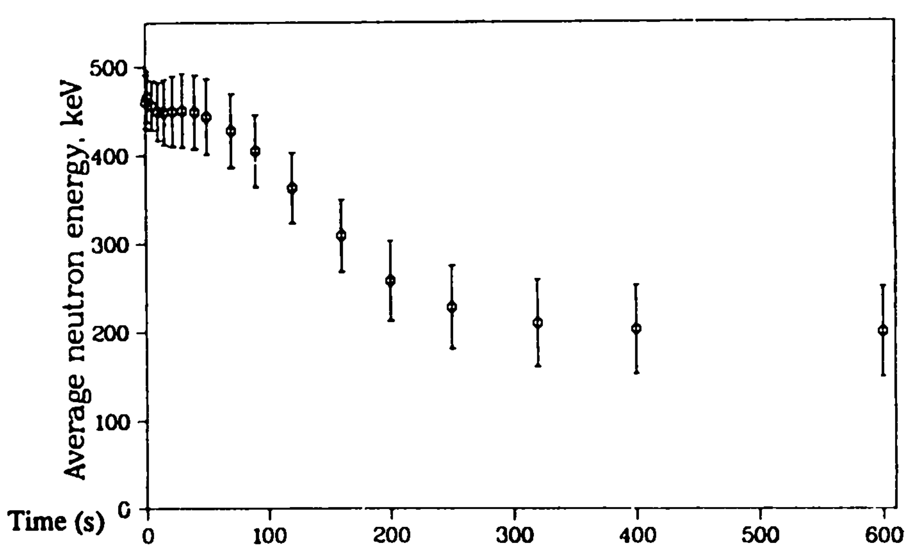

Fig. 15. Average neutron energy after ^{235}U fission.

APPENDIX A

The table below is a partial updating of Ref. 12 in the main text, obtained by including preliminary results from the Studsvik 1989-90 experiment on delayed neutrons [G. Rudstam, K. Aleklett, and L. Sihver (in progress)]. The table is limited to precursors in the mass range 79-100.

Certain values from literature, determined via fission yields or gamma-counting of a long-lived daughter, or normalized against another Pn-value, have been updated using new yields or branching ratios of the nuclides involved in the determination. The method used in the determination of the branching ratios is also indicated in the table in an abbreviated form. The explanation of the symbols is as follows:

- n/B - The experiment was performed with the neutron-beta coincidence technique;
- n-B - Neutrons and beta particles were counted separately;
- ion - The number of atoms was determined by ion counting;
- fiss - The Pn-value was evaluated from the fission yield and the neutron yield in terms of number of neutrons for 104 fissions. The original values are given within brackets. They are updated using yields from A. Wahl's recent review (WAHL88) in which the recommended values for the Zp-model were chosen.
- gAZ - The abundance of the precursor was determined by gamma counting of a long-lived daughter.
- PnAZ - The neutron counter was normalized against the known Pn-value of the precursor AZ. Updating was done using average Pn-values from the present report.

TABLE A-1

Pn VALUES

Nuclide	Studsvik 89/90 %	Literature: This work %	Method	Reference	Comment	Pn-value used in this work %
79Ga	0.101+-0.010	0.098+-0.016	n-B	OSI80		0.085+-0.015
		0.055+-0.012	n/B	SOL85		
80Ga	0.91+-0.04	0.84+-0.06	n-B	OSI80		0.88+-0.04
		0.69+-0.16	n/B	SOL85		
81Ga	11.9+-0.5	12.0+-0.9	n-B	OSI80		11.9+-0.4
		11.7+-1.2	n/B	SOL85		
82Ga	26.3+-3.7	21.4+-2.2	n-B	OSI80		21.9+-1.4
		20.9+-2.2	n/B	SOL85		
83Ga	14.2+-1.7	43.0+-7.0	n-B	OSI80	Discrepant	19.0+-9.0
		62.8+-6.3	n/B	SOL85	values	

TABLE A-1 (Cont.)

Nuclide	Studs-vik 89/90 %	Literature: This work %	Method	Refer-ence	Comment	Pn-value used in this work %
84Ge	10.7+-1.0					10.7+-1.0
84As	0.29+-0.03	0.08+-0.04	fiss	MAI73	Excluded, too uncertain	0.29+-0.03
85As	50.4+-2.0	67+-11	fiss	HAR68		51.1+-2.1
		54+-10	fiss	MAI73		
		22+-8	fiss	LOH78	Excluded, uncertain b-id	
86As	31.7+-3.5	12+-8	fiss	LOH78	Literature values excluded, too uncertain	31.7+-3.5
		15+-11	fiss	MAI73		
87As	14.5+-2.5	51+-35	fiss	LOH78	Excluded, too uncertain	14.5+-2.5
87Se	0.60+-0.09	0.51+-0.17	fiss	MAI70	Discrepant values, unweighted average	0.36+-0.08
		0.26+-0.07	Pn87Br	MOL70		
		0.24+-0.08	Pn87Br	MAI70		
		0.17+-0.03	Pn87Br	HAR71		
87Br	2.40+-0.10	3.1+-0.6	n-B	RUS64		2.46+-0.06
	2.50+-0.10	2.3+-0.3	g87Kr	MOL71		
	Av: 2.45+-0.07	2.4+-0.4	fiss	MAI72		
		2.6+-0.5	fiss	MAI74		
		2.57+-0.15	n-B	OSI80		
		2.1+-0.3	ion	SOL80		
90Br	25.4+-1.7	30+-7	fiss	MAI72		24.7+-0.9
		20+-5	fiss	MAI74		
		22.6+-3.1	n-B	LOH75		
		24.6+-1.7	n-B	OSI80a		
		24.8+-1.5	n-B	ISO84		
91Br	18+-8	16+-5	fiss	MAI74	Discrepant values	19.2+-3.3
		9.9+-2.0	n-B	LOH75		
		19.2+-1.3	n-B	OSI80a		
		30.1+-2.1	n-B	ISO84		
		25.5+-3.5	?	MAI88		
92Rb	0.0117+-0.0005	0.012+-0.004	g92Sr	TRI69		0.0112+-0.0004
		0.0125+-0.0015	n-B	ARI75		
		0.0092+-0.0015	ion	SOL80		
		0.0098+-0.0010	ion	SOL80		
		0.0109+-0.0012	n-B	OSI80		

TABLE A-1 (Cont.)

Nuclide	Studsvik 89/90 %	Literature: This work %	Method	Reference	Comment	Pn-value used in this work %
93Rb	1.31+-0.05	1.65+-0.30	g93Y	TRI69		1.32+-0.04
		1.43+-0.18	ion	ORS69		
		1.85+-0.53	fiss	MAI72		
		1.24+-0.14	n-B	ORS74		
		1.16+-0.08	n-B	ARI75		
		1.2+-0.1	n-B	LOH75		
		1.37+-0.10	ion	SOL80		
		1.36+-0.14	ion	SOL80		
		1.39+-0.08	n-B	OSI80		
		1.97+-0.22	n-B	SOLI81		
94Rb	9.6+-0.4	11.1+-1.1	ion	ORS69		9.83+-0.22
		10.3+-1.6	fiss	MAI72		
		8.5+-0.9	n-B	ORS74		
		9.6+-0.8	n-B	LOH75		
		9.7+-0.5	n-b	OST78		
		10.0+-1.0	ion	SOL80		
		10.1+-0.5	n-B	OSI80		
		11.1+-0.9	n-B	SOLI81		
96Rb	13.3+-0.7	12.7+-1.5	ion	ORS69		13.2+-0.4
		13.0+-1.4	n-B	ORS74		
		12.6+-0.9	ion	SOL80		
		14.5+-1.5	ion	SOL80		
		12.5+-0.9	n-B	OST78		
		13.5+-0.9	n-B	OSI80		
		14.2+-1.2	n-B	SOLI81		
97Rb	23.8+-1.4	27.2+-3.0	n-B	ORS74		25.2+-0.8
	26.4+-2.4	25.2+-1.8	n-B	OST78		
Av:	24.5+-1.2	26.9+-1.9	ion	SOL80		
		27.9+-3.1	ion	SOL80		
		21.5+-2.6	n-B	SOLI81		
		26.1+-5.4	n/B	SOL85		
98Sr	0.30+-0.02	0.36+-0.11	n-B	SOLI81		0.29+-0.02
		0.8+-0.2	n-B	OST82	Excluded	
		0.23+-0.05	n/B	SOL85		
98Y	0.30+-0.10	0.3+-0.1	n-B	OST82		0.25+-0.04
		0.23+-0.05	n/B	SOL85		
99Y	1.99+-0.08	1.2+-0.8	n-B	LOH75	Discrepant values	1.80+-0.32
		3.0+-0.2	n-B	OST82		
		1.09+-0.11	n/B	SOL85		
100Sr	1.04+-0.08	0.75+-0.08	n/B	SOL86		0.90+-0.14
100Y	1.24+-0.07	0.85+-0.09	n/B	SOL86		1.09+-0.19

TABLE A-1 (Cont.)

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(Abbreviated form)

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APPENDIX B

Preliminary results are from the Studsvik delayed-neutron experiment (G. Rudstam, K. Aleklett, L. Sihver, work in progress, to ' for presentation at the International Conference on Nuclear Data for Science and Technology, Jülich, FRG, May 13-17, 1991.

TABLE B-1

AVERAGE DELAYED NEUTRON ENERGIES

Nuclide	Studsvik 89/90 <En> keV	Literature <En> keV	Literature Reference	Value used in this work <En>, keV
79Ga	270+-50	350	RUD82	270+-50
80Ga	290+-50	360	RUD82	290+-50
81Ga	480+-40	370	RUD82	480+-40
82Ga	530+-50			530+-50
83Ga	<100			50+-50
84As	<100			50+-50
84Ge	<100			50+-50
85As	650+-40	728-50+25 700	KRA79 RUD82	690+-40
86As	480+-180			480+-180
87As	<100			50+-50
87Br	200+-50*	217+-10 105 200	KRA79 REE81 RUD82	200+-50
88Br	200+-50	190 250	REE81 RUD82	200+-50
89Br	470+-40*	474 430	REE81 RUD82	470+-40
90Br	550+-40	500	RUD82	550+-40
91Br	430+-70	300	RUD82	430+-70
92Rb	150+-40*	199+-10 123 210	KRA79 REE81 RUD82	150+-40
93Rb	400+-40*	414+-20 419 360	KRA79 REE82 RUD82	400+-40

TABLE B-1 (Cont.)

Nuclide	Studs-vik 89/90 <En> keV	Literature <En> keV	Refer-ence	Value used in this work <En>, keV
94Rb	410+-40*	474+-20	KRA79	410+-40
		413	REE81	
		400	RUD82	
95Rb	390+-40	508+-25	KRA79	390+-40
		406	REE81	
		360	RUD82	
96Rb	350+-40	481+-25	KRA79	350+-40
		433	REE81	
		450	RUD82	
97Rb	420+-50*	533+-35	KRA79	420+-50
		540	REE81	
99Rb	490+-90			490+-90
99Y	380+-40			380+-40
100Sr	490+-230			490+-230
100Y	210+-110			210+-110
133Sn	360+-130			360+-130
134Sn	780+-50			780+-50
134Sb	210+-90			210+-90
135Sb	860+-40*	1033-100+50	KRA79	860+-40
		680	RUD82	
136Sb	730+-70			730+-70
136Te	360+-40	325+-35	KRA79	360+-40
137Te	250+-90			250+-90
137I	640+-40	579+-25	KRA79	640+-40
		540	RUD82	
139I	660+-160	400	RUD82	660+-160
147Cs	530+-40	507	KRA79	530+-40
148Cs	540+-150			540+-150

[a]Used for establishing the calibration curve. For this curve, the following nuclides were used (with "best value" energies from Ref. REE81B: 420 ± 20 keV; ^{89}Br - 460 ± 20 keV; ^{135}Rb - 860 ± 80 keV.

TABLE B-1 (Cont.)

REFERENCES IN TABLE B-1

(Abbreviated form)

KRA79 Proc. Consultants' Mtg. Delayed Neutron Properties, Vienna, March 26-30, 1979, IAEA publication INDC(NDS) - 107/G + Special, p.103 (1979).

REE81 P. L. Reeder and R. A. Warner, Nucl. Instrum. Methods 180, 173 (1981).

REE81B P. L. Reeder and R. A. Warner, Nucl. Sci. Eng. 79, 56 (1981).

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APPENDIX C

Preliminary results are from the Studsvik delayed-neutron experiments 1989-90 (G. Rudstam, K. Aleklett, and L. Sihver, work in progress). Note that the literature search is incomplete. The values given in this table are essentially those from delayed-neutron experiments carried out at different laboratories.

TABLE C-1
HALF-LIVES

Nuclide	Studs-vik 89/90 Halflife s	Literature Halflife s	Literature Refer-ence	Literature Comment	Half-life used in this work s
79Ga	2.790+-0.032	2.63+-0.09	OSI80	2.846+-0.014 (W)	2.846+-0.014
	2.771+-0.055	2.85+-0.01	SOL85		
	2.850+-0.010				
	Av:2.843+-0.015				
80Ga	1.647+-0.008	1.66+-0.02	OSI80	1.68+-0.01 (W)	1.670+-0.014
	1.668+-0.014	1.69+-0.01	SOL85		
	1.606+-0.024				
	Av:1.649+-0.011				
81Ga	1.209+-0.002	1.23+-0.01	OSI80	1.22+-0.01 (W)	1.213+-0.003
	1.210+-0.003	1.218+-0.004	SOL85		
	1.216+-0.003				
	1.214+-0.004				
	1.192+-0.009				
	1.192+-0.021				
	Av:1.211+-0.002				
82Ge	4.36+-0.04			4.6+-0.4 (W)	4.36+-0.04
82Ga	0.597+-0.003	0.600+-0.010	OSI80	0.607+-0.003 (W)	0.605+-0.004
	0.602+-0.005	0.609+-0.003	SOL85		
	0.569+-0.015				
	Av:0.598+-0.004				
83Ge	2.33+-0.06			1.9+-0.1 (W)	2.33+-0.06
				(if used for average:2.22+-0.19)	
83Ga	0.314+-0.005	0.310+-0.010	OSI80	0.31+-0.04 (W)	0.309+-0.003
	0.297+-0.007	0.308+-0.004	SOL85		
	0.321+-0.022				
	Av:0.309+-0.006				
84As	4.062+-0.067			5.5+-0.3 (W)	4.03+-0.03
	4.017+-0.029				
	Av:4.024+-0.027				

TABLE C-1 (Cont.)

Nuclide	Studsvik 89/90 Halflife s	Literature Halflife s	Reference	Comment	Half-life used in this work s
84Ge	0.984+-0.013			1.2+-0.3 (W)	0.970+-0.018
	0.920+-0.029				
	0.937+-0.037				
Av:	0.970+-0.018				
85As	1.961+-0.006	2.05+-0.05	MAI73	2.03+-0.01 (W)	2.002+-0.012
	1.962+-0.006	1.9+-0.1	LOH78		
	2.018+-0.004				
	2.026+-0.005				
	2.169+-0.058				
	2.034+-0.011				
Av	2.002+-0.013				
86As	0.938+-0.012	0.9+-0.2	MAI73	0.9+-0.2 (W)	0.945+-0.008
	0.961+-0.014				
	0.937+-0.015				
Av:	0.945+-0.008				
87As	0.41+-0.14	0.73	LOH78	No error given	0.49+-0.04
	0.58+-0.36			0.8+-0.1 (W)	
	0.50+-0.04				
Av:	0.49+-0.04				
88Br	16.46+-0.01	16.4+-0.6	MAI72	16.4+-0.1 (W)	16.34+-0.04
	16.29+-0.01	16.7+- ?	OSI80		
	16.29+-0.01				
	16.31+-0.04				
	16.33+-0.02				
Av:	16.34+-0.04				
89Br	4.369+-0.015	4.44+-0.20	MAI74	4.37+-0.03 (W)	4.369+-0.019
	4.306+-0.020	4.37+-0.03	OSI80		
Av:	4.364+-0.043	4.37+-0.03	OSI80a		
90Br	1.907+-0.003	1.71+-0.14	MAI74	1.9+-0.1 (W)	1.910+-0.003
	1.911+-0.014	1.92+-0.02	OSI80a		
	1.914+-0.012	1.92+-0.06	ISO84		
	1.903+-0.010				
	1.925+-0.007				
Av:	1.910+-0.003				
91Br	0.552+-0.013	0.63+-0.07	MAI74	0.54+-0.01 (W)	0.541+-0.007
	0.530+-0.009	0.60+-0.05	LOH75		
	0.574+-0.016	0.54+-0.01	OSI80A		
	0.557+-0.025	0.53+-0.03	ISO84		
	0.582+-0.042	0.51+-0.02	MAI88		
Av:	0.545+-0.009				

TABLE C-1 (Cont.)

Nuclide	Studs-vik 89/90 Halflife s	Literature Halflife s	Reference	Comment	Half-life used in this work s
92Rb	4.499+-0.045	4.48+-0.02	ARI75	4.48+-0.02 (W)	4.484+-0.006
	4.481+-0.003	4.54+-0.02	SOL80		
	4.385+-0.043				
	4.222+-0.070				
Av:	4.484+-0.003				
93Rb	5.865+-0.002	5.86+-0.13	TRI69	5.85+-0.02 (W)	5.864+-0.004
	5.843+-0.007	5.89+-0.04	ORS69		
	5.868+-0.008	6.39+-0.35	ORS74		
	5.873+-0.010	5.85+-0.13	ARI75		
Av:	5.864+-0.004	5.86+-0.05	LOH75		
		6.12+-0.08	SOL80		
		5.85+-0.03	OSI80		
		5.74+-0.08	SOLI81		
94Rb	2.707+-0.001	2.76+-0.08	ORS74	2.71+-0.01 (W)	2.712+-0.005
	2.713+-0.001	2.67+-0.06	LOH75		
	2.721+-0.002	2.73+-0.02	OST78		
	2.711+-0.002	2.83+-0.03	SOL80		
Av:	2.711+-0.003	2.69+-0.02	OSI80		
		2.76+-0.06	SOLI81		
95Rb	0.378+-0.001	0.383+-0.006	ORS74	0.377+-0.001 (W)	0.378+-0.001
	0.379+-0.001	0.37+-0.04	LOH75		
	0.379+-0.001	0.377+-0.006	OST78		
	0.378+-0.001	0.377+-0.004	SOL80		
Av:	0.379+-0.001	0.40+-0.01	OSI80		
		0.40+-0.01	SOLI81		
		0.377+-0.001	SOL85		
96Rb	0.194+-0.002	0.199+-0.004	ORS74	0.199+-0.002 (W)	0.201+-0.001
	0.200+-0.001	0.197+-0.005	OST78		
	0.202+-0.001	0.205+-0.004	SOL80		
	0.201+-0.001	0.203+-0.003	OSI80		
Av:	0.201+-0.001	0.22+-0.01	SOLI81		
97Rb	0.167+-0.001	0.172+-0.005	ORS74	0.169+-0.002 (W)	0.169+-0.001
	0.168+-0.001	0.171+-0.004	OST78		
	0.168+-0.001	0.182+-0.007	SOL80		
	0.168+-0.001	0.20+-0.02	SOLI81		
Av:	0.168+-0.001	0.169+-0.001	SOL85		
98Zr	30.04+-0.04			30.7+-0.4 (W)	
98Rb	0.102+-0.002	0.106+-0.006	ORS74	0.107+-0.001 (W)	0.104+-0.001
	0.100+-0.002	0.114+-0.013	OST78		
Av:	0.101+-0.001	0.11+-0.02	SOLI81		
		0.106+-0.001	SOL85		

Nuclide	Studsvik 89/90 Halflife s	Literature Halflife s	Literature Reference	Literature Comment	Half-life used in this work s
99Rb	0.051+-0.001	0.059+-0.001	SOL86	0.059+-0.001 (W)	0.053+-0.004
	0.051+-0.001				
	0.049+-0.001				
	Av: 0.0503+-0.0007				
100Sr	0.131+-0.015	0.204+-0.002	SOL86	0.201+-0.002 (W)	0.203+-0.007
	0.144+-0.021				
	0.177+-0.009				
	0.166+-0.018				
	Av: 0.163+-0.011				
101Y	0.48+-0.11	0.431+-0.007	SOL86	0.43+-0.01 (W)	0.431+-0.007
	0.30+-0.11				
	Av: 0.39+-0.09				
129In	0.76+-0.09	0.59+-0.02	OSI80	0.63+-0.04 (W)	0.631+-0.024
	0.673+-0.012	0.61+-0.01	SOL85		
	Av: 0.675+-0.012				
132In	0.227+-0.014	0.22+-0.03	OSI80	0.20+-0.01 (W)	0.208+-0.005
	0.201+-0.027	0.204+-0.006	SOL85		
	Av: 0.222+-0.012				
133Sn	1.225+-0.035			1.44+-0.04 (W)	1.19+-0.07
	1.034+-0.080				
	Av: 1.194+-0.070				
134Sn	1.042+-0.026			1.04+-0.02 (W)	1.034+-0.006
	1.034+-0.006				
	Av: 1.034+-0.006				
135Sb	1.641+-0.003	1.69+-0.02	HAR68	1.71+-0.01 (W)	1.641+-0.003
	1.641+-0.003	1.60+-0.15	LOH78		
	Av: 1.641+-0.002				
136Sb	0.926+-0.020	0.75+-0.20	MAI77	0.82+-0.02 (W)	0.927+-0.016
	0.934+-0.026	0.9+-0.1	LOH78		
	Av: 0.929+-0.016				
136Te	17.4+-0.3	17.5+-0.2	LOH78	17.5+-0.2 (W)	17.5+-0.2
137Te	2.39+-0.12	2.1+-0.5	LOH75	2.5+-0.1 (W)	2.33+-0.10
	2.25+-0.17				
	Av: 2.34+-0.10				
147Cs	0.229+-0.001	0.214+-0.030	OST78	0.227+-0.002 (W)	0.229+-0.001
	0.228+-0.001	0.229+-0.001	SOL85		
	Av: 0.229+-0.001				

TABLE C-1 (Cont.)

Nuclide	Studsvik 89/90 Halflife s	Literature Halflife s	Reference	Comment	Half-life used in this work s
147Ba	0.900+-0.035	0.70+-0.04	SOLI81	0.892+-0.001 (W)	0.83+-0.06
	0.890+-0.048	0.70+-0.05	OST82		
	Av: 0.897+-0.028	0.91+-0.04	SOL85		
148Cs?	0.154+-0.011			0.15+-0.01 (W)	0.139+-0.017
	0.120+-0.012				
	Av: 0.139+-0.017				
149La	1.088+-0.037	1.17+-0.12	SOL85	1.10+-0.03 (W)	1.095+-0.035

REFERENCES IN TABLE C-1

MAI77 W. Rudolph, K. L. Kratz, and G. Herrmann, J. Inorg. Nucl. Chem. 39, 753 (1977).

MAI88 K. L. Kratz *et al.*, Z. Phys. A 230, 229 (1988).

W Data sent to T. R. England from R. William Walker, dated 11/16/89. Tabulation of fission product half-lives for mass chains 66-172 is to be used on the new (' 14th) edition of the G.E. Chart of the Nuclides.

For other references, see Appendix A.

APPENDIX D

TABLE D-1

SET OF NUCLIDES FOR THE SUMMATION CALCULATION

Note: Nuclides are denoted Z-A(m).

Flags ib and ig are for the average beta and gamma energy defined as follows:

- Flag 0: Average energy from decay schemes.
- Flag 1: Average energy "directly" measured at Studsvik.
- Flag 2: Average energy from gross beta theory complemented by incomplete experimental information.
- Flag 3: Average energy from gross beta theory.

Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig
30- 71m	0	0	30- 71	0	0	31- 71	0	0						
27- 72	3	3	28- 72	3	3	29- 72	3	3	30- 72	0	0	31- 72	0	0
32- 72	0	0												
27- 73	3	3	28- 73	3	3	29- 73	3	3	30- 73	2	2	31- 73	0	0
32- 73m	0	0	32- 73	0	0									
27- 74	3	3	28- 74	3	3	29- 74	3	3	30- 74	2	2	31- 74m	0	0
31- 74	0	0	32- 74	0	0	33- 74	0	0						
27- 75	3	3	28- 75	3	3	29- 75	3	3	30- 75	0	0	31- 75	0	0
32- 75m	0	0	32- 75	0	0	33- 75	0	0	34- 75	0	0			
28- 76	3	3	29- 76	3	3	30- 76	2	2	31- 76	0	0	32- 76	0	0
33- 76	0	0	34- 76	0	0									
28- 77	3	3	29- 77	3	3	30- 77	2	0	31- 77	3	3	32- 77m	0	0
32- 77	0	0	33- 77	0	0	34- 77m	0	0	34- 77	0	0			
29- 78	3	3	30- 78	0	0	31- 78	0	0	32- 78	0	0	33- 78m	0	0
33- 78	0	0	34- 78	0	0	35- 78	0	0						
29- 79	3	3	30- 79	3	3	31- 79	1	1	32- 79m	0	0	32- 79	1	1
33- 79	1	1	34- 79m	0	0	34- 79	0	0	35- 79m	0	0	35- 79	0	0
36- 79m	0	0	36- 79	0	0									
29- 80	3	3	30- 80	3	3	31- 80	1	1	32- 80	1	1	33- 80	1	1
34- 80	0	0	35- 80m	0	0	35- 80	0	0	36- 80	0	0			
29- 81	3	3	30- 81	3	3	31- 81	1	1	32- 81m	3	3	32- 81	1	1
33- 81	1	1	34- 81m	0	0	34- 81	0	0	35- 81	0	0	36- 81m	0	0
36- 81	0	0												
30- 82	3	3	31- 82	1	1	32- 82	1	1	33- 82m	1	1	33- 82	1	1
34- 82	0	0	35- 82m	0	0	35- 82	0	0	36- 82	0	0			
30- 83	3	3	31- 83	3	3	32- 83	1	1	33- 83	1	1	34- 83m	1	1
34- 83	1	1	35- 83	0	0	36- 83m	0	0	36- 83	0	0			
31- 84	3	3	32- 84	3	3	33- 84	1	1	34- 84	0	0	35- 84m	0	0
35- 84	1	1	36- 84	0	0									
31- 85	3	3	32- 85	3	3	33- 85	1	1	34- 85	1	1	35- 85	1	[illegible]
36- 85m	0	0	36- 85	0	0	37- 85	0	0	38- 85m	0	0	38- 85	0	0
32- 86	3	3	33- 86	1	1	34- 86	0	0	35- 86m	0	0	35- 86	1	1
36- 86	0	0	37- 86m	0	0	37- 86	0	0	38- 86	0	0			
32- 87	3	3	33- 87	3	3	34- 87	3	3	35- 87	1	1	36- 87	1	1
37- 87	[illegible]	0	38- 87m	0	0	38- 87	0	0						
32- 88	3	3	33- 88	3	3	34- 88	3	3	35- 88	1	1	36- 88	0	0
37- 88	1	1	38- 88	0	0	39- 88	0	0						
33- 89	3	3	34- 89	3	3	35- 89	1	1	36- 89	1	1	37- 89	1	1
38- 89	0	0	39- 89m	0	0	39- 89	0	0						

TABLE D-1 (Cont.)

Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig
33- 90	3	3	34- 90	3	3	35- 90	1	1	36- 90	0	0	37- 90m	1	1
37- 90	1	1	38- 90	0	0	39- 90m	0	0	39- 90	0	0	40- 90m	0	0
40- 90	0	0												
34- 91	3	3	35- 91	3	3	36- 91	1	1	37- 91	1	1	38- 91	0	0
39- 91m	0	0	39- 91	0	0	40- 91	0	0						
34- 92	3	3	35- 92	3	3	36- 92	0	0	37- 92	1	1	38- 92	1	1
39- 92	0	0	40- 92	0	0									
34- 93	3	3	35- 93	3	3	36- 93	0	0	37- 93	1	1	38- 93	1	1
39- 93m	0	0	39- 93	0	0	40- 93	0	0	41- 93m	0	0	41- 93	0	0
35- 94	3	3	36- 94	3	3	37- 94	1	1	38- 94	1	1	39- 94	0	1
40- 94	0	0	41- 94m	0	0	41- 94	0	0	42- 94	0	0			
35- 95	3	3	36- 95	3	3	37- 95	1	1	38- 95	1	1	39- 95	0	1
40- 95	0	0	41- 95m	0	0	41- 95	0	0	42- 95	0	0			
35- 96	3	3	36- 96	3	3	37- 96	1	1	38- 96	1	1	39- 96m	0	2
39- 96	1	1	40- 96	0	0	41- 96	0	0	42- 96	0	0			
36- 97	3	3	37- 97	1	1	38- 97	1	1	39- 97m	1	1	39- 97	1	1
40- 97	0	0	41- 97m	0	0	41- 97	0	0	42- 97	0	0			
36- 98	3	3	37- 98	3	2	38- 98	1	1	39- 98m	0	0	39- 98	1	1
40- 98	2	3	41- 98m	0	0	41- 98	2	2	42- 98	0	0			
37- 99	3	3	38- 99	1	1	39- 99	1	1	40- 99	1	1	41- 99m	1	1
41- 99	1	0	42- 99	0	2	43- 99m	0	0	43- 99	0	0			
37-100	3	3	38-100	2	2	39-100m	0	0	39-100	1	1	40-100	2	2
41-100m	0	0	41-100	0	0	42-100	0	0	43-100	0	0	44-100	0	0
37-101	3	3	38-101	3	3	39-101	3	3	40-101	3	3	41-101	0	0
42-101	3	3	43-101	0	0	44-101	0	0						
38-102	3	3	39-102	3	3	40-102	3	3	41-102m	3	3	41-102	3	3
42-102	0	2	43-102m	0	0	43-102	2	2	44-102	0	0			
38-103	3	3	39-103	3	3	40-103	3	3	41-103	3	3	42-103	3	3
43-103	2	2	44-103	0	0	45-103m	0	0	45-103	0	0			
38-104	3	3	39-104	3	3	40-104	3	3	41-104m	3	3	41-104	3	3
42-104	2	2	43-104	2	0	44-104	0	0	45-104m	0	0	45-104	0	0
46-104	0	0												
39-105	3	3	40-105	3	3	41-105	3	3	42-105	3	3	43-105	0	0
44-105	0	0	45-105m	0	0	45-105	0	0	46-105	0	0			
39-106	3	3	40-106	3	3	41-106	3	3	42-106	3	3	43-106	2	2
44-106	0	0	45-106m	0	0	45-106	0	0	46-106	0	0			
39-107	3	3	40-107	3	3	41-107	3	3	42-107	3	3	43-107	2	2
44-107	2	2	45-107	0	0	46-107m	0	0	46-107	0	0	47-107m	0	0
47-107	0	0												
40-108	3	3	41-108	3	3	42-108	3	3	43-108	2	2	44-108	0	0
45-108m	2	2	45-108	2	2	46-108	0	0	47-108m	0	0	47-108	0	0
48-108	0	0												
40-109	3	3	41-109	3	3	42-109	3	3	43-109	3	3	44-109m	3	3
44-109	3	3	45-109	0	0	46-109m	0	0	46-109	0	0	47-109m	0	0
47-109	0	0												
41-110	3	3	42-110	3	3	43-110	3	3	44-110	3	3	45-110m	2	2
45-110	2	2	46-110	0	0	47-110m	0	0	47-110	0	0	48-110	0	0
41-111	3	3	42-111	3	3	43-111	3	3	44-111	3	3	45-111	3	3
46-111m	0	0	46-111	0	0	47-111m	0	0	47-111	0	0	48-111m	0	0
48-111	0	0												
41-112	3	3	42-112	3	3	43-112	3	3	44-112	3	3	45-112	3	3
46-112	0	0	47-112	0	0	48-112	0	0						
42-113	3	3	43-113	3	3	44-113	3	3	45-113	3	3	46-113	3	3
47-113m	0	0	47-113	0	0	48-113m	0	0	48-113	0	0	49-113	0	0
42-114	3	3	43-114	3	3	44-114	3	3	45-114	3	3	46-114	2	2
47-114m	0	0	47-114	2	2	48-114	0	0						

TABLE D-1 (Cont.)

Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig
42-115	3	3	43-115	3	3	44-115	3	3	45-115	3	3	46-115	3	3
47-115m	3	3	47-115	0	0	48-115m	0	0	48-115	0	0	49-115m	0	0
49-115	0	0	50-115	0	0									
43-116	3	3	44-116	3	3	45-116	3	3	46-116	2	2	47-116m	2	2
47-116	0	0	48-116	0	0	49-116m	0	0	49-116	0	0	50-116	0	0
43-117	3	3	44-117	3	3	45-117	3	3	46-117	3	3	47-117m	0	0
47-117	2	0	48-117m	0	0	48-117	0	0	49-117m	0	0	49-117	0	0
50-117m	0	0	50-117	0	0									
43-118	3	3	44-118	3	3	45-118	3	3	46-118	3	3	47-118m	0	0
47-118	0	0	48-118	0	3	49-118m	0	0	49-118	0	0	50-118	0	0
44-119	3	3	45-119	3	3	46-119	3	3	47-119	2	2	48-119m	0	0
48-119	0	0	49-119m	2	2	49-119	0	0	50-119m	0	0	50-119	0	0
44-120	3	3	45-120	3	3	46-120	3	3	47-120m	3	3	47-120	3	3
48-120	2	3	49-120m	0	0	49-120	0	2	50-120	0	0			
45-121	3	3	46-121	3	3	47-121	3	3	48-121m	3	3	48-121	3	3
49-121m	0	0	49-121	0	0	50-121m	0	0	50-121	0	0	51-121	0	0
45-122	3	3	46-122	3	3	47-122	3	3	48-122	3	3	49-122m	2	0
49-122	2	2	50-122	0	0	51-122m	0	0	51-122	0	0	52-122	0	0
45-123	3	3	46-123	3	3	47-123	3	3	48-123	3	3	49-123m	0	0
49-123	0	0	50-123m	0	0	50-123	0	0	51-123	0	0			
46-124	3	3	47-124	3	3	48-124	3	3	49-124m	0	0	49-124	0	0
50-124	0	0	51-124m	0	0	51-124	0	0	52-124	0	0			
46-125	3	3	47-125	3	3	48-125	3	3	49-125m	2	2	49-125	0	0
50-125m	0	0	50-125	0	0	51-125	0	0	52-125m	0	0	52-125	0	0
46-126	3	3	47-126	3	3	48-126	3	3	49-126m	0	0	49-126	2	0
50-126	2	2	51-126m	0	0	51-126	0	0	52-126	0	0			
47-127	3	3	48-127	3	3	49-127m	2	2	49-127	0	0	50-127m	2	2
50-127	0	0	51-127	0	0	52-127m	0	2	52-127	0	0	53-127	0	0
47-128	3	3	48-128	3	3	49-128m	1	2	49-128	1	0	50-128	0	0
51-128m	0	0	51-128	0	0	52-128	0	0	53-128	0	0	54-128	0	0
48-129	3	3	49-129m	2	2	49-129	0	0	50-129m	2	2	50-129	1	1
51-129m	0	0	51-129	0	0	52-129m	0	0	52-129	0	0	53-129	0	0
54-129m	0	0	54-129	0	0									
48-130	3	3	49-130m	0	0	49-130	0	0	50-130m	1	1	50-130	1	1
51-130m	0	0	51-130	0	0	52-130	0	0	53-130m	0	0	53-130	0	0
54-130	0	0												
48-131	3	3	49-131m	3	3	49-131	3	3	50-131m	3	3	50-131	1	1
51-131	1	1	52-131m	0	0	52-131	0	0	53-131	0	0	54-131m	0	0
54-131	0	0												
48-132	3	3	49-132	0	0	50-132	1	1	51-132m	0	0	51-132	0	0
52-132	0	0	53-132m	2	0	53-132	0	0	54-132	0	0			
49-133	3	3	50-133	1	1	51-133	1	1	52-133m	1	1	52-133	0	0
53-133m	0	0	53-133	0	0	54-133m	0	0	54-133	0	0	55-133	0	0
50-134	3	3	51-134m	3	3	51-134	1	1	52-134	0	0	53-134m	0	0
53-134	0	0	54-134m	0	0	54-134	0	0	55-134m	0	0	55-134	0	0
56-134	0	0												
50-135	3	3	51-135	1	1	52-135	1	1	53-135	1	1	54-135m	0	0
54-135	0	0	55-135m	0	0	55-135	0	0						
50-136	3	3	51-136	1	1	52-136	1	1	53-136m	1	1	53-136	1	1
54-136	0	0	55-136m	0	0	55-136	0	0	56-136m	0	0	56-136	0	0
51-137	1	3	52-137	1	3	53-137	1	1	54-137	1	1	55-137	0	0
56-137m	0	0	56-137	0	0									
51-138	3	3	52-138	3	3	53-138	1	1	54-138	0	0	55-138m	1	1
55-138	0	0	56-138	0	0									
51-139	3	3	52-139	3	3	53-139	1	1	54-139	1	1	55-139	0	1

TABLE D-1 (Cont.)

Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig	Nuclide	ib	ig
56-139	0	0	57-139	0	0									
52-140	3	3	53-140	1	1	54-140	0	2	55-140	1	2	56-140	0	0
57-140	0	0	58-140	0	0									
52-141	3	3	53-141	3	3	54-141	1	1	55-141	1	1	56-141	1	1
57-141	0	2	58-141	0	0	59-141	0	0						
52-142	3	3	53-142	3	3	54-142	3	3	55-142	1	1	56-142	0	0
57-142	0	0	58-142	0	0	59-142m	0	0	59-142	0	0	60-142	0	0
53-143	3	3	54-143	3	3	55-143	1	1	56-143	1	1	57-143	1	1
58-143	0	0	59-143	0	0	60-143	0	0						
53-144	3	3	54-144	3	3	55-144	1	1	56-144	1	1	57-144	1	1
58-144	0	0	59-144m	0	0	59-144	0	0	60-144	0	0			
53-145	3	3	54-145	3	3	55-145	1	1	56-145	1	1	57-145	1	1
58-145	1	1	59-145	0	0	60-145	0	0						
54-146	3	3	55-146	1	1	56-146	1	1	57-146m	0	0	57-146	1	1
58-146	1	1	59-146	0	0	60-146	0	0						
54-147	3	3	55-147	3	3	56-147	1	1	57-147	1	1	58-147	1	1
59-147	1	1	60-147	0	0	61-147	0	0	62-147	0	0			
55-148	3	3	56-148	2	2	57-148	0	0	58-148	0	0	59-148m	2	2
59-148	2	2	60-148	0	0	61-148m	0	0	61-148	0	0	62-148	0	0
55-149	3	3	56-149	3	3	57-149	3	3	58-149	3	3	59-149	2	2
60-149	0	0	61-149	0	0	62-149	0	0						
55-150	3	3	56-150	3	3	57-150	3	3	58-150	3	3	59-150	0	0
60-150	0	0	61-150	0	0	62-150	0	0						
56-151	3	3	57-151	3	3	58-151	3	3	59-151	2	2	60-151	0	0
61-151	0	0	62-151	0	0	63-151	0	0						
56-152	3	3	57-152	3	3	58-152	3	3	59-152	3	3	60-152	0	0
61-152m	0	0	61-152	0	0	62-152	0	0	63-152m	0	0	63-152	0	0
57-153	3	3	58-153	3	3	59-153	3	3	60-153	3	3	61-153	3	3
62-153	0	0	63-153	0	0									
57-154	3	3	58-154	3	3	59-154	3	3	60-154	3	3	61-154m	2	2
61-154	0	0	62-154	0	0	63-154m	0	0	63-154	0	0	64-154	0	0
57-155	3	3	58-155	3	3	59-155	3	3	60-155	3	3	61-155	3	3
62-155	0	0	63-155	0	0	64-155	0	0						
58-156	3	3	59-156	3	3	60-156	3	3	61-156	3	3	62-156	0	0
63-156	0	0	64-156	0	0									
58-157	3	3	59-157	3	3	60-157	3	3	61-157	3	3	62-157	3	3
63-157	0	0	64-157	0	0									
59-158	3	3	60-158	3	3	61-158	3	3	62-158	0	2	63-158	0	0
64-158	0	0												
59-159	3	3	60-159	3	3	61-159	3	3	62-159	3	3	63-159	3	2
64-159	0	0	65-159	0	0									
60-160	3	3	61-160	3	3	62-160	3	3	63-160	0	0	64-160	0	0
65-160	0	0	66-160	0	0									
60-161	3	3	61-161	3	3	62-161	3	3	63-161	3	3	64-161	0	0
65-161	0	0	66-161	0	0									
61-162	3	3	62-162	3	3	63-162	3	3	64-162	2	2	65-162	0	0
66-162	0	0												
62-163	3	3	63-163	3	3	64-163	3	3	65-163	3	3	66-163	0	0
62-164	3	3	63-164	3	3	64-164	3	3	65-164	0	0	66-164	0	0
62-165	3	3	63-165	3	3	64-165	3	3	65-165	0	0	66-165m	0	0
66-165	0	0	67-165	0	0									
65-166	0	0	66-166	0	0	67-166m	0	0	67-166	0	0	68-166	0	0
66-167	0	0	67-167	0	0	68-167m	0	0	68-167	0	0			

APPENDIX E

TABLE E-1

DELAYED-NEUTRON YIELDS AT EQUILIBRIUM
(THERMAL FISSION OF ^{235}U)

Number of neutrons/10 000 fissions = 0.1626e + 03 +/- 0.7539e + 01.
Nuclide contributions (per cent) in order.

nr	nuclide	contribution	nr	nuclide	contribution
1	(53,137)	0.1332e+02+/-0.1247e+01	2	(37, 94)	0.1038e+02+/-0.3744e+00
3	(35, 89)	0.9461e+01+/-0.5089e+00	4	(35, 90)	0.8166e+01+/-0.9900e+00
5	(35, 88)	0.7101e+01+/-0.4586e+00	6	(53,138)	0.4928e+01+/-0.5805e+00
7	(53,139)	0.4888e+01+/-0.8207e+00	8	(33, 85)	0.4267e+01+/-0.2690e+01
9	(37, 95)	0.4000e+01+/-0.1944e+00	10	(35, 91)	0.3364e+01+/-0.1313e+01
11	(35, 87)	0.3073e+01+/-0.1157e+00	12	(37, 93)	0.2872e+01+/-0.1065e+00
13	(34, 91)	0.2294e+01+/-0.1992e+01	14	(39, 99)	0.2288e+01+/-0.4776e+00
15	(39, 97)	0.1565e+01+/-0.4446e+00	16	(50,133)	0.1558e+01+/-0.1192e+01
17	(55,143)	0.1450e+01+/-0.1005e+00	18	(37, 96)	0.1363e+01+/-0.8691e+00
19	(51,135)	0.1354e+01+/-0.2103e+00	20	(33, 86)	0.1121e+01+/-0.7244e+00
21	(39,102)	0.9678e+00+/-0.6932e+00	22	(55,144)	0.8338e+00+/-0.1060e+00
23	(53,140)	0.8005e+00+/-0.2036e+00	24	(52,137)	0.7125e+00+/-0.1732e+00
25	(55,145)	0.6817e+00+/-0.8362e-01	26	(37, 97)	0.5866e+00+/-0.5069e-01
27	(36, 93)	0.5847e+00+/-0.4115e-01	28	(53,141)	0.5603e+00+/-0.2536e+00
29	(35, 92)	0.5428e+00+/-0.3534e+00	30	(52,136)	0.5386e+00+/-0.3109e+00
31	(33, 87)	0.4748e+00+/-0.3077e+00	32	(39,101)	0.3952e+00+/-0.9720e-01
33	(36, 94)	0.3032e+00+/-0.1244e+00	34	(52,138)	0.2561e+00+/-0.1864e+00
35	(51,136)	0.2549e+00+/-0.3494e+00	36	(39, 98)	0.2402e+00+/-0.7398e-01
37	(34, 89)	0.2299e+00+/-0.8557e-01	38	(32, 84)	0.1938e+00+/-0.5566e-01
39	(34, 88)	0.1759e+00+/-0.9065e-01	40	(34, 87)	0.1654e+00+/-0.3927e-01
41	(55,142)	0.1547e+00+/-0.1494e-01	42	(38, 98)	0.1418e+00+/-0.1666e-01
43	(54,142)	0.1107e+00+/-0.1048e-01	44	(55,141)	0.8930e-01+/-0.3575e-01
45	(31, 82)	0.8663e-01+/-0.5564e-01	46	(55,146)	0.6708e-01+/-0.1601e-01
47	(56,147)	0.5953e-01+/-0.3508e-01	48	(31, 81)	0.5562e-01+/-0.1790e-01
49	(39,100)	0.5439e-01+/-0.3306e-01	50	(49,130)	0.5163e-01+/-0.1289e-01
51	(49,129m)	0.4449e-01+/-0.1056e-01	52	(33, 84)	0.4024e-01+/-0.4667e-02
53	(55,147)	0.3828e-01+/-0.2466e-01	54	(36, 92)	0.3403e-01+/-0.3247e-02
55	(37, 92)	0.3316e-01+/-0.1303e-02	56	(54,141)	0.3306e-01+/-0.2183e-02
57	(57,148)	0.3007e-01+/-0.1854e-01	58	(50,134)	0.2362e-01+/-0.1798e-01
59	(49,131)	0.2167e-01+/-0.1223e-01	60	(37, 98)	0.2040e-01+/-0.1313e-01
61	(49,132)	0.1909e-01+/-0.7663e-02	62	(57,147)	0.1899e-01+/-0.5597e-02
63	(51,134)	0.8838e-02+/-0.5858e-02	64	(57,149)	0.8706e-02+/-0.8259e-02
65	(38, 99)	0.831[illegible]e-02+/-0.2315e-02	66	(49,127)	0.8018e-02+/-0.1804e-02
67	(49,130m)	0.7137e-02+/-0.2204e-02	68	(31, 80)	0.6277e-02+/-0.1473e-02
69	(49,129)	0.4928e-02+/-0.1720e-02	70	(38,100)	0.4401e-02+/-0.2906e-02
71	(31, 83)	0.2298e-02+/-0.1099e-01	72	(37, 99)	0.1266e-02+/-0.8218e-03
73	(31, 79)	0.9493e-03+/-0.2207e-03	74	(49,128)	0.6300e-03+/-0.2547e-03
75	(47,121)	0.1095e-03+/-0.7192e-04	76	(47,122)	0.1080e-03+/-0.8569e-04
77	(55,148)	0.1053e-03+/-0.6809e-04	78	(47,123)	0.3100e-04+/-0.2030e-04
79	(37,100)	0.6875e-05+/-0.5003e-05			

TABLE E-2

DELAYED-NEUTRON YIELDS AT EQUILIBRIUM (THERMAL FISSION OF ^{238}U)

Number of neutrons/10 000 fissions = 0.3649e + 03 +/- 0.3141e + 02.
Nuclide contributions (per cent) in order.

nr	nuclide	contribution	nr	nuclide	contribution
1	(53,137)	0.9372e+01+/-0.1350e+01	2	(37, 94)	0.8451e+01+/-0.2447e+01
3	(35, 90)	0.8320e+01+/-0.2497e+01	4	(35, 89)	0.7456e+01+/-0.2164e+01
5	(33, 85)	0.5979e+01+/-0.3600e+01	6	(53,139)	0.5099e+01+/-0.1587e+01
7	(53,138)	0.4620e+01+/-0.1381e+01	8	(37, 95)	0.3938e+01+/-0.1190e+01
9	(35, 91)	0.3759e+01+/-0.2453e+01	10	(37, 96)	0.3654e+01+/-0.2271e+01
11	(51,135)	0.3602e+01+/-0.2322e+01	12	(50,133)	0.2844e+01+/-0.2166e+01
13	(35, 88)	0.2534e+01+/-0.7325e+00	14	(39, 99)	0.2349e+01+/-0.7907e+00
15	(55,145)	0.2231e+01+/-0.1416e+01	16	(53,140)	0.1711e+01+/-0.1090e+01
17	(35, 92)	0.1709e+01+/-0.1105e+01	18	(33, 86)	0.1614e+01+/-0.1022e+01
19	(51,136)	0.1506e+01+/-0.2063e+01	20	(37, 93)	0.1503e+01+/-0.3126e+00
21	(55,144)	0.1447e+01+/-0.4524e+00	22	(39, 97)	0.1316e+01+/-0.3797e+00
23	(36, 94)	0.1308e+01+/-0.9794e+00	24	(53,141)	0.1260e+01+/-0.9257e+00
25	(55,143)	0.1225e+01+/-0.3369e+00	26	(52,137)	0.1059e+01+/-0.3999e+00
27	(35, 87)	0.1043e+01+/-0.1992e+00	28	(52,138)	0.8951e+00+/-0.6498e+00
29	(39,101)	0.8388e+00+/-0.2750e+00	30	(36, 93)	0.7970e+00+/-0.9801e-01
31	(52,136)	0.7466e+00+/-0.4862e+00	32	(39,102)	0.7119e+00+/-0.5057e+00
33	(50,134)	0.7106e+00+/-0.5408e+00	34	(34, 89)	0.7047e+00+/-0.5129e+00
35	(37, 97)	0.6160e+00+/-0.3919e+00	36	(55,146)	0.4096e+00+/-0.2616e+00
37	(37, 98)	0.2628e+00+/-0.1688e+00	38	(32, 84)	0.2199e+00+/-0.1415e+00
39	(39,100)	0.2106e+00+/-0.7987e-01	40	(38, 98)	0.2078e+00+/-0.6855e-01
41	(33, 87)	0.2014e+00+/-0.1347e+00	42	(54,142)	0.1828e+00+/-0.5922e-01
43	(39, 98)	0.1820e+00+/-0.5053e-01	44	(34, 88)	0.1291e+00+/-0.1002e+00
45	(55,142)	0.9623e-01+/-0.2178e-01	46	(34, 87)	0.8906e-01+/-0.3432e-01
47	(34, 91)	0.8332e-01+/-0.7234e-01	48	(55,147)	0.7798e-01+/-0.5024e-01
49	(38,100)	0.7764e-01+/-0.5116e-01	50	(56,147)	0.6811e-01+/-0.5684e-01
51	(49,132)	0.5868e-01+/-0.4008e-01	52	(31, 81)	0.5648e-01+/-0.3552e-01
53	(31, 82)	0.5194e-01+/-0.3316e-01	54	(55,141)	0.4805e-01+/-0.2017e-01
55	(51,134)	0.4423e-01+/-0.1594e-01	56	(57,148)	0.4350e-01+/-0.2329e-01
57	(54,141)	0.3655e-01+/-0.3591e-02	58	(57,149)	0.3154e-01+/-0.2931e-01
59	(49,129m)	0.2771e-01+/-0.1829e-01	60	(38, 99)	0.2688e-01+/-0.1056e-01
61	(33, 84)	0.2685e-01+/-0.1447e-01	62	(36, 92)	0.2576e-01+/-0.3153e-02
63	(57,147)	0.2088e-01+/-0.6649e-02	64	(49,130m)	0.1696e-01+/-0.1108e-01
65	(31, 83)	0.1610e-01+/-0.7697e-01	66	(37, 92)	0.1275e-01+/-0.1439e-02
67	(49,127)	0.6212e-02+/-0.3967e-02	68	(55,143)	0.5232e-02+/-0.3382e-02
69	(49,130)	0.4224e-02+/-0.2795e-02	70	(31, 80)	0.3558e-02+/-0.2129e-02
71	(49,129)	0.1774e-02+/-0.1265e-02	72	(49,131)	0.1769e-02+/-0.1477e-02
73	(37,100)	0.1095e-02+/-0.7968e-03	74	(49,128)	0.8463e-03+/-0.6103e-03
75	(47,123)	0.5261e-03+/-0.3417e-03	76	(31, 79)	0.4965e-03+/-0.2888e-03
77	(47,121)	0.4184e-03+/-0.2568e-03	78	(47,122)	0.4121e-03+/-0.3202e-03

TABLE E-3

DELAYED-NEUTRON YIELDS AT EQUILIBRIUM (THERMAL FISSION OF ^{239}Pu)

Number of neutrons/10 000 fissions = 0.6830e + 02 +/- 0.2957e + 01.
Nuclide contributions (per cent) in order.

nr	nuclide	contribution	nr	nuclide	contribution
1	(53,137)	0.2391e+02+/-0.2135e+01	2	(37, 94)	0.1040e+02+/-0.1632e+01
3	(53,138)	0.9816e+01+/-0.1284e+01	4	(35, 90)	0.7675e+01+/-0.8854e+00
5	(35, 89)	0.7034e+01+/-0.3828e+00	6	(37, 95)	0.5337e+01+/-0.1233e+01
7	(35, 88)	0.4674e+01+/-0.3556e+00	8	(53,139)	0.4452e+01+/-0.1050e+01
9	(39, 99)	0.3891e+01+/-0.8916e+00	10	(39, 97)	0.2764e+01+/-0.8961e+00
11	(37, 93)	0.2743e+01+/-0.1684e+00	12	(35, 87)	0.2489e+01+/-0.3421e+00
13	(33, 85)	0.1665e+01+/-0.1058e+01	14	(55,143)	0.1662e+01+/-0.3862e+00
15	(51,135)	0.1511e+01+/-0.9850e+00	16	(50,133)	0.1034e+01+/-0.7907e+00
17	(37, 96)	0.9070e+00+/-0.4914e+00	18	(53,140)	0.8181e+00+/-0.5299e+00
19	(55,144)	0.8109e+00+/-0.2705e+00	20	(55,145)	0.6923e+00+/-0.4466e+00
21	(52,136)	0.5960e+00+/-0.5103e+00	22	(52,137)	0.5693e+00+/-0.3825e+00
23	(35, 91)	0.5413e+00+/-0.3588e+00	24	(39, 98)	0.4929e+00+/-0.1056e+00
25	(33, 86)	0.2791e+00+/-0.1807e+00	26	(37, 97)	0.2561e+00+/-0.1319e+00
27	(39,101)	0.254[illegible]+00+/-0.1643e+00	28	(53,141)	0.2292e+00+/-0.1716e+00
29	(55,142)	0.2117e+00+/-0.4812e-01	30	(36, 94)	0.2018e+00+/-0.1400e+00
31	(36, 93)	0.1995e+00+/-0.2174e-01	32	(51,136)	0.1769e+00+/-0.2424e+00
33	(55,141)	0.1730e+00+/-0.7317e-01	34	(38, 98)	0.1387e+00+/-0.8978e-01
35	(35, 92)	0.1291e+00+/-0.8408e-01	36	(52,138)	0.1085e+00+/-0.7898e-01
37	(49,129m)	0.1012e+00+/-0.6672e-01	38	(50,134)	0.1008e+00+/-0.7673e-01
39	(39,100)	0.9488e-01+/-0.5678e-01	40	(54,142)	0.8724e-01+/-0.9584e-02
41	(34, 87)	0.7276e-01+/-0.4922e-01	42	(49,130m)	0.6126e-01+/-0.4001e-01
43	(34, 89)	0.5586e-01+/-0.4087e-01	44	(39,102)	0.5355e-01+/-0.3837e-01
45	(55,146)	0.4995e-01+/-0.3211e-01	46	(34, 88)	0.4623e-01+/-0.3628e-01
47	(51,134)	0.3765e-01+/-0.1142e-01	48	(32, 84)	0.3360e-01+/-0.2173e-01
49	(57,147)	0.3290e-01+/-0.2059e-01	50	(37, 92)	0.3123e-01+/-0.1853e-02
51	(54,141)	0.3047e-01+/-0.2009e-02	52	(31, 81)	0.3012e-01+/-0.1925e-01
53	(33, 84)	0.2868e-01+/-0.1809e-01	54	(33, 87)	0.2795e-01+/-0.1879e-01
55	(49,127)	0.2604e-01+/-0.1680e-01	56	(57,148)	0.2456e-01+/-0.1551e-01
57	(56,147)	0.2009e-01+/-0.1686e-01	58	(49,130)	0.1551e-01+/-0.1011e-01
59	(36, 92)	0.1490e-01+/-0.1422e-02	60	(37, 98)	0.1416e-01+/-0.9115e-02
61	(49,132)	0.1267e-01+/-0.8671e-02	62	(57,149)	0.1021e-01+/-0.9706e-02
63	(38,100)	0.9076e-02+/-0.5993e-02	64	(31, 82)	0.7885e-02+/-0.5067e-02
65	(49,129)	0.6491e-02+/-0.4618e-02	66	(31, 80)	0.6475e-02+/-0.4112e-02
67	(38, 99)	0.5309e-02+/-0.3607e-02	68	(49,131)	0.3766e-02+/-0.3130e-02
69	(49,128)	0.3127e-02+/-0.2255e-02	70	(31, 83)	0.8142e-03+/-0.3892e-02
71	(31, 79)	0.7018e-03+/-0.4542e-03	72	(55,147)	0.6700e-03+/-0.4322e-03
73	(47,121)	0.2945e-03+/-0.1942e-03	74	(47,122)	0.1802e-03+/-0.1432e-03
75	(47,123)	0.4805e-04+/-0.3147e-04	76	(55,148)	0.3995e-04+/-0.2583e-04
77	(37,100)	0.1696e-04+/-0.1234e-04			

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