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STATUS OF FISSION YIELD EVALUATIONS

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ABSTRACT

Very few yield compilations are also evaluations, and very few contain an extensive global library of measured data and extensive models for unmeasured data. The earlier U.K. evaluations and U.S. evaluations were comparable up to the retirements of the primary evaluators. Only the effort in the U.S. has been continued and expanded. The previous U.K. evaluations have been published. In this paper we summarize the current status of the U.S. evaluation, philosophy, and various integral yield tests for 34 fissioning nuclides at one or more neutron incident energies and/or for spontaneous fission. Currently there are 50 yield sets and for each we have independent and cumulative yields and uncertainties for approximtely 1100 fission products. When finalized, the recommended data will become part of the next version of the U.S. Evaluated Nuclear Data File (ENDF/B-VI). The complete set of data, including the basic input of measured yields, will be issued as a sequel to the General Electric evaluation reports (better known by the authors' names: Rider--or earlier--Meek and Rider).

1. INTRODUCTION

Many compilations and, in a few cases, evaluations of fission yields have been published since the discovery of fission in 1939. Most have been limited to the yields of the major fissionable nuclides and/or limited to mass chain yields or otherwise limited in the scope of data included. Very few compilations could also be classed as evaluations. Since 1972, two efforts, Crouch in the U.K.[1] and Rider and Meek in the U.S.[2], are outstanding in the range of data considered and in their attempt to make global evaluations. Of these, the continued evaluations of Rider, along with the

guidance and assistance from the ENDF/B Yields Subcommittee, are the most recent and extensive. The U.K. and U.S. evaluation procedures differ in philosophy, in the measured data accepted for inclusion, and in the evaluation of uncertainties; but prior to Crouch's retirement, mean chain yields were comparable and tending to converge for the larger chain yields.

The ENDF/B-IV and -V yields are based on Rider's evaluation prior to his retirement from G.E. in December 1981, and the work has subsequently continued at Los Alamos in close consultation with Rider. Crouch's unpublished data base has received some updating through 1980; however, as of early 1983, his 1977 evaluations have been halted. Rider and Crouch did exchange data bases through 1980 and resolved most of the differences due to errors and/or interpretation of published data through 1980, thereby improving both bases.

This paper will summarize the status of the continued and more extensive ENDF/B evaluations. These incorporate the recent measurements at ANL, ORNL, University of Illinois (HIAWATHA), Grenoble (Lohengrin), chain yields of Maeck (this conference), and other, less extensive data, as referenced in [2] (approximately 1274 references). (We assume that other papers at this conference will summarize the status of measured data.) Also, we expect that the U.S. evaluation work will be continued and that the U.K. evaluations will be resumed, with a cooperative exhange of the data bases as a consequence of these endeavors. In addition, we anticipate continued cooperation with France, Sweden, Japan, Germany, and other countries, particularly in supplying data for inclusion in the evaluations.

There is a reduced level of support for ENDF/B-VI evaluations and cooperation is even more essential now than formerly for Versions -IV and -V. In this regard, the compilations of measured data in progress at BNL (V. McLane) are expected to be very important to the final ENDF/B-VI evaluation. Also, the evaluation of parameters used in modeling yield distributions where measured data do not exist are vital. Essential contributions are being made in this area by J. Blachot and H. Denschlag (this conference), A. C. Wahl (Washington University, retired) and Wahl's colleagues at Los Alamos and Livermore. Obviously, the evaluation of Pn values are also important to the yield evaluation process. These have been completed in a mutual Hanford Engineering/Los Alamos effort, a report submitted for publication in Nuclear Science and Engineering, and preliminary values published in Ref. [3]. (See also F. Mann, this conference.) We anticipate some assistance from HEDL in the conclusive evaluations for ENDF/B-VI.

II. EVALUATIONS FOR ENDF/B

Existing ENDF/B yield sets have been based on the basic evaluations by B. F. Rider prior to his retirement from General Electric. Several codes were written at Los Alamos to expand each mass chain to include each nuclide and isomeric state in the ENDF/B decay files or to cover at least four charge units on the neutron rich side of the most probable charge. In addition, these codes were used to check for errors in the decay branchings, to provide various integral tests [4,5], and to ultimately provide an output normalized to 200% in the required ENDF/B format structure. The ENDF/B-IV

and -V results will therefore differ slightly from basic evaluations published in any of the successive versions of the G.E. publications [2].

Since early 1982, the evaluation work has continued at Los Alamos with Rider's assistance. All of the G.E. codes had to be modified to replace machine-dependent subroutines, and all master data files contained one missing column that required a tedious, but essential, replacement and checking effort before the addition of new data. This paper is based on Version E to distinguish it from the last available version listed under Ref. [2]. Some data are now current to mid-1983 and all data are current to at least mid-to-late 1981. In addition, duplicate measured data, resulting from more than one publication or laboratory report by the same author, have been largely--hopefully, entirely--removed.

We plan to update all data sets through 1984 (or later) for ENDF/B-VI and to modify the yield distribution parameters and decay-branching ratios.

Current evaluations now include 34 fissionable nuclides at one or more fission energies, including spontaneous fission, for a total of 50 yield sets. This is an expansion by a factor of 2½ over ENDF/B-V (11 fissionable nuclides and 20 yield sets). ENDF/B-IV, unlike ENDF/B-V and the current evaluations, contained only independent yields, no uncertainties, and it covered only six fissionable nuclides for ten yield sets. The current evaluations include independent yields prior to delayed neutron emission and cumulative yields along each mass chain subsquent to delayed emission along with the uncorrelated uncertaintites in each quantity.

Table I lists the fissionable nuclides and yield sets included in ENDF/B-IV, -V, and the preliminary evaluations for ENDF/B-VI. Table II briefly summarizes the characteristics of each version.

III. COMMENTS ON THE GENERAL EVALUATION

For each yield set the mass chain yields are evaluated in increasing order. Each chain consists of nine elements plus significant branchings to first isomeric states and to delayed neutron emitters (treated as isomeric states). There are up to 12 nuclides per mass chain for mass numbers 66 through 172, or over 1100 nuclides in each yield set. The delayed neutron emitters couple the mass chains, hence the evaluation procedure must account for the loss and/or gain from such couplings; this is accomplished in part during the evaluation of each mass chain and in part by specified iterations during the evaluation of each yield set. The nuclide yields are inverse variance weighted; but, before this is accomplished, several complications are considered:

(a) Most yields have been measured subsequent to delayed neutron emission, but many are now measured prior to emission. The different types are keyed in the data set.

(b) Chain yields generally have a smaller uncertainty than independent yields, yet the recommended uncertainties must be consistent (see Sec. V).

(c) Some measured yields are relative to other fission nuclides and even products from other fissioning nuclides; these must be converted to absolute yields and some must be updated to new reference values.

(d) Some yield uncertainties receive special treatment numbers (see Ref.[2]) that modify the originally quoted uncertainty.

(e) Some yields are clearly discrepant and are rejected based on statistical criteria (e.g., the Dixon Range Test).

(f) Yields and uncertainties are required for all nuclides, yet very few independent yields have been measured. The distribution of the chain yields is based on the models discussed in Sec. IV, but these are given large uncertainties and have little effect on their weighting with measured values.

These comments are intended to provide the reader with an idea of the complexity of considerations used in the evaluations, but a complete list of these and special treatment flags (listed in Ref. [2]) is too extensive for this paper. We do provide more detail on the evaluation procedure in Sec. V. Reference [5] presents some additional insight.

IV. DISTRIBUTION MODELING

Relatively few independent yields have been measured. They are being used where they exist. Otherwise we use a modification of the "Zp" model, which is a phenomenological Gaussian distribution about a most probable charge per mass chain (see work by A. C. Wahl in Ref. [6]). The original model is illustrated in Fig. 1. In particular, the basic distribution is given by Eq. (1) where Zp is the most probable charge per mass chain and σ the Gaussian width:

$$P(Z,A) = \frac{1}{(2\pi\sigma^2)^{\frac{1}{2}}} \exp\left[-\frac{(Z-Zp)^2}{2\sigma^2}\right] \quad . \tag{1}$$

[All results in this presentation assumed that σ was a constant 0.56 and used Zp values based on Ref. [7]. As noted in the next section, the Zp's are modified and σ will be modified for the final evaluation for ENDF/B-VI, including any dependence on the chain mass.]

Using Eq. (1), the fractional independent and cumulative yields (ignoring pairing effects) are computed using Eqs. (2) and (3), respectively:

$$FIY'(Z,A) = \int_{Z-\frac{1}{2}}^{Z+\frac{1}{2}} P(A,Z)dZ \tag{2}$$

$$FCY(Z,A) = \int_{-\infty}^{Z+\frac{1}{2}} P(A,Z)dZ \qquad (3)$$

These distributions must be modified to account for proton and neutron pairing effects and isomeric states. In particular we use

$$FIY(Z,A) = FIY'(Z,A)(1 \pm X)(1 \pm Y)/NORM \quad , \qquad (4)$$

where X and Y are the Z and N pairing and NORM is the factor necessary to renormalize the mass chain distribution to unity. The "+" sign is used for products having an even Z or N and the "-" sign for odd Z or N. That is, there are four products possible. The particular factors X,Y used for this paper are listed in Table III and are based on the earlier parameter evaluation at Los Alamos [Ref. 8]. These require an updating using the more extensive independent yield measurements that have since become available. The large Z pairing for ^{238}U is now known to be too large, as will be discussed in a later section.

We have also developed and used a spin-and-energy-dependent model for isomeric state distributions Ref. [9]. The model requires an estimate of the total angular momentum, J_{rms}, of the fragment and a statistical model is used for this. The details of the isomeric state model are readily available in Ref. [9]. Measurements of isomeric vs ground state yields made since the publication of Ref. [9] have shown remarkably good and bad agreement with the model; however, most of the cases in which agreement was poor had very questionable spin assignments or spurious identification of the ground vs. isomeric state assignments. In many cases, no estimates of the spins were available and the independent yields are assumed to split equally between the states.

Although we have no plans to further modify the basic distribution models (only the parameters), the reader should be aware that a similar Gaussian model based on element yields (the "Ap" model) is being developed [10] (see also Blachot, this conference). It is possible that the Ap model is more accurate, especially for users intending to rely only on calculated distributions. For ENDF/B-VI, we will retain the use of the Zp model, along with improvements in its parameters, because of the extensive existing coding that permits us to include measured distributions and mass chain yields with the model values.

V. SPECIFIC TREATMENT FOR RECOMMENDED YIELDS AND UNCERTAINTIES

Because there have been some comments to the effect that our assignment of uncertainties is generally too small, the following summary of the method used for recommended yields and uncertaintites is provided in more detail than we would normally prefer for this review paper. However, this summary is still incomplete in that many yields receive special consideration before incorporation into the basic files and also special treatment flags in the

evaluation codes [2]. As is seen in Sec. VI, the integral calculations show larger uncertainties than would be suggested by the comparisons with measured integral quantities. The suggestion that our resulting uncertainties are too small is probably based on the small uncertainties for some frequently measured mass chain yields. As evidenced in Sec. VII, some of these are less than 1%; this is a natural result of the weighting of many measurements. We do treat all uncertainty values as independent and uncorrelated. The integral calculations clearly indicate that, on the average, the uncertainties are either too large or there are large negative correlations. Suggestions have been made that the recommended uncertainty should never be permitted to be less than 1%. However, we prefer to retain the methods described below and leave the option of utilizing this suggestion and its defense to the discretion of the user.

A. Merging Model Distributions with Experimental Values

The model independent yields are normalized so that their sum equals the chain yield. Large (100%) errors are initially given to the model yields. These model yields are merged statistically with weighted averages of measured yields. One set of cumulative yields is calculated by adding independent yields starting with the initial nuclide and ending with the chain yield. A second set of cumulative yields is calculated by starting with the chain yields and substracting independent yields ending with the initial nuclide. These two sets are averaged using reciprocal variance weighting. The first set dominates the initial nuclide yield averages. The second set dominates the final chain member yield averages because of the small errors caused by the constraint imposed at 0% and 100% of the chain yield, respectively. This technique and resulting error analysis is essentially that recommended by B. I. Spinrad [11]. Spinrad and Wu [12] have developed a general correlation for independent fission-product-yield uncertainties. Measurements of independent fission-product yields from thermal-neutron fission of ^{235}U, ^{239}Pu, ^{233}U, and ^{241}Pu were compared with expected yields from the semiempirical model in our evaluation. A general correlation between the experimental to theoretical ratio and the distance of the nuclide from Zp was constructed based on measured distributions from ^{235}U, ^{239}Pu, ^{233}U, ^{241}Pu fission. This correlation serves as a basis for assigning uncertainties to theoretical yield estimates. The correlation is

$$\text{Abs}\ (\ell n(YT(I)/YE(I)) = 0.143 + 0.108\ (Z(I) - Zp)^2, \qquad (4)$$

where YT and YE are theoretical and experimental fractional independent yields of nuclide (I), Z is the charge of nuclide (I), and Zp is the most probable charge for the mass chain.

B. Treatment of Experimental Uncertainties and Yields

The original values reported in the literature have been tabulated in the master files along with the reference value (if any) against which they were determined. An updated value was then calculated by using the most

current recommended value for the fission yield of the reference nuclide from our files. All the updated values were adjusted by a small adder to ensure that the chain yields about each mass peak would total 100% except for the small difference between iterations. To determine this adder, the variance of the sum is obtained by summing the variances of each chain yield. Any difference from 100% is apportioned to each chain yield in the proportion its variance bears to the total variance. That is, to a chain yield whose variance contributes 10% to the total variance is added 10% of the total difference from 100%. This method results in a negligible adjustment to accurately determined absolute yields and ensures the adjustment is made mainly in the lesser known yields. Yet these lesser known values are adjusted by only a fraction of their standard deviation or well within their experimental uncertainty.

The relative standard deviation reported in the literature was not allowed to be better than (smaller than) 0.5% for mass spectrometric or 5% for GE(Li)-era radiochemical and other special measurements made since 1965; 10% for sodium-iodide-era measurements between 1955 and 1965; and 20% for Geiger-counter-era measurements before 1955. Estimates are generally no better than 10% and are defaulted at 30%. If separate plus- and minus-errors were reported, the smaller value plus two-thirds the difference was used. If no uncertainty was reported in the literature, it was assumed to be three times the lower limit. For relative values, the resultant uncertainty was combined statistically with the uncertainty in the recommended yield of the reference nuclide from the previous iteration to give an error of the updated value. For absolute values, a 2% upper limit of conceivable systematic error was combined with the reported random uncertainty.

Average experimental independent yields and experimental cumulative yields were determined for each nuclide. The individual values in the average were weighted by the inverse square of the relative standard deviation. If more than the above standardized treatment is required, a special treatment number has been assigned so that these various cases can be individually treated. A detailed description of the special treatment numbers are given in Ref. [2].

C. Constraints Used in the Evaluation

There are several integral conservations or constraints one could use in the evaluation procedure as has been done, for example, by Crouch [1]. However, we prefer to use these as a test of the general quality of the various yield sets, as discussed in the Sec. VI. We do impose essentially two constraints during the evaluation iterations. The yields about each mass peak are normalized to 100% except for small variations that occur during the final iteration, and the independent yield weighted charge of of products is forced to sum to the fission nuclide charge (minus the small ternary fission charge) by adjusting the model Zp value within its ± 0.1 charge unit uncertainty, if necessary. The midpoint mass value used for separating the two peaks is not critical because of the small yields near symmetric fission. We use the nearest integral mass value to the quantity

$$A_{mid} \cong (A_f + 1 - \bar{\nu}_t)/2 \qquad (5)$$

where $\bar{\nu}_t$ = the total delayed neutron yield or some assumed value if it is unknown,
A_f = the mass number of the fissioning nuclide.

For spontaneous fission, the added unity is, of course, not used.

The final ENDF/B yields are normalized to 200%; this is required by the ENDF procedure and the change is insignificant.

While it is not imposed as an integral constraint, we do attempt to account for the coupling of mass chains due to delayed neutron emission (for ~ 102 nuclides in the current evaluation), as noted previously, for the cumulative yields. This is necessary because the ENDF yields require independent values before delayed neutron emission and cumulative values after emission.

D. Energy Definitions

Yields do depend on the neutron fission energy. Future evaluations, especially of mass chain yields for fast reactors, may require either information of the dependence for some important nuclides used, e.g., on burn-up monitors, or on the use of two or more pools of fast-yield data. At a Los Alamos CSEWG meeting in December 1982, W. Maeck questioned the ENDF/B-V evaluation based on a comparison of the energy dependence implied by our evaluated yields labeled thermal and fast with his chain yield measurements in two or more fast spectra (see Maeck's review of this conference). It is both quite possible and probable that evaluated thermal-to-fast ratios based on several experiments will not show the same energey dependence as the more limited data from a single measurer made in different fast spectra. Such measurements could be useful in specifying the energy dependence for the few nuclides where it is available, but otherwise evaluations cannot ignore the mean cumulative yield values based on the results from several experiments. That is, the data produced by a single measurer is more likely to be correct in the qualitative behavior of yields vs energy than in the absolute fission yield. In any case, energy dependence is one area in which evaluations could be expanded and improved. To date, we use only four general designations for energy: thermal-, fast-, high- (~ 14.7 MeV) and spontaneous. These are denoted in the tables following this section by T, F, H, S, respectively.

A fission-neutron spectrum is defined as one giving a CD-115 ground state R-value of 2.80 for ^{235}U fission, using ^{99}Mo as a reference nuclide. As an expedient, yields measured in the core of a fast reactor and selected yields measured in monoenergetic neutron energies between 0.5 and 2.0 MeV have been pooled with fission-neutron spectrum yields. The definitions of thermal- and high-energy neutrons in practice are fairly consistent. Thermal neutrons are obtained from a reactor and are assumed to have been moderated to thermal equilibirum. The high-energy neutrons are obtained from the $^{3}H(D,N)^{4}He$ Reaction. The actual energies quoted vary from 14 to 15 MeV with 14.7 MeV being the most frequently listed mean value. The ENDF/B format requires an assigned energy for each yield set. For fast yields, this has been listed as 0.5 MeV in Version IV and V. This value is obviously arbitrary because some nuclides have a higher threshold energy for fission.

E. Final Recommended Yield Procedure

The weighted average experimental independent yields, the weighted average experimental cumulative yields, and the calculated cumulative yields were combined statistically to form a single, self-consistent recommended value. The following is a summary of the procedure used to obtain the recommended values.

The calculated charge distribution was essentially used only when no data were available and even then was normalized to the nearest experimentally determined yields to ensure that the experimental and recommended values will closely agree. A large uncertainty was assumed for the calculated yields to ensure that any respectable experimental data would dominate. The contributions of all precursors were added. The total precursor contribution was then subtracted from the experimental cumulative yield, when available, or the normalized calculated yield, to obtain an independent yield. (Note: independent yields so obtained that are less than 0.1% are given no weight and negative values are discarded.) This independent yield was then averaged with the experimental independent yield, if available, or the calculated independent yield and stored for later use. A cumulative yield was then obtained by adding the precursor contribution to the independent yield previously obtained. This cumulative yield was averaged with the experimental cumulative yields, if available, or the calculated yield to obtain a cumulative yield that was then stored as input for the next member of the chain. After this procedure has been performed for all members of the chain, the mass chain yield was obtained by adding the stored cumulative yields of all stable nuclides. The stored independent yields were then normalized so that their total equals the chain yield (after adjustment for delayed neutron emission). The recommended cumulative yields were obtained by adding the independent yields of all precursors to the independent yield of the nuclide. The total of the chain yields about each peak was then obtained. The difference between 100% and this total was distributed among the chain yields in proportion to their variances. This method ensures the reported chain yields about each peak will total nearly 100%. This procedure preserves the independent yield significance of the differences among the recommended yields and it allows unstable nuclides to affect the chain yields if independent yields have been measured or if the calculated charge distribution indicates the yield of the nuclide is very near the chain yield.

VI. TESTS

Tabular data in this section are listed in the order of evaluation of each set. This order roughly corresponds to the amount and/or quality of the yields for each fissioning nuclide and incident neutron energy.

A. Code and Master File Verifications at Los Alamos

As previously noted, all input files required some reconstruction due to a missing column on the magnetic tapes received at Los Alamos. All FORTRAN DO-loops had to be altered in the primary evaluation routines and

some system dependent routines had to be rewritten. In addition we incorporated 196 new data in the basic files, corrected several input data errors, and eliminated some duplicate data due to multiple publications. Therefore, we had to do some extensive testing to verify the resulting files and codes.

One test was simply to plot the resulting mass chain yields, giving the familiar double-peaked shape, as in Fig. 2. A more useful test was to compare the 20 sets common to ENDF/B-V, as in Fig. 3. Here the uncertainty values are from the current evaluation. Exact agreement is not expected because of additions in the basic data following the release of ENDF/B-V. The primary utility o such familiar plots is to discover gross errors in the evaluations; for this reason, we examined the plots of all 50 yield sets. Otherwise, we compared the yields for some specific nuclides that we expected would remain nearly constant due to small uncertainties in measured data. In addition, one routine in the code compares measured values for gross errors, lack of a normal distribution, etc.

We are now satisfied that the codes and data files are correctly operating on the Los Alamos computers using only standard FORTRAN-V (not -IV) routines.

B. Average Charge

Table IV lists the average charge, computed from the independent yields, and its deviation from the fission nuclide charge. Except for the small component lost due to ternary fission, and the small deviation due to a finite number of interations in the evaluation, the deviations should be zero. Z_{ave} in the table was computed from:

$$Z_{ave} = \sum_i YI(Z,A)_i Z_i, \tag{6}$$

where $YI(Z,A)_i$ = independent yield of nuclide i,

and Z_i = charge of nuclide i.

Clearly this simple check of each evaluation is satisfactory. The most interesting feature in this table is that the largest deviation, 0.06%, occurs for $^{235}U(T)$, the set having the largest number of measured input yields. Prior to adding the Lohengrin independent yield measurements, a closer charge balance could be achieved, but we expect the final evaluation for ENDF/B-VI to show a closer balance.

C. Delayed Neutrons

Other reviews at this conference will be discussing delayed neutron calculations. However, we have been using evaluated emission probabilities, P_n, and yields as one important test of the quality of the fission yields, as in Ref. [13]. The calculation is simply made with

$$\bar{\nu}_d = \sum_i YC(Z,A)_i Pn_i, \tag{7}$$

where $YC(Z,A)_i$ = cumulative yield of each precursor,

and Pn_i = total neutron emission probability following precursor decay.

This test is particularly sensitive to the pairing values used in the model distributions (Table III). As noted in Ref. [13], more than 90% of the delayed neutrons come from the decay of odd-Z precursors. Accordingly, if the Z-pairing is too large, the computed $\bar{\nu}_d$ will be too small. This was long suspected to be the case with ^{238}U because our energy-dependent model, Ref. [8,9], used an incident neutron energy too close to the fission threshold. The result was a 33% pairing effect. Recent results reported by Blachot (this conference) indicate that the pairing is essentially constant for a given fissionable element and incident neutron energy. When we use 15%, the same value used for $^{235}U(F)$, the result for $^{238}U(F)$ is 4.04 ± 0.4 in agreement with the ENDF/B-V evaluation within the computed uncertainty.

All calculations using the pairing in Table III, our recent Pn evaluations Ref. [3], and the current yield evaluations are listed in Table V, along with the ENDF/B-V aggregate evaluations. The listed computed uncertainty includes that from both the Pn values and yields, and these individual components are roughly equal for many yield sets. For 17 of the 50 sets, the Pn uncertainty is dominant (this includes the thermal and fast yields of the major fissioning nuclides, ^{235}U, ^{233}U, ^{238}U, ^{239}Pu, and ^{241}Pu).

D. Total Neutrons Released Per Fission

It is possible to compute the number of prompt neutrons per fission from

$$\bar{\nu}_p = N_f + 1 - \sum_i YI(A,Z)_i N_i \quad , \tag{8}$$

where N_f = the number of neutrons in the fissioning nuclide (the unity is replaced by zero for spontaneous fission).

N_i = the number of neutrons in the directly yielded fission product.

Assuming the nuclear charge is conserved, the N_f can be replaced by A_f, the total number of prompt neutrons can be computed from

$$\bar{\nu}_p = A_f + 1 - \sum_i YCH(A)_i A_i - \bar{\nu}_d \tag{9}$$

and the total number of neutrons from

$$\bar{\nu}_t = \bar{\nu}_p + \bar{\nu}_d \quad , \tag{10}$$

where YCH(A) = the mass chain yield

and A_i = the mass number of the chain.

Again, this assumes charge is conserved, otherwise it can be corrected using the results from Table IV. Using Eqs. (9) and (10), the uncorrected values of $\bar{\nu}_t$ and comparisons with the aggregate evaluations in ENDF/B-V are listed in Table VI. (Correcting the ^{235}U thermal value for lack of charge balance gives $\bar{\nu}_t = 2.60 \pm 0.29$).

Apart from the generally good agreement, one should note the large uncertainty. This is entirely due to yield uncertainties and, of course, is actually the uncertainty in the weighted mass number wherein the yield uncertainties are treated as independent and uncorrelated in the expression

$$\Delta N \equiv \Delta\bar{\nu}_t \cong \left(\sum_i (N_i \Delta YCH(A)_i)\right)^{1/2} , \qquad (11)$$

where Δ denotes one σ in each quantity and the small contribution to the uncertainty in $\bar{\nu}_t$ from delayed neutrons has been ignored.

Recalling the discussion of uncertainty in Sec. V, and particularly the concern that uncertainties are too small in our evaluation, the large uncertainty here, we think, clearly shows that yield uncertainties are not generally small. In fact, had we used the independent yields and uncertainties, ΔN would be even larger for most of the fissioning systems. The results in Table VI were unexpected: the large uncertainties compared to the relatively good agreement of calculated and evaluated $\bar{\nu}_t$ values indicates that our uncertainties are either generally too large or that there are significant negative correlations, as noted in Sec. V.

^{233}U measurements at the University of Illinois (HIAWATHA) demonstrated that, with few exceptions (those near closed shells), our earlier evaluations were in good agreement with measurements and it was concluded that our uncertainties were generally too large [14]. (The above measurements were not incorporated into the earlier evaluations, but are now part of the basic data files.)

As previously stated, there are some small uncertainties in mass chain yields for frequently measured nuclides. The simple unweighted average of all uncertainties for cumulative yields $\geq$ 1% and $\leq$ 1% are listed in Table VII.

E. Pairing Effects

A simple plot of elemental yields vs the Z value should show the pairing diminishing with neutron fission energy. Figure 4 and similar plots for all other cases having a non-zero pairing listed in Table III clearly show this effect.

F. Other Integral Tests

All yields summed to 200% within ± 0.5%. For the integral calculations

in this section, all sets were first normalized to 200%, as they would be for final ENDF/B files.

Fission product yields are generally a direct multiplier in the estimation of the content of any product, unlike, for example, their cross sections; therefore, there are many possible tests.

A very sensitive test would be a calculation of the total energy release per fission. This can be done using the mass of each fission product, and it was done for the 20 sets in ENDF/B-V where we found remarkably good agreement with measured values (generally within 5-15%, depending on the yield set). This test is very sensitive because a mass loss of only ~ 0.2 mass units would account for the ~ 200 MeV/fission. Even the calculated uncertainties in $\bar{\nu}_t$ all exceed this. Due to the demands of time, we have not calculated the energy loss for the current evaluation as we did for ENDF/B-V, but our intention is to do so later; we suggest that other evaluators or measurers perform this test.

The early impetus for new yield evaluations was generated primarily by the need for decay heat calculations following a loss of flow or cooling in nuclear reactors, and for the beta and gamma spectra of fission products. These important quantitites, as well as the buildup of neutron absorption with depletion of fuels, depend on other quantities and have not been calculated for the current evaluation. Results for ENDF/B-V, and -IV are available in Refs. [15] and [16], and similar calculations will be presented in other reviews at the conference.

VII. CHAIN YIELDS

Individual nuclide yields, both independent and cumulative, are included in the ENDF/B files but not the mass chain yields. Table VIII lists the mass yields and uncertainties for ten yield sets from the current evaluation. These are not the final values we anticipate having for the final evaluations for ENDF/B-IV, but changes in the chain yields should be less than those in the cumulative and independent yields. In Fig. 5, the ratios of ^{238}U(F) and ^{239}Pu(F) chain yields to ^{235}U(F) values are plotted. This type of plot is more informative than the usual log-linear plots.

VIII. CONCLUSION

We have described the current evaluation for 50 yield sets, including the methods used and the results of various integral tests. No yield evaluation can be regarded as final and this one is no exception. In fact, we are well aware of the impossibility of generating a set of yields that even temporarily will satisfy all users and measurers. However, we are also aware of the continuing need for a reference data set and the general acceptance and wide usage of the yields in this series.

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FIGURE CAPTIONS

Fig. 1. Schematic of yield distribution model.

Fig. 2. $^{235}U(F)$ mass yields (Version E)

Fig. 3. $^{235}U(F)$ mass yields (Version E) and ENDF/B-V values.

Fig. 4. Sum of direct yields by charge.

Fig. 5. Ratio of $^{238}U(F)$ and $^{239}Pu(F)$ chain yields to $^{235}U(F)$ (Version F).

TABLE I

ENDF/B Fission-Product Yield Sets[a]

Nuclide	Neutron Energy: Thermal	Fast	14 MeV	Spon
^{227}Th	6			
^{229}Th	6			
^{232}Th		456	56	
^{231}Pa		6		
^{232}U		6		
^{233}U	456	56	56	
^{234}U		6	6	
^{235}U	453	456	456	
^{236}U		56	6	
^{237}U		6		
^{238}U		456	456	6
^{237}Np		56	6	
^{238}Np		6		
^{238}Pu		6		
^{239}Pu	456	456	56	
^{240}Pu		56	6	
^{241}Pu	456	56		

Nuclide	Neutron Energy: Thermal	Fast	14 MeV	Spon
^{242}Pu		56		
^{241}Am	6	6	6	
^{242}Am	6			
^{243}Am		6		
^{242}Cm		6		
^{244}Cm				6
^{245}Cm	6			
^{248}Cm				6
^{249}Cf	6			
^{250}Cf				6
^{251}Cf	6			
^{252}Cf				56
^{253}Es				6
^{254}Es	6			
^{254}Fm				6
^{256}Fm	6			
^{256}Fm				6

[a]The numbers 4, 5, and 6 refer to ENDF/B versions IV, V, and preliminary VI. ENDF/B-IV contains only independent yields and does not include uncertainties.

TABLE II

Summary of ENDF Evaluations[a]

QUANTITY	ENDF/B-IV	ENDF/B-V	PRELIM. ENDF/B-VI
YEAR	1974	1978	1983
FISSIONABLE NUCS	6	11	34
NO. OF YIELD SETS	10	20	50
ISOMER RATIO EST.	50/50	YES	YES
PAIRING	NO	YES	YES
DELAYED NEUTRON	NO	YES	YES
CHARGE BALANCE	NO	YES	YES
TERNARY FISSION	NO	YES	YES
INDEP. YIELDS[b]	YES	YES	YES
CUMULATIVE YIELDS	NO	YES	YES
UNCERTAINTIES	NO	YES	YES
NO. OF REFERENCES	956	1119	1274
NO. OF YIELDS	11000	44000	110000

[a]ENDF/B yields through ENDF/B-V have been based on compilations by B. F. Rider at G.E. and modified at Los Alamos to extend the chains. G.E. compilations are NEDO-12154-1 (1974), -12154-2E (1978), -12154-3B (1980), and 12154-3C (1981). Current results are based on corrections and some added experimental data to the 1981 compilation.

[b]Beginning with ENDF/B-V, delayed neutron branching fractions have been incorporated into evaluations. Independent yields apply before delayed neutron emission and cumulative yields apply after emission.

TABLE III

Pairing Effects Used in Evaluation

NUCLIDE	PROTON EFFECT,X	NEUTRON EFFECT,Y
[illegible] (T)	0.228 +/- 0.034	0.044 +/- 0.034
[illegible] (TF)	0.151 +/- 0.179	0.029 +/- 0.039
[illegible] (TH)	0.015 +/- 0.016	0.003 +/- 0.004
[illegible] (TF)	0.329 +/- 0.479	0.063 +/- 0.100
[illegible] (TH)	0.018 +/- 0.019	0.003 +/- 0.004
[illegible] (TT)	0.171 +/- 0.206	0.033 +/- 0.044
[illegible] (TF)	0.124 +/- 0.143	0.024 +/- 0.031
[illegible] (TT)	0.206 +/- 0.256	0.040 +/- 0.055
[illegible] (TT)	0.210 +/- 0.264	0.041 +/- 0.056
[illegible] (TF)	0.327 +/- 0.469	0.063 +/- 0.098
[illegible] (TF)	0.143 +/- 0.166	0.028 +/- 0.037
[illegible] (TH)	0.015 +/- 0.016	0.003 +/- 0.004
[illegible] (TF)	0.166 +/- 0.200	0.032 +/- 0.043
[illegible] (TH)	0.015 +/- 0.018	0.003 +/- 0.004
[illegible] (TF)	0.244 +/- 0.321	0.047 +/- 0.021
[illegible] (TF)	0.141 +/- 0.166	0.027 +/- 0.036
[illegible] (TF)	0.364 +/- 0.554	0.070 +/- 0.114
[illegible] (TH)	0.016 +/- 0.019	0.003 +/- 0.004
[illegible] (TF)	0	0
[illegible] (TF)	0.050 +/- 0.040	0.010 +/- 0.040
[illegible] (TF)	0.079 +/- 0.089	0.015 +/- 0.020
[illegible] (TF)	0.102 +/- 0.116	0.020 +/- 0.024
[illegible] (TH)	0.117 +/- 0.132	0.023 +/- 0.030
[illegible] (TH)	0.016 +/- 0.018	0.003 +/- 0.005
[illegible] (TH)	0.017 +/- 0.019	0.003 +/- 0.004
[illegible] (TF)	0	0
[illegible] (TF)	0	0
[illegible] (TF)	0	0
[illegible] (TF)	0	0
[illegible] (TT)	0.087 +/- 0.074	0.013 +/- 0.016
[illegible] (TT)	0	0
[illegible] (TT)	0.274 +/- 0.301	0.053 +/- 0.058
[illegible] (TT)	0	0
[illegible] (TH)	0	0
[illegible] (TH)	0	0
[illegible] (TT)	0	0
[illegible] (TT)	0.109 +/- 0.120	0.021 +/- 0.023
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0
[illegible] (TS)	0	0

TABLE IV

Average Charge (Independent Yields, Version E)

NUCLIDE		Zf	Z-AVE	% DEV
^{235}U	(T)	92	91.94	-0.06
^{235}U	(F)	92	91.99	-0.01
^{235}U	(H)	92	91.97	-0.03
^{238}U	(F)	92	91.99	-0.01
^{238}U	(H)	92	91.98	-0.02
^{239}Pu	(T)	94	94.01	0.01
^{239}Pu	(F)	94	93.99	-0.01
^{241}Pu	(T)	94	94.01	0.01
^{238}U	(T)	92	91.98	-0.02
^{232}Th	(F)	90	89.97	-0.03
^{238}U	(F)	92	92.00	0.00
^{238}U	(H)	92	91.99	-0.01
^{238}U	(F)	92	91.99	-0.01
^{239}Pu	(H)	94	94.00	0.00
^{240}Pu	(F)	94	93.99	-0.01
^{241}Pu	(F)	94	93.99	-0.01
^{242}Pu	(F)	94	94.00	0.00
^{232}Th	(H)	90	89.98	-0.02
^{237}Np	(F)	93	92.98	-0.02
^{252}Cf	(S)	98	97.99	-0.01
^{234}U	(F)	92	92.00	0.00
^{237}U	(F)	92	92.00	0.00
^{240}Pu	(H)	94	94.00	0.00
^{234}U	(H)	92	92.00	0.00
^{238}U	(H)	92	92.00	0.00
^{239}Pu	(F)	94	94.00	0.00
^{241}Am	(F)	95	95.00	0.00
^{243}Am	(F)	95	95.00	0.00
^{238}Np	(F)	93	93.00	0.00
^{242}Cm	(F)	96	96.00	-0.01
^{227}Th	(T)	90	90.00	0.00
^{229}Th	(T)	90	90.02	0.02
^{231}Pa	(F)	91	91.00	0.00
^{241}Am	(T)	95	95.00	0.00
^{241}Am	(H)	95	94.99	-0.01
^{242M}Am	(T)	95	95.00	0.00
^{245}Cm	(T)	96	95.99	-0.01
^{249}Cf	(T)	98	98.01	0.01
^{251}Cf	(T)	98	97.99	-0.01
^{254}Es	(T)	99	98.99	-0.01
^{250}Cf	(S)	98	97.99	-0.01
^{244}Cm	(S)	96	95.98	-0.02
^{246}Cm	(S)	96	95.99	-0.01
^{253}Es	(S)	99	98.99	-0.01
^{254}Fm	(S)	100	99.99	-0.01
^{255}Fm	(S)	100	99.99	-0.01
^{256}Fm	(S)	100	99.99	-0.01
^{237}Np	(H)	93	93.00	0.00
^{232}U	(T)	92	91.99	-0.01
^{238}U	(S)	92	92.00	0.00

TABLE V

Delayed Neutron Comparison (Version E Yields)

FISSIONABLE NUCLIDE		CALCULATED VALUES PER 100 FISSIONS	ENDF/B-V EVAL.
^{235}U	(T)	1.77+/- 0.14	1.67
^{235}U	(F)	2.06+/- 0.27	1.67
^{235}U	(H)	1.08+/- 0.18	0.90
^{238}U	(F)	3.54+/- 0.36	4.40
^{238}U	(H)	2.71+/- 0.35	2.60
^{239}Pu	(T)	0.76+/- 0.05	0.65
^{239}Pu	(F)	0.68+/- 0.09	0.65
^{241}Pu	(T)	1.39+/- 0.12	1.62
^{233}U	(T)	0.96+/- 0.22	0.74
^{232}Th	(F)	5.69+/- 1.05	5.27
^{233}U	(F)	0.91+/- 0.15	0.74
^{233}U	(H)	0.70+/- 0.13	0.47
^{236}U	(F)	2.32+/- 0.31	----
^{239}Pu	(H)	0.38+/- 0.07	0.43
^{240}Pu	(F)	0.81+/- 0.11	0.90
^{241}Pu	(F)	1.39+/- 0.16	1.62
^{242}Pu	(F)	1.40+/- 0.16	1.50
^{232}Th	(H)	4.16+/- 1.05	.00
^{237}Np	(F)	1.14+/- 0.15	----
^{252}Cf	(S)	0.61+/- 0.07	----
^{234}U	(F)	1.30+/- 0.21	----
^{237}U	(F)	3.50+/- 0.38	----
^{240}Pu	(H)	0.50+/- 0.09	0.62
^{234}U	(H)	0.76+/- 0.15	----
^{236}U	(H)	1.54+/- 0.23	----
^{238}Pu	(F)	0.78+/- 0.11	----
^{241}Am	(F)	0.50+/- 0.07	----
^{243}Am	(F)	0.79+/- 0.10	----
^{238}Np	(F)	2.15+/- 0.24	----
^{242}Cm	( )	0.13+/- 0.03	----
^{227}Th	(T)	1.41+/- 0.41	----
^{229}Th	(T)	1.81+/- 0.58	----
^{231}Pa	(F)	1.60+/- 0.35	----
^{241}Am	(T)	0.53+/- 0.07	----
^{241}Am	(H)	0.25+/- 0.05	----
^{242M}Am	(T)	0.76+/- 0.11	----
^{245}Cm	(T)	0.60+/- 0.09	----
^{249}Cf	(T)	0.16+/- 0.03	----
^{251}Cf	(T)	0.73+/- 0.09	----
^{254}Es	(T)	0.39+/- 0.06	----
^{250}Cf	(S)	0.34+/- 0.05	----
^{244}Cm	(S)	0.44+/- 0.07	----
^{246}Cm	(S)	1.19+/- 0.14	----
^{253}Es	(S)	0.19+/- 0.04	----
^{254}Fm	(S)	0.06+/- 0.02	----
^{256}Fm	(T)	0.25+/- 0.04	----
^{256}Fm	(S)	0.16+/- 0.03	----
^{237}Np	(H)	0.98+/- 0.13	----
^{238}U	(T)	0.52+/- 0.09	----
^{238}U	(S)	5.67+/- 0.49	----

TABLE VI

Total Neutron Comparisons (Version E Yields)

NUCLIDE		CALCULATED	ENDF/B-V EVAL.
^{236}U	(T)	2.66+/- 0.29	2.44
^{236}U	(F)	2.15+/- 0.34	2.18
^{236}U	(H)	4.37+/- 1.87	4.40
^{238}U	(F)	2.99+/- 0.64	2.47
^{238}U	(H)	4.48+/- 1.68	4.43
^{239}Pu	(T)	2.91+/- 0.84	2.89
^{239}Pu	(F)	2.90+/- 0.62	2.95
^{241}Pu	(T)	2.95+/- 1.10	2.96
^{233}U	(T)	2.52+/- 1.06	2.50
^{232}Th	(F)	2.36+/- 1.60	2.02
^{233}U	(F)	2.50+/- 0.64	2.51
^{233}U	(H)	3.58+/- 3.31	4.27
^{235}U	(F)	2.81+/- 3.35	2.38
^{239}Pu	(H)	4.63+/- 2.57	4.92
^{240}Pu	(F)	3.[illegible]0+/- 2.49	2.88
^{241}Pu	(F)	2.96+/- 1.31	2.96
^{242}Pu	(F)	3.53+/- 3.68	2.89
^{232}Th	(H)	3.91+/- 1.67	3.94
^{237}Np	(F)	2.76+/- 0.95	2.77
^{252}Cf	(S)	4.05+/- 2.04	----
^{234}U	(F)	2.72+/- 4.30	2.42
^{237}U	(F)	2.71+/- 5.64	2.50
^{240}Pu	(H)	4.62+/- 4.05	4.93
^{234}U	(H)	4.18+/- 4.86	4.24
^{236}U	(H)	4.24+/- 4.64	4.15
^{238}Pu	(F)	2.01+/- 5.99	2.97
^{241}Am	(F)	2.98+/- 4.61	3.17
^{243}Am	(F)	4.02+/- 6.07	3.36
^{238}Np	(F)	2.29+/- 5.98	2.86
^{242}Cm	(F)	3.60+/- 6.33	3.53
^{227}Th	(T)	1.39+/- 5.22	----
^{229}Th	(T)	2.45+/- 2.23	----
^{231}Pa	(F)	2.47+/- 4.72	2.34
^{241}Am	(T)	2.76+/- 3.36	3.09
^{241}Am	(H)	4.46+/- 3.90	5.33
^{242m}Am	(T)	2.92+/- 4.62	3.26
^{245}Cm	(T)	3.37+/- 2.94	3.83
^{249}Cf	(T)	4.17+/- 4.04	4.06
^{251}Cf	(T)	[illegible]34+/- 5.02	4.14
^{254}Es	(T)	[illegible]52+/- 4.72	----
^{250}Cf	(S)	3.30+/- 4.15	----
^{244}Cm	(S)	2.22+/- 3.60	----
^{248}Cm	(S)	3.80+/- 4.38	----
^{253}Es	(S)	4.38+/- 5.08	----
^{254}Fm	(S)	4.23+/- 5.04	----
^{256}Fm	(T)	3.15+/- 5.48	----
^{256}Fm	(S)	4.43+/- 5.54	----
^{237}Np	(H)	3.38+/- 4.85	4.74
^{232}U	(T)	2.94+/- 4.84	3.13
^{238}U	(S)	1.72+/- 2.57	----

TABLE VII

Mean Value of Uncertainty in Cumulative Yields

		YC > 1.0%		YC < 1.0%	
		MEAN σ	# NUC	MEAN σ	# NUC
^{235}U	(T)	5.21	190	44.22	818
^{236}U	(F)	8.00	196	49.81	820
^{236}U	(H)	12.92	242	51.64	818
^{238}U	(F)	7.73	220	48.26	775
^{238}U	(H)	10.09	252	49.21	776
^{239}Pu	(T)	7.96	193	49.27	854
^{240}Pu	(F)	9.10	190	52.21	850
^{241}Pu	(T)	9.66	208	49.84	824
^{235}U	(T)	11.99	172	50.90	854
^{235}Th	(F)	11.38	186	47.98	807
^{235}U	(F)	10.48	180	53.41	856
^{235}U	(H)	16.15	231	55.10	841
^{235}U	(F)	13.56	205	53.80	815
^{239}Pu	(H)	14.67	231	54.83	845
^{240}Pu	(F)	13.87	201	52.65	845
^{241}Pu	(F)	12.08	212	52.18	825
^{242}Pu	(F)	17.07	224	54.30	802
^{233}Th	(H)	13.39	275	49.19	756
^{237}Np	(f)	11.20	203	51.33	832
^{252}Cf	(S)	11.21	209	51.10	839
^{234}U	(F)	17.88	193	55.44	851
^{237}U	(F)	19.12	219	53.69	789
^{240}Pu	(H)	15.23	240	54.32	832
^{234}U	(H)	20.93	244	56.13	825
^{238}U	(H)	20.37	255	54.25	798
^{238}Pu	(F)	20.34	198	55.87	852
^{241}Am	(F)	19.62	195	55.02	863
^{243}Am	(F)	20.63	197	55.72	849
^{238}Np	(F)	19.98	214	54.24	814
^{245}Cm	(F)	20.57	172	57.18	901
^{227}Th	(T)	18.09	164	54.41	830
^{228}Th	(T)	12.41	150	49.52	835
^{231}Pa	(F)	15.55	170	54.19	879
^{241}Am	(T)	13.48	188	53.60	856
^{241}Am	(H)	15.89	235	55.75	850
^{243}Am	(T)	15.97	200	53.77	849
^{245}Cm	(T)	12.79	217	53.67	833
^{249}Cf	(T)	14.96	208	54.42	856
^{251}Cf	(T)	17.08	215	54.25	841
^{254}Es	(T)	18.18	244	54.55	709
^{250}Cf	(S)	14.84	193	55.23	884
^{244}Cm	(S)	16.14	181	54.30	885
^{248}Cm	(S)	15.67	213	54.12	822
^{253}Es	(S)	17.68	197	55.66	885
^{254}Fm	(S)	17.18	180	56.34	898
^{256}Fm	(T)	19.44	224	56.01	847
^{256}Fm	(S)	19.29	204	56.38	873
^{237}Np	(H)	20.43	245	56.63	820
^{238}U	(T)	17.18	163	56.37	918
^{238}U	(S)	14.72	195	51.43	759

TABLE VIII

Chain Yields per 100 Fissions and Uncertainties, Version E

MASS	U235T		U235F		U235H		U238F		U238H	
66	6.608E-08	+/- 32.00	6.569E-07	+/- 23.00	2.930E-04	+/- 8.00	3.726E-06	+/- 32.00	8.449E-05	+/- 11.00
67	3.428E-07	+/- 32.00	2.110E-06	+/- 23.00	6.696E-04	+/- 8.00	2.155E-05	+/- 32.00	1.386E-04	+/- 16.00
68	5.658E-07	+/- 32.00	3.661E-06	+/- 23.00	9.088E-04	+/- 11.00	9.954E-06	+/- 16.00	2.985E-04	+/- 16.00
69	1.227E-06	+/- 32.00	7.901E-06	+/- 23.00	1.414E-03	+/- 32.00	1.290E-05	+/- 16.00	5.008E-04	+/- 16.00
70	2.841E-06	+/- 32.00	1.732E-05	+/- 23.00	2.418E-03	+/- 11.00	1.604E-05	+/- 16.00	9.002E-04	+/- 16.00
71	6.598E-06	+/- 32.00	4.220E-05	+/- 23.00	4.042E-03	+/- 11.00	2.009E-05	+/- 16.00	1.591E-03	+/- 16.00
72	2.524E-05	+/- 11.00	1.506E-04	+/- 23.00	6.066E-03	+/- 8.00	6.076E-05	+/- 32.00	2.994E-03	+/- 11.00
73	9.604E-05	+/- 32.00	4.910E-04	+/- 16.00	1.161E-02	+/- 11.00	2.080E-04	+/- 23.00	5.220E-03	+/- 11.00
74	3.209E-04	+/- 23.00	1.081E-03	+/- 23.00	1.[illegible]E-02	+/- 11.00	2.787E-04	+/- 32.00	8.001E-03	+/- 16.00
75	1.054E-03	+/- 23.00	6.936E-03	+/- 16.00	2.764E-02	+/- 11.00	4.645E-04	+/- 32.00	1.386E-02	+/- 16.00
76	3.300E-03	+/- 32.00	1.127E-02	+/- 23.00	4.097E-02	+/- 11.00	8.025E-04	+/- 23.00	2.197E-02	+/- 16.00
77	7.553E-03	+/- 8.00	2.925E-02	+/- 11.00	6.815E-02	+/- 11.00	3.310E-03	+/- 11.00	3.127E-02	+/- 8.00
78	2.070E-02	+/- 8.00	5.429E-02	+/- 11.00	1.022E-01	+/- 11.00	1.126E-02	+/- 23.00	4.084E-02	+/- 11.00
79	4.329E-02	+/- 6.00	8.505E-02	+/- 11.00	1.716E-01	+/- 8.00	3.278E-02	+/- 23.00	1.690E-01	+/- 11.00
80	1.270E-01	+/- 6.00	1.146E-01	+/- 23.00	2.596E-01	+/- 11.00	4.721E-02	+/- 32.00	2.127E-01	+/- 16.00
81	1.906E-01	+/- 4.00	2.091E-01	+/- 11.00	2.980E-01	+/- 11.00	1.083E-01	+/- 16.00	3.324E-01	+/- 11.00
82	3.224E-01	+/- 2.80	3.262E-01	+/- 11.00	6.077E-01	+/- 11.00	2.133E-01	+/- 16.00	4.526E-01	+/- 16.00
83	5.394E-01	+/- 0.50	5.734E-01	+/- 1.00	1.111E+00	+/- 6.00	3.952E-01	+/- 1.40	6.690E-01	+/- 2.80
84	1.003E+00	+/- 0.70	1.024E+00	+/- 1.40	1.544E+00	+/- 11.00	8.194E-01	+/- 1.40	1.124E+00	+/- 2.80
85	1.317E+00	+/- 0.35	1.350E+00	+/- 0.70	1.658E+00	+/- 2.80	7.398E-01	+/- 1.00	1.003E+00	+/- 1.40
86	1.968E+00	+/- 0.50	1.939E+00	+/- 1.00	2.626E+00	+/- 11.00	1.286E+00	+/- 1.00	1.571E+00	+/- 2.80
87	2.558E+00	+/- 0.50	2.482E+00	+/- 1.00	2.440E+00	+/- 4.00	1.604E+00	+/- 1.00	1.685E+00	+/- 2.00
88	3.565E+00	+/- 0.70	3.483E+00	+/- 0.70	3.374E+00	+/- 4.00	2.054E+00	+/- 1.40	2.215E+00	+/- 2.00
89	4.771E+00	+/- 1.00	4.412E+00	+/- 1.40	4.139E+00	+/- 2.80	2.784E+00	+/- 2.00	2.914E+00	+/- 2.00
90	5.755E+00	+/- 1.00	5.444E+00	+/- 0.70	4.594E+00	+/- 2.80	3.238E+00	+/- 1.40	3.166E+00	+/- 2.80
91	5.910E+00	+/- 1.00	5.721E+00	+/- 0.70	4.871E+00	+/- 4.00	3.979E+00	+/- 2.00	3.764E+00	+/- 2.80
92	5.977E+00	+/- 1.00	5.830E+00	+/- 1.00	5.164E+00	+/- 8.00	4.288E+00	+/- 2.80	3.926E+00	+/- 2.80
93	6.349E+00	+/- 0.70	6.244E+00	+/- 0.70	5.250E+00	+/- 6.00	4.882E+00	+/- 2.00	4.475E+00	+/- 2.80
94	6.417E+00	+/- 1.00	6.288E+00	+/- 0.70	5.221E+00	+/- 11.00	4.765E+00	+/- 4.00	4.894E+00	+/- 8.00
95	6.507E+00	+/- 1.00	6.414E+00	+/- 0.50	5.180E+00	+/- 4.00	5.106E+00	+/- 1.00	4.963E+00	+/- 2.00
96	6.274E+00	+/- 1.00	6.190E+00	+/- 0.70	5.299E+00	+/- 8.00	5.996E+00	+/- 4.00	5.578E+00	+/- 11.00
97	5.937E+00	+/- 0.70	5.984E+00	+/- 0.50	5.564E+00	+/- 6.00	5.546E+00	+/- 0.70	5.305E+00	+/- 2.00
98	5.747E+00	+/- 1.00	5.911E+00	+/- 0.50	4.215E+00	+/- 8.00	5.862E+00	+/- 1.00	5.457E+00	+/- 11.00
99	6.091E+00	+/- 1.00	5.765E+00	+/- 1.40	5.088E+00	+/- 2.80	6.163E+00	+/- 1.40	5.685E+00	+/- 1.40
100	6.232E+00	+/- 1.00	6.274E+00	+/- 1.00	4.042E+00	+/- 8.00	6.672E+00	+/- 1.00	4.996E+00	+/- 11.00
101	5.170E+00	+/- 1.00	5.199E+00	+/- 1.40	3.532E+00	+/- 8.00	6.202E+00	+/- 1.40	5.611E+00	+/- 2.80
102	4.308E+00	+/- 1.00	4.355E+00	+/- 1.00	3.333E+00	+/- 11.00	6.440E+00	+/- 1.00	4.609E+00	+/- 8.00
103	3.030E+00	+/- 1.00	3.241E+00	+/- 1.00	3.198E+00	+/- 2.80	6.299E+00	+/- 1.00	4.651E+00	+/- 2.00
104	1.909E+00	+/- 1.40	2.067E+00	+/- 2.00	2.187E+00	+/- 8.00	5.033E+00	+/- 1.00	3.587E+00	+/- 6.00
105	9.603E-01	+/- 1.40	1.169E+00	+/- 2.80	1.875E+00	+/- 4.00	4.075E+00	+/- 2.00	3.233E+00	+/- 2.00
106	3.999E-01	+/- 1.40	5.309E-01	+/- 1.00	1.577E+00	+/- 4.00	2.473E+00	+/- 1.40	2.434E+00	+/- 4.00
107	1.449E-01	+/- 2.80	2.763E-01	+/- 11.00	1.320E+00	+/- 11.00	1.234E+00	+/- 8.00	1.728E+00	+/- 6.00
108	5.091E-02	+/- 4.00	1.144E-01	+/- 16.00	1.210E+00	+/- 11.00	6.010E-01	+/- 16.00	1.222E+00	+/- 16.00
109	2.993E-02	+/- 8.00	8.254E-02	+/- 11.00	1.263E+00	+/- 4.00	2.423E-01	+/- 11.00	1.217E+00	+/- 8.00
110	2.514E-02	+/- 4.00	6.055E-02	+/- 16.00	1.113E+00	+/- 11.00	1.347E-01	+/- 16.00	1.026E+00	+/- 11.00
111	1.849E-02	+/- 4.00	4.266E-02	+/- 2.00	1.127E+00	+/- 2.80	7.478E-02	+/- 2.00	1.040E+00	+/- 2.80
112	1.279E-02	+/- 4.00	3.705E-02	+/- 2.00	1.104E+00	+/- 8.00	5.527E-02	+/- 4.00	1.006E+00	+/- 6.00
113	1.444E-02	+/- 6.00	3.219E-02	+/- 2.80	1.111E+00	+/- 5.00	5.146E-02	+/- 8.00	9.289E-01	+/- 6.00
114	1.251E-02	+/- 6.00	3.193E-02	+/- 2.80	1.086E+00	+/- 11.00	3.828E-02	+/- 16.00	7.184E-01	+/- 11.00
115	1.044E-02	+/- 8.00	2.831E-02	+/- 6.00	9.867E-01	+/- 4.00	3.294E-02	+/- 6.00	8.392E-01	+/- 4.00
116	1.521E-02	+/- 6.00	3.369E-02	+/- 2.00	1.085E+00	+/- 11.00	3.940E-02	+/- 11.00	6.753E-01	+/- 11.00
117	9.834E-03	+/- 8.00	2.946E-02	+/- 11.00	1.082E+00	+/- 8.00	3.658E-02	+/- 11.00	7.090E-01	+/- 8.00
118	7.034E-03	+/- 16.00	2.875E-02	+/- 11.00	1.104E+00	+/- 11.00	3.984E-02	+/- 11.00	8.344E-01	+/- 11.00
119	7.283E-03	+/- 11.00	2.804E-02	+/- 8.00	1.108E+00	+/- 11.00	3.439E-02	+/- 16.00	7.353E-01	+/- 11.00

TABLE VIII (Cont.)

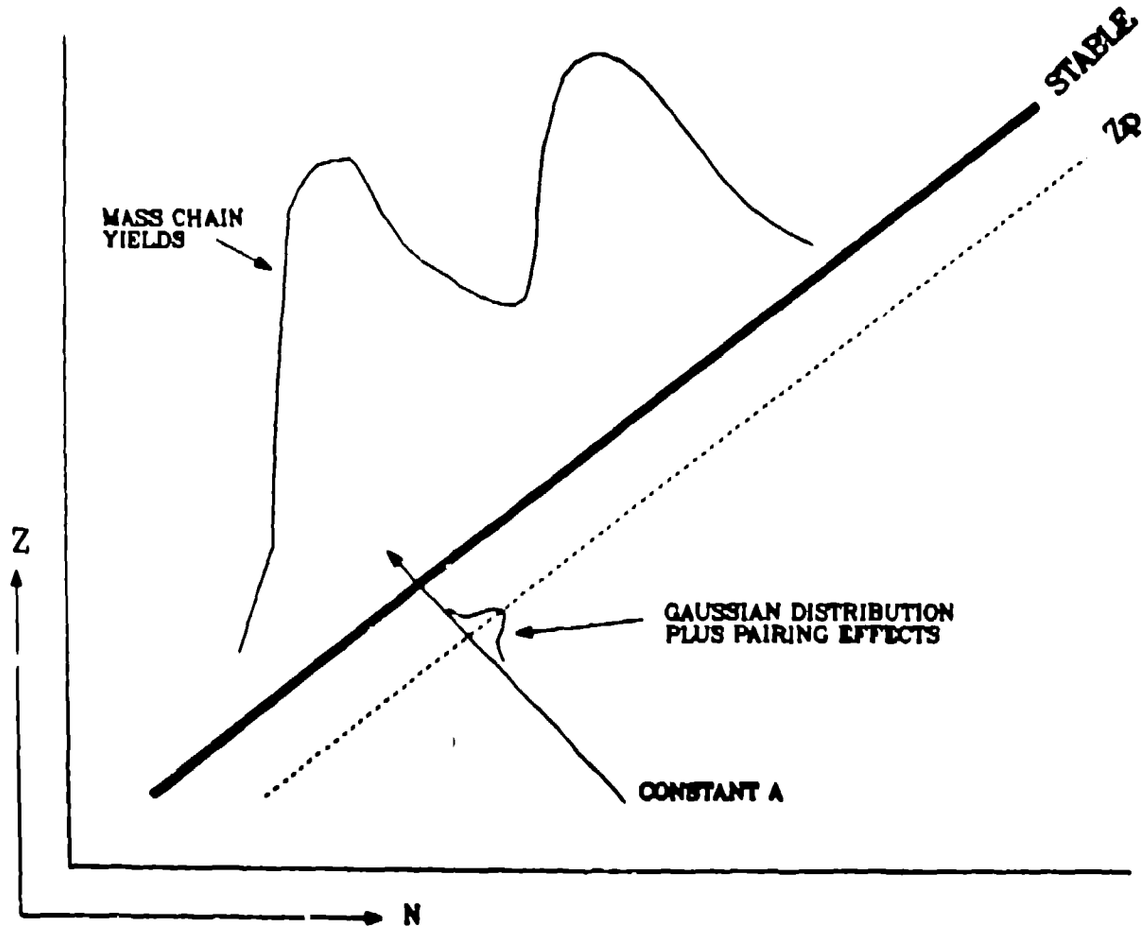
MASS	U235T		U235F		U235H		U238F		U238H	
120	7.514E-03 +/-	11.00	2.857E-02 +/-	6.00	1.113E+00 +/-	8.00	3.443E-02 +/-	16.00	7.898E-01 +/-	11.00
121	1.152E-02 +/-	6.00	3.209E-02 +/-	8.00	9.804E-01 +/-	6.00	3.773E-02 +/-	11.00	7.651E-01 +/-	4.00
122	8.785E-03 +/-	11.00	2.726E-02 +/-	11.00	1.170E+00 +/-	11.00	3.619E-02 +/-	16.00	8.627E-01 +/-	11.00
123	1.443E-02 +/-	4.00	3.890E-02 +/-	11.00	1.217E+00 +/-	11.00	3.891E-02 +/-	16.00	9.357E-01 +/-	11.00
124	1.737E-02 +/-	11.00	4.684E-02 +/-	11.00	1.316E+00 +/-	11.00	4.269E-02 +/-	16.00	1.050E+00 +/-	11.00
125	2.683E-02 +/-	4.00	5.411E-02 +/-	8.00	1.488E+00 +/-	8.00	4.565E-02 +/-	8.00	1.193E+00 +/-	6.00
126	4.454E-02 +/-	8.00	8.572E-02 +/-	11.00	1.503E+00 +/-	4.00	5.109E-02 +/-	8.00	1.365E+00 +/-	16.00
127	1.161E-01 +/-	4.00	3.024E-01 +/-	4.00	2.040E+00 +/-	4.00	1.331E-01 +/-	4.00	1.505E+00 +/-	6.00
128	3.315E-01 +/-	2.80	3.953E-01 +/-	11.00	2.490E+00 +/-	11.00	4.179E-01 +/-	6.00	1.675E+00 +/-	8.00
129	6.607E-01 +/-	6.00	8.443E-01 +/-	4.00	3.567E+00 +/-	8.00	9.441E-01 +/-	4.00	2.076E+00 +/-	8.00
130	1.733E+00 +/-	2.00	1.713E+00 +/-	6.00	3.648E+00 +/-	8.00	1.839E+00 +/-	6.00	3.202E+00 +/-	11.00
131	2.6[illegible]E+00 +/-	0.50	3.209E+00 +/-	0.70	4.098E+00 +/-	2.80	3.232E+00 +/-	1.40	4.050E+00 +/-	2.00
132	4.282E+00 +/-	0.35	4.651E+00 +/-	0.70	4.883E+00 +/-	2.80	5.137E+00 +/-	1.40	4.846E+00 +/-	1.40
133	6.654E+00 +/-	0.35	6.716E+00 +/-	0.50	5.587E+00 +/-	6.00	6.748E+00 +/-	0.50	6.125E+00 +/-	2.00
134	7.780E+00 +/-	0.50	7.641E+00 +/-	0.50	5.729E+00 +/-	2.80	7.845E+00 +/-	2.00	6.547E+00 +/-	2.00
135	6.492E+00 +/-	0.35	6.565E+00 +/-	0.70	5.456E+00 +/-	4.00	6.950E+00 +/-	0.70	5.890E+00 +/-	2.00
136	6.267E+00 +/-	0.35	6.216E+00 +/-	0.50	5.334E+00 +/-	4.00	6.897E+00 +/-	2.80	5.744E+00 +/-	2.00
137	6.136E+00 +/-	0.50	6.210E+00 +/-	0.35	4.924E+00 +/-	2.80	5.999E+00 +/-	0.70	4.986E+00 +/-	2.00
138	6.627E+00 +/-	0.70	6.666E+00 +/-	0.70	4.584E+00 +/-	6.00	5.694E+00 +/-	1.40	4.859E+00 +/-	2.80
139	6.235E+00 +/-	1.00	6.327E+00 +/-	0.50	4.749E+00 +/-	4.00	5.630E+00 +/-	1.00	5.046E+00 +/-	2.80
140	6.134E+00 +/-	0.70	5.949E+00 +/-	0.70	4.493E+00 +/-	2.80	5.813E+00 +/-	0.70	4.619E+00 +/-	1.40
141	5.711E+00 +/-	1.00	5.891E+00 +/-	1.40	4.490E+00 +/-	4.00	5.404E+00 +/-	2.00	4.357E+00 +/-	2.80
142	5.733E+00 +/-	0.70	5.510E+00 +/-	1.00	4.248E+00 +/-	6.00	4.564E+00 +/-	1.00	4.100E+00 +/-	4.00
143	5.945E+00 +/-	0.35	5.715E+00 +/-	0.50	3.827E+00 +/-	2.80	4.584E+00 +/-	0.70	3.933E+00 +/-	2.80
144	5.443E+00 +/-	0.35	5.265E+00 +/-	0.70	3.147E+00 +/-	2.80	4.539E+00 +/-	0.70	3.655E+00 +/-	2.80
145	3.910E+00 +/-	0.35	3.765E+00 +/-	0.50	2.732E+00 +/-	6.00	3.776E+00 +/-	0.70	3.014E+00 +/-	4.00
146	2.977E+00 +/-	0.35	2.915E+00 +/-	0.50	2.235E+00 +/-	11.00	3.415E+00 +/-	0.70	2.094E+00 +/-	11.00
147	2.218E+00 +/-	0.50	2.120E+00 +/-	0.70	1.626E+00 +/-	4.00	2.542E+00 +/-	1.00	2.094E+00 +/-	2.00
148	1.657E+00 +/-	0.35	1.679E+00 +/-	0.35	1.218E+00 +/-	11.00	2.090E+00 +/-	0.70	1.759E+00 +/-	16.00
149	1.054E+00 +/-	1.00	1.031E+00 +/-	0.70	6.602E-01 +/-	8.00	1.613E+00 +/-	1.00	1.427E+00 +/-	6.00
150	6.434E-01 +/-	0.50	6.839E-01 +/-	0.50	5.183E-01 +/-	11.00	1.263E+00 +/-	1.00	1.099E+00 +/-	16.00
151	4.052E-01 +/-	0.70	4.110E-01 +/-	0.70	3.623E-01 +/-	8.00	8.017E-01 +/-	1.40	8.144E-01 +/-	6.00
152	2.587E-01 +/-	1.00	2.758E-01 +/-	2.00	2.621E-01 +/-	11.00	5.235E-01 +/-	1.00	5.888E-01 +/-	16.00
153	1.480E-01 +/-	2.80	1.602E-01 +/-	2.80	2.070E-01 +/-	11.00	3.818E-01 +/-	2.00	3.928E-01 +/-	6.00
154	7.225E-02 +/-	1.00	7.438E-02 +/-	4.00	3.137E-02 +/-	11.00	2.143E-01 +/-	1.00	2.564E-01 +/-	16.00
155	2.935E-02 +/-	4.00	4.043E-02 +/-	11.00	6.480E-02 +/-	11.00	1.278E-01 +/-	16.00	1.579E-01 +/-	16.00
156	1.341E-02 +/-	2.80	2.027E-02 +/-	2.80	5.378E-02 +/-	2.80	6.728E-02 +/-	2.00	1.093E-01 +/-	2.80
157	5.162E-03 +/-	8.00	6.766E-03 +/-	16.00	3.837E-02 +/-	11.00	3.714E-02 +/-	16.00	8.379E-02 +/-	16.00
158	1.989E-03 +/-	16.00	6.208E-03 +/-	16.00	2.389E-02 +/-	11.00	1.660E-02 +/-	16.00	4.334E-02 +/-	16.00
159	8.893E-04 +/-	6.00	2.756E-03 +/-	11.00	1.225E-02 +/-	8.00	7.158E-03 +/-	16.00	2.635E-02 +/-	11.00
160	1.146E-04 +/-	32.00	1.083E-03 +/-	16.00	7.301E-03 +/-	11.00	3.047E-03 +/-	23.00	1.594E-02 +/-	16.00
161	7.845E-05 +/-	4.00	3.241E-04 +/-	8.00	5.167E-03 +/-	8.00	1.154E-03 +/-	8.00	8.340E-03 +/-	4.00
162	6.909E-06 +/-	32.00	5.392E-05 +/-	23.00	2.832E-03 +/-	11.00	2.751E-04 +/-	32.00	6.040E-03 +/-	16.00
163	2.778E-06 +/-	32.00	8.991E-06 +/-	23.00	1.613E-03 +/-	11.00	1.649E-04 +/-	32.00	3.453E-03 +/-	16.00
164	8.708E-07 +/-	32.00	5.401E-06 +/-	23.00	9.931E-04 +/-	11.00	1.007E-04 +/-	32.00	2.027E-03 +/-	16.00
165	6.578E-07 +/-	23.00	2.158E-06 +/-	23.00	5.471E-04 +/-	11.00	6.574E-05 +/-	23.00	1.116E-03 +/-	16.00
166	2.920E-07 +/-	23.00	8.957E-07 +/-	23.00	2.780E-04 +/-	8.00	4.579E-05 +/-	32.00	6.349E-04 +/-	8.00
167	1.675E-07 +/-	23.00	3.590E-07 +/-	23.00	1.885E-04 +/-	11.00	3.904E-05 +/-	16.00	3.753E-04 +/-	16.00
168	3.825E-08 +/-	23.00	8.931E-08 +/-	23.00	1.084E-04 +/-	11.00	2.292E-05 +/-	32.00	2.035E-04 +/-	16.00
169	1.565E-08 +/-	23.00	5.334E-08 +/-	23.00	7.901E-05 +/-	8.00	1.375E-05 +/-	32.00	1.305E-04 +/-	8.00
170	3.281E-09 +/-	23.00	1.805E-08 +/-	23.00	2.299E-05 +/-	11.00	8.235E-06 +/-	32.00	6.058E-05 +/-	16.00
171	1.565E-09 +/-	23.00	6.269E-09 +/-	23.00	1.794E-05 +/-	11.00	4.611E-06 +/-	32.00	3.358E-05 +/-	16.00
172	5.397E-10 +/-	23.00	1.792E-09 +/-	23.00	1.662E-05 +/-	8.00	8.606E-06 +/-	32.00	2.161E-05 +/-	16.00

TABLE VIII (Cont.)

MASS	PU239T		PU239F		PU241T		U233T		TH232F	
120	3.613E-02	+/- 11.00	5.657E-02	+/- 11.00	2.618E-02	+/- 23.00	1.425E-02	+/- 8.00	5.416E-02	+/- 16.00
121	3.730E-02	+/- 8.00	6.161E-02	+/- 11.00	2.667E-02	+/- 32.00	1.554E-02	+/- 11.00	4.728E-02	+/- 6.00
122	5.472E-02	+/- 11.00	7.256E-02	+/- 11.00	2.668E-02	+/- 32.00	1.528E-02	+/- 11.00	3.642E-02	+/- 16.00
123	4.011E-02	+/- 23.00	7.310E-02	+/- 16.00	2.773E-02	+/- 32.00	1.905E-02	+/- 32.00	2.926E-02	+/- 16.00
124	1.003E-01	+/- 11.00	1.235E-01	+/- 11.00	3.308E-02	+/- 32.00	2.520E-02	+/- 11.00	2.639E-02	+/- 16.00
125	1.131E-01	+/- 8.00	1.345E-01	+/- 8.00	4.905E-02	+/- 8.00	1.103E-01	+/- 11.00	3.360E-02	+/- 11.00
126	2.549E-01	+/- 8.00	2.863E-01	+/- 8.00	8.294E-02	+/- 16.00	2.518E-01	+/- 16.00	4.795E-02	+/- 16.00
127	4.981E-01	+/- 6.00	5.107E-01	+/- 8.00	2.333E-01	+/- 4.00	5.585E-01	+/- 11.00	7.551E-02	+/- 6.00
128	6.939E-01	+/- 11.00	8.923E-01	+/- 6.00	3.876E-01	+/- 23.00	8.098E-01	+/- 11.00	1.821E-01	+/- 16.00
129	1.387E+00	+/- 4.00	1.495E+00	+/- 6.00	8.381E-01	+/- 23.00	1.616E+00	+/- 16.00	2.824E-01	+/- 4.00
130	2.049E+00	+/- 16.00	2.372E+00	+/- 8.00	1.839E+00	+/- 11.00	2.165E+00	+/- 23.00	8.084E-01	+/- 16.00
131	3.874E+00	+/- 0.50	3.885E+00	+/- 0.70	3.091E+00	+/- 1.40	3.495E+00	+/- 1.00	1.615E+00	+/- 2.00
132	5.420E+00	+/- 0.70	5.323E+00	+/- 1.00	4.563E+00	+/- 1.40	4.799E+00	+/- 1.40	2.898E+00	+/- 1.40
133	7.019E+00	+/- 0.70	6.951E+00	+/- 0.70	6.736E+00	+/- 1.00	6.043E+00	+/- 1.00	3.944E+00	+/- 2.00
134	7.666E+00	+/- 0.70	7.389E+00	+/- 0.70	7.321E+00	+/- 1.40	6.133E+00	+/- 1.00	5.351E+00	+/- 2.00
135	7.610E+00	+/- 0.70	7.561E+00	+/- 0.70	7.243E+00	+/- 1.40	6.163E+00	+/- 2.00	5.491E+00	+/- 2.00
136	7.182E+00	+/- 1.00	7.040E+00	+/- 1.40	7.117E+00	+/- 1.40	6.865E+00	+/- 4.00	5.623E+00	+/- 2.00
137	6.685E+00	+/- 0.50	6.581E+00	+/- 0.70	6.720E+00	+/- 1.40	6.818E+00	+/- 0.70	5.800E+00	+/- 4.00
138	6.102E+00	+/- 1.40	6.129E+00	+/- 1.00	6.599E+00	+/- 2.00	5.906E+00	+/- 2.00	7.021E+00	+/- 11.00
139	5.534E+00	+/- 4.00	5.602E+00	+/- 1.40	6.231E+00	+/- 2.00	6.292E+00	+/- 4.00	7.146E+00	+/- 2.00
140	5.378E+00	+/- 1.00	5.293E+00	+/- 0.70	5.732E+00	+/- 2.00	6.515E+00	+/- 1.40	7.815E+00	+/- 2.00
141	5.299E+00	+/- 2.00	5.091E+00	+/- 2.80	4.892E+00	+/- 1.40	6.525E+00	+/- 2.80	7.320E+00	+/- 2.80
142	4.894E+00	+/- 1.00	4.803E+00	+/- 0.70	4.784E+00	+/- 1.40	6.694E+00	+/- 1.40	6.495E+00	+/- 4.00
143	4.442E+00	+/- 0.50	4.343E+00	+/- 0.50	4.590E+00	+/- 1.40	5.942E+00	+/- 1.00	6.588E+00	+/- 2.00
144	3.744E+00	+/- 0.50	3.692E+00	+/- 1.00	4.209E+00	+/- 1.00	4.671E+00	+/- 1.00	7.893E+00	+/- 2.80
145	2.997E+00	+/- 0.50	3.007E+00	+/- 0.50	3.269E+00	+/- 1.40	3.428E+00	+/- 1.00	5.287E+00	+/- 2.80
146	2.466E+00	+/- 0.50	2.457E+00	+/- 0.70	2.789E+00	+/- 1.40	2.569E+00	+/- 0.70	4.539E+00	+/- 2.80
147	2.027E+00	+/- 1.40	1.986E+00	+/- 1.00	2.285E+00	+/- 1.40	1.746E+00	+/- 2.80	2.926E+00	+/- 4.00
148	1.639E+00	+/- 0.50	1.654E+00	+/- 0.35	1.938E+00	+/- 1.00	1.289E+00	+/- 1.00	1.992E+00	+/- 2.80
149	1.226E+00	+/- 1.00	1.240E+00	+/- 0.70	1.476E+00	+/- 1.40	7.731E-01	+/- 2.80	1.059E+00	+/- 6.00
150	9.677E-01	+/- 0.50	9.922E-01	+/- 0.70	1.216E+00	+/- 1.40	5.066E-01	+/- 1.40	3.471E-01	+/- 16.00
151	7.545E-01	+/- 2.00	7.644E-01	+/- 1.40	9.134E-01	+/- 1.40	3.138E-01	+/- 2.00	3.551E-01	+/- 6.00
152	5.795E-01	+/- 1.40	5.977E-01	+/- 2.80	7.192E-01	+/- 1.40	2.124E-01	+/- 2.80	7.527E-02	+/- 16.00
153	3.502E-01	+/- 6.00	4.191E-01	+/- 4.00	5.411E-01	+/- 4.00	9.735E-02	+/- 6.00	6.443E-02	+/- 8.00
154	2.657E-01	+/- 1.40	2.619E-01	+/- 2.00	3.802E-01	+/- 2.00	4.641E-02	+/- 2.80	6.842E-03	+/- 23.00
155	1.593E-01	+/- 11.00	2.023E-01	+/- 11.00	2.422E-01	+/- 8.00	2.141E-02	+/- 23.00	3.598E-03	+/- 23.00
156	1.188E-01	+/- 2.80	1.434E-01	+/- 4.00	1.719E-01	+/- 2.80	1.153E-02	+/- 6.00	2.541E-03	+/- 11.00
157	7.258E-02	+/- 6.00	1.039E-01	+/- 8.00	1.353E-01	+/- 4.00	5.313E-03	+/- 8.00	9.271E-04	+/- 23.00
158	3.737E-02	+/- 23.00	6.232E-02	+/- 16.00	9.426E-02	+/- 23.00	2.260E-03	+/- 32.00	4.611E-04	+/- 32.00
159	1.974E-02	+/- 6.00	3.691E-02	+/- 11.00	4.800E-02	+/- 4.00	7.773E-04	+/- 6.00	9.699E-05	+/- 32.00
160	8.549E-03	+/- 32.00	2.228E-02	+/- 16.00	2.095E-02	+/- 23.00	3.175E-04	+/- 32.00	6.868E-05	+/- 32.00
161	4.681E-03	+/- 6.00	7.984E-03	+/- 4.00	8.464E-03	+/- 4.00	1.113E-04	+/- 6.00	1.440E-05	+/- 23.00
162	2.126E-03	+/- 32.00	5.602E-03	+/- 23.00	2.723E-03	+/- 23.00	1.527E-05	+/- 32.00	7.929E-06	+/- 32.00
163	8.594E-04	+/- 32.00	2.539E-03	+/- 45.00	9.824E-04	+/- 23.00	7.142E-06	+/- 32.00	4.611E-06	+/- 32.00
164	3.243E-04	+/- 32.00	1.566E-03	+/- 45.00	3.152E-04	+/- 23.00	2.351E-06	+/- 32.00	2.021E-06	+/- 32.00
165	1.284E-04	+/- 23.00	8.150E-04	+/- 32.00	9.845E-05	+/- 23.00	7.450E-07	+/- 23.00	3.512E-07	+/- 23.00
166	6.387E-05	+/- 16.00	5.899E-04	+/- 32.00	6.598E-05	+/- 23.00	4.524E-07	+/- 32.00	1.372E-07	+/- 32.00
167	1.758E-05	+/- 32.00	2.574E-04	+/- 32.00	2.985E-05	+/- 23.00	6.323E-08	+/- 32.00	9.701E-08	+/- 32.00
168	4.915E-06	+/- 32.00	7.365E-05	+/- 32.00	1.361E-05	+/- 23.00	1.627E-08	+/- 32.00	5.262E-08	+/- 32.00
169	1.666E-06	+/- 32.00	2.481E-05	+/- 32.00	5.760E-06	+/- 23.00	5.515E-09	+/- 32.00	2.672E-08	+/- 32.00
170	3.499E-07	+/- 64.00	7.271E-06	+/- 32.00	1.676E-06	+/- 23.00	1.638E-09	+/- 32.00	1.061E-08	+/- 32.00
171	1.672E-07	+/- 32.00	2.478E-06	+/- 32.00	3.142E-07	+/- 23.00	5.429E-10	+/- 32.00	4.611E-09	+/- 32.00
172	4.934E-08	+/- 32.00	7.367E-07	+/- 32.00	1.047E-07	+/- 23.00	1.808E-10	+/- 32.00	2.371E-09	+/- 32.00

TABLE VIII (Cont.)

MASS	PU239T		PU239F		PU241T		U233T		TH232F	
66	1.877E-07 +/-	23.00	8.183E-07 +/-	16.00	1.370E-07 +/-	23.00	2.602E-07 +/-	23.00	1.184E-06 +/-	32.00
67	3.754E-07 +/-	23.00	2.699E-06 +/-	16.00	2.545E-07 +/-	23.00	1.179E-06 +/-	23.00	4.077E-06 +/-	32.00
68	1.313E-06 +/-	23.00	7.929E-06 +/-	16.00	5.874E-07 +/-	23.00	3.629E-06 +/-	23.00	1.494E-05 +/-	32.00
69	4.690E-06 +/-	23.00	2.941E-05 +/-	16.00	1.273E-06 +/-	23.00	9.980E-06 +/-	23.00	3.450E-05 +/-	32.00
70	1.591E-05 +/-	23.00	8.133E-05 +/-	16.00	4.604E-06 +/-	23.00	3.913E-05 +/-	23.00	6.752E-05 +/-	23.00
71	2.899E-05 +/-	23.00	1.772E-04 +/-	32.00	6.853E-06 +/-	23.00	1.724E-04 +/-	23.00	1.715E-04 +/-	23.00
72	9.726E-05 +/-	45.00	4.529E-04 +/-	32.00	2.545E-05 +/-	23.00	4.986E-04 +/-	23.00	4.247E-04 +/-	16.00
73	2.365E-04 +/-	23.00	7.006E-04 +/-	23.00	5.909E-05 +/-	16.00	1.086E-03 +/-	23.00	6.519E-04 +/-	16.00
74	5.477E-04 +/-	32.00	1.633E-03 +/-	16.00	9.790E-05 +/-	23.00	2.722E-03 +/-	23.00	1.179E-03 +/-	16.00
75	1.277E-03 +/-	32.00	2.332E-03 +/-	23.00	2.937E-04 +/-	23.00	8.159E-03 +/-	23.00	2.898E-03 +/-	16.00
76	2.828E-03 +/-	32.00	5.453E-03 +/-	16.00	9.791E-04 +/-	23.00	1.452E-02 +/-	23.00	6.890E-03 +/-	16.00
77	6.686E-03 +/-	11.00	1.207E-02 +/-	8.00	1.958E-03 +/-	23.00	2.601E-02 +/-	23.00	1.159E-02 +/-	8.00
78	2.752E-02 +/-	11.00	2.808E-02 +/-	16.00	8.973E-03 +/-	6.00	5.444E-02 +/-	23.00	4.559E-02 +/-	8.00
79	4.667E-02 +/-	23.00	5.929E-02 +/-	8.00	1.536E-02 +/-	16.00	1.502E-01 +/-	11.00	7.818E-02 +/-	11.00
80	1.147E-01 +/-	16.00	9.745E-02 +/-	16.00	2.991E-02 +/-	16.00	2.359E-01 +/-	23.00	1.985E-01 +/-	16.00
81	1.713E-01 +/-	16.00	1.346E-01 +/-	11.00	6.355E-02 +/-	16.00	3.670E-01 +/-	4.00	4.773E-01 +/-	11.00
82	2.081E-01 +/-	23.00	2.103E-01 +/-	8.00	1.380E-01 +/-	8.00	5.855E-01 +/-	2.80	1.100E+00 +/-	16.00
83	2.967E-01 +/-	0.70	3.108E-01 +/-	2.00	2.016E-01 +/-	2.00	1.014E+00 +/-	1.00	2.175E+00 +/-	2.00
84	4.724E-01 +/-	2.00	4.923E-01 +/-	1.40	3.526E-01 +/-	2.00	1.688E+00 +/-	1.00	3.992E+00 +/-	2.00
85	5.753E-01 +/-	0.50	6.016E-01 +/-	1.00	4.068E-01 +/-	1.40	2.227E+00 +/-	1.00	4.158E+00 +/-	1.40
86	7.647E-01 +/-	0.70	7.805E-01 +/-	1.40	5.960E-01 +/-	2.00	2.848E+00 +/-	1.40	6.553E+00 +/-	2.00
87	9.990E-01 +/-	0.70	1.023E+00 +/-	1.40	7.575E-01 +/-	2.00	4.034E+00 +/-	1.40	6.934E+00 +/-	2.80
88	1.342E+00 +/-	1.40	1.323E+00 +/-	1.40	9.788E-01 +/-	2.00	5.459E+00 +/-	1.40	7.291E+00 +/-	2.00
89	1.691E+00 +/-	2.80	1.727E+00 +/-	2.00	1.221E+00 +/-	4.00	6.335E+00 +/-	2.00	7.559E+00 +/-	4.00
90	2.082E+00 +/-	2.00	2.032E+00 +/-	1.00	1.539E+00 +/-	2.00	6.838E+00 +/-	1.40	7.968E+00 +/-	4.00
91	2.488E+00 +/-	1.00	2.499E+00 +/-	1.40	1.871E+00 +/-	2.00	6.551E+00 +/-	1.00	7.385E+00 +/-	2.00
92	3.003E+00 +/-	1.40	3.014E+00 +/-	1.00	2.333E+00 +/-	2.00	6.542E+00 +/-	1.40	6.852E+00 +/-	2.80
93	3.840E+00 +/-	1.40	3.811E+00 +/-	1.00	2.986E+00 +/-	2.00	6.953E+00 +/-	1.40	6.786E+00 +/-	4.00
94	4.340E+00 +/-	2.00	4.199E+00 +/-	1.00	3.430E+00 +/-	2.00	6.797E+00 +/-	1.40	5.713E+00 +/-	6.00
95	4.878E+00 +/-	2.00	4.670E+00 +/-	1.00	3.963E+00 +/-	2.00	6.347E+00 +/-	1.40	5.665E+00 +/-	2.80
96	4.956E+00 +/-	2.80	4.811E+00 +/-	1.00	4.431E+00 +/-	2.00	5.635E+00 +/-	1.00	4.444E+00 +/-	6.00
97	5.340E+00 +/-	2.00	5.318E+00 +/-	0.70	4.698E+00 +/-	2.00	5.498E+00 +/-	1.40	4.465E+00 +/-	1.40
98	5.894E+00 +/-	2.00	5.653E+00 +/-	1.00	4.977E+00 +/-	2.00	5.175E+00 +/-	1.40	3.709E+00 +/-	6.00
99	6.169E+00 +/-	2.00	5.956E+00 +/-	2.00	6.077E+00 +/-	2.00	4.877E+00 +/-	2.00	2.961E+00 +/-	2.00
100	6.819E+00 +/-	4.00	6.556E+00 +/-	0.70	6.272E+00 +/-	2.00	4.379E+00 +/-	1.40	1.282E+00 +/-	6.00
101	5.997E+00 +/-	1.40	6.653E+00 +/-	1.00	6.286E+00 +/-	2.00	3.168E+00 +/-	1.40	7.249E-01 +/-	11.00
102	6.075E+00 +/-	2.00	6.706E+00 +/-	1.00	6.658E+00 +/-	2.00	2.404E+00 +/-	1.40	3.737E-01 +/-	11.00
103	6.947E+00 +/-	2.00	6.846E+00 +/-	1.00	6.739E+00 +/-	4.00	1.593E+00 +/-	2.00	1.565E-01 +/-	4.00
104	6.017E+00 +/-	2.00	6.535E+00 +/-	1.00	7.099E+00 +/-	2.00	9.755E-01 +/-	2.80	9.175E-02 +/-	11.00
105	5.586E+00 +/-	2.00	5.344E+00 +/-	2.80	6.254E+00 +/-	2.80	4.939E-01 +/-	2.80	5.180E-02 +/-	2.80
106	4.328E+00 +/-	2.80	4.362E+00 +/-	1.40	6.127E+00 +/-	2.00	2.453E-01 +/-	2.00	5.320E-02 +/-	8.00
107	3.263E+00 +/-	6.00	2.957E+00 +/-	8.00	5.145E+00 +/-	11.00	1.131E-01 +/-	4.00	5.189E-02 +/-	11.00
108	2.115E+00 +/-	6.00	1.927E+00 +/-	8.00	3.599E+00 +/-	11.00	7.287E-02 +/-	6.00	6.272E-02 +/-	16.00
109	1.639E+00 +/-	8.00	1.590E+00 +/-	6.00	2.259E+00 +/-	6.00	4.326E-02 +/-	8.00	5.252E-02 +/-	6.00
110	6.279E-01 +/-	6.00	6.213E-01 +/-	8.00	1.340E+00 +/-	8.00	3.713E-02 +/-	4.00	7.259E-02 +/-	16.00
111	2.935E-01 +/-	2.80	3.547E-01 +/-	2.00	5.704E-01 +/-	4.00	1.944E-02 +/-	8.00	7.451E-02 +/-	6.00
112	1.229E-01 +/-	2.80	1.903E-01 +/-	2.80	2.366E-01 +/-	4.00	1.381E-02 +/-	8.00	8.004E-02 +/-	6.00
113	7.979E-02 +/-	4.00	1.268E-01 +/-	2.00	1.545E-01 +/-	6.00	1.312E-02 +/-	8.00	8.034E-02 +/-	4.00
114	5.877E-02 +/-	4.00	9.366E-02 +/-	2.00	7.342E-02 +/-	23.00	1.251E-02 +/-	8.00	7.507E-02 +/-	16.00
115	3.687E-02 +/-	4.00	7.017E-02 +/-	6.00	4.481E-02 +/-	16.00	1.258E-02 +/-	6.00	5.781E-02 +/-	4.00
116	4.840E-02 +/-	8.00	5.896E-02 +/-	6.00	2.913E-02 +/-	32.00	1.313E-02 +/-	11.00	7.362E-02 +/-	16.00
117	4.825E-02 +/-	8.00	6.859E-02 +/-	11.00	2.547E-02 +/-	23.00	1.204E-02 +/-	8.00	5.916E-02 +/-	2.80
118	3.933E-02 +/-	11.00	6.159E-02 +/-	11.00	2.428E-02 +/-	32.00	1.261E-02 +/-	8.00	6.298E-02 +/-	11.00
119	4.028E-02 +/-	11.00	5.966E-02 +/-	11.00	2.428E-02 +/-	32.00	1.293E-02 +/-	8.00	5.703E-02 +/-	16.00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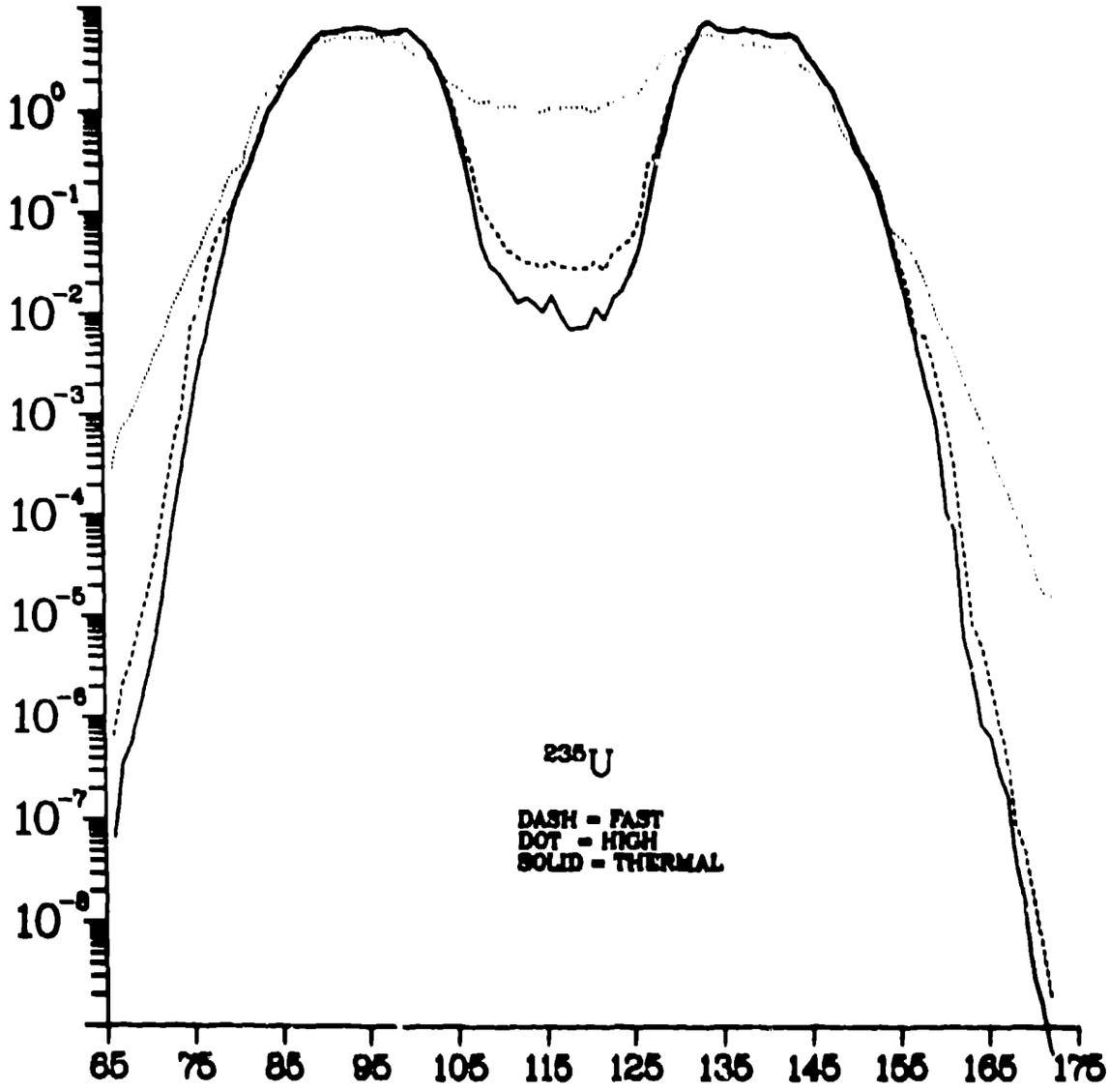
GAUSSIAN DISTRIBUTION
PLUS PAIRING EFFECTS
CONSTANT A
Z
N

Fig. 1.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10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
^{235}U
DASH = FAST
DOT = HIGH
SOLID = THERMAL
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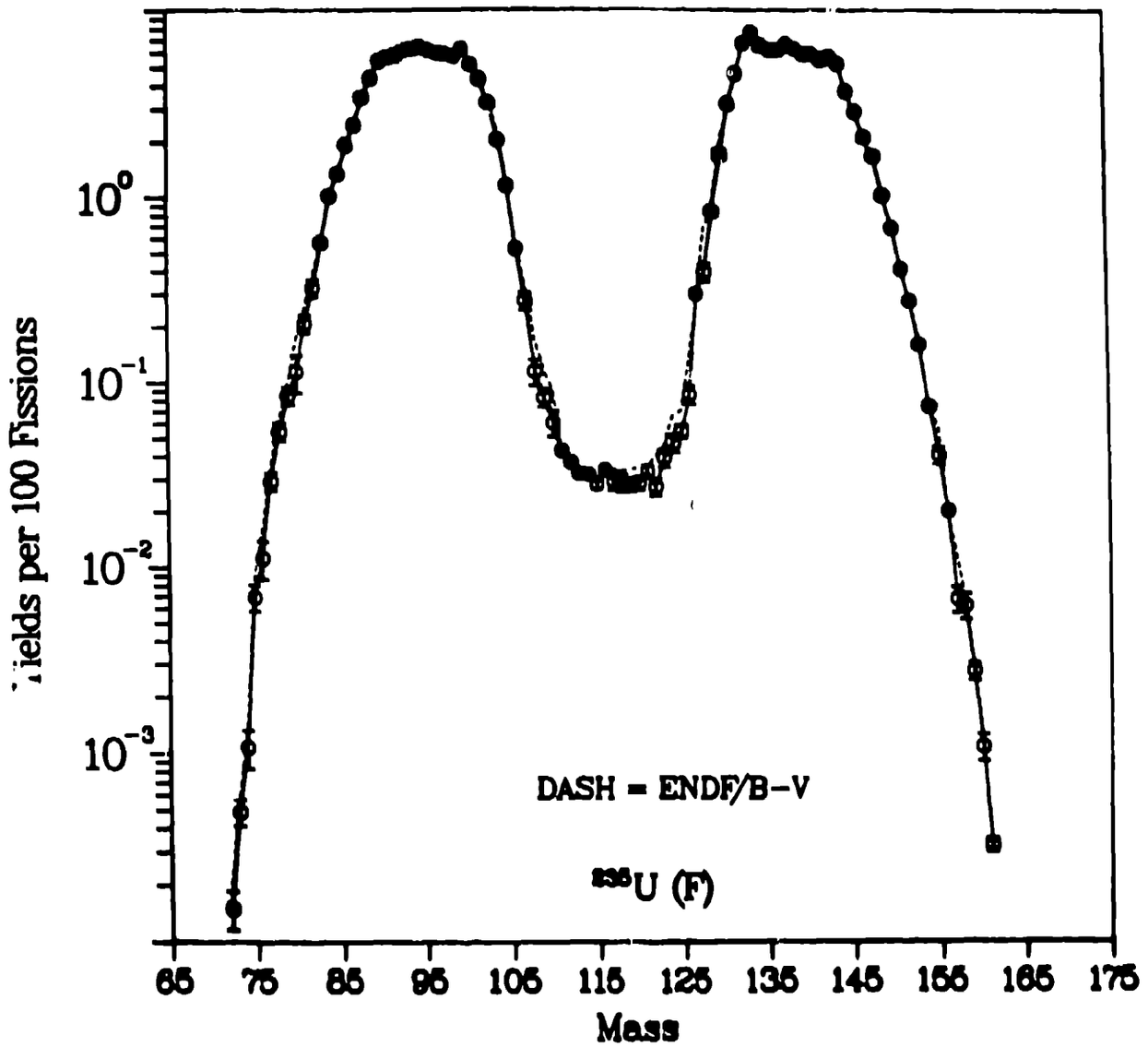
75
85
95
105
115
125
135
145
155
165
175

Fig. 2.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10^{-2}
10^{-3}
DASH = ENDF/B-V
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85
95
105
115
125
135
145
155
165
175
Mass

Fig. 3.

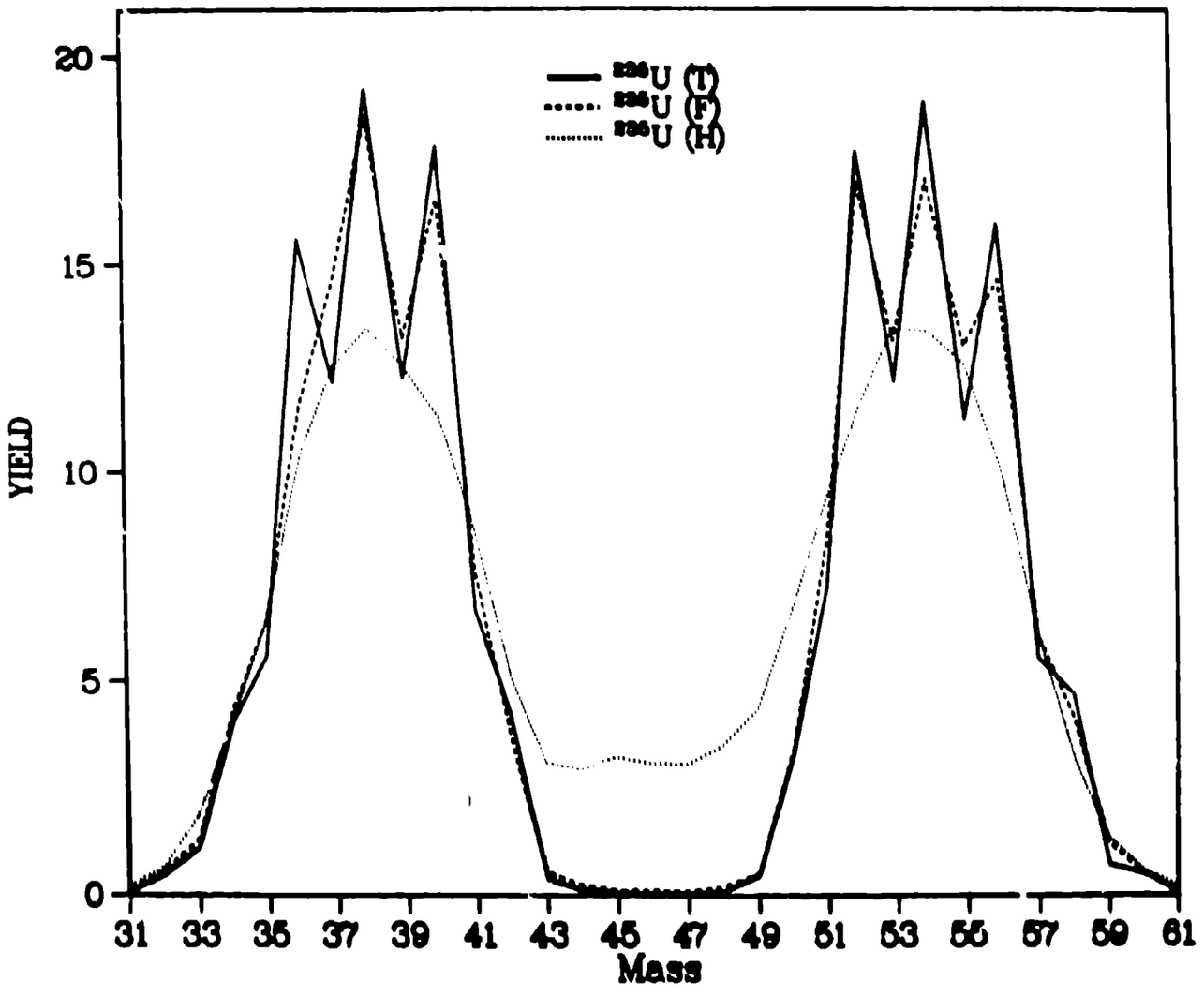
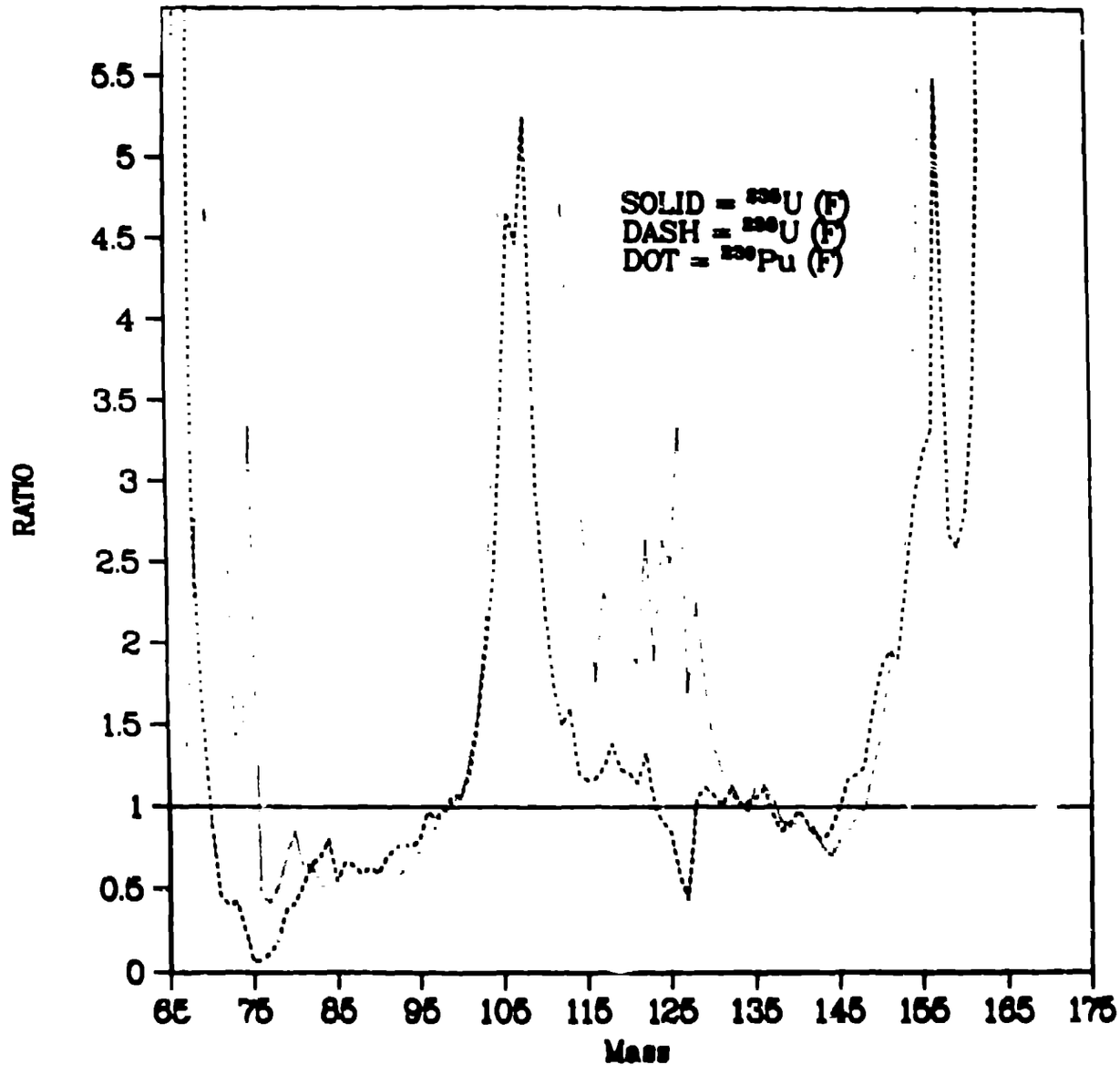

20
15
10
5
0
YIELD
31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61
Mass
(T)
(F)
(H)

Fig. 4.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DASH = ^{238}U (F)
DOT = ^{239}Pu (F)
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2.5
3
3.5
4
4.5
5
5.5
65
75
85
95
105
115
125
135
145
155
165
175

Fig. 5.