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REVIEW OF AVAILABLE BENCHMARK EXPERIMENTS FOR KINETIC PARAMETER VALIDATION

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TITULO: Review of available benchmark experiments for kinetic parameter validation

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ABSTRACT:

This report presents the results of the work performed by CIEMAT within SANDA Task 4.4. We have performed a bibliographic search (ICSBEP and IRPhE databases and the scientific literature) for nuclear reactor benchmark experiments containing experimental information about kinetics parameters, namely the effective delayed neutron fraction (β_{eff}), the effective mean neutron generation time (Λ_{eff}) and the prompt neutron decay constant (α). This report presents the results of this search. Furthermore, to determine the level of sensitivity to nuclear data of these parameters, S/U analyses have been performed with the SUMMON code alongside with sensitivity coefficients calculated with the MCNP 6.2 code (KSEN card) and the JEFF-3.3 nuclear data library. For uncertainty quantification, covariance matrices from ENDF/B-VIII.0, JEFF-3.3 and JENDL-4.0u have been used.

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1. INTRODUCTION

Evaluation of nuclear data is an essential part of the nuclear data cycle and it is key to assure the suitability of nuclear data libraries for their required applications. Sensitivity and uncertainty (S/U) analyses play an important role in the evaluation process, as they allow determining the data with the largest impact in the calculation results (sensitivity) and estimating the uncertainty in the calculated results due to the uncertainty in the input data. For this reason, EU H2020 SANDA project (grant agreement 847552), which intends to coordinate all nuclear data activities carried out in Europe, includes Work Package no. 4 which is focused in nuclear data evaluation and uncertainties.

The aims of this work package include "*recommending a set of preferred systems (or benchmarks) for the validation of the new evaluations*". These activities are carried out within task 4.4. More specifically, in the description of the task, it is stated that while validation of nuclear data has traditionally been focused on the criticality constant (k_{eff}) it should also consider other types of measurements, namely shielding and kinetic benchmarks. Hence, "*a review of different suites of inputs used in ICSBEP*" in search of kinetic parameter information is proposed within this task.

This report answers to this requirement. We have performed a search in the major available databases, namely ICSBEP [NEA 2020a] and IRPhE [NEA 2020b], and the scientific literature for systems for which there is available both detailed description (benchmark level) and experimental values of the kinetic parameters. A summary of the results of this search is presented in section 2. The list of all benchmark experiments that have been identified, alongside with the experimental values of the kinetic parameters and the references, is presented in Annex I.

Furthermore, task 4.4 also requires a "*selection/classification of benchmarks for different levels of nuclear data sensitivities for benchmarking and validation of nuclear data*". To answer to this requirement, we have performed a sensitivity and uncertainty analysis of the kinetic parameters. This has been performed with the SUMMON code [Romojaro 2017, Romojaro 2019a, Romojaro 2019b] developed at CIEMAT, using sensitivity coefficients calculated with the MCNP 6.2 code [Werner 2017] and the JEFF-3.3 library [Plompen 2020]. The methodology employed for these analyses is described in section 3, while a summary of the results is presented in sections 4, for the case of the effective delayed neutron fraction (β_{eff}), and 5, for the case of the effective mean neutron generation time (Λ_{eff}). The results of the integrated sensitivity coefficients (ISCs) for the most relevant reactions are presented in Annex II (β_{eff}) and Annex IV (Λ_{eff}). Uncertainty analyses have been performed using covariance matrices from ENDF/B-VIII.0 [Brown 2018], JEFF-3.3 and JENDL-4.0u [Shibata 2011]. Major contributors to the uncertainty due to nuclear data with all these matrices are listed in Annexes II and IV. Finally, a comparison with the sensitivity coefficients for β_{eff} obtained in [Kodeli 2013] for some benchmark systems is also provided in Annex III.

Finally, it must be remarked that in addition to their utility for validating nuclear data, an adequate knowledge of reactor kinetic parameters is important for designing nuclear reactor facilities, since they determine the time behavior of a nuclear reactor. Also, they are very important for applying reactivity measurement and monitoring techniques, of particular importance for the development of accelerator driven systems.

2. BENCHMARK SYSTEMS FOR KINETIC PARAMETERS

The primary source of benchmark systems information for this work have been the ICSBEP and IRPhE databases. It must be noticed that although IRPhE is the primary source of experimental reactor physics information, it only contains experimental kinetic parameter information for a handful of systems, namely Orsphere (β_{eff}, Λ_{eff}, α[1]), BFS1-73 (β_{eff}), IPEN/MB-01 (β_{eff}, Λ_{eff}), SNEAK-7A (β_{eff}) and SNEAK-7B (β_{eff}). That is to say, a total of 5 systems with experimental values of β_{eff} and two systems with experimental values of Λ_{eff}. Furthermore, experimental inverse period information is provided for the CROCUS reactor.

On the other hand, although ICSBEP is in principle limited to criticality experiments, kinetic information is sometimes provided in the benchmark documentation or can be found in the literature. Finally, a very useful reference has been [Okajima 2002], which describes a total of five configurations of the MASURCA and FCA-XIX reactors specifically designed for the measurement of β_{eff} and measured in the 1990s within an international program under OECD/NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC) subgroup 6. All benchmark experiments considered in this work come from one of these three sources. The total number of systems that have been identified, classified by the fuel and the neutron spectrum, are summarized in Table 1. The complete list of benchmark systems, alongside with the experimental values of the kinetic parameters and the references, is presented in Annex I.

Table 1. Total number of benchmark systems with kinetic information identified within this work.

Fuel	Spectrum	β_{eff}	Λ_{eff}	α
^{235}U systems	Fast & intermediate	13	3	14
	Thermal	2	1	8
Pu & mixed fuel systems	Fast & intermediate	10	1	1
	Thermal	---	---	---
^{233}U systems	Fast & intermediate	2	1	1
	Thermal	---	---	---
Total		27	6	24

It is worthwhile to comment that there are much more systems with experimental information for the prompt neutron decay constant α than for Λ_{eff}. Hence, it can be a more useful parameter to validate nuclear data than Λ_{eff}. However, in this work we have not considered it because at the moment our tools (in particular, our S/U analysis tools, see section 3) are not yet prepared for the calculation of this parameter.

As a final comment, kinetic parameters have also been measured in several experiments during EU Framework programs, namely MUSE-4 [Mellier 2005] and VENUS-F [Doliguez 2015, Geslot 2015, Panizo 2021], but since a detailed description of the benchmark systems is not publicly available, they have not been included in this report.

[1] The prompt neutron decay constant or Rossi- α is defined as $\alpha = -\beta_{eff}/\Lambda_{eff}$.

3. CALCULATION METHODOLOGY

As stated in the introduction, in this work, we have used the SUMMON code developed at CIEMAT to calculate the values of β_{eff} and Λ_{eff} as well as the sensitivity coefficients for these parameters and the uncertainty due to nuclear data. β_{eff} and Λ_{eff} are calculated by SUMMON from a pair of values of the criticality constant, the reference (unperturbed) value and a perturbed value. These perturbations are different depending on the parameter being calculated and the technique being used. They are explained in sections 4 and 5, respectively. Similarly, SUMMON calculates the sensitivity coefficients of β_{eff} and Λ_{eff} from the sensitivity coefficients of the two values of the criticality constant, the perturbed and unperturbed ones. These *sensitivity coefficients* are the derivative of a calculated parameter f (in our case, Λ_{eff} or β_{eff}) with respect to the input parameters α_i (in our case, the value of a cross section in a given energy range), namely:

$$s_{\alpha_i} = \frac{\alpha_i}{f}\frac{\partial f}{\partial \alpha_i} \qquad (3.1)$$

In this work, we have used the Monte Carlo code MCNP 6.2 [Werner 2017] to obtain the values of the perturbed and unperturbed criticality constants and their sensitivity coefficients (using the KSEN card). The JEFF-3.3 library has been used for these calculations. The sensitivity coefficients have been calculated using the 33 energy group structure described in [Palmiotti 2010], then converted to the SDF format [Rearden 2018] and supplied to SUMMON to obtain the sensitivity coefficients for β_{eff} and Λ_{eff}.

With the vector of sensitivity coefficients $\vec{s} = (s_{\alpha_i}, \dots, s_{\alpha_N})$ (i.e. the sensitivity profile) for β_{eff} and Λ_{eff}, SUMMON can also calculate the uncertainties in these parameters. The methodology used by SUMMON to calculate uncertainties in reactor parameters is based on first-order (linear) propagation of the uncertainty in the input parameters (i.e. nuclear data) using the so-called *"sandwich rule"* [Cacuci 2003]:

$$\mathrm{Var}(f) = \sum_i \left(\frac{\partial f}{\partial \alpha_i}\right)^2 \mathrm{Var}(\alpha_i) + \sum_{i,j} \frac{\partial f}{\partial \alpha_i}\frac{\partial f}{\partial \alpha_j}\mathrm{Cov}(\alpha_i, \alpha_j) = \vec{s}V\vec{s}^T \qquad (3.2)$$

$\mathrm{Var}(\alpha_i)$ and $\mathrm{Cov}(\alpha_i, \alpha_j)$ denote, respectively, the relative variance and covariance of the input parameters, and together make up the covariance matrix V. Covariance matrices for the nuclear data are included in some of the latest releases of nuclear data libraries. In this work we have calculated the uncertainty in Λ_{eff} or β_{eff} using covariance matrices from the ENDF/B-VIII.0, JEFF-3.3 and JENDL-4.0u libraries[2]. In this work, we have calculated both the total uncertainties due to nuclear data and the uncertainties due to individual reactions. Notice that in the tables in the annex, reactions are always listed in pairs. When both reactions in the pair are the same, it means that the uncertainty value listed represents the uncertainty due to the variance of this reaction (taking into account the covariance between energy ranges of the incident particles), while when two different reactions appear in the pair, the listed value represents the contribution to the uncertainty of the covariance between this pair of reactions, which can be a negative quantity if the two reactions are negatively correlated. Also notice that the total uncertainty is the square sum of all individual pairs of reactions (with negative

[2] Since sensitivity profiles have been calculated with the Monte Carlo code MCNP and its calculation requires long computational times, for this work they have only been calculated with the JEFF-3.3 library. However, since SUMMON uses deterministic techniques for calculating uncertainties (eq. 3.2), these sensitivity profiles have been combined with covariance matrices from all three ENDF/B-VIII.0, JEFF-3.3 and JENDL-4.0u libraries to calculate uncertainties due to nuclear data.

sign if its contribution is negative), i.e. the total uncertainty due to nuclear data is smaller than the sum of all the individual contributions.

An important issue when calculating uncertainties with this approach is the fact that sensitivity profiles calculated with Monte Carlo codes are affected by statistical errors (covariance matrices are assumed to be exact). Hence, the uncertainty due to nuclear data $\mathrm{Var}(f)$ calculated using eq. 3.2 is also affected by a statistical uncertainty, which needs to be correctly assessed in order to assure that the values of the uncertainty calculated using eq. 3.2 are really due to the uncertainties present in nuclear data. The methodology implemented in SUMMON for this purpose is also based on first-order error propagation, in this case of the statistical errors (let us denote them by $\vec{\sigma}(s) = (\sigma_{s_1}, \dots, \sigma_{s_N})$) of the sensitivity profiles $\vec{s}$. Hence, denoting by $\sigma^2(\mathrm{Var}(f))$ the statistical variance of $\mathrm{Var}(f)$:

$$\sigma^2(\mathrm{Var}(f)) = \sum_\alpha \left(\frac{\partial(\vec{s}V\vec{s}^T)}{\partial s_\alpha}\sigma_{s_\alpha}\right)^2 \qquad (3.3)$$

Where the index α ranges over all reactions (and isotopes) involved, as well as over all energy groups. Developing equation 3.3 (details are omitted) we have finally arrived at the following expression for the statistical variance (σ^2) of $\mathrm{Var}(f)$:

$$\sigma^2(\mathrm{Var}(f)) = \sum_\beta \left(2\sum_\alpha s_\alpha V \sigma_{s_\beta}^T\right)^2 \qquad (3.4)$$

And finally, the statistical standard deviation of the uncertainty due to nuclear data turns out to be[3]:

$$\mathrm{s.d.}(f) = \sqrt{\mathrm{Var}(f)} \Rightarrow \sigma(\mathrm{s.d.}(f)) = \frac{\sigma(\mathrm{Var}(f))}{2\sqrt{\mathrm{Var}(f)}} = \frac{\sqrt{\sum_\beta\left(2\sum_\alpha s_\alpha V \sigma_{s_\beta}^T\right)^2}}{\sqrt{\sum_{\alpha,\beta} s_\alpha V s_\beta^T}} \qquad (3.5)$$

In order to check the correctness of this methodology, we have performed a large number (100) of independent calculations of β_{eff} and Λ_{eff} of some selected benchmark systems, using different random number sequences, and calculating with SUMMON the uncertainty due to nuclear data ($\mathrm{s.d.}(f)$) for every independent calculation. Then, we have represented them in a histogram and from the histogram we have calculated the statistical standard deviation of $\mathrm{s.d.}(f)$, $\sigma(\mathrm{s.d.}(f))$. Finally, we have compared with the results obtained with equation 3.5. Some results are shown in Figure 1 and Figure 2. In general, it can be concluded that SUMMON is capable in all cases to correctly determine at least the order of magnitude of the statistical error in the uncertainty due to nuclear data, which we consider that is enough in most cases. We have observed, however, that the discrepancy may be of a factor up to about three with the values calculated from the histogram. Further research will be required to determine the reasons (insufficient statistics, non-linear effects…).

[3] In [Iwamoto 2018] another formula is used. At the time of the writing of this report we have not cross-checked it with our method.

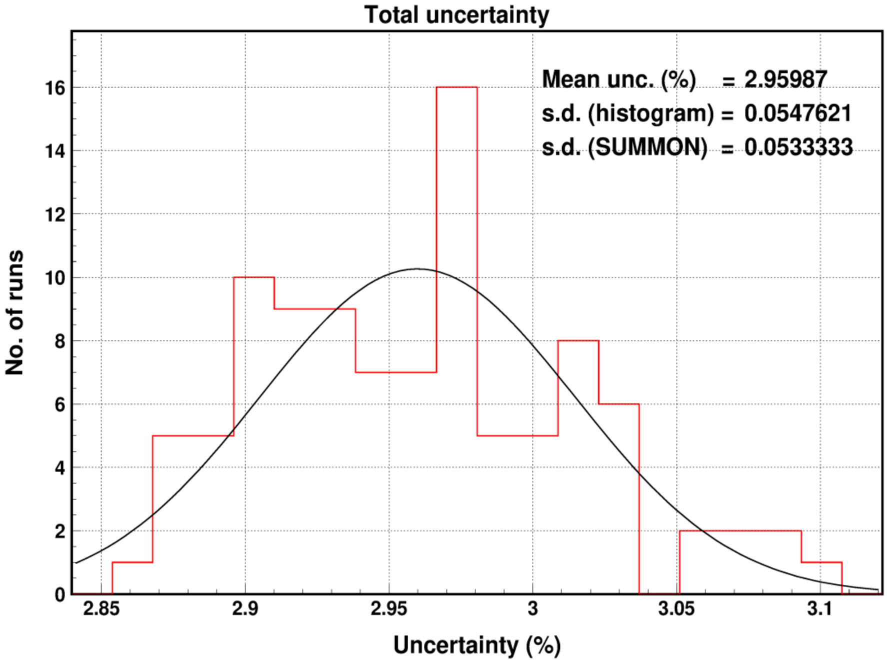

Figure 1. Total uncertainty due to nuclear data in the β_{eff} of the Godiva reactor (HEU-MET-FAST-001). "s.d. (histogram)" is the uncertainty calculated from the histogram, while "s.d. (SUMMON)" is the uncertainty calculated by SUMMON using equation 3.5. The value of the mean uncertainty is calculated from the histogram.

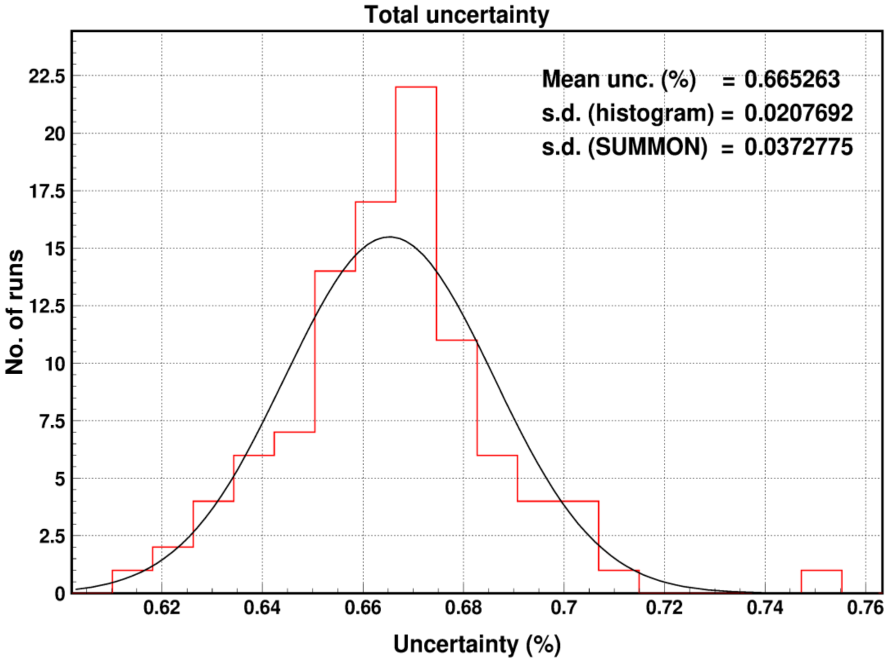

Figure 2. Total uncertainty due to nuclear data in the Λ_{eff} of the IPEN/MB-01 reactor (LEU-COMP-THERM-067). Same comments than in Figure 1.

4. EFFECTIVE DELAYED NEUTRON FRACTION

As stated above and as it can be observed in Annex I, a total of 27 systems have been identified for which experimental values of β_{eff} are available. They comprise 15 ^{235}U systems, 10 Pu or mixed fuel systems and two ^{233}U systems.

Two different methods have been implemented in SUMMON for effective delayed neutron fraction calculation: the k-prompt or Bretscher method [Bretscher 1997] and Chiba's perturbative method [Chiba 2009]. Bretscher method is based in performing two different criticality calculations, the reference one (i.e. in the unperturbed system), to obtain a value of k_{eff}, and a second one without delayed neutrons (which in MCNP can be achieved with the TOTNU NO card), to obtain a value denoted by k_p:

$$\beta_{eff} = 1 - \frac{k_p}{k_{eff}} \qquad (4.1)$$

Sensitivity profiles can then be obtained as:

$$s_{\beta_{eff},\alpha_i} = \frac{\alpha_i}{\beta_{eff}}\frac{\partial \beta_{eff}}{\partial \alpha_i} = \frac{\alpha_i}{\beta_{eff}}\frac{\partial}{\partial \alpha_i}\left(1 - \frac{k_p}{k_{eff}}\right) = \frac{k_p}{k_{eff}-k_p}\left(s_{k_{eff},\alpha_i} - s_{k_p,\alpha_i}\right) \qquad (4.2)$$

This method has the disadvantage that, since k_p and k_{eff} take very similar values, the relative uncertainty in the difference is usually very large, thus requiring very precise values of k_p and k_{eff}. This problem can be worked around by using Chiba's method. In this method, the value of β_{eff} is determined though the formula:

$$\beta_{eff} = \frac{1}{a}\left(\frac{\bar{k}_{eff}}{k_{eff}} - 1\right) \qquad (4.3)$$

where k_{eff} is again the reference (unperturbed) criticality constant and $\bar{k}_{eff}$ is the value of the criticality constant obtained by perturbing the system by introducing a times the number of delayed neutrons. This is achieved by multiplying by $a + 1$ the value of the average number of delayed neutron per fission ($\bar{\nu}_d$) in the nuclear data files used by the Monte Carlo code and increasing accordingly the total number of neutrons per fission ($\bar{\nu}_t$). Sensitivity profiles are obtained in a similar way than before:

$$s_{\beta_{eff},\alpha_i} = \frac{\alpha_i}{\beta_{eff}}\frac{\partial \beta_{eff}}{\partial \alpha_i} = \frac{\alpha_i}{\beta_{eff}}\frac{\partial}{\partial \alpha_i}\left(\frac{1}{a}\left(\frac{\bar{k}_{eff}}{k_{eff}} - 1\right)\right) = \frac{\bar{k}_{eff}}{k_{eff}-\bar{k}_{eff}}\left(s_{k_{eff},\alpha_i} - s_{\bar{k}_{eff},\alpha_i}\right) \qquad (4.4)$$

Since the value of the perturbation a can be made larger in Chiba's method that in Bretscher's method, the difference between k_{eff} and $\bar{k}_{eff}$ can be made larger than the difference between k_{eff} and and k_p and hence the statistical uncertainty can be reduced (notice that Bretscher's method can be understood as a particular case of Chiba's method where $a = -1$). The disadvantage of this method with respect to Bretscher's method lays in the fact that a large value of a will reduce the statistical uncertainty but can introduce a significant bias in the results. Furthermore, Chiba's method is more cumbersome to apply since it requires a modification of nuclear data libraries to alter the value of a. In any case, in this work we have found Bretscher's method unpractical since it requires prohibitively large computational resources to calculate the sensitivity profiles $s_{\beta_{eff}}$ with enough accuracy. Hence, all uncertainty results presented in this report have been obtained with Chiba's method, considering a value of $a = 20$.

The calculated results of the β_{eff} for ^{235}U systems, Pu and ^{233}U are presented, respectively, in Table 2, Table 3 and Table 4, as well as graphically in Figure 3 and Figure 5 (in the figures, the values of β_{eff} displayed were obtained with Chiba's method). Furthermore, in Annex II, the values of the integrated sensitivity profiles (ISCs, i.e. the sum of all the sensitivity coefficients over the entire energy range) for the nuclear data with the largest impact on β_{eff} are presented. The values of the largest contributions to the total uncertainty of individual reactions, are also presented in Annex II, for all three ENDF/B-VIII.0, JEFF-3.3 and JENDL-4.0u libraries.

Both β_{eff} results obtained with Bretscher and Chiba's methodologies are listed in the tables. It can be observed that the difference between the two techniques depends strongly on the system and ranges from less than 1 pcm (Jezebel) to up to about 25 pcm (Big Ten). Nevertheless, since this is the order of magnitude of the experimental errors and the errors due to nuclear data, β_{eff} results obtained with Chiba's method may actually match experimental results better that Bretscher's method results.

Overall, a very good agreement between experimental and calculated results is observed when the experimental uncertainties and the uncertainties due to nuclear data are taken into account. This is remarkable since many experimental values come from very old experiments. The only exception is a couple of configurations of the FR0 reactor (FR0-3X and FR0-8). This can be partly explained by the bias introduced by Chiba's method when compared to Bretscher's. Furthermore, as stated in Annex I, smaller experimental values were listed in other reference, which would offer a better match with the calculated ones (experimental values listed in Table 2 were taken from the most recent reference).

Another important fact to remark is that there is large variation in the results of the total uncertainty due to nuclear data that results from using covariance matrices from different nuclear data libraries, as it can be observed in Figure 4 and Figure 6. To understand this effect, it is useful to have a look first to the integrated sensitivity profiles presented in Annex II. It can be observed there that the most relevant nuclear data for the sensitivity of β_{eff} is the average number of delayed neutrons per fission ($\bar{\nu}_d$). In all cases, the sum of the ISCs of fissioning isotopes was close to 1 in units of %/%, implying that a change of 1% in the value of $\bar{\nu}_d$ will result in a similar 1% change of β_{eff}. Hence, the value of the uncertainty due to nuclear data obtained with a certain set of covariance matrices will depend essentially on the presence or not of covariance matrices for $\bar{\nu}_d$ in a given evaluation (apart, of course, of the values of these covariance matrices). ENDF/B-VIII.0 includes covariance data for $\bar{\nu}_d$ for uranium isotopes, but not for plutonium. JEFF-3.3, for its part, included covariance data for $\bar{\nu}_d$ only for the case of ^{233}U. JENDL-4.0u contains the most complete set of covariance data for $\bar{\nu}_d$, both for U and Pu isotopes.

There are also clearly noticeable differences between uncertainty values obtained with different libraries even when they contain covariance data for $\bar{\nu}_d$. In the case of uranium (^{235}U) systems, the values of uncertainty obtained with the ENDF/B-VIII.0 covariance matrices are significantly larger than those obtained with JENDL-4.0u. For its part, in the case of ^{233}U systems, where there are covariance data for $\bar{\nu}_d$ in all three libraries, uncertainty obtained with JEFF-3.3 covariance matrices are higher than for ENDF/B-VIII.0 and JENDL-4.0u.

Although we have not performed a detailed analysis of these effects, an examination of the figures of the covariance matrices of $\bar{\nu}_d$ for the most relevant isotopes may be useful and therefore they have been included in Annex V. They have been processed into the Boxer format with NJOY 21 [NJOY 21] for use with the SUMMON code. If compared the values of $\Delta\bar{\nu}_d/\bar{\nu}_d$ (upper graph in the figures), it can be observed that they are higher in a large part of the energy spectra for ^{235}U in ENDF/B-VIII.0 than in JENDL-4.0u, which can explain the larger values of the uncertainty obtained with the first library for the case of ^{235}U systems. In the case of ^{238}U, $\Delta\bar{\nu}_d/\bar{\nu}_d$ is higher in JENDL-4.0u than in ENDF/B-VIII.0, though. Finally, in the case of ^{233}U, $\Delta\bar{\nu}_d/\bar{\nu}_d$ values are higher in JEFF-3.3 that in the other two libraries (which appear to share the same covariance matrices), which explain the larger values of the uncertainty in the β*eff* of ^{233}U systems obtained with this library. So finally, we can conclude that the three covariance matrices sets considered contain large enough differences to have a significant impact on the uncertainty quantification for β*eff*.

Another effect worth mentioning is that in the ISCs in Annex II it can be observed that β*eff* appears to have a large sensitivity to $\bar{\nu}_p$ (average number of prompt fissions per neutron), similar in value to the sensitivity to $\bar{\nu}_d$, but with negative sign. This effect is also observed in [Kodeli 2013] and [Iwamoto 2018], in the first case in sensitivity calculations performed with the SUSD3D code using direct and adjoint fluxes calculated with the deterministic DANSYS code. A figure with both sensitivity profiles for $\bar{\nu}_d$ and $\bar{\nu}_p$, for the case of the Godiva reactor, is presented in Figure 7. The sensitivity to $\bar{\nu}$ (total number of neutrons per fission) seems to be approximately the sum of the sensitivities to $\bar{\nu}_d$ and $\bar{\nu}_p$, and hence usually takes a small value. We can attempt to explain this behaviour by looking at the definition of β*eff*:

$$\beta_{eff} = \frac{\langle\psi^\dagger|\hat{F}_d\psi\rangle}{\langle\psi^\dagger|\hat{F}\psi\rangle} = \frac{\langle\psi^\dagger|\chi_d\nu_d\Sigma_f\psi\rangle}{\langle\psi^\dagger|\chi\nu\Sigma_f\psi\rangle} = \frac{\langle\psi^\dagger|\chi_d\nu_d\Sigma_f\psi\rangle}{\langle\psi^\dagger|(\chi_p\nu_p\Sigma_f + \chi_d\nu_d\Sigma_f)\psi\rangle} \simeq \frac{\langle\psi^\dagger|\chi_d\nu_d\Sigma_f\psi\rangle}{\langle\psi^\dagger|\chi_p\nu_p\Sigma_f\psi\rangle} \qquad (4.5)$$

Where ψ and $\psi^\dagger$ are, respectively, the direct and adjoint fluxes; Σ_f is the macroscopic fission cross section; ν_p, ν_d and ν are the prompt, delayed and total number of neutrons by fission and χ_p, χ_d and χ are the prompt, delayed and total fission spectra. Brackets denote integration over all relevant variables (variable dependency of the parameters in eq. 4.5 has been omitted for simplicity).

From the right hand term in eq. 4.5 it can be easily understood that an increase in ν_d (in the numerator) will result in a proportional increase in β*eff* and hence the positive sensitivity of β*eff* to ν_d. On the other hand, an increase in ν_p (in the denominator) will result in a decrease in β*eff* and hence the negative sensitivity to ν_p. Notice that in this way a similarly negative sensitivity to ν could be also expected, but as stated above this is not observed. It could be explained in MCNP not considering ν when both ν_p and ν_d are available, but we have found no information about this in MCNP's manual.

As a final comment, it is worth mentioning that in the case of the SNEAK-7A&B systems, the sensitivity of β*eff* to the $\bar{\nu}_d$ of ^{238}U is larger than the sensitivity to the $\bar{\nu}_d$ of ^{239}Pu.

Finally, in Table 5 the results of the total uncertainty obtained in this work are compared with the results obtained in [Kodeli 2013] for some reactors. As stated above, in this paper, an S/U analysis for β*eff* was performed with the deterministic SUSD3D code, using Bretscher's method to calculate sensitivity coefficients and COMMARA-2 and JENDL-4.0m covariance matrices to determine the uncertainty. As it can be observed, the results are very similar to the results obtained in this work with the JENDL-4.0u covariance matrix set. It must be remarked that in the calculations with the JENDL-4.0m matrices in [Kodeli 2013], an estimate of the contribution to the uncertainty of the delayed fission neutron spectra is included, that is not considered in this work, but its contribution to the total uncertainty was found to be small.

In Annex III, ISCs obtained in this work are also compared with those obtained with SUSD3D in [Kodeli 2013]. A good agreement is observed. The uncertainty results from individual reactions cannot be directly compared with the results of this work, since we obtain values for the contribution to the uncertainty of these reactions (the impact of other reactions correlated with it, which can be negative, are obtained separately) while in [Kodeli 2013] values of "variance penalty" are listed (which takes into account the contribution to the uncertainty for a given reaction and the ones correlated with it).

Table 2. Experimental and calculated values of β_{eff} for uranium systems, including uncertainties due to nuclear data.

System	β_{eff} (exp)	β_{eff} (Bretscher)	β_{eff} (Chiba)	Total unc. (%) ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0u
Godiva	659 ± 10	650.9 ± 1.4	648.0 ± 0.1	4.5907 ± 0.0021	1.416 ± 0.014	2.943 ± 0.005
Orsphere	657 ± 9	646.3 ± 1.4	648.6 ± 0.1	4.5804 ± 0.0021	1.399 ± 0.011	2.936 ± 0.004
Tospsy	665 ± 13	692.1 ± 1.4	687.2 ± 0.1	3.9762 ± 0.0019	1.004 ± 0.008	2.691 ± 0.004
Coral	663 ± 17	699.6 ± 2.8	687.5 ± 0.2	3.9670 ± 0.0027	0.976 ± 0.014	2.676 ± 0.006
ZPR-9/34	667 ± 13	682.1 ± 2.8	684.2 ± 0.1	4.560 ± 0.003	0.655 ± 0.018	2.662 ± 0.007
FCA-XIX-1	742 ± 24	764.2 ± 2.8	760.1 ± 0.2	4.3069 ± 0.0029	0.586 ± 0.006	2.4461 ± 0.0027
MASURCA R2	721 ± 11	739.6 ± 2.8	727.2 ± 0.2	3.6241 ± 0.0023	0.626 ± 0.010	2.430 ± 0.004
Big Ten	720 ± 7	739.4 ± 1.4	714.9 ± 0.1	2.8061 ± 0.0015	0.793 ± 0.013	2.548 ± 0.005
ZPR-6/9	725 ± 15	738.0 ± 2.8	713.6 ± 0.2	2.798 ± 0.005	0.855 ± 0.028	2.553 ± 0.010
FR0-3X	774 ± 17	750.3 ± 1.4	728.4 ± 0.1	3.2613 ± 0.0016	0.708 ± 0.010	2.426 ± 0.004
FR0-5	752 ± 18	764.4 ± 1.4	750.0 ± 0.1	3.1811 ± 0.0016	0.587 ± 0.009	2.063 ± 0.004
FR0-8	780 ± 17	747.4 ± 1.3	729.9 ± 0.1	3.2814 ± 0.0016	0.644 ± 0.009	2.201 ± 0.004
BFS1-73	735 ± 13	736.3 ± 2.2	720.2 ± 0.2	3.3311 ± 0.0023	0.669 ± 0.013	2.447 ± 0.005
TCA 1.83U	771 ± 19	795.4 ± 1.4	787.6 ± 0.1	3.8114 ± 0.0011	0.626 ± 0.005	2.7842 ± 0.0011
IPEN MB-01[4]	750 ± 19	775.7 ± 2.8	767.3 ± 0.2	3.9719 ± 0.0016	0.595 ± 0.006	2.8831 ± 0.0013

[4] MCNP model was taken from LEU-COMP-THERM-067.

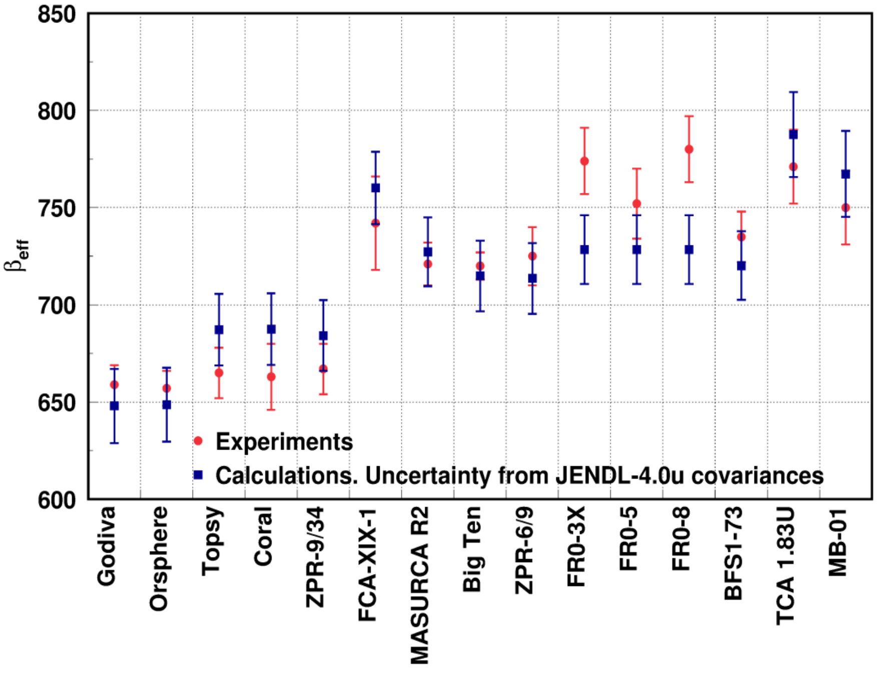

Figure 3. Comparison between calculated and experimental results of β_{eff} for ^{235}U systems. JENDL-4.0u covariance matrices.

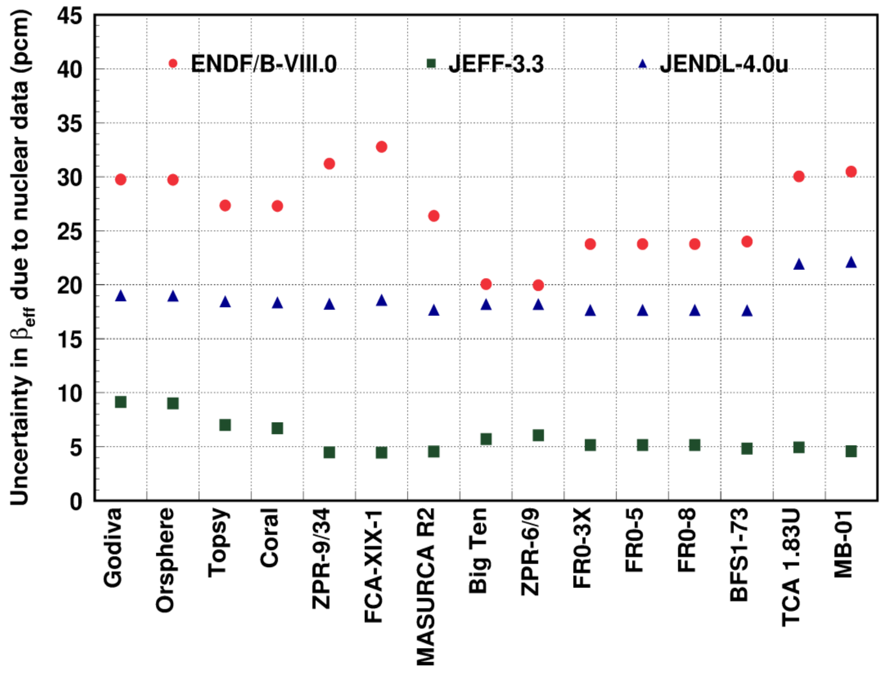

Figure 4. Uncertainty in β_{eff} due to nuclear data for ^{235}U systems with covariance matrices from different libraries.

Table 3. Experimental and calculated values of β_{eff} for plutonium and mixed fuel systems, including uncertainties due to nuclear data.

System	β_{eff} (exp)	β_{eff} (Bretscher)	β_{eff} (Chiba)	Total unc. (%)		
				ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0u
Jezebel	194 ± 10	188.1 ± 1.4	188.5 ± 0.1	0.689 ± 0.022	0.806 ± 0.019	2.4095 ± 0.0021
Popsy	276 ± 7	287.0 ± 2.2	284.1 ± 0.1	0.816 ± 0.024	0.980 ± 0.019	2.739 ± 0.016
ZPR-6/10	221.7 ± 4	234.4 ± 2.8	233.1 ± 0.1	0.64 ± 0.09	0.764 ± 0.006	4.85 ± 0.03
ZPR-3/59	233 ± 10	249.5 ± 2.9	248.6 ± 0.1	0.71 ± 0.04	0.75 ± 0.04	4.179 ± 0.007
ZPR-9/31	381 ± 8	387.9 ± 1.4	375.6 ± 0.1	1.132 ± 0.014	1.30 ± 0.04	2.890 ± 0.019
MASURCA ZONA 2	349 ± 6	352.9 ± 2.8	345.4 ± 0.1	0.995 ± 0.019	1.19 ± 0.03	2.644 ± 0.016
FCA-XIX-2	364 ± 9	362.6 ± 2.3	357.1 ± 0.1	1.078 ± 0.019	1.02 ± 0.04	2.440 ± 0.017
FCA-XIX-3	251 ± 4	256.4 ± 2.8	257.8 ± 0.1	0.692 ± 0.029	0.65 ± 0.05	2.734 ± 0.023
SNEAK-7A	395 ± 16	387.3 ± 2.8	372.4 ± 0.1	0.988 ± 0.016	1.38 ± 0.04	2.911 ± 0.022
SNEAK-7B	429 ± 17	437.9 ± 1.4	417.6 ± 0.1	1.219 ± 0.013	1.25 ± 0.04	2.861 ± 0.023

Table 4. Experimental and calculated values of β_{eff} for ^{233}U systems, including uncertainties due to nuclear data.

System	β_{eff} (exp)	β_{eff} (Bretscher)	β_{eff} (Chiba)	Total unc. (%)		
				ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0u
Skidoo	290 ± 10	287.7 ± 1.4	293.7 ± 0.1	7.427 ± 0.005	9.235 ± 0.005	7.429 ± 0.005
Flattop-23	360 ± 14	376.7 ± 2.2	374.3 ± 0.1	5.336 ± 0.004	6.628 ± 0.004	5.602 ± 0.006

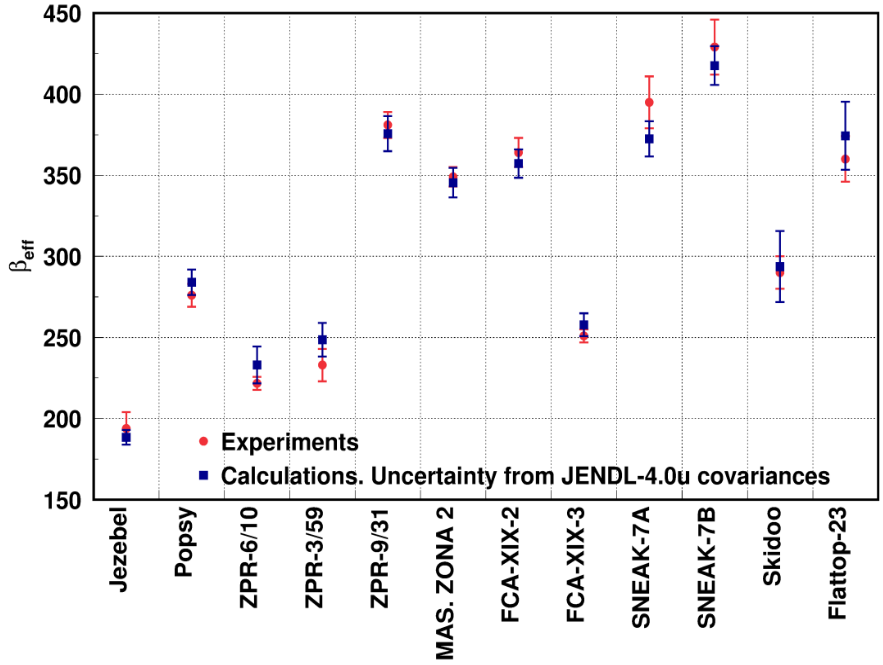

Figure 5. Comparison between calculated and experimental results of β_{eff} for Pu, mixed fuel and ^{233}U systems. JENDL-4.0u covariance matrices.

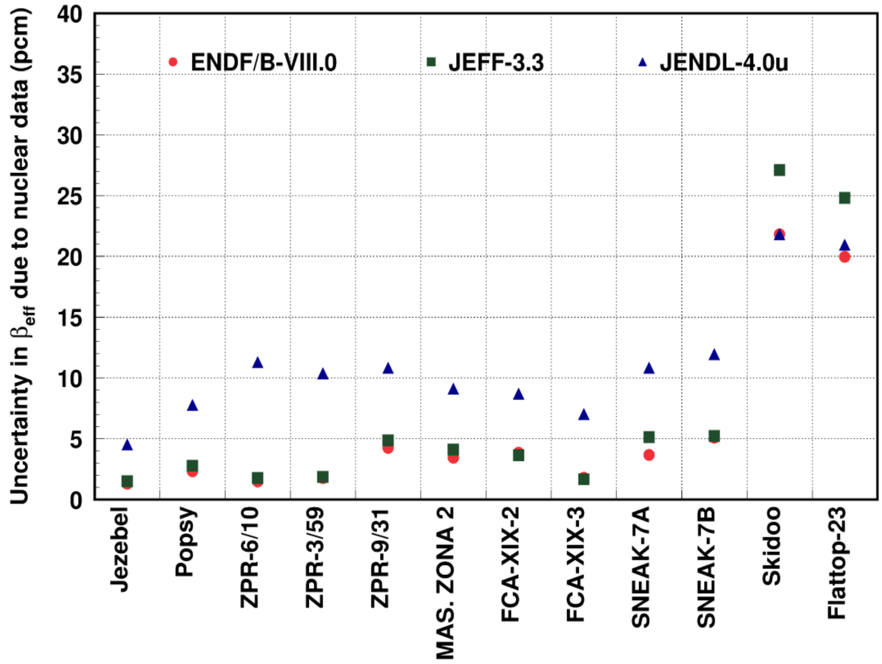

Figure 6. Uncertainty in β_{eff} due to nuclear data for Pu, mixed fuel and ^{233}U systems with covariance matrices from different libraries.

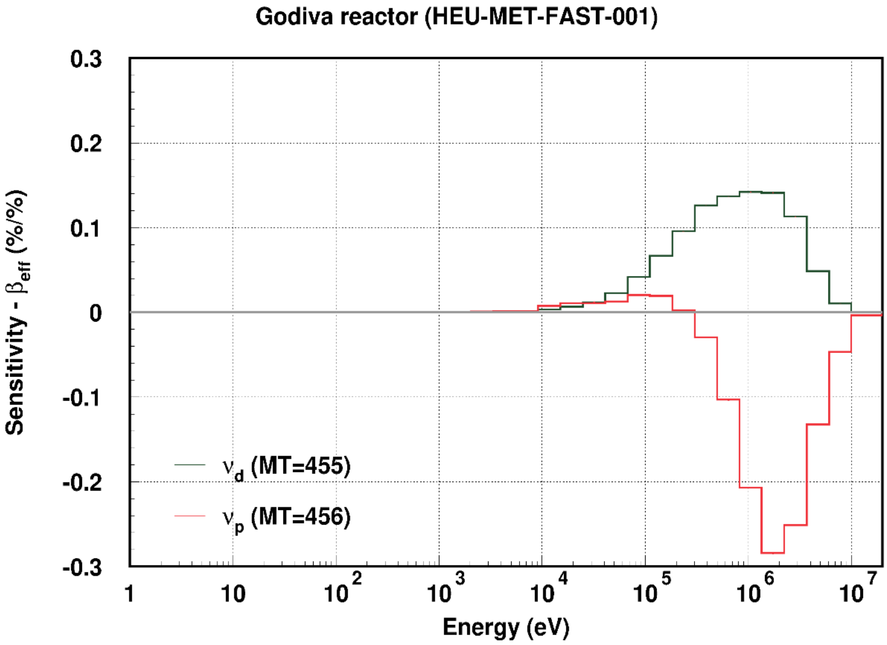

Figure 7. Sensitivity profiles for $\bar{\nu}_d$ and $\bar{\nu}_p$ of ^{235}U for the Godiva reactor.

Table 5. Total uncertainty in β_{eff} due to nuclear data in several benchmark systems obtained in this work and in [Kodeli 2013].

System	This work (JENDL-4.0u)	[Kodeli 2013] (JENDL-4.0m)	[Kodeli 2013] (COMMARA-2)
Topsy	2.691 ± 0.004	2.7	---
Big ten	2.548 ± 0.005	2.5	---
Jezebel	2.4095 ± 0.0021	2.5	---
Popsy	2.739 ± 0.016	2.6	3.4
SNEAK-7A	2.911 ± 0.022	2.7	2.6
SNEAK-7B	2.861 ± 0.023	2.9	3.0
Skidoo	7.414 ± 0.005	7.1	8.9
Flattop-23	5.602 ± 0.006	5.5	6.9

5. EFFECTIVE MEAN NEUTRON GENERATION TIME

As stated above, a total of six benchmark systems with experimental information for Λ_{eff} have been identified. The effective mean neutron generation time has been calculated with the perturbative method described in [Verboomen 2006]. In this method, the system is perturbed by introducing a homogeneous concentration $N(c)$ of a fictitious isotope with a cross section of the shape A/v. From perturbation theory, it can be obtained that the perturbation in the system reactivity is related to Λ_{eff} by the equation:

$$\rho_c - \rho_0 = -N(c) \cdot A \cdot \Lambda_{eff} \Rightarrow \Lambda_{eff} = -\frac{\rho_c - \rho_0}{N(c) \cdot A} \qquad (5.1)$$

where ρ_c and ρ_0 are, respectively, the perturbed and reference (unperturbed) values of the reactivity of the system. The constant A should not be very large, in order to keep the quantities of the fictitious isotope small and hence not having to adjust the composition of the other isotopes in the material. In our calculations we have considered A = 10^{12} barn·cm/s = 10^{-12} cm^3/s. As it was explained before when introducing Chiba's method, the values of the density $N(c)$ should be adjusted so that the value of $\Delta\rho$ is large enough to have small statistical uncertainties in the results while keeping the systematic effects (biases) low. We have found that for fast systems a value of $N(c)$ = 5×10^{17} at/cm^3 is adequate, while for thermal systems this concentration should be reduced to $N(c)$ = 5×10^{15} at/cm^3.

From eq. 5.1, sensitivity profiles for Λ_{eff} can be obtained as:

$$S_{\Lambda_{eff},\alpha_i} = \frac{\alpha}{\Lambda_{eff}}\frac{\partial \Lambda_{eff}}{\partial \alpha} = \frac{\alpha}{\Lambda_{eff}}\frac{\partial}{\partial \alpha}\left(\frac{\rho_0 - \rho_c}{N(c)\cdot A}\right) = \frac{\alpha}{\Lambda_{eff}N(c)A}\frac{\partial}{\partial \alpha}\left(\frac{1}{k_c} - \frac{1}{k_0}\right) = \frac{1}{\Lambda_{eff}N(c)A}\left(\frac{S_{k_0,\alpha}}{k_0} - \frac{S_{k_c,\alpha}}{k_c}\right) \qquad (5.2)$$

The results for Λ_{eff} obtained with eqs. 5.1 and 5.2 are presented in Table 6 and graphically in Figure 8 (calculation vs. experimental values) and Figure 9 (uncertainty with different libraries). Some conclusions can be obtained from them. First of all, it can be observed that the uncertainty in Λ_{eff} is about 2-3% for fast systems while is less than 1% for the sole thermal system analysed. Unlike the case of β_{eff}, uncertainty in nuclear data is not enough to explain in all cases the observed differences between experimental and calculated values, which can amount to ~15% (FR0-5). However, it must be taken into account that Λ_{eff}, unlike β_{eff}, is strongly dependent on the moderation level of the system and can vary over many orders of magnitude between thermal and fast systems. Hence, the reasons of the discrepancies between calculations and experiments is due to uncertainties in the amounts of moderator material in the description of the benchmark models rather than uncertainties in the nuclear data. On the other hand, if a logarithmic scale is used to plot the experimental and calculated values of Λ_{eff} (Figure 8), which seems to be more convenient than a linear one given the huge variation of Λ_{eff}, the agreement between experimental and calculated values appears to be very good.

Concerning the differences between libraries regarding the uncertainty in Λ_{eff} due to nuclear data (Figure 9), it can be observed that they seem to be less relevant than in the case of β_{eff}. To have a better understanding on these effects, it is useful to examine the tables of ISCs provided and the contribution to the uncertainty of individual reactions presented in Annex IV.

First, upon examination of the ICSs, it can be observed that all systems present a large, negative sensitivity to fission related nuclear data ($\bar{\nu}$, $\bar{\nu}_p$, (n,f)) of the most relevant fissioning isotopes. On the other hand, fast and intermediate spectrum systems (but not thermal) show also a relatively large, positive, sensitivity to scattering (elastic and inelastic) of the major isotopes present is the system. This behaviour can be explained by looking at the definition of Λ_{eff}:

$$\Lambda_{eff} = \frac{\langle \psi^{\dagger} | \frac{1}{v} \psi \rangle}{\langle \psi^{\dagger} | \hat{F} \psi \rangle} \qquad (5.3)$$

The presence of the fission operator in the denominator of eq. 5.3 explain the negative sensitivity to fission-related nuclear data, since an increase of the number of fissions in the system will result in a decrease of Λ_{eff}. On the other hand, in the nominator appears the inverse neutron velocity, $1/v$. This explains why an increase of scattering cross sections will lead to an increase of the moderation in the system, hence a decrease of the neutron velocity (i.e. its energy) and an increase in Λ_{eff}. The only thermal system (MB-01) analysed does not show this sensitivity to scattering reactions, however. This can be explained by the system being already thermalized that an increase in the scattering cross section will not lead to a significant increase of the thermal flux.

Finally, by looking at the major contributors to the uncertainty listed in Annex IV, it can be observed that the reactions with the largest ISCs (fission and scattering related) are also the largest contributors to the uncertainty in the nuclear data. There is, however, considerable variation between libraries in the individual contributions to the uncertainty, even if the total uncertainty does not change Λ_{eff} so much between libraries. As a final comment, it is worth remarking that sensitivity coefficients of scattering reactions are calculated with large statistical uncertainties, which in turn results in large values of the statistical uncertainties (up to ~20%) of the uncertainty due to nuclear data in Λ_{eff}.

Table 6. Experimental and calculated values of Λ_{eff}.

System	Λ_{eff}, exp (s)	Λ_{eff}, calc (s)	N(c) (cm^{-3})	Total unc. (%) ENDF/B-VIII.0	JEFF-3.3	JENDL-4.0u
Orsphere	5.94 (± 0.08) × 10^{-9}	5.909 (± 0.0028) × 10^{-9}	5×10^{17}	1.92 ± 0.11	2.3 ± 0.4	3.0 ± 0.3
Topsy	1.74 (± 0.03) × 10^{-8}	1.7247 (± 0.0028) × 10^{-8}	5×10^{17}	2.41 ± 0.10	2.40 ± 0.13	2.72 ± 0.14
Popsy	1.21 (± 0.03) × 10^{-8}	1.3058 (± 0.0028) × 10^{-8}	5×10^{17}	2.62 ± 0.15	2.65 ± 0.16	2.95 ± 0.17
Flattop-23	1.33 (± 0.05) × 10^{-8}	1.24 (± 0.06) × 10^{-8}	5×10^{17}	2.64 ± 0.11	2.48 ± 0.014	3.28 ± 0.16
FR0-5	2.84 (± 0.03) × 10^{-7}	2.455 (± 0.003) × 10^{-7}	5×10^{16}	1.48 ± 0.03	2.47 ± 0.10	1.63 ± 0.13
IPEN MB-01	3.196 (± 0.106) × 10^{-5}	2.9712 (± 0.0007) × 10^{-5}	5×10^{15}	0.9896 ± 0.0017	0.919 ± 0.004	0.654 ± 0.004

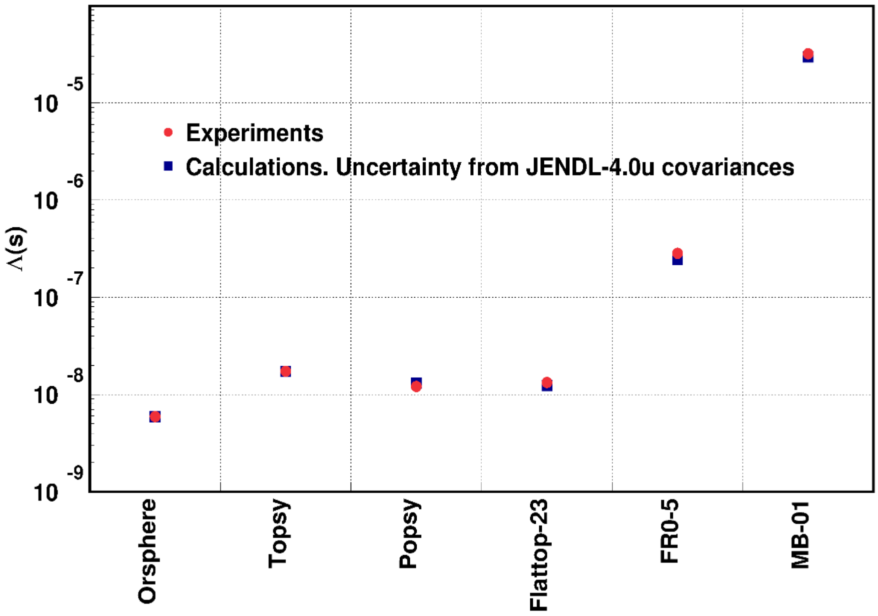

Figure 8. Comparison between calculated and experimental results of Λ_{eff}. JENDL-4.0u covariance matrices.

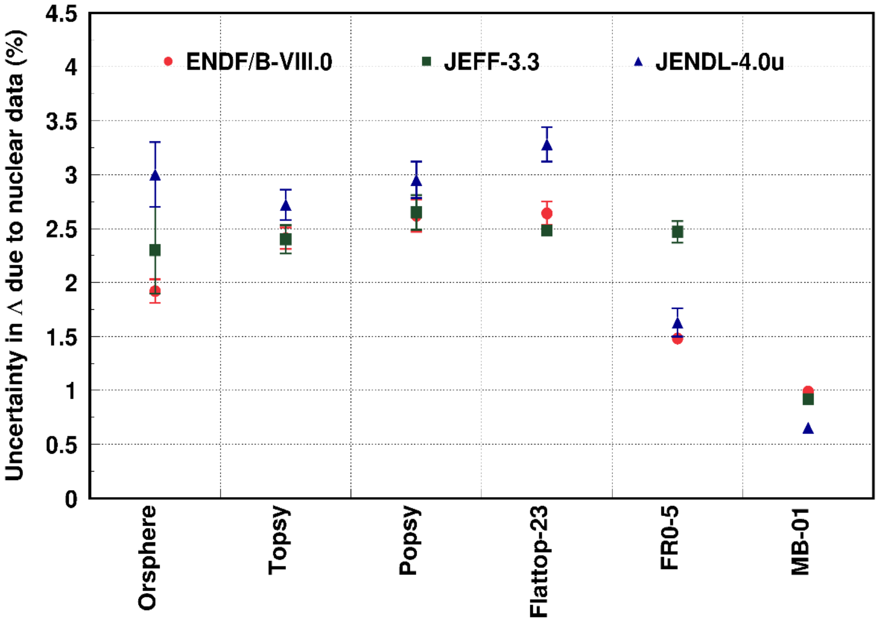

Figure 9. Uncertainty in Λ_{eff} due to nuclear data with covariance matrices from different libraries.

6. CONCLUSIONS

In order to answer to the requirements of SANDA Task 4.4, we have carried out a search of available databases (ICSBEP, IRPhE) and the scientific literature for reactor benchmark experiments that include experimental information about the kinetic parameters. A total of 27 systems have been found containing experimental information for the effective delayed neutron fraction (β_{eff}), 6 for the effective mean neutron generation time (Λ_{eff}), and also 24 for the prompt neutron decay constant (α) not used in this work. Furthermore, sensitivity and uncertainty analyses have been carried with the SUMMON code (using sensitivity profiles calculated with the MCNP KSEN card and the JEFF-3.3 library) in order to assess the level of sensitivity to nuclear data of these parameters. Covariance matrices from the ENDF/B-VIII.0, JEFF-3.3 and JENDL-4.0u have been considered for the uncertainty analyses.

For the case of β_{eff}, a high positive sensitivity to the average number of delayed neutrons per fission ($\bar{\nu}_d$) of the major fissioning isotopes of the specific systems has been found, as well a similarly high, but negative, sensitivity average number of prompt neutrons per fission ($\bar{\nu}_p$). For its part, Λ_{eff} shows a strong negative sensitivity to fission-related nuclear data of the most relevant fissioning isotopes of the specific system, mainly the fission cross section and average total and prompt number of neutrons per fission ($\bar{\nu}$ and $\bar{\nu}_p$). For fast and intermediate spectrum systems, but not for thermal systems, there is also a positive sensitivity to scattering cross sections (both elastic and inelastic).

Concerning uncertainty values, the results largely depend on the covariance matrix set chosen, especially for β_{eff}, where it strongly depends on the inclusion of covariance data for $\bar{\nu}_d$ in the library, being JENDL-4.0u the most complete library in this aspect. Overall, we can assess the uncertainty due to nuclear data in β_{eff} to lay in the range 2.5 to 4%, reaching up to ~9% in some ^{233}U systems. In the case of Λ_{eff}, the uncertainty due to nuclear data was smaller, in the range of 2-3% for fast and intermediate spectrum systems and ~1% for thermal systems. The reactions with the largest sensitivities (fission and scattering related) are the largest contributors, but with significant variations between libraries.

ACKNOWLEDGEMENTS

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REFERENCES

[Bretscher 1997] M. M. Bretscher, *Evaluation of reactor kinetic parameters without the need for perturbation codes*. International Meeting on Reduced Enrichment for Research and Test Reactors, Jackson Hole, Wyoming, USA, 5-10 October 1997.

[Brown 2018] D. A. Brown *et al.*, *ENDF/B-VIII.0: The 8th Major Release of the Nuclear Reaction Data Library with CIELO-project Cross Sections, New Standards and Thermal Scattering Data*, Nuclear Data Sheets 148 (2018) 1-142.

[Cacuci 2003] D. G. Cacuci, *Sensitivity and uncertainty analysis*. Chapman & Hall, 2003.

[Chiba 2009] G. Chiba, *Calculation of Effective Delayed Neutron Fraction Using a Modified k-Ratio Method*. Journal of Nuclear Science and Technology 46 (2009) 399-402.

[Doliguez 2015] X. Doliguez *et al.*, *Effective delayed neutron fraction measurement in the critical VENUS-F reactor using noise techniques*. In ANIMMA 2015, Lisbon (Portugal) 20-24 April 2015.

[Geslot 2015] B. Geslot *et al.*, *Kinetic parameters of the GUINEVERE reference configuration in VENUS-F reactor obtained from a pile noise experiment using Rossi and Feynman methods*. In ANIMMA 2015, Lisbon (Portugal) 20-24 April 2015.

[Iwamoto 2018] H. Iwamoto *et al.*, *Monte Carlo uncertainty quantification of the effective delayed neutron fraction*. Journal on Nuclear Science and Technology 55 (2018) 539-547.

[Kodeli 2013] I. Kodeli, *Sensitivity and uncertainty in the effective delayed neutron fraction (β_{eff})*. Nuclear Instruments and Methods in Physics Research A 715 (2013) 70–78.

[Mellier 2005] F. Mellier *et al.*, *The MUSE experiments for sub critical neutronics validation*. EU FP5 MUSE project (contract no. FIKW-CT-2000-00063) deliverable no. 8 (final report), June 2005.

[NEA 2020a] ICSBEP Handbook 2020, *International Criticality Safety Benchmark Evaluation Project Handbook (database)*. DOI: 10.1787/7e0ebc50-en (accessed on 05 September 2022).

[NEA 2020b] IRPhE Handbook 2020, *International Reactor Physics Evaluation Project Handbook* (database). DOI: 10.1787/d863e360-en (accessed on 05 September 2022).

[NJOY 21] NJOY21—NJOY for the 21st Century. https://www.njoy21.io. (accessed on 28 September 2022).

[Okajima 2002] S. Okajima *et al.*, *Summary on International Benchmark Experiments for Effective Delayed Neutron Fraction (β_{eff})*, Progress in Nuclear Energy 41 (2002) 285-301.

[Panizo 2021] S. Panizo *et al.*, *Neutron noise measurements in the VENUS-F LBE fast reactor within WP5 of the MYRTE Project (H2020)*. CIEMAT report DFN/IN-04/II-21, September 2021.

[Palmiotti 2010] G. Palmiotti *et al.*, *Nuclear Data Target Accuracies for Generation-IV Systems Based on the Use of New Covariance Data*. International Conference on Nuclear Data for Science and Technology 2010, Jeju Island (Korea) 26 - 30 April 2010.

[Plompen 2020] A. J. M. Plompen *et al.*, *The joint evaluated fission and fusion nuclear data library, JEFF-3.3*. European Physical Journal A 56 (2020) 181. DOI: 10.1140/epja/s10050-020-00141-9.

[Rearden 2018] B. T. Rearden and M. A. Jessee (Eds.), *SCALE Code System Version 6.2.3*, section 6.3A. ORNL report TM-20005/39, March 2018.

[Romojaro 2017] P. Romojaro *et al.*, *SUMMON: A Sensitivity And Uncertainty Methodology For MONte Carlo Codes*. Proceedings of International Conference on Mathematics & Computational Methods Applied to Nuclear Science & Engineering (M&C 2017), Jeju (Korea) 16-20 April 2017.

[Romojaro 2019a] P. Romojaro *et al.*, *Sensitivity methods for effective delayed neutron fraction and neutron generation time with summon*, Annals of Nuclear Energy 126 (2019) 410–418.

[Romojaro 2019b] P. Romojaro, *Nuclear data analyses for improving the safety of advanced lead-cooled reactors*, PhD Thesis, Universidad Politécnica de Madrid (2019).

[Shibata 2011] K. Shibata *et al.*, *JENDL-4.0: A New Library for Nuclear Science and Engineering*. Journal of Nuclear Science and Technology 48 (2011) 1-30.

[Verboomen 2006] B. Verboomen *et al.*, *Monte Carlo calculation of the effective neutron generation time*. Annals of Nuclear Energy 33 (2006) 911-916.

[Werner 2017] C. J. Werner (ed.) et al., *MCNP User’s Manual. Code version 6.2*. Los Alamos National Laboratory report LA-UR-17-29981 (2017).

ANNEXES

Annex I. List of benchmark experiments with experimental kinetic parameter information

Annex II. Integrated sensitivity coefficients and uncertainty due to nuclear data in β_{eff}

Annex III. Sensitivity coefficients for β_{eff}. MCNP vs. SUS-3D

Annex IV. Integrated sensitivity coefficients and uncertainty due to nuclear data in Λ_{eff}

Annex V. Covariance data of $\bar{\nu}_d$ for the most relevant isotopes

ANNEX I

List of benchmark experiments with experimental kinetic parameter information

Contents

Table 1. Summary of ^{235}U benchmark systems with kinetic information.

System	ICSBEP/IRPhE name	β_{eff} (pcm)	Λ (s)	α (s^{-1})	References
Godiva LANL 1950s 94% U_{MET} sphere No reflector	HEU-MET-FAST-001	659 ± 10	---	---	[Meulekamp 2006] [Leppänen 2014]
Orsphere ORNL 1970s 93% U_{MET} sphere No reflector	HEU-MET-FAST-100 ORSPHERE-FUND-EXP-001	657 ± 9[1]	5.94 ± 0.08 × 10^{-9}	-1.1061 (±0.0009) × 10^{6}	ICSBEP, p. 32 IRPhE, p. 28-33
Tospsy LANL 1964-66 93% U_{MET} sphere Natural U_{MET} reflector	HEU-MET-FAST-028	665 ± 13	---	---	[Meulekamp 2006] [Leppänen 2014]
Coral CIEMAT 1973 90% U_{MET} cylinder Natural U_{MET} reflector	HEU-MET-FAST-062	663 ± 17	---	---	[De Francisco 1973]
ZPR-9/34 (ZPR-HEU) ANL 1979 93% ^{235}U fuel. Reflected by SS	HEU-MET-INTER-001	667 ± 2%	---	---	[ANL-81-72] p. 7 [Leppänen 2014]
ZPR-3/23 ANL 1959 93% U_{MET}/Al fuel Reflected by DU	HEU-MET-FAST-055	---	---	-5.63 (± 2%) × 10^{4}	[ANL 6681] p.14
ZPR-9/4 ANL 1964 93% U_{MET} + W core Al reflector	HEU-MET-FAST-060	---	---	-5.19 (± 5%) × 10^{4}	[ANL 7007] p.34
ZPR-9/6 ANL 1959 93% U_{MET}/Al fuel Reflected by DU	HEU-MET-FAST-067	---	---	-4.67 (± 0.31) × 10^{4}	[ANL 7208] p. 99
ZPR-9/7 ANL 1959 93% U_{MET}/Al fuel Reflected by DU	HEU-MET-FAST-070	---	---	-1.51 (± 0.95) × 10^{3}	[ANL 7208] p. 99

[1] β_{eff} = 657 ± 2 pcm is reported in IRPhE and 657 ± 9 in ICSBEP. A lower value of β_{eff} = 602 ± 8 pcm is reported in [Mihalczo 1976], but it is considered wrong in IRPHE's documentation.

Table 2. Summary of ^{235}U benchmark systems with kinetic information (cont.).

System	ICSBEP/IRPhE name	β_{eff} (pcm)	Λ (s)	α (s^{-1})	References
ZPR-9/8 ANL 1959 93% U_{MET}/W/Al/Al_2O_3 core Al/Al_2O_3/Be/BeO reflector	HEU-MET-FAST-070	---	---	-1.27 (± 0.27) × 10^3	[ANL 7208] p. 99
FCA-XIX-1 JAEA 1996-98 94% ^{235}U /C core (depl.) UO_2/Na reflector	---	742 ± 24	---	---	[Okajima 2002] [Leppänen 2014]
MASURCA R2 CEA 1993-94 75% ^{235}U fuel (depl.) UO_2/Na reflector	---	721 ± 11	---	---	[Okajima 2002] [Leppänen 2014]
Big Ten LANL 1971 10% ^{235}U fuel (depl.) U reflector	IEU-MET-FAST-007	720 ± 7	---	---	[Meulekamp 2006] [Leppänen 2014]
ZPR-6/9 (ZPR-U9) ANL 1980-81 9% ^{235}U fuel DU reflector	IEU-MET-FAST-010	725 ± 2%	---	---	[ANL-81-72] p. 7 [Leppänen 2014]
ZPR-3/41 ANL 1962 16% U_{MET}/Al/SS core DU reflector	IEU-MET-FAST-012	---	---	-5.55 (± 3%) × 10^4	[ANL 6681] p.14
ZPR-9/1 ANL 1964 ~11% U_{MET} core Al reflector	IEU-MET-FAST-013	---	---	-8.67 (± 5%) × 10^4	[ANL 7007] p.34
ZPR-9/2 ANL 1964 ~16% U_{MET} + W core Al reflector	IEU-MET-FAST-014	---	---	-6.9 (± 5%) × 10^4	[ANL 7007] p.34
ZPR-9/3 ANL 1964 ~21% U_{MET} + W core Al reflector	IEU-MET-FAST-014	---	---	-6.57 (± 5%) × 10^4	[ANL 7007] p.34
ZPR-3/6F ANL 1957 47% U/Al/SS core DU reflector	IEU-MET-FAST-015	---	---	-9.4 (± 3%) × 10^4	[ANL 6681] p.14

Table 3. Summary of 235U benchmark systems with kinetic information (cont.).

System	ICSBEP/IRPhE name	β_{eff} (pcm)	Λ (s)	α (s^{-1})	References
ZPR-3/11 ANL 1958 ~12% U core DU reflector	IEU-MET-FAST-016	---	---	-10.3 (± 3%) $\times 10^4$	[ANL 6681] p.14
ZPR-6/6A ANL 1969-70 DU/Na/FeO/depl. U_3O_8 /93% $^{235}U_{MET}$ core DU reflector	IEU-COMP-FAST-001	---	---	-10.0 (± 5%) $\times 10^4$	[ANL 7007] p. 34
FR0-3X Studsvik 1964-71 20% U_{MET}/C core Copper reflector	IEU-MET-FAST-022	719[2] ± 16 774 ± 17	---	---	ICSBEP, p. 57 [Kockum 1970] Table 2, p. 13 [Moberg 1972] Table 7, p. 17 [Moberg 1973] Table II, p. 348
FR0-5 Studsvik 1964-71 20% U_{MET}/CH_2/C/Al core Copper reflector	IEU-MET-FAST-022	735[3] ± 18 752 ± 18	2.84[4] ± 0.03 $\times 10^{-7}$	---	
FR0-8 Studsvik 1964-71 20% U_{MET}/CH_2/C core Copper reflector	IEU-MET-FAST-022	735[5] ± 16 780 ± 17	---	---	
BFS1-73 IPPE (Russia) 1997 18.5% U_{MET}/Na core Depl. UO_2 reflector	BFS1-LMFR-EXP-001	720[6] ± 27 740 ± 15	---	---	IRPhE, p. 40
TCA 1.83U[7] JAEA (Japan) 1964 2.6% UO_2 fuel rods Water moderator	LEU-COMP-THERM-006	771 ± 19	---	---	[Nakajima 2001] [Meulekamp 2006] [Leppänen 2014]
MB-01 IPEN 2014-16 4.35% UO_2 fuel rods Water moderator	LEU-COMP-THERM-077 IPEN(MB01)-LWR-RESR-001	750 ± 19	31.96 ± 1.06 $\times 10^{-6}$	---	IRPhE, p. 228-229

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[2] Upper value from [Moberg 1972] and lower value from [Moberg 1973].
[3] Upper value from [Moberg 1972] and lower value from [Moberg 1973].
[4] Taken from [Kockum 1970] table 2, p. 13. Measured in a slightly subcritical configuration. Rossi-α values also listed, but all correspond to subcritical configurations.
[5] Upper value from [Moberg 1972] and lower value from [Moberg 1973].
[6] Upper value was measured with the ^{252}Cf source technique and lower value was measured with the Rossi-α technique. A weighted average value of 735 ± 13 is recommended.
[7] β_{eff} measurement described in [Nakajima 2001] was performed in a variant of the 1.83U lattice described in the benchmark (cases 4 to 8) with a cylindrical instead of square arrangement of fuel rods.

Table 4. Summary of ^{235}U benchmark systems with kinetic information (cont.).

System	ICSBEP/IRPhE name	β_{eff} (pcm)	Λ (s)	α (s^{-1})	References
Winco Slab Tanks[8] LANL 1989 93.1% uranyl nitrate sol. No reflector	HEU-SOL-THERM-038	1500[9] ± 12% 1450 ± 13%	---	-1109.3 ± 0.3% -1152.7 ± 1.2%	[Spriggs 1993] [Meulekamp 2006] [Leppänen 2014]
Stacy run 29 JAEA 1995 10% uranyl nitrate sol. Water reflector	LEU-SOL-THERM-004	---	---	-122.7 ± 4.1	[Tonoike 2002] [Meulekamp 2006] [Leppänen 2014]
Stacy run 30 JAEA 1995 10% uranyl nitrate sol. Water reflector	LEU-SOL-THERM-004	---	---	-126.8 ± 2.9	[Tonoike 2002] [Meulekamp 2006] [Leppänen 2014]
Stacy run 33 JAEA 1995 10% uranyl nitrate sol. Water reflector	LEU-SOL-THERM-004	---	---	-116.7 ± 3.9	[Tonoike 2002] [Meulekamp 2006] [Leppänen 2014]
Stacy run 46 JAEA 1995 10% uranyl nitrate sol. Water reflector	LEU-SOL-THERM-004	---	---	-106.2 ± 3.7	[Tonoike 2002] [Meulekamp 2006] [Leppänen 2014]
Stacy run 125 JAEA 1997 10% uranyl nitrate sol. Water reflector	LEU-SOL-THERM-016	---	---	-152.8 ± 2.6	[Tonoike 2002] [Meulekamp 2006] [Leppänen 2014]
Stacy run 215 JAEA 1998 10% uranyl nitrate sol. No reflector	LEU-SOL-THERM-021	---	---	-109.2 ± 1.8	[Tonoike 2002] [Meulekamp 2006] [Leppänen 2014]

[8] In [Meulekamp 2006] it is stated that the measurements correspond to Case 5 in the benchmark, we consider it to correspond more likely to Case 1 (no absorber/reflector). Nevertheless, in [Spriggs 1993] it is stated that the critical separation between uranyl tanks was ~9.9 cm, while in the benchmark's documentation it is listed as 9.38cm for Case 1 and 9.27cm for Case 5.
[9] Upper values for β_{eff} and α were obtained with a single ^{3}He detector and lower values were obtained with a combination of four ^{3}He detectors in the assembly midplane. Experimental values for β_{eff} seem too large; in [Spriggs 1993] inaccuracies in "*the measurement of the intrinsic source strength of the fuel*" are given as a possible explanation.

Table 5. Summary of Pu and mixed fuel benchmark systems with kinetic information.

System	ICSBEP/IRPhE name	β_{eff} (pcm)	Λ (s)	α (s^{-1})	References
Jezebel LANL 1950s Pu sphere No reflector	PU-MET-FAST-001	194 ± 10	---	---	[Meulekamp 2006] [Leppänen 2014]
Popsy LANL 1960s Pu sphere Natural U_{MET} reflector	PU-MET-FAST-006	276 ± 7	1.21 ± 0.03 $\times 10^{-8}$	-22.9 $\times 10^{4}$	[ANL 6681] p.14 [Meulekamp 2006] [Leppänen 2014]
ZPR-6/10 (ZPR-Pu) ANL 1981-82 Pu/C/SS core SS/Fe reflector	PU-MET-INTER-002	221.7 ± 2%	---	---	[ANL-81-72] p. 7
ZPR-3/59 ANL 1969 Pu/C core Pb reflector	PU-MET-INTER-004	233 ± 10	---	---	[Carpenter 1972]
ZPR-9/31 (ZPR-MOX) ANL 1976-77 (Pu, U)C core Depl. UC reflector	MIX-COMP-FAST-005	381 ± 2%	---	---	[ANL-81-72] p. 7 [Leppänen 2014]
SNEAK-7A KIT 1970-71 MOX fuel Graphite reflector	SNEAK-LMFR-EXP-001	395 ± 4%	---	---	IRPhE p. 36 [Fischer 1977] [Leppänen 2014]
SNEAK-7B KIT 1970-71 MOX fuel Natural UO_2 reflector	SNEAK-LMFR-EXP-001	429 ± 4%	---	---	IRPhE p. 36 [Fischer 1977] [Leppänen 2014]
MASURCA Zona2 CEA 1993 MOX/Na core (depl.) UO_2/Na reflector	---	349 ± 6	---	---	[Okajima 2002] [Leppänen 2014]
FCA XIX-2 JAEA 1996/98 Pu/NU/Na core (depl.) UO_2/Na reflector	---	364 ± 9	---	---	[Sakurai 1999] [Okajima 2002] [Leppänen 2014]
FCA XIX-3 JAEA 1996/98 Pu core (depl.) UO_2/Na reflector	---	251 ± 4	---	---	[Sakurai 1999] [Okajima 2002] [Leppänen 2014]

Table 6. Summary of ^{233}U benchmark systems with kinetic information.

System	ICSBEP/IRPhE name	β_{eff} (pcm)	Λ (s)	α (s^{-1})	References
Skidoo LANL 1961 ^{233}U sphere No reflector	U233-MET-FAST-001	290 ± 10	---	---	[Meulekamp 2006] [Leppänen 2014]
Flattop 23 LANL 1964 ^{233}U sphere Natural U_{MET} reflector	U233-MET-FAST-006	360 ± 14[10]	1.33 ± 0.05 × 10^{-8}	-2.71 ± 0.03 × 10^{5}	ICSBEP p. 6 [Meulekamp 2006] [Leppänen 2014] [ANL 6681] p.14

[10] In [Meulekamp 2006] and [Leppänen 2014], an uncertainty is listed as ±9.

REFERENCES

[ANL 6681] G. S. Brunson *et al.*, *A survey of prompt-neutron lifetimes in fast critical systems*. ANL-6681 (1963).

[ANL 7007] R. C. Doerner *et al.*, *Physics measurements in tungsten-based aluminium-reflected fast reactors*. ANL-7007 (1967).

[ANL 7208] R. C. Doerner *et al.*, *ZPR-9 assemblies no. 6-9 critical experiments*. ANL-7208 (1967).

[ANL-81-72] E. F. Bennett, *An experimental method for reactor-noise measurements of effective beta*. ANL-81-72 (1981).

[Carpenter 1972] S. G. Carpenter *et al.*, *Measurements of the Effective Delayed-Neutron Fraction in Two Fast Critical Experiments*. Nuclear Science and Engineering 49 (1972) 236-239.

[De Francisco 1973] J. L. de Francisco *et al.*, *Determinación de la fracción efectiva de neutrones retardados en el Reactor CORAL-I*, J.E.N report No. 275.

[Fischer 1977] E. A. Fischer, *Integral Measurements of the Effective Delayed Neutron Fractions in the Fast Critical Assembly SNEAK*, Nuclear Science and Engineering 62 (1977) 105-106.

[Kockum 1970] J. Kockum, *Analysis of Pulsed Source Experiments Performed in Cooper-Reflected Fast Assemblies*. Atomenergi report AE-399, 1970.

[Leppänen 2014] J. Leppänen et al., *Calculation of effective point kinetics parameters in the Serpent 2 Monte Carlo code*. Annals of Nuclear Energy 65 (2014) 272-279.

[Meulekamp 2006] R. K. Meulekamp and S. C. van der Marck, *Calculating the Effective Delayed Neutron Fraction with Monte Carlo*. Nuclear Science and Enginnering 152 (2006) 142-148.

[Mihalczo 1976] J. T. Mihalczo, *The Effective Delayed Neutron Fraction from Fission in an Unreflected Uranium Sphere from Time Correlation Measurements with Californium-252*. Nuclear Science and Engineering 60 (1976) 262-275.

[Moberg 1972] L. Moberg and J. Kockum, *Measurement of the Effective Delayed Neutron Fraction in Three Different FR0-cores*. Atomenergi report AE-456, 1972.

[Moberg 1973] L. Moberg and J. Kockum, *Measurement of the Effective Delayed Neutron Fraction in Three Different Cores of the Fast Assembly FR0*. Nuclear Science and Engineering 52 (1973) 343-349.

[Nakajima 2001] K. Nakajima, *Re-evaluation of the Effective Delayed Neutron Fraction Measured by the Substitution Technique for a Light Water Moderated Low-enriched Uranium Core*, Journal of Nuclear Science and Technology 38 (2001) 1120-1125.

[Okajima 2002] S. Okajima *et al.*, *Summary on international benchmark experiments for effective delayed neutron fraction* (β_{eff}). Progress in Nuclear Energy 41 (2002) 285-301.

[Sakurai 1999] T. Sakurai *et al.*, *Experimental Cores for Benchmark Experiments of Effective Delayed Neutron Fraction (*β_{eff}*) at FCA*. Progress in Nuclear Energy 35 (1999) 131-156.

[Spriggs 1993] G. D. Spriggs, *A Measurement of the Effective Delayed Neutron Fraction of the Westinghouse Idaho Nuclear Company Slab Tank Assembly Using Rossi-α Techniques*. Nuclear Science and Engineering 115 (1993) 76-80.

[Tonoike 2002] K. Tonoike *et al.*, *Kinetic Parameter* β_{eff}/l *Measurement on Low Enriched Uranyl Nitrate Solution with Single Unit Cores (600φ, 280T, 800φ) of STACY*. Journal of Nuclear Science and Technology 39 (2002) 1227-1236.

NOTE: the page number mentioned when ICSBEP and IRPhE are given as references refers to the page of the specific benchmark documentation. The references to ICSBEP and IRPhE databases are:

[NEA 2020] *ICSBEP Handbook 2020*, International Criticality Safety Benchmark Evaluation Project Handbook (database), DOI: 10.1787/7e0ebc50-en (accessed on 05 September 2022).

[NEA 2020] *IRPhe Handbook 2020*, International Reactor Physics Evaluation Project Handbook (database), DOI: 10.1787/d863e360-en (accessed on 05 September 2022).

ANNEX II

Integrated sensitivity coefficients and uncertainty due to nuclear data in β_{eff}

Contents

1. INTEGRATED SENSITIVITY COEFFICIENTS (ISC) FOR β_{EFF}

1.1. ^{235}U SYSTEMS

Godiva (HEU-MET-FAST-001)

Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.9698 ± 0.0016
^{235}U, (n,n)	0.050 ± 0.014
^{238}U, $\bar{\nu}_d$	0.02035 ± 0.00003
^{238}U, (n,f)	0.00682 ± 0.00011
^{234}U, $\bar{\nu}_d$	0.004650 ± 0.000007
	…
^{234}U, $\bar{\nu}_p$	-0.01254 ± 0.00007
^{238}U, $\bar{\nu}_p$	-0.01624 ± 0.00008
^{235}U, (n,γ)	-0.0458 ± 0.0009
^{235}U, (n,f)	-0.054 ± 0.012
^{235}U, $\bar{\nu}_p$	-0.966 ± 0.010

Orsphere (HEU-MET-FAST-100)

Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.9676 ± 0.0015
^{235}U, (n,n)	0.052 ± 0.011
^{238}U, $\bar{\nu}_d$	0.02303 ± 0.00003
^{238}U, (n,f)	0.00464 ± 0.00010
^{238}U, $\bar{\nu}$	0.00463 ± 0.00009
	…
^{234}U, $\bar{\nu}_p$	-0.01214 ± 0.00005
^{238}U, $\bar{\nu}_p$	-0.01839 ± 0.00007
^{235}U, (n,γ)	-0.0454 ± 0.0008
^{235}U, (n,f)	-0.053 ± 0.010
^{235}U, $\bar{\nu}_p$	-0.965 ± 0.008

Topsy (HEU-MET-FAST-028)

Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.8405 ± 0.0015
^{238}U, $\bar{\nu}_d$	0.1392 ± 0.0004
^{238}U, (n,n)	0.043 ± 0.013
^{238}U, (n,f)	0.0231 ± 0.0014
^{235}U, (n,n)	0.012 ± 0.011
	…
^{235}U, (n,γ)	-0.0390 ± 0.0008
^{235}U, (n,f)	-0.053 ± 0.009
^{238}U, (n,n')	-0.057 ± 0.005
^{238}U, $\bar{\nu}_p$	-0.1327 ± 0.0012
^{235}U, $\bar{\nu}_p$	-0.841 ± 0.008

Coral (HEU-MET-FAST-062)

Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.8387 ± 0.0019
^{238}U, $\bar{\nu}_d$	0.1425 ± 0.0005
^{238}U, (n,n)	0.050 ± 0.025
^{238}U, (n,f)	0.0263 ± 0.0023
^{235}U, (n,n)	0.009 ± 0.019
	…
^{235}U, (n,γ)	-0.0387 ± 0.0013
^{238}U, (n,n')	-0.044 ± 0.009
^{238}U, (n,f)	-0.056 ± 0.015
^{238}U, $\bar{\nu}_p$	-0.135 ± 0.002
^{235}U, $\bar{\nu}_p$	-0.842 ± 0.013

ZPR-9/34 (HEU-MET-INTER-001)

Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.988 ± 0.003
^{54}Fe, (n,n)	0.01 ± 0.04
^{53}Cr, (n,n)	0.009 ± 0.018
^{235}U, (n,n)	0.006 ± 0.025
^{57}Fe, (n,n)	0.006 ± 0.023
	…
^{50}Cr, (n,n)	-0.009 ± 0.010
^{235}U, (n,f)	-0.015 ± 0.021
^{235}U, (n,γ)	-0.0191 ± 0.0019
^{56}Fe, (n,n)	-0.03 ± 0.13
^{235}U, $\bar{\nu}_p$	-0.986 ± 0.019

FCA-XIX-1

Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.942 ± 0.003
^{238}U, $\bar{\nu}_d$	0.0429 ± 0.0003
^{238}U, (n,γ)	0.0084 ± 0.0019
^{238}U, (n,n)	0.006 ± 0.026
^{238}U, (n,f)	0.0054 ± 0.0013
	…
^{235}U, (n,γ)	-0.0327 ± 0.0022
^{235}U, (n,f)	-0.038 ± 0.021
^{238}U, $\bar{\nu}_p$	-0.0444 ± 0.0012
^{0}C, (n,n)	-0.05 ± 0.09
^{235}U, $\bar{\nu}_p$	-0.94 ± 0.02

MASURCA R2	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.765 ± 0.002
^{238}U, $\bar{\nu}_d$	0.2091 ± 0.0005
^{238}U, (n,f)	0.0444 ± 0.0022
^{56}Fe, (n,n)	0.01 ± 0.03
^{238}U, $\bar{\nu}$	0.0097 ± 0.0021
	...
^{235}U, (n,γ)	-0.0245 ± 0.0014
^{238}U, (n,n')	-0.025 ± 0.010
^{235}U, (n,f)	-0.033 ± 0.016
^{238}U, $\bar{\nu}_p$	-0.1994 ± 0.0018
^{235}U, $\bar{\nu}_p$	-0.774 ± 0.014

Big Ten (IEU-MET-FAST-007)	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.5678 ± 0.0011
^{238}U, $\bar{\nu}_d$	0.3907 ± 0.0007
^{238}U, (n,f)	0.043 ± 0.003
^{235}U, $\bar{\nu}$	0.038 ± 0.008
^{235}U, (n,f)	0.017 ± 0.009
	...
^{238}U, $\bar{\nu}$	-0.0356 ± 0.0029
^{238}U, (n,n')	-0.040 ± 0.013
^{238}U, (n,γ)	-0.0432 ± 0.0025
^{238}U, $\bar{\nu}_p$	-0.4263 ± 0.0026
^{235}U, $\bar{\nu}_p$	-0.530 ± 0.008

ZPR-6/9 (IEU-MET-FAST-010)	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.5627 ± 0.0019
^{238}U, $\bar{\nu}_d$	0.3960 ± 0.0011
^{238}U, (n,f)	0.043 ± 0.005
^{235}U, $\bar{\nu}$	0.038 ± 0.015
^{235}U, (n,f)	0.022 ± 0.016
	...
^{238}U, $\bar{\nu}$	-0.036 ± 0.005
^{238}U, (n,γ)	-0.043 ± 0.005
^{238}U, (n,n')	-0.048 ± 0.023
^{238}U, $\bar{\nu}_p$	-0.432 ± 0.004
^{235}U, $\bar{\nu}_p$	-0.525 ± 0.014

FR0-3X (IEU-MET-FAST-022)	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.6824 ± 0.0013
^{238}U, $\bar{\nu}_d$	0.2835 ± 0.0005
^{238}U, (n,f)	0.0522 ± 0.0020
^{238}U, (n,n)	0.011 ± 0.029
^{235}U, (n,n)	0.003 ± 0.013
	...
^{235}U, (n,γ)	-0.0210 ± 0.0009
^{238}U, (n,γ)	-0.0289 ± 0.0015
^{238}U, (n,n')	-0.040 ± 0.009
^{238}U, $\bar{\nu}_p$	-0.2811 ± 0.0017
^{235}U, $\bar{\nu}_p$	-0.682 ± 0.009

FR0-5 (IEU-MET-FAST-022)	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.7221 ± 0.0018
^{238}U, $\bar{\nu}_d$	0.2460 ± 0.0005
^{238}U, (n,f)	0.0481 ± 0.0018
^{238}U, (n,n)	0.009 ± 0.031
^{235}U, $\bar{\nu}$	0.0065 ± 0.0017
	...
^{63}Cu, (n,n)	-0.024 ± 0.023
^{235}U, (n,f)	-0.032 ± 0.015
^{238}U, (n,n')	-0.042 ± 0.007
^{238}U, $\bar{\nu}_p$	-0.2395 ± 0.0015
^{235}U, $\bar{\nu}_p$	-0.727 ± 0.013

FR0-8 (IEU-MET-FAST-022)	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.6939 ± 0.0016
^{238}U, $\bar{\nu}_d$	0.2733 ± 0.0005
^{238}U, (n,f)	0.0533 ± 0.0019
^{63}Cu, (n,n)	0.0029 ± 0.0006
^{238}U, $\bar{\nu}$	0.020 ± 0.019
	...
^{238}U, (n,γ)	-0.0270 ± 0.0019
^{63}Cu, (n,n)	-0.027 ± 0.020
^{238}U, (n,n')	-0.037 ± 0.009
^{238}U, $\bar{\nu}_p$	-0.2713 ± 0.0016
^{235}U, $\bar{\nu}_p$	-0.694 ± 0.011

BFS1-73	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.6984 ± 0.0018
^{238}U, $\bar{\nu}_d$	0.2694 ± 0.0006
^{238}U, (n,f)	0.0526 ± 0.0026
^{238}U, (n,n)	0.02 ± 0.05
^{238}U, $\bar{\nu}$	0.0052 ± 0.0025
	…
^{235}U, (n,f)	-0.018 ± 0.014
^{238}U, (n,γ)	-0.0251 ± 0.0026
^{238}U, (n,n')	-0.034 ± 0.012
^{238}U, $\bar{\nu}_p$	-0.2642 ± 0.0022
^{235}U, $\bar{\nu}_p$	-0.702 ± 0.012

TCA 1.83U (LEU-COMP-THERM-006)	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.8656 ± 0.0007
^{238}U, $\bar{\nu}_d$	0.1127 ± 0.0002
^{238}U, (n,f)	0.0259 ± 0.0009
^{1}H, (n,γ)	0.0129 ± 0.0005
^{238}U, $\bar{\nu}$	0.0093 ± 0.0009
	…
^{238}U, (n,n')	-0.0301 ± 0.0025
^{16}O, (n,n)	-0.037 ± 0.020
^{238}U, $\bar{\nu}_p$	-0.1034 ± 0.0008
^{1}H, (n,n)	-0.11 ± 0.03
^{235}U, $\bar{\nu}_p$	-0.875 ± 0.003

MB-01 (LEU-COMP-THERM-067)	
Reaction	ISC (%/%)
^{235}U, $\bar{\nu}_d$	0.90435 ± 0.00010
^{238}U, $\bar{\nu}_d$	0.0777 ± 0.0002
^{238}U, (n,f)	0.0200 ± 0.0011
^{1}H, (n,γ)	0.0087 ± 0.0006
^{238}U, $\bar{\nu}$	0.0086 ± 0.0011
	…
^{238}U, (n,n')	-0.019 ± 0.003
^{16}O, (n,n)	-0.034 ± 0.027
^{238}U, $\bar{\nu}_p$	-0.0691 ± 0.0010
^{1}H, (n,n)	-0.12 ± 0.05
^{235}U, $\bar{\nu}_p$	-0.913 ± 0.006

1.2. PU AND MIXED FUEL SYSTEMS

Jezebel (PU-MET-FAST-001)

Reaction	ISC (%/%)
^{239}Pu, $\bar{\nu}_d$	0.9483 ± 0.0007
^{239}Pu, (n,n)	0.082 ± 0.010
^{240}Pu, $\bar{\nu}_d$	0.04218 ± 0.00003
^{241}Pu, $\bar{\nu}_d$	0.006865 ± 0.000006
^{240}Pu, (n,n)	0.0048 ± 0.0024
	…
^{240}Pu, $\bar{\nu}$	-0.0067 ± 0.0003
^{239}Pu, (n,f)	-0.013 ± 0.012
^{239}Pu, (n,γ)	-0.0206 ± 0.0003
^{240}Pu, $\bar{\nu}_p$	-0.0489 ± 0.0003
^{239}Pu, $\bar{\nu}_p$	-0.946 ± 0.011

Popsy (PU-MET-FAST-006)

Reaction	ISC (%/%)
^{239}Pu, $\bar{\nu}_d$	0.5790 ± 0.0012
^{238}U, $\bar{\nu}_d$	0.3516 ± 0.0011
^{238}U, $\bar{\nu}$	0.256 ± 0.004
^{238}U, (n,f)	0.246 ± 0.004
^{238}U, (n,n)	0.12 ± 0.03
	…
^{238}U, $\bar{\nu}_p$	-0.095 ± 0.003
^{238}U, (n,n')	-0.160 ± 0.011
^{239}Pu, $\bar{\nu}$	-0.269 ± 0.017
^{239}Pu, (n,f)	-0.285 ± 0.018
^{239}Pu, $\bar{\nu}_p$	-0.848 ± 0.017

ZPR-6/10 (PU-MET-INTER-002)

Reaction	ISC (%/%)
^{239}Pu, $\bar{\nu}_d$	0.976 ± 0.003
^{58}Ni, (n,n)	0.07 ± 0.13
^{52}Cr, (n,n)	0.04 ± 0.12
^{0}C, (n,n)	0.02 ± 0.21
^{54}Fe, (n,n)	0.02 ± 0.07
	…
^{239}Pu, (n,f)	-0.03 ± 0.06
^{239}Pu, (n,n)	-0.03 ± 0.06
^{239}Pu, (n,γ)	-0.046 ± 0.008
^{56}Fe, (n,n)	-0.13 ± 0.29
^{239}Pu, $\bar{\nu}_p$	-0.98 ± 0.06

ZPR-3/59 (PU-MET-INTER-004)

Reaction	ISC (%/%)
^{239}Pu, $\bar{\nu}_d$	0.968 ± 0.004
^{56}Fe, (n,n)	0.02 ± 0.11
^{239}Pu, (n,n)	0.02 ± 0.06
^{58}Ni, (n,n)	0.02 ± 0.04
^{240}Pu, $\bar{\nu}_d$	0.01597 ± 0.00007
	…
^{207}Pb, (n,n)	-0.03 ± 0.10
^{239}Pu, (n,f)	-0.06 ± 0.06
^{0}C, (n,n)	-0.07 ± 0.22
^{239}Pu, (n,γ)	-0.068 ± 0.007
^{239}Pu, $\bar{\nu}_p$	-0.97 ± 0.05

ZPR-9/31 (MIX-COMP-FAST-005)

Reaction	ISC (%/%)
^{238}U, $\bar{\nu}_d$	0.5265 ± 0.0012
^{239}Pu, $\bar{\nu}_d$	0.3816 ± 0.0012
^{238}U, (n,f)	0.289 ± 0.005
^{238}U, $\bar{\nu}$	0.248 ± 0.005
^{235}U, $\bar{\nu}_d$	0.01865 ± 0.00018
	…
^{238}U, (n,n')	-0.105 ± 0.021
^{239}Pu, (n,f)	-0.200 ± 0.024
^{239}Pu, $\bar{\nu}$	-0.244 ± 0.024
^{238}U, $\bar{\nu}_p$	-0.279 ± 0.004
^{239}Pu, $\bar{\nu}_p$	-0.626 ± 0.024

MASURCA ZONA 2

Reaction	ISC (%/%)
^{238}U, $\bar{\nu}_d$	0.4422 ± 0.0011
^{239}Pu, $\bar{\nu}_d$	0.4295 ± 0.0014
^{238}U, (n,f)	0.261 ± 0.004
^{238}U, $\bar{\nu}$	0.231 ± 0.004
^{240}Pu, $\bar{\nu}_d$	0.03800 ± 0.00011
	…
^{240}Pu, $\bar{\nu}_p$	-0.0790 ± 0.0016
^{239}Pu, (n,f)	-0.182 ± 0.027
^{239}Pu, $\bar{\nu}$	-0.210 ± 0.026
^{238}U, $\bar{\nu}_p$	-0.211 ± 0.004
^{239}Pu, $\bar{\nu}_p$	-0.639 ± 0.026

FCA-XIX-2

Reaction	ISC (%/%)
^{239}Pu, $\bar{\nu}_d$	0.4400 ± 0.0014
^{238}U, $\bar{\nu}_d$	0.3718 ± 0.0009
^{238}U, (n,f)	0.229 ± 0.003
^{238}U, $\bar{\nu}$	0.198 ± 0.003
^{235}U, $\bar{\nu}_d$	0.1415 ± 0.0011
	...
^{238}U, (n,n')	-0.084 ± 0.019
^{238}U, $\bar{\nu}_p$	-0.174 ± 0.003
^{239}Pu, (n,f)	-0.228 ± 0.026
^{239}Pu, $\bar{\nu}$	-0.274 ± 0.026
^{239}Pu, $\bar{\nu}_p$	-0.714 ± 0.025

FCA-XIX-3

Reaction	ISC (%/%)
^{239}Pu, $\bar{\nu}_d$	0.7669 ± 0.0025
^{235}U, $\bar{\nu}_d$	0.1008 ± 0.0013
^{238}U, $\bar{\nu}_d$	0.0889 ± 0.0007
^{235}U, $\bar{\nu}$	0.073 ± 0.010
^{235}U, (n,f)	0.068 ± 0.010
	...
^{240}Pu, $\bar{\nu}_p$	-0.0370 ± 0.0011
^{58}Ni, (n,n)	-0.05 ± 0.07
^{239}Pu, $\bar{\nu}$	-0.13 ± 0.04
^{239}Pu, (n,f)	-0.14 ± 0.04
^{239}Pu, $\bar{\nu}_p$	-0.90 ± 0.04

SNEAK-7A

Reaction	ISC (%/%)
^{238}U, $\bar{\nu}_d$	0.4683 ± 0.0012
^{239}Pu, $\bar{\nu}_d$	0.4117 ± 0.0014
^{238}U, (n,f)	0.261 ± 0.005
^{238}U, $\bar{\nu}$	0.232 ± 0.004
^{235}U, $\bar{\nu}_d$	0.0594 ± 0.0006
	...
^{238}U, (n,n')	-0.155 ± 0.020
^{239}Pu, (n,f)	-0.224 ± 0.027
^{238}U, $\bar{\nu}_p$	-0.236 ± 0.004
^{239}Pu, $\bar{\nu}$	-0.258 ± 0.026
^{239}Pu, $\bar{\nu}_p$	-0.670 ± 0.026

SNEAK-7B

Reaction	ISC (%/%)
^{238}U, $\bar{\nu}_d$	0.5270 ± 0.0011
^{239}Pu, $\bar{\nu}_d$	0.3091 ± 0.0009
^{238}U, (n,f)	0.251 ± 0.005
^{238}U, $\bar{\nu}$	0.207 ± 0.005
^{235}U, $\bar{\nu}_d$	0.1044 ± 0.0007
	...
^{238}U, (n,n')	-0.130 ± 0.021
^{239}Pu, (n,f)	-0.217 ± 0.020
^{239}Pu, $\bar{\nu}$	-0.252 ± 0.020
^{238}U, $\bar{\nu}_p$	-0.320 ± 0.004
^{239}Pu, $\bar{\nu}_p$	-0.561 ± 0.020

1.3. ^{233}U SYSTEMS

Skidoo (U233-MET-FAST-001)

Reaction	ISC (%/%)
^{233}U, $\bar{\nu}_d$	0.9824 ± 0.0016
^{233}U, (n,n)	0.064 ± 0.020
^{234}U, $\bar{\nu}_d$	0.00947 ± 0.00001
^{238}U, $\bar{\nu}_d$	0.00472 ± 0.00001
^{238}U, (n,f)	0.00336 ± 0.00002
	...
^{233}U, (n,n')	-0.010 ± 0.008
^{234}U, $\bar{\nu}_p$	-0.01141 ± 0.00012
^{233}U, (n,γ)	-0.0211 ± 0.0006
^{233}U, (n,f)	-0.066 ± 0.022
^{233}U, $\bar{\nu}_p$	-0.984 ± 0.020

Flattop-23 (U233-MET-FAST-006)

Reaction	ISC (%/%)
^{233}U, $\bar{\nu}_d$	0.6921 ± 0.0013
^{238}U, $\bar{\nu}_d$	0.2669 ± 0.0008
^{238}U, (n,f)	0.1625 ± 0.0026
^{238}U, $\bar{\nu}$	0.1623 ± 0.0026
^{238}U, (n,n)	0.085 ± 0.022
	...
^{238}U, $\bar{\nu}_p$	-0.1043 ± 0.0022
^{238}U, (n,n')	-0.119 ± 0.008
^{233}U, $\bar{\nu}$	-0.176 ± 0.014
^{233}U, (n,f)	-0.227 ± 0.015
^{233}U, $\bar{\nu}_p$	-0.868 ± 0.013

2. UNCERTAINTY IN β_{EFF}. ENDF/B-VIII.0 COVARIANCE MATRICES

2.1. ^{235}U SYSTEMS

Godiva (HEU-MET-FAST-001)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	χ	^{235}U	χ	0.918 ± 0.021
^{235}U	(n,f)	^{235}U	(n,f)	0.839 ± 0.006
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4717 ± 0.0015
^{235}U	(n,γ)	^{235}U	(n,γ)	0.3879 ± 0.0022
^{235}U	(n,n')	^{235}U	(n,f)	0.3570 ± 0.0024
^{235}U	(n,f)	^{235}U	(n,γ)	-0.2759 ± 0.0013
^{235}U	(n,n)	^{235}U	(n,f)	0.1681 ± 0.0011
^{235}U	(n,2n)	^{235}U	(n,f)	-0.1287 ± 0.0010
^{235}U	(n,n')	^{235}U	(n,γ)	-0.1279 ± 0.0006
^{234}U	(n,f)	^{234}U	(n,f)	0.1064 ± 0.0007
TOTAL				1.410 ± 0.014

Orsphere (HEU-MET-FAST-100)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	χ	^{235}U	χ	0.894 ± 0.016
^{235}U	(n,f)	^{235}U	(n,f)	0.832 ± 0.005
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4713 ± 0.0012
^{235}U	(n,γ)	^{235}U	(n,γ)	0.3851 ± 0.0018
^{235}U	(n,n')	^{235}U	(n,f)	0.3654 ± 0.0020
^{235}U	(n,f)	^{235}U	(n,γ)	-0.2711 ± 0.0011
^{235}U	(n,n)	^{235}U	(n,f)	0.1708 ± 0.0009
^{235}U	(n,n')	^{235}U	(n,γ)	-0.1327 ± 0.0006
^{235}U	(n,2n)	^{235}U	(n,f)	-0.1223 ± 0.0007
^{234}U	(n,f)	^{234}U	(n,f)	0.1030 ± 0.0005
TOTAL				1.391 ± 0.011

Topsy (HEU-MET-FAST-028)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	0.657 ± 0.005
^{235}U	χ	^{235}U	χ	0.467 ± 0.015
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4187 ± 0.0011
^{238}U	(n,n')	^{238}U	(n,n')	0.380 ± 0.011
^{235}U	(n,γ)	^{235}U	(n,γ)	0.3276 ± 0.0020
^{238}U	(n,n)	^{238}U	(n,n')	-0.300 ± 0.009
^{235}U	(n,f)	^{235}U	(n,γ)	-0.1903 ± 0.0010
^{238}U	(n,n')	^{238}U	(n,f)	-0.143 ± 0.007
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.1259 ± 0.0005
^{238}U	(n,n)	^{238}U	(n,n)	0.122 ± 0.007
TOTAL				1.020 ± 0.008

Coral (HEU-MET-FAST-062)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	0.626 ± 0.008
^{235}U	χ	^{235}U	χ	0.460 ± 0.026
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4205 ± 0.0019
^{235}U	(n,γ)	^{235}U	(n,γ)	0.324 ± 0.003
^{238}U	(n,n')	^{238}U	(n,n')	0.299 ± 0.019
^{238}U	(n,n)	^{238}U	(n,n')	-0.277 ± 0.018
^{235}U	(n,f)	^{235}U	(n,γ)	-0.1810 ± 0.0015
^{235}U	(n,n)	^{235}U	(n,f)	0.1451 ± 0.0016
^{238}U	(n,n')	^{238}U	(n,f)	-0.145 ± 0.009
^{238}U	(n,n)	^{238}U	(n,n)	0.133 ± 0.013
TOTAL				0.976 ± 0.014

ZPR-9/34 (HEU-MET-INTER-001)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.5426 ± 0.0022
^{235}U	χ	^{235}U	χ	0.178 ± 0.025
^{57}Fe	(n,n)	^{57}Fe	(n,n)	0.15 ± 0.05
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.13 ± 0.05
^{235}U	(n,f)	^{235}U	(n,f)	0.117 ± 0.007
^{54}Fe	(n,n)	^{54}Fe	(n,n)	0.10 ± 0.03
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0899 ± 0.0018
^{56}Fe	(n,γ)	^{56}Fe	(n,γ)	0.085 ± 0.004
^{235}U	(n,f)	^{235}U	(n,γ)	0.079 ± 0.003
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.07 ± 0.04
TOTAL				0.653 ± 0.018

FCA-XIX-1

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.5124 ± 0.0021
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1370 ± 0.0019
^{235}U	(n,f)	^{235}U	(n,f)	0.134 ± 0.007
^{235}U	χ	^{235}U	χ	0.114 ± 0.023
^{238}U	(n,n')	^{238}U	(n,n')	0.082 ± 0.012
^{0}C	(n,n)	^{0}C	(n,n)	0.072 ± 0.006
^{238}U	(n,n)	^{238}U	(n,n')	-0.066 ± 0.009
^{235}U	(n,n')	^{235}U	(n,γ)	0.0598 ± 0.0008
^{235}U	(n,n')	^{235}U	(n,n')	0.052 ± 0.016
^{16}O	(n,n)	^{16}O	(n,n)	0.049 ± 0.009
TOTAL				0.585 ± 0.006

MASURCA R2				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4156 ± 0.0018
^{235}U	(n,f)	^{235}U	(n,f)	0.231 ± 0.008
^{235}U	χ	^{235}U	χ	0.216 ± 0.022
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.1938 ± 0.0008
^{238}U	(n,n')	^{238}U	(n,n')	0.179 ± 0.021
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1564 ± 0.0020
^{238}U	(n,n')	^{238}U	(n,f)	-0.154 ± 0.005
^{235}U	(n,f)	^{235}U	(n,γ)	0.1473 ± 0.0021
^{238}U	(n,n)	^{238}U	(n,n')	-0.113 ± 0.014
^{238}U	(n,f)	^{238}U	(n,f)	0.0922 ± 0.0028
TOTAL				0.626 ± 0.010

Big Ten (IEU-MET-FAST-007)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	χ	^{235}U	χ	0.406 ± 0.017
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.4051 ± 0.0011
^{235}U	(n,f)	^{235}U	(n,f)	0.316 ± 0.006
^{238}U	(n,n')	^{238}U	(n,n')	0.31 ± 0.03
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.2812 ± 0.0012
^{238}U	(n,n')	^{238}U	(n,f)	-0.140 ± 0.013
^{235}U	(n,n')	^{235}U	(n,f)	-0.1396 ± 0.0028
^{238}U	(n,n)	^{238}U	(n,n')	-0.135 ± 0.012
^{238}U	(n,n')	^{238}U	(n,γ)	0.130 ± 0.005
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1259 ± 0.0015
TOTAL				0.796 ± 0.013

ZPR-6/9 (IEU-MET-FAST-010)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	χ	^{235}U	χ	0.44 ± 0.03
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.4120 ± 0.0020
^{238}U	(n,n')	^{238}U	(n,n')	0.38 ± 0.06
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.2815 ± 0.0023
^{235}U	(n,f)	^{235}U	(n,f)	0.279 ± 0.011
^{238}U	(n,n')	^{238}U	(n,γ)	0.191 ± 0.009
^{238}U	(n,n')	^{238}U	(n,f)	-0.13 ± 0.03
^{235}U	(n,f)	^{235}U	(n,γ)	0.124 ± 0.003
^{238}U	(n,γ)	^{238}U	(n,γ)	0.1113 ± 0.0022
^{235}U	(n,n')	^{235}U	(n,f)	0.109 ± 0.005
TOTAL				0.849 ± 0.029

FR0-3X (IEU-MET-FAST-022)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.3632 ± 0.0013
^{235}U	(n,f)	^{235}U	(n,f)	0.285 ± 0.006
^{235}U	χ	^{235}U	χ	0.285 ± 0.016
^{238}U	(n,n')	^{238}U	(n,n')	0.283 ± 0.020
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.2691 ± 0.0008
^{238}U	(n,n')	^{238}U	(n,f)	-0.190 ± 0.006
^{235}U	(n,f)	^{235}U	(n,γ)	0.1589 ± 0.0018
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1569 ± 0.0016
^{238}U	(n,n')	^{238}U	(n,γ)	0.1358 ± 0.0023
^{238}U	(n,n)	^{238}U	(n,n')	-0.126 ± 0.008
TOTAL				0.708 ± 0.010

FR0-5 (IEU-MET-FAST-022)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.3918 ± 0.0014
^{238}U	(n,n')	^{238}U	(n,n')	0.292 ± 0.017
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2292 ± 0.0007
^{238}U	(n,n')	^{238}U	(n,f)	-0.194 ± 0.005
^{235}U	χ	^{235}U	χ	0.188 ± 0.016
^{238}U	(n,n)	^{238}U	(n,n')	-0.144 ± 0.008
^{235}U	(n,f)	^{235}U	(n,f)	0.143 ± 0.005
^{238}U	(n,f)	^{238}U	(n,f)	0.0978 ± 0.0025
^{238}U	(n,n')	^{238}U	(n,γ)	0.0938 ± 0.0024
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0932 ± 0.0013
TOTAL				0.597 ± 0.009

FR0-8 (IEU-MET-FAST-022)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.3707 ± 0.0013
^{238}U	(n,n')	^{238}U	(n,n')	0.260 ± 0.019
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2594 ± 0.0007
^{235}U	(n,f)	^{235}U	(n,f)	0.231 ± 0.006
^{235}U	χ	^{235}U	χ	0.218 ± 0.016
^{238}U	(n,n')	^{238}U	(n,f)	-0.193 ± 0.005
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1332 ± 0.0016
^{235}U	(n,f)	^{235}U	(n,γ)	0.1304 ± 0.0020
^{238}U	(n,n')	^{238}U	(n,γ)	0.1180 ± 0.0023
^{238}U	(n,f)	^{238}U	(n,f)	0.1091 ± 0.0026
TOTAL				0.645 ± 0.009

BFS1-73				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.3782 ± 0.0017
^{235}U	χ	^{235}U	χ	0.314 ± 0.022
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.2561 ± 0.0010
^{238}U	(n,n')	^{238}U	(n,n')	0.241 ± 0.028
^{235}U	(n,f)	^{235}U	(n,f)	0.213 ± 0.008
^{238}U	(n,n')	^{238}U	(n,f)	-0.180 ± 0.007
^{238}U	(n,n)	^{238}U	(n,n')	-0.145 ± 0.016
^{238}U	(n,n')	^{238}U	(n,γ)	0.1385 ± 0.0029
^{235}U	(n,f)	^{235}U	(n,γ)	0.1327 ± 0.0022
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1212 ± 0.0018
TOTAL				0.670 ± 0.013

TCA 1.83U (LEU-COMP-THERM-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4907 ± 0.0006
^{235}U	χ	^{235}U	χ	0.273 ± 0.010
^{238}U	(n,n')	^{238}U	(n,n')	0.191 ± 0.006
^{1}H	(n,n)	^{1}H	(n,n)	0.185 ± 0.003
^{238}U	(n,n')	^{238}U	(n,f)	-0.119 ± 0.003
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.0980 ± 0.0004
^{16}O	(n,n)	^{16}O	(n,n)	0.060 ± 0.007
^{238}U	(n,f)	^{238}U	(n,f)	0.0562 ± 0.0013
^{238}U	(n,n')	^{238}U	(n,2n)	0.054 ± 0.003
^{238}U	(n,n)	^{238}U	(n,n')	-0.0482 ± 0.0014
TOTAL				0.629 ± 0.005

MB-01 (LEU-COMP-THERM-067)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.5119 ± 0.0010
^{235}U	χ	^{235}U	χ	0.199 ± 0.015
^{1}H	(n,n)	^{1}H	(n,n)	0.180 ± 0.005
^{238}U	(n,n')	^{238}U	(n,n')	0.122 ± 0.007
^{238}U	(n,n')	^{238}U	(n,f)	-0.085 ± 0.003
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.0654 ± 0.0004
^{16}O	(n,n)	^{16}O	(n,n)	0.054 ± 0.010
^{238}U	(n,f)	^{238}U	(n,f)	0.045 ± 0.002
^{238}U	(n,n')	^{238}U	(n,2n)	0.036 ± 0.004
^{238}U	(n,n)	^{238}U	(n,n')	-0.0230 ± 0.0013
TOTAL				0.596 ± 0.006

2.2. ^{239}PU AND MIXED FUEL SYSTEMS

Jezebel (PU-MET-FAST-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	χ	^{239}Pu	χ	0.699 ± 0.022
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.3673 ± 0.0015
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.1589 ± 0.0011
^{239}Pu	(n,n)	^{239}Pu	(n,f)	-0.1326 ± 0.0025
^{239}Pu	(n,f)	^{239}Pu	(n,γ)	0.1199 ± 0.0005
^{239}Pu	(n,n)	^{239}Pu	(n,γ)	-0.1194 ± 0.0005
^{239}Pu	(n,n)	^{239}Pu	(n,n)	0.115 ± 0.005
^{239}Pu	(n,n)	^{239}Pu	(n,n')	0.079 ± 0.019
^{239}Pu	(n,n')	^{239}Pu	(n,f)	-0.0772 ± 0.0010
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.0650 ± 0.0003
TOTAL				0.809 ± 0.019

Popsy (PU-MET-FAST-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.040 ± 0.025
^{238}U	(n,n')	^{238}U	(n,f)	-0.948 ± 0.007
^{238}U	(n,n)	^{238}U	(n,n')	-0.669 ± 0.015
^{238}U	(n,f)	^{238}U	(n,f)	0.630 ± 0.005
^{238}U	(n,n)	^{238}U	(n,f)	0.494 ± 0.004
^{238}U	χ	^{238}U	χ	0.410 ± 0.011
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.3410 ± 0.0021
^{238}U	(n,f)	^{238}U	(n,γ)	0.275 ± 0.004
^{239}Pu	χ	^{239}Pu	χ	0.27 ± 0.03
^{238}U	(n,n)	^{238}U	(n,n)	0.225 ± 0.015
TOTAL				1.120 ± 0.019

ZPR-6/10 (PU-MET-INTER-002)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.451 ± 0.005
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.39 ± 0.10
^{54}Fe	(n,n)	^{54}Fe	(n,n)	0.23 ± 0.08
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.228 ± 0.015
^{58}Ni	(n,n)	^{58}Ni	(n,n)	0.22 ± 0.08
^{57}Fe	(n,n)	^{57}Fe	(n,n)	0.16 ± 0.06
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.132 ± 0.025
^{239}Pu	(n,n)	^{239}Pu	(n,γ)	-0.126 ± 0.010
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.09 ± 0.05
^{62}Ni	(n,n)	^{62}Ni	(n,n)	0.08 ± 0.06
TOTAL				0.767 ± 0.006

ZPR-3/59 (PU-MET-INTER-004)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.435 ± 0.005
^{239}Pu	χ	^{239}Pu	χ	0.43 ± 0.06
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.282 ± 0.012
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.231 ± 0.020
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.16 ± 0.08
^{208}Pb	(n,n)	^{208}Pb	(n,n)	0.114 ± 0.040
^{239}Pu	(n,n)	^{239}Pu	(n,γ)	-0.113 ± 0.004
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.11 ± 0.04
^{239}Pu	(n,f)	^{239}Pu	(n,γ)	-0.090 ± 0.005
^{207}Pb	(n,n')	^{207}Pb	(n,n')	0.070 ± 0.024
TOTAL				0.76 ± 0.04

ZPR-9/31 (MIX-COMP-FAST-005)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	χ	^{239}Pu	χ	0.97 ± 0.03
^{238}U	(n,n')	^{238}U	(n,f)	-0.819 ± 0.008
^{238}U	(n,n')	^{238}U	(n,n')	0.70 ± 0.05
^{238}U	(n,f)	^{238}U	(n,f)	0.701 ± 0.006
^{238}U	χ	^{238}U	χ	0.449 ± 0.014
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.282 ± 0.003
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2680 ± 0.0018
^{238}U	(n,n')	^{238}U	(n,γ)	0.217 ± 0.009
^{238}U	(n,f)	^{238}U	(n,γ)	-0.177 ± 0.005
^{238}U	(n,n)	^{238}U	(n,f)	-0.1559 ± 0.0015
TOTAL				1.37 ± 0.03

MASURCA ZONA 2				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	χ	^{239}Pu	χ	0.91 ± 0.04
^{238}U	(n,n')	^{238}U	(n,f)	-0.665 ± 0.006
^{238}U	(n,f)	^{238}U	(n,f)	0.641 ± 0.005
^{238}U	(n,n')	^{238}U	(n,n')	0.50 ± 0.04
^{238}U	χ	^{238}U	χ	0.327 ± 0.012
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.283 ± 0.003
^{240}Pu	(n,f)	^{240}Pu	(n,f)	0.210 ± 0.005
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2032 ± 0.0015
^{238}U	(n,n)	^{238}U	(n,f)	0.1818 ± 0.0016
^{238}U	(n,n)	^{238}U	(n,n')	-0.182 ± 0.015
TOTAL				1.24 ± 0.03

FCA-XIX-2				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	χ	^{239}Pu	χ	0.69 ± 0.04
^{238}U	(n,n')	^{238}U	(n,f)	-0.647 ± 0.006
^{238}U	(n,n')	^{238}U	(n,n')	0.56 ± 0.04
^{238}U	(n,f)	^{238}U	(n,f)	0.558 ± 0.005
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.320 ± 0.003
^{238}U	(n,n)	^{238}U	(n,n')	0.300 ± 0.023
^{238}U	(n,n)	^{238}U	(n,f)	-0.294 ± 0.003
^{238}U	(n,n')	^{238}U	(n,γ)	0.199 ± 0.006
^{235}U	(n,f)	^{235}U	(n,f)	0.197 ± 0.004
^{238}U	χ	^{238}U	χ	0.182 ± 0.010
TOTAL				1.07 ± 0.04

FCA-XIX-3				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.405 ± 0.004
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.27 ± 0.10
^{239}Pu	χ	^{239}Pu	χ	0.20 ± 0.05
^{238}U	(n,n')	^{238}U	(n,f)	-0.189 ± 0.005
^{238}U	(n,n')	^{238}U	(n,n')	0.19 ± 0.03
^{238}U	(n,f)	^{238}U	(n,f)	0.156 ± 0.003
^{54}Fe	(n,n)	^{54}Fe	(n,n)	0.15 ± 0.03
^{235}U	(n,f)	^{235}U	(n,f)	0.139 ± 0.005
^{238}U	(n,n)	^{238}U	(n,n')	-0.131 ± 0.022
^{238}U	(n,n)	^{238}U	(n,f)	0.113 ± 0.003
TOTAL				0.66 ± 0.05

SNEAK-7A				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.04 ± 0.04
^{239}Pu	χ	^{239}Pu	χ	0.94 ± 0.03
^{238}U	(n,n')	^{238}U	(n,f)	-0.935 ± 0.009
^{238}U	(n,f)	^{238}U	(n,f)	0.634 ± 0.006
^{238}U	χ	^{238}U	χ	0.368 ± 0.014
^{238}U	(n,n')	^{238}U	(n,γ)	0.303 ± 0.011
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.296 ± 0.003
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2256 ± 0.0017
^{238}U	(n,n)	^{238}U	(n,n')	-0.186 ± 0.008
^{238}U	(n,n')	^{238}U	(n,2n)	0.164 ± 0.029
TOTAL				1.47 ± 0.04

SNEAK-7B				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	0.86 ± 0.05
^{238}U	(n,n')	^{238}U	(n,f)	-0.845 ± 0.009
^{239}Pu	χ	^{239}Pu	χ	0.780 ± 0.029
^{238}U	(n,f)	^{238}U	(n,f)	0.609 ± 0.006
^{238}U	χ	^{238}U	χ	0.448 ± 0.015
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.3061 ± 0.0018
^{238}U	(n,n')	^{238}U	(n,γ)	0.296 ± 0.009
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.2509 ± 0.0022
^{238}U	(n,n)	^{238}U	(n,n')	0.228 ± 0.011
^{235}U	χ	^{235}U	χ	0.193 ± 0.009
TOTAL				1.32 ± 0.04

2.3. ^{233}U SYSTEMS

Skidoo (U233-MET-FAST-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{233}U	$\bar{\nu}_d$	^{233}U	$\bar{\nu}_d$	9.191 ± 0.005
^{233}U	χ	^{233}U	χ	0.677 ± 0.023
^{233}U	(n,γ)	^{233}U	(n,γ)	0.2889 ± 0.0021
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_d$	0.27426 ± 0.00015
^{233}U	(n,n)	^{233}U	(n,n)	0.269 ± 0.013
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_p$	0.2220 ± 0.0013
^{233}U	(n,n')	^{233}U	(n,n')	0.175 ± 0.026
^{233}U	(n,n)	^{233}U	(n,γ)	0.1385 ± 0.0010
^{233}U	(n,n)	^{233}U	(n,n')	-0.129 ± 0.022
^{233}U	(n,f)	^{233}U	(n,f)	0.1016 ± 0.0018
TOTAL				9.234 ± 0.005

Flattop-23 (U233-MET-FAST-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{233}U	$\bar{\nu}_d$	^{233}U	$\bar{\nu}_d$	6.577 ± 0.004
^{238}U	(n,n')	^{238}U	(n,n')	0.777 ± 0.018
^{238}U	(n,n')	^{238}U	(n,f)	-0.664 ± 0.006
^{233}U	(n,n')	^{233}U	(n,n')	0.547 ± 0.028
^{238}U	(n,n)	^{238}U	(n,n')	-0.534 ± 0.012
^{238}U	(n,f)	^{238}U	(n,f)	0.412 ± 0.004
^{238}U	(n,n)	^{238}U	(n,f)	0.365 ± 0.003
^{233}U	(n,n)	^{233}U	(n,n')	-0.316 ± 0.016
^{233}U	(n,γ)	^{233}U	(n,γ)	0.2349 ± 0.0019
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_p$	0.1956 ± 0.0008
TOTAL				6.642 ± 0.004

3. UNCERTAINTY IN β_{EFF}. JEFF-3.3 COVARIANCE MATRICES

3.1. ^{235}U SYSTEMS

Godiva (HEU-MET-FAST-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	χ	^{235}U	χ	0.918 ± 0.021
^{235}U	(n,f)	^{235}U	(n,f)	0.839 ± 0.006
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4717 ± 0.0015
^{235}U	(n,γ)	^{235}U	(n,γ)	0.3879 ± 0.0022
^{235}U	(n,n')	^{235}U	(n,f)	0.3570 ± 0.0024
^{235}U	(n,f)	^{235}U	(n,γ)	-0.2759 ± 0.0013
^{235}U	(n,n)	^{235}U	(n,f)	0.1681 ± 0.0011
^{235}U	(n,2n)	^{235}U	(n,f)	-0.1287 ± 0.0010
^{235}U	(n,n')	^{235}U	(n,γ)	-0.1279 ± 0.0006
^{234}U	(n,f)	^{234}U	(n,f)	0.1064 ± 0.0007
TOTAL				1.410 ± 0.014

Orsphere (HEU-MET-FAST-100)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	χ	^{235}U	χ	0.894 ± 0.016
^{235}U	(n,f)	^{235}U	(n,f)	0.832 ± 0.005
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4713 ± 0.0012
^{235}U	(n,γ)	^{235}U	(n,γ)	0.3851 ± 0.0018
^{235}U	(n,n')	^{235}U	(n,f)	0.3654 ± 0.0020
^{235}U	(n,f)	^{235}U	(n,γ)	-0.2711 ± 0.0011
^{235}U	(n,n)	^{235}U	(n,f)	0.1708 ± 0.0009
^{235}U	(n,n')	^{235}U	(n,γ)	-0.1327 ± 0.0006
^{235}U	(n,2n)	^{235}U	(n,f)	-0.1223 ± 0.0007
^{234}U	(n,f)	^{234}U	(n,f)	0.1030 ± 0.0005
TOTAL				1.391 ± 0.011

Topsy (HEU-MET-FAST-028)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	0.657 ± 0.005
^{235}U	χ	^{235}U	χ	0.467 ± 0.015
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4187 ± 0.0011
^{238}U	(n,n')	^{238}U	(n,n')	0.380 ± 0.011
^{235}U	(n,γ)	^{235}U	(n,γ)	0.3276 ± 0.0020
^{238}U	(n,n)	^{238}U	(n,n')	-0.300 ± 0.009
^{235}U	(n,f)	^{235}U	(n,γ)	-0.1903 ± 0.0010
^{238}U	(n,n')	^{238}U	(n,f)	-0.143 ± 0.007
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.1259 ± 0.0005
^{238}U	(n,n)	^{238}U	(n,n)	0.122 ± 0.007
TOTAL				1.020 ± 0.008

Coral (HEU-MET-FAST-062)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	0.626 ± 0.008
^{235}U	χ	^{235}U	χ	0.460 ± 0.026
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4205 ± 0.0019
^{235}U	(n,γ)	^{235}U	(n,γ)	0.324 ± 0.003
^{238}U	(n,n')	^{238}U	(n,n')	0.299 ± 0.019
^{238}U	(n,n)	^{238}U	(n,n')	-0.277 ± 0.018
^{235}U	(n,f)	^{235}U	(n,γ)	-0.1810 ± 0.0015
^{235}U	(n,n)	^{235}U	(n,f)	0.1451 ± 0.0016
^{238}U	(n,n')	^{238}U	(n,f)	-0.145 ± 0.009
^{238}U	(n,n)	^{238}U	(n,n)	0.133 ± 0.013
TOTAL				0.976 ± 0.014

ZPR-9/34 (HEU-MET-INTER-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.5426 ± 0.0022
^{235}U	χ	^{235}U	χ	0.178 ± 0.025
^{57}Fe	(n,n)	^{57}Fe	(n,n)	0.15 ± 0.05
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.13 ± 0.05
^{235}U	(n,f)	^{235}U	(n,f)	0.117 ± 0.007
^{54}Fe	(n,n)	^{54}Fe	(n,n)	0.10 ± 0.03
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0899 ± 0.0018
^{56}Fe	(n,γ)	^{56}Fe	(n,γ)	0.085 ± 0.004
^{235}U	(n,f)	^{235}U	(n,γ)	0.079 ± 0.003
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.07 ± 0.04
TOTAL				0.653 ± 0.018

FCA-XIX-1				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.5124 ± 0.0021
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1370 ± 0.0019
^{235}U	(n,f)	^{235}U	(n,f)	0.134 ± 0.007
^{235}U	χ	^{235}U	χ	0.114 ± 0.023
^{238}U	(n,n')	^{238}U	(n,n')	0.082 ± 0.012
^{0}C	(n,n)	^{0}C	(n,n)	0.072 ± 0.006
^{238}U	(n,n)	^{238}U	(n,n')	-0.066 ± 0.009
^{235}U	(n,n')	^{235}U	(n,γ)	0.0598 ± 0.0008
^{235}U	(n,n')	^{235}U	(n,n')	0.052 ± 0.016
^{16}O	(n,n)	^{16}O	(n,n)	0.049 ± 0.009
TOTAL				0.585 ± 0.006

MASURCA R2

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4156 ± 0.0018
^{235}U	(n,f)	^{235}U	(n,f)	0.231 ± 0.008
^{235}U	χ	^{235}U	χ	0.216 ± 0.022
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.1938 ± 0.0008
^{238}U	(n,n')	^{238}U	(n,n')	0.179 ± 0.021
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1564 ± 0.0020
^{238}U	(n,n')	^{238}U	(n,f)	-0.154 ± 0.005
^{235}U	(n,f)	^{235}U	(n,γ)	0.1473 ± 0.0021
^{238}U	(n,n)	^{238}U	(n,n')	-0.113 ± 0.014
^{238}U	(n,f)	^{238}U	(n,f)	0.0922 ± 0.0028
TOTAL				0.626 ± 0.010

Big Ten (IEU-MET-FAST-007)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	χ	^{235}U	χ	0.406 ± 0.017
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.4051 ± 0.0011
^{235}U	(n,f)	^{235}U	(n,f)	0.316 ± 0.006
^{238}U	(n,n')	^{238}U	(n,n')	0.31 ± 0.03
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.2812 ± 0.0012
^{238}U	(n,n')	^{238}U	(n,f)	-0.140 ± 0.013
^{235}U	(n,n')	^{235}U	(n,f)	-0.1396 ± 0.0028
^{238}U	(n,n)	^{238}U	(n,n')	-0.135 ± 0.012
^{238}U	(n,n')	^{238}U	(n,γ)	0.130 ± 0.005
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1259 ± 0.0015
TOTAL				0.796 ± 0.013

ZPR-6/9 (IEU-MET-FAST-010)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	χ	^{235}U	χ	0.44 ± 0.03
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.4120 ± 0.0020
^{238}U	(n,n')	^{238}U	(n,n')	0.38 ± 0.06
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.2815 ± 0.0023
^{235}U	(n,f)	^{235}U	(n,f)	0.279 ± 0.011
^{238}U	(n,n')	^{238}U	(n,γ)	0.191 ± 0.009
^{238}U	(n,n')	^{238}U	(n,f)	-0.13 ± 0.03
^{235}U	(n,f)	^{235}U	(n,γ)	0.124 ± 0.003
^{238}U	(n,γ)	^{238}U	(n,γ)	0.1113 ± 0.0022
^{235}U	(n,n')	^{235}U	(n,f)	0.109 ± 0.005
TOTAL				0.849 ± 0.029

FR0-3X (IEU-MET-FAST-022)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.3632 ± 0.0013
^{235}U	(n,f)	^{235}U	(n,f)	0.285 ± 0.006
^{235}U	χ	^{235}U	χ	0.285 ± 0.016
^{238}U	(n,n')	^{238}U	(n,n')	0.283 ± 0.020
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.2691 ± 0.0008
^{238}U	(n,n')	^{238}U	(n,f)	-0.190 ± 0.006
^{235}U	(n,f)	^{235}U	(n,γ)	0.1589 ± 0.0018
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1569 ± 0.0016
^{238}U	(n,n')	^{238}U	(n,γ)	0.1358 ± 0.0023
^{238}U	(n,n)	^{238}U	(n,n')	-0.126 ± 0.008
TOTAL				0.708 ± 0.010

FR0-5 (IEU-MET-FAST-022)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.3918 ± 0.0014
^{238}U	(n,n')	^{238}U	(n,n')	0.292 ± 0.017
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2292 ± 0.0007
^{238}U	(n,n')	^{238}U	(n,f)	-0.194 ± 0.005
^{235}U	χ	^{235}U	χ	0.188 ± 0.016
^{238}U	(n,n)	^{238}U	(n,n')	-0.144 ± 0.008
^{235}U	(n,f)	^{235}U	(n,f)	0.143 ± 0.005
^{238}U	(n,f)	^{238}U	(n,f)	0.0978 ± 0.0025
^{238}U	(n,n')	^{238}U	(n,γ)	0.0938 ± 0.0024
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0932 ± 0.0013
TOTAL				0.597 ± 0.009

FR0-8 (IEU-MET-FAST-022)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.3707 ± 0.0013
^{238}U	(n,n')	^{238}U	(n,n')	0.260 ± 0.019
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2594 ± 0.0007
^{235}U	(n,f)	^{235}U	(n,f)	0.231 ± 0.006
^{235}U	χ	^{235}U	χ	0.218 ± 0.016
^{238}U	(n,n')	^{238}U	(n,f)	-0.193 ± 0.005
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1332 ± 0.0016
^{235}U	(n,f)	^{235}U	(n,γ)	0.1304 ± 0.0020
^{238}U	(n,n')	^{238}U	(n,γ)	0.1180 ± 0.0023
^{238}U	(n,f)	^{238}U	(n,f)	0.1091 ± 0.0026
TOTAL				0.645 ± 0.009

BFS1-73				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.3782 ± 0.0017
^{235}U	χ	^{235}U	χ	0.314 ± 0.022
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.2561 ± 0.0010
^{238}U	(n,n')	^{238}U	(n,n')	0.241 ± 0.028
^{235}U	(n,f)	^{235}U	(n,f)	0.213 ± 0.008
^{238}U	(n,n')	^{238}U	(n,f)	-0.180 ± 0.007
^{238}U	(n,n)	^{238}U	(n,n')	-0.145 ± 0.016
^{238}U	(n,n')	^{238}U	(n,γ)	0.1385 ± 0.0029
^{235}U	(n,f)	^{235}U	(n,γ)	0.1327 ± 0.0022
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1212 ± 0.0018
TOTAL				0.670 ± 0.013

TCA 1.83U (LEU-COMP-THERM-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4907 ± 0.0006
^{235}U	χ	^{235}U	χ	0.273 ± 0.010
^{238}U	(n,n')	^{238}U	(n,n')	0.191 ± 0.006
^{1}H	(n,n)	^{1}H	(n,n)	0.185 ± 0.003
^{238}U	(n,n')	^{238}U	(n,f)	-0.119 ± 0.003
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.0980 ± 0.0004
^{16}O	(n,n)	^{16}O	(n,n)	0.060 ± 0.007
^{238}U	(n,f)	^{238}U	(n,f)	0.0562 ± 0.0013
^{238}U	(n,n')	^{238}U	(n,2n)	0.054 ± 0.003
^{238}U	(n,n)	^{238}U	(n,n')	-0.0482 ± 0.0014
TOTAL				0.629 ± 0.005

MB-01 (LEU-COMP-THERM-067)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.5119 ± 0.0010
^{235}U	χ	^{235}U	χ	0.199 ± 0.015
^{1}H	(n,n)	^{1}H	(n,n)	0.180 ± 0.005
^{238}U	(n,n')	^{238}U	(n,n')	0.122 ± 0.007
^{238}U	(n,n')	^{238}U	(n,f)	-0.085 ± 0.003
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.0654 ± 0.0004
^{16}O	(n,n)	^{16}O	(n,n)	0.054 ± 0.010
^{238}U	(n,f)	^{238}U	(n,f)	0.045 ± 0.002
^{238}U	(n,n')	^{238}U	(n,2n)	0.036 ± 0.004
^{238}U	(n,n)	^{238}U	(n,n')	-0.0230 ± 0.0013
TOTAL				0.596 ± 0.006

3.2. PU AND MIXED FUEL SYSTEMS

Jezebel (PU-MET-FAST-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	χ	^{239}Pu	χ	0.699 ± 0.022
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.3673 ± 0.0015
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.1589 ± 0.0011
^{239}Pu	(n,n)	^{239}Pu	(n,f)	-0.1326 ± 0.0025
^{239}Pu	(n,f)	^{239}Pu	(n,γ)	0.1199 ± 0.0005
^{239}Pu	(n,n)	^{239}Pu	(n,γ)	-0.1194 ± 0.0005
^{239}Pu	(n,n)	^{239}Pu	(n,n)	0.115 ± 0.005
^{239}Pu	(n,n)	^{239}Pu	(n,n')	0.079 ± 0.019
^{239}Pu	(n,n')	^{239}Pu	(n,f)	-0.0772 ± 0.0010
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.0650 ± 0.0003
TOTAL				0.809 ± 0.019

Popsy (PU-MET-FAST-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.040 ± 0.025
^{238}U	(n,n')	^{238}U	(n,f)	-0.948 ± 0.007
^{238}U	(n,n)	^{238}U	(n,n')	-0.669 ± 0.015
^{238}U	(n,f)	^{238}U	(n,f)	0.630 ± 0.005
^{238}U	(n,n)	^{238}U	(n,f)	0.494 ± 0.004
^{238}U	χ	^{238}U	χ	0.410 ± 0.011
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.3410 ± 0.0021
^{238}U	(n,f)	^{238}U	(n,γ)	0.275 ± 0.004
^{239}Pu	χ	^{239}Pu	χ	0.27 ± 0.03
^{238}U	(n,n)	^{238}U	(n,n)	0.225 ± 0.015
TOTAL				1.120 ± 0.019

ZPR-6/10 (PU-MET-INTER-002)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.451 ± 0.005
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.39 ± 0.10
^{54}Fe	(n,n)	^{54}Fe	(n,n)	0.23 ± 0.08
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.228 ± 0.015
^{58}Ni	(n,n)	^{58}Ni	(n,n)	0.22 ± 0.08
^{57}Fe	(n,n)	^{57}Fe	(n,n)	0.16 ± 0.06
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.132 ± 0.025
^{239}Pu	(n,n)	^{239}Pu	(n,γ)	-0.126 ± 0.010
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.09 ± 0.05
^{62}Ni	(n,n)	^{62}Ni	(n,n)	0.08 ± 0.06
TOTAL				0.767 ± 0.006

ZPR-3/59 (PU-MET-INTER-004)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.435 ± 0.005
^{239}Pu	χ	^{239}Pu	χ	0.43 ± 0.06
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.282 ± 0.012
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.231 ± 0.020
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.16 ± 0.08
^{208}Pb	(n,n)	^{208}Pb	(n,n)	0.114 ± 0.040
^{239}Pu	(n,n)	^{239}Pu	(n,γ)	-0.113 ± 0.004
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.11 ± 0.04
^{239}Pu	(n,f)	^{239}Pu	(n,γ)	-0.090 ± 0.005
^{207}Pb	(n,n')	^{207}Pb	(n,n')	0.070 ± 0.024
TOTAL				0.76 ± 0.04

ZPR-9/31 (MIX-COMP-FAST-005)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	χ	^{239}Pu	χ	0.97 ± 0.03
^{238}U	(n,n')	^{238}U	(n,f)	-0.819 ± 0.008
^{238}U	(n,n')	^{238}U	(n,n')	0.70 ± 0.05
^{238}U	(n,f)	^{238}U	(n,f)	0.701 ± 0.006
^{238}U	χ	^{238}U	χ	0.449 ± 0.014
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.282 ± 0.003
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2680 ± 0.0018
^{238}U	(n,n')	^{238}U	(n,γ)	0.217 ± 0.009
^{238}U	(n,f)	^{238}U	(n,γ)	-0.177 ± 0.005
^{238}U	(n,n)	^{238}U	(n,f)	-0.1559 ± 0.0015
TOTAL				1.37 ± 0.03

MASURCA ZONA 2				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	χ	^{239}Pu	χ	0.91 ± 0.04
^{238}U	(n,n')	^{238}U	(n,f)	-0.665 ± 0.006
^{238}U	(n,f)	^{238}U	(n,f)	0.641 ± 0.005
^{238}U	(n,n')	^{238}U	(n,n')	0.50 ± 0.04
^{238}U	χ	^{238}U	χ	0.327 ± 0.012
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.283 ± 0.003
^{240}Pu	(n,f)	^{240}Pu	(n,f)	0.210 ± 0.005
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2032 ± 0.0015
^{238}U	(n,n)	^{238}U	(n,f)	0.1818 ± 0.0016
^{238}U	(n,n)	^{238}U	(n,n')	-0.182 ± 0.015
TOTAL				1.24 ± 0.03

FCA-XIX-2				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	χ	^{239}Pu	χ	0.69 ± 0.04
^{238}U	(n,n')	^{238}U	(n,f)	-0.647 ± 0.006
^{238}U	(n,n')	^{238}U	(n,n')	0.56 ± 0.04
^{238}U	(n,f)	^{238}U	(n,f)	0.558 ± 0.005
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.320 ± 0.003
^{238}U	(n,n)	^{238}U	(n,n')	0.300 ± 0.023
^{238}U	(n,n)	^{238}U	(n,f)	-0.294 ± 0.003
^{238}U	(n,n')	^{238}U	(n,γ)	0.199 ± 0.006
^{235}U	(n,f)	^{235}U	(n,f)	0.197 ± 0.004
^{238}U	χ	^{238}U	χ	0.182 ± 0.010
TOTAL				1.07 ± 0.04

FCA-XIX-3				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.405 ± 0.004
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.27 ± 0.10
^{239}Pu	χ	^{239}Pu	χ	0.20 ± 0.05
^{238}U	(n,n')	^{238}U	(n,f)	-0.189 ± 0.005
^{238}U	(n,n')	^{238}U	(n,n')	0.19 ± 0.03
^{238}U	(n,f)	^{238}U	(n,f)	0.156 ± 0.003
^{54}Fe	(n,n)	^{54}Fe	(n,n)	0.15 ± 0.03
^{235}U	(n,f)	^{235}U	(n,f)	0.139 ± 0.005
^{238}U	(n,n)	^{238}U	(n,n')	-0.131 ± 0.022
^{238}U	(n,n)	^{238}U	(n,f)	0.113 ± 0.003
TOTAL				0.66 ± 0.05

SNEAK-7A				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.04 ± 0.04
^{239}Pu	χ	^{239}Pu	χ	0.94 ± 0.03
^{238}U	(n,n')	^{238}U	(n,f)	-0.935 ± 0.009
^{238}U	(n,f)	^{238}U	(n,f)	0.634 ± 0.006
^{238}U	χ	^{238}U	χ	0.368 ± 0.014
^{238}U	(n,n')	^{238}U	(n,γ)	0.303 ± 0.011
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.296 ± 0.003
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2256 ± 0.0017
^{238}U	(n,n)	^{238}U	(n,n')	-0.186 ± 0.008
^{238}U	(n,n')	^{238}U	(n,2n)	0.164 ± 0.029
TOTAL				1.47 ± 0.04

SNEAK-7B				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	0.86 ± 0.05
^{238}U	(n,n')	^{238}U	(n,f)	-0.845 ± 0.009
^{239}Pu	χ	^{239}Pu	χ	0.780 ± 0.029
^{238}U	(n,f)	^{238}U	(n,f)	0.609 ± 0.006
^{238}U	χ	^{238}U	χ	0.448 ± 0.015
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.3061 ± 0.0018
^{238}U	(n,n')	^{238}U	(n,γ)	0.296 ± 0.009
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.2509 ± 0.0022
^{238}U	(n,n)	^{238}U	(n,n')	0.228 ± 0.011
^{235}U	χ	^{235}U	χ	0.193 ± 0.009
TOTAL				1.32 ± 0.04

3.3. ^{233}U SYSTEMS

Skidoo (U233-MET-FAST-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{233}U	$\bar{\nu}_d$	^{233}U	$\bar{\nu}_d$	9.191 ± 0.005
^{233}U	χ	^{233}U	χ	0.677 ± 0.023
^{233}U	(n,γ)	^{233}U	(n,γ)	0.2889 ± 0.0021
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_d$	0.27426 ± 0.00015
^{233}U	(n,n)	^{233}U	(n,n)	0.269 ± 0.013
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_p$	0.2220 ± 0.0013
^{233}U	(n,n')	^{233}U	(n,n')	0.175 ± 0.026
^{233}U	(n,n)	^{233}U	(n,γ)	0.1385 ± 0.0010
^{233}U	(n,n)	^{233}U	(n,n')	-0.129 ± 0.022
^{233}U	(n,f)	^{233}U	(n,f)	0.1016 ± 0.0018
TOTAL				9.234 ± 0.005

Flattop-23 (U233-MET-FAST-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{233}U	$\bar{\nu}_d$	^{233}U	$\bar{\nu}_d$	6.577 ± 0.004
^{238}U	(n,n')	^{238}U	(n,n')	0.777 ± 0.018
^{238}U	(n,n')	^{238}U	(n,f)	-0.664 ± 0.006
^{233}U	(n,n')	^{233}U	(n,n')	0.547 ± 0.028
^{238}U	(n,n)	^{238}U	(n,n')	-0.534 ± 0.012
^{238}U	(n,f)	^{238}U	(n,f)	0.412 ± 0.004
^{238}U	(n,n)	^{238}U	(n,f)	0.365 ± 0.003
^{233}U	(n,n)	^{233}U	(n,n')	-0.316 ± 0.016
^{233}U	(n,γ)	^{233}U	(n,γ)	0.2349 ± 0.0019
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_p$	0.1956 ± 0.0008
TOTAL				6.642 ± 0.004

4. UNCERTAINTY IN β_{EFF}. JENDL-4.0U COVARIANCE MATRICES

4.1. ^{235}U SYSTEMS

Godiva (HEU-MET-FAST-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.7300 ± 0.0013
^{235}U	χ	^{235}U	χ	0.594 ± 0.013
^{235}U	(n,n)	^{235}U	(n,n)	0.487 ± 0.020
^{235}U	(n,n’)	^{235}U	(n,n’)	0.445 ± 0.017
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.3824 ± 0.0008
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.3507 ± 0.0009
^{235}U	(n,γ)	^{235}U	(n,γ)	0.2227 ± 0.0011
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.2085 ± 0.0007
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_d$	0.16411 ± 0.00011
^{235}U	(n,f)	^{235}U	(n,f)	0.1385 ± 0.0008
TOTAL				2.936 ± 0.005

Orsphere (HEU-MET-FAST-100)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.7272 ± 0.0013
^{235}U	χ	^{235}U	χ	0.586 ± 0.010
^{235}U	(n,n)	^{235}U	(n,n)	0.483 ± 0.016
^{235}U	(n,n’)	^{235}U	(n,n’)	0.436 ± 0.013
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.3805 ± 0.0006
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.3486 ± 0.0007
^{235}U	(n,γ)	^{235}U	(n,γ)	0.2237 ± 0.0009
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.2071 ± 0.0006
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_d$	0.16368 ± 0.00011
^{235}U	(n,f)	^{235}U	(n,f)	0.1373 ± 0.0006
TOTAL				2.929 ± 0.004

Topsy (HEU-MET-FAST-028)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.4829 ± 0.0013
^{238}U	(n,n’)	^{238}U	(n,n')	0.601 ± 0.010
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.4664 ± 0.0006
^{235}U	(n,n’)	^{235}U	(n,n')	0.334 ± 0.013
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.2970 ± 0.0006
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.2683 ± 0.0006
^{235}U	χ	^{235}U	χ	0.240 ± 0.009
^{238}U	(n,n)	^{238}U	(n,n)	0.198 ± 0.019
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1771 ± 0.0007
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.1693 ± 0.0005
TOTAL				2.686 ± 0.004

Coral (HEU-MET-FAST-062)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.4802 ± 0.0017
^{238}U	(n,n’)	^{238}U	(n,n')	0.540 ± 0.019
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.4778 ± 0.0008
^{235}U	(n,n’)	^{235}U	(n,n')	0.310 ± 0.021
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.2928 ± 0.0010
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.2622 ± 0.0011
^{238}U	(n,n)	^{238}U	(n,n)	0.26 ± 0.03
^{235}U	χ	^{235}U	χ	0.225 ± 0.015
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1771 ± 0.0012
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.1653 ± 0.0009
TOTAL				2.671 ± 0.006

ZPR-9/34 (HEU-MET-INTER-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.6274 ± 0.0018
^{235}U	χ	^{235}U	χ	0.248 ± 0.016
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.24 ± 0.07
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1902 ± 0.0008
^{56}Fe	(n,n)	^{56}Fe	(n,n')	-0.16 ± 0.07
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.12 ± 0.05
^{235}U	(n,f)	^{235}U	(n,f)	0.092 ± 0.007
^{56}Fe	(n,γ)	^{56}Fe	(n,γ)	0.077 ± 0.004
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0759 ± 0.0013
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.06 ± 0.04
TOTAL				2.663 ± 0.007

FCA-XIX-1				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.3983 ± 0.0016
^{235}U	χ	^{235}U	χ	0.278 ± 0.014
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1778 ± 0.0008
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.1446 ± 0.0005
^{235}U	(n,n')	^{235}U	(n,n')	0.137 ± 0.014
^{235}U	(n,γ)	^{235}U	(n,γ)	0.1285 ± 0.0019
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.127 ± 0.015
^{235}U	(n,f)	^{235}U	(n,f)	0.120 ± 0.008
^{238}U	(n,n')	^{238}U	(n,n')	0.117 ± 0.010
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_d$	0.09573 ± 0.00011
TOTAL				2.4458 ± 0.0027

MASURCA R2

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.2621 ± 0.0016
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.7044 ± 0.0009
^{238}U	(n,n')	^{238}U	(n,n')	0.308 ± 0.023
^{235}U	χ	^{235}U	χ	0.269 ± 0.014
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1706 ± 0.0007
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.1238 ± 0.0005
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.11 ± 0.03
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.109 ± 0.015
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0944 ± 0.0008
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.0937 ± 0.0009
TOTAL				2.430 ± 0.004

Big Ten (IEU-MET-FAST-007)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	1.9739 ± 0.0011
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	1.3102 ± 0.0011
^{235}U	χ	^{235}U	χ	0.689 ± 0.009
^{238}U	(n,n’)	^{238}U	(n,n')	0.452 ± 0.024
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2560 ± 0.0007
^{238}U	χ	^{238}U	χ	0.196 ± 0.004
^{238}U	(n,γ)	^{238}U	(n,γ)	0.1730 ± 0.0017
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1348 ± 0.0005
^{238}U	(n,n)	^{238}U	(n,n)	0.12 ± 0.05
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_d$	0.10563 ± 0.00007
TOTAL				2.547 ± 0.005

ZPR-6/9 (IEU-MET-FAST-010)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	1.9601 ± 0.0021
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	1.3291 ± 0.0018
^{235}U	χ	^{235}U	χ	0.720 ± 0.016
^{238}U	(n,n’)	^{238}U	(n,n')	0.44 ± 0.05
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.2608 ± 0.0013
^{238}U	χ	^{238}U	χ	0.220 ± 0.007
^{238}U	(n,γ)	^{238}U	(n,γ)	0.178 ± 0.003
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1289 ± 0.0010
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_d$	0.0967 ± 0.0001
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	0.0807 ± 0.0006
TOTAL				2.552 ± 0.010

FR0-3X (IEU-MET-FAST-022)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.1247 ± 0.0012
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.9521 ± 0.0008
^{235}U	χ	^{235}U	χ	0.440 ± 0.009
^{238}U	(n,n')	^{238}U	(n,n')	0.393 ± 0.018
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.1707 ± 0.0005
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1591 ± 0.0005
^{238}U	(n,γ)	^{238}U	(n,γ)	0.1112 ± 0.0007
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.0940 ± 0.0007
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_d$	0.08944 ± 0.00007
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0835 ± 0.0004
TOTAL				2.425 ± 0.004

FR0-5 (IEU-MET-FAST-022)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	1.7877 ± 0.0009
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.8259 ± 0.0008
^{238}U	(n,n')	^{238}U	(n,n')	0.462 ± 0.017
^{235}U	χ	^{235}U	χ	0.276 ± 0.010
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.1453 ± 0.0004
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1354 ± 0.0004
^{235}U	(n,f)	^{235}U	(n,f)	0.091 ± 0.004
^{235}U	(n,n')	^{235}U	(n,n')	0.090 ± 0.008
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0837 ± 0.0012
^{238}U	(n,γ)	^{238}U	(n,γ)	0.0771 ± 0.0006
TOTAL				2.063 ± 0.004

FR0-8 (IEU-MET-FAST-022)

Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	1.8915 ± 0.0010
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.9176 ± 0.0008
^{238}U	(n,n')	^{238}U	(n,n')	0.409 ± 0.019
^{235}U	χ	^{235}U	χ	0.389 ± 0.009
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.1644 ± 0.0005
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1469 ± 0.0004
^{235}U	(n,f)	^{235}U	(n,f)	0.103 ± 0.004
^{238}U	(n,γ)	^{238}U	(n,γ)	0.1020 ± 0.0007
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.0905 ± 0.0006
^{235}U	(n,γ)	^{235}U	(n,γ)	0.0871 ± 0.0007
TOTAL				2.200 ± 0.004

BFS1-73				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.1694 ± 0.0016
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.9067 ± 0.0011
^{235}U	χ	^{235}U	χ	0.463 ± 0.013
^{238}U	(n,n')	^{238}U	(n,n')	0.344 ± 0.024
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.1636 ± 0.0007
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.1580 ± 0.0007
^{238}U	(n,n)	^{238}U	(n,n)	0.13 ± 0.06
^{238}U	(n,γ)	^{238}U	(n,γ)	0.1122 ± 0.0011
^{238}U	χ	^{238}U	χ	0.080 ± 0.004
^{23}Na	(n,n')	^{23}Na	(n,n')	0.080 ± 0.014
TOTAL				2.447 ± 0.005

TCA 1.83U (LEU-COMP-THERM-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.7234 ± 0.0008
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.3776 ± 0.0004
^{238}U	(n,n')	^{238}U	(n,n')	0.305 ± 0.007
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.2614 ± 0.0003
^{235}U	χ	^{235}U	χ	0.136 ± 0.004
^{16}O	(n,n)	^{16}O	(n,n)	0.084 ± 0.003
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.0617 ± 0.0002
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	-0.03010±0.00014
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.02819 ± 0.00003
^{238}U	(n,γ)	^{238}U	(n,γ)	0.02297 ± 0.00009
TOTAL				2.7842 ± 0.0011

MB-01 (LEU-COMP-THERM-067)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	2.8477 ± 0.0012
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.2720 ± 0.0006
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.2604 ± 0.0005
^{238}U	(n,n')	^{238}U	(n,n')	0.191 ± 0.009
^{235}U	χ	^{235}U	χ	0.119 ± 0.004
^{16}O	(n,n)	^{16}O	(n,n)	0.076 ± 0.005
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.0412 ± 0.0003
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.035 ± 0.004
^{56}Fe	(n,n)	^{56}Fe	(n,n')	-0.029 ± 0.004
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.027 ± 0.005
TOTAL				2.8831 ± 0.0013

4.2. PU AND MIXED FUEL SYSTEMS

Jezebel (PU-MET-FAST-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	2.2735 ± 0.0006
^{239}Pu	(n,n)	^{239}Pu	(n,n)	0.356 ± 0.008
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.34986±0.00002
^{239}Pu	$\bar{\nu}$	^{239}Pu	$\bar{\nu}_p$	0.34693 ± 0.0001
^{239}Pu	χ	^{239}Pu	χ	0.316 ± 0.004
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.2063 ± 0.0003
^{240}Pu	$\bar{\nu}_d$	^{240}Pu	$\bar{\nu}_d$	0.2005 ± 0.0001
^{239}Pu	$\bar{\nu}$	^{239}Pu	$\bar{\nu}$	0.1981 ± 0.0002
^{239}Pu	(n,n')	^{239}Pu	(n,n')	0.163 ± 0.006
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.1337 ± 0.0001
TOTAL				2.410 ± 0.012

Popsy (PU-MET-FAST-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.819 ± 0.023
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	1.3439 ± 0.0008
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	1.1760 ± 0.0017
^{239}Pu	χ	^{239}Pu	χ	0.470 ± 0.016
^{238}U	χ	^{238}U	χ	0.406 ± 0.007
^{238}U	(n,n)	^{238}U	(n,n)	0.39 ± 0.04
^{239}Pu	(n,n')	^{239}Pu	(n,n')	0.312 ± 0.016
^{239}Pu	$\bar{\nu}$	^{239}Pu	$\bar{\nu}_p$	0.2993 ± 0.0012
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.2632 ± 0.0011
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.2533 ± 0.0024
TOTAL				2.733 ± 0.016

ZPR-6/10 (PU-MET-INTER-002)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	4.789 ± 0.004
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.66 ± 0.22
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.27 ± 0.10
^{56}Fe	(n,n)	^{56}Fe	(n,n')	-0.26 ± 0.10
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.16 ± 0.09
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.140 ± 0.002
^{239}Pu	$\bar{\nu}$	^{239}Pu	$\bar{\nu}_d$	0.1351 ± 0.0001
^{52}Cr	(n,n)	^{52}Cr	(n,n)	0.13 ± 0.08
^{239}Pu	(n,n)	^{239}Pu	(n,n)	0.13 ± 0.04
^{58}Ni	(n,n)	^{58}Ni	(n,n)	0.13 ± 0.05
TOTAL				4.85 ± 0.03

ZPR-3/59 (PU-MET-INTER-004)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	4.133 ± 0.004
^{239}Pu	χ	^{239}Pu	χ	0.41 ± 0.04
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.17 ± 0.09
^{239}Pu	$\bar{\nu}$	^{239}Pu	$\bar{\nu}_d$	0.1631 ± 0.0002
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.1618 ± 0.0017
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.143 ± 0.006
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.1274 ± 0.0023
^{239}Pu	(n,n')	^{239}Pu	(n,n')	0.117 ± 0.044
^{208}Pb	(n,n)	^{208}Pb	(n,n)	0.114 ± 0.040
^{55}Mn	(n,n)	^{55}Mn	(n,n)	0.105 ± 0.048
TOTAL				4.178 ± 0.007

ZPR-9/31 (MIX-COMP-FAST-005)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	1.7689 ± 0.0019
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	1.5671 ± 0.0015
^{238}U	(n,n')	^{238}U	(n,n')	1.16 ± 0.04
^{239}Pu	χ	^{239}Pu	χ	0.942 ± 0.019
^{238}U	χ	^{238}U	χ	0.522 ± 0.009
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.270 ± 0.025
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	-0.2347 ± 0.0016
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_d$	0.2252 ± 0.0002
^{23}Na	(n,n')	^{23}Na	(n,n')	0.220 ± 0.024
^{238}U	(n,f)	^{238}U	(n,f)	0.1803 ± 0.0012
TOTAL				2.892 ± 0.019

MASURCA ZONA 2				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	1.6550 ± 0.0016
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	1.4864 ± 0.0017
^{238}U	(n,n')	^{238}U	(n,n')	0.925 ± 0.042
^{239}Pu	χ	^{239}Pu	χ	0.842 ± 0.020
^{238}U	χ	^{238}U	χ	0.359 ± 0.007
^{23}Na	(n,n')	^{23}Na	(n,n')	0.29 ± 0.03
^{23}Na	(n,n)	^{23}Na	(n,n')	-0.211 ± 0.022
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.206 ± 0.025
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_d$	0.1984 ± 0.0002
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	-0.1955±0.0015
TOTAL				2.646 ± 0.016

FCA-XIX-2				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	1.6233 ± 0.0015
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	1.2499 ± 0.0015
^{238}U	(n,n')	^{238}U	(n,n')	0.90 ± 0.04
^{239}Pu	χ	^{239}Pu	χ	0.671 ± 0.020
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	0.3996 ± 0.0008
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.31 ± 0.03
^{238}U	χ	^{238}U	χ	0.213 ± 0.006
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_d$	0.1687 ± 0.0002
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	-0.1659 ± 0.0013
^{23}Na	(n,n')	^{23}Na	(n,n')	0.162 ± 0.023
TOTAL				2.441 ± 0.017

FCA-XIX-3				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	2.6300 ± 0.0024
^{56}Fe	(n,n)	^{56}Fe	(n,n)	0.40 ± 0.15
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.3000 ± 0.0011
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	0.2705 ± 0.0009
^{238}U	(n,n')	^{238}U	(n,n')	0.250 ± 0.028
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.18 ± 0.08
^{239}Pu	χ	^{239}Pu	χ	0.17 ± 0.03
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.1568 ± 0.0015
^{56}Fe	(n,n)	^{56}Fe	(n,n')	-0.13 ± 0.06
^{240}Pu	$\bar{\nu}_d$	^{240}Pu	$\bar{\nu}_d$	0.1323 ± 0.0001
TOTAL				2.734 ± 0.023

SNEAK-7A				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	1.6389 ± 0.0016
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	1.5729 ± 0.0019
^{238}U	(n,n')	^{238}U	(n,n')	1.48 ± 0.04
^{239}Pu	χ	^{239}Pu	χ	0.857 ± 0.020
^{238}U	χ	^{238}U	χ	0.411 ± 0.008
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	-0.2064 ± 0.0016
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_d$	0.2053 ± 0.0002
^{56}Fe	(n,n')	^{56}Fe	(n,n')	0.170 ± 0.020
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	0.1614 ± 0.0004
^{238}U	(n,f)	^{238}U	(n,f)	0.1613 ± 0.0012
TOTAL				2.911 ± 0.022

SNEAK-7B				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	1.7697 ± 0.0019
^{238}U	(n,n')	^{238}U	(n,n')	1.48 ± 0.04
^{239}Pu	$\bar{\nu}_d$	^{239}Pu	$\bar{\nu}_d$	1.2660 ± 0.0012
^{239}Pu	χ	^{239}Pu	χ	0.806 ± 0.016
^{238}U	χ	^{238}U	χ	0.533 ± 0.009
^{235}U	$\bar{\nu}_d$	^{235}U	$\bar{\nu}_d$	0.3047 ± 0.0006
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	-0.2276 ± 0.0014
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_d$	0.2065 ± 0.0002
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.1937 ± 0.0011
^{235}U	χ	^{235}U	χ	0.192 ± 0.005
TOTAL				2.861 ± 0.023

4.3. ^{233}U SYSTEMS

Skidoo (U233-MET-FAST-001)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{233}U	$\bar{\nu}_d$	^{233}U	$\bar{\nu}_d$	7.246 ± 0.004
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_p$	0.842 ± 0.004
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}_p$	0.828 ± 0.004
^{233}U	χ	^{233}U	χ	0.677 ± 0.023
^{233}U	(n,n)	^{233}U	(n,n)	0.494 ± 0.022
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}$	0.480 ± 0.003
^{233}U	(n,n')	^{233}U	(n,n')	0.42 ± 0.03
^{233}U	(n,γ)	^{233}U	(n,γ)	0.2903 ± 0.0022
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}_d$	0.2264 ± 0.0001
^{233}U	(n,f)	^{233}U	(n,f)	0.1719 ± 0.0021
TOTAL				7.414 ± 0.005

Flattop-23 (U233-MET-FAST-006)				
Reaction				$\Delta\beta_{eff}/\beta_{eff}$ (%)
^{233}U	$\bar{\nu}_d$	^{233}U	$\bar{\nu}_d$	5.202 ± 0.003
^{238}U	(n,n')	^{238}U	(n,n')	1.346 ± 0.017
^{238}U	$\bar{\nu}_d$	^{238}U	$\bar{\nu}_d$	0.8919 ± 0.0012
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}_p$	0.6882 ± 0.0023
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_p$	0.6400 ± 0.0020
^{233}U	(n,n')	^{233}U	(n,n')	0.590 ± 0.022
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}$	0.4128 ± 0.0020
^{238}U	(n,n)	^{238}U	(n,n)	0.363 ± 0.030
^{233}U	(n,γ)	^{233}U	(n,γ)	0.2274 ± 0.0019
^{233}U	(n,f)	^{233}U	(n,f)	0.2068 ± 0.0021
TOTAL				5.589 ± 0.006

ANNEX III

Sensitivity coefficients for β_{eff}. MCNP vs. SUS-3D

Contents

INTRODUCTION

This appendix contains a comparison of the values of the integrated sensitivity coefficients (ISCs) obtained in this work with those obtained with the deterministic code SUS-3D and published in I. Kodeli, *Sensitivity and uncertainty in the effective delayed neutron fraction (β_{eff})*. Nuclear Instruments and Methods in Physics Research A 715 (2013) 70–78.

Table 1. ISC (%/%) for β_{eff}. Topsy (HEU-MET-FAST-028).

Iso.	(n,n)	(n,n')	(n,f)	(n,γ)	$\bar{\nu}_d$	$\bar{\nu}_p$	$\bar{\nu}$
	2×10^{-4}	*-2×10^{-4}*	*-0.004*	*-3×10^{-4}*	*0.004*	*-0.010*	*-0.005*
^{234}U	8 (± 12)	-1 (± 5)	-0.00509	-2.90 (± 0.08)	0.003430	-0.00973	-0.00630
	$\times 10^{-4}$	$\times 10^{-4}$	± 0.00005	$\times 10^{-4}$	± 0.000006	± 0.00005	± 0.00005
	0.016	*-0.014*	*-0.059*	*-0.033*	*0.836*	*-0.843*	*-0.007*
^{235}U	0.012	-0.013	-0.053	-0.0390	0.8405	-0.841	0.000
	± 0.011	± 0.005	± 0.009	± 0.0008	± 0.0015	± 0.008	± 0.008
	0.047	*-0.051*	*0.028*	*-0.013*	*0.153*	*-0.140*	*0.013*
^{238}U	0.043	-0.057	0.0231	-0.0117	0.1392	-0.1327	0.0065
	± 0.013	± 0.005	± 0.0014	± 0.0009	± 0.0004	± 0.0012	± 0.0014

Upper ISC values (in italics) were obtained by I.Kodeli with the SUS-3D code and lower values were obtained in this work with MCNP.

Table 2. ISC (%/%) for β_{eff}. Big Ten (HEU-MET-FAST-007).

Iso.	(n,n)	(n,n')	(n,f)	(n,γ)	$\bar{\nu}_d$	$\bar{\nu}_p$	$\bar{\nu}$
	1×10^{-5}	*-3×10^{-5}*	*-0.001*	*-8×10^{-5}*	*0.001*	*-0.003*	*-0.002*
^{234}U	0.0002	0.0001	-0.00150	-9.0 (± 0.5)	0.000944	-0.00280	-0.00186
	± 0.0011	± 0.0004	± 0.00003	$\times 10^{-5}$	± 0.000002	± 0.00003	± 0.00003
	0.001	*-0.005*	*0.016*	*-0.012*	*0.548*	*-0.516*	*0.032*
^{235}U	0.003	-0.004	0.017	-0.0157	0.5678	-0.530	0.038
	± 0.011	± 0.004	± 0.009	± 0.0006	± 0.0011	± 0.008	± 0.008
	0.009	*-0.061*	*0.046*	*-0.041*	*0.443*	*-0.473*	*-0.030*
^{238}U	0.01	-0.040	0.043	-0.0432	0.3907	-0.4263	-0.0356
	± 0.04	± 0.013	± 0.003	± 0.0025	± 0.0007	± 0.0026	± 0.0029

Upper ISC values (in italics) were obtained by I.Kodeli with the SUS-3D code and lower values were obtained in this work with MCNP.

Table 3. ISC (%/%) for β_{eff}. Jezebel (PU-MET-FAST-001).

Iso.	(n,n)	(n,n')	(n,f)	(n,γ)	$\bar{\nu}_d$	$\bar{\nu}_p$	$\bar{\nu}$
	0.079	*0.009*	*−0.014*	*−0.022*	*0.948*	*−0.947*	*0.002*
^{239}Pu	0.082	0.004	-0.013	-0.0206	0.9483	-0.946	0.002
	± 0.010	± 0.005	± 0.012	± 0.0003	± 0.0007	± 0.011	± 0.012
	0.0053	*3×10^{-4}*	*−0.002*	*−0.001*	*0.043*	*−0.049*	*−0.007*
^{240}Pu	0.0048	1 (± 12)	-0.0021	-0.001411	0.04218	-0.0489	-0.0067
	± 0.0024	× 10^{-4}	± 0.0003	± 0.000027	± 0.00003	± 0.0003	± 0.0003
	2×10^{-4}	*7×10^{-5}*	*0.005*	*-7×10^{-5}*	*0.007*	*−0.002*	*0.005*
^{241}Pu	3 (± 6)	3 (± 3)	0.00450	-8.48 (± 0.15)	0.006865	-0.00215	0.00471
	× 10^{-4}	× 10^{-4}	± 0.00004	×10^{-5}	± 0.000006	± 0.00004	± 0.00004

Upper ISC values (in italics) were obtained by I.Kodeli with the SUS-3D code and lower values were obtained in this work with MCNP.

Table 4. ISC (%/%) for β_{eff}. Popsy (PU-MET-FAST-006).

Iso.	(n,n)	(n,n')	(n,f)	(n,γ)	$\bar{\nu}_d$	$\bar{\nu}_p$	$\bar{\nu}$
	0.001	*-0.001*	*0.027*	*-0.001*	*0.020*	*0.010*	*0.030*
^{235}U	0.0004	-0.0006	0.0260	-0.00085	0.02040	0.0089	0.0293
	± 0.0024	± 0.0009	± 0.0017	± 0.00003	± 0.00027	± 0.0016	± 0.0017
	0.103	*-0.170*	*0.261*	*-0.050*	*0.361*	*-0.083*	*0.278*
^{238}U	0.12	-0.160	0.246	-0.0497	0.3516	-0.095	0.256
	± 0.03	± 0.011	± 0.004	± 0.0020	± 0.0011	± 0.003	± 0.004
	-0.010	*-0.042*	*-0.305*	*-0.017*	*0.588*	*-0.879*	*-0.292*
^{239}Pu	-0.06	-0.032	-0.285	-0.0181	0.5790	-0.848	-0.269
	± 0.018	± 0.007	± 0.018	± 0.0007	± 0.0012	± 0.017	± 0.017
	-3×10^{-4}	*-0.002*	*-0.015*	*-0.001*	*0.024*	*-0.043*	*-0.019*
^{240}Pu	-0.002	-0.0028	-0.0147	0.00126	0.00233	-0.0418	-0.0185
	± 0.004	± 0.0017	± 0.0005	± 0.00006	± 0.00004	± 0.0004	± 0.0005
	-4×10^{-5}	*-1×10^{-4}*	*0.002*	*-5×10^{-5}*	*0.005*	*-0.002*	*0.002*
^{241}Pu	-4 (± 10)	-2 (± 4)	0.00218	-7.4 (± 0.3)	-0.004476	-0.00209	-0.00239
	× 10^{-4}	× 10^{-4}	± 0.00007	× 10^{-5}	± 0.000010	± 0.00006	± 0.00007

Upper ISC values (in italics) were obtained by I.Kodeli with the SUS-3D code and lower values were obtained in this work with MCNP.

Table 5. ISC (%/%) for β_{eff}. SNEAK-7A.

Iso.	(n,n)	(n,n')	(n,f)	(n,γ)	$\bar{\nu}_d$	$\bar{\nu}_p$	$\bar{\nu}$
	-2 × 10⁻⁴	*-0.001*	*0.052*	*-0.001*	*0.080*	*-0.025*	*0.055*
^{235}U	0.003	-0.0012	0.036	-0.00108	0.0594	-0.022	0.038
	± 0.007	± 0.0017	± 0.005	± 0.00022	± 0.0006	± 0.004	± 0.005
	-0.011	*-0.151*	*0.276*	*-0.017*	*0.488*	*-0.233*	*0.255*
^{238}U	0.00	-0.155	0.261	-0.025	0.4683	-0.236	0.232
	± 0.08	± 0.020	± 0.005	± 0.005	± 0.0012	± 0.004	± 0.004
	-0.002	*-0.012*	*-0.252*	*-0.006*	*0.402*	*-0.700*	*-0.298*
^{239}Pu	-0.006	-0.007	-0.224	-0.0137	0.4117	-0.670	-0.258
	± 0.031	± 0.007	± 0.027	± 0.0021	± 0.0014	± 0.026	± 0.026
	-3 × 10⁻⁴	*-0.001*	*-0.012*	*-4 × 10⁻⁴*	*0.014*	*-0.030*	*-0.016*
^{240}Pu	-0.001	-0.0020	-0.0129	-9 (± 3)	0.01353	-0.0305	-0.0170
	± 0.010	± 0.0021	± 0.0007	× 10⁻⁴	± 0.00005	± 0.0007	± 0.0007
	-2 × 10⁻⁵	*-1 × 10⁻⁴*	*0.005*	*-2 × 10⁻⁵*	*0.011*	*-0.007*	*0.005*
^{241}Pu	0.0002	0.0000	0.0051	-9.2 (± 1.6)	0.01119	-0.0061	0.0050
	± 0.0028	± 0.0006	± 0.0004	× 10⁻⁵	± 0.00005	± 0.0004	± 0.0004
	-0.043	*-1 × 10⁻⁴*					
^{16}O	-0.03	-0.3 (± 2.7)					
	± 0.06	× 10⁻⁴					

Upper ISC values (in italics) were obtained by I.Kodeli with the SUS-3D code and lower values were obtained in this work with MCNP.

Table 6. ISC (%/%) for β_{eff}. Skidoo[1] (U233-MET-FAST-001).

Iso.	(n,n)	(n,n')	(n,f)	(n,γ)	$\bar{\nu}_d$	$\bar{\nu}_p$	$\bar{\nu}$
	0.056	*−0.005*	*−0.068*	*−0.021*	*0.980*	*−0.983*	*−0.003*
^{233}U	0.064	-0.010	-0.066	-0.0211	0.9824	-0.984	-0.001
	± 0.020	± 0.008	± 0.022	± 0.0006	± 0.0016	± 0.020	± 0.021
	0.001	*-2 × 10⁻⁴*	*0.001*	*-3 × 10⁻⁴*	*0.012*	*-0.012*	*1 × 10⁻⁴*
^{234}U	0.0011	1 (± 11)	-0.00060	-3.01 (± 0.13)	0.00947	-0.01141	-0.00194
	± 0.0024	× 10⁻⁴	± 0.00013	× 10⁻⁴	± 0.00001	± 0.00012	± 0.00012
	5 × 10⁻⁴	*-2 × 10⁻⁴*	*0.003*	*-1 × 10⁻⁴*	*0.005*	*-0.002*	*0.003*
^{238}U	3 (± 16)	-3 (± 9)	0.00336	-0.89 (± 0.04)	0.00472	-0.001603	0.00311
	× 10⁻⁴	× 10⁻⁴	± 0.00002	*× 10⁻⁴*	± 0.00001	± 0.000015	± 0.00002

Upper ISC values (in italics) were obtained by I.Kodeli with the SUS-3D code and lower values were obtained in this work with MCNP.

[1] Also referred as Jezebel 23 in [Kodeli 2013].

Table 7. ISC (%/%) for β_{eff}. SNEAK-7B[2].

Iso.	(n,n)	(n,n')	(n,f)	(n,γ)	$\bar{\nu}_d$	$\bar{\nu}_p$	$\bar{\nu}$
	-2×10^{-4}	*-0.002*	*0.061*	*-0.001*	*0.114*	*-0.052*	*0.061*
^{235}U	0.001	-0.0020	0.055	-0.00145	0.1044	-0.048	0.056
	± 0.009	± 0.0022	± 0.006	± 0.00025	± 0.0007	± 0.005	± 0.006
	-0.019	*-0.164*	*0.267*	*0.011 (*)*	*0.564*	*-0.334*	*0.230*
^{238}U	-0.02	-0.130	0.251	-0.011	0.5270	-0.320	0.207
	± 0.08	± 0.021	± 0.005	± 0.005	± 0.0011	± 0.004	± 0.005
	-0.001	*-0.008*	*-0.233*	*-0.001*	*0.300*	*-0.579*	*-0.280*
^{239}Pu	-0.006	-0.006	-0.217	-0.0067	0.3091	-0.561	-0.252
	± 0.024	± 0.006	± 0.020	± 0.0012	± 0.0009	± 0.020	± 0.020
	-1×10^{-4}	*-0.001*	*-0.010*	*5×10^{-5} (*)*	*0.009*	*-0.022*	*-0.013*
^{240}Pu	-0.002	-0.0010	-0.0106	-4.0 (± 1.5)	0.009076	-0.0227	-0.0137
	± 0.008	± 0.0017	± 0.0005	$\times 10^{-4}$	± 0.000029	± 0.0005	± 0.0005
	-7×10^{-6}	*-7×10^{-5}*	*0.003*	*1×10^{-5} (*)*	*0.008*	*-0.005*	*0.003*
^{241}Pu	0.0005	-1 (± 5)	0.00321	-3.5 (± 0.9)	0.00827	-0.00521	0.00306
	± 0.0021	$\times 10^{-4}$	± 0.00027	$\times 10^{-5}$	± 0.00003	± 0.00026	± 0.00027
	-0.0040	*2×10^{-4}*					
^{16}O	-0.057	0 (± 3)					
	± 0.066	$\times 10^{-4}$					
Upper ISC values (in italics) were obtained by I.Kodeli with the SUS-3D code and lower values were obtained in this work with MCNP.							

Table 8. ISC (%/%) for β_{eff}. Flattop-23 (U233-MET-FAST-006).

Iso.	(n,n)	(n,n')	(n,f)	(n,γ)	$\bar{\nu}_d$	$\bar{\nu}_p$	$\bar{\nu}$
	−0.005	*−0.034*	*−0.231*	*−0.016*	*0.700*	*−0.885*	*−0.185*
^{233}U	-0.009	-0.036	-0.227	-0.0166	0.6921	-0.868	-0.176
	± 0.014	± 0.005	± 0.015	± 0.0005	± 0.0013	± 0.013	± 0.014
	2×10^{-5}	*−0.001*	*−0.001*	*-2×10^{-4}*	*0.007*	*-0.009*	*-0.002*
^{234}U	0.0004	-0.0004	-0.00226	-2.4 (0.1)	0.005574	-0.00885	-0.00328
	± 0.0017	± 0.0007	± 0.00008	$\times 10^{-4}$	± 0.000009	± 0.00007	± 0.00007
	0.001	*−0.001*	*0.015*	*−0.001*	*0.015*	*0.002*	*0.017*
^{235}U	0.0008	-0.0004	0.0149	-0.000561	0.01520	0.0016	0.0168
	± 0.0019	± 0.0007	± 0.0013	± 0.000028	± 0.00020	± 0.0012	± 0.0013
	0.075	*−0.129*	*0.167*	*−0.033*	*0.274*	*−0.104*	*0.170*
^{238}U	0.085	-0.119	0.1625	-0.0307	0.2669	-0.1043	0.1623
	± 0.022	± 0.008	± 0.0026	± 0.0015	± 0.0008	± 0.0022	± 0.0026
Upper ISC values (in italics) were obtained by I.Kodeli with the SUS-3D code and lower values were obtained in this work with MCNP.							

[2] The values marked with (*) are likely to have the wrong sign in [Kodeli 2013].

ANNEX IV

Integrated sensitivity coefficients and uncertainty due to nuclear data in Λ_{eff}

Contents

1. INTEGRATED SENSITIVITY COEFFICIENTS (ISC) FOR Λ_{EFF}

HEU-MET-FAST-100 (Orsphere)

Reaction	ISC (%/%)
^{235}U, (n,n)	0.26 ± 0.08
^{235}U, (n,n')	0.20 ± 0.04
^{238}U, (n,n)	0.012 ± 0.020
^{238}U, (n,n')	0.011 ± 0.012
^{234}U, (n,n')	0.009 ± 0.004
…	
^{238}U, $\bar{\nu}$	-0.0165 ± 0.0010
^{235}U, (n,γ)	-0.081 ± 0.005
^{235}U, $\bar{\nu}_p$	-0.97 ± 0.06
^{235}U, $\bar{\nu}$	-0.97 ± 0.06
^{235}U, (n,f)	-1.11 ± 0.07
NOTE: N(c)=5×10^{17} at·cm^{-3}	

HEU-MET-FAST-028 (Topsy)

Reaction	ISC (%/%)
^{238}U, (n,n)	0.38 ± 0.04
^{238}U, (n,n')	0.155 ± 0.015
^{235}U, (n,n')	0.022 ± 0.013
^{235}U, $(n,2n)$	0.0005 ± 0.0014
^{238}U, $(n,2n)$	0.0002 ± 0.0010
…	
^{235}U, (n,γ)	-0.0923 ± 0.0020
^{238}U, (n,γ)	-0.3444 ± 0.0026
^{235}U, $\bar{\nu}_p$	-0.957 ± 0.023
^{235}U, $\bar{\nu}$	-0.959 ± 0.023
^{235}U, (n,f)	-1.111 ± 0.024
NOTE: N(c)=5×10^{17} at·cm^{-3}	

PU-MET-FAST-006 (Popsy)

Reaction	ISC (%/%)
^{238}U, (n,n)	0.40 ± 0.04
^{238}U, (n,n')	0.176 ± 0.019
^{235}U, $\bar{\nu}$	0.0616 ± 0.0026
^{235}U, $\bar{\nu}_p$	0.0612 ± 0.0026
^{235}U, (n,f)	0.0356 ± 0.0026
…	
^{239}Pu, (n,n)	-0.061 ± 0.026
^{238}U, (n,γ)	-0.417 ± 0.003
^{239}Pu, $\bar{\nu}_p$	-1.014 ± 0.027
^{239}Pu, $\bar{\nu}$	-1.016 ± 0.027
^{239}Pu, (n,f)	-1.10 ± 0.03
NOTE: N(c)=5×10^{17} at·cm^{-3}	

U233-MET-FAST-006 (Flattop-23)

Reaction	ISC (%/%)
^{238}U, (n,n)	0.327 ± 0.045
^{238}U, (n,n')	0.148 ± 0.019
^{235}U, $\bar{\nu}$	0.0600 ± 0.0026
^{235}U, $\bar{\nu}_p$	0.0596 ± 0.0026
^{238}U, $\bar{\nu}$	0.036 ± 0.008
…	
^{238}U, (n,n)	-0.084 ± 0.027
^{238}U, (n,γ)	-0.440 ± 0.003
^{233}U, $\bar{\nu}_p$	-1.081 ± 0.029
^{233}U, $\bar{\nu}$	-1.085 ± 0.029
^{233}U, (n,f)	-1.20 ± 0.03
NOTE: N(c)=5×10^{17} at·cm^{-3}	

IEU-MET-FAST-022 (Studsvik FR0-5)

Reaction	ISC (%/%)
^{1}H, (n,n)	0.238 ± 0.005
^{238}U, (n,n')	0.087 ± 0.003
^{63}Cu, (n,n)	0.037 ± 0.007
^{65}Cu, (n,n)	0.021 ± 0.005
^{235}U, (n,n')	0.0193 ± 0.0015
…	
^{238}U, $\bar{\nu}_p$	-0.2853 ± 0.0011
^{238}U, $\bar{\nu}$	-0.2893 ± 0.0011
^{235}U, $\bar{\nu}_p$	-0.704 ± 0.004
^{235}U, $\bar{\nu}$	-0.707 ± 0.004
^{235}U, (n,f)	-1.051 ± 0.004
NOTE: N(c)=5×10^{16} at·cm^{-3}	

LEU-COMP-THERM-067 (IPEN MB-01)

Reaction	ISC (%/%)
^{238}U, (n,γ)	0.0718 ± 0.0005
^{235}U, (n,γ)	0.0333 ± 0.0003
^{16}O, (n,α)	0.001705 ± 0.000024
^{56}Fe, (n,γ)	0.00170 ± 0.00018
^{234}U, (n,γ)	0.000966 ± 0.000028
…	
^{1}H, (n,γ)	-0.0970 ± 0.0004
^{1}H, (n,n)	-0.272 ± 0.009
^{235}U, (n,f)	-0.8133 ± 0.0026
^{235}U, $\bar{\nu}_p$	-0.9085 ± 0.0022
^{235}U, $\bar{\nu}$	-0.9152 ± 0.0022
NOTE: N(c)=5×10^{15} at·cm^{-3}	

2. UNCERTAINTY IN Λ_{EFF}. ENDF/B-VIII.0 COVARIANCE MATRICES

Orsphere (HEU-MET-FAST-100)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	1.34 ± 0.08
^{235}U	(n,n)	^{235}U	(n,n)	0.64 ± 0.20
^{235}U	(n,n')	^{235}U	(n,n')	0.59 ± 0.11
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.57 ± 0.04
^{235}U	(n,n)	^{235}U	(n,n')	0.49 ± 0.11
^{235}U	(n,n')	^{235}U	(n,f)	-0.48 ± 0.10
^{235}U	(n,γ)	^{235}U	(n,γ)	0.447 ± 0.028
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.402 ± 0.025
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.400 ± 0.025
^{235}U	χ	^{235}U	χ	0.31 ± 0.04
TOTAL				1.92 ± 0.11
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Topsy (HEU-MET-FAST-028)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	1.343 ± 0.028
^{238}U	(n,n)	^{238}U	(n,n')	1.08 ± 0.11
^{238}U	(n,n')	^{238}U	(n,n')	1.07 ± 0.10
^{238}U	(n,n)	^{238}U	(n,n)	0.80 ± 0.08
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.571 ± 0.012
^{238}U	(n,γ)	^{238}U	(n,γ)	0.553 ± 0.004
^{235}U	(n,γ)	^{235}U	(n,γ)	0.493 ± 0.011
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.404 ± 0.009
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.404 ± 0.009
^{238}U	(n,n')	^{238}U	(n,γ)	-0.372 ± 0.003
TOTAL				2.41 ± 0.10
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Popsy (PU-MET-FAST-006)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{239}Pu	(n,f)	^{239}Pu	(n,f)	1.38 ± 0.04
^{238}U	(n,n')	^{238}U	(n,n')	1.26 ± 0.13
^{238}U	(n,n)	^{238}U	(n,n')	1.13 ± 0.13
^{238}U	(n,n)	^{238}U	(n,n)	0.88 ± 0.10
^{238}U	(n,γ)	^{238}U	(n,γ)	0.678 ± 0.005
^{239}Pu	χ	^{239}Pu	χ	0.64 ± 0.06
^{239}Pu	(n,n)	^{239}Pu	(n,n)	0.44 ± 0.19
^{239}Pu	$\bar{\nu}$	^{239}Pu	$\bar{\nu}$	0.433 ± 0.009
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.432 ± 0.009
^{238}U	(n,n')	^{238}U	(n,γ)	-0.390 ± 0.004
TOTAL				2.62 ± 0.15
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Flattop-23 (U233-MET-FAST-006)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.20 ± 0.13
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}_p$	1.120 ± 0.023
^{238}U	(n,n)	^{238}U	(n,n')	0.98 ± 0.15
^{233}U	(n,f)	^{233}U	(n,f)	0.80 ± 0.02
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}$	0.792 ± 0.016
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_p$	0.792 ± 0.016
^{238}U	(n,γ)	^{238}U	(n,γ)	0.712 ± 0.006
^{238}U	(n,n)	^{238}U	(n,n)	0.68 ± 0.10
^{233}U	(n,γ)	^{233}U	(n,γ)	0.452 ± 0.013
^{233}U	(n,n')	^{233}U	(n,n')	0.34 ± 0.14
TOTAL				2.64 ± 0.11
NOTE: N(c)=5×10^{17} at·cm^{-3}				

FR0-5 (IEU-MET-FAST-022)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	1.128 ± 0.028
^{235}U	(n,n')	^{235}U	(n,f)	-0.57 ± 0.03
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.522 ± 0.019
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	0.515 ± 0.015
^{238}U	(n,n')	^{238}U	(n,f)	-0.376 ± 0.016
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.370 ± 0.014
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.370 ± 0.014
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.364 ± 0.011
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.364 ± 0.011
^{238}U	(n,f)	^{238}U	(n,f)	0.301 ± 0.012
TOTAL				1.48 ± 0.03
NOTE: N(c)=5×10^{16} at·cm^{-3}				

MB-01 (LEU-COMP-THERM-067)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.5858 ± 0.0014
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.4151 ± 0.0010
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.4141 ± 0.0010
^{235}U	(n,f)	^{235}U	(n,f)	0.3485 ± 0.0012
^{1}H	(n,γ)	^{1}H	(n,γ)	0.2007 ± 0.0009
^{235}U	(n,n')	^{235}U	(n,f)	0.1561 ± 0.0005
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	0.1445 ± 0.0009
^{1}H	(n,n)	^{1}H	(n,n)	0.132 ± 0.006
^{238}U	(n,n')	^{238}U	(n,f)	0.1166 ± 0.0010
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}$	0.1023 ± 0.0007
TOTAL				0.9896 ± 0.0017
NOTE: N(c)=5×10^{15} at·cm^{-3}				

3. UNCERTAINTY IN Λ_{eff}, JEFF-3.3 COVARIANCE MATRICES

Orsphere (HEU-MET-FAST-100)				
Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	(n,n')	^{235}U	(n,n')	2.0 ± 0.4
^{235}U	χ	^{235}U	χ	1.6 ± 0.4
^{235}U	(n,n')	^{235}U	(n,f)	-1.2 ± 0.4
^{235}U	(n,n')	^{235}U	(n,γ)	-1.05 ± 0.06
^{235}U	(n,f)	^{235}U	(n,f)	0.94 ± 0.09
^{235}U	(n,γ)	^{235}U	(n,γ)	0.68 ± 0.04
^{235}U	(n,f)	^{235}U	(n,γ)	-0.63 ± 0.04
^{235}U	(n,n)	^{235}U	(n,n')	-0.60 ± 0.12
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.48 ± 0.03
^{235}U	(n,n)	^{235}U	(n,f)	0.38 ± 0.08
TOTAL				2.3 ± 0.4
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Topsy (HEU-MET-FAST-028)				
Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{238}U	(n,n)	^{238}U	(n,n')	1.22 ± 0.12
^{238}U	(n,n')	^{238}U	(n,n')	1.17 ± 0.11
^{235}U	χ	^{235}U	χ	0.94 ± 0.14
^{235}U	(n,f)	^{235}U	(n,f)	0.90 ± 0.04
^{238}U	(n,n)	^{238}U	(n,n)	0.76 ± 0.06
^{235}U	(n,γ)	^{235}U	(n,γ)	0.75 ± 0.017
^{238}U	(n,γ)	^{238}U	(n,γ)	0.701 ± 0.006
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.471 ± 0.012
^{235}U	(n,n')	^{235}U	(n,f)	-0.43 ± 0.04
^{238}U	(n,n)	^{238}U	(n,f)	-0.42 ± 0.05
TOTAL				2.40 ± 0.13
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Popsy (PU-MET-FAST-006)				
Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.37 ± 0.14
^{238}U	(n,n)	^{238}U	(n,n')	1.30 ± 0.13
^{239}Pu	χ	^{239}Pu	χ	1.24 ± 0.16
^{238}U	(n,γ)	^{238}U	(n,γ)	0.877 ± 0.007
^{238}U	(n,n)	^{238}U	(n,n)	0.73 ± 0.07
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.525 ± 0.013
^{238}U	(n,n)	^{238}U	(n,γ)	0.508 ± 0.013
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.407 ± 0.012
^{238}U	(n,n')	^{238}U	(n,f)	-0.38 ± 0.10
^{238}U	(n,n')	^{238}U	(n,γ)	0.38 ± 0.04
TOTAL				2.65 ± 0.16
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Flattop-23 (U233-MET-FAST-006)				
Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.19 ± 0.14
^{233}U	(n,f)	^{233}U	(n,f)	1.12 ± 0.03
^{238}U	(n,n)	^{238}U	(n,n')	1.11 ± 0.14
^{238}U	(n,γ)	^{238}U	(n,γ)	0.915 ± 0.008
^{238}U	(n,n)	^{238}U	(n,n)	0.65 ± 0.08
^{233}U	(n,γ)	^{233}U	(n,γ)	0.524 ± 0.013
^{238}U	(n,n)	^{238}U	(n,γ)	0.443 ± 0.014
^{238}U	(n,n')	^{238}U	(n,γ)	0.42 ± 0.03
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}_p$	0.370 ± 0.010
^{233}U	(n,n)	^{233}U	(n,n)	0.36 ± 0.11
TOTAL				2.48 ± 0.014
NOTE: N(c)=5×10^{17} at·cm^{-3}				

FR0-5 (IEU-MET-FAST-022)				
Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	1.95 ± 0.06
^{235}U	χ	^{235}U	χ	1.05 ± 0.19
^{238}U	(n,f)	^{238}U	(n,f)	0.67 ± 0.03
^{238}U	(n,n')	^{238}U	(n,f)	-0.568 ± 0.025
^{235}U	(n,γ)	^{235}U	(n,γ)	0.555 ± 0.015
^{235}U	(n,f)	^{235}U	(n,γ)	0.50 ± 0.05
^{238}U	(n,n')	^{238}U	(n,n')	0.38 ± 0.19
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.368 ± 0.016
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.281 ± 0.008
^{235}U	(n,n')	^{235}U	(n,f)	-0.247 ± 0.012
TOTAL				2.47 ± 0.10
NOTE: N(c)=5×10^{16} at·cm^{-3}				

MB-01 (LEU-COMP-THERM-067)				
Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	0.5433 ± 0.0018
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.5093 ± 0.0012
^{1}H	(n,γ)	^{1}H	(n,γ)	0.2476 ± 0.0011
^{1}H	(n,n)	^{1}H	(n,n)	0.207 ± 0.005
^{238}U	(n,f)	^{238}U	(n,f)	0.2034 ± 0.0017
^{235}U	χ	^{235}U	χ	0.201 ± 0.015
^{238}U	(n,n')	^{238}U	(n,f)	0.1795 ± 0.0015
^{16}O	(n,n)	^{16}O	(n,n)	0.160 ± 0.010
^{238}U	(n,n')	^{238}U	(n,n')	0.119 ± 0.007
^{238}U	$\bar{\nu}_p$	^{238}U	$\bar{\nu}_p$	0.0788 ± 0.0005
TOTAL				0.919 ± 0.004
NOTE: N(c)=5×10^{15} at·cm^{-3}				

4. UNCERTAINTY IN Λ_{eff}, JENDL-4.0U COVARIANCE MATRICES

Orsphere (HEU-MET-FAST-100)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	(n,n)	^{235}U	(n,n)	1.7 ± 0.4
^{235}U	(n,n')	^{235}U	(n,n')	1.7 ± 0.3
^{235}U	χ	^{235}U	χ	1.49 ± 0.24
^{235}U	(n,f)	^{235}U	(n,f)	0.55 ± 0.03
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.55 ± 0.03
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.388 ± 0.018
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.387 ± 0.018
^{235}U	(n,γ)	^{235}U	(n,γ)	0.290 ± 0.021
^{234}U	(n,n')	^{234}U	(n,n')	0.22 ± 0.10
^{238}U	(n,n')	^{238}U	(n,n')	0.11 ± 0.09
TOTAL				3.0 ± 0.3
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Topsy (HEU-MET-FAST-028)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.59 ± 0.17
^{238}U	(n,n)	^{238}U	(n,n)	1.58 ± 0.16
^{238}U	(n,γ)	^{238}U	(n,γ)	0.759 ± 0.007
^{235}U	χ	^{235}U	χ	0.65 ± 0.08
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.572 ± 0.009
^{235}U	(n,f)	^{235}U	(n,f)	0.562 ± 0.011
^{235}U	(n,n)	^{235}U	(n,n)	0.43 ± 0.15
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.405 ± 0.006
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.404 ± 0.006
^{235}U	(n,γ)	^{235}U	(n,γ)	0.297 ± 0.006
TOTAL				2.72 ± 0.14
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Popsy (PU-MET-FAST-006)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.98 ± 0.21
^{238}U	(n,n)	^{238}U	(n,n)	1.37 ± 0.18
^{239}Pu	χ	^{239}Pu	χ	0.98 ± 0.09
^{238}U	(n,γ)	^{238}U	(n,γ)	0.900 ± 0.008
^{239}Pu	(n,f)	^{239}Pu	(n,f)	0.715 ± 0.017
^{239}Pu	$\bar{\nu}$	^{239}Pu	$\bar{\nu}_p$	0.463 ± 0.008
^{239}Pu	$\bar{\nu}$	^{239}Pu	$\bar{\nu}$	0.328 ± 0.006
^{239}Pu	$\bar{\nu}_p$	^{239}Pu	$\bar{\nu}_p$	0.327 ± 0.006
^{239}Pu	(n,γ)	^{239}Pu	(n,γ)	0.304 ± 0.006
^{239}Pu	(n,n)	^{239}Pu	(n,n)	0.20 ± 0.09
TOTAL				2.95 ± 0.17
NOTE: N(c)=5×10^{17} at·cm^{-3}				

Flattop-23 (U233-MET-FAST-006)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{238}U	(n,n')	^{238}U	(n,n')	1.86 ± 0.22
^{238}U	(n,n)	^{238}U	(n,n)	1.63 ± 0.21
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}_p$	1.120 ± 0.023
^{238}U	(n,γ)	^{238}U	(n,γ)	0.951 ± 0.009
^{233}U	(n,f)	^{233}U	(n,f)	0.800 ± 0.020
^{233}U	$\bar{\nu}$	^{233}U	$\bar{\nu}$	0.792 ± 0.016
^{233}U	$\bar{\nu}_p$	^{233}U	$\bar{\nu}_p$	0.792 ± 0.016
^{233}U	(n,γ)	^{233}U	(n,γ)	0.452 ± 0.013
^{233}U	(n,n')	^{233}U	(n,n')	0.34 ± 0.14
^{233}U	χ	^{233}U	χ	0.33 ± 0.10
TOTAL				3.28 ± 0.16
NOTE: N(c)=5×10^{17} at·cm^{-3}				

FR0-5 (IEU-MET-FAST-022)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	(n,f)	^{235}U	(n,f)	0.88 ± 0.05
^{238}U	(n,n')	^{238}U	(n,n')	0.75 ± 0.19
^{235}U	χ	^{235}U	χ	0.74 ± 0.11
^{238}U	(n,n)	^{238}U	(n,n)	0.40 ± 0.30
^{235}U	(n,γ)	^{235}U	(n,γ)	0.339 ± 0.017
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.313 ± 0.006
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	0.253 ± 0.008
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.222 ± 0.005
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.221 ± 0.005
^{235}U	(n,n')	^{235}U	(n,n')	0.22 ± 0.09
TOTAL				1.63 ± 0.13
NOTE: N(c)=5×10^{16} at·cm^{-3}				

MB-01 (LEU-COMP-THERM-067)

Reaction				$\Delta\Lambda_{eff}/\Lambda_{eff}$ (%)
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}_p$	0.3642 ± 0.0009
^{235}U	(n,f)	^{235}U	(n,f)	0.2629 ± 0.0009
^{235}U	$\bar{\nu}$	^{235}U	$\bar{\nu}$	0.2584 ± 0.0007
^{235}U	$\bar{\nu}_p$	^{235}U	$\bar{\nu}_p$	0.2575 ± 0.0007
^{235}U	χ	^{235}U	χ	0.176 ± 0.010
^{238}U	(n,n')	^{238}U	(n,n')	0.1476 ± 0.0090
^{16}O	(n,n)	^{16}O	(n,n)	0.104 ± 0.005
^{238}U	(n,γ)	^{238}U	(n,γ)	0.0831 ± 0.0005
^{238}U	$\bar{\nu}$	^{238}U	$\bar{\nu}_p$	0.0703 ± 0.0005
^{235}U	(n,f)	^{235}U	(n,γ)	0.0630 ± 0.0015
TOTAL				0.654 ± 0.004
NOTE: N(c)=5×10^{15} at·cm^{-3}				

ANNEX V

Covariance data of $\bar{\nu}_d$ for the most relevant isotopes

Contents

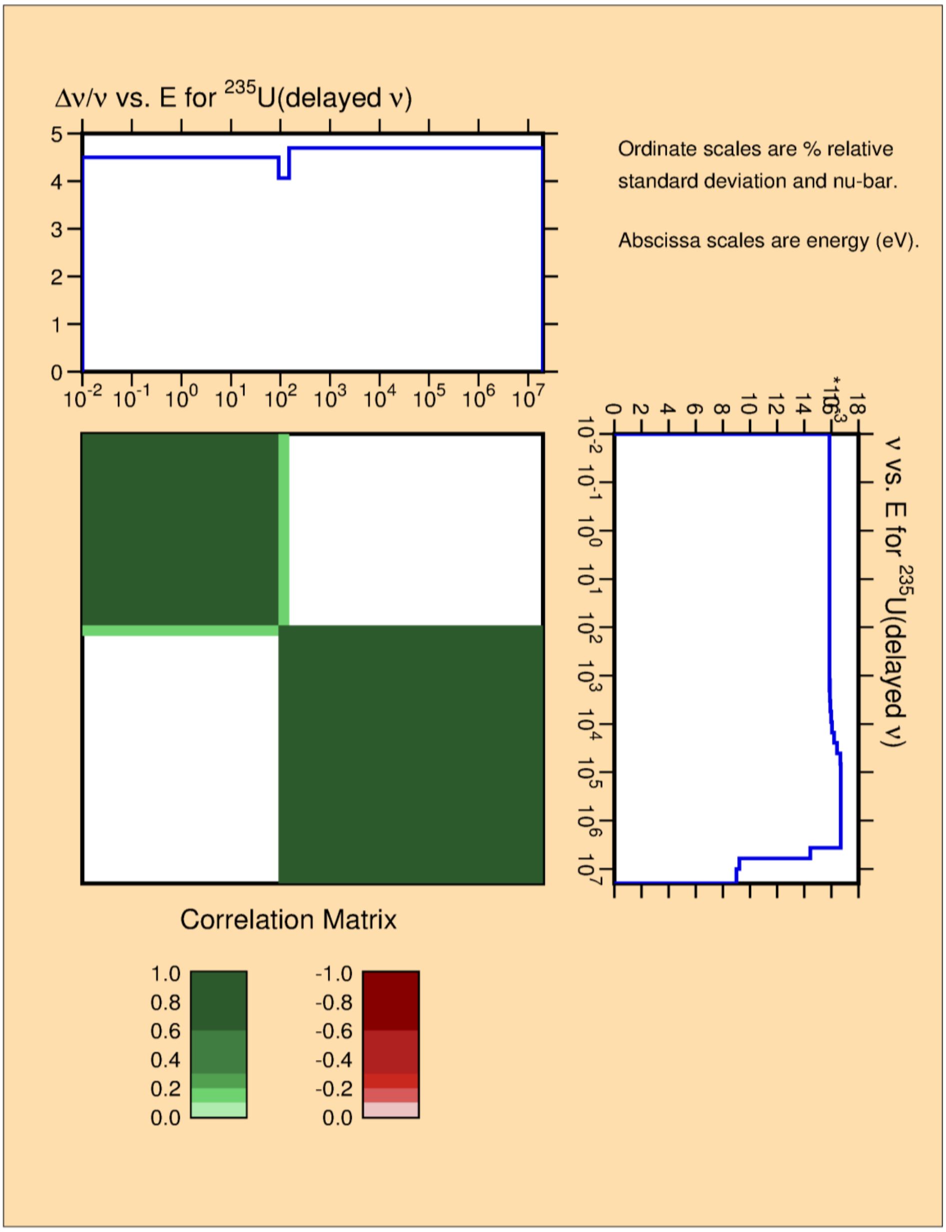

Figure 1. Covariance data for the nubar delayed of ^{235}U. ENDF/B-VIII.0 library.

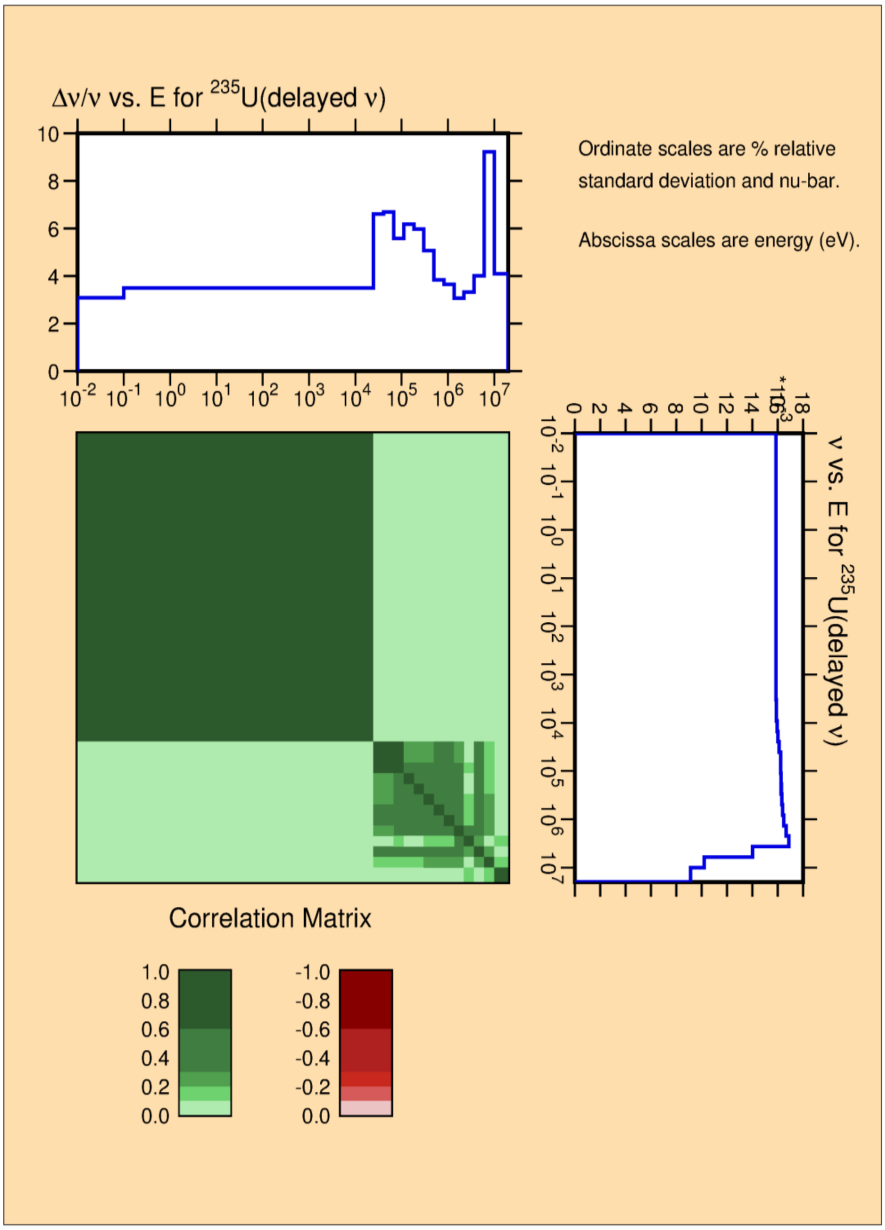

Figure 2. Covariance data for the nubar delayed of ^{235}U. JENDL-4.0u library.

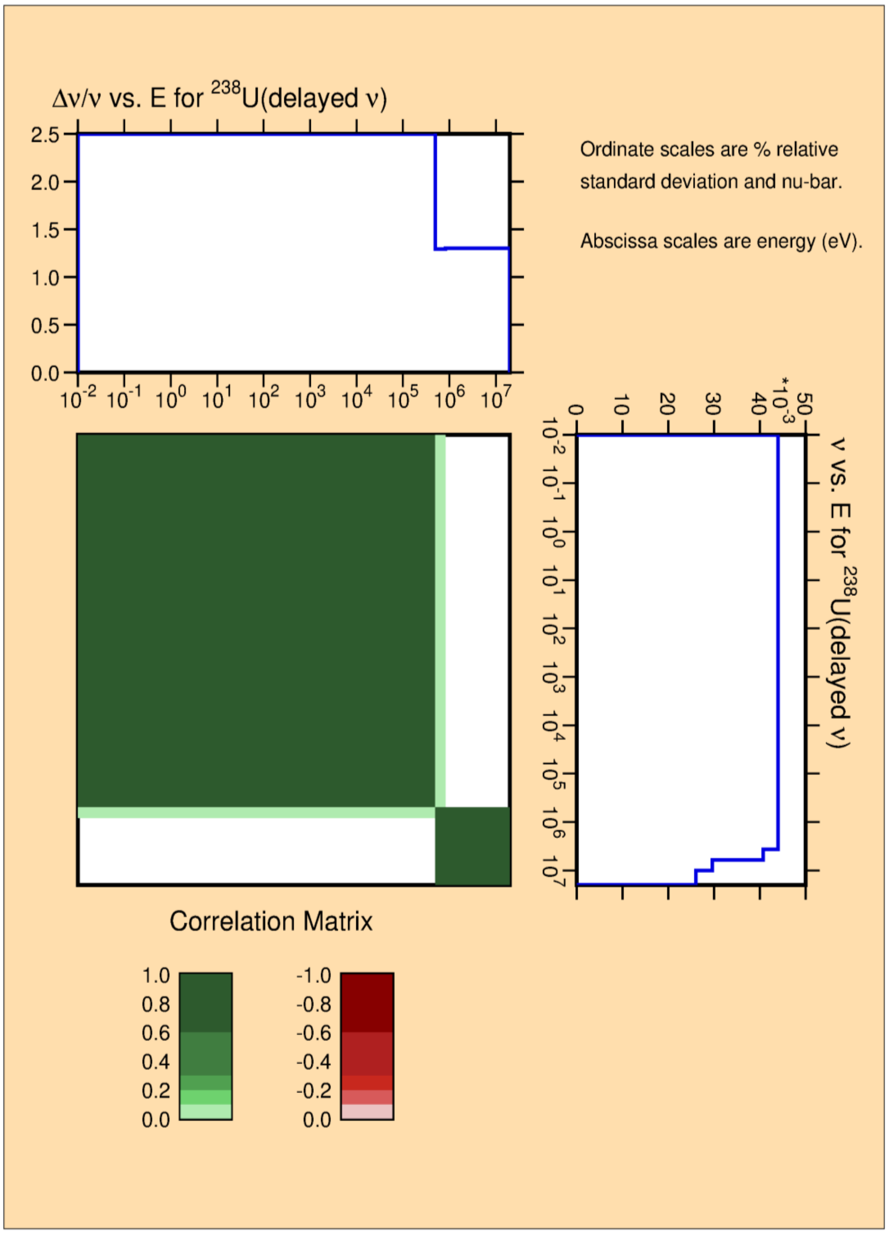

Figure 3. Covariance data for the nubar delayed of ^{238}U. ENDF/B-VIII.0 library.

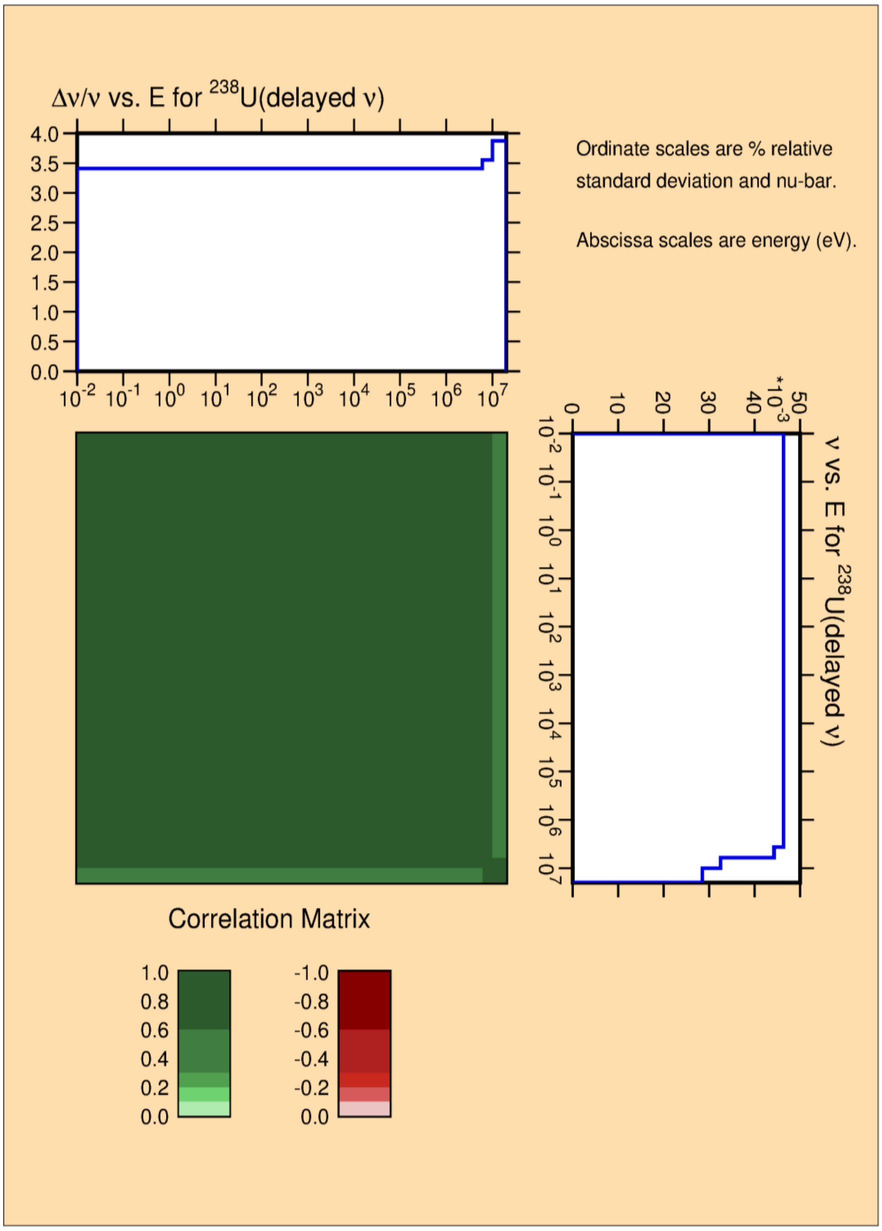

Figure 4. Covariance data for the nubar delayed of ^{238}U. JENDL-4.0u library.

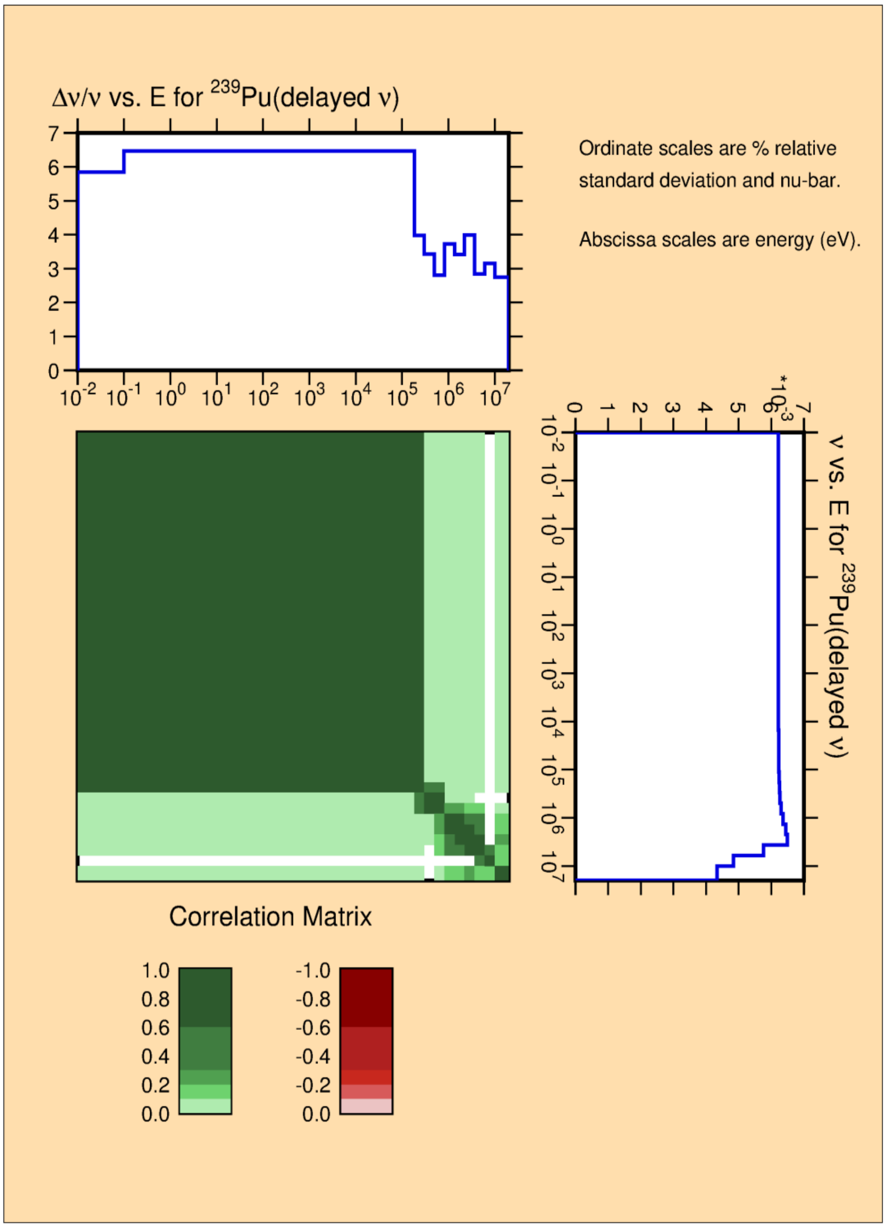

Figure 5. Covariance data for the nubar delayed of ^{239}Pu. JENDL-4.0u library.

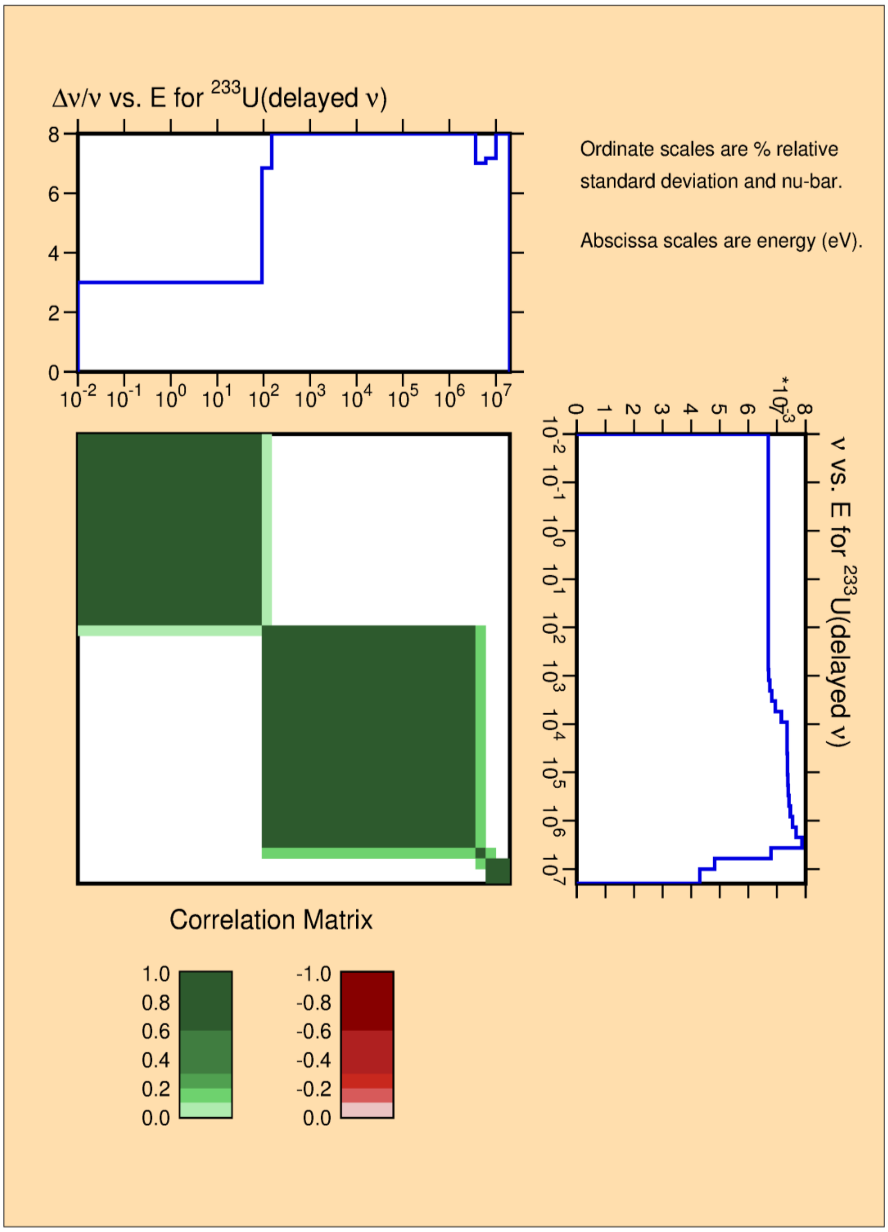

Figure 6. Covariance data for the nubar delayed of ^{233}U. ENDF/B-VIII.0 and JENDL-4.0u libraries.

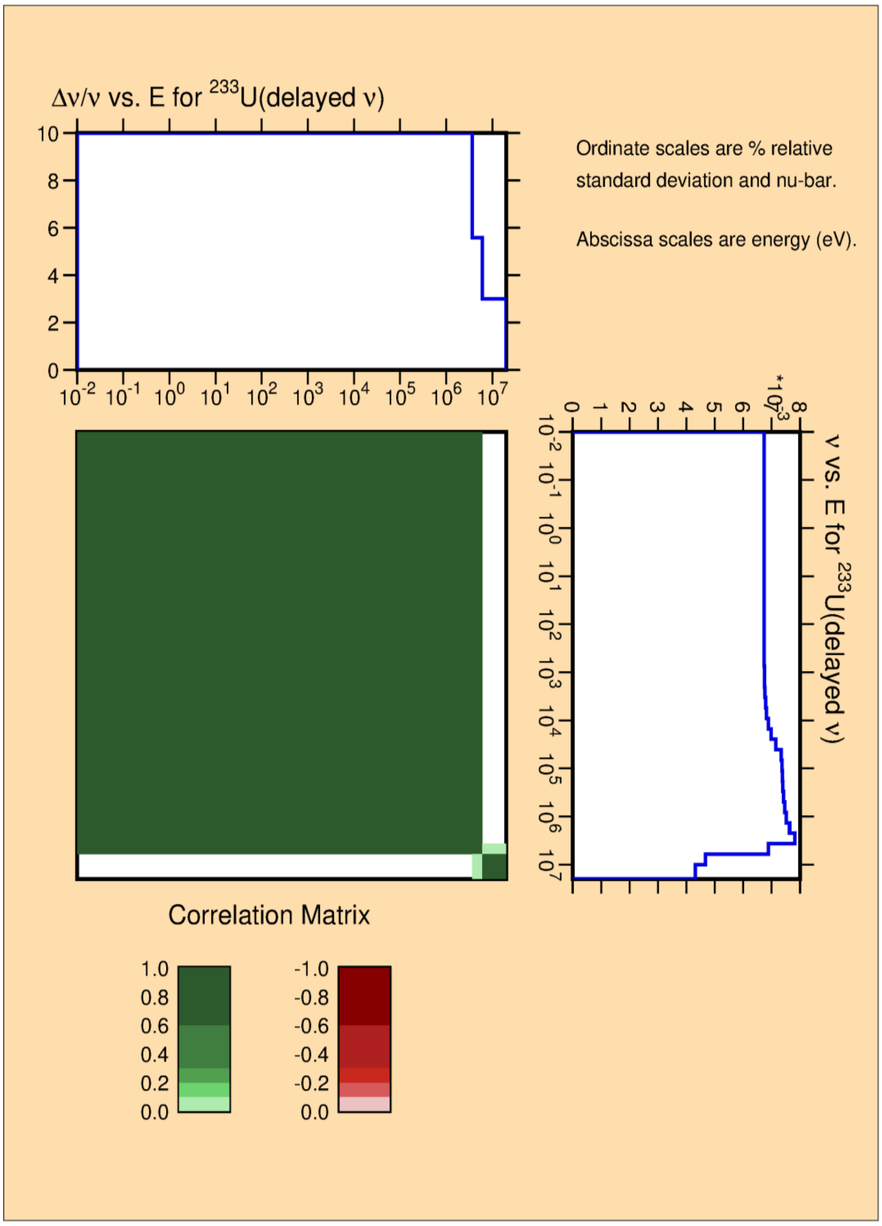

Figure 7. Covariance data for the nubar delayed of ^{233}U. JEFF-3.3 library.

FIRMANTE	NOMBRE	FECHA	NOTAS
FIRMANTE[1]	**VICENTE BECARES PALACIOS**	**07/10/2022 17:00**	
FIRMANTE[2]	**FRANCISCO ALVAREZ VELARDE**	**10/10/2022 08:57 | Sin acción específica**	
FIRMANTE[3]	**M.SOLEDAD FERNANDEZ FERNANDEZ**	**10/10/2022 09:30 | Sin acción específica**	
FIRMANTE[4]	**ENRIQUE MIGUEL GONZALEZ ROMERO**	**13/10/2022 12:35 | Sin acción específica**	