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Application of the SCALE TSUNAMI Tools for the Validation of Criticality Safety Calculations Involving ^{233}U

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Nuclear Science and Technology Division

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ABSTRACT

The Radiochemical Development Facility at Oak Ridge National Laboratory has been storing solid materials containing ^{233}U for decades. Preparations are under way to process these materials into a form that is inherently safe from a nuclear criticality safety perspective. This will be accomplished by down-blending the ^{233}U materials with depleted or natural uranium. At the request of the U.S. Department of Energy, a study has been performed using the SCALE sensitivity and uncertainty analysis tools to demonstrate how these tools could be used to validate nuclear criticality safety calculations of selected process and storage configurations. ISOTEK nuclear criticality safety staff provided four models that are representative of the criticality safety calculations for which validation will be needed. The SCALE TSUNAMI-1D and TSUNAMI-3D sequences were used to generate energy-dependent k_{eff} sensitivity profiles for each nuclide and reaction present in the four safety analysis models, also referred to as the applications, and in a large set of critical experiments. The SCALE TSUNAMI-IP module was used together with the sensitivity profiles and the cross-section uncertainty data contained in the SCALE covariance data files to propagate the cross-section uncertainties ($\Delta\sigma/\sigma$) to k_{eff} uncertainties ($\Delta k/k$) for each application model. The SCALE TSUNAMI-IP module was also used to evaluate the similarity of each of the 672 critical experiments with each application. Results of the uncertainty analysis and similarity assessment are presented in this report. A total of 142 experiments were judged to be similar to application 1, and 68 experiments were judged to be similar to application 2. None of the 672 experiments were judged to be adequately similar to applications 3 and 4. Discussion of the uncertainty analysis and similarity assessment is provided for each of the four applications. Example upper subcritical limits (USLs) were generated for application 1 based on trending of the energy of average lethargy of neutrons causing fission, trending of the TSUNAMI similarity parameters, and use of data adjustment techniques.

1. INTRODUCTION

Sensitivity/uncertainty analyses have been performed using the SCALE 5.1 TSUNAMI tools on a set of four typical safety analysis models provided by ISOTEK Nuclear Criticality Safety (NCS) staff. Where appropriate, upper subcritical limits (USLs) have been produced. The goal of this report is to describe the analysis performed and to provide guidance that ISOTEK NCS staff could use in validation studies to support criticality safety analyses.

Validation is performed to establish the relationship between calculated k_{eff} values and the actual system neutron multiplication factors. Validation analysis typically involves modeling of critical experiments that are similar to one or more safety analysis cases, referred to in this report as applications. Statistical analysis of the results is performed to generate bias and bias uncertainty values that can be used in developing safety limits.

It is important that the critical experiments used for validation are similar to the applications. A significant part of the computational bias is attributed to errors in nuclear data or in how the nuclear data are used. In a conventional bias determination analysis, the true bias of an application can be produced from critical experiments only if the experiments and application use the same nuclear data and the critical experiment and application k_{eff} values are affected by the nuclear data errors in the same way. Of course, perfect matches between applications and experiments are rarely achieved.

Historically, the determination of similarity has been largely qualitative in nature; criteria such as the presence of the same fissionable nuclides, moderating, and absorbing materials were frequently used. In some cases, similarity determination has relied upon comparison of one or more system characteristic parameters, such as the hydrogen-to-fissile atom ratio (H/X) or the Energy of Average Lethargy of neutrons causing Fission (EALF). The level of similarity of critical experiments with the safety applications has varied significantly, depending on who performed the determination and on the availability of suitable critical experiments.

The SCALE TSUNAMI sensitivity/uncertainty analysis tools permit detailed energy-, nuclide-, and reaction-dependent comparison of critical experiments with safety applications. The TSUNAMI-1D[1] and TSUNAMI-3D[2] sensitivity analysis tools are described in the SCALE manual Sections C8 and C9, respectively. The TSUNAMI-IP module, described in SCALE manual Section M18, uses the sensitivity data to quantify the similarity of experiments to safety applications based on sensitivity/uncertainty criteria. The sensitivity data were coupled with the uncertainty in the cross-section data to produce an uncertainty in k_{eff} due to uncertainties in the basic nuclear data. As cross-section data are believed to be the primary cause of computational biases, a benchmark experiment with uncertainties in k_{eff} that are highly correlated to the uncertainties in the design system will provide a good indication of the expected computational bias. TSUNAMI-IP[3] processes the sensitivity data and cross-section-covariance data and produces a correlation coefficient, denoted c_k, that provides an indication of the similarity of a given benchmark experiment to a design system in terms of the correlations in the uncertainties between the two systems. This correlation coefficient is normalized such that a c_k value of 1.0 indicates that the two systems are identical. The c_k correlation coefficient is a global integral index in that it produces a single value from information about all nuclides and all reactions of both systems on an energy-dependent basis. Thus, the computed value of c_k provides an indication of the overall similarity of two systems.

In general, a critical experiment is considered to be adequately similar to an application if the c_k value is 0.90 or higher. Such experiments are said to be "applicable" to the validation of the safety basis model calculation. Experiments with a c_k value of 0.8 or higher are said to be "marginally similar" or are "marginally applicable." A c_k value of 0.8 means that the application and experiment share about 80% of the reactivity uncertainties associated with nuclear data uncertainties. Experiments with c_k values below 0.8 are considered "not applicable" to the validation of the application. A low c_k value means that there are many differences between the application and the compared experiment.

Calculations for the application models and the ^{233}U critical experiments used in this study were performed using SCALE 5.1 and a 238-neutron-energy-group ENDV/B-VI nuclear data library augmented with updated ^{233}U data (ENDF/B-VII). Updated ^{233}U pointwise data was also used for the CENTRM/CENTRMST unit cell calculations. The analysis also utilized some additional sensitivity data files generated for non-^{233}U critical experiments. These sensitivity data files had been previously generated using either the 238-neutron-energy-group ENDF/B-V or ENDF/B-VI nuclear data library and either NITAWLST or CENTRMST for unit cell calculations. In general, the use of differing codes and nuclear data libraries is not acceptable for bias determination purposes. Such data was included in this analysis to assist in identifying additional critical experiments that are similar to the applications and for use in illustrative analysis examples. Sensitivity calculations were performed using TSUNAMI-1D or TSUNAMI-3D. The similarity assessment was performed using the TSUNAMI-IP module and the 44-group ENDF/B-VI recommended covariance data set augmented with pre-release ENDF/B-VII covariance data for the ^{233}U reactions.

The work discussed in this report involved identifying critical experiments that may be similar to the applications, performing sensitivity analysis of the applications and critical experiments using TSUNAMI-1D or TSUNAMI-3D, comparing the critical experiments with the applications using TSUNAMI-IP, using the comparison results to identify which critical experiments are similar to each application, and calculation of upper subcritical limits. The sections following this one describe the applications, the selection of the candidate critical configurations, the quantitative similarity assessment, USL determination, and some suggestions for handling applications that do not have an adequate set of similar critical experiments. Appendix A includes the TSUNAMI-3D input listings for the four application models. Appendix B contains a listing of the critical experiments considered. Appendix C is the TSUNAMI-IP input file for application 1. Appendix D is a list of critical experiments sorted by decreasing similarity for each application. Appendix E contains the USLSTATS input deck used to calculate one of the USLs for application 1.

2. APPLICATIONS

Similarity was assessed for four applications provided by ISOTEK staff. Input decks are provided in Appendix A for each application. The remainder of this section is a summary of each application.

Application 1 is a 12.2-cm-radius sphere of 220 g U per liter uranyl nitrate solution with no excess acid. The uranium is 100 wt % ^{233}U. The solution sphere is reflected by 0.25 cm of Type 304 stainless steel (ss-304) and 2 cm of water. The EALF calculated for this application was 0.282 eV. The k_{eff} calculated for this system is 1.0028 ± 0.0002.

Application 2 is a 14.0-cm-radius sphere of 220 g U per liter uranyl nitrate solution with no excess acid. The uranium is from the Consolidated Edison Uranium Solidification Project (CEUSP). [4] This project converted liquid waste containing uranium enriched in ^{233}U and ^{235}U into a solid form. The CEUSP isotopics are 9.7 wt % ^{233}U, 1.4 wt % ^{234}U, 76.5 wt % ^{235}U, 5.6 wt% ^{236}U, and 6.8 wt% ^{238}U. The solution sphere is reflected by 0.25 cm of ss-304 and 2 cm of water. The EALF calculated for this application was 0.121 eV. The k_{eff} calculated for this system is 0.9889 ± 0.0002.

Application 3 is a 53.0-cm-radius sphere of 600 g U per liter uranyl nitrate solution with no excess acid. The solution temperature is 80°C (353 K). The uranium is 3 wt % ^{233}U, 0.2 wt % ^{235}U, and 96.8 wt % ^{238}U. The fissile solution sphere is reflected by 0.25 cm of ss-304 and 2.0 cm of water. The EALF calculated for this application was 0.0631 eV. The k_{eff} calculated for this system is 0.9690 ± 0.0002.

Application 4 is a storage array loaded with uranium mixed with hydrogen (H/U 0.21), oxygen (O/U 3.1), and carbon (C/U 4.7). The uranium is 9.7 wt % ^{233}U, 1.4 wt% ^{234}U, 76.5 wt % ^{235}U, 5.6 wt % ^{236}U, and 6.8 wt % ^{238}U. The array is moderated by concrete and steel and reflected by concrete. Figure 1 shows some of the detail from the application 4 model. The EALF calculated for this application was 2.63 eV. The k_{eff} calculated for this system is 0.751 ± 0.0001.

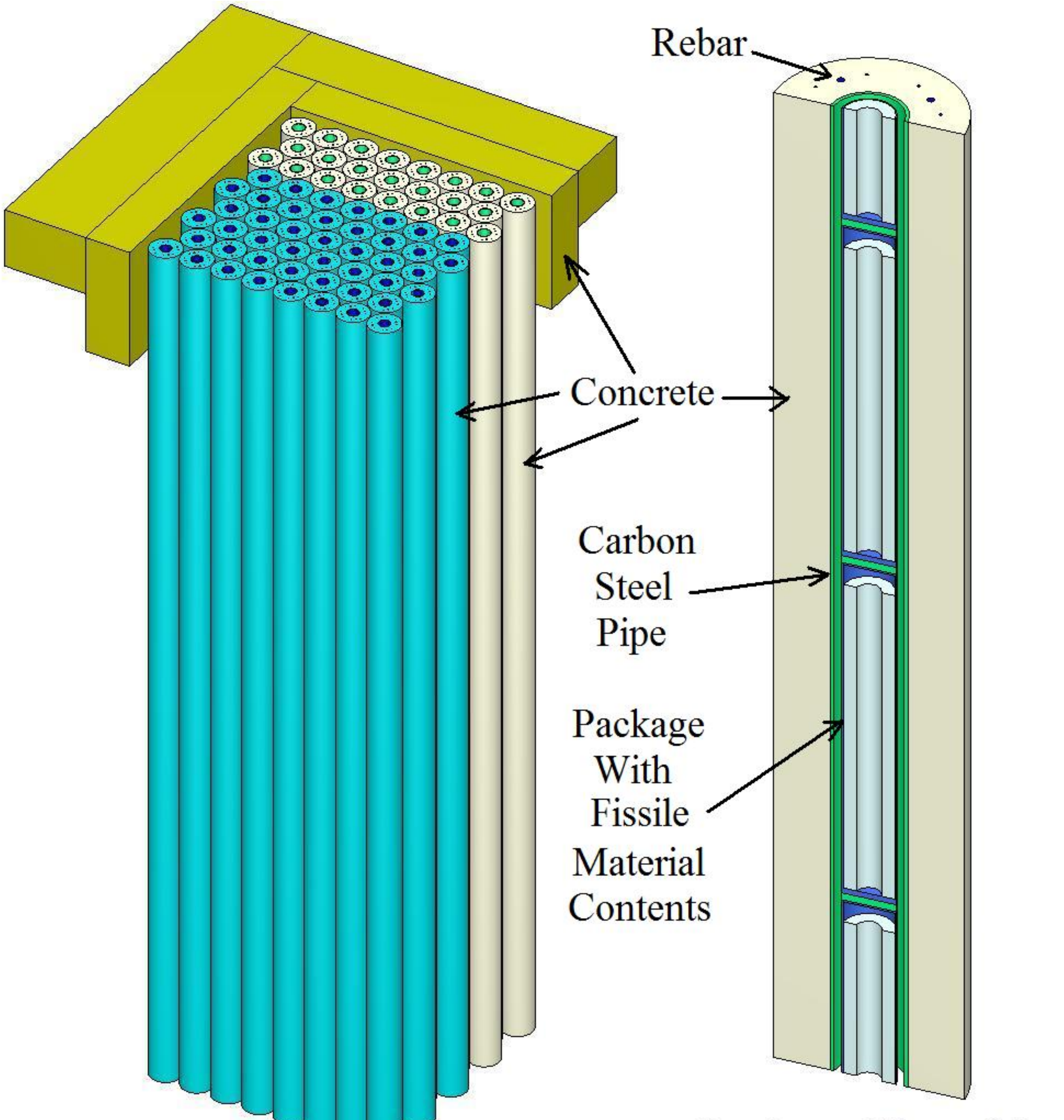

Fig. 1. Application 4—storage well model.

2.1 SENSITIVITY ANALYSIS

As used in this report, sensitivity is a prediction of how a change in nuclear data would affect the system multiplication factor, k_{eff}. The particular implementation in the TSUNAMI tools is that sensitivity is the fractional change in k_{eff} caused by a fractional change in the nuclear data. A sensitivity of -0.1 means that a 1% increase in the nuclear data will cause a 0.1% reduction in k_{eff}.

Sensitivity is calculated by the TSUNAMI-1D and TSUNAMI-3D sequences using the first-order linear perturbation theory method as described in the SCALE manual sections for these sequences. The results are energy-, nuclide-, and reaction-dependent sensitivity profiles. The data are saved in sensitivity data files that usually end with a ".sdf" suffix.

Correct use of the TSUNAMI-3D sequence to obtain sensitivity data can be difficult. Thus it is very important to verify the results by checking that the forward and adjoint k_{eff} values are close, ideally only a few tenths of a percent Δk apart, and by performing direct perturbation calculations.

Direct perturbation calculations involve performing additional criticality calculations in which the number density of a key nuclide is changed some small amount. The resulting k_{eff} values are then used to manually calculate a total sensitivity coefficient to be compared with the total sensitivity coefficient generated by TSUNAMI-1D or TSUNAMI-3D. The TSUNAMI and direct perturbation results should be within 1 or 2 standard deviations of each other. Direct perturbation calculations were performed for the applications and for representative critical experiment models to ensure that the TSUNAMI calculation approach was appropriate for the applications and experiments.

The names of the sensitivity data files for the critical experiments are listed in the TSUNAMI-IP input file in Appendix C.

Figures 2–7 provide sensitivity profiles for the four applications in the SCALE 238-group energy structure. Figure 2 shows the sensitivity of k_{eff} to changes in the ^{233}U fission cross-section data for each application. Figure 3 shows the sensitivity of k_{eff} to the ^{1}H total cross section for each application. Note that the total cross section includes contributions from capture and scattering reactions.

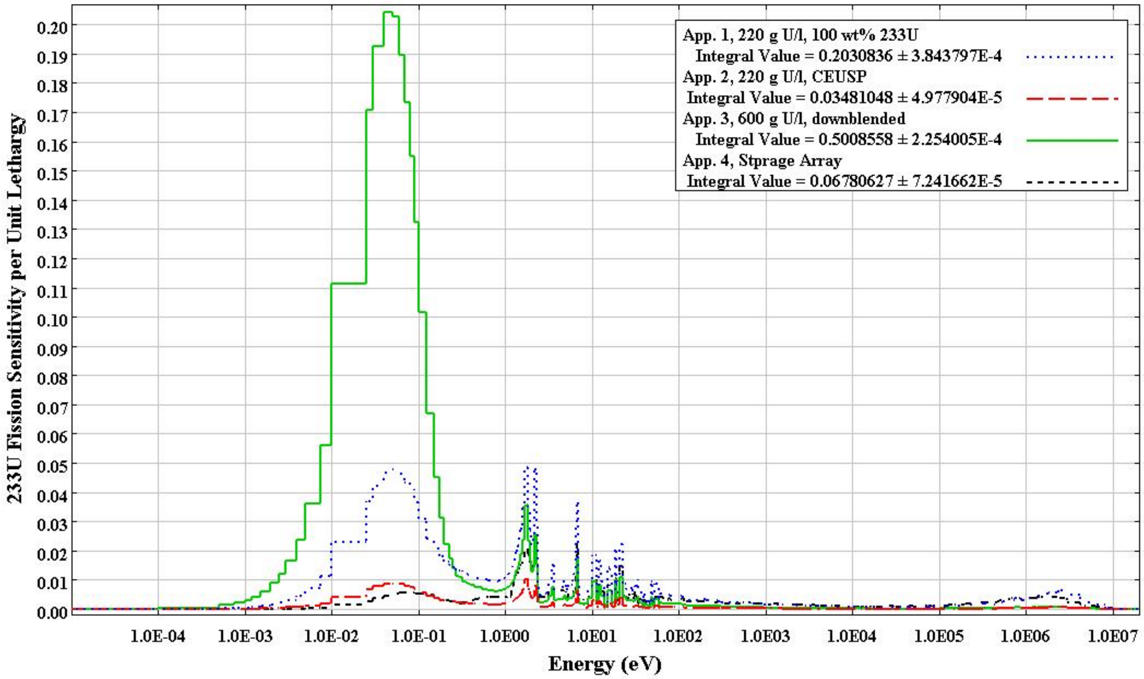

Fig. 2. ^{233}U fission sensitivity for all applications.

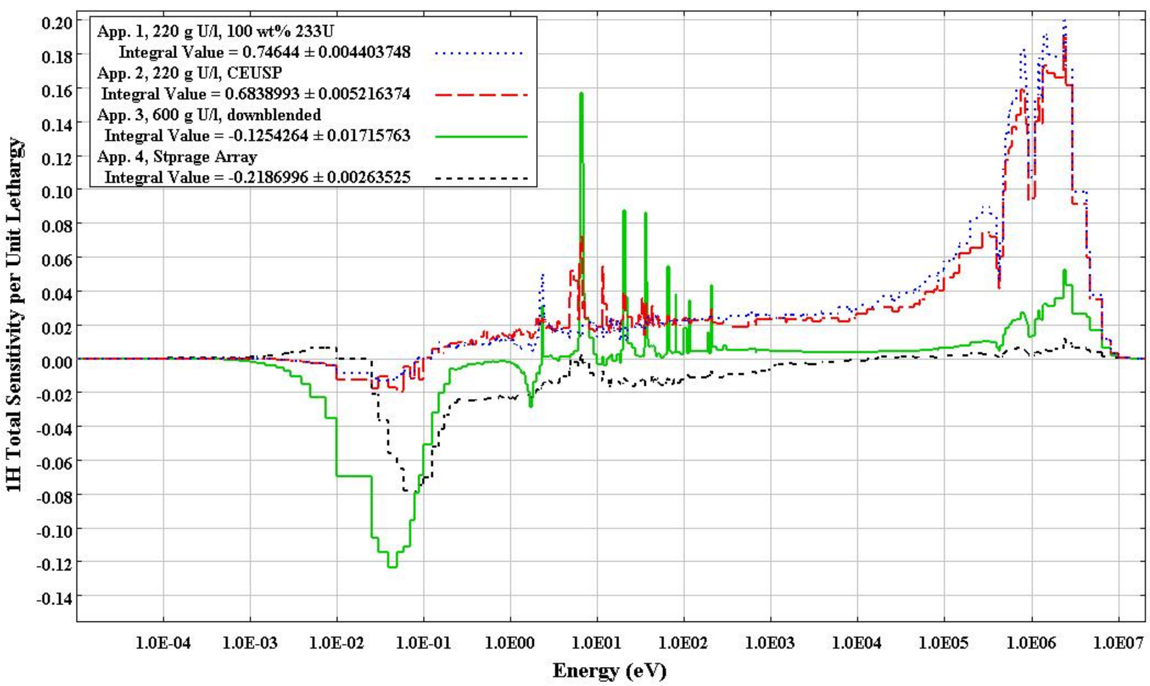

Fig. 3. ^{1}H total sensitivity for all applications.

Figures 4–7 show the sensitivity of k_{eff} to changes in the cross sections for the most important nuclides or mixtures for each of the four applications. From Fig. 7, note the relative importance of the carbon steel and concrete used to model the concrete logs. Keep in mind that similarity, as implemented in the TSUNAMI c_k parameter, also considers the uncertainty in the cross-section data associated with each data point. While the nuclides shown are those that have the largest effect on the application systems, the uncertainty in the nuclear data for some of these nuclides is relatively small. Other nuclides to which k_{eff} is less sensitive may have much larger uncertainties and, hence, are more likely candidates for contributing to the overall bias. Detailed evaluations of similarity and nonsimilarity relative to benchmark experiments are provided in Section 5.

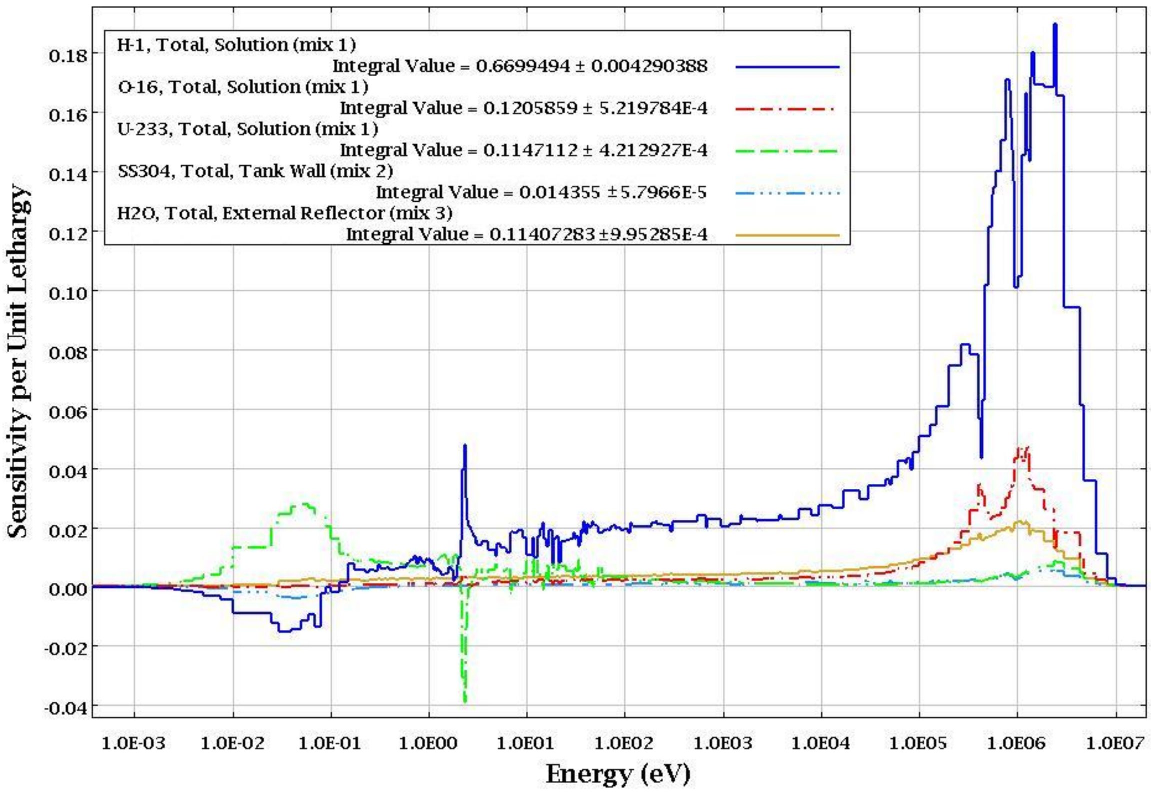

Fig. 4. Major total sensitivities for application 1.

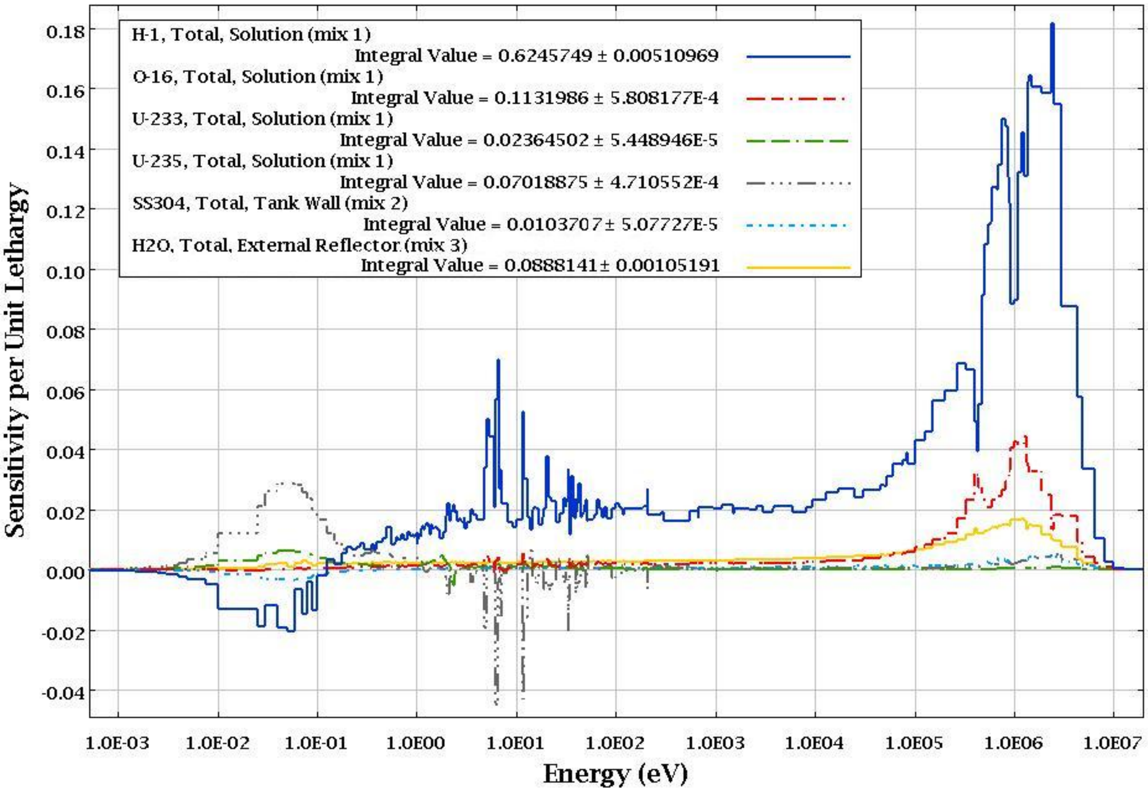

Fig. 5. Major total sensitivities for application 2.

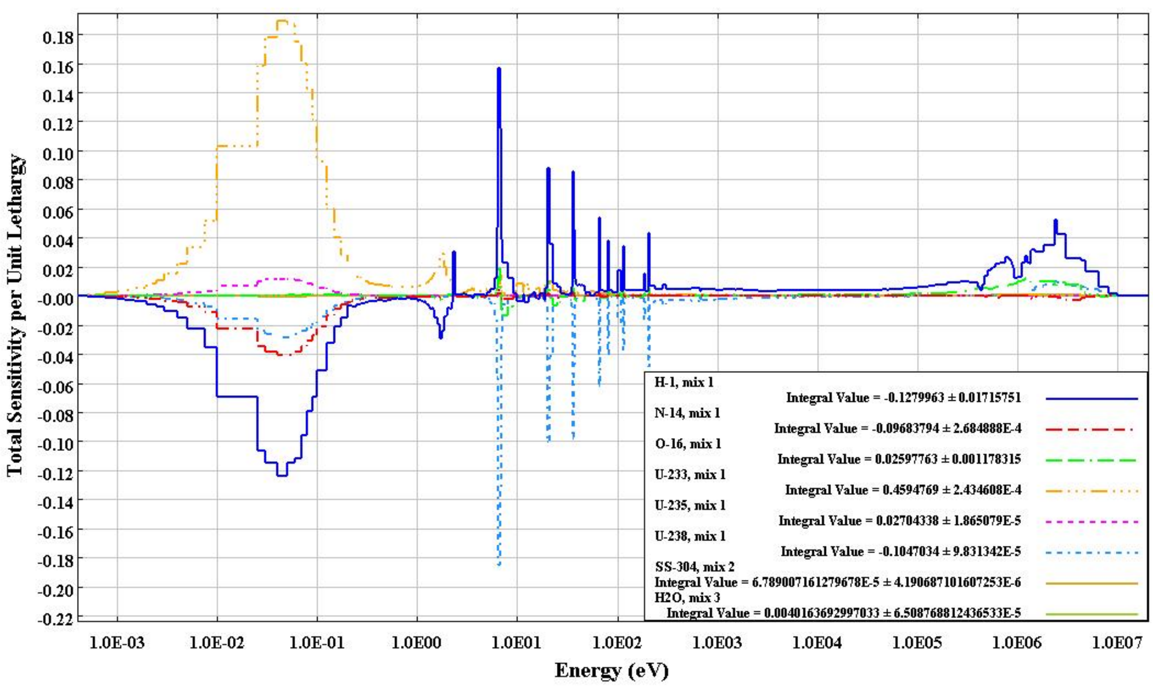

Fig. 6. Major total sensitivities for application 3.

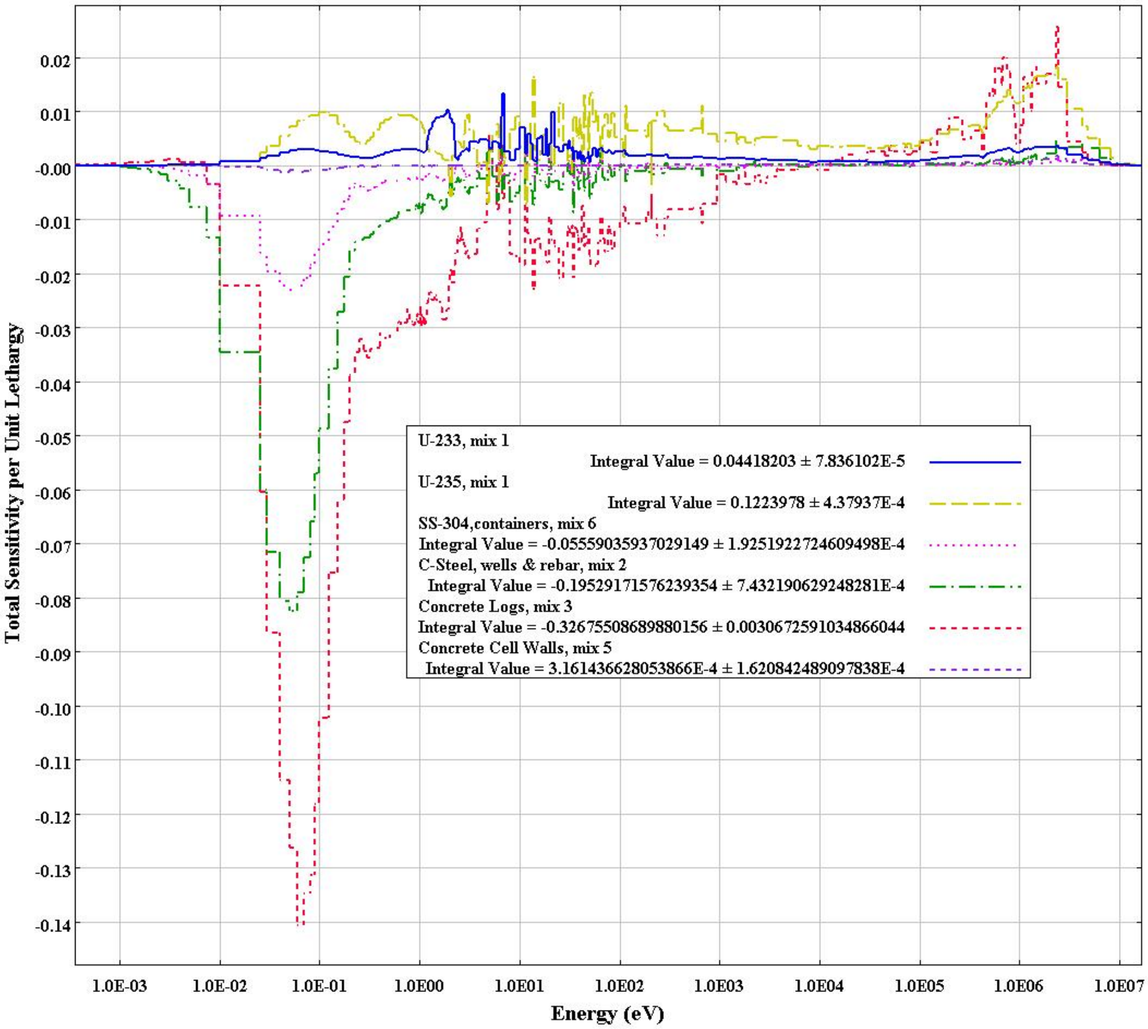

Fig. 7. Major total sensitivities for application 4.

2.2 UNCERTAINTY ANALYSIS

The uncertainty in the computed k_{eff} due to the cross-section-covariance data from the ENDF/B-VI-recommended covariance data set from SCALE 5.1 was determined for each application system considered in this study. The relative standard deviations in k_{eff} ($\Delta k_{eff}/k_{eff}$), in percent, for each of the four systems considered in the analysis are shown in Table 1 along with the relative standard deviations for the top six nuclide-reaction pairs that contribute to the k_{eff} uncertainty. The combined relative uncertainty is calculated by subtracting the sum of the squares of the negative values from the sum of the squares of the positive values and taking the square root of the result. Negative values result from negative correlations in uncertainty data that can exist between reactions for a nuclide or between different nuclides. Negative correlations can be generated due to cross-nuclide calibration practices or when nuclear data from one reaction is used to infer nuclear data for another reaction. In these cases, some of the uncertainty is shared. Thus the combined uncertainty associated with both reactions needs to be reduced to account for this shared uncertainty. In the evaluated application systems, the top six nuclide-reaction pairs produce ~98% of the total cross-section uncertainty. Thus, because these nuclides are the largest contributors to the uncertainty, they are the most likely source of computational biases. Note that applications 1 and 2 exhibit high k_{eff} uncertainties due to uncertainties in the fission spectrum, chi. The use of chi data will be addressed in a subsequent discussion on system similarity.

Table 1. Uncertainty in k_{eff} due to cross-section-covariance data

System	Standard deviation (%)	Top six contributors and standard deviation (%)	
Application 1	0.937	^{233}U chi to ^{233}U chi	0.819
		^{1}H elastic to ^{1}H elastic	0.320
		^{16}O elastic to ^{16}O elastic	0.194
		^{233}U n,γ to ^{233}U n,γ	0.174
		^{233}U nubar to ^{233}U nubar	0.145
		^{233}U fission to ^{233}U fission	0.117
Application 2	0.752	^{235}U chi to ^{235}U chi	0.578
		^{1}H elastic to ^{1}H elastic	0.286
		^{235}U nubar to ^{235}U nubar	0.253
		^{235}U n,γ to ^{235}U n,γ	0.180
		^{16}O elastic to ^{16}O elastic	0.180
		^{233}U chi to ^{233}U chi	0.098
Application 3	0.515	^{14}N n,p to ^{14}N n,p	0.346
		^{238}U n,γ to ^{238}U n,γ	0.233
		^{233}U fission to ^{233}U fission	0.173
		^{1}H n,γ to ^{1}H n,γ	0.145
		^{233}U chi to ^{233}U chi	0.136
		^{233}U nubar to ^{233}U nubar	0.135
Application 4	1.354	^{56}Fe n,γ to ^{56}Fe n,γ	1.151
		Ca n,γ to Ca n,γ	0.485
		^{56}Fe elastic to ^{56}Fe elastic	0.266
		^{235}U n,γ to ^{235}U n,γ	0.234
		^{235}U fission to ^{235}U fission	0.222
		^{235}U nubar to ^{235}U nubar	0.196

It is important to note that the top contributor to uncertainty is not necessarily the nuclide to which k_{eff} is most sensitive. The uncertainty calculation considers the sensitivity of the system, on an energy-dependent basis as well as the uncertainty in the cross section, also on an energy-dependent basis. The uncertainty calculations consider not only the uncertainty at specific energies, but also the covariance, or shared uncertainty, in ranges of energies for the same nuclide and reaction, between reactions of the same nuclide, and between different nuclides.

Uncertainty data for some of the more significant nuclide-reaction pairs are shown in Figs. 8–10 in the SCALE 44-group energy structure. Note that uncertainty calculations are performed within the TSUNAMI codes by first collapsing the 238-group sensitivity to the 44-group structure, then performing the necessary mathematical operations. The reader may also use the SCALE Javapeño program[5] to view three-dimensional plots of the covariance data for a specific nuclide-reaction pair. Figure 11 shows the covariance data for the ^{233}U (n,γ) reaction.

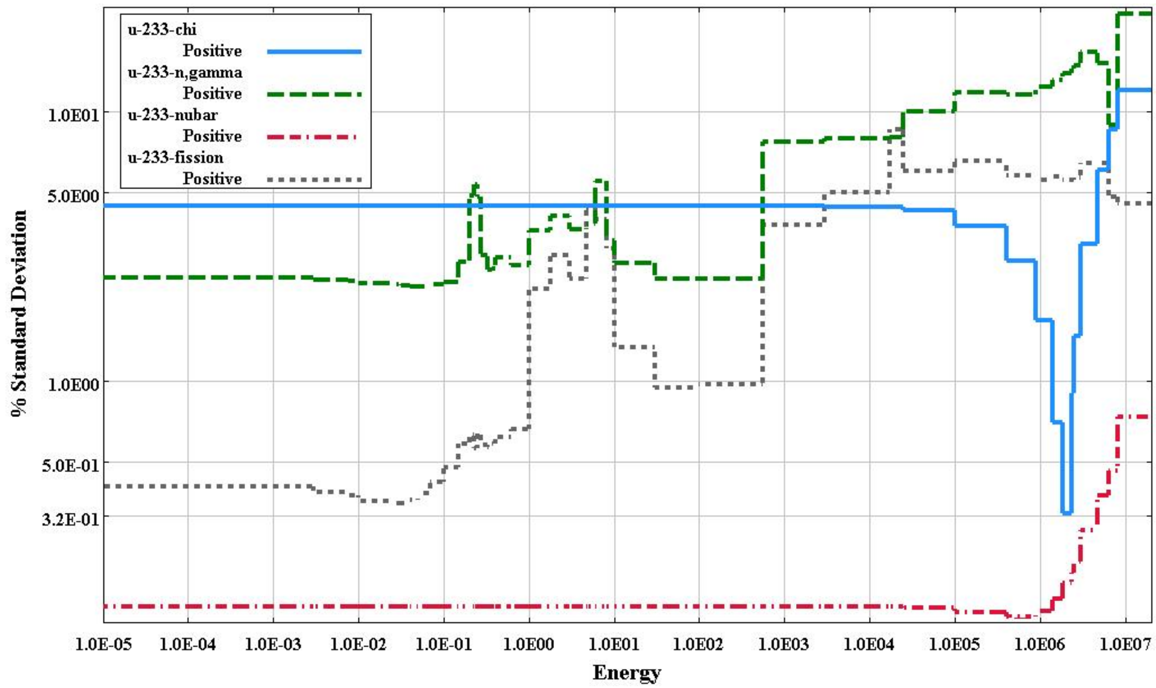

Fig. 8. Most significant nuclear data uncertainties for ^{233}U.

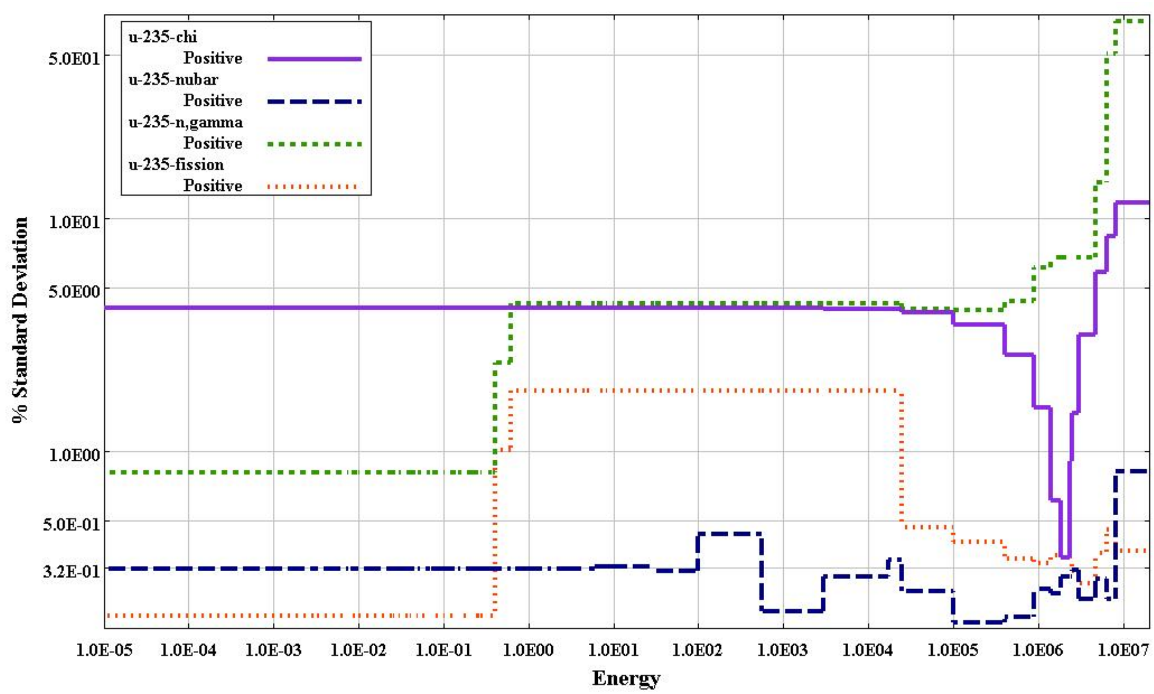

Fig. 9. Most significant nuclear data uncertainties for ^{235}U.

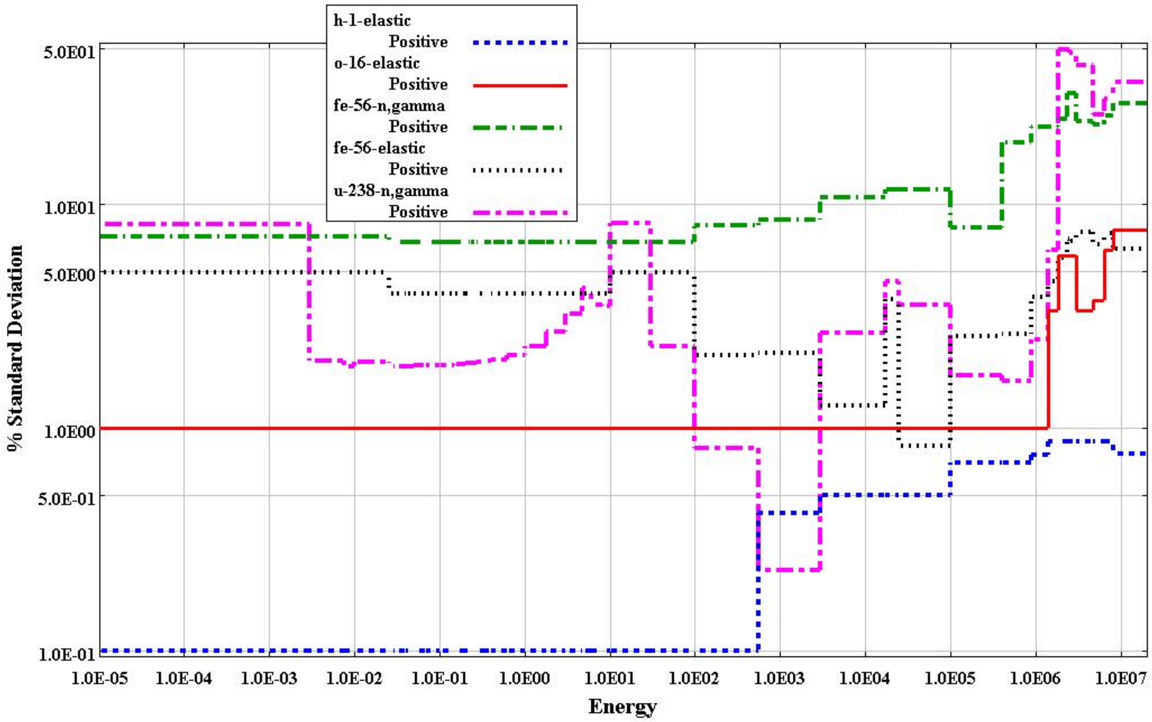

Fig. 10. Most significant nuclear data uncertainties for ^{1}H, ^{16}O, ^{56}Fe, and ^{238}U.

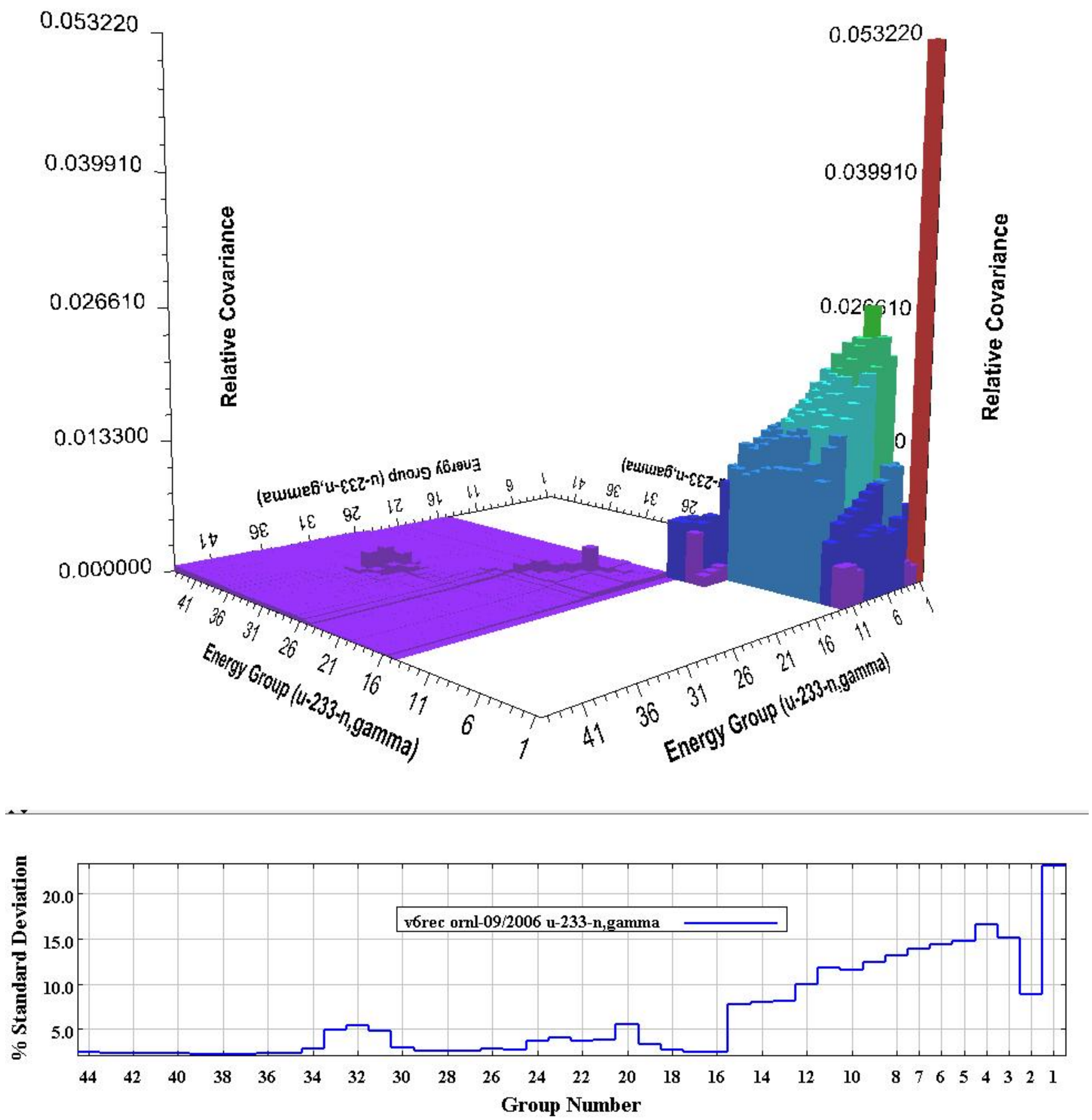

Fig. 11. Three-dimensional plot of covariance data for the ^{233}U (n,γ) reaction.

3. CRITICAL EXPERIMENT DATABASE

Criticality safety validation requires a range of valid critical benchmark experiments that span the important parameters of the systems and operations of interest. The benchmark descriptions for all the experiments used in this validation study are provided in the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* (IHECSBE),[6] which is published yearly as part of the International Criticality Safety Benchmark Evaluation Program. The initial experimental database used in this work was derived from 101 individual evaluations from the IHECSBE, containing a total of 672 critical configurations. The initial prescreening validation set included 232 ^{233}U, 28 mixed U+Pu, 4 intermediate-enrichment-uranium (IEU), 153 high-enrichment-uranium (HEU), and 255 low-enrichment-uranium (LEU) critical configurations. This wide range of critical benchmarks was included in the initial screening to maximize the identification of critical configurations that are similar to the four applications described in Section 2. of this report. Each of the four applications was compared to all 672 critical configurations.

The primary fissile components represented in the applications are ^{233}U and ^{235}U. The IHECSBE evaluations documenting the critical benchmark configurations and the number of configurations modeled are listed in Table 2. During processing, the material will be dissolved prior to down blending, which involves the addition of significant quantities of hydrogen to the fissile material. This area of applicability (AOA) should be covered by the ^{233}U solution thermal set of benchmarks. The ^{233}U is stored in many forms: ^{233}U metal, uranium oxides, uranium fluorides, different combinations of ^{233}U and ^{235}U, and as CEUSP material. To cover the range of other materials, including enriched ^{235}U mixed with ^{233}U, 440 critical configurations were included that contain no ^{233}U.

The IHECSBE should be consulted for detailed descriptions of the critical configurations considered for use in this validation study.

The following list shows the relationship between the IHECSBE identifiers used in this report and the full identifiers used in the handbook.

hct = HEU-COMP-THERM
hmf = HEU-MET-FAST
hmt = HEU-MET-THERM
hst = HEU-SOL-THERM
imf = IEU-MET-FAST
mci = MIX-COMP-INTER
mcf = MIX-COMP-FAST
mcm = MIX-COMP-MIXED
mmf = MIX-MET-FAST
lct = LEU-COMP-THERM
lst = LEU SOL-THERM
uct = U233-COMP-THERM
umf = U233-MET-FAST
usi = U233-SOL-INTER
ust = U233-SOL-THERM

TSUNAMI-1D or TSUNAMI-3D was used to generate 238-group sensitivity data for each of the experiments identified in the section.

Table 2. Summary of IHECSBE critical configurations considered in initial screening

IHECSBE eval. ID	Exps.	IHECSBE eval. ID	Exps.	IHECSBE eval. ID	Exps.
uct001	3	hct010	15	lct009	26
umf001	1	hct011	3	lct010	30
umf002	2	hct012	2	lct012	10
umf003	2	hct013	2	lct017	29
umf004	2	hct014	2	lct018	1
umf005	2	hmf030	1	lct019	3
umf006	1	hmt006	23	lct020	7
usi001	33	hmt025	2	lct021	6
ust001	5	hst001	10	lct022	7
ust002	17	hst005	5	lct023	6
ust003	10	hst006	4	lct024	2
ust004	8	hst007	17	lct025	4
ust005	2	hst009	4	lct026	4
ust006	25	hst010	4	lct032	9
ust008	1	hst011	2	lct040	3
ust009	4	hst012	1	lct042	7
ust012	8	hst013	1	lct049	18
ust013	21	hst014	1	lct079	10
ust014	16	hst015	2	lst001	1
ust015	31	hst016	1	lst003	9
ust016	31	hst017	3	lst004	7
ust017	7	hst018	3	lst005	3
^{233}U total	232	hst019	1	lst006	5
		hst025	4	lst007	5
mcf001	1	hst027	1	lst008	4
mci005	1	hst028	9	lst009	3
mcm001	19	hst029	1	lst010	4
mmf008	7	hst030	2	lst016	7
Pu & U mixed total	28	hst032	1	lst017	6
		hst033	9	lst018	5
imf003	1	hst035	3	lst019	6
imf004	1	hst037	3	lst020	4
imf005	1	hst042	8	lst021	4
imf006	1	hst043	3	**LEU total**	255
IEU total	4	**HEU total**	153		
		Total evaluations	101		
		Total critical configurations	672		

4. SIMILARITY OF CRITICAL EXPERIMENTS

Effectively all nuclear data, whether pointwise or multigroup, has errors. The errors result from uncertainties in the experimental setup used to measure the nuclear data; the conduct of the experiment; collection, interpretation, adjustment, and reporting of the measurements; evaluation of the measurement results to produce neutron-energy-dependent nuclear data libraries; and, for multigroup libraries, the techniques used to collapse the data to the desired group structure and to incorporate the unresolved and resolved resonances. When using robust three-dimensional neutron transport techniques to predict the criticality of a system, the most likely sources of computational bias are errors in the nuclear data. In order to quantify the effect of these errors on computed results, efforts have been made by the experimentalists measuring the data and the nuclear data evaluators to quantify the uncertainty on the nuclear data values. Where it exists, this uncertainty information is contained in the evaluated nuclear data files. Nuclear data uncertainties have been processed into a 44-energy-group format[7] and are contained in the cross-section covariance data files distributed with SCALE. Given that nuclear data errors do exist, each error contributes toward an overall computational bias. The individual biases may be positive, resulting in a high calculated k_{eff} value, or negative, resulting in a low calculated k_{eff} value. The overall bias is the simple sum of the many biases. Providing a quantified estimate of this overall bias is the primary goal of validation.

If the experiments and the safety application have the same k_{eff} sensitivity to the same nuclear data, the experiments and the application will have the same k_{eff} bias. However, where materials are present in the application and not in the experiment, no bias can be determined for the materials not present in the experiments. Where materials are present in the experiments and not in the application, the bias calculated from the experiments includes some contribution from the extra materials. If the bias contribution of the extra materials is positive, the calculated overall bias will be nonconservative. Thus, care must be taken to account for differences in material compositions as dissimilarities that increase the uncertainty in the bias to ensure that the upper subcritical limits are sufficient to ensure safety.

It is not enough to simply have the same materials in both the experiments and the application. For example, if an experiment is ten times more sensitive to the boron capture cross sections than is the application, the overall bias calculated from the experiments will have ten times too much contribution from the boron capture cross section errors. This is not necessarily conservative. If the boron capture cross section is too low, the calculated k_{eff} value would be too high, and the bias associated with the boron capture would be positive and ten times too large. Furthermore, this nonconservative contribution may be obscured by other compensating biases. The correct overall bias is then obtained if the experiments and the application contain the same materials and have similar k_{eff} sensitivities to these materials. The TSUNAMI-IP module can provide application-specific estimates of the impact of nuclear data uncertainties on the k_{eff} value calculated for the application. Examples of such data are provided in Section 2.

Identification of critical experiments that are sufficiently similar to a nuclear criticality safety application can be problematic. Fortunately, some nuclear data is well known (i.e., has a low uncertainty) and criticality safety calculations frequently have low sensitivity to some of the materials present in the calculation. The TSUNAMI-IP c_k parameter is an integral similarity parameter that considers both of these effects. Similarity is affected very little by nuclides that have very low uncertainties and by nuclides to which the system k_{eff} value has little sensitivity. If the system is not sensitive to the presence of a nuclide, then a small error in the cross-section data for that nuclide will not contribute appreciably to the system bias. If the nuclear data have relatively low uncertainties, then the bias associated with those nuclear data is likely small.

A modified form of the c_k parameter was used in the work presented in this report. This parameter, referred to as c_r, excludes consideration of the fission spectrum (chi) sensitivities/uncertainties when determining similarity. Based on recent examinations by ORNL staff, as bolstered by the findings of the OECD/NEA Working Party on International Data Evaluation Co-operation (WPEC) Subgroup 26, the fission spectrum sensitivities computed using the classical approach implemented in TSUNAMI do not consider the normalization of the fission spectrum to unity when computing group-wise chi sensitivities. Fission spectrum data are different from the other nuclear data because, by definition, the fission spectrum for a given nuclide must integrate to one. The classical approach to calculate chi sensitivity coefficients ignores this normalization such that the sensitivity to each group is computed independent of the offsetting effects that would be observed in preserving the normalization. In uncertainty calculations, the chi covariance data generated for SCALE does account for the anti-correlations in the data; if one value is increased, others must be decreased. However, it has not been proven that this covariance treatment is always equivalent to preserving the normalization with the sensitivity data. Increasing chi in one energy group without adjusting the others is equivalent to adjusting nu-bar, which is already considered separately in the calculation of the nu-bar sensitivities. Errors in the shape of the chi distribution could contribute toward the system bias, but the current treatment in TSUNAMI-IP exaggerates the importance of chi, especially for the application systems considered in this study. Due to compensating adjustments, small variations in the shape of the chi distribution should have little effect on k_{eff}. Differences in the uncertainty in k_{eff} for a single system based on constrained or unconstrained chi are small due to the anti-correlations present in the cross-section-covariance data for chi. The TSUNAMI techniques for fission spectrum sensitivities will be modified to implement the preferred constrained calculation in SCALE 6.

The c_r parameter is calculated by TSUNAMI-IP by including the keywords "*cr*" and "*cr_long*" in the parameter block and by including "*chi*" in the exclusions block.

The input file for the TSUNAMI-IP calculation for application 1 is shown in Appendix C. The *covariance* input block, which begins with *read covariance* and terminates with *end covariance*, in the application 1 input file includes nuclide-reaction pair default values to use for correcting the cross-section covariance data. The format for the data is described in the TSUNAMI-IP documentation.[3] The nuclide-reaction pairs that needed individual corrections were identified by reviewing the warning messages in the output generated using an earlier version of the input file. The values specified in the application 1 input file were selected by using the Javapeño graphical data display program to examine energy-dependent trends in uncertainty data. Reasonable values were selected based on energy-dependent trends near the energy group or groups that were being modified by TSUNAMI-IP. For example, energy group 10 of the ^{62}Ni (n,α) reaction had an uncertainty value of 1800% in the cross-section covariance data file. This large uncertainty appears to be caused by cross sections for this "threshold" reaction dropping off to near zero within energy group 10. Energy group 9 has an uncertainty value that is nearly 600%, and energy group 11 has an uncertainty of zero. It was decided to use the 600% value for group 10. This was accomplished by specifying a 6.0 fractional uncertainty value for the ^{62}Ni (n,α) reaction in the covariance data block.

The input file also includes input to correct a code discrepancy related to removing excessively large values in threshold reaction uncertainties from the covariance data. The *cov_fix* parameter of TSUNAMI-IP triggers the use of user-specified uncertainties whenever actual covariance data is excessively large or is not provided in the covariance data file. During this work, it was discovered that TSUNAMI-IP was not properly correcting large values in the ^{238}U fission covariance data. The warning messages provided by TSUNAMI-IP indicated that all of the ^{238}U fission covariance data were replaced with the default value specified by parameter *udcov*. The proper corrections should have been to replace the data for one energy group, which had a large uncertainty value, and to use the user-specified data for 2 energy groups, in which no covariance data were provided, leaving the remaining 41 energy groups unmodified. The work-around for this problem was to specify the parameter "*use_icov*" and then to provide covariance data for ^{238}U fission in the read covariance data block. This work-around is shown in the TSUNAMI-IP input file in Appendix C. The SCALE 6 version of TSUNAMI-IP will correct this discrepancy.

TSUNAMI-IP calculations compared each of the 672 critical experiments to each application. Sections 4.1 through 4.4 discuss the similarity results for each of the four applications.

4.1 APPLICATION 1—220 g U (100 wt % ^{233}U)/LITER SPHERE

Table 3 and Fig. 12 show the distribution of c_r values calculated for the 672 critical configurations examined. Analysis of the similarity results follows Fig. 12. The analysis was initially performed using only experiments through experiment number 282. HEU, IEU, and LEU experiments were added in an attempt to identify additional critical experiments that could be used for validation of the applications. Descriptions of each of the critical experiments and their experiment numbers are provided in Appendix B. Experiment numbers 283 and higher include the additional HEU, IEU, and LEU critical experiments.

Table 3. Application 1 similarity summary

Similarity index range	Number of experiments	Applicability
$c_r < 0.1$	43	Low
$0.1 \leq c_r < 0.2$	80	Low
$0.2 \leq c_r < 0.3$	136	Low
$0.3 \leq c_r < 0.4$	140	Low
$0.4 \leq c_r < 0.5$	63	Low
$0.5 \leq c_r < 0.6$	30	Low
$0.6 \leq c_r < 0.7$	14	Low
$0.7 \leq c_r < 0.8$	7	Low
$0.8 \leq c_r < 0.9$	17	Marginal
$0.9 \leq c_r < 0.95$	60	Applicable
$0.95 \leq c_r < 1.0$	82	High
All	672	

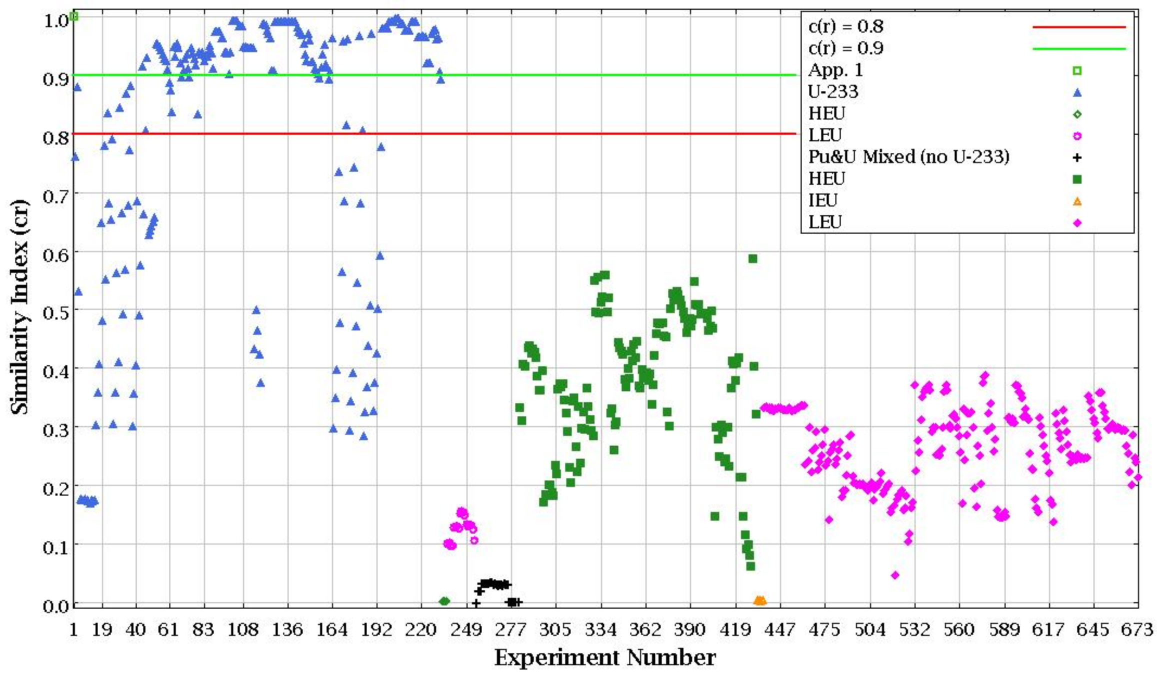

Fig. 12. Application 1 similarity index values (c_r) for 672 critical experiments.

The similarity results for application 1 demonstrate that 82 of the experiments, those yielding c_r values above 0.95, are considered highly similar and 60 additional experiments yielded c_r values between 0.9 and 0.95 and are considered similar. All 142 of the similar and highly similar experiments are ^{233}U experiments and are recommended for use in validation for application 1. An additional 17 critical configurations are considered to be only marginally similar ($0.9 > c_r > 0.8$) to application 1. Considering that there are 144 configurations that are highly or adequately similar to application 1, use of the marginally similar configurations is not recommended. A list of critical experiments ordered by decreasing similarity is provided for each application in Appendix D.

The TSUNAMI-IP output for this application includes results from a detailed calculation of the c_r value of the application compared with itself. This edit indicates that the most important contributors to c_r for this application are the ^{1}H elastic scattering, ^{16}O elastic scattering, ^{233}U n,gamma capture, ^{233}U nu-bar, and ^{233}U fission reactions.

The highest c_r value, 0.995, was for experiment U233-SOL-THERM-016, case 10. Figures 13-17 show the sensitivity profiles for the four reactions identified above for both the application and the experiment. Results from U233-SOL-THERM-006, case 10 are also provided. This experiment yielded the lowest c_r value that was greater than 0.9.

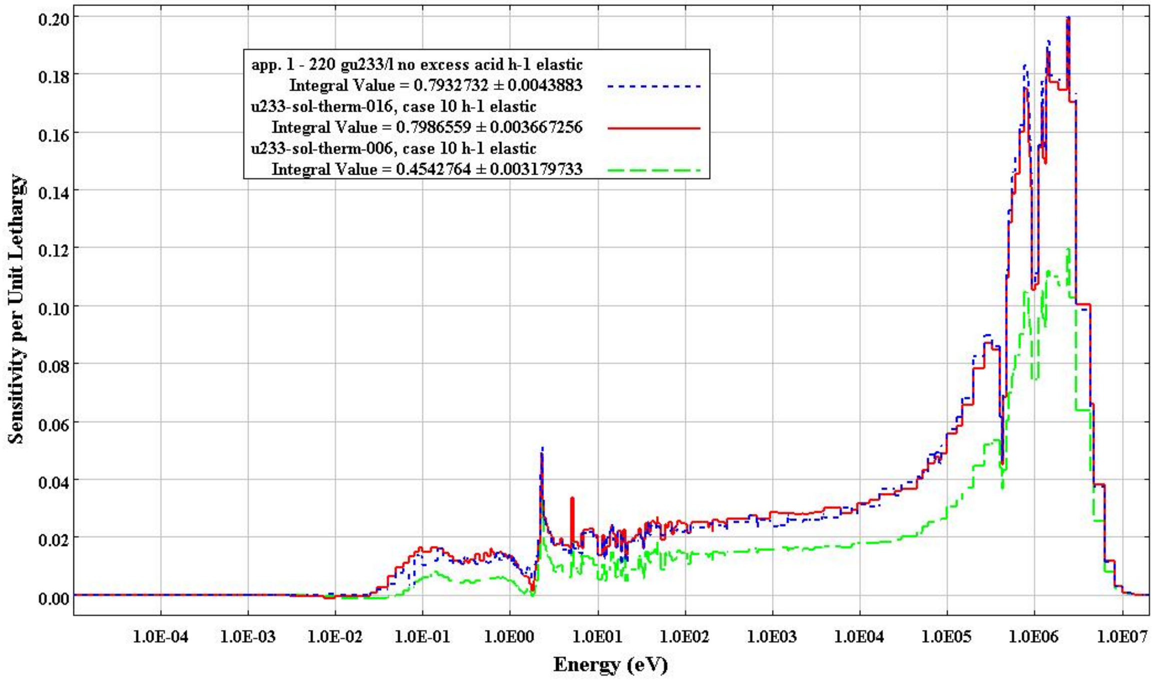

Fig. 13. ^{1}H elastic scattering sensitivity profiles for application 1 and experiments UST-016, case 10 and UST-006, case 10.

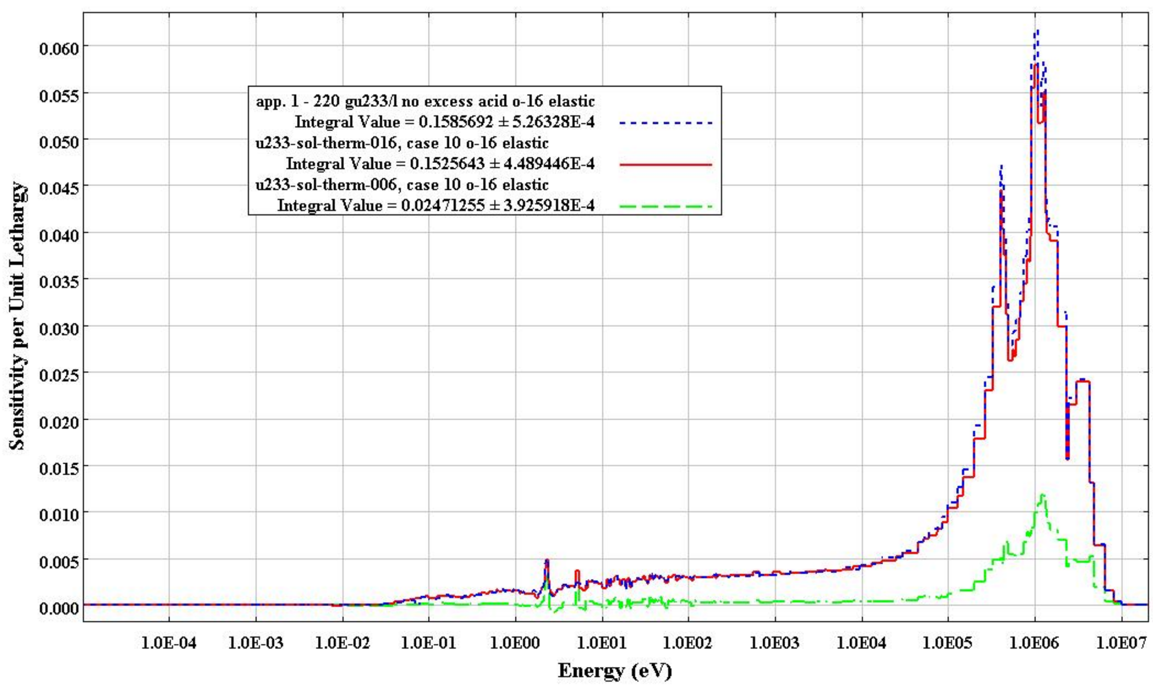

Fig. 14. ^{16}O elastic scattering sensitivity profiles for application 1 and experiments UST-016, case 10 and UST-006, case 10.

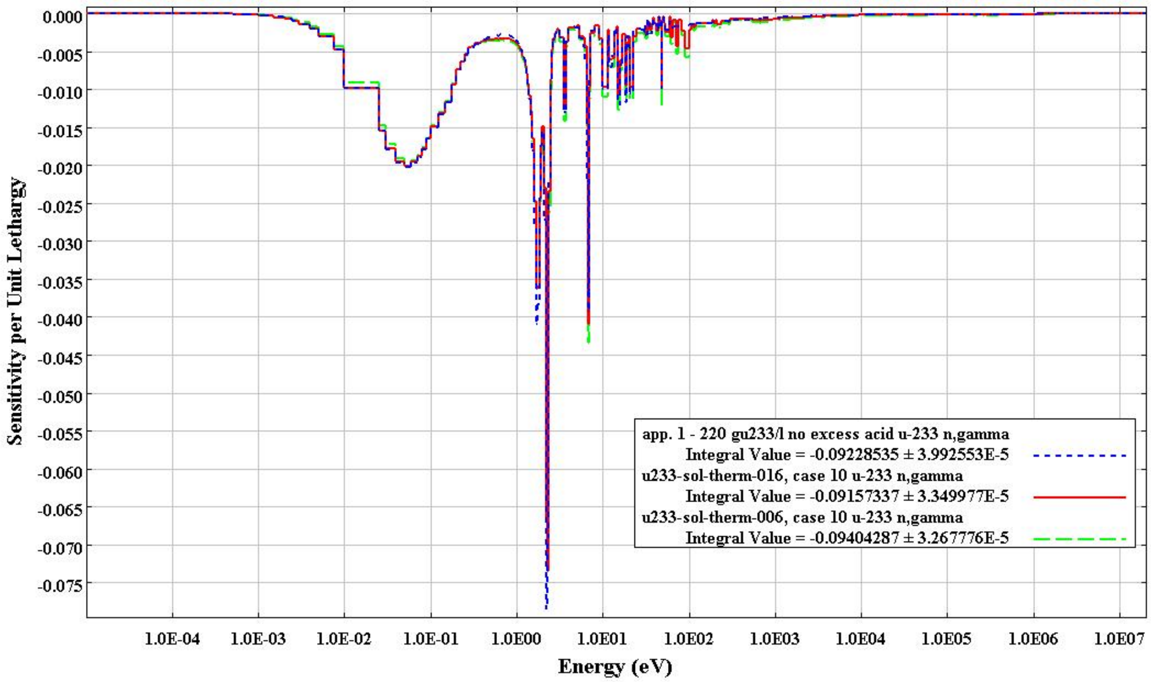

Fig. 15. ^{233}**U (n,γ) reaction sensitivity profiles for application 1 and experiments UST-016, case 10 and UST-006, case 10.**

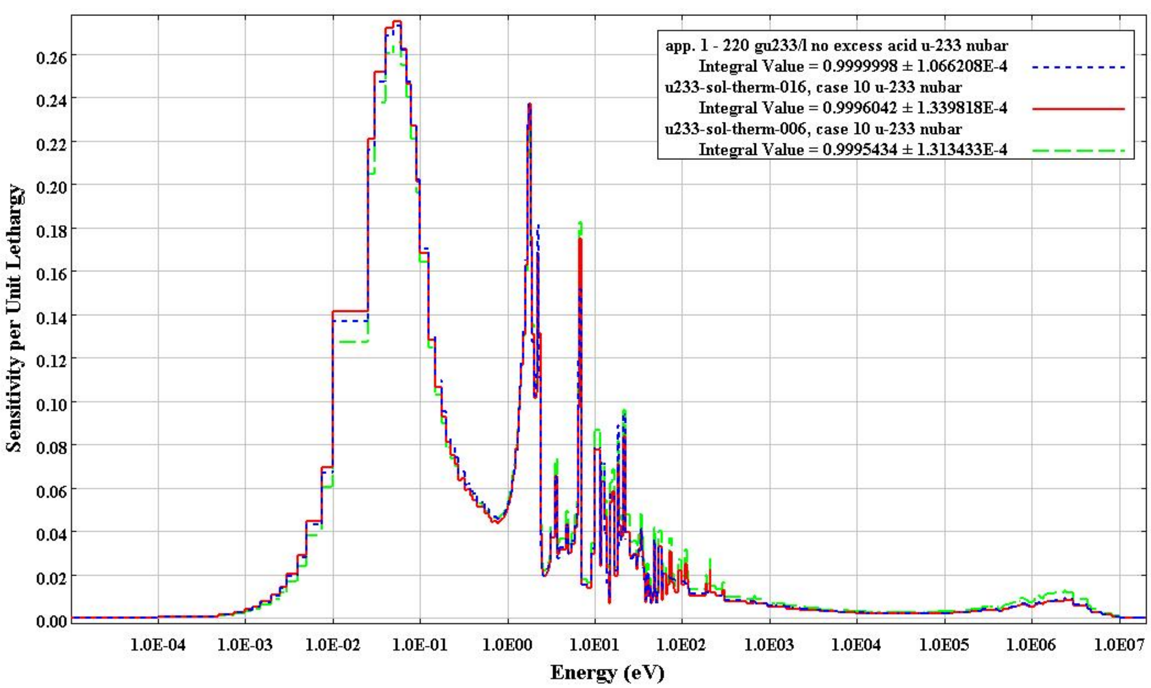

Fig. 16. ^{233}**U Nu-bar sensitivity profiles for application 1 and experiments UST-016, case 10 and UST-006, case 10.**

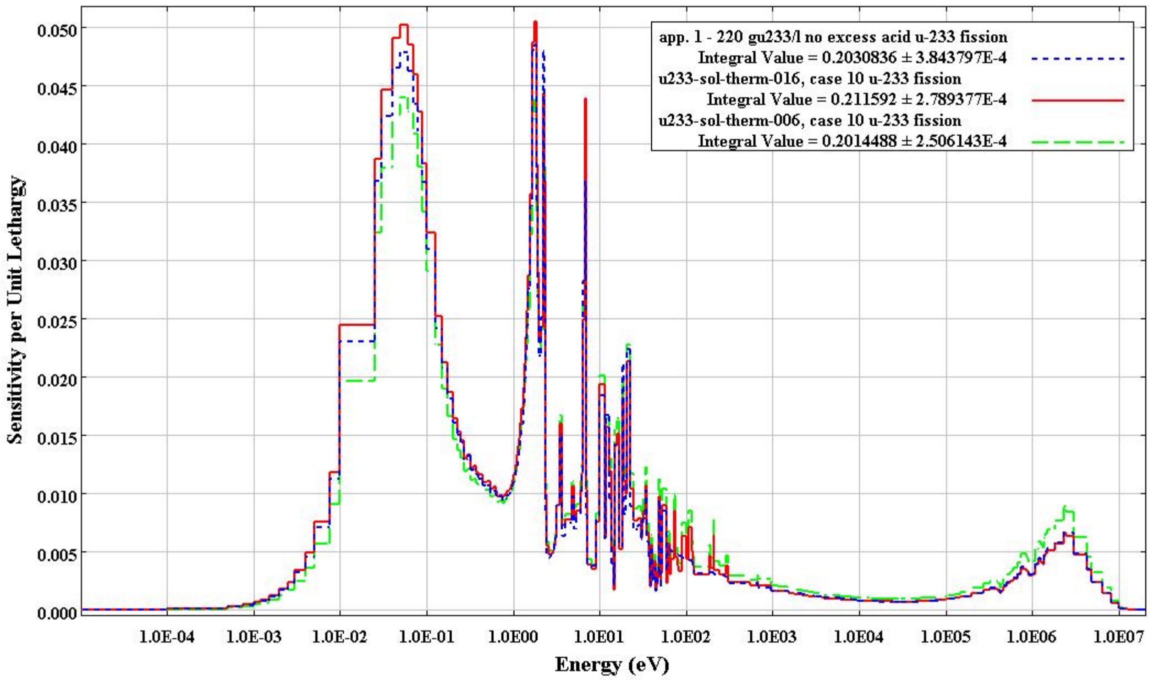

Fig. 17. ^{233}U fission reaction sensitivity profiles for application 1 and experiments UST-016, case 10 and UST-006, case 10.

One method of quantifying the contribution of each nuclide reaction towards applicability is to examine the extended c_r edit generated when the application is compared to itself. By definition, the c_r value of a system compared to itself is 1.0 since every energy-dependent sensitivity coefficient exactly matches between the application and the "experiment," which is the application itself. The extended c_r edit shows the contributions of each nuclide and reaction to this perfect similarity, ranked in descending order. This edit provides a guide to which nuclides and reactions are important to validate the application in terms of the uncertainty-weighted sensitivities. Table 4 shows the top contributors toward similarity for application 1 compared to itself. The data show some of the characteristics of the ideal critical experiment for validation of application 1.

Table 4. Top contributors to similarity (c_r) for application 1 compared to itself

Covariance matrix				Contribution to similarity (c_r)
Nuclide reaction with nuclide reaction				
^{1}H	Elastic	^{1}H	elastic	0.494
^{16}O	Elastic	^{16}O	elastic	0.181
^{233}U	n,γ	^{233}U	n,γ	0.145
^{233}U	nu-bar	^{233}U	nu-bar	0.101
^{233}U	Fission	^{233}U	fission	0.066

Tables 5 and 6 show the top contributors to similarity for the application compared to the experiments with the highest c_r value and the lowest "similar" c_r value. Differences between the partial c_r values shown in Table 4 for the application compared to itself and in Tables 5 and 6 for the application compared to each of these experiments are quantified with the Δc_r values in Tables 5 and 6. Any non-zero Δc_r indicates differences in the sensitivities between the application and the experiment, which will lead to decreased c_r values. A negative Δc_r value indicates that the sensitivity of the experiment is generally lower than that of the application, especially in energy regions where the uncertainty in the cross section is higher. A negative Δc_r value leads directly to reduced values of c_r. A positive Δc_r value indicates that the sensitivity of the experiment is generally greater than that of the application, especially in energy regions where the cross section uncertainty is greater (see Figs. 8–11). These values also lead to a reduction in c_r by increasing the overall uncertainty in k_{eff} for the experiment, which increases the denominator of the c_r equation, resulting in a smaller value of c_r. The Δc_r values identify the nuclide-reaction pairs that are limiting similarity for the two experiments. Note that for experiment UST-006 case 10 the Δc_r values with the largest magnitude are for ^{1}H elastic scattering and ^{16}O elastic scattering. Both of these values are negative, and the sensitivities of the experiments are much lower than those of the application, as shown in Figs. 13 and 14, respectively. The Δc_r for the ^{233}U (n,γ) reaction has a small positive value, due to the experiment sensitivity slightly exceeding that of the application at intermediate energies where the cross-section uncertainties are higher, as shown in Fig. 11.

Table 5. Top contributors to similarity (c_r) for application 1 compared to UST-016, case 10

Covariance matrix: Nuclide reaction with nuclide reaction				Contribution to similarity (c_r)	Change from optimum similarity (Δc_r[a])
^{1}H	elastic	^{1}H	elastic	0.495	0.001
^{16}O	elastic	^{16}O	elastic	0.177	-0.004
^{233}U	n,γ	^{233}U	n,γ	0.146	0.000
^{233}U	nu-bar	^{233}U	nu-bar	0.102	0.002
^{233}U	fission	^{233}U	fission	0.069	0.002

[a] $\Delta c_r \equiv c_{r,experiment} - c_{r,application}$

Table 6. Top contributors to similarity (c_r) for application 1 compared to UST-006, case 10

Covariance matrix: Nuclide reaction with nuclide reaction				Contribution to similarity (c_r)	Change from optimum similarity (Δc_r)
^{1}H	elastic	^{1}H	elastic	0.400	-0.094
^{16}O	elastic	^{16}O	elastic	0.046	-0.135
^{233}U	n,γ	^{233}U	n,γ	0.199	0.054
^{233}U	nu-bar	^{233}U	nu-bar	0.137	0.036
^{233}U	fission	^{233}U	fission	0.104	0.037

The TSUNAMI-IP output may be used in this way to identify why an experiment is not similar to an application and what variations to the experiment might identify experiments that are more similar to the target application.

4.2 APPLICATION 2—300 g U (WITH CEUSP U ISOTOPICS)/LITER SPHERE

Table 7 and Fig. 18 show the distribution of c_r values calculated for the 672 critical configurations examined. Analysis of the similarity results follows Fig. 18.

Table 7. Application 2 similarity summary

Similarity index range	Number of experiments	Applicability
$c_r < 0.1$	43	Low
$0.1 \leq c_r < 0.2$	18	Low
$0.2 \leq c_r < 0.3$	21	Low
$0.3 \leq c_r < 0.4$	19	Low
$0.4 \leq c_r < 0.5$	32	Low
$0.5 \leq c_r < 0.6$	115	Low
$0.6 \leq c_r < 0.7$	158	Low
$0.7 \leq c_r < 0.8$	150	Low
$0.8 \leq c_r < 0.9$	48	Marginal
$0.9 \leq c_r < 0.95$	42	Applicable
$0.95 \leq c_r < 1.0$	26	High
All	672	

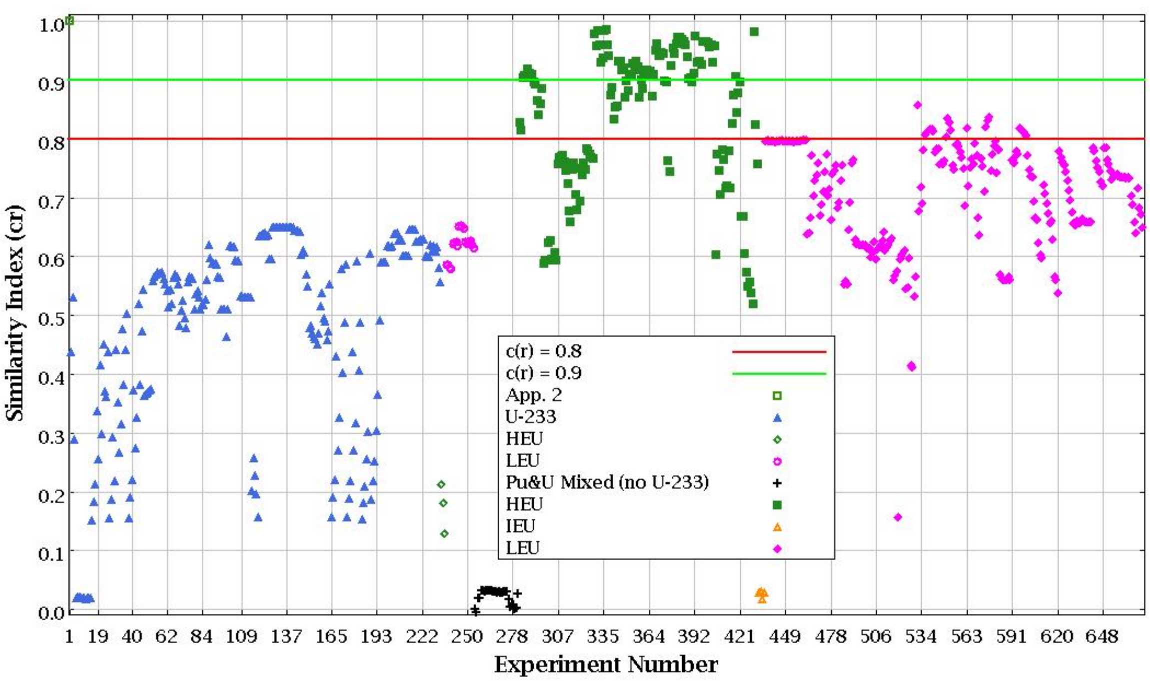

Fig. 18. Application 2 similarity index values (c_r) for 672 critical experiments.

The similarity results for application 2 demonstrate that 26 of the evaluated critical configurations are considered to be highly similar ($c_r > 0.95$) to application 2. An additional 42 critical configurations are considered to be adequately similar ($0.95 > c_r > 0.90$) to application 2. An additional 48 critical configurations are considered to be only marginally similar ($0.9 > c_r > 0.8$) to application 2. Considering that there are 68 configurations that are highly or adequately similar to application 2, use of the marginally similar configurations is not recommended. A list of critical experiments ordered by decreasing similarity is provided in Appendix D.

The TSUNAMI-IP output for this application includes a detailed calculation of the c_r value of the application compared with itself. This edit indicates that the most important contributors to c_r for this application are ^{1}H elastic scattering, ^{235}U nu-bar, ^{235}U (n,γ), ^{16}O elastic scattering, and ^{235}U fission reactions.

The highest c_r value, 0.985, was generated by comparing experiment HST-001, case 8 to application 2. Of the c_r values above 0.9, the lowest value, 0.901, was generated by comparing experiment HST-007, case 11 to the application. Figures 19–23 show the sensitivity profiles for the five reactions identified above for application 2 and for HST-001, case 8 and HST-007, case 11.

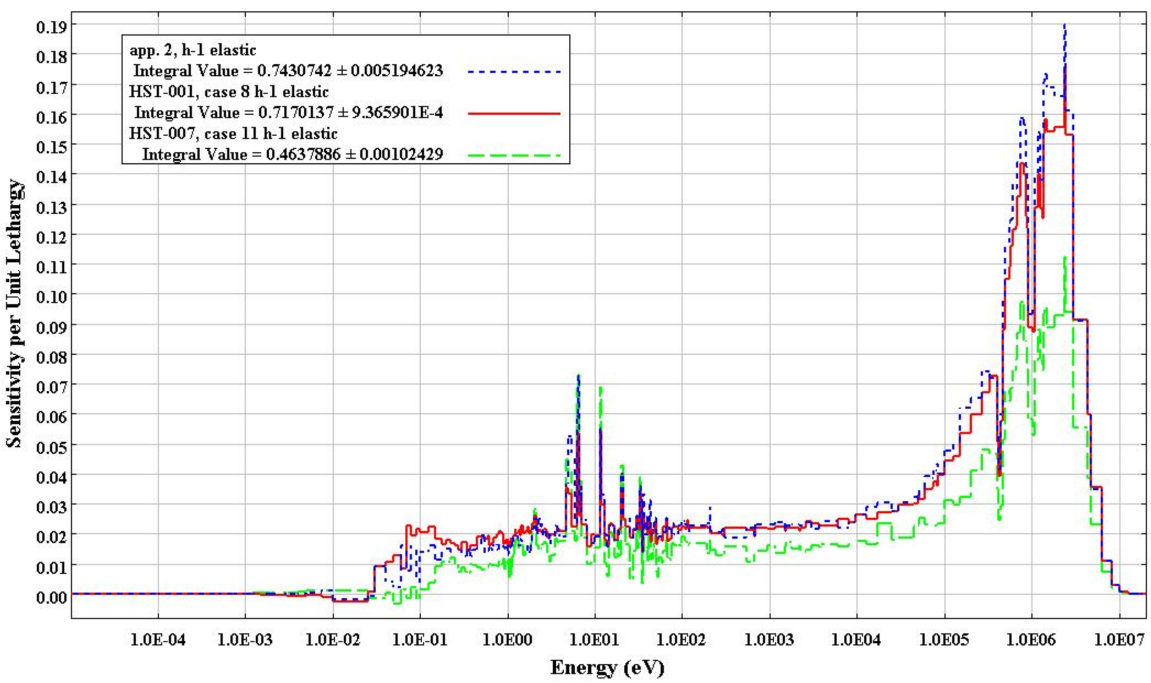

Fig. 19. ^{1}H elastic scattering reaction sensitivity profiles for application 2 and experiments HST-001, case 8 and HST-007, case 11.

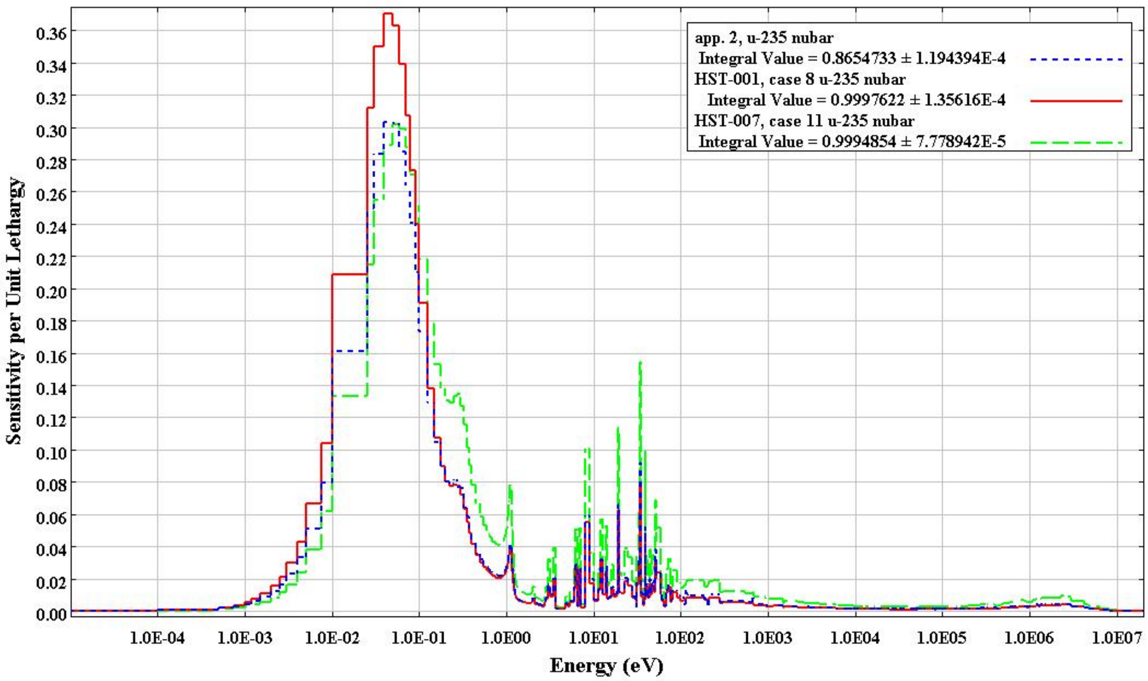

Fig. 20. ^{235}U Nu-bar sensitivity profiles for application 2 and experiments HST-001, case 8 and HST-007, case 11.

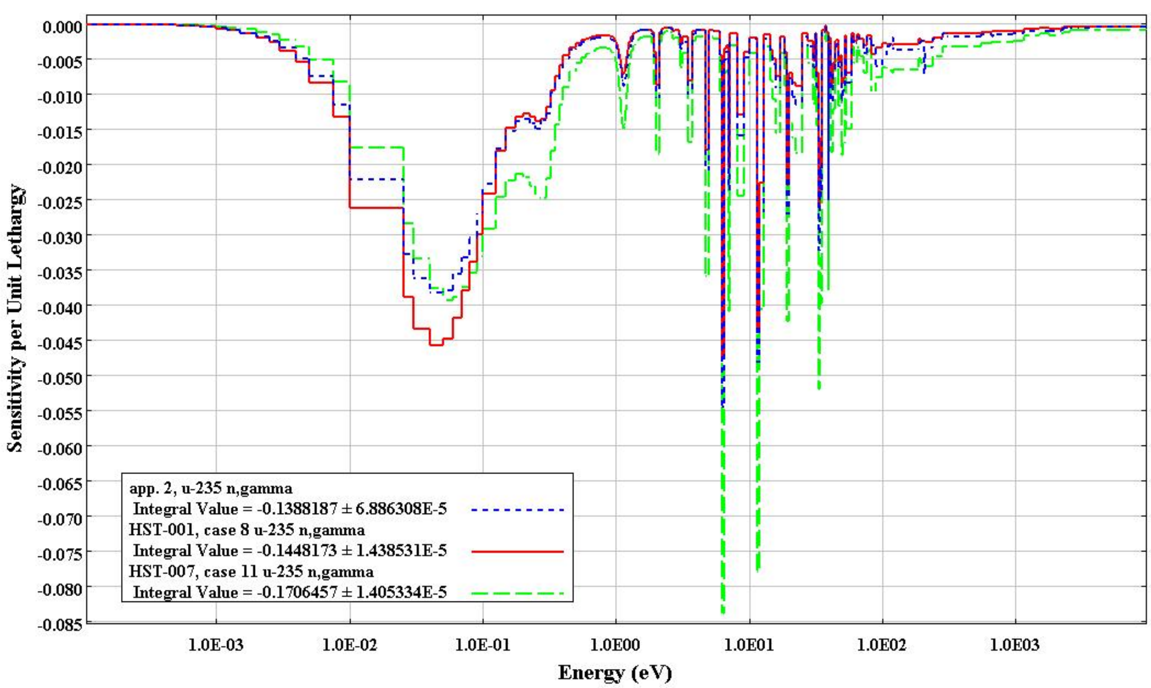

Fig. 21. ^{235}U (n,γ) reaction sensitivity profiles for application 2 and experiments HST-001, case 8 and HST-007, case 11.

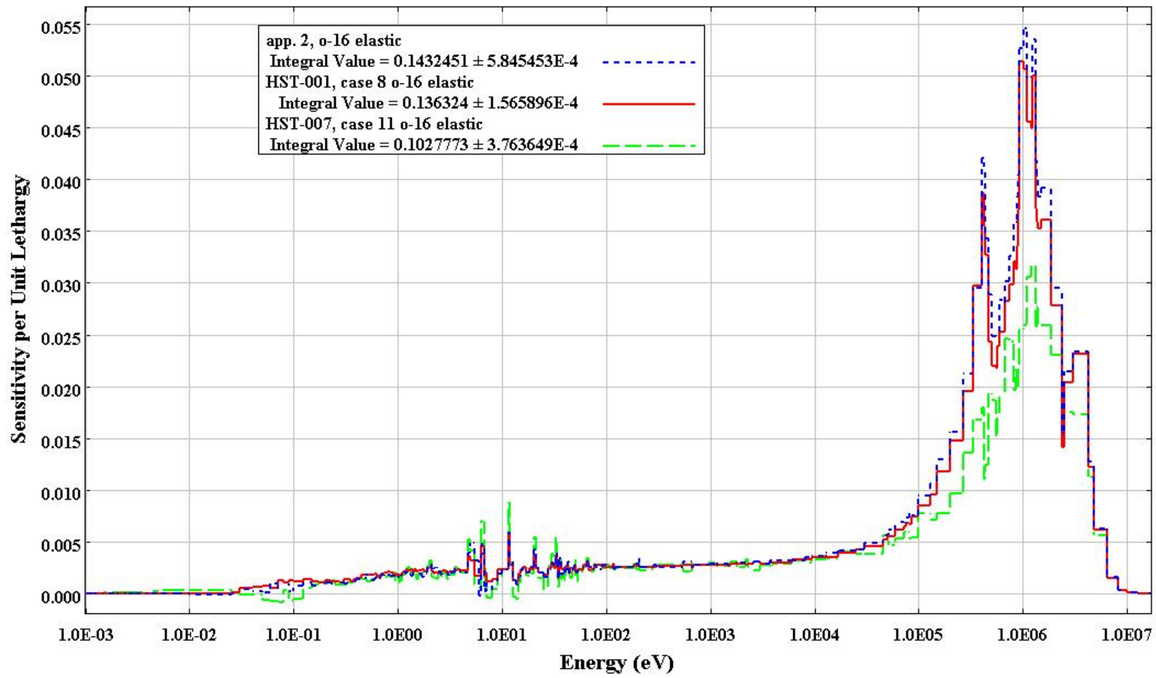

Fig. 22. ^{16}O elastic scattering reaction sensitivity profiles for application 2 and experiments HST-001, case 8 and HST-007, case 11.

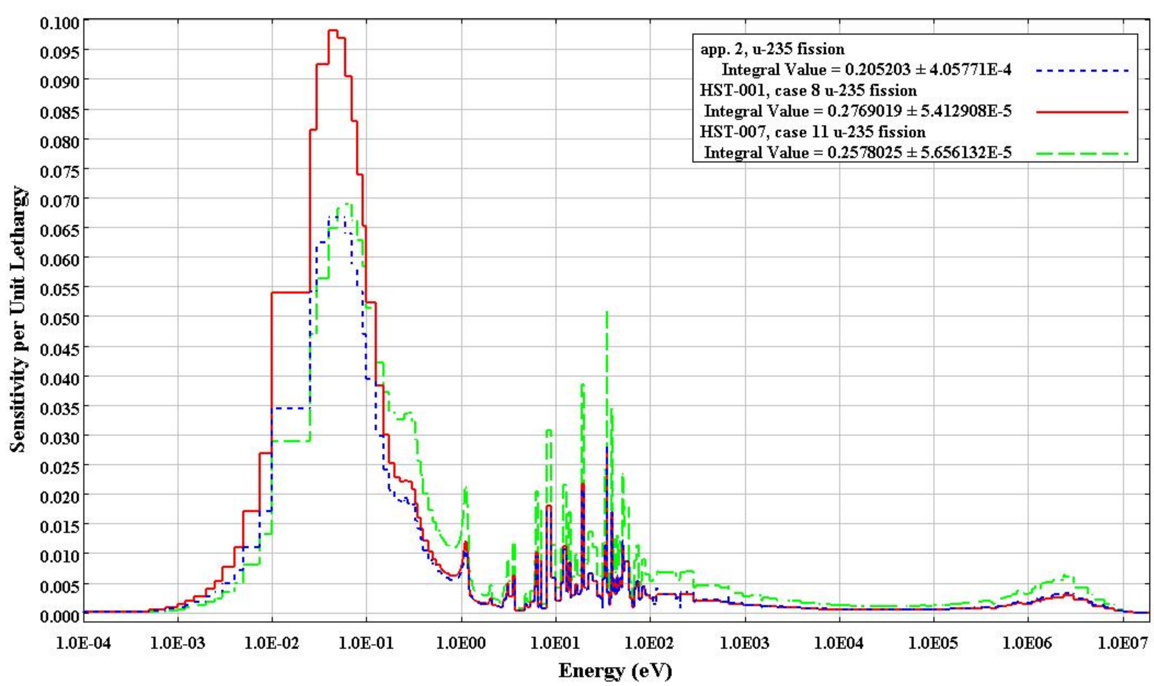

Fig. 23. ^{235}U fission reaction sensitivity profiles for application 2 and experiments HST-001, case 8 and HST-007, case 11.

Table 8 shows the top contributors toward similarity for application 2 compared to itself. The data show some of the characteristics of the ideal critical experiment for validation of application 2.

Table 8. Top contributors to similarity (c_r) for application 2 compared to itself

Covariance matrix: Nuclide reaction with nuclide reaction				Contribution to similarity (c_r)
^{1}H	elastic	^{1}H	elastic	0.369
^{235}U	nu-bar	^{235}U	nu-bar	0.290
^{235}U	n,γ	^{235}U	n,γ	0.147
^{16}O	elastic	^{16}O	elastic	0.146
^{235}U	fission	^{235}U	fission	0.021

Tables 9 and 10 show the top contributors toward similarity for the application compared to the experiments with the highest c_r value and the lowest c_r value that is greater than 0.9. Differences between the partial c_r values shown in Table 8 for the application compared to itself and Tables 9 and 10 for the application compared to each of these experiments are quantified with the Δc_r values shown in Tables 9 and 10. For an explanation of these values, see Section 4.1. Note that for experiment HST-007 case 11, the Δc_r values with the largest negative magnitude are for ^{1}H elastic scattering and ^{16}O elastic scattering, reflecting their reduced sensitivity relative to the application, as shown in Figs. 19 and 22. The largest positive Δc_r is for ^{235}U n,γ, where the sensitivity of the experiment exceeds that of the application, especially at intermediate energies, where the cross-section uncertainties are higher, as shown in Fig. 21.

Table 9. Top contributors to similarity (c_r) for application 2 compared to experiment HST-001, case 8

Covariance matrix: Nuclide reaction with nuclide reaction				Contribution to similarity (c_r)	Change from optimum similarity (Δc_r)
^{1}H	Elastic	^{1}H	elastic	0.344	-0.026
^{235}U	nu-bar	^{235}U	nu-bar	0.338	0.048
^{235}U	n,γ	^{235}U	n,γ	0.129	-0.018
^{16}O	elastic	^{16}O	elastic	0.138	-0.008
^{235}U	fission	^{235}U	fission	0.023	0.002

Table 10. Top contributors to similarity (c_r) for application 2 compared to experiment HST-007, case 11

Covariance matrix: Nuclide reaction with nuclide reaction				Contribution to similarity (c_r)	Change from optimum similarity (Δc_r)
^{1}H	elastic	^{1}H	elastic	0.210	-0.159
^{235}U	nu-bar	^{235}U	nu-bar	0.311	0.021
^{235}U	n,γ	^{235}U	n,γ	0.224	0.077
^{16}O	elastic	^{16}O	elastic	0.104	-0.042
^{235}U	fission	^{235}U	fission	0.037	0.016

4.3 APPLICATION 3—600 g U (DOWNBLENDED U ISOTOPICS)/LITER SPHERE

Table 11 and Fig. 24 show the distribution of c_r values calculated for the 672 critical configurations examined. Analysis of the similarity results follows Fig. 24.

Table 11. Application 3 similarity summary

Similarity index range	Number of experiments	Applicability
$c_r < 0.1$	54	Low
$0.1 \leq c_r < 0.2$	124	Low
$0.2 \leq c_r < 0.3$	141	Low
$0.3 \leq c_r < 0.4$	176	Low
$0.4 \leq c_r < 0.5$	79	Low
$0.5 \leq c_r < 0.6$	68	Low
$0.6 \leq c_r < 0.7$	30	Low
$0.7 \leq c_r < 0.8$	0	Low
$0.8 \leq c_r < 0.9$	0	Marginal
$0.9 \leq c_r < 0.95$	0	Applicable
$0.95 \leq c_r < 1.0$	0	High
All	672	

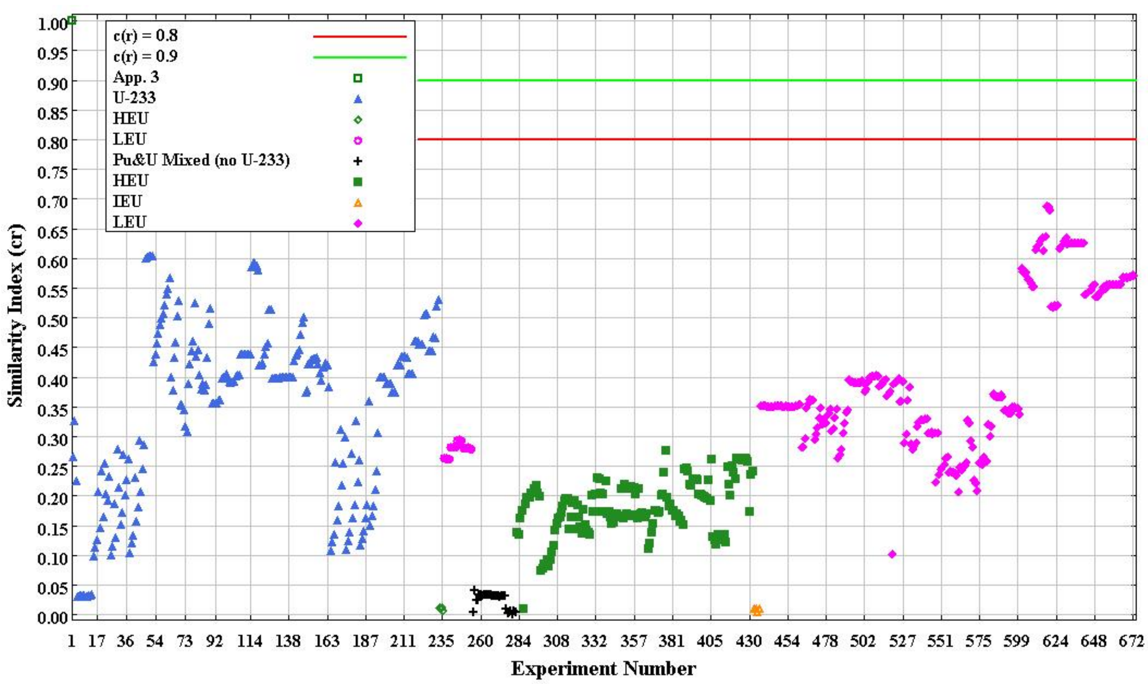

Fig. 24. Application 3 similarity index values (c_r) for 672 critical experiments.

The similarity results for application 3 demonstrate that none of the 672 critical experiments are even marginally similar ($c_r \geq 0.8$). This should not be particularly surprising because none of the experiments involve low enrichment of ^{233}U as the principal fissionable nuclide. The neutronic interaction between the 96.8 wt% ^{238}U and the 3 wt% ^{233}U is not exemplified by any available critical experiments. This lack of applicable critical experiments will be addressed in the discussion addressing validation gaps presented in Section 6. Experiment LST-005, case 1 yielded the highest c_r value, which is 0.687.

The TSUNAMI-IP output for this application includes a detailed calculation of the c_r value of the application compared with itself. This edit indicates that the five most important contributors to c_r for this application are ^{14}N (n,p), ^{238}U (n,γ), ^{233}U fission, ^{1}H (n,γ), and ^{233}U nu-bar. Figures 25-29 show the sensitivity profiles for application 3 and for the most similar experiment, LST-005, case 1, for each of these reactions. Note that LST-005 contains no ^{233}U and, therefore, is not shown in Figs. 27 or 29.

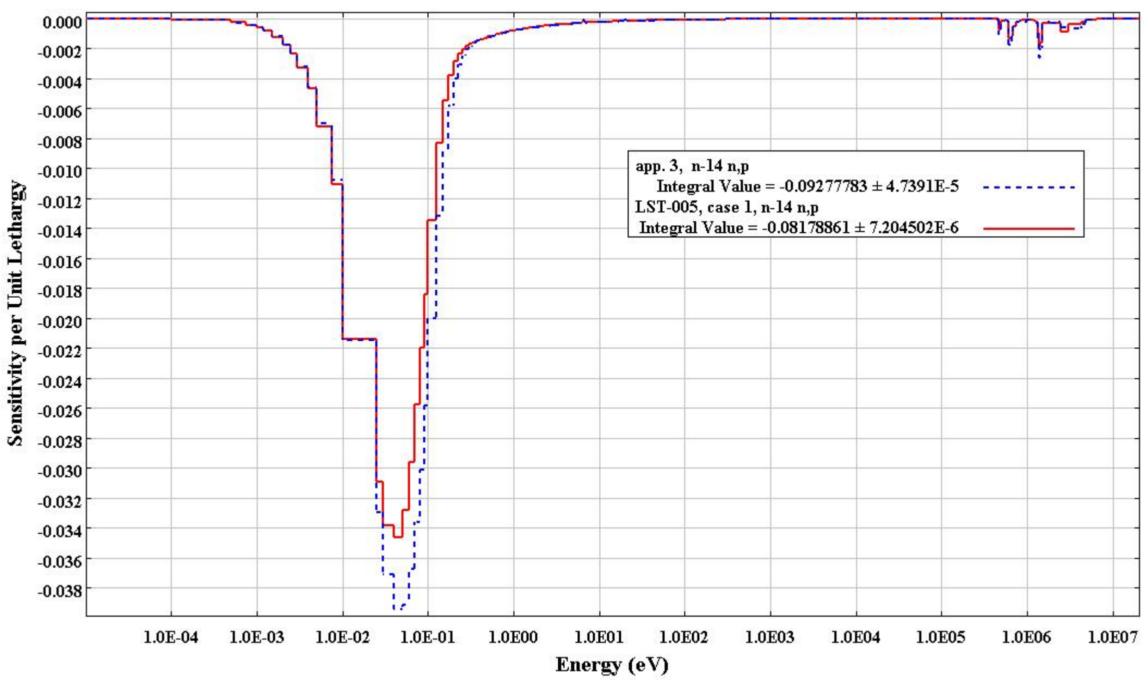

Fig. 25. ^{14}N (n,p) reaction sensitivity profiles for application 3 and experiment LST-005, case 1.

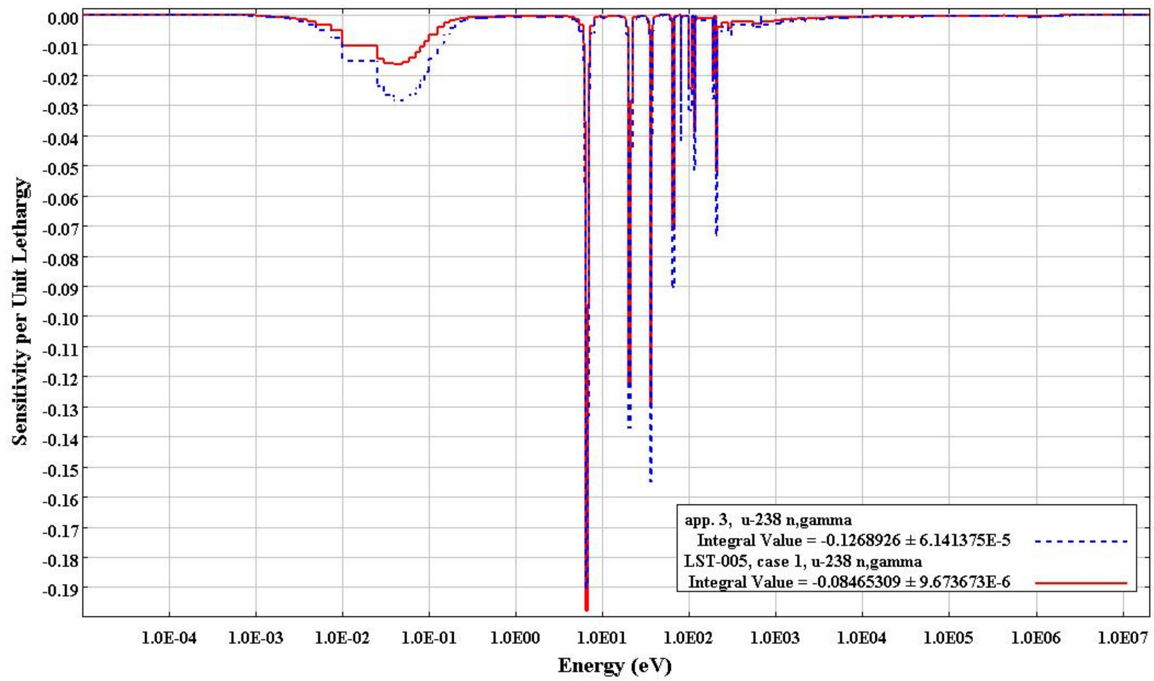

Fig. 26. ^{238}U (n,γ) reaction sensitivity profiles for application 3 and experiment LST-005, case 1.

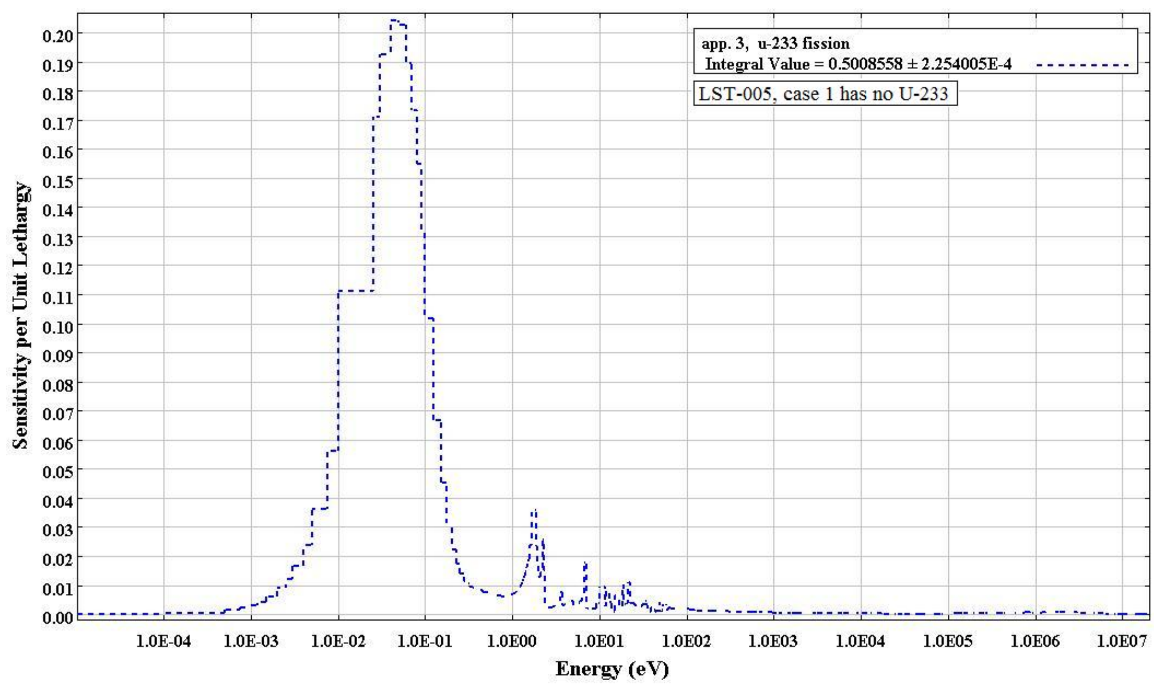

Fig. 27. ^{233}U fission reaction sensitivity profile for application 3.

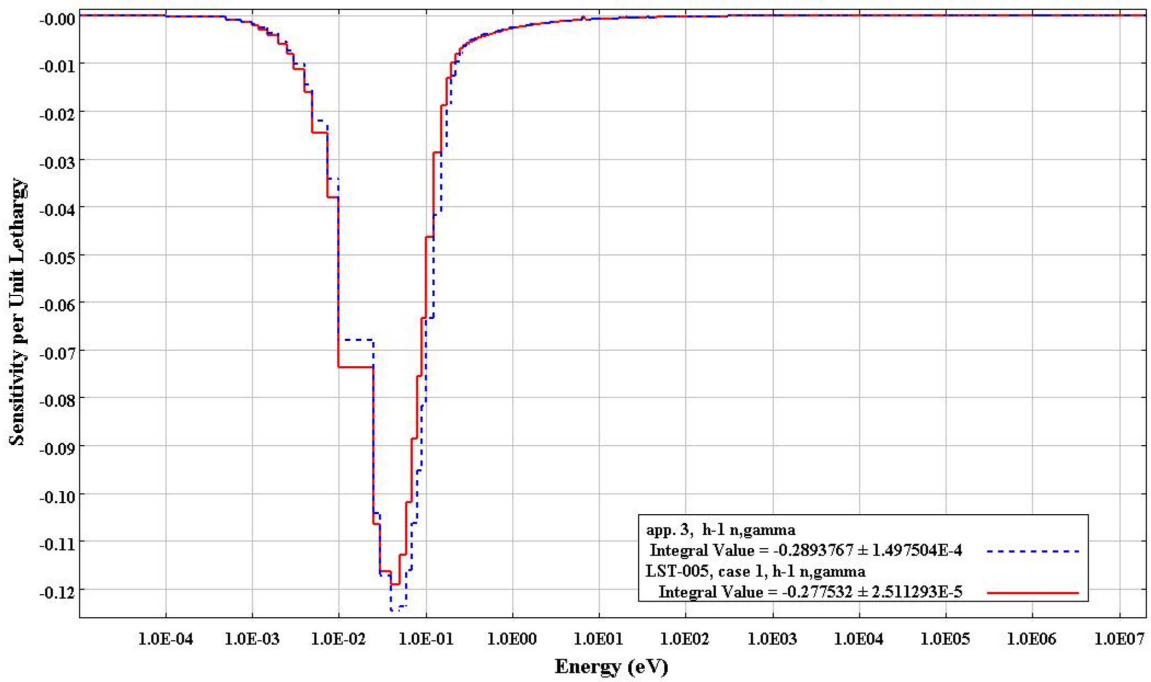

Fig. 28. ^{1}H (n,γ) reaction sensitivity profiles for application 3 and experiment LST-005, case 1.

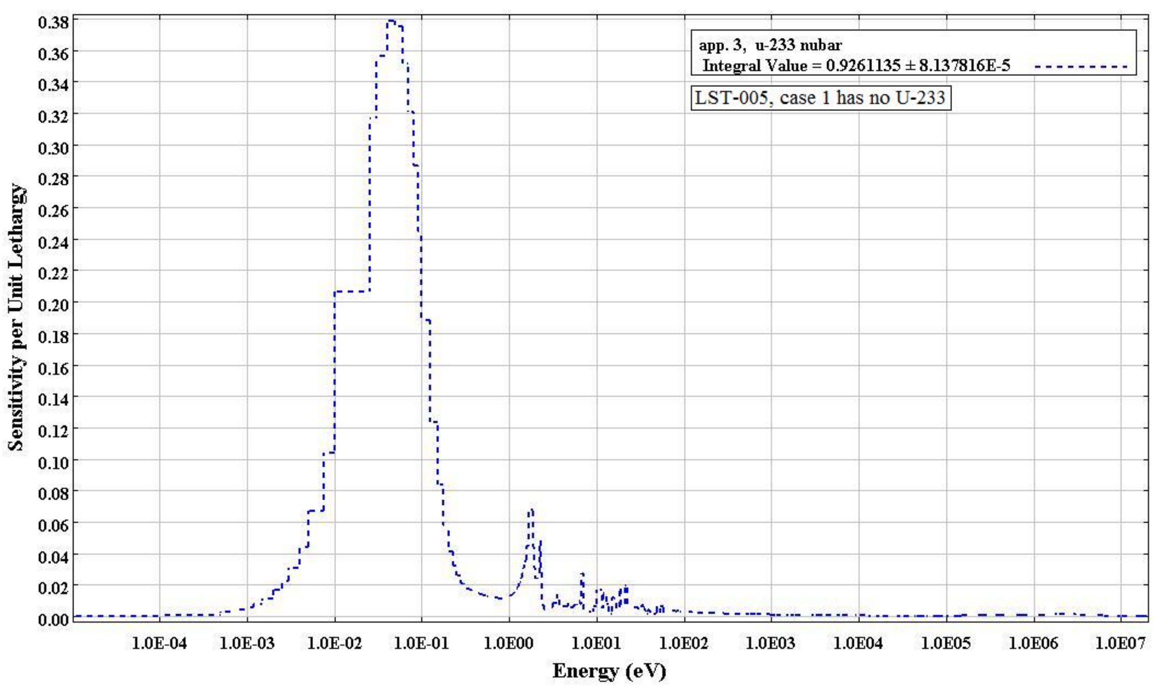

Fig. 29. ^{233}U Nu-bar sensitivity profile for application 3.

A review of the detailed c_r information from TSUNAMI-IP shows that the biggest differences between application 3 and the most similar critical experiment, LST-005, case 1, are for ^{14}N (n,p),

^{238}U (n,γ),^{233}U fission, ^{1}H (n,γ), and ^{233}U nu-bar. Note that LST-005, case 1 has no ^{233}U, which is the primary fissionable nuclide in the application.

Table 12 shows the top contributors toward similarity for application 3 compared to itself. The data show some of the characteristics of the ideal critical experiment for validation of application 3.

Table 12. Top contributors to similarity (c_r) for application 3 compared to itself

Covariance matrix				Contribution to similarity (c_r)
Nuclide reaction with nuclide reaction				
^{14}N	n,p	^{14}N	n,p	0.486
^{238}U	n,γ	^{238}U	n,γ	0.219
^{233}U	fission	^{233}U	fission	0.122
^{1}H	n,γ	^{1}H	n,γ	0.085
^{233}U	nu-bar	^{233}U	nu-bar	0.074

Table 13 shows the top contributors toward similarity for the application compared to the experiment with the highest similarity (LST-005, case 1, $c_r = 0.687$). Differences between the c_r values shown in Tables 12 and 13, presented as Δc_r in Table 13, indicate which nuclide reactions contribute toward similarity reduction. These values identify the nuclide reactions that are limiting similarity. Note that the Δc_r values with the largest magnitude are for ^{233}U fission and nu-bar.

Table 13. Top contributors to similarity (c_r) for application 3 compared to experiment LST-005, case 1

Covariance matrix				Contribution to similarity (c_r)	Change from optimum similarity (Δc_r)
Nuclide reaction with nuclide reaction					
^{14}N	n,p	^{14}N	n,p	0.427	-0.059
^{238}U	n,γ	^{238}U	n,γ	0.150	-0.068
^{233}U	fission	^{233}U	fission	0	-0.122
^{1}H	n,γ	^{1}H	n,γ	0.081	-0.004
^{233}U	nu-bar	^{233}U	nu-bar	0	-0.074

4.4 APPLICATION 4—STORAGE ARRAY, CEUSP CONTAINERS

Table 14 and Fig. 30 show the distribution of c_r values calculated for the 672 critical configurations examined. Analysis of the similarity results follows Fig. 30.

Table 14. Application 4 similarity summary

Similarity index range	Number of experiments	Applicability
$c_r < 0.1$	253	Low
$0.1 \leq c_r < 0.2$	315	Low
$0.2 \leq c_r < 0.3$	103	Low
$0.3 \leq c_r < 0.4$	1	Low
$0.4 \leq c_r < 0.5$	0	Low
$0.5 \leq c_r < 0.6$	0	Low
$0.6 \leq c_r < 0.7$	0	Low
$0.7 \leq c_r < 0.8$	0	Low
$0.8 \leq c_r < 0.9$	0	Marginal
$0.9 \leq c_r < 0.95$	0	Applicable
$0.95 \leq c_r < 1.0$	0	High
All	672	

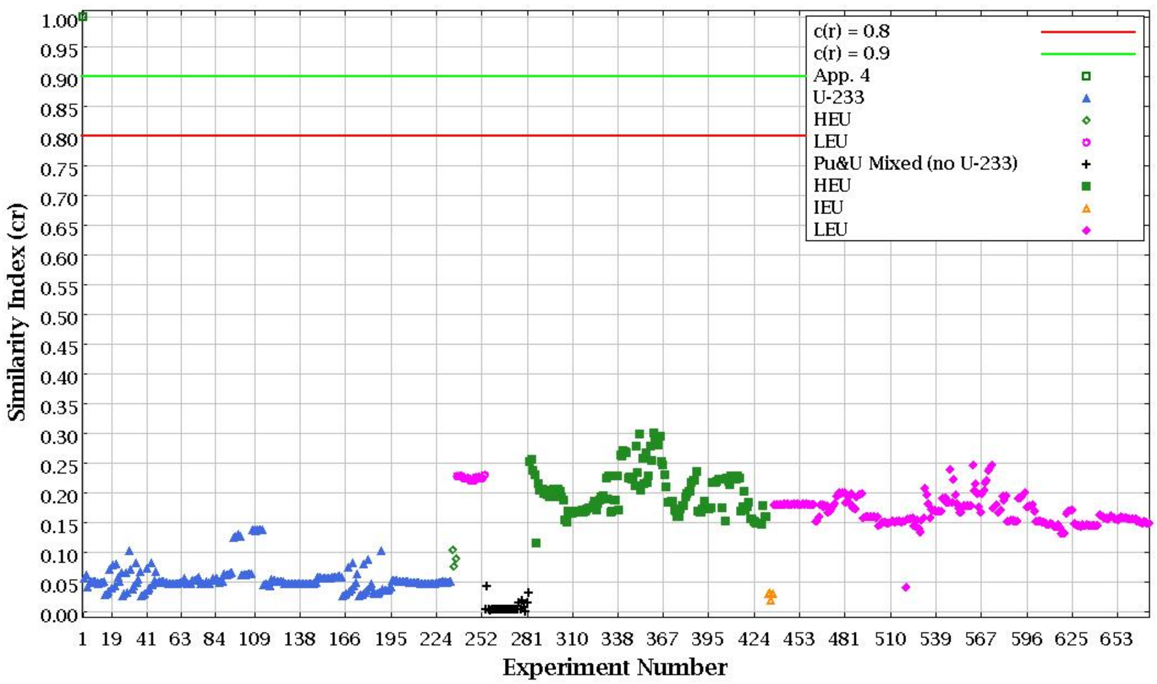

Fig. 30. Application 4 similarity index values (c_r) for 672 critical experiments.

The similarity results for application 4 demonstrate that none of the 672 critical experiments would be considered even marginally applicable. The highest similarity index (c_r) value was 0.301 for experiment HST-007, case 13.

The TSUNAMI-IP output for this application includes a detailed calculation of the c_r value of the application compared with itself. This edit indicates that the most important contributors to c_r for this application are ^{56}Fe (n,γ), Ca (n,γ), ^{56}Fe elastic scattering, ^{235}U (n,γ), ^{235}U fission, and ^{235}U nu-bar.

The highest c_r value, 0.301, generated by comparing the experiments to the application was experiment HEU-SOL-THERM-007, case 13. Figures 31–35 show the sensitivity profiles for these reactions for both the application and the experiment. In order to achieve an acceptable level of similarity when compared to application 4, it looks like a critical experiment would need to have fissile units with thick layers of steel and concrete, similar to the concrete surrounding the storage tubes, between the units.

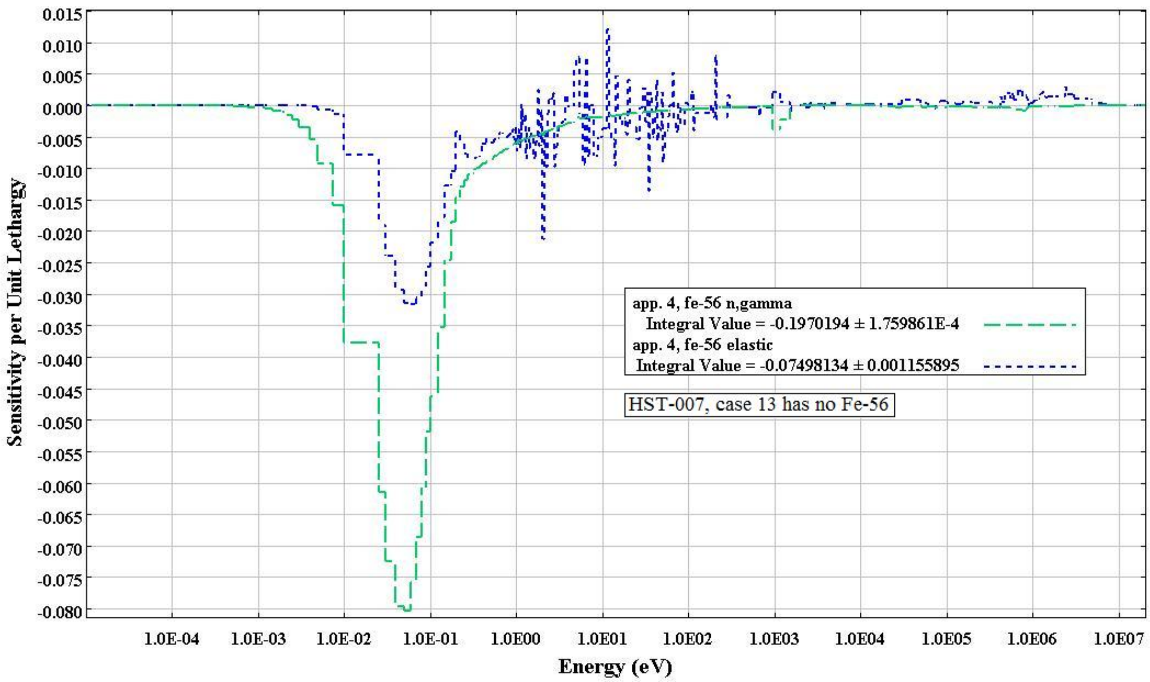

Fig. 31. ^{56}Fe (n,γ) and ^{56}Fe elastic scattering reaction sensitivity profiles for application 4. Experiment HST-007, case 13 has no ^{56}Fe.

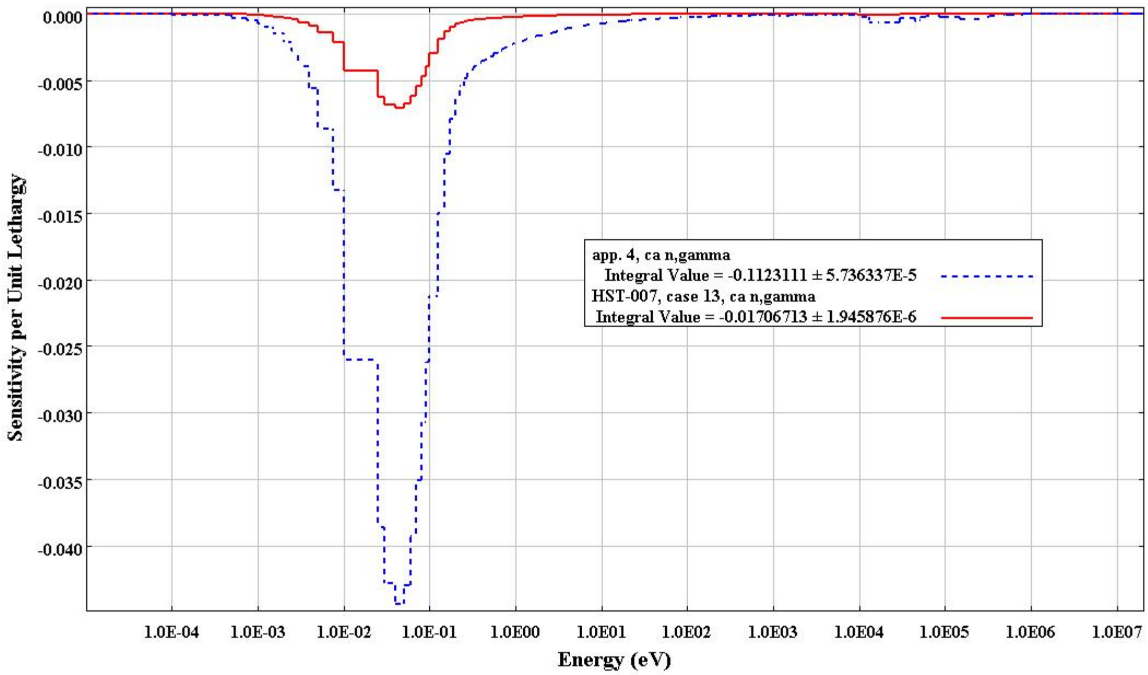

Fig. 32. Ca (n,γ) reaction sensitivity profile for application 4 and experiment HST-007, case 13.

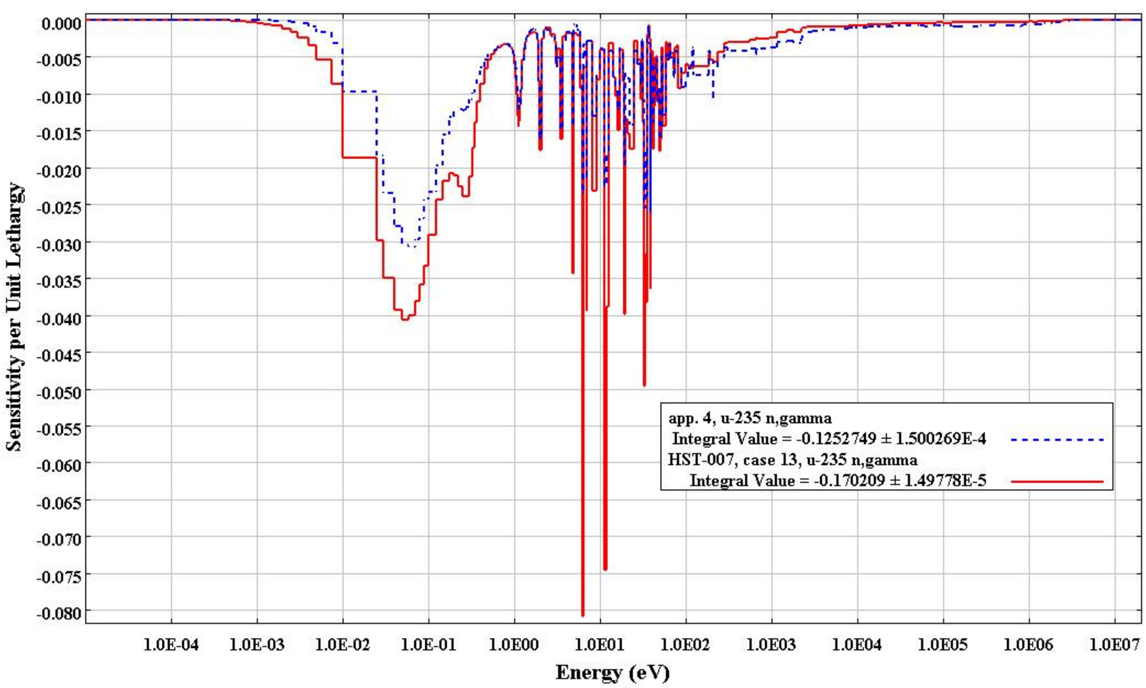

Fig. 33. ^{235}U (n,γ) reaction sensitivity profile for application 4 and experiment HST-007, case 13.

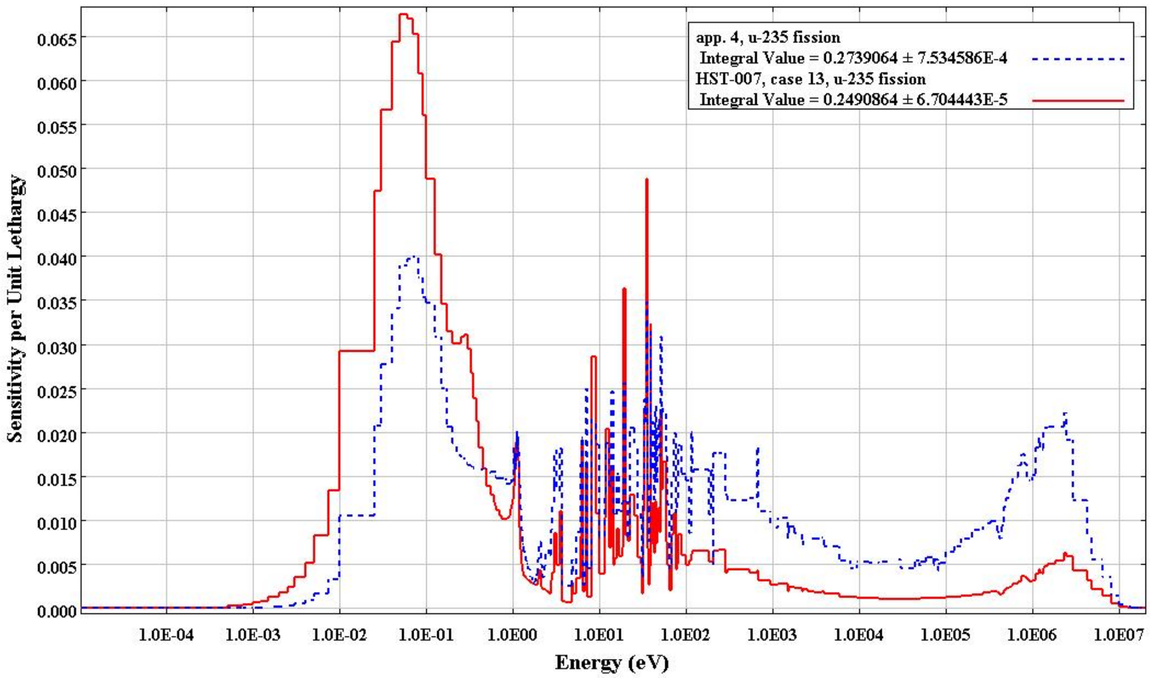

Fig. 34. ^{235}U fission reaction sensitivity profile for application 4 and experiment HST-007, case 13.

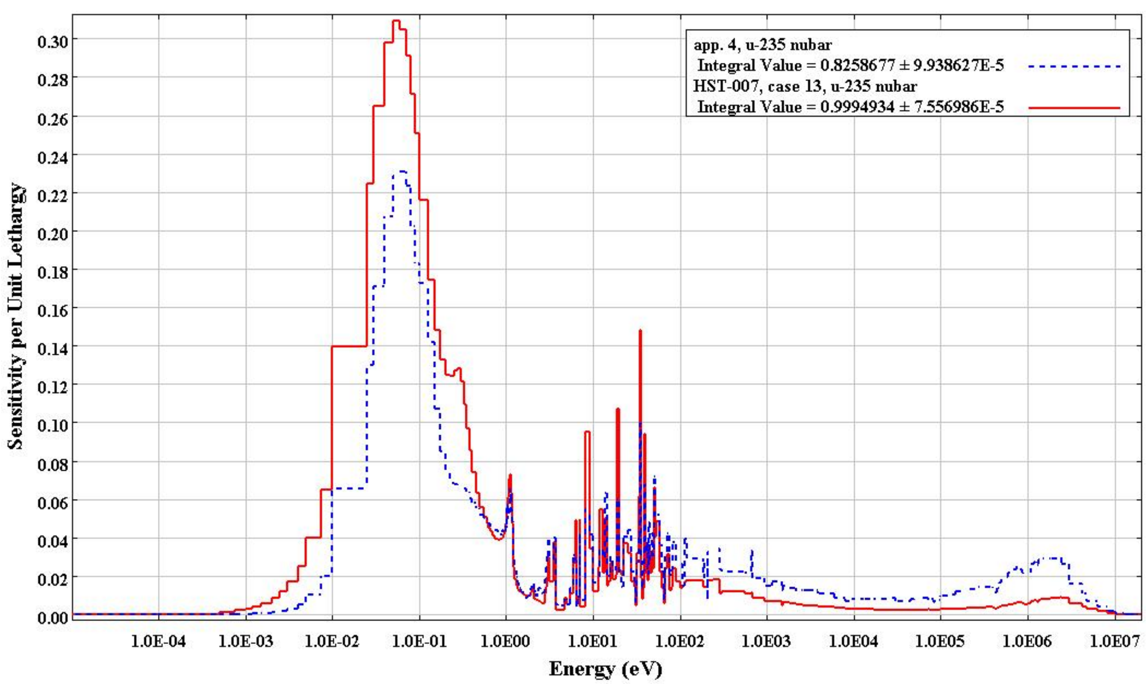

Fig. 35. ^{235}U Nu-bar sensitivity profile for application 4 and experiment HST-007, case 13.

A review of the c_r information from TSUNAMI-IP shows that the biggest differences between application 4 and the most similar critical experiment are in the ^{56}Fe (n,γ) and Ca (n,γ) reaction sensitivities. The experiment has no iron and, as can be seen in Fig. 32, application 4 is much more sensitive to the Ca (n,γ) than the experiment.

Table 15 shows the top contributors toward similarity for application 4 compared to itself. The data show some of the characteristics of the ideal critical experiment for validation of application 4.

Table 15. Top contributors to similarity (c_r) for application 4 compared to itself

Covariance matrix: Nuclide reaction with nuclide reaction				Contribution to similarity (c_r)
^{56}Fe	n,γ	^{56}Fe	n,γ	0.730
Ca	n,γ	Ca	n,γ	0.129
^{56}Fe	elastic	^{56}Fe	elastic	0.039
^{235}U	n,γ	^{235}U	n,γ	0.030
^{235}U	fission	^{235}U	fission	0.027
^{235}U	nu-bar	^{235}U	nu-bar	0.021

The high importance of iron and calcium is due to the design of the storage array, which involves thick steel pipes with thick concrete between the pipes.

Table 16 shows the top contributors toward similarity for the application compared to the experiment with the highest c_r value, 0.301. Differences between the c_r values shown in Tables 15 and 16, Δc_r in Table 16, indicate which nuclide reactions contribute toward similarity reduction (negative Δc_r). The smaller positive values are generated due to differences in normalization of the correlation coefficients for the application compared to itself versus the application compared to the experiment. The non-zero Δc_r values identify the nuclide-reaction pairs that are limiting similarity for the two experiments. Note that the Δc_r values with the largest magnitude are for ^{56}Fe (n,γ) and Ca (n,γ) reactions.

Table 16. Top contributors to similarity (c_r) for application 4 compared to experiment HST-007, case 13

Covariance matrix: Nuclide reaction with nuclide reaction				Contribution to similarity (c_r)	Change from optimum similarity (Δc_r)
^{56}Fe	n,γ	^{56}Fe	n,γ	0	-0.730
Ca	n,γ	Ca	n,γ	0.056	-0.073
^{56}Fe	elastic	^{56}Fe	elastic	0	-0.039
^{235}U	n,γ	^{235}U	n,γ	0.099	0.069
^{235}U	fission	^{235}U	fission	0.040	0.013
^{235}U	nu-bar	^{235}U	nu-bar	0.084	0.063

Examination of application 4 and HST-007, case 13 models reveals that the difference in the ^{56}Fe sensitivity is due to the importance of the carbon steel in the application and the lack of any iron in the experiment. If one were trying to quantify the bias due to errors in the iron and calcium data, using this experiment would not be appropriate.

4.5 SIMILARITY SUMMARY

Table 17 is a summary of the similarity analysis results for a pool of 672 candidate critical configurations. Similarity analyses presented in Sections 4.1–4.4 indicate that the candidate set of critical experiments did not include any experiments that are considered adequately similar to applications 3 and 4. There are a significant number of applicable experiments for applications 1 and 2.

Table 17. Summary of similarity analysis results

Similarity index range	Applicability	Application			
		1	2	3	4
		Number of experiments in each category			
$c_r < 0.1$	Low	43	43	54	253
$0.1 \leq c_r < 0.2$	Low	80	18	124	315
$0.2 \leq c_r < 0.3$	Low	136	21	141	103
$0.3 \leq c_r < 0.4$	Low	140	19	176	1
$0.4 \leq c_r < 0.5$	Low	63	32	79	0
$0.5 \leq c_r < 0.6$	Low	30	115	68	0
$0.6 \leq c_r < 0.7$	Low	14	158	30	0
$0.7 \leq c_r < 0.8$	Low	7	150	0	0
$0.8 \leq c_r < 0.9$	Marginal	17	48	0	0
$0.9 \leq c_r < 0.95$	Applicable	60	42	0	0
$0.95 \leq c_r < 1.0$	High	82	26	0	0

Section 6. provides some discussion as to how to address a lack of applicable critical experiments to perform validation of critical calculations.

5. USL DETERMINATION

Typically, the purpose of validation is to support determination of an upper subcritical limit (USL) to which a safety analysis case or "application" may be compared. ANSI/ANS-8.24 (Ref. 8) provides the following definition for a USL:

> Upper subcritical limit: A limit on the calculated k-effective value established to ensure that conditions calculated to be subcritical will actually be subcritical.

The work presented in this report to this point has been directed toward identifying critical experiments that are similar to the applications, to support determination of USL values. The USL examples provided below focus on determination of calculational margins to account for nuclear data uncertainties and the consequent biases in computed results. The USL examples do not include any additional margin to account for process condition uncertainties, which could lead to process conditions that differ from the application models.

Of the four applications evaluated, only for applications 1 and 2 were good sets of critical experiments identified as applicable for validation. USLs may be determined for applications 1 and 2 using standard statistical techniques such as those documented in NUREG/CR-6698, *Guide for Validation of Nuclear Criticality Safety Calculational Methodology*[9] and computer codes such as USLSTATS.[10] Many statistical methods, including those implemented in USLSTATS, require that the population of k_{eff} values have a normal distribution. For these methods, if the distribution is not approximately normal, the conclusions related to the "confidence level" of the limit are not valid. The normality test implemented in USLSTATS is a rather crude 5-bin chi-squared normality test. If a normality test is failed, the evaluator may also examine the normality of the data using other, more sophisticated tests.

No critical experiments similar to applications 3 and 4 were identified. For applications such as these, the evaluator needs to supplement the margin of subcriticality with some additional margin to be applied to USLs determined with the best data available. Section 7 of the report discusses some options and data available from the TSUNAMI tools to help identify and defend the selected additional margin.

The rest of this section will document calculation of USLs for application 1 using the USLSTATS code. Section 5.1 is a standard USL determination based on trending of the EALF parameter. Section 5.2 documents another way in which the TSUNAMI tools may be used for validation analysis. Use of the same procedure for application 2 is not included here but would be appropriate.

5.1 USL FOR APPLICATION 1 USING TRENDING OF EALF

The similarity determination documented in Section 4.1 identified 142 critical experiments that were identified as applicable ($0.95 > c_r > 0.9$) or highly applicable ($c_r > 0.95$) to the validation of application 1. An additional 17 critical experiments were identified as marginally applicable ($0.9 > c_r > 0.8$).

Four USLSTATS calculations were performed with trending as a function of critical experiment energy of average lethargy of neutrons causing fission (EALF). These calculations used results from (1) all 672 critical experiments without regard for similarity, (2) all 159 critical experiments with $c_r \geq 0.8$, (3) the 142 critical configurations with $c_r \geq 0.9$, and (4) the 82 critical experiments with $c_r \geq$ 0.95. The EALF for application 1 is 0.282 eV. The USLSTATS calculations all used the following input parameters:

- Proportion of population = 0.999
- Confidence of fit = 0.950
- Confidence on proportion = 0.950
- Average standard deviation of all input k_{eff} values = -1 (directing USLSTATS to use values input for each experiment)
- Additional margin (sometimes referred to as administrative margin) = 0.02

The EALF and k_{eff} values were taken from a set of TSUNAMI-3D or TSUNAMI-1D forward calculations performed for each of the experiments. The uncertainty provided for each experiment is the experimental uncertainty, taken from the IHECSBE, combined with the Monte Carlo uncertainty from the forward KENO calculations.

Table 18 provides the results from these calculations. Case 1 includes 513 cases with c_r values less than 0.8. The application 1 EALF is 0.282 eV, and the experiment EALF values range from 0.03 eV to 1.1 MeV. The use of experiments with significantly higher EALF values is clearly not appropriate. The impact of including only increasingly similar experiments is seen by comparing the results from the various cases. Note that with increasely high c_r criteria, the range of EALF of the best matching experiments narrows to more closely match that of the application. Table 18 also includes the results for cases 5 through 8, which are discussed in Section 5.2.

Table 18. Application 1 USLSTATS results

USL case	Number of experiments	Normality test	USL-1[a]	Description
1	672	Failed	0.9626	EALF trending, all experiments
2	159	Passed	0.9608	EALF trending, $c_r > 0.8$
3	142	Passed	0.9619	EALF trending, $c_r > 0.9$
4	82	Passed	0.9652	EALF trending, $c_r > 0.95$
5	666	Failed	0.9649	c_r trending, all experiments with $c_r \geq 0$
6	159	Passed	0.9619	c_r trending, $c_r > 0.8$
7	142	Passed	0.9559	c_r trending, $c_r > 0.9$
8	82	Passed	0.9649	c_r trending, $c_r > 0.95$

[a]Application 1 EALF = 0.282 eV and c_r = 1.0

Figures 36–39 show the trending analysis for each of the first 4 cases. The USLSTATS input deck for USL case 4 is provided in Appendix E.

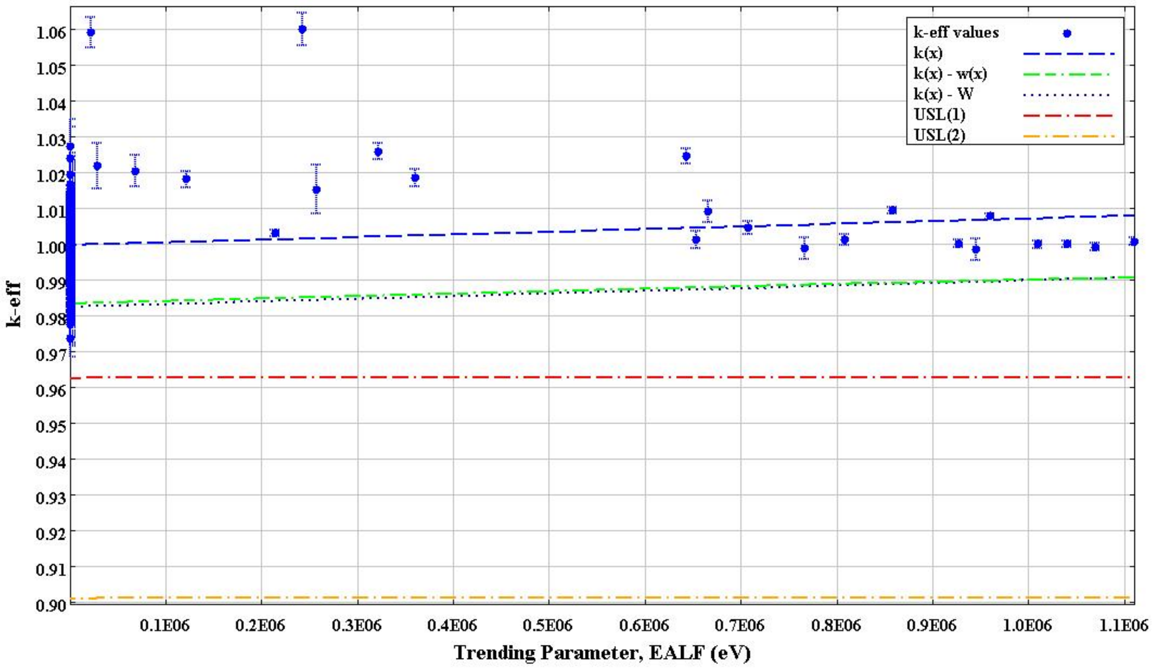

Fig. 36. USLSTATS plot for EALF trending of all experiments.

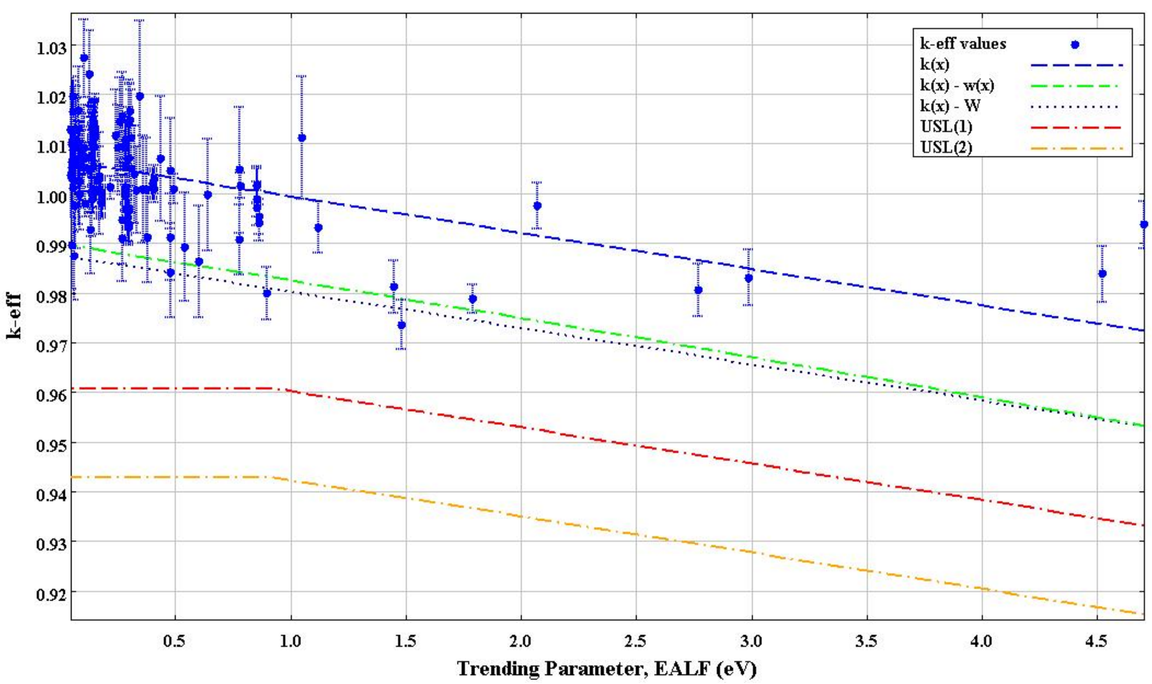

Fig. 37. USLSTATS plot for EALF trending of experiments with $c_r \geq 0.8$.

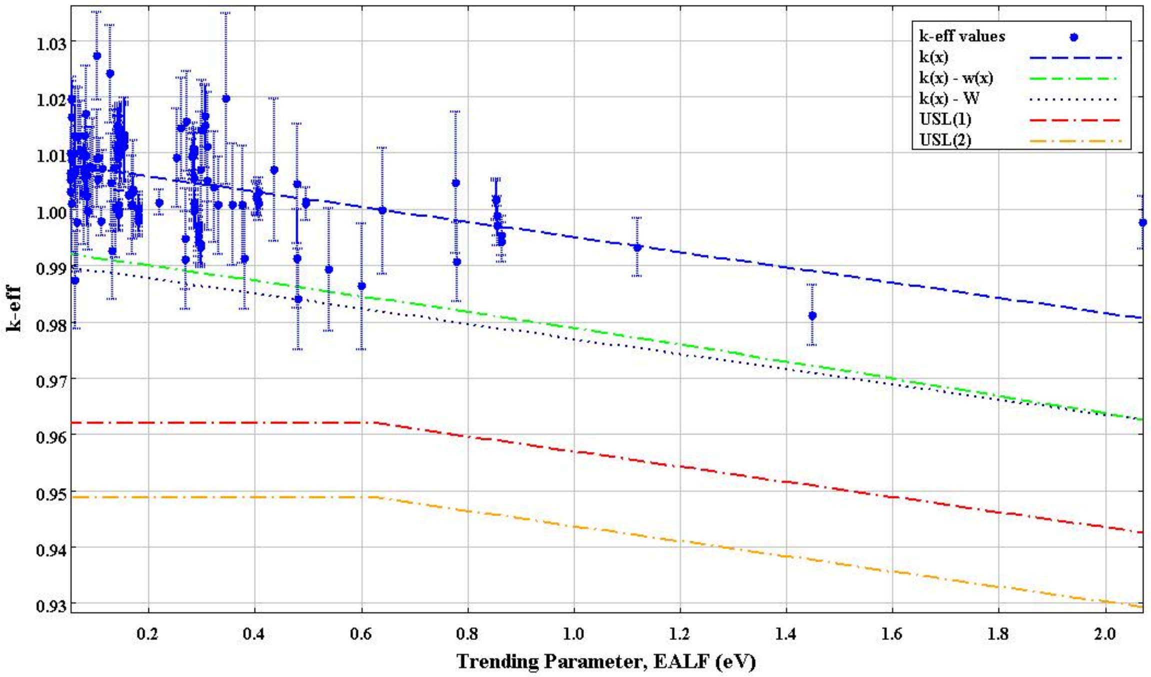

Fig. 38. USLSTATS plot for EALF trending of experiments with $c_r \geq 0.9$.

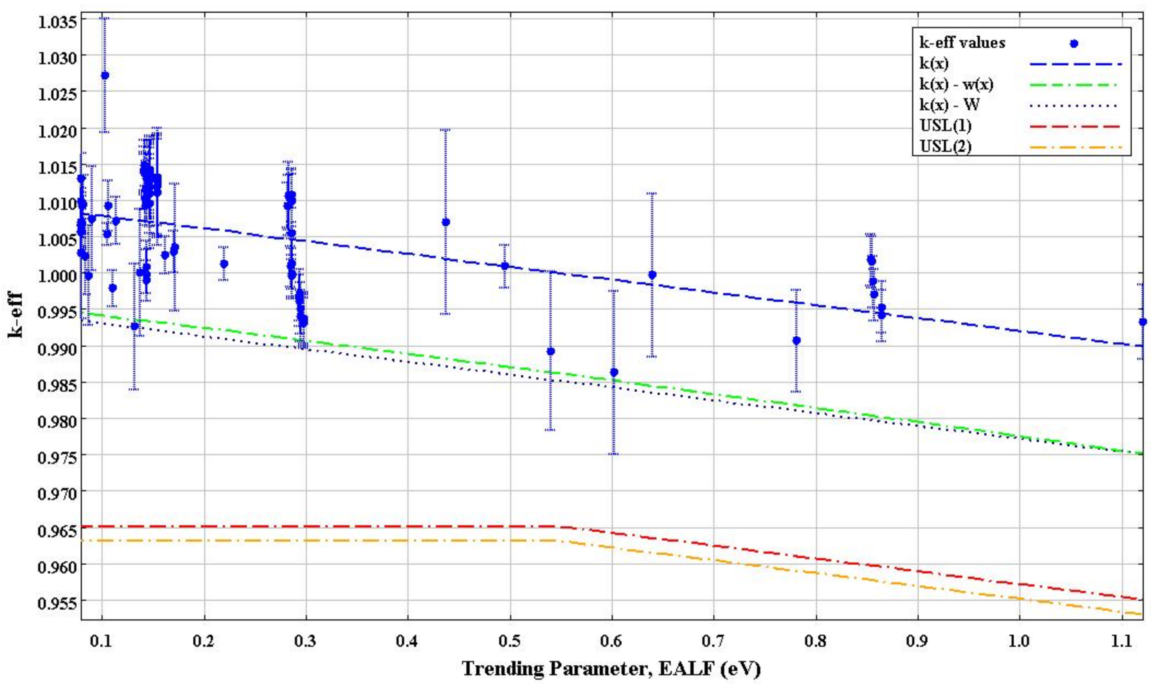

Fig. 39. USLSTATS plot for EALF trending of experiments with $c_r \geq 0.95$.

5.2 USL FOR APPLICATION 1 USING TRENDING OF THE c_r SIMILARITY PARAMETER

Table 18 also includes the results for four cases in which the trending parameter was the modified similarity index (c_r). The unmodified similarity index (c_k) could also have been used as the trending parameter. In the work presented in this report, the difference between the two is in the handling of the sensitivity of k_{eff} to the variations in the fission spectrum (chi). As was discussed in Section 4., the chi sensitivity calculated using SCALE 5.1 ignores the fact that the chi data is constrained by definition to sum to one. Due to normalization, any chi data errors must be accompanied by one or more offsetting errors so that the distribution still sums to one. For critical experiments that are very similar to the application, c_k and c_r are nearly identical. Inclusion of the chi sensitivity tends to emphasize differences in the sensitivity of the fissionable nuclides. Thus trending of results, using many similar experiments, to perfect similarity (i.e., c_k or c_r equal to one) should have negligible impact on the calculated USL.

For these cases, trending is performed as a function of similarity with the results extrapolated to complete similarity (i.e., $c_r = 1.0$). USLSTATS accounts for the extrapolation with a quadratic confidence band, where the width of the confidence band increases as the extrapolation distance from the highest c_r value to unity increases. Note that USL(2) is a closed interval approach that is not valid outside the range of the experimental data. Thus, extrapolation to $c_r = 1$ for USL(2) is not valid. Figures 40–43 show the USLSTATS plots for the c_r trending cases.

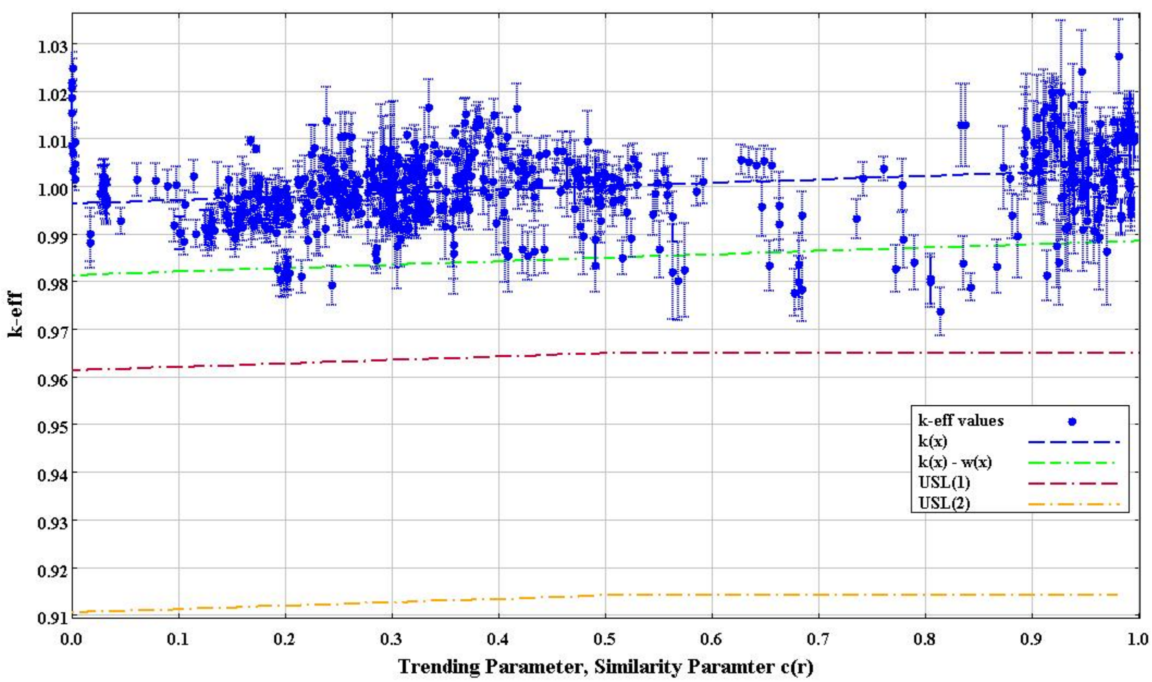

Fig. 40. USLSTATS plot for c_r trending of all experiments.

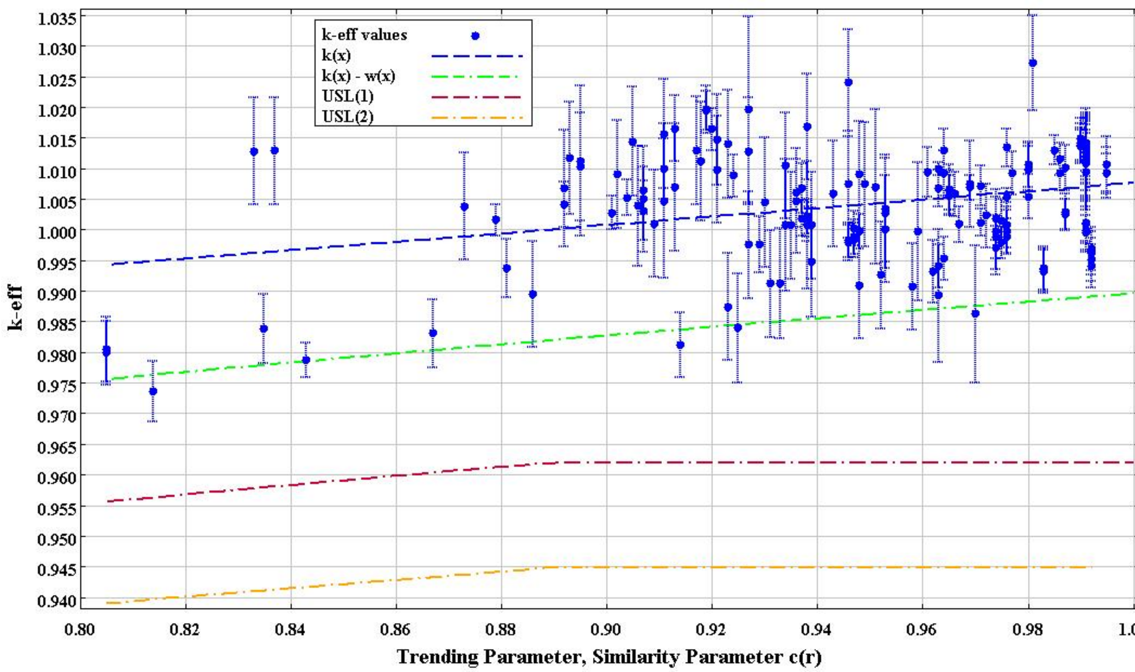

Fig. 41. USLSTATS plot for c_r trending of experiments with $c_r \geq$ 0.8.

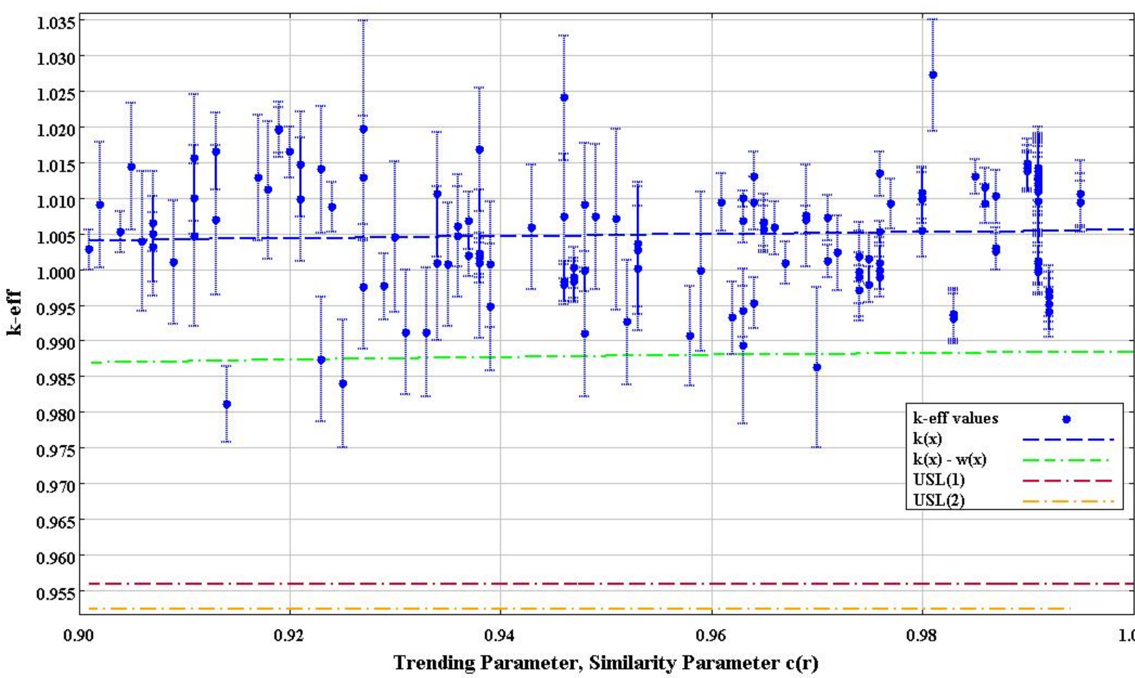

Fig. 42. USLSTATS plot for c_r trending of experiments with $c_r \geq$ 0.9.

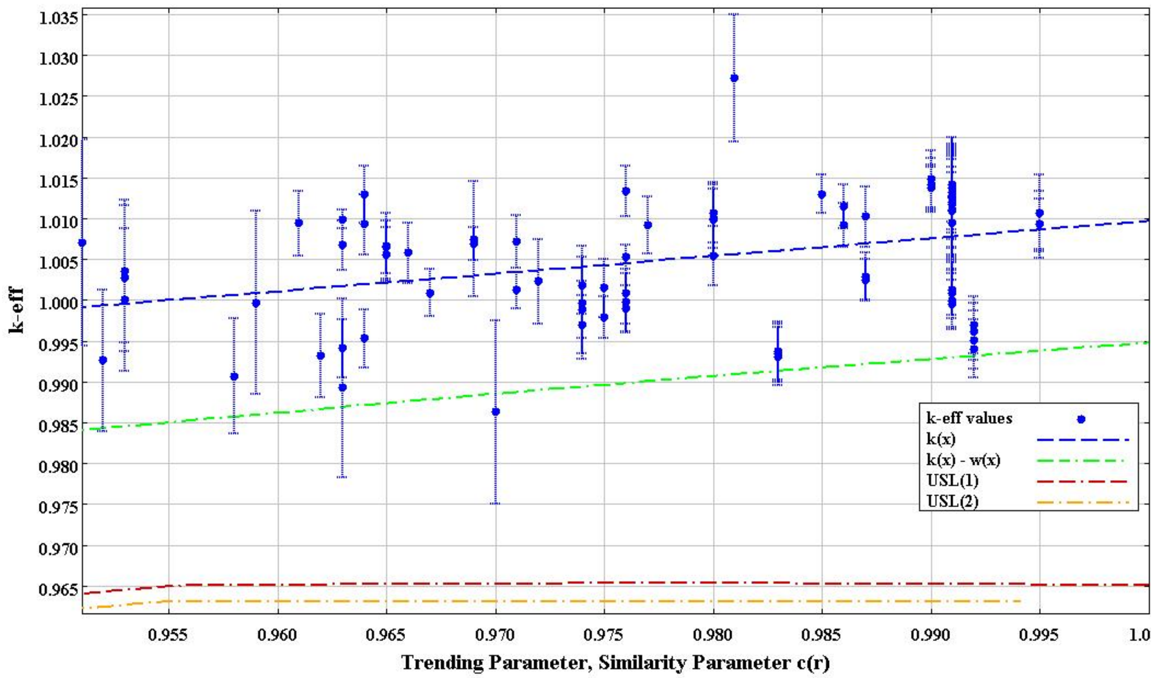

Fig. 43. USLSTATS plot for c_r trending of experiments with $c_r \geq$ 0.95.

5.3 USL FOR APPLICATIONS 1–4 USING TSURFER DATA ADJUSTMENT TECHNIQUES

In the near future, the evaluator may be able predict computational biases with a nuclear data adjustment tool such as the TSURFER code,[11] which will be distributed with SCALE 6 in 2009. This code identifies a single set of adjustments to nuclear data that will result in the computational models all producing k_{eff} values close to their experimental k_{eff} value. Then the same data adjustments are used to predict an unbiased k_{eff} value for the application and an uncertainty on the adjusted k_{eff} value. The difference between the originally calculated k_{eff} value and the new post-adjustment k_{eff} value represents the bias in the original calculation, and the uncertainty in the adjusted value represents the uncertainty in this bias. If similar experiments are available to validate the use of a particular nuclide in the application, the uncertainty of the bias for this nuclide is reduced. If similar experiments are not available, the uncertainty in the bias for the given nuclide is high. Thus, with a complete set of experiments to validate important components in the application, a precise bias with a small uncertainty can be predicted. Where the experimental coverage is lacking, a bias can be predicted with an appropriately large uncertainty. As experienced is gained with TSURFER, it is expected to become a preferred tool for rigorous bias and bias uncertainty determination, particularly for applications for which nearly identical critical experiments are not available.

A calculation was performed using the SCALE 6 version of TSURFER, the new SCALE 6 covariance data library, and 1066 critical experiments to calculate the set of cross-section adjustments that minimize the overall chi-square statistic of the data adjustments. An additional important input to the TSURFER calculation is the set of correlations between experiment k_{eff} values. For purposes of this study, it was assumed that all experiments within any one IHECSBE evaluation were 90% correlated and that there were no correlations between experiments in different evaluations. This approximation is arbitrary. In reality, the same fuel rods or plates are used in multiple evaluations and the correlations are far more complex than the simple assumption stated above.

The TSURFER-calculated bias and bias uncertainty values are shown in Table 19. Note that the bias uncertainty values are the uncertainties in the adjusted k_{eff} values. The reduction in these uncertainties relative to the original uncertainties in the applications is due to inclusion of additional information, the critical experiments, in the validation process. The original uncertainties in the applications, due to cross section covariance data, shown in Table 1, are 0.937, 0.752, 0.515 and 1.354 % $\Delta k/k$, respectively. For applications 1 and 2, the uncertainty are reduced to approximately 10% of their original values, confirming that the benchmarks selected lead to adjustments in the cross sections that are the largest sources of uncertainty, and thus the largest potential sources of computational bias, for these cases. For application 3, the uncertainty in the bias is 31% of the original application uncertainty, indicating marginal coverage by the benchmark set. For application 4, the uncertainty in the bias is 96% of the original uncertainty, confirming the lack of available benchmarks to validate this application.

Where the 2% additional margin used in Section 5.1 is applied, any positive bias disallowed, and a 95% confidence (2σ) applied for the bias uncertainty, the USL values are shown in Table 19. However, the USL values for applications 3 and 4 should be used with caution, perhaps with an increased additional margin, as it has been demonstrated that sufficient benchmarks are not available for the validation of these cases.

Table 19. Bias, bias uncertainty, and USL values computed with TSURFER

Application	Bias (% $\Delta k/k$)	Bias uncertainty (% $\Delta k/k$)	USL
1	0.341	0.071	0.979
2	0.331	0.076	0.978
3	-0.091	0.159	0.976
4	1.304	1.257	0.955

Through further examination of the results for application 1, the individual sources of bias can be identified according the impact of the adjusted cross section on the application k_{eff} value. TSURFER ranks the bias contributions according to an L1 norm, which is based on the absolute values of the group-wise cross section adjustments. The top contributors to bias for application 1 are shown in Table 20. Comparing the TSURFER-predicted contribution to bias with the top sources of uncertainty shown in Table 1, one finds that the ^{233}U reactions and ^{16}O elastic rank at top of both tables. However, ^{1}H elastic scattering, the second highest source of uncertainty, appears as the 11th highest source of bias. For all nuclides and reactions, the bias contribution is approximately the same or less than the uncertainty shown in Table 1, as the adjustments in the cross sections are bounded with a χ^2 of 1.2.

Table 20. Top contributors to TSURFER-determined bias for application 1

Nuclide	Reaction	Contribution to bias % $\Delta k/k$	Fraction of bias L1-norm
^{233}U	chi	3.2738E-01	2.7907E-01
^{233}U	n,γ	9.8989E-02	2.5125E-01
^{16}O	elastic	-1.8796E-01	1.9356E-01
^{233}U	nubar	1.6175E-01	1.3797E-01
^{233}U	fission	-3.5477E-02	6.8533E-02
^{233}U	n,n'	-3.7597E-02	3.2049E-02
^{233}U	elastic	6.2944E-03	5.7039E-03
^{56}Fe	n,γ	6.4198E-03	5.4725E-03
^{14}N	n,p	6.1571E-03	5.2583E-03
^{1}H	n,γ	5.4157E-03	4.6187E-03
^{1}H	elastic	-4.9899E-03	4.4406E-03

The energy-dependent adjustments for selected cross sections are shown in Fig. 44. A maximum adjustment of 7.3% is given for ^{233}U fission where ^{1}H elastic receives a maximum adjustment of <0.1%.

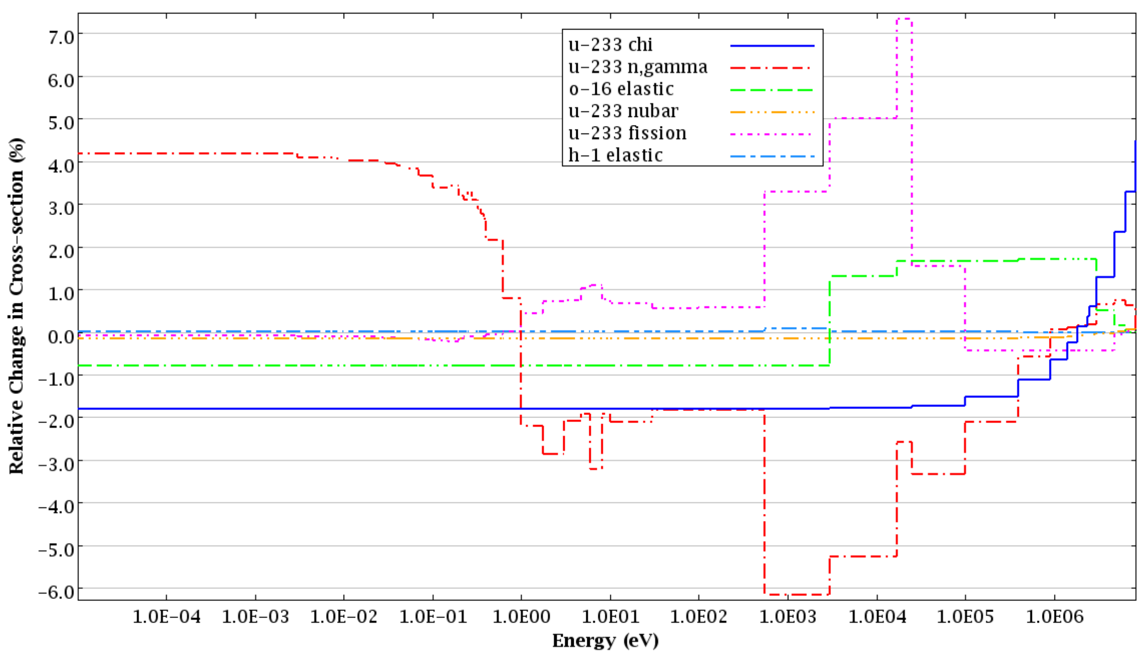

Fig. 44. Select cross-section adjustments from TSURFER analysis.

The energy-dependent cross-section adjustments can be multiplied with the energy-dependent sensitivity of the application's k_{eff} to the cross sections to form an energy-dependent bias due to a specific nuclide-reaction pair. As shown in Fig. 45, the application bias is dependent on which cross sections were modified in the adjustment procedure, and how sensitive the application is to those adjustments. For example, the maximum adjustment, shown in Fig. 44, occurs around 20 keV. However, the application is not very sensitive to the cross section in this energy range, and the bias due to this adjustment is small. In the intermediate energies, the adjustment is on the order of 1%, but the application is more sensitive at these energies, so a larger bias contribution results. Also, as the thermal- and fast-energy cross sections are reduced where the intermediate-energy cross sections are increased, a negative contribution to the bias is observed for thermal and fast energies and a positive contribution to the bias is observed for intermediate energies.

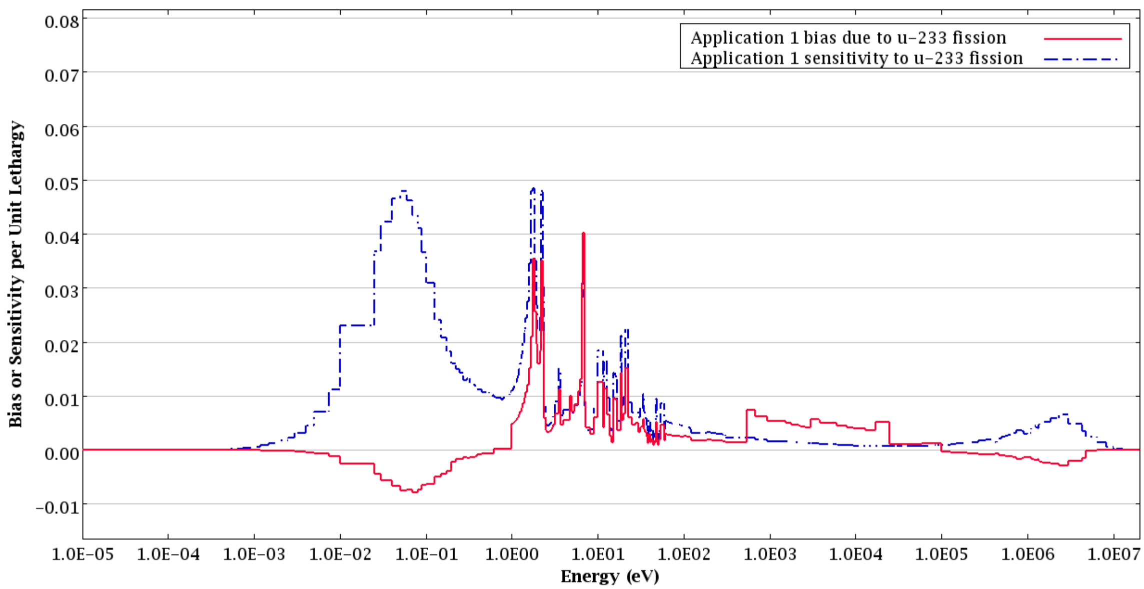

Fig. 45. Energy-dependent bias and sensitivity for ^{233}U fission for application 1.

As the TSURFER bias uncertainty is simply the uncertainty in the adjusted, or unbiased, cross-section data, the adjusted covariance matrix resulting from the TSURFER procedure can be used to provide contributions to the bias uncertainty by individual covariance matrices using the extended uncertainty edit of TSUNAMI-IP. The contributions to the uncertainty in the bias are shown in Table 21. Here, anti-correlations in the adjusted covariance data become important components in the reduced uncertainty. Since all cross sections are adjusted from the same set of benchmark experiments, the number of cross-correlations in uncertainties for different nuclides and reactions greatly increases. Where sufficient quality benchmarks are available to validate a given nuclide reaction, the uncertainty in that nuclide reaction is reduced. However, due to correlations introduced in the adjustment procedure, the uncertainty in the cross section may be increased if only limited benchmarks that have significant sensitivities to a given nuclide reaction are available.

In comparing the results shown in Table 1 to those of Table 21, the uncertainties for all nuclide-reaction pairs in applications 1–3 are reduced and new cross-correlations are introduced which further reduce the uncertainty. For application 4, the post-adjustment uncertainties for ^{233}U and ^{235}U are sufficiently reduced so they do not appear as significant sources of bias uncertainty.

However, the uncertainties for ^{56}Fe n,γ, Ca n,γ, and ^{56}Fe elastic show only a small reduction and increased uncertainties are observed for Ca n,p, Ca n,α, and Mg elastic. These results further confirm the lack of validation coverage from these components of application 4.

Table 21. TSURFER bias uncertainty due to cross-section-covariance data

System	Standard deviation (%)	Top six contributors and standard deviation (%)	
Application 1	0.071	^{233}U chi to ^{233}U chi	0.201
		^{233}U n,γ to ^{233}U chi	-0.198
		^{233}U nubar to ^{233}U chi	-0.157
		^{233}U n,γ to ^{233}U n,γ	0.152
		^{233}U nubar to ^{233}U nubar	0.129
		^{16}O elastic to ^{233}U chi	-0.080
Application 2	0.076	^{235}U n,γ to ^{235}U nubar	-0.176
		^{235}U nubar to ^{235}U nubar	0.176
		^{235}U n,γ to ^{235}U n,γ	0.143
		^{235}U chi to ^{235}U chi	0.137
		^{235}U nubar to ^{235}U chi	-0.127
		^{235}U n,γ to ^{235}U chi	-0.114
Application 3	0.159	^{233}U fission to ^{233}U fission	0.132
		^{233}U nubar to ^{233}U nubar	0.120
		^{14}N n,p to ^{14}N n,p	0.104
		^{233}U fission to ^{233}U nubar	-0.100
		^{1}H n,γ to ^{233}U fission	-0.086
		^{238}U n,γ to ^{238}U n,γ	0.078
Application 4	1.257	^{56}Fe n,γ to ^{56}Fe n,γ	1.027
		Ca n,p to Ca n,p	0.482
		Ca n,γ to Ca n,γ	0.477
		^{56}Fe elastic to ^{56}Fe elastic	0.266
		Ca n,α to Ca n,α	0.236
		Mg elastic to Mg elastic	0.197

6. ADDRESSING VALIDATION WEAKNESSES AND GAPS

No critical experiments were identified that are adequately similar to applications 3 and 4. In general, when an adequate set of critical experiments is not available to validate an application, the evaluator has a few choices in how to establish a USL.

The evaluator may be able to locate additional critical experiments that are more similar to the application based on knowledge gained through the similarity assessment. Applications 1 through 4 were compared to a 672 critical configurations. This set includes only a subset of the configurations available through the IHECSBE and does not include any configurations not documented in the IHECSBE. The analyst may be able to use the information obtained from similarity analysis, such as is documented in Section 5. of this report, to identify additional critical configurations that are similar to the applications.

The evaluator may be able to revise the application model, or the application itself, such that it is more similar to available critical experiments and provide logic in the NCS evaluation as to why the new application is bounding compared to the originally identified application. For example, as can be seen from the negative sensitivity coefficients in Fig. 25, the ^{14}N in application 3 reduces k_{eff}. From Table 12, the ^{14}N sensitivity accounts for about 50% of the ideal c_r value for application 3. If the k_{eff} margin resulting from the presence of ^{14}N is not needed, one could revise application 3, removing the ^{14}N and potentially increasing the similarity of additional critical configurations. Then the analyst would provide logic in the criticality evaluation justifying the revised application 3 model as a conservative approximation.

A frequently used option is to supplement the margin of subcriticality with an additional margin penalty to cover uncertainties associated with having a validation set that is not adequately similar to the application. The TSUNAMI tools can assist with quantifying and defending such a penalty. The TSUNAMI tools combine the application sensitivity profiles with nuclear data uncertainty information contained in the covariance data files to estimate the total uncertainty on k_{eff} due to uncertainty in the nuclear data. Figure 46 shows the top part of such an edit for application 4. A note of caution is in order when the cross-section uncertainty data is used for this purpose. The TSUNAMI-IP module typically modifies the cross-section covariance data file specified by the user to correct obviously incorrect uncertainty data and to provide uncertainty data where it is missing. The inclusion of the TSUNAMI-IP parameter "*cov_fix*" directs TSUNAMI-IP to correct obviously large values (>1000% uncertainty) and to fill in missing data. In this case, TSUNAMI-IP creates a working covariance data set that includes the following types of cross-section uncertainty data:

- Detailed energy- and reaction-dependent uncertainty data generated by the experimentalists and the cross section evaluators.

- Detailed energy- and reaction-dependent uncertainty data generated after the fact by cross section evaluators.

- Approximate uncertainty data based on relatively sparse or broad energy range measurement uncertainties, such as application of the uncertainty on the 2200 m/second cross-section data available in the *Atlas of Neutron Resonances*[12] over the entire thermal neutron energy range.

- User-specified data for specific nuclides and reactions.

- A user-specified default value used when no other data is provided.

```
----------------------------------------------------------------------------------------------------
  the relative standard deviation of k-eff (% delta-k/k)
  with user input standard deviations for unknown covariance data
  and the default standard deviation of 0.05 for unspecified covariance data is:
   1.3541 +/- 0.0016 percent
----------------------------------------------------------------------------------------------------

    * indicates default covariance data

  *** indicates default covariance data used to correct zeros or large values in some groups

 **** indicates user input covariance data used to correct zeros or large values in some groups

  contributions to uncertainty in k-eff (% delta-k/k) by individual energy covariance matrices:

                     covariance matrix
          nuclide-reaction    with    nuclide-reaction        % delta-k/k due to this matrix
        ----------------------      -----------------------   -----------------------------------
                fe-56 n,gamma            fe-56 n,gamma           1.1507E+00 +/- 5.2024E-04
                   ca n,gamma               ca n,gamma           4.8451E-01 +/- 1.4085E-04 ***
                fe-56 elastic            fe-56 elastic           2.6639E-01 +/- 1.7920E-03
                u-235 n,gamma            u-235 n,gamma           2.3423E-01 +/- 1.9543E-04
                u-235 fission            u-235 fission           2.2152E-01 +/- 1.9919E-04
                u-235 nubar              u-235 nubar             1.9621E-01 +/- 1.5247E-05
                u-235 chi                u-235 chi               1.3657E-01 +/- 7.8281E-04
                u-233 fission            u-233 fission           8.2154E-02 +/- 5.0941E-05
                fe-54 n,gamma            fe-54 n,gamma           8.1996E-02 +/- 3.7030E-05
                 o-16 elastic             o-16 elastic           7.9689E-02 +/- 1.0024E-03
                 o-16 n,alpha             o-16 n,alpha           6.6110E-02 +/- 6.3559E-05
                   ca n,p                   ca n,p               4.9267E-02 +/- 3.3961E-05 *
                   mg n,gamma               mg n,gamma           4.9166E-02 +/- 1.3971E-05 ***
                cr-53 n,gamma            cr-53 n,gamma           4.3862E-02 +/- 3.5947E-05
                fe-57 n,gamma            fe-57 n,gamma           4.3818E-02 +/- 2.0007E-05
                  h-1 n,gamma              h-1 n,gamma           3.2944E-02 +/- 8.9308E-06
                u-233 chi                u-233 chi               3.1124E-02 +/- 1.6875E-04
                ni-58 n,gamma            ni-58 n,gamma           2.9629E-02 +/- 2.3904E-05
                   ca n,alpha               ca n,alpha           2.8897E-02 +/- 1.2485E-05 *
                u-233 n,gamma            u-233 n,gamma           2.6612E-02 +/- 4.4847E-05
                u-233 nubar              u-233 nubar             2.3994E-02 +/- 1.0838E-06
```

Fig. 46. Extended uncertainty edit for application 4.

The analyst should consider the impact of using default cross-section uncertainty data on the k_{eff} uncertainty values generated by TSUNAMI-IP. For example, the second data row in Fig. 46 is for the Ca (n,γ) reaction. The asterisks on the right-hand side of the row indicate that default covariance data was used to correct zeros or large cross-section uncertainty values for some energy groups. A review of the warning messages in the TSUNAMI-IP output indicates that the default value of 5% was used to replace zero values for neutron energy groups 1 through 25 in the 44-energy group structure. This means that a default value of 5% was used for the Ca (n,γ) cross-section uncertainties for neutron energies above 0.625 eV. As can be seen in Fig. 32, application 4 is relatively insensitive to the Ca (n,γ) cross sections above 0.625 eV. Thus the use of default covariance data above 0.625 eV has little effect on the resulting k_{eff} uncertainty value. If this were not the case, the user should carefully consider the uncertainty value input for the Ca (n,γ) reaction in the TSUNAMI-IP covariance data block.

From the extended uncertainty edit, the 1-standard-deviation total uncertainty in k_{eff} due to cross-section-covariance data for application 4 is 1.3541 ± 0.0016 % $\Delta k/k$. There is overlap between this nuclear data uncertainty, the bias and bias uncertainty that could be calculated by using critical experiments that are as similar as possible to the application, and the additional margin that is frequently adopted. Unfortunately, it is not possible to quantify how much these quantities overlap.

It could be argued that, in general, the bias and bias uncertainty calculated using critical experiments, which are similar to the application, should be consistent with the nuclear data uncertainty. The bias and bias uncertainty should be bounded by two times the nuclear data uncertainty. One can be confident that the bias and bias uncertainty will be conservatively bounded by three times the nuclear data uncertainty.

As can be seen in Table 18, the USLs for application 1 vary from 0.9559 through 0.9652. These USLs include a 2% Δk additional margin. With the additional margin removed, the USLs become 0.9759 through 0.9852, and the corresponding bias and bias uncertainty vary from -2.41 to -1.48 % Δk. As was reported in Table 1, the nuclear data uncertainty for application 1 was calculated to be 0.937 % $\Delta k/k$. Three times this nuclear data uncertainty easily bounds the bias and bias uncertainty calculated for application 1. Where a statistically significant set of critical experiments similar to the application is not available, three times the nuclear data uncertainty should provide an adequate bounding estimate of the potential bias and bias uncertainty. Thus for application 4 with its 1.3541% $\Delta k/k$ nuclear data uncertainty, the USL with no additional margin should be greater than 0.9594 (i.e., 1.0 – 3*0.013541).

The extended uncertainty edit also includes individual uncertainties for nuclide and reaction pairs. For example, the total one-standard-deviation uncertainty associated with ^{56}Fe (n,γ), Ca (n,γ), and ^{56}Fe elastic scattering reactions in application 4 is 1.28 % $\Delta k/k$, which is computed from the values shown in Table 1 by adding the squares of the individual values and then taking the square root of the sum. The total for all other contributors, not just those shown in Table 1, is only 0.451% $\Delta k/k$. These three reactions account for more than 80% of the reduction in similarity shown in Table 16. Considering the sensitivity of these reactions in the application 4 model, the large reactivity uncertainties associated with the nuclear data, and the lack of good validation, it would be imprudent to ignore this significant gap in the validation. In this case one could adopt a 2 or 3 standard deviation penalty (e.g., 2.54% $\Delta k/k$ or 3.81% $\Delta k/k$) in addition to whatever bias and bias uncertainty values result from the validation study. Further studies of other critical experiments with iron and/or calcium may yield some indication of the sign and magnitude of errors that may exist in associated nuclear data. Such information might be used to justify reducing or eliminating the penalty.

Note that with the TSURFER analysis, gaps in the experimental validation coverage are accounted for with the post-adjustment uncertainty, which is applied as the uncertainty in the bias. If a perfect set of consistent experiments were available to validate every nulide reaction in the application model, the post-adjustment uncertainty would be negligible, as there would be no remaining gap in the validation coverage.

7. CONCLUSIONS

In this work, SCALE TSUNAMI tools were used to assess the similarity of four application models, provided by ISOTEK NCS staff, with a set of 672 critical experiments identified by ORNL staff as potentially useful for validation of the applications. The similarity assessment identified a large number of experiments that could be used for validation of criticality safety calculations similar to applications 1 and 2. No experiments were identified that were adequately similar to applications 3 and 4. Analysis of the similarity assessment was provided for each application.

The USLSTATS code was used to calculate USLs for application 1 for various sets of critical experiments as trended using EALF and the similarity index c_r. The TSURFER code was applied to determine USLs for all four applications using data adjustment techniques. These limits provide the margins needed to address uncertainty in the computational method, primarily due to nuclear data uncertainties.

Some discussion was provided as to possible approaches that could be used to address validation where an adequate set of critical experiments was not available to validate applications.

8. REFERENCES

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APPENDIX A

INPUT DECKS FOR APPLICATIONS

A.1 APPLICATION 1

```
< /projects/tsunami/isotek/library_map
=tsunami-3d  parm=centrmst
app. 1 - 220 gU233/l no excess acid
v6-238g_u233
read comp
  U-233  1 0  5.6850E-04 end
  N      1 0  1.1370E-03 end
  O      1 0  3.5497E-02 end
  H      1 0  6.1898E-02 end
  ss304  2 1    end
  h2o    3 1    end
end comp
read celldata
  multiregion spherical  end
           1        12.20
           2        12.45
           3        14.45
      end zone
    centrm data  demin=0.2  end centrm
end celldata
read parm
  gen=3050
  nsk=50
  npg=3000
  sig=0.00020
  htm=no
  agn=3050
  ask=50
  apg=10000
  asg=0.001
  pnm=3
  tfm=yes
end parm
read geometry
global unit 1
  sphere 1 1  4
  sphere 1 1  6
  sphere 1 1  8
  sphere 1 1  10
  sphere 1 1  11
  sphere 1 1  12
  sphere 1 1  12.20
  sphere 2 1  12.35
  sphere 2 1  12.45
  sphere 3 1  13
  sphere 3 1  13.5
  sphere 3 1  14
  sphere 3 1  14.45
end geometry
end data
read sams
  prtimp
  nohtml
end sams
end
```

A.2 APPLICATION 2

```
< /projects/tsunami/isotek/library_map
=tsunami-3d      parm=centrmst
app. 2 - 220 gU233/l no excess acid, CEUSP isotopics
v6-238g_u233
read comp
  U-233  1 0  5.5145E-05 end
  U-234  1 0  7.9252E-06 end
  U-235  1 0  4.3121E-04 end
  U-236  1 0  3.1432E-05 end
  U-238  1 0  3.7845E-05 end
  N      1 0  1.1271E-03 end
  O      1 0  3.5478E-02 end
  H      1 0  6.1939E-02 end
  ss304  2 1    end
  h2o    3 1    end
end comp
read celldata
  multiregion spherical  end
           1        14.0
           2        14.25
           3        16.25
      end zone
    centrm data  demin=0.2  end centrm
end celldata
read parm
  gen=3050
  nsk=50
  npg=3000
  sig=0.00020
  htm=no
  agn=3050
  ask=50
  apg=10000
  asg=0.001
  pnm=3
  tfm=yes
end parm
read geometry
global unit 1
  sphere 1 1   4.0
  sphere 1 1   8.0
  sphere 1 1  11.0
  sphere 1 1  13.0
  sphere 1 1  14.0
  sphere 2 1  14.125
  sphere 2 1  14.25
  sphere 3 1  15
  sphere 3 1  16
  sphere 3 1  16.25
end geometry
end data
read sams
  prtimp
  nohtml
end sams
end
```

A.3 APPLICATION 3

```
=shell
cp /cpesrv/home05/dw8/u233/scale.rev02.xn238v6_withendf7_u233 v6-238g_u233
cp /cpesrv/home05/dw8/u233/u233_dist/centrmlib/92233-0 92233-0
end
=tsunami-3d    parm=centrmst
app. 3 - 600 gU233/l no excess acid, 3% U-233
v6-238g_u233
read comp
  U-233  1 0  4.6514E-05 353 end
  U-235  1 0  3.0746E-06 353 end
  U-238  1 0  1.4693E-03 353 end
  N      1 0  3.0378E-03 353 end
  O      1 0  3.8560E-02 353 end
  H      1 0  5.2818E-02 353 end
  ss304  2 1    end
  h2o    3 1    end
end comp
read celldata
  multiregion spherical  end
           1        53.0
           2        53.25
           3        55.25
      end zone
    centrm data  demin=0.2  end centrm
end celldata
read parm
  gen=8050
  nsk=50
  npg=8000
  sig=0.00020
  htm=no
  agn=8050
  ask=50
  apg=50000
  asg=0.001
  pnm=3
  tfm=yes
end parm
read geometry
global unit 1
  sphere 1 1  20
  sphere 1 1  30
  sphere 1 1  40
  sphere 1 1  45
  sphere 1 1  50
  sphere 1 1  52
  sphere 1 1  53.0
  sphere 2 1  53.125
  sphere 2 1  53.25
  sphere 3 1  54.0
  sphere 3 1  55.0
  sphere 3 1  55.25
end geometry
end data
read sams
  prtimp
  nohtml
end sams
end
```

A.4 APPLICATION 4

```
< /projects/tsunami/isotek/library_map
=tsunami-3d    parm=centrmst
App. 4, case_007 same as _004, 75% annular fill
v6-238g_u233
read composition
 u-233       1 0 0.00033514 300   end
 u-234       1 0 4.7869e-05 300   end
 u-235       1 0 0.002624 300   end
 u-236       1 0 0.00019122 300   end
 u-238       1 0 0.00023023 300   end
 o           1 0 0.0091424 300   end
 h           1 0 0.00071643 300   end
 o           1 0 0.00035825 300   end
 c           1 0 0.0010731 300   end
 o           1 0 0.0010731 300   end
 c           1 0 9.0168e-05 300   end
 o           1 0 0.00013524 300   end
 c           1 0 0.014817 300   end
'
 carbonsteel 2 1 300   end
'
 h           3 0 0.0063624 300   end
 c           3 0 0.01081 300   end
 o           3 0 0.041204 300   end
 na          3 0 1.1715e-05 300   end
 mg          3 0 0.0055627 300   end
 al          3 0 0.00026417 300   end
 si          3 0 0.00088812 300   end
 s           3 0 7.7758e-05 300   end
 k           3 0 1.1715e-05 300   end
 ca          3 0 0.0083052 300   end
 fe          3 0 7.7972e-05 300   end
'mixture 4 is not used
 s           5 0 3.1772e-05 300   end
 na          5 0 0.00014991 300   end
 mg          5 0 0.00018512 300   end
 al          5 0 0.0012046 300   end
 si          5 0 0.019563 300   end
 k           5 0 0.00033911 300   end
 ca          5 0 0.0026908 300   end
 fe          5 0 0.00035913 300   end
 o           5 0 0.046695 300   end
 h           5 0 0.004016 300   end
'
 ss304       6 1 300   end
'repeat mixtures 1, 2, 3 and 6 for use in unit 2
 u-233       11 0 0.00033514 300   end
 u-234       11 0 4.7869e-05 300   end
 u-235       11 0 0.002624 300   end
 u-236       11 0 0.00019122 300   end
 u-238       11 0 0.00023023 300   end
 o           11 0 0.0091424 300   end
 h           11 0 0.00071643 300   end
 o           11 0 0.00035825 300   end
```

```
 c           11 0 0.0010731 300   end
 o           11 0 0.0010731 300   end
 c           11 0 9.0168e-05 300   end
 o           11 0 0.00013524 300   end
 c           11 0 0.014817 300   end
'
 carbonsteel 12 1 300   end
'
 h           13 0 0.0063624 300   end
 c           13 0 0.01081 300   end
 o           13 0 0.041204 300   end
 na          13 0 1.1715e-05 300   end
 mg          13 0 0.0055627 300   end
 al          13 0 0.00026417 300   end
 si          13 0 0.00088812 300   end
 s           13 0 7.7758e-05 300   end
 k           13 0 1.1715e-05 300   end
 ca          13 0 0.0083052 300   end
 fe          13 0 7.7972e-05 300   end
'
 ss304       16 1 300   end
end composition
read celldata
'cell for unit 300 in unit 1 vault tube
  multiregion cylindrical right_bdy=white end
    0 2.13614
    1 4.27228
    6 4.4831
    0 5.18825
    2 5.715
    3 15.66975  end zone
    centrm data demin=0.2 end centrm
'cell for unit 300 can in unit 2 vault tube
  multiregion cylindrical right_bdy=white end
     0 2.13614
    11 4.27228
    16 4.4831
     0 5.7785
    12 6.35
    13 15.66975  end zone
    centrm data demin=0.2 end centrm
'remaining concrete treated as infhommedium
  inf 5 end
    centrm data demin=0.2 end centrm
end celldata
read parameter
  gen=10050
  nsk=50
  npg=5000
  sig=0.0002
  htm=no
  ask=50
  apg=200000
  asg=0.001
```

```
  mfx=yes
  msh=10
  pnm=2
  tfm=no
end parameter
read geometry
unit 1
 zcylinder 0 1 5.18825   875.03        0
  hole 300       0        0        0
  hole 300       0        0  61.7855
  hole 300       0        0  123.571
  hole 300       0        0  185.3565
  hole 300       0        0  247.142
  hole 300       0        0  308.9275
  hole 300       0        0  370.713
  hole 300       0        0  432.4985
  hole 300       0        0  494.284
  hole 300       0        0  556.0695
  hole 300       0        0  617.855
  hole 300       0        0  679.6405
  hole 300       0        0  741.426
  hole 300       0        0  803.2115
 zcylinder 2 1   5.715   875.03        0
 zcylinder 3 1 15.66975   875.03        0
  hole 201 7.408711  7.408711        0
  hole 201 7.408711  -7.408711        0
  hole 201 -7.408711  7.408711        0
  hole 201 -7.408711  -7.408711        0
  hole 202 10.26661  4.25257        0
  hole 202 10.26661  -4.25257        0
  hole 202 -10.26661  4.25257        0
  hole 202 -10.26661  -4.25257        0
  hole 202 4.25257  10.26661        0
  hole 202 4.25257  -10.26661        0
  hole 202 -4.25257  10.26661        0
  hole 202 -4.25257  -10.26661        0
unit 2
 zcylinder 0 11  5.7785   875.03        0
  hole 400       0        0        0
  hole 400       0        0  61.7855
  hole 400       0        0  123.571
  hole 400       0        0  185.3565
  hole 400       0        0  247.142
  hole 400       0        0  308.9275
  hole 400       0        0  370.713
  hole 400       0        0  432.4985
  hole 400       0        0  494.284
  hole 400       0        0  556.0695
  hole 400       0        0  617.855
  hole 400       0        0  679.6405
  hole 400       0        0  741.426
  hole 400       0        0  803.2115
 zcylinder 12 1    6.35   875.03        0
 zcylinder 13 1 15.66975   875.03        0
```

```
  hole 201 7.408711  7.408711        0
  hole 201 7.408711  -7.408711        0
  hole 201 -7.408711  7.408711        0
  hole 201 -7.408711  -7.408711        0
  hole 202 10.26661  4.25257        0
  hole 202 10.26661  -4.25257        0
  hole 202 -10.26661  4.25257        0
  hole 202 -10.26661  -4.25257        0
  hole 202 4.25257  10.26661        0
  hole 202 4.25257  -10.26661        0
  hole 202 -4.25257  10.26661        0
  hole 202 -4.25257  -10.26661        0
unit 3
 zcylinder 0 1 5.18825   875.03        0
 zcylinder 2 1   5.715   875.03        0
 zcylinder 3 1 15.66975   875.03        0
  hole 201 7.408711  7.408711        0
  hole 201 7.408711  -7.408711        0
  hole 201 -7.408711  7.408711        0
  hole 201 -7.408711  -7.408711        0
  hole 202 10.26661  4.25257        0
  hole 202 10.26661  -4.25257        0
  hole 202 -10.26661  4.25257        0
  hole 202 -10.26661  -4.25257        0
  hole 202 4.25257  10.26661        0
  hole 202 4.25257  -10.26661        0
  hole 202 -4.25257  10.26661        0
  hole 202 -4.25257  -10.26661        0
unit 4
 zcylinder 0 1  5.7785   875.03        0
 zcylinder 2 1    6.35   875.03        0
 zcylinder 3 1 15.66975   875.03        0
  hole 201 7.408711  7.408711        0
  hole 201 7.408711  -7.408711        0
  hole 201 -7.408711  7.408711        0
  hole 201 -7.408711  -7.408711        0
  hole 202 10.26661  4.25257        0
  hole 202 10.26661  -4.25257        0
  hole 202 -10.26661  4.25257        0
  hole 202 -10.26661  -4.25257        0
  hole 202 4.25257  10.26661        0
  hole 202 4.25257  -10.26661        0
  hole 202 -4.25257  10.26661        0
  hole 202 -4.25257  -10.26661        0
unit 100
 cuboid 5 1   320.04        0    45.72        0   120.65        0
unit 101
 cuboid 5 1    45.72        0   274.32        0   120.65        0
unit 102
 cuboid 5 1    609.6        0   259.08        0    59.69        0
unit 103
 cuboid 5 1   289.55        0   320.04        0    59.69        0
unit 201
 zcylinder 2 1 0.616694   875.03        0
```

A.4 APPLICATION 4 (continued)

```
unit 202
 zcylinder 2 1 0.240228   875.03        0
unit 300
 zcylinder 0 1 2.13614  56.54802   0.9525
 zcylinder 1 1 4.27228  56.54802   0.9525
 zcylinder 0 1 4.27228   60.198   0.9525
 zcylinder 6 1  4.4831  60.5155        0
 zcylinder 2 1  4.4831  61.7854        0
unit 400
'copy of unit 300 for use in unit 2 cell
 zcylinder  0 1 2.13614  56.54802   0.9525
 zcylinder 11 1 4.27228  56.54802   0.9525
 zcylinder  0 1 4.27228   60.198   0.9525
 zcylinder 16 1  4.4831  60.5155        0
 zcylinder 12 1  4.4831  61.7854        0
global unit 10
 cuboid 0 1   274.32        0   274.32        0   875.03        0
  hole 1 24.92375  23.8125        0
  hole 1 24.92375  56.1975        0
  hole 1 24.92375  88.5825        0
  hole 1 24.92375  120.9675        0
  hole 1 24.92375  153.3525        0
  hole 1 24.92375  185.7375        0
  hole 1 24.92375  218.1225        0
  hole 1 24.92375  250.5075        0
  hole 1 52.98281   40.005        0
  hole 1 52.98281    72.39        0
  hole 1 52.98281  104.775        0
  hole 1 52.98281   137.16        0
  hole 1 52.98281  169.545        0
  hole 1 52.98281   201.93        0
  hole 1 52.98281  234.315        0
  hole 1 81.04188  23.8125        0
  hole 1 81.04188  56.1975        0
  hole 1 81.04188  88.5825        0
  hole 1 81.04188  120.9675        0
  hole 1 81.04188  153.3525        0
  hole 1 81.04188  185.7375        0
  hole 1 81.04188  218.1225        0
  hole 1 81.04188  250.5075        0
  hole 1 109.1009   40.005        0
  hole 1 109.1009    72.39        0
  hole 1 109.1009  104.775        0
  hole 1 109.1009   137.16        0
  hole 1 109.1009  169.545        0
  hole 1 109.1009   201.93        0
  hole 1 109.1009  234.315        0
  hole 1  137.16  23.8125        0
  hole 1  137.16  56.1975        0
  hole 1  137.16  88.5825        0
  hole 1  137.16  120.9675        0
  hole 1  137.16  153.3525        0
  hole 1  137.16  185.7375        0
  hole 1  137.16  218.1225        0
```

A.4 APPLICATION 4 (continued)

```
  hole 1  137.16  250.5075        0
  hole 1 165.2191   40.005        0
  hole 1 165.2191    72.39        0
  hole 1 165.2191  104.775        0
  hole 1 165.2191   137.16        0
  hole 1 165.2191  169.545        0
  hole 1 165.2191   201.93        0
  hole 1 165.2191  234.315        0
  hole 2 193.2781  23.8125        0
  hole 2 193.2781  56.1975        0
  hole 2 193.2781  88.5825        0
  hole 2 193.2781  120.9675        0
  hole 2 193.2781  153.3525        0
  hole 2 193.2781  185.7375        0
  hole 2 193.2781  218.1225        0
  hole 2 193.2781  250.5075        0
  hole 2 221.3372   40.005        0
  hole 2 221.3372    72.39        0
  hole 2 221.3372  104.775        0
  hole 2 221.3372   137.16        0
  hole 2 221.3372  169.545        0
  hole 2 221.3372   201.93        0
  hole 2 221.3372  234.315        0
  hole 2 249.3963  23.8125        0
  hole 2 249.3963  56.1975        0
  hole 2 249.3963  88.5825        0
  hole 2 249.3963  120.9675        0
  hole 2 249.3963  153.3525        0
  hole 2 249.3963  185.7375        0
  hole 2 249.3963  218.1225        0
  hole 2 249.3963  250.5075        0
 cuboid 0 1    609.6        0   579.12        0   875.03        0
  hole 100       0   274.32   754.38
  hole 101  274.32        0   754.38
  hole 102       0   320.04   815.34
  hole 103  320.04        0   815.34
 cuboid 5 1      762   -152.4   731.52  -121.92  973.455   -152.4
end geometry
read start
  nst=6
  tfx=137.16 tfy=120.968 tfz=399.5 lnu=1000
end start
read mixt
  eps=0.0003
end mixt
end data
read sams
  prtimp
  nohtml
end sams
end
```

APPENDIX B

LIST OF CRITICAL EXPERIMENTS

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}*	Normalized k_{eff}	Normalized σ_{comb}
2	uct001t02	1.54E+00	1.0015	0.0025	1.0053	0.0005	1.0037	0.0025
3	uct001t03	7.82E-01	1.0007	0.0025	1.0023	0.0005	1.0016	0.0025
4	uct001t04	4.63E-01	1.0015	0.0026	1.0058	0.0003	1.0043	0.0026
5	umf001t00x	1.11E+06	1.0000	0.0010	1.0008		1.0008	0.0010
6	umf002t01x	1.04E+06	1.0000	0.0010	1.0000		1.0000	0.0010
7	umf002t02x	1.07E+06	1.0000	0.0011	0.9993		0.9993	0.0011
8	umf003t01x	1.01E+06	1.0000	0.0010	0.9999		0.9999	0.0010
9	umf003t02x	9.27E+05	1.0000	0.0010	1.0002		1.0002	0.0010
10	umf004t01x	9.60E+05	1.0000	0.0007	1.0078		1.0078	0.0007
11	umf004t02x	8.58E+05	1.0000	0.0008	1.0095		1.0095	0.0008
12	umf005t01x	9.45E+05	1.0000	0.0030	0.9985		0.9985	0.0030
13	umf005t02x	7.67E+05	1.0000	0.0030	0.9990		0.9990	0.0030
14	umf006t00x	8.08E+05	1.0000	0.0014	1.0013		1.0013	0.0014
15	usi001t01x	6.78E+00	1.0000	0.0083	0.9910		0.9910	0.0083
16	usi001t02x	7.92E+00	1.0000	0.0085	0.9859		0.9859	0.0085
17	usi001t03x	8.52E+00	1.0000	0.0066	0.9865		0.9865	0.0066
18	usi001t04x	3.71E+00	1.0000	0.0061	0.9956		0.9956	0.0061
19	usi001t05x	9.12E+00	1.0000	0.0082	0.9895		0.9895	0.0082
20	usi001t06x	4.27E+00	1.0000	0.0061	0.9889		0.9889	0.0061
21	usi001t07x	9.55E+00	1.0000	0.0059	0.9866		0.9866	0.0059
22	usi001t08x	4.52E+00	1.0000	0.0056	0.9838		0.9838	0.0056
23	usi001t09x	7.31E+00	1.0000	0.0068	0.9835		0.9835	0.0068
24	usi001t10x	1.00E+01	1.0000	0.0053	0.9833		0.9833	0.0053
25	usi001t11x	7.72E+00	1.0000	0.0057	0.9840		0.9840	0.0057
26	usi001t12x	4.41E+00	1.0000	0.0091	0.9875		0.9875	0.0091
27	usi001t13x	5.03E+00	1.0000	0.0071	0.9877		0.9877	0.0071
28	usi001t14x	2.29E+00	1.0000	0.0052	0.9936		0.9936	0.0052
29	usi001t15x	5.40E+00	1.0000	0.0075	0.9853		0.9853	0.0075
30	usi001t16x	1.79E+00	1.0000	0.0028	0.9788		0.9788	0.0028
31	usi001t17x	2.53E+00	1.0000	0.0055	0.9920		0.9920	0.0055
32	usi001t18x	5.79E+00	1.0000	0.0057	0.9834		0.9834	0.0057
33	usi001t19x	6.03E+00	1.0000	0.0083	0.9801		0.9801	0.0083
34	usi001t20x	2.99E+00	1.0000	0.0056	0.9831		0.9831	0.0056
35	usi001t21x	6.28E+00	1.0000	0.0050	0.9777		0.9777	0.0050
36	usi001t22x	6.43E+00	1.0000	0.0049	0.9827		0.9827	0.0049
37	usi001t23x	4.70E+00	1.0000	0.0047	0.9937		0.9937	0.0047
38	usi001t24x	1.97E+00	1.0000	0.0081	0.9989		0.9989	0.0081
39	usi001t25x	2.25E+00	1.0000	0.0081	0.9911		0.9911	0.0081
40	usi001t26x	2.37E+00	1.0000	0.0065	0.9945		0.9945	0.0065
41	usi001t27x	1.24E+00	1.0000	0.0051	0.9938		0.9938	0.0051

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
42	usi001t28x	2.53E+00	1.0000	0.0061	0.9887		0.9887	0.0061
43	usi001t29x	2.62E+00	1.0000	0.0098	0.9824		0.9824	0.0098
44	usi001t30x	1.45E+00	1.0000	0.0053	0.9812		0.9812	0.0053
45	usi001t31x	2.67E+00	1.0000	0.0071	0.9959		0.9959	0.0071
46	usi001t32x	2.77E+00	1.0000	0.0053	0.9805		0.9805	0.0053
47	usi001t33x	2.07E+00	1.0000	0.0046	0.9976		0.9976	0.0046
48	ust001t01x	3.90E-02	1.0000	0.0031	1.0055		1.0055	0.0031
49	ust001t02x	3.96E-02	1.0005	0.0033	1.0055		1.0050	0.0033
50	ust001t03x	4.02E-02	1.0006	0.0033	1.0050		1.0044	0.0033
51	ust001t04x	4.08E-02	0.9998	0.0033	1.0050		1.0052	0.0033
52	ust001t05x	4.14E-02	0.9999	0.0033	1.0043		1.0044	0.0033
53	ust002t01	1.71E-01	1.0040	0.0087	1.0075	0.0005	1.0035	0.0087
54	ust002t02	1.32E-01	1.0040	0.0087	0.9966	0.0003	0.9926	0.0087
55	ust002t03	1.03E-01	1.0040	0.0087	1.0130	0.0005	1.0090	0.0087
56	ust002t04	8.34E-02	1.0040	0.0087	1.0099	0.0005	1.0059	0.0087
57	ust002t05	7.27E-02	1.0040	0.0087	1.0145	0.0005	1.0105	0.0087
58	ust002t06	6.47E-02	1.0040	0.0087	1.0015	0.0005	0.9975	0.0087
59	ust002t07	6.12E-02	1.0040	0.0087	0.9913	0.0005	0.9874	0.0087
60	ust002t08	5.63E-02	1.0040	0.0087	1.0050	0.0005	1.0010	0.0087
61	ust002t09	5.08E-02	1.0040	0.0087	0.9935	0.0005	0.9895	0.0087
62	ust002t10	4.91E-02	1.0040	0.0087	1.0078	0.0005	1.0038	0.0087
63	ust002t11	4.57E-02	1.0040	0.0087	1.0170	0.0005	1.0129	0.0087
64	ust002t12	2.69E-01	1.0040	0.0087	0.9949	0.0005	0.9909	0.0087
65	ust002t13	4.80E-01	1.0040	0.0087	0.9951	0.0005	0.9912	0.0087
66	ust002t14	1.37E-01	1.0040	0.0087	1.0041	0.0005	1.0001	0.0087
67	ust002t15	9.38E-02	1.0040	0.0087	1.0114	0.0005	1.0074	0.0087
68	ust002t16	6.23E-02	1.0040	0.0087	1.0138	0.0005	1.0098	0.0087
69	ust002t17	5.33E-02	1.0040	0.0087	1.0143	0.0005	1.0103	0.0087
70	ust003t01	3.10E-01	0.9995	0.0087	1.0045	0.0005	1.0050	0.0087
71	ust003t02	3.45E-01	0.9991	0.0151	1.0186	0.0005	1.0196	0.0151
72	ust003t03	3.31E-01	1.0007	0.0087	1.0014	0.0005	1.0007	0.0087
73	ust003t04	7.79E-01	1.0015	0.0126	1.0062	0.0005	1.0047	0.0126
74	ust003t05	1.05E+00	1.0006	0.0122	1.0118	0.0005	1.0112	0.0122
75	ust003t06	1.27E-01	1.0012	0.0087	1.0252	0.0005	1.0240	0.0087
76	ust003t07	8.21E-02	1.0016	0.0087	1.0185	0.0005	1.0168	0.0087
77	ust003t08	6.77E-02	1.0016	0.0087	1.0144	0.0005	1.0128	0.0087
78	ust003t09	6.07E-02	1.0018	0.0087	1.0147	0.0005	1.0128	0.0087
79	ust003t10	4.53E-02	1.0008	0.0087	1.0136	0.0005	1.0128	0.0087
80	ust004t01	1.69E-01	1.0039	0.0088	1.0046	0.0005	1.0007	0.0088
81	ust004t02	1.30E-01	1.0034	0.0086	1.0081	0.0005	1.0047	0.0086

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
82	ust004t03	2.69E-01	1.0041	0.0089	0.9988	0.0005	0.9947	0.0089
83	ust004t04	4.82E-01	1.0051	0.0089	0.9890	0.0005	0.9840	0.0089
84	ust004t05	3.80E-01	1.0037	0.0090	0.9949	0.0003	0.9912	0.0090
85	ust004t06	4.79E-01	1.0020	0.0105	1.0065	0.0005	1.0045	0.0105
86	ust004t07	3.77E-01	1.0020	0.0104	1.0028	0.0005	1.0008	0.0104
87	ust004t08	1.36E-01	1.0020	0.0102	1.0094	0.0005	1.0074	0.0102
88	ust005t01x	6.06E-02	1.0000	0.0040	1.0068		1.0068	0.0040
89	ust005t02	5.33E-02	1.0000	0.0049	1.0099	0.0005	1.0099	0.0049
90	ust006t01	8.55E-01	1.0000	0.0035	1.0015	0.0005	1.0015	0.0035
91	ust006t02	8.56E-01	1.0000	0.0035	0.9988	0.0005	0.9988	0.0035
92	ust006t03	8.57E-01	1.0000	0.0035	0.9970	0.0005	0.9970	0.0035
93	ust006t04	8.54E-01	1.0000	0.0035	1.0018	0.0005	1.0018	0.0035
94	ust006t05	8.65E-01	1.0000	0.0035	0.9953	0.0005	0.9953	0.0035
95	ust006t06	8.65E-01	1.0000	0.0035	0.9941	0.0005	0.9941	0.0035
96	ust006t07	4.08E-01	1.0000	0.0028	1.0009	0.0005	1.0009	0.0028
97	ust006t08	4.04E-01	1.0000	0.0028	1.0022	0.0005	1.0022	0.0028
98	ust006t09	4.04E-01	1.0000	0.0028	1.0019	0.0005	1.0019	0.0028
99	ust006t10	4.07E-01	1.0000	0.0028	1.0028	0.0005	1.0028	0.0028
100	ust006t11	4.05E-01	1.0000	0.0028	1.0017	0.0005	1.0017	0.0028
101	ust006t12	2.94E-01	1.0000	0.0035	0.9962	0.0005	0.9962	0.0035
102	ust006t13	2.94E-01	1.0000	0.0035	0.9970	0.0005	0.9970	0.0035
103	ust006t14	2.95E-01	1.0000	0.0035	0.9940	0.0005	0.9940	0.0035
104	ust006t15	2.95E-01	1.0000	0.0035	0.9951	0.0005	0.9951	0.0035
105	ust006t16	2.98E-01	1.0000	0.0035	0.9931	0.0005	0.9931	0.0035
106	ust006t17	2.98E-01	1.0000	0.0035	0.9938	0.0005	0.9938	0.0035
107	ust006t18	2.98E-01	1.0000	0.0035	0.9935	0.0005	0.9935	0.0035
108	ust006t19	1.81E-01	1.0000	0.0028	0.9997	0.0005	0.9997	0.0028
109	ust006t20	1.81E-01	1.0000	0.0028	0.9988	0.0005	0.9988	0.0028
110	ust006t21	1.82E-01	1.0000	0.0028	0.9979	0.0005	0.9979	0.0028
111	ust006t22	1.81E-01	1.0000	0.0028	0.9983	0.0005	0.9983	0.0028
112	ust006t23	1.81E-01	1.0000	0.0028	0.9983	0.0005	0.9983	0.0028
113	ust006t24	1.81E-01	1.0000	0.0028	0.9983	0.0005	0.9983	0.0028
114	ust006t25	1.81E-01	1.0000	0.0028	1.0002	0.0005	1.0002	0.0028
115	ust008t01x	3.68E-02	1.0006	0.0029	1.0042		1.0036	0.0029
116	ust009t01	3.70E-02	0.9966	0.0044	0.9994	0.0005	1.0028	0.0044
117	ust009t02	3.67E-02	0.9981	0.0040	1.0033	0.0005	1.0052	0.0040
118	ust009t03	3.63E-02	0.9989	0.0038	1.0036	0.0005	1.0047	0.0038
119	ust009t04	3.59E-02	0.9998	0.0038	1.0019	0.0005	1.0021	0.0038
120	ust012t01	1.70E-01	0.9990	0.0028	1.0019	0.0005	1.0029	0.0028
121	ust012t02	1.62E-01	0.9993	0.0025	1.0018	0.0005	1.0025	0.0025

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
122	ust012t03	1.44E-01	0.9994	0.0023	1.0124	0.0005	1.0130	0.0024
123	ust012t04	1.05E-01	1.0000	0.0015	1.0053	0.0003	1.0053	0.0015
124	ust012t05	8.96E-02	1.0000	0.0071	1.0076	0.0005	1.0076	0.0071
125	ust012t06x	7.89E-02	0.9987	0.0011	1.0086		1.0099	0.0011
126	ust012t07	5.23E-02	1.0000	0.0038	1.0064	0.0003	1.0064	0.0038
127	ust012t08	5.23E-02	1.0000	0.0048	1.0031	0.0005	1.0031	0.0048
128	ust013t01	1.54E-01	0.9992	0.0073	1.0103	0.0005	1.0111	0.0073
129	ust013t02	1.54E-01	0.9992	0.0070	1.0112	0.0005	1.0120	0.0070
130	ust013t03	1.54E-01	0.9992	0.0069	1.0112	0.0005	1.0120	0.0069
131	ust013t04	1.54E-01	0.9992	0.0073	1.0118	0.0005	1.0126	0.0073
132	ust013t05	1.54E-01	0.9992	0.0067	1.0124	0.0005	1.0132	0.0067
133	ust013t06	1.47E-01	0.9992	0.0050	1.0124	0.0005	1.0132	0.0050
134	ust013t07	1.47E-01	0.9992	0.0054	1.0110	0.0005	1.0118	0.0054
135	ust013t08	1.47E-01	0.9992	0.0050	1.0129	0.0005	1.0137	0.0050
136	ust013t09	1.47E-01	0.9992	0.0045	1.0124	0.0005	1.0132	0.0045
137	ust013t10	1.47E-01	0.9992	0.0046	1.0134	0.0005	1.0142	0.0046
138	ust013t11	1.47E-01	0.9992	0.0054	1.0101	0.0005	1.0109	0.0054
139	ust013t12	1.47E-01	0.9992	0.0050	1.0119	0.0005	1.0128	0.0050
140	ust013t13	1.47E-01	0.9992	0.0062	1.0087	0.0003	1.0095	0.0062
141	ust013t14	1.47E-01	0.9992	0.0051	1.0119	0.0005	1.0127	0.0051
142	ust013t15	1.03E-01	0.9996	0.0077	1.0268	0.0005	1.0272	0.0077
143	ust013t16	8.68E-02	0.9996	0.0069	0.9993	0.0005	0.9997	0.0069
144	ust013t17	8.35E-02	0.9996	0.0052	1.0019	0.0005	1.0023	0.0052
145	ust013t18	7.87E-02	0.9996	0.0020	1.0065	0.0005	1.0069	0.0021
146	ust013t19	7.89E-02	0.9996	0.0089	1.0023	0.0005	1.0027	0.0089
147	ust013t20	6.03E-02	0.9996	0.0056	1.0056	0.0005	1.0060	0.0056
148	ust013t21	5.55E-02	0.9996	0.0034	1.0084	0.0005	1.0088	0.0034
149	ust014t01	6.02E-01	0.9976	0.0112	0.9839	0.0005	0.9863	0.0112
150	ust014t02	6.40E-01	0.9976	0.0112	0.9973	0.0005	0.9997	0.0112
151	ust014t03	3.06E-01	1.0000	0.0074	1.0147	0.0005	1.0147	0.0074
152	ust014t04	3.00E-01	1.0000	0.0089	1.0140	0.0005	1.0140	0.0089
153	ust014t05	2.71E-01	1.0000	0.0089	1.0156	0.0005	1.0156	0.0089
154	ust014t06	2.62E-01	1.0000	0.0089	1.0144	0.0005	1.0144	0.0089
155	ust014t07	2.54E-01	1.0000	0.0088	1.0091	0.0005	1.0091	0.0088
156	ust014t08	2.44E-01	1.0000	0.0091	1.0117	0.0005	1.0117	0.0091
157	ust014t09	3.06E-01	1.0000	0.0054	1.0165	0.0005	1.0165	0.0054
158	ust014t10	3.59E-01	0.9992	0.0108	1.0000	0.0005	1.0008	0.0108
159	ust014t11	4.37E-01	0.9992	0.0126	1.0062	0.0005	1.0070	0.0126
160	ust014t12	3.11E-01	0.9992	0.0097	1.0103	0.0005	1.0111	0.0097
161	ust014t13	2.98E-01	0.9992	0.0104	1.0061	0.0005	1.0069	0.0104

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	σ_{exp}	Calculated k_{eff}	σ_{keff}	Normalized k_{eff}	σ_{comb}
162	ust014t14	2.96E-01	0.9966	0.0095	1.0034	0.0005	1.0068	0.0095
163	ust014t15	3.23E-01	0.9966	0.0098	1.0005	0.0005	1.0039	0.0098
164	ust014t16	5.40E-01	0.9965	0.0109	0.9858	0.0005	0.9892	0.0109
165	ust015t01x	1.09E+00	1.0000	0.0075	0.9970		0.9970	0.0075
166	ust015t02x	1.22E+00	1.0000	0.0070	0.9916		0.9916	0.0070
167	ust015t03x	1.29E+00	1.0000	0.0068	0.9923		0.9923	0.0068
168	ust015t04x	7.10E-01	1.0000	0.0041	0.9931		0.9931	0.0041
169	ust015t05x	1.35E+00	1.0000	0.0055	0.9916		0.9916	0.0055
170	ust015t06x	1.40E+00	1.0000	0.0099	0.9820		0.9820	0.0099
171	ust015t07x	7.81E-01	1.0000	0.0070	0.9907		0.9907	0.0070
172	ust015t08x	1.45E+00	1.0000	0.0067	0.9782		0.9782	0.0067
173	ust015t09x	1.48E+00	1.0000	0.0050	0.9736		0.9736	0.0050
174	ust015t10x	1.12E+00	1.0000	0.0051	0.9932		0.9932	0.0051
175	ust015t11x	6.83E-01	1.0000	0.0075	1.0004		1.0004	0.0075
176	ust015t12x	7.56E-01	1.0000	0.0069	1.0002		1.0002	0.0069
177	ust015t13x	7.96E-01	1.0000	0.0069	0.9978		0.9978	0.0069
178	ust015t14x	4.58E-01	1.0000	0.0036	1.0016		1.0016	0.0036
179	ust015t15x	8.35E-01	1.0000	0.0060	0.9952		0.9952	0.0060
180	ust015t16x	8.56E-01	1.0000	0.0043	0.9939		0.9939	0.0043
181	ust015t17x	4.95E-01	1.0000	0.0029	1.0009		1.0009	0.0029
182	ust015t18x	8.86E-01	1.0000	0.0056	0.9797		0.9797	0.0056
183	ust015t19x	9.00E-01	1.0000	0.0052	0.9799		0.9799	0.0052
184	ust015t20x	2.84E-01	1.0000	0.0079	1.0032		1.0032	0.0079
185	ust015t21x	3.11E-01	1.0000	0.0070	1.0050		1.0050	0.0070
186	ust015t22x	3.25E-01	1.0000	0.0062	1.0027		1.0027	0.0062
187	ust015t23x	3.38E-01	1.0000	0.0055	1.0003		1.0003	0.0055
188	ust015t24x	3.46E-01	1.0000	0.0051	0.9966		0.9966	0.0051
189	ust015t25x	2.20E-01	1.0000	0.0023	1.0012		1.0012	0.0023
190	ust015t26x	1.25E-01	1.0000	0.0066	1.0020		1.0020	0.0066
191	ust015t27x	1.29E-01	1.0000	0.0063	1.0059		1.0059	0.0063
192	ust015t28x	1.31E-01	1.0000	0.0058	1.0036		1.0036	0.0058
193	ust015t29x	1.33E-01	1.0000	0.0051	1.0019		1.0019	0.0051
194	ust015t30x	1.35E-01	1.0000	0.0048	1.0010		1.0010	0.0048
195	ust015t31x	1.36E-01	1.0000	0.0055	1.0001		1.0001	0.0055
196	ust016t01	2.86E-01	0.9987	0.0037	1.0094	0.0005	1.0107	0.0037
197	ust016t02	2.86E-01	0.9983	0.0044	1.0081	0.0005	1.0098	0.0044
198	ust016t03	2.86E-01	0.9992	0.0036	1.0092	0.0005	1.0100	0.0036
199	ust016t04	2.86E-01	0.9992	0.0035	1.0046	0.0005	1.0054	0.0035
200	ust016t06	2.86E-01	0.9993	0.0034	1.0005	0.0005	1.0012	0.0034
201	ust016t07	2.86E-01	1.0008	0.0034	1.0007	0.0005	0.9999	0.0034

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
202	ust016t08	2.86E-01	1.0011	0.0028	1.0007	0.0005	0.9996	0.0028
203	ust016t09	2.85E-01	1.0000	0.0027	1.0009	0.0005	1.0009	0.0027
204	ust016t10	2.82E-01	1.0000	0.0030	1.0093	0.0005	1.0093	0.0030
205	ust016t11	2.83E-01	0.9992	0.0041	1.0085	0.0005	1.0093	0.0041
206	ust016t12	2.83E-01	0.9992	0.0047	1.0098	0.0005	1.0106	0.0047
207	ust016t13	1.42E-01	0.9993	0.0036	1.0095	0.0005	1.0102	0.0036
208	ust016t14	1.42E-01	1.0000	0.0026	1.0092	0.0005	1.0092	0.0026
209	ust016t15	1.42E-01	1.0000	0.0027	1.0116	0.0005	1.0116	0.0027
210	ust016t16	1.43E-01	0.9994	0.0031	1.0128	0.0005	1.0134	0.0031
211	ust016t17	1.44E-01	1.0000	0.0028	0.9989	0.0005	0.9989	0.0028
212	ust016t18	1.43E-01	0.9988	0.0036	0.9996	0.0005	1.0008	0.0036
213	ust016t19	1.43E-01	1.0000	0.0035	0.9997	0.0005	0.9997	0.0035
214	ust016t21	1.41E-01	1.0000	0.0028	1.0137	0.0005	1.0137	0.0028
215	ust016t22	1.41E-01	1.0000	0.0034	1.0148	0.0005	1.0148	0.0034
216	ust016t23	1.41E-01	1.0000	0.0031	1.0142	0.0005	1.0142	0.0031
217	ust016t24	1.41E-01	1.0012	0.0024	1.0150	0.0005	1.0138	0.0025
218	ust016t25	7.98E-02	0.9981	0.0040	1.0047	0.0005	1.0066	0.0040
219	ust016t26	7.97E-02	0.9980	0.0034	1.0109	0.0005	1.0129	0.0034
220	ust016t27	7.98E-02	0.9988	0.0037	1.0081	0.0005	1.0094	0.0037
221	ust016t28	7.95E-02	0.9986	0.0037	1.0044	0.0005	1.0058	0.0037
222	ust016t29	7.95E-02	0.9985	0.0031	1.0050	0.0005	1.0065	0.0031
223	ust016t30	7.96E-02	0.9993	0.0032	1.0049	0.0005	1.0056	0.0032
224	ust016t31	5.61E-02	0.9990	0.0034	1.0154	0.0005	1.0164	0.0034
225	ust016t32	5.61E-02	0.9985	0.0032	1.0180	0.0004	1.0195	0.0032
226	ust016t33	5.61E-02	0.9986	0.0039	1.0182	0.0005	1.0196	0.0039
227	ust017t01	1.13E-01	0.9997	0.0032	1.0069	0.0005	1.0072	0.0032
228	ust017t02	1.10E-01	1.0000	0.0025	0.9979	0.0005	0.9979	0.0025
229	ust017t03	1.06E-01	1.0001	0.0035	1.0093	0.0005	1.0092	0.0035
230	ust017t04	8.13E-02	0.9994	0.0040	1.0088	0.0005	1.0094	0.0040
231	ust017t05	7.95E-02	1.0000	0.0029	1.0067	0.0005	1.0067	0.0029
232	ust017t06	5.29E-02	1.0000	0.0029	1.0052	0.0005	1.0052	0.0029
233	ust017t07	5.39E-02	1.0000	0.0037	1.0042	0.0005	1.0042	0.0037
234	hmt025t01	2.74E+00	1.0037	0.0047	1.0123	0.0005	1.0085	0.0047
235	hmt025t02	1.93E-01	1.0007	0.0054	1.0076	0.0005	1.0069	0.0054
236	hmf030t00	2.14E+05	1.0000	0.0009	1.0031	0.0005	1.0031	0.0010
237	lct049t01	2.13E+00	1.0000	0.0034	0.9902	0.0005	0.9902	0.0034
238	lct049t02	2.14E+00	1.0000	0.0034	0.9902	0.0005	0.9902	0.0034
239	lct049t03	2.26E+00	1.0000	0.0034	0.9917	0.0005	0.9917	0.0034
240	lct049t04	2.37E+00	1.0000	0.0034	0.9918	0.0005	0.9918	0.0034
241	lct049t05	1.20E+00	1.0000	0.0042	0.9895	0.0005	0.9895	0.0042

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
242	lct049t06	1.21E+00	1.0000	0.0042	0.9919	0.0005	0.9919	0.0042
243	lct049t07	1.16E+00	1.0000	0.0042	0.9907	0.0005	0.9907	0.0042
244	lct049t08	1.25E+00	1.0000	0.0042	0.9908	0.0005	0.9908	0.0042
245	lct049t09	7.71E-01	1.0000	0.0037	0.9889	0.0005	0.9889	0.0037
246	lct049t10	7.76E-01	1.0000	0.0037	0.9913	0.0005	0.9913	0.0037
247	lct049t11	7.75E-01	1.0000	0.0037	0.9905	0.0005	0.9905	0.0037
248	lct049t12	8.17E-01	1.0000	0.0037	0.9903	0.0004	0.9903	0.0037
249	lct049t13	1.48E+00	1.0000	0.0036	0.9906	0.0005	0.9906	0.0036
250	lct049t14	1.48E+00	1.0000	0.0036	0.9918	0.0005	0.9918	0.0036
251	lct049t15	1.48E+00	1.0000	0.0036	0.9926	0.0005	0.9926	0.0036
252	lct049t16	1.15E+00	1.0000	0.0036	0.9911	0.0005	0.9911	0.0036
253	lct049t17	1.23E+00	1.0000	0.0036	0.9914	0.0005	0.9914	0.0036
254	lct049t18	1.06E+00	1.0000	0.0030	0.9960	0.0005	0.9960	0.0030
255	mcf001t01	1.22E+05	0.9866	0.0023	1.0045	0.0005	1.0181	0.0024
256	mci005t00	1.72E+02	1.1526	0.0056	1.1642	0.0005	1.0101	0.0056
257	mcm001t01	4.03E+02	0.9999	0.0056	0.9898	0.0005	0.9899	0.0056
258	mcm001t02	4.05E+02	0.9996	0.0053	0.9878	0.0005	0.9882	0.0053
259	mcm001t03	4.31E+01	1.0011	0.0039	0.9973	0.0005	0.9962	0.0039
260	mcm001t04	4.24E+01	1.0004	0.0036	0.9982	0.0005	0.9978	0.0036
261	mcm001t05	4.31E+01	1.0005	0.0043	1.0020	0.0005	1.0015	0.0043
262	mcm001t06	3.99E+01	0.9970	0.0042	0.9974	0.0005	1.0004	0.0042
263	mcm001t07	3.82E+01	0.9990	0.0038	0.9960	0.0005	0.9970	0.0038
264	mcm001t08	3.66E+01	0.9985	0.0044	0.9957	0.0005	0.9972	0.0044
265	mcm001t09	3.61E+01	1.0001	0.0046	0.9968	0.0005	0.9967	0.0046
266	mcm001t10	3.60E+01	0.9988	0.0045	0.9987	0.0005	0.9999	0.0045
267	mcm001t11	4.33E+01	0.9998	0.0040	1.0002	0.0005	1.0004	0.0040
268	mcm001t12	4.35E+01	0.9995	0.0037	1.0013	0.0005	1.0018	0.0037
269	mcm001t13	4.44E+01	1.0007	0.0040	0.9992	0.0005	0.9985	0.0040
270	mcm001t14	4.41E+01	0.9989	0.0039	1.0009	0.0005	1.0020	0.0039
271	mcm001t15	4.54E+01	1.0004	0.0041	1.0006	0.0005	1.0002	0.0041
272	mcm001t16	4.77E+01	1.0009	0.0041	0.9993	0.0005	0.9984	0.0041
273	mcm001t17	4.32E+01	1.0001	0.0041	1.0018	0.0005	1.0017	0.0041
274	mcm001t18	4.24E+01	1.0010	0.0041	1.0008	0.0005	0.9998	0.0041
275	mcm001t19	4.22E+01	1.0007	0.0038	0.9988	0.0005	0.9981	0.0038
276	mmf008t01	2.91E+04	0.9920	0.0063	1.0137	0.0005	1.0219	0.0063
277	mmf008t02	3.22E+05	1.0010	0.0023	1.0270	0.0005	1.0259	0.0023
278	mmf008t03	6.87E+04	0.9860	0.0044	1.0062	0.0005	1.0205	0.0044
279	mmf008t04	2.43E+05	0.9730	0.0045	1.0315	0.0005	1.0601	0.0045
280	mmf008t05	2.57E+05	1.0060	0.0069	1.0214	0.0005	1.0153	0.0069
281	mmf008t06	2.19E+04	0.9710	0.0042	1.0285	0.0005	1.0592	0.0042

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
282	mmf008t07	3.60E+05	1.0300	0.0025	1.0491	0.0005	1.0185	0.0025
283	hct010-01	7.81E-01	1.0000	0.0050	0.9990	0.0003	0.9990	0.0050
284	hct010-02	7.87E-01	1.0000	0.0050	0.9960	0.0003	0.9960	0.0050
285	hct010-03	3.12E-01	1.0000	0.0050	0.9987	0.0003	0.9987	0.0050
286	hct010-04	1.87E-01	1.0000	0.0050	0.9981	0.0003	0.9981	0.0050
287	hct010-05	1.36E-01	1.0000	0.0050	0.9998	0.0003	0.9998	0.0050
288	hct010-06	1.37E-01	1.0000	0.0050	0.9976	0.0003	0.9976	0.0050
289	hct010-07	1.09E-01	1.0000	0.0050	1.0010	0.0003	1.0010	0.0050
290	hct010-08	1.09E-01	1.0000	0.0050	1.0012	0.0003	1.0012	0.0050
291	hct010-09	1.11E-01	1.0000	0.0050	0.9997	0.0003	0.9997	0.0050
292	hct010-10	9.57E-02	1.0000	0.0050	1.0025	0.0003	1.0025	0.0050
293	hct010-11	9.63E-02	1.0000	0.0050	1.0001	0.0003	1.0001	0.0050
294	hct010-12	8.61E-02	1.0000	0.0050	0.9992	0.0003	0.9992	0.0050
295	hct010-13	8.05E-02	1.0000	0.0050	1.0017	0.0003	1.0017	0.0050
296	hct010-14	9.51E-02	1.0000	0.0050	1.0008	0.0003	1.0008	0.0050
297	hct010-15	1.00E-01	1.0000	0.0050	1.0009	0.0003	1.0009	0.0050
298	hct011-01	7.21E-01	0.9988	0.0042	0.9941	0.0003	0.9953	0.0042
299	hct011-02	5.53E-01	0.9988	0.0042	0.9953	0.0003	0.9965	0.0042
300	hct011-03	4.33E-01	0.9988	0.0042	0.9961	0.0003	0.9973	0.0042
301	hct012-01	6.04E-01	0.9987	0.0032	0.9939	0.0003	0.9952	0.0032
302	hct012-02	4.59E-01	0.9987	0.0034	0.9937	0.0003	0.9950	0.0034
303	hct013-01	4.56E-01	0.9988	0.0042	0.9960	0.0003	0.9972	0.0042
304	hct013-02	3.17E-01	0.9988	0.0043	0.9959	0.0003	0.9971	0.0043
305	hct014-01	1.17E-01	0.9986	0.0048	1.0002	0.0003	1.0016	0.0048
306	hct014-02	9.78E-02	0.9986	0.0049	1.0001	0.0003	1.0015	0.0049
307	hmt006-01	8.46E-02	1.0000	0.0044	0.9957	0.0003	0.9957	0.0044
308	hmt006-02	7.03E-02	1.0000	0.0040	0.9956	0.0003	0.9956	0.0040
309	hmt006-03	6.31E-02	1.0000	0.0040	1.0011	0.0003	1.0011	0.0040
310	hmt006-04	6.18E-02	1.0000	0.0040	0.9949	0.0003	0.9949	0.0040
311	hmt006-05	5.83E-02	1.0000	0.0040	0.9949	0.0003	0.9949	0.0040
312	hmt006-06	5.58E-02	1.0000	0.0040	0.9936	0.0003	0.9936	0.0040
313	hmt006-07	5.41E-02	1.0000	0.0040	0.9923	0.0003	0.9923	0.0040
314	hmt006-08	5.22E-02	1.0000	0.0040	0.9899	0.0002	0.9899	0.0040
315	hmt006-09	5.19E-02	1.0000	0.0040	0.9933	0.0002	0.9933	0.0040
316	hmt006-10	8.21E-02	1.0000	0.0040	1.0029	0.0003	1.0029	0.0040
317	hmt006-11	6.21E-02	1.0000	0.0040	0.9959	0.0003	0.9959	0.0040
318	hmt006-12	5.40E-02	1.0000	0.0040	0.9989	0.0003	0.9989	0.0040
319	hmt006-15	5.63E-02	1.0000	0.0040	0.9885	0.0003	0.9885	0.0040
320	hmt006-13	8.24E-02	1.0000	0.0061	1.0164	0.0003	1.0164	0.0061
321	hmt006-14	5.68E-02	1.0000	0.0040	0.9911	0.0003	0.9911	0.0040

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
322	hmt006-16	6.32E-02	1.0000	0.0040	0.9980	0.0003	0.9980	0.0040
323	hmt006-17	7.43E-02	1.0000	0.0040	0.9931	0.0003	0.9931	0.0040
324	hmt006-18	8.02E-02	1.0000	0.0040	0.9928	0.0003	0.9928	0.0040
325	hmt006-19	5.23E-02	1.0000	0.0040	0.9961	0.0003	0.9961	0.0040
326	hmt006-20	6.45E-02	1.0000	0.0040	0.9957	0.0003	0.9957	0.0040
327	hmt006-21	6.91E-02	1.0000	0.0040	0.9992	0.0003	0.9992	0.0040
328	hmt006-22	7.39E-02	1.0000	0.0040	0.9988	0.0003	0.9988	0.0040
329	hmt006-23	7.57E-02	1.0000	0.0040	1.0015	0.0003	1.0015	0.0040
330	hst001-01	8.21E-02	1.0004	0.0060	1.0010	0.0004	1.0006	0.0060
331	hst001-02	2.80E-01	1.0021	0.0072	0.9992	0.0004	0.9971	0.0072
332	hst001-03	8.06E-02	1.0003	0.0035	1.0035	0.0004	1.0032	0.0035
333	hst001-04	2.99E-01	1.0008	0.0053	1.0001	0.0004	0.9993	0.0053
334	hst001-05	4.30E-02	1.0001	0.0049	1.0013	0.0003	1.0012	0.0049
335	hst001-06	4.46E-02	1.0002	0.0046	1.0041	0.0004	1.0039	0.0046
336	hst001-07	7.78E-02	1.0008	0.0040	0.9991	0.0004	0.9983	0.0040
337	hst001-08	8.22E-02	0.9998	0.0038	1.0000	0.0004	1.0002	0.0038
338	hst001-09	2.99E-01	1.0008	0.0054	0.9966	0.0004	0.9958	0.0054
339	hst001-10	4.62E-02	0.9993	0.0054	0.9939	0.0003	0.9946	0.0054
340	hst005-11	2.49E-01	1.0000	0.0083	0.9994	0.0003	0.9994	0.0083
341	hst005-12	2.56E-01	1.0000	0.0084	1.0082	0.0003	1.0082	0.0084
342	hst005-14	2.66E-01	1.0000	0.0058	1.0072	0.0003	1.0072	0.0058
343	hst005-15	2.27E-01	1.0000	0.0059	1.0022	0.0003	1.0022	0.0059
344	hst005-17	3.29E-01	1.0000	0.0057	0.9887	0.0003	0.9887	0.0057
345	hst006-01	2.11E-01	0.9973	0.0050	0.9841	0.0004	0.9867	0.0050
346	hst006-08	2.01E-01	0.9973	0.0050	0.9837	0.0003	0.9863	0.0050
347	hst006-12	2.12E-01	0.9973	0.0050	0.9826	0.0004	0.9853	0.0050
348	hst006-27	2.09E-01	0.9973	0.0050	0.9841	0.0004	0.9868	0.0050
349	hst007-01	4.74E-02	1.0000	0.0035	1.0135	0.0003	1.0135	0.0035
350	hst007-02	2.70E-01	1.0000	0.0050	1.0132	0.0003	1.0132	0.0050
351	hst007-03	4.63E-02	1.0000	0.0035	1.0117	0.0003	1.0117	0.0035
352	hst007-04	2.40E-01	1.0000	0.0035	1.0140	0.0003	1.0140	0.0035
353	hst007-05	5.04E-02	1.0000	0.0035	1.0070	0.0003	1.0070	0.0035
354	hst007-06	2.76E-01	1.0000	0.0035	1.0042	0.0004	1.0042	0.0035
355	hst007-07	4.97E-02	1.0000	0.0035	1.0065	0.0003	1.0065	0.0035
356	hst007-08	2.71E-01	1.0000	0.0035	1.0032	0.0003	1.0032	0.0035
357	hst007-09	5.14E-02	1.0000	0.0035	1.0069	0.0003	1.0069	0.0035
358	hst007-10	5.30E-02	1.0000	0.0035	1.0150	0.0003	1.0150	0.0035
359	hst007-11	2.58E-01	1.0000	0.0035	1.0091	0.0003	1.0091	0.0035
360	hst007-12	5.13E-02	1.0000	0.0035	1.0149	0.0003	1.0149	0.0035
361	hst007-13	2.33E-01	1.0000	0.0035	1.0127	0.0003	1.0127	0.0035

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
362	hst007-14	2.41E-01	1.0000	0.0035	1.0105	0.0003	1.0105	0.0035
363	hst007-15	2.43E-01	1.0000	0.0035	1.0087	0.0003	1.0087	0.0035
364	hst007-16	2.57E-01	1.0000	0.0035	1.0071	0.0004	1.0071	0.0035
365	hst007-17	2.42E-01	1.0000	0.0035	1.0098	0.0003	1.0098	0.0035
366	hst009-01	5.28E-01	0.9990	0.0043	1.0030	0.0004	1.0040	0.0043
367	hst009-02	3.23E-01	1.0000	0.0039	1.0037	0.0003	1.0037	0.0039
368	hst009-03	1.60E-01	1.0000	0.0036	1.0031	0.0003	1.0031	0.0036
369	hst009-04	9.10E-02	0.9986	0.0035	0.9975	0.0003	0.9989	0.0035
370	hst010-01	5.25E-02	1.0000	0.0029	1.0033	0.0003	1.0033	0.0029
371	hst010-02	5.31E-02	1.0000	0.0029	1.0033	0.0003	1.0033	0.0029
372	hst010-04	5.62E-02	0.9992	0.0029	0.9991	0.0003	0.9999	0.0029
373	hst010-03	5.53E-02	1.0000	0.0029	1.0014	0.0003	1.0014	0.0029
374	hst011-01	3.96E-02	1.0000	0.0023	1.0072	0.0003	1.0072	0.0023
375	hst011-02	3.94E-02	1.0000	0.0023	1.0035	0.0003	1.0035	0.0023
376	hst012-01	3.24E-02	0.9999	0.0058	1.0023		1.0024	0.0058
377	hst013-01	3.23E-02	1.0012	0.0026	1.0000		0.9988	0.0026
378	hst014-01	4.59E-02	1.0000	0.0028	1.0018	0.0003	1.0018	0.0028
379	hst015-01	5.76E-02	1.0000	0.0032	1.0056	0.0003	1.0056	0.0032
380	hst015-02	5.59E-02	1.0000	0.0034	0.9973	0.0003	0.9973	0.0034
381	hst016-01	7.82E-02	1.0000	0.0036	0.9998	0.0003	0.9998	0.0036
382	hst017-01	9.77E-02	1.0000	0.0028	1.0003	0.0003	1.0003	0.0028
383	hst017-02	1.08E-01	1.0000	0.0040	0.9891	0.0004	0.9891	0.0040
384	hst017-03	1.02E-01	1.0000	0.0036	0.9850	0.0004	0.9850	0.0036
385	hst018-01	1.60E-01	1.0000	0.0034	0.9991	0.0003	0.9991	0.0034
386	hst018-02	1.87E-01	1.0000	0.0046	0.9926	0.0004	0.9926	0.0046
387	hst018-03	1.71E-01	1.0000	0.0042	0.9969	0.0004	0.9969	0.0042
388	hst019-01	3.12E-01	1.0000	0.0041	1.0073	0.0003	1.0073	0.0041
389	hst025-01	4.06E-02	1.0002	0.0025	1.0025	0.0003	1.0023	0.0025
390	hst025-02	4.06E-02	1.0007	0.0025	1.0021	0.0003	1.0014	0.0025
391	hst025-04	4.14E-02	1.0003	0.0027	1.0029	0.0003	1.0026	0.0027
392	hst025-05	4.88E-02	1.0013	0.0030	1.0048	0.0003	1.0035	0.0030
393	hst027-01	7.46E-02	1.0000	0.0046	0.9985	0.0004	0.9985	0.0046
394	hst28i-1	4.67E-02	1.0000	0.0023	0.9998	0.0003	0.9998	0.0023
395	hst28i-3	4.68E-02	1.0000	0.0026	1.0018	0.0003	1.0018	0.0026
396	hst28i-5	4.69E-02	1.0000	0.0031	0.9970	0.0003	0.9970	0.0031
397	hst28i-7	4.71E-02	1.0000	0.0038	1.0013	0.0003	1.0013	0.0038
398	hst28i-9	1.44E-01	1.0000	0.0049	1.0009	0.0004	1.0009	0.0049
399	hst28i-11	1.45E-01	1.0000	0.0051	1.0023	0.0004	1.0023	0.0051
400	hst28i-13	1.48E-01	1.0000	0.0058	1.0014	0.0003	1.0014	0.0058
401	hst28i-15	1.49E-01	1.0000	0.0064	1.0094	0.0003	1.0094	0.0064

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
402	hst28i-17	1.51E-01	1.0000	0.0066	1.0001	0.0003	1.0001	0.0066
403	hst29i-01	1.57E-01	1.0000	0.0066	1.0030	0.0003	1.0030	0.0066
404	hst30i-01	4.74E-02	1.0000	0.0039	1.0000	0.0003	1.0000	0.0039
405	hst30i-04	1.58E-01	1.0000	0.0064	1.0051	0.0004	1.0051	0.0064
406	hst032-01	3.11E-02	1.0015	0.0026	0.9991	0.0002	0.9976	0.0026
407	hst033-02a	3.10E-01	0.9979	0.0112	0.9992	0.0003	1.0013	0.0112
408	hst033-02b	3.19E-01	1.0000	0.0109	0.9987	0.0003	0.9987	0.0109
409	hst033-02c	3.23E-01	0.9979	0.0067	0.9981	0.0003	1.0002	0.0067
410	hst033-03a	2.96E-01	0.9942	0.0115	1.0005	0.0003	1.0064	0.0115
411	hst033-03b	2.93E-01	0.9979	0.0112	1.0037	0.0003	1.0058	0.0112
412	hst033-03c	2.75E-01	0.9979	0.0072	1.0115	0.0003	1.0136	0.0072
413	hst033-10c	2.77E-01	0.9979	0.0072	1.0034	0.0003	1.0055	0.0072
414	hst033-10a	2.96E-01	0.9942	0.0115	1.0002	0.0003	1.0060	0.0115
415	hst033-10d	3.01E-01	0.9979	0.0106	0.9937	0.0003	0.9958	0.0106
416	hst035-01	3.73E-02	1.0000	0.0031	1.0021	0.0003	1.0021	0.0031
417	hst035-05	4.94E-02	1.0000	0.0033	1.0044	0.0003	1.0044	0.0033
418	hst035-07	8.06E-02	1.0000	0.0035	1.0054	0.0003	1.0054	0.0035
419	hst037-01	3.83E-02	0.9980	0.0034	1.0103	0.0003	1.0123	0.0034
420	hst037-03	4.42E-02	0.9970	0.0042	1.0072	0.0003	1.0102	0.0042
421	hst037-06	5.12E-02	0.9960	0.0051	1.0122	0.0003	1.0163	0.0051
422	hst042-01	3.14E-02	0.9957	0.0039	0.9970	0.0002	1.0013	0.0039
423	hst042-02	3.14E-02	0.9965	0.0036	0.9970	0.0002	1.0005	0.0036
424	hst042-03	3.08E-02	0.9994	0.0028	1.0007	0.0002	1.0013	0.0028
425	hst042-04	3.06E-02	1.0000	0.0034	1.0021	0.0002	1.0021	0.0034
426	hst042-05	3.04E-02	1.0000	0.0034	1.0000	0.0002	1.0000	0.0034
427	hst042-06	3.05E-02	1.0000	0.0037	1.0003	0.0002	1.0003	0.0037
428	hst042-07	3.04E-02	1.0000	0.0036	1.0011	0.0002	1.0011	0.0036
429	hst042-08	3.03E-02	1.0000	0.0035	1.0014	0.0002	1.0014	0.0035
430	hst043-01	7.34E-02	0.9986	0.0031	0.9975	0.0004	0.9989	0.0031
431	hst043-02	3.34E-02	0.9995	0.0026	1.0078	0.0003	1.0083	0.0026
432	hst043-03	3.20E-02	0.9990	0.0025	1.0028	0.0002	1.0038	0.0025
433	imf003	7.08E+05	1.0000	0.0017	1.0046		1.0046	0.0017
434	imf004	6.66E+05	1.0000	0.0030	1.0091		1.0091	0.0030
435	imf005	6.43E+05	1.0000	0.0021	1.0246		1.0246	0.0021
436	imf006	6.54E+05	1.0000	0.0023	1.0013		1.0013	0.0023
437	lct009-01	1.15E-01	1.0000	0.0021	0.9946	0.0002	0.9946	0.0021
438	lct009-02	1.15E-01	1.0000	0.0021	0.9943	0.0003	0.9943	0.0021
439	lct009-03	1.15E-01	1.0000	0.0021	0.9939	0.0003	0.9939	0.0021
440	lct009-04	1.15E-01	1.0000	0.0021	0.9945	0.0003	0.9945	0.0021
441	lct009-05	1.16E-01	1.0000	0.0021	0.9956	0.0003	0.9956	0.0021

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
442	lct009-06	1.15E-01	1.0000	0.0021	0.9946	0.0003	0.9946	0.0021
443	lct009-07	1.16E-01	1.0000	0.0021	0.9956	0.0003	0.9956	0.0021
444	lct009-08	1.15E-01	1.0000	0.0021	0.9946	0.0002	0.9946	0.0021
445	lct009-09	1.16E-01	1.0000	0.0021	0.9952	0.0003	0.9952	0.0021
446	lct009-10	1.16E-01	1.0000	0.0021	0.9941	0.0003	0.9941	0.0021
447	lct009-11	1.15E-01	1.0000	0.0021	0.9940	0.0003	0.9940	0.0021
448	lct009-13	1.15E-01	1.0000	0.0021	0.9947	0.0003	0.9947	0.0021
449	lct009-14	1.16E-01	1.0000	0.0021	0.9931	0.0003	0.9931	0.0021
450	lct009-15	1.15E-01	1.0000	0.0021	0.9953	0.0003	0.9953	0.0021
451	lct009-16	1.16E-01	1.0000	0.0021	0.9946	0.0003	0.9946	0.0021
452	lct009-17	1.15E-01	1.0000	0.0021	0.9953	0.0003	0.9953	0.0021
453	lct009-18	1.16E-01	1.0000	0.0021	0.9941	0.0003	0.9941	0.0021
454	lct009-19	1.15E-01	1.0000	0.0021	0.9953	0.0002	0.9953	0.0021
455	lct009-20	1.16E-01	1.0000	0.0021	0.9948	0.0002	0.9948	0.0021
456	lct009-21	1.15E-01	1.0000	0.0021	0.9952	0.0003	0.9952	0.0021
457	lct009-22	1.16E-01	1.0000	0.0021	0.9946	0.0003	0.9946	0.0021
458	lct009-23	1.16E-01	1.0000	0.0021	0.9950	0.0003	0.9950	0.0021
459	lct009-24	1.15E-01	1.0000	0.0021	0.9938	0.0003	0.9938	0.0021
460	lct009-25	1.14E-01	1.0000	0.0021	0.9945	0.0003	0.9945	0.0021
461	lct009-26	1.14E-01	1.0000	0.0021	0.9947	0.0003	0.9947	0.0021
462	lct009-27	1.14E-01	1.0000	0.0021	0.9950	0.0003	0.9950	0.0021
463	lct010-01	1.21E-01	1.0000	0.0021	1.0059	0.0003	1.0059	0.0021
464	lct010-02	1.18E-01	1.0000	0.0021	1.0054	0.0003	1.0054	0.0021
465	lct010-03	1.16E-01	1.0000	0.0021	1.0034	0.0003	1.0034	0.0021
466	lct010-04	1.13E-01	1.0000	0.0021	0.9930	0.0003	0.9930	0.0021
467	lct010-05	3.85E-01	1.0000	0.0021	0.9955	0.0002	0.9955	0.0021
468	lct010-06	2.80E-01	1.0000	0.0021	0.9961	0.0003	0.9961	0.0021
469	lct010-07	2.20E-01	1.0000	0.0021	0.9979	0.0003	0.9979	0.0021
470	lct010-08	1.93E-01	1.0000	0.0021	0.9941	0.0003	0.9941	0.0021
471	lct010-09	1.25E-01	1.0000	0.0021	1.0005	0.0002	1.0005	0.0021
472	lct010-10	1.21E-01	1.0000	0.0021	1.0003	0.0003	1.0003	0.0021
473	lct010-11	1.18E-01	1.0000	0.0021	0.9998	0.0003	0.9998	0.0021
474	lct010-12	1.15E-01	1.0000	0.0021	0.9976	0.0003	0.9976	0.0021
475	lct010-13	1.13E-01	1.0000	0.0021	0.9934	0.0003	0.9934	0.0021
476	lct010-14	3.22E-01	1.0000	0.0028	0.9965	0.0003	0.9965	0.0028
477	lct010-15	3.08E-01	1.0000	0.0028	0.9969	0.0003	0.9969	0.0028
478	lct010-16	2.97E-01	1.0000	0.0028	0.9962	0.0019	0.9962	0.0034
479	lct010-17	2.91E-01	1.0000	0.0028	0.9964	0.0003	0.9964	0.0028
480	lct010-18	2.87E-01	1.0000	0.0028	0.9958	0.0003	0.9958	0.0028
481	lct010-19	2.80E-01	1.0000	0.0028	0.9940	0.0003	0.9940	0.0028

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
482	lct010-20	3.08E-01	1.0000	0.0028	0.9993	0.0003	0.9993	0.0028
483	lct010-21	2.99E-01	1.0000	0.0028	0.9990	0.0003	0.9990	0.0028
484	lct010-22	2.86E-01	1.0000	0.0028	0.9972	0.0003	0.9972	0.0028
485	lct010-23	2.79E-01	1.0000	0.0028	0.9942	0.0002	0.9942	0.0028
486	lct010-24	6.55E-01	1.0000	0.0028	0.9917	0.0003	0.9917	0.0028
487	lct010-25	6.04E-01	1.0000	0.0028	0.9930	0.0003	0.9930	0.0028
488	lct010-26	5.57E-01	1.0000	0.0028	0.9941	0.0003	0.9941	0.0028
489	lct010-27	5.17E-01	1.0000	0.0028	0.9942	0.0003	0.9942	0.0028
490	lct010-28	4.84E-01	1.0000	0.0028	0.9947	0.0003	0.9947	0.0028
491	lct010-29	2.86E-01	1.0000	0.0028	0.9858	0.0003	0.9858	0.0028
492	lct010-30	2.84E-01	1.0000	0.0028	0.9845	0.0003	0.9845	0.0028
493	lct012-01	1.74E-01	1.0000	0.0034	0.9810	0.0003	0.9810	0.0034
494	lct012-02	1.81E-01	1.0000	0.0034	0.9816	0.0002	0.9816	0.0034
495	lct012-03	1.83E-01	1.0000	0.0034	0.9813	0.0003	0.9813	0.0034
496	lct012-04	1.90E-01	1.0000	0.0034	0.9817	0.0002	0.9817	0.0034
497	lct012-05	1.89E-01	1.0000	0.0034	0.9805	0.0003	0.9805	0.0034
498	lct012-06	1.89E-01	1.0000	0.0034	0.9829	0.0002	0.9829	0.0034
499	lct012-07	1.90E-01	1.0000	0.0034	0.9834	0.0003	0.9834	0.0034
500	lct012-08	1.84E-01	1.0000	0.0049	0.9817	0.0003	0.9817	0.0049
501	lct012-09	1.71E-01	1.0000	0.0034	0.9803	0.0003	0.9803	0.0034
502	lct012-10	1.80E-01	1.0000	0.0034	0.9827	0.0003	0.9827	0.0034
503	lct017-01	1.00E-01	1.0000	0.0031	0.9992	0.0003	0.9992	0.0031
504	lct017-02	9.87E-02	1.0000	0.0031	0.9987	0.0002	0.9987	0.0031
505	lct017-03	9.67E-02	1.0000	0.0031	0.9956	0.0003	0.9956	0.0031
506	lct017-04	2.14E-01	1.0000	0.0031	0.9937	0.0003	0.9937	0.0031
507	lct017-05	1.88E-01	1.0000	0.0031	0.9952	0.0002	0.9952	0.0031
508	lct017-06	1.77E-01	1.0000	0.0031	0.9953	0.0003	0.9953	0.0031
509	lct017-07	1.67E-01	1.0000	0.0031	0.9950	0.0002	0.9950	0.0031
510	lct017-08	1.38E-01	1.0000	0.0031	0.9935	0.0002	0.9935	0.0031
511	lct017-09	1.12E-01	1.0000	0.0031	0.9923	0.0003	0.9923	0.0031
512	lct017-10	1.02E-01	1.0000	0.0031	0.9954	0.0002	0.9954	0.0031
513	lct017-11	1.00E-01	1.0000	0.0031	0.9953	0.0003	0.9953	0.0031
514	lct017-12	9.87E-02	1.0000	0.0031	0.9951	0.0003	0.9951	0.0031
515	lct017-13	9.72E-02	1.0000	0.0031	0.9945	0.0002	0.9945	0.0031
516	lct017-14	9.66E-02	1.0000	0.0031	0.9946	0.0003	0.9946	0.0031
517	lct017-15	1.84E-01	1.0000	0.0028	0.9925	0.0003	0.9925	0.0028
518	lct017-16	1.77E-01	1.0000	0.0028	0.9940	0.0003	0.9940	0.0028
519	lct017-17	1.72E-01	1.0000	0.0028	0.9945	0.0003	0.9945	0.0028
520	lct017-18	1.71E-01	1.0000	0.0028	0.9927	0.0003	0.9927	0.0028
521	lct017-19	1.68E-01	1.0000	0.0028	0.9929	0.0003	0.9929	0.0028

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	σ_{exp}	Calculated k_{eff}	σ_{keff}	Normalized k_{eff}	σ_{comb}
522	lct017-20	1.66E-01	1.0000	0.0028	0.9910	0.0002	0.9910	0.0028
523	lct017-21	1.65E-01	1.0000	0.0028	0.9912	0.0003	0.9912	0.0028
524	lct017-22	1.64E-01	1.0000	0.0028	0.9901	0.0002	0.9901	0.0028
525	lct017-23	1.76E-01	1.0000	0.0028	0.9952	0.0003	0.9952	0.0028
526	lct017-24	1.71E-01	1.0000	0.0028	0.9958	0.0003	0.9958	0.0028
527	lct017-25	1.63E-01	1.0000	0.0028	0.9917	0.0003	0.9917	0.0028
528	lct017-26	4.08E-01	1.0000	0.0028	0.9883	0.0002	0.9883	0.0028
529	lct017-27	3.47E-01	1.0000	0.0028	0.9900	0.0003	0.9900	0.0028
530	lct017-28	3.01E-01	1.0000	0.0028	0.9913	0.0002	0.9913	0.0028
531	lct017-29	2.67E-01	1.0000	0.0028	0.9916	0.0003	0.9916	0.0028
532	lct18c1	2.03E-01	1.0000	0.0020	0.9972	0.0003	0.9972	0.0020
533	lct19c1	3.34E-01	1.0000	0.0063	1.0066	0.0003	1.0066	0.0063
534	lct19c2	1.65E-01	1.0000	0.0058	1.0025	0.0003	1.0025	0.0058
535	lct19c3	5.45E-02	1.0000	0.0061	1.0040	0.0002	1.0040	0.0061
536	lct20c1	7.99E-02	1.0000	0.0061	0.9935	0.0003	0.9935	0.0061
537	lct20c2	6.92E-02	1.0000	0.0061	0.9988	0.0003	0.9988	0.0061
538	lct20c3	6.72E-02	1.0000	0.0061	1.0012	0.0003	1.0012	0.0061
539	lct20c4	6.63E-02	1.0000	0.0061	1.0007	0.0002	1.0007	0.0061
540	lct20c5	6.52E-02	1.0000	0.0061	1.0017	0.0002	1.0017	0.0061
541	lct20c6	6.45E-02	1.0000	0.0061	1.0025	0.0003	1.0025	0.0061
542	lct20c7	6.25E-02	1.0000	0.0061	1.0016	0.0003	1.0016	0.0061
543	lct21c1	1.34E-01	1.0000	0.0072	1.0075	0.0003	1.0075	0.0072
544	lct21c2	1.31E-01	1.0000	0.0072	1.0076	0.0003	1.0076	0.0072
545	lct21c3	1.28E-01	1.0000	0.0072	1.0076	0.0003	1.0076	0.0072
546	lct21c4	7.55E-02	1.0000	0.0050	1.0103	0.0002	1.0103	0.0050
547	lct21c5	7.44E-02	1.0000	0.0050	1.0106	0.0002	1.0106	0.0050
548	lct22c1	7.11E-01	1.0000	0.0046	0.9942	0.0003	0.9942	0.0046
549	lct21c6	7.25E-02	1.0000	0.0050	1.0102	0.0002	1.0102	0.0050
550	lct22c2	2.97E-01	1.0000	0.0046	0.9998	0.0003	0.9998	0.0046
551	lct22c3	1.28E-01	1.0000	0.0036	1.0019	0.0003	1.0019	0.0036
552	lct22c4	8.44E-02	1.0000	0.0037	1.0045	0.0003	1.0045	0.0037
553	lct22c5	6.98E-02	1.0000	0.0038	1.0009	0.0003	1.0009	0.0038
554	lct22c6	5.50E-02	1.0000	0.0046	1.0004	0.0002	1.0004	0.0046
555	lct22c7	5.46E-02	1.0000	0.0046	1.0029	0.0003	1.0029	0.0046
556	lct23c1	8.30E-02	1.0000	0.0044	1.0020	0.0001	1.0020	0.0044
557	lct23c2	7.73E-02	1.0000	0.0044	1.0014	0.0001	1.0014	0.0044
558	lct23c3	7.55E-02	1.0000	0.0044	1.0014	0.0001	1.0014	0.0044
559	lct23c4	7.38E-02	1.0000	0.0044	1.0021	0.0001	1.0021	0.0044
560	lct23c5	7.23E-02	1.0000	0.0044	1.0013	0.0001	1.0013	0.0044
561	lct23c6	7.09E-02	1.0000	0.0044	1.0006	0.0001	1.0006	0.0044

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
562	lct24c1	1.07E+00	1.0000	0.0054	0.9926	0.0003	0.9926	0.0054
563	lct24c2	1.46E-01	1.0000	0.0040	1.0028	0.0003	1.0028	0.0040
564	lct25c1	4.49E-01	1.0000	0.0041	0.9791	0.0003	0.9791	0.0041
565	lct25c2	2.07E-01	1.0000	0.0044	0.9869	0.0003	0.9869	0.0044
566	lct25c3	1.00E-01	1.0000	0.0047	0.9943	0.0003	0.9943	0.0047
567	lct25c4	7.04E-02	1.0000	0.0052	0.9978	0.0003	0.9978	0.0052
568	lct26c1	2.48E-01	1.0000	0.0034	0.9970	0.0003	0.9970	0.0034
569	lct26c2	4.20E-01	0.9996	0.0034	0.9957	0.0003	0.9961	0.0034
570	lct26c3	1.04E+00	1.0018	0.0062	0.9993	0.0003	0.9975	0.0062
571	lct26c4	1.64E+00	0.9978	0.0062	0.9962	0.0003	0.9983	0.0062
572	lct32a1	7.11E-01	1.0000	0.0045	0.9980	0.0003	0.9980	0.0045
573	lct32a2	9.40E-01	1.0000	0.0041	0.9974	0.0003	0.9974	0.0041
574	lct32a3	1.36E+00	1.0000	0.0042	0.9969	0.0003	0.9969	0.0042
575	lct32a4	6.98E-02	1.0000	0.0037	1.0061	0.0003	1.0061	0.0037
576	lct32a5	1.04E-01	1.0000	0.0032	1.0015	0.0003	1.0015	0.0032
577	lct32a6	1.23E-01	1.0000	0.0033	1.0012	0.0003	1.0012	0.0033
578	lct32a7	5.46E-02	1.0000	0.0045	1.0077	0.0002	1.0077	0.0045
579	lct32a8	7.91E-02	1.0000	0.0038	1.0089	0.0002	1.0089	0.0038
580	lct32a9	9.18E-02	1.0000	0.0037	1.0087	0.0003	1.0087	0.0037
581	lct040-01	1.50E-01	1.0000	0.0039	0.9954	0.0003	0.9954	0.0039
582	lct040-02	1.72E-01	1.0000	0.0041	0.9933	0.0003	0.9933	0.0041
583	lct040-03	1.62E-01	1.0000	0.0041	0.9921	0.0003	0.9921	0.0041
584	lct042-01	1.75E-01	1.0000	0.0016	0.9926	0.0002	0.9926	0.0016
585	lct042-02	1.82E-01	1.0000	0.0016	0.9924	0.0003	0.9924	0.0016
586	lct042-03	1.89E-01	1.0000	0.0016	0.9940	0.0002	0.9940	0.0016
587	lct042-04	1.87E-01	1.0000	0.0017	0.9939	0.0002	0.9939	0.0017
588	lct042-05	1.84E-01	1.0000	0.0033	0.9938	0.0003	0.9938	0.0033
589	lct042-06	1.75E-01	1.0000	0.0016	0.9933	0.0002	0.9933	0.0016
590	lct042-07	1.79E-01	1.0000	0.0018	0.9922	0.0002	0.9922	0.0018
591	lct079-1	3.11E-01	0.9999	0.0016	0.9915	0.0005	0.9916	0.0017
592	lct079-2	3.13E-01	1.0002	0.0016	0.9911	0.0005	0.9909	0.0017
593	lct079-3	3.17E-01	1.0005	0.0016	0.9917	0.0005	0.9912	0.0017
594	lct079-4	3.20E-01	1.0004	0.0016	0.9912	0.0005	0.9908	0.0017
595	lct079-5	3.26E-01	1.0004	0.0016	0.9925	0.0005	0.9921	0.0017
596	lct079-6	1.10E-01	0.9994	0.0008	0.9956	0.0005	0.9962	0.0009
597	lct079-7	1.11E-01	1.0003	0.0008	0.9959	0.0005	0.9956	0.0009
598	lct079-8	1.11E-01	1.0008	0.0008	0.9970	0.0005	0.9962	0.0009
599	lct079-9	1.12E-01	1.0003	0.0008	0.9950	0.0005	0.9947	0.0009
600	lct079-10	1.13E-01	1.0009	0.0008	0.9961	0.0005	0.9952	0.0009
601	lst01c1	6.43E-02	0.9991	0.0029	1.0026	0.0003	1.0035	0.0029

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	Expected σ_{exp}	Calculated k_{eff}	Calculated σ_{keff}	Normalized k_{eff}	Normalized σ_{comb}
602	lst03c1	4.10E-02	0.9997	0.0039	0.9970	0.0002	0.9973	0.0039
603	lst03c2	3.91E-02	0.9993	0.0042	0.9964	0.0003	0.9971	0.0042
604	lst03c3	3.88E-02	0.9995	0.0042	1.0005	0.0002	1.0010	0.0042
605	lst03c4	3.86E-02	0.9995	0.0042	0.9942	0.0003	0.9946	0.0042
606	lst03c5	3.59E-02	0.9997	0.0048	1.0076	0.0002	1.0079	0.0048
607	lst03c6	3.56E-02	0.9999	0.0049	0.9980	0.0003	0.9981	0.0049
608	lst03c7	3.54E-02	0.9994	0.0049	0.9965	0.0002	0.9970	0.0049
609	lst03c8	3.44E-02	0.9993	0.0052	1.0002	0.0002	1.0009	0.0052
610	lst03c9	3.43E-02	0.9996	0.0052	0.9968	0.0002	0.9972	0.0052
611	lst04-R1	4.16E-02	0.9994	0.0008	0.9943	0.0002	0.9949	0.0008
612	lst04-R29	4.06E-02	0.9999	0.0009	0.9954	0.0003	0.9954	0.0009
613	lst04-R33	3.93E-02	0.9999	0.0009	0.9944	0.0002	0.9945	0.0009
614	lst04-R34	3.86E-02	0.9999	0.0010	0.9961	0.0002	0.9961	0.0010
615	lst04-R46	3.80E-02	0.9999	0.0010	0.9966	0.0002	0.9967	0.0010
616	lst04-R51	3.74E-02	0.9994	0.0011	1.0043	0.0002	1.0049	0.0011
617	lst04-R54	3.71E-02	0.9996	0.0011	0.9960	0.0002	0.9964	0.0011
618	lst05c1	4.07E-02	1.0000	0.0042	0.9980	0.0002	0.9980	0.0042
619	lst05c2	4.07E-02	1.0000	0.0051	0.9984	0.0003	0.9984	0.0051
620	lst05c3	4.09E-02	1.0000	0.0064	0.9986	0.0003	0.9986	0.0064
621	lst06c1	4.80E-02	1.0000	0.0037	0.9990	0.0003	0.9990	0.0037
622	lst06c2	4.82E-02	1.0000	0.0038	1.0061	0.0003	1.0061	0.0038
623	lst06c3	4.86E-02	1.0000	0.0041	0.9992	0.0003	0.9992	0.0041
624	lst06c4	4.87E-02	1.0000	0.0041	1.0000	0.0003	1.0000	0.0041
625	lst06c5	4.92E-02	1.0000	0.0047	1.0025	0.0004	1.0025	0.0047
626	lst07-R14	4.23E-02	0.9961	0.0009	0.9963	0.0002	1.0002	0.0009
627	lst07-R30	4.10E-02	0.9973	0.0009	0.9980	0.0002	1.0007	0.0009
628	lst07-R32	3.97E-02	0.9985	0.0010	0.9971	0.0002	0.9986	0.0010
629	lst07-R36	3.89E-02	0.9988	0.0011	0.9998	0.0002	1.0010	0.0011
630	lst07-R49	3.83E-02	0.9983	0.0011	0.9987	0.0002	1.0004	0.0011
631	lst08-R72	3.79E-02	0.9999	0.0014	1.0037	0.0002	1.0038	0.0014
632	lst08-R74	3.80E-02	1.0002	0.0015	1.0003	0.0002	1.0001	0.0015
633	lst08-R76	3.80E-02	0.9999	0.0014	1.0026	0.0003	1.0027	0.0014
634	lst08-R78	3.80E-02	0.9999	0.0014	1.0034	0.0002	1.0035	0.0014
635	lst09-R92	3.85E-02	0.9998	0.0014	0.9969	0.0002	0.9971	0.0014
636	lst09-R93	3.85E-02	0.9999	0.0014	0.9997	0.0002	0.9998	0.0014
637	lst09-R94	3.85E-02	0.9999	0.0014	1.0018	0.0002	1.0019	0.0014
638	lst10-R83	3.80E-02	0.9999	0.0015	1.0017	0.0002	1.0018	0.0015
639	lst10-R85	3.80E-02	0.9999	0.0014	1.0016	0.0003	1.0017	0.0014
640	lst10-R86	3.80E-02	1.0000	0.0014	1.0020	0.0002	1.0020	0.0014
641	lst10-R88	3.80E-02	1.0001	0.0014	1.0021	0.0003	1.0020	0.0014

Exp. No.	IHECSBE ID	EALF (eV)	Expected k_{eff}	σ_{exp}	Calculated k_{eff}	σ_{keff}	Normalized k_{eff}	σ_{comb}
642	lst16-105	5.14E-02	0.9996	0.0013	1.0064	0.0004	1.0068	0.0014
643	lst16-R113	4.90E-02	0.9999	0.0013	1.0068	0.0004	1.0069	0.0014
644	lst16-R125	4.52E-02	0.9994	0.0014	1.0053	0.0004	1.0059	0.0015
645	lst16-R129	4.39E-02	0.9996	0.0014	1.0103	0.0004	1.0107	0.0015
646	lst16-R131	4.26E-02	0.9995	0.0014	1.0040	0.0003	1.0045	0.0014
647	lst16-R140	4.17E-02	0.9992	0.0015	1.0030	0.0004	1.0038	0.0015
648	lst16-R196	4.11E-02	0.9994	0.0015	1.0042	0.0003	1.0048	0.0015
649	lst17-R104	5.16E-02	0.9981	0.0013	1.0094	0.0003	1.0113	0.0013
650	lst17-R122	4.93E-02	0.9986	0.0013	1.0042	0.0003	1.0056	0.0013
651	lst17-R123	4.52E-02	0.9989	0.0014	1.0027	0.0003	1.0038	0.0014
652	lst17-R126	4.40E-02	0.9992	0.0014	1.0031	0.0003	1.0039	0.0014
653	lst17-R130	4.27E-02	0.9987	0.0015	1.0027	0.0003	1.0040	0.0015
654	lst17-R147	4.20E-02	0.9996	0.0015	1.0023	0.0003	1.0027	0.0015
655	lst18c1	4.16E-02	0.9992	0.0010	1.0025	0.0003	1.0033	0.0010
656	lst18c3	4.19E-02	0.9996	0.0010	1.0028	0.0003	1.0032	0.0010
657	lst18c4	4.20E-02	0.9997	0.0010	0.9920	0.0002	0.9922	0.0010
658	lst18c5	4.20E-02	0.9992	0.0010	1.0024	0.0003	1.0032	0.0010
659	lst18c6	4.20E-02	0.9996	0.0010	1.0023	0.0002	1.0027	0.0010
660	lst19c1	4.21E-02	0.9994	0.0009	1.0022	0.0003	1.0028	0.0009
661	lst19c2	4.20E-02	0.9997	0.0009	1.0039	0.0002	1.0042	0.0009
662	lst19c3	4.20E-02	0.9995	0.0009	1.0037	0.0002	1.0042	0.0009
663	lst19c4	4.21E-02	0.9999	0.0009	1.0042	0.0003	1.0043	0.0009
664	lst19c5	4.21E-02	0.9996	0.0009	1.0041	0.0003	1.0045	0.0009
665	lst19c6	4.21E-02	0.9998	0.0009	1.0046	0.0003	1.0048	0.0009
666	lst20c1	3.78E-02	0.9995	0.0010	1.0003	0.0002	1.0008	0.0010
667	lst20c2	3.69E-02	0.9996	0.0010	0.9991	0.0003	0.9995	0.0010
668	lst20c3	3.59E-02	0.9997	0.0012	0.9988	0.0002	0.9991	0.0012
669	lst20c4	3.54E-02	0.9998	0.0012	0.9994	0.0002	0.9996	0.0012
670	lst21c1	3.80E-02	0.9983	0.0009	0.9983	0.0002	1.0000	0.0009
671	lst21c2	3.71E-02	0.9985	0.0010	0.9985	0.0002	1.0000	0.0010
672	lst21c3	3.60E-02	0.9989	0.0011	0.9974	0.0002	0.9985	0.0011
673	lst21c4	3.55E-02	0.9993	0.0012	0.9994	0.0002	1.0001	0.0012

* Where the calculation σ_{keff} is omitted, the case is a 1-dimensional discrete ordinance calculation that used a k_{eff} convergence criterion of 10^{-6}.

APPENDIX C

INPUT FILE FOR TSUNAMI-IP CALCULATION FOR APPLICATION 1

```
=tsunami-ip
ISOTEK Application 1, 100 wt% 233U, patched covariance data
read parameter

  coverx=44groupv6recu233

  cov_fix
  dcov1=0.0
  dcov2=0.1
  dcov3=0.25
  use_dcov
  udcov=0.05
  use_icov

  c
  c_long
  csummary
  cvalue=0.8

  cr
  cr_long
  crsummary
  crvalue=0.8

  uncert
  uncert_long

  html
  plot
  inptcase
  sencut=0.02
  usename
  values

end parameter
read apps
/projects/tsunami/isotek/don/new/tsu3d/app1b.sdf
end apps
read exps
/projects/tsunami/isotek/don/new/tsu3d/app1b.sdf

/projects/tsunami/verified/scale5.1/v6_endf7_u233/uct001t02.sdf
/projects/tsunami/verified/scale5.1/v6_endf7_u233/uct001t03.sdf
/projects/tsunami/verified/scale5.1/v6_endf7_u233/uct001t04.sdf

/projects/tsunami/verified/scale5.1/v6_endf7_u233/umf001t00x.sdf

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```

```
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/projects/tsunami/verified/scale5.1/v6_endf7_u233/usi001t04x.sdf
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/projects/tsunami/leu/lst17-R126.sdf
/projects/tsunami/leu/lst17-R130.sdf
/projects/tsunami/leu/lst17-R147.sdf

/projects/tsunami/leu/lst18c1.sdf
/projects/tsunami/leu/lst18c3.sdf
/projects/tsunami/leu/lst18c4.sdf
/projects/tsunami/leu/lst18c5.sdf
/projects/tsunami/leu/lst18c6.sdf

/projects/tsunami/leu/lst19c1.sdf
/projects/tsunami/leu/lst19c2.sdf
/projects/tsunami/leu/lst19c3.sdf
/projects/tsunami/leu/lst19c4.sdf
```

```
/projects/tsunami/leu/lst19c5.sdf
/projects/tsunami/leu/lst19c6.sdf

/projects/tsunami/leu/lst20c1.sdf
/projects/tsunami/leu/lst20c2.sdf
/projects/tsunami/leu/lst20c3.sdf
/projects/tsunami/leu/lst20c4.sdf

/projects/tsunami/leu/lst21c1.sdf
/projects/tsunami/leu/lst21c2.sdf
/projects/tsunami/leu/lst21c3.sdf
/projects/tsunami/leu/lst21c4.sdf

end exps

read exclusions
  chi
end exclusions

read covariance
  c       n,alpha  0.05
  cr-50   n,p      2.00
  cr-52   n,alpha  3.50
  cr-54   n,p      0.25
  cr-54   n,alpha  4.00
  fe-56   n,d      1.00
  fe-56   n,t      1.00
  fe-58   n,alpha  5.00
  ni-60   n,p      1.00
  ni-62   n,p      0.20
  ni-62   n,alpha  6.00
  ni-64   n,alpha  2.20
   n-14   elastic  0.03
   n-14   n,gamma  0.30
   n-14   n,n'     2.80
   n-14   n,2n     3.00
   p-31   elastic  0.07
   p-31   n,gamma  0.24
   u-238  fission  0.05
end covariance

read reactions

end reactions

read html
  bg_clr=papayawhip
  h1_clr=maroon
  h2_clr=navy
  txt_clr=black
  lnk_clr=mediumorchid
  lnk_dec=underline
  vlnk_clr=green
  max_clr=blue
  cut_clr=red
end html
```

```
end
```

APPENDIX D

SIMILARITY LISTING FOR APPLICATIONS 1 THROUGH 4

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
ust016t10	0.995	hst001-08	0.985	lst05c1	0.687	hst007-13	0.301
ust016t11	0.995	hst001-03	0.984	lst05c2	0.687	hst007-04	0.299
ust016t12	0.995	hst001-07	0.983	lst05c3	0.681	hst007-17	0.295
ust006t13	0.992	hst043-01	0.983	lst04-R54	0.637	hst007-14	0.294
ust006t12	0.992	hst001-01	0.979	lst07-R49	0.634	hst007-15	0.293
ust006t14	0.992	hst027-01	0.974	lst04-R46	0.634	hst007-16	0.281
ust006t15	0.992	hst017-01	0.974	lst04-R34	0.630	hst007-11	0.279
ust013t01	0.991	hst017-02	0.973	lst07-R36	0.629	hst007-02	0.278
ust013t02	0.991	hst018-01	0.969	lst09-R94	0.626	hst005-14	0.272
ust013t03	0.991	hst017-03	0.968	lst10-R83	0.626	hst005-15	0.269
ust013t04	0.991	hst28i-11	0.966	lst10-R86	0.625	hst005-17	0.268
ust013t05	0.991	hst28i-9	0.966	lst10-R88	0.625	hst007-08	0.268
ust016t06	0.991	hst28i-13	0.965	lst08-R74	0.625	hst005-11	0.263
ust016t09	0.991	hst018-02	0.965	lst09-R93	0.625	hst005-12	0.262
ust016t07	0.991	hst28i-15	0.964	lst10-R85	0.625	hst007-06	0.259
ust016t08	0.991	hst009-04	0.962	lst08-R76	0.625	hct010-02	0.256
ust013t06	0.991	hst016-01	0.961	lst08-R78	0.625	hst007-12	0.254
ust013t07	0.991	hst001-09	0.961	lst09-R92	0.625	hct010-01	0.253
ust013t08	0.991	hst001-04	0.960	lst07-R32	0.624	hst009-01	0.253
ust013t09	0.991	hst018-03	0.960	lst04-R33	0.624	lct32a3	0.248
ust013t11	0.991	hst29i-01	0.960	lst08-R72	0.624	hst009-02	0.247
ust013t12	0.991	hst001-02	0.959	lst04-R29	0.621	lct24c1	0.247
ust013t13	0.991	hst30i-04	0.958	lst07-R30	0.620	lct32a2	0.242
ust013t14	0.991	hst28i-17	0.956	lst07-R14	0.616	lct22c1	0.239
ust013t10	0.991	hst015-01	0.954	lst04-R1	0.614	hct010-03	0.239
ust016t21	0.990	hst009-03	0.950	lst04-R51	0.613	lct32a1	0.239
ust016t22	0.990	hst010-04	0.947	ust001t05x	0.604	hst019-01	0.235
ust016t23	0.990	hst010-03	0.946	ust001t04x	0.604	hst007-03	0.235
ust016t24	0.990	hst015-02	0.946	ust001t03x	0.603	hst009-03	0.231
ust012t01	0.987	hst010-01	0.942	ust001t02x	0.601	hct010-04	0.231
ust012t02	0.987	hst010-02	0.942	ust001t01x	0.600	lct049t18	0.230
ust016t13	0.987	hst001-10	0.941	ust009t01	0.593	hst033-03a	0.229
ust016t14	0.986	hst019-01	0.939	ust009t02	0.591	hst033-10a	0.229
ust016t15	0.986	hst001-06	0.937	ust009t03	0.586	hst001-04	0.229
ust012t03	0.985	hst007-08	0.933	ust008t01x	0.585	lct049t02	0.229
ust006t16	0.983	hst006-01	0.932	lst03c1	0.584	lct049t03	0.229
ust006t18	0.983	hst28i-5	0.932	ust009t04	0.579	lct049t01	0.229
ust006t17	0.983	hst006-08	0.931	lst03c2	0.578	lct049t04	0.229
ust013t15	0.981	hst28i-3	0.931	lst03c4	0.576	hst007-10	0.228
ust016t01	0.980	hst28i-1	0.931	lst03c3	0.574	hst001-09	0.228

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
ust016t04	0.980	hst001-05	0.930	lst21c3	0.572	hst033-03c	0.227
ust016t02	0.980	hst30i-01	0.929	lst21c4	0.570	lct049t13	0.227
ust016t03	0.980	hst007-06	0.928	lst21c2	0.569	hst006-08	0.227
ust017t03	0.977	hst28i-7	0.926	lst20c3	0.569	hst033-03b	0.227
ust012t04	0.976	hst014-01	0.925	lst21c1	0.568	lct049t15	0.226
ust016t19	0.976	hst007-09	0.923	lst20c1	0.568	lct049t14	0.226
ust016t16	0.976	hst006-27	0.920	lst20c4	0.567	hst006-27	0.226
ust016t18	0.976	hct010-06	0.918	ust002t11	0.567	hst001-02	0.226
ust016t17	0.976	hst006-12	0.917	lst20c2	0.566	hst033-10d	0.226
ust017t02	0.975	hst007-07	0.917	lst03c5	0.564	hst033-02a	0.225
ust006t01	0.975	hst007-15	0.917	lst03c6	0.563	lct049t17	0.225
ust006t02	0.974	hst007-14	0.916	lst03c7	0.557	lct049t05	0.225
ust006t03	0.974	hst007-17	0.915	lst18c3	0.556	lct049t06	0.225
ust006t04	0.974	hst025-05	0.912	lst18c5	0.556	lct049t16	0.225
ust013t16	0.974	hct010-07	0.911	lst18c6	0.556	lct049t07	0.225
ust013t17	0.972	hst007-05	0.910	lst19c2	0.556	hst006-01	0.224
ust015t25x	0.971	hst009-02	0.909	lst19c6	0.556	lct049t08	0.224
ust017t01	0.971	hst007-13	0.909	lst16-R196	0.556	hst033-10c	0.223
ust014t01	0.970	hct010-09	0.909	lst19c5	0.556	hst30i-04	0.223
ust012t05	0.969	hst007-16	0.909	lst19c4	0.556	lct22c2	0.223
ust013t18	0.969	hst007-04	0.908	lst19c1	0.556	hst006-12	0.223
ust015t17x	0.967	hct010-04	0.908	lst19c3	0.556	hst28i-17	0.223
ust016t28	0.966	hst035-07	0.906	lst18c4	0.555	hst29i-01	0.222
ust016t30	0.965	hct010-08	0.905	lst16-R140	0.554	hst018-03	0.222
ust016t29	0.965	hct010-03	0.903	lst03c8	0.552	lct26c4	0.221
ust016t25	0.965	hst025-02	0.903	lst17-R147	0.552	lct049t12	0.221
ust016t27	0.964	hst025-01	0.903	lst03c9	0.552	lct049t09	0.221
ust016t26	0.964	hst007-11	0.901	ust002t10	0.549	lct049t11	0.221
ust006t05	0.964	hst011-01	0.899	lst18c1	0.548	lct049t10	0.221
ust006t06	0.963	hst007-02	0.898	lst16-R131	0.546	hst018-02	0.221
ust014t16	0.963	hst011-02	0.897	lst16-R129	0.545	hst28i-15	0.220
ust012t06x	0.963	hst025-04	0.897	lst17-R130	0.544	hst033-02b	0.220
ust017t05	0.963	hst037-06	0.897	lst16-R125	0.543	hst28i-13	0.218
ust015t10x	0.962	hct010-10	0.897	lst17-R126	0.542	hst018-01	0.218
ust017t04	0.961	hct010-11	0.892	lst17-R123	0.541	lct26c3	0.218
ust014t02	0.959	hst005-12	0.887	lst16-R113	0.540	hst28i-11	0.218
ust015t07x	0.958	hst007-12	0.886	ust002t09	0.540	hst28i-9	0.217
ust013t19	0.953	hct010-15	0.885	lst16-105	0.539	hst007-09	0.217
ust002t14	0.953	hst007-03	0.882	lst17-R122	0.536	lct25c1	0.216
ust002t01	0.953	hst037-03	0.879	lst17-R104	0.535	hst007-07	0.216

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
ust002t02	0.952	hst005-11	0.875	ust017t07	0.531	hct010-06	0.215
ust014t11	0.951	hst035-05	0.874	ust002t17	0.528	hst033-02c	0.213
ust004t08	0.949	hst009-01	0.873	ust003t10	0.524	hst007-01	0.212
ust002t03	0.948	hst007-10	0.871	ust002t08	0.521	hst009-04	0.210
ust002t12	0.948	hst007-01	0.870	lst06c5	0.521	lct18c1	0.207
ust006t19	0.948	hct010-12	0.864	lst06c3	0.520	hct011-01	0.207
ust006t20	0.947	hct010-14	0.860	ust017t06	0.520	hct010-08	0.207
ust006t24	0.947	lct18c1	0.858	lst06c1	0.519	hct010-09	0.206
ust006t25	0.947	hst005-17	0.857	lst06c4	0.519	hct012-01	0.206
ust006t23	0.947	hst005-15	0.853	lst06c2	0.518	hct010-15	0.205
ust006t22	0.946	hst037-01	0.845	ust005t02	0.514	hct010-14	0.205
ust006t21	0.946	hct010-13	0.841	ust012t07	0.513	hst007-05	0.205
ust003t06	0.946	lct32a6	0.836	ust012t08	0.512	lct26c2	0.205
ust002t15	0.946	lct22c3	0.835	ust002t07	0.505	hct010-07	0.204
ust002t04	0.943	hst005-14	0.833	ust016t32	0.505	lct24c2	0.204
ust004t03	0.939	lct32a5	0.832	ust016t33	0.505	hst035-07	0.203
ust004t01	0.939	lct22c4	0.829	ust016t31	0.505	hct012-02	0.202
ust006t07	0.938	hct010-01	0.828	ust002t16	0.502	hst017-03	0.202
ust006t11	0.938	hst035-01	0.826	ust013t21	0.500	hst017-02	0.202
ust006t08	0.938	hst043-02	0.825	ust002t06	0.499	lct010-16	0.201
ust004t07	0.938	lct32a4	0.821	ust013t20	0.491	lct010-19	0.201
ust003t07	0.938	lct24c2	0.819	ust005t01x	0.490	lct079-5	0.201
ust006t09	0.937	lct079-6	0.819	ust002t05	0.487	lct010-18	0.200
ust005t01x	0.937	lct20c6	0.818	ust002t04	0.472	hct010-11	0.200
ust004t02	0.936	lct079-7	0.817	ust013t19	0.471	hst017-01	0.200
ust013t20	0.936	lct20c5	0.816	ust017t04	0.467	lct010-23	0.200
ust003t03	0.935	hct010-02	0.816	ust017t05	0.466	lct079-4	0.200
ust002t05	0.934	lct20c4	0.814	ust016t26	0.460	lct010-30	0.200
ust014t10	0.934	lct22c5	0.814	ust016t27	0.460	lct010-17	0.199
ust004t05	0.933	lct20c7	0.812	ust003t09	0.459	lct26c1	0.199
ust002t13	0.931	lct079-8	0.812	ust016t25	0.459	lct25c2	0.198
ust004t06	0.930	lct20c3	0.812	ust002t15	0.458	hct010-10	0.198
usi001t33x	0.929	lct079-9	0.811	ust012t06x	0.456	lct010-29	0.198
ust003t02	0.927	lct20c2	0.807	ust002t03	0.456	lct22c3	0.198
ust003t08	0.927	lct079-10	0.806	ust016t29	0.455	hct011-02	0.197
ust002t06	0.927	lct22c2	0.803	ust016t30	0.455	lct010-28	0.197
ust004t04	0.925	lct009-27	0.798	ust016t28	0.454	lct19c1	0.197
ust013t21	0.924	lct009-26	0.798	ust012t05	0.451	hct010-12	0.196
ust002t07	0.923	lct009-25	0.798	ust004t02	0.446	hmt006-23	0.196
ust014t04	0.923	lct009-02	0.797	ust013t18	0.445	lct040-03	0.196

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
ust014t03	0.921	lct009-11	0.797	ust017t01	0.444	lct010-15	0.196
ust002t16	0.921	lct009-06	0.797	ust017t03	0.444	lct040-01	0.195
ust016t31	0.920	lct009-18	0.797	ust003t08	0.443	lct010-14	0.195
ust016t33	0.919	lct009-23	0.797	ust017t02	0.443	lct010-22	0.194
ust016t32	0.919	lct009-04	0.797	ust013t17	0.439	lct010-27	0.194
ust014t12	0.918	lct040-01	0.797	ust012t04	0.438	hct013-01	0.193
ust003t09	0.917	lct009-10	0.797	ust006t21	0.438	hct011-03	0.193
usi001t30x	0.914	lct009-01	0.797	ust006t22	0.438	hct010-13	0.193
ust014t13	0.913	lct009-03	0.797	ust006t23	0.438	hmt006-22	0.193
ust014t09	0.913	lct009-08	0.797	ust002t02	0.438	hst016-01	0.193
ust003t04	0.911	lct009-09	0.796	ust006t25	0.438	lct079-3	0.193
ust014t05	0.911	lct009-13	0.796	ust006t24	0.438	lct21c1	0.192
ust005t02	0.911	lct009-16	0.796	ust006t20	0.437	lct079-2	0.192
ust002t08	0.909	lct009-24	0.796	ust006t19	0.437	lct079-1	0.192
ust012t08	0.907	lct009-05	0.796	ust013t16	0.436	lct21c2	0.192
ust012t07	0.907	lct009-15	0.796	ust016t16	0.434	lct21c3	0.192
ust003t01	0.907	lct009-14	0.796	ust004t01	0.434	hst001-01	0.189
ust014t15	0.906	lct009-19	0.796	ust016t17	0.433	hst001-03	0.189
ust014t06	0.905	lct009-21	0.796	ust016t18	0.433	hst001-08	0.189
ust017t06	0.904	lct009-22	0.796	ust004t08	0.433	lct040-02	0.188
ust014t07	0.902	lct009-17	0.795	ust014t08	0.433	hct013-02	0.188
ust006t10	0.901	lct009-07	0.795	ust016t19	0.433	hmt006-21	0.187
ust002t17	0.895	lct009-20	0.794	ust002t14	0.432	hst001-07	0.187
ust003t05	0.895	lct26c1	0.793	ust014t07	0.431	hst010-04	0.187
ust014t08	0.893	lct23c2	0.792	ust014t06	0.430	hst010-03	0.186
ust014t14	0.892	lct23c1	0.790	ust014t05	0.428	hst027-01	0.186
ust017t07	0.892	lct32a9	0.789	ust013t15	0.426	hmt006-18	0.185
ust002t09	0.886	lct23c3	0.788	ust002t01	0.426	lct010-21	0.185
usi001t23x	0.881	lst16-105	0.785	ust012t03	0.424	hst010-02	0.185
uct001t03	0.879	lst17-R104	0.785	ust014t14	0.422	lct010-20	0.185
ust002t10	0.873	lst17-R122	0.785	ust014t03	0.422	lct21c4	0.184
usi001t20x	0.867	hmt006-19	0.784	ust003t07	0.421	lct21c5	0.184
usi001t16x	0.843	lct21c3	0.783	ust014t09	0.421	hst010-01	0.184
ust002t11	0.837	lct21c2	0.783	ust014t04	0.421	hst037-06	0.183
usi001t08x	0.835	hst033-03a	0.782	ust012t02	0.420	lct21c6	0.183
ust003t10	0.833	lct040-03	0.781	ust012t01	0.420	lct22c4	0.182
ust015t09x	0.814	lct20c1	0.781	ust016t15	0.419	hmt006-20	0.182
usi001t32x	0.805	hmt006-20	0.780	ust016t14	0.419	lct009-07	0.182
ust015t19x	0.805	hst033-10a	0.780	ust014t15	0.419	lct009-20	0.182
usi001t11x	0.789	lct079-4	0.779	ust016t13	0.419	lct19c2	0.182

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
usi001t06x	0.779	lst16-R113	0.779	ust014t13	0.417	lct009-14	0.182
ust015t31x	0.778	lst06c1	0.779	ust014t12	0.416	lct009-09	0.182
usi001t22x	0.772	lct23c4	0.778	ust014t10	0.407	lct009-16	0.182
uct001t02	0.761	lct21c1	0.778	ust016t22	0.404	lct009-22	0.182
ust015t14x	0.742	lct079-5	0.774	ust016t24	0.404	lct010-13	0.182
ust015t04x	0.735	hmt006-21	0.774	ust006t10	0.404	lct009-05	0.181
usi001t27x	0.685	hst033-02a	0.774	ust016t21	0.404	lct009-15	0.181
ust015t08x	0.684	lct32a8	0.773	ust016t23	0.404	lct009-19	0.181
usi001t09x	0.681	lct010-13	0.773	ust004t03	0.403	lct009-17	0.181
ust015t18x	0.681	lct26c2	0.773	lct017-08	0.402	lct009-21	0.181
usi001t21x	0.677	lst01c1	0.772	ust006t17	0.402	lct009-08	0.181
usi001t17x	0.663	lct010-04	0.772	ust006t18	0.402	lct32a6	0.181
usi001t31x	0.663	hmt006-04	0.771	lct017-09	0.402	lct009-01	0.181
ust001t05x	0.656	hmt006-03	0.769	ust006t16	0.401	lct009-18	0.181
usi001t10x	0.654	hmt006-22	0.769	lct017-07	0.401	lct009-03	0.181
ust001t04x	0.649	lst06c2	0.769	lct017-05	0.401	lct009-06	0.181
usi001t04x	0.647	lct23c5	0.768	lct017-06	0.401	lct009-23	0.181
ust001t03x	0.642	hmt006-02	0.768	lct017-04	0.400	lct009-02	0.181
ust001t02x	0.635	hmt006-23	0.767	ust016t02	0.400	lct009-04	0.181
ust001t01x	0.627	lct32a1	0.766	ust002t12	0.399	lct009-11	0.181
ust015t30x	0.592	lct25c3	0.766	ust016t03	0.399	lct009-13	0.181
hst043-01	0.586	lst17-R123	0.765	ust013t14	0.399	lct009-10	0.181
usi001t29x	0.574	hst033-03b	0.765	ust006t09	0.399	lct009-24	0.181
usi001t19x	0.568	lct079-2	0.765	ust013t10	0.399	lct009-25	0.180
ust015t06x	0.563	lct010-30	0.765	ust016t04	0.399	lct009-26	0.180
usi001t14x	0.563	lct079-1	0.764	ust013t13	0.399	lct009-27	0.180
hst001-08	0.559	lst16-R125	0.764	ust016t01	0.399	lct010-04	0.180
hst001-07	0.558	lct21c6	0.763	ust013t07	0.399	lct010-05	0.180
hst001-03	0.555	hst012-01	0.762	ust006t08	0.399	lct079-10	0.180
usi001t07x	0.551	hmt006-05	0.762	ust013t08	0.399	hst015-02	0.180
hst001-01	0.549	lst06c3	0.760	ust013t09	0.399	hmt006-17	0.179
hst027-01	0.547	lct010-08	0.760	ust013t12	0.399	hst015-01	0.179
ust015t16x	0.545	lct079-3	0.760	ust013t06	0.399	lct079-9	0.179
uct001t04	0.531	lct21c5	0.759	ust013t11	0.399	lct23c1	0.179
hst017-01	0.530	lct010-29	0.759	lct017-22	0.398	lct010-24	0.179
hst015-01	0.527	hmt006-11	0.758	ust006t07	0.398	hst043-01	0.178
hst017-02	0.524	hmt006-17	0.758	ust006t11	0.398	lct010-07	0.178
hst001-06	0.521	lct25c4	0.758	ust013t05	0.398	lct010-08	0.178
hst001-10	0.520	lct22c1	0.758	ust013t02	0.397	lct079-8	0.178
hst017-03	0.516	hmt006-01	0.757	ust013t01	0.397	lct23c4	0.178

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
hst015-02	0.515	lct21c4	0.757	ust013t03	0.397	lct23c5	0.178
hst016-01	0.515	lst17-R126	0.757	ust013t04	0.397	lct23c6	0.178
hst001-05	0.513	hst043-03	0.756	lct017-14	0.396	lct32a5	0.178
hst28i-5	0.509	lct010-23	0.755	lct012-01	0.396	lct010-12	0.178
hst28i-1	0.508	lst06c4	0.755	ust014t11	0.394	lct23c2	0.178
ust015t24x	0.507	lct010-19	0.755	lct017-21	0.394	lct23c3	0.178
hst28i-3	0.507	lct22c6	0.755	lct017-13	0.394	hst035-05	0.178
hst018-01	0.506	lct32a2	0.754	lct012-09	0.394	lct25c3	0.177
ust015t29x	0.501	lst16-R129	0.752	lct017-03	0.392	lct079-7	0.177
hst014-01	0.500	lct25c2	0.752	lct012-02	0.392	lct079-6	0.177
ust009t01	0.499	lct23c6	0.750	lct012-03	0.392	hst037-03	0.177
hst30i-01	0.497	hmt006-13	0.749	ust006t14	0.392	lct010-06	0.176
hst001-09	0.496	lct22c7	0.749	ust006t15	0.391	lct010-25	0.176
hst018-02	0.496	lst03c1	0.748	lct017-25	0.391	lct32a4	0.176
hst001-02	0.495	hmt006-10	0.747	ust006t12	0.391	hst28i-7	0.175
hst28i-11	0.494	hmt006-18	0.747	lct012-10	0.391	lct22c5	0.175
hst001-04	0.493	hmt006-06	0.746	lct012-06	0.391	hst30i-01	0.175
hst28i-7	0.491	lct32a7	0.746	lct012-08	0.391	hmt006-14	0.175
usi001t18x	0.491	lct010-18	0.746	ust006t13	0.391	hmt006-16	0.174
hst28i-9	0.491	lst17-R130	0.746	lct012-07	0.391	hmt006-13	0.174
hst28i-13	0.491	hst033-02b	0.745	lct017-20	0.391	hmt006-15	0.174
usi001t28x	0.491	hst013-01	0.745	lct012-05	0.390	hst025-05	0.173
hst025-02	0.485	lst06c5	0.744	lct012-04	0.390	lct010-26	0.173
hst018-03	0.484	lst16-R131	0.744	lct017-12	0.389	hst28i-3	0.173
hst28i-15	0.484	lct010-12	0.743	ust016t08	0.388	hst28i-5	0.173
hst025-05	0.483	lct040-02	0.742	ust003t06	0.388	lct010-11	0.173
usi001t05x	0.480	lct010-17	0.740	ust004t05	0.388	lct20c1	0.173
ust015t05x	0.477	lst18c4	0.740	lct017-19	0.388	hst28i-1	0.173
hst010-04	0.477	lct010-07	0.738	ust016t07	0.388	hst014-01	0.172
hst010-01	0.477	hmt006-16	0.738	ust016t06	0.387	lst06c5	0.172
hst010-03	0.477	lst03c2	0.737	ust016t09	0.387	hmt006-10	0.171
hst025-01	0.475	lst18c3	0.737	ust004t07	0.386	hst037-01	0.171
hst010-02	0.475	lst18c1	0.737	lct017-11	0.386	lct20c2	0.171
hst025-04	0.472	lst18c5	0.736	lct017-10	0.384	lct32a9	0.171
ust015t15x	0.471	lst19c1	0.736	ust014t16	0.383	lst06c4	0.171
hst29i-01	0.471	lst19c3	0.735	lct017-29	0.383	hst011-01	0.170
hst30i-04	0.467	lst18c6	0.735	ust004t04	0.378	lct20c3	0.170
hst28i-17	0.464	lst19c2	0.735	lct017-02	0.378	hmt006-19	0.170
ust009t02	0.464	lst03c3	0.735	ust004t06	0.377	hst001-10	0.170
hst019-01	0.460	lst19c5	0.735	ust014t02	0.377	lct20c4	0.170

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
hst009-04	0.458	lst19c6	0.734	ust002t13	0.376	hst011-02	0.170
hst011-01	0.455	lst19c4	0.733	lct017-17	0.375	lst06c3	0.170
hst011-02	0.453	lst17-R147	0.731	lct017-01	0.375	lct20c7	0.170
hst007-09	0.445	lct010-22	0.730	ust016t11	0.374	lct20c5	0.170
hst006-01	0.443	lst07-R14	0.730	ust016t10	0.374	hmt006-01	0.170
hst007-07	0.439	lct010-06	0.729	ust016t12	0.374	hmt006-08	0.170
hct010-07	0.438	lst16-R140	0.728	ust014t01	0.373	lct20c6	0.170
ust015t23x	0.438	hmt006-07	0.724	lct042-01	0.372	hmt006-09	0.169
hst006-08	0.434	lst04-R1	0.722	lct017-16	0.371	lct32a8	0.169
hct010-06	0.434	lct25c1	0.720	lct042-06	0.370	lst01c1	0.169
ust008t01x	0.432	hst033-10c	0.720	lct042-02	0.369	hmt006-07	0.169
hct010-09	0.432	lst16-R196	0.720	lct017-15	0.367	hmt006-12	0.169
hst006-12	0.428	lct19c2	0.717	lct042-07	0.367	hst035-01	0.169
hst007-05	0.428	hst033-03c	0.717	lct042-05	0.367	hmt006-06	0.169
hct010-10	0.427	hst033-10d	0.716	lct042-04	0.366	hst025-01	0.169
ust015t28x	0.424	lst21c1	0.716	lct042-03	0.366	lct010-10	0.169
hct010-08	0.424	lct010-15	0.714	lct010-06	0.362	hst001-06	0.169
ust009t03	0.423	lst07-R30	0.713	lct010-07	0.361	lst06c2	0.169
hst006-27	0.423	lct32a3	0.711	lct010-08	0.361	lct22c6	0.168
hst009-03	0.420	lct010-11	0.711	ust006t06	0.361	lct32a7	0.168
hct010-11	0.418	lst04-R29	0.707	ust006t05	0.360	hst025-04	0.168
hst007-08	0.418	hst033-02c	0.706	lct017-28	0.360	hst001-05	0.168
hst037-06	0.417	hmt006-12	0.705	lct017-24	0.359	lct25c4	0.168
hst007-06	0.412	lct010-14	0.703	ust015t25x	0.359	hmt006-05	0.167
hst035-05	0.411	lct010-05	0.703	lct017-23	0.358	lct22c7	0.167
usi001t15x	0.409	lst20c1	0.702	ust006t04	0.356	hst025-02	0.167
hst037-03	0.408	lst07-R32	0.696	lct010-05	0.355	hmt006-11	0.167
hst035-07	0.406	hmt006-14	0.694	ust006t01	0.355	lct010-09	0.167
usi001t03x	0.406	lst03c4	0.694	ust006t02	0.355	hmt006-02	0.167
hct010-03	0.406	lct010-21	0.693	ust006t03	0.355	lst06c1	0.167
usi001t26x	0.405	lct010-28	0.691	lct009-26	0.353	hmt006-03	0.166
hct010-04	0.403	lst04-R33	0.691	lct009-27	0.353	hmt006-04	0.165
hst043-02	0.403	lct19c3	0.690	ust003t01	0.352	lst16-105	0.163
hst007-03	0.400	lct010-10	0.689	lct009-25	0.352	lst16-R113	0.162
ust015t03x	0.398	lst20c2	0.689	lct009-24	0.352	lst17-R104	0.161
hst007-12	0.396	lct24c1	0.687	lct009-04	0.352	hst043-02	0.161
hct010-15	0.395	lst21c2	0.683	ust003t02	0.351	lct012-04	0.161
hst007-14	0.392	lct010-20	0.683	lct009-01	0.351	lct012-08	0.161
ust015t13x	0.391	hmt006-15	0.679	lct009-02	0.351	lct012-05	0.160
hst007-15	0.391	hmt006-08	0.678	lct009-03	0.351	lct012-07	0.160

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
hst007-17	0.390	lct19c1	0.678	lct009-13	0.351	lst17-R122	0.160
lct32a6	0.387	lst07-R36	0.675	lct009-11	0.351	lct012-06	0.160
hct010-12	0.386	lst04-R34	0.673	lct009-10	0.351	lct012-02	0.160
lct32a5	0.386	lst21c3	0.671	lct009-15	0.351	lct012-03	0.160
hst007-13	0.383	lct010-09	0.670	lct009-18	0.351	lst16-R125	0.160
hst007-04	0.382	hst042-01	0.669	lct009-14	0.351	hst012-01	0.160
hst007-01	0.380	hst042-02	0.669	lct009-05	0.350	hst043-03	0.160
hst037-01	0.379	lct26c3	0.667	lct009-06	0.350	lct012-10	0.160
hst007-16	0.378	lst03c5	0.665	lct009-23	0.350	hst013-01	0.160
ust015t27x	0.375	lct010-03	0.665	lct009-08	0.350	lct010-03	0.160
ust009t04	0.375	lst09-R92	0.664	lct009-21	0.350	lst18c1	0.159
lct32a4	0.374	lst03c6	0.663	lct009-17	0.350	lst16-R129	0.159
hmt006-04	0.373	lct010-16	0.663	lct009-19	0.350	lct012-01	0.159
hmt006-02	0.372	lst09-R93	0.661	lct009-16	0.350	lst18c6	0.159
lct22c4	0.372	lst04-R51	0.660	lct009-07	0.350	lst18c5	0.159
lct079-6	0.371	lst08-R74	0.660	lct009-20	0.350	lct012-09	0.158
hst009-02	0.371	lst20c3	0.659	lct009-22	0.350	lst16-R131	0.158
lct20c6	0.371	lst09-R94	0.659	lct079-6	0.350	lst17-R123	0.158
lct18c1	0.371	lst10-R83	0.659	lct009-09	0.349	lct19c3	0.158
hst007-10	0.370	lst10-R86	0.659	lct079-7	0.349	lct017-29	0.158
lct079-7	0.368	lst10-R88	0.659	lct079-8	0.349	lst18c4	0.158
hst007-02	0.368	lst08-R76	0.659	lct010-13	0.348	lct017-22	0.158
lct20c5	0.367	lst10-R85	0.658	lct010-04	0.348	lst18c3	0.158
ust015t22x	0.367	hmt006-09	0.658	lct079-9	0.347	lst17-R126	0.157
hmt006-03	0.367	lst07-R49	0.657	lct079-10	0.346	lst19c5	0.157
hmt006-19	0.366	lst08-R78	0.656	lct010-19	0.345	lst19c6	0.157
hst007-11	0.366	lst04-R46	0.656	lct010-23	0.345	lst19c4	0.157
hst035-01	0.365	lst08-R72	0.654	ust003t03	0.345	lst19c3	0.157
lct20c4	0.364	lct049t10	0.653	lct010-30	0.345	hst042-01	0.157
hmt006-01	0.363	lct049t09	0.652	lct079-1	0.344	hst042-02	0.157
lct22c5	0.363	lct049t11	0.651	lct079-2	0.344	lst19c2	0.157
hct010-13	0.362	ust013t11	0.649	lct079-3	0.343	lct017-21	0.157
hct010-14	0.362	ust013t07	0.649	lct010-29	0.340	lst16-R140	0.157
lct20c7	0.361	ust013t08	0.649	lct010-18	0.338	lst17-R130	0.157
lct22c3	0.360	ust013t09	0.649	lct079-4	0.338	lst19c1	0.156
lct20c3	0.360	ust013t06	0.649	lct079-5	0.338	lct017-19	0.156
lct079-8	0.359	ust013t10	0.649	lst01c1	0.336	lct017-20	0.156
lst17-R104	0.359	ust013t12	0.649	lct010-17	0.334	lst16-R196	0.156
lst17-R122	0.359	ust013t13	0.649	lct010-12	0.331	lst17-R147	0.155
usi001t13x	0.358	ust013t14	0.649	lct010-22	0.330	lct017-25	0.155

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
usi001t02x	0.358	ust013t03	0.649	lct20c7	0.329	hct014-01	0.155
usi001t25x	0.357	ust013t01	0.649	lct20c6	0.329	lct017-28	0.154
lct079-9	0.357	lst21c4	0.649	lct20c5	0.328	lct042-03	0.154
lst16-105	0.352	ust013t02	0.649	lct20c4	0.327	lct042-04	0.154
lct20c2	0.351	ust013t04	0.649	lct20c3	0.327	lct042-02	0.154
ust015t02x	0.350	ust013t05	0.648	lct26c1	0.327	lct042-05	0.154
hmt006-11	0.348	lct049t12	0.647	uct001t03	0.327	lst20c1	0.154
lct079-10	0.348	lct010-27	0.646	ust015t17x	0.326	hst042-03	0.153
hmt006-05	0.345	ust016t21	0.645	lct20c2	0.324	lst03c1	0.153
lst16-R113	0.344	ust016t23	0.645	lct010-15	0.324	hst032-01	0.153
ust015t12x	0.343	ust016t24	0.645	lct010-28	0.322	lct017-14	0.153
hmt006-10	0.342	ust016t22	0.645	lct010-16	0.322	lst03c3	0.153
lct32a9	0.340	ust013t17	0.643	lct26c2	0.321	lst21c1	0.153
hst009-01	0.337	ust013t16	0.643	lct010-14	0.320	lct017-09	0.153
lct009-27	0.336	ust013t15	0.643	lct040-01	0.320	lct042-01	0.153
lst17-R123	0.336	lct017-09	0.642	ust003t04	0.317	lst20c2	0.153
lct009-26	0.336	ust013t18	0.641	lct040-03	0.316	lct017-13	0.153
lct009-25	0.335	lct010-02	0.641	lct20c1	0.316	lct017-17	0.153
hmt006-13	0.335	lst20c4	0.640	lct010-11	0.315	lct042-07	0.153
hmt006-20	0.334	ust012t04	0.640	lct010-21	0.312	lst03c2	0.153
lct009-02	0.333	ust016t12	0.639	ust015t07x	0.310	lct010-01	0.152
lct009-04	0.333	ust016t11	0.639	lct010-20	0.310	lct017-12	0.152
lct009-11	0.333	lct010-01	0.639	ust003t05	0.307	lst03c4	0.152
lct009-10	0.333	ust016t10	0.639	lct21c3	0.307	lct042-06	0.152
hct010-01	0.332	ust012t03	0.638	lct010-27	0.306	lct010-02	0.152
lct009-24	0.332	ust012t02	0.637	lct21c2	0.306	lct017-16	0.152
lct009-18	0.332	lct26c4	0.637	lct21c6	0.306	lct017-10	0.152
lct009-06	0.332	ust012t06x	0.636	lct21c5	0.305	lst21c2	0.152
lct009-23	0.332	ust012t05	0.635	ust015t31x	0.305	lct017-15	0.152
lct009-01	0.332	ust012t01	0.635	lct21c1	0.305	lct017-11	0.152
lct009-03	0.332	lct017-14	0.630	lct21c4	0.304	hst042-04	0.151
lct009-13	0.331	lct012-01	0.629	lct017-27	0.304	lct017-03	0.151
hst005-12	0.331	ust016t28	0.629	lct010-10	0.303	lct017-08	0.151
lct009-08	0.331	ust016t30	0.629	lct040-02	0.299	hct014-02	0.151
lct24c2	0.330	ust016t29	0.628	ust015t10x	0.298	lst03c5	0.151
lst03c1	0.330	lst04-R54	0.628	lct010-03	0.296	lst20c3	0.151
lct009-09	0.329	ust016t13	0.628	lct010-09	0.295	lst03c6	0.150
lct009-05	0.329	ust016t14	0.627	lct049t10	0.294	lct017-04	0.150
lct009-15	0.329	hct012-02	0.627	lct049t11	0.293	lct017-05	0.150
lct009-14	0.329	lct017-13	0.627	lct049t09	0.293	hst042-06	0.150

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
lct009-16	0.329	ust016t15	0.627	usi001t30x	0.293	lct017-07	0.150
lct009-21	0.329	lct017-08	0.627	lct049t12	0.292	lst21c3	0.150
lct009-19	0.329	lct049t16	0.627	lct26c3	0.292	lct017-06	0.150
lst07-R14	0.329	ust016t25	0.626	lct017-26	0.289	hst042-05	0.149
lct009-17	0.328	lct017-03	0.625	lct19c3	0.289	lst20c4	0.149
lct009-22	0.328	ust016t27	0.625	lct18c1	0.287	lst04-R1	0.149
lst16-R125	0.328	ust016t26	0.625	usi001t33x	0.286	lst07-R14	0.149
ust015t26x	0.328	lct049t13	0.625	lct19c2	0.284	lst03c7	0.149
lct009-07	0.327	lct049t07	0.624	lct049t16	0.282	lst21c4	0.149
lct009-20	0.326	hct012-01	0.624	lct010-02	0.282	hst042-07	0.149
lst17-R126	0.325	lst03c7	0.624	lct049t06	0.281	lst07-R30	0.148
lct26c1	0.325	lct049t06	0.623	lct049t07	0.281	lst04-R29	0.147
hst012-01	0.325	lct049t15	0.623	lct010-01	0.281	hst042-08	0.147
hmt006-17	0.324	lct049t05	0.622	lct049t05	0.281	lst03c8	0.147
ust015t21x	0.324	lct012-02	0.622	lct049t08	0.281	lst03c9	0.147
lct25c4	0.323	lct049t14	0.622	lct26c4	0.281	lst08-R72	0.147
lst06c1	0.323	lct012-03	0.621	lct049t17	0.281	lst08-R78	0.147
hmt006-06	0.323	lct012-05	0.620	lct049t15	0.280	lct017-02	0.146
hst005-11	0.323	lct017-12	0.620	lct049t14	0.280	lst04-R51	0.146
lct25c3	0.322	lct012-04	0.620	lct049t13	0.279	lst07-R32	0.146
lct32a8	0.322	lct012-07	0.620	usi001t16x	0.279	lst08-R76	0.146
hst043-03	0.321	lct012-06	0.619	lct049t18	0.278	lst04-R33	0.146
lct23c2	0.321	ust017t01	0.619	lct19c1	0.278	lct017-01	0.146
lct23c1	0.319	lct049t17	0.619	lct010-26	0.277	lst09-R92	0.146
lst01c1	0.318	lct017-07	0.619	hst013-01	0.277	lst09-R93	0.146
lst03c2	0.317	ust005t01x	0.619	ust015t14x	0.270	lst09-R94	0.146
lst04-R1	0.316	lct049t08	0.618	usi001t20x	0.269	lst08-R74	0.145
lct079-2	0.316	lct012-08	0.618	lct010-25	0.269	lst07-R36	0.145
lct079-1	0.315	ust016t06	0.618	uct001t02	0.265	lst10-R83	0.145
lst16-R129	0.314	ust006t13	0.618	lct22c7	0.265	lst10-R85	0.145
lct079-4	0.314	ust016t09	0.618	lct32a7	0.264	lst10-R86	0.145
lct23c3	0.313	ust017t03	0.618	lct22c6	0.264	lst10-R88	0.145
lst17-R130	0.313	ust006t12	0.617	lct049t02	0.264	lct017-23	0.144
lst03c3	0.312	ust016t07	0.617	hst042-01	0.264	lst04-R34	0.144
hmt006-21	0.312	ust016t08	0.617	hst042-02	0.264	lct017-24	0.144
lct20c1	0.311	ust006t14	0.617	lct049t01	0.264	lst07-R49	0.143
hct010-02	0.311	ust006t15	0.616	hst042-06	0.263	lst04-R46	0.143
lst07-R30	0.310	lct017-11	0.616	lct010-24	0.262	lst04-R54	0.141
lct079-3	0.309	lct017-06	0.615	lct049t03	0.262	lct017-26	0.140
hst005-17	0.308	ust017t05	0.615	hst042-03	0.262	ust006t25	0.138

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
lct079-5	0.306	lct012-09	0.614	usi001t23x	0.262	ust006t23	0.137
lst16-R131	0.306	lct012-10	0.614	lct049t04	0.262	ust006t19	0.137
usi001t12x	0.305	lct049t18	0.613	hst032-01	0.261	ust006t22	0.137
lst06c2	0.305	lct017-05	0.612	hst042-07	0.260	ust006t24	0.137
lst18c4	0.304	ust017t02	0.611	lct32a8	0.260	ust006t20	0.137
hst005-15	0.303	lct017-22	0.611	hst042-04	0.260	ust006t21	0.137
lct22c6	0.303	lct017-10	0.610	ust015t19x	0.259	lct017-27	0.134
usi001t01x	0.303	ust013t20	0.610	hst042-05	0.259	lst05c3	0.133
hst033-03a	0.302	ust017t04	0.609	lct32a9	0.258	lst05c1	0.133
lst04-R29	0.302	ust013t21	0.607	hst042-08	0.258	lst05c2	0.133
hst013-01	0.301	hct014-01	0.607	lct25c4	0.256	ust006t10	0.131
usi001t24x	0.301	lct017-02	0.606	lct32a4	0.256	ust006t08	0.127
lst18c3	0.300	lct017-21	0.606	ust015t04x	0.255	ust006t09	0.127
lct21c3	0.299	ust015t25x	0.604	ust015t09x	0.254	ust006t11	0.126
lst19c1	0.299	hst042-03	0.604	usi001t08x	0.254	ust006t07	0.125
lct010-04	0.299	lst03c8	0.604	lct32a5	0.253	hct010-05	0.116
lct040-01	0.299	ust013t19	0.603	lct22c5	0.252	hmt025t01	0.105
lct26c2	0.299	hst032-01	0.602	lct32a6	0.252	usi001t16x	0.103
hst033-10a	0.299	lct017-20	0.602	lct25c3	0.251	ust015t25x	0.102
lct21c2	0.299	ust016t19	0.601	hst037-01	0.250	hmf030t00	0.089
lct23c4	0.299	ust016t16	0.600	lct22c4	0.249	ust015t17x	0.088
hst033-02a	0.299	ust016t31	0.600	lct24c2	0.249	usi001t30x	0.083
lct22c2	0.299	ust016t17	0.600	lct25c2	0.249	ust015t07x	0.083
lst17-R147	0.297	ust016t18	0.600	hst035-01	0.248	usi001t20x	0.082
hmt006-16	0.297	ust016t32	0.600	hst025-02	0.247	ust015t14x	0.081
lst18c5	0.297	ust016t33	0.600	hst025-01	0.246	usi001t08x	0.081
ust015t01x	0.297	lct017-01	0.599	lct22c3	0.245	usi001t06x	0.079
lst19c3	0.297	lst03c9	0.597	usi001t32x	0.245	hmt025t02	0.077
lst19c2	0.296	lct017-25	0.597	lct25c1	0.243	ust015t04x	0.076
lct22c7	0.296	ust005t02	0.597	usi001t06x	0.241	usi001t27x	0.074
hmt006-18	0.295	lct017-04	0.596	hst043-03	0.241	usi001t17x	0.072
lst18c6	0.295	ust012t08	0.595	ust015t30x	0.241	usi001t04x	0.072
lct010-13	0.295	hct013-01	0.595	hst025-04	0.241	usi001t23x	0.068
lst19c5	0.295	lct017-19	0.595	lct23c2	0.240	usi001t33x	0.068
lst18c1	0.295	ust012t07	0.595	lct23c3	0.240	ust006t06	0.066
ust015t11x	0.294	hct013-02	0.594	hst012-01	0.240	ust006t05	0.066
lst19c6	0.294	hct011-03	0.594	hst037-03	0.239	usi001t14x	0.065
lst19c4	0.293	ust006t16	0.593	lct23c4	0.239	usi001t11x	0.065
hmt006-22	0.293	hct011-02	0.593	lct23c1	0.239	ust006t17	0.065
lct32a7	0.293	hct014-02	0.593	lct23c5	0.238	ust015t10x	0.065

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
lct21c1	0.292	ust006t18	0.592	lct22c2	0.236	ust006t18	0.064
lst07-R32	0.292	ust006t17	0.592	hst043-02	0.235	ust006t16	0.064
lct010-08	0.291	ust015t17x	0.591	lct23c6	0.234	ust006t01	0.063
hmt006-07	0.291	ust016t01	0.590	usi001t11x	0.232	ust006t04	0.063
hst033-03b	0.290	ust016t04	0.590	hst001-05	0.231	ust006t02	0.063
lst16-R140	0.289	ust016t02	0.590	usi001t27x	0.229	ust006t03	0.063
lst06c3	0.289	ust016t03	0.590	hst28i-1	0.229	uct001t03	0.062
lct25c2	0.286	hct011-01	0.589	hst28i-3	0.229	ust006t12	0.062
lct010-30	0.286	ust006t01	0.588	hst001-06	0.228	ust006t14	0.062
lst21c1	0.286	ust006t03	0.588	hst28i-5	0.228	ust006t13	0.061
lst04-R33	0.285	ust006t02	0.587	hst037-06	0.228	ust006t15	0.061
lct010-29	0.285	ust006t04	0.587	usi001t22x	0.227	ust014t15	0.060
lct23c5	0.284	ust015t10x	0.586	hst28i-7	0.226	ust014t14	0.060
hmt006-23	0.283	lct049t02	0.586	lct32a1	0.226	ust014t12	0.059
ust015t20x	0.283	lct049t01	0.586	hst30i-01	0.226	ust003t05	0.059
lst16-R196	0.281	ust017t06	0.580	uct001t04	0.225	ust014t02	0.059
lst06c4	0.281	lct049t03	0.580	hst001-10	0.224	ust014t10	0.059
hst033-02b	0.278	ust015t07x	0.579	ust015t18x	0.223	ust014t13	0.059
lct040-03	0.278	lct049t04	0.579	lct22c1	0.222	ust014t11	0.059
lct19c2	0.277	lct017-17	0.575	lct32a2	0.221	ust014t16	0.058
lct010-23	0.272	hst042-04	0.573	hst035-05	0.220	usi001t09x	0.058
lst07-R36	0.270	ust002t04	0.573	hst025-05	0.220	ust014t01	0.058
lct010-12	0.269	ust002t07	0.573	hst007-03	0.218	ust003t04	0.057
lct010-19	0.269	ust002t06	0.571	ust015t08x	0.218	ust014t09	0.057
lst04-R34	0.268	ust002t05	0.571	hct010-13	0.218	ust014t05	0.057
lst20c1	0.267	ust002t15	0.570	hst027-01	0.216	ust014t06	0.057
lct32a1	0.267	ust014t01	0.569	hst007-07	0.216	ust014t08	0.057
hmt006-12	0.266	ust002t03	0.569	hst007-09	0.214	ust014t03	0.057
lct010-07	0.264	lct042-01	0.569	usi001t17x	0.214	ust014t04	0.057
lst06c5	0.262	lct017-16	0.568	hct010-12	0.212	ust014t07	0.057
lct21c6	0.262	lct017-29	0.566	hst007-05	0.212	uct001t02	0.057
lct010-18	0.261	ust002t02	0.566	hst007-12	0.211	ust002t13	0.057
lct010-06	0.261	lst05c1	0.566	hst007-01	0.211	ust004t06	0.056
hst005-14	0.260	ust002t16	0.566	ust015t29x	0.209	ust004t04	0.056
lct010-22	0.260	ust006t05	0.565	lct32a3	0.209	usi001t22x	0.055
lct040-02	0.258	lct042-06	0.565	usi001t31x	0.206	ust004t07	0.055
lct010-17	0.257	ust003t07	0.565	usi001t04x	0.206	ust004t05	0.055
lct23c6	0.257	ust002t14	0.565	lct24c1	0.205	ust012t01	0.054
lct21c5	0.256	ust003t08	0.565	hct010-10	0.205	ust012t02	0.054
lct19c3	0.255	ust006t06	0.564	hst001-07	0.205	ust012t03	0.053

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
lst03c4	0.254	ust002t08	0.563	hct010-11	0.204	ust003t02	0.053
lst20c2	0.254	lct042-02	0.562	hct010-14	0.204	ust002t12	0.053
lct21c4	0.252	ust003t09	0.562	hst001-03	0.203	ust004t03	0.052
lst09-R92	0.252	lct017-15	0.561	usi001t09x	0.203	usi001t32x	0.052
lst07-R49	0.252	lct042-05	0.561	hst001-08	0.203	ust003t03	0.052
lct32a2	0.251	lst05c2	0.560	hst28i-9	0.203	ust016t02	0.052
lct22c1	0.251	ust004t08	0.560	hst28i-11	0.203	ust016t03	0.052
lst04-R46	0.251	lct042-03	0.560	hst007-10	0.202	ust016t04	0.052
lct010-11	0.250	lct042-04	0.560	hst011-02	0.202	ust016t01	0.052
lct010-28	0.250	lct042-07	0.560	hst001-01	0.201	ust003t01	0.052
hst033-02c	0.249	ust002t01	0.558	usi001t21x	0.201	ust012t04	0.052
lst08-R74	0.249	lct010-25	0.557	hst28i-13	0.201	ust016t07	0.052
lst09-R93	0.248	ust017t07	0.557	hst011-01	0.201	ust016t08	0.052
lst10-R83	0.247	ust003t06	0.556	hst035-07	0.201	ust003t10	0.052
lst08-R76	0.246	hst042-06	0.556	hst28i-15	0.200	ust016t06	0.052
lst21c2	0.246	ust002t17	0.553	hct010-15	0.199	ust016t09	0.052
lst10-R86	0.246	ust014t16	0.553	hct010-07	0.198	ust012t07	0.051
lst10-R88	0.246	lct010-24	0.553	hct010-08	0.197	ust012t08	0.051
lst10-R85	0.246	ust002t09	0.552	hst28i-17	0.197	ust017t01	0.051
lst09-R94	0.246	lct010-26	0.552	hct010-09	0.197	ust012t05	0.051
lct010-21	0.244	hst042-05	0.548	hst014-01	0.196	ust005t02	0.051
hst033-10c	0.244	ust014t02	0.548	hst29i-01	0.196	umf006t00x	0.051
lct25c1	0.244	lct017-24	0.547	hmt006-09	0.195	usi001t10x	0.051
lst08-R78	0.243	lct017-23	0.545	hmt006-08	0.194	ust012t06x	0.051
lct010-03	0.242	usi001t33x	0.543	hst30i-04	0.192	umf002t01x	0.051
lct010-15	0.241	ust002t12	0.543	usi001t10x	0.191	ust001t05x	0.051
lst04-R51	0.241	ust002t10	0.542	hmt006-15	0.191	ust001t04x	0.051
lst08-R72	0.240	ust004t02	0.542	hmt006-07	0.191	umf003t02x	0.050
lct010-10	0.240	ust014t11	0.538	hmt006-12	0.188	ust001t03x	0.050
lct010-02	0.240	hst042-07	0.538	hct010-06	0.187	umf002t02x	0.050
lst21c3	0.239	lst05c3	0.537	hst015-02	0.185	ust017t03	0.050
hst033-03c	0.239	ust004t01	0.536	usi001t14x	0.185	ust005t01x	0.050
hmt006-14	0.238	lct017-28	0.533	hmt006-14	0.185	ust016t10	0.050
lct010-01	0.236	ust006t19	0.532	ust015t24x	0.185	ust016t11	0.050
lct010-20	0.235	ust006t20	0.532	ust015t16x	0.183	ust016t12	0.050
hct014-01	0.234	ust006t24	0.531	hmt006-06	0.183	ust017t06	0.050
lct010-14	0.233	ust006t25	0.531	ust015t06x	0.183	ust001t02x	0.050
hst033-10d	0.232	ust004t03	0.531	hst015-01	0.183	ust017t02	0.050
hmt006-08	0.230	ust006t23	0.530	ust015t28x	0.182	ust017t07	0.050
lst03c5	0.228	ust006t22	0.530	usi001t29x	0.180	umf003t01x	0.050

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
lst03c6	0.227	uct001t03	0.530	hmt006-19	0.177	ust002t01	0.050
lct010-09	0.226	ust006t21	0.530	hct010-04	0.175	ust001t01x	0.050
lct19c1	0.225	ust004t07	0.527	hst010-01	0.175	usi001t21x	0.050
lst20c3	0.223	ust003t03	0.524	hst010-02	0.174	ust004t01	0.050
lct010-05	0.223	ust004t05	0.520	hst017-01	0.174	ust017t04	0.050
hmt006-15	0.222	hst042-08	0.520	hst016-01	0.174	ust017t05	0.050
lst04-R54	0.221	ust002t13	0.519	hst001-02	0.173	umf001t00x	0.049
lct017-09	0.220	usi001t30x	0.518	hst001-09	0.173	umf005t01x	0.049
hct014-02	0.219	ust004t06	0.518	hst010-03	0.172	ust015t09x	0.049
lct010-27	0.218	ust014t10	0.515	hst043-01	0.172	ust016t32	0.049
lct012-01	0.216	ust002t11	0.514	hst005-12	0.172	umf004t01x	0.049
lst21c4	0.214	ust003t10	0.511	hst001-04	0.172	ust002t11	0.049
hst042-01	0.213	ust006t11	0.511	usi001t19x	0.172	ust016t16	0.049
hst042-02	0.213	ust006t07	0.510	hst010-04	0.172	ust016t31	0.049
lct017-08	0.206	ust006t08	0.510	hmt006-05	0.171	ust016t33	0.049
lct012-02	0.204	ust004t04	0.509	hst007-14	0.170	ust016t17	0.049
lct017-03	0.204	ust006t09	0.509	hst007-13	0.170	umf005t02x	0.049
hmt006-09	0.204	ust003t02	0.507	hst007-17	0.170	ust016t18	0.049
lct012-03	0.202	usi001t23x	0.502	hst007-15	0.170	ust016t19	0.049
lct017-14	0.202	ust003t04	0.495	hst006-08	0.170	ust016t13	0.049
lct012-05	0.202	ust014t12	0.494	hst005-11	0.169	ust016t14	0.049
lct32a3	0.202	ust015t31x	0.492	hst007-04	0.169	ust016t15	0.049
lct012-07	0.202	ust014t13	0.489	hst017-03	0.169	ust002t14	0.049
lct012-06	0.201	ust015t09x	0.488	hst007-08	0.168	ust004t08	0.049
lst20c4	0.201	ust015t19x	0.488	hst006-01	0.168	ust002t10	0.048
lct012-04	0.201	ust003t01	0.483	hst017-02	0.166	ust013t21	0.048
hct012-02	0.201	ust014t04	0.482	hst007-06	0.166	ust002t02	0.048
lct017-07	0.201	ust003t05	0.479	hst006-27	0.166	umf004t02x	0.048
hct012-01	0.200	ust014t03	0.478	ust015t27x	0.165	ust003t06	0.048
lct017-13	0.199	usi001t20x	0.477	hst018-01	0.165	ust003t09	0.048
lct012-08	0.199	usi001t32x	0.473	hst007-16	0.165	ust004t02	0.048
lct017-06	0.197	ust014t15	0.472	hst006-12	0.165	ust002t09	0.048
lct017-02	0.196	ust014t09	0.470	usi001t07x	0.164	ust002t17	0.048
lct012-09	0.196	ust014t05	0.469	hst005-14	0.164	ust013t20	0.048
lct26c3	0.194	ust006t10	0.464	hmt006-04	0.164	ust016t26	0.048
lct017-12	0.194	ust014t06	0.463	hmt006-11	0.163	ust016t21	0.048
lct012-10	0.193	ust014t07	0.459	hmt006-16	0.163	ust016t22	0.048
lct017-05	0.193	ust014t14	0.458	ust015t23x	0.163	ust016t23	0.048
lct017-22	0.192	usi001t08x	0.451	hst007-11	0.163	ust016t24	0.048
lct010-26	0.192	ust014t08	0.451	hst007-02	0.162	ust016t27	0.048

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
lct010-25	0.191	usi001t22x	0.441	hmt006-03	0.162	ust002t03	0.048
lct017-01	0.191	usi001t16x	0.440	hct010-03	0.161	ust003t08	0.048
lct017-11	0.191	ust015t14x	0.438	ust015t15x	0.161	ust016t25	0.048
hct013-01	0.188	uct001t02	0.438	ust015t05x	0.158	ust013t02	0.047
lct017-21	0.186	usi001t11x	0.437	hst018-03	0.158	ust013t03	0.047
lct017-10	0.185	ust015t04x	0.431	usi001t28x	0.157	ust013t04	0.047
hct011-02	0.184	usi001t06x	0.414	hst018-02	0.156	ust013t05	0.047
lct017-20	0.183	lct017-26	0.414	hst005-17	0.154	ust002t08	0.047
hct013-02	0.183	lct017-27	0.412	hst005-15	0.154	ust013t01	0.047
hct011-03	0.182	ust015t18x	0.406	hmt006-02	0.152	ust013t10	0.047
lct017-25	0.181	ust015t08x	0.403	hst009-04	0.152	ust013t14	0.047
lct010-24	0.181	usi001t21x	0.381	usi001t18x	0.151	ust013t06	0.047
lst03c7	0.177	usi001t31x	0.381	hst019-01	0.150	ust013t07	0.047
lct017-19	0.176	ust001t05x	0.375	hmt006-20	0.150	ust013t08	0.047
umf001t00x	0.176	usi001t27x	0.373	ust015t26x	0.149	ust013t09	0.047
umf003t01x	0.176	ust001t04x	0.372	hmt006-17	0.147	ust013t11	0.047
umf002t02x	0.175	usi001t09x	0.371	usi001t05x	0.145	ust013t13	0.047
umf003t02x	0.175	ust001t03x	0.369	hmt006-13	0.144	ust002t15	0.047
umf005t01x	0.175	ust001t02x	0.366	hmt006-10	0.143	ust003t07	0.047
lct017-04	0.175	ust015t30x	0.365	hmt006-21	0.143	ust013t12	0.047
lst05c1	0.175	ust001t01x	0.363	hmt006-01	0.142	ust002t16	0.047
umf006t00x	0.175	usi001t10x	0.361	ust015t22x	0.141	ust013t15	0.047
umf002t01x	0.175	usi001t17x	0.351	hct010-01	0.138	ust002t04	0.047
umf005t02x	0.174	usi001t04x	0.336	hst009-03	0.138	ust016t29	0.047
umf004t01x	0.173	usi001t29x	0.326	hmt006-22	0.137	ust016t30	0.047
lct017-29	0.171	ust015t06x	0.325	ust015t13x	0.137	ust002t06	0.047
hct011-01	0.171	ust015t16x	0.317	hmt006-18	0.136	ust002t07	0.047
lct24c1	0.169	usi001t19x	0.314	hmt006-23	0.135	ust016t28	0.047
umf004t02x	0.168	ust015t29x	0.304	hst033-03a	0.135	ust009t01	0.047
lst05c2	0.168	ust015t24x	0.301	ust015t03x	0.135	ust013t19	0.047
lct017-17	0.165	usi001t07x	0.299	hct010-02	0.135	ust015t19x	0.047
lct26c4	0.163	usi001t14x	0.292	hst033-10a	0.134	ust002t05	0.047
lst03c8	0.161	uct001t04	0.288	hst033-03b	0.133	ust013t18	0.047
lct017-16	0.161	usi001t28x	0.273	usi001t26x	0.132	ust013t16	0.046
lct017-28	0.161	ust015t05x	0.270	hst033-02a	0.131	ust013t17	0.046
lct017-24	0.161	ust015t15x	0.270	usi001t15x	0.128	ust009t02	0.046
lct042-01	0.158	usi001t18x	0.267	ust015t21x	0.128	ust008t01x	0.045
lct017-23	0.157	ust009t01	0.256	hst033-03c	0.125	usi001t31x	0.045
lct049t10	0.156	usi001t05x	0.256	hst033-02b	0.125	ust009t03	0.045
lct042-06	0.155	ust015t23x	0.255	usi001t03x	0.125	usi001t07x	0.044

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
lst03c9	0.155	ust015t28x	0.252	hst033-10c	0.125	ust009t04	0.043
lct017-15	0.155	ust009t02	0.228	ust015t12x	0.123	ust015t08x	0.043
lct049t11	0.154	ust015t03x	0.220	ust015t02x	0.121	usi001t19x	0.043
lct049t09	0.153	usi001t26x	0.220	hst033-10d	0.121	mci005t00	0.043
lct049t12	0.149	ust015t13x	0.219	hst009-02	0.121	ust015t31x	0.042
hst042-03	0.147	ust015t27x	0.218	usi001t25x	0.119	uct001t04	0.042
lct042-02	0.147	usi001t15x	0.217	hst033-02c	0.117	lct017-18	0.041
hst032-01	0.147	hmt025t01	0.212	hct014-02	0.116	ust015t18x	0.041
lct042-07	0.147	usi001t03x	0.212	ust015t20x	0.116	usi001t29x	0.040
lct042-05	0.146	ust015t22x	0.208	usi001t13x	0.114	usi001t05x	0.039
lct042-03	0.145	ust008t01x	0.202	usi001t02x	0.112	usi001t18x	0.038
lct042-04	0.145	ust009t03	0.195	hst009-01	0.111	ust015t26x	0.038
lct010-16	0.141	usi001t25x	0.191	ust015t11x	0.109	ust015t30x	0.038
lst05c3	0.137	ust015t02x	0.190	ust015t01x	0.106	ust015t06x	0.037
lct049t13	0.134	ust015t12x	0.188	hct014-01	0.106	ust015t29x	0.036
lct049t15	0.132	usi001t13x	0.186	usi001t24x	0.104	ust015t27x	0.036
lct049t16	0.132	ust015t26x	0.186	lct017-18	0.102	usi001t28x	0.035
lct049t06	0.131	usi001t02x	0.183	usi001t12x	0.100	ust015t16x	0.035
lct049t14	0.131	hmt025t02	0.181	usi001t01x	0.097	ust015t28x	0.035
lct049t07	0.130	ust015t21x	0.180	hct013-02	0.093	usi001t03x	0.034
lct049t05	0.128	lct017-18	0.156	hct012-02	0.092	ust015t05x	0.033
lct049t08	0.126	ust015t11x	0.156	hct011-03	0.085	ust015t24x	0.033
lct049t17	0.125	ust009t04	0.156	hct012-01	0.083	usi001t15x	0.033
lct017-27	0.117	ust015t01x	0.156	hct013-01	0.080	mmf008t07	0.033
hst042-04	0.115	usi001t24x	0.156	hct011-02	0.077	ust015t15x	0.032
lct049t18	0.107	usi001t12x	0.154	hct011-01	0.073	imf004	0.032
lct017-26	0.105	ust015t20x	0.153	mci005t00	0.040	ust015t20x	0.032
lct049t02	0.102	usi001t01x	0.151	mcm001t09	0.034	usi001t02x	0.031
lct049t01	0.101	hmf030t00	0.129	mcm001t08	0.034	ust015t23x	0.031
hst042-06	0.098	mcm001t08	0.032	mcm001t07	0.034	usi001t26x	0.031
lct049t03	0.096	mcm001t09	0.032	mcm001t06	0.034	imf006	0.030
lct049t04	0.096	mcm001t03	0.032	mcm001t10	0.033	usi001t13x	0.030
hst042-05	0.090	mcm001t06	0.032	umf006t00x	0.033	ust015t03x	0.030
hst042-07	0.079	mcm001t07	0.032	mcm001t04	0.033	ust015t21x	0.030
hst042-08	0.062	mcm001t04	0.031	mcm001t03	0.033	ust015t22x	0.030
lct017-18	0.046	imf004	0.031	mcm001t05	0.032	imf003	0.030
mcm001t08	0.033	mcm001t05	0.031	mcm001t11	0.032	ust015t13x	0.029
mcm001t09	0.033	mcm001t11	0.030	umf003t02x	0.032	usi001t25x	0.029
mcm001t03	0.033	mcm001t17	0.030	mcm001t14	0.032	usi001t01x	0.028
mcm001t06	0.032	mcm001t14	0.030	mcm001t19	0.032	ust015t02x	0.028

Application 1		Application 2		Application 3		Application 4	
Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r	Exp. ID	c_r
mcm001t07	0.032	mcm001t19	0.030	mcm001t17	0.032	ust015t12x	0.028
mcm001t04	0.032	mcm001t10	0.030	mcm001t18	0.032	usi001t12x	0.028
mcm001t05	0.031	mcm001t18	0.030	mcm001t12	0.032	ust015t11x	0.028
mcm001t11	0.031	mcm001t12	0.030	umf003t01x	0.031	usi001t24x	0.027
mcm001t17	0.031	mcm001t15	0.029	mcm001t15	0.031	ust015t01x	0.027
mcm001t14	0.031	imf006	0.029	mcm001t13	0.031	mmf008t03	0.019
mcm001t19	0.031	imf003	0.029	umf005t02x	0.031	imf005	0.019
mcm001t10	0.030	mcm001t13	0.028	umf002t01x	0.031	mmf008t01	0.016
mcm001t18	0.030	mcm001t16	0.027	umf002t02x	0.031	mmf008t06	0.015
mcm001t12	0.030	mmf008t07	0.026	umf005t01x	0.031	mmf008t04	0.009
mcm001t15	0.029	umf002t01x	0.021	umf004t01x	0.030	mcf001t01	0.005
mcm001t13	0.029	umf002t02x	0.020	mcm001t16	0.030	mmf008t02	0.005
mcm001t16	0.027	mcm001t01	0.019	umf001t00x	0.030	mcm001t03	0.004
mcm001t01	0.018	umf005t01x	0.019	umf004t02x	0.030	mcm001t04	0.004
mcm001t02	0.018	umf005t02x	0.019	mcm001t01	0.024	mcm001t05	0.004
imf003	0.004	umf006t00x	0.019	mcm001t02	0.023	mcm001t06	0.004
imf004	0.004	mcm001t02	0.019	hmt025t02	0.012	mcm001t07	0.004
imf006	0.004	umf003t01x	0.019	hmt025t01	0.011	mcm001t08	0.004
hmf030t00	0.002	umf003t02x	0.019	imf006	0.009	mcm001t09	0.004
imf005	0.002	umf001t00x	0.019	hct010-05	0.009	mcm001t10	0.004
hmt025t02	0.002	umf004t01x	0.018	imf003	0.009	mcm001t11	0.004
hmt025t01	0.001	umf004t02x	0.018	imf004	0.009	mcm001t14	0.004
mmf008t07	0.001	imf005	0.018	mmf008t01	0.009	mcm001t17	0.004
mmf008t01	0.000	mmf008t01	0.016	mmf008t06	0.006	mcm001t18	0.004
mmf008t03	0.000	mmf008t04	0.008	mmf008t04	0.005	mcm001t19	0.004
mmf008t05	0.000	mmf008t03	0.007	hmf030t00	0.005	mcm001t12	0.004
mmf008t02	-0.001	mmf008t02	0.003	imf005	0.005	mcm001t13	0.004
mmf008t04	-0.001	mmf008t06	0.001	mcf001t01	0.005	mcm001t15	0.004
mcf001t01	-0.002	mmf008t05	0.000	mmf008t03	0.005	mcm001t16	0.004
mmf008t06	-0.013	mcf001t01	0.000	mmf008t07	0.003	mcm001t01	0.004
mci005t00	-0.024	mci005t00	-0.005	mmf008t02	0.002	mcm001t02	0.004
hct010-05	-0.408	hct010-05	-0.071	mmf008t05	0.000	mmf008t05	0.001

APPENDIX E

EXAMPLE USLSTATS INPUT FILE FOR APPLICATION 1, CASE 4

USLSTATS input file for USL case 4 – EALF trending of experiments with $c_r \geq 0.95$. Experiment and Monte-Carlo uncertainties are included for each experiment.

```
EALF Trend for c(r) > 0.95
0.999  0.950  0.950  0.0  0.000 -1  0.02
  2.82E-1  1.00928  0.00304
  2.83E-1  1.00930  0.00413
  2.83E-1  1.01064  0.00473
  2.94E-1  0.99696  0.00353
  2.94E-1  0.99615  0.00354
  2.95E-1  0.99404  0.00353
  2.95E-1  0.99513  0.00353
  1.54E-1  1.01114  0.00732
  1.54E-1  1.01196  0.00702
  1.54E-1  1.01202  0.00692
  1.54E-1  1.01261  0.00732
  1.54E-1  1.01321  0.00672
  2.86E-1  1.00118  0.00344
  2.85E-1  1.00086  0.00275
  2.86E-1  0.99987  0.00344
  2.86E-1  0.99956  0.00284
  1.47E-1  1.01321  0.00502
  1.47E-1  1.01180  0.00542
  1.47E-1  1.01370  0.00502
  1.47E-1  1.01319  0.00453
  1.47E-1  1.01094  0.00542
  1.47E-1  1.01275  0.00502
  1.47E-1  1.00953  0.00621
  1.47E-1  1.01267  0.00512
  1.47E-1  1.01419  0.00463
  1.41E-1  1.01368  0.00284
  1.41E-1  1.01477  0.00344
  1.41E-1  1.01417  0.00314
  1.41E-1  1.01378  0.00245
  1.70E-1  1.00288  0.00284
  1.62E-1  1.00250  0.00255
  1.42E-1  1.01016  0.00363
  1.42E-1  1.00916  0.00265
  1.42E-1  1.01155  0.00275
  1.44E-1  1.01299  0.00235
  2.98E-1  0.99311  0.00353
  2.98E-1  0.99349  0.00354
  2.98E-1  0.99377  0.00353
  1.03E-1  1.02717  0.00772
  2.86E-1  1.01073  0.00373
  2.86E-1  1.00536  0.00353
  2.86E-1  1.00981  0.00443
  2.86E-1  1.00998  0.00363
  1.06E-1  1.00922  0.00353
  1.05E-1  1.00534  0.00153
  1.43E-1  0.99973  0.00354
  1.43E-1  1.01344  0.00314
  1.43E-1  1.00076  0.00363
  1.44E-1  0.99892  0.00284
  1.10E-1  0.99787  0.00255
  8.55E-1  1.00149  0.00354
```

8.56E-1	0.99883	0.00353
8.57E-1	0.99700	0.00353
8.54E-1	1.00179	0.00354
8.68E-2	0.99966	0.00692
8.35E-2	1.00232	0.00522
2.20E-1	1.00123	0.00230
1.13E-1	1.00719	0.00324
6.02E-1	0.98629	0.01121
8.96E-2	1.00755	0.00712
7.87E-2	1.00691	0.00206
4.95E-1	1.00089	0.00290
7.95E-2	1.00585	0.00373
7.96E-2	1.00557	0.00324
7.95E-2	1.00646	0.00314
7.98E-2	1.00659	0.00403
7.98E-2	1.00935	0.00373
7.97E-2	1.01295	0.00344
8.65E-1	0.99530	0.00353
8.65E-1	0.99410	0.00354
5.40E-1	0.98924	0.01091
7.89E-2	1.00992	0.00110
7.95E-2	1.00665	0.00294
1.12E+0	0.99322	0.00510
8.13E-2	1.00939	0.00403
6.40E-1	0.99971	0.01121
7.81E-1	0.99070	0.00700
7.89E-2	1.00268	0.00891
1.37E-1	1.00008	0.00871
1.71E-1	1.00349	0.00871
1.32E-1	0.99262	0.00870
4.37E-1	1.00697	0.01261