The VIBE Tool of SCALE – Validation, Interpretation, and Bias Estimation

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VIBE is a new graphical user interface to identify and interpret sensitivity data from SCALE/TSUNAMI that was distributed with SCALE 6.0. VIBE enables users to group-collapse sensitivity data and then sort and filter the collapsed data to identify important processes in applications or experiments, providing an improved means of preselecting experiments for use in criticality code validation. VIBE also enables users to query DICE, the database of ICSBEP, to gain more information about experiments present in the handbook. Data from VIBE can be exported for criticality code validation studies with other TSUNAMI sensitivity and uncertainty analysis tools. VIBE also supports other sensitivity data distributed by ICSBEP and will be integrated with DICE for the 2009 release of the IHECSBE.

I. INTRODUCTION

The Tools for Sensitivity and Uncertainty Analysis Methodology Implementation (TSUNAMI) software developed at Oak Ridge National Laboratory (ORNL) as part of the SCALE (Standardized Computer Analysis for Licensing Evaluation) code system provide a unique means of determining the similarity of nuclear criticality experiments to safety applications.[1] Instead of using an average physical parameter to characterize a system, correlation coefficients are developed by propagating the uncertainties in neutron cross-section data to uncertainties in the computed neutron multiplication factor for experiments and safety applications via sensitivity coefficients. The bias in the experiments, as a function of correlation with the intended application, is extrapolated to predict the bias and bias uncertainty in the application. Additionally, TSUNAMI in SCALE 6.0 includes the data adjustment tool, TSURFER (Tool for Sensitivity/Uncertainty Analysis of Response Functions using Experimental Results), which can assimilate biases from many different sources to project the bias and bias uncertainty of an application.

For TSUNAMI analysis, sensitivity data are generated for each application and each experiment used in the validation. The validation of diverse sets of applications requires potentially thousands of data files to be maintained and organized by the user, and a growing number of these files are available through the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* (IHECSBE) distributed through the International Criticality Safety Benchmark Evaluation Program (ICSBEP).[2] General information regarding the usefulness of any individual experiment for a given application is largely unavailable prior to performing the TSUNAMI analysis or consulting documentation of the experiment itself.

To help streamline the code validation process, a new software package, VIBE (Validation, Interpretation and Bias Estimation), has been developed at ORNL. This paper focuses on user features of VIBE in the interpretation and use of TSUNAMI sensitivity data distributed with the 2008 ICSBEP handbook to validate a demonstration application distributed to SCALE 6.0.

II. OVERVIEW OF VIBE

VIBE will scan a computer file system and locate all available TSUNAMI sensitivity data files (SDFs), which can include sensitivity data for the user's application as well as files from the ICSBEP handbook. Because an SDF can contain millions of data points, VIBE helps the user consolidate these points by collapsing the data along one dimension (energy), and then allowing the user to sort and filter the data along other dimensions (nuclide, reaction, sensitivity values, etc). Once the data points are parsed with VIBE, the user can select the benchmarks most similar to the application based on sensitivity criteria. Lists of matching files can be stored in groups and passed to the SCALE 6 ExSITE (Extensible SCALE Intelligent Text Editor) input generator, where further options for TSUNAMI-IP and TSURFER are set and the TSUNAMI analysis is conducted. VIBE is also capable of querying the DICE (Database for the International Handbook of Evaluated Criticality Safety Benchmark Experiments) database distributed with the ICSBEP handbook to display the characteristic parameters of each benchmark (enrichment, EALF, H/X, etc.) along with the experimental and computed k_{eff} values and uncertainties in a tabular format. These data can be exported for further analysis, such as traditional trending analysis with USLSTATS[3] and for comparison with the TSUNAMI results.

III. SENSITIVITY DATA DISTRIBUTED WITH 2008 IHECSBE

For 2008 the IHECSBE included 281 SDFs generated by ORNL using SCALE 5.1 with the 238-group ENDF/B-VI.7 cross-section library that included the ENDF/B-VII.0 cross section for ^{233}U. The files distributed with the IHECSBE were generated as part of a study published as *Application of the SCALE TSUNAMI Tools for the Validation of Criticality Safety Calculations Involving ^{233}U*, ORNL/TM-2008-196,[4] and primarily consist of critical configurations of ^{233}U, as shown in Table I. Distribution of additional SDFs generated with SCALE 6.0 using ENDF/B-VII.0 data is planned for the 2009 edition of the IHECSBE.

TABLE I. Evaluations with TSUNAMI Sensitivity Data in 2008 IHECSBE

ICSBEP Evaluation ID	No. Exps.	ICSBEP Evaluation ID	No. Exps.	ICSBEP Evaluation ID	No. Exps.
U233-COMP-THERM-001	3	U233-SOL-THERM-004	8	HEU-MET-FAST-030	1
U233-MET-FAST 001	1	U233-SOL-THERM-005	2	HEU-MET-THERM-025	2
U233-MET-FAST 002	2	U233-SOL-THERM-006	25	**HEU total**	3
U233-MET-FAST 003	2	U233-SOL-THERM-008	1		
U233-MET-FAST 004	2	U233-SOL-THERM-009	4	LEU-COMP-THERM-049	18
U233-MET-FAST 005	2	U233-SOL-THERM-012	8	**LEU total**	18
U233-MET-FAST-006	1	U233-SOL-THERM-013	21		
U233-SOL-INTER-001	33	U233-SOL-THERM-014	16	MIX-COMP-FAST-001	1
U233-SOL-THERM-001	5	U233-SOL-THERM-015	31	MIX-COMP-INTER-005	1
U233-SOL-THERM-002	17	U233-SOL-THERM-016	31	MIX-COMP-MIXED-001	19
U233-SOL-THERM-003	10	U233-SOL-THERM-017	7	MIX-MET-FAST-008	7
		^{233}U total	232	**Pu & U mixed total**	28

IV. EXAMPLE SYSTEM

Because of the availability of SDFs for ^{233}U experiments in the IHECSBE, a ^{233}U system was selected to demonstrate the TSUNAMI methods for selection of benchmark experiments that are similar to the application system. The example system, referred to as Application 1 in ORNL/TM-2008/196, is a 12.2 cm radius sphere of 220 g uranium 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 SS304 and 2 cm of water. The EALF calculated for this application is 0.282 eV. The k_{eff} calculated for this system is 1.0028 ± 0.0002. This example system is also used in *TSUNAMI Primer*,[5] and the SDF for this system was distributed with SCALE 6.0 in the directory *scale6/primers/TSUNAMI/files*.

V. INTERPRETING SENSITIVITY DATA WITH VIBE

The VIBE analysis of the applications system begins by loading the directory containing the SDF into VIBE using `Add database location…` from the `File` menu. The directory tree leading to the `files` directory will appear in the left pane of the VIBE application, as shown in Fig. 1.

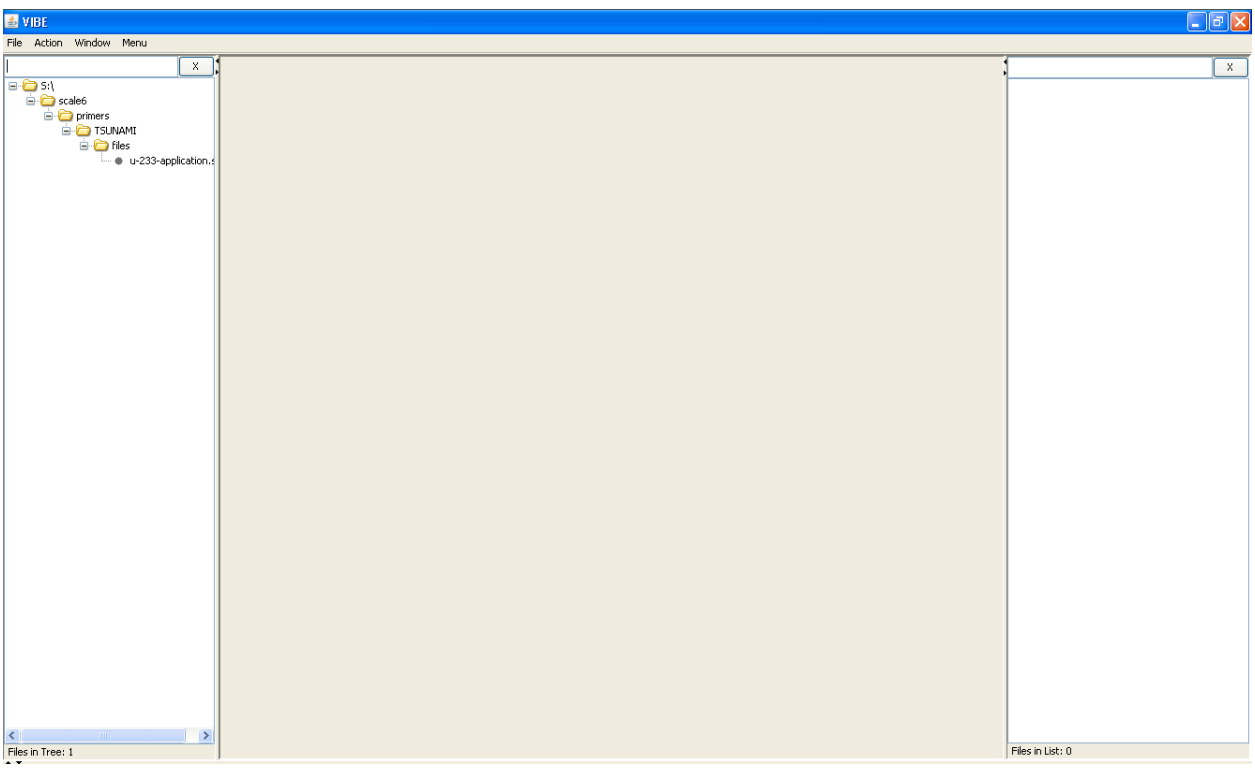


Fig. 1. VIBE application with directory tree.

A right click on the SDF will open a pop-up menu with some options. Select `Open in Javapeno` to view the TSUNAMI data in Javapeño. Plots of the fission and n,gamma sensitivities for ^{233}U reveal a high sensitivity at thermal energies, as expected, and some sensitivities at intermediate energies, as shown in Fig. 2.

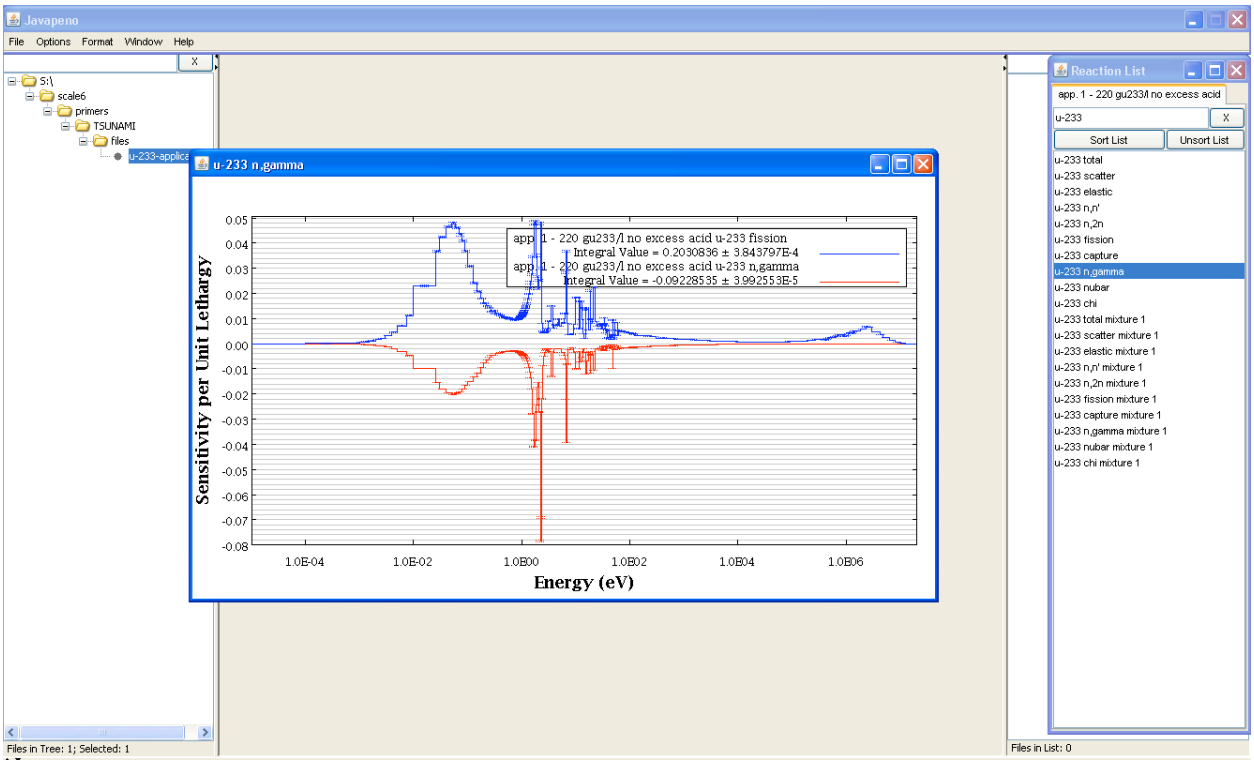


Fig. 2. Plotting ^{233}U fission and n,gamma for a ^{233}U application.

Performing a group collapse of the sensitivity data and applying VIBE's sorting and filtering capabilities will assist in identifying important processes in this system. To manipulate sensitivity data, the SDFs of interest must first be gathered in the VIBE *benchmark set* by dragging the desired files to the center panel of VIBE and naming the set *u-233 application*, as shown in Fig. 3.

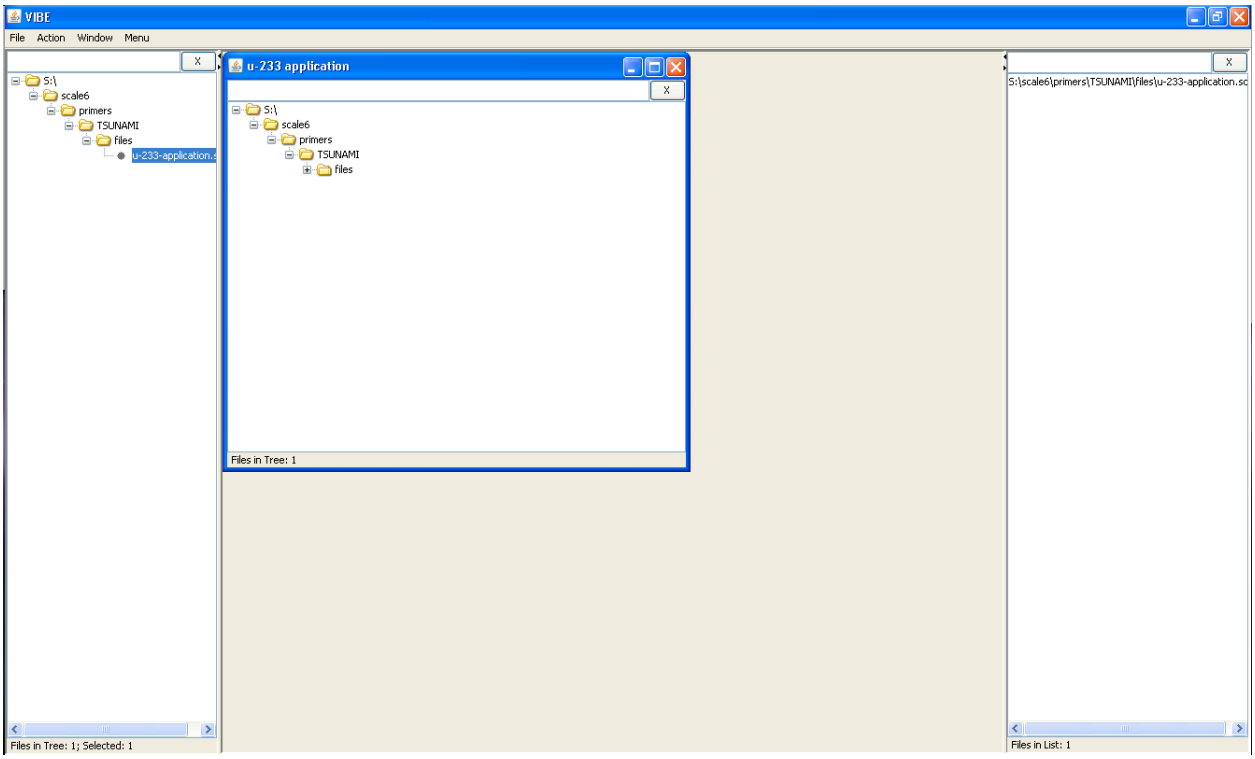


Fig. 3. VIBE with new benchmark set.

With a simple benchmark set established, a group collapse of the sensitivity data can be performed. In the `Collapse Benchmark Set` dialog, shown in Fig. 4, the boundaries for the group collapse can be selected by hand by clicking on the checkbox next to each desired boundary, or they can be set automatically using predefined group structures. The group structures available are 3-, 4-, 44-, and 238-group. By clicking the checkbox next to `Use Predefined Structures`, the 3-group structure, consistent with the ICSBEP 3-group boundaries, is selected.

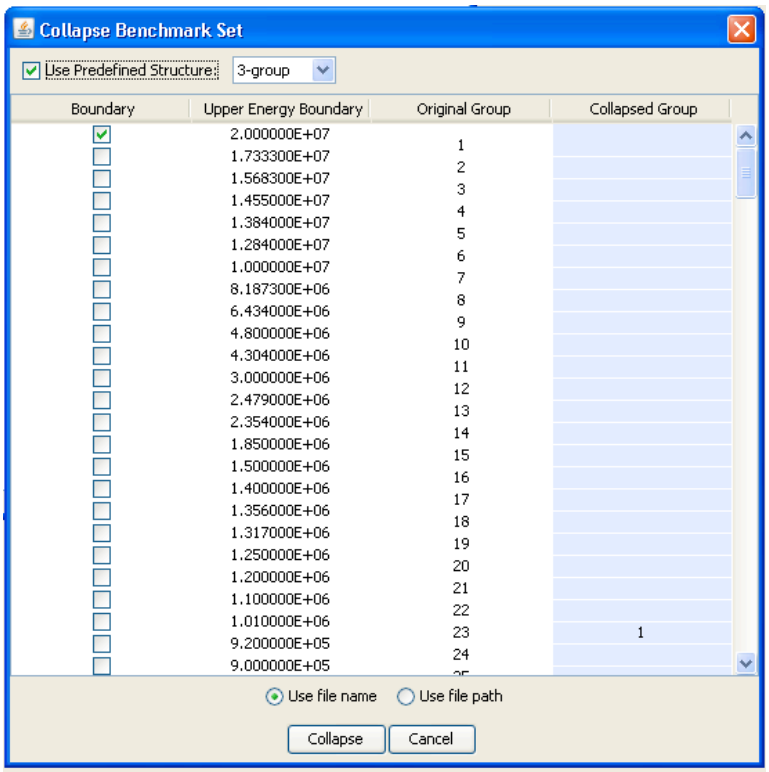
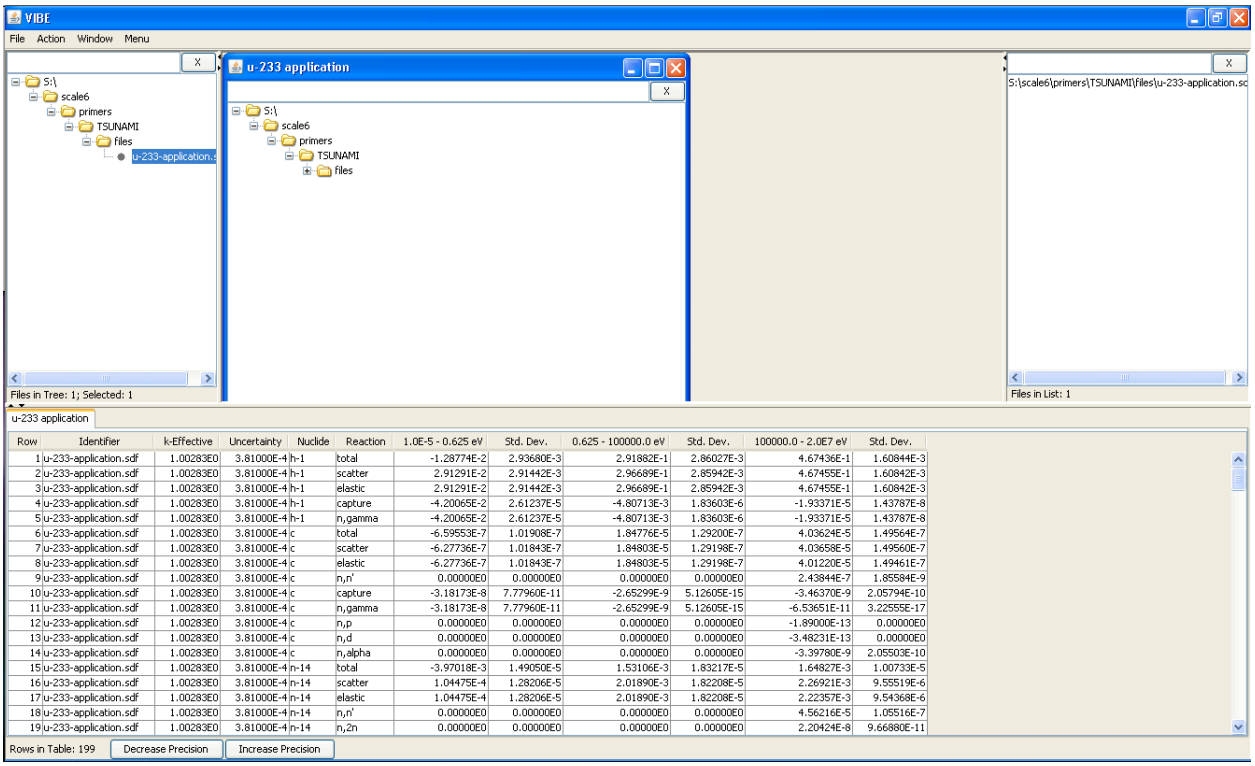


Fig. 4. VIBE group-collapse dialog.

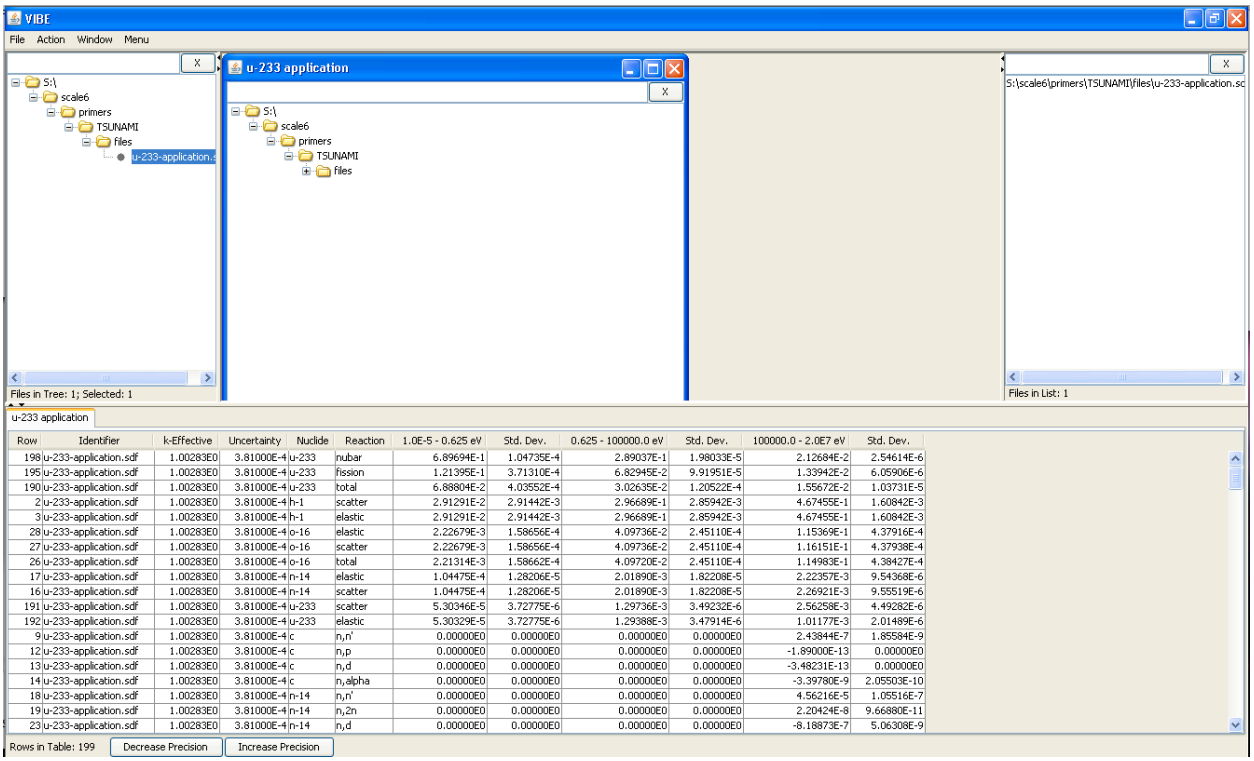
A new table will appear with the collapsed data, as shown in Fig. 5. The collapsed table contains columns for row number, SDF identifier, computed k_{eff} and its uncertainty, nuclide and reaction for the sensitivity data, and 3-group sensitivity data and their uncertainties. The energy range for each collapsed group is shown at the top of the columns, and the statistical uncertainties due to the TSUNAMI-3D Monte Carlo calculations are shown for each group in the column labeled "Std. Dev." The table contains a row for the nuclide-reaction pair for which sensitivity data are available on the SDF. For this file, there are 199 rows in the table, as shown in the lower left corner of the table pane. With so many rows, it may be difficult to visually inspect the data to identify the highest sensitivities for which validation data are desired. To simplify this process, the VIBE sorting capabilities can be used.



Row	Identifier	k-Effective	Uncertainty	Nuclide	Reaction	1.0E-5 - 0.625 eV	Std. Dev.	0.625 - 100000.0 eV	Std. Dev.	100000.0 - 2.0E7 eV	Std. Dev.
1	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	total	-1.28774E-2	2.93680E-3	2.91882E-1	2.86027E-3	4.67436E-1	1.60844E-3
2	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	scatter	2.91291E-2	2.91442E-3	2.96689E-1	2.85942E-3	4.67455E-1	1.60842E-3
3	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	elastic	2.91291E-2	2.91442E-3	2.96689E-1	2.85942E-3	4.67455E-1	1.60842E-3
4	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	capture	-4.20065E-2	2.61237E-5	-4.80713E-3	1.83603E-6	-1.93371E-5	1.43787E-8
5	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	n,gamma	-4.20065E-2	2.61237E-5	-4.80713E-3	1.83603E-6	-1.93371E-5	1.43787E-8
6	u-233-application.sdf	1.00283E0	3.81000E-4	c	total	-6.59553E-7	1.01908E-7	1.84776E-5	1.29200E-7	4.03624E-5	1.49564E-7
7	u-233-application.sdf	1.00283E0	3.81000E-4	c	scatter	-6.27736E-7	1.01843E-7	1.84803E-5	1.29198E-7	4.03658E-5	1.49560E-7
8	u-233-application.sdf	1.00283E0	3.81000E-4	c	elastic	-6.27736E-7	1.01843E-7	1.84803E-5	1.29198E-7	4.01220E-5	1.49461E-7
9	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,n'	0.00000E0	0.00000E0	0.00000E0	0.00000E0	2.43844E-7	1.85584E-9
10	u-233-application.sdf	1.00283E0	3.81000E-4	c	capture	-3.18173E-8	7.77960E-11	-2.65299E-9	5.12605E-15	-3.46370E-9	2.05794E-10
11	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,gamma	-3.18173E-8	7.77960E-11	-2.65299E-9	5.12605E-15	-6.53651E-11	3.22555E-17
12	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,p	0.00000E0	0.00000E0	0.00000E0	0.00000E0	-1.89000E-13	0.00000E0
13	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,d	0.00000E0	0.00000E0	0.00000E0	0.00000E0	-3.48231E-13	0.00000E0
14	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,alpha	0.00000E0	0.00000E0	0.00000E0	0.00000E0	-3.39780E-9	2.05503E-10
15	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	total	-3.97018E-3	1.49050E-5	1.53106E-3	1.83217E-5	1.64827E-3	1.00733E-5
16	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	scatter	1.04475E-4	1.28206E-5	2.01890E-3	1.82208E-5	2.26921E-3	9.55519E-6
17	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	elastic	1.04475E-4	1.28206E-5	2.01890E-3	1.82208E-5	2.22357E-3	9.54368E-6
18	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	n,n'	0.00000E0	0.00000E0	0.00000E0	0.00000E0	4.56216E-5	1.05516E-7
19	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	n,2n	0.00000E0	0.00000E0	0.00000E0	0.00000E0	2.20424E-8	9.66880E-11

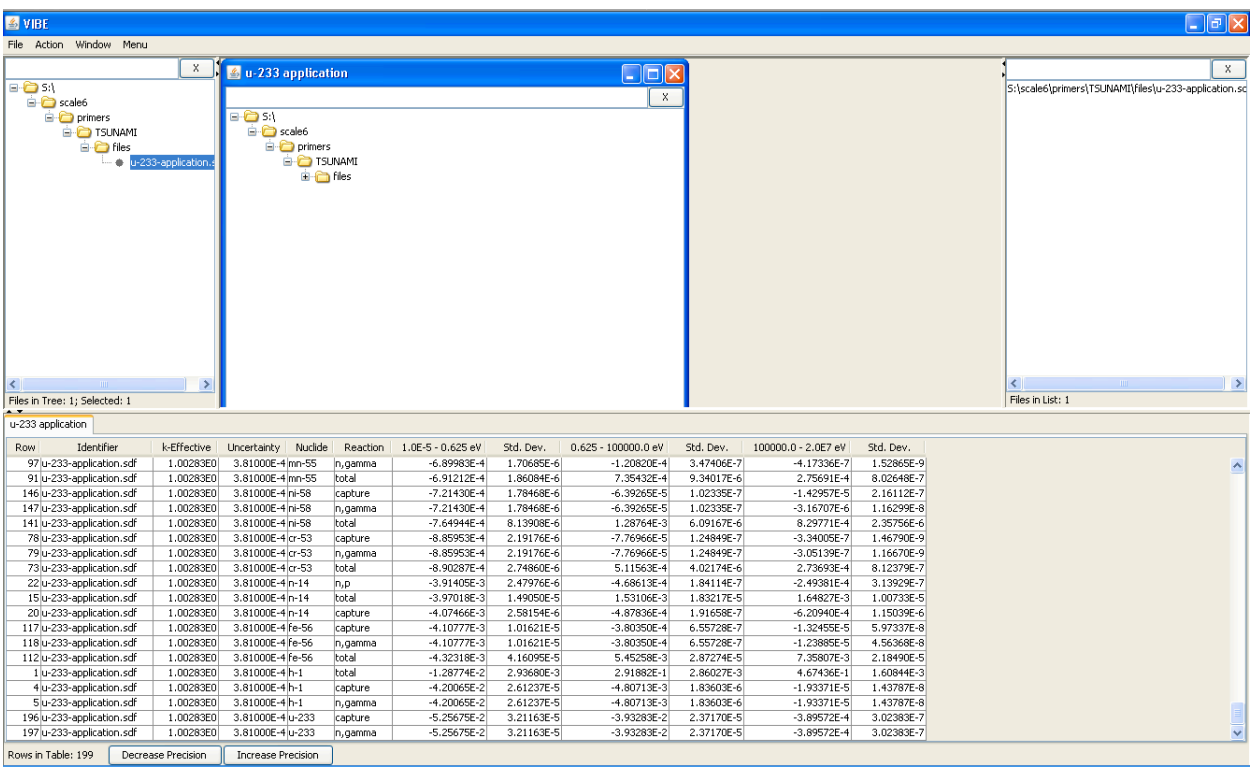
Fig. 5. VIBE with group-collapsed sensitivity data.

The data can be sorted based on several criteria. The sensitivities sorted according to the thermal sensitivity in descending order appear as shown in Fig. 6. As expected, the ^{233}U sensitivities have the highest positive values, followed by ^{1}H and ^{16}O. It is also important to check the bottom of the table for sensitivities with large negative values, as shown in Fig. 7. Here the capture reactions of ^{233}U and ^{1}H have the largest magnitudes. The next most negative isotope is ^{56}Fe, but its values are an order of magnitude smaller than those of ^{233}U and ^{1}H. Thus, it is expected to be of secondary importance for validation.



Row	Identifier	k-Effective	Uncertainty	Nuclide	Reaction	1.0E-5 - 0.625 eV	Std. Dev.	0.625 - 100000.0 eV	Std. Dev.	100000.0 - 2.0E7 eV	Std. Dev.
198	u-233-application.sdf	1.00283E0	3.81000E-4	u-233	nubar	6.89694E-1	1.04735E-4	2.89037E-1	1.98033E-5	2.12684E-2	2.54614E-6
195	u-233-application.sdf	1.00283E0	3.81000E-4	u-233	fission	1.21395E-1	3.71310E-4	6.82945E-2	9.91951E-5	1.33942E-2	6.05906E-6
190	u-233-application.sdf	1.00283E0	3.81000E-4	u-233	total	6.88804E-2	4.03552E-4	3.02635E-2	1.20522E-4	1.55672E-2	1.03731E-5
2	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	scatter	2.91291E-2	2.91442E-3	2.96689E-1	2.85942E-3	4.67455E-1	1.60842E-3
3	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	elastic	2.91291E-2	2.91442E-3	2.96689E-1	2.85942E-3	4.67455E-1	1.60842E-3
28	u-233-application.sdf	1.00283E0	3.81000E-4	o-16	elastic	2.22679E-3	1.58656E-4	4.09736E-2	2.45110E-4	1.15369E-1	4.37916E-4
27	u-233-application.sdf	1.00283E0	3.81000E-4	o-16	scatter	2.22679E-3	1.58656E-4	4.09736E-2	2.45110E-4	1.16151E-1	4.37938E-4
26	u-233-application.sdf	1.00283E0	3.81000E-4	o-16	total	2.21314E-3	1.58662E-4	4.09720E-2	2.45110E-4	1.14983E-1	4.38427E-4
17	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	elastic	1.04475E-4	1.28206E-5	2.01890E-3	1.82208E-5	2.22357E-3	9.54368E-6
16	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	scatter	1.04475E-4	1.28206E-5	2.01890E-3	1.82208E-5	2.26921E-3	9.55519E-6
191	u-233-application.sdf	1.00283E0	3.81000E-4	u-233	scatter	5.30346E-5	3.72775E-6	1.29736E-3	3.49232E-6	2.56258E-3	4.49282E-6
192	u-233-application.sdf	1.00283E0	3.81000E-4	u-233	elastic	5.30329E-5	3.72775E-6	1.29388E-3	3.47914E-6	1.01177E-3	2.01489E-6
9	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,n'	0.00000E0	0.00000E0	0.00000E0	0.00000E0	2.43844E-7	1.85584E-9
12	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,p	0.00000E0	0.00000E0	0.00000E0	0.00000E0	-1.89000E-13	0.00000E0
13	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,d	0.00000E0	0.00000E0	0.00000E0	0.00000E0	-3.48231E-13	0.00000E0
14	u-233-application.sdf	1.00283E0	3.81000E-4	c	n,alpha	0.00000E0	0.00000E0	0.00000E0	0.00000E0	-3.39780E-9	2.05503E-10
18	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	n,n'	0.00000E0	0.00000E0	0.00000E0	0.00000E0	4.56216E-5	1.05516E-7
19	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	n,2n	0.00000E0	0.00000E0	0.00000E0	0.00000E0	2.20424E-8	9.66880E-11
23	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	n,d	0.00000E0	0.00000E0	0.00000E0	0.00000E0	-8.18873E-7	5.06308E-9

Fig. 6. VIBE with thermal sensitivity data sorted in descending order.



Row	Identifier	k-Effective	Uncertainty	Nuclide	Reaction	1.0E-5 - 0.625 eV	Std. Dev.	0.625 - 100000.0 eV	Std. Dev.	100000.0 - 2.0E7 eV	Std. Dev.
97	u-233-application.sdf	1.00283E0	3.81000E-4	mn-55	n,gamma	-6.89983E-4	1.70685E-6	-1.20820E-4	3.47406E-7	-4.17336E-7	1.52865E-9
91	u-233-application.sdf	1.00283E0	3.81000E-4	mn-55	total	-6.91212E-4	1.86084E-6	7.35432E-4	9.34017E-6	2.75691E-4	8.02648E-7
146	u-233-application.sdf	1.00283E0	3.81000E-4	ni-58	capture	-7.21430E-4	1.78468E-6	-6.39265E-5	1.02335E-7	-1.42957E-5	2.16112E-7
147	u-233-application.sdf	1.00283E0	3.81000E-4	ni-58	n,gamma	-7.21430E-4	1.78468E-6	-6.39265E-5	1.02335E-7	-3.16707E-6	1.16299E-8
141	u-233-application.sdf	1.00283E0	3.81000E-4	ni-58	total	-7.64944E-4	8.13908E-6	1.28764E-3	6.09167E-6	8.29771E-4	2.35756E-6
78	u-233-application.sdf	1.00283E0	3.81000E-4	cr-53	capture	-8.85953E-4	2.19176E-6	-7.76966E-5	1.24849E-7	-3.34005E-7	1.46790E-9
79	u-233-application.sdf	1.00283E0	3.81000E-4	cr-53	n,gamma	-8.85953E-4	2.19176E-6	-7.76966E-5	1.24849E-7	-3.05139E-7	1.16670E-9
73	u-233-application.sdf	1.00283E0	3.81000E-4	cr-53	total	-8.90287E-4	2.74860E-6	5.11563E-4	4.02174E-6	2.73693E-4	8.12379E-7
22	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	n,p	-3.91405E-3	2.47976E-6	-4.68613E-4	1.84114E-7	-2.49381E-4	3.13929E-7
15	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	total	-3.97018E-3	1.49050E-5	1.53106E-3	1.83217E-5	1.64827E-3	1.00733E-5
20	u-233-application.sdf	1.00283E0	3.81000E-4	n-14	capture	-4.07466E-3	2.58154E-6	-4.87836E-4	1.91658E-7	-6.20940E-4	1.15039E-6
117	u-233-application.sdf	1.00283E0	3.81000E-4	fe-56	capture	-4.10777E-3	1.01621E-5	-3.80350E-4	6.55728E-7	-1.32455E-5	5.97337E-8
118	u-233-application.sdf	1.00283E0	3.81000E-4	fe-56	n,gamma	-4.10777E-3	1.01621E-5	-3.80350E-4	6.55728E-7	-1.23885E-5	4.56368E-8
112	u-233-application.sdf	1.00283E0	3.81000E-4	fe-56	total	-4.32318E-3	4.16095E-5	5.45258E-3	2.87274E-5	7.35807E-3	2.18490E-5
1	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	total	-1.28774E-2	2.93680E-3	2.91882E-1	2.86027E-3	4.67436E-1	1.60844E-3
4	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	capture	-4.20065E-2	2.61237E-5	-4.80713E-3	1.83603E-6	-1.93371E-5	1.43787E-8
5	u-233-application.sdf	1.00283E0	3.81000E-4	h-1	n,gamma	-4.20065E-2	2.61237E-5	-4.80713E-3	1.83603E-6	-1.93371E-5	1.43787E-8
196	u-233-application.sdf	1.00283E0	3.81000E-4	u-233	capture	-5.25675E-2	3.21163E-5	-3.93283E-2	2.37170E-5	-3.89572E-4	3.02383E-7
197	u-233-application.sdf	1.00283E0	3.81000E-4	u-233	n,gamma	-5.25675E-2	3.21163E-5	-3.93283E-2	2.37170E-5	-3.89572E-4	3.02383E-7

Fig. 7. VIBE showing bottom of table with thermal sensitivity data sorted in descending order.

VI. INITIAL SCREENING OF AVAILABLE EXPERIMENTS WITH VIBE

The SDFs distributed in the IHECSBE are located on the handbook DVD in the directory *Dice/data/ornl*. After this directory is mounted, a VIBE benchmark set called *handbook* can be created. Collapsing the sensitivity data in the same 3-group structure as the application will allow identification of experiments with sensitivities, and thus computational biases, similar to those of the application. Here, the 3-group structure is selected for consistency with other data in the handbook and should adequately characterize this thermal system. Other group structures may be more appropriate in different analyses. The resulting collapsed data will appear as shown in Fig. 8. Note at the lower left corner of the table that the status line states there are 59,661 rows in this collapsed table. The number of rows corresponds to the number of sensitivity profiles in all 281 SDFs considered. Note that the initial order of the table corresponds to the order of the SDFs in the benchmark set and the order of the profiles within each SDF.

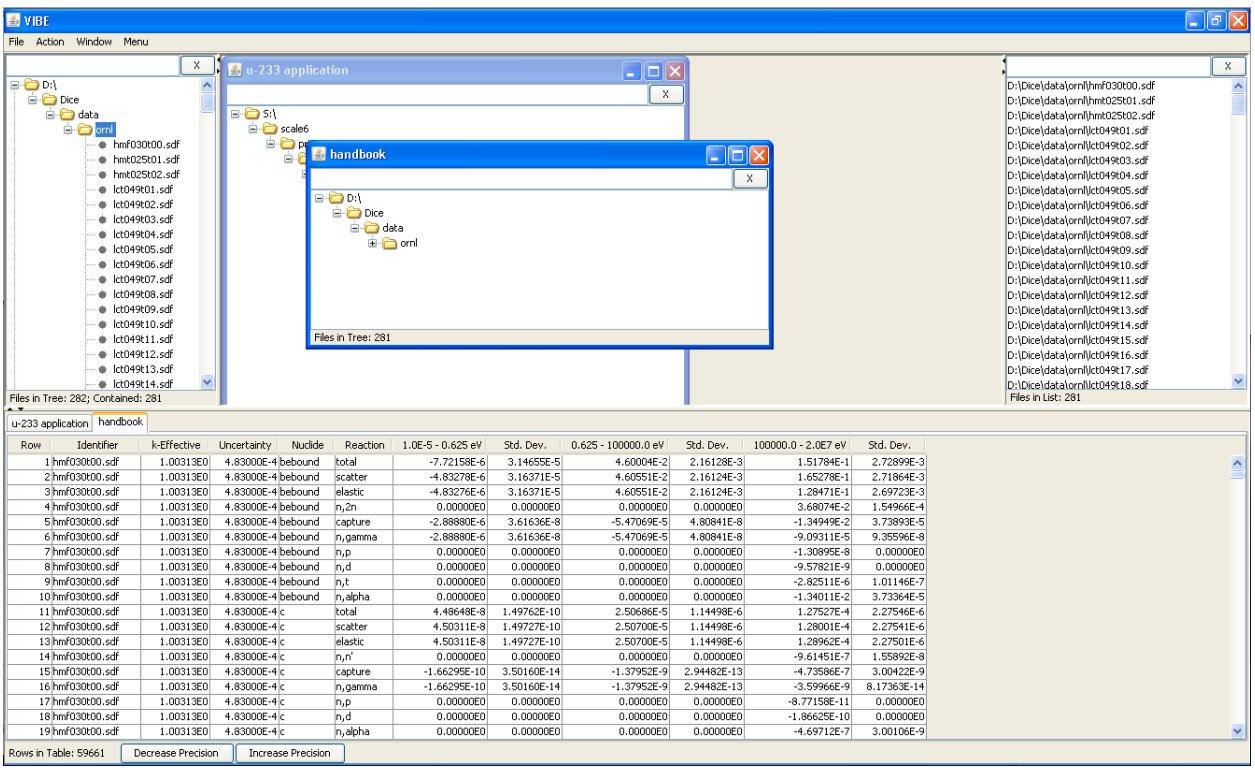


Fig. 8. VIBE with group-collapsed sensitivity data for benchmarks in the ICSBEP handbook.

To examine the availability of sensitivities in the benchmarks that are similar to those in the application, VIBE's sorting and filtering capabilities can be used to show only systems with ^{233}U nubar sensitivities with values between 0.67 and 0.71, inclusive, as shown in Fig. 9. Once the filter is applied, the number of matching benchmarks is 33, as shown in Fig. 10.

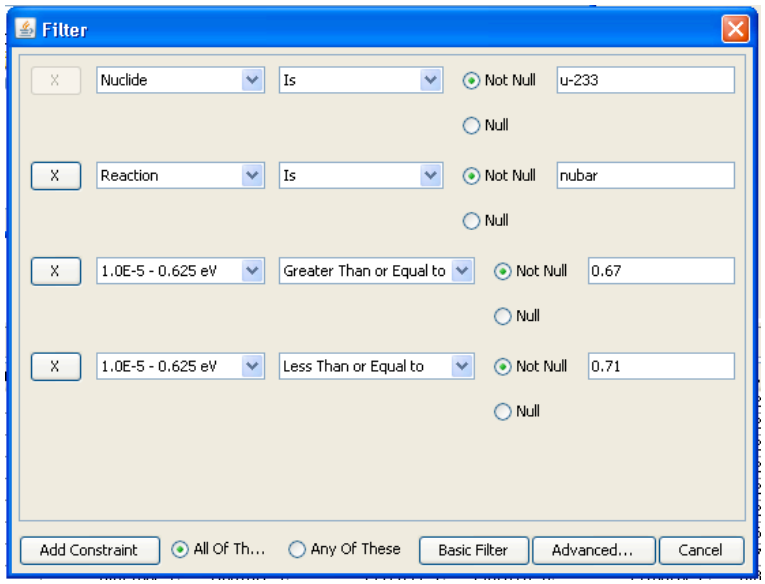


Fig. 9. VIBE filter dialog for thermal ^{233}U nubar sensitivities with values ≥ 0.67 and ≤ 0.71.

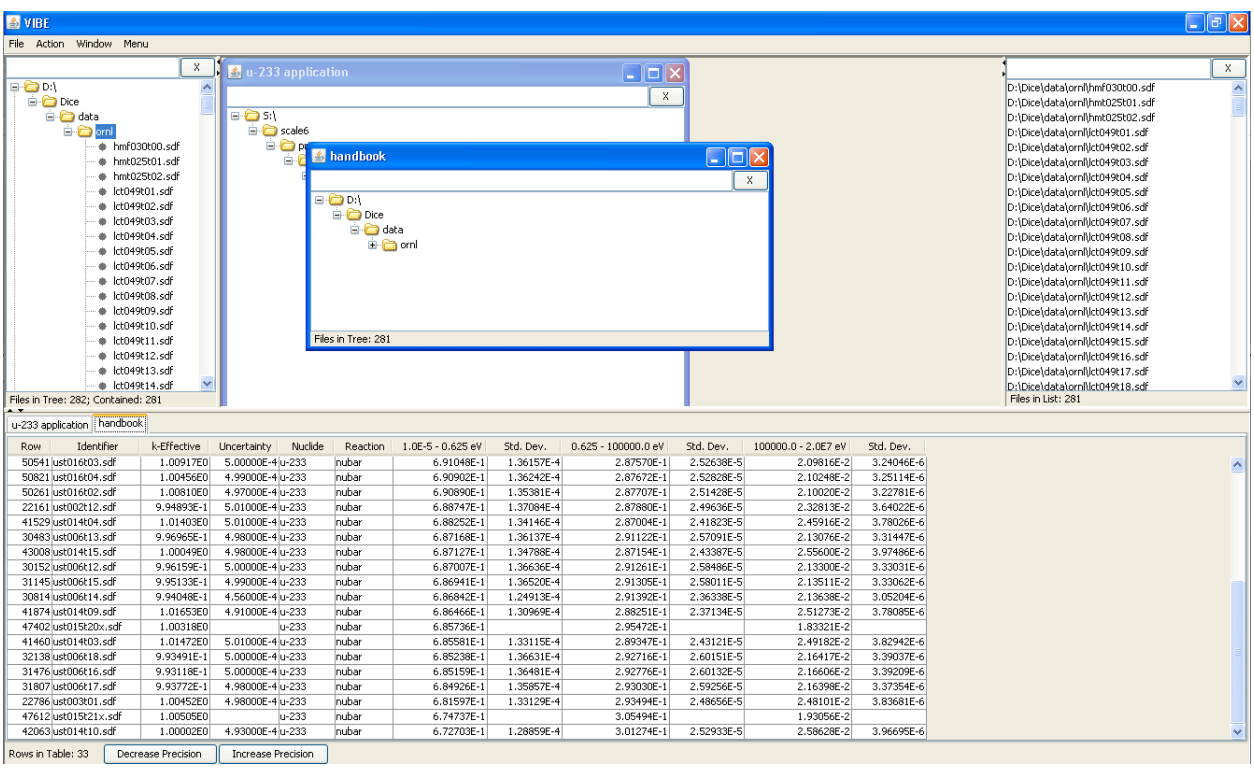


Fig. 10. VIBE with ^{233}U nubar thermal sensitivities near 0.69 filter applied to ICSBEP handbook data.

The energy-dependent sensitivity data for the benchmarks can be visually compared to the sensitivities of the application using Javapeño, as shown in Fig. 11. The two profiles are nearly identical across the entire energy spectrum, indicating that these two systems should have very similar bias in term of ^{233}U nubar. Other nuclides and reactions for this or other systems can be inspected in a similar manner.

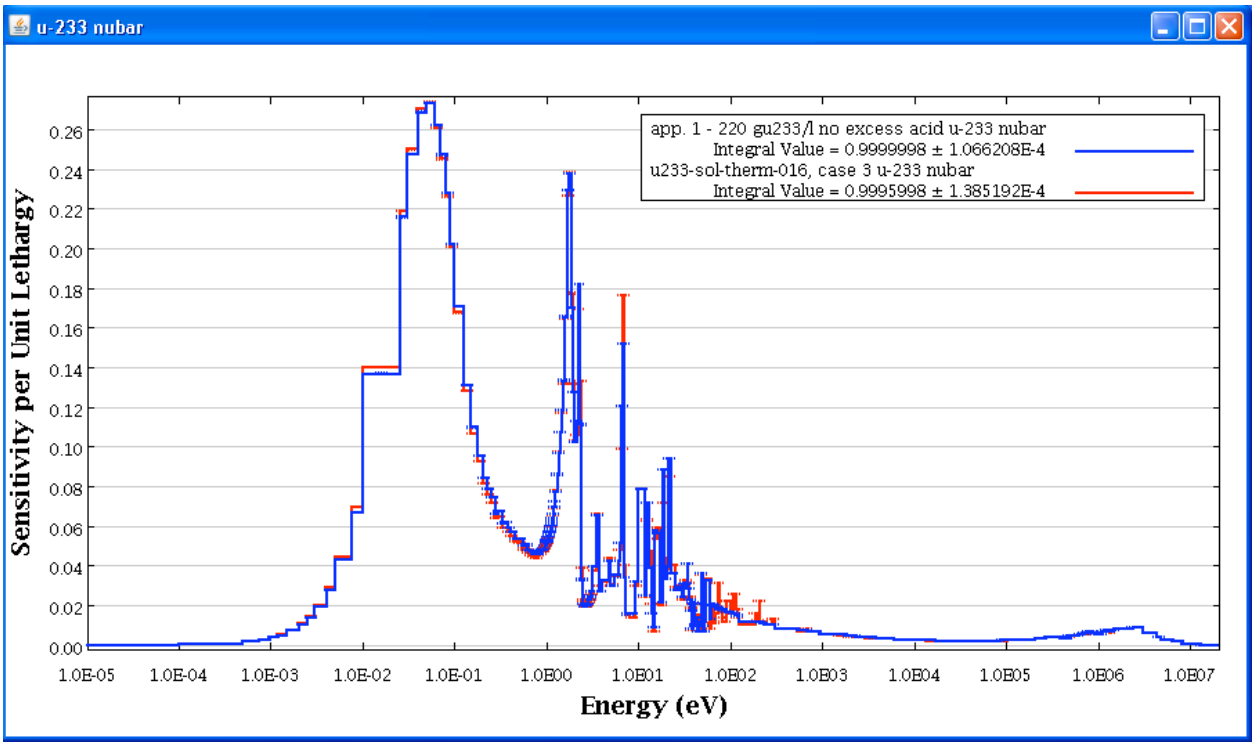


Fig. 11. Javapeño plot of ^{233}U nubar sensitivities for ^{233}U application and U233-SOL-THERM-016 case 3.

VII. DICE DATABASE QUERY

VIBE can also query the DICE database distributed with the IHECSBE using the DICE query dialog shown in Fig. 12. The query capability allows users to conveniently assess the physical characteristic of systems selected with sensitivity criteria. Often, systems that are physically different will have similar sensitivities based on their physics. The results of a DICE query for all experiments in evaluation U233-SOL-THERM-002 are shown in Fig. 13. Here it can be observed that these experiments have a uranium content that is 97.5 wt % ^{233}U. Also, the solution concentration varies from 44.69 to 203.98 g/L. Recall that the application system was 100 wt % ^{233}U with a concentration of 200 g/L. Note that the 11 cases identified as having the ^{233}U nubar thermal sensitivities near that of the application are the cases with solution concentrations of 200 g/L. The selection of the same 11 experiments based on TSUNAMI sensitivity criteria or solution concentration criteria confirms the validity of the TSUNAMI approach in comparison to more traditional ones.

Using VIBE with a DICE query and filter applied to the resulting table to identify U233-SOL-THERM experiments with solution concentrations between 180 and 220 g/L reveals 29 matching cases, as shown in Fig. 14. Here U233-SOL-THERM-002 case 1 is shown to have a solution concentration of 200.45 g/L, indicating potential similarity to the application. However, based on the ^{233}U nubar sensitivity, TSUNAMI data did not identify U233-SOL-THERM-002 case 1 as highly similar, but did identify case 12. Using another DICE query to examine all cases from U233-SOL-THERM-002, shown in Fig. 15, reveals that case 12 has a concentration of 277.585 g/L or nearly 50% greater than the application.

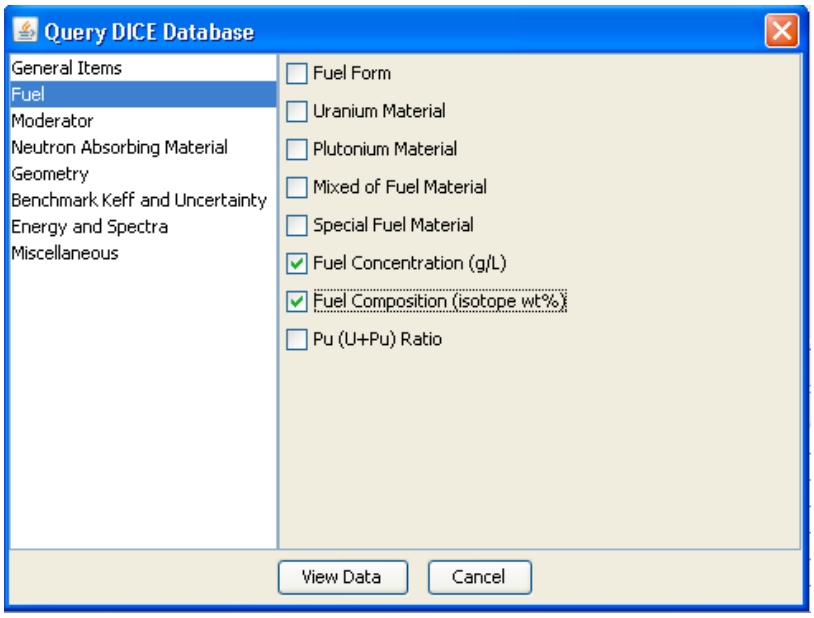


Fig. 12. Fuel options in DICE database query dialog.

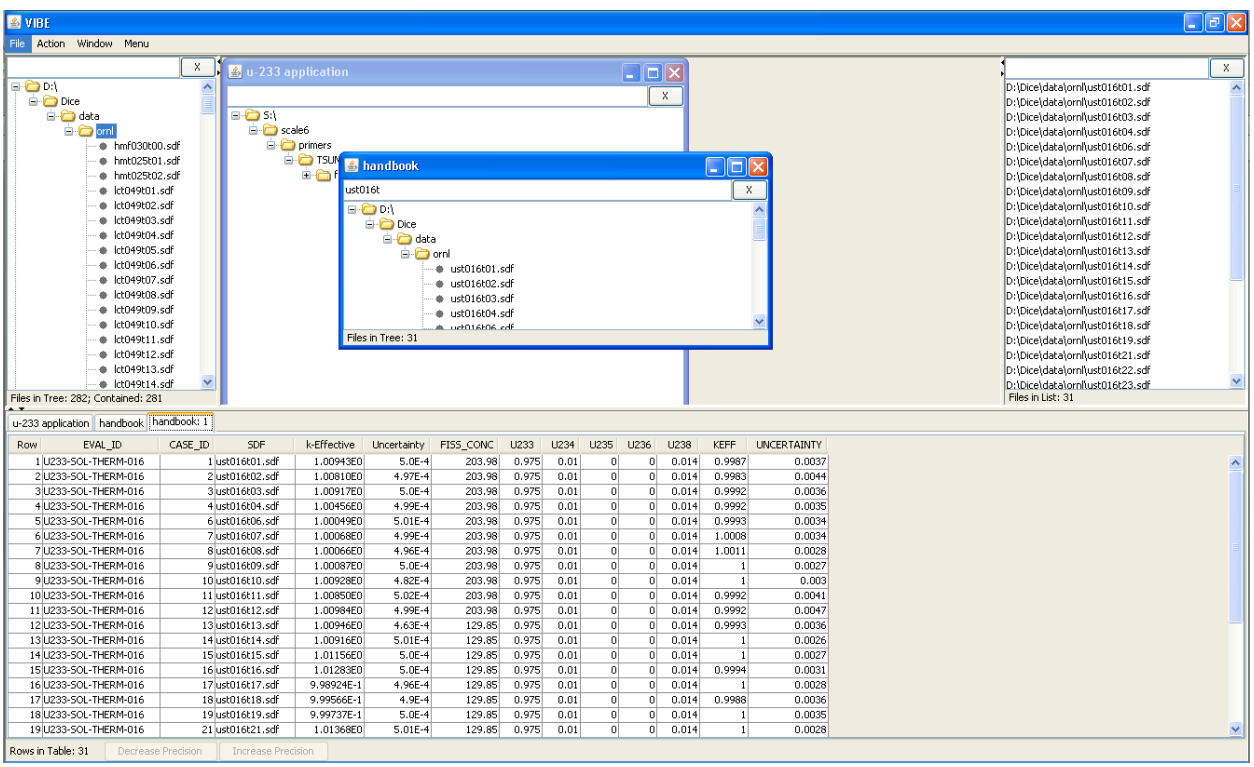


Fig. 13. VIBE with table of DICE query results.

u-233 application | handbook | handbook: 1 | handbook: 2 | handbook: 3

Row	EVAL_ID	CASE_ID	SDF	k-Effective	Uncertainty	FISS_CONC
105	U233-SOL-THERM-002	1	ust002t01.sdf	1.00750E0	4.99E-4	200.45
132	U233-SOL-THERM-004	1	ust004t01.sdf	1.00461E0	5.02E-4	200.453
153	U233-SOL-THERM-006	12	ust006t12.sdf	9.96159E-1	5.0E-4	203.8
154	U233-SOL-THERM-006	13	ust006t13.sdf	9.96965E-1	4.98E-4	203.8
155	U233-SOL-THERM-006	14	ust006t14.sdf	9.94048E-1	4.56E-4	203.8
156	U233-SOL-THERM-006	15	ust006t15.sdf	9.95133E-1	4.99E-4	203.8
157	U233-SOL-THERM-006	16	ust006t16.sdf	9.93118E-1	5.0E-4	203.8
158	U233-SOL-THERM-006	17	ust006t17.sdf	9.93772E-1	4.98E-4	203.8
159	U233-SOL-THERM-006	18	ust006t18.sdf	9.93491E-1	5.0E-4	203.8
160	U233-SOL-THERM-006	19	ust006t19.sdf	9.99731E-1	4.99E-4	203.8
161	U233-SOL-THERM-006	20	ust006t20.sdf	9.98818E-1	5.01E-4	203.8
162	U233-SOL-THERM-006	21	ust006t21.sdf	9.97874E-1	4.98E-4	203.8
163	U233-SOL-THERM-006	22	ust006t22.sdf	9.98336E-1	5.0E-4	203.8
164	U233-SOL-THERM-006	23	ust006t23.sdf	9.98317E-1	4.99E-4	203.8
165	U233-SOL-THERM-006	24	ust006t24.sdf	9.98268E-1	4.98E-4	203.8
166	U233-SOL-THERM-006	25	ust006t25.sdf	1.00019E0	5.0E-4	203.8
173	U233-SOL-THERM-012	1	ust012t01.sdf	1.00188E0	4.85E-4	200.2
174	U233-SOL-THERM-012	2	ust012t02.sdf	1.00180E0	4.98E-4	190.4
244	U233-SOL-THERM-016	1	ust016t01.sdf	1.00943E0	5.0E-4	203.98

Rows in Table: 29 | Decrease Precision | Increase Precision

Fig. 14. VIBE DICE query results for all U233-SOL-THERM experiments filtered from concentrations near 200 g/L.

u-233 application | handbook | handbook: 1 | handbook: 2 | handbook: 3

Row	EVAL_ID	CASE_ID	SDF	k-Effective	Uncertainty	FISS_CONC	U233	U234	U238
1	U233-SOL-THERM-002	1	ust002t01.sdf	1.00750E0	4.99E-4	200.45	0.987	0.005	0.009
2	U233-SOL-THERM-002	2	ust002t02.sdf	9.96591E-1	2.98E-4	162.77	0.987	0.005	0.009
3	U233-SOL-THERM-002	3	ust002t03.sdf	1.01302E0	5.0E-4	128.734	0.987	0.005	0.009
4	U233-SOL-THERM-002	4	ust002t04.sdf	1.00994E0	4.91E-4	101.685	0.987	0.005	0.009
5	U233-SOL-THERM-002	5	ust002t05.sdf	1.01453E0	4.97E-4	85.173	0.987	0.005	0.009
6	U233-SOL-THERM-002	6	ust002t06.sdf	1.00154E0	4.99E-4	71.448	0.987	0.005	0.009
7	U233-SOL-THERM-002	7	ust002t07.sdf	9.91344E-1	5.01E-4	64.522	0.987	0.005	0.009
8	U233-SOL-THERM-002	8	ust002t08.sdf	1.00503E0	4.97E-4	55.604	0.987	0.005	0.009
9	U233-SOL-THERM-002	9	ust002t09.sdf	9.93469E-1	4.95E-4	44.235	0.987	0.005	0.009
10	U233-SOL-THERM-002	10	ust002t10.sdf	1.00781E0	5.01E-4	40.852	0.986	0.005	0.009
11	U233-SOL-THERM-002	11	ust002t11.sdf	1.01698E0	4.97E-4	34.198	0.987	0.005	0.009
12	U233-SOL-THERM-002	12	ust002t12.sdf	9.94893E-1	5.01E-4	277.585	0.987	0.005	0.009
13	U233-SOL-THERM-002	13	ust002t13.sdf	9.95133E-1	4.96E-4	385.8	0.987	0.005	0.009
14	U233-SOL-THERM-002	14	ust002t14.sdf	1.00408E0	4.99E-4	169.097	0.987	0.005	0.009
15	U233-SOL-THERM-002	15	ust002t15.sdf	1.01141E0	5.0E-4	117.549	0.987	0.005	0.009
16	U233-SOL-THERM-002	16	ust002t16.sdf	1.01383E0	5.01E-4	67.341	0.987	0.005	0.009
17	U233-SOL-THERM-002	17	ust002t17.sdf	1.01430E0	4.99E-4	50.011	0.987	0.005	0.009

Rows in Table: 17 | Decrease Precision | Increase Precision

Fig. 15. VIBE DICE query results for U233-SOL-THERM-002 benchmarks.

Using VIBE to open the SDFs in Javapeño and then plotting ^{233}U nubar for the two benchmarks and the application reveals a higher sensitivity to ^{233}U nubar for case 1 than for case 12, which more closely matches the sensitivity of the application. In this case the moderation of the solutions is different enough to shift the spectra, causing the case with the higher solution concentration to more closely match the application. In this instance a thorough and potentially time-consuming review of data from the handbook evaluation or the DICE database could have revealed these subtleties to an expert, whereas the TSUNAMI sensitivity data quickly revealed similarity in terms of the physics of the systems, not just the characteristics of the compositions.

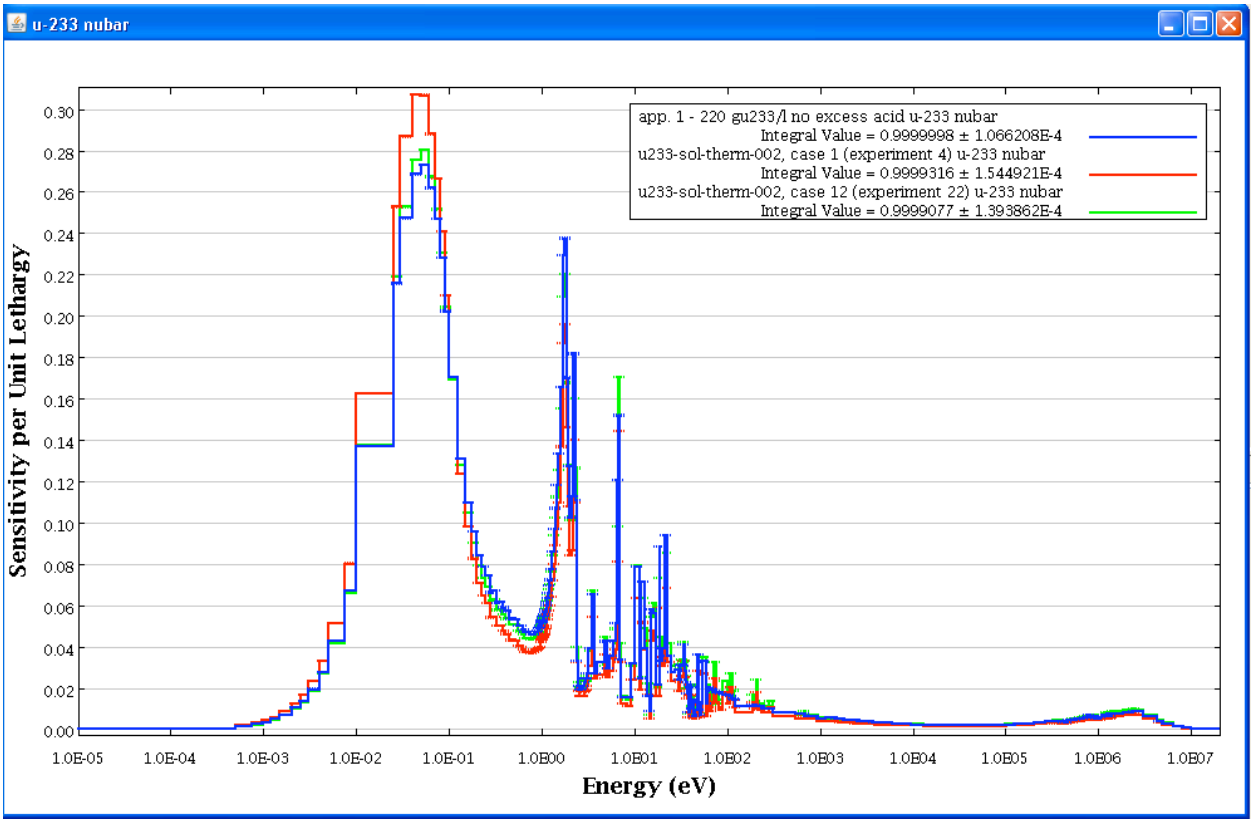


Fig. 16. Sensitivity profiles for ^{233}U nubar from ^{233}U application and U233-SOL-THERM-002 cases 1 and 12.

VIII. ACCESSING VIBE DATA IN EXSITE

A final step in the use of VIBE is to export the desired files in a format suitable for more advanced analysis with TSUNAMI-IP and TSURFER. Sets of SDFs can be exported as a VIBE data file (VDF) for use in the ExSITE interface. After all 281 SDFs from the handbook are exported to *handbook.vdf*, the VDF can be imported to ExSITE and used directly in TSUNAMI-IP or TSURFER analysis. As shown in Fig. 17, the VDF is added as an icon called *handbook* in `My Palette` on the right side of the screen, and the 281 SDFs are added to the *read experiments* block of the input file with a simple drag and drop.

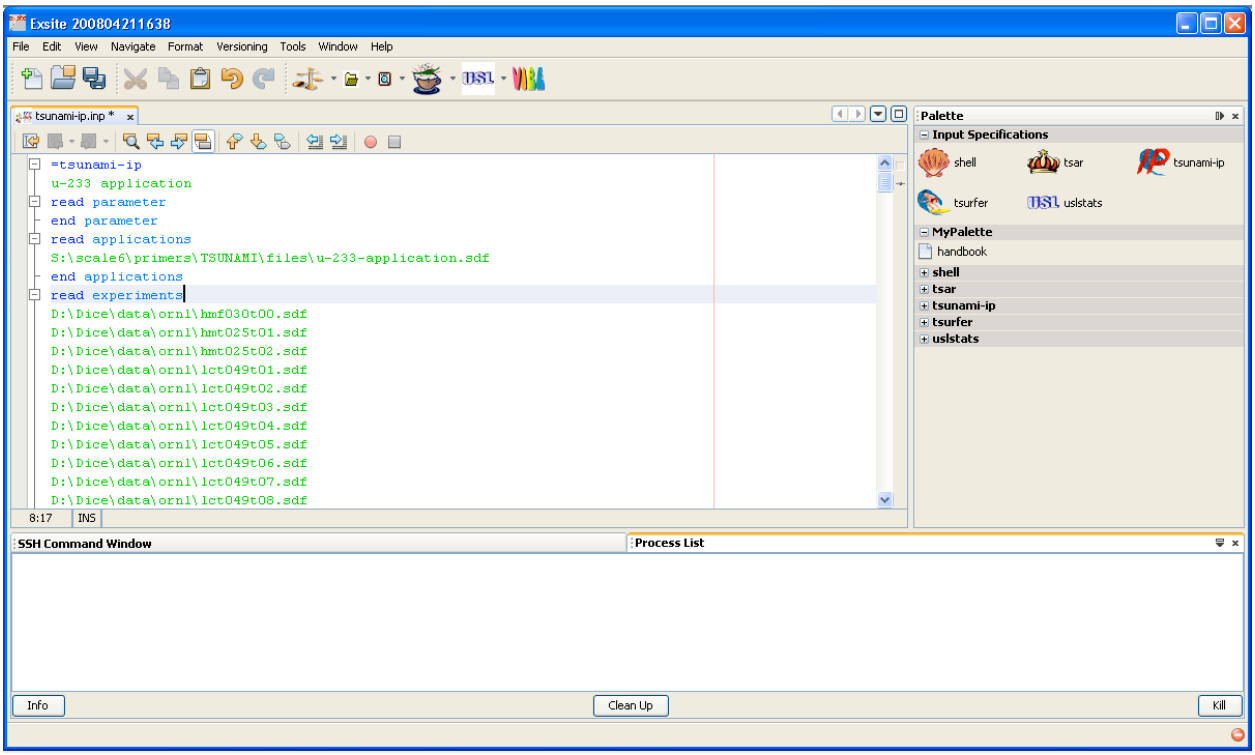


Fig. 17. ExSITE with handbook data added to the palette and to the read experiments input block.

IX. IMPROVING RESULTS BY INCLUDING EXPERIMENTAL VALUES

Although many experimental cases in the IHECSBE have experiment k_{eff} values of 1.0, many others have values slightly above or slightly below that number. Also, unless otherwise instructed, TSUNAMI-IP inputs a default experimental uncertainty of 0.3% Δk/k for each experiment. With the ability to easily query the DICE database for each experiment, these assumed values are replaced with the actual values. The existing *handbook.vdf* can be reloaded into VIBE to perform a new DICE query to extract the desired benchmark k_{eff} and benchmark k_{eff} uncertainty information from the database, as shown in Fig. 18 in the columns labeled *KEFF* and *UNCERTAINTY*, respectively. The data in the table can be exported for subsequent use in analyses. ExSITE with the updated TSUNAMI-IP input is shown in Fig. 19. The validation of this application with TSUNAMI-IP and USLSTATS c_k trending reveals a bias of 1.0045% Δk/k, and a bias uncertainty of 0.0194% Δk/k.

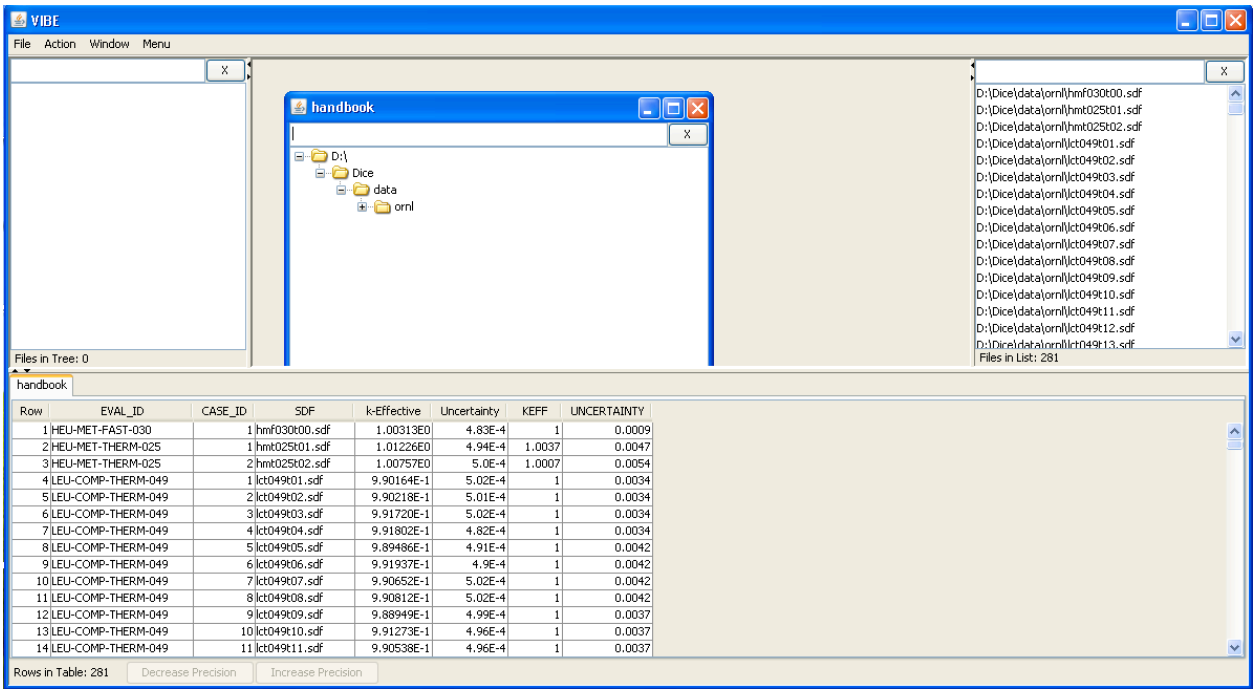


Fig. 18. VIBE query results for benchmark k_{eff} and k_{eff} uncertainty.

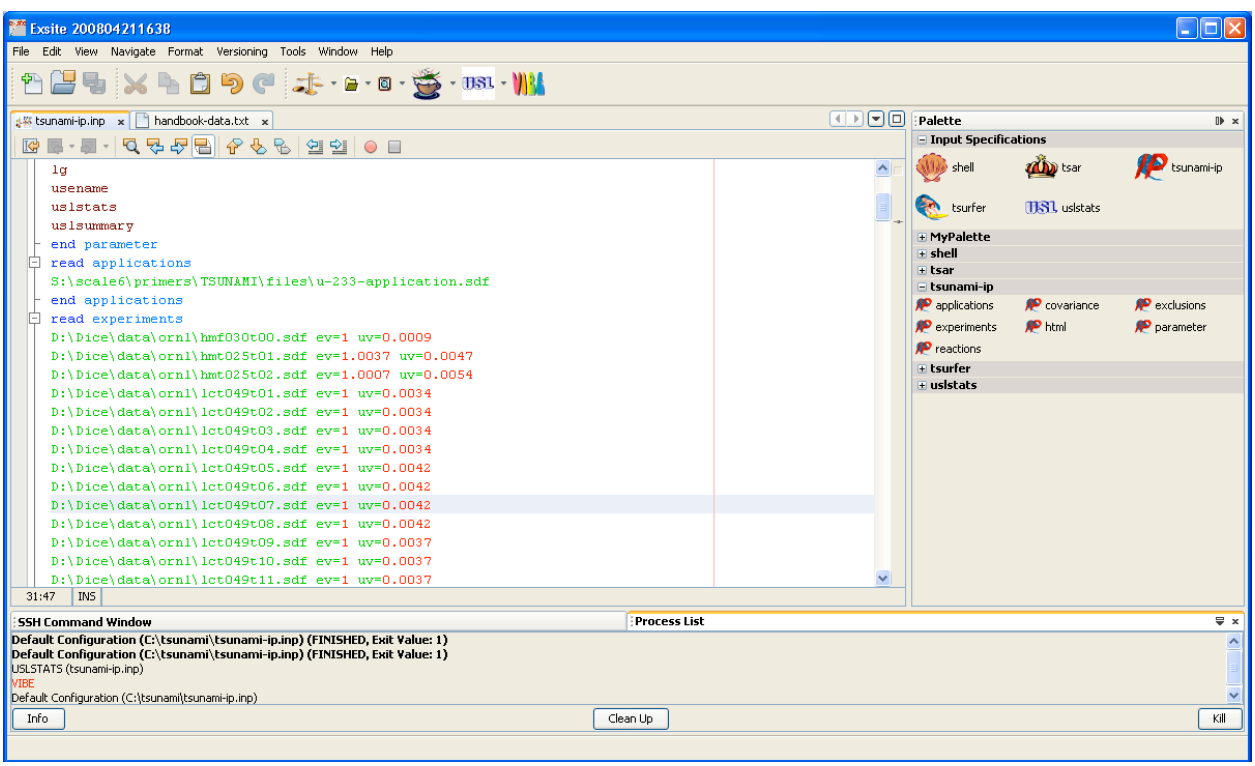


Fig. 19. ExSITE with TSUNAMI-IP input including benchmark k_{eff} and benchmark k_{eff} uncertainty values.

X. INTEGRATION OF VIBE WITH DICE

VIBE will be integrated as a component of DICE for the September 2009 release of the IHECSBE to facilitate the use of sensitivity data distributed through the handbook, including data from TSUNAMI as well as other sensitivity data generated by the Institute of Physics and Power Engineering (IPPE), which have been distributed with ICSBEP for several years. Future plans for VIBE include close integration of the USLSTATS tool for first-cut bias assessments without the need for auxiliary tools and addition of TSUNAMI-based techniques to identify weaknesses and gaps in the experiments selected to validate a particular application.

XI. CONCLUSIONS

VIBE provides a convenient means of accessing and analyzing sensitivity data from TSUNAMI and IPPE. VIBE's sorting and filtering capabilities allow users to identify experiments that are similar to applications based on detailed sensitivity criteria instead of relying on the selection of traditional system-averaged quantities such as EALF or H/X. Where data represent benchmark experiments from the IHECSBE, VIBE can access information from the DICE database to extract experimental k_{eff} and uncertainty values or to compare them with traditional trending parameters. VIBE will be integrated with DICE for the 2009 edition of ICSBEP to provide the community with convenient access to its capabilities.

XII. REFERENCES

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4. D. E. MUELLER, B. T. REARDEN, and D. F. HOLLENBACH, *Application of the SCALE TSUNAMI Tools for the Validation of Criticality Safety Calculations Involving* ^{233}U, ORNL/TM-2008/196, Oak Ridge National Laboratory, Oak Ridge, Tennessee (January 2009).
5. B. T. REARDEN et al., *TSUNAMI Primer: A Primer for Sensitivity/Uncertainty Calculations with SCALE*, ORNL/TM-2009/027, Oak Ridge National Laboratory, Oak Ridge, Tennessee (January 2009).