

Reference integral experiments databases and validation of nuclear data

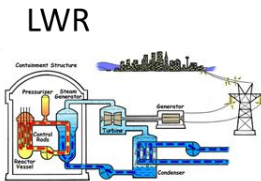
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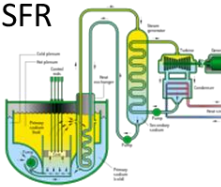
E-mail: oscar.cabellos@upm.es

- ❑ *What is an integral experiment*
- ❑ *Integral experiments databases: ICSBEP and IRPHEP*
- ❑ *Visualization and databases search tools: DICE and IDAT*
- ❑ *NDaST tool*
- ❑ *Examples of validations*

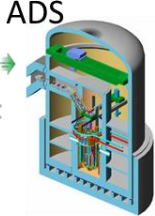
□ The importance of Nuclear Data for energy and non-energy applications




LWR




SFR



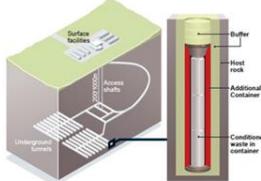
ADS



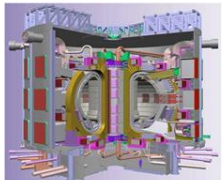
SMRs



Spent Fuel




DGR

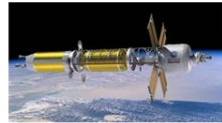


Fusion/ITER

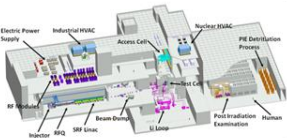
Nuclear Data for Applications (fission and fusion, radiation protection, nuclear medicine, nuclear security, object and materials analysis,...)
and Science (reactions and structure of nuclei, astrophysics, basic physics,...)



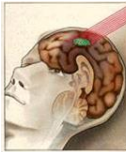
Neutrino's physics




Space technology



IFMIF/DONES



Medical applications



Astrophysics

□ Nuclear Data in the modelling

Boltzmann equation: Neutron transport, photon transport, charge particle transport, etc ... → criticality, fission power distribution, reactivity coefficients, shielding, spent fuel storage, etc... safety analysis

Bateman equation: Inventory evolution → radioactivity, decay heat, dose rates, waste management and environmental impact, etc ...

$$\frac{dN_i}{dt} = -\lambda_i N_i - r_i N_i + \sum_{j \neq i} \{\lambda_{j \rightarrow i} + r_{j \rightarrow i}\} N_j$$

Modelling for criticality, radiation damage, activation analysis, safeguards, reactor emergency core cooling, shielding calculations, radioprotection,

$$\frac{1}{v} \frac{\partial f}{\partial t} + \mathbf{\Omega} \cdot \nabla f + \Sigma_T f = S + \int dE' d\mathbf{\Omega}' f(E', \mathbf{\Omega}') \Sigma_S(E' \rightarrow E, \mathbf{\Omega}' \rightarrow \mathbf{\Omega})$$

$$S = S_{PF} + S_{dn} + S_{\alpha n} + S_{ext}$$

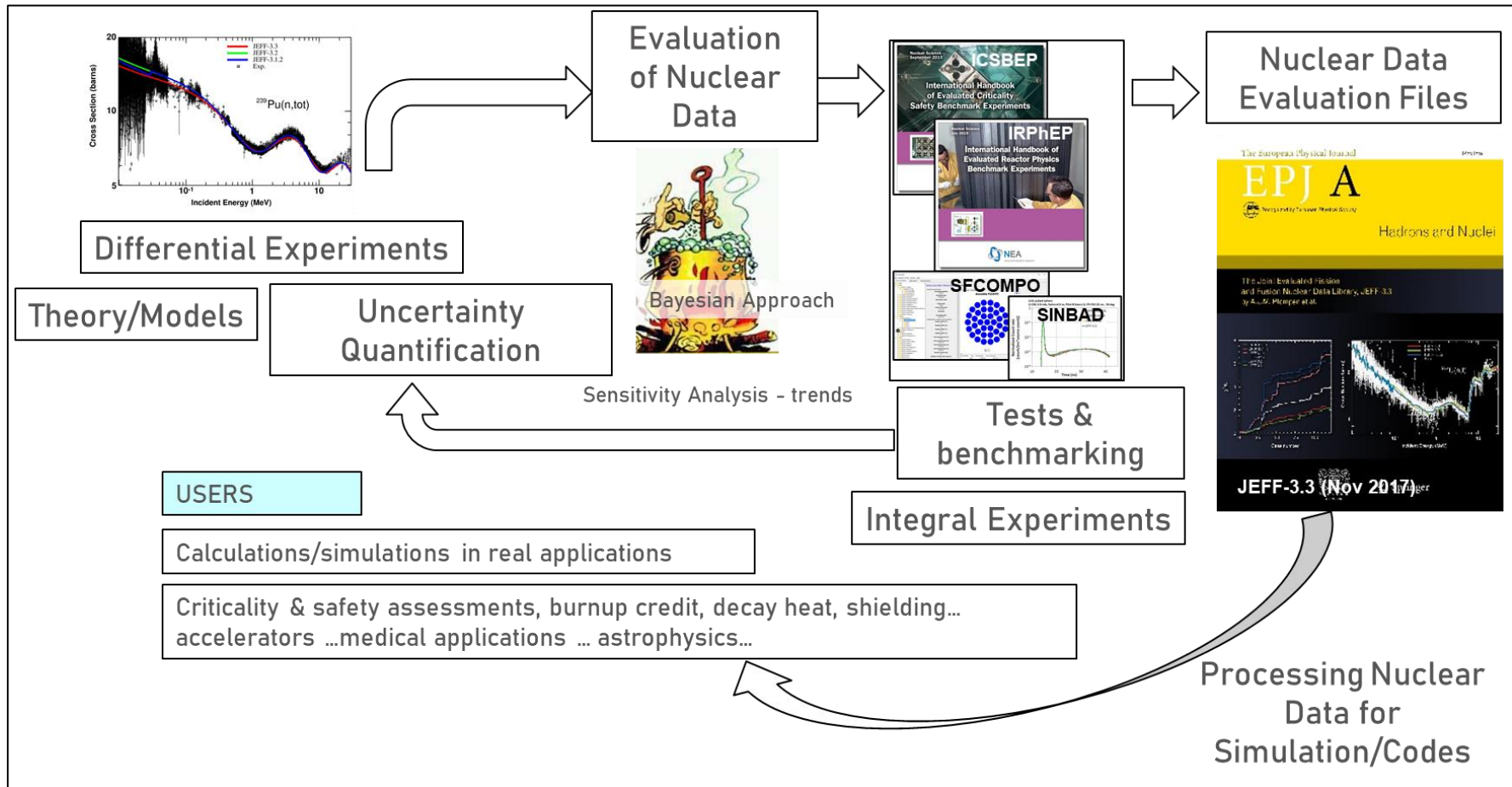
$$S_{PF} = \sum_i N_i \int dE' f(E') \bar{v}_i(E') \sigma_{F,i}(E') f_{P,i}(E', E)$$

$$\Sigma_{S(E \rightarrow E', \mathbf{\Omega} \rightarrow \mathbf{\Omega}')} = \sum_i N_i \frac{d^2 \sigma_{s,i}}{dE' d\mathbf{\Omega}'}(E, E', \mathbf{\Omega} \cdot \mathbf{\Omega}')$$

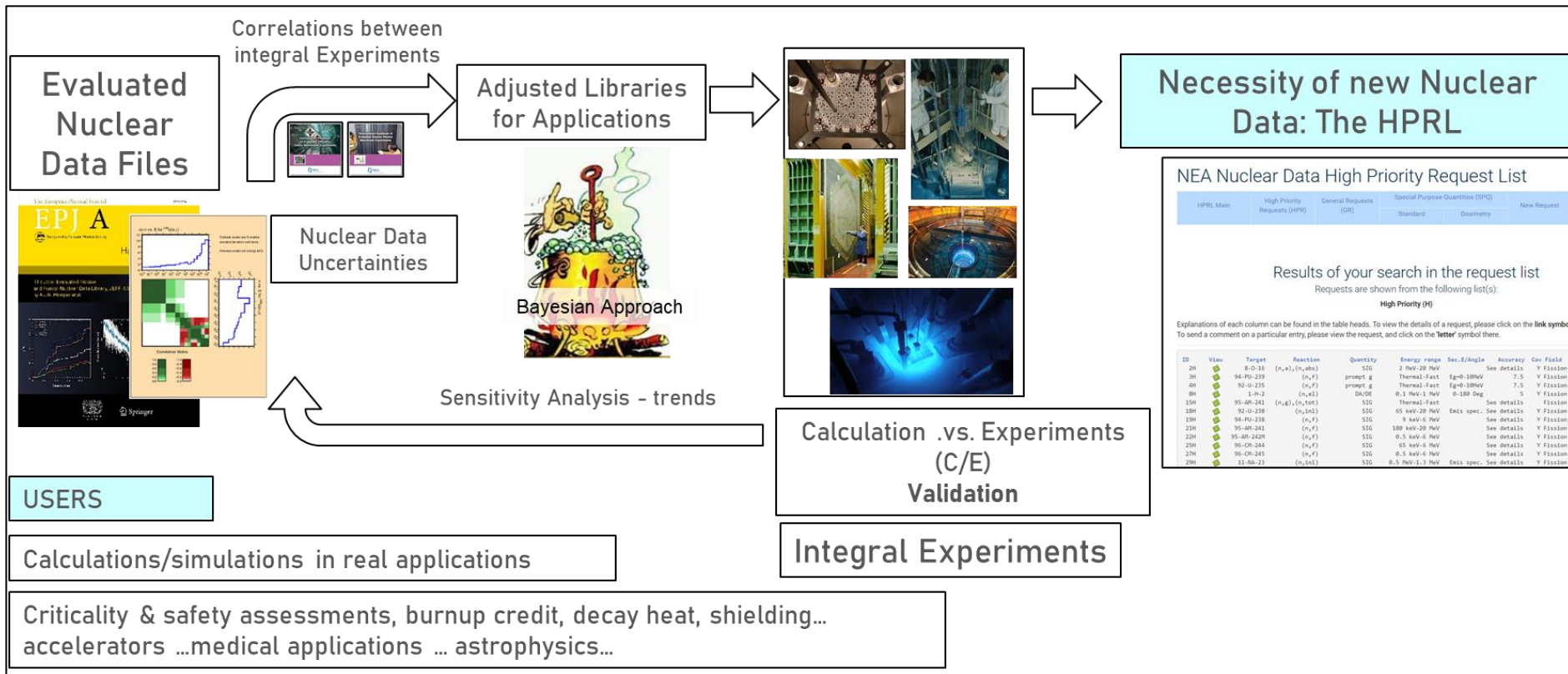
$$\Sigma_T = \sum_i N_i \sigma_{T,i}$$

Doppler ignored
 $\Sigma_T = \Sigma_a + \Sigma_s$
 $\Sigma_s = \int dE' d\mathbf{\Omega}' \Sigma_{s,i}(E \rightarrow E', \mathbf{\Omega} \rightarrow \mathbf{\Omega}')$

- Nuclear Data are the bridge between the nuclear physics/the differential experiments and the simulations for applications

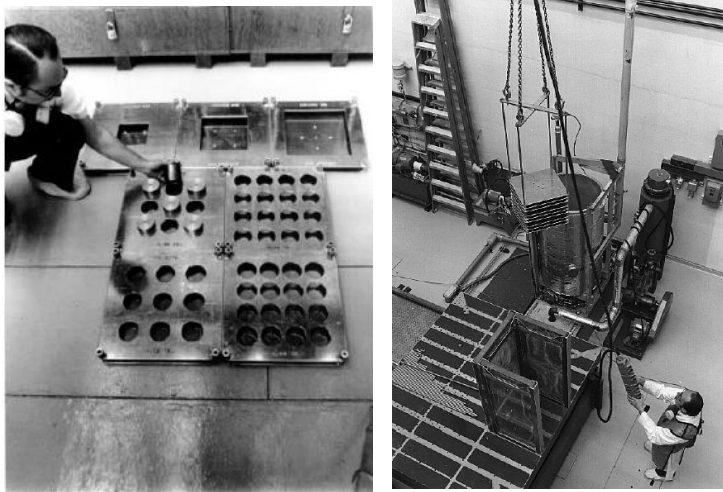


□ The End-Users are the bridge between the applications and the necessity of new nuclear data

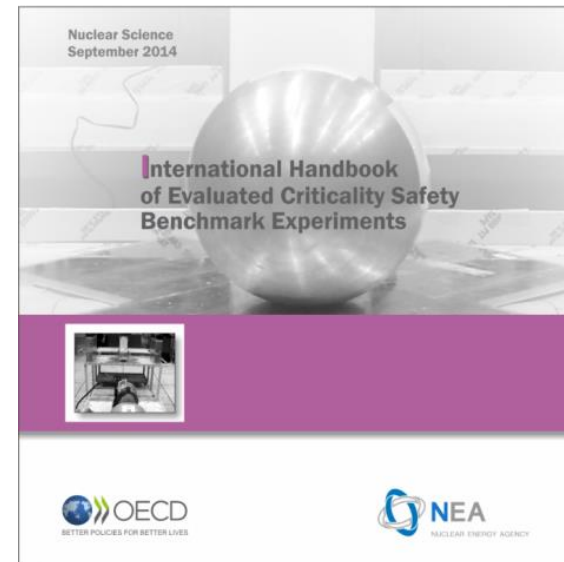


ICSBEP (International Handbook of Evaluated Criticality Safety Benchmark Experiments Project) is a project whose objective is:

- To compile critical and subcritical benchmark experiment data into a standardised format that allows criticality safety analysis
- To easily use the data to validate calculation tools and cross-section libraries.
- Established 1992/1995, Handbook Released Yearly (DVD or Online)
- Over 5000 critical, subcritical and physics configurations



Rocky Flats Critical Mass Laboratory



https://www.oecd-nea.org/jcms/pl_24498/international-criticality-safety-benchmark-evaluation-project-icsbep

❑ “Benchmarks” are “Evaluated Experiments”

Content of an evaluation

- 1) Experimental data
- 2) Experiment and uncertainty evaluation ... Experimental uncertainty: detectors,... Δk_{eff}^{exp}
- 3) Benchmark Model ... Model versus the “Real” experiment
 - Dimension (e.g. radii,..), compositions, impact of these simplifications Δk_{eff}^{model} ?
 - correlation between experiments ?
 - Simplified Model – versus – detailed model.... differences in Sensitivity profiles? (e.g.PMI-2)
- 4) Sample calculations
- 5) Appendixes

$$k_{eff}^{EXP} \pm \Delta k_{eff}^{EXP} \rightarrow k_{eff}^{Model_1} \pm \Delta k_{eff}^{Model_1} \dots \leftrightarrow k_{eff}^{CALC:Model_1:MCNP+JEFF-3.3} \pm \Delta k_{eff}^{CALC:Model_1:MCNP+JEFF-3.3}$$

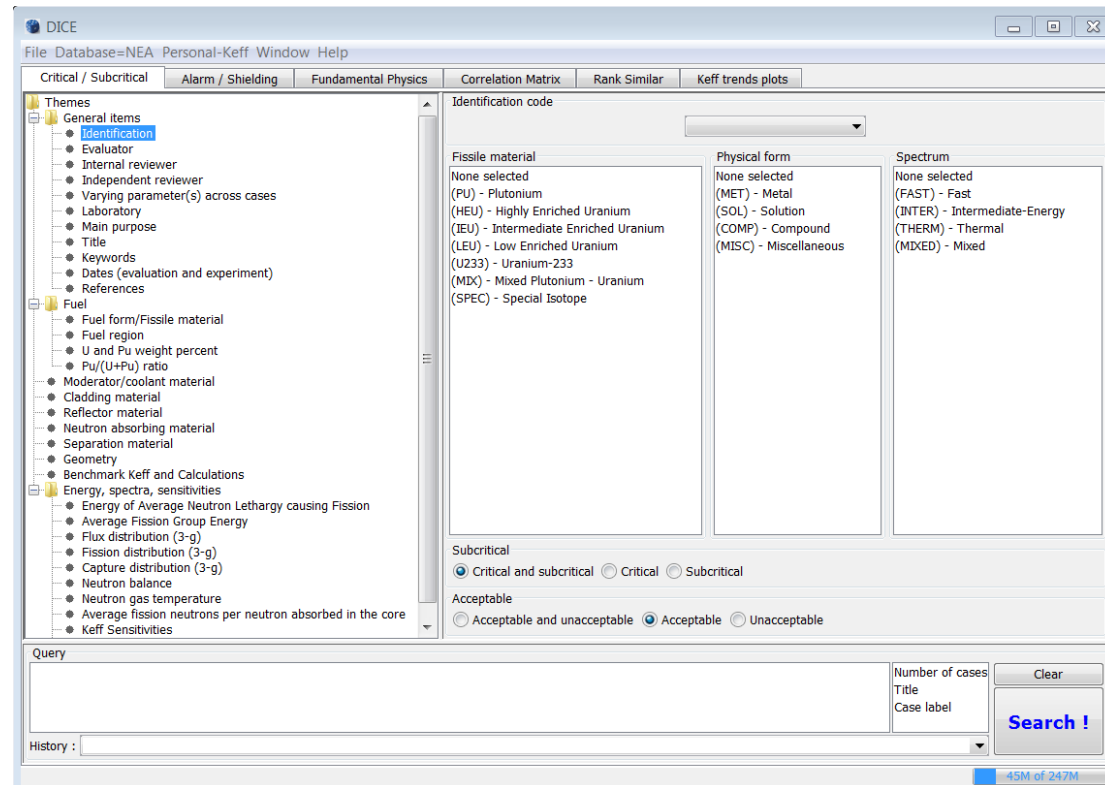
$$\rightarrow k_{eff}^{Model_2} \pm \Delta k_{eff}^{Model_2} \dots \leftrightarrow k_{eff}^{CALC:Model_2:MCNP+JEFF-3.3} \pm \Delta k_{eff}^{CALC:Model_2:MCNP+JEFF-3.3}$$

❑ ICSBEP was primarily devoted for “Criticality Safety Assessment” (CSA)

- Validation of computer-nuclear data
- Nuclear data validation or adjustment

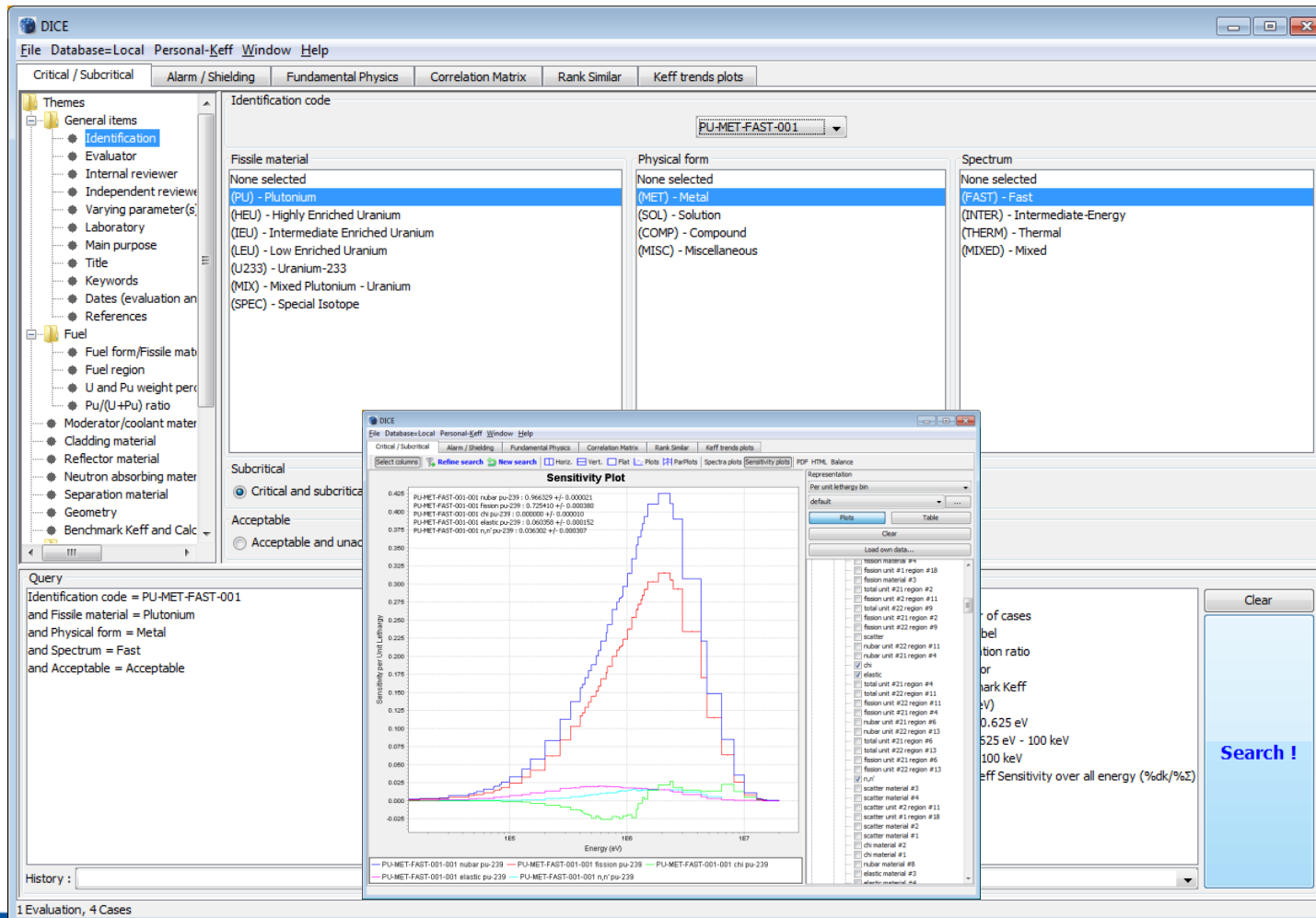
DICE is the Database for ICSBEP, provided with a searching tool in JAVA

- Distributed with Handbook since 2001
- Relational database
- User Friendly Way to Search
- DICE includes: Sensitivity data, tools using sensitivity data to identify useful benchmarks, load your own keff data, etc...



<https://www.oecd-nea.org/science/wpncs/icsbep/dice.html>

Accessing benchmark information: PDFs for reading, inputs, ...



The screenshot displays the DICE software interface. The main window shows the 'Identification code' dropdown set to 'PU-MET-FAST-001'. Below this, three panels are visible: 'Fissile material' (listing options like (PU) - Plutonium, (HEU) - Highly Enriched Uranium, etc.), 'Physical form' (listing options like (MET) - Metal, (SOL) - Solution, etc.), and 'Spectrum' (listing options like (FAST) - Fast, (INTER) - Intermediate-Energy, etc.).

An inset window titled 'Sensitivity Plot' is open, showing a graph of 'Sensitivity per Unit Library' versus 'Energy (eV)'. The plot features several curves representing different parameters, with a prominent peak around 10⁶ eV. The legend at the bottom of the plot identifies the curves: mubar pu-239, fission pu-239, chi pu-239, elastic pu-239, and n pu-239.

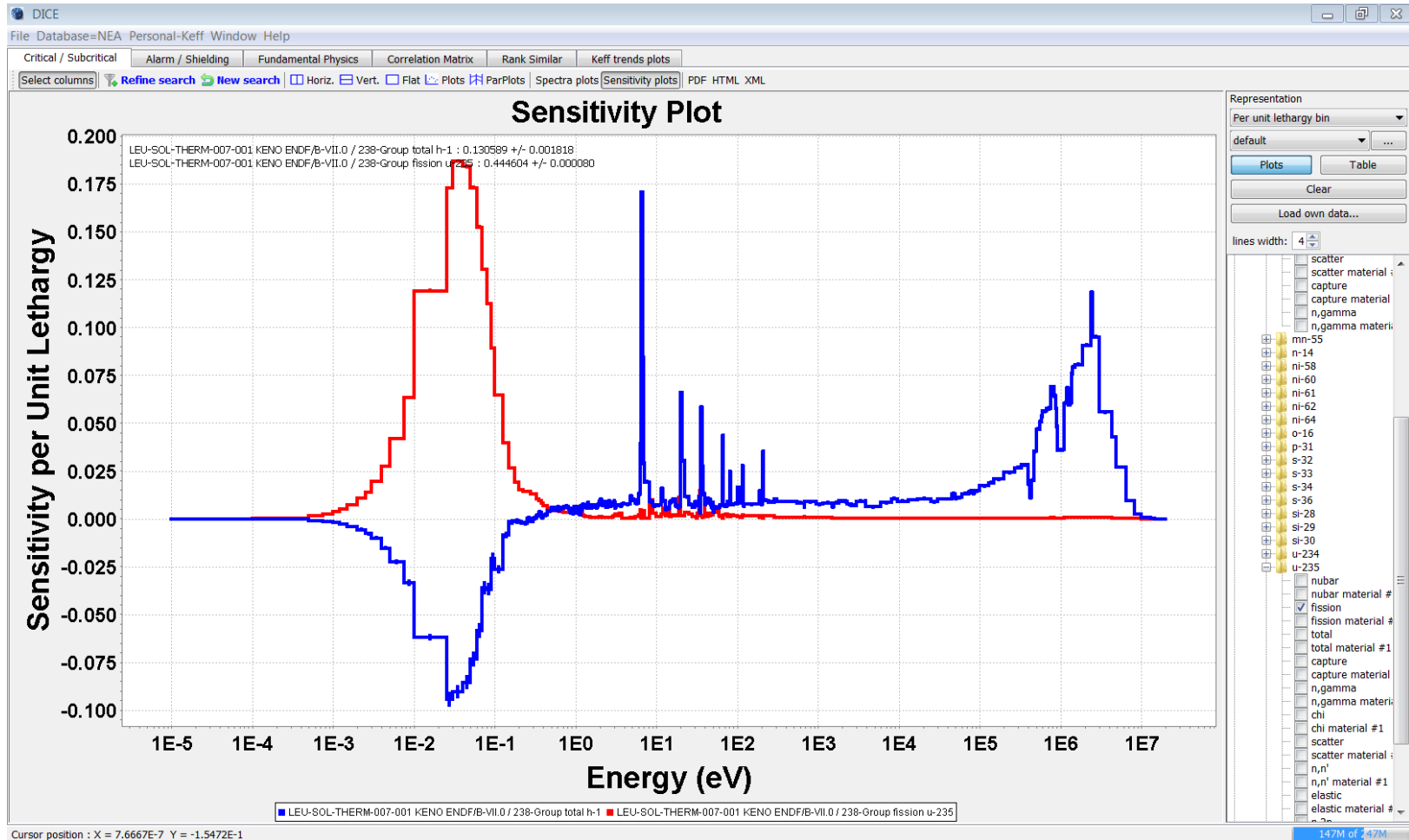
At the bottom of the main window, a 'Query' section displays the following information:

```

Identification code = PU-MET-FAST-001
and Fissile material = Plutonium
and Physical form = Metal
and Spectrum = Fast
and Acceptable = Acceptable
    
```

The bottom status bar indicates '1 Evaluation, 4 Cases'.

ND Sensitivity Viewer



Representation
 Per unit lethargy bin
 default
 Plots Table
 Clear
 Load own data...

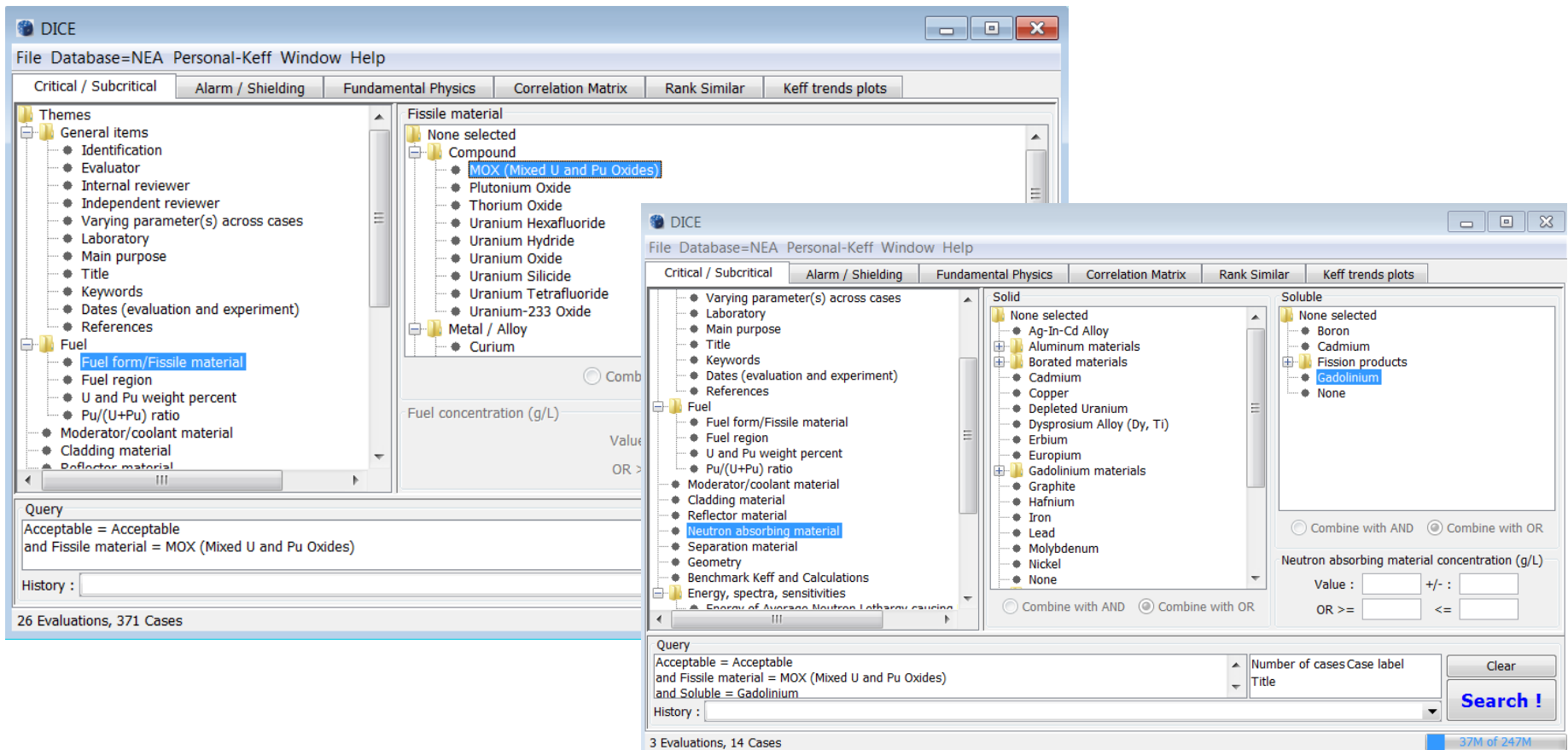
lines width: 4

- scatter
- scatter material #
- capture
- capture material #
- n,gamma
- n,gamma materi
- mn-55
- n-14
- ni-58
- ni-60
- ni-61
- ni-62
- ni-64
- o-16
- p-31
- s-32
- s-33
- s-34
- s-36
- si-28
- si-29
- si-30
- u-234
- u-235
- nubar
- nubar material #
- fission
- fission material #
- total
- total material #1
- capture
- capture material #
- n,gamma
- n,gamma materi
- chi
- chi material #1
- scatter
- scatter material #
- n,n'
- n,n' material #1
- elastic
- elastic material #

147M of 247M

Searching experimental benchmarks using different fields:

An example: MOX Experiments With Soluble Gd



The image displays two screenshots of the DICE software interface, illustrating a search process for experimental benchmarks.

Top Screenshot: The interface shows the 'Fundamental Physics' tab selected. The search criteria are defined as:

- Acceptable = Acceptable
- and Fissile material = MOX (Mixed U and Pu Oxides)

 The results show 26 Evaluations and 371 Cases. The 'Fissile material' tree is expanded to 'Compound', with 'MOX (Mixed U and Pu Oxides)' selected.

Bottom Screenshot: The search criteria are refined to include a soluble material:

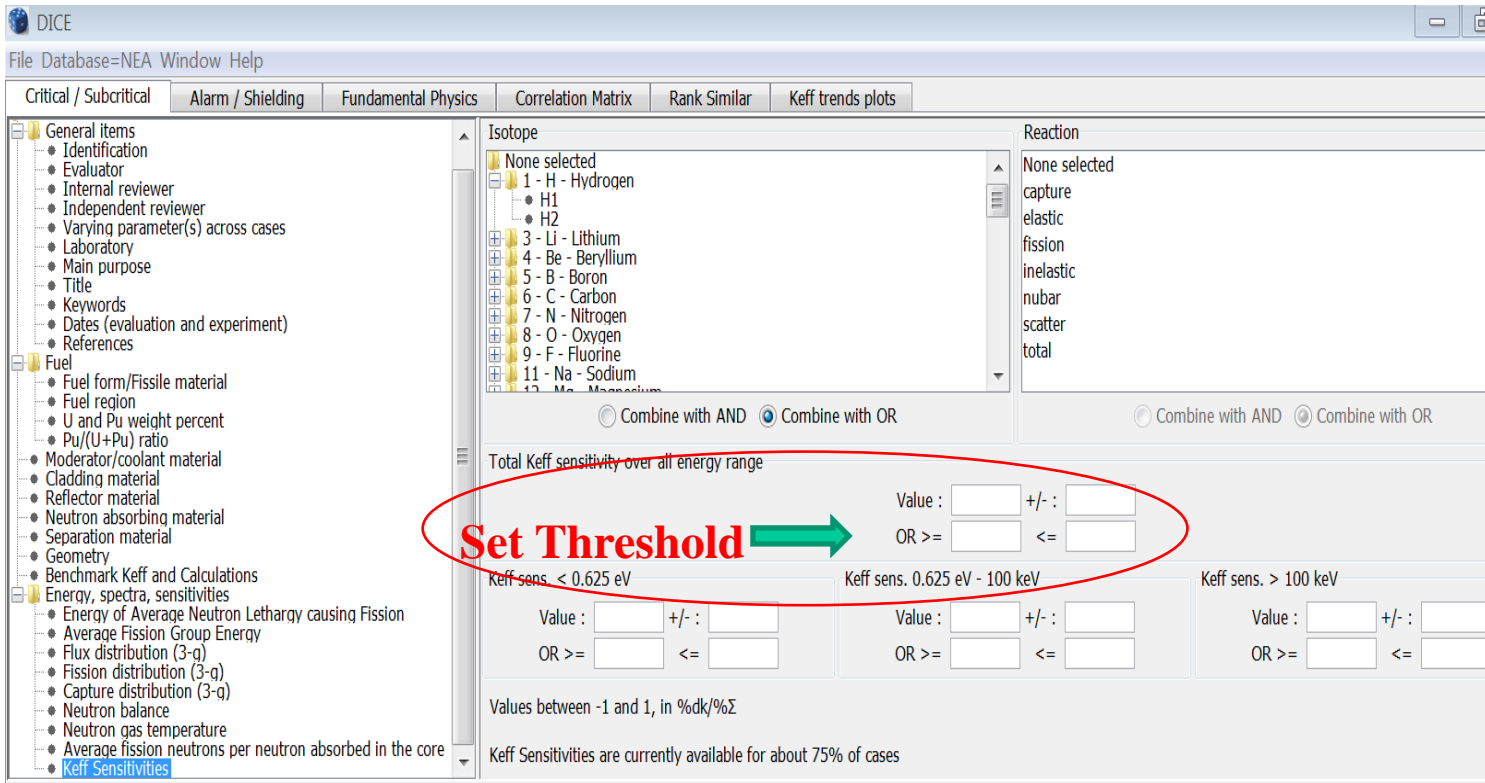
- Acceptable = Acceptable
- and Fissile material = MOX (Mixed U and Pu Oxides)
- and Soluble = Gadolinium

 The results are updated to 3 Evaluations and 14 Cases. The 'Soluble' tree is expanded to 'Gadolinium', with 'Gadolinium' selected. The 'Neutron absorbing material concentration (g/L)' field is visible with a value of 37M of 247M.

Searching experimental benchmarks using different fields:

e.g. Sensitivities

3-g search, full 238 Group SDF's are stored for plotting and computations

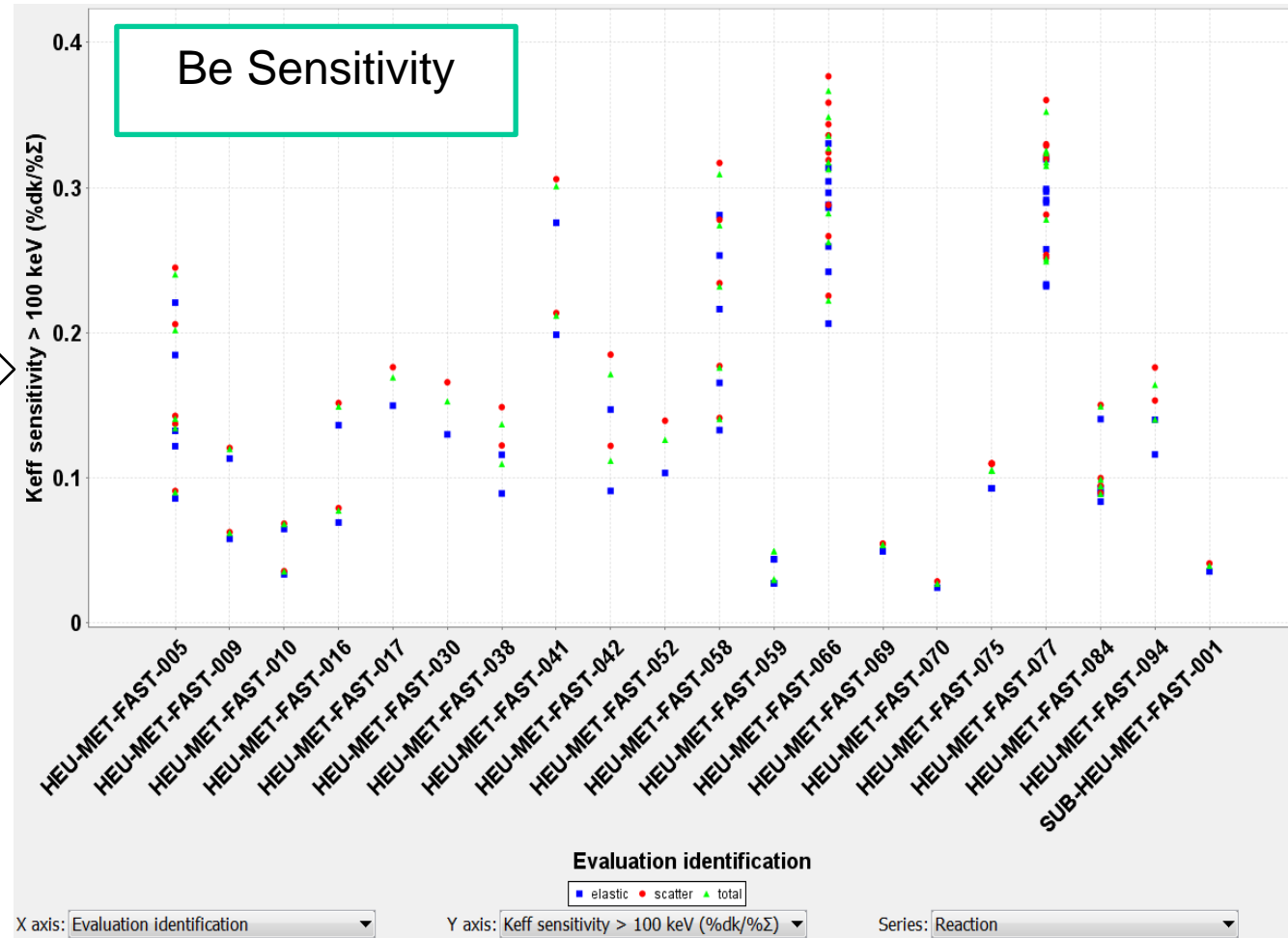
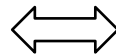


The screenshot shows the DICE software interface with the following components:

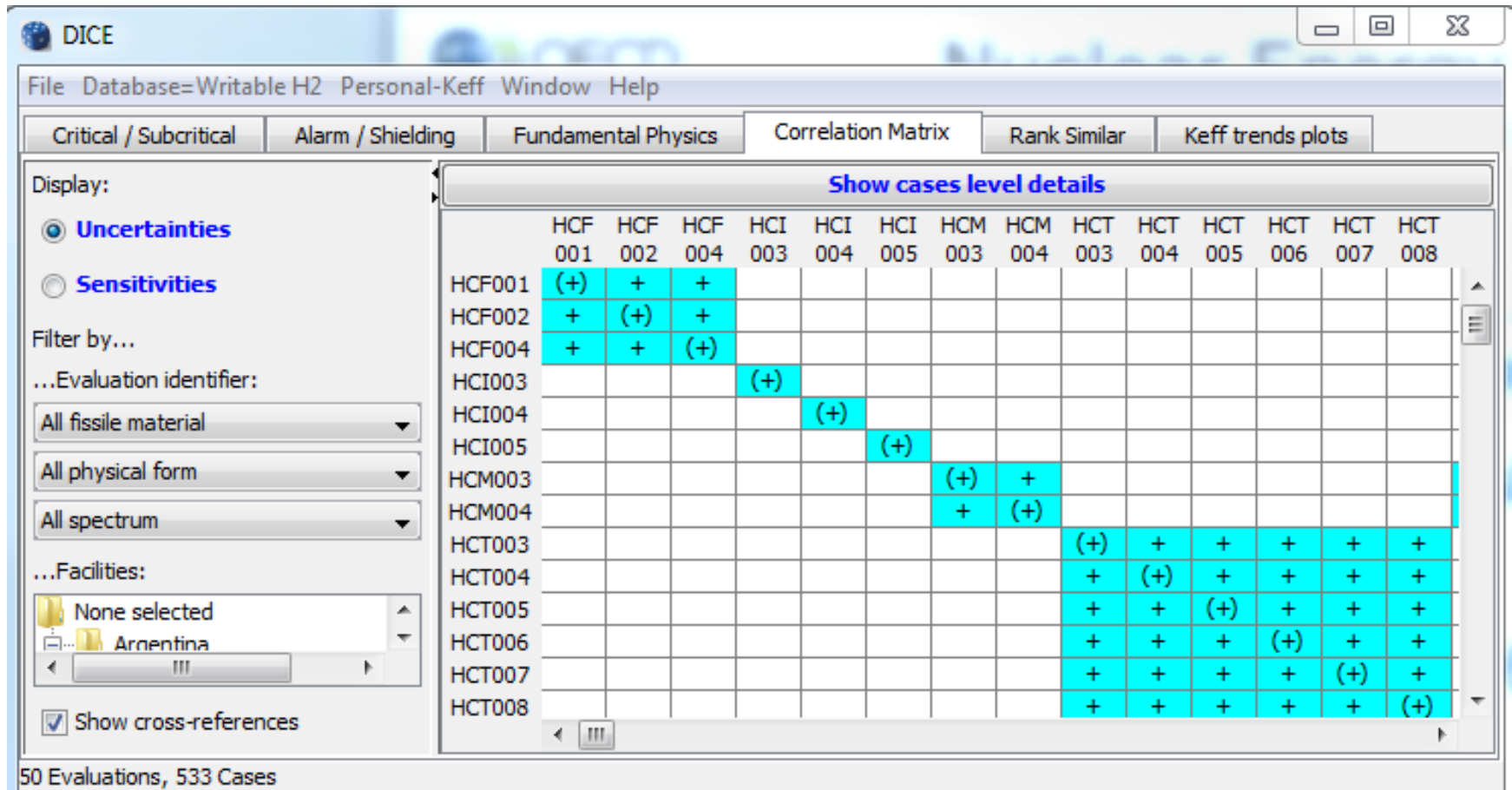
- Left Panel:** A tree view of search criteria including 'General items', 'Fuel', 'Moderator/coolant material', 'Energy, spectra, sensitivities', and 'Keff Sensitivities'.
- Top Panel:** Tabs for 'Critical / Subcritical', 'Alarm / Shielding', 'Fundamental Physics', 'Correlation Matrix', 'Rank Similar', and 'Keff trends plots'.
- Center Panel:** 'Isotope' selection list with options like 'None selected', '1 - H - Hydrogen', '3 - Li - Lithium', etc.
- Right Panel:** 'Reaction' selection list with options like 'None selected', 'capture', 'elastic', 'fission', etc.
- Search Criteria Section:**
 - Total Keff sensitivity over all energy range:** Value: [] +/-: [] OR >= [] <= []
 - Keff sens. < 0.625 eV:** Value: [] +/-: [] OR >= [] <= []
 - Keff sens. 0.625 eV - 100 keV:** Value: [] +/-: [] OR >= [] <= []
 - Keff sens. > 100 keV:** Value: [] +/-: [] OR >= [] <= []
- Bottom Panel:** 'Values between -1 and 1, in %dk/%Σ' and a note: 'Keff Sensitivities are currently available for about 75% of cases'.

Example: DICE Plotting of Be Sensitivity > 0.005 for HMF

Can also read as
1000 pcm/1%
change in Σ



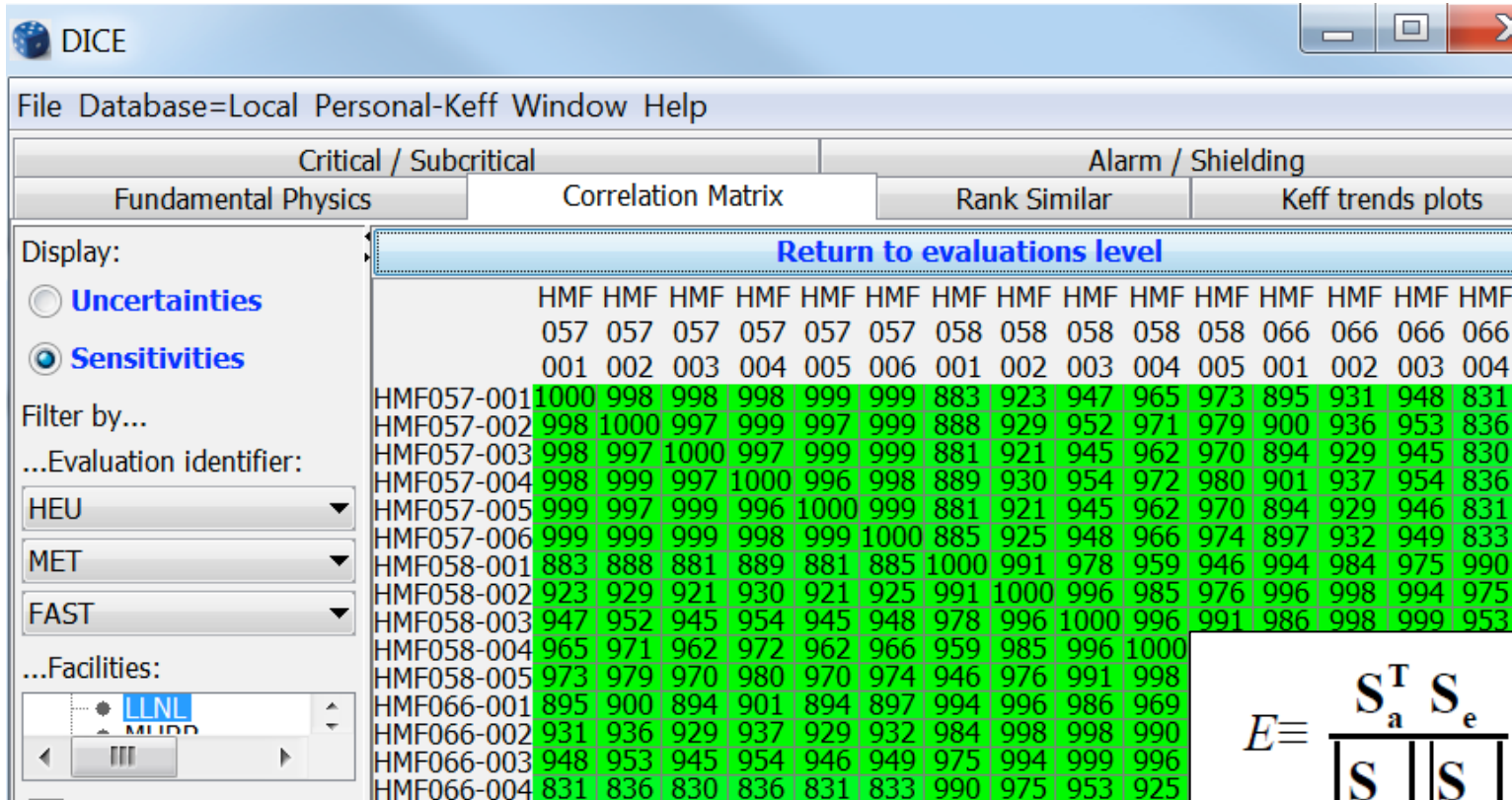
Status of existing correlations “of benchmark model uncertainties”



The screenshot shows the DICE software interface with the 'Correlation Matrix' tab selected. The interface includes a menu bar (File, Database=Writable H2, Personal-Keff, Window, Help) and several tabs: Critical / Subcritical, Alarm / Shielding, Fundamental Physics, Correlation Matrix, Rank Similar, and Keff trends plots. On the left, there are controls for 'Display' (Uncertainties selected, Sensitivities), 'Filter by...' (Evaluation identifier, All fissile material, All physical form, All spectrum), and 'Facilities' (None selected, Argentina). A 'Show cross-references' checkbox is checked. The main area displays a correlation matrix titled 'Show cases level details' with 14 columns and 14 rows. The columns are labeled HCF 001, HCF 002, HCF 004, HCI 003, HCI 004, HCI 005, HCM 003, HCM 004, HCT 003, HCT 004, HCT 005, HCT 006, HCT 007, and HCT 008. The rows are labeled HCF001, HCF002, HCF004, HCI003, HCI004, HCI005, HCM003, HCM004, HCT003, HCT004, HCT005, HCT006, HCT007, and HCT008. The matrix shows positive correlations (+) and (+) in various cells, with some cells containing (+) in parentheses. The status bar at the bottom indicates '50 Evaluations, 533 Cases'.

	HCF 001	HCF 002	HCF 004	HCI 003	HCI 004	HCI 005	HCM 003	HCM 004	HCT 003	HCT 004	HCT 005	HCT 006	HCT 007	HCT 008
HCF001	(+)	+	+											
HCF002	+	(+)	+											
HCF004	+	+	(+)											
HCI003				(+)										
HCI004					(+)									
HCI005						(+)								
HCM003							(+)	+						
HCM004							+	(+)						
HCT003									(+)	+	+	+	+	+
HCT004									+	(+)	+	+	+	+
HCT005									+	+	(+)	+	+	+
HCT006									+	+	+	(+)	+	+
HCT007									+	+	+	+	(+)	+
HCT008									+	+	+	+	+	(+)

- Cosine similarity of sensitivity profiles using the TSUNAMI-IP metric

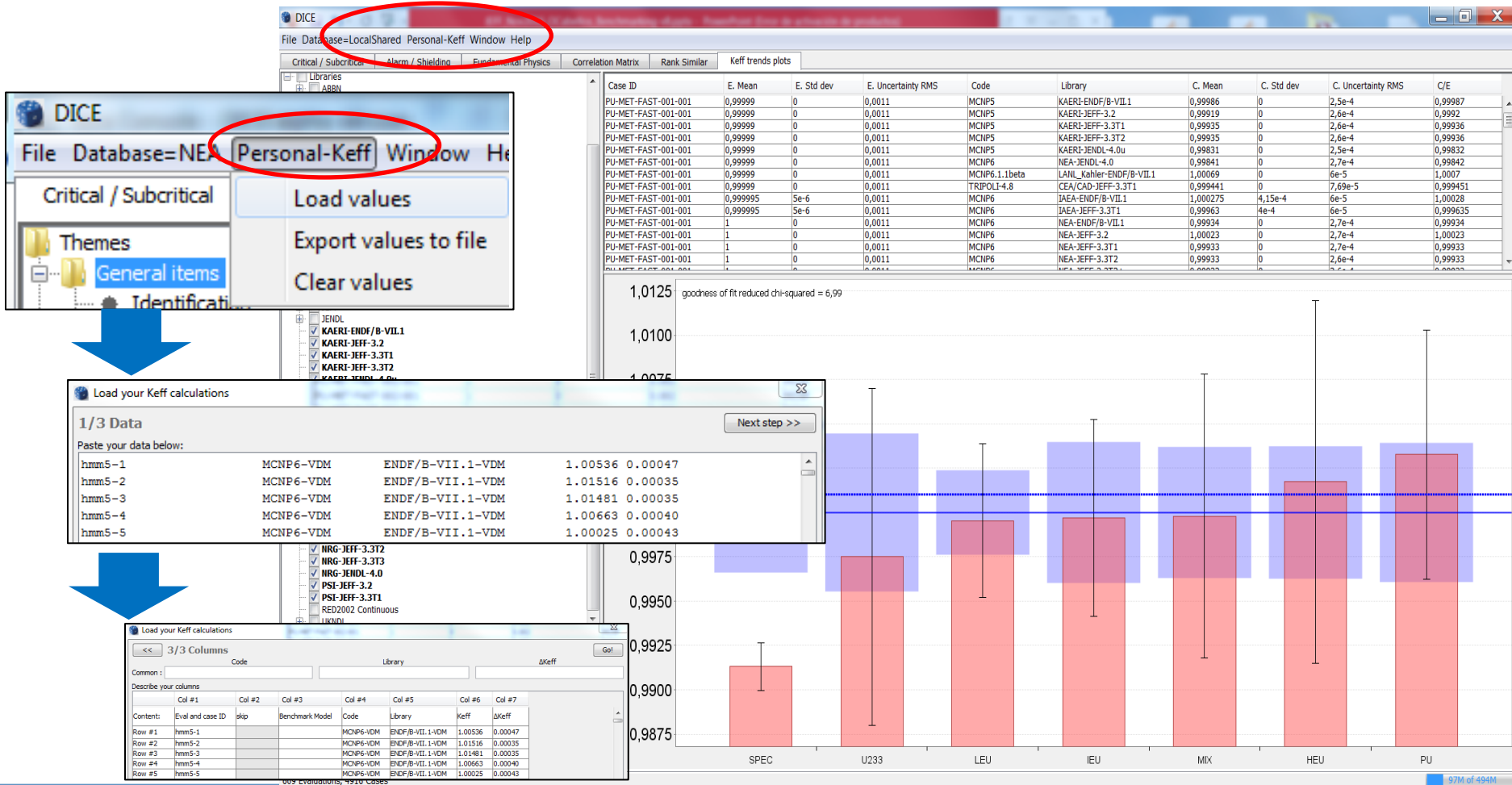


The screenshot shows the DICE software interface with the 'Correlation Matrix' tab selected. The matrix displays cosine similarity values for 16 evaluation identifiers. The diagonal elements are all 1000, representing a self-correlation of 1.0. The off-diagonal elements represent the cosine similarity between different evaluation identifiers, with values ranging from approximately 831 to 999.

	HMF057-001	HMF057-002	HMF057-003	HMF057-004	HMF057-005	HMF057-006	HMF058-001	HMF058-002	HMF058-003	HMF058-004	HMF058-005	HMF066-001	HMF066-002	HMF066-003	HMF066-004
HMF057-001	1000	998	998	998	999	999	883	923	947	965	973	895	931	948	831
HMF057-002	998	1000	997	999	997	999	888	929	952	971	979	900	936	953	836
HMF057-003	998	997	1000	997	999	999	881	921	945	962	970	894	929	945	830
HMF057-004	998	999	997	1000	996	998	889	930	954	972	980	901	937	954	836
HMF057-005	999	997	999	996	1000	999	881	921	945	962	970	894	929	946	831
HMF057-006	999	999	999	998	999	1000	885	925	948	966	974	897	932	949	833
HMF058-001	883	888	881	889	881	885	1000	991	978	959	946	994	984	975	990
HMF058-002	923	929	921	930	921	925	991	1000	996	985	976	996	998	994	975
HMF058-003	947	952	945	954	945	948	978	996	1000	996	991	986	998	999	953
HMF058-004	965	971	962	972	962	966	959	985	996	1000					
HMF058-005	973	979	970	980	970	974	946	976	991	998					
HMF066-001	895	900	894	901	894	897	994	996	986	969					
HMF066-002	931	936	929	937	929	932	984	998	998	990					
HMF066-003	948	953	945	954	946	949	975	994	999	996					
HMF066-004	831	836	830	836	831	833	990	975	953	925					

$$E \equiv \frac{S_a^T S_e}{|S_a| |S_e|}$$

Providing own keff-calculated results of benchmarking



The screenshot illustrates the workflow in the DICE software for loading personal keff results. The main window shows the 'Personal-Keff' menu highlighted. Below it, two 'Load your Keff calculations' dialog boxes are shown. The first dialog shows a table of data to be pasted:

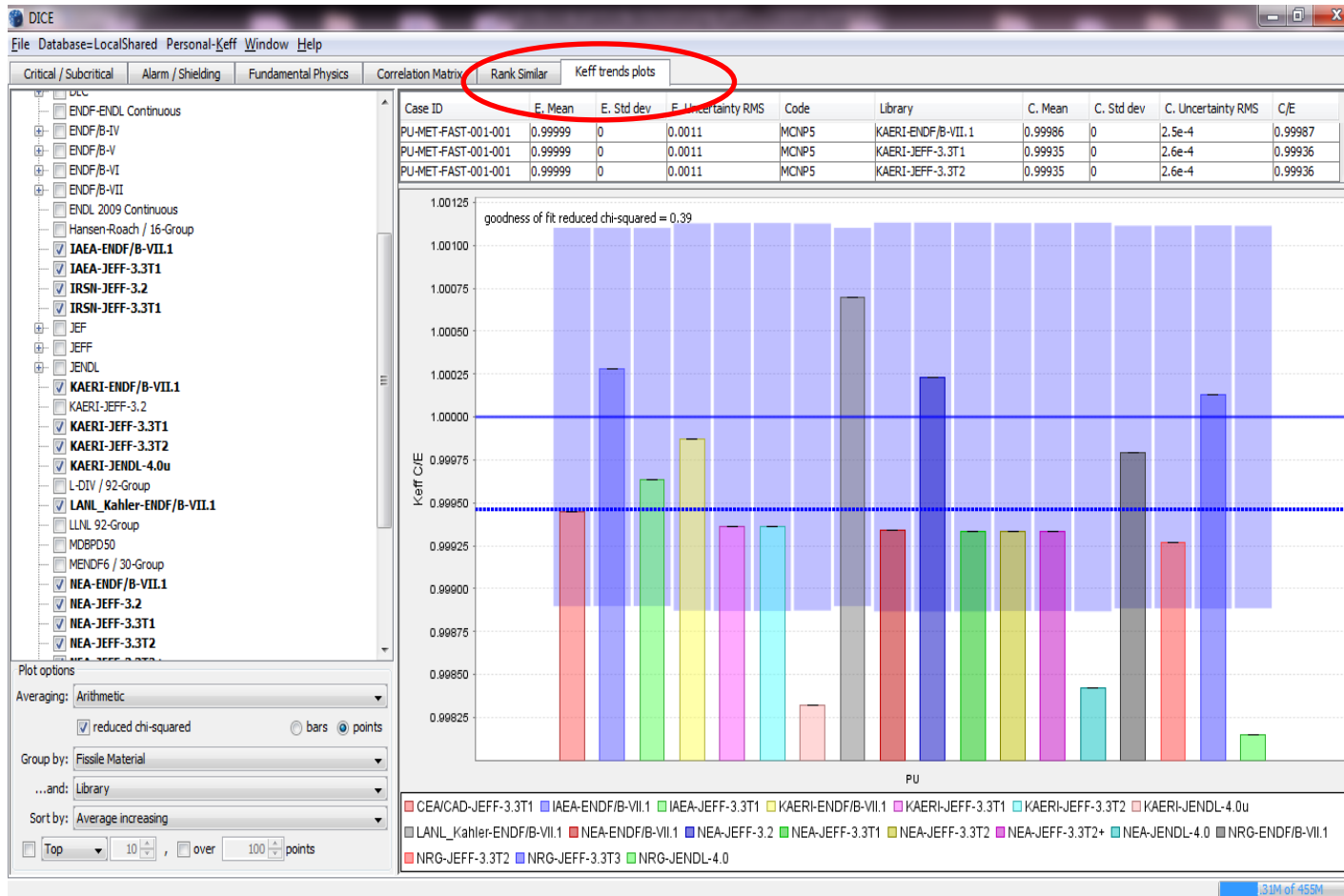
Code	Library	kEff
hmm5-1	MCNP6-VDM ENDF/B-VII.1-VDM	1.00536 0.00047
hmm5-2	MCNP6-VDM ENDF/B-VII.1-VDM	1.01516 0.00035
hmm5-3	MCNP6-VDM ENDF/B-VII.1-VDM	1.01481 0.00035
hmm5-4	MCNP6-VDM ENDF/B-VII.1-VDM	1.00663 0.00040
hmm5-5	MCNP6-VDM ENDF/B-VII.1-VDM	1.00025 0.00043

The second dialog shows a table with 7 columns for describing the data:

Col #1	Col #2	Col #3	Col #4	Col #5	Col #6	Col #7
Eval and case ID	skip	Benchmark Model	Code	Library	Keff	kEff
Row #1	hmm5-1		MCNP6-VDM	ENDF/B-VII.1-VDM	1.00536	0.00047
Row #2	hmm5-2		MCNP6-VDM	ENDF/B-VII.1-VDM	1.01516	0.00035
Row #3	hmm5-3		MCNP6-VDM	ENDF/B-VII.1-VDM	1.01481	0.00035
Row #4	hmm5-4		MCNP6-VDM	ENDF/B-VII.1-VDM	1.00663	0.00040
Row #5	hmm5-5		MCNP6-VDM	ENDF/B-VII.1-VDM	1.00025	0.00043

On the right, a bar chart displays benchmarking results for various cases: SPEC, U233, LEU, IEU, MIX, HEU, and PU. The y-axis represents the keff value, ranging from 0.9875 to 1.0125. Each bar includes a red base and a blue top section, with vertical error bars indicating uncertainty. A horizontal blue line is drawn across the chart at approximately 0.9993.

keff trends plots... to see the performance of your own calculations



□ The use of Figure of Merit (FoM) to assess the performance of ND in keff

These metrics can give reliable indications of the nuclear data performance

□ **Average C/E**

□ **Average difference, r.m.s. Delta-k**

- magnitude of the average difference between C and E
- smaller values better fit to benchmark

$$\langle |\Delta| \rangle = \sum \frac{|k_{calc} - k_{exp}|}{n}$$

□ **Residuals:** $(k_{calc} - k_{exp}) / \Delta k_{exp}$

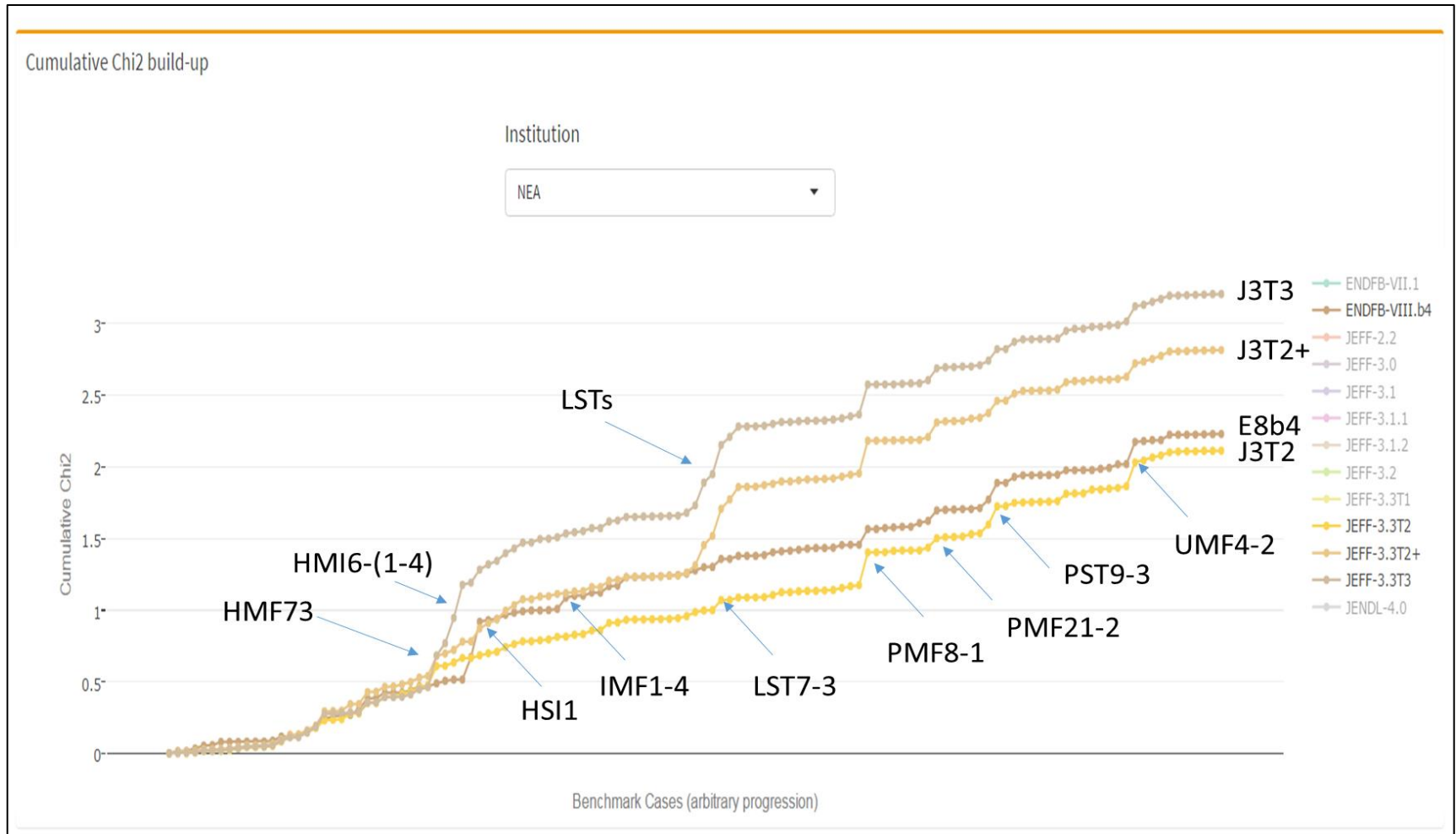
□ **Chi-squared, X²/DoF**

- accounts for the uncertainty in the experimental value
- sensitive to cases with unrealistically small uncertainties
- If $\chi < 1$ then , on average calculations match benchmarks to within one exp. std.

$$\chi^2 = \sum \frac{((k_{calc} - k_{exp}) / \delta k_{exp})^2}{n}$$

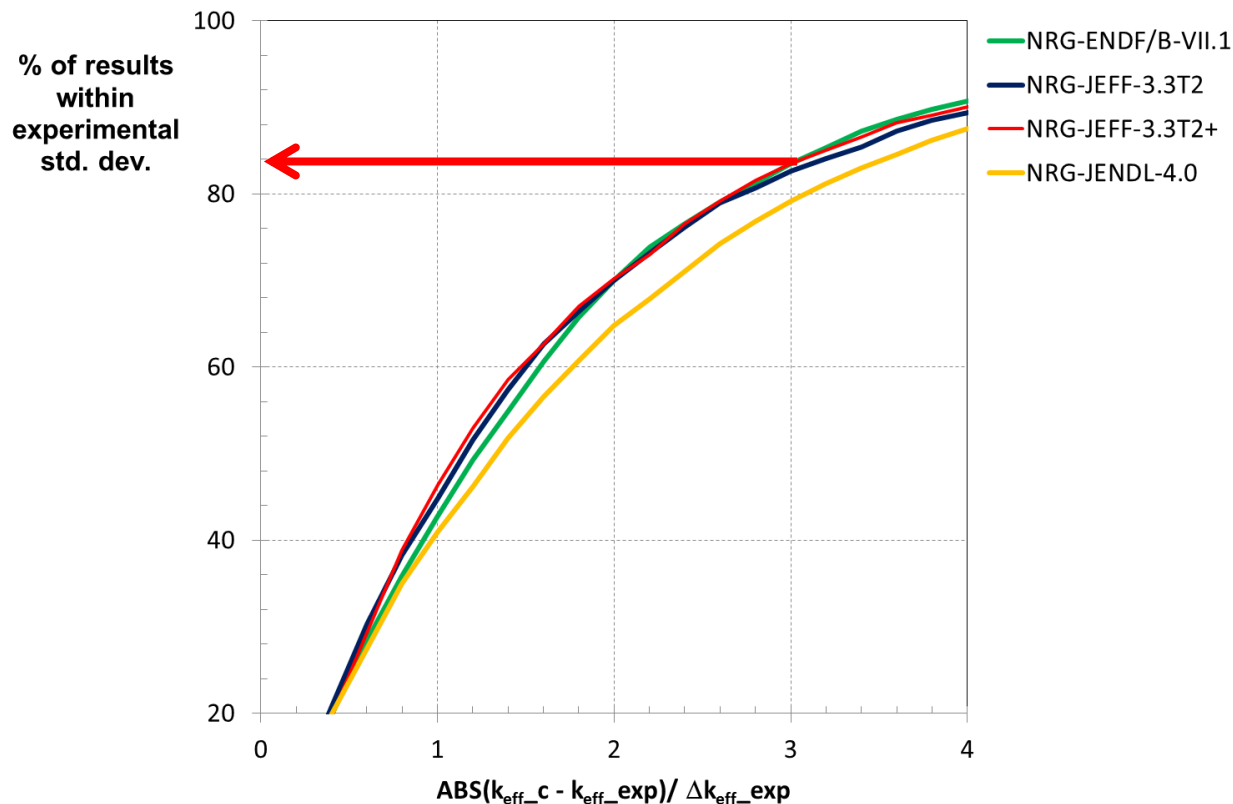
□ **PDFs, CDFs, ... % of results within experimental std. dev**

Results of criticality benchmarking using ICSBEP



□ Results of criticality benchmarking using ICSBEP

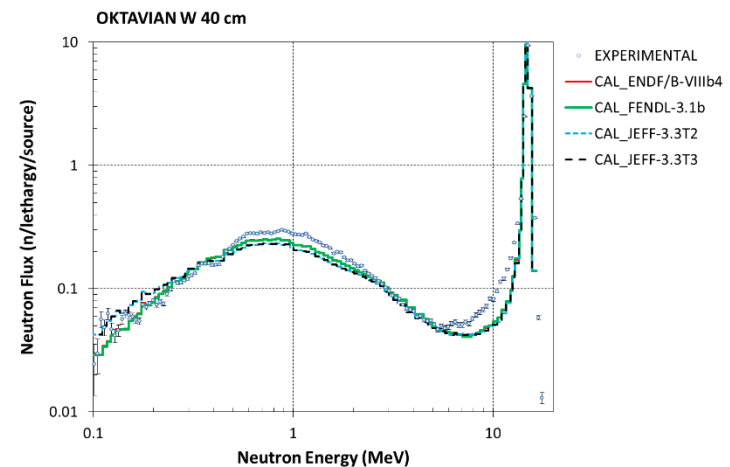
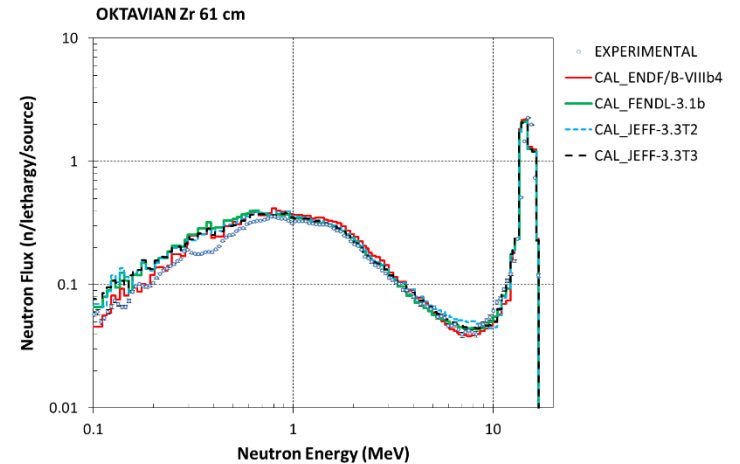
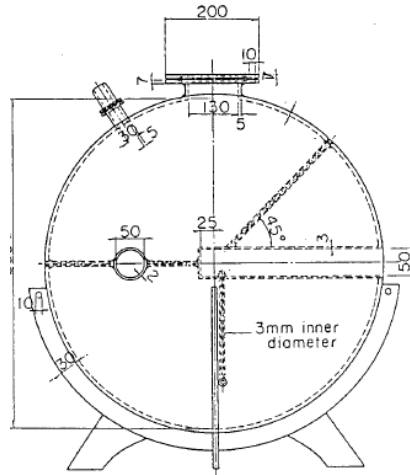
Figure. % of results within experimental std. dev.



Shielding and fusion application: **SINBAD Database**

- Reactor shielding (46)
- Fusion neutronics shielding (31)
- Accelerator shielding (23)

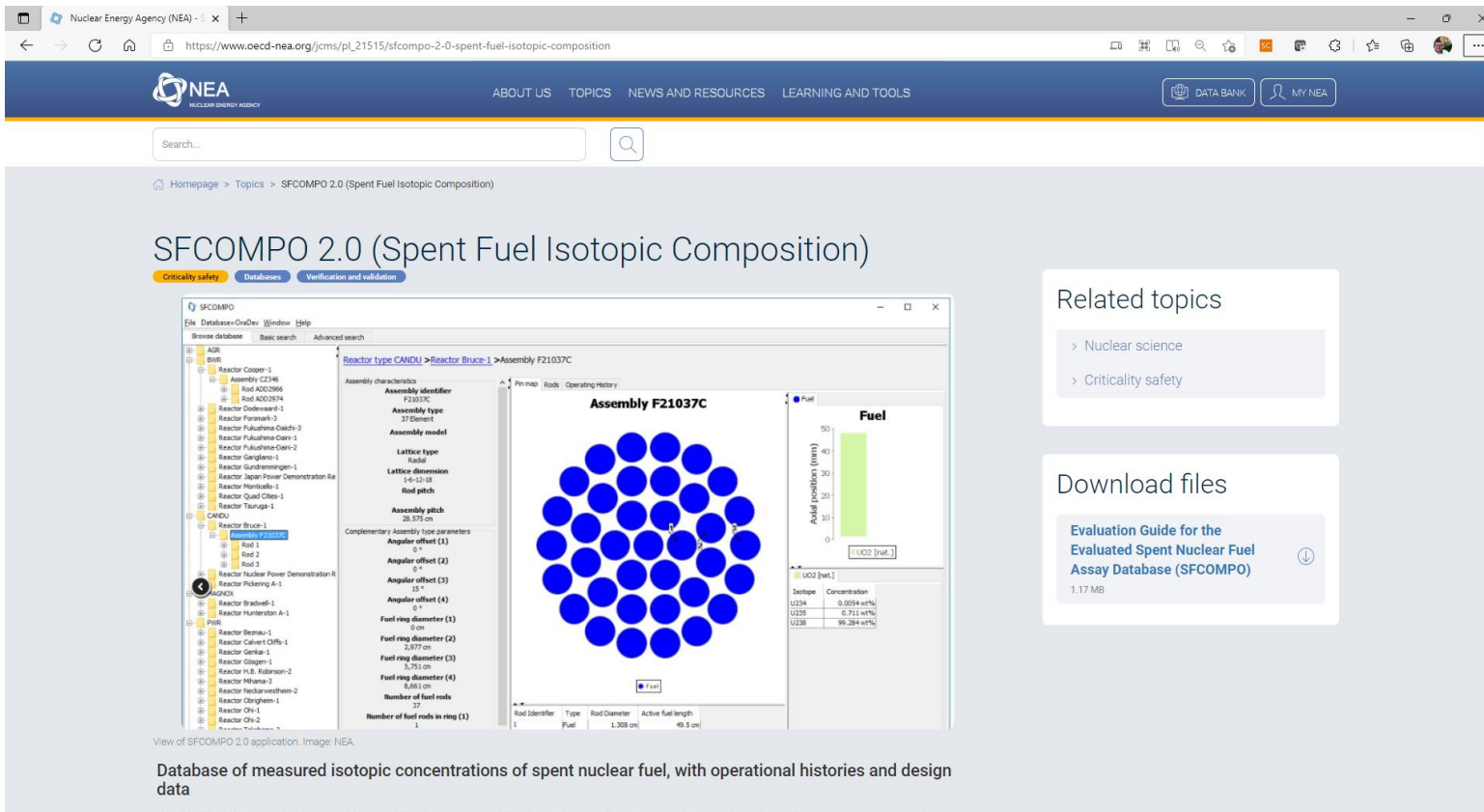
Figure. An example: Neutron leakage from OKTAVIAN pulsed sphere 61 cm sphere - Type I



https://www.oecd-nea.org/jcms/pl_32139/shielding-integral-benchmark-archive-and-database-sinbad

SFCOMPO: Post Irradiation Experimental Measurements

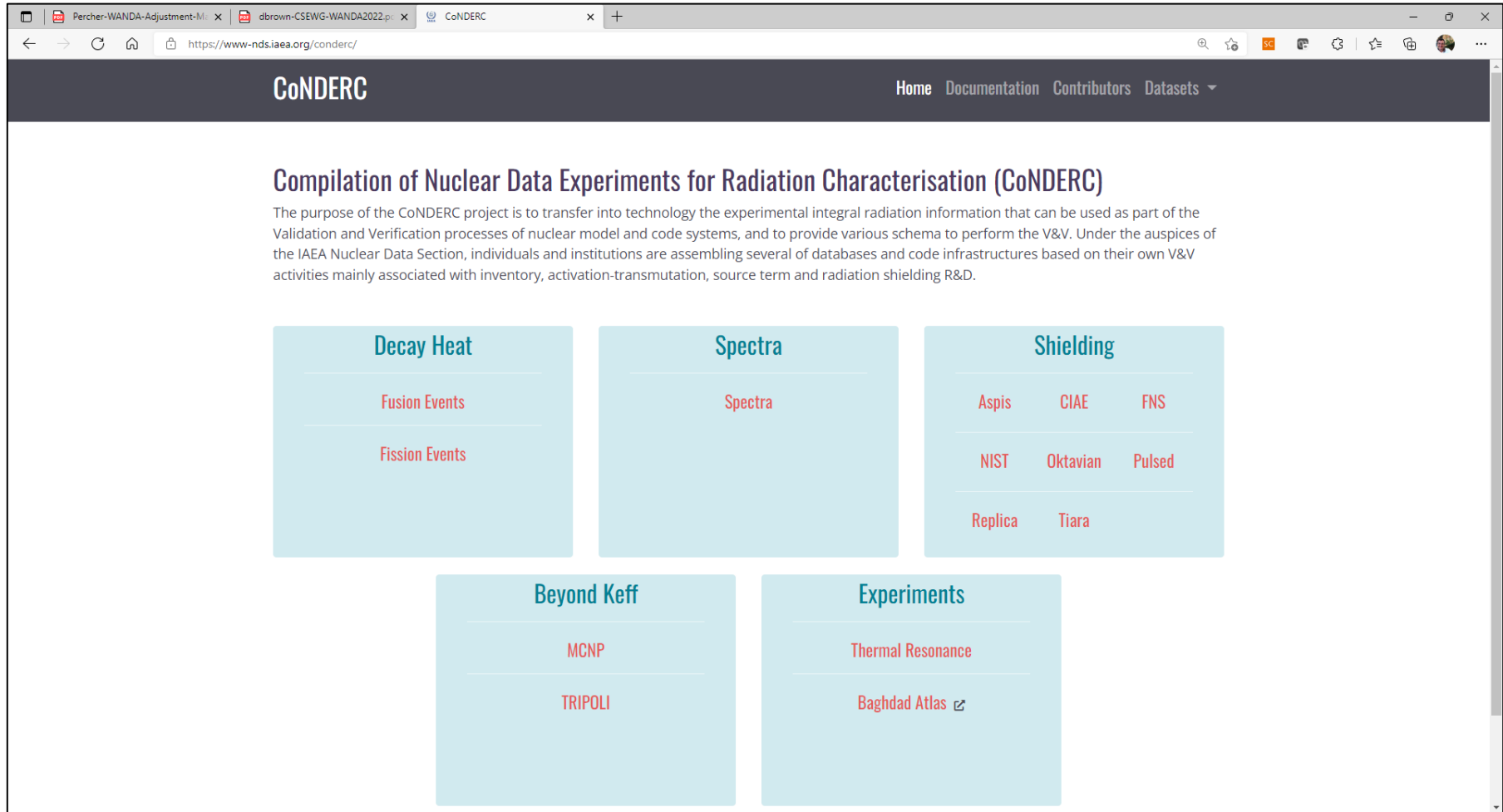
- 700 samples



Database of measured isotopic concentrations of spent nuclear fuel, with operational histories and design data

Isotope	Concentration
U234	0.0054 wt%
U235	0.7114 wt%
U238	99.284 wt%

https://www.oecd-nea.org/jcms/pl_21515/sfcompo-2-0-spent-fuel-isotopic-composition

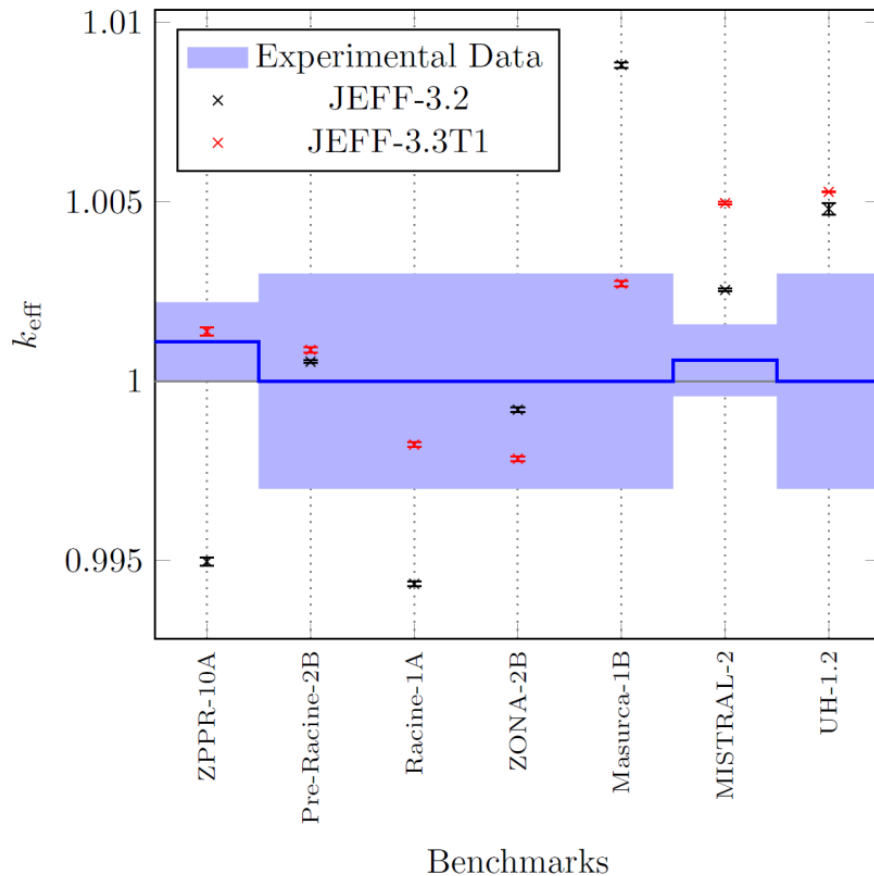


The screenshot shows a web browser window displaying the CoNDERC website. The browser's address bar shows the URL <https://www-nds.iaea.org/conderc/>. The website has a dark header with the CoNDERC logo on the left and navigation links for Home, Documentation, Contributors, and Datasets on the right. The main content area features a title "Compilation of Nuclear Data Experiments for Radiation Characterisation (CoNDERC)" followed by a paragraph explaining the project's purpose. Below this, there are five light blue boxes representing different data categories: "Decay Heat" (with sub-items Fusion Events and Fission Events), "Spectra" (with sub-item Spectra), "Shielding" (with sub-items Aspis, CIAE, FNS, NIST, Oktavian, Pulsed, Replica, and Tiara), "Beyond Keff" (with sub-items MCNP and TRIPOLI), and "Experiments" (with sub-items Thermal Resonance and Baghdad Atlas with an external link icon).

<https://www-nds.iaea.org/conderc/>

Experimental reactors

Ref. P. Tamagno, JEF/DOC-1752 (2016)



Experiment	$\Delta\rho(\text{JEFF33T1-JEFF32})$ [pcm]
ZPPR-10A	+644
Pre-Racine-2B	+33
Racine-1A	+391
ZONA-2B	-137
Masurca-1B	-603
Mistral-2	+240
UH1.2	+51

Computational Benchmarking

Reference: John C. Wagner and Georgeta Radulescu, Specification for Phase VII Benchmark UO₂ Fuel: Study of spent fuel compositions for long-term disposal, NEA Expert Group on Burn-up Credit, November, 2008

Keff Fresh Fuel

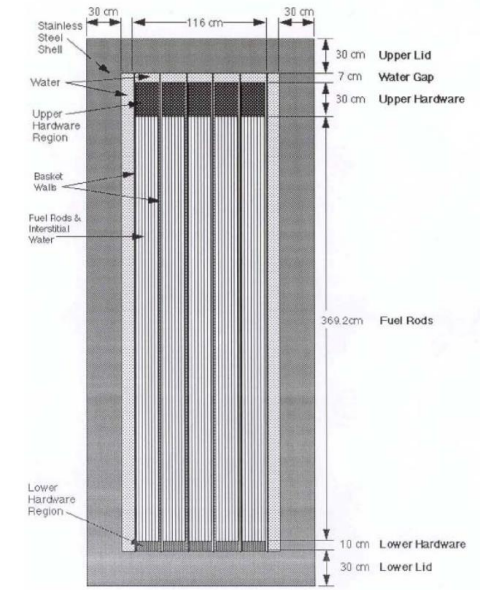
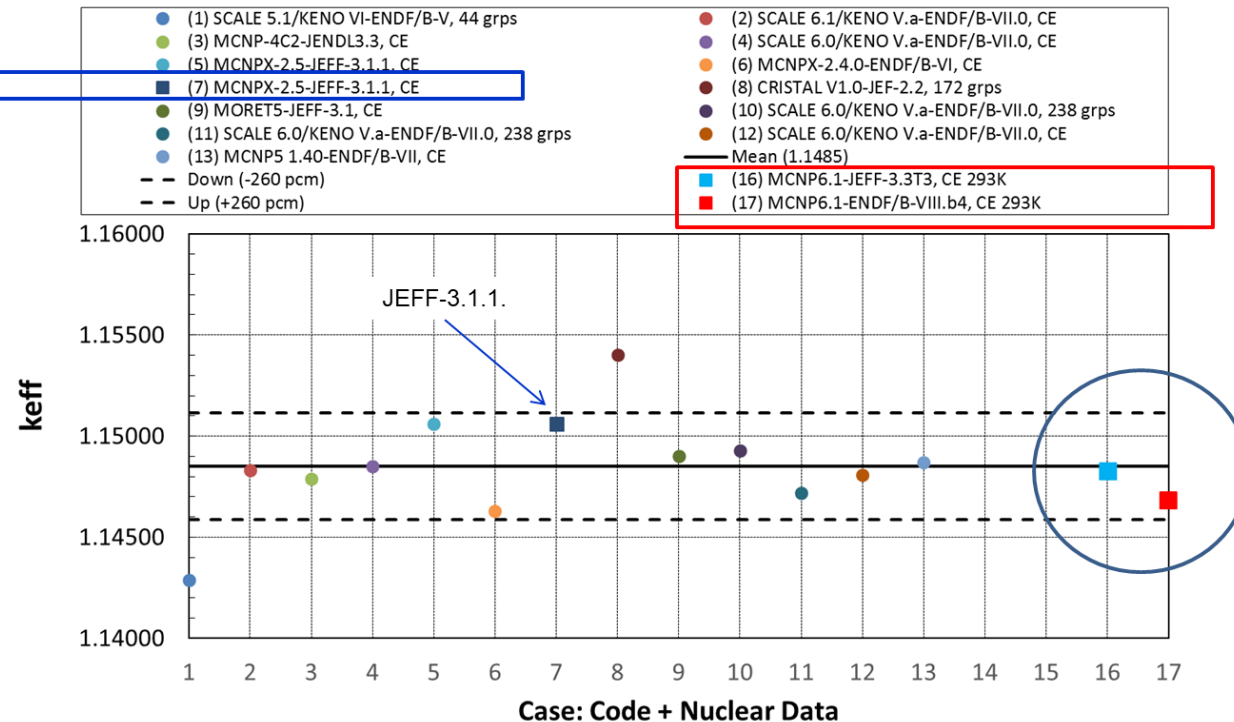
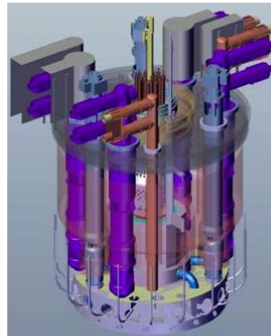


Figure. Cask model (side view)

Computational Benchmarking: new reactor designs

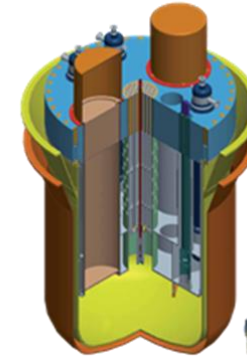
ASTRID prototype
(600 MWe)
Interm. Na circuit
Driver core ~ MOX



MOX	JEFF-3.2	JEFF-3.3T1	Diff.
k_{eff}	0.99829	1.0018	+351 pcm
Total fission probability	0.340	0.344	+1.0%
Total capture probability	0.658	0.654	-0.6%

P. Romojaro, JEFF/DOC-1756(2016)

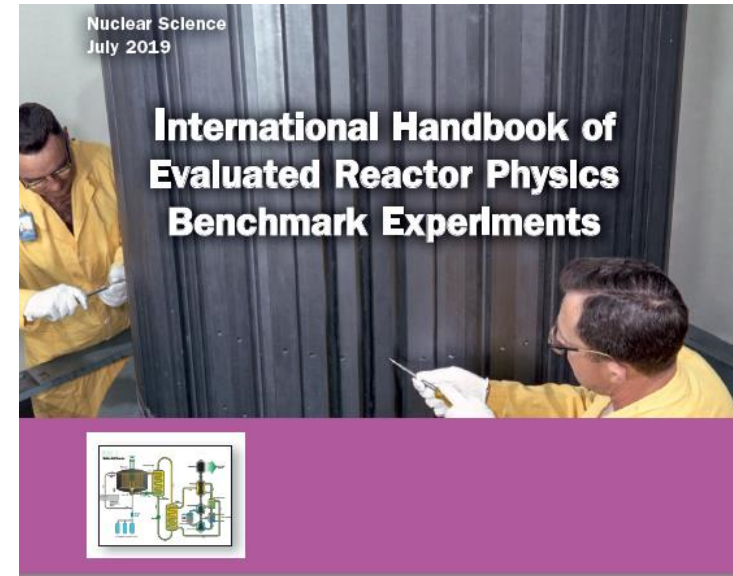
MYRRHA concept
(50-100 MWe)
Cooled by lead-bismuth I
Driver core ~ MOX
Start-up core ~ UO₂ fuel



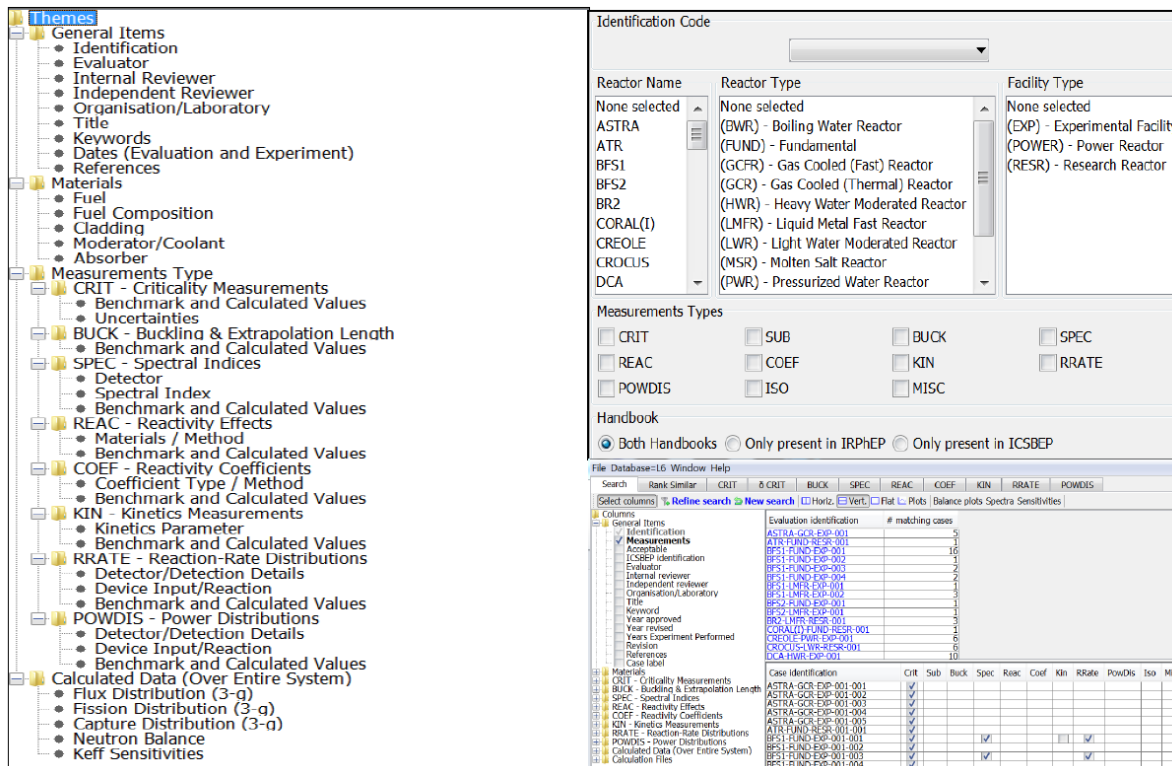
MOX	JEFF-3.2	JEFF-3.3T1	Diff.
k_{eff}	1.00479	1.00737	+258 pcm
Total fission probability	0.343	0.346	+1.0%
Total capture probability	0.664	0.660	-0.5%
UO2	JEFF-3.2	JEFF-3.3T1	Diff.
k_{eff}	1.01003	1.00001	-1002 pcm
Total fission probability	0.408	0.404	-1.0%
Total capture probability	0.596	0.600	+0.7%

International Reactor Physics Benchmark Experiment Evaluation Project

- Established in 2000
- 10+ types of measurements. (Only k-eff in ICSBEP ... with exceptions see FUND)
Reaction Rate Distribution, Spectral Characteristics, Power Distributions, Reactivity Effects, Isotopic Composition, Reactivity Coefficients, ...
 - 200 reactor benchmarks
 - 200 spectra benchmarks
- Organised by reactor type
- Similar format to ICSBEP, with subsections for each measurement type



- ❑ The IRPhEP Database and Analysis Tool (IDAT) was first released in 2013 and is included on the IRPhE Handbook DVD. This database and corresponding user interface allows easy access to handbook information.



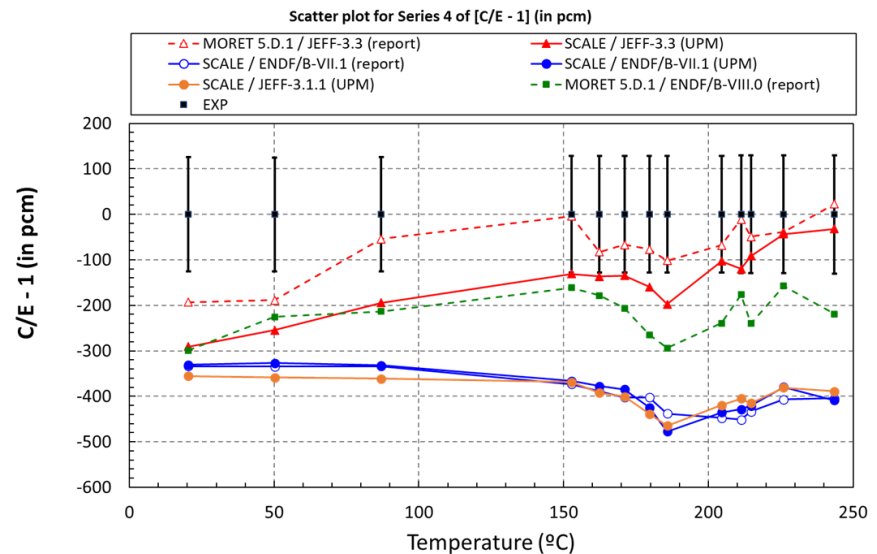
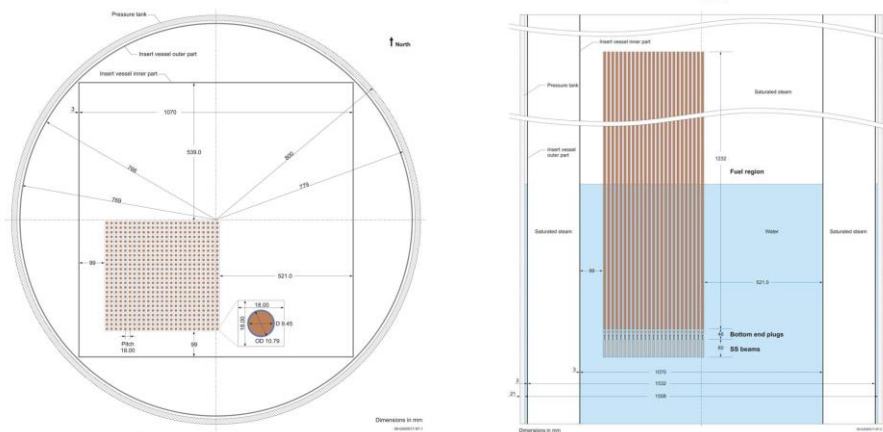
The screenshot displays the IDAT software interface. On the left is a tree view of 'Themes' including categories like General Items, Materials, Measurements Type, REAC, COEF, KIN, RRATE, POWDIS, and Calculated Data. The main window shows search filters for Reactor Name, Reactor Type, and Facility Type. Below these are checkboxes for various measurement types (CRIT, REAC, POWDIS, etc.) and handbook options. At the bottom, a table shows search results with columns for Case Identification and various measurement parameters.

Case Identification	CRIT	Sub	Back	Spec	Reac	Coef	Kin	RRate	PowDis	Iso	Misc
ASTRA-GCR-EXP-001	✓										
ASTRA-GCR-EXP-002	✓										
ASTRA-GCR-EXP-003	✓										
ASTRA-GCR-EXP-004	✓										
ASTRA-GCR-EXP-005	✓										
ASTRA-GCR-EXP-006	✓										
ASTRA-GCR-EXP-007	✓										
ASTRA-GCR-EXP-008	✓										
ASTRA-GCR-EXP-009	✓										
ASTRA-GCR-EXP-010	✓										
ASTRA-GCR-EXP-011	✓										
ASTRA-GCR-EXP-012	✓										
ASTRA-GCR-EXP-013	✓										
ASTRA-GCR-EXP-014	✓										
ASTRA-GCR-EXP-015	✓										
ASTRA-GCR-EXP-016	✓										
ASTRA-GCR-EXP-017	✓										
ASTRA-GCR-EXP-018	✓										
ASTRA-GCR-EXP-019	✓										
ASTRA-GCR-EXP-020	✓										
ASTRA-GCR-EXP-021	✓										
ASTRA-GCR-EXP-022	✓										
ASTRA-GCR-EXP-023	✓										
ASTRA-GCR-EXP-024	✓										
ASTRA-GCR-EXP-025	✓										
ASTRA-GCR-EXP-026	✓										
ASTRA-GCR-EXP-027	✓										
ASTRA-GCR-EXP-028	✓										
ASTRA-GCR-EXP-029	✓										
ASTRA-GCR-EXP-030	✓										
ASTRA-GCR-EXP-031	✓										
ASTRA-GCR-EXP-032	✓										
ASTRA-GCR-EXP-033	✓										
ASTRA-GCR-EXP-034	✓										
ASTRA-GCR-EXP-035	✓										
ASTRA-GCR-EXP-036	✓										
ASTRA-GCR-EXP-037	✓										
ASTRA-GCR-EXP-038	✓										
ASTRA-GCR-EXP-039	✓										
ASTRA-GCR-EXP-040	✓										
ASTRA-GCR-EXP-041	✓										
ASTRA-GCR-EXP-042	✓										
ASTRA-GCR-EXP-043	✓										
ASTRA-GCR-EXP-044	✓										
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ASTRA-GCR-EXP-048	✓										
ASTRA-GCR-EXP-049	✓										
ASTRA-GCR-EXP-050	✓										
ASTRA-GCR-EXP-051	✓										
ASTRA-GCR-EXP-052	✓										
ASTRA-GCR-EXP-053	✓										
ASTRA-GCR-EXP-054	✓										
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ASTRA-GCR-EXP-062	✓										
ASTRA-GCR-EXP-063	✓										
ASTRA-GCR-EXP-064	✓										
ASTRA-GCR-EXP-065	✓										
ASTRA-GCR-EXP-066	✓										
ASTRA-GCR-EXP-067	✓										
ASTRA-GCR-EXP-068	✓										
ASTRA-GCR-EXP-069	✓										
ASTRA-GCR-EXP-070	✓										
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ASTRA-GCR-EXP-072	✓										
ASTRA-GCR-EXP-073	✓										
ASTRA-GCR-EXP-074	✓										
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ASTRA-GCR-EXP-080	✓										
ASTRA-GCR-EXP-081	✓										
ASTRA-GCR-EXP-082	✓										
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ASTRA-GCR-EXP-093	✓										
ASTRA-GCR-EXP-094	✓										
ASTRA-GCR-EXP-095	✓										
ASTRA-GCR-EXP-096	✓										
ASTRA-GCR-EXP-097	✓										
ASTRA-GCR-EXP-098	✓										
ASTRA-GCR-EXP-099	✓										
ASTRA-GCR-EXP-100	✓										

https://www.oecd-nea.org/jcms/pl_20296/international-reactor-physics-handbook-database-and-analysis-tool-idat

❑ **An example IRPHEP Benchmark:** Light-water reactor lattices at KRITZ reactor in Studsvik (Sweden) for criticality at room and elevated temperatures

Figure 1. Schematic top and side views of the core are presented

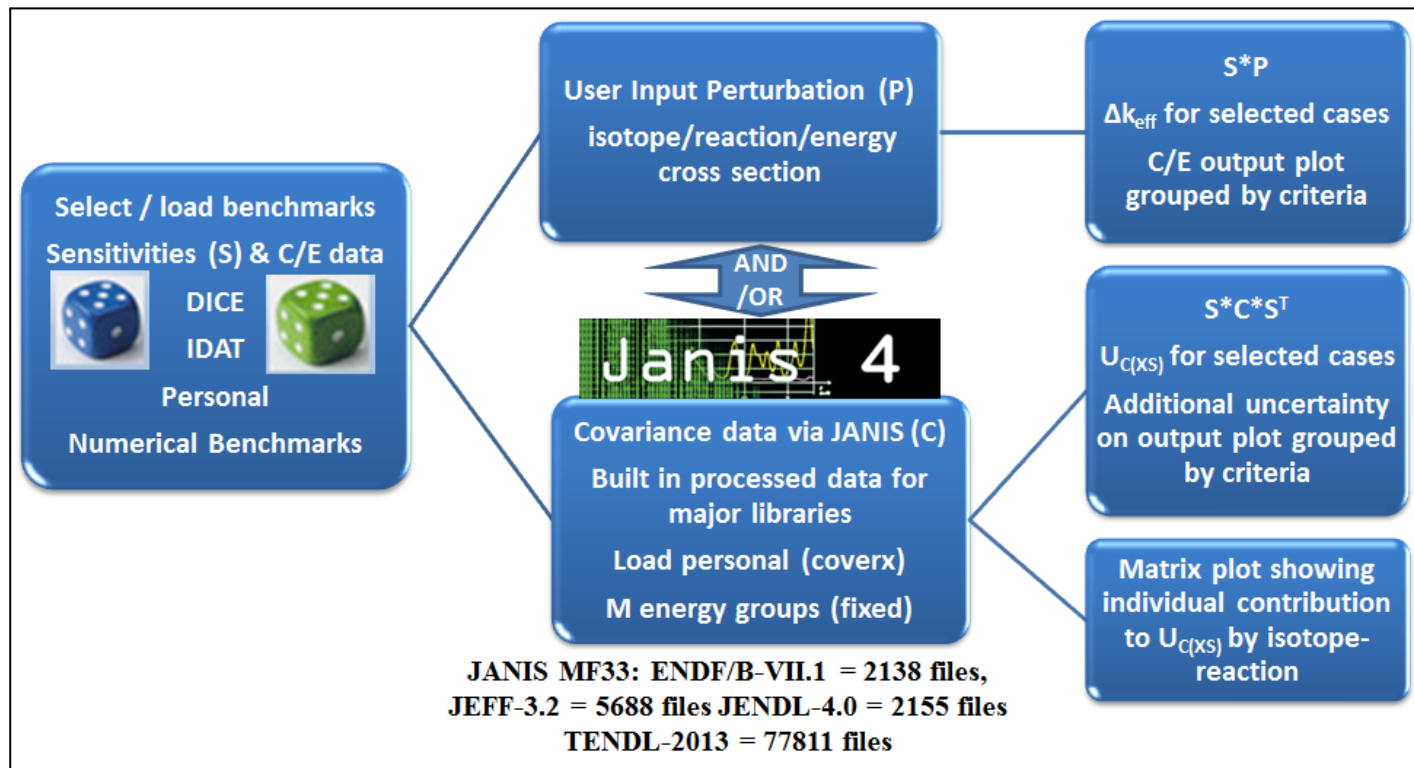


- IRPHEP “KRITZ-LWR-RESR-004 Evaluation Report. 2019 Rev.0”
- 37 criticality measurements at room and elevated temperatures (critical water heights of active fuel covered by water)
- UO₂ fuels 1.35wt% in ²³⁵U

❑ In JEFF-3.3, the trend with temperature becomes stronger

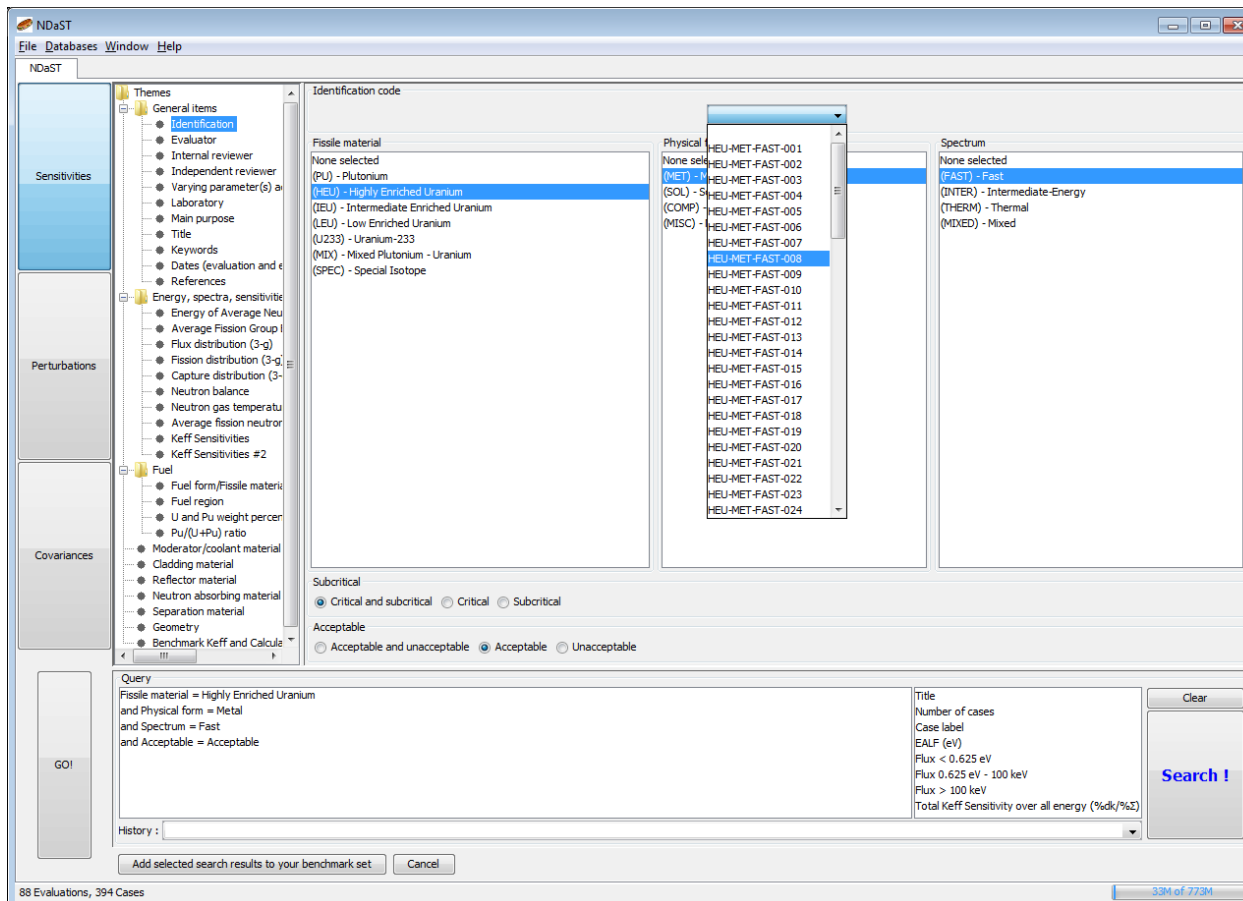
NDAST (**N**uclear **D**ata **S**ensitivity **T**ool) brings together the existing capabilities of both DICE and JANIS, whose main objective is:

- to quickly propagate the impact of changes in nuclear data cross sections and nuclear data covariances to benchmarks



https://www.oecd-nea.org/jcms/pl_32450/nuclear-data-sensitivity-tool-ndast

Sensitivities Panel: Data needs to be added in order to provide the cases for which the subsequent calculations will be carried out



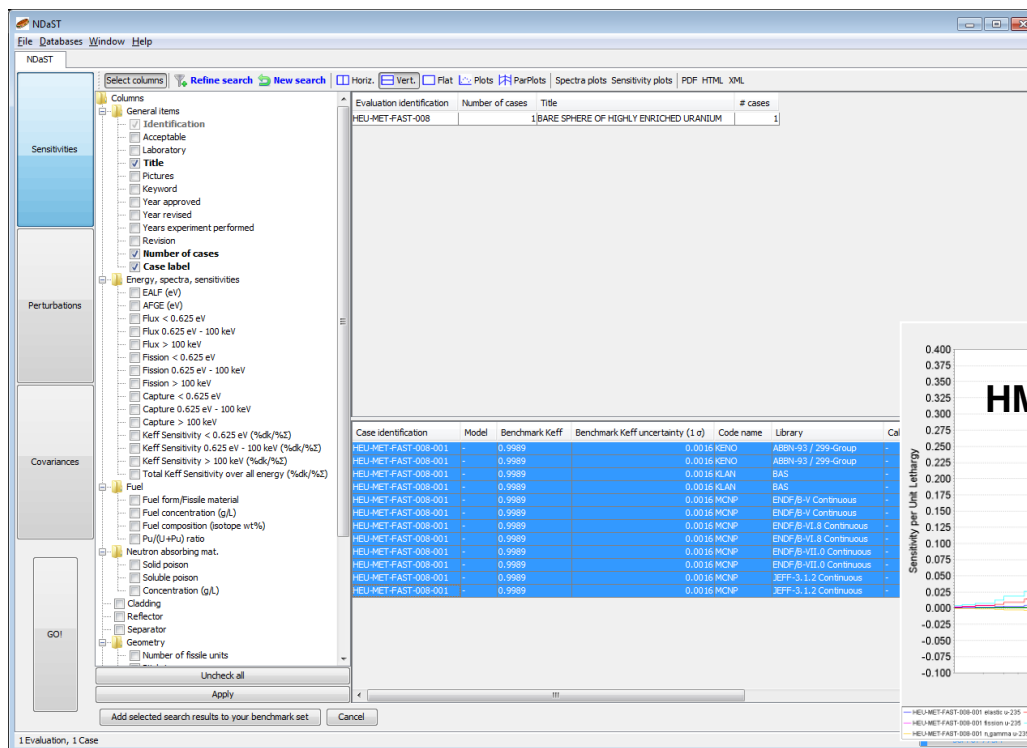
The screenshot shows the NDAST Sensitivities Panel interface. On the left, there is a tree view under 'Themes' with categories: Sensitivities, Perturbations, and Covariances. The 'Sensitivities' category is expanded, showing sub-items like 'Identification', 'Evaluator', 'Internal reviewer', etc. The main area is divided into three panes: 'Identification code', 'Physical', and 'Spectrum'. The 'Identification code' pane lists various material types like 'None selected', '(PU) - Plutonium', '(HEU) - Highly Enriched Uranium', etc. The 'Physical' pane lists codes like '(MET) - Metal', '(SOL) - Solid', '(COMP) - Compressed', '(MISC) - Miscellaneous'. The 'Spectrum' pane lists codes like '(FAST) - Fast', '(INTER) - Intermediate-Energy', '(THERM) - Thermal', '(MIXED) - Mixed'. Below these panes are radio buttons for 'Subcritical' (Critical and subcritical, Critical, Subcritical) and 'Acceptable' (Acceptable and unacceptable, Acceptable, Unacceptable). At the bottom, there is a 'Query' section with a text box containing a search query: 'Fissile material = Highly Enriched Uranium and Physical form = Metal and Spectrum = Fast and Acceptable = Acceptable'. To the right of the query is a 'Search!' button. Below the query is a 'History' dropdown and a 'Clear' button. The status bar at the bottom indicates '88 Evaluations, 394 Cases' and '33M of 773M'.

Current Databases:

- Experimental benchmarks in DICE and IDAT (useful only when benchmarks have sensitivity profiles)
- Nuclear data covariance in JANIS database

Formats

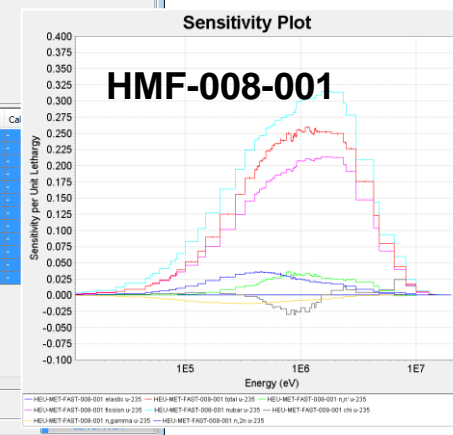
- Sensitivity data: SCALE, ABBN formats
- Covariance data: ENDF-6, BOXER and COVERX (SCALE6.1)



The screenshot shows the NDaST application window. On the left, there are several filter panels: 'Sensitivities', 'Perturbations', 'Covariances', and 'GOI'. The 'Sensitivities' panel is active, showing a tree view of search criteria. The main window displays a table with the following columns: Evaluation identification, Number of cases, Title, and # cases. One entry is visible: HEU-MET-FAST-008 with 1 case and the title 'BARE SPHERE OF HIGHLY ENRICHED URANIUM'. Below the table, there is a detailed view of the selected case, showing a table with columns: Case identification, Model, Benchmark Keff, Benchmark Keff uncertainty (1 σ), Code name, Library, and Cal. The table lists various models and their corresponding benchmark keff values and uncertainties.

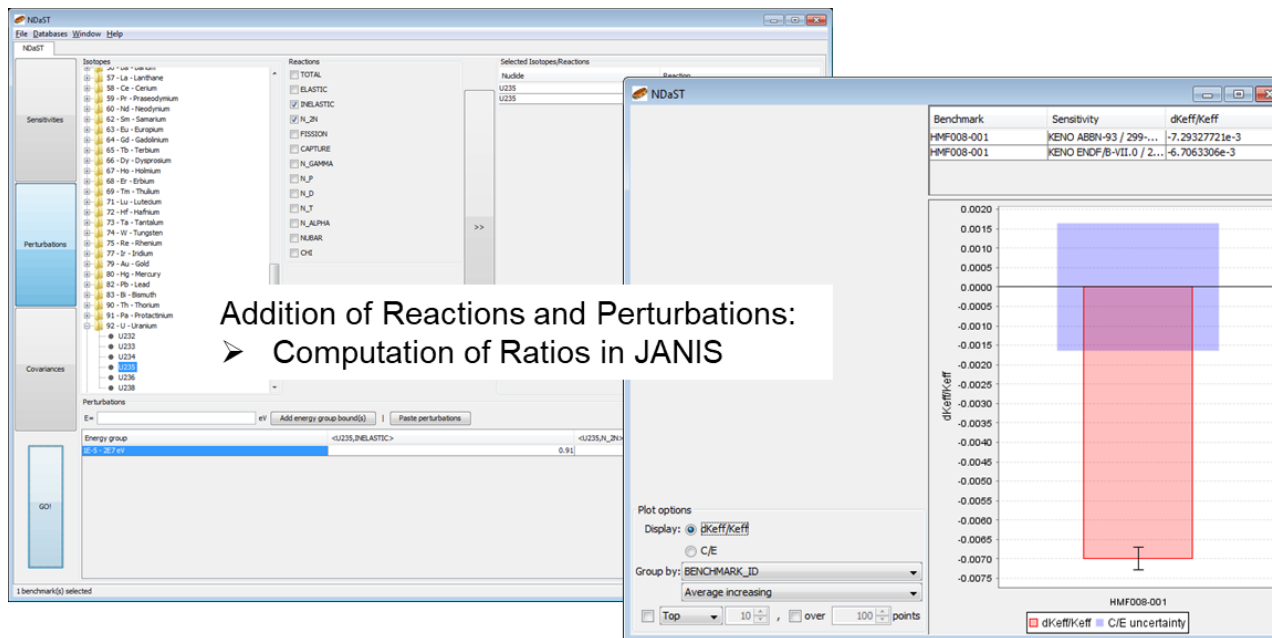
Case identification	Model	Benchmark Keff	Benchmark Keff uncertainty (1 σ)	Code name	Library	Cal
HEU-MET-FAST-008-001	0.9989	0.0016	KENO	ABBN-93 / 299-Group		
HEU-MET-FAST-008-001	0.9989	0.0016	KENO	ABBN-93 / 299-Group		
HEU-MET-FAST-008-001	0.9989	0.0016	KLAN	BAS		
HEU-MET-FAST-008-001	0.9989	0.0016	KLAN	BAS		
HEU-MET-FAST-008-001	0.9989	0.0016	MCNP	ENDF-B-V Continuous		
HEU-MET-FAST-008-001	0.9989	0.0016	MCNP	ENDF-B-V Continuous		
HEU-MET-FAST-008-001	0.9989	0.0016	MCNP	ENDF-B-VI.8 Continuous		
HEU-MET-FAST-008-001	0.9989	0.0016	MCNP	ENDF-B-VI.8 Continuous		
HEU-MET-FAST-008-001	0.9989	0.0016	MCNP	ENDF-B-VII.0 Continuous		
HEU-MET-FAST-008-001	0.9989	0.0016	MCNP	ENDF-B-VII.0 Continuous		
HEU-MET-FAST-008-001	0.9989	0.0016	MCNP	JEFF-3.1.2 Continuous		
HEU-MET-FAST-008-001	0.9989	0.0016	MCNP	JEFF-3.1.2 Continuous		

“Add selected search results to your benchmark set” at bottom left of the panel



- **NDAST performs matrix multiplication** for calculating keff perturbations and keff uncertainties
- **Plotting capability:**
 - experimental keff + uncertainty
 - calculated keff + perturbation (including breakdown) + uncertainty
- **Save status** (benchm./perturb./covariance selections) in XML format file

Perturbation Panel



□ Computation of ratios in JANIS

Create perturbation from JANIS

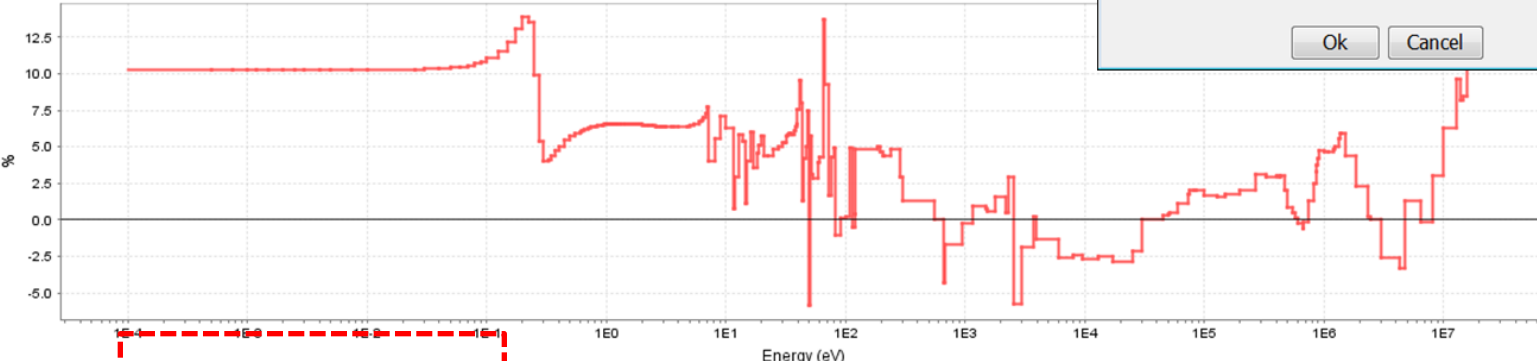
Nuclide: Reaction:

Numerator				
ENDF>endfb7.1	NEA>ENDF/B-VI.8	NEA>JEF-2.2	NEA>JENDL-3.3	NEA>TENDL-2010
JEFF>JEFF-3.2	NEA>ENDF/B-VII.0	NEA>JEFF-3.0	NEA>JENDL-4.0	NEA>TENDL-2011

Denominator				
JEFF>JEFF-3.2	NEA>ENDF/B-VII.0	NEA>JEFF-3.0	NEA>JENDL-4.0	NEA>TENDL-2011
JENDL>JENDL4	NEA>ENDF/B-VII.1	NEA>JEFF-3.1	NEA>JENDL/AC-2008	NEA>TENDL-2012

Group:

Spectrum:



Perturbation label:

Ok Cancel

Group structure

Group t...

Choose ...

Spectrum

Spectrum t...

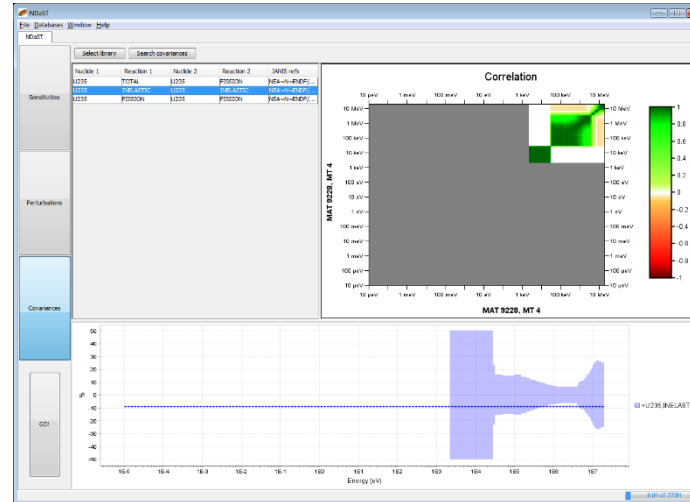
Constant v...

Ok Cancel

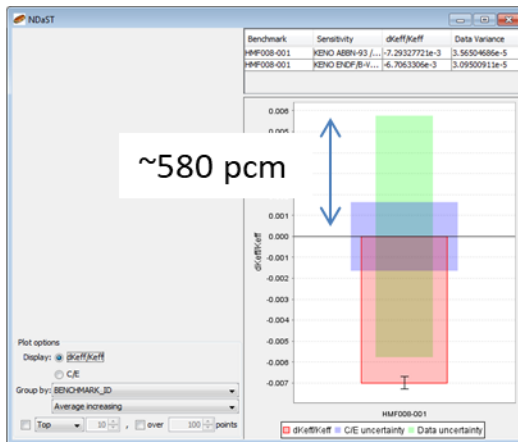
Covariances Panel

Search covariances and press 'ok':

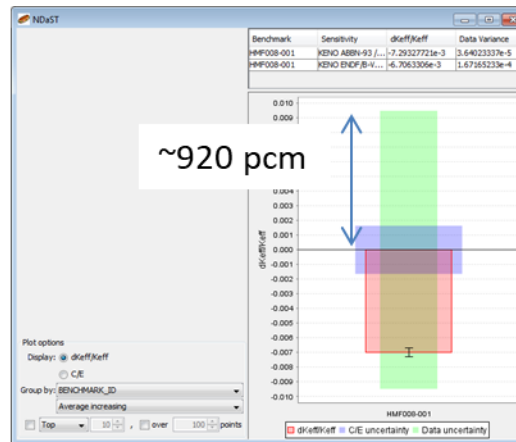
- JANIS Database
- Format: ENDF, BOXER



Go! and Output Results Panel



Only inelastic ENDF/B-VII.1



All ENDF/B-VII.1 covariances

- $\Delta k/k$ perturbation (red)
- $\Delta k/k$ benchmark uncertainty (blue)
- $\Delta k/k$ based on the ENDF7.1 covariance file (green)

- ❑ *What is an integral experiment*
- ❑ *Integral experiments databases: ICSBEP and IRPHEP*
- ❑ *Visualization and databases search tools: DICE and IDAT*
- ❑ *NDaST tool*
- ❑ *Examples of validations*

❑ Create a new database in JANIS

... to be used with NDAST

Import WIZARD tool

- Use the “Database > Import Wizard” to create a permanent database



Following steps:

- 1) **New folder** shall be created with three sub-folders, one per type of file (i.e. hendf, boxer and inter). Then, the files generated shall be copied to their corresponding sub-folders. **IMPORTANT!** Delete those empty files
- 2) Open JANIS, and at the toolbar click on “**database -> import wizard**”
- 3) Add HENDF/PENDF files. For that use either “**Add directory**” or “**add files**” options. Click on “next”
- 4) “**Automatic detection**” should work fine. Click on “next”
- 5) Choose a **library name**, e.g. JEFF-4.0T1, (less than 20 characters). Click on “next”
- 6) Select “**a new base**” when importing HENDF, that means for the first import. For BOXER and INTER files, “an existing base” shall be selected, and then, selecting the created database for HENDF files
- 7) Choose “**path to the folder**” where the database will be created. Click on “next”

❑ Create a new database in JANIS



Following steps:

- 7)
- 8) The **“base root”** shall point to the folder created with the three sub-folders (one for each kind of file type). Click on **“next”**
- 9) Type a **“database” name**, e.g. **“NUDATA”**, for showing later in JANIS. Click on **“next”**
- 10) **A summary** of the task to do, plus input parameters, is presented before importing data from files. Click on **“Finish”**
- 11) Once imported HENDF files, for BOXER and INTER files **repeat these instructions** until step (5), where to change to **“existing base”** option
- 12) **Errors might arise** if empty files are read, so remove them from the importing list
- 13) **Check that once the BOXER** files have been imported into the database, a **“Others”** tag does not appear in the **“Nuclide / Compound tree”**. If this tag exists, then, there is an issue in regard to cross-correlation covariance data, likely to be missing data for one of the two isotopes present in the cross-correlation matrix
- 14) At the end of this process, a **“db.h2.db”** file is created, plus the importing logs

□ Two distinct methods of **nuclear data adjustment methodologies**:

○ **Deterministic**

- Generalized Linear Least Squares (GLLS)

$$[E - C'(\sigma')]^T V_E^{-1} [E - C'(\sigma')] + [\sigma' - \sigma_0]^T V_\sigma^{-1} [\sigma' - \sigma_0] = \chi_{min}^2$$

Assumptions:

- Experimental and nuclear data are normally distributed
- Linear approximations between all observables
- Model and experimental data are uncorrelated

○ **Stochastic/Monte Carlo methods**

- Bayesian MC techniques -> direct application of Bayes' Theorem

$$(\sigma|E) \propto p_0(\sigma|\sigma_C, V_C) \times L(y_E, V_E|\sigma)$$

- To avoid the need to linearize non-linear models
- To handle model which are not necessarily normally distributed

□ Generalized Linear Least Squares (GLLS)

- First-order Taylor series approximation

$$C(\sigma) \approx C(\sigma_0) + S(\sigma - \sigma_0)$$

$$V_C \approx SV_{\sigma_0} S^T$$

- “A posteriori” mean and variance-covariance matrix

$$\sigma' = \sigma_0 + V_{\sigma_0} S^T [SV_{\sigma_0} S^T + V_E]^{-1} [E - C(\sigma_0)]$$

$$V_{\sigma'} = V_{\sigma_0} - V_{\sigma_0} S^T [SV_{\sigma_0} S^T + V_E]^{-1} SV_{\sigma_0}$$

$$C'(\sigma') \approx C(\sigma_0) + S(\sigma' - \sigma_0) = C(\sigma_0) + SV_{\sigma_0} S^T [SV_{\sigma_0} S^T + V_E]^{-1} [E - C(\sigma_0)]$$

$$V'_C \approx SV'_{\sigma} S^T = SV_{\sigma_0} S^T - SV_{\sigma_0} S^T [SV_{\sigma_0} S^T + V_E]^{-1} SV_{\sigma_0} S^T$$

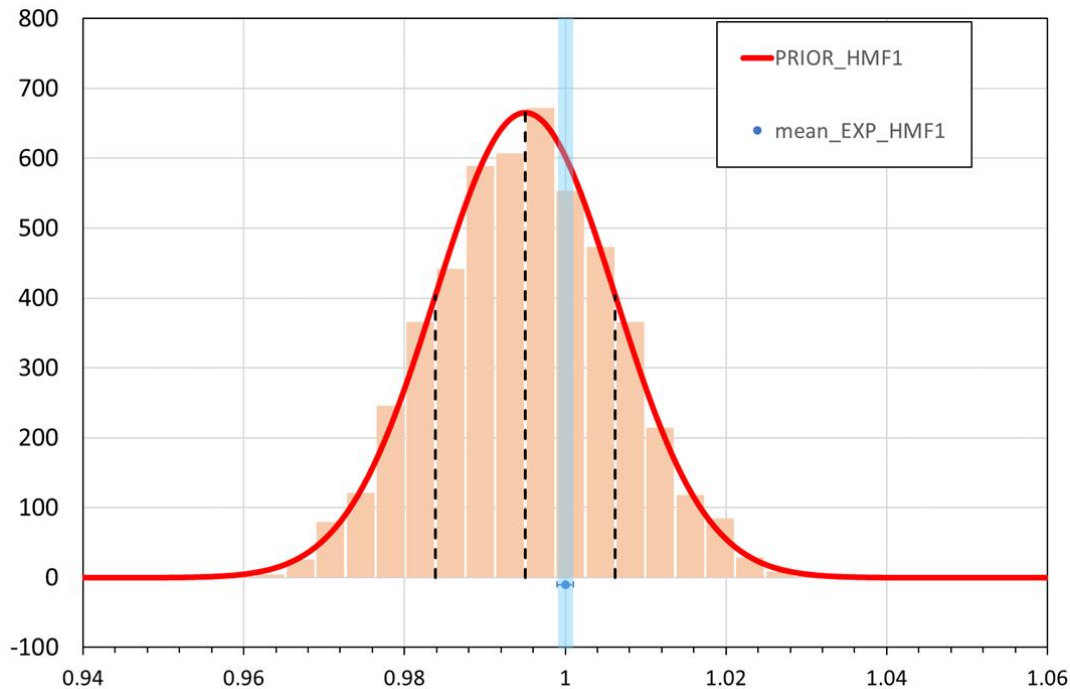
$$V'_E = V_E - V_E [SV_{\sigma_0} S^T + V_E]^{-1} V_E$$

$$V'_{E-\sigma} = V_E [SV_{\sigma_0} S^T + V_E]^{-1} SV_{\sigma_0}$$

GLLS: “This approach is a Bayesian approach in the sense that experimental data are used to adjust prior values. Although probability density functions are not considered explicitly.”



□ HMF1 – Godiva Benchmark

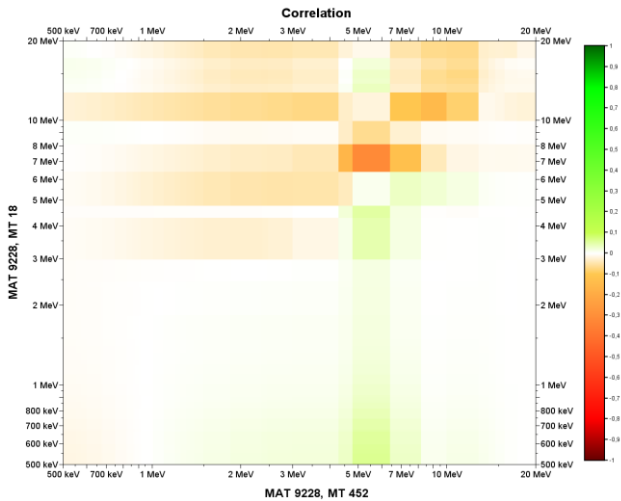


	HMF1	
	keff (MEAN)	Dkeff (STD)
PRIOR....	0.99504	0.01119
POST....	0.99992	0.00100

- **Exercise:** BMC adjustment with criticality
5000 random files 235U/TENDL2014
Calculations with MCNP6.1.1

Correlation: MT18 –MT452

PRIOR



POSTERIOR with HMF1

