

# Using Sensitivity Data in DICE to identify CIELO benchmarks, and the Nuclear Data and Sensitivity Testing Tool

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**WPEC Joint SG38-39-40 Meeting  
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## Overview

- **Sensitivity Data in DICE (Database for ICSBEP)**
- **Searching For CIELO Benchmarks with DICE**
- **Tools for Iron**
- **Sensitivity \* Perturbation =**
- **Nuclear Data and Sensitivity Testing Tool (NDaST)**

FYI: Sensitivity data tells you how much  $k_{\text{eff}}$  will change (%) if the nuclear data changes (%). [not discussing GPT at the moment...]

Fictional Example: I change the  $\text{U}^{238}$  fission cross section by 1% uniformly in energy. The sensitivity data tells me HMF-001  $k_{\text{eff}}$  will change by 0.05% or 50 pcm.

## DICE Sensitivity Data....Recently Much Improved!

Handbook Edition	Number of Unique Cases	Sources
2012	727	TSUNAMI1D+TSUNAMI3D [VALID]+ MMK-KENO
2013	3575	Previous + Non VALID cases SCALE6.0 from Balance Inputs
2014	4011	Previous + MCNP6* + SCALE6.2BClutch

Script and examples given those wishing to compute their own sensitivity data; including S. van der marck (Data tester), J. Bess (ICSBEP Chair), T.Kozlowski (UAM). Also participated in comparison of sensitivity data across codes, spearheaded by E.Ivanov.

	THERM	INTER	FAST	MIXED
PU	525/608	4/10	114/121	9/9
HEU	664/895	21/32	383/403	75/84
IEU	142/180	5/21	31/43	7/23
LEU	1424/1612	0/0	1/1	5/5
U233	186/197	29/29	8/10	8/8
MIX	323/436	2/7	40/67	1/26
SPEC	0/0	0/0	4/20	0/0

## DICE $k_{\text{eff}}$ Sensitivities Search

3 Group search, full 238 Group SDF's are stored and distributed. Thus you can do your own search in a different group structure...I'll even email you a script to do this if you ask me.

DICE

File Database=NEA Window Help

Critical / Subcritical Alarm / Shielding Fundamental Physics Correlation Matrix Rank Similar Keff trends plots

General items

- Identification
- Evaluator
- Internal reviewer
- Independent reviewer
- Varying parameter(s) across cases
- Laboratory
- Main purpose
- Title
- Keywords
- Dates (evaluation and experiment)
- References

Fuel

- Fuel form/Fissile material
- Fuel region
- U and Pu weight percent
- Pu/(U+Pu) ratio
- Moderator/coolant material
- Cladding material
- Reflector material
- Neutron absorbing material
- Separation material
- Geometry
- Benchmark Keff and Calculations

Energy, spectra, sensitivities

- Energy of Average Neutron Lethargy causing Fission
- Average Fission Group Energy
- Flux distribution (3-g)
- Fission distribution (3-q)
- Capture distribution (3-q)
- Neutron balance
- Neutron gas temperature
- Average fission neutrons per neutron absorbed in the core
- Keff Sensitivities**

Isotope

None selected

- 1 - H - Hydrogen
  - H1
  - H2
- 3 - Li - Lithium
- 4 - Be - Beryllium
- 5 - B - Boron
- 6 - C - Carbon
- 7 - N - Nitrogen
- 8 - O - Oxygen
- 9 - F - Fluorine
- 11 - Na - Sodium
- 12 - Mg - Magnesium

Combine with AND ☒ Combine with OR

Reaction

None selected

- capture
- elastic
- fission
- inelastic
- nubar
- scatter
- total

Combine with AND ☐ Combine with OR ☒

Total Keff sensitivity over all energy range

**Set Threshold** → Value :  +/- :  OR >=  <=  **Negative over here**

Keff sens. < 0.625 eV

Value :  +/- :

OR >=  <=

Keff sens. 0.625 eV - 100 keV

Value :  +/- :

OR >=  <=

Keff sens. > 100 keV

Value :  +/- :

OR >=  <=

Values between -1 and 1, in %dk/%Σ

Keff Sensitivities are currently available for about 75% of cases

**Also used!**

## Example: Iron Elastic Scattering Sensitivity

Search



Results

Isotope

- 17 - Cl - Chlorine
- 18 - Ar - Argon
- 19 - K - Potassium
- 20 - Ca - Calcium
- 22 - Ti - Titanium
- 23 - V - Vanadium
- 24 - Cr - Chromium
- 25 - Mn - Manganese
- 26 - Fe - Iron
  - Fe (natural)
  - Fe54
  - Fe56
  - Fe57
  - Fe58

Reaction

- None selected
- capture
- elastic
- fission
- inelastic
- nubar
- scatter
- total

☐ Combine with AND ☐ Combine with AND

Total Keff sensitivity over all energy range

Value :  +/- :

OR >= 0.05 <=

Keff sens. < 0.625 eV Keff sens. 0.625 eV - 1... Keff sens. > 100 keV

Value :  +/- :  Value :  +/- :  Value :  +/- :

OR >= <= OR >= <= OR >= <=

Values between -1 and 1, in %dk/%Σ

Keff Sensitivities are currently available for about 83% of cases

Evaluation identification	Title
PU-MET-FAST-015	IRON-REFLECTED ARRAY OF PLUTONIUM FUEL RODS
PU-MET-FAST-026	SPHERICAL ASSEMBLY OF 239PU(δ, 98%) WITH 11.9-CM STEEL REFLECTOR
PU-MET-FAST-028	STEEL-REFLECTED SPHERICAL ASSEMBLY OF 239PU(δ, 89%)
PU-MET-FAST-032	STEEL-REFLECTED SPHERICAL ASSEMBLY OF 239PU(a, 88%)
PU-MET-FAST-045	CRITICAL EXPERIMENTS PERFORMED FOR LAMPRE, THE LOS ALAMOS MOLTEN PLUTON
PU-MET-INTER-002	ZPR-6 ASSEMBLY 10: A CYLINDRICAL PLUTONIUM/CARBON/STAINLESS STEEL ASSEMB
HEU-MET-FAST-013	SPHERE OF HIGHLY ENRICHED URANIUM REFLECTED BY STEEL
HEU-MET-FAST-021	STEEL-REFLECTED SPHERICAL ASSEMBLY OF 235U(90%)
HEU-MET-FAST-043	HEU CYLINDERS AXIALLY REFLECTED BY STEEL
HEU-MET-FAST-072	ZEUS: FAST-SPECTRUM CRITICAL ASSEMBLIES WITH AN IRON - HEU CORE SURROUND
HEU-MET-FAST-075	ZPPR-20 PHASE C: A CYLINDRICAL ASSEMBLY OF U METAL REFLECTED BY BERYLLIUM
HEU-MET-FAST-084	HEU METAL CYLINDERS WITH MAGNESIUM, TITANIUM, ALUMINUM, GRAPHITE, MILD S
HEU-MET-FAST-085	HIGHLY ENRICHED URANIUM METAL SPHERES SURROUNDED BY COPPER, CAST IRON,
HEU-MET-INTER-001	THE URANIUM/IRON BENCHMARK ASSEMBLY: A 235U(93%)/IRON CYLINDER REFLECTE
HEU-SOL-THERM-033	HIGHLY ENRICHED URANYL NITRATE IN ANNULAR TANKS WITH CONCRETE REFLECTIO
HEU-SOL-THERM-038	WINCO SLAB TANKS: TWO INTERACTING TANKS OF HIGHLY ENRICHED URANYL NITRA
HEU-SOL-THERM-044	CONCRETE-REFLECTED URANYL NITRATE SOLUTION CYLINDER CONTAINING PERIODI
HEU-COMP-INTER-003	REFLECTED URANIUM-HYDRIDE CYLINDRICAL ASSEMBLIES

### Thermal/Intermediate/Fast/Total

Case identification	Isotope	Reaction	Keff sen...	Keff sen...	Keff sen...	Total K...
HEU-MET-INTER-001-001	Fe (natural)	elastic	-0.00011	0.02834	0.14435	0.17258
HEU-MET-INTER-001-001	Fe (natural)	elastic	-0.00011	0.02834	0.14435	0.17258
HEU-MET-INTER-001-001	Fe (natural)	elastic	-0.00011	0.02834	0.14435	0.17258
HEU-MET-INTER-001-001	Fe (natural)	elastic	-0.00011	0.02834	0.14435	0.17258
HEU-MET-INTER-001-001	Fe (natural)	elastic	-0.00011	0.02834	0.14435	0.17258
PU-MET-FAST-015-001	Fe (natural)	elastic	0	0.00741	0.1435	0.15091
PU-MET-FAST-026-001	Fe56	elastic	0	0.00499	0.11646	0.12145
MIX-MET-INTER-003-001	Fe56	elastic	-0.00008	0.02824	0.09205	0.12021
PU-MET-FAST-028-001	Fe56	elastic	0	0.00503	0.11054	0.11558
PU-MET-INTER-002-001	Fe56	elastic	-0.00004	0.03585	0.07886	0.11467
HEU-MET-FAST-085-003	Fe56	elastic	0	0.00697	0.09838	0.10535
SPEC-MET-FAST-014-001	Fe (natural)	elastic	0	0.00508	0.09818	0.10326
SPEC-MET-FAST-014-001	Fe (natural)	elastic	0	0.00508	0.09818	0.10326
SPEC-MET-FAST-014-001	Fe (natural)	elastic	0	0.00508	0.09818	0.10326
HEU-MET-FAST-021-001	Fe56	elastic	0	0.00564	0.09299	0.09863
IEU-MET-FAST-005-001	Fe56	elastic	0	0.00744	0.08338	0.09082
HEU-MET-FAST-013-001	Fe56	elastic	0	0.00407	0.06921	0.07328
HEU-SOL-THERM-044-004	Fe56	elastic	0.00468	0.03531	0.03254	0.07253
HEU-COMP-INTER-003-0...	Fe56	elastic	0.00009	0.02457	0.0472	0.07187
HEU-MET-FAST-072-003	Fe56	elastic	-0.00062	0.01469	0.05739	0.07147
HEU-MET-FAST-072-001	Fe56	elastic	0	0.00862	0.05755	0.06617
PU-MET-FAST-032-001	Fe56	elastic	0	0.00234	0.06304	0.06538
HEU-SOL-THERM-033-003	Fe (natural)	elastic	0.00196	0.0318	0.03131	0.06507
HEU-MET-FAST-084-007	Fe56	elastic	0	0.00349	0.0607	0.06419

Actually you don't even need the  
DVD to do this (just java)...  
google 'DICE ICSBEP'

Exercise: Use DICE to find good benchmarks for Fe56 testing.

Q: Would you find the same benchmarks as the existing test suites?

Q: Given the same 'loose' question, would two people involved with ICSBEP come up with similar benchmarks?

## Fun Exercise: Use DICE to find Fe56 benchmarks...compare to current testing suite

Eval-Case	Hill	Dyrda	Kahler	Trkov	KAPL	Eval-Case	Hill	Dyrda	Kahler	Trkov	KAPL
ALARM-CF-FE-SHIELD-001		X <sup>10</sup>				IMF006-001				X	
FUND-IPPE-VDG-MULTI-TRANS-001		X <sup>10</sup>			X	LCT001 <sup>5</sup>			*LCT017		
HCI003-004		X			X	LCT002 <sup>5</sup>			*LCT010		X
HCT014-001		X				LCT007 <sup>5</sup>					X
HCT014-002		X				LCT008 <sup>5</sup>					X
HMF013-011			X <sup>4</sup>	X		LCT010 <sup>5</sup>	X		X <sup>3</sup>		X
HMF021-001	X	X	X <sup>4</sup>	X	X	LCT017 <sup>5</sup>	X		X <sup>3</sup>		
HMF024-001			X <sup>4</sup>	X		LCT037 <sup>5</sup>					X
HMF033-001			X <sup>3</sup>			LCT042-001				X	
HMF034-003	X <sup>2</sup>		X <sup>3</sup>		X	LCT042-002				X	
HMF043-?	X <sup>2</sup>		X <sup>3</sup>			LCT043-?				X	
HMF085-003	X	X				LCT045-007	X				
HMF087-001	X <sup>2</sup>		X <sup>3,4</sup>	X		LMT015-?				X	
HMF088-001			X <sup>4</sup>	X		LST001 <sup>5</sup>					X
HMF088-002			X <sup>4</sup>	X		LST003 <sup>5</sup>					X
HMI001-001	X	X <sup>9</sup>		X		LST004 <sup>5</sup>					X
HMM006-001	X					LST007 <sup>5</sup>					X
HMM018-002		X				LST016 <sup>5</sup>					X
HMT013-001	X <sup>1</sup>	X		X		MCF001-001				X	
HMT015-001				X		MCF005-001				X	
HST001-001					X	MCF006-001				X	
HST024-001		X				MMF011-001					X
HST024-002		X				MMF011-002					X
HST032-001					X	MMI003-001	X				
HST038 <sup>5</sup>	X	X				PMF015-001	X	X <sup>9</sup>		X	
HST042-006					X	PMF025-001			X <sup>4</sup>	X	
HST044-004		X <sup>11</sup>				PMF026-001	X	X	X <sup>4</sup>	X	
HST044-031		X <sup>11</sup>				PMF028-001	X	X	X <sup>4</sup>	X	
ICT009-001		X				PMF032-001			X <sup>4</sup>	X	
IMF005-001	X			X	X	PMF045-007		X			
						PMI002-001	X			X	
						SPECMF014-001	X	X <sup>9</sup>			

Table of Benchmarks With Total Sensitivity Above Threshold

Element or Isotope	Threshold(pcm/% $\Sigma$ )	Benchmark Cases
Deuterium	>100	HST001(1-2), HST004(3-6),HST020(1-5), HCI006(6), HCT017(1-9), HCM002(7,10,11,20), LMT001(1),LMT002(1-12), LMT015(1-22)
Fe	<-100 >100	PMF015(1),PMF026(1),PMF028(1),PMI002(1),HMF021(1), HMF085(3),HMI001(1), IMF005(1),MMI003(1),SPECMF014(1), <b>HMI001(1)</b>
Cu	>100	PMF013(1),HMF072(1-3),HMF073(1),HMF085(1-2), HMI006(1-4),IMF020(2,4-5)
Gd <sup>157</sup>	<-100	PST034(3-6),HST014(3),HST016(2,3),LCT005(3,4,9-11), LCT052(1-6),MST006(4-6),MST007(3-7),MMCT004(4-6)
W	<-50 and >50	<b>HMF060(1),HMF067(1-2),HMF070(1-3),IMF014(2)</b> ,PMF005(1),HMF003(8-11), HMF049(3),HMF050(1),HMF084(14),HMF085(6)



## Missing Stuff + Limitations

- 1<sup>st</sup> order
- Not All Cases
- Used SCALE 238 Group Energy structure
- Reactions (Not all are loaded into database)
- Angular Sensitivity
- Correlations required for reactivity effect benchmarks (just launched a task force within ICSBEP for these)

## Next step

**Lofty Goal:** Given a new evaluation, give evaluators a tool to tell how the changes they've made will impact integral benchmarks...**in under 30 seconds.**

- Nuclear Data and Sensitivity Testing Tool

## Integrating Sensitivity Data With Nuclear Data

**Idea:** Potential scoping tool that leverages sensitivity data to make rapid predictions of the integral responses to changes in nuclear data.

- Changes and trends in  $\Delta k_{\text{eff}}$  for broad nuclear data perturbations
- Propagation of nuclear covariance data to benchmark C/E results

**Integral Data Sources:** Criticality (DICE), Reactor Physics (IDAT), Spent fuel (SFCOMPO), Numerical benchmarks, Shielding (SINBAD).

**Nuclear Data:** Evaluated nuclear covariance data files are accessible via the NEA JANIS application

A revival?

- Sensitivity analyses are successfully performed for decades
- NRG proposal: “3D uncertainty calculations with MCNP”  
A. Hogenbirk,  
S. van der Marck,  
JEF/DOC-1286,  
June 2009.

### Conclusions

- Automated 3D uncertainty calculations can easily be performed for all (benchmark) problems for which MCNP inputs exist
- Method works well for both shielding and  $k_{\text{eff}}$  benchmarks
- Method could be applied to exploit the large source of experimental benchmark data available
- Result: automated feedback to evaluator possible and hence reduced time for updated evaluation

JEFF Meeting, December 2010

OECD NEA – E. Dupont

### Sensitivity/Uncertainty tools

Status:

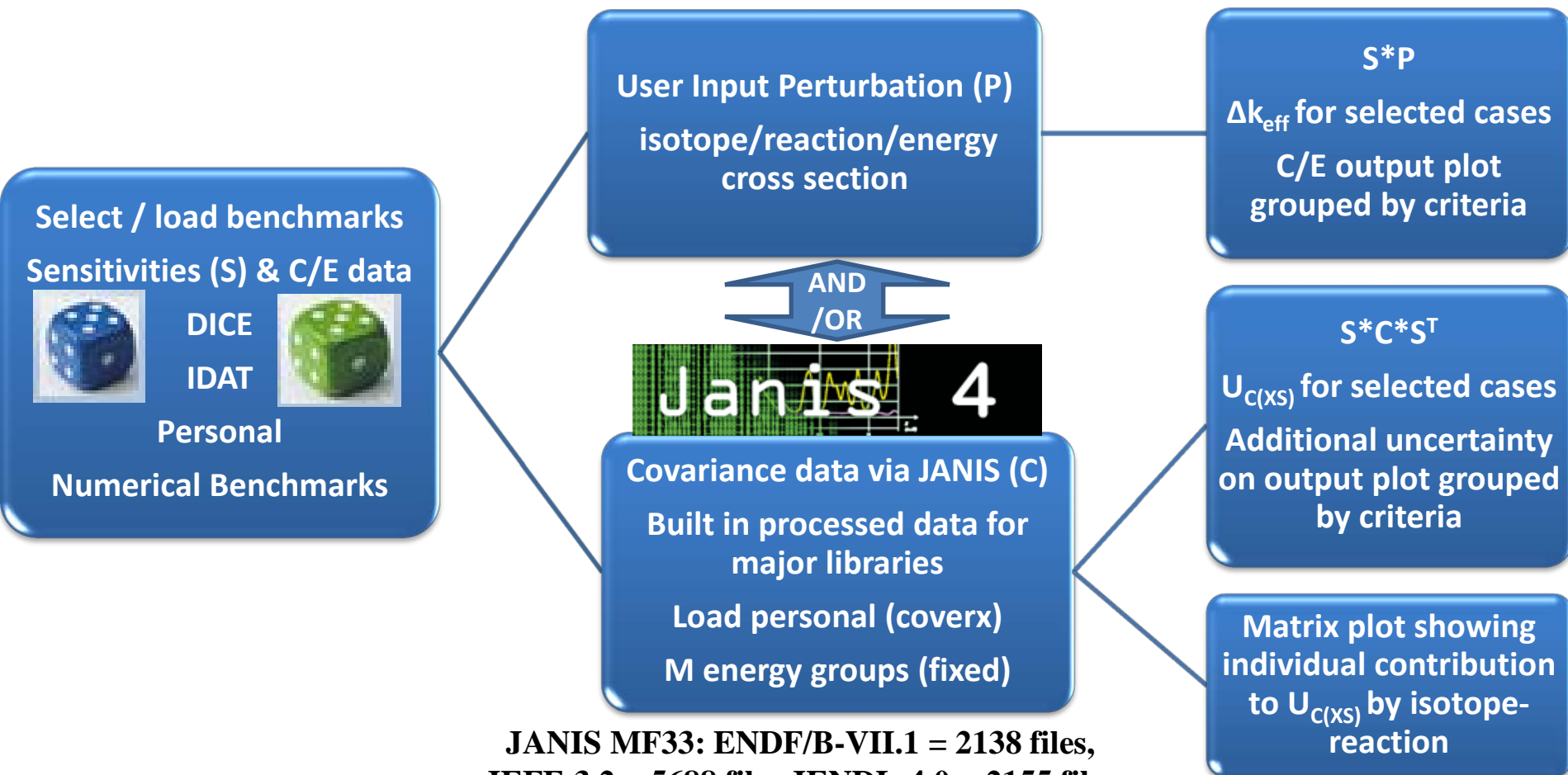
- \* Sensitivity/uncertainty tools were developed in the '70s and '80s
- \* No substantial recent developments
- \* Almost all tools based on deterministic methodology

*5 years later, NDaST is now being developed, a Web (Java based) tool. Currently in alpha. Summer beta version.*

*Contact [james.dyrda@oecd.org](mailto:james.dyrda@oecd.org) to become a beta user.*

## Nuclear Data Sensitivity Tool (NDaST) Flowchart

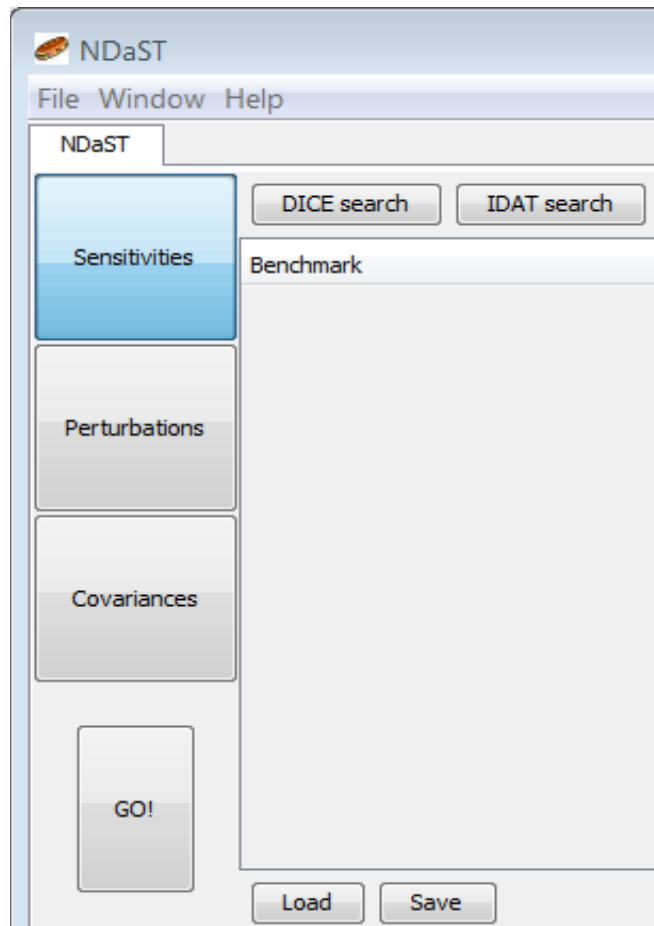
Benchmarks (Sensitivities) → Nuclear Data (% Change or Covariance) → Integral Results



**JANIS MF33: ENDF/B-VII.1 = 2138 files,  
JEFF-3.2 = 5688 files JENDL-4.0 = 2155 files  
TENDL-2013 = 77811 files**

## Panel 1: Select Benchmark Sensitivity Data

Currently can select benchmarks via DICE and IDAT criteria.  
Finalised search options are undergoing refinement.



- Save/load customised benchmark list e.g. CIELO, CSEWG
- Enable sending/sharing of datasets for inter-comparisons (xml files)
- Load personal case results & sensitivity data

NDaST - NDaST	
DICE search IDAT search	
Benchmark	Calculations
LST002-001	8 calc(s)
HMF032-002	6 calc(s)
PMF012-001	4 calc(s)
MCF005-001	3 calc(s)
HMF002-005	5 calc(s)
LMT015-004	2 calc(s)
IMF004-001 (Detailed Model)	5 calc(s)
HMF003-004	6 calc(s)
IMF003-001 (Detailed Model)	5 calc(s)
LCT043-004	6 calc(s)
LMT015-014	2 calc(s)
LCT043-003	6 calc(s)
HMF014-001	6 calc(s)
LMT015-012	2 calc(s)
HMF002-006	5 calc(s)

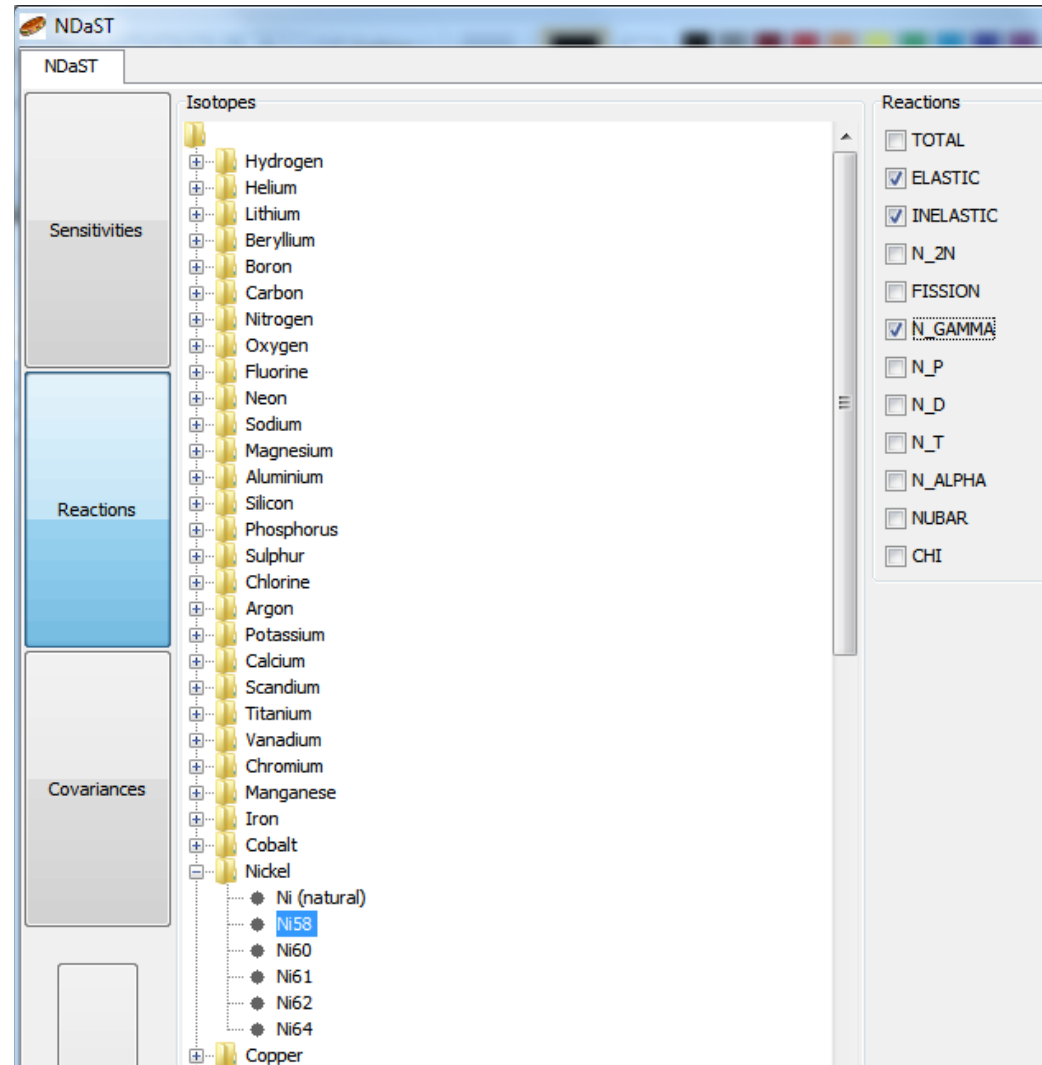
## Panel 2: Isotope-Reaction-Energy Perturbations

Each isotope-reaction represented by a column with N energy group rows

### Loading Options:

- Manually
- Loaded from file
- Auto-computed by dividing 2 evaluated files (via JANIS)

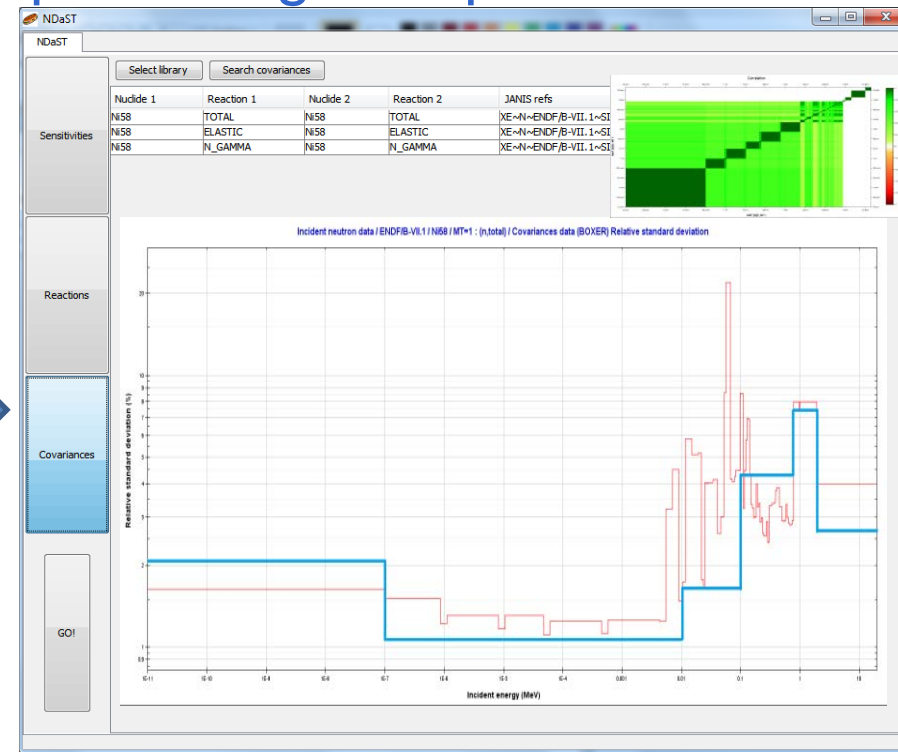
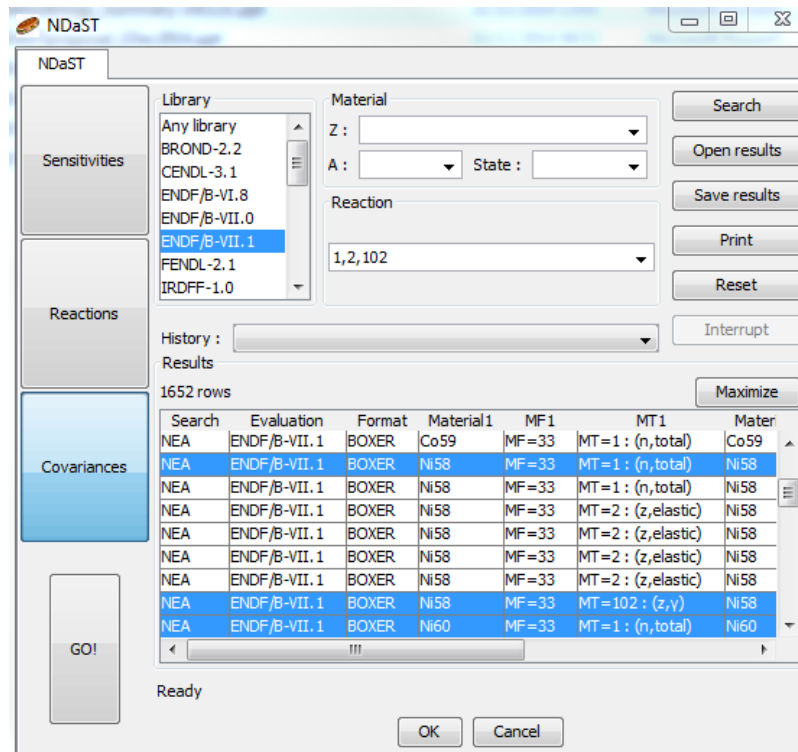
Example: *ENDF/B-VII.1*  
÷ *ENDF/B-VII.0*



## Panel 3: Select XS Covariance Data

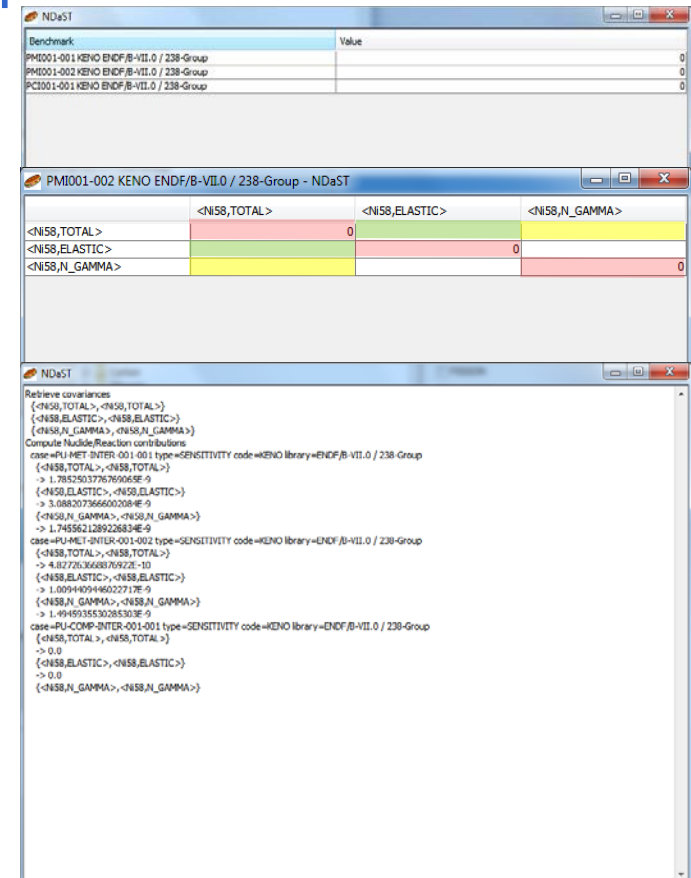
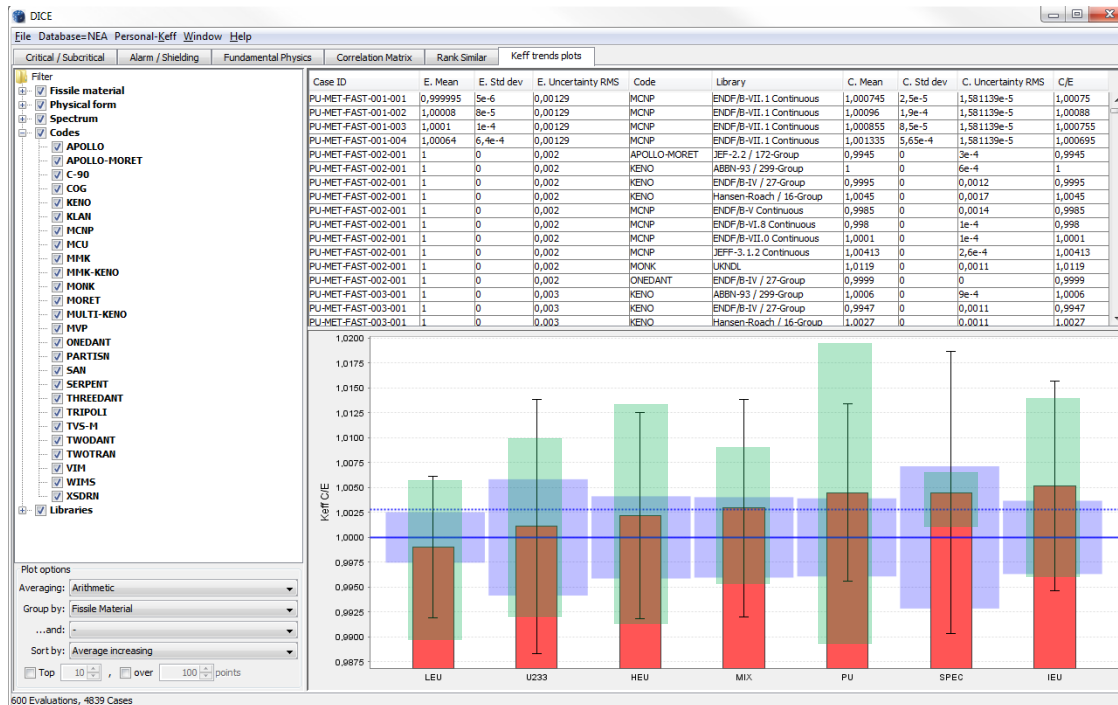
Covariance data selected from JANIS for uncertainty propagation calculation

- Correlation plot
- Relative standard deviations plotted against perturbations



## Output Windows and Plots

- Results panel showing individual results of  $C/E$  or  $\Delta k_{\text{eff}}/k_{\text{eff}}$  XS uncertainty and a grouped trend plot

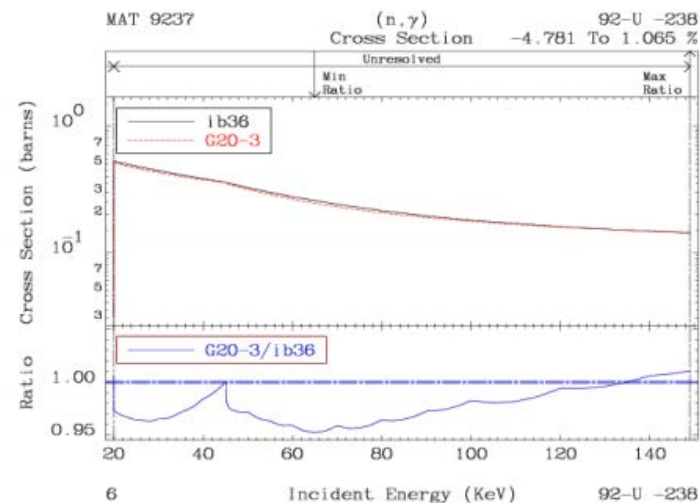
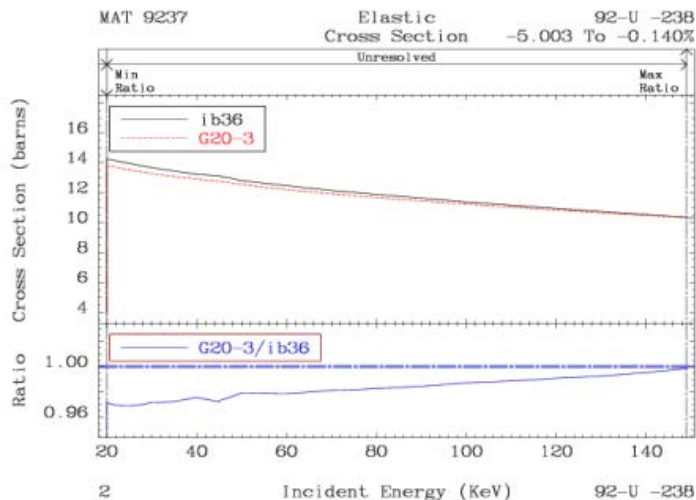


- Grouped metrics also to come
  - $C/E$  mean, st. dev., chi-square



## Example: $^{238}\text{U}$ CIELO

- Testing of integral benchmark experiments to iterations of the evaluated data
- <https://www-nds.iaea.org/CIELO/>
  - A. Trkov (IAEA), “Benchmarking of the CIELO  $^{238}\text{U}$  Evaluated Data File”, December 2014
- CIELO Files U238ib36 and U238ib36ur
  - amendments to URR cross section 20 keV – 149 keV





## Simple Benchmark Selection

The screenshot shows the NDaST (Nuclear Data Analysis Software Tool) interface. The main window is titled "NDaST" and has a menu bar with "File", "Window", and "Help". The interface is divided into several sections:

- Left Panel:** Contains a tree view of "Themes" and "Sensitivities". The "Themes" tree is expanded, showing "General items" (with "Identification" selected) and "Fuel". The "Sensitivities" section is also visible.
- Identification code section:** Contains three lists:
  - Fissile material:** None selected, (PU) - Plutonium, (HEU) - Highly Enriched Uranium (selected), (IEU) - Intermediate Enriched Uranium, (LEU) - Low Enriched Uranium, (U233) - Uranium-233, (MIX) - Mixed Plutonium - Uranium, (SPEC) - Special Isotope.
  - Physical form:** None selected, (MET) - Metal (selected), (SOL) - Solution, (COMP) - Compound, (MISC) - Miscellaneous.
  - Spectrum:** None selected, (FAST) - Fast (selected), (INTER) - Intermediate-Energy, (THERM) - Thermal, (MIXED) - Mixed.
- Subcritical section:** Contains radio buttons for "Critical and subcritical" (selected), "Critical", and "Subcritical".
- Acceptable section:** Contains radio buttons for "Acceptable and unacceptable", "Acceptable" (selected), and "Unacceptable".
- Query section:** Displays the current search criteria: "Fissile material = Highly Enriched Uranium and Physical form = Metal and Spectrum = Fast and Acceptable = Acceptable".
- History section:** A text box for entering search history.
- Buttons:** "GO!" (on the left), "Add selected search results to your benchmark set", "Cancel", and a large "Search !" button (highlighted with a red dashed box).
- Bottom Bar:** Shows "85 Evaluations, 385 Cases" and a progress bar indicating "107M of 773M".

## Addition of Benchmarks to Set

NDaST

File Window Help

NDaST

Select columns Refine search New search Horiz. Vert. Flat Plots ParPlots Spectra plots Sensitivity plots PDF HTML Balance

**Sensitivities**

- ☒ Benchmark Keff
- ☒ Benchmark Keff uncertainty
- Calculations
  - ☐ Calculated Keff
  - ☐ Calculated Keff uncertainty
  - ☐ C/E
- Energy, spectra, sensitivities
  - ☐ EALF (eV)
  - ☐ AFGE (eV)
  - ☐ Flux < 0.625 eV
  - ☐ Flux 0.625 eV - 100 keV
  - ☐ Flux > 100 keV
  - ☐ Fission < 0.625 eV
  - ☐ Fission 0.625 eV - 100 keV
  - ☐ Fission > 100 keV
  - ☐ Capture < 0.625 eV
  - ☐ Capture 0.625 eV - 100 keV
  - ☐ Capture > 100 keV
  - ☐ Neutron gas temperature (°K)
  - ☐ Avg fiss. neut. per neut. absorbed in the core
  - ☐ Keff Sensitivity < 0.625 eV (%dk/%Σ)
  - ☐ Keff Sensitivity 0.625 eV - 100 keV (%dk/%Σ)
  - ☐ Keff Sensitivity > 100 keV (%dk/%Σ)
  - ☐ Total Keff Sensitivity over all energy (%dk/%Σ)
- Calculation Files
  - ☐ Inputs
  - ☐ Balances
  - ☒ Sensitivities
  - ☐ Spectra

**Perturbations**

**Covariances**

GO!

Uncheck all

Apply

Add selected search results to your benchmark set Cancel

85 Evaluations, 385 Cases

76M of 773M

Evaluation identification	Title
HEU-MET-FAST-001	BARE, HIGHLY ENRICHED URANIUM SPHERE (GODIVA)
HEU-MET-FAST-002	TOPSY 8-INCH-TUBALLOY-REFLECTED ORALLOY ASSEMBLIES
HEU-MET-FAST-003	REFLECTED ORALLOY SPHERICAL ASSEMBLIES
HEU-MET-FAST-004	WATER-REFLECTED, HIGHLY ENRICHED URANIUM SPHERE
HEU-MET-FAST-005	BERYLLIUM- AND MOLYBDENUM-REFLECTED CYLINDERS OF HIGHLY ENRICHED URANIUM
HEU-MET-FAST-006	LATTICES OF ORALLOY CUBES IN WATER
HEU-MET-FAST-007	URANIUM METAL SLABS MODERATED WITH POLYETHYLENE, PLEXIGLAS, AND TEFLON
HEU-MET-FAST-008	BARE SPHERE OF HIGHLY ENRICHED URANIUM
HEU-MET-FAST-009	SPHERES OF HIGHLY ENRICHED URANIUM REFLECTED BY BERYLLIUM OR BERYLLIUM OXIDE
HEU-MET-FAST-010	SPHERES OF HIGHLY ENRICHED URANIUM REFLECTED BY BORON+BERYLLIUM OR BORON+BERYLLIUM OXIDE
HEU-MET-FAST-011	SPHERE OF HIGHLY ENRICHED URANIUM REFLECTED BY POLYETHYLENE
HEU-MET-FAST-012	SPHERE OF HIGHLY ENRICHED URANIUM REFLECTED BY ALUMINUM
HEU-MET-FAST-013	SPHERE OF HIGHLY ENRICHED URANIUM REFLECTED BY STEEL
HEU-MET-FAST-014	SPHERE OF HIGHLY ENRICHED URANIUM REFLECTED BY DEPLETED URANIUM
HEU-MET-FAST-015	UNREFLECTED CYLINDER OF HIGHLY ENRICHED URANIUM
HEU-MET-FAST-016	BERYLLIUM-REFLECTED AND BERYLLIUM OXIDE-REFLECTED CYLINDERS OF HIGHLY ENRICHED URANIUM
HEU-MET-FAST-017	BERYLLIUM-MODERATED AND -REFLECTED CYLINDER OF HIGHLY ENRICHED URANIUM
HEU-MET-FAST-018	BARE SPHERICAL ASSEMBLY OF 235U(90%)
HEU-MET-FAST-019	GRAPHITE-REFLECTED SPHERICAL ASSEMBLY OF 235U(90%)
HEU-MET-FAST-020	BERYLLIUM-REFLECTED SPHERICAL ASSEMBLY OF 235U(90%)

Case identification	Model	Benchmark Keff	Benchmark Keff uncertainty (1 σ)	Sensitivities Code	Sensitivities Library	Sensitivities
HEU-MET-FAST-001-001	Godiva	1.000	0.001	KENO	ABBN-93 / 299-Group	<a href="#">Sensitivity</a>
HEU-MET-FAST-001-001	Shell Model	1.000	0.001	KENO	ABBN-93 / 299-Group	<a href="#">Sensitivity</a>
HEU-MET-FAST-002-001	-	1.000	0.003	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
HEU-MET-FAST-002-002	-	1.000	0.003	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
HEU-MET-FAST-002-003	-	1.000	0.003	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
HEU-MET-FAST-002-004	-	1.000	0.003	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
HEU-MET-FAST-002-005	-	1.000	0.003	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
HEU-MET-FAST-002-006	-	1.000	0.003	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>

Windows taskbar: 09:52 23/04/2015

## Sensitive Benchmark Search

The screenshot shows the NDaST (Nuclear Data Analysis Software Tool) interface. The left sidebar contains a tree view with categories: Sensitivities, Perturbations, Covariances, and GO!. The 'Sensitivities' category is expanded, showing a list of parameters including 'Keff Sensitivities'. The main window is divided into several panels:

- Isotope:** A list of isotopes including 92 - U - Uranium (U232, U233, U234, U235, U236, U238), 93 - Np - Neptunium, and 94 - Pu - Plutonium. U238 is selected.
- Reaction:** A list of reactions including 'capture', 'elastic', 'fission', 'inelastic', 'nubar', and 'total'. 'capture' is selected.
- Query:** A text area containing the query: 'Acceptable = Acceptable and Isotope = U238 and Reaction = capture and Keff sens. 0.625 eV - 100 keV <= -0.15'.
- Results:** A table showing the results of the search. The first row is highlighted in red and contains the text '17 Evaluations, 92 Cases'.

The bottom status bar shows the system clock as 09:53 on 23/04/2015.

## Filter in Order of Sensitivity

NDaST

File Window Help

NDaST

Select columns Refine search New search Horiz. Vert. Flat Plots ParPlots Spectra plots Sensitivity plots PDF HTML Balance

**Sensitivities**

- ☐ Pu/(U+Pu) ratio
- ☒ Moderator/coolant
  - ☐ Moderator/coolant
  - ☐ Moderation ratio type
  - ☐ Moderation ratio
  - ☐ Moderator to fuel ratio
  - ☐ Moderator to fissile ratio
- ☒ Neutron absorbing mat.
  - ☐ Solid poison
  - ☐ Soluble poison
  - ☐ Concentration (g/L)
- ☒ Perturbations
  - ☐ Cladding
  - ☐ Reflector
  - ☐ Separator
- ☒ Geometry
  - ☐ Core geometry
  - ☐ Core description
  - ☐ Number of fissile units
  - ☐ Pitch type
  - ☐ Pitch (cm)
  - ☐ Fuel unit geometry
- ☒ Covariances
  - ☐ Fuel area composition
    - ☐ % Fissions
    - ☐ % Captures
  - ☒ Benchmark Keff and uncertainty
    - ☐ Benchmark Keff
    - ☐ Benchmark Keff uncertainty
  - ☒ Calculations
    - ☐ Calculated Keff
    - ☐ Calculated Keff uncertainty

GO!

Uncheck all Apply

Add selected search results to your benchmark set Cancel

17 Evaluations, 92 Cases

Evaluation identification	Title
IEU-COMP-INTER-005	ZPR-6 ASSEMBLY 6A: A CYLINDRICAL ASSEMBLY WITH URANIUM OXIDE FUEL AND SODIUM WITH A THICK DEPLETED-URANIUM BLANKET
LEU-COMP-THERM-005	CRITICAL EXPERIMENTS WITH LOW-ENRICHED URANIUM DIOXIDE FUEL RODS IN WATER CONTAINING DISSOLVED GADOLINIUM
LEU-COMP-THERM-015	THE VVER EXPERIMENTS: REGULAR AND PERTURBED HEXAGONAL LATTICES OF LOW-ENRICHED UO <sub>2</sub> FUEL RODS IN LIGHT WATER
LEU-COMP-THERM-026	WATER-MODERATED U(4.92)O <sub>2</sub> FUEL RODS IN 1.29, 1.09, AND 1.01 CM PITCH HEXAGONAL LATTICES AT DIFFERENT TEMPERATURES
LEU-COMP-THERM-033	REFLECTED AND UNREFLECTED ASSEMBLIES OF 2 AND 3%-ENRICHED URANIUM FLUORIDE IN PARAFFIN
LEU-COMP-THERM-045	PLEXIGLAS OR CONCRETE-REFLECTED U(4.46)308 WITH H/U=0.77 AND INTERSTITIAL MODERATION
LEU-COMP-THERM-048	LIGHT WATER MODERATED AND REFLECTED LOW-ENRICHED (3 WT. % 235U) URANIUM DIOXIDE ROD LATTICES
LEU-COMP-THERM-049	MARACAS PROGRAMME: POLYTHENE-REFLECTED CRITICAL CONFIGURATIONS WITH LOW-ENRICHED AND LOW-MODERATED URANIUM DIOXIDE
LEU-COMP-THERM-055	LIGHT-WATER MODERATED AND REFLECTED LOW-ENRICHED URANIUM (3 wt. % 235U) DIOXIDE ROD LATTICES
LEU-COMP-THERM-068	PLEXIGLAS-REFLECTED, CONCRETE-REFLECTED, OR THIN STEEL-REFLECTED U(4.48)308 WITH H/U=1.25 OR H/U=2.03 AND HEU DRIVERS
LEU-COMP-THERM-069	PLEXIGLAS-REFLECTED U(4.48)308 WITH H/U=1.25 OR H/U=2.03 AND INTERSTITIAL MODERATION
LEU-COMP-THERM-076	LIGHT WATER MODERATED AND REFLECTED LOW ENRICHED URANIUM (3 WT. % 235U) DIOXIDE ROD LATTICES WITH EX-CORE DETECTOR FE
LEU-COMP-THERM-094	VVER PHYSICS EXPERIMENTS: REGULAR HEXAGONAL (1.10 CM PITCH) TWO-REGION LATTICES OF LOW-ENRICHED U(6.5 AND 4.4 WT. % 235U)
MIX-COMP-FAST-001	ZPR-6 ASSEMBLY 7: A CYLINDRICAL ASSEMBLY WITH MIXED (PU,U)-OXIDE FUEL AND SODIUM WITH A THICK DEPLETED-URANIUM REFLECTOR
MIX-COMP-FAST-005	ZPR-9 ASSEMBLY 31: A CYLINDRICAL ASSEMBLY WITH MIXED (PU,U)-CARBIDE FUEL AND DEPLETED URANIUM CARBIDE BLANKET
MIX-COMP-FAST-006	ZPR-2: A CYLINDRICAL ASSEMBLY WITH MIXED (PU,U)-OXIDE FUEL AND SODIUM REFLECTED BY DU, SODIUM AND STEEL
MIX-MISC-FAST-001	K-INFINITY EXPERIMENTS FOR 238U IN FAST NEUTRON SPECTRA: MEASUREMENTS WITH ENRICHED URANIUM OR PLUTONIUM MIXED WITH D

Case identification	Isotope	Reaction	Keff sensitivity 0.625 eV - 100 keV (%dk/%Σ)	Sensitivities Code	Sensitivities Library	Sensitivities
LEU-COMP-THERM-005-013	U238	capture	-0.20415	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
LEU-COMP-THERM-068-015	U238	capture	-0.19876	MCNP	ENDF/B-VII.0 Continuous	<a href="#">Sensitivity</a>
LEU-COMP-THERM-068-015	U238	capture	-0.19876	MCNP	ENDF/B-VII.0 Continuous	<a href="#">Sensitivity</a>
LEU-COMP-THERM-068-015	U238	capture	-0.19876	MCNP	ENDF/B-VII.0 Continuous	<a href="#">Sensitivity</a>
LEU-COMP-THERM-049-004	U238	capture	-0.1984	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
LEU-COMP-THERM-049-003	U238	capture	-0.19687	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
LEU-COMP-THERM-049-002	U238	capture	-0.19618	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
LEU-COMP-THERM-033-049	U238	capture	-0.19518	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>
LEU-COMP-THERM-049-001	U238	capture	-0.19457	KENO	ENDF/B-VII.0 / 238-Group	<a href="#">Sensitivity</a>

71M of 773M

09:55  
23/04/2015

## Save and Load Customised xml File

NDaST - NDaST

DICE search IDAT search

	Benchmark	Calculations	Sensitivities
Sensitivities	LST002-001	8 calc(s)	1 sensitivity(ies)
	HMF032-002	6 calc(s)	1 sensitivity(ies)
	PMF012-001	4 calc(s)	1 sensitivity(ies)
	MCF005-001	3 calc(s)	1 sensitivity(ies)
	HMF002-005	5 calc(s)	1 sensitivity(ies)
Perturbations	LMT015-004	2 calc(s)	1 sensitivity(ies)
	IMF004-001 (Detailed Model)	5 calc(s)	1 sensitivity(ies)
	HMF003-004	6 calc(s)	1 sensitivity(ies)
	IMF003-001 (Detailed Model)	5 calc(s)	1 sensitivity(ies)
	LCT043-004		
	LMT015-014		
	LCT043-003		
	HMF014-001		
	LMT015-012		
	HMF002-006		
Covariances	LST002-002		
	MMI004-001		
	LCT008-008		
	PMF010-001		
	HMF003-006		
	MCF001-001		
	HMF003-005		
	LMT015-022		
	HMF013-001		
	LMT015-003		
	LMT015-013		
	HMF032-003		
	PMF041-001		
	HMF087-001		
	HMT015-001 (Detailed Model)		
HMF003-007			
LCT008-007			
LCT043-002			
	HMT013-002 (Detailed Model)		

GO!

Load Save

CIELO\_BMs.txt x

```

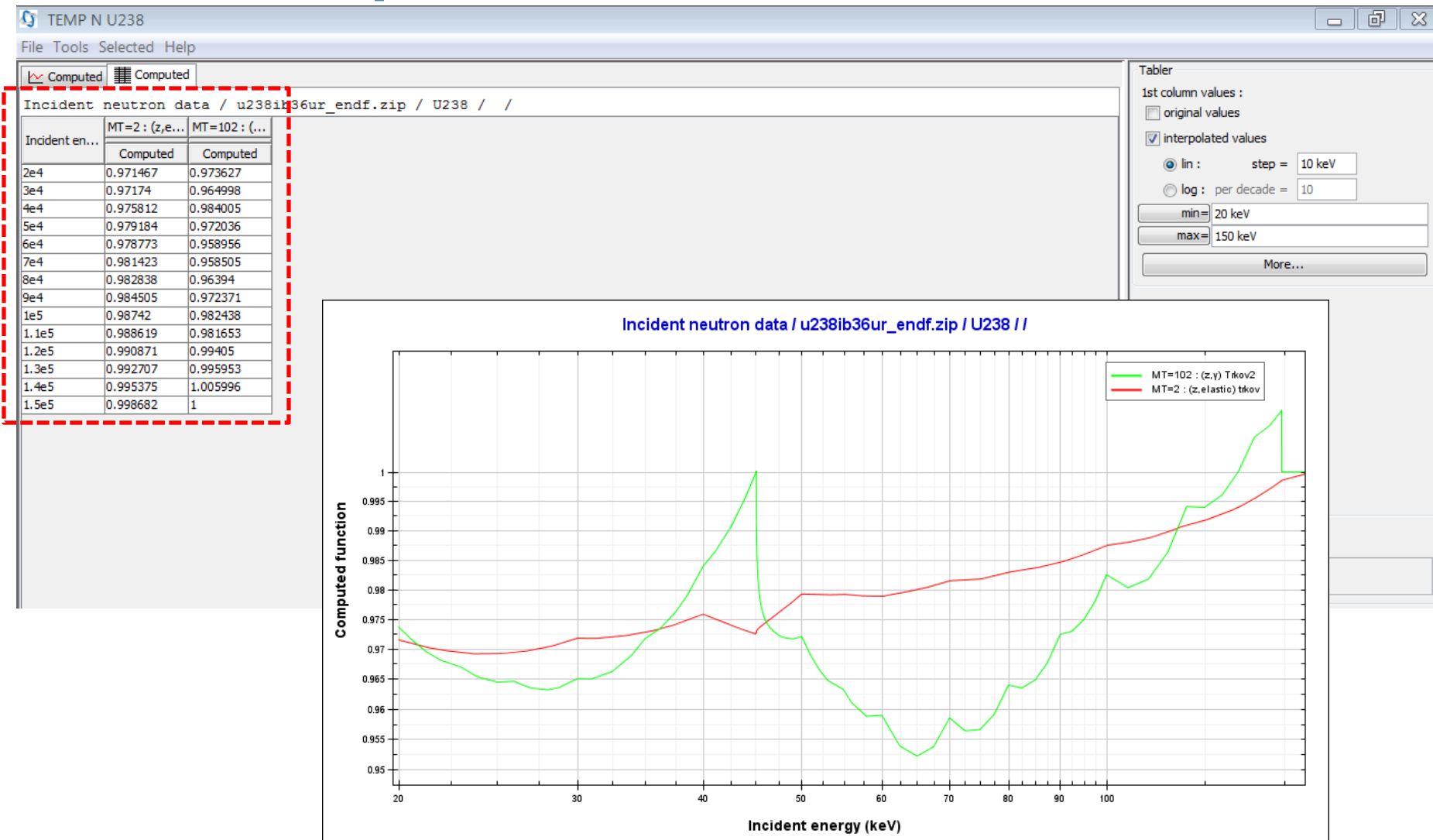
1 <benchmarks>
2   <benchmark>
3     <id type="DICE" case="HEU-MET-FAST-002-002" model=""/>
4     <exp val="1.0" unc="0.003"/>
5     <calc type="DICE" code="TWODANT" lib="ENDF/B-IV / 27-Group" freetext="" val="1.0079" unc="NaN"/>
6     <calc type="DICE" code="MCNP" lib="ENDF/B-V Continuous" freetext="" val="1.003" unc="0.001"/>
7     <calc type="DICE" code="KENO" lib="ABBN-93 / 299-Group" freetext="" val="1.002" unc="3.0E-4"/>
8     <calc type="DICE" code="KENO" lib="ENDF/B-IV / 27-Group" freetext="" val="1.0082" unc="9.0E-4"/>
9     <calc type="DICE" code="MONK" lib="UKNDL" freetext="" val="1.0118" unc="0.0011"/>
10    <calc type="DICE" code="KENO" lib="Hansen-Roach / 16-Group" freetext="" val="0.9973" unc="7.0E-4"/>
11    <sens type="DICE" case="HEU-MET-FAST-002-002" code="KENO" lib="ENDF/B-VII.0 / 238-Group"/>
12  </benchmark>
13  <benchmark>
14    <id type="DICE" case="LEU-MET-THERM-015-022" model=""/>
15    <exp val="1.0" unc="0.0051"/>
16    <calc type="DICE" code="MCNP" lib="ENDF/B-VI Continuous" freetext="" val="1.0025" unc="5.0E-4"/>
17    <calc type="DICE" code="KENO" lib="ABBN-93 / 299-Group" freetext="" val="1.0048" unc="2.0E-4"/>
18    <sens type="DICE" case="LEU-MET-THERM-015-022" code="KENO" lib="ENDF/B-VII.0 / 238-Group"/>
19  </benchmark>
20  <benchmark>
21    <id type="DICE" case="LEU-SOL-THERM-007-002" model=""/>
22    <exp val="0.9973" unc="9.0E-4"/>
23    <calc type="DICE" code="MCNP" lib="JENDL-3.2 Continuous" freetext="" val="1.0034" unc="2.0E-4"/>
24    <calc type="DICE" code="MCNP" lib="ENDF/B-V Continuous" freetext="" val="0.9992" unc="7.0E-4"/>

```

09:59  
23/04/2015



## Computation of Ratios in JANIS



## Addition of Reactions and Perturbations

NDaST

File Window Help

NDaST

Sensitivities

Perturbations

Covariances

GO!

Isotopes

- Hafnium
- Tantalum
- Tungsten
- Rhenium
- Iridium
- Gold
- Mercury
- Lead
- Bismuth
- Thorium
- Protactinium
- Uranium
  - U232
  - U233
  - U234
  - U235
  - U236
  - U238**
- Neptunium
- Plutonium
- Americium
- Curium
- Californium

Reactions

- ☐ TOTAL
- ☒ ELASTIC
- ☐ INELASTIC
- ☐ N\_2N
- ☐ FISSION
- ☒ CAPTURE
- ☐ N\_GAMMA
- ☐ N\_P
- ☐ N\_D
- ☐ N\_T
- ☐ N\_ALPHA
- ☐ NUBAR
- ☐ CHI

Selected Isotopes/Reactions

Nuclide	Reaction
U238	ELASTIC
U238	CAPTURE

Perturbations

E=  eV

Energy group	<U238,ELASTIC>	<U238,CAPTURE>
[120000.0, 130000.0]	0.991	0.994
[130000.0, 140000.0]	0.993	0.996
[140000.0, 150000.0]	0.995	1.006
[150000.0, 2.0E7]	1	1

17 Evaluations, 92 Cases

83M of 773M

10:01  
23/04/2015

## JANIS Covariance Search

NDaST

File Window Help

NDaST

Sensitivities

Perturbations

Covariances

GO!

Library

Any library  
BROND-2.2  
CENDL-3.1  
ENDF/B-VI.8  
ENDF/B-VII.0  
ENDF/B-VII.1  
FENDL-2.1  
IRDF-2002

Material

Z : 92 (U) Uranium  
A : 238  
State :  
Reaction  
2,102

History :  
Results

Search

Open results  
Save results  
Print  
Reset  
Interrupt  
Maximize

Search	Evaluation	Format	Material1	MF1	MT1	Material2	MF2	MT2
NEA	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=2 : (z,elastic)
NEA	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=4 : (z,n')
NEA	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=16 : (z,2n)
NEA	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=17 : (z,3n)
NEA	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	BOXER	U238	MF=33	MT=102 : (z,y)	U238	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	ENDF	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=2 : (z,elastic)
NEA	ENDF/B-VII.1	ENDF	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	ENDF	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	ENDF	U238	MF=33	MT=102 : (z,y)	Au197	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	ENDF	U238	MF=33	MT=102 : (z,y)	U235	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	ENDF	U238	MF=33	MT=102 : (z,y)	U238	MF=33	MT=102 : (z,y)
XE	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=2 : (z,elastic)
XE	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=4 : (z,n')
XE	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=16 : (z,2n)
XE	ENDF/B-VII.1	BOXER	U238	MF=33	MT=2 : (z,elastic)	U238	MF=33	MT=17 : (z,3n)

Ready

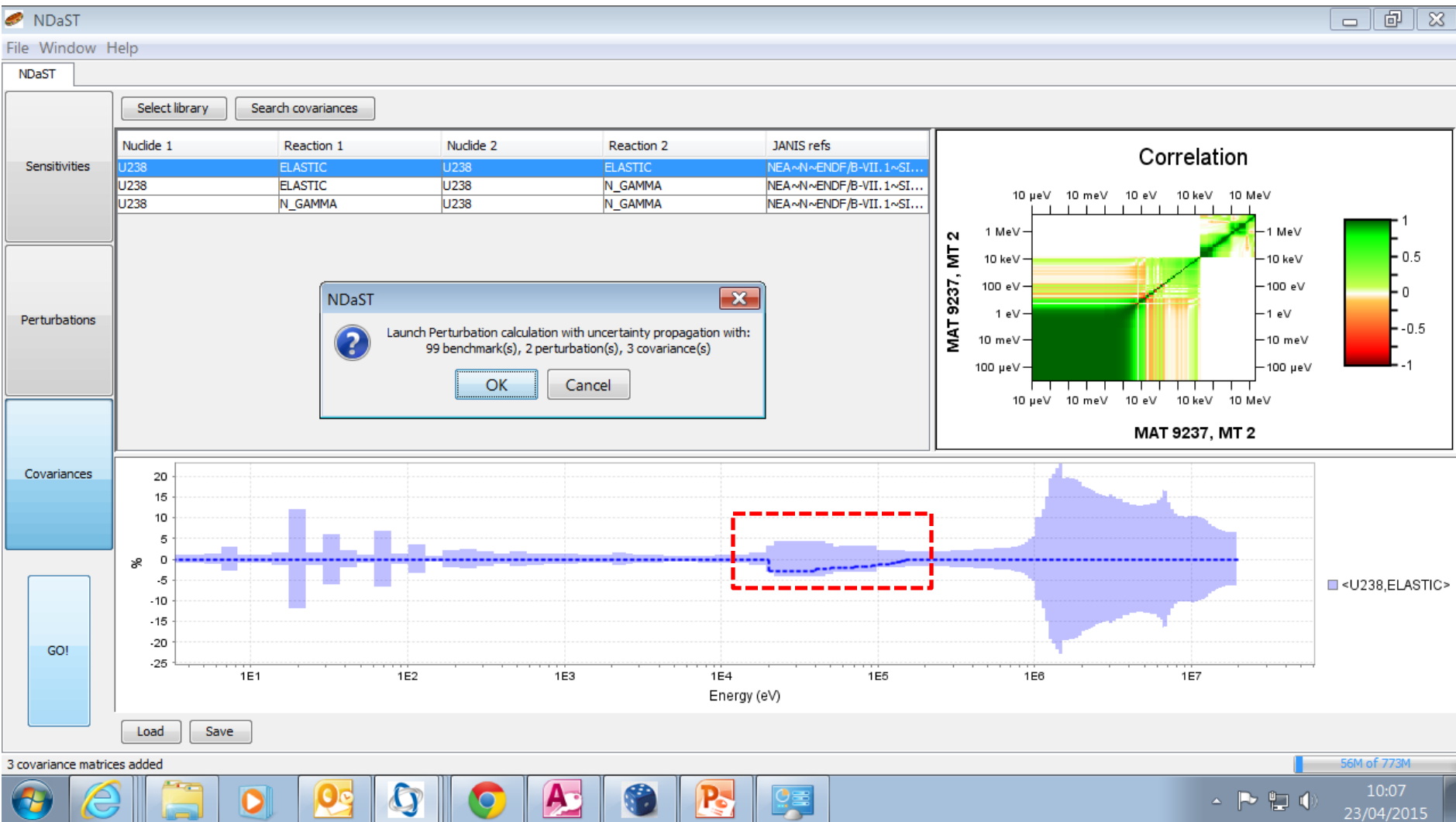
OK Cancel

30M of 773M

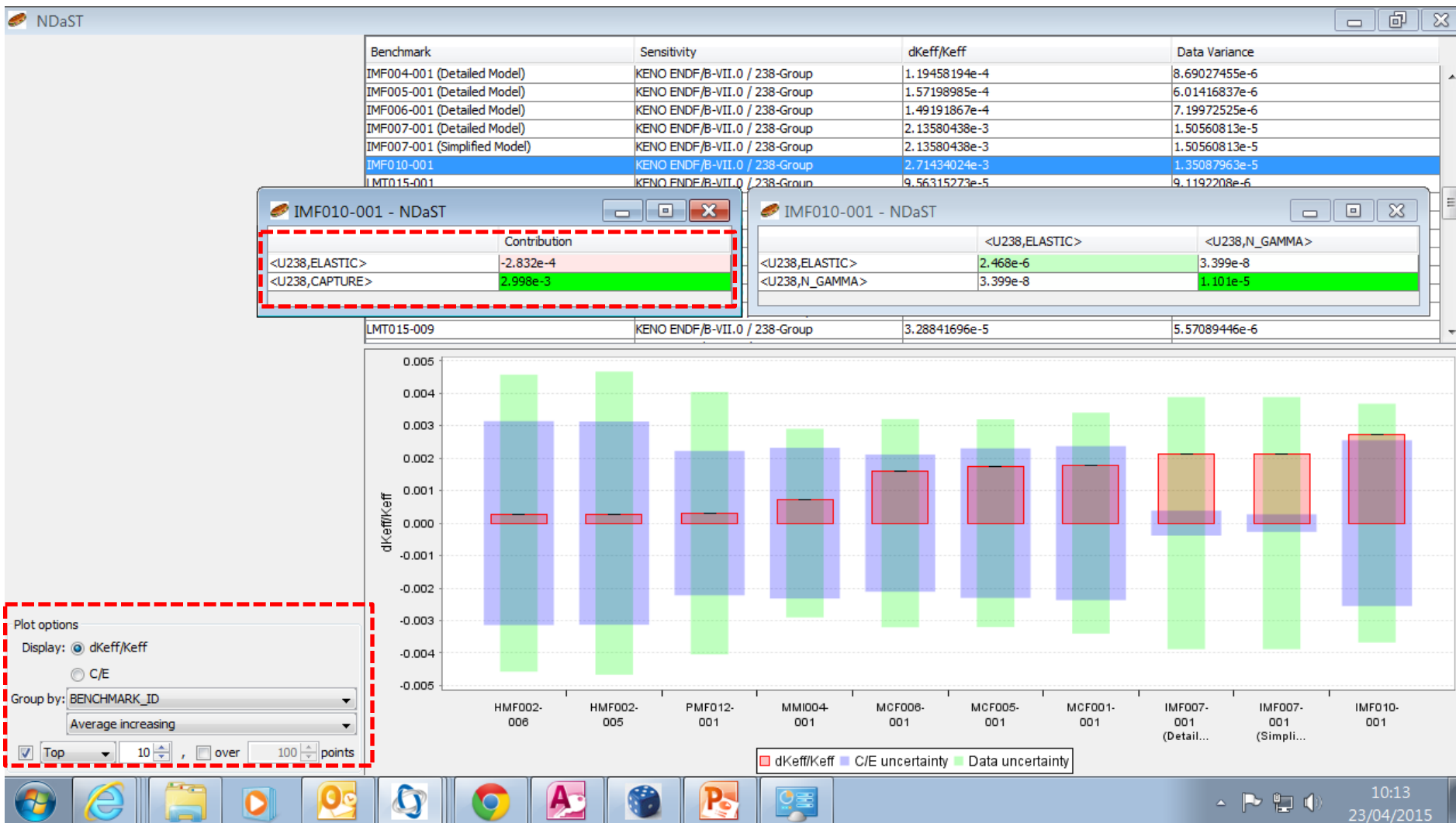
10:05  
23/04/2015



## Visualisation of Covariance



## Delta $k_{\text{eff}}$ Output and Plot



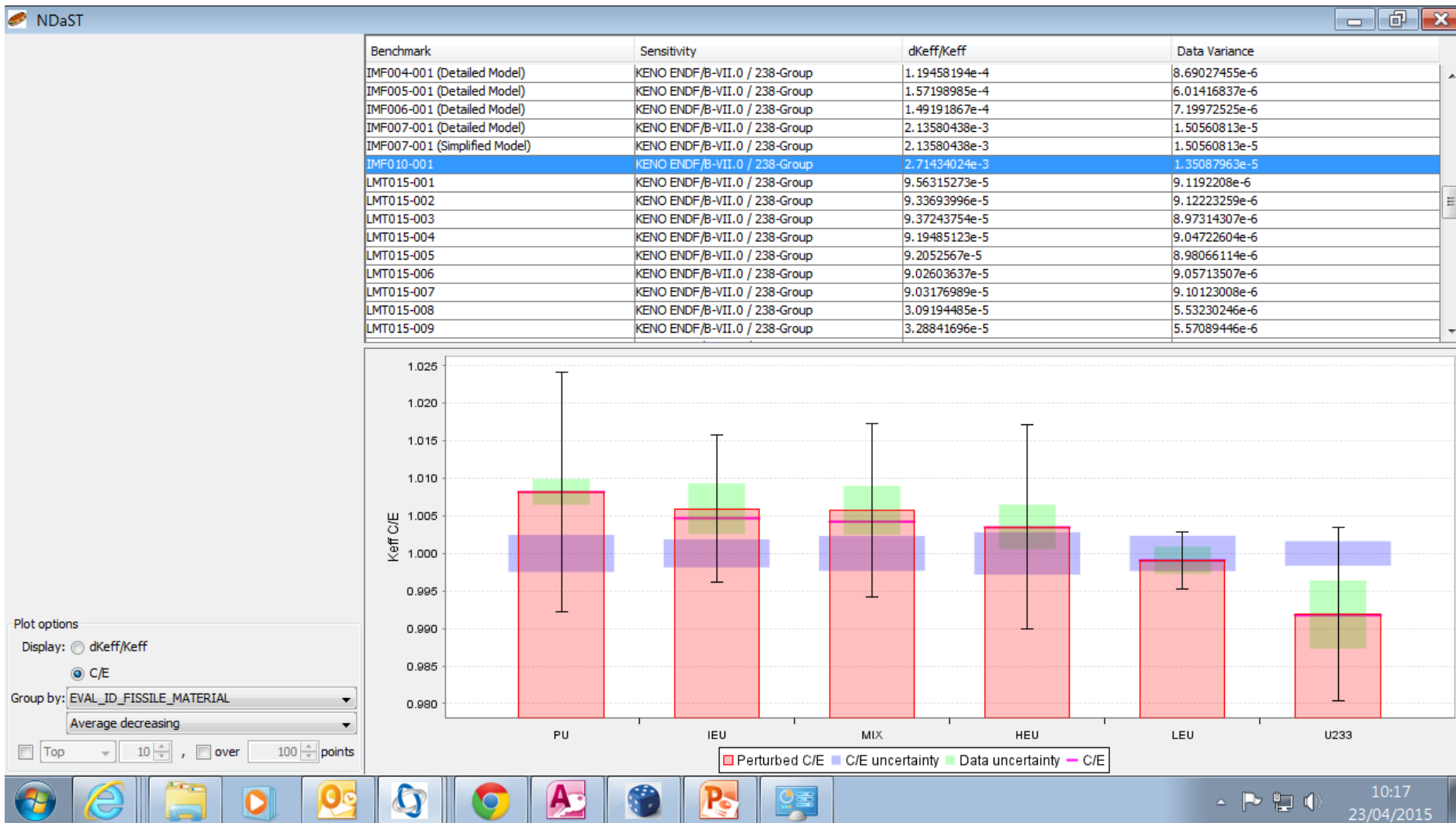
## Refinement of Sensitive Benchmarks

ICSBEP Evaluation ID	Experiment Name	Sensitivity File	Delta-k/k	ND Uncertainty
IMF010-001	ZPR-6/9(U9)	KENO ENDF/B-VII.0 / 238-Group	0.00271	0.00368
IMF007-001 (Detailed Model)	Big Ten	KENO ENDF/B-VII.0 / 238-Group	0.00214	0.00388
IMF007-001 (Simplified Model)	Big Ten	KENO ENDF/B-VII.0 / 238-Group	0.00214	0.00388
MCF001-001	ZPR-6/7	KENO ENDF/B-VII.0 / 238-Group	0.00178	0.00340
MCF005-001	ZPR-9/31	KENO ENDF/B-VII.0 / 238-Group	0.00175	0.00320
MCF006-001	ZPPR-2	KENO ENDF/B-VII.0 / 238-Group	0.00160	0.00321
MMI004-001	ZPR-3/53	KENO ENDF/B-VII.0 / 238-Group	0.00071	0.00290

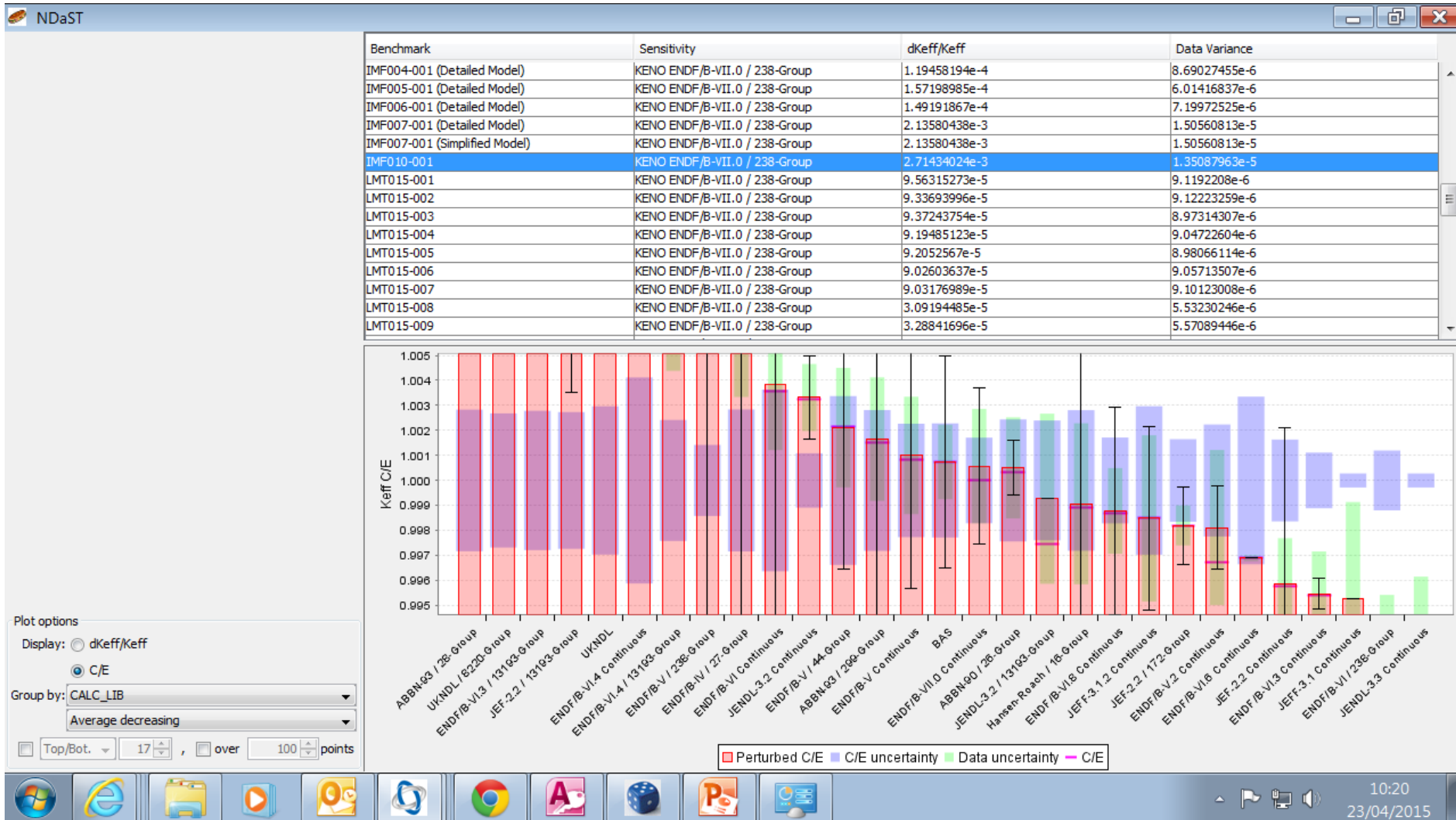
Cases shown with a >50 pcm effect due to this specific perturbation

- Energy breakdown also to be developed and included
- Cases to be run by rigorous calculation can be refined / minimised
- Allows analysis of competing effects at low computational cost
- An extra level of QA / checking has been performed

## C/E Output Plot by Fissile Material



## C/E Output Plot by Data Library



## Summary

- ✓ 4011 cases (>80%) have 3 group sensitivity data and full sensitivity profiles within DICE – many also in IDAT
- ✓ Useful tool for identifying possible benchmarks, complements existing methods
- ✓ An open web-based JAVA tool named NDaST is being developed to take advantage of these data – beta testers welcomed!
- ✓ Complement to full testing calculations e.g. via the NEA Nuclear Data Evaluation Cycle (NDEC)
- ✓ Enable rapid scoping of changes to nuclear data and to propagate nuclear covariance data uncertainties