

# Status of NEA Nuclear Data Tools

## **DICE & NDaST**

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**Working Party on Evaluation Co-Operation (WPEC)**

**SG-39 Meeting**

**May 16-17, 2017**

**OECD Conference Centre, Paris**

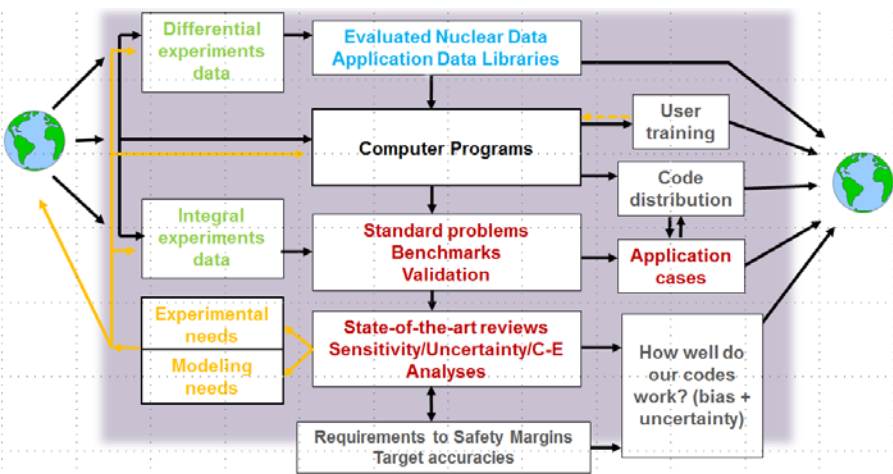


# Science and the 'Knowledge Machine'

ar Er

## DICE

## UACSA



- Find Criticality Benchmarks
- Store Experimental Correlations
- Trending Tool
- Sensitivity Coefficients

- Uncertainty Analysis in Criticality Safety
- Tools for uncertainty analysis+Covariance

## NDaST

## VANDAL

## NDEC

## CIELO



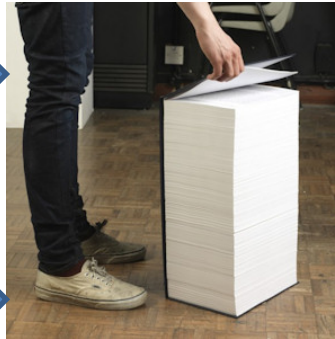
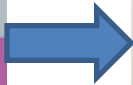
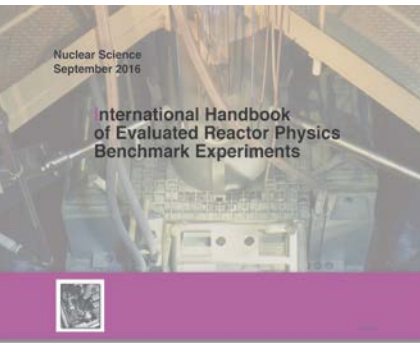
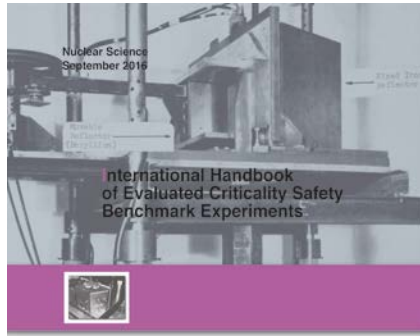
- Link DICE+JANIS
- Leverage Sensitivities
- Perform Uncertainty Propagation

- Agree on Validation inputs
- Tests for Inputs
- Store Inputs

- Nuclear data evaluation cycle
- Similar to ADVANCE

- Collaboration between libraries
- Important XS's being revised

## Nuclear Science – Data Bank ‘Knowledge Machine’ Accessing Benchmarks

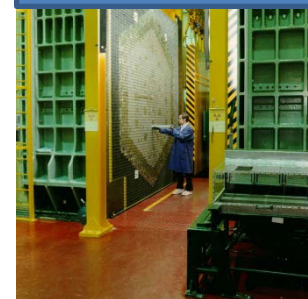


ICSBEP Handbook: 4913 Benchmarks  
IRPhE Handbook: 898 Benchmarks  
CSNI Documents: ~250 Benchmarks

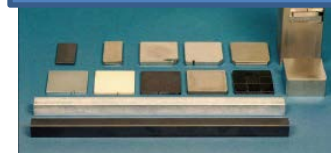
UK: ZEBRA



USA: ZPPR



GER: SNEAK



Standard problems  
Benchmarks  
Validation



How well do our  
codes work?  
(bias +  
uncertainty)



NEA Databases  
And Tools  
Examples: DICE, IDAT

## Integral Experiments for Criticality Safety

### International Criticality Safety Benchmark Evaluation Project (ICSBEP)

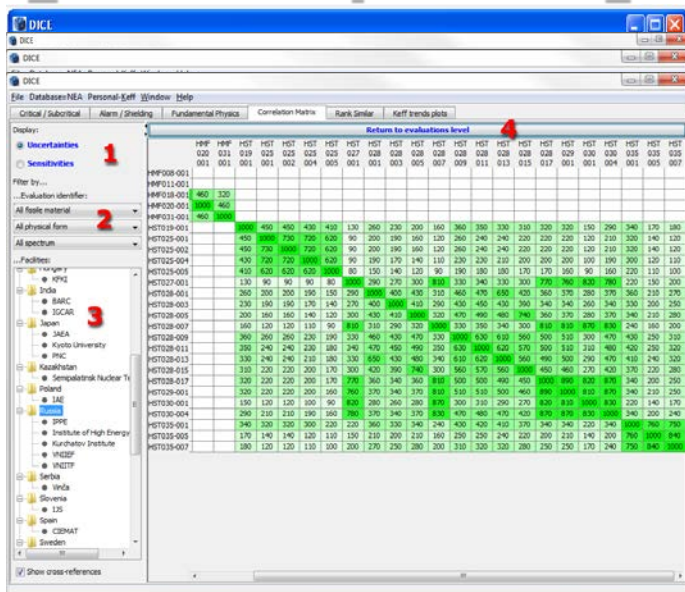
- Est 1992/1995. Handbook Released Yearly
- ICSBEP Handbook contains criticality benchmark data

The latest edition of the Handbook contains

- 4913 critical, near-critical and sub-critical configurations
- 231 alarm/shielding and fundamental physics experiments
- Distributed on DVD, available on-line



### Database for the International Criticality Safety Benchmark Evaluation Project (DICE)



- Allows easy access to benchmark data and supplemented calculated data (neutron balance, flux, reaction rate,  $k_{\text{eff}}$  sensitivity to neutron cross sections, C/E from several codes/cross-section sets etc. )
- Trend and identify suitable benchmark experiments
- Included on the ICSBEP Handbook DVD, available on-line
- On-going work on experimental correlations

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



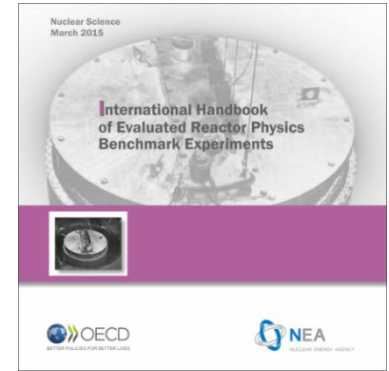
## Integral Experiments for Reactor Physics

### International Reactor Physics Experiment Evaluation (IRPhE) Project

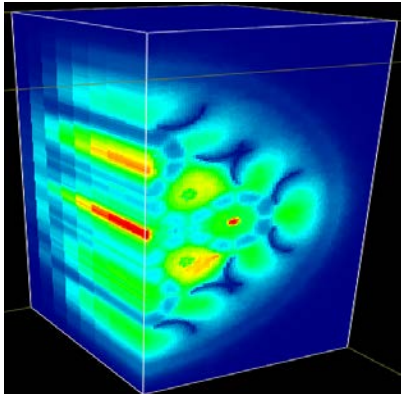
- Initiated by NEA/NSC in 1999
- IRPhE Handbook contains benchmark data for reactor-type experiments:  
reactivity effects/coefficients, spectral indices,  
reaction rates, kinetic parameters, and others

The 2015 edition of the Handbook contains

- 898 experiments performed at 50 nuclear facilities  
47 series performed at Research Reactors including TRIGA Mark II (Slovenia, USA), ATR (USA), HTTR and JOYO (Japan), HTR-1 (China) and others
- Distributed on DVD, available on-line



### International Reactor Physics Handbook Database and Analysis Tool (IDAT)



- Released in 2013
- Allows easy access to benchmark data and supplemented calculated data
- Trend and identify suitable benchmark experiments
- Included on the IRPhE Handbook DVD, available on-line

<https://www.oecd-nea.org/science/wprs/irphe/>

## Increasing the Speed of Validation! NDaST tool

Website: [www.oecd-nea.org/ndast/](http://www.oecd-nea.org/ndast/)

**Evaluated Nuclear Data  
Application Data Libraries**

**NEA Databases  
And Tools  
Example: JANIS**

- ✓ An open web-based JAVA tool to take advantage ICSBEP and IRPhE benchmark case nuclear data sensitivities
- ✓ Enables rapid scoping of changes to nuclear data and to propagate nuclear covariance data uncertainties
- ✓ It also gives access to JANIS for automation of computations and use of processed nuclear covariance data
- ✓ 2016 marks the full release, new features to be added on an annual basis as needed by users



**NDaST**

**NEA Databases  
And Tools  
Examples: DICE, IDAT**

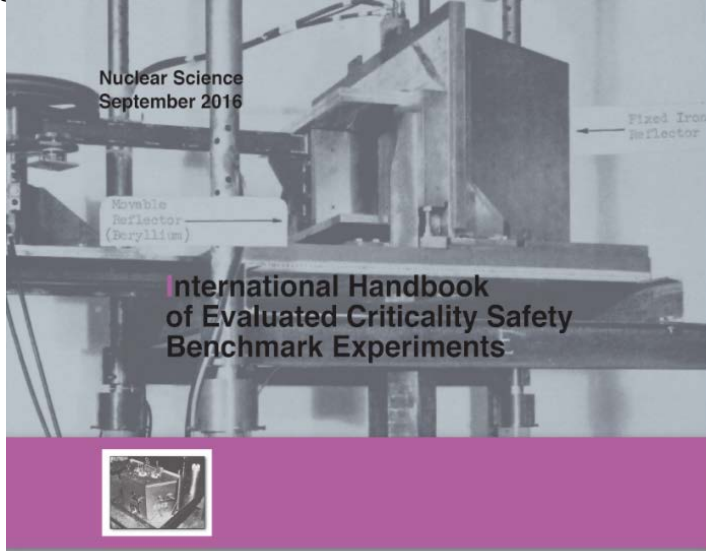


**Code bias  
and  
uncertainty  
for nuclear  
applications**

## *Database for ICSBEP (DICE)*

### Handbook (est 1992/1995)

**4913 Critical and Subcritical Benchmarks,  
Organized by Fissile Material, Form and Fission**



Technical review group met Apr 18th-19<sup>th</sup>  
2016 @NEA

6 New evaluations reviewed  
7 Revisions discussed

### DICE

## *Answers How to Efficiently Search the Handbook*

- Distributed with Handbook since 2001
- Relational database
- User Friendly Way to Search

- 1) New Sensitivity Data Angular Scattering
- 2) Read Local keffs [Links to other tools]
- 3) Input files retrievable from DICE [VANDAL]
- 4) Ability to generate XML files of returned benchmark cases
- 5) Stores Correlation Data

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

## Status: DICE Sensitivity Coefficients

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
2015	4065	Previous + New Cases
2016	~4200	Previous + New Cases + P1 Sensitivities [~400 cases]

**Sensitivity Coefficients are guides to which benchmarks may be good for testing nuclear data changes!**

In all TSUNAMI studies, most significant effort is generation of sensitivity data for experiments from ICSBEP handbook.

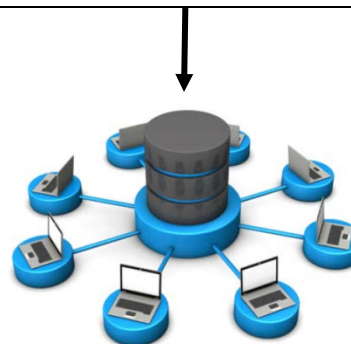
#1 request from TSUNAMI users is to have TSUNAMI data distributed with ICSBEP Handbook for use in scoping calculations.



**NEA Databases  
And Tools**  
Examples: DICE, IDAT

Original cost estimate for sensitivity data \$100,000 per 100 cases

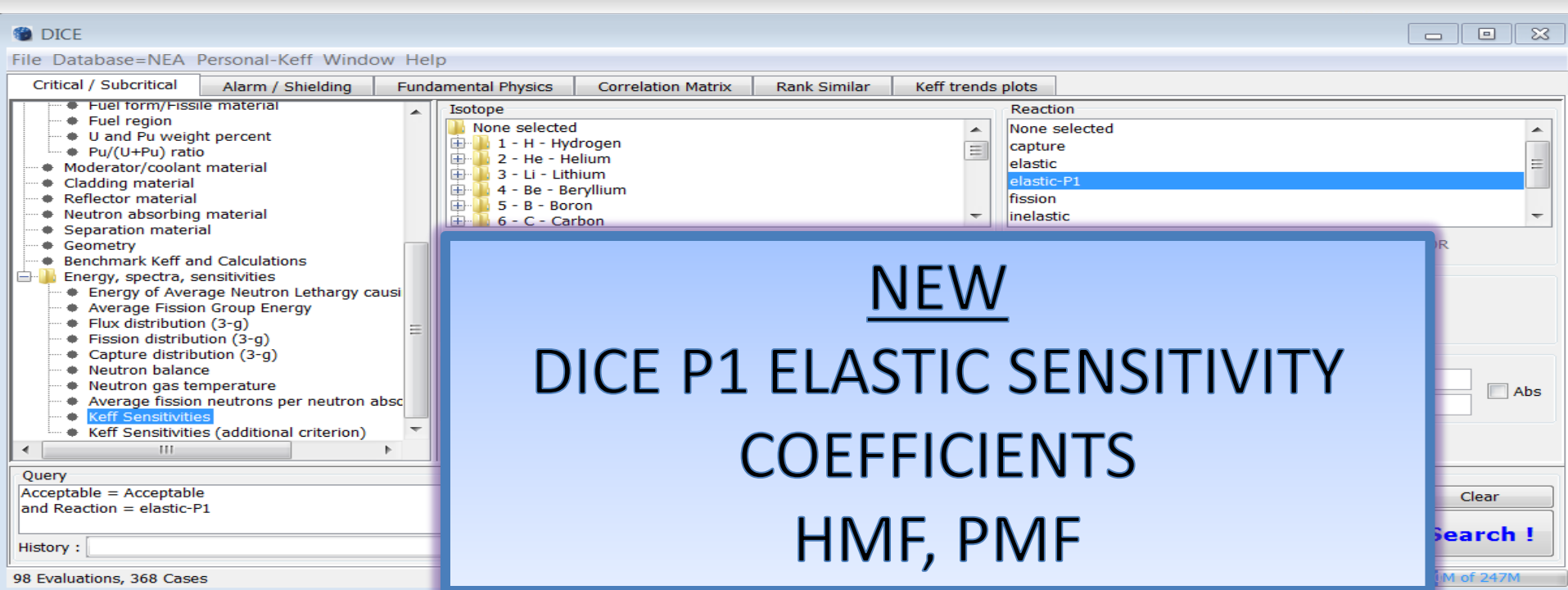
**Standard problems  
Benchmarks  
Validation**



**Code bias  
and  
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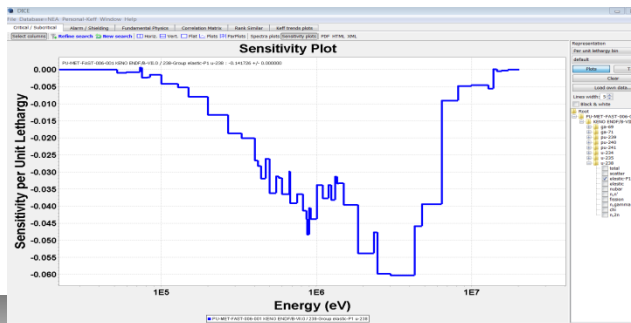


JANIS  
DD-XS,XS,P1

MCNP6  
Sensitivity  
Coefficient,  
Cosine Bins,  
Energy Bins

PYTHON  
Fitting,  
Integration,  
Averaging

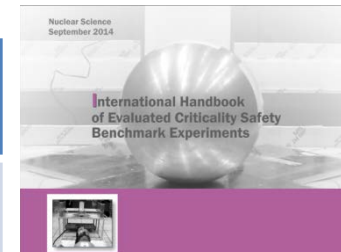
P1 Sensitivity  
Coefficients



Benchmark	Isotope	Uncertainty (pcm)
PMF026-001	Fe <sup>56</sup>	326
PMF015-001	Fe <sup>56</sup>	326
PMF032-001	Fe <sup>56</sup>	255
HMF001-001	U <sup>235</sup>	463
HMF007-019	U <sup>235</sup>	434
HMF043-001	U <sup>235</sup>	406
PMF006-001	U <sup>238</sup>	322
PMF041-001	U <sup>238</sup>	296
HMF003-003	U <sup>238</sup>	305
PMF001-001	Pu <sup>239</sup>	161
PMF022-001	Pu <sup>239</sup>	156
PMF025-001	Pu <sup>239</sup>	134

## Database for ICSBEP [DICE] Sensitivity Data Status

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
2015	4065	Previous + New Cases
2016	~4200	Previous + New Cases + P1 Sensitivities [~400 cases]



**DATABASES WITH SENSITIVITY PROFILES**  
Sensitivities (S) & C/E data  
DICE



2015	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 freely accessible. NB. Access to evaluations and input decks **are restricted to NEA member countries and participating organisations.**

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-q)
- 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

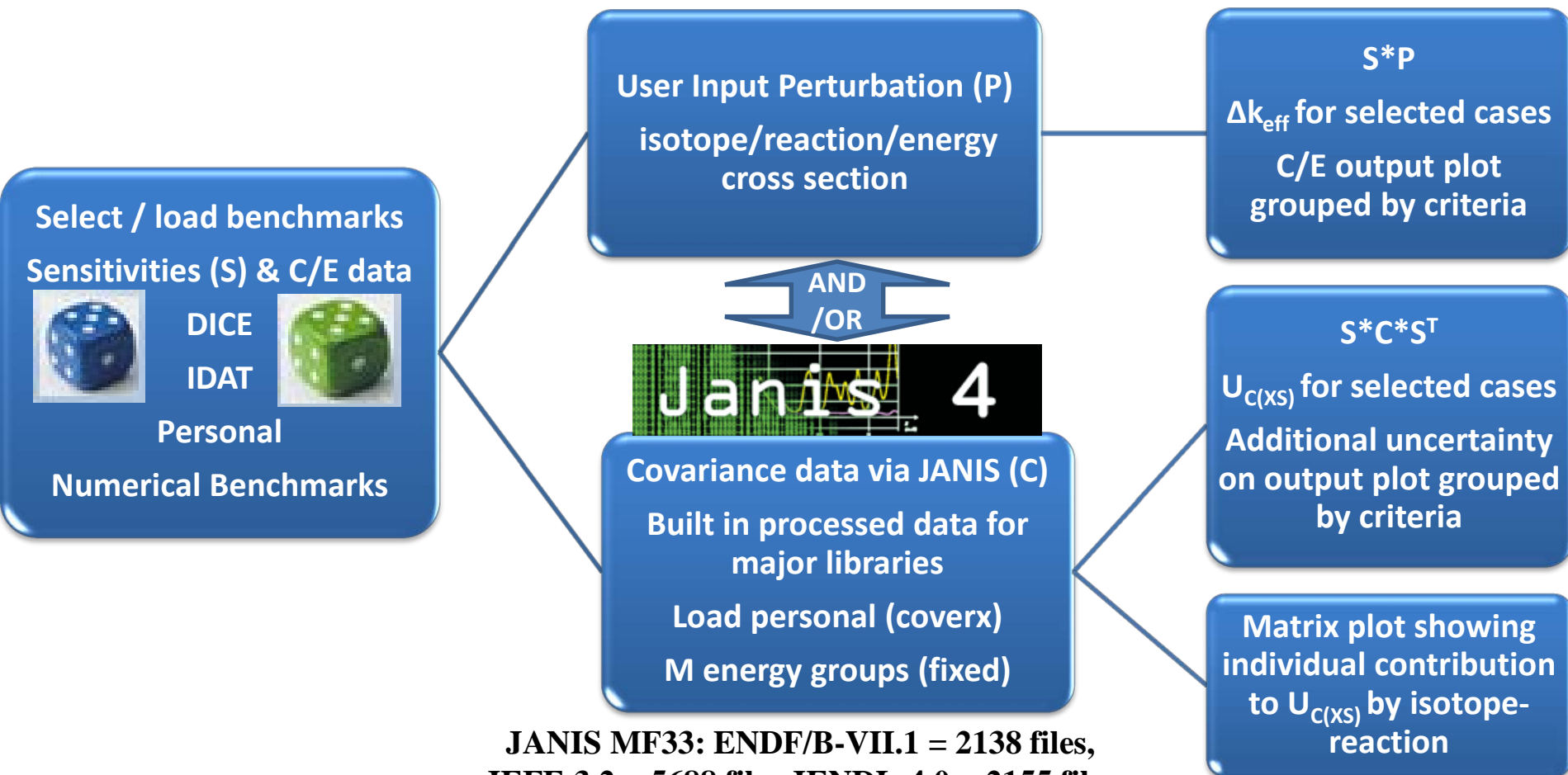
**Also useful!**

## Integrating Sensitivity Data With Nuclear Data via NDaST

- There was existing Sensitivity Data in DICE (Database for ICSBEP) and IDAT (Database for IRPhEP)
- This could be ‘viewed’ or used to select or order benchmarks, but little further application
- No means to link DICE and integral benchmarks to nuclear data or JANIS – expand or build specific tool?
- The Nuclear Data Sensitivity Tool (NDaST) was developed in 2015 to accomplish this
- It has already seen application use in the CIELO and JEFF nuclear data projects and SFR benchmark

## 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**



# Depending on What You Want Benchmarking Can Be Computer Intensive

**To assess the impact on all PU-SOL-THERM**

→ Run 600 Benchmarks,  $k_{\text{eff}}$  5 pcm

**To assess the impact of each reaction on the benchmarks**

→ 600 X #Reactions [Look what is driving the  $k_{\text{eff}}$  change]

**To assess the impact of each reaction and each energy range on the benchmarks**

→ 600 X #Reactions X #Energies [Look at energy region driving the change]

**To decide between different options in each reaction and energy**

→ 600 X #Reactions X #Energies X #Options



**Example:** 10 h per run, 5 reactions, 10 energy groups, 5 options

= 600 X 10 h X 5 X 10 X 5 = **1.5 Million Computer Hours** or **171 Computer Years!** (per isotope 😊)

Attempt to reduce this to minutes!

## Benefits

**Goal:** Given a new nuclear data evaluation, provide evaluators and other users a tool to see how the changes they've made will impact integral benchmarks...in minutes.

- See individual reaction effects, not just final totals
- Analyse how these 'compete' if they are correlated
- Understand specifically which energy regions matter
- How do perturbations compare with given uncertainties
- Propagate uncertainties and judge their reasonability
- Do this time and time again as small iterations take place
- Allow internationally co-operating projects to manage these processes more easily

## Limitations

- All based on simple, first order approximations
  - These might not hold beyond certain limits, depending on strength of secondary effects
- Not all cases (around 85% of the total database)
- Sensitivities mostly the SCALE 238 group energy structure
  - Bad choice for certain types of systems & perturbations e.g. movement of large resonances across group boundaries
- Reactions (not all are loaded into database)
  - Difficult to properly handle the energy-dependent PFNS
- Angular sensitivity (being addressed – 400 P1 sensitivities)
- Experimental correlations are not considered
  - This is not (yet) an adjustment tool

## Launching the Software

- NDaST is another JAVA based tool and feels very similar to DICE and IDAT
- It's free, there's no password and is run by launching from the NEA website
  - [www.oecd-neo.org/ndast/](http://www.oecd-neo.org/ndast/)
- Your DICE and IDAT settings will be reused
- Any personal 'bases' you have loaded into JANIS can be connected for use
- Computational load on your computer is minimal – designed to let NEA servers bear the brunt, while you reap the benefits!

## Some Results of Swapping Files, vs Summing the Separate Effect and NDaST

Eval-Case	MT18		MT102		MT452		PNFS		Total		
	Direct	NDaST	Direct	NDaST	Direct	NDaST	Direct	NDaST	Direct	Sep	NDaST <sup>a</sup>
PST001-004	-52	-10	-1	32	-231	-212	-143	N/A	-394	-427	-333
PST004-001	-150	-119	-8	0	-199	-200	-117	N/A	-466	-474	-436
PST012-010	-156	-116	-21	-2	-197	-182	-67	N/A	-415	-441	-367
PST018-006	-116	-79	-1	-8	-183	-155	-36	N/A	-311	-342	-278
PST034-004	-73	-8	-7	-7	-215	-221	-63	N/A	-384	-372	-299
PST034-015	234	398	-32	26	-220	-209	-53	N/A	-75	-71	162

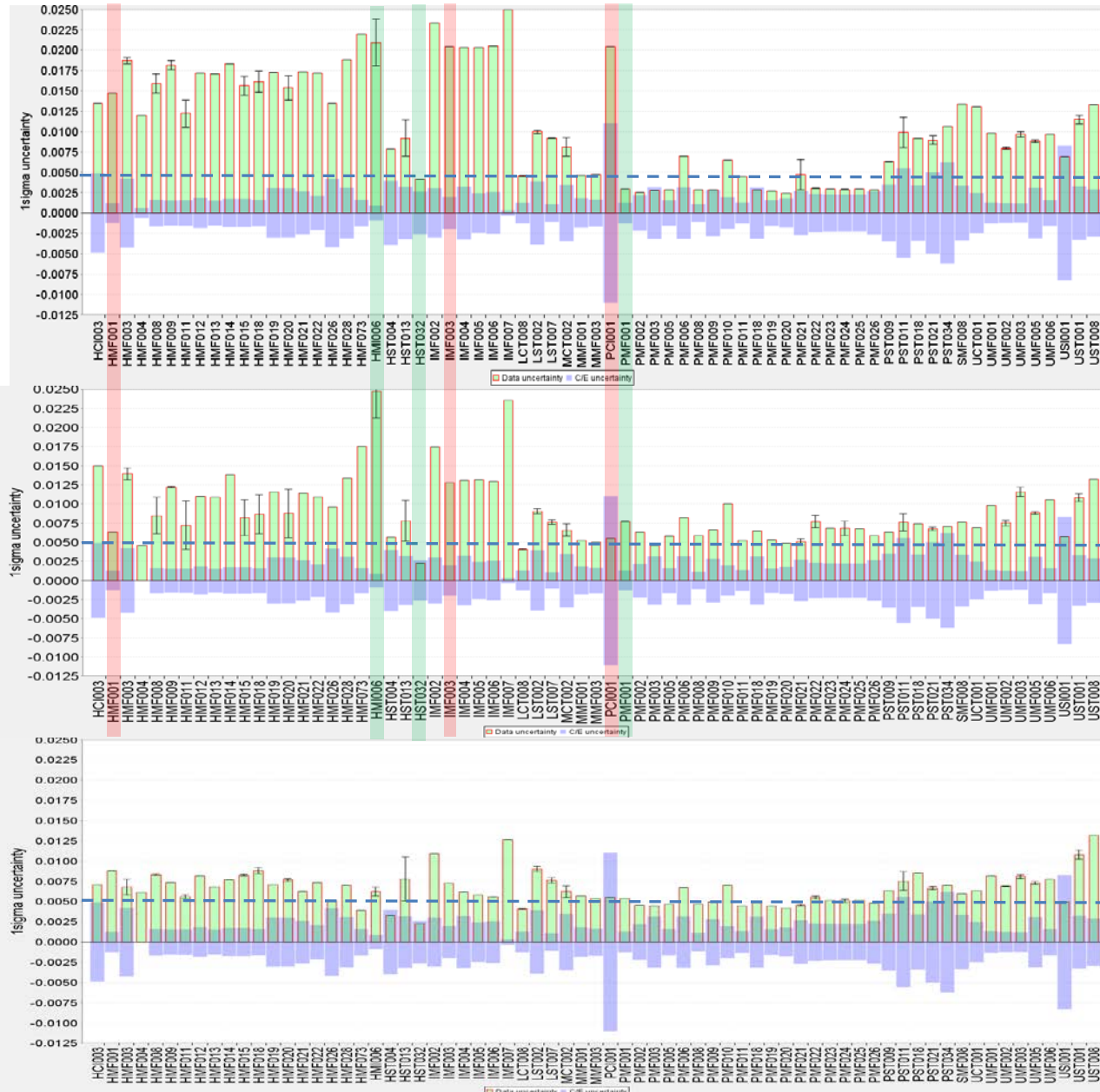
a) NDaST Total is the sum of (MT18+MT102+MT452) from NDaST + PNFS from Direct

- Limitation; CIELO files contain an energy dependent PFNS
- Existing NDaST and underlying sensitivity data currently use an energy independent PFNS
- PST034-015 is complicated by its intermediate sensitivity, plus coincident shifts in resonances. Also high Gd poison content.

See latest ANS proceedings for Ian Hill's full paper



## Testing JEFF-3.3 Covariances All Results by Evaluation ID



JEFF-3.3T3  
Mean = 1100 pcm

JEFF-3.3T1  
Mean = 1043 pcm

ENDF/B-VII.1  
Mean = 922 pcm

JENDL-4.0  
Mean = 668 pcm

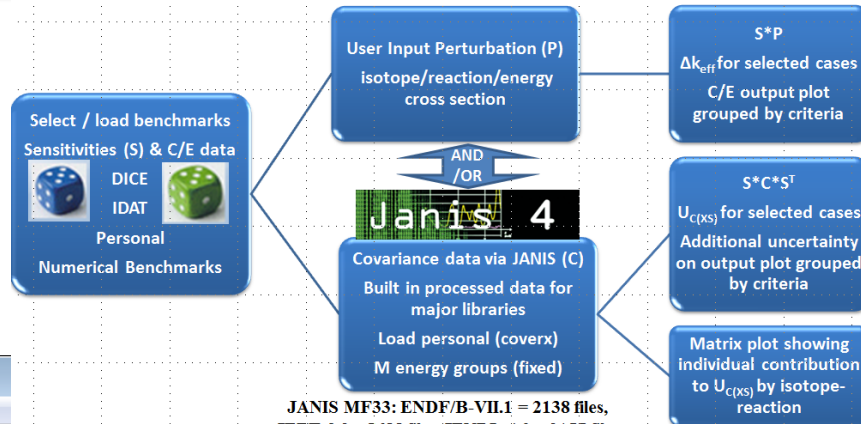
## Testing JEFF-3.3 Covariances

### Selected Example Benchmark Uncertainties

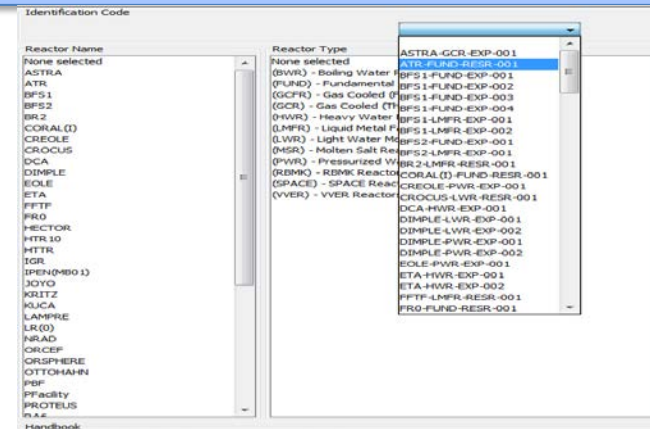
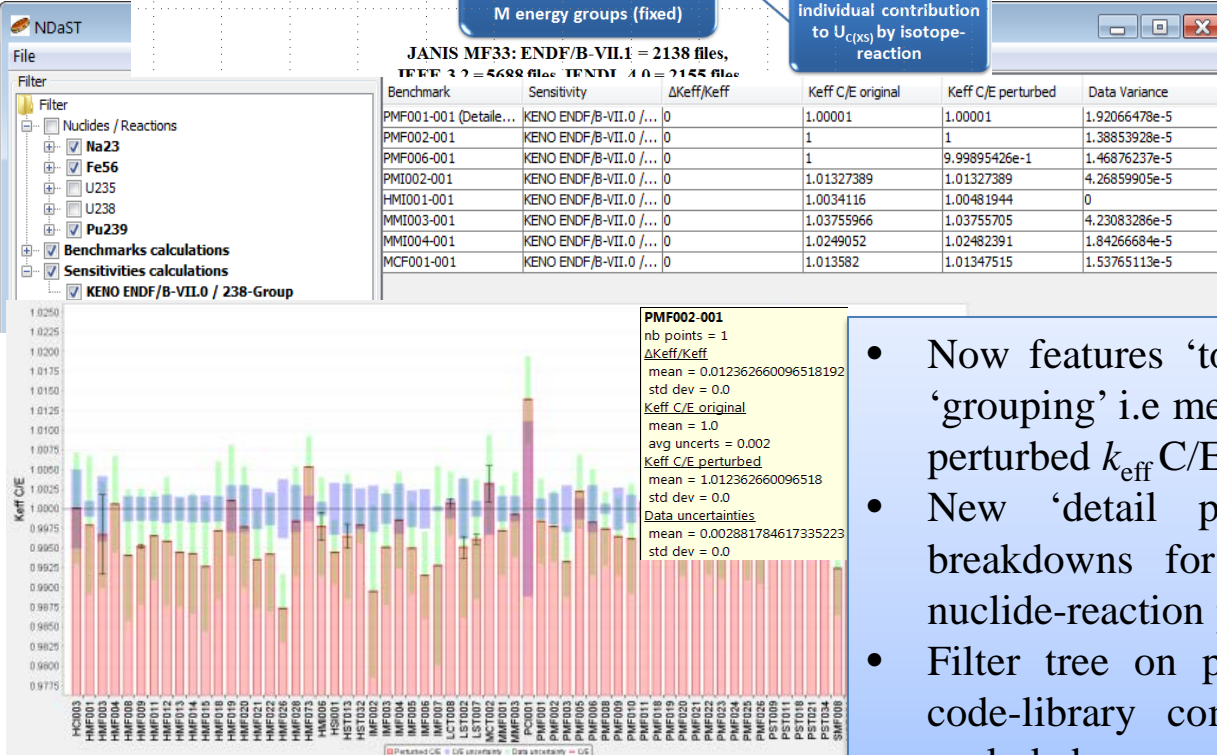
Case label	Sensitivity Code	1 $\sigma$ JEFF-3.3 T3	1 $\sigma$ JEFF-3.3 T1	Diff J33T3 – J33T1 (pcm)	1 $\sigma$ ENDF/B-VII.1	1 $\sigma$ JENDL-4.0	Ratio J33T1 / E7.1
PCI001-001	KENO ENDF/B-VII.0 / 238-Group	0.020410	0.020364	+5	0.005471	0.006559	3.72
HMF001-001 (Godiva)	KENO ABBN-93 / 299-Group	0.014788	0.014788	0	0.006302	0.008816	2.34
IMF003-001 (Detailed Model)	KENO ENDF/B-VII.0 / 238-Group	0.020409	0.020409	0	0.012785	0.007286	1.59
PST011-006	KENO ENDF/B-VII.0 / 238-Group	0.011741	0.009639	+481	0.009423	0.009537	1.02
UMF001-001	KENO ENDF/B-VII.0 / 238-Group	0.009813	0.009813	0	0.009813	0.008172	1.00
LCT008-001	KENO ENDF/B-VII.0 / 238-Group	0.004455	0.002937	+151	0.003879	0.004038	0.76
HST032-001	KENO ABBN-93 / 299-Group	0.004103	0.001186	+292	0.002306	0.002300	0.51
HMI006-001	KENO ENDF/B-VII.0 Continuous	0.017284	0.015995	+129	0.019962	0.006437	0.80
PMF001-001 (Detailed Model)	KENO ENDF/B-VII.0 / 238-Group	0.002943	0.003036	-9	0.007796	0.005421	0.38

## STATUS

Several new features for NDaST have been developed for the December 2016 release version.



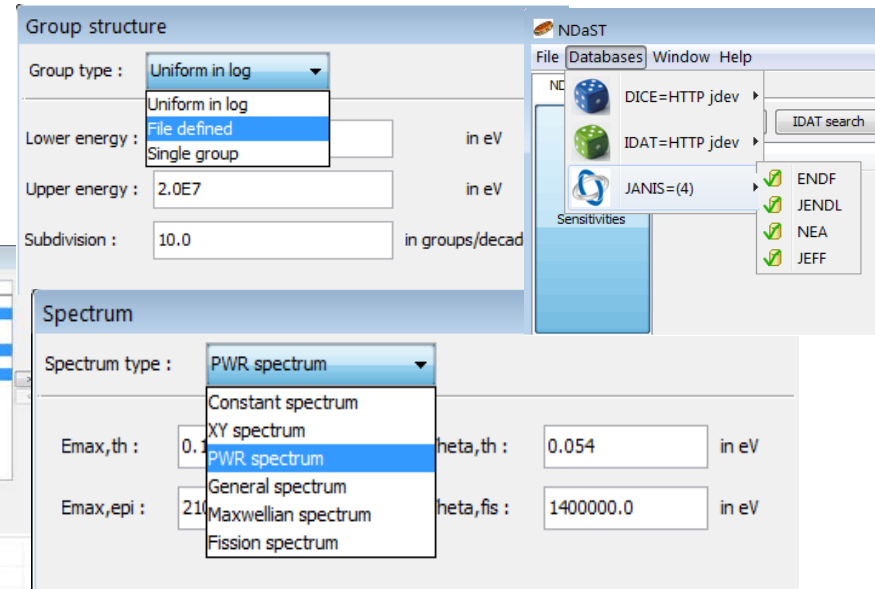
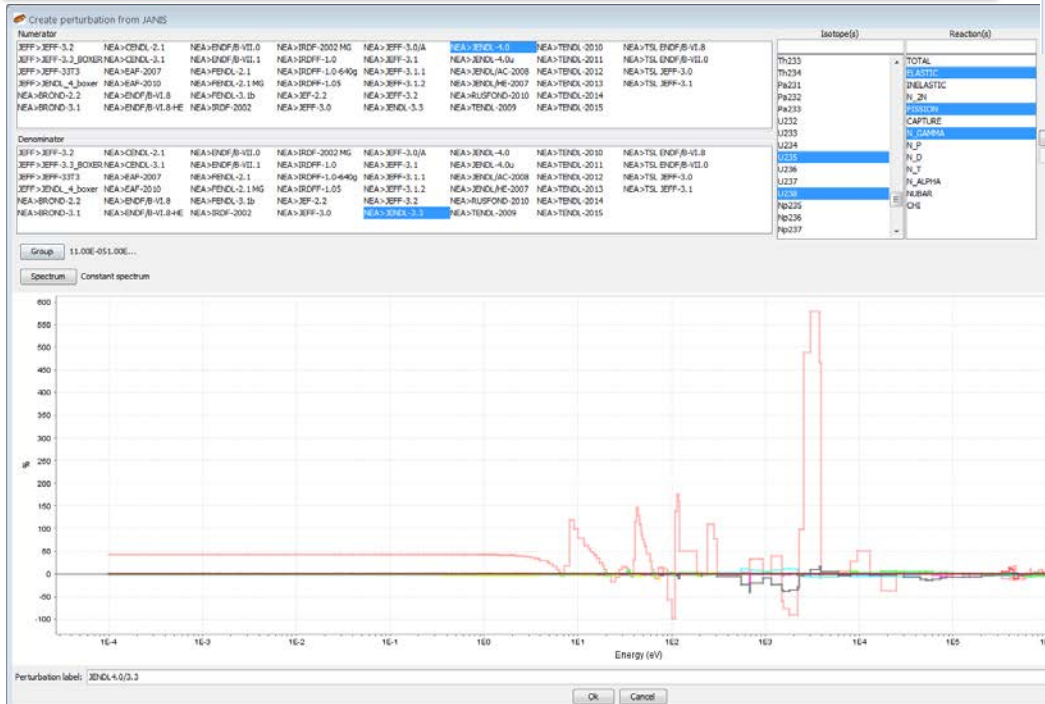
- In addition to DICE, the release version allows access to the International Reactor Physics Handbook Database and Analysis Tool (IDAT).



- Now features ‘tool-tips’; access data behind each plot ‘grouping’ i.e mean and s.d. values for  $\Delta k_{\text{eff}}$ , original and perturbed  $k_{\text{eff}}$  C/E values and nuclear data uncertainty.
- New ‘detail popup’ for each benchmark shows breakdowns for each code-library combination and nuclide-reaction pair.
- Filter tree on plot allows nuclide-reaction pairs and code-library combination results to be included or excluded

## NDaST: Automated JANIS Computations

- An automated link has been introduced to the JANIS nuclear data software to generate the perturbation ratios between two evaluations.
- Represented within any energy group structure required.
- Analytical or personal spectrum weightings may also be applied

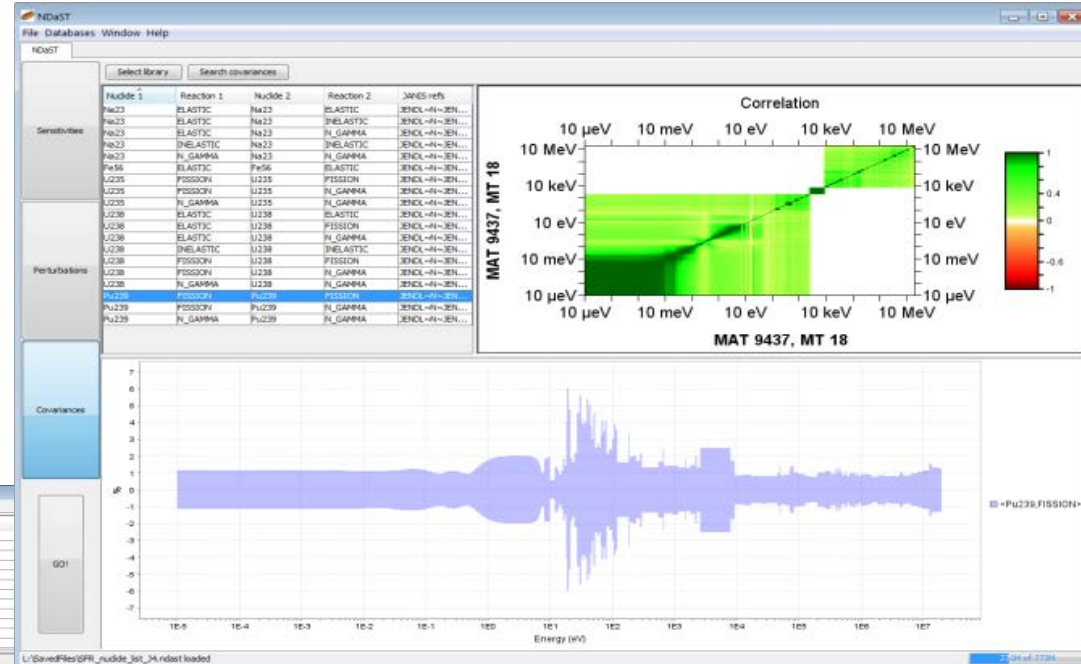


- Multiple perturbations of the same nuclide-reaction can now be input for faster comparison with one single run
- NDaST will also have a 'file upload' feature, to avoid needing to already have libraries held in a JANIS base.



## NDaST: Energy Dependence Breakdown

- Breakdown of either a perturbation ( $\Delta k_{\text{eff}}$ ) or uncertainty (covariance in  $k_{\text{eff}}$ ) calculation as a function of the contributing nuclide-reaction pairings did not allow a deeper analysis of which energy regions constitute the greatest or smallest contribution to the total.



- In order that totals over different ranges of energy can be quickly computed and displayed, region selection bars may be used over the breakdown plot, which is colour-coded by magnitude.



## ***NDaST: Future Outlook and Collaboration***

Some planned new features (development begins April 2017):

- Complete covariance library selection option
- **Allow JANIS ENDF file import through NDaST – TMC / Half Monte Carlo**
- Compensating effects dialogue (e.g. perturbations to preserve totals)
- Pre-loadable benchmark set selections (e.g. JEFF, CSEWG, MCNP testing suites)
- **Representativity values (i.e. calculation of Ck correlations)**
- **Spectrum weighted Chi perturbations more compatible with Chi sensitivities**
- Automatic selection of nuclides/reaction covariances from sensitivity sdf file

Collaboration areas of interest:

- Additional sensitivity files and C/E results to populate the databases
- Supported sensitivity and covariance formats (e.g. COVERX libraries)
- Compatibility with the NDEC system – propagation of test file perturbations
- Xml format to contain input / output; benchmark data, perturbations, covariances etc.

**Described in the ‘How-to’ guide at the website**

**<http://www.oecd-nea.org/ndast/>**

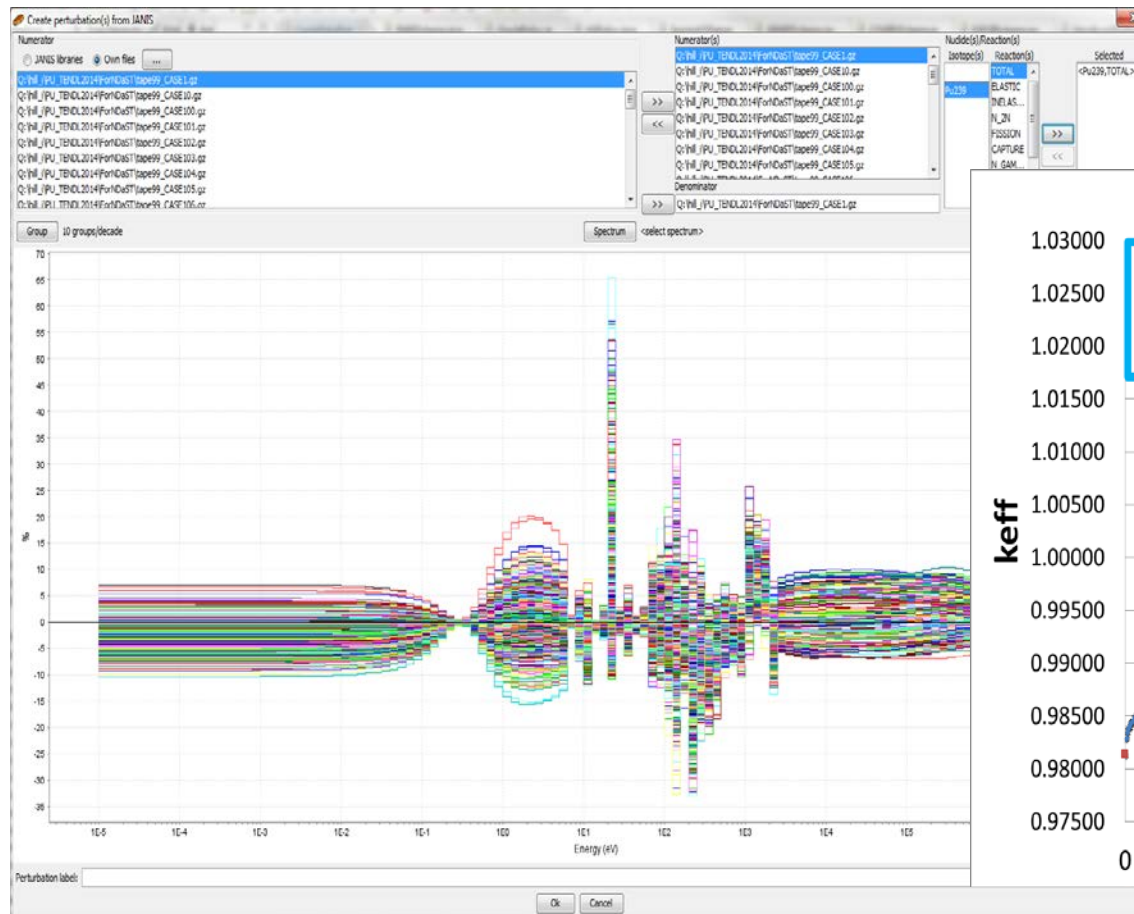
## Half Monte Carlo Method

- How can we solve the uncertainty propagation problem of non-linear dependencies? Currently with TMC.
- $K_{\text{eff}}$  sensitivities in general are not the problem, they remain linear over a large range, the same cannot always be said for nuclear data parameters and cross-sections.
- Instead of running hundreds or thousands of neutronics calculations, can we just take 1000 sampled cross section files and perform cheap perturbations with NDaST?
- Hopefully the answer is yes – we can have the normal NDaST benefits (a deeper analysis of the effects) without the normal computational burden.

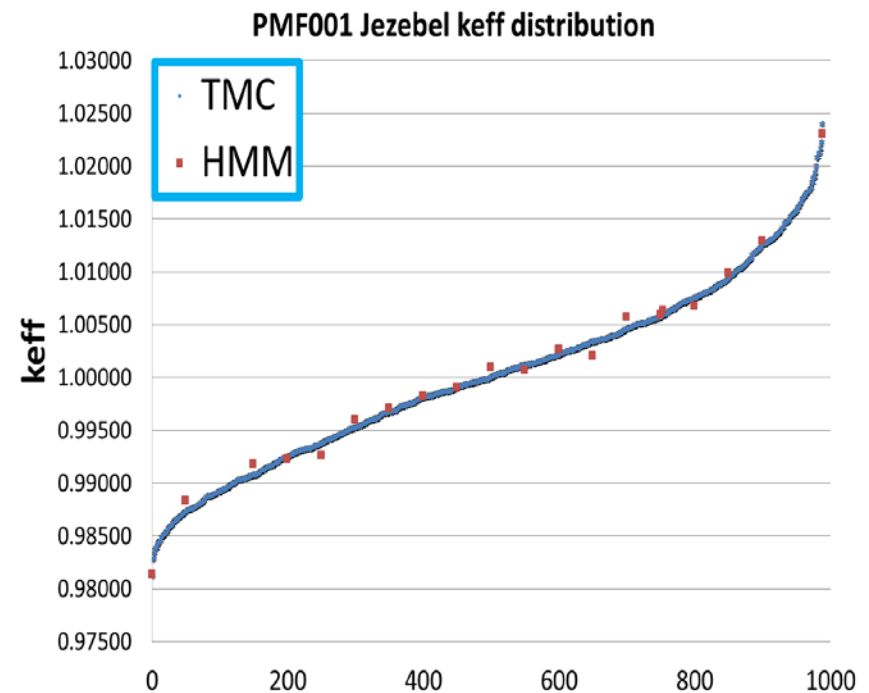
Delta keff (pcm)																				
Case Number																				
	24	34	38	170	431	436	455	476	494	527	558	591	643	670	680	710	738	772	782	993
Elastic	606	-217	-157	-441	513	59	-520	59	216	-47	606	-222	-490	-348	42	364	629	-481	393	-253
Inelastic	110	252	-19	75	-190	139	119	132	384	-9	-130	219	1	-206	81	-192	69	-14	-143	-45
N,2N	-3	-1	-4	-3	-4	1	-6	1	2	-6	-3	-4	-3	-3	-4	-4	-1	-6	-7	2
Fission	-800	120	780	566	1488	486	-272	485	-877	16	827	-940	-974	-537	541	-1258	-767	314	-486	-367
N,Gamma	-29	3	13	22	19	-30	-27	-30	10	-18	-22	-10	21	-42	-51	-28	-22	23	5	34
nubar	-249	113	126	-27	610	225	-175	-48	-189	138	-221	272	-428	-2	-230	315	482	-200	221	207
Chi	144	-129	-187	-219	-254	-15	-62	-129	-76	-130	111	-208	-117	-154	130	-61	55	59	95	1
Total	-221	141	552	-27	2183	865	-943	470	-530	-56	1170	-893	-1989	-1291	508	-864	444	-305	79	-421

## Half Monte Carlo Results

PMF001 Jezebel 1000 SERPENT runs with different random TENDL-2014 Pu239 files, plotted with the HMM  $k_{\text{eff}}$  predictions for 20 samples



$k_{\text{eff}}$  distribution, sorted  
lowest  $k_{\text{eff}}$  to highest



## Summary

- ✓ ~4200 cases (~85%) have 3 group sensitivity data and full sensitivity profiles within DICE – similar also in IDAT
- ✓ An open web-based JAVA tool named NDaST is now available to take advantage of these data
- ✓ Enable rapid scoping of changes to nuclear data and to propagate nuclear covariance data uncertainties
- ✓ It also gives access to JANIS for automation of computations and use of processed nuclear covariance data; Half Monte Carlo Method
- ✓ Complement to ‘knowledge machine’ and more specific V&V calculations e.g. via the NEA Nuclear Data Evaluation Cycle (NDEC)
- ✓ Full release in 2016 following a beta testing period, with updates following this expected on an annual basis

## EXTRA VIEWGRAPHS for How to Use NDaST



## Contents

- 1. Introduction, means of use, benefits & limitations...**
- 2. Loading benchmark sensitivities and results**
- 3. Inputting nuclear data perturbations**
- 4. Launch, visualise and interpret results**

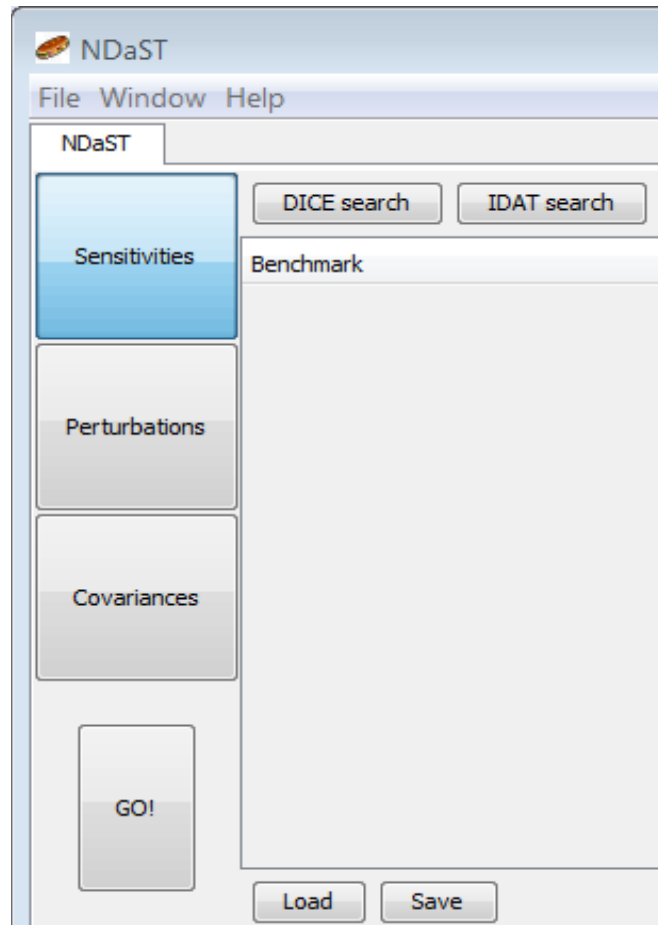
**Class exercise 1 – steps 2, 3 & 4**

- 5. Adding covariance matrices to the calculation**
- 6. More visualisation possibilities**
- 7. Future developments to be made**

**Class exercise 2 – try out steps 5 & 6**

## Panel 1: Select Benchmark Sensitivity Data

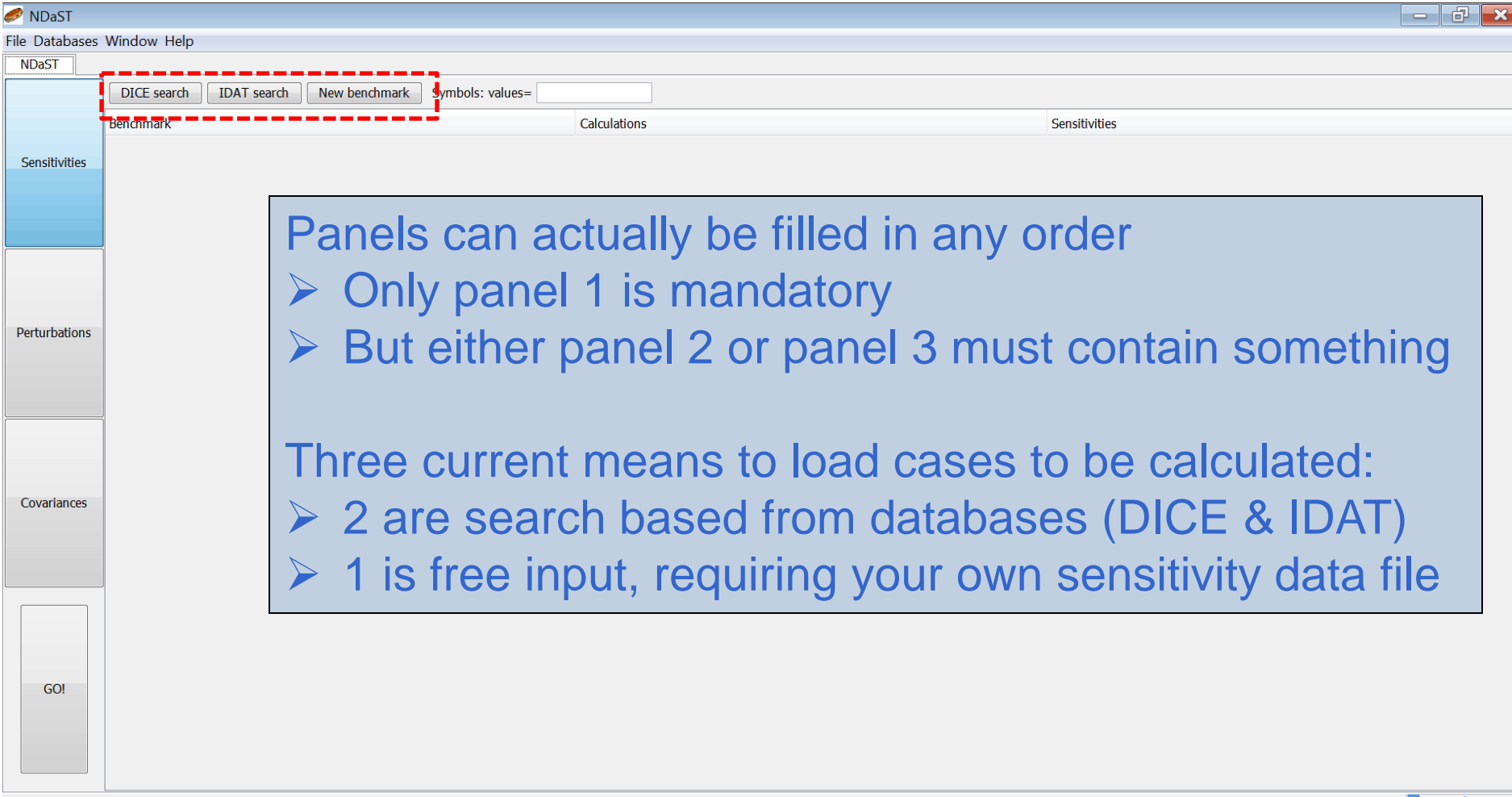
Currently can select benchmarks via DICE and IDAT plug-ins.



- Search using all the usual DB attributes
- Modify the results or add personal case results & sensitivity data
- 'Create' your own personal benchmark
- Save/load custom benchmark suite e.g. CSEWG
- Enable sharing of editable xml file datasets for collaborators / inter-comparisons

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 1: Select Benchmark Sensitivity Data



NDAST

File Databases Window Help

NDAST

DICE search IDAT search New benchmark Symbols: values=

Benchmark Calculations Sensitivities

Sensitivities

Perturbations

Covariances

GO!

Panels can actually be filled in any order

- Only panel 1 is mandatory
- But either panel 2 or panel 3 must contain something

Three current means to load cases to be calculated:

- 2 are search based from databases (DICE & IDAT)
- 1 is free input, requiring your own sensitivity data file

## Simple Benchmark Selection - ID

NDaST

File Databases Window Help

NDaST

Sensitivities

Perturbations

Covariances

GO!

Themes

- General items
  - Identification
  - Laboratory
  - Title
  - Keywords
  - Dates (evaluation and experiment)
- Energy, spectra, sensitivities
  - Energy of Average Neutron Lethargy causing Fission
  - Average Fission Group Energy
  - Flux distribution (3-g)
  - Fission distribution (3-g)
  - Capture distribution (3-g)
  - Neutron balance
  - Keff Sensitivities
  - Keff Sensitivities (additional criterion)
- Fuel
  - Fuel form/Fissile material
  - U and Pu weight percent
  - Pu/(U+Pu) ratio
  - Moderator/coolant material
  - Cladding material
  - Reflector material
  - Neutron absorbing material
  - Separation material
  - Benchmark Keff and Calculations

Identification code

Fissile material

None selected

(PU) - Plutonium

(HEU) - Highly Enriched Uranium

(IEU) - Intermediate Enriched Uranium

(LEU) - Low Enriched Uranium

(U233) - Uranium-233

(MIX) - Mixed Plutonium - Uranium

(SPEC) - Special Isotope

Physical form

None selected

(MET) - Metal

(SOL) - Solution

(COMP) - Compound

(MISC) - Miscellaneous

Spectrum

None selected

(FAST) - Fast

(INTER) - Intermediate-Energy

(THERM) - Thermal

(MIXED) - Mixed

Subcritical

☒ Critical and subcritical ☐ Critical ☐ Subcritical

Acceptable

☐ Acceptable and unacceptable ☒ Acceptable ☐ Unacceptable

Query

Fissile material = Plutonium  
and Spectrum = Intermediate-Energy  
and Acceptable = Acceptable

History :

Add selected search results to your benchmark set Cancel

6 Evaluations, 10 Cases

Number of cases  
Title  
Case label

Clear

Search !

133M of 773M

Counter is live before you hit Search button

## Simple Benchmark Selection - Flux

NDaST

File Databases Window Help

NDaST

Sensitivities

Perturbations

Covariances

GO!

Themes

- General Items
  - Identification
  - Organisation/Laboratory
  - Title
  - Keywords
  - Dates (Evaluation and Experiment)
- Calculated Data (Over Entire System)
  - Flux Distribution (3-g)
  - Fission Distribution (3-g)
  - Capture Distribution (3-g)
  - Neutron Balance
  - Keff Sensitivities
- Materials
  - Fuel
  - Fuel Composition
  - Cladding
  - Moderator/Coolant
  - Absorber
- CRIT - Criticality Measurements
  - Benchmark and Calculated Values
  - Uncertainties

Percent of flux below 0.625 eV

Value :  +/- :

OR >=  <=

Percent of flux between 0.625 eV and 100 keV

Value : 30 +/- : 2

OR >=  <=

Percent of flux above 100 keV

Value :  +/- :

OR >= 55 <=

Spectra and Neutron Balance Data are currently available for about 73% of cases in the IRPhEP Handbook

More specific searches can be performed, normally combined with AND logic operations

Query

Percent of flux between 0.625 eV and 100 keV >= 28 and <= 32  
and Percent of flux above 100 keV >= 55

History :

Add selected search results to your benchmark set Cancel

6 Evaluations, 7 Cases

107M of 773M

## Simple Benchmark Selection - Library

NDaST

File Databases Window Help

NDaST

**Sensitivities**

- Themes
  - General Items
    - Identification
    - Organisation/Laboratory
    - Title
    - Keywords
    - Dates (Evaluation and Experiment)
  - Calculated Data (Over Entire System)
    - Flux Distribution (3-q)
    - Fission Distribution (3-q)
    - Capture Distribution (3-q)
    - Neutron Balance
    - Keff Sensitivities
  - Materials
    - Fuel
    - Fuel Composition
    - Cladding
    - Moderator/Coolant
    - Absorber
  - CRIT - Criticality Measurements
    - Benchmark and Calculated Values
    - Uncertainties

**Perturbations**

**Covariances**

**GO!**

**Benchmark Keff**

Value :  +/- :   
OR >=  <=

**Code name**

- None selected
- APOLLO
- APOLLO-MORET
- APOLLO2-MORET4
- CITATION
- COG
- KENO
- MCNP
- MCU
- MMKKENO
- MONK
- MVP
- SERPENT
- TRIPOLI4
- TWODANT
- VIM
- WIMS

☐ Combine with AND ☒ Combine with OR

**Calculated Keff**

Value :  +/- :   
OR >=  <=

**Benchmark Keff uncertainty**

Value :  +/- :   
OR >=  <=

**Library**

- None selected
- ABBN
- ADJ2000R
- CEA93.V6 172G
- CENDL-3.1
- DLC-MCU
- ENDF/B-IV
- ENDF/B-V
- ENDF/B-VI
- ENDF/B-VI.1 Continuous
- ENDF/B-VII
- ENDF/B-VII.0
- ENDF/B-VII.0 238G
- ENDF/B-VII.1
- Hansen-Roach 16G
- JEF-2.2
- JENDL-3
- JENDL-4.0
- JFS-3-33
- JFS-3-33.2R
- ROSFOND-2009
- TENDL-2013
- UKNDL

☐ Combine with AND ☒ Combine with OR

**Calculated Keff uncertainty**

Value :  +/- :   
OR >=  <=

**Query**

Library = ENDF/B-VII.1

**History :**

Add selected search results to your benchmark set Cancel

Clear

Search !

8 Evaluations 14 Cycles

104M of 773M

Calculations provided generally within the evaluations are held as C/E data



## Sensitive Benchmark Search

NDaST

File Databases Window Help

NDaST

**Sensitivities**

- Themes
  - General items
    - Identification
    - Laboratory
    - Title
    - Keywords
    - Dates (evaluation and experiment)
  - 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
    - Keff sensitivities**
    - Keff Sensitivities (additional criterion)
  - Fuel
    - Fuel form/Fissile material
    - U and Pu weight percent
    - Pu/(U+Pu) ratio
- Perturbations
  - Moderator/coolant material
  - Cladding material
  - Reflector material
  - Neutron absorbing material
  - Separation material
  - Benchmark Keff and Calculations
- Covariances

**Isotope**

- 50 - Sn - Tin
- 55 - Cs - Caesium
- 56 - Ba - Barium
- 60 - Nd - Neodymium
- 62 - Sm - Samarium
- 63 - Eu - Europium
- 64 - Gd - Gadolinium
- 66 - Dy - Dysprosium
- 72 - Hf - Hafnium
- 73 - Ta - Tantalum
- 74 - W - Tungsten
- 75 - Re - Rhenium
- 79 - Au - Gold
- 80 - Hg - Mercury
- 82 - Pb - Lead
- 83 - Bi - Bismuth
- 90 - Th - Thorium
- 92 - U - Uranium
- 93 - Np - Neptunium
- 94 - Pu - Plutonium
  - Pu238
  - Pu239**
  - Pu240
  - Pu241
  - Pu242
- 95 - Am - Americium

☐ Combine with AND ☒ Combine with OR

**Reaction**

- None selected
- capture
- elastic
- elastic-P1
- fission**
- inelastic
- nubar
- total

☐ Combine with AND ☒ Combine with OR

Total Keff sensitivity over all energy range

Value :  +/- :  ☐ Abs

OR >=  <=

Keff sens. < 0.625 eV

Value :  +/- :  ☐ Abs

OR >=  <=

Keff sens. 0.625 eV - 100 keV

Value :  +/- :  ☐ Abs

OR >=  <=

Keff sens. > 100 keV

Value :  +/- :  ☐ Abs

OR >=  <=

Values between -1 and 1, in %dk/%Σ - Keff Sensitivities are currently available for about 83% of cases

Query

Acceptable = Acceptable  
and Isotope = Pu239  
and Reaction = fission  
and Keff sens. 0.625 eV - 100 keV >= 0.2

GO!

History

Add selected search results to your benchmark set Cancel

12 Evaluations, 14 Cases

133M of 773M

Title

Number of cases

Case label

Keff Sensitivity 0.625 eV - 100 keV (%dk/%Σ)

Clear

Search !

This is where NDaST is really focused!

## Addition of Benchmarks to Set

NDaST

File Databases Window Help

NDaST

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

Columns

- General items
  - Identification
    - Acceptable
    - Laboratory
    - Title
    - Pictures
    - Year approved
    - Year revised
    - Years experiment performed
    - Revision
  - Number of cases
  - Case label
- 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
  - Keff Sensitivity < 0.625 eV (%dk/%Σ)
  - Keff Sensitivity > 100 keV (%dk/%Σ)
  - Total Keff Sensitivity over all energy (%dk/%Σ)
- Fuel
  - Fuel form/Fissile material
  - Fuel concentration (g/L)
  - Fuel composition (Isotope wt%)
  - Pu/(U+Pu) ratio
- Neutron absorbing mat.
  - Solid poison
  - Soluble poison
  - Concentration (g/L)
- Cladding
  - Reflector
  - Separator
- Geometry
  - Number of fissile units
  - Pitch type
  - Pitch (cm)
  - Fuel unit geometry
- Benchmark Keff and uncertainty

Uncheck all

Apply

Add selected search results to your benchmark set Cancel

12 Evaluations, 14 Cases

Evaluation identification	Title	Number of cases	# cases
PU-MET-INTER-001	CRITICAL EXPERIMENTS WITH HETEROGENEOUS COMPOSITIONS OF PLUTONIUM, SILICON DIOXIDE, AN...	6	2
PU-MET-INTER-002	ZPR-6 ASSEMBLY 10: A CYLINDRICAL PLUTONIUM/CARBON/STAINLESS STEEL ASSEMBLY WITH STAINLE...	1	1
PU-MET-MIXED-001	CRITICAL EXPERIMENTS WITH HETEROGENEOUS COMPOSITIONS OF PLUTONIUM, SILICON DIOXIDE, AN...	6	1
PU-COMP-INTER-001	K-INFINITY EXPERIMENTS IN INTERMEDIATE NEUTRON SPECTRA FOR 239PU	1	1
PU-COMP-MIXED-002	PLEXIGLAS REFLECTED SLABS OF POLYSTYRENE-MODERATED PLUTONIUM OXIDE	29	2
MIX-MET-INTER-003	ZPR-3 ASSEMBLY 54: A CYLINDRICAL ASSEMBLY OF PLUTONIUM METAL, DEPLETED URANIUM, AND GRA...	1	1
MIX-MET-INTER-004	ZPR-3 ASSEMBLY 53: A CYLINDRICAL ASSEMBLY OF PLUTONIUM METAL, DEPLETED URANIUM AND GRAP...	1	1
MIX-COMP-FAST-001	ZPR-6 ASSEMBLY 7: A CYLINDRICAL ASSEMBLY WITH MIXED (PU,U)-OXIDE FUEL AND SODIUM WITH A T...	1	1
MIX-COMP-FAST-005	ZPR-9 ASSEMBLY 31: A CYLINDRICAL ASSEMBLY WITH MIXED (PU,U)-CARBIDE FUEL AND DEPLETED URA...	1	1
MIX-COMP-FAST-006	ZPR-2: A CYLINDRICAL ASSEMBLY WITH MIXED (PU,U)-OXIDE FUEL AND SODIUM REFLECTED BY DU, SO...	1	1
MIX-MISC-FAST-002	BFS-49 ASSEMBLIES: CRITICAL EXPERIMENTS WITH HETEROGENEOUS COMPOSITIONS OF PLUTONIUM, ...	2	1
MIX-MISC-MIXED-001	BFS-97, -99, -101 ASSEMBLIES: CRITICAL EXPERIMENTS WITH HETEROGENEOUS COMPOSITIONS OF PLU...	11	1

Case identification	Case label	Isotope	Reaction	Keff sensitivity 0.625 eV - 100 keV (%dk/%Σ)	Model	Benchmark Keff	Benchmark Keff uncertainty (1 σ)	Code r
PU-MET-INTER-001-001	BFS-81/1	Pu239	fission	0.3118 -	1.0002		0.0037 MMK-K	
PU-MET-INTER-001-001	BFS-81/1	Pu239	fission	0.3118 -	1.0002		0.0037 MCNP	
PU-MET-INTER-001-001	BFS-81/1	Pu239	fission	0.3118 -	1.0002		0.0037 MCNP	
PU-MET-INTER-001-001	BFS-81/1	Pu239	fission	0.3118 -	1.0002		0.0037 MONK	
PU-MET-INTER-001-001	BFS-81/1	Pu239	fission	0.3118 -	1.0002		0.0037 MONK	
PU-MET-INTER-001-001	BFS-81/1	Pu239	fission	0.3118 -	1.0002		0.0037 MCNP	
PU-MET-INTER-001-002	BFS-81/1A	Pu239	fission	0.2982 -	1.0002		0.0032 MCNP	
PU-MET-INTER-001-002	BFS-81/1A	Pu239	fission	0.2982 -	1.0002		0.0032 MCNP	
PU-MET-INTER-001-002	BFS-81/1A	Pu239	fission	0.2982 -	1.0002		0.0032 MCNP	
PU-MET-INTER-001-002	BFS-81/1A	Pu239	fission	0.2982 -	1.0002		0.0032 MONK	
PU-MET-INTER-001-002	BFS-81/1A	Pu239	fission	0.2982 -	1.0002		0.0032 MMK-K	
PU-MET-INTER-002-001	ZPR-6/10	Pu239	fission	0.3402 -	0.9869		0.0026 MCNP	
PU-MET-INTER-002-001	ZPR-6/10	Pu239	fission	0.3402 -	0.9869		0.0026 MONK	
PU-MET-INTER-002-001	ZPR-6/10	Pu239	fission	0.3402 -	0.9869		0.0026 KENO	
PU-MET-INTER-002-001	ZPR-6/10	Pu239	fission	0.3402 -	0.9869		0.0026 MCNP	
PU-MET-INTER-002-001	ZPR-6/10	Pu239	fission	0.3402 -	0.9869		0.0026 VIM	
PU-MET-INTER-002-001	ZPR-6/10	Pu239	fission	0.3402 -	0.9869		0.0026 KENO	
PU-MET-INTER-002-001	ZPR-6/10	Pu239	fission	0.3402 -	0.9869		0.0026 MONK	
PU-MET-INTER-002-001	ZPR-6/10	Pu239	fission	0.3402 -	0.9869		0.0026 MONK	

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Tip: Order your table and use Ctrl+click or Ctrl+a

## Addition of Benchmarks to Set

NDaST

File Databases Window Help

NDaST

DICE search IDAT search New benchmark Symbols: values= Keff

Benchmark	Calculations	Sensitivities	ICBSENS_G3.ISOTOPE	ICBSENS_G3.INTER	ICBEVALS.NUMBER_CASES	ICBSENS_G3.REACTION
PC1001-001	9 calc(s)	1 sensitivity(ies)	Pu239	0.5996	1	fission
PCM002-006	3 calc(s)	1 sensitivity(ies)	Pu239	0.2039	29	fission
PCM002-008	3 calc(s)	1 sensitivity(ies)	Pu239	0.2001	29	fission
PM1001-001	6 calc(s)	1 sensitivity(ies)	Pu239	0.3118	6	fission
PM1001-002	6 calc(s)	1 sensitivity(ies)	Pu239	0.2982	6	fission
PM1002-001	11 calc(s)	1 sensitivity(ies)	Pu239	0.3402	1	fission
PMM001-004	6 calc(s)	1 sensitivity(ies)	Pu239	0.2116	6	fission

Perturbations

Covariances

GO!

7 benchmark(s) selected

103M of 773M

This is just a summary table of everything retrieved from the search

The actual data can be viewed and modified by double-clicking on an entry

## Edit Benchmark Data

NDaST

File Databases Window Help

NDaST

Label: PCT001-001

Experimental value: 1.0

Experimental uncertainty: 0.011

Calculations

Label	Value	Uncertainty
<input checked="" type="checkbox"/> MONK JEF-2.2 Continuous	0.997	0
<input checked="" type="checkbox"/> MCNP ENDF/B-V Continuous	1.002	0
<input checked="" type="checkbox"/> MCNP ENDF/B-VI.4 Continuous	1.01	0.001
<input checked="" type="checkbox"/> KENO ENDF/B-V / 238-Group	0.998	0
<input checked="" type="checkbox"/> MCNP JEFF-3.1.2 Continuous	1.008	0
<input checked="" type="checkbox"/> TRIPOLI JEF-2.2 Continuous	0.993	0.001
<input checked="" type="checkbox"/> APOLLO JEF-2.2 / 172-Group	0.991	0
<input checked="" type="checkbox"/> KENO ABBN-93 / 299-Group	1.008	0
<input checked="" type="checkbox"/> JEFF-2.2 / 172-Group	0.991	0
<input checked="" type="checkbox"/> MCNP ENDF-7.1 continuous	0.992	0

Perturbations

Covariances

GO!

Sensitivities

Add sensitivities

Sensitivity

☒ KENO ENDF/B-VII.0 / 238-Group

Ok Cancel

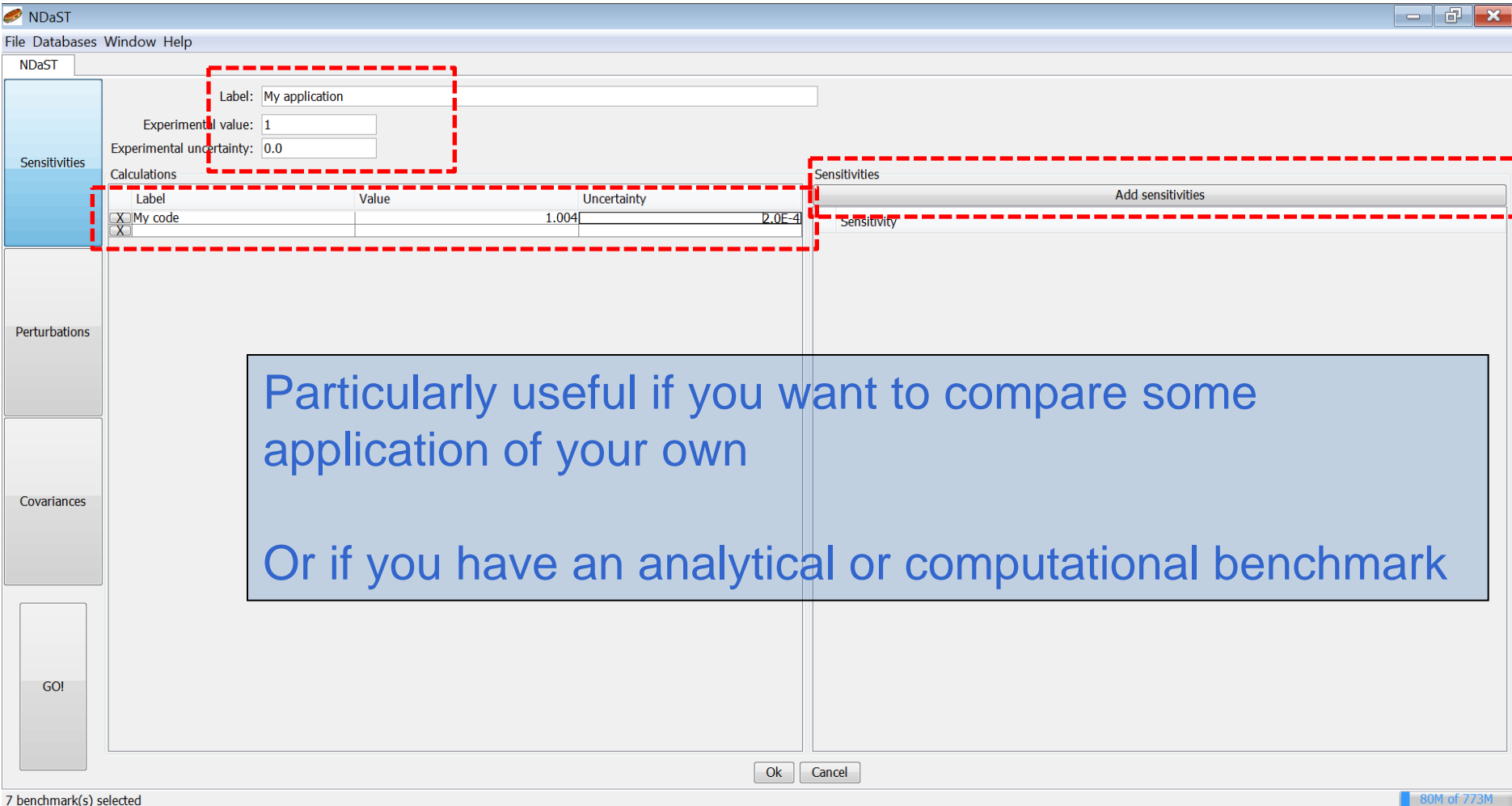
6 Evaluations. 10 Cases

38M of 773M

If the C/E results and trends are important to you, most likely you'll want to input your own for comparison

Sensitivity data has, for the most part, been shown to be not highly dependent on the ND library used

## Add 'New Benchmark'



NDaST

File Databases Window Help

NDaST

Sensitivities

Experimental value: 1

Experimental uncertainty: 0.0

Calculations

Label	Value	Uncertainty
<input checked="" type="checkbox"/> My code	1.004	2.0E-4

Sensitivities

Add sensitivities

Sensitivity

Perturbations

Covariances

GO!

Ok Cancel

7 benchmark(s) selected

80M of 773M

Particularly useful if you want to compare some application of your own

Or if you have an analytical or computational benchmark

## Save and Load Options

NDaST

File Databases Window Help

NDaST

DICE search IDAT search New benchmark Symbols: values= Keff

Benchmark	Calculations	Sensitivities	ICBSENS_G3.ISOTOPE	ICBSENS_G3.INTER	ICBEVALS.N
PCI001-001	9 calc(s)	1 sensitivity(ies)	Pu239	0.5996	1
PCM002-006	3 calc(s)	1 sensitivity(ies)	Pu239	0.2039	29
PCM002-008	3 calc(s)	1 sensitivity(ies)	Pu239	0.2001	29
PMI001-001	6 calc(s)	1 sensitivity(ies)	Pu239	0.3118	6
PMI001-002	6 calc(s)	1 sensitivity(ies)	Pu239	0.2982	6
PMI002-001	11 calc(s)	1 sensitivity(ies)	Pu239	0.3402	1
PMM001-004	6 calc(s)	1 sensitivity(ies)	Pu239	0.2116	6

Sensitivities

Perturbations

Covariances

Save as

Look in: SavedFiles

Recent I... Desktop My Doc... Computer Network

MCNP6\_VnV\_Exp  
SavedFiles - Shortcut  
@b,p,c.ndast  
@b,p,c\_results.ndast  
@b,p,c\_results\_RESAVED.ndast  
@results\_DEV.ndast  
@results\_DEV\_resaved.ndast  
@test\_filter.ndast  
@test\_save\_categories.ndast

aef.ndast  
CSEWG.ndast  
CSEWG\_expanded.ndast  
CSEWG\_expanded\_ser  
CSEWG\_senonly.ndast  
DICE1.ndast  
DICE2.ndast  
DICE3.ndast  
error\_test53.ndast

Parts to save:  
☒ benchmarks  
☐ perturbations  
☐ covariances  
☐ results

File name: GENTLE\_PuInter\_example  
Files of type: NDaST Parameters (\*.ndast)

Save as Cancel



## Editable xml File

```
<?xml version="1.0" encoding="UTF-8" ?>
<ndast>
  <params>
    <benchmarks symbolValue="Keff" symbolDelta="Î"Keff">
      <benchmark>
        <id type="DICE" case="PU-MET-INTER-001-001" model=""/>
        <exp val="1.0002" unc="0.0037"/>
        <calc type="DICE" code="MCNP" lib="ENDF/B-VI.4
Continuous" freetext="" val="1.012" unc="5.0E-4"/>
        <calc type="DICE" code="MMK-KENO" lib="ABBN-93 / 299-
Group" freetext="" val="1.0107" unc="6.0E-4"/>
        <calc type="DICE" code="MCNP" lib="ENDF/B-V
Continuous" freetext="" val="0.9996" unc="5.0E-4"/>
        <calc type="DICE" code="MONK" lib="JEF-2.2 Continuous"
freetext="" val="1.0124" unc="0.001"/>
        <calc type="DICE" code="MCNP" lib="ENDF/B-VI
Continuous" freetext="" val="1.0148" unc="6.0E-4"/>
        <calc type="DICE" code="MONK" lib="ENDF/B-VI.3
Continuous" freetext="" val="1.0157" unc="0.001"/>
        <sens type="DICE" case="PU-MET-INTER-001-001"
code="MCNP" lib="ENDF/B-VI Continuous"/>
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        <category key="ICBSSENS_G3.INTER">0.3118</category>
        <category key="ICBEVALS.NUMBER_CASES">6</category>
        <category key="ICBSSENS_G3.REACTION">fission</category>
      </benchmark>
    </benchmarks>
  </params>
</ndast>
```

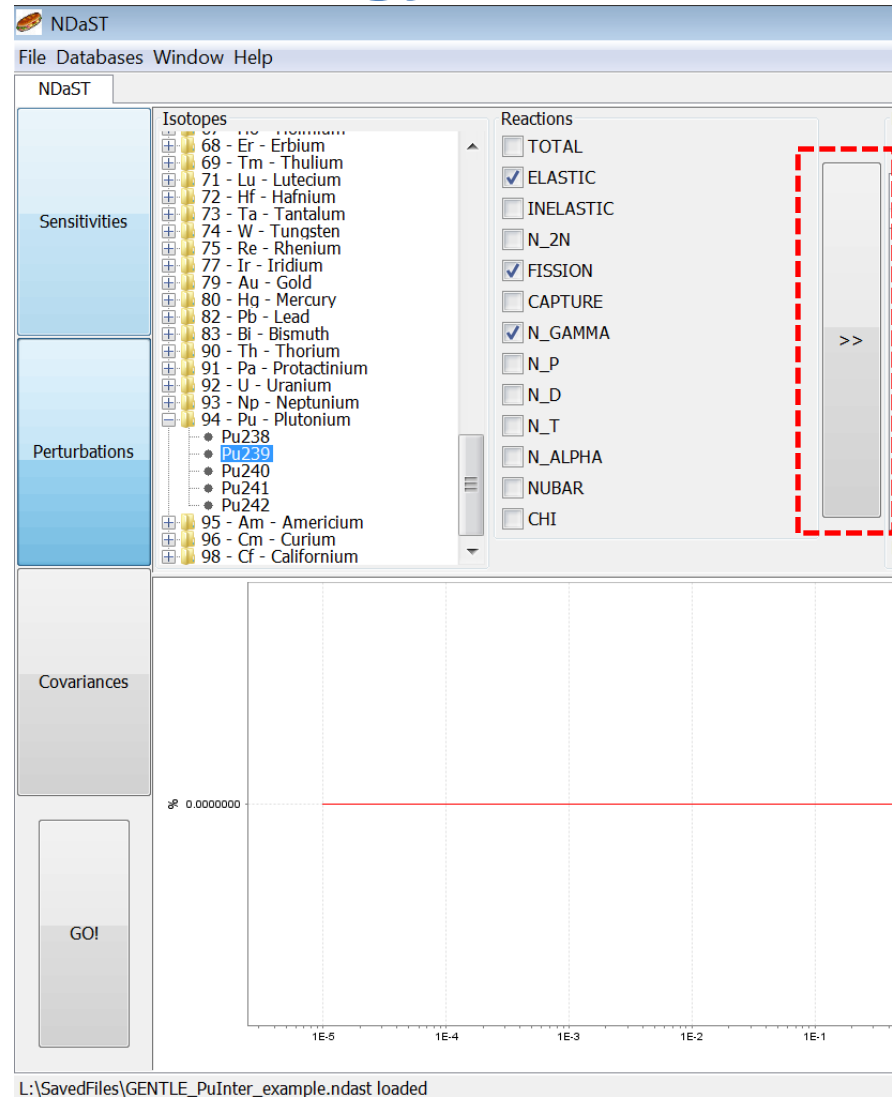
Consult your 'How To NDAST' guide for format

## Panel 2: Isotope-Reaction-Energy Perturbations

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

### Loading Options:

- Manually
- Copy/paste e.g. from file
- Auto-computed by dividing 2 evaluated files (via JANIS) Example:  
CIELO ÷ ENDF/B-VII.1
- Save in isolation or with panel 1 benchmarks



## Add Energy & Perturbation Manually

NDaST

File Databases Window Help

NDaST

Sensitivities

Perturbations

Covariances

GO!

Isotopes

- 68 - Er - Erbium
- 69 - Tm - Thulium
- 71 - Lu - Lutetium
- 72 - Hf - Hafnium
- 73 - Ta - Tantalum
- 74 - W - Tungsten
- 75 - Re - Rhenium
- 77 - Ir - Iridium
- 79 - Au - Gold
- 80 - Hg - Mercury
- 82 - Pb - Lead
- 83 - Bi - Bismuth
- 90 - Th - Thorium
- 91 - Pa - Protactinium
- 92 - U - Uranium
- 93 - Np - Neptunium
- 94 - Pu - Plutonium
  - Pu238
  - **Pu239**
  - Pu240
  - Pu241
  - Pu242
- 95 - Am - Americium
- 96 - Cm - Curium
- 98 - Cf - Californium

Reactions

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

Perturbations

E= 0.625 eV Add energy group bound(s) Paste perturbations JANIS ratio

Energy group	<Pu239,ELASTIC>	<Pu239,FISSION>	<Pu239,N_GAMMA>
1E-5 - 2E7 eV			

Perturbation label:

Energy (eV)

0.0000000

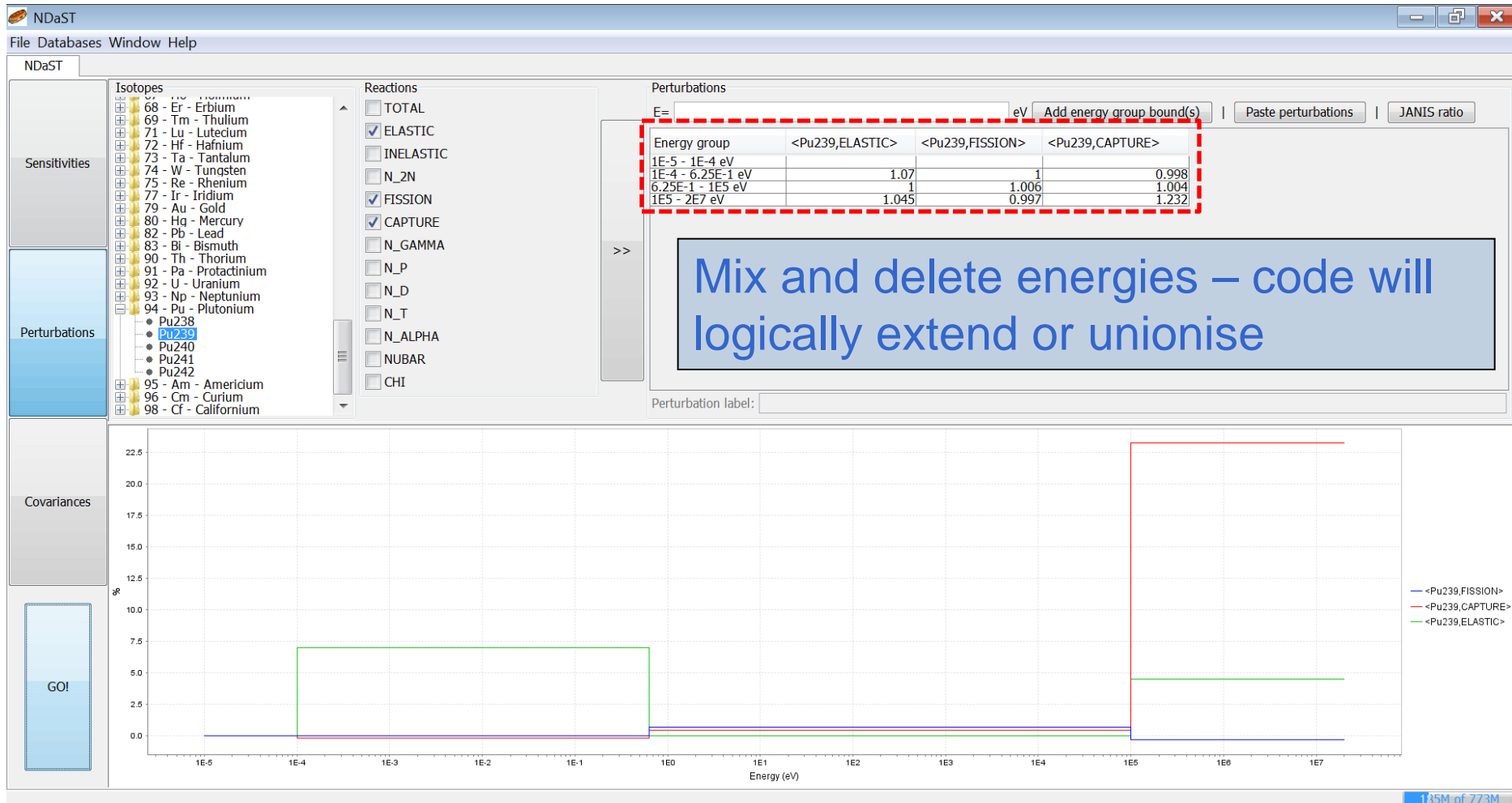
1E-5 1E-4 1E-3 1E-2 1E-1 1E0 1E2 1E3 1E4 1E5 1E6 1E7

<Pu239,N\_GAMMA>

I:\SavedFiles\GFNTIF PuInter example.ndast loaded

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## Add Energy & Perturbation Manually



## Paste Energies & Perturbations

NDaST

File Databases Window Help

NDaST

**Sensitivities**

**Perturbations**

**Covariances**

**GO!**

**Isotopes**

- 68 - Er - Erbium
- 69 - Tm - Thulium
- 71 - Lu - Lutetium
- 72 - Hf - Hafnium
- 73 - Ta - Tantalum
- 74 - W - Tungsten
- 75 - Re - Rhenium
- 77 - Ir - Iridium
- 79 - Au - Gold
- 80 - Hg - Mercury
- 82 - Pb - Lead
- 83 - Bi - Bismuth
- 90 - Th - Thorium
- 91 - Pa - Protactinium
- 92 - U - Uranium
- 93 - Np - Neptunium
- 94 - Pu - Plutonium
  - Pu238
  - **Pu239**
  - Pu240
  - Pu241
  - Pu242
- 95 - Am - Americium
- 96 - Cm - Curium
- 98 - Cf - Californium

**Reactions**

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

**Perturbations**

E=  eV Add energy group bound(s) | Paste perturbations | JANIS ratio

Energy...	<Pu23...	<Pu23...	<Pu23...
1E-5 - ...	1.103	1.004	
1E-4 - ...	1.103	1.004	
1E-3 - ...	1.103	1.002	
1E-2 - ...	1.105	1.002	
1E-1 - ...	1.065	0.999	
1E0 - 1...	1.062	1.028	
1E1 - 1...	1.031	0.995	
1E2 - 1...	1.005	0.993	
1E3 - 1...	0.984	1.018	
1E4 - 1...	1.001	1.006	
1E5 - 1...	1.02	1	
1E6 - 1...	1.006	1.001	
1E7 - 2...	1.094	0.993	

Perturbation label:

**Paste perturbations - NDaST**

Paste or enter "energy ; multiplication factor" lines, separators can be spaces, tabs or semicolons. Energies to be given in eV, in any order. Lines starting with '#' or '/' are skipped. First/last bound can be entered as a line with only a single value.

☐ lower energies (upper bound of 2E7 eV assumed if not given)

☒ upper energies (lower bound of 1E-5 eV assumed if not given)

```

1E-5
1E-4 ; 1.012
1E-3 ; 1.011
1E-2 ; 1.01
1E-1 ; 0.999
1E0 ; 0.998
1E1 ; 0.957
1E2 ; 1.017
1E3 ; 0.974
1E4 ; 0.97
1E5 ; 1.026
1E6 ; 1.109
1E7 ; 2.364
2E7 ; 0.365

```

Label:

OK Cancel

51M of 773M

## 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

11.00E-051.00E...
  Constant spectrum

Perturbation label:

Ok Cancel

Group structure

Group t...

Choose ...

Spectrum

Spectrum t...

Constant v...

Ok Cancel



## Launch Perturbation Calculation

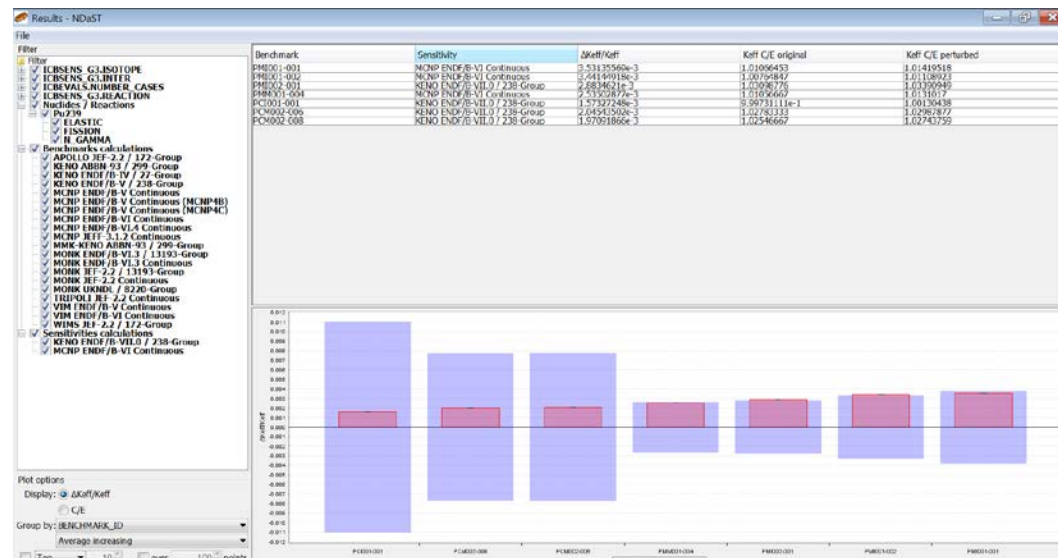
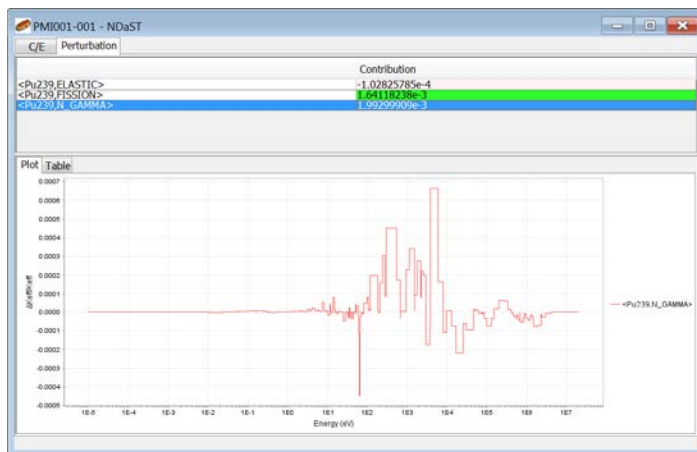
```

File
PERT> DICE[PCI001-001;]
PERT> DICE[case=PU-COMP-INTER-001-001 type=SENSITIVITY code=KENO library=ENDF/B-VII.0 / 238-Group]
UNCER> -> 6.08441252864059E-6
UNCER> {<Pu239,FISSION>,<Pu239,N_GAMMA>}
UNCER> -> 1.687825268113648E-7
UNCER> {<Pu239,ELASTIC>,<Pu239,N_GAMMA>}
UNCER> -> -1.1965019794201889E-8
UNCER> {<Pu239,ELASTIC>,<Pu239,FISSION>}
UNCER> -> 1.5416086410375235E-8
UNCER> DICE[PCM002-008;]
UNCER> DICE[case=PU-COMP-MIXED-002-008 type=SENSITIVITY code=KENO library=ENDF/B-VII.0 / 238-Group]
UNCER> {<Pu239,ELASTIC>,<Pu239,ELASTIC>}
UNCER> -> 5.242279257862125E-8
UNCER> {<Pu239,FISSION>,<Pu239,FISSION>}
PERT> DICE[PMI001-002;]
PERT> DICE[case=PU-MET-INTER-001-002 type=SENSITIVITY code=MCNP library=ENDF/B-VI Continuous]
UNCER> -> 5.0727034537967136E-6
UNCER> {<Pu239,N_GAMMA>,<Pu239,N_GAMMA>}
UNCER> -> 4.7570066074159375E-6
UNCER> {<Pu239,FISSION>,<Pu239,N_GAMMA>}
UNCER> -> 3.1421634518774925E-9
UNCER> {<Pu239,ELASTIC>,<Pu239,N_GAMMA>}
UNCER> -> 1.986559163054255E-8
UNCER> {<Pu239,ELASTIC>,<Pu239,FISSION>}
UNCER> -> 4.0788668839728676E-10
UNCER> DICE[PCI001-001;]
UNCER> DICE[case=PU-COMP-INTER-001-001 type=SENSITIVITY code=KENO library=ENDF/B-VII.0 / 238-Group]
UNCER> {<Pu239,ELASTIC>,<Pu239,ELASTIC>}
UNCER> -> 1.2538544368114808E-7
UNCER> {<Pu239,FISSION>,<Pu239,FISSION>}
UNCER> -> 2.489041557364693E-5
UNCER> {<Pu239,N_GAMMA>,<Pu239,N_GAMMA>}
UNCER> -> 7.035549444764207E-6
UNCER> {<Pu239,FISSION>,<Pu239,N_GAMMA>}
UNCER> -> -2.0381817191270436E-6
UNCER> {<Pu239,ELASTIC>,<Pu239,N_GAMMA>}
UNCER> -> -1.5883094343585428E-7
UNCER> {<Pu239,ELASTIC>,<Pu239,FISSION>}
UNCER> -> -8.747587206254423E-8
UNCER> DICE[PMI001-002;]
UNCER> DICE[case=PU-MET-INTER-001-002 type=SENSITIVITY code=MCNP library=ENDF/B-VI Continuous]
UNCER> {<Pu239,ELASTIC>,<Pu239,ELASTIC>}
PERT> DICE[PMI002-001;]
PERT> DICE[case=PU-MET-INTER-002-001 type=SENSITIVITY code=KENO library=ENDF/B-VII.0 / 238-Group]
UNCER> -> 2.7880762358182364E-8
UNCER> {<Pu239,FISSION>,<Pu239,FISSION>}
UNCER> -> 5.484742575128667E-6
UNCER> {<Pu239,N_GAMMA>,<Pu239,N_GAMMA>}

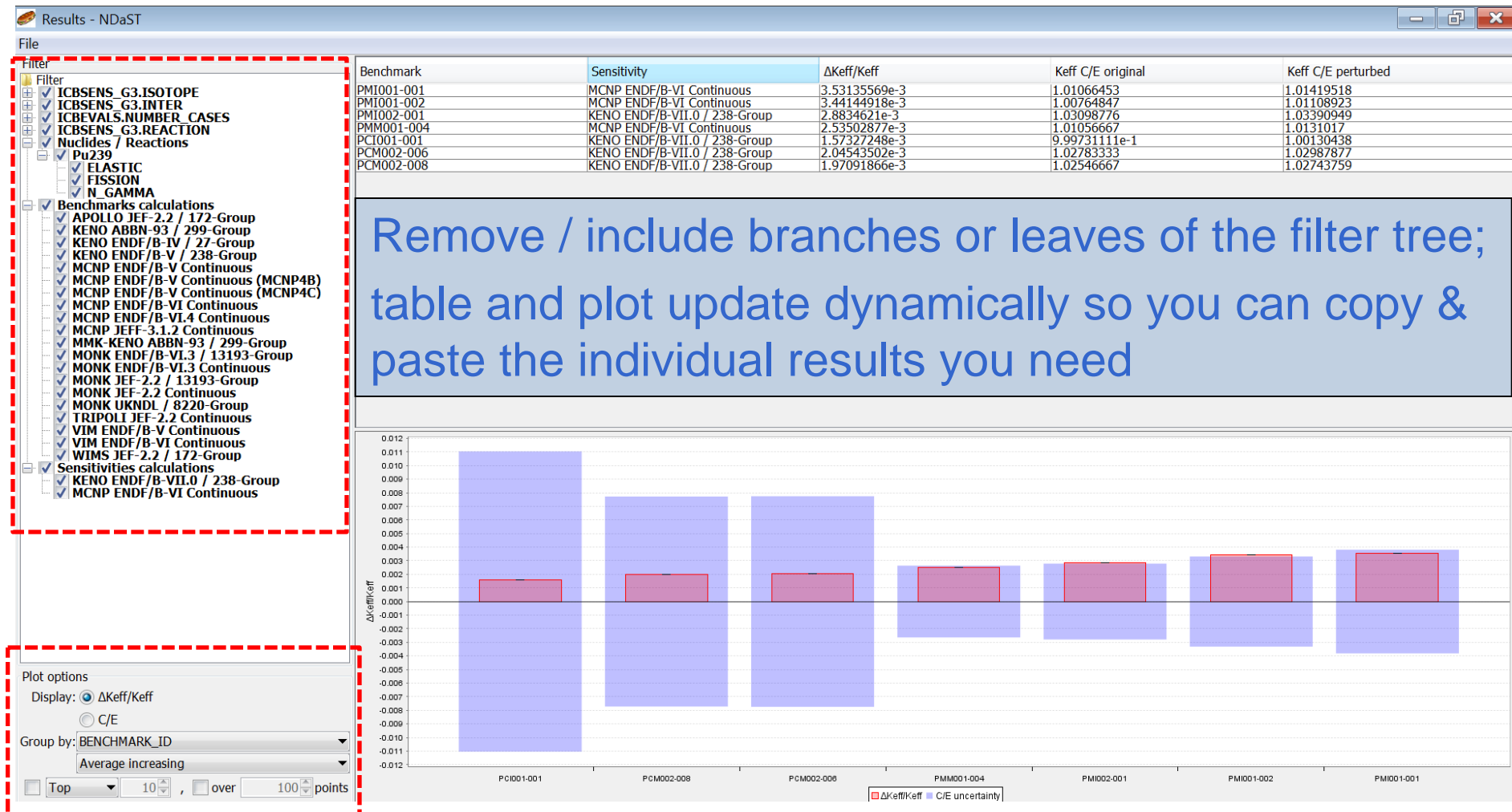
```

## Output Window and Plots (1)

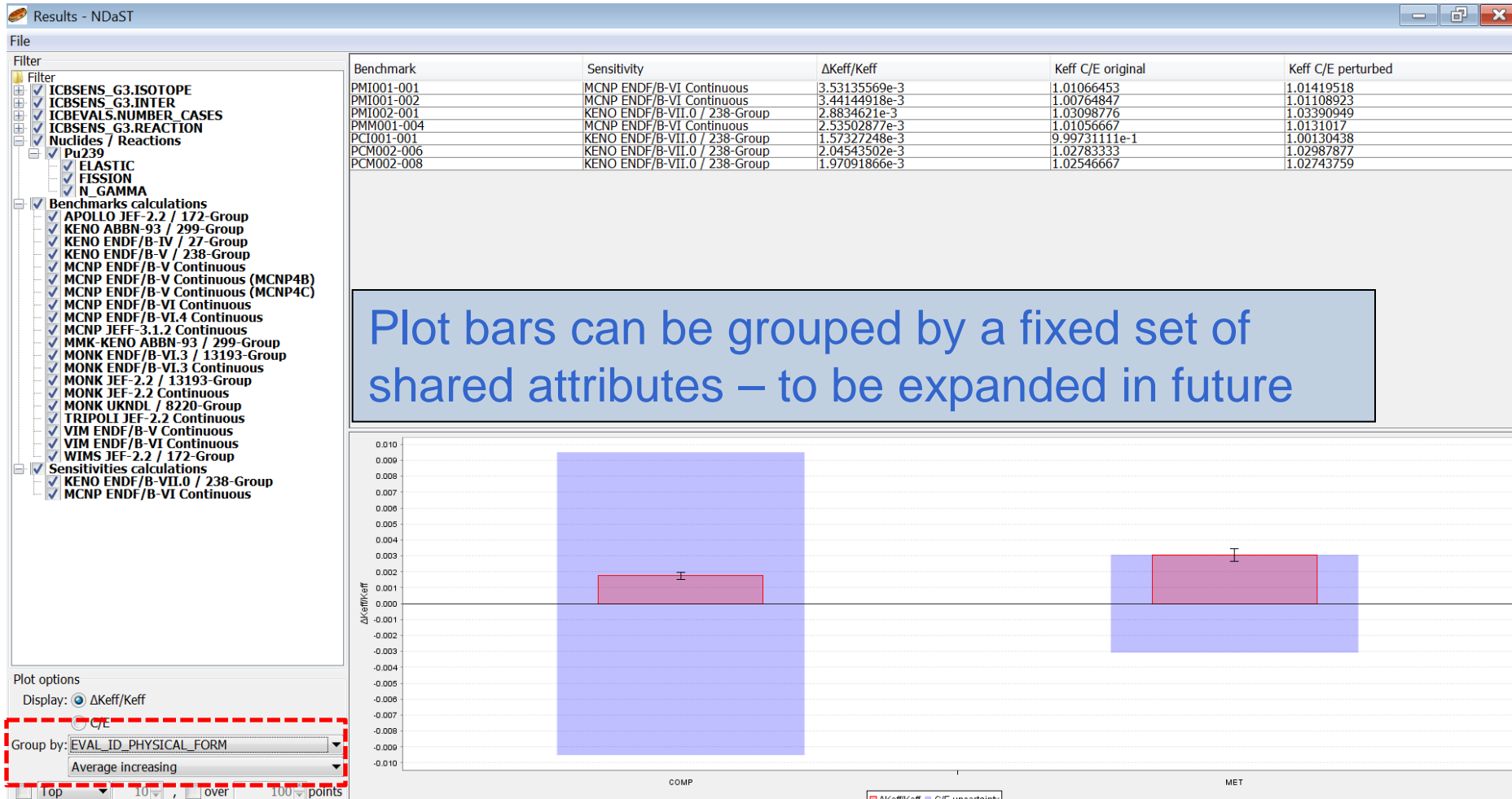
- Window with results table of  $\Delta k_{\text{eff}}/k_{\text{eff}}$ , original & perturbed mean C/E
- Filter tree to the side – dynamic inclusion by nuclide, reaction, fuel, code...
- Grouped plot below – toggle either  $\Delta k_{\text{eff}}$  or C/E
- Grouping and sorting options, plus tool-tip data for the plot
- Detail pop-up to see complete data behind each benchmark in the table
  - Nuclide-reaction breakdown of total  $\Delta k_{\text{eff}}$
  - Individual C/E for all results loaded to that case
  - Energy breakdown of  $\Delta k_{\text{eff}}$



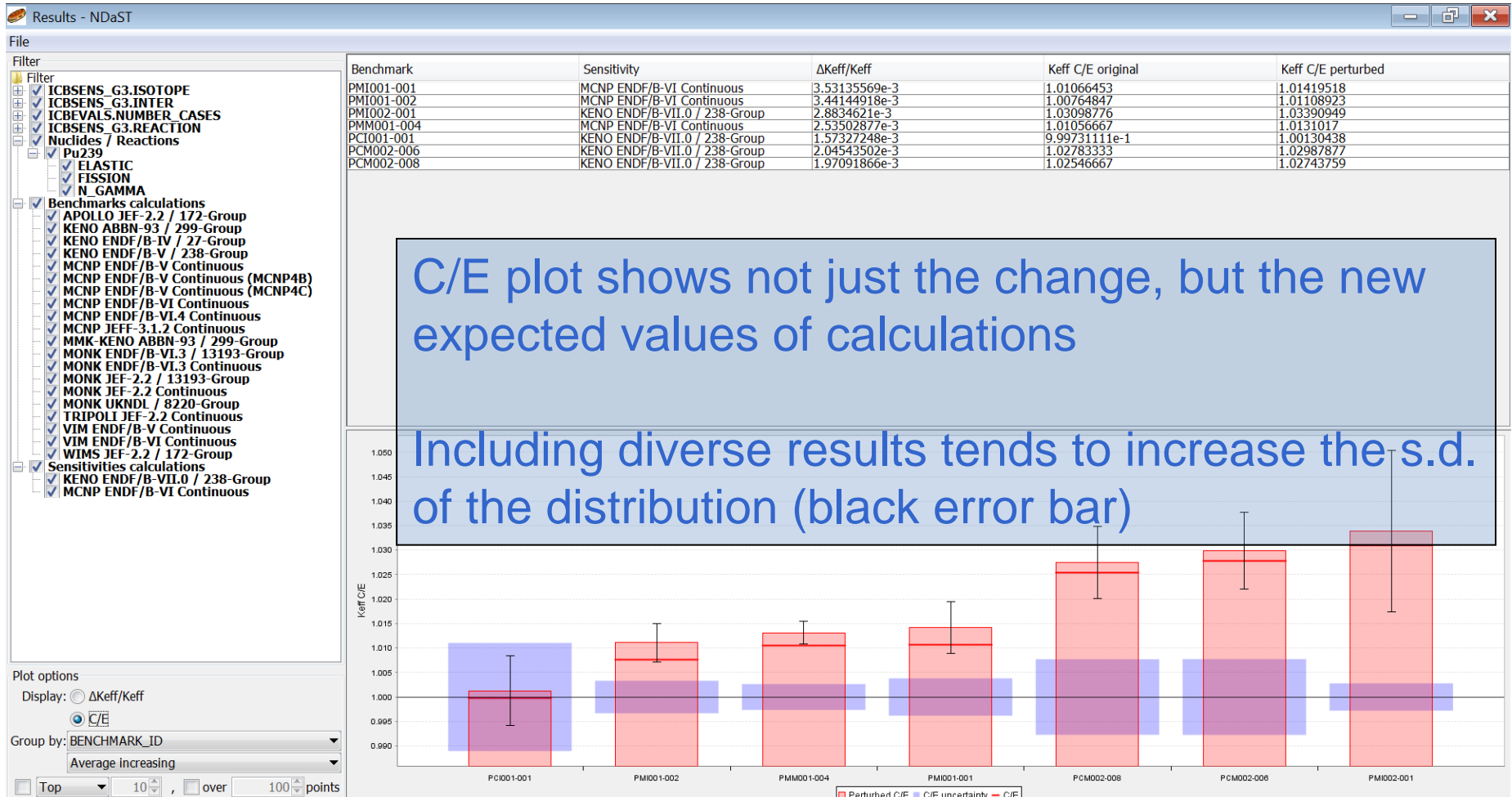
## Delta $k_{\text{eff}}$ Output and Plot



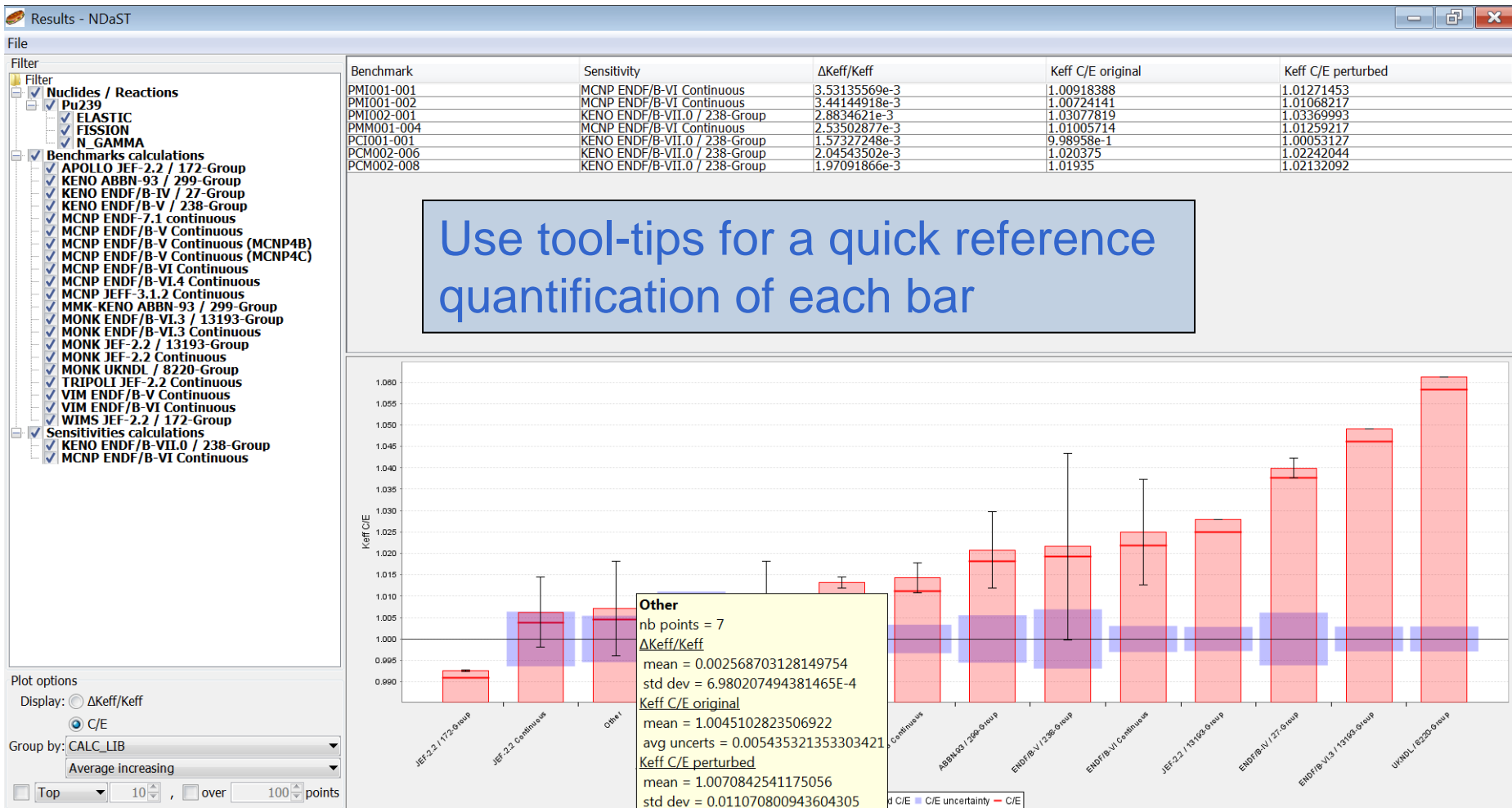
## Delta $k_{\text{eff}}$ Output: Physical Form



## C/E Output Plot: BM ID



## C/E Output Plot: Calculation Library + Tooltips





## Output Table: Detail Popup (C/E)

PMI001-001 - NDaST

C/E

Perturbation

Benchmark Keff = 1.0002

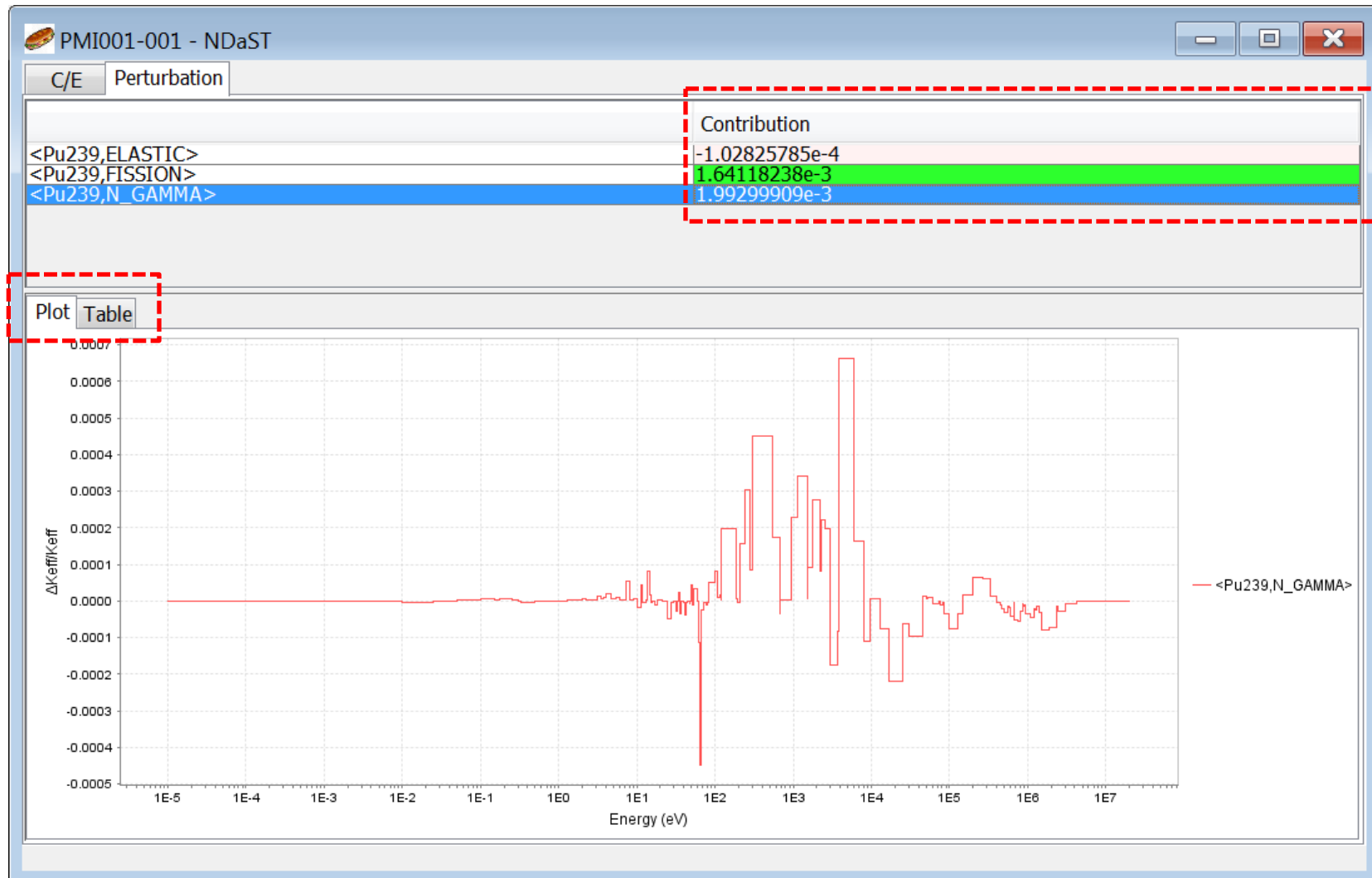
Benchmark Keff uncertainty = 0.0037

Perturbation  $\Delta K_{eff}/K_{eff} = 3.53135569e-3$

Calculation	Keff	Keff unc.	Keff C/E original	Keff C/E unc.	Keff C/E perturbed
MCNP ENDF/B-VI.4 Continuous	1.012		1.011798	3.777679e-3	1.015328
MMK-KENO ABBN-93 / 299-Group	1.011	0.00	1.010498	3.787683e-3	1.014029
MCNP ENDF/B-V Continuous	1		0.999400	3.731391e-3	1.002931
MONK JEF-2.2 Continuous	1.012	0.00	1.012198	3.879504e-3	1.015728
MCNP ENDF/B-VI Continuous	1.015	0.00	1.014597	3.803048e-3	1.018128
MONK ENDF/B-VI.3 Continuous	1.016	0.00	1.015497	3.892149e-3	1.019028

Double click a table entry to see the detail behind the average values i.e. complete breakdowns

## Output Table: Detail Popup (Perturbation)



## Exercise 1 - Perturbations

- I. Choose BMs based on some sensitivity criteria to Pu239
  - Select top cases (max ~10)
- II. Edit the cases with 'personal'  $k_{\text{eff}}$  calculations
- III. Input a simple 3 group perturbation for 3 main reactions
  - Elastic, capture, fission
- IV. Run the tool and get an output sorted by spectrum
  - Try excluding all non 'personal' results
- V. Decide if this improves each of the results
- VI. Do this again, but with a full 'JANIS ratio' computation
- VII. Analyse which energy region has the biggest impact

## Exercise 1 – Example Perturbations

Search DICE for

- Pu fuel cases sensitive to intermediate fission
- $\geq 0.2 \%dk/\%d\Sigma$

- Add data from these tables

Predict effect of replacing  
JENDL-4.0 / ENDF/B-VII.1

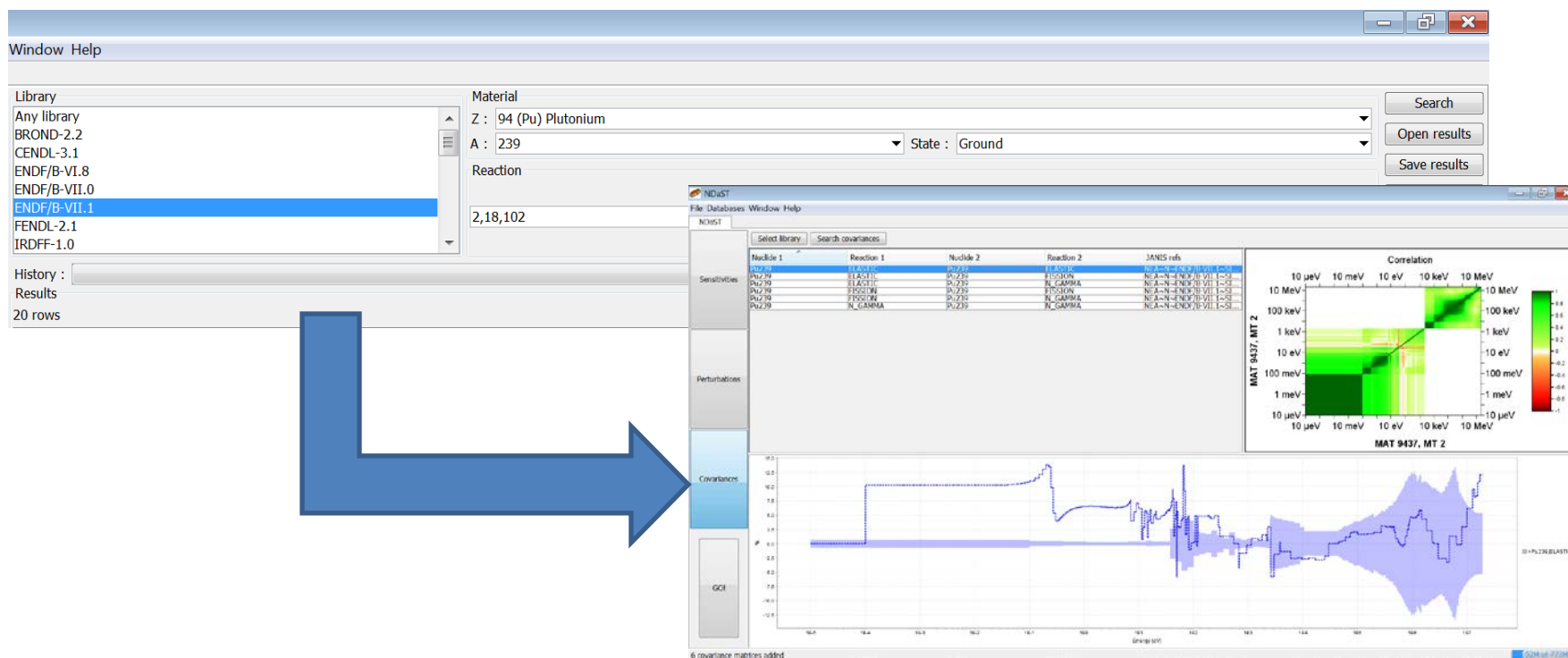
Benchmark	ENDF/B-VII.1 Calculation
PCI001-001	$1.0095 \pm 0.0002$
PCM002-006	$1.0150 \pm 0.0002$
PCM002-008	$1.0180 \pm 0.0002$
PMI001-001	$0.9970 \pm 0.0002$
PMI001-002	$0.9980 \pm 0.0002$
PMI002-001	$1.0050 \pm 0.0002$
PMM001-004	$1.0120 \pm 0.0002$

	Pu239 elastic	Pu239 fission	Pu239 capture
1E-4 - 0.625 eV	1.070	1.000	0.998
0.625 - 100 keV	1.000	1.006	1.004
100 keV - 20 MeV	1.045	0.997	1.232

## Panel 3: Select XS Covariance Data

Covariance data selected from JANIS for uncertainty propagation calculation

- Many different sources of covariance in NEA base
- You can also add your own to JANIS and use within NDaST (slightly advanced)
- Correlation and standard deviation plots from JANIS are shown
- Relative standard deviations plotted against perturbations if they exist



## JANIS Covariance Search

NDaST

File Databases Window Help

NDaST

Sensitivities

Library

- Any library
- BROND-2.2
- CENDL-3.1
- ENDF/B-VI.8
- ENDF/B-VII.0
- ENDF/B-VII.1
- FENDL-2.1
- IRDFF-1.0

Material

Z : 94 (Pu) Plutonium

A : 239

State : Ground

Reaction

2,18,102

History :

Results

20 rows

Search	Evaluation	Format	Material1	MF1	MT1	Material2	MF2	MT2
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=2 : (z,elastic)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=4 : (z,n)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=16 : (z,2n)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=17 : (z,3n)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=37 : (z,4n)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=18 : (z,fission)	Pu239	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=18 : (z,fission)	Pu239	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	BOXER	Pu239	MF=33	MT=102 : (z,y)	Pu239	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=2 : (z,elastic)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=2 : (z,elastic)	Pu239	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=18 : (z,fission)	Li6	MF=33	MT=105 : (z,t)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=18 : (z,fission)	Au197	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=18 : (z,fission)	U235	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=18 : (z,fission)	U238	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=18 : (z,fission)	Pu239	MF=33	MT=18 : (z,fission)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=18 : (z,fission)	Pu239	MF=33	MT=102 : (z,y)
NEA	ENDF/B-VII.1	ENDF	Pu239	MF=33	MT=102 : (z,y)	Pu239	MF=33	MT=102 : (z,y)

GO!

Ready

OK Cancel

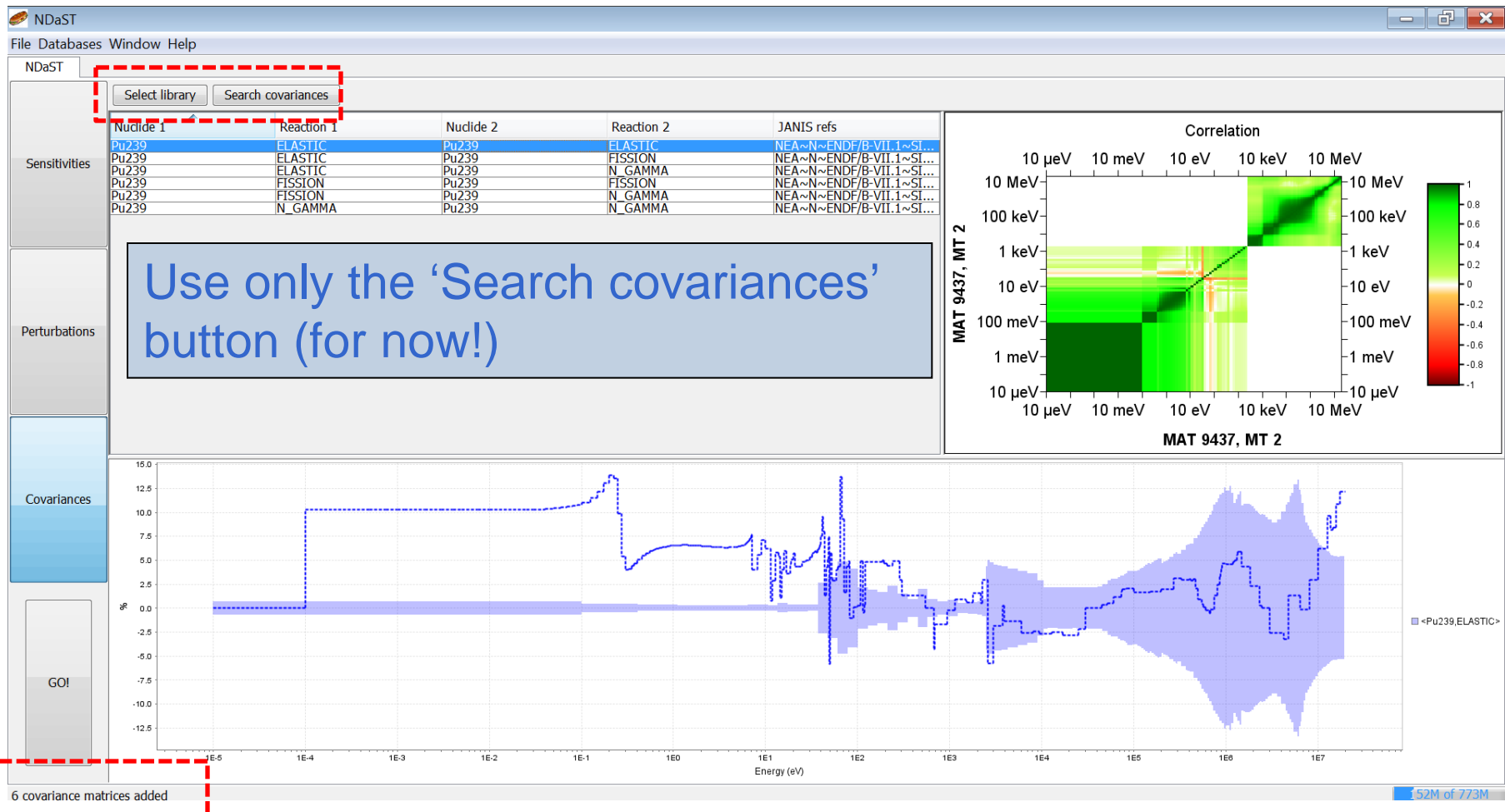
118M of 773M

Note use of commas in search

Only add BOXER format data

Use the ctrl+click row function

## View Selected Covariance Files





## Launch Uncertainty Calculation

NDaST

File Databases Window Help

NDaST

Select library Search covariances

Nuclide 1	Reaction 1	Nuclide 2	Reaction 2
Pu239	ELASTIC	Pu239	ELASTIC
Pu239	ELASTIC	Pu239	FISSION
Pu239	ELASTIC	Pu239	N_GAMMA
Pu239	FISSION	Pu239	FISSION
Pu239	FISSION	Pu239	N_GAMMA
Pu239	N_GAMMA	Pu239	N_GAMMA

Sensitivities

Perturbations

Covariances

GO!

6 covariance matrices added

Results - NDaST

File

```

PERT> DICE[PCI001-001;]
PERT> DICE[case=PU-COMP-INTER-001-001 type=SENSITIVITY code=KENO library=ENDF/B-VII.0 / 238-Group]
UNCER> -> 6.08441252864059E-6
UNCER> {<Pu239,FISSION>,<Pu239,N_GAMMA>}
UNCER> -> 1.687825268113648E-7
UNCER> {<Pu239,ELASTIC>,<Pu239,N_GAMMA>}
UNCER> -> -1.1965019794201889E-8
UNCER> {<Pu239,ELASTIC>,<Pu239,FISSION>}
UNCER> -> 1.5416086410375235E-8
UNCER> DICE[PCM002-008;]
UNCER> DICE[case=PU-COMP-MIXED-002-008 type=SENSITIVITY code=KENO library=ENDF/B-VII.0 / 238-Group]
UNCER> {<Pu239,ELASTIC>,<Pu239,ELASTIC>}
UNCER> -> 5.242279257862125E-8
UNCER> {<Pu239,FISSION>,<Pu239,FISSION>}
PERT> DICE[PMI001-002;]
PERT> DICE[case=PU-MET-INTER-001-002 type=SENSITIVITY code=MCNP library=ENDF/B-VI Continuous]
UNCER> -> 5.0727034537967136E-6
UNCER> {<Pu239,N_GAMMA>,<Pu239,N_GAMMA>}
UNCER> -> 4.7570066074159375E-6
UNCER> {<Pu239,FISSION>,<Pu239,N_GAMMA>}
UNCER> -> 3.1421634518774925E-9
UNCER> {<Pu239,ELASTIC>,<Pu239,N_GAMMA>}
UNCER> -> 1.986559163054255E-8
UNCER> {<Pu239,ELASTIC>,<Pu239,FISSION>}
UNCER> -> 4.0788668839728676E-10
UNCER> DICE[PCI001-001;]
UNCER> DICE[case=PU-COMP-INTER-001-001 type=SENSITIVITY code=KENO library=ENDF/B-VII.0 / 238-Group]
UNCER> {<Pu239,ELASTIC>,<Pu239,ELASTIC>}
UNCER> -> 1.2538544368114808E-7
UNCER> {<Pu239,FISSION>,<Pu239,FISSION>}
UNCER> -> 2.489041557364693E-5
UNCER> {<Pu239,N_GAMMA>,<Pu239,N_GAMMA>}
UNCER> -> 7.035549444764207E-6
UNCER> {<Pu239,FISSION>,<Pu239,N_GAMMA>}
UNCER> -> -2.0381817191270436E-6
UNCER> {<Pu239,ELASTIC>,<Pu239,N_GAMMA>}
UNCER> -> -1.5883094343585428E-7
UNCER> {<Pu239,ELASTIC>,<Pu239,FISSION>}
UNCER> -> -8.747587206254423E-8
UNCER> DICE[PMI001-002;]
UNCER> DICE[case=PU-MET-INTER-001-002 type=SENSITIVITY code=MCNP library=ENDF/B-VI Continuous]
UNCER> {<Pu239,ELASTIC>,<Pu239,ELASTIC>}
PERT> DICE[PMI002-001;]
PERT> DICE[case=PU-MET-INTER-002-001 type=SENSITIVITY code=KENO library=ENDF/B-VII.0 / 238-Group]
UNCER> -> 2.7880762358182364E-8
UNCER> {<Pu239,FISSION>,<Pu239,FISSION>}
UNCER> -> 5.484742575128667E-6
UNCER> {<Pu239,N_GAMMA>,<Pu239,N_GAMMA>}

```

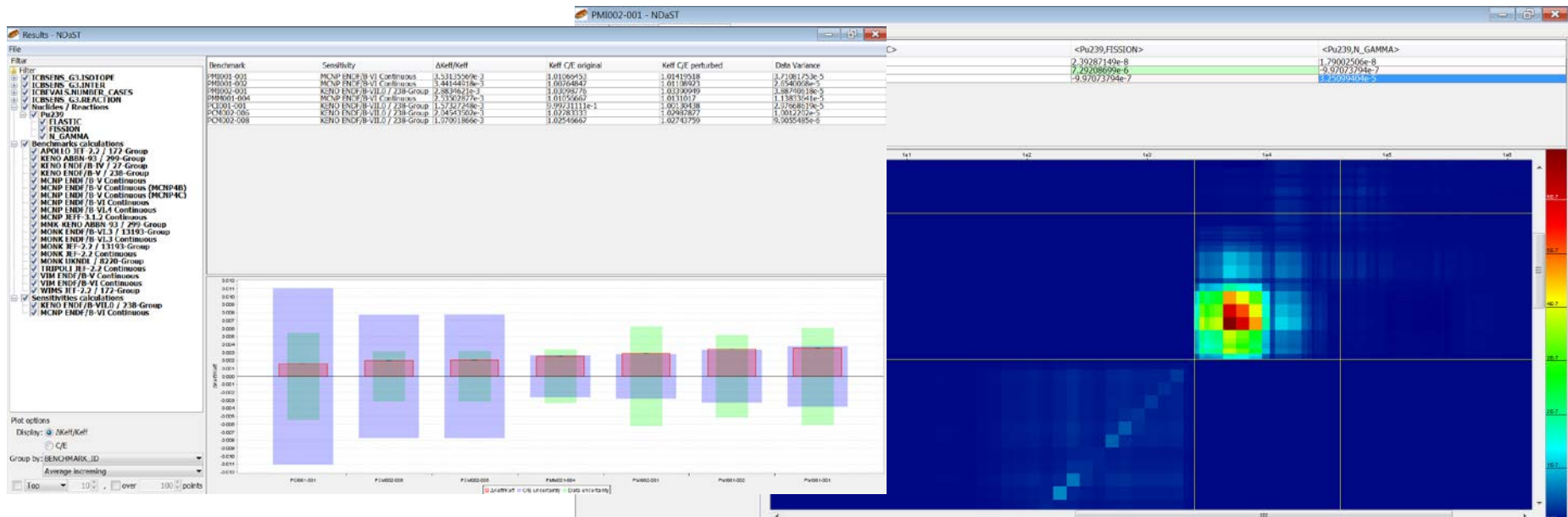
NDaST

Launch Perturbation calculation with uncertainty propagation with:  
7 benchmark(s), 3 perturbation(s), 6 covariance(s)

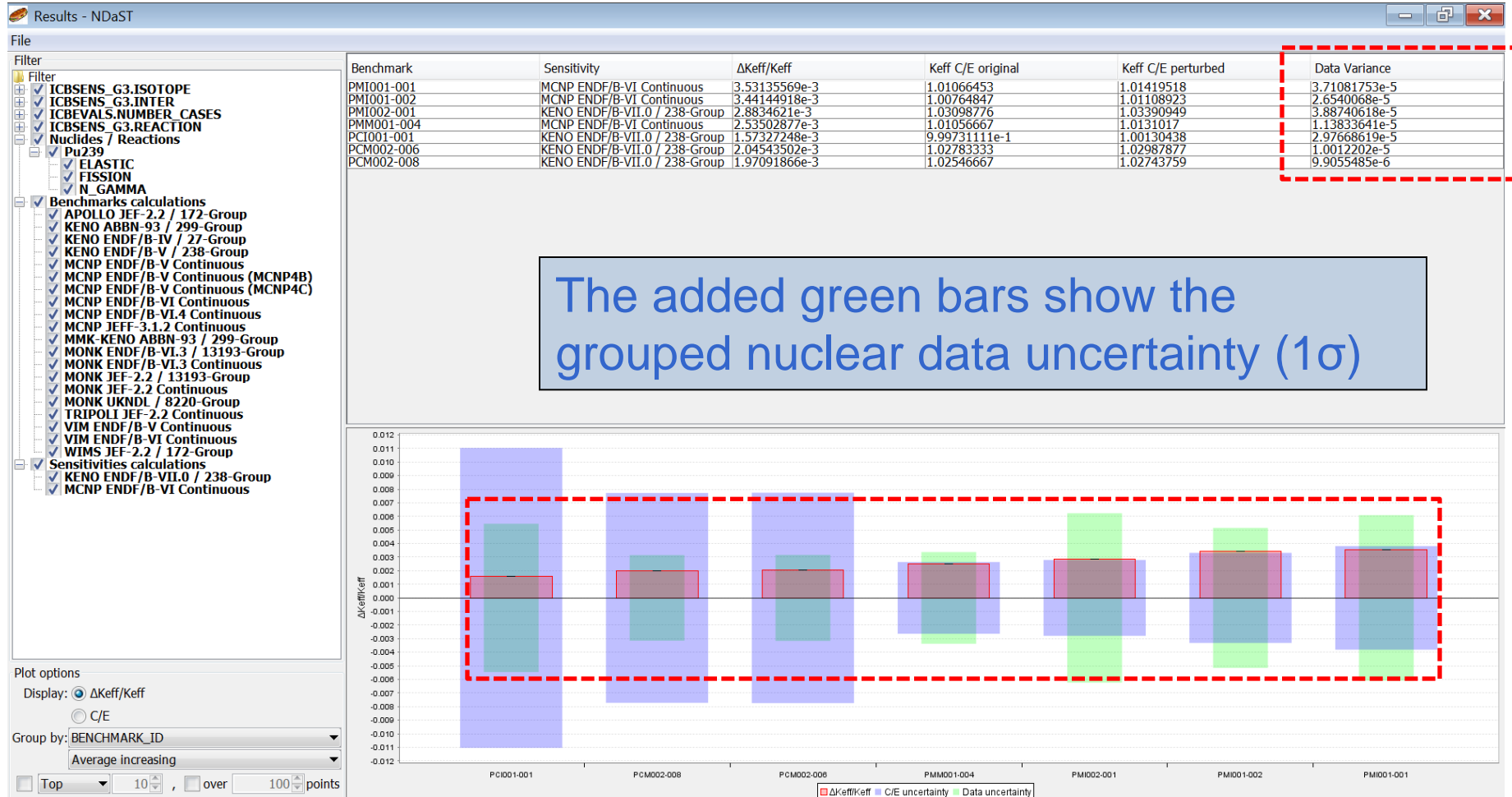
OK Cancel

## Output Window and Plots (2)

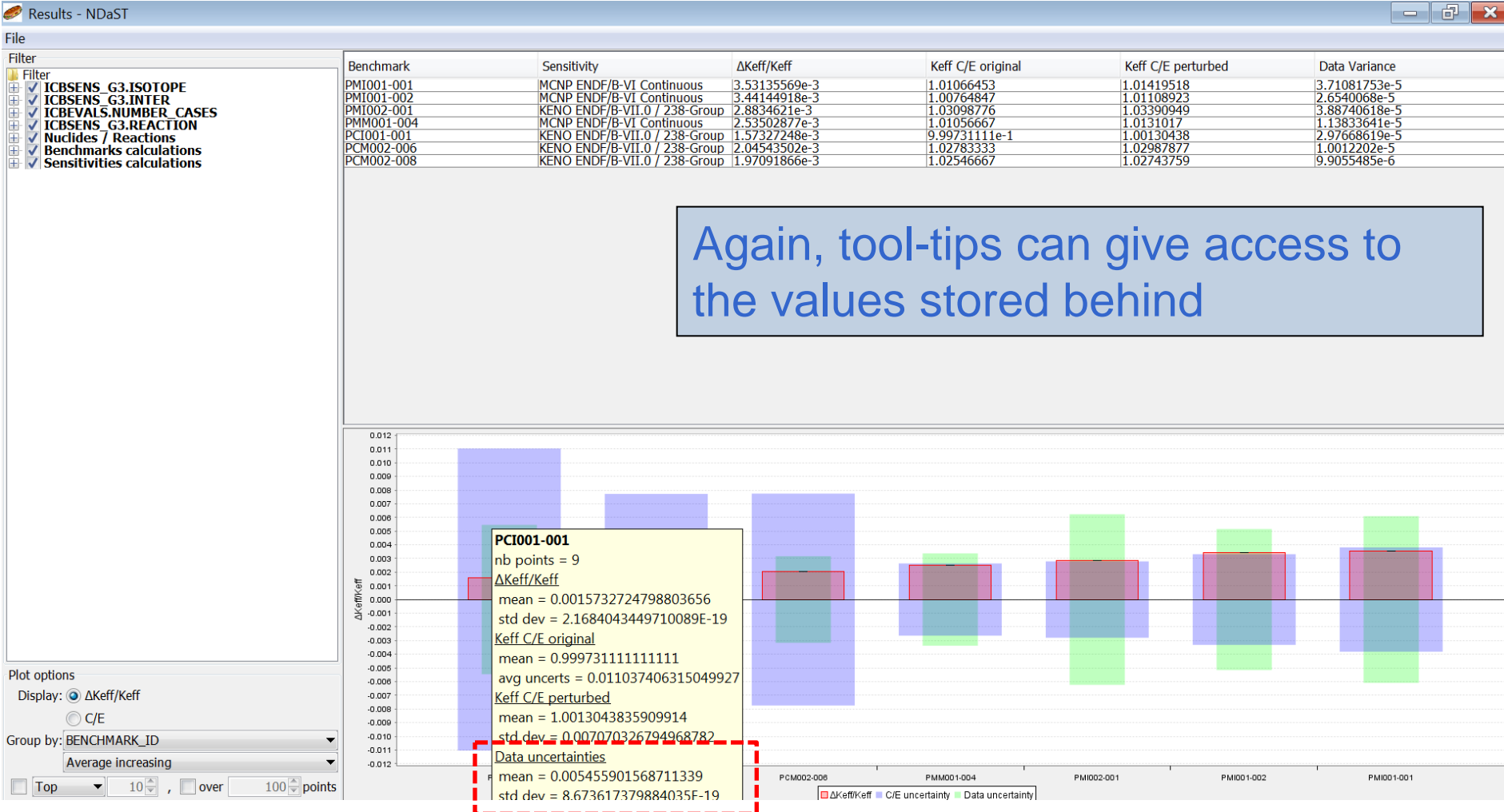
- Results table of  $\Delta k_{\text{eff}}/k_{\text{eff}}$ , original & perturbed C/E + XS uncertainty
- Grouped plot below – toggle either  $\Delta k_{\text{eff}}$  or C/E + XS uncertainty bar
- Detail pop-up to see complete data behind each benchmark in the table
  - Nuclide-reaction breakdown of total  $\Delta k_{\text{eff}}$  + XS uncertainty (new tab)
  - Energy breakdown of XS uncertainty as colour / heat map
  - Range selection of heat map to quantify contributions + clipboarding



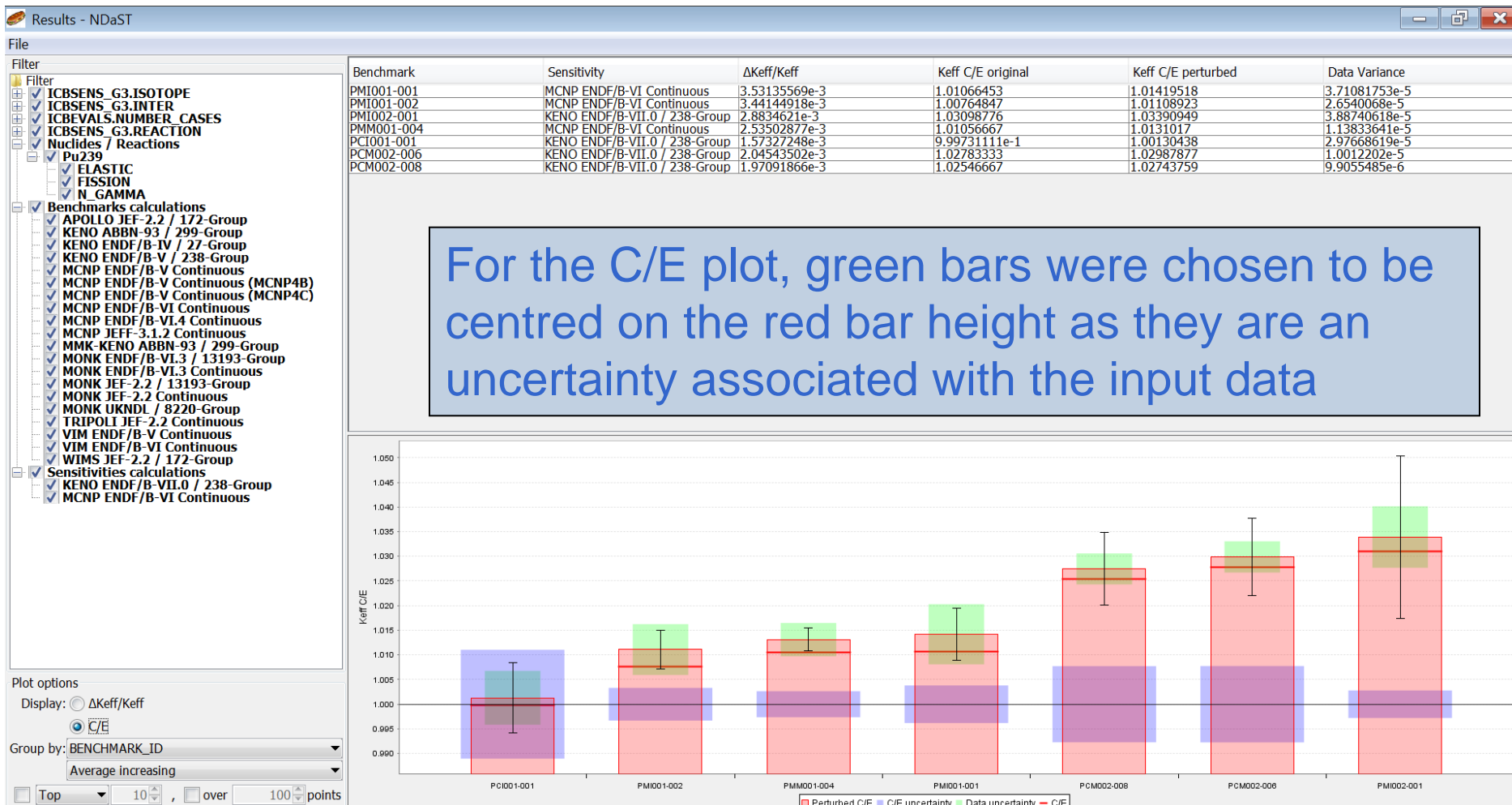
## Delta $k_{\text{eff}}$ Output and Plot



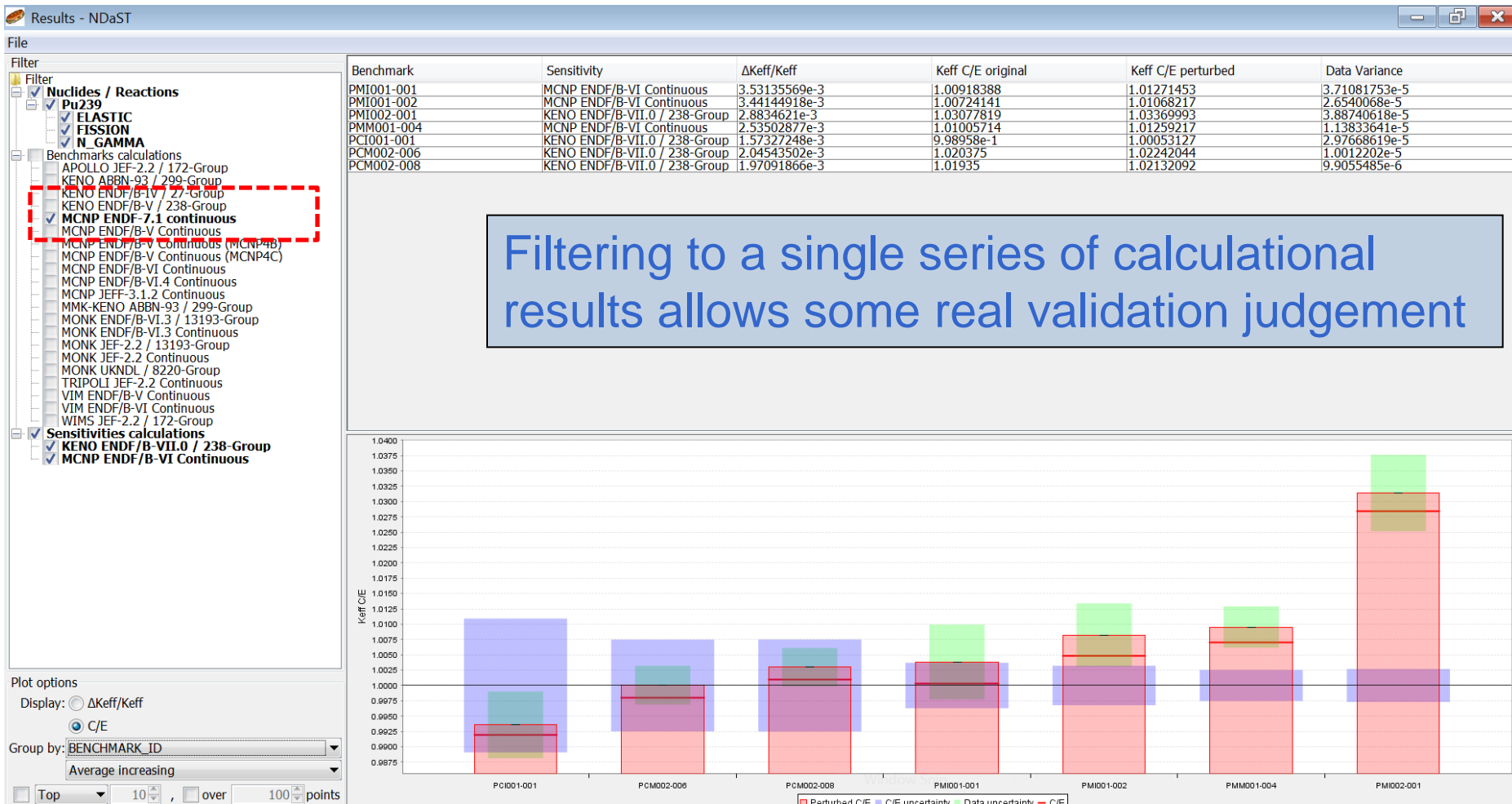
## Delta $k_{\text{eff}}$ Output: Tooltips



## C/E Output Plot: BM ID



## C/E Output Plot: BM ID Filtered





## Save Output Data

Results - NDAST

**File**

Filter

- Nuclides / Reactions
  - ☒ Pu239
  - ☒ ELASTIC
  - ☒ FISSION
  - ☒ N\_GAMMA
- Benchmarks calculations
  - APOLLO JEF-2.2 / 172-Group
  - KENO ABBN-93 / 299-Group
  - KENO ENDF/B-IV / 27-Group
  - KENO ENDF/B-V / 238-Group
  - ☒ MCNP ENDF-7.1 continuous
    - MCNP ENDF/B-V Continuous
    - MCNP ENDF/B-V Continuous (MCNP4B)
    - MCNP ENDF/B-V Continuous (MCNP4C)
    - MCNP ENDF/B-VI Continuous
    - MCNP ENDF/B-VI.4 Continuous
    - MCNP JEFF-3.1.2 Continuous
    - MMK-KENO ABBN-93 / 299-Group
    - MONK ENDF/B-VI.3 / 13193-Group
    - MONK ENDF/B-VI.3 Continuous
    - MONK JEF-2.2 / 13193-Group
    - MONK JEF-2.2 Continuous
    - MONK UKNDL / 8220-Group
    - TRIPOLI JEF-2.2 Continuous
    - VIM ENDF/B-V Continuous
    - VIM ENDF/B-VI Continuous
    - WIMS JEF-2.2 / 172-Group
- Sensitivities calculations
  - ☒ KENO ENDF/B-VII.0 / 238-Group
  - ☒ MCNP ENDF/B-VI Continuous

Benchmark	Sensitivity	$\Delta K_{eff}/K_{eff}$	Keff C/E original	Keff C/E perturbed	Data Variance
PM1001-001	MCNP ENDF/B-VI Continuous	3.53135569e-3	1.00918388	1.01271453	3.71081753e-5
PM1001-002	MCNP ENDF/B-VI Continuous	3.44144918e-3	1.00724141	1.01068217	2.6540068e-5
PM1002-001	KENO ENDF/B-VII.0 / 238-Group	2.8834621e-3	1.03077819	1.03369993	3.88740618e-5
PMM001-004	MCNP ENDF/B-VI Continuous	2.53502877e-3	1.01005714	1.01259217	1.13833641e-5
PCI001-001	KENO ENDF/B-VII.0 / 238-Group	1.57327248e-3	9.98958e-1	1.00053127	2.97668619e-5
PCM002-006	KENO ENDF/B-VII.0 / 238-Group	2.04543502e-3	1.020375	1.02242044	1.0012202e-5
PCM002-008	KENO ENDF/B-VII.0 / 238-Group	1.97091866e-3	1.01935	1.02132092	9.9055485e-6

**Save as**

Look in: SavedFiles

Recent I... st  
only.ndast

Desktop

My Doc...

Computer

Network

File name: GENTLE\_PuInter\_example.ndast

Files of type: NDAST Parameters (\*.ndast)

Parts to save:

- ☒ benchmarks
- ☒ perturbations
- ☒ covariances
- ☒ results

Save as

Cancel

Plot options

Display: ☐  $\Delta K_{eff}/K_{eff}$   
☒ C/E

Group by: BENCHMARK\_ID

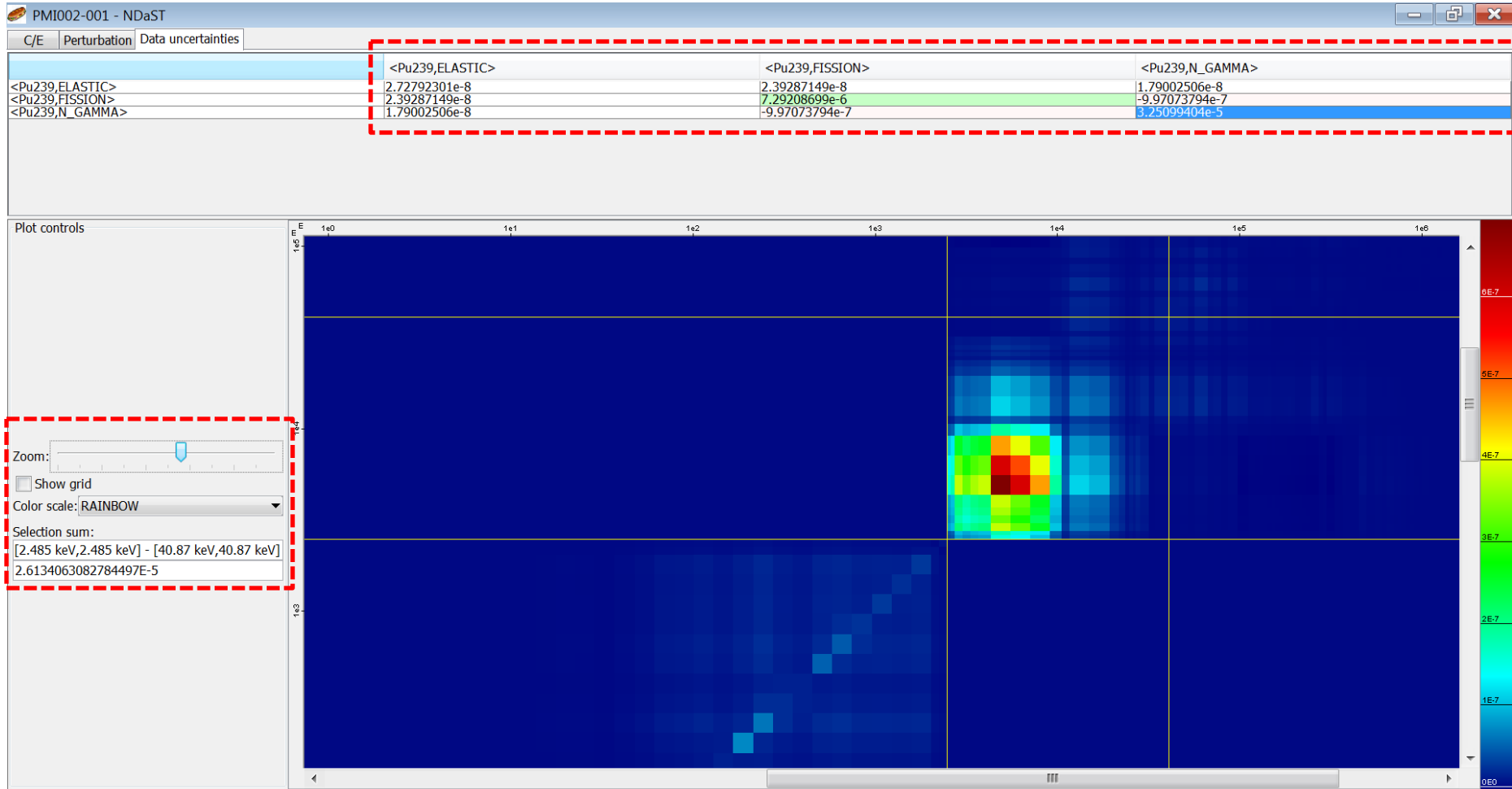
Average increasing

Top 10, over 100 points

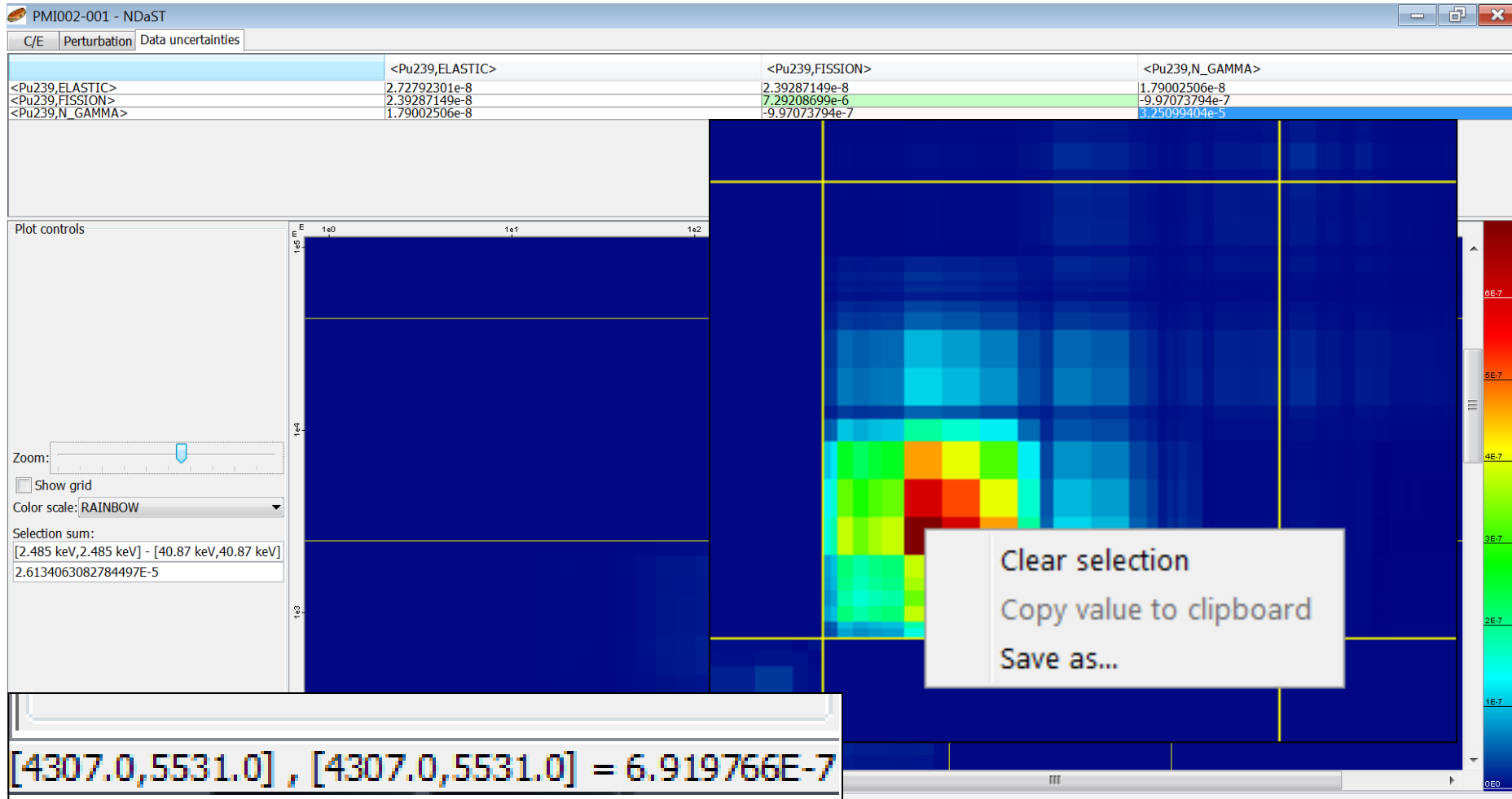
Legend: Perturbed C/E, C/E uncertainty, Data uncertainty, C/E



## Output Table: Detail Popup (Uncertainty)



## Output Table: Detail Popup (Uncertainty)



## Future NDaST Plans

*NDaST principles: 1. Fast 2. Provides Insight 3. Integrates NEA Tools*

**Applications / End results (features for users higher up the application chain)**

– Phase 2:

- Continue to improve GUI features – e.g. automatically fill available nuclides
- Provide useful statistical metrics – representativity ( $C_k$ ), chi-square values, adjustment based quantities
- Total NDaST – multiple files randomly generated + statistical analysis of distribution
- Link to NDEC – automatic perturbation generation from checking cycle

– Phase 3+:

- With access to correlation coefficients, a full adjustment / GLS tool is possible.
- Application specific features e.g. parameters to trend criticality safety / burn-up credit analyses.

## Future NDaST Plans

*NDaST principles: 1. Fast 2. Provides Insight 3. Integrates NEA Tools*

**Physics / Fundamentals (features for users closer to the basic data)**

– Phase 2:

- Compensating effect analysis – automatically preserve well known values e.g. total cross-section.
- Incorporation of further sensitivity and covariance data formats.
- Make available additional covariance data – allow comparison of all major modern libraries.
- Handling of angular sensitivity data and MF34 uncertainty propagation.

– Phase 3+:

- Generation / comparison of analytical models – e.g. Maxwellian & Watt PFNS representations. Analytical covariances?
- Re-fitting experimental data to make fundamental ENDF-format file perturbations.

## Exercise (2) – Add Covariances

- I. Find covariance data for the 3 reactions
- II. Add these + cross-nuclide matrices (Find all 6)
- III. Check the perturbations against the s.d. values
- IV. Re-run and look at the plot with green bar added
  - Check consistency of perturbation against uncertainty
- V. Look at the diagonal / off-diagonal breakdown
  - View energy breakdown
  - Use region selection and clipboarding
- VI. Try replacing with another library's covariances and re-run
  - Put the two output plots side-by-side

## Thank you for your attention

Now you're trained, please try out NDaST in your own time, for your own applications

- We are interested in all feedback (good and bad) as we build and understand the user base
- New features will be prioritised according to our estimation of user interest

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