SANDA Project Subtask 5.2.1: correlations in integral experiments

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Subtask 5.2.1: correlations in integral experiments

- SANDA subtask 5.2.1: Assessing correlations in integral experiments

Subtask 5.2.1: Assessing correlations in integral experiments
While a considerable effort has been given to nuclear data covariances in recent years, much less attention has been paid to correlations in integral experiments used in validation, adjustment, and assimilation studies. In point of fact, correlation coefficient data for criticality cases are available for only 93 integral experiments of the DICE database associated with the ICSBEP Handbook.
Although this project will not attempt to produce adjusted nuclear data libraries nor to assimilate validation information, ***CIEMAT, JSI, CEA/DEN, and UPM will share their best experts' opinions on the "missing correlations in integral experiments" problem, with the goal of assessing its impact on nuclear data validation studies****.* ***Simulations will be made to estimate the correlations between the experimental uncertainties of integral experiments and quantify their impact on some reactor concept.***

- Work already performed:
  - CIEMAT&UPM: literature review (next slides)
  - UKAEA & JSI: correlations in shielding benchmarks (ASPIS-Fe88, PCA-REPLICA)
  - CEA: correlations in configurations of the EOLE reactor (CAMELEON program)

  } SANDA GM March 2022
- Simulations?
- **D5.6 *Report on correlations between integral experiments*** (CIEMAT, JSI, CEA, UPM).

Proposed structure for D5.6

1. Introduction
2. Origin of experimental correlations
3. Impact of experimental correlations
   - 2.1. Criticality safety
   - 2.2. Reactor physics
   - 2.3. Radiation shielding
   - 2.4. Nuclear data
4. Status of existing correlations
5. Methodologies to produce correlations
   - 4.1 Expert judgement/ deterministic
   - 4.2 Monte Carlo
6. Applications

Status of existing correlations (I)

- ***Cuantitavive*** correlations in DICE for 93 cases (out of 5121 cases in ICSBEP)
  - 55 cases correspond to four sets of HEU-SOL-THERM benchmarks.

	HST 019 001	HST 025 001	HST 025 002	HST 025 004	HST 025 005	HST 027 001	HST 028 001	HST 028 003	HST 028 005	HST 028 007	HST 028 009	HST 028 011	HST 028 013	HST 028 015	HST 028 017	HST 029 001	HST 030 001	HST 030 004	HST 035 001	HST 035 005	HST 035 007
HST019-001	1000	450	450	430	410	130	260	230	200	160	360	350	330	310	320	320	150	290	340	170	180
HST025-001	450	1000	730	720	620	90	200	190	160	120	260	240	240	220	220	220	120	210	320	140	120
HST025-002	450	730	1000	720	620	90	200	190	160	120	260	240	240	220	220	220	120	210	320	140	120
HST025-004	430	720	720	1000	620	90	190	170	140	110	230	230	210	200	200	200	100	190	300	120	110
HST025-005	410	620	620	620	1000	80	150	140	120	90	190	180	180	170	170	160	90	160	220	110	100
HST027-001	130	90	90	90	80	1000	290	270	300	810	330	340	330	300	770	760	820	780	220	150	200
HST028-001	260	200	200	190	150	290	1000	400	430	310	460	470	650	420	360	370	280	370	360	210	270
HST028-003	230	190	190	170	140	270	400	1000	410	290	430	450	430	390	340	340	260	340	330	200	250
HST028-005	200	160	160	140	120	300	430	410	1000	320	470	490	480	740	360	370	280	370	340	210	280
HST028-007	160	120	120	110	90	810	310	290	320	1000	330	350	340	300	810	810	870	830	240	160	200
HST028-009	360	260	260	230	190	330	460	430	470	330	1000	630	610	560	500	510	300	470	430	250	310
HST028-011	350	240	240	230	180	340	470	450	490	350	630	1000	620	570	500	510	310	480	420	250	320
HST028-013	330	240	240	210	180	330	650	430	480	340	610	620	1000	560	490	500	290	470	410	240	320
HST028-015	310	220	220	200	170	300	420	390	740	300	560	570	560	1000	450	460	270	420	370	220	280
HST028-017	320	220	220	200	170	770	360	340	360	810	500	500	490	450	1000	890	820	870	340	200	250
HST029-001	320	220	220	200	160	760	370	340	370	810	510	510	500	460	890	1000	810	870	340	210	250
HST030-001	150	120	120	100	90	820	280	260	280	870	300	310	290	270	820	810	1000	830	220	140	170
HST030-004	290	210	210	190	160	780	370	340	370	830	470	480	470	420	870	870	830	1000	340	200	240
HST035-001	340	320	320	300	220	220	360	330	340	240	430	420	410	370	340	340	220	340	1000	760	750
HST035-005	170	140	140	120	110	150	210	200	210	160	250	250	240	220	200	210	140	200	760	1000	840
HST035-007	180	120	120	110	100	200	270	250	280	200	310	320	320	280	250	250	170	240	750	840	1000

IPPE: 21 (HST019/025/027/028/029/030/035)

T. Ivanova *et al.*, *Influence of the Correlations of Experimental Uncertainties on Criticality Prediction*. NSE 145 (2003) 97–104

	HST 009 001	HST 009 002	HST 009 003	HST 009 004	HST 010 001	HST 010 002	HST 010 003	HST 010 004	HST 011 001	HST 011 002	HST 012 001	HST 013 001	HST 032 001	HST 042 001	HST 042 002	HST 042 003	HST 042 004	HST 042 005	HST 042 006	HST 042 007	HST 042 008	HST 043 001	HST 043 002	HST 043 003
HST009-001	1000	610	580	250	180	180	180	180	230	230	290											130	290	290
HST009-002	610	1000	600	240	170	170	170	170	200	200	250											140	250	260
HST009-003	580	600	1000	200	150	150	150	150	160	160	180											120	190	190
HST009-004	250	240	200	1000	130	130	130	130	120	120	130											100	130	130
HST010-001	180	170	150	130	1000	540	540	540	110	110	120											80	120	120
HST010-002	180	170	150	130	540	1000	540	540	110	110	120											80	120	120
HST010-003	180	170	150	130	540	540	1000	540	110	110	120											80	120	120
HST010-004	180	170	150	130	540	540	540	1000	110	110	120											80	120	120
HST011-001	230	200	160	120	110	110	110	110	1000	530	240											470	240	250
HST011-002	230	200	160	120	110	110	110	110	530	1000	240											470	240	250
HST012-001	290	250	180	130	120	120	120	120	240	240	1000											50	470	360
HST013-001												1000	410	290	310	380	360	370	350	360	350			110
HST032-001												410	1000	310	350	420	420	420	380	400	410			
HST042-001												290	310	1000	460	380	360	350	420	370	350			
HST042-002												310	350	460	1000	400	390	380	440	400	370			
HST042-003												380	420	380	400	1000	460	460	440	450	450			
HST042-004												360	420	360	390	460	1000	480	470	480	480			
HST042-005												370	420	350	380	460	480	1000	470	480	480			
HST042-006												350	380	420	440	440	470	470	1000	510	500			
HST042-007												360	400	370	400	450	480	480	510	1000	520			
HST042-008												350	410	350	370	450	480	480	500	520	1000			
HST043-001	130	140	120	100	80	80	80	80	470	470	50											1000	60	50
HST043-002	290	250	190	130	120	120	120	120	240	240	470											60	1000	350
HST043-003	290	260	190	130	120	120	120	120	250	250	360	110										50	350	1000

HST042-003 / HST011-001

ORNL: 14 (HST009/ /010/011/012/043) + 10 (HST013/032/042)

	HST 001 001	HST 001 002	HST 001 003	HST 001 004	HST 001 005	HST 001 006	HST 001 007	HST 001 008	HST 001 009	HST 001 010
HST001-001	1000	470	460	440	420	420	460	570	440	440
HST001-002	470	1000	420	580	420	420	410	440	580	460
HST001-003	460	420	1000	460	430	430	460	460	420	430
HST001-004	440	580	460	1000	420	420	420	440	770	460
HST001-005	420	420	430	420	1000	540	480	470	460	480
HST001-006	420	420	430	420	540	1000	480	470	460	480
HST001-007	460	410	460	420	480	480	1000	510	450	430
HST001-008	570	440	460	440	470	470	510	1000	480	440
HST001-009	440	580	420	770	460	460	450	480	1000	460
HST001-010	440	460	430	460	480	480	430	440	460	1000

Rocky Flats: 10 (HST001)

Status of existing correlations (II)

ZPR & ZPPR @ ANL (33 cases)

	HMF 055 001	HMF 060 001	HMF 061 001	HMF 067 001	HMF 067 002	HMF 070 001	HMF 070 002	HMF 070 003	HMF 075 001	HMI 001 001	HMM 012 001	ICF 004 001	ICI 005 001	IMF 010 001	IMF 012 001	IMF 013 001	IMF 014 001	IMF 014 002	IMF 015 001	IMF 016 001	MCF 001 001	MCF 002 001	MCF 003 001	MCF 003 002	MCF 004 001	MMF 011 001	MMF 011 002	MMF 011 003	MMF 011 004	PMF 033 001	PMI 002 001	SHMF 001 001	SHMM 001 001
HMF055-001	1000	300	250	290	290	260	250	270	210	210	270	480	290	220	330	280	300	310	540	370			340	340	280	40	120	150	210			50	90
HMF060-001	300	1000	510						430		540	530			330				540	480						80	240	310	430			100	190
HMF061-001	250	510	1000	500	500	440	430	450	870	370	760	470	510	460	280	480	530	550	480	430	160	150	10	10		690	800	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HMF067-001	290		500	1000					420		520	510			320				530	460						80	230	300	420			100	180
HMF067-002	290		500		1000				420		520	510			310				520	460						80	230	300	420			100	180
HMF070-001	260		440			1000			370		470	460			280				470	410						70	210	270	370			90	160
HMF070-002	250		430				1000		360		460	450			280				460	400						70	200	260	360			80	160
HMF070-003	270		450					1000	380		480	470			290				480	420						70	210	280	380			90	170
HMF075-001	210	430	870	420	420	370	360	380	1000	310	810	370	420	360	230	400	430	450	380	340	130	120				710	800	840	870	650	80	230	350
HMI001-001	210		370						310	1000	380	370			230				380	330						80	190	240	320	20		70	130
HMM012-001	270	540	760	520	520	470	460	480	810	380	1000	470	520	400	290	500	550	570	480	420	30	30				460	600	650	720	390	20	180	310
ICF004-001	480	530	470	510	510	460	450	470	370	370	470	1000	650	820	520	510	690	670	910	910			400	410	140	90	220	280	390			90	160
ICI005-001	290		510						420		520	650	1000		380				630	640			160	160	50	100	250	320	430	20		100	180
IMF010-001	220		460						360		400	820		1000	440				750	910			280	280		150	260	310	390	70		80	140
IMF012-001	330	330	280	320	310	280	280	290	230	230	290	520	380	440	1000	310	400	390	520	510			270	270	140	50	140	170	240			50	100
IMF013-001	280		480						400		500	510			310	1000			520	470			10	10		80	220	290	400			90	170
IMF014-001	300		530						430		550	690			400		1000		670	680			100	100		90	250	320	440			100	190
IMF014-002	310		550						450		570	670			390			1000	660	650			70	70		90	260	330	460			100	200
IMF015-001	540	540	480	530	520	470	460	480	380	380	480	910	630	750	520	520	670	660	1000	860			410	420	150	80	230	290	390			90	170
IMF016-001	370	480	430	460	460	410	400	420	340	330	420	910	640	910	510	470	680	650	860	1000			390	400	80	80	210	260	350			80	150
MCF001-001			160						130		30										1000				180	220	210	200	180	220		10	10
MCF002-001			150						120		30											1000	70	60	120	210	200	190	170	220		10	10
MCF003-001	340		10									400	160	280	270	10	100	70	410	390		70	1000	850	210	20	20	20	10	20	70		
MCF003-002	340		10									410	160	280	270	10	100	70	420	400		60	850	1000	210	20	20	10	10	20	60		
MCF004-001	280											140	50		140				150	80	180	120	210	210	1000						20		
MMF011-001	40	80	690	80	80	70	70	70	710	80	460	90	100	150	50	80	90	90	80	80	220	210	20	20		1000	850	820	760	870	130	110	160
MMF011-002	120	240	800	230	230	210	200	210	800	190	600	220	250	260	140	220	250	260	230	210	210	200	20	20		850	1000	870	850	820	120	150	220
MMF011-003	150	310	850	300	300	270	260	280	840	240	650	280	320	310	170	290	320	330	290	260	200	190	20	10		820	870	1000	880	790	120	170	260
MMF011-004	210	430	900	420	420	370	360	380	870	320	720	390	430	390	240	400	440	460	390	350	180	170	10	10		760	850	880	1000	700	110	170	270
PMF033-001			620						650	20	390		20	70							220	220	20	20		870	820	790	700	1000	180	100	140
PMI002-001			130						80		20												70	60	20	130	120	120	110	180	1000	10	10
SHMF001-001	50	100	170	100	100	90	80	90	230	70	180	90	100	80	50	90	100	100	90	80	10	10				110	150	170	170	100	10	1000	940
SHMM001-001	90	190	270	180	180	160	160	170	350	130	310	160	180	140	100	170	190	200	170	150	10	10				160	220	260	270	140	10	940	1000

HMF055-001 / MMF011-002 : 0.12

G. Palmiotti *et al., Combined Use of Integral Experiments and Covariance Data*. NDS 118 (2014) 596-636.

ICSBEP no.	Facility/core	No. Cases
HMF055	ZPR-3/23	1
HMF060	ZPR-9/4	1
HMF061	ZPR-21F	1
HMF067	ZPR-9/5 & 6	2
HMF070	ZPR-9/7, 8 & 9	3
HMF075	ZPPR-20/C	1
HMI001	ZPR-9/34	1
HMM012	ZPPR-20/D	1
ICF004	ZPR-3/12	1
ICI005	ZPR-6/6A	1
IMF010	ZPR-6/9	1
IMF012	ZPR-3/41	1
IMF013	ZPR-9/1	1
IMF014	ZPR-9/2&3	2
IMF015	ZPR-3/6F	1
IMF016	ZPR-3/11	1
MCF001	ZPR-6/7	1
MCF002	ZPR-6/7 (Pu-240)	1
MCF003	ZPR-3/48	2
MCF004	ZPR-3/56	1
MMF011	ZPPR-21	4
PMF033	ZPPR-21A	1
PMI002	ZPR-6/10	1
SHMF001	ZPPR-20/E	2

VNIIEF (3 cases)

	HMF 018 001	HMF 020 001	HMF 031 001
HMF018-001	1000	460	320
HMF020-001	460	1000	460
HMF031-001	320	460	1000

ICSBEP no.	Facility/core
HMF018	CTF, bare U235 (90%) sphere
HMF020	CTF, U235 (90%) sphere, PE reflector
HMF031	CTF, U235 (90%) sphere, PE central area and reflector

VNIITF (2 cases)

	HMF 008 001	HMF 011 001
HMF008-001	1000	210
HMF011-001	210	1000

ICSBEP no.	Facility/core
HMF008	FKBN, HEU sphere
HMF011	FKBN, HEU sphere and PE reflector

References by methodology (I)

- Expert judgement / deterministic methodologies

Ivanova *et al.* (2003) Intl. Conf. Nuc. Crit. Ivanova *et al.* (2003) NSE 145 97–104	Methodology described. Correlations in k_{eff} unc. for 77 HEU-SOL-THERM cases: 34 from IPPE, 10 from Rocky Flats, 29 from ORNL and 4 from LANL. No numerical information.
Ivanova *et al.* (2009) ANE 36 305–309	Correlations in k_{eff} unc. for 10 cases from IPPE's BFS-99, 99 and 101 (MMCF003/004, MMCM001)
Dos Santos (2013) PhD Thesis Dos Santos *et al.* (2013) ANNIMA2013	Methodology described. Correlations in k_{eff} unc. for 6 systems, including 3 cases from ICSBEP (ZPR-10A(?) and MCT001).
Ivanova *et al.* (2014) NSE 178 1-15	Correlations in k_{eff} unc. for some fast benchmarks from IRPhE (ZEBRA, ZPR, SNEAK, NEA-NSC-WPEC-SG33) and thermal benchmarks for ICSBEP (LCT007-039, UACSA Benchmark Phase IV)
NEA/NSC/WPEC/DOC(2013)445 Salvatores *et al.* (2014) NDS 118 38-71	Correlations in k_{eff} unc. for ZPR-6/7 and ZPPR-9, correlations in spectral indexes in some other systems.
Palmiotti *et al.* (2014) NDS 118 596-636	Correlations in k_{eff} unc. for 33 ZPR benchmark experiments. Results of US DOE Nuclear Data Adjustment Project.
Jeong *et al.* (2017) M&C2017	Correlation matrices for some LEU-COMP-THERM and HEU-COMP-FAST cases. No numerical information.

References by methodology (II)

- ## Monte Carlo methodologies

Buss *et al.* (2010) PHYSOR2010	Correlations in k_{eff} unc. for 97 LEU-COMP-THERM and MIX-COMP-THERM cases. MC code used: SCALE 6. No numerical information.
Stuke *et al.* (2016) GRS-440 Kilger *et al.* (2016) ANE 96 354-362	Correlations in k_{eff} unc. for 9 LCT cases (LCT006 and LCT035/062, JAEA's TCA) and 43 PST cases (PST003/006/020/21) (no numerical information). MC code used: KENO.
Marshall (2017) PhD. Thesis	Correlations in k_{eff} unc. for a series of cases of LCT007/039 (CEA Valduc), LCT042 (PNL) and HST001 (Rocky Flats) benchmarks. MC code used: KENO
Sommer & Stuke (2021) ANE 157 108209	S2Cor methodology for efficient MC sampling to calculate correlatons. Applied to some LCT007 (CEA Valduc) cases. MC code used: KENO

- ## Comprehensive documents

Stuke [Ed.] (2016) GRS-414 Stuke *et al.* (2019) ICNC 2019 NEA/NSC/R(2021)1	Results of EG UACSA Benchmark Phase IV. Intercomparison of methodologies for generating correlation matrices in LCT-007 (4 cases) and LCT-039 (17 cases) (Apparatus-B @ CEA Valduc)

Missing correlations (I)

IPPE: 30 additional benchmarks in three facilities with correlated uncertainties

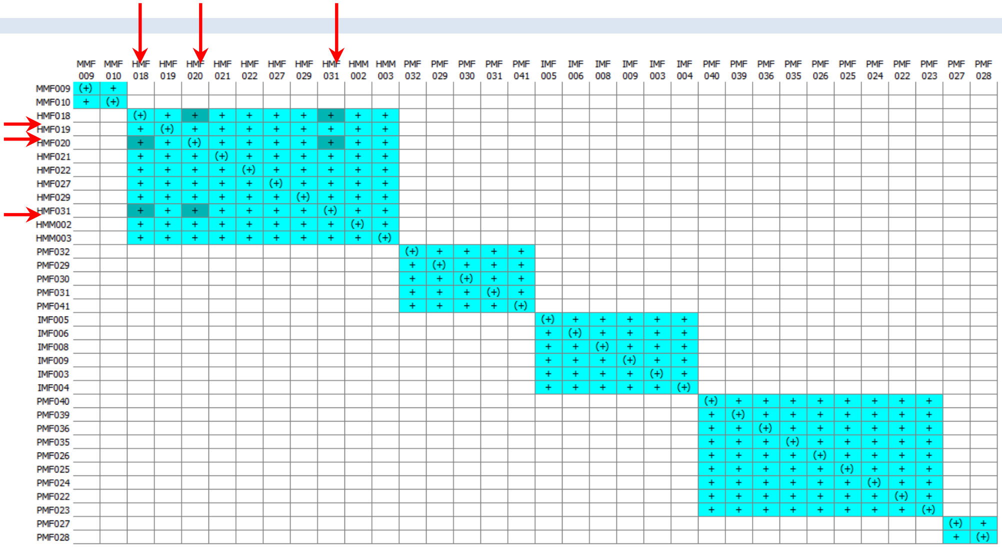
- BRR-1-1: 4 (PMF012 & rel.)
- KBR & BFS: 26 (experimental correlations?)

	PMM 001	HMF 068	HMI 005	HMI 008	HMT 005	HMM 005	HCI 005	IMF 017	ICF 002	ICI 001	ICI 002	ICT 005	MMF 006	MMF 015	MMCF 001	MMCF 002	MMCF 003	MMCF 004	MMCM 001	PMI 001	PMT 001
PMM001	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	(+)
HMF068	+	(+)	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
HMI005	+	+	(+)	+	(+)	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
HMI008	+	(+)	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
HMT005	+	+	(+)	+	(+)	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
HMM005	+	+	(+)	+	(+)	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
HCI005	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+
IMF017	+	+	+	+	+	+	+	(+)	+	+	(+)	+	+	(+)	(+)	+	+	+	+	+	+
ICF002	+	+	+	+	+	+	+	+	(+)	(+)	+	(+)	+	+	+	+	+	+	+	+	+
ICI001	+	+	+	+	+	+	+	+	(+)	(+)	+	(+)	+	+	+	+	+	+	+	+	+
ICI002	+	+	+	+	+	+	+	(+)	+	+	(+)	+	+	(+)	(+)	+	+	+	+	+	+
ICT005	+	+	+	+	+	+	+	+	(+)	(+)	+	(+)	+	+	+	+	+	+	+	+	+
MMF006	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+
MMF015	+	+	+	+	+	+	+	(+)	+	+	(+)	+	+	(+)	(+)	+	+	+	+	+	+
MMCF001	+	+	+	+	+	+	+	(+)	+	+	(+)	+	+	(+)	(+)	+	+	+	+	+	+
MMCF002	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+
MMCF003	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	(+)	+	+
MMCF004	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+
MMCM001	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	(+)	+	+
PMI001	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	(+)
PMT001	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	(+)

T. Ivanova *et al.*, *Towards validation of criticality calculations for systems with MOX powders*. ANE 36 (2009) 305-309

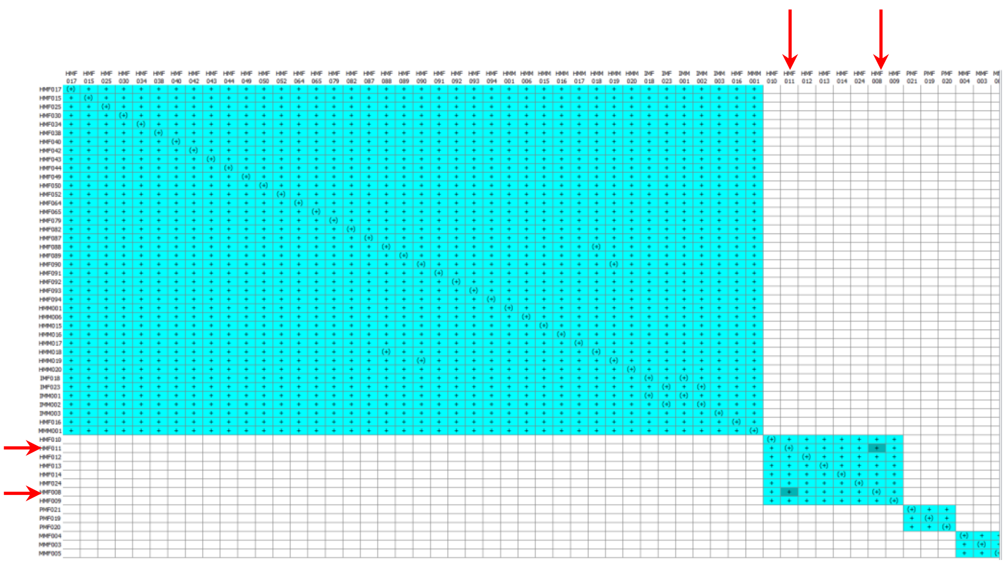
	Facility/core	Year
HCI005	KBR-7/9/10/15/16	1970-90
ICF002	KBR-18	1990-94
ICI001	KBR-19/20	
ICT005	KBR-21	
HMF068	KBR-22	
HMI008	KBR-23	
MMCF001	BFS-31/42	1977-79
ICI002	BFS-33	
IMF017	BFS-35	
MMF015	BFS-38	
MMCF002	BFS-49	1985
MMF006	BFS-61	1999
HMM005	BFS-79-1/2	
HMT005	BFS-79-3	
HMI005	BFS-79-4/5	
PMI001	BFS-81-1/2	
PMM001	BFS-81-3	
PMT001	BFS-81-4/5	1999-2000
MMCF003	BFS-97-1/2, BFS-101-1	2004-05
MMCF004	BFS-97-3/4, BFS-99-1/2, BFS-101-2/3	
MMCM001	BFS-97-5/6/7	2008-09

Missing correlations (II)



CTF @ VNIIEF (34 bench. in 6 groups)

1. Pu(98%)/U(90%): 2 (MMF009-010)
2. U(90%): 10 (HMF018 & rel.)
3. Pu(89%): 5 (PMF029 & rel.)
4. U(36%): 6 (IMF003 & rel.)
5. Pu(98%): 9 (PMF022 & rel.)
6. Pu(88%): 2 (PMF027-028)



FKBN @ VNIITF (54 bench. in 4 groups)

1. U/Pu, cyl. conf.: 40 (HMF015 & rel.)
2. HEU, sph. conf.: 8 (HMF008 & rel.)
3. Pu, cyl. & sph. confs.: 3 (PMF019-021)
4. Pu/HEU, sph. conf.: 3 (MMF003-005)

Correlations for a few cases included in DICE.

Missing correlations (III)

	LCT 053	LCT 070	LCT 075	LCT 030	LCT 085	LCT 094	LCT 061	LCT 064	LCT 025	LCT 022	LCT 032	LCT 023	LCT 024	HCT 013	HCT 014	HCT 011	HCT 012	HCM 003	HCT 009	HCM 004	HCT 008	HCT 007	HCT 006	HCT 005	HCT 003	HCT 004	LCT 019	LCT 020	LCT 021	LCT 031
LCT053	(+)	+	+	+	+	+	+	+																						
LCT070	+	(+)	+	+	+	+	+	+																						
LCT075	+	+	(+)	+	+	+	+	+																						
LCT030	+	+	+	(+)	+	+	+	+																						
LCT085	+	+	+	+	(+)	+	+	+																						
LCT094	+	+	+	+	+	(+)	+	+																						
LCT061	+	+	+	+	+	+	(+)	+																						
LCT064	+	+	+	+	+	+	+	(+)																						
LCT025									(+)	+	+	+	+																	
LCT022									+	(+)	+	+	+																	
LCT032									+	+	(+)	+	+																	
LCT023									+	+	+	(+)	+																	
LCT024									+	+	+	+	(+)																	
HCT013														(+)	+	+	+													
HCT014														+	(+)	+	+													
HCT011														+	+	(+)	+													
HCT012														+	+	+	(+)													
HCM003																		(+)	(+)	+										
HCT009																		(+)	(+)	+										
HCM004																		+	+	(+)										
HCT008																					(+)	+	+	+	+	+				
HCT007																					+	(+)	+	+	+	+				
HCT006																					+	+	(+)	+	+	+				
HCT005																					+	+	+	(+)	+	+				
HCT003																					+	+	+	+	(+)	+				
HCT004																					+	+	+	+	+	(+)				
LCT019																											(+)	+	+	+
LCT020																											+	(+)	+	+
LCT021																											+	+	(+)	+
LCT031																											+	+	+	(+)

Kurchatkov inst. (30 bench. in 6 groups)

1. SF-9: 8 (LCT053 & rel.)
2. Tank facility: 5 (LCT022-025, LCT032)
3. Tank facility: 4 (HCT011-014)
4. Narciss-M: 3 (HCM003-004, HCT009)
5. Tank facility: 6 (HCT003-008)
6. Tank facility: 4 (LCT019-021, LCT031)

Missing correlations (IV)

	LCT 062	LCT 065	MCT 004	LCT 006	LCT 035	LST 019	LST 020	LST 021	LST 022	LST 023	LST 024	LST 025	LMCT 001	LMCT 002	LMCT 003	LMCT 005	LMCT 006	LMCT 007	LST 018	LST 017	LST 016	LST 011	LST 010	LST 009	LST 008	LST 004	LST 007	LST 012	LST 013
LCT062	(+)	+	+	+	+																								
LCT065	+	(+)	+	+	+																								
MCT004	+	+	(+)	+	+																								
LCT006	+	+	+	(+)	+																								
LCT035	+	+	+	+	(+)																								
LST019						(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
LST020						+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
LST021						+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
LST022						+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
LST023						+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
LST024						+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
LST025						+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
LMCT001						+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
LMCT002						+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+		
LMCT003						+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+		
LMCT005						+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+		
LMCT006						+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+		
LMCT007						+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+		
LST018						+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+		
LST017						+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+		
LST016						+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+		
LST011						+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+		
LST010						+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+		
LST009						+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+		
LST008						+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+		
LST004						+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+		
LST007						+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)		
LST012																												(+)	+
LST013																												+	(+)

JAEA (29 bench. in 3 groups)

1. TCA: 5 (LCT062 & rel.)
2. STACY: 22 (LST004 & rel.)
3. STACY: 2 (LST012-013)

	LCT 043	LCT 044	LCT 046	LCT 054	LCT 058	LCT 067	LCT 077	LCT 082	LCT 083	LCT 084	LCT 088	LCT 089	LCT 090	LCT 091	LCT 092	LCT 103	SLCT 002	SLCT 003
LCT043	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
LCT044	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
LCT046	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
LCT054	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+	+
LCT058	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+	+
LCT067	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+	+
LCT077	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+	+
LCT082	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+	+
LCT083	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+	+
LCT084	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+	+
LCT088	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+	+
LCT089	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+	+
LCT090	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+	+
LCT091	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+	+
LCT092	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+	+
LCT103	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+	+
SLCT002	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)	+
SLCT003	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	(+)

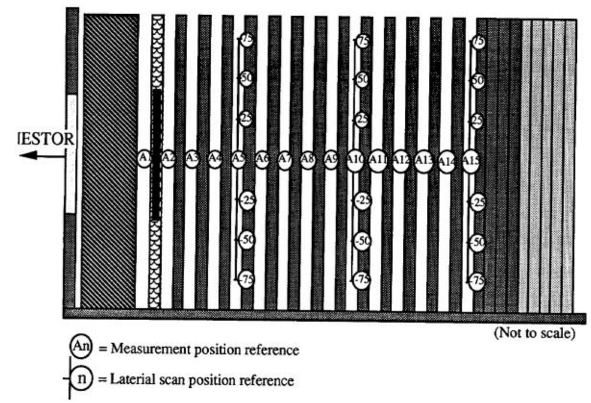
IPEN/MB-01 (18 bench.)

Summary and conclusions

- DICE contains cuantitive data for correlations in k_{eff} experimental uncertainty for 93 benchmark cases:
  - 55 HST cases from IPPE, ORNL and Rocky Flats.
  - 33 cases from ZPR@ANL.
  - 3 cases from VNIIEF and 2 from VNIITF.
- Correlation information for some more systems is available in the literature (obtained by different institutions with different methodologies):
  - 10 MMC/MMCM cases from BFS @IPPE (Ivanova *et al.* ANE 36 (2009) 305-309).
  - 21 LCT cases from *Apparatus-B* @CEA Valduc (EG UACSA Benchmark Phase IV).
  - 9 LCT cases from TCA @JAEA (GRS-440).
  - 7 LCT cases from Critical Mass Lab @PNL (W. J. Marshall's Ph. D. Thesis).
- UKAEA & JSI: correlations in shielding benchmarks (ASPIS-Fe88, PCA-REPLICA)
- CEA: correlations in configurations of the EOLE reactor (CAMELEON program)
- Several sets of benchmark experiments with correlated experimental uncertainties in k_{eff} can be identified from DICE. Simulations?

UK Atomic
Energy
Authority

UKAEA & IJS activities (I)

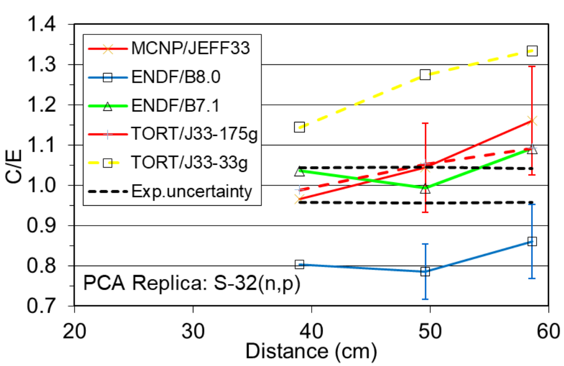


ASPIS IRON-88 and PCA REPLICA shielding benchmarks

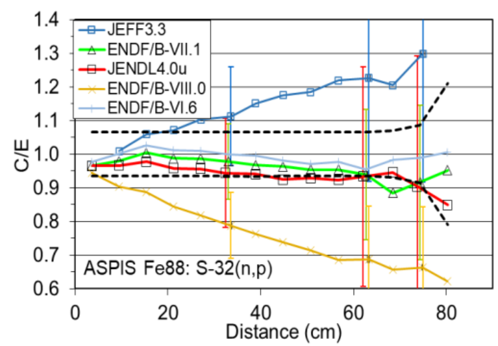
Correlation coefficients among measured reaction rates

- Au, Rh, In, S and Al activation foils installed in 7.4-mm air gaps.

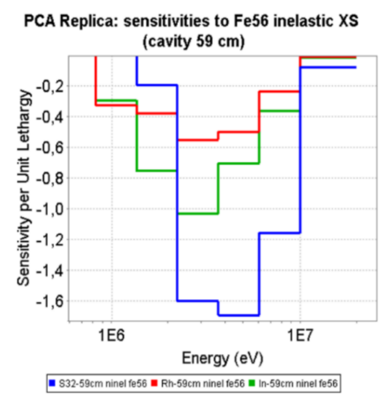
C/E PCA Replica

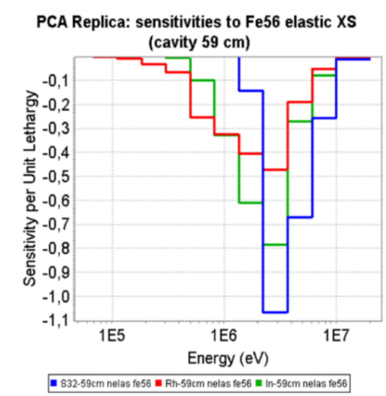


ASPIS Fe88



Sensitivity: PCA Replica





ASPIS-Fe88 covariance matrix for measured RR

Assuming totally correlated power normalisation uncertainty

Det.			Au			Rh		In		S			Al
	Pos.	(cm)	26	46	62	26	62	26	46	26	52	62	26
	(cm)	1σ(%)	4,2	4,2	4,2	5,1	5,1	4,5	4,7	6,5	6,5	8,6	4,7
Au	26	4,2	1	0,95	0,95	0,75	0,75	0,85	0,81	0,59	0,59	0,44	0,81
	46	4,2	0,95	1	0,95	0,75	0,75	0,85	0,81	0,59	0,59	0,44	0,81
	62	4,2	0,95	0,95	1	0,75	0,75	0,85	0,81	0,59	0,59	0,44	0,81
Rh	26	5,1	0,75	0,75	0,75	1	0,96	0,7	0,67	0,48	0,48	0,37	0,67
	62	5,1	0,75	0,75	0,75	0,96	1	0,7	0,67	0,48	0,48	0,37	0,67
In	26	4,5	0,85	0,85	0,85	0,7	0,7	1	0,93	0,55	0,55	0,41	0,76
	46	4,7	0,81	0,81	0,81	0,67	0,67	0,93	1	0,52	0,52	0,4	0,72
S	26	6,5	0,59	0,59	0,59	0,48	0,48	0,55	0,52	1	0,97	0,73	0,52
	52	6,5	0,59	0,59	0,59	0,48	0,48	0,55	0,52	0,97	1	0,73	0,52
	62	8,6	0,44	0,44	0,44	0,37	0,37	0,41	0,4	0,73	0,73	1	0,4
Al	26	4,7	0,81	0,81	0,81	0,67	0,67	0,76	0,72	0,52	0,52	0,4	1

ASPIS-Fe88 covariance matrix for measured RR ratios (R_i/R_1)

Det	Ratio cm/cm	1σ (%)	Au		Rh	In	S		Al
			A11/A7	A14/A7	A14/A7	A11/A7	A12/A7	A14/A7	A7
			2,0	2,1	1,8	2,0	2,9	7,7	6,1
Au	46/26	2,0	1	0,5	0	0	0	0	0
	62/26	2,1	0,5	1	0	0	0	0	0
Rh	62/26	1,8	0	0	1	0	0	0	0
In	46/26	2,0	0	0	0	1	0	0	0
S	52/26	2,9	0	0	0	0	1	0,05	0
	62/26	7,7	0	0	0	0	0,05	1	0
Al	26	6,1	0	0	0	0	0	0	1

UKAEA & IJS activities (VI)

Overview of correlations in SFCOMPO

- **Common experimental sources of uncertainty: nuclide vector**
  - Use of same methodology (e.g. mass spectrometry or gamma-ray spectrometry)
  - Nuclear data (e.g. gamma-ray emission probabilities, half-lives)
- **Common sources of uncertainty in analysis/calculations:**
  - Normalisation to BU: $BU = N_f E_f / m_{HM}$; $N_{BI} = N_f \gamma_{BI}$ → correlations due to N_{BI} and E_f, γ_{BI}, (exp. + nuclear data)
  - Normalisation to BI: $N_{BI} = N_f \gamma_{BI}$ → correlations only due to N_{BI} (experimental data)
- **Propagation to calculated nuclide vector:**

$$\mathrm{cov}(N_{x,i}, N_{y,j}) = S_{x,i}\mathrm{cov}(N_{BI,i}, N_{BI,j})S_{y,j}$$

$$S_{x,i} = \frac{\partial N_{x,i}}{\partial N_{BI,i}}$$

$$\mathrm{corr}(N_{x,i}, N_{y,j}) = corr(N_{BI,i}, N_{BI,j}) = ?$$

x,y – nuclides

i,j – experiments/benchmarks

BI – burnup indicator (nuclide)

CEA activities (I)

Subtask 5.2.1 – Assessing correlations in integral experiments

While a considerable effort has been given to nuclear data covariances in recent years, much less attention has been paid to correlations in integral experiments used in validation, adjustment, and assimilation studies.

Deliverable: Report at M36

- **Principle: derive an experimental correlation from uncertainties on common "technological parameters" (fuel enrichment, cell pitch, cladding thickness…) and uncertainties due to the measurement technique**
- **Relies on the sensitivities of the considered observables to the technological parameters**
- **[1] proposed an expression of the experimental correlation coefficient:**

$$r_{i,j} = \frac{S_{TP,i}{}^{T}.D_{TP}.S_{TP,j} + \varepsilon_{ij}^{2}}{\delta Ei.\delta Ej}$$

- $S_{TP,i}$ (resp. $S_{TP,j}$) = sensitivity vector of experiment i (resp. j) to technological parameters
- D_{TP} = covariance matrix for technological parameters
- ε_{ij} = uncertainty due to experimental technique if the technique is identical between i and j; 0 otherwise
- δEi (resp. δEj) = total experimental uncertainty

[1] : N. Dos Santos et al., «Impact of mock-up experimental correlations and uncertainties in the transposition process», *Proceedings of ANIMMA,* 2013

CEA activities (II)

Subtask 5.2.1 – Assessing correlations in integral experiments

While a considerable effort has been given to nuclear data covariances in recent years, much less attention has been paid to correlations in integral experiments used in validation, adjustment, and assimilation studies.

Deliverable: Report at M36

- **The expression proposed in [1] was tested here on the CAMELEON program on the EOLE mock-up reactor for several physical quantities measured with different experimental techniques on similar core configurations:**
  i) ρ_{RES} residual reactivity of a mixed UOx / UOx-Gd
  ii) $\Delta\rho$ reactivity worth of UOx-Gd
  iii) FR fission rate ratio on a fuel pin

- **Input data to be tested for integral data assimilation**

	ρ_{RES}	$\Delta\rho$	FR
ρ_{RES}	100	63.7	44.5
$\Delta\rho$		100	0.0
FR			100

[1] : N. Dos Santos et al., «Impact of mock-up experimental correlations and uncertainties in the transposition process», *Proceedings of ANIMMA,* 2013