DE LA RECHERCHE À L'INDUSTRIE

Working Party on Nuclear Criticality Safety

*1st Meeting on **Subgroup 2***

BLIND BENCHMARK ON MOX DAMP POWDERS

Co-ordinator :

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A. Jinaphanh / N.Leclaire *(IRSN, France),*

D. Mennerdahl *(EMS, Sweden)*

NEA Nuclear Energy Agency

WPNCS-2018 Meetings, 92100 Boulogne-Billancourt, France

JULY 5, 2018

www.cea.fr

SUBGROUP ACTIVITIES

- **Results & Discussion**
- **Complementary results**
- **Deliverable and schedule**

PARTICIPANTS

- **CEA, France** – C. Carmouze
- **EMS, Sweden**, D. Mennerdahl
- **IPPE, Russia** – Y. Golovko
- **IRSN, France** – N. Leclaire, *A. Jinaphanh*
- **ORNL, USA** – C. Perfectti

CODE, ND LIBRARY & COVARIANCE MATRIX

	n-transport Code	Nuclear Data Evaluation	Covariance Matrix
CEA, France	CRISTAL V2.0 / TRIPOLI-4.8	JEFF-3.1.1	COMAC V2 database (**15** groups)
EMS, Sweden	*SCALE 6.2.3*	ENDF/B-VII.1	SCALE 6.2.2 (**56** groups)
IPPE Russia	MMK-K + MCNP5	**RUSFOND**, **ABBN-RF,** *ENDF/B-VII.0, JEFF-3.2, JENDL-4.0*	ABBN (? groups)
IRSN, France	MORET 5.C.1	ENDF/B-VII.0	SCALE 6.2 (**44** groups)
ORNL, USA	SCALE 6.2	ENDF/B-VII.1	*SCALE 6.0 (**44** groups)* SCALE 6.2 (**56** groups)

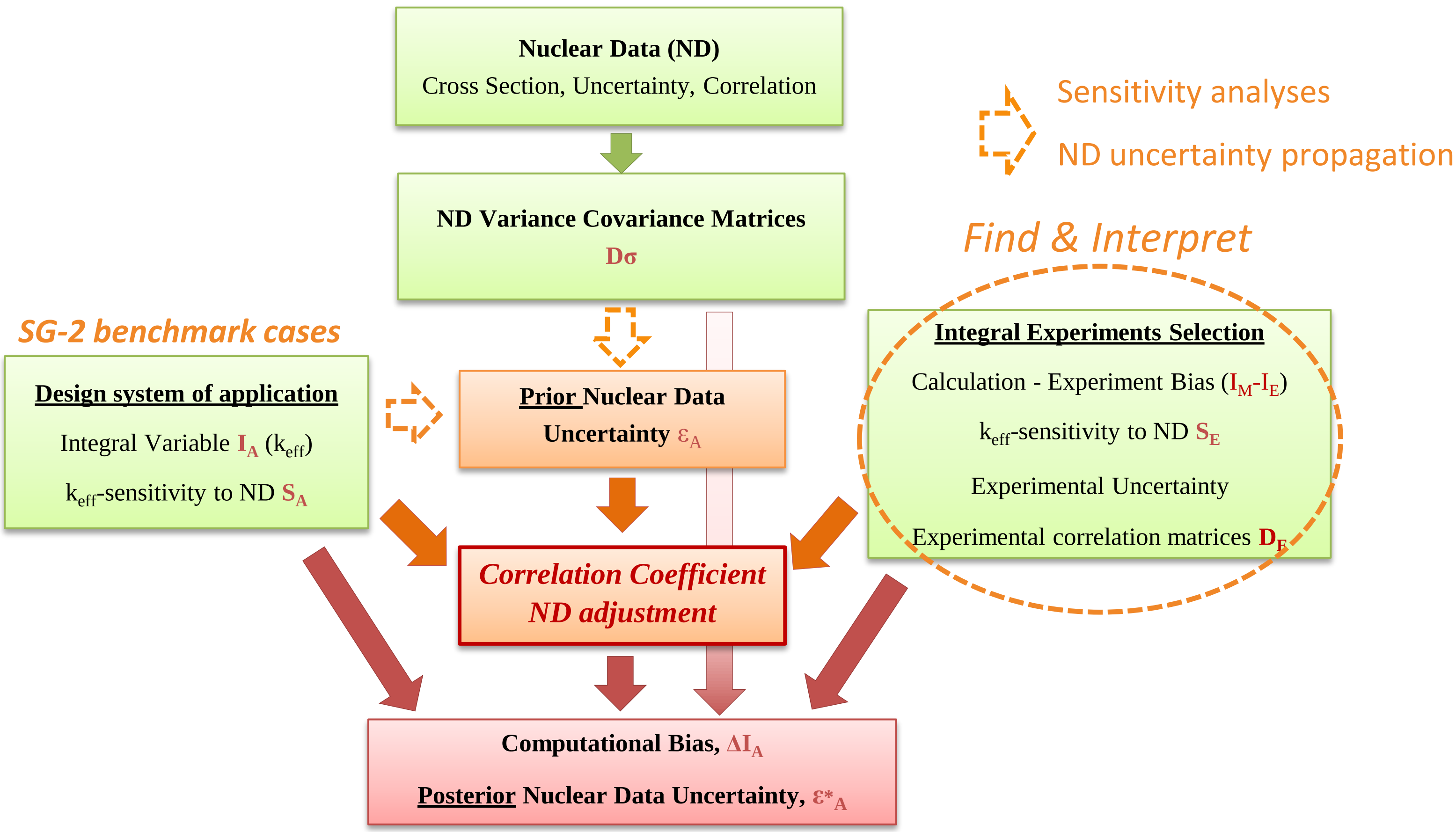
?

CODES, ND LIBRARIES & COVARIANCE MATRIX

	k_{eff}-sensitivity profiles	Bias and ND uncertainty reduction
CEA, France	TRIPOLI-4.dev (IFP method)	RIB TOOLS (**GLLSM**)
EMS, Sweden	*KENO VI SCALE 6.3 /TSUNAMI 3D*	*SCALE 6.2.2* / TSURFER (**GLLSM**)
IPPE Russia	MMK-K, ABBN-RF	**GLLSM**
IRSN, France	MORET-5.C.1 DICE Database	SCALE 6.2 / TSURFER (**GLLSM**)
ORNL, USA	SCALE 6.2 / TSUNAMI 3D + CLUTCH (IFP + Direct Perturb.)	SCALE 6.2 / TSURFER (**GLLSM**)

CALCULATION METHOD

Involve similarity / transposition studies for the bias & uncertainty quantification of the k_{eff} of damp MOx powders systems



CALCULATION METHOD

Use experimental information to infer the bias du to nuclear data and reduce nuclear data uncertainty *(ND adjustment)*

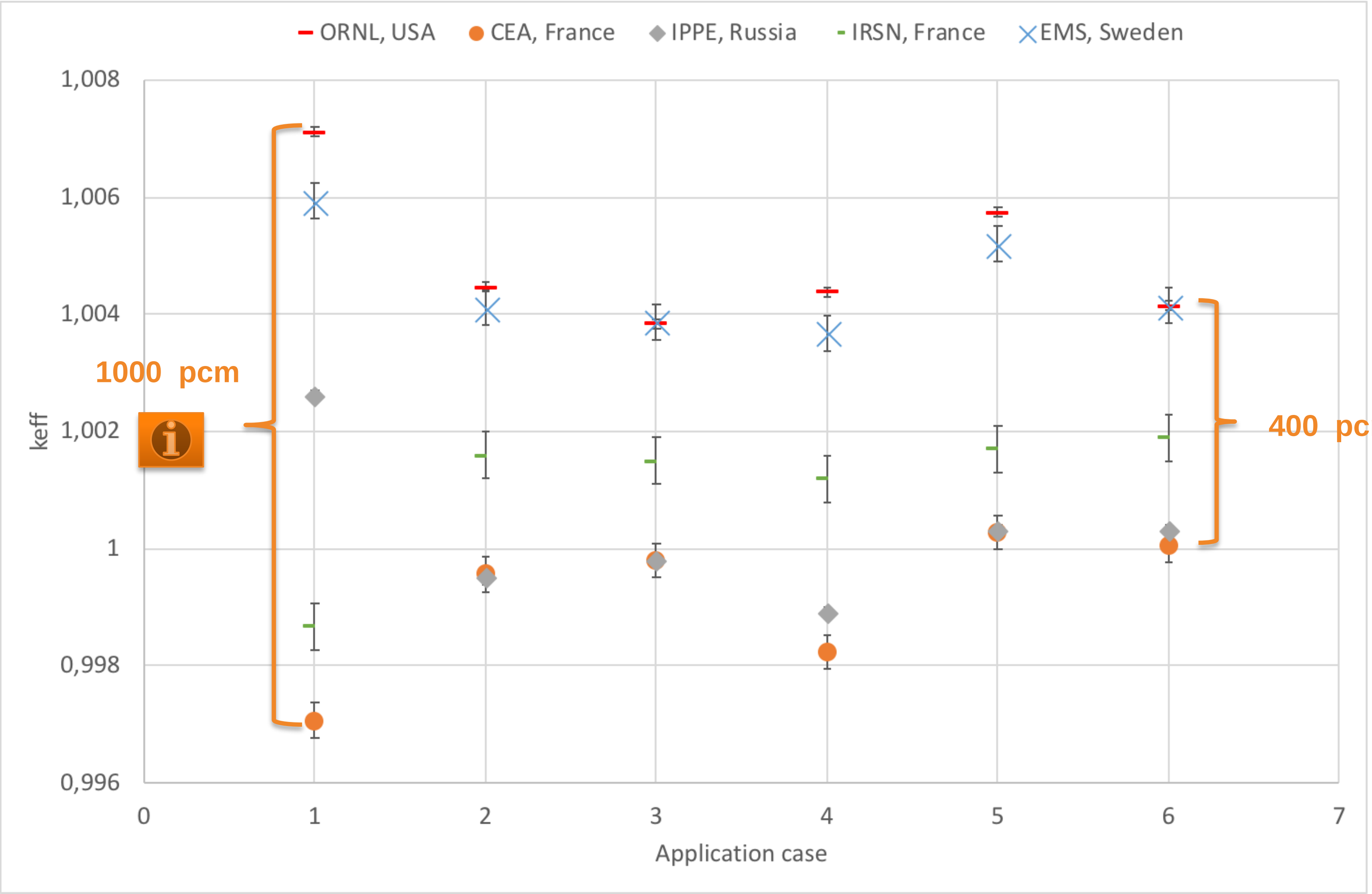
- The S / T method involves the **determination of sensitivity profiles** of the parameter of interest to nuclear data.

- The S / T method implies **the a priori knowledge** of the uncertainty due to nuclear data.

  The **a priori uncertainty** results from **uncertainty propagation** computations.

- Both methods (uncertainty propagation and bias transposition) rely on the **availability and quality of variance / covariance matrices**.

k_{eff} of the 15 benchmark cases (1/2)



k_{eff} of the 15 benchmark cases (2/2)

Application Case	ORNL, USA		CEA, France		IPPE, Russia		IRSN, France		EMS, Sweden	
	keff	± σ (pcm)	keff	± σ (pcm)	keff	± σ (pcm)	keff	± σ (pcm)	keff	± σ (pcm)
1	1,00712	8	0,99706	34	1,0026	10	0,99867	35	1,00594	29
2	1,00447	8	0,99957	32	0,9995	10	1,0016	38	1,00412	27
3	1,00384	7	0,99981	32	0,9998	10	1,0015	35	1,00387	28
4	1,00438	8	0,99824	33	0,9989	10	1,0012	33	1,00368	28
5	1,00574	7	1,00028	33	1,0003	10	1,0017	38	1,0052	28
6	1,00414	7	1,00007	34	1,0003	10	1,0019	31	1,00415	27
7	0,95566	7	0,94737	34	**0,9474**	10	0,95391	38	0,95454	27
8	0,9365	7	0,93109	34	**0,9302**	10	0,93407	38	0,93548	26
9	0,98875	8	0,98519	32	**0,9841**	10	0,98744	33	0,98831	26
10	0,96211	7	0,95288	35	0,9585	10	0,95996	32	0,96071	28
11	0,92665	7	0,92062	32	0,9226	10	0,9237	36	0,92538	25
12	0,93182	6	0,92503	32	0,9275	10	0,92901	31	0,93083	27
13	1,05544	8	1,04417	38	1,0502	10	1,0518	39	1,05471	29
14	1,05927	8	1,05454	36	1,0543	10	1,057	37	1,05922	27
15	1,04245	7	1,03935	33	1,0393	10	1,0409	33	1,04265	26

max. values
$600 < \Delta k_{eff} < 1100$ pcm

Prior Nuclear Data Uncertainty (pcm)

Application Cases	ORNL, USA	CEA, France	IPPE, Russia	IRSN, France	EMS, Sweden
1	527	810	950	845	523
2	493	739	840	786	493
3	461	795	900	715	463
4	499	815	930	835	497
5	453	794	840	748	455
6	533	824	950	734	529
7	*527*	995	1160	1011	572
8	*493*	710	950	912	552
9	*461*	840	950	866	435
10	*499*	890	1010	829	494
11	*453*	745	810	705	450
12	*533*	795	810	696	566
13	571	832	920	893	540
14	512	800	890	824	485
15	457	847	960	762	436

≈

≈

k_{eff} sensitivity profiles to ND

Ex. cases 1,7,13 (max. Δkeff discrepancies)

		Case 1					Case 7					Case 13				
Application case		**EMS, Sweden**	**IPP, Russia**	**ORNL, USA**	**IRSN, France**	**CEA, France**	**EMS, Sweden**	**IPP, Russia**	**ORNL, USA**	**IRSN, France**	**CEA, France**	**EMS, Sweden**	**IPP, Russia**	**ORNL, USA**	**IRSN, France**	**CEA, France**
Fission	**^{239}Pu**	419	409	419	422	421	545	534	*419*	543	575	403	394	402	401	388
	^{240}Pu	46	42	45	46	48	10	10	*45*	11	11	40	37	40	41	40
	^{241}Pu	87	88	87	88	88	0	0	*87*	0	0	90	91	90	90	87
	^{242}Pu	2	2	2	2	2	0	0	*2*	0	0	2	2	2	2	2
	^{235}U	0	0	0	0	0	0	0	*0*	0	0	0	0	0	0	0
	^{238}U	0	0	0	0	0	0	0	*0*	0	0	0	0	0	0	0
ν	**^{239}Pu**	759	764	759	758	756	986	995	*759*	986	1035	755	762	756	756	721
	^{240}Pu	64	60	64	65	67	14	14	*64*	15	16	58	54	58	59	57
	^{241}Pu	174	179	174	173	174	93	0	*174*	0	0	184	188	184	183	175
	^{242}Pu	3	3	3	3	3	0	0	*3*	0	0	3	3	3	3	3
	^{235}U	0	0	0	0	0	0	0	*0*	0	0	0	0	0	0	0
	^{238}U	0	0	0	0	0	0	0	*0*	0	0	0	0	0	0	0
Capture	**^{239}Pu**	-105	-120	-105	-104	-104	-134	-152	*-105*	-135	-142	-116	-133	-116	-117	-111
	^{240}Pu	-27	-32	-27	-27	-27	-12	-14	*-27*	-12	-13	-30	-36	-30	-30	-28
	^{241}Pu	-20	-20	-20	-20	-20	0	0	*-20*	0	0	-22	-21	-22	-22	-21
	^{242}Pu	-2	-2	-2	-2	-2	0	0	*-2*	0	0	-2	-2	-2	-2	-2
	^{235}U	0	0	0	0	0	0	0	*0*	0	0	0	0	0	0	0
	^{238}U	0	0	0	0	0	0	0	*0*	0	0	0	0	0	0	0
	^{16}O	-2	-2	136	0	0	-1	-2	*136*	0	2	-2	-3	132	0	-2
	$^{1}H\_H_2O$	-86	-103	-86	-86	-84	-96	-112	*-86*	-96	96	-74	-93	-75	-76	67
Scattering	**^{239}Pu**	25	20	25	24	21	31	26	*25*	30	22	27	20	27	25	23
	^{240}Pu	8	6	8	7	9	2	1	*8*	1	0	8	6	9	8	7
	^{241}Pu	4	4	4	3	3	0	0	*4*	0	0	4	4	4	4	3
	^{242}Pu	0	0	0	0	O	0	0	*0*	0	0	0	0	0	1	0
	^{235}U	0	0	0	0	O	0	0	*0*	0	0	0	0	0	0	0
	^{238}U	0	0	0	0	O	0	0	*0*	0	0	0	0	0	0	0
	^{16}O	137	90	138	138	136	143	93	*138*	144	120	133	86	134	135	131
	$^{1}H\_H_2O$	167	225	156	156	220	189	248	*156*	178	212	170	242	178	182	198

Selected experiments

	Number of exp.	LST	LCT	HMF	HMM	HST	PST	PMF	PCM	MST	MMT	MCT	MCM	MCF	MMF	MMM (BFS)	IMF	BIG TEN	KRITZ-1 (IRPHE draft)	Experimental Correlations
ORNL USA	**56**	3	5	9	1	4	5	4	1	2	1	4	0	1	1	11	4	0	0	YES
IPPE Russia	**101**	0	0	0	0	0	63	8	0	9	0	0	0	0	0	13	0	1	0	?
EMS Sweden	**33**	0	10	0	0	0	4	3	0	3	2	1	1	0	0	1	7	0	1	YES
IRSN France	**18**	0	0	0	0	0	0	0	1	0	0	8	0	0	0	9	0	0	0	YES
CEA France	**12**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	YES

- **Ck values / useful ? / negative values ?**
- **Expert judgment ?**
- **Independent experiments ?**

Computational bias and ND uncertainty reduction

	ORNL	IRSN	IPPE	EMS	CEA
Comp. Bias Range (pcm)	-65 -> 838	-274 -> +838	-330 -> + 470	14 -> 143	97 -> 1100
ND uncertainty reduction range (%)	43 - 74	46 - 79	32 - 77	35 - 54	46 - 82

- Significant reduction of ND uncertainty by using exp. Information
- The range is quite similar between the participants (ND uncertainties reduction)
- Impact of the selected experiments has to be analysed
- Impact of the covariance matrices has to be analysed

SUBGROUP ACTIVITIES

- Discussion of results
- **Complementary results**
- Deliverable and schedule

Update with complementary tools + other points of interest

Complementary codes and methods ?

- IRSN + MACSENS ?
- MCNP6 / Whisper ?

Complementary work

- Impact of the selected experiments (characteristics, number, etc.)
- Impact of the correlations between integral experiments
- Impact of the nuclear data covariance matrices

SUBGROUP ACTIVITIES

- First discussion of results
- Complementary results
- **Deliverable and schedule**

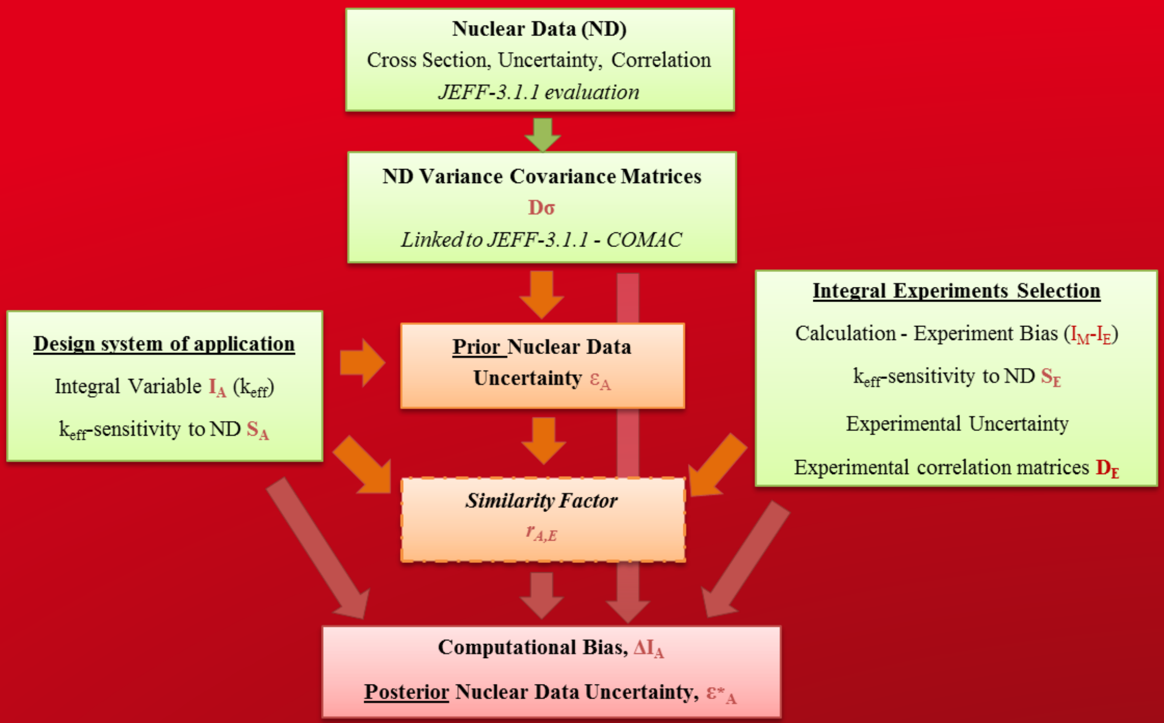
Deliverable and schedule

- **Update participants results until December 2018 (+ 6 months)**

- **Draft Report** will be send to participants on **June 2019 (+ 6 months)**

- **Final Report** is expected for the **next WPNCS meeting (≈ + 3 months)**

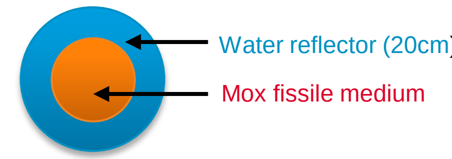
Thank you for listening !



The authors are indebted to Orano & EDF for financial support

SPECIFICATIONS

- Simple **1D geometry** : sphere of MOx powder surrounded by 20 cm of water



- **15 cases**
  - 3 PuO_2 contents : **100, 30 and 12.5%** (representative of GEN-IV & GEN-II / III)
  - 3 Pu isotopic vectors : **71/17/11/1% ; 64/23/10/3% ; 96/4/0/0%**
  - 3 powder moisture rates : **1, 3 (base value), and 5 wt.% H_2O**

➔ The MOx fissile medium is MOx quasi-critical radii determined using the French criticality-safety package CRISTAL V2 (standard route)

Table I. Specifications of the MOX wet powder benchmark

Benchmark	M_{H2O}/M_{MOX}	MOX Radius	M_{PuO2}/M_{MOX}	$^{239}Pu/Pu$	$^{240}Pu/Pu$	$^{241}Pu/Pu$	$^{242}Pu/Pu$
Case 1	3%	17.0 cm	100%				
Case 2	3%	22.5 cm	30%	71%	17%	11%	1%
Case 3	3%	46.0 cm	12.5%				
Case 4	3%	17.7 cm	100%				
Case 5	3%	24.1 cm	30%	64%	23%	10%	3%
Case 6	3%	52.5 cm	12.5%				
Case 7	3%	15.0 cm	100%				
Case 8	3%	19.0 cm	30%	96%	4%	0%	0%
Case 9	3%	40.0 cm	12.5%				
Case 10	1%	17.0 cm	100%				
Case 11	1%	22.5 cm	30%	71%	17%	11%	1%
Case 12	1%	46.0 cm	12.5%				
Case 13	5%	17.0 cm	100%				
Case 14	5%	22.5 cm	30%	71%	17%	11%	1%
Case 15	5%	46.0 cm	12.5%				