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Abstract

JHR (see Figure 1) reactivity sensitivities to nuclear cross-sections have been calculated for two core configurations using the first-order sensitivity feature of the Monte Carlo code TRIPOLI-4® [1]:

- a fresh start-up core – Configuration 1,
- a just-refueled 38 GWj/t – Configuration 2.

Sensitivities to all isotopes have been obtained for a 26-group energy structure, consistent with the structure of the COMAC-V2.1 covariance library [2], in order to propagate nuclear cross-section uncertainties.

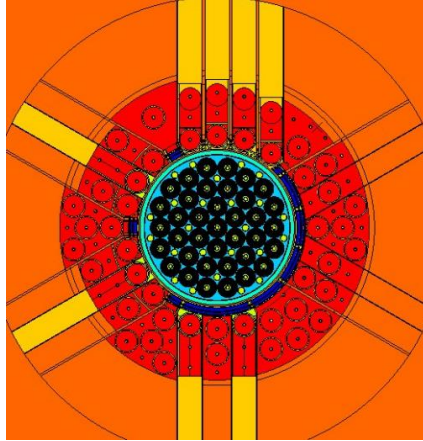


Figure 1 : horizontal view of the JHR geometry used in TRIPOLI-4®

References

- [1] N. Terranova, D. Mancusi, A. Zoia, New perturbation and sensitivity capabilities in Tripoli-4®, *Annals of Nuclear Energy*, 335-349 (2018), doi:101016/janucene201807031.
- [2] P. Archier, COMAC. Nuclear data covariance matrices library for reactor applications, PHYSOR2014.

Notes on reactions and naming conventions

TRIPOLI-4® calculates first-order sensitivity coefficients using the *Iterated Fission Probability* method [1]. A coefficient is obtained for each reaction, each isotope and each energy group. These coefficients are then aggregated in macro-reactions to be presented and used more easily:

- CAPTURE : $(n,g)+(n,p)+(n,t)+(n,a)+(n,^3\text{He})+(n,d)$
- ELASTIC SCATTERING : $(n,n)+\text{coherent elastic}+\text{incoherent elastic}+\text{incoherent inelastic}$
- INELASTIC SCATTERING : $\text{discrete inelastic}+\text{continuous inelastic}+(n,n+2a)+(n,n+a)+(n,n+p)$
- NXN : $(n,2n)+(n,3n)+(n,4n)+(n,2n+a)$
- FISSION : (n,f)
- NU : total mean number of neutrons per fission
- DISTRIBUTION : fission spectrum

Notes on isotopes and reactions selection

Computing IFP sensitivities for a large number of isotopes and reactions requires a large amount of memory per cpu. Therefore, tallies have been distributed over several independent calculations. In a first calculation, all sensitivities are calculated using a single energy group. The smallest sensitivity tallies are then discarded in subsequent runs. Sensitivities on the 26 group energy structure are converged for the selected isotopes and reactions.

TABLES 1 and 2 show 26 energy-groups lumped sensitivities and their associated statistical uncertainties (1σ).

TABLES 3 and 4 show the first order Taylor's expansion uncertainties of JHR reactivity to nuclear cross-sections.

Sensitivities

TABLE 1 : Configuration 1								
ISOTOPE REACTION	S [pcm/%]	1 σ	ISOTOPE REACTION	S [pcm/%]	1 σ	ISOTOPE REACTION	S [pcm/%]	1 σ
U235_NU	990	0	U234_CAPTURE	-1.95	0.00	Cu63_CAPTURE	-0.62	0.00
H1_H2O_ELASTIC	391	1	Zr90_ELASTIC	1.87	0.07	U236_CAPTURE	-0.58	0.00
U235_FISSION	320	0	Hf180_CAPTURE	-1.62	0.00	Hf180_INELASTIC	0.56	0.02
U235_CAPTURE	-139	0	Hf177_ELASTIC	-1.51	0.04	Zr92_ELASTIC	0.54	0.04
H1_H2O_CAPTURE	-72.3	0.0	B10_CAPTURE	-1.48	0.01	Zr94_ELASTIC	0.52	0.04
Al27_ELASTIC	62.4	0.5	Mn55_CAPTURE	-1.45	0.00			
Al27_CAPTURE	-56.2	0.0	Si28_ELASTIC	1.36	0.08			
U238_CAPTURE	-53.0	0.0	Hf180_ELASTIC	-1.33	0.06			
O16_ELASTIC	41.1	0.4	Zr91_CAPTURE	-1.30	0.00			
Hf177_CAPTURE	-23.6	0.0	O16_CAPTURE	-1.15	0.00			
Al27_INELASTIC	18.3	0.1	Hf176_CAPTURE	-1.08	0.00			
U238_NU	10.3	0.0	Fe56_CAPTURE	-1.01	0.00			
U238_ELASTIC	8.13	0.16	Hf179_ELASTIC	-1.01	0.04			
Hf179_CAPTURE	-7.52	0.01	Mg24_ELASTIC	0.96	0.06			
Be9_ELASTIC	7.26	0.21	Be9_CAPTURE	-0.90	0.00			
U238_FISSION	6.99	0.02	Si28_CAPTURE	-0.90	0.00			
Hf178_CAPTURE	-5.67	0.01	Be9_NXN	0.87	0.01			
U238_INELASTIC	3.78	0.05	U235_INELASTIC	0.67	0.02			
Hf178_ELASTIC	-2.36	0.06	Ni58_CAPTURE	-0.65	0.00			

TABLE 2 : Configuration 2								
ISOTOPE REACTION	S [pcm/%]	1 σ	ISOTOPE REACTION	S [pcm/%]	1 σ	ISOTOPE REACTION	S [pcm/%]	1 σ
U235_NU	935	0	Pu240_CAPTURE	-6.69	0.01	U234_CAPTURE	-1.53	0.00
H1_H2O_ELASTIC	333	1	Sm149_CAPTURE	-6.54	0.00	K39_CAPTURE	-1.47	0.00
U235_FISSION	327	0	U238_FISSION	5.95	0.05	Zr91_CAPTURE	-1.46	0.00
U235_CAPTURE	-129	0.0	U236_CAPTURE	-4.46	0.01	B10_CAPTURE	-1.43	0.01
H1_H2O_CAPTURE	-69.5	0.0	Nd143_CAPTURE	-4.01	0.00	Fe56_ELASTIC	1.35	0.10
Al27_ELASTIC	60.9	0.5	Pu241_NU	3.97	0.02	Si28_ELASTIC	1.31	0.08
Al27_CAPTURE	-57.4	0.0	Hf179_CAPTURE	-3.26	0.01	Sm152_CAPTURE	-1.28	0.00
Pu239_NU	51.9	0.1	U238_INELASTIC	3.12	0.05	O16_CAPTURE	-1.16	0.00
U238_CAPTURE	-46.4	0.0	Sm151_CAPTURE	-2.79	0.00	Hf178_ELASTIC	-1.08	0.04
O16_ELASTIC	37.6	0.4	Hf178_CAPTURE	-2.35	0.01	Nd145_CAPTURE	-1.06	0.00
Xe135_CAPTURE	-28.7	0.0	Pm147_CAPTURE	-2.31	0.00	Pm148m_CAPTURE	-1.04	0.00
Pu239_FISSION	23.6	0.1	Zr90_ELASTIC	2.23	0.07	Be9_NXN	0.93	0.01
Al27_INELASTIC	18.89	0.08	Cs133_CAPTURE	-2.10	0.00	Rh105_CAPTURE	-0.85	0.00
Pu239_CAPTURE	-14.82	0.00	Rh103_CAPTURE	-1.94	0.00	Si28_CAPTURE	-0.82	0.00
Hf177_CAPTURE	-9.89	0.02	Xe131_CAPTURE	-1.90	0.00	Be9_CAPTURE	-0.80	0.00
U238_NU	8.89	0.02	Pu241_FISSION	1.89	0.04	Zr92_ELASTIC	0.78	0.05
Be9_ELASTIC	8.44	0.19	Mn55_CAPTURE	-1.85	0.00	Np237_CAPTURE	-0.77	0.00
Fe56_CAPTURE	-7.33	0.01	Ni58_CAPTURE	-1.75	0.00	Mg24_ELASTIC	0.76	0.06
U238_ELASTIC	6.91	0.14	Cr53_CAPTURE	-1.73	0.00	Pu241_CAPTURE	-0.75	0.00

Uncertainties

TABLE 3 : Configuration 1, TOTAL UNCERTAINTY = 729 pcm					
ISOTOPE REACTION	U [pcm]	ISOTOPE REACTION	U [pcm]	ISOTOPE REACTION	U [pcm]
Al27_INELASTIC	328	Hf178_ELASTIC	24	Mn55_CAPTURE	2
Al27_CAPTURE	291	Hf180_CAPTURE	21	Ni62_CAPTURE	2
U235_NU	288	Hf179_ELASTIC	18	Zr92_ELASTIC	2
Al27_ELASTIC	265	Hf178_CAPTURE	17	Zr94_ELASTIC	2
H1_ELASTIC	235	Zr91_CAPTURE	11	U236_CAPTURE	2
H1_CAPTURE	185	Zr92_CAPTURE	10	Cr53_CAPTURE	1
U235_CAPTURE	185	Hf176_CAPTURE	7	Zr91_ELASTIC	1
U235_DISTRIBUTION	174	U238_NXN	7	Be9_ELASTIC	1
U235_FISSION	102	Zr90_ELASTIC	6	Mg25_ELASTIC	1
Hf177_CAPTURE	77	U238_NU	6	Zr90_CAPTURE	1
Hf179_CAPTURE	62	U234_CAPTURE	5	U234_FISSION	1
U238_CAPTURE	50	Ni58_CAPTURE	4	Ni60_CAPTURE	1
O16_ELASTIC	50	U235_INELASTIC	4	Mg24_INELASTIC	1
Hf180_ELASTIC	43	U235_ELASTIC	4	Mn55_ELASTIC	1
U238_INELASTIC	28	U238_DISTRIBUTION	3	Zr90_INELASTIC	1
Hf177_ELASTIC	28	Hf176_ELASTIC	3	U235_NXN	1
O16_CAPTURE	27	Mg24_ELASTIC	3	Cr52_CAPTURE	1
U238_ELASTIC	27	Fe56_CAPTURE	3	B10_CAPTURE	1
U238_FISSION	25	Hf174_CAPTURE	3	Fe56_ELASTIC	1

TABLE 4 : Configuration 2, TOTAL UNCERTAINTY = 769 pcm							
ISOTOPE REACTION	U [pcm]	ISOTOPE REACTION	U [pcm]	ISOTOPE REACTION	U [pcm]	ISOTOPE REACTION	U [pcm]
Al27_INELASTIC	337	U238_INELASTIC	23	Pr143_CAPTURE	8	Pu239_NU	4
Al27_CAPTURE	297	Fe56_CAPTURE	21	Hf179_ELASTIC	8	Eu156_CAPTURE	4
Xe135_CAPTURE	286	U238_FISSION	21	Nd147_CAPTURE	8	U235_INELASTIC	4
Al27_ELASTIC	272	Pu239_DISTRIBUTION	20	U237_CAPTURE	8	Fe56_ELASTIC	4
U235_NU	271	Hf180_ELASTIC	19	Hf178_CAPTURE	7	Ru103_CAPTURE	4
H1_ELASTIC	215	Sm151_CAPTURE	18	Zr90_ELASTIC	7	Sm152_CAPTURE	4
H1_CAPTURE	178	Pu239_FISSION	17	Rh103_CAPTURE	7	Np237_CAPTURE	4
U235_CAPTURE	170	U236_CAPTURE	16	Eu155_CAPTURE	7	Mn55_CAPTURE	3
U235_DISTRIBUTION	163	Pu240_CAPTURE	14	Ni62_CAPTURE	6	Fe54_CAPTURE	3
U235_FISSION	104	Hf177_ELASTIC	13	Pu241_DISTRIBUTION	6	Zr94_ELASTIC	3
O16_ELASTIC	47	Zr91_CAPTURE	12	U238_NXN	5	Ce141_CAPTURE	3
U238_CAPTURE	45	Ni58_CAPTURE	11	Xe133_CAPTURE	5	Zr92_ELASTIC	3
Pm147_CAPTURE	43	Zr92_CAPTURE	11	U238_NU	5	U238_DISTRIBUTION	3
Hf177_CAPTURE	33	Hf178_ELASTIC	11	U236_FISSION	5	Hf176_CAPTURE	3
Hf179_CAPTURE	27	Pm149_CAPTURE	10	Na23_CAPTURE	5	Pu241_FISSION	3
O16_CAPTURE	27	Cs133_CAPTURE	10	U235_ELASTIC	5	Mg24_ELASTIC	3
Rh105_CAPTURE	26	Hf180_CAPTURE	9	Cr53_CAPTURE	5	Eu154_CAPTURE	3
Pu239_CAPTURE	26	Np239_CAPTURE	9	Ni61_CAPTURE	4	Ni60_CAPTURE	3
U238_ELASTIC	24	Sm149_CAPTURE	8	U234_CAPTURE	4	Cr52_CAPTURE	2