

S/U Analysis of Selected Benchmarks and COMMARA-2 Processing by ANGELO Code to Arbitrary Group Structure

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Scope of presentation

- *Note on COMMARA-2 processing using ANGELO and verification by LAMBDA code*
- *K_{eff} sensitivity and uncertainty analysis (JEZEBEL, FLATTOP, TOPSY, ZPR6-7).*
- *Comparison COMMARA 2 - SCALE 6 – JENDL 4 covariance data*

Computational Methods and Procedures

- DANTSYS

- SN transport code (1D, 2D, 3D)

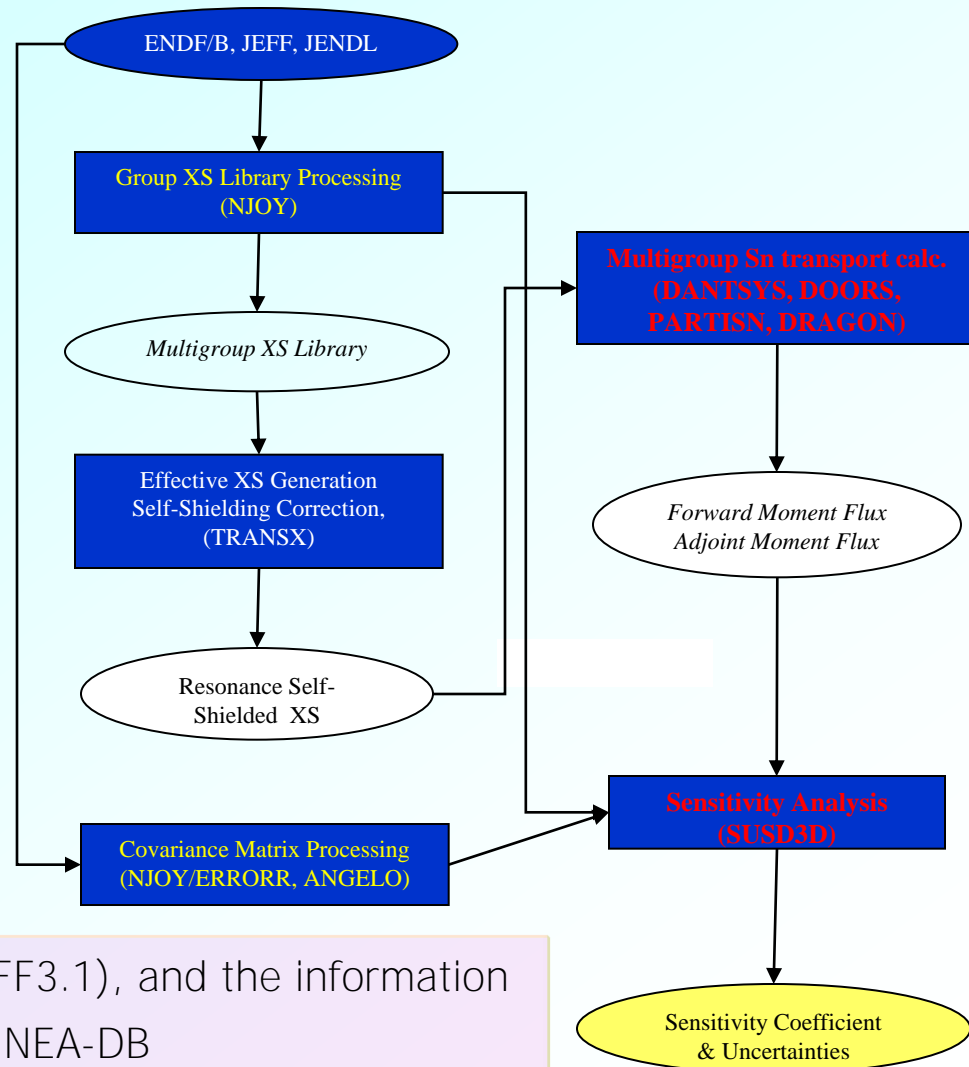
- TRANSX

- Processes MATXS format library for SN transport code
- Self-shielding factor method

- SUS3D

- Multi-dimensional, SN based XS sensitivity and uncertainty
- First-order perturbation theory

- All computer codes, XS library (KAFAX, JEFF3.1), and the information on benchmarks publicly available through NEA-DB



COMMARA-2 Processing by ANGELO/LAMBDA Codes

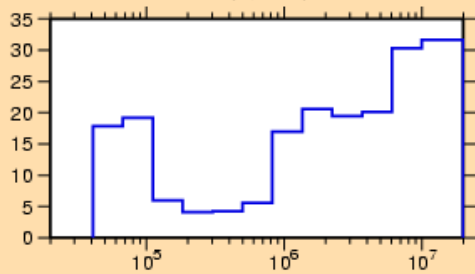
- **ANGELO2.3** code for interpolation of covariance matrices to user defined energy group structure; only file-33 covariance matrices can be treated. (Cross-correlation between reactions are treated correctly but not cross-correlations between nuclides)

ADVANTAGES: easy to use & fast alternative to NJOY processing

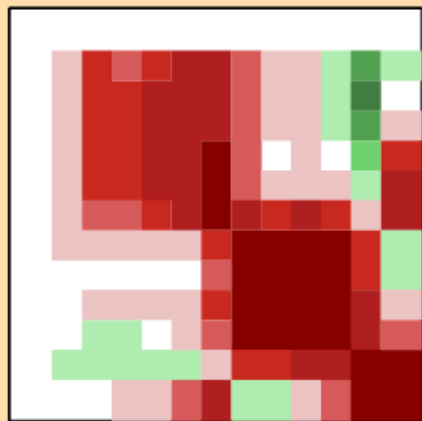
DISADVANTAGES: no flux or cross-section weighting

- **LAMBDA2.3** code for verification of mathematical properties of covariance matrices.
- **Covariance matrices:**
 - library format:
 - **BOXER** or **COVERX** (ZZ-SCALE6/COVA-44G, ZZ-VITAMIN-J/COVA);
 - **FREE FORMAT: correlation matrix and standard deviations supplied in the input (option used here)**
 - energy group structure: arbitrary.

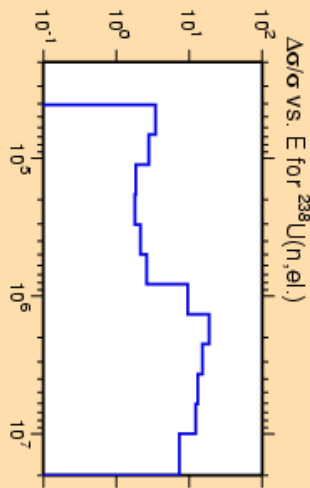
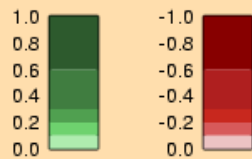
$\Delta\sigma/\sigma$ vs. E for $^{238}\text{U}(n,\text{inel.})$



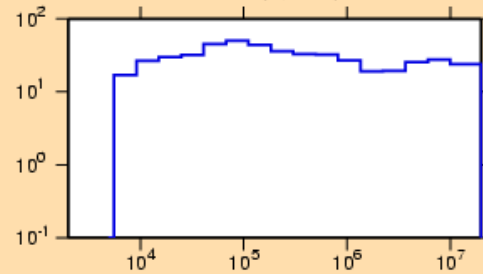
Ordinate scale is % relative standard deviation.
Abscissa scales are energy (eV).



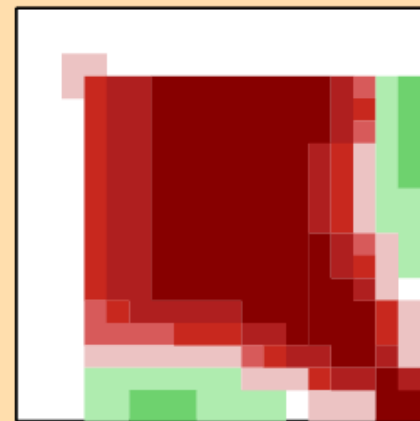
Correlation Matrix



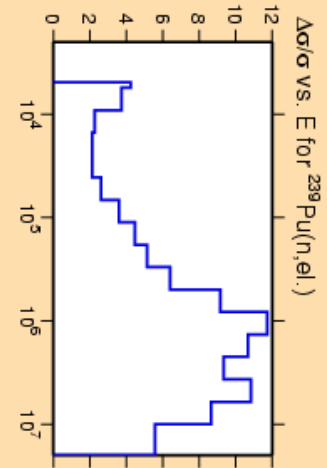
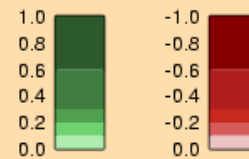
$\Delta\sigma/\sigma$ vs. E for $^{239}\text{Pu}(n,\text{inel.})$



Ordinate scale is % relative standard deviation.
Abscissa scales are energy (eV).
Warning: some uncertainty data were suppressed.



Correlation Matrix



JEZEBEL, FLATTOP, TOPSY, ZPR 6-7

JEZEBEL-Pu239: ONEDANT 1D, $r=6.3849$ cm, 60I, P_5 , S_{48}

XS from ENDF/B-VII processed by NJOY (80 n groups) $k_{\text{eff}}=0.998396$ (dir),
0.998397 (adj)

FLATTOP: ONEDANT 1D, $r_1=4.5332$ cm, $r_2=24.1420$ cm, 725I, P_5 , S_{48}

XS from ENDF/B-VII (80 n groups) $k_{\text{eff}}=1.00143$ (dir), 1.00141 (adj)

TOPSY: ONEDANT 1D, $r_1=6.1156$ cm, $r_2=24.1242$ cm, 237I, P_5 , S_{48}

XS from ENDF/B-VII (80 n groups)

ZPR 6-7: TWODANT 2D R-Z

NEA-1650 ZZ-KAFAX-F22 (80 n groups JEFF 2.2) $k_{\text{eff}}=0.985169$ (P_1S_4)

NEA-1815: ZZ-KAFAX-E70 150 n groups ENDF/B-VII.0 (^{238}U data

recalculated since $k_{\text{eff}}\sim 1.08$ was obtained with original ^{238}U)

$k_{\text{eff}}=1.0009163$ (P_1S_4 , direct)

$k_{\text{eff}}=1.0009171$ (P_1S_4 , adjoint)

$k_{\text{eff}}=1.0006591$ (P_3S_4 , direct)

JEZEBEL

	Sensitivity (%/%)					
	Elastic	Inel.	(n,2n)	(n,f)	(n, γ)	Nu-bar
²³⁹Pu	$6.44 \cdot 10^{-2}$	$4.53 \cdot 10^{-2}$	$-6.20 \cdot 10^{-4}$	$7.29 \cdot 10^{-1}$	$-7.59 \cdot 10^{-3}$	$9.66 \cdot 10^{-1}$
²⁴⁰Pu	$3.55 \cdot 10^{-3}$	$1.91 \cdot 10^{-3}$	$1.47 \cdot 10^{-5}$	$2.35 \cdot 10^{-2}$	$-6.15 \cdot 10^{-4}$	$3.13 \cdot 10^{-2}$
²⁴¹Pu	$1.69 \cdot 10^{-4}$	$1.56 \cdot 10^{-4}$	$9.56 \cdot 10^{-6}$	$2.10 \cdot 10^{-3}$	$-4.54 \cdot 10^{-5}$	$2.79 \cdot 10^{-3}$

JEZEBEL

COMMARA	Standard deviation (% %)					
	²³⁹ Pu-elas.	²³⁹ Pu-inel.	²³⁹ Pu (n,2n)	²³⁹ Pu (n,f)	²³⁹ Pu (n,g)	²³⁹ Pu (v)
²³⁹ Pu-elas	50.05%	-96.37%	0	-0.52%	0.17%	0
²³⁹ Pu-inel.	-96.37%	211.25%	0	0	0	0
²³⁹ Pu (n,2n)	0	0	0.03%	0	0	0
²³⁹ Pu (n,f)	-0.52%	0	0	29.23%	0	0
²³⁹ Pu (n,g)	0.17%	0	0	0	1.29%	0
²³⁹ Pu (v)	0	0	0	0	0	1.60%

Total uncertainty = **0.649 %**

JEZEBEL

SCALE-6	Standard deviation (% %)							
	²⁴⁰ Pu-inel.	²⁴⁰ Pu (n,f)	²⁴⁰ Pu (v)	²³⁹ Pu-elas.	²³⁹ Pu-inel.	²³⁹ Pu (n,f)	²³⁹ Pu (n,g)	²³⁹ Pu (v)
²⁴⁰ Pu-inel.	0.01%	0	0	0	0	0	0	0
²⁴⁰ Pu (n,f)	0	0.01%	0	0	0	0	0	0
²⁴⁰ Pu (v)	0	0	0.18%	0	0	0	0	0
²³⁹ Pu-elas.	0	0	0	7.75%	0.00%	0	0	0
²³⁹ Pu-inel.	0	0	0	0	32.79%	0	0	0
²³⁹ Pu (n,f)	0	0	0	0	0	4.50%	0	0
²³⁹ Pu (n,g)	0	0	0	0	0	0	0.20%	0
²³⁹ Pu (v)	0	0	0	0	0	0	0	54.56%

Total uncertainty = 1.67 %

JEZEBEL

JENDL4	Standard deviation (% %)							
	²⁴⁰ Pu-inel.	²⁴⁰ Pu (n,f)	²⁴⁰ Pu (v)	²³⁹ Pu-elas.	²³⁹ Pu-inel.	²³⁹ Pu (n,f)	²³⁹ Pu (n,γ)	²³⁹ Pu (v)
²⁴⁰ Pu-inel.	0.06%	0	0	0	0	0	0	0
²⁴⁰ Pu (n,f)	0	0.04%	0	0	0	0	0	0
²⁴⁰ Pu (v)	0	0	0.07%	0	0	0.80%	0	0
²³⁹ Pu-elas.	0	0	0	11.37%	0	0	0	0
²³⁹ Pu-inel.	0	0	0	0	26.52%	0	0	0
²³⁹ Pu (n,f)	0	0	0.80%	0	0	48.08%	0	0
²³⁹ Pu (n,g)	0	0	0	0	0	0	0.90%	0
²³⁹ Pu (v)	0	0	0	0	0	0	0	11.23%

Total uncertainty = **0.63 %**

FLATTOP

	Sensitivity (%/%)					
	Elastic	Inelastic	(n,2n)	(n,f)	(n, γ)	Nu-bar
²³⁵ U	$6.44 \cdot 10^{-4}$	$3.48 \cdot 10^{-4}$	$-9.40 \cdot 10^{-6}$	$7.58 \cdot 10^{-3}$	$-5.44 \cdot 10^{-4}$	$1.05 \cdot 10^{-2}$
²³⁸ U	$1.39 \cdot 10^{-1}$	$6.53 \cdot 10^{-2}$	$-1.82 \cdot 10^{-3}$	$5.79 \cdot 10^{-2}$	$-3.98 \cdot 10^{-2}$	$7.90 \cdot 10^{-2}$
²³⁹ Pu	$2.21 \cdot 10^{-2}$	$1.72 \cdot 10^{-2}$	$-5.90 \cdot 10^{-4}$	$6.33 \cdot 10^{-1}$	$-1.29 \cdot 10^{-2}$	$8.81 \cdot 10^{-1}$
²⁴⁰ Pu	$1.27 \cdot 10^{-3}$	$5.92 \cdot 10^{-4}$	$8.15 \cdot 10^{-6}$	$1.91 \cdot 10^{-2}$	$-9.91 \cdot 10^{-4}$	$2.66 \cdot 10^{-2}$
²⁴¹ Pu	$6.00 \cdot 10^{-5}$	$5.07 \cdot 10^{-5}$	$5.95 \cdot 10^{-6}$	$1.94 \cdot 10^{-3}$	$-6.31 \cdot 10^{-5}$	$2.71 \cdot 10^{-3}$

FLATTOP

COMMARA		Standard deviation (% %)								
	²³⁸ U-el.	²³⁸ U-inel.	²³⁸ U (n,f)	²³⁸ U (n,γ)	²³⁸ U (ν)	²³⁹ Pu- elas.	²³⁹ Pu- inel.	²³⁹ Pu (n,f)	²³⁹ Pu (n,γ)	²³⁹ Pu (ν)
²³⁸ U-el.	75.96%	-115.50%	0	0.01%	0	0	0	0	0	0
²³⁸ U-inel.	-115.50%	205.01%	0	0	0	0	0	0	0	0
²³⁸ U (n,f)	0	0	0.30%	0	0	0	0	0	0	0
²³⁸ U (n,γ)	0.01%	0	0	0.83%	0	0	0	0	0	0
²³⁸ U (ν)	0	0	0	0	2.75%	0	0	0	0	0
²³⁹ Pu-el.	0	0	0	0	0	10.02%	-19.66%	-0.23%	0.13%	0
²³⁹ Pu- inel.	0	0	0	0	0	-19.66%	42.60%	0	0	0
²³⁹ Pu (n,f)	0	0	0	0	0	-0.23%	0	27.09%	0	0
²³⁹ Pu (n,γ)	0	0	0	0	0	0.13%	0	0	4.05%	0
²³⁹ Pu (ν)	0	0	0	0	0	0	0	0	0	1.66%

Total uncertainty = 0.554 %

FLATTOP

SCALE-6		Standard deviation (% %)								
	²³⁸ U-el.	²³⁸ U-inel.	²³⁸ U (n,f)	²³⁸ U (n,γ)	²³⁸ U (ν)	²³⁹ Pu- elas.	²³⁹ Pu- inel.	²³⁹ Pu (n,f)	²³⁹ Pu (n,γ)	²³⁹ Pu(ν)
²³⁸ U-el.	14.92%	-21.67%	0	0.01%	0	0	0	0	0	0
²³⁸ U-inel.	-21.67%	39.41%	0	0	0	0	0	0	0	0
²³⁸ U (n,f)	0	0	0.06%	0	0	0	0	0	0	0
²³⁸ U (n,γ)	0.01%	0	0	0.16%	0	0	0	0	0	0
²³⁸ U (ν)	0	0	0	0	0.51%	0	0	0	0	0
²³⁹ Pu-el.	0	0	0	0	0	1.93%	0	0	0	0
²³⁹ Pu- inel.	0	0	0	0	0	0	8.28%	0	0	0
²³⁹ Pu (n,f)	0	0	0	0	0	0	0	5.25%	0	0
²³⁹ Pu (n,γ)	0	0	0	0	0	0	0	0	0.80%	0
²³⁹ Pu (ν)	0	0	0	0	0	0	0	0	0	71.73%

Total uncertainty = 1.27 %

FLATTOP

JENDL-4		Standard deviation (% %)								
	²³⁸ U-el.	²³⁸ U-inel.	²³⁸ U (n,f)	²³⁸ U (n,γ)	²³⁸ U (ν)	²³⁹ Pu- elas.	²³⁹ Pu- inel.	²³⁹ Pu (n,f)	²³⁹ Pu (n,γ)	²³⁹ Pu (ν)
²³⁸ U-el.	23.16%	0	0	0	0	0	0	0	0	0
²³⁸ U-inel.	0	33.50%	0	0	0	0	0	0	0	0
²³⁸ U (n,f)	0	0	0.22%	0	0	0	0	1.06%	0	0
²³⁸ U (n,γ)	0	0	0	0.94%	0	0	0	0	0	0
²³⁸ U (ν)	0	0	0	0	0.44%	0	0	0	0	0
²³⁹ Pu-el.	0	0	0	0	0	0.94%	0	0	0	0
²³⁹ Pu inel	0	0	0	0	0	0	2.69%	0	0	0
²³⁹ Pu (n,f)	0	0	1.06%	0	0	0	0	26.90%	0	0
²³⁹ Pu (n,γ)	0	0	0	0	0	0	0	0	1.71%	0
²³⁹ Pu (ν)	0	0	0	0	0	0	0	0	0	5.89%

Total uncertainty = 0.716 %

CONCLUSIONS

- **ZPR 6-7, JEZEBEL and FLATTOP benchmarks were analysed using SUS3D-DANTSYS cross-section sensitivity-uncertainty package.**
- **COMMARA-2 data available in 33-group structure were extended by ANGELO to new group structure. All processed covariances were found to be positive. The procedure can be made available to other users if needed.**
- **Covariance matrices of different origin were used: COMMARA-2, SCALE-6 and JENDL-4. Reasonably good consistency was observed.**

U-235(n,f)

