

## Processing into JANIS format: Uncertainty Quantification with different evaluations using NDaST code

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- ❑ **Processing JENDL-5.0upd into HENDF format (NJOY2016.69 + PREPRO-2021)**
  - ENDF/PENDF + INTER + BOXER (MF31+MF32/MF33 + MF34 and MF35 if exist)
  
- ❑ **Uncertainty Quantification of HENDF/JENDL-5.0upd in ICSBEP using the NDaST**

## Processing JEFF-4T2.2/JENDL5-0upd to JANIS: HENDF + INTER + BOXER

Figure 1. Flowchart of processing JANIS database from ENDF tapes

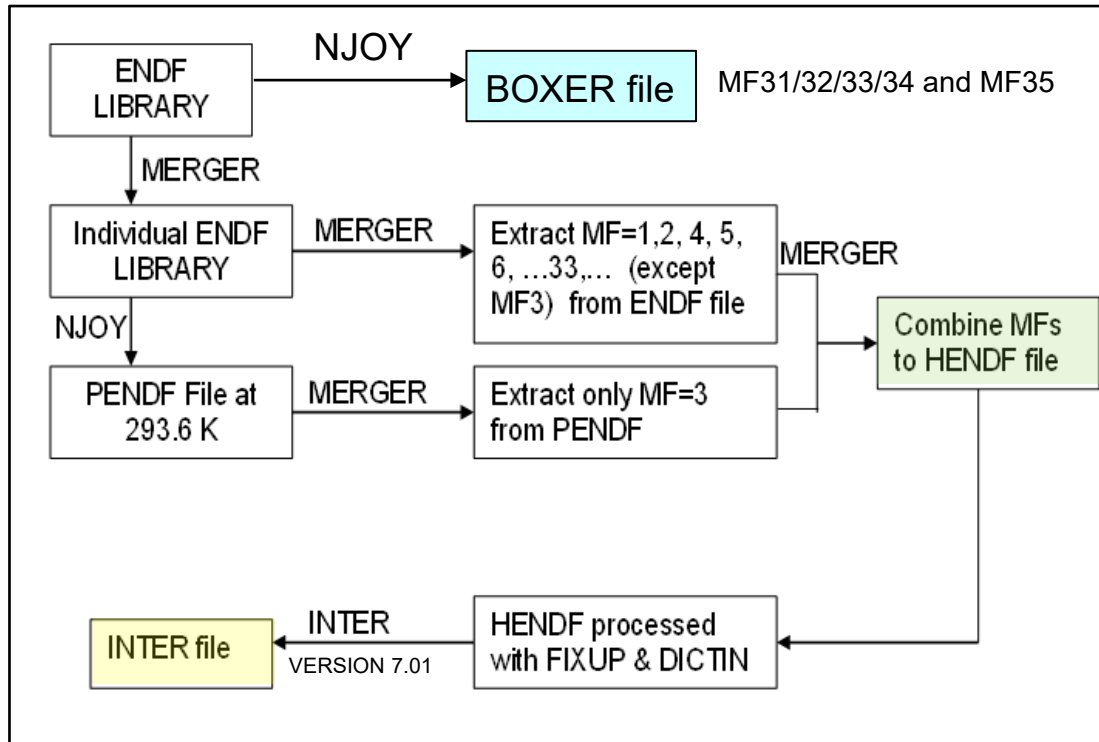


Figure 2. Example of input deck to process in PENDF format

```

moder /tape20 from MERGER                                tape20 = ENDF file
20 -31                                                     =====
reconr /Reconstruct XS data
-31 -32
' PENDF tape      ' /
9437 2 /
.005 /
' MAT=pu239  ENDF Library:JENDL-5.0upd' /
' Processed NJOY2016-UPM,2023
0/
broadr /Doppler broaden XS
-31 -32 -33
9437 1 /
.005 /
.293.60
0/
thermr / Add thermal scattering data
0 -33 -34
0 9437 12 1 1 0 0 1 221 0
.293.60
0.005 10.0
unresr
-31 -34 -35
9437 1 1 0 /
.293.60
1.0e+10 /
0/
heatr / Add heating kerma and damage energy
-31 -35 -36 40/
9437 7 0 0 0 2/
302 303 304 318 401 403 407 /
heatr / Add heating kerma and damage energy
-31 -36 -37 41/
9437 6 0 0 0 2 0 1/
442 443 444 445 446 447 /
gaspr /Gas production
-31 -37 -38
moder
-38 26
stop
  
```

## Processing JENDL5-0upd in BOXER

```

moder /
1 21
'094-Pu-239 '
20 9437 /
0/
reconr /
21 22
'094-Pu-239 '
9437 2 /
0.005 /
'Reconstructed'/
'Processed'/
0/
broadr /
21 22 23
9437 1 0 0 0./
0.005 /
300.0 /
0/
unresr /
21 23 24
9437 1 1 0 /
300.0 /
1.0E+10 /
0 /
groupr /
21 24 0 31/
9437 1 0 2 0 1 1 1 /
'GENDF- 238g' /
300.0
1.E10
238 /
1.00000E-05
1.00000E-04
5.00000E-04
...
1.73300E+07
2.0000E+07 /
3/
3 18/
3 251/
3 452 nubar_t/
3 455 nubar_g/
3 456 nubar_p/
5 455 nubar_spc/
0/
0/

```

```

errorr
21 24 0 77 /
9437 1 2 1 1 /
1 300.0 / Just only one temperature
0 33 /
33 /
1.00000E-05
1.00000E-01
...
6.06531E+06
1.00000E+07
1.9640E+07 /
covr
77 0 81 /
1/
/
9437 0 0 0 /
viewr
81 82
covr
77 78 /
4 1
'LIB_JENDL-5.0upd ' /
'BOXER format'/
9437 0 0 0 /
stop

```

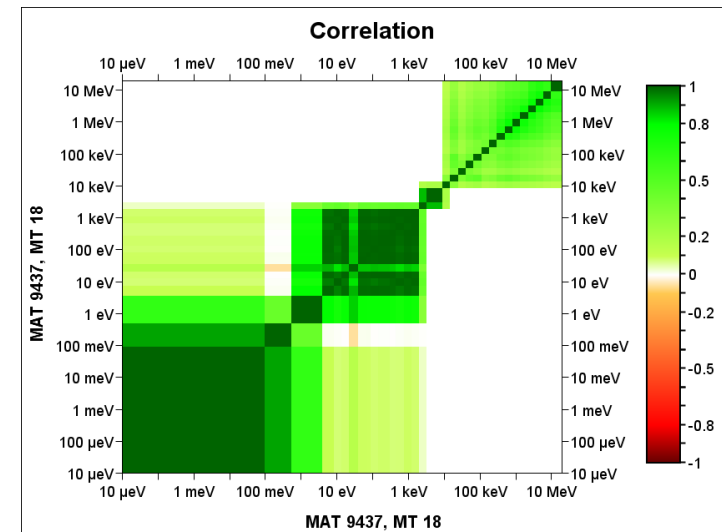
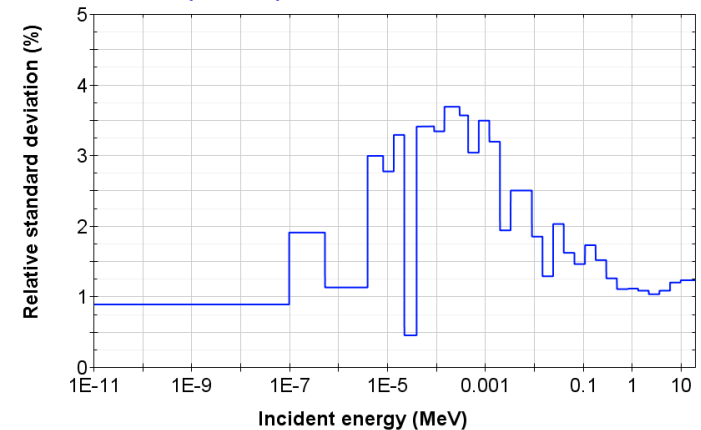
**Figure 3.** Input deck to process MF32/33 covariances

```

tape20 = ENDF Pu239
=====

```

Incident neutron data / JENDL-5.0upd /  
Pu239 / MT:18 : (z,fission) / Covariances  
data (BOXER) Relative standard deviation



**Processing JEFF-4T2.2 library into JANIS format:**

# - HENDF: Hybrid format ENDF+PENDF including KERMA and DAMAGE cross-sections

# - INTER

# - BOXER: covariances MF31, MF32/MF33, MF34 and MF35

<https://drive.upm.es/s/fGSomTs8N7YIVTN>

password: janis

In addition, **JENDL-5.0-upd into JANIS format**

<https://drive.upm.es/s/E4KBmhbtrl5yWQI>

password: janis

## □ Uncertainty Analysis based on S/A - Error propagation

- **Being any response as (first order approach) :**

$$k_{eff}(\alpha_1, \alpha_2 \dots \alpha_k) = k_{eff}(\alpha_1^0, \alpha_2^0, \dots, \alpha_k^0) + \sum_{i=1}^k \left( \frac{\partial k_{eff}}{\partial \alpha_{i_1}} \right)_{\alpha^0} \delta \alpha_{i_1}$$

- **The sandwich formula gives:**

$$var[k_{eff}] = \left[ \sum_{i=1}^k S_i^2 var(\alpha_i) + 2 \sum_{i \neq j=1}^k S_i S_j cov(\alpha_i, \alpha_j) \right] = \mathbf{S} \cdot \mathbf{V}_\alpha \cdot \mathbf{S}^T$$

where:

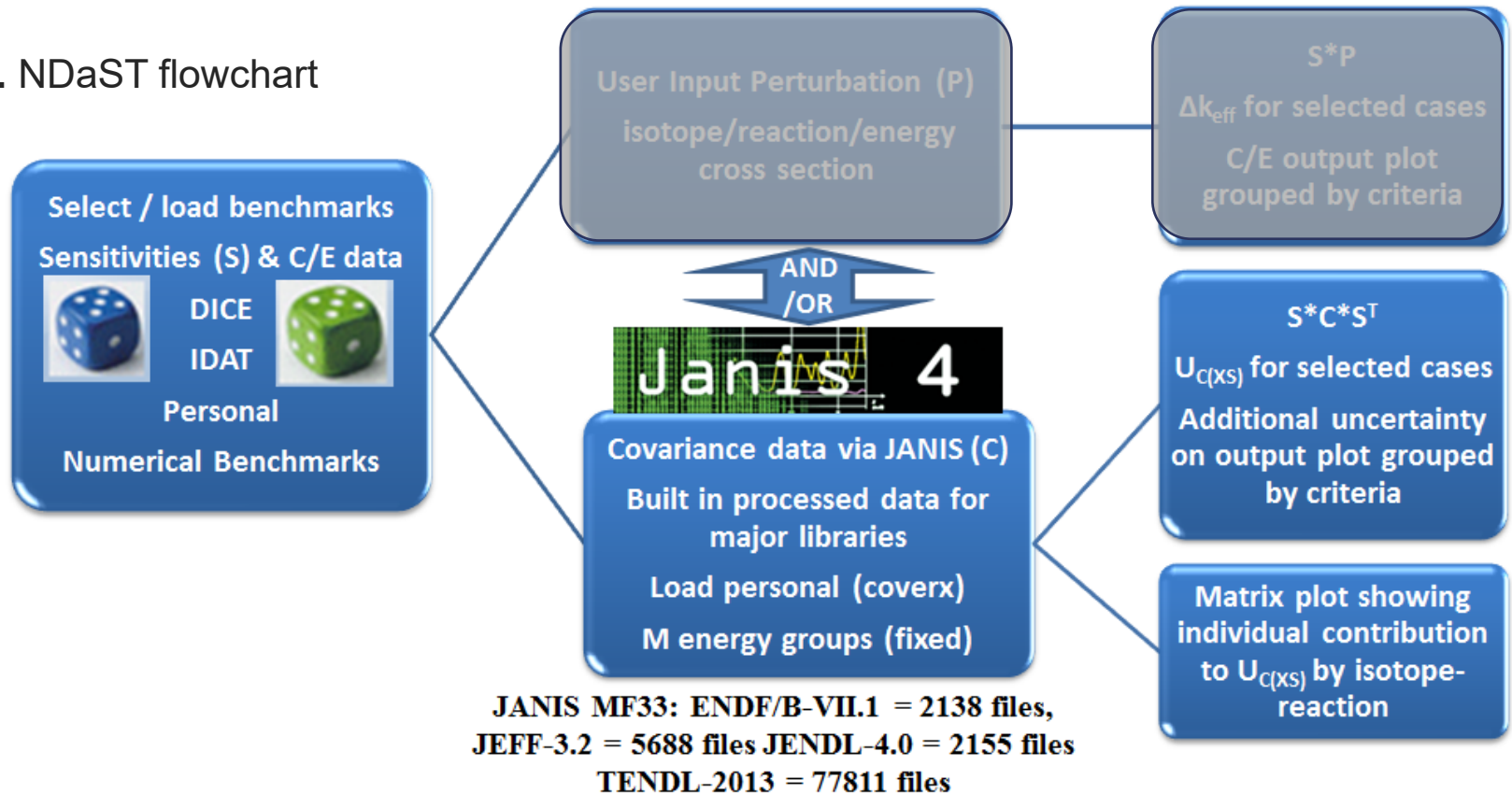
- $\mathbf{S}$  (1xK) are the Sensitivity coefficients of the  $k_{eff}$  response to all ND parameters:

$$\mathbf{S} = \left[ \frac{\partial k_{eff}}{\partial \alpha_1} \quad \dots \quad \frac{\partial k_{eff}}{\partial \alpha_k} \right]_{\alpha^0}$$

- $\mathbf{V}_\alpha$  is the covariance matrix (KxK): 
$$\mathbf{V}_\alpha = \begin{bmatrix} var(\alpha_1) & \dots & cov(\alpha_1, \alpha_K) \\ \vdots & \ddots & \vdots \\ cov(\alpha_K, \alpha_1) & \dots & var(\alpha_K) \end{bmatrix}$$

- Visualization tools (<https://www.oecd-nea.org/ndast/webstart/NDaST.jnlp>)

Figure 4. NDaST flowchart



## Verification ND uncertainties...

- HENDF/JENDL-5.0upd: Uncertainty Quantification in ICSBEP using NDaST

**Plutonium-239**

Fissile Material		Pu			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		152	4	9	601
Experimental Uncertainty (pcm)		368	505	606	371
ENDF/B-VIII.0b5	Total (pcm)	893	1550	1108	1157
	Cross-sections	856	1538	1047	1059
	Nubar	214	146	232	333
	Chi	120	85	275	259
JEFF-3.3T4	Total (pcm)	572	1555	1050	967
	Cross-sections	240	1451	749	520
	Nubar	412	462	446	463
	Chi	287	182	580	558
ENDF/B-VII.1	Total (pcm)	438	577	475	608
	Cross-sections	409	561	368	493
	Nubar	76	93	117	166
	Chi	120	85	276	260
JENDL-4.0u1	Total (pcm)	527	513	563	689
	Cross-sections	448	473	348	493
	Nubar	189	123	82	78
	Chi	182	131	434	404
SCALE-6.2rev8	Total (pcm)	343	572	465	605
	Cross-sections	305	556	357	489
	Nubar	76	92	118	176
	Chi	114	85	279	256

Fissile material		PU			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		152	4	9	624
Experimental Uncertainty (pcm)		334	710	587	426
JENDL-5.0	Total (pcm)	704	1449	1049	1099
	Cross-sections	646	1430	962	985
	P1-elastic	69	-	-	-
	Nubar	189	120	85	80
	Chi/PFNS	171	142	408	441

NEW calculations with NDaST tool: only Pu239 covariances

**This Work!**

Ref. O.Cabellos, J.Dyrda and N.Soppera, "Checking, Processing and Verification of Nuclear Data Covariances" CW2017, Aix-en-Provence, Oct 2017





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## Processing JENDL5-0upd in BOXER

**Figure 4.** Input deck to process covariances in files with MF32-only

```

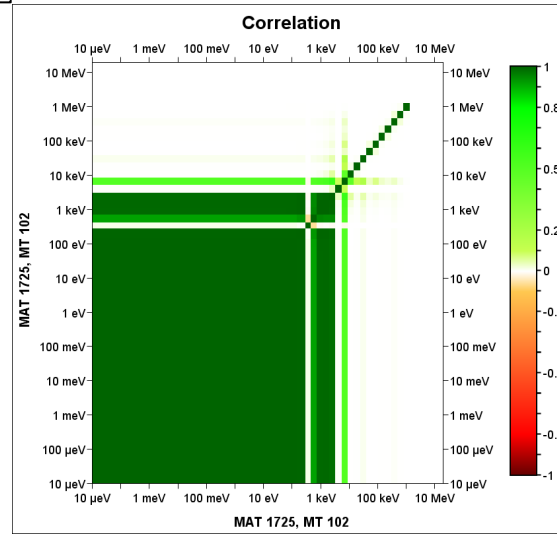
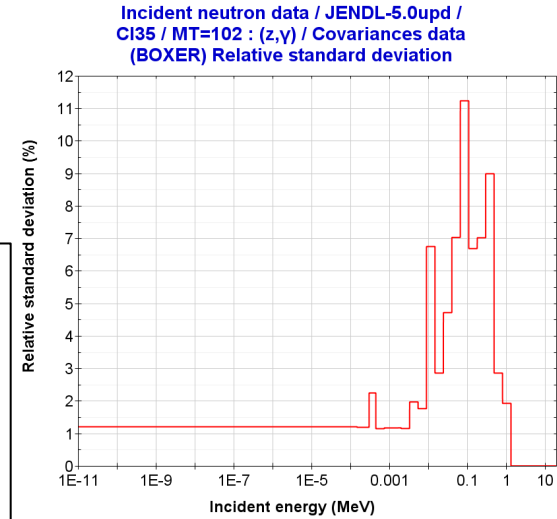
moder      tape20 = ENDF C135
1 21
'017-c1-35 ' =====
20 1725 /
0/
reconr
21 22
'017-c1-35 '
1725 2 /
0.005 /
'Reconstructed'/
'Processed'/
0/
broadr
21 22 23
1725 1 0 0 0./
0.005 /
300.0 /
0/
unresr
21 23 24
1725 1 1 0 /
300.0 /
1.0E+10 /
0 /

errorr
999/
21 88/
1 / MT1
2 / MT2
102 / MT102
600 / MT600
0/
errorr
88 24 0 77 /
1725 1 2 1 1 /
1 300.0 / Just only one temperature
0 33 /
33 /
1.00000E-05
1.00000E-01
5.40000E-01
...
1.00000E+07
1.9640E+07 /
covr
77 0 81 /
1/
/
/
1725 0 0 0 /
viewr
81 82
covr
77 78 /
4 1
'LIB_JENDL-5.0upd ' /
'BOXER format'/
1725 0 0 0 /
stop

```

Materials with only MF32

**JENDL-5.0:**  
C135, Cr50, Cr54



## Processing JENDL5-0upd in BOXER

```

moder /
2 99
' 9437 and 9228' /
91 9437 /
92 9228 /
0/
errorr
21 0 99 26 61 /
9437 1 2 1 1 /
1 300.0 / Just only one temperature
2 33 /
9228 18 /
0 /
33 /
1.00000E-05
1.00000E-01
...
1.00000E+07
1.9640E+07 /
covr
26 0 81 /
1/
/
/
9437 18 9228 18 /
viewr
81 82
covr
26 27 /
4 1
'LIB_JENDL-5.0upd ' /
'BOXER format'/
9437 18 9228 18 /
stop

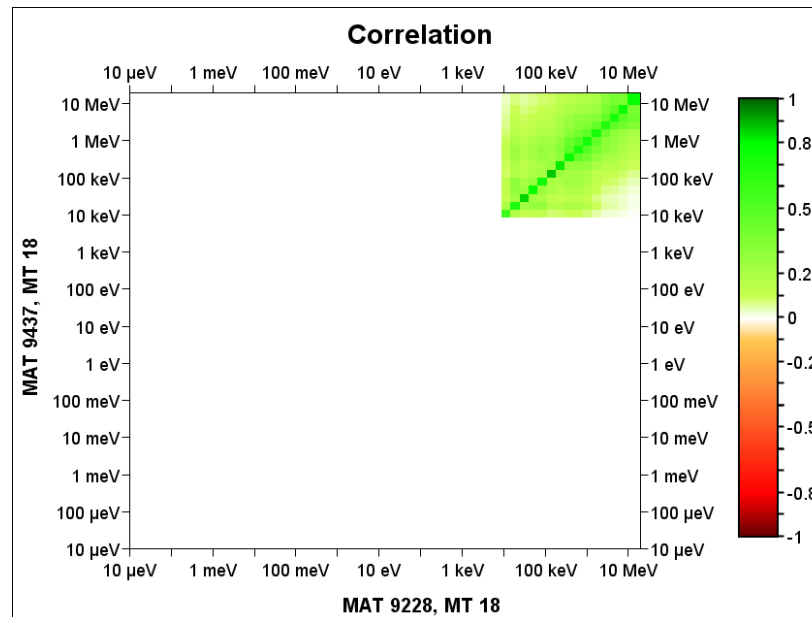
```

**Figure 5.** Input deck to process MF33 covariances between different materials

```

tape21 = ENDF Pu239
tape91 = GENDF-238g Pu239
tape92 = GENDF-238g U235
tape61 = input cov. tape77 (ERRORR output) for U235
=====

```



## □ Verification ND uncertainties...

- HENDF/JENDL-5.0upd: Uncertainty Quantification in ICSBEP using NDaST

Uranium-233					
Fissile Material		U233			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		8	29	8	194
Experimental Uncertainty (pcm)		156	662	590	548
ENDF/B-VIII.0b5	Total (pcm)	810	1154	1175	1157
	Cross-sections	643	310	323	565
	Nubar	478	496	500	509
	Chi	106	994	1013	814
JEFF-3.3T4	Total (pcm)	763	474	461	496
	Cross-sections	733	353	293	202
	Nubar	210	314	356	451
	Chi	-	-	-	-
ENDF/B-VII.1	Total (pcm)	763	474	461	496
	Cross-sections	733	353	293	202
	Nubar	210	314	356	451
	Chi	-	-	-	-
JENDL-4.0u1	Total (pcm)	810	1143	1154	991
	Cross-sections	643	264	235	187
	Nubar	478	496	500	509
	Chi	106	994	1013	814
SCALE-6.2rev8	Total (pcm)	743	1083	1094	951
	Cross-sections	705	342	287	201
	Nubar	212	323	363	453
	Chi	97	974	991	794

Fissile material		U233			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		8	29	8	223
Experimental Uncertainty (pcm)		174	670	601	600
JENDL-5.0	Total (pcm)	948	1121	1133	1005
	Cross-sections	808	275	243	190
	P1-elastic	-	-	-	-
	Nubar	484	496	501	508
	Chi	95.2	967	987	837

Calculations with NDaST tool: only U233 covariances

**This Work!**

Ref. O.Cabellos, J.Dyrda and N.Soppera, "Checking, Processing and Verification of Nuclear Data Covariances" CW2017, Aix-en-Provence, Oct 2017

## Verification ND uncertainties...

- HENDF/JENDL-5.0upd: Uncertainty Quantification in ICSBEP using NDaST

Uranium-235					
Fissile Material		HEU			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		463	21	78	802
Experimental Uncertainty (pcm)		210	343	419	468
JENDL-4.0u1	Total (pcm)	679	680	587	667
	Cross-sections	614	576	459	219
	Nubar	263	182	177	289
	Chi	134	291	303	523

Uranium-238					
Fissile Material		HEU			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		463	21	78	802
Experimental Uncertainty (pcm)		210	343	419	468
JENDL-4.0u1	Total (pcm)	78	64	24	7
	Cross-sections	77	64	24	7
	Nubar	9	4	3	0
	Chi	5	2	1	0

Fissile material		HEU			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		477	21	78	798
Experimental Uncertainty (pcm)		225	310	415	473
JENDL-5.0 only U235 covariances	Total (pcm)	759	555	549	660
	Cross-sections	685	403	400	144
	P1-elastic	102	23	23	1
	Nubar	245	181	177	288
	Chi	133	292	303	536
JENDL-5.0 only U238 covariances	Total (pcm)	68	93	21	6
	Cross-sections	64	93	21	6
	P1-elastic	15	1	1	0
	Nubar	8	5	3	0
	Chi	4	3	1	0

Ref. O.Cabellos, J.Dyrda and N.Soppera, "Checking, Processing and Verification of Nuclear Data Covariances" CW2017, Aix-en-Provence, Oct 2017

Calculations with NDaST: only U235/238 covariances

**This Work!**

### Verification ND uncertainties...

- HENDF/JENDL-5.0upd: Uncertainty Quantification in ICSBEP using NDaST

Uranium-235					
Fissile Material		IEU			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		57	8	8	142
Experimental Uncertainty (pcm)		177	203	311	511
JENDL-4.0u1	Total (pcm)	602	584	498	782
	Cross-sections	403	456	294	240
	Nubar	204	174	197	290
	Chi	381	284	336	682
Uranium-238					
Fissile Material		IEU			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		57	8	8	142
Experimental Uncertainty (pcm)		177	203	311	511
JENDL-4.0u1	Total (pcm)	636	394	238	85
	Cross-sections	621	387	236	84
	Nubar	97	64	28	4
	Chi	96	36	17	5

Fissile material		IEU			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		58	8	8	143
Experimental Uncertainty (pcm)		175	166	360	514
<b>JENDL-5.0</b> only U235 covariances	<b>Total (pcm)</b>	<b>626</b>	<b>407</b>	<b>479</b>	<b>736</b>
	Cross-sections	452	295	184	131
	P1-elastic	1	-	11	0
	Nubar	192	156	202	283
	Chi	381	226	357	663
<b>JENDL-5.0</b> only U238 covariances	<b>Total (pcm)</b>	<b>583</b>	<b>310</b>	<b>213</b>	<b>84</b>
	Cross-sections	565	298	211	84
	P1-elastic	-	-	5	-
	Nubar	101	74	24	6
	Chi	94	36	15	7

Ref. O.Cabellos, J.Dyrda and N.Soppera, "Checking, Processing and Verification of Nuclear Data Covariances" CW2017, Aix-en-Provence, Oct 2017

Calculations with NDaST: only U235/238 covariances

**This Work!**

## Verification ND uncertainties...

- HENDF/JENDL-5.0upd: Uncertainty Quantification in ICSBEP using NDaST

Uranium-235				
Fissile Material		LEU		
Spectrum		FAST	MIXED	THERM
Number of Benchmarks		1	5	1512
Experimental Uncertainty (pcm)		270	348	259
JENDL-4.0u1	Total (pcm)	523	427	444
	Cross-sections	444	357	232
	Nubar	222	183	283
	Chi	164	146	228
Uranium-238				
Fissile Material		LEU		
Spectrum		FAST	MIXED	THERM
Number of Benchmarks		1	5	1512
Experimental Uncertainty (pcm)		270	348	259
JENDL-4.0u1	Total (pcm)	179	211	272
	Cross-sections	177	208	270
	Nubar	21	36	28
	Chi	6	10	10

Fissile material		LEU			
Spectrum		FAST	INTER	MIXED	THERM
Number of Benchmarks		1	-	5	1565
Experimental Uncertainty (pcm)		274	-	353	240
<u>JENDL-5.0 only U235 covariances</u>	<b>Total (pcm)</b>	<b>586</b>	<b>-</b>	<b>458</b>	<b>419</b>
	Cross-sections	520	-	396	155
	P1-elastic	-	-	-	-
	Nubar	221	-	182	281
	Chi	157	-	139	250
<u>JENDL-5.0 only U238 covariances</u>	<b>Total (pcm)</b>	<b>172</b>	<b>-</b>	<b>168</b>	<b>208</b>
	Cross-sections	170	-	163	205
	P1-elastic	-	-	-	-
	Nubar	20	-	35	29
	Chi	6	-	9	11

Ref. O.Cabellos, J.Dyrda and N.Soppera, "Checking, Processing and Verification of Nuclear Data Covariances" CW2017, Aix-en-Provence, Oct 2017

Calculations with NDaST: only U235/238 covariances

**This Work!**