The European Commission’s science and knowledge service

Joint Research Centre
JEFF-3.3

Arjan Plompen

OECD-NEA, 17 May 2018
The JEFF-3.3 release is now official

• Many thanks to all contributors
  • For providing (parts of) the files
  • For fixing files
  • For testing
  • For providing feedback
  • For lively discussions
  • For the support given by NEA
Contents

  • Short history
  • Contents
  • Performance
• The future

Information collected from the last two JEFF-CHANDA meetings, November 2017, April 2018. Full presentations are on the JEFF webpage.
Short history

• JEFF – 3.2, 5 March 2014.
• JEFF – 3.3T0/T1, 19 Feb 2016 (Decision Nov. 2015).
• JEFF – 3.3T2, June 2016
• JEFF – 3.3T3, March 2017
• JEFF – 3.3T4, June 2017
• JEFF – 3.3, 20 November 2017
Short history

- New major actinides (Morillon, Romain, De Saint Jean, Leal)
- New thermal scattering data (April 2017, Cantargi, Granada, Marquez Damian, Noguere)
- Radioactive Decay Data File (Oct. 2016, M. Kellett & O. Bersillon, JEF/DOC-1792)
- FY beta file UKFY3.7, adjustment to new RDD pending (Wednesday)
- New covariances, larger subset of MTs, some proposals still not ENDF format
- Removal of legacy files, update of adopted files to latest release.
- Increased reliance on TENDL for completeness and decay heat (D. Rochman, M. Flemming)
- Improved gamma-data and energy balance for emission (C. Jouanne, R. Perry, G. Noguere, O. Serot, ...) 
- Restoration of 8 group structure for delayed neutrons (P. Leconte)
- New Cu files (Pereslavitsev, Leal)
- Many issues resolved (many contributors)
Evaluated $^{238}\text{U}(n,f)$ & standard cross section

JEFF-3.3 adopts the fission standards
JEFF 3.3 T1

- March 2016, 559 materials
  - Impose the fission standards: new CEA-IRSN actinide files
  - Covariances for all important nuclides.
  - Many specific issues with nuclides Cr, Cu, Cd, Ta, W, Hf, Au, Pb, Bi, ...
  - Replacement of legacy files
  - New TENDL files; includes replacing earlier TENDL.
  - Activation library performance upgrade (Sublet)
  - Many bug-fixes (Jouanne, Haeck, Rochman, a.o.)
Fission standards

Adopted for U-235 & U-238
JEFF 3.3 T2

- T2 June 2016, 559 materials
  - 44 changes from T1
  - 40 photoproduction from TENDL: Y89, Zr93, Nb95, Mo, Ru, Pd, In, I, Xe, Cs, Ba134, La139, Ce, Pr, Nd, Pm, Sm, Eu, Gd157, Dy, Hf (Perry)
  - 304 changes to covariances from TENDL
  - Restore 2H, 0C, Cd, W, Au
  - Restore and mod INL of Cr Pb-206,206,208, Bi-209
  - Cu-63,65: KIT+3.2-RR
  - Add 81Br, remove 80Br
  - Recoil data Sauvan 54,56,57,58Fe
  - Ni-59 Helgesson
  - MF1 updates Noguere, Plompen, …
  - Many bugfixes discovered in processing Jouanne, Haeck, NDEC/Diez, …
JEFF 3.3 T3

- New Radioactive Decay Data file (Kellett)
- Adjustment of the new Fission Yields file to new RDD UKFY3.7 (Mills)
  - So far the old RDD
  - Still needs covariances (several options)
- Covariances U-235
- Updates to gamma-emission: capture, inelastic, pfgs
- Restoration of 8 group structure delayed neutron data
- New cases (Rochman, Fleming, decay heat)
- O-16
- TSL H, D, O
- Fe CIELO/ENDF/B-VIII.0beta
- Cu KIT + ORNL/IRSN resonance parameters
- Zr chain, fusion (KIT and partners)
- Corrections Jouanne, Rochman
JEFF 3.3

- Turn back Fe
- Improve Cu files (merge resonance file with KIT fast range)
- Improve covariances nu-bar for Pu-239
- UK FY3.7 adopted after verification against new RDD file; still working on covariances.
- DPA files adopted
New Radioactive Decay Data

• Oct. 2016, M. Kellett & O. Bersillon
• This week: JEF/DOC-1792, M. Kellett
JEFF-3.3: Improvements

**From JEFF-3.1.1 to JEFF-3.3**

**JEFF-3.3 (released October 2016):**

- Complete re-assessment and update to all 900 evaluations coming from ENSDF
- Assessment of IAEA actinide decay data (85 nuclei)
- Assessment of IRDFF decay data library (~80 nuclei)
- Inclusion of updated UKPADD-6.12 library (~50 additional nuclei)
- Assessment of new DDEP evaluations (~30 additional nuclei)
- Inclusion of initial TAGS results from University of Valencia (2010)
- Inclusion of first TAGS results from University of Nantes (2015)
- Inclusion of further TAGS results from University of Valencia (2016)
- Corrections based on limited feedback to JEFF-3.1.1
### JEFF-3.3: Source libraries

Contents of JEFF-3.2 (March 2015) and JEFF-3.3 (October 2016)

<table>
<thead>
<tr>
<th>Library</th>
<th>JEFF-3.2</th>
<th>JEFF-3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUBASE</td>
<td>2 297</td>
<td>2 295</td>
</tr>
<tr>
<td>ENSDF</td>
<td>861</td>
<td>849</td>
</tr>
<tr>
<td>UKPADD-6.x</td>
<td>441</td>
<td>441</td>
</tr>
<tr>
<td>UKHEDD-2.x</td>
<td>46</td>
<td>59</td>
</tr>
<tr>
<td>DDEP</td>
<td>128</td>
<td>140</td>
</tr>
<tr>
<td>IAEA</td>
<td>79</td>
<td>66</td>
</tr>
<tr>
<td>IRDFF</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>3 852</td>
<td>3 852</td>
</tr>
</tbody>
</table>
JEFF-3.3: Some remarks

It was found that ~100 or so evaluations, from the 900 evaluations coming from ENSDF, were less consistent than before, i.e. energy balance is now worse than 2%. Original files from JEFF-3.1.1 have been kept for JEFF-3.3.

Many issues were identified with the ENSDF formatted files coming from DDEP and IAEA – these were all recreated and tested, before conversion to the ENDF format.

Very limited manpower available for producing new evaluations. However, I have managed to recruit three new part-time DDEP evaluators from the metrology community: NIST (USA), NIM (China) and PTB (Germany) and CTBTO are currently funding a fourth person to produce new/updated evaluations for Xe-133, Xe-133m, Xe-135 and Xe-135m.
A new UK fission yield evaluation – UKFY3.7

Dr Robert W Mills, NNL

(From his contribution to ND2016)
# Important fissioning systems

<table>
<thead>
<tr>
<th>Nuclides</th>
<th>Max. Fraction of Fission Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>233\text{U} \text{TH}</td>
<td>\text{&gt;10%}</td>
</tr>
<tr>
<td>235\text{U} \text{TH}</td>
<td>\text{1-10%}</td>
</tr>
<tr>
<td>238\text{U} \text{TH}</td>
<td>\text{0.1%-1%}</td>
</tr>
<tr>
<td>239\text{Pu} \text{TH}</td>
<td>\text{Spont. fission}</td>
</tr>
<tr>
<td>241\text{Pu} \text{TH}</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nuclides</th>
<th>Max. Fraction of Fission Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>240\text{Pu} \text{F} \text{Cm} \text{TF}</td>
<td>\text{&gt;10%}</td>
</tr>
<tr>
<td>252\text{Cf} \text{Sp} \text{Cm} \text{Sp}</td>
<td>\text{1-10%}</td>
</tr>
<tr>
<td>242\text{Cm} \text{Sp} \text{Cm} \text{Sp}</td>
<td>\text{0.1%-1%}</td>
</tr>
<tr>
<td>244\text{Cm} \text{Sp}</td>
<td>\text{Spont. fission}</td>
</tr>
</tbody>
</table>

* Nuclides in UKFY1 and previous UK libraries.

T Thermal fission.
F Fast fission.
H 14Mev Fission.
Sp Spontaneous fission.
• New data split into systems:

<table>
<thead>
<tr>
<th>Neutron spectra</th>
<th>Fissioning nuclide</th>
<th>UKFY3.6</th>
<th>New data</th>
<th>UKFY3.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal</td>
<td>Th229</td>
<td>337</td>
<td>72</td>
<td>409</td>
</tr>
<tr>
<td>Thermal</td>
<td>U233</td>
<td>757</td>
<td>188</td>
<td>945</td>
</tr>
<tr>
<td>Thermal</td>
<td>U235</td>
<td>2390</td>
<td>151</td>
<td>2541</td>
</tr>
<tr>
<td>Thermal</td>
<td>Np238</td>
<td>115</td>
<td>63</td>
<td>178</td>
</tr>
<tr>
<td>Thermal</td>
<td>Pu239</td>
<td>861</td>
<td>225</td>
<td>1086</td>
</tr>
<tr>
<td>Thermal</td>
<td>Pu241</td>
<td>334</td>
<td>63</td>
<td>397</td>
</tr>
<tr>
<td>Thermal</td>
<td>Cm245</td>
<td>161</td>
<td>219</td>
<td>380</td>
</tr>
<tr>
<td>Thermal</td>
<td>Cf249</td>
<td>305</td>
<td>239</td>
<td>544</td>
</tr>
<tr>
<td>Fast</td>
<td>U235</td>
<td>724</td>
<td>5</td>
<td>729</td>
</tr>
<tr>
<td>Fast</td>
<td>Pu239</td>
<td>390</td>
<td>5</td>
<td>395</td>
</tr>
<tr>
<td>Fast</td>
<td>Pu241</td>
<td>111</td>
<td>5</td>
<td>116</td>
</tr>
</tbody>
</table>

• Fast yields refer to Neodymium cumulative yields.
Covariances

• Overview: O. Cabellos, CW2017, Aix-en-Provence
• Major nuclides: U-235, U-238, Pu-239 (CEA)
• TENDL-2015 + updates (D. Rochman)
• TSL: H in H₂O (G. Noguere)
• Processing w. NJOY2012.99 (O. Cabellos, J. Dyrda)
• Accessible through JANIS
• Verified through NDaST (chi, nubar, ...
I. JEFF-3.3T4 (562 files)

Table 1: List of isotopes with covariances in JEFF-3.3T4

<table>
<thead>
<tr>
<th>MFs</th>
<th>Isotopes</th>
<th>#ENDF Files</th>
<th>#Processed Files</th>
</tr>
</thead>
<tbody>
<tr>
<td>MF31</td>
<td>89-Ac-225 89-Ac-226 89-Ac-227 ...</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>MF32</td>
<td>6-C-13 8-O-17 8-O-18 ...</td>
<td>352</td>
<td></td>
</tr>
<tr>
<td>MF33</td>
<td>1-H-1 1-H-2 3-Li-6 3-Li-7 ...</td>
<td>442</td>
<td></td>
</tr>
<tr>
<td>MF32/MF33</td>
<td></td>
<td>446</td>
<td></td>
</tr>
<tr>
<td>MF34</td>
<td>6-C-13 8-O-17 8-O-18 ...</td>
<td>359</td>
<td>346</td>
</tr>
<tr>
<td>MF35</td>
<td>89-Ac-225 89-Ac-226 89-Ac-227 ...</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>MF40</td>
<td>13-Al-26 15-P-31 17-Cl-36 ...</td>
<td>286</td>
<td>0</td>
</tr>
<tr>
<td>MF31...MF40</td>
<td></td>
<td>447</td>
<td></td>
</tr>
<tr>
<td>No Covariance</td>
<td>1-H-3 2-He-3 2-He-4 6-C-0 ...</td>
<td>115</td>
<td></td>
</tr>
</tbody>
</table>

- MF31: U235, U238, Pu239, ...
- MF35 - Chi(E): U235, U238, Pu239, ...
- U233 MF31-only delayed and prompt
- U233: No MF35
Further covariances for Hf
Many from TENDL (D. Rochman)
U-235, MT18

Incident neutron data // MT=18 : (z,fission) /

Relative standard deviation (%) vs. Incident energy (MeV)

- JEFF-3.3T4
- CIELO1
- SCALE6.2rev8
- ENDF/B-VII.1
- JENDL-4.0u

Correlation heat map for MAT 9228, MT 18
Incident neutron data / / / MT=452 : nubar total /

Relative standard deviation (%) vs. Incident energy (MeV)

Incident neutron data / / / /

Relative standard deviation (%) vs. Incident energy (MeV)
Incident neutron data / / / MT=102 : (z,γ) /
V.1 Verifying Covariance Data: Pu cases (21 Benchmarks)

- NDaST (Nuclear Data Sensitivity Tool) tool

Figure. PU’s Mosteller Benchmark Suite (21 Benchmarks): ..... only Pu239/JEFF-3.3-T4
### V.2 Verifying Covariance Data: Pu cases (21 Benchmarks)

The impact of evaluations: JENDL-4.0u, ENDF/B-VII.1 and JEFF-3.3T4

Fig. Pu’s Mosteller Benchmark Suite (21 Benchmarks) …only **Pu239 cross-sections covariance**

<table>
<thead>
<tr>
<th></th>
<th>ENDF/B-VII.1</th>
<th>JENDL4</th>
<th>JEFF-3.3T4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Elastic Inel. Fission Gamma</td>
<td>All Elastic Inel. Fission Gamma</td>
<td>All Elastic Inel. Fission Gamma</td>
</tr>
<tr>
<td>PMF001-001</td>
<td>780 439 797 331 74</td>
<td>542 197 250 434 60</td>
<td>294 90 150 305 30</td>
</tr>
<tr>
<td>PMF002-001</td>
<td>628 382 629 281 62</td>
<td>453 194 369 50</td>
<td>250 78 118 262 25</td>
</tr>
<tr>
<td>PMF003-003</td>
<td>457 272 346 317 77</td>
<td>447 119 416 61</td>
<td>277 55 62 293 31</td>
</tr>
<tr>
<td>PMF005-001</td>
<td>579 257 539 315 111</td>
<td>471 107 411 92</td>
<td>286 51 103 301 45</td>
</tr>
<tr>
<td>PMF006-001</td>
<td>401 175 292 286 113</td>
<td>396 68 74 371 95</td>
<td>275 52 280 46</td>
</tr>
<tr>
<td>PMF008-001</td>
<td>588 276 553 316 105</td>
<td>470 115 76 412 87</td>
<td>286 54 107 320 24</td>
</tr>
<tr>
<td>PMF009-001</td>
<td>664 326 652 321 91</td>
<td>498 141 215 420 73</td>
<td>284 65 124 300 36</td>
</tr>
<tr>
<td>PMF010-001</td>
<td>514 252 460 304 97</td>
<td>439 107 132 397 80</td>
<td>275 50 85 291 39</td>
</tr>
<tr>
<td>PMF022-001</td>
<td>852 467 884 339 76</td>
<td>571 210 284 445 61</td>
<td>306 95 168 312 31</td>
</tr>
<tr>
<td>PMF023-001</td>
<td>683 340 673 329 91</td>
<td>510 149 215 432 75</td>
<td>290 68 128 305 37</td>
</tr>
<tr>
<td>PMF024-001</td>
<td>777 379 799 319 97</td>
<td>527 163 263 419 81</td>
<td>291 75 153 297 56</td>
</tr>
<tr>
<td>PMF025-001</td>
<td>678 381 663 334 81</td>
<td>515 169 203 438 66</td>
<td>292 77 124 309 33</td>
</tr>
<tr>
<td>PMF026-001</td>
<td>584 279 541 325 100</td>
<td>481 122 170 425 82</td>
<td>287 56 102 304 41</td>
</tr>
<tr>
<td>MMF001-001</td>
<td>449 221 407 262 72</td>
<td>382 97 122 344 59</td>
<td>230 45 75 244 29</td>
</tr>
<tr>
<td>MMF003-001</td>
<td>408 195 363 245 70</td>
<td>350 86 94 321 58</td>
<td>216 39 64 228 28</td>
</tr>
</tbody>
</table>

*Figures indicate Pu239 cross-sections covariance with lower values for JEFF-3.3T4.*
V.3 Verifying Covariance Data

- H in H2O covariances
- CONRAD calculations, by G. Noguere
Thermal scattering

- 20 files, 14 new, first covariances for H in H$_2$O.
- Cantargi, Granada, Marquez Damian
  - D in D$_2$O, Ortho D$_2$, Para D$_2$
  - H in ice, mesitylene, Ortho H$_2$, Para H$_2$, toluene
  - O-16 in D$_2$O, Al$_2$O$_3$
  - Al in Al2O$_3$
  - Si in Si
- Mg in Mg (Mounier)
- H in CaH$_2$, Ca in CaH$_2$ (Serot)
- Keinert, Mattes
  - H in H$_2$O, CH$_2$, ZrH (Keinert, Mattes)
  - Be in Be (Keinert, Mattes)
  - C in graphite (Keinert, Mattes)
Benchmarking

- Mosteller suite
- ICSBEP
- Institute dependent subsets of ICSBEP
- Institute dependent proprietary benchmarks

- Criticality
- Some decay heat
An example of a critical assembly

• JEZEBEL criticality benchmark, modeled as a Pu sphere
  • $k=1$
  • 1 nuclide: $^{239}$Pu
• One of the Mosteller suite of 123 cases used for nuclear data library development.
• Much wider suite: ICSBEP
  www.oecd-nea.org/science/wpnics/icsbep/
K-eff is a balance

JEZEBEL \( k_{\text{eff}}(\text{BRC}) = 1.00082(11) \quad k_{\text{eff}}(\text{B-VII}) = 1.00060(12) \)

\[ \text{BRC} \leftarrow \text{mf3mt102 B-VII} \]
\[ \gamma +275 \]
\[ n,n' +522 \]
\[ \text{BRC} \leftarrow \text{mf3mt4.51-91+mf4mt4.51-90} \]
\[ +\text{mf6mt91 B-VII} \]
\[ \text{BRC} \leftarrow \text{mf3mt18 B-VII} \]
\[ n,f -122 \]

\[ \text{BRC} \leftarrow \text{mf3mt52+455+456} \]
\[ \nu -16 \]
\[ +\text{mf5mt18 B-VII} \]

\[ \text{el} -638 \]
\[ \text{BRC} \leftarrow \text{mf3mt2+mf4mt2 B-VII} \]

\[ \text{BRC} \leftarrow \text{mf3mt16+mf6mt16 B-VII} \]
\[ n,2n -14 \]

\[ k_{\text{eff}}(\text{BRC-origin}) \]
\[ k_{\text{eff}}(\text{BR - VII}) = 1.00066(12) \]
\[ k_{\text{eff}}(\text{BR - VII}) = 1.00341(12) \]
\[ k_{\text{eff}}(\text{BR - VII}) = 0.99703(12) \]
\[ k_{\text{eff}}(\text{BR - VII}) = 0.99689(12) \]
\[ k_{\text{eff}}(\text{BR - VII}) = 1.00211(12) \]
\[ k_{\text{eff}}(\text{BR - VII}) = 1.00089(12) \]
K-eff is a balance, a ratio of two integrals

- Partial cross section differences between evaluations have k-eff impacts well beyond the desired uncertainty.
- Fortuitous cancellations must be expected!
- How cancellations affect predictability out of the benchmarking domain is even less clear than within.
- There is no substitute for understanding.
- We must continue to improve our understanding despite the ability for & with the aid of massive computation and comparison.
Mosteller suite testing of JEFF-3.3Tn

F. Michel Sendis (NEA)
JEFF-3.3Tn testing against ICSBEP

S. van der Marck (NRG)
Benchmarking and Validation Activities within JEFF Project

O. Calabrettoa\textsuperscript{1,2}, F. Alvarez-Velarde\textsuperscript{3}, M. Angeline\textsuperscript{1}, C.J. Dietz\textsuperscript{4}, I. Dryka\textsuperscript{5}, L. Fiorita\textsuperscript{6}, U. Fischer\textsuperscript{7}, M. Fleming\textsuperscript{8}, W. Haack\textsuperscript{9}, I. Hill\textsuperscript{10}, R. Ichou\textsuperscript{11}, D. H. Kim\textsuperscript{12}, A. Klix\textsuperscript{13}, I. Kockel\textsuperscript{14}, P. Lecomte\textsuperscript{15}, F. Michel-Sendis\textsuperscript{16}, E. Nannenmann\textsuperscript{17}, M. Peclica\textsuperscript{18}, Y. Penelart\textsuperscript{19}, A. Plompert\textsuperscript{20}, D. Rochman\textsuperscript{21}, P. Romojarra\textsuperscript{13}, A. Stankowsk\textsuperscript{22}, J. Ch Subler\textsuperscript{1}, P. Tanagho\textsuperscript{23}, S. van der March\textsuperscript{24}

1 NEA, OECD, Paris, France
2 CIFMAT, Madrid, Spain
3 FNEA, Frascati, Italy
4 SCK-CEN, Mol, Belgium
5 KIT, Eggenstein-Leopoldshafen, Germany
6 UKAEA, Abingdon, Oxfordshire, United Kingdom
7 IRSN, Paris, France
8 KAERI, Daejeon, South Korea
9 JSL, Ljubljana, Slovenia
10 CEA, DEN, DER, SPRC, Cadarache, France
11 PSI, Villigen, Switzerland
12 JRC, Geel, Belgium
13 UPM, Madrid, Spain
14 NRG, Petten, The Netherlands

Abstract. The challenge for any nuclear data evaluation project is to periodically release a revised, fully consistent and complete library, with all needed data and covariances, and ensure that it is robust and reliable for a variety of applications. Within an evaluation effort, benchmarking activities play an important role in validating proposed libraries. The Joint Evaluated Fission and Fusion (JEFF) Project aims to provide such a nuclear data library, and thus, requires a coherent and efficient benchmarking process. The aim of this paper is to present the activities carried out by the new JEFF Benchmarking and Validation Working Group, and to describe the role of the NEA Data Bank in this context. The paper will also review the status of preliminary benchmarking for the next JEFF-3.3 candidate cross-section files.
I. Main changes in JEFF-3.3T4

Table: Main changes in JEFF3.3T4 beta files for criticality + uncertainty assessment

<table>
<thead>
<tr>
<th></th>
<th>JEFF-3.3T2</th>
<th>JEFF-3.3T2+</th>
<th>JEFF-3.3T3</th>
<th>JEFF-3.3T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pu239</td>
<td>JEFF-3.3T2</td>
<td>JEFF-3.3T2</td>
<td>JEFF-3.3T2</td>
<td>nubar uncertainties</td>
</tr>
<tr>
<td>U235</td>
<td>JEFF-3.3T2</td>
<td>JEFF-3.3T2</td>
<td>JEFF-3.3T2</td>
<td>fission and nubar uncertainties</td>
</tr>
<tr>
<td>U238</td>
<td>JEFF-3.3T2</td>
<td>JEFF-3.3T2+RR/JRC</td>
<td>JEFF-3.3T2+RR-JRC</td>
<td>JEFF-3.3T2+RR-JRC</td>
</tr>
<tr>
<td>O16</td>
<td>ENDF/B-VII.1</td>
<td>O16-Luiz</td>
<td>O16-Luiz</td>
<td>ENDF/B-VII.1</td>
</tr>
<tr>
<td>TSLs</td>
<td>JEFF-3.1.1</td>
<td>H2O Bariloche</td>
<td>H2O Bariloche</td>
<td>H2O – JEFF-3.1.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D2OBariloche</td>
<td>D2OBariloche</td>
<td>D2O – ENDF/B-VIIIb4</td>
</tr>
<tr>
<td>Cu</td>
<td>KIT1+Sobes/Luiz</td>
<td>ENDF/B-VII.1</td>
<td>KIT1-rev+Sobes/Luiz</td>
<td>KIT2-rev+Sobes+RR/JRC</td>
</tr>
<tr>
<td>Fe54/56</td>
<td>JEFF-3.2</td>
<td>JEFF-3.2</td>
<td>ENDF/B-VIIIb4</td>
<td>JEFF-3.2</td>
</tr>
<tr>
<td>Al27</td>
<td>JEFF-3.2</td>
<td>JEFF-3.2</td>
<td>JEFF-3.2</td>
<td>Generate and add covariances using TENDL approach</td>
</tr>
</tbody>
</table>
## II. XSs, PFNS and nubar Uncertainties

Table: Jezebel (PMF1) and Godiva (HMF1) criticality k-eff uncertainty (in pcm), based on NDaST and MCNP simulations

|                | Jezebel |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|----------------|---------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|                | CIELO-1 | B-VII.1 | JEFF-3.3 | JENDL-4.0u1 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| fission        | 903     | 331    | 305    | 434    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| nubar          | 241     | 81     | 413    | 209    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| PFNS $E_{av}$  | 185     | 186    | 443    | 286    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| elastic        | 463     | 438    | 90     | 198    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| inelastic      | 797     | 797    | 150    | 250    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| capture        | 67      | 74     | 30     | 59     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Summed         | 1025    | 562    | 645    | 648    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Exp. unc.      | 110     | 110    | 110    | 110    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| |C-E|       | 15      | 12     | 68     | 185    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

|                | Godiva  |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|                | CIELO-1 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| fission        | 788     | 269    | 648    | 320    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| nubar          | 540     | 545    | 510    | 274    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| PFNS $E_{av}$  | 132     | 276    | 364    | 176    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| elastic        | 276     | 294    | 109    | 426    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| inelastic      | 698 (est.) | 616  | 698    | 681    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| capture        | 281     | 873    | 375    | 269    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Summed         | 1039 (est.) | 1220 | 1342   | 962    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Exp. unc.      | 100     | 100    | 100    | 100    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| |C-E|       | 6       | 8      | 16     | 167    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
III. Results of criticality benchmarking

Figure: Cumulative Chi-2 build-up (SENDIS output)
Results of criticality benchmarking using ICSBEP

Table: Evaluation of general performance for extended validation suites. Values are “reduced” Chi-squared, number of cases in brackets

<table>
<thead>
<tr>
<th>NEA (based on Mosteller’s suite ... “Expert Judgement”)</th>
<th>ENDF/B-VII.1</th>
<th>ENDF/B-VIIIb4</th>
<th>JEFF-3.1.1</th>
<th>JEFF-3.2</th>
<th>JEFF-3.3.T2</th>
<th>JEFF-3.3T2+</th>
<th>JEFF-3.3T3</th>
<th>JEFF-3.3T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>PU</td>
<td>4.2 (29)</td>
<td>2.2 (29)</td>
<td>2.9 (29)</td>
<td>3.6 (29)</td>
<td>2.8 (29)</td>
<td>2.4 (29)</td>
<td>2.4 (29)</td>
<td>2.7 (29)</td>
</tr>
<tr>
<td>HEU</td>
<td>6.1 (42)</td>
<td>3.4 (42)</td>
<td>5.3 (42)</td>
<td>11.8 (42)</td>
<td>2.2 (42)</td>
<td>3.5 (42)</td>
<td>3.9 (42)</td>
<td>2.8 (42)</td>
</tr>
<tr>
<td>IEU</td>
<td>5.0 (12)</td>
<td>1.9 (12)</td>
<td>11.3 (12)</td>
<td>4.9 (12)</td>
<td>2.7 (12)</td>
<td>2.1 (12)</td>
<td>2.2 (12)</td>
<td>2.4 (12)</td>
</tr>
<tr>
<td>LEU</td>
<td>0.9 (13)</td>
<td>1.4 (13)</td>
<td>1.4 (13)</td>
<td>0.9 (13)</td>
<td>1.8 (13)</td>
<td>3.7 (13)</td>
<td>4.0 (13)</td>
<td>2.3 (13)</td>
</tr>
<tr>
<td>U233</td>
<td>1.7 (18)</td>
<td>2.1 (18)</td>
<td>9.5 (18)</td>
<td>1.2 (18)</td>
<td>1.7 (18)</td>
<td>1.9 (18)</td>
<td>1.7 (18)</td>
<td>1.6 (18)</td>
</tr>
<tr>
<td>MIX</td>
<td>0.7 (8)</td>
<td>1.0 (8)</td>
<td>1.2 (8)</td>
<td>0.9 (8)</td>
<td>0.9 (8)</td>
<td>1.0 (8)</td>
<td>0.8 (8)</td>
<td>1.0 (8)</td>
</tr>
<tr>
<td>SPEC (C/E)</td>
<td>0.99249 (1)</td>
<td>0.99338 (1)</td>
<td>0.98719 (1)</td>
<td>0.98847 (1)</td>
<td>0.99142 (1)</td>
<td>0.99145 (1)</td>
<td>0.99118 (1)</td>
<td>0.99107 (1)</td>
</tr>
<tr>
<td>Total</td>
<td>3.7 (123)</td>
<td>2.0 (123)</td>
<td>6.5 (123)</td>
<td>5.6 (123)</td>
<td>2.0 (123)</td>
<td>2.9 (123)</td>
<td>3.1 (123)</td>
<td>2.2 (123)</td>
</tr>
</tbody>
</table>
## Results of criticality benchmarking using ICSBEP

Table: Evaluation of general performance for extended validation suites. Values are "reduced" Chi-squared, number of cases in brackets.

<table>
<thead>
<tr>
<th></th>
<th>JENDL-4.0</th>
<th>ENDF/B-VII.1</th>
<th>ENDF/B-VIIIb4</th>
<th>JEFF-3.1.1</th>
<th>JEFF-3.3T4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PU</strong></td>
<td>6.4 (479)</td>
<td>6.0 (479)</td>
<td>5.2 (479)</td>
<td>5.6 (479)</td>
<td>6.3 (479)</td>
</tr>
<tr>
<td><strong>HEU</strong></td>
<td>9.0 (653)</td>
<td>6.0 (653)</td>
<td>5.9 (653)</td>
<td>6.3 (653)</td>
<td>6.2 (653)</td>
</tr>
<tr>
<td><strong>IEU</strong></td>
<td>8.7 (43)</td>
<td>1.8 (43)</td>
<td>1.2 (43)</td>
<td>5.2 (43)</td>
<td>2.0 (43)</td>
</tr>
<tr>
<td><strong>LEU</strong></td>
<td>3.4 (415)</td>
<td>3.3 (415)</td>
<td>3.7 (415)</td>
<td>4.0 (415)</td>
<td>3.9 (415)</td>
</tr>
<tr>
<td><strong>U233</strong></td>
<td>2.2 (66)</td>
<td>6.5 (66)</td>
<td>2.6 (66)</td>
<td>2.0 (66)</td>
<td>4.4 (66)</td>
</tr>
<tr>
<td><strong>MIX</strong></td>
<td>7.9 (168)</td>
<td>6.5 (168)</td>
<td>7.0 (168)</td>
<td>5.5 (168)</td>
<td>7.0 (168)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>7.4 (1824)</td>
<td>5.1 (1824)</td>
<td>4.8 (1824)</td>
<td>5.2 (1824)</td>
<td>5.3 (1824)</td>
</tr>
</tbody>
</table>
III. NRG-results: ENDF/B-VIII.0b4 versus JEFF-3.3T4

Changes in cumulative Chi-2 (in %): JEFF-3.3T4 - ENDF/B-VIII.0b4

- NRG – Steven van der Mark
  - 2348 – JEFF-3.3T4
  - 2348 – ENDF/B-VIII.0b4
  - 2445 – JENDL-4.0
  - 2445 – ENDF/B-VII.1
  - 1908 – JEFF-3.1.1

common set of benchmarks ...1824 !!

- Analysis of $\chi^2$ .....
  - Exp. Correl. in Eval. Cases?
    - None
  - Cases with large C/E bias!!
    - LCT5s
    - HCT21s
    - PCT2s
Results of criticality benchmarking using ICSBEP

Table: Evaluation of general performance for extended validation suites. Values are “reduced” Chi-squared, number of cases in brackets.

<table>
<thead>
<tr>
<th></th>
<th>NRG – Steven van der Mark (based on ICSBEP ... “excluding benchmarks with large bias”)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JENDL-4.0</td>
</tr>
<tr>
<td>PU</td>
<td>4.6 (444)</td>
</tr>
<tr>
<td>HEU</td>
<td>6.7 (595)</td>
</tr>
<tr>
<td>IEU</td>
<td>8.4 (37)</td>
</tr>
<tr>
<td>LEU</td>
<td>3.1 (407)</td>
</tr>
<tr>
<td>U233</td>
<td>2.2 (66)</td>
</tr>
<tr>
<td>MIX</td>
<td>7.0 (165)</td>
</tr>
<tr>
<td>Total</td>
<td>6.1 (1714)</td>
</tr>
</tbody>
</table>

Only common cases, except for cases with \((k_C-k_E) > 5^* \Delta k_{\text{exp}}\)
Results of criticality benchmarking using ICSBEP

**Table:** Evaluation of general performance for extended validation suites. Values are “reduced” Chi-squared, number of cases in brackets

<table>
<thead>
<tr>
<th>NRG – Steven van der Mark</th>
<th>JENDL-4.0</th>
<th>ENDF/B-VII.1</th>
<th>ENDF/B-VIIIb4</th>
<th>JEFF-3.1.1</th>
<th>JEFF-3.3T4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FAST</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.3</td>
<td>3.0</td>
<td>2.8</td>
<td>5.0</td>
<td>2.8</td>
</tr>
<tr>
<td>(256)</td>
<td>(255)</td>
<td>(255)</td>
<td>(255)</td>
<td>(255)</td>
<td>(255)</td>
</tr>
<tr>
<td><strong>INTER</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.3</td>
<td>9.6</td>
<td>4.7</td>
<td>11.2</td>
<td>6.8</td>
</tr>
<tr>
<td>(26)</td>
<td>(21)</td>
<td>(21)</td>
<td>(21)</td>
<td>(21)</td>
<td>(21)</td>
</tr>
<tr>
<td><strong>THERM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.6</td>
<td>3.7</td>
<td>3.4</td>
<td>3.3</td>
<td>3.6</td>
</tr>
<tr>
<td>(1399)</td>
<td>(1367)</td>
<td>(1367)</td>
<td>(1367)</td>
<td>(1367)</td>
<td>(1367)</td>
</tr>
<tr>
<td><strong>MIXED</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.6</td>
<td>4.3</td>
<td>5.5</td>
<td>4.7</td>
<td>5.4</td>
</tr>
<tr>
<td>(33)</td>
<td>(33)</td>
<td>(33)</td>
<td>(33)</td>
<td>(33)</td>
<td>(33)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.1</td>
<td>3.8</td>
<td>3.3</td>
<td>3.8</td>
<td>3.6</td>
</tr>
<tr>
<td>(1714)</td>
<td>(1714)</td>
<td>(1714)</td>
<td>(1714)</td>
<td>(1714)</td>
<td>(1714)</td>
</tr>
</tbody>
</table>

Only common cases, except for cases with \((k_C-k_E) > 5* \Delta k_{exp}\).
JEFF-3.3 is available for GEANT4, courtesy CIEMAT, Emilio Mendoza Cembranos, Daniel Cano Ott

Summary and conclusions

JEFF-3.3, together with other nuclear data libraries, will be soon available for download from the IAEA nuclear data service: https://www-nds.iaea.org/geant4/.

A comparison between Geant4 and MCNP6 when using JEFF-3.3 has been performed concerning the neutron transport. Some of the differences have been quantified. According to our comparison, JEFF-3.3 is the library that yields more similar results between both codes.

A large set of plots containing energy distributions from Geant4 and MCNP6 simulations of the secondary neutrons, γ-rays, p, d, t, ³He and α will be available from the IAEA nuclear data service together with the libraries.

Future work (“CHANDA2” EOI):
- Systematic comparison between Geant4 and MCNP6 concerning the charged particle production.
- Convert to the G4NDL format the TENDL-2017 library (JEFF-3.3) for incident charged particles.
ASPI-SI-IRON-88

Figure 1: Graph showing the comparison of different models for Al-27(n,a) reaction.

Figure 2: Graph showing the comparison of different models for S-32(n,p) reaction.

Figure 3: Graph showing the comparison of different models for In-115(n,n') reaction.

Figure 4: Graph showing the comparison of different models for Rh-103(n,n') reaction.
### $\beta_{\text{eff}}$ results (Big Ten)

<table>
<thead>
<tr>
<th>Big Ten $\beta_{\text{eff}}$ [pcm]</th>
<th>Benchmark</th>
<th>SUSD3D p. k-ratio</th>
<th>MCNP6 (KOPTS)</th>
<th>C/E</th>
<th>C/E KOPTS</th>
<th>$K_{\text{eff}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>720 ± 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENDF/B-VII.0</td>
<td>720</td>
<td>723 ± 4</td>
<td>725 ± 5</td>
<td>1.00</td>
<td>1.01</td>
<td>0.99969</td>
</tr>
<tr>
<td>ENDF/B-VII.1</td>
<td></td>
<td>719 ± 4</td>
<td>732 ± 5</td>
<td>1.00</td>
<td>1.02</td>
<td>0.99948</td>
</tr>
<tr>
<td>JEFF-3.2</td>
<td></td>
<td>752 ± 4</td>
<td>743 ± 5</td>
<td>1.04</td>
<td>1.03</td>
<td>0.99954</td>
</tr>
<tr>
<td>JEFF-3.3T2</td>
<td></td>
<td>752 ± 4</td>
<td>743 ± 5</td>
<td>1.04</td>
<td>1.03</td>
<td>1.00013</td>
</tr>
<tr>
<td>JEFF-3.3T4</td>
<td></td>
<td>728 ± 4</td>
<td>727 ± 5</td>
<td>1.01</td>
<td>1.01</td>
<td>0.99991</td>
</tr>
<tr>
<td>CIELO</td>
<td>720 ± 4</td>
<td>719 ± 5</td>
<td></td>
<td>1.00</td>
<td>1.00</td>
<td>1.000066</td>
</tr>
</tbody>
</table>

**Prompt k-ratio:** $\beta_{\text{eff}}$ (Big Ten) results are presented in the table above. The k-ratio values are calculated based on the effective capture rates and compared with existing benchmarks. The $K_{\text{eff}}$ values indicate the relative accuracy of the simulations against experimental data.

**Graphs:**
- Left: Sensitivity per unit intensity (N/A).
- Right: Summary of k-ratio values and C/E comparisons between different benchmarks.

**Romojarco & Garcia-Herranz, UPM**

**Meeting – Paris, 20-21 November 2017**

---

**Caption:**
Prompt k-ratio -> prompt / (prompt + delayed) KOPTS method -> based on iterated fission probability interpretation of adjoint flux.
Findings: - JENDL-3.3T4 = ENDF/B-VII.1 and ENDF/B-VIII.0 are practically indistinguishable - however among them, the ENDF/B-VIII.0 is slightly better
Before MCNP modelling we:
- replaced $^{252}$Cf(s.f.) neutron spectrum given in the ICSBEP MCNP input (as Watt with Froehner parameters) by PFNS Standard (Mannhart evaluation), $\nu_p = 3.7590$
- added delayed neutrons ($\nu_d = 0.0086$) with DFNS spectrum from ENDF/B-VII.1

Observations from C/E comparison:
JEFF-3.3T4 looks even more preferable than others
III. Ta: Results – Neutron Leakage from two LLNL Spheres with D-T source

Observations:
- ENDF/B-VIII.0 & JEFF-3.3T4 equally and nearly reasonable reproduce LLL spheres
- essential progress is observed when comparing with previous versions (ENDF/B-VI)
III. Ta: Results - Neutron leakage from Lewis Sphere with Am-Be source

**Observations:**

- **JEFF-3.3T4** reasonably agrees with this benchmark

- **ENDF/B-VII.1 = ENDF/B-VIII.0** (both based on TALYS) seem behave a bit worse than **JEFF-3.3T4**
DPA, Konobeev

1. JEFF-3.3 extension using TENDL-2017

Conclusion

Atomic displacement cross-sections were obtained for materials from Be to Bi using arc-dpa and NRT model.

Main improvements compared to DXS-2017:
- JEFF-3.3 + TENDL-2017
- Calculations applying CEM03 and ECIS at energies above 50 MeV
- arc-dpa model with BCA corrections for Al, Fe, Cu, and W
Analysis of the JEFF-3.3 library for the UQ of Gen-IV reactor concepts

P. Romojaro, F. Álvarez-Velarde
pablo.romojaro@ciemat.es, francisco.alvarez@ciemat.es

CIEMAT – Nuclear Innovation Unit

- Significant gaps between current uncertainties and target accuracies have been shown in the past

Target accuracy for fast reactors \( k_{\text{eff}} = 300 \text{ pcm} \)

- Objective: benchmarking and UQ analysis with state-of-the-art ND for Gen-IV reactor concepts
  - MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications)
  - ALFRED (Advanced Lead Fast Reactor European Demonstrator)
  - ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration)
<table>
<thead>
<tr>
<th>MYRRHA</th>
<th>ALFRED</th>
<th>ASTRID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Difference</td>
<td></td>
</tr>
<tr>
<td>$k_{\text{eff}}$</td>
<td>1.00475</td>
<td>1.00722</td>
</tr>
<tr>
<td>$\nu$</td>
<td>2.930</td>
<td>2.908</td>
</tr>
<tr>
<td>Total fission probability</td>
<td>0.343</td>
<td>0.346</td>
</tr>
<tr>
<td>Total capture probability</td>
<td>0.664</td>
<td>0.660</td>
</tr>
</tbody>
</table>

**MYRRHA – ISC (‰/‰)**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>JEFF-3.2</th>
<th>JEFF-3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{239}\text{Pu}$ $\nu$</td>
<td>0.694</td>
<td>0.696</td>
</tr>
<tr>
<td>$^{239}\text{Pu}$ $(n,f)$</td>
<td>0.484</td>
<td>0.482</td>
</tr>
<tr>
<td>$^{238}\text{U}$ $(n,\gamma)$</td>
<td>-0.114</td>
<td>-0.112</td>
</tr>
<tr>
<td>$^{240}\text{Pu}$ $\nu$</td>
<td>0.081</td>
<td>0.081</td>
</tr>
<tr>
<td>$^{239}\text{Pu}$ $(n,\gamma)$</td>
<td>-0.057</td>
<td>-0.053</td>
</tr>
</tbody>
</table>

- **Reactivity increase** in MYRRHA, ALFRED and ASTRID with JEFF-3.3
- JEFF-3.2 and JEFF-3.3 yield similar ISC and sensitivity profiles
- Good agreement between JEFF-3.3 and ENDF/B-VIII.0 for total $k_{\text{eff}}$ uncertainty in reactor concepts
- Very different magnitude and contributors to the total uncertainty
- $k_{\text{eff}}$ target accuracy is exceeded at least by a factor of two for all considered reactors
Calculation of Integral experiments with the MORET 5 code in support to the validation of JEFF-3.3 nuclear data

Selection of 238 cases covering:

- FAST energy range,
- INTERMEDIATE energy range,
- THERMAL energy range,
- SPECIAL isotopes ($^{233}\text{U}$, $^{237}\text{Np}$,..)

LECLAIRE Nicolas
© IRSN
April, 19th 2018
Conclusions (comparison 3.3t3/3.3)

**Thermal energy spectrum**
- No deterioration or improvement of results for Pu, LEU and MOX in lattices
- Slight improvement of results for LEU, HEU solutions in water due to $O_{16}$, except for lead as reflector
- Improvement of results for solutions in heavy water: TSL of $H_2-D_2O$ and $O_{16}-D_2O$
- Improvement of results for uranium when compared with JEFF-3.2

**Intermediate energy spectrum**
- Slight improvement of results with Cu JEFF-3.3 in ZEUS experiments
- Deterioration of results with $^{56}$Fe JEFF-3.3 in the fissile

**Fast energy spectrum**
- Pu without reflector: no improvement of results
- HEU without reflector: good agreement and improvement when compared with JEFF-3.2
Conclusions (continued)

- Fast energy spectrum
  - Deterioration of $k_{\text{eff}}$ results for systems with Fe (JEFF-3.3/JEFF-3.3t3)
  - Still bad results for systems with $\text{CH}_2$ reflectors: evaluation?, processing?
    - Better results with JEFF-3.2

- Analysis based on a restricted number of experiments
  - Focus on few isotopes
    - Main tendencies highlighted
  - Need to go more deeply to explain all the results (compensation between various isotopes)

- To be done:
  - Use of sensitivity coefficients to better understand trends
JEFF 3.3 processing

- Processed with NJOY 2016.03

- NOT every nuclide “passes”:
  - BE-METAL: error of space in temperatures in ENDF, corrected
  - Zr92, Zr94, Sn116, Sn117: make NJOY crash
  - Be9, Ar39, Cs135 (run but no covariance produced)
  - D-D2O and O-D2O: Problem of numbering of lines (absent), but OK for NJOY

- The case of probability table with negative values:
  - Ag109
  - Hf174
  - Np238
  - Cf252

- The case of non-positive elastic cross sections - RECONR:

  ---message from emerge---nonpositive elastic cross sections found.

  - JEF 2.2: 61Ni, 128Te, 152Eu, 154Eu, 157Gd, 176Lu, 185Re, 240Pu, 241Am, 244Cm
  - JEFF 3.1: 40Ar, 61Ni, 111Cd, 113Cd, 128Te, 157Gd, 182W, 244Cm
  - JEFF 3.2: 32Si, 36S, 40Ar, 61Ni, 128Te, 152Gd, 157Gd, 240U
  - JEFF 3.3: 40Ar, 61Ni, 152Gd, 157Gd, 240U
Validation of JEFF-3.3 and ENDF/B-VIII.0 on SCK•CEN projects

Alexey Stankovskiy

SCK•CEN, Belgium
astankov@sckcen.be

- VENUS-F fast spectrum zero power facility
- Decay heat benchmark

Contributions:
A. Krása, D. Gérard (SCK•CEN)
K.-H. Schmidt
JEFF-3.3 compared to JEFF-3.2

- large change for $^{235}\text{U}$ (-890 pc.m) and $^{238}\text{U}$ (+370 pc.m), $^{208}\text{Pb}$ (+485 pc.m)
- intermediate change for $^{206}\text{Pb}$ (+100 pc.m), $^{207}\text{Pb}$ (-80 pc.m), $^{209}\text{Bi}$ (-70 pc.m)
- small change (-70 pc.m) when altering all isotopes

ENDF/B-VIII.0 compared to ENDF/B-VII.1

- change only for $^{235}\text{U}$ (-100 pc.m) and $^{56}\text{Fe}$ (-90 pc.m)
- -150 pc.m when altering all isotopes
Decay heat of PWR assemblies

ENDF/B-VIII.0 vs ENDF/B-VII.1: consistent decrease → globally worsening
JEFF-3.3 vs JEFF-3.1.2: consistent increase → globally improvement
Decay heat of BWR assemblies

Comparison of relative errors between different libraries for BWR.

ENDF/B-VIII.0 vs ENDF/B-VII.1: consistent decrease → globally worsening
JEFF-3.3 vs JEFF-3.1.2: consistent increase → globally improvement
<table>
<thead>
<tr>
<th>PWR assembles</th>
<th>C/E-1, %</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENDF/B-VII.1</td>
<td>0.27</td>
<td>2.61</td>
</tr>
<tr>
<td>ENDF/B-VIII.0</td>
<td>-1.18</td>
<td>4.57</td>
</tr>
<tr>
<td>ENDF/B-VIII.0+GEFY</td>
<td>-1.70</td>
<td>6.79</td>
</tr>
<tr>
<td>JEFF-3.1.2</td>
<td>-1.85</td>
<td>7.97</td>
</tr>
<tr>
<td>JEFF-3.2</td>
<td>-1.75</td>
<td>7.72</td>
</tr>
<tr>
<td>JEFF-3.3</td>
<td>-0.61</td>
<td>3.64</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BWR assembles</th>
<th>C/E-1, %</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENDF/B-VII.1</td>
<td>1.43</td>
<td>1.93</td>
</tr>
<tr>
<td>ENDF/B-VIII.0</td>
<td>-0.03</td>
<td>2.09</td>
</tr>
<tr>
<td>ENDF/B-VIII.0+GEFY</td>
<td>-0.76</td>
<td>2.14</td>
</tr>
<tr>
<td>JEFF-3.1.2</td>
<td>-0.77</td>
<td>2.50</td>
</tr>
<tr>
<td>JEFF-3.2</td>
<td>-0.61</td>
<td>2.40</td>
</tr>
<tr>
<td>JEFF-3.3</td>
<td>0.40</td>
<td>1.78</td>
</tr>
</tbody>
</table>

- ENDF/B-VII.1 wins
- BWR results better than PWR for all libs
- JEFF-3.3 better than JEFF-3.1.2 and JEFF-3.2
$^{235}$U FPDH

Differences < 6%
Differences < 4%
$^{239}\text{Pu FPDH}$

Differences up to 15%
Summation calculations and validation with integral experiments

A. Sánchez, D. Cano-Ott, E. Mendoza, P. Romojaro

CIEMAT – Unidad de Innovación Nuclear

**Standard evaluated libraries** **JEFF-3.3** and **ENDF/B-VIII.0**

In addition, **4 modified libraries** are used (for each standard library):

- **V01**: \( \nu_d \) (and total) replaced with new values from summation calculations of the main fissioning systems using fission yields and decay data from standard library.

- **V02**: \( \nu_d \) (and total) replaced with new values from summation calculations of the main fissioning systems using fission yields and decay data from standard library complemented with new evaluated IAEA CRP \( P_n \) values (Oct. 2017).

- **V03**: \( \nu_d \) (and total) replaced with new values from summation calculations of the main fissioning systems using FY from JEFF-3.3 and decay data from ENDF/B-VIII.0.

- **V04**: same as V03 but also it adds the new evaluated \( P_n \) values.

<table>
<thead>
<tr>
<th>Name</th>
<th>Relative contribution to ( \beta_{\text{eff}} )(%)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>POPSY</td>
<td>52.5% ( ^{239}\text{Pu} ), 40.9% ( ^{238}\text{U} )</td>
<td>Pu core</td>
</tr>
<tr>
<td>TOPSY</td>
<td>72.7% ( ^{235}\text{U} ), 25.4% ( ^{238}\text{U} )</td>
<td>HEU core</td>
</tr>
<tr>
<td>JEZEBEL</td>
<td>90.9 ( ^{239}\text{Pu} ), 7.1% ( ^{240}\text{Pu} )</td>
<td>Bare Pu sphere</td>
</tr>
<tr>
<td>SKIDOO</td>
<td>97.2% ( ^{239}\text{U} ), 1.3% ( ^{238}\text{U} )</td>
<td>Bare ( ^{233}\text{U} ) sphere</td>
</tr>
<tr>
<td>FLAT-TOP 23</td>
<td>65.7% ( ^{233}\text{U} ), 30.3% ( ^{238}\text{U} )</td>
<td>( ^{233}\text{U} ) core</td>
</tr>
</tbody>
</table>

Main fissioning systems: \( ^{233}\text{U} \), \( ^{235}\text{U} \), \( ^{238}\text{U} \) and \( ^{239}\text{Pu} \).
Summary and conclusions

- $k_{\text{eff}}$ shows **negligible effects** when modifying delayed neutron yields.
- When new $P_n$ values added, $\nu_d$ always incremented.
- In both **standard** libraries, $\nu_d$ of $^{238}\text{U}$ seems to be overestimated, when compared with experiment.
- ENDF/B-VIII.0 shows slightly better agreement in $\beta_{\text{eff}}$.
- Using FY from JEFF-3.3 and decay data from ENDF/B-VIII.0 in summation calculations seems to yield **good results**.
- The $\beta_{\text{eff}}$ benchmark should be extended to more **integral experiments**.
The future

• Towards JEFF-4
### Challenges for evaluated data libraries

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluated</td>
<td>Best available knowledge for the user.</td>
</tr>
<tr>
<td>Completeness</td>
<td>All required data should be available to the user.</td>
</tr>
<tr>
<td>Reliability</td>
<td>Success should be independent of the application.</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Uncertainties less than 5%, 2%, ... 0.3%.</td>
</tr>
<tr>
<td>Covariances</td>
<td>Users need to know how good the data are. They need to handle that knowledge quantitatively for propagating uncertainty and safe margins.</td>
</tr>
</tbody>
</table>
Best science, as complete as we can, for applications

• Either from models or from experiment.
• Evaluators must judge which should prevail.
• We must master assembling files with best input for its parts.

• Checking is absolutely essential.

• Automation will continue to mature further as a means.
First **true** general purpose file
Serving all needs
Best physics estimates
completeness in sections and incident particles

Methods of production to be reconsidered.
Combination of model estimates and best data.
Take the TENDL approach as a starting point?

Variances, co-variances

**Quality assurance of evaluations**
automation of assembly, physics and format correctness, validation, transparency, traceability

**Serving a wide-range of user codes**
automation and quality assurance of processing
Knowledge management

Is the essence of what we are trying to achieve: bring scientific and technological key developments to the users!

Our goals must be realistic.

A lot of scientific and technology oriented work has not made it to the files and modeling codes yet, no matter how good it is.

Our goals should also be ambitious!

‘We shouldn’t have to put up with that.’
Why JEFF?

Harbor the interests in our community.

Large scale modeling
• Nuclear systems design, development and performance estimates.
• Emphasis on safety analyses
• Design and interpretation of experiments for cost effective development.

Recognized SNETP/SRIA & SRA

Recognized EUROSSAFE

Trends
• Nuclear safety & economy
• Nuclear waste
• Security and emergencies
• Decommissioning

Sources of data needs
• Projects
• HPRL
• Sensitivity analyses
• Literature

Challenging needs require
• High quality experiments
• High quality calculations
• Good equipment & facilities
Your contributions to JEFF

We want to build the bridge across the gap between science and application. Your contributions are needed on all these aspects as the responsibility to build the bridge is a joint one.

This requires a joint work of experiments, evaluations, benchmarking and validation. It will be stronger if we can build it together.
Method development

- Rizzo Darwin PIE ND-adjustment (CEA)
- Voirin from FY experiments to new evaluations (CEA/CNRS)
- Rochmann, Correlations from integral constraints
- Noguere, NRA, thermal constants, thermal scattering
- Bauge, Identify and eliminate sources of uncertainty in nuclear modeling
- Bouland, Interpretation of surrogate reaction data to improve modeling
- De Saint Jean, Influence of systematic uncertainties on evaluations
- Schnabel, Modern statistical tools for global nuclear model assessments
- Jansky, understanding Fe shielding benchmark (Rez, IPPE)