Summary report for special agreement TAL-NAPC20200423-002

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September 29, 2020

1 Introduction

This document presents results of criticality benchmarks calculated using four of the latest evaluation libraries made available in recent years : TENDL-17[1], TENDL-19[1], JEFF-3.3[2], and ENDF/B-VIII[3]. For these comparisons, we used the Monte Carlo codes TRIPOLI-4® [4] and MCNP5[5]. Most of the results in this document were obtained using TRIPOLI-4® , but for a few specific points, we also performed MCNP calculations. This is particularly the case for neutron flux and reaction rates studies on a short list of configurations where the unresolved resonance range plays an important role.
TRIPOLI-4 is the fourth generation of the continuous-energy three-dimensional transport Monte Carlo code developed by the Service d'Études des Réacteurs et de Mathématiques Appliquées (SERMA) at CEA Saclay (FRANCE). TRIPOLI-4 is devoted to shielding, reactor physics with depletion, criticality safety and nuclear instrumentation for both fission and fusion systems. The code has been has been developed starting from the mid 90s in C++, with a few parts in C and Fortran. The latest release of TRIPOLI-4 is version 11, as of November 2018.

The four nuclear data libraries for neutron transport have been produced in a similar way with the nuclear data processing code NJOY2016.49[6] . The cross section files used by TRIPOLI-4® require the use of NJOY's RECONR, BROADR and THERMR modules to produce "free gas" cross sections in PENDF files :

- RECONR : Reconstruction using linearization precision of 0.1%
- BROADR : Doppler broadening using 0.1% precision

TRIPOLI-4® code uses additional processed data from evaluation files. These data are generated and stored in ENDF-like files[10] the first time the TRIPOLI-4® code is used with the new evaluation files. These files contain kinematic data of the particles coming out of the reactions induced by the incident particle (energetic and angular distributions for example). These files will be available for later use of the materials in various simulations, regardless of the temperature of the materials. Finally, the thermal scattering data (H1/H2O, H1/CH2, C/Graphite) are produced using the THERMR module of NJOY2016.49.

Probability tables The probability tables in the unresolved resonance range are produced by the CALENDF code [7]. This type of probability tables file is the same one used since the 1980s. The probability tables are given directly in multigroup forms and not in a psuedo pointwise representation as those produced by NJOY's PURR module. These probability tables cover the total, elastic and radiative capture, fission total cross sections but also any other reactions existing in the unresolved range (e. g. inelastic scattering in the case of U238).

1.1 Nuclear data corrections on evaluation files

The processing of these four libraries, JEFF-3.3, TENDL-17, TENDL-19 and ENDF/B-VIII for the TRIPOLI-4® code implies the verification of nuclear data contained in evaluation files. Sometimes, corrections are required to be used with the TRIPOLI-4® code. To carry out the calculations presented later, many corrections have been made to a number of evaluation files of the nuclei present in the compositions of the benchmarks studied in this document.

JEFF-3.3 The JEFF-3.3 library released in November 2017 had been extensively tested in its beta versions. There are no major corrections required for use with TRIPOLI-4®.

ENDF/B-VIII.0 The prompt fission neutron and gamma-ray multiplicity probabilities have been included for the first time in evaluation files in ENDF/B-VIII library. The latest version of TRIPOLI-4® is able to read this evolution of the ENDF format. However, these data are not currently used in Monte Carlo TRIPOLI-4® simulations.
The CALENDF code is not able to process energy-dependent scattering radius in the unresolved domain as it is the case for the U238 evaluation. We have imposed a constant scattering radius as it was the case in previous evaluations. The value used is 0.9295.
The first calculations made with TRIPOLI-4® using this ENDF/B-VIII library showed very significant differences with TRIPOLI-4® calculations using the ENDF/B-VII.1 library[8] and MCNP calculations with ENDF/B-VIII.0 for benchmarks that contain Pu239. Figure 1 shows different results on a series of benchmarks containing Pu239:

- MCNP + ENDF/B-VII.1 in blue
- MCNP + ENDF/B-VIII in green
- TRIPOLI-4, version 11 + ENDF/B-VII.1 in black
- TRIPOLI-4, version 11 + ENDF/B-VIII in red

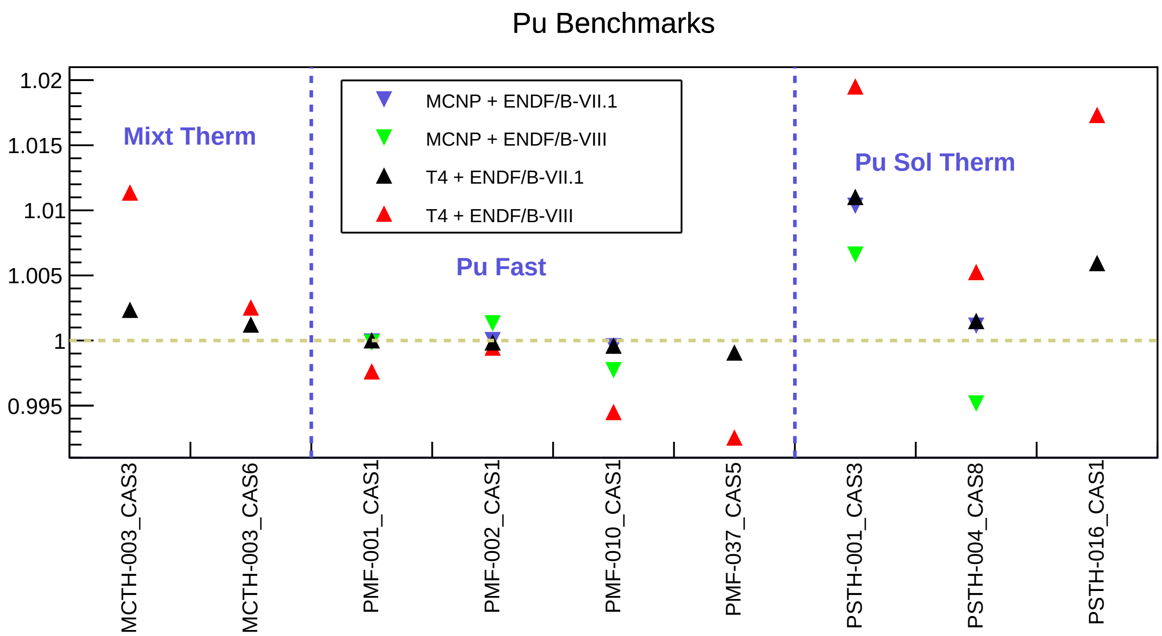

Figure 1: MCNP and TRIPOLI-4® k_{eff} calculations on a series of Pu benchmarks using ENDF/B-VII.1 and ENDF/B-VIII libraries

A very good agreement is obtained between the MCNP and TRIPOLI-4® results for the ENDF/B-VII.1 library (blue and black results). However, the change of library from ENDF/B-VII.1 to ENDF/B-VIII does not produce the same modifications for the MCNP and TRIPOLI-4® codes. The analysis of the modifications on the Pu239 nuclear data between the ENDF/B-VII.1 and ENDF/B-VIII evaluations shows that the total cross section (MF=3, MT=1) is not equal to the sum of the partial cross sections (elastic and inelastic scatterings, capture, fission) in the unresolved resonance range. The use of the LSSF=1 flag in this range implies that the probability tables must be normalized to the cross sections given in MF=3. CALENDF does not calculate correctly the probability tables if this legitimate equality is not verified. We have corrected the total cross section in the unresolved range and obtained the new results presented in Figure 2. The TRIPOLI-4® results obtained using this corrected evaluation file (black star) are in a very good agreement with the expected values and with the MCNP results. **It is very important to note that this correction on the Pu239 evaluation is also used for the TENDL-17 and TENDL-19 libraries**.

TENDL-17 Corrections applied to the evaluation files U238 and Pu239 for the ENDF/B-VIII library were reported in TENDL-17 evaluation files. In order to calculate all the ICSBEP configurations selected for this comparison, we had applied corrections to part of the library's evaluation files. These corrections concern the normalization of PFNS distributions for the following nuclei: Am241, Pu238, Pu240, Pu241, Pu242, U234 and U236.

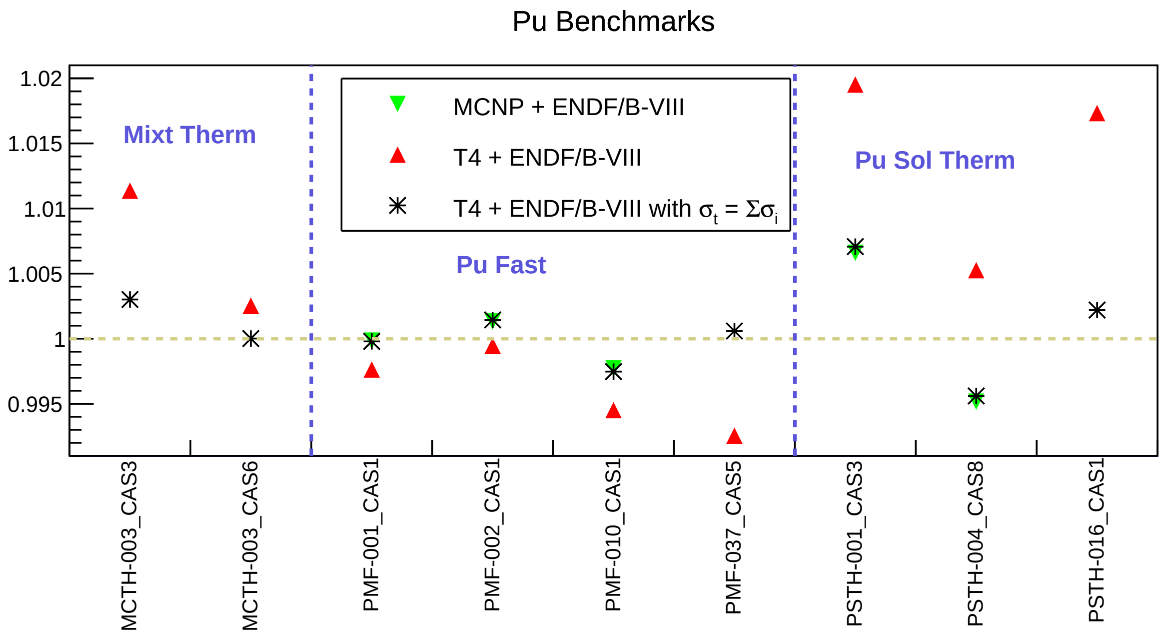

Figure 2: MCNP and TRIPOLI-4® calculations on a serie of Pu benchmarks using ENDF/B-VIII libraries

Other nuclei could be concerned by this correction but they do not appear in the configurations studied in this report.

TENDL-19 Corrections applied to the evaluation files U238 and Pu239 for the ENDF/B-VIII library were reported in TENDL-19 evaluation files. Incorrectly normalized PFNS for the TENDL-17 library have been corrected for this new version of the TENDL library.

2 Criticality Benchmarks calculations

Several configurations from ICSBEP database[9] were studied with the four libraries ENDF/B-VIII, JEFF-3.3, TENDL-17 and TENDL-19. Table 1 summarizes results for the list of benchmarks selected for this study. The general trends of these four libraries are quite consistent.

Ident	ENDF/B-VIII (σ)	JEFF-3.3 (σ)	TENDL-17 (σ)	TENDL-19 (σ)
hmf001c1	1.00018 (12)	1.00029 (12)	1.00008 (12)	1.00002 (11)
hmf001c2	0.99994 (12)	1.00032 (12)	0.99980 (12)	1.00008 (12)
hmf028	1.00075 (11)	1.00429 (11)	1.00072 (11)	1.00075 (11)
hst001c1	0.99907 (17)	1.00042 (17)	0.99922 (17)	0.99910 (17)
hst001c2	0.99542 (17)	0.99883 (17)	0.99550 (17)	0.99563 (17)
hst001c3	1.00267 (17)	1.00394 (17)	1.00211 (17)	1.00255 (17)
hst001c4	0.99808 (17)	1.00105 (17)	0.99770 (17)	0.99758 (17)
hst001c5	0.99935 (16)	1.00054 (16)	0.99949 (16)	0.99929 (16)
hst001c6	1.00312 (16)	1.00351 (16)	1.00264 (16)	1.00269 (16)
hst001c7	0.99865 (17)	1.00036 (17)	0.99839 (17)	0.99844 (17)
hst001c8	0.99918 (16)	1.00030 (17)	0.99888 (17)	0.99870 (17)
hst001c9	0.99334 (17)	0.99735 (17)	0.99371 (17)	0.99347 (17)
hst009c1	1.00144 (17)	1.00301 (17)	1.00119 (16)	1.00138 (16)
hst009c2	1.00240 (16)	1.00333 (16)	1.00243 (16)	1.00232 (16)
hst009c3	1.00262 (16)	1.00248 (16)	1.00245 (16)	1.00262 (16)
hst009c4	0.99788 (16)	0.99665 (16)	0.99713 (16)	0.99752 (16)
hst010c1	1.00284 (16)	1.00188 (16)	1.00269 (16)	1.00227 (16)
hst010c2	1.00312 (16)	1.00206 (16)	1.00314 (16)	1.00283 (16)
hst010c3	1.00033 (16)	0.99985 (16)	1.00088 (16)	1.00046 (16)
hst010c4	0.99838 (16)	0.99775 (16)	0.99858 (16)	0.99843 (16)
hst011c1	1.00596 (16)	1.00512 (16)	1.00554 (16)	1.00605 (16)
hst011c2	1.00200 (16)	1.00115 (16)	1.00169 (16)	1.00190 (16)
hst012c1	1.00088 (16)	1.00053 (16)	1.00090 (16)	1.00112 (16)
hst013c1	0.99860 (16)	0.99828 (16)	0.99831 (16)	0.99846 (16)
hst013c2	0.99772 (16)	0.99734 (16)	0.99797 (16)	0.99769 (16)
hst013c3	0.99460 (16)	0.99378 (16)	0.99456 (16)	0.99440 (16)
hst013c4	0.99627 (16)	0.99540 (16)	0.99597 (16)	0.99634 (16)
hst014c1	0.99517 (16)	0.99484 (16)	0.99494 (16)	0.99491 (16)
hst014c2	1.01117 (16)	1.01118 (16)	1.01086 (16)	1.01134 (16)
hst014c3	1.01983 (16)	1.01932 (16)	1.01920 (16)	1.01984 (16)
hst018c1	0.99088 (16)	0.99100 (16)	0.99055 (16)	0.99047 (16)
hst018c2	0.98517 (17)	0.98659 (16)	0.98493 (17)	0.98523 (16)
hst018c3	0.98911 (16)	0.98953 (16)	0.98903 (16)	0.98866 (16)
hst019c1	0.99742 (16)	0.99874 (17)	0.99724 (16)	0.99720 (16)
hst032	0.99863 (16)	0.99746 (16)	0.99822 (16)	0.99848 (16)
imf001c2	0.99708 (13)	0.99837 (13)	0.99705 (13)	0.99731 (13)
imf001c3	0.99826 (12)	0.99959 (12)	0.99820 (13)	0.99859 (13)
imf001c4	0.99895 (12)	1.00064 (13)	0.99907 (12)	0.99922 (12)
imf002c1	0.99633 (11)	0.99663 (11)	0.99623 (11)	0.99621 (11)
imf007d	1.00466 (13)	1.00525 (13)	1.00511 (13)	1.00471 (13)
imf007s	1.00415 (13)	1.00447 (13)	1.00410 (13)	1.00388 (13)
imf010c1	0.99660 (12)	0.99906 (12)	0.99705 (12)	0.99722 (12)
imf012c1	1.00184 (13)	1.00463 (13)	1.00045 (13)	1.00227 (13)

imf7tzh	0.99511 (13)	0.99548 (13)	0.99531 (12)	0.99511 (13)
lct005c1	1.00266 (13)	1.00360 (13)	1.00278 (13)	1.00266 (13)
lct005c10	0.99986 (13)	1.00804 (13)	0.99997 (13)	1.00012 (13)
lct005c11	1.00047 (13)	1.00856 (13)	1.00009 (13)	1.00072 (13)
lct005c12	1.00420 (13)	1.00912 (13)	1.00417 (13)	1.00398 (13)
lct005c13	1.01021 (13)	1.01609 (13)	1.00958 (13)	1.00997 (13)
lct005c14	0.99824 (13)	0.99961 (13)	0.99851 (13)	0.99866 (13)
lct005c15	1.01719 (13)	1.01908 (13)	1.01707 (13)	1.01720 (13)
lct005c16	1.01248 (13)	1.01469 (13)	1.01232 (13)	1.01275 (13)
lct005c2	0.99987 (13)	1.00117 (13)	0.99999 (13)	0.99973 (13)
lct005c3	0.99901 (13)	1.00228 (13)	0.99880 (13)	0.99916 (13)
lct005c4	0.99763 (13)	1.00135 (13)	0.99759 (13)	0.99796 (13)
lct005c5	1.00374 (13)	1.00733 (13)	1.00347 (13)	1.00394 (13)
lct005c6	1.00468 (13)	1.00945 (13)	1.00476 (13)	1.00510 (13)
lct005c7	0.99989 (13)	1.00591 (13)	0.99971 (13)	1.00011 (13)
lct005c8	0.99985 (13)	1.00720 (13)	0.99979 (13)	1.00006 (13)
lct005c9	1.00077 (13)	1.00854 (13)	1.00027 (13)	1.00117 (13)
lct006c01	0.99995 (12)	1.00131 (12)	0.99984 (12)	1.00007 (12)
lct006c03	1.00022 (9)	1.00196 (9)	1.00007 (9)	1.00023 (9)
lct006c04	1.00006 (12)	1.00113 (12)	0.99996 (12)	1.00010 (12)
lct006c08	1.00018 (12)	1.00133 (12)	1.00011 (12)	1.00006 (12)
lct006c09	1.00033 (12)	1.00082 (12)	1.00019 (12)	1.00052 (12)
lct006c13	1.00004 (12)	1.00089 (12)	0.99982 (12)	1.00008 (12)
lct006c14	1.00012 (12)	1.00041 (12)	1.00004 (12)	1.00041 (12)
lct006c18	0.99986 (12)	1.00051 (12)	0.99981 (12)	1.00019 (12)
lct007c01	0.99761 (12)	0.99957 (34)	0.99735 (12)	0.99800 (12)
lct007c02	0.99960 (15)	1.00046 (15)	0.99948 (15)	1.00009 (15)
lct007c03	0.99896 (15)	0.99816 (15)	0.99843 (15)	0.99869 (15)
lct007c05	0.99688 (15)	0.99910 (15)	0.99662 (15)	0.99698 (15)
lct007c06	0.99976 (15)	1.00018 (15)	0.99971 (15)	0.99974 (15)
lct007c07	0.99958 (15)	0.99927 (15)	0.99971 (15)	0.99958 (15)
lct010c01	1.00577 (12)	1.00932 (12)	1.00496 (12)	1.01317 (12)
lct010c20	1.00392 (12)	1.00751 (12)	1.00315 (12)	1.00867 (12)
lct027c01	1.00302 (12)	1.01022 (12)	0.99919 (12)	1.02000 (12)
lct035c1	0.99994 (9)	1.00166 (9)	0.99991 (9)	1.00038 (9)
lct035c2	0.99895 (9)	1.00066 (9)	0.99895 (9)	0.99912 (9)
lct035c3	0.99530 (9)	0.99725 (9)	0.99539 (9)	0.00000 (0)
lct039c01	0.99716 (15)	0.99849 (15)	0.99702 (15)	0.99741 (15)
lct039c04	0.99663 (15)	0.99765 (15)	0.99679 (15)	0.99693 (15)
lct039c06	0.99796 (15)	0.99885 (15)	0.99753 (15)	0.99813 (15)
mct004c1	0.99536 (13)	0.99628 (13)	0.99499 (13)	0.99414 (13)
mct004c10	0.99662 (13)	0.99587 (13)	0.99571 (13)	0.99475 (13)
mct004c4	0.99570 (13)	0.99616 (13)	0.99485 (13)	0.99396 (13)
mct004c7	0.99597 (13)	0.99624 (13)	0.99547 (13)	0.99447 (13)

pmf001	0.99986 (15)	0.99931 (15)	1.00014 (15)	1.00029 (15)
pmf002	1.00136 (15)	1.00142 (15)	1.00496 (15)	1.00378 (15)
pst001c01	1.00152 (12)	1.00096 (12)	1.00145 (13)	1.00143 (13)
pst001c02	1.00396 (13)	1.00276 (12)	1.00375 (13)	1.00386 (13)
pst001c03	1.00711 (12)	1.00574 (12)	1.00718 (13)	1.00721 (13)
pst001c04	1.00182 (13)	1.00014 (12)	1.00161 (13)	1.00155 (12)
pst001c05	1.00590 (13)	1.00408 (12)	1.00555 (12)	1.00561 (13)
pst001c06	1.00869 (13)	1.00757 (13)	1.00831 (13)	1.00867 (13)
pst009c1a	1.03943 (11)	1.04017 (11)	1.03965 (11)	1.03948 (11)
pst009c2a	1.01294 (11)	1.01380 (11)	1.01328 (11)	1.01284 (11)
pst009c3a	1.01294 (11)	1.01382 (11)	1.01294 (11)	1.01293 (11)
pst011c16-1	1.00398 (13)	1.00641 (13)	1.00417 (13)	1.00377 (13)
pst011c16-5	1.00041 (13)	1.00251 (13)	1.00053 (13)	1.00034 (13)
pst011c18-1	0.98799 (13)	0.99102 (13)	0.98808 (13)	0.98802 (13)
pst011c18-6	0.99385 (13)	0.99689 (13)	0.99397 (13)	0.99399 (13)
pst013c01	1.00029 (13)	1.00061 (12)	1.00015 (13)	1.00035 (13)
pst013c02	1.00002 (13)	1.00051 (12)	0.99984 (13)	1.00007 (13)
pst013c04	0.99281 (13)	0.99332 (12)	0.99258 (13)	0.99255 (13)
topsyni	1.00354 (17)	1.01010 (18)	1.02598 (18)	0.00
topsyu	1.00854 (16)	1.01421 (16)	1.00872 (16)	0.00

Table 1: ICSBEP Benchmarks : TRIPOLI-4® calculations using ENDF/B-VIII, JEFF-3.3, TENDL-17 and TENDL-19 libraries

3 Benchmark analysis

We focus on five bechmarks for which we compared neutron flux and reaction rates for calculations performed with the different libraries and codes MCNP-5.1.40 and TRIPOLI-4®. The results available on the conderc website with the code MCNP6 are used in this section to validate the calculations we have made with MCNP5.1.40 and TRIPOLI4®. We have selected 28 reaction rates classically used and we also calculate the neutron fluxes in the fuel volumes of these various benchmarks. Table 2 gives the different reactions considered and Figures 3, 4 and 5 show the cross sections for the calculations of reaction rates in the fuels of the various configurations studied. All of these cross sections make it possible to cover a large energy range with various energy specificities. The results on the reaction rates are reported in tables for each configuration. The fluxes are presented as a spectrum in 2-part figures. The upper part is the representation of the flux, the lower part presents the ratios compared to the results obtained with MCNP5.1.40 and TENDL-19.

U233(n,fission)	U235(n,fission)	U238(n,fission)	U238(n,2n)
U238(n,γ)	(n,fission)	Np237(n,2n)	Am241(n,γ)
Au197(n,γ)	Pu239(n,fission)	Pu239(n,2n)	P31(n,p)
V31(n,γ)”	Mn55(n,γ)	Fe56(n,p)	Cu63(n,γ)
Cu63(n,2n)	Pb209(n,γ)	Nb93(n,γ)	Rh103(n,γ)
Ag107(n,γ)	Sb121(n,γ)	La139(n,γ)	Tm169(n,2n)
Tm169(n,γ)	Ir191(n,2n)	Ir191(n,γ)	Ir193(n,γ)

Table 2: Reaction rates considered in the following benchmarks

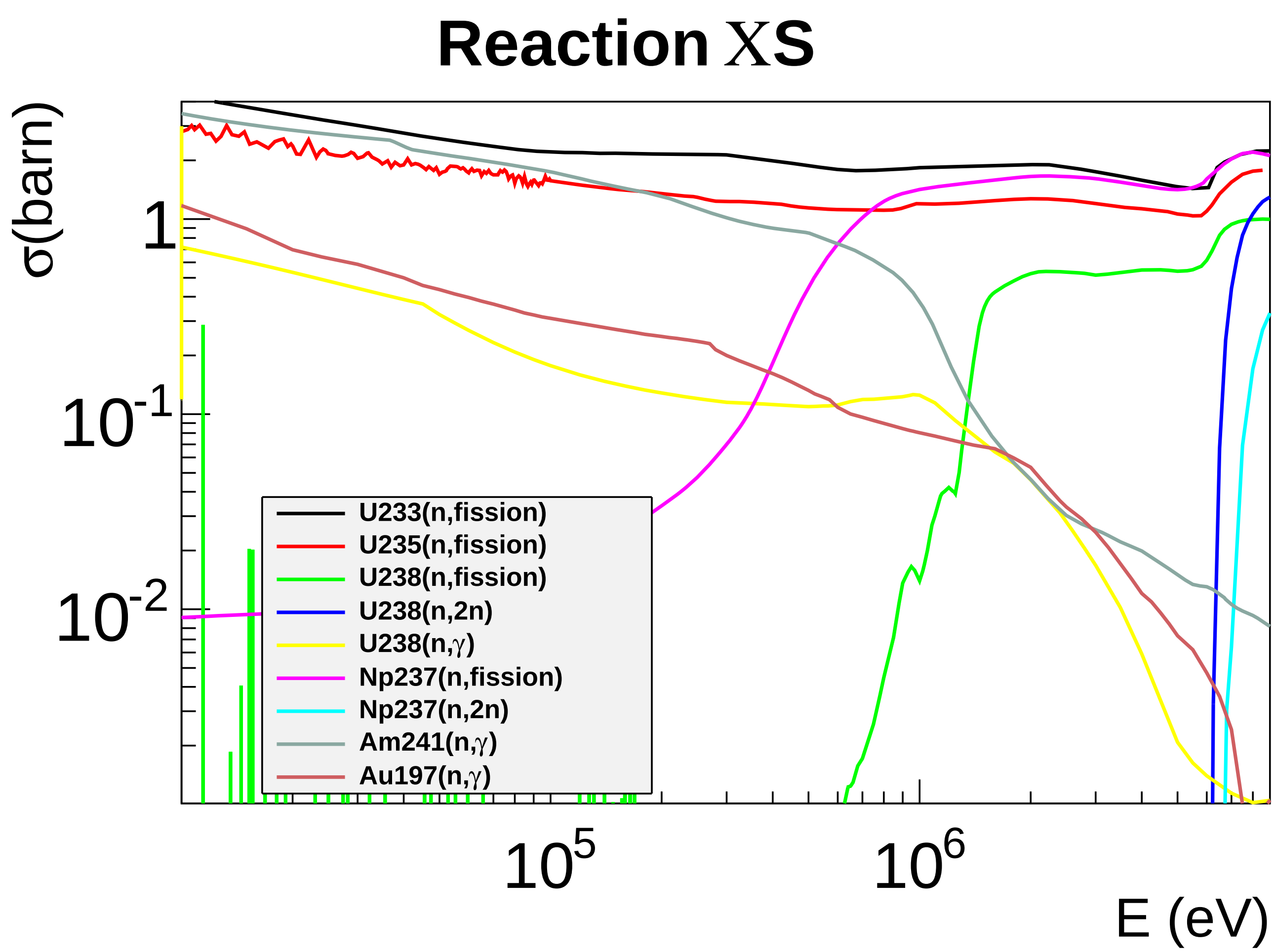

Figure 3: reaction cross sections considered for reaction rates in the following benchmarks

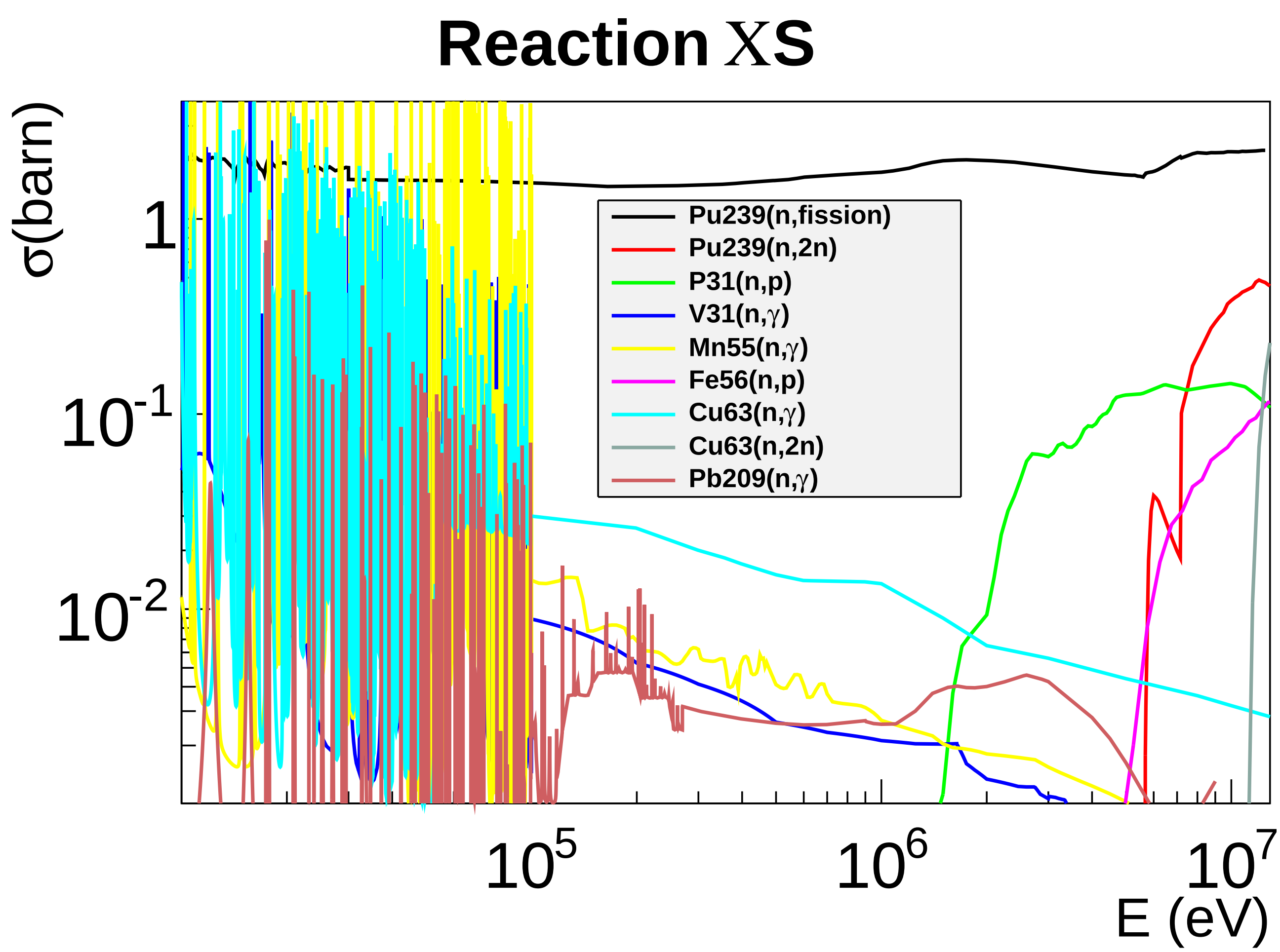

Figure 4: reaction cross sections considered for reaction rates in the following benchmarks

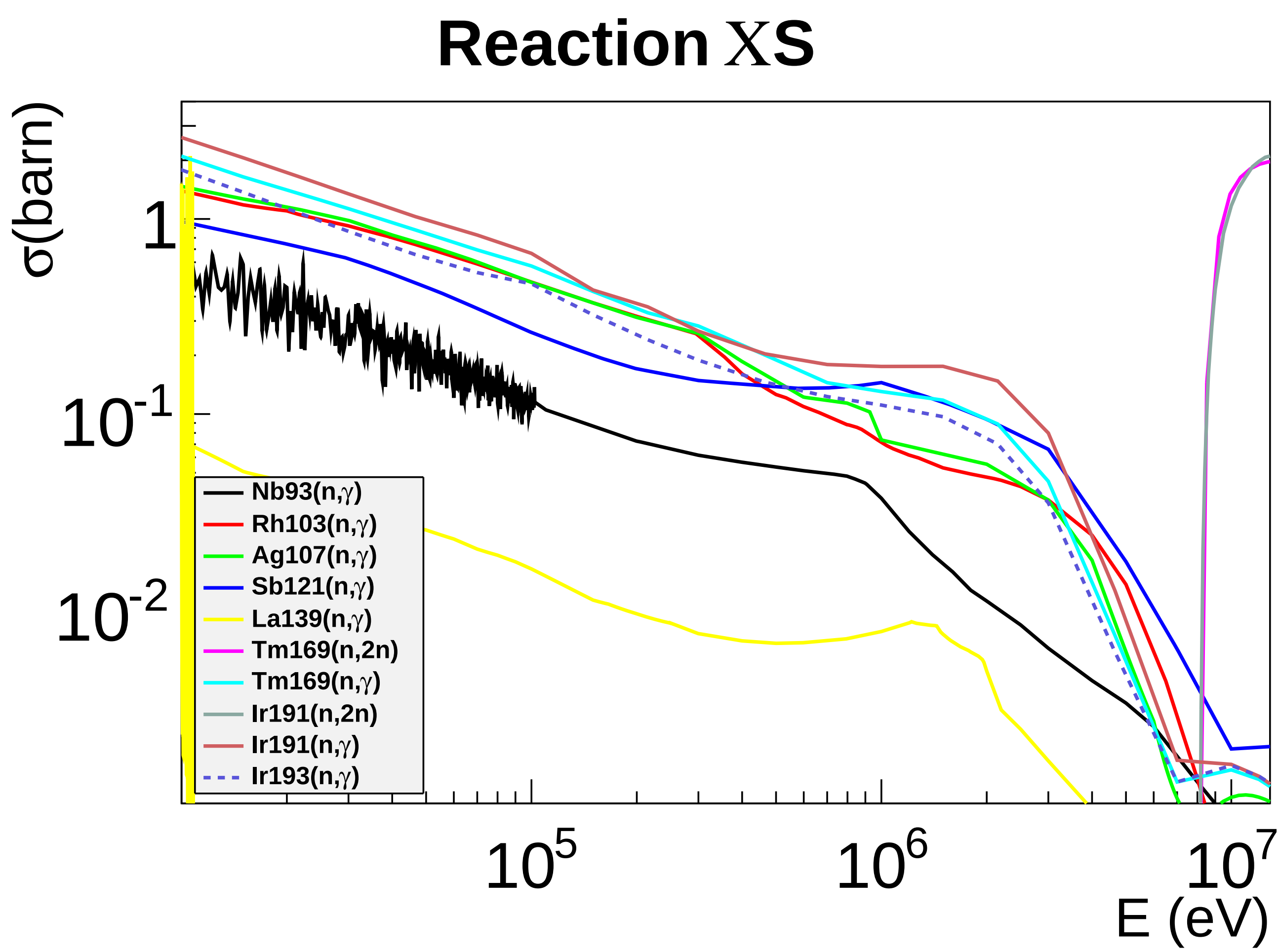

Figure 5: reaction cross sections considered for reaction rates in the following benchmarks

3.1 PMF1

This benchmark, named Jezebel, consists of a 6.3849cm sphere made of plutonium and gallium. Figure 6 and Table 3 present results obtained with MCNP6, MCNP5.1.40 and TRIPOLI-4® using various libraries.

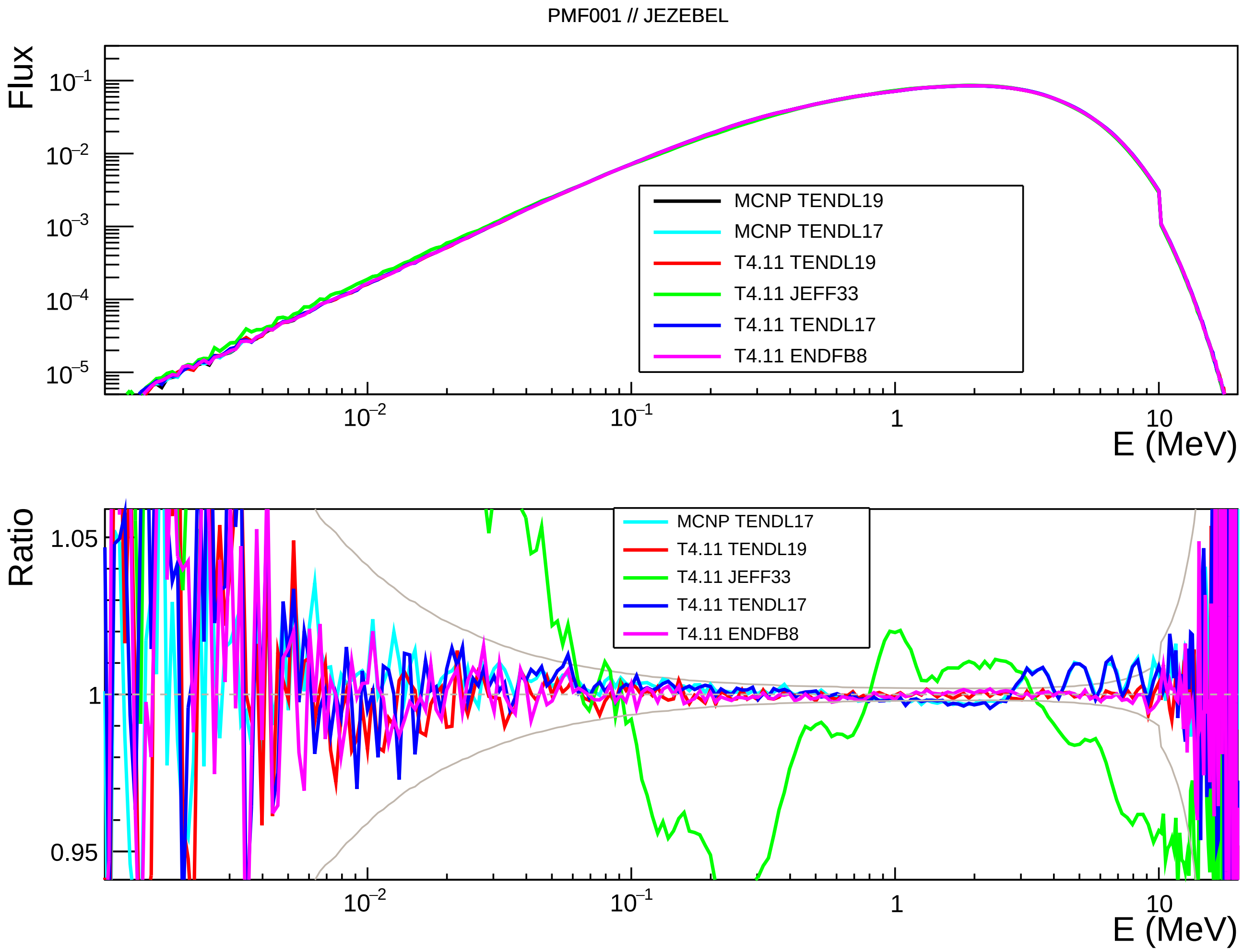

Figure 6: Results on neutron flux for PMF1 benchmark Jezebel. Upper part : neutron flux. Lower part : ratio to MCNP5.1.40 + TENDL-19.

Reaction	MCNP6-T17	MCNP5-T17	T4-T17	MCNP5-T19	T4-T19	MCNP5-B8	T4-B8	MCNP5-J33	T4-J33
U233(n,f)	8.27938E-03	8.29362E-03	8.296558e-03	8.29278E-03	8.292769e-03	8.29425E-03	8.294405e-03	8.18889E-03	8.190554e-03
U235(n,f)	5.28707E-03	5.29624E-03	5.298010e-03	5.29534E-03	5.294859e-03	5.29602E-03	5.296395e-03	5.26228E-03	5.263291e-03
U238(n,f)	1.13583E-03	1.13876E-03	1.137583e-03	1.13726E-03	1.136411e-03	1.13728E-03	1.137766e-03	1.12135E-03	1.121138e-03
U238(n,2n)	7.18549E-05	7.18141E-05	7.175539e-05	7.16140E-05	7.183066e-05	7.13902E-05	7.171145e-05	6.83254E-05	6.847491e-05
U238(n,γ)	3.37064E-04	3.37291E-04	3.377282e-04	3.37456E-04	3.384660e-04	3.37400E-04	3.373592e-04	3.26280E-04	3.266468e-04
Np237(n,f)	5.17850E-03	5.18936E-03	5.188745e-03	5.18919E-03	5.187007e-03	5.22701E-03	5.227994e-03	5.23581E-03	5.236227e-03
Np237(n,2n)	1.25054E-05	1.24714E-05	1.245608e-05	1.24715E-05	1.251320e-05	1.26615E-05	1.274661e-05	1.21331E-05	1.212122e-05
Pu239(n,f)	7.56519E-03	7.57903E-03	7.580403e-03	7.57820E-03	7.577506e-03	7.57954E-03	7.580020e-03	7.57626E-03	7.577610e-03
Pu239(n,2n)	1.78448E-05	1.78450E-05	1.784072e-05	1.77856E-05	1.782832e-05	1.77263E-05	1.777217e-05	2.00651E-05	2.009878e-05
Am241(n,γ)	1.69189E-03	1.69339E-03	1.696364e-03	1.69333E-03	1.693860e-03	1.69178E-03	1.691563e-03	1.65466E-03	1.655566e-03
P31(n,p)	1.30267E-04	1.30682E-04	1.304696e-04	1.31311E-04	1.312601e-04	1.23827E-04	1.237769e-04	1.04234E-04	1.041991e-04
V51(n,γ)	1.42872E-05	1.43216E-05	1.433364e-05	1.24206E-05	1.242038e-05	1.18471E-05	1.183658e-05	1.19095E-05	1.191647e-0
Mn55(n,γ)	1.46271E-05	1.46450E-05	1.465906e-05	1.46494E-05	1.460841e-05	1.46385E-05	1.467635e-05	1.45952E-05	1.461173e-05
Fe56(n,p)	4.99861E-06	5.00116E-06	4.998744e-06	4.98716E-06	4.997014e-06	4.96808E-06	4.974931e-06	4.71241E-06	4.714713e-06
Cu63(n,2n)	5.82179E-07	5.82346E-07	6.024709e-07	5.90156E-07	5.909219e-07	5.63301E-07	5.508287e-07	5.75790E-07	5.616431e-07
Cu63(n,γ)	4.60100E-05	4.59924E-05	4.612122e-05	4.69842E-05	4.693367e-05	5.28357E-05	5.275522e-05	5.30150E-05	5.294978e-05
Nb93(n,γ)	1.34547E-04	1.34703E-04	1.348956e-04	1.33024E-04	1.329815e-04	1.42848E-04	1.429707e-04	1.42620E-04	1.427597e-04
Rh103(n,γ)	4.69135E-04	4.69695E-04	4.701774e-04	4.63783E-04	4.639178e-04	4.08087E-04	4.079816e-04	4.44458E-04	4.444763e-04
Ag107(n,γ)	4.17793E-04	4.18344E-04	4.192793e-04	3.24659E-04	3.244345e-04	5.47306E-04	5.474643e-04	3.25536E-04	3.254952e-04
Sb121(n,γ)	4.39018E-04	4.39584E-04	4.402166e-04	3.80136E-04	3.801029e-04	4.78485E-04	4.783730e-04	3.86773E-04	3.867614e-04
La139(n,γ)	3.12997E-05	3.13437E-05	3.138831e-05	3.06758E-05	3.067103e-05	3.25038E-05	3.248457e-05	3.24619E-05	3.244297e-05
Tm169(n,2n)	2.04225E-05	2.03333E-05	2.043323e-05	2.04827E-05	2.053678e-05	2.01329E-05	2.030405e-05	1.87005E-05	1.851040e-05
Tm169(n,γ)	4.36638E-04	4.36921E-04	4.385700e-04	4.30793E-04	4.308613e-04	5.49649E-04	5.494414e-04	4.35495E-04	4.362130e-04
Ir191(n,2n)	2.39397E-05	2.38422E-05	2.393460e-05	2.27884E-05	2.285136e-05	2.03264E-05	2.048594e-05	1.94520E-05	1.925742e-05
Ir191(n,γ)	1.03021E-03	1.03161E-03	1.032755e-03	1.04247E-03	1.042426e-03	8.09746E-04	8.096712e-04	8.03063E-04	8.038320e-04
Ir193(n,γ)	4.60566E-04	4.60898E-04	4.617270e-04	4.76295E-04	4.762223e-04	5.90064E-04	5.901451e-04	5.84835E-04	5.854537e-04
Au197(n,γ)	4.00513E-04	4.00923E-04	4.020298e-04	3.98869E-04	3.988168e-04	4.00129E-04	4.002252e-04	3.95411E-04	3.958399e-04
Bi209(n,γ)	1.03231E-05	1.03434E-05	1.034446e-05	1.02217E-05	1.021177e-05	1.17014E-05	1.170285e-05	9.05853E-06	9.070718e-06

Table 3: PMF1 benchmark Jezebel : MCNP6, MCNP5.1.40 and TRIPOLI-4.11 reaction rates calculations using ENDF/B-VIII, JEFF-3.3,TENDL-17 and TENDL-19 libraries

3.2 PMF2

This benchmark, named Jezebel-Pu40, consists of a 6.6595cm sphere made of plutonium and gallium. The concentration of Pu240 is much higher than in PMF1. Figure 7 and Table 4 present results obtained with MCNP6, MCNP5.1.40 and TRIPOLI-4.11 using various libraries.

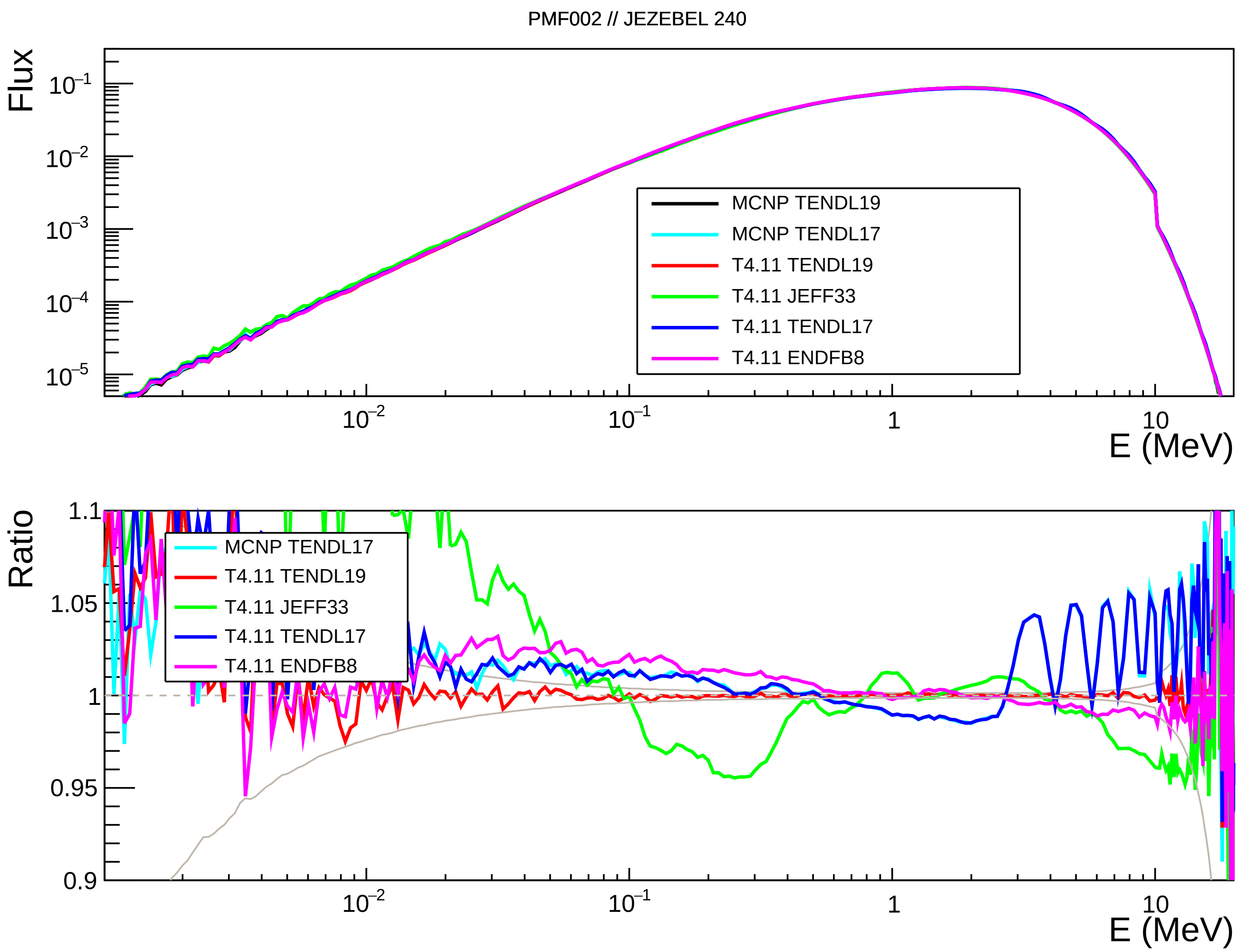

Figure 7: Results on neutron flux for PMF2 benchmark Jezebel-Pu40. Upper part : neutron flux. Lower part : ratio to MCNP5.1.40 + TENDL-19.

Reaction	MCNP6-T17	MCNP5-T17	T4-T17	MCNP5-T19	T4-T19	MCNP5-B8	T4-B8	MCNP5-J33	T4-J33
U233(n,f)		7.73748E-03	7.737733e-03	7.72401E-03	7.724477e-03	7.74316E-03	7.740979e-03	7.64058E-03	7.639249e-03
U235(n,f)	4.93921E-03	4.93861E-03	4.938759e-03	4.92771E-03	4.927937e-03	4.93951E-03	4.937966e-03	4.90500E-03	4.904180e-03
U238(n,f)	1.03608E-03	1.03654E-03	1.035993e-03	1.02711E-03	1.027111e-03	1.02466E-03	1.024406e-03	1.01415E-03	1.013891e-03
U238(n,2n)		6.61454E-05	6.626135e-05	6.43189E-05	6.419944e-05	6.37464E-05	6.377570e-05	6.20700E-05	6.206213e-05
U238(n,γ)		3.19339E-04	3.196273e-04	3.20128E-04	3.201396e-04	3.21900E-04	3.217922e-04	3.09987E-04	3.098228e-04
Np237(n,f)	4.74894E-03	4.74871E-03	4.748689e-03	4.73990E-03	4.741331e-03	4.76909E-03	4.768460e-03	4.77958E-03	4.779254e-03
Np237(n,2n)		1.15259E-05	1.153985e-05	1.11751E-05	1.115880e-05	1.13203E-05	1.131861e-05	1.10235E-05	1.103131e-05
Pu239(n,f)		7.03800E-03	7.037981e-03	7.02447E-03	7.025190e-03	7.03608E-03	7.034469e-03	7.03140E-03	7.030439e-03
Pu239(n,2n)		1.64675E-05	1.648580e-05	1.59812E-05	1.594798e-05	1.58255E-05	1.583896e-05	1.81962E-05	1.819493e-05
Am241(n,γ)		1.63789E-03	1.638428e-03	1.63617E-03	1.635817e-03	1.64495E-03	1.643935e-03	1.60698E-03	1.606488e-03
P31(n,p)		1.19811E-04	1.197150e-04	1.18234E-04	1.182072e-04	1.11042E-04	1.109963e-04	9.42909E-05	9.425422e-05
V51(n,γ)		1.37013E-05	1.370588e-05	1.19153E-05	1.191355e-05	1.14570E-05	1.142407e-05	1.14662E-05	1.144941e-05
Mn55(n,γ)		1.40488E-05	1.407074e-05	1.40254E-05	1.403142e-05	1.41683E-05	1.412531e-05	1.40657E-05	1.405291e-05
Fe56(n,p)		4.61486E-06	4.615981e-06	4.48127E-06	4.470536e-06	4.43461E-06	4.437555e-06	4.26963E-06	4.271064e-06
Cu63(n,2n)		5.51455E-07	5.374458e-07	5.28674E-07	5.184178e-07	4.98678E-07	4.980749e-07	5.18109E-07	5.191623e-07
Cu63(n,γ)		4.38291E-05	4.387167e-05	4.47537E-05	4.478211e-05	5.05418E-05	5.053258e-05	5.06248E-05	5.058992e-05
Nb93(n,γ)		1.29629E-04	1.296930e-04	1.27899E-04	1.278414e-04	1.38136E-04	1.380533e-04	1.37409E-04	1.372871e-04
Rh103(n,γ)		4.55013E-04	4.551636e-04	4.47860E-04	4.476726e-04	3.97082E-04	3.967880e-04	4.30895E-04	4.306641e-04
Ag107(n,γ)		4.03126E-04	4.032520e-04	3.12567E-04	3.125892e-04	5.26642E-04	5.262192e-04	3.14894E-04	3.147544e-04
Sb121(n,γ)		4.16434E-04	4.165420e-04	3.59993E-04	3.600757e-04	4.56013E-04	4.556866e-04	3.66168E-04	3.661315e-04
La139(n,γ)		2.95511E-05	2.956604e-05	2.88583E-05	2.886830e-05	3.07306E-05	3.070662e-05	3.05829E-05	3.056187e-05
Tm169(n,2n)		1.88480E-05	1.885137e-05	1.82759E-05	1.821230e-05	1.80263E-05	1.800676e-05	1.69712E-05	1.699727e-05
Tm169(n,γ)		4.24364E-04	4.245689e-04	4.17627E-04	4.175018e-04	5.32957E-04	5.326077e-04	4.23889E-04	4.237548e-04
Ir191(n,2n)		2.20842E-05	2.209176e-05	2.03374E-05	2.027025e-05	1.81980E-05	1.817793e-05	1.76539E-05	1.768017e-05
Ir191(n,γ)		9.79643E-04	9.800627e-04	9.89234E-04	9.892993e-04	7.79706E-04	7.792337e-04	7.70594E-04	7.703430e-04
Ir193(n,γ)		4.45620E-04	4.457982e-04	4.58912E-04	4.589674e-04	5.71833E-04	5.714175e-04	5.64520E-04	5.642972e-04
Au197(n,γ)		3.84467E-04	3.847303e-04	3.81984E-04	3.820598e-04	3.86194E-04	3.860758e-04	3.80350E-04	3.802591e-04
Bi209(n,γ)		9.57496E-06	9.576451e-06	9.44772E-06	9.451899e-06	1.09588E-05	1.095827e-05	8.36632E-06	8.368420e-06

Table 4: PMF2 benchmark Jezebel-Pu40 : MCNP6, MCNP5.1.40 and TRIPOLI-4.11 reaction rates calculations using ENDF/B-VIII, JEFF-3.3,TENDL-17 and TENDL-19 libraries

3.3 HMF1

This benchmark, named Godiva, consists of a 8.7407cm enriched uranium sphere. Figure 8 and Table 5 present results obtained with MCNP6, MCNP5.1.40 and TRIPOLI-4.11 using various libraries.

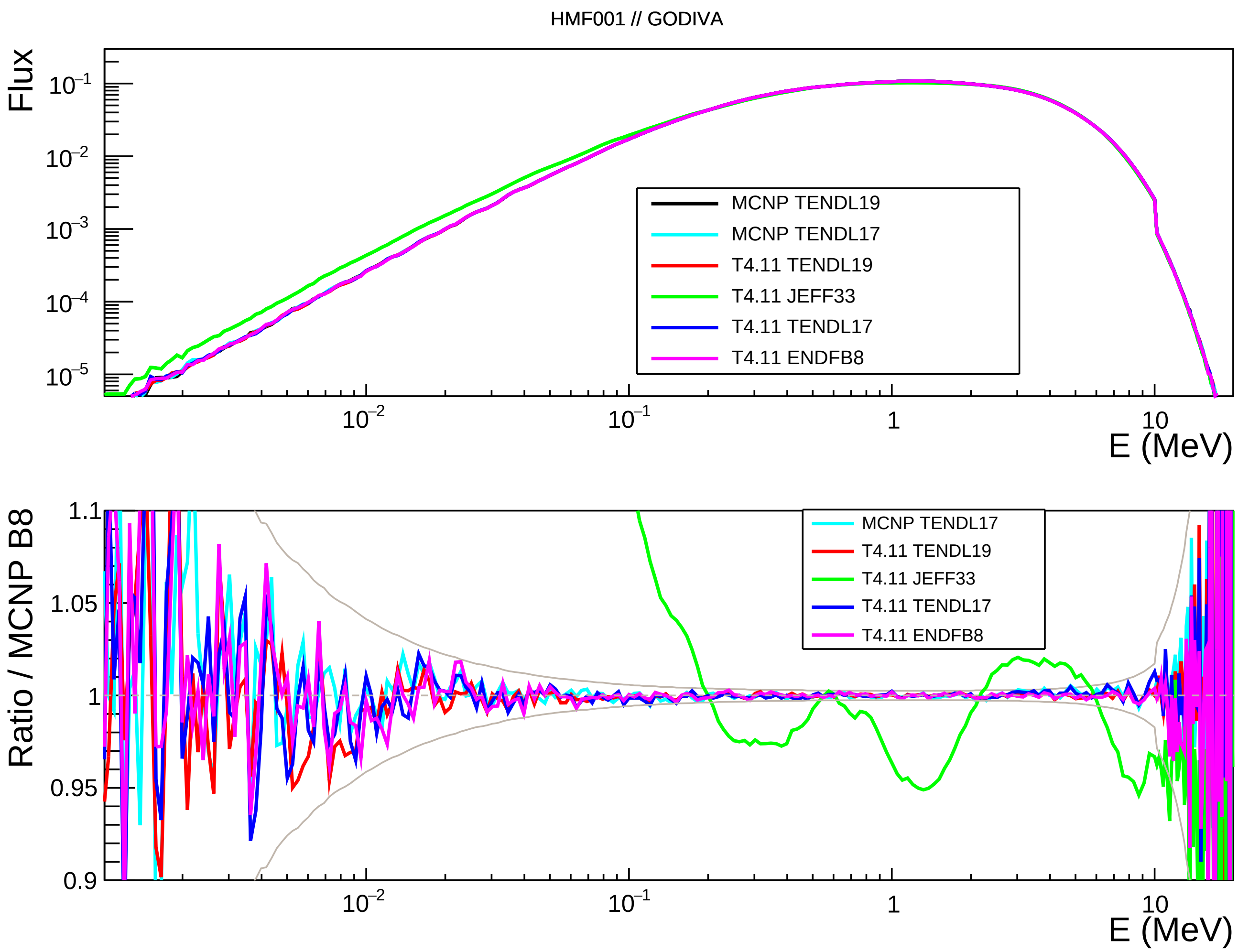

Figure 8: Results on neutron flux for HMF1 benchmark Godiva. Upper part : neutron flux. Lower part : ratio to MCNP5.1.40 + TENDL-19.

Reaction	MCNP6-T17	MCNP5-T17	T4-T17	MCNP5-T19	T4-T19	MCNP5-B8	T4-B8	MCNP5-J33	T4-J33
U233(n,f)	4.75202E-03	4.75224E-03	4.750995e-03	4.75168E-03	4.751028e-03	4.75181E-03	4.751352e-03	4.72430E-03	4.721938e-03
U235(n,f)	3.00858E-03	3.00869E-03	3.007848e-03	3.00825E-03	3.007851e-03	3.00836E-03	3.008117e-03	3.01537E-03	3.013933e-03
U238(n,f)	4.86035E-04	4.85930E-04	4.857210e-04	4.85515E-04	4.856673e-04	4.85523E-04	4.855393e-04	4.77644E-04	4.773249e-04
U238(n,2n)	2.48530E-05	2.48199E-05	2.478223e-05	2.47467E-05	2.473801e-05	2.47096E-05	2.480021e-05	2.36227E-05	2.357733e-05
U238(n,γ)	2.21408E-04	2.21441E-04	2.213390e-04	2.21477E-04	2.213695e-04	2.21475E-04	2.214378e-04	2.18674E-04	2.185285e-04
Np237(n,f)	2.52703E-03	2.52672E-03	2.526218e-03	2.52576E-03	2.526704e-03	2.54072E-03	2.541024e-03	2.50724E-03	2.506390e-03
Np237(n,2n)		4.13463E-06	4.129693e-06	4.12687E-06	4.123919e-06	4.21634E-06	4.223299e-06	4.04409E-06	4.037812e-06
Pu239(n,f)	4.18074E-03	4.18079E-03	4.179831e-03	4.18004E-03	4.179993e-03	4.18015E-03	4.179918e-03	4.18442E-03	4.182566e-03
Pu239(n,2n)		6.25037E-06	6.238941e-06	6.23367E-06	6.230457e-06	6.22558E-06	6.245482e-06	7.12103E-06	7.108516e-06
Am241(n,γ)		1.25209E-03	1.251472e-03	1.25240E-03	1.251250e-03	1.23218E-03	1.231741e-03	1.28254E-03	1.281431e-03
P31(n,p)	5.26047E-05	5.25719E-05	5.258246e-05	5.29829E-05	5.302902e-05	4.99833E-05	4.998801e-05	4.24272E-05	4.238332e-05
V51(n,γ)	9.65297E-06	9.64627E-06	9.645987e-06	8.68119E-06	8.666205e-06	8.11684E-06	8.111745e-06	8.77859E-06	8.771151e-06
Mn55(n,γ)	1.00906E-05	1.00902E-05	1.007029e-05	1.00879E-05	1.008978e-05	1.01031E-05	1.008959e-05	1.07096E-05	1.070187e-05
Fe56(n,p)	1.76592E-06	1.76428E-06	1.761760e-06	1.76042E-06	1.760016e-06	1.75730E-06	1.761497e-06	1.67410E-06	1.671237e-06
Cu63(n,2n)		1.60233E-07	1.581569e-07	1.61741E-07	1.636451e-07	1.55757E-07	1.520557e-07	1.59445E-07	1.564255e-07
Cu63(n,γ)	3.08857E-05	3.08405E-05	3.085232e-05	3.17656E-05	3.171521e-05	3.52997E-05	3.529955e-05	3.67060E-05	3.669344e-05
Nb93(n,γ)	9.54770E-05	9.55249E-05	9.543253e-05	9.40958E-05	9.399403e-05	1.00329E-04	1.002764e-04	1.05411E-04	1.053032e-04
Rh103(n,γ)	3.42773E-04	3.42900E-04	3.425856e-04	3.38971E-04	3.385418e-04	2.96290E-04	2.961346e-04	3.42296E-04	3.419915e-04
Ag107(n,γ)	3.01389E-04	3.01443E-04	3.012791e-04	2.33280E-04	2.329860e-04	3.75086E-04	3.749671e-04	2.48639E-04	2.483319e-04
Sb121(n,γ)	2.82751E-04	2.82790E-04	2.826143e-04	2.45295E-04	2.450997e-04	3.12210E-04	3.120496e-04	2.54416E-04	2.542090e-04
La139(n,γ)	1.94882E-05	1.94808E-05	1.948420e-05	1.89742E-05	1.896893e-05	2.00897E-05	2.008069e-05	2.05673E-05	2.053841e-05
Tm169(n,2n)		6.36246E-06	6.344756e-06	6.36822E-06	6.364935e-06	6.32593E-06	6.306354e-06	5.90175E-06	5.884564e-06
Tm169(n,γ)		3.25290E-04	3.248575e-04	3.20754E-04	3.203873e-04	3.91736E-04	3.916265e-04	3.46612E-04	3.462244e-04
Ir191(n,2n)		7.49818E-06	7.478129e-06	7.10575E-06	7.102160e-06	6.37038E-06	6.346827e-06	6.12621E-06	6.105303e-06
Ir191(n,γ)		6.78221E-04	6.777700e-04	6.82742E-04	6.821638e-04	5.56510E-04	5.564624e-04	5.76440E-04	5.759429e-04
Ir193(n,γ)	3.35468E-04	3.35545E-04	3.353170e-04	3.44369E-04	3.439460e-04	4.18453E-04	4.182415e-04	4.36855E-04	4.364237e-04
Au197(n,γ)	2.80201E-04	2.80254E-04	2.801796e-04	2.78386E-04	2.780632e-04	2.79558E-04	2.793831e-04	2.88225E-04	2.879456e-04
Bi209(n,γ)	5.57362E-06	5.57278E-06	5.575107e-06	5.52445E-06	5.525247e-06	6.90739E-06	6.905265e-06	4.82744E-06	4.821285e-06

Table 5: HMF1 benchmark Godiva : MCNP6, MCNP5.1.40 and TRIPOLI-4.11 reaction rates calculations using ENDF/B-VIII, JEFF-3.3,TENDL-17 and TENDL-19 libraries

3.4 HMF28

This benchmark, named Flattop, consists of a 6.1156cm enriched uranium sphere reflected by natural uranium. Figure 9 and Table 6 present results obtained with MCNP5.1.40 and TRIPOLI-4.11 using various libraries. The modelling of the geometry used for comparisons of fluxes and reaction rates is not exactly the same as that now considered in the CONDERC/MCNP6 document. Therefore, we have not reported these results obtained with MCNP6.

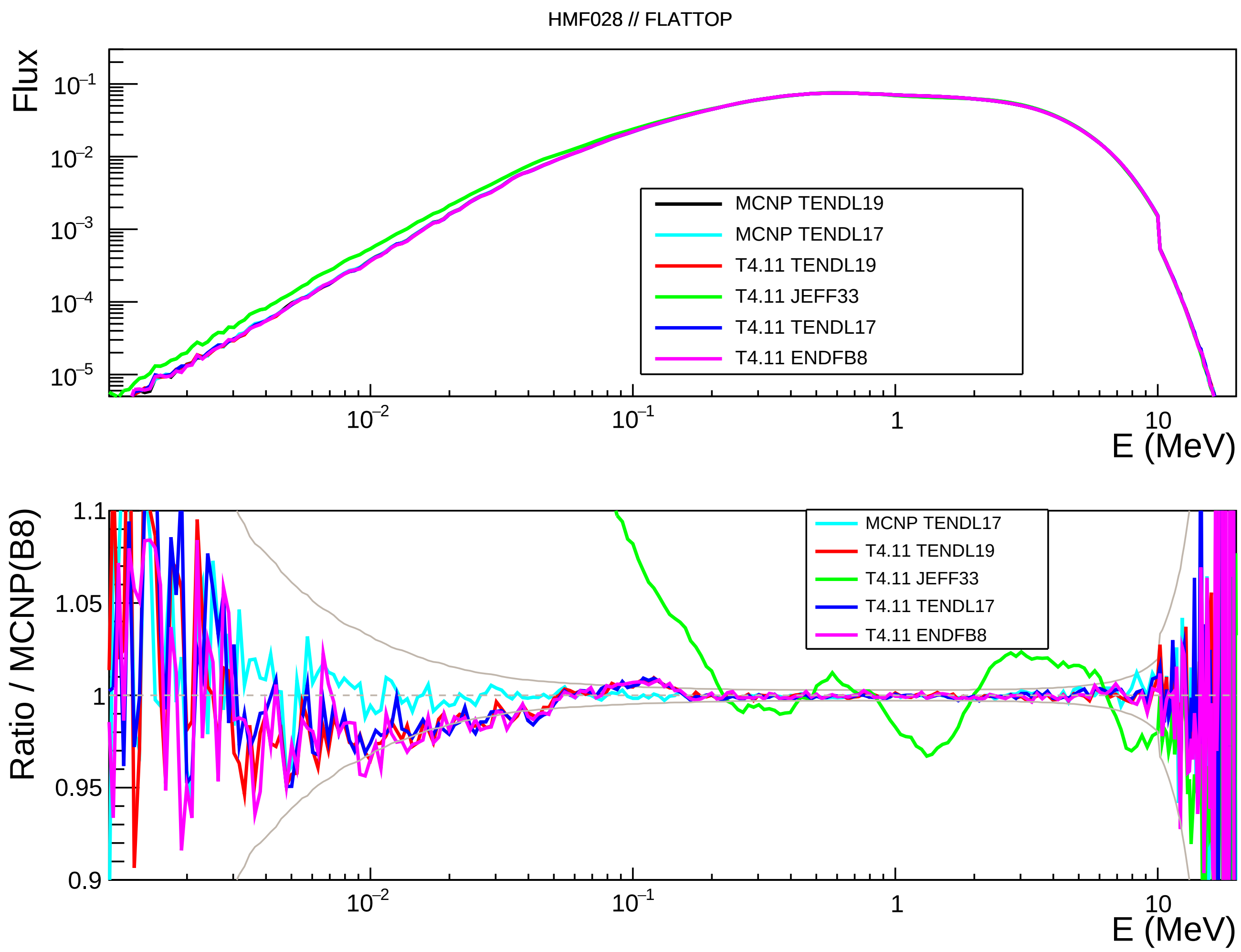

Figure 9: Results on neutron flux for HMF28 benchmark Flattop. Upper part : neutron flux. Lower part : ratio to MCNP5.1.40 + TENDL-19.

Reaction	MCNP5-T17	T4-T17	MCNP5-T19	T4-T19	MCNP5-B8	T4-B8	MCNP5-J33	T4-J33
U233(n,f)	1.09373E-02	1.093031e-02	1.09404E-02	1.094907e-02	1.09434E-02	1.093880e-02	1.10416E-02	1.103042e-02
U235(n,f)	6.94109E-03	6.936375e-03	6.94288E-03	6.948166e-03	6.94464E-03	6.941763e-03	7.05829E-03	7.051140e-03
U238(n,f)	8.90446E-04	8.899996e-04	8.90274E-04	8.898490e-04	8.90419E-04	8.897910e-04	8.83439E-04	8.814822e-04
U238(n,2n)	4.39828E-05	4.384238e-05	4.39049E-05	4.363154e-05	4.38576E-05	4.382186e-05	4.26263E-05	4.261077e-05
U238(n,γ)	5.66924E-04	5.659554e-04	5.67141E-04	5.673070e-04	5.67182E-04	5.666403e-04	5.66540E-04	5.658444e-04
Np237(n,f)	4.88038E-03	4.878675e-03	4.88282E-03	4.881723e-03	4.90912E-03	4.905487e-03	4.90291E-03	4.896012e-03
Np237(n,2n)	7.31928E-06	7.279021e-06	7.29874E-06	7.224961e-06	7.47413E-06	7.431031e-06	7.27044E-06	7.299005e-06
Pu239(n,f)	9.27340E-03	9.268410e-03	9.27627E-03	9.282402e-03	9.27886E-03	9.274519e-03	9.41773E-03	9.408050e-03
Pu239(n,2n)	1.10934E-05	1.107016e-05	1.10709E-05	1.102335e-05	1.10619E-05	1.105551e-05	1.28598E-05	1.286093e-05
Am241(n,γ)	3.55489E-03	3.550726e-03	3.55538E-03	3.560928e-03	3.45921E-03	3.458437e-0	33.66680E-03	3.663362e-03
P31(n,p)	9.58815E-05	9.582738e-05	9.66609E-05	9.662451e-05	9.11922E-05	9.113971e-05	7.77628E-05	7.754650e-05
V51(n,γ)	2.69544E-05	2.691238e-05	2.54373E-05	2.538574e-05	2.34897E-05	2.341715e-05	2.54922E-05	2.541573e-05
Mn55(n,γ)	2.84441E-05	2.837424e-05	2.84918E-05	2.848708e-05	2.84686E-05	2.844921e-05	3.06269E-05	3.060265e-05
Fe56(n,p)	3.13846E-06	3.132272e-06	3.13191E-06	3.121009e-06	3.12824E-06	3.125181e-06	3.02218E-06	3.023627e-06
Cu63(n,2n)	2.78056E-07	2.791822e-07	2.84591E-07	2.674855e-07	2.72524E-07	2.728521e-07	2.77354E-07	2.787481e-07
Cu63(n,γ)	8.08313E-05	8.069389e-05	8.44228E-05	8.441342e-05	9.20549E-05	9.199054e-05	9.77896E-05	9.756719e-05
Nb93(n,γ)	2.68218E-04	2.676480e-04	2.63081E-04	2.633445e-04	2.79114E-04	2.788484e-04	2.97153E-04	2.965550e-04
Rh103(n,γ)	1.01408E-03	1.012144e-03	1.00277E-03	1.003889e-03	8.56301E-04	8.558388e-04	9.97702E-04	9.962862e-04
Ag107(n,γ)	8.59004E-04	8.577331e-04	6.78047E-04	6.788342e-04	1.03284E-03	1.032353e-03	7.26200E-04	7.249624e-04
Sb121(n,γ)	7.39064E-04	7.378703e-04	6.43903E-04	6.442991e-04	7.99386E-04	7.981708e-04	6.66072E-04	6.648733e-04
La139(n,γ)	5.05435E-05	5.047119e-05	4.81535E-05	4.819895e-05	5.03986E-05	5.036115e-05	5.23463E-05	5.223217e-05
Tm169(n,2n)	1.12696E-05	1.115898e-05	1.12483E-05	1.108432e-05	1.12069E-05	1.103225e-05	1.05056E-05	1.062513e-05
Tm169(n,γ)	9.67524E-04	9.657560e-04	9.54380E-04	9.558021e-04	1.11313E-03	1.112537e-03	1.03550E-03	1.033504e-03
Ir191(n,2n)	1.32796E-05	1.315818e-05	1.25513E-05	1.237018e-05	1.12822E-05	1.110842e-05	1.08970E-05	1.102509e-05
Ir191(n,γ)	1.80796E-03	1.805894e-03	1.81428E-03	1.816265e-03	1.52423E-03	1.523817e-03	1.59493E-03	1.592974e-03
Ir193(n,γ)	9.72815E-04	9.713914e-04	9.91099E-04	9.924116e-04	1.18121E-03	1.180664e-03	1.24357E-03	1.241715e-03
Au197(n,γ)	7.74280E-04	7.731368e-04	7.66541E-04	7.677834e-04	7.70046E-04	7.696378e-04	8.01948E-04	8.008465e-04
Bi209(n,γ)	1.21990E-05	1.218419e-05	1.22122E-05	1.221950e-05	1.59846E-05	1.598672e-05	1.06048E-05	1.058366e-05

Table 6: HMF28 benchmark Flattop : MCNP5.1.40 and TRIPOLI-4.11 reaction rates calculations using ENDF/B-VIII, JEFF-3.3,TENDL-17 and TENDL-19 libraries

3.5 IMF7

The modelling of the geometry used for comparisons of fluxes and reaction rates is not exactly the same as that now considered in the CONDERC/MCNP6 document. Therefore, we have not reported these results obtained with MCNP6. We considered the Two Zone homogenized configuration, Figure 10 and Table 7 present results obtained with MCNP6, MCNP5.1.40 and TRIPOLI-4.11 using various libraries.

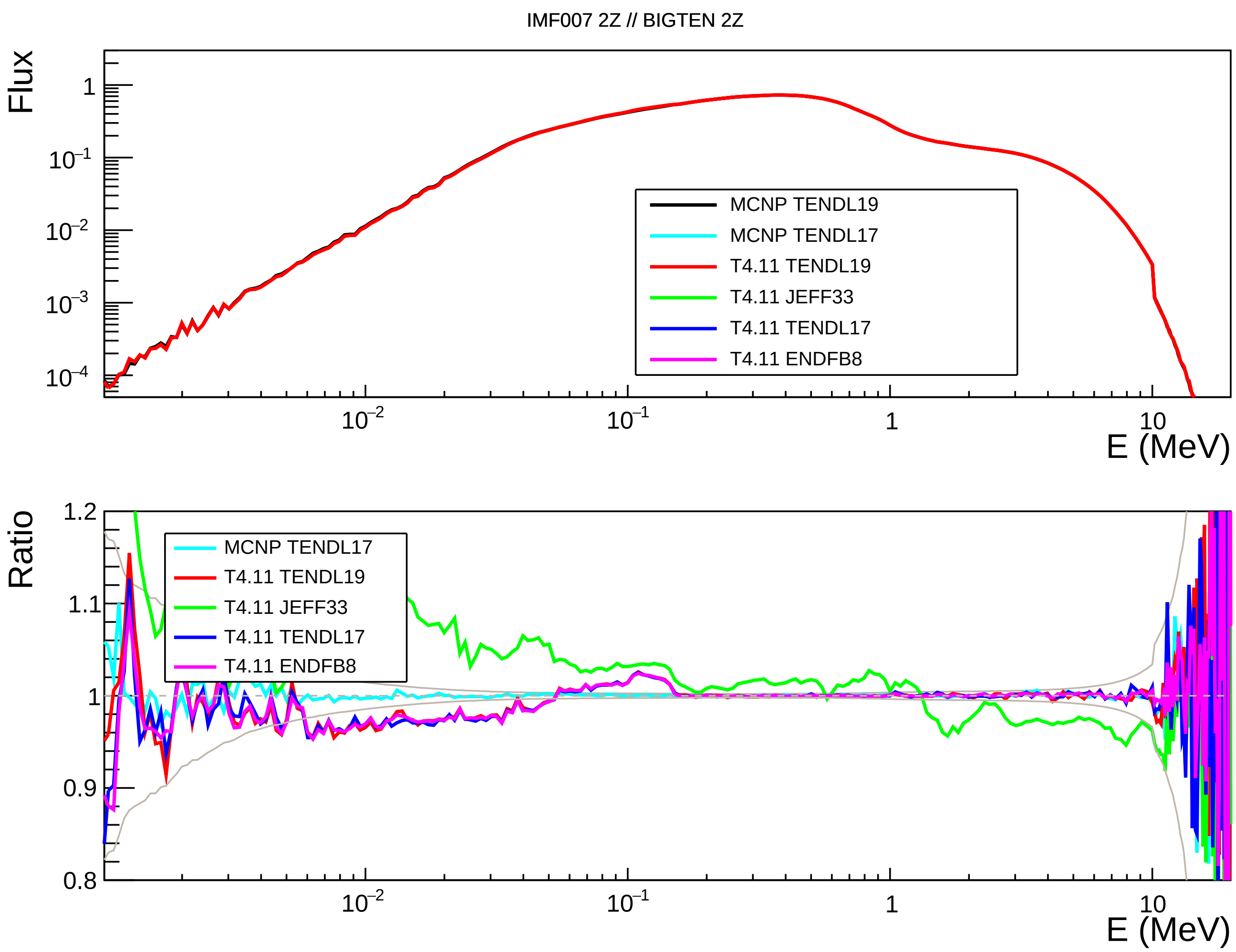

Figure 10: Results on neutron flux for IMF7-2Z benchmark BigTen-2Z. Upper part : neutron flux. Lower part : ratio to MCNP5.1.40 + TENDL-19.

Reaction	MCNP5-T17	T4-T17	MCNP5-T19	T4-T19	MCNP5-B8	T4-B8	MCNP5-J33	T4-J33
U233(n,f)	7.03322E-04	7.044232e-04	7.03004E-04	7.041795e-04	7.03215E-04	7.038236e-04	7.15961E-04	7.169851e-04
U235(n,f)	4.55206E-04	4.558276e-04	4.55012E-04	4.556819e-04	4.55093E-04	4.554169e-04	4.64246E-04	4.642608e-04
U238(n,f)	1.53863E-05	1.538083e-05	1.53682E-05	1.538459e-05	1.53993E-05	1.537944e-05	1.47897E-05	1.479131e-05
U238(n,2n)	7.17097E-07	7.180098e-07	7.22828E-07	7.221305e-07	7.21036E-07	7.201163e-07	6.77982E-07	6.855862e-07
U238(n,γ)	4.85988E-05	4.852248e-05	4.85812E-05	4.850807e-05	4.85716E-05	4.847363e-05	4.78884E-05	4.779877e-05
Np237(n,f)	1.35822E-04	1.358375e-04	1.35786E-04	1.357873e-04	1.36020E-04	1.359250e-04	1.36256E-04	1.358853e-04
Np237(n,2n)	1.19038E-07	1.189710e-07	1.20134E-07	1.200000e-07	1.22429E-07	1.222596e-07	1.15080E-07	1.168701e-07
Pu239(n,f)	5.27392E-04	5.282958e-04	5.27142E-04	5.281160e-04	5.27380E-04	5.278769e-04	5.39157E-04	5.395118e-04
Pu239(n,2n)	1.81638E-07	1.820258e-07	1.83135E-07	1.828760e-07	1.82392E-07	1.824254e-07	2.06188E-07	2.079107e-07
Am241(n,γ)	3.68900E-04	3.693691e-04	3.68802E-04	3.692608e-04	3.51637E-04	3.518523e-04	3.74436E-04	3.761210e-04
P31(n,p)	1.61663E-06	1.613886e-06	1.62902E-06	1.630140e-06	1.53815E-06	1.536143e-06	1.25459E-06	1.257821e-06
V51(n,γ)	2.86845E-06	2.856082e-06	2.93296E-06	2.918927e-06	2.67940E-06	2.667674e-06	2.78946E-06	2.783051e-06
Mn55(n,γ)	3.05295E-06	3.036757e-06	3.05236E-06	3.036331e-06	3.04567E-06	3.033999e-06	3.23172E-06	3.236202e-06
Fe56(n,p)	5.17282E-08	5.177357e-08	5.20382E-08	5.196992e-08	5.17776E-08	5.181867e-08	4.85706E-08	4.894591e-08
Cu63(n,2n)	4.35882E-09	4.482062e-09	4.47971E-09	4.500604e-09	4.10858E-09	4.258323e-09	4.41155E-09	4.400685e-09
Cu63(n,γ)	7.36974E-06	7.353174e-06	7.92305E-06	7.909613e-06	8.17116E-06	8.168701e-06	8.91151E-06	8.875829e-06
Nb93(n,γ)	2.84329E-05	2.838510e-05	2.76194E-05	2.757131e-05	2.89330E-05	2.888170e-05	3.05911E-05	3.050127e-05
Rh103(n,γ)	1.14999E-04	1.150040e-04	1.13786E-04	1.138005e-04	9.34257E-05	9.340386e-05	1.06858E-04	1.067347e-04
Ag107(n,γ)	9.13297E-05	9.135541e-05	7.54451E-05	7.540784e-05	1.03741E-04	1.037237e-04	7.88380E-05	7.931280e-05
Sb121(n,γ)	6.85595E-05	6.848456e-05	6.03967E-05	6.030521e-05	6.94075E-05	6.920962e-05	5.98523E-05	6.073566e-05
La139(n,γ)	4.78463E-06	4.759800e-06	4.21194E-06	4.209298e-06	4.28060E-06	4.277842e-06	4.41832E-06	4.406275e-06
Tm169(n,2n)	1.80558E-07	1.826537e-07	1.85715E-07	1.849371e-07	1.82294E-07	1.823422e-07	1.66349E-07	1.688441e-07
Tm169(n,γ)	1.12461E-04	1.123863e-04	1.11036E-04	1.109715e-04	1.18853E-04	1.188007e-04	1.17211E-04	1.179770e-04
Ir191(n,2n)	2.13077E-07	2.152775e-07	2.07191E-07	2.063810e-07	1.83331E-07	1.835044e-07	1.72359E-07	1.750692e-07
Ir191(n,γ)	1.70726E-04	1.708139e-04	1.70111E-04	1.702055e-04	1.51531E-04	1.514531e-04	1.56369E-04	1.602261e-04
Ir193(n,γ)	1.06321E-04	1.063908e-04	1.06983E-04	1.070370e-04	1.24560E-04	1.244406e-04	1.28691E-04	1.310334e-04
Au197(n,γ)	7.78909E-05	7.791546e-05	7.66503E-05	7.661595e-05	7.68238E-05	7.683628e-05	7.89757E-05	7.886460e-05
Bi209(n,γ)	6.63321E-07	6.641368e-07	6.95984E-07	6.962519e-07	1.01679E-06	1.018136e-06	5.67787E-07	5.652955e-07

Table 7: IMF7-2Z benchmark BigTen-2Z : MCNP5.1.40 and TRIPOLI-4.11 reaction rates calculations using ENDF/B-VIII, JEFF-3.3,TENDL-17 and TENDL-19 libraries

4 Conclusion

The processing of the four libraries JEFF-3.3, ENDF/B-VIII, TENDL-17 and TENDL-19 for use with the Monte Carlo code TRIPOLI-4 gives the opportunity to test these libraries in similar conditions of use. We were able to identify deficiencies, for example for Pu239 of ENDF/B-VIII and TENDL libraries, which were not systematically observed by other Monte Carlo codes coupled to their processing systems. The comparison of some benchmarks containing Plutonium shows a very good agreement between MCNP and TRIPOLI-4 with the same nuclear data libraries. Not surprisingly, the results obtained with the TENDL and ENDF/B-VIII libraries are in a very good agreement, since actinide evaluations are quite similar between the two libraries. Overall, the trends are consistent across the three libraries. In particular, a detailed analysis of reaction rates will provide a better understanding of the differences.

Remarks on PMF benchmarks The TRIPOLI-4 and MCNP results with TENDL-19 and ENDF/B-VIII give very similar results (reaction rates and neutron flux) with the same library. The neutron flux calculated with the JEFF-3.3 library are very different from those obtained with the other libraries even if the keff are quite close (especially for PMF1).
We observe some discrepancies between TENDL-19 and ENDF/B-VIII for a small number of dosimeters in the case of PMF1, which is mainly sensitive to Pu239. For this benchmark, all libraries give very similar keff values.
The Pu240 evaluation has a significant impact on the neutron flux for both JEZEBEL and JEZEBEL-40. The high energy oscillations characteristic of TENDL17 disappear with TENDL19 and we observe fluxes close to the JEFF-3.3 and ENDF/B-VIII libraries.
For the PMF2 benchmark (JEZEBZL-40), the JEFF-3.3 and ENDF/B-VIII libraries give similar results while the two TENDL libraries lead to different results, pointing to other Pu's isotopes.

HMF1-Godiva benchmark keff calculations are in very good agreement for all libraries. On the other hand, once again, the neutron flux is significantly different for the JEFF33 library. Some dosimeters give distinct results between the TENDL and ENDF libraries even if the neutron fluxes seem to be very close.

HMF28-Flattop benchmark We can share the same remarks as on the previous benchmark. We can also note that for the TENDL and ENDF/B-VIII libraries, the TRIPOLI-4 neutron flux slightly overestimates the MCNP flux at the upper energy limit (150 keV) of the U238's URR and underestimates them at the lower energy limit (20keV).

IMF7-Bigten-2Z benchmark We remind the reader that for neutron flux and reaction rate calculations, this is the two-zone homogenized configuration. This benchmark is particularly sensitive to U238 probability tables, with an impact of around 350 pcm for calculations with or without probability tables. We observe again a slope on the T4/MCNP flux ratio for the

TENDL and ENDF/B-VIII libraries with an overestimation of T4 around 150 keV and an underestimation around 20keV, i.e. on the energy range of the U238's URR. It is impossible to determine with this configuration which of the two results is possibly the more correct. The keffs and reaction rates are in good agreement.
It would be interesting to go further in the analysis of the impacts of different approaches in the production of probability tables on even more discriminant configurations.

References

[1] KONING, A. J., ROCHMAN, D., SUBLET, J.-Ch, et al. "TENDL: complete nuclear data library for innovative nuclear science and technology". Nuclear Data Sheets, 2019, **155**, p. 1-55.

[2] Plompen, A. J. M., & al. *The joint evaluated fission and fusion nuclear data library, JEFF-3.3.*, The European Physical Journal A, 2020, **56.7**, 1-108.

[3] BROWN, David A., CHADWICK, M. B., CAPOTE, R., et al. "ENDF/B-VIII. 0: the 8th major release of the nuclear reaction data library with CIELO-project cross sections, new standards and thermal scattering data". Nuclear Data Sheets, 2018, **148**, p. 1-142.

[4] BRUN, E. et al., "Tripoli-4®, CEA, EDF and AREVA reference Monte Carlo code", Annals of Nuclear Energy **82**, 151-160 (2015).

[5] MCNP 5.1.40 RSICC Release Notes, Los Alamos Report, LA-UR-05-8617, (2005).

[6] KAHLER III, A. C. and MACFARLANE, R. NJOY2016. Los Alamos National Lab. (LANL), Los Alamos, NM (United States), 2016. LA-UR-17_20093 (2017).

[7] SUBLET, J.-Ch, RIBON, P., and COSTE-DELCLAUX, M. "CALENDF-2010: user manual". 2011. CEA-R-6277 (2011).

[8] CHADWICK, M. B., HERMAN, M., OBLOŽINSKÝ, P., et al. "ENDF/B-VII. 1 nuclear data for science and technology: cross sections, covariances, fission product yields and decay data". Nuclear data sheets, 2011, **112**, no 12, p. 2887-2996.

[9] BRIGGS, J., et al. "International handbook of evaluated criticality safety benchmark experiments". Nuclear Energy Agency, NEA/NSC/DOC (95), 2004, **3**, p. l.

[10] MCLANE, V. "ENDF-102 data formats and procedures for the evaluated nuclear data file ENDF-6". Brookhaven National Lab., 2001.