IMPACT OF ENDF/B-VII.0 RELEASE ON FUSION EVALUATED NUCLEAR DATA LIBRARY FENDL-2.1

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FENDL-2.1 Background

- Revision to FENDL-2.0 (1995/96)
- Compiled November 2003, INDC(NDS)-451
- 71 elements/isotopes
- Working libraries prepared by IAEA/NDS, see INDC(NDS)-467 (2004)
- Processing performed using NJOY-99.90 at IAEA-NDS and resulting processed files are available in ACE format for MCNP and in MATXS format for multi-group transport calculations (175n-42g)
- New reference data library for ITER neutronics calculations

Data Source for FENDL-2.1

No.	Library	NMAT	Materials
1	ENDF/B-VI.8 (E6)	40	^{2}H, ^{3}H, ^{4}He, ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, ^{11}B, ^{16}O, ^{19}F, $^{28-30}$Si, ^{31}P, S, ^{35,37}Cl, K, $^{50,52-54}$Cr, ^{54,57,58}Fe, ^{59}Co, ^{61,62,64}Ni, ^{63,65}Cu, ^{197}Au, $^{206-208}$Pb, ^{209}Bi, $^{182-184,186}$W
2	JENDL-3.3 (J33)	18	^{1}H, ^{3}He, ^{23}Na, $^{46-50}$Ti, , ^{55}Mn, $^{92,94-98,100}$Mo, ^{181}Ta,V
3	JENDL-3.2 (J32)	3	Mg, Ca, Ga
4	JENDL-FF (JFF)	4	^{12}C, ^{14}N, Zr, ^{93}Nb
5	JEFF-3 (EFF) JEFF3	4	^{27}Al, ^{56}Fe, ^{58}Ni, ^{60}Ni
6	BROND-2.1 (BR2)	2	^{15}N, Sn

- Data for 40 isotopes/elements taken from ENDF/B-VI.8
- ENDF/B-VII.0 library officially released on December 15, 2006
- We examined changes made in data for these 40 isotopes/elements and assessed possible impact on nuclear analysis of ITER and other fusion system

Assessment of changes made in data for the 40 isotopes/elements taken from ENDF/B-VI.8

Isotopes for which data did not change (7 isotopes)

H-2, He-4, Li-7, B-11, Fe-58, Co-59, Bi-209

"ENDF/B-VII CONVERTED FROM ENDF/B-VI BY NNDC OCT 2004"

For the following isotopes only change is in the product energy-angle distributions (MF=6) using corrected gnash code to fix an earlier bug (19 isotopes)

Si-28, Si-29, Si-30, P-31, Cr-50, Cr-52, Cr-53, Cr-54, Fe-54, Fe-57, Ni-61, Ni-62, Ni-64, Cu-63, Cu-65, W-182, W-183, W-184, W-186

"Possible impact is reduced secondary particle production for new ENDF/B-VII release"

Assessment of changes made in data for the 40 isotopes/elements taken from ENDF/B-VI.8

Pb-206, Pb-207: ENDF/B-VII.0 data were taken from JEFF-3.1
Only minor change in cross sections above ~5 MeV

S-32, S-33, S-34, S-36, K-39, K-40, K-41: Only isotopic data provided in ENDF/B-VII.0 for S and K
Data for S and K isotopes taken from JENDL-3.3 with Large changes in cross sections

H-3: Large changes in elastic scattering and (n,2n) cross sections with expected impact on inertial confinement fusion (ICF) target neutronics

Li-6: Minor changes in (n,t) cross sections observed at very low and high energies that could lead to minor impact on predicting tritium production in breeding blankets

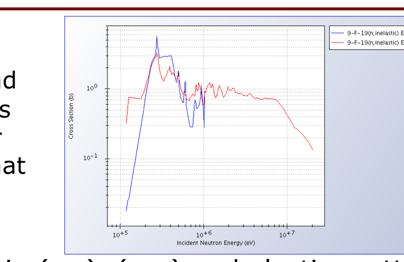
Be-9: Only minor change in elastic scattering

B-10: Only minor change in (n,α) and elastic scattering

O-16: Only minor change in (n,α) and elastic scattering

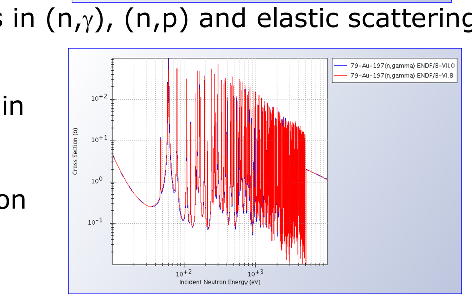
Assessment of changes made in data for the 40 isotopes/elements taken from ENDF/B-VI.8

F-19: Large changes in (n,γ) and inelastic scattering cross sections observed with impact on nuclear analysis for breeding blankets that utilize Flibe



Cl-35, Cl-37: Large changes in (n,γ), (n,p) and elastic scattering cross sections

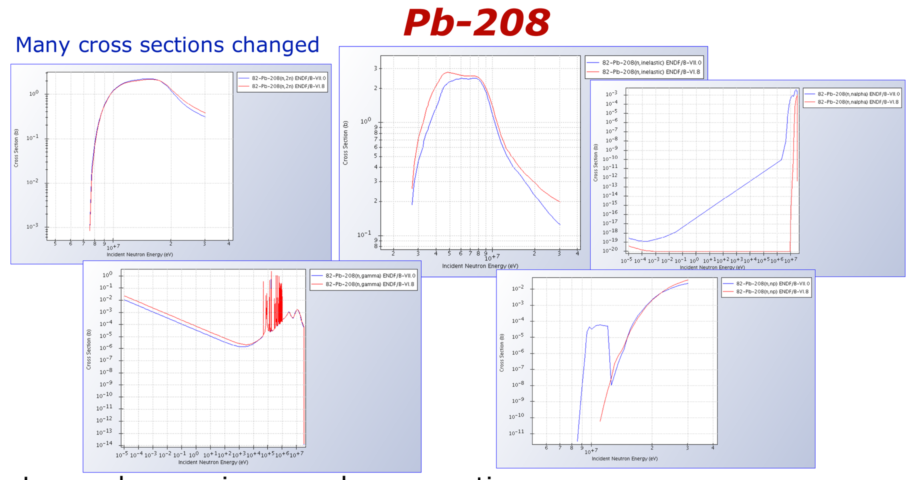
Au-197: Moderate changes in (n,γ) and elastic scattering cross sections in resonance region with possible impact on ICF target neutronics



Assessment of changes made in data for the 40 isotopes/elements taken from ENDF/B-VI.8

Many cross sections changed

Pb-208



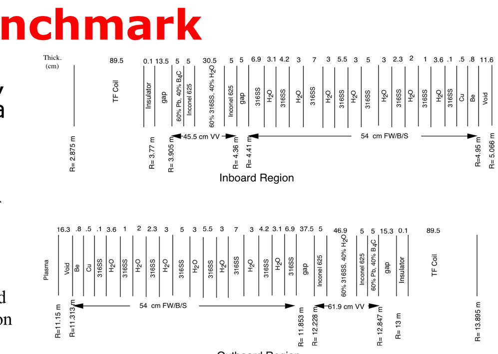
Large changes in several cross sections
Possible impact on analysis for breeding blankets with PbLi

Findings of Data Comparison

- Minor impact on ITER nuclear analysis is expected except for ITER-TBM nuclear analysis due to changes in data for Li-6, Pb-208, and F-19
- Effects of changes could be large in other fusion systems
  - Power plants with breeding blankets
  - Inertial fusion systems (e.g., H-3 and Au-197 data are important for ICF target neutronics)

Analysis for ITER Calculational Benchmark

To quantify these observations, we performed calculations for a 1-D cylindrical geometry calculational benchmark representative of an early ITER design that was utilized during FENDL development process
M. Sawan, "FENDL Neutronics Benchmark: Specifications for the Calculational Neutronics and Shielding Benchmark," IAEA Nuclear Data Section Report INDC(NDS)-316 (December 1994).



- This benchmark problem has been mainly used in discrete ordinate calculations using FENDL multi-group data
- FZK prepared MCNP geometry input and compared nuclear responses using the different versions of FENDL, namely FENDL-1.0, 2.0 and 2.1
- We used this MCNP model to carry out calculations using the FENDL-2.1 library with data for the 40 isotopes/elements replaced by the recent data from ENDF/B-VII.0 processed by NJOY-99.161

Peak Neutron and Gamma Flux Results

	FENDL-2.1		FENDL-2.1 +ENDF/B-VII.0		% Change	FENDL-2.1		FENDL-2.1 +ENDF/B-VII.0		% Change
	Neutron Flux	% Error	Neutron Flux	% Error		Gamma Flux	% Error	Gamma Flux	% Error	
IB										
FW										
Be	3.52E+14	0.05%	3.52E+14	0.05%	0.05%	3.18E+14	0.05%	3.18E+14	0.05%	0.12%
Cu	3.09E+14	0.05%	3.09E+14	0.05%	0.08%	3.08E+14	0.05%	3.08E+14	0.05%	0.10%
SS	2.96E+14	0.06%	2.96E+14	0.06%	0.10%	3.07E+14	0.06%	3.07E+14	0.06%	0.09%
VV	8.43E+11	0.19%	8.46E+11	0.19%	0.29%	4.84E+11	0.17%	4.85E+11	0.17%	0.26%
Magnet	3.42E+09	0.45%	3.45E+09	0.45%	1.04%	9.34E+08	0.42%	9.41E+08	0.42%	0.71%
OB										
FW										
Be	4.37E+14	0.03%	4.37E+14	0.03%	0.12%	3.61E+14	0.04%	3.62E+14	0.04%	0.15%
Cu	3.95E+14	0.03%	3.95E+14	0.03%	0.13%	3.60E+14	0.04%	3.61E+14	0.04%	0.14%
SS	3.80E+14	0.03%	3.80E+14	0.03%	0.14%	3.66E+14	0.04%	3.66E+14	0.04%	0.13%
VV	1.17E+12	0.09%	1.17E+12	0.09%	0.34%	6.60E+11	0.08%	6.62E+11	0.08%	0.27%
Magnet	4.93E+08	0.41%	4.97E+08	0.41%	0.79%	1.38E+08	0.40%	1.39E+08	0.40%	0.49%

Using ENDF/B-VII.0 data results in slightly higher flux values. However, the change is <1% with much smaller differences at the front FW zones facing the plasma

Nuclear Heating, Radiation Damage and Gas Production Results

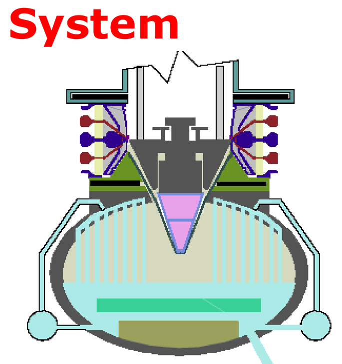
- Comparison of calculated nuclear heating showed large differences with ~55%, ~10%, and ~4% reduction for the Be, Cu, and SS zones of FW and smaller differences in VV and magnet
- Differences in gamma heating are negligible (<0.5%) and large differences in total heating are fully attributed to differences in neutron heating
- This large difference was attributed to a bug in versions of NJOY between 99.115 and 99.180 that led to erroneously low neutron heating values. This bug was fixed in subsequent versions of NJOY and new ACE formatted data are being processed
- Comparing dpa results showed also large reductions of ~70% in Cu dpa and ~ 6% in Fe dpa. This is due to the bug in HEATER module of NJOY

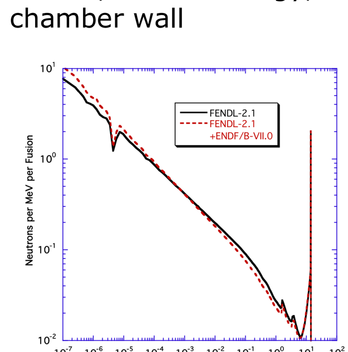
Calculated gas production rates (helium, hydrogen, and tritium) were very close using the two libraries

	FENDL-2.1		FENDL-2.1 +ENDF/B-VII.0		% Change
	He Prod.	% Error	He Prod.	% Error	
IB					
FW					
Be	4.10E+03	0.07%	4.10E+03	0.07%	0.06%
Cu	2.10E+02	0.07%	2.10E+02	0.07%	0.04%
SS	1.77E+02	0.06%	1.77E+02	0.06%	0.05%
VV SS	7.62E-02	0.22%	7.63E-02	0.22%	0.18%
Magnet	3.30E-04	0.63%	3.36E-04	0.62%	1.72%
OB					
FW					
Be	5.98E+03	0.03%	5.98E+03	0.03%	0.06%
Cu	3.23E+02	0.03%	3.23E+02	0.03%	0.04%
SS	2.45E+02	0.03%	2.45E+02	0.03%	0.03%
VV SS	1.08E-01	0.11%	1.08E-01	0.11%	0.28%
Magnet	4.86E-05	0.59%	4.94E-05	0.58%	1.69%

Analysis for ICF System

- We performed 3-D calculations for the chamber of a power plant concept that utilizes the Z-pinch driven inertial confinement technology
- Thick PbLi jets are utilized to breed tritium, absorb energy, and shield the chamber wall

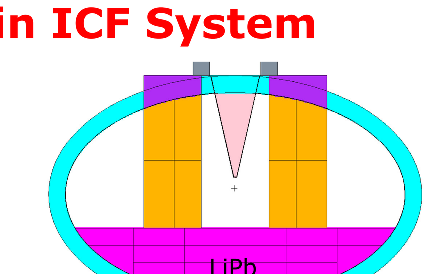




- Changes in ENDF/B-VII.0 result in softer neutron spectrum emitted from target
- Total number of neutrons emitted from target per fusion reduces from 1.047 to 1.039. This is primarily due to reduced neutron multiplication in tritium. Gamma production in target per fusion changed slightly from 4.73×10^{-3} to 4.75×10^{-3}

Tritium Breeding, Nuclear Heating and Damage in ICF System

	FENDL-2.1		FENDL-2.1+ENDF/B-VII.0		% Change
	Tritons per fusion	% error	Tritons per fusion	% error	
Jets	7.13E-01	0.12%	7.15E-01	0.12%	0.28%
Nozzle	5.32E-02	0.27%	5.46E-02	0.27%	2.59%
Pool	3.64E-01	0.21%	3.75E-01	0.21%	3.20%
RTL	5.44E-03	0.27%	5.42E-03	0.27%	0.52%
TBR	1.14E+00		1.15E+00		1.32%



- Tritium breeding in different PbLi zones was calculated
- The overall TBR increased by 1.32%
- Changes in nuclear heating and dpa rates are much higher (up to ~70%) and are caused by the bug in the NJOY version used for processing ENDF/B-VII.0
- Peak He production in chamber wall changed only by 0.08%
- Fast neutron (E>0.1 MeV) fluence at the insulator stack increased by 2%

Conclusions

- Modifying FENDL-2.1 to include the most recent ENDF/B-VII.0 is not urgently needed for ITER analysis
- The larger changes in calculated ICF target neutronics parameters and tritium breeding confirm the need for updating FENDL-2.1 for use in analysis of fusion systems beyond ITER
- Additional calculations are in progress for 3 integral experimental benchmarks to fully understand the impact of data changes introduced in ENDF/B-VII.0 as compared against experimental data