Validation and Testing of the Starter FENDL-3.0 General Purpose Neutron Library

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Fusion Evaluated Nuclear Data Library (FENDL)

- FENDL-2.1 is revision to FENDL-2.0 (1995/96)
- Compiled November 2003, INDC(NDS)-451
- 71 elements/isotopes
- Working libraries prepared by IAEA/NDS, INDC(NDS)-467 (2004)
- Reference data library for nuclear analysis of ITER and other fusion systems

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, $^{28\text{-}30}$Si, ^{31}P, S, ^{35,37}Cl, K, $^{50,52\text{-}54}$Cr, ^{54,57,58}Fe, ^{59}Co, ^{61,62,64}Ni, ^{63,65}Cu, ^{197}Au, $^{206\text{-}208}$Pb, ^{209}Bi, $^{182\text{-}184,186}$W
2	JENDL-3.3 (J33)	18	^{1}H, ^{3}He, ^{23}Na, $^{46\text{-}50}$Ti, , ^{55}Mn, $^{92,94\text{-}98,100}$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

- The International Atomic Energy Agency (IAEA) in cooperation with several national nuclear data centers and research groups started an effort in 1987 to develop the Fusion Evaluated Nuclear Data Library (FENDL)
- Validated using ITER computational benchmark and integral experiments with 14 MeV point sources in Europe and Japan

FENDL-3 Development

(http://www-nds.iaea.org/fendl3/)

- An effort was initiated by the IAEA in 2008 to update the FENDL library to improve status of nuclear databases for fusion devices including IFMIF
- The library (FENDL-3) is a substantial extension of FENDL-2.1 library toward higher energies, with inclusion of incident charged particles and the evaluation of related uncertainties (covariance data)
- A starter FENDL-3 with 180 isotopes was released at the end of the 3 years of the Coordinated Research Project (CRP) activities and the fourth release is being validated and tested

FENDL-3.0 Content

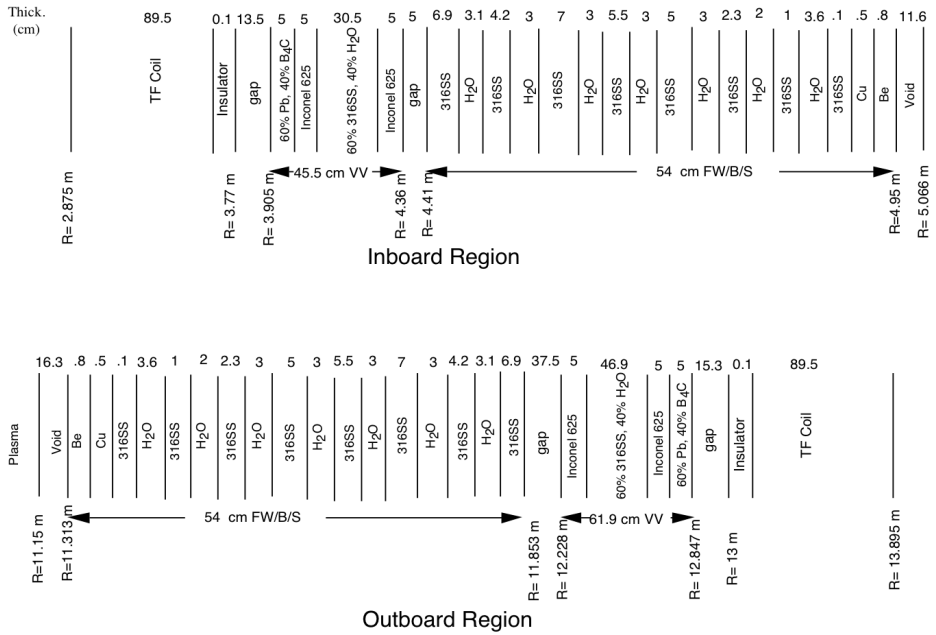
FENDL-3 (neutron) working files (Update: 2012-05-29)

#)	MAT	Material	Lab.	Date	Authors	Source	Emax(eV)	Size	File
1)	125	1-H-1	LANL	EVAL-OCT05	G.M.Hale	FENDL-3.0	1.50E+08	58kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
2)	128	1-H-2	LANL	EVAL-FEB97	P.G.Young,G.M.Hale,M.B.Chadwick	ENDF/B-VII	1.50E+08	85kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
3)	131	1-H-3	LANL	EVAL-NOV01	G.M.Hale	ENDF/B-VII	6.00E+07	99kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
4)	225	2-He-3	JAERI	EVAL-JUN87	K.SHIBATA	JENDL-4	6.00E+07	41kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
5)	228	2-He-4	LANL	EVAL-SEP10	Hale	ENDF/B-VII	6.00E+07	227kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
6)	325	3-Li-6	LANL	EVAL-APR06	G.M.Hale,P.G.Young	FENDL-3.0	2.00E+08	1432kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
7)	328	3-Li-7	LANL	EVAL-AUG88	P.G.Young	FENDL-3.0	2.00E+08	1066kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
8)	425	4-Be-9	LLNL,LANL	EVAL-OCT09	G.HALE,PERKINS ET AL,FRANKLE	FENDL-3.0	2.00E+08	1961kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
9)	525	5-B-10	LANL	EVAL-APR06	G.M.Hale,P.G.Young	FENDL-3.0	2.00E+08	1483kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
10)	528	5-B-11	LANL	EVAL-MAY89	P.G.Young	FENDL-3.0	2.00E+08	1519kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
11)	625	6-C-12	Kyushu U.	EVAL-JUL03	Y.Watanabe	FENDL-3.0	1.50E+08	6082kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
12)	628	6-C-13	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	1632kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
13)	715	7-N-15	LANL	EVAL-DEC05	V.KOSCHEEV	FENDL-3.0	2.00E+08	1249kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
14)	725	7-N-14	JNDC	EVAL-JUN89	Y.KANDA(KYU) T.MURATA(NAIG)+	FENDL-3.0	1.50E+08	8185kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
15)	825	8-O-16	LANL	EVAL-DEC05	Hale,Young,Chadwick,Caro,Lubitz	ENDF/B-VII	1.50E+08	2986kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
16)	828	8-O-17	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	2134kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
17)	831	8-O-18	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	1933kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
18)	925	9-F-19	CNDC,ORNL	EVAL-OCT03	Z.X.Zhao,C.Y.Fu,D.C.Larson,Leal+	FENDL-3.0	1.50E+08	5963kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
19)	1125	11-NA-23	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	FENDL-3.0	1.50E+08	6073kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
20)	1225	12-MG-24	KYUSHU	EVAL-DEC 3	Sun Weili,Y.Watanabe	FENDL-3.0	1.50E+08	11481kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
21)	1228	12-MG-25	KYUSHU	EVAL-DEC 3	Sun Weili,Y.Watanabe	FENDL-3.0	1.50E+08	11423kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
22)	1231	12-MG-26	KYUSHU	EVAL-DEC 3	Sun Weili,Y.Watanabe	FENDL-3.0	1.50E+08	11291kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
23)	1325	13-Al-27	LANL	EVAL-FEB97	M.B.CHADWICK & P.G.YOUNG	JEFF-311	1.50E+08	2195kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
24)	1425	14-Si-28	LANL,ORNL	EVAL-DEC02	M.B.Chadwick,P.G.Young,D.Hetrick	ENDF/B-VII	1.50E+08	1870kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
25)	1428	14-Si-29	LANL,ORNL	EVAL-JUN97	M.B.Chadwick,P.G.Young,D.Hetrick	ENDF/B-VII	1.50E+08	1846kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
26)	1431	14-Si-30	LANL,ORNL	EVAL-JUN97	M.B.Chadwick,P.G.Young,D.Hetrick	ENDF/B-VII	1.50E+08	1570kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
27)	1525	15-P-31	NRG	EVAL-OCT10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	2443kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
28)	1625	16-S-32	NRG	EVAL-OCT10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	2514kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
29)	1628	16-S-33	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	2685kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
30)	1631	16-S-34	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	2322kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
31)	1637	16-S-36	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	2093kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
32)	1725	17-Cl-35	ORNL,LANL	EVAL-OCT03	Sayer,Guber,Leal,Larson,Young+	FENDL-3.0	1.50E+08	10829kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
33)	1731	17-Cl-37	ORNL,LANL	EVAL-OCT03	Sayer,Guber,Leal,Larson,Young+	FENDL-3.0	1.50E+08	7423kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
34)	1825	18-AR-36	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	FENDL-3.0	1.50E+08	5719kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
35)	1831	18-AR-38	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	FENDL-3.0	1.50E+08	5703kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
36)	1837	18-AR-40	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	FENDL-3.0	1.50E+08	5539kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
37)	1925	19-K-39	NRG	EVAL-FEB12	A.J.Koning,D.Rochman	TENDL-2012	2.00E+08	2958kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
38)	1928	19-K-40	NRG	EVAL-FEB12	A.J.Koning,D.Rochman	TENDL-2012	2.00E+08	3197kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
39)	1931	19-K-41	NRG	EVAL-FEB12	A.J.Koning,D.Rochman	TENDL-2012	2.00E+08	2913kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
40)	2025	20-CA-40	SAEI	EVAL-MAY 3	K.Kosako	FENDL-3.0	1.50E+08	6164kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
41)	2031	20-CA-42	SAEI	EVAL-MAY 3	K.Kosako	FENDL-3.0	1.50E+08	6350kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
42)	2034	20-CA-43	SAEI	EVAL-MAY 3	K.Kosako	FENDL-3.0	1.50E+08	6413kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
43)	2037	20-CA-44	SAEI	EVAL-MAY 3	K.Kosako	FENDL-3.0	1.50E+08	6003kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
44)	2043	20-CA-46	SAEI	EVAL-MAY 3	K.Kosako	FENDL-3.0	1.50E+08	5689kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
45)	2049	20-CA-48	SAEI	EVAL-MAY 3	K.Kosako	FENDL-3.0	1.50E+08	5394kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
46)	2125	21-Sc-45	NRG	EVAL-OCT04	A.J.Koning	JEFF-311	2.00E+08	2204kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
47)	2225	22-Ti-46	LANL	EVAL-Feb09	T.Kawano,S-Y.Oh,A.Kahler	FENDL-3.0	1.50E+08	5984kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
48)	2228	22-Ti-47	LANL	EVAL-Feb09	T.Kawano,S-Y.Oh,A.Kahler	FENDL-3.0	1.50E+08	6160kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
49)	2231	22-Ti-48	LANL,ORNL	EVAL-Aug10	T.Kawano,L.Leal,A.Kahler	FENDL-3.0	1.50E+08	5935kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
50)	2234	22-Ti-49	LANL	EVAL-Feb09	T.Kawano,S-Y.Oh,A.Kahler	FENDL-3.0	1.50E+08	6002kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
51)	2237	22-Ti-50	LANL	EVAL-Feb09	T.Kawano,S-Y.Oh,A.Kahler	FENDL-3.0	1.50E+08	5762kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
52)	2300	23-V-51	SAEI	EVAL-MAY 3	K.Kosako	FENDL-3.0	1.50E+08	7285kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
53)	2325	23-V-50	JAEA	EVAL-Mar10	N.Iwamoto	FENDL-3.0	2.00E+08	3222kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
54)	2425	24-Cr-50	KIT	EVAL-MAR10	P.Pereslavtsev,A.Konobeyev	KIT-2010	2.00E+08	18537kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
55)	2431	24-Cr-52	FZK/INR	EVAL-APR09	P.Pereslavtsev et al.	ENDF/A-1	1.50E+08	12766kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
56)	2434	24-Cr-53	KIT	EVAL-MAR10	P.Pereslavtsev,A.Konobeyev	KIT-2010	2.00E+08	16892kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
57)	2437	24-Cr-54	KIT	EVAL-MAR10	P.Pereslavtsev,A.Konobeyev	KIT-2010	2.00E+08	9710kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
58)	2525	25-Mn-55	IAEA	Eval-Feb11	IAEA Evaluation Consortium	INDL/V-3	6.00E+07	6282kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
59)	2625	26-Fe-54	LANL,ORNL	EVAL-SEP96	M.B.Chadwick,P.G.Young,D.Hetrick	ENDF/B-VII	1.50E+08	1877kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
60)	2631	26-Fe-56	NRG	EVAL-FEB04	EUROPEAN JOINT COLLABORATION	FENDL-3.0	1.50E+08	9068kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
61)	2634	26-Fe-57	LANL,ORNL	EVAL-SEP96	M.B.Chadwick,P.G.YOung,D.Hetrick	ENDF/B-VII	1.50E+08	2169kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
62)	2637	26-Fe-58	NRG	EVAL-OCT04	A.J.Koning	JEFF-311	2.00E+08	1816kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
63)	2725	27-Co-59	ANL,ORNL	EVAL-JUL89	A.Smith+,G.Desaussure+	FENDL-3.0	1.50E+08	5631kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
64)	2825	28-Ni-58	LANL,ORNL	EVAL-SEP97	S.Chiba,M.B.Chadwick,Larson	ENDF/B-VII	1.50E+08	17187kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
65)	2831	28-Ni-60	LANL,ORNL	EVAL-SEP97	S.Chiba,M.B.Chadwick,Larson	ENDF/B-VII	1.50E+08	16571kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
66)	2834	28-Ni-61	LANL,ORNL	EVAL-SEP97	S.Chiba,M.B.Chadwick,Hetrick	ENDF/B-VII	1.50E+08	2090kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
67)	2837	28-Ni-62	LANL,ORNL	EVAL-SEP97	S.Chiba,M.B.Chadwick,Hetrick	ENDF/B-VII	1.50E+08	1842kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
68)	2843	28-Ni-64	LANL,ORNL	EVAL-SEP97	S.Chiba,M.B.Chadwick,Hetrick	ENDF/B-VII	1.50E+08	1848kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
69)	2925	29-Cu-63	LANL,ORNL	EVAL-FEB98	A.Koning,M.Chadwick,Hetrick	ENDF/B-VII	1.50E+08	2034kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
70)	2931	29-Cu-65	LANL,ORNL	EVAL-FEB98	A.Koning,M.Chadwick,Hetrick	ENDF/B-VII	1.50E+08	1954kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
71)	3025	30-ZN-64	SIT.SHIMZ	EVAL-AUG 7	K.Kosako	FENDL-3.0	1.50E+08	6800kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
72)	3031	30-ZN-66	SIT.SHIMZ	EVAL-AUG 7	K.Kosako	FENDL-3.0	1.50E+08	6082kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
73)	3034	30-ZN-67	SIT.SHIMZ	EVAL-AUG 7	K.Kosako	FENDL-3.0	1.50E+08	6326kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
74)	3037	30-ZN-68	SIT.SHIMZ	EVAL-AUG 7	K.Kosako	FENDL-3.0	1.50E+08	6235kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
75)	3043	30-ZN-70	SIT.SHIMZ	EVAL-AUG 7	K.Kosako	FENDL-3.0	1.50E+08	5731kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
76)	3125	31-GA-69	SIT.SHIMZ	EVAL-MAY 7	K.Kosako	FENDL-3.0	1.50E+08	5466kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
77)	3131	31-GA-71	SIT.SHIMZ	EVAL-MAY 7	K.Kosako	FENDL-3.0	1.50E+08	5476kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
78)	3225	32-Ge-70	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2335kb	[endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]

FENDL-3.0 Content

78)	3225	32-Ge-70	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2335kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
79)	3231	32-Ge-72	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2091kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
80)	3234	32-Ge-73	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2266kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
81)	3237	32-Ge-74	NRG	EVAL-OCT04	A.J.Koning	JEFF-311	2.00E+08	1882kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
82)	3243	32-Ge-76	NRG	EVAL-OCT04	A.J.Koning	JEFF-311	2.00E+08	1702kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
83)	3525	35-Br-79	JAEA	EVAL-AUG09	K.Shibata,A.Ichihara,S.Kunieda	JENDL-4	2.00E+08	2191kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
84)	3531	35-Br-81	JAEA	EVAL-AUG09	K.Shibata,A.Ichihara,S.Kunieda	JENDL-4	2.00E+08	2127kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
85)	3925	39-Y-89	BNL-LANL	EVAL-AUG06	Rochman,Chadwick,Herman,Kawano+	FENDL-3.0	2.00E+08	5091kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
86)	4025	40-Zr-90	JNDC	EVAL-AUG89	JNDC FP NUCLEAR DATA W.G.	FENDL-3.0	1.50E+08	6572kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
87)	4028	40-Zr-91	JAEA	EVAL-JUL 7	S.Kunieda	ENDF/B-III	1.50E+08	6591kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
88)	4031	40-Zr-92	JAEA	EVAL-JUL 7	S.Kunieda	ENDF/B-III	1.50E+08	6608kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
89)	4037	40-Zr-94	JAEA	EVAL-JUL 7	S.Kunieda	ENDF/B-III	1.50E+08	6645kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
90)	4043	40-Zr-96	JAEA	EVAL-JUL 7	S.Kunieda	ENDF/B-III	1.50E+08	6615kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
91)	4125	41-Nb-93	JAEA	EVAL-JUL 7	S.Kunieda	ENDF/B-III	1.50E+08	6623kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
92)	4225	42-Mo-92	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	JENDL-3	1.50E+08	5417kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
93)	4231	42-Mo-94	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	JENDL-3	1.50E+08	5418kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
94)	4234	42-Mo-95	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	JENDL-3	1.50E+08	5582kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
95)	4237	42-Mo-96	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	JENDL-3	1.50E+08	5498kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
96)	4240	42-Mo-97	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	JENDL-3	1.50E+08	5589kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
97)	4243	42-Mo-98	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	JENDL-3	1.50E+08	5412kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
98)	4249	42-Mo-100	SIT.SHIMZ	EVAL-MAY 6	K.Kosako	JENDL-3	1.50E+08	5470kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
99)	4525	45-Rh-103	CAD,BRC,+	EVAL-FEB05	E.DUPONT,E.BAUGE,M.C.Moxon	FENDL-3.0	2.00E+08	5605kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
100)	4725	47-Ag-107	JAERI,BNL	EVAL-MAR05	Liu+,Mughabghab	FENDL-3.0	2.00E+08	2260kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
101)	4731	47-Ag-109	BNL,KAERI	EVAL-FEB06	Kim,Herman,Oh,Mughabghab+	FENDL-3.0	2.00E+08	3551kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
102)	4825	48-Cd-106	IRMM,JNDC	EVAL-OCT10	I.Sirakov,S.Kopecky+,JNDC FPND WG	FENDL-3.0	2.00E+08	2032kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
103)	4831	48-Cd-108	IRMM,UA,ANL	EVAL-OCT10	I.Sirakov,S.Kopecky+,J.McCabe+	FENDL-3.0	2.00E+08	1726kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
104)	4837	48-Cd-110	IRMM,UA,ANL	EVAL-OCT10	I.Sirakov,S.Kopecky+,J.McCabe+	FENDL-3.0	2.00E+08	1724kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
105)	4840	48-Cd-111	IRMM,JNDC	EVAL-OCT10	I.Sirakov,S.Kopecky+,JNDC FPND WG	FENDL-3.0	2.00E+08	1998kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
106)	4843	48-Cd-112	IRMM,UA,ANL	EVAL-OCT10	I.Sirakov,S.Kopecky+,J.McCabe+	FENDL-3.0	2.00E+08	1661kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
107)	4846	48-Cd-113	BNL, CNDL	EVAL-MAR05	Mughabghab,J.W.Zhao+,	FENDL-3.0	2.00E+08	2316kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
108)	4849	48-Cd-114	IRMM,UA,ANL	EVAL-OCT10	I.Sirakov,S.Kopecky+,J.McCabe+	FENDL-3.0	2.00E+08	1646kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
109)	4855	48-Cd-116	IRMM,UA,ANL	EVAL-OCT10	I.Sirakov,S.Kopecky+,J.McCabe+	FENDL-3.0	2.00E+08	1613kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
110)	5025	50-Sn-112	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	3341kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
111)	5031	50-Sn-114	JAEA	EVAL-Dec09	N.Iwamoto	FENDL-3.0	2.00E+08	3515kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
112)	5034	50-Sn-115	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	3759kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
113)	5037	50-Sn-116	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	3313kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
114)	5040	50-Sn-117	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	3212kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
115)	5043	50-Sn-118	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	3302kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
116)	5046	50-Sn-119	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	3080kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
117)	5049	50-Sn-120	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	2976kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
118)	5055	50-Sn-122	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	2814kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
119)	5061	50-Sn-124	JAEA	EVAL-Dec09	N.Iwamoto,K.Shibata	FENDL-3.0	2.00E+08	2653kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
120)	5125	51-Sb-121	CNDC,BNL	EVAL-DEC04	Zhao+,Mughabghab	FENDL-3.0	2.00E+08	2107kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
121)	5131	51-Sb-123	CNDC,BNL	EVAL-DEC04	Zhang+,Mughabghab	FENDL-3.0	2.00E+08	2024kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
122)	5325	53-I-127	LANL,BNL	EVAL-JAN05	Young,MacFarlane,Mughabghab	FENDL-3.0	2.00E+08	3215kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
123)	5525	55-Cs-133	JAEA+	EVAL-Apr09	N.Iwamoto,H.Matsunobu	FENDL-3.0	2.00E+08	5220kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
124)	5625	56-Ba-130	JNDC,BNL	EVAL-JAN05	JNDC FPND W.G.,Mughabghab	FENDL-3.0	2.00E+08	1793kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
125)	5631	56-Ba-132	JNDC,BNL	EVAL-JAN05	JNDC FPND W.G.,Mughabghab	FENDL-3.0	2.00E+08	1792kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
126)	5637	56-Ba-134	JNDC,BNL	EVAL-JAN05	JNDC FPND W.G.,Mughabghab	FENDL-3.0	2.00E+08	1819kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
127)	5640	56-Ba-135	JNDC,BNL	EVAL-JAN05	JNDC FPND W.G.,Mughabghab	FENDL-3.0	2.00E+08	1824kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
128)	5643	56-Ba-136	JNDC,BNL	EVAL-JAN05	JNDC FPND W.G.,Mughabghab	FENDL-3.0	2.00E+08	1800kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
129)	5646	56-Ba-137	JNDC,BNL	EVAL-JAN05	JNDC FPND W.G.,Mughabghab	FENDL-3.0	2.00E+08	1779kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
130)	5649	56-Ba-138	CNDC,BNL	EVAL-JAN05	W.N.Su+,Mughabghab	FENDL-3.0	2.00E+08	1771kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
131)	5725	57-La-138	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3242kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
132)	5728	57-La-139	NRG	EVAL-OCT10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3049kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
133)	5825	58-Ce-136	BNL	EVAL-MAR06	Herman,Oblozinsky,Mughabghab	FENDL-3.0	2.00E+08	3552kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
134)	5831	58-Ce-138	BNL	EVAL-MAR06	Herman,Oblozinsky,Mughabghab	FENDL-3.0	2.00E+08	3700kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
135)	5837	58-Ce-140	JNDC,BNL	EVAL-JAN05	JNDC FPND W.G.,Mughabghab	FENDL-3.0	2.00E+08	1813kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
136)	5843	58-Ce-142	JNDC,BNL	EVAL-JAN05	JNDC FPND W.G.,Mughabghab	FENDL-3.0	2.00E+08	1766kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
137)	6425	64-Gd-152	JAEA+	EVAL-Dec09	N.Iwamoto,A.Zukeran,K.Shibata	FENDL-3.0	2.00E+08	4016kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
138)	6431	64-Gd-154	JAEA+	EVAL-Dec09	N.Iwamoto,A.Zukeran,K.Shibata	FENDL-3.0	2.00E+08	3567kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
139)	6434	64-Gd-155	JAEA+	EVAL-Dec09	N.Iwamoto,A.Zukeran,K.Shibata	FENDL-3.0	2.00E+08	4084kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
140)	6437	64-Gd-156	JAEA+	EVAL-Dec09	N.Iwamoto,A.Zukeran,K.Shibata	FENDL-3.0	2.00E+08	3588kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
141)	6440	64-Gd-157	JAEA+	EVAL-Dec09	N.Iwamoto,A.Zukeran,K.Shibata	FENDL-3.0	2.00E+08	3407kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
142)	6443	64-Gd-158	JAEA+	EVAL-Dec09	N.Iwamoto,A.Zukeran,K.Shibata	FENDL-3.0	2.00E+08	3091kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
143)	6449	64-Gd-160	JAEA+	EVAL-Dec09	N.Iwamoto,A.Zukeran,K.Shibata	FENDL-3.0	2.00E+08	2748kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
144)	6825	68-Er-162	TIT	EVAL-SEP00	A.K.M.Harun-Ar-Rashid+	FENDL-3.0	2.00E+08	2147kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
145)	6831	68-Er-164	TIT	EVAL-SEP00	A.K.M.Harun-Ar-Rashid+	FENDL-3.0	2.00E+08	2094kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
146)	6837	68-Er-166	TIT,BNL	EVAL-JAN05	Harun-Ar-Rashid+,Mughabghab	FENDL-3.0	2.00E+08	2178kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
147)	6840	68-Er-167	TIT,BNL	EVAL-JAN05	Harun-Ar-Rashid+,Mughabghab	FENDL-3.0	2.00E+08	2247kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
148)	6843	68-Er-168	TIT,BNL	EVAL-JAN05	Harun-Ar-Rashid+,Mughabghab	FENDL-3.0	2.00E+08	2153kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
149)	6849	68-Er-170	TIT,BNL	EVAL-JAN05	Harun-Ar-Rashid+,Mughabghab	FENDL-3.0	2.00E+08	1977kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
150)	7125	71-Lu-175	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3282kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
151)	7128	71-Lu-176	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3185kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
152)	7225	72-Hf-174	JAEA	EVAL-JUL09	K.Shibata (JAEA)	JENDL-4	2.00E+08	2198kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
153)	7231	72-Hf-176	JAEA	EVAL-JUL09	K.Shibata (JAEA)	JENDL-4	2.00E+08	2193kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
154)	7234	72-Hf-177	JAEA	EVAL-JUL09	K.Shibata (JAEA)	JENDL-4	2.00E+08	2079kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
155)	7237	72-Hf-178	JAEA	EVAL-AUG09	K.Shibata (JAEA)	JENDL-4	2.00E+08	2216kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
156)	7240	72-Hf-179	JAEA	EVAL-JUL09	K.Shibata (JAEA)	JENDL-4	2.00E+08	2167kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
157)	7243	72-Hf-180	JAEA	EVAL-JUL09	K.Shibata (JAEA)	JENDL-4	2.00E+08	2193kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
158)	7328	73-TA-181	JAEA	EVAL-JUL 6	S.Chiba,Y.Watanabe,T.Fukahori	FENDL-3.0	1.50E+08	6408kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
159)	7425	74-W-180	IAEA	Eval090806		INDL/V-3	1.50E+08	9153kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
160)	7431	74-W-182	IAEA	Eval090806		INDL/V-3	1.50E+08	9549kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
161)	7434	74-W-183	IAEA	Eval090806		INDL/V-3	1.50E+08	10160kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
162)	7437	74-W-184	IAEA	Eval090806		INDL/V-3	1.50E+08	8494kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
163)	7443	74-W-186	IAEA	Eval090806		INDL/V-3	1.50E+08	9618kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
164)	7525	75-Re-185	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3175kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
165)	7531	75-Re-187	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3089kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
166)	7825	78-Pt-190	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3306kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
167)	7831	78-Pt-192	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3155kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
168)	7837	78-Pt-194	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3006kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
169)	7840	78-Pt-195	NRG	EVAL-OCT10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	3077kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
170)	7843	78-Pt-196	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	2867kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
171)	7849	78-Pt-198	NRG	EVAL-NOV10	A.J.Koning,D.Rochman	TENDL-2010	2.00E+08	2719kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
172)	7925	79-Au-197	LANL	EVAL-JAN84	P.G.Young	FENDL-3.0	1.50E+08	7170kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
173)	8225	82-Pb-204	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2405kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
174)	8231	82-Pb-206	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2430kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
175)	8234	82-Pb-207	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2212kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
176)	8237	82-Pb-208	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2009kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
177)	8325	83-Bi-209	NRG	EVAL-DEC04	A.J.Koning	JEFF-311	2.00E+08	2632kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
178)	9040	90-Th-232	IAEA	Eval-Feb06	CRP/Th-U Co-ordinator A.Trkov	INDL/V-3	6.00E+07	13592kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
179)	9228	92-U-235	ORNL,LANL,+	EVAL-SEP06	Young,Chadwick,Talou,Madland,Leal	FENDL-3.0	1.50E+08	69737kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]
180)	9237	92-U-238	ORNL,LANL+	EVAL-SEP06	Young,Chadwick,Derrien,Courcelle	FENDL-3.0	1.50E+08	48649kb [endf][ace][xdr][gendf][matxs][fig:ace,htr][njoy:inp,out]

ITER Computational Benchmark



- FENDL-2.1 is the reference library for ITER
- Results for flux, heating, dpa, and gas production were compared to the results of FENDL-2.1
- Results provide guidance to ITER regarding the need of changing the reference library to FENDL-3.0 or just adding a correction/safety factor to the the current results

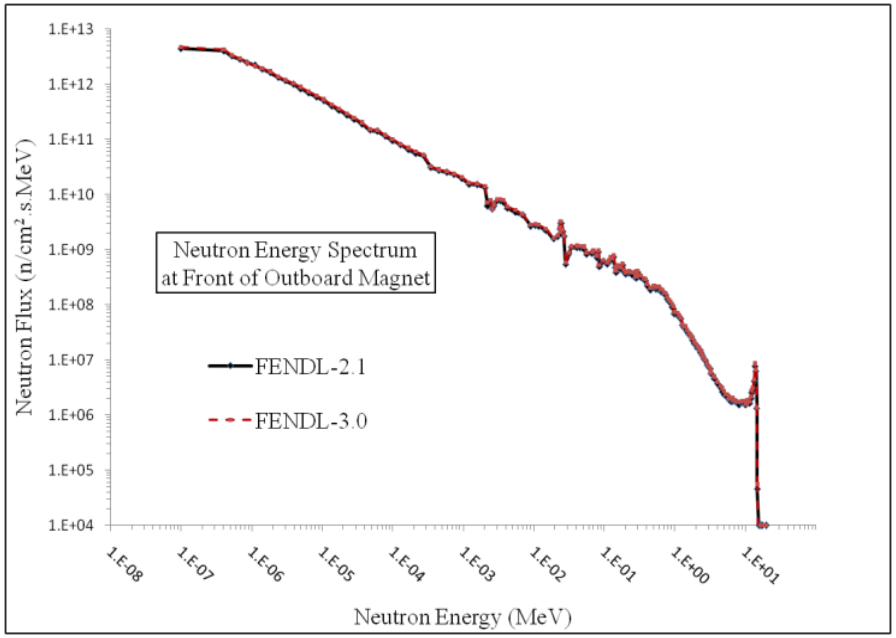
Peak Neutron and Gamma Flux Results

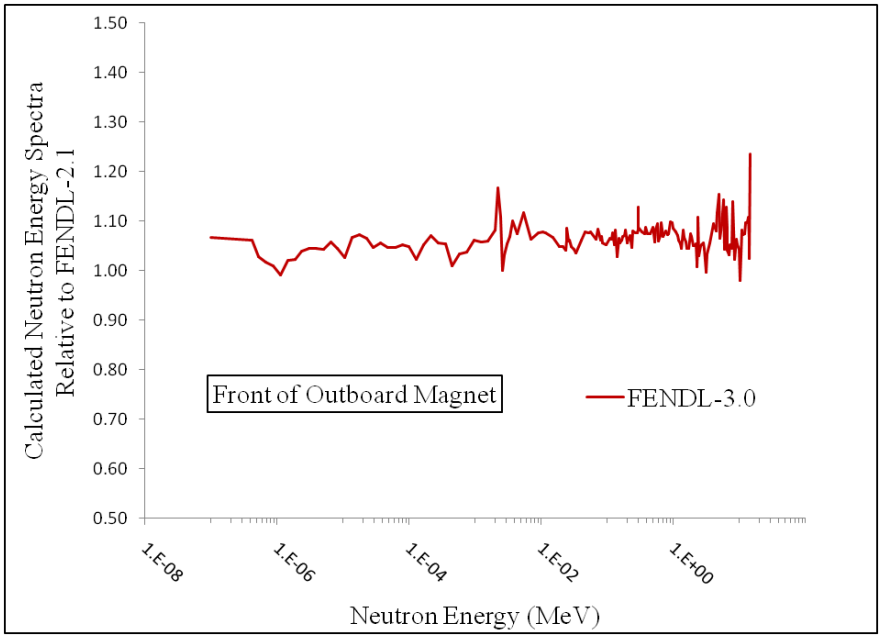
	FENDL-2.1		FENDL-3.0		% Change
	Neutron Flux	1 σ % Error	Neutron Flux	1 σ % Error	
IB					
FW					
Be	3.516E+14	0.05	3.515E+14	0.05	-0.03
Cu	3.086E+14	0.05	3.086E+14	0.05	-0.01
SS	2.958E+14	0.06	2.958E+14	0.06	0.01
VV	8.473E+11	0.19	8.659E+11	0.19	2.20
Magnet	3.368E+09	0.45	3.504E+09	0.45	4.06
OB					
FW					
Be	4.368E+14	0.03	4.366E+14	0.03	-0.05
Cu	3.945E+14	0.03	3.943E+14	0.03	-0.06
SS	3.798E+14	0.03	3.796E+14	0.03	-0.05
VV	1.170E+12	0.09	1.202E+12	0.09	2.74
Magnet	4.799E+08	0.41	5.124E+08	0.41	6.78

	FENDL-2.1		FENDL-3.0		% Change
	Gamma Flux	1 σ % Error	Gamma Flux	1 σ % Error	
IB					
FW					
Be	3.177E+14	0.05	3.209E+14	0.05	1.00
Cu	3.074E+14	0.05	3.104E+14	0.05	0.98
SS	3.068E+14	0.06	3.099E+14	0.06	1.01
VV	4.859E+11	0.17	4.855E+11	0.17	-0.08
Magnet	1.428E+09	0.37	1.458E+09	0.37	2.09
OB					
FW					
Be	3.616E+14	0.04	3.641E+14	0.04	0.70
Cu	3.605E+14	0.04	3.633E+14	0.04	0.78
SS	3.659E+14	0.04	3.693E+14	0.04	0.92
VV	6.607E+11	0.08	6.623E+11	0.08	0.24
Magnet	2.071E+08	0.35	2.116E+08	0.35	2.21

- Larger changes in neutron flux (2-7%) occur in VV and magnet that are heavily shielded by water-cooled steel
- Smaller changes in gamma flux

Neutron Spectrum at Inner Surface of OB Magnet





- There is approximately <10% increase in neutron flux at the front of the outboard magnet for much of the energy regime, with larger spikes (up to 20%) in neutron flux in the high energy region
- The neutron spectrum behind the large volume of water-cooled SS is harder with FENDL-3.0

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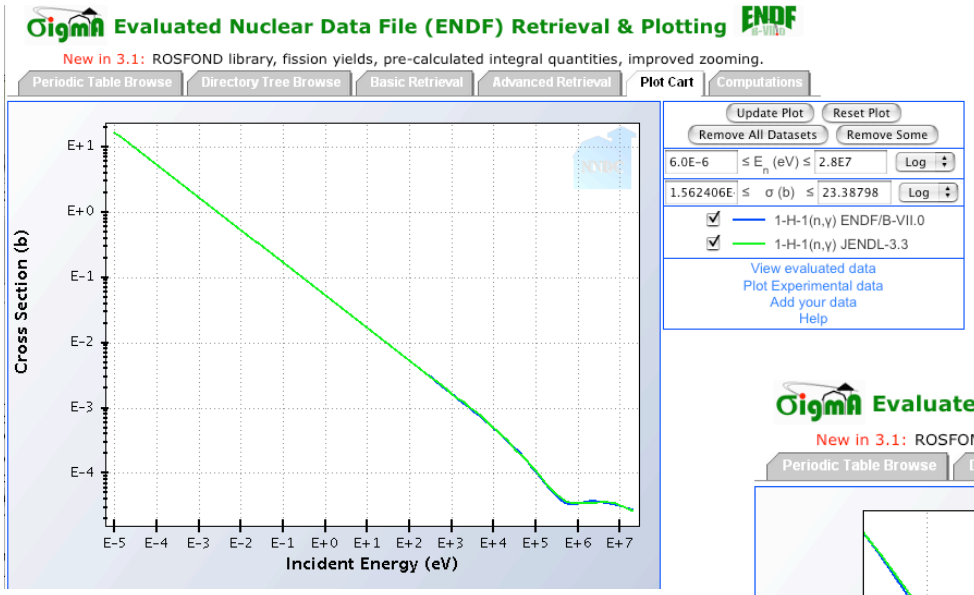
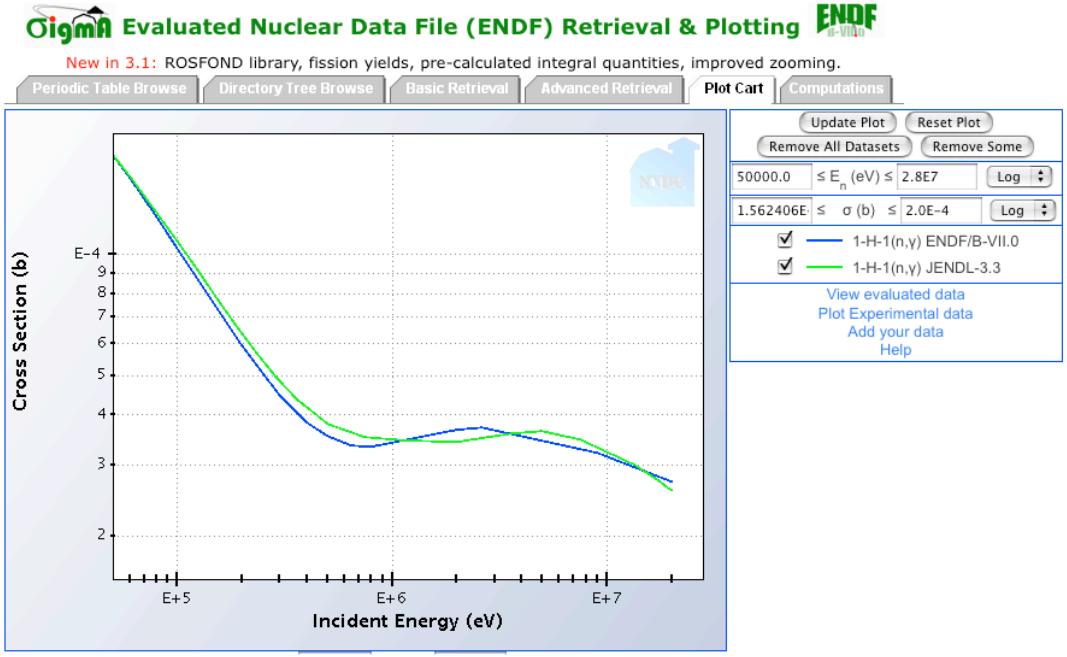
H-1 Data in FENDL-3 vs. FENDL-2.1



Notable change in FENDL-3 is switch for H-1 from JENDL-3.3 to ENDF/B-VII.0



Lower (n,γ) cross sections at high energy could be reason for higher and harder neutron flux in regions heavily shielded by water-cooled SS

Peak Nuclear Heating Results

	FENDL-2.1		FENDL-3.0		
	Power Density	1 σ % Error	Power Density	1 σ % Error	% Change
IB					
FW					
Be	1.008E+01	0.05	1.007E+01	0.05	-0.06
Cu	2.017E+01	0.06	1.990E+01	0.07	-1.34
SS	1.785E+01	0.08	1.773E+01	0.08	-0.65
VV SS	2.635E-02	0.18	2.597E-02	0.18	-1.43
Magnet	5.422E-05	0.45	5.509E-05	0.45	1.60
OB					
FW					
Be	1.391E+01	0.03	1.390E+01	0.03	-0.07
Cu	2.476E+01	0.04	2.444E+01	0.05	-1.29
SS	2.230E+01	0.05	2.221E+01	0.05	-0.39
VV SS	3.576E-02	0.09	3.536E-02	0.09	-1.13
Magnet	7.800E-06	0.43	7.941E-06	0.43	1.81

- The harder and higher neutron flux in VV and magnet results in higher neutron heating
- Gamma heating is the dominant nuclear heating.
- Lower gamma heating resulting in ~1% lower nuclear heating in VV (neutron heating increased by ~16% compared to ~3% decrease in gamma heating) and only ~2% higher nuclear heating in magnet (~8% increase in neutron heating and <0.7% increase in gamma heating)

Peak IB Magnet Radiation Parameters

	FENDL-2.1		FENDL-3.0		% Change
	Value	1 σ % Error	Value	1 σ % Error	
Fast fluence ($n/cm^2/FPY$)	6.208E+16	0.45	6.480E+16	0.45	4.38
Insulator dose (Gy/FPY)	6.859E+05	0.43	7.091E+05	0.43	3.38
Cu dpa/FPY	3.898E-05	0.48	4.064E-05	0.48	4.27
Heating (mW/cm^3)	5.422E-02	0.40	5.509E-02	0.40	1.60

- Nuclear parameters at magnet are higher by ~1.6-4.4% than predicted by FENDL-2.1
- Largest effect is on fast n fluence (>4%) due to the harder and larger neutron flux
- Similar effect observed in Cu dpa produced by high energy neutrons
- Increase in insulator dose and winding pack nuclear heating is reduced due to the contribution from gamma heating

Peak dpa/FPY Values

	FENDL-2.1		FENDL-3.0		
	dpa/FPY	1 σ % Error	dpa/FPY	1 σ % Error	% Change
IB					
FW					
Cu	9.165E+00	0.06	9.135E+00	0.06	-0.33
SS (Fe)	7.790E+00	0.07	7.784E+00	0.07	-0.08
VV					
Inconel (Ni)	1.016E-02	0.21	1.041E-02	0.21	2.52
SS (Fe)	3.368E-03	0.24	3.448E-03	0.24	2.37
Magnet (Cu)	3.898E-05	0.48	4.064E-05	0.48	4.27
OB					
FW					
Cu	1.377E+01	0.03	1.373E+01	0.03	-0.28
SS (Fe)	1.182E+01	0.03	1.182E+01	0.03	-0.02
VV					
Inconel (Ni)	1.382E-02	0.10	1.425E-02	0.10	3.11
SS (Fe)	5.021E-03	0.12	5.171E-03	0.12	2.98
Magnet (Cu)	5.627E-06	0.43	6.020E-06	0.42	6.99

- Atomic displacement damage is higher in VV and magnet due to higher and harder neutron flux
- Effect is more pronounced in the outboard magnet because of the thicker water-cooled SS in front of it

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Peak He appm/FPY Values

	FENDL-2.1		FENDL-3.0		
	He appm/FPY	1 σ % Error	He appm/FPY	1 σ % Error	% Change
IB					
FW					
Be	4.100E+03	0.07	4.103E+03	0.07	0.06
CuBeNi	2.103E+02	0.07	2.111E+02	0.07	0.38
SS316	1.773E+02	0.06	1.847E+02	0.06	4.21
VV					
Inconel	6.811E-02	0.32	7.995E-02	0.31	17.37
SS316	7.659E-02	0.22	8.249E-02	0.22	7.70
Magnet (Cu)	3.819E-04	0.62	4.020E-04	0.61	5.27
OB					
FW					
Be	5.981E+03	0.03	5.984E+03	0.03	0.05
CuBeNi	3.233E+02	0.03	3.248E+02	0.03	0.48
SS316	2.454E+02	0.03	2.561E+02	0.03	4.36
VV					
Inconel	9.042E-02	0.16	1.069E-01	0.16	18.28
SS316	1.076E-01	0.11	1.164E-01	0.11	8.19
Magnet (Cu)	5.570E-05	0.57	6.002E-05	0.56	7.75

- Helium is produced by high energy neutrons and is higher in VV and magnet due to higher and harder neutron flux
- An increase of ~18% is observed in Inconel with FENDL-3.0

Peak H appm/FPY Values

	FENDL-2.1		FENDL-3.0		
	H appm/FPY	1 σ % Error	H appm/FPY	1 σ % Error	% Change
IB					
FW					
Be	6.103E+01	0.07	6.106E+01	0.07	0.05
CuBeNi	6.463E+02	0.07	6.461E+02	0.07	-0.03
SS316	6.020E+02	0.08	5.950E+02	0.08	-1.16
VV					
Inconel	5.762E-01	0.30	5.783E-01	0.30	0.37
SS316	1.170E-01	0.35	1.196E-01	0.34	2.16
Magnet (Cu)	1.080E-03	0.65	1.135E-03	0.64	5.07
OB					
FW					
Be	8.968E+01	0.03	8.968E+01	0.03	0.01
CuBeNi	9.994E+02	0.03	1.000E+03	0.03	0.06
SS316	9.414E+02	0.03	9.307E+02	0.03	-1.14
VV					
Inconel	7.670E-01	0.15	7.757E-01	0.15	1.14
SS316	1.677E-01	0.17	1.731E-01	0.17	3.18
Magnet (Cu)	1.566E-04	0.61	1.684E-04	0.60	7.50

- Hydrogen is produced by high energy neutrons and is higher in VV and magnet due to higher and harder neutron flux
- The increase is less pronounced than for Helium production due to the lower threshold energy for H production reactions
- Effect in Inconel is much lower than for He production

Peak T appm/FPY Values

	FENDL-2.1		FENDL-3.0		
	T appm/FPY	1 σ % Error	T appm/FPY	1 σ % Error	% Change
IB					
FW					
Be	6.101E+01	0.07	6.104E+01	0.07	0.05
CuBeNi	1.564E+00	0.07	1.563E+00	0.07	-0.04
SS316	1.196E-01	0.08	1.203E-01	0.08	0.63
VV					
Inconel	2.951E-06	0.52	6.922E-06	0.45	134.54
SS316	2.487E-05	0.36	2.546E-05	0.36	2.37
Magnet (Cu)	1.354E-06	0.87	1.431E-06	0.85	5.67
OB					
FW					
Be	8.964E+01	0.03	8.965E+01	0.03	0.01
CuBeNi	2.447E+00	0.03	2.448E+00	0.03	0.04
SS316	1.869E-01	0.04	1.882E-01	0.04	0.73
VV					
Inconel	3.782E-06	0.26	9.027E-06	0.23	138.66
SS316	3.574E-05	0.18	3.695E-05	0.18	3.37
Magnet (Cu)	1.825E-07	0.86	1.982E-07	0.84	8.62

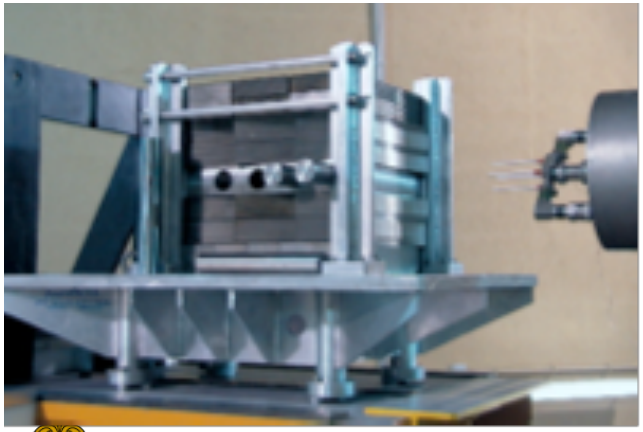
- Tritium production is higher in VV and magnet due to higher and harder neutron flux
- Extremely large increase of more than a factor of two is observed for Inconel
- While T production is included in total H production, the very small magnitude of T production in Inconel did not end up significantly changing the total H production

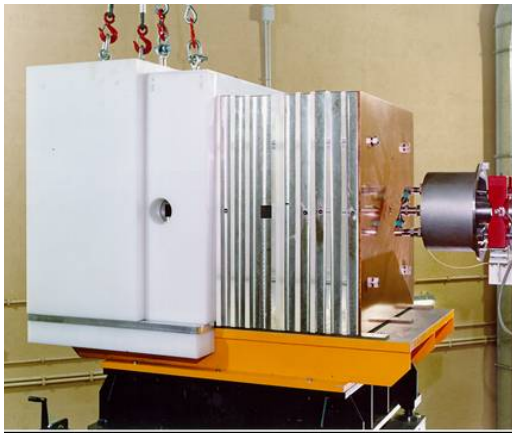
Why Do We Get Large Differences in Gas Production?

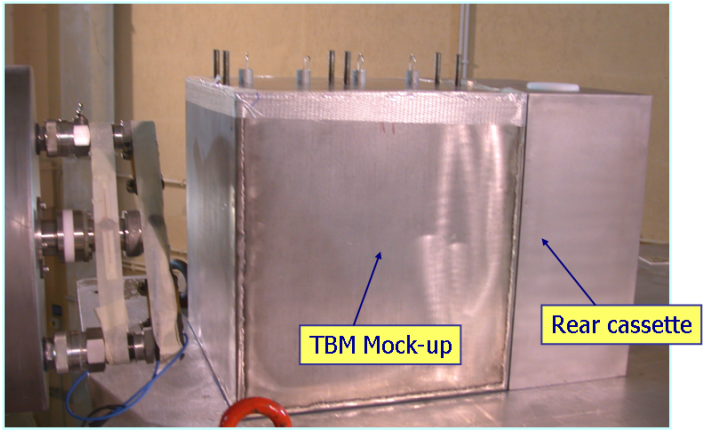
- We ran numerous test simulations and concluded there is no single isotope in Inconel that can be pinpointed for causing all the excess production rates
- Some of the FENDL-3.0 evaluations raised the production rates, while others lowered them
- Careful examination of reaction rates for gas production indicated that the differences are due to large differences in missing reactions in the two FENDL libraries
- We created a large Excel file to compare all missing reactions between FENDL-2.1, FENDL-3.0, and ENDF/B-VII.0. These include D production (204), T production (205), ^{3}He production (206)
- We found that ENDF/B-VII.0 had the most missing reactions and FENDL-3.0 had the least
- With respect to Inconel, there is a difference in missing reaction status for every major constituent isotope when comparing FENDL-2.1 to FENDL-3.0
- Additionally, we specifically examined Al-27 because this isotope had a particularly large effect on T production in inconel
- Including only the FENDL-3.0 evaluation of Al-27 caused T production in the front of the Inconel VV to more than double the FENDL-2.1 results
- T production reaction (205) was missing in FENDL-2.1, but present in FENDL-3.0
- Using all ENDF/B-VII.0 data yielded T production in the Inconel VV that was very similar to that found in FENDL-3.0. Not surprisingly, reaction 205 is present in ENDF/B-VII.0
- We conclude that it is very important that the processed data for FENDL-3.0 include all necessary reactions used for gas production by adding the missing reactions (204, 205, 206)

ITER Relevant Benchmark Experiments

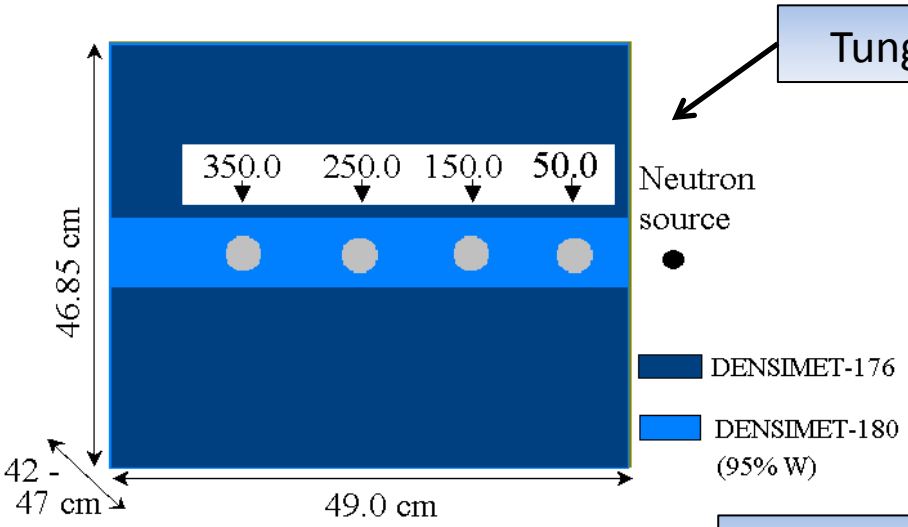
- ENEA, Frascati Research Centre (Italy)
- 14-MeV Frascati Neutron Generator (FNG)
  - Accelerator based
  - T(d,n)α E_d=300 keV
- Operating since 1992
- 14-MeV neutron intensity 10^{11} n/s
- Variety of mockups:

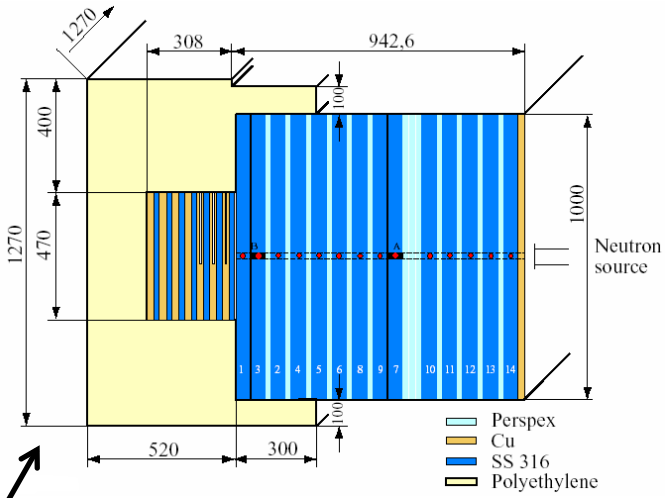




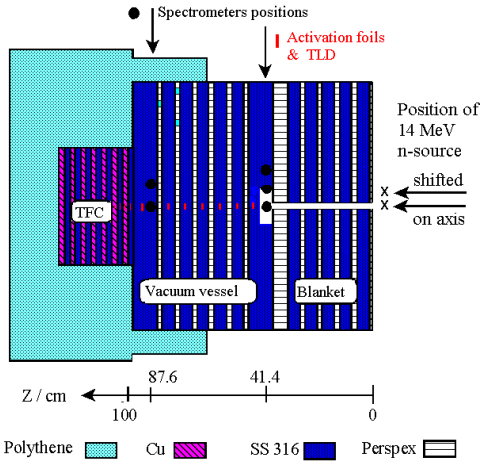


Schematic of ITER Relevant Experiments

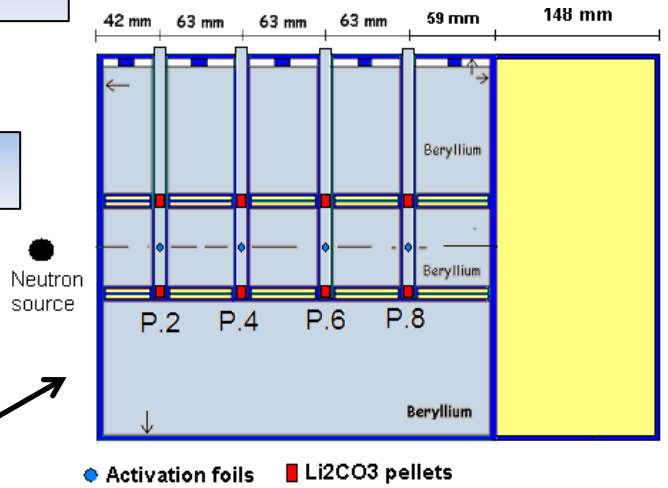




Bulk shielding



Streaming



HCPB breeder

Tungsten experiment activation foils

Average/Maximum of C/E Values

		FENDL-2.1	FENDL-3.0		
	$E_{threshold}$ (MeV)	C/E	C/E	% Change Average	% Change Max
Mn-55(n,γ) Mn-56	0	1.454/ 1.785	1.348/ 1.477	-7.29	-17.25
Au197(n,γ) Au-198	0	0.981/ 0.905	0.941/ 0.914	-4.08	0.99
Ni-58(n,p) Co-58	0.8	1.061/ 1.094	1.062/ 1.094	0.09	0.00
In115(n,n') In-115m*	0.8	0.929/ 0.869	0.917/ 0.901	-1.29	3.68
Al-27(n,α) Na-24	3	1.030/ 1.055	1.033/ 1.069	0.29	1.33
Fe-56(n,p) Mn-56	3	0.961/ 0.945	0.958/ 0.943	-0.31	-0.21
Ni58(n,2n) Ni-57	10	1.020/ 1.034	1.133/ 1.179	11.08	14.02
Zr90(n,2n) Zr-89	10	1.034/ 1.049	1.074/ 1.095	3.87	4.39
Nb93(n,2n) Nb-92	10	1.024/ 1.080	1.031/ 1.064	0.68	-1.48

- Activation rates were measured in four positions within the tungsten block
- We display the C/E results averaged over all positions and also show the C/E value in a given set of measurements that had the maximum deviation from unity
- FENDL-3.0 performed worse than FENDL-2.1 and the only reaction that improved was Mn55(n,γ)Mn56

Bulk Shielding experiment activation foils

Average/Maximum of C/E Values

		FENDL-2.1	FENDL-3.0		
	$E_{threshold}$ (MeV)	C/E	C/E	% Change Average	% Change Max
Mn-55(n,γ) Mn-56	0	0.902/ 0.763	0.843/ 0.688	-6.54	-9.83
Au197(n,γ) Au-198	0	0.910/ 0.789	0.920/ 0.729	1.10	-7.60
Ni-58(n,p) Co-58	0.8	0.944/ 0.728	0.952/ 0.763	0.85	4.81
In115(n,n') In-115m*	0.8	0.751/ 0.501	0.761/ 0.498	1.33	-0.60
Al-27(n,α) Na-24	3	0.912/ 0.848	0.936/ 0.873	2.63	2.95
Fe-56(n,p) Mn-56	3	0.897/ 0.827	0.926/ 0.885	3.23	7.01
Ni58(n,2n) Ni-57	10	0.923/ 0.873	1.045/ 1.085	13.22	24.28
Nb93(n,2n) Nb-92	10	0.916/ 0.782	0.942/ 0.784	2.84	0.26

- The FENDL-3.0 results were superior to that of FENDL-2.1 in all but one reaction, Mn55(n,γ)Mn56, which worsened by 6.54%
- Improvements in the other reactions ranged from 0.85% to 13.22%
- We found it intriguing that the bulk shield experiment performed better with FENDL-3.0, while the tungsten foil experiment performed worse
- Only the tungsten foil experiment contains tungsten evaluations
- FENDL-2.1 used ENDF/B-VI.8 for tungsten data, while FENDL-3.0 used INDL/V-3.0 and FENDL-2.1 is missing W180

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Conclusions

- FENDL-3.0 general purpose neutron library has the advantage over FENDL-2.1 of increased number of materials (from 71 to 180) and increasing the upper energy to 150 MeV
- Results for the ITER relevant computational benchmark indicate that a small impact on ITER nuclear analysis is expected by switching to FENDL-3.0 with higher enhancements in flux, heating, and damage levels of up to ~7% in the VV and magnet that are shielded by water-cooled SS
- Caution should be observed when calculating gas production due to missing D, T, He-3 reactions for several materials. These need to be added in future releases
- The C/E improved for most activation foils in the bulk shield experiment using FENDL-3.0 compared to FENDL-2.1 while the C/E was worse for most activation foils in the tungsten experiment