NMLIB

Chikara KONNO
Center for Proton Accelerator Facilities, Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken 319-1195 JAPAN
e-mail: konno@cens.tokai.jaeri.go.jp

Yujiro IKEDA
Center for Proton Accelerator Facilities, Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken 319-1195 JAPAN
e-mail: ikeda@cens.tokai.jaeri.go.jp

Koji NIITA
Research Organization for Information Science & Technology
Tokai-mura, Naka-gun, Ibaraki-ken 319-1106 JAPAN
e-mail: niita@hadron03.tokai.jaeri.go.jp

A new general purpose neutron incident nuclear data library, NMLIB, for neutron energy up to 3 GeV is generated by using NMTC/JAM for neutron cross sections above 20 MeV and JENDL-3.2 or -3.3 for neutron cross sections below 20 MeV. MATXS files (NMLIB/MG) and ACE files (NMLIB/MC) of NMLIB are also produced from NMLIB with the NJOY code. A simple test calculation suggests that NMLIB, NMLIB/MG and NMLIB/MC have no problem except for self-shielding.

1. Introduction

Various shielding designs have been underway in JAERI-KEK Joint (JKJ) project [1]. Simple methods (Moyer's model [2] and DUCT-III [3]) and Monte Carlo codes (NMTC/JAM [4] and MCNPX [5]) were used in the designs. The calculation time of the simple methods is very short, while that of Monte Carlo calculations is very long for deep penetration. In the SNS project [6] the HILO2K [7] multigroup library for neutron energy up to 2 GeV is widely used in order to reduce calculation time. At first we hoped to generate a multigroup library for neutron energy up to 3 GeV, which is an energy of proton incident to neutron source in JKJ project, from JENDL High Energy File [8]. But the release of JENDL High Energy File is too delayed. Then we planned to generate a general purpose neutron incident nuclear data library, NMLIB, for neutron energy up to 3 GeV separately and produce MATXS files (NMLIB/MG) and ACE files (NMLIB/MC) from NMLIB. An overview and a simple test calculation of NMLIB, NMLIB/MG and NMLIB/MC will be described in this paper.

2. Overview of NMLIB

NMLIB is a general purpose neutron incident nuclear data library for neutron energy up to 3 GeV of the ENDF format [9]. The high energy neutron cross section data (> 20 MeV) in NMLIB were calculated with the modified NMTC/JAM code (default option parameter), which outputs neutron cross section data, and were stored as (n,x) reaction, except for elastic scattering. The low energy neutron cross section data (< 20 MeV) in NMLIB were JENDL-3.2 [10] or JENDL-3.3 [11]. NMLIB includes hydrogen, carbon, nitrogen, oxygen, aluminum, silicon, calcium, iron and copper at this time for concrete and iron shields and beam dump.

MATXS files (neutron 195 groups up to 3 GeV, gamma 35 groups up to 3 GeV, P_{14} expansion), NMLIB/MG, of NMLIB were produced with the NJOY99.67 [12] code modified for neutrons up to 3 GeV and Legendre order higher than 7. The energy boundary of the group structure is shown in Table 1. The photo-atomic data file, EPDL97 [13], for gamma energy up to 10 GeV was used for this processing. The specifications of the NJOY processing are the following;1) the temperature is 300 K, 2) weight functions are a thermal Maxwellian at low energies + 1/E for neutron and 1/E for gamma, 3) background cross sections are 10^6, 10^4, 10^3, 300, 100, 30, 10, 1, 0.1, 10^{-5} for neutron. A multigroup library for Sn calculations was prepared with the TRANSX2.15 [14] code from NMLIB/MG. New format ACE files, NMLIB/MC, of NMLIB were also produced with the modified NJOY code. The temperature is 300 K.

3. Test Calculation

We performed a simple test calculation to validate NMLIB. The model of this test consisted of a concrete sphere or an iron sphere of 5 m in radius with an isotropic 3 GeV neutron source in the center. Neutron dose rates and neutron spectra in the sphere were calculated. The codes and libraries used are the following;

1) Monte Carlo code PHITS [15] with JENDL-3.2 or -3.3 (neutron only mode),
2) Monte Carlo code PHITS with NMLIB/MC (neutron only mode),
3) Sn code ANISN [16] with NMLIB/MG
   (Bondarenko's self-shielding correction [17], P_9 expansion,
   Extended transport approximation [14]),

where PHITS is a successor of NMTC/JAM, which is used to obtain neutron (> 20 MeV) cross sections of NMLIB. It was judged through comparison with the PHITS calculation with JENDL-3.2 or -3.3 whether NMLIB/MC and NMLIB/MG have any problems.

The calculated neutron dose rates and neutron spectra in the spheres are shown in Figs. 1 - 8. In the concrete sphere all the calculated neutron dose rates and neutron spectra are almost the same together. On the other hand, in the iron sphere the PHITS calculation with NMLIB/MC agrees with the PHITS calculation with JENDL, while a discrepancy between the ANISN calculation with NMLIB/MG and the PHITS calculations increases with the distance from the center. The calculated neutron spectra suggest that the discrepancy between the ANISN calculation with NMLIB/MG and the PHITS calculations mainly comes from the difference in the neutron flux below 1 MeV, where the resonance peaks of iron cause self-shielding. Although the Bondarenko's self-shielding correction was performed in the ANISN calculation, it is considered that the correction is not enough for the iron assembly thicker than 2 m in the case of the neutron group structure shown in Table 1. Thus it is concluded that the discrepancy between the ANISN calculation with NMLIB/MG and the PHITS calculations comes from limitation of the Bondarenko's self-shielding correction rather than a proper problem in NMLIB/MG.

4. Conclusion

A general purpose neutron incident nuclear data library, NMLIB, for neutron energy up to 3 GeV was prepared for JKJ project. MATXS (NMLIB/MG) and ACE (NMLIB/MC) files are produced from NMLIB with NJOY modified for NMLIB. Test calculations with NMLIB suggested the followings;

1) The calculations with NMLIB agree well with PHITS calculations with JENDL-3.2 or -3.3 in the concrete sphere case.
2) In the iron sphere case the calculations with NMLIB/MC agree well with PHITS calculations with JENDL-3.2 or -3.3, while those with NMLIB/MG do not in the deep positions. Simple self-shielding correction in NMLIB/MG is considered to be not enough for very thick iron assembly.

It is concluded that NMLIB/MC and NMLIB have no problem. The self-shielding correction of NMLIB/MG is not adequate for very thick iron assembly. It is noted that this is not a defect of only NMLIB/MG but limitation of the Bondarenko's self-shielding correction.

References

[1] The Joint Project team of JAERI and KEK : JAERI-Tech 2000-003 (2000) [in Japanese].
[2] Moyer B.J. : Proc. 1st Int. Conf. Shielding around High Energy Accelerators, p. 65 (1962).
[3] Tayama R., et al. : KEK Internal 2001-8 (2001) [in Japanese].
[4] Niita K., et al. : JAERI-Data/Code 2001-007 (2001).
[5] Hughes H.G., et al. : Proc. of Int. Conf. on Mathematics & Computation, Reactor Physics & Environmental, Analysis in Nuclear Applications, p. 939 (1999).
[6] Appleton B.R. : ORNL/TM-6063 (1997).
[7] Lillie R.A. and Gallmeier F.X. : Proc. 4th Int. Top. Meet. Nucl. Applicat. Accel. Tech., p.302 (2000).
[8] Fukahori T., et al. : J. Nucl. Sci. Technol., Supplement 2, 25 (2002).
[9] McLane V. (Ed.) : BNL-NCS-44945-01/04-Rev (1998).
[10] Nakagawa T., et al. : J. Nucl. Sci. Technol., 32, 1259 (1995).
[11] Nakagawa T. and Shibata K. : JAERI-Conf 2001-006, p. 27 (2001).
[12] MacFarlane R.E. and Muir D.W. : LA-12740-M (1994).
[13] Cullen D.E., et al. : UCRL-ID-50400, Vol. 6, Rev 5 (1997).
[14] MacFarlane R.E. : LA-12312-MS (1993).
[15] Iwase H., et al. : J. Nucl. Sci. Technol., 39, 1142 (2002).
[16] DOORS3.2 : One, Two- and Three-Dimensional Discrete Ordinates Neutron/Photon Transport Code System, RSICC CODE PACKAGE CCC-650 (1998).
[17] Bondarenko I.I. (Ed.) : Group Constants for Nuclear Reactor Calculations, Consultants Bureau, New York, (1964).

Table 1 Energy boundary of group structure.

Neutron 195 group								Gamma 35 group	
Group	Upper energy [eV]	Group	Upper energy [eV]	Group	Upper energy [eV]	Group	Upper energy [eV]	Group	Upper energy [eV]
1	3.0000e+09	51	5.2205e+06	101	3.6883e+05	151	5.5308e+03	1	3.0000e+09
2	2.0000e+09	52	4.9658e+06	102	3.3373e+05	152	4.3074e+03	2	2.0000e+09
3	1.5000e+09	53	4.7237e+06	103	3.0197e+05	153	3.7074e+03	3	1.5000e+09
4	1.0000e+09	54	4.4933e+06	104	2.9849e+05	154	3.3546e+03	4	1.0000e+09
5	7.0000e+08	55	4.0657e+06	105	2.9721e+05	155	3.0354e+03	5	7.5000e+08
6	5.0000e+08	56	3.6788e+06	106	2.9452e+05	156	2.7465e+03	6	5.0000e+08
7	3.5000e+08	57	3.3287e+06	107	2.8725e+05	157	2.6126e+03	7	3.0000e+08
8	2.5000e+08	58	3.1664e+06	108	2.7324e+05	158	2.4852e+03	8	2.0000e+08
9	2.2500e+08	59	3.0119e+06	109	2.4724e+05	159	2.2487e+03	9	1.5000e+08
10	2.0000e+08	60	2.8651e+06	110	2.3518e+05	160	2.0347e+03	10	1.0000e+08
11	1.8000e+08	61	2.7253e+06	111	2.2371e+05	161	1.5846e+03	11	7.5000e+07
12	1.6000e+08	62	2.5924e+06	112	2.1280e+05	162	1.2341e+03	12	5.0000e+07
13	1.4000e+08	63	2.4660e+06	113	2.0242e+05	163	9.6112e+02	13	3.0000e+07
14	1.3000e+08	64	2.3852e+06	114	1.9255e+05	164	7.4852e+02	14	2.0000e+07
15	1.2000e+08	65	2.3653e+06	115	1.8316e+05	165	5.8295e+02	15	1.4000e+07
16	1.1000e+08	66	2.3457e+06	116	1.7422e+05	166	4.5400e+02	16	1.2000e+07
17	1.0000e+08	67	2.3069e+06	117	1.6573e+05	167	3.5358e+02	17	1.0000e+07
18	9.0000e+07	68	2.2313e+06	118	1.5764e+05	168	2.7536e+02	18	8.0000e+06
19	8.0000e+07	69	2.1225e+06	119	1.4996e+05	169	2.1445e+02	19	7.5000e+06
20	7.0000e+07	70	2.0190e+06	120	1.4264e+05	170	1.6702e+02	20	7.0000e+06
21	6.5000e+07	71	1.9205e+06	121	1.3569e+05	171	1.3007e+02	21	6.5000e+06
22	6.0000e+07	72	1.8268e+06	122	1.2907e+05	172	1.0130e+02	22	6.0000e+06
23	5.5000e+07	73	1.7377e+06	123	1.2277e+05	173	7.8893e+01	23	5.5000e+06
24	5.0000e+07	74	1.6530e+06	124	1.1679e+05	174	6.1442e+01	24	5.0000e+06
25	4.5000e+07	75	1.5724e+06	125	1.1109e+05	175	4.7851e+01	25	4.5000e+06
26	4.0000e+07	76	1.4957e+06	126	9.8037e+04	176	3.7267e+01	26	4.0000e+06
27	3.5000e+07	77	1.4227e+06	127	8.6517e+04	177	2.9023e+01	27	3.5000e+06
28	3.0000e+07	78	1.3534e+06	128	8.2503e+04	178	2.2603e+01	28	3.0000e+06
29	2.7500e+07	79	1.2873e+06	129	7.9499e+04	179	1.7604e+01	29	2.5000e+06
30	2.5000e+07	80	1.2246e+06	130	7.1998e+04	180	1.3710e+01	30	2.0000e+06
31	2.2500e+07	81	1.1648e+06	131	6.7379e+04	181	1.0677e+01	31	1.5000e+06
32	1.9600e+07	82	1.1080e+06	132	5.6562e+04	182	8.3153e+00	32	1.0000e+06
33	1.7500e+07	83	1.0026e+06	133	5.2475e+04	183	6.4760e+00	33	4.0000e+05
34	1.4900e+07	84	9.6164e+05	134	4.6309e+04	184	5.0435e+00	34	2.0000e+05
35	1.3500e+07	85	9.0718e+05	135	4.0868e+04	185	3.9279e+00	35	1.0000e+05
36	1.2200e+07	86	8.6294e+05	136	3.4307e+04	186	3.0590e+00		1.0000e+04
37	1.0000e+07	87	8.2085e+05	137	3.1828e+04	187	2.3824e+00		
38	9.5123e+06	88	7.8082e+05	138	2.8501e+04	188	1.8554e+00		
39	9.0484e+06	89	7.4274e+05	139	2.7000e+04	189	1.4450e+00		
40	8.6071e+06	90	7.0651e+05	140	2.6058e+04	190	1.1254e+00		
41	8.1873e+06	91	6.7205e+05	141	2.4788e+04	191	8.7643e-01		
42	7.7880e+06	92	6.3928e+05	142	2.4176e+04	192	6.8256e-01		
43	7.4082e+06	93	6.0810e+05	143	2.3579e+04	193	5.3158e-01		
44	7.0469e+06	94	5.7844e+05	144	2.1875e+04	194	4.1399e-01		
45	6.7032e+06	95	5.5023e+05	145	1.9305e+04	195	1.0000e-01		
46	6.5924e+06	96	5.2340e+05	146	1.5034e+04		1.0000e-05		
47	6.3763e+06	97	4.9787e+05	147	1.1709e+04				
48	6.0653e+06	98	4.5049e+05	148	1.0595e+04				
49	5.7695e+06	99	4.0762e+05	149	9.1188e+03				
50	5.4881e+06	100	3.8774e+05	150	7.1017e+03				

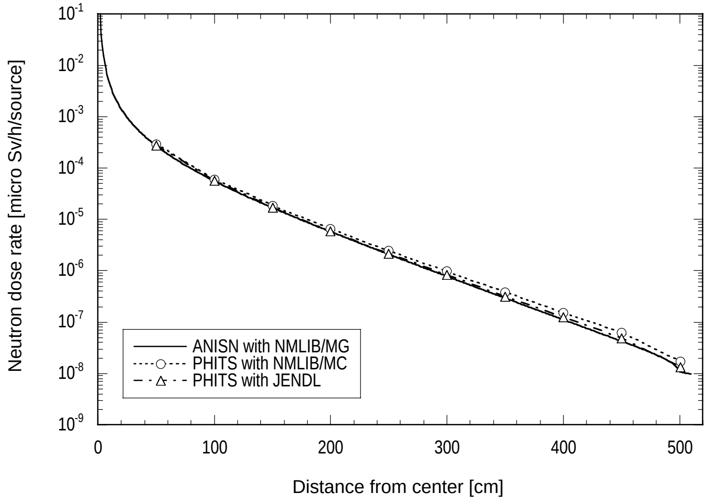

Fig. 1 Calculated neutron dose rates in the concrete sphere.

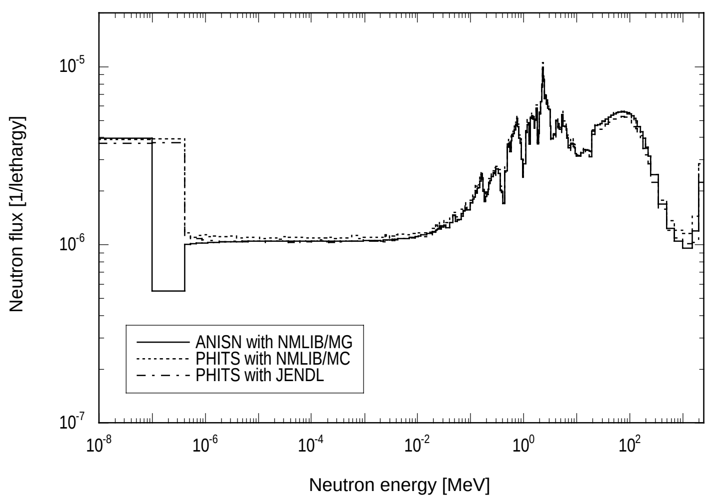

Fig. 2 Calculated neutron spectra at 1 m from the center in the concrete sphere.

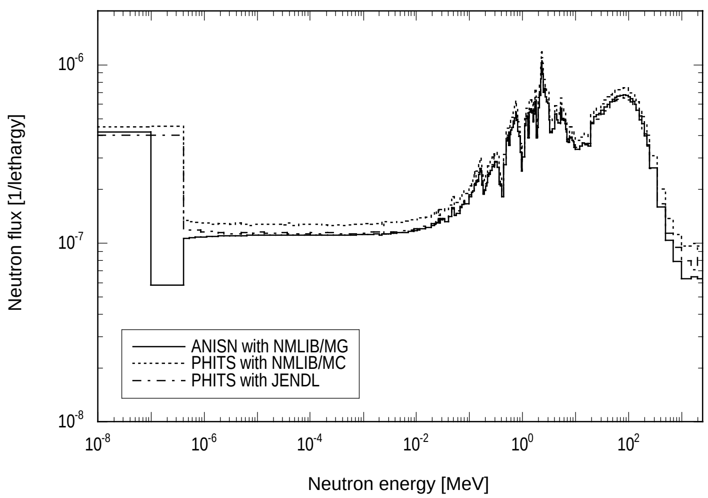

Fig. 3 Calculated neutron spectra at 2 m from the center in the concrete sphere.

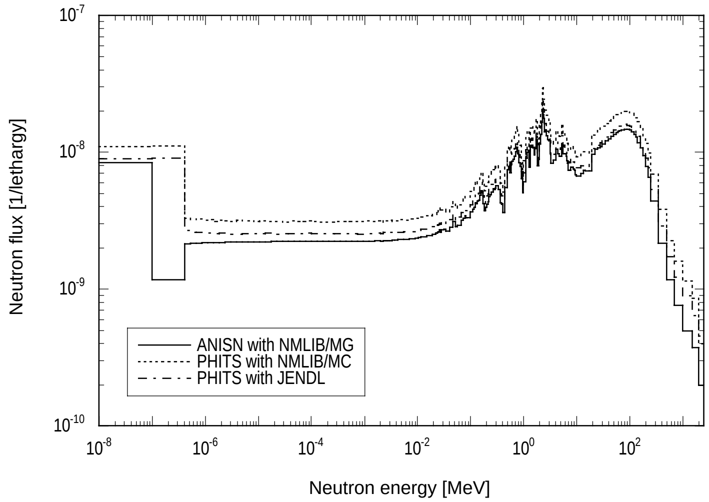

Fig. 4 Calculated neutron spectra at 4 m from the center in the concrete sphere.

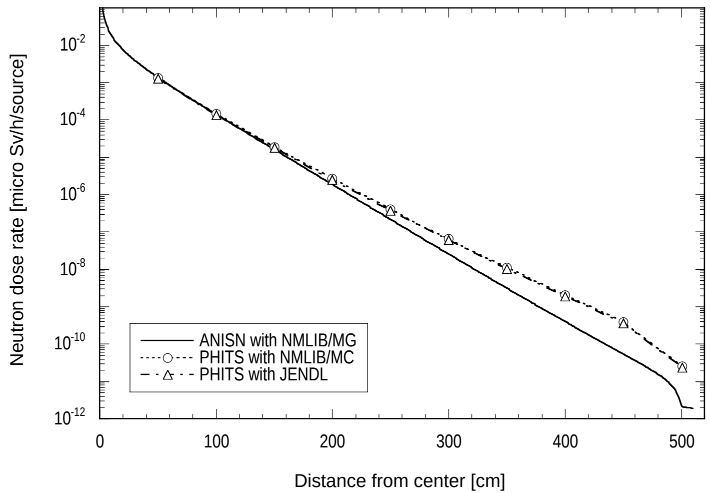

Fig. 5 Calculated neutron dose rates in the iron sphere.

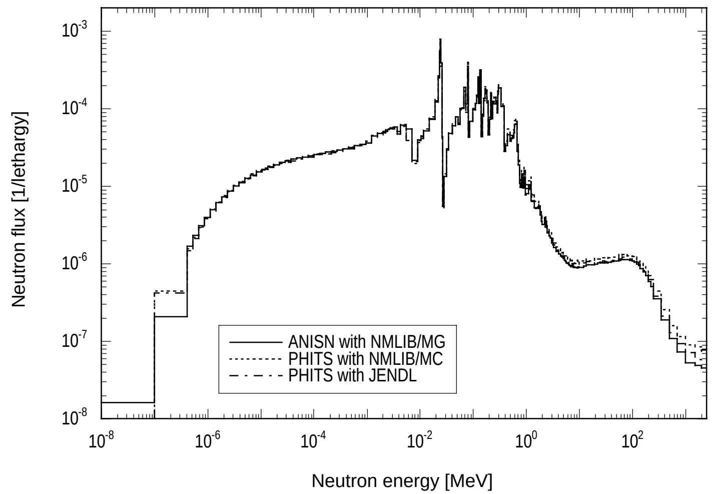

Fig. 6 Calculated neutron spectra at 1 m from the center in the iron sphere.

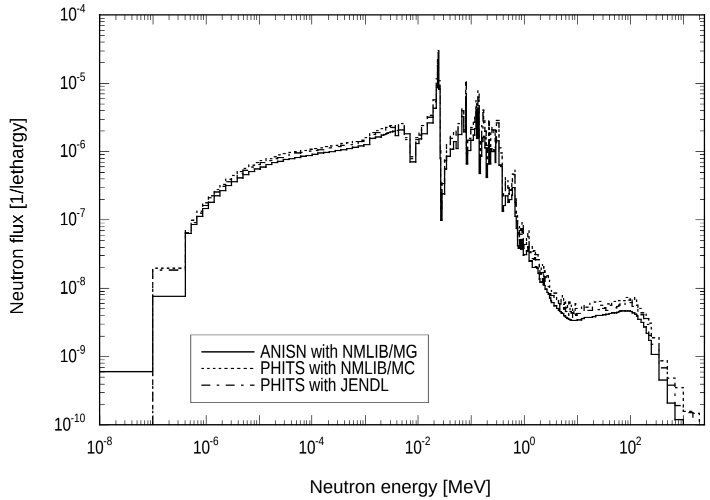

Fig. 7 Calculated neutron spectra at 2 m from the center in the iron sphere.

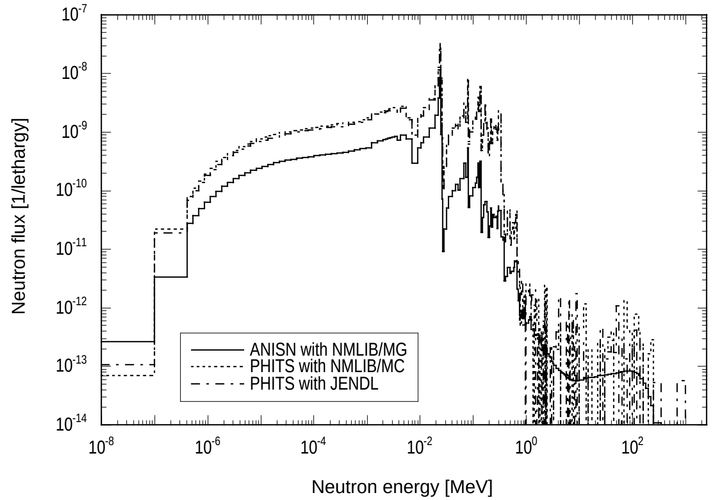

Fig. 8 Calculated neutron spectra at 4 m from the center in the iron sphere.