Status of the compiled Neutron Spectra in EXFOR, work after the Compilers Workshop 6-10 Oct. 2014 and the "Prompt" Summary of oral discussion at this Workshop.

1. History

The issue of compilation of the Neutron Spectra in EXFOR was firstly addressed at the IAEA Consultants' Meeting on "Neutron Sources Spectra for EXFOR" (13- 15 April 2011, IAEA), see:

- Summary Report INDC(NDS)-0590
  https://www-nds.iaea.org/publications/indc/indc-nds-0590-rev.pdf
- Presentations: *https://www-nds.iaea.org/index-meeting-crp/CM-2011_web/*

2. Current status of EXFOR

NDS has searched EXFOR for the Entries with the Neutron and Photon Source Spectra information (energy distribution) collected under the keyword INC-SPECT.

The non-monoenergetic neutron sources are used by authors usually for measurement of the Spectrum Averaged cross sections (SPA), fission yields and other physical quantities. Such quantities are compiled in the same Entry as Reaction string.

The results of search are summarised in Table 1 (with energy spectra – around 17 Entries) and in Table 2 (without) in INC-SPECT.

Table 1. Entries with the Neutron Source Spectra information (energy distribution) coded under keyword INC-SPECT.

INC-SOURC	**Lab First Author**	**n-Source description**	**EXFOR Entries with INC-SPECT having n-Source spectral information**
Reactor facilities			
REAC	AERE, Dhaka M.S. Uddin	TRIGA Mark II LEU fuel, core	31733 http://www-nds.iaea.org/EXFOR/31733.002
REAC	KUR, I. Kimura	^{6}Li-D convertor behind C-column	22214 http://www-nds.iaea.org/EXFOR/22214.007
REAC	TOK, Tokyo H. Harada	YAYOI Reactor, Glory hole	23075 http://www-nds.iaea.org/EXFOR/23075.002
REAC	CEA, Cadarache A. Cricchio	Rapsodie fast reactor fuel pins	21816 http://www-nds.iaea.org/EXFOR/21816.002
REAC	INL, Idaho I. Glagolenko	EBR-II, control rods	31686 http://www-nds.iaea.org/EXFOR/31686.002
REAC	IPPE, Obninsk V.I. Ivanov	BR-5, PuO_2 core	40308 http://www-nds.iaea.org/EXFOR/40308.007
REAC	IPPE, Obninsk G.V. Anikin	beam from BR-5, Shapes of 6 n-lines ?	40080 http://www-nds.iaea.org/EXFOR/40080.001

INC-SOURC	**Lab First Author**	**n-Source description**	**EXFOR Entries with INC-SPECT having n-Source spectral information**
Radioactive sources			
AM-BE	Bangladesh S. Qaim	Am-Be in polyethylene	31724 http://www-nds.iaea.org/EXFOR/31724.002
Accelerator based sources			
P-LI7	TIT, Tokyo T. Matsumoto	thick ^{7}Li(p,n) E_p = 1.9 – 2.3 MeV	22850 http://www-nds.iaea.org/EXFOR/22850.005
P-LI7	TIT, Tokyo K.Terada	thick ^{7}Li(p,n) E_p = 1.9, ?? MeV	23187 http://www-nds.iaea.org/EXFOR/23187.003
P-LI7	TIT, Tokyo T. Wang	thin ^{7}Li(p,n) E_p = 1.9, 2.3 MeV	23103 http://www-nds.iaea.org/EXFOR/23103.002
P-LI7	Manipal H. Naik	thin ^{7}Li(p,n) E_p = 5.6 MeV	33033 http://www-nds.iaea.org/EXFOR/33033.004
P-LI7	KFK, Karlsruhe F. Kaeppeler	thick ^{7}Li(p,n)	O1963 http://www-nds.iaea.org/EXFOR/O1963.002 this source was used to measure many (n,γ) SPA, e.g. http://www-nds.iaea.org/EXFOR/22996.003 (link to O1963 should be included in such Entries ?)
P-LI7	TSL, Uppsala R. Bevilacqua	thin ^{7}Li(p,n) E_p = 179 MeV	23129 http://www-nds.iaea.org/EXFOR/23129.002 (should be compiled as separated p-Li spectrum ?)
P-BE9	WERC, Japan M.S. Uddin	Be(p,xn) E_p = 7.7 MeV	23238 http://www-nds.iaea.org/EXFOR/23238.002 (4 energy groups flux is given)
D-BE9	ANL S. Liskien	thick ^{9}Be(d,xn) E_d = 7 MeV	21857 http://www-nds.iaea.org/EXFOR/21857.002
SPALL	JINR, Dubna C. Bhatia	Pb + U blanket E_d = 1.6 GeV	41529 http://www-nds.iaea.org/EXFOR/41529.002 41565 http://www-nds.iaea.org/EXFOR/41565.002
D-D *D-T*	*FNG, Frascati M. Pillon*	*solid TiT, D targets E_d = 0.3 MeV*	*23127 http://www-nds.iaea.org/EXFOR/23127.002 (n-spectra is available - has to be compiled)*

Comments: *italic font* – incident spectra were found and compiled after Workshop.

Table 2. Entries which have some numerical information about spectrum but do not contain energy distribution in INC-SPECT:

INC-SOURC	**Lab First Author**	**n-Source description**	**EXFOR Entries with INC-SPECT having n-Source spectral information**
P-LI7	IRMM, Geel	^{7}LiF(p,n), T(p,n)	23054 http://www-nds.iaea.org/EXFOR/23054.002
P-T	E. Birgersson	E_p = MeV	(only neutron energy resolution is given …)
D-D	Mexico	D(d,xn)	31687 http://www-nds.iaea.org/EXFOR/31687.002
	E. Chavez	E_d = 3.7 -5.2 MeV	(only dependence of En vs. Angle is given)
REAC	ILL, Grenoble	High Flux reactor,	22941 http://www-nds.iaea.org/EXFOR/22941.002
	A. Letourneau	2 channels in moder.	(only total and thermal fluxes)
D-BE9	*Julich*	*thick ^{9}Be(d,xn)*	*There are many Entries with S.Qaim's SPA[1]*
	S. Qaim	*E_d = 9.7, 14, 30, 53 MeV*	*(corresponding n-spectra have to be referred or compiled)*
D-D *D-T*	*IRRM, Geel M. Pillon*	*solid TiT, gas D, E_d = 7 - 25 MeV*	*23142 http://www-nds.iaea.org/EXFOR/23142.002 (only Emin, Emax, Emean are given)*

INC-SOURC	Lab First Author	n-Source description	EXFOR Entries with INC-SPECT having n-Source spectral information
REAC	*IJD, Kyiv* *O. Gritzay*	*WWR-M* *filtered n-beam*	*32216 http://www-nds.iaea.org/EXFOR/32216.002* *(Emean, Yields of the main and satellite lines)* *(corresponding n-spectra have to be compiled)*

Other Entries which have some information on the incident spectrum but do not contain energy distribution in INC-SPECT:

11467; 20139; 20436; 20534; 20735; 21812; 22007; 22089; 22105; 22340; 22392; 22658; 22661; 22748; 22794; 22837; 22838; 22858; 22882; 22903; 23027; 23067; 23078; 23105; 23222; 40063; 40476; 40924; C0228; C1516; G0002; M0536; O0291.

3. Progress work on inclusion of Neutron Spectra in EXFOR (after Workshop)

Examples of Incident Neutron Spectra received from authors by NDS but not included in EXFOR yet.

- FNG facility, D-D and D-T n-sources:

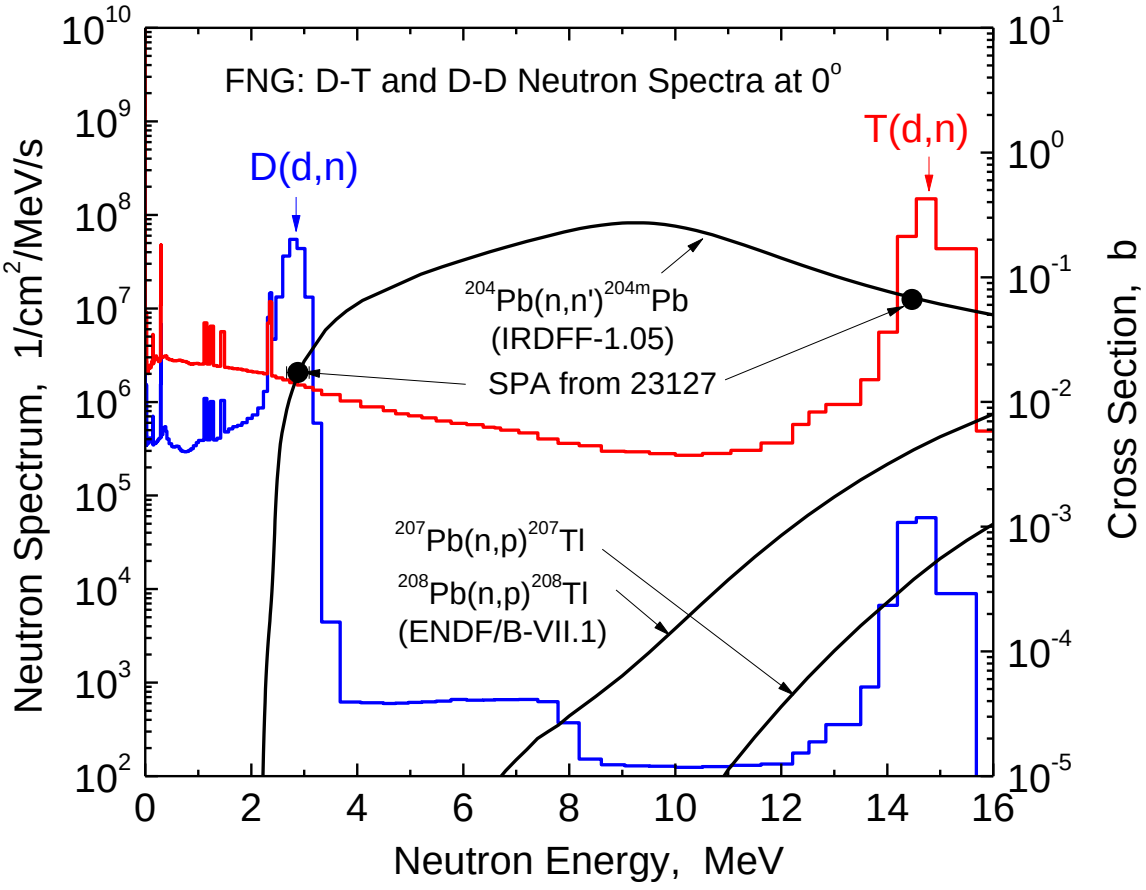

Fig. 1. Neutron Spectra from D-T and D-D Sources received in Nov 2014 from M. Pillon et al. in the 175 groups presentation.

- The spectrum averaged cross sections measured by A. Zvonarev at fast reactor assembly BR-1 (IPPE).

These SPA were early compiled in *41068*.

This entry was updated now:

- 14 group energy spectrum from the authors' publication was added under INC-SPECT.
- reference to ICSBEP(*https://www.oecd-nea.org/science/wpncs/icsbep/)* was added where this assembly (including the MCNP deck for the spectrum calculation) is described as Benchmark FUND-IPPE-FR-MULT-RRR-001.

- D-Be n-sources at FZJ Julich (S. Qaim et al.)

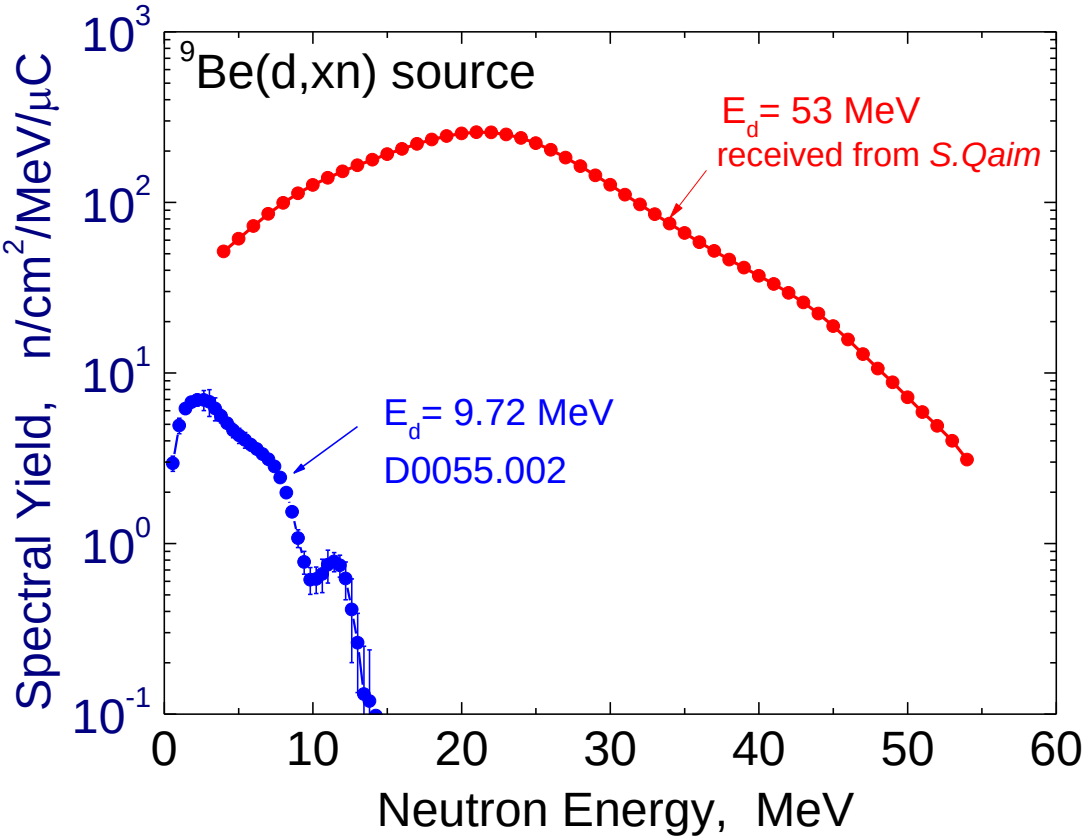

Fig. 2. Neutron Spectra from D-Be Sources from S. Qaim et al. at 53 MeV (51 points)

The summary on spectra used in the measurements carried out by S Qaim's et al. see in INDC(NDS)-0590, p. 35 and summary information collected by NDS in Table 3.

Table 3. Information for the d(Be) neutron spectra applied for the spectrum average cross sections measurements performed at *Institut fur Nuklearchemie, Forschungszentrum Julich GmbH, D-52425 Julich*, Germany and corresponding EXFOR compilations.

Reference	Ed, MeV	n-Spectrum Data / Units	Incident spectrum additional information	EXFOR Entry	How n-Spectra are compiled now
NP/A,100,537,1967	53.8	Table n/(μC MeV sr)		O1924 http://www-nds.iaea.org/EXFOR/O1924.002	REACTION (4-BE-9(D,X)0-NN-,,TTY/PY/DA/DE)
NP/A,329,63,1979	53.8	Text n/(μC MeV sr)	Adopted from NP/A,100,537,1967 and Phys.Med.Biol.20(1975)235 Num. data provided by S.M Qaim	21009 http://www-nds.iaea.org/EXFOR/21009.003	EN-MEAN = 22.5MEV ; EN-RSL-FW = 15.8 MEV
RCA,62,107,1993	53.8	Text n/(μC MeV sr)	Adopted from NP/A,100,537,1967 and Phys.Med.Biol.20(1975)235 Num. data provided by S.M Qaim	22708 http://www-nds.iaea.org/EXFOR/22708.002 Data compiled without SF8=SPA	EN=53 MEV
NP/A,410,421,1983	53.8	Text n/(μC MeV sr)	Adopted from NP/A,100,537,1967 and Phys.Med.Biol.20(1975)235 Num. data provided by S.M Qaim	21916 http://www-nds.iaea.org/EXFOR/21916	EN = 22.5MEV ; EN-RSL-HW = 7.9 MEV
JIN,36,3639,1974	53.8	Figure n/(μC MeV sr)	Adopted from NP/A,100,537,1967 and Phys.Med.Biol.20(1975)235 Num. data provided by S.M Qaim	20524 http://www-nds.iaea.org/EXFOR/20524	EN-APRX = 22.5 MeV
ARI,30,3,1979	53.8	Text	From NP/A,100,537,1967 Num. data provided by S.M Qaim	21878 http://www-nds.iaea.org/EXFOR/21878	EN = 22.5MEV ; EN-RSL-HW = 7.9 MEV
NP/A,295,150,1978	53.8	Text	From NP/A,100,537,1967 Num. data provided by S.M Qaim	20840 http://www-nds.iaea.org/EXFOR/20840	EN-DUMMY = 22.5 MEV
NSE,91,162,1985	17.5, 20, 22.5, 25, 27.5 30	Tables n/(cm^2s MeV)		21988 (Cross sections determined from the SPA measured at given d(Be) spectra) http://www-nds.iaea.org/EXFOR/21988	no information given
91JUELIC,,297,1991	20 and 25	Text	From NSE,91,162,1985	22444 http://www-nds.iaea.org/EXFOR/22444	EN-MIN = 2 MEV
NP/A,423,130,1984	30	Figure n/(sr μCs MeV)		21934 http://www-nds.iaea.org/EXFOR/21934	EN-DUMMY 12 MeV
76GARMIS,,589,197 606	30	Figure n/(sr μC s MeV)		20721 http://www-nds.iaea.org/EXFOR/20721	EN-DUMMY = 11.5 MEV
BNL-NCS-51245,539,1980	30	Figure n/(sr μA s MeV)		21649 http://www-nds.iaea.org/EXFOR/21649	EN-DUMMY = 20 MeV

Reference	Ed, MeV	n-Spectrum Data / Units	Incident spectrum additional information	EXFOR Entry	How n-Spectra are compiled now
RCA,51,49,1990	31	Figure $cm^{-1}s^{-1}$ rel.scale		30977 http://www-nds.iaea.org/EXFOR/30977	EN-DUMMY = 10 MEV
NIM/A,404,373,1998	9.72 ATOMKI	Figure n/(cm^2s MeV)		d(Be) spectrum compiled in D0055 http://www-nds.iaea.org/EXFOR/D0055.002	REACTION (4-BE-9(D,N)5-B-10,,TTY/MLT/DE,,REL)
				Data compiled in 31495 http://www-nds.iaea.org/EXFOR/31495.016 http://www-nds.iaea.org/EXFOR/31495.040	EN-MEAN = 4.3 MEV
	13.55 Juelich	Figure arb. Units			
ARI,64,717,2006 RCA,92,183,2004	14	Figure arb. units	From NIM/A,404(1998)373	22857 http://www-nds.iaea.org/EXFOR/22857	EN-DUMMY = 3 MeV
ARI,54,655,2001	14	Text	From NIM/A,404(1998)373	22664 http://www-nds.iaea.org/EXFOR/22664.011	EN-MEAN = 13.6 MeV
INDC(GER)-049,10,2003	14	Text	From NIM/A,404(1998)373	22832 http://www-nds.iaea.org/EXFOR/22832	EN-MEAN = 14 MeV

4. Summary of oral discussions at Workshop "EXFOR Compilation" (6-10 Oct 2014).

Following two Alternatives for the Neutron source compilations were considered.

(i). First Alternative: use the REACTION string for incident spectrum

Create the new special SubEntry to code the incident Spectrum as Reaction string:

REACTION (U-238-SRC(0,0),,DE,,SPD)

which will specify Spectrum for already existing SubEntry with reaction SPA cross section coded by proper spectrum code SF8 = MXA, EPI, FIS, FSR, BRA, SPA in:

REACTION (6-C-12(N,TOT) , , , ,SPA

(ii). Second Alternative: continue to use INC–SPECT for incident spectrum

Put spectrum information (reference, or link to file with spectrum) in INC–SPECT:

INC-SPECT ***[or extended version INC-SPECT(DE,…) for searching, plotting etc. ?]***

as free text description of spectrum and how it was obtained

E	Sp
eV	1/eV
10000.	.0001
……	……
19999	.0009

or (E, Sp, Npoints) to read by retrieving system

or ***link to file or text explaining where data could be found, e.g.:***

- ***to File with Spectrum*** *if spectrum array is rather long*
- ***to IRDFF-2002 research reactor Spectra database***
  (https://www-nds.iaea.org/irdf2002/data/irdf2002_spectra.dat):
  for ISNF spectrum from G.P.Lamaze 13153, B.M.Oliver 13752
  for Sig-Sig spectrum from A.Fabry 20948, A.Hannan 20950, I.Garlea 30452, 30568
  for CFRMF spectrum - Y.Harker 10218, E.P.Lippincott 13756
  for YAYOI spectrum - K.Kobayashi 21589, K.Kobayashi 20693
- ***to ENDF or Standards for the case of Cf, U(n,f) source***
- ***to ICSBEP(*** *https://www.oecd-nea.org/science/wpncs/icsbep/):*
  e.g.. to Benchmark FUND-IPPE-FR-MULT-RRR-001 from A. Zvonarev 41068