The Area #1 EXFOR project

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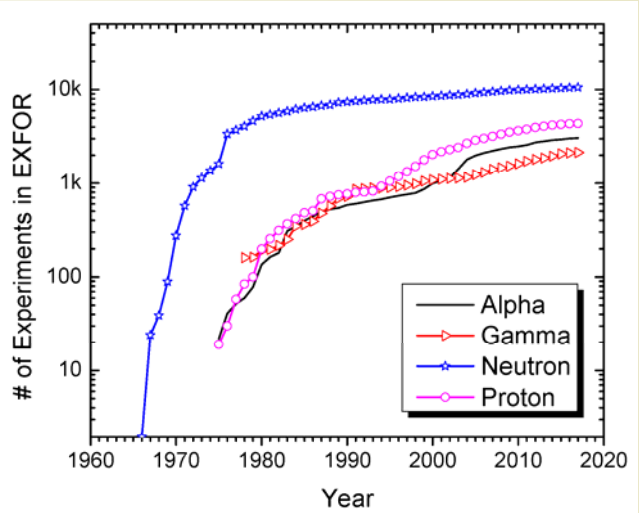
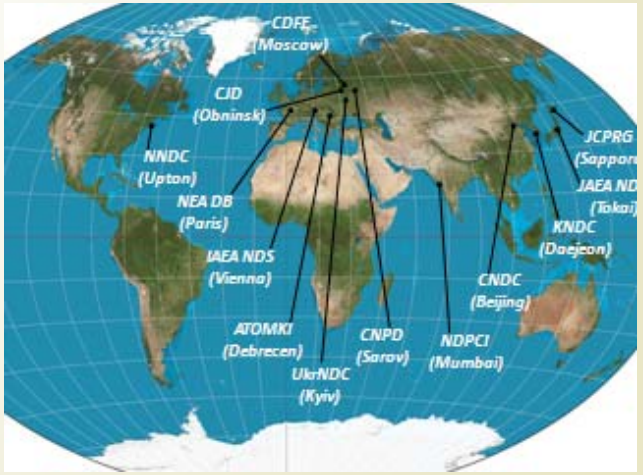
Nuclear Reaction Data Compilations

- Experimental neutron reaction data compilations have been pioneered at the Metallurgical Laboratory, University of Chicago and Los Alamos National Laboratory in 1945-1947.
- Brookhaven National Laboratory hired many *Manhattan Project* alumni when it was founded in 1947, and the lab got involved in nuclear data.
- Donald J. Hughes (1915-1960) was behind the BNL-170 (1952); it is a precursor of BNL-325 (Atlas of Neutron Resonances).
- SCISRS (Sigma Center Information and Retrieval System) at BNL (1964) was a precursor of EXFOR.
- Other data centers were created in Paris, France (NEA-Databank), Vienna, Austria (NDS-IAEA), and Obninsk, USSR (IPPE) in 1963-1964.
- Around 1970 four neutron data centers agreed on the data interchange format (EXFOR). The four centers could store data locally in its formats. The Nuclear Data Centres Reaction (NRDC) network was founded in 1979 under the auspices of the IAEA.

EXFOR - Experimental Nuclear Reaction Data

- The largest experimental nuclear reaction database: 25,536 experiments (multiple publications are grouped into a single measurement), 169,827 subentries, 186,485 data sets as of June 11, 2025.
- **EXFOR is a starting point for Evaluated Nuclear Data File (ENDF) libraries evaluations (many evaluated but a single experimental data library), it includes the uncertainties used by evaluators.**
- Presently run by the Nuclear Reaction Data Centres (NRDC) internationally.
- ***EXFOR philosophy is to compile data as they were published (in consultation with authors) unless obvious errors are found.*** **Published nuclear reaction data contain outliers and discrepancies.**





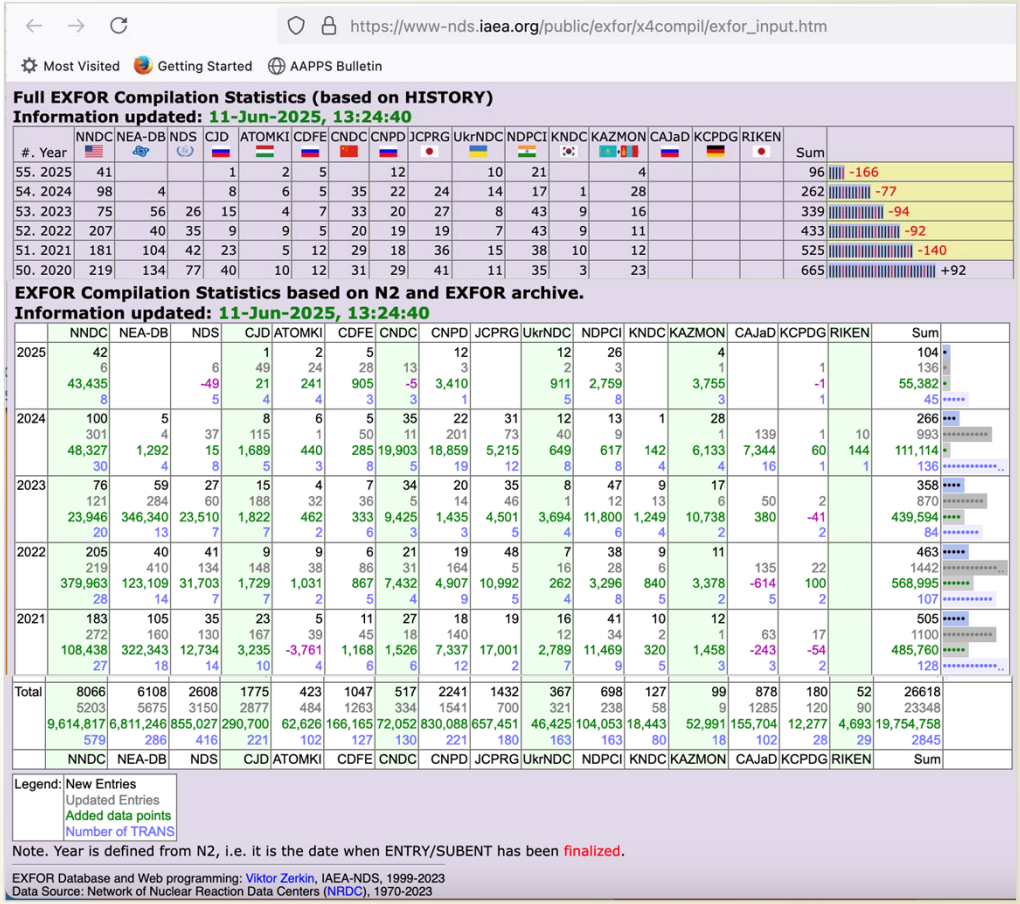
Area #1 FY 2024 (10/1/2023-9/30/2024) Statistics

- Team effort: B.Pritychenko (BNL), O.Schwerer, O.Gritsay (Volunteers/Contractors).
- Multiple contributions by N. Otuka improved the Area #1 compilation process and statistics.
- Software help from V. Zerkin.
- Former contributor: S.Hlavac.

EXFOR	FY2022	FY2023	FY2024
New Compilations	158	152	95
Updated Compilations	210	181	95
Preliminary Transmissions	29	19	15
Final Transmissions	31	22	20
Database Updates	41	40	15

The IAEA EXFOR compilation control system

- EXFOR compilation control system is one of the tools used for this co-ordination (Developed by Viktor Zerkin, IAEA, retired on October 31, 2023).
- Top panel: New entries only.
- Bottom panel: New and Updated entries, number of data points and transmissions.
- Overall performance of the Area #1 is very good.
- Potential issue is EXFOR maintenance or correction of existing entries.
- Area #1 has the largest number of entries 8,006. Only 5,203 (~64.9%) of entries were corrected. One calendar year ago the corrected entries number was ~61.3%.
- Total number of data points is 9,614,817.



https://www-nds.iaea.org/public/exfor/x4compil/exfor_input.htm

Most Visited | Getting Started | AAPPS Bulletin

Full EXFOR Compilation Statistics (based on HISTORY)
Information updated: 11-Jun-2025, 13:24:40

#. Year	NNDC	NEA-DB	NDS	CJD	ATOMKI	CDFE	CNDC	CNPD	JCPRG	UkrNDC	NDPCI	KNDC	KAZMON	CAJaD	KCPDG	RIKEN	Sum	
55. 2025	41			1	2	5		12		10	21		4				96	-166
54. 2024	98	4		8	6	5	35	22	24	14	17	1	28				262	-77
53. 2023	75	56	26	15	4	7	33	20	27	8	43	9	16				339	-94
52. 2022	207	40	35	9	9	5	20	19	19	7	43	9	11				433	-92
51. 2021	181	104	42	23	5	12	29	18	36	15	38	10	12				525	-140
50. 2020	219	134	77	40	10	12	31	29	41	11	35	3	23				665	+92

EXFOR Compilation Statistics based on N2 and EXFOR archive.
Information updated: 11-Jun-2025, 13:24:40

	NNDC	NEA-DB	NDS	CJD	ATOMKI	CDFE	CNDC	CNPD	JCPRG	UkrNDC	NDPCI	KNDC	KAZMON	CAJaD	KCPDG	RIKEN	Sum
2025	42			1	2	5		12		12	26		4				104
	6		6	49	24	28	13	3		2	3		1		1		136
	43,435		-49	21	241	905	-5	3,410		911	2,759		3,755		-1		55,382
	8		5	4	4	3	3	1		5	8		3		1		45
2024	100	5		8	6	5	35	22	31	12	13	1	28				266
	301	4	37	115	1	50	11	201	73	40	9		1	139	1	10	993
	48,327	1,292	15	1,689	440	285	19,903	18,859	5,215	649	617	142	6,133	7,344	60	144	111,114
	30	4	8	5	3	8	5	19	12	8	8	4	4	16	1	1	136
2023	76	59	27	15	4	7	34	20	35	8	47	9	17				358
	121	284	60	188	32	36	5	14	46	1	12	13	6	50	2		870
	23,946	346,340	23,510	1,822	462	333	9,425	1,435	4,501	3,694	11,800	1,249	10,738	380	-41		439,594
	20	13	7	7	2	6	3	3	5	4	6	4	2		2		84
2022	205	40	41	9	9	6	21	19	48	7	38	9	11				463
	219	410	134	148	38	86	31	164	5	16	28	6		135	22		1442
	379,963	123,109	31,703	1,729	1,031	867	7,432	4,907	10,992	262	3,296	840	3,378	-614	100		568,995
	28	14	7	7	2	5	4	9	5	4	8	5	2	5	2		107
2021	183	105	35	23	5	11	27	18	19	16	41	10	12				505
	272	160	130	167	39	45	18	140		12	34	2	1	63	17		1100
	108,438	322,343	12,734	3,235	-3,761	1,168	1,526	7,337	17,001	2,789	11,469	320	1,458	-243	-54		485,760
	27	18	14	10	4	6	6	12	2	7	9	5	3	3	2		128
Total	8066	6108	2608	1775	423	1047	517	2241	1432	367	698	127	99	878	180	52	26618
	5203	5675	3150	2877	484	1263	334	1541	700	321	238	58	9	1285	120	90	23348
	9,614,817	6,811,246	855,027	290,700	62,626	166,165	72,052	830,088	657,451	46,425	104,053	18,443	52,991	155,704	12,277	4,693	19,754,758
	579	286	416	221	102	127	130	221	180	163	163	80	18	102	28	29	2845
	NNDC	NEA-DB	NDS	CJD	ATOMKI	CDFE	CNDC	CNPD	JCPRG	UkrNDC	NDPCI	KNDC	KAZMON	CAJaD	KCPDG	RIKEN	Sum

Legend: New Entries / Updated Entries / Added data points / Number of TRANS

Note. Year is defined from N2, i.e. it is the date when ENTRY/SUBENT has been finalized.

EXFOR Database and Web programming: Viktor Zerkin, IAEA-NDS, 1999-2023
Data Source: Network of Nuclear Reaction Data Centers (NRDC), 1970-2023

Recent EXFOR entries

- #14847: A. Stamatopoulos et al., Di
  Neutron-Capture Cross Section and
  - Our data reveal a resonance at 0.1
    section of 771 000±31 000 b, in good
    contrast, the neutron-capture reson
    15 210±670 b and is roughly a facto
- #14836: J.M. Brown et al., New Mea
  Evaluated Model Parameters of 18
  - To resolve discrepancies in evaluate
    libraries, energy-differential neutron
    were measured from 0.15 to 100 ke
- #14782: A. Daskalakis, D. Barry, Tran
  Isotopes
  - ~200,000 lines of data, 12.5 MB

```
ENTRY          14847   20250325   20250605   20250605       1518
SUBENT      14847001   20250325   20250605   20250605       1518
BIB               11         50
TITLE      Discovery of the Origin of the Enormous 88Zr
           Neutron-Capture Cross Section and Quantifying Its
           Impact on Applications
AUTHOR     (A.Stamatopoulos,P.E.Koehler,B.Digiovine,V.Mocko,
           A.Matyskin,Ch.Vermeulen,A.Couture,A.Cooper,J.Morrell,
           E.O'Brien)
REFERENCE  (J,PRL,134,112702,2025) Main reference.
           #doi:10.1103/PhysRevLett.134.112702
           (J,PR/C,111,034613,2025) Experimental details.
```

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ENTRY          14836   20250206   20250605   20250605       1518
SUBENT      14836001   20250206   20250605   20250605       1518
BIB               13         73
TITLE      New Measurements to Resolve Discrepancies in
           Evaluated Model Parameters of 181Ta
AUTHOR     (J.M.Brown,D.P.Barry,R.C.Block,A.Youmans,H.Choun,
           A.Ney,E.Blain,M.J.Rapp,Y.Danon)
REFERENCE  (J,NSE,198,1155,2024)
           #doi:10.1080/00295639.2023.2249786
```

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TRANS           1519   20250515                                10000000    0
ENTRY          14782   20250424                                14782000    1
SUBENT      14782001   20250424                                14782001    1
BIB               11         23                                14782001    2
TITLE      Transmission Measurements for Mo-92 and Mo-94 Isotopes 14782001    3
AUTHOR     (D.Barry)                                           14782001    4
REFERENCE  (W,BARRY,20250424)                                  14782001    5
INSTITUTE  (1USAKAP)                                           14782001    6
FACILITY   (LINAC,1USARPI)                                     14782001    7
INC-SOURCE (PHOTO) Neutrons were produced by ~50 MeV electron  14782001    8
           beam impinging on tantalum target. Repetition frequency14782001    9
           was 400 Hz and pulse width 10-13 ns. Water moderator 14782001   10
           with diameter of 22.54 cm and thickness of 2.54 cm  14782001   11
           was used. Nominal beam power was 600-900 W.         14782001   12
```
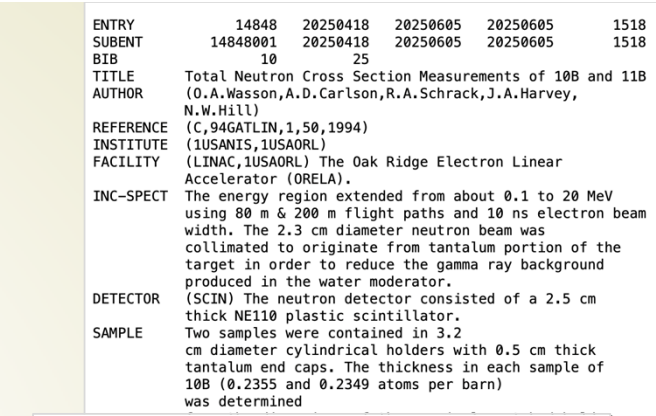

Not Recent Experiments

- #14848: Total Neutron Cross Section Measurements of 10B and 11B
- I was recently contacted by Allan Carlson, who provided data from a 1994 publication.
- It was released as TRANS.1518.
- 2003 publication of J. Blackmon et al., C1138. It is digitized in EXFOR because the compiler failed to obtain data from the author.
- While working on the C3072 compilation, it was discovered that the LSU group re-analyzed C1138 and extracted resonance parameters.
- I contacted the group and secured a commitment to provide the 2003 data.
- Sometimes it is possible to recover 20-30-year-old data.



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ENTRY           14848   20250418   20250605   20250605       1518
SUBENT       14848001   20250418   20250605   20250605       1518
BIB                10         25
TITLE      Total Neutron Cross Section Measurements of 10B and 11B
AUTHOR     (O.A.Wasson,A.D.Carlson,R.A.Schrack,J.A.Harvey,
           N.W.Hill)
REFERENCE  (C,94GATLIN,1,50,1994)
INSTITUTE  (1USANIS,1USAORL)
FACILITY   (LINAC,1USAORL) The Oak Ridge Electron Linear
           Accelerator (ORELA).
INC-SPECT  The energy region extended from about 0.1 to 20 MeV
           using 80 m & 200 m flight paths and 10 ns electron beam
           width. The 2.3 cm diameter neutron beam was
           collimated to originate from tantalum portion of the
           target in order to reduce the gamma ray background
           produced in the water moderator.
DETECTOR   (SCIN) The neutron detector consisted of a 2.5 cm
           thick NE110 plastic scintillator.
SAMPLE     Two samples were contained in 3.2
           cm diameter cylindrical holders with 0.5 cm thick
           tantalum end caps. The thickness in each sample of
           10B (0.2355 and 0.2349 atoms per barn)
           was determined
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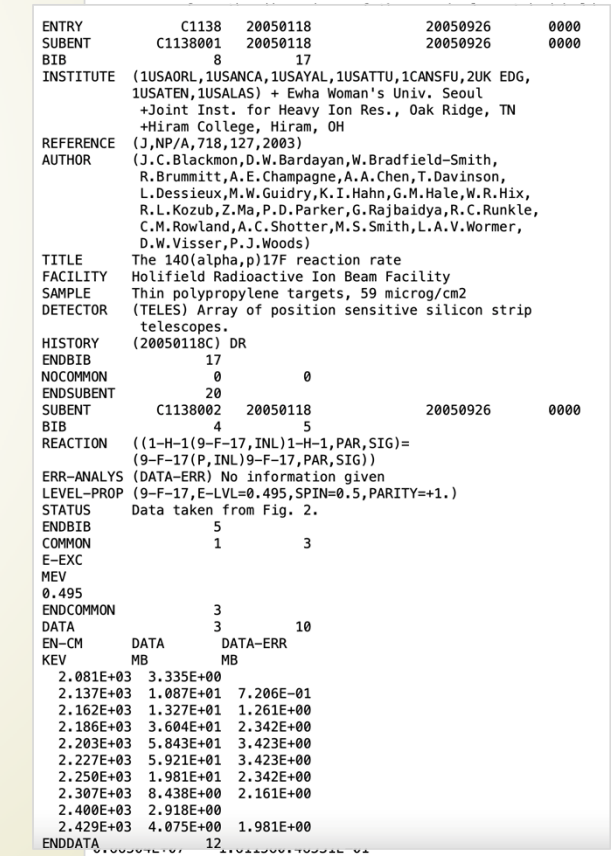
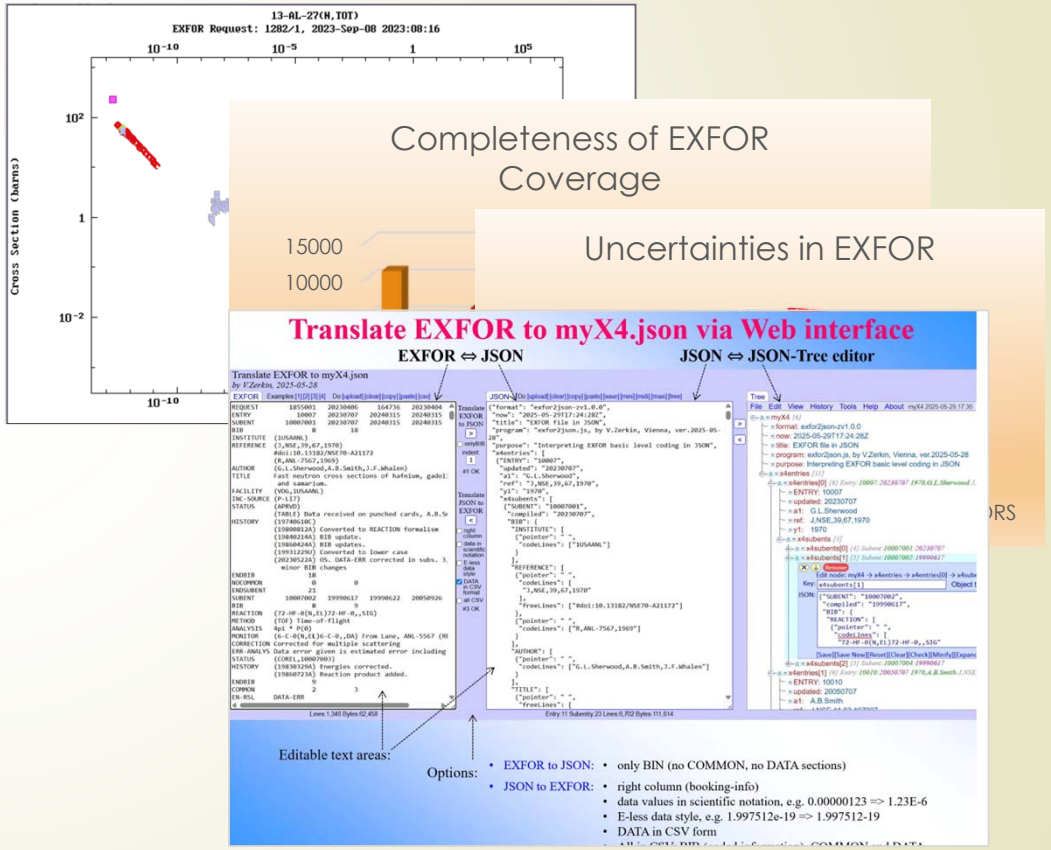


```
ENTRY           C1138   20050118             20050926       0000
SUBENT       C1138001   20050118             20050926       0000
BIB                 8         17
INSTITUTE  (1USAORL,1USANCA,1USAYAL,1USATTU,1CANSFU,2UK EDG,
           1USATEN,1USALAS) + Ewha Woman's Univ. Seoul
            +Joint Inst. for Heavy Ion Res., Oak Ridge, TN
            +Hiram College, Hiram, OH
REFERENCE  (J,NP/A,718,127,2003)
AUTHOR     (J.C.Blackmon,D.W.Bardayan,W.Bradfield-Smith,
            R.Brummitt,A.E.Champagne,A.A.Chen,T.Davinson,
            L.Dessieux,M.W.Guidry,K.I.Hahn,G.M.Hale,W.R.Hix,
            R.L.Kozub,Z.Ma,P.D.Parker,G.Rajbaidya,R.C.Runkle,
            C.M.Rowland,A.C.Shotter,M.S.Smith,L.A.V.Wormer,
            D.W.Visser,P.J.Woods)
TITLE      The 14O(alpha,p)17F reaction rate
FACILITY   Holifield Radioactive Ion Beam Facility
SAMPLE     Thin polypropylene targets, 59 microg/cm2
DETECTOR   (TELES) Array of position sensitive silicon strip
            telescopes.
HISTORY    (20050118C) DR
ENDBIB             17
NOCOMMON            0          0
ENDSUBENT          20
SUBENT       C1138002   20050118             20050926       0000
BIB                 4          5
REACTION   ((1-H-1(9-F-17,INL)1-H-1,PAR,SIG)=
           (9-F-17(P,INL)9-F-17,PAR,SIG))
ERR-ANALYS (DATA-ERR) No information given
LEVEL-PROP (9-F-17,E-LVL=0.495,SPIN=0.5,PARITY=+1.)
STATUS     Data taken from Fig. 2.
ENDBIB              5
COMMON              1          3
E-EXC
MEV
0.495
ENDCOMMON           3
DATA                3         10
EN-CM      DATA       DATA-ERR
KEV        MB         MB
  2.081E+03  3.335E+00
  2.137E+03  1.087E+01  7.206E-01
  2.162E+03  1.327E+01  1.261E+00
  2.186E+03  3.604E+01  2.342E+00
  2.203E+03  5.843E+01  3.423E+00
  2.227E+03  5.921E+01  3.423E+00
  2.250E+03  1.981E+01  2.342E+00
  2.307E+03  8.438E+00  2.161E+00
  2.400E+03  2.918E+00
  2.429E+03  4.075E+00  1.981E+00
ENDDATA             12
```

EXFOR Database Modernization

- EXFOR is 75-year-old: It has to capitalize on modern computer technologies: Automatization of the EXFOR life and production cycle
- NEA WPEC SG54: Curated EXFOR: developing a machine-readable, comprehensive, and corrected by evaluators experimental nuclear reaction database
- New data formats: JSON (JavaScript Object Notation) lightweight data interchange format for EXFOR is now in progress at the SG54 (N.Otuka, V.Zerkin).
- Future compilation of corrected EXFOR data sets.
- SG54 collaboration: BNL, IAEA, LBNL, NEA-DB, Los Alamos, LLNL, ORNL, …
- BNL/ORNL/LANL Proposal: From measurement to discovery: an automated nuclear data workflow.



Update on NRDC Actions

- A9: Continued
- A14: Continued
- A15: Finished
- A16: Lanier not original data.
- A16-A24 finished
- A26 Continued

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Outlook

- NNDC EXFOR compilation efforts are complex and well-organized: B. Pritychenko (BNL), S. Gritzay (Former contractor) O. Schwerer, N.Otuka, V. Zerkin (IAEA).
- EXFOR modernization is needed.
- We should contribute to SG54.
- Finalize JSON format, explore free text to JSON conversion, work on JSON conversion quality assurance (QA).
- Collect curated EXFOR data sets.
- People is the most important resource in nuclear data; we lost Dr. Stanislav Hlavac.

Nuclear Data Newsletter No. 77, August 2024

In Memoriam

Stanislav Hlavac

On 12 July 2024 Stanislav Hlaváč, gifted experimental physicist and recognized EXFOR compiler, passed away at the age of 77. Stanislav was born experimentalist, mastered nanosecond fast timing techniques and performed first time-of-flight experiments with fast neutrons in the then Czechoslovakia. Considerable recognition brought him also the EU project DIAMINE for detection and imaging of antipersonal landmines by neutron backscattering. His expertise in neutron-induced reactions was appreciated by the National Nuclear Data Center, USA and since 2006 used for numerous US contributions to the experimental cross section data library EXFOR. Stanislav hosted the NRDC 2014 meeting (https://nds.iaea.org/nrdc/nrdc_2014/) in Smolenice, allowing to discuss EXFOR compilations in the beautiful castle owned by the SAS and known as famous venue for nuclear data events. Over a quarter of century, Stanislav collaborated with the Society for Heavy Ion Research (GSI) in Darmstadt and Max Planck Institute in Heidelberg. Stanislav contributed to development and use of the ultimate gamma-ray detector Crystal Ball, Two Arms Photon Spectrometer (TAPS) and the High Acceptance Di-Electron Spectrometer (HADES). Stanislav inspired young generation of physicists, loved sport and excelled in swimming. The international nuclear data community will miss his truly professional approach to neutron data compilation, deep sense for co-operation, his modest and friendly personality.

(*written by Pavel Oblozinsky, July 2024*)

International Network of Nuclear Reaction Data Centres (NRDC)

- The International Network of Nuclear Reaction Data Centres (NRDC) constitutes a worldwide cooperation of nuclear data centres under the auspices of the International Atomic Energy Agency. The Network was established to coordinate the world-wide collection, compilation and dissemination of nuclear reaction data.

Technical Meeting on International Network of Nuclear Reaction Data Centres
IAEA Headquarters, Vienna, Austria, 9 – 12 May 2023

The International Atomic Energy Agency: (https://www.iaea.org/about/mission)

- is an independent intergovernmental, science and technology-based organization, in the United Nations family, that serves as the global focal point for nuclear cooperation;
- assists its Member States, in the context of social and economic goals, in planning for and using nuclear science and technology for various peaceful purposes, including the generation of electricity, and facilitates the transfer of such technology and knowledge in a sustainable manner to developing Member States;
- develops nuclear safety standards and, based on these standards, promotes the achievement and maintenance of high levels of safety in applications of nuclear energy, as well as the protection of human health and the environment against ionizing radiation;
- verifies through its inspection system that States comply with their commitments, under the Non-Proliferation Treaty and other non-proliferation agreements, to use nuclear material and facilities only for peaceful purposes.