

Area #1 EXFOR Project

Boris Pritychenko

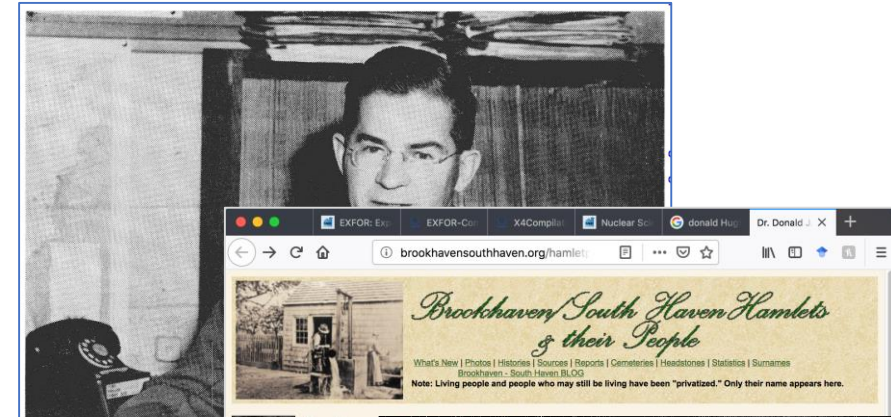
National Nuclear Data Center, BNL, Upton, NY 11973

BROOKHAVEN
NATIONAL LABORATORY

 U.S. DEPARTMENT OF
ENERGY

Nuclear Reaction Data Compilations

- Experimental neutron reaction data compilations have been pioneered at Brookhaven National Laboratory.
- Donald J. Hughes (1915-1960) compiled data since 1950.
- BNL-170 was published in 1952; it is a precursor of BNL-325.
- Second UN International Conference on Peaceful Uses of Atomic Energy, Geneva, 1958.
- SCISRS (Sigma Center Information and Retrieval System) at BNL (1964) was a precursor of EXFOR.
- Other data centers were created in Vienna, Austria (NDS-IAEA), Paris, France (NEA-Databank) and Obninsk, USSR (IPPE) in 1963-1964.
- Data Centers Interchange Format (EXFOR) was introduced in 1970 and Nuclear Data Centres Reaction (NRDC) network was formed under the auspices of the IAEA.
- NNDC EXFOR Team: B. Pritychenko, S. Hlavac, O. Schwerer, and V. Zerkin (IAEA) covers U.S. and Canada.



Technical Meeting on the
International Network of Nuclear Reaction Data Centres
1-4 May, 2018, GCNEP, Bahadurgarh, India

What is EXFOR???

- The EXchange FORmat (EXFOR) experimental nuclear reaction database and format for low- and intermediate-energy physics (February 2019)
 - 22,376 experimental works
 - 172,641 reaction data tables
 - Total and differential cross sections, resonance parameters, fission yields, thick-target and product yields, multiplicities,
 - Originally neutron-induced reactions, charged particles and photons were added later.
 - All compilations go through a strict quality assurance process.
- Available at <https://www.nndc.bnl.gov/exfor> and <https://www-nds.iaea.org/exfor>.
- EXFOR statistics, the IAEA official count of compilations: https://www-nds.iaea.org/public/exfor/x4compil/exfor_input.htm.
- Data compilations were started in United States, centers split data geographically. Therefore NNDC has the largest individual contribution to the EXFOR library followed by NEA-IEA (Paris), NDS-IAEA (Vienna) and others.

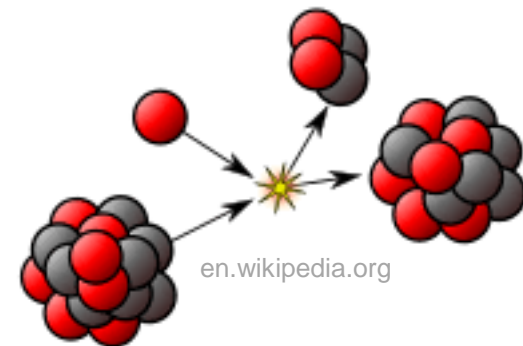
The screenshot displays the EXFOR website interface. On the left, there's a search form with fields for Target, Reaction, Quantity, Product, Energy, and Author(s). A 'Request' button is visible. On the right, there's a 'Full EXFOR Compilation Statistics (based on HISTORY)' table. The table shows data from 1972 to 2018, with columns for various countries and their contributions. A 3D pie chart is overlaid on the table, showing the relative contributions of different countries. The legend for the pie chart includes: NNDC, NEA-IEA, NDS, CJD, ATOMKI, CDFE, and NDPCI. The total number of entries is 7052.

Year	USA	FR	UK	CH	RU	JP	DE	IT	IN	Other	Sum	Change			
2018	52	26	68	6	16	19	9	26	16	14	14	7	266	-156	
2017	116	39	39	30	21	33	24	29	15	11	54	11	422	+24	
2016	119	71	52	5	29	7	31	27	26	16	8	7	398	-43	
2015	103	69	58	7	17	27	30	29	21	12	49	19	441	+3	
2014	92	104	54	7	23	21	26	42	27	14	23	4	438	-19	
2013	124	83	35	14	11	12	7	25	59	16	51	3	456	-155	
2012	128	201	45	9	22	20	18	41	63	10	19	9	611	+72	
2011	78	97	54	19	16	37	10	50	51	13	59	8	539	+57	
2010	75	100	67	20	8	20	19	53	57	9	14	10	482	-262	
2009	132	178	85	11	26	19	11	70	104	19	63	7	744	+84	
2008	94	192	145	19	15	27	84	22	27	15	20		660	+60	
2007	125	196	37	21	15	25	84	149	34	34			720	+40	
2006	159	158	99	26	16	26	21	50	80	25	10		680	-256	
2005	459	127	119	16	12	16	2	67	100	7	11		936	+89	
2004	204	129	187	8	9	16		107	72	5	60		847	+312	
2003	72	114	22	22	31	8	4	136	93	3	30		535	+122	
2002	92	122	7	18	1	15	1	34	54	1	68		413	-6	
2001	128	125	15	14	22	11	7	72	5	3	17		419	-123	
2000	209	190	4	17	16	66					32		542	+38	
1999	173	173	18	1	2	39	2				11		227	+81	
1998	92	116	10	48	1	26					39		423	+59	
1997	110	127	17	46	18	21	8	2			15		364	+8	
1996	81	167	10	48	17	11	2	11			7		356	+111	
1995	10	112	10	16	38	4	15	3	6		31		245	+18	
1994	4	107	18								5		127	+36	
1993	47	12	54								16		111	+15	
1992	42	54									11		206	-115	
1991	10										3		321	+95	
1990	17	30									7		226	-292	
1989	7	45									3		515	+186	
1988	33	33									65		235	+152	
1987	27	21									14		6	484	+178
1986	63	15									30		4	306	-102
1985	63	15									16		9	408	-131
1984	67	15									16		6	539	+43
1983	47	12									30		6	496	+113
1982	33	46									15		383	-4	
1981	33	46									15		387	-503	
1980	33	46									15		890	+233	
1979	33	46									15		657	+177	
1978	33	46									15		489	+65	
1977	33	46									15		415		
1976	33	46									15		1808		
1975	33	46									15		294		
1974	33	46									15		246		
1973	33	46									15		235		
1972	33	46									15		349		
1971	33	46									15		300		
1970	33	46									15		194		
1969	33	46									15		52		
1968	33	46									15		15		
1967	33	46									15		24		
1966	33	46									15		3		
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1888	33	46									15		3		
1887	33	46									15		3		
1886	33	46									15		3		
1885	33	46									15		3		
1884	33	46									15		3		
1883	33	46									15				

EXFOR Effort in the U.S. and Canada

- EXFOR Team: B. Pritychenko, S. Hlavac, O. Schwerer, V. Zerkin (IAEA), and O. Gritzay (KINR).
 - NNDC: Overall database and contracts management, website support, compilation and correction of missing and older references.
 - Bratislava: Mainly new references compilation.
 - Vienna: Overall quality assurance and transmission handling.
 - IAEA: Web and database software development.
 - KINR: Compilation of Fission Product yields.
- Smooth operation based on efforts of BNL staff, contractors and collaborators.
- Contractors (S. Hlavac, O. Schwerer, and O. Gritzay) are essential for the overall success of the NNDC EXFOR effort.

FY 2018 EXFOR Statistics



- New entries: $43 + 87$ (BNL) = 130.
- Corrected entries: $158 + 53$ (BNL) = 211.
- 24 Preliminary and 24 final data transmissions (Preliminary transmissions go through the NRDC network quality assurance system, after implemented corrections final transmission are loaded into the database).
- EXFOR database was updated 24 times, and CINDA database was updated 10 times.
- More compilation details in the IAEA system based on calendar years: <http://www-nds.iaea.org/exfor-master/x4compil/>.
- Fission yields compilation pilot project was completed.

EXFOR Web Dissemination

- NNDC serves as a standard in nuclear data Web dissemination worldwide. The Center has the most complete collections of nuclear data.
- We operate on 24seven basis: three Web and two database servers.
- Strict U.S. government operation and cyber security requirements.
- Great interaction between NNDC and Viktor Zerkin (IAEA) on EXFOR database updates. All previous issues with delayed database update have been resolved.
- We adopted Viktor's Web statistics system: example of a server log contains the list of countries that use data and have an expertise in nuclear science.
- General comment from an EXFOR user on compiled entries: MISC - Dr. Ramona Vogt cannot figure it out, and so many of her colleagues.

2019 International Conference | Coram, Statistics of usage from 201803 to 201903
 Web Server: www3.nndc.bnl.gov
 Generated: 2019-03-29 08:45:01

ENDF

#	Action	Counts
1	e4.eval	2195
2	e4.getEvalSum	657
3	e4.getSectSum	1568
4	e4.getTabSect	3729
5	e4.get_e4	1124
6	e4.get_e4pen	12
7	e4.get_e4zip	87
8	e4.get_gnd	141
9	e4.interp	1140
10	e4.plot	10939
11	e4.plot2	899
12	e4.plot2d	237
13	e4.sect	1571

Total counts:24299

#	Month	Counts
1	201807	1478
2	201808	1950
3	201809	2609
4	201810	3947
5	201811	2622
6	201812	2333
7	201901	3139
8	201902	3129
9	201903	3092

Total counts:24299
(per Month:2700)

#	Client	Counts	Country
1	192.12.184.7	646	United States
2	95.222.214.179	509	Germany
3	192.12.184.6	470	United States
4	160.91.17.66	317	United States
5	128.115.190.33	261	United States
6	123.126.113.100	250	China
7	202.38.129.244	247	China
8	202.38.129.241	193	China
9	133.53.248.253	184	Japan
10	128.219.49.13	163	United States
11	151.100.7.10	144	Italy
12	176.138.168.141	140	France
13	146.115.6.251	133	United States
14	80.94.174.15	132	Belarus
15	198.102.155.100	124	United States
16	192.188.177.1	120	United States
17	111.202.100.123	119	China
18	219.246.33.80	113	China
19	166.111.32.48	99	China
20	198.102.155.120	94	United States
...
2615	73.108.11.52	1	United States

Total counts:24299

#	Counts	%	Country
1	11186	46.0%	United States
2	3949	16.3%	China
3	1091	4.5%	France
4	955	3.9%	Japan
5	835	3.4%	Germany
6	736	3.0%	Russian Federation
7	702	2.9%	Czech Republic
8	669	2.8%	Canada
9	556	2.3%	Korea, Republic of
10	476	2.0%	Italy
11	251	1.0%	Iran, Islamic Republic of
12	246	1.0%	Belarus
13	229	0.9%	Israel
14	185	0.8%	United Kingdom
15	175	0.7%	Australia
16	159	0.7%	India
17	154	0.6%	Brazil
18	150	0.6%	Switzerland
19	135	0.6%	Austria
20	129	0.5%	Ukraine
...
1	70	0.0%	Slovenia

Total counts:24299

IBANDL

#	Action	Counts
1	plot	2
2	r33.save	1
3	r33my.view	1
4	search-TargProj	5

Total counts:9

#	Month	Counts
1	201903	9

Total counts:9

#	Client	Counts	Country
1	114.242.248.249	9	China

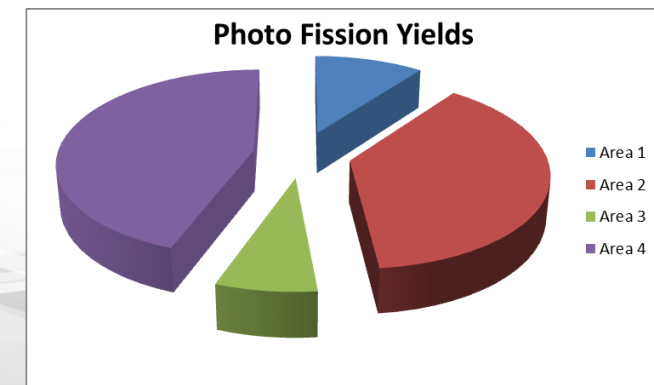
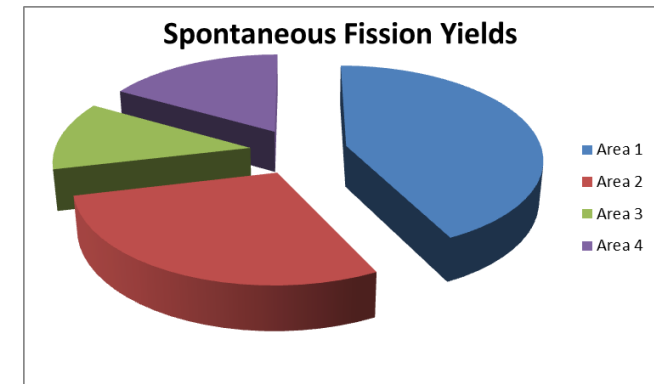
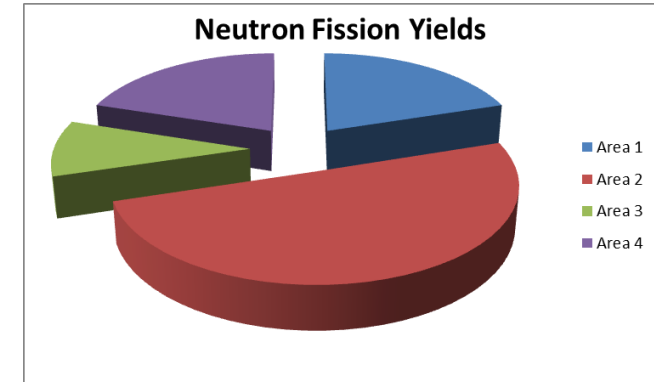
Total counts:9

#	Counts	%	Country
1	9	100.0%	China

Total counts:9

FY Compilation Completeness

- Fission Yields (FY) are fundamental for many applications.
- Do we have a complete FY record in EXFOR?
- The completeness of EXFOR (22,294 experiments) was verified using the NSR database (229,594 references) by NNDC team (B. Pritychenko, O. Schwerer) with help of V. Zerkin (IAEA).
- Nuclear structure-like search for FY NSR references was conducted at NNDC:
 - Potentially Missing Neutron FY: 384
 - Potentially Missing Spontaneous FY: 142
 - Potentially Missing Photo FY: 126
 - Non-uniform findings in the areas: #3 small (IAEA), #2 large (NEA)
- Data were sorted by EXFOR areas, #1 is US and Canada, #2 Western Europe + Japan, ... and verified by O. Schwerer.
- This work would provide a foundation for a future BNL-LANL evaluation.



FY Project

- BNL-LANL FY data evaluation project is fully funded by DOE.
- NNDC is responsible for completeness of EXFOR compilations.
- We produced three NRDC memos on NSR database analysis: CP-C/464 (Spontaneous fission), CP-C/465 (photo fission), and CR-C/466 (Neutron-induced fission).
- Surprisingly fission yields are not complete in EXFOR (missing data publications):
 - Spontaneous fission: $49 + 28 (\#2) + 16 (\#3) + 21(\#4) = 114$
 - Photo fission: $8 + 32 (\#2) + 7 (\#3) + 41 (\#4) = 88$
 - Neutron-induced fission: $35 + 124 (\#2) + 26 (\#3) + 49 (\#4) = 234$
- Volume of work in the Area #1:
 - Spontaneous fission: 49
 - Photo fission: 8
 - Neutron-induced fission: 35
- Dr. Olena Gritzay is hired by NNDC to work on fission yields compilations in the Area #1.
- If other Areas are not able to process the data in a timely fashion then NNDC would step in and complete the task.

Memo issued on behalf of
National Nuclear Data Center
Brookhaven National Laboratory
USA

Memo CP-C/464

Date: 29 November 2018
To: Distribution
From: O. Schwerer, B. Pritychenko
Subject: Completeness check EXFOR vs. NSR: Spontaneous Fission Yields

Memo issued on behalf of
National Nuclear Data Center
Brookhaven National Laboratory
USA

Memo CP-C/465

Date: 30 January 2019
To: Distribution
From: O. Schwerer, B. Pritychenko
Subject: Completeness check EXFOR vs. NSR: Photofission Yields
Reference: CP-C/464

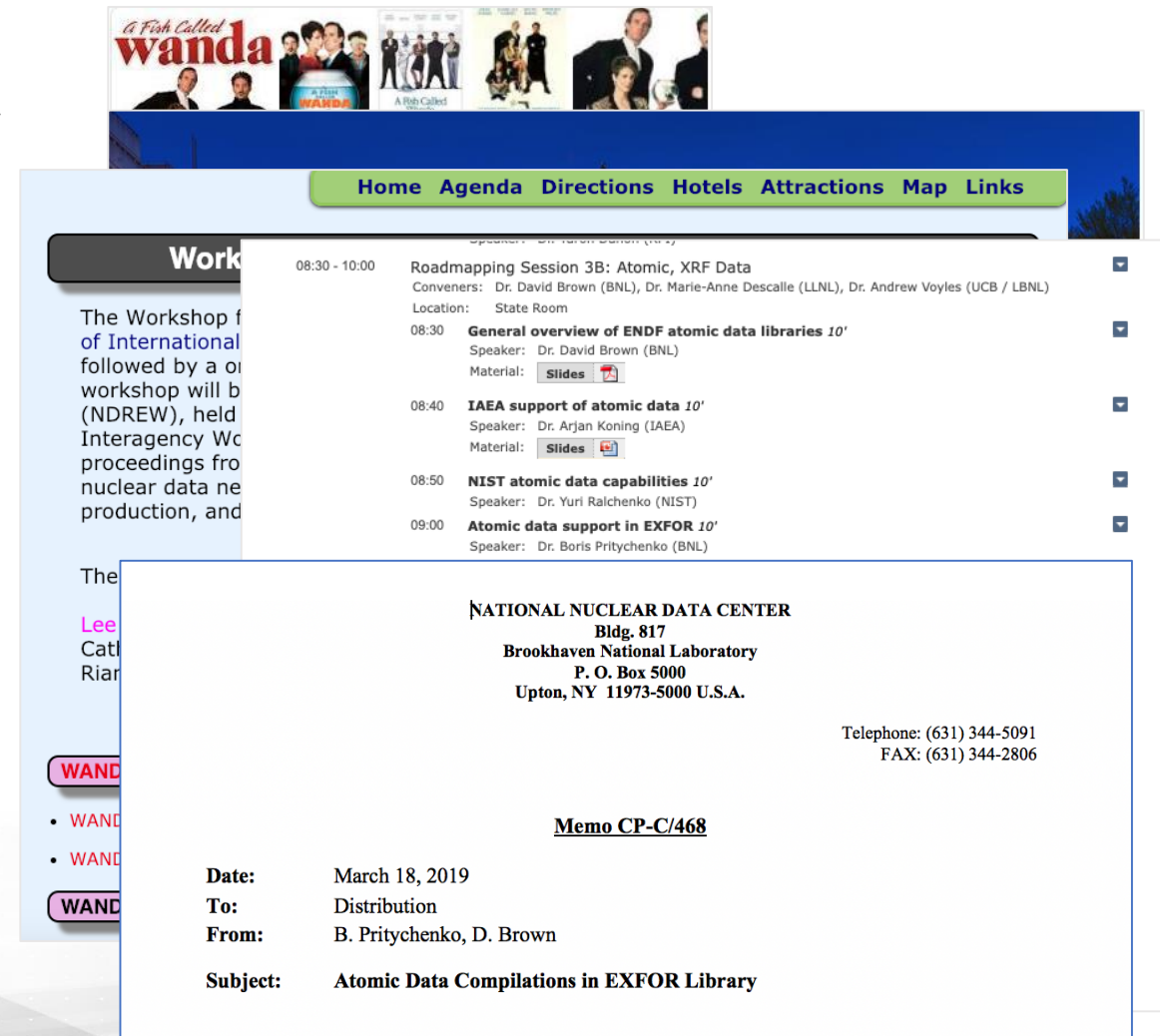
Memo issued on behalf of
National Nuclear Data Center
Brookhaven National Laboratory
USA

Memo CP-C/466

Date: 19 February 2019
To: Distribution
From: O. Schwerer, B. Pritychenko
Subject: Completeness check EXFOR vs. NSR: Neutron-induced fission yields
Reference: CP-C/464, CP-C/465

New Ideas: Atomic Data

- The Workshop for Applied Nuclear Data Activities (WANDA) at the George Washington University, January 22-24, 2019: <https://nucleardata.berkeley.edu/wanda/>.
- Atomic data included in three ENDF sublibraries, and ENSDF.
- EXFOR was designed to support ENDF.
- EXFOR has four atomic data subentries: L0143, L0216, M0041, M0420 + L0241 (in progress)
- We need an SF8=ATM modifier to distinguish such data (Memo CP-C/468).
- We need to compile them and NNDC will produce a list of missing photoatomic cross sections.
- NRDC memo CP-C/468:



The screenshot shows the WANDA workshop website. At the top, there is a banner with the text "A Fish Called Wanda" and several photos of people. Below the banner is a navigation menu with links: Home, Agenda, Directions, Hotels, Attractions, Map, Links. The main content area displays an agenda for the workshop, listing sessions from 08:30 to 10:00. The sessions include: Roadmapping Session 3B: Atomic, XRF Data; General overview of ENDF atomic data libraries; IAEA support of atomic data; NIST atomic data capabilities; and Atomic data support in EXFOR. A sidebar on the left contains a "Workshop" section with a description of the workshop and a "Lee" section. Below the agenda, there is a box containing the address of the National Nuclear Data Center and contact information. At the bottom, there is a memo header and a distribution list.

Home Agenda Directions Hotels Attractions Map Links

Workshop

08:30 - 10:00 **Roadmapping Session 3B: Atomic, XRF Data**
Conveners: Dr. David Brown (BNL), Dr. Marie-Anne Descalle (LLNL), Dr. Andrew Voyles (UCB / LBNL)
Location: State Room

08:30 **General overview of ENDF atomic data libraries 10'**
Speaker: Dr. David Brown (BNL)
Material: [Slides](#)

08:40 **IAEA support of atomic data 10'**
Speaker: Dr. Arjan Koning (IAEA)
Material: [Slides](#)

08:50 **NIST atomic data capabilities 10'**
Speaker: Dr. Yuri Raichenko (NIST)

09:00 **Atomic data support in EXFOR 10'**
Speaker: Dr. Boris Pritychenko (BNL)

The
Lee
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WANDA

• WANDA
• WANDA
• WANDA

NATIONAL NUCLEAR DATA CENTER
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Brookhaven National Laboratory
P. O. Box 5000
Upton, NY 11973-5000 U.S.A.

Telephone: (631) 344-5091
FAX: (631) 344-2806

Memo CP-C/468

Date: March 18, 2019
To: Distribution
From: B. Pritychenko, D. Brown
Subject: Atomic Data Compilations in EXFOR Library

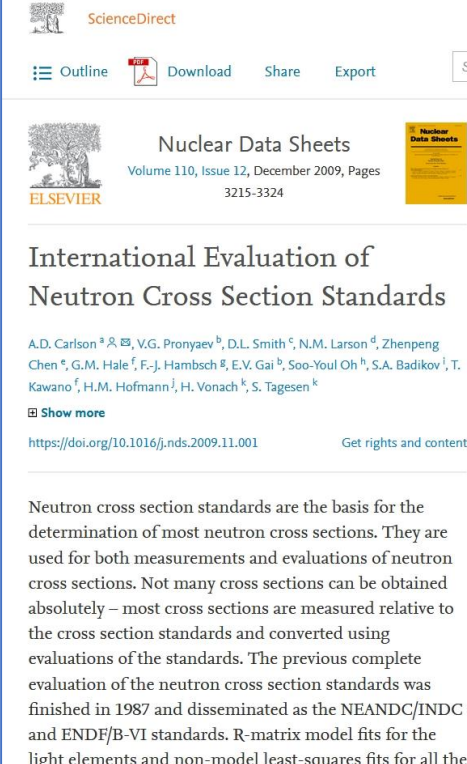
Comments on EXFOR Submission Process

- EXFOR quality assurance assumes submission of preliminary entries that become final after the NRDC review.
- It usually takes 5-6 months, while some entries from two centers go in just a month over X-Mass New Year breaks.
- Most people celebrate Merry X-Mass and Happy New Year while other people work.
- Recent X-Mass examples: 41656 (20181112), 41657 (20181119), E2269 (20181220), E2591 (20181220), E2593 (20181218).
- We should analyze and evaluate these entries because they did not go through regular QA.
- Examples from [January282019.txt](#) file.



Comments on the Length of EXFOR Data Processing

- Elsevier rules strictly prohibit journal editors from processing its own articles/submissions: it is wrong when one submits and accepts his/her own compilations or articles.
- EXFOR submissions are not spell checked by NDS/IAEA.
- We deal with different time scales for compilation processing from different centers: 1 month – years.
- NNDC compilation of Neutron Cross Section Standards for V series (Important data not stored in ENDF).
- It is unacceptable when V1003.exf is sitting at NDS/IAEA since 2013 and getting in to EXFOR.
- This issue was raised during the CSEWG meeting, and I promised to fix it.
- Finally, we all should celebrate major holidays.



ScienceDirect

Outline Download Share Export

Nuclear Data Sheets
Volume 110, Issue 12, December 2009, Pages 3215-3324

ELSEVIER

International Evaluation of Neutron Cross Section Standards

A.D. Carlson^a, V.G. Pronyaev^b, D.L. Smith^c, N.M. Larson^d, Zhenpeng Chen^e, G.M. Hale^f, F.-J. Hamsch^g, E.V. Gai^b, Soo-Youl Oh^h, S.A. Badikovⁱ, T. Kawano^f, H.M. Hofmann^j, H. Vonach^k, S. Tagesen^k

Show more

<https://doi.org/10.1016/j.nds.2009.11.001> Get rights and content

Neutron cross section standards are the basis for the determination of most neutron cross sections. They are used for both measurements and evaluations of neutron cross sections. Not many cross sections can be obtained absolutely – most cross sections are measured relative to the cross section standards and converted using evaluations of the standards. The previous complete evaluation of the neutron cross section standards was finished in 1987 and disseminated as the NEANDC/INDC and ENDF/B-VI standards. R-matrix model fits for the light elements and non-model least-squares fits for all the



Complimentary Search with Nuclear Science References Database

- USNDP database, currently managed by NNDC.
- NSR is a primary nuclear and atomic physics bibliography database
 - Total number of references is 230,432
 - Total number of nuclei is 7,211
 - Total number of reactions is 8,438
 - Total number of decays is 738
- Simple text search for “inelastic cross” produced twenty two entries for a NUCLEAR REACTIONS topic.
- While search of NSR keywords for experimental (n,n') in 2134 references.
- NNDC NSR team: B. Pritychenko, J. Totans, B. Singh (J.Batchelder), E. Betak, and V. Zerkin (IAEA).

The screenshot displays the NNDC National Nuclear Data Center website. The browser address bar shows the URL https://www.nndc.bnl.gov/nsr/text_form.jsp. The page header includes the NNDC logo and navigation links for various databases: NuDat, NSR, XUNDL, ENSDF, MIRDB, ENDF, CSISRS, and Sigma. The main content area is titled "NSR Query Results" and displays the following information:

- Publication year range: 1896 to 2019
- Primary and secondary references.
- Experimental quantity required.
- Output year order: Descending
- Format: Normal
- NSR database version of February 20, 2019.
- Indexed quantity search: Reaction=(N,N')
- Found 2134 matches. Showing 1 to 100. [Next]
- Back to query form

The search results list includes the following entry:

2018AW01 Phys.Rev. C 98, 045802 (2018)
C.Awe, P.S.Barbeau, J.I.Collar, S.Hedges, L.Li
Liquid scintillator response to proton recoils in the 10-100 keV range

Below the entry, there is a description of the nuclear reaction: "NUCLEAR REACTIONS $^1\text{H}(n, n')$, (n, p), E=244.6 keV; measured proton recoil spectra, time of flight for scattered neutrons, np-coinc, low-energy quenching factors (QF) for proton recoils in liquid organic scintillators. Comparison with simulated and previous experimental data. Discussed relevance to searches for low-mass particle dark matter."

The DOI for this entry is [10.1103/PhysRevC.98.045802](https://doi.org/10.1103/PhysRevC.98.045802).

Conclusions

- NNDC data compilation effort is complex and well-organized.
- It based on direct interactions with research laboratories and universities in U.S. and Canada, and users worldwide.
- NNDC has officially launched a FY compilation project.
- Historically, EXFOR compilations stayed away from atomic data; however, it is designed to support ENDF, and an argument can be made for complete support of reaction data sets in ENDF libraries.
- We would be happy to collect constructive feed back and valuable comments from all nuclear reaction data users in order to get better.

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.