Area #1 EXFOR Project

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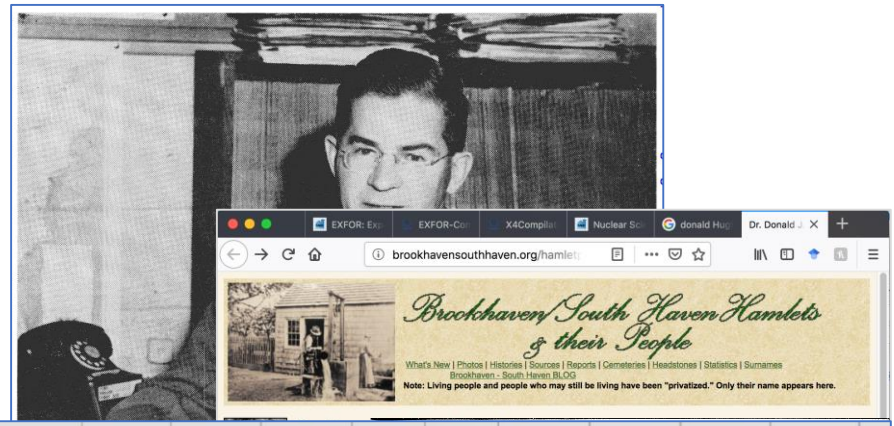
U.S. DEPARTMENT OF ENERGY

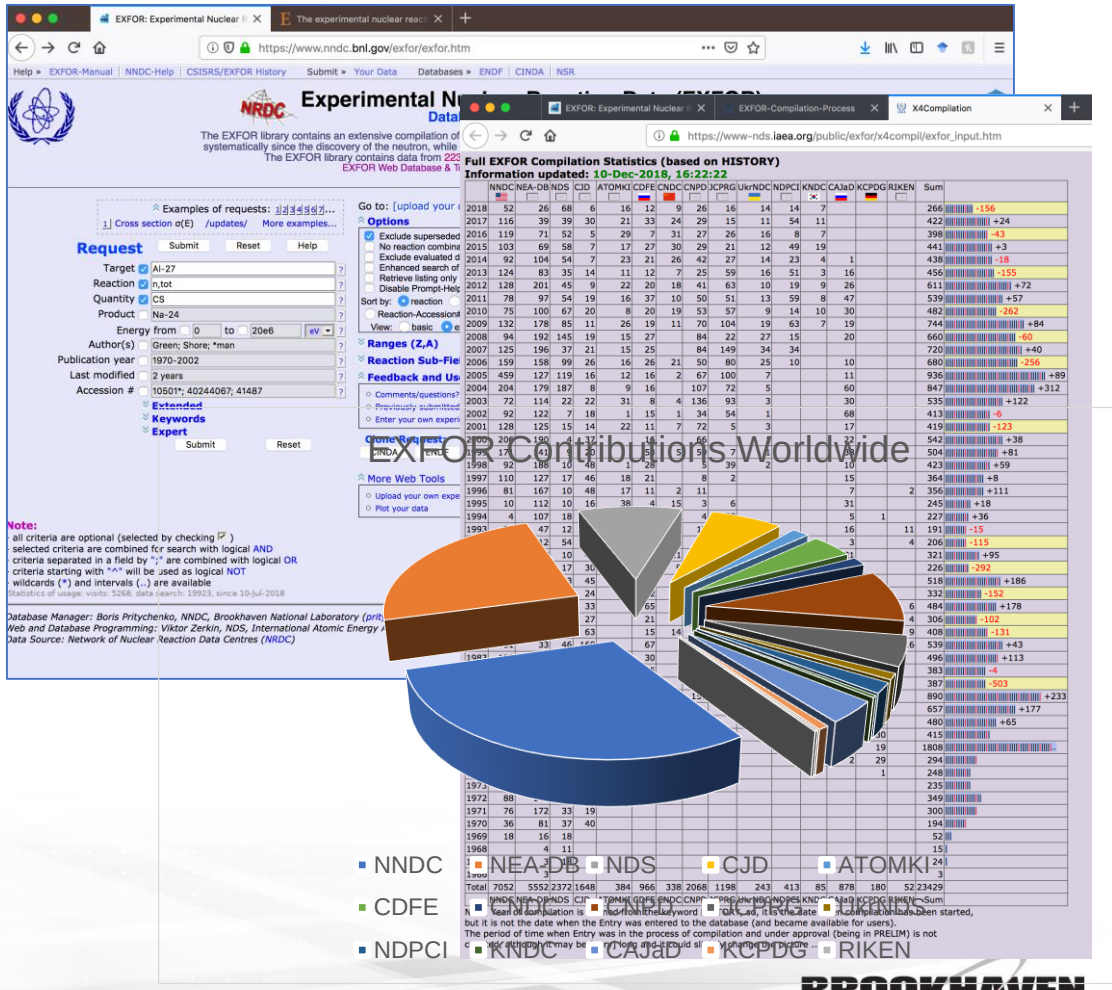
Nuclear Reaction Data Compilations

- 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.



What is EXFOR???

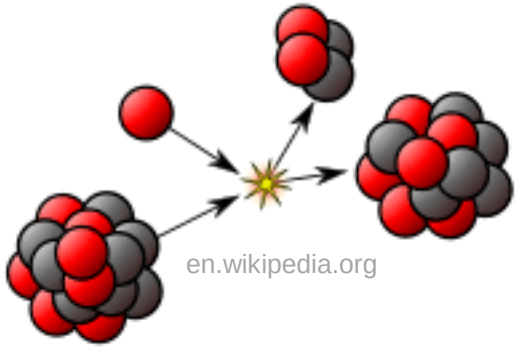
- The EXchange FORmat (EXFOR) experimental nuclear reaction database and format for low- and intermediate-energy physics (February 2019)
  - 22,376 experimental works
  - 172,641 reaction data tables
  - Total and differential cross sections, resonance parameters, fission yields, thick-target and product 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-Databank (Paris), NDS-IAEA (Vienna) and others.



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 stuff, contractors and collaborators.
- Contractors (S. Hlavac, O. Schwerer, and O. Gritzay) are essential for the overall success of the NNDC EXFOR effort.

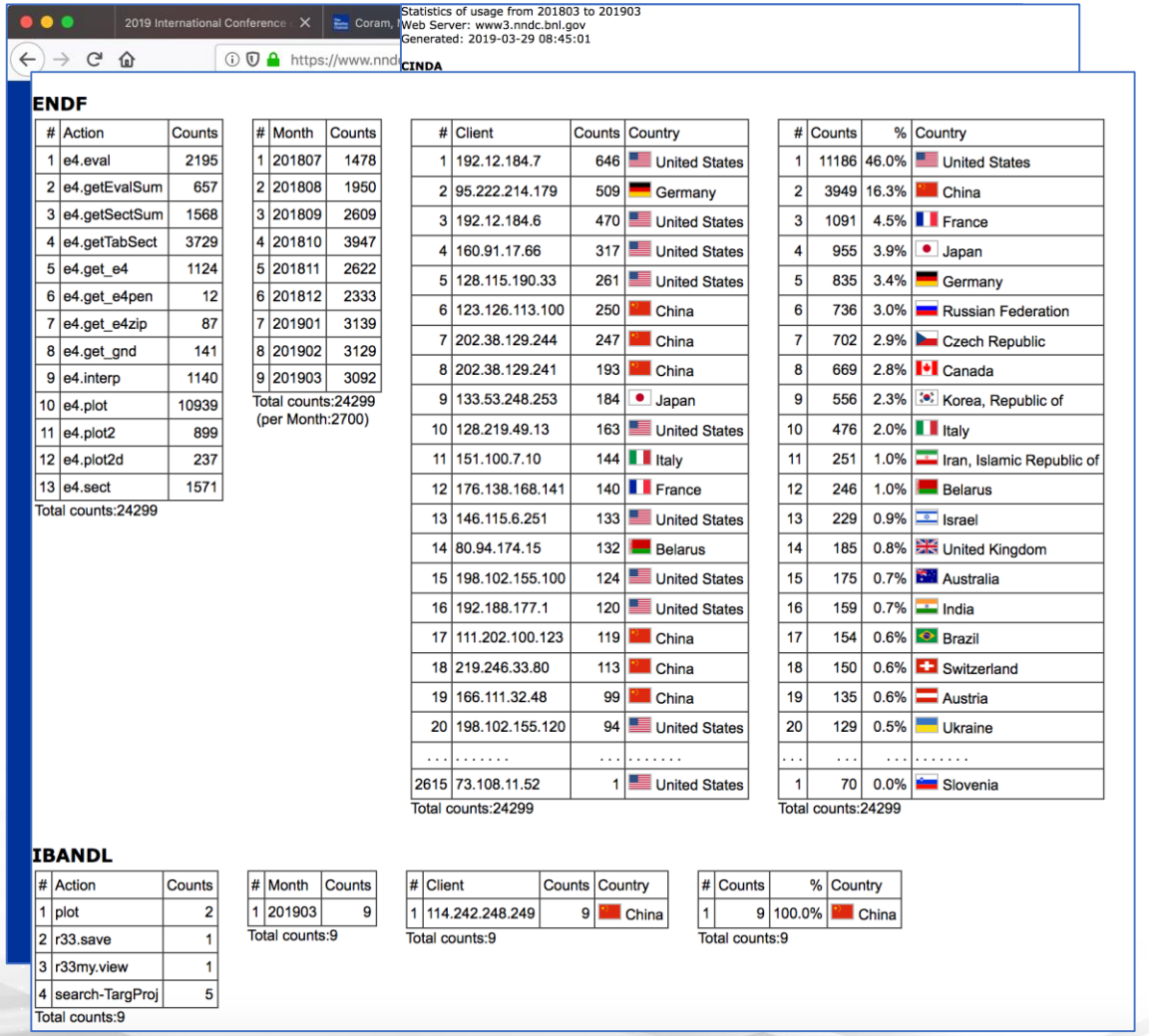
FY 2018 EXFOR Statistics



- 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.



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

CINDA

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

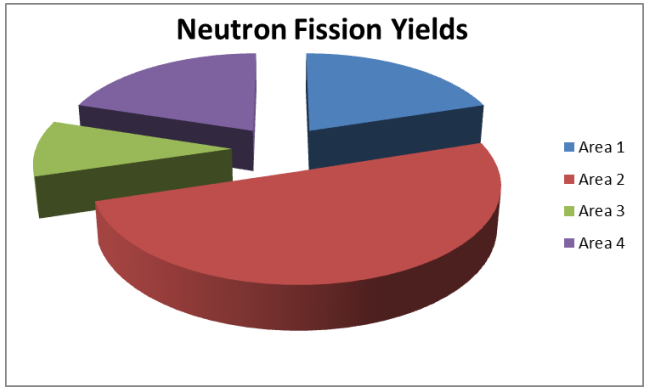
Total counts:9

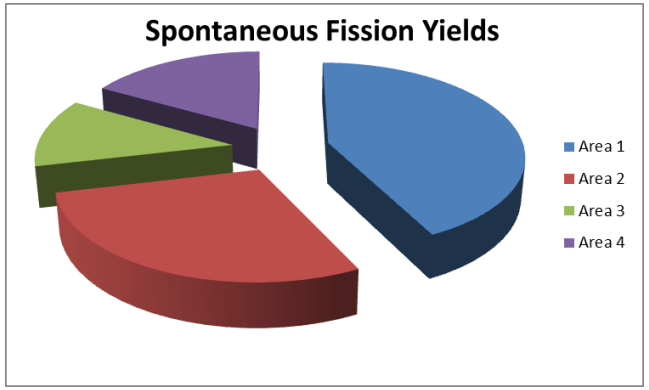
#	Counts	%	Country
1	9	100.0%	China

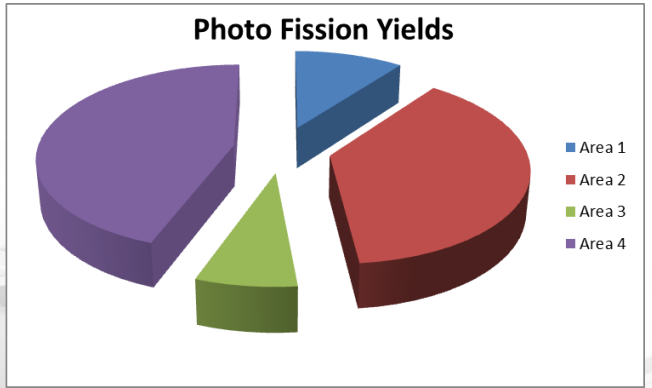
Total counts:9

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.

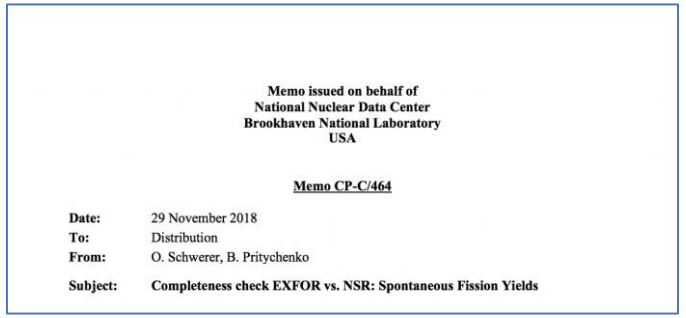






FY Project

- 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.

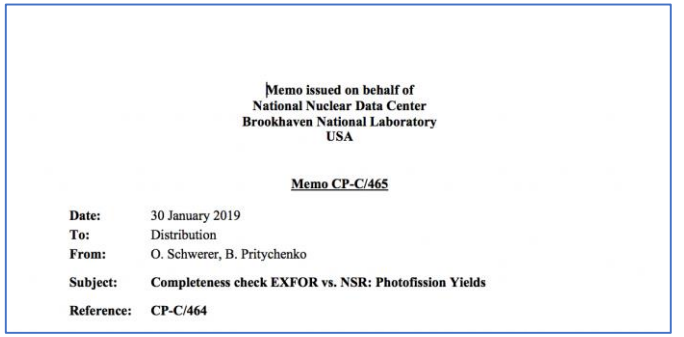


Memo issued on behalf of
National Nuclear Data Center
Brookhaven National Laboratory
USA

Memo CP-C/464

Date: 29 November 2018
To: Distribution
From: O. Schwerer, B. Pritychenko

Subject: Completeness check EXFOR vs. NSR: Spontaneous Fission Yields



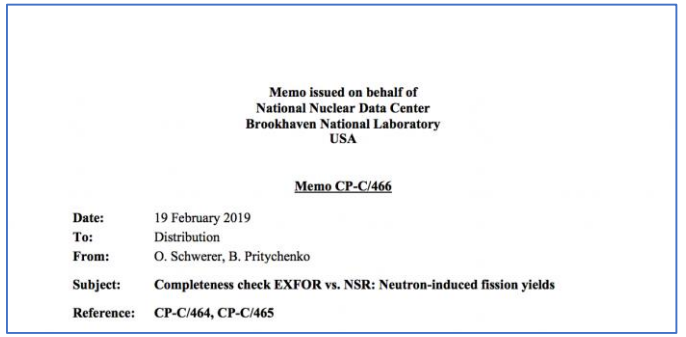
Memo issued on behalf of
National Nuclear Data Center
Brookhaven National Laboratory
USA

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

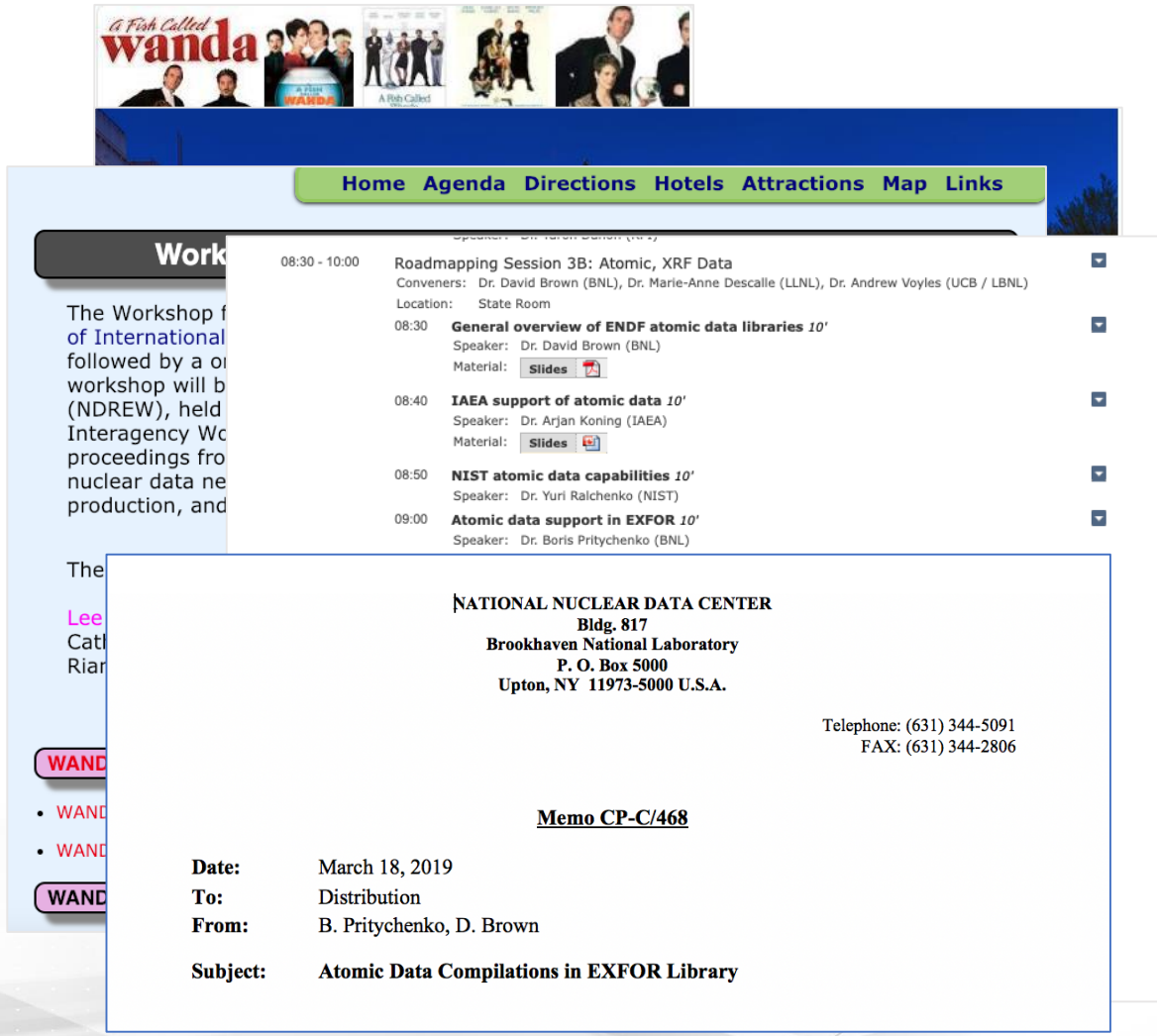
Date: 19 February 2019
To: Distribution
From: O. Schwerer, B. Pritychenko

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:

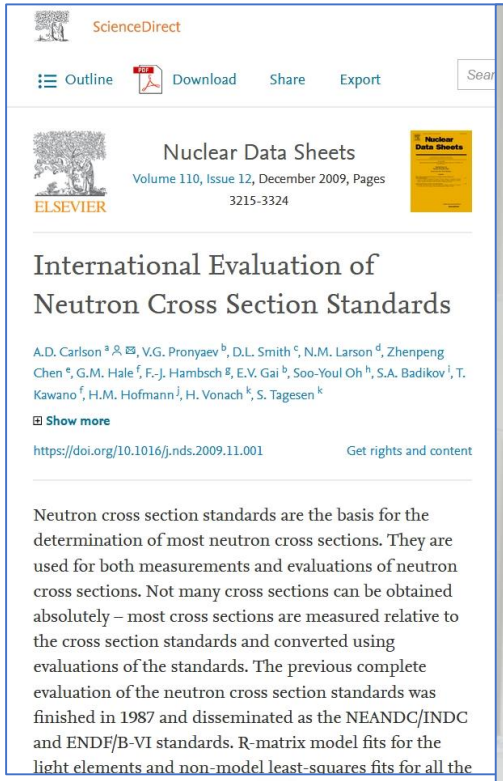


Comments on EXFOR Submission Process

- 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.

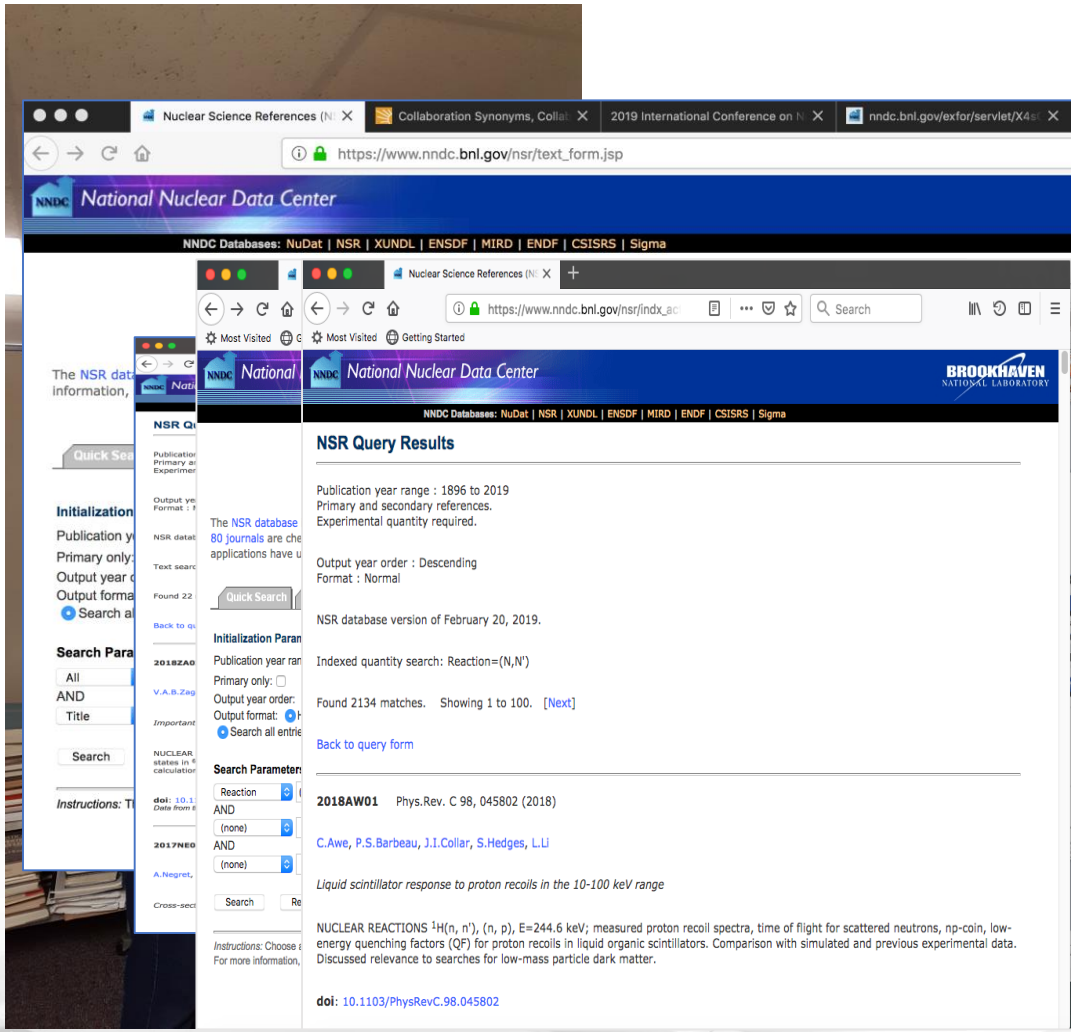
Comments on the Length of EXFOR Data Processing

- 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.



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).



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.