The Present Status of the EXFOR Project: Area #1

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Nuclear Reaction Data Compilations in USA & Worldwide

- 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.

75 Years of Experimental Nuclear Reaction Data Compilations
Invited Talk at the ND2022 Conference

- 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.

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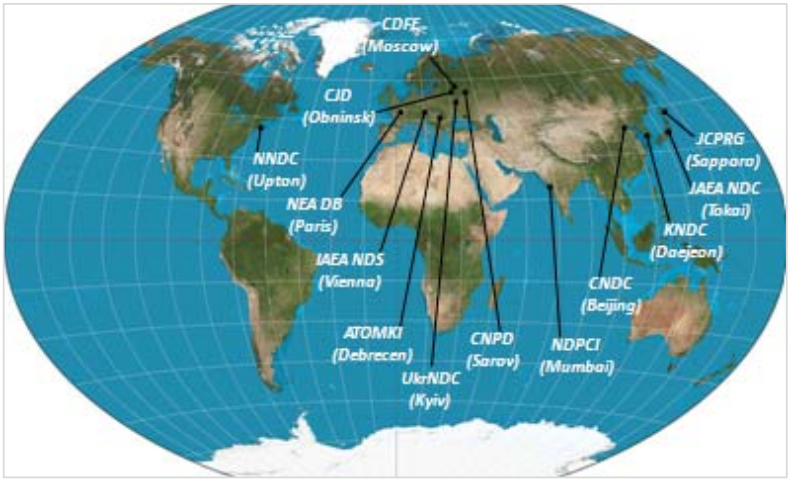
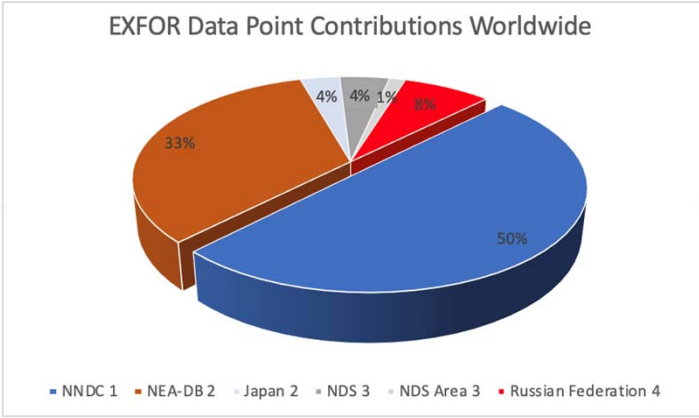
EXFOR - Experimental Nuclear Reaction Data

The largest experimental nuclear reaction database (*www.nndc.bnl.gov/exfor* or *www-nds.iaea.org/exfor*)

- 24,560 experiments (multiple publications are grouped into a single measurement).
- 183,390 data sets as of May 2, 2023.
- Essential for Evaluated Nuclear Data File (ENDF) libraries worldwide.
- Presently run by the Nuclear Reaction Data Centres (NRDC), internationally. This is an IAEA network which is coordinated by the IAEA.
- Two largest contributors: NNDC & NEA-Databank.
- Every second, third and sixth data points in the library were contributed by the NNDC, NEA-Databank and the rest of NRDC network, respectively.

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 2022 Statistics

- New compilations: 158
- Updated compilations: 210
- Finished compilation of missing Los Alamos reports, UNOBT data, p-, d-induced reactions.
- Actively worked on missing α-induced reactions and Mughabghab's references.
- Preliminary NRDC transmissions: 29
- Final NRDC transmissions: 31
- EXFOR DB Updates: 41

Final Transmissions: Area #1 FY 2022 Statistics

- Overall NNDC performance, and performance of individual compilers are very good.
- All data are from https://www-nds.iaea.org/public/exfor/x4compil/.

Full EXFOR Compilation Statistics (based on HISTORY)
Information updated: 30-Apr-2023, 14:22:06

#. Year	NNDC	NEA-DB	NDS	CJD	ATOMKI	CDFE	CNDC	CNPD	JCPRG	UkrNDC	NDPCI	KNDC	KAZMON	CAJaD	KCPDG	RIKEN	Sum	
53. 2023								3	1								4	-288
52. 2022	100	35	27	9	9	5	18	19	17	4	34	7	8				292	-228
51. 2021	181	102	40	23	5	12	29	18	35	15	38	10	12				520	-143
50. 2020	217	134	77	40	10	12	31	29	41	11	35	3	23				663	+90
49. 2019	124	108	44	24	4	34	18	31	37	58	79	7	5				573	+54
48. 2018	123	111	79	13	16	13	29											
47. 2017	116	62	39	30	21	33	25											
46. 2016	119	72	52	6	29	7	31											

Nuclear Data Centers abbreviations

1	NNDC	US National Nuclear Data Center, Brookhaven, USA
2	NEA-DB	OECD/NEA Nuclear Data Bank, Boulogne-Billancourt, France
3	NDS	IAEA Nuclear Data Section, Vienna, Austria
4	CJD	Nuclear Data Centre, Obninsk, Russia
5	ATOMKI	ATOMKI Nuclear Reaction Data Group, Debrecen, Hungary
6	CDFE	Centre for Photonuclear Experiments Data, Moscow State University, Russia
7	CNDC	China Nuclear Data Center, Beijing, China
8	CNPD	Center of Nuclear Physics Data, Russian Federal Nuclear Center (VNIIEF), Sarov, Russia
9	JCPRG	Japan Charged Particle Nuclear Reaction Data Group, Hokkaido University, Sapporo, Japan
10	UkrNDC	Ukrainian Nuclear Data Center, Institute for Nuclear Research, Kyiv, Ukraine
11	NDPCI	Indian Compilation Group: BARC and others, India
12	KNDC	KAERI Nuclear Data Evaluation Group, Daejeon, Republic of Korea
13	KAZMON	Kazakhstan+Mongolia team
14	CAJaD	Russian Nuclear Structure and Reaction Data Centre, Kurchatov Institute, Moscow, Russia
15	KCPDG	Karlsruhe Charged Particle Data Group, Germany (extinct)
16	RIKEN	RIKEN Nuclear Data Group, Japan (extinct)

Personal Contributions to EXFOR
Based on Free-text of SUBENT-1 HISTORY Code: (<date>
Information updated: 30-Apr-2023, 14:22:06 //by V.Zerki
Options

#	Initials	Name	Center	#Entries	Area:Entries // Year
1	BP	B.Pritychenko	NNDC	99 /633/	NNDC:99 2022:40 2021:59
2	SH	S.Hlavach	NNDC	90 /950/	NNDC:90 2022:18 2021:72
3	OG	O.Gritzay	UkrNDC	89 /173/	NNDC:89 2022:42 2021:47
4	VT	Vidya Thakur	NDPCI	80 /138/	NDPCI:58 NDS:22 2022:49 2021:31
5	VS	V.Semkova	NDS	76 /272/	NEA-DB:62 NDS:14 2022:24 2021:52
6	MM	M.Mikhailyukova	CJD	71 /656/	NEA-DB:41 CJD:30 2022:7 2021:64
7	ON	N.Otsuka	NDS	57 /529/	NDS:28 JCPRG:3 NE/ 2022:17 2021:40
8	JIMIN	Wang Jimin	CNDC	20 /59/	CNDC:20 2022:9 2021:11
9	UKRNDC	KINR, Kiev	UkrNDC	19 /299/	UkrNDC:19 2022:4 2021:15
10	VV	V.Varlamov	CDFE	17 /359/	CDFE:17 2022:5 2021:12

EXFOR Compilation Statistics based on N2 and EXFOR archive.
Information updated: 30-Apr-2023, 14:22:06

	NNDC	NEA-DB	NDS	CJD	ATOMKI	CDFE	CNDC	CNPD	JCPRG	UkrNDC	NDPCI	KNDC	KAZMON	CAJaD	KCPDG	RIKEN	Sum
2023		1		11		2		3	13								17
	1	1		194				4									19
		7,351						448	1,205								9,198
	10	3	4	4	1	2	2	3	1	2	3	3	1		1		40
2022	100	36	33	9	9	6	20	19	48	4	34	7	9				334
	171	407	118	148	30	86	28	164	5	15	27	6		134	20		1359
	265,747	122,771	30,783	1,729	1,035	867	7,396	4,907	10,992	204	2,872	769	3,347	-614	110		452,915
	28	14	7	7	2	5	4	9	5	4	8	5	2	5	2		107
2021	183	105	34	23	5	11	27	18	19	16	41	10	12				504
	272	160	130	167	39	45	18	140		12	34	2	1	63	17		1100
	108,438	322,343	12,683	3,235	-3,780	1,168	1,526	7,337	17,001	2,789	11,469	320	1,458	-243	-54		485,690
	27	18	14	10	4	6	6	12	2	7	9	5	3	3	2		128
2020	221	129	80	39	10	12	32	29	36	13	33	3	26				663
	307	379	53	143	9	19	9	223	12	13	8	6		61			1242
	27,119	314,506	53,204	5,348	1,276	350	5,642	3,809	7,505	1,484	2,638	733	27,399	-410			450,603
	24	15	10	7	2	6	5	13	8	6	8	3	4	3		1	115

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Work Distribution Within Area #1

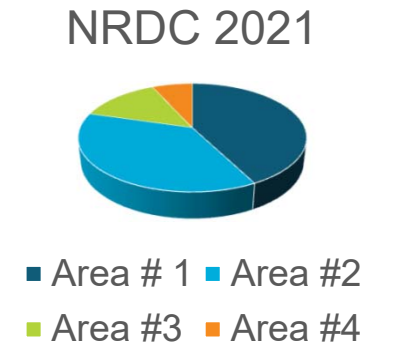
- Stanislav Hlavac is responsible for new experimental data compilations.
- Olena Gritzay finished compilation of four NRDC memos: CP/C-0464, CP/C-0465, CP/C-0466, and CP/D-979 (*Experimental fission product yields missing in EXFOR*). Olena presently works on CP-D/937 (*Proton-induced reaction articles in NSR/CINDA but not in EXFOR*), CP-D/947 (*Alpha-induced reaction articles in NSR/CINDA but not in EXFOR*).
- Boris Pritychenko provides the overall project and database management, compilation of individual user requests, charged particle fission yields, historic Manhattan Project data, and the NNDC library data.
- Otto Shwerer provides quality assurance in the Area #1, preliminary and final transmission handling, fixes errors and bugs in the existing entries.
- Viktor Zerkin (IAEA) helps with Web dissemination and database management.
- Compartmentalization, the division of something into sections or categories.

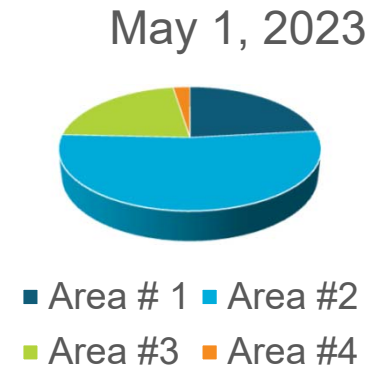
Missing (Unobtainable) Data: Existing EXFOR Entries

C32 The subentry coded with STATUS= UNOBT may be deleted if the dataset is not suitable for digitization or optical character recognition (OCR) data recovery, and the source article was published before 2000.

- NRDC 2021:
  - Area #1: 130
  - Area #2: 114
  - Area #3: 42
  - Area #4: 21
- NRDC 2022, June 10, 2022:
  - Area #1: 66
  - Area #2: 117
  - Area #3: 46
  - Area #4: 20
- NRDC 2023, May 31, 2022:
  - Area #1: 47
  - Area #2: 106
  - Area #3: 44
  - Area #4: 5

All Area #1 entries are processed, and submitted as preliminary and final transmissions.





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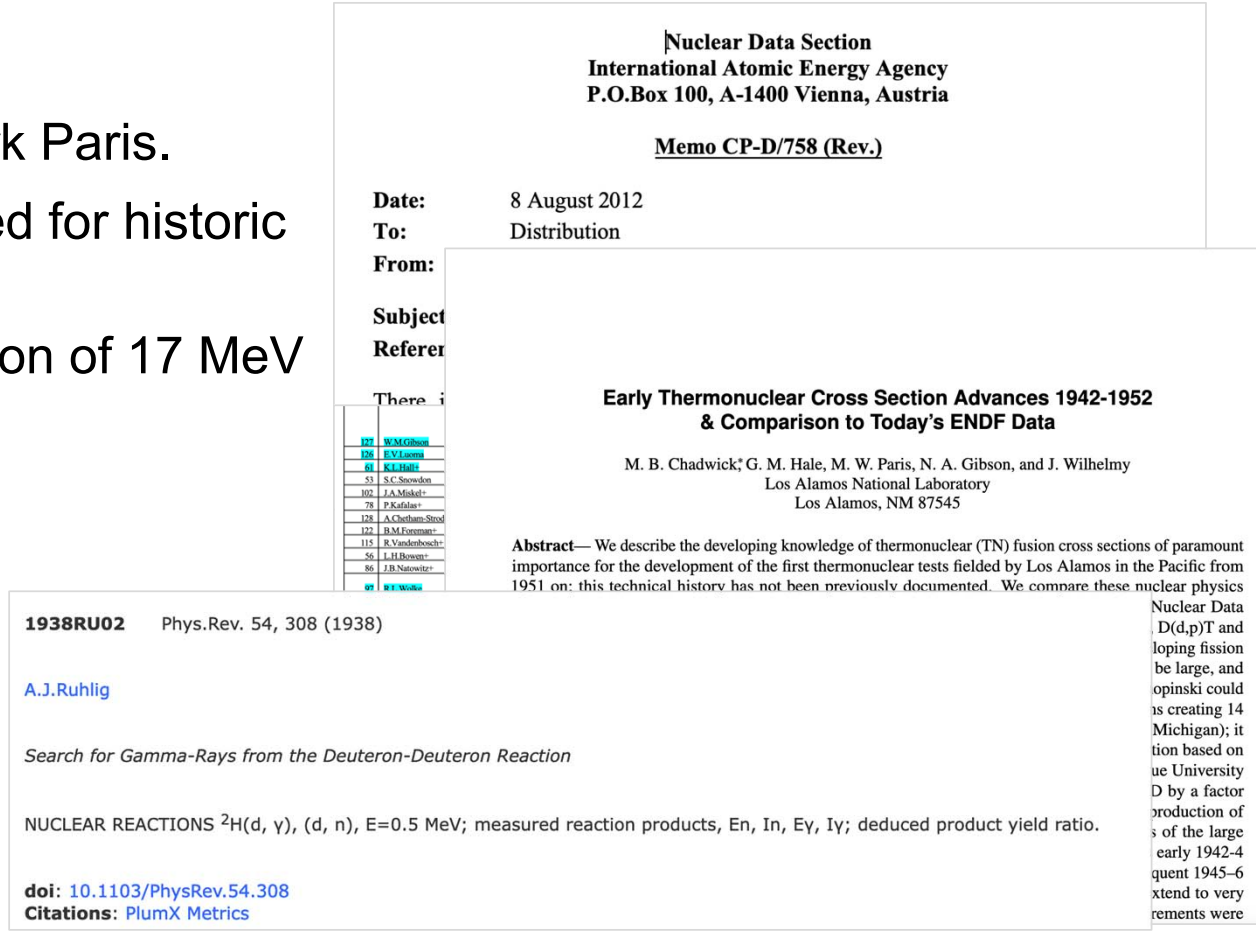
Missing Data: Deuteron-Induced Reactions

- Memo 4C-3/395 (Rev.)
- Los Alamos work, courtesy of Mark Paris.
- Upcoming publication was scanned for historic references.
- 1938Ru02, C2844: First observation of 17 MeV neutrons.



Nuclear Data Section
International Atomic Energy Agency
P.O.Box 100, A-1400 Vienna, Austria

Memo CP-D/758 (Rev.)

Date: 8 August 2012
To: Distribution
From:
Subject
Referen

There i

127	W.M.Gibson
126	E.V.Lisoma
61	K.L.Hall+
53	S.C.Snowdon
102	J.A.Miskel+
78	P.Kafalas+
128	A.Chetham-Strod
122	B.M.Foreman+
115	R.Vandenbosch+
56	L.H.Bowen+
86	J.B.Natowitz+
97	R.L.Wolke

Early Thermonuclear Cross Section Advances 1942-1952 & Comparison to Today's ENDF Data

M. B. Chadwick*, G. M. Hale, M. W. Paris, N. A. Gibson, and J. Wilhelmy
Los Alamos National Laboratory
Los Alamos, NM 87545

Abstract— We describe the developing knowledge of thermonuclear (TN) fusion cross sections of paramount importance for the development of the first thermonuclear tests fielded by Los Alamos in the Pacific from 1951 on; this technical history has not been previously documented. We compare these nuclear physics

1938RU02 Phys.Rev. 54, 308 (1938)

A.J.Ruhlig

Search for Gamma-Rays from the Deuteron-Deuteron Reaction

NUCLEAR REACTIONS ^{2}H(d, γ), (d, n), E=0.5 MeV; measured reaction products, En, In, Eγ, Iγ; deduced product yield ratio.

doi: 10.1103/PhysRev.54.308
Citations: PlumX Metrics

Nuclear Data
D(d,p)T and
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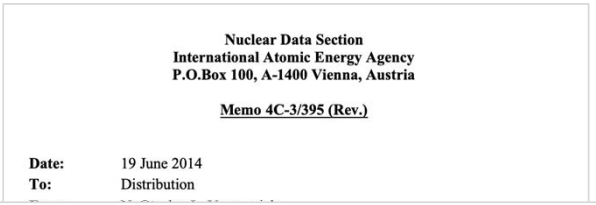
Missing Data: Atlas of Neutron Resonances

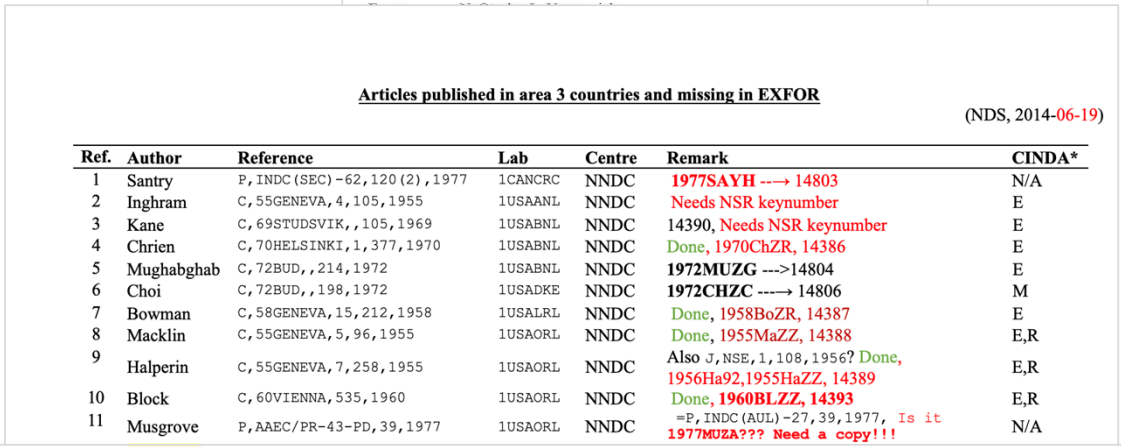
- EXFOR completeness was checked against Mughabghab's Atlas: Memo 4C-3/395 (Rev.)
- Budapest Conference: Proc. Intern. Conf. Nuclear Structure Study with Neutrons, Budapest, 31 Juy - 5 Aug. 1972, J. Ero, J. Szucs, Eds. Plenum Press, p.218 (1974)
- Two different proceedings books: proceedings and abstracts.
- Both books were scanned ad added to NSR/EXFOR.
- One article of 55Geneva is still n



Nuclear Data Section
International Atomic Energy Agency
P.O.Box 100, A-1400 Vienna, Austria

Memo 4C-3/395 (Rev.)

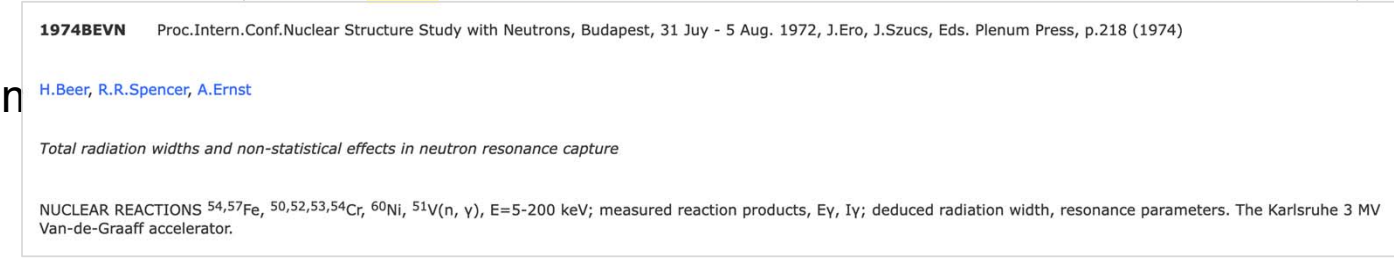
Date: 19 June 2014
To: Distribution



Articles published in area 3 countries and missing in EXFOR

(NDS, 2014-06-19)

Ref.	Author	Reference	Lab	Centre	Remark	CINDA*
1	Santry	P,INDC(SEC)-62,120(2),1977	1CANCRC	NNDC	**1977SAYH** --→ 14803	N/A
2	Inghram	C,55GENEVA,4,105,1955	1USAANL	NNDC	Needs NSR keynumber	E
3	Kane	C,69STUDSVIK,,105,1969	1USABNL	NNDC	14390, Needs NSR keynumber	E
4	Chrien	C,70HELSINKI,1,377,1970	1USABNL	NNDC	Done, 1970ChZR, 14386	E
5	Mughabghab	C,72BUD,,214,1972	1USABNL	NNDC	**1972MUZG** --->14804	E
6	Choi	C,72BUD,,198,1972	1USADKE	NNDC	**1972CHZC** --→ 14806	M
7	Bowman	C,58GENEVA,15,212,1958	1USALRL	NNDC	Done, 1958BoZR, 14387	E
8	Macklin	C,55GENEVA,5,96,1955	1USAORL	NNDC	Done, 1955MaZZ, 14388	E,R
9	Halperin	C,55GENEVA,7,258,1955	1USAORL	NNDC	Also J,NSE,1,108,1956? Done, 1956Ha92,1955HaZZ, 14389	E,R
10	Block	C,60VIENNA,535,1960	1USAORL	NNDC	Done, **1960BLZZ, 14393**	E,R
11	Musgrove	P,AAEC/PR-43-PD,39,1977	1USAORL	NNDC	=P,INDC(AUL)-27,39,1977, Is it **1977MUZA??? Need a copy!!!**	N/A



1974BEVN Proc.Intern.Conf.Nuclear Structure Study with Neutrons, Budapest, 31 Juy - 5 Aug. 1972, J.Ero, J.Szucs, Eds. Plenum Press, p.218 (1974)

H.Beer, R.R.Spencer, A.Ernst

Total radiation widths and non-statistical effects in neutron resonance capture

NUCLEAR REACTIONS $^{54,57}Fe$, $^{50,52,53,54}Cr$, ^{60}Ni, $^{51}V(n, \gamma)$, E=5-200 keV; measured reaction products, Eγ, Iγ; deduced radiation width, resonance parameters. The Karlsruhe 3 MV Van-de-Graaff accelerator.

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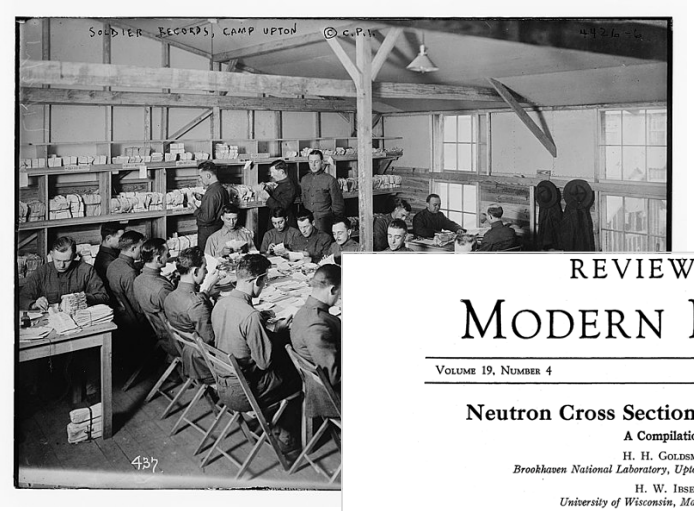
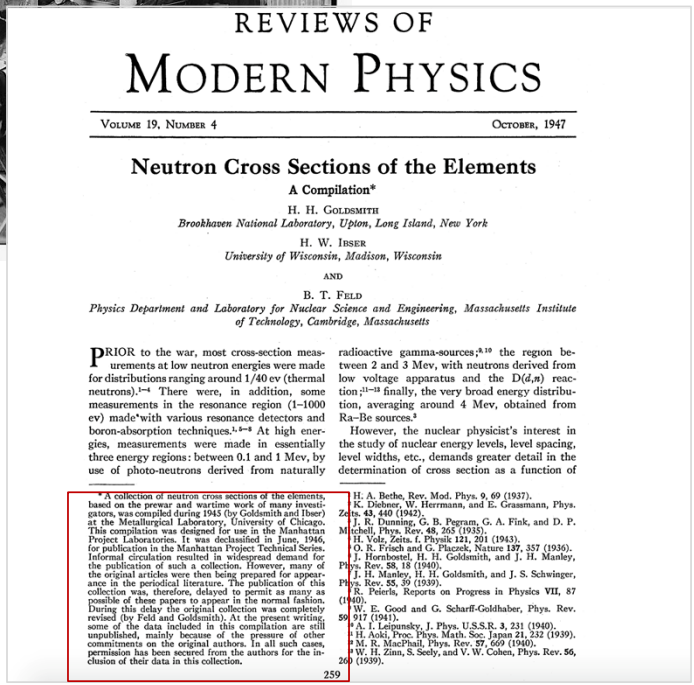
Takeaways

- NNDC (or camp Upton) EXFOR compilation efforts are complex and well-organized: B. Pritychenko (BNL), O. Schwerer, S. Hlavac, O. Gritzay (Under contract with BNL), V. Zerkin (IAEA).
- FY 2022: 158 new and 210 updated compilations.
- UNOBT, d-, p-induced reaction (missing data) issues are fixed in EXFOR.
- 75th anniversary of nuclear reaction data compilations talk was presented at the ND2022 conference.





REVIEWS OF
MODERN PHYSICS

VOLUME 19, NUMBER 4 OCTOBER, 1947

Neutron Cross Sections of the Elements

A Compilation*

H. H. GOLDSMITH
Brookhaven National Laboratory, Upton, Long Island, New York
H. W. IBSER
University of Wisconsin, Madison, Wisconsin
AND
B. T. FELD
Physics Department and Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts

PRIOR to the war, most cross-section measurements at low neutron energies were made for distributions ranging around 1/40 ev (thermal neutrons).[1–4] There were, in addition, some measurements in the resonance region (1–1000 ev) made with various resonance detectors and boron-absorption techniques.[5–8] At high energies, measurements were made in essentially three energy regions: between 0.1 and 1 Mev, by use of photo-neutrons derived from naturally radioactive gamma-sources;[9,10] the region between 2 and 3 Mev, with neutrons derived from low voltage apparatus and the $D(d,n)$ reaction;[11–13] finally, the very broad energy distribution, averaging around 4 Mev, obtained from Ra–Be sources.[3]

However, the nuclear physicist's interest in the study of nuclear energy levels, level spacing, level widths, etc., demands greater detail in the determination of cross section as a function of

* A collection of neutron cross sections of the elements, based on the prewar and wartime work of many investigators, was compiled during 1945 (by Goldsmith and Ibser) at the Metallurgical Laboratory, University of Chicago. This compilation was designed for use in the Manhattan Project Laboratories. It was declassified in June, 1946, for publication in the Manhattan Project Technical Series. Informal circulation resulted in widespread demand for the publication of such a collection. However, many of the original articles were then being prepared for appearance in the periodical literature. The publication of this collection was, therefore, delayed to permit as many as possible of these papers to appear in the normal fashion. During this delay the original collection was completely revised (by Feld and Goldsmith). At the present writing, some of the data included in this compilation are still unpublished, mainly because of the pressure of other commitments on the original authors. In all such cases, permission has been secured from the authors for the inclusion of their data in this collection.

[1] H. A. Bethe, Rev. Mod. Phys. 9, 69 (1937).
[2] K. Diebner, W. Herrmann, and E. Grassmann, Phys. Zeits. 43, 440 (1942).
[3] J. R. Dunning, G. B. Pegram, G. A. Fink, and D. P. Mitchell, Phys. Rev. 48, 265 (1935).
[4] H. Volz, Zeits. f. Physik 121, 201 (1943).
[5] O. R. Frisch and G. Placzek, Nature 137, 357 (1936).
[6] J. Hornbostel, H. H. Goldsmith, and J. H. Manley, Phys. Rev. 58, 18 (1940).
[7] J. H. Manley, H. H. Goldsmith, and J. S. Schwinger, Phys. Rev. 55, 39 (1939).
[8] R. Peierls, Reports on Progress in Physics VII, 87 (1940).
[9] W. E. Good and G. Scharff-Goldhaber, Phys. Rev. 59, 917 (1941).
[10] A. I. Leipunsky, J. Phys. U.S.S.R. 3, 231 (1940).
[11] H. Aoki, Proc. Phys. Math. Soc. Japan 21, 232 (1939).
[12] M. R. MacPhail, Phys. Rev. 57, 669 (1940).
[13] W. H. Zinn, S. Seely, and V. W. Cohen, Phys. Rev. 56, 260 (1939).

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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.