



The Present Status of the EXFOR Project: Area #1

B. Pritychenko¹, O. Schwerer², S. Hlavac², O. Gritzay², V.V. Zerkin³

1 National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA

2 Under contract with National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA

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





75 Years of Experimental Nuclear Reaction Data Compilations

Nuclear Reaction Data Compilations in USA & Worldwide

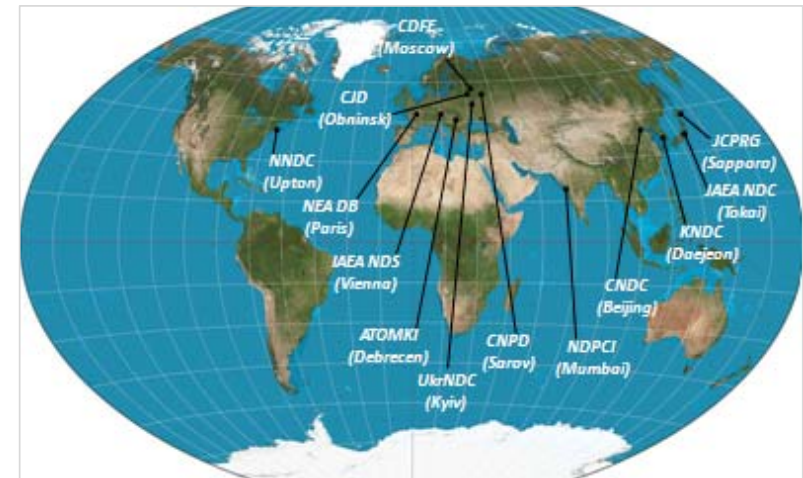
- Experimental neutron reaction data compilations have been pioneered at the Metallurgical Laboratory, University of Chicago and Los Alamos National Laboratory in 1945-1947.
- Brookhaven National Laboratory hired many *Manhattan Project* alumni when it was founded in 1947, and the lab got involved in nuclear data.
- (1952), it is a precursor of BNL-525 (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

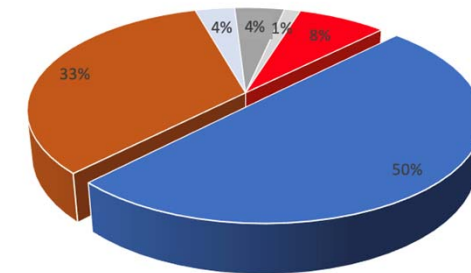
The largest experimental nuclear reaction database (www.nndc.bnl.gov/exfor)

- 24,225 experiments (multiple publications are grouped into a single measurement).
- 182,512 data sets as of May 31, 2022.
- 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.



EXFOR Data Point Contributions Worldwide



■ NNDC 1 ■ NEA-DB 2 ■ Japan 2 ■ NDS 3 ■ NDS Area 3 ■ Russian Federation 4

Area #1 FY 2021 Statistics

- FY 2021: October 1, 2020 - September 30, 2021.
- New compilations: 131
- Updated compilations: 303
- Finished compilations of missing fission yields, NRDC memos: CP/C-0464, CP/C-0465, CP/C-0466, and CP/D-979.
- Preliminary NRDC transmissions: 26
- Final NRDC transmissions: 17
- EXFOR DB Updates: 40
- EXFOR Web retrievals
 - CINDA: 1,479
 - ENDF: 101,045
 - EXFOR: 44,387

Nuclear Data Centers abbreviations

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

EXFOR Compilation Statistics based on N2 and EXFOR archive.

Information updated: 10-Jun-2022, 14:08:07

	NNDC	NEA-DB	NDS	CJD/ATOMKI	CDFE	CNDC	CNPD	JCPRG	UkrNDC	NDPCI	KNDC	KAZMON	CAJaD	KCPDG	RIKEN	Sum
2022	5	107	71	51	9	20	2		2	15	2				14	43
	344	580	15,112	108	-53				54	1,288	333	314				18,106
	15	7	6	5	2	3			4	8	5	2			2	81
2021	154	98	34	23	5	11	26	15	19	16	41	10	12			464
	270	149	129	167	39	43	18	139		12	34	2	1	63	17	1083
	92,050	130,955	12,683	3,235	-3,780	1,152	1,497	5,517	17,001	2,789	11,469	320	1,458	-243	-54	276,049
	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	377	52	142	9	19	9	223	12	13	8	6		61		1238
	27,119	314,005	51,704	5,348	1,276	350	5,642	3,809	7,505	1,484	2,638	733	27,399	-410		448,802
	24	15	10	7	2	6	5	13	8	6	8	3	4	3	1	115

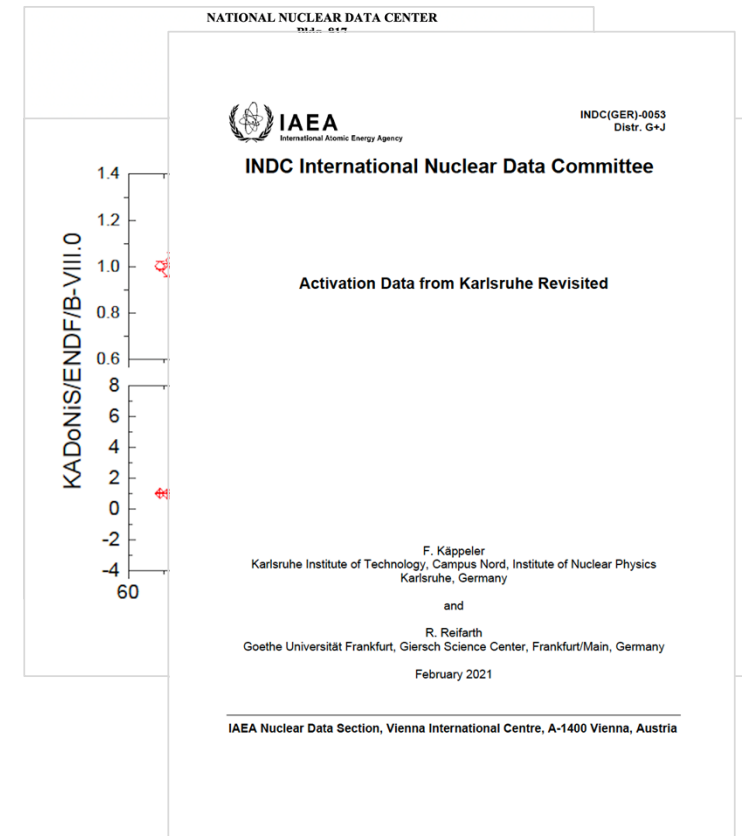
Work Distribution Within Area #1

- 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 Shwerner 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.

Karlsruhe Corrections

- Present status of Karlsruhe cross sections (CP-C/472).
- 5-7% deviations in $^{197}\text{Au}(n,\gamma)$ cross sections produce 20-30% deviations in *r*-process abundances: B. Pritychenko, J. Phys. (London) **G48**, 08LT01 (2021).
- C30 The activation cross sections measured by the Karlsruhe renormalized with a new gold standard cross section are published as INDC(GER)-053 and the relevant EXFOR entries must be updated. See also CP-C/472=WP2021-27.

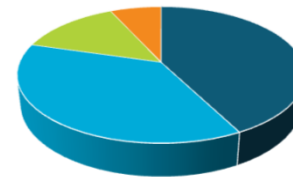


Area #1 corrections are finished.

Unobtainable Data

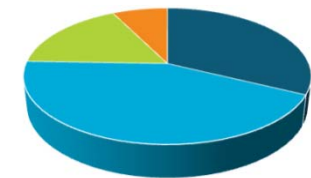
- C32 The subentry coded with STATUS= UNOBT may be deleted if the dataset is not suitable for digitization or optical character recognition (OCR) data recovery, and the source article was published before 2000.
- NRDC 2021:
 - Area #1: 130
 - Area #2: 114
 - Area #3: 42
 - Area #4: 21
- May 31, 2022=>June 10, 2022:
 - Area #1: 87 => 66
 - Area #2: 117
 - Area #3: 46
 - Area #4: 20

NRDC 2021



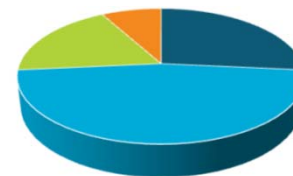
■ Area # 1 ■ Area #2
■ Area #3 ■ Area #4

May 31, 2022



■ Area # 1 ■ Area #2
■ Area #3 ■ Area #4

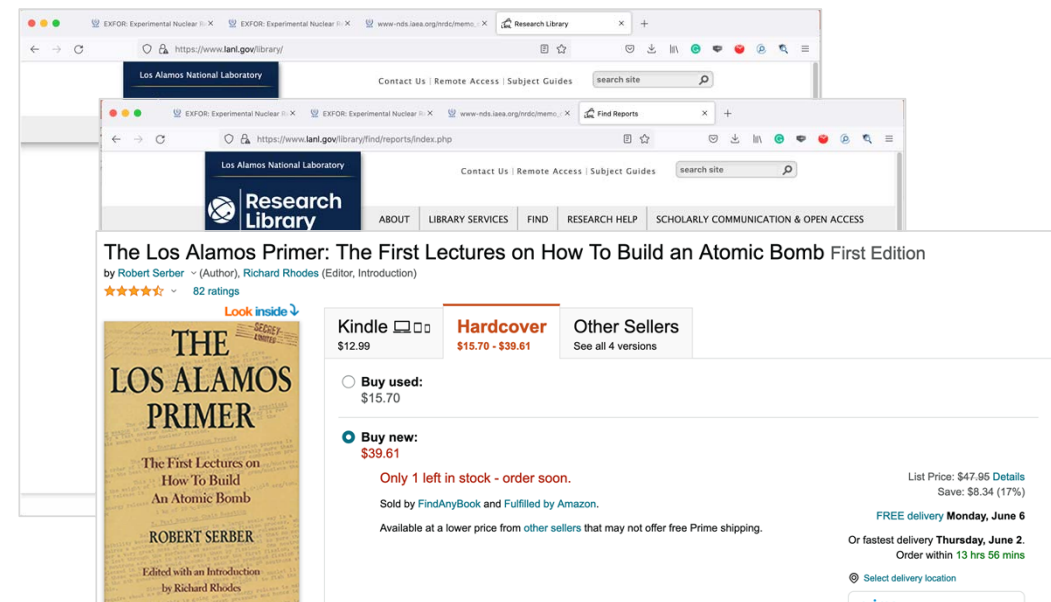
June 10, 2022



■ Area # 1 ■ Area #2
■ Area #3 ■ Area #4

Los Alamos Reports

- Over 500 reports were added to NSR: 1943-1953.
- LA-1, Los Alamos Primer.
- All reports were checked for EXFOR related contents: 24 new entries, updated multiple existing entries.



The Los Alamos Primer: The First Lectures on How To Build an Atomic Bomb First Edition
by Robert Serber (Author), Richard Rhodes (Editor, Introduction)
★★★★☆ 82 ratings

Kindle \$12.99 Hardcover \$15.70 - \$39.61 Other Sellers See all 4 versions

Buy used: \$15.70

Buy new: \$39.61

Only 1 left in stock - order soon.

List Price: \$47.95 Details Save: \$8.34 (17%)

FREE delivery Monday, June 6

Or fastest delivery Thursday, June 2. Order within 13 hrs 56 mins

Select delivery location

1943SEZY LA-1 (1943)

R.Serber

The Los Alamos primer

NUCLEAR REACTIONS $^{235,238}\text{U}(n, F)$, $E \sim 2 \text{ MeV}$; analyzed available data; deduced neutron multiplicity, σ , practical military weapon.

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 2021: 131 new and 303 updated compilations.
- $^{197}\text{Au}(n,\gamma)$ issue is fixed in EXFOR.
- 75th anniversary of nuclear reaction data compilations in 2021-2022.

79-Au-197(n,gamma) ENDF/B-VII.1

Cross Section (b)

Incident Neutron Energy (eV)

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. ISSER
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.⁵⁻⁹ 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;^{8,10} 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 Isser) 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.

H. A. Bethe, *Rev. Mod. Phys.* 9, 69 (1937).
 K. Diebner, W. Herrmann, and E. Grassmann, *Phys. Zets.* 43, 440 (1942).
 J. R. Dunning, G. B. Pegram, G. A. Fink, and D. P. Mitchell, *Phys. Rev.* 48, 265 (1935).
 H. Vofsi, *Zeits. f. Physik* 121, 201 (1943).
 O. R. Frisch and G. Pascoli, *Nature* 147, 357 (1940).
 J. Hornbostel, H. H. Goldsmith, and J. H. Manley, *Phys. Rev.* 58, 18 (1940).
 J. H. Manley, H. H. Goldsmith, and J. S. Swinger, *Phys. Rev.* 55, 59 (1940).
 R. Peterli, *Reports on Progress in Physics* VII, 87 (1940).
 W. E. Good and G. Scharff-Goldhaber, *Phys. Rev.* 59, 917 (1941).
 A. I. Leipunsky, *J. Phys. U.S.S.R.* 3, 231 (1940).
 H. Aoki, *Proc. Phys. Math. Soc. Japan* 21, 232 (1939).
 W. R. MacPhail, *Phys. Rev.* 37, 669 (1940).
 W. H. Zinn, S. Seely, and V. W. Cohen, *Phys. Rev.* 56, 267 (1939).

259

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.