Nuclear Data

J.H. Kelley (NCSU/TUNL) - USNDP Structure Group Leader

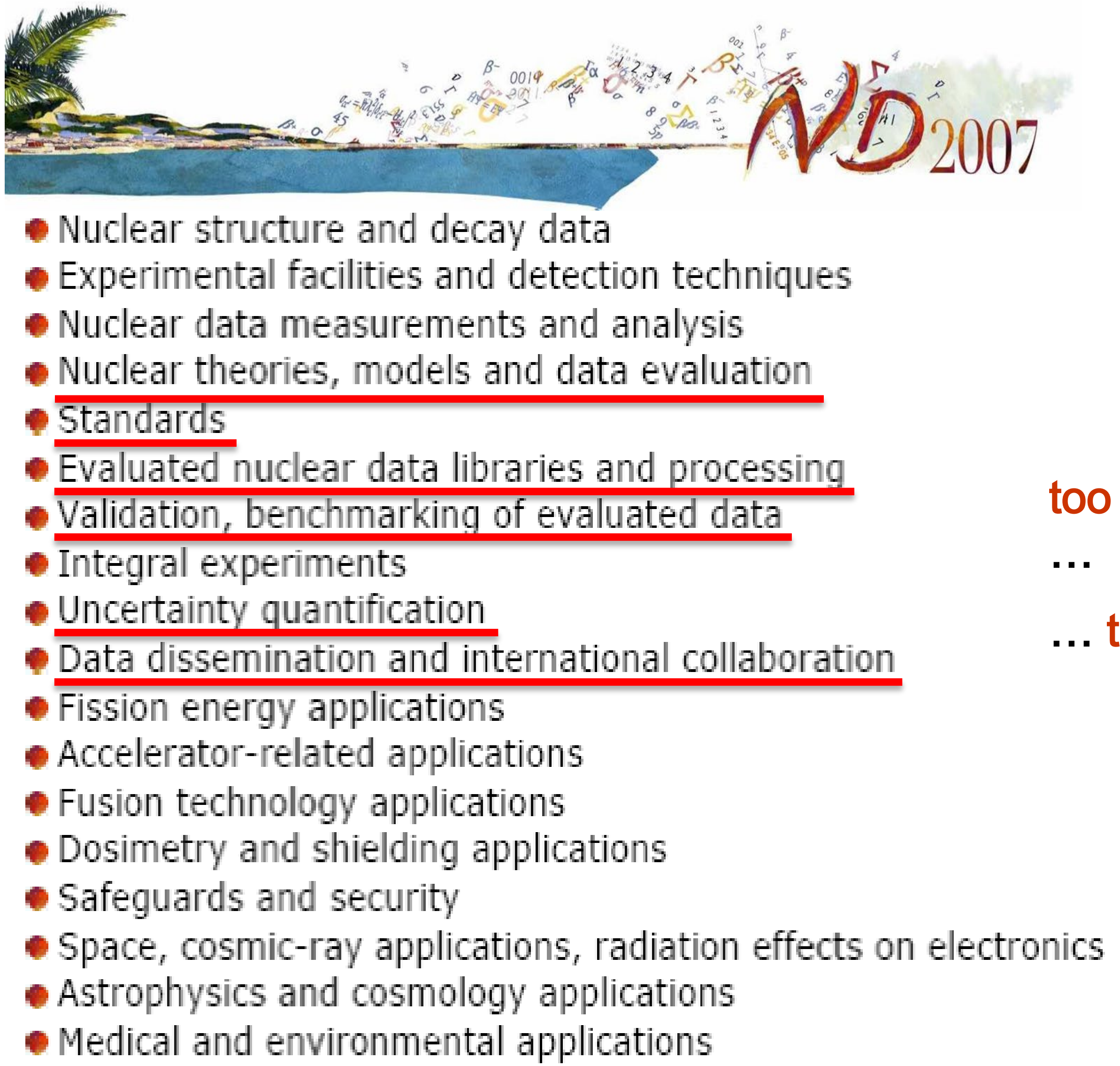
Nuclear Data

1. What is it?
2. Where do I get it from?
3. What is my role?

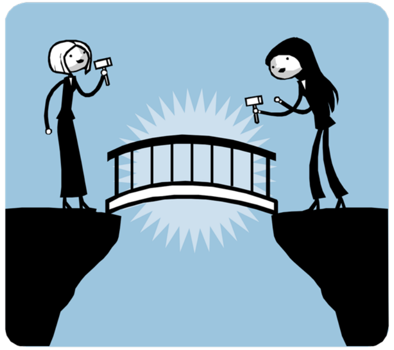
What is Nuclear Data?

- Early “large-scale” Nuclear Data Program was strongly correlated with the Manhattan Project.
  - Fission and criticality
  - Neutron cross-sections
  - β-decay energy production
- Description is too narrow
- Nuclear data is the product of nuclear science research.
- Description is perhaps too broad

Nuclear Data Evaluation



- Nuclear structure and decay data
- Experimental facilities and detection techniques
- Nuclear data measurements and analysis
- Nuclear theories, models and data evaluation
- Standards
- Evaluated nuclear data libraries and processing
- Validation, benchmarking of evaluated data
- Integral experiments
- Uncertainty quantification
- Data dissemination and international collaboration
- Fission energy applications
- Accelerator-related applications
- Fusion technology applications
- Dosimetry and shielding applications
- Safeguards and security
- Space, cosmic-ray applications, radiation effects on electronics
- Astrophysics and cosmology applications
- Medical and environmental applications



too academic for the applied science community

…

… too applied for the basic research community

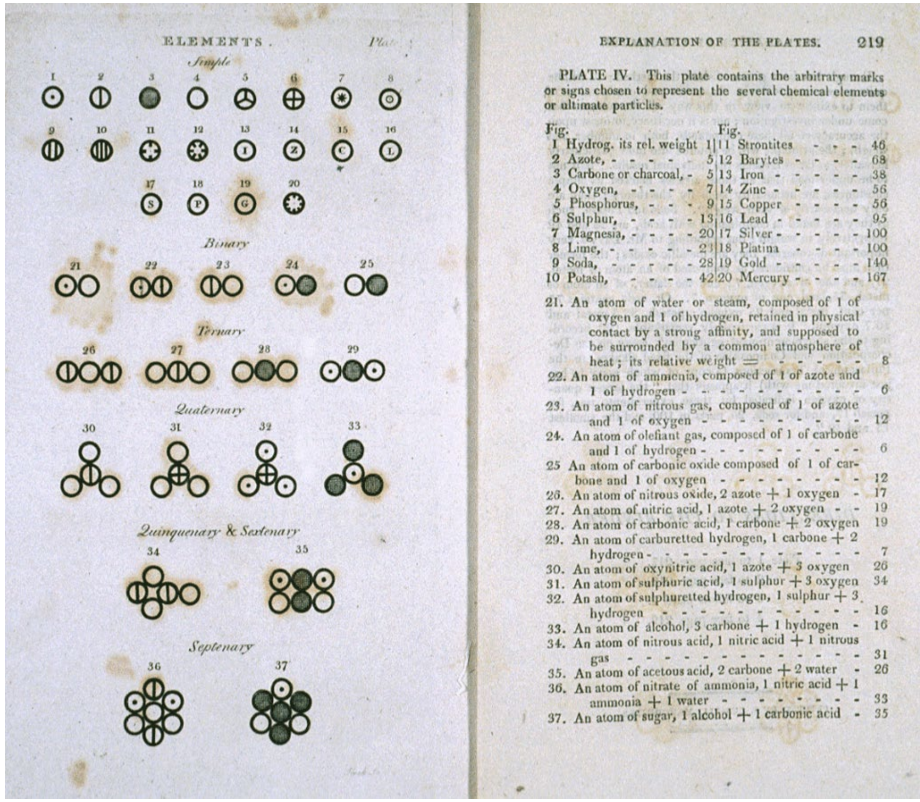
In this talk I will focus on Compilation, Evaluation and Dissemination of nuclear data, and on organizations that perform these activities.

Compiled and evaluated nuclear data libraries

- Today we have several original data libraries for Compiled and Evaluated data. These include:
  - NSR: Nuclear Science Reference Database: how to find original publications
  - ENSDF: Evaluated Nuclear Structure Data File: recommended level parameter data and decay data
  - ENDF: Evaluated Nuclear Data File: Recommended cross section and decay data
- How did we get to the “modern” era?

Precursor to Nuclear Data – **“Timeline of chemical element discoveries”** (Wikipedia)

- Discovery begins with a simple understanding of data: earth, water, air, fire, and aether.



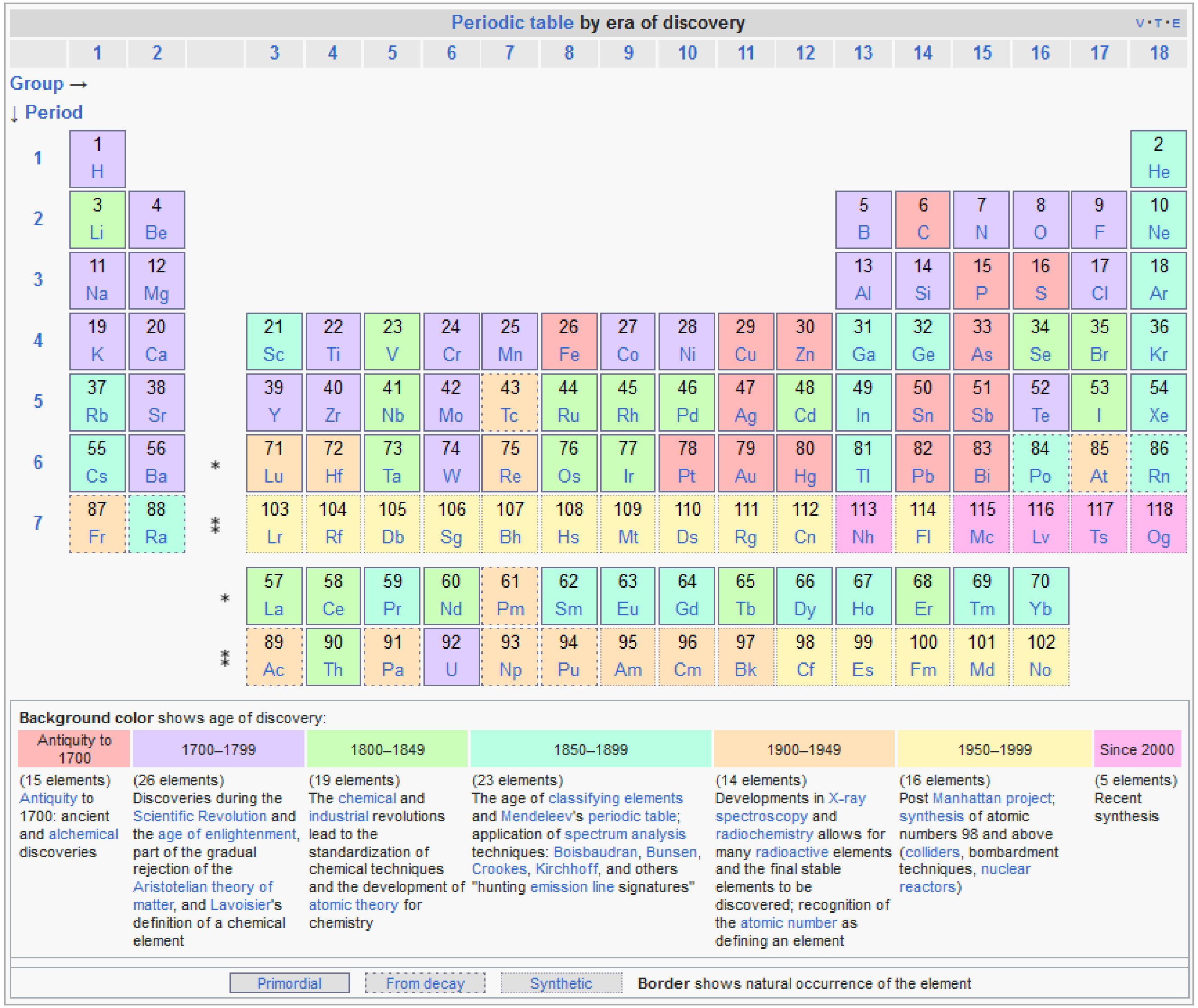
EXPLANATION OF THE PLATES. 219

PLATE IV. This plate contains the arbitrary marks or signs chosen to represent the several chemical elements or ultimate particles.

Fig.			Fig.		
1	Hydrog. its rel. weight	1	11	Strontites - - -	46
2	Azote, - - - - -	5	12	Barytes - - - -	68
3	Carbone or charcoal, -	5	13	Iron - - - - - -	38
4	Oxygen, - - - - -	7	14	Zinc - - - - - -	56
5	Phosphorus, - - -	9	15	Copper - - - - -	56
6	Sulphur, - - - -	13	16	Lead - - - - - -	95
7	Magnesia, - - - -	20	17	Silver - - - - - -	100
8	Lime, - - - - - -	23	18	Platina - - - -	100
9	Soda, - - - - - -	28	19	Gold - - - - - -	140
10	Potash, - - - - -	42	20	Mercury - - - - -	167

21. An atom of water or steam, composed of 1 of oxygen and 1 of hydrogen, retained in physical contact by a strong affinity, and supposed to be surrounded by a common atmosphere of heat; its relative weight = - - - - - - 8
22. An atom of ammonia, composed of 1 of azote and 1 of hydrogen - - - - - - - - - - - - 6
23. An atom of nitrous gas, composed of 1 of azote and 1 of oxygen - - - - - - - - - - 12
24. An atom of olefiant gas, composed of 1 of carbone and 1 of hydrogen - - - - - - - - - - 6
25 An atom of carbonic oxide composed of 1 of carbone and 1 of oxygen - - - - - - - - - 12
26. An atom of nitrous oxide, 2 azote + 1 oxygen - 17
27. An atom of nitric acid, 1 azote + 2 oxygen - - 19
28. An atom of carbonic acid, 1 carbone + 2 oxygen 19
29. An atom of carburetted hydrogen, 1 carbone + 2 hydrogen - - - - - - - - - - - - - 7
30. An atom of oxynitric acid, 1 azote + 3 oxygen 26
31. An atom of sulphuric acid, 1 sulphur + 3 oxygen 34
32. An atom of sulphuretted hydrogen, 1 sulphur + 3 hydrogen - - - - - - - - - - - - 16
33. An atom of alcohol, 3 carbone + 1 hydrogen - 16
34. An atom of nitrous acid, 1 nitric acid + 1 nitrous gas - - - - - - - - - - - - - - 31
35. An atom of acetous acid, 2 carbone + 2 water - 26
36. An atom of nitrate of ammonia, 1 nitric acid + 1 ammonia + 1 water - - - - - - - - - 33
37. An atom of sugar, 1 alcohol + 1 carbonic acid - 35

John Dalton's 1808 book *A New System of Chemical Philosophy*



Periodic table by era of discovery

Group →
↓ Period

	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	‡	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
			‡	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

Background color shows age of discovery:

Antiquity to 1700	1700–1799	1800–1849	1850–1899	1900–1949	1950–1999	Since 2000
(15 elements) Antiquity to 1700: ancient and alchemical discoveries	(26 elements) Discoveries during the Scientific Revolution and the age of enlightenment, part of the gradual rejection of the Aristotelian theory of matter, and Lavoisier's definition of a chemical element	(19 elements) The chemical and industrial revolutions lead to the standardization of chemical techniques and the development of atomic theory for chemistry	(23 elements) The age of classifying elements and Mendeleev's periodic table; application of spectrum analysis techniques: Boisbaudran, Bunsen, Crookes, Kirchhoff, and others "hunting emission line signatures"	(14 elements) Developments in X-ray spectroscopy and radiochemistry allows for many radioactive elements and the final stable elements to be discovered; recognition of the atomic number as defining an element	(16 elements) Post Manhattan project; synthesis of atomic numbers 98 and above (colliders, bombardment techniques, nuclear reactors)	(5 elements) Recent synthesis

Primordial   From decay   Synthetic   **Border** shows natural occurrence of the element

Compilation and Evaluation

Oxford Dictionaries

The world's most trusted dictionaries

Compilation: from Latin *compilare (14th cent)*

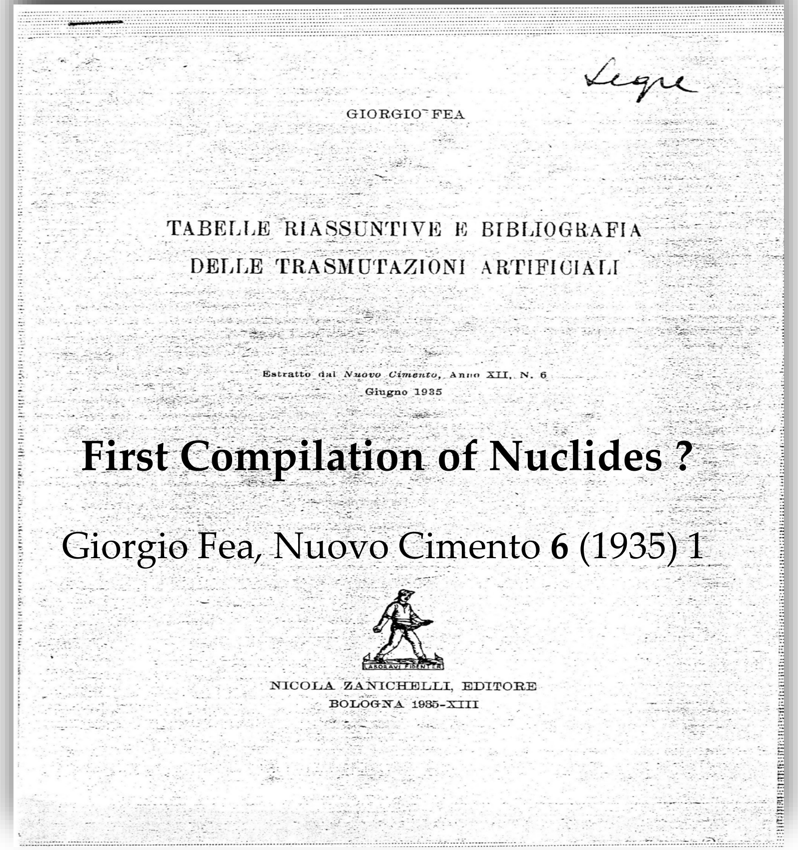
"the action or process of producing something by assembling information collected from other sources"

in scientific fields it serves as a convenient source of detailed information

Evaluation: from French *évaluation (1842)*

"the making of a judgment about the amount, number, or value of something; assessment"

a good "evaluation" always involves "compilation"



Segre

GIORGIO FEA

TABELLE RIASSUNTIVE E BIBLIOGRAFIA
DELLE TRASMUTAZIONI ARTIFICIALI

Estratto dal *Nuovo Cimento*, Anno XII, N. 6
Giugno 1935

LABORAVI FIDENTER

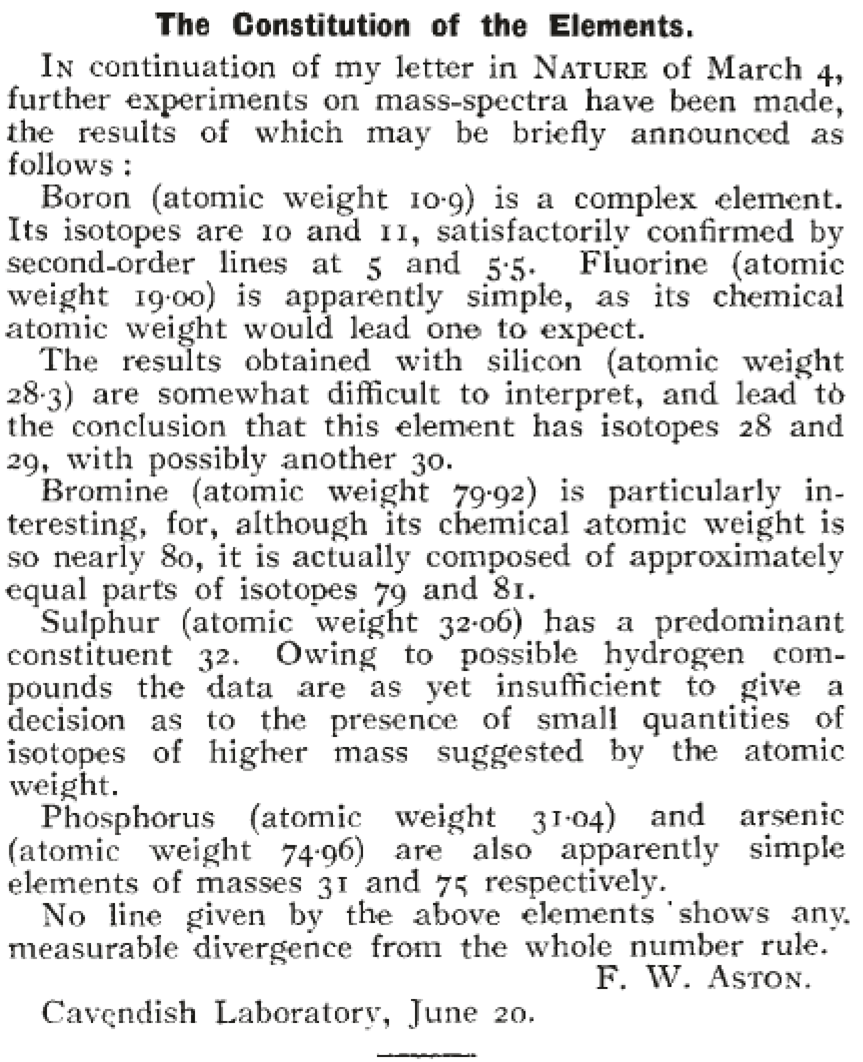
NICOLA ZANICHELLI, EDITORE
BOLOGNA 1935-XIII

First Compilation of Nuclides ?

Giorgio Fea, Nuovo Cimento **6** (1935) 1

courtesy of E. Browne (LBNL)

A walk back in time…



The Constitution of the Elements.

In continuation of my letter in Nature of March 4, further experiments on mass-spectra have been made, the results of which may be briefly announced as follows:

Boron (atomic weight 10·9) is a complex element. Its isotopes are 10 and 11, satisfactorily confirmed by second-order lines at 5 and 5·5. Fluorine (atomic weight 19·00) is apparently simple, as its chemical atomic weight would lead one to expect.

The results obtained with silicon (atomic weight 28·3) are somewhat difficult to interpret, and lead to the conclusion that this element has isotopes 28 and 29, with possibly another 30.

Bromine (atomic weight 79·92) is particularly interesting, for, although its chemical atomic weight is so nearly 80, it is actually composed of approximately equal parts of isotopes 79 and 81.

Sulphur (atomic weight 32·06) has a predominant constituent 32. Owing to possible hydrogen compounds the data are as yet insufficient to give a decision as to the presence of small quantities of isotopes of higher mass suggested by the atomic weight.

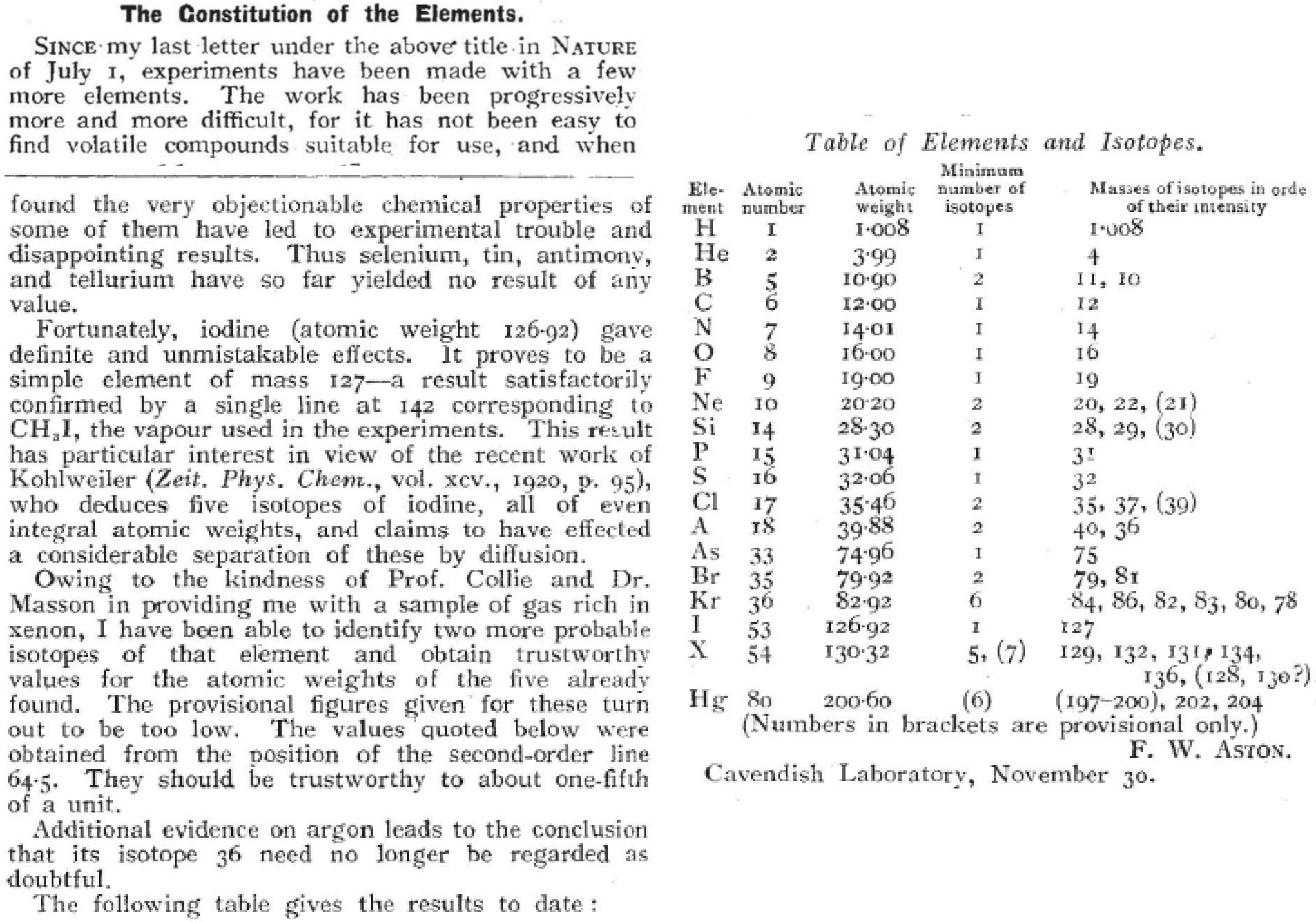
Phosphorus (atomic weight 31·04) and arsenic (atomic weight 74·96) are also apparently simple elements of masses 31 and 75 respectively.

No line given by the above elements shows any measurable divergence from the whole number rule.

F. W. Aston.

Cavendish Laboratory, June 20.

Nature, July 1920



The Constitution of the Elements.

Since my last letter under the above title in Nature of July 1, experiments have been made with a few more elements. The work has been progressively more and more difficult, for it has not been easy to find volatile compounds suitable for use, and when found the very objectionable chemical properties of some of them have led to experimental trouble and disappointing results. Thus selenium, tin, antimony, and tellurium have so far yielded no result of any value.

Fortunately, iodine (atomic weight 126·92) gave definite and unmistakable effects. It proves to be a simple element of mass 127—a result satisfactorily confirmed by a single line at 142 corresponding to CH_3I, the vapour used in the experiments. This result has particular interest in view of the recent work of Kohlweiler (*Zeit. Phys. Chem.*, vol. xcv., 1920, p. 95), who deduces five isotopes of iodine, all of even integral atomic weights, and claims to have effected a considerable separation of these by diffusion.

Owing to the kindness of Prof. Collie and Dr. Masson in providing me with a sample of gas rich in xenon, I have been able to identify two more probable isotopes of that element and obtain trustworthy values for the atomic weights of the five already found. The provisional figures given for these turn out to be too low. The values quoted below were obtained from the position of the second-order line 64·5. They should be trustworthy to about one-fifth of a unit.

Additional evidence on argon leads to the conclusion that its isotope 36 need no longer be regarded as doubtful.

The following table gives the results to date:

Table of Elements and Isotopes.

Element	Atomic number	Atomic weight	Minimum number of isotopes	Masses of isotopes in orde of their intensity
H	1	1·008	1	1·008
He	2	3·99	1	4
B	5	10·90	2	11, 10
C	6	12·00	1	12
N	7	14·01	1	14
O	8	16·00	1	16
F	9	19·00	1	19
Ne	10	20·20	2	20, 22, (21)
Si	14	28·30	2	28, 29, (30)
P	15	31·04	1	31
S	16	32·06	1	32
Cl	17	35·46	2	35, 37, (39)
A	18	39·88	2	40, 36
As	33	74·96	1	75
Br	35	79·92	2	79, 81
Kr	36	82·92	6	84, 86, 82, 83, 80, 78
I	53	126·92	1	127
X	54	130·32	5, (7)	129, 132, 131, 134, 136, (128, 130?)
Hg	80	200·60	(6)	(197–200), 202, 204

(Numbers in brackets are provisional only.)

F. W. Aston.

Cavendish Laboratory, November 30.

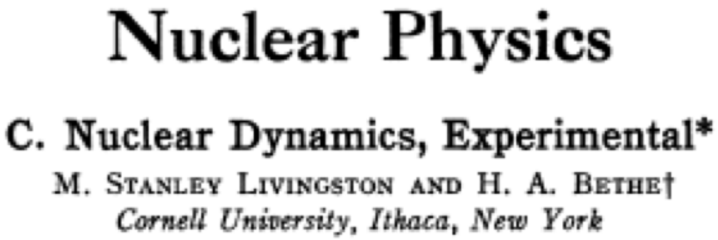
Nature, December1920

Approaching the modern system

REVIEWS OF

MODERN PHYSICS

VOLUME 9 JULY, 1937 NUMBER 3



Nuclear Physics

C. Nuclear Dynamics, Experimental*

M. STANLEY LIVINGSTON AND H. A. BETHE†

Cornell University, Ithaca, New York

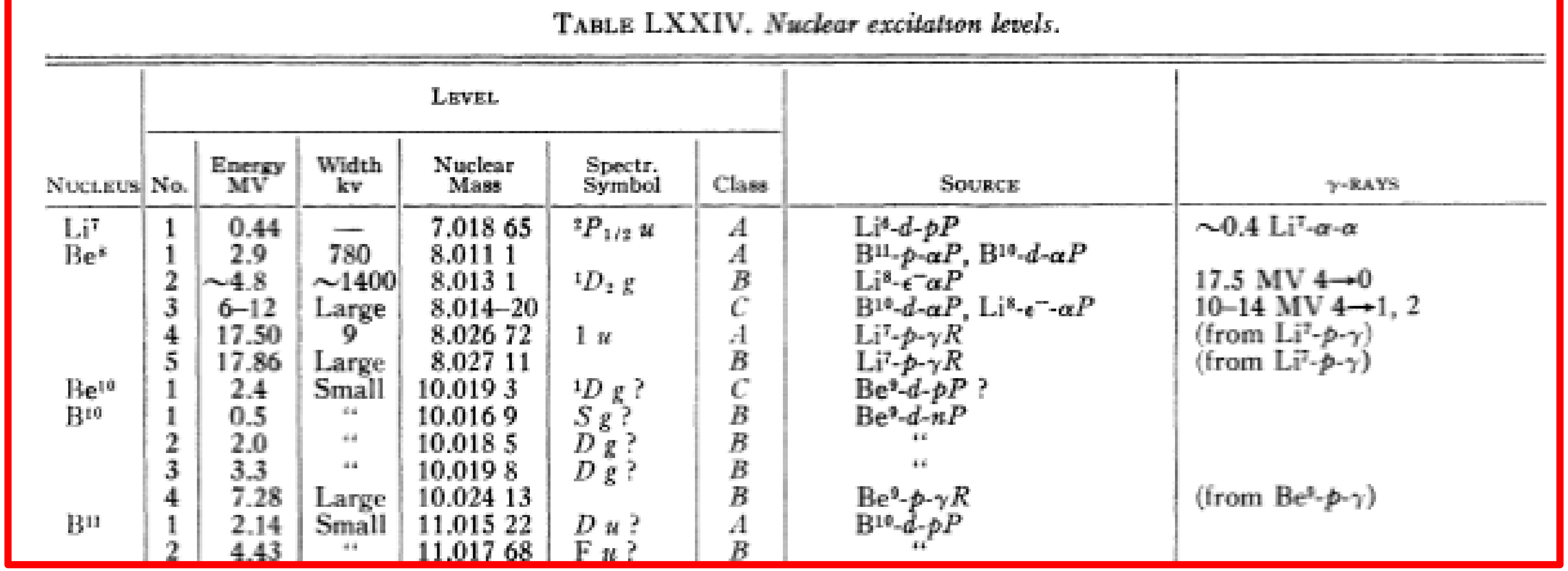
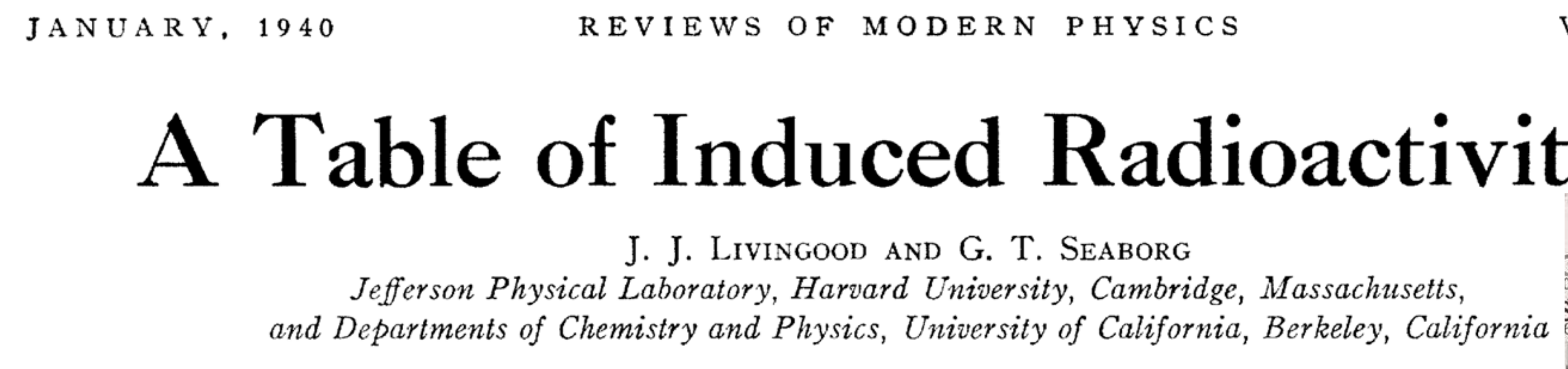


TABLE LXXIV. *Nuclear excitation levels.*

	LEVEL							
NUCLEUS	No.	Energy MV	Width kv	Nuclear Mass	Spectr. Symbol	Class	SOURCE	γ-RAYS
Li^7	1	0.44	—	7.018 65	$^2P_{1/2}\ u$	*A*	Li^6-d-pP	~0.4 Li^7-α-α
Be^8	1	2.9	780	8.011 1		*A*	B^{11}-p-αP, B^{10}-d-αP	
	2	~4.8	~1400	8.013 1	$^1D_2\ g$	*B*	Li^8-$\epsilon^-\alpha P$	17.5 MV 4→0
	3	6–12	Large	8.014–20		*C*	B^{10}-d-αP, Li^8-ϵ^--αP	10–14 MV 4→1, 2
	4	17.50	9	8.026 72	$1\ u$	*A*	Li^7-p-γR	(from Li^7-p-γ)
	5	17.86	Large	8.027 11		*B*	Li^7-p-γR	(from Li^7-p-γ)
Be^{10}	1	2.4	Small	10.019 3	$^1D\ g$?	*C*	Be^9-d-pP ?	
B^{10}	1	0.5	"	10.016 9	$S\ g$?	*B*	Be^9-d-nP	
	2	2.0	"	10.018 5	$D\ g$?	*B*	"	
	3	3.3	"	10.019 8	$D\ g$?	*B*	"	
	4	7.28	Large	10.024 13		*B*	Be^9-p-γR	(from Be^9-p-γ)
B^{11}	1	2.14	Small	11.015 22	$D\ u$?	*A*	B^{10}-d-pP	
	2	4.43	"	11.017 68	$F\ u$?	*B*	"	

decay energy, half-life/width, production mechanism, decay mode

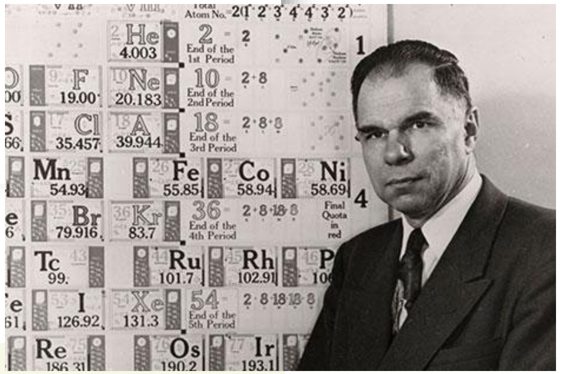


JANUARY, 1940 REVIEWS OF MODERN PHYSICS VOLUME 12

A Table of Induced Radioactivities

J. J. LIVINGOOD AND G. T. SEABORG

Jefferson Physical Laboratory, Harvard University, Cambridge, Massachusetts,
and Departments of Chemistry and Physics, University of California, Berkeley, California



The subsequent editions of **Table of Isotopes**

G.T. Seaborg, *ibid.* 16, 1 (**1944**)

G.T. Seaborg, I. Perlman, *ibid.* 20, 585 (**1948**)

J. M. Hollander, I. Perlman, and G.T. Seaborg, ibid., 25, 469 (**1953**)

D. Strominger, J.M. Hollander, G.T. Seaborg, ibid., 30, 585 (**1958**)

Katherine Way

In 1938 Kay Way earned a PhD in nuclear theory from the University of North Carolina with John Wheeler. Wheeler once noted she nearly stumbled on a theory for fission when she could not resolve the behavior of a high-spin and high-charge liquid drop. Eventually she landed in the Manhattan Project at the Metallurgical Laboratory in Chicago, where she worked on reactor design, evaluation of reactor constants and the organization of radioactivity data on fission products. Theoretical work there with Eugene Wigner led to what became known as the Way-Wigner formula for fission-product decay.

Kay systematized the vast quantities of Manhattan Project results, at first as a hobby and eventually as the work that absorbed her effort for the remainder of her professional career.

In 1945, Kay joined the Clinton Laboratories in Oak Ridge and continued her analysis of fission products and began collecting and organizing data on nuclear decay. Kay also provided the seminal idea for what has become Oak Ridge Associated Universities.

Moving to the National Bureau of Standards (DC) in 1947, she devoted herself full-time to the data evaluation needs of the basic and applied research communities. She coauthored a series of nuclear data sheets that later evolved into the Evaluated Nuclear Structure Data File (ENSDF) and with endorsement of the National Academy of Science she created the Nuclear Data Project in 1953.

In 1964, Kay moved to ORNL and arranged with Academic Press to establish a journal *Nuclear Data (Sheets)* to publish the extensive data that she and her colleagues had prepared, and in 1965 she was instrumental in establishing a second journal, now titled *Atomic Data and Nuclear Data Tables*. Kay persuaded the editors of *Nuclear Physics* to add keywords to the title page of each article, a practice that has evolved into the Nuclear Science Reference File. After retiring from ORNL in 1968, Kay relocated to TUNL where she continued as ADNDT editor until 1982 before retiring in 1988. (Sources: Physics Today obituary/Wikipedia)

Evolution of the USNDP and National Nuclear Data Center

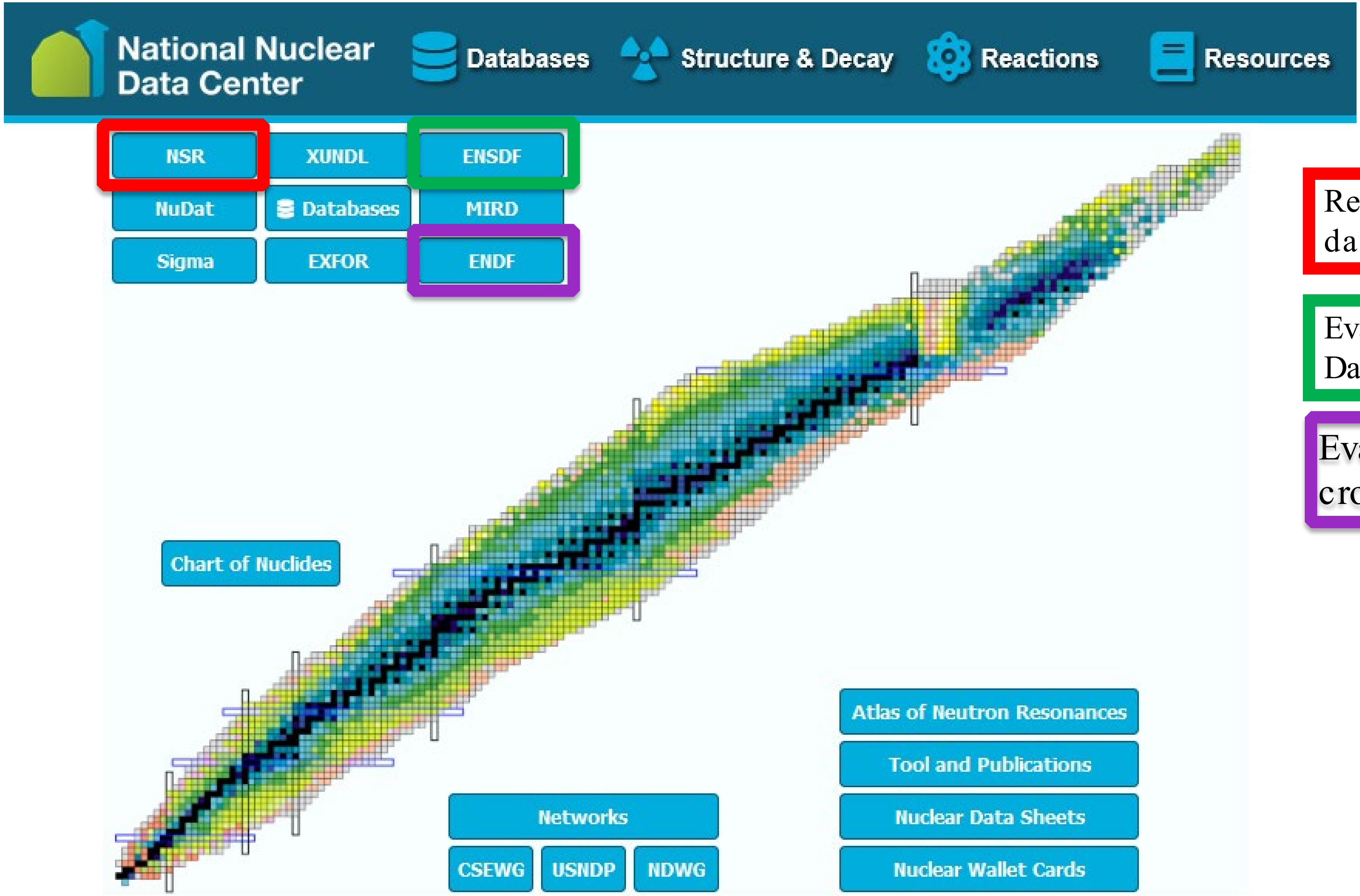
In the early 70's, the NSF and National Academy supported creation of two rounds of NIRA scholarships (71' and 73') that supported 12 post-docs to carry out a prompt update of structure information for Nuclear Data Sheets. Soon after this, the structure and decay data centers formed the US Nuclear Data Program formally connecting NDP/ORNL, Isotopes/LBL, Idaho(Charlie Reich), U Penn(Fay Selove) and BNL(with Sol Pearlstein). Around 1974, the US and international collaborators formed the Nuclear Structure and Decay Data (NSDD) network of evaluators that is coordinated by the IAEA. The network accepted the general policies and procedures developed by Kay Way and followed by the NDP/ORNL. The NSDD developed and took on responsibility to maintain the Evaluated Nuclear Structure Data File (ENSDF).

At Brookhaven, the Neutron Cross Section Compilation Group seeded from the Manhattan Project in 1951; they produced the BNL-325 neutron cross-section evaluations. Around 1960 the group was renamed as the Sigma Center and a new Cross-Section Evaluation Group was formed that worked closely with the Sigma Center. In 1967 the two groups merged and became the National Neutron Cross Section Center, and they began producing the Evaluated Nuclear Data File (ENDF).

In 1977, with the hire of Jag Tuli, BNL took on additional responsibilities involving nuclear structure and decay data evaluation and they became the National Nuclear Data Center. The NNDC began providing access to nuclear data via telnet in 1986, and via WWW in 1994. In the late 1990s, under Charlie Dunford's direction, the scope of the USNDP was broadened to include management of the ENDF.

TUNL joined the NSDD in 1992 following Fay Ajzenberg-Selove's retirement.

National Nuclear Data Center: the primary ND dissemination center in the US

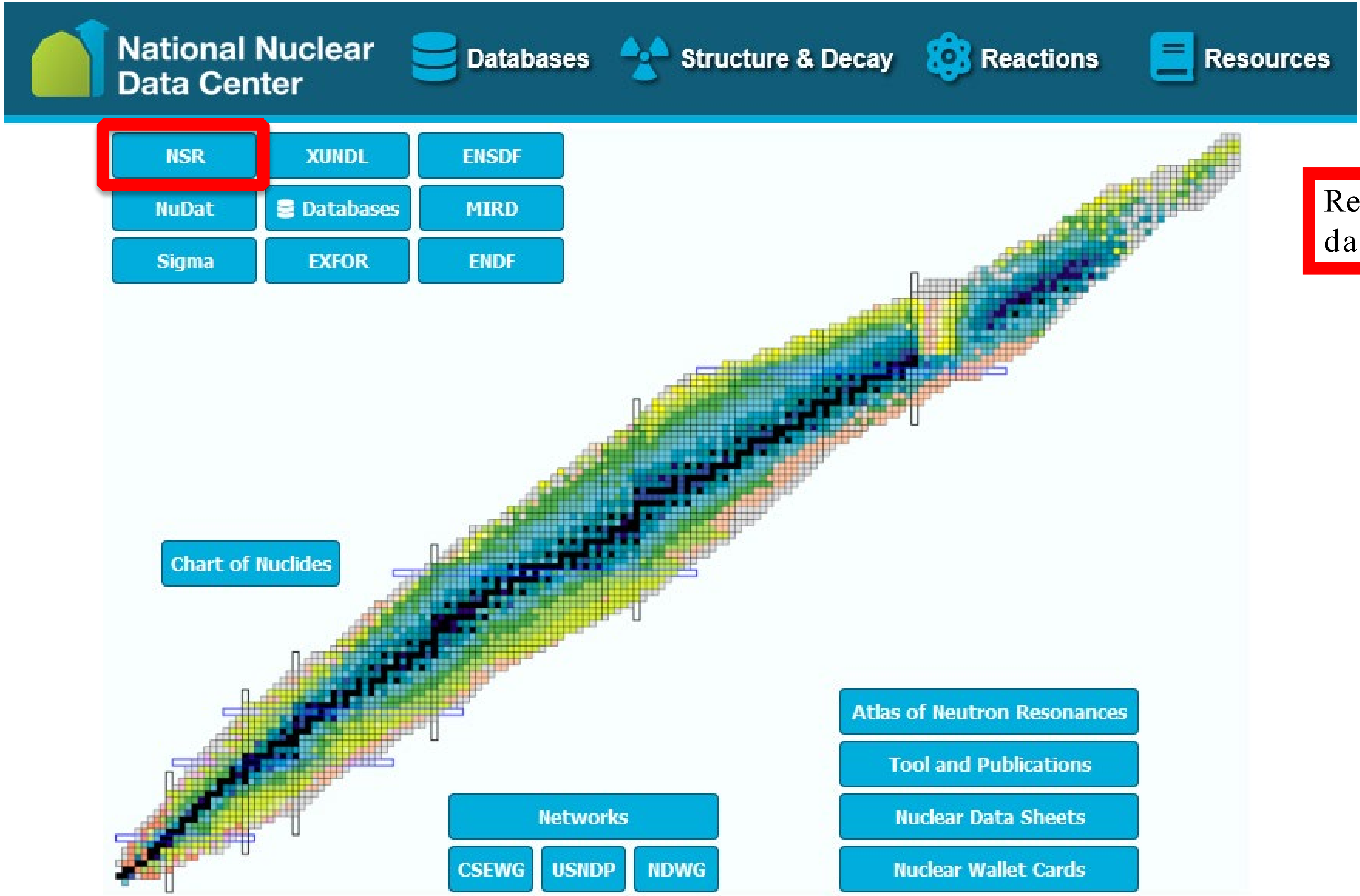


Reference and publication database

Evaluated Nuclear Structure Data

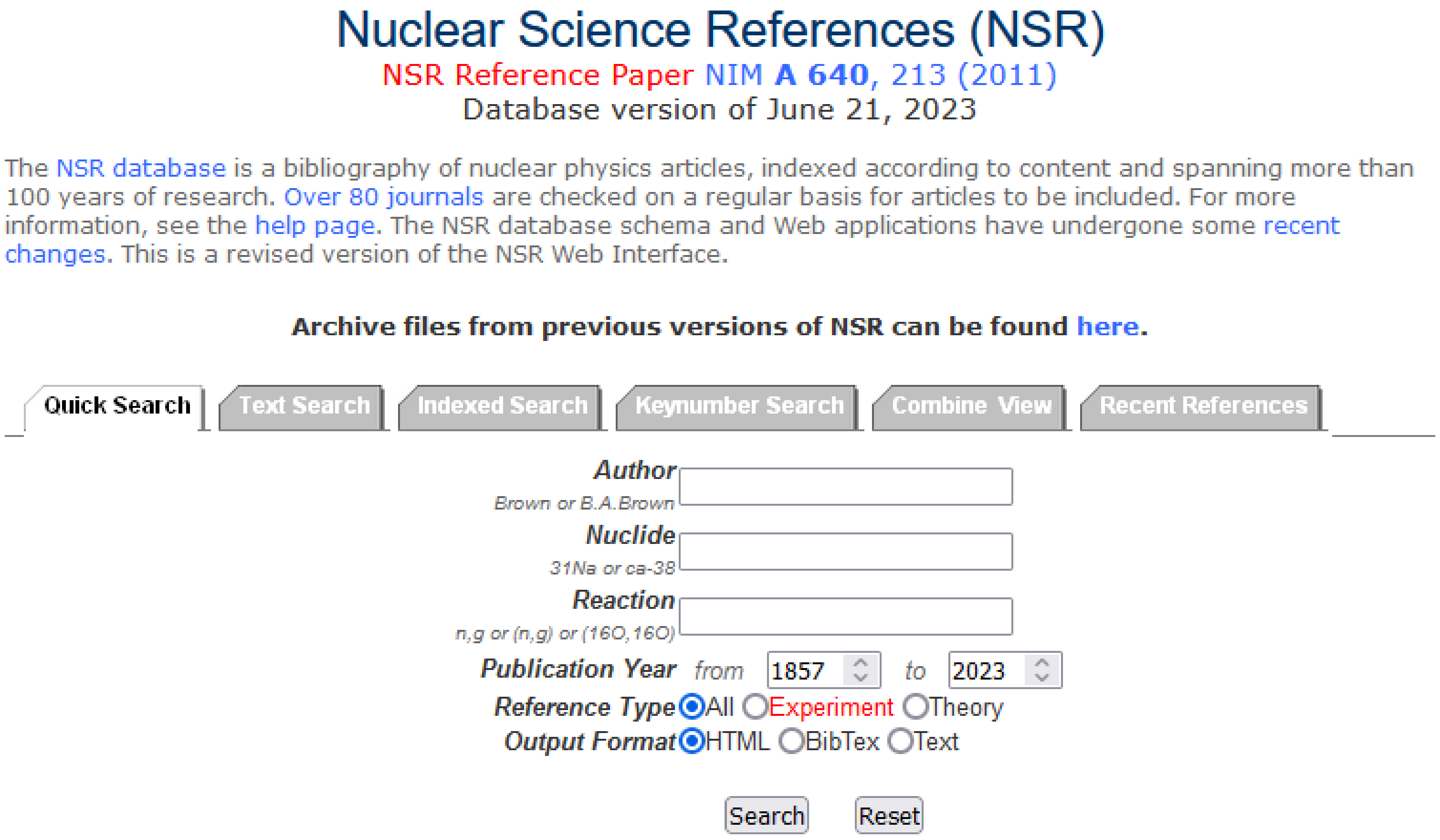
Evaluated Nuclear Reaction cross section data

National Nuclear Data Center: the primary ND dissemination center in the US



Reference and publication database

Evaluation begins with Compilation of published results



Nuclear Science References (NSR)

NSR Reference Paper NIM **A 640**, 213 (2011)
Database version of June 21, 2023

The NSR database is a bibliography of nuclear physics articles, indexed according to content and spanning more than 100 years of research. Over 80 journals are checked on a regular basis for articles to be included. For more information, see the help page. The NSR database schema and Web applications have undergone some recent changes. This is a revised version of the NSR Web Interface.

Archive files from previous versions of NSR can be found here.

Author *Brown or B.A.Brown*
Nuclide *31Na or ca-38*
Reaction *n,g or (n,g) or (16O,16O)*
Publication Year *from* 1857 *to* 2023
Reference Type ● All ○ Experiment ○ Theory
Output Format ● HTML ○ BibTex ○ Text

Nuclear Science Reference database (NSR)

Initialization Parameters

Publication year range: 1857 to 2023

Primary only: ☑ View All: ☐ Require measured quantity: ☑ Not in EXFOR: ☐

Output year order: ○ Ascending ● Descending

Output format: ● HTML ○ BibTex ○ Text ○ Keynum ○ Exchange

● Search all entries ○ Search entries added since 6 / 22 / 2023 (month/day/year)

Search Parameters

Nuclide: 100Sn
AND
- Target: 9Be
AND
- Measured: B+-DECAY

2019PA16 Phys.Rev. C 99, 034313 (2019)

J.Park, R.Krucken, D.Lubos, R.Gernhauser, M.Lewitowicz, S.Nishimura, D.S.Ahn, H.Baba, B.Blank, A.Blazhev, P.Boutachkov, F.Browne, I.Celikovic, G.de France, P.Doornenbal, T.Faestermann, Y.Fang, N.Fukuda, J.Giovinazzo, N.Goel, M.Gorska, H.Grawe, S.Ilieva, N.Inabe, T.Isobe, A.Jungclaus, D.Kameda, G.D.Kim, Y.-K.Kim, I.Kojouharov, T.Kubo, N.Kurz, Y.K.Kwon, G.Lorusso, K.Moschner, D.Murai, I.Nishizuka, Z.Patel, M.M.Rajabali, S.Rice, H.Sakurai, H.Schaffner, Y.Shimizu, L.Sinclair, P.-A.Soderstrom, K.Steiger, T.Sumikama, H.Suzuki, H.Takeda, Z.Wang, H.Watanabe, J.Wu, Z.Y.Xu

New and comprehensive β- and βp-decay spectroscopy results in the vicinity of ^{100}Sn

The value of the NSR is from the effort to produce usable keywords

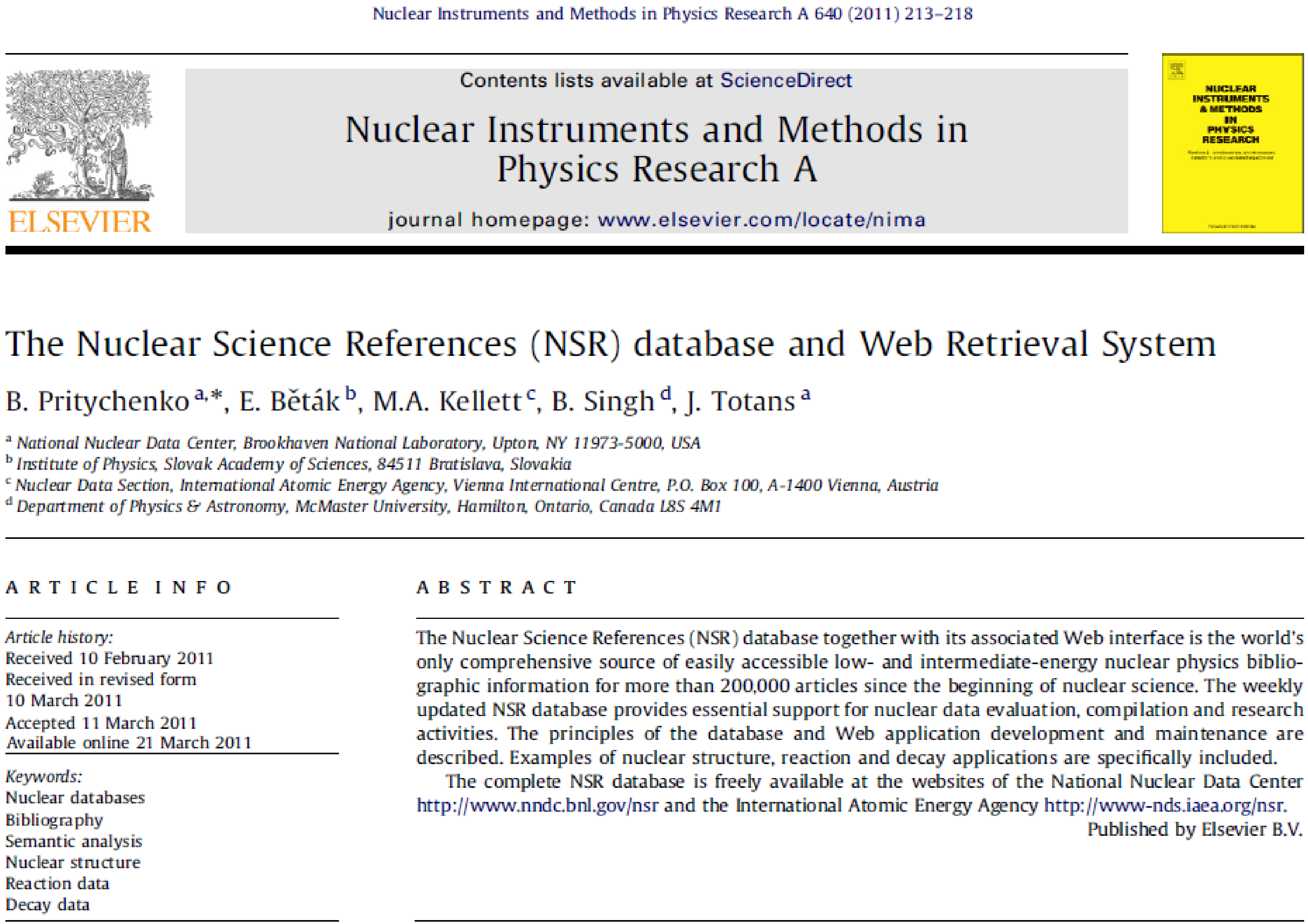
RADIOACTIVITY ^{87,88,88m}Tc, ^{88,89,91,91m}Ru, ^{90,90m,91,91m,92,92m}Rh, ^{92,93,94,95,95m}Pd, ^{94,94m,95,96,96m}Ag, ^{96,96m,97,97m,98,99}Cd, ^{98,98m,99,100,101}In, ^{101}Sn(β^+), (β^+p)[from ^{9}Be(^{124}Xe, X), E=345 MeV/nucleon]; measured Eγ, Iγ, γγ- and βγ-coin, β^+p spectra, half-lives of ground states and isomers from β decay βγ-coin, and βp decay curves, Q(β^+), and %b$^+$p branching ratios using the WAS3ABi double-sided silicon strip detector array for β^+ detection and the Euroball-RIKEN Cluster Array for γ detection at RIKEN Nishina Center. ^{88}Mo, ^{88,89,91}Tc, ^{90,91,92}Ru, ^{92,93,94}Rh, ^{95,96}Pd, ^{96,97}Ag, ^{98}Cd; deduced levels, J , π, multipolarities, β feedings and logft. Comparison with Serduke-Lawson-Gloeckner empirical shell model in proton and neutron $p_{1/2}$ and $g_{9/2}$ model space below ^{100}Sn core.

NUCLEAR REACTIONS ^{9}Be(^{124}Xe, X)^{87}Ru/^{88}Ru/^{89}Ru/^{90}Ru/^{91}Ru/^{92}Ru/^{93}Ru/^{90}Rh/^{91}Rh/^{92}Rh/^{93}Rh/^{94}Rh/^{95}Rh/^{91}Pd/^{92}Pd/^{93}Pd/^{94}Pd/^{95}Pd/^{96}Pd/^{97}Pd/^{93}Ag/^{94}Ag/^{95}Ag/^{96}Ag/^{97}Ag/^{98}Ag/^{95}Cd/^{96}Cd/^{97}Cd/^{98}Cd/^{99}Cd/^{97}In/^{98}In/^{99}In/^{100}In/^{99}Sn/^{100}Sn/^{101}Sn, E=345 MeV/nucleon; measured yields, particle identification plot using BigRIPS and the ZeroDegree spectrometers, Bρ-TOF-ΔE technique with position-sensitive parallel-plate avalanche counters, plastic scintillators and gas-filled ionization chamber at RIBF-RIKEN facility.

doi: 10.1103/PhysRevC.99.034313

Learn More

TUNL



Nuclear Instruments and Methods in Physics Research A 640 (2011) 213–218

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The Nuclear Science References (NSR) database and Web Retrieval System

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ABSTRACT

The Nuclear Science References (NSR) database together with its associated Web interface is the world's only comprehensive source of easily accessible low- and intermediate-energy nuclear physics bibliographic information for more than 200,000 articles since the beginning of nuclear science. The weekly updated NSR database provides essential support for nuclear data evaluation, compilation and research activities. The principles of the database and Web application development and maintenance are described. Examples of nuclear structure, reaction and decay applications are specifically included.

The complete NSR database is freely available at the websites of the National Nuclear Data Center http://www.nndc.bnl.gov/nsr and the International Atomic Energy Agency http://www-nds.iaea.org/nsr.

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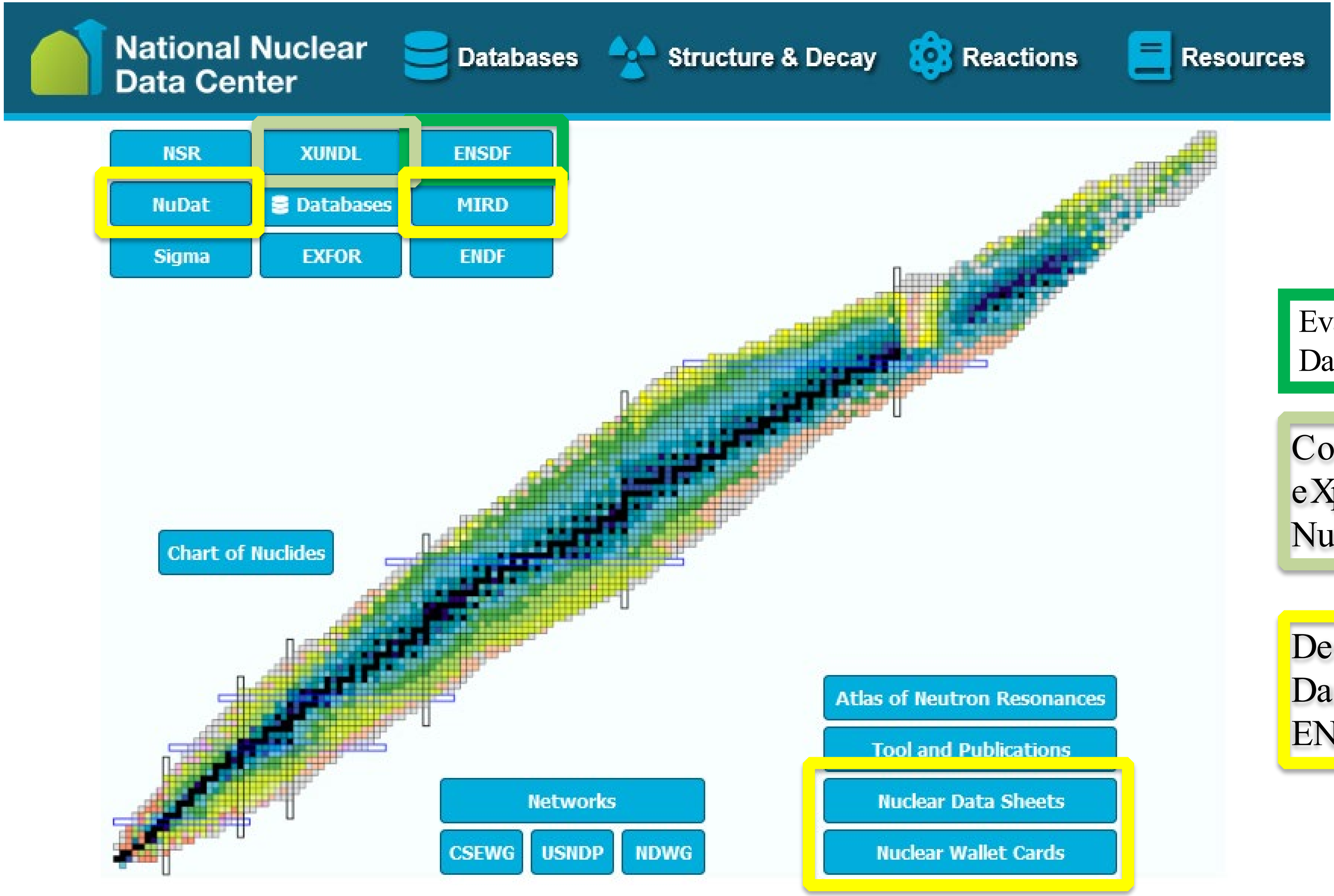
Nuclear Structure Databases



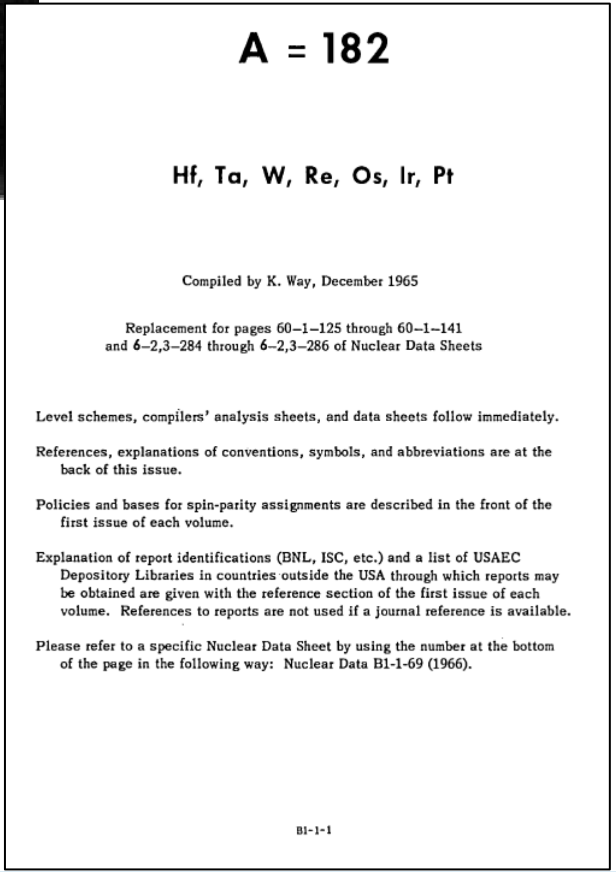
Evaluated Nuclear Structure Data File

Compiled NS Data
eXperimental UNevaluated Nuclear Data Library

Derivative Library
Databases/GUI that presents ENSDF data in a different format

Evaluated Nuclear Structure Data File (ENSDF)

Kay Way worked on evaluation of reactor constants and the organization of radioactivity data on fission products. She systematized the vast quantities of Manhattan Project results, at first as a hobby and eventually as the work that absorbed her effort for the remainder of her professional career; she coauthored a series of nuclear data sheets that later evolved into the Evaluated Nuclear Structure Data File (ENSDF) and with endorsement of the National Academy of Science she created the Nuclear Data Project in 1953.



A = 182

Hf, Ta, W, Re, Os, Ir, Pt

Compiled by K. Way, December 1965

Replacement for pages 60–1–125 through 60–1–141
and 6–2,3–284 through 6–2,3–286 of Nuclear Data Sheets

Level schemes, compilers' analysis sheets, and data sheets follow immediately.

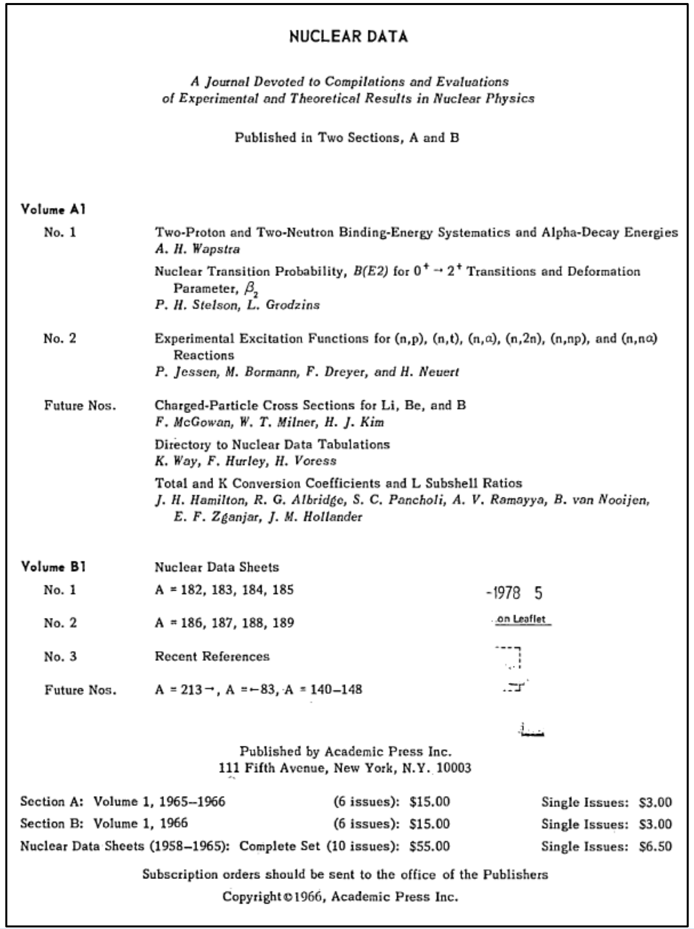
References, explanations of conventions, symbols, and abbreviations are at the back of this issue.

Policies and bases for spin-parity assignments are described in the front of the first issue of each volume.

Explanation of report identifications (BNL, ISC, etc.) and a list of USAEC Depository Libraries in countries outside the USA through which reports may be obtained are given with the reference section of the first issue of each volume. References to reports are not used if a journal reference is available.

Please refer to a specific Nuclear Data Sheet by using the number at the bottom of the page in the following way: Nuclear Data B1-1-69 (1966).

B1-1-1



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A Journal Devoted to Compilations and Evaluations
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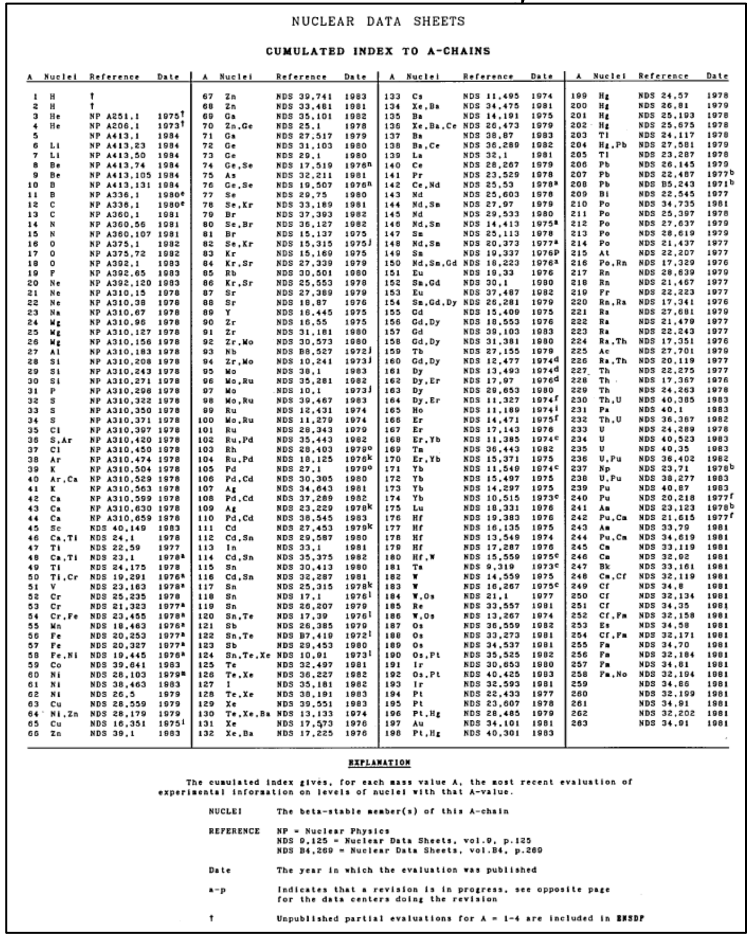


NUCLEAR DATA SHEETS

CUMULATED INDEX TO A-CHAINS

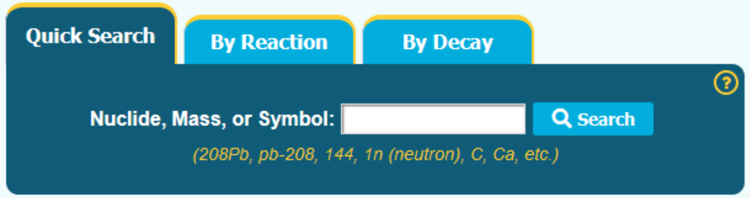
A	Nuclei	Reference	Date	A	Nuclei	Reference	Date	A	Nuclei	Reference	Date	A	Nuclei	Reference	Date
1	H	†		67	Zn	NDS 39,741	1983	133	Cs	NDS 11,495	1974	199	Hg	NDS 24,57	1978
2	H	†		68	Zn	NDS 33,481	1981	134	Xe,Ba	NDS 34,475	1981	200	Hg	NDS 26,81	1979
3	He	NP A251,1	1975†	69	Ga	NDS 35,101	1982	135	Ba	NDS 14,191	1975	201	Hg	NDS 25,193	1978
4	He	NP A206,1	1973†	70	Zn,Ge	NDS 25,1	1978	136	Xe,Ba,Ce	NDS 26,473	1979	202	Hg	NDS 25,675	1978
5		NP A413,1	1984	71	Ga	NDS 27,517	1979	137	Ba	NDS 38,87	1983	203	Tl	NDS 24,117	1978
6	Li	NP A413,23	1984	72	Ge	NDS 31,103	1980	138	Ba,Ce	NDS 36,289	1982	204	Hg,Pb	NDS 27,581	1979
7	Li	NP A413,50	1984	73	Ge	NDS 29,1	1980	139	La	NDS 32,1	1981	205	Tl	NDS 23,287	1978
8	Be	NP A413,74	1984	74	Ge,Se	NDS 17,519	1976^{n}	140	Ce	NDS 28,267	1979	206	Pb	NDS 26,145	1979
9	Be	NP A413,105	1984	75	As	NDS 32,211	1981	141	Pr	NDS 23,529	1978	207	Pb	NDS 22,487	1977^{b}
10	B	NP A413,131	1984	76	Ge,Se	NDS 19,507	1976^{n}	142	Ce,Nd	NDS 25,53	1978^{a}	208	Pb	NDS B5,243	1971^{b}
11	B	NP A336,1	1980^{e}	77	Se	NDS 29,75	1980	143	Nd	NDS 25,603	1978	209	Bi	NDS 22,545	1977
12	C	NP A336,1	1980^{e}	78	Se,Kr	NDS 33,189	1981	144	Nd,Sm	NDS 27,97	1979	210	Po	NDS 34,735	1981
13	C	NP A360,1	1981	79	Br	NDS 37,393	1982	145	Nd	NDS 29,533	1980	211	Po	NDS 25,397	1978
14	N	NP A360,56	1981	80	Se,Br	NDS 36,127	1982	146	Nd,Sm	NDS 14,413	1975^{a}	212	Po	NDS 27,637	1979
15	N	NP A360,107	1981	81	Br	NDS 15,137	1975	147	Sm	NDS 25,113	1978	213	Po	NDS 28,619	1979
16	O	NP A375,1	1982	82	Se,Kr	NDS 15,315	1975^{j}	148	Nd,Sm	NDS 20,373	1977^{a}	214	Po	NDS 21,437	1977
17	O	NP A375,72	1982	83	Kr	NDS 15,169	1975	149	Sm	NDS 19,337	1976^{p}	215	At	NDS 22,207	1977
18	O	NP A392,1	1983	84	Kr,Sr	NDS 27,339	1979	150	Nd,Sm,Gd	NDS 18,223	1976^{a}	216	Po,Rn	NDS 17,329	1976
19	F	NP A392,65	1983	85	Rb	NDS 30,501	1980	151	Eu	NDS 19,33	1976	217	Rn	NDS 28,639	1979
20	Ne	NP A392,120	1983	86	Kr,Sr	NDS 25,553	1978	152	Sm,Gd	NDS 30,1	1980	218	Rn	NDS 21,467	1977
21	Ne	NP A310,15	1978	87	Sr	NDS 27,389	1979	153	Eu	NDS 37,487	1982	219	Fr	NDS 22,223	1977
22	Ne	NP A310,38	1978	88	Sr	NDS 18,87	1976	154	Sm,Gd,Dy	NDS 26,281	1979	220	Rn,Ra	NDS 17,341	1976
23	Na	NP A310,67	1978	89	Y	NDS 16,445	1975	155	Gd	NDS 15,409	1975	221	Ra	NDS 27,681	1979
24	Mg	NP A310,96	1978	90	Zr	NDS 16,55	1975	156	Gd,Dy	NDS 18,553	1976	222	Ra	NDS 21,479	1977
25	Mg	NP A310,127	1978	91	Zr	NDS 31,181	1980	157	Gd	NDS 39,103	1983	223	Ra	NDS 22,243	1977
26	Mg	NP A310,156	1978	92	Zr,Mo	NDS 30,573	1980	158	Gd,Dy	NDS 31,381	1980	224	Ra,Th	NDS 17,351	1976
27	Al	NP A310,183	1978	93	Nb	NDS B8,527	1972^{j}	159	Tb	NDS 27,155	1979	225	Ac	NDS 27,701	1979
28	Si	NP A310,208	1978	94	Zr,Mo	NDS 10,241	1973^{j}	160	Gd,Dy	NDS 12,477	1974^{d}	226	Ra,Th	NDS 20,119	1977
29	Si	NP A310,243	1978	95	Mo	NDS 38,1	1983	161	Dy	NDS 13,493	1974^{d}	227	Th	NDS 22,275	1977
30	Si	NP A310,271	1978	96	Mo,Ru	NDS 35,281	1982	162	Dy,Er	NDS 17,97	1976^{d}	228	Th	NDS 17,367	1976
31	P	NP A310,298	1978	97	Mo	NDS 10,1	1973^{j}	163	Dy	NDS 29,653	1980	229	Th	NDS 24,263	1978
32	S	NP A310,322	1978	98	Mo,Ru	NDS 39,467	1983	164	Dy,Er	NDS 11,327	1974^{f}	230	Th,U	NDS 40,385	1983
33	S	NP A310,350	1978	99	Ru	NDS 12,431	1974	165	Ho	NDS 11,189	1974^{i}	231	Pa	NDS 40,1	1983
34	S	NP A310,371	1978	100	Mo,Ru	NDS 11,279	1974	166	Er	NDS 14,471	1975^{f}	232	Th,U	NDS 36,367	1982
35	Cl	NP A310,397	1978	101	Ru	NDS 28,343	1979	167	Er	NDS 17,143	1976	233	U	NDS 24,289	1978
36	S,Ar	NP A310,420	1978	102	Ru,Pd	NDS 35,443	1982	168	Er,Yb	NDS 11,385	1974^{c}	234	U	NDS 40,523	1983
37	Cl	NP A310,450	1978	103	Rh	NDS 28,403	1979^{o}	169	Tm	NDS 36,443	1982	235	U	NDS 40,35	1983
38	Ar	NP A310,474	1978	104	Ru,Pd	NDS 18,125	1976^{k}	170	Er,Yb	NDS 15,371	1975	236	U,Pu	NDS 36,402	1982
39	K	NP A310,504	1978	105	Pd	NDS 27,1	1979^{o}	171	Yb	NDS 11,549	1974^{c}	237	Np	NDS 23,71	1978^{b}
40	Ar,Ca	NP A310,529	1978	106	Pd,Cd	NDS 30,305	1980	172	Yb	NDS 15,497	1975	238	U,Pu	NDS 38,277	1983
41	K	NP A310,563	1978	107	Ag	NDS 34,643	1981	173	Yb	NDS 14,297	1975	239	Pu	NDS 40,87	1983
42	Ca	NP A310,599	1978	108	Pd,Cd	NDS 37,289	1982	174	Yb	NDS 10,515	1973^{c}	240	Pu	NDS 20,218	1977^{f}
43	Ca	NP A310,630	1978	109	Ag	NDS 23,229	1978^{k}	175	Lu	NDS 18,331	1976	241	Am	NDS 23,123	1978^{b}
44	Ca	NP A310,659	1978	110	Pd,Cd	NDS 38,545	1983	176	Hf	NDS 19,383	1976	242	Pu,Cm	NDS 21,615	1977^{f}
45	Sc	NDS 40,149	1983	111	Cd	NDS 27,453	1979^{k}	177	Hf	NDS 16,135	1975	243	Am	NDS 33,79	1981
46	Ca,Ti	NDS 24,1	1978	112	Cd,Sn	NDS 29,587	1980	178	Hf	NDS 13,549	1974	244	Pu,Cm	NDS 34,619	1981
47	Ti	NDS 22,59	1977	113	In	NDS 33,1	1981	179	Hf	NDS 17,287	1976	245	Cm	NDS 33,119	1981
48	Ca,Ti	NDS 23,1	1978^{a}	114	Cd,Sn	NDS 35,375	1982	180	Hf,W	NDS 15,559	1975^{c}	246	Cm	NDS 32,92	1981
49	Ti	NDS 24,175	1978	115	Sn	NDS 30,413	1980	181	Ta	NDS 9,319	1973^{c}	247	Bk	NDS 33,161	1981
50	Ti,Cr	NDS 19,291	1976^{a}	116	Cd,Sn	NDS 32,287	1981	182	W	NDS 14,559	1975	248	Cm,Cf	NDS 32,119	1981
51	V	NDS 23,163	1978^{a}	117	Sn	NDS 25,315	1978^{k}	183	W	NDS 16,267	1975^{c}	249	Cf	NDS 34,8	1981
52	Cr	NDS 25,235	1978	118	Sn	NDS 17,1	1976^{l}	184	W,Os	NDS 21,1	1977	250	Cf	NDS 32,134	1981
53	Cr	NDS 21,323	1977^{a}	119	Sn	NDS 26,207	1979	185	Re	NDS 33,557	1981	251	Cf	NDS 34,35	1981
54	Cr,Fe	NDS 23,455	1978^{a}	120	Sn,Te	NDS 17,39	1976^{l}	186	W,Os	NDS 13,267	1974	252	Cf,Fm	NDS 32,158	1981
55	Mn	NDS 18,463	1976^{a}	121	Sb	NDS 26,385	1979	187	Os	NDS 36,559	1982	253	Es	NDS 34,58	1981
56	Fe	NDS 20,253	1977^{a}	122	Sn,Te	NDS B7,419	1972^{l}	188	Os	NDS 33,273	1981	254	Cf,Fm	NDS 32,171	1981
57	Fe	NDS 20,327	1977^{a}	123	Sb	NDS 29,453	1980	189	Os	NDS 34,537	1981	255	Fm	NDS 34,70	1981
58	Fe,Ni	NDS 19,445	1976^{a}	124	Sn,Te,Xe	NDS 10,91	1973^{l}	190	Os,Pt	NDS 35,525	1982	256	Fm	NDS 32,184	1981
59	Co	NDS 39,641	1983	125	Te	NDS 32,497	1981	191	Ir	NDS 30,653	1980	257	Fm	NDS 34,81	1981
60	Ni	NDS 28,103	1979^{m}	126	Te,Xe	NDS 36,227	1982	192	Os,Pt	NDS 40,425	1983	258	Fm,No	NDS 32,194	1981
61	Ni	NDS 38,463	1983	127	I	NDS 35,181	1982	193	Ir	NDS 32,593	1981	259		NDS 34,86	1981
62	Ni	NDS 26,5	1979	128	Te,Xe	NDS 38,191	1983	194	Pt	NDS 22,433	1977	260		NDS 32,199	1981
63	Cu	NDS 28,559	1979	129	Xe	NDS 39,551	1983	195	Pt	NDS 23,607	1978	261		NDS 34,91	1981
64	Ni,Zn	NDS 28,179	1979	130	Te,Xe,Ba	NDS 13,133	1974	196	Pt,Hg	NDS 28,485	1979	262		NDS 32,202	1981
65	Cu	NDS 16,351	1975^{l}	131	Xe	NDS 17,573	1976	197	Au	NDS 34,101	1981	263		NDS 34,91	1981
66	Zn	NDS 39,1	1983	132	Xe,Ba	NDS 17,225	1976	198	Pt,Hg	NDS 40,301	1983				

EXPLANATION

The cumulated index gives, for each mass value A, the most recent evaluation of experimental information on levels of nuclei with that A-value.

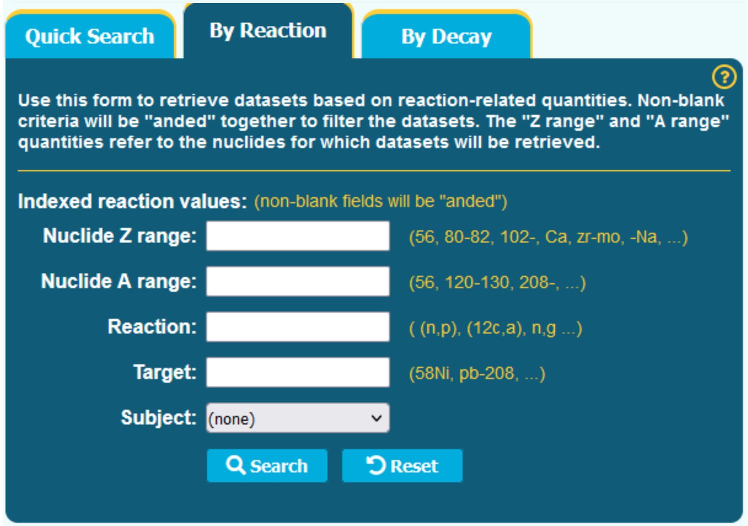
NUCLEI	The beta-stable member(s) of this A-chain
REFERENCE	NP = Nuclear Physics NDS 9,125 = Nuclear Data Sheets, vol.9, p.125 NDS B4,269 = Nuclear Data Sheets, vol.B4, p.269
Date	The year in which the evaluation was published
a–p	Indicates that a revision is in progress, see opposite page for the data centers doing the revision
†	Unpublished partial evaluations for A = 1–4 are included in ENSDF

ENSDF interface



Nuclide, Mass, or Symbol:

(208Pb, pb-208, 144, 1n (neutron), C, Ca, etc.)



Use this form to retrieve datasets based on reaction-related quantities. Non-blank criteria will be "anded" together to filter the datasets. The "Z range" and "A range" quantities refer to the nuclides for which datasets will be retrieved.

Indexed reaction values: (non-blank fields will be "anded")

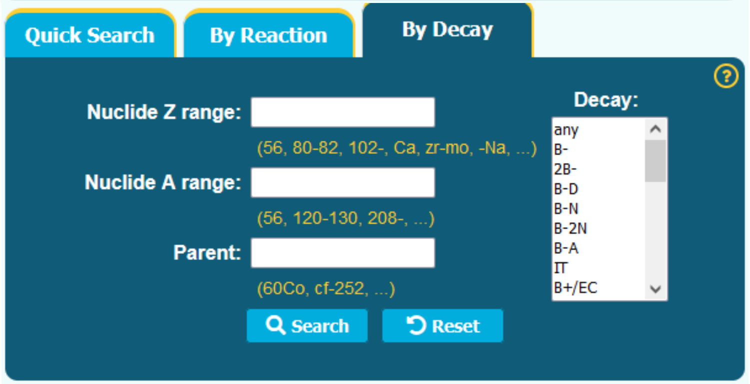
Nuclide Z range: (56, 80-82, 102-, Ca, zr-mo, -Na, ...)

Nuclide A range: (56, 120-130, 208-, ...)

Reaction: ((n,p), (12c,a), n,g ...)

Target: (58Ni, pb-208, ...)

Subject: (none)



Nuclide Z range: (56, 80-82, 102-, Ca, zr-mo, -Na, ...)

Nuclide A range: (56, 120-130, 208-, ...)

Parent: (60Co, cf-252, ...)

Decay:
- any
- B-
- 2B-
- B-D
- B-N
- B-2N
- B-A
- IT
- B+/EC

$^{24}_{12}$Mg$_{12}$-1 From ENSDF - Evaluated March 2022 $^{24}_{12}$Mg$_{12}$-1

Adopted Levels, Gammas

History

Type	Author	Citation	Literature Cutoff Date
Full Evaluation	M. Shamsuzzoha Basunia, Anagha Chakraborty	NDS 186, 2 (2022)	31-Mar-2022

$Q(\beta^-)$=−13884.77 *23*; S(n)=16531.22 *3*; S(p)=11692.69 *1*; $Q(\alpha)$=−9316.56 *1* 2021Wa16
S(2n)=29676.23 *16*, S(2p)=20486.805 *22* (2021Wa16).
Other reactions:
2004Be18, 2004Be08: ^{12}C(^{24}Mg, ^{12}C), E=130 MeV; measured Eγ, (particle)γ-coin.
2011Fr14: ^{12}C(^{13}C,n) E=12, 13.5, 20 MeV; measured reaction products ^{25}Mg; deduced ^{24}Mg excited states and reported resonance energies at 13.25 MeV *20* and 14.25 MeV *20*.
2001Di12: ^{11}B(^{13}N,X), (^{13}N,^{12}C), E=29.5, 45 MeV. Measured particle spectra, fusion σ. Deduced ^{24}Mg 6−α decay features, isospin purity/mixing in ^{24}Mg at excitation energy ~47 MeV, GDR γ-emission features.
2006Va20: ^{28}Si(p,p′X)^{24}Mg, E=1 GeV; measured Eγ; deduced σ.

^{24}Mg Levels

Cross Reference (XREF) Flags

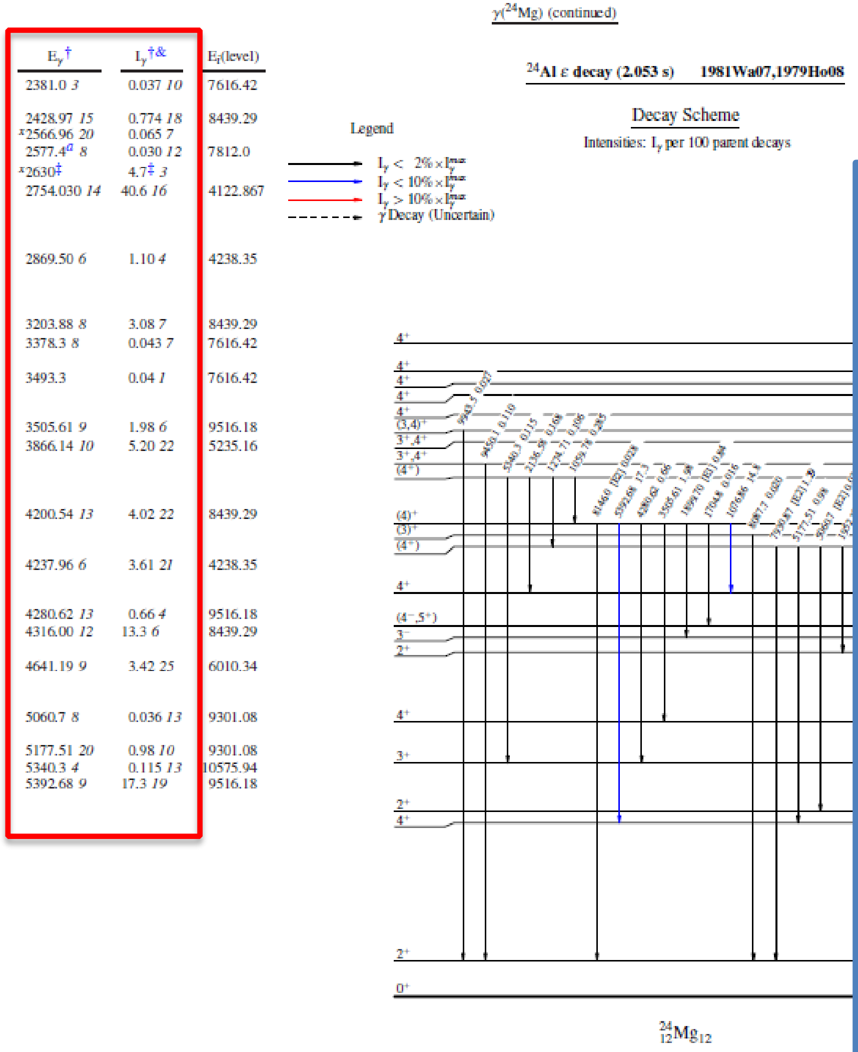
				Others:	
A	^{24}Na β^- decay (14.956 h)	N	^{20}Ne(α,γ):Resonances	AA	Coulomb excitation
B	^{24}Na β^- decay (20.18 ms)	O	^{20}Ne(α,α),(α,α'):Resonances	AB	^{24}Mg($\alpha,\alpha'\gamma$)
C	^{24}Al ε decay (2.053 s)	P	^{20}Ne(^{6}Li,d),(^{7}Li,t)	AC	^{24}Mg(^{6}Li,^{6}Li′)
D	^{24}Al ε decay (130.7 ms)	Q	^{22}Ne(^{3}He,n)	AD	^{24}Mg(^{16}O,^{16}O′)
E	^{25}Si εp decay	R	^{23}Na(p,γ),(p,p′),(p,X),	AE	^{25}Mg(p,d)
F	^{26}P ε2p decay	S	^{23}Na(^{3}He,d),(^{3}He,dγ)	AF	^{25}Mg(^{3}He,^{4}He)
G	^{28}P $\varepsilon\alpha$ decay	T	^{24}Mg(γ,γ')	AG	^{27}Al($\mu^-,\nu3n\gamma$)
H	^{12}C(^{12}C,γ)	U	^{24}Mg(e,e′)	AH	^{27}Al(p,α)
I	^{12}C(^{12}C,p):Resonances	V	^{24}Mg($\pi^+,\pi^{+\prime}$),($\pi^-,\pi^{-\prime}$)	AI	^{28}Si(d,^{6}Li)
J	^{12}C(^{14}N,d)	W	^{24}Mg(p,p′),(pol p,p′),	AJ	^{28}Si(^{28}Si,Xγ)
K	^{12}C(^{24}Mg,^{12}Cγ)	X	^{24}Mg(n,n′γ)		
L	^{12}C(^{16}O,α),(^{16}O,$\alpha\gamma$)	Y	^{24}Mg(^{3}He,^{3}He′)		
M	^{12}C(^{24}Mg,2^{12}C),(^{20}Ne,2^{12}C)	Z	^{24}Mg(α,α')		

E(level)†	J$^{\pi}$	T$_{1/2}$ or Γ^{J}	XREF	Comments
0^{P}	0$^+$	stable	ABCDEFGH JKL N PQRSTUVWXYZ	XREF: Others: AA, AB, AD, AE, AF, AG, AH, AI, AJ δ<r^2>(^{26}Mg,^{24}Mg)=+0.140 fm^2 *5* (stat) *25* (syst) (2012Yo01). <r^2>$^{1/2}$(^{24}Mg)=3.0570 *16* (charge radius) (2013An02 evaluation). Others: 3.0570 fm *7* (stat) *48* (syst) (2012Yo01), 3.030 fm *30* (1971Li26 – (e,e′)).
1368.667^{P} 5	2$^+$	1.36 ps *3*	A CDEF H JKL N PQRSTUVWXYZ	XREF: Others: AA, AB, AC, AD, AE, AF, AG, AH, AI, AJ μ=+1.08 *3*; Q=−0.29 *3* g=0.538 *13* (2015Ku05) T=0 (2015Ku05) J$^{\pi}$: L=2 in ^{24}Mg(p,p′). E2 to 0$^+$. T$_{1/2}$ or Γ: From τ=1.96 ps *5*: weighted average of mean lifetimes of (α,γ): 2.25 ps *9* (1973Br33), (^{16}O,α),(^{16}O,$\alpha\gamma$): 1.82 ps *14* (1974Fo11), 2.11 ps *16* (1970Al10), 2.09 ps *13* (1975Ho15), 2.07 ps *34* (1970Cu02); (e,e′): 1.9 ps 2 (1956He83), 1.87 ps *5* (1969Ti01), 1.9 ps 2 (1972Na06), 1.97 ps *11* (1974Jo10); (γ,γ'): 1.76 ps *21* (1981Ca10), 1.8 ps *2* (1977Ca14), 1.92 ps *15* (1971Sw07), 1.95 ps *26* (1966Sk01); Coul Ex: 1.91 ps *10* (1979Fe05), 1.92 ps *10* (1977Sc36), 2.00 ps *14* (1970Ha04), 2.02 ps *10* (1971Vi01), 1.93 ps *13* (1975Bi03), 1.65 ps *15* (1969Pe11); (p,γ): 1.97 ps *16*

Continued on next page (footnotes at end of table)

Compiled and evaluated structure and decay data from various reactions

ENSDF: building the database from observations



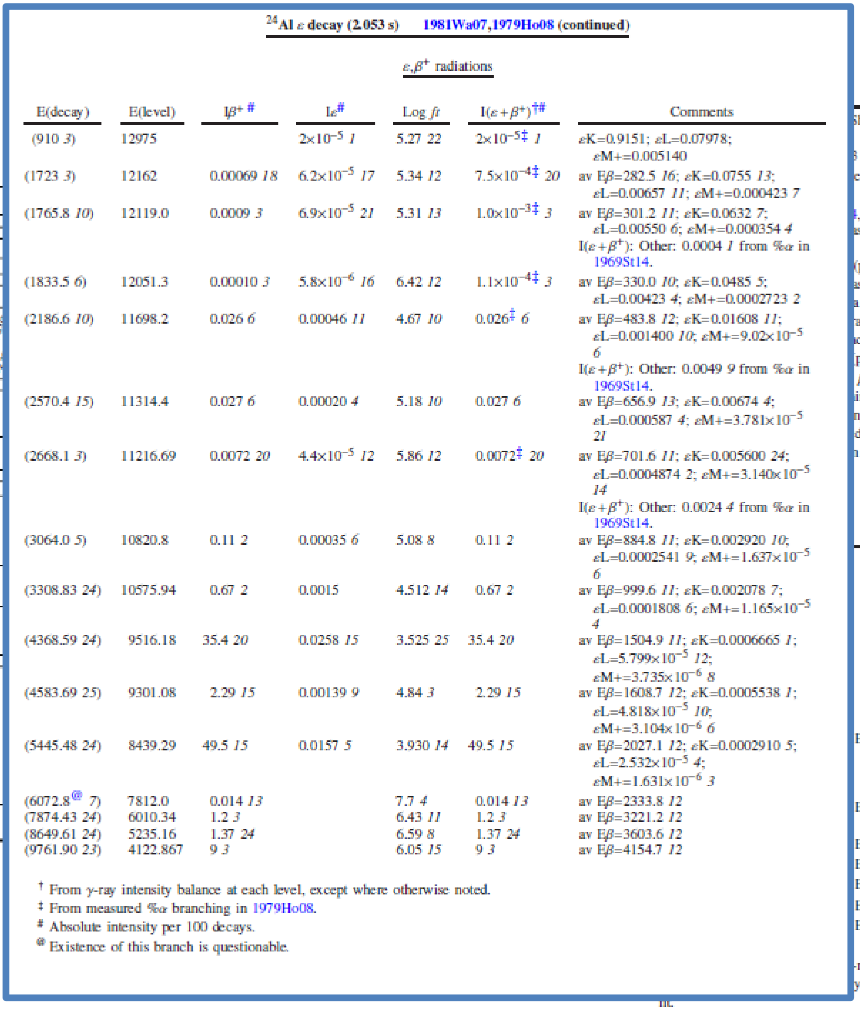
γ(^{24}Mg) (continued)

E_γ[†]	I_γ[†&]	E_i(level)
2381.0 3	0.037 10	7616.42
2428.97 15	0.774 18	8439.29
^{x}2566.96 20	0.065 7	
2577.4[a] 8	0.030 12	7812.0
^{x}2630[‡]	4.7[‡] 3	
2754.030 14	40.6 16	4122.867
2869.50 6	1.10 4	4238.35
3203.88 8	3.08 7	8439.29
3378.3 8	0.043 7	7616.42
3493.3	0.04 1	7616.42
3505.61 9	1.98 6	9516.18
3866.14 10	5.20 22	5235.16
4200.54 13	4.02 22	8439.29
4237.96 6	3.61 21	4238.35
4280.62 13	0.66 4	9516.18
4316.00 12	13.3 6	8439.29
4641.19 9	3.42 25	6010.34
5060.7 8	0.036 13	9301.08
5177.51 20	0.98 10	9301.08
5340.3 4	0.115 13	10575.94
5392.68 9	17.3 19	9516.18

^{24}Al ε decay (2.053 s) 1981Wa07,1979Ho08

Decay Scheme

Intensities: I_γ per 100 parent decays

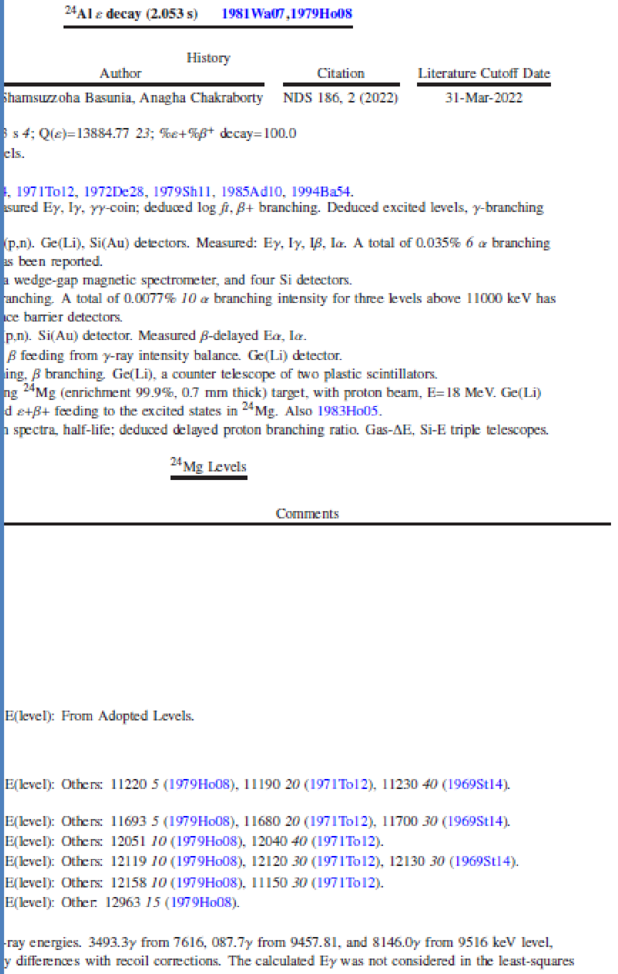


^{24}Al ε decay (2.053 s) 1981Wa07,1979Ho08 (continued)

ε,β^+ radiations

E(decay)	E(level)	$I\beta^+$[#]	$I\varepsilon$[#]	Log ft	$I(\varepsilon+\beta^+)$[†#]	Comments
(910 3)	12975		2×10^{-5} 1	5.27 22	2×10^{-5}[‡] 1	εK=0.9151; εL=0.07978; εM+=0.005140
(1723 3)	12162	0.00069 18	6.2×10^{-5} 17	5.34 12	7.5×10^{-4}[‡] 20	av Eβ=282.5 16; εK=0.0755 13; εL=0.00657 11; εM+=0.000423 7
(1765.8 10)	12119.0	0.0009 3	6.9×10^{-5} 21	5.31 13	1.0×10^{-3}[‡] 3	av Eβ=301.2 11; εK=0.0632 7; εL=0.00550 6; εM+=0.000354 4 $I(\varepsilon+\beta^+)$: Other: 0.0004 1 from %α in 1969St14.
(1833.5 6)	12051.3	0.00010 3	5.8×10^{-6} 16	6.42 12	1.1×10^{-4}[‡] 3	av Eβ=330.0 10; εK=0.0485 5; εL=0.00423 4; εM+=0.0002723 2
(2186.6 10)	11698.2	0.026 6	0.00046 11	4.67 10	0.026[‡] 6	av Eβ=483.8 12; εK=0.01608 11; εL=0.001400 10; εM+=9.02×10^{-5} 6 $I(\varepsilon+\beta^+)$: Other: 0.0049 9 from %α in 1969St14.
(2570.4 15)	11314.4	0.027 6	0.00020 4	5.18 10	0.027 6	av Eβ=656.9 13; εK=0.00674 4; εL=0.000587 4; εM+=3.781×10^{-5} 21
(2668.1 3)	11216.69	0.0072 20	4.4×10^{-5} 12	5.86 12	0.0072[‡] 20	av Eβ=701.6 11; εK=0.005600 24; εL=0.0004874 2; εM+=3.140×10^{-5} 14 $I(\varepsilon+\beta^+)$: Other: 0.0024 4 from %α in 1969St14.
(3064.0 5)	10820.8	0.11 2	0.00035 6	5.08 8	0.11 2	av Eβ=884.8 11; εK=0.002920 10; εL=0.0002541 9; εM+=1.637×10^{-5} 6
(3308.83 24)	10575.94	0.67 2	0.0015	4.512 14	0.67 2	av Eβ=999.6 11; εK=0.002078 7; εL=0.0001808 6; εM+=1.165×10^{-5} 4
(4368.59 24)	9516.18	35.4 20	0.0258 15	3.525 25	35.4 20	av Eβ=1504.9 11; εK=0.0006665 1; εL=5.799×10^{-5} 12; εM+=3.735×10^{-6} 8
(4583.69 25)	9301.08	2.29 15	0.00139 9	4.84 3	2.29 15	av Eβ=1608.7 12; εK=0.0005538 1; εL=4.818×10^{-5} 10; εM+=3.104×10^{-6} 6
(5445.48 24)	8439.29	49.5 15	0.0157 5	3.930 14	49.5 15	av Eβ=2027.1 12; εK=0.0002910 5; εL=2.532×10^{-5} 4; εM+=1.631×10^{-6} 3
(6072.8[@] 7)	7812.0	0.014 13		7.7 4	0.014 13	av Eβ=2333.8 12
(7874.43 24)	6010.34	1.2 3		6.43 11	1.2 3	av Eβ=3221.2 12
(8649.61 24)	5235.16	1.37 24		6.59 8	1.37 24	av Eβ=3603.6 12
(9761.90 23)	4122.867	9 3		6.05 15	9 3	av Eβ=4154.7 12

[†] From γ-ray intensity balance at each level, except where otherwise noted.
[‡] From measured %α branching in 1979Ho08.
[#] Absolute intensity per 100 decays.
[@] Existence of this branch is questionable.



^{24}Al ε decay (2.053 s) 1981Wa07,1979Ho08

History

Author	Citation	Literature Cutoff Date
hamsuzzoha Basunia, Anagha Chakraborty	NDS 186, 2 (2022)	31-Mar-2022

s 4; Q(ε)=13884.77 23; %ε+%β^+ decay=100.0
els.

, 1971To12, 1972De28, 1979Sh11, 1985Ad10, 1994Ba54.
sured Eγ, Iγ, γγ-coin; deduced log ft, β+ branching. Deduced excited levels, γ-branching

(p,n). Ge(Li), Si(Au) detectors. Measured: Eγ, Iγ, Iβ, Iα. A total of 0.035% 6 α branching
s been reported.
a wedge-gap magnetic spectrometer, and four Si detectors.
anching. A total of 0.0077% 10 α branching intensity for three levels above 11000 keV has
ce barrier detectors.
p,n). Si(Au) detector. Measured β-delayed Eα, Iα.
β feeding from γ-ray intensity balance. Ge(Li) detector.
ing, β branching. Ge(Li), a counter telescope of two plastic scintillators.
ng ^{24}Mg (enrichment 99.9%, 0.7 mm thick) target, with proton beam, E=18 MeV. Ge(Li)
d ε+β+ feeding to the excited states in ^{24}Mg. Also 1983Ho05.
spectra, half-life; deduced delayed proton branching ratio. Gas-ΔE, Si-E triple telescopes.

^{24}Mg Levels

Comments

E(level): From Adopted Levels.

E(level): Others: 11220 5 (1979Ho08), 11190 20 (1971To12), 11230 40 (1969St14).

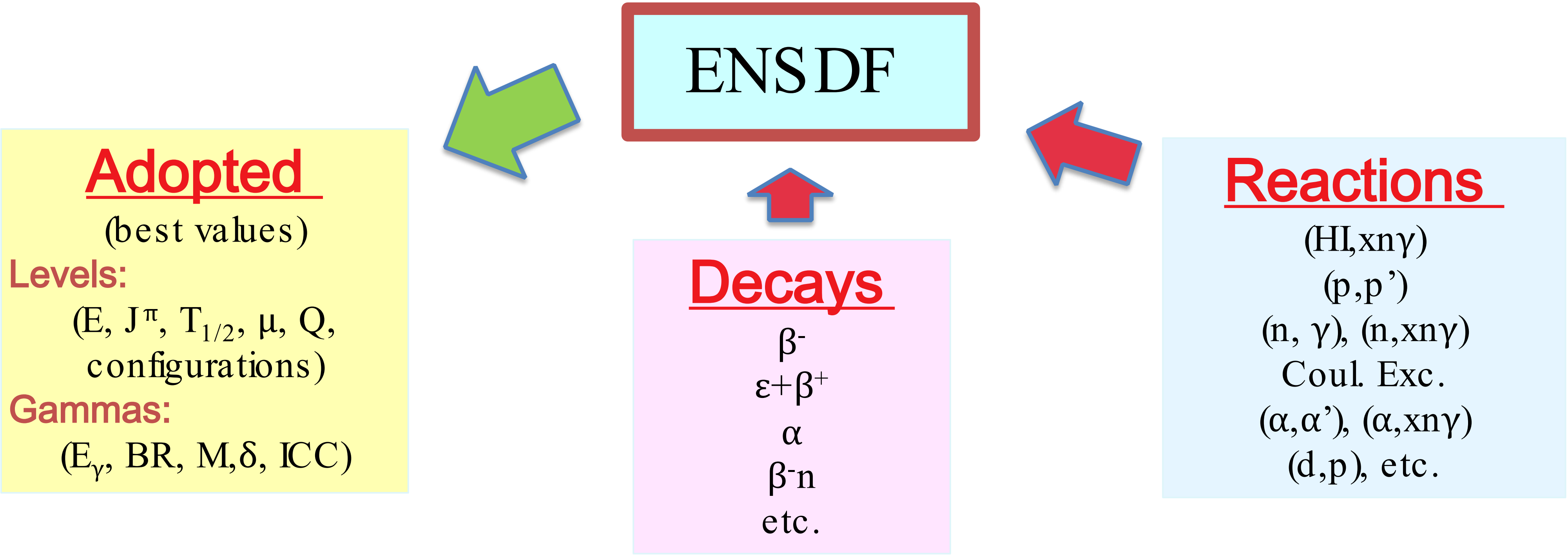
E(level): Others: 11693 5 (1979Ho08), 11680 20 (1971To12), 11700 30 (1969St14).
E(level): Others: 12051 10 (1979Ho08), 12040 40 (1971To12).
E(level): Others: 12119 10 (1979Ho08), 12120 30 (1971To12), 12130 30 (1969St14).
E(level): Others: 12158 10 (1979Ho08), 11150 30 (1971To12).
E(level): Other: 12963 15 (1979Ho08).

-ray energies. 3493.3γ from 7616, 087.7γ from 9457.81, and 8146.0γ from 9516 keV level,
γ differences with recoil corrections. The calculated Eγ was not considered in the least-squares
fit.

[‡] From Adopted Levels.

ENSDF: Building the database

Contents: Evaluated nuclear structure and decay data for all known nuclei, organized in over 290 mass chains



ENSDF

Adopted

(best values)

Levels:

(E, J^{π}, $T_{1/2}$, μ, Q, configurations)

Gammas:

(E_{γ}, BR, M,δ, ICC)

Decays

β^-

$\varepsilon+\beta^+$

α

β^-n

etc.

Reactions

(HI,xnγ)

(p,p')

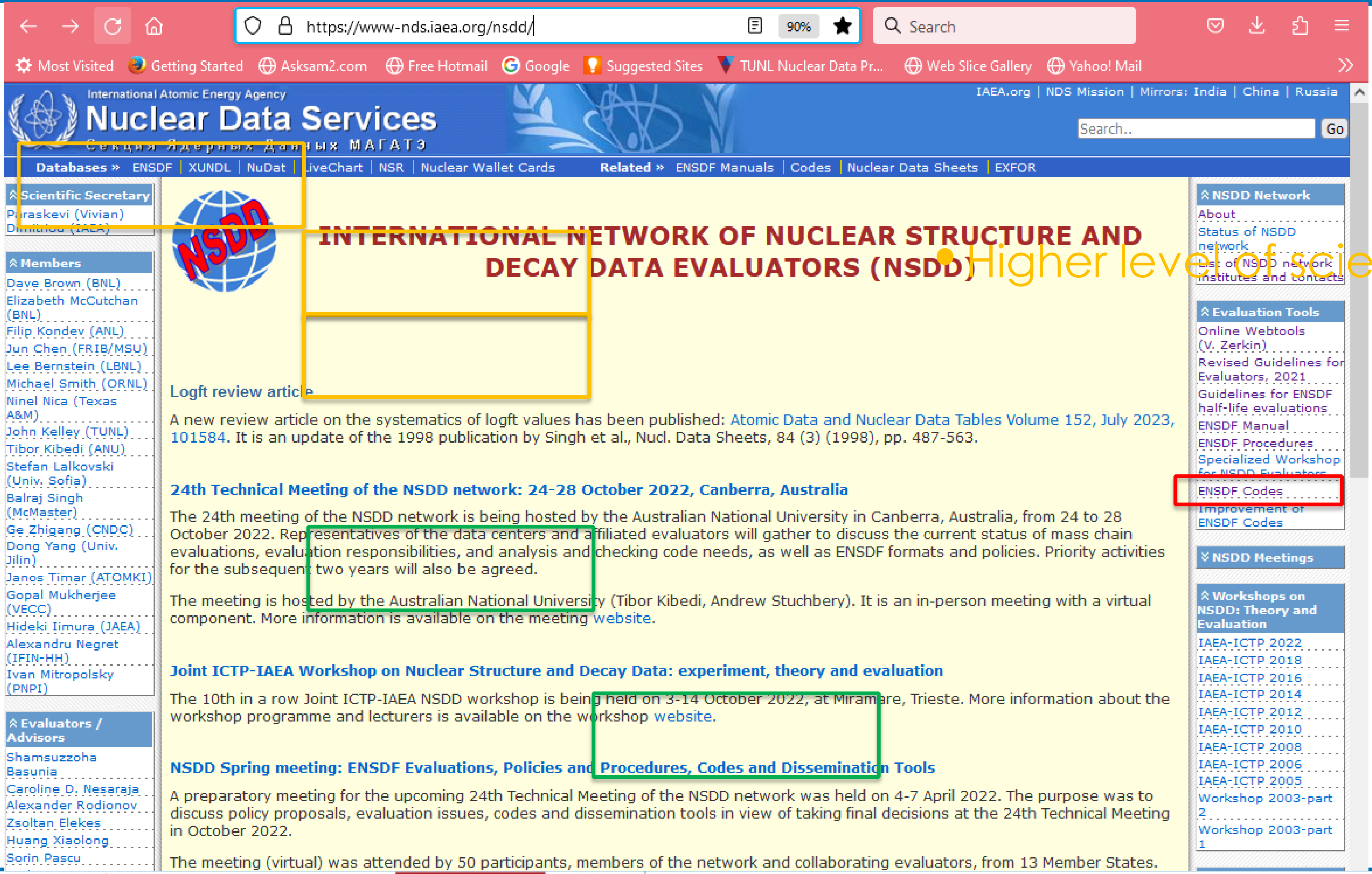
(n, γ), (n,xnγ)

Coul. Exc.

(α,α'), (α,xnγ)

(d,p), etc.

NSDD analysis and utility codes: https://www-nds.iaea.org/public/ensdf_pgm/index.htm



Scientific Secretary

Paraskevi (Vivian) Dimitriou (IAEA)

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- Elizabeth McCutchan (BNL)
- Filip Kondev (ANL)
- Jun Chen (FRIB/MSU)
- Lee Bernstein (LBNL)
- Michael Smith (ORNL)
- Ninel Nica (Texas A&M)
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- Balraj Singh (McMaster)
- Ge Zhigang (CNDC)
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- Janos Timar (ATOMKI)
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- Hideki Iimura (JAEA)
- Alexandru Negret (IFIN-HH)
- Ivan Mitropolsky (PNPI)

Evaluators / Advisors

- Shamsuzzoha Basunia
- Caroline D. Nesaraja
- Alexander Rodionov
- Zsoltan Elekes
- Huang Xiaolong
- Sorin Pascu

INTERNATIONAL NETWORK OF NUCLEAR STRUCTURE AND DECAY DATA EVALUATORS (NSDD)

Logft review article

A new review article on the systematics of logft values has been published: Atomic Data and Nuclear Data Tables Volume 152, July 2023, 101584. It is an update of the 1998 publication by Singh et al., Nucl. Data Sheets, 84 (3) (1998), pp. 487-563.

24th Technical Meeting of the NSDD network: 24-28 October 2022, Canberra, Australia

The 24th meeting of the NSDD network is being hosted by the Australian National University in Canberra, Australia, from 24 to 28 October 2022. Representatives of the data centers and affiliated evaluators will gather to discuss the current status of mass chain evaluations, evaluation responsibilities, and analysis and checking code needs, as well as ENSDF formats and policies. Priority activities for the subsequent two years will also be agreed.

The meeting is hosted by the Australian National University (Tibor Kibedi, Andrew Stuchbery). It is an in-person meeting with a virtual component. More information is available on the meeting website.

Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data: experiment, theory and evaluation

The 10th in a row Joint ICTP-IAEA NSDD workshop is being held on 3-14 October 2022, at Miramare, Trieste. More information about the workshop programme and lecturers is available on the workshop website.

NSDD Spring meeting: ENSDF Evaluations, Policies and Procedures, Codes and Dissemination Tools

A preparatory meeting for the upcoming 24th Technical Meeting of the NSDD network was held on 4-7 April 2022. The purpose was to discuss policy proposals, evaluation issues, codes and dissemination tools in view of taking final decisions at the 24th Technical Meeting in October 2022.

The meeting (virtual) was attended by 50 participants, members of the network and collaborating evaluators, from 13 Member States.

NSDD Network

- About
- Status of NSDD network
- List of NSDD network institutes and contacts

Evaluation Tools

- Online Webtools (V. Zerkin)
- Revised Guidelines for Evaluators, 2021
- Guidelines for ENSDF half-life evaluations
- ENSDF Manual
- ENSDF Procedures
- Specialized Workshop for NSDD Evaluators
- ENSDF Codes
- Improvement of ENSDF Codes

NSDD Meetings

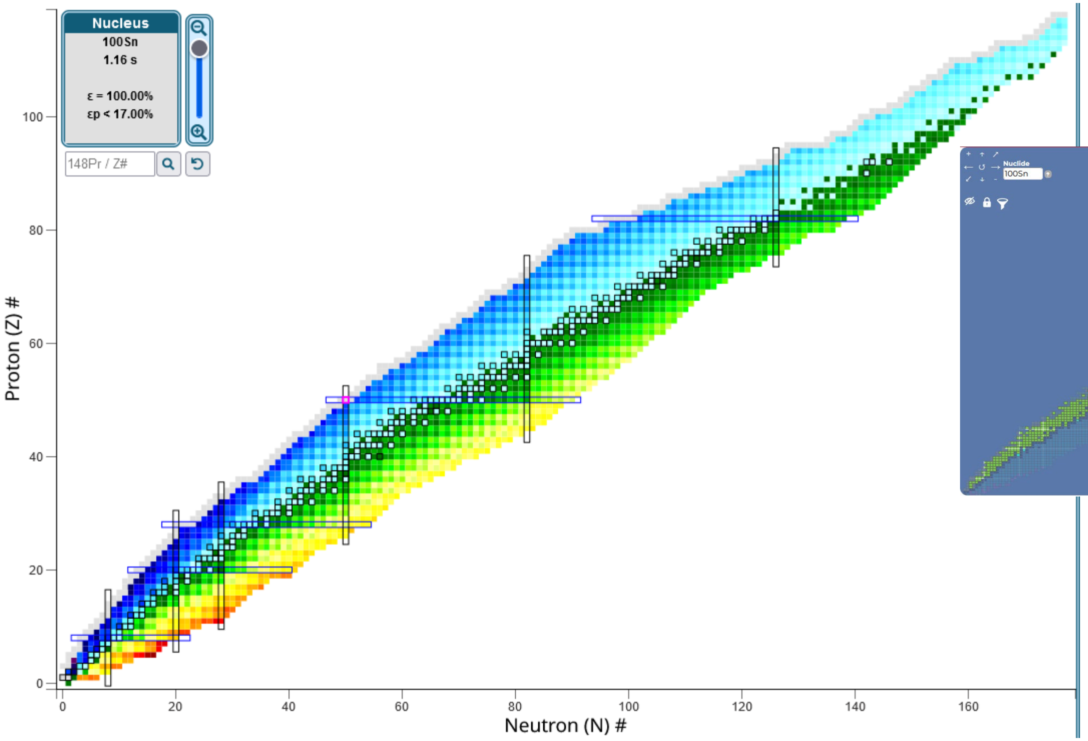
Workshops on NSDD: Theory and Evaluation

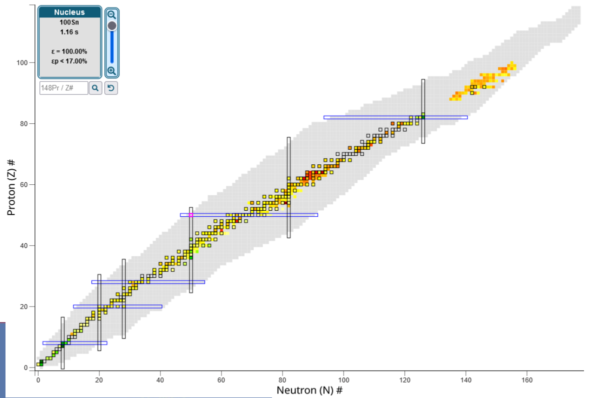
- IAEA-ICTP 2022
- IAEA-ICTP 2018
- IAEA-ICTP 2016
- IAEA-ICTP 2014
- IAEA-ICTP 2012
- IAEA-ICTP 2010
- IAEA-ICTP 2008
- IAEA-ICTP 2006
- IAEA-ICTP 2005
- Workshop 2003-part 2
- Workshop 2003-part 1

- Higher level of scientific detail

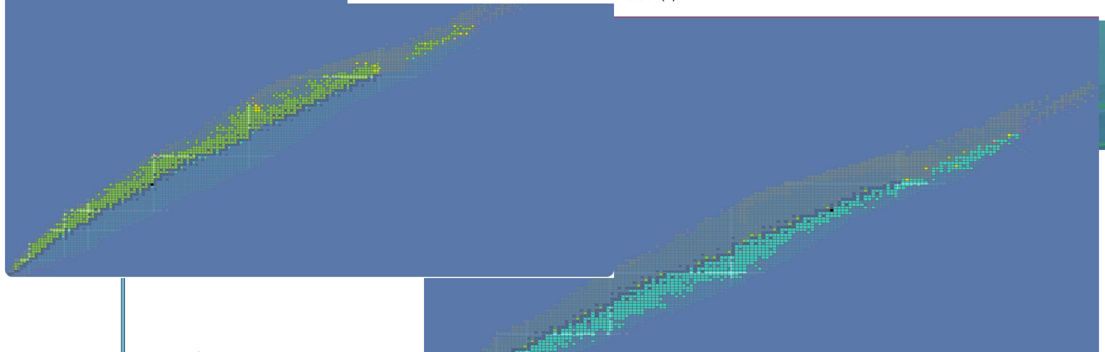
International Atomic Energy Agency: Nuclear Structure and Decay Data Network

ENSDF is world unique: aims to provide evaluated data for all nuclei

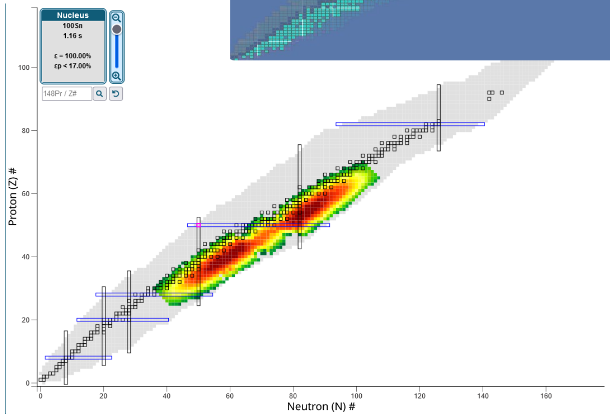




EGAF: Evaluated Gamma-ray Activation File covers only 250 nuclides



Laboratoire National Henri Becquerel covers ~210 nuclides



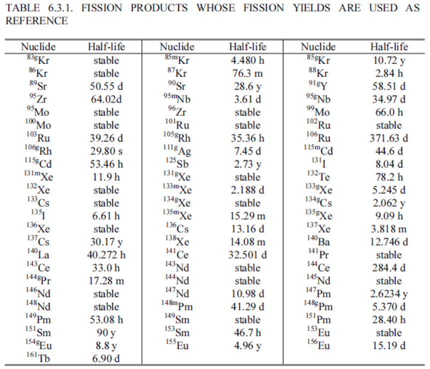


TABLE 6.3.1. FISSION PRODUCTS WHOSE FISSION YIELDS ARE USED AS REFERENCE

Nuclide	Half-life	Nuclide	Half-life	Nuclide	Half-life
^{83g}Kr	stable	^{85m}Kr	4.480 h	^{85g}Kr	10.72 y
^{86}Kr	stable	^{87}Kr	76.3 m	^{88}Kr	2.84 h
^{89}Sr	50.55 d	^{90}Sr	28.6 y	^{91g}Y	58.51 d
^{95}Zr	64.02d	^{95m}Nb	3.61 d	^{95g}Nb	34.97 d
^{95}Mo	stable	^{96}Zr	stable	^{99}Mo	66.0 h
^{100}Mo	stable	^{101}Ru	stable	^{102}Ru	stable
^{103}Ru	39.26 d	^{105g}Rh	35.36 h	^{106}Ru	371.63 d
^{106g}Rh	29.80 s	^{111g}Ag	7.45 d	^{115m}Cd	44.6 d
^{115g}Cd	53.46 h	^{125}Sb	2.73 y	^{131}I	8.04 d
^{131m}Xe	11.9 h	^{131g}Xe	stable	^{132}Te	78.2 h
^{132}Xe	stable	^{133m}Xe	2.188 d	^{133g}Xe	5.245 d
^{133}Cs	stable	^{134g}Xe	stable	^{134g}Cs	2.062 y
^{135}I	6.61 h	^{135m}Xe	15.29 m	^{135g}Xe	9.09 h
^{136}Xe	stable	^{136}Cs	13.16 d	^{137}Xe	3.818 m
^{137}Cs	30.17 y	^{138}Xe	14.08 m	^{140}Ba	12.746 d
^{140}La	40.272 h	^{141}Ce	32.501 d	^{141}Pr	stable
^{143}Ce	33.0 h	^{143}Nd	stable	^{144}Ce	284.4 d
^{144g}Pr	17.28 m	^{144}Nd	stable	^{145}Nd	stable
^{146}Nd	stable	^{147}Nd	10.98 d	^{147}Pm	2.6234 y
^{148}Nd	stable	^{148m}Pm	41.29 d	^{148g}Pm	5.370 d
^{149}Pm	53.08 h	^{149}Sm	stable	^{151}Pm	28.40 h
^{151}Sm	90 y	^{153}Sm	46.7 h	^{153}Eu	stable
^{154g}Eu	8.8 y	^{155}Eu	4.96 y	^{156}Eu	15.19 d
^{161}Tb	6.90 d				

FPY studies utilize decay data from a few hundred nuclides.

IAEA-TECDOC-1168

ENSDF – the core database – cont.

ENSDF is the only Nuclear Structure database that is updated continuously – contains information for ALL nuclei and ALL nuclear level properties & radiations – currently contributed by members of the Nuclear Structure and Decay Data Network, under auspices of IAEA. It is maintained by NNDC and the NSDD role is indispensible!

No viable alternative exists in the world!

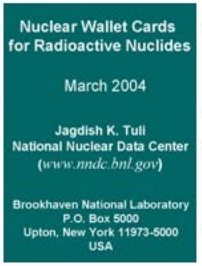
ENSDF

Applications

Nuclear Energy

MIRD

PGAA



Nuclear Wallet Cards
for Radioactive Nuclides

March 2004

Jagdish K. Tuli
National Nuclear Data Center
(*www.nndc.bnl.gov*)

Brookhaven National Laboratory
P.O. Box 5000
Upton, New York 11973-5000
USA

IRDFF

RNAL

Safeguards

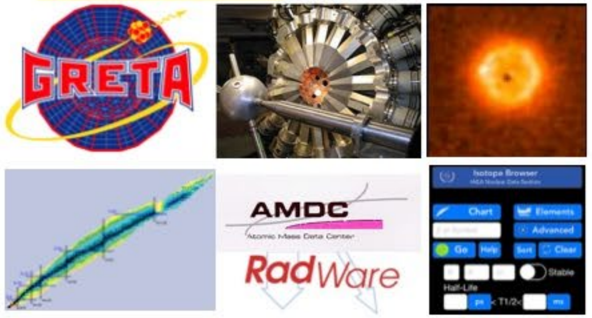
Simulations

Monte-Carlo Codes

MCNP, GEANT4, EGS
ORIGEN, CINDER90

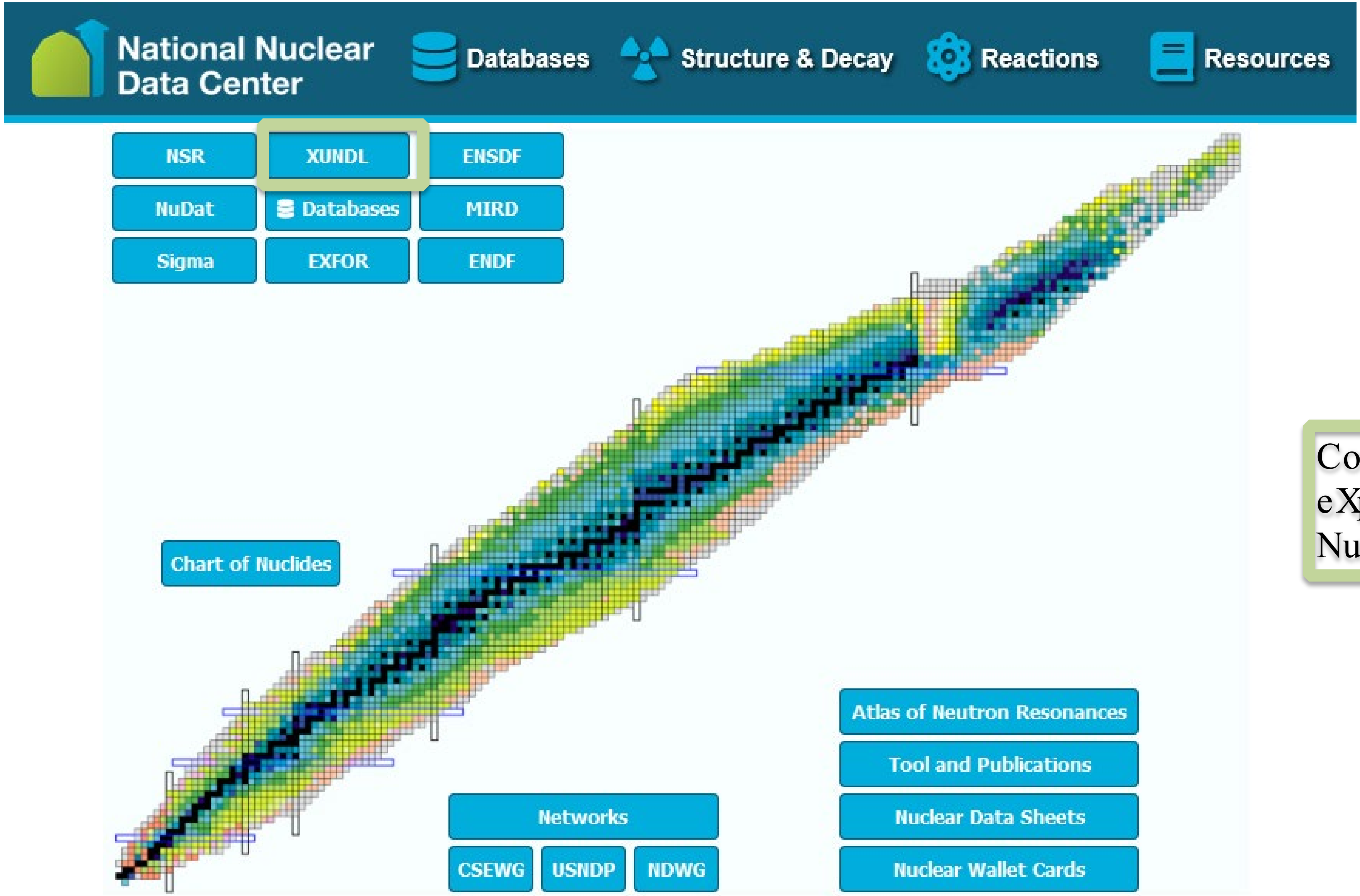
Basic Science

Nuclear Data Sheets



From Filip Kondev

Nuclear Structure Databases



Compiled NS Data
eXperimental UNevaluated
Nuclear Data Library

eXperimental Unevaluated Nuclear Data Library

In the late 1990-2000’s the high-spin physics community needed ND support via availability of new data in an accessible format.

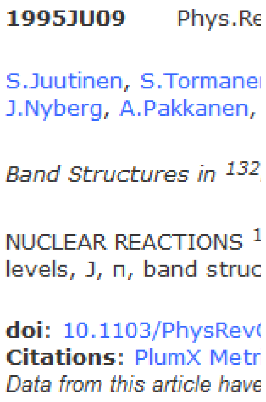
The XUNDL database was created to meet this need.

Initial focus was on high-spin and superdeformed data. Level and gamma-ray data was compiled into the ENSDF format with little evaluation of review.

Gave researchers quick access to data that could be imported into other utility files.

Ability to understand evolution of bands/band structures without delay of full evaluation.

Earliest files I could find are 1994Fr11, 1995Ju09



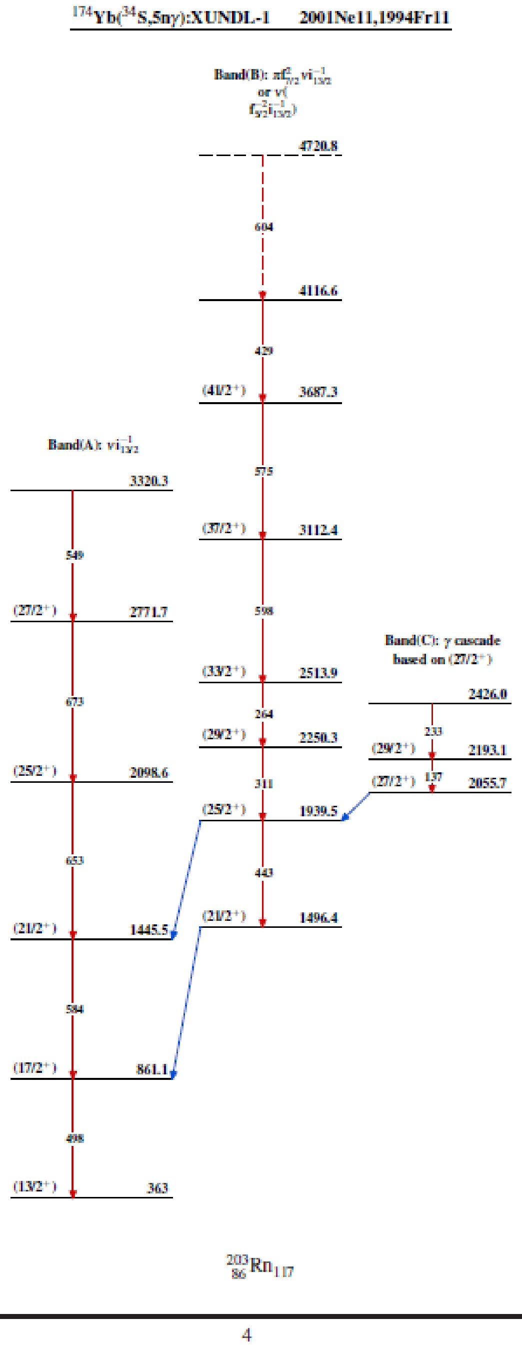
1995JU09 Phys.Re

S.Juutinen, S.Tormane :.Julin, A.Lampinen, T.Lonnroth,
J.Nyberg, A.Pakkanen, rtanen

Band Structures in ^{132}

NUCLEAR REACTIONS ^{1} (θ), γγ-coin. ^{132}Ba deduced
levels, J, π, band struc

doi: 10.1103/PhysRev(
Citations: PlumX Metr
Data from this article have *ion, click here.*



eXperimen

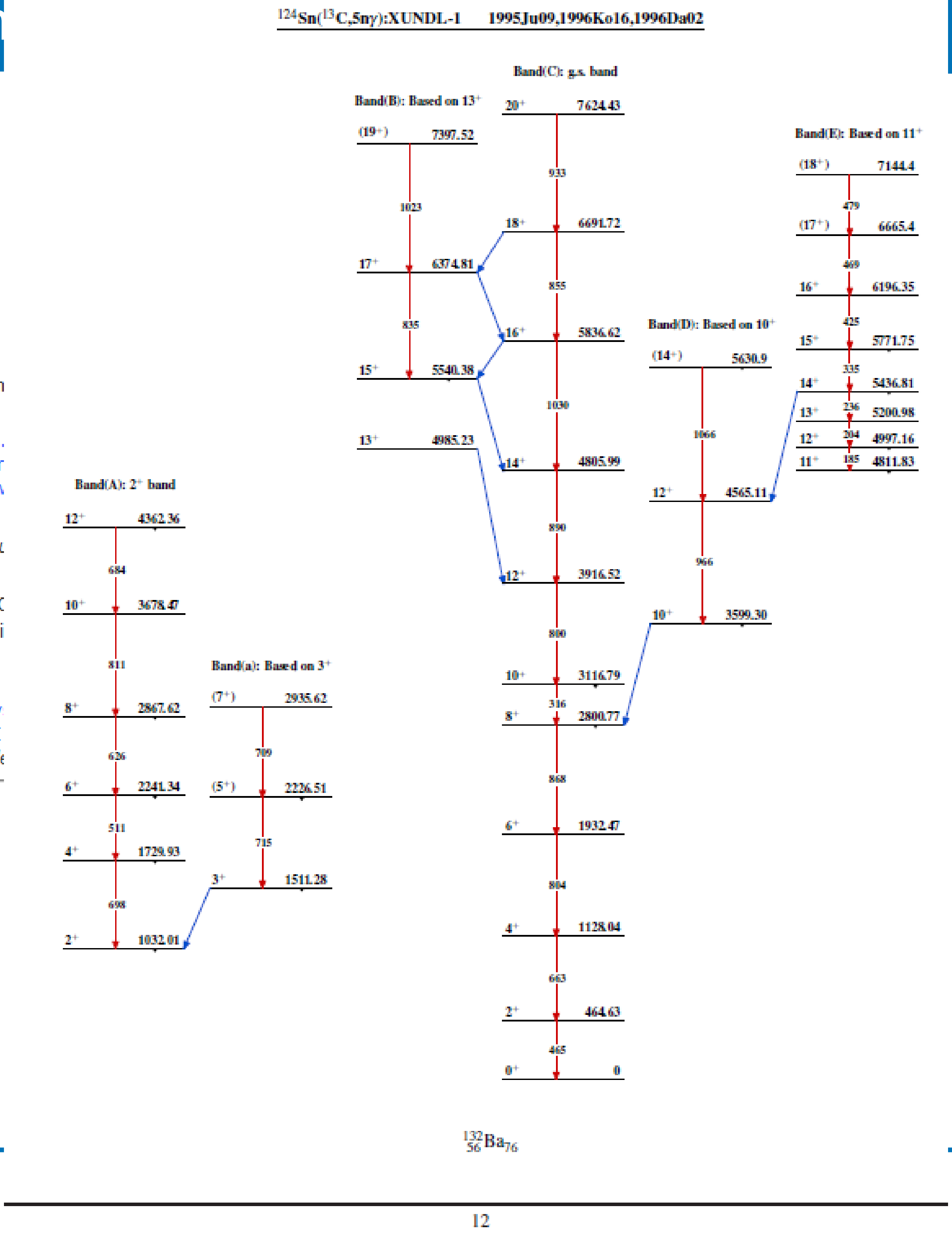
1994FR11 Ph

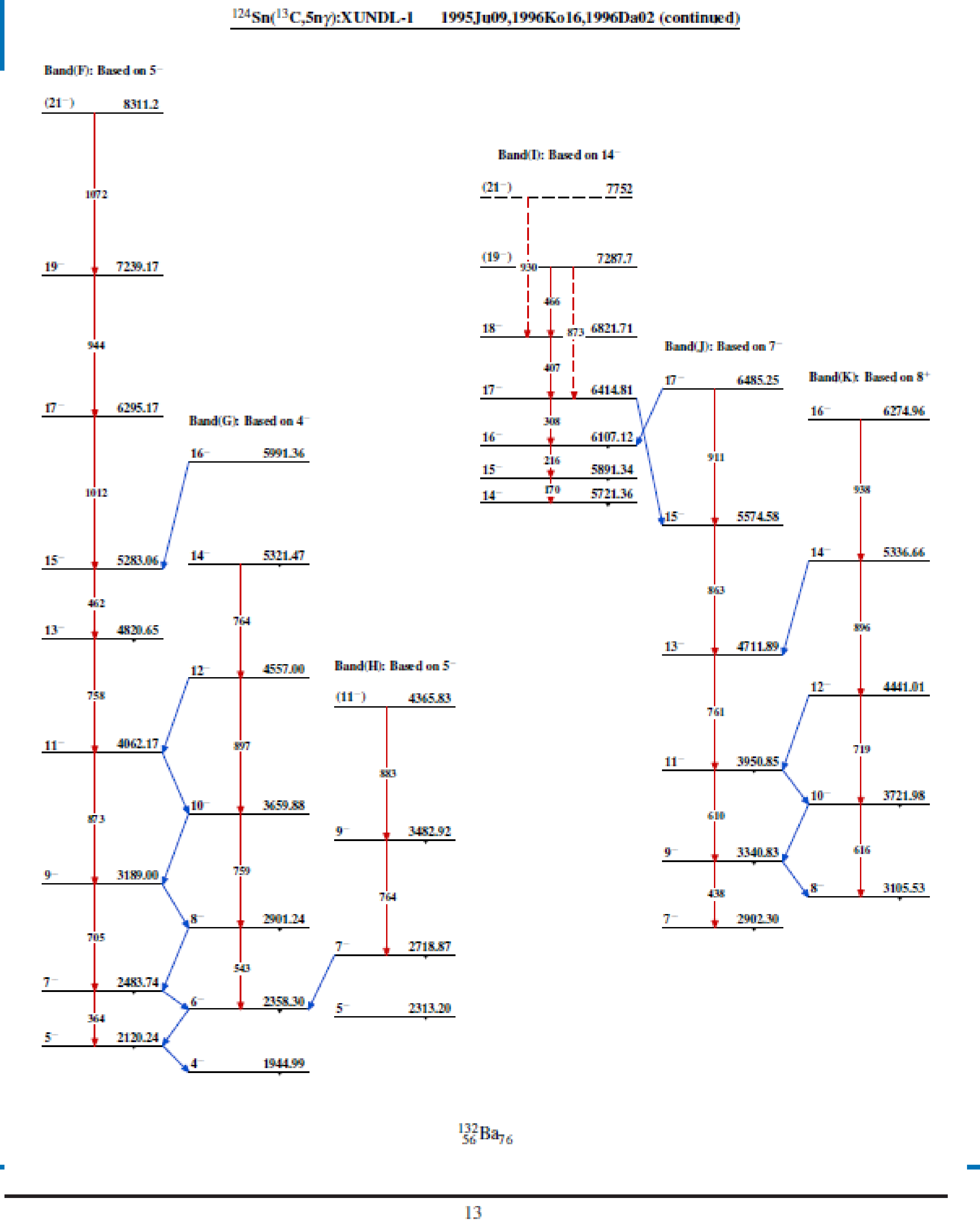
S.J.Freeman, A.G.
C.N.Davids, D.Her
J.A.Becker, P.Chov

Low-Lying Structu

NUCLEAR REACTIC
γ(recoil)-, γγ-coi
enriched target.

doi: 10.1103/Phy
Citations: PlumX
Data from this article





eXperimental Unevaluated Nuclear Data Library

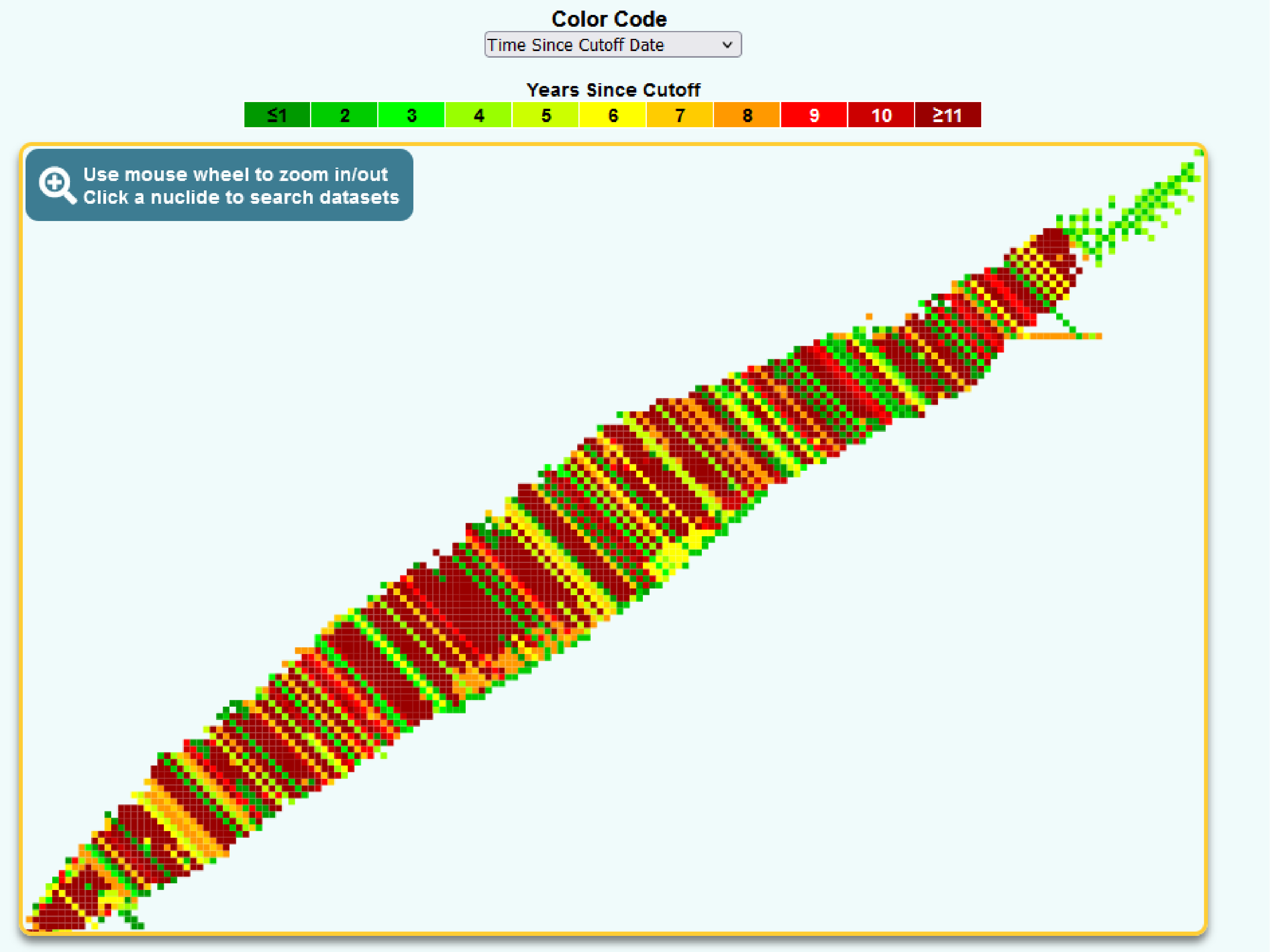
ENSDF has a problem

In the late 2000s, as the first generation of ENSDF evaluators began to retire, it became clear that currency was an issue for ENSDF.

Often mentioned a 5-7 year turn-around time between A-chain evaluations. Never met that goal.

Around 2008 XUNDL was expanded to cover all nuclear structure, with the aim of providing reasonably concise and up-to-date information to users.

But it is no substitute for ENSDF evaluated data.



Nuclear Structure Databases: Derived from ENSDF

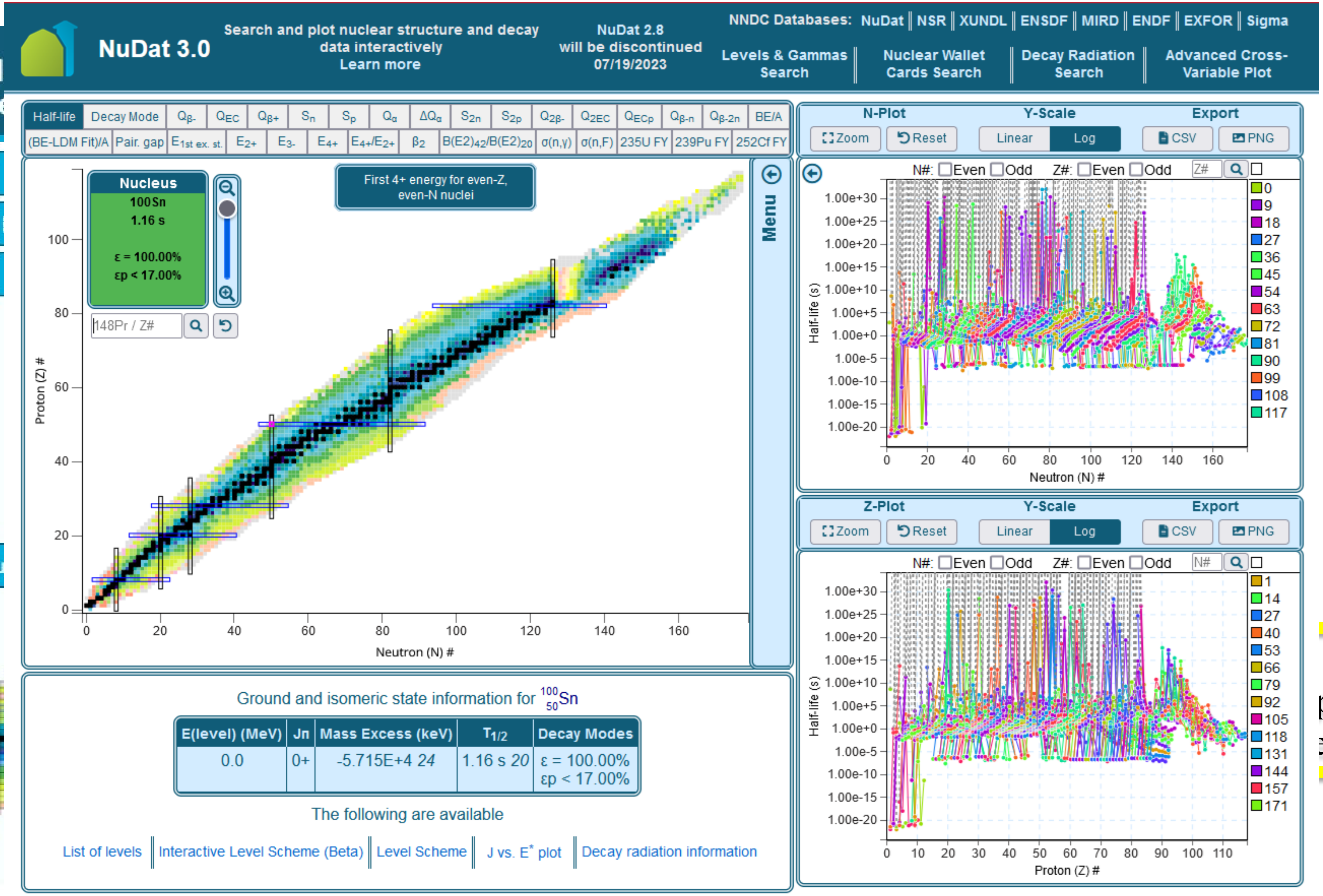
National N
Data Cente

NSR

NuDat

Sigma

Chart of Nu

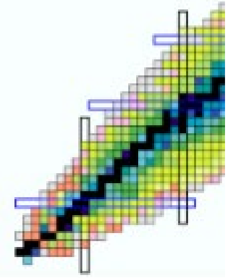


Ground and isomeric state information for $^{100}_{50}$Sn

E(level) (MeV)	Jπ	Mass Excess (keV)	T1/2	Decay Modes
0.0	0+	-5.715E+4 *24*	1.16 s *20*	ε = 100.00% εp < 17.00%

The following are available

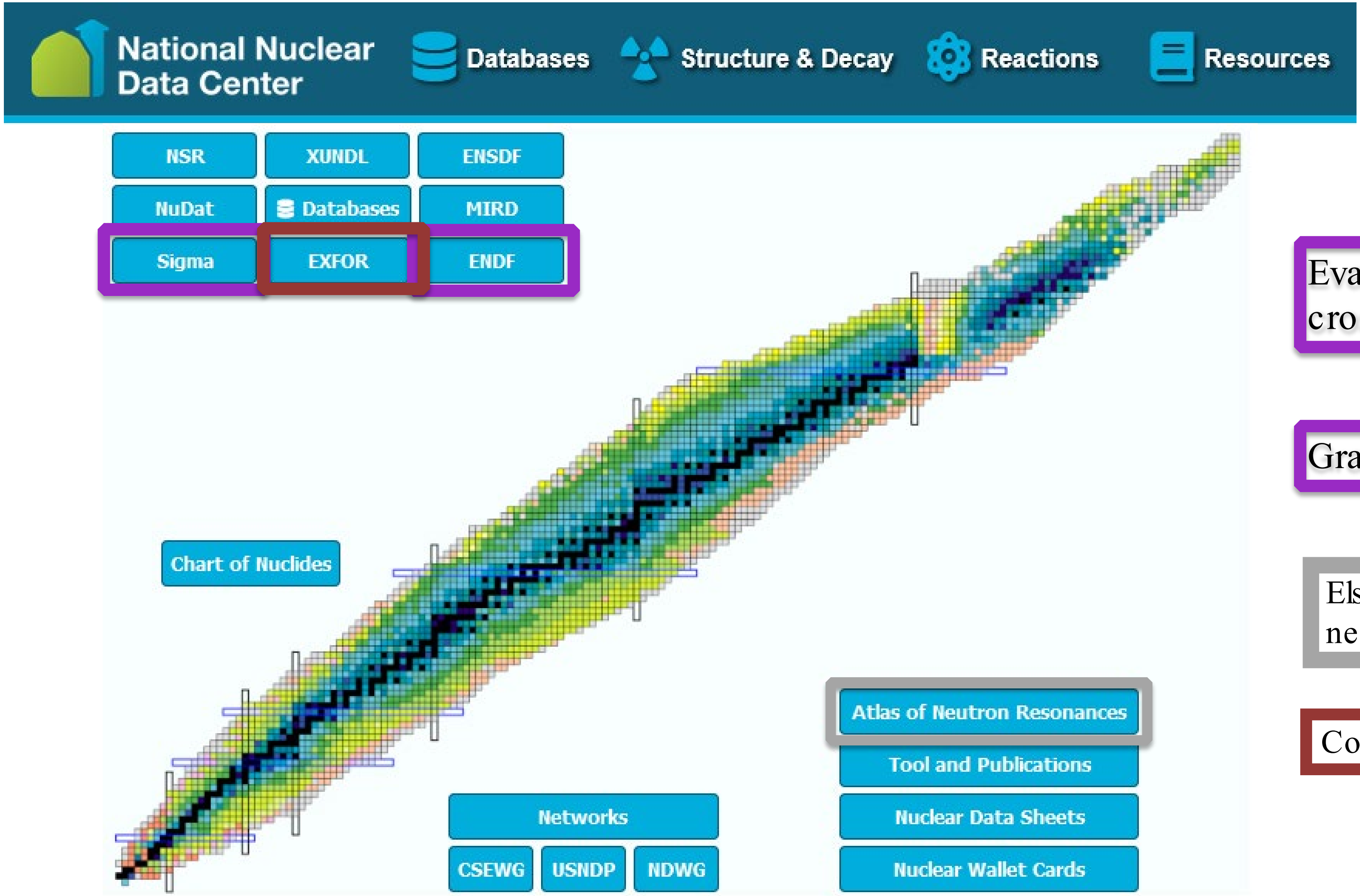
List of levels | Interactive Level Scheme (Beta) | Level Scheme | J vs. E* plot | Decay radiation information



presents
erent format

Donnie Mason

National Nuclear Data Center: the primary ND dissemination center in the US



Evaluated Nuclear Reaction cross section data

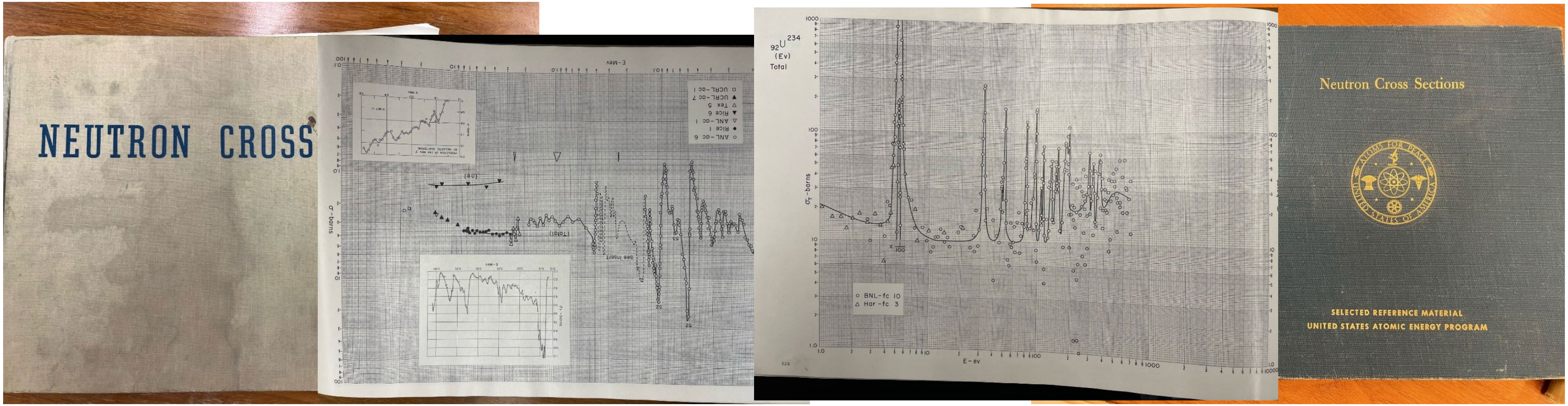
Graphical interface

Elsevier publication of evaluated neutron resonances

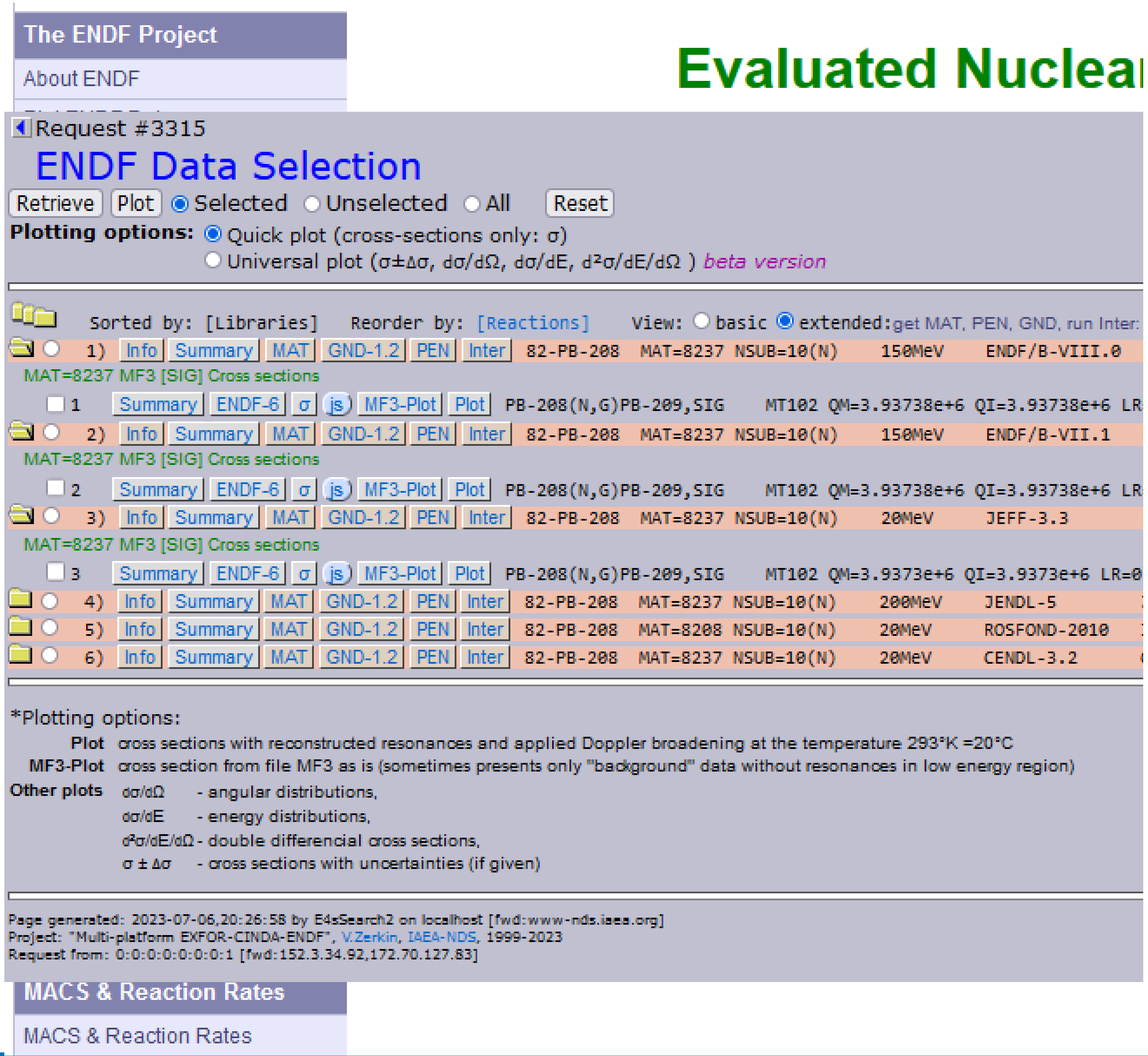
Compiled reaction data

ENDF: Evaluated Nuclear Data File

- At Brookhaven, the Neutron Cross Section Compilation Group seeded from the Manhattan Project in 1951; they produced the BNL-325 neutron cross-section evaluations. Around 1960 the group was renamed as the Sigma Center and a new Cross-Section Evaluation Group was formed that worked closely with the Sigma Center. In 1967 the two groups merged and became the National Neutron Cross Section Center, and they began producing the Evaluated Nuclear Data File (ENDF).



ENDF Interface @NNDC



Request #3315

ENDF Data Selection

Retrieve | Plot | ● Selected ○ Unselected ○ All | Reset

Plotting options: ● Quick plot (cross-sections only: σ)
○ Universal plot (σ±Δσ, dσ/dΩ, dσ/dE, d²σ/dE/dΩ) *beta version*

Sorted by: [Libraries] Reorder by: [Reactions] View: ○ basic ● extended: get MAT, PEN, GND, run Inter

○ 1) Info Summary MAT GND-1.2 PEN Inter 82-PB-208 MAT=8237 NSUB=10(N) 150MeV ENDF/B-VIII.0
MAT=8237 MF3 [SIG] Cross sections
☐ 1 Summary ENDF-6 σ js MF3-Plot Plot PB-208(N,G)PB-209,SIG MT102 QM=3.93738e+6 QI=3.93738e+6 LR

○ 2) Info Summary MAT GND-1.2 PEN Inter 82-PB-208 MAT=8237 NSUB=10(N) 150MeV ENDF/B-VII.1
MAT=8237 MF3 [SIG] Cross sections
☐ 2 Summary ENDF-6 σ js MF3-Plot Plot PB-208(N,G)PB-209,SIG MT102 QM=3.93738e+6 QI=3.93738e+6 LR

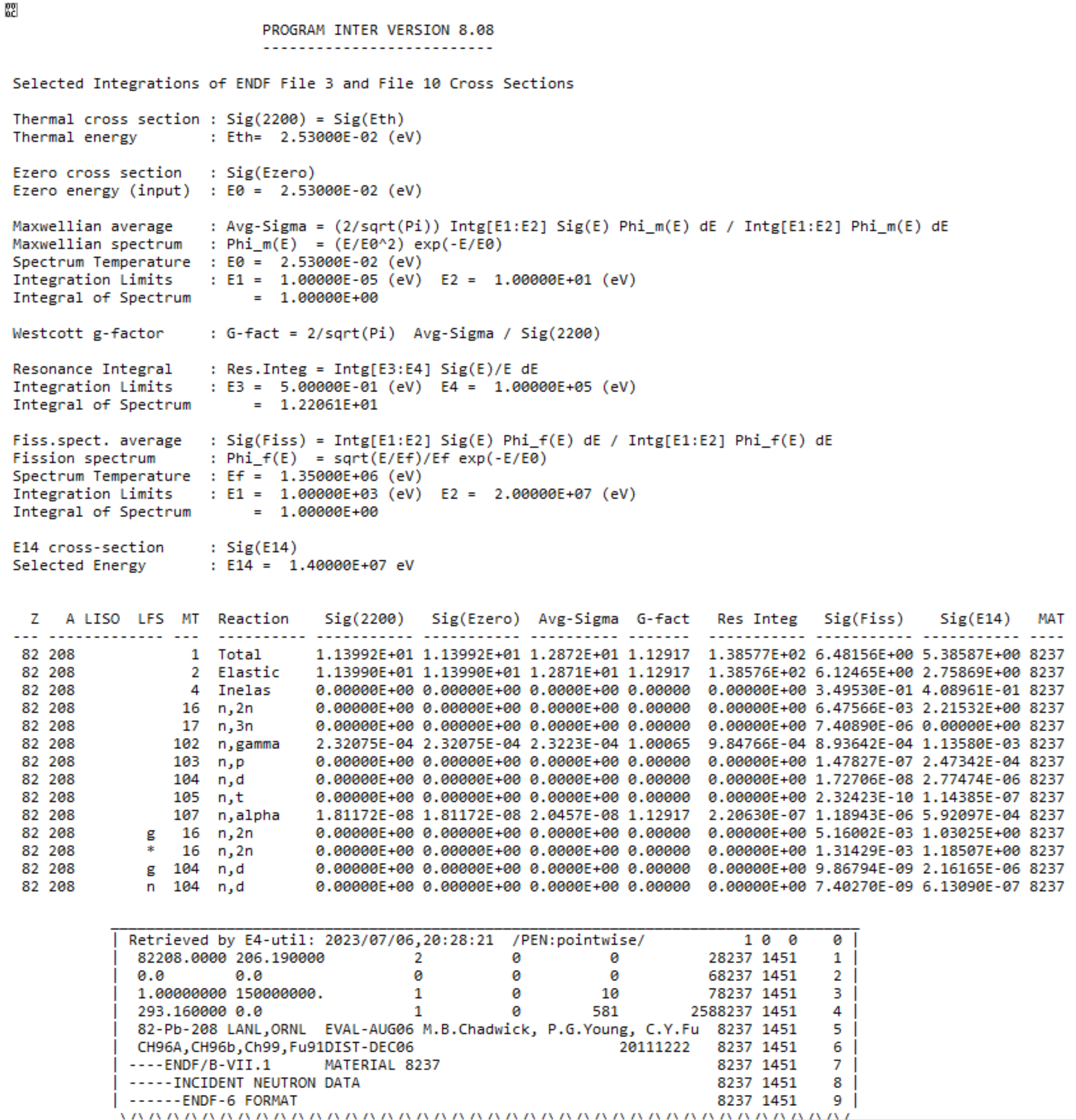
○ 3) Info Summary MAT GND-1.2 PEN Inter 82-PB-208 MAT=8237 NSUB=10(N) 20MeV JEFF-3.3
MAT=8237 MF3 [SIG] Cross sections
☐ 3 Summary ENDF-6 σ js MF3-Plot Plot PB-208(N,G)PB-209,SIG MT102 QM=3.9373e+6 QI=3.9373e+6 LR=0

○ 4) Info Summary MAT GND-1.2 PEN Inter 82-PB-208 MAT=8237 NSUB=10(N) 200MeV JENDL-5
○ 5) Info Summary MAT GND-1.2 PEN Inter 82-PB-208 MAT=8208 NSUB=10(N) 20MeV ROSFOND-2010
○ 6) Info Summary MAT GND-1.2 PEN Inter 82-PB-208 MAT=8237 NSUB=10(N) 20MeV CENDL-3.2

*Plotting options:

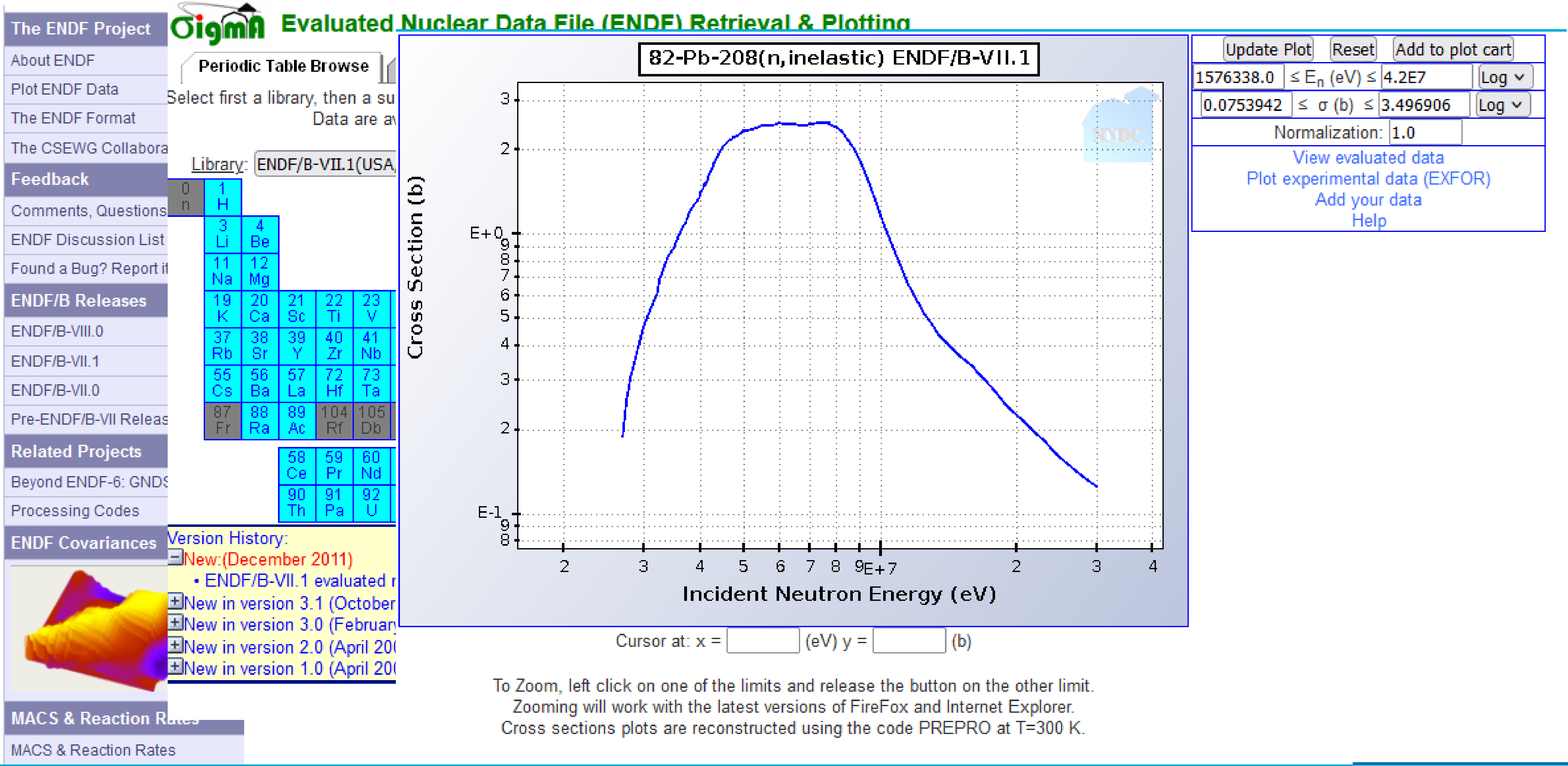
Plot	cross sections with reconstructed resonances and applied Doppler broadening at the temperature 293°K =20°C
MF3-Plot	cross section from file MF3 as is (sometimes presents only "background" data without resonances in low energy region)
Other plots	dσ/dΩ - angular distributions,
	dσ/dE - energy distributions,
	d²σ/dE/dΩ - double differencial cross sections,
	σ ± Δσ - cross sections with uncertainties (if given)

Page generated: 2023-07-06,20:26:58 by E4sSearch2 on localhost [fwd:www-nds.iaea.org]
Project: "Multi-platform EXFOR-CINDA-ENDF", V.Zerkin, IAEA-NDS, 1999-2023
Request from: 0:0:0:0:0:0:0:1 [fwd:152.3.34.92,172.70.127.83]



```
                       PROGRAM INTER VERSION 8.08
                       --------------------------

Selected Integrations of ENDF File 3 and File 10 Cross Sections

Thermal cross section : Sig(2200) = Sig(Eth)
Thermal energy        : Eth=  2.53000E-02 (eV)

Ezero cross section   : Sig(Ezero)
Ezero energy (input)  : E0 =  2.53000E-02 (eV)

Maxwellian average    : Avg-Sigma = (2/sqrt(Pi)) Intg[E1:E2] Sig(E) Phi_m(E) dE / Intg[E1:E2] Phi_m(E) dE
Maxwellian spectrum   : Phi_m(E)  = (E/E0^2) exp(-E/E0)
Spectrum Temperature  : E0 =  2.53000E-02 (eV)
Integration Limits    : E1 =  1.00000E-05 (eV)  E2 =  1.00000E+01 (eV)
Integral of Spectrum       =  1.00000E+00

Westcott g-factor     : G-fact = 2/sqrt(Pi)  Avg-Sigma / Sig(2200)

Resonance Integral    : Res.Integ = Intg[E3:E4] Sig(E)/E dE
Integration Limits    : E3 =  5.00000E-01 (eV)  E4 =  1.00000E+05 (eV)
Integral of Spectrum       =  1.22061E+01

Fiss.spect. average   : Sig(Fiss) = Intg[E1:E2] Sig(E) Phi_f(E) dE / Intg[E1:E2] Phi_f(E) dE
Fission spectrum      : Phi_f(E)  = sqrt(E/Ef)/Ef exp(-E/E0)
Spectrum Temperature  : Ef =  1.35000E+06 (eV)
Integration Limits    : E1 =  1.00000E+03 (eV)  E2 =  2.00000E+07 (eV)
Integral of Spectrum       =  1.00000E+00

E14 cross-section     : Sig(E14)
Selected Energy       : E14 =  1.40000E+07 eV


  Z   A LISO  LFS  MT  Reaction     Sig(2200)   Sig(Ezero)  Avg-Sigma  G-fact    Res Integ   Sig(Fiss)    Sig(E14)   MAT
--- ------------- ---  ----------  ----------- ----------- ---------- -------  ----------- ----------- ----------- ----
 82 208               1  Total      1.13992E+01 1.13992E+01 1.2872E+01 1.12917  1.38577E+02 6.48156E+00 5.38587E+00 8237
 82 208               2  Elastic    1.13990E+01 1.13990E+01 1.2871E+01 1.12917  1.38576E+02 6.12465E+00 2.75869E+00 8237
 82 208               4  Inelas     0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 3.49530E-01 4.08961E-01 8237
 82 208              16  n,2n       0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 6.47566E-03 2.21532E+00 8237
 82 208              17  n,3n       0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 7.40890E-06 0.00000E+00 8237
 82 208             102  n,gamma    2.32075E-04 2.32075E-04 2.3223E-04 1.00065  9.84766E-04 8.93642E-04 1.13580E-03 8237
 82 208             103  n,p        0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 1.47827E-07 2.47342E-04 8237
 82 208             104  n,d        0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 1.72706E-08 2.77474E-06 8237
 82 208             105  n,t        0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 2.32423E-10 1.14385E-07 8237
 82 208             107  n,alpha    1.81172E-08 1.81172E-08 2.0457E-08 1.12917  2.20630E-07 1.18943E-06 5.92097E-04 8237
 82 208          g   16  n,2n       0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 5.16002E-03 1.03025E+00 8237
 82 208          *   16  n,2n       0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 1.31429E-03 1.18507E+00 8237
 82 208          g  104  n,d        0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 9.86794E-09 2.16165E-06 8237
 82 208          n  104  n,d        0.00000E+00 0.00000E+00 0.0000E+00 0.00000  0.00000E+00 7.40270E-09 6.13090E-07 8237

          __________________________________________________________________________________
          | Retrieved by E4-util: 2023/07/06,20:28:21  /PEN:pointwise/          1 0  0    0 |
          |  82208.0000 206.190000          2          0          0         28237 1451    1 |
          |  0.0        0.0                 0          0          0         68237 1451    2 |
          |  1.00000000 150000000.          1          0         10         78237 1451    3 |
          |  293.160000 0.0                 1          0        581       2588237 1451    4 |
          |  82-Pb-208 LANL,ORNL  EVAL-AUG06 M.B.Chadwick, P.G.Young, C.Y.Fu  8237 1451    5 |
          |  CH96A,CH96b,Ch99,Fu91DIST-DEC06                        20111222  8237 1451    6 |
          | ----ENDF/B-VII.1      MATERIAL 8237                               8237 1451    7 |
          | -----INCIDENT NEUTRON DATA                                        8237 1451    8 |
          | ------ENDF-6 FORMAT                                               8237 1451    9 |
           \/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/\/
```

σigma: graphical interface



Select first a library, then a su

Data are av

Library: ENDF/B-VII.1(USA,

Version History:

⊟New:(December 2011)

- ENDF/B-VII.1 evaluated r

⊞New in version 3.1 (October

⊞New in version 3.0 (February

⊞New in version 2.0 (April 20

⊞New in version 1.0 (April 20

1576338.0 ≤ E_n (eV) ≤ 4.2E7 Log

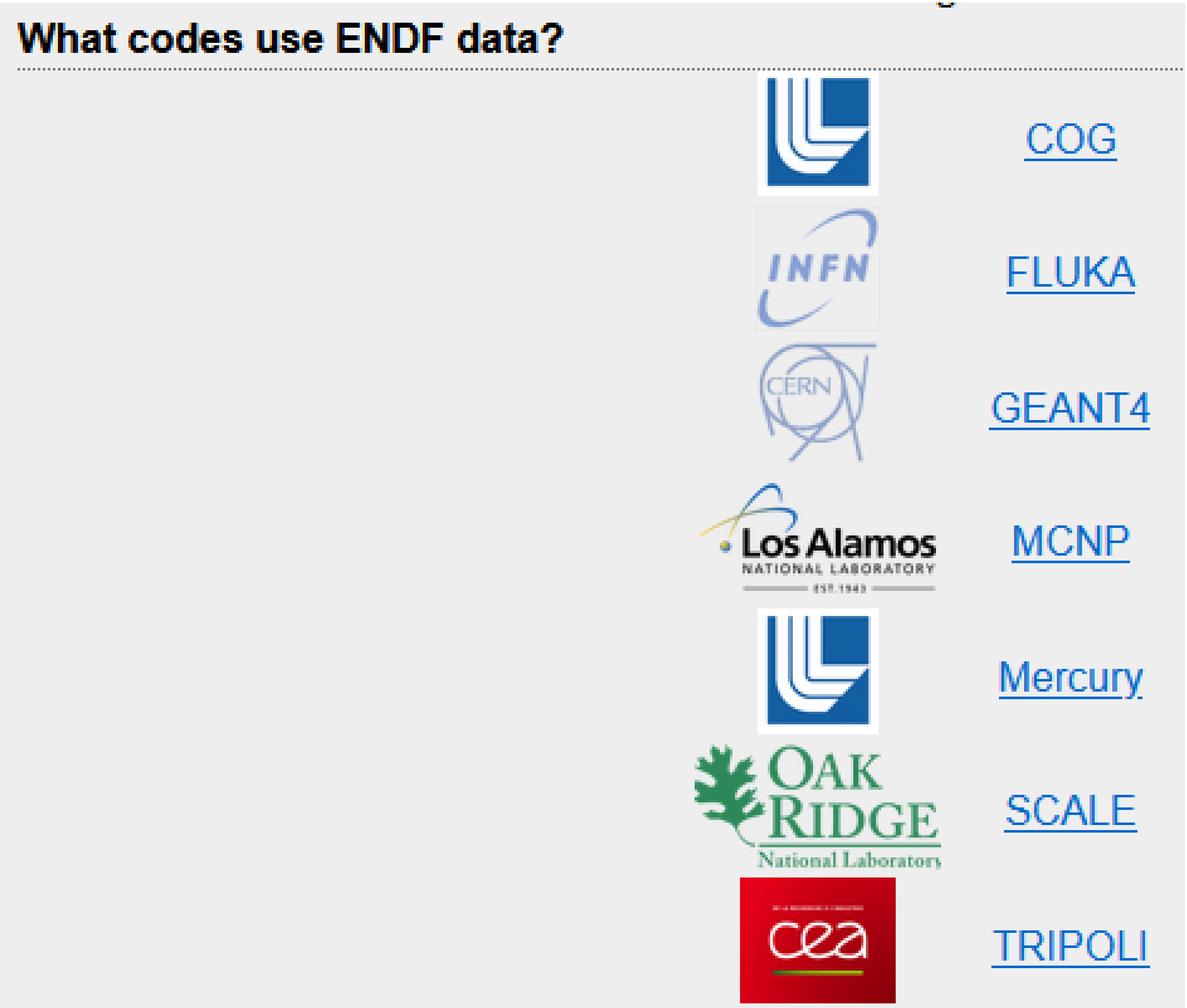
0.0753942 ≤ σ (b) ≤ 3.496906 Log

Normalization: 1.0

Cursor at: x = (eV) y = (b)

To Zoom, left click on one of the limits and release the button on the other limit.
Zooming will work with the latest versions of FireFox and Internet Explorer.
Cross sections plots are reconstructed using the code PREPRO at T=300 K.

ENDF: utility data often hidden from users



What codes use ENDF data?

	COG
INFN	FLUKA
CERN	GEANT4
Los Alamos National Laboratory	MCNP
	Mercury
Oak Ridge National Laboratory	SCALE
cea	TRIPOLI

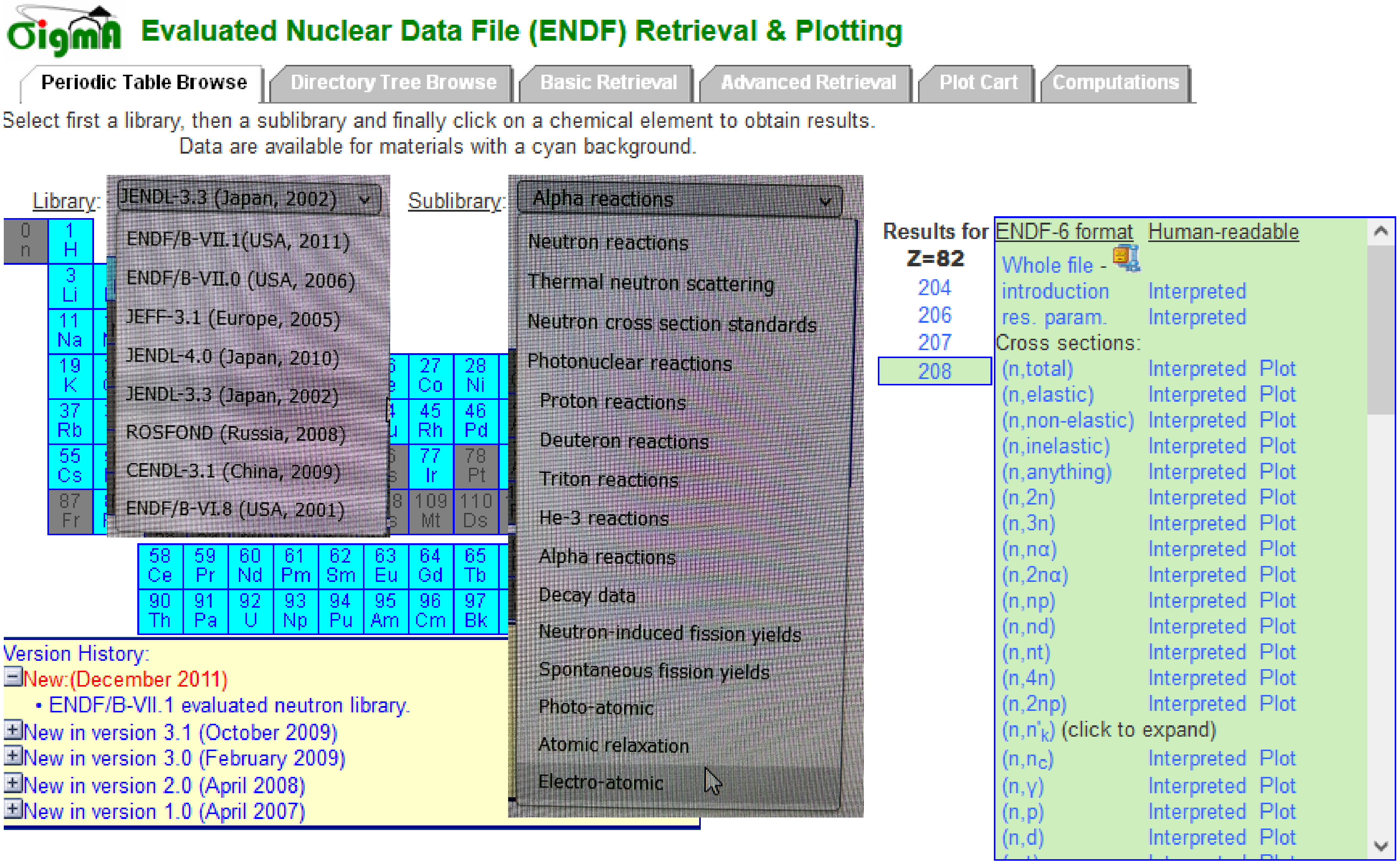
- **Basic Physics**
  - Testing theoretical models
  - Designing experiments
  - Analyzing experimental data
- **Astrophysics**
  - Origin of elements
- **Nuclear Energy Systems**
  - Reactors R&D
  - Fuel cycle
  - Nuclear batteries
  - Operation safety
  - Radiation shielding
  - Waste disposal, transportation and transmutation
- **Nuclear Medicine**
  - Radioisotope production
  - Dose calculation
  - Radiotherapy
  - Diagnostics
- **National/Homeland Security**
  - Device R&D
  - Stockpile stewardship
  - Criticality safety
  - Nuclear forensics
  - Detecting illicit trafficking of nuclear materials
  - Emergency response
- **Industrial Applications**
  - Oil well logging

CSEWG 2019: Cross Section Evaluation Working Group

CSEWG Member Organizations

#	Laboratory Name
1	Atomic Energy of Canada Ltd., Canada
2	Argonne National Laboratory
3	Atomic Weapons Establishment, UK
4	Brookhaven National Laboratory
5	Canadian Nuclear Laboratories, Canada
6	Centro Atómico Bariloche, Argentina
7	Defense Nuclear Facilities Safety Board
8	General Atomics
9	Idaho National Engineering and Environmental Laboratory
10	International Atomic Energy Agency
11	Institut De Radioprotection Et De Sûreté Nucléaire, France
12	Los Alamos National Laboratory
13	Lawrence Berkeley National Laboratory
14	Lawrence Livermore National Laboratory
15	National Institute of Standards and Technology
16	Naval Nuclear Laboratory
17	North Carolina State University
18	Oak Ridge National Laboratory
19	Ohio University
20	Pacific Northwest National Laboratory
21	Purdue University
22	Rensselaer Polytechnic Institute
23	Sandia National Laboratories
24	University of California, Berkeley
25	Westinghouse Electric Corp.

More here than you might expect?



Evaluated Nuclear Data File (ENDF) Retrieval & Plotting

Select first a library, then a sublibrary and finally click on a chemical element to obtain results.
Data are available for materials with a cyan background.

Version History:

⊟New:(December 2011)

- ENDF/B-VII.1 evaluated neutron library.

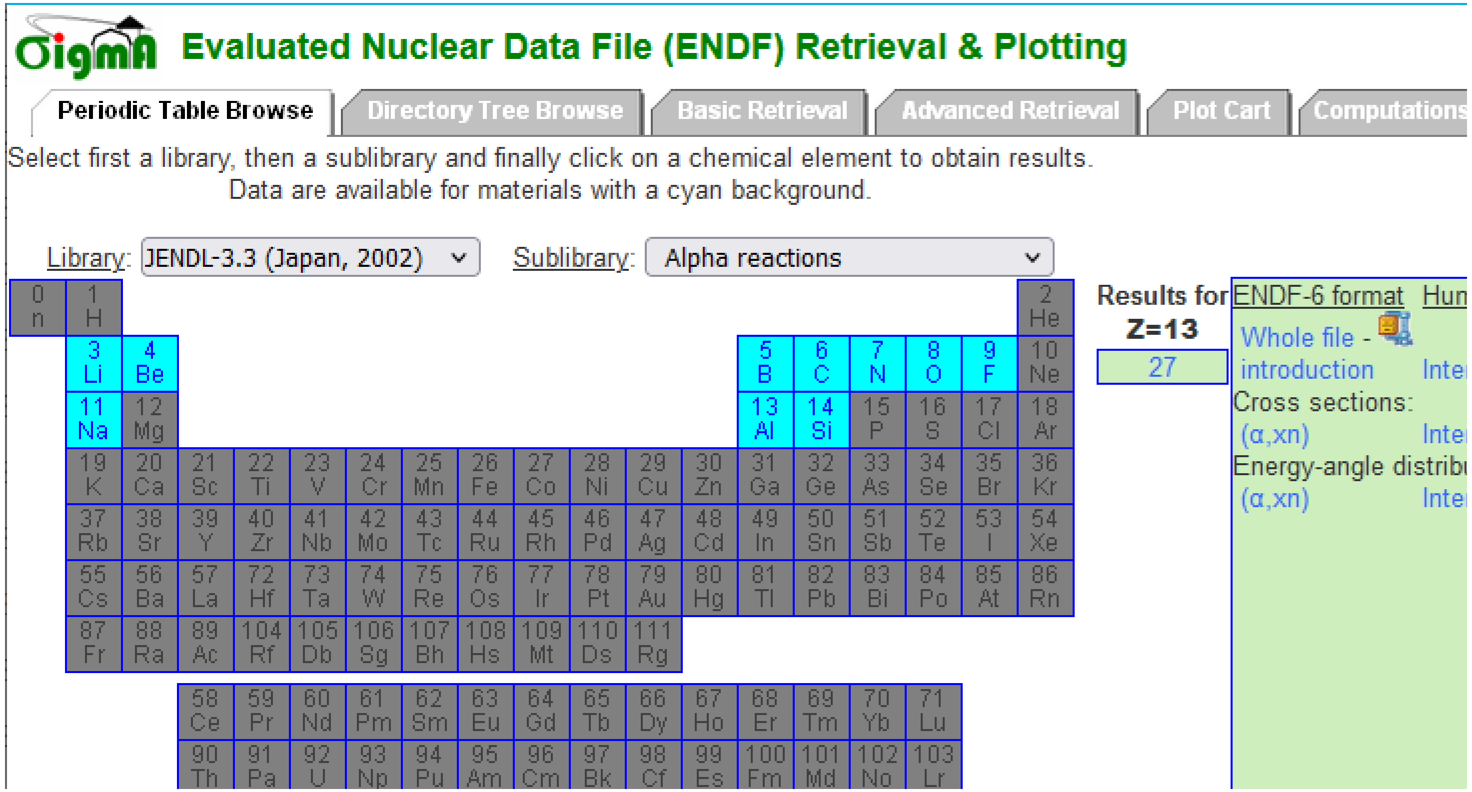
⊞New in version 3.1 (October 2009)
⊞New in version 3.0 (February 2009)
⊞New in version 2.0 (April 2008)
⊞New in version 1.0 (April 2007)

Results for Z=82

204
206
207
208

ENDF-6 format	Human-readable	
Whole file -		
introduction	Interpreted	
res. param.	Interpreted	
Cross sections:		
(n,total)	Interpreted	Plot
(n,elastic)	Interpreted	Plot
(n,non-elastic)	Interpreted	Plot
(n,inelastic)	Interpreted	Plot
(n,anything)	Interpreted	Plot
(n,2n)	Interpreted	Plot
(n,3n)	Interpreted	Plot
(n,nα)	Interpreted	Plot
(n,2nα)	Interpreted	Plot
(n,np)	Interpreted	Plot
(n,nd)	Interpreted	Plot
(n,nt)	Interpreted	Plot
(n,4n)	Interpreted	Plot
(n,2np)	Interpreted	Plot
(n,n'_k) (click to expand)		
(n,n_c)	Interpreted	Plot
(n,γ)	Interpreted	Plot
(n,p)	Interpreted	Plot
(n,d)	Interpreted	Plot

Evaluated charged particle data: harder to find



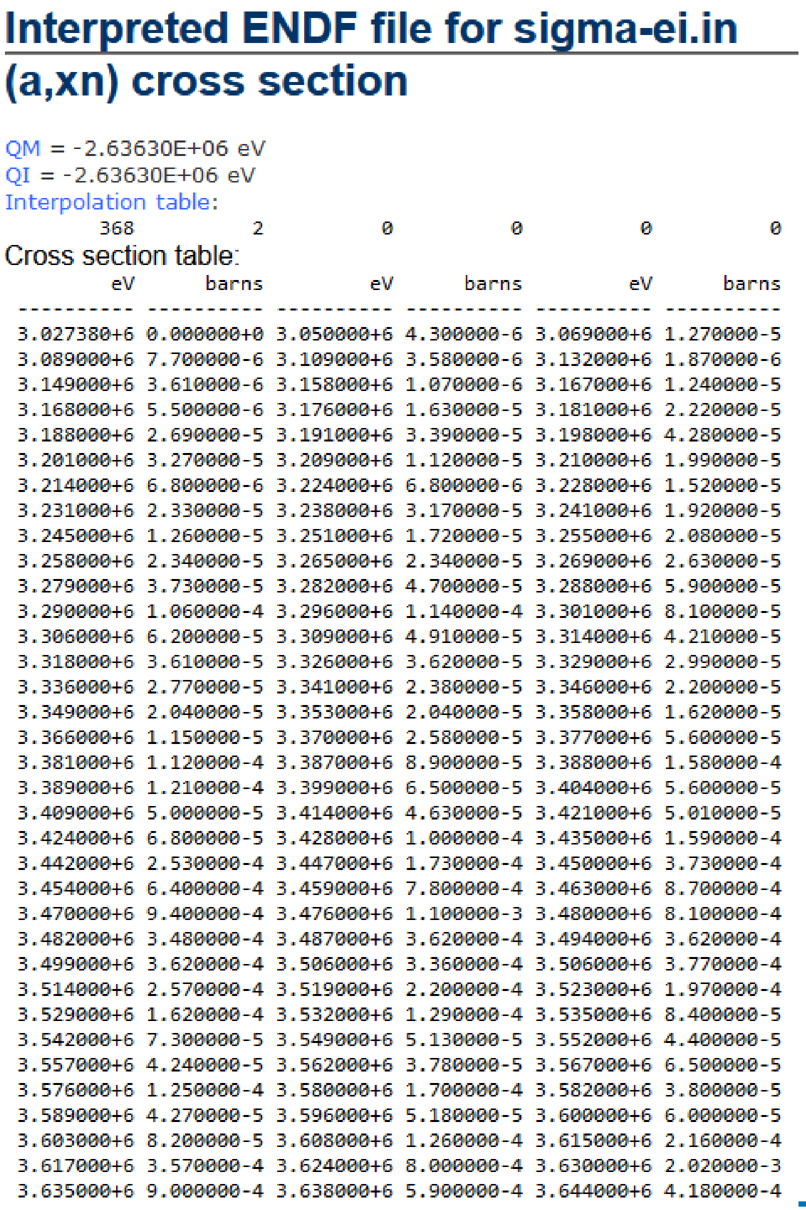
Evaluated Nuclear Data File (ENDF) Retrieval & Plotting

Select first a library, then a sublibrary and finally click on a chemical element to obtain results.
Data are available for materials with a cyan background.

Library: JENDL-3.3 (Japan, 2002)
Sublibrary: Alpha reactions

Results for Z=13
27

Whole file - introduction
Cross sections:
(α,xn)
Energy-angle distribu
(α,xn)

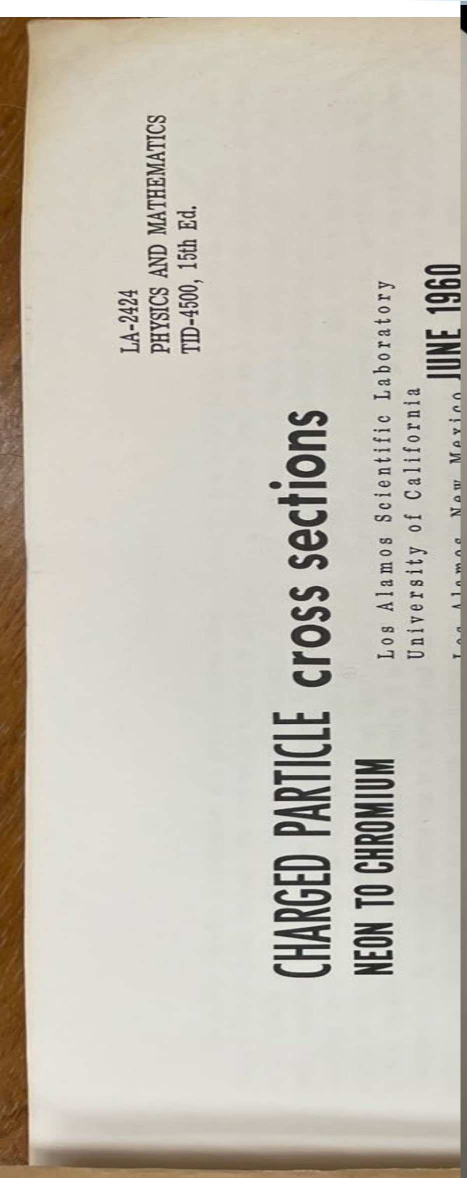


Interpreted ENDF file for sigma-ei.in

(a,xn) cross section

```
QM = -2.63630E+06 eV
QI = -2.63630E+06 eV
Interpolation table:
        368           2           0           0           0           0
Cross section table:
         eV       barns          eV       barns          eV       barns
 ----------- ----------- ----------- ----------- ----------- -----------
 3.027380+6 0.000000+0 3.050000+6 4.300000-6 3.069000+6 1.270000-5
 3.089000+6 7.700000-6 3.109000+6 3.580000-6 3.132000+6 1.870000-6
 3.149000+6 3.610000-6 3.158000+6 1.070000-6 3.167000+6 1.240000-5
 3.168000+6 5.500000-6 3.176000+6 1.630000-5 3.181000+6 2.220000-5
 3.188000+6 2.690000-5 3.191000+6 3.390000-5 3.198000+6 4.280000-5
 3.201000+6 3.270000-5 3.209000+6 1.120000-5 3.210000+6 1.990000-5
 3.214000+6 6.800000-6 3.224000+6 6.800000-6 3.228000+6 1.520000-5
 3.231000+6 2.330000-5 3.238000+6 3.170000-5 3.241000+6 1.920000-5
 3.245000+6 1.260000-5 3.251000+6 1.720000-5 3.255000+6 2.080000-5
 3.258000+6 2.340000-5 3.265000+6 2.340000-5 3.269000+6 2.630000-5
 3.279000+6 3.730000-5 3.282000+6 4.700000-5 3.288000+6 5.900000-5
 3.290000+6 1.060000-4 3.296000+6 1.140000-4 3.301000+6 8.100000-5
 3.306000+6 6.200000-5 3.309000+6 4.910000-5 3.314000+6 4.210000-5
 3.318000+6 3.610000-5 3.326000+6 3.620000-5 3.329000+6 2.990000-5
 3.336000+6 2.770000-5 3.341000+6 2.380000-5 3.346000+6 2.200000-5
 3.349000+6 2.040000-5 3.353000+6 2.040000-5 3.358000+6 1.620000-5
 3.366000+6 1.150000-5 3.370000+6 2.580000-5 3.377000+6 5.600000-5
 3.381000+6 1.120000-4 3.387000+6 8.900000-5 3.388000+6 1.580000-4
 3.389000+6 1.210000-4 3.399000+6 6.500000-5 3.404000+6 5.600000-5
 3.409000+6 5.000000-5 3.414000+6 4.630000-5 3.421000+6 5.010000-5
 3.424000+6 6.800000-5 3.428000+6 1.000000-4 3.435000+6 1.590000-4
 3.442000+6 2.530000-4 3.447000+6 1.730000-4 3.450000+6 3.730000-4
 3.454000+6 6.400000-4 3.459000+6 7.800000-4 3.463000+6 8.700000-4
 3.470000+6 9.400000-4 3.476000+6 1.100000-3 3.480000+6 8.100000-4
 3.482000+6 3.480000-4 3.487000+6 3.620000-4 3.494000+6 3.620000-4
 3.499000+6 3.620000-4 3.506000+6 3.360000-4 3.506000+6 3.770000-4
 3.514000+6 2.570000-4 3.519000+6 2.200000-4 3.523000+6 1.970000-4
 3.529000+6 1.620000-4 3.532000+6 1.290000-4 3.535000+6 8.400000-5
 3.542000+6 7.300000-5 3.549000+6 5.130000-5 3.552000+6 4.400000-5
 3.557000+6 4.240000-5 3.562000+6 3.780000-5 3.567000+6 6.500000-5
 3.576000+6 1.250000-4 3.580000+6 1.700000-4 3.582000+6 3.800000-5
 3.589000+6 4.270000-5 3.596000+6 5.180000-5 3.600000+6 6.000000-5
 3.603000+6 8.200000-5 3.608000+6 1.260000-4 3.615000+6 2.160000-4
 3.617000+6 3.570000-4 3.624000+6 8.000000-4 3.630000+6 2.020000-3
 3.635000+6 9.000000-4 3.638000+6 5.900000-4 3.644000+6 4.180000-4
```

Early compilations of charged particle data

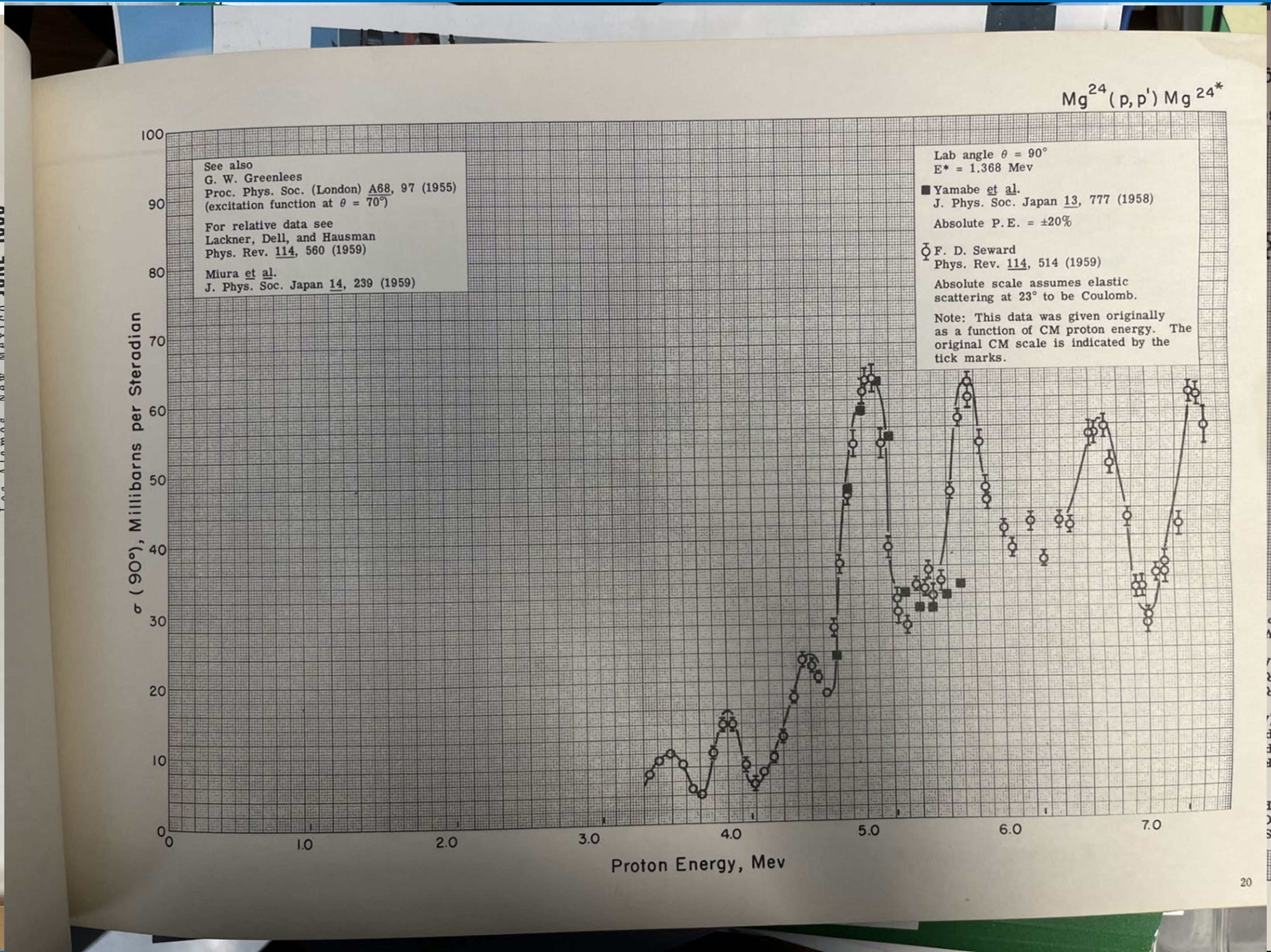


LA-2424
PHYSICS AND MATHEMATICS
TID-4500, 15th Ed.

CHARGED PARTICLE cross sections
NEON TO CHROMIUM

Los Alamos Scientific Laboratory
University of California

JUNE 1960



$Mg^{24}(p,p')Mg^{24*}$

See also
G. W. Greenlees
Proc. Phys. Soc. (London) A68, 97 (1955)
(excitation function at θ = 70°)

For relative data see
Lackner, Dell, and Hausman
Phys. Rev. 114, 560 (1959)

Miura et al.
J. Phys. Soc. Japan 14, 239 (1959)

Lab angle θ = 90°
E* = 1.368 Mev

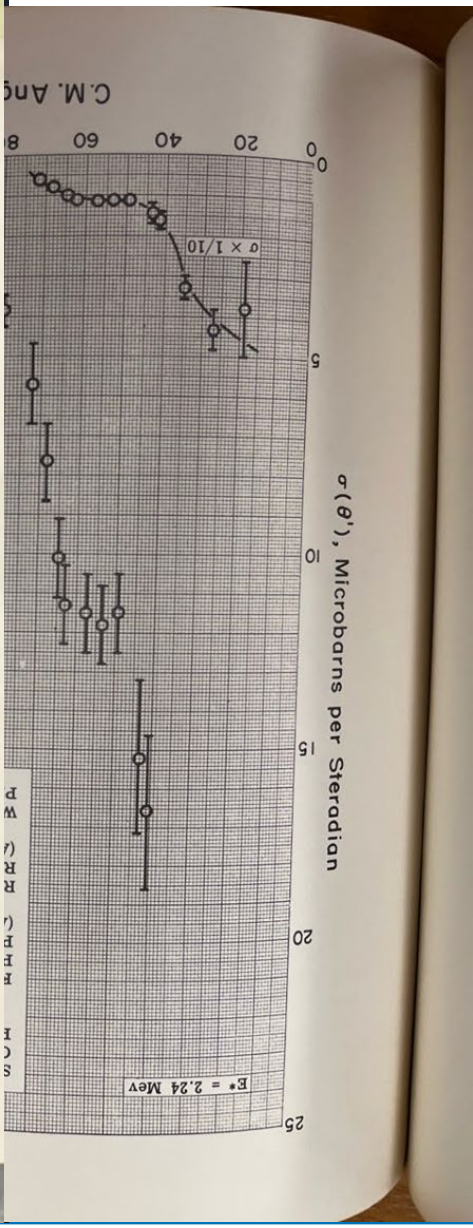
■ Yamabe et al.
J. Phys. Soc. Japan 13, 777 (1958)

Absolute P.E. = ±20%

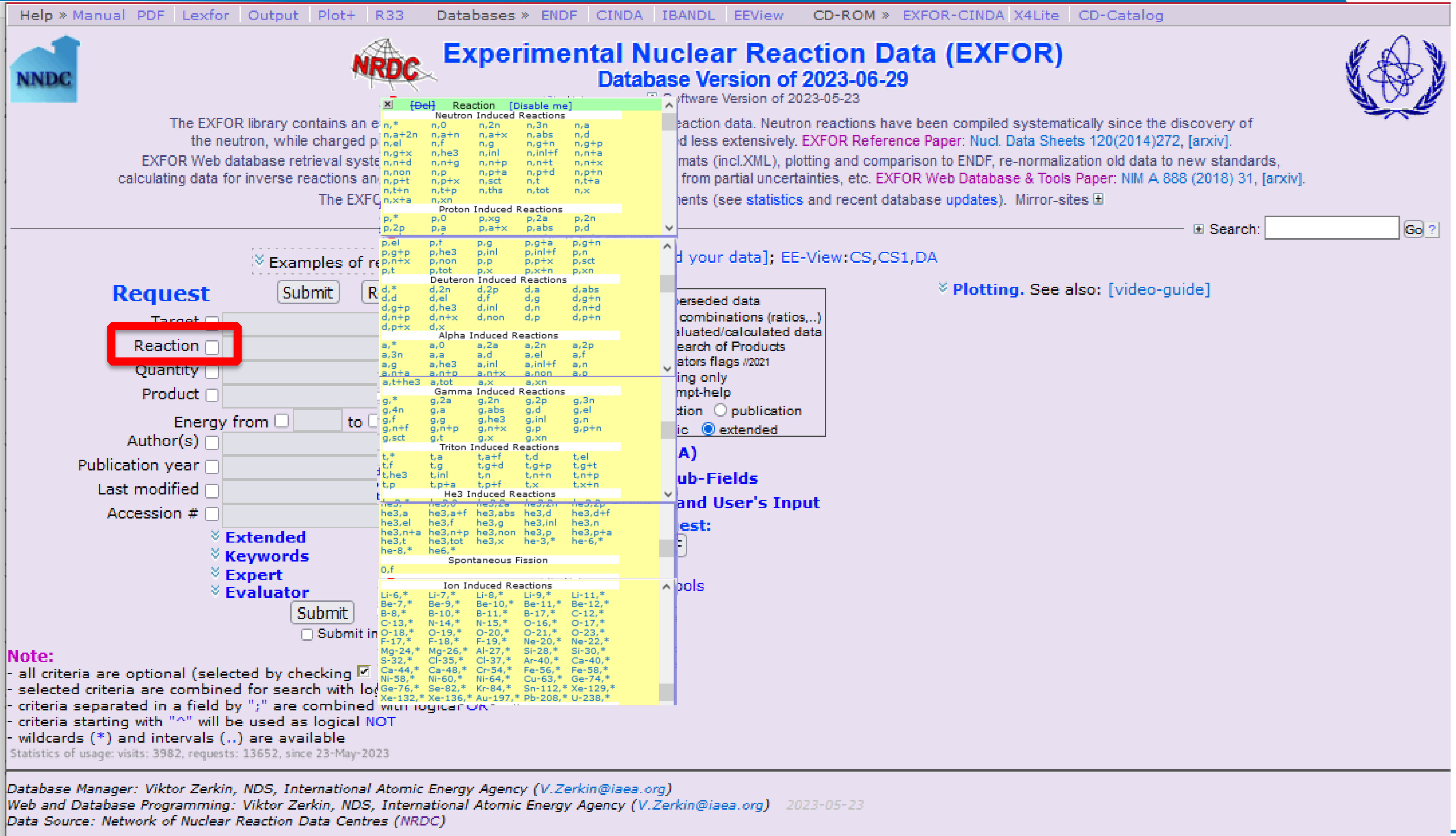
ǫ F. D. Seward
Phys. Rev. 114, 514 (1959)

Absolute scale assumes elastic scattering at 23° to be Coulomb.

Note: This data was given originally as a function of CM proton energy. The original CM scale is indicated by the tick marks.



EXFOR: Compiled reaction data



Help » Manual PDF | Lexfor | Output | Plot+ | R33   Databases » ENDF | CINDA | IBANDL | EEView   CD-ROM » EXFOR-CINDA | X4Lite | CD-Catalog

Experimental Nuclear Reaction Data (EXFOR)

Database Version of 2023-06-29

ftware Version of 2023-05-23

The EXFOR library contains an e … eaction data. Neutron reactions have been compiled systematically since the discovery of
the neutron, while charged p … d less extensively. EXFOR Reference Paper: Nucl. Data Sheets 120(2014)272, [arxiv].
EXFOR Web database retrieval syste … mats (incl.XML), plotting and comparison to ENDF, re-normalization old data to new standards,
calculating data for inverse reactions an … from partial uncertainties, etc. EXFOR Web Database & Tools Paper: NIM A 888 (2018) 31, [arxiv].
The EXFO … ents (see statistics and recent database updates). Mirror-sites ⊞

☒ [Del] Reaction [Disable me]

Neutron Induced Reactions
n,* n,0 n,2n n,3n n,a
n,a+2n n,a+n n,a+x n,abs n,d
n,el n,f n,g n,g+n n,g+p
n,g+x n,he3 n,inl n,inl+f n,n+a
n,n+d n,n+g n,n+p n,n+t n,n+x
n,non n,p n,p+a n,p+d n,p+n
n,p+t n,p+x n,sct n,t n,t+a
n,t+n n,t+p n,ths n,tot n,x
n,x+a n,xn

Proton Induced Reactions
p,* p,0 p,xg p,2a p,2n
p,2p p,a p,a+x p,abs p,d
p,el p,f p,g p,g+a p,g+n
p,g+p p,he3 p,inl p,inl+f p,n
p,n+x p,non p,p p,p+x p,sct
p,t p,tot p,x p,x+n p,xn

Deuteron Induced Reactions
d,* d,2n d,2p d,a d,abs
d,d d,el d,f d,g d,g+n
d,g+p d,he3 d,inl d,n d,n+d
d,n+p d,n+x d,non d,p d,p+n
d,p+x d,x

Alpha Induced Reactions
a,* a,0 a,2a a,2n a,2p
a,3n a,a a,d a,el a,f
a,g a,he3 a,inl a,inl+f a,n
a,n+a a,n+p a,n+x a,non a,p
a,t+he3 a,tot a,x a,xn

Gamma Induced Reactions
g,* g,2a g,2n g,2p g,3n
g,4n g,a g,abs g,d g,el
g,f g,g g,he3 g,inl g,n
g,n+f g,n+p g,n+x g,p g,p+n
g,sct g,t g,x g,xn

Triton Induced Reactions
t,* t,a t,a+f t,d t,el
t,f t,g t,g+d t,g+p t,g+t
t,he3 t,inl t,n t,n+n t,n+p
t,p t,p+a t,p+f t,x t,x+n

He3 Induced Reactions
he3,* he3,0 he3,2a he3,2n he3,2p
he3,a he3,a+f he3,abs he3,d he3,d+f
he3,el he3,f he3,g he3,inl he3,n
he3,n+a he3,n+p he3,non he3,p he3,p+a
he3,t he3,tot he3,x he-3,* he-6,*
he-8,* he6,*

Spontaneous Fission
0,f

Ion Induced Reactions
Li-6,* Li-7,* Li-8,* Li-9,* Li-11,*
Be-7,* Be-9,* Be-10,* Be-11,* Be-12,*
B-8,* B-10,* B-11,* B-17,* C-12,*
C-13,* N-14,* N-15,* O-16,* O-17,*
O-18,* O-19,* O-20,* O-21,* O-23,*
F-17,* F-18,* F-19,* Ne-20,* Ne-22,*
Mg-24,* Mg-26,* Al-27,* Si-28,* Si-30,*
S-32,* Cl-35,* Cl-37,* Ar-40,* Ca-40,*
Ca-44,* Ca-48,* Cr-54,* Fe-56,* Fe-58,*
Ni-58,* Ni-60,* Ni-64,* Cu-63,* Ge-74,*
Ge-76,* Se-82,* Kr-84,* Sn-112,* Xe-129,*
Xe-132,* Xe-136,* Au-197,* Pb-208,* U-238,*

⊞ Search: Go ?

Examples of re … d your data]; EE-View:CS,CS1,DA

Plotting. See also: [video-guide]

Request Submit R

Target ☐
Reaction ☐
Quantity ☐
Product ☐
Energy from ☐ to ☐
Author(s) ☐
Publication year ☐
Last modified ☐
Accession # ☐

erseded data
combinations (ratios,..)
luated/calculated data
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ing only
mpt-help
tion ○ publication
ic ● extended

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Keywords
Expert
Evaluator

Submit

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Note:
- all criteria are optional (selected by checking ☑
- selected criteria are combined for search with lo
- criteria separated in a field by ";" are combined with logical OR
- criteria starting with "^" will be used as logical NOT
- wildcards (*) and intervals (..) are available

Statistics of usage: visits: 3982, requests: 13652, since 23-May-2023

Database Manager: Viktor Zerkin, NDS, International Atomic Energy Agency (V.Zerkin@iaea.org)
Web and Database Programming: Viktor Zerkin, NDS, International Atomic Energy Agency (V.Zerkin@iaea.org) 2023-05-23
Data Source: Network of Nuclear Reaction Data Centres (NRDC)

Class Input? What "industries" need nuclear data?

- Nuclear Medicine

Where can you fit in?

- Nuclear Medicine
  - Isotope production
  - Decay energy/Dose
  - Irradiation dose

- Nuclear Energy

- Space exploration

- Defense

- Non-proliferation

- Industry
  - Interrogation

- Construction
  - shielding

- Stewardship

- Basic science
  - Reaction models

- Basic science
  - Structure models

NDIAWG (1 of 1)

- **The Nuclear Data InterAgency Working Group (NDIAWG)** continues quarterly meetings for collaboration and coordination
- **Agency program membership increased from 8 to 15 since 2020** and highlights the diverse areas where nuclear data has impact

- SC (NP, HEP, FES)
- NNSA
- Nuclear Energy

- CWMD

- Human Spaceflight
- Electronics
- Propulsion/power
- Spectroscopy

- DTRA
- Missile Defense Agency

Nuclear Physics (Experiment and Theory)

U.S.NRC

- National Cancer Institute

Boxes indicate new membership since 2020

NDWG Roster as of January 2022

PARTNERS	NDWG Member	Organization
DOE/SC/Nuclear Physics	Lee Bernstein Catherine Romano	LBNL Aerospace Corp
NNSA/DNN R&D/PD/NA-22	Fredrik Tovesson	ANL
NNSA/DNN R&D/Forensics	Todd Bredeweg Jason Burke	LANL LLNL
NNSA/DNN R&D/SNDD	Ron Soltz David Gerts	LLNL LANL
NNSA/NCSP/NA-511	Mike Zerkle Marco Pigni	NNL ORNL
NNSA/NR/NA-30	Mike Zerkle	NNL
NNSA/Defense Prog./NA-113	Jo Ressler Shea Mosby	LLNL LANL
NNSA/Defense Prog./NA-114	Nathan Gibson Robert Casperson	LANL LLNL
DOE/Nuclear Energy	Matthew Jesse Javier Ortensi	ORNL INL
NRC	Will Wieselquist Jesse Brown	ORNL
NNSA/Office of Nuclear Forensics/NA-83	Corey Keith Chris Krenn	LANL LLNL
DOE/SC/Isotope Office	Etienne Vermeulen	LANL
NNSA/Emergency Response/NA-82	John Koglin Pete Jaegers	LLNL LANL
NIST	Brian Zimmerman	NIST
US Nuclear Data Program	Dave Brown	BNL
NNSA/Nuclear Safeguards and Security/NA-24	Young Ham	Tech Advisor
Missile Defense Agency/Rad Hardness	Courtney Matzkind	MDA

49 Members
17 programs
11 national laboratories

LAB	NDWG Member
ANL	Filip Kondev
ANL	Guy Savard
BNL	Alejandro Sonzogni
INL	Sebastian Schunert
JLAB	Mike Dion
LANL	Mark Chadwick
LANL	Robert Little
LBNL	Brian Quiter
LBNL	Bethany Goldblum
LLNL	Teresa Bailey
LLNL	Tim Rose
ORNL	TBD
PNNL	Stephanie Lyons
PNNL	Bruce Pierson
SNL	Pat Griffin
SNL	Phil Dreike
SRNL	Kalee Fenker
SRNL	Chris McGrath

AT LARGE MEMBERS	
Jim Koster	LANL
Patrick Talou	LANL
John Engle	Univ. WISC
Teresa Bailey	LLNL
Morgan White	LANL

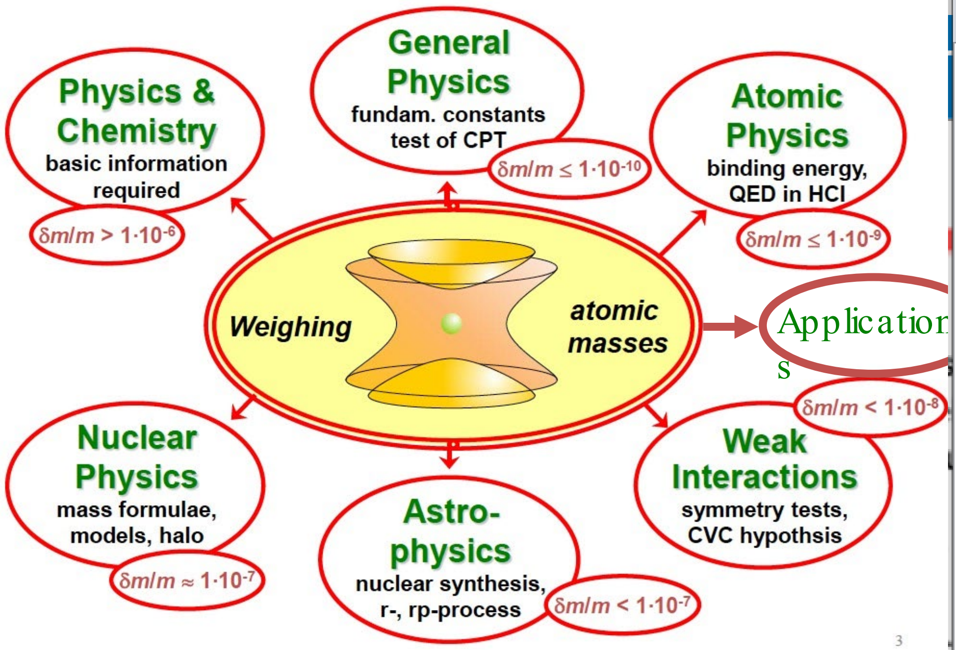
Kathy Romano
WANDA 2023

Extra thoughts: Horizontal Evaluations

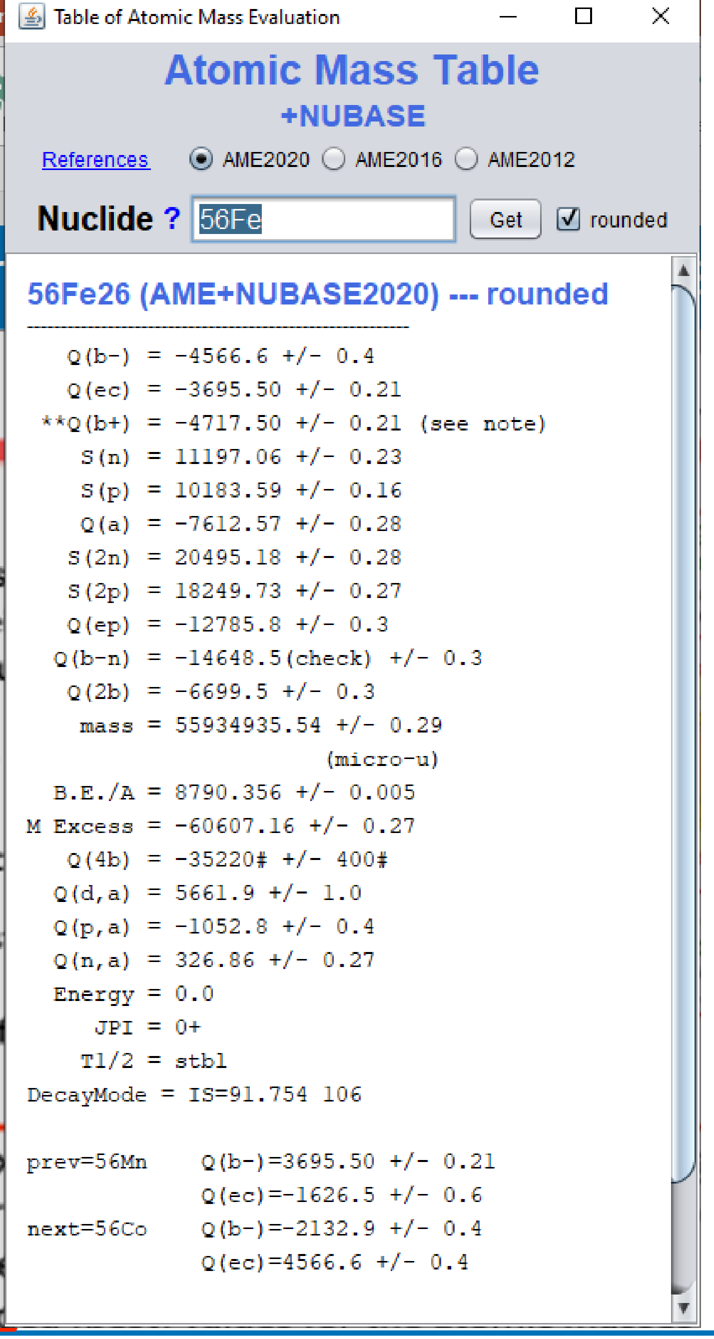
Java app by Jun Chen

Atomic Mass Evaluation & NuBase

- ☐ **Binding energies**
  - ✓ **mass models**
  - ✓ **shell structure**
- ☐ **Reaction & decay phase space**
  - ✓ **Q values**
  - ✓ **decay & reaction probabilities**
- ☐ **The limits of existence**
  - ✓ **drip lines**
  - ✓ **specific configurations and topologies**



- ☐ combines the experimental results from mass and energy measurements produced in many nuclear physics laboratories using a procedure established by A.H. Wapstra in the early 1950's
  - ✓ recommended (best) values for the atomic masses and their uncertainties
  - ✓ extrapolation to the extremes using the smoothness of the mass surface



Atomic Mass Table
+NUBASE

References ● AME2020 ○ AME2016 ○ AME2012

Nuclide ? 56Fe Get ☑ rounded

56Fe26 (AME+NUBASE2020) --- rounded

```
------------------------------------------------
   Q(b-) = -4566.6 +/- 0.4
  Q(ec) = -3695.50 +/- 0.21
**Q(b+) = -4717.50 +/- 0.21 (see note)
   S(n) = 11197.06 +/- 0.23
   S(p) = 10183.59 +/- 0.16
   Q(a) = -7612.57 +/- 0.28
  S(2n) = 20495.18 +/- 0.28
  S(2p) = 18249.73 +/- 0.27
  Q(ep) = -12785.8 +/- 0.3
 Q(b-n) = -14648.5(check) +/- 0.3
  Q(2b) = -6699.5 +/- 0.3
   mass = 55934935.54 +/- 0.29
                    (micro-u)
 B.E./A = 8790.356 +/- 0.005
M Excess = -60607.16 +/- 0.27
  Q(4b) = -35220# +/- 400#
 Q(d,a) = 5661.9 +/- 1.0
 Q(p,a) = -1052.8 +/- 0.4
 Q(n,a) = 326.86 +/- 0.27
 Energy = 0.0
    JPI = 0+
   T1/2 = stbl
DecayMode = IS=91.754 106


prev=56Mn     Q(b-)=3695.50 +/- 0.21
              Q(ec)=-1626.5 +/- 0.6
next=56Co     Q(b-)=-2132.9 +/- 0.4
              Q(ec)=4566.6 +/- 0.4
```

Horizontal Evaluations & Topical Reviews

Nuclear Data Sheets v. 97 (2002) 241

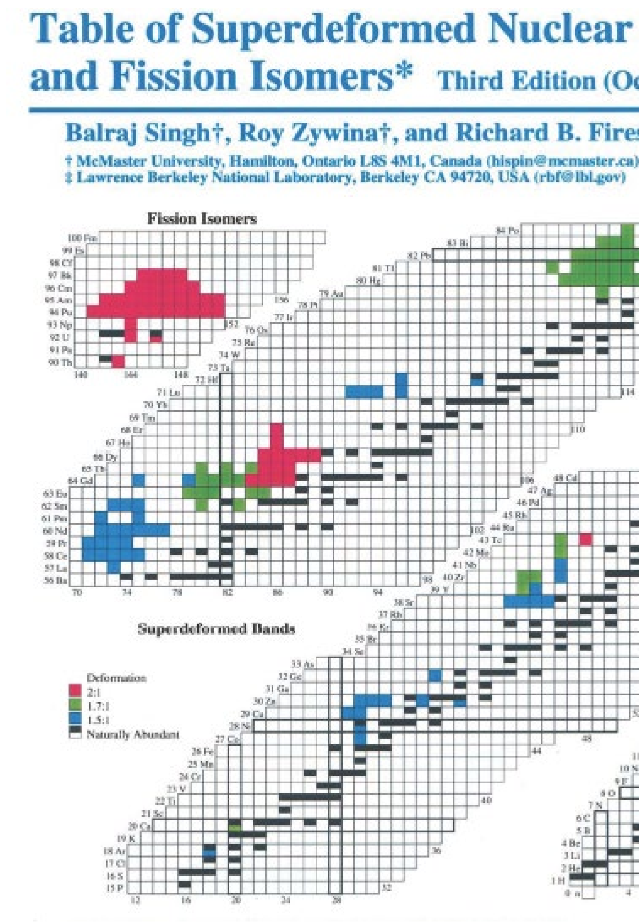


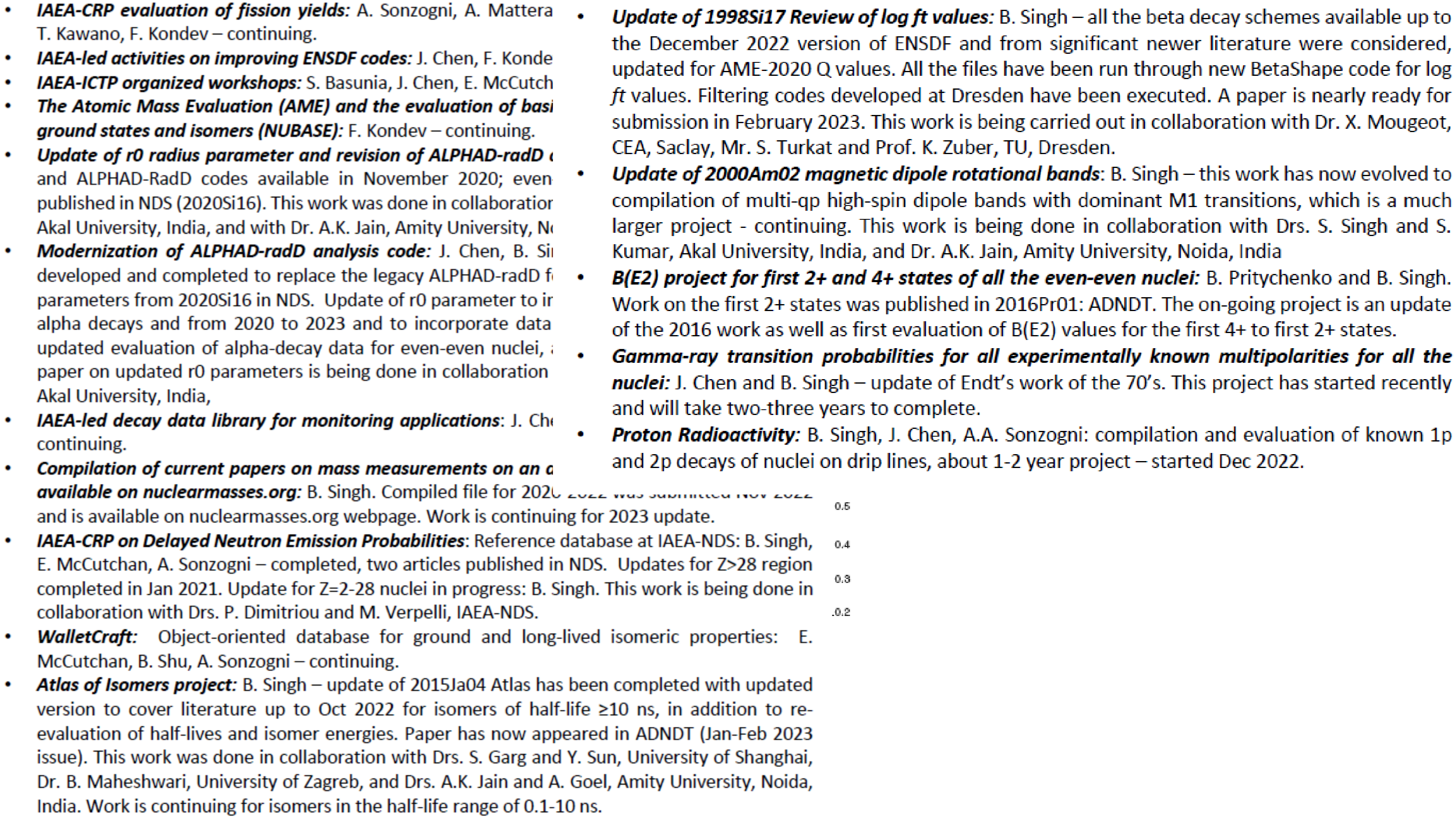
Table of Superdeformed Nuclear and Fission Isomers* Third Edition (O

Balraj Singh†, Roy Zywina†, and Richard B. Fire

† McMaster University, Hamilton, Ontario L8S 4M1, Canada (bspin@mcmaster.ca)
‡ Lawrence Berkeley National Laboratory, Berkeley CA 94720, USA (rbf@lbl.gov)

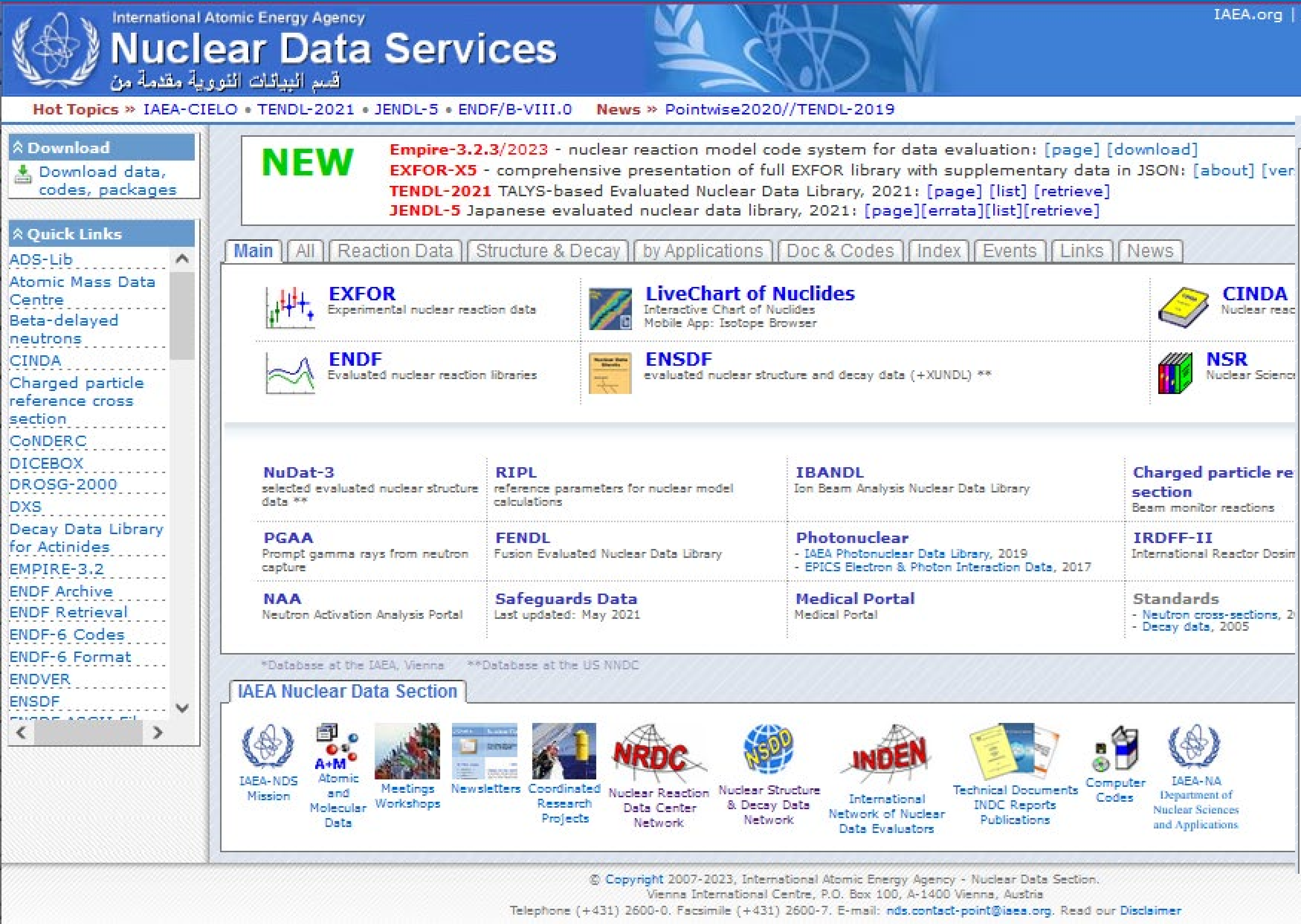
From F. Kondev

❑ Log *ft* values in β-/(e+b+) decay



- ***IAEA-CRP evaluation of fission yields:*** A. Sonzogni, A. Mattera T. Kawano, F. Kondev – continuing.
- ***IAEA-led activities on improving ENSDF codes:*** J. Chen, F. Konde
- ***IAEA-ICTP organized workshops:*** S. Basunia, J. Chen, E. McCutch
- ***The Atomic Mass Evaluation (AME) and the evaluation of basi ground states and isomers (NUBASE):*** F. Kondev – continuing.
- ***Update of r0 radius parameter and revision of ALPHAD-radD*** and ALPHAD-RadD codes available in November 2020; even published in NDS (2020Si16). This work was done in collaboratior Akal University, India, and with Dr. A.K. Jain, Amity University, N
- ***Modernization of ALPHAD-radD analysis code:*** J. Chen, B. Si developed and completed to replace the legacy ALPHAD-radD f parameters from 2020Si16 in NDS. Update of r0 parameter to ir alpha decays and from 2020 to 2023 and to incorporate data updated evaluation of alpha-decay data for even-even nuclei, paper on updated r0 parameters is being done in collaboration Akal University, India,
- ***IAEA-led decay data library for monitoring applications:*** J. Ch continuing.
- ***Compilation of current papers on mass measurements on an a available on nuclearmasses.org:*** B. Singh. Compiled file for 202 and is available on nuclearmasses.org webpage. Work is continuing for 2023 update.
- ***IAEA-CRP on Delayed Neutron Emission Probabilities***: Reference database at IAEA-NDS: B. Singh, E. McCutchan, A. Sonzogni – completed, two articles published in NDS. Updates for Z>28 region completed in Jan 2021. Update for Z=2-28 nuclei in progress: B. Singh. This work is being done in collaboration with Drs. P. Dimitriou and M. Verpelli, IAEA-NDS.
- ***WalletCraft:*** Object-oriented database for ground and long-lived isomeric properties: E. McCutchan, B. Shu, A. Sonzogni – continuing.
- ***Atlas of Isomers project***: B. Singh – update of 2015Ja04 Atlas has been completed with updated version to cover literature up to Oct 2022 for isomers of half-life ≥10 ns, in addition to re-evaluation of half-lives and isomer energies. Paper has now appeared in ADNDT (Jan-Feb 2023 issue). This work was done in collaboration with Drs. S. Garg and Y. Sun, University of Shanghai, Dr. B. Maheshwari, University of Zagreb, and Drs. A.K. Jain and A. Goel, Amity University, Noida, India. Work is continuing for isomers in the half-life range of 0.1-10 ns.

- ***Update of 1998Si17 Review of log ft values:*** B. Singh – all the beta decay schemes available up to the December 2022 version of ENSDF and from significant newer literature were considered, updated for AME-2020 Q values. All the files have been run through new BetaShape code for log *ft* values. Filtering codes developed at Dresden have been executed. A paper is nearly ready for submission in February 2023. This work is being carried out in collaboration with Dr. X. Mougeot, CEA, Saclay, Mr. S. Turkat and Prof. K. Zuber, TU, Dresden.
- ***Update of 2000Am02 magnetic dipole rotational bands***: B. Singh – this work has now evolved to compilation of multi-qp high-spin dipole bands with dominant M1 transitions, which is a much larger project - continuing. This work is being done in collaboration with Drs. S. Singh and S. Kumar, Akal University, India, and Dr. A.K. Jain, Amity University, Noida, India
- ***B(E2) project for first 2+ and 4+ states of all the even-even nuclei:*** B. Pritychenko and B. Singh. Work on the first 2+ states was published in 2016Pr01: ADNDT. The on-going project is an update of the 2016 work as well as first evaluation of B(E2) values for the first 4+ to first 2+ states.
- ***Gamma-ray transition probabilities for all experimentally known multipolarities for all the nuclei:*** J. Chen and B. Singh – update of Endt's work of the 70's. This project has started recently and will take two-three years to complete.
- ***Proton Radioactivity:*** B. Singh, J. Chen, A.A. Sonzogni: compilation and evaluation of known 1p and 2p decays of nuclei on drip lines, about 1-2 year project – started Dec 2022.



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- DICEBOX
- DROSG-2000
- DXS
- Decay Data Library for Actinides
- EMPIRE-3.2
- ENDF Archive
- ENDF Retrieval
- ENDF-6 Codes
- ENDF-6 Format
- ENDVER
- ENSDF

NEW

Empire-3.2.3/2023 - nuclear reaction model code system for data evaluation: [page] [download]
EXFOR-X5 - comprehensive presentation of full EXFOR library with supplementary data in JSON: [about] [ver
TENDL-2021 TALYS-based Evaluated Nuclear Data Library, 2021: [page] [list] [retrieve]
JENDL-5 Japanese evaluated nuclear data library, 2021: [page][errata][list][retrieve]

EXFOR
Experimental nuclear reaction data

LiveChart of Nuclides
Interactive Chart of Nuclides
Mobile App: Isotope Browser

CINDA
Nuclear reac

ENDF
Evaluated nuclear reaction libraries

ENSDF
evaluated nuclear structure and decay data (+XUNDL) **

NSR
Nuclear Scienc

NuDat-3
selected evaluated nuclear structure data **

RIPL
reference parameters for nuclear model calculations

IBANDL
Ion Beam Analysis Nuclear Data Library

Charged particle re section
Beam monitor reactions

PGAA
Prompt gamma rays from neutron capture

FENDL
Fusion Evaluated Nuclear Data Library

Photonuclear
- IAEA Photonuclear Data Library, 2019
- EPICS Electron & Photon Interaction Data, 2017

IRDFF-II
International Reactor Dosin

NAA
Neutron Activation Analysis Portal

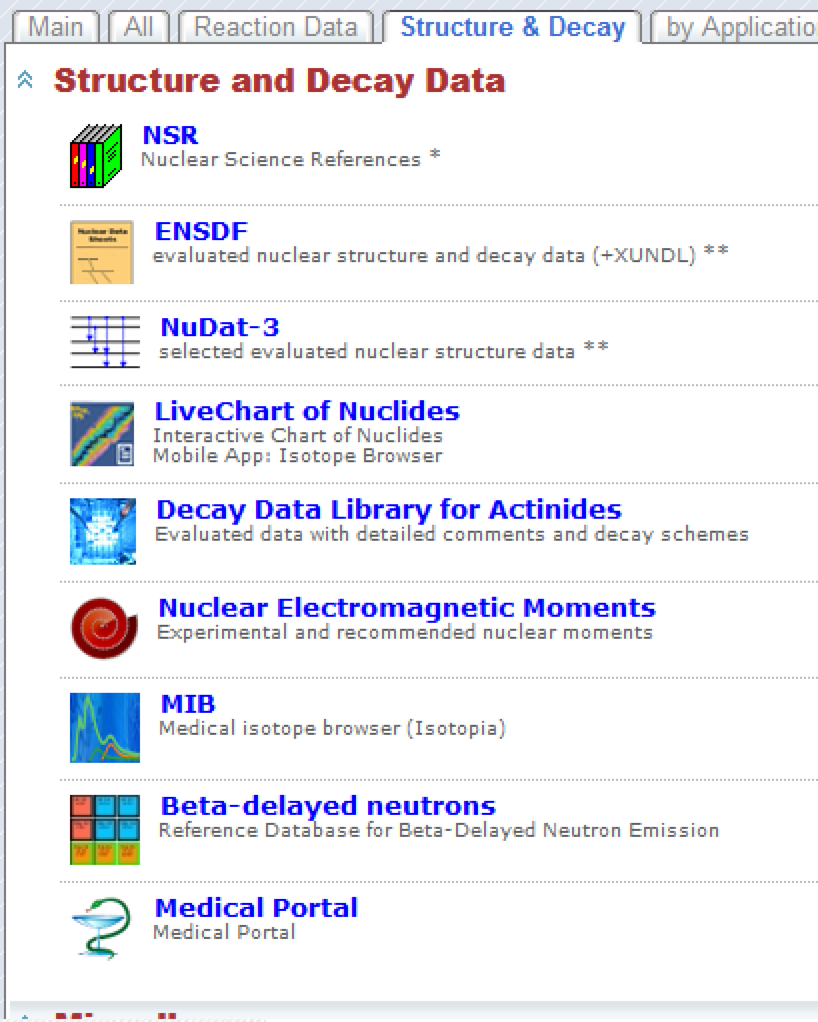
Safeguards Data
Last updated: May 2021

Medical Portal
Medical Portal

Standards
- Neutron cross-sections, 2
- Decay data, 2005

*Database at the IAEA, Vienna **Database at the US NNDC

IAEA Nuclear Data Section



Structure and Decay Data

NSR
Nuclear Science References *

ENSDF
evaluated nuclear structure and decay data (+XUNDL) **

NuDat-3
selected evaluated nuclear structure data **

LiveChart of Nuclides
Interactive Chart of Nuclides
Mobile App: Isotope Browser

Decay Data Library for Actinides
Evaluated data with detailed comments and decay schemes

Nuclear Electromagnetic Moments
Experimental and recommended nuclear moments

MIB
Medical isotope browser (Isotopia)

Beta-delayed neutrons
Reference Database for Beta-Delayed Neutron Emission

Medical Portal
Medical Portal