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international centre for theoretical physics

ICTP 40th Anniversary

SMR.1555 - 19

Workshop on Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

16 February - 12 March 2004

IAEA-NDS
Nuclear Data Services

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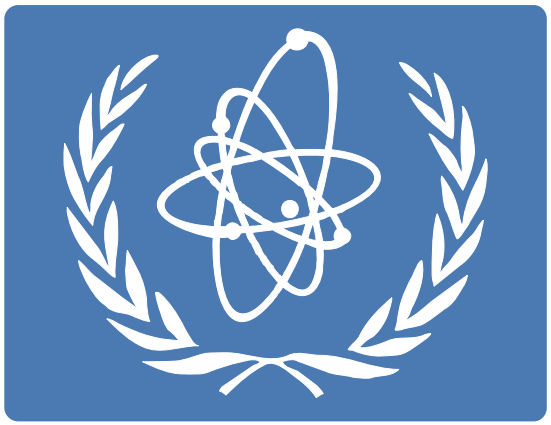
AUSTRIA

Introduction to IAEA Nuclear Data Services



Workshop on Nuclear Reaction Data and Nuclear Reactors:
Physics, Design and Safety
Trieste, 16 February - 12 March 2004

Otto Schwerer

IAEA Nuclear Data Section, Vienna, Austria

I. Lecture

1. Introduction

1.1 The mission of NDS

1.2 What is “nuclear data”?

1.3 Data center networks

2. Overview of libraries and databases

2.1 General purpose libraries

2.2 Selected specialized libraries

3. Data access and services

4. Conclusion

II. Demonstrations

III.Exercises

1.1 The Mission of NDS

The IAEA Nuclear Data Section (NDS)

- provides *nuclear data services* to scientists worldwide (data libraries, bibliographies and related materials) through Internet, CD-ROM and other media
- produces new databases through its *data development* programme
- assists developing countries through *technology transfer* activities

Data Center Activities

- Compilation
  - Compile new data (neutron-induced) in EXFOR and CINDA
  - Keep master files in cooperation with other centers
  - Collect evaluated and specialized libraries for users
- Online and Off-line data services with particular emphasis on meeting the needs of developing countries
- Data Center Network Co-ordination

Data Development Activities

- Main mechanism: *Co-ordinated Research Projects (CRPs)*
  - 5-15 participating groups, duration 3-4 years
  - Research contracts, research agreements
  - Research co-ordination meetings
  - Objectives: new or upgraded database
  - Results (data and documentation) made available (TECDOC, Web, CD-ROM)

Recent Coordinated Research Projects

Short Title	Duration	Participants
Fission Yield Data (<20 MeV)	1991-96	7
CS f.Medical Radioisotope Production	1995-99	7
Photonuclear Data	1996-2000	7
Fiss.Yield Data for Transmut. (<150 MeV)	1997-2002	10
X- and Gamma-Ray Standards	1998-2002	11
Input Parameter Testing (RIPL-II)	1998-2002	8
Prompt Gamma Activation Analysis	1999-2003	7
Nuclear data for Th-U cycle	2002-2006	13
Standard Cross Sections for Light Elem.	2002-2006	9
N.D.Eval.for emerging technol.(RIPL-III)	2003-2006	
N.D.for prod.of therapeutic radionuclides	2003-2007	

Technology Transfer Activities

- **Technical Cooperation Projects**
  - Latin American “Mirror Server” Project
    Started operation at IPEN, Sao Paulo, Brazil in March 2000
  - Ghana Project: installed “Mini-data center” on WinNT workstation
- **Workshops**
  - Bi-annual workshops on “Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety” at ICTP Trieste, Italy (all even years)
  - ICTP workshops on Nuclear Data for Science and Technology (odd years, several weeks).
    - 1999: Medical Physics
    - 2001: Accelerator Driven Waste Incineration
    - 2003: Materials analysis
  - Also 2003 at ICTP: Nuclear Structure and Decay Data: Theory and Evaluation
  - Occasionally small workshops at IAEA Vienna

Atomic and Molecular Data Unit

- Databases for fusion energy and other plasma research and other applications
- Additional CRPs
- Separate database server (AMDIS)
  - Numerical data: ALADDIN
  - Bibliographic data: AMBDAS
- Publications, e.g. CIAMDA
- Separate activity under NDS organizational unit

1.2 What is “nuclear data”?

- *Quantitative* results of any scientific investigation of the nuclear properties of matter: nuclear physics data, or “nuclear constants”.
- ***Examples:*** cross sections, half-lives, decay modes and decay radiation properties, γ-rays from radionuclides

Applications of nuclear data

- Energy applications
  - Fission power
  - Fusion reactor technology
- Non-energy applications
  - Nuclear medicine
  - Materials analysis and process control
  - Safeguards
  - Radiation safety
  - Waste management
  - Environmental research
  - Basic research (e.g. nuclear astrophysics) and education

Nuclear Data Types

- **Bibliographic** data (e.g. CINDA, NSR)
- **Experimental** data (e.g. EXFOR)
- **Evaluated** data (e.g. ENDF)
- Nuclear **reaction** data (e.g. EXFOR, ENDF)
- Nuclear **structure and decay** data (e.g. ENSDF)

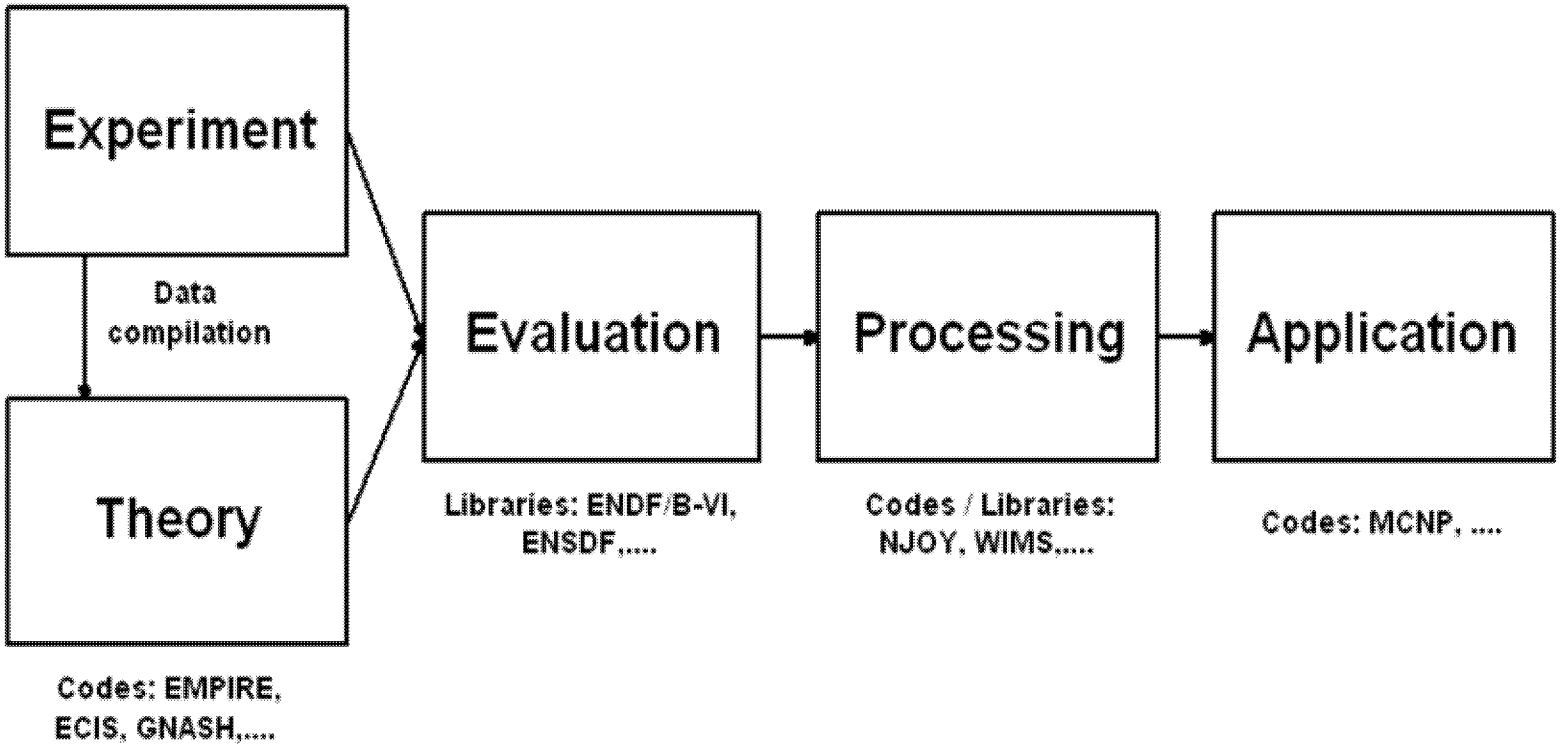
1.3 Data center networks

Nuclear data centers:

- organize collection and distribution of nuclear data on a world-wide scale
- are involved in all stages of data preparation between measurement and application: compilation, review, evaluation, processing, distribution
- The work of international, regional and national nuclear data centers is co-ordinated by the IAEA in two specialized **data center networks** for maximum efficiency and work sharing

From experimental nuclear data to applications

Laboratory → Data Center → User



Nuclear Data Center Networks

- **Network of 13 *Nuclear Reaction Data Centers***
  - **4 "core centers":**
    - **IAEA Nuclear Data Section**, Vienna
    - **OECD NEA Data Bank**, Paris, France
    - **U.S. National Nuclear Data Center**, Brookhaven, USA
    - **Russia Nuclear Data Center**, Obninsk, Russia
  - **Expanded network** includes additional co-operating specialized centers in Russia, China, Japan, Hungary, Korea, and Ukraine
- ***Nuclear Structure Data Centers Network***
  - **IAEA Nuclear Data Section**, Vienna (Co-ordination)
  - **U.S. National Nuclear Data Center**, Brookhaven, USA (Master database)
  - **13 data evaluation centers** in USA, Russia, China, France, Japan, Kuwait, Belgium, Canada
  - **Data dissemination centers** (IAEA, OECD-NEA, USA, France, Sweden)

2. Overview of libraries and databases

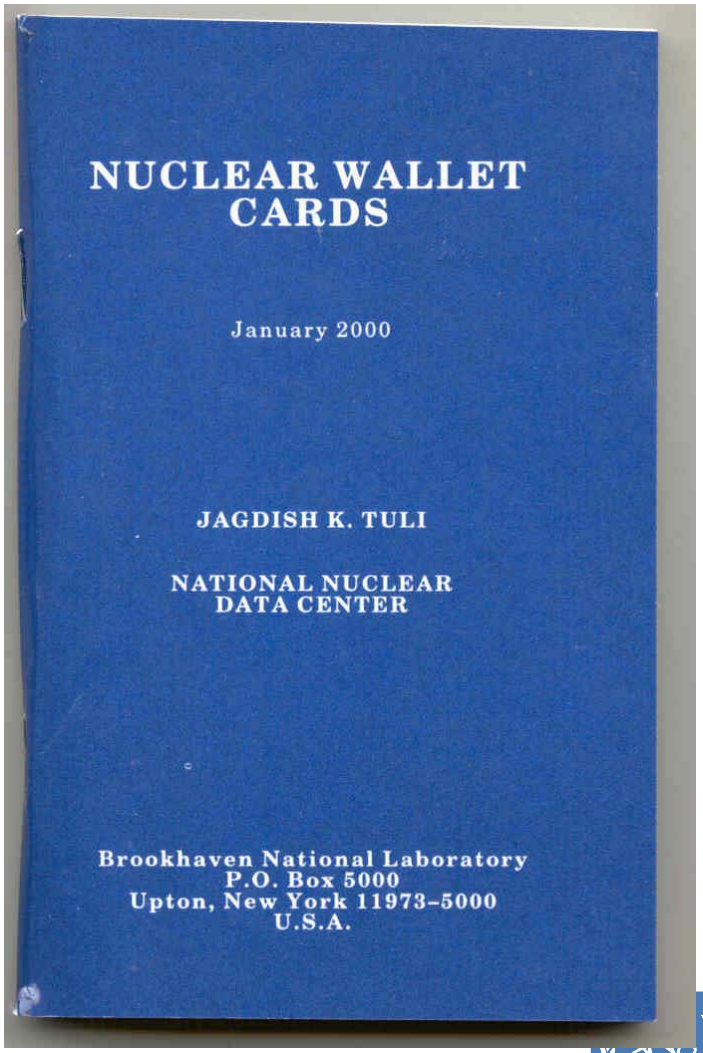
- Most comprehensive collection of nuclear data libraries worldwide - enormous value
- All data available free of charge to scientists in IAEA member states, on informal request or by Internet
- Overview:
  - "Index of Nuclear Data Libraries available from the IAEA Nuclear Data Section", Report IAEA-NDS-7, ed. by O. Schwerer and H.D. Lemmel (July 2002) , see also *http://www-nds.iaea.or.at/reports/nds-7.pdf*
  - IAEA Nuclear Data Guide, *http://www-nds.iaea.or.at/indg_intro.html*
- Brief documentations of contents and/or format for most libraries are published in the ***IAEA-NDS-*** report series (some reports and index IAEA-NDS-0 available also online), e.g.
  IAEA-NDS-1*: EXFOR,* ***IAEA-NDS-100****: ENDF/B-VI,* ***IAEA-NDS-136****: MENDL-2*

2.1 General Purpose Libraries

- Nuclear Wallet Cards
- NUDAT
- MIRD
- ENSDF
- NSR
- CINDA
- EXFOR
- ENDF

Nuclear Wallet Cards

- Basic properties of ground and metastable states
- Available in several formats:
  - Pocket booklet
  - WWW: (display of tables for each element)
  - WWW as part of NUDAT (interactive retrievals by various criteria)
  - Telnet: as part of NUDAT, same functions as in WWW



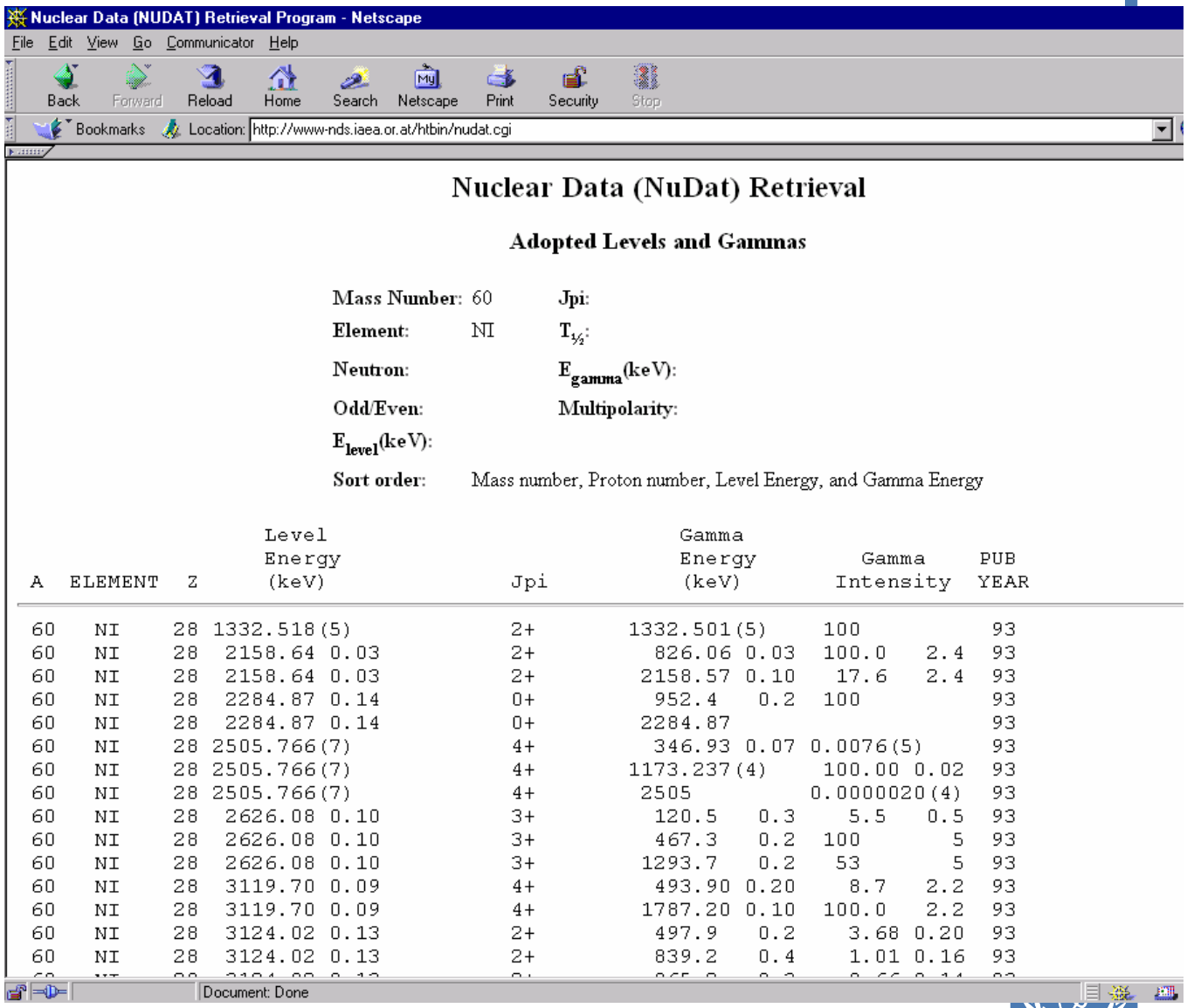
Nuclear Wallet Card - Z(24)

Isotope [1] Z	El	A	Jpi[2]	delta (MeV)[3]	$T_{½}$, Width, or Abundance[4]	Decay Mode[5]
24	**Cr**	42	0+	6.0*s*	> 350 ns	EC ,2P ?
		43	(3/2+)	-2.14*s*	21 ms *+4-3*	EC,EP 18%,E2P
		44	0+	-13.5*s*	53 ms *+4-3*	EC,EP > 7%
		45		-19.4*s*	50 ms *6*	EC,EP > 27%
		46	0+	-29.47	0.26 s *6*	EC
		47	3/2-	-34.55	500 ms *15*	EC
		48	0+	-42.815	21.56 h *3*	EC
		49	5/2-	-45.325	42.3 m *1*	EC
		50	0+	-50.255	> 1.8E+17 y	2EC
					4.345% *13*	
		51	7/2-	-51.445	27.7025 d *24*	EC
		52	0+	-55.413	**83.789% *18***	
		53	3/2-	-55.281	**9.501% *17***	
		54	0+	-56.928	**2.365% *7***	
		55	3/2-	-55.103	3.497 m *3*	B-
		56	0+	-55.289	5.94 m *10*	B-
		57	3/2-,5/2-,7/	-52.39	21.1 s *10*	B-
		58	0+	-51.9	7.0 s *3*	B-
		59		-47.9	0.74 s *24*	B-
		60	0+	-46.8	0.57 s *6*	B-
		61		-42.8	0.27 s *2*	B-
		62	0+	-41.2	0.19 s *3*	B-,BN 1.04%
		63		-35.5*s*	0.11 s *7*	B- ,BN 1.42%

NUDAT

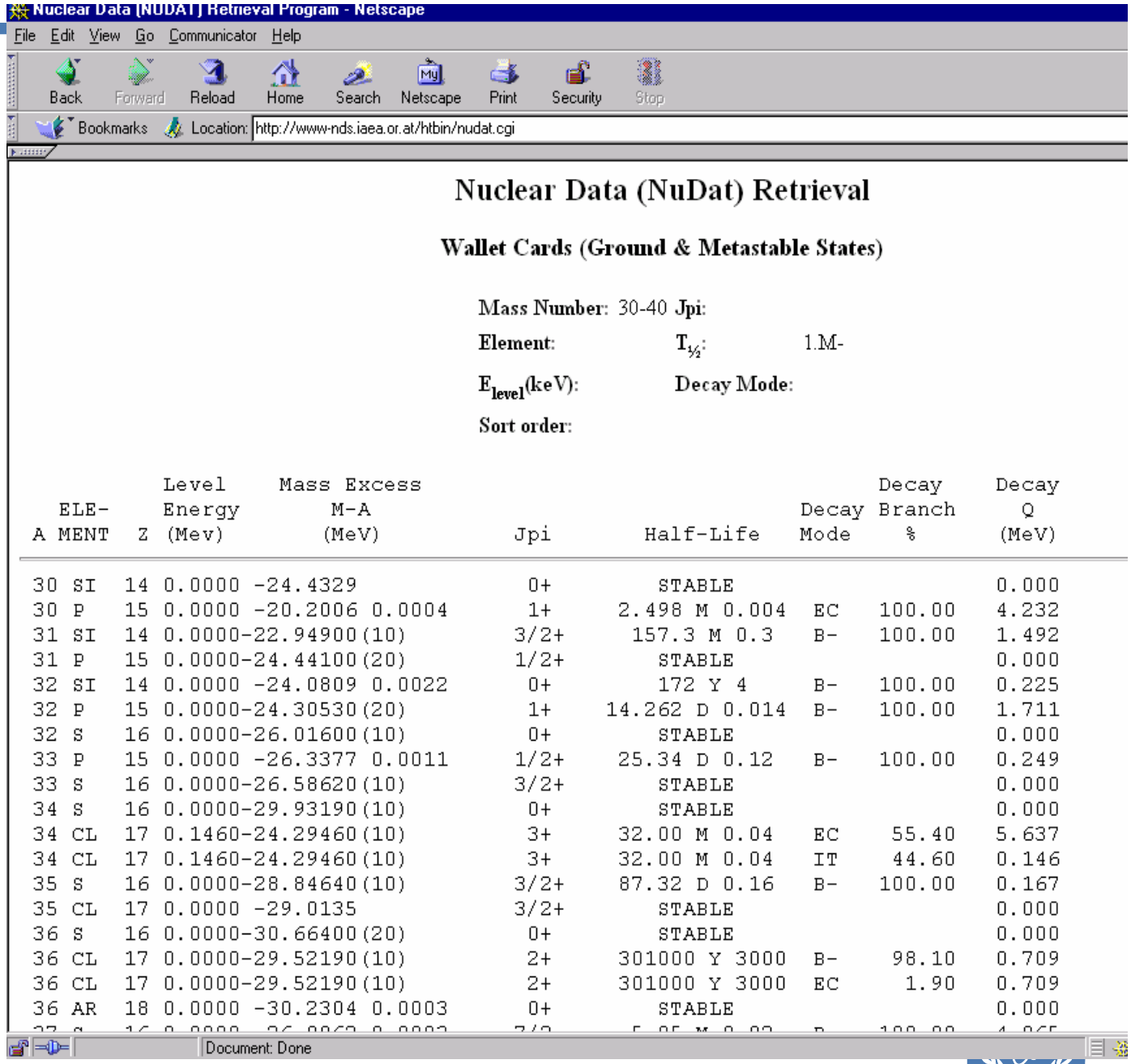
- User-friendly extract of most important data (for applications) from ENSDF, plus thermal neutron data (cross sections and resonance integrals)
- Consists of 6 modules:
  - Levels / Gammas / Levels and Gammas / Wallet Cards / Decay Radiations / Neutron Data
- Available online through WWW and Telnet. Interactive retrievals by various criteria
- PC version can be downloaded (PCNUDAT).

NUDAT/ Adopted Levels and Gammas for ^{60}Ni



A	ELEMENT	Z	Level Energy (keV)	Jpi	Gamma Energy (keV)	Gamma Intensity	PUB YEAR
60	NI	28	1332.518(5)	2+	1332.501(5)	100	93
60	NI	28	2158.64 0.03	2+	826.06 0.03	100.0 2.4	93
60	NI	28	2158.64 0.03	2+	2158.57 0.10	17.6 2.4	93
60	NI	28	2284.87 0.14	0+	952.4 0.2	100	93
60	NI	28	2284.87 0.14	0+	2284.87		93
60	NI	28	2505.766(7)	4+	346.93 0.07	0.0076(5)	93
60	NI	28	2505.766(7)	4+	1173.237(4)	100.00 0.02	93
60	NI	28	2505.766(7)	4+	2505	0.0000020(4)	93
60	NI	28	2626.08 0.10	3+	120.5 0.3	5.5 0.5	93
60	NI	28	2626.08 0.10	3+	467.3 0.2	100 5	93
60	NI	28	2626.08 0.10	3+	1293.7 0.2	53 5	93
60	NI	28	3119.70 0.09	4+	493.90 0.20	8.7 2.2	93
60	NI	28	3119.70 0.09	4+	1787.20 0.10	100.0 2.2	93
60	NI	28	3124.02 0.13	2+	497.9 0.2	3.68 0.20	93
60	NI	28	3124.02 0.13	2+	839.2 0.4	1.01 0.16	93

NUDAT/ Wallet Cards Retrieval for A=30-40, $T_{1/2}$>1 min



Nuclear Data (NuDat) Retrieval

Wallet Cards (Ground & Metastable States)

Mass Number: 30-40 **Jpi:**

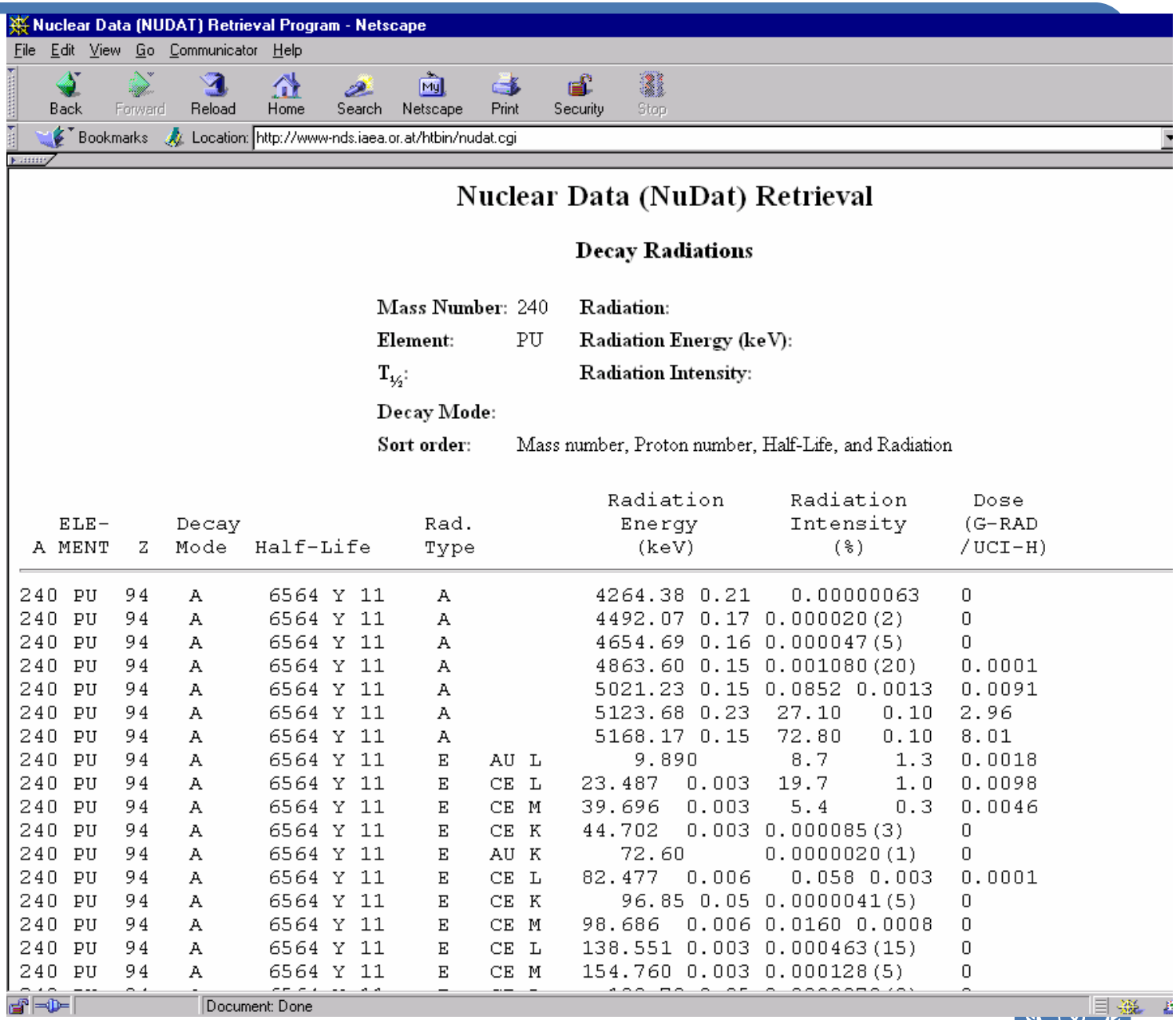
Element: **$T_{½}$:** 1.M-

E_{level}(keV): **Decay Mode:**

Sort order:

A	ELEMENT	Z	Level Energy (Mev)	Mass Excess M-A (MeV)	Jpi	Half-Life	Decay Mode	Decay Branch %	Decay Q (MeV)
30	SI	14	0.0000	-24.4329	0+	STABLE			0.000
30	P	15	0.0000	-20.2006 0.0004	1+	2.498 M 0.004	EC	100.00	4.232
31	SI	14	0.0000	-22.94900(10)	3/2+	157.3 M 0.3	B-	100.00	1.492
31	P	15	0.0000	-24.44100(20)	1/2+	STABLE			0.000
32	SI	14	0.0000	-24.0809 0.0022	0+	172 Y 4	B-	100.00	0.225
32	P	15	0.0000	-24.30530(20)	1+	14.262 D 0.014	B-	100.00	1.711
32	S	16	0.0000	-26.01600(10)	0+	STABLE			0.000
33	P	15	0.0000	-26.3377 0.0011	1/2+	25.34 D 0.12	B-	100.00	0.249
33	S	16	0.0000	-26.58620(10)	3/2+	STABLE			0.000
34	S	16	0.0000	-29.93190(10)	0+	STABLE			0.000
34	CL	17	0.1460	-24.29460(10)	3+	32.00 M 0.04	EC	55.40	5.637
34	CL	17	0.1460	-24.29460(10)	3+	32.00 M 0.04	IT	44.60	0.146
35	S	16	0.0000	-28.84640(10)	3/2+	87.32 D 0.16	B-	100.00	0.167
35	CL	17	0.0000	-29.0135	3/2+	STABLE			0.000
36	S	16	0.0000	-30.66400(20)	0+	STABLE			0.000
36	CL	17	0.0000	-29.52190(10)	2+	301000 Y 3000	B-	98.10	0.709
36	CL	17	0.0000	-29.52190(10)	2+	301000 Y 3000	EC	1.90	0.709
36	AR	18	0.0000	-30.2304 0.0003	0+	STABLE			0.000

NUDAT/ Decay Radiations for ^{240}Pu



Nuclear Data (NuDat) Retrieval

Decay Radiations

Mass Number: 240 **Radiation:**

Element: PU **Radiation Energy (keV):**

$T_{1/2}$: **Radiation Intensity:**

Decay Mode:

Sort order: Mass number, Proton number, Half-Life, and Radiation

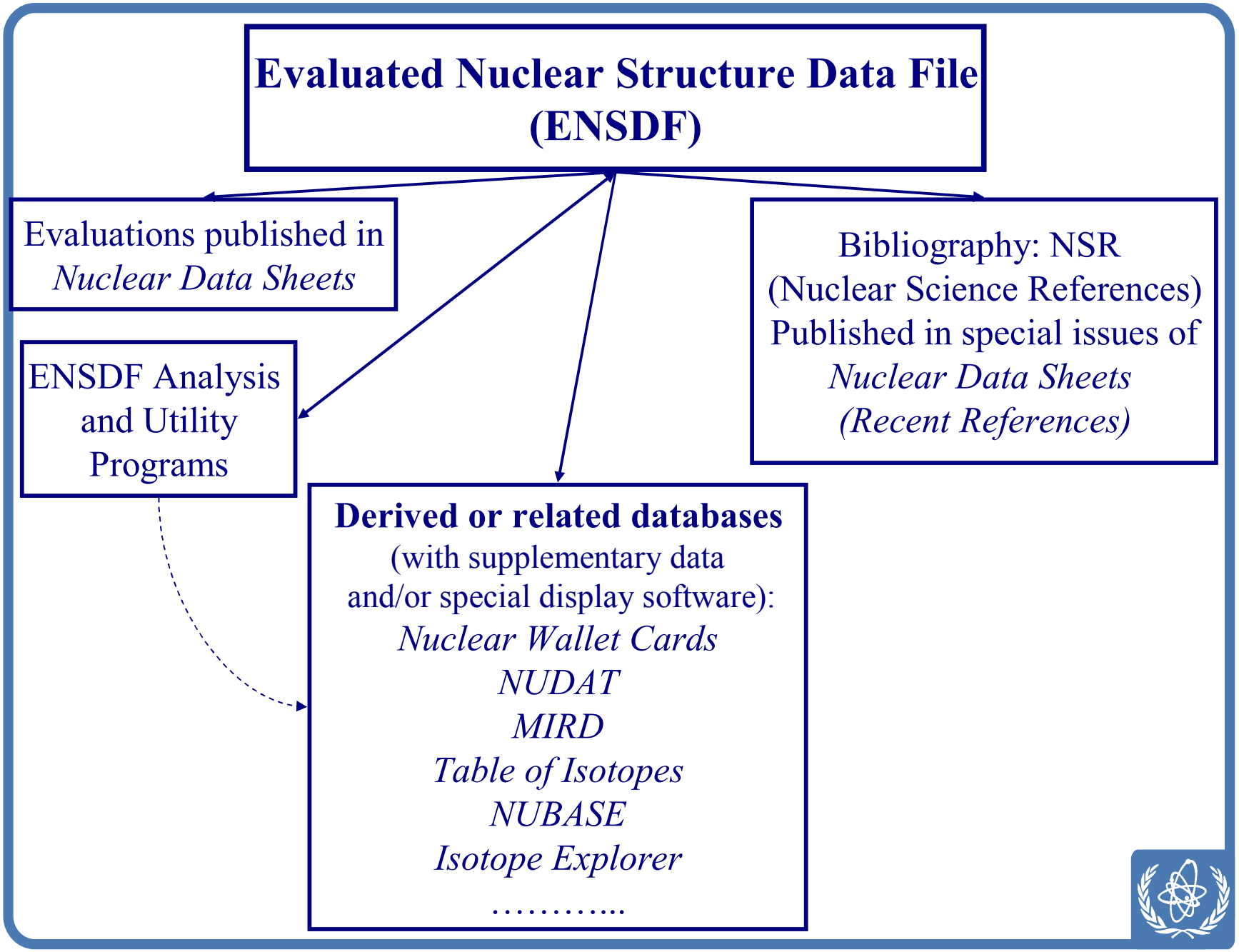
A	ELEMENT	Z	Decay Mode	Half-Life	Rad. Type		Radiation Energy (keV)		Radiation Intensity (%)		Dose (G-RAD/UCI-H)
240	PU	94	A	6564 Y 11	A		4264.38	0.21	0.00000063		0
240	PU	94	A	6564 Y 11	A		4492.07	0.17	0.000020(2)		0
240	PU	94	A	6564 Y 11	A		4654.69	0.16	0.000047(5)		0
240	PU	94	A	6564 Y 11	A		4863.60	0.15	0.001080(20)		0.0001
240	PU	94	A	6564 Y 11	A		5021.23	0.15	0.0852	0.0013	0.0091
240	PU	94	A	6564 Y 11	A		5123.68	0.23	27.10	0.10	2.96
240	PU	94	A	6564 Y 11	A		5168.17	0.15	72.80	0.10	8.01
240	PU	94	A	6564 Y 11	E	AU L	9.890		8.7	1.3	0.0018
240	PU	94	A	6564 Y 11	E	CE L	23.487	0.003	19.7	1.0	0.0098
240	PU	94	A	6564 Y 11	E	CE M	39.696	0.003	5.4	0.3	0.0046
240	PU	94	A	6564 Y 11	E	CE K	44.702	0.003	0.000085(3)		0
240	PU	94	A	6564 Y 11	E	AU K	72.60		0.0000020(1)		0
240	PU	94	A	6564 Y 11	E	CE L	82.477	0.006	0.058	0.003	0.0001
240	PU	94	A	6564 Y 11	E	CE K	96.85	0.05	0.0000041(5)		0
240	PU	94	A	6564 Y 11	E	CE M	98.686	0.006	0.0160	0.0008	0
240	PU	94	A	6564 Y 11	E	CE L	138.551	0.003	0.000463(15)		0
240	PU	94	A	6564 Y 11	E	CE M	154.760	0.003	0.000128(5)		0

MIRD - “Medical Internal Radiation Dose”

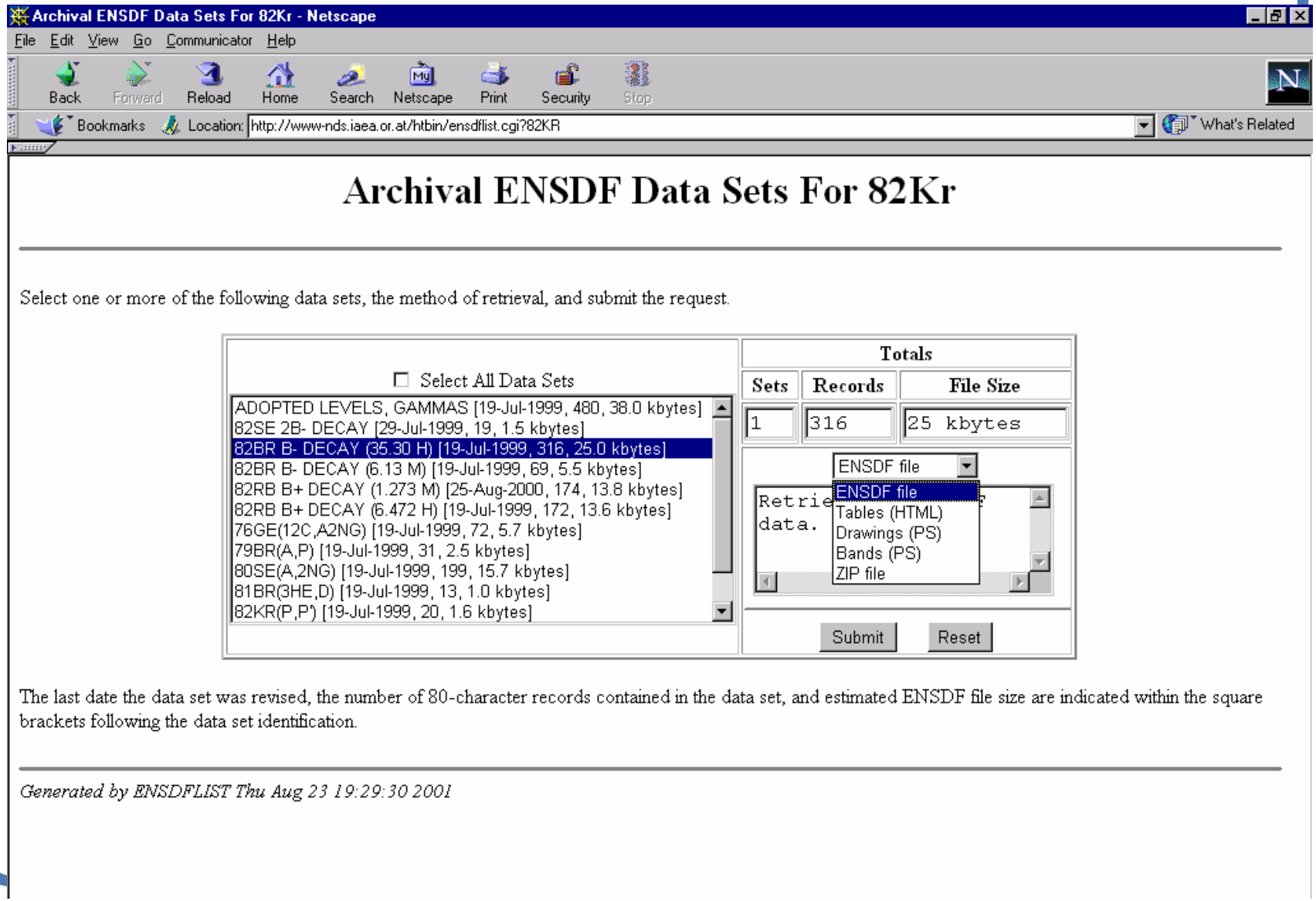
- Based on ENSDF, data processed with code “RADLST”. Input: only nuclide selection
- Output: Tables with intensities, energies and dose of all produced radiations, including X-rays, Auger electrons, etc., and decay scheme plots
- Output in HTML/GIF or PostScript
- NUDAT option “Decay radiations” provides similar function (table only)
- “Advanced” or “custom” tables: use RADLST separately (available for downloading)

ENSDF (Evaluated Nuclear Structure Data File)

- "Master library" for structure and decay data
- International evaluation effort coordinated by IAEA, master file maintained by US-NNDC
- Covers mass range 1 - 277
- Organized by nuclide; several "data sets" per nuclide
- Evaluations done for mass chains (e.g. A=235), published in journal *Nuclear Data Sheets*
- Special internal format
- Standard output: Tables and/or plots (HTML, PostScript)

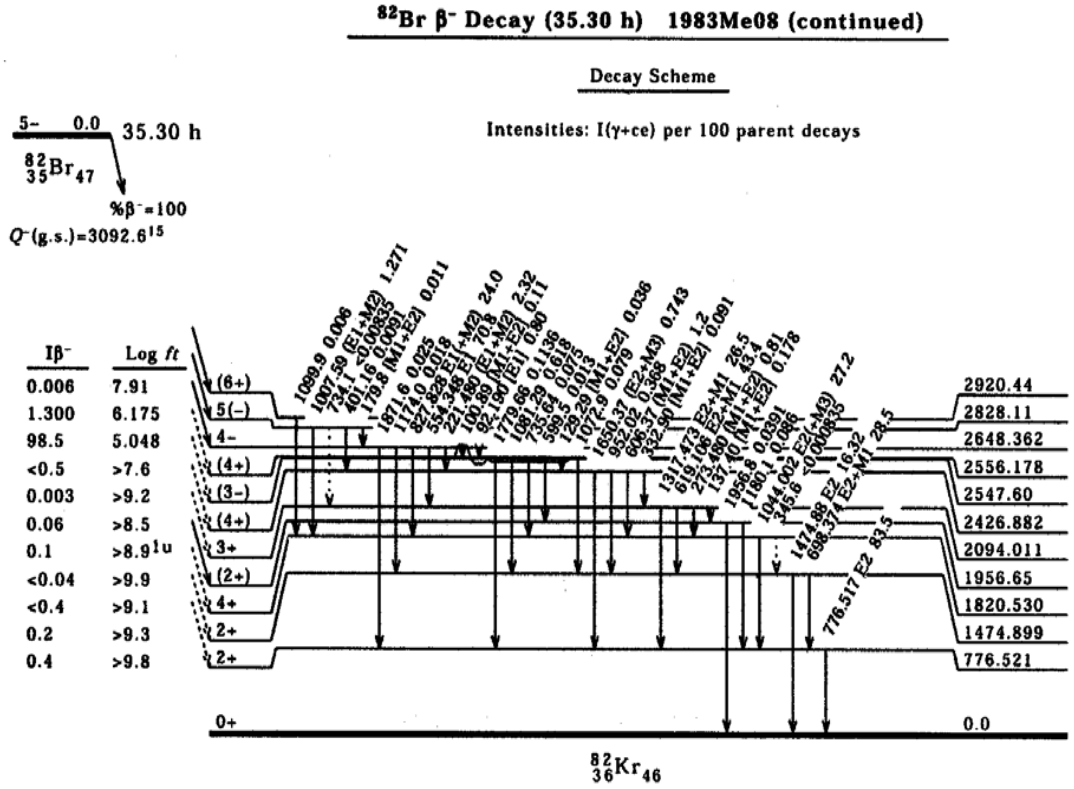

Evaluated Nuclear Structure Data File (ENSDF)
Evaluations published in Nuclear Data Sheets
ENSDF Analysis and Utility Programs
Bibliography: NSR (Nuclear Science References) Published in special issues of Nuclear Data Sheets (Recent References)
Derived or related databases
(with supplementary data and/or special display software):
Nuclear Wallet Cards
NUDAT
MIRD
Table of Isotopes
NUBASE
Isotope Explorer
.....

ENSDF: Data sets for ^{82}Kr



ENSDF Plot (^{82}Br β-decay)

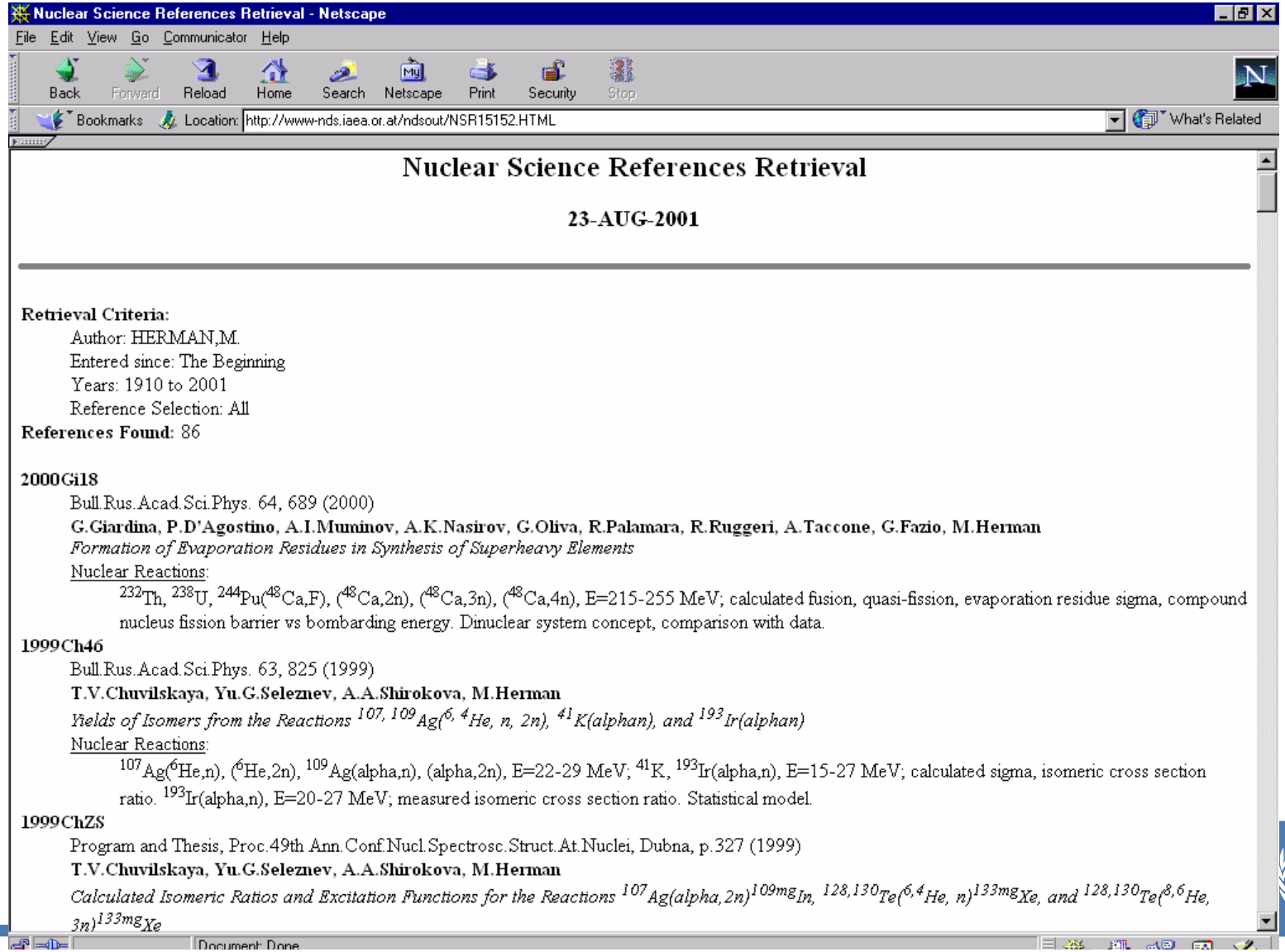
$^{82}_{36}Kr_{46}$ $^{82}_{36}Kr_{46}$



NSR (Nuclear Science References)

- **NSR** (***N****uclear* ***S****cience* ***R****eferences,* previously called *Nuclear Structure References*)
  - Bibliographic database for low and intermediate energy nuclear physics. Main bibliography for structure and decay data and for non-neutron reaction data
  - 1910 - present
  - Published regularly in the journal *Nuclear Data Sheets (Recent References)*
  - Closely linked to ENSDF
  - Retrieval by nuclide, reaction, quantity, keywords, authors,…
  - Access by WWW or Telnet

NSR retrieval (on author)

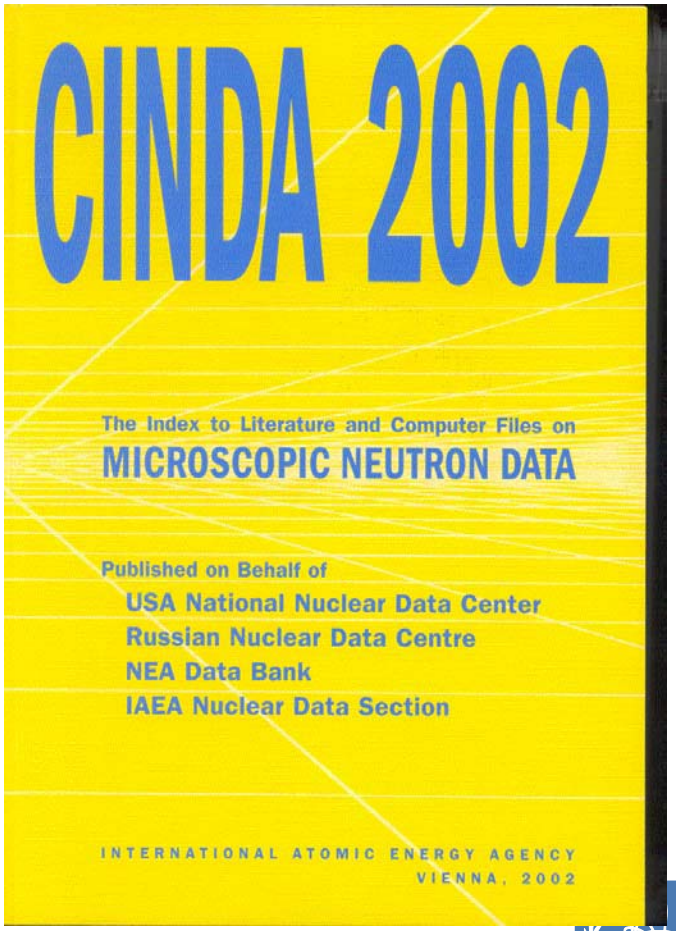


CINDA (Computer Index of Neutron Data)

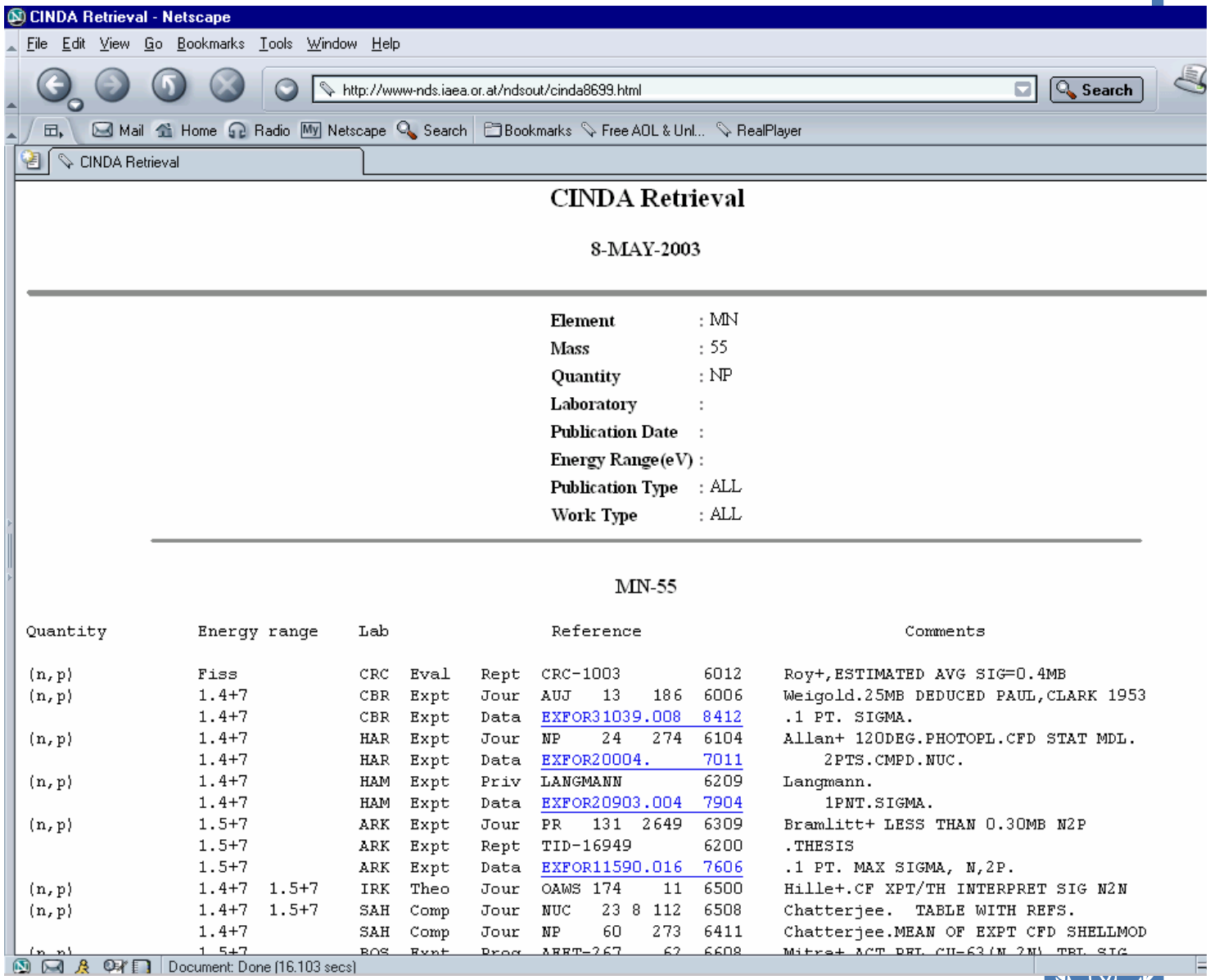
- Bibliography of neutron data (literature, inofficial publications, computer files); (γ,n), (γ,f) and spontaneous fission data also included
- Entries primarily sorted by nuclide, reaction/quantity, laboratory; therefore separate entries for each measured reaction of one publication
- Unique feature: all entries describing the same experiment are listed together ("CINDA blocks")
- Extension of database to include **charged-particle induced** and (all) **photonuclear** reactions is under preparation

CINDA products and retrievals

- **CINDA book**
  - **Complete file contained in several volumes:**
    - **Archival 1935-1987 (5 volumes)**
    - **CINDA2002 (1988-2002)**
- **Selective online retrievals through WWW and Telnet. WWW output with hyperlinks to EXFOR and electronic journals**
- **CD-ROM**



CINDA Retrieval for ^{55}Mn(n,p)



CINDA Retrieval

8-MAY-2003

Element : MN
Mass : 55
Quantity : NP
Laboratory :
Publication Date :
Energy Range(eV) :
Publication Type : ALL
Work Type : ALL

MN-55

Quantity	Energy range		Lab			Reference		Comments
(n,p)	Fiss		CRC	Eval	Rept	CRC-1003	6012	Roy+,ESTIMATED AVG SIG=0.4MB
(n,p)	1.4+7		CBR	Expt	Jour	AUJ 13 186	6006	Weigold.25MB DEDUCED PAUL,CLARK 1953
	1.4+7		CBR	Expt	Data	EXFOR31039.008	8412	.1 PT. SIGMA.
(n,p)	1.4+7		HAR	Expt	Jour	NP 24 274	6104	Allan+ 120DEG.PHOTOPL.CFD STAT MDL.
	1.4+7		HAR	Expt	Data	EXFOR20004.	7011	2PTS.CMPD.NUC.
(n,p)	1.4+7		HAM	Expt	Priv	LANGMANN	6209	Langmann.
	1.4+7		HAM	Expt	Data	EXFOR20903.004	7904	1PNT.SIGMA.
(n,p)	1.5+7		ARK	Expt	Jour	PR 131 2649	6309	Bramlitt+ LESS THAN 0.30MB N2P
	1.5+7		ARK	Expt	Rept	TID-16949	6200	.THESIS
	1.5+7		ARK	Expt	Data	EXFOR11590.016	7606	.1 PT. MAX SIGMA, N,2P.
(n,p)	1.4+7	1.5+7	IRK	Theo	Jour	OAWS 174 11	6500	Hille+.CF XPT/TH INTERPRET SIG N2N
(n,p)	1.4+7	1.5+7	SAH	Comp	Jour	NUC 23 8 112	6508	Chatterjee. TABLE WITH REFS.
	1.4+7		SAH	Comp	Jour	NP 60 273	6411	Chatterjee.MEAN OF EXPT CFD SHELLMOD

Another nuclear bibliography: INIS

- INIS (International Nuclear Information System): a multi-gigabyte general nuclear bibliography maintained by IAEA
- **Not** specialized on nuclear data, **not** maintained by Nuclear Data Section. Wide scope, including reactor technology, nuclear law, nuclear medicine. Occasionally useful for nuclear data searches
- Available through WWW (license required, or through scientific library) or commercial CD-ROM

EXFOR

- Unified computerized system (library and format) by which international, regional and national data analysis centers exchange experimental nuclear reaction data
- Compilation and exchange coordinated by IAEA
- CSISRS = US implementation of EXFOR
- Coverage is complete for neutron data (in particular up to 20 MeV)
- Coverage less complete (but improving) for higher energy neutrons, charged particle-induced and photonuclear data
- More than 60 000 data sets, more than 3 million data points

More on EXFOR

- Library contains numerical tables and structured abstract with experimental and bibliographic information
- Neutron data: bibliographic link to CINDA
  (non-neutron data will be added to CINDA in 1-2 years)
- Main users:
  - Evaluators (EXFOR database is starting point for all evaluations)
  - Applied users, if no evaluation available
  - Anybody measuring or calculating cross section data

Access to EXFOR

- Available for interactive retrievals through WWW and Telnet
- New improved web retrieval available for testing
- Two CD-ROM versions (same database, different retrieval software), developed by NDS
- Complicated retrievals available individually on request from IAEA-NDS
- Output in various formats:
  - Standard format (EXchange FORmat)
  - Computational formats for plotting etc.
  - Online plots for intercomparison with evaluated data: “BNL325”, “ZVView”

EXFOR "Standard" format

Same data in computational ("table") format

e30670.txt - WordPad

File Edit View Insert Format Help

```
SUBENT         30670002     840912                                  30670002    1
BIB                 2          4                                    30670002    2
REACTION    (94-PU-239(N,F),,SIG)                                   30670002    3
STATUS      DATA FROM YUAN HAN-RONG AS PRIV.COMM.,83/12/07, WHICH   30670002    4
            CORRESPOND TO THE CURVE (FIG 4) OF CHINESE J.OF NUCL.   30670002    5
            PHYS.,4,(2) (1982)131.                                  30670002    6
ENDBIB              4                                               30670002    7
NOCOMMON            0          0                                    30670002    8
DATA                3         16                                    30670002    9
EN          DATA        DATA-ERR                                    30670002   10
MEV         B           B                                           30670002   11
 1.0000E+00 1.8600E+00 5.2000E-02                                   30670002   12
 1.2000E+00 1.8760E+00 5.3000E-02                                   30670002   13
 1.4000E+00 1.9840E+00 5.6000E-02                                   30670002   14
 1.6000E+00 1.9580E+00 5.5000E-02                                   30670002   15
 3.4000E+00 1.8520E+00 5.1000E-02                                   30670002   16
 3.6000E+00 1.8240E+00 5.1000E-02                                   30670002   17
 3.8000E+00 1.8250E+00 5.1000E-02                                   30670002   18
 4.0000E+00 1.7960E+00 5.0000E-02                                   30670002   19
 4.2000E+00 1.7810E+00 5.0000E-02                                   30670002   20
 4.4000E+00 1.7670E+00 4.0000E-02                                   30670002   21
 4.6000E+00 1.7560E+00 4.0000E-02                                   30670002   22
 4.8000E+00 1.6980E+00 4.7000E-02                                   30670002   23
 5.0000E+00 1.6960E+00 4.7000E-02                                   30670002   24
 5.2000E+00 1.6640E+00 4.6000E-02                                   30670002   25
 5.4000E+00 1.6600E+00 4.6000E-02                                   30670002   26
 5.6000E+00 1.6830E+00 4.7000E-02                                   30670002   27
ENDDATA            18                                               30670002   28
ENDSUBENT           3                                               3067000299999

PHYSENT             1          0         16 1.0000E+06 5.6000E+06    1  0    0
 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00    1  1    0
 1.0000E+06 0.0000E+00 0.0000E+00 1.8600E+00 5.2000E-02 5.2000E-02    1  1    1
 1.2000E+06 0.0000E+00 0.0000E+00 1.8760E+00 5.3000E-02 5.3000E-02    1  1    1
 1.4000E+06 0.0000E+00 0.0000E+00 1.9840E+00 5.6000E-02 5.6000E-02    1  1    1
 1.6000E+06 0.0000E+00 0.0000E+00 1.9580E+00 5.5000E-02 5.5000E-02    1  1    1
 3.4000E+06 0.0000E+00 0.0000E+00 1.8520E+00 5.1000E-02 5.1000E-02    1  1    1
 3.6000E+06 0.0000E+00 0.0000E+00 1.8240E+00 5.1000E-02 5.1000E-02    1  1    1
 3.8000E+06 0.0000E+00 0.0000E+00 1.8250E+00 5.1000E-02 5.1000E-02    1  1    1
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 4.2000E+06 0.0000E+00 0.0000E+00 1.7810E+00 5.0000E-02 5.0000E-02    1  1    1
 4.4000E+06 0.0000E+00 0.0000E+00 1.7670E+00 4.0000E-02 4.0000E-02    1  1    1
 4.6000E+06 0.0000E+00 0.0000E+00 1.7560E+00 4.0000E-02 4.0000E-02    1  1    1
 4.8000E+06 0.0000E+00 0.0000E+00 1.6980E+00 4.7000E-02 4.7000E-02    1  1    1
 5.0000E+06 0.0000E+00 0.0000E+00 1.6960E+00 4.7000E-02 4.7000E-02    1  1    1
 5.2000E+06 0.0000E+00 0.0000E+00 1.6640E+00 4.6000E-02 4.6000E-02    1  1    1
 5.4000E+06 0.0000E+00 0.0000E+00 1.6600E+00 4.6000E-02 4.6000E-02    1  1    1
 5.6000E+06 0.0000E+00 0.0000E+00 1.6830E+00 4.7000E-02 4.7000E-02    1  1    1
```
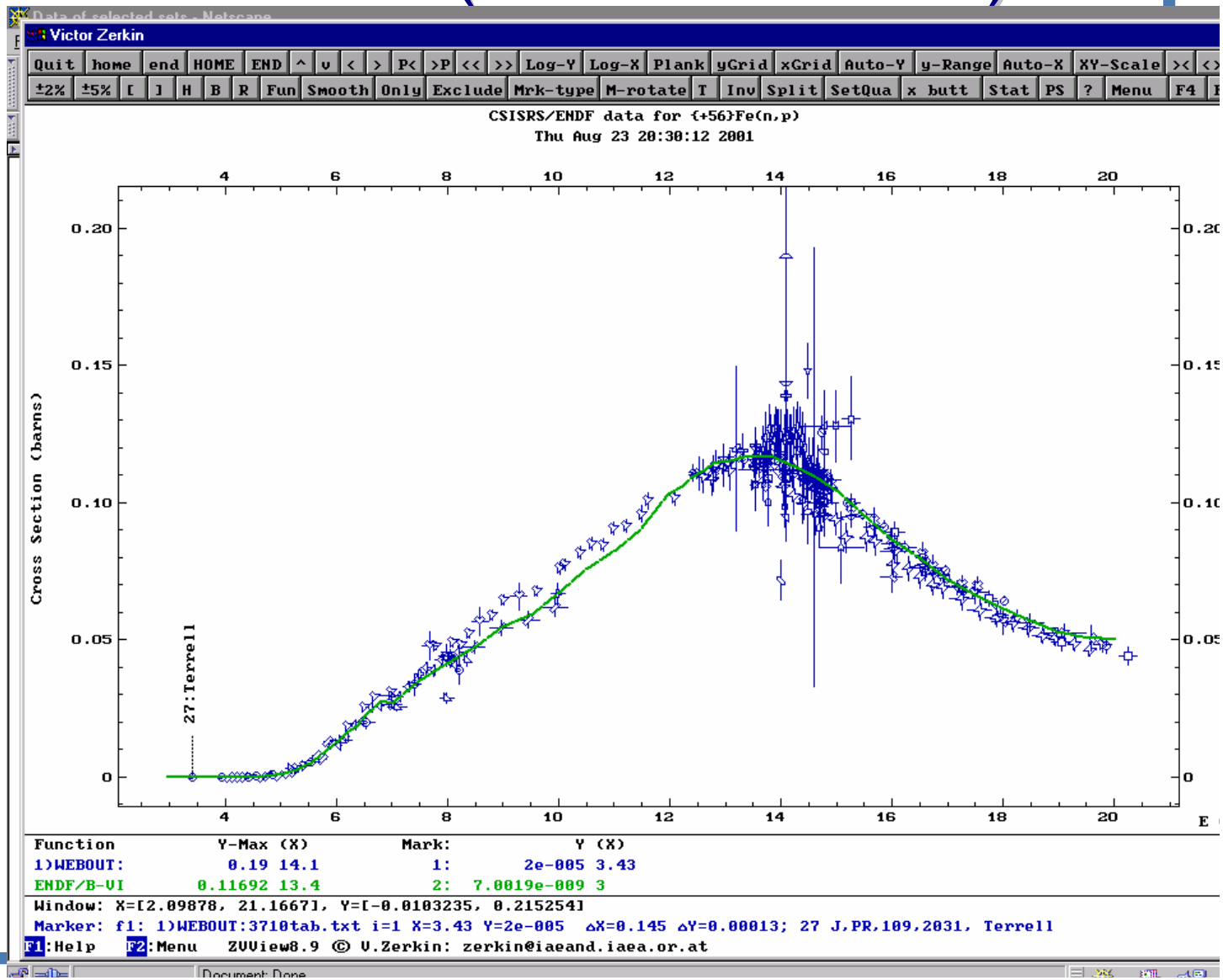

For Help, press F1

EXFOR retrieval (WWW/ZVView)

^{56}Fe(n,p) cs Exp. data with ENDF/B-VI evaluation



ENDF (Evaluated Nuclear Data File)

- ENDF-6: internationally agreed format for evaluated nuclear reaction data (and related decay data). Used for major libraries ENDF/B-VI, JEF, BROND, JENDL, CENDL, and others
- ENDF/B-VI: Version 6 of the U.S. nuclear data library, released by US-NNDC
  - Contents: for summary see report IAEA-NDS-100
  - Format Manual: BNL-NCS-44945(=ENDF-102), Rev.April 2001
  - Summary documentation of evaluations: BNL-NCS-17541, 4th ed. (=ENDF-201), 1991, with supplement (1996)

Contents of ENDF/B-VI

- **ENDF/B-VI General Purpose Library** (320 materials from ^{1}H to ^{99}Es. Neutron data, mostly 0-20 MeV, some materials extended to 150 MeV)
  - Basic file
  - 300 K point data file (Resonance parameters converted to cross sections)
- **Subfiles** for *Standards, Dosimetry, Neutron activation, Fission products cs data, Actinides cs data* are included in General Purpose file but are available separately
- Other **sublibaries** for:
  - Incident charged particles
  - Decay data
  - Photo-atomic interaction
  - Thermal scattering law data
  - Fission product yields (neutron-induced and spontaneous)
  - High-energy (up to 1 GeV), incident neutrons and protons, few materials only

ENDF File Structure

- "Sublibrary" determines incident particle and basic data type (neutron data, proton data, decay data,…)
- Hierarchical file organization:
  - "Tape" (Unit of data release, full sublibrary or update)
    - Material (MAT number, up to 4 digits)
      - File (MF number): Data category
        - Section (Reaction Type, MT number).

File numbers (MF):
1=General information
2=Resonance parameters
3=reaction cs
4=angular distributions
5=energy distributions
6=energy-angular distributions
8=decay data
etc.

Reaction Type numbers (MT):
1=total cs
16=(z,2n) cs (z=projectile dep. on sublibrary)

102=(z,γ) cs
103=(z,p) cs
etc.

Access to major ENDF libraries

- **Major libraries** ENDF/B-VI, JEF, BROND, JENDL, CENDL available online through Telnet and WWW (interactive, retrieval by material, reaction and data type, energy): database **"ENDF"**
- Various **utilities** for file handling, plotting, pre-processing: ENDF *Pre-Processing Codes* and *Utility Codes*, available for downloading
- **CD-ROM** (libraries and codes), only from IAEA *(WINENDF)*. Separate: "POINT2003" (Point data from ENDF/B-VI at 8 temperatures)
- **Output:**
  - ENDF-format (all definitions coded with numerical flags)
  - Table format and plots available online

2.2 Selected Specialized Libraries (including many IAEA products)

- FENDL-2
- IAEA Photonuclear Data Library
- Medical Radiosotope Prod. Cs Library
- RNAL
- RIPL-2
- ……

FENDL-2 (Fusion Evaluated Nuclear Data Library)

- Result of **worldwide effort** coordinated by IAEA
- Aimed at **fusion** applications (ITER project)
- Extensively **tested**, therefore recommended also for other applications
- **Sublibraries:**
  - FENDL-E/2.0: **Transport:** n-interactions, γ-production for 57 nuclides; photon-atom interactions for 34 elements; basic data as well as processed data for MCNP and **multigroup** calculations
  - FENDL/A-2.0: **Activation** (636 nuclides, 11000 reactions)
  - FENDL/C-2.0: **Fusion** (light charged-particle fusion reactions)
  - FENDL/D-2.0: **Decay data** for 2900 nuclides
  - FENDL/DS-2.0: **Neutron activation** reactions from IRDF-90
- Available for downloading from IAEA website and on CD-ROM (47 directories, 810 files, 1 Gbyte data)

IAEA Photonuclear Data Library

- Evaluated photonuclear data for 164 nuclides mostly up to 140 MeV
- Cross sections and emission spectra
- Result of IAEA CRP
- Available from IAEA website
- Handbook IAEA-TECDOC-1178 (October 2000)
- Various applications: radiation shielding, radiotherapy, waste transmutation and others

Charged-particle cross section database for medical radioisotope production

- Evaluated cross sections for 48 reactions induced by light charged particles with incident energies of several tens of MeV (max.100)
  - Production cross sections for diagnostic radioisotopes
  - Cross sections for beam monitor reactions
- Result of IAEA CRP
- Data and documentation available from NDS website
- Handbook IAEA-TECDOC-1211 (May 2001)

RNAL (Reference Neutron Activation Library)

- Evaluated cross sections for 255 neutron-induced reactions leading to radioactive products
- For activation analysis and various other applications
- Product of IAEA CRP. Evaluations extracted from various projects
- Data, plots, and documentation available from NDS website and on CD-ROM

RIPL-2 (Reference Input Parameter Library for Nuclear Model Calculations)

- Result of IAEA coordinated project, released 2003
- Input parameters for theoretical calculations of nuclear reaction cross sections involving light particles up to about 100 MeV
- Contents:
  - Atomic masses and deformations
  - Discrete level and decay schemes
  - Spacings of neutron resonances
  - Optical model parameters
  - Level densities
  - Gamma-ray strength functions and giant resonance parameters
  - Fission barriers
- Available from IAEA web pages and on CD-ROM. Handbook (IAEA-TECDOC) in preparation

MENDL-2 and MENDL2-P
(Medium Energy Nuclear Data Library)

- Libraries for activation and transmutation (formation of radioactive product nuclides) at indermediate energies, for 505 stable and unstable target nuclides between ^{26}Al and ^{210}Po, by Shubin et al., Obninsk, Russia
- Based largely on calculations
- MENDL-2: Neutron-induced reactions up to 100 MeV, altogether 57500 reactions
- MENDL2-P: Proton-induced reactions up to 200 MeV, altogether 87000 reactions
- Available by FTP or off-line

Databases for Reactor Dosimetry

- IRDF-90: International Reactor Dosimetry File (Version 2 of 1993): Cross sections for neutron dosimetry by foil activation, radiation damage cross sections, benchmark neutron spectra.
  New version IRDF-2002 is being finalized
- RRDF-98: Russian Reactor Dosimetry File. Cross sections and covariance data for 22 reactions
- NMF-90: Neutron Metrology File. Integrated database for neutron spectrum unfolding calculations (PC codes and data).

Data for Actinides and Fission Products

- Neutron cross sections for actinides, fission product yields, and cross sections and decay data for fission products, are included in major evaluated neutron data libraries
- Some special libraries:
  - **Minsk Actinides Library** by Maslov et al: Evaluated neutron reaction data for Th-232, Pa, U, Np, Pu, Am and Cm isotopes (1995-2003). Available on WWW
  - **WIND** and **WIND-2**: For waste incineration. Neutron cross sections for U, Np, Pu isotopes up to 100 MeV. Proton data for ^{238}U. Neutron activation data for ^{239}Pu up to 2 GeV.
  - **SGNucDat** (Nuclear Data for Safeguards). Actinides and fission products data for safeguards. Available from WWW, on diskette and as handbook

Latest additions

- PGAA-IAEA: Database for prompt gamma-ray neutron activation analysis
  - 32000 prompt γ rays
  - 3000 γ rays emitted by radioactive decay
  - Data for all stable isotopes
  - γ energies, partial production cross sections, k_0 factors (relative to H standard), all with uncertainties
- IBANDL: Experimental cross sections for ion beam analysis

And there is much more….

- Many additional data libraries available from NDS can be found in IAEA-NDS-7 (*http://www-nds.iaea.or.at/reports/nds-7.pdf*)
- Direct links to some minor databases, and index of IAEA-NDS-documentation series: IAEA-NDS-0 (*http://www-nds.iaea.or.at/nds-0.html)*

3. Data Access and Services

- WWW
- FTP
- Telnet
- Mail and hardcopy
- Computer codes

- Alternative entry points
- How to reference the data
- Future trends

Online Services

- IAEA-NDS:
  - WWW (Worldwide Web):
    - Interactive access to most important libraries
    - IAEA Nuclear Data Guide
    - Documents, Links, General information
  - FTP (Internet File Transfer):
    - downloading complete files, libraries and documents
  - Telnet service (NDIS) *(will be phased out)*
    - Interactive access to most important libraries, some utilities and documents
- *US-NNDC, OECD/NEA Data Bank* (restricted), partly other centers, offer similar services

WWW (Worldwide Web)

- ***IAEA Nuclear Data Services*** homepage:
  http://www-nds.iaea.or.at or
  http://www-nds.iaea.org

- Brazil mirror server:
  http://www-nds.ipen.br

- General IAEA homepage:
  http://www.iaea.org "Worldatom"

FTP (Internet file transfer)

- Command: ftp iaeand.iaea.or.at *or* ftp iaeand.iaea.org
- IAEA-NDS keeps several FTP accounts requiring no password:
  - ANONYMOUS contains several complete libraries and utility codes
  - FENDL2 contains FENDL-2 files
  - RIPL contains RIPL-1 files
  - NDSONL contains files saved by Telnet users
  - NDSOPEN for bilateral file exchange

Mail and hardcopy services by NDS

- Data by mail
  - Complete files on magnetic tape, CD-ROM or diskette
  - Specific retrievals on diskette, printout or by e-mail
- Hardcopy documents
  - Manuals and data library documentation
  - Handbooks
  - Meeting reports
  - Research reports
  - Nuclear Data Newsletter

Many new documents (almost all of those published by NDS) are made available also on the WWW in PDF format.

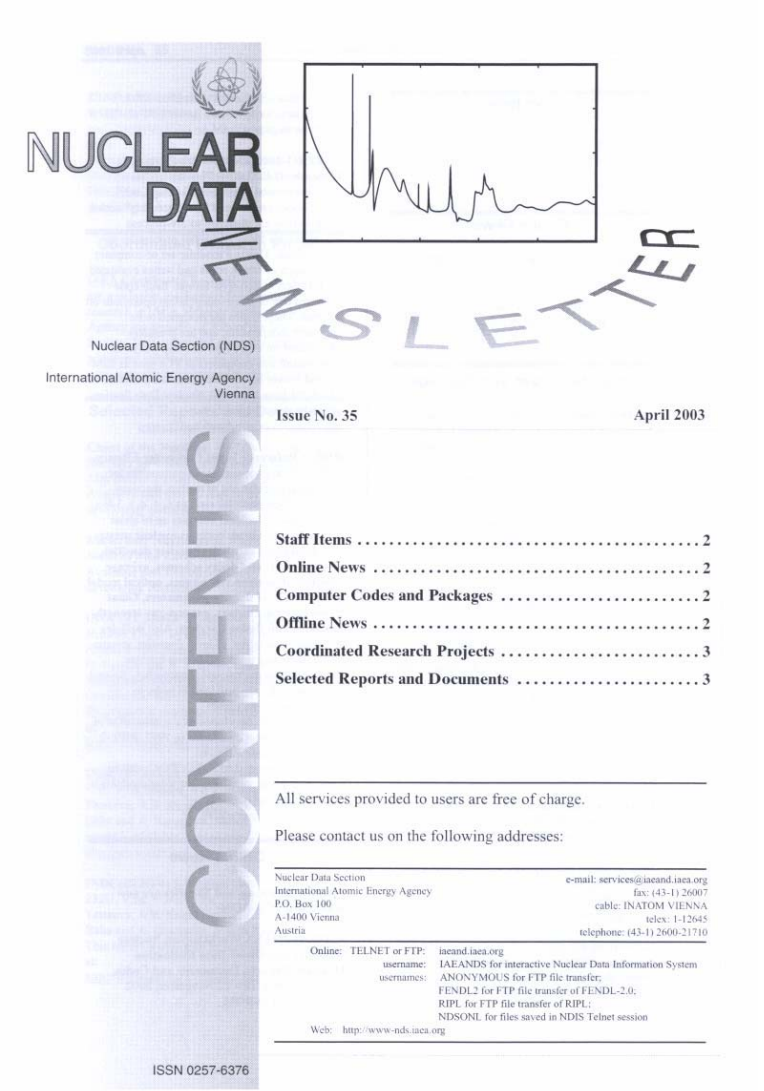
How to request mail services

- e-mail:
  services@iaeand.iaea.org for data requests,
  online@iaeand.iaea.org for questions on online services, or
  schwerer@iaeand.iaea.org
- Fax: +43-1-26007
- Mail:

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

Want to be kept informed?

Available as hardcopy and from WWW in PDF format



NUCLEAR DATA NEWSLETTER

Nuclear Data Section (NDS)

International Atomic Energy Agency
Vienna

Issue No. 35 April 2003

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Online News 2
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Coordinated Research Projects 3
Selected Reports and Documents 3

All services provided to users are free of charge.

Please contact us on the following addresses:

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International Atomic Energy Agency
P.O. Box 100
A-1400 Vienna
Austria

e-mail: services@iaeand.iaea.org
fax: (43-1) 26007
cable: INATOM VIENNA
telex: 1-12645
telephone: (43-1) 2600-21710

Online: TELNET or FTP: iaeand.iaea.org
username: IAEANDS for interactive Nuclear Data Information System
usernames: ANONYMOUS for FTP file transfer;
FENDL2 for FTP file transfer of FENDL-2.0;
RIPL for FTP file transfer of RIPL;
NDSONL for files saved in NDIS Telnet session
Web: http://www-nds.iaea.org

ISSN 0257-6376

Computer codes

- Most computer codes for nuclear data processing have to be requested from the OECD-NEA Data Bank at Issy-les-Moulineaux near Paris, France (or from Radiation Shielding Information Computational Center (RSICC), Oak Ridge, for codes originating from USA)
- The following codes are available from NDS (mostly also on CD-ROM):
  - EMPIRE-II: System of codes for nuclear reaction calculations
  - ENDF Utility codes and ENDF Preprocessing codes
  - ENDVER: ENDF verification support package
  - ENSDF analysis and utility programs
  - ZVVIEW package for interactive plotting

Alternative entry points

- Same basic data are available online (or on CD-ROM) from various sources
- Possible reasons for using alternative sources:
  - Better network connection to your location
  - Different user interface
- Possible problems:
  - Sources from outside the *Data Centers Networks* may not always be fully up-to-date
  - Some products available only commercially

How to reference the data

- Data obtained from databases of the Nuclear Data Centers Networks should be properly cited
- Citation should include
  - original source of information **and**
  - database from which data were extracted (which may contain essential information not existing in a published article) with date of retrieval
- Example: How to cite the MENDL-2 library
  - Yu.N. Shubin, V.P. Lunev, A.Yu. Konobeyev, A.I. Ditjuk, “Cross-section data library MENDL-2 to study activation as transmutation of materials irradiated by nucleons of intermediate energies”, report INDC(CCP)-385 (International Atomic Energy Agency, May 1995). Data library MENDL-2 received from the IAEA Nuclear Data Section
- Detailed citation guidelines for data retrieved online:
  - V. McLane, Citation Guidelines for Nuclear Data Retrieved from Databases Resident at the Nuclear Data Centers Network, Report BNL-NCS-63381 (July 1996). Available online in PostScript from *http://www-nds.iaea.or.at/ndspub/documents/online/*

Nuclear data services: Trends

- Advanced database software, combined "nuclear reaction database" with common user interface
- Databases on CD-ROM with retrieval software (and, optionally, update possibility through Internet), in parallel to online service
- "Mirror sites" to improve WWW accessibility worldwide
- *IAEA-NDS* intends to keep all ways of data distribution for medium term future, with emphasis on WWW and CD-ROM

4. Conclusion

- Starting point for nuclear data searches: IAEA Nuclear Data Services

  http://www-nds.iaea.or.at or *http://www-nds.iaea.org*

  - Most complete collection of nuclear data libraries with documentations published in *IAEA-NDS*- report series
  - Online services
  - Customized retrievals and off-line data service available cost-free on request
- What are the most important databases for your field of application? Send your feedback to IAEA-NDS
- Data requests and feedback: e-mail to *services@iaeand.iaea.or.at*

IAEA headquarters (Vienna International Centre)