



**The Abdus Salam  
International Centre for Theoretical Physics**



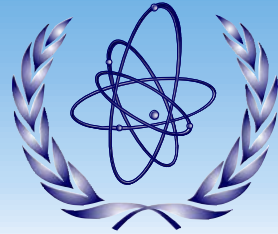
**2055-24**

**Joint ICTP/IAEA School on Physics and Technology of Fast Reactor Systems**

*9 - 20 November 2009*

**Nuclear Data for Fast Reactor Systems - 1**

D. Abriola  
*International Atomic Energy Agency  
IAEA  
Vienna*



**International Atomic Energy Agency**

**Nuclear Data  
for  
Fast Reactor Systems**

**D. Abriola**

**Nuclear Data Section  
Department of Nuclear Sciences and Applications**

**ICTP Trieste, Nov. 2009**

# Nuclear Data for Fast Reactor Systems

Nuclear Data

Nuclear Reactions

Nuclear structure and decay



# Nuclear Data for Fast Reactor Systems

## Nuclear Reactions

**X (a , b) Y**

**X = Target    a = Projectile**

**Y = Residual    b = Ejectile**



# Nuclear Data for Fast Reactor Systems

Neutron-induced reactions

**$X (n , x) Y$**

**$X = \text{Target} \quad n = \text{Projectile}$**

**$Y = \text{Residual} \quad x = \text{Ejectile}$**

**i.e if  $x = n$  the reaction is scattering**

**i.e. If  $x = \gamma$  the reaction is Radiative Capture**



# Nuclear Data for Fast Reactor Systems

The probability that a reaction occurs depends on Energy

Temperature (K)	Energy (eV)	Speed (m/s)
300	0.026	2200
1000	0.086	4000

**“slow” or thermal neutrons  $\rightarrow E \sim 0.03 \text{ eV}$**

**“fast” neutrons  $\rightarrow E \sim 1 \text{ MeV}$**



# Nuclear Data for Fast Reactor Systems

For Slow neutrons

**The most important reactions:**

- **Scattering** (ELA:  $(n,n)$  ; INE:  $(n,n')$ )
- **Capture:**
  - $(n,\gamma)$
  - $(n,\alpha)$  only low Z
  - $(n,p)$  only low Z
  - $(n,f)$



# Nuclear Data for Fast Reactor Systems

For Fast neutrons

**The most important reactions:**

- **Scattering** (ELA:  $(n,n)$  ; INE:  $(n,n')$ )

- **Capture:**

$(n,\gamma)$

$(n,\alpha)$  ;  $(n,2n)$  ;  $(n,3n)$  ...

$(n,p)$  ;  $(n,np)$  ;  $(n,2np)$ ...

$(n,f)$





# Nuclear Data for Fast Reactor Systems

## Cross Section

**The probability of a particular reaction is proportional to its “cross section”**

**Let us assume a uniform beam of neutrons of intensity  $I$  (neutrons/cm<sup>2</sup>s)**

**The target is a layer “one atom thick” of  $N$  atoms/cm<sup>2</sup> and  $C$  is the number of interactions for example neutron captures per cm<sup>2</sup>s**



# Nuclear Data for Fast Reactor Systems

## Cross Section

Then the cross section  $\sigma$  is defined:

$$\sigma = \frac{C \text{ (n/cm}^2\text{.s)}}{I \text{ (n/cm}^2\text{.s)} \quad Na \text{ (nucleus/cm}^2\text{)}}$$

Units:  
(cm<sup>2</sup> per nucleus)



# Nuclear Data for Fast Reactor Systems

## Cross Section

### Rearranging terms:

$$\sigma_{Na} = \frac{C}{I}$$

If every neutron falling on target reacted, then  $C=I$   
fraction reacting = 1 (100%)

$\sigma_{Na}$  Represents the fraction of surface that undergoes capture. That is from one cm<sup>2</sup>

$$\sigma_{Na} \text{ cm}^2$$

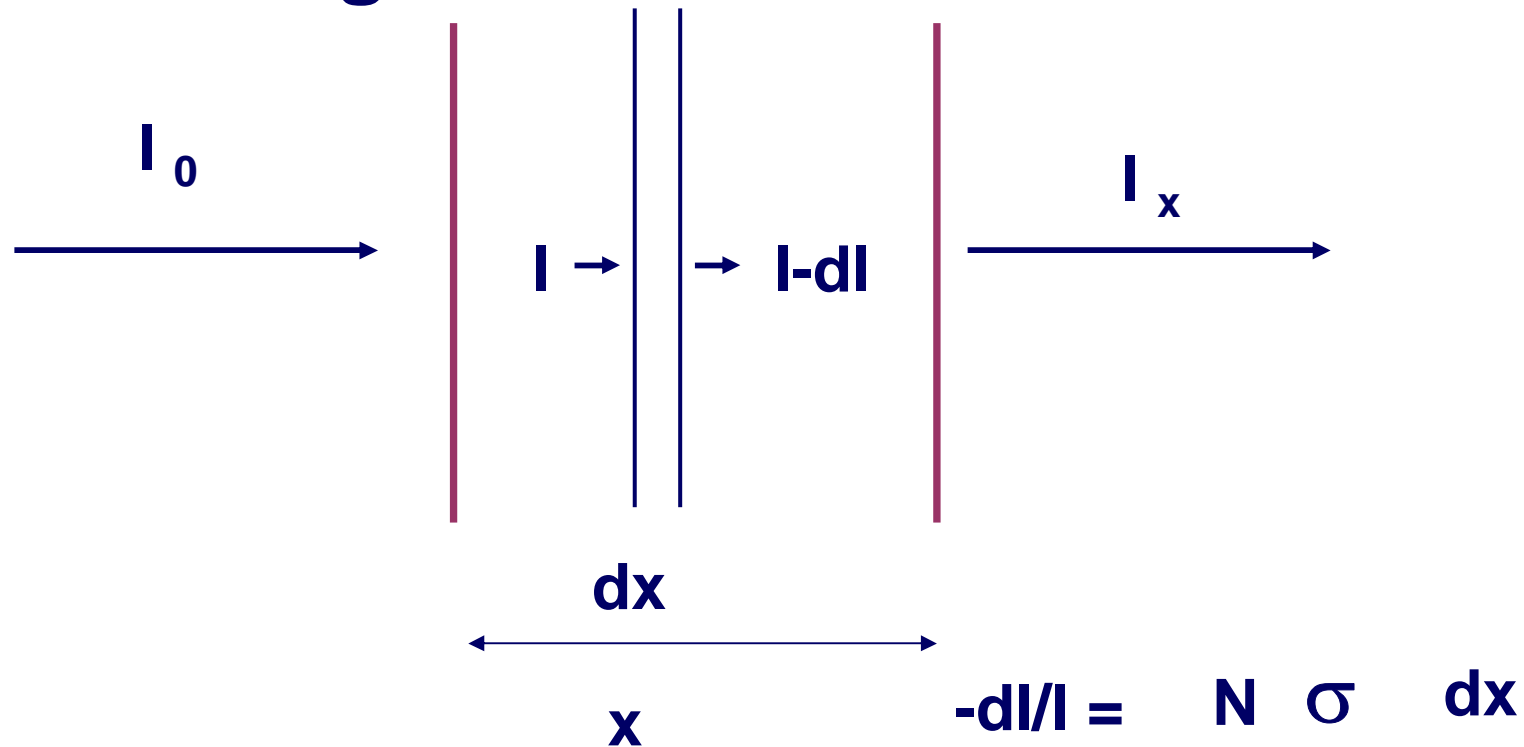


# Nuclear Data for Fast Reactor Systems

## Cross Section

Now generalizing to any thickness:

$N = \text{\#of target nucleus/cm}^3$



# Nuclear Data for Fast Reactor Systems

Cross Section

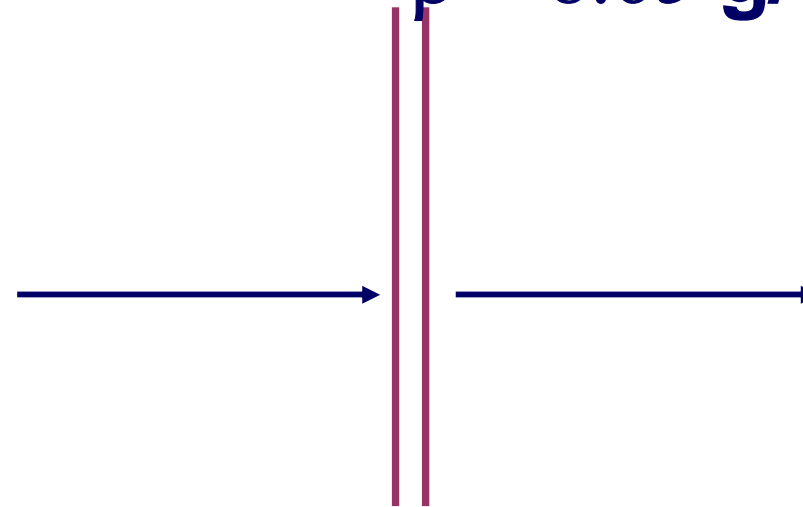
Integrating....

$$\frac{I_x}{I_0} = e^{-N \sigma x}$$

$$\frac{I_x}{I_0} = 0.30$$

Example: Cd

$$\rho = 8.65 \text{ g/cm}^2$$

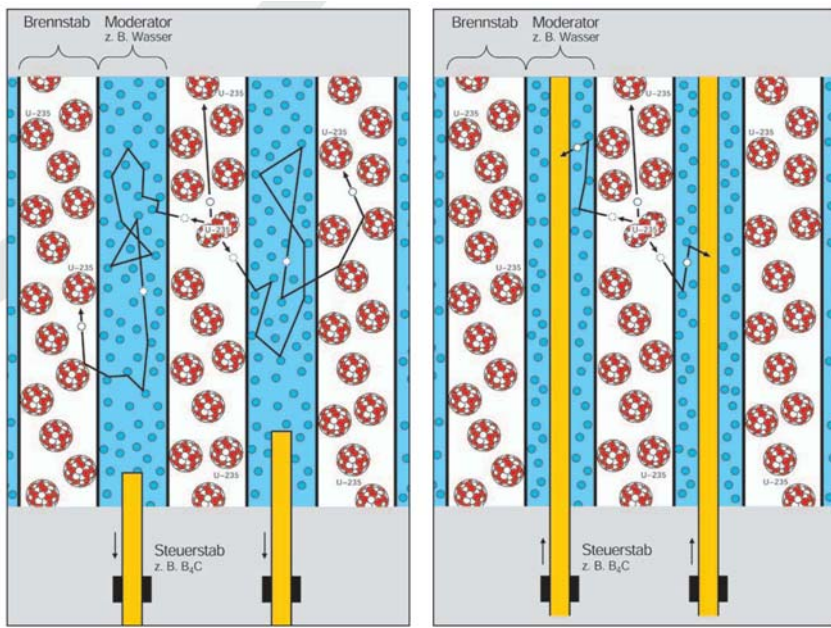


$$dx = 0.01 \text{ cm}$$

$$\sigma = ?$$



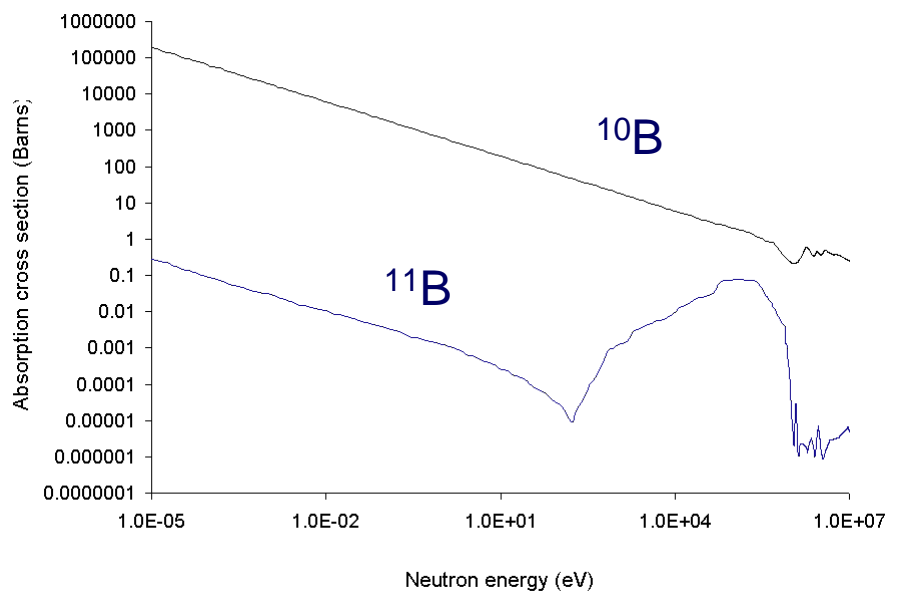
# Neutron-induced reactions



a) Anfahren eines Reaktors ( $k > 1$ )  
 b) Abschalten des Reaktors ( $k < 1$ )

Abb. 5.10: Stellung der Steuerstäbe beim Anfahren und beim Abschalten eines Reaktors

## Control Rod Insertion



## Boron-10 Thermal Absorption Cross Section

# Nuclear Data for Fast Reactor Systems

Nuclear Data

Nuclear Reactions

**Nuclear structure and decay**



# Nuclear structure and decay

Beta decay

B<sup>-</sup>, B<sup>+</sup>

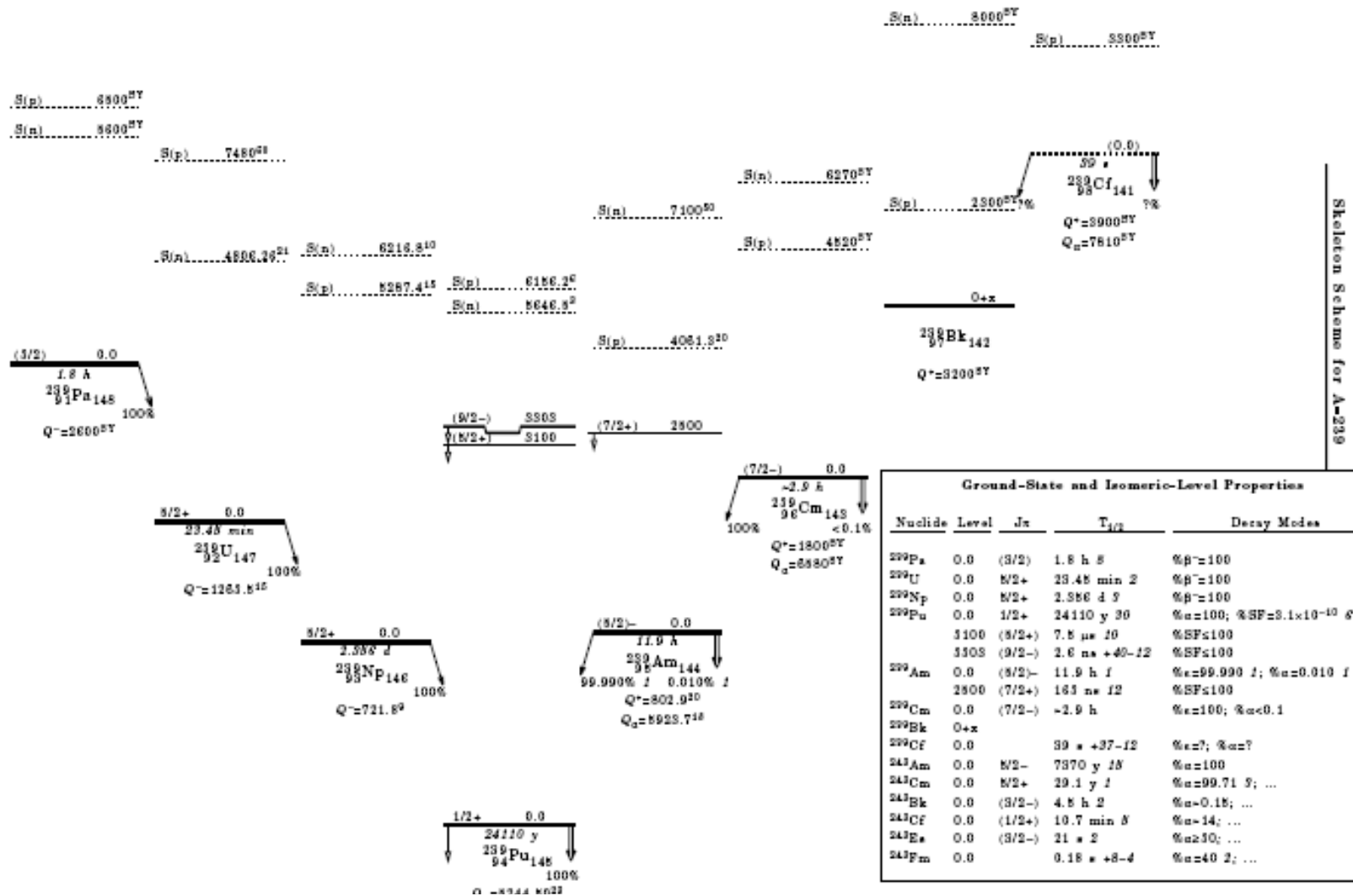
Beta-delayed neutrons

Alpha decay

Exotic decays...



# Example: A=239



# Where to get nuclear data?

# Nuclear Data for Fast Reactor Systems

## International Nuclear Data Centers

**IAEA – Nuclear Data Section**

**[www-nds.iaea.org](http://www-nds.iaea.org)**

**OECD – Nuclear Energy Agency Data Bank**

**[www.nea.fr](http://www.nea.fr)**

**CERN – Particle Data Group**

**[www.cern.ch](http://www.cern.ch)**



# Nuclear Data for Fast Reactor Systems

## National Nuclear Data Centres

BNL – National Nuclear Data Center

JAEA – Japan Atomic Energy Agency

IPPE Obninsk – Nuclear Data Center

TUNL Nuclear Data Project

...(\*)

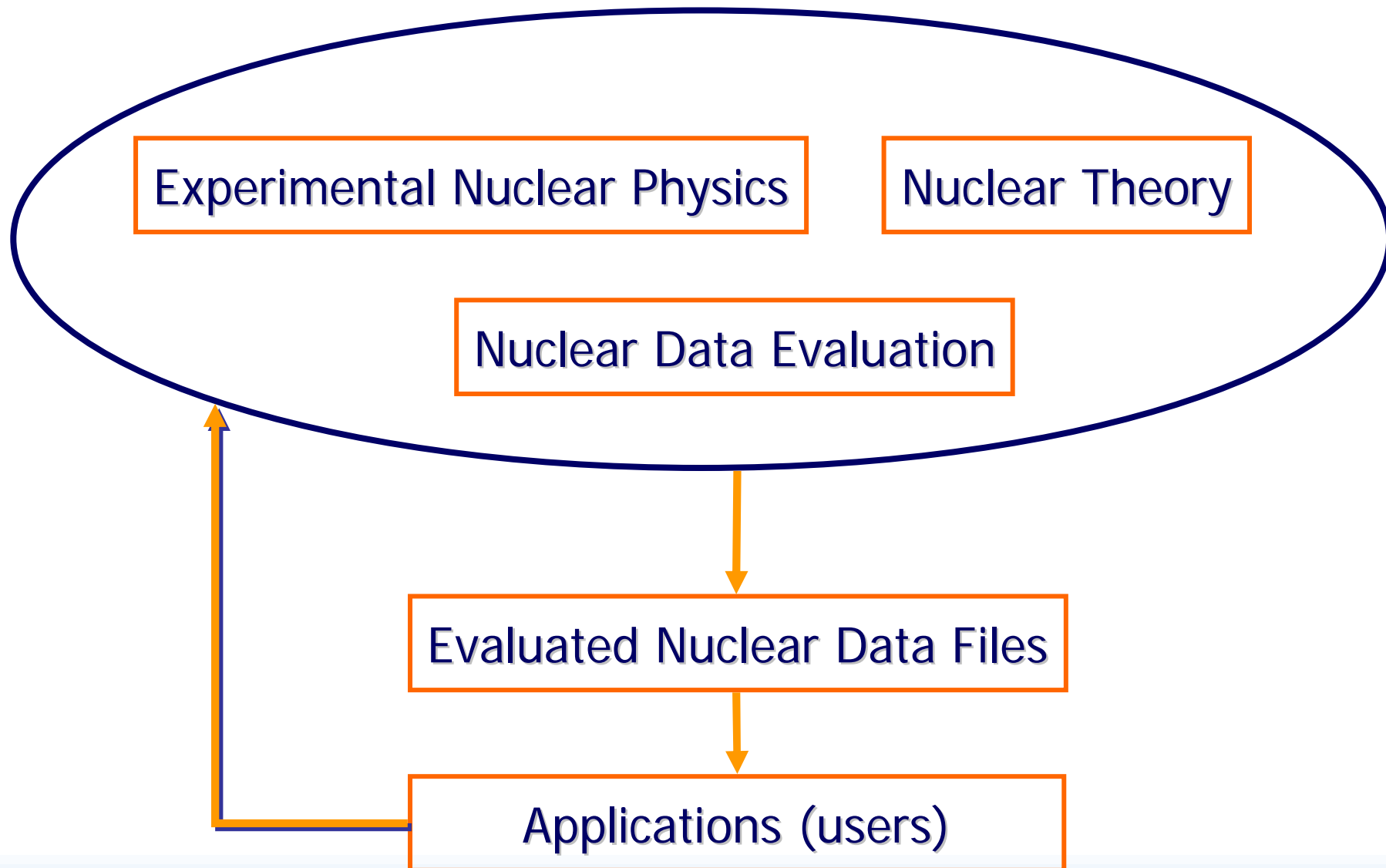
\* for a longer list see this [JAEA link](#)

D.Abriola, ICTP FRSystems 2009

International Atomic Energy Agency



# Nuclear Data for Fast Reactor Systems



# Nuclear Data for Fast Reactor Systems

## Nuclear Data: Libraries

Experimental : EXFOR

Evaluated : ENDF/B, JENDL, JEF, BROND, ... (reactions)  
ENSDF (nuclear structure)  
FENDL (nuclear data for fusion applications)

Bibliographic : NSR, CINDA, ...

Others : RIPL (nuclear model parameters)  
IRDF (reactor dosimetry file)  
IBANDL (ion beam analysis)  
NACRE (nuclear astrophysics)



## Nuclear Data: Libraries

- Applications :
- ADS-lib, FENDL-2.1
  - Medical radioisotope production  
(charged-particles reactions)
  - Prompt Gamma-ray Activation Analysis (PGAA)
  - Photonuclear
  - Thermal neutron capture gamma-ray



## Nuclear Data: Libraries

- Applications :
- ADS-lib, FENDL-2.1
  - Medical radioisotope production  
(charged-particles reactions)
  - Prompt Gamma-ray Activation Analysis (PGAA)
  - Photonuclear
  - Thermal neutron capture gamma-ray





# Nuclear Data for Fast Reactor Systems

## Example: part of an evaluated data file

Z and A values	nuclear mass		formalism flag	number of resonances	material number	MF number	MT number
7.919700+4	1.952740+2	0	0	1	07925	2151	1
7.919700+4	1.000000+0	0	0	1	07925	2151	2
1.000000-5	5.000000+3	1	2	0	07925	2151	3
1.500000+0	9.800000-1	0	0	1	07925	2151	4
1.952740+2	0.000000+0	0	0	1578	2637925	2151	5
-3.380000+1	2.000000+0	2.562000-1	1.562000-1	1.000000-1	0.000000+07925	2151	6
4.906000+0	2.000000+0	1.377000-1	1.520000-2	1.225000-1	0.000000+07925	2151	7
4.645000+1	1.000000+0	1.241300-1	1.300000-4	1.240000-1	0.000000+07925	2151	8
5.810000+1	1.000000+0	1.164000-1	4.400000-3	1.120000-1	0.000000+07925	2151	9

Labels for columns (from left to right):  
 Z and A values, nuclear mass, (blank), formalism flag, number of resonances, material number, MF number, MT number.

Labels for rows (from bottom to top):  
 resonance energy, spin, total width, neutron width, gamma width, fission width, line number.

Too complicated to be read by humans!



# Nuclear Data for Fast Reactor Systems

## Files for a material from report ENDF-102 (ENDF manual)

<b>1 General information</b>	<b>9 Multiplicities for radioactive nuclide production</b>	<b>30 Data Covariances obtained from parameter covariances and sensitivities</b>
<b>2 Resonance parameter data</b>	<b>10 Cross sections for photon production</b>	<b>31 Data covariances for nubar</b>
<b>3 Reaction cross sections</b>	<b>12 Multiplicities for photon production</b>	<b>32 Data covariances for resonance parameters</b>
<b>4 Angular distributions for emitted particles</b>	<b>13 Cross sections for photon production</b>	<b>33 Data covariances for reaction cross sections</b>
<b>5 Energy distributions for emitted particles</b>	<b>14 Angular distributions for photon production</b>	<b>34 Data covariances for angular distributions</b>
<b>6 Energy-angle distributions for emitted particles</b>	<b>15 Energy distributions for photon production</b>	<b>35 Data covariances for energy distributions</b>
<b>7 Thermal neutron scattering law data</b>	<b>23 Photo-atomic interaction cross sections</b>	<b>39 Data covariances for radionuclide production yields</b>
<b>8 Radioactivity and fission-product yield data</b>	<b>27 Atomic form factors or scattering functions for photo-atomic interactions</b>	<b>40 Data covariances for radionuclide production cross sections</b>



# Nuclear Data for Fast Reactor Systems

Examples:

EXFOR : U-238 inelastic

ENDF : U-238 capture (example of plots of MF=3 as raw data)

ENSDF : Fe-56

IBANDL : p + C-12, calc for angle=175deg

IRDF : plots, MAT-MT list, Fe-54

Others : delayed neutron emission ([data](#), MT=455)  
medical radioisotope production ([gamma emitters](#))  
PGAA ([Al-27](#))  
Photonuclear ([Sm-154](#))

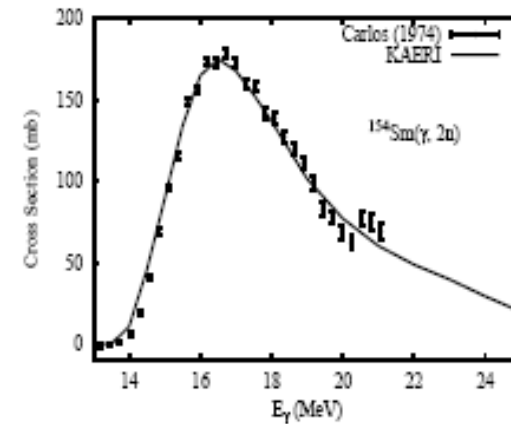
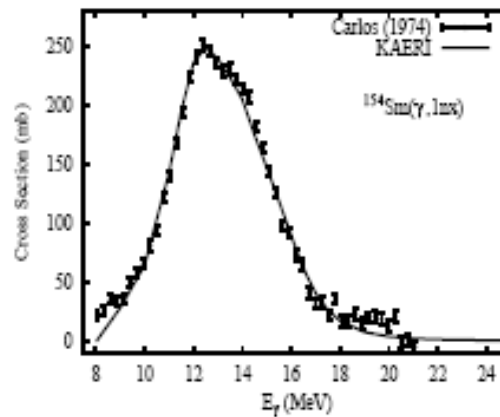
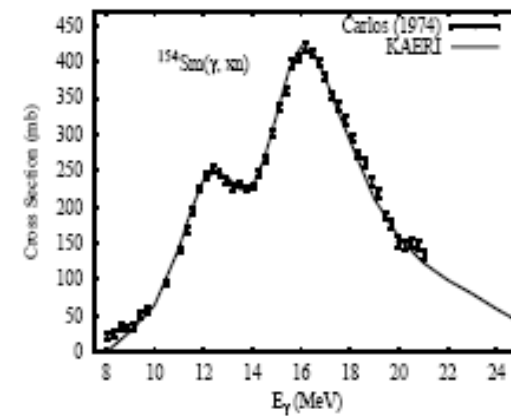
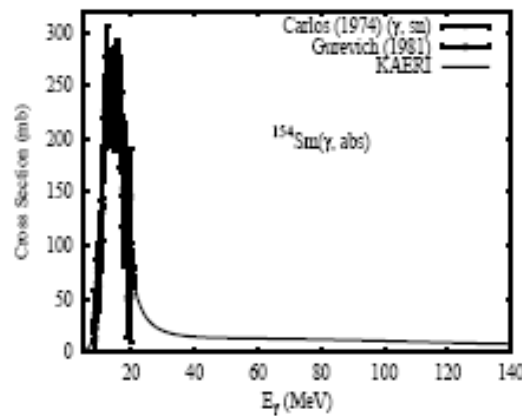


# Nuclear Data for Fast Reactor Systems

## Photonuclear

$\gamma + {}^{154}\text{Sm}$

Abundance (%)	Threshold Energies (MeV)								
	$\gamma, n$	$\gamma, p$	$\gamma, t$	$\gamma, \text{He-3}$	$\gamma, \alpha$	$\gamma, 2n$	$\gamma, np$	$\gamma, 2p$	$\gamma, 3n$
22.70	7.97	9.09	14.02	16.44	1.20	13.83	16.56	16.88	22.09

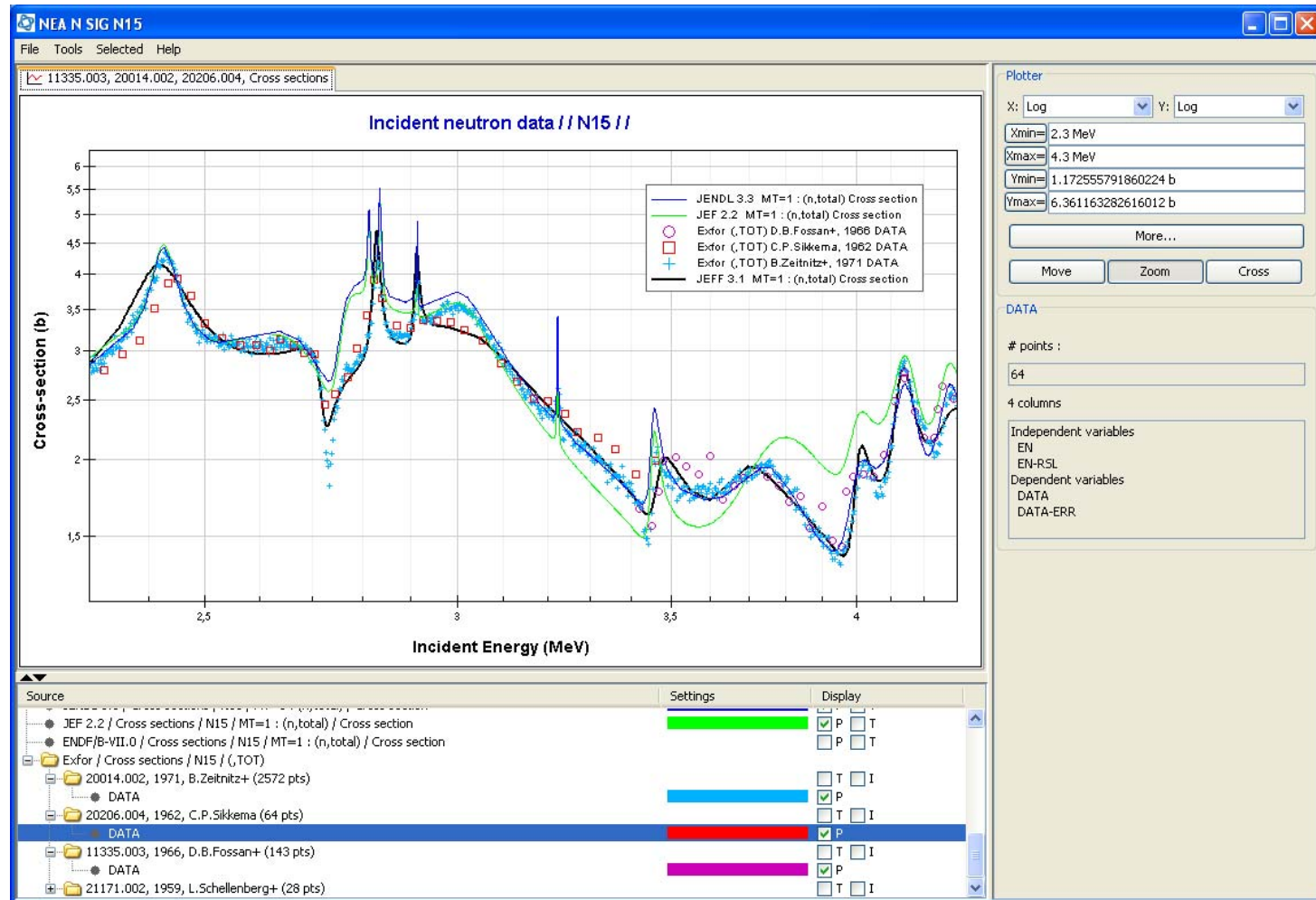


[<< back](#)



# Nuclear Data for Fast Reactor Systems

JANIS 3.0



# Nuclear Data for Fast Reactor Systems

Q. Where to get Nuclear Data?

A. The Internet

**Example:**

what is the capture cross section  
of Zr-91 at  $E_n = 30 \text{ keV}$  ?

# Nuclear Data for Fast Reactor Systems

## Nuclear Data Online

www-nds.iaea.org

The screenshot shows a web browser window with the URL <http://www-nds.iaea.org/>. The page features the IAEA logo and the text "IAEA.org International Atomic Energy Agency". The main heading is "Welcome to the IAEA Nuclear Data Centre Nuclear Data Services". A search bar is present with the text "Search NDS" and a "Go" button. The page is organized into several sections:

- NDS Mirror Sites:** Includes links for India and Brazil.
- Navigation:** A vertical list of navigation options including Content Browser, Quick Links, ADS-Lib, AMDC, CINDA, DROSG-2000, ENDF, ENSDF, ENSDF ASCII Files, EXFOR, FENDL-2.1, IBANDL, INDL/TSL, IRDF-2002, Masses 2003, Medical Radioisotopes Production, MIRD, Minsk Actinides, NGATLAS, NuDat 2.1, NSR, PADF Proton Activation Data File, PGAA-IAEA, Photonuclear, Photon+Electron Interaction, POINT2007, POINT2004, Q-values, Thresholds, RIPL, RNAL, Safeguards data, SigmaCalc, Standards, Stopping Power Data, Thermal Neutron Capture Gamma Rays, and Thorium-Uranium Fuel Cycle.
- Major Databases:** A list of databases with descriptions: CINDA (neutron reaction data bibliography), ENDF (evaluated nuclear reaction cross section libraries), ENDF-6 (experimental nuclear reaction data), ENSDF (evaluated nuclear structure and decay data (Includes XUNDL)), NSR (Nuclear Science References), and NuDat 2.2 (selected evaluated nuclear data).
- Nuclear Databases and Files:** A section titled "General" listing various data sets: Atomic Mass Data Center (2003 atomic mass evaluation, NUBASE, PC-NUCLEUS, etc.), Q-values, Thresholds (atomic masses, Q-values and threshold energies), RIPL (reference parameters for nuclear model calculations), Thermal neutron capture gamma rays (by target and by energy), and Wallet cards (ground and metastable state properties).
- Other evaluated data libraries in ENDF format:** A list of libraries: IAEA Photonuclear Data Library (cross sections and spectra up to 140MeV), INDL/TSL (IAEA Evaluated Nuclear Data Library / Thermal Scattering Law), IRDF-2002 (International Reactor Dosimetry File), Minsk Actinides Library (evaluated neutron reactions data (Maslov et al.)), NGATLAS (atlas of neutron capture cross sections (old-version is here)), PADF 2007 (Proton Activation Data File), POINT2007 (Pointwise data of ENDF/B-VII.0 processed into temperature dependent form), POINT2004 (Pointwise data of ENDF/B-VI Release 8 at 8 temperatures), RNAL (Reference Neutron Activation Library), Standards (Neutron Cross-section Standards 2006), and Th-U (Evaluated nuclear data for the Thorium-Uranium fuel cycle).
- Evaluated libraries in different formats:** A list of libraries: ADS-Lib (Application test library in ACE and MATXS format for ADS neutronics design), Charged-particle cross section database for medical radioisotope production, FENDL-2.1 (Fusion Evaluated Nuclear Data Library, Version 2.1), IAEA-NDS-0 (index to IAEA NDS documentation series), IBANDL (Ion Beam Analysis Nuclear Data Library), MIRD (medical internal radiation dose tables), Nuclear Data for Safeguards (recommendations, 2007), PGAA-IAEA (database of prompt gamma rays from slow neutron capture), Photon and Electron Interaction Data (EPDL, EADL, EEDL, EXDL and ASF), SigmaCalc (Evaluated (recommended) differential cross sections for Ion Beam Analysis), Stopping Power Data for Light Ions (Graphs, data, programs, compiled by H. Paul), X and Gamma-rays standards (Decay data standards for detector calibration), WIMSD-IAEA Library (multigroup data library for the WIMS-D code), and Various Specialized Evaluated Data Libraries in ENDF and other formats.
- NDS Events:** A section listing upcoming events: Meetings & Workshops, Joint ICTP-IAEA Workshop on Nuclear Structure and Decay Data: Theory and Evaluation (28 April - 9 May, 2008, ICTP, Trieste, Italy), Joint ICTP-IAEA Workshop on Nuclear Reaction Data for Advanced Reactor Technologies (18 - 30 May, 2008, ICTP, Trieste, Italy), and International Symposium on Reactor Dosimetry (25 - 30 May, 2008, Alkmaar, Netherlands).

# Nuclear Data for Fast Reactor Systems

## Nuclear Data Online

The screenshot shows a web browser window with the URL <http://www-nds.iaea.org/exfor/endl.htm>. The page title is "ENDF: Evaluated Nuclear Data File". The main heading is "Evaluated Nuclear Data File (ENDF)" with a sub-heading "Database Version of March 28, 2008". A "News & History" section lists updates from 2008/04, including JENDL/AC-2008, JENDL/AN-2005, JENDL/G-2005, and JENDL/HE-2004. A "Standard Request" form is visible, with fields for Target, Reaction, and Quantity, and a "Libraries" section with radio buttons for "All", "Selected", "Major Libraries", "Special Libraries", "Archival", and "Derived". The "Options" section has a "Sort by" dropdown set to "Reactions". A "Note" section provides search criteria details. At the bottom, there is contact information for the Database Manager, Viktor Zerkin, and the Data Source, Nuclear Energy Agency International Working Party on Evaluation Cooperation.

ENDF: Evaluated Nuclear Data File

File Edit View History Bookmarks Develop Window Help

<http://www-nds.iaea.org/exfor/endl.htm> Google

### Evaluated Nuclear Data File (ENDF)

Database Version of March 28, 2008  
Software Version of 2008.03.31 Old interface is [here](#)

#### News & History

2008/04 New and updated libraries:

- 1) JENDL/AC-2008: JENDL Actinoid File 2008 [\[page\]](#)
- 2) JENDL/AN-2005: (Alpha,n) Reaction Data File 2005 [\[page\]](#)
- 3) JENDL/G-2005: Photoreaction Data File 2004 [\[page\]](#)
- 4) JENDL/HE-2004: High Energy File 2004 [\[page\]](#)

Core nuclear reaction database contain recommended, evaluated cross sections, spectra, angular distributions, fission product yields, photo-atomic and thermal scattering law data, with emphasis on neutron induced reactions. The data were analyzed by experienced nuclear physicists to produce recommended libraries for one of the national nuclear data projects (USA, Europe, Japan, Russia and China). All data are stored in the internationally-adopted ENDF-6 format maintained by CSEWG.

#### Standard Request (example); Go to: [Advanced Request](#)

Parameters:

Target

Reaction

Quantity

[More Parameters...](#)

Libraries:  All  Selected

Major Libraries  Special Libraries

1) ENDF/B-VII.0 (USA,2006)  Archival

2) JEFF-3.1 (Europe,2005)  Derived

3) JENDL-3.3 (Japan,2002)

4) BROND-2.2 (Russia,1992)

5) CENDL-2 (China,1991)

Options:

Sort by:  Reactions  Evaluations

Clone Request:

Feedback:

**Note:**

- all criteria are optional (selected by checking )
- selected criteria are combined for search with logical AND
- criteria separated in a field by ";" are combined with logical OR
- wildcards and intervals are available
- pointwise libraries contain reconstructed resonances using parameters from MF=2 and applied Doppler broadening at a given temperature.

Extensive temperature dependent pointwise libraries: [Point-2004 \(ENDFB-VI.8\)](#), [Point-2007 \(ENDFB-VII.0\)](#)

Database Manager: Viktor Zerkin, NDS, International Atomic Energy Agency ([V.Zerkin@iaea.org](mailto:V.Zerkin@iaea.org))  
Web and Database Programming: Viktor Zerkin, NDS, International Atomic Energy Agency ([V.Zerkin@iaea.org](mailto:V.Zerkin@iaea.org))  
Data Source: Nuclear Energy Agency International Working Party on Evaluation Cooperation (<http://www.nea.fr/html/science/wpec/>)  
and Cross Section Evaluation Working Group (<http://www.nndc.bnl.gov/csewg/>)



# Nuclear Data for Fast Reactor Systems

## Nuclear Data Online

The screenshot shows a web browser window titled "ENDF: Evaluated Nuclear Data File" with the URL "http://www-nds.iaea.org/exfor/endl.htm". The page header includes the IAEA logo and the text "Evaluated Nuclear Data File (ENDF) Database Version of March 28, 2008". A "News & History" section lists updates from 2008/04, including JENDL/AC-2008, JENDL/AN-2005, JENDL/G-2005, and JENDL/HE-2004. A "Standard Request" form is visible, with fields for Target (Zr-91), Reaction (n,g), and Quantity (cs). A blue arrow points to the "Submit" button. The form also includes options for Libraries (Major, Special, Archival, Derived) and Options (Reactions, Evaluations). A "Note" section provides search criteria details, and a "Feedback" section includes buttons for EXFOR, CINDA, and Comments/Questions.

ENDF: Evaluated Nuclear Data File

File Edit View History Bookmarks Develop Window Help

http://www-nds.iaea.org/exfor/endl.htm

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Database Version of March 28, 2008  
Software Version of 2008.03.31 Old interface is [\[here\]](#)

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#### Standard Request (example); Go to: [Advanced Request](#)

Parameters:

Target  Zr-91

Reaction  n,g

Quantity  cs

[More Parameters...](#)

(indicated by a blue arrow)

Libraries:  All  Selected

Major Libraries  Special Libraries

1) ENDF/B-VII.0 (USA,2006)  Archival

2) JEFF-3.1 (Europe,2005)  Derived

3) JENDL-3.3 (Japan,2002)

4) BROND-2.2 (Russia,1992)

5) CENDL-2 (China,1991)

Options:

Sort by:  Reactions  Evaluations

Clone Request:

Feedback:  (with envelope icon)

**Note:**

- all criteria are optional (selected by checking  )
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Data Source: Nuclear Energy Agency International Working Party on Evaluation Cooperation (<http://www.nea.fr/html/science/wpec/>) and Cross Section Evaluation Working Group (<http://www.nndc.bnl.gov/csewg/>)

# Nuclear Data for Fast Reactor Systems

## Nuclear Data Online

E4/Servlet: Select

File Edit View History Bookmarks Develop Window Help

http://www-nds.iaea.org/exfor/servlet/E4sSearch2

E4/Servlet: Select

Request # 1402

### ENDF Data Selection

Retrieve Plot  Selected  Unselected  All

Plotting options:  Quick plot (cross-sections only:  $\sigma$ )  MF3-Plot  
 Universal plot ( $\sigma \pm \Delta\sigma$ ,  $\sigma\sigma/d\Omega$ ,  $\sigma\sigma/dE$ ,  $\sigma^2\sigma/dE/d\Omega$ ) *beta version*

Sorted by: [Reactions] Reorder by: [Libraries] View:  basic  extended

1) ZR-91 (N, G) ZR-92, SIG MT=102 MF=3 NSUB=10

MF3 - SIG Cross sections, MT102, IN-G1 Radiative capture

<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot					
<input checked="" type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	ENDF/B-VII.0	E=20MeV	Lab=JNDC, BNL	Date=DIST-DEC06	JNDC FPND W.G., Mughabghab
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	JEFF-3.1	E=20MeV	Lab=JNDC	Date=050504	JNDC FP NUCLEAR DATA W.G.
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	JENDL-3.3	E=20MeV	Lab=JNDC	Date=20010810	JNDC FP NUCLEAR DATA W.G.
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	JENDL-3.3	E=20MeV	Lab=JNDC	Date=20010810 T=300	JNDC FP NUCLEAR DATA W.G.
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	ENDF/B-VI	E=20MeV	Lab=SAI, BNL	Date=20011108	M. DRAKE, D. SARGIS, T. MAUNG, P. ROSE
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	ENDF/B-VI	E=20MeV	Lab=SAI, BNL	Date=20010926 T=300	M. DRAKE, D. SARGIS, T. MAUNG, P. ROSE
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	BROND-2.2		Lab=CJD+IATE	Date=REV1-SEP9	GRUDZEVICH O.T. ET. AL.
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	JEFF-3.1/A	E=20MeV	Lab=UKAEA	Date=DIST-JUL03 T=293	Forrest, Kopecky, Sublet, Koning
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	JEFF-2.2		Lab=NEA	Date=920101	H. GRUPPELAAR, E. MENAPACE
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	JEFF-3.0	E=20MeV	Lab=JNDC	Date=DIST-APR02	JNDC FP NUCLEAR DATA W.G.
<input type="checkbox"/>	ENDF-6	Interpreted	$\sigma$	Plot	JENDL/HE-2004	E=3000MeV	Lab=KYUSHU	Date=REV1-	S. KUNIEDA, N. SHIGYO, K. ISHIBASHI

\*Plotting options:

**MF3-Plot** cross section from file MF3 as is. Quick, but sometimes presents only "background" data (without resonances in low energy region)  
 includes reconstructed resonances and applied Doppler broadening at the temperature 293°K ~20°C

**Cross section**

**Other plots**

- $\sigma\sigma/d\Omega$  - angular distributions,
- $\sigma\sigma/dE$  - energy distributions,
- $\sigma^2\sigma/dE/d\Omega$  - double differential cross sections,
- $\sigma \pm \Delta\sigma$  - cross sections with uncertainties (if given)

[Glossary]: meaning of abbreviations and variables  
 [About]: a few words on ENDF-6 format

Page generated: 2008/04/17 16:24:02 by E4-Servlet on www-nds.iaea.org  
 Project: "Multi-platform EXFOR-CINDA-ENDF", V.Zerkin, IAEA-NDS, 1999-2008  
 Request from: pc32330.iaea.org (161.5.149.213)

Attention. Data for Output: changed to "Selected"

# Nuclear Data for Fast Reactor Systems

## Nuclear Data Online

E4/Servlet: Output

File Edit View History Bookmarks Develop Window Help

http://www-nds.iaea.org/exfor/servlet/E4sMakeE4

E4/Servlet: Output

ENDF Request #1402 (974)

**Output Data**

Format	Data (Size)
ENDF	Text (31Kb) ZIP (8Kb)

**Cross Section**

Note: The data shown on this plot were converted to the pointwise presentation (T=293K).

ENDF Request 1402, 2008-Apr-17, 16:26:41

EXFOR Find and add to the plot experimental data

1) ENDF/B-VII.0: ZR-91(N,G)ZR-92

2) Use my data [example]

Columns: x y [dy [dx]]

Type:  Curve  Points

Title: My data

Multiply by: X: 1 Y: 1

See: [plotted data \(556Kb\)](#)

Log: XY X Y Lin: XY X Y Auto-range: XY X Y Page: >> << Zoom: <> >> << Grid: VH 0 V H Pts: Txt| Box| PL| Print

Reset Repaint Legend Authors Info+ PostScript Manual options: [+]

Data for plotting: ZVD (536Kb), [send to ZVView](#); download ZVView

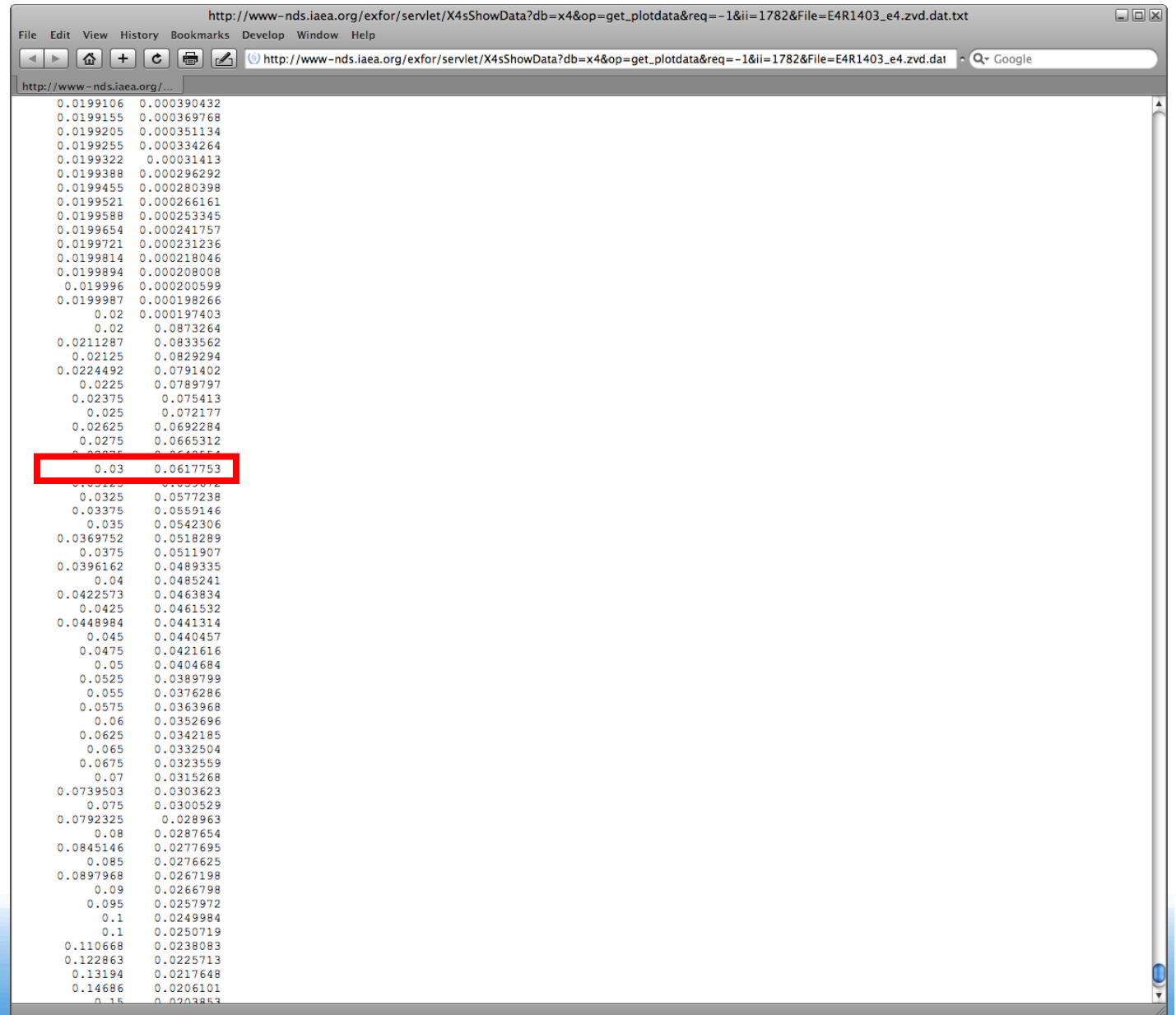
Note. Zoom and other interactive plotting features were tested under Web-browsers: MS-Internet Explorer 5.5, Firefox 2.0, Safari, Opera 9.1, Netscape v-7.2

Page generated: 2008/04/17, 16:26:42 by E4-Servlet on www-nds.iaea.org  
Project: "Multi-platform EXFOR CINDA-ENDF", V.Zerkin, IAEA-NDS, 1999-2008  
Request from: pc32330.iaea.org (161.5.149.213)

# Nuclear Data for Fast Reactor Systems

## Nuclear Data Online

$^{91}\text{Zr}$  capture cross  
section  
at  $E_n=30$  keV:  
61.8 mb



http://www-nds.iaea.org/exfor/servlet/X4sShowData?db=x4&op=get\_plotdata&req=-1&ii=1782&File=E4R1403\_e4.zvd.dat.txt

0.0199106	0.000390432
0.0199155	0.000369768
0.0199205	0.000351134
0.0199255	0.000334264
0.0199322	0.00031413
0.0199388	0.000296292
0.0199455	0.000280398
0.0199521	0.000266161
0.0199588	0.000253345
0.0199654	0.000241757
0.0199721	0.000231236
0.0199814	0.000218046
0.0199894	0.000208008
0.019996	0.000200599
0.0199987	0.000198266
0.02	0.000197403
0.02	0.0873264
0.0211287	0.0833562
0.02125	0.0829294
0.0224492	0.0791402
0.0225	0.0789797
0.02375	0.075413
0.025	0.072177
0.02625	0.0692284
0.0275	0.0665312
0.02875	0.0640554
0.03	0.0617753
0.03125	0.0595072
0.0325	0.0577238
0.03375	0.0559146
0.035	0.0542306
0.0369752	0.0518289
0.0375	0.0511907
0.0396162	0.0489335
0.04	0.0485241
0.0422573	0.0463834
0.0425	0.0461532
0.0448984	0.0441314
0.045	0.0440457
0.0475	0.0421616
0.05	0.0404684
0.0525	0.0389799
0.055	0.0376286
0.0575	0.0363968
0.06	0.0352696
0.0625	0.0342185
0.065	0.0332504
0.0675	0.0323559
0.07	0.0315268
0.0739503	0.0303623
0.075	0.0300529
0.0792325	0.0289663
0.08	0.0287654
0.0845146	0.0277695
0.085	0.0276625
0.0897968	0.0267198
0.09	0.0266798
0.095	0.0257972
0.1	0.0249984
0.1	0.0250719
0.110668	0.0238083
0.122863	0.0225713
0.13194	0.0217648
0.14686	0.0206101
0.15	0.0203853

# Nuclear Data for Fast Reactor Systems

## Nuclear Data Online

How about experimental data?

The screenshot displays the 'E4/Servlet: Output' web interface. At the top, a browser window shows the URL 'http://www-nds.iaea.org/exfor/Servlet/E4sMakeE4'. The main content area is titled 'ENDF Request #1402 (974)' and 'Output Data'. Below this, there is a table with 'Format' set to 'Data (Size)' and 'ENDF' options for 'Text (31Kb)' and 'ZIP (8Kb)'. A 'Cross Section' section follows, with a note: 'Note: The data shown on this plot were converted to the pointwise presentation (T=293K)'. The plot itself is a log-log graph of 'Cross Section (barns)' versus 'Incident Energy (MeV)'. The y-axis ranges from 10<sup>-4</sup> to 10<sup>2</sup>, and the x-axis ranges from 10<sup>-10</sup> to 1. The plot shows a smooth curve at low energies that becomes highly oscillatory at higher energies. To the right of the plot is an 'EXFOR' search panel with a button labeled 'EXFOR' and a tooltip 'Find and add to the plot experimental data'. The panel contains a list of data entries, with the first one selected: '1) ENDF/B-VII.0: ZR-91(N,G)ZR-92'. Below the list are options for 'Type' (Curve or Points), a 'Title' field, and 'Multiply by' fields for X and Y. At the bottom of the plot area, there are various interactive controls like 'Log', 'Lin', 'Zoom', and 'Grid'. A footer section contains page generation information: 'Page generated: 2008/04/17 16:26:42 by E4-Servlet on www-nds.iaea.org'.

# Nuclear Data for Fast Reactor Systems

## Nuclear Data Online

X4/Servlet: Select

File Edit View History Bookmarks Develop Window Help

http://www-nds.iaea.org/exfor/servlet/X4sMakeX4

X4/Servlet: Select

EXFOR Request #2157/823 (following ENDF Request #1402)

### Output Data

Format	Data (Size)
EXFOR	<a href="#">Text (32Kb)</a> <a href="#">ZIP (8Kb)</a>
Bibliography	<a href="#">html (10Kb)</a> <a href="#">BibTeX (4Kb)</a>

ENDF Request 1402, 2008-Apr-17, 16:26:41  
EXFOR Request: 2157/1, 2008-Apr-17 16:41:31

Incident Energy (MeV)

- 1) 40-ZR-91(N,G)40-ZR-92,,SIG
- 2) ENDF/B-VII.0: ZR-91(N,G)ZR-92
- 3) Use my data [\[example\]](#)

See: [plotted\\_data \(563Kb\)](#)

Log: [XY](#) [X](#) [Y](#) Lin: [XY](#) [X](#) [Y](#) Auto-range: [XY](#) [X](#) [Y](#) Page: [>>](#) [<<](#) Zoom: [<](#) [>](#) Grid: [VH](#) [O](#) [V](#) [H](#) Pts: [Txt](#) [Box](#) [PL](#) [Print](#)

Reset [Repaint](#)  Legend  Authors  Info+ [PostScript](#) Manual options: [\[+\]](#)

Data for plotting: [ZVD \(544Kb\)](#), [send to ZVView](#); download [ZVView](#)

Note. Zoom and other interactive plotting features were tested under Web-browsers:  
MS-Internet Explorer 5.5, Firefox 2.0, Safari, Opera 9.1, Netscape v-7.2

Page generated: 2008/04/17, 16:41:32 by X4-Servlet on www-nds.iaea.org  
Project: "Multi-platform EXFOR-CINDA-ENDF", V.Zerkin, IAEA-NDS, 1999-2008  
Request from: pc32330.iaea.org (161.5.149.213)

# EXFOR statistics

## EXFOR General Statistics

Information updated: 02-Apr-2008, 13:22:52

Database as of: April 02, 2008

Number of ENTRY	17082	experimental works
Number of SUBENT	116011	data tables (can contain data of more than one reaction)
Number of Datasets	128649	data tables of reactions

Percent: [Counts]/[Number of ENTRY], i.e. = [Counts]/17082

Note.  $\Sigma$ [Percent] of a table below can be > 100% because one experimental work can contain many data tables with data of many types

## EXFOR Quantity

#	Code	Quantity	Counts	Percent
1	CS	Cross section data	8833	51.7
2	DA	Differential data with respect to angle	3273	19.1
3	DAP	Partial differential data with respect to angle	2945	17.2
4	RP	Resonance parameters	1634	9.56
5	CSP	Partial cross section data	1402	8.2
6	POL	Polarization data	912	5.33
7	FY	Fission product yields	901	5.27
8	DAE	Differential data with respect to angle and energy	782	4.57
9	SP	Gamma spectra	416	2.43
10	MFQ	Miscellaneous fission quantities	413	2.41
11	RI	Resonance integrals	370	2.16
12	DE	Differential data with respect to energy	342	2
13	TT	Thick target yields	235	1.37
14	E	Kinetic energies	213	1.24
15	L	Scattering amplitudes	182	1.06
16	PY	Product yields	111	0.64
17	INT	Cross section integral over incident energy	107	0.62
18	NQ	Nuclear quantities	93	0.54
19	RR	Reaction rates	44	0.25
20	MLT	Outgoing particle multiplicities	39	0.22
21	TTD	Differential thick target yields	26	0.15
22	CST	Temperature dependent cross section data	16	0.093
23	SQ	Special quantities	12	0.07
24	COR	Secondary particle correlations	6	0.035
25	TTP	Partial thick target yields	6	0.035
26	DEP	Partial differential data with respect to energy	3	0.017

[a.mengoni@iaea.org](mailto:a.mengoni@iaea.org)



# EXFOR statistics

EXFOR Targets (el.)

#	Target	Counts	Percent
1	U	2243	13.1
2	C	1484	8.68
3	H	1251	7.32
4	Fe	1153	6.74
5	Al	1147	6.71
6	Ni	1099	6.43
7	Pb	1043	6.1
8	Cu	956	5.59
9	Li	873	5.11
10	Pu	852	4.98
11	O	775	4.53
12	Be	733	4.29
13	Th	688	4.02
14	Au	659	3.85
15	Si	658	3.85
16	Zr	647	3.78
17	B	608	3.55
18	Zn	596	3.48
19	Mg	591	3.45
20	Bi	588	3.44
21	Ca	563	3.29
22	Sn	546	3.19
23	Co	545	3.19
24	Mo	539	3.15
25	Ti	528	3.09
26	Ag	493	2.88
27	N	488	2.85
28	Ta	476	2.78
29	Nb	448	2.62
30	In	441	2.58
31	Cr	440	2.57
32	V	431	2.52
33	W	423	2.47
34	He	420	2.45
35	Cd	409	2.39
36	S	366	2.14
37	Mn	361	2.11
38	Na	350	2.04

EXFOR Targets

#	Target	Counts	Percent
1	U-235	1144	6.69
2	Al-27	1131	6.62
3	C-12	1031	6.03
4	U-238	942	5.51
5	Be-9	700	4.09
6	Au-197	650	3.8
7	Th-232	632	3.69
8	Pu-239	606	3.54
9	Bi-209	585	3.42
10	H-1	580	3.39
11	Ni-58	577	3.37
12	O-16	568	3.32
13	Fe-0	553	3.23
14	Cu-0	551	3.22
15	H-2	547	3.2
16	Co-59	530	3.1
17	Pb-0	516	3.02
18	Li-7	493	2.88
19	Li-6	467	2.73
20	Fe-56	452	2.64
21	Nb-93	445	2.6
22	Pb-208	435	2.54
23	U-233	404	2.36
24	Ni-0	371	2.17
25	Ta-181	360	2.1
26	Si-28	358	2.09
27	Zr-90	355	2.07
28	Mn-55	353	2.06
29	Cu-63	341	1.99
30	N-14	335	1.96
31	V-51	332	1.94
32	C-0	330	1.93
33	Na-23	329	1.92
34	F-19	322	1.88
35	B-10	321	1.87
36	Ca-40	304	1.77
37	Fe-54	302	1.76
38	Ni-60	299	1.75

EXFOR Incident particles

#	Projectile	Counts	Percent
1	N	9317	54.5
2	P	3231	18.9
3	D	1269	7.42
4	A	1207	7.06
5	G	896	5.24
6	HE3	493	2.88
7	0	328	1.92
8	6-C-12	158	0.92
9	T	155	0.9
10	8-O-16	119	0.69
11	3-LI-6	111	0.64
12	3-LI-7	97	0.56
13	2-HE-6	55	0.32
14	7-N-14	48	0.28
15	4-BE-9	35	0.2
16	5-B-11	34	0.19
17	8-O-18	30	0.17
18	9-F-19	30	0.17
19	10-NE-20	29	0.16
20	18-AR-40	29	0.16
21	E	21	0.12
22	14-SI-28	19	0.11
23	92-U-238	19	0.11
24	PIN	19	0.11
25	PIP	18	0.1
26	3-LI-8	16	0.093
27	4-BE-7	16	0.093
28	5-B-10	16	0.093
29	6-C-13	16	0.093
30	10-NE-22	14	0.081
31	3-LI-9	14	0.081
32	3-LI-11	13	0.076
33	9-F-17	13	0.076
34	2-HE-8	12	0.07
35	4-BE-11	12	0.07
36	9-F-18	12	0.07
37	16-S-32	11	0.064
38	5-B-8	11	0.064

EXFOR Reactions

#	Reaction	Counts	Percent
1	N,G	2423	14.1
2	N,EL	2026	11.8
3	N,F	1819	10.6
4	N,TOT	1646	9.63
5	N,INL	1179	6.9
6	N,0	1158	6.77
7	N,P	947	5.54
8	N,A	908	5.31
9	P,X	882	5.16
10	N,2N	840	4.91
11	P,EL	722	4.22
12	P,N	585	3.42
13	N,X	475	2.78
14	P,INL	458	2.68
15	D,P	427	2.49
16	A,EL	347	2.03
17	P,G	341	1.99
18	G,N	328	1.92
19	A,N	311	1.82
20	N,ABS	308	1.8
21	D,N	275	1.6
22	P,A	275	1.6
23	O,F	264	1.54
24	G,X	237	1.38
25	A,X	227	1.32
26	D,EL	214	1.25
27	P,F	210	1.22
28	D,A	196	1.14
29	A,2N	188	1.1
30	A,INL	181	1.05
31	N,THS	178	1.04
32	D,X	170	0.99
33	G,P	166	0.97
34	N,T	160	0.93
35	G,F	159	0.93
36	N,N+P	146	0.85
37	A,P	143	0.83
38	N,D	138	0.8



## **EXFOR database (present status):**

- **63626 experimental data sets with results of microscopic and integral measurements**
- **7369 data sets (12%) obtained with use of the reactor as a neutron source**
- **1863 data sets (3%) contain results of integral (Maxwellian or other spectrum averaged) cross section measurements**



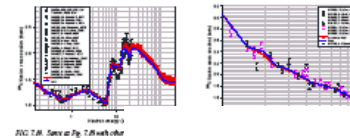
## Distributed by year of publication:

- 1946 – 1950 -> 22 datasets  
first compiled work where reactor is used as a neutron source: G.T. Seaborg and collaborators (1946), measurements of  $^{241}\text{Am}(n,\gamma)$ ,  $^{10}\text{B}(n,\alpha)$  and  $^{158}\text{Gd}(n,\gamma)$
- 1951 – 1960 -> 525 datasets
- 1961 – 1970 -> 1700 datasets
- 1971 – 1980 -> 2705 datasets
- 1981 – 2000 -> 556 datasets
- 2001 – present -> 611 datasets  
~200 – for fission products, ~400 – for actinides;  
from them  
14 – for target nuclides in metastable state  
12 – for long- and short-lived fission products  
16 – for short- and long-lived actinides

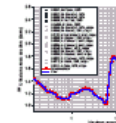


# International neutron cross-section standards

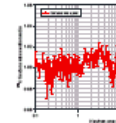
- well documented (text, data tables and plots in IAEA Rep. STI/PUB/1291 (2006), will be published in Nucl. Data Sheets, 110 (12) (2009))
- achieved low uncertainties justified:
  - in independent analysis (2007);
  - by testing in integral experiments (2006-2008)



JNC 7.06. Same as Fig. 7.06 with color



JNC 7.06. Same as Fig. 7.06 with color



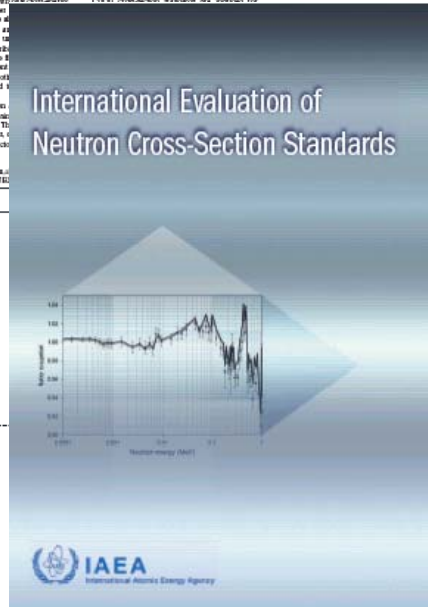
JNC 7.01. Ratio of  $\sigma_{238U}$  to  $\sigma_{235U}$

(15 keV) to 10-20 keV (labeled 15 keV). The ratio of  $\sigma_{238U}$  to  $\sigma_{235U}$  cross-sections represents the average ratio of  $\sigma_{238U}$  to  $\sigma_{235U}$  which is often used to normalize some cross-sections. Cross-sections (cross-sections) are not given because of their size. Although they have been included in two different sets of evaluated data files in ENDF-6 format. One of these sets of data contains cross-sections (cross-sections) and cross-sections cross-sections. The second set of cross-sections cross-sections is a complete presentation of the standards. Only those data cross-sections included in the best cross-sections cross-sections ratio higher than 0.2. All of cross-sections have been judged and are not included.

and times and the average neutron yield per fission. Furthermore, the average neutron yield per fission for  $^{235}\text{U}$  is specified. The evaluated thermal cross-sections and the cross-section ratios of their cross-sections are given in section 7, along with plots comparing the new and old standards with experimental data. Cross-sections for the  $^{238}\text{U}$ ,  $^{235}\text{U}$  and  $^{239}\text{Pu}$  cross-section standards are included for

TABLE 6.1.  $\sigma_{238U}/\sigma_{235U}$  Ratio of the Incident Neutrons

Neutron energy (MeV)
0.02500E+01
0.04000E+01
0.05000E+01
0.06000E+01
0.07000E+01
0.08000E+01
0.09000E+01
0.10000E+01
0.12000E+01
0.15000E+01
0.20000E+01
0.25000E+01
0.30000E+01
0.40000E+01
0.50000E+01
0.60000E+01
0.70000E+01
0.80000E+01
0.90000E+01
1.00000E+01



(free available at <http://www-nds.iaea.org/standards/>)



# International neutron cross-section standards

- include evaluation of 24 thermal constants:  
elastic scattering, capture and fission cross sections, Westcott g-factors and total fission neutron yields for  $^{235,238}\text{U}$  and  $^{239,241}\text{Pu}$ ;  
their covariance matrix of uncertainties
- Axton's pre-evaluated values (1986) and new experimental data were used in the combined least-squares fit with all standard cross sections (2006)
- Independent Devadeenam's evaluation (1984) of thermal constants done with inclusion of integral measurements was used by Mughabghab in preparation of Atlas of Neutron Resonances (2006)



# Providing On-line Services: Retrieval and Display Tools

Other Nuclear Data libraries available for display & retrieval:

Libraries:  All  Selected

<input type="radio"/> Major Libraries	<input type="radio"/> Special Libraries
<input type="checkbox"/> 1) ENDF/B-VII.0 (USA,2006)	<input type="checkbox"/> 6) ENDF/HE-VI (High Energy)
<input type="checkbox"/> 2) JEFF-3.1 (Europe,2005)	<input type="checkbox"/> 7) JEFF-3.1/A (Activation)
<input type="checkbox"/> 3) JENDL-3.3 (Japan,2002)	<input type="checkbox"/> 8) IRDF-2002 (Dosimetry)
<input type="checkbox"/> 4) BROND-2.2 (Russia,1992)	<input type="checkbox"/> 9) INDL/TSL (Thermal Scattering Law)
<input type="checkbox"/> 5) CENDL-2 (China,1991)	<input type="checkbox"/> 10) IAEA-Medical (for radioisotope prod.)
	<input type="checkbox"/> 11) IAEA-Standards, 2006
	<input type="checkbox"/> 12) Proton Activation Data File, 2007
	<input type="checkbox"/> 13) IBA-EVAL Differential data for ion beam analysis
	<input type="checkbox"/> 14) JENDL/AC-2008, JENDL Actinoid File 2008
	<input type="checkbox"/> 15) JENDL/AN-2005, (alpha,n) Reaction Data File
	<input type="checkbox"/> 16) JENDL/G-2005, Photoreaction Data
	<input type="checkbox"/> 17) JENDL/HE-2004, High Energy (neutron, proton)
	<input type="checkbox"/> 18) MENDL-2, Medium Energy, 1995-1998
	<input type="checkbox"/> 19) MINKS-ACT, Actinides Library (Maslov et al.)
	<input type="checkbox"/> 20) Wind, U,Np,Pu (up to 100 MeV)
	<input type="checkbox"/> 21) Yavshits (neutron, proton induced fission for Pb-Pu)
	<input checked="" type="radio"/> Archival
	<input type="checkbox"/> 22) JEF-2.2
	<input type="checkbox"/> 23) JEFF-3.0
	<input type="checkbox"/> 24) ENDF/B-VI.8 (USA,2001)
	<input checked="" type="radio"/> Derived
	<input type="checkbox"/> 25) ENDF/B-VI.8 300°K (Pointwise)
	<input type="checkbox"/> 26) JENDL-3.3 300°K (Pointwise)
	<input type="checkbox"/> 27) IRDF-2002/G (Groupwise)

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# Providing On-line Services: Repository of Data Libraries

ADS-Lib	ENDF - evaluated nuclear reaction c
AMDC	EXFOR - experimental nuclear reacti
CINDA	ENSDF - evaluated nuclear structure
DROSG-2000	NSR - Nuclear Science References
ENDF	NuDat 2.2 - selected evaluated nucl
ENSDF	
ENSDF ASCII Files	<b>Nuclear Databases and Files</b>
EXFOR	<b>General</b>
FENDL-2.1	Atomic Mass Data Center - 2003 ator
IBANDL	Q-values, Thresholds - atomic masse
INDL/TSL	RIPL - reference parameters for nuc
IRDF-2002	Thermal neutron capture gamma rays
Masses 2003	Wallet cards - ground and metastab
Medical Radioisotopes Production	
MIRD	<b>Other evaluated data libraries in ENDF form</b>
Minsk Actinides	IAEA Photonuclear Data Library - cro:
NGATLAS	INDL/TSL - IAEA Evaluated Nuclear I
NuDat 2.1	IRDF-2002 - International Reactor D
NSR	Minsk Actinides Library - evaluated n
PGAA-IAEA	NGATLAS - atlas of neutron capture
Photonuclear	POINT2007 - Pointwise data of ENDF
Photon+Electron Interaction	POINT2004 - Pointwise data of ENDF
POINT2007	RNAL - Reference Neutron Activatio
POINT2004	Standards - Neutron Cross-section !
Q-values, Thresholds	Th-U - Evaluated nuclear data for th
RIPL	
RNAL	<b>Evaluated libraries in different formats</b>
Safeguards data	ADS-Lib Application test library in AC
SigmaCalc	Charged-particle cross section databa
Standards	FENDL-2.1 - Fusion Evaluated Nucle
Stopping Power Data	IAEA-NDS-0 - index to IAEA NDS doc
Thermal Neutron Capture Gamma Rays	IBANDL - Ion Beam Analysis Nuclear
Thorium-Uranium Fuel Cycle	MIRD - medical internal radiation do:
Wallet cards	Nuclear Data for Safeguards - recomi
WIMSD Library	PGAA-IAEA - database of prompt gai
	Photon and Electron Interaction Data
	SigmaCalc - Evaluated (recommende
	Stopping Power Data for Light Ions -
	X and Gamma-rays standards - Deca
	WIMSD-IAEA Library - multigroup dat
	Various Specialized Evaluated Data Li
	<b>Electronic Documents</b>
	Citation Guidelines - online data ser
	ENDF Format Manual - ENDF-102 Jur



INTERNATIONAL ATOMIC ENERGY AGENCY

## NUCLEAR DATA SERVICES

DOCUMENTATION SERIES OF THE IAEA NUCLEAR DATA SECTION

IAEA-NDS-7  
2007/7

### Index of Nuclear Data Libraries available from the IAEA Nuclear Data Section

edited by

O. Schwerer

**Abstract:** This document lists **more than 100 nuclear data libraries** together with references that give more detailed information about these libraries. The data libraries include neutron cross-sections, resonance parameters, fission-product yields, nuclear structure and decay data, gamma-rays from radionuclides, data of nuclear reactions induced by charged particles or heavy ions, photonuclear data, photoatomic interaction data, and many others, partly with related data processing computer codes. All data and documentation references are available through WWW or on request from the IAEA Nuclear Data Section, free of charge, on CD-ROM or other computer media.

July 2007

# Providing On-line Services: Repository of Data Libraries

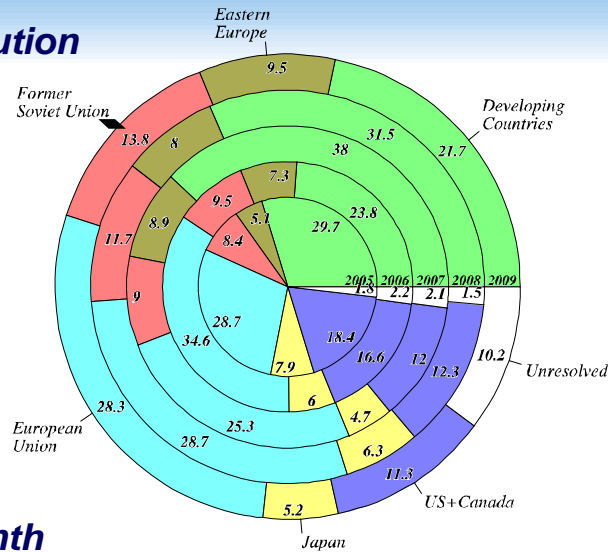


Marco Verpelli

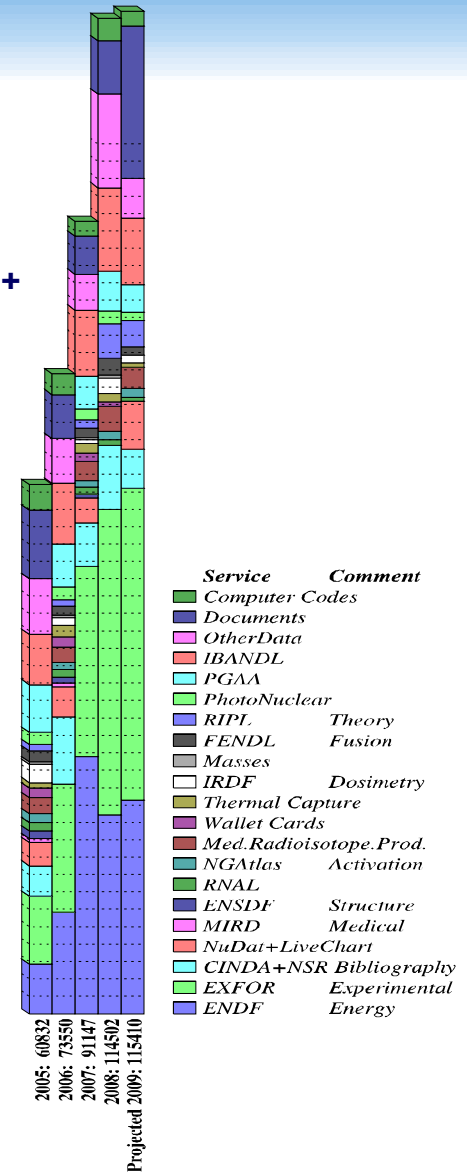
The screenshot shows a web browser window titled "NDS Data Libraries". The address bar contains the URL "http://nds121.iaea.org/datalib/DocStore.html#Browse". The browser's search bar shows "Okinawa Prefectural Unive". The website content includes a navigation menu with "by topic", "by name", "about", and "manage" buttons. Below this is a blue header with the text "Index of Nuclear Data Libraries". A search bar labeled "Search by keywords" is present. The main content area displays a list of data libraries under the heading "Data Libraries", with a sub-heading "Expand all - 154 Libraries grouped in 27 topics". The list includes categories such as "Neutron nuclear data, experimental", "ENDF format for evaluated nuclear data files", "Evaluated neutron nuclear data: Comprehensive libraries", "Thermal neutron cross-sections, resonance-parameters and resonance-integrals", "Actinides", "Fission product yields", "Neutron induced gamma-rays", "Neutron activation general application", "Neutron activation for dosimetry", "IRDF-2002", "NMF-90, Neutron Metrology File", "Neutron Excitation Function Guide for Reactor Dosimetry", "RRDF-98, Russian Reactor Dosimetry File", "Other dosimetry reaction files", "Miscellaneous specialized neutron data libraries", "Photonuclear data", "Photo-atomic interaction data", "Charged-particle nuclear reaction data", "Intermediate energy nuclear data", "Nuclear data for thermonuclear fusion", "Nuclear model parameters and codes", "Nuclear structure and decay data", "Gamma ray analysis", "Nuclear constants, Charts of Nuclides", "Atomic data", and "Bibliographic files". A "Description" section is also visible, titled "Other dosimetry reaction files", with the text: "Other dosimetry reaction files may be included in the 'General purpose evaluated neutron nuclear data'." A "Help" link is located in the top right corner of the content area.

# Nuclear Data Services: Web Statistics

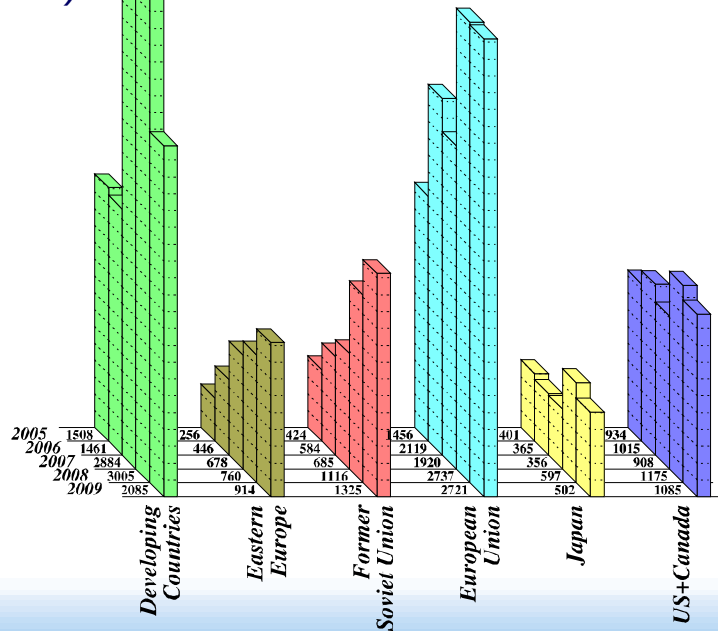
**Geographical Distribution (%)**



**Total per Year (Number of accesses + retrievals)**



**Average per Month (Number of accesses + retrievals)**



Service	Comment
Computer Codes	
Documents	
OtherData	
IBANDL	
PGAA	
PhotoNuclear	
RIPI	Theory
FENDL	Fusion
Masses	
IRDF	Dosimetry
Thermal Capture	
Wallet Cards	
Med.Radioisotope.Prod.	
NGAtlas	Activation
RNAL	
ENSDF	Structure
MIRD	Medical
NuDat+LiveChart	
CINDA+NSR Bibliography	
EXFOR	Experimental
ENDF	Energy



# Nuclear Data for Fast Reactor Systems

## Conclusion

Nuclear Data Libraries are freely available from various international as well as national nuclear data centers.

The development of advanced nuclear technological devices benefits from this availability. Meanwhile, additional experimental, theoretical and evaluation activities are needed for continuous update and improvement of the quality of nuclear data libraries.

