



IAEA

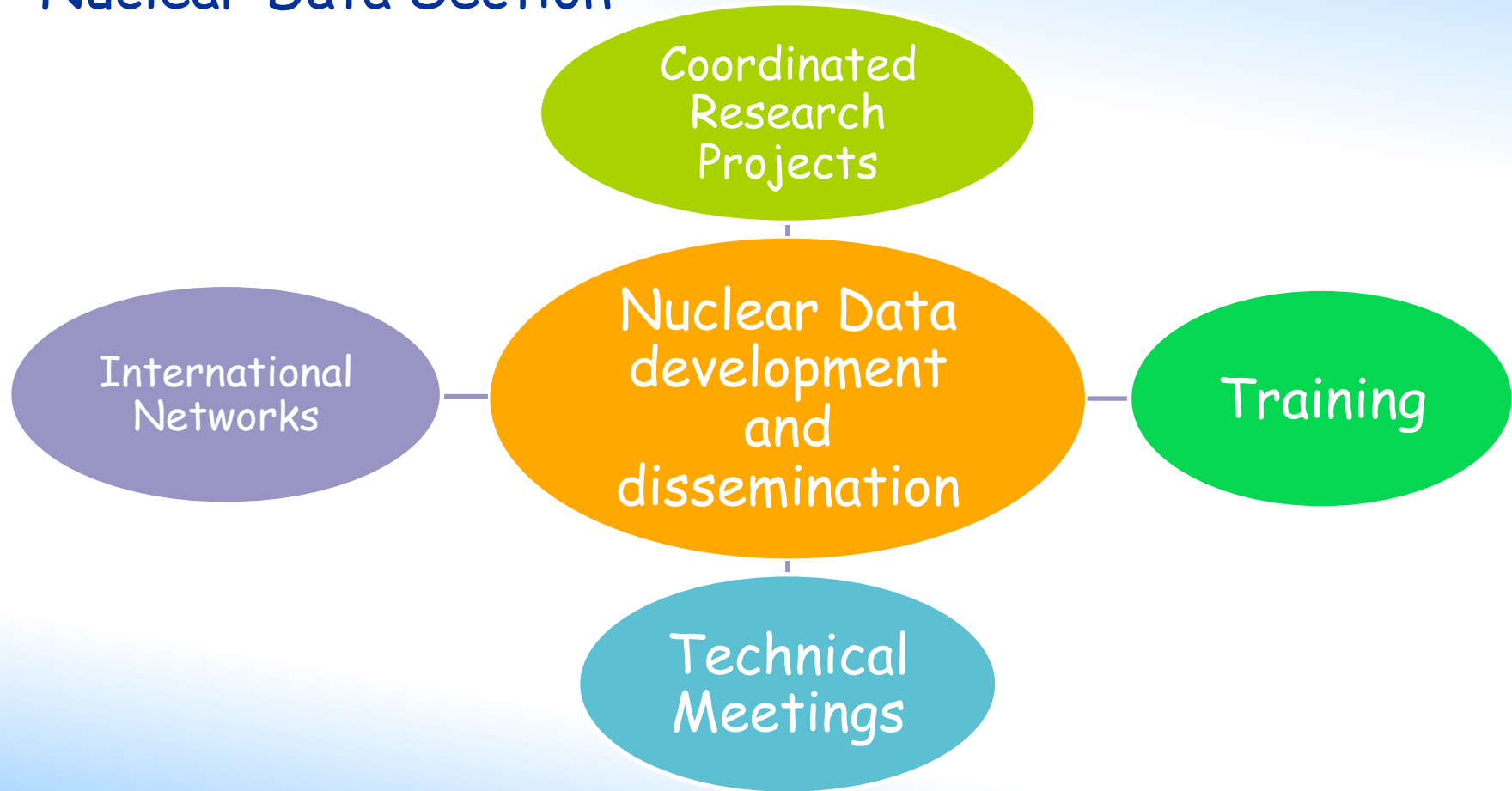
60 Years

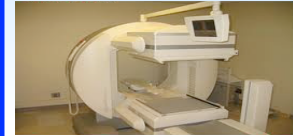
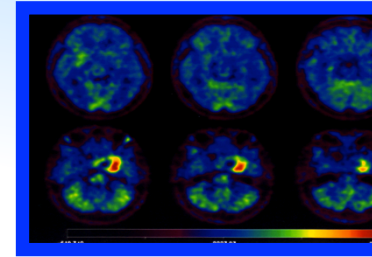
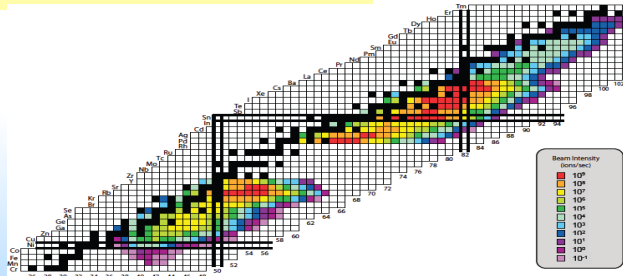
*Atoms for Peace and Development*

# Nuclear Data for Basic Sciences and Applications

Paraskevi (Vivian) Dimitriou  
Nuclear Data Section,  
International Atomic Energy Agency,  
Vienna, Austria

# Division of Physical and Chemical Sciences: Nuclear Data Section





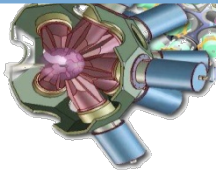
Applications:

- Dosimetry, radiation protection,
- reactor operation+ safety,
- forensics, Homeland security,
- Cultural heritage, environmental
- Control

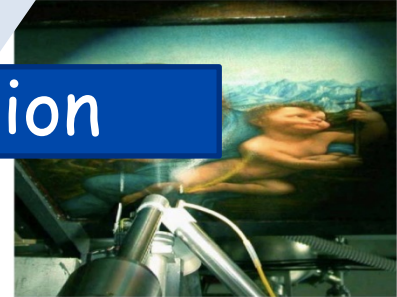
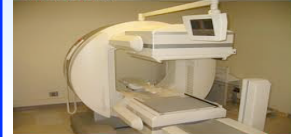
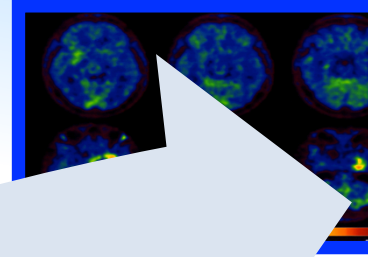
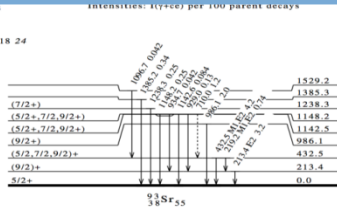
# Nuclear Data



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$^{85}\text{Rb}_{57}$   
2.702 s  
 $Q(\beta^-n)=3462^{+11}$   
 $Q(\beta^-)=10.18\ 24$



Dissemination

Evaluation

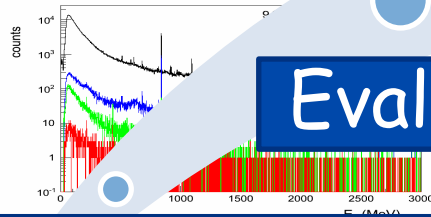
Compilation

Applications:

Dosimetry, radiation protection, reactor operation and safety, forensics, homeland security, Cultural heritage, environmental Control



JYFLTRAP Penning trap



# Databases: Compiled data



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Atoms for Peace and Development



International Atomic Energy Agency  
**Nuclear Data Services**  
Provided by the Nuclear Data Section

IAEA NDS Main Databases: ENDF | EXFOR | CINDA | LiveChart | NuDat | NSR | XUNDL | ENSDF | MIRD

National Nuclear Data Center

NNDC

## Nuclear Science References (NSR)

NSR Reference Paper NIM A 640, 213 (2011)

Database version of August 29, 2016

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.

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



## Experimental Nuclear Reaction Data (EXFOR)

Database Version of 2016-09-05

Software Version of 2016-09-02

The EXFOR library contains an extensive compilation of experimental nuclear reaction data. Neutron reactions have been compiled systematically since the discovery of the neutron, while charged particle and photon reactions have been covered less extensively.

The library contains data from 21401 experiments (see [statistics](#) and recent [updates](#)).

EXFOR Reference Paper: Nucl. Data Sheets 120(2014)272



National Nuclear Data Center

BROOKHAVEN  
NATIONAL LABORATORY  
Home

NNDC Databases: NuDat | NSR | XUNDL | ENSDF | MIRD | ENDF | CSISRS | Sigma

Search the NNDC:

ENSDF Format Manual

Procedures Manual

ENSDF Analysis and Utility Codes

Q Values

Log ft's



## XUNDL: Experimental Unevaluated Nuclear Data List Search and Retrieval

Last updated 2016-09-06

XUNDL contains compiled experimental nuclear structure data from more than 3500 recent papers. For evaluated nuclear data, see ENSDF.



Send Feedback

XUNDL Activity

59 new datasets  
added/modified in the  
last month!



# Evaluated Nuclear Data File (ENDF)



60 Years  
Atoms for Peace and Development

Help » ENDF-6 Format | Plot+ | Databases » Medical | NGAtlas | RIPL | FENDL | IRDF-2002 | IRDFF | EXFOR | CINDA

## Evaluated Nuclear Data File (ENDF)

Database Version of 2016-02-26

Software Version of 2016-06-20

### News & History

2016/02 Updated libraries:

- 1) JENDL-4.0u2: Update /20160106/ of Japanese evaluated nuclear data library (2010) [page]
- 2) IBA-EVAL: Differential data for ion beam analysis, 2013 [page] [example]; go to: [SigmaCalc] [IBANDL]

2015/12 Added libraries:

- 1) JENDL-4.0/HE: JENDL-4.0 High Energy File 2015 (neutron, proton with energy up to 200 MeV) [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. See database summary [here].

**Standard Request** Examples: [1](#)[2](#)[3](#)[4](#)[5](#)[6](#)[7](#) ⌄ Go to: [Advanced Request](#); [ENDF-Explorer](#)

Examples of requests:

- 1 Cross section: MF3
- 2 Angular distributions: MF4
- 3 Energy distributions of secondary particles: MF5
- 4 Product energy-angle distributions: MF6
- 5 Cross sections for production of radioactive elements: MF10
- 6 Search for production cross section (includes MF6/MT5/Law=0)
- 7 Covariances of neutron cross sections: MF33
- 8 Covariances for production of radioactive nuclei: MF40
- 9 Covariances for energy distributions of secondary particles: MF35
- 10 Search for Decay data in the ENDF files (NSUB=4)
- 11 Search for Differential data for ion beam analysis (IBA-EVAL)

Parameters:

Submit

Reset

Libraries: ☒ All ☐ Selected [Check](#) [Reset](#)

⌄ How to plot

- |  |   |
|--|---|
| <input checked="" type="radio"/> Major Libraries       | <input type="radio"/> Special Libraries |
| <input type="checkbox"/> 1) ENDF/B-VII.1 (USA,2011)    | <input type="radio"/> Archival          |
| <input type="checkbox"/> 2) JEFF-3.2 (Europe,2014)     | <input type="radio"/> Derived           |
| <input type="checkbox"/> 3) JENDL-4.0u2 (Japan,2012)   |   |
| <input type="checkbox"/> 4) CENDL-3.1 (China,2009)     |   |
| <input type="checkbox"/> 5) ROSFOND-2010 (Russia,2010) |   |
| <input type="checkbox"/> 6) BROND-2.2 (Russia,1992)    |   |

# Evaluated Nuclear Data File (ENDF)



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ia, with  
s (USA,

Help » ENDF-6 Format | P

2016/02 Up  
1) JE  
2) IB  
2015/12 Ac  
1) JE

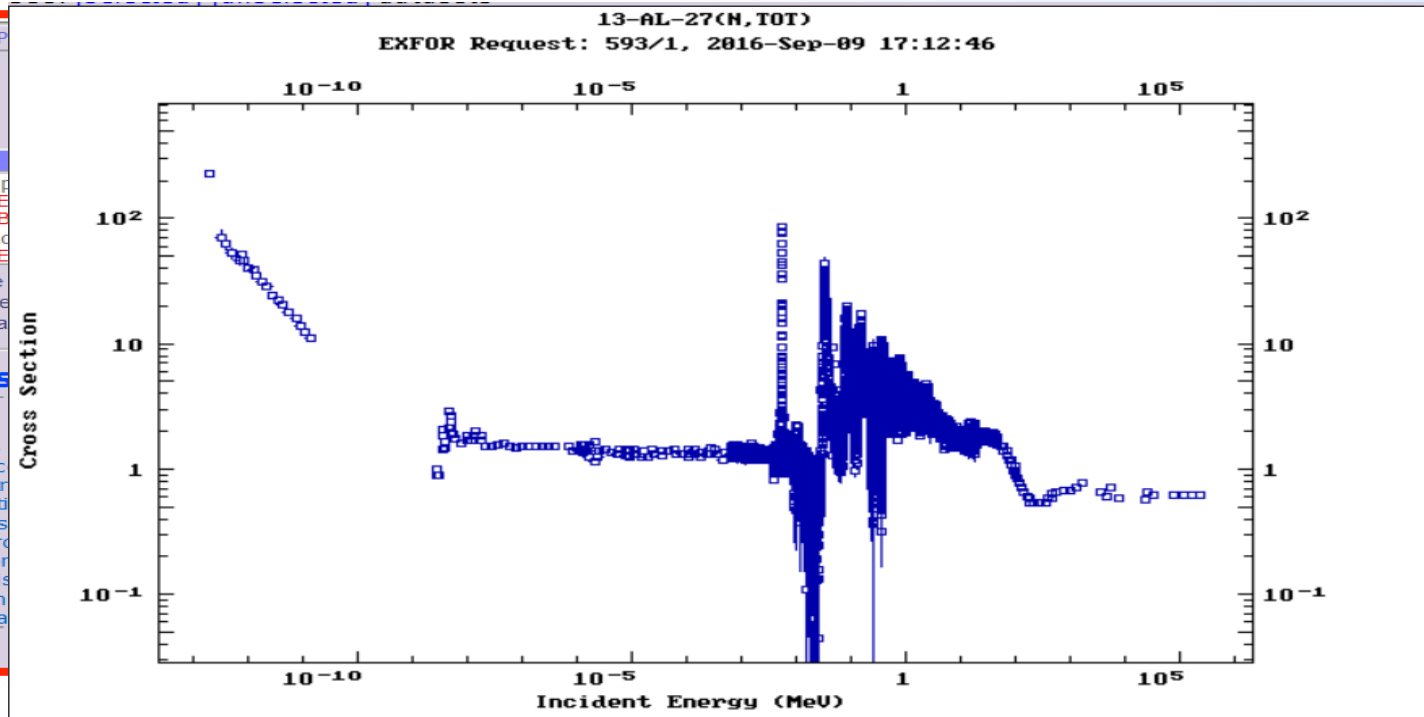
Core nuclear reaction database  
emphasis on neutron induced re  
Europe, Japan, Russia and China

## Standard Request

Examples of requests:

- 1 Cross section: MF3
- 2 Angular distributions: MF4
- 3 Energy distributions of sec
- 4 Product energy-angle distr
- 5 Cross sections for producti
- 6 Search for production cros
- 7 Covariances of neutron cro
- 8 Covariances for production
- 9 Covariances for energy dis
- 10 Search for Decay data in
- 11 Search for Differential da

Parameters:



# Evaluated Nuclear Data File (ENDF)



60 Years  
Atoms for Peace and Development



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s (USA,

Help » ENDF-6 Format | P

2016/02 Up  
1) JE  
2) IB  
2015/12 Ac  
1) JE

Core nuclear reaction database  
emphasis on neutron induced re  
Europe, Japan, Russia and China

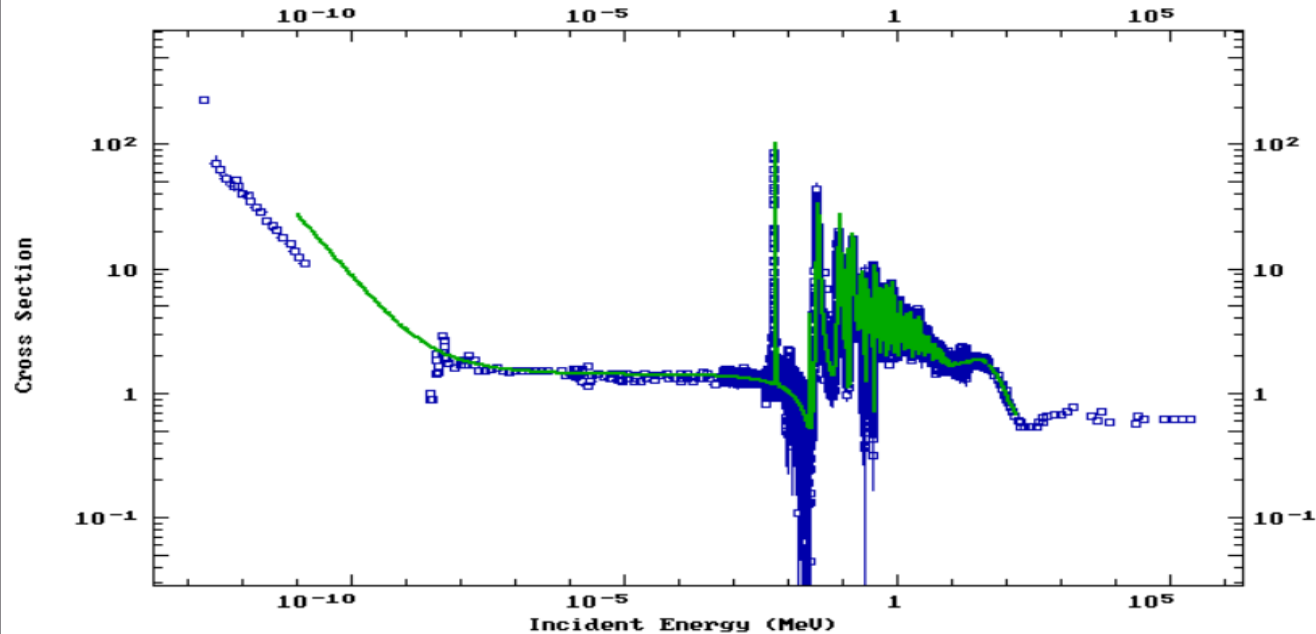
## Standard Requests

Examples of requests:

- 1 Cross section: MF3
- 2 Angular distributions: MF4
- 3 Energy distributions of sec
- 4 Product energy-angle distr
- 5 Cross sections for product
- 6 Search for production cros
- 7 Covariances of neutron cro
- 8 Covariances for production
- 9 Covariances for energy dis
- 10 Search for Decay data in
- 11 Search for Differential da

Parameters:

ENDF Request 377, 2016-Sep-09,17:13:55  
EXFOR Request: 593/1, 2016-Sep-09 17:12:46





# Evaluated Nuclear Data File (ENDF)

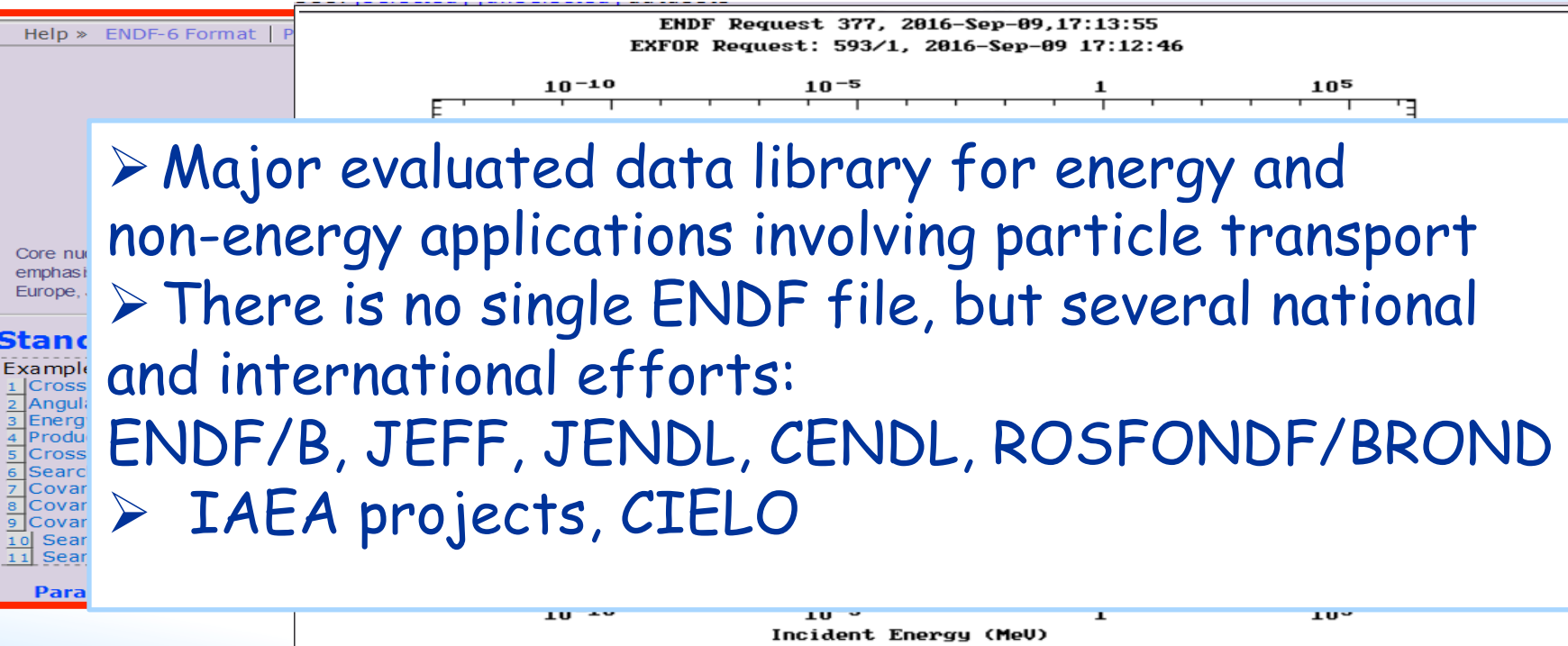


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, with  
(USA,

- Major evaluated data library for energy and non-energy applications involving particle transport
- There is no single ENDF file, but several national and international efforts:  
ENDF/B, JEFF, JENDL, CENDL, ROSFONDF/BROND
- IAEA projects, CIELO



# Evaluated Nuclear Structure Data File (ENSDF)



60 Years  
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National Nuclear Data Center



NNDC Databases: NuDat | NSR | XUNDL | ENSDF | MIRD | ENDF | CSISRS | Sigma

Search the NNDC:

ENSDF Format Manual

Procedures Manual

ENSDF Analysis and Utility Codes

Q Values

Log ft's

Archived ENSDF Files

BrIcc

Listing of Mass Chain Evaluations

## ENSDF: Evaluated Nuclear Structure Data File Search and Retrieval

Last updated 2016-07-27

ENSDF provides recommended nuclear structure and decay information.  
To find more recent nuclear data which has not yet been evaluated, please visit  
[XUNDL](#).

[Quick Search](#)

[By Nuclide](#)

[By Reaction](#)

[By Decay](#)

Nuclide or mass:

Contact



[Send Feedback](#)

[Request new data evaluation](#)

ENSDF Activity

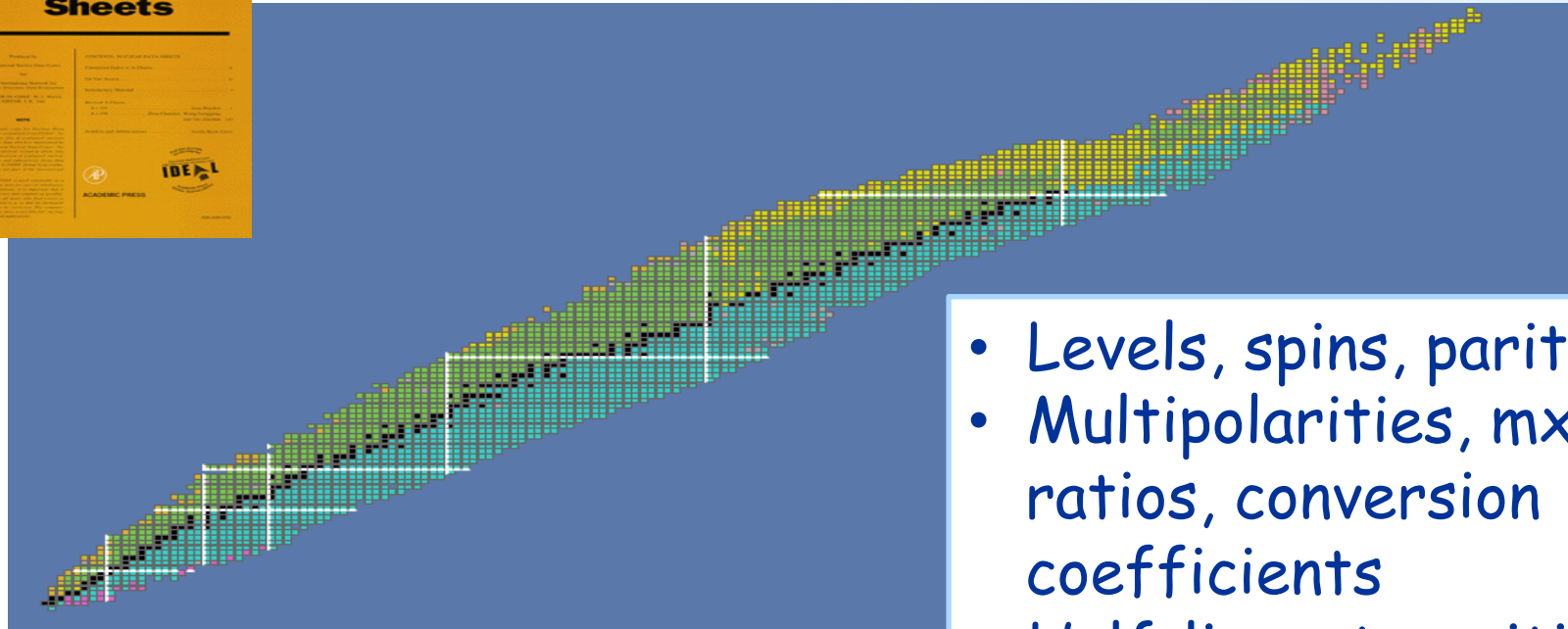
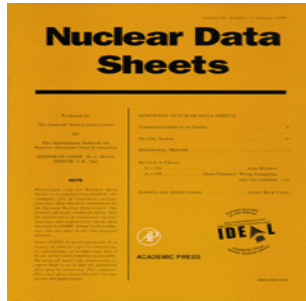
0 new datasets  
added/modified in  
the last month!

## Matching datasets in ENSDF

Retrieve selected ENSDF datasets:

Dataset	Last Revised	References
<input type="checkbox"/> Select All		
<input type="checkbox"/> ADOPTED LEVELS, GAMMAS	2012-10	<a href="#">All references</a>
<input type="checkbox"/> 92KR B- DECAY	2012-10	<a href="#">All references</a>
<input type="checkbox"/> 93KR B-N DECAY	2012-10	<a href="#">All references</a>
<input type="checkbox"/> 94Zr B- DECAY	2012-10	<a href="#">All references</a>

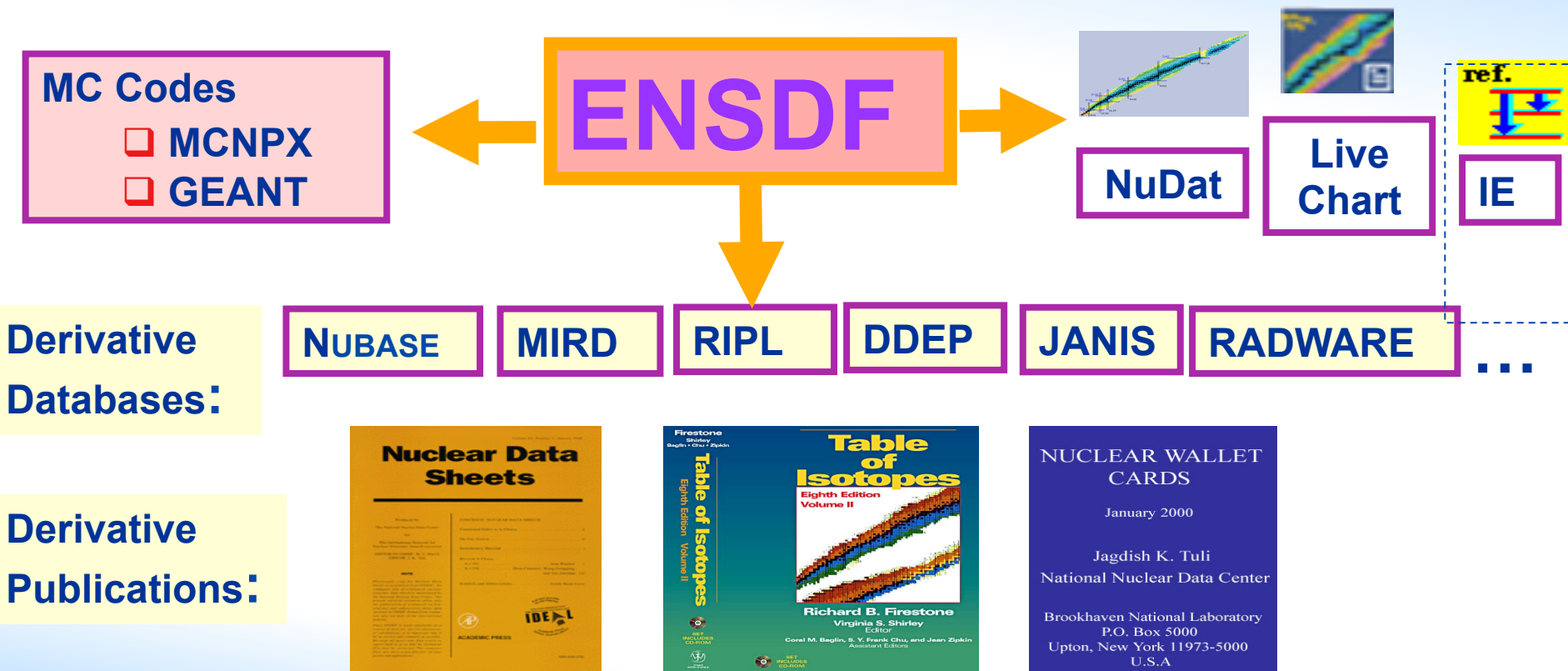
# ENSDF Evaluation



- Continuously updated
- Complete

- Levels, spins, parities
- Multipolarities, mixing ratios, conversion coefficients
- Half-lives, transitions strengths, emission probabilities...

# ENSDF: Major Data Sources and Derivatives



# Widely used ENSDF retrieval systems



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National Nuclear Data Center

## NuDat 2.6

Search and plot nuclear structure and decay data interactively. [More.](#)

### Levels and Gammas Search

Ground and excited states (energy,  $T_{1/2}$ , spin/parity, decay modes), gamma rays (energy, intensity, multipolarity, coinc.)

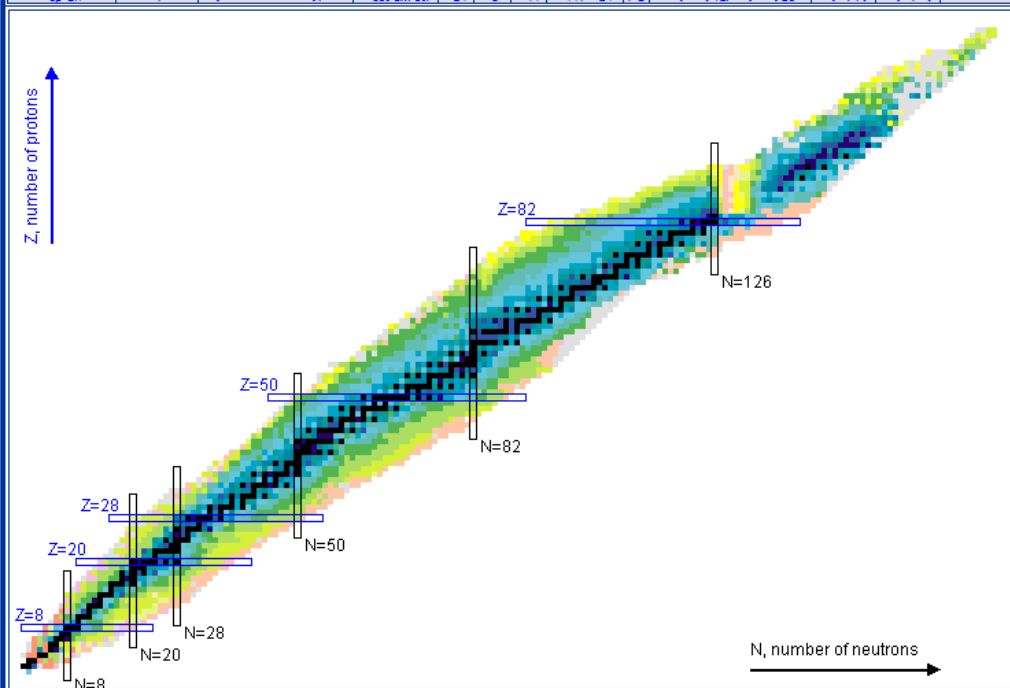
### Nuclear Wallet Cards Search

Latest Ground and isomeric states properties

### Decay Radiation Search

Radiation type, energy, intensity and dose following nuclear decay

Color code	Half-life	Decay Mode	$Q_{\beta^-}$	$Q_{\beta^+}$	$Q_{EC}$	$S_n$	$S_p$	$Q_{\alpha}$	$S_{2n}$	$S_{2p}$	$Q_{2\beta^-}$	$Q_{2EC}$	$Q_{2\beta^+}$
$Q_{\beta^-2n}$	BE/A	(BE-LDM Fit)/A	$E_{\beta^-}$ ex. st.	$E_{\beta^+}$	$E_{EC}$	$E_{n-}$	$E_{p-}/E_{2+}$	$\beta_2$	$B(E2)_{42}/B(E2)_{20}$	$\sigma(n,\gamma)$	$\sigma(n,F)$	235U FY	239Pu FY



Tooltips

On

Off

Zoom

1

2

3

4

5

6

7

Uncertainty

NDS

Standard

Screen Size

Narrow

Wide

Nucleus

go

Seconds

> 10+15

10+10

10+07

10+05

10+04

10+03

10+02

10+01

10+00

10-01

10-02

10-03

10-04

10-05

10-06

10-07

10-08

10-09

10-10

10-11

10-12

10-13

10-14

10-15

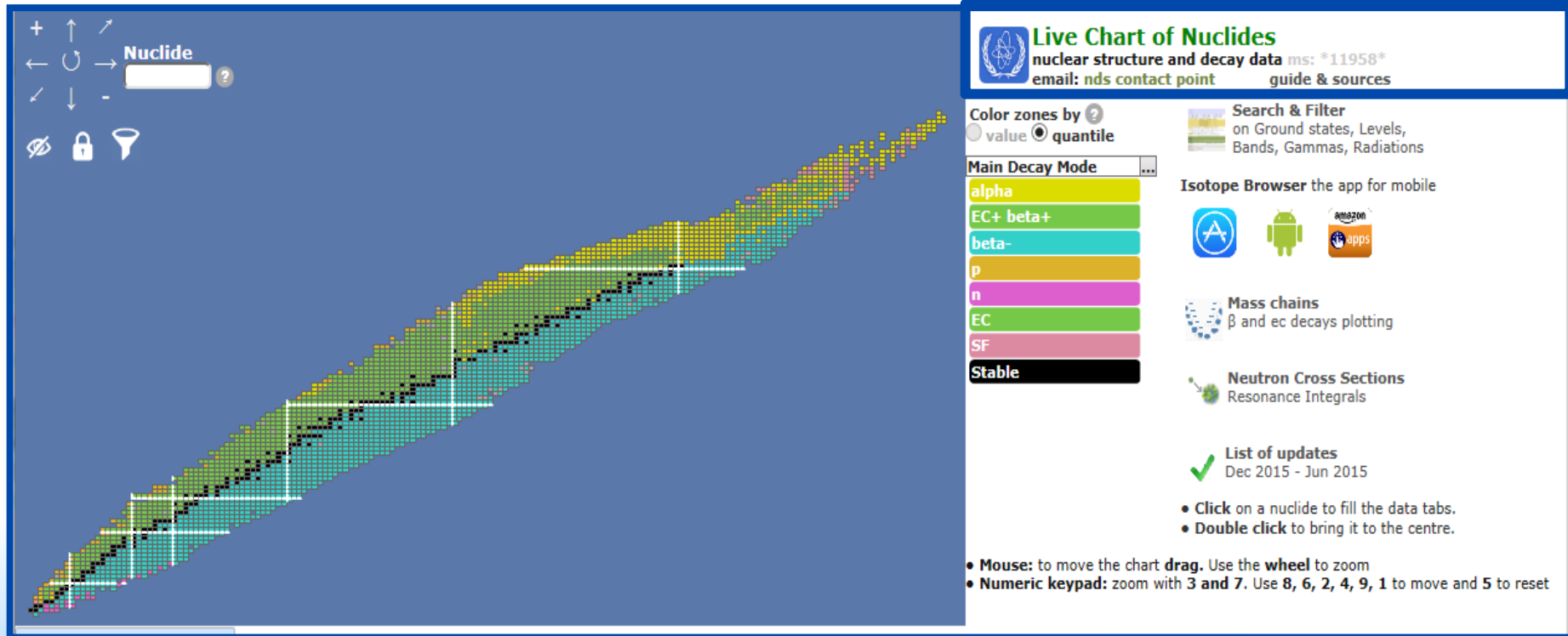
< 10-15

unknown

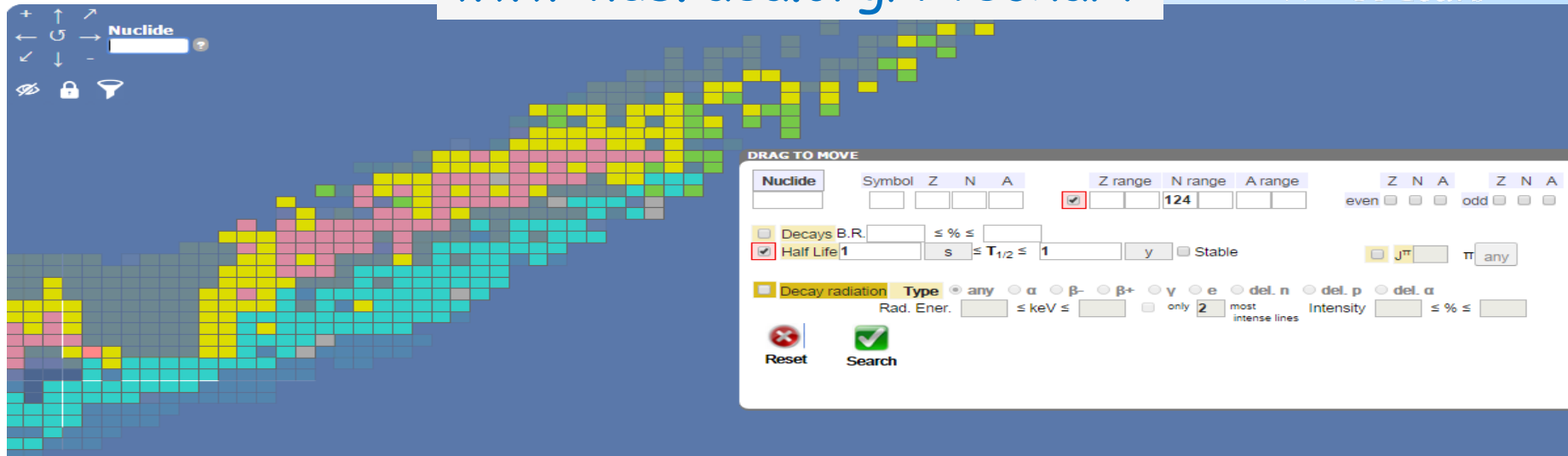
# Widely used ENSDF retrieval systems



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Ground State - Isomers

Levels

Gammas

Decay Radiation

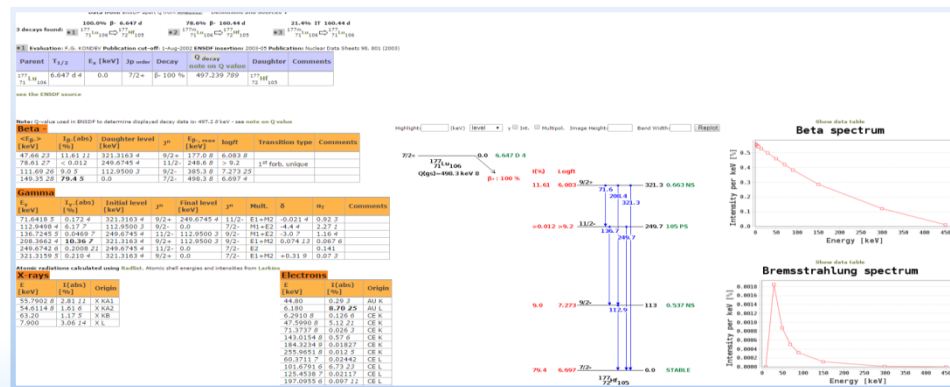
Nuclear Moments

Ther. Neutrons Capture

Fission Yields

Schema plot

- Nuclides Chart with filter
- ENSDF + other NS properties
- Data tables with evaluators' comments
- Level and decay schemas, decay radiation,  $\beta$  and bremsstrahlung spectra
- CSV download



## Build your query on ENSDF

- Custom plotting
- Data tables, level and decay schemes
- CSV data downloading

**NUCLIDE ground state**

Nuclide	Symbol	Z	N	A	Z range	N range	A range	Z N A	Z N A
								even <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	odd <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>

☐ More fields : Q-values, separation energies, atomic masses, radius

**LEVELS**

☐ Energy  ≤ keV ≤

☐ Decays B.R.  ≤ % ≤  ☒ Only Ground State and Metastables ☐ Isospin

☐ Half Life  3.68E-8 fs ≤ T<sub>1/2</sub> ≤  7.7E24 y ☐ Stable ☐  $\pi$   ☐ weak order ☐  $\pi$  any

☐ More fields : nuclear moments

**GAMMA transitions**

☐ Energy  ≤ keV ≤

☐ Final level  ≤ keV ≤  J  order ☐  $\pi$  any

☐ More fields : conversion coefficients, multipolarity, mixing ratio

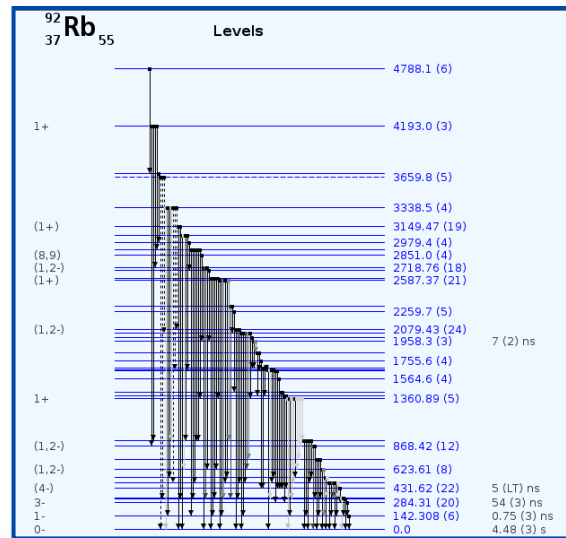
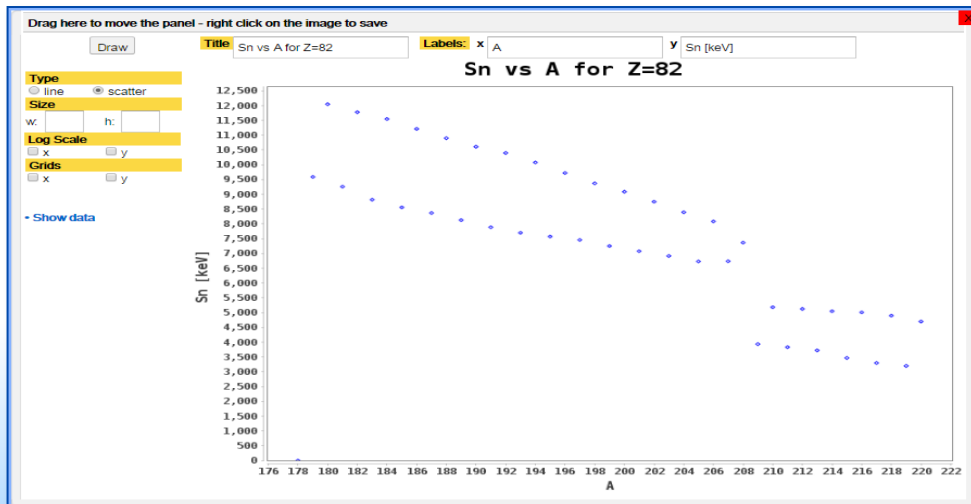
**DECAY radiation emitted by the daughter**

☐ Type ☐ any ☐  $\alpha$  ☐  $\beta^-$  ☐  $\beta^+$  ☐  $\gamma$  ☐ e

delayed ☐ n ☐ p ☐  $\alpha$

Energy  ≤ keV ≤  ☐ only  2 most intense lines

Intensity  ≤ % ≤



# IAEA Isotope Browser - for mobile devices



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**Isotope Browser**  
IAEA Nuclear Data Section

Chart Element

Go Clear Expert

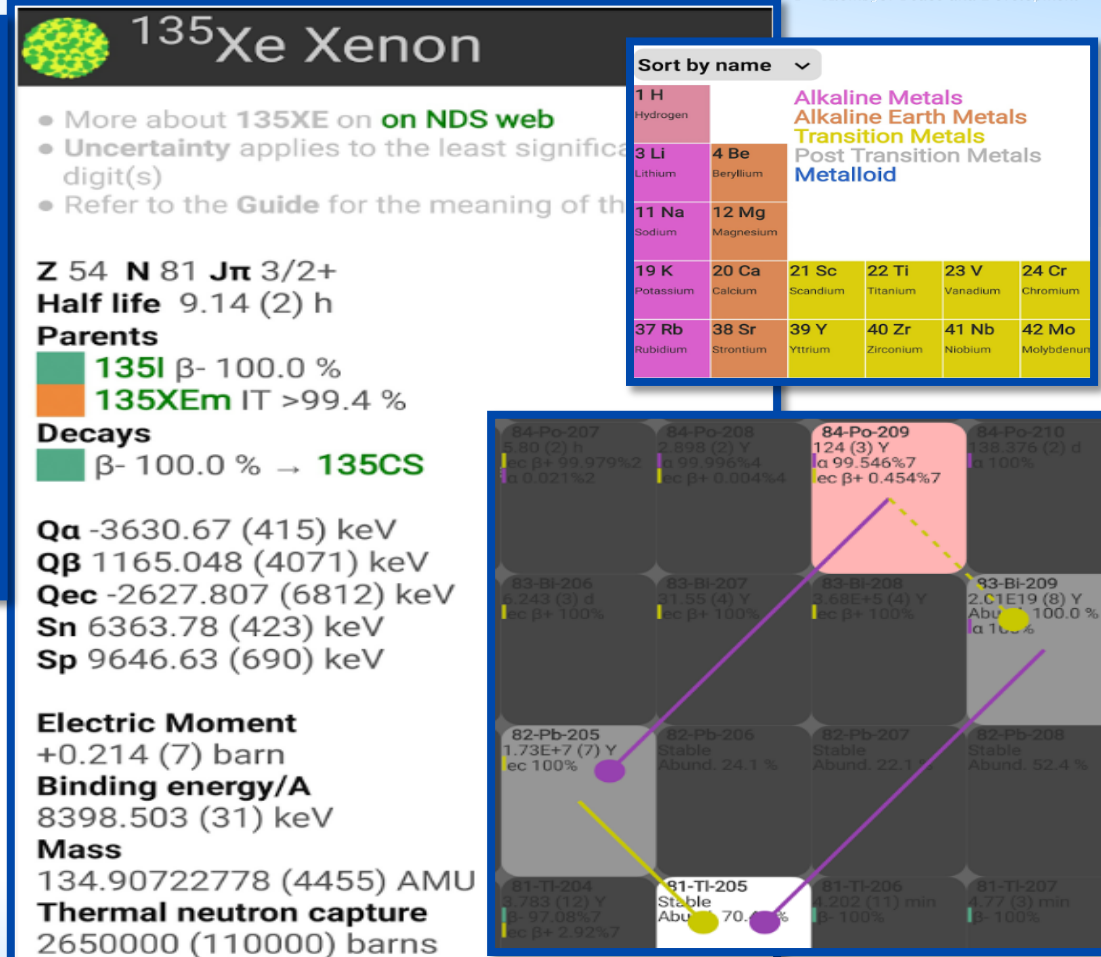
☐ Stable

**Decay and Main Radiations**

Decay mode

Decay Rad.

- ENSDF + other NS data
- Query tool
- Chart with decay path





# International Network of Nuclear Structure and Decay Data Evaluators

IAEA 60 Years  
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TUNL Nuclear Data  
Evaluation Project



ITT Roorkee



Petersburg Nuclear  
McMaster University Physics Institute



China Institute of Atomic Energy





# International Network of Nuclear



Since 1974 under auspices of

Nuclear Data Section  
International Atomic Energy Agency



ITT Roorkee



Petersburgh Nuclear

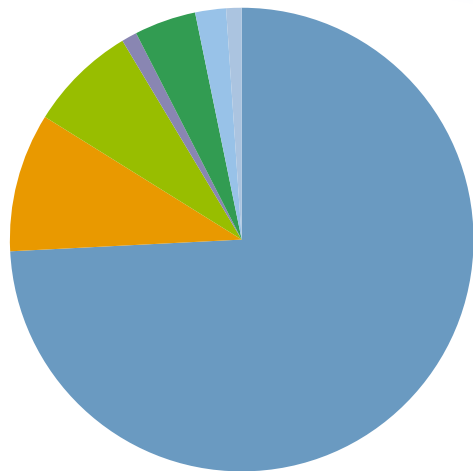
McMaster University Physics Institute



China Institute of Atomic Energy



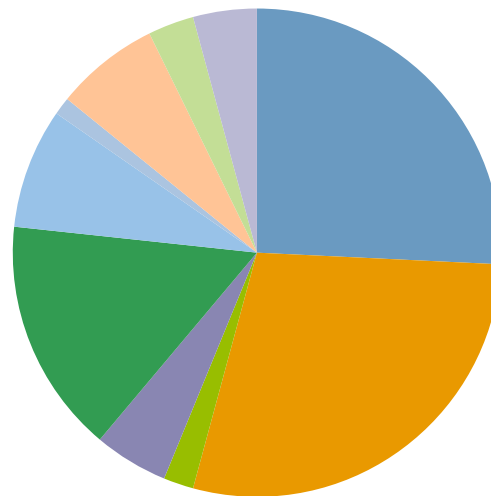
# NSDD evaluation vs Usage



- USA
- Europe
- IND
- RUS
- PRC
- JAP
- AUS

Downloads (%)  
from Nuclear  
Data Sheets

FTE  
contribution to  
ENSDF



- USA
- Europe
- India
- Russia
- PR China
- Japan
- Australia
- Saudi Arabia
- S. Korea



# A bit of history



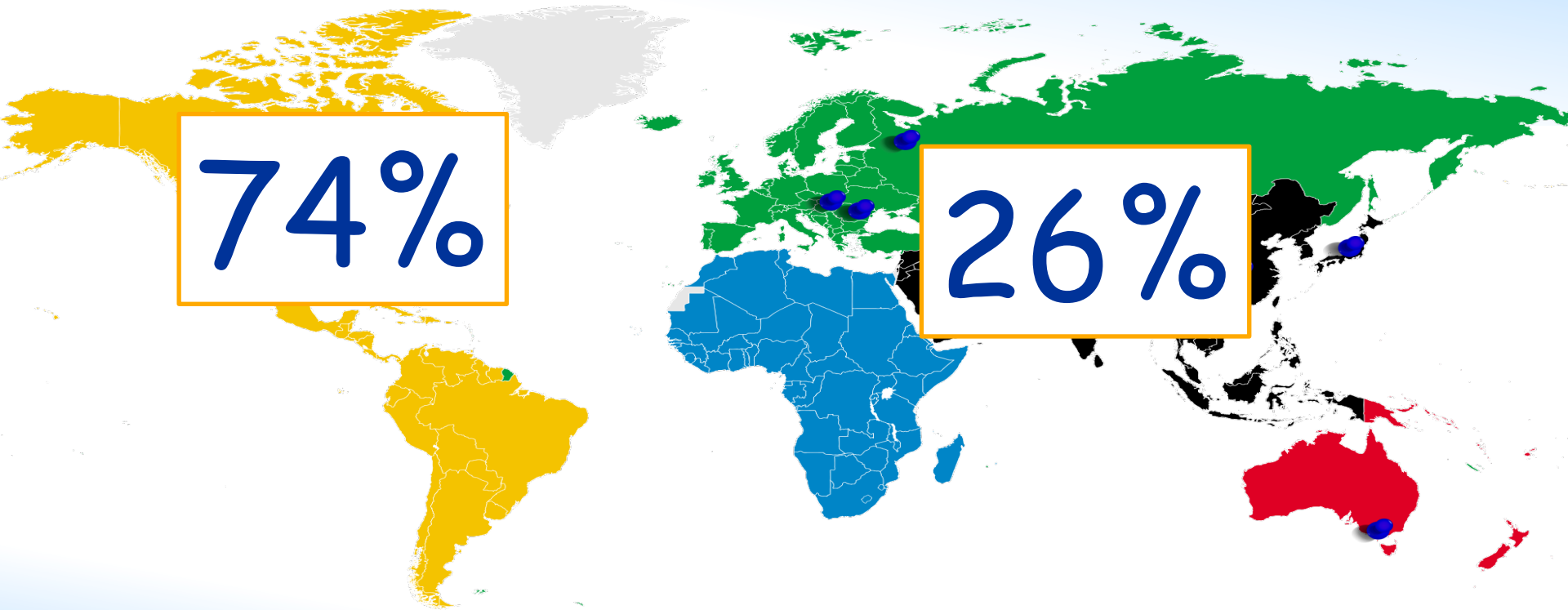
**Table 2.** Multinational mass chain evaluations for ENSDF – numbers of responsible laboratories/ institutes.

	Year			
	1981	1986	1996	2008
North America	6	6	6	6
Europe	6	5	4	1(→ 0)
Russia	2	2	2	1
Japan	1	1	1	1
China	-	-	1	2
Rest of the World	1	1	1	3
	16	15	15	14(→ 13)

**10-11 November 2008**

**IAEA Technical Meeting on Reference Data Libraries for Nuclear Applications - ENSDF**

# Perspectives



- 15 NSDD centres

# Present and Future

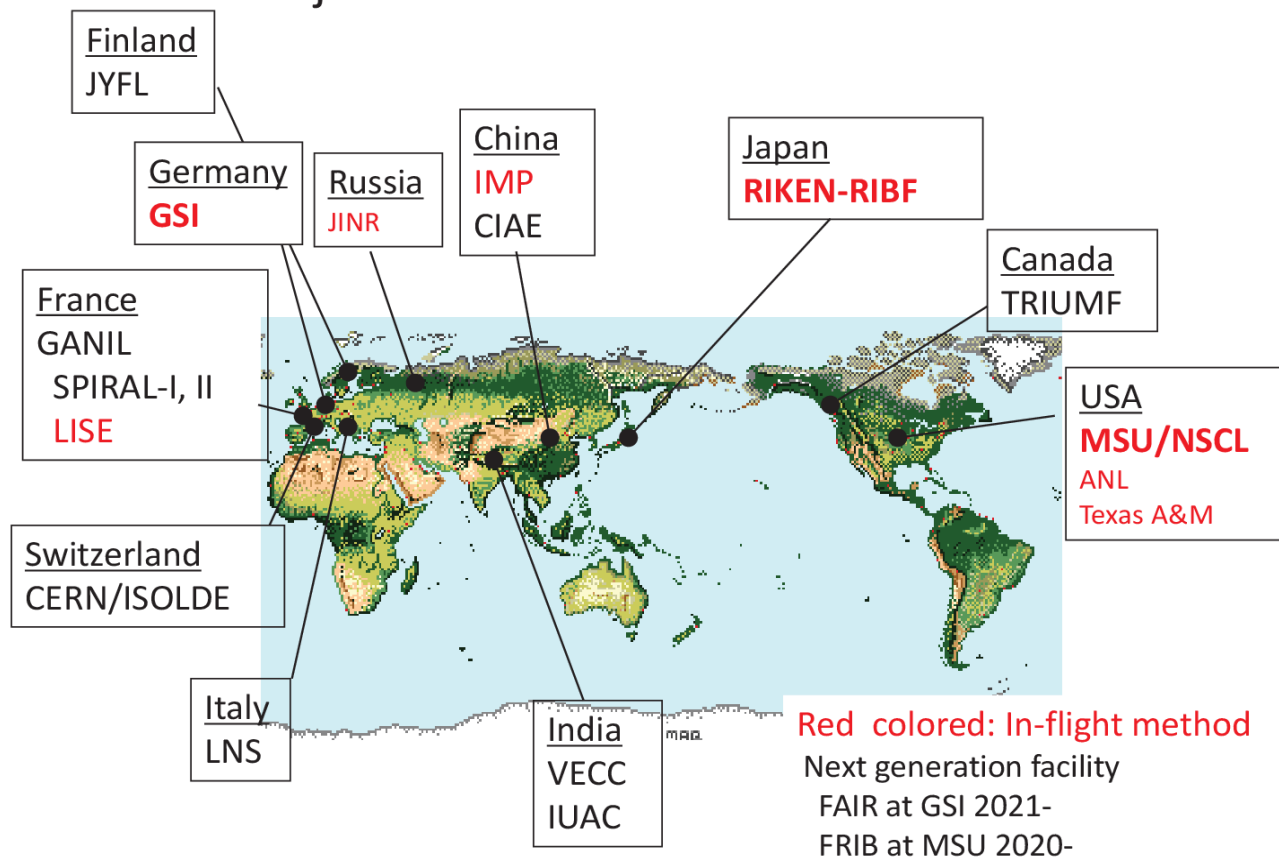


60 Years  
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- Require 12 full-time evaluators to keep ENSDF updated every 10 years - have only 9
- Limited funding
- Retirement of experienced evaluators
- Rapid growth in new data
- Increasing demands for reliable up-to-date nuclear data

- NSDD centres

## Major RI Beam Facilities in the world



## Major RI Beam Facilities in the world

Development

Contribution from the major facilities all around the world is **CRUCIAL !**

GANIL  
SPIRAL-I, II  
LISE

Switzerland  
CERN/ISOLDE

Italy  
LNS

-RIBF

Canada  
TRIUMF

- Maintain expertise in nuclear data
- Keep ENSDF current
- Provide top quality data for applications and basic research



# Web site: <http://www-nds.iaea.org/>



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International Atomic Energy Agency

## Nuclear Data Services

Sección Datos Nucleares, OIEA

[IAEA.org](#) | [NDS Mission](#) | [About Us](#) | [Mirrors: India](#) | [China](#)

Search

Go

**Hot Topics** » [ENDF/B-VII.1](#) • [TENDL-2014](#) • [JENDL-4.0u2](#) • [IBANDL](#) **News** » [Damage cross section database extended by SS-316 and Eurofer](#)

### Request

CD/DVD with documentation, data, codes, etc.

### Quick Links

[ADS-Lib](#)  
[Atomic Mass Data Centre](#)  
[CINDA](#)  
[Charged particle reference cross section](#)  
[DROSG-2000](#)  
[DXS](#)  
[EMPIRE-3.2](#)  
[ENDF Archive](#)  
[ENDF Retrieval](#)  
[ENDF-6 Codes](#)  
[ENDF-6 Format](#)  
[ENDVER](#)  
[ENSDF](#)  
[ENSDF ASCII Files](#)  
[ENSDF programs](#)  
[EXFOR](#)  
[Electron and Photon Interaction Data](#)  
[FENDL](#)  
[Fission Yields](#)  
[GANDR](#)

**NEW**

**GRUCON** - ENDF Data Processing Package [\[page\]](#)  
**Prepro-2015** - ENDF/B Pre-Processing Codes [\[page\]](#)  
**IRDF** - International Reactor Dosimetry and Fusion File v1.05 [\[page\]](#)

**Main** | [All](#) | [Reaction Data](#) | [Structure & Decay](#) | [by Applications](#) | [Doc & Codes](#) | [Index](#) | [Events](#) | [Links](#) | [News](#)



#### EXFOR

Experimental nuclear reaction data



#### LiveChart of Nuclides

Interactive Chart of Nuclides



#### CINDA

Nuclear reaction bibliography



#### ENDF

Evaluated nuclear reaction libraries



#### ENSDF

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



#### NSR

Nuclear Science References \*

#### NuDat 2.6

selected evaluated nuclear structure data \*\*

#### RIPL

reference parameters for nuclear model calculations

#### IBANDL

Ion Beam Analysis Nuclear Data Library

#### Charged particle reference cross section

Beam monitor reactions

#### PGAA

Prompt gamma rays from neutron capture

#### FENDL

Fusion Evaluated Nuclear Data Library

#### Photonuclear

cross sections and spectra up to 140 MeV

#### IRDF

International Reactor Dosimetry and Fusion File

#### NAA

Neutron Activation Analysis Portal

#### Safeguards Data

recommendations, August 2008

#### Medical Portal

Data for Medical Applications

#### Standards

- Neutron cross-sections, 2006  
- Decay data, 2005

\* Database at the IAEA, Vienna

\*\* Database at the US NNDC

### IAEA Nuclear Data Section



IAEA-NDS  
Mission, Staff  
and more



A-M  
Atomic  
and  
Molecular  
Data



Meetings  
Workshops



Newsletters



Coordinated  
Research  
Projects



Nuclear Reaction  
Data Center  
Network



Nuclear Structure  
& Decay Data  
Network



Technical Documents  
INDC Reports  
Publications



Computer  
Codes

### Mirrors

### Partners

### Events «2:3»



24<sup>th</sup> International  
Seminar on Interaction  
of Neutrons with Nuclei  
(ISINN-24)  
May 23-27, 2016  
Dubna, Russian  
Federation



13<sup>th</sup> Computer  
Simulation of Radiation  
Effects in Solids  
(COSIRES 2016)  
June 19-24, 2016  
Loughborough  
University,  
Leicestershire, UK

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*Thank you!*

