



May 2, 2025

# Fundamental Insights to the Evaluated Nuclear Structure Data File (ENSDF)

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U.S. DEPARTMENT OF  
**ENERGY**

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# The Reality of Nuclear Data Evaluation

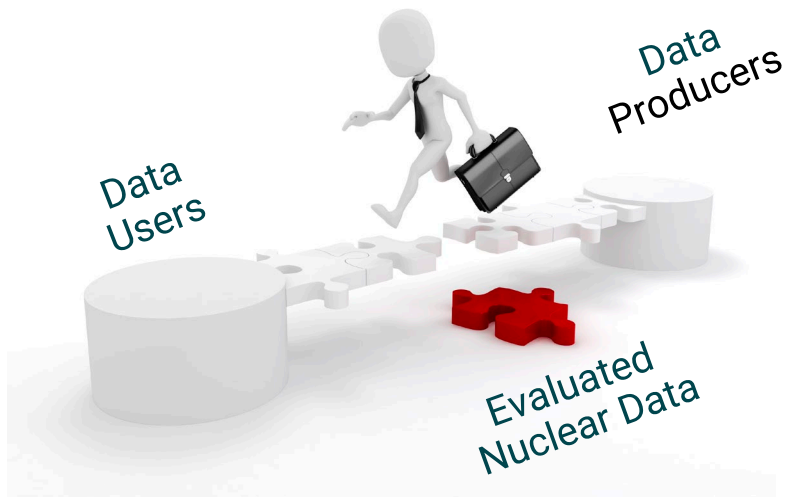
The nitty gritty details are about as exciting as watching paint dry



# The Reality of Nuclear Data Evaluation

But the end product can be a masterpiece

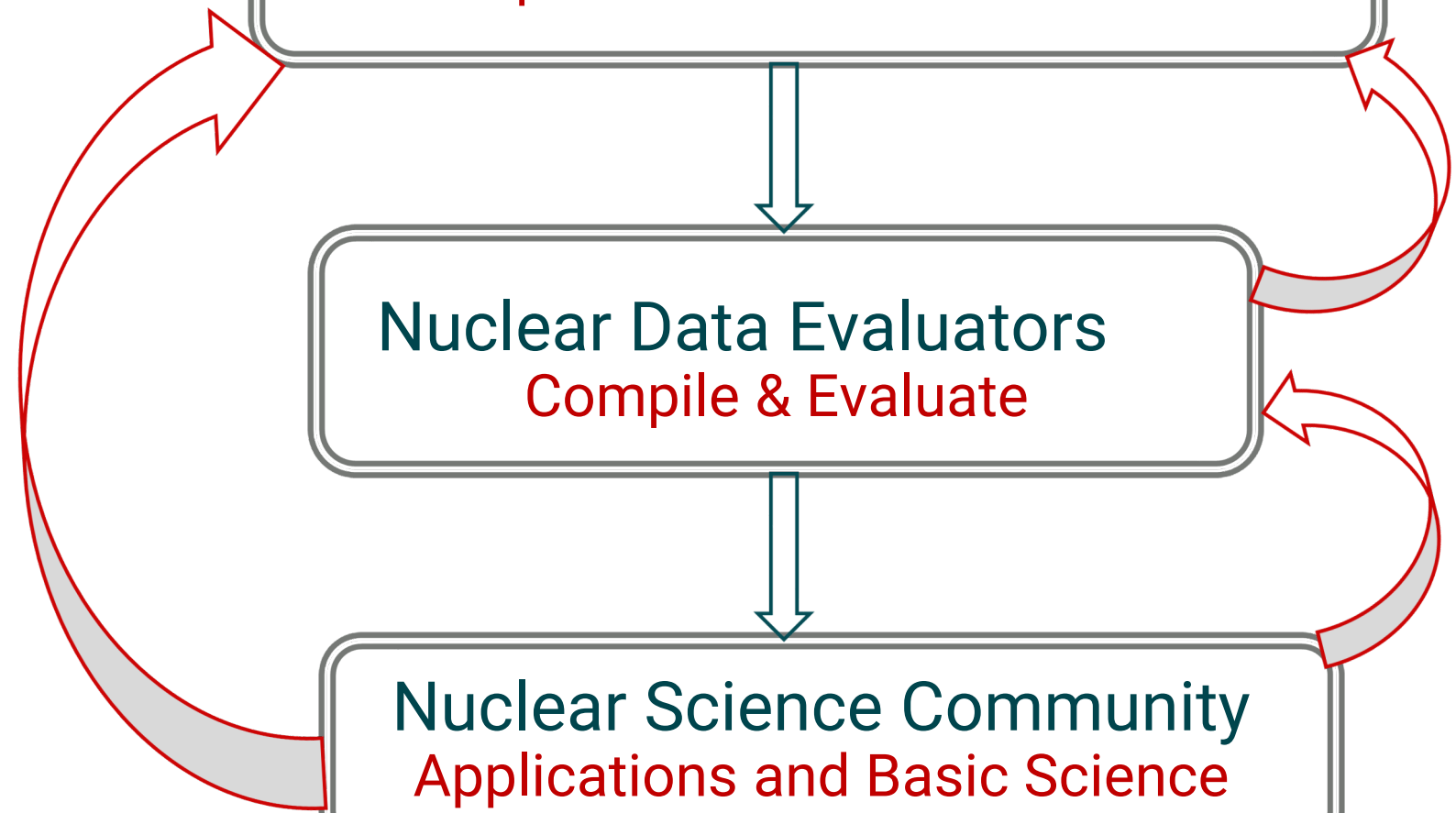




**Nuclear Science Researchers**  
Experimenters & Theorists

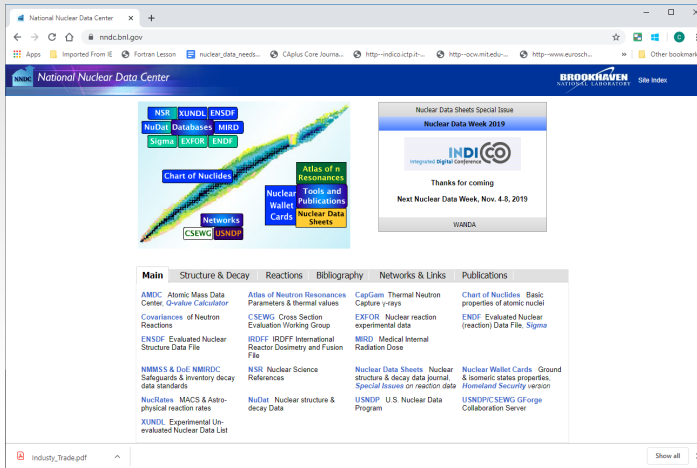
**Nuclear Data Evaluators**  
Compile & Evaluate

**Nuclear Science Community**  
Applications and Basic Science



## NNDC-ENSDF

<https://www.nndc.bnl.gov/>



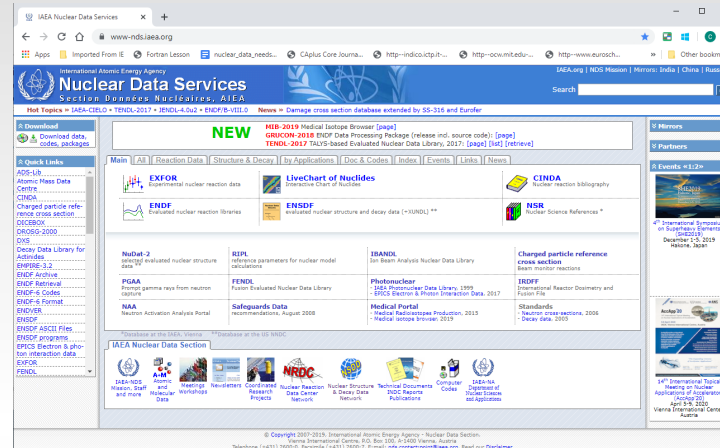
National Nuclear Data Center at Brookhaven National Laboratory, USA

Evaluated Nuclear Structure Data File (ENSDF)

United States Nuclear Data Program (USNDP)

## IAEA-Nuclear Data Services

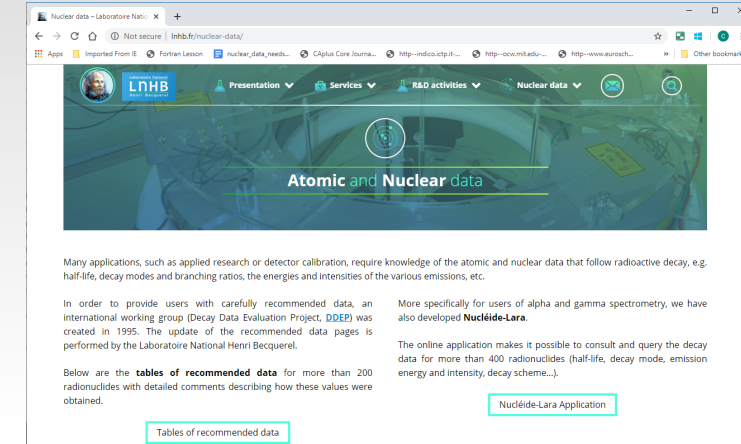
<https://www-nds.iaea.org/>



- International Atomic Energy Agency, Austria
- International Nuclear Structure and Decay Data Network (NSDD)
- Coordinated Research Projects (CRPs) – IAEA Scientific & Technical Report

## LNHB-DDEP

<http://www.lnhb.fr/nuclear-data/>



Many applications, such as applied research or detector calibration, require knowledge of the atomic and nuclear data that follow radioactive decay, e.g. half-life, decay modes and branching ratios, the energies and intensities of the various emissions, etc.

In order to provide users with carefully recommended data, an international working group (Decay Data Evaluation Project, DDEP) was created in 1995. The update of the recommended data pages is performed by the Laboratoire National Henri Becquerel.

Below are the **tables of recommended data** for more than 200 radionuclides with detailed comments describing how these values were obtained.

More specifically for users of alpha and gamma spectrometry, we have also developed **Nuclide-Lara**.

The online application makes it possible to consult and query the decay data for more than 400 radionuclides (half-life, decay mode, emission energy and intensity, decay scheme...).

- Laboratoire National Henri Becquerel, CEA. France
- Decay Data Evaluation Project (DDEP)
- Adopted and supported by the Bureau International des Poids et Mesures (BIPM)

# Evaluated Nuclear Structure Data File (ENSDF)

## Brief Exploration of ENSDF

ENSDF is a database that consists of complex nuclear level schemes and tables of numerical values and quantum numbers for structure and decay properties of nuclides

National Nuclear Data Center  
 NNDC Databases: NuDat | NSR | XUNDL | ENSDF | MIRD | ENDF | CSISRS | Sigma

**ENSDF: Evaluated Nuclear Structure Data File Search and Retrieval**  
 Last updated 2019-11-26  
 ENSDF provides recommended nuclear structure and decay information.  
 For more recent nuclear data which has not yet been evaluated, please visit XUNDL.

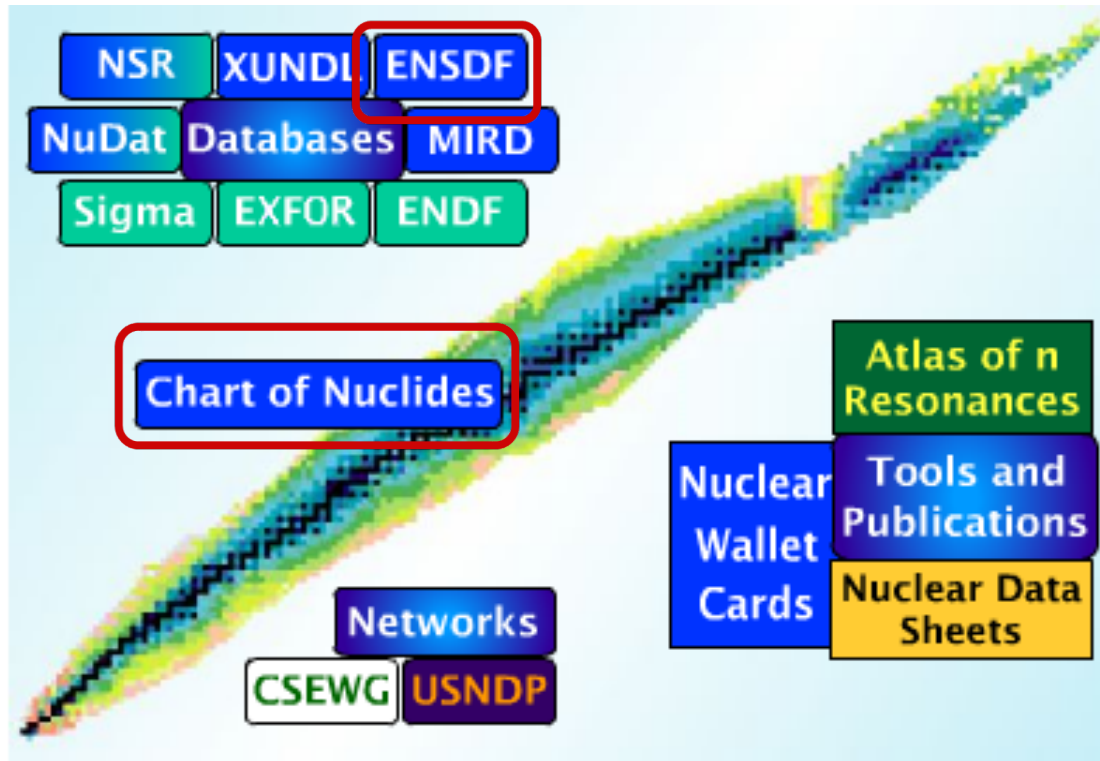
0 new datasets added/modified in the last month!

Suggestions or comments? Please [let us know!](#)

Quick Search | By Nuclide | By Reaction | By Decay | Recently Added

Nuclide or mass:  Search  
*(<sup>208</sup>Pb, pb-208, 144, 1n (neutron), etc.)*

Check out the [Summary of ENSDF!](#)  
 A listing of when nuclides were last evaluated and recent XUNDL datasets.



**NuDat 2.7**  
 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	$Q_{\beta^-}$	$Q_{EC}$	$Q_{\beta^+}$	$S_{\beta^-}$	$S_{\beta^+}$	$Q_{\alpha}$	$\Delta Q_{\alpha}$	$S_{2n}$	$S_{2p}$	$Q_{\beta^-}$	$Q_{EC}$	$Q_{\beta^+}$	$Q_{\beta^-}$
$Q_{\beta^-}$	BE/A	(BE-LDM Fit)/A	Pair. gap	$E_{1st\ ex.}\ at.$	$E_{2^-}$	$E_{3^-}$	$E_{4^-}$	$E_{4^+}/E_{2^+}$	$\beta_2$	$B(E2)_{42}/B(E2)_{20}$	$\sigma(n,\gamma)$	$\sigma(n,f)$	235U FY	239Pu FY	252Cf FY

Interactive Chart of Nuclides  
 Click on a nucleus to obtain information

Tools: Tooltips (On/Off), Zoom (1-7), Uncertainty (NDS, Standard, Screen Size, Narrow, Wide), Nucleus (go), Seconds (10+15 to <10-15, unknown)

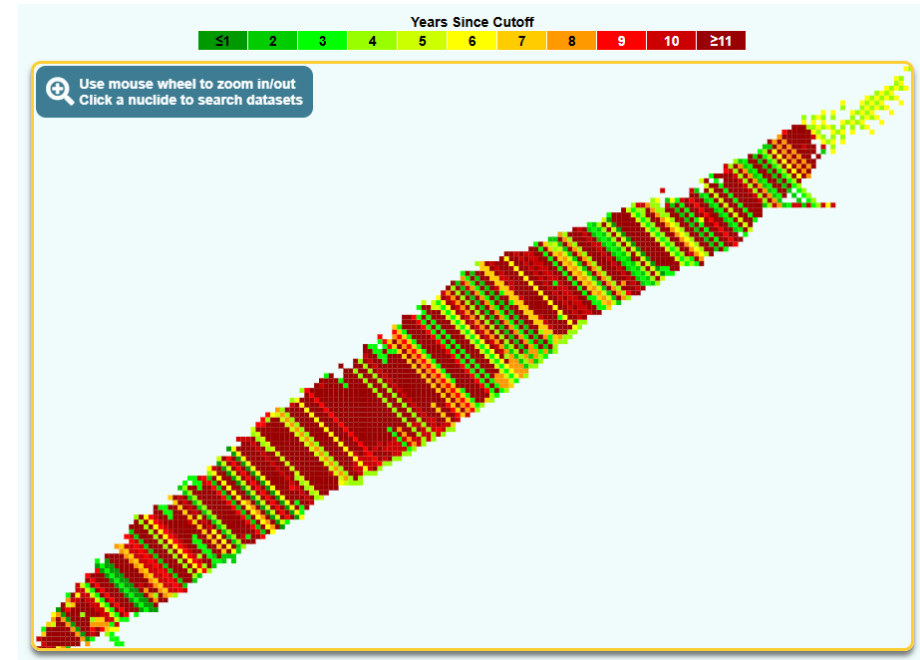
# Structure and Decay Data Evaluators

## Nuclear Structure and Decay Data network (NSDD)

International group coordinated by IAEA



## United States Nuclear Data Program (USNDP)



LLNL-TR-840465

### First Report of the Nuclear Data Subcommittee of the Nuclear Science Advisory Committee

F. Bostelmann, M. Carpenter, M. Chadwick, M. Fratoni, A. Hawari, L. Heilbronn, C. Howell, J. Ressler, C. Keppel, A. Koning, K. LaBel, T. Turflinger, C. Nesaraja, S. Qaim, C. Romano, A. Spyrou, S. Siem, C. Vermeulen, R. Vogt

September 29, 2022



LLNL-TR-845408

### Second Report of the Nuclear Data Subcommittee of the Nuclear Science Advisory Committee

L. A. Bernstein, F. Bostelmann, M. Carpenter, M. Chadwick, M. Fratoni, A. Hawari, L. Heilbronn, C. Howell, J. Ressler, C. Keppel, A. Koning, K. LaBel, T. Turflinger, C. Nesaraja, S. Qaim, C. Romano, A. Spyrou, S. Siem, C. Vermeulen, R. Vogt

February 22, 2023

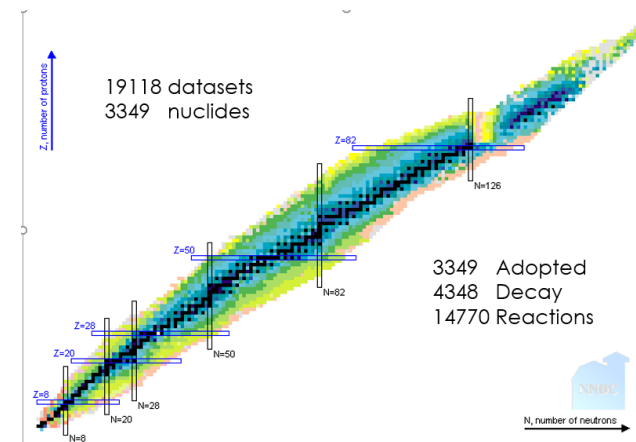
# Evaluated Nuclear Structure Data File (ENSDF)

## Decay and Reaction

- All experimental results published are compiled into datasets
- Types of Experiments  
Reaction: Transfer, Heavy Ion, Coulomb Ex. Inelastic Scattering, Capture, Resonance, Charge Exchange, etc.  
Decay: alpha, beta, electron capture, etc.
- Properties: Level energy, spin, parity, half-life, decay modes, branching ratio, radiation energy, intensities etc.

## Adopted Level and Gammas

- “Best Value” derived from critical analysis of individual decay and reaction datasets
- As data continue to expand and improve as experimental techniques grow and become more sophisticated, the Adopted Data too is updated to reflect the latest measurements



courtesy of E.A. McCutchan at NNDC, BNL

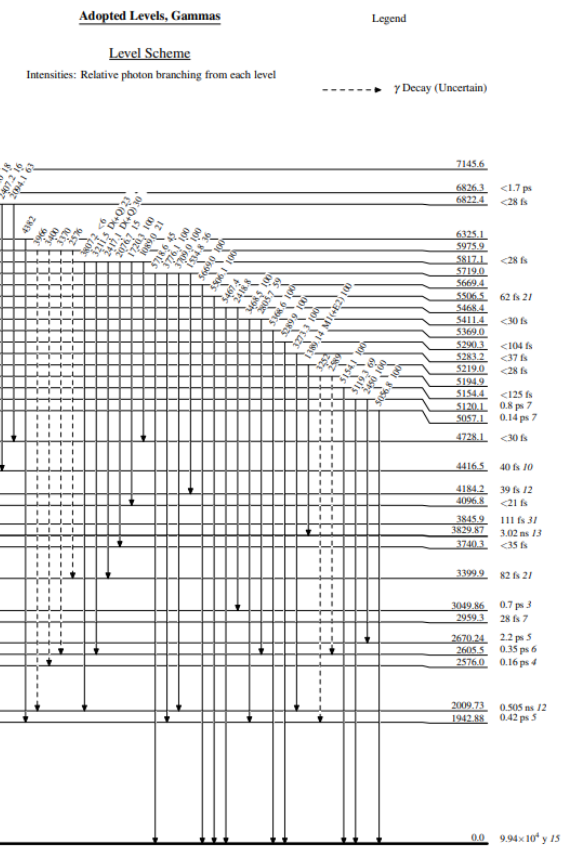
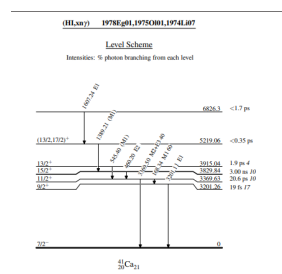
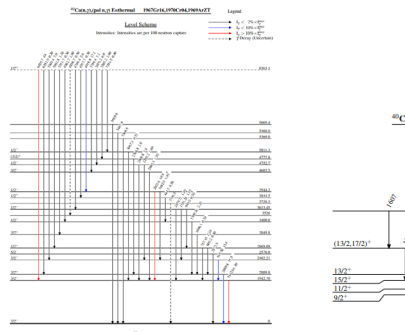
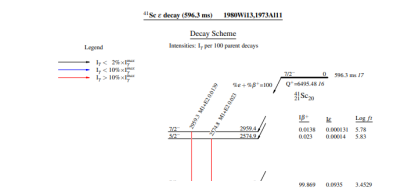
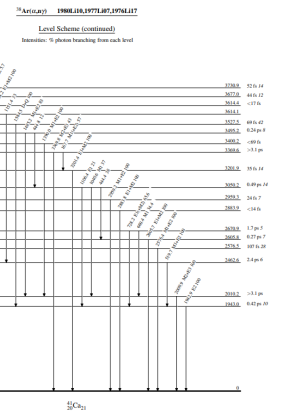
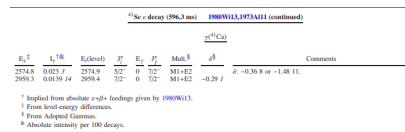
# Evaluated Nuclear Structure Data File (ENSDF)

## Decay and Reaction

## Adopted

- |   |  |  |
|---|--|--|
| <b>A</b> $^{41}\text{Sc}$ $\alpha$ decay (596.3 ms)   | <b>O</b> $^{40}\text{Ca}$ (pol d,p),(d,p)                              | <b>AB</b> $^{40}\text{Ca}$ ( $^9\text{Be}$ , $^8\text{Be}$ )       |
| <b>B</b> (HL,xny)   | <b>P</b> $^{40}\text{Ca}$ (d,py), $^2\text{H}$ ( $^{40}\text{Ca}$ ,py) | <b>AC</b> $^{40}\text{Ca}$ ( $^{11}\text{B}$ , $^{10}\text{B}$ )   |
| <b>C</b> $^{38}\text{Ar}$ ( $\alpha$ ,ny)   | <b>Q</b> $^{40}\text{Ca}$ (t,d)  | <b>AD</b> $^{40}\text{Ca}$ ( $^{12}\text{C}$ , $^{11}\text{C}$ )   |
| <b>D</b> $^{39}\text{K}$ ( $^7\text{Li}$ , $\alpha$ ny), $^{40}\text{Ca}$ ( $^3\text{He}$ ,2py) | <b>R</b> $^{40}\text{Ca}$ ( $\alpha$ , $^3\text{He}$ )                 | <b>AE</b> $^{40}\text{Ca}$ ( $^{13}\text{C}$ , $^{12}\text{C}$ )   |
| <b>E</b> $^{40}\text{Ca}$ ( $\alpha$ ,2pn)  | <b>S</b> $^{40}\text{Ca}$ (p, $\pi^+$ ), (pol p, $\pi^+$ )             | <b>AF</b> $^{40}\text{Ca}$ ( $^{14}\text{C}$ , $^{13}\text{C}$ )   |
| <b>F</b> $^{40}\text{Ca}$ (n, $\gamma$ ),(pol n, $\gamma$ ) E=thermal                           | <b>T</b> $^{41}\text{Ca}$ (p,p')                                       | <b>AG</b> $^{40}\text{Ca}$ ( $^{14}\text{N}$ , $^{13}\text{N}$ )   |
| <b>G</b> $^{40}\text{Ca}$ (n, $\gamma$ )  | <b>U</b> $^{41}\text{Ca}$ ( $\alpha$ , $\alpha'$ )                     | <b>AH</b> $^{40}\text{Ca}$ ( $^{17}\text{O}$ , $^{16}\text{O}$ )   |
| <b>H</b> $^{39}\text{K}$ ( $^3\text{He}$ ,p)  | <b>V</b> $^{42}\text{Ca}$ (p,d)  | <b>AI</b> $^{40}\text{Ca}$ ( $^{18}\text{O}$ , $^{17}\text{O}$ )   |
| <b>I</b> $^{39}\text{K}$ ( $^3\text{He}$ ,py)   | <b>W</b> $^{42}\text{Ca}$ (d,t)  | <b>AJ</b> $^{40}\text{Ca}$ ( $^{28}\text{Si}$ , $^{27}\text{Si}$ ) |
| <b>J</b> $^{39}\text{K}$ ( $\alpha$ ,d)   | <b>X</b> $^{42}\text{Ca}$ ( $^3\text{He}$ , $\alpha$ )                 | <b>AK</b> $^{40}\text{Ca}$ ( $^{32}\text{S}$ , $^{31}\text{S}$ )   |
| <b>K</b> $^{40}\text{K}$ (d,n)  | <b>Y</b> $^{42}\text{Ca}$ ( $^3\text{He}$ , $\alpha$ ny)               | <b>AL</b> $^{42}\text{Ca}$ ( $^{48}\text{Ti}$ , $^{49}\text{Ti}$ ) |
| <b>L</b> $^{40}\text{K}$ ( $^3\text{He}$ ,d)  | <b>Z</b> $^{43}\text{Ca}$ (p,t)  | <b>AM</b> $^{41}\text{Ca}$ (e,e)                                   |
| <b>M</b> $^{41}\text{K}$ (p,ny)   | <b>Others:</b>   | <b>AN</b> $^{40}\text{Ca}$ (n,n):resonances                        |
| <b>N</b> $^{41}\text{K}$ ( $^3\text{He}$ ,t)  | <b>AA</b> $^{40}\text{Ca}$ ( $^7\text{Li}$ , $^6\text{Li}$ )           |  |

Reconcile multiple dataset types and derive a recommended set of Adopted Values



# Evaluation Process

1. Retrieve all references in journals, proceedings, reports, theses etc. using the Nuclear Science Reference (NSR) and other resources.

The screenshot shows the NSR website with the following elements:

- Browser address bar: [nndc.bnl.gov/nsr/](http://nndc.bnl.gov/nsr/)
- Navigation menu: NNDc Databases: NuDat | NSR | XUNDL | ENSDF | MIRD | ENDF | CSISRS | Sigma
- Page title: Nuclear Science References (NSR)
- Subtitle: NSR Reference Paper NIM A 640, 213 (2011)
- Text: Database version of December 13, 2019
- Search tabs: Quick Search, Text Search, Indexed Search, Keynumber Search, Combine View, Recent References
- Search form fields: Author (Brown or B.A. Brown), Nuclide (31Na or ca-38), Reaction (g or (n,g) or (16O, 16O)), Publication Year (from 1896 to 2020), Reference Type (All, Experiment, Theory), Output Format (HTML, BibTex, Text)
- Buttons: Search, Reset
- Footer: Database Manager: Boris Pritychenko, NNDc, Brookhaven National Laboratory; Web Programming: Boris Pritychenko, NNDc, Brookhaven National Laboratory; Data Source: NNDc, Brookhaven National Laboratory, HDG, McMaster University

The diagram illustrates the components of a reference entry:

- NSR key number:** 2016JU05
- Reference:** Appl.Radiat.Isot. 118, 215 (2016)
- Keywords describing the article:** Determiation of  $^{137}\text{Cs}$  half-life with an ionization chamber
- Abstract/Summary:** RADIOACTIVITY  $^{137}\text{Cs}(\beta^-)$ ; measured decay products,  $E\beta$ ,  $I\beta$ ; deduced  $T_{1/2}$  and uncertainties. Comparison with available data.
- DOI:** 10.1016/j.apradiso.2016.09.002
- Link to article:** Data from this article have been entered in the XUNDL database. For more information, click here.



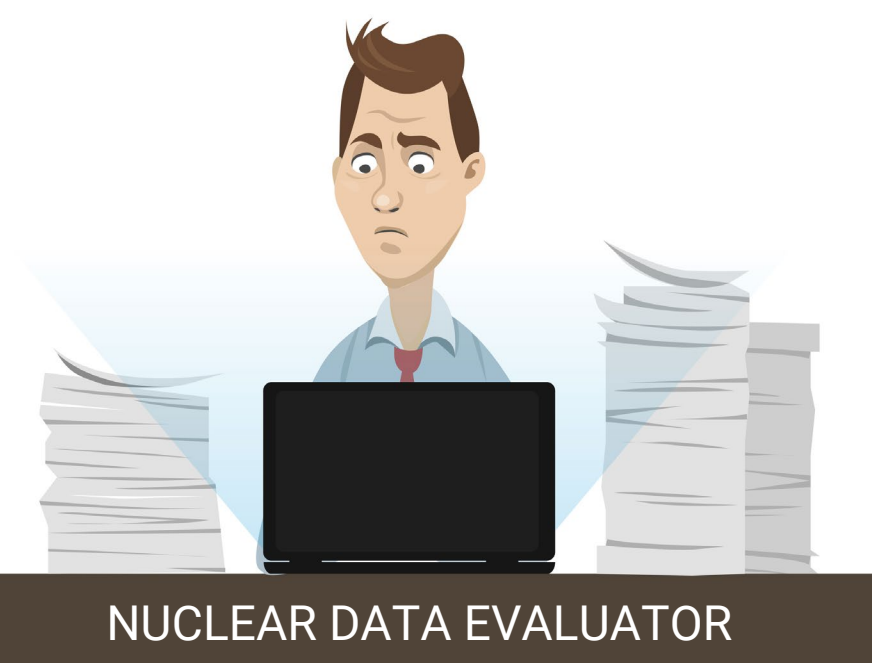
Search parameters

Link to article (requires subscription)

[www.nndc.bnl.gov/nsr](http://www.nndc.bnl.gov/nsr)

NSR contains references to publications from over 80 major journals, as well as internal reports from labs throughout the world

## 2. Compile & critically analyze all published results



NUCLEAR DATA EVALUATOR

# 3. Prepare datasets for each type of reaction and decay

Compiled data has to be prepared into datasets using specific ENSDF procedures and guidelines.

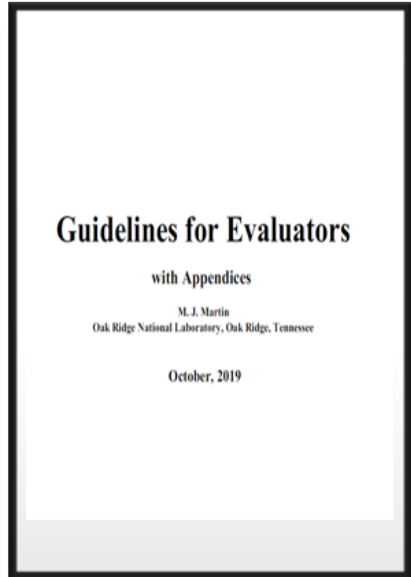
NSDD is the governing body that determines the rules for the evaluation process

ENSDF Standard 80-character Formatted Records

Record	1	2	3	4	5	6	7	8
IDENT	NUCID	blank	DSID	blank	DSREF	blank	PUB	DATE
XREF	NUCID	blank	DSID	blank	blank	blank	blank	blank
REF	AAA	blank	SYNFLAG	blank	REFERENCE	blank	blank	blank
HIST	NUCID	blank	HTEXT	blank	blank	blank	blank	blank
Q-VALUE	NUCID	blank	Q	DOJ	SN	DSN	SP	DSP
G COMM	NUCID	blank	blank	blank	blank	blank	blank	blank
F/R COMM	NUCID	blank	blank	blank	blank	blank	blank	blank
PARENT	NUCID	blank	E	DE	J	T	DT	blank
NORM	NUCID	blank	NR	DNR	NT	DNT	BR	DBR
P NORM	NUCID	blank	NR*BR	UNC	NT*BR	DNC	blank	blank
LEVEL	NUCID	blank	E	DE	J	T	DT	L
BETA	NUCID	blank	E	DE	IB	DIB	blank	LOGFT
EC	NUCID	blank	E	DE	IB	DIB	IE	DIE
ALPHA	NUCID	blank	E	DE	IA	DIA	IP	DIP
PART	NUCID	blank	E	DE	IP	DIP	ED	T
GAMMA	NUCID	blank	E	DE	RI	DR	M	MR

```

41CA 33AR(A,N) 1980L10,1977L107,1976L117
41CA H TYP=FULZNF-E.A. MCCUTCHAN and C. D. NESARAJACUT=30-March-2015
41CA 0 All references are from the same group with E(a)=7.5-14 MeV. Deduced
41CA2c levels. Fig. 1g, 1d, 1f.
41CA 0 1980L101E(a)=9.6-13.0 MeV. Gammas detected with Ge(Li) detector
41CA2c and [p-44] linear polarisation measured with three Ge(Li) Compton
41CA3c polarimeter. Measured E(g), I(g), I(g|lin pol), I(d for most
41CA2c of the levels
41CA 0 1977L109: I(g) and I(g|lin pol) data for J(p assignments for
41CA2c 3369, 3830, 3914, 3976, 4519 and 5219 levels
41CA 0 1976L117E(a)=7.5-14.5 MeV. Measured I(g) coin. and level lifetimes
41CA2c by Doppler-shift attenuation method (DSAM)
41CA 0 L T(F)From DSM (1976L117),c
41CA 0 L T(A)FFrom DSM (1980L10)
41CA 0 J(F)From Adopted Levels. Most of these assignments
41CA2c agree with those from 1980L10 which were based on I(g)
41CA2c and I(g|lin pol) data
41CA 0 E(F)From 1980L10
41CA 0 E(F)From 1976L117, unless otherwise stated
41CA 0 E(B)FFrom 1980L10
41CA 0 H,R(F)From I(g) and I(g|lin pol) data (1980L10,1977L109),
41CA2c combined with BUL
41CA 0 RI(A)FFrom (d,p) (1974M01) since 444 I(g) and 445 I(g) form an unresolved
41CA2c doublet in (h,n)
41CA 0 RI(C)FFrom (d,p) (1975T13)
41CA 0 7
41CA 0 7/2-
41CA L 1943.0 33/2- 0.42 PS 10
41CA G 1942.9 5 100 ES
41CA G 2420.-0.48 1A, A+0.01 L, POL=+0.14 2
41CA L 2010.2 33/2- 3.1 PS 9T
41CA G 2009.9 5 100 M+E3 40.16 2
41CA G 2420.-0.02 1, A+0.01 L, POL=-0.10 2
41CA L 2462.6 43/2- 2.4 PS 6
41CA G 2149.7 2 100 M+E2 40.03 1
41CA G 2420.-0.22 1, A+0.02 L, POL=+0.30 2
41CA L 2874.5 65/2- 107 PS 28
41CA G 2974.9 4 100 M+E2
41CA 0 Ev from level-energy differences
41CA 0 H,R(F)From Adopted Gammas
41CA 0 7/2- 566.3 MS 17 6950.40 16
41CA N 1.0 1.0 1.0
41CA 0 4
41CA L 0 7/2-
41CA E 99.963 3
41CA 0 L00T23-736 (114) (Gamow-Teller part only,1980M13)
41CA L 2574.9 5 7/2-
41CA E 0.023 3
41CA 0 E Tioether: < 0.2 (1973A11)
41CA G 2874.8 0.023 3 M+E2
41CA 0 M2-0.36 8 or -1.48 11
41CA L 2959.4 4 7/2-
41CA P 0.0166 14
    
```



## 4. Nuclear Physics computer codes used to analyze datasets



### ANALYSIS CODES

- ALPHAD
- BrIcc
- GABS
- GTOL
- BETASHAPE
- JAVA RULER

### UTILITY CODES

- CONSISTENCY CHECK
- FMTCHK
- JAVA-NDS
- V.AVELIB
- XLS2ENS

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

IAEA.org | NDS Mission | Mirrors: India | China | Russia

Databases » ENSDF XUNDL NuDat LiveChart NSR Nuclear Wallet Cards Related » ENSDF Manuals Codes Nuclear Data Sheets EXFOR

### ENSDF Analysis and Utility Programs

The Brookhaven National Nuclear Data Center maintains and distributes various programs in support of the International Atomic Energy Agency sponsored Nuclear Structure and Decay Data Network. These programs generally use as input files in the Evaluated Nuclear Structure Data File (ENSDF) format.<sup>[1]</sup>

The tab 'Test and Validation' contains new codes which are in beta versions or still under development and require further testing by the users. Bugs or other problems should be sent to the code developers at the email address indicated.

✖ List of modifications:

Please address any issue regarding this page to [nds.contact-point@iaea.org](mailto:nds.contact-point@iaea.org) Last updating: 23 October 2019.

Analysis Utility Testing/Validation PNP1 Codes NSDFLIB SETMDC

#### ENSDF Analysis Programs

When present, documentation is included in the compressed files

#	Program	Version/Last Change	Notes	ANSI	Linux	Windows	MacOS
1	<b>ALPHAD</b> Calculates alpha HF's and theoretical half-lives.				compressed file with makefile	compressed file with makefile	compressed file with makefile
2	<b>BrIcc</b> Calculates the conversion electron, electron-positron pair conversion coefficients and the E0 electronic factors		2015-01-20 New Windows executables correcting runtime problems		Compressed file	Self-extracting archive	Compressed file
3	<b>BrIccMixing</b> Calculates the multipole mixing ratio - Requires BrIcc	New 64-bit executables	2019-09		Compressed file	Self-extracting archive	Compressed file
4	<b>DELTA</b> Analyzes gamma-gamma angular correlations from unaligned states.			Source code Compressed file	Source code Executable Compressed file	Source code Executable Compressed file	
5	<b>GABS new version</b> Gamma-ray absolute intensity and normalization calculation.	2019-09	Sample files		executable	executable	executable
6	<b>GTOL</b> Performs a least-squares fit to the gamma-energies to obtain level energies and calculates the net feedings to levels. Samples	2013-5-24		Source code	Source code 64-bit executable Compressed file	Source code Executable	Source code Compressed file with readme
7	<b>HSICC</b> Interpolates Hager-Seltzer and Dragoun internal conversion coefficients.			Source code for building ICC tables Source code for ICC calculations Source code for merging data Source code for recreating ASCII sequential file Compressed file	Source code for building ICC tables Source code for ICC calculations Source code for merging data Source code for recreating ASCII sequential file Executable for building ICC tables	Source code for building ICC tables Source code for ICC calculations Source code for merging data Source code for recreating ASCII sequential file Executable for building ICC tables	

Source: [https://www-nds.iaea.org/public/ensdf\\_pgm/index.htm](https://www-nds.iaea.org/public/ensdf_pgm/index.htm)

## 5. Adopted Dataset - the HEART of the evaluation



Nuclear data evaluators are frequently confronted with the problem of deriving a **recommended value**, or “**best value**”

## 5. Adopted Dataset - the HEART of the evaluation



Nuclear data evaluators are frequently confronted with the problem of deriving a **recommended value, or “best value”**



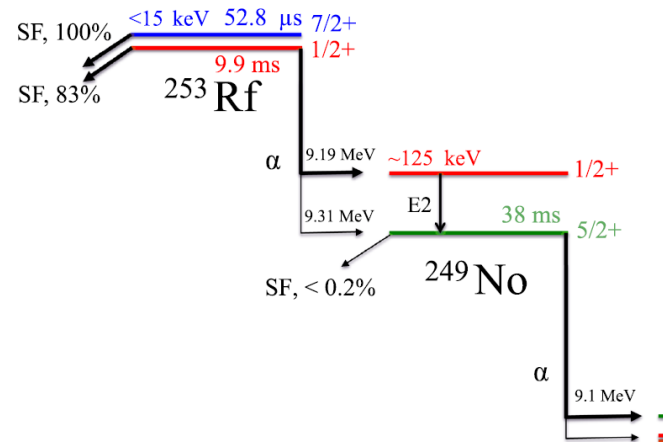
- Consider the measurement technique used
- Check inconsistencies or disagreements between different experiments
- Note any systematic deviation
- Distinguish between actual measured value and assumed or calculated value
- Note unrealistic uncertainties
- Identify possible outliers

# $^{249}\text{No}$ : $^{253}\text{Rf}$ $\alpha$ decay

## FLNR-JINR-Dubna

(2022Lo03, 2022Te01, 2021Sv02)

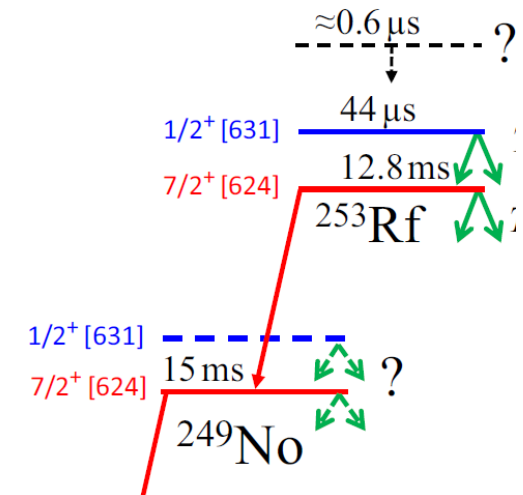
- (ER)- $\alpha$ - $\alpha$  correlated decays using SHELS fragment separator and implanted into the GABRIELA setup at FLNR-JINR-Dubna.
- DSSD; 15-20 keV energy resolution for ranging from 6-10 MeV
- measured  $E_{\alpha}=9210$  keV (20) and 9310 keV (20)



## GSI

(2021Kh07)

- (ER)- $\alpha$ - $\alpha$  correlated decays using TASCA separator
- DSSD: FWHM  $\sim 40$  keV for 5.8 MeV alpha particles
- measured  $E_{\alpha}=9170$  keV (20)



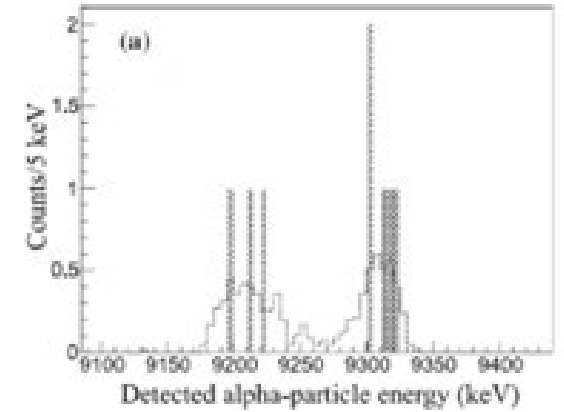
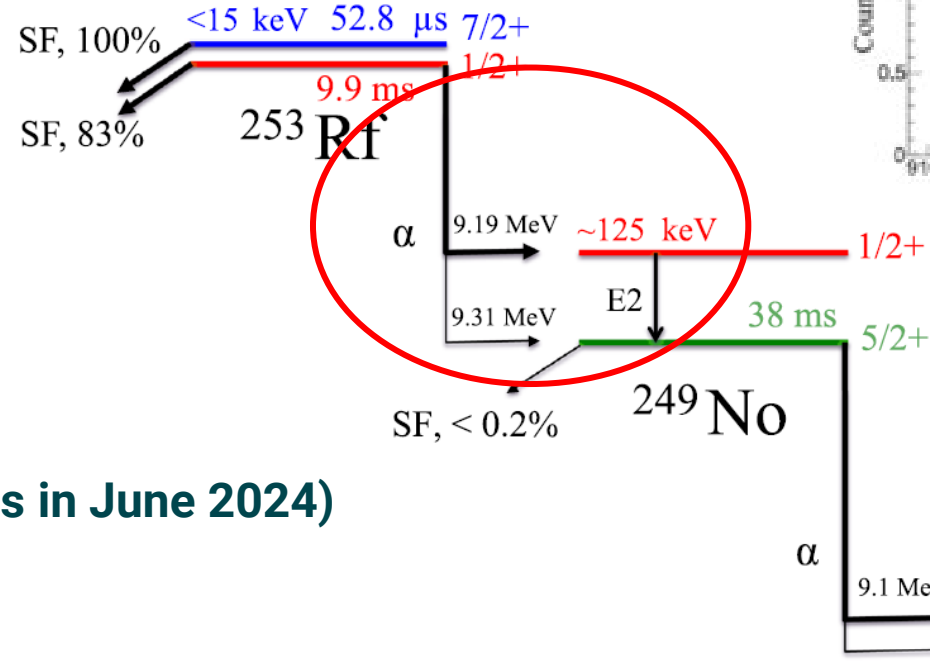
2022Lo03

- measured  $E_{\alpha}=9210$  keV (20) and 9310 keV (20)

2022Te01

- $E_x \sim 125$  keV using simulation Geant4.

No other experimental information was given in the paper.



Poor statistics !

Adopted (Published in Nuclear Data Sheets in June 2024)

$$E_x = Q \text{ value} - KE(\alpha)$$

$$E_x = 102 (30) \text{ keV using } E_{\alpha}=9210 (20) \text{ keV}$$

Comments were provided that  $\approx 95\%$  of  $\alpha$  decays proceed to the 125-keV level, but no experimental evidence is provided.



from co-author 2022Te01 on 9 April 2025...

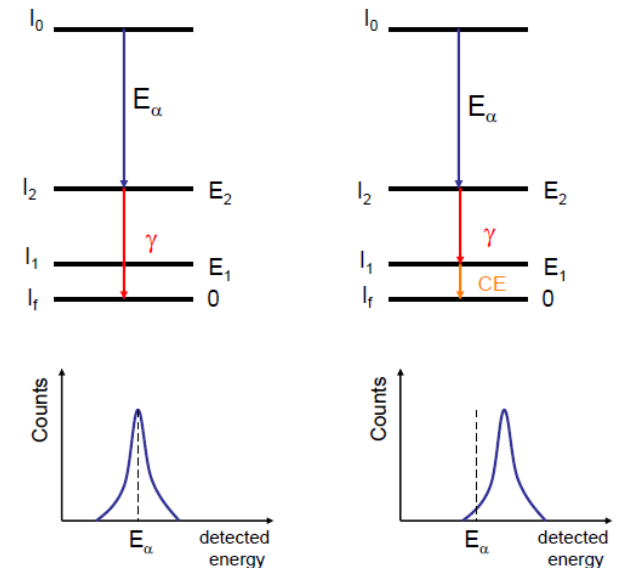
“evaluation has missed important information”

**NONE OF THE INFORMATION WAS AVAILBLE IN ANY OF THE PAPERS !!!**

In  $\alpha$ -decay experiments where the heavy nuclei of interest are implanted into a Si detector, there can be partial or total summing of the alpha particle energy with the

- subsequent internal conversion electrons and auger electrons
- Xrays that accompany the internal conversion process.

....We simulated these effects and deduced a level excitation energy of 125 keV



# WATCHING PAINT DRY TO PRODUCING A MASTERPIECE

**Critically analyze all published results**  
(watching paint dry)

**Recommend best values**  
(producing the Mona Lisa)

Best Recommended Values  
(Adopted Levels, Gammas)

## Decays

$\beta^-$   
 $\beta^+ + \epsilon$   
 $\alpha$   
...

## Reactions

(H, $xn$ )  
(d,p), (p,t)  
Coulomb Ex.  
(p,p')  
(n, $\gamma$ )  
....

