

2358-9

**Joint ICTP-IAEA Workshop on Nuclear Structure Decay Data: Theory and
Evaluation**

6 - 17 August 2012

NuDat

A. Sonzogni
*Brookhaven National Lab.
USA*

NuDat

*Alejandro Sonzogni
National Nuclear Data Center*

BROOKHAVEN
NATIONAL LABORATORY

a passion for discovery



NuDat

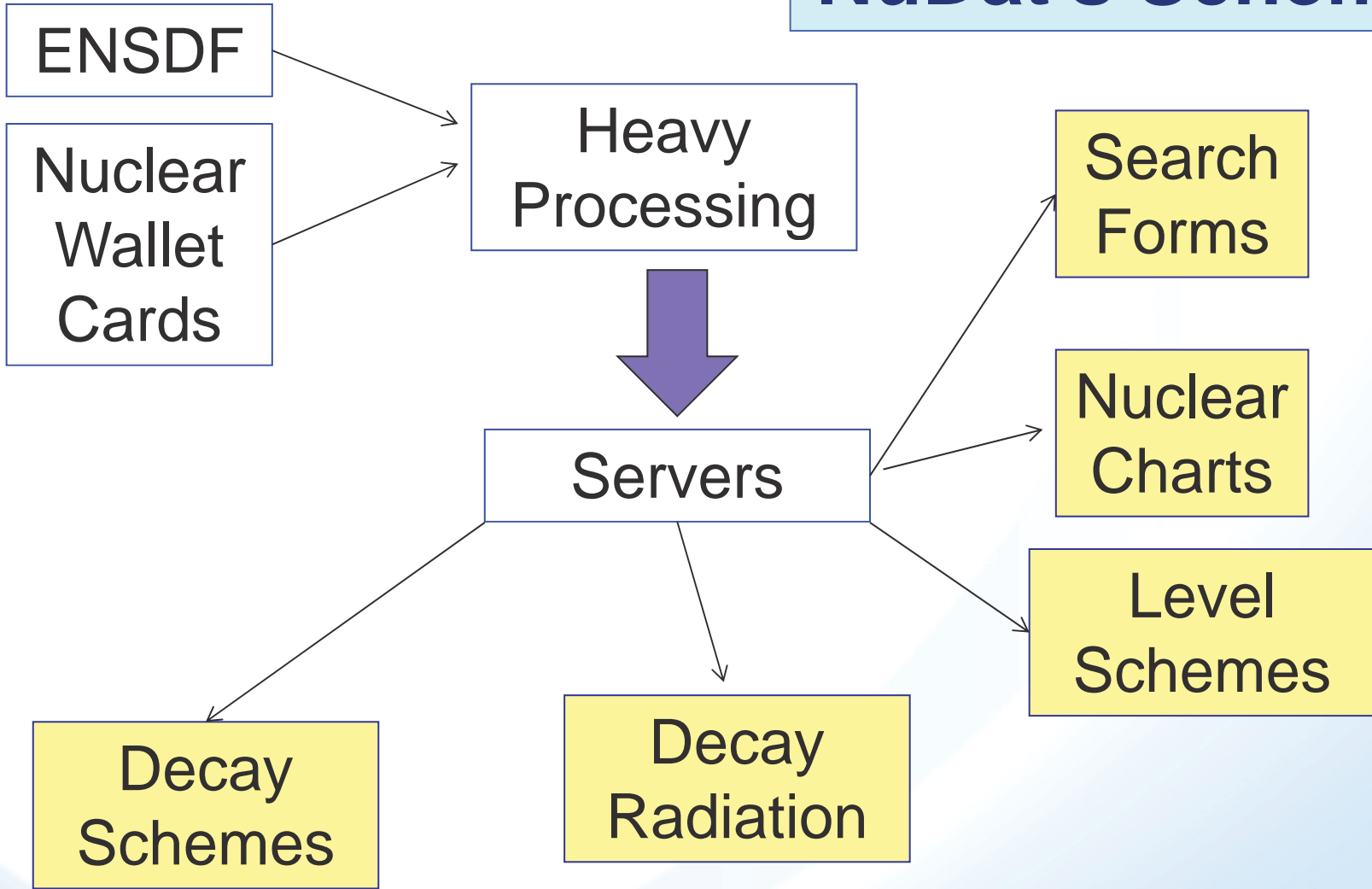
www.nndc.bnl.gov/nudat2

NuDat is a web application with two main goals, a) to present nuclear structure and decay information from ENSDF in a user-friendly way, and b) to allow users to execute complex search operations in the wealth of data contained in ENSDF. NuDat provides an interactive chart of nuclides for navigation and an output in the Table of Isotopes style. NuDat contents are updated regularly as new evaluations are entered into ENSDF.

NuDat 2 was developed by the National Nuclear Data Center (NNDC) in Brookhaven National Laboratory. Using NuDat 2, it is possible to search for nuclear level properties (energy, half-life, spin-parity), gamma-ray information (energy, intensity, multipolarity, coincidences), radiation information following nuclear decay (energy, intensity, dose).

More on www.nndc.bnl.gov/nudat2/help

NuDat's Scheme



NuDat front page

Help

Search forms

NuDat 2.5

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.)

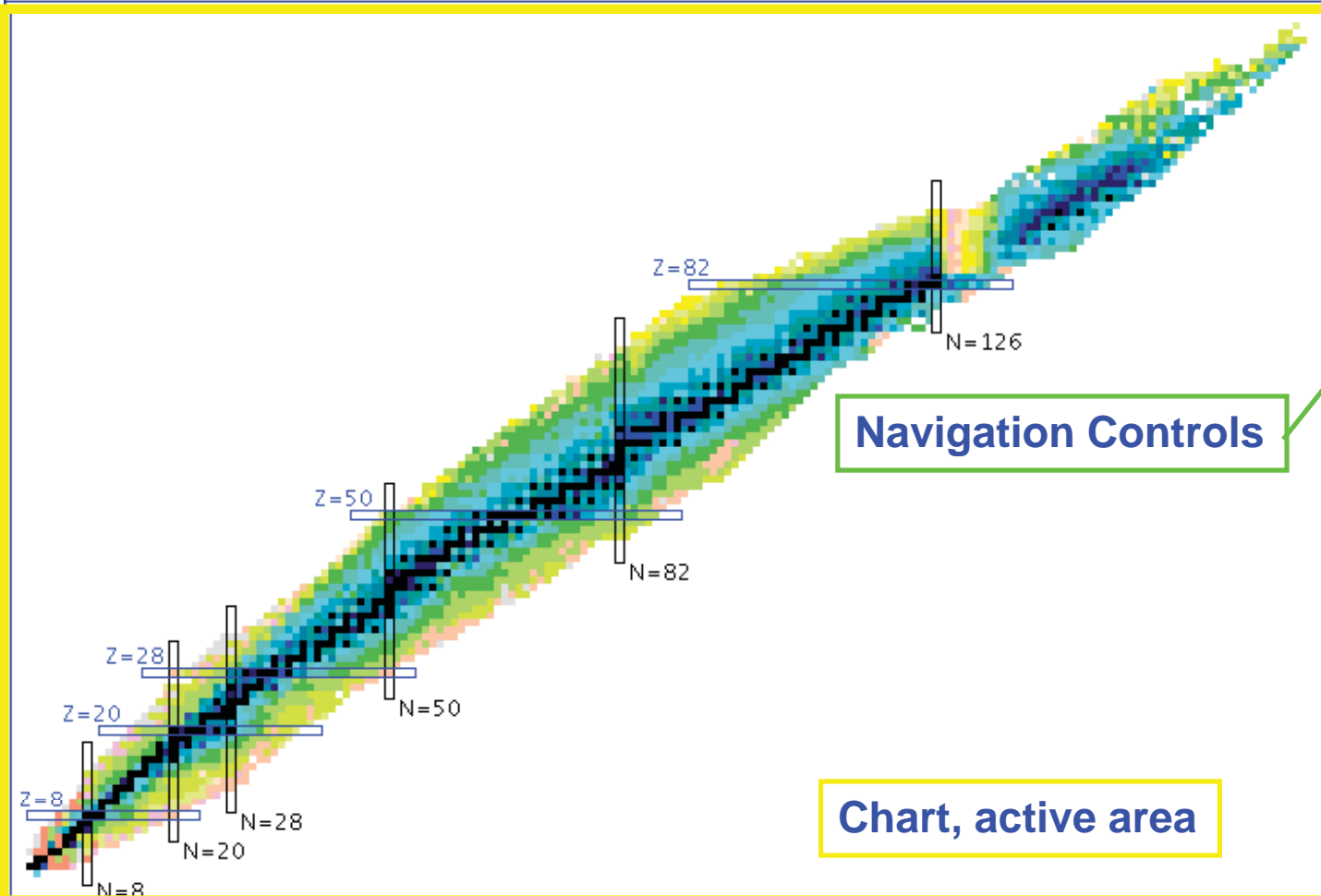
Nuclear Wallet Cards Search

Latest Ground and isomeric states properties

Decay Radiation Search

Radiation type, energy, intensity and dose following nuclear decay

Color code	Half-life	Decay Mode	S_n	S_p	Q_α	S_{2n}	S_{2p}	$Q_{2\beta^-}$	Q_{2EC}	Q_{ECp}	Q_{β^-n}
BE/A	(BE-LDM Fit)/A	E_{2+}	E_{3-}	E_{4+}	E_{4+}/E_{2+}	β_2	$B(E2)_{42}/B(E2)_{20}$	$\sigma(n,\gamma)$	$\sigma(n,F)$	235U FY	239Pu FY



Navigation Controls

Chart, active area

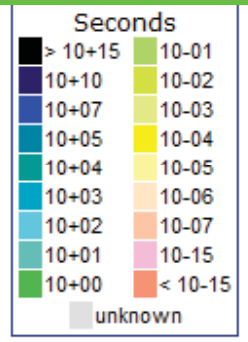
Tooltips
 On
 Off

Zoom
 1
 2
 3
 4
 5
 6
 7

Uncertainty
 NDS
 Standard

Screen Size
 Narrow
 Wide

Nucleus



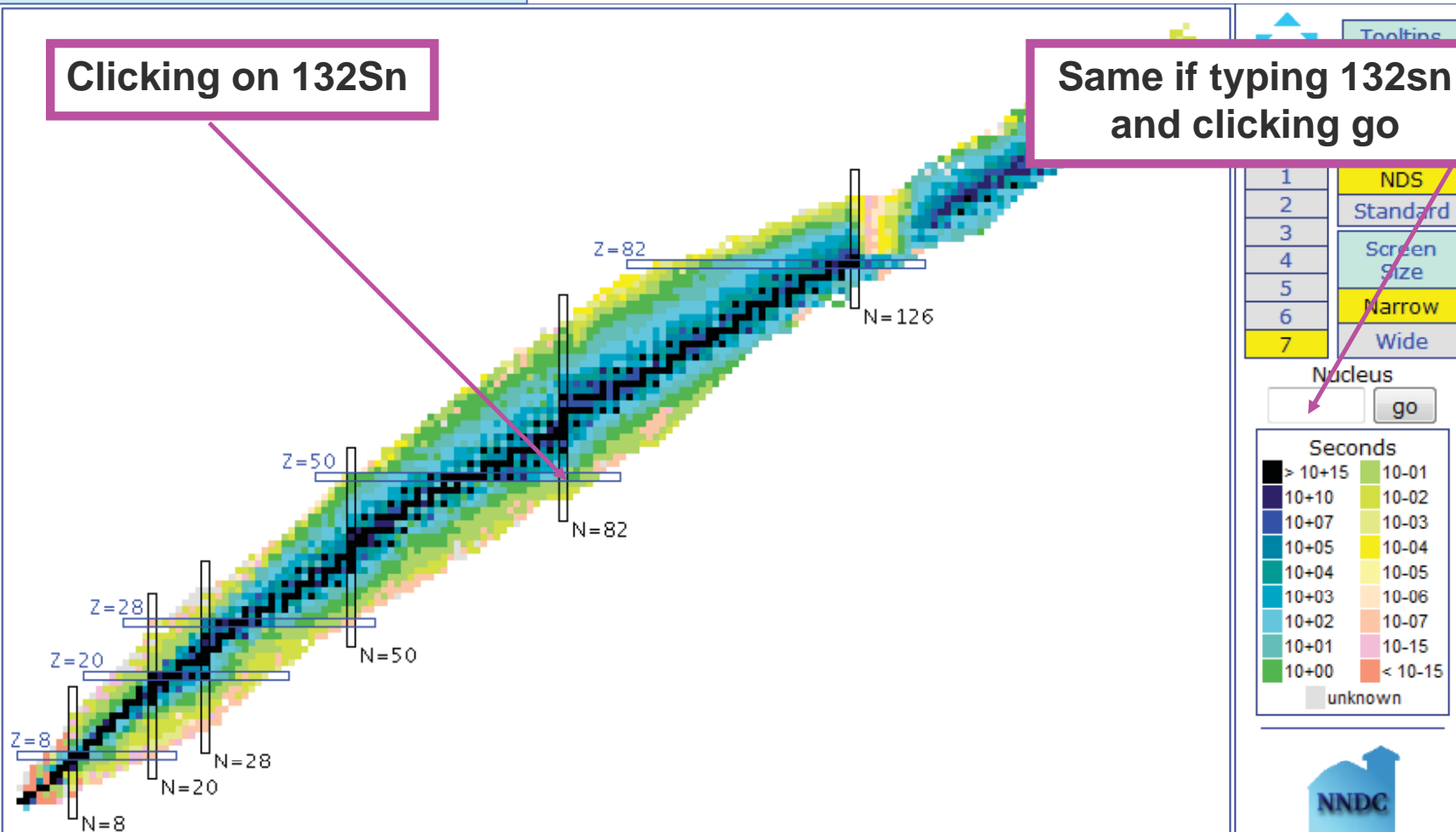
NNDC ENSDF NSR
 Nuclear Wallet Cards

Interactive Chart of Nuclides
 Click on a nucleus to obtain information

NuDat's chart

Clicking on ^{132}Sn

Same if typing 132sn and clicking go



Ground and isomeric state information for $^{132}_{50}\text{Sn}$

E(level) (MeV)	J π	Δ (MeV)	T $_{1/2}$	Decay Modes
0.0	0+	-76.5542	39.7 s 8	β^- : 100.00 %
4.8485	(8+)	-71.7057	2.03 μ s 4	IT : 100.00 %

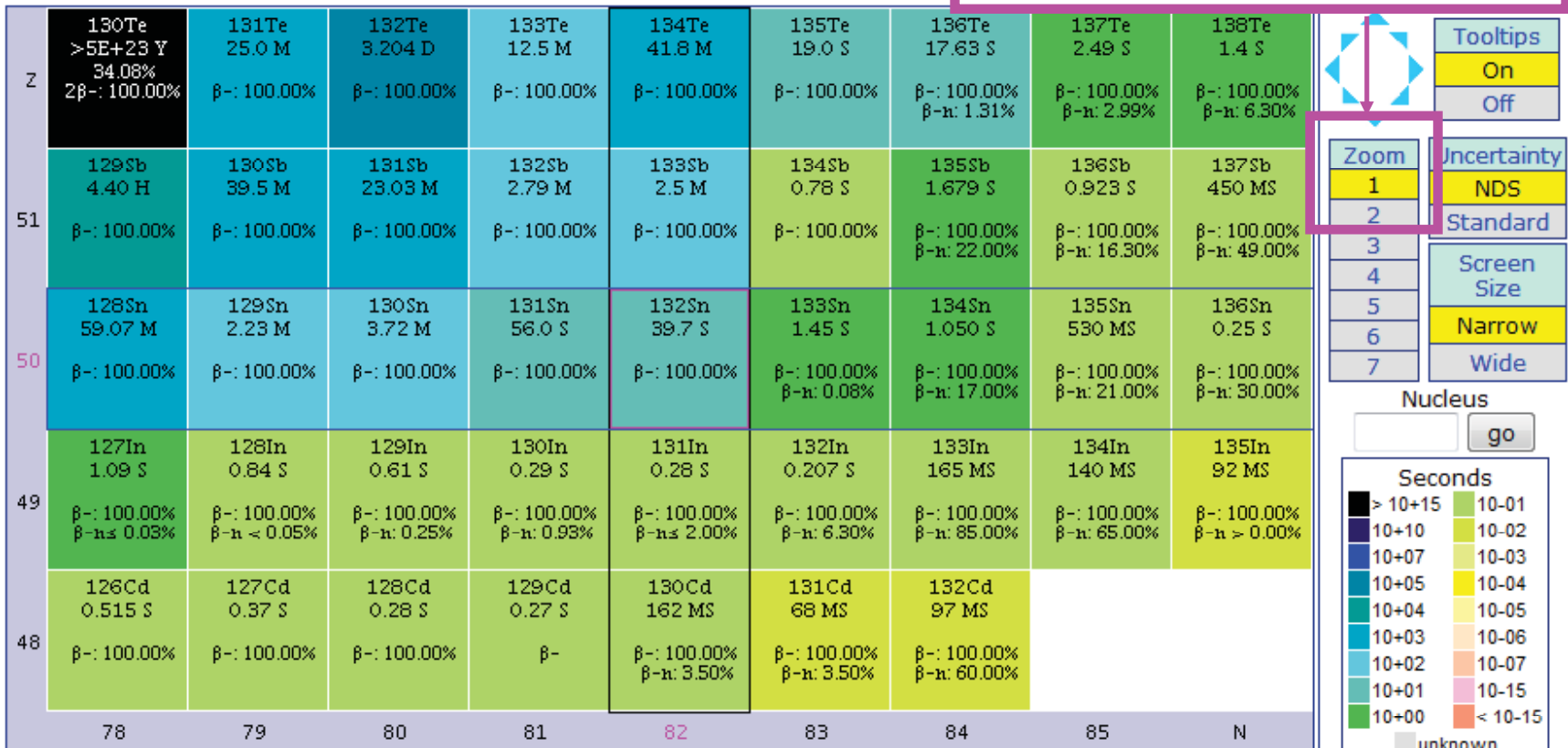
A list of levels, a level scheme and decay radiation information are available

Basic info + links to more details

NNDC ENSDF NSR
Nuclear Wallet Cards

NuDat's chart

Changing the zoom value



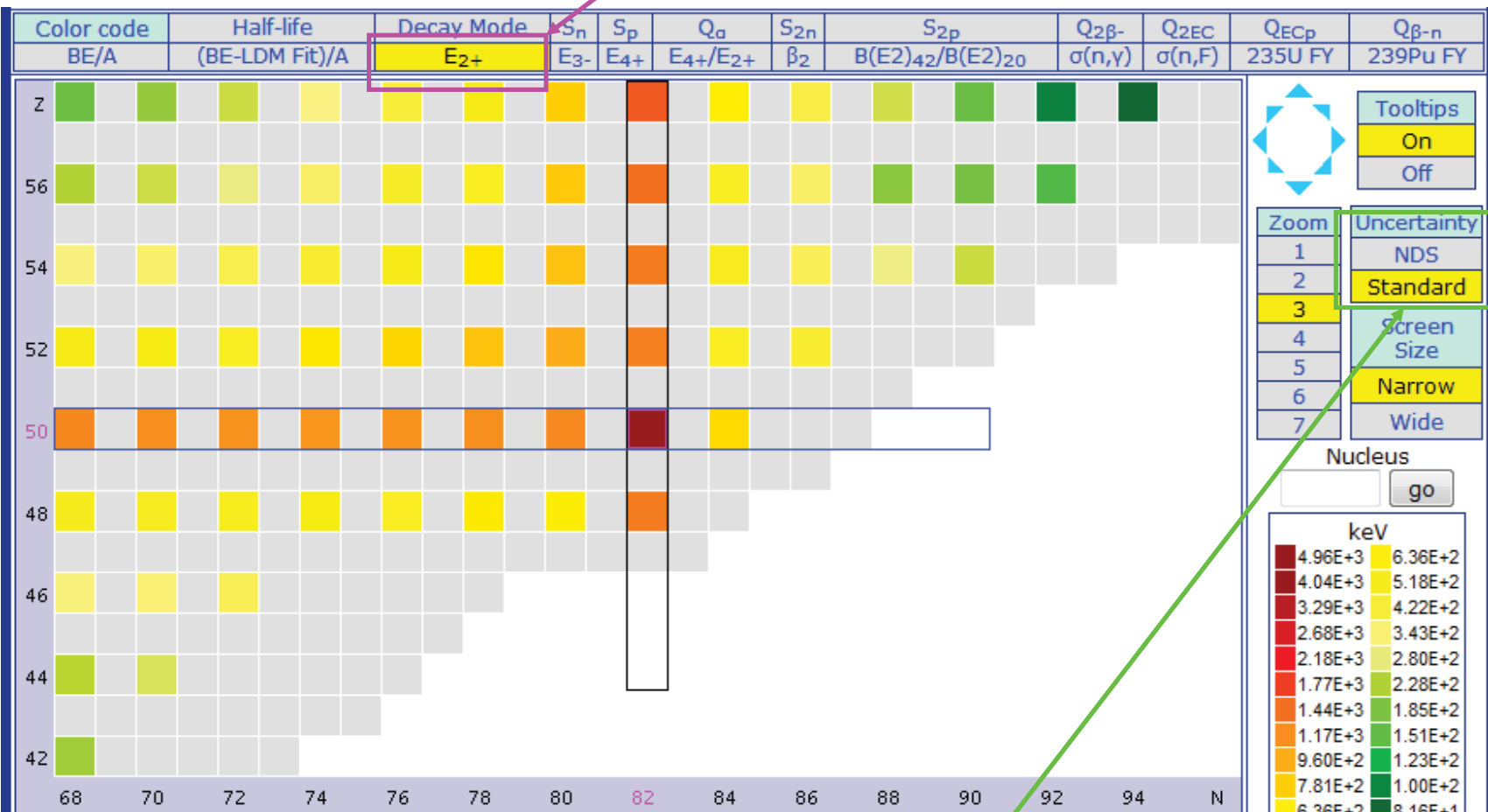
Ground and isomeric state information for $^{132}_{50}\text{Sn}$

E(level) (MeV)	J _n	Δ(MeV)	T _{1/2}	Decay Modes
0.0	0+	-76.5542	39.7 s 8	β ⁻ : 100.00 %
4.8485	(8+)	-71.7057	2.03 μS 4	IT : 100.00 %

A list of levels, a level scheme and decay radiation information are available

NuDat's chart

E2+ colors



Ground and isomeric state information for $^{132}_{50}\text{Sn}$

E(level) (MeV)	J π	Δ (MeV)	$T_{1/2}$	Decay Modes	E_{2+} (keV)
0.0	0+	-76.5542	39.7 s 0.8	β^+ : 100.00 %	4.04E+3 1.50E-1
4.8485	(8+)	-71.7057	2.03 μ s 0.04	IT: 100.00 %	

A list of levels, a level scheme

Standard uncertainties style

Tooltips
 On
 Off

Zoom
 1
 2
 3
 4
 5
 6
 7

Uncertainty
 NDS
 Standard
 Screen Size
 Narrow
 Wide

Nucleus
 go

keV
 4.96E+3 6.36E+2
 4.04E+3 5.18E+2
 3.29E+3 4.22E+2
 2.68E+3 3.43E+2
 2.18E+3 2.80E+2
 1.77E+3 2.28E+2
 1.44E+3 1.85E+2
 1.17E+3 1.51E+2
 9.60E+2 1.23E+2
 7.81E+2 1.00E+2
 6.36E+2 8.16E+1
 unknown

Nuclear Decay

A process where the protons and neutrons in a given nucleus are rearranged into a lower energy state. The transition may involve states of the same nucleus (gamma emission, electron conversion) or levels of different nucleus. Each different process is known as a 'decay mode':

- * Gamma emission, electron conversion
- * β^- decay
- * β^+ decay
- * Electron Capture (EC)
- * β -delayed particle emission
- * Double β decay
- * Proton decay
- * Alpha decay
- * Cluster decay
- * Spontaneous Fission (SF)

The probability of undergoing a given nuclear decay is often indicated using the percent sign followed by the decay mode name and the probability per 100 decays.

For instance, $\% \beta^- = 100$ means 100% probability of β^- decay.

The energy released during the decay is called 'Q-value'. For a given decay mode to have a probability larger than 0, the Q-value has to be positive.

Uncertainties

The uncertainty associated with a given quantity can be expressed in the so-called [Nuclear Data Sheets](#) style, or in a standard style. The Nuclear Data Sheets style has been used for a long time since it facilitates data storage, which was crucial in the early days. A table with a brief explanation of the Nuclear Data Sheet style is given below:

NDS Style	Standard style and meaning
4.623 3	4.623 +- 0.003
4.6 h 12	4.6 +- 1.2 hours
5.4×10^3 2	5400 + - 200
4.2 +8-10	4.2 + 0.8 - 1.0
9.22 SY	9.22 is a result of a systematic study
9.22 CA	9.22 value is not an experimental one, but the result of a theoretical calculation

Ground and isomeric state information for $^{132}_{50}\text{Sn}$

E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Decay Modes
0.0	0+	-76.5542	39.7 s 8	β^- : 100.00 %
4.8485	(8+)	-71.7057	2.03 μ s 4	IT : 100.00 %

A list of levels, a level scheme and decay radiation information are available

ADOPTED LEVELS, GAMMAS for ^{132}Sn

Author: YU. KHAZOV, A.A. RODIONOV AND S. SAKHAROV, BALRAJ SINGH

[Full ENSDF file](#)

Q(β^-)=3119 keV 9 S_n= 7311 keV 25 S_p= 15710 keV 30 Q $_{\alpha}$ = 11.69E3 keV 29

References:

- A: ^{132}Sn β^- DECAY (0.207 S)
- B: ^{132}Sn IT DECAY (2.03 μ s)
- C: ^{133}In β -N DECAY (165 MS)
- D: 248CM SF DECAY
- E: COULOMB EXCITATION

ENSDF file for ^{132}SN

- ADOPTED LEVELS, GAMMAS
- ^{132}IN B- DECAY (0.207 S)
- ^{132}SN IT DECAY (2.03 US)
- ^{133}IN B-N DECAY (165 MS)
- 248CM SF DECAY
- COULOMB EXCITATION

Retrieve selected datasets

Retrieve all datasets

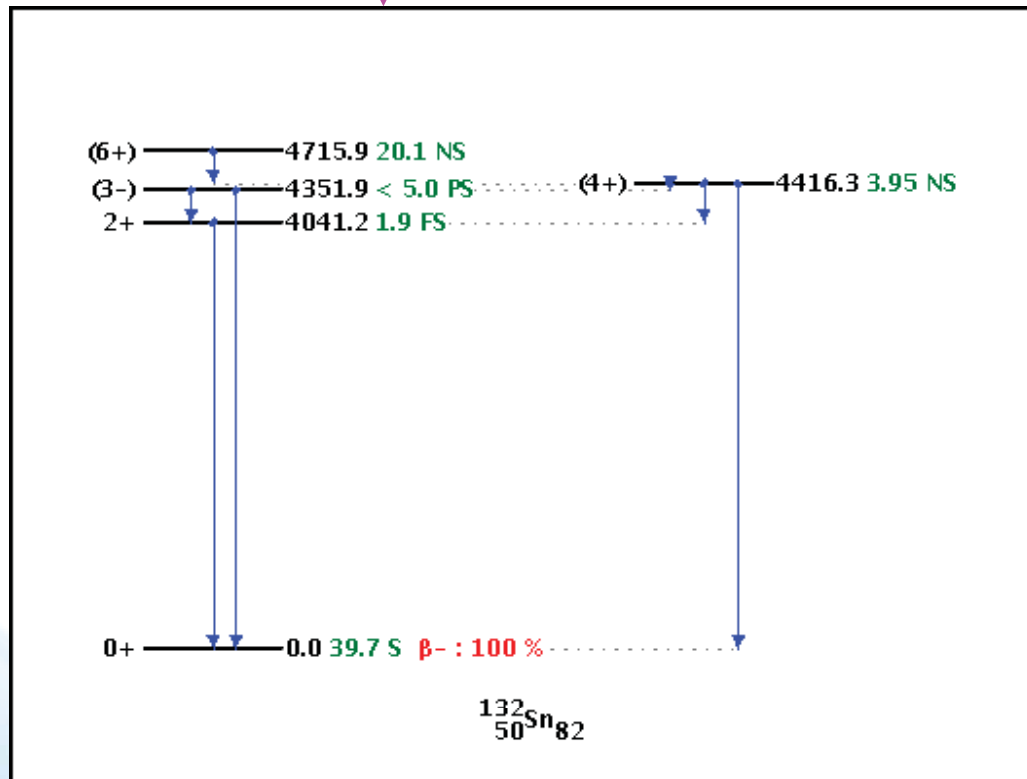
E _{level} (keV)	XREF	J π	T _{1/2}	E _{γ} (keV)	I _{γ}	γ mult.	Final level	
0.0	ABCDE	0+	39.7 s 8 % β^- = 100					
4041.20 15	AB DE	2+	1.9 fs +14-6	4041.1	100		0.0	0+
4351.94 14	A D	(3-)	< 5.0 ps	310.7 4351.9	11.0 100	(E1) [E3]	4041.20 0.0	2+ 0+
4416.29 14	AB D	(4+)	3.95 ns 13	64.4 375.1 4416.2	1.3 100 3 17 3	[E1] (E2) [E4]	4351.94 4041.20 0.0	(3-) 2+ 0+

Ground and isomeric state information for $^{132}_{50}\text{Sn}$

E(level) (MeV)	J π	Δ (MeV)	T _{1/2}	Decay Modes
0.0	0+	-76.5542	39.7 s 8	β^- : 100.00 %
4.6485	(6+)	-71.7057	2.03 μ s 4	IT : 100.00 %

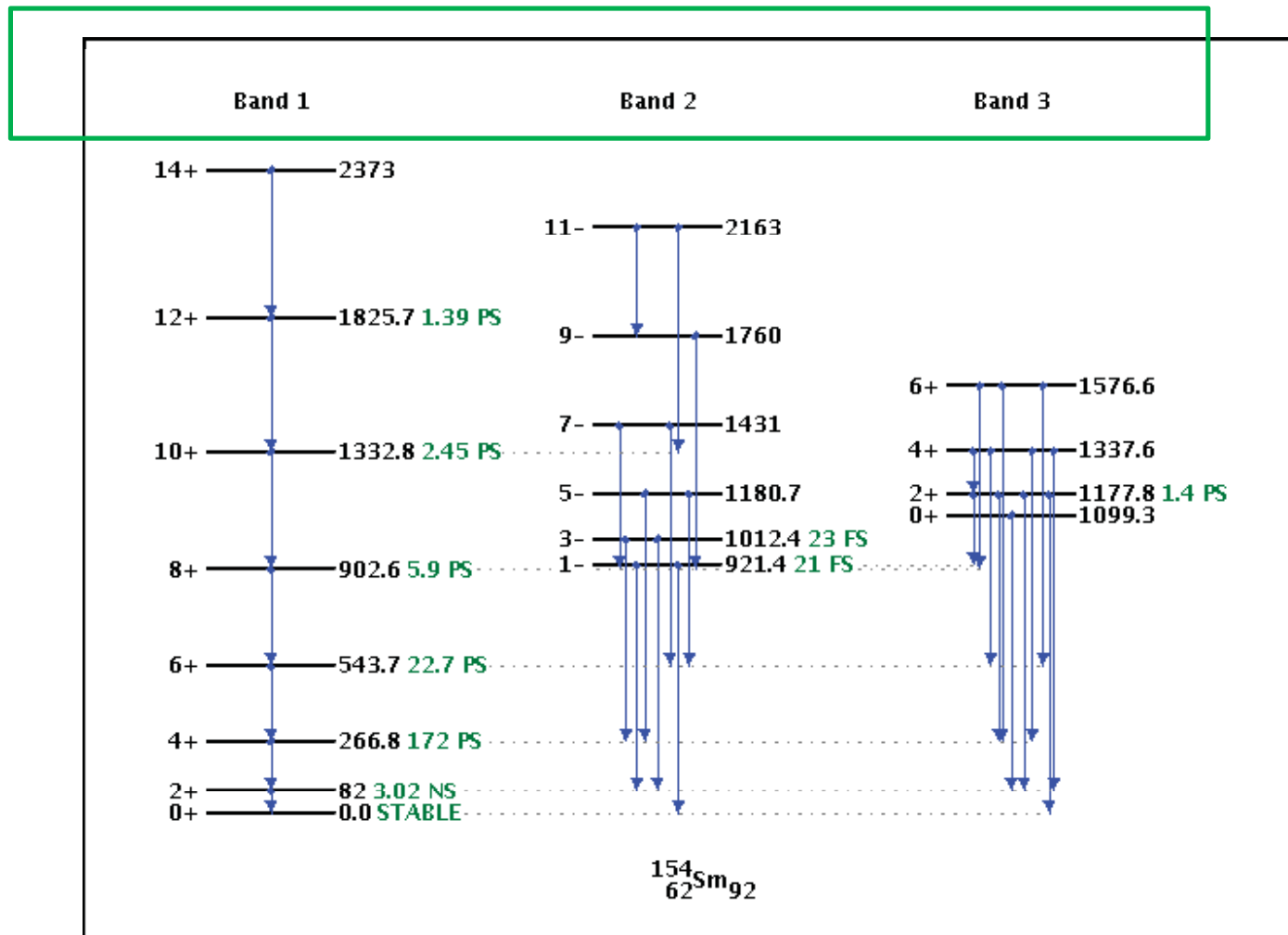
A list of levels, a level scheme and decay radiation information are available

Interactive Level Scheme



^{132}Sn is doubly magic, how does a level scheme of a nucleus at mid-shell?

Rotational bands

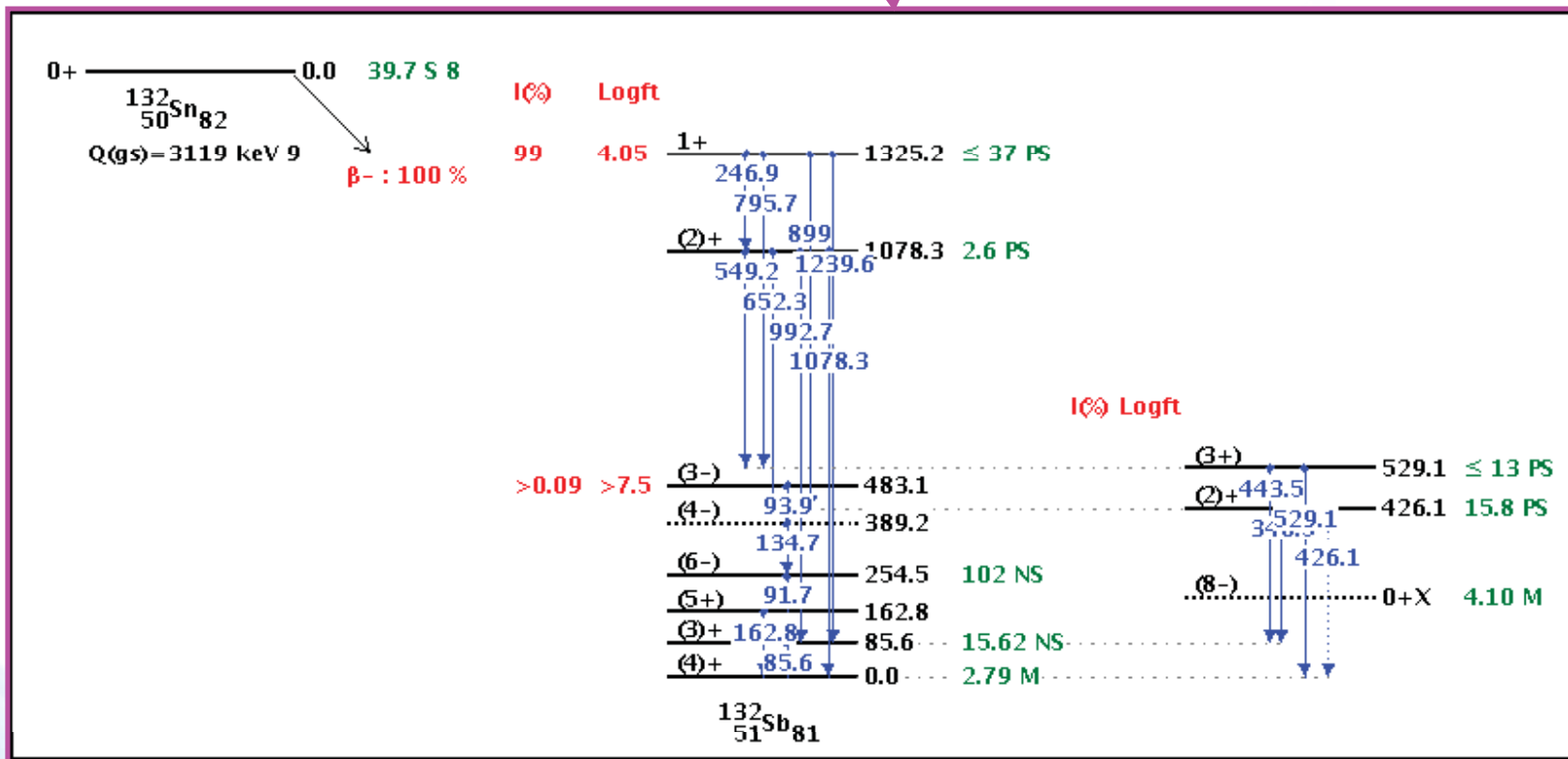


Partial view of ^{154}Sm level scheme

Ground and isomeric state information for $^{132}_{50}\text{Sn}$

E(level) (MeV)	J π	Δ (MeV)	T $_{1/2}$	Decay Modes
0.0	0+	-76.5542	39.7 s 8	β^- : 100.00 %
4.8485	(8+)	-71.7057	2.03 μ s 4	IT : 100.00 %

A list of levels, a level scheme and decay radiation information are available



Levels Search

Search for first 2+ states in N=86 Nuclides

Nuclear Levels and Gammas Search

(Help)

Specify Nuclei :

Nucleus: Ex: 232TH or th232 or 232-Th or th-232 or

Z / Element: A: N: 86

≤ Z ≤ ≤ A ≤ ≤ N ≤

Even Z Any A Any N

E(level) condition: enabled disabled 0 ≤ E_{level}(keV) ≤ 40000

Decay Mode condition: enabled disabled Decay Mode ANY

Jn(level) condition: enabled disabled J = 2 Order : 1st Parity : +

T_{1/2}(level) condition: enabled disabled 0 fs ≤ T_{1/2} ≤ 1E10 Gy

No Upper/Lower limit values

γ condition #1: enabled disabled 0 ≤ E_γ(keV) ≤ 40000 Multipolarity: ANY Not mixed

γ condition #2: enabled disabled 0 ≤ E_γ(keV) ≤ 40000 Multipolarity: ANY Not mixed

γ condition #3: enabled disabled 0 ≤ E_γ(keV) ≤ 40000 Multipolarity: ANY Not mixed

γ coincidence condition : any coincident Coincidence gate ≤ 1 us

γ reduced transition probability: enabled disabled 0 ≤ B(M_λ,E_λ)(Weisskopf units) ≤ 40000 **NEW**

Ordering: Z, A, E(level),E(gamma) Output: Web Page Formatted File

Uncertainties: Nuclear Data Sheets style Standard style

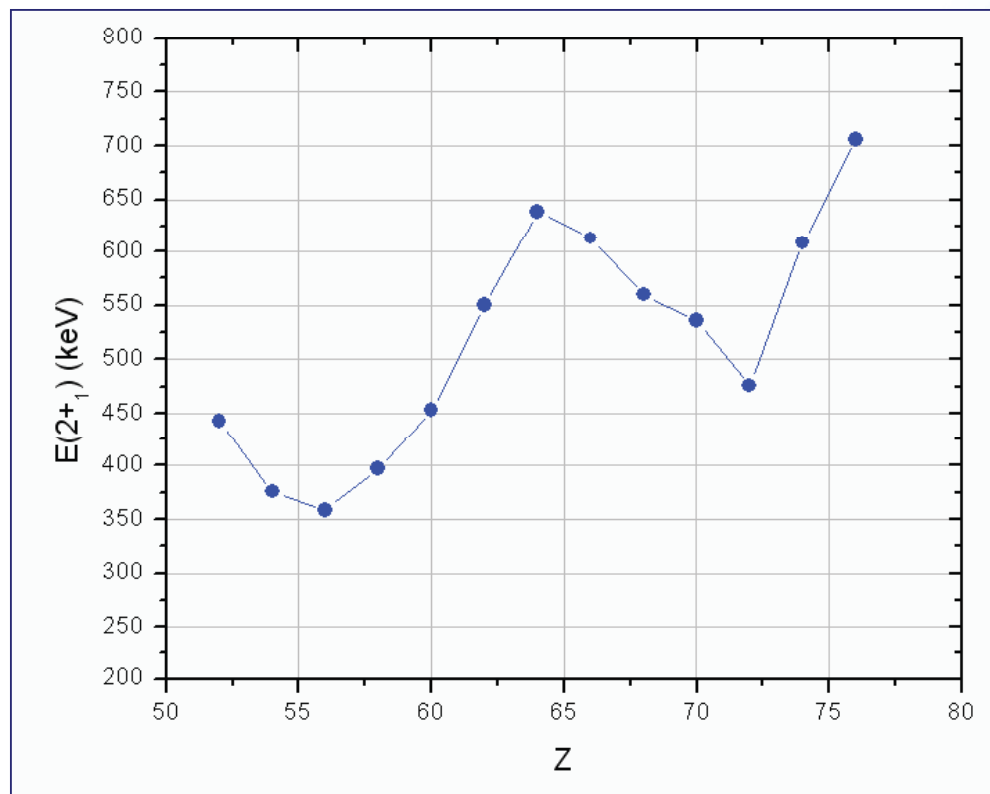
Levels and Gammas database version of 4/11/2008

Results

Nucleus	$E_{level}(keV)$	J^{π}	$T_{1/2}$
138TE	443.1 <i>10</i>	(2+)	
140XE	376.658 <i>15</i>	2+	70.5 ps <i>22</i>
142BA	359.597 <i>14</i>	2+	65 ps <i>2</i>
144CE	397.441 <i>9</i>	2+	35.4 ps <i>20</i>
146ND	453.77 <i>5</i>	2+	21.6 ps <i>13</i>
148SM	550.255 <i>8</i>	2+	7.72 ps <i>32</i>
150GD	638.045 <i>14</i>	2+	
152DY	613.82 <i>7</i>	2+	10 ps <i>5</i>
154ER	560.8 <i>1</i>	2+	
156YB	536.4 <i>1</i>	2+	
158HF	476.36 <i>11</i>	2+	
160W	609.9 <i>2</i>	2+	
162OS	706.7 <i>3</i>	(2+)	

For more search examples,
see Help file

Tool for systematic studies



Decay Search

Decay Radiation Search

[Help](#)

Specify Parent Nuclei : **Nucleus:** *Ex 232TH or th232 or 232-Th or th-232 or*

Z / Element: **A:** **N:**

≤ **Z** ≤ ≤ **A** ≤ ≤ **N** ≤

Parent $T_{1/2}$ condition: enabled disabled ≤ $T_{1/2}$ ≤ No Upper/Lower limit values

Decay Mode condition: enabled disabled **Decay Mode**

Radiation Type condition: enabled disabled **Radiation Type**

Radiation Energy condition: enabled disabled ≤ **Energy (keV)** ≤

Radiation Intensity condition: enabled disabled ≤ **Intensity (%)** ≤

Ordering: Output: Web Page Formatted File

Uncertainties: Nuclear Data Sheets style Standard style

Decay Radiation database version of 4/11/2008

Author: AGDA ARTNA-COHEN Citation: Nuclear Data Sheets 80, 723 (1997)

Results

Parent Nucleus	Parent E(level)	Parent J π	Parent T _{1/2}	Decay Mode	GS-GS Q-value (keV)	Daughter Nucleus	Decay Scheme
²³² ₉₀ Th	0	0+	14.05E+9 y 6	α : 100 %	4082.8 14	²²⁸ ₈₈ Ra	

Alphas:

Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
3811.1 14	0.069 % 13	0.0026 5
3947.2 20	21.7 % 13	0.86 5
4012.3 14	78.2 % 13	3.14 5

Electrons:

	Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
Auger L	9.09	8.7 % 5	7.9E-4 4
CE K	36.958 13	0.0060 % 11	2.2E-6 4
CE L	44.573 10	15.8 % 8	0.0070 3
CE M	58.988 10	4.27 % 21	0.00252 12
CE NP	62.602 10	1.53 % 8	9.6E-4 5
Auger K	65.9	1.9E-4 % 4	1.3E-7 3
CE L	121.643 10	0.031 % 6	3.8E-5 7
CE M	136.058 10	0.0084 % 16	1.14E-5 22
CE NP	139.672 10	0.0030 % 6	4.3E-6 8

Gamma and X-ray radiation:

	Energy (keV)	Intensity (%)	Dose (MeV/Bq-s)
XR 1	12.3	7.1 % 5	8.8E-4 6
	63.81 1	0.263 % 13	1.68E-4 8
XR ka2	85.431	0.0017 % 3	1.4E-6 3
XR ka1	88.471	0.0028 % 5	2.4E-6 5
XR k β 3	99.432	3.4E-4 % 6	3.3E-7 6
XR k β 1	100.13	6.4E-4 % 12	6.5E-7 12
XR k β 2	102.498	2.4E-4 % 5	2.5E-7 5
	140.88 1	0.021 % 4	3.0E-5 6

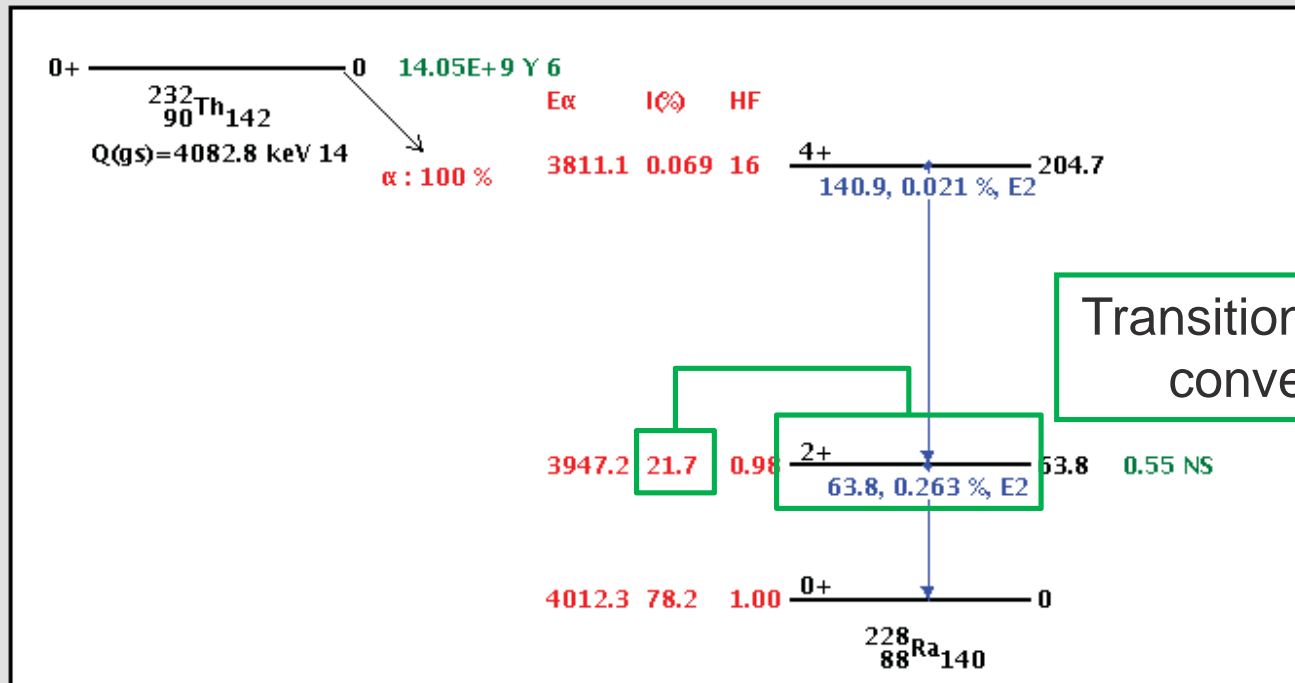
Where are the electrons coming from?



Interactive Decay Scheme

²³²Th α decay

0.0 < E(level) < 225.0	<input checked="" type="checkbox"/> Level Energy	<input checked="" type="checkbox"/> Level T1/2	<input checked="" type="checkbox"/> Level Spin-parity	<input checked="" type="checkbox"/> Final Level
Highlight: <input type="text"/> Level <input type="text"/>	<input checked="" type="checkbox"/> Gamma Energy	<input checked="" type="checkbox"/> Gamma Intensity	<input checked="" type="checkbox"/> Gamma Multipolarity	<input checked="" type="checkbox"/> Decay Information
Image Height: 350	Level Width: 100	Band Spacing: 20	<input type="button" value="Plot"/>	<input type="button" value="Clear"/>



Transition heavily converted

Q-calc

www.nndc.bnl.gov/qcalc

Nuclear reaction and decay Q-values can be calculated using the Q-Calculator tool, which uses the 2003 atomic mass evaluation of Audi et al., G.Audi, A.H. Wapstra, C. Thibault, Nucl. Phys. A729, 337 (2003).

For a nucleus with Z protons, N neutrons and mass $M(Z,N)$, the most common decay Q-values are:

β^-	$Q(\beta^-) = M(Z,N) - M(Z+1,N-1)$
Electron capture	$Q(\text{EC}) = M(Z,N) - M(Z-1,N+1)$
β^+	$Q(\beta^+) = M(Z,N) - M(Z-1,N+1) - 2m_e$
Alpha emission	$Q(\alpha) = M(Z,N) - M(Z-2,N-2) - M(2,2)$
Proton emission	$Q(p) = M(Z,N) - M(Z-1,N-1) - M(1,1)$
Double β^-	$Q(2\beta^-) = M(Z,N) - M(Z+2,N-2)$
Double EC	$Q(2\text{EC}) = M(Z,N) - M(Z-2,N+2)$

The neutron and proton separation energies are defined as:

$$S(p) = -Q(p)$$

$$S(n) = -Q(n)$$

Target(s)
56fe, Fe-56, 26056, cr50-fe56

Projectile
4He, He-4, 2-he-4, a, alpha, 2004

Ejectile
*g, n, n+p, 2n+a, 2a+12c (reaction)
 b-, ec, 2b-, b-n, ecp, 18O (decay)*

E_{lab} (MeV)

Uncertainties
 Standard style
 Nuclear Data Sheets style

In ENSDF evaluation, most of the time we are interested in decay Q-values, which can be obtained by simply giving the nucleus of interest

Mass and decay Q-values for ¹⁴⁴Sm

Quantity	(keV)
Mass Excess	-81971.96 2.81
Binding Energy/A	8303.723 0.019
Atomic Mass (AMU)	143.912 0.00301 *
Atomic Mass/neutron Atomic Mass	142.67574 0.00299 **
Q _{β-}	-6350.3 10.9
Q _{EC}	-550.85 2.55
Q _{β+}	-1573.05 2.55
Q _n	-10520.08 2.36
Q _p	-6295.19 2.73
Q _{2n}	-19121.7 5.63
Q _{2p}	-10594.7 1.79
Q _α	-145.1 28.1
Q _{2β-}	-10212.5 28.1

Q-calc

www.nndc.bnl.gov/qcalc/qcalc4eval.jsp

Q-value Calculator for ENSDF evaluators

Nuclide
56fe, Fe-56, fe, 56

Uncertainties Nuclear Data Sheets style
 Standard style

Nucleus	KeyNumber	Q_{β^-}	SY	ΔQ_{β^-}	S_n	SY	ΔS_n	S_p	SY	ΔS_p	Q_{α}	SY	ΔQ_{α}	$Q_{\beta-n}$	SY	$\Delta Q_{\beta-n}$	Q_{ECp}	SY	ΔQ_{ECp}
^{94}Sr	2003AU03	3508		8	6827		10	13512		10	-6295		20	-2689		13	-2.211E+4		10
	2009AUZZ	3510		8	6827		10	13509		11	-6307		7	-2686		13	-21994		8