The Abdus Salam
International Centre
for Theoretical Physics

2358-15

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

6 - 17 August 2012

IAEA - NSDD Network: Recent Relevant CRPs and other activities

D.H. Abriola
IAEA
Austria

International Atomic Energy Agency

IAEA - NSDD Network: Recent Relevant CRPs and other activities

D. Abriola

Nuclear Data Section

Department of Nuclear Sciences and Applications

ICTP ENSDF WORKSHOP 2012

Outline

- IAEA Nuclear Data Section (NDS)
- Coordination of the NSDD network
- NSDD-related activities
  - ENSDF evaluations / NSR compilations
  - Financial support for ENSDF evaluators and horizontal evaluation/compilation activities
- CRPs
  - Beta-delayed neutron emission
- Workshops
- Dissemination, new tools
- Conclusions

NAPC: Physics and Nuclear Data Sections

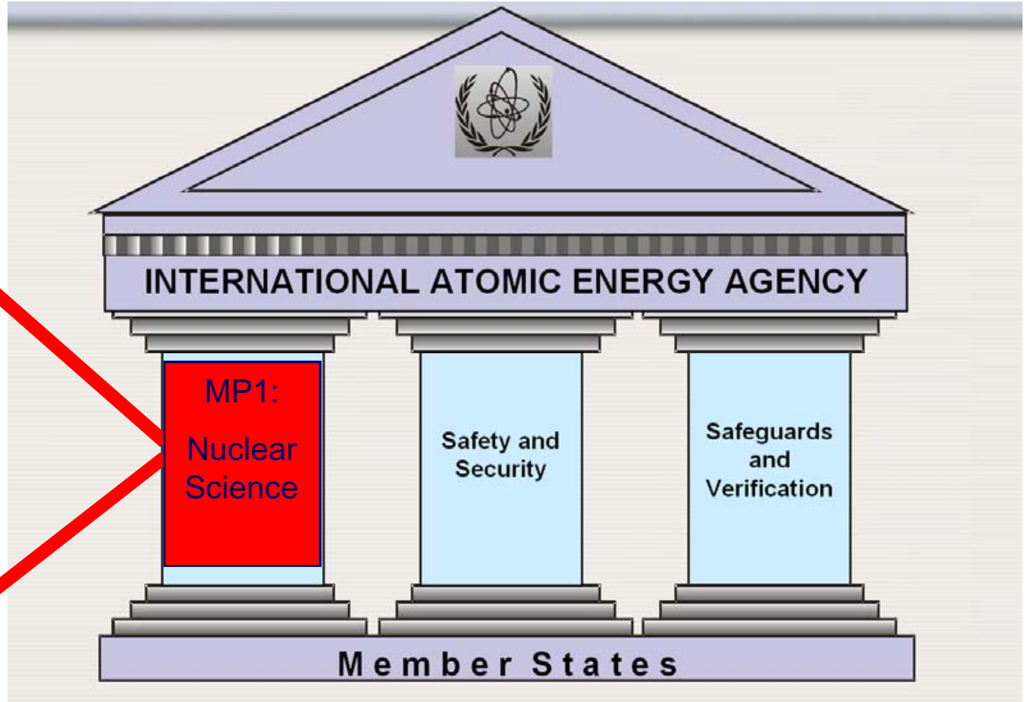
Physics Section

Research Reactors

Accelerators

Instrumentation

Fusion



Nuclear Data Section

Nuclear Data

Atomic and Molecular Data

IAEA Nuclear Data Section

Nuclear Data Section

Organization Chart
(June 2012)

Section Office (and INDC Secretariat)

Section Head: **R.A. Forrest**
Nuclear Data Physicist
(21709/21710)

Deputy Section Head: **D. Abriola**
Nuclear Data Physicist
(21712/21711)

Section Secretary: **L. Vrapcenjak**
(21710)

Nuclear Data Services Unit	Nuclear Data Development Unit	Atomic & Molecular Data Unit
S. Simakov Unit Head (21717)	**D.H. Abriola** Unit Head (21712)	**B.J. Braams** Unit Head (21731)
V. Zerkin Software Engineer (21714)	**R. Capote Noy** Nuclear Physicist (21713)	**W.M. Costello** (IT Systems Analyst) (21724)
V. Semkova Nuclear Physicist (21727)	**P. Demetriou** Nuclear Physicist (21708)	**H.-K. Chung** Atomic Physicist (21729)
N. Otsuka Nuclear Data Physicist (21715)	**K. Nathani** Clerk (21711)	**Marco Verpelli** Systems Analyst/Programmer (21723)
J. Roberts Nuclear Data Services Assistant (21725)		**K. Sheikh** Database Assistant (21730)
A. Oechs Clerk (21716)		**A. Vasaroš** IT Systems Engineer (temp.) (21724)
		M. O'Connell (25%) Applications Programmer (21722)

Three Units

17 staff

IAEA Nuclear Data Section

Role

- Provision of atomic and nuclear data services to scientists worldwide (data libraries, bibliographies, documents) through the internet, CD and other media
- Coordination of three international atomic and nuclear data networks
- Production of new databases through Coordinated Research Projects (CRPs) and Data Development projects
- Assist developing countries through technology transfer activities

Activities of the NDS

- Maintain and develop databases
- Network coordination (IRDC + NSDD +A&M)
- Coordinated Research Projects (10-15…)
- Staff technical work + contracts + consultants
- Technology transfer + Workshops

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International Network of NSDD evaluators

Biennial meetings of the International Network of Nuclear Structure and Decay Data Evaluators (NSDD) are funded and organized under the auspices of NDS

The 19th meeting of NSDD network was held at the IAEA Vienna, Austria, 4–8 April 2011 (INDC(NDS)-0595). This meeting was attended by 35 scientists from 20 Member States

International Network of NSDD evaluators

International Network of NSDD evaluators

14 Centres

A-Chain Evaluation Responsibility

Center	Mass Chains	Center	Mass Chains
a. US/NNDC	45-50,57,58,60-73(ex 62-64),82-88 (ex83), 94-97,99,118,119,136-148,150, 152-165 (ex 164), 180-183, 185, 189, 230-240,>249	g. Russia/StP	130-135,146
		h. PRC	51-56,62,63,195-198
		i. France	113-117
		j. Japan	120-129
b. US/NDP	241-249	k. Kuwait	74-80
c. US/LBNL	21-30,59,81,83,90-93,166-171,184,186,187, 191-193,210-217	l. Canada	1,31-44,64,89,98,100,149, 151,164,188,190,194
d. US/TUNL	2-20	m. Australia	172-175
e. US/ANL	106-112,176-179,199-209	n. Hungary	101-105
f. India	218-229		

International Network of NSDD evaluators

Specific mass chain activities, horizontal evaluations and technical issues

Problems are still being experienced in maintaining suitable numbers of mass chain evaluators (expressed as FTE – Full Time Effort)

Thanks to IAEA efforts, evaluators are being supported and are actively performing evaluations

NDS staff will continue to support new evaluators and collaborate in mass chain evaluations

International Network of NSDD evaluators

List of 51 actions

27	NNDC	XUNDL compilation date	Expand XUNDL index to show compilation date by nuclide.
28	Firestone	ENSDF into XML	Look into possibilities working with LLNL.
29	Kibedi	Calculate conversion coefficients. *Recommendation*	Mixing ratio default to be determined statistically or by evaluator, in either case comments should appear.
30	Kibedi	Mixing ratio for E0, E2, M1.	Suggest changes to format in order to define mixing ratios.
31	Sonzogni, Kibedi	Improve data that quantify Auger electron and continuum beta spectra.	Develop and recommend analysis codes to provide more detailed presentations of Auger electrons and continuum beta spectra.
32	Network	New production code for Nuclear Data Sheets.	Provide comments to B. Singh based on two mass chains (A=40, A=182) placed on the web site.
33	NNDC	Checking code *Recommendation*	Download Mitropolski code and incorporate into FMTCHK.
34	All evaluators	Atomic masses *Recommendation*	Use 2011AuZZ masses and quote 2003Au03 in a comment.
35	Audi	Atomic masses	Provide 2011 evaluation to NNDC by end of April 2011 (2011AuZZ).
36	Evaluators	BE2 compilation	Comments and feedback on the presentation and the paper attached to B. Prytichenko and B.Singh.
37	All	Masses *Recommendation*	To obtain masses for new nuclides, communicate directly with AMDC

International Network of NSDD evaluators

Bilateral visits:

- **M.A. Kellett (IAEA-NDS) to CIEMAT. Attendance at the 3rd Workshop of Radioactive Decay Data Evaluators. 9–11 June 2010**
- **D.H. Abriola (IAEA-NDS) to NNDC. Attendance at USNDP meeting and carry out ENSDF evaluation work. 20 Oct–3 Nov 2010**
- **B. Pritychenko, NNDC to NDS. Install and load NSR database on NDS MySQL database server, discuss NSR compilations and revise technical procedures. 19–26 November 2010**

International Network of NSDD evaluators

- *Bilateral visits (cont.):*

- B. Singh, McMaster University to NDS. Collaborate on the update of the most neutron deficient nuclides of A=148: 148Tm, 148Er and 148Ho for ENSDF database. 14–16 June 2011

- D.H. Abriola (IAEA-NDS) to McMaster University. Collaborative work with B. Singh on beta-delayed neutron emission evaluation. 7–11 November 2011

- D.H. Abriola (IAEA-NDS) to NNDC. Attendance at USNDP meeting, and carry out ENSDF work. 13–23 November 2011

- B. Pritychenko, NNDC to NDS. Install and load NSR database on NDS MySQL database server and revise technical procedures. 21–25 November 2011

International Network of NSDD evaluators

Next meeting in Kuwait, January 2013

KUWAIT UNIVERSITY

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ENSDF evaluations (D. Abriola)

- Collaboration with A. Sonzogni,
  A=72 NDS 111 (2010) 1-140.

- New Mass chain A=144 to be submitted Nov. 2012 in collaboration with A. Sonzogni
  (17 nuclei, 93 new experimental references,
  21 XUNDL-files)

NSR compilations (M. Kellett)

IAEA has compiled [and keyworded] the following papers:

2005:	**258 [134] (from Sept to Dec)**
2006:	**479 [348]**
2007:	**869 [495]**
2008:	**529 [298]**
2009:	**670 [217]**
2010:	**596 [298]**
2011:	**259 [108]**

Total: 3660 [1898] (in ~5.5 years)

6+2+1 Contracts – 2010…2012

1. Joshi and Jain (India)
2. Wang and Audi (China) Atomic Mass Evaluation (Horizontal)
3. Zuber (Poland)
4. A. Negret (Romania)

5. J. Timar – Z. Elekes (Hungary)

6. N. Stone (USA)
Nuclear Moments (Horizontal):
Compilation and evaluation

7. Lalkovski (Bulgaria)

8. Abusaleem Kalifeh (Jordan)

9. S. Erturk (Turkey August 2012)

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Nuclear Data Projects – Status, May 2012

Coordinated Research Projects

- 8 completed
- 3 active
- 3 planned

Data Development Projects

- 8 active

Completed CRPs

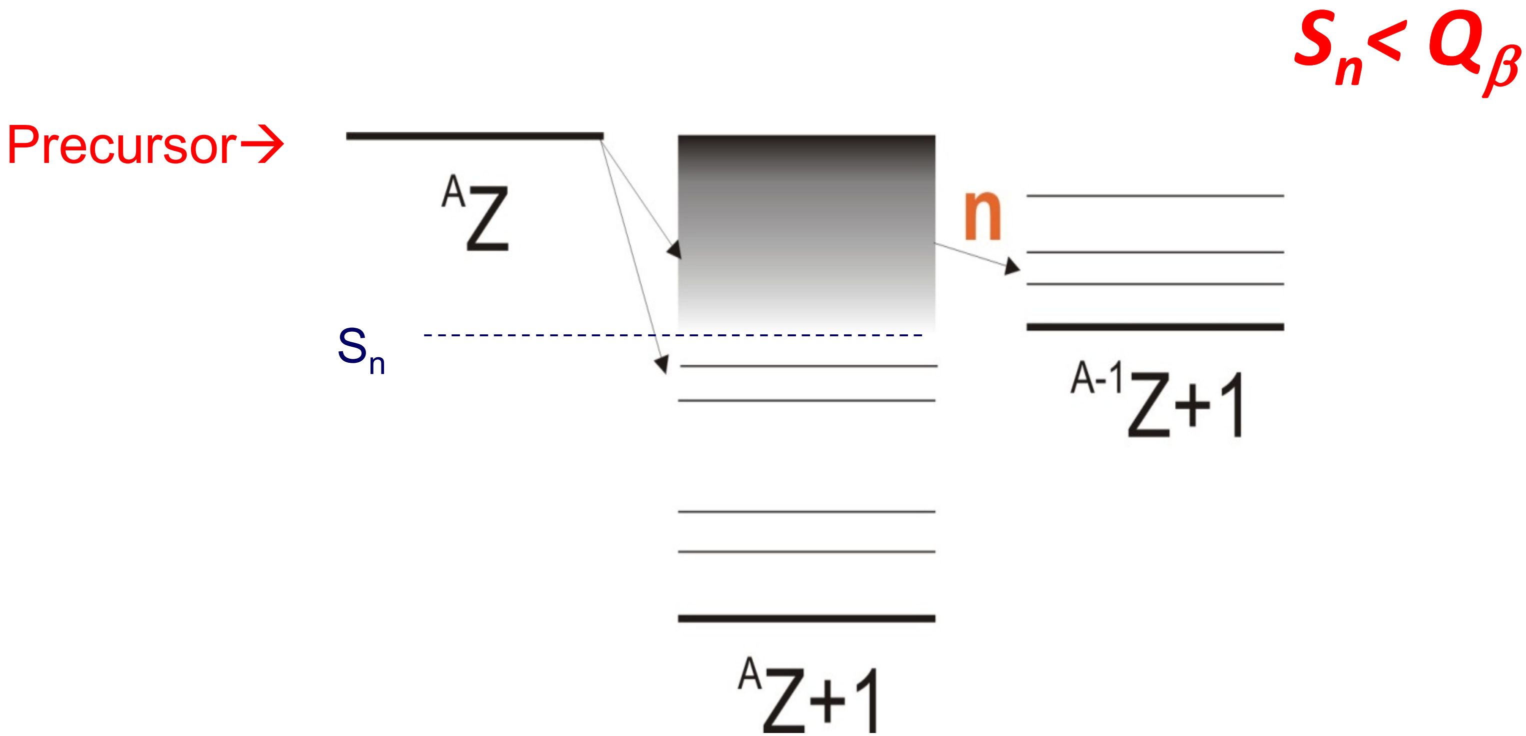
Table 3. Status of Coordinated Research Projects Dedicated to Nuclear Data

No.	Short title	Duration	Participants (contracts)	Project Officer	Status	Section
1	Nuclear data for Th-U fuel cycle	2002–2007	11 (6)	Trkov Capote	Completed (2010) IAEA STI/PUB/1435 and webpage	6.1.1
2	RIPL-3	2003–2008	11 (5)	Capote	Completed (2009) Nucl. Data Sheets paper and webpage	6.1.2
3	Nuclear data for the production of therapeutic radionuclides	2003–2007	9 (4)	Capote	Completed (2012) IAEA TRS 473 and webpage	6.1.3
4	Reference database for ion beam analysis	2005–2010	10 (4)	Abriola	Completed/ document in preparation	6.1.4
5	Reference database for neutron activation analysis	2005–2010	7 (4)	Kellett	Completed/ document undergoing final editing	6.1.5
6	Updated decay data library for actinides	2005–2010	7 (4)	Kellett	Completed/ document in press	6.1.6
7	Heavy charged-particle interaction data for radiotherapy	2007–2010	12 (2)	Capote	Completed/ document in preparation	6.1.7
8	Minor actinide neutron reaction data (MANREAD)	2007–2011	12 (4)	Otsuka	Completed/ document in preparation	6.1.8

On-going and Planned CRPs

9	Nuclear data libraries for advanced systems: fusion devices (FENDL-3)	2007–2011	15 (3)	Forrest	On-going	6.1.9
10	Prompt fission neutron spectra for actinides	2009–2012	12 (6)	Capote	On-going	6.1.10
11	Charged-Particle Monitor Reactions and Nuclear Data for Medical Isotope Production	2012–2015	~15 (6)	Capote	Approved by CCRA	6.1.11
12	Nuclear data for Particle Induced Gamma Ray Emission (PIGE) analysis	2011–2014	11 (6)	Abriola	On-going	6.1.12
13	Validation of the International Dosimetry Library IRDFF	2013–2017	-	Simakov Capote	Planned	6.1.13
14	Beta-delayed Neutron Emission Evaluation	2013–2017	-	Abriola	Planned	6.1.14

Beta-delayed neutron emission evaluation



Important nuclear structure information
P_n : β-strength above S_n
$t_{1/2}(^{A}Z+1)$: sensitive to low-lying β-strength

Beta-delayed neutron emission evaluation (2013-2017) D. Abriola

Motivation:

- **Beta-delayed neutrons are important for energy production, astrophysics and nuclear theory**
- **Most of the data available are from precursors coming from fission fragments**
- **New experimental facilities are available which will be able to produce new precursors in the neutron-rich region**
- **Last evaluation with theoretical comparisons is from 2002**
- **There is no database that compiles all relevant data**

Beta-delayed neutron emission evaluation

Consultant’s meeting

- **A related CM was held at IAEA Vienna, 10-12 October, 2011 , the consultants pointed out the need of a CRP on the topic**

Beta-delayed neutron emission evaluation

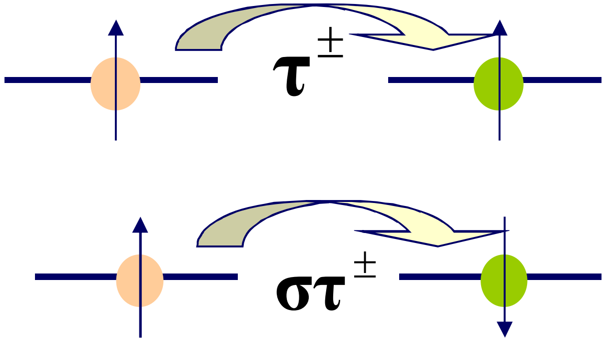
LIST OF PARTICIPANTS

CANADA Balraj Singh Department of Physics and Astronomy A.N. Bourns Science Building 241 McMaster University	SPAIN Daniel Cano Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT)
GERMANY Iris Dillmann GSI Darmstadt and Justus-Liebig-Universität	USA Alejandro Sonzogni Brookhaven National Laboratory National Nuclear Data Center
GERMANY Bernd Pfeiffer GSI Helmholtzzentrum für Schwerionenforschung	Daniel Abriola NAPC Nuclear Data Section
SPAIN José L. Tain Instituto de Fisica Corpuscular Centro Mixto CSIC-Univ. Valencia	Mark A. Kellett NAPC Nuclear Data Section

The PARTICIPANTS, reviewed the status of the field, Theory, measurements, compilations and evaluations. Report INDC(NDS)-599

$$\beta^- : {}^{A}Z \rightarrow {}^{A}(Z+1) + e^- + \bar{\nu}_e$$

• β-decay is a "simple" process which is very **sensitive to the nuclear wave function**



Fermi / Gamow-Teller:

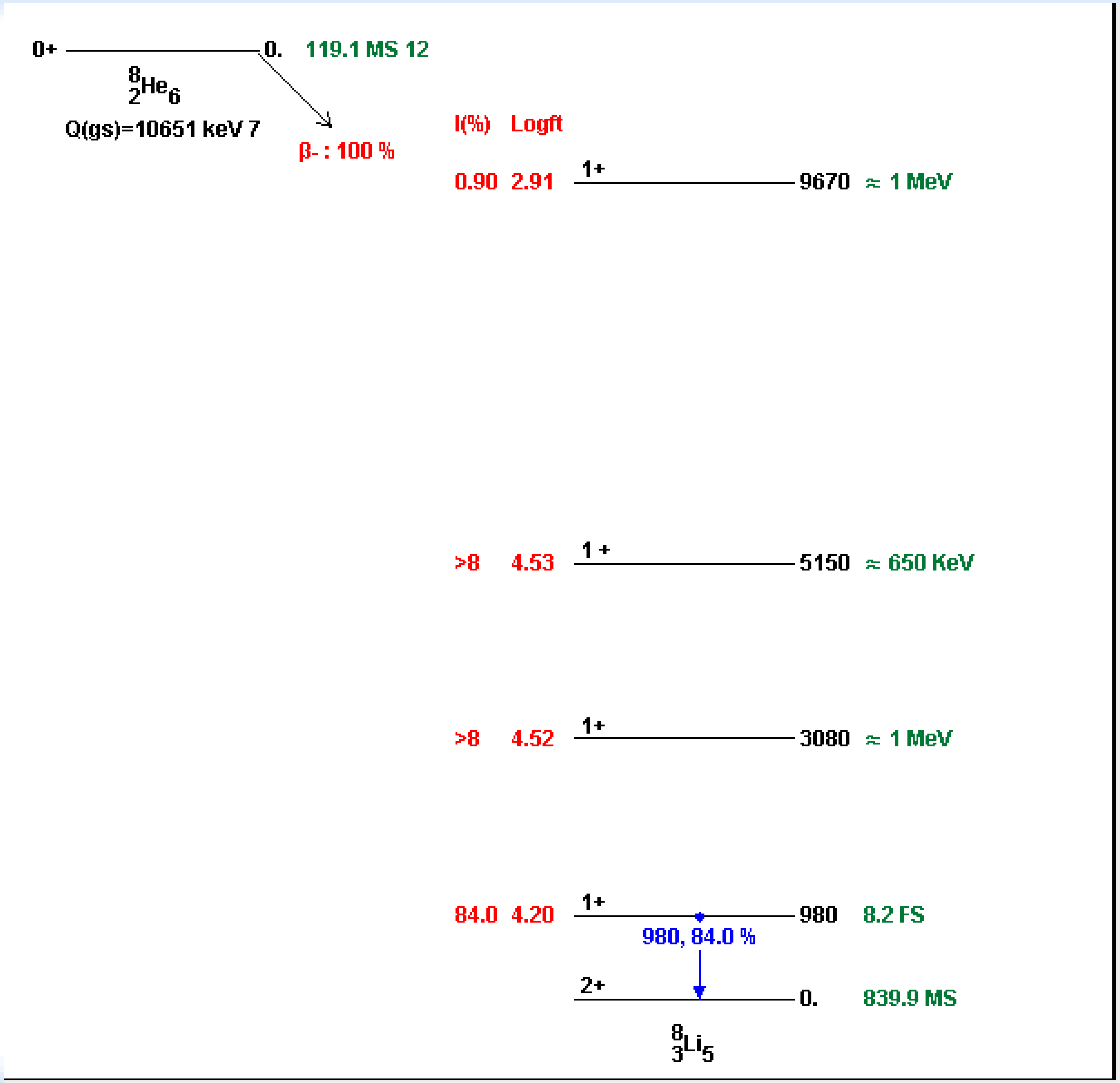
$$B_{i\rightarrow f} = \left| \left\langle \Psi_f \middle| \tau^{\pm} \ or \ \sigma\tau^{\pm} \middle| \Psi_i \right\rangle \right|^2$$

(allowed: *l=0*)

transition probability or strength

• **An accurate knowledge of the distribution of the β-decay probability over the daughter-nucleus levels provides information for the understanding of the structure of nuclei**

• **In itself the knowledge of these data is of importance for applications, notably in the fields of nuclear technology and astrophysics**


0+
0.
119.1 MS 12
$^{8}_{2}He_{6}$
Q(gs)=10651 keV 7
β- : 100 %
I(%) Logft
0.90 2.91
1+
9670 ≈ 1 MeV
>8 4.53
1 +
5150 ≈ 650 KeV
>8 4.52
1+
3080 ≈ 1 MeV
84.0 4.20
1+
980 8.2 FS
980, 84.0 %
2+
0. 839.9 MS
$^{8}_{3}Li_{5}$

log ft

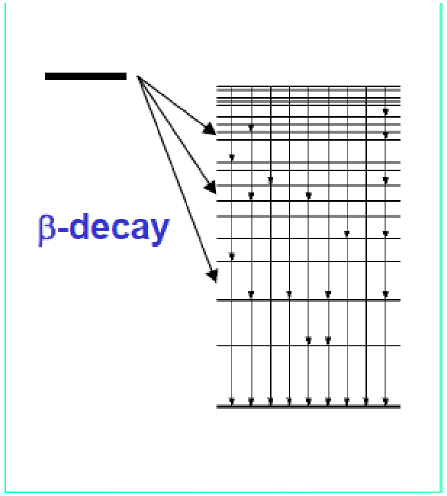
$$\lambda = \frac{g^2 \left| M_{if} \right|^2}{2\pi^3 \hbar^7 c^3} \int_0^{p_{\max}} F(Z_D, p_e) p_e^2 (Q - T_e)^2 \, dp$$

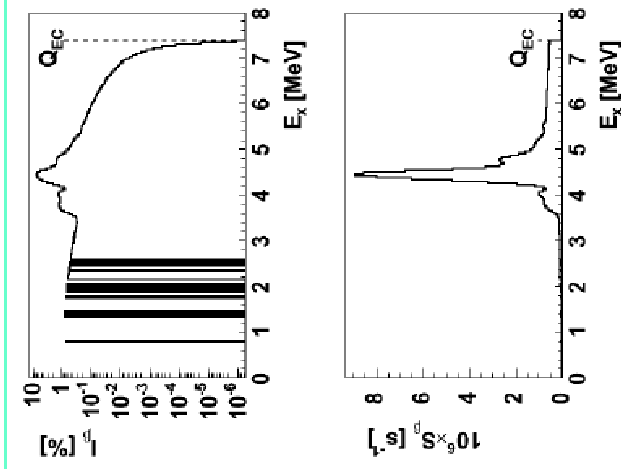
$$\lambda = \frac{g^2 \left| M \right|^2 m_e^5 c^4}{2\pi^3 \hbar^7} f(Z_D, Q)$$

f=Fermi integral

$$ft_{1/2} = \ln 2 \frac{2\pi^3 \hbar^7}{g^2 \left| M \right|^2 m_e^5 c^4} \propto \frac{1}{g^2 \left| M \right|^2}$$

Beta-strength S_β and Beta Intensity I_β





I_β S_β

Experimental

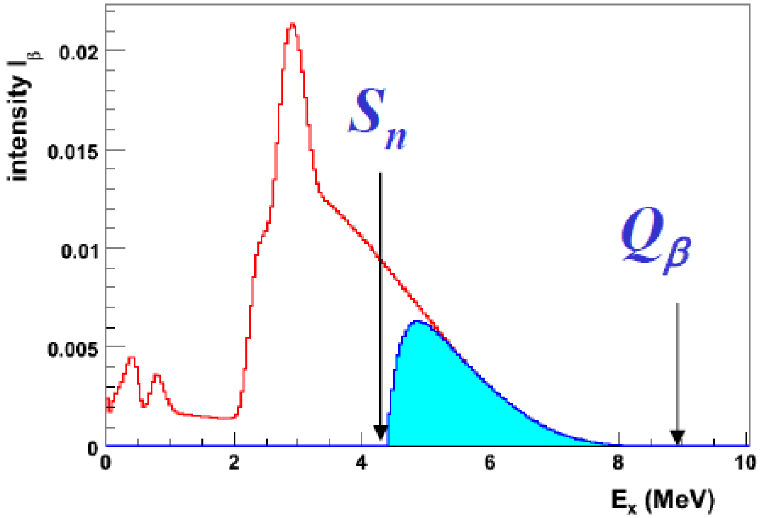
$$S_\beta(E_x) = \frac{I_\beta(E_x)}{f(Q_\beta - E_x)T_{1/2}}[s^{-1}]$$

Beta-strength S_β and Beta Intensity I_β

How to estimate P_n?

$$\frac{1}{T_{1/2}} = \int_0^{Q_\beta} S_\beta(E_x).f(Q_\beta - E_x)dE_x$$

$$P_n = \frac{\int_{S_n}^{Q_\beta} S_\beta(E_x).f(Q_\beta - Ex).\frac{\Gamma_n}{\Gamma_n + \Gamma_\gamma} dE_x}{\int_0^{Q_\beta} S_\beta(E_x).f(Q_\beta - Ex)dE_x}$$



Kratz-Herrmann model

Assuming strength function=0 below cut-off value C

$$P_n = a.\left[\frac{(Q_\beta - S_n)}{(Q_\beta - C)}\right]^b$$

$$C = \begin{cases} 0 & \text{e-e} \\ 13/A^{1/2} & \text{o-mass} \\ 26/A^{1/2} & \text{o-o} \end{cases}$$

Z. Phys.263 (1973) 435

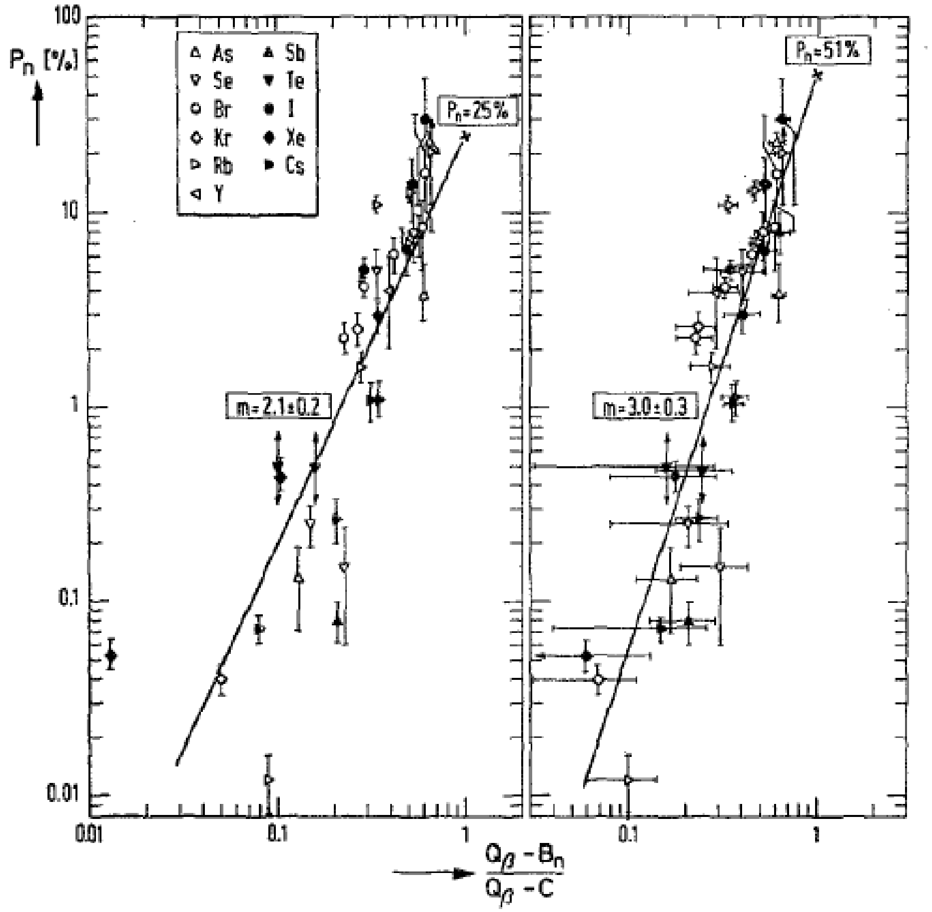
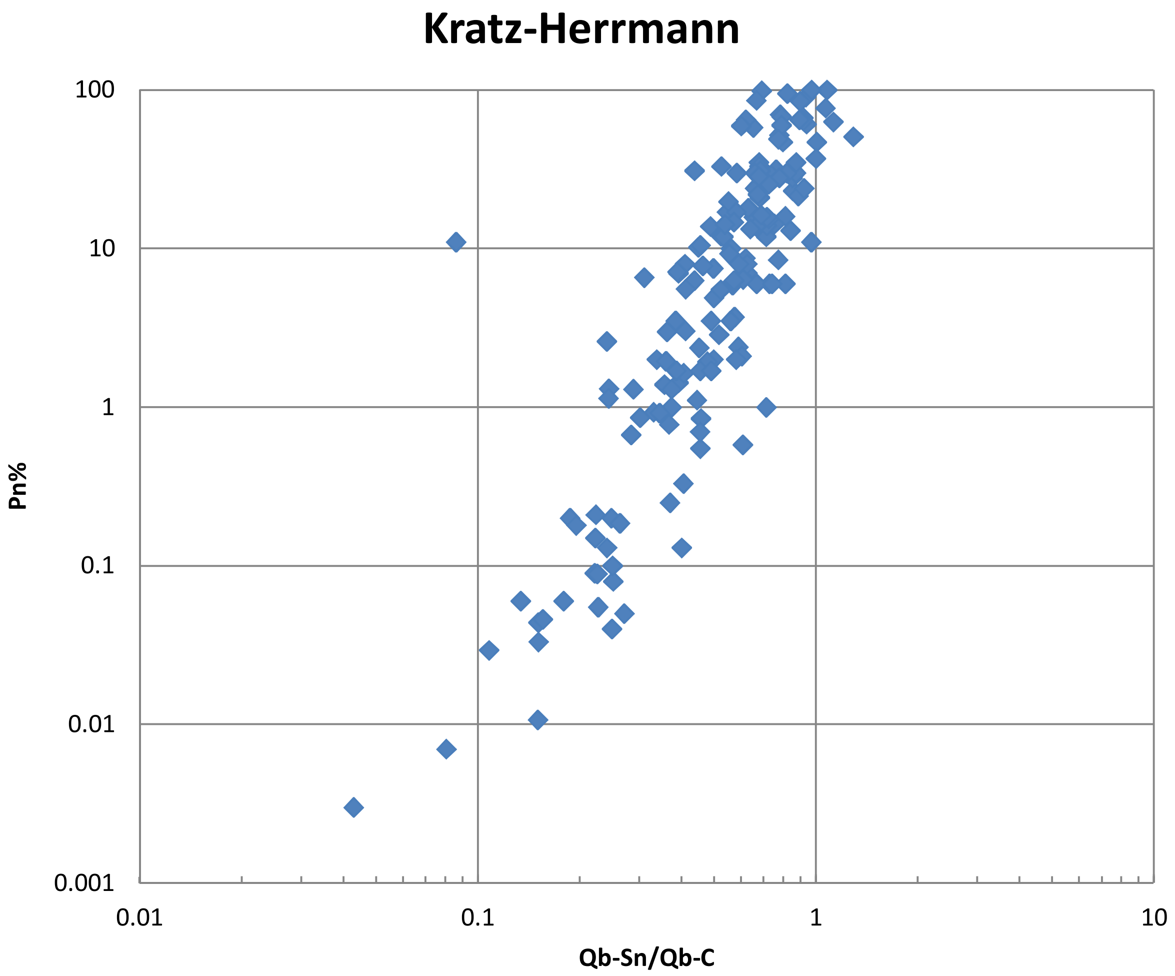


Fig. 1. Plot of the neutron emission probability, P_n, versus the reduced energy window, $(Q_\beta - B_n)/(Q_\beta - C)$. In the left diagram, Q_β and B_n values were taken from the mass formula of Garvey *et al.* [17], for the right diagram, averages obtained from four different mass formulae [17–20] were used

March 2012 data



Experimental techniques (Pn)

Produce and separate the Precursor
Measure β
Measure n (long counters (NERO, BELEN, ^{3}Hen…)
Measure γ...

- "n/β": Neutron-beta coincidences. Beta efficiency not required. Neutron efficiency is determined in absolute terms:

$$P_n = 1/\varepsilon_n * N_{\beta n}/N_\beta$$

- "n-β": Neutrons and betas counted separately (no coincidences) but simultaneously.

$$P_n = \varepsilon_\beta/\varepsilon_n * N_n/N_\beta$$

Experimental techniques (n-spectrum)

Neutron Spectrometers:
3 He(n,p)T + 764 keV
p-recoil
TOF
NE213 (MONSTER)
BC537 (DESCANT)
...

The ideal neutron detector for decay experiments

Conclusions of "Workshop on neutron detectors for DESPEC-FAIR and other facilities" (CIEMAT – Madrid, July 2006)

n-γ discrimination ⇒ **necessary** for reducing backgrounds, enable β-2n,3n ... detection
→ Liquid scintillators **NE213** (or "new" solid scintillators – Neutromania project)

improved $\Delta E_n/E_n$
→ thin, small volume detectors with increased **d_{flight}~3,4 m** (space for both n and γ setups)

lowest possible threshold in E_n → check with thin, small volume detectors + digital electronics (**30 keV E_n**)

cross-talk rejection ⇒ enable β-2n, 3n… detection
→ modular, highly granular array (**>100 detectors**) + variable geometry (cm alignement precision is Ok).

MINISTERIO DE EDUCACION Y CIENCIA

D. Cano-Ott, β-delayed neutron meeting, 10th of October 2011 Vienna

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

high ε_n $\Rightarrow$ identification

$\rightarrow$ $1\pi \leq \Delta\Omega_n \leq 2\pi$

and ε_γ for combined neutron/gamma measurements $\Rightarrow$ identification of n-decay to excited states

$\rightarrow$ large volume high efficiency Ge det's (conflict with the need for high $\Delta\Omega_n$)

digital electronics $\Rightarrow$ control of systematic uncertainties.

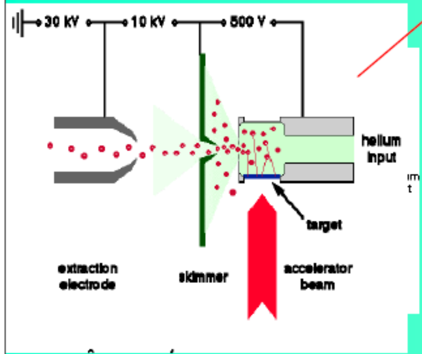
JYFL (Jyväskylä, Finland)

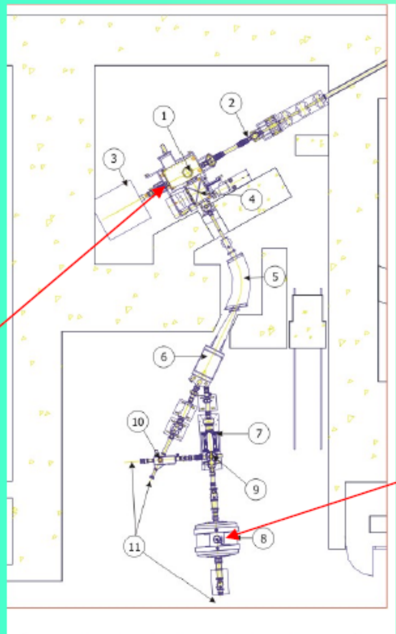
Courtesy
J.L. Tain

JYFL Accelerator Laboratory

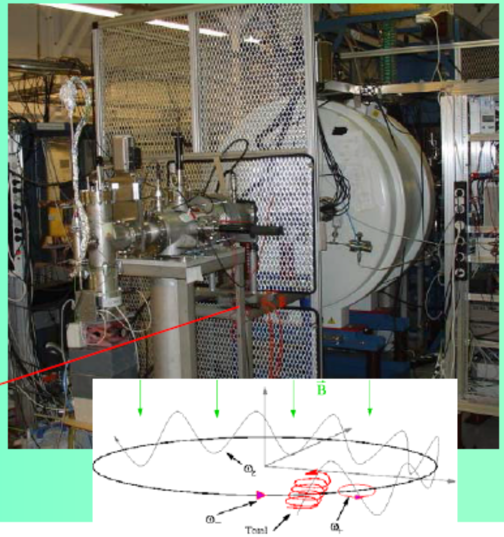
IGISOL separator
+ ion guide
source: refractory elements

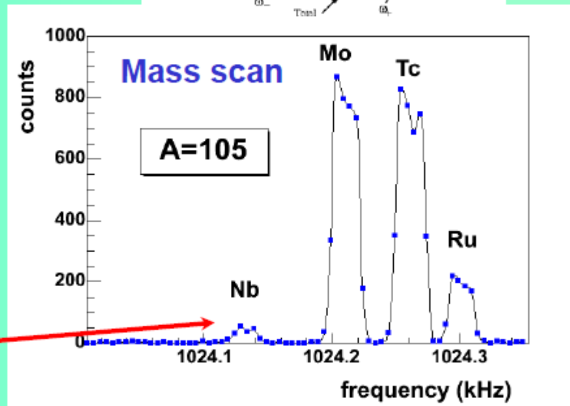
p(25MeV)/d(35MeV) + U





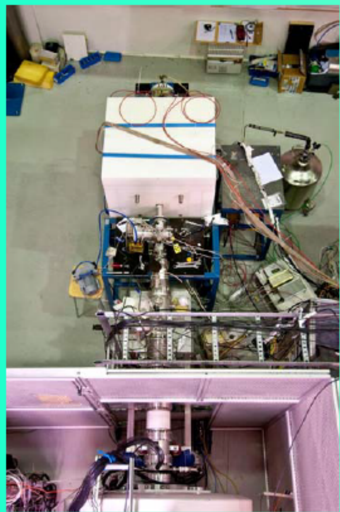
JYFLTRAP Penning trap:
isotopic purification



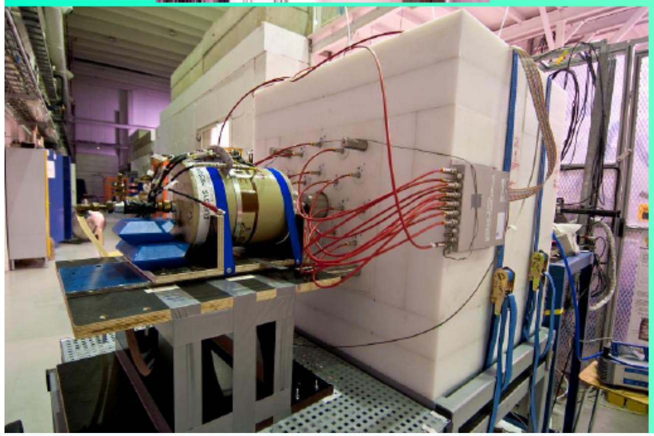


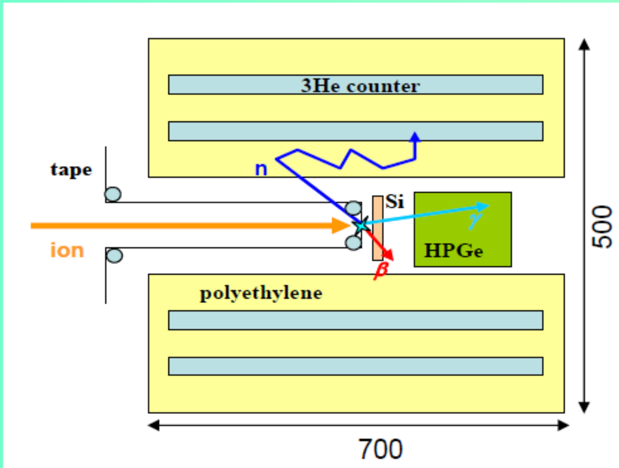
JYFL 2009: "Decay properties of β-delayed neutron emitters"

(A. Algora-IFIC, D.Cano-CIEMAT, B.Gomez-UPC, et al.)



- Measured: ^{88}Br, ^{94,95}Rb, ^{138}I
- Calibration/verification measurements
- 20 ^{3}He proportional counters
- PE moderation matrix + shielding
- Si detector for β-counting
- Ge detector for additional source decomposition
- Implantation/decay cycles optimized according $T_{1/2}$





Beta-delayed neutron emission evaluation

Motivation

Creation of Database is timely:

1. Much better mass measurements, mass-evaluations and theoretical predictions
2. Last evaluation in 1993 last compilation in 2002, 60+ papers not yet included
3. Radioactive beam facilities (RIB) in France (Spiral-2), Germany (FAIR), Japan (RIBF), and the USA (FRIB)
4. Theoreticians need a reliable basis of experimental data to set constraints on their models, and in turn help experimentalists to better plan new measurements

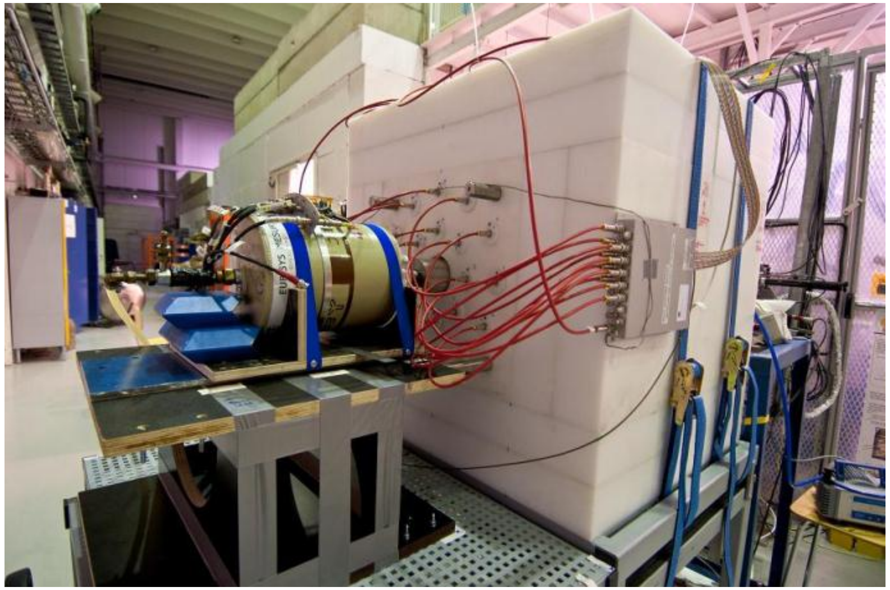
5. Human component : many scientists who have been working in the field of β-delayed neutrons for decades are retiring now

Beta-delayed neutron emission evaluation

Motivation

New experimental facilities and detectors

Radioactive beam facilities (RIB) in France (Spiral-2), Germany (FAIR), Japan (RIBF), and the USA (FRIB)



BELEN neutron detector at the IGISOL-JFLTRAP facility

Beta-delayed neutron emission evaluation

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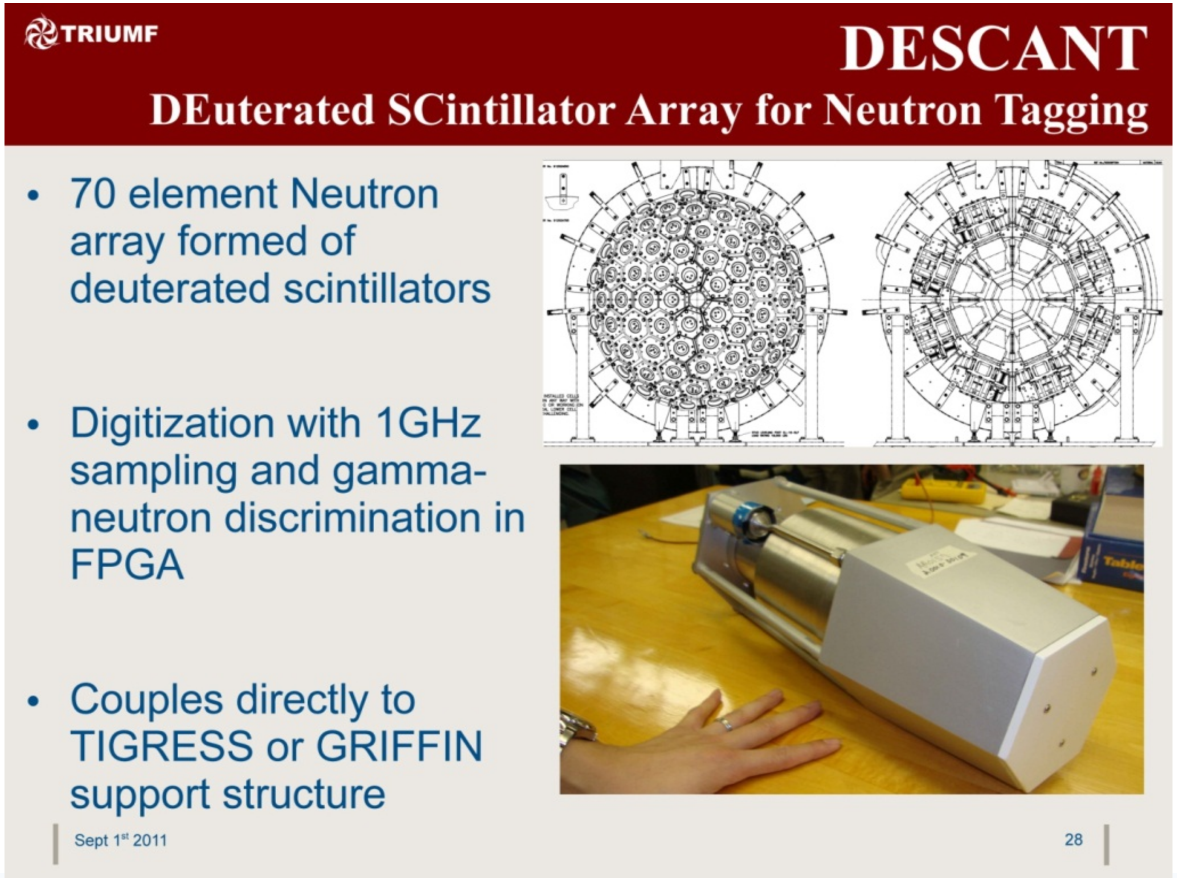

Beta-delayed neutron emission evaluation

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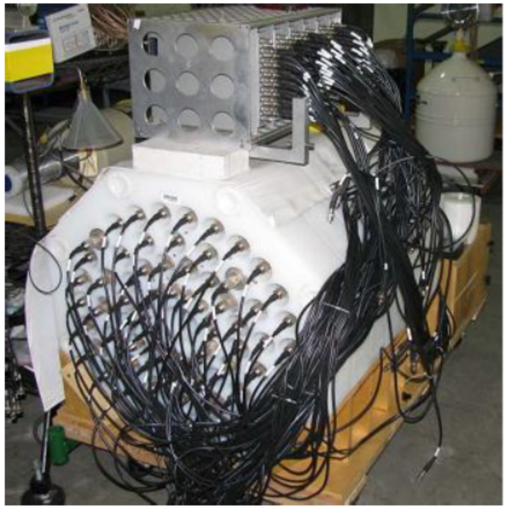


(HRIBF@Oak Ridge)

74 counters, Ø 1" and 2", 60 cm long, 10 atm ^{3}He

Beta-delayed neutron emission evaluation

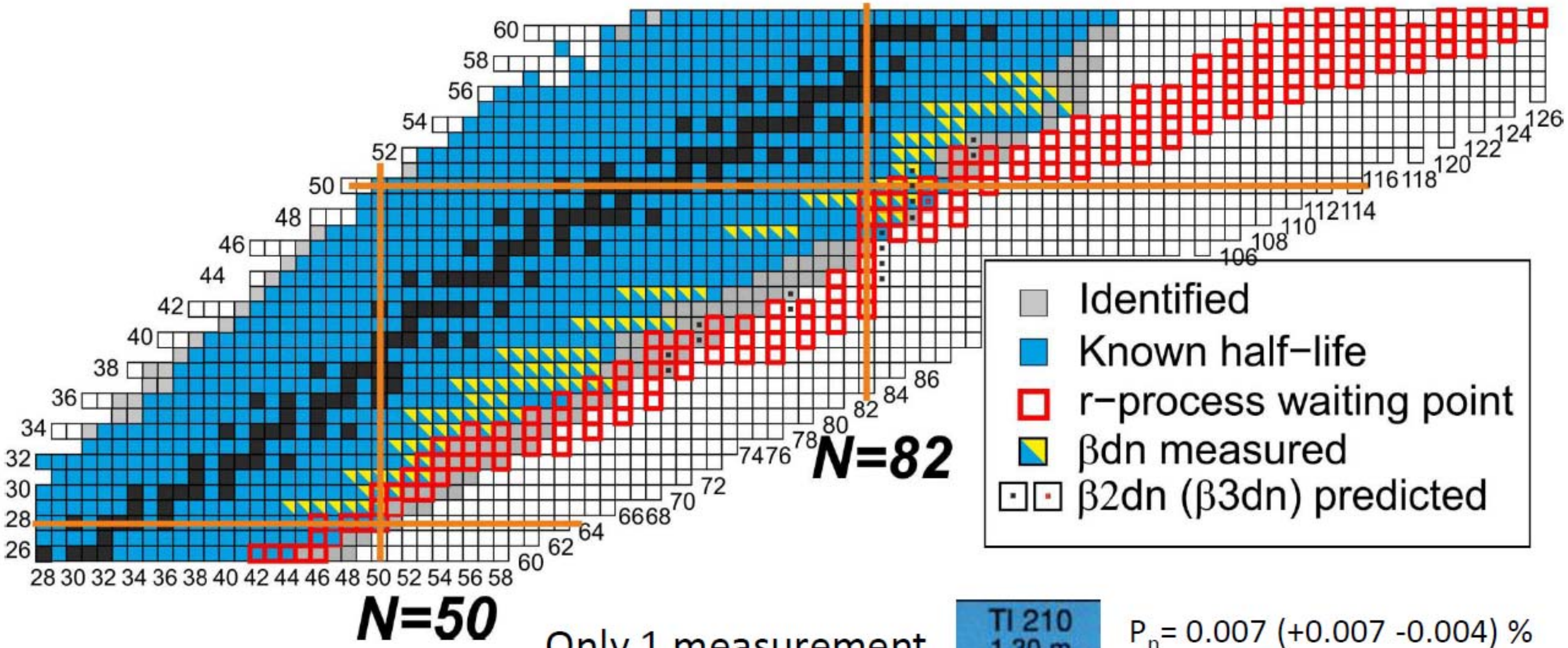
Interest of the comunity:

1. Nuclear physics (astrophysics/ structure) improvement of the accuracy of P_n values, which will help theoreticians to improve their models and, in turn, make extrapolations to more neutron-rich isotopes more reliable. New measurements in the heavier mass region A>150 (the so-called "terra incognita") are desired, and also more measurements of multiple neutron emitters will become possible in the next years.

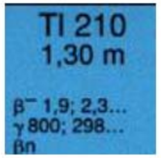
2. Reactor physics and homeland security in the US, an accurate knowledge of decay properties of fissile nuclei is required, including a detailed knowledge of delayed neutron precursors and fission yields. Although the six-group-parameterization from Keepin 1957 still satisfies the requirements of commercial organizations, a higher accuracy of the delayed neutron yields and a better energy resolution in the delayed neutron spectra is desired.

Beta-delayed neutron emission evaluation

Astrophysics & Nuclear Structure



Only 1 measurement for A>150:



P_n= 0.007 (+0.007 -0.004) %

Validation missing

G. Stetter, Nucl. Sci. Abstr. 16, 1409, Abstr.10963 (1962)

Missing experimental information for r-process above A>150

Beta-delayed neutron emission evaluation

Delayed fraction nuclear reactors

	6-group	8-group
Group	Half-life (s)	Half-life (s)
1	55.72	55.6
2	22.72	24.5
3	6.22	16.3
4	2.3	5.21
5	0.614	2.37
6	0.23	1.04
7		0.424
8		0.195

^{87}Br

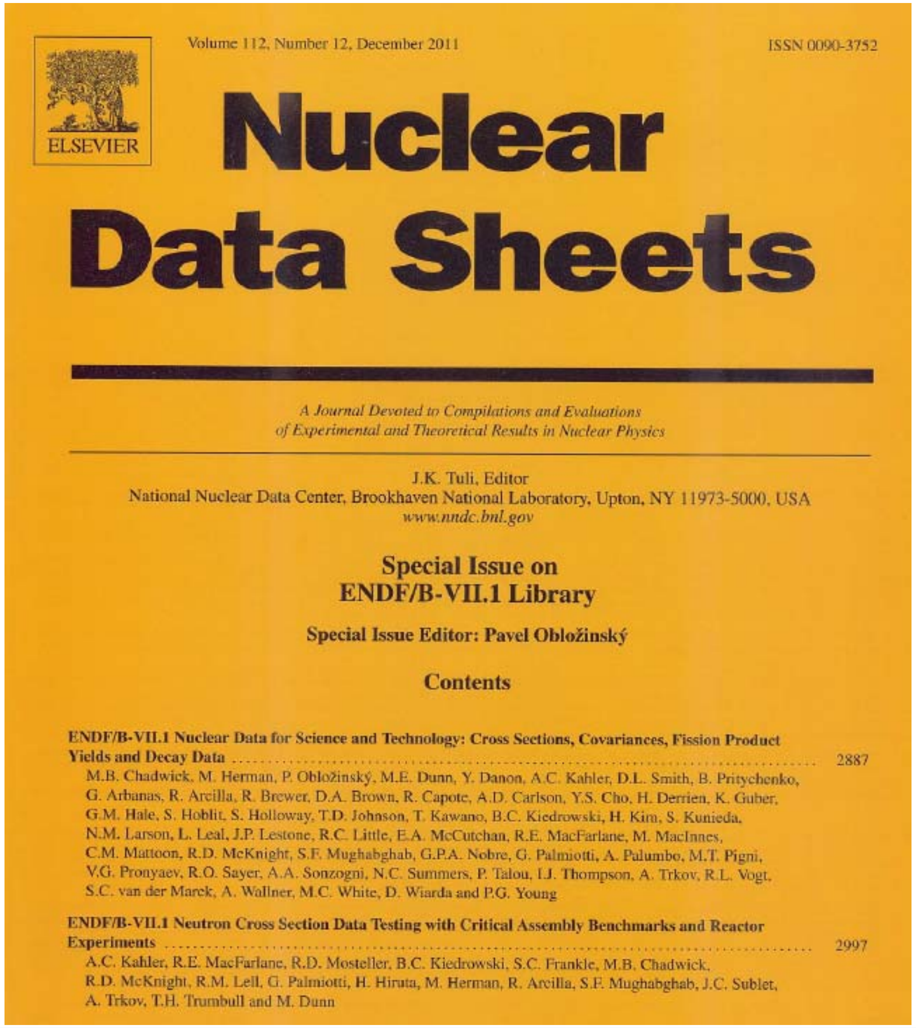
^{137}I

^{88}Br

Beta-delayed neutron emission evaluation

NDS 112,2887, December 2011

Special Issue on ENDF/B-VII.1 Library


ELSEVIER

Volume 112, Number 12, December 2011

ISSN 0090-3752

Nuclear
Data Sheets

A Journal Devoted to Compilations and Evaluations of Experimental and Theoretical Results in Nuclear Physics

J.K. Tuli, Editor
National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA
www.nndc.bnl.gov

Special Issue on ENDF/B-VII.1 Library

Special Issue Editor: Pavel Obložinský

Contents

Beta-delayed neutron emission evaluation

NDS 112,2887, December 2011 Special Issue on ENDF/B-VII.1 Library

"Significant differences, on the order of a factor of two to four , have been observed in the decay constants for the short-lived delayed precursor groups between ENDF/B-VII and other published values (e.g., Keepin, ENDF/B-VI)..." Pg.2950

"…While a detailed analysis on delayed neutron precursors should be performed, present resources are such that the most favorable short-term solution is to revert to the ENDF/B-VI 6-group delayed data…." Pg.2951

Beta-delayed neutron emission evaluation

Previous Compilations and evaluations:

1989 Evaluation M.C. Brady evaluation and simulation of neutron spectra and compilation of P_n values. Experimental neutron spectra for 34 delayed-neutron emitters Spectra for about 237 b-delayed neutron precursors were calculated based on statistical model. The values of P_n were compiled and evaluated for 89 fission fragments from ^{75}Cu to ^{149}La

1993 Evaluation G. Rudstam, *et al.* :evaluation and measurements for fission produced precursors. Data for 93 nuclides from ^{75}Cu to ^{150}La, including P_n values measured for 64 nuclei

2002 Compilation B. Pfeiffer, *et al.* 338 fission produced nuclides listed in this paper with experimental (compiled) values for 129 nuclides. Theoretical values from QRPA models and systematic values from Kratz-Herrmann formula for all the 338 nuclides

Beta-delayed neutron emission evaluation

Assessment ^{87}Br data

Reference	Half-life (s)	%P(n)	Method	Comments
1993Ru01*	55.6(3)	2.56(10)	n, β-	
1980Lu04	55.5(3)	2.57(15)	n, β-	Same lab as 1993Ru01
1980ReZQ*		2.1(3)	ion counting	Also 1977Re05
1978Kr15	55.9(6)	2.6(4)	fission	Also 1974Kr21
1974Gr29	55.96(34)		n	Same group as 1993Ru01
1972Sc48	-	2.3(4)	fission	
1971De35*	55.6(3)	2.3(3)	Kr-87, γ	
1967Pa26		2.63(5)	fission	
1967Ga19		3(1)	Fission, time groups	
1966Si09	55.8(3)			
1964Ar24*	56	3.1(6)	n, β-	
1957Ke67	54.5(9)			

*: value used to calculate the weighted average

Weighted Average = 2.43 (14) %, reduced χ^2=1.0.

Uncertainty of 0.10 in 1993Ru01 increased to 0.20 to limit weight to 50%.

1993Ru01, 2002Pf04: recommended value= 2.52 (7) %

^{87}Br neutron spectrum (1985)

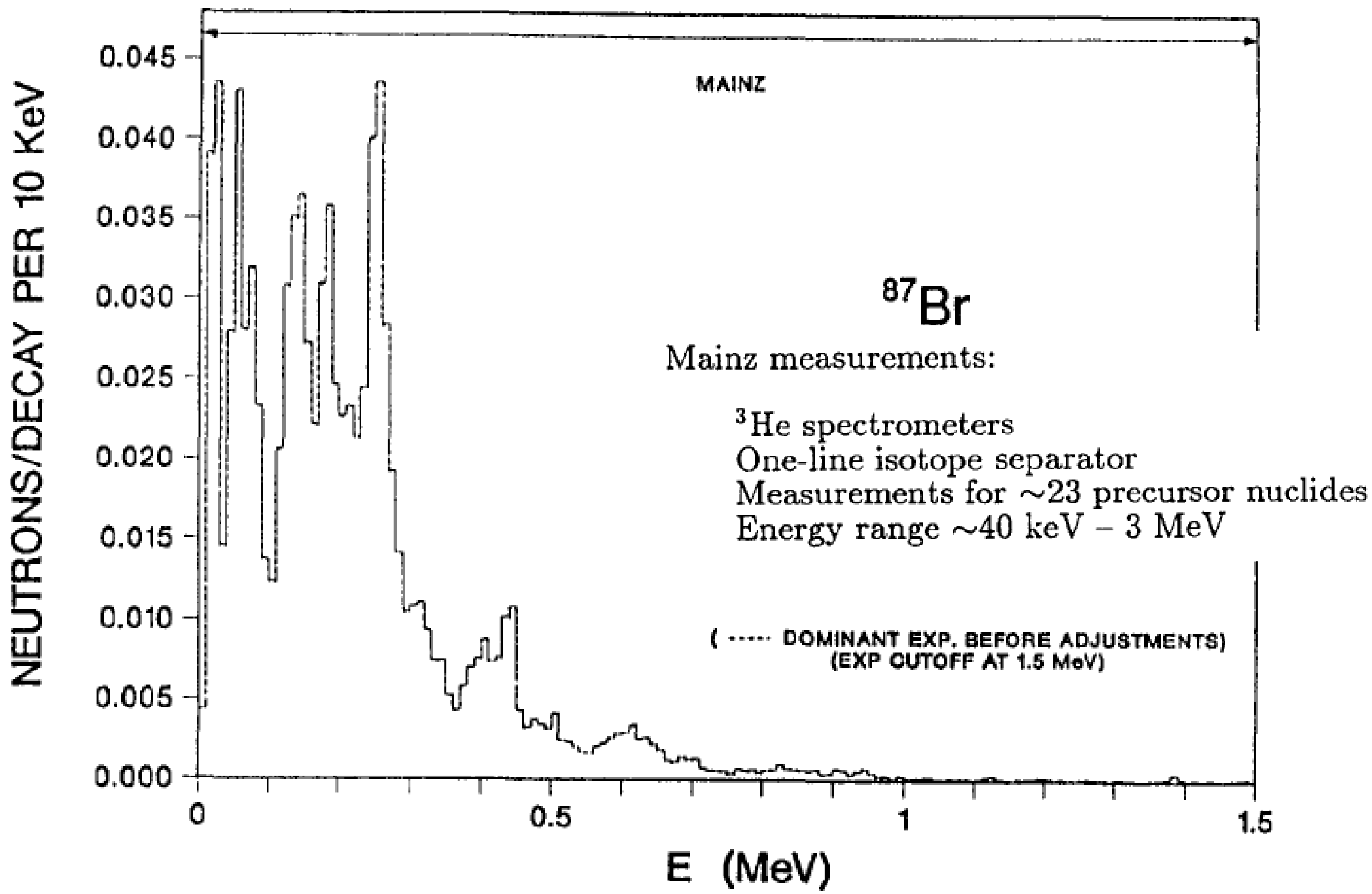


Fig. 16. Normalized delayed neutron spectra for ^{87}Br.

Beta-delayed neutron emission evaluation

Assessment ^{138}I data

Reference	Half-life (s)	%P(n)	Method	Comments
2011GO37*		**5.32(20)***		Penning Trap beam separator
2010MaZS		~5.4	n	Preliminary result
1993Ru01*	**6.233(31)**	**5.56(22)***	**n, β-**	**Also 1976Lu02**
1980ReZQ		5.1(30)	ion counting	Also 1977Re05, P(n)=6.0(35)
1980Lu04	6.5	5.5(4)	n, β-	Same group as 1993Ru01
1978Kr15	6.21(20)	4.5(9)	fission	Also 1974Kr21
1975As03	6.5(2)	2.58(22)	n, β-	
1974Gr29	6.44(26), 7.03(26)		n	Same group as 1993Ru01
1972Sc48		4.5(10)	fission	Adjusted in 1993Ru01 from 3.0(8). Also 1969ScZY
1964Ar24	6.3	2.0(5)	n, β-	
1959Pe28	6.3(7)	2.0(5)	fission	Adjusted in 1969De35

*: value used to calculate the weighted average

The discrepant data: 2.58 (22) % in 1975As03 and 2.0(5) % in 1964Ar24 were not included in averaging.

LWM weighted average= 5.43 (20) % where the uncertainty of 0.15 given by the LWM was increased to the lowest value of the dataset: 0.20, reduced χ^2=0.65

CAUTION IF USED AS STANDARD: ONLY TWO INDEPENDENT MEASUREMENTS

Beta-delayed neutron emission evaluation

Example of Pn values in ENSDF (from LiveChart):

A	Z	Nuclide	N	Energy (keV)	J^{π}	$T_{1/2}$	Decays	
8	2	He	6	0	0+	119.1 ms *12*	β-	100
							β- n	16 *1*
9	3	Li	6	0	3/2-	178.3 ms *4*	β-	100
							β- n	50.8 *2*
12	4	Be	8	0	0+	21.3 ms *1*	β-	100
							β- n	≤ 1
14	4	Be	10	0		4.35 ms *17*	β- 2n	5 *2*
							β-	100
							β- n	81 *4*
17	5	B	12	0	(3/2-)	5.08 ms *5*	β-	100
							β- n	63 *1*
							β- 2n	11 *7*
							β- 3n	3.5 *7*
							β- 4n	0.4 *3*
16	6	C	10	0	0+	0.747 s *8*	β-	100
							β- n	99.0 *3*
17	6	C	11	0		193 ms *13*	β-	100
							β- n	32 *3*
18	6	C	12	0	(0+)	92 ms *2*	β-	100
							β- n	31.5 *15*
20	6	C	14	0		14 ms *+6-5*	β-	100
							β- n	72 *14*
22	6	C	16	0	0+	6.1 ms *+14-12*	β-	100
							β- n	61 *+14-13*
							β- 2n	< 37
17	7	N	10	0	1/2-	4.173 s *4*	β-	100
							β- n	95.1 *7*
18	7	N	11	0	1-	624 ms *12*	β-	100
							β- α	12.2 *6*
							β- n	14.3 *20*
19	7	N	12	0		271 ms *8*	β-	100
							β- n	54.6 *14*
20	7	N	13	0		130 ms *7*	β-	100
							β- n	57 *3*
21	7	N	14	0	(1/2-)	85 ms *7*	β-	100
							β- n	81 *7*
21	7	N	14	0	(1/2-) *2*	83 ms *8*	β-	100
							β- n	90.5 *42*

Beta-delayed neutron emission evaluation

Inclusion of delayed neutron data – EXFOR, JEFF, ENDF/B, ENSDF

Neutron spectra (discrete or continous) – EXFOR
Make available to JEFF, ENDF/B

Pn & T1/2 – ENSDF
Make available to JEFF, ENDF/B

Beta-delayed neutron emission evaluation

Possible participants in a CRP

USA	– BNL, LANL, MSU/NSCL, ORNL
CANADA	– McMaster U., Triumf, Univ. Guelph
GERMANY	– GSI Darmstadt/ Univ. Giessen
SPAIN	– IFIC Valencia, CIEMAT Madrid, UPC Barcelona
FRANCE	– Orsay, GANIL, LPC Caen, ILL Grenoble
CHINA	– Chinese Acad of Sci, Lanzhou
FINLAND	– Jyvaskyla (JYFL)
JAPAN	– JAEA, RIKEN
RUSSIA	– JINR Dubna, IPPE Obninsk
SOUTH KOREA	- KAERI
ARGENTINA	– CNEA
BRAZIL	– U. Sao Paulo
INDIA	– VECC, Kolkata

Beta-delayed neutron emission evaluation

Suggested Objectives:

- To create a reference database of evaluated data for beta-delayed neutron emision
- The database should contain evaluated half-lives, emission probabilities and neutron spectra for individual precursors.
- The evaluation methodology should be described
- Agregate quantities like group values should be derived and stored in the database
- The CRP should produce a priority list for evaluations and new experiments and improvements in the theoretical predictions

Beta-delayed neutron emission evaluation

Suggested Outputs:

- Priority list for measurements
- Database of evaluated data (format should be defined)
- Old and New measurements compiled into database
- Agregate quantities like group values stored in the database
- Technical report

Outline

- IAEA Nuclear Data Section (NDS)
- Coordination of the NSDD network
- NSDD-related activities
  - ENSDF evaluations / NSR compilations
  - Financial support for ENSDF evaluators and horizontal evaluation/compilation activities
- CRPs
  - Beta-delayed neutron emission
- **Workshops**
- Dissemination, new tools
- Conclusions

Workshops 2010

1. Nuclear Reaction Data for Advanced Reactor Technologies, ICTP, Trieste, 3 April to 14 May 2010 JOINT ICTP-IAEA

NDS Workshop Director: R.Capote

Objective:

To provide training and information exchange for nuclear physicists, nuclear engineers, and other users of Nuclear Data for advanced technological applications

Workshops 2010

2. Nuclear Structure and Decay Data: Theory and Evaluation, ICTP, Trieste, 11-15 October 2010 HOSTED

NDS Workshop Director: D.Abriola

Objective

- To familiarize students with new experimental data that characterize the nucleus
- Modern nuclear models
- Train participants in methodology of NSDD evaluations
- Production of evaluated nuclear structure and decay data (as ENSDF mass-chain evaluations)

Workshops 2010

3. Nuclear Data for science and technology: Analytical Applications , ICTP, Trieste, 8-12 Nov. 2010

NDS Workshop Directors: D.Abriola, M.A. Kellett

JOINT ICTP-IAEA

- Experimental techniques in NAA and IBA (RBS and PIGE)
- Analysis software availability and use
- Nuclear data requirements for analytical science: NAA and IBA
- Available nuclear data for IBA analysis – the IBANDL database
- On-line retrieval of nuclear data
- Nuclear data compilation and dissemination

Lectures + exercises, 23 participants

Workshops 2010

3. Nuclear Data for science and technology: Analytical Applications , ICTP, Trieste, 11-15 October 2010 JOINT ICTP-IAEA

NDS Workshop Directors: D.Abriola, M.A.Kellett

Activities

Lectures each morning and computer-based exercises each afternoon.

Hands-on introduction of participants to the *k_0-IAEA* software for neutron activation analysis, the *SIMNRA* software for NRA spectral analysis and the online services of the NDS, including EXFOR, ENDF and IBANDL databases.

23 participants

Workshops 2011

1. *Monte Carlo radiation transport and associated data needs for medical applications, ICTP, Trieste, 17-28 October 2011* HOSTED

NDS Workshop Director: R.Capote

- Based on EGSnrc system, National Research Council of Canada for the coupled transport of electrons, photons and positrons.
- The BEAMnrc code was also covered allowing participants to learn how to model specific linear accelerators and other radiation sources employed in both diagnosis and radiotherapy.
- IAEA phsp (phase-space) database with EGSnrc/BEAMnrc

110 applications 55 participants

Workshops 2011

2. IAEA Workshop on Development of Nuclear Data Libraries, IAEA, 28 November-2 December 2011

Experimental covariance information and EXFOR retrieval.
Theory and hands-on training: GANDR system code for nuclear data evaluation.
A total of 20 hours of lectures and 22 hours of computer exercises were provided

9 participants

Workshops 2012

1. Nuclear Structure and Decay Data: Theory and Evaluation, ICTP, Trieste, August 2012 NOW!

Topics

- ENSDF evaluation philosophy and analysis programs
- NSDD network, relevant IAEA activities, access to appropriate web pages and Nuclear Reactions
- Nuclear models
- Radioactive Decays
- Adopted Levels
- Databases and Web resources

Outline

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- Conclusions

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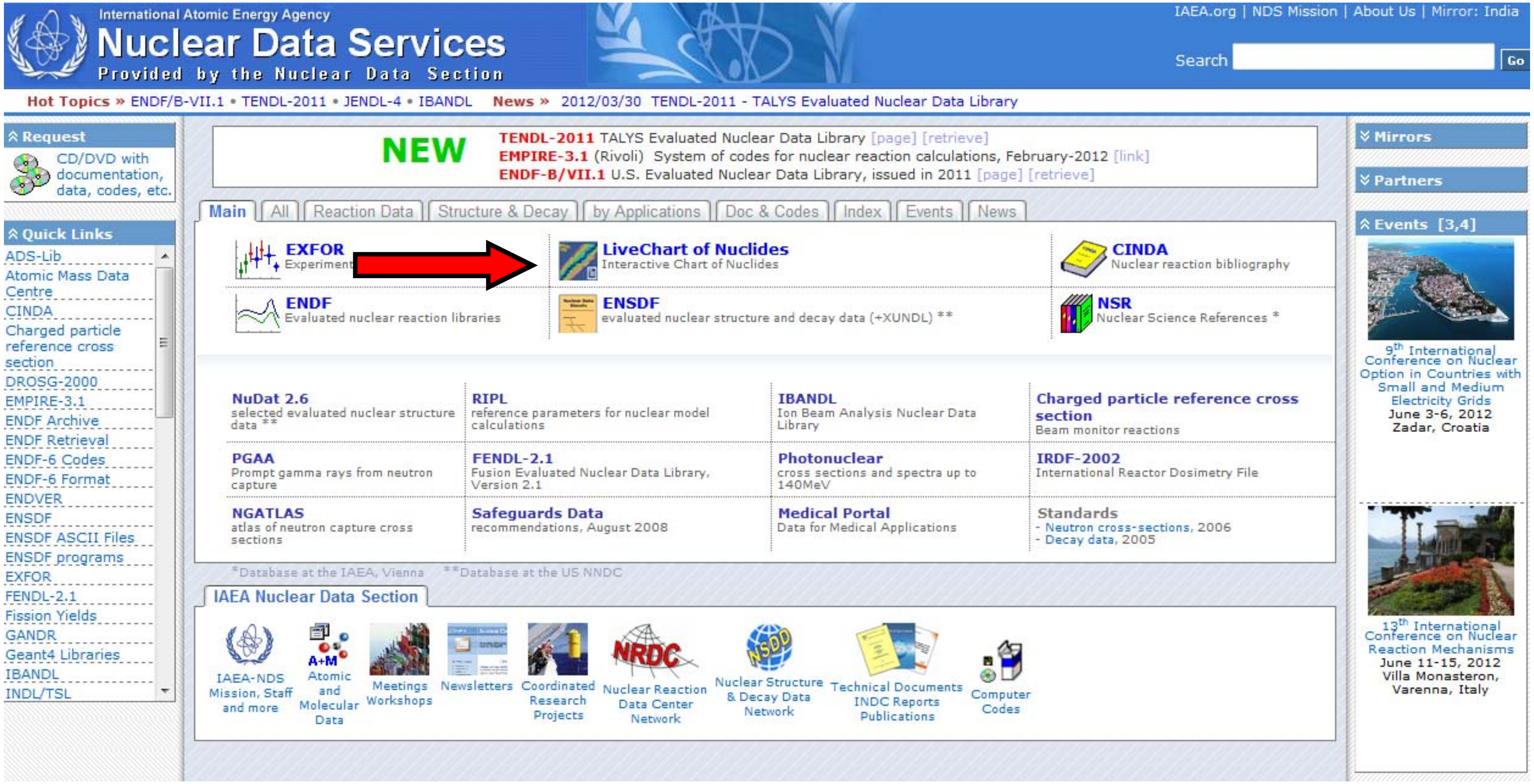
[IAEA Nuclear Data Services]
Provides access to databases, documents, programs and files. Maintained by the **IAEA's** Nuclear Data Centre.
www-**nds**.**iaea**.org/ - Cached - Similar

[RIPL-2 (Index)]
Handbook for calculations of nuclear reaction data, RIPL-2. IAEA-TECDOC-1506 (IAEA, Vienna, 2006). Available online at http://www-**nds**.**iaea**.org/RIPL-2/ **...**
www-**nds**.**iaea**.org/ripl2/ - Cached

[Cross-Section database for medical radioisotope production: **IAEA**-CRP]
A description of the formatting procedure is given in the report **IAEA-NDS**-210 (pdf, 68 KB). Complete documentation is available, including evaluation **...**
www-**nds**.**iaea**.org/medical/ - Cached - Similar

[IBANDL]
Sep 27, 2010 **...** This is the Ion Beam Analysis Nuclear Data Library produced according to the recommendations of the **IAEA** Technical Meeting held at the **IAEA** **...**
www-**nds**.**iaea**.org/ibandl/ - Cached - Similar

NDS Web page



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EMPIRE-3.1 (Rivoli) System of codes for nuclear reaction calculations, February-2012 [link]
ENDF-B/VII.1 U.S. Evaluated Nuclear Data Library, issued in 2011 [page] [retrieve]
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EXFOR
Experiment
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Interactive Chart of Nuclides
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Nuclear reaction bibliography
ENDF
Evaluated nuclear reaction libraries
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evaluated nuclear structure and decay data (+XUNDL) **
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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-2.1
Fusion Evaluated Nuclear Data Library, Version 2.1
Photonuclear
cross sections and spectra up to 140MeV
IRDF-2002
International Reactor Dosimetry File
NGATLAS
atlas of neutron capture cross sections
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
Atomic and Molecular Data
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Newsletters
Coordinated Research Projects
Nuclear Reaction Data Center Network
Nuclear Structure & Decay Data Network
Technical Documents INDC Reports Publications
Computer Codes
Mirrors
Partners
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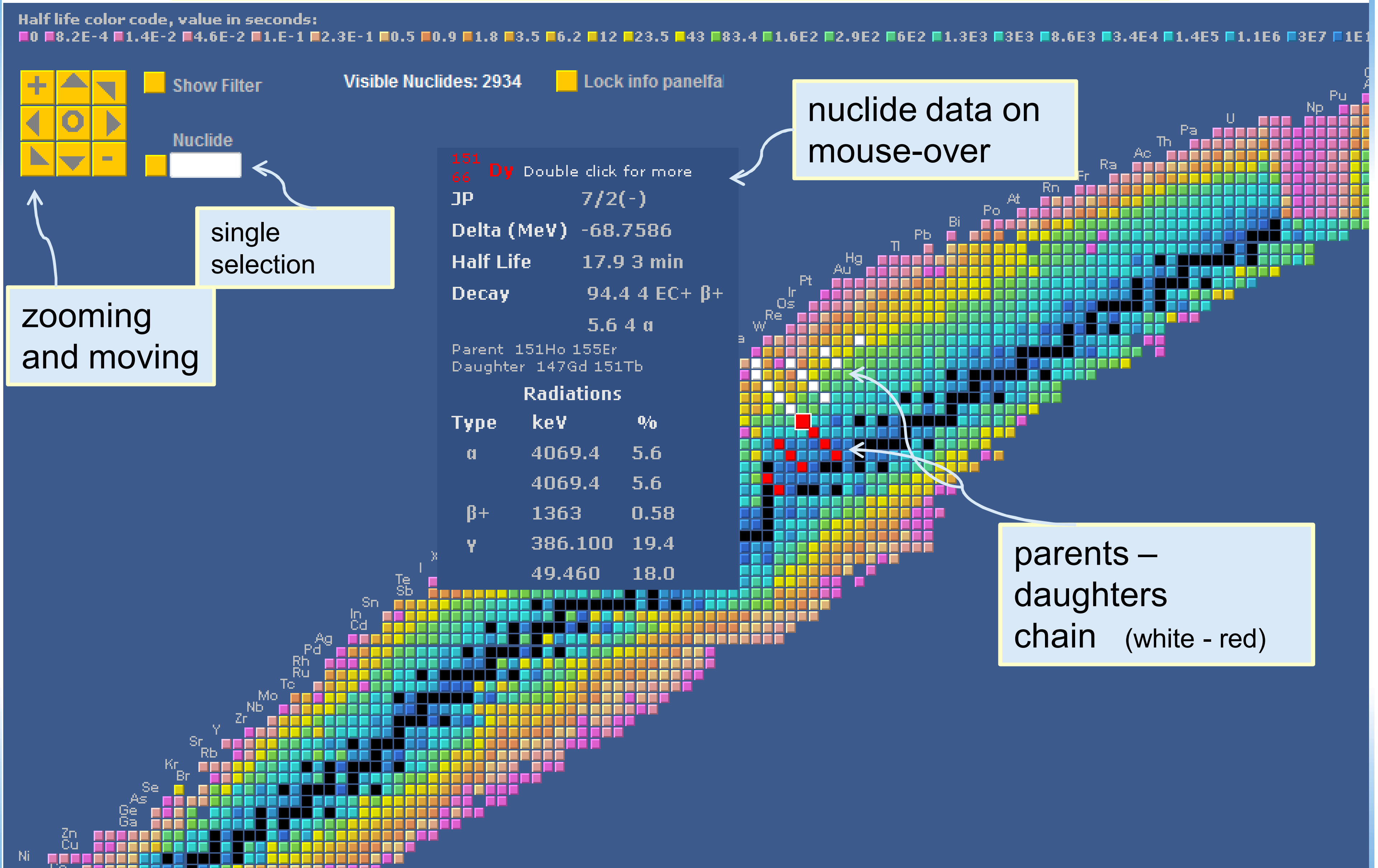
9th International Conference on Nuclear Option in Countries with Small and Medium Electricity Grids
June 3-6, 2012
Zadar, Croatia
13th International Conference on Nuclear Reaction Mechanisms
June 11-15, 2012
Villa Monasteron, Varenna, Italy

Livechart



nuclide data on mouse-over

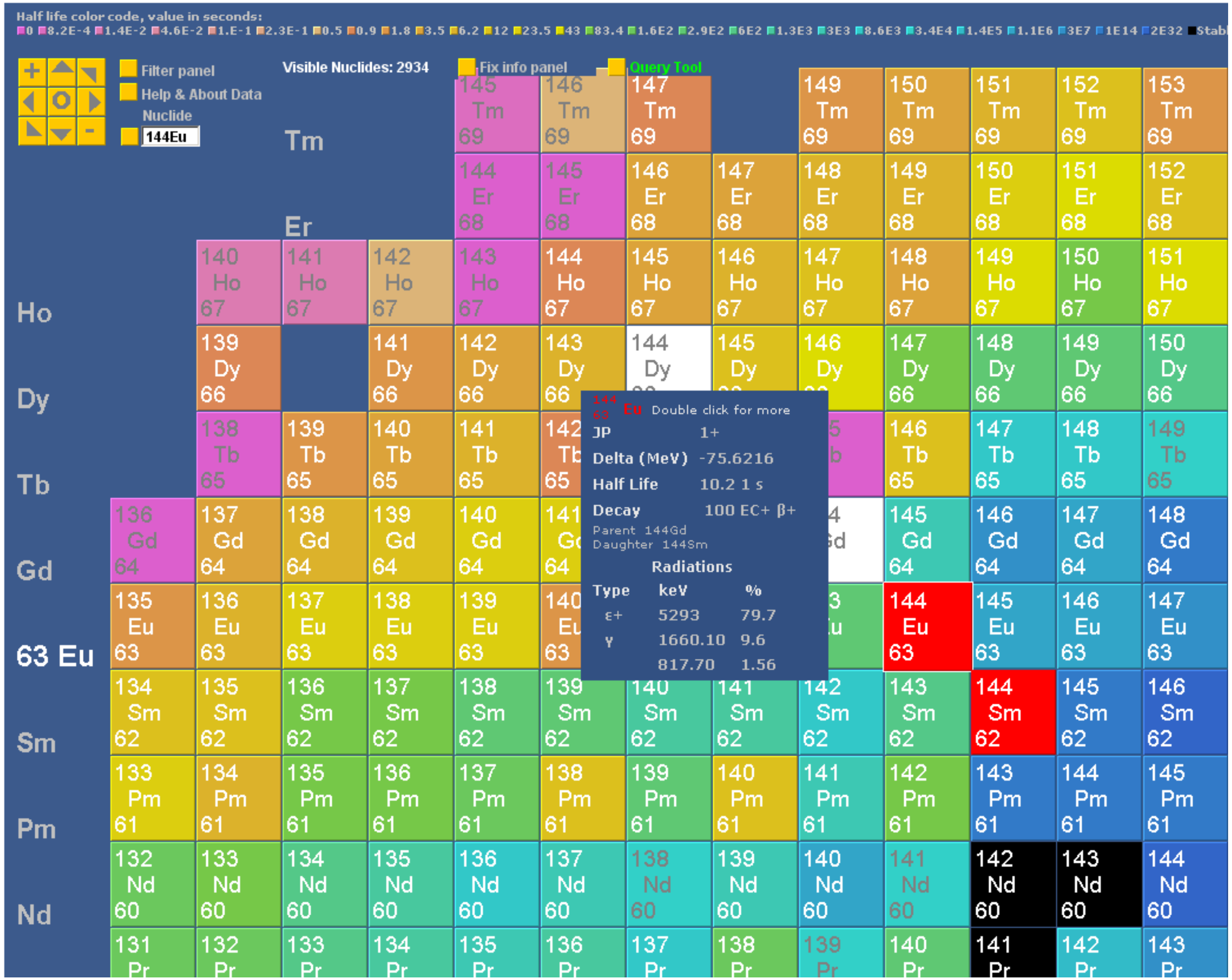
single selection

zooming and moving

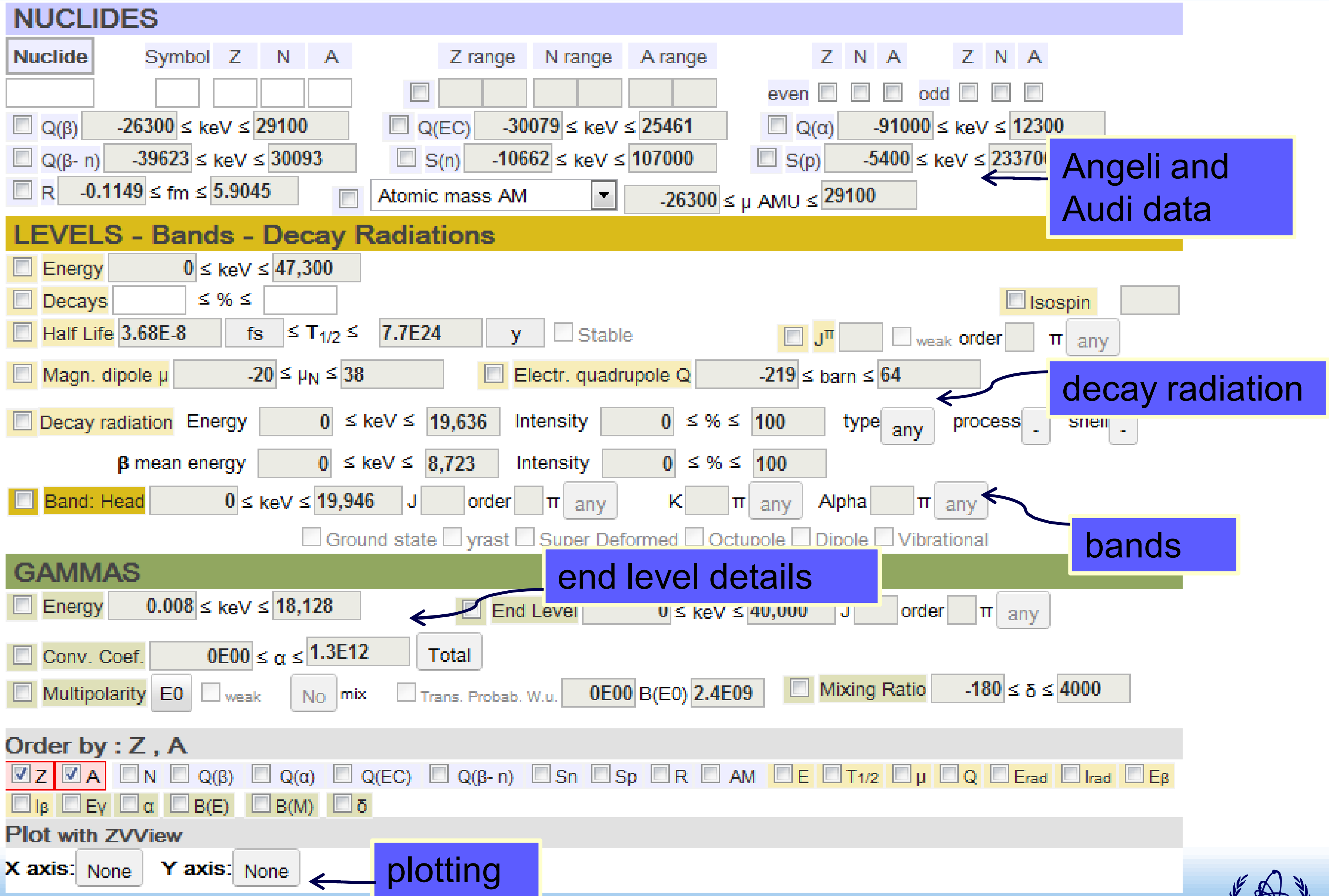
parents – daughters chain (white - red)

Data sources: ENSDF + Radlist, AMDC 2011, Angeli, Stone

LiveChart: M.Verpeli & A.Vasaros



Query tool


NUCLIDES
Nuclide
Symbol Z N A
Z range N range A range
Z N A Z N A
even odd
Q(β) -26300 ≤ keV ≤ 29100
Q(EC) -30079 ≤ keV ≤ 25461
Q(α) -91000 ≤ keV ≤ 12300
Q(β- n) -39623 ≤ keV ≤ 30093
S(n) -10662 ≤ keV ≤ 107000
S(p) -5400 ≤ keV ≤
R -0.1149 ≤ fm ≤ 5.9045
Atomic mass AM
-26300 ≤ μ AMU ≤ 29100
Angeli and Audi data
LEVELS - Bands - Decay Radiations
Energy 0 ≤ keV ≤ 47,300
Decays ≤ % ≤
Isospin
Half Life 3.68E-8 fs ≤ T1/2 ≤ 7.7E24 y
Stable
Jπ weak order π any
Magn. dipole μ -20 ≤ μN ≤ 38
Electr. quadrupole Q -219 ≤ barn ≤ 64
decay radiation
Decay radiation Energy 0 ≤ keV ≤ 19,636 Intensity 0 ≤ % ≤ 100 type any process -
β mean energy 0 ≤ keV ≤ 8,723 Intensity 0 ≤ % ≤ 100
Band: Head 0 ≤ keV ≤ 19,946 J order π any K π any Alpha π any
bands
Ground state yrast Super Deformed Octupole Dipole Vibrational
GAMMAS
end level details
Energy 0.008 ≤ keV ≤ 18,128
End Level order π any
Conv. Coef. 0E00 ≤ α ≤ 1.3E12 Total
Multipolarity E0 weak No mix
Trans. Probab. W.u. 0E00 B(E0) 2.4E09
Mixing Ratio -180 ≤ δ ≤ 4000
Order by : Z , A
Z A N Q(β) Q(α) Q(EC) Q(β- n) Sn Sp R AM E T1/2 μ Q Erad Irad Eβ
Iβ Eγ α B(E) B(M) δ
Plot with ZVView
X axis: None Y axis: None
plotting

Output example :
Filter all nuclides with superdeformed bands

☑ Band: Head | 0 ≤ keV ≤ 19,946 | J | order | π any | K | π any | Alpha | π any

☐ Ground state ☐ yrast ☑ Super Deformed ☐ Octupole ☐ Dipole ☐ Vibrational

Tab-panel with details for each nuclide

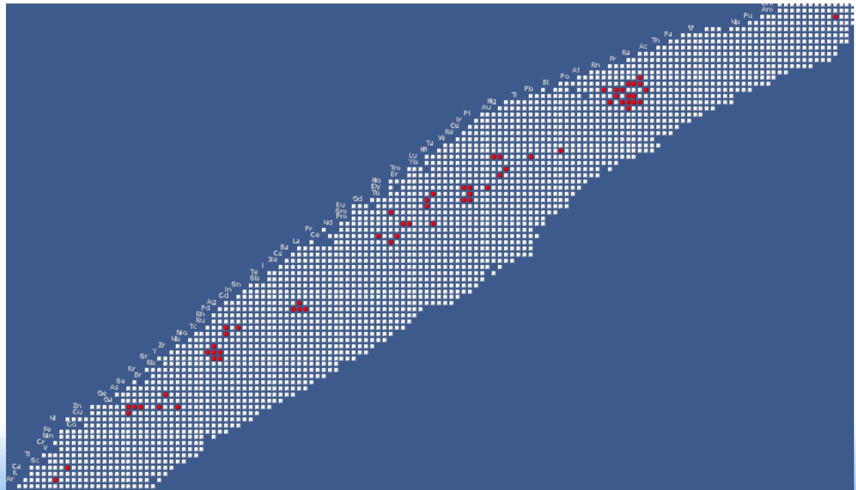
You requested: **Band head** 0 ≤ E_l ≤ 19,946 parity any parity(K) any parity(alpha) any Super Def

Nuclide | Levels | Gammas | Bands | Decay Radiation | Magn. Mom. | El. Mom. | Ther. Neutrons Capture | Cum. Fission Yields

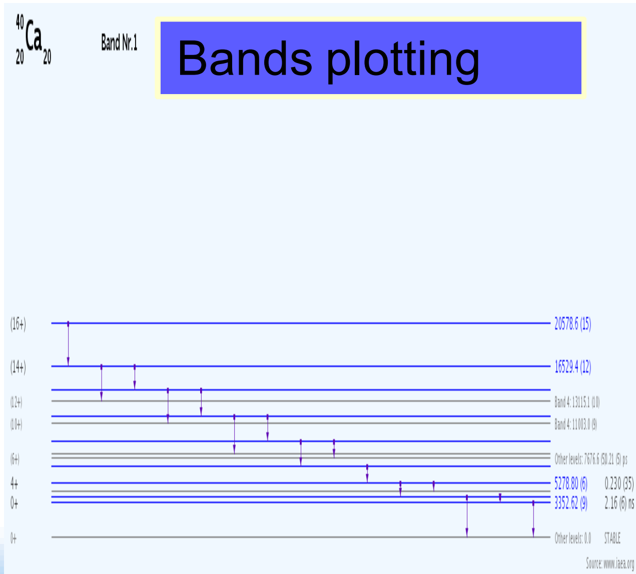
Click on nuclide symbol to show the level schema

Nuclide	Q_{β^-} [keV]	Q_α [keV]	Q_{EC} [keV]	$Q_{\beta^- n}$ [keV]	S_n [keV]	S_p [keV]	R [fm]	Mass Excess [keV]
^{36}Ar 18 18	-12814.207 *345*	-6640.92 *3*	-709.546 *46*	-27129.95 *51*	15255.47 *75*	8506.99 *5*	3.3905 *23*	-30231.538 *27*

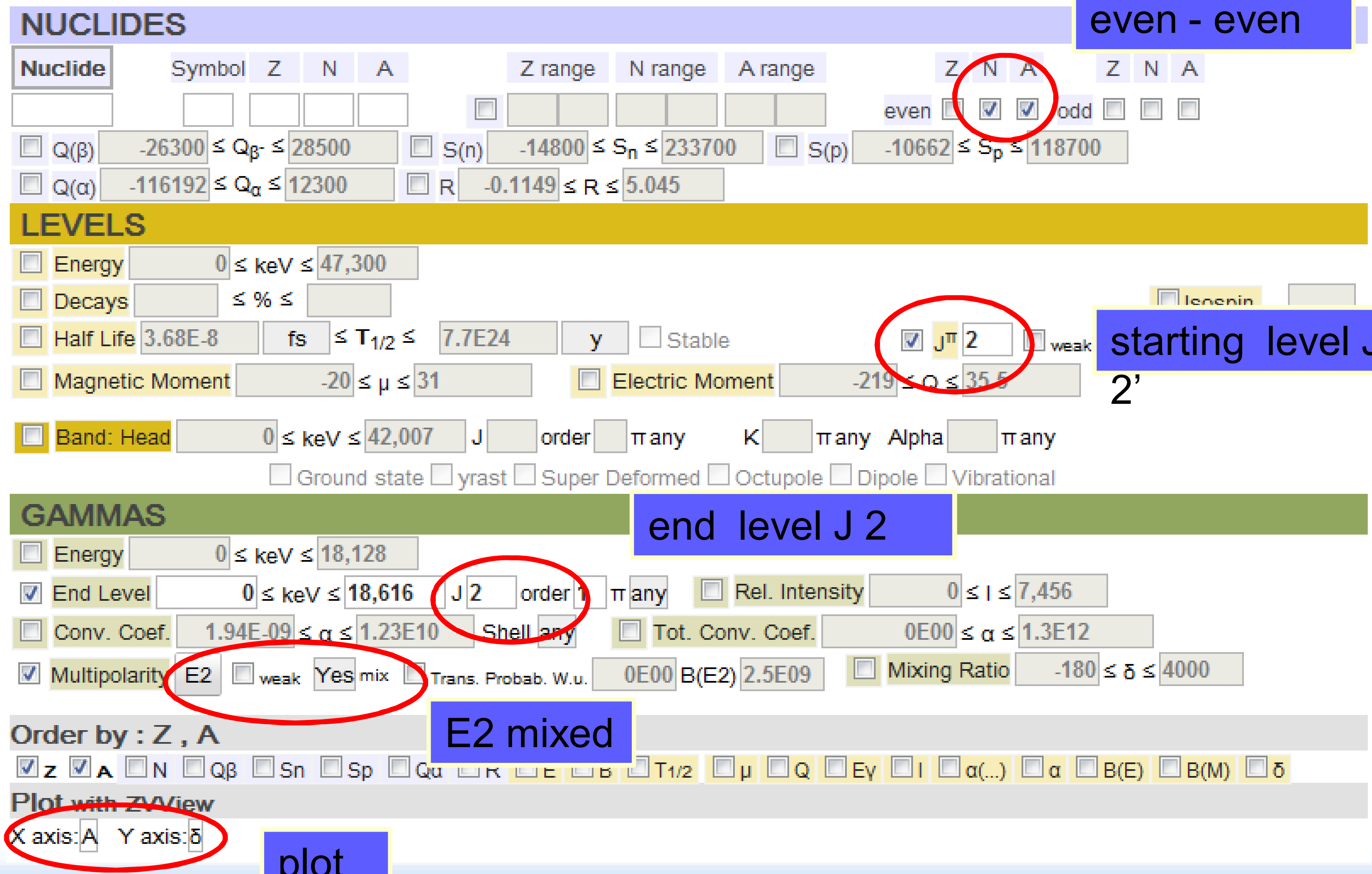
Visual map of filtered nuclides



Bands plotting



Plot example:
mass number versus mixing of E2 mixed gamma transactions from a level J 2` to a level J 2 in even-even nuclides – use log on Y axis



even - even

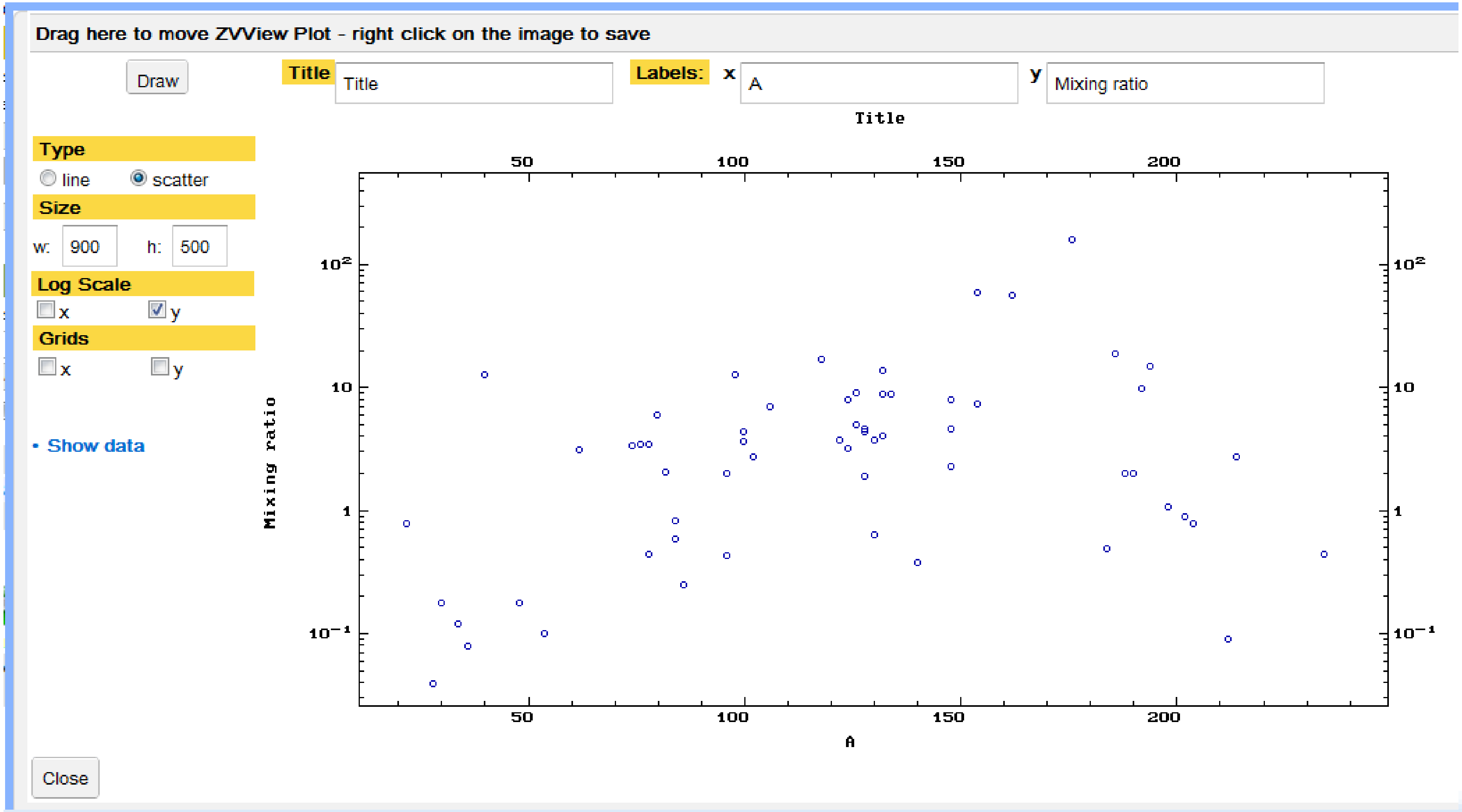
starting level J 2'

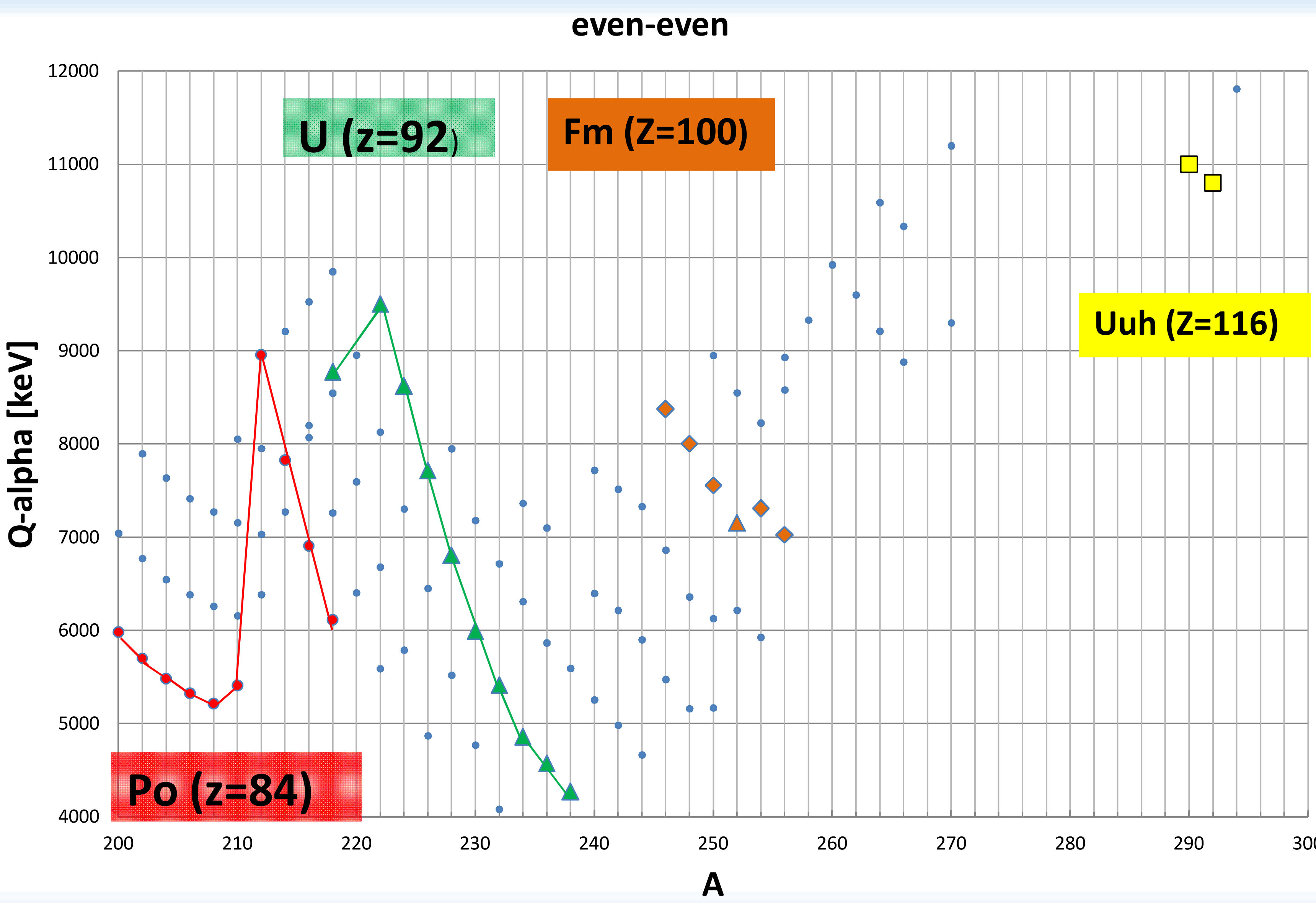
end level J 2

E2 mixed

plot

Plot mass number versus mixing of E2 mixed gamma transactions from a level J 2` to a level J 2 in even-even nuclides – use log on Y axis




even-even
Q-alpha [keV]
A
U (z=92)
Fm (Z=100)
Uuh (Z=116)
Po (z=84)
12000
11000
10000
9000
8000
7000
6000
5000
4000
200
210
220
230
240
250
260
270
280
290
300

Outline

- IAEA Nuclear Data Section (NDS)
- Coordination of the NSDD network
- NSDD-related activities
  - ENSDF evaluations / NSR compilations
  - Financial support for ENSDF evaluators and horizontal evaluation/compilation activities
- CRPs
  - Beta-delayed neutron emission
- Workshops
- Dissemination, new tools
- Conclusions

Conclusions

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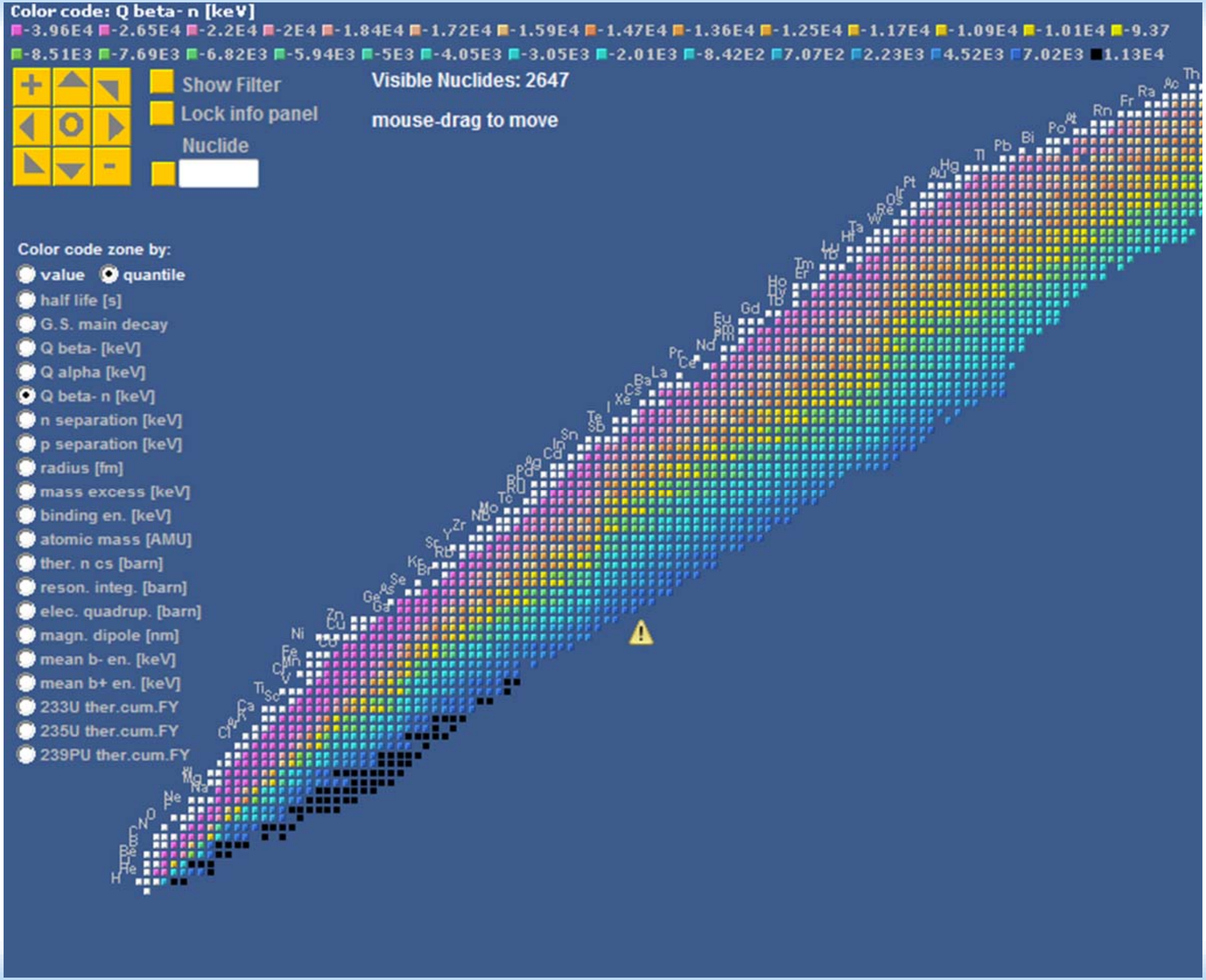
Conclusions

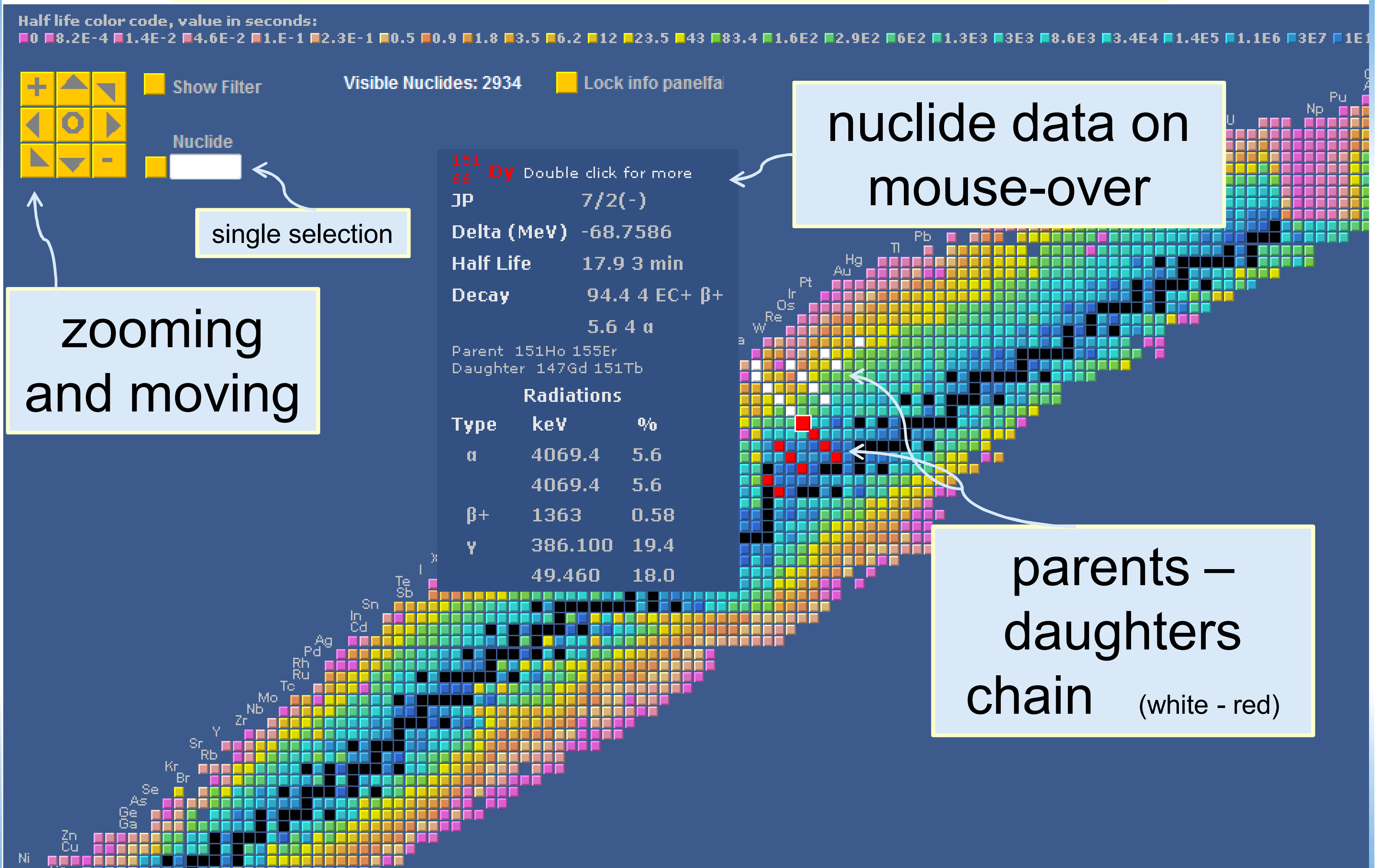
- There is a continued need of new ENSDF evaluators
- Would you be interested…?
- At the end of the Workshop talk to:

Prof. Jag. K. Tuli

Thank you


Color code: Q beta- n [keV]
-3.96E4 -2.65E4 -2.2E4 -2E4 -1.84E4 -1.72E4 -1.59E4 -1.47E4 -1.36E4 -1.25E4 -1.17E4 -1.09E4 -1.01E4 -9.37
-8.51E3 -7.69E3 -6.82E3 -5.94E3 -5E3 -4.05E3 -3.05E3 -2.01E3 -8.42E2 7.07E2 2.23E3 4.52E3 7.02E3 1.13E4
Show Filter
Lock info panel
Nuclide
Visible Nuclides: 2647
mouse-drag to move
Color code zone by:
value
quantile
half life [s]
G.S. main decay
Q beta- [keV]
Q alpha [keV]
Q beta- n [keV]
n separation [keV]
p separation [keV]
radius [fm]
mass excess [keV]
binding en. [keV]
atomic mass [AMU]
ther. n cs [barn]
reson. integ. [barn]
elec. quadrup. [barn]
magn. dipole [nm]
mean b- en. [keV]
mean b+ en. [keV]
233U ther.cum.FY
235U ther.cum.FY
239PU ther.cum.FY

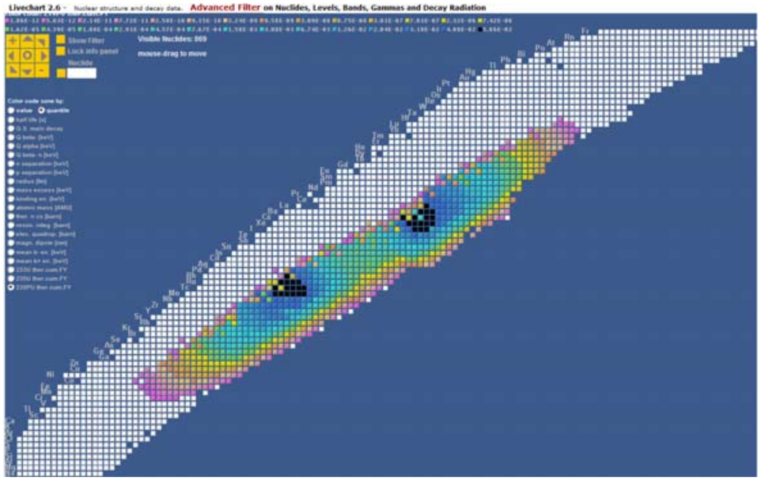
Livechart



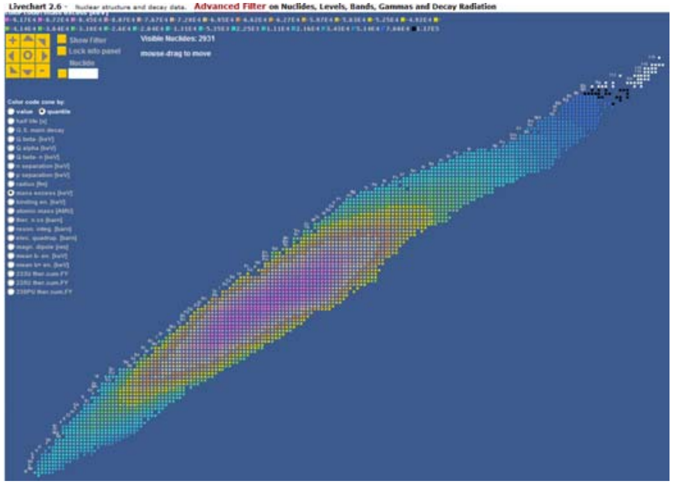
Data sources: ENSDF + Radlist, AMDC

Color code examples

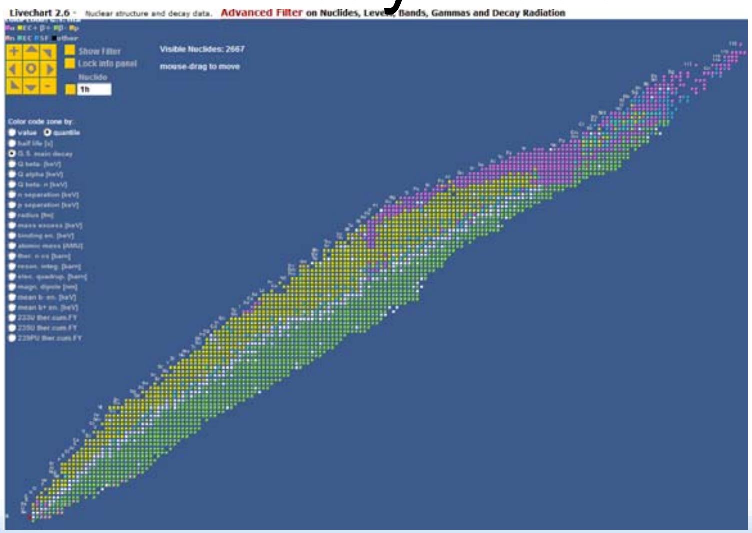
Fission Yields



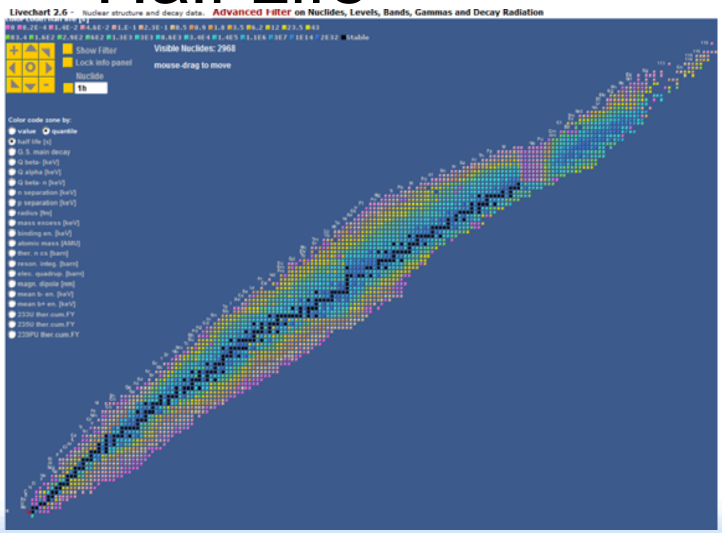
Mass excess



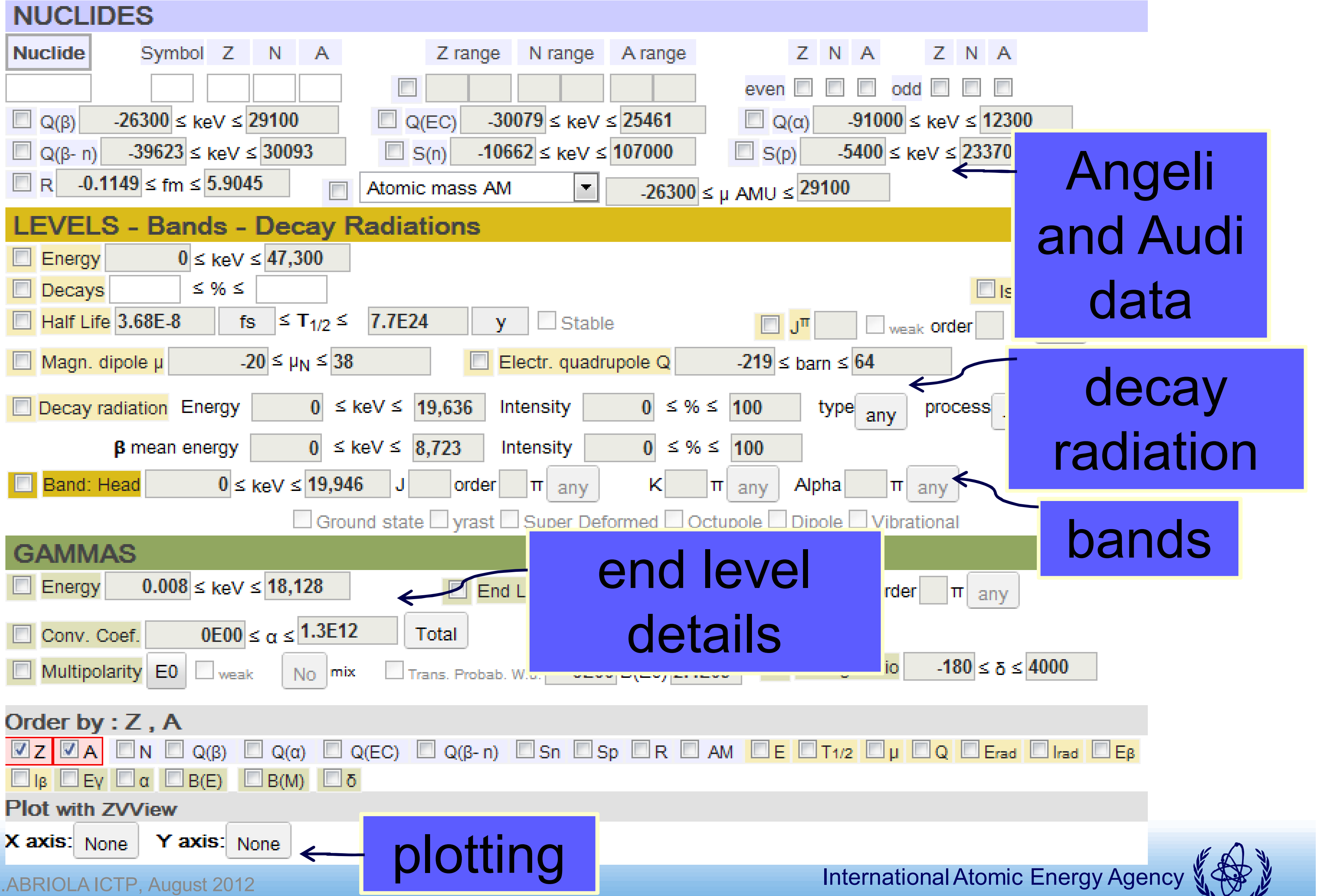
Decay Mode



Half Life



Query tool


NUCLIDES
Nuclide
Symbol Z N A
Z range N range A range
Z N A Z N A
even odd
Q(β) -26300 ≤ keV ≤ 29100
Q(EC) -30079 ≤ keV ≤ 25461
Q(α) -91000 ≤ keV ≤ 12300
Q(β- n) -39623 ≤ keV ≤ 30093
S(n) -10662 ≤ keV ≤ 107000
S(p) -5400 ≤ keV ≤ 23370
R -0.1149 ≤ fm ≤ 5.9045
Atomic mass AM -26300 ≤ μ AMU ≤ 29100
LEVELS - Bands - Decay Radiations
Energy 0 ≤ keV ≤ 47,300
Decays ≤ % ≤
Half Life 3.68E-8 fs ≤ T1/2 ≤ 7.7E24 y Stable
Jπ weak order
Magn. dipole μ -20 ≤ μN ≤ 38
Electr. quadrupole Q -219 ≤ barn ≤ 64
Decay radiation Energy 0 ≤ keV ≤ 19,636 Intensity 0 ≤ % ≤ 100 type any process
β mean energy 0 ≤ keV ≤ 8,723 Intensity 0 ≤ % ≤ 100
Band: Head 0 ≤ keV ≤ 19,946 J order π any K π any Alpha π any
Ground state yrast Super Deformed Octupole Dipole Vibrational
GAMMAS
Energy 0.008 ≤ keV ≤ 18,128
End L
rder π any
Conv. Coef. 0E00 ≤ α ≤ 1.3E12 Total
Multipolarity E0 weak No mix Trans. Probab. W.u.
io -180 ≤ δ ≤ 4000
Order by : Z , A
Z A N Q(β) Q(α) Q(EC) Q(β- n) Sn Sp R AM E T1/2 μ Q Erad Irad Eβ
Iβ Eγ α B(E) B(M) δ
Plot with ZVView
X axis: None Y axis: None
Angeli and Audi data
decay radiation
bands
end level details
plotting

Output example :
Filter all nuclides with superdeformed bands

☑ Band: Head | 0 ≤ keV ≤ 19,946 | J | order | π any | K | π any | Alpha | π any

☐ Ground state ☐ yrast ☑ Super Deformed ☐ Octupole ☐ Dipole ☐ Vibrational

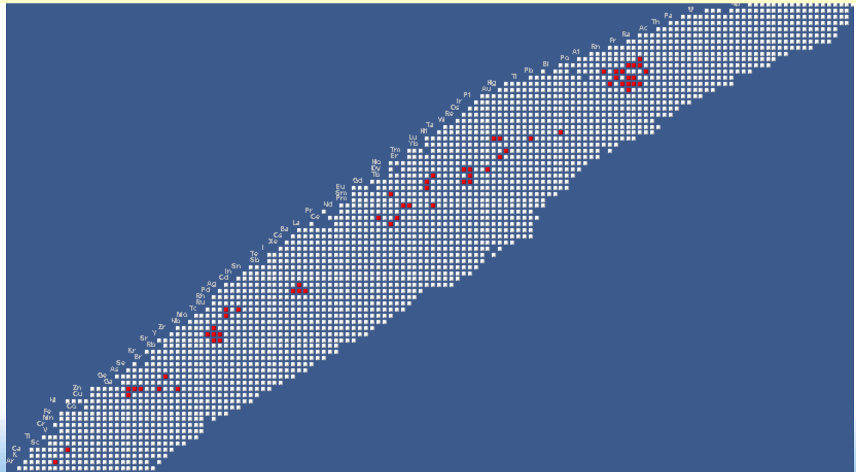
Tab-panel with details

Nuclide | Levels | Gammas | Bands | Decay Radiation | Magn. Mom. | El. Mom. | Ther. Neutrons Capture | Cum. Fission Yields

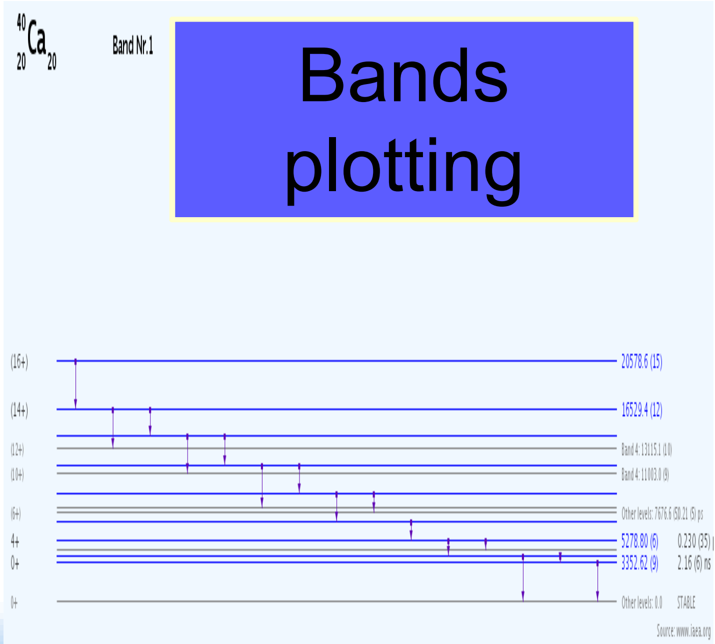
Click on nuclide symbol to show the level schema

Nuclide	Q_{β^-} [keV]	Q_α [keV]	Q_{EC} [keV]	$Q_{\beta^- n}$ [keV]	S_n [keV]	S_p [keV]	R [fm]	Mass Excess [keV]	Binding [keV]	Atomic Mass [μ u]
$^{36}_{18}Ar_{18}$	-12814.207 *345*	-6640.92 *3*	-709.546 *46*	-27129.95 *51*	15255.47 *75*	8506.99 *5*	3.3905 *23*	-30231.538 *27*	8519.909 *1*	35967545.107 *29*
$^{40}_{20}Ca_{20}$	-14323.049 *2828*	-7039.76 *3*	-1310.895 *60*	-28745.01 *2400*	15635.00 *60*	8328.17 *2*	3.4776 *19*	-34846.387 *21*	8551.304 *1*	39962590.863 *22*

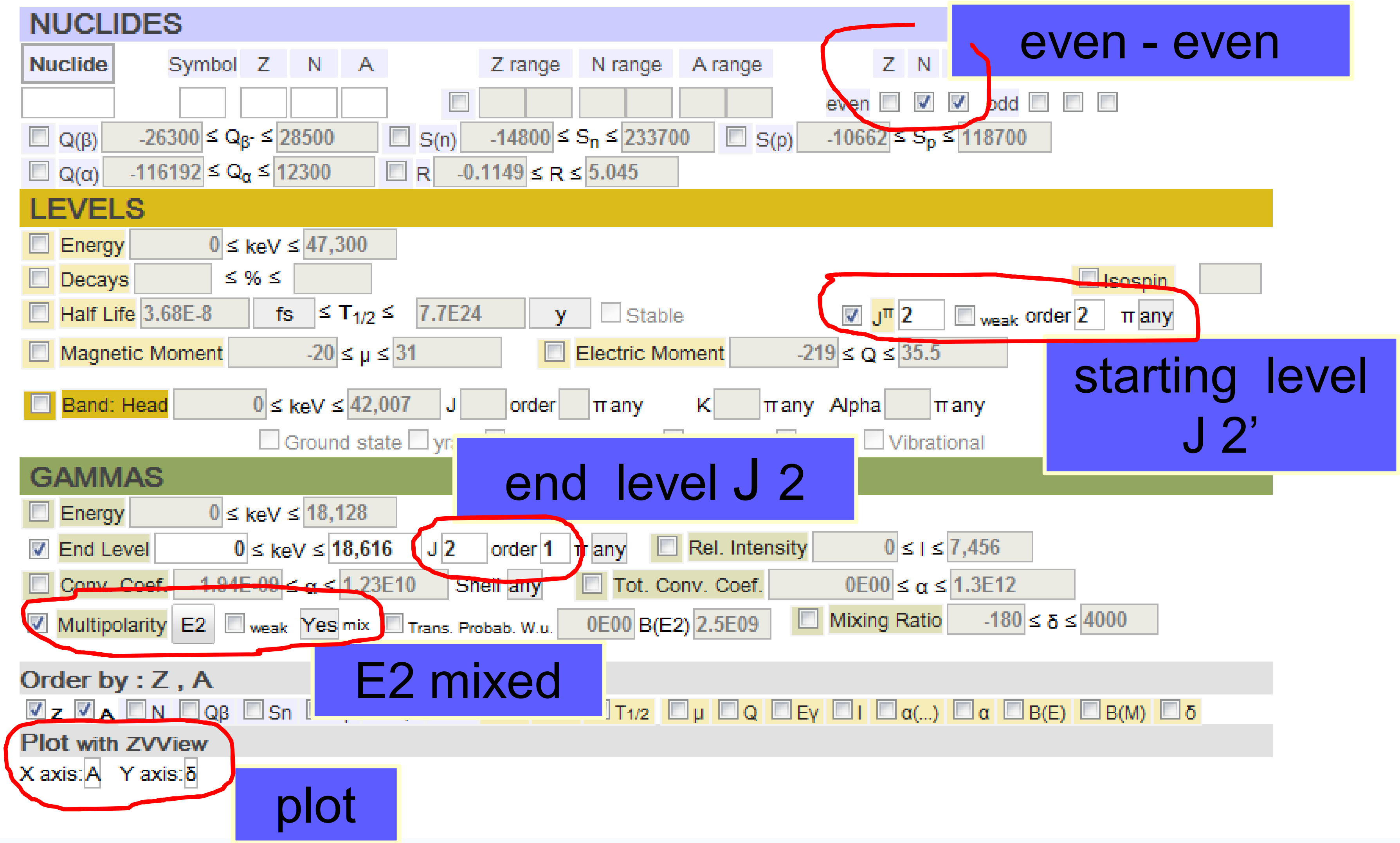
Visual map of filtered nuclides



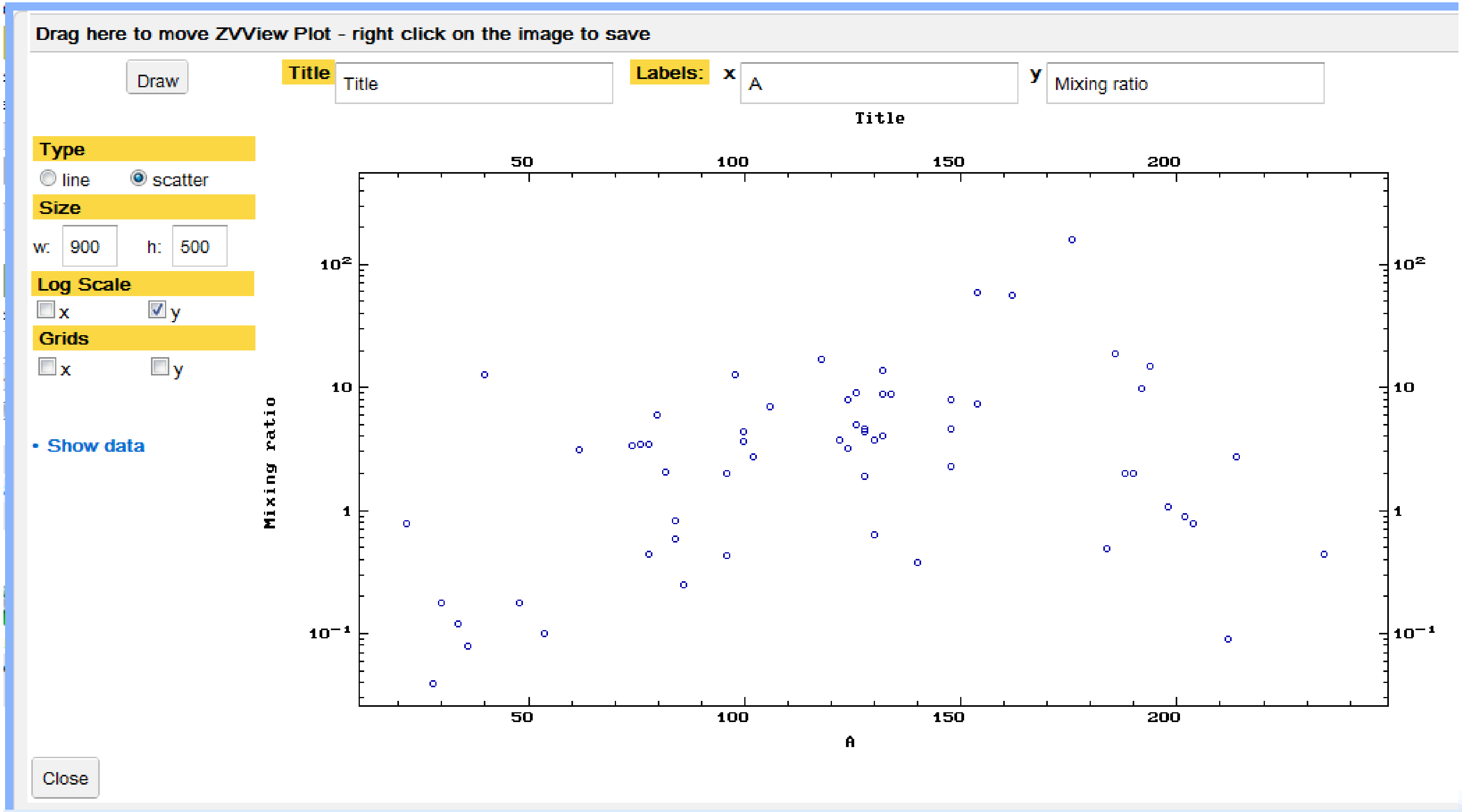
Bands plotting



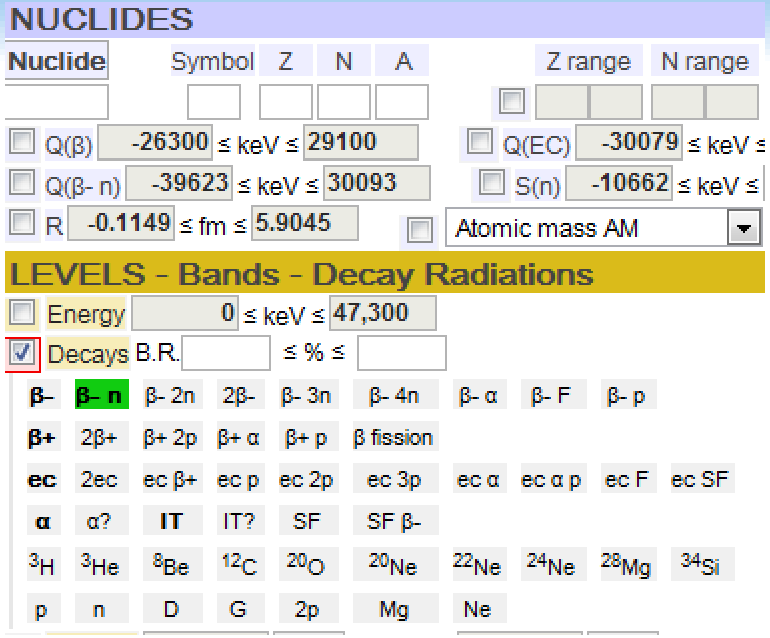
Plot example:
mass number versus mixing of E2 mixed gamma transactions from a level J 2` to a level J 2 in even-even nuclides – use log on Y axis

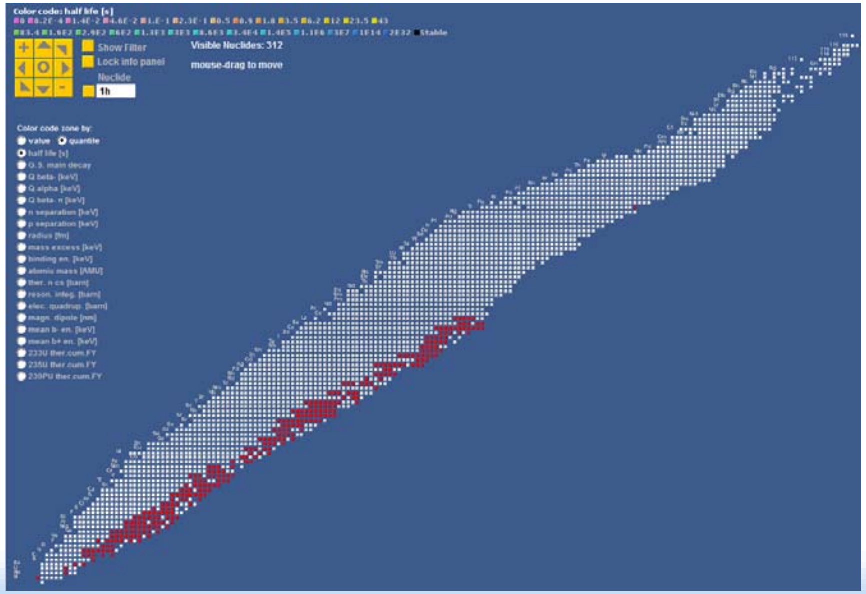


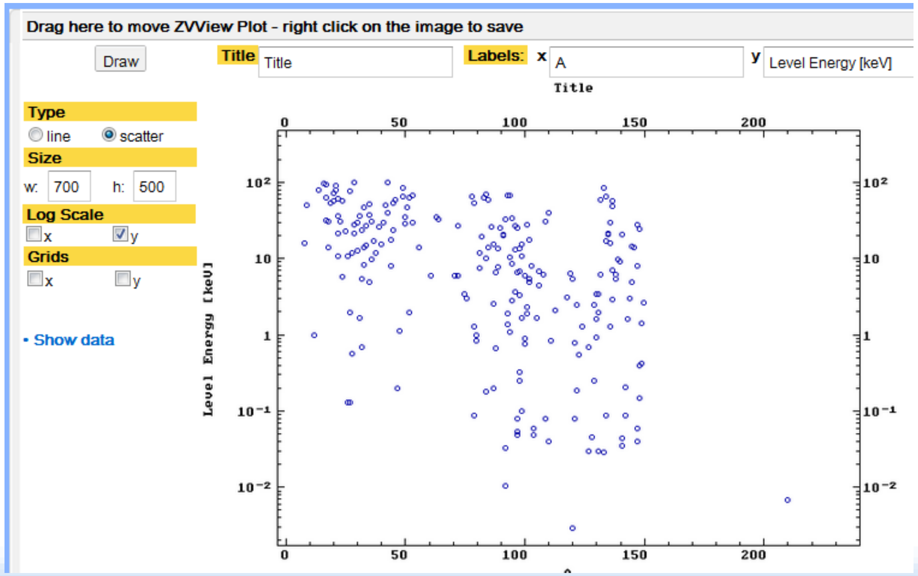
Plot mass number versus mixing of E2 mixed gamma transactions from a level J 2` to a level J 2 in even-even nuclides – use log on Y axis



Select β- n decay and plot A vs Branching Ration in log scale







NSDD activities in the IAEA