

The code operates under MS Windows environment and provides a highly user-friendly interface.  
It can be freely downloaded from the following internet addresses:

<http://www.nsl.msui.edu/lise>

**version 8.3.140**

**To estimate FRIB potential it is necessary to know half-lives and drip-lines locations**

<http://groups.nsl.msui.edu/frib/rates/>

Fragment	A	136	Decrease A	Increase A
	Z	50	Decrease Z	Increase Z
	N	86		
		Sn		
T1/2		2.50E-01	sec	

Beam	AZ	238U_fission
	Energy	203 MeV/u
Target	Thickness	0.34 g/cm2

Fragment	Yield	2.9E+3	pps
	Energy	169.67	MeV/u
	Brho(Q=Z)	5.328	Tm
	Q-ratio	81.54	%

FRIB rates at GS=	2.6E+03	pps
Stopped beam rate=	1.1E+03	pps
Reaccelerated beam rate =	4.2E+02	pps

136 Sn		KTUY [4]	
S1n	4.04		
S2n	6.16		
S4n	12.85		
S1p	16.19		
S2p	30.43		
beta-	7.61		
beta+	-15.10		
alpha	-7.34		
	MeV		

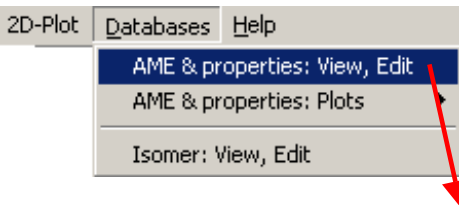
Mass model  
 HFB 17  
 KTUY  
 TUYU

**FRIB**

FRIB Estimated Rates Version 1.04  
by G.Bollen, B.M.Sherrill, O.B.Tarasov

A). The rates are estimated based on the EPAX 2.15<sup>[1]</sup> cross section parameterization for fragmentation and the LISE++ 3EER model<sup>[2,3]</sup> for in-flight fission.  
 B). Reaccelerated and stopped beam rates above 1E+9 are very uncertain. The use of solid catchers may yield higher rates in some cases.  
 C). Estimated rates may change as the various assumptions are tested and refined.

[1] -K. Summner and B. Blank, Phys. Rev. C 61 (2000) 034607.  
 [2] - O.B.Tarasov and D.Bazin, NIM B 266 (2008) 4657-466.  
 [3] - O.B. Tarasov, "LISE++ development: Abrasion-Fission", Tech.Rep. MSUCL1300, NSCL, Michigan State University 2005.  
 [4] - H. Koura, T. Tachibana, M. Uno, and M. Yamada, Prog.Theo. Phys. 113, 305 (2005).



**Databases**

DataBase: 0 - AME2003 (A&W)

A: 127, Element: Pm, Z: 61, N: 66  
Unknown

Database Index: 61066  
T 1/2: 1 sec

	Value	Error	
Mass Excess	-45.0600		MeV
Binding Energy	1022.350	0.6000	MeV
Beta- decay energy	-12.3742	0.9491	MeV
Beta+ decay energy	10.3600	0.7211	MeV
S 2n	*	*	MeV
S 2p	1.7230	0.7180	MeV
Q alpha	2.8570	0.8430	MeV
S 1n	13.5580	0.7800	MeV
S 1p	-0.5450	0.7180	MeV

Put "\*" into a cell if value is unknown

Half-life (sec)

Experimental (database)	beta decay	alpha decay	proton emission
1.00e+00	3.32e-01	1.75e+11	1.9e+04

Buttons: Save, Quit, calculations, Add Record, Delete Record, Show Structure, 1706, Help

Experimental values: AME2003

Calculations:

Beta- & Beta+ database in LISE++ package  
*"bin\beta\_halfives.ltime"*

Alpha database in LISE++ package  
*"bin\alpha\_halfives.ltime"*

Proton emission - calculated in LISE++ based on the tools provided by B.A.Brown

**About Half-life Calculations**

beta+ : P.Moller, J.R.Nix and K.-L.Kratz, Atomic Data and Nuclear Data Tables Volume 66, Issue 2, July 1997, Pages 131-343  
<http://dx.doi.org/10.1006/adnd.1997.0746>

beta- : P.Moller, B.Pfeiffer and K.-L.Kratz, PRC 67, 055802 (2003)  
<http://t16web.lanl.gov/Moller/abstracts.html>

alpha : P.Moller, J.R.Nix, W.D.Myers, and W.J.Swiatecki, Atomic Data Nucl. Data Tables 59 (1995), 185-381  
<http://t2.lanl.gov/data/astro/molnix96/alpha.dat>

proton: The program tunnel.f was written by T. Kajino and B. A. Brown to calculate the single-particle widths for charged particle decay. see the "Proton Radioactivity" dialog (menu "Utilities")

OK

Utilities 1D-Plot 2D-Plot Databases Help

Spectrometric Calculator by J.Kantele  
The code "CHARGE"  
The code "GLOBAL"  
Units Converter  
BI (search of 2-dimensional peaks)  
Converter of FORTRAN-files to C-files

PACE4 (fusion-evaporation code)  
PACE4's calculations plot  
MOTER (ray tracing code)  
MOTER's calculations plot

Reaction's Characteristics  
**Proton radioactivity**  
Radiation length  
Electromagnetic excitation plots  
Create an initial file for nucleon pick-up (beta)

Plot of Fragment Range in material versus Energy  
Plot of Fragment Stopping Power (dE/dx) in material versus Energy  
Plot of Angular Straggling in material versus Energy  
Plot of Equilibrium Thickness versus Energy

Range optimizer  
Gas pressure optimization for gas-filled dipole  
Brho Analyzer  
Calculation of Angle on the LISE3 target  
MSP-144 utility  
Twinsol (solenoid) utility  
ISOL catcher utility  
User cross-sections analysis using Abrasion-Ablation model  
Rate & transmission calculation: batch mode  
Stripper foil lifetime

## About "Tunnel.f"

The program tunnel.f was written by T. Kajino and B. A. Brown to calculate the single-particle widths for charged particle decay.

It uses the Coulomb wavefunction program from [1] to calculate the barrier penetration probability and multiplies this with the Wigner single-particle estimate to obtain the total width and lifetime [2].

1) COULFG - Coulomb and Bessel Functions and their Derivatives, for Real Arguments, by Steed Method, Computer Physics Communications 27,147 (1982).

2) Diproton Decay of Nuclei on the Proton Drip Line, B. A. Brown, Phys. Rev. C43, R1513 (1991); Phys. Rev. C44, 924 (1991).



**Proton Radioactivity**

A Element Z  
25 S 16

Table of Nuclides  
Z N

Properties from Database / Mass formula  
1p unbound

Masses from : AME2003 (A<sub>W</sub>) + LDM#2

Code  
0 - tunnel.f  1 - proton.f

Width and lifetime

L	1p-emission		2p-emission	
	Width [MeV]	T (sec)	Width [MeV]	T (sec)
0	7.7e-01	5.9e-22	2.3e-02	2.0e-20
1	3.1e-01	1.5e-21	1.2e-02	3.8e-20
2	4.8e-02	9.5e-21	3.4e-03	1.4e-19
3	3.5e-03	1.3e-19	5.5e-04	8.3e-19

One-particle Proton levels (spherical case)  
Configuration = 2s 1/2 [2/2]  
L = 0

Shells in a harmonic oscillator  
 Make it default

Final result for p-emission: 5.9e-22 T1/2 sec

Recommended (default) values

R = 1.17 fm

Assume the next momentum for decays

1p - emission Calculation (spherical case)

2p - emission L = 0

Result being used in the code

Use both 1p and 2p cases

Final result for p-emission: 5.9e-22 T1/2 sec

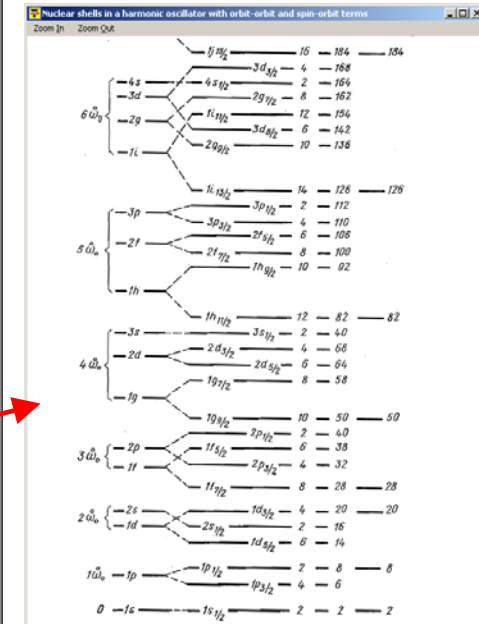


Рис. 2.2. Схема одночастичных уровней гармонического осциллятора со спин-орбитальным взаимодействием: слева для сферы уровней потенциала без спин-орбитальной части; в середине — спин-орбитальное расщепление; справа указана величина числа нейтронов (протонов) в оболочках; внизу — полное число частиц для потенциальной ямы и, наконец, числа заполнения оболочек.

**Proton Radioactivity**

A: 35, Element: Sc, Z: 21

Doesn't exist!

Table of Nuclides

Properties from Database / Mass formula: 1p unbound

Masses from: AME2003 ( $A_W$ ) + LDM#2

Code: 0 - tunnel\_f, 1 - proton\_f (selected)

Value [MeV]:

S_1p	-2.206
S_2p	-1.307
S_1p + CB	2.381
S_2p + CB	6.999

R = 1.17 fm

Assume the next momentum for decays

1p - emission: Calculation (spherical case)

2p - emission: L = 0

L	1p-emission		2p-emission	
	Width (MeV)	T (sec)	Width (MeV)	T (sec)
0	1.7e-01	2.7e-21	7.5e-11	6.1e-12
1	6.6e-02	6.9e-21	3.8e-11	1.2e-11
2	1.1e-02	4.3e-20	9.8e-12	4.7e-11
3	8.6e-04	5.3e-19	1.4e-12	3.3e-10

One-particle Proton levels (spherical case)

Configuration = 1 f 7/2 [1/8]

L = 3

Shells in a harmonic oscillator

Result being used in the code

Use: both 1p and 2p cases

Final result for p-emission: 5.3e-19 T1/2 sec

Make it default

Ok, Quit

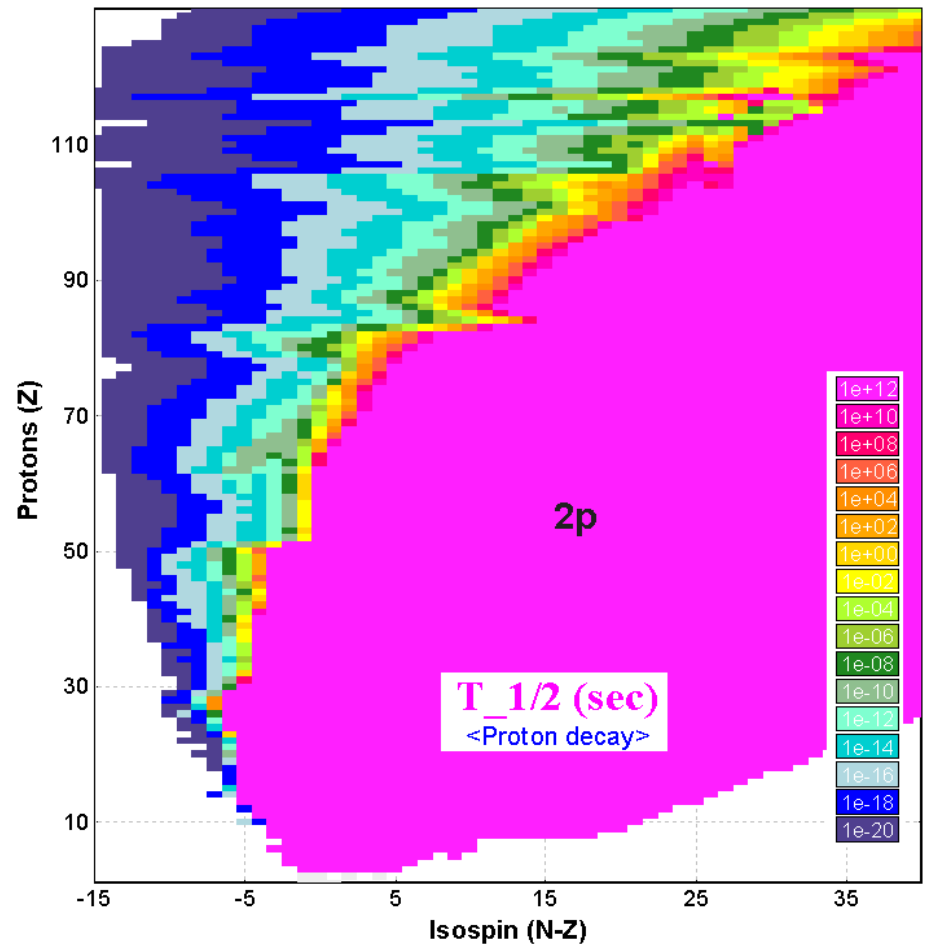
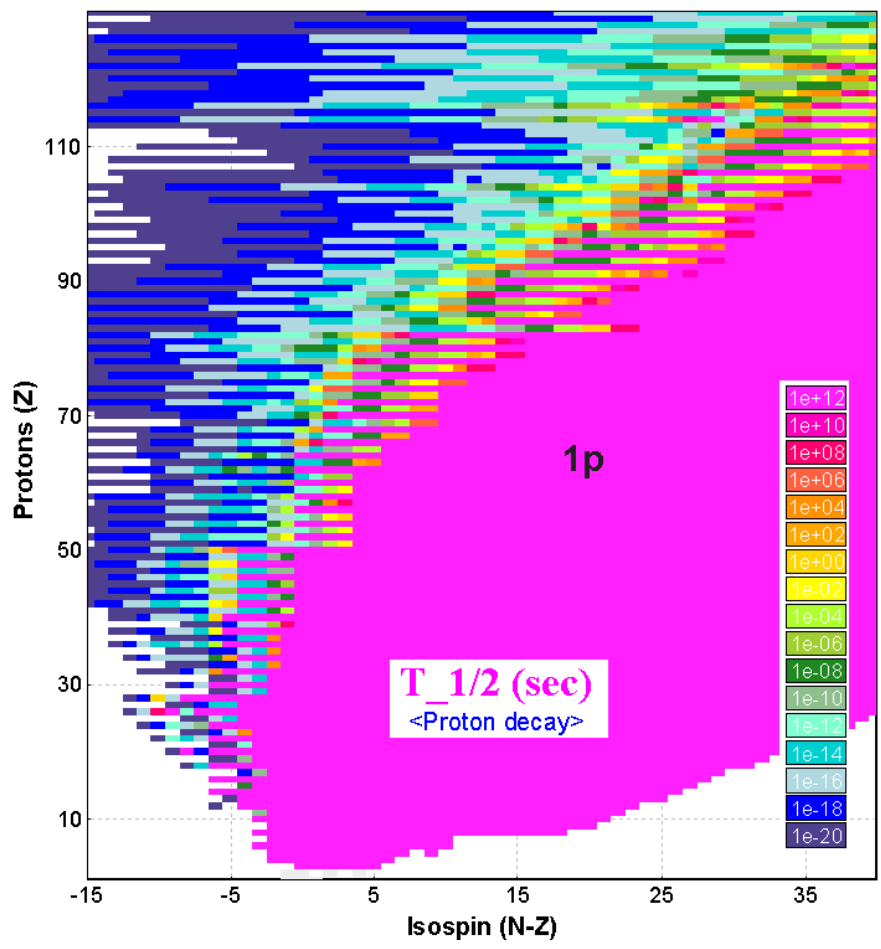
minimum

# Proton decay : 1p & 2p cases

Masses from :  
User's ME file [ktuy] + LDM#2

Use

Use



Both codes have been transported to C++ and implemented in LISE++

```
(tarasov@beryllium)~/buffer>./alex_v2
Z1, Z2, A1, A2 --- ?
20 1 36 1
LMAX --- ?
3
R(fm),E(MeV)
1.17 2.041
ETA, R, KR, RM, W = 2.183 5.033 1.558 0.973 2.518
PENETRABILITY (0,1..)= 3.357E-02 1.270E-02 2.007E-03 1.557E-04
TOTAL WIDTH (0,1..)= 1.690E-01 6.395E-02 1.011E-02 7.840E-04
R(fm),E(MeV)
```

v.8.3.138

```
(tarasov@beryllium)~/buffer>./p_orig
-----
Af,Zf (Ai+p = Af), Q value
37.,21.,2.041

ip Af Zf Rz L - Width - - T1/2 -
(MeV) (sec)
1 37.0 21.0 1.200 0 0.1209E+00 0.3782E-20 0.4583E-02 0.9980E-19
2 37.0 21.0 1.200 0 0.6052E-06 0.7557E-15 0.2476E-12 0.1847E-08
1 37.0 21.0 1.200 1 0.4661E-01 0.9813E-20 0.6808E-03 0.6718E-18
2 37.0 21.0 1.200 1 0.3199E-06 0.1430E-14 0.6917E-13 0.6612E-08
1 37.0 21.0 1.200 2 0.7588E-02 0.6028E-19 0.1804E-04 0.2535E-16
2 37.0 21.0 1.200 2 0.9239E-07 0.4951E-14 0.5769E-14 0.7928E-07
1 37.0 21.0 1.200 3 0.6094E-03 0.7506E-18 0.1164E-06 0.3931E-14
2 37.0 21.0 1.200 3 0.1541E-07 0.2968E-13 0.1605E-15 0.2850E-05
1 37.0 21.0 1.200 4 0.2792E-04 0.1638E-16 0.2443E-09 0.1872E-11
2 37.0 21.0 1.200 4 0.1582E-08 0.2891E-12 0.1692E-17 0.2703E-03
1 37.0 21.0 1.200 5 0.8129E-06 0.5626E-15 0.2071E-12 0.2209E-08
2 37.0 21.0 1.200 5 0.1065E-09 0.4296E-11 0.7662E-20 0.5970E-01
```

Utilities | 1D-Plot | 2D-Plot | Databases | Help

Spectrometric Calculator by J.Kantele  
The code "CHARGE"  
The code "GLOBAL"  
Units Converter  
BI (search of 2-dimensional peaks)  
Converter of FORTRAN-files to C-files

PACE4 (fusion-evaporation code)  
PACE4's calculations: plot  
MOTER (ray tracing code)  
MOTER's calculations plot

Proton radioactivity  
**Alpha decay**

Reaction's Characteristics  
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Twinsol (solenoid) utility  
ISOL catcher utility  
User cross-sections analysis using Abrasion-Ablation model  
Rate & transmission calculation: batch mode

### Alpha decay

A: 210    Element: At    Z: 85

Table of Nuclides

Decays: Alpha, Beta+

Masses from: User's ME file [hfb17] + LDM#2

Value [MeV]  
Q\_alpha: 4.965  
Q\_alpha - CB: -17.363

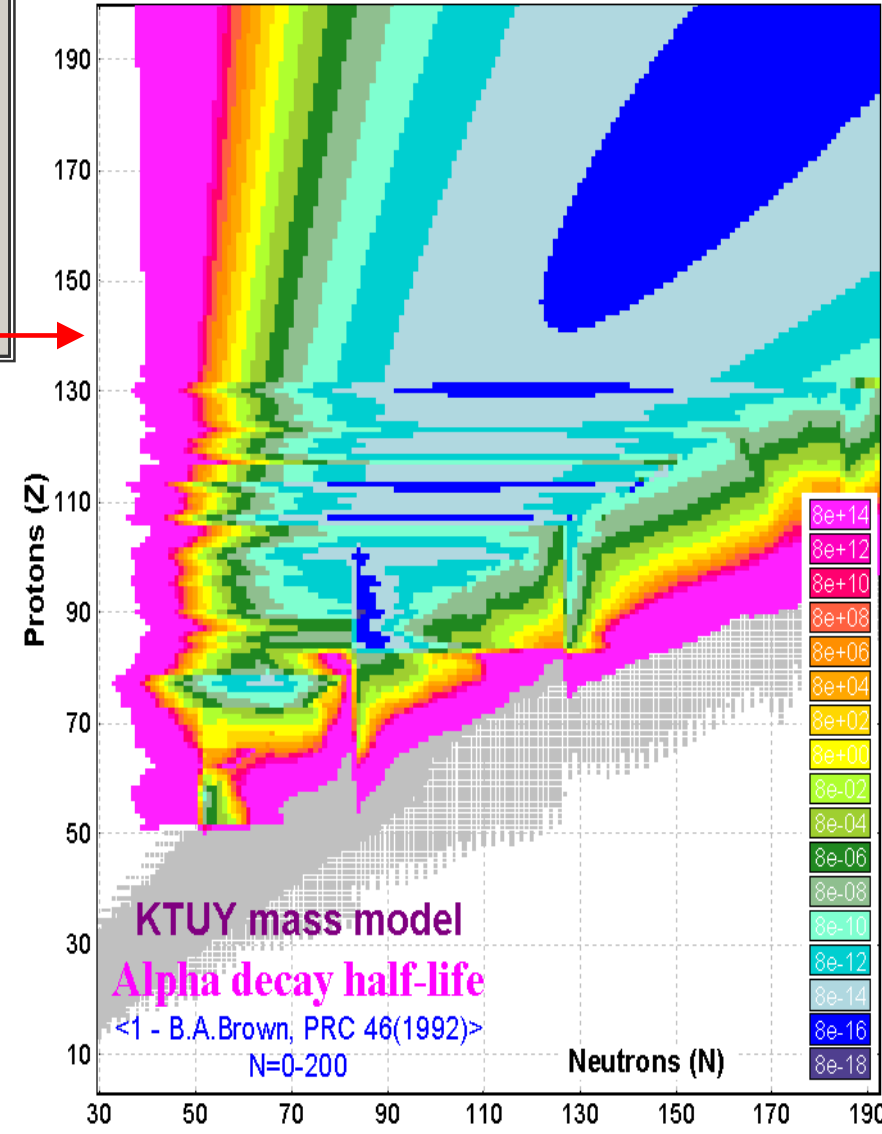
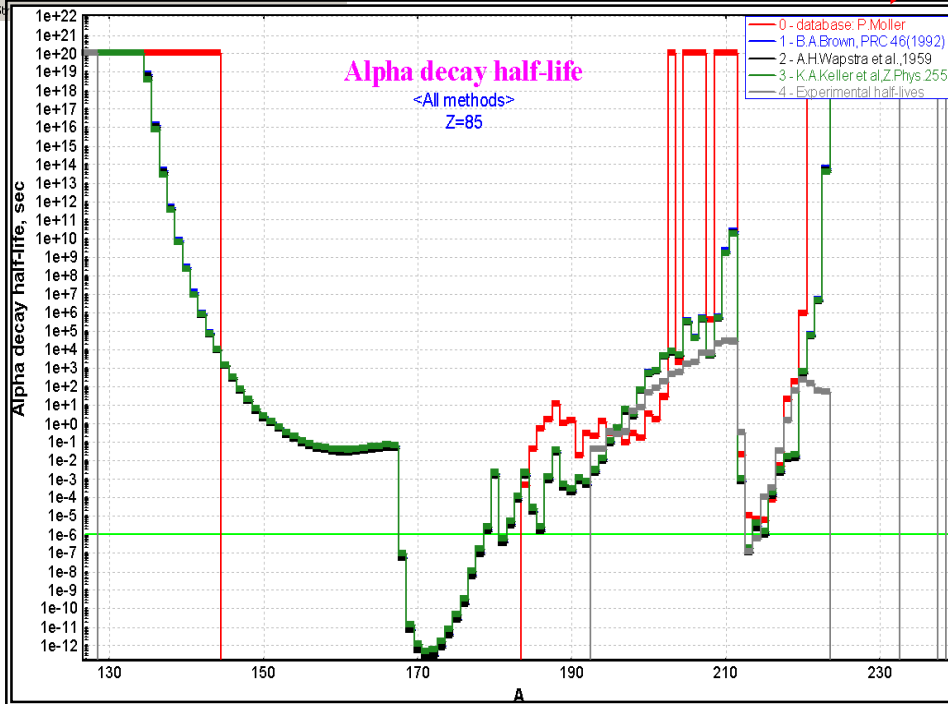
Alpha decay half-life, sec  
 1.0e+20    0 - database: P.Moller et al., ADNDT 59 (1995) 185-381  
 2.0e+09    1 - B.A.Brown, PRC 46 (1992) 811  
 1.6e+09    2 - A.H.Wapstra et al., Nuclear Spectroscopy Tables, North-Holland, 1959  
 1.5e+09    3 - K.A.Keller and H.Z.Munzel, Z.Phys.255 (1972) 419; R.Taagepera et al.

Equations. Current set mass model will be used for Q $\alpha$

Result being used in the code  
Model = 1

Final result in the code for alpha decay (T $_{1/2}$ ,sec)  
2.0e+09

Make it default



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Utilities 1D-Plot 2D-Plot Databases Help

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Proton radioactivity  
 Alpha decay  
**Cluster radioactivity**  
 Reaction's Characteristics  
 Radiation length  
 Electromagnetic excitation plots  
 Create an initial file for nucleon pick-up (beta)

**Cluster Radioactivity**

Parent: A 226, Element th, Z 90  
 Masses from: AME2003 (AW) + LDM#2

Alpha decay

Cluster (Lighter product): 180 Choose  
 Residue (Heavier product): 208Pb

Code:  0 - tunnel\_f  1 - proton\_f

Lifetime: cluster emission  
 L Log10[ T1/2(sec) ] 16.99

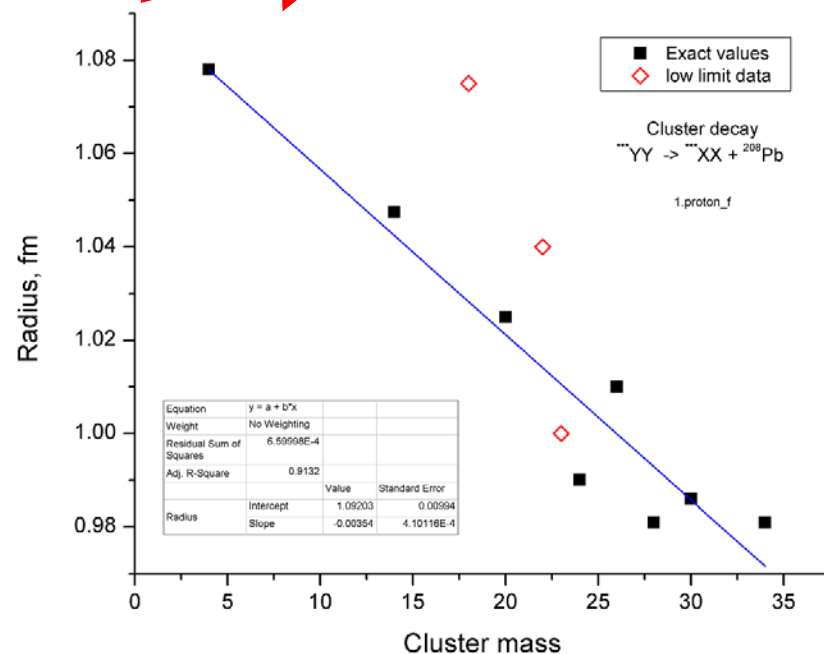
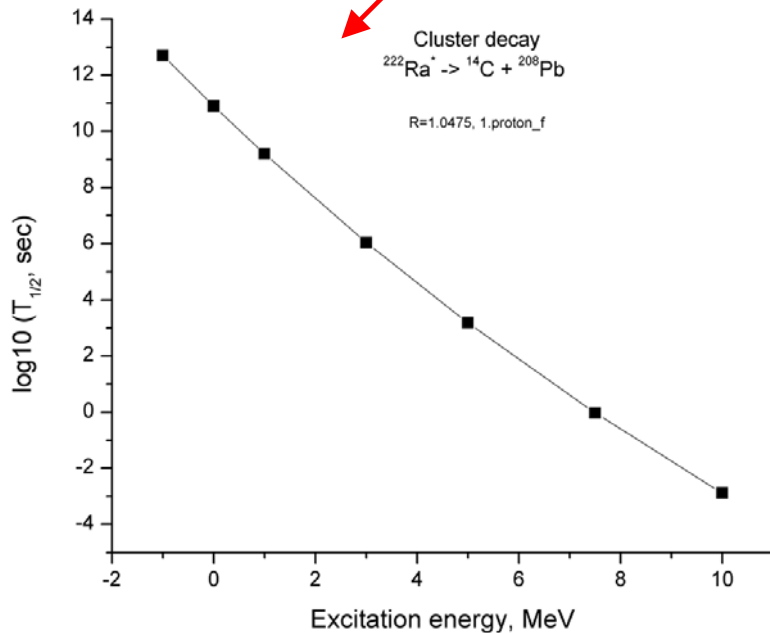
Value [MeV]  
 Excitation energy 0  
 Q\_cluster 45.73  
 Q\_cluster - CB -32.09

R = 1.04 fm

PHYSICAL REVIEW C 79, 064616 (2009)

Parent	Cluster	R	Expt. Half-lives log <sub>10</sub> T <sub>1/2</sub>
<sup>222</sup> Ra	<sup>14</sup> C	<b>1.0475</b>	11.01
<sup>226</sup> Th	<sup>18</sup> O	<b>1.075</b>	> 15.3
<sup>228</sup> Th	<sup>20</sup> O	<b>1.025</b>	20.87
<sup>231</sup> Pa	<sup>23</sup> F	<b>1.00</b>	> 24.61
<sup>230</sup> U	<sup>22</sup> Ne	<b>1.04</b>	> 18.2
<sup>232</sup> U	<sup>24</sup> Ne	<b>0.99</b>	21.05
<sup>234</sup> U	<sup>26</sup> Ne	<b>1.01</b>	25.06
<sup>236</sup> Pu	<sup>28</sup> Mg	<b>0.981</b>	21.67
<sup>238</sup> Pu	<sup>30</sup> Mg	<b>0.985</b>	25.70
<sup>242</sup> Cm	<sup>34</sup> Si	<b>0.981</b>	23.24

B.A.Brown's demand





2D-Plot Databases Help

- AME & properties: View, Edit
- AME & properties: Plots**
  - S 1n
  - S 2n
  - S 1p
  - S 2p
  - Q alpha
  - Beta- decay
  - Beta+ decay
  - T 1/2**
  - Mass Excess
  - Binding energy
  - Binding energy per A
- Isomer: View, Edit

**Choose a Plot Type**

Select a data set to plot

Exper, Beta, Alpha, Proton  Include "unbound" isotopes  
 compilation set: min(Beta, Alpha, Proton)

0 - Experimental values

0 - Experimental values

1 - Beta decay: P. Moller et al., ADNDT66(1997); PRC67,055802(2003)

2 - Alpha decay: P. Moller et al., ADNDT59(1995)

3 - Proton decay: see Proton Radioactivity dialog

All methods

Dimension of the plot

ONE-dimensional  
 TWO-dimensional

Plot type

Isotopes, Z=const  
 Isobars, A=const  
 Isotones, N=const  
 Isospin, N-Z=const  
 Isospin, N-ZZ=const

Z (protons)  
 A (nucleons)  
 N (neutrons)  
 N-Z (isospin)  
 N-ZZ

Zmin = 16

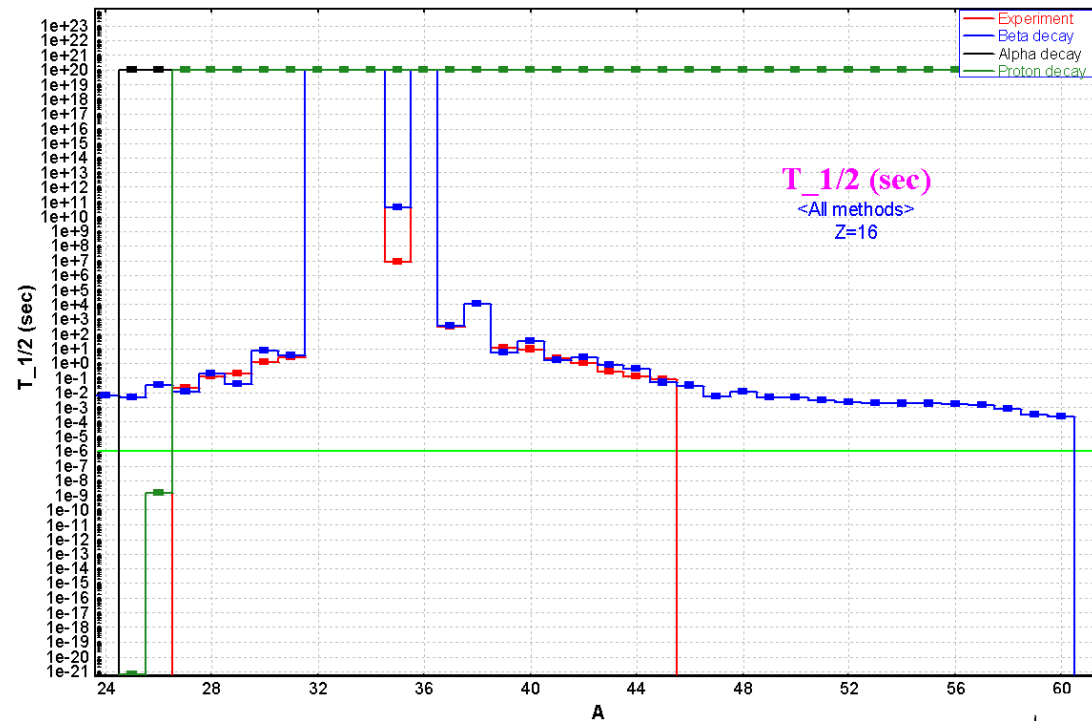
Zmax = 16

All  
 Odd  
 Even

NZ chart

OK

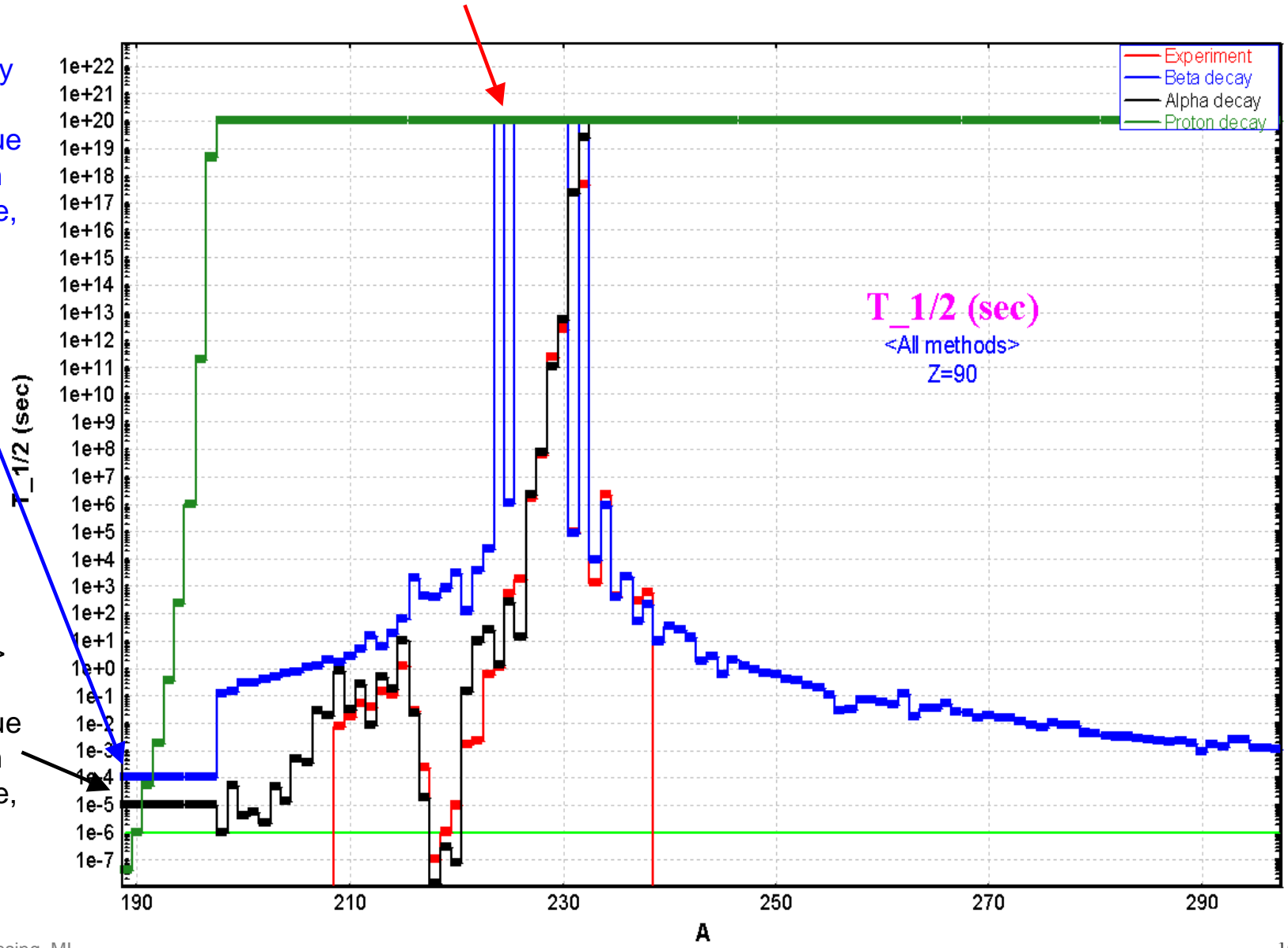
Cancel



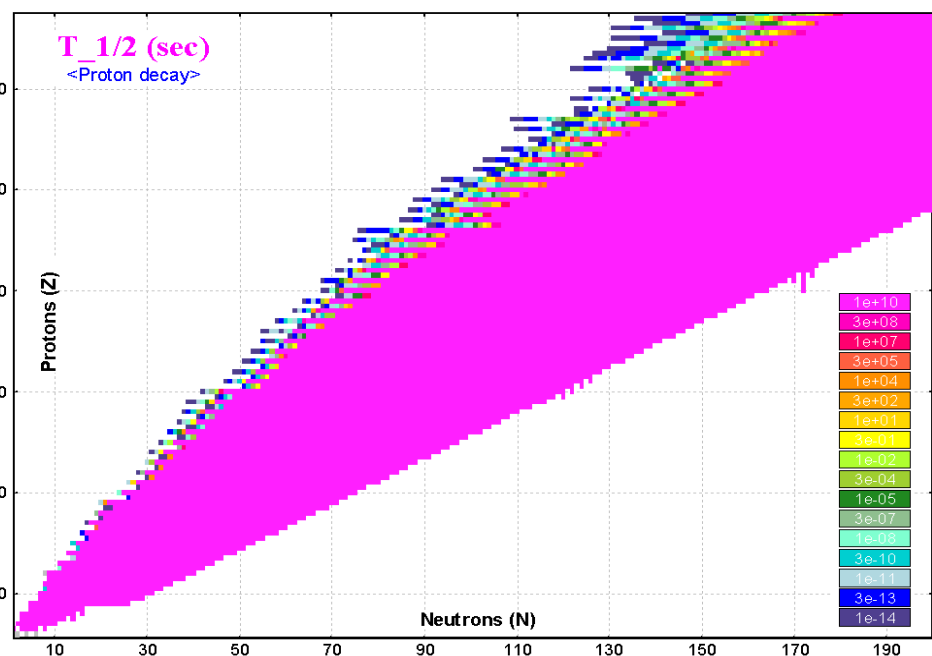
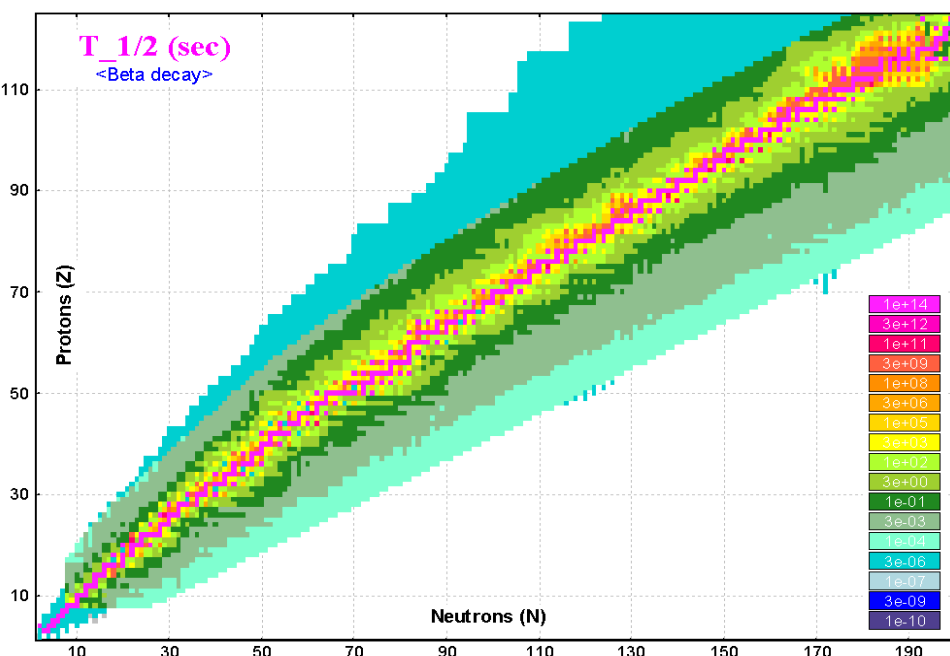
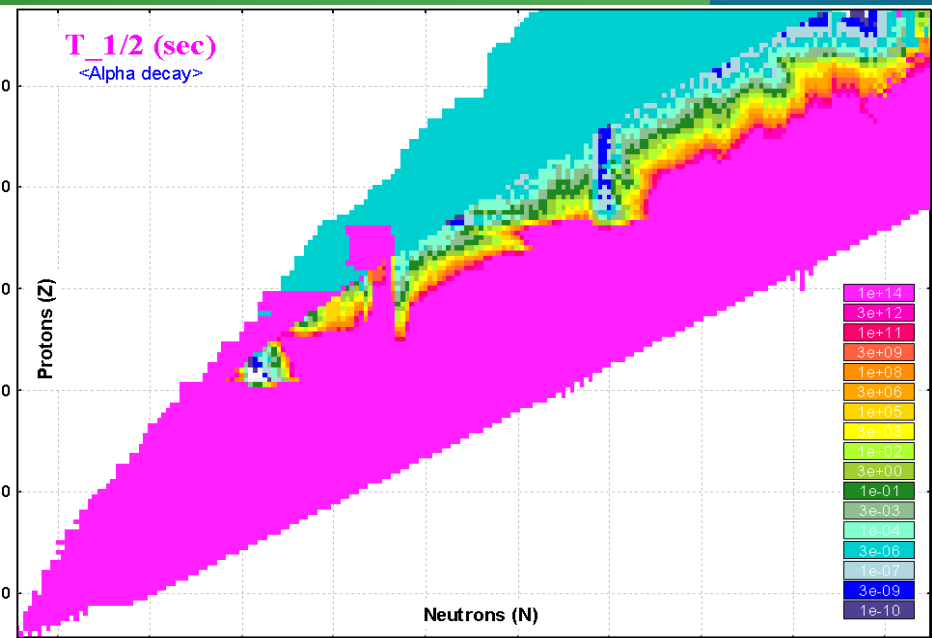
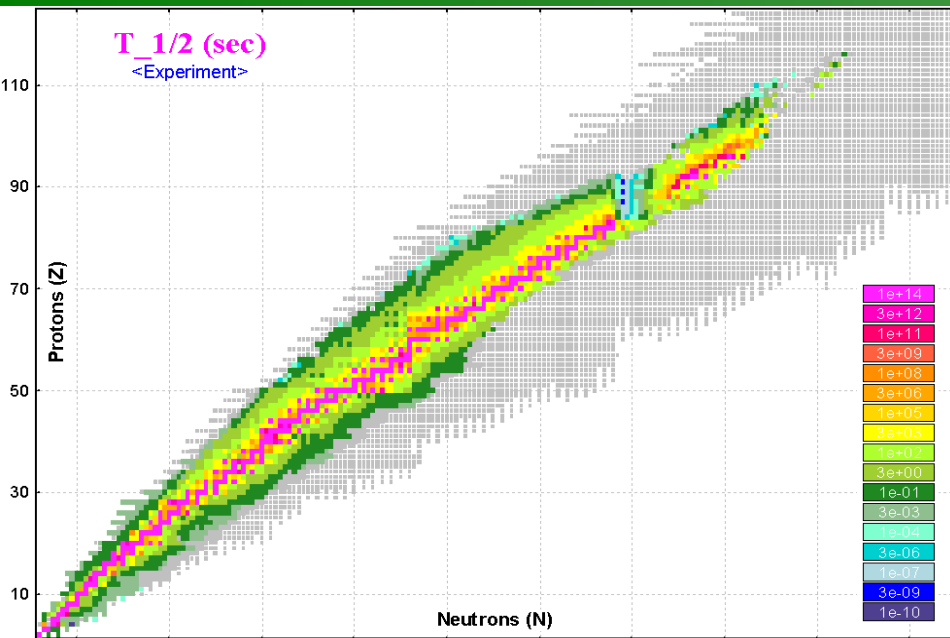
If  $T_{1/2} > 1e20$  sec , or isotope is stable then the code plots  $1e20$

If beta-decay energy  $> 0$ , but  $T_{1/2}$  value is absent in the database, then value  $1e-4$  sec is used

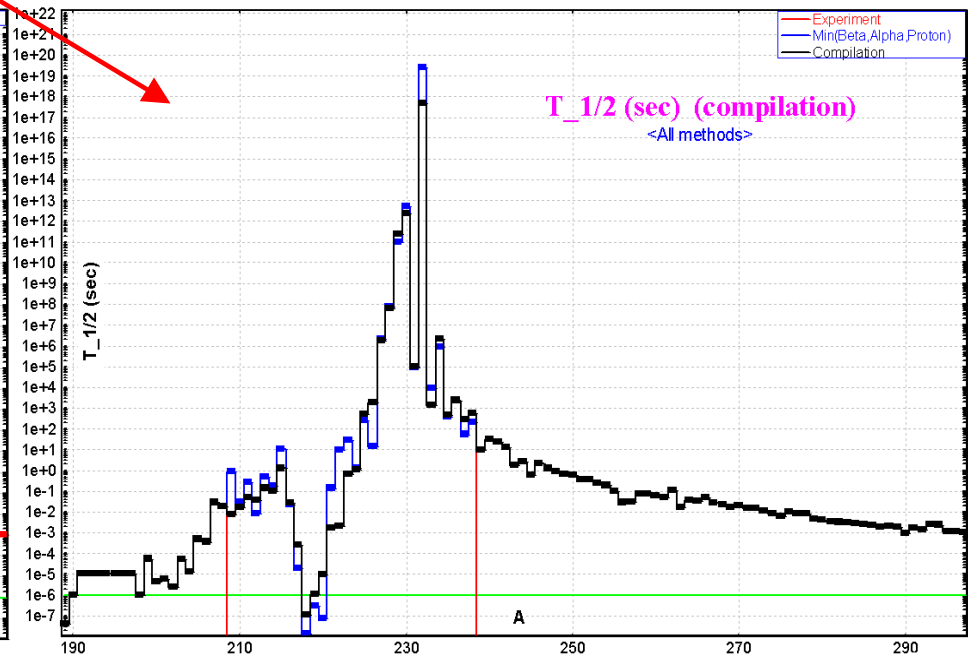
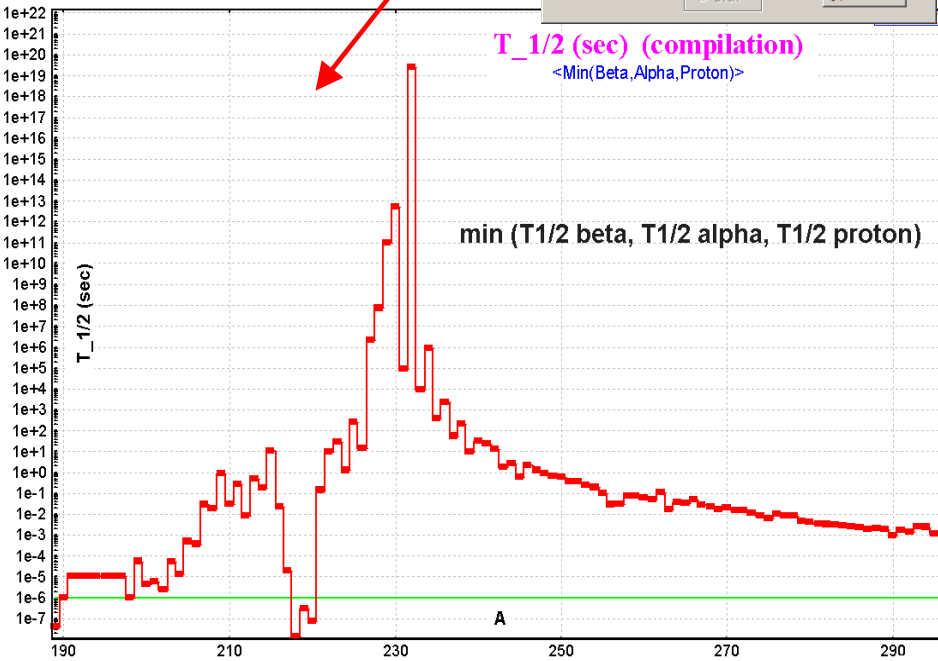
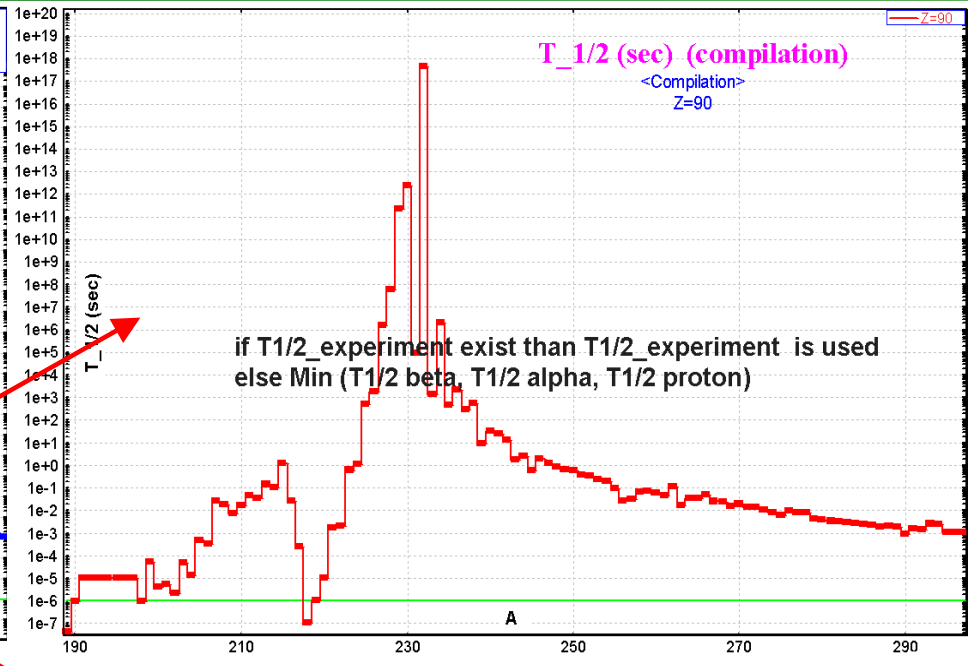
If  $Q_{\alpha} > 6\text{MeV}$ , but  $T_{1/2}$  value is absent in the database, then value  $1e-5$  sec is used



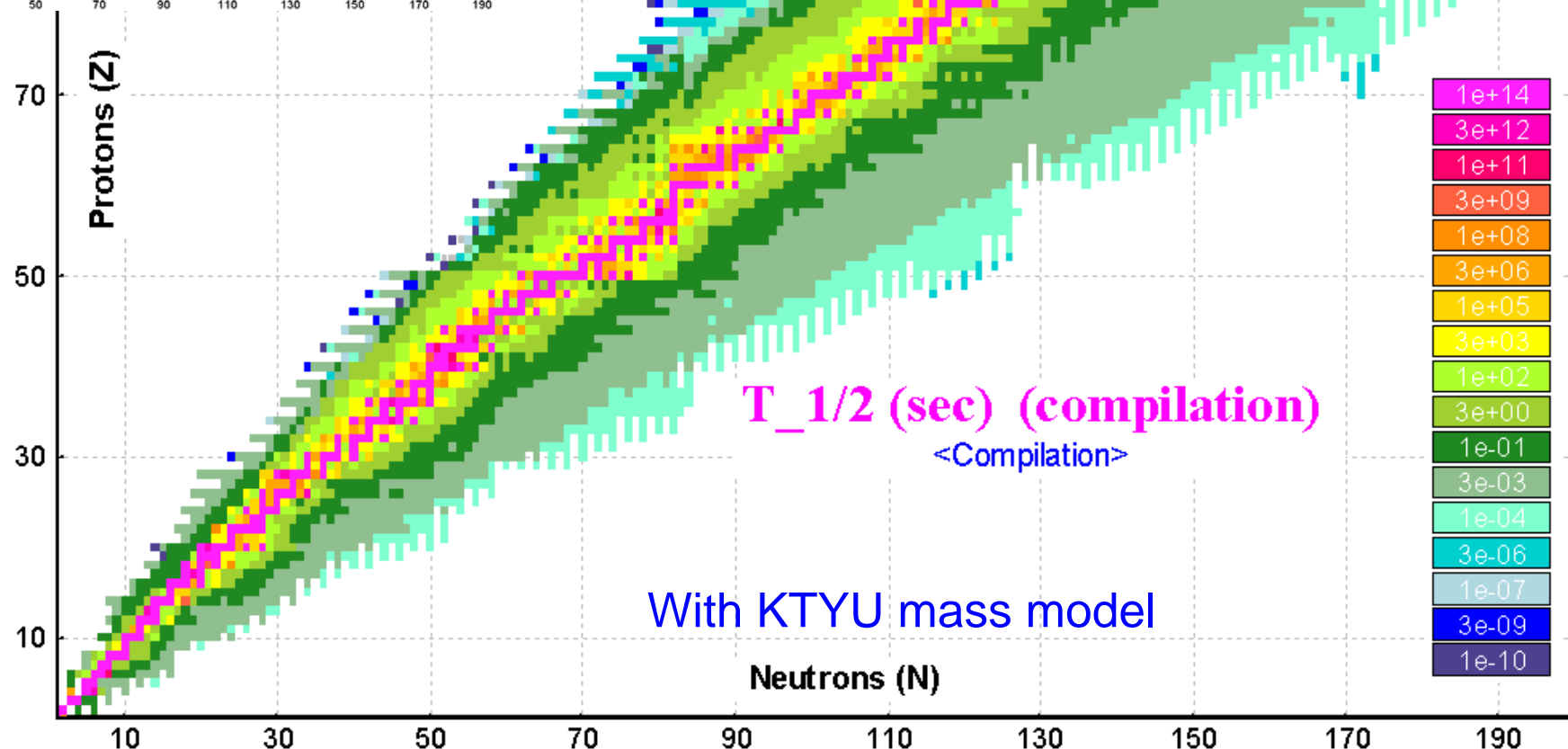
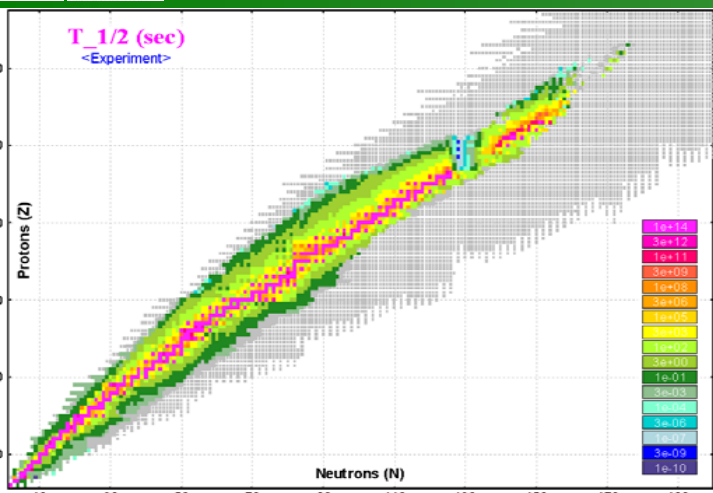
# 2D half-lives plots : decays



# Half-life compilation



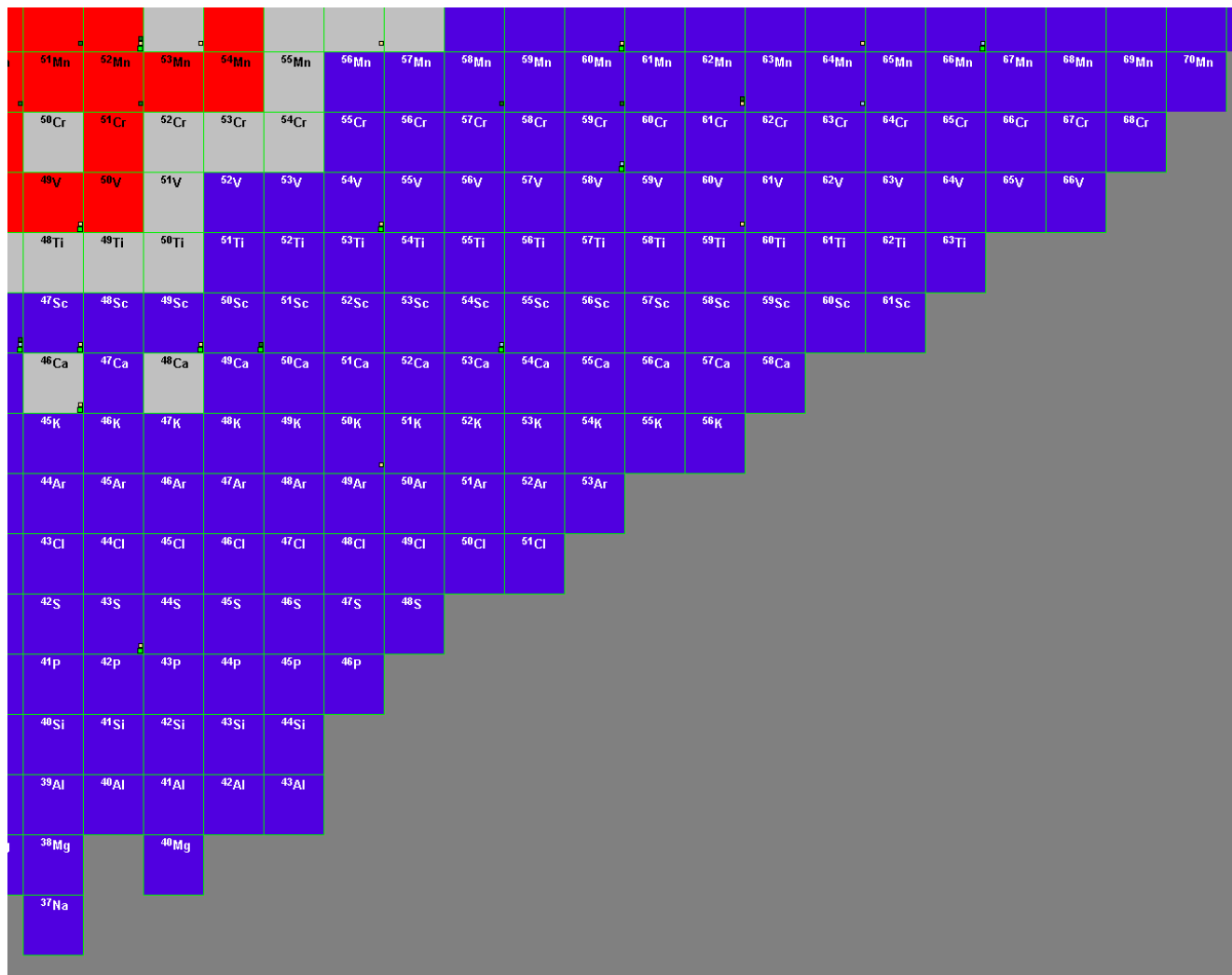
# 2D half-life compilation

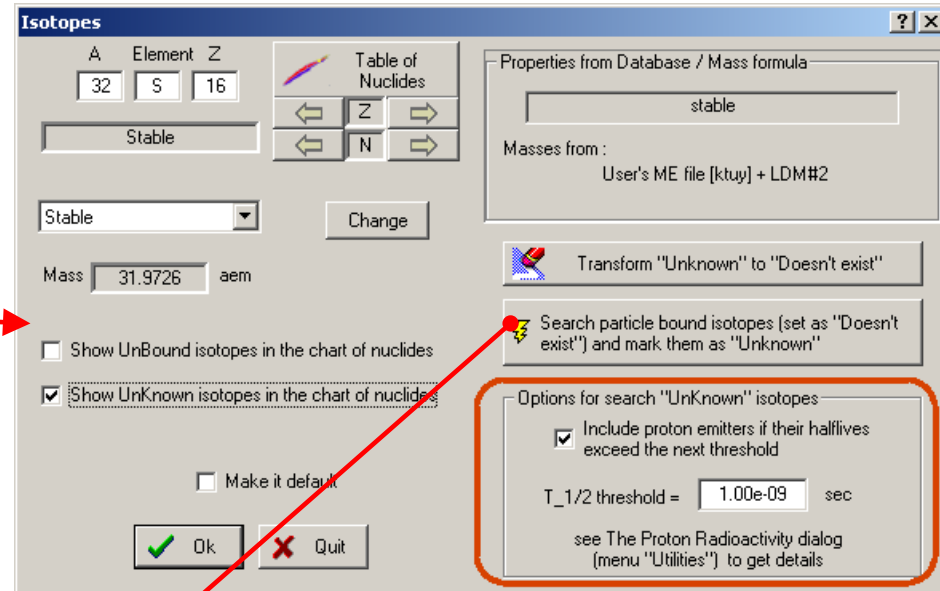
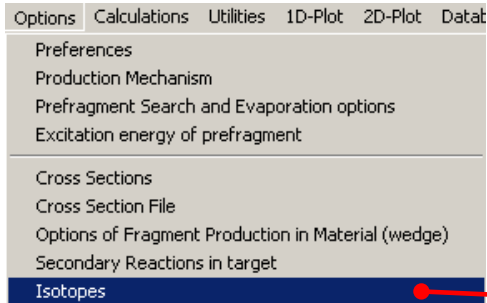


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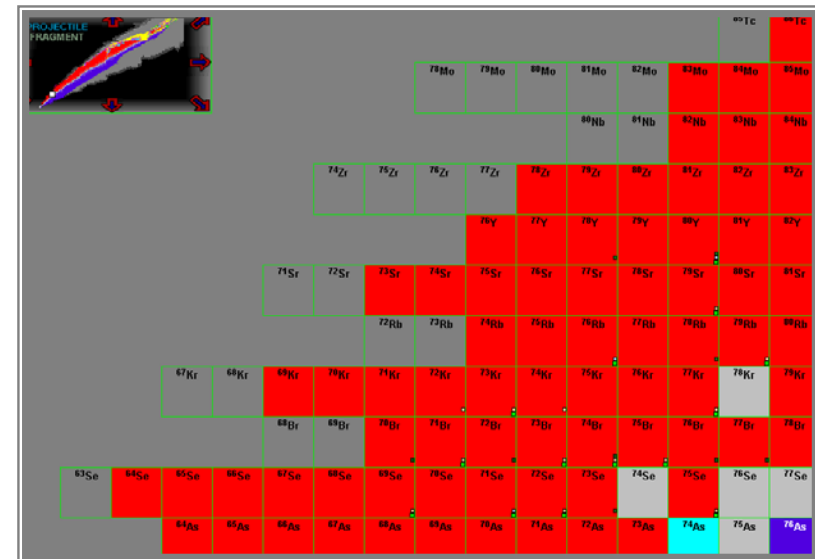
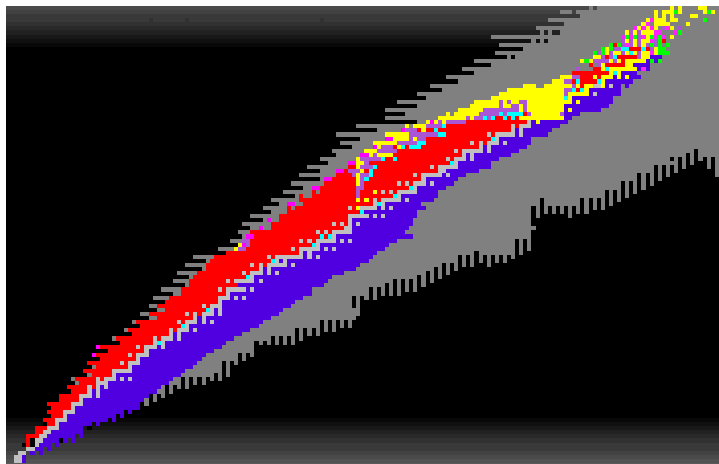
Based on AME2003 experimental half-lives have been updated.

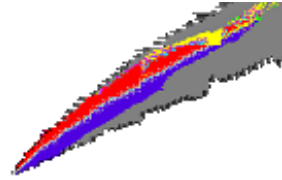
Decay modes have been revised for the table of nuclides,  
As well as for Observed / Non-observed case





Unknown isotopes in the Table of nuclides for version 8.3.138 have been generated with the KTUY mass model including proton emitters (threshold > 1ns)





Thanks to

Prof. B.A.Brown, Prof. M.Thoennessen,

Dr. A.Lisetsky, Prof. A.Gade

(NSCL/MSU)

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