Gamow-Teller and first forbidden transitions in neutron-rich nuclei

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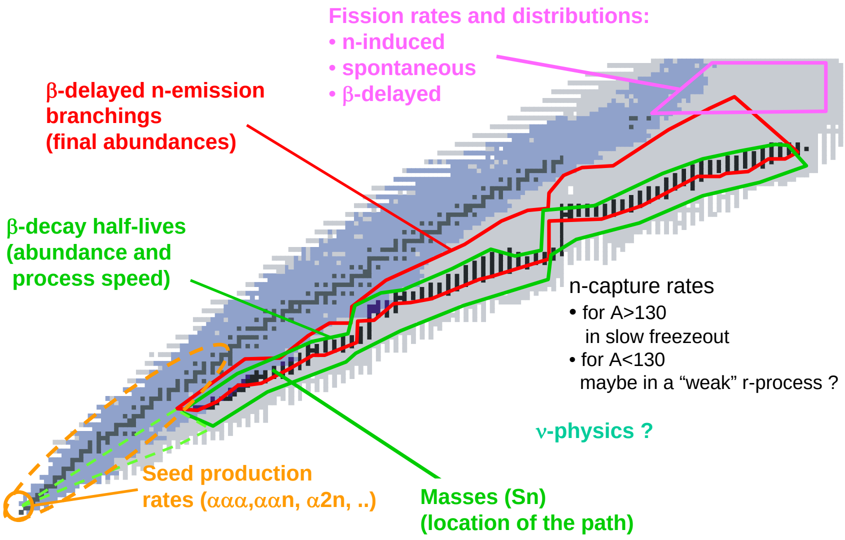
Introduction



Transitions are obtained by solving the pn-RQRPA equations

$$\begin{pmatrix} A & B \\ B^* & A^* \end{pmatrix} \begin{pmatrix} X^\lambda \\ Y^\lambda \end{pmatrix} = E_\lambda \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} X^\lambda \\ Y^\lambda \end{pmatrix}$$

Residual interaction is derived from the Lagrangian density

$$\mathcal{L}_{\rho+\pi} = -g_\rho \bar{\psi} \gamma_\mu \vec{\rho}^\mu \vec{\tau} \psi - \frac{f_\pi}{m_\pi} \bar{\psi} \gamma_5 \gamma^\mu \partial_\mu \vec{\pi} \vec{\tau} \psi$$

Total strength of a particular transition

$$B_{\lambda,J}(GT) = \left| \sum_{pn} \left\langle p \left\| \hat{O}_J \right\| n \right\rangle \left(X_{pn}^{\lambda,J} u_p v_n - Y_{pn}^{\lambda,J} v_p u_n \right) \right|^2$$

Decay rate:

$$\lambda_i = D \int_1^{W_{0,i}} W\sqrt{W^2-1}\,\left(W_{0,i}-W\right)^2 F(Z,W)C(W)dW$$

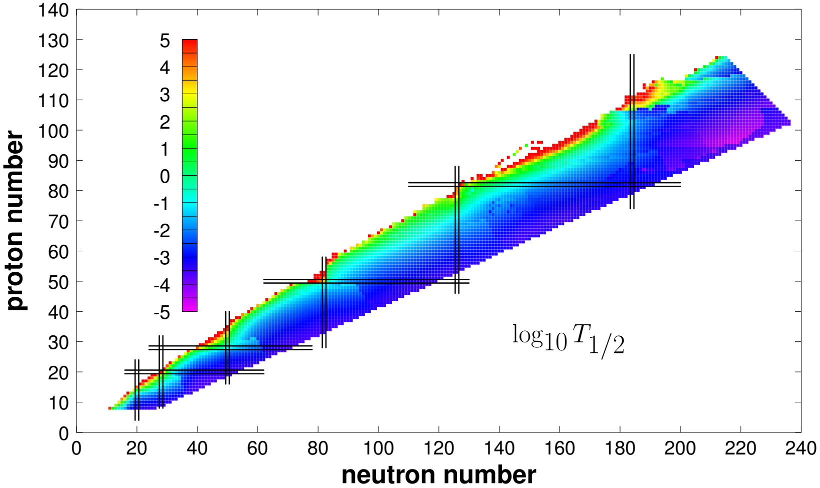
$$T_{1/2} = \frac{\ln 2}{\lambda}, \qquad D = \frac{(G_F V_{ud})^2}{2\pi^3}\frac{\left(m_e c^2\right)^5}{\hbar}$$

Allowed decays shape factor:

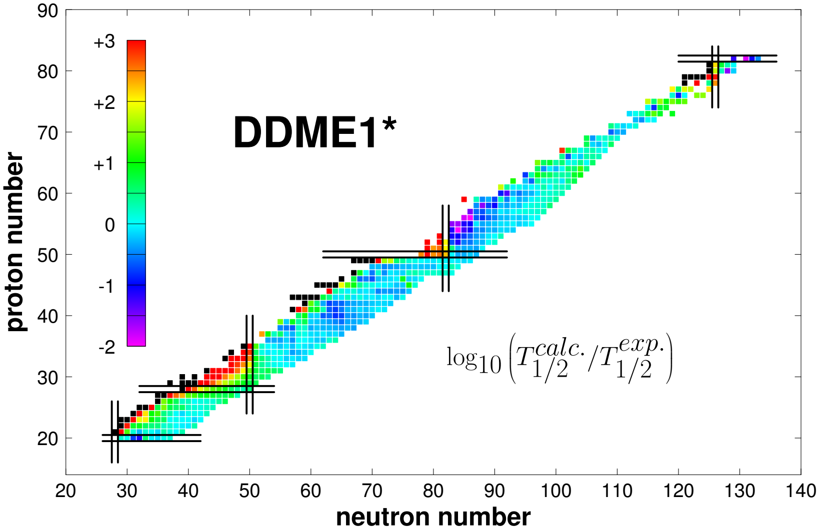
$$C(W) = B(GT)$$

First-forbidden decays shape factor:

$$C(W) = k\left(1 + aW + bW^{-1} + cW^2\right)$$



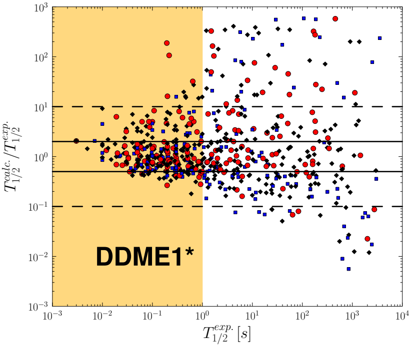
proton number
neutron number
$\log_{10} T_{1/2}$
5
4
3
2
1
0
-1
-2
-3
-4
-5


DDME1*
proton number
neutron number
$\log_{10}\left(T_{1/2}^{calc.}/T_{1/2}^{exp.}\right)$
+3
+2
+1
0
-1
-2
90
80
70
60
50
40
30
20
20
30
40
50
60
70
80
90
100
110
120
130
140

$$r_i = \log \frac{T_{1/2}^{calc.}}{T_{1/2}^{exp.}}$$

$$\bar{r} = \frac{1}{N}\sum_{i=1}^{N} r_i$$

$$\sigma = \left[\frac{1}{N}\sum_{i=1}^{N}(r_i - \bar{r})^2\right]^{1/2}$$



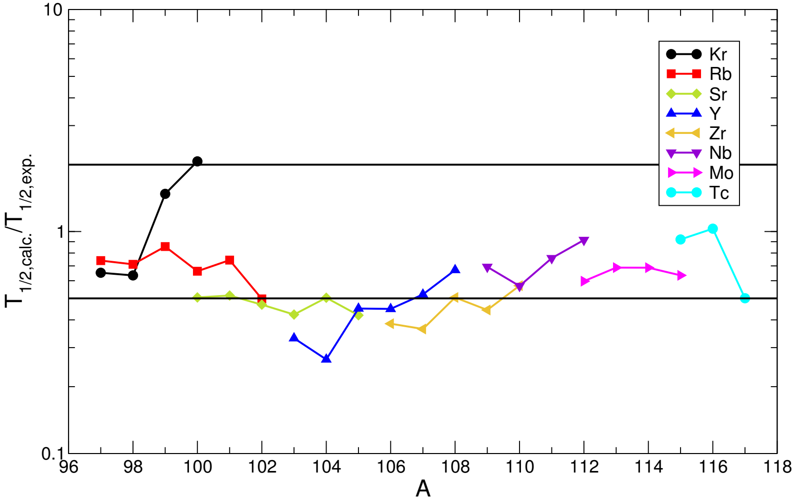
$$\bar{r}_{even} = 0.0315, \qquad \sigma = 0.3446$$

$$\bar{r}_{odd\,Z} = 0.1499, \qquad \sigma = 0.4035$$

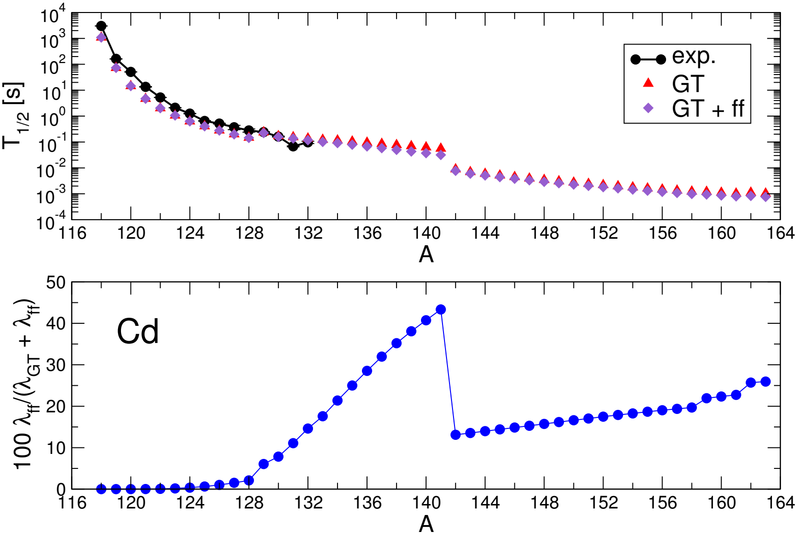
$$\bar{r}_{odd\,N} = 0.0442, \qquad \sigma = 0.4041$$

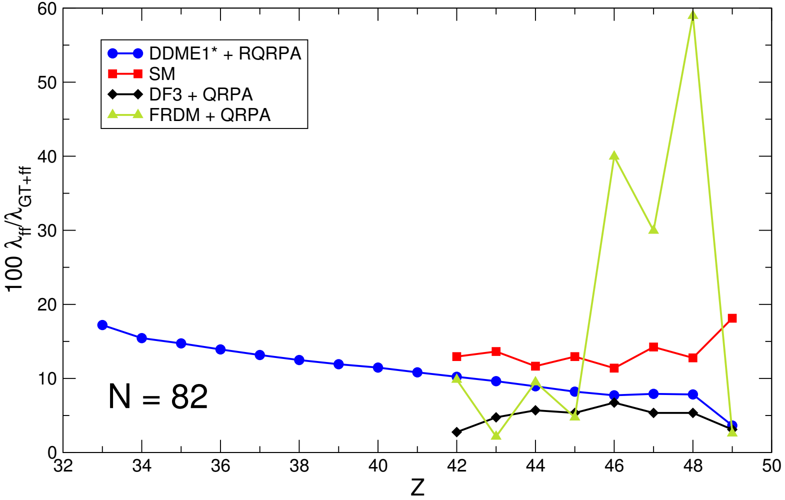
$$\bar{r}_{odd} = 0.1604, \qquad \sigma = 0.5127$$

$$\bar{r}_{total} = 0.1009, \qquad \sigma = 0.4292$$

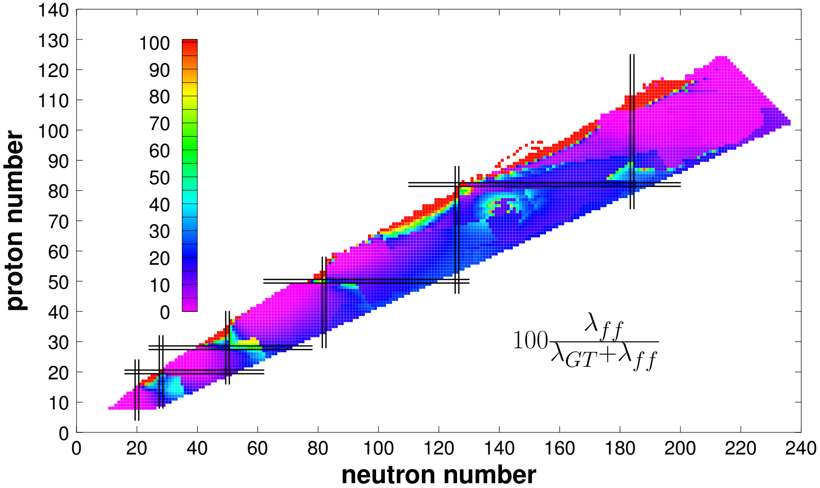


S. Nishimura *et al.*, Phys. Rev. Lett. 106, 052502 (2011)

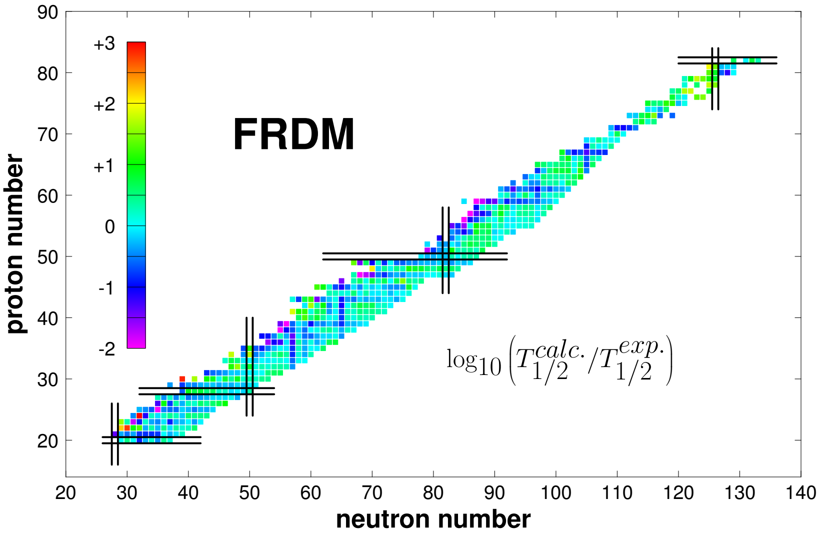

exp.
GT
GT + ff
$T_{1/2}$ [s]
A
Cd
$100\ \lambda_{ff}/(\lambda_{GT} + \lambda_{ff})$
A



DDME1* + RQRPA
SM
DF3 + QRPA
FRDM + QRPA
N = 82
100 λ_ff/λ_GT+ff
Z
0
10
20
30
40
50
60
32
34
36
38
40
42
44
46
48
50


proton number
neutron number
100
90
80
70
60
50
40
30
20
10
0
$100\frac{\lambda_{ff}}{\lambda_{GT}+\lambda_{ff}}$

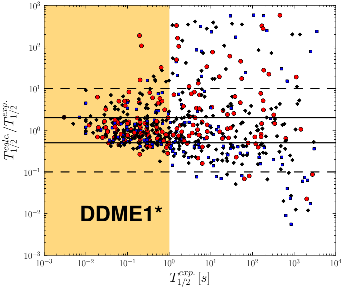
Comparison with FRDM



P. Möller *et al.*, Phys. Rev. C 67, 055802 (2003)

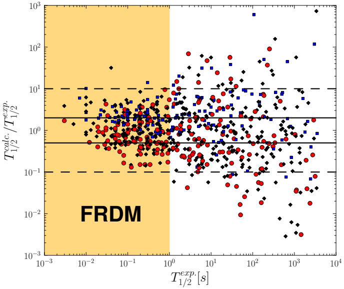
DDME1*

$$\bar{r}_{even} = 0.0315, \quad \sigma = 0.3446$$
$$\bar{r}_{odd\ Z} = 0.1499, \quad \sigma = 0.4035$$
$$\bar{r}_{odd\ N} = 0.0442, \quad \sigma = 0.4041$$
$$\bar{r}_{odd} = 0.1604, \quad \sigma = 0.5127$$
$$\bar{r}_{total} = 0.1009, \quad \sigma = 0.4292$$



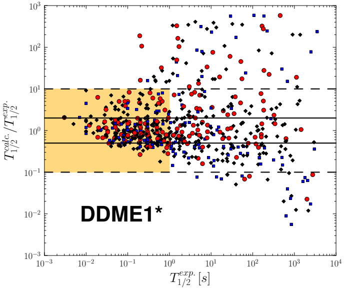
FRDM

$$\bar{r}_{even} = 0.3466, \quad \sigma = 0.2427$$
$$\bar{r}_{odd\ Z} = -0.0437, \quad \sigma = 0.3434$$
$$\bar{r}_{odd\ N} = 0.1739, \quad \sigma = 0.4068$$
$$\bar{r}_{odd} = -0.1228, \quad \sigma = 0.3842$$
$$\bar{r}_{total} = 0.0728, \quad \sigma = 0.3973$$



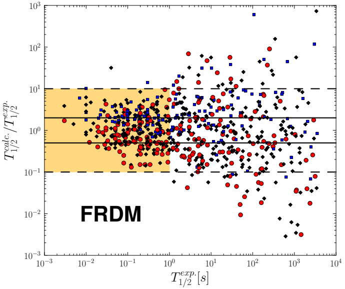
DDME1*

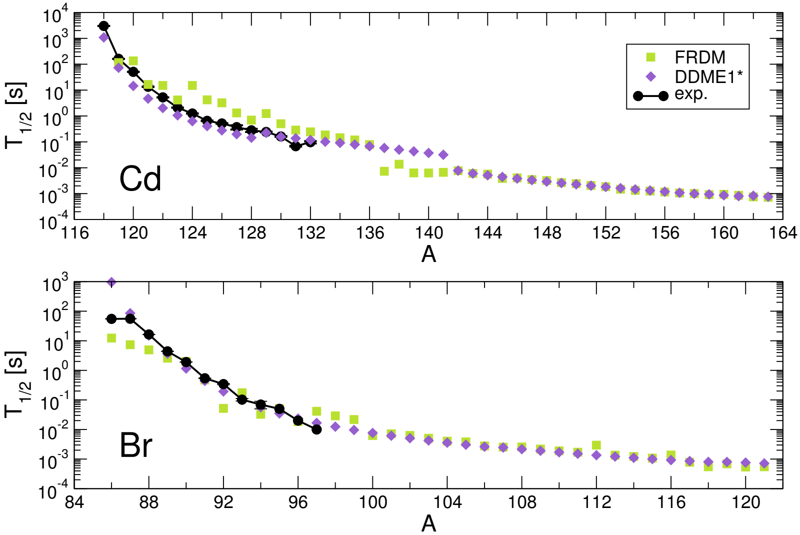
$$\bar{r}_{even} = 0.0129, \quad \sigma = 0.3141$$
$$\bar{r}_{odd\ Z} = 0.1024, \quad \sigma = 0.3345$$
$$\bar{r}_{odd\ N} = -0.0064, \quad \sigma = 0.3314$$
$$\bar{r}_{odd} = 0.0765, \quad \sigma = 0.3559$$
$$\bar{r}_{total} = 0.0488, \quad \sigma = 0.3382$$



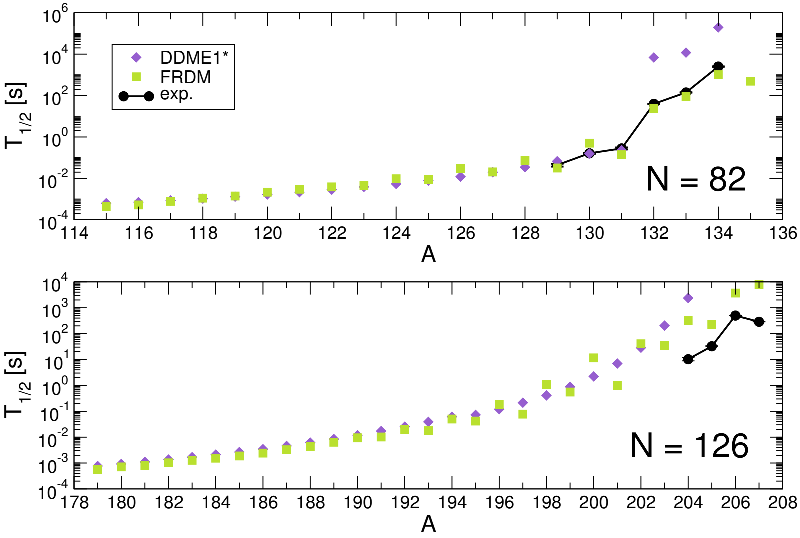
FRDM

$$\bar{r}_{even} = 0.3230, \quad \sigma = 0.2068$$
$$\bar{r}_{odd\ Z} = -0.0437, \quad \sigma = 0.3434$$
$$\bar{r}_{odd\ N} = 0.1549, \quad \sigma = 0.3772$$
$$\bar{r}_{odd} = -0.1228, \quad \sigma = 0.3842$$
$$\bar{r}_{total} = 0.0609, \quad \sigma = 0.3811$$

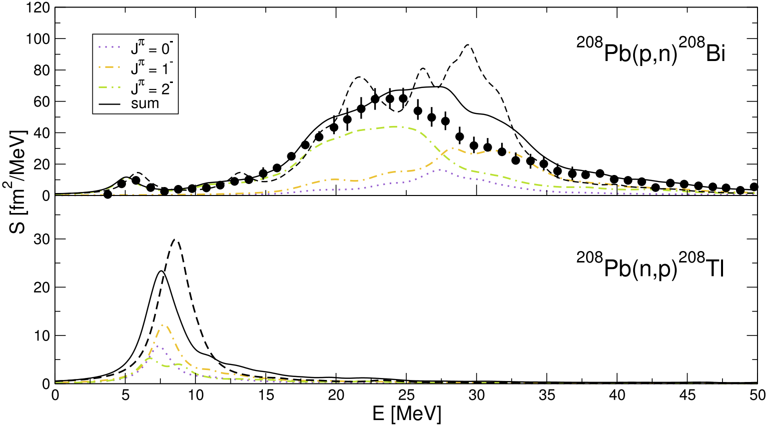




FRDM
DDME1*
exp.
Cd
Br
$T_{1/2}$ [s]
A


DDME1*
FRDM
exp.
N = 82
$T_{1/2}$ [s]
A
N = 126
$T_{1/2}$ [s]
A

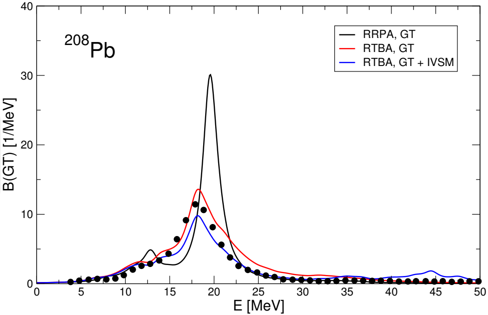
Future developments

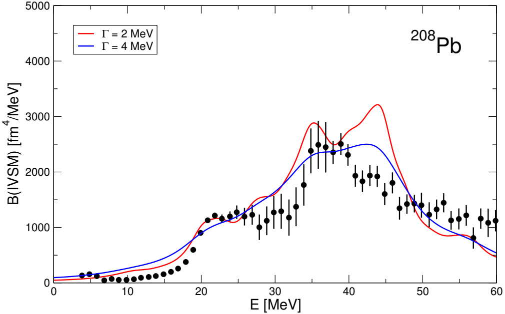


T. Marketin *et al.*, Phys. Lett. B 706, 477 (2012)
T. Wakasa *et al.*, Phys. Rev. C 85, 064606 (2012)

$$\hat{O} = \left(\boldsymbol{\sigma\tau} - \frac{q^2 r^2}{6} \boldsymbol{\sigma\tau} + \cdots \right)$$

- p-h⊗phonon components enrich the spectrum
- additional states lead to fragmentation
- significant contribution of the $0\hbar\omega$ component of the IVSM at the resonance
- low energy strength remains unaffected





T. Wakasa *et al.*, Phys. Rev. C 85, 064606 (2012)

$$k = \left[\zeta_0^2 + \frac{1}{9}w^2\right]_0 + \left[\zeta_1^2 + \frac{1}{9}(x+u)^2 - \frac{4}{9}\mu_1\gamma_1 u(x+u) + \frac{1}{18}W_0^2(2x+u)^2 - \frac{1}{18}\lambda_2(2x-u)^2\right]_1 + \left[\frac{1}{12}z^2\left(W_0^2 - \lambda_2\right)\right]_2$$

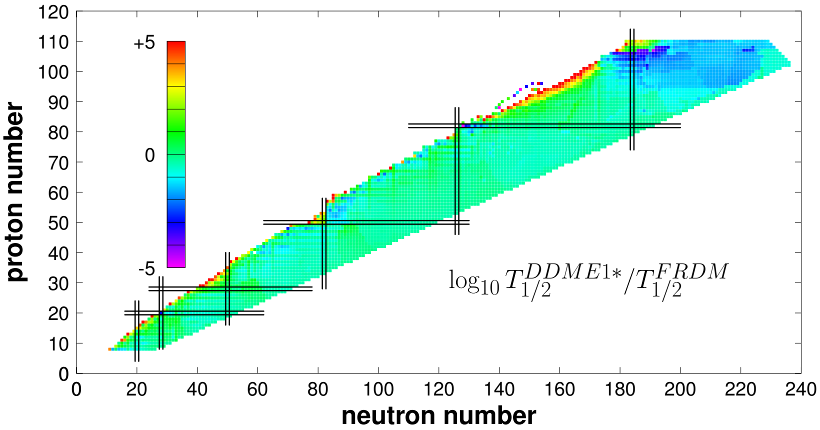
$$ka = \left[-\frac{4}{3}uY - \frac{1}{9}W_0\left(4x^2 + 5u^2\right)\right]_1 + \left[\frac{1}{12}z^2\left(W_0^2 - \lambda_2\right)\right]_2$$

$$kb = \frac{2}{3}\mu_1\gamma_1\left\{[\zeta_0 w]_0 + [\zeta_1(x+u)]_1\right\}$$

$$kc = \frac{1}{18}\left[8u^2 + (2x+u)^2 + \lambda_2(2x-u)^2\right]_1 + \frac{1}{12}\left[z^2(1+\lambda_2)\right]_2$$

$$V = \xi' v + \xi w', \qquad \zeta_0 = V + \frac{1}{3}wW_0$$

$$Y = \xi' y - \xi\left(u' + x'\right), \qquad \zeta_1 = Y + \frac{1}{3}(u-x)W_0$$



proton number
neutron number
+5
0
-5
$\log_{10} T_{1/2}^{DDME1*}/T_{1/2}^{FRDM}$
0
10
20
30
40
50
60
70
80
90
100
110
120
0
20
40
60
80
100
120
140
160
180
200
220
240