Large scale evaluation of β-decay rates of r-process nuclei

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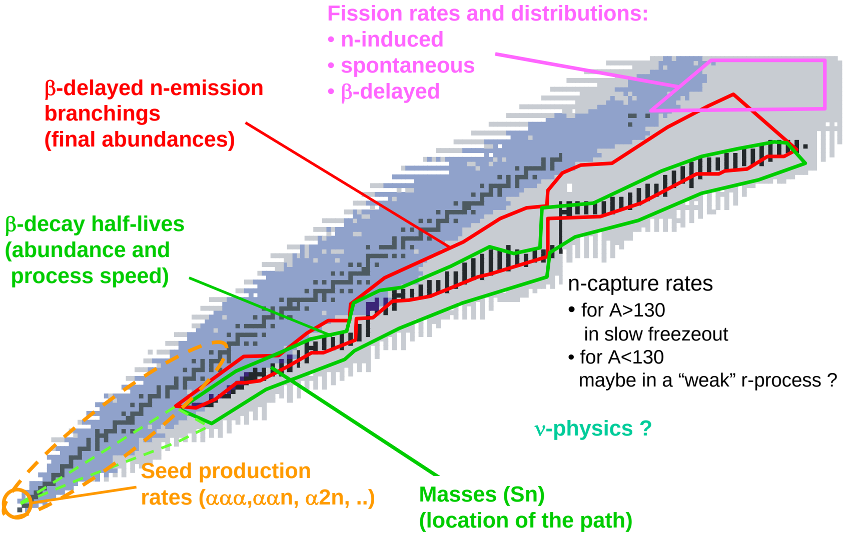
Introduction



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 same density functional used to obtain the ground state

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

Total strength of a particular transition

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

Decay rate:

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

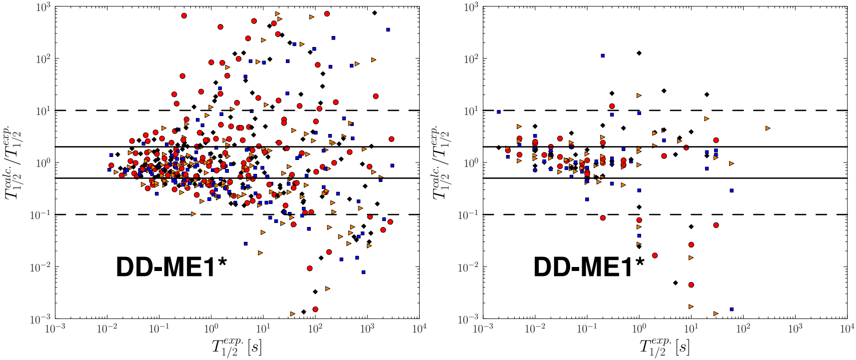
$$T_{1/2} = \frac{\ln 2}{\lambda}, \qquad D = \frac{(G_F V_{ud})^2}{2\pi^3}\frac{\left(m_e c^2\right)^5}{\hbar}$$

Allowed decay shape factor:

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

First-forbidden decay shape factor:

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

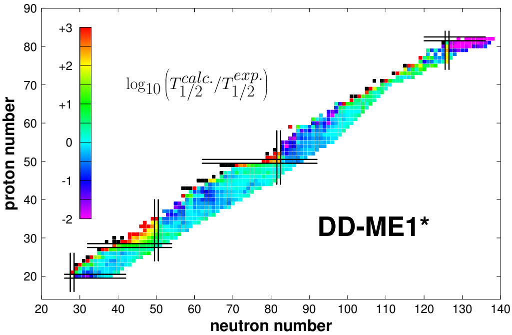


$$\bar{r} = \frac{1}{N}\sum_i \log \frac{T_{\text{th.}}}{T_{\text{exp.}}}$$

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

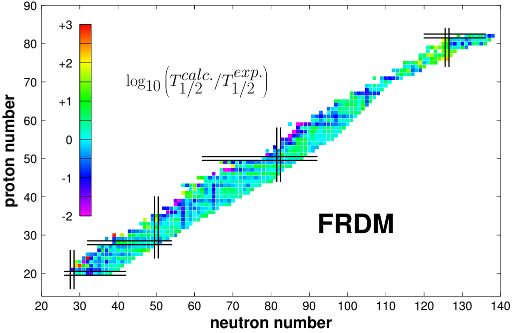
	DD-ME1*		FRDM	
$T_{\text{exp.}}$ [s]	$\bar{r}$	σ	$\bar{r}$	σ
< 1000	0.044	0.876	0.021	0.660
< 100	0.077	0.803	0.040	0.580
< 10	0.064	0.631	0.046	0.515
< 1	-0.005	0.424	0.019	0.409
< 0.1	-0.065	0.233	0.021	0.354

G. Audi *et al.*, CPC 36, 1157 (2012)



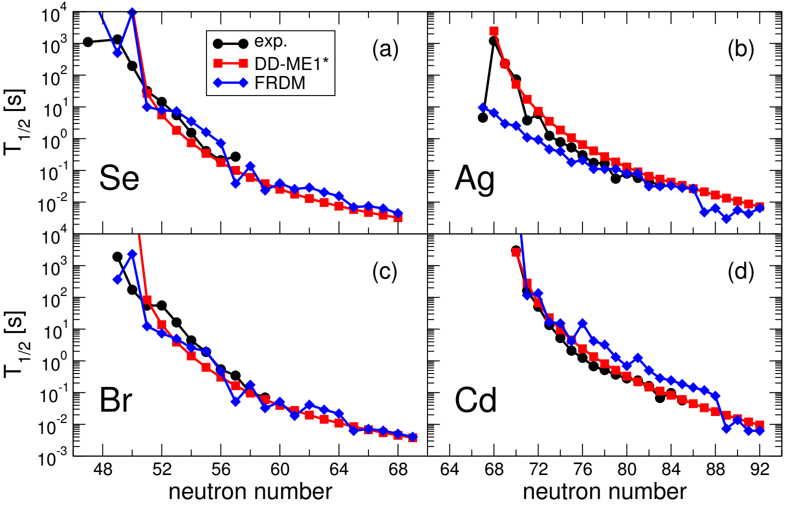
DD-ME1*

	$\bar{r}$	σ
even-even	-0.083	0.295
odd-Z	0.045	0.300
odd-N	-0.108	0.371
odd-odd	0.094	0.581
total	-0.005	0.424

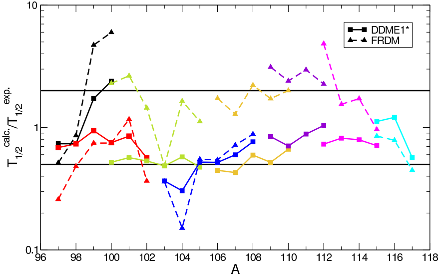


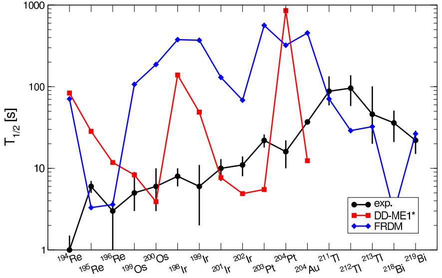
FRDM

	$\bar{r}$	σ
even-even	0.333	0.226
odd-Z	-0.128	0.288
odd-N	0.124	0.436
odd-odd	-0.179	0.409
total	0.019	0.409



- FRDM + QRPA predicts erratic behaviour of the half-lives along isotopic (and isotonic) chains

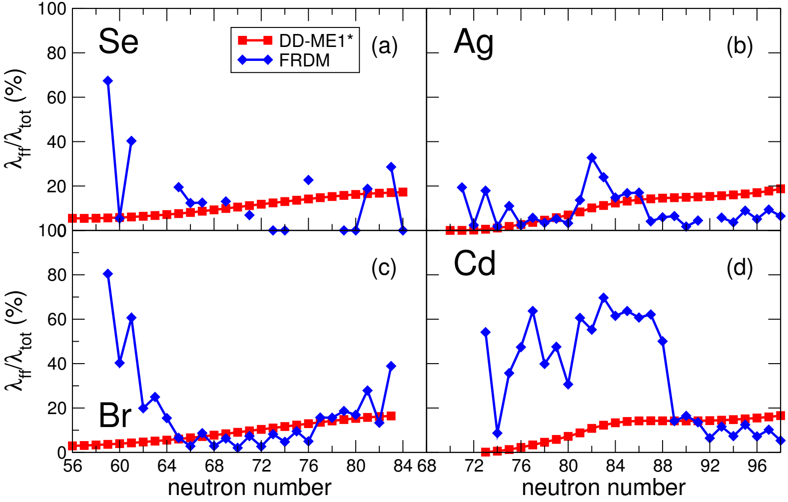




- Half-lives of medium mass nuclei (from Kr to Tc) are reproduced well with both models
- Deformation plays a significant role in some nuclei (e.g. Re isotopes)
- Description of heavy nuclei, with long $T_{1/2}$ is still challenging

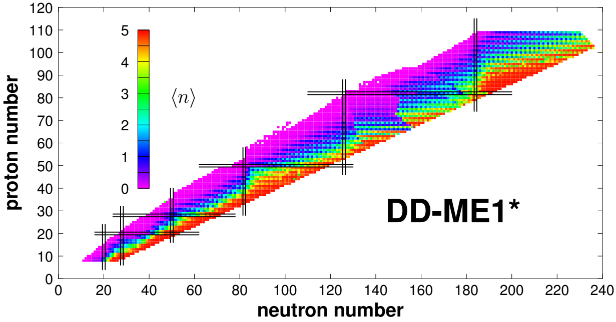
S. Nishimura *et al.*, Phys. Rev. Lett. 106, 052502 (2011)

J. Benlliure *et al.*, J. Phys. Conf. Ser. 337, 012070 (2012)

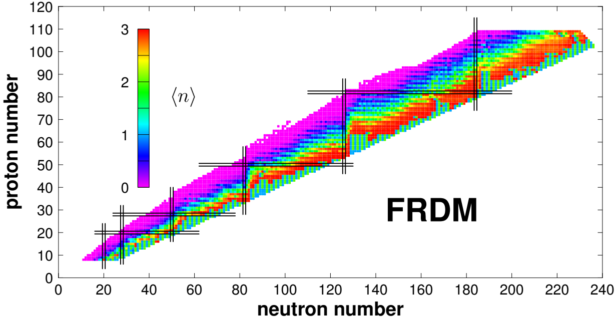


P. Möller, J. R. Nix, and K.-L. Kratz, Atomic Data and Nuclear Data Tables 66, 131 (1997)

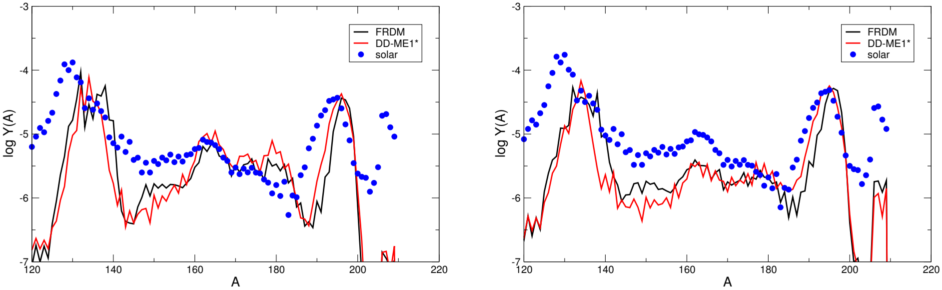
P. Möller, B. Pfeiffer, and K.-L. Kratz, Phys. Rev. C 67, 055802 (2003)



$$P_{xn} = \frac{1}{\lambda_{tot}} \sum_{E_i = S_{xn}}^{S_{(x+1)n}} \lambda_i$$



$$\langle n \rangle = \sum_i i P_{in}$$

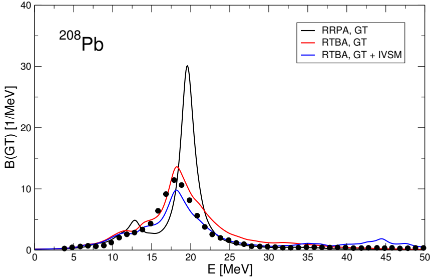


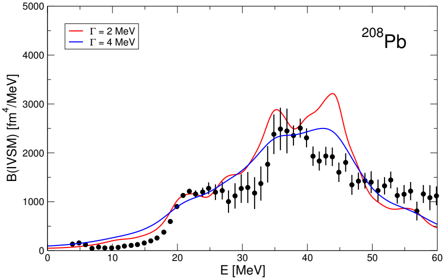
- All thigs being equal, different half-lifes have a significant impact on the resulting abundances
- Additionally changing other input, such as masses will result with even larger differences in the final results
- There is a need for microscopic, fully self-consistent calculations of all relevant nuclear input for use in r-process simulations

Future developments

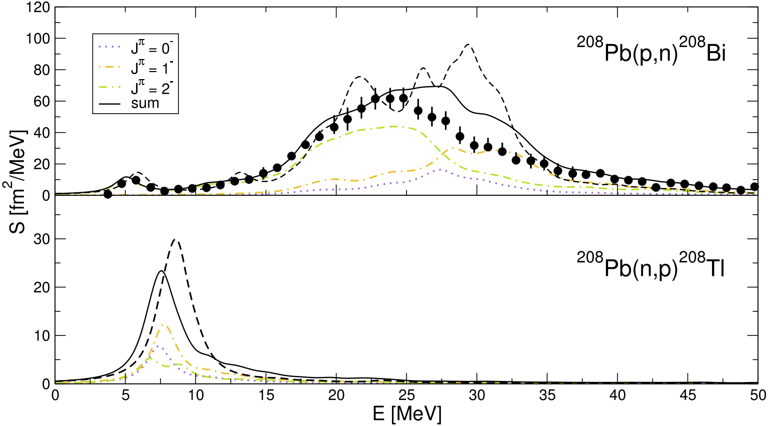
$$\hat{O} = \left(\sigma\tau - \frac{q^2 r^2}{6} \sigma\tau + \cdots \right)$$

- 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)



^{208}Pb(p,n)^{208}Bi
^{208}Pb(n,p)^{208}Tl
$J^\pi = 0^-$
$J^\pi = 1^-$
$J^\pi = 2^-$
sum
S [fm^2/MeV]
E [MeV]