Decay properties of heavy and super-heavy nuclei

M. Markova[1], T. Shneydman[2], N. Antonenko[2],
T. Tretyakova[3].

[1] Lomonosov Moscow State University, Faculty of Physics
[2] Joint Institute of Nuclear Research, BLTP, Dubna
[3] SINP MSU, Moscow

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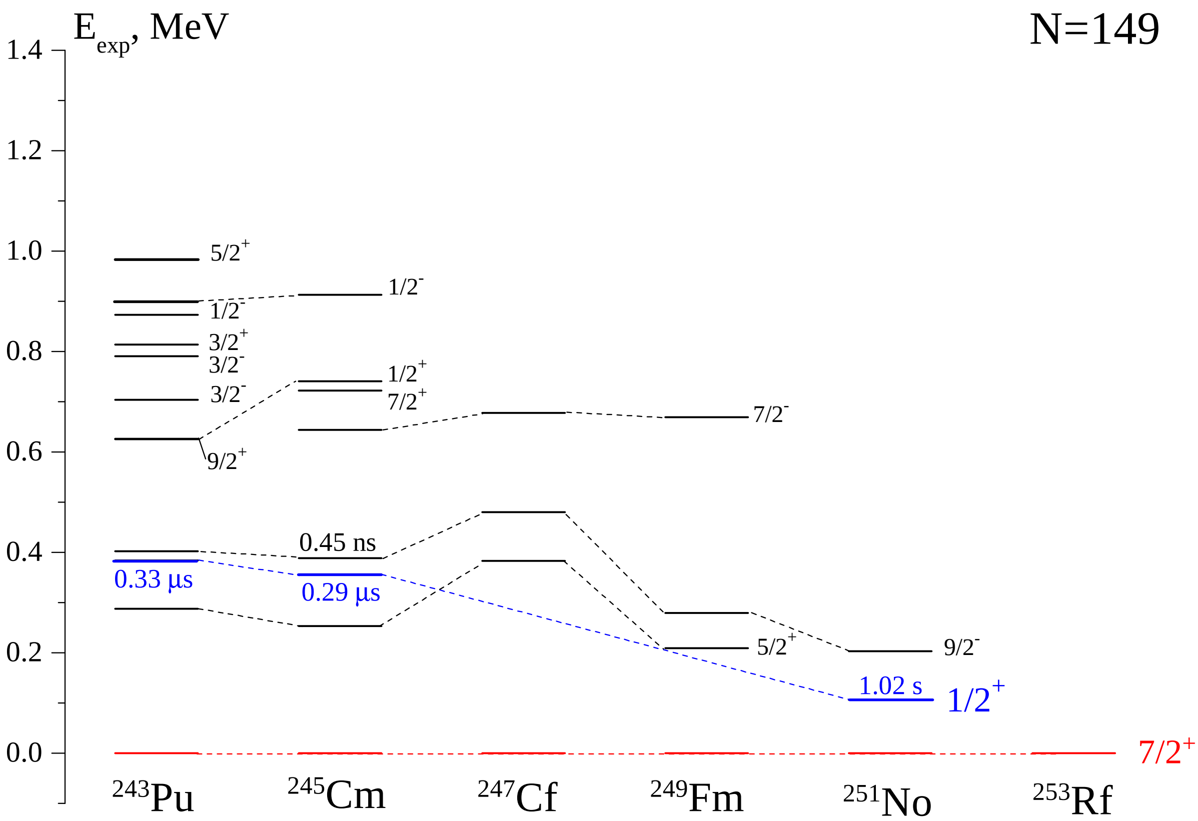
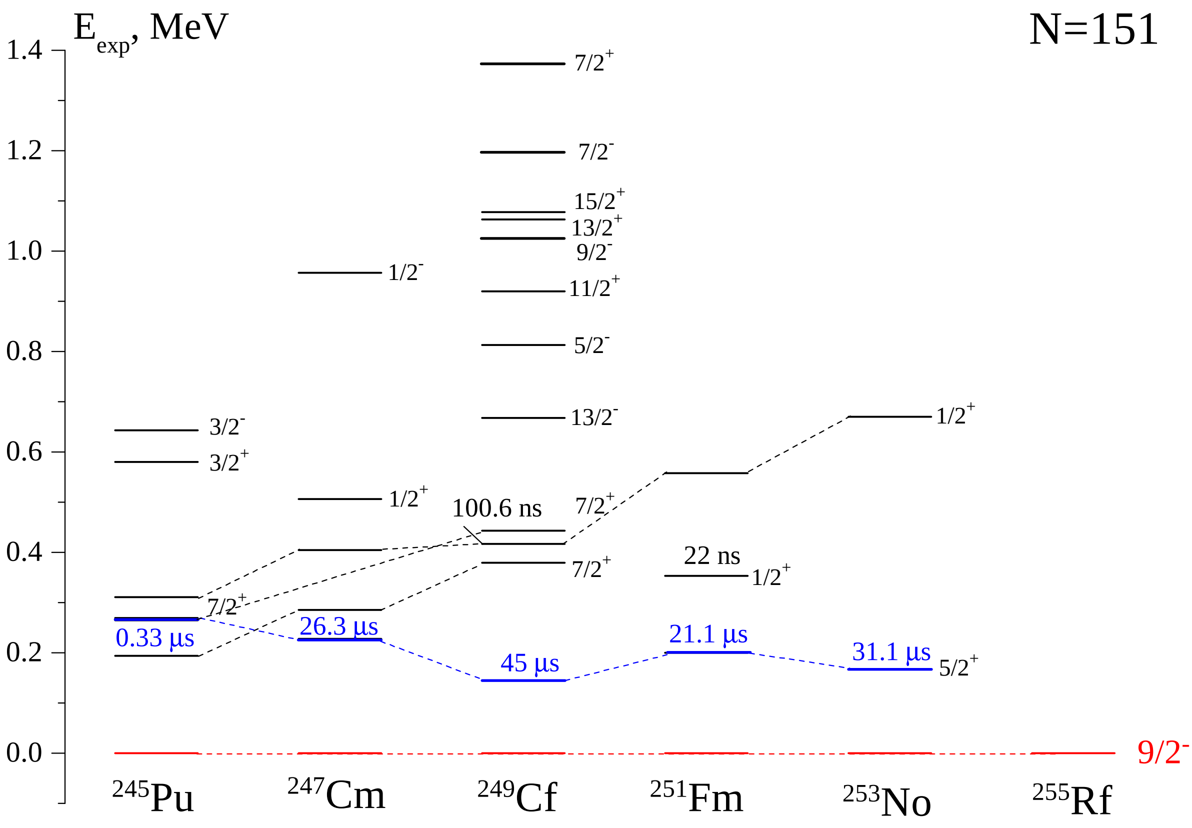
Introduction

- Nowadays experimental investigation of energy spectra of heavy and super-heavy nuclei is a relevant issue of particular interest in nuclear physics.
- Correct theoretical models are required for a detailed theoretical description and predictions on inner structure of nuclei in the vicinity of neutron drip line.
- Long living isomeric states and their description present important theoretical issue .
- As an investigation object isotonic chains with $N = 149$, $N = 151$, and $N = 153$ were chosen. These nuclei reveal the set of comparatively long living low lying isomeric states.

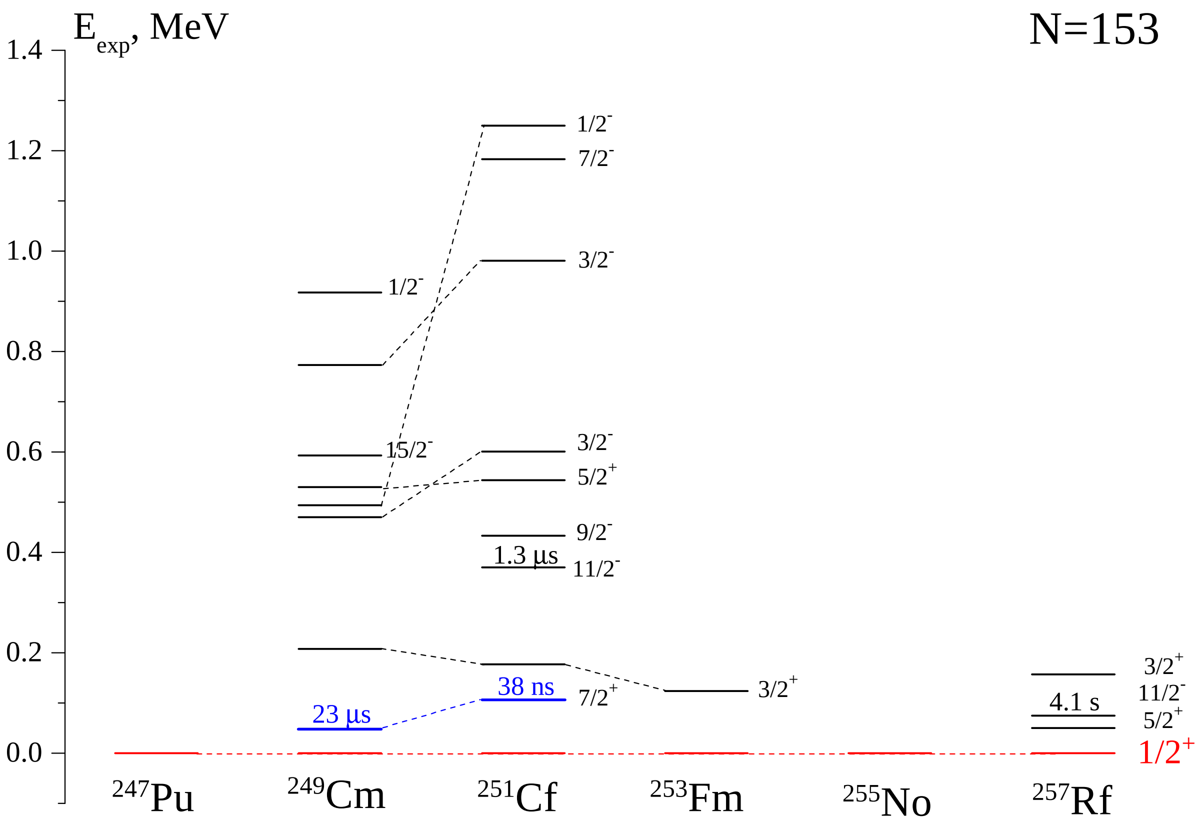
Experimental spectra for isotones with $N = 149$



Experimental spectra for isotones with $N = 151$



Experimental spectra for isotones with $N = 153$



The Coriolis effect for heavy deformed nuclei

In the present work N-odd Z-even nuclei under investigation were considered as axial symmetric deformed nuclei.The Particle-plus-rotor model was applied. Total angular momentum of the investigated system (even-even solid core and valence particle):

$$\vec{I} = \vec{J} + \vec{R} = \vec{j_n} + \vec{R}, \qquad (1)$$

The total Hamiltonian of a system:

$$H_{tot} = H_{intr} + H_{col} = H_{intr} + H_{rot} + H_{cor} =$$
$$= H_{intr} + \frac{I^2 - I_3^2}{2\Im} + \frac{j_1^2 + j_2^2}{2\Im} - \frac{I_+ j_- + I_- j_+}{2\Im}, \qquad (2),$$

here the Coriolis term $H_{cor} = -\frac{I_+ J_- + I_- J_+}{2\Im}$ is capable of wave function mixing with respect to the 3-component of total angular momentum K.

Two Center Shell Model

The Hamiltonian of the Two Center Shell Model:

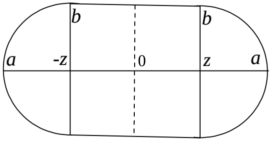
$$H_{TCSHM} = -\frac{\hbar^2 \nabla^2}{2m_0} + V(\rho, z) + V_{LS}(\vec{r}, \vec{p}, \vec{s}) + V_{L^2}(\vec{r}, \vec{l}). \quad (3)$$

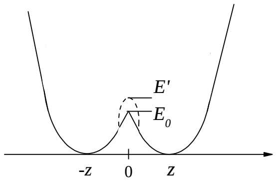
Single-particle wave functions in the Two Center Shell Model:

$$\psi(\rho, z, \phi) = \mu(z)\chi(\rho)\eta(\phi). \quad (4)$$

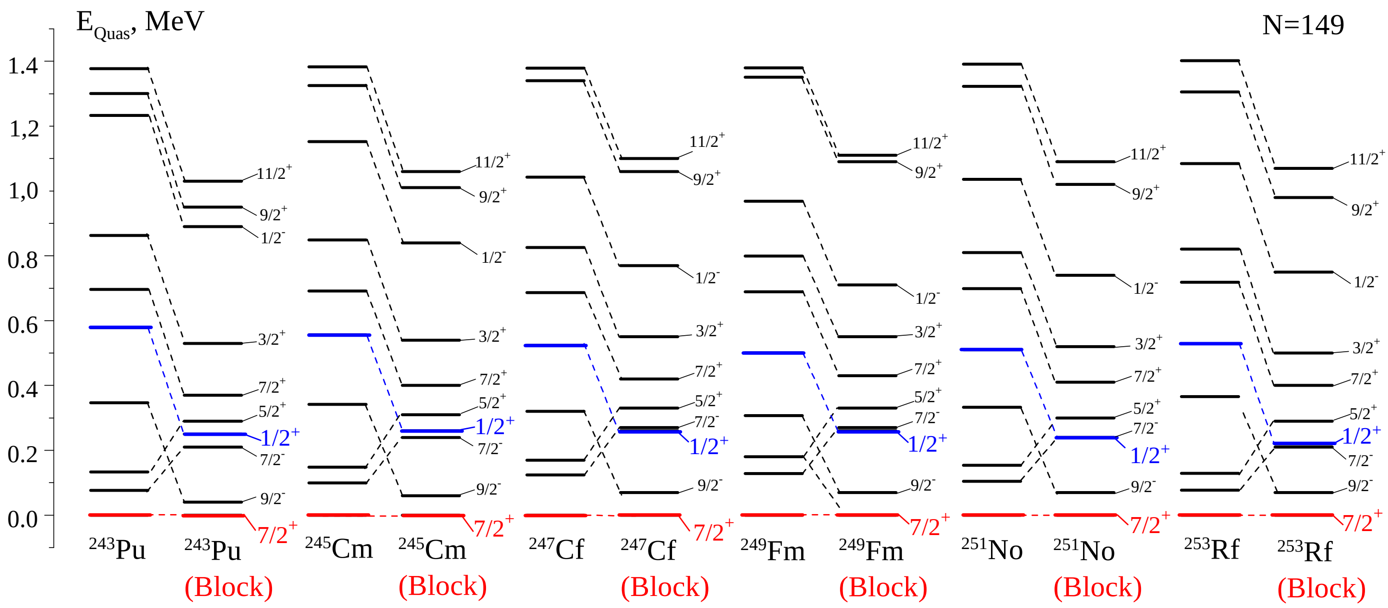
Collective parameters of the model:

Elongation $\lambda = \frac{l}{2R_0}$, deformation of a fragment $\beta_1 = \beta_2 = \frac{a_{1,2}}{b_{1,2}}$

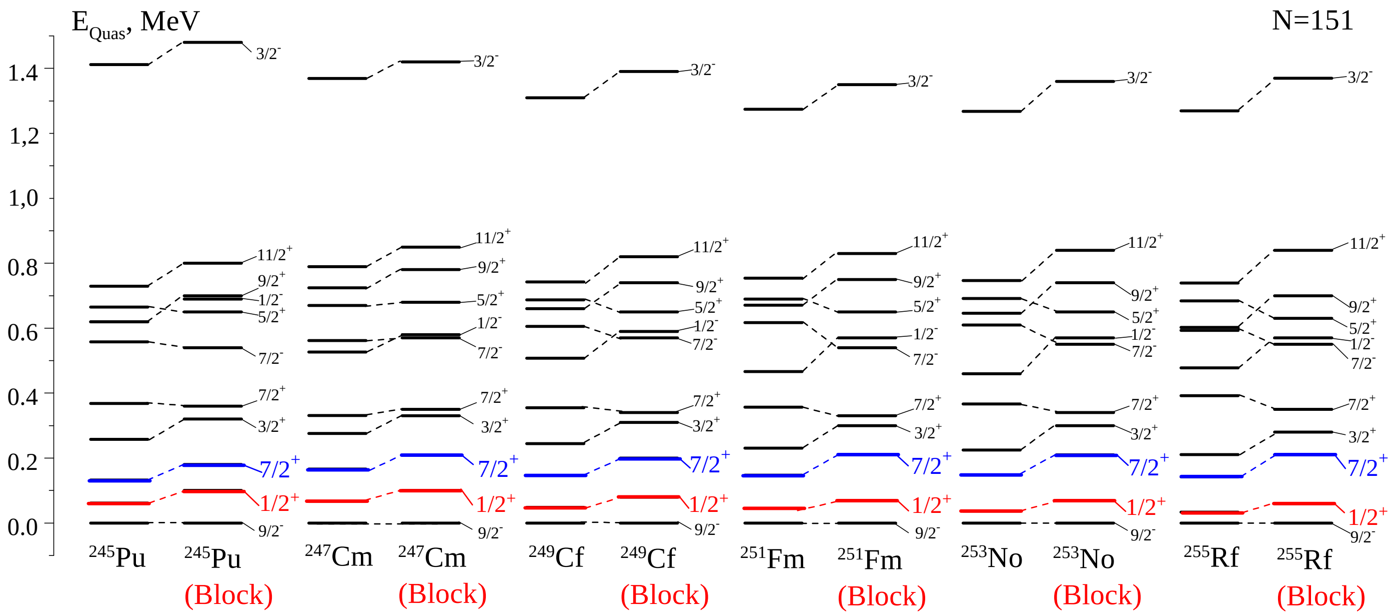




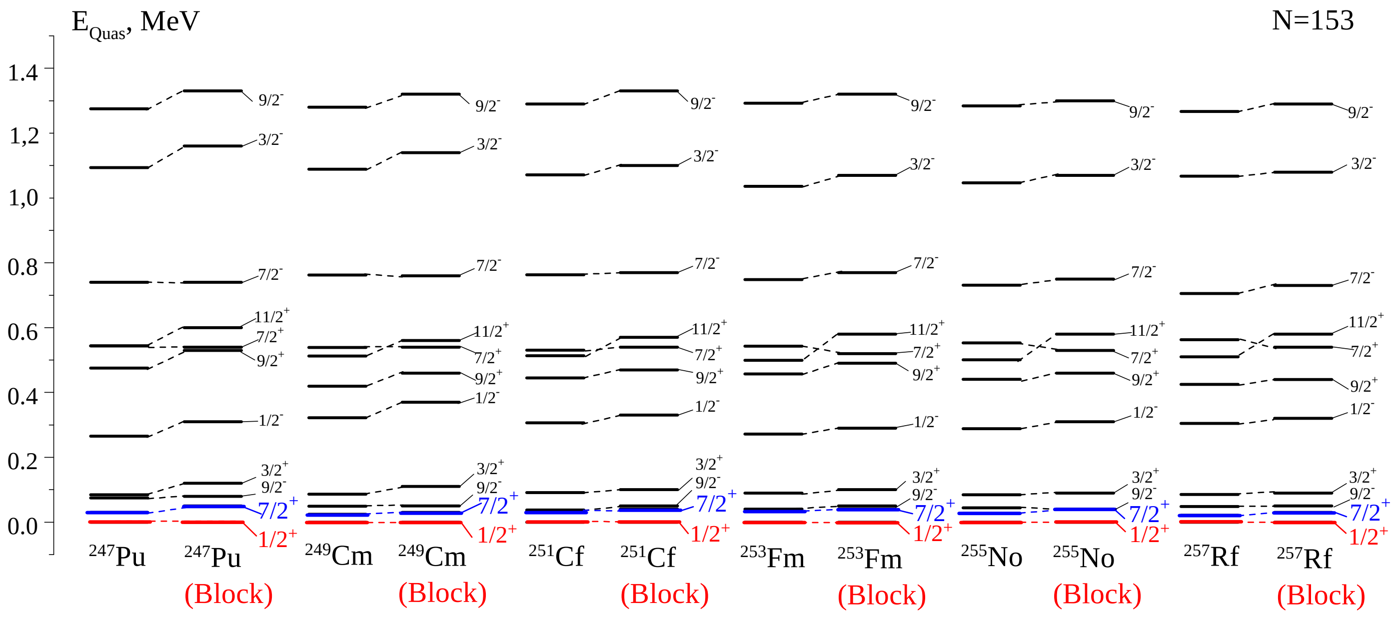
Quasi-neutron spectra for isotones with $N = 149$, TCSHM, TCSHM+Blocking



Quasi-neutron spectra for isotones with $N = 151$, TCSHM, TCSHM+Blocking



Quasi-neutron spectra for isotones with $N = 153$, TCSHM, TCSHM+Blocking



Probabilities of $E2$ transitions and corresponding half-lives of excited states for the $N = 149$ chain

$$T = (1,223 \cdot 10^9 E^5 \cdot B(E2))^{-1}$$

Half-lives of $1/2^+$ states for $1/2^+ \rightarrow 5/2^+$ transitions, s			
Isotone	TCSHM	Coriolis	Coriolis+Blocking
^{243}Pu	$7{,}818\cdot10^{-10}$	$6{,}9845\cdot10^{-10}$	$1{,}227\cdot10^{-5}$
^{245}Cm	$1{,}194\cdot10^{-9}$	$1{,}066\cdot10^{-9}$	$1{,}152\cdot10^{-5}$
^{247}Cf	$2{,}375\cdot10^{-9}$	$2{,}630\cdot10^{-9}$	$1{,}495\cdot10^{-5}$
^{249}Fm	$3{,}888\cdot10^{-9}$	$4{,}669\cdot10^{-9}$	$1{,}288\cdot10^{-5}$
^{251}No	$2{,}306\cdot10^{-9}$	$2{,}071\cdot10^{-9}$	$1{,}643\cdot10^{-5}$
^{253}Rf	$1{,}293\cdot10^{-9}$	$1{,}455\cdot10^{-9}$	$2{,}664\cdot10^{-5}$

Admixture of $5/2^+$ component in the ground state $7/2^+$ due to the Coriolis interaction is approximately $\sim 3\%$.

Probabilities of $E2$ transitions and corresponding half-lives of excited states for the $N = 151$ chain

$$T = (1,223 \cdot 10^9 E^5 \cdot B(E2))^{-1}$$

Half-lives of $7/2^+$ states for $5/2^+ \to 1/2^+$ transitions, s		
Isotone	Coriolis	Coriolis+Blocking
^{245}Pu	$4{,}051 \cdot 10^{-2}$	$2{,}225 \cdot 10^{-2}$
^{247}Cm	$2{,}845 \cdot 10^{-3}$	$1{,}727 \cdot 10^{-3}$
^{249}Cf	$3{,}207 \cdot 10^{-3}$	$1{,}143 \cdot 10^{-3}$
^{251}Fm	$1{,}938 \cdot 10^{-3}$	$4{,}049 \cdot 10^{-4}$
^{253}No	$7{,}037 \cdot 10^{-4}$	$2{,}181 \cdot 10^{-4}$
^{255}Rf	$7{,}489 \cdot 10^{-4}$	$1{,}477 \cdot 10^{-3}$

Admixture of $5/2^+$ component in the excited $7/2^+$ state due to the Coriolis interaction is approximately $\sim 4\%$.

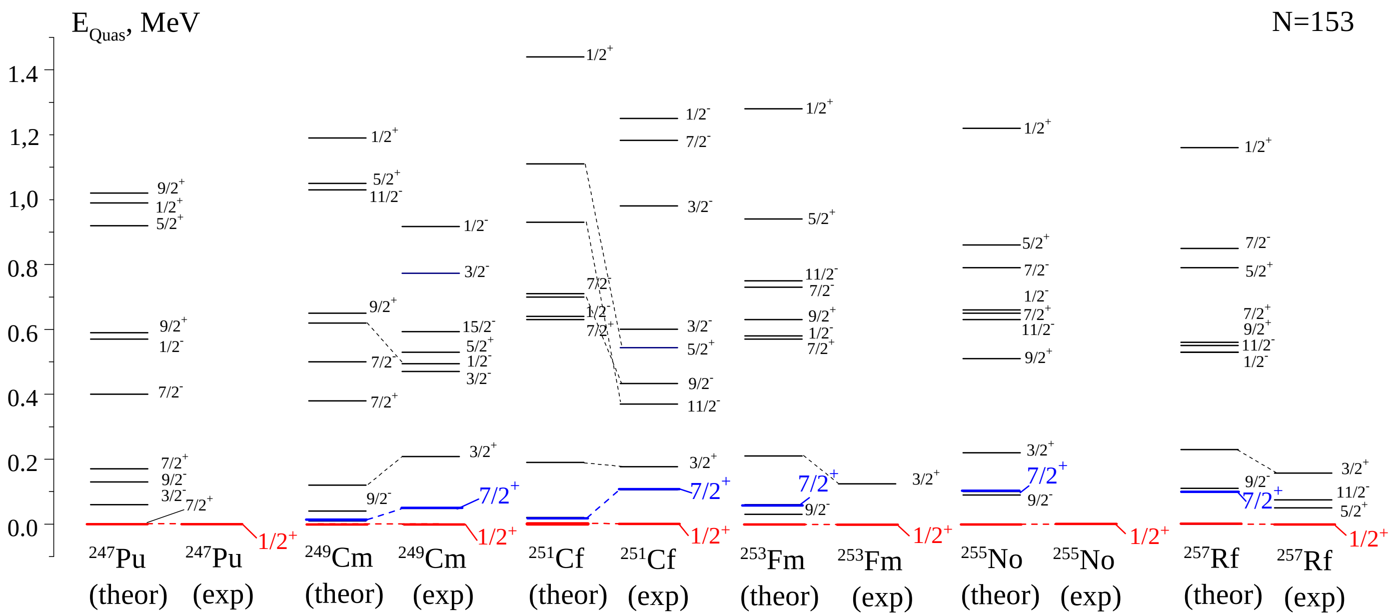
Probabilities of $E2$ transitions and corresponding half-lives of excited states for the $N = 153$ chain

$$T = (1,223 \cdot 10^9 E^5 \cdot B(E2))^{-1}$$

Half-lives of $7/2^+$ states for $5/2^+ \to 1/2^+$ transitions, s		
Isotone	Coriolis	Coriolis+Blocking
^{245}Pu	$5{,}217{\cdot}10^{-1}$	$4{,}129{\cdot}10^{-2}$
^{247}Cm	1,479	$5{,}082{\cdot}10^{-1}$
^{249}Cf	$6{,}455{\cdot}10^{-1}$	$2{,}840{\cdot}10^{-1}$
^{251}Fm	$2{,}170{\cdot}10^{-1}$	$7{,}476{\cdot}10^{-2}$
^{253}No	$1{,}860{\cdot}10^{-1}$	$3{,}128{\cdot}10^{-1}$
^{255}Rf	$5{,}076{\cdot}10^{-2}$	$4{,}373{\cdot}10^{-2}$

Admixture of $5/2^+$ component in the excited $7/2^+$ state due to the Coriolis interaction is approximately $\sim 5\%$.

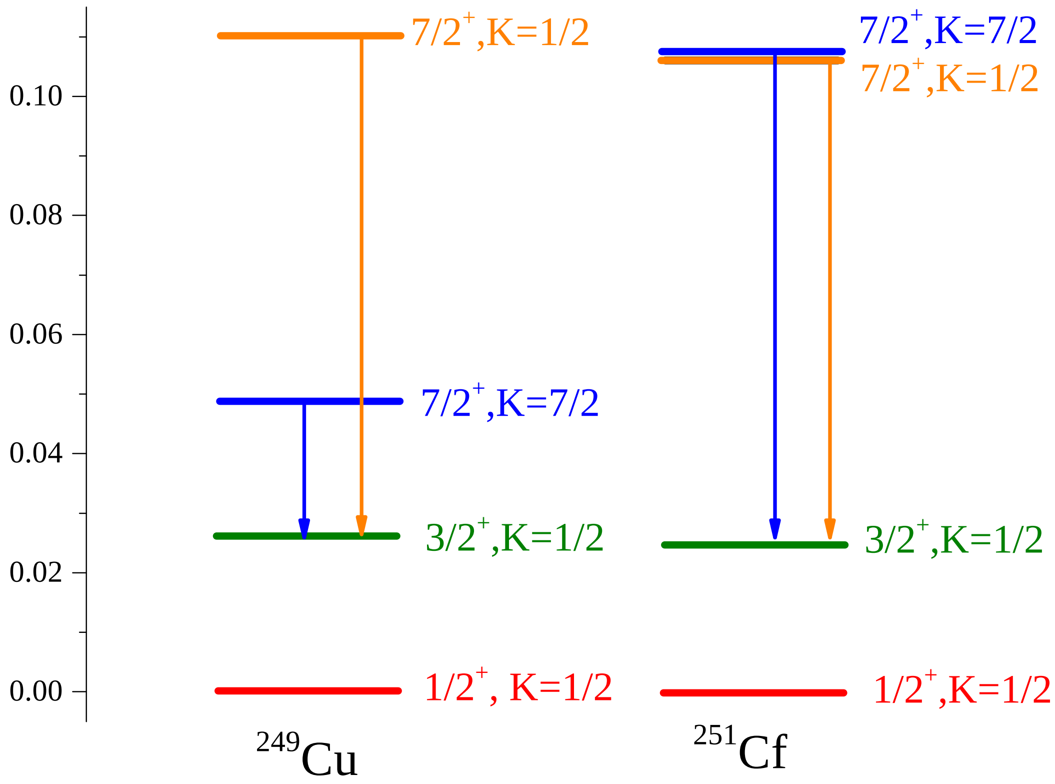
Quasi-neutron spectra for isotones with $N = 153$,TCSHM+Blocking, variable parametrization



$$\kappa_n = -0.076 + 0.0058(N - Z) - 6.53 \cdot 10^{-5}(N - Z)^2 + 0.002A^{1/3} \quad (5)$$

$$\mu_n = 1.598 - 0.0295(N - Z) + 3.036 \cdot 10^{-4}(N - Z)^2 - 0.095A^{1/3} \quad (6)$$

E2 transitions in N=153 chain



Probabilities of $E2$ transitions and corresponding half-lives of excited states for the $N = 153$ chain, variable parametrization

$$T = (1,223 \cdot 10^9 E^5 \cdot B(E2))^{-1}$$

Half-lives of $7/2^+$ states for transitions $7/2^+ \to 3/2^+$(member of $K = 1/2$ rotational band), s			
Isotone	Experiment	$7/2^+$ single-particle	$7/2^+$ rotational
^{249}Cm	$23 \cdot 10^{-6}$	$8.911 \cdot 10^{-3}$	$6{,}262 \cdot 10^{-10}$
^{251}Cf	$38 \cdot 10^{-9}$	$1,332 \cdot 10^{-6}$	$1{,}206 \cdot 10^{-10}$

Results

- Quasi-neutron and single-neutron spectra were calculated for the isotonic chains with $N = 149$, $N = 151$, and $N = 153$ in the frame of the TCSHM.
- For low lying excited states $1/2^+$ in the $N = 149$ chain and $7/2^+$ states in the $N = 151$ and $N = 153$ chains $E2$ transitions probabilities and corresponding half-lives were calculated for transitions to ground states and low lying excited states.
- Taking the Coriolis effect into account and blocking effect for $N = 149$ chain leads to appearance of a transition from the $1/2^+$ state to the ground state due to the $5/2^+$ admixture.
- $E2$ transition in the $N = 151$ and $N = 153$ chains appears only due to the Coriolis effect and $5/2^+$ admixture in the $7/2^+$ state.

Thank you for your attention!